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CEM03.01 User Manual

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Abstract

The Fortran 77 code CEM03.01 is an extended and improved version of the earlier code CEM2k+GEM2, which is based in turn on its predecessor codes CEM2k, CEM97, CEM95, CEM92M, CEM92, and MARIAG, which implement versions of the **C**ascade-**E**xciton **M**odel (**CEM**) of nuclear reactions. CEM03.01 calculates total reaction and fission cross-sections, nuclear fissilities, excitation functions, nuclide distributions (yields) of all produced isotopes separately as well as their A- and Z-distributions, energy and angular spectra, double-differential cross-sections, mean multiplicities, *i.e.* the number of ejectiles per inelastic interaction of the projectile with the target, ejectile yields and their mean energies for n, p, d, t, ^3He, ^4He, π^+, π^-, and π^0. In addition, CEM03.01 provides in its output separately the yields of **F**orward (**F**) and **B**ackward (**B**) produced isotopes, their mean kinetic energies, A- and Z-distributions of the mean emission angle, their parallel velocities, and the F/B ratio of all products in the laboratory system, distributions of the mean angle between two fission fragments, of neutron multiplicity, of the excitation energy, of momentum and angular momentum, and of mass and charge numbers of residual nuclei after the INC and preequilibrium stages of reactions, as well as for fissioning nuclei before and after fission.

CEM03.01 calculates reactions induced by nucleons, pions, bremsstrahlung and monochromatic photons on not too light targets at incident energies from ∼10 MeV (∼ 30 MeV, in the case of $\gamma + A$) up to several GeV. This Manual describes the basic assumptions of the improved CEM as realized in the code CEM03.01, essential technical details of the code such as the description of the input and output files, and provides the user with necessary information for practical use of and for possible modification of the CEM03.01 output, if required.

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1. Introduction

The Cascade-Exciton Model (CEM) of nuclear reactions was proposed 25 years ago at the Laboratory of Theoretical Physics, Joint Institute for Nuclear Reserach, Dubna, USSR by Gudima, Mashnik, and Toneev [1, 2]. Is is based on the Dubna IntraNuclear Cascade (INC) [3, 4] and the Modified Exciton Model (MEM) [5, 6]. It was extended to consider photonuclear reactions [7] and to describe fission cross sections using different options for nuclear masses, fission barriers, and level densities [8] and its 1995 version, CEM95, was released to the public via NEA/OECD, Paris as the code IAEA1247, and via the Radiation Safety Information Computational Center (RSICC) at Oak Ridge, USA, as the RSICC code packege PSR-357 [9].

The *International Code Comparison for Intermediate Energy Nuclear Data* [10, 11] organized during 1993–1994 at NEA/OECD in Paris to address the subject of codes and models used to calculate nuclear reactions from 20 to 1600 MeV showed that CEM95 had one of the best predictive powers to describe nucleon-induced reactions at energies above about 150 MeV when compared to other models and codes available at that time.

CEM95 and/or its predecessors and its successors CEM97 [12, 13], CEM2k [14], CEM2k+GEM2 [15]–[17], CEM03 [18, 19], and the latest version, CEM03.01 [20], are used as stand-alone codes to study different nuclear reactions for applications and fundamental nuclear physics (see, *e.g.*, [21]–[27] and references therein). Parts of different versions of the CEM code are used in many other stand-alone codes, like **PICA95** [28], **PICA3** [29], **CASCADO** [30], **CAMO** [31], **MCFX** [32], **ECM** [33], and **NUCLEUS** [34]. CEM95 and some of its predecessor or successor versions are incorporated wholly, or in part in different transport codes used in many applications, like **CASCADE** [35], **MARS** [36], **MCNPX** [37] **GEANT4** [38, 39], **SHIELD** [40], **RTS&T** [41], **SONET** [42], **CALOR** [43], **HETC-3STEP** [44], **CASCADE/INPE** [45], **HADRON** [46], and others.

All CEM code versions still have some problems to be solved, just as all similar models do. Following an increased interest in intermediate-energy nuclear data in relation to such projects as the Accelerator Transmutation of nuclear Wastes (ATW), the Accelerator Production of Tritium (APT), the Spallation Neutron Source (SNS), the Rare Isotope Accelerator (RIA), Proton Radiography (PRAD) as a radiographic probe for the Advanced Hydro-test Facility, and others, for several years the US Department of Energy has supported our work on the development of an improved version of the CEM which has led to the code CEM03.01 described here.

2. A Brief Survey of CEM03.01 Physics

The CEM03.01 code calculates nuclear reactions induced by nucleons, pions, and photons. It assumes that the reactions occur generally in three stages. The first stage is the IntraNuclear Cascade (INC), in which primary particles can be re-scattered and produce secondary particles several times prior to absorption by, or escape from the nucleus. When the cascade stage of a reaction is completed, CEM03.01 uses the coalescence model to "create" high-energy d, t, ^{3}He, and ^{4}He by final-state interactions among emitted cascade nucleons, already outside of the target. The emission of the cascade particles determines the particle-hole configuration, Z, A, and the excitation energy that is the starting point for the second, preequilibrium stage of the reaction. The subsequent relaxation of the nuclear excitation is treated in terms of an improved version of the modified exciton model of preequilibrium decay followed by the equilibrium evaporation/fission stage of the reaction. Generally, all four components may contribute

to experimentally measured particle spectra and other distributions. But if the residual nuclei after the INC have atomic numbers with $A \leq 12$, CEM03.01 uses the Fermi break-up model to calculate their further disintegration instead of using the preequilibrium and evaporation models. Fermi break-up is much faster to calculate and gives results very similar to the continuation of the more detailed models to much lighter nuclei. In the following we highlight the main assumptions of the models contained in CEM03.01.

2.1. The INC

The intranuclear cascade model in CEM03.01 is based on the standard (non-time-dependent) version of the Dubna cascade model [3, 4]. All the cascade calculations are carried out in a three-dimensional geometry. The nuclear matter density $\rho(r)$ is described by a Fermi distribution with two parameters taken from the analysis of electron-nucleus scattering, namely

$$\rho(r) = \rho_p(r) + \rho_n(r) = \rho_0\{1 + exp[(r-c)/a]\} \ , \tag{1}$$

where $c = 1.07A^{1/3}$ fm, A is the mass number of the target, and $a = 0.545$ fm. For simplicity, the target nucleus is divided by concentric spheres into seven zones in which the nuclear density is considered to be constant. The energy spectrum of the target nucleons is estimated in the perfect Fermi-gas approximation with the local Fermi energy $T_F(r) = \hbar^2[3\pi^2\rho(r)]^{2/3}/(2m_N)$, where m_N is the nucleon mass. The influence of intranuclear nucleons on the incoming projectile is taken into account by adding to its laboratory kinetic energy an effective real potential V, as well as by considering the Pauli principle which forbids a number of intranuclear collisions and effectively increases the mean free path of cascade particles inside the target. For incident nucleons $V \equiv V_N(r) = T_F(r) + \epsilon$, where $T_F(r)$ is the corresponding Fermi energy and ϵ is the binding energy of the nucleons. For pions, CEM03.01 uses a square-well nuclear potential with the depth $V_\pi \simeq 25$ MeV, independently of the nucleus and pion energy, as was done in the initial Dubna INC [3, 4].

The interaction of the incident particle with the nucleus is approximated as a series of successive quasifree collisions of the fast cascade particles (N, π, or γ) with intranuclear nucleons:

$$NN \to NN, \qquad NN \to \pi NN, \qquad NN \to \pi_1, \cdots, \pi_i NN \ , \tag{2}$$

$$\pi N \to \pi N, \qquad \pi N \to \pi_1, \cdots, \pi_i N \qquad (i \geq 2) \ . \tag{3}$$

In the case of pions, besides the elementary processes (3), CEM03.01 also takes into account pion absorption on nucleon pairs

$$\pi NN \to NN. \tag{4}$$

The momenta of the two nucleons participating in the absorption are chosen randomly from the Fermi distribution, and the pion energy is distributed equally between these nucleons in the center-of-mass system of the three particles participating in the absorption. The direction of motion of the resultant nucleons in this system is taken as isotropically distributed in space. The effective cross section for absorption is related (but not equal) to the experimental cross sections for pion absorption by deuterons.

In the case of photonuclear reactions, CEM03.01 follows [19] the ideas of the photonuclear version of the Dubna INC proposed initially 35 years ago by one of us (KKG) in collaboration with Iljinov and Toneev [47] to describe photonuclear reactions at energies above the Giant Dipole Resonance (GDR) region [48]. [At photon energies T_γ = 10–40 MeV, the de Broglie

wavelength $\lambda/2\pi$ is of the order of 20–5 fm, greater than the average inter-nucleonic distance in the nucleus; the photons interact with the nuclear dipole resonance as a whole, thus the INC is not applicable.] Below the pion-production threshold, the Dubna INC considers absorption of photons on only "quasi-deuteron" pairs according to the Levinger model [49]:

$$\sigma_{\gamma A} = L\frac{Z(A-Z)}{A}\sigma_{\gamma d} \ , \tag{5}$$

where A and Z are the mass and charge numbers of the nucleus, $L \approx 10$, and $\sigma_{\gamma d}$ is the total photoabsorption cross section on deuterons as defined from experimental data.

At photon energies above the pion-production threshold, the Dubna INC considers production of one or two pions; the specific mode of the reaction is chosen by the Monte-Carlo method according to the partial cross sections (defined from available experimental data):

$$\begin{aligned}
\gamma + p &\rightarrow p + \pi^0 \ , && (6)\\
&\rightarrow n + \pi^+ \ , && (7)\\
&\rightarrow p + \pi^+ + \pi^- \ , && (8)\\
&\rightarrow p + \pi^0 + \pi^0 \ , && (9)\\
&\rightarrow n + \pi^+ + \pi^0 \ . && (10)
\end{aligned}$$

The cross sections of $\gamma + n$ interactions are derived from consideration of isotopic invariance, *i.e.* it is assumed that $\sigma(\gamma + n) = \sigma(\gamma + p)$. The Compton effect on intranuclear nucleons is neglected, as its cross section is less than $\approx 2\%$ of other reaction modes (see, *e.g.* Fig. 6.13 in Ref. [50]). The Dubna INC does not consider processes involving production of three and more pions; this limits the model's applicability to photon energies $T_\gamma \lesssim 1.5$ GeV [for T_γ higher than the threshold for three-pion production, the sum of the cross sections (8)–(10) is assumed to be equal to the difference between the total inelastic $\gamma + p$ cross section and the sum of the cross sections of the two-body reactions (6)–(7)].

The integral cross sections for the free NN, πN, and γN interactions (2)–(10) are approximated in the Dubna INC model [3] used in CEM95 and its predecessors using a special algorithm of interpolation/extrapolation through a number of picked points, mapping as well as possible the experimental data. This was done very accurately by the group of Prof. Barashenkov using all experimental data available at that time, about 35 years ago. Currently the experimental data on cross sections is much more complete than at that time; therefore we have revised the approximations of all the integral elementary cross sections used in CEM95 and its predecessors. We started by collecting all published experimental data from all available sources. Then we developed an improved, as compared with the standard Dubna INC [3], algorithm for approximation of cross sections and developed simple and fast approximations for elementary cross sections which fit very well presently available experimental data not only to 5 GeV, the upper recommended energy for the present version of the CEM, but up to 50–100 GeV and higher, depending on availability of data (see details in [12, 19]). So far, we have in CEM03.01 new approximations for 34 different types of elementary cross sections induced by nucleons, pions, and gammas. Integral cross sections for other types of interactions taken into account in CEM03.01 are calculated from isospin considerations using the former as input.

The kinematics of two-body elementary interactions and absorption of photons and pions by a pair of nucleons is completely defined by a given direction of emission of one of the secondary particles. The cosine of the angle of emission of secondary particles in the c.m. system is

calculated by the Dubna INC [3] as a function of a random number ξ, distributed uniformly in the interval [0,1] as

$$\cos\theta = 2\xi^{1/2}\left[\sum_{n=0}^{N} a_n\xi^n + (1-\sum_{n=0}^{N} a_n)\xi^{N+1}\right] - 1 \ , \tag{11}$$

where $N = M = 3$,

$$a_n = \sum_{k=0}^{M} a_{nk}T_i^k \ . \tag{12}$$

The coefficients a_{nk} were fitted to the then available experimental data at a number of incident kinetic energies T_i , then interpolated and extrapolated to other energies (see details in [3, 47, 48] and references therein). The distribution of secondary particles over the azimuthal angle φ is assumed isotropic. For elementary interactions with more than two particles in the final state, the Dubna INC uses the statistical model to simulate the angles and energies of products (see details in [3]).

For the improved version of the INC in CEM03.01, we use currently available experimental data and recently published systematics proposed by other authors and have developed new approximations for angular and energy distributions of particles produced in nucleon-nucleon and photon-proton interactions. So, for pp, np, and nn interactions at energies up to 2 GeV, we did not have to develop our own approximations analogous to the ones described by Eqs. (11) and (12), since reliable systematics have been developed recently by Cugnon *et al.* for the Liege INC [51], then improved still further by Duarte for the BRIC code [52]; we simply incorporate into CEM03.01 the systematics by Duarte [52]. Similarly, for γN interactions, we take advantage of the event generators for γp and γn reactions from the Moscow INC [53] kindly sent us by Dr. Igor Pshenichnov. In CEM03.01, we use part of a data file with smooth approximations through presently available experimental data, developed for the Moscow INC [53] and have ourselves developed a simple and fast algorithm to simulate unambiguously $d\sigma/d\Omega$ and to choose the corresponding value of Θ for any E_γ, using a single random number ξ uniformly distributed in the interval [0,1] (see details in [19]).

The analysis of experimental data has shown that the channel (8) of two-pion photoproduction proceeds mainly through the decay of the Δ^{++} isobar listed in the last Review of Particle Physics by the Particle Data Group as having the mass $M = 1232$ MeV

$$\begin{aligned} \gamma + p &\rightarrow \Delta^{++} + \pi^- \ , \\ \Delta^{++} &\rightarrow p + \pi^+ \ , \end{aligned} \tag{13}$$

whereas the production cross section of other isobar components $\left(\frac{3}{2},\frac{3}{2}\right)$ are small and can be neglected. The Dubna INC uses the Lindenbaum-Sternheimer resonance model [54] to simulate the reaction (13). In this model, the mass of the isobar M is determined from the distribution

$$\frac{\mathrm{d}W}{\mathrm{d}M} \sim F(E,M)\sigma(M) \ , \tag{14}$$

where E is the total energy of the system, F is the two-body phase space of the isobar and π^- meson, and σ is the isobar production cross section which is assumed to be equal to the cross section for elastic π^+p scattering.

The c.m. emission angle of the isobar is approximated using Eqs. (11) and (12) with the coefficients a_{nk} listed in Tab. 3 of Ref. [48]; isotropy of the decay of the isobar in its c.m. system is assumed.

In order to calculate the kinematics of the non-resonant part of the reaction (8) and the two remaining three-body channels (9) and (10), the Dubna INC uses the statistical model. The total energies of the two particles (pions) in the c.m. system are determined from the distribution

$$\frac{\mathrm{d}W}{\mathrm{d}E_{\pi_1}\mathrm{d}E_{\pi_2}} \sim (E - E_{\pi_1} - E_{\pi_2})E_{\pi_1}E_{\pi_2}/E \ , \tag{15}$$

and that of the third particle (nucleon, N) from conservation of energy. The actual simulation of such reactions is done as follows: Using a random number ξ, we simulate in the beginning the energy of the first pion using

$$E_{\pi_1} = m_{\pi_1} + \xi(E_{\pi_1}^{max} - m_{\pi_1}),$$

where

$$E_{\pi_1}^{max} = [E^2 + m_{\pi_1}^2 - (m_{\pi_2} + m_N)^2]/2E.$$

Then, we simulate the energy of the second pion E_{π_2} according to Eq. (15) using the Monte-Carlo rejection method. The energy of the nucleon is calculated as $E_N = E - E_{\pi_1} - E_{\pi_2}$, following which we check that the "triangle law" for momenta

$$|p_{\pi_1} - p_{\pi_2}| \leq p_N \leq |p_{\pi_1} + p_{\pi_2}|$$

is fulfilled, otherwise this sampling is rejected and the procedure is repeated. The angles Θ and φ of the pions are sampled assuming an isotropic distribution of particles in the c.m. system,

$$\cos\Theta_{\pi_1} = 2\xi_1 - 1, \qquad \cos\Theta_{\pi_2} = 2\xi_2 - 1, \qquad \varphi_{\pi_1} = 2\pi\xi_3, \qquad \varphi_{\pi_2} = 2\pi\xi_4,$$

and the angles of the nucleon are defined from momentum conservation, $\vec{p}_N = -(\vec{p}_{\pi_1} + \vec{p}_{\pi_2})$. More details on our new approximations for differential elementary cross sections may be found in [18, 19].

The Pauli exclusion principle at the cascade stage of the reaction is handled by assuming that nucleons of the target occupy all the energy levels up to the Fermi energy. Each simulated elastic or inelastic interaction of the projectile (or of a cascade particle) with a nucleon of the target is considered forbidden if the "secondary" nucleons have energies smaller than the Fermi energy. If they do, the trajectory of the particle is traced further from the forbidden point and a new interaction point, a new partner and a new interaction mode are simulated for the traced particle, *etc.*, until the Pauli principle is satisfied or the particle leaves the nucleus.

In this version of the INC, the kinetic energy of the cascade particles is increased or decreased as they move from one of the seven potential regions (zones) to another, but their directions remain unchanged. That is, in our calculations, refraction or reflection of cascade nucleons at potential boundaries is neglected. CEM03.01 allows us to take into account refractions and reflections of cascade nucleons at potential boundaries; for this, one needs to change the value of the parameter **irefrac** from 0 to 1 in the subroutine **initial**. But this option provides somewhat worse overall agreement of calculations with some experimental data, therefore the option of no refractions/reflections was chosen as the default in CEM03.01.

This INC does not take into account the so-called "trawling" effect [3]. That is, in the beginning of the simulation of each event, the nuclear density distributions for the protons and

neutrons of the target are calculated according to Eq. (1) and a subsequent decrease of the nuclear density with the emission of cascade particles is not taken into account. Our detailed analysis of different characteristics of nucleon- and pion-induced reactions for targets from C to Am has shown that this effect may be neglected at incident energies below about 5 GeV in the case of heavy targets like actinides and below about 1 GeV for light targets like carbon. At higher incident energies the progressive decrease of nuclear density with the development of the intranuclear cascade has a strong influence on the calculated characteristics and this effect has to be taken into account [3]. Therefore, in transport codes that use as event generators both CEM03.01 and our high-energy code LAQGSM03.01 [20], we recommend simulating nuclear reactions with CEM03.01 at incident energies up to about 1 GeV for light nuciei like C and up to about 5 GeV for actinide nuclei, and to switch to simulations using LAQGSM03.01, which considers the "trawling" effect, at higher energies of transported particles.

An important ingredient of the CEM is the criterion for transition from the intranuclear cascade to the preequilibrium model. In conventional cascade-evaporation models (like ISABEL and Bertini's INC used in MCNPX [37], fast particles are traced down to some minimal energy, the cutoff energy T_{cut} (or one compares the duration of the cascade stage of a reaction with a cutoff time, in "time-like" INC models, such as the Liege INC [51]). This cutoff is usually less than $\simeq 10$ MeV above the Fermi energy, below which particles are considered to be absorbed by the nucleus. The CEM uses a different criterion to decide when a primary particle is considered to have left the cascade.

An effective local optical absorptive potential $W_{opt.\,mod.}(r)$ is defined from the local interaction cross section of the particle, including Pauli-blocking effects. This imaginary potential is compared to one defined by a phenomenological global optical model $W_{opt.\,exp.}(r)$. We characterize the degree of similarity or difference of these imaginary potentials by the parameter

$$\mathcal{P} = \mid (W_{opt.\,mod.} - W_{opt.\,exp.})/W_{opt.\,exp.} \mid . \tag{16}$$

When $\mathcal{P}$ increases above an empirically chosen value, the particle leaves the cascade, and is then considered to be an exciton. From a physical point of view, such a smooth transition from the cascade stage of the reaction seems to be more attractive than the "sharp cut-off" method. In addition, as was shown in Ref. [2], this improves the agreement between the calculated and experimental spectra of secondary nucleons, especially at low incident energies and backward angles of the detected nucleons (see *e.g.*, Figs. 3 and 11 of Ref. [2]). More details about this can be found in [2, 14, 55].

CEM03.01 uses a fixed value $\mathcal{P} = 0.3$ (at incident energies below 100 MeV), just as all its predecessors did. With this value, we find that the cascade stage of the CEM is generally shorter than that in other cascade models. This fact leads to an overestimation of preequilibrium particle emission at incident energies above about 150 MeV, and correspondingly to an underestimation of neutron production from such reactions, as was established in Ref. [14]. In Ref. [14], this problem was solved temporarily in a very rough way by using the transition from the INC to the preequilibrium stage according to Eq. (16) when the incident energy of the projectile is below 150 MeV, and by using the "sharp cut-off" method with a cutoff energy $T_{cut} = 1$ MeV for higher incident energies. This "ad hoc" rough criterion solved the problem of underestimating neutron production at high energies, providing meanwhile a reasonably good description of reactions below 150 MeV. But it provides an unphysical discontinuity in some observables calculated by MCNPX using CEM2k [14] as an event generator, observed but not undersood by Broeders and Konobeev [56]. In CEM03.01, this problem is solved by using a

smooth transition from the first criterion to the second one in the energy interval from 75 to 225 MeV, so that no discontinuities are produced in results from CEM03.01.

Beside the changes to the Dubna INC mentioned above, we also made in the INC a number of other improvements and refinements, such as imposing momentum-energy conservation for each simulated event (the Monte-Carlo algorithm previously used in the CEM provided momentum-energy conservation only statistically, on the average, but not exactly for each simulated event) and using real binding energies for nucleons in the cascade instead of the approximation of a constant separation energy of 7 MeV used in previous versions of the CEM. We have also improved many algorithms used in the Monte-Carlo simulations in many subroutines, decreasing the computing time by up to a factor of 6 for heavy targets, which is very important when performing practical simulations with transport codes like MCNPX or MARS.

Let us mention that in the CEM the initial configuration for the preequilibrium decay (number of excited particles and holes, *i.e.* excitons $n_0 = p_0 + h_0$, excitation energy E_0^*, linear momentum $\boldsymbol{P}_0$, and angular momentum $\boldsymbol{L}_0$ of the nucleus) differs significantly from that usually postulated in exciton models. Our calculations [2, 57, 58] have shown that the distributions of residual nuclei remaining after the cascade stage of the reaction, *i.e.* before the preequilibrium emission, with respect to n_0, p_0, h_0, E_0^*, $\boldsymbol{P}_0$, and $\boldsymbol{L}_0$ are rather broad.[1]

2.2. The Coalescence Model

When the cascade stage of a reaction is completed, CEM03.01 uses the coalescence model described in Refs. [59, 60] to "create" high-energy d, t, ^{3}He, and ^{4}He by final-state interactions among emitted cascade nucleons, already outside of the target nucleus. In contrast to most other coalescence models for heavy-ion induced reactions, where complex particle spectra are estimated simply by convolving the measured or calculated inclusive spectra of nucleons with corresponding fitted coefficients (see, *e.g.*, [61] and references therein), CEM03.01 uses in its simulation of particle coalescence real information about all emitted cascade nucleons and does not use integrated spectra. CEM03.01 assumes that all the cascade nucleons having differences in their momenta smaller than p_c and the correct isotopic content form an appropriate composite particle. This means that the formation probability for, *e.g.* a deuteron is

$$W_d(\vec{p},b) = \int\int d\vec{p}_p d\vec{p}_n \rho^C(\vec{p}_p,b)\rho^C(\vec{p}_n,b)\delta(\vec{p}_p+\vec{p}_n-\vec{p})\Theta(p_c-|\vec{p}_p-\vec{p}_n|), \tag{17}$$

where the particle density in momentum space is related to the one-particle distribution function f by

$$\rho^C(\vec{p},b) = \int d\vec{r} f^C(\vec{r},\vec{p},b). \tag{18}$$

Here, b is the impact parameter for the projectile interacting with the target nucleus and the superscript index C shows that only cascade nucleons are taken into account for the coalescence

[1] Unfortunately, this fact was misunderstood by the authors of the code HETC-3STEP [44]. In spite of the fact that it has been stressed explicitly, and figures with distributions of excited nuclei after the cascade stage of a reaction with respect to the number of excitons and other characteristics were shown in a number of publications (see, *e.g.*, Fig. 5 in Ref. [2], Fig. 1 in Ref. [58], p. 109 in Ref. [57], and p. 706 in Ref. [22]), the authors of Ref. [44] misstated this fact as *"Gudima et al. assumed the state of two particles and one hole at the beginning ··· Hence, their assumption is not valid for the wide range of incident energy"*, claiming this as a weakness of the CEM and a priority of the code HETC-3STEP, where smooth distributions of excited nuclei after the cascade stage of reactions with respect to n_0 are used. This had already been done in the CEM [1, 2].

process. The coalescence radii p_c were fitted for each composite particle in Ref. [59] to describe available data for the reaction Ne+U at 1.04 GeV/nucleon, but the fitted values turned out to be quite universal and were subsequently found to satisfactorily describe high-energy complex-particle production for a variety of reactions induced both by particles and nuclei at incident energies up to about 200 GeV/nucleon, when describing nuclear reactions with the Los Alamos version of the Quark-Gluon String Model (LAQGSM) [20, 62] or with its predecessor, the Quark-Gluon String Model (QGSM) [63]. These parameters are:

$$p_c(d) = 90 \text{ MeV/c}; \qquad p_c(t) = p_c(^3\text{He}) = 108 \text{ MeV/c}; \qquad p_c(^4\text{He}) = 115 \text{ MeV/c} . \tag{19}$$

As the INC of CEM03.01 is different from those of LAQGSM or QGSM, it is natural to expect different best values for p_c as well. Our recent studies show that the values of parameters p_c defined by Eq. (19) are also good for CEM03.01 for projectile particles with kinetic energies T_0 lower than 300 MeV and equal to or above 1 GeV. For incident energies in the interval 300 MeV $< T_0 \leq 1$ GeV, a better overall agreement with the available experimental data is obtained by using values of p_c equal to 150, 175, and 175 MeV/c for d, t(^{3}He), and ^{4}He, respectively. These values of p_c are fixed as defaults in CEM03.01. If several cascade nucleons are chosen to coalesce into composite particles, they are removed from the distributions of nucleons and do not contribute further to such nucleon characteristics as spectra, multiplicities, *etc.*

2.3. Preequilibrium Reactions

The subsequent preequilibrium interaction stage of nuclear reactions is considered by the CEM in the framework of an extension of the Modified Exciton Model (MEM) [5, 6]. At the preequilibrium stage of a reaction we take into account all possible nuclear transitions changing the number of excitons n with $\Delta n = +2, -2$, and 0, as well as all possible multiple subsequent emissions of n, p, d, t, ^{3}He, and ^{4}He. The corresponding system of master equations describing the behavior of a nucleus at the preequilibrium stage is solved by the Monte-Carlo technique [1, 2].

For a preequilibrium nucleus with excitation energy E and number of excitons $n = p + h$, the partial transition probabilities changing the exciton number by Δn are

$$\lambda_{\Delta n}(p,h,E) = \frac{2\pi}{\hbar}|M_{\Delta n}|^2 \omega_{\Delta n}(p,h,E) \ . \tag{20}$$

The emission rate of a nucleon of the type j into the continuum is estimated according to the detailed balance principle

$$\begin{aligned} \Gamma_j(p,h,E) &= \int\limits_{V_j^c}^{E-B_j} \lambda_c^j(p,h,E,T)dT \ , \\ \lambda_c^j(p,h,E,T) &= \frac{2s_j+1}{\pi^2\hbar^3}\mu_j \Re_j(p,h) \frac{\omega(p-1,h,E-B_j-T)}{\omega(p,h,E)} T\sigma_{inv}(T) \ , \end{aligned} \tag{21}$$

where s_j, B_j, V_j^c, and μ_j are the spin, binding energy, Coulomb barrier, and reduced mass of the emitted particle, respectively. The factor $\Re_j(p,h)$ ensures the condition for the exciton chosen to be the particle of type j and can easily be calculated by the Monte-Carlo technique.

Assuming an equidistant level scheme with the single-particle density g, we have the level density of the n-exciton state as [64]

$$\omega(p,h,E) = \frac{g(gE)^{p+h-1}}{p!h!(p+h-1)!} \ . \tag{22}$$

This expression should be substituted into Eq. (21). For the transition rates (20), one needs the number of states taking into account the selection rules for intranuclear exciton-exciton scattering. The appropriate formulae have been derived by Williams [65] and later corrected for the exclusion principle and indistinguishability of identical excitons in Refs. [66, 67]:

$$\begin{aligned}
\omega_+(p,h,E) &= \frac{1}{2}g\frac{[gE-\mathcal{A}(p+1,h+1)]^2}{n+1}\Big[\frac{gE-\mathcal{A}(p+1,h+1)}{gE-\mathcal{A}(p,h)}\Big]^{n-1} \ , \\
\omega_0(p,h,E) &= \frac{1}{2}g\frac{[gE-\mathcal{A}(p,h)]}{n}[p(p-1)+4ph+h(h-1)] \ , \\
\omega_-(p,h,E) &= \frac{1}{2}gph(n-2) \ ,
\end{aligned} \tag{23}$$

where $\mathcal{A}(p,h) = (p^2+h^2+p-h)/4 - h/2$. By neglecting the difference of matrix elements with different Δn, $M_+ = M_- = M_0 = M$, we estimate the value of M for a given nuclear state by associating the $\lambda_+(p,h,E)$ transition with the probability for quasi-free scattering of a nucleon above the Fermi level on a nucleon of the target nucleus. Therefore, we have

$$\frac{<\sigma(v_{rel})v_{rel}>}{V_{int}} = \frac{\pi}{\hbar}|M|^2\frac{g[gE-\mathcal{A}(p+1,h+1)]}{n+1}\Big[\frac{gE-\mathcal{A}(p+1,h+1)}{gE-\mathcal{A}(p,h)}\Big]^{n-1} \ . \tag{24}$$

Here, V_{int} is the interaction volume estimated as $V_{int} = \frac{4}{3}\pi(2r_c + \lambda/2\pi)^3$, with the de Broglie wave length $\lambda/2\pi$ corresponding to the relative velocity $v_{rel} = \sqrt{2T_{rel}/m_N}$. A value of the order of the nucleon radius is used for r_c in the CEM: $r_c = 0.6$ fm.

The averaging in the left-hand side of Eq. (24) is carried out over all excited states taking into account the Pauli principle in the approximation

$$<\sigma(v_{rel})v_{rel}> \simeq <\sigma(v_{rel})><v_{rel}> \ . \tag{25}$$

The averaged cross section $<\sigma(v_{rel})>$ is calculated by the Monte-Carlo simulation method and by introducing a factor η effectively taking into account the Pauli principle exactly as is done in the Fermi-gas model (see, *e.g.*, [68])[2]

$$\sigma(v_{rel}) = \frac{1}{2}[\sigma_{pp}(v_{rel}) + \sigma_{pn}(v_{rel})]\eta(T_F/T) \ , \text{ where} \tag{26}$$

$$\eta(x) = \begin{cases} 1-\frac{7}{5}x, & \text{if } x \le 0.5 \ , \\ 1-\frac{7}{5}x+\frac{2}{5}x(2-\frac{1}{x})^{5/2}, & \text{if } x > 0.5 \ . \end{cases} \tag{27}$$

Here, v_{rel} is the relative velocity of the excited nucleon (exciton) and the target nucleon in units of the speed of light and T is the kinetic energy of the exciton. The free-particle interaction

[2]Unfortunately, formula (27) as presented in Ref. [2] had some misprints; in the prior publication [1], it was correct.

cross sections $\sigma_{pp}(v_{rel})$ and $\sigma_{pn}(v_{rel})$ in Eq. (26) are estimated using the relations suggested by Metropolis *et al.* [69]

$$\sigma_{pp}(v_{rel}) = \frac{10.63}{v_{rel}^2} - \frac{29.92}{v_{rel}} + 42.9 \ ,$$
$$\sigma_{pn}(v_{rel}) = \frac{34.10}{v_{rel}^2} - \frac{82.2}{v_{rel}} + 82.2 \ , \qquad (28)$$

where the cross sections are given in mb.

The relative kinetic energy of colliding particles necessary to calculate $< v_{rel} >$ and the factor η in Eqs. (26,27) are estimated in the so-called "right-angle collision" approximation [5], *i.e.* as a sum of the mean kinetic energy of an excited particle (exciton) measured from the bottom of the potential well $T_p = T_F + E/n$ plus the mean kinetic energy of an intranuclear nucleon partner $T_N = 3T_F/5$, that is $T_{rel} = T_p + T_N = 8T_F/5 + E/n$.

Combining (20), (22) and (24), we get finally for the transition rates:

$$\begin{aligned}
\lambda_+(p,h,E) &= \frac{<\sigma(v_{rel})v_{rel}>}{V_{int}} \ , \\
\lambda_0(p,h,E) &= \frac{<\sigma(v_{rel})v_{rel}>}{V_{int}} \frac{n+1}{n} \Big[\frac{gE - \mathcal{A}(p,h)}{gE - \mathcal{A}(p+1,h+1)}\Big]^{n+1} \frac{p(p-1)+4ph+h(h-1)}{gE-\mathcal{A}(p,h)} \ , \\
\lambda_-(p,h,E) &= \frac{<\sigma(v_{rel})v_{rel}>}{V_{int}} \Big[\frac{gE - \mathcal{A}(p,h)}{gE - \mathcal{A}(p+1,h+1)}\Big]^{n+1} \frac{ph(n+1)(n-2)}{[gE-\mathcal{A}(p,h)]^2} \ . \qquad (29)
\end{aligned}$$

CEM considers the possiblility of fast d, t, ^{3}He, and ^{4}He emission at the preequilibrium stage of a reaction in addition to the emission of nucleons. We assume that in the course of a reaction p_j excited nucleons (excitons) are able to condense with probability γ_j forming a complex particle which can be emitted during the preequilibrium state. A modification of Eq. (21) for the complex-particle emission rates is described in detail in Refs. [1, 2]. The "condensation" probability γ_j is estimated in those references as the overlap integral of the wave function of independent nucleons with that of the complex particle (cluster)

$$\gamma_j \simeq p_j^3 (V_j/V)^{p_j - 1} = p_j^3 (p_j/A)^{p_j - 1} \ . \qquad (30)$$

This is a rather crude estimate. In the usual way the values γ_j are taken from fitting the theoretical preequilibrium spectra to the experimental ones, which gives rise to an additional, as compared to (30), dependence of the factor γ_j on p_j and excitation energy (see, *e.g.*, Refs. [70, 71]), for each considered reaction.

The single-particle density g_j for complex particle states is found in the CEM by assuming the complex particles move freely in a uniform potential well whose depth is equal to the binding energy of this particle in a nucleus [2]

$$g_j(T) = \frac{V(2s_j+1)(2\mu_j)^{3/2}}{4\pi^2\hbar^3}(T + B_j)^{1/2} \ . \qquad (31)$$

As we stated previously, this is a crude approximation and it does not provide a good prediction of emission of preequilibrium α particles (see, *e.g.*, [55] and references therein). In CEM03.01, to improve the description of preequilibrium complex-particle emission, we estimate γ_j by multiplying the estimate provided by Eq. (30) by an empirical coefficient $M_j(A, Z, T_0)$ whose values are fitted to available nucleon-induced experimental complex-particle spectra. We

fix the fitted values of $M_j(A,Z,T_0)$ in data commons of CEM03.01 and complement them with routines **gambetn** and **gambetp** for their interpolation outside the region covered by our fitting. As shown in one example in Fig. 6 of Appendix 3, after fitting $M_j(A,Z,T_0)$, CEM03.01 describes quite well the measured spectra of all complex particles, providing a much better agreement with experimental data than all its predecessors did.

The CEM predicts forward peaked (in the laboratory system) angular distributions for preequilibrium particles. For instance, CEM03.01 assumes that a nuclear state with a given excitation energy E^* should be specified not only by the exciton number n but also by the momentum direction Ω. Following Ref. [72], the master equation (11) from Ref. [2] can be generalized for this case provided that the angular dependence for the transition rates λ_+, λ_0, and λ_- (Eq. (29)) is factorized. In accordance with Eqs. (24) and (25), in the CEM it is assumed that

$$< \sigma > \rightarrow < \sigma > F(\Omega) \ , \tag{32}$$

where

$$F(\Omega) = \frac{d\sigma^{free}/d\Omega}{\int d\Omega' d\sigma^{free}/d\Omega'} \ . \tag{33}$$

The scattering cross section $d\sigma^{free}/d\Omega$ is assumed to be isotropic in the reference frame of the interacting excitons, thus resulting in an asymmetry in both the nucleus center-of-mass and laboratory frames. The angular distributions of preequilibrium complex particles are assumed [2] to be similar to those for the nucleons in each nuclear state.

This calculational scheme is easily realized by the Monte-Carlo technique. It provides a good description of double differential spectra of preequilibrium nucleons and a not-so-good but still statisfactory description of complex-particle spectra from different types of nuclear reactions at incident energies from tens of MeV to several GeV. For incident energies below about 200 MeV, Kalbach [73] has developed a phenomenological systematics for preequilibrium-particle angular distributions by fitting available measured spectra of nucleons and complex particles. As the Kalbach systematics are based on measured spectra, they describe very well the double-differential spectra of preequilibrium particles and generally provide a better agreement of calculated preequilibrium complex particle spectra with data than does the CEM approach based on Eqs. (32,33). This is why we have incorporated into CEM03.01 the Kalbach systematics [73] to describe angular distributions of both preequilibrium nucleons and complex particles at incident energies up to 210 MeV. At higher energies, we use in CEM03.01 the CEM appproach based on Eqs. (32,33).

By "preequilibrium particles" we mean particles which are emitted after the cascade stage of a reaction but before achieving statistical equilibrium at a time t_{eq}, which is fixed by the condition $\lambda_+(n_{eq},E) = \lambda_-(n_{eq},E)$ from which we get

$$n_{eq} \simeq \sqrt{2gE} \ . \tag{34}$$

At $t \geq t_{eq}$ (or $n \geq n_{eq}$), the behavior of the remaining excited compound nucleus is described in the framework of both the Weisskopf-Ewing statistical theory of particle evaporation [74] and fission competition according to Bohr-Wheeler theory [75].

The parameter g entering into Eqs. (29) and (34) is related to the level-density parameter of single-particle states $a = \pi^2 g/6$. At the preequilibrium stage, we calculate the level-density parameter a with our own approximation [13] in the form proposed initially by Ignatyuk *et al.*

[76], following the method by Iljinov *et al.* [77]:

$$a(Z,N,E^*) = \tilde{a}(A)\left\{1 + \delta W_{gs}(Z,N)\frac{f(E^*-\Delta)}{E^*-\Delta}\right\}, \tag{35}$$

where

$$\tilde{a}(A) = \alpha A + \beta A^{2/3} B_s \tag{36}$$

is the asymptotic Fermi-gas value of the level density parameter at high excitation energies. Here, B_s is the ratio of the surface area of the nucleus to the surface area of a sphere of the same volume (for the ground state of a nucleus, $B_s \approx 1$), and

$$f(E) = 1 - exp(-\gamma E)\ . \tag{37}$$

E^* is the total excitation energy of the nucleus, related to the "thermal" energy U by: $U = E^* - E_R - \Delta$, where E_R and Δ are the rotational and pairing energies, respectively.

We use the shell correction $\delta W_{gs}(Z,N)$ by Möller *et al.* [78] and the pairing energy shifts from Möller, Nix, and Kratz [79]. The values of the parameters α, β, and γ were derived in Ref. [13] by fitting the the same data analyzed by Iljinov *et al.* [77] (we discovered that Iljinov *et al.* used $11/\sqrt{A}$ for the pairing energies Δ in deriving their level-density systematics instead of the value of $12/\sqrt{A}$ stated in Ref. [77] and we also found several misprints in the nuclear level-density data shown in their Tables. 1 and 2 used in the fit). We find:

$$\alpha = 0.1463,\ \beta = -0.0716, \text{ and } \gamma = 0.0542\ .$$

As mentioned in Section 2.2, the standard version of the CEM [2] provides an overestimation of preequilibrium particle emission from different p+A and A+A reactions we have analyzed (see more details in [14, 15]). One way to solve this problem suggested in Ref. [14] is to change the criterion for the transition from the cascade stage to the preequilibrium one, as described in Section 2.2. Another easy way suggested in Ref. [14] to shorten the preequilibrium stage of a reaction is to arbitrarily allow only transitions that increase the number of excitons, $\Delta n = +2$, *i.e.*, only allow the evolution of a nucleus toward the compound nucleus. In this case, the time of the equilibration will be shorter and fewer preequilibrium particles will be emitted, leaving more excitation energy for the evaporation. Such a "never-come-back" approach is used by some other exciton models, for instance, by the Multistage Preequilibrium Model (MPM) used in LAHET [80] and by FLUKA [81]. This approach was used in the CEM2k [14] version of the CEM and it allowed us to describe much better the p+A reactions measured at GSI in inverse kinematics at energies around 1 GeV/nucleon. Nevertheless, the "never-come-back" approach seems unphysical, therefore we no longer use it. We now address the problem of emitting fewer preequilibrium particles in the CEM by following Veselský [82]. We assume that the ratio of the number of quasiparticles (excitons) n at each preequilibrium reaction stage to the number of excitons in the equilibrium configuration n_{eq}, corresponding to the same excitation energy, to be a crucial parameter for determining the probability of preequilibrium emission P_{pre}. This probability for a given preequilibrium reaction stage is evaluated using the formula

$$P_{pre}(n/n_{eq}) = 1 - \exp\Big(-\frac{(n/n_{eq}-1)}{2\sigma_{pre}^2}\Big) \tag{38}$$

for $n \leq n_{eq}$ and equal to zero for $n > n_{eq}$. The basic assumption leading to Eq. (38) is that P_{pre} depends exclusively on the ratio n/n_{eq} as can be deduced from the results of Böhning [83]

where the density of particle-hole states is approximately described using a Gaussian centered at n_{eq}. The parameter σ_{pre} is a free parameter and we assume no dependence on excitation energy [82]. Our calculations of several reactions using different values of σ_{pre} show that an overall reasonable agreement with available data can be obtained using $\sigma_{pre} = 0.4$–0.5 (see Fig. 11 in Ref. [15]). In CEM03.01, we choose the fixed value $\sigma_{pre} = 0.4$ and use Eqs. (34,38) as criteria for the transition from the preequilibrium stage of reactions to evaporation, instead of using the "never-come-back" approach along with Eq. (34), as was done in CEM2k.

2.4. Evaporation

CEM03.01 uses an extension of the Generalized Evaporation Model (GEM) code GEM2 by Furihata [84]–[86] after the preequilibrium stage of reactions to describe evaporation of nucleons, complex particles, and light fragments heavier than ^{4}He (up to ^{28}Mg) from excited compound nuclei and to describe their fission, if the compound nuclei are heavy enough to fission ($Z \geq 65$). The GEM is an extension by Furihata of the Dostrovsky evaporation model [87] as implemented in LAHET [80] to include up to 66 types of particles and fragments that can be evaporated from an excited compound nucleus plus a modification of the version of Atchison's fission model [88, 89] used in LAHET. Many of the parameters were adjusted by Furihata for a better description of fission reactions when using it in conjunction with the extended evaporation model.

A very detailed description of the GEM, together with a large amount of results obtained for many reactions using the GEM coupled either with the Bertini or ISABEL INC models in LAHET may be found in [84, 85]. Therefore, we present here only the main features of the GEM, following mainly [85] and using as well information obtained in private communications with Dr. Furihata.

Furihata did not change in the GEM the general algorithms used in LAHET to simulate evaporation and fission. The decay widths of evaporated particles and fragments are estimated using the classical Weisskopf-Ewing statistical model [74]. In this approach, the decay probability P_j for the emission of a particle j from a parent compound nucleus i with the total kinetic energy in the center-of-mass system between ϵ and $\epsilon + d\epsilon$ is

$$P_j(\epsilon)d\epsilon = g_j \sigma_{inv}(\epsilon) \frac{\rho_d(E - Q - \epsilon)}{\rho_i(E)} \epsilon d\epsilon, \tag{39}$$

where E [MeV] is the excitation energy of the parent nucleus i with mass A_i and charge Z_i, and d denotes a daughter nucleus with mass A_d and charge Z_d produced after the emission of ejectile j with mass A_j and charge Z_j in its ground state. σ_{inv} is the cross section for the inverse reaction, ρ_i and ρ_d are the level densities $[\text{MeV}]^{-1}$ of the parent and the daughter nucleus, respectively. $g_j = (2S_j + 1)m_j/\pi^2\hbar^2$, where S_j is the spin and m_j is the reduced mass of the emitted particle j. The Q-value is calculated using the excess mass $M(A, Z)$ as $Q = M(A_j, Z_j) + M(A_d, Z_d) - M(A_i, Z_i)$. In GEM2, four mass tables are used to calculate Q-values, according to the following priorities, where a lower priority table is only used outside the range of validity of the higher priority one: (1) the Audi-Wapstra mass table [90], (2) theoretical masses calculated by Möller *et al.* [78], (3) theoretical masses calculated by Comay *et al.* [91], (4) the mass excess calculated using the old Cameron formula [92]. As does LAHET, GEM2 uses Dostrovsky's formula [87] to calculate the inverse cross section σ_{inv} for all emitted

particles and fragments

$$\sigma_{inv}(\epsilon) = \sigma_g \alpha \left(1 + \frac{\beta}{\epsilon}\right) \ , \tag{40}$$

which is often written as

$$\sigma_{inv}(\epsilon) = \begin{cases} \sigma_g c_n (1 + b/\epsilon) & \text{for neutrons} \\ \sigma_g c_j (1 - V/\epsilon) & \text{for charged particles} \ , \end{cases}$$

where $\sigma_g = \pi R_b^2$ [fm^2] is the geometrical cross section, and

$$V = k_j Z_j Z_d e^2 / R_c \tag{41}$$

is the Coulomb barrier in MeV.

One new ingredient in GEM2 in comparison with LAHET, which considers evaporation of only 6 particles (n, p, d, t, ^{3}He, and ^{4}He), is that Furihata includes the possibility of evaporation of up to 66 types of particles and fragments and incorporates into GEM2 several alternative sets of parameters b, c_j, k_j, R_b, and R_c for each particle type.

The 66 ejectiles considered by GEM2 for evaporation are selected to satisfy the following criteria: (1) isotopes with $Z_j \leq 12$; (2) naturally existing isotopes or isotopes near the stability line; (3) isotopes with half-lives longer than 1 ms. All the 66 ejectiles considered by GEM2 are shown in Table 1.

Table 1. The evaporated particles considered by GEM2

Z_j	Ejectiles						
0	n						
1	p	d	t				
2	^{3}He	^{4}He	^{6}He	^{8}He			
3	^{6}Li	^{7}Li	^{8}Li	^{9}Li			
4	^{7}Be	^{9}Be	^{10}Be	^{11}Be	^{12}Be		
5	^{8}B	^{10}B	^{11}B	^{12}B	^{13}B		
6	^{10}C	^{11}C	^{12}C	^{13}C	^{14}C	^{15}C	^{16}C
7	^{12}N	^{13}N	^{14}N	^{15}N	^{16}N	^{17}N	
8	^{14}O	^{15}O	^{16}O	^{17}O	^{18}O	^{19}O	^{20}O
9	^{17}F	^{18}F	^{19}F	^{20}F	^{21}F		
10	^{18}Ne	^{19}Ne	^{20}Ne	^{21}Ne	^{22}Ne	^{23}Ne	^{24}Ne
11	^{21}Na	^{22}Na	^{23}Na	^{24}Na	^{25}Na		
12	^{22}Mg	^{23}Mg	^{24}Mg	^{25}Mg	^{26}Mg	^{27}Mg	^{28}Mg

GEM2 includes several options for the parameter set in expressions (40,41):

1) The "simple" parameter set is given as $c_n = c_j = k_j = 1$, $b = 0$, and $R_b = R_c = r_0(A_j^{1/3} + A_d^{1/3})$ [fm]; users need to input r_0.

2) The "precise" parameter set is used in GEM2 as the default, and we use this set in our present work.

A) For all light ejectiles up to α ($A_j \leq 4$), the parameters determined by Dostrovsky *et al.* [87] are used in GEM2, namely: $c_n = 0.76 + c_a A_d^{-1/3}$, $b = (b_a A_d^{-2/3} - 0.050)/(0.76 + c_a A_d^{-1/3})$ (and $b = 0$ for $A_d \geq 192$), where $c_a = 1.93$ and $b_a = 1.66$, $c_p = 1 + c$, $c_d = 1 + c/2$, $c_t = 1 + c/3$, $c_{^3He} = c_\alpha = 0$, $k_p = k$, $k_d = k + 0.06$, $k_t = k + 0.12$, $k_{^3He} = k_\alpha - 0.06$, where c, k, and k_α

are listed in Table 2 for a set of Z_d. Between the Z_d values listed in Table 2, c, k, and k_α are interpolated linearly.The nuclear distances are given by $R_b = 1.5A^{1/3}$ for neutrons and protons, and $1.5(A_d^{1/3} + A_j^{1/3})$ for d, t, ^{3}He, and α.

Table 2. k, k_α, and c parameters used in GEM2

Z_d	k	k_α	c
≤ 20	0.51	0.81	0.0
30	0.60	0.85	-0.06
40	0.66	0.89	-0.10
≥ 50	0.68	0.93	-0.10

The nuclear distance for the Coulomb barrier is expressed as $R_c = R_d + R_j$, where $R_d = r_0^c A^{1/3}$, $r_0^c = 1.7$, and $R_j = 0$ for neutrons and protons, and $R_j = 1.2$ for d, t, ^{3}He, and ^{4}He. We note that several of these parameters are similar to the original values published by Dostrovsky *et al.* [87] but not exactly the same. Dostrovsky *et al.* [87] had $c_a = 2.2$, $b_a = 2.12$, and $r_0^c = 1.5$. Also, for the k, k_α, and c parameters shown in Table 2, they had slightly different values, shown in Table 3.

Table 3. k_p, c_p, k_α, and c_α parameters from Ref. [87]

Z_d	k_p	c_p	k_α	c_α
10	0.42	0.50	0.68	0.10
20	0.58	0.28	0.82	0.10
30	0.68	0.20	0.91	0.10
50	0.77	0.15	0.97	0.08
≥ 70	0.80	0.10	0.98	0.06

B) For fragments heavier than α ($A_j \geq 4$), the "precise" parameters of GEM2 use values by Matsuse *et al.* [93], namely: $c_j = k = 1$, $R_b = R_0(A_j) + R_0(A_d) + 2.85$ [fm], $R_c = R_0(A_j) + R_0(A_d) + 3.75$ [fm], where $R_0(A) = 1.12A^{1/3} - 0.86A^{-1/3}$.

3) The code GEM2 contains two other options for the parameters of the inverse cross sections.

A) A set of parameters due to Furihata for light ejectiles in combination with Matsuse's parameters for fragments heavier than α. Furihata and Nakamura determined k_j for p, d, t, ^{3}He, and α as follows [86]:

$$k_j = c_1 \log(Z_d) + c_2 \log(A_d) + c_3.$$

The coefficients c_1, c_2, and c_3 for each ejectile are shown in Table 4.

Table 4. c_1, c_2, and c_3 for p, d, t, ^{3}He, and α from [86]

Ejectile	c_1	c_2	c_3
p	0.0615	0.0167	0.3227
d	0.0556	0.0135	0.4067
t	0.0530	0.0134	0.4374
^{3}He	0.0484	0.0122	0.4938
α	0.0468	0.0122	0.5120

When these parameters are chosen in GEM2, the following nuclear radius R is used in the calculation of V and σ_g:

$$R = \begin{cases} 0 & \text{for } A = 1 \ , \\ 1.2 & \text{for } 2 \leq A \leq 4 \ , \\ 2.02 & \text{for } 5 \leq A \leq 6 \ , \\ 2.42 & \text{for } A = 7 \ , \\ 2.83 & \text{for } A = 8 \ , \\ 3.25 & \text{for } A = 9 \ , \\ 1.414 A_d^{1/3} + 1 & \text{for } A \geq 10 \ . \end{cases}$$

B) The second new option in GEM2 is to use Furihata's parameters for light ejectiles up to α and the Botvina *et al.* [94] parameterization for inverse cross sections for heavier ejectiles. Botvina *et al.* [94] found that σ_{inv} can be expressed as

$$\sigma_{inv} = \sigma_g \begin{cases} (1 - V/\epsilon) & \text{for } \epsilon \geq V + 1 \text{ [MeV]}, \\ \exp[\alpha(\epsilon - V - 1)]/(V + 1) & \text{for } \epsilon < V + 1 \text{ [MeV]}, \end{cases} \tag{42}$$

where

$$\alpha = 0.869 + 9.91/Z_j,$$

$$V = \frac{Z_j Z_d}{r_0^b (A_j^{1/3} + A_d^{1/3})},$$

$$r_0^b = 2.173 \frac{1 + 6.103 \times 10^{-3} Z_j Z_d}{1 + 9.443 \times 10^{-3} Z_j Z_d} \text{ [fm]}.$$

The expression of σ_{inv} for $\epsilon < V + 1$ shows the fusion reaction in the sub-barrier region. When using Eq. (42) instead of Eq. (40), the total decay width for a fragment emission can not be calculated analytically. Therefore, the total decay width must be calculated numerically and takes much CPU time.

The total decay width Γ_j is calculated by integrating Eq. (39) with respect to the total kinetic energy ϵ from the Coulomb barrier V up to the maximum possible value, $(E - Q)$. The good feature of Dostrovsky's approximation for the inverse cross sections, Eq. (40), is its simple energy dependence that allows the analytic integration of Eq. (39). By using Eq. (40) for σ_{inv}, the total decay width for the particle emission is

$$\Gamma_j = \frac{g_j \sigma_g \alpha}{\rho_i(E)} \int_V^{E-Q} \epsilon \left(1 + \frac{\beta}{\epsilon}\right) \rho_d(E - Q - \epsilon) d\epsilon. \tag{43}$$

The level density $\rho(E)$ is calculated in GEM2 according to the Fermi-gas model using the expression [95]

$$\rho(E) = \frac{\pi}{12} \frac{\exp(2\sqrt{a(E - \delta)})}{a^{1/4}(E - \delta)^{5/4}}, \tag{44}$$

where a is the level density parameter and δ is the pairing energy in MeV. As does LAHET, GEM2 uses the δ values evaluated by Cook *et al.* [96]. For those values not evaluated by Cook *et al.*, δ's from Gilbert and Cameron [95] are used instead. The simplest option for the level-density parameter in GEM2 is $a = A_d/8$ [MeV^{-1}], but the default is the Gilbert-Cameron-Cook-Ignatyuk (GCCI) parameterization from LAHET [80]:

$$a = \tilde{a} \frac{1 - e^{-u}}{u} + a_I \left(1 - \frac{1 - e^{-u}}{u}\right), \tag{45}$$

where $u = 0.05(E - \delta)$, and

$$a_I = (0.1375 - 8.36 \times 10^{-5} A_d) \times A_d,$$

$$\tilde{a} = \begin{cases} A_d/8 & \text{for } Z_d < 9 \text{ or } N_d < 9, \\ A_d(a' + 0.00917S) & \text{for others.} \end{cases}$$

For deformed nuclei with $54 \leq Z_d \leq 78$, $86 \leq Z_d \leq 98$, $86 \leq N_d \leq 122$, or $130 \leq N_d \leq 150$, $a' = 0.12$ while $a' = 0.142$ for other nuclei. The shell corrections S is expressed as a sum of separate contributions from neutrons and protons, *i.e.* $S = S(Z_d) + S(N_d)$ from [95, 96] and are tabulated in [84].

The level density is calculated using Eq. (44) only for high excitation energies, $E \geq E_x$, where $E_x = U_x + \delta$ and $U_x = 2.5 + 150/A_d$ (all energies are in MeV). At lower excitation energies, the following [95] is used for the level density:

$$\rho(E) = \frac{\pi}{12} \frac{1}{T} \exp((E - E_0)/T), \tag{46}$$

where T is the nuclear temperature defined as $1/T = \sqrt{a/U_x} - 1.5/U_x$. To provide a smooth connection of Eqs. (44) and (46) at $E = E_x$, E_0 is defined as $E_0 = E_x - T(\log T - 0.25 \log a - 1.25 \log U_x + 2\sqrt{aU_x})$.

For $E - Q - V < E_x$, substituting Eq. (46) into Eq. (44) we can calculate the integral analytically, if we neglect the dependence of the level density parameter a on E:

$$\Gamma_j = \frac{\pi g_j \sigma_g \alpha}{12 \rho_i(E)} \{I_1(t,t) + (\beta + V) I_0(t)\}, \tag{47}$$

where $I_0(t)$ and $I_1(t, t_x)$ are expressed as

$$\begin{aligned} I_0(t) &= e^{-E_0/T}(e^t - 1), \\ I_1(t, t_x) &= e^{-E_0/T} T\{(t - t_x + 1)e^{t_x} - t - 1\}, \end{aligned}$$

where $t = (E - Q - V)/T$ and $t_x = E_x/T$. For $E - Q - V \geq E_x$, the integral of Eq. (43) cannot be solved analytically because of the denominator in Eq. (44). However, it is approximated as

$$\Gamma_j = \frac{\pi g_j \sigma_g \alpha}{12 \rho_i(E)} [I_1(t, t_x) + I_3(s, s_x)e^s + (\beta + V)\{I_0(t_x) - I_2(s, s_x)e^s\}], \tag{48}$$

where $I_2(s, s_x)$ and $I_3(s, s_x)$ are given by

$$I_2(s, s_x) = 2\sqrt{2}\{s^{-3/2} + 1.5s^{-5/2} + 3.75s^{-7/2} - (s_x^{-3/2} + 1.5s_x^{-5/2} + 3.75s_x^{-7/2})e^{s_x - s}\},$$

$$\begin{aligned} I_3(s, s_x) &= (\sqrt{2}a)^{-1}[2s^{-1/2} + 4s^{-3/2} + 13.5s^{-5/2} + 60.0s^{-7/2} + 325.125s^{-9/2} \\ &- \{(s^2 - s_x^2)s_x^{-3/2} + (1.5s^2 + 0.5s_x^2)s_x^{-5/2} + (3.75s^2 + 0.25s_x^2)s_x^{-7/2} + (12.875s^2 \\ &+ 0.625s_x^2)s_x^{-9/2} + (59.0625s^2 + 0.9375s_x^2)s_x^{-11/2} + (324.8s_x^2 + 3.28s_x^2)s_x^{-13/2}\}e^{s_x - s}], \end{aligned}$$

with $s = 2\sqrt{a(E - Q - V - \delta)}$ and $s_x = 2\sqrt{a(E_x - \delta)}$.

The particle type j to be evaporated is selected in GEM2 by the Monte-Carlo method according to the probability distribution calculated as $P_j = \Gamma_j / \sum_j \Gamma_j$, where Γ_j is given by Eqs. (47) or (48). The total kinetic energy ϵ of the emitted particle j and the recoil energy of

the daughter nucleus is chosen according to the probability distribution given by Eq. (39). The angular distribution of ejectiles is simulated to be isotropic in the center-of-mass system.

According to Friedman and Lynch [97], it is important to include excited states in the particle emitted via the evaporation process along with evaporation of particles in their ground states, because it greatly enhances the yield of heavy particles. Taking this into consideration, GEM2 includes evaporation of complex particles and light fragments both in the ground states and excited states. An excited state of a fragment is included in calculations if its half-lifetime $T_{1/2}(s)$ satisfies the following condition:

$$\frac{T_{1/2}}{\ln 2} > \frac{\hbar}{\Gamma_j^*}, \tag{49}$$

where Γ_j^* is the decay width of the excited particle (resonance). GEM2 calculates Γ_j^* in the same manner as for a ground-state particle emission. The Q-value for the resonance emission is expressed as $Q^* = Q + E_j^*$, where E_J^* is the excitation energy of the resonance. The spin state of the resonance S_j^* is used in the calculation of g_j, instead of the spin of the ground state S_j. GEM2 uses the ground state masses m_j for excited states because the difference between the masses is negligible.

Instead of treating a resonance as an independent particle, GEM2 simply enhances the decay width Γ_j of the ground state particle emission as follows:

$$\Gamma_j = \Gamma_j^0 + \sum_n \Gamma_j^n, \tag{50}$$

where Γ_j^0 is the decay width of the ground state particle emission, and Γ_j^n is that of the nth excited state of the particle j emission which satisfies Eq. (49).

The total-kinetic-energy distribution of the excited particles is assumed to be the same as that of the ground-state particle. S_j^*, E_j^*, and $T_{1/2}$ used in GEM2 are extracted from the Evaluated Nuclear Structure Data File (ENSDF) database maintained by the National Nuclear Data Center at Brookhaven National Laboratory [98].

Note that when including evaporation of up to 66 particles in GEM2, its running time increases significantly compared to the case when evaporating only 6 particles, up to ^{4}He. The major particles emitted from an excited nucleus are n, p, d, t, ^{3}He, and ^{4}He. For most cases, the total emission probability of particles heavier than α is negligible compared to those for the emission of light ejectiles. Our detailed study of different reactions (see, *e.g.*, [99] and references therein) shows that if we study only nucleon and complex-particle spectra or only spallation and fission products and are not interested in light fragments, we can consider evaporation of only 6 types of particles in GEM2 and save much time, getting results very close to the ones calculated with the more time consuming "66" option. In CEM03.01, we have introduced an input parameter called **nevtype** that defines the number of types of particles to be considered at the evaporation stage. The index of each type of particle that can be evaporated corresponds to the particle arangement in Table 1, with values, *e.g.*, of 1, 2, 3, 4, 5, and 6 for n, p, d, t, ^{3}He, and ^{4}He, with succeeding values up to 66 for ^{28}Mg. All 66 particles that can possibly evaporate are listed in CEM03.01 together with their mass number, charge, and spin values in the **block data bdejc**. For all ten examples of inputs and outputs of CEM03.01 included in Appendices 1 and 2, whose results are plotted in the figures in Appendix 3, we have performed calculations taking into account only 6 types of evaporated particles (**nevtype = 6**) as well as with the "66" option (**nevtype = 66**) and we provide the corresponding computing time

for these examples in the captions to the appropriate figures shown in Appendix 3. The "6" option can be up to several times faster than the "66" option, providing meanwhile almost the same results. Therefore we recommend that users of CEM03.01 use 66 for the value of the input parameter **nevtype** only when they are interested in all fragments heavier than ^{4}He; otherwise, we recommend the default value of 6 for **nevtype**, saving computing time. Alternatively, users may choose intermediate values of **nevtype**, for example 9 if one wants to calculate the production of ^{6}Li, or 14 for modeling the production of ^{9}Be and lighter fragments and nucleons only, while still saving computing time compared to running the code with the maximum value of 66.

2.5. Fission

The fission model used in GEM2 is based on Atchison's model [88, 89] as implemented in LAHET [80], often referred in the literature as the Rutherford Appleton Laboratory (RAL) fission model, which is where Atchison developed it. In GEM2 there are two choices of parameters for the fission model: one of them is the original parameter set by Atchison [88, 89] as implemented in LAHET [80], and the other is a parameter set developed by Furihata [84, 85].

2.5.1. Fission Probability. The Atchison fission model is designed to describe only fission of nuclei with $Z \geq 70$. It assumes that fission competes only with neutron emission, *i.e.*, from the widths Γ_j of n, p, d, t, ^{3}He, and ^{4}He, the RAL code calculates the probability of evaporation of any particle. When a charged particle is selected to be evaporated, no fission competition is taken into account. When a neutron is selected to be evaporated, the code does not actually simulate its evaporation, instead it considers that fission may compete, and chooses either fission or evaporation of a neutron according to the fission probability P_f. This quantity is treated by the RAL code differently for the elements above and below $Z = 89$. The reasons Atchison split the calculation of the fission probability P_f are: (1) there is very little experimental information on fission in the region $Z = 85$ to 88, (2) the marked rise in the fission barrier for nuclei with Z^2/A below about 34 (see Fig. 2 in [89]) together with the disappearance of asymmetric mass splitting, indicates that a change in the character of the fission process occurs. If experimental information were available, a split between regions around $Z^2/A \approx 34$ would be more sensible [89].

1) $70 \leq Z_j \leq 88$. For fissioning nuclei with $70 \leq Z_j \leq 88$, GEM2 uses the original Atchison calculation of the neutron emission width Γ_n and fission width Γ_f to estimate the fission probability as

$$P_f = \frac{\Gamma_f}{\Gamma_f + \Gamma_n} = \frac{1}{1 + \Gamma_n/\Gamma_f}. \tag{51}$$

Atchison uses [88, 89] the Weisskopf and Ewing statistical model [74] with an energy-independent pre-exponential factor for the level density (see Eq. (44)) and Dostrovsky's [87] inverse cross section for neutrons and estimates the neutron width Γ_n as

$$\Gamma_n = 0.352(1.68J_0 + 1.93A_i^{1/3}J_1 + A_i^{2/3}(0.76J_1 - 0.05J_0)), \tag{52}$$

where J_0 and J_1 are functions of the level density parameter a_n and $s_n (= 2\sqrt{a_n(E - Q_n - \delta)})$,

$$J_0 = \frac{(s_n - 1)e^{s_n} + 1}{2a_n},$$

$$J_1 = \frac{(2s_n^2 - 6s_n + 6)e^{s_n} + s_n^2 - 6}{8a_n^2}.$$

Note that the RAL model uses a fixed value for the level density parameter a_n, namely

$$a_n = (A_i - 1)/8, \tag{53}$$

and this approximation is kept in GEM2 when calculating the fission probability according to Eq. (51), although it differs from the GCCI parameterization (45) used in GEM2 to calculate particle evaporation widths. The fission width for nuclei with $70 \leq Z_j \leq 88$ is calculated in the RAL model and in the GEM as

$$\Gamma_f = \frac{(s_f - 1)e^{s_f} + 1}{a_f}, \tag{54}$$

where $s_f = 2\sqrt{a_f(E - B_f - \delta)}$ and the level density parameter in the fission mode a_f is fitted by Atchison to describe the measured Γ_f/Γ_n to be [89]:

$$a_f = a_n\Big(1.08926 + 0.01098(\chi - 31.08551)^2\Big), \tag{55}$$

and $\chi = Z^2/A$. The fission barriers B_f [MeV] are approximated by

$$B_f = Q_n + 321.2 - 16.7\frac{Z_i^2}{A} + 0.218\left(\frac{Z_i^2}{A_i}\right)^2. \tag{56}$$

Note that neither the angular momentum nor the excitation energy of the nucleus are taken into account in finding the fission barriers.

2) $Z_j \geq 89$. For heavy fissioning nuclei with $Z_j \geq 89$ GEM2 follows the RAL model [88, 89] and does not calculate at all the fission width Γ_f and does not use Eq. (51) to estimate the fission probability P_f. Instead, the following semi-empirical expression obtained by Atchison [88, 89] by approximating the experimental values of Γ_n/Γ_f published by Vandenbosch and Huizenga [100] is used to calculate the fission probability:

$$\log(\Gamma_n/\Gamma_f) = C(Z_i)(A_i - A_0(Z_i)), \tag{57}$$

where $C(Z)$ and $A_0(Z)$ are constants depending on the nuclear charge Z only. The values of these constants are those used in the current version of LAHET [80] and are tabulated in Table 5 (note that some adjustments of these values have been done since Atchison's papers [88, 89] were published).

In this approach the fission probability P_f is independent of the excitation energy of the fissioning nucleus and its angular momentum.

2.5.2. Mass Distribution. The selection of the mass of the fission fragments depends on whether the fission is symmetric or asymmetric. For a pre-fission nucleus with $Z_i^2/A_i \leq 35$, only symmetric fission is allowed. For $Z_i^2/A_i > 35$, both symmetric and asymmetric fission are allowed, depending on the excitation energy of the fissioning nucleus. No new parameters were determined for asymmetric fission in GEM2.

For nuclei with $Z_i^2/A_i > 35$, whether the fission is symmetric or not is determined by the asymmetric fission probability P_{asy}

$$P_{asy} = \frac{4870e^{-0.36E}}{1 + 4870e^{-0.36E}}. \tag{58}$$

Table 5. $C(Z)$ and $A_0(Z)$ values used in GEM2

Z	$C(Z)$	$A_0(Z)$
89	0.23000	219.40
90	0.23300	226.90
91	0.12225	229.75
92	0.14727	234.04
93	0.13559	238.88
94	0.15735	241.34
95	0.16597	243.04
96	0.17589	245.52
97	0.18018	246.84
98	0.19568	250.18
99	0.16313	254.00
100	0.17123	257.80
101	0.17123	261.30
102	0.17123	264.80
103	0.17123	268.30
104	0.17123	271.80
105	0.17123	275.30
106	0.17123	278.80

2.5.2.a. Asymmetric fission. For asymmetric fission, the mass of one of the post-fission fragments A_1 is selected from a Gaussian distribution of mean $A_f = 140$ and width $\sigma_M = 6.5$. The mass of the second fragment is $A_2 = A_i - A_1$.

2.5.2.b. Symmetric fission. For symmetric fission, A_1 is selected from the Gaussian distribution of mean $A_f = A_i/2$ and two options for the width σ_M as described below.

The first option for choosing σ_M is the original Atchison approximation:

$$\sigma_M = \begin{cases} 3.97 + 0.425(E - B_f) - 0.00212(E - B_f)^2, \\ 25.27, \end{cases} \tag{59}$$

for $(E - B_f)$ below or above 100 MeV, respectively. In this expression all values are in MeV and the fission barriers B_f are calculated according to Eq. (56) for nuclei with $Z_i \leq 88$. For nuclei with $Z_i > 88$, the expression by Neuzil and Fairhall [101] is used:

$$B_f = C - 0.36(Z_i^2/A_i), \tag{60}$$

where $C = 18.8, 18.1, 18.1$, and 18.5 [MeV] for odd-odd, even-odd, odd-even, and even-even nuclei, respectively.

The second option in GEM2 for σ_M (used here) was found by Furihata[37,38] as:

$$\sigma_M = C_3(Z_i^2/A_i)^2 + C_4(Z_i^2/A_i) + C_5(E - B_f) + C_6. \tag{61}$$

The constants $C_3 = 0.122$, $C_4 = -7.77$, $C_5 = 3.32 \times 10^{-2}$, and $C_6 = 134.0$ were obtained by fitting with GEM2 the recent Russian collection of experimental fission-fragment mass distributions [102]. In this expression, the fission barriers B_f by Myers and Swiatecki [103] are used. More details may be found in Ref. [85].

2.5.3. Charge Distribution. The charge distribution of fission fragments is assumed to be a Gaussian distribution of mean Z_f and width σ_Z. Z_f is expressed as

$$Z_f = \frac{Z_i + Z_1' - Z_2'}{2}, \tag{62}$$

where

$$Z_l' = \frac{65.5A_l}{131 + A_l^{2/3}}, l = 1 \text{ or } 2. \tag{63}$$

The original Atchison model uses $\sigma_Z = 2.0$. An investigation by Furihata [85] suggests that $\sigma_Z = 0.75$ provides a better agreement with data; therefore $\sigma_Z = 0.75$ is used in GEM2 and in our code.

2.5.4. Kinetic Energy Distribution. The kinetic energy of fission fragments [MeV] is determined by a Gaussian distribution with mean ϵ_f and width σ_{ϵ_f}.

The original parameters in the Atchison model are:

$$\epsilon_f = 0.133Z_i^2/A_i^{1/3} - 11.4,$$

$$\sigma_{\epsilon_f} = 0.084\epsilon_f.$$

Furihata's parameters in the GEM, which we also use, are:

$$\epsilon_f = \begin{cases} 0.131Z_i^2/A_i^{1/3}, \\ 0.104Z_i^2/A_i^{1/3} + 24.3, \end{cases} \tag{64}$$

for $Z_i^2/A_i^{1/3} \leq 900$ and $900 < Z_i^2/A_i^{1/3} \leq 1800$, respectively, according to Rusanov *et al.* [102]. By fitting the experimental data by Itkis *et al.* [104], Furihata found the following expression for σ_{ϵ_f}

$$\sigma_{\epsilon_f} = \begin{cases} C_1(Z_i^2/A_i^{1/3} - 1000) + C_2, \\ C_2, \end{cases} \tag{65}$$

for $Z_i^2/A_i^{1/3}$ above and below 1000, respectively, and the values of the fitted constants are $C_1 = 5.70 \times 10^{-4}$ and $C_2 = 86.5$. The experimental data used by Furihata for fitting are the values extrapolated to the nuclear temperature 1.5 MeV by Itkis *et al.* [104]. More details may be found in [85].

We note that Atchison has also modified his original version using recent data and published [105] improved (and more complicated) parameterizations for many quantities and distributions in his model, but these modifications [105] have not been included either in LAHET or in GEM2.

2.5.5. Modifications to GEM2 in CEM03.01. First, we fixed several observed uncertainties and small errors in the 2002 version of GEM2 Dr. Furihata kindly sent us. Then, we extended GEM2 to describe fission of lighter nuclei, down to $Z \geq 65$, and modified it [17] so that it provides a good description of fission cross sections when it is used after our INC and preequilibrium models.

If we had merged GEM2 with the INC and preequilibrium-decay modules of CEM03.01 without any modifications, the new code would not describe correctly fission cross sections (and the yields of fission fragments). This is because Atchison fitted the parameters of his RAL fission model when it followed the Bertini INC [106] which differs from ours. In addition,

Atchison did not model preequilibrium emission. Therefore, the distributions of fissioning nuclei in A, Z, and excitation energy E^* simulated by Atchison differ significantly from the distributions we get; as a consequence, all the fission characteristics are also different. Furihata used GEM2 coupled either with the Bertini INC [106] or with the ISABEL [107] INC code, which also differs from our INC, and did not include preequilibrium particle emission. Therefore the distributions of fissioning nuclei simulated by Furihata differ from those in our simulations, so the parameters adjusted by Furihata to work well with her INC are not appropriate for us. To get a good description of fission cross sections (and fission-fragment yields) we have modified at least two parameters in GEM2 as used in CEM03.01 (see more details in [15, 16]).

The main parameters that determine the fission cross sections calculated by GEM2 are the level density parameter in the fission channel, a_f (or more exactly, the ratio a_f/a_n as calculated by Eq. (55)) for preactinides, and parameter $C(Z)$ in Eq. (57) for actinides. The sensitivity of results to these parameters is much higher than to either the fission barrier heights used in a calculation or other parameters of the model. Therefore we choose [17] to adjust only these two parameters in our merged code. We do not change the form of systematics (55) and (57) derived by Atchison. We only introduce additional coefficients both to a_f and $C(Z)$, replacing $a_f \rightarrow C_a \times a_f$ in Eq. (55) and $C(Z_i) \rightarrow C_c \times C(Z_i)$ in Eq. (57) and fit C_a and C_c to experimental proton-induced fission cross sections covered by Prokofiev's systematics [108]. No other parameters in GEM2 have been changed. For preactinides, we fit only C_a. The values of C_a found in our fit to Prokofiev's systematics are close to one and vary smoothly with the proton energy and the charge or mass number of the target. This result gives us some confidence in our procedure, and allows us to interpolate the values of C_a for nuclei and incident proton energies not analyzed by Prokofiev. For actinides, as described in [15, 16], we have to fit both C_a and C_c. The values of C_a we find are also very close to one, while the values of C_c are more varied, but both of them change smoothly with the proton energy and Z or A of the target, which again allows us to interpolate them for nuclei and energies outside Prokofiev's systematics.

We fix the fitted values of C_a and C_c in data blocks in our code and use the routines **fitafpa** and **fitafac** to interpolate to nuclei not covered by Prokofiev's systematics. We believe that such a procedure provides a reasonably accurate fission cross section calculation, at least for proton energies and target nuclei not too far from the ones covered by the systematics.

2.6. The Fermi Break-Up Model

After calculating the coalescence stage of a reaction, CEM03.01 moves to the description of the last slow stages of the interaction, namely to preequilibrium decay and evaporation, with a possible competition of fission. But as mentioned above, if the residual nuclei have atomic numbers with $A < 13$, CEM03.01 uses the Fermi break-up model [109] to calculate their further disintegration instead of using the preequilibrium and evaporation models.

All formulas and details of the algorithms used in the version of the Fermi break-up model developed in the former group of Prof. Barashenkov at Joint Institute for Nuclear Research (JINR), Dubna, Russia and released in CEM03.01 may be found in [38]. All the information needed to calculate the break-up of an excited nucleus is its excitation energy U and the mass and charge numbers A and Z. The total energy of the nucleus in the rest frame will be $E = U + M(A, Z)$, where M is the mass of the nucleus. The total probability per unit time for a nucleus to break up into n components in the final state (*e.g.*, a possible residual nucleus,

nucleons, deuterons, tritons, alphas, *etc.*) is given by

$$W(E,n) = (V/\Omega)^{n-1}\rho_n(E), \tag{66}$$

where ρ_n is the density of final states, V is the volume of the decaying system and $\Omega = (2\pi\hbar)^3$ is the normalization volume. The density $\rho_n(E)$ can be defined as a product of three factors:

$$\rho_n(E) = M_n(E)S_nG_n. \tag{67}$$

The first one is the phase space factor defined as

$$M_n(E) = \int_{-\infty}^{+\infty}\cdots\int_{-\infty}^{+\infty}\delta\left(\sum_{b=1}^{n}\vec{p}_b\right)\delta\left(E-\sum_{b=1}^{n}\sqrt{p^2+m_b^2}\right)\prod_{b=1}^{n}d^3p_b, \tag{68}$$

where $\vec{p}_b$ are fragment momenta. The second one is the spin factor

$$S_n = \prod_{b=1}^{n}(2s_b+1), \tag{69}$$

which gives the number of states with different spin orientations. The last one is the permutation factor

$$G_n = \prod_{j=1}^{k}\frac{1}{n_j!}, \tag{70}$$

which takes into account identical particles in the final state (n_j is the number of components of j-type particles and k is defined by $n = \sum_{j=1}^{k} n_j$). For example, if we have in the final state six particles ($n = 6$) and two of them are alphas, three are nucleons, and one is a deuteron, then $G_6 = 1/(2!3!1!) = 1/12$. For the non-relativistic case, the integration in Eq. (68) can be evaluated analytically (see, *e.g.*, [38]) and the probability for a nucleus to disintegrate into n fragments with masses m_b, where $b = 1, 2, 3, \ldots, n$ is

$$W(E,n) = S_nG_n\left(\frac{V}{\Omega}\right)^{n-1}\left(\frac{1}{\sum_{b=1}^{n}m_b}\prod_{b=1}^{n}m_b\right)^{3/2}\frac{(2\pi)^{3(n-1)/2}}{\Gamma(3(n-1)/2)}E^{(3n-5)/2}, \tag{71}$$

where $\Gamma(x)$ is the gamma function.

The angular distribution of n emitted fragments is assumed to be isotropic in the c.m. system of the disintegrating nucleus and their kinetic energies are calculated from momentum-energy conservation. The Monte-Carlo method is used to randomly select the decay channel according to probabilities defined by Eq. (71). Then, for a given channel, CEM03.01 calculates kinematical quantities for each fragment according to the n-body phase space distribution using Kopylov's method [110]. Generally, CEM03.01 considers formation of fragments only in their ground and those low-lying states which are stable for nucleon emission. However, several unstable fragments with large lifetimes: ^{5}He, ^{5}Li, ^{8}Be, ^{9}B, *etc.* are considered as well. The randomly chosen channel will be allowed to decay only if the total kinetic energy E_{kin} of all fragments at the moment of break-up is positive, otherwise a new simulation will be performed and a new channel will be selected. The total kinetic energy E_{kin} can be calculated according to the equation:

$$E_{kin} = U + M(A,Z) - E_{Coulomb} - \sum_{b=1}^{n}(m_b+\epsilon_b), \tag{72}$$

where m_b and ϵ_b are masses and excitation energies of fragments, respectively, and $E_{Coulomb}$ is the Coulomb barrier for the given channel. It is approximated by

$$E_{Coulomb} = \frac{3}{5}\frac{e^2}{r_0}\left(1+\frac{V}{V_0}\right)^{-1/3}\left(\frac{Z^2}{A^{1/3}} - \sum_{b=1}^{n}\frac{Z_b^2}{A_b^{1/3}}\right), \tag{73}$$

where A_b and Z_b are the mass number and the charge of the b-th particle of a given channel, respectively. V_0 is the volume of the system corresponding to normal nuclear density and $V = kV_0$ is the decaying system volume (we assume $k = 1$ in CEM03.01).

Thus, the Fermi break-up model used here has only one free parameter, V or V_0, the volume of decaying system, which is estimated as follows:

$$V = 4\pi R^3/3 = 4\pi r_0^3 A/3, \tag{74}$$

where we use $r_0 = 1.4$ fm. This parameter is used to calculate the quantity **bl** in the routine **gitab**.

There is no limitation on the number n of fragments a nucleus may break up into in our version of the break-up model, in contrast to implementations in other codes, such as $n \leq 3$ in MCNPX, or $n \leq 7$ in LAHET.

2.7. Total Reaction Cross Sections (Normalization)

CEM03.01 (just like many other INC-based models) calculates the total reaction cross section, σ_{in}, by the Monte-Carlo method using the geometrical cross section, σ_{geom}, and the number of inelastic, N_{in}, and elastic, N_{el}, simulated events, namely: $\sigma_{in} = \sigma_{geom}N_{in}/(N_{in} + N_{el})$. The value of the total reaction cross section calculated this way is printed in the beginning of the CEM03.01 output labeled as *Monte Carlo inelastic cross section*. This approach provides a good agreement with available data for reactions induced by nucleons, pions, and photons at incident energies above about 100 MeV, but is not reliable enough at energies below 100 MeV (see, *e.g.*, Fig. 4 and Ref. [16] and Figs. 4 and 5 in Ref. [19]).

To address this problem, we have incorporated [16] into CEM03.01 the NASA systematics by Tripathi *et al.* [111] for all incident protons and for neutrons with energies above the maximum in the NASA reaction cross sections, and the Kalbach systematics [112] for neutrons of lower energy. For reactions induced by monochromatic and bremsstrahlung photons, we incorporate into CEM03.01 [19] the recent systematics by Kossov [113]. Details on these systematics together with examples of several total inelastic cross sections calculated with them compared with available experimental data may be found in [16, 19]. Our analysis of many different reactions has shown that at incident energies below about 100 MeV these systematics generally describe the total inelastic cross sections better that the Monte-Carlo method does, and no worse than the Monte-Carlo method at higher energies. Therefore we choose these systematics as the default for normalization of all CEM03.01 results. The total reaction cross sections calculated by these systematics are printed in the CEM03.01 output labeled as *Inelasic cross section used here*. (Of course, users may renormalize all the CEM03.01 results to the Monte-Carlo total reaction cross sections by making a small change to the code in the subroutine **typeout**).

3. Storage of Simulation Results

Although we have extended significantly the variety of characteristics printed in the CEM03.01 output as compared to its predecessors, no predetermined outputs can satisfy the needs of all

users. Therefore we provide below the necessary information to help users to modify the output according to their specific needs.

Almost all information about all particles, light fragments, and residual nuclei (there may be two residual nuclei in the case of fission) from every inelastic simulated event is stored in two arrays, **spt(5,150)** and **parz(6,150)**. The second index of both these arrays shows the serial number **k** of a particular particle or nucleus stored in these arrays. These arrays contain physical information only for $1 < k \leq k_{max}$, where k_{max} is the number of all products from a particular inelastic event; all their elements for $k > k_{max}$ are equal to zero. For historical reasons, there is some redundancy in the arrays; for example Θ, T_k, and Z are available from more than one array element. The contents of the arrays **spt(i,k)** and **parz(j,k)** are as follows (all values are in the laboratory system; all energies and masses are in MeV; all angles are in degrees):

1) spt(1,k) = $\sin\Theta$ of particle k
2) spt(2,k) = $\cos\Theta$ of particle k
3) spt(3,k) = T_k, kinetic energy of particle k
4) spt(4,k) = electric charge (Z) of particle k
5) spt(5,k) = rest mass of particle k

1) parz(1,k) = particle type (index), defined as:
   - 1 = n
   - 2 = p
   - 3 = d
   - 4 = t
   - 5 = ^{3}He
   - 6 = ^{4}He
   - 7 = π^-
   - 8 = π^0
   - 9 = π^+
   - 1000Z+N = A + 999Z, for products heavier than ^{4}He

2) parz(2,k) = T_k, kinetic energy of particle k
3) parz(3,k) = Θ of particle k
4) parz(4,k) = φ of particle k
5) parz(5,k) = reaction mechanism type (index), as following:
   - if < 100, the "k" particle was emitted at the INC stage of reaction; the value stored here is equal to the number of successive interaction acts n_c before emission of particle k (see more details in [22])
   - = 100 for preequilibrium emission
   - = 200 for particles produced via coalescence
   - = 1000 for evaporation from spallation residue (and for residue itself)
   - = 1500 for Fermi breakup
   - = 2000 for evaporation from fission product (and for fragments themselves)

6) parz(6,k) = electric charge of particle k.

The code does not store the value of k_{max} for each simulated event. To retrieve information about the products from an inelastic event, users should read (in **vlobd**) either array in a loop over k from 1 to 150 looking, *e.g.*, at the mass of products stored in **spt(5,k)** until they get

for $k = (k_{max} + 1)$ a zero value, indicating that there are no more products from this event, thereby determining k_{max}.

CEM03.01 does not describe emission of γ's from residual nuclei with an excitation energy below the threshold of particle evaporation, *i.e.* a few MeV. (It neglects also emission of γ's with higher energy, as a competitor to evaporation and preequilibrium-particle emission, since the cross sections of such processes are insignificant compared to those of particle emission.) When using CEM03.01 as an event generator in a transport code, it should be supplemented by a module with the same function as the **PHT** code from LAHET [80], which can describe the cooling of such excited nuclei via γ emission. For this, one needs to know the excitation energy of all residual nuclei provided by CEM03.01.

Note that in the case of Fermi break-up, we have no excited residual nuclei; it is assumed that all fragments are already in their ground states (unstable fragments are allowed to decay before filling the arrays **spt** and **parz**. For such events, we do not have to look for a residual nucleus to deposit its excitation energy via γ-emission. To know if this is the case, we have to look at the value of the parameter **fusion** stored in the common block: **common /dele/ sfu, wf, fusion, sigfw**. If **fusion = 0**, this is an event that ended with Fermi break-up and we have no excited residual nuclei.

If **fusion = -1**, this is an event without Fermi break-up and without fission and we have only one residual nucleus. Its excitation energy, **ut** (in MeV), is stored in the common block: **common /bl1003/ ut, at, zt**.

If **fusion = +1**, this is an event that ended with fission, so that we have two excited residual nuclei. Their excitation energy (in MeV) are equal to **ex12(1)** and **ex12(2)**, their mass and charge numbers are equal to **af12(1)** and **af12(2)**, and **zf12(1)** and **zf12(2)**, respectively, and their kinetic energy (in MeV) are equal to **tf12(1)** and **tf12(2)**, correspondingly. All this information is stored in the common block: **common /ifiss/ af12(2), zf12(2), tf12(2), ex12(2), bf12(2,3), ifiss**. In the case of fission, the parameter **ifiss** has a values of 1 (**ifiss = 0** for events without fission); its value can be also used to determine if fission occurred in a particular event, in addition to checking the parameter **fusion**.

Unfortunately, GEM2 as used in CEM03.01 does not consider at all the angular momenta of evaporated particles, the residual nucleus, and fission fragments. This is why the code does not provide values of angular momenta for the final reaction products. This is one problem we plan to address in the next version of CEM. We do calculate angular momenta of excited nuclei after the cascade and preequilibrium stages of reactions. After the cascade stage, their values (in units of $\hbar$), $L_x = amnucl(1)$, $L_y = amnucl(2)$, and $L_z = amnucl(3)$ are provided as output of the **subroutine cascad (enext, atwght, charge, pnucl, amnucl, kstart, obr, nel)**. After the preequilibrium stage, their values $L_x = angmom(1)$, $L_y = angmom(2)$, and $L_z = angmom(3)$ are stored in the common block: **common /resid/ angmom(3), v(3), remn**. These values are used to build several distributions printed in the CEM03.01 output. They are presently of only "academic" interest to study nuclear reactions but are not ready for applications, as GEM2 does not consider angular momenta and CEM03.01 does not provide angular momenta for the final reaction products.

With this information and our routines **vlobd**, **resdist**, **opandis**, and **disnmul** as examples of how to build the histograms of needed characteristics and our routines **prinp** and **typeout** that write them into our output file, users should be able to write their own customized output tables.

4. Input File

CEM03.01 has four data files: **mass.tbl, level.tbl, gamman.tbl, and level.tbl**, which should not be changed by users. It uses one user-specified input file called **cem03.inp** that must be prepared to define a calculation. It has 24 obligatory lines that describe the reaction to be calculated and the desired format of the output, and can contain also up to 10 lines of text with comments to be printed near the beginning of the output file.

4.1. 1st Input Line

This line defines the name of an auxiliary output file where some diagnostic information is printed (no results of calculations are stored in this file; the information printed in it is very useful if we uncounter an unexpected problem in calculation of a specific reaction, like a "bug"). This name may contain up to 30 characters.

4.2. 2nd Input Line

This line defines the name for the CEM03.01 output file, again with up to 30 characters.

4.3. 3rd to 5th Input Lines

The 3rd line defines the projectile. Use prot for protons, neut for neutrons, pipl for π^+, pimi for π^-, pize for π^0, gamm for monochromatic γ's, and gamb for bremsstrahlung γ's. The 4th and 5th lines continue the description of the line 3 input, which is too long to fit entirely on the 3rd line.

4.4. 6th Input Line

This line defines the projectile kinetic energy in MeV, t0mev, for the case where we need to calculate only one energy and the reaction is not induced by bremsstrahlung γ's. When we need to calculate a reaction at several energies (with a step defined by the 10th line and the final energy by the 11th line), t0mev is the initial energy. For reactions induced by bremsstrahlung (**only**), we recomend using 30.0 on this line; it is the value of E_{min}, the minimum energy of the bremsstrahlung γ spectrum to be considered in calculations (above the GDR region), as described in [19].

4.5. 7th Input Line

This line defines the mass number of the target nucleus.

4.6. 8th Input Line

This line defines the atomic number of the target nucleus.

4.7. 9th Input Line

This line defines the number of inelastic events to be simulated for this particular reaction. The appropriate value for this number depends on the characteristics of a reaction in which we are interested, as well as on the target and projectile: To calculate only fission cross sections of actinides or the mean multiplicities of nucleons from any reaction, 5000 inelastic events would be more than enough. To get double differential spectra of particles with small energy and angle bins, we may need to simulatee 1,000,000 inelastic events. To have statisfactory statistics for the cross sections for production of isotopes in regions between spallation and fission and between fission and fragmentation (whose yields are very small) and for their mean energies and angles of emission, we may need to simulate 10,000,000 or even more inelastic events. The 10 examples shown in Appendix 3 may give guidance on choosing this number for different reactions.

4.8. 10th Input Line

This line defines the step of the projectile kinetic energy in MeV for calculating several incident energies in a single run. For only one incident energy, use a negative number, for example -5.0 for this parameter.

4.9. 11th Input Line

This line defines the maximum (final) kinetic energy of the projectile in MeV when we calculate a reaction at several energies, with a step defined on line 10 and the initial energy on line 6. Alternatively, for reactions induced by bremsstrahlung photons only, this parameter defines the end-point (maximum) energy in MeV of the bremsstrahlung γ spectrum, usually denoted in the literature as E_0; see details on bremsstrahlung reactions in [19] and in our Example 10 below.

Important Hint:

The code stops at energies higher than this number, therefore users should check that this number is not less than the initial projectile energy defined by the line 6, otherwise CEM03.01 will not run.

Useful Hints:

When we need to calculate only one incident energy, *e.g.*, 100 MeV, we suggest using for the t0mev parameter on the 6th line the value 100.0, for the parameter dt0 on the 10th line, any negative number, like -5.0, and for the parameter t0max on this line, any number bigger than 100.0, *e.g.*, 5000.0.

If we need to calculate a reaction at three incident energies, *e.g.*, 100, 200, and 300 MeV, use for t0mev on the 6th line the value 100.0, for the parameter dt0 on the 10th line, use the value 100.0, and for t0max on this line, use the values 300.5: The code will run in a loop at 100, 200, and 300 MeV, and will stop after 300 MeV, as with the incident energy step of 100 MeV the next incident energy would be 400 MeV, which is higher than 300.5 MeV given by the t0max on this line, so the code will stop.

4.10. 12th Input Line

This line defines the step-size $\Delta\Theta$ in degrees in the ejectile angular spectra $d\sigma/d\Omega$ [mb/sr]. It is used only when we calulate $d\sigma/d\Omega$, which is selected by the input parameter mang defined on the 18th line having the value 1 or 2.

4.11. 13th Input Line

This line defines whether we wish or not to calculate the angle-integrated energy spectra of ejectiles $d\sigma/dT$ in mb/MeV. Use 0 for the parameter mspec on this line to not calculate the energy spectra, and 1 to calculate them. When we use mspec = 1, the code provides $d\sigma/dT$ for particles produced by all nuclear-reaction mechanisms considered in CEM03.01 labeled as Total, as well as their components from particles emitted at the intranuclear cascade (or produced via coalescence, in the case of complex particles), preequilibrium, and evaporation stages of reactions labeled as Cascade, Precompound, and Total Evaporation, respectively. Particles produced via Fermi break-up are included into the Total Evaporation component; in case of evaporation from heavy nuclei that fission, this component includes particles evaporated both before fission (often called in the literature "pre-fission") and evaporated from fission fragments after fission (called in the literature "post-fission"). At the end of each spectrum, its integral over the entire energy range (*i.e.* particle "yield" in mb) is provided, labeled as Integrated.

There is an additional option for this parameter, namely having it equal to 2 instead of 1, to study in more detail fission reactions: If we choose the value 2 for mspec, the code will provide energy spectra of ejectiles only from events that do fission (particles from events of this reaction that do not fission will be not included into $d\sigma/dT$ calculated with the option mspec = 2) and the normalization of spectra is made to the fissioning events only and not to the total number of simulated events as is done for mspec = 1. These spectra do not represent the spectra of all emitted particles and they can not be compared directly with the measured spectra that include all particles produced from events both with and without fission. This option is useful for comparing to coincidence experiments, where particles are measured in coincidence with fission fragments.

In adition to $d\sigma/dT$ in mb/MeV, the option mspec = 2 provides also spectra of particles normalized to one (*i.e.* probability spectra), often used in the literature when studying fission induced by low energy projectiles. The option mspec = 2 provides separately "pre-fission" and "post-fission" components of particle spectra labeled as Prefission and Fission Fragments, in addition to the Total, Cascade, Precompound, and Total Evaporation components of the spectra.

4.12. 14th Input Line

This line defines whether we wish or not to calculate secondary-particle multiplicities, yields (in mb), and mean kinetic energies (in MeV). If we use 0 for the parameter mpyld on this line, these charactertistics will not be calculated. When mpyld = 1, these characteristics will be calculated and printed in a table near the beginning of the output. This table contains the total (labeled as T) mean multiplicity, yield, and kinetic energy of n, p, d, t, ^{3}He, ^{4}He, π^-, π^0, and π^+, when these values are non-zero, as well as their components from cascade, preequilibrium, evaporation from events without fission (spallation), evaporation events that will fission just before fission, evaporation from fission fragments, the sum of all evaporated particles, and from coalescence, labeled as C, P, Sp, Pf, F, E, and Co, respectively. Particles produced via Fermi Break-up are included in "evaporation" (E). As in the case of the parameter mspec defined on the 13th line, there is an aditional option for this parameter, mpyld = 2, to study in more detail fission. In this case, only events with fission will be consided and the mean multiplicities, yields, and kinetic energies of particles produced only in fission events will be included in this table; their normalization is done to the fission events only. As mentioned above about particle spectra, these characteristics obtained with the option mpyld = 2 can be compared directly

only with models or data from coincidence measurements which select fission reactions.

4.13. 15th Input Line

This line defines whether we wish or not to calculate cross sections of 192 possible specific "channels" of reactions that contribute to the production of final isotopes. Knowledge of excitation functions for such "channels" are of mainly "academic" interest rather than for applications, as it splits the conributions to the production of a specific final isotope into different reaction channels. The γ-spectrometry method frequently used to measure nuclide production cross sections from, let us say, a photonuclear reaction on a target [Z,A], provides us only the cross section (yield) of a final isotope, *e.g.*, [(Z-y),(A-x-y)] considering it to be produced via a (γ,xnyp) reaction, without any information about the emitted x neutrons and y protons; have they been emitted as independent nucleons or contained in emitted complex particles? The option mchy = 1 of CEM03.01 defined on this line helps us to address this question, as it provides cross sections for different possible "channels" of a reaction that lead to the same final product nuclide. The option mchy = 1 requires significant additional computing time, so we recommend using it only when the contributions to the production of final isotopes from different processes need to be studied in detail. When not needed, use the faster option mchy = 0, in order to ignore such "channel" cross sections.

4.14. 16th Input Line

This line defines whether we wish or not to calculate cross sections ("yields") in mb of all nuclide products. The option misy = 0 does not provide such yields.

With the option misy = 1, CEM03.01 calculates yields of all isotopes produced in a reaction, as well as the integrated mass and charge yields in mb and the mass and charge distributions of their mean kinetic energies and their variances in MeV. In all cases, lines with all zero values not written to the output file.

The option misy = 2 provides the same as misy = 1, plus:

it provides also yields of all nuclei, mass and charge distributions of cross sections and of mean kinetic energy of products emitted separately in the forward and backward directions in the laboratory system;

the average kinetic energy in MeV of all products;

mass yield and mean and variance of the laboratory emission angle in degrees as functions of the product mass number;

mean and variance of the z-velocity (parallel to the projectile beam) of all products in units of v/c and the ratio of the mass yields of products emitted in the forward direction in the laboratory system to those for the backward direction (the F/B ratio) and its variance as functions of product mass numbers;

similar distributions as functions of the atomic number of the products.

Finally, the most detailed option misy = 3 provides the same as misy = 2, plus:

mass distributions of excited nuclei after the cascade and preequilibrium stages of a reaction and distributions at the beginning of the evaporation stage of nuclei that will not fission, of ones that will fission, and of all nuclei just prior to fission, after any possible prefission evaporation;

similar distributions of nuclei as functions of their atomic number;

excitation energy distributions in 1/MeV of nuclei after the cascade and preequilibrium stages and distributions at the beginning of the evaporation stage of nuclei that will not fission,

of ones that will fission, and of all nuclei just prior to fission;

similar distributions for linear momentum of nuclei in 1/MeV/c;

similar distributions for angular momentum of nuclei in $1/\hbar$;

distrubutions of fission-fragment opening angles in the laboratory system in 1/degrees in different bins of neutron multiplicity $< n >$, namely, for $< n >= 0 - 5$, $< n >= 6 - 8$, $< n >= 9 - 12$, $< n >= 13 - 15$, $< n >= 16 - 19$, and $< n >\geq 20$, respectively;

neutron-multiplicity probabilities for all events, as well as for the emission of neutrons only during the cascade and preequilibrium stages of reaction, and for evaporation from events without fission (labeled in the output as Evap. res., from evaporation before fission for events that will fission (labeled in the output as Pre-fiss, and from evaporation from fission fragments after fission (labeled in the output as Post-fiss).

At the end of tables with these distributions, the mean values (labeled as $< ... >$), their standard deviations (labeled as St dv), and the corresponding normalization factor (labeled as norm.) are printed in the output, respectively.

4.15. 17th Input Line

The parameter mdubl on this line defines whether to calculate or not double-differential spectra of ejectiles $d^2\sigma/(dTd\Omega)$ in mb/(MeV sr). Use for the parameter mdubl values of 0, 1, or 2 to not calculate, to calculate, or to calculate only for fission events $d^2\sigma/(dTd\Omega)$ of ejectiles, in the same manner as described above for the parameter mspec defined on the 13th line.

4.16. 18th Input Line

The parameter mang on this line defines whether to calculate or not energy-integrated angular spectra of ejectiles $d\sigma/d\Omega$ in mb/sr. Use for the parameter mang values of 0, 1, or 2 to not calculate, to calculate, or to calculate only for fission events $d\sigma/d\Omega$ of ejectiles, in the same manner as described above for the parameter mspec defined on the 13th line.

4.17. 19th Input Line

The parameters ipar1 and ipar2 on this line define the range of the ejectile types for calculations of spectra $d\sigma/dT$, $d\sigma/d\Omega$, and $d^2\sigma/(dTd\Omega)$, with the notation of the particle "type" (ID) as described above: 1, 2, 3, 4, 5, 6, 7, 8, and 9 for n, p, d, t, ^{3}He, ^{4}He, π^-, π^0, and π^+, respectively. Note that the code does not allow us to calculate electively spectra of only several particles when their ID are not ordered: *E.g.*, if we need spectra of only n, d, and π^+, we will have to calulate in a loop spectra of all 9 types of particles, using ipar1 = 1 and ipar1 = 9. To calculate spectra (and multiplicities) of fragments heavier than ^{4}He, users will have to modify the writing to the output file for themselves.

4.18. 20th Input Line

This line defines up to 10 angle bins $\Theta(j)$ from $\Theta_1(j)$ to $\Theta_2(j)$ in degrees for double-differential spectra calculations (when mdubl = 1). The code calculates in a loop either 10 spectra starting with $j = 1$ to $j = 10$, or until a value of $\Theta_1(j)$ read from this line is negative. If we need, *e.g.*, $d^2\sigma/(dTd\Omega)$ for only two angles ($\Theta(1) < \Theta(2)$), define on this line the corresponding values of $\Theta_1(1)$, $\Theta_2(1)$, and $\Theta_1(2)$, $\Theta_2(2)$, and use any negative number for $\Theta_1(3)$,

like -5.0, then include values for the rest of $\Theta_1(j)$, $\Theta_2(j)$, up to $j = 10$ as well, since the code expects to encounter all 20 values.

4.19. 21st Input Line

This line defines energy bins $\Delta T(j)$ for four energy regions j, from $T_1(j)$ to $T_2(j)$ ($j = 1, 4$) in MeV for angle-integrated energy spectra $d\sigma/dT$ and double-differential spectra $d^2\sigma/(dTd\Omega)$ calculations (when mspec ≥ 1 or/and mdubl ≥ 1). Take care that the whole possible energy region is covered by the four energy regions chosen on this line, so that $T_2(1) = T_1(2)$, $T_2(2) = T_1(3)$, and $T_2(3) = T_1(4)$, as is done in our examples of inputs shown in Appendix 1. It is also important that the value of $T_2(4)$ be as large as the maximum energy particle to be encountered.

4.20. 22nd Input Line

The parameter nevtype on this line defines the number of up to 66 different types of particles to be possibly evaporated, as described above in Section 2.4. We recommend using for the parameter nevtype on this line values in the range 7–66 only when fragments heavier than ^{4}He, need to be considered; otherwise, we suggest using a default value of 6, saving much computing time. See more details at the end of Section 2.4.

4.21. 23rd Input Line

The parameter nh on this line defines the number of up to 10 lines of commentary text to be printed in the beginning of the output as a header describing the given calculation. It could be zero, if users do not need to have any comments in their output.

4.22. Input Lines from 24 to 33

Here, users put up to 10 lines of commentary text to be printed in the beginning of the output as a header, as described above (up to 72 characters per line).

4.23. Input lines from 23 + nh + 1 to ...

All lines from 3 to 23 + nh may be repeated (with appropriately changed input values) as many times as desired in order to study other energy ranges, target isotopes, projectiles, *etc.*

4.24. The Last Input Line

On the last line of the input should be: stop.

5. Output File

The CEM03.01 output has plenty of captions and descriptions of all quantities printed, therefore we hope that users will have few problems in understanding it, given the information in the previous Section. We mention here only a few points about the output.

In the beginning of the output, all CEM03.01 input parameters and appoximations for the level-density parameters used at the preequilibrium stage of the reaction are listed.

Then the total reaction cross section is listed, as described in Section 2.7.

The total number of inelastic and elastic simulated events are printed. Note that the elastic cross section printed after that is only to give users an idea about its order of magnitude: CEM03.01, like many other INC-based models does not pretend to describe reliably elastic cross sections.

Following this are several tables with statistical information about the mean values of the excitation energy, charge, mass, and angular momentum of nuclei after the cascade and preequilibrium stages of reactions, as well as similar distributins (plus a little more) for fissioning nuclei. Possible negative values for the minimum excitation energy of nuclei after the INC labeled as E*min may occur for some reactions. This does not indicate that CEM03.01 met a problem in calculating that specific reaction or something was wrong. A negative "excitation energy" may appear in occasional cases at the beginning of the preequilibrium stage of a reaction, when the real excitation energy of a nucleus after the INC is positive but very small. We subtract from it at the preequilibrium stage the pairing energy and the rotational energy (which are ignored by the classical INC). These rare cases are handled internally by counting them the same as any other case exiting from the cascade with an excitation energy less than a particle binding energy (listed as a residual nucleus with only cascade particles in the particle arrays **spt** and **parz**).

Following these tables, the fission probability (labeled as Fissility) and the fission crosss section in mb, if the target was heavy enough to fission, are presented. CEM03.01 calculates the fission probability and cross section in two different ways: by the direct Monte-Carlo method and using the statistical weight-function method (see details in [9]), and results from both methods are printed in the output. All the yields of all products are calculated in CEM03.01 using the direct Monte-Carlo method, using the fission cross section calculated by this method. Therefore, we suggest that users use the fission probability and cross section calculated by the direct Monte-Carlo method, if the statistics of the calculation are high enough so that the fission cross section provided by the Monte-Carlo method is not too small, and greater than its statistical error printed in the output. At low incident energies, for reactions on light preactinide nuclei, the fission cross sections calculated by the Monte-Carlo method may be too small (or even zero), with big statistical errors. In such cases, users should instead use the fission probabilities and cross sections calulated by the statistical weight-function method.

We would like to emphasize that all results provided by CEM03.01 for reactions induced by bremsstrahlung γ's are normalized to the so-called "equivalent γ quanta", as is usually done in the literature (see details on bremsstrahlung reactions in [19]). This point is mentioned in the CEM03.01 output, but the situation is different from all other types of reactions considered by the code, so we wish to again remind users about this. The output and the figures for Example 10 in the Appendices illustrate this difference.

Finally, for the input parameters mspec, mpyld, mdubl, and mang having the value 2 instead of 1, the spectra, particle multiplicities and the mean kinetic energies printed in the output are for events with fission only but not for all simulated events.

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We ask users of CEM03.01 to contact us (specifically, SGM and AJS) using the E-mail addresses provided on the first page in case of questions on our code. We thank them in advance for comments and information about possible problems in using the code or "bugs" they will find.

References

[1] K. K. Gudima, S. G. Mashnik, and V. D. Toneev, "Cascade-Exciton Model of Nuclear Reactions: Model Formulation," JINR Communication P2-80-774, Dubna (1980); "Cascade-Exciton Model of Nuclear Reactions: Comparison with Experiment," JINR Communication P2-80-777, Dubna (1980).

[2] K. K. Gudima, S. G. Mashnik, and V. D. Toneev, "Cascade-Exciton Model of Nuclear Reactions," Nucl. Phys. **A401** (1983) 329–361.

[3] V. S. Barashenkov and V. D. Toneev, *Interaction of High Energy Particle and Nuclei with Atomic Nuclei*, Atomizdat, Moscow (1972).

[4] V. S. Barashenkov, A. S. Iljinov, N. M. Sobolevskii, and V. D. Toneev, "Interaction of Particles and Nuclei of High and Ultrahigh Energy with Nuclei," Usp. Fiz. Nauk **109**, (1973) 91–136 [Sov. Phys. Usp. **16** (1973) 31–52].

[5] K. K. Gudima, G. A. Ososkov, and V. D. Toneev, "Model for Pre-Equilibrium Decay of Excited Nuclei," Yad. Fiz. **21** (1975) 260–272 [Sov. J. Nucl. Phys. **21** (1975) 138–143].

[6] S. G. Mashnik and V. D. Toneev, "MODEX—the Program for Calculation of the Energy Spectra of Particles Emitted in the Reactions of Pre-Equilibrium and Equilibrium Statistical Decays," JINR Communication P4-8417, Dubna (1974).

[7] T. Gabriel, G. Maino, and S. G. Mashnik, "Analysis of Intermediate Energy Photonuclear Reactions," JINR Preprint E2-94-424, Dubna (1994); Proc. XII Int. Sem. on High Energy Phys. Problems *Relativistic Nuclear Physics & Quantum Chromodynamics*, Dubna, Russia, September 12–17, 1994, Eds. A. M. Baldin and V. V. Burov, Dubna, JINR Publish Department, 1997, JINR E1,2-97-79, pp. 309–318.

[8] S. G. Mashnik, "Cascade-Exciton Model Analysis of Excitation Functions for Proton-Induced Reactions at Low and Intermediate Energies, Izv. RAN, Ser. Fiz. **60** (1996) 73–84 [Bull. of the Russian Acad. Sci., Physics, **60** (1996) 58–67].

[9] S. G. Mashnik, "User Manual for the Code CEM95," (1995), Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Reserach, Dubna, Russia; OECD Nuclear Energy Agency Data Bank, Le Seine Saint-Germain 12, Boulevard des Iles, F-92130 Issy-les-Moulineax, Paris, France http://www.nea.fr/abs/html/iaea1247.html;
Radiation Safety Information Computational Center (RSICC), Oak Ridge, USA, http://www-rsicc.ornl.gov/codes/psr/psr3/psr-357.html.

[10] M. Blann, H. Gruppelar, P. Nagel, and J. Rodens, *International Code Comparison for Intermediate Energy Nuclear Data*, NEA OECD, Paris (1994).

[11] P. Nagel, J. Rodens, M. Blann, and H. Gruppelar, "Intermediate Energy Nuclear Reaction Code Intercomparison: Application to Transmutation of Long-Lived Reactor Wastes," Nucl. Sci. Eng. **119** (1995) 97–107.

[12] S. G. Mashnik and A. J. Sierk, "Improved Cascade-Exciton Model of Nuclear Reactions," LANL Report LA-UR-98-5999 (1998); E-print: nucl-th/9812069; Proc. SARE-4, Knoxville, TN, September 13–16, 1998, edited by Tony A. Gabriel (ORNL, 1999), pp. 29–51.

[13] A. J. Sierk and S. G. Mashnik, "Modeling Fission in the Cascade-Exciton Model," LANL Report LA-UR-98-5998 (1998); E-print: nucl-th/9812070; Proc. SARE-4, Knoxville, TN, September 13–16, 1998, edited by Tony A. Gabriel (ORNL, 1999), pp. 53–67.

[14] S. G. Mashnik and A. J. Sierk, "CEM2k—Recent Developments in CEM," Proc. AccApp00, November 12–16, 2000, Washington, DC (USA), American Nuclear Society, La Grange Park, IL, 2001, pp. 328–341; E-print: nucl-th/0011064.

[15] S. G. Mashnik, K. K. Gudima, and A. J. Sierk, "Merging the CEM2k and LAQGSM Codes with GEM2 to Describe Fission and Light-Fragment Production," LANL Report LA-UR-03-2261, Los Alamos (2003); E-print: nucl-th/0304012; Proc. SATIF-6, April 10–12, 2002, Stanford Linear Accelerator Center, CA 94025, USA, (NEA/OECD, Paris, France, 2004), pp. 337–366.

[16] Stepan G. Mashnik, Arnold J. Sierk, and Konstantin K. Gudima, "Complex Particle and Light Fragment Emission in the Cascade-Exciton Model of Nuclear Reactions," LANL Report LA-UR-02-5185, Los Alamos (2002); E-print: nucl-th/0208048.

[17] M. Baznat, K. Gudima, and S. Mashnik, "Proton-Induced Fission Cross Section Calculation with the LANL Codes CEM2k+GEM2 and LAQGSM+GEM2," LANL Report LA-UR-03-3750, Los Alamos (2003); Proc. AccApp03, San Diego, California, June 1–5, 2003, (ANS, La Grange Park, IL 60526, USA, 2004), pp. 976–985; E-print: nucl-th/0307014.

[18] S. G. Mashnik, K. K. Gudima, A. J. Sierk, and R. E. Prael, "Improved Intranuclear Cascade Models for the Codes CEM2k and LAQGSM," LA-UR-05-0711, Los Alamos (2005); E-print: nucl-th/0502019; Proc. ND2004, September 26–October 1, 2004, Santa Fe, NM, USA, edited by R. C. Haight, M. B. Chadwick, T. Kawano, and P. Talou, (AIP Conference Proceedings, Volume 769, Melville, New York, 2005), pp. 1188–1192.

[19] S. G. Mashnik, M. I. Baznat, K. K. Gudima, A. J. Sierk, and R. E. Prael, "Extension of the CEM2k and LAQGSM Codes to Describe Photo-Nuclear Reactions," LANL Report LA-UR-05-2013, Los Alamos (2005), E-print: nucl-th/0503061, to be published in Journal of Nuclear and Radiochemical Science, Vol. 6, No. 2, 2005.

[20] S. G. Mashnik, K. K. Gudima, M. I. Baznat, A. J. Sierk, R. E. Prael, and N. V. Mokhov, "CEM03.01 and LAQGSM03.01 Versions of the Improved Cascade-Exciton Model (CEM) and Los Alamos Quark-Gluon String Model (LAQGSM) Codes," LANL Research Note X-5-RN (U) 05-11, LA-UR-05-2686 (2005).

[21] M. G. Gornov, Yu. B. Gurov, A. L. Iljin, S. G. Mashnik, P. V. Morokhov, V. A. Pechkurov, M. A. Polikarpov, V. I. Saveliev, F. M. Sergeev, S. A. Smirnov, A. A. Khomutov, B. A. Chernyshev, R. R. Shafigullin, and A. V. Shishkov, "Emission of Protons on Absorption of Stopped Negative Pions by Be, C, Si, Cu, and Ge Nuclei," Yad. Fiz. **47** (1988) 959–967 [Sov. J. Nucl. Phys. **47** (1988) 612–617]; "Emission of Composite Particles in the Absorption of Stopped Negative Pions by Nuclei of Be, C, Si, Cu, and Ge," Yad. Fiz. **47** (1988) 1193–1200 [Sov. J. Nucl. Phys. **47** (1988) 760–764]; http://www.osti.gov/energycitations/product.biblio.jsp?osti_id=6721591&query_id=0.

[22] S. G. Mashnik, "Neutron-Induced Particle Production in the Cumulative and Noncumulative Regions at Intermediate Energies," Nucl. Phys. **A568** (1994) 703–726.

[23] S. G. Mashnik, R. J. Peterson, A. J. Sierk, and M. R. Braunstein. "Pion-Induced Transport of π Mesons in Nuclei," Phys. Rev. C **61** (2000) 034601.

[24] R. J. Peterson, S. de Barros, H. Schechter, A. G. DaSilva, J. C. Suita, and S. G. Mashnik, "Fission Probabilities Across the π-Nucleon Delta Resonance," Euro. Phys. J. A **10** (2001) 69–71. A. V. Prokofiev, S. G. Mashnik, and A. J. Sierk, "Cascade-Exciton Model Analysis of Nucleon-Induced Fission Cross Sections of Lead and Bismuth at Energies from 45 to 500 MeV," Nucl. Sci. Eng. **131** (1999) 78–95.

[25] Yu. E. Titarenko, O. V. Shvedov, V. F. Batyaev, E. I. Karpikhin, V. M. Zhivun, A. B. Koldobsky, R. D. Mulambetov, S. V. Kvasova, A. N. Sosnin, S. G. Mashnik, R. E. Prael, A. J. Sierk, T. A. Gabriel, M. Saito, and H. Yasuda, "Cross Sections for Nuclide Production in 1 GeV Proton-Irradiated ^{208}Pb," Phys. Rev. C **65** (2002) 064610.

[26] K. A. Van Riper, S. G. Mashnik, and W. B. Wilson, "A Computer Study of Radionuclide Production in High Power Accelerators for Medical and Industrial Applications," Nucl. Instr. Meth. A **463** (2001) 576–585.

[27] S. G. Mashnik, K. K. Gudima, I. V. Moskalenko, R. E. Prael, and A. J. Sierk, "CEM2k and LAQGSM as Event Generators for Space-Radiation-Shielding and Cosmic-Ray-Propagation Applications," Advances in Space Research **34** (2004) 1288–1296.

[28] C. Y. Fu, T. A. Gabriel, and R. A. Lillie, "PICA95: an Intranuclear-Cascade Code for 25 MeV to 3.5 GeV Photon-Induced Nuclear Reactions," Proc. 3rd Specialists Meeting on Shielding Aspects of Accelerators, Targets and Irradiation Facilities (SATIF-3), Tohoku University, Sendai, Japan, May 12–13, 1997, NEA/OECD, 1998, pp. 49–60; http://www.osti.gov/bridge/product.biblio.jsp?osti_id=474922.

[29] T. Sato, K. Shin, S. Ban, T. A. Gabriel, C. Y. Fu, and H. S. Lee, "PICA3, an Updated Code of Photo-Nuclear Cascade Evaporation Code PICA95, and Its Benchmark Experiments," Proc. MC2000, Lisbon, Portugal, 2000, edited by A. Kling, F. J. C. Barão, M. Nakagawa, L. Távora, and P. Vaz, Springer, Berlin, (2001), pp. 1139–1144.

[30] A. V. Ignatyuk, N. T. Kulagin, V. P. Lunev, and K.-H. Schmidt, "Analysis of Spallation Residues within the Intranuclear Cascade Model," Proc. XV Workshop on Physics of Nuclear Fission, Obninsk, 3–6 October, 2000, www-w2k.gsi.de/charms/Preprints/Obninsk2000/Cascado-v7.pdf.

[31] A. V. Ignatyuk, N. T. Kulagin, V. P. Lunev, Yu. N. Shubin, N. N. Titarenko, V. F. Batyaev, Yu. E. Titarenko, and V. M. Zhivun, "Analysis of Spallation and Fission Residues for Separated Lead Isotopes Irradiated by Protons at Energies 0.15, 1.0, and 2.6 GeV," Proc. ND2004, September 26–October 1, 2004, Santa Fe, NM, USA, edited by R. C. Haight, M. B. Chadwick, T. Kawano, and P. Talou, (AIP Conference Proceedings, Volume 769, Melville, New York, 2005), pp. 1307–1312.

[32] S. Yavshits, G. Boykov, V. Ippolitov, S. Pakhomov, and O. Grudzwvich, "Multiconfiguration Fission Cross Sections at Transitional Energy Region 20–200 MeV," Voprosy Atomnoj Nauki i Tekhniki, seriya Yadernye Konstanty (Nuclear Constants) **1** (2000) 62–70 (in Russian), translated to Engish in Report INDC(CCP)-430 (2001), pp. 83–94, http://www.ippe.obninsk.ru/podr/cjd/vant/00-1/1-07.pdf.

[33] Zs. Schram, Gy. Kluge, and K. Sailer, "Exciton Cascade Model for Fast Neutron Reactions," International Atomic Energy Agency Report INDC(HUN)-023/L, Vienna, Austria, June 1987.

[34] T. Nishida, Y. Nakahara, and T. Tsutsui, "Development of a Nuclear Spallation Simulation Code Calculation of Primary Spallation Products," *JAERI-M-86-116* (1986) T. Nishida, Y. Nakahara, and T. Tsutsui, "Analysis of the Mass Formula Dependence of the Spallation Product Distribution," JAERI-M-87-088 (1987); T. Nishida, H. Takada, and Y. Nakahara, "NUCLEUS," "Proc. Int. Conf. on Nuclear Data for Science and Technology," Jülich, Germany, May 13–17, 1991, Ed. S. M. Qaim, "Springer-Verlag", Berlin (1992), pp. 152–157; H. Takada, Y. Nakahara, T. Nishida, K. Ishibashi, and N. Yoshizawa, "Microscopic Cross Section Calculations with NUCLEUS and HETC-3STEP," pp. 121–136 in Ref. [10].

[35] V. S. Barashenkov, Le Van Ngok, L. G. Levchuk, Zh. Zh. Musul'manbekov, A. N. Sosnin, V. D. Toneev and S. Yu. Shmakov, "Cascade Program Complex for Monte-Carlo Simula-

tion of Nuclear Processes Initiated by High Energy Particles and Nuclei in Gaseous and Condensed Matter," JINR Report R2-85-173, Dubna (1985);

[36] N. V. Mokhov, "The MARS Code System User's Guide," Fermilab-FN-628, 1995; more references and many details on MARS may be found at the Web page http://www-ap.fnal.gov/MARS/.

[37] *MCNPX User's Manual, Version 2.3.0*, Laurie S. Waters, Editor, LANL Report LA-UR-02-2607 (April, 2002); more references and many details on MCNPX may be found at the Web page http://mcnpx.lanl.gov/.

[38] Nikolai Amelin, *Physics and Algorithms of the Hadronic Monte-Carlo Event Generators. Notes for a Developer*, CERN/IT/ASD Report CERN/IT/99/6, Geneva, Switzerland and JINR/LHE, Dubna, Russia; *Geant4 User's Documents*, **Physics Reference Manual**, December 8, 1998, http://wwwinfo.cern.ch/asd/geant/geant4_public/G4UsersDocuments/Overview/html/index.html/.

[39] V. Lara, "Object-Oriented Approach to Preequilibrium and Equilibrium Decays in Geant4," Proc. MC2000, Lisbon, Portugal, 2000, edited by A. Kling, F. J. C. Barão, M. Nakagawa, L. Távora, and P. Vaz, Springer, Berlin, (2001), pp. 1039–1044; Vichente Lara and Johannes Peter Wellisch, "Preequilibrium and Equilibrium Decays in Geant4," chep2000.pd.infn.it/short_p/spa_a096.pdf; more references and many details on GEANT4 may be found at the Web page http://wwwasd.web.cern.ch/wwwasd/geant4/geant4.html.

[40] N. M. Sobolevsky, "The SHIELD Code (Version 1996.hadr.0) Short User's Manual," CCC-667 SHIELD, RSICC Computer Code Collection, ORNL, 1998; A. V. Dementyev and N. M. Sobolevsky, "SHIELD—Universal Monte Carlo Hadron Transport Code: Scope and Applications," Radiation Measurements **30** (1999) 553–557; more references and many details on SHIELD may be found at the Web pages http://www.nea.fr/abs/html/iaea1287.html; http://www-rsicc.ornl.gov/codes/ccc/ccc6/ccc-667.html.

[41] I. I. Degtyarev, A. E. Lokhovitskii, M. A. Maslov, I. A. Yazynin, V. I. Belyakov-Bodin, and A. I. Blokhin, "RTS&T Main Features," Proc. Fourth Int. Workshop on Simulating Accelerator Radiation Environments (SARE-4), Hyatt Regency, Knoxville, TN, September 13–16, 1998, edited by Tony A. Gabriel, ORNL, 1999, pp. 141–149; I. I. Degtyarev, O. A. Liashenko, I. A. Yazynin, V. I. Belyakov-Bodin, and A. I. Blokhin, "Calculational Estimations of Neutron Yield From ADS Targets," Proc. of the 2001 Particle Accelerator Conference, Chicago, USA, Voprosy Atomnoi Nauki i Tekhniki **01-1** (2001) 2796–2798, www.ippe.obninsk.ru/podr/cjd/vant/01-1/2-03.pdf.

[42] S. E. Chigrinov, A. I. Kievitskaia, I. L. Rakhno, and C. K. Rutkovskaia, "The Code SONET to Calculate Accelerator Driven System Performance," Proc. Int. Conf. on Accelerator-Driven Transmutation Technologies and Applications (ADTT'99), Praha, Czech Republic, June 7–11, 1999, paper Mo-O-C12 on the Conference CD-ROM and Web page http://fjfi.cvut.cz/con_adtt99.

[43] C. Y. Fu and T. A. Gabriel, "CALOR As A Single Code Including A Modular Version of HETC," Proc. Fourth Int. Workshop on Simulating Accelerator Radiation Environments (SARE-4), Hyatt Regency, Knoxville, TN, September 13–16, 1998, ORNL, 1999, pp. 23–27, http://www.osti.gov/bridge/product.biblio.jsp?osti_id=1769; T. A. Gabriel and L. A. Carlson, "Charged and Neutral Particle Transport Methods and Applications: The CALOR Code System," Proc. Joint Int. Conf. on Mathematical Methods and Supercomputing for Nuclear Applications, Satatoga Springs, NY, Oct. 6–10, 1997, http://www.osti.gov/bridge/product.biblio.jsp?osti_id=527544.

[44] N. Yoshizawa, K. Ishibashi, and H. Takada, "Development of High Energy Transport Code HETC-3STEP Applicable to the Nuclear Reaction with Incident Energies above 20 MeV," J. Nucl. Sci. Techn. **32** (1995) 601-607; H. Takada, Y. Nakahara, T. Nishida, K. Ishibashi, and N. Yoshizawa, "Microscopic Cross Section Calculations with NUCLEUS and HETC-3STEP," pp. 121–136 in Ref. [10].

[45] V. S. Barashenkov, A. Yu. Konobeev, Yu. A. Korovin, and V. N. Sosnin, "CASCADE/INPE Code System," Atomnaya Energiya **87** (1999) 283–286 [Atomic Evergy **87** (1999) 742–744].

[46] A. V. Sannikov and E. N. Savitskaya, "Physics of the HADRON Code: Recent Status and Comparison with Experiment," Nucl. Instr. Meth. A **450** (2000) 127–137.

[47] K. K. Gudima, A. S. Iljinov, and V. D. Toneev, "A Cascade Model for Photonuclear Reactions," Communication JINR P2-4661, Dubna (1969).

[48] V. S. Barashenkov, F. G. Geregi, A. S. Iljinov, G. G. Jonsson, and V. D. Toneev, "A Cascade-Evaporation Model for Photonuclear Reactions," Nucl. Phys. **A231** (1974) 462–476.

[49] J. S. Levinger, "The High Energy Nuclear Photoeffect," Phys. Rev. **84** (1951) 43–51; *Nuclear Photo-Disintegration* (Oxford University Press, 1960); Phys. Lett. B **82**, (1979) 181–182.

[50] W. O. Lock and D. F. Measday, *Intermediate Energy Nuclear Physics*, London, Methuen; [Distributed in the U.S.A. by Barnes and Noble, 1970].

[51] J. Cugnon, C. Volant, and S. Vuillier, "Improved Intranuclear Cascade Model for Nucleon-Nucleus Interactions," Nucl. Phys. **A620** (1997) 475–509; Th. Aoust and J. Cugnon, "Effects of Isospin and Energy Dependences of the Nuclear Mean Field in Spallation Reactions," Eur. Phys. J. A **21** (2004) 79–85.

[52] Helder Duarte, "An Intranuclear Cascade Model for High Energy Transport Codes," Proc. Int. Conf. on Accelerator-Driven Transmutation Technologies and Applications (ADTT'99), Praha, Czech Republic, June 7–11, 1999, paper Mo–O–C17 on the Conference CD–ROM and Web page http://fjfi.cvut.cz/con_adtt99.

[53] A. S. Iljinov, I. A. Pshenichnov, N. Bianchi, E. De Sanctis, V. Muccifora, M. Mirazita, and P. Rossi, "Extension of the Intranuclear Cascade Model for Photonuclear Reactions at Energies up to 10 GeV," Nucl. Phys. **A616** (1997) 575–605.

[54] S. J. Lindenbaum and R. M. Sternheimer, "Isobaric Nucleon Model for Pion Production in Nucleon-Nucleon Collisions," Phys. Rev. **105** (1957) 1874–1899.

[55] S. G. Mashnik, A. J. Sierk, O. Bersillon, and T. Gabriel, "Cascade-Exciton Model Detailed Analysis of Proton Spallation at Energies from 10 MeV to 5 GeV," LANL Report LA-UR-97-2905 (1997), http://t2.lanl.gov/publications/publications.html.

[56] C. H. M. Broeders and A. Yu. Konobeev, "Evaluation of He-4 Production Cross-Section for Tantalum, Tungsten and Gold Irradiated with Neutrons and Protons at the Energies up to 1 GeV," Nucl. Instr. Meth. B **234** (2005) 387–411.

[57] S. G. Mashnik, "Physics of the CEM92M Code," pp. 107–120 in [10].

[58] K. K. Gudima, S. G. Mashnik, and V. D. Toneev, "Preequilibrium Emission in Hadron-Nuclear Reactions at $T_0 < 1$–2 GeV," Proc. Europhysics Topical Conference June 21–25, 1982, Smollenice, Neutron Induced Reactions. Physics and Applications **10** (1982) 347–351.

[59] V. D. Toneev and K. K. Gudima, "Particle Emission in Light and Heavy-Ion Reactions," Nucl. Phys. **A400** (1983) 173c–190c.

[60] K. K. Gudima, G. Röpke, H. Schulz, and V. D. Toneev, "The Coalescence Model and Pauli Quenching in High-Energy Heavy-Ion Collisions," Joint Institute for Nuclear Research Preprint JINR-E2-83-101, Dubna (1983); H. Schulz, G. Röpke, K. K. Gudima, and V. D. Toneev, "The Coalescence Phenomenon and the Pauli Quenching in High-Energy Heavy-Ion Collisions," Phys. Lett. B **124** (1983) 458–460.

[61] Joseph I. Kapusta, "Mechanisms for Deuteron Production in Relativistic Nuclear Collisions," Phys. Rev. C **21** (1980) 1301–1310.

[62] Konstantin K. Gudima, Stepan G. Mashnik, and Arnold J. Sierk, "User Manual for the code LAQGSM," LANL Report LA-UR-01-6804; http://lib-www.lanl.gov/la-pubs/00818645.pdf.

[63] N. S. Amelin, K. K. Gudima, and V. D. Toneev, "The Quark-Gluon String Model and Ultrarelativistic Heavy-Ion Collisions," Yad. Fiz. **51** (1990) 512–523 [Sov. J. Nucl. Phys. **51** (1990) 327–333], N. S. Amelin, K. K. Gudima, and V. D. Toneev, "Further Development of the Model of Quark-Gluon Strings for the Description of High-Energy Collisions with a Target Nucleus," Yad. Fiz. **52** (1990) 272–282 [Sov. J. Nucl. Phys. **52** (1990) 172–178].

[64] T. Ericson, "The Statistical Model and Nuclear Level Densities," Adv. in Physics **9** (1960) 425–511.

[65] F. C. Williams Jr., "Intermediate State Transition Rates in the Griffin Model," Phys. Lett. B **31** (1970) 184–186.

[66] F. C. Williams Jr., Particle-Hole State Density in the Uniform Spacing Model," Nucl. Phys. **A161** (1971) 231–240.

[67] I. Ribansky, P. Oblozinsky, and E. Betak, "Pre-Equilibrium Decay and the Exciton Model," Nucl. Phys. **A205** (1973) 545–560.

[68] K. Kikuchi and M. Kawai, *Nuclear Matter and Nuclear Reactions*, North-Holland, Amsterdam (1968).

[69] N. Metropolis, R. Bivins, M. Storm, A. Turkevich, J. M. Miller, and G. Friedlander, "Monte Carlo Calculations on Intranuclear Cascades. I. Low-Energy Studies," Phys. Rev. **110** (1958) 185–203.

[70] E. Betak, "Complex Particle Emission in the Exciton Model of Nuclear Reactions," Acta Phys. Slov. **26** (1976) 21–24.

[71] J. R. Wu and C. C. Chang, "Complex-Particle Emission in the Pre-Equilibrium Exciton Model," Phys. Rev. C **17** (1978) 1540–1549.

[72] G. Mantzouranis, H. A. Weidenmüller, and D. Agassi, "Generalized Exciton Model for the Description of Preequilibrium Angular Distributions," Z. Phys. A **276** (1976) 145–154.

[73] C. Kalbach, "Systematics of Continuum Angular Distributions: Extensions to Higher Energies," Phys. Rev. **37** (1988) 2350–2370.

[74] V. F. Weisskopf and D. H. Ewing, "On the Yield of Nuclear Reactions with Heavy Elements," Phys. Rev. **57** (1940) 472–483.

[75] N. Bohr and J. A. Wheeler, "The Mechanism of Nuclear Fission," Phys. Rev. **56** (1939) 426–450.

[76] A. V. Ignatyuk, G. N. Smirenkin, and A. S. Tishin, "Phenomenological Description of the Energy Dependence of the Level Density Parameter," Yad. Fiz. **21** (1975) 485–490 [Sov. J. Nucl. Phys. **21** (1975) 255–257]; A. V. Ignatyuk, M. G. Itkis, V. N. Okolovich, G. N. Smirenkin, and A. S. Tishin, "Fission of Pre-Actinide Nuclei. Excitation Functions for the (α, f) Reactions," Yad. Fiz. **21** (1975) 1185–1205 Sov. J. Nucl. Phys. **21** (1975) 612–621].

[77] A. S. Iljinov, M. V. Mebel, N. Bianchi, E. De Sanctis, C. Guaraldo, V. Lucherini, V. Muccifora, E. Polli, A. R. Reolon, and P. Rossi, "Phenomenological Statistical Analysis of Level Densities, Decay Width and Lifetimes of Excited Nuclei," Nucl. Phys. **A543** (1992) 517–557.

[78] P. Möller, J. R. Nix, W. D. Myers, and W. J. Swiatecki, "Nuclear Ground-States Masses and Deformations," Atomic Data and Nuclear Data Tables, **59** (1995) 185–381.

[79] P. Möller, J. R. Nix, and K.-L. Kratz, "Nuclear Properties for Astrophysical and Radioactive-Ion-Beam Application," Atomic Data and Nuclear Data Tables, **66** (1997) 131–343.

[80] R. E. Prael and H. Lichtenstein, *User guide to LCS: The LAHET Code System*, LANL Report No. LA-UR-89-3014, Los Alamos (1989).

[81] A. Ferrari, J. Ranft, S. Roesler, and P. R. Sala, "Cascade Particles, Nuclear Evaporation, and Residual Nuclei in High Energy Hadron-Nucleus Interactions," Z. Phys. C **70** (1996) 413–426.

[82] M. Veselský, "Production Mechanism of Hot Nuclei in Violent Collisions in the Fermi Energy Domain," Nucl Phys. **A705** (2002) 193–222; M. Veselský, Š. Šáro, F. P. Heßberger, V. Ninov, S. Hofmann, and D. Ackermann, "Production of Fast Evaporation Residues by the Reaction ^{20}Ne + ^{208}Pb at Projectile Energies of 8.6, 11.4 and 14.9 A MeV," Z. Phys. A **356** (1997) 403–410.

[83] M. Böhning, "Density of Particle-hole States in the Equidistant-Spacing Model," Nucl. Phys. **A152** (1970) 529–546.

[84] S. Furihata, "Statistical Analysis of Light Fragment Production from Medium Energy Proton-Induced Reactions," Nucl. Instr. Meth. B **171** (2000) 252–258; "The Gem Code—the Generalized Evaporation Model and the Fission Model," Proc. MC2000, Lisbon, Portugal, 2000, edited by A. Kling, F. J. C. Barão, M. Nakagawa, L. Távora, and P. Vaz, Springer, Berlin, (2001), pp. 1045–1050; *The Gem Code Version 2 Users Manual*, Mitsubishi Research Institute, Inc., Tokyo, Japan (November 8, 2001).

[85] S. Furihata, K. Niita, S. Meigo, Y. Ikeda, and F. Maekawa, "The Gem Code—a Simulation Program for the Evaporation and Fission Process of an Excited Nucleus," JAERI-Data/Code 2001-015, JAERI, Tokai-mura, Naka-gam, Ibaraki-ken, Japan (2001).

[86] Shiori Furihata, *Development of a Generalized Evaporation Model and Study of Residual Nuclei Production*, Ph.D. thesis, Tohoku University, March, 2003; S. Furihata and T. Nakamura, "Calculation of Nuclide Production from Proton Induced Reactions on Heavy Targets with INC/GEM," J. Nucl. Sci. Technol. Suppl. **2** (2002) 758–761.

[87] I. Dostrovsky, Z. Frankel, and G. Friedlander, "Monte Carlo Calculations of Nuclear Evaporation Processes. III. Application to Low-Energy Reactions," Phys. Rev. **116** (1959) 683–702.

[88] F. Atchison, "Spallation and Fission in Heavy Metal Nuclei under Medium Energy Proton Bombardment," in Proc. Meeting on Targets for Neutron Beam Spallation Source, Julich, June 11–12, 1979, pp. 17–46, G. S. Bauer, Ed., Jul-Conf-34, Kernforschungsanlage Julich GmbH, Germany (1980).

[89] F. Atchison, "A Treatment of Fission for HETC," in Intermediate Energy Nuclear Data: Models and Codes, pp. 199–218, Proc. of a Specialists's Meeting, May 30–June 1, 1994, Issy-Les-Moulineaux, France, OECD, Paris, France (1994).

[90] G. Audi and A. H. Wapstra, "The 1995 Update to the Atomic Mass Evaluation," Nucl. Phys. **A595** (1995) 409–480.

[91] P. E. Haustein, "An Overview of the 1986–1987 Atomic Mass Predictions," Atomic Data and Nuclear Data Tables **39** (1988) 185–393.

[92] A. G. W. Cameron, "A Revised Semiempirical Atomic Mass Formula," Can. J. Phys. **35** (1957) 1021–1032.

[93] T. Matsuse, A. Arima, and S. M. Lee, "Critical Distance in Fusion Reactions," Phys. Rev. C **26** (1982) 2338–2341.

[94] A. S. Botvina, A. S. Iljinov, I. N. Mishustin, J. P. Bondorf, R. Donangelo, and K. Snappen, "Statistical Simulation of the Break-up of Highly Excited Nuclei," Nucl. Phys. **A475** (1987) 663–686.

[95] A. Gilbert and A. G. W. Cameron, "A Composite Nuclear-Level Density Formula with Shell Corrections," Can. J. Phys. **43** (1965) 1446–1496.

[96] J. L. Cook, H. Ferguson, and A. R. del Musgrove, "Nuclear Level Densities in Intermediate and Heavy Nuclei," Australian Journal of Physics **20** (1967) 477–487.

[97] W. A. Friedman and W. G. Lynch, "Statistical Formalism for Particle Emission," Phys. Rev. C **28** (1983) 16–23.

[98] The Evaluated Nuclear Structure Data File (ENSDF) maintained by the National Nuclear Data Center (NNDC), Brookhaven National Laboratory, http://www.nndc.bnl.gov/.

[99] S. G. Mashnik, K. K. Gudima, R. E. Prael, and A. J. Sierk, "Analysis of the GSI A+p and A+A Spallation, Fission, and Fragmentation Measurements with the LANL CEM2k and LAQGSM Codes," in Proc. TRAMU@GSI, Darmstadt, Germany, 2003, Eds. A. Kelic and K.-H. Schmidt, ISBN 3-00-012276-1, http://ww-wnt.gsi.de/tramu; E-print: nucl-th/0404018.

[100] R. Vandenbosch and J. R. Huizenga, *Nuclear Fission*, Academic Press, New York (1973).

[101] E. F. Neuzil and A. W. Fairhall, "Fission Product Yields in Helium Ion-Induced Fission of Au^{197}, Pb^{204}, and Pb^{206} Targets," Phys. Rev. **129** (1963) 2705–2710.

[102] A. Ya. Rusanov, M. G. Itkis, and V. N. Okolovich, "Features of Mass Distributions of Hot Rotating Nuclei," Yad. Fiz. **60** (1997) 773–803 [Phys. At. Nucl. **60** (1997) 683–712]; M. G. Itkis, Yu. A. Muzychka, Yu. Ts. Oganesyan, V. N. Okolovich, V. V. Pashkevich, A. Ya. Rusanov, V. S. Salamatin, G. N. Smirenkin, and G. G. Chubaryan, "Fission of Excited Nuclei with Z^2/A =20–33: Mass-Energy Distributions of Fragments, Angular Momentum, and Liquid-Drop Model," Yad. Fiz. **58 (1995)** 2140–2165 [Phys. At. Nucl. **58** (1995) 2026–2051].

[103] W. D. Myers and W. J. Swiatecki, "Thomas-Fermi Fission Barriers," Phys. Rev. C **60** (1999) 014606.

[104] M. G. Itkis, S. M. Luk'yanov, V. N. Okolovich, Yu. E. Penionzhkevich, A. Ya. Rusanov, V. S. Salamatin, G. N. Smirenkin, and G. G. Chubaryan, "Experimental Study of the Mass and Energy Distributions of Fragments from Fission," Ya. Fiz. **52** (1990) 23–35 [Sov. J. Nucl. Phys. **52** (1990) 15–22].

[105] F. Atchison, "A Revised Calculational Model for Fission," Paul Scherrer Insititut Report No. 98-12, Villigen PSI (1998).

[106] H. W. Bertini, "Low-Energy Intranuclear Cascade Calculation," Phys. Rev. **131** (1963) 1801–1871; "Intranuclear Cascade Calculation of the Secondary Nucleon Spectra from Nucleon-Nucleus Interactions in the Energy Range 340 to 2900 MeV and Comparison with Experiment," Phys. Rev. **188** (1969) 1711–1730.

[107] Y. Yariv and Z. Frankel, "Intranuclear Cascade Calculation of High-Energy Heavy-Ion Interactions," Phys. Rev. C **20** (1979) 2227–2243; "Inclusive Cascade Calculation of High Energy Heavy Ion Collisions: Effect of Interactions between Cascade Particles," Phys. Rev. C **24 (1981)** 488–494.

[108] A. V. Prokofiev, "Compilation and Systematics of Proton-Induced Fission Cross-Section Data," Nucl. Instr. Meth. A **463** (2001) 557–575; A. V. Prokofiev, S. G. Mashnik, and W. B. Wilson, "Systematics of Proton-Induced Fission Cross Sections for Intermediate Energy Applications," LANL Report LA-UR-02-5837, Los Alamos, 2002, E-print: nucl-th/0210071.

[109] E. Fermi, "High Energy Nuclear Events", Prog. Theor. Phys. **5** (1950) 570–583.

[110] G. I. Kopylov, *Principles of Resonance Kinematics*, Moscow, Nauka (1970) [in Russian].

[111] R. K. Tripathi, F. A. Cucinotta, and J. W. Wilson, "Accurate Universal Parameterization of Absorption Cross Sections," Nucl. Instr. Meth. B **117 (1996)** 347–349.

[112] C. Kalbach, "Towards a Global Exciton Model; Lessons at 14 MeV," J. Phys. G **24 (1998)** 847–866.

[113] M. V. Kossov, "Approximation of Photonuclear Interaction Cross-Sections," Eur. Phys. J. A **14** (2002) 377–392.

[114] K. Ukai and T. Nakamura, "Data Compilation of Single Pion Photoproduction Below 2 GeV", INS-T-550, March 1997, Inst. for Nucl. Study, University of Tokyo, and private communication from K. Ukai to SGM (1997).

[115] G. Roy, L. Greeniaus, G. A. Moss, D. A. Hutcheon, R. Liljestrand, R. M. Woloshyn, D. H. Boal, A. W. Stetz, K. Aniol, A. Willis, N. Willis, and R. McCamis, "Inclusive Scattering of Protons on Helium, Nickel, and Tantalum at 500 MeV," Phys. Rev. C **23** (1981) 16711–1678.

[116] J. Ouyang, *Quasi-Free Pion Single Charge Exchange*, Ph.D. thesis U. of Colorado (LANL Report No. LA-12457-T, UC-413, 1992).

[117] Melynda Louise Brooks, *Neutron Induced Pion Production on C, Al, Cu, and W at Neutron Energies of 200–600 MeV*, Ph.D. thesis, U. of New Mexico, (LA-12210-T, UC-910, Oct., 1991, Los Alamos); M. L. Brooks, B. Bassalleck, B. D. Dieterle, R. A. Reeder, D. M. Lee, J. A. McGill, M. E. Schillaci, R. A. Ristinen, and W. R. Smythe, "Neutron Induced Pion Production on C, Al, Cu, and W at 200–600 MeV," Phys. Rev. C **45** (1992) 2343–2354.

[118] T. Nakamoto, K. Ishibashi, N. Matsufuji, N. Shigyo, K. Maehata, H. Arima, S. Meigo, H. Takada, S. Chiba, and M. Numajiri, "Experimental Neutron-Production Double-Differential Cross Section for the Nuclear Reaction by 1.5 GeV π^+ Mesons Incident on Iron," J. Nucl. Sci. and Techn. **34** (1997) 860–862.

[119] P. Staples, N. W. Hill, and P. W. Lisowski, "Fission Cross Section Ratios of ^{nat}Pb and ^{209}Bi Relative to ^{235}U for Neutron Energies from Threshold to 400 MeV," Bull. Am. Phys.

Soc., **40** (1995) 962; Parrish Staples and Kevin Morley, "Neutron-Induced Fission Cross-Section Reactions for ^{239}Pu, ^{240}Pu, ^{242}Pu, and ^{244}Pu Relative to ^{235}U from 0.5 to 400 MeV," Nucl. Sci. Eng. **129** (1998) 149–163, and private communication from P. Staples to T-2, LANL, 1996.

[120] A. V. Prokofiev, P.-U. Renberg, and N. Olson, "Measurement of Neutron-Induced Fission Cross Sections for ^{nat}Pb, ^{208}Pb, ^{197}Au, ^{nat}W, and ^{181}Ta in the Intermediate Energy Region," Uppsala University Neutron Physics Report UU-NF 01#6 (March 2001).

[121] A. N. Smirnov, V. P. Eismont, N. P. Filatov, J. Blumgren, H. Condé, A. V. Prokofiev, P.-U. Renberg, and N. Olsson, "Measurements of Neutron-Induced Fission Cross Sections for ^{209}Bi, ^{nat}Pb, ^{208}Pb, ^{197}Au, ^{nat}W, and ^{181}Ta in the Intermediate Energy Region," Phys. Rev. C **70** (2004) 054603.

[122] A. Guertin, N. Marie, S. Auduc, V. Blideanu, Th. Delbar, P. Eudes, Y. Foucher, F. Haddad, T. Kirchner, Ch. Le Brun, C. Lebrun, F. R. Lecolley, J. F. Lecolley, X. Ledoux, F. Lefèbvres, T. Lefort, M. Louvel, A. Ninane, Y. Patin, Ph. Pras, G. Rivière, and C. Varignon, "Neutron and Light-Charged-Particle Productions in Proton-Induced Reactions on ^{208}Pb at 62.9 MeV," Eur. Phys. J. **A23** (2005) 49–60.

[123] F. Rejmund, B. Mustapha, P. Armbruster, J. Benlliure, M. Bernas, A. Boudard, J. P. Dufour, T. Enqvist, R. Legrain, S. Leray, K.-H. Schmidt, C. Stéphan, J. Taieb, L. Tassan-Got, and C. Volant, "Measurement of Isotopic Cross Sections of Spallation Residues in 800 A MeV ^{197}Au + p Collisions," Nucl. Phys. **A683** (2001) 540–565; J. Benlliure, P. Armbruster, M. Bernas, A. Boudard, J. P. Dufour, T. Enqvist, R. Legrain, S. Leray, B. Mustapha, F. Rejmund, K.-H. Schmidt, C. Stéphan, L. Tassan-Got, and C. Volant, "Isotopic Production Cross Sections of Fission Residues in ^{197}Au-on-Proton Collisions at 800 A MeV," Nucl. Phys. **A683** (2001) 513–539.

[124] Carmen Villagrasa-Canton, "Etude de la production des noyaux résiduels dans la réaction de spallation Fe + p à 5 énergies (300–1500 MeV/A) et application au calcul de dommage sur une fenêtre de système hybride," PhD Thesis, Universite de Paris XI Orsay, December 5, 2003, http://www-w2k.gsi.de/charms/theses.htm, and private communication from Dr. Villagrasa to SGM, March 11, 2004.

[125] Paolo Napolitani, "New Findings on the Onset of Thermal Disassembly in Spallation Reactions," PhD Thesis, University Paris XI Orsay, IPNO-T-04-14, September 24, 2004; P. Napolitani, K.-H. Schmidt, A. S. Botvina, F. Rejmund, L. Tassan-Got, and C. Villagrasa, "High-Resolution Velocity Measurements on Fully Identified Light Nuclides Produced in ^{56}Fe + Hydrogen and ^{56}Fe + Titanium Systems," Phys. Rev. C **70** (2004) 054607.

[126] R. A. Schumacher, G. S. Adams, D. R. Ingham, J. L. Matthews, W. W. Sapp, R. S. Turley, R. O. Owens, and B. L. Roberts, "Cu(γ, p)X Reaction at E_γ = 150 and 300 MeV," Phys. Rev. C **25** (1982) 2269–2277.

[127] Koh Sakamoto, "Radiochemical Study on Photonuclear Reactions of Complex Nuclei at Intermediate Energies," J. Nucl. Radiochem. Sci. **4** (2003) A9–A31.

Appendix 1

CEM03.01 Input Example 1

```
p500Ni6.inf                   /File name for diagnostic output. (30 char.)
p500Ni6.res                   /File name for results of calculation. (30 char.)
prot    /pname/ projectile particle name:
              prot - proton, neut - neutron, pipl - pi+, pimi - pi-, pize - pi0,
              gamm - gamma with fixed energy, gamb - bremss. gamma, stop - no more calc.
500.0  /t0mev/  minimum (initial) projectile kinetic energy in MeV; [tgmin for gamb]
58.    /anucl/  target mass number
28.    /znucl/  target atomic number
10000  /limc/   total number of inelastic events, normally 2000-500000
-20.    /dt0/    projectile kinetic energy step-size in MeV [Only 1 energy if <0.]
500.5  /t0max/  maximum (final) projectile kinetic energy in MeV, [tgmax for gamb]
10.    /dteta/  step-size (degrees) in ejectile angular distributions [mang > 0]
0      /mspec/  (0/1,2) if ejectile energy spectra (are not/are) needed
1      /mpyld/  (0/1,2) if particle yield tables (are not/are) needed
0      /mchy/   (0/1) if particle channel yields (are not/are) needed
0      /misy/   (0/1,2,3) if isotope yields (are not/are) needed
1      /mdubl/  (0/1,2) if double differential spectra (are not/are) needed
0      /mang/   (0/1,2) if angular distributions (are not/are) needed
2 2  /ipar1,ipar2/ range of ejectile types for spectrum calcs. [Below, ang. bins for mdubl > 0]
60.0 70.0 85.0 95.0 115.0 125.0 155.0 165.0 -5.0 65.0 75.0 85.0 95.0 105.0 115.0 125.0 135.0 145.0 155.0 165.0
0. 22. 1. 22. 100. 3. 100. 500. 10. 500. 5000. 200. /tmin, tmax, dt, j=1-4/
6      /nevtype/ number of evaporated particle types (see table in bldatgem.f).
1       /nh/     Lines of text (<11) to be read in; printed on results file (line 2).
Example No. 1: Proton spectra from 500 MeV p  + Ni58; 10,000 events
stop
```

CEM03.01 Input Example 2

```
pim500Cu.inf                  /File name for diagnostic output. (30 char.)
pim500Cu.res                  /File name for results of calculation. (30 char.)
pimi    /pname/ projectile particle name:
              prot - proton, neut - neutron, pipl - pi+, pimi - pi-, pize - pi0,
              gamm - gamma with fixed energy, gamb - bremss. gamma, stop - no more calc.
500.0  /t0mev/  minimum (initial) projectile kinetic energy in MeV; [tgmin for gamb]
64.    /anucl/  target mass number
29.    /znucl/  target atomic number
10000  /limc/   total number of inelastic events, normally 2000-500000
-20.    /dt0/    projectile kinetic energy step-size in MeV [Only 1 energy if <0.]
500.5  /t0max/  maximum (final) projectile kinetic energy in MeV, [tgmax for gamb]
10.    /dteta/  step-size (degrees) in ejectile angular distributions [mang > 0]
1      /mspec/  (0/1,2) if ejectile energy spectra (are not/are) needed
1      /mpyld/  (0/1,2) if particle yield tables (are not/are) needed
0      /mchy/   (0/1) if particle channel yields (are not/are) needed
0      /misy/   (0/1,2,3) if isotope yields (are not/are) needed
1      /mdubl/  (0/1,2) if double differential spectra (are not/are) needed
0      /mang/   (0/1,2) if angular distributions (are not/are) needed
8 8  /ipar1,ipar2/ range of ejectile types for spectrum calcs. [Below, ang. bins for mdubl > 0]
25.0 35.0 45.0 55.0 65.0 75.0 -55.0 165.0 55.0 65.0 75.0 85.0 95.0 105.0 115.0 125.0 135.0 145.0 155.0 165.0
0. 500. 10. 500. 600. 10. 600. 700. 10. 700. 5000. 20. /tmin, tmax, dt, j=1-4/
6      /nevtype/ number of evaporated particle types (see table in bldatgem.f).
1       /nh/     Lines of text (<11) to be read in; printed on results file (line 2).
Example No. 2: pi0 spectra from 500 MeV pim  + Cu64; 10,000 events
stop
```

CEM03.01 Input Example 3

```
n562cu.inf                        /File name for diagnostic output. (30 char.)
n562cu.res                        /File name for results of calculation. (30 char.)
neut    /pname/ projectile particle name:
              prot - proton, neut - neutron, pipl - pi+, pimi - pi-, pize - pi0,
              gamm - gamma with fixed energy, gamb - bremss. gamma, stop - no more calc.
562.5  /t0mev/  minimum (initial) projectile kinetic energy in MeV; [tgmin for gamb]
64.    /anucl/  target mass number
29.    /znucl/  target atomic number
10000  /limc/   total number of inelastic events, normally 2000-500000
-10.    /dt0/    projectile kinetic energy step-size in MeV [Only 1 energy if <0.]
600.5  /t0max/  maximum (final) projectile kinetic energy in MeV, [tgmax for gamb]
10.    /dteta/  step-size (degrees) in ejectile angular distributions [mang > 0]
0      /mspec/  (0/1,2) if ejectile energy spectra (are not/are) needed
1      /mpyld/  (0/1,2) if particle yield tables (are not/are) needed
0      /mchy/   (0/1) if particle channel yields (are not/are) needed
0      /misy/   (0/1,2,3) if isotope yields (are not/are) needed
1      /mdubl/  (0/1,2) if double differential spectra (are not/are) needed
0      /mang/   (0/1,2) if angular distributions (are not/are) needed
9 9  /ipar1,ipar2/ range of ejectile types for spectrum calcs. [Below, ang. bins for mdubl > 0]
25.0 35.0 55.0 65.0 75.0 85.0 115.0 125.0 -5.0 65.0 75.0 85.0 95.0 105.0 115.0 125.0 135.0 145.0 155.0 165.0
0. 500. 20. 500. 600. 20. 600. 700. 20. 700. 5000. 20. /tmin, tmax, dt, j=1-4/
6     /nevtype/ number of evaporated particle types (see table in bldatgem.f).
1       /nh/     Lines of text (<11) to be read in; printed on results file (line 2).
Example No. 3: pip spectra from 562.5 MeV n  + Cu64; 10,000 events
stop
```

CEM03.01 Input Example 4

```
pip1_5fe.inf                    /File name for diagnostic output. (30 char.)
pip1_5fe.res                    /File name for results of calculation. (30 char.)
pipl    /pname/ projectile particle name:
              prot - proton, neut - neutron, pipl - pi+, pimi - pi-, pize - pi0,
              gamm - gamma with fixed energy, gamb - bremss. gamma, stop - no more calc.
1500.0  /t0mev/  minimum (initial) projectile kinetic energy in MeV; [tgmin for gamb]
56.    /anucl/  target mass number
26.    /znucl/  target atomic number
10000  /limc/   total number of inelastic events, normally 2000-500000
-10.    /dt0/    projectile kinetic energy step-size in MeV [Only 1 energy if <0.]
1600.5  /t0max/  maximum (final) projectile kinetic energy in MeV, [tgmax for gamb]
10.    /dteta/  step-size (degrees) in ejectile angular distributions [mang > 0]
0      /mspec/  (0/1,2) if ejectile energy spectra (are not/are) needed
1      /mpyld/  (0/1,2) if particle yield tables (are not/are) needed
0      /mchy/   (0/1) if particle channel yields (are not/are) needed
0      /misy/   (0/1,2,3) if isotope yields (are not/are) needed
1      /mdubl/  (0/1,2) if double differential spectra (are not/are) needed
0      /mang/   (0/1,2) if angular distributions (are not/are) needed
1 1  /ipar1,ipar2/ range of ejectile types for spectrum calcs. [Below, ang. bins for mdubl > 0]
25.0 35.0 85.0 95.0 145.0 155.0 -15.0 125.0 -5.0 65.0 75.0 85.0 95.0 105.0 115.0 125.0 135.0 145.0 155.0 165.0
0. 10. 1. 10. 100. 10. 100. 1500. 100. 1500. 5000. 200. /tmin, tmax, dt, j=1-4/
6     /nevtype/ number of evaporated particle types (see table in bldatgem.f).
1       /nh/     Lines of text (<11) to be read in; printed on results file (line 2).
Example N. 4: n spectra from 1.5 GeV pip + Fe56; 10,000 events
stop
```

CEM03.01 Input Example 5

```
nAu6.inf                        /File name for diagnostic output. (30 char.)
nAu6.res                        /File name for results of calculation. (30 char.)
neut    /pname/ projectile particle name:
              prot - proton, neut - neutron, pipl - pi+, pimi - pi-, pize - pi0,
              gamm - gamma with fixed energy, gamb - bremss. gamma, stop - no more calc.
30.0  /t0mev/  minimum (initial) projectile kinetic energy in MeV; [tgmin for gamb]
197.    /anucl/  target mass number
79.    /znucl/  target atomic number
10000  /limc/   total number of inelastic events, normally 2000-500000
10.    /dt0/    projectile kinetic energy step-size in MeV [Only 1 energy if <0.]
300.5  /t0max/  maximum (final) projectile kinetic energy in MeV, [tgmax for gamb]
10.    /dteta/  step-size (degrees) in ejectile angular distributions [mang > 0]
0      /mspec/  (0/1,2) if ejectile energy spectra (are not/are) needed
1      /mpyld/  (0/1,2) if particle yield tables (are not/are) needed
0      /mchy/   (0/1) if particle channel yields (are not/are) needed
0      /misy/   (0/1,2,3) if isotope yields (are not/are) needed
0      /mdubl/  (0/1,2) if double differential spectra (are not/are) needed
0      /mang/   (0/1,2) if angular distributions (are not/are) needed
2 2  /ipar1,ipar2/ range of ejectile types for spectrum calcs. [Below, ang. bins for mdubl > 0]
25.0 35.0 45.0 55.0 65.0 75.0 -55.0 165.0 55.0 65.0 75.0 85.0 95.0 105.0 115.0 125.0 135.0 145.0 155.0 165.0
0. 500. 10. 500. 600. 10. 600. 700. 10. 700. 5000. 20. /tmin, tmax, dt, j=1-4/
6     /nevtype/ number of evaporated particle types (see table in bldatgem.f).
2       /nh/     Lines of text (<11) to be read in; printed on results file (line 2).
Example No. 5: fission cross section of Au197 bumbarded with
neutrons from 30 to 300 MeV with a step of 10 MeV; 10,000 events
stop
```

CEM03.01 Input Example 6

```
p62_9Pb6.inf                   /File name for diagnostic output. (30 char.)
p62_9Pb6.res                   /File name for results of calculation. (30 char.)
prot    /pname/ projectile particle name:
              prot - proton, neut - neutron, pipl - pi+, pimi - pi-, pize - pi0,
              gamm - gamma with fixed energy, gamb - bremss. gamma, stop - no more calc.
62.9  /t0mev/  minimum (initial) projectile kinetic energy in MeV; [tgmin for gamb]
208.    /anucl/  target mass number
82.    /znucl/  target atomic number
10000  /limc/   total number of inelastic events, normally 2000-500000
-10.    /dt0/    projectile kinetic energy step-size in MeV [Only 1 energy if <0.]
200.5  /t0max/  maximum (final) projectile kinetic energy in MeV, [tgmax for gamb]
10.    /dteta/  step-size (degrees) in ejectile angular distributions [mang > 0]
1      /mspec/  (0/1,2) if ejectile energy spectra (are not/are) needed
1      /mpyld/  (0/1,2) if particle yield tables (are not/are) needed
0      /mchy/   (0/1) if particle channel yields (are not/are) needed
0      /misy/   (0/1,2,3) if isotope yields (are not/are) needed
1      /mdubl/  (0/1,2) if double differential spectra (are not/are) needed
1      /mang/   (0/1,2) if angular distributions (are not/are) needed
1 6  /ipar1,ipar2/ range of ejectile types for spectrum calcs. [Below, ang. bins for mdubl > 0]
22.5 27.5 52.5 57.5 72.5 77.5 92.5 97.5 112.5 117.5 152.5 157.5 -5.0 105.0 115.0 125.0 135.0 145.0 155.0 165.0
0. 22. 1. 22. 120. 2. 120. 400. 10. 400. 1000. 20. /tmin, tmax, dt, j=1-4/
6     /nevtype/ number of evaporated particle types (see table in bldatgem.f).
2       /nh/     Lines of text (<11) to be read in; printed on results file (line 2).
Example No. 6: energy, angular, and double-differential spectra
of n to He from  62.9 MeV p  + Pb208; 10,000 events
stop
```

CEM03.01 Input Example 7

```
p800Au6.inf                   /File name for diagnostic output. (30 char.)
p800Au6.res                   /File name for results of calculation. (30 char.)
prot    /pname/ projectile particle name:
              prot - proton, neut - neutron, pipl - pi+, pimi - pi-, pize - pi0,
              gamm - gamma with fixed energy, gamb - bremss. gamma, stop - no more calc.
800.0  /t0mev/  minimum (initial) projectile kinetic energy in MeV; [tgmin for gamb]
197.    /anucl/  target mass number
79.    /znucl/  target atomic number
10000  /limc/   total number of inelastic events, normally 2000-500000
-20.    /dt0/    projectile kinetic energy step-size in MeV [Only 1 energy if <0.]
1000.5  /t0max/  maximum (final) projectile kinetic energy in MeV, [tgmax for gamb]
10.    /dteta/  step-size (degrees) in ejectile angular distributions [mang > 0]
0      /mspec/  (0/1,2) if ejectile energy spectra (are not/are) needed
1      /mpyld/  (0/1,2) if particle yield tables (are not/are) needed
0      /mchy/   (0/1) if particle channel yields (are not/are) needed
1      /misy/   (0/1,2,3) if isotope yields (are not/are) needed
0      /mdubl/  (0/1,2) if double differential spectra (are not/are) needed
0      /mang/   (0/1,2) if angular distributions (are not/are) needed
2 2  /ipar1,ipar2/ range of ejectile types for spectrum calcs. [Below, ang. bins for mdubl > 0]
25.0 35.0 45.0 55.0 65.0 75.0 -55.0 165.0 55.0 65.0 75.0 85.0 95.0 105.0 115.0 125.0 135.0 145.0 155.0 165.0
0. 500. 10. 500. 600. 10. 600. 700. 10. 700. 5000. 20. /tmin, tmax, dt, j=1-4/
6     /nevtype/ number of evaporated particle types (see table in bldatgem.f).
2       /nh/     Lines of text (<11) to be read in; printed on results file (line 2).
Example No. 7: xsec and kinetic energy of all products measued
at GSI in inverse kinematics for 800 MeV p + Au197; 10,000 events
stop
```

CEM03.01 Input Example 8

```
p1000Fe6.inf                  /File name for diagnostic output. (30 char.)
p1000Fe6.res                  /File name for results of calculation. (30 char.)
prot    /pname/ projectile particle name:
              prot - proton, neut - neutron, pipl - pi+, pimi - pi-, pize - pi0,
              gamm - gamma with fixed energy, gamb - bremss. gamma, stop - no more calc.
1000.0  /t0mev/  minimum (initial) projectile kinetic energy in MeV; [tgmin for gamb]
56.    /anucl/  target mass number
26.    /znucl/  target atomic number
10000  /limc/   total number of inelastic events, normally 2000-500000
-20.    /dt0/    projectile kinetic energy step-size in MeV [Only 1 energy if <0.]
1000.5  /t0max/  maximum (final) projectile kinetic energy in MeV, [tgmax for gamb]
10.    /dteta/  step-size (degrees) in ejectile angular distributions [mang > 0]
0      /mspec/  (0/1,2) if ejectile energy spectra (are not/are) needed
1      /mpyld/  (0/1,3) if particle yield tables (are not/are) needed
0      /mchy/   (0/1) if particle channel yields (are not/are) needed
3      /misy/   (0/1,2,3) if isotope yields (are not/are) needed
0      /mdubl/  (0/1,2) if double differential spectra (are not/are) needed
0      /mang/   (0/1,2) if angular distributions (are not/are) needed
2 2  /ipar1,ipar2/ range of ejectile types for spectrum calcs. [Below, ang. bins for mdubl > 0]
25.0 35.0 45.0 55.0 65.0 75.0 -55.0 165.0 55.0 65.0 75.0 85.0 95.0 105.0 115.0 125.0 135.0 145.0 155.0 165.0
0. 500. 10. 500. 600. 10. 600. 700. 10. 700. 5000. 20. /tmin, tmax, dt, j=1-4/
6     /nevtype/ number of evaporated particle types (see table in bldatgem.f).
3       /nh/     Lines of text (<11) to be read in; printed on results file (line 2).
Example No. 8: yields, mean kinetic energy, angle of emission,
and much more (the most complete output) of all products measured
at GSI in inverse kinematics for 1000 MeV p  + Fe56; 10,000 events
stop
```

CEM03.01 Input Example 9

```
g300Cu.inf                    /File name for diagnostic output. (30 char.)
g300Cu.res                    /File name for results of calculation. (30 char.)
gamm    /pname/ projectile particle name:
              prot - proton, neut - neutron, pipl - pi+, pimi - pi-, pize - pi0,
              gamm - gamma with fixed energy, gamb - bremss. gamma, stop - no more calc.
300.0  /t0mev/  minimum (initial) projectile kinetic energy in MeV; [tgmin for gamb]
64.    /anucl/  target mass number
29.    /znucl/  target atomic number
10000  /limc/   total number of inelastic events, normally 2000-500000
-5.    /dt0/    projectile kinetic energy step-size in MeV [Only 1 energy if <0.]
300.5  /t0max/  maximum (final) projectile kinetic energy in MeV, [tgmax for gamb]
10.    /dteta/  step-size (degrees) in ejectile angular distributions [mang > 0]
0      /mspec/  (0/1,2) if ejectile energy spectra (are not/are) needed
1      /mpyld/  (0/1,2) if particle yield tables (are not/are) needed
0      /mchy/   (0/1) if particle channel yields (are not/are) needed
0      /misy/   (0/1,2,3) if isotope yields (are not/are) needed
1      /mdubl/  (0/1,2) if double differential spectra (are not/are) needed
0      /mang/   (0/1,2) if angular distributions (are not/are) needed
2 2  /ipar1,ipar2/ range of ejectile types for spectrum calcs. [Below, ang. bins for mdubl > 0]
42.5 47.5 87.5 92.5 132.5 137.5 -55.0 165.0 55.0 65.0 75.0 85.0 95.0 105.0 115.0 125.0 135.0 145.0 155.0 165.0
0. 22. 1. 22. 120. 2. 120. 400. 10. 400. 1000. 20. /tmin, tmax, dt, j=1-4/
6     /nevtype/ number of evaporated particle types (see table in bldatgem.f).
2       /nh/     Lines of text (<11) to be read in; printed on results file (line 2).
Example No. 9: p spectra from monochromatic 300 MeV gamma + 64Cu;
10,000 events
stop
```

CEM03.01 Input Example 10

```
b1000Au6.inf                  /File name for diagnostic output. (30 char.)
b1000Au6.res                  /File name for results of calculation. (30 char.)
gamb    /pname/ projectile particle name:
              prot - proton, neut - neutron, pipl - pi+, pimi - pi-, pize - pi0,
              gamm - gamma with fixed energy, gamb - bremss. gamma, stop - no more calc.
30.0  /t0mev/  minimum (initial) projectile kinetic energy in MeV; [tgmin for gamb]
197.    /anucl/  target mass number
79.    /znucl/  target atomic number
10000  /limc/   total number of inelastic events, normally 2000-500000
-20.    /dt0/    projectile kinetic energy step-size in MeV [Only 1 energy if <0.]
1000.0  /t0max/  maximum (final) projectile kinetic energy in MeV, [tgmax for gamb]
10.    /dteta/  step-size (degrees) in ejectile angular distributions [mang > 0]
0      /mspec/  (0/1,2) if ejectile energy spectra (are not/are) needed
1      /mpyld/  (0/1,2) if particle yield tables (are not/are) needed
0      /mchy/   (0/1) if particle channel yields (are not/are) needed
3      /misy/   (0/1,2,3) if isotope yields (are not/are) needed
0      /mdubl/  (0/1,2) if double differential spectra (are not/are) needed
0      /mang/   (0/1,2) if angular distributions (are not/are) needed
2 2  /ipar1,ipar2/ range of ejectile types for spectrum calcs. [Below, ang. bins for mdubl > 0]
25.0 35.0 45.0 55.0 65.0 75.0 -55.0 165.0 55.0 65.0 75.0 85.0 95.0 105.0 115.0 125.0 135.0 145.0 155.0 165.0
0. 500. 10. 500. 600. 10. 600. 700. 10. 700. 5000. 20. /tmin, tmax, dt, j=1-4/
6     /nevtype/ number of evaporated particle types (see table in bldatgem.f).
4       /nh/     Lines of text (<11) to be read in; printed on results file (line 2).
Example No. 10: yields, mean kinetic energy, emission andle,
neutron multiplicities, Forward/Backward ratios, and much more
(the most complete output) of all products from E_max = 1000 MeV
bremsstrahlung gammas + 197Au; 10,000 events
stop
```

Appendix 2

To save space, parts of long tables shown in all 10 examples of the CEM03.01 output are deleted and replaced here with a dashed line, keeping only the first two and the last two lines of each table. We also deleted the information about the level-density parameter used in the preequilibrium calculations in all examples except the first one.

CEM03.01 Output Example 1

```
 Sun Aug 21 11:48:33 2005
Example No. 1: Proton spectra from 500 MeV p  + Ni58; 10,000 events
 Number of types of evaporated particles =  6

    M      T0     A    Z   Q  B   limc   idel
 0.9383 0.5000   58.  28.  1  1   10000   1

 dt0 =  -20.0, t0max =  500.5, dteta = 10.0

  nnnp  mspec mpyld  mchy  misy mdubl mang  ipar1 ipar2
    0     0     1     0     0     1     0     2     2

 r0m =  1.2, \& cevap = 12.0.

    Theta1     Theta2     Theta3     Theta4     Theta5     Theta6
  60.0  70.0  85.0  95.0 115.0 125.0 155.0 165.0  -5.0  65.0  75.0  85.0

    Theta7     Theta8     Theta9    Theta10
  95.0 105.0 115.0 125.0 135.0 145.0 155.0 165.0

 Tmin, Tmax, dT{1};Tmin, Tmax, dT{2};Tmin, Tmax, dT{3};Tmin, Tmax, dT{4}.
   0.0  22.0  1.00  22.0 100.0  3.00  100.  500.  10.0  500. 5000.  200.

 lim =     100000 .

 Geometrical cross section = 1387.69 mb.
 Calculation takes into account fission and evaporation processes
 using Furihata-s GEM2 code.
 The following level density parameters were used in
 the preequilibrium part of this calculation:
 a(Z,N,E) was calculated with Moller, Nix, Myers \& Swiatecki microscopic
 corrections; [Atomic Data Nucl. Data Tables, 59, 185 (1995)];
 Level density is from a shifted Fermi-gas formula, with the shift given by
  0, delta-p, delta-n, or delta-p + delta-n, for odd-odd; odd-n, even-p;
 odd-p, even-n; and even-even nuclei, respectively for the compound
 nucleus, and similarly using deltaM-p and deltaM-n for the saddle point.
 delta-n and delta-p are tabulated by Moller, Nix \& Kratz and
 deltaM-n and deltaM-p are 4.80 MeV * Bs * {1/N**(1/3) or 1/Z**(1/3)}.
 Bs is the surface area of the saddle-point shape with respect to a sphere.

   Inelastic cross section used here =  684.39 mb
 Monte Carlo inelastic cross section =  699.16 mb

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                500.0 MeV (Z =  1, A = 1) + (Z = 28., A =  58.)

 Number of inelastic interactions =    10000,
 Number of elastic interactions   =     9848,
 Reaction cross section =  684.39 mb, Elastic cross section =  673.99 mb.

  The mean excitation energy, charge, mass, and angular momentum
  of the    10000 nuclei after the
  cascade and before preequilibrium decay are:
  E*av =  84.4 +/- 74.2 MeV;  E*min =  -3.5;  E*max = 410.7
   Zav =  27.2 +/-  1.1;       Zmin =  22.;    Zmax =  30.
   Aav =  55.7 +/-  1.6;       Amin =  48.;    Amax =  58.
   Lav =   5.3 +/-  3.4 h-bar; Lmin =   0.;    Lmax =  26.

  The mean charge, mass, and angular momentum
  of the     580 residual nuclei with less than
  3 MeV of excitation energy after the cascade are:
   Zav =  28.1 +/-  0.3;       Zmin =  28.;   Zmax =  29.
   Aav =  57.1 +/-  0.5;       Amin =  55.;   Amax =  58.
   Lav =   2.5 +/-  1.5 h-bar; Lmin =   0.;   Lmax =  11.

  The mean excitation energy, charge, mass, and angular momentum
  of the    9420 nuclei after preequilibrium
  decay and before the start of statistical decay are:
  E*av =  73.4 +/-  62.9 MeV; E*min =   1.1;  E*max = 398.6
   Zav =  26.7 +/-  1.3;       Zmin =  20.;   Zmax =  30.
   Aav =  54.9 +/-  2.2;       Amin =  43.;   Amax =  58.
   Lav =   6.2 +/-  4.1 h-bar; Lmin =   0.;   Lmax =  35.

  The mean kinetic energy, charge, mass, and angular momentum
  of the   10000 residual nuclei are:
  Ekav =   2.6 +/-  3.5 MeV;  Ekmin =  0.0;  Ekmax =  49.3
   Zav =  23.7 +/-  3.4;       Zmin =  10.;   Zmax =  29.
   Aav =  49.5 +/-  6.8;       Amin =  20.;   Amax =  58.
   Lav =   6.0 +/-  4.1 h-bar; Lmin =   0.;   Lmax =  35.
```

```
 Number of coalesced d, t, He3, He4 =     2479     444     349     174

 Mean multiplicities, yields, and mean energies of ejected particles:
 (Notation: T - all production mechanisms, C - cascade, P - preequilibrium,
 Sp - from spallation residues, Pf - from nuclei before fission,
 F - from fission fragments, E - total evaporation = Sp + Pf + F,
 Co - Coalescence from cascade;
 Values which are identically zero are not printed.

 Part.     Multiplicities            Yields [mb]     <TKE> [MeV]
 ************************************************************
 T  n     2.4754 +/- 0.0157    1694.140 +/-  10.768     53.75
 C  n     1.0704 +/- 0.0103     732.572 +/-   7.081    117.07
 P  n     0.0995 +/- 0.0032      68.097 +/-   2.159     17.37
 Sp n     1.3055 +/- 0.0114     893.472 +/-   7.820      4.60
 E  n     1.3055 +/- 0.0114     893.472 +/-   7.820      4.60
 ************************************************************
 T  p     3.4962 +/- 0.0187    2392.766 +/-  12.797     66.51
 C  p     1.4179 +/- 0.0119     970.397 +/-   8.149    151.55
 P  p     0.1362 +/- 0.0037      93.214 +/-   2.526     19.53
 Sp p     1.9421 +/- 0.0139    1329.155 +/-   9.538      7.72
 E  p     1.9421 +/- 0.0139    1329.155 +/-   9.538      7.72
 ************************************************************
 T  d     0.5950 +/- 0.0077     407.212 +/-   5.279     31.10
 P  d     0.0818 +/- 0.0029      55.983 +/-   1.957     22.87
 Sp d     0.2653 +/- 0.0052     181.569 +/-   3.525      9.89
 E  d     0.2653 +/- 0.0052     181.569 +/-   3.525      9.89
 Co d     0.2479 +/- 0.0050     169.660 +/-   3.408     56.52
 ************************************************************
 T  t     0.1029 +/- 0.0032      70.424 +/-   2.195     23.19
 P  t     0.0266 +/- 0.0016      18.205 +/-   1.116     26.41
 Sp t     0.0319 +/- 0.0018      21.832 +/-   1.222     10.52
 E  t     0.0319 +/- 0.0018      21.832 +/-   1.222     10.52
 Co t     0.0444 +/- 0.0021      30.387 +/-   1.442     30.37
 ************************************************************
 T He3    0.1111 +/- 0.0033      76.036 +/-   2.281     26.83
 P He3    0.0308 +/- 0.0018      21.079 +/-   1.201     29.34
 SpHe3    0.0454 +/- 0.0021      31.071 +/-   1.458     14.24
 E He3    0.0454 +/- 0.0021      31.071 +/-   1.458     14.24
 CoHe3    0.0349 +/- 0.0019      23.885 +/-   1.279     41.00
 ************************************************************
 T He4    0.4213 +/- 0.0065     288.334 +/-   4.442     14.18
 P He4    0.0251 +/- 0.0016      17.178 +/-   1.084     39.07
 SpHe4    0.3788 +/- 0.0062     259.247 +/-   4.212     11.93
 E He4    0.3788 +/- 0.0062     259.247 +/-   4.212     11.93
 CoHe4    0.0174 +/- 0.0013      11.908 +/-   0.903     27.14
 ************************************************************
 pi-      0.0194 +/- 0.0014      13.277 +/-   0.953     49.83
 pi0      0.0638 +/- 0.0025      43.664 +/-   1.729     54.43
 pi+      0.0429 +/- 0.0021      29.360 +/-   1.418     53.90
 ************************************************************

 ********************************  protons   ********************************
 Double differential cross sections [mb/MeV/sr];
 Lab. angle =  60.0 to  70.0 degrees.

    Tp  [MeV]            Total                Cascade               Precompound        Total Evaporation
    1.0-   2.0  1.379E-01 +/- 9.75E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.379E-01 +/- 9.75E-02
    2.0-   3.0  2.620E+00 +/- 4.25E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 2.620E+00 +/- 4.25E-01
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  350.0- 360.0  6.895E-03 +/- 6.89E-03 6.895E-03 +/- 6.89E-03 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
  360.0- 370.0  6.895E-03 +/- 6.89E-03 6.895E-03 +/- 6.89E-03 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00

  Integrated:   2.241E+02 +/- 3.93E+00 9.901E+01 +/- 2.61E+00 9.722E+00 +/- 8.19E-01 1.154E+02 +/- 2.82E+00

 Double differential cross sections [mb/MeV/sr];
 Lab. angle =  85.0 to  95.0 degrees.

    Tp  [MeV]            Total                Cascade               Precompound        Total Evaporation
    1.0-   2.0  4.999E-01 +/- 1.77E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 4.999E-01 +/- 1.77E-01
    2.0-   3.0  3.687E+00 +/- 4.80E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 3.687E+00 +/- 4.80E-01
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  200.0- 210.0  6.249E-03 +/- 6.25E-03 6.249E-03 +/- 6.25E-03 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
  220.0- 230.0  6.249E-03 +/- 6.25E-03 6.249E-03 +/- 6.25E-03 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00

  Integrated:   1.556E+02 +/- 3.12E+00 4.218E+01 +/- 1.62E+00 7.874E+00 +/- 7.01E-01 1.055E+02 +/- 2.57E+00

 Double differential cross sections [mb/MeV/sr];
 Lab. angle = 115.0 to 125.0 degrees.

    Tp  [MeV]            Total                Cascade               Precompound        Total Evaporation
    1.0-   2.0  5.051E-01 +/- 1.91E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 5.051E-01 +/- 1.91E-01
    2.0-   3.0  4.041E+00 +/- 5.40E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 4.041E+00 +/- 5.40E-01
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  150.0- 160.0  7.216E-03 +/- 7.22E-03 7.216E-03 +/- 7.22E-03 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
  160.0- 170.0  1.443E-02 +/- 1.02E-02 1.443E-02 +/- 1.02E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00

  Integrated:   1.198E+02 +/- 2.94E+00 1.407E+01 +/- 1.01E+00 5.195E+00 +/- 6.12E-01 1.005E+02 +/- 2.69E+00

 Double differential cross sections [mb/MeV/sr];
 Lab. angle = 155.0 to 165.0 degrees.

    Tp  [MeV]            Total                Cascade               Precompound        Total Evaporation
    0.0-   1.0  1.827E-01 +/- 1.83E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.827E-01 +/- 1.83E-01
    1.0-   2.0  1.644E+00 +/- 5.48E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.644E+00 +/- 5.48E-01
```

```
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  120.0- 130.0  1.827E-02 +/- 1.83E-02 1.827E-02 +/- 1.83E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
  150.0- 160.0  1.827E-02 +/- 1.83E-02 1.827E-02 +/- 1.83E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00

  Integrated:   1.045E+02 +/- 4.37E+00 6.943E+00 +/- 1.13E+00 4.750E+00 +/- 9.32E-01 9.281E+01 +/- 4.12E+00

 Elapsed cpu time  =  0. min and 23.450 sec.
```

CEM03.01 Output Example 2

```
 Sun Aug 21 11:50:11 2005

Example No. 2: pi0 spectra from 500 MeV pim  + Cu64; 10,000 events
 Number of types of evaporated particles =  6

    M      T0     A    Z   Q  B   limc   idel
 0.1396 0.5000   64.  29. -1  0   10000   1

 dt0 =  -20.0, t0max =  500.5, dteta = 10.0

  nnnp  mspec mpyld  mchy  misy mdubl mang  ipar1 ipar2
    0     1     1     0     0     1     0     8     8

 r0m =  1.2, & cevap = 12.0.

    Theta1     Theta2     Theta3     Theta4     Theta5     Theta6
  25.0  35.0  45.0  55.0  65.0  75.0 -55.0 165.0  55.0  65.0  75.0  85.0

    Theta7     Theta8     Theta9    Theta10
  95.0 105.0 115.0 125.0 135.0 145.0 155.0 165.0


 Tmin, Tmax, dT{1};Tmin, Tmax, dT{2};Tmin, Tmax, dT{3};Tmin, Tmax, dT{4}.
   0.0 500.0 10.00 500.0 600.0 10.00  600.  700.  10.0  700. 5000.   20.

 lim =     100000 .

 Geometrical cross section = 1445.99 mb.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   Inelastic cross section used here =  673.37 mb
 Monte Carlo inelastic cross section =  673.37 mb

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                500.0 MeV (Z = -1, A = 0) + (Z = 29., A =  64.)

 Number of inelastic interactions =    10000,
 Number of elastic interactions   =    11474,

 Reaction cross section =  673.37 mb, Elastic cross section =  772.62 mb.

  The mean excitation energy, charge, mass, and angular momentum
  of the    10000 nuclei after the
  cascade and before preequilibrium decay are:
  E*av = 103.9 +/- 91.4 MeV;  E*min =  -3.2;  E*max = 488.3
   Zav =  27.7 +/-  1.2;       Zmin =  21.;    Zmax =  30.
   Aav =  60.8 +/-  2.4;       Amin =  52.;    Amax =  64.
   Lav =   5.2 +/-  3.2 h-bar; Lmin =   0.;    Lmax =  24.

  The mean charge, mass, and angular momentum
  of the     453 residual nuclei with less than
  3 MeV of excitation energy after the cascade are:
   Zav =  29.0 +/-  0.2;       Zmin =  27.;   Zmax =  29.
   Aav =  62.9 +/-  0.5;       Amin =  59.;   Amax =  64.
   Lav =   2.5 +/-  1.5 h-bar; Lmin =   0.;   Lmax =  12.

  The mean excitation energy, charge, mass, and angular momentum
  of the    9546 nuclei after preequilibrium
  decay and before the start of statistical decay are:
  E*av =  89.9 +/-  79.6 MeV; E*min =   0.2;  E*max = 483.5
   Zav =  27.2 +/-  1.6;       Zmin =  18.;   Zmax =  30.
   Aav =  59.9 +/-  3.1;       Amin =  47.;   Amax =  64.
   Lav =   6.2 +/-  4.2 h-bar; Lmin =   0.;   Lmax =  37.

  The mean kinetic energy, charge, mass, and angular momentum
  of the   10000 residual nuclei are:
  Ekav =   2.3 +/-  3.0 MeV;  Ekmin =  0.0;  Ekmax =  30.4
   Zav =  24.7 +/-  3.8;       Zmin =  10.;   Zmax =  30.
   Aav =  53.3 +/-  8.5;       Amin =  20.;   Amax =  64.
   Lav =   6.1 +/-  4.2 h-bar; Lmin =   0.;   Lmax =  37.

 Number of coalesced d, t, He3, He4 =     2310     688     172     141

 Mean multiplicities, yields, and mean energies of ejected particles:
 (Notation: T - all production mechanisms, C - cascade, P - preequilibrium,
 Sp - from spallation residues, Pf - from nuclei before fission,
 F - from fission fragments, E - total evaporation = Sp + Pf + F,
 Co - Coalescence from cascade;
 Values which are identically zero are not printed.

 Part.     Multiplicities            Yields [mb]     <TKE> [MeV]
 ****************************************************************
 T  n     4.9621 +/- 0.0223    3341.317 +/-  15.000     27.36
 C  n     1.9518 +/- 0.0140    1314.279 +/-   9.407     60.88
```

```
 P  n     0.1825 +/- 0.0043     122.890 +/-   2.877     17.41
 Sp n     2.8278 +/- 0.0168    1904.149 +/-  11.323      4.87
 E  n     2.8278 +/- 0.0168    1904.149 +/-  11.323      4.87
 ***************************************************************
 T  p     1.8339 +/- 0.0135    1234.889 +/-   9.119     30.11
 C  p     0.4837 +/- 0.0070     325.708 +/-   4.683     87.55
 P  p     0.1183 +/- 0.0034      79.659 +/-   2.316     21.51
 Sp p     1.2319 +/- 0.0111     829.521 +/-   7.474      8.39
 E  p     1.2319 +/- 0.0111     829.521 +/-   7.474      8.39
 ***************************************************************
 T  d     0.6772 +/- 0.0082     456.004 +/-   5.541     24.55
 P  d     0.0929 +/- 0.0030      62.556 +/-   2.052     24.50
 Sp d     0.3566 +/- 0.0060     240.123 +/-   4.021     10.22
 E  d     0.3566 +/- 0.0060     240.123 +/-   4.021     10.22
 Co d     0.2277 +/- 0.0048     153.326 +/-   3.213     47.02
 ***************************************************************
 T  t     0.1861 +/- 0.0043     125.314 +/-   2.905     22.02
 P  t     0.0399 +/- 0.0020      26.867 +/-   1.345     29.02
 Sp t     0.0783 +/- 0.0028      52.725 +/-   1.884     10.78
 E  t     0.0783 +/- 0.0028      52.725 +/-   1.884     10.78
 Co t     0.0679 +/- 0.0026      45.722 +/-   1.755     30.86
 ***************************************************************
 T He3    0.0870 +/- 0.0029      58.583 +/-   1.986     24.85
 P He3    0.0317 +/- 0.0018      21.346 +/-   1.199     31.28
 SpHe3    0.0387 +/- 0.0020      26.059 +/-   1.325     14.62
 E He3    0.0387 +/- 0.0020      26.059 +/-   1.325     14.62
 CoHe3    0.0166 +/- 0.0013      11.178 +/-   0.868     36.43
 ***************************************************************
 T He4    0.4384 +/- 0.0066     295.204 +/-   4.458     14.15
 P He4    0.0229 +/- 0.0015      15.420 +/-   1.019     40.73
 SpHe4    0.4015 +/- 0.0063     270.357 +/-   4.267     12.43
 E He4    0.4015 +/- 0.0063     270.357 +/-   4.267     12.43
 CoHe4    0.0140 +/- 0.0012       9.427 +/-   0.797     19.89
 ***************************************************************
 pi-      0.5451 +/- 0.0074     367.053 +/-   4.972    285.58
 pi0      0.2729 +/- 0.0052     183.762 +/-   3.518    151.40
 pi+      0.0636 +/- 0.0025      42.826 +/-   1.698     75.34
 ***************************************************************

 ******************************** neut pions *******************************

 -------------------------- Energy Spectrum [mb/MeV] -------------------------
     Energy spectrum from   0.0 to  570.0 MeV (zero values suppressed).

    Tpi0[MeV]       Total = Cascade
    0.0-  10.0  7.878E-01 +/- 7.28E-02
   10.0-  20.0  1.205E+00 +/- 9.01E-02
- - - - - - - - - - - - - - - - - - - - -
  480.0- 490.0  1.145E-01 +/- 2.78E-02
  490.0- 500.0  2.693E-02 +/- 1.35E-02

  Integrated:   1.838E+02 +/- 3.52E+00

 Double differential cross sections [mb/MeV/sr];
 Lab. angle =  25.0 to  35.0 degrees.

    Tpi0[MeV]       Total = Cascade
    0.0-  10.0  4.919E-02 +/- 2.46E-02
   10.0-  20.0  6.148E-02 +/- 2.75E-02
- - - - - - - - - - - - - - - - - - - - -
  480.0- 490.0  2.459E-02 +/- 1.74E-02
  490.0- 500.0  1.230E-02 +/- 1.23E-02

  Integrated:   3.197E+01 +/- 1.98E+00

 Double differential cross sections [mb/MeV/sr];
 Lab. angle =  45.0 to  55.0 degrees.

    Tpi0[MeV]       Total = Cascade
    0.0-  10.0  7.223E-02 +/- 2.41E-02
   10.0-  20.0  6.421E-02 +/- 2.27E-02
- - - - - - - - - - - - - - - - - - - - -
  430.0- 440.0  1.605E-02 +/- 1.14E-02
  450.0- 460.0  1.605E-02 +/- 1.14E-02

  Integrated:   1.541E+01 +/- 1.11E+00

 Double differential cross sections [mb/MeV/sr];
 Lab. angle =  65.0 to  75.0 degrees.

    Tpi0[MeV]       Total = Cascade
    0.0-  10.0  3.926E-02 +/- 1.60E-02
   10.0-  20.0  1.374E-01 +/- 3.00E-02
- - - - - - - - - - - - - - - - - - - - -
  410.0- 420.0  1.309E-02 +/- 9.25E-03
  430.0- 440.0  6.543E-03 +/- 6.54E-03

  Integrated:   1.354E+01 +/- 9.41E-01

 Elapsed cpu time  =  0. min and 27.110 sec.
```

CEM03.01 Output Example 3

```
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Example No. 3: pip spectra from 562.5 MeV n  + Cu64; 10,000 events
 Number of types of evaporated particles =  6

    M      T0     A    Z   Q  B   limc   idel
 0.9396 0.5625   64.  29.  0  1   10000   1

 dt0 =  -10.0, t0max =  600.5, dteta = 10.0

  nnnp  mspec mpyld  mchy  misy mdubl mang  ipar1 ipar2
    0     0     1     0     0     1     0     9     9

 r0m =  1.2, & cevap = 12.0.

    Theta1     Theta2     Theta3     Theta4     Theta5     Theta6
  25.0  35.0  55.0  65.0  75.0  85.0 115.0 125.0  -5.0  65.0  75.0  85.0

    Theta7     Theta8     Theta9    Theta10
  95.0 105.0 115.0 125.0 135.0 145.0 155.0 165.0


 Tmin, Tmax, dT{1};Tmin, Tmax, dT{2};Tmin, Tmax, dT{3};Tmin, Tmax, dT{4}.
   0.0 500.0 20.00 500.0 600.0 20.00  600.  700.  20.0  700. 5000.   20.

 lim =     100000 .

 Geometrical cross section = 1445.99 mb.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   Inelastic cross section used here =  807.64 mb
 Monte Carlo inelastic cross section =  760.25 mb

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                562.5 MeV (Z =  0, A = 1) + (Z = 29., A =  64.)

 Number of inelastic interactions =    10000,
 Number of elastic interactions   =     9020,

 Reaction cross section =  807.64 mb, Elastic cross section =  728.49 mb.

  The mean excitation energy, charge, mass, and angular momentum
  of the    10000 nuclei after the
  cascade and before preequilibrium decay are:
  E*av =  95.5 +/- 80.4 MeV;  E*min =  -2.0;  E*max = 496.5
   Zav =  28.0 +/-  1.0;       Zmin =  23.;    Zmax =  31.
   Aav =  61.3 +/-  1.9;       Amin =  53.;    Amax =  64.
   Lav =   5.8 +/-  3.7 h-bar; Lmin =   0.;    Lmax =  29.

  The mean charge, mass, and angular momentum
  of the     471 residual nuclei with less than
  3 MeV of excitation energy after the cascade are:
   Zav =  29.0 +/-  0.0;       Zmin =  29.;   Zmax =  29.
   Aav =  63.0 +/-  0.3;       Amin =  61.;   Amax =  64.
   Lav =   2.4 +/-  1.3 h-bar; Lmin =   0.;   Lmax =  10.

  The mean excitation energy, charge, mass, and angular momentum
  of the    9529 nuclei after preequilibrium
  decay and before the start of statistical decay are:
  E*av =  82.0 +/-  69.1 MeV; E*min =   0.1;  E*max = 422.4
   Zav =  27.6 +/-  1.3;       Zmin =  20.;   Zmax =  30.
   Aav =  60.4 +/-  2.6;       Amin =  48.;   Amax =  64.
   Lav =   6.7 +/-  4.6 h-bar; Lmin =   0.;   Lmax =  39.

  The mean kinetic energy, charge, mass, and angular momentum
  of the   10000 residual nuclei are:
  Ekav =   2.6 +/-  3.5 MeV;  Ekmin =  0.0;  Ekmax =  31.6
   Zav =  25.2 +/-  3.2;       Zmin =  12.;   Zmax =  30.
   Aav =  54.3 +/-  7.4;       Amin =  25.;   Amax =  64.
   Lav =   6.5 +/-  4.6 h-bar; Lmin =   0.;   Lmax =  39.

 Number of coalesced d, t, He3, He4 =     2551     679     229     178

 Mean multiplicities, yields, and mean energies of ejected particles:
 (Notation: T - all production mechanisms, C - cascade, P - preequilibrium,
 Sp - from spallation residues, Pf - from nuclei before fission,
 F - from fission fragments, E - total evaporation = Sp + Pf + F,
 Co - Coalescence from cascade;
 Values which are identically zero are not printed.

 Part.     Multiplicities            Yields [mb]     <TKE> [MeV]
 ****************************************************************
 T  n     4.9771 +/- 0.0223    4019.691 +/-  18.018     59.11
 C  n     2.2029 +/- 0.0148    1779.144 +/-  11.987    126.92
 P  n     0.1659 +/- 0.0041     133.987 +/-   3.290     17.21
 Sp n     2.6083 +/- 0.0162    2106.560 +/-  13.044      4.51
 E  n     2.6083 +/- 0.0162    2106.560 +/-  13.044      4.51
 ****************************************************************
 T  p     2.0408 +/- 0.0143    1648.226 +/-  11.538     52.33
 C  p     0.6940 +/- 0.0083     560.500 +/-   6.728    135.95
 P  p     0.1146 +/- 0.0034      92.555 +/-   2.734     20.65
 Sp p     1.2322 +/- 0.0111     995.171 +/-   8.965      8.17
 E  p     1.2322 +/- 0.0111     995.171 +/-   8.965      8.17
 ****************************************************************
```

```
T  d     0.6466 +/- 0.0080     522.218 +/-   6.494     32.07
P  d     0.0956 +/- 0.0031      77.210 +/-   2.497     22.78
Sp d     0.2960 +/- 0.0054     239.061 +/-   4.394      9.71
E  d     0.2960 +/- 0.0054     239.061 +/-   4.394      9.71
Co d     0.2550 +/- 0.0050     205.947 +/-   4.078     61.49
****************************************************************
T  t     0.1654 +/- 0.0041     133.583 +/-   3.285     23.62
P  t     0.0369 +/- 0.0019      29.802 +/-   1.551     28.35
Sp t     0.0606 +/- 0.0025      48.943 +/-   1.988     10.13
E  t     0.0606 +/- 0.0025      48.943 +/-   1.988     10.13
Co t     0.0679 +/- 0.0026      54.839 +/-   2.105     33.10
****************************************************************
T He3    0.0809 +/- 0.0028      65.338 +/-   2.297     28.29
P He3    0.0284 +/- 0.0017      22.937 +/-   1.361     29.35
SpHe3    0.0296 +/- 0.0017      23.906 +/-   1.390     14.61
E He3    0.0296 +/- 0.0017      23.906 +/-   1.390     14.61
CoHe3    0.0229 +/- 0.0015      18.495 +/-   1.222     44.65
****************************************************************
T He4    0.4224 +/- 0.0065     341.146 +/-   5.249     14.65
P He4    0.0229 +/- 0.0015      18.495 +/-   1.222     41.56
SpHe4    0.3818 +/- 0.0062     308.356 +/-   4.990     12.33
E He4    0.3818 +/- 0.0062     308.356 +/-   4.990     12.33
CoHe4    0.0177 +/- 0.0013      14.295 +/-   1.074     29.80
****************************************************************
pi-      0.0925 +/- 0.0030      74.706 +/-   2.456     66.51
pi0      0.0886 +/- 0.0030      71.557 +/-   2.404     60.81
pi+      0.0161 +/- 0.0013      13.003 +/-   1.025     62.49
****************************************************************

********************************* pos. pions *********************************

Double differential cross sections [mb/MeV/sr];
Lab. angle =  25.0 to  35.0 degrees.

   Tpi+[MeV]      Total = Cascade
  20.0-  40.0  1.475E-02 +/- 1.04E-02
  60.0-  80.0  7.374E-03 +/- 7.37E-03
 100.0- 120.0  7.374E-03 +/- 7.37E-03
 160.0- 180.0  7.374E-03 +/- 7.37E-03
 180.0- 200.0  7.374E-03 +/- 7.37E-03

 Integrated:   8.849E-01 +/- 3.61E-01

Double differential cross sections [mb/MeV/sr];
Lab. angle =  55.0 to  65.0 degrees.

   Tpi+[MeV]      Total = Cascade
   0.0-  20.0  1.703E-02 +/- 8.51E-03
  20.0-  40.0  2.554E-02 +/- 1.04E-02
  40.0-  60.0  4.257E-03 +/- 4.26E-03
  60.0-  80.0  4.257E-03 +/- 4.26E-03
 100.0- 120.0  4.257E-03 +/- 4.26E-03
 120.0- 140.0  4.257E-03 +/- 4.26E-03
 220.0- 240.0  4.257E-03 +/- 4.26E-03
 240.0- 260.0  4.257E-03 +/- 4.26E-03

 Integrated:   1.362E+00 +/- 3.41E-01

Double differential cross sections [mb/MeV/sr];
Lab. angle =  75.0 to  85.0 degrees.

   Tpi+[MeV]      Total = Cascade
   0.0-  20.0  1.498E-02 +/- 7.49E-03
  20.0-  40.0  2.246E-02 +/- 9.17E-03
  40.0-  60.0  7.488E-03 +/- 5.29E-03
  60.0-  80.0  3.744E-03 +/- 3.74E-03
 100.0- 120.0  3.744E-03 +/- 3.74E-03
 120.0- 140.0  3.744E-03 +/- 3.74E-03

 Integrated:   1.123E+00 +/- 2.90E-01

Double differential cross sections [mb/MeV/sr];
Lab. angle = 115.0 to 125.0 degrees.

   Tpi+[MeV]      Total = Cascade
   0.0-  20.0  1.277E-02 +/- 7.37E-03
  20.0-  40.0  8.515E-03 +/- 6.02E-03
  40.0-  60.0  4.257E-03 +/- 4.26E-03
  60.0-  80.0  1.277E-02 +/- 7.37E-03
  80.0- 100.0  8.515E-03 +/- 6.02E-03

 Integrated:   9.366E-01 +/- 2.82E-01

Elapsed cpu time  =  0. min and 26.160 sec.
```

CEM03.01 Output Example 4

```
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Example N. 4: n spectra from 1.5 GeV pip + Fe56; 10,000 events
 Number of types of evaporated particles =  6

    M      T0     A    Z   Q  B   limc   idel
 0.1396 1.5000   56.  26.  1  0   10000   1

 dt0 =  -10.0, t0max = 1600.5, dteta = 10.0

  nnnp  mspec mpyld  mchy  misy mdubl mang  ipar1 ipar2
    0     0     1     0     0     1     0     1     1

 r0m =  1.2, & cevap = 12.0.

    Theta1     Theta2     Theta3     Theta4     Theta5     Theta6
  25.0  35.0  85.0  95.0 145.0 155.0 -15.0 125.0  -5.0  65.0  75.0  85.0

    Theta7     Theta8     Theta9    Theta10
  95.0 105.0 115.0 125.0 135.0 145.0 155.0 165.0


 Tmin, Tmax, dT{1};Tmin, Tmax, dT{2};Tmin, Tmax, dT{3};Tmin, Tmax, dT{4}.
   0.0  10.0  1.00  10.0 100.0 10.00  100. 1500. 100.0 1500. 5000.  200.

 lim =     100000 .

 Geometrical cross section = 1367.65 mb.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   Inelastic cross section used here =  684.17 mb
 Monte Carlo inelastic cross section =  684.17 mb

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               1500.0 MeV (Z =  1, A = 0) + (Z = 26., A =  56.)

 Number of inelastic interactions =    10000,
 Number of elastic interactions   =     9990,

 Reaction cross section =  684.17 mb, Elastic cross section =  683.48 mb.

  The mean excitation energy, charge, mass, and angular momentum
  of the    10000 nuclei after the
  cascade and before preequilibrium decay are:
  E*av = 214.4 +/-165.6 MeV;  E*min =  -3.4;  E*max = 898.7
   Zav =  23.9 +/-  1.9;       Zmin =  14.;    Zmax =  29.
   Aav =  50.2 +/-  4.1;       Amin =  34.;    Amax =  56.
   Lav =   7.2 +/-  4.6 h-bar; Lmin =   0.;    Lmax =  32.

  The mean charge, mass, and angular momentum
  of the     174 residual nuclei with less than
  3 MeV of excitation energy after the cascade are:
   Zav =  26.0 +/-  0.2;       Zmin =  24.;   Zmax =  27.
   Aav =  55.0 +/-  0.4;       Amin =  53.;   Amax =  56.
   Lav =   2.4 +/-  1.7 h-bar; Lmin =   0.;   Lmax =  14.

  The mean excitation energy, charge, mass, and angular momentum
  of the    9826 nuclei after preequilibrium
  decay and before the start of statistical decay are:
  E*av = 190.5 +/- 159.7 MeV; E*min =   1.3;  E*max = 879.9
   Zav =  23.4 +/-  2.2;       Zmin =  13.;   Zmax =  28.
   Aav =  49.1 +/-  4.5;       Amin =  32.;   Amax =  56.
   Lav =   8.4 +/-  5.3 h-bar; Lmin =   0.;   Lmax =  34.

  The mean kinetic energy, charge, mass, and angular momentum
  of the   10000 residual nuclei are:
  Ekav =   5.6 +/-  6.9 MeV;  Ekmin =  0.0;  Ekmax =  92.0
   Zav =  17.0 +/-  6.5;       Zmin =   1.;   Zmax =  27.
   Aav =  35.8 +/- 14.0;       Amin =   3.;   Amax =  56.
   Lav =   8.3 +/-  5.3 h-bar; Lmin =   0.;   Lmax =  34.

 Number of coalesced d, t, He3, He4 =     3970     685     355     242

 Mean multiplicities, yields, and mean energies of ejected particles:
 (Notation: T - all production mechanisms, C - cascade, P - preequilibrium,
 Sp - from spallation residues, Pf - from nuclei before fission,
 F - from fission fragments, E - total evaporation = Sp + Pf + F,
 Co - Coalescence from cascade;
 Values which are identically zero are not printed.

 Part.     Multiplicities            Yields [mb]     <TKE> [MeV]
 ***************************************************************
 T  n     6.0528 +/- 0.0246    4141.138 +/-  16.832     43.38
 C  n     2.5470 +/- 0.0160    1742.579 +/-  10.919     90.94
 P  n     0.1473 +/- 0.0038     100.778 +/-   2.626     21.63
 Sp n     3.3585 +/- 0.0183    2297.782 +/-  12.538      8.26
 E  n     3.3585 +/- 0.0183    2297.782 +/-  12.538      8.26
 ***************************************************************
 T  p     5.0726 +/- 0.0225    3470.516 +/-  15.409     56.65
 C  p     2.1066 +/- 0.0145    1441.271 +/-   9.930    119.09
 P  p     0.1416 +/- 0.0038      96.878 +/-   2.575     24.94
 Sp p     2.8244 +/- 0.0168    1932.367 +/-  11.498     11.67
 E  p     2.8244 +/- 0.0168    1932.367 +/-  11.498     11.67
 ***************************************************************
```

```
T  d     1.7409 +/- 0.0132    1191.070 +/-   9.027     22.20
P  d     0.1177 +/- 0.0034      80.527 +/-   2.347     27.57
Sp d     1.2325 +/- 0.0111     843.238 +/-   7.596     13.40
E  d     1.2325 +/- 0.0111     843.238 +/-   7.596     13.40
Co d     0.3907 +/- 0.0063     267.305 +/-   4.276     48.33
****************************************************************
T  t     0.3590 +/- 0.0060     245.617 +/-   4.099     19.50
P  t     0.0524 +/- 0.0023      35.850 +/-   1.566     32.57
Sp t     0.2397 +/- 0.0049     163.995 +/-   3.350     13.38
E  t     0.2397 +/- 0.0049     163.995 +/-   3.350     13.38
Co t     0.0669 +/- 0.0026      45.771 +/-   1.770     31.18
****************************************************************
T He3    0.3233 +/- 0.0057     221.192 +/-   3.890     23.03
P He3    0.0538 +/- 0.0023      36.808 +/-   1.587     36.52
SpHe3    0.2349 +/- 0.0048     160.711 +/-   3.316     16.94
E He3    0.2349 +/- 0.0048     160.711 +/-   3.316     16.94
CoHe3    0.0346 +/- 0.0019      23.672 +/-   1.273     43.36
****************************************************************
T He4    0.8910 +/- 0.0094     609.595 +/-   6.458     14.72
P He4    0.0473 +/- 0.0022      32.361 +/-   1.488     48.53
SpHe4    0.8207 +/- 0.0091     561.498 +/-   6.198     12.46
E He4    0.8207 +/- 0.0091     561.498 +/-   6.198     12.46
CoHe4    0.0230 +/- 0.0015      15.736 +/-   1.038     25.92
****************************************************************
pi-      0.3517 +/- 0.0059     240.622 +/-   4.057    227.02
pi0      0.7005 +/- 0.0084     479.260 +/-   5.726    228.28
pi+      0.7732 +/- 0.0088     529.000 +/-   6.016    461.74
****************************************************************

*********************************  neutrons  ********************************

Double differential cross sections [mb/MeV/sr];
Lab. angle =  25.0 to  35.0 degrees.

   Tn  [MeV]            Total                Cascade               Precompound        Total Evaporation
   0.0-   1.0  1.562E+01 +/- 1.40E+00 0.000E+00 +/- 0.00E+00 1.249E-01 +/- 1.25E-01 1.549E+01 +/- 1.39E+00
   1.0-   2.0  2.399E+01 +/- 1.73E+00 4.997E+00 +/- 7.90E-01 1.249E-01 +/- 1.25E-01 1.887E+01 +/- 1.54E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 900.0-1000.0  8.746E-03 +/- 3.31E-03 8.746E-03 +/- 3.31E-03 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
1000.0-1100.0  2.499E-03 +/- 1.77E-03 2.499E-03 +/- 1.77E-03 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00

 Integrated:   4.957E+02 +/- 7.87E+00 2.701E+02 +/- 5.81E+00 1.074E+01 +/- 1.16E+00 2.149E+02 +/- 5.18E+00

Double differential cross sections [mb/MeV/sr];
Lab. angle =  85.0 to  95.0 degrees.

   Tn  [MeV]            Total                Cascade               Precompound        Total Evaporation
   0.0-   1.0  1.393E+01 +/- 9.33E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.393E+01 +/- 9.33E-01
   1.0-   2.0  2.168E+01 +/- 1.16E+00 3.311E+00 +/- 4.55E-01 6.247E-02 +/- 6.25E-02 1.830E+01 +/- 1.07E+00
   2.0-   3.0  1.961E+01 +/- 1.11E+00 3.561E+00 +/- 4.72E-01 1.874E-01 +/- 1.08E-01 1.587E+01 +/- 9.96E-01
   3.0-   4.0  2.186E+01 +/- 1.17E+00 2.998E+00 +/- 4.33E-01 2.499E-01 +/- 1.25E-01 1.862E+01 +/- 1.08E+00
   4.0-   5.0  1.880E+01 +/- 1.08E+00 2.936E+00 +/- 4.28E-01 2.499E-01 +/- 1.25E-01 1.562E+01 +/- 9.88E-01
   5.0-   6.0  1.580E+01 +/- 9.94E-01 3.436E+00 +/- 4.63E-01 1.874E-01 +/- 1.08E-01 1.218E+01 +/- 8.72E-01
   6.0-   7.0  1.449E+01 +/- 9.51E-01 2.249E+00 +/- 3.75E-01 2.499E-01 +/- 1.25E-01 1.199E+01 +/- 8.66E-01
   7.0-   8.0  1.018E+01 +/- 7.98E-01 2.374E+00 +/- 3.85E-01 1.874E-01 +/- 1.08E-01 7.621E+00 +/- 6.90E-01
   8.0-   9.0  1.162E+01 +/- 8.52E-01 2.998E+00 +/- 4.33E-01 3.748E-01 +/- 1.53E-01 8.246E+00 +/- 7.18E-01
   9.0-  10.0  9.308E+00 +/- 7.63E-01 2.061E+00 +/- 3.59E-01 6.247E-01 +/- 1.98E-01 6.622E+00 +/- 6.43E-01
  10.0-  20.0  5.872E+00 +/- 1.92E-01 1.955E+00 +/- 1.11E-01 2.249E-01 +/- 3.75E-02 3.692E+00 +/- 1.52E-01
  20.0-  30.0  2.430E+00 +/- 1.23E-01 1.281E+00 +/- 8.94E-02 1.187E-01 +/- 2.72E-02 1.031E+00 +/- 8.02E-02
  30.0-  40.0  1.331E+00 +/- 9.12E-02 9.807E-01 +/- 7.83E-02 9.370E-02 +/- 2.42E-02 2.561E-01 +/- 4.00E-02
  40.0-  50.0  1.018E+00 +/- 7.98E-02 8.808E-01 +/- 7.42E-02 5.622E-02 +/- 1.87E-02 8.121E-02 +/- 2.25E-02
  50.0-  60.0  6.747E-01 +/- 6.49E-02 6.497E-01 +/- 6.37E-02 6.247E-03 +/- 6.25E-03 1.874E-02 +/- 1.08E-02
  60.0-  70.0  5.310E-01 +/- 5.76E-02 4.997E-01 +/- 5.59E-02 1.874E-02 +/- 1.08E-02 1.249E-02 +/- 8.83E-03
  70.0-  80.0  4.997E-01 +/- 5.59E-02 4.873E-01 +/- 5.52E-02 0.000E+00 +/- 0.00E+00 1.249E-02 +/- 8.83E-03
  80.0-  90.0  3.998E-01 +/- 5.00E-02 3.811E-01 +/- 4.88E-02 1.249E-02 +/- 8.83E-03 6.247E-03 +/- 6.25E-03
  90.0- 100.0  3.623E-01 +/- 4.76E-02 3.561E-01 +/- 4.72E-02 6.247E-03 +/- 6.25E-03 0.000E+00 +/- 0.00E+00
 100.0- 200.0  1.412E-01 +/- 9.39E-03 1.406E-01 +/- 9.37E-03 6.247E-04 +/- 6.25E-04 0.000E+00 +/- 0.00E+00
 200.0- 300.0  2.249E-02 +/- 3.75E-03 2.249E-02 +/- 3.75E-03 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 300.0- 400.0  4.997E-03 +/- 1.77E-03 4.997E-03 +/- 1.77E-03 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00

 Integrated:   3.053E+02 +/- 4.37E+00 1.174E+02 +/- 2.71E+00 7.808E+00 +/- 6.98E-01 1.801E+02 +/- 3.35E+00

Double differential cross sections [mb/MeV/sr];
Lab. angle = 145.0 to 155.0 degrees.

   Tn  [MeV]            Total                Cascade               Precompound        Total Evaporation
   0.0-   1.0  1.337E+01 +/- 1.29E+00 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.337E+01 +/- 1.29E+00
   1.0-   2.0  1.849E+01 +/- 1.52E+00 1.999E+00 +/- 5.00E-01 0.000E+00 +/- 0.00E+00 1.649E+01 +/- 1.44E+00
   2.0-   3.0  1.974E+01 +/- 1.57E+00 2.749E+00 +/- 5.86E-01 1.249E-01 +/- 1.25E-01 1.687E+01 +/- 1.45E+00
   3.0-   4.0  1.774E+01 +/- 1.49E+00 1.374E+00 +/- 4.14E-01 2.499E-01 +/- 1.77E-01 1.612E+01 +/- 1.42E+00
   4.0-   5.0  1.487E+01 +/- 1.36E+00 2.249E+00 +/- 5.30E-01 0.000E+00 +/- 0.00E+00 1.262E+01 +/- 1.26E+00
   5.0-   6.0  1.212E+01 +/- 1.23E+00 1.749E+00 +/- 4.67E-01 0.000E+00 +/- 0.00E+00 1.037E+01 +/- 1.14E+00
   6.0-   7.0  1.262E+01 +/- 1.26E+00 1.874E+00 +/- 4.84E-01 2.499E-01 +/- 1.77E-01 1.049E+01 +/- 1.15E+00
   7.0-   8.0  1.012E+01 +/- 1.12E+00 3.123E+00 +/- 6.25E-01 0.000E+00 +/- 0.00E+00 6.996E+00 +/- 9.35E-01
   8.0-   9.0  8.496E+00 +/- 1.03E+00 1.749E+00 +/- 4.67E-01 7.496E-01 +/- 3.06E-01 5.997E+00 +/- 8.66E-01
   9.0-  10.0  6.247E+00 +/- 8.83E-01 7.496E-01 +/- 3.06E-01 0.000E+00 +/- 0.00E+00 5.497E+00 +/- 8.29E-01
  10.0-  20.0  4.198E+00 +/- 2.29E-01 1.249E+00 +/- 1.25E-01 1.499E-01 +/- 4.33E-02 2.799E+00 +/- 1.87E-01
  20.0-  30.0  1.462E+00 +/- 1.35E-01 5.497E-01 +/- 8.29E-02 4.997E-02 +/- 2.50E-02 8.621E-01 +/- 1.04E-01
  30.0-  40.0  8.621E-01 +/- 1.04E-01 6.622E-01 +/- 9.10E-02 3.748E-02 +/- 2.16E-02 1.624E-01 +/- 4.50E-02
  40.0-  50.0  6.996E-01 +/- 9.35E-02 5.497E-01 +/- 8.29E-02 8.746E-02 +/- 3.31E-02 6.247E-02 +/- 2.79E-02
  50.0-  60.0  4.123E-01 +/- 7.18E-02 3.873E-01 +/- 6.96E-02 1.249E-02 +/- 1.25E-02 1.249E-02 +/- 1.25E-02
  60.0-  70.0  3.998E-01 +/- 7.07E-02 3.748E-01 +/- 6.84E-02 1.249E-02 +/- 1.25E-02 1.249E-02 +/- 1.25E-02
  70.0-  80.0  3.248E-01 +/- 6.37E-02 3.248E-01 +/- 6.37E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
  80.0-  90.0  2.998E-01 +/- 6.12E-02 2.998E-01 +/- 6.12E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
  90.0- 100.0  8.746E-02 +/- 3.31E-02 8.746E-02 +/- 3.31E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 100.0- 200.0  7.746E-02 +/- 9.84E-03 7.746E-02 +/- 9.84E-03 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
```

```
 200.0- 300.0  4.997E-03 +/- 2.50E-03 4.997E-03 +/- 2.50E-03 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 Integrated:   2.295E+02 +/- 5.35E+00 7.071E+01 +/- 2.97E+00 4.873E+00 +/- 7.80E-01 1.539E+02 +/- 4.39E+00
Elapsed cpu time  =  0. min and 41.350 sec.
```

CEM03.01 Output Example 5

```
 Sun Aug 21 11:55:02 2005

Example No. 5: fission cross section of Au197 bumbarded with
neutrons from 30 to 300 MeV with a step of 10 MeV; 10,000 events
 Number of types of evaporated particles =  6

    M      T0     A    Z   Q  B   limc   idel
 0.9396 0.0300  197.  79.  0  1   10000   1

 dt0 =   10.0, t0max =  300.5, dteta = 10.0

  nnnp  mspec mpyld  mchy  misy mdubl mang  ipar1 ipar2
    0     0     1     0     0     0     0     2     2

 r0m =  1.2, & cevap = 12.0.

 lim =     100000 .

 Geometrical cross section = 2394.46 mb.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   Inelastic cross section used here = 2333.73 mb
 Monte Carlo inelastic cross section = 1646.70 mb

     Sun Aug 21 11:55:02 2005

                30.0 MeV (Z =  0, A = 1) + (Z = 79., A = 197.)

 Number of inelastic interactions =    10000,
 Number of elastic interactions   =     4541,

 Reaction cross section = 2333.73 mb, Elastic cross section = 1059.75 mb.

  The mean excitation energy, charge, mass, and angular momentum
  of the    10000 nuclei after the
  cascade and before preequilibrium decay are:
  E*av =  34.7 +/-  5.4 MeV;  E*min =   0.0;  E*max =  36.3
   Zav =  79.0 +/-  0.0;       Zmin =  78.;    Zmax =  79.
   Aav = 197.9 +/-  0.3;       Amin = 195.;    Amax = 198.
   Lav =   6.1 +/-  2.4 h-bar; Lmin =   0.;    Lmax =  11.

  The mean charge, mass, and angular momentum
  of the      52 residual nuclei with less than
  3 MeV of excitation energy after the cascade are:
   Zav =  79.0 +/-  0.0;       Zmin =  79.;   Zmax =  79.
   Aav = 196.4 +/-  0.5;       Amin = 195.;   Amax = 197.
   Lav =   2.8 +/-  1.8 h-bar; Lmin =   0.;   Lmax =   8.

  The mean excitation energy, charge, mass, and angular momentum
  of the    9946 nuclei after preequilibrium
  decay and before the start of statistical decay are:
  E*av =  28.0 +/-  10.7 MeV; E*min =   0.1;  E*max =  36.2
   Zav =  79.0 +/-  0.2;       Zmin =  77.;   Zmax =  79.
   Aav = 197.5 +/-  0.6;       Amin = 194.;   Amax = 198.
   Lav =   6.5 +/-  2.7 h-bar; Lmin =   0.;   Lmax =  20.

  The mean kinetic energy, charge, mass, and angular momentum
  of the   10000 residual nuclei are:
  Ekav =   0.2 +/-  0.1 MeV;  Ekmin =  0.0;  Ekmax =   1.1
   Zav =  79.0 +/-  0.2;       Zmin =  77.;   Zmax =  79.
   Aav = 194.8 +/-  0.8;       Amin = 192.;   Amax = 197.
   Lav =   6.5 +/-  2.7 h-bar; Lmin =   0.;   Lmax =  20.

              Statistical Weight Functions Method:
 Fissility =  0.0000,
 Fission cross section = 1.35184E-02 mb.

 Number of coalesced d, t, He3, He4 =        0       0       0       0

 Mean multiplicities, yields, and mean energies of ejected particles:
 (Notation: T - all production mechanisms, C - cascade, P - preequilibrium,
 Sp - from spallation residues, Pf - from nuclei before fission,
 F - from fission fragments, E - total evaporation = Sp + Pf + F,
 Co - Coalescence from cascade;
 Values which are identically zero are not printed.

 Part.     Multiplicities            Yields [mb]     <TKE> [MeV]
 ****************************************************************
 T  n     3.1273 +/- 0.0177    7298.286 +/-  41.270      2.73
 C  n     0.0813 +/- 0.0029     189.733 +/-   6.654      9.56
 P  n     0.3078 +/- 0.0055     718.323 +/-  12.947     10.93
 Sp n     2.7382 +/- 0.0165    6390.230 +/-  38.617      1.60
 E  n     2.7382 +/- 0.0165    6390.230 +/-  38.617      1.60
 ****************************************************************
 T  p     0.0305 +/- 0.0017      71.179 +/-   4.076     16.99
 C  p     0.0002 +/- 0.0001       0.467 +/-   0.330      8.92
 P  p     0.0299 +/- 0.0017      69.779 +/-   4.035     17.15
 Sp p     0.0004 +/- 0.0002       0.933 +/-   0.467      8.80
 E  p     0.0004 +/- 0.0002       0.933 +/-   0.467      8.80
 ****************************************************************
 T  d     0.0110 +/- 0.0010      25.671 +/-   2.448     17.00
 P  d     0.0109 +/- 0.0010      25.438 +/-   2.436     17.07
 Sp d     0.0001 +/- 0.0001       0.233 +/-   0.233      9.46
 E  d     0.0001 +/- 0.0001       0.233 +/-   0.233      9.46
 ****************************************************************
```

```
 T  t     0.0024 +/- 0.0005       5.601 +/-   1.143     15.30
 P  t     0.0023 +/- 0.0005       5.368 +/-   1.119     15.59
 Sp t     0.0001 +/- 0.0001       0.233 +/-   0.233      8.75
 E  t     0.0001 +/- 0.0001       0.233 +/-   0.233      8.75
 ************************************************************
 T He4    0.0027 +/- 0.0005       6.301 +/-   1.213     25.25
 P He4    0.0025 +/- 0.0005       5.834 +/-   1.167     25.79
 SpHe4    0.0002 +/- 0.0001       0.467 +/-   0.330     18.43
 E He4    0.0002 +/- 0.0001       0.467 +/-   0.330     18.43
 ************************************************************

 Geometrical cross section = 2394.46 mb.

   Inelastic cross section used here = 2222.93 mb
 Monte Carlo inelastic cross section = 1650.33 mb

     Sun Aug 21 11:55:31 2005

                40.0 MeV (Z =  0, A = 1) + (Z = 79., A = 197.)

 Number of inelastic interactions =    10000,
 Number of elastic interactions   =     4509,
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
               Direct Monte Carlo Simulation Method:
 Fissility =  0.0001 +/-  0.0001,
 Fission cross section = 2.22293E-01 +/- 2.22E-01 mb.

               Statistical Weight Functions Method:
 Fissility =  0.0000,
 Fission cross section = 8.63675E-02 mb.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


   Inelastic cross section used here = 2135.39 mb
 Monte Carlo inelastic cross section = 1585.84 mb

     Sun Aug 21 11:56:04 2005

                50.0 MeV (Z =  0, A = 1) + (Z = 79., A = 197.)

 Number of inelastic interactions =    10000,
 Number of elastic interactions   =     5099,
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
               Direct Monte Carlo Simulation Method:
 Fissility =  0.0001 +/-  0.0001,
 Fission cross section = 2.13539E-01 +/- 2.14E-01 mb.

               Statistical Weight Functions Method:
 Fissility =  0.0001,
 Fission cross section = 1.97457E-01 mb.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


   Inelastic cross section used here = 2066.02 mb
 Monte Carlo inelastic cross section = 1564.39 mb

     Sun Aug 21 11:56:39 2005

                60.0 MeV (Z =  0, A = 1) + (Z = 79., A = 197.)

 Number of inelastic interactions =    10000,
 Number of elastic interactions   =     5306,
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
               Direct Monte Carlo Simulation Method:
 Fissility =  0.0003 +/-  0.0002,
 Fission cross section = 6.19806E-01 +/- 3.58E-01 mb.

               Statistical Weight Functions Method:
 Fissility =  0.0002,
 Fission cross section = 4.36174E-01 mb.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


   Inelastic cross section used here = 2010.61 mb
 Monte Carlo inelastic cross section = 1551.22 mb

     Sun Aug 21 11:57:15 2005

                70.0 MeV (Z =  0, A = 1) + (Z = 79., A = 197.)

 Number of inelastic interactions =    10000,
 Number of elastic interactions   =     5436,
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
               Direct Monte Carlo Simulation Method:
 Fissility =  0.0006 +/-  0.0002,
 Fission cross section = 1.20637E+00 +/- 4.92E-01 mb.

               Statistical Weight Functions Method:
 Fissility =  0.0003,
 Fission cross section = 6.60330E-01 mb.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


   Inelastic cross section used here = 1966.01 mb
 Monte Carlo inelastic cross section = 1526.40 mb
```

```
     Sun Aug 21 11:57:53 2005

                80.0 MeV (Z =  0, A = 1) + (Z = 79., A = 197.)

 Number of inelastic interactions =    10000,
 Number of elastic interactions   =     5687,
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
               Direct Monte Carlo Simulation Method:
 Fissility =  0.0005 +/-  0.0002,
 Fission cross section = 9.83003E-01 +/- 4.40E-01 mb.

               Statistical Weight Functions Method:
 Fissility =  0.0005,
 Fission cross section = 1.04597E+00 mb.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


   Inelastic cross section used here = 1929.85 mb
 Monte Carlo inelastic cross section = 1534.81 mb

     Sun Aug 21 11:58:31 2005

                90.0 MeV (Z =  0, A = 1) + (Z = 79., A = 197.)

 Number of inelastic interactions =    10000,
 Number of elastic interactions   =     5601,
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
               Direct Monte Carlo Simulation Method:
 Fissility =  0.0007 +/-  0.0003,
 Fission cross section = 1.35090E+00 +/- 5.11E-01 mb.

               Statistical Weight Functions Method:
 Fissility =  0.0007,
 Fission cross section = 1.40912E+00 mb.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


   Inelastic cross section used here = 1900.36 mb
 Monte Carlo inelastic cross section = 1499.91 mb

     Sun Aug 21 11:59:10 2005

                100.0 MeV (Z =  0, A = 1) + (Z = 79., A = 197.)

 Number of inelastic interactions =    10000,
 Number of elastic interactions   =     5964,
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
               Direct Monte Carlo Simulation Method:
 Fissility =  0.0010 +/-  0.0003,
 Fission cross section = 1.90036E+00 +/- 6.01E-01 mb.

               Statistical Weight Functions Method:
 Fissility =  0.0010,
 Fission cross section = 1.95842E+00 mb.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


   Inelastic cross section used here = 1876.16 mb
 Monte Carlo inelastic cross section = 1484.48 mb

     Sun Aug 21 11:59:50 2005

                110.0 MeV (Z =  0, A = 1) + (Z = 79., A = 197.)

 Number of inelastic interactions =    10000,
 Number of elastic interactions   =     6130,
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
               Direct Monte Carlo Simulation Method:
 Fissility =  0.0014 +/-  0.0004,
 Fission cross section = 2.62662E+00 +/- 7.02E-01 mb.

               Statistical Weight Functions Method:
 Fissility =  0.0013,
 Fission cross section = 2.35115E+00 mb.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


   Inelastic cross section used here = 1856.20 mb
 Monte Carlo inelastic cross section = 1458.88 mb

     Sun Aug 21 12:00:30 2005

                120.0 MeV (Z =  0, A = 1) + (Z = 79., A = 197.)

 Number of inelastic interactions =    10000,
 Number of elastic interactions   =     6413,
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
               Direct Monte Carlo Simulation Method:
 Fissility =  0.0010 +/-  0.0003,
 Fission cross section = 1.85620E+00 +/- 5.87E-01 mb.

               Statistical Weight Functions Method:
 Fissility =  0.0016,
 Fission cross section = 2.89276E+00 mb.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
```

```
  Inelastic cross section used here = 1839.67 mb
 Monte Carlo inelastic cross section = 1494.76 mb

     Sun Aug 21 12:01:09 2005

               130.0 MeV (Z =  0, A = 1) + (Z = 79., A = 197.)

 Number of inelastic interactions =    10000,
 Number of elastic interactions   =     6019,
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
               Direct Monte Carlo Simulation Method:
 Fissility =  0.0019 +/-  0.0004,
 Fission cross section = 3.49537E+00 +/- 8.02E-01 mb.

               Statistical Weight Functions Method:
 Fissility =  0.0021,
 Fission cross section = 3.94922E+00 mb.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


  Inelastic cross section used here = 1825.92 mb
 Monte Carlo inelastic cross section = 1473.60 mb

     Sun Aug 21 12:01:47 2005

               140.0 MeV (Z =  0, A = 1) + (Z = 79., A = 197.)

 Number of inelastic interactions =    10000,
 Number of elastic interactions   =     6249,
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
               Direct Monte Carlo Simulation Method:
 Fissility =  0.0022 +/-  0.0005,
 Fission cross section = 4.01703E+00 +/- 8.56E-01 mb.

               Statistical Weight Functions Method:
 Fissility =  0.0025,
 Fission cross section = 4.47416E+00 mb.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


  Inelastic cross section used here = 1814.46 mb
 Monte Carlo inelastic cross section = 1456.57 mb

     Sun Aug 21 12:02:25 2005

               150.0 MeV (Z =  0, A = 1) + (Z = 79., A = 197.)

 Number of inelastic interactions =    10000,
 Number of elastic interactions   =     6439,
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
               Direct Monte Carlo Simulation Method:
 Fissility =  0.0025 +/-  0.0005,
 Fission cross section = 4.53616E+00 +/- 9.07E-01 mb.

               Statistical Weight Functions Method:
 Fissility =  0.0029,
 Fission cross section = 5.21324E+00 mb.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


  Inelastic cross section used here = 1804.90 mb
 Monte Carlo inelastic cross section = 1448.47 mb

     Sun Aug 21 12:03:01 2005

               160.0 MeV (Z =  0, A = 1) + (Z = 79., A = 197.)

 Number of inelastic interactions =    10000,
 Number of elastic interactions   =     6531,
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
               Direct Monte Carlo Simulation Method:
 Fissility =  0.0034 +/-  0.0006,
 Fission cross section = 6.13666E+00 +/- 1.05E+00 mb.

               Statistical Weight Functions Method:
 Fissility =  0.0034,
 Fission cross section = 6.21793E+00 mb.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


  Inelastic cross section used here = 1796.92 mb
 Monte Carlo inelastic cross section = 1452.95 mb

     Sun Aug 21 12:03:35 2005

               170.0 MeV (Z =  0, A = 1) + (Z = 79., A = 197.)

 Number of inelastic interactions =    10000,
 Number of elastic interactions   =     6480,
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
               Direct Monte Carlo Simulation Method:
 Fissility =  0.0042 +/-  0.0006,
 Fission cross section = 7.54706E+00 +/- 1.16E+00 mb.

               Statistical Weight Functions Method:
```

```
 Fissility =  0.0040,
 Fission cross section = 7.18882E+00 mb.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


   Inelastic cross section used here = 1790.27 mb
 Monte Carlo inelastic cross section = 1437.16 mb

     Sun Aug 21 12:04:08 2005

                180.0 MeV (Z =  0, A = 1) + (Z = 79., A = 197.)

 Number of inelastic interactions =    10000,
 Number of elastic interactions   =     6661,
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
               Direct Monte Carlo Simulation Method:
 Fissility =  0.0051 +/-  0.0007,
 Fission cross section = 9.13037E+00 +/- 1.28E+00 mb.

               Statistical Weight Functions Method:
 Fissility =  0.0048,
 Fission cross section = 8.51760E+00 mb.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


   Inelastic cross section used here = 1784.75 mb
 Monte Carlo inelastic cross section = 1448.29 mb

     Sun Aug 21 12:04:38 2005

                190.0 MeV (Z =  0, A = 1) + (Z = 79., A = 197.)

 Number of inelastic interactions =    10000,
 Number of elastic interactions   =     6533,
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
               Direct Monte Carlo Simulation Method:
 Fissility =  0.0055 +/-  0.0007,
 Fission cross section = 9.81610E+00 +/- 1.32E+00 mb.

               Statistical Weight Functions Method:
 Fissility =  0.0053,
 Fission cross section = 9.53862E+00 mb.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


   Inelastic cross section used here = 1780.19 mb
 Monte Carlo inelastic cross section = 1452.95 mb

     Sun Aug 21 12:05:07 2005

                200.0 MeV (Z =  0, A = 1) + (Z = 79., A = 197.)

 Number of inelastic interactions =    10000,
 Number of elastic interactions   =     6480,
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
               Direct Monte Carlo Simulation Method:
 Fissility =  0.0063 +/-  0.0008,
 Fission cross section = 1.12152E+01 +/- 1.41E+00 mb.

               Statistical Weight Functions Method:
 Fissility =  0.0061,
 Fission cross section = 1.08604E+01 mb.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


   Inelastic cross section used here = 1776.46 mb
 Monte Carlo inelastic cross section = 1443.49 mb

     Sun Aug 21 12:05:35 2005

                210.0 MeV (Z =  0, A = 1) + (Z = 79., A = 197.)

 Number of inelastic interactions =    10000,
 Number of elastic interactions   =     6588,
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
               Direct Monte Carlo Simulation Method:
 Fissility =  0.0059 +/-  0.0008,
 Fission cross section = 1.04811E+01 +/- 1.36E+00 mb.

               Statistical Weight Functions Method:
 Fissility =  0.0070,
 Fission cross section = 1.23665E+01 mb.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


   Inelastic cross section used here = 1773.46 mb
 Monte Carlo inelastic cross section = 1433.72 mb

     Sun Aug 21 12:06:03 2005

                220.0 MeV (Z =  0, A = 1) + (Z = 79., A = 197.)

 Number of inelastic interactions =    10000,
 Number of elastic interactions   =     6701,
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
               Direct Monte Carlo Simulation Method:
```

```
 Fissility =  0.0081 +/-  0.0009,
 Fission cross section = 1.43650E+01 +/- 1.60E+00 mb.

              Statistical Weight Functions Method:
 Fissility =  0.0074,
 Fission cross section = 1.30941E+01 mb.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


   Inelastic cross section used here = 1771.09 mb
 Monte Carlo inelastic cross section = 1448.99 mb

     Sun Aug 21 12:06:31 2005

               230.0 MeV (Z =  0, A = 1) + (Z = 79., A = 197.)

 Number of inelastic interactions =    10000,
 Number of elastic interactions   =     6525,
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
              Direct Monte Carlo Simulation Method:
 Fissility =  0.0087 +/-  0.0009,
 Fission cross section = 1.54085E+01 +/- 1.65E+00 mb.

              Statistical Weight Functions Method:
 Fissility =  0.0081,
 Fission cross section = 1.44286E+01 mb.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


   Inelastic cross section used here = 1769.28 mb
 Monte Carlo inelastic cross section = 1429.36 mb

     Sun Aug 21 12:06:59 2005

               240.0 MeV (Z =  0, A = 1) + (Z = 79., A = 197.)

 Number of inelastic interactions =    10000,
 Number of elastic interactions   =     6752,
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
              Direct Monte Carlo Simulation Method:
 Fissility =  0.0081 +/-  0.0009,
 Fission cross section = 1.43311E+01 +/- 1.59E+00 mb.

              Statistical Weight Functions Method:
 Fissility =  0.0090,
 Fission cross section = 1.59599E+01 mb.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


   Inelastic cross section used here = 1767.95 mb
 Monte Carlo inelastic cross section = 1445.49 mb

     Sun Aug 21 12:07:27 2005

               250.0 MeV (Z =  0, A = 1) + (Z = 79., A = 197.)

 Number of inelastic interactions =    10000,
 Number of elastic interactions   =     6565,
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
              Direct Monte Carlo Simulation Method:
 Fissility =  0.0085 +/-  0.0009,
 Fission cross section = 1.50276E+01 +/- 1.63E+00 mb.

              Statistical Weight Functions Method:
 Fissility =  0.0095,
 Fission cross section = 1.68672E+01 mb.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


   Inelastic cross section used here = 1767.06 mb
 Monte Carlo inelastic cross section = 1458.17 mb

     Sun Aug 21 12:07:56 2005

               260.0 MeV (Z =  0, A = 1) + (Z = 79., A = 197.)

 Number of inelastic interactions =    10000,
 Number of elastic interactions   =     6421,
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
              Direct Monte Carlo Simulation Method:
 Fissility =  0.0092 +/-  0.0010,
 Fission cross section = 1.62570E+01 +/- 1.69E+00 mb.

              Statistical Weight Functions Method:
 Fissility =  0.0098,
 Fission cross section = 1.73745E+01 mb.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


   Inelastic cross section used here = 1766.56 mb
 Monte Carlo inelastic cross section = 1444.01 mb

     Sun Aug 21 12:08:25 2005

               270.0 MeV (Z =  0, A = 1) + (Z = 79., A = 197.)
```

```
 Number of inelastic interactions =    10000,
 Number of elastic interactions   =     6582,
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
              Direct Monte Carlo Simulation Method:
 Fissility =  0.0101 +/-  0.0010,
 Fission cross section = 1.78423E+01 +/- 1.78E+00 mb.

              Statistical Weight Functions Method:
 Fissility =  0.0111,
 Fission cross section = 1.96704E+01 mb.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


   Inelastic cross section used here = 1766.41 mb
 Monte Carlo inelastic cross section = 1427.06 mb

     Sun Aug 21 12:08:55 2005

               280.0 MeV (Z =  0, A = 1) + (Z = 79., A = 197.)

 Number of inelastic interactions =    10000,
 Number of elastic interactions   =     6779,
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
              Direct Monte Carlo Simulation Method:
 Fissility =  0.0106 +/-  0.0010,
 Fission cross section = 1.87239E+01 +/- 1.82E+00 mb.

              Statistical Weight Functions Method:
 Fissility =  0.0117,
 Fission cross section = 2.05921E+01 mb.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


   Inelastic cross section used here = 1766.57 mb
 Monte Carlo inelastic cross section = 1447.24 mb

     Sun Aug 21 12:09:24 2005

               290.0 MeV (Z =  0, A = 1) + (Z = 79., A = 197.)

 Number of inelastic interactions =    10000,
 Number of elastic interactions   =     6545,
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
              Direct Monte Carlo Simulation Method:
 Fissility =  0.0124 +/-  0.0011,
 Fission cross section = 2.19055E+01 +/- 1.97E+00 mb.

              Statistical Weight Functions Method:
 Fissility =  0.0122,
 Fission cross section = 2.15995E+01 mb.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -


   Inelastic cross section used here = 1767.01 mb
 Monte Carlo inelastic cross section = 1449.43 mb

     Sun Aug 21 12:09:55 2005

               300.0 MeV (Z =  0, A = 1) + (Z = 79., A = 197.)

 Number of inelastic interactions =    10000,
 Number of elastic interactions   =     6520,

 Reaction cross section = 1767.01 mb, Elastic cross section = 1152.09 mb.

  The mean excitation energy, charge, mass, and angular momentum
  of the    10000 nuclei after the
  cascade and before preequilibrium decay are:
  E*av = 100.3 +/- 67.7 MeV;  E*min =  -0.9;  E*max = 304.6
   Zav =  78.6 +/-  0.6;       Zmin =  75.;    Zmax =  80.
   Aav = 195.0 +/-  1.3;       Amin = 189.;    Amax = 198.
   Lav =   8.3 +/-  4.7 h-bar; Lmin =   0.;    Lmax =  33.

  The mean charge, mass, and angular momentum
  of the     302 residual nuclei with less than
  3 MeV of excitation energy after the cascade are:
   Zav =  79.0 +/-  0.0;       Zmin =  79.;   Zmax =  79.
   Aav = 196.0 +/-  0.4;       Amin = 194.;   Amax = 197.
   Lav =   3.4 +/-  1.9 h-bar; Lmin =   0.;   Lmax =  11.

  The mean excitation energy, charge, mass, and angular momentum
  of the    9698 nuclei after preequilibrium
  decay and before the start of statistical decay are:
  E*av =  81.3 +/-  54.2 MeV; E*min =   0.8;  E*max = 293.1
   Zav =  78.2 +/-  0.9;       Zmin =  74.;   Zmax =  80.
   Aav = 194.0 +/-  2.0;       Amin = 184.;   Amax = 198.
   Lav =   9.4 +/-  5.6 h-bar; Lmin =   0.;   Lmax =  46.

  The mean kinetic energy, charge, mass, and angular momentum
  of the    9842 residual nuclei are:
  Ekav =   0.7 +/-  0.8 MeV;  Ekmin =  0.0;  Ekmax =  11.3
   Zav =  77.8 +/-  1.2;       Zmin =  71.;   Zmax =  80.
   Aav = 186.9 +/-  6.0;       Amin = 165.;   Amax = 197.
   Lav =   9.2 +/-  5.6 h-bar; Lmin =   0.;   Lmax =  46.

  The mean excitation energy, charge, mass, angular momentum, and
```

```
 fission barrier height of the     158 fissioning nuclei are:
 E*av = 137.1 +/- 48.2 MeV; E*min =  42.7; E*max =  247.6
  Zav =  78.3 +/- 0.8;         Zmin =  75.;  Zmax =  80.
  Aav = 190.4 +/- 3.5;         Amin = 178.;  Amax = 196.
  Lav =  12.1 +/- 5.9 h-bar;  Lmin =   1.;  Lmax =  28.
 Bfav =  18.7 +/- 1.5 MeV;   Bfmin = 15.1; Bfmax = 22.2

The mean total fission product kinetic energy after neutron emission is 129.44 MeV.

              Direct Monte Carlo Simulation Method:
Fissility =  0.0158 +/-  0.0013,
Fission cross section = 2.79188E+01 +/- 2.22E+00 mb.

              Statistical Weight Functions Method:
Fissility =  0.0151,
Fission cross section = 2.66336E+01 mb.

Number of coalesced d, t, He3, He4 =     1054     398      40      22

Mean multiplicities, yields, and mean energies of ejected particles:
(Notation: T - all production mechanisms, C - cascade, P - preequilibrium,
Sp - from spallation residues, Pf - from nuclei before fission,
F - from fission fragments, E - total evaporation = Sp + Pf + F,
Co - Coalescence from cascade;
Values which are identically zero are not printed.

Part.     Multiplicities            Yields [mb]     <TKE> [MeV]
****************************************************************
T  n     9.3677 +/- 0.0306   16552.824 +/-  54.082     17.88
C  n     2.4158 +/- 0.0155    4268.744 +/-  27.464     59.20
P  n     0.4518 +/- 0.0067     798.335 +/-  11.877     15.04
Sp n     6.2866 +/- 0.0251   11108.488 +/-  44.304      2.68
Pf n     0.0461 +/- 0.0021      81.459 +/-   3.794      4.92
F  n     0.1674 +/- 0.0041     295.798 +/-   7.230      3.66
E  n     6.5001 +/- 0.0255   11485.744 +/-  45.050      2.72
****************************************************************
T  p     0.6789 +/- 0.0082    1199.623 +/-  14.559     53.72
C  p     0.2768 +/- 0.0053     489.108 +/-   9.297    106.70
P  p     0.1826 +/- 0.0043     322.656 +/-   7.551     24.71
Sp p     0.2138 +/- 0.0046     377.787 +/-   8.170     11.09
Pf p     0.0025 +/- 0.0005       4.418 +/-   0.884     12.18
F  p     0.0032 +/- 0.0006       5.654 +/-   1.000      7.87
E  p     0.2195 +/- 0.0047     387.859 +/-   8.279     11.05
****************************************************************
T  d     0.2532 +/- 0.0050     447.407 +/-   8.891     28.78
P  d     0.0920 +/- 0.0030     162.565 +/-   5.360     26.52
Sp d     0.0538 +/- 0.0023      95.065 +/-   4.099     11.62
Pf d     0.0009 +/- 0.0003       1.590 +/-   0.530     13.62
F  d     0.0011 +/- 0.0003       1.944 +/-   0.586     11.19
E  d     0.0558 +/- 0.0024      98.599 +/-   4.174     11.64
Co d     0.1054 +/- 0.0032     186.243 +/-   5.737     39.82
****************************************************************
T  t     0.0827 +/- 0.0029     146.132 +/-   5.081     23.72
P  t     0.0217 +/- 0.0015      38.344 +/-   2.603     29.46
Sp t     0.0199 +/- 0.0014      35.164 +/-   2.493     12.15
Pf t     0.0007 +/- 0.0003       1.237 +/-   0.468     13.03
F  t     0.0006 +/- 0.0002       1.060 +/-   0.433     14.24
E  t     0.0212 +/- 0.0015      37.461 +/-   2.573     12.24
Co t     0.0398 +/- 0.0020      70.327 +/-   3.525     26.70
****************************************************************
T He3    0.0167 +/- 0.0013      29.509 +/-   2.283     37.29
P He3    0.0118 +/- 0.0011      20.851 +/-   1.919     38.06
SpHe3    0.0009 +/- 0.0003       1.590 +/-   0.530     26.17
E He3    0.0009 +/- 0.0003       1.590 +/-   0.530     26.17
CoHe3    0.0040 +/- 0.0006       7.068 +/-   1.118     37.51
****************************************************************
T He4    0.1013 +/- 0.0032     178.998 +/-   5.624     22.80
P He4    0.0040 +/- 0.0006       7.068 +/-   1.118     42.41
SpHe4    0.0935 +/- 0.0031     165.215 +/-   5.403     22.09
PfHe4    0.0003 +/- 0.0002       0.530 +/-   0.306     23.68
F He4    0.0013 +/- 0.0004       2.297 +/-   0.637     14.50
E He4    0.0951 +/- 0.0031     168.043 +/-   5.449     21.99
CoHe4    0.0022 +/- 0.0005       3.887 +/-   0.829     21.95
****************************************************************
pi-      0.0107 +/- 0.0010      18.907 +/-   1.828     34.27
pi0      0.0043 +/- 0.0007       7.598 +/-   1.159     24.32
pi+      0.0007 +/- 0.0003       1.237 +/-   0.468     27.61
****************************************************************

Elapsed cpu time  = 15. min and 16.160 sec.
```

CEM03.01 Output Example 6

```
 Sun Aug 21 12:13:40 2005

Example No. 6: energy, angular, and double-differential spectra
of n to He from  62.9 MeV p  + Pb208; 10,000 events
 Number of types of evaporated particles =  6

    M      T0     A    Z   Q  B   limc   idel
 0.9383 0.0629  208.  82.  1  1   10000   1

 dt0 =  -10.0, t0max =  200.5, dteta = 10.0

  nnnp  mspec mpyld  mchy  misy mdubl mang  ipar1 ipar2
    0     1     1     0     0     1     1     1     6

 r0m =  1.2, & cevap = 12.0.

    Theta1     Theta2     Theta3     Theta4     Theta5     Theta6
  22.5  27.5  52.5  57.5  72.5  77.5  92.5  97.5 112.5 117.5 152.5 157.5

    Theta7     Theta8     Theta9    Theta10
  -5.0 105.0 115.0 125.0 135.0 145.0 155.0 165.0


 Tmin, Tmax, dT{1};Tmin, Tmax, dT{2};Tmin, Tmax, dT{3};Tmin, Tmax, dT{4}.
   0.0   22.0  1.00  22.0 120.0  2.00  120.  400.  10.0  400. 1000.   20.

 lim =     100000 .

 Geometrical cross section = 2457.28 mb.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   Inelastic cross section used here = 1962.23 mb
 Monte Carlo inelastic cross section = 1639.39 mb

     Sun Aug 21 12:13:40 2005

                62.9 MeV (Z =  1, A = 1) + (Z = 82., A = 208.)

 Number of inelastic interactions =    10000,
 Number of elastic interactions   =     4989,

 Reaction cross section = 1962.23 mb, Elastic cross section =  978.96 mb.

  The mean excitation energy, charge, mass, and angular momentum
  of the    10000 nuclei after the
  cascade and before preequilibrium decay are:
  E*av =  47.9 +/- 22.0 MeV;  E*min =  -1.2;  E*max =  65.5
   Zav =  82.7 +/-  0.5;       Zmin =  81.;    Zmax =  83.
   Aav = 208.5 +/-  0.6;       Amin = 206.;    Amax = 209.
   Lav =   6.6 +/-  3.1 h-bar; Lmin =   0.;    Lmax =  16.

  The mean charge, mass, and angular momentum
  of the     355 residual nuclei with less than
  3 MeV of excitation energy after the cascade are:
   Zav =  82.2 +/-  0.4;       Zmin =  82.;   Zmax =  83.
   Aav = 207.4 +/-  0.5;       Amin = 206.;   Amax = 208.
   Lav =   3.1 +/-  2.1 h-bar; Lmin =   0.;   Lmax =  11.

  The mean excitation energy, charge, mass, and angular momentum
  of the    9640 nuclei after preequilibrium
  decay and before the start of statistical decay are:
  E*av =  33.6 +/-  18.9 MeV; E*min =   0.1;  E*max =  65.1
   Zav =  82.5 +/-  0.6;       Zmin =  81.;   Zmax =  83.
   Aav = 207.8 +/-  0.8;       Amin = 203.;   Amax = 209.
   Lav =   7.7 +/-  3.9 h-bar; Lmin =   0.;   Lmax =  30.

  The mean kinetic energy, charge, mass, and angular momentum
  of the    9948 residual nuclei are:
  Ekav =   0.3 +/-  0.2 MeV;  Ekmin =  0.0;  Ekmax =   2.3
   Zav =  82.5 +/-  0.6;       Zmin =  81.;   Zmax =  83.
   Aav = 204.8 +/-  1.6;       Amin = 200.;   Amax = 208.
   Lav =   7.5 +/-  3.9 h-bar; Lmin =   0.;   Lmax =  30.

  The mean excitation energy, charge, mass, angular momentum, and
  fission barrier height of the      52 fissioning nuclei are:
  E*av =  57.0 +/-  7.2 MeV; E*min =  36.8; E*max =   65.1
   Zav =  83.0 +/- 0.0;        Zmin =  83.;  Zmax =  83.
   Aav = 208.2 +/- 0.7;        Amin = 207.;  Amax = 209.
   Lav =   8.3 +/- 3.0 h-bar;  Lmin =   1.;  Lmax =  13.
  Bfav =  23.6 +/- 0.2 MeV;   Bfmin = 23.0; Bfmax = 23.9

 The mean total fission product kinetic energy after neutron emission is 193.70 MeV.

               Direct Monte Carlo Simulation Method:
 Fissility =  0.0052 +/-  0.0007,
 Fission cross section = 1.02036E+01 +/- 1.41E+00 mb.

               Statistical Weight Functions Method:
 Fissility =  0.0052,
 Fission cross section = 1.01413E+01 mb.

 Number of coalesced d, t, He3, He4 =       37       0       0       0

 Mean multiplicities, yields, and mean energies of ejected particles:
 (Notation: T - all production mechanisms, C - cascade, P - preequilibrium,
```

```
Sp - from spallation residues, Pf - from nuclei before fission,
F - from fission fragments, E - total evaporation = Sp + Pf + F,
Co - Coalescence from cascade;
Values which are identically zero are not printed.

Part.     Multiplicities           Yields [mb]     <TKE> [MeV]
*****************************************************************
T  n     3.6235 +/- 0.0190    7110.150 +/-  37.352      4.64
C  n     0.2756 +/- 0.0052     540.791 +/-  10.301     22.30
P  n     0.2977 +/- 0.0055     584.157 +/-  10.706     15.10
Sp n     3.0217 +/- 0.0174    5929.279 +/-  34.110      2.02
Pf n     0.0033 +/- 0.0006       6.475 +/-   1.127      2.47
F  n     0.0252 +/- 0.0016      49.448 +/-   3.115      2.35
E  n     3.0502 +/- 0.0175    5985.202 +/-  34.270      2.02
*****************************************************************
T  p     0.4700 +/- 0.0069     922.249 +/-  13.452     29.39
C  p     0.2483 +/- 0.0050     487.222 +/-   9.778     32.31
P  p     0.2143 +/- 0.0046     420.506 +/-   9.084     26.67
Sp p     0.0074 +/- 0.0009      14.521 +/-   1.688     10.30
E  p     0.0074 +/- 0.0009      14.521 +/-   1.688     10.30
*****************************************************************
T  d     0.0434 +/- 0.0021      85.161 +/-   4.088     26.61
P  d     0.0391 +/- 0.0020      76.723 +/-   3.880     27.45
Sp d     0.0006 +/- 0.0002       1.177 +/-   0.481      9.55
E  d     0.0006 +/- 0.0002       1.177 +/-   0.481      9.55
Co d     0.0037 +/- 0.0006       7.260 +/-   1.194     20.50
*****************************************************************
T  t     0.0107 +/- 0.0010      20.996 +/-   2.030     21.89
P  t     0.0101 +/- 0.0010      19.819 +/-   1.972     22.55
Sp t     0.0006 +/- 0.0002       1.177 +/-   0.481     10.73
E  t     0.0006 +/- 0.0002       1.177 +/-   0.481     10.73
*****************************************************************
T He3    0.0011 +/- 0.0003       2.158 +/-   0.651     40.05
P He3    0.0011 +/- 0.0003       2.158 +/-   0.651     40.05
*****************************************************************
T He4    0.0089 +/- 0.0009      17.464 +/-   1.851     29.19
P He4    0.0075 +/- 0.0009      14.717 +/-   1.699     30.53
SpHe4    0.0014 +/- 0.0004       2.747 +/-   0.734     22.01
E He4    0.0014 +/- 0.0004       2.747 +/-   0.734     22.01
*****************************************************************

*********************************  neutrons  ********************************

--------------------------- Energy Spectrum [mb/MeV] --------------------------
    Energy spectrum from   0.0 to   64.0 MeV (zero values suppressed).

   Tn  [MeV]            Total                Cascade               Precompound        Total Evaporation
   0.0-   1.0  1.846E+03 +/- 1.90E+01 0.000E+00 +/- 0.00E+00 8.830E+00 +/- 1.32E+00 1.837E+03 +/- 1.90E+01
   1.0-   2.0  1.826E+03 +/- 1.89E+01 3.002E+01 +/- 2.43E+00 1.511E+01 +/- 1.72E+00 1.781E+03 +/- 1.87E+01
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  56.0-  58.0  4.317E+00 +/- 6.51E-01 4.121E+00 +/- 6.36E-01 1.962E-01 +/- 1.39E-01 0.000E+00 +/- 0.00E+00
  58.0-  60.0  2.257E+00 +/- 4.71E-01 2.158E+00 +/- 4.60E-01 9.811E-02 +/- 9.81E-02 0.000E+00 +/- 0.00E+00

 Integrated:   7.110E+03 +/- 3.74E+01 5.408E+02 +/- 1.03E+01 5.842E+02 +/- 1.07E+01 5.985E+03 +/- 3.43E+01

----------------Normalized Energy Probability Spectrum [1/MeV] ----------------
    Energy spectrum from   0.0 to   64.0 MeV (zero values suppressed).

   Tn  [MeV]            Total                Cascade               Precompound        Total Evaporation
   0.0-   1.0  2.596E-01 +/- 2.68E-03 0.000E+00 +/- 0.00E+00 1.242E-03 +/- 1.85E-04 2.583E-01 +/- 2.67E-03
   1.0-   2.0  2.569E-01 +/- 2.66E-03 4.222E-03 +/- 3.41E-04 2.125E-03 +/- 2.42E-04 2.505E-01 +/- 2.63E-03
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  56.0-  58.0  6.071E-04 +/- 9.15E-05 5.796E-04 +/- 8.94E-05 2.760E-05 +/- 1.95E-05 0.000E+00 +/- 0.00E+00
  58.0-  60.0  3.174E-04 +/- 6.62E-05 3.036E-04 +/- 6.47E-05 1.380E-05 +/- 1.38E-05 0.000E+00 +/- 0.00E+00

 Integrated:   1.000E+00 +/- 5.25E-03 7.606E-02 +/- 1.45E-03 8.216E-02 +/- 1.51E-03 8.418E-01 +/- 4.82E-03

----------------------- Angular Distributions [mb/sr] -----------------------

 Ang.n          Total                Cascade               Precompound         Total Evaporation
 [deg.]
   5.0   6.948E+02 +/- 3.78E+01 9.250E+01 +/- 1.38E+01 1.110E+02 +/- 1.51E+01 4.913E+02 +/- 3.18E+01
  15.0   7.365E+02 +/- 2.26E+01 1.329E+02 +/- 9.59E+00 8.237E+01 +/- 7.55E+00 5.212E+02 +/- 1.90E+01
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 165.0   4.659E+02 +/- 1.80E+01 2.077E+00 +/- 1.20E+00 2.146E+01 +/- 3.85E+00 4.423E+02 +/- 1.75E+01
 175.0   5.057E+02 +/- 3.22E+01 2.056E+00 +/- 2.06E+00 1.850E+01 +/- 6.17E+00 4.851E+02 +/- 3.16E+01

Integ.   7.110E+03 +/- 3.74E+01 5.408E+02 +/- 1.03E+01 5.842E+02 +/- 1.07E+01 5.985E+03 +/- 3.43E+01

Double differential cross sections [mb/MeV/sr];
Lab. angle =  22.5 to  27.5 degrees.

   Tn  [MeV]            Total                Cascade               Precompound        Total Evaporation
   0.0-   1.0  1.720E+02 +/- 1.21E+01 0.000E+00 +/- 0.00E+00 1.694E+00 +/- 1.20E+00 1.703E+02 +/- 1.20E+01
   1.0-   2.0  1.533E+02 +/- 1.14E+01 1.694E+00 +/- 1.20E+00 1.694E+00 +/- 1.20E+00 1.499E+02 +/- 1.13E+01
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  56.0-  58.0  3.812E+00 +/- 1.27E+00 3.812E+00 +/- 1.27E+00 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
  58.0-  60.0  1.694E+00 +/- 8.47E-01 1.694E+00 +/- 8.47E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00

 Integrated:   7.666E+02 +/- 2.55E+01 1.482E+02 +/- 1.12E+01 1.042E+02 +/- 9.39E+00 5.142E+02 +/- 2.09E+01

Double differential cross sections [mb/MeV/sr];
Lab. angle =  52.5 to  57.5 degrees.

   Tn  [MeV]            Total                Cascade               Precompound        Total Evaporation
   0.0-   1.0  1.468E+02 +/- 8.01E+00 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.468E+02 +/- 8.01E+00
```

```
    1.0-   2.0  1.473E+02 +/- 8.02E+00 4.370E+00 +/- 1.38E+00 1.748E+00 +/- 8.74E-01 1.412E+02 +/- 7.85E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   56.0-  58.0  2.185E-01 +/- 2.19E-01 2.185E-01 +/- 2.19E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
   58.0-  60.0  6.555E-01 +/- 3.78E-01 6.555E-01 +/- 3.78E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00

  Integrated:   6.376E+02 +/- 1.67E+01 8.391E+01 +/- 6.06E+00 6.861E+01 +/- 5.48E+00 4.851E+02 +/- 1.46E+01

 Double differential cross sections [mb/MeV/sr];
 Lab. angle =  72.5 to  77.5 degrees.

    Tn  [MeV]            Total                Cascade               Precompound        Total Evaporation
    0.0-   1.0  1.549E+02 +/- 7.58E+00 0.000E+00 +/- 0.00E+00 7.412E-01 +/- 5.24E-01 1.542E+02 +/- 7.56E+00
    1.0-   2.0  1.468E+02 +/- 7.38E+00 2.965E+00 +/- 1.05E+00 1.112E+00 +/- 6.42E-01 1.427E+02 +/- 7.27E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   48.0-  50.0  1.853E-01 +/- 1.85E-01 0.000E+00 +/- 0.00E+00 1.853E-01 +/- 1.85E-01 0.000E+00 +/- 0.00E+00
   50.0-  52.0  1.853E-01 +/- 1.85E-01 0.000E+00 +/- 0.00E+00 1.853E-01 +/- 1.85E-01 0.000E+00 +/- 0.00E+00

  Integrated:   5.693E+02 +/- 1.45E+01 3.780E+01 +/- 3.74E+00 4.633E+01 +/- 4.14E+00 4.851E+02 +/- 1.34E+01

 Double differential cross sections [mb/MeV/sr];
 Lab. angle =  92.5 to  97.5 degrees.

    Tn  [MeV]            Total                Cascade               Precompound        Total Evaporation
    0.0-   1.0  1.383E+02 +/- 7.05E+00 0.000E+00 +/- 0.00E+00 1.078E+00 +/- 6.22E-01 1.373E+02 +/- 7.02E+00
    1.0-   2.0  1.459E+02 +/- 7.24E+00 7.187E-01 +/- 5.08E-01 2.515E+00 +/- 9.51E-01 1.427E+02 +/- 7.16E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   36.0-  38.0  1.797E-01 +/- 1.80E-01 0.000E+00 +/- 0.00E+00 1.797E-01 +/- 1.80E-01 0.000E+00 +/- 0.00E+00
   42.0-  44.0  3.593E-01 +/- 2.54E-01 0.000E+00 +/- 0.00E+00 3.593E-01 +/- 2.54E-01 0.000E+00 +/- 0.00E+00

  Integrated:   5.261E+02 +/- 1.37E+01 1.797E+01 +/- 2.54E+00 3.917E+01 +/- 3.75E+00 4.690E+02 +/- 1.30E+01

 Double differential cross sections [mb/MeV/sr];
 Lab. angle = 112.5 to 117.5 degrees.

    Tn  [MeV]            Total                Cascade               Precompound        Total Evaporation
    0.0-   1.0  1.458E+02 +/- 7.59E+00 0.000E+00 +/- 0.00E+00 7.900E-01 +/- 5.59E-01 1.450E+02 +/- 7.57E+00
    1.0-   2.0  1.450E+02 +/- 7.57E+00 2.370E+00 +/- 9.68E-01 3.950E-01 +/- 3.95E-01 1.422E+02 +/- 7.49E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   40.0-  42.0  1.975E-01 +/- 1.97E-01 0.000E+00 +/- 0.00E+00 1.975E-01 +/- 1.97E-01 0.000E+00 +/- 0.00E+00
   50.0-  52.0  1.975E-01 +/- 1.97E-01 0.000E+00 +/- 0.00E+00 1.975E-01 +/- 1.97E-01 0.000E+00 +/- 0.00E+00

  Integrated:   4.910E+02 +/- 1.39E+01 7.505E+00 +/- 1.72E+00 2.409E+01 +/- 3.08E+00 4.594E+02 +/- 1.35E+01

 Double differential cross sections [mb/MeV/sr];
 Lab. angle = 152.5 to 157.5 degrees.

    Tn  [MeV]            Total                Cascade               Precompound        Total Evaporation
    0.0-   1.0  1.338E+02 +/- 1.06E+01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.338E+02 +/- 1.06E+01
    1.0-   2.0  1.288E+02 +/- 1.04E+01 8.471E-01 +/- 8.47E-01 1.694E+00 +/- 1.20E+00 1.262E+02 +/- 1.03E+01
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   21.0-  22.0  8.471E-01 +/- 8.47E-01 0.000E+00 +/- 0.00E+00 8.471E-01 +/- 8.47E-01 0.000E+00 +/- 0.00E+00
   46.0-  48.0  4.235E-01 +/- 4.24E-01 0.000E+00 +/- 0.00E+00 4.235E-01 +/- 4.24E-01 0.000E+00 +/- 0.00E+00

  Integrated:   4.515E+02 +/- 1.96E+01 8.471E-01 +/- 8.47E-01 1.694E+01 +/- 3.79E+00 4.337E+02 +/- 1.92E+01

 ********************************  protons   ********************************

 --------------------------- Energy Spectrum [mb/MeV] --------------------------
     Energy spectrum from   0.0 to   64.0 MeV (zero values suppressed).

    Tp  [MeV]            Total                Cascade               Precompound        Total Evaporation
    7.0-   8.0  1.962E-01 +/- 1.96E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.962E-01 +/- 1.96E-01
    8.0-   9.0  1.786E+01 +/- 1.87E+00 1.393E+01 +/- 1.65E+00 1.962E-01 +/- 1.96E-01 3.728E+00 +/- 8.55E-01
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   60.0-  62.0  2.551E+00 +/- 5.00E-01 2.453E+00 +/- 4.91E-01 9.811E-02 +/- 9.81E-02 0.000E+00 +/- 0.00E+00
   62.0-  64.0  1.962E-01 +/- 1.39E-01 1.962E-01 +/- 1.39E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00

  Integrated:   9.222E+02 +/- 1.35E+01 4.872E+02 +/- 9.78E+00 4.205E+02 +/- 9.08E+00 1.452E+01 +/- 1.69E+00

 ------------------------ Angular Distributions [mb/sr] ------------------------

  Ang.p           Total                Cascade               Precompound         Total Evaporation
  [deg.]
    5.0   2.117E+02 +/- 2.09E+01 1.233E+02 +/- 1.59E+01 8.223E+01 +/- 1.30E+01 6.167E+00 +/- 3.56E+00
   15.0   3.288E+02 +/- 1.51E+01 2.333E+02 +/- 1.27E+01 9.484E+01 +/- 8.10E+00 6.922E-01 +/- 6.92E-01
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  165.0   8.307E+00 +/- 2.40E+00 0.000E+00 +/- 0.00E+00 7.614E+00 +/- 2.30E+00 6.922E-01 +/- 6.92E-01
  175.0   1.645E+01 +/- 5.81E+00 0.000E+00 +/- 0.00E+00 1.645E+01 +/- 5.81E+00 0.000E+00 +/- 0.00E+00

 Integ.   9.222E+02 +/- 1.35E+01 4.872E+02 +/- 9.78E+00 4.205E+02 +/- 9.08E+00 1.452E+01 +/- 1.69E+00

 Double differential cross sections [mb/MeV/sr];
 Lab. angle =  22.5 to  27.5 degrees.

    Tp  [MeV]            Total                Cascade               Precompound        Total Evaporation
    8.0-   9.0  2.541E+00 +/- 1.47E+00 1.694E+00 +/- 1.20E+00 0.000E+00 +/- 0.00E+00 8.471E-01 +/- 8.47E-01
    9.0-  10.0  4.235E+00 +/- 1.89E+00 3.388E+00 +/- 1.69E+00 0.000E+00 +/- 0.00E+00 8.471E-01 +/- 8.47E-01
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   58.0-  60.0  2.541E+00 +/- 1.04E+00 1.694E+00 +/- 8.47E-01 8.471E-01 +/- 5.99E-01 0.000E+00 +/- 0.00E+00
   60.0-  62.0  4.235E-01 +/- 4.24E-01 4.235E-01 +/- 4.24E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00

  Integrated:   3.185E+02 +/- 1.64E+01 2.440E+02 +/- 1.44E+01 7.285E+01 +/- 7.86E+00 1.694E+00 +/- 1.20E+00

 Double differential cross sections [mb/MeV/sr];
 Lab. angle =  52.5 to  57.5 degrees.
```

```
    Tp  [MeV]            Total                Cascade               Precompound        Total Evaporation
    8.0-   9.0  2.185E+00 +/- 9.77E-01 2.185E+00 +/- 9.77E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
    9.0-  10.0  3.933E+00 +/- 1.31E+00 3.496E+00 +/- 1.24E+00 0.000E+00 +/- 0.00E+00 4.370E-01 +/- 4.37E-01
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   56.0-  58.0  6.555E-01 +/- 3.78E-01 4.370E-01 +/- 3.09E-01 2.185E-01 +/- 2.19E-01 0.000E+00 +/- 0.00E+00
   58.0-  60.0  2.185E-01 +/- 2.19E-01 0.000E+00 +/- 0.00E+00 2.185E-01 +/- 2.19E-01 0.000E+00 +/- 0.00E+00

  Integrated:   1.180E+02 +/- 7.18E+00 6.686E+01 +/- 5.41E+00 5.026E+01 +/- 4.69E+00 8.740E-01 +/- 6.18E-01

 Double differential cross sections [mb/MeV/sr];
 Lab. angle =  72.5 to  77.5 degrees.

    Tp  [MeV]            Total                Cascade               Precompound        Total Evaporation
    8.0-   9.0  3.706E-01 +/- 3.71E-01 3.706E-01 +/- 3.71E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
    9.0-  10.0  1.112E+00 +/- 6.42E-01 7.412E-01 +/- 5.24E-01 0.000E+00 +/- 0.00E+00 3.706E-01 +/- 3.71E-01
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   52.0-  54.0  1.853E-01 +/- 1.85E-01 0.000E+00 +/- 0.00E+00 1.853E-01 +/- 1.85E-01 0.000E+00 +/- 0.00E+00
   56.0-  58.0  1.853E-01 +/- 1.85E-01 0.000E+00 +/- 0.00E+00 1.853E-01 +/- 1.85E-01 0.000E+00 +/- 0.00E+00

  Integrated:   4.633E+01 +/- 4.14E+00 9.636E+00 +/- 1.89E+00 3.521E+01 +/- 3.61E+00 1.482E+00 +/- 7.41E-01

 Double differential cross sections [mb/MeV/sr];
 Lab. angle =  92.5 to  97.5 degrees.

    Tp  [MeV]            Total                Cascade               Precompound        Total Evaporation
    9.0-  10.0  1.437E+00 +/- 7.19E-01 3.593E-01 +/- 3.59E-01 7.187E-01 +/- 5.08E-01 3.593E-01 +/- 3.59E-01
   10.0-  11.0  2.156E+00 +/- 8.80E-01 3.593E-01 +/- 3.59E-01 1.797E+00 +/- 8.04E-01 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   44.0-  46.0  1.797E-01 +/- 1.80E-01 0.000E+00 +/- 0.00E+00 1.797E-01 +/- 1.80E-01 0.000E+00 +/- 0.00E+00
   52.0-  54.0  1.797E-01 +/- 1.80E-01 0.000E+00 +/- 0.00E+00 1.797E-01 +/- 1.80E-01 0.000E+00 +/- 0.00E+00

  Integrated:   2.659E+01 +/- 3.09E+00 1.797E+00 +/- 8.04E-01 2.408E+01 +/- 2.94E+00 7.187E-01 +/- 5.08E-01

 Double differential cross sections [mb/MeV/sr];
 Lab. angle = 112.5 to 117.5 degrees.

    Tp  [MeV]            Total                Cascade               Precompound        Total Evaporation
    8.0-   9.0  3.950E-01 +/- 3.95E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 3.950E-01 +/- 3.95E-01
   11.0-  12.0  3.950E-01 +/- 3.95E-01 0.000E+00 +/- 0.00E+00 3.950E-01 +/- 3.95E-01 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   40.0-  42.0  1.975E-01 +/- 1.97E-01 0.000E+00 +/- 0.00E+00 1.975E-01 +/- 1.97E-01 0.000E+00 +/- 0.00E+00
   44.0-  46.0  1.975E-01 +/- 1.97E-01 0.000E+00 +/- 0.00E+00 1.975E-01 +/- 1.97E-01 0.000E+00 +/- 0.00E+00

  Integrated:   1.540E+01 +/- 2.47E+00 1.185E+00 +/- 6.84E-01 1.343E+01 +/- 2.30E+00 7.900E-01 +/- 5.59E-01

 Double differential cross sections [mb/MeV/sr];
 Lab. angle = 152.5 to 157.5 degrees.

    Tp  [MeV]            Total                Cascade               Precompound        Total Evaporation
   10.0-  11.0  1.694E+00 +/- 1.20E+00 0.000E+00 +/- 0.00E+00 8.471E-01 +/- 8.47E-01 8.471E-01 +/- 8.47E-01
   14.0-  15.0  8.471E-01 +/- 8.47E-01 0.000E+00 +/- 0.00E+00 8.471E-01 +/- 8.47E-01 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   22.0-  24.0  4.235E-01 +/- 4.24E-01 0.000E+00 +/- 0.00E+00 4.235E-01 +/- 4.24E-01 0.000E+00 +/- 0.00E+00
   34.0-  36.0  4.235E-01 +/- 4.24E-01 0.000E+00 +/- 0.00E+00 4.235E-01 +/- 4.24E-01 0.000E+00 +/- 0.00E+00

  Integrated:   7.624E+00 +/- 2.54E+00 0.000E+00 +/- 0.00E+00 6.776E+00 +/- 2.40E+00 8.471E-01 +/- 8.47E-01

 ********************************* deuterons  *********************************

 --------------------------- Energy Spectrum [mb/MeV] --------------------------
     Energy spectrum from   0.0 to   64.0 MeV (zero values suppressed).

    Td  [MeV]            Total               Coalescence            Precompound         Total Evaporation
    6.0-   7.0  3.924E-01 +/- 2.78E-01 3.924E-01 +/- 2.78E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
    7.0-   8.0  3.924E-01 +/- 2.78E-01 3.924E-01 +/- 2.78E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   54.0-  56.0  2.943E-01 +/- 1.70E-01 0.000E+00 +/- 0.00E+00 2.943E-01 +/- 1.70E-01 0.000E+00 +/- 0.00E+00
   56.0-  58.0  9.811E-02 +/- 9.81E-02 0.000E+00 +/- 0.00E+00 9.811E-02 +/- 9.81E-02 0.000E+00 +/- 0.00E+00

  Integrated:   8.516E+01 +/- 4.09E+00 7.260E+00 +/- 1.19E+00 7.672E+01 +/- 3.88E+00 1.177E+00 +/- 4.81E-01

 ----------------------- Angular Distributions [mb/sr] -----------------------

  Ang.d           Total              Coalescence             Precompound         Total Evaporation
  [deg.]
    5.0   3.906E+01 +/- 8.96E+00 1.850E+01 +/- 6.17E+00 2.056E+01 +/- 6.50E+00 0.000E+00 +/- 0.00E+00
   15.0   2.284E+01 +/- 3.98E+00 2.769E+00 +/- 1.38E+00 2.007E+01 +/- 3.73E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  155.0   2.544E+00 +/- 1.04E+00 0.000E+00 +/- 0.00E+00 2.544E+00 +/- 1.04E+00 0.000E+00 +/- 0.00E+00
  165.0   6.922E-01 +/- 6.92E-01 0.000E+00 +/- 0.00E+00 6.922E-01 +/- 6.92E-01 0.000E+00 +/- 0.00E+00

 Integ.   8.516E+01 +/- 4.09E+00 7.260E+00 +/- 1.19E+00 7.672E+01 +/- 3.88E+00 1.177E+00 +/- 4.81E-01

 Double differential cross sections [mb/MeV/sr];
 Lab. angle =  22.5 to  27.5 degrees.

    Td  [MeV]            Total               Coalescence            Precompound         Total Evaporation
   11.0-  12.0  1.694E+00 +/- 1.20E+00 8.471E-01 +/- 8.47E-01 8.471E-01 +/- 8.47E-01 0.000E+00 +/- 0.00E+00
   13.0-  14.0  1.694E+00 +/- 1.20E+00 8.471E-01 +/- 8.47E-01 8.471E-01 +/- 8.47E-01 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   44.0-  46.0  4.235E-01 +/- 4.24E-01 0.000E+00 +/- 0.00E+00 4.235E-01 +/- 4.24E-01 0.000E+00 +/- 0.00E+00
   52.0-  54.0  4.235E-01 +/- 4.24E-01 0.000E+00 +/- 0.00E+00 4.235E-01 +/- 4.24E-01 0.000E+00 +/- 0.00E+00

  Integrated:   1.948E+01 +/- 4.06E+00 2.541E+00 +/- 1.47E+00 1.694E+01 +/- 3.79E+00 0.000E+00 +/- 0.00E+00

 Double differential cross sections [mb/MeV/sr];
```

```
 Lab. angle =  52.5 to  57.5 degrees.

    Td  [MeV]           Total               Coalescence            Precompound         Total Evaporation
    7.0-   8.0  4.370E-01 +/- 4.37E-01 4.370E-01 +/- 4.37E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
   12.0-  13.0  8.740E-01 +/- 6.18E-01 0.000E+00 +/- 0.00E+00 8.740E-01 +/- 6.18E-01 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   44.0-  46.0  2.185E-01 +/- 2.19E-01 0.000E+00 +/- 0.00E+00 2.185E-01 +/- 2.19E-01 0.000E+00 +/- 0.00E+00
   48.0-  50.0  2.185E-01 +/- 2.19E-01 0.000E+00 +/- 0.00E+00 2.185E-01 +/- 2.19E-01 0.000E+00 +/- 0.00E+00

  Integrated:   1.005E+01 +/- 2.10E+00 8.740E-01 +/- 6.18E-01 9.177E+00 +/- 2.00E+00 0.000E+00 +/- 0.00E+00

 Double differential cross sections [mb/MeV/sr];
 Lab. angle =  72.5 to  77.5 degrees.

    Td  [MeV]           Total               Coalescence            Precompound         Total Evaporation
   10.0-  11.0  3.706E-01 +/- 3.71E-01 0.000E+00 +/- 0.00E+00 3.706E-01 +/- 3.71E-01 0.000E+00 +/- 0.00E+00
   16.0-  17.0  3.706E-01 +/- 3.71E-01 0.000E+00 +/- 0.00E+00 3.706E-01 +/- 3.71E-01 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   36.0-  38.0  1.853E-01 +/- 1.85E-01 0.000E+00 +/- 0.00E+00 1.853E-01 +/- 1.85E-01 0.000E+00 +/- 0.00E+00
   38.0-  40.0  1.853E-01 +/- 1.85E-01 0.000E+00 +/- 0.00E+00 1.853E-01 +/- 1.85E-01 0.000E+00 +/- 0.00E+00

  Integrated:   4.447E+00 +/- 1.28E+00 0.000E+00 +/- 0.00E+00 4.447E+00 +/- 1.28E+00 0.000E+00 +/- 0.00E+00

 Double differential cross sections [mb/MeV/sr];
 Lab. angle =  92.5 to  97.5 degrees.

    Td  [MeV]           Total               Coalescence            Precompound         Total Evaporation
   15.0-  16.0  3.593E-01 +/- 3.59E-01 0.000E+00 +/- 0.00E+00 3.593E-01 +/- 3.59E-01 0.000E+00 +/- 0.00E+00
   16.0-  17.0  3.593E-01 +/- 3.59E-01 0.000E+00 +/- 0.00E+00 3.593E-01 +/- 3.59E-01 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   42.0-  44.0  1.797E-01 +/- 1.80E-01 0.000E+00 +/- 0.00E+00 1.797E-01 +/- 1.80E-01 0.000E+00 +/- 0.00E+00
   44.0-  46.0  3.593E-01 +/- 2.54E-01 0.000E+00 +/- 0.00E+00 3.593E-01 +/- 2.54E-01 0.000E+00 +/- 0.00E+00

  Integrated:   4.672E+00 +/- 1.30E+00 0.000E+00 +/- 0.00E+00 4.672E+00 +/- 1.30E+00 0.000E+00 +/- 0.00E+00

 Double differential cross sections [mb/MeV/sr];
 Lab. angle = 112.5 to 117.5 degrees.

    Td  [MeV]           Total               Coalescence            Precompound         Total Evaporation
   17.0-  18.0  3.950E-01 +/- 3.95E-01 0.000E+00 +/- 0.00E+00 3.950E-01 +/- 3.95E-01 0.000E+00 +/- 0.00E+00
   20.0-  21.0  3.950E-01 +/- 3.95E-01 0.000E+00 +/- 0.00E+00 3.950E-01 +/- 3.95E-01 0.000E+00 +/- 0.00E+00
   22.0-  24.0  1.975E-01 +/- 1.97E-01 0.000E+00 +/- 0.00E+00 1.975E-01 +/- 1.97E-01 0.000E+00 +/- 0.00E+00
   46.0-  48.0  1.975E-01 +/- 1.97E-01 0.000E+00 +/- 0.00E+00 1.975E-01 +/- 1.97E-01 0.000E+00 +/- 0.00E+00

  Integrated:   1.580E+00 +/- 7.90E-01 0.000E+00 +/- 0.00E+00 1.580E+00 +/- 7.90E-01 0.000E+00 +/- 0.00E+00

 Double differential cross sections [mb/MeV/sr];
 Lab. angle = 152.5 to 157.5 degrees.

    Td  [MeV]           Total               Coalescence            Precompound         Total Evaporation
   19.0-  20.0  8.471E-01 +/- 8.47E-01 0.000E+00 +/- 0.00E+00 8.471E-01 +/- 8.47E-01 0.000E+00 +/- 0.00E+00
   24.0-  26.0  4.235E-01 +/- 4.24E-01 0.000E+00 +/- 0.00E+00 4.235E-01 +/- 4.24E-01 0.000E+00 +/- 0.00E+00
   26.0-  28.0  4.235E-01 +/- 4.24E-01 0.000E+00 +/- 0.00E+00 4.235E-01 +/- 4.24E-01 0.000E+00 +/- 0.00E+00
   28.0-  30.0  4.235E-01 +/- 4.24E-01 0.000E+00 +/- 0.00E+00 4.235E-01 +/- 4.24E-01 0.000E+00 +/- 0.00E+00
   34.0-  36.0  4.235E-01 +/- 4.24E-01 0.000E+00 +/- 0.00E+00 4.235E-01 +/- 4.24E-01 0.000E+00 +/- 0.00E+00

  Integrated:   4.235E+00 +/- 1.89E+00 0.000E+00 +/- 0.00E+00 4.235E+00 +/- 1.89E+00 0.000E+00 +/- 0.00E+00

 **********  tritons  **********

 ---------- Energy Spectrum [mb/MeV] ----------
     Energy spectrum from   0.0 to   64.0 MeV (zero values suppressed).

    Tt  [MeV]           Total               Coalescence            Precompound         Total Evaporation
    8.0-   9.0  1.962E-01 +/- 1.96E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.962E-01 +/- 1.96E-01
   10.0-  11.0  7.849E-01 +/- 3.92E-01 0.000E+00 +/- 0.00E+00 1.962E-01 +/- 1.96E-01 5.887E-01 +/- 3.40E-01
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   40.0-  42.0  9.811E-02 +/- 9.81E-02 0.000E+00 +/- 0.00E+00 9.811E-02 +/- 9.81E-02 0.000E+00 +/- 0.00E+00
   50.0-  52.0  9.811E-02 +/- 9.81E-02 0.000E+00 +/- 0.00E+00 9.811E-02 +/- 9.81E-02 0.000E+00 +/- 0.00E+00

  Integrated:   2.100E+01 +/- 2.03E+00 0.000E+00 +/- 0.00E+00 1.982E+01 +/- 1.97E+00 1.177E+00 +/- 4.81E-01

 ---------- Angular Distributions [mb/sr] ----------

  Ang.t           Total              Coalescence             Precompound         Total Evaporation
  [deg.]
    5.0   2.056E+00 +/- 2.06E+00 0.000E+00 +/- 0.00E+00 2.056E+00 +/- 2.06E+00 0.000E+00 +/- 0.00E+00
   15.0   2.769E+00 +/- 1.38E+00 0.000E+00 +/- 0.00E+00 2.769E+00 +/- 1.38E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  115.0   9.884E-01 +/- 4.42E-01 0.000E+00 +/- 0.00E+00 9.884E-01 +/- 4.42E-01 0.000E+00 +/- 0.00E+00
  125.0   8.749E-01 +/- 4.37E-01 0.000E+00 +/- 0.00E+00 6.561E-01 +/- 3.79E-01 2.187E-01 +/- 2.19E-01

 Integ.   2.100E+01 +/- 2.03E+00 0.000E+00 +/- 0.00E+00 1.982E+01 +/- 1.97E+00 1.177E+00 +/- 4.81E-01

 Double differential cross sections [mb/MeV/sr];
 Lab. angle =  22.5 to  27.5 degrees.

    Tt  [MeV]           Total               Coalescence            Precompound         Total Evaporation
   13.0-  14.0  8.471E-01 +/- 8.47E-01 0.000E+00 +/- 0.00E+00 8.471E-01 +/- 8.47E-01 0.000E+00 +/- 0.00E+00
   18.0-  19.0  8.471E-01 +/- 8.47E-01 0.000E+00 +/- 0.00E+00 8.471E-01 +/- 8.47E-01 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   26.0-  28.0  4.235E-01 +/- 4.24E-01 0.000E+00 +/- 0.00E+00 4.235E-01 +/- 4.24E-01 0.000E+00 +/- 0.00E+00
   34.0-  36.0  4.235E-01 +/- 4.24E-01 0.000E+00 +/- 0.00E+00 4.235E-01 +/- 4.24E-01 0.000E+00 +/- 0.00E+00

  Integrated:   6.776E+00 +/- 2.40E+00 0.000E+00 +/- 0.00E+00 6.776E+00 +/- 2.40E+00 0.000E+00 +/- 0.00E+00
```

```
Double differential cross sections [mb/MeV/sr];
Lab. angle =  52.5 to  57.5 degrees.

    Tt  [MeV]           Total               Coalescence            Precompound         Total Evaporation
  16.0-  17.0  8.740E-01 +/- 6.18E-01 0.000E+00 +/- 0.00E+00 8.740E-01 +/- 6.18E-01 0.000E+00 +/- 0.00E+00
  18.0-  19.0  4.370E-01 +/- 4.37E-01 0.000E+00 +/- 0.00E+00 4.370E-01 +/- 4.37E-01 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  28.0-  30.0  2.185E-01 +/- 2.19E-01 0.000E+00 +/- 0.00E+00 2.185E-01 +/- 2.19E-01 0.000E+00 +/- 0.00E+00
  50.0-  52.0  2.185E-01 +/- 2.19E-01 0.000E+00 +/- 0.00E+00 2.185E-01 +/- 2.19E-01 0.000E+00 +/- 0.00E+00

 Integrated:   4.370E+00 +/- 1.38E+00 0.000E+00 +/- 0.00E+00 4.370E+00 +/- 1.38E+00 0.000E+00 +/- 0.00E+00

Double differential cross sections [mb/MeV/sr];
Lab. angle =  72.5 to  77.5 degrees.

    Tt  [MeV]           Total               Coalescence            Precompound         Total Evaporation
  12.0-  13.0  3.706E-01 +/- 3.71E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 3.706E-01 +/- 3.71E-01
  21.0-  22.0  3.706E-01 +/- 3.71E-01 0.000E+00 +/- 0.00E+00 3.706E-01 +/- 3.71E-01 0.000E+00 +/- 0.00E+00
  22.0-  24.0  1.853E-01 +/- 1.85E-01 0.000E+00 +/- 0.00E+00 1.853E-01 +/- 1.85E-01 0.000E+00 +/- 0.00E+00
  30.0-  32.0  1.853E-01 +/- 1.85E-01 0.000E+00 +/- 0.00E+00 1.853E-01 +/- 1.85E-01 0.000E+00 +/- 0.00E+00

 Integrated:   1.482E+00 +/- 7.41E-01 0.000E+00 +/- 0.00E+00 1.112E+00 +/- 6.42E-01 3.706E-01 +/- 3.71E-01

Double differential cross sections [mb/MeV/sr];
Lab. angle =  92.5 to  97.5 degrees.

    Tt  [MeV]           Total               Coalescence            Precompound         Total Evaporation
  11.0-  12.0  3.593E-01 +/- 3.59E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 3.593E-01 +/- 3.59E-01
  17.0-  18.0  3.593E-01 +/- 3.59E-01 0.000E+00 +/- 0.00E+00 3.593E-01 +/- 3.59E-01 0.000E+00 +/- 0.00E+00
  18.0-  19.0  3.593E-01 +/- 3.59E-01 0.000E+00 +/- 0.00E+00 3.593E-01 +/- 3.59E-01 0.000E+00 +/- 0.00E+00
  24.0-  26.0  1.797E-01 +/- 1.80E-01 0.000E+00 +/- 0.00E+00 1.797E-01 +/- 1.80E-01 0.000E+00 +/- 0.00E+00
  40.0-  42.0  1.797E-01 +/- 1.80E-01 0.000E+00 +/- 0.00E+00 1.797E-01 +/- 1.80E-01 0.000E+00 +/- 0.00E+00

 Integrated:   1.797E+00 +/- 8.04E-01 0.000E+00 +/- 0.00E+00 1.437E+00 +/- 7.19E-01 3.593E-01 +/- 3.59E-01

Double differential cross sections [mb/MeV/sr];
Lab. angle = 112.5 to 117.5 degrees.

    Tt  [MeV]           Total               Coalescence            Precompound         Total Evaporation
  18.0-  19.0  3.950E-01 +/- 3.95E-01 0.000E+00 +/- 0.00E+00 3.950E-01 +/- 3.95E-01 0.000E+00 +/- 0.00E+00
  21.0-  22.0  3.950E-01 +/- 3.95E-01 0.000E+00 +/- 0.00E+00 3.950E-01 +/- 3.95E-01 0.000E+00 +/- 0.00E+00
  22.0-  24.0  1.975E-01 +/- 1.97E-01 0.000E+00 +/- 0.00E+00 1.975E-01 +/- 1.97E-01 0.000E+00 +/- 0.00E+00

 Integrated:   1.185E+00 +/- 6.84E-01 0.000E+00 +/- 0.00E+00 1.185E+00 +/- 6.84E-01 0.000E+00 +/- 0.00E+00

 ********************************  Helium-3  ********************************

 --------------------------- Energy Spectrum [mb/MeV] --------------------------
     Energy spectrum from   0.0 to   64.0 MeV (zero values suppressed).

    THe3[MeV]           Total               Coalescence            Precompound         Total Evaporation
  30.0-  32.0  9.811E-02 +/- 9.81E-02 0.000E+00 +/- 0.00E+00 9.811E-02 +/- 9.81E-02 0.000E+00 +/- 0.00E+00
  32.0-  34.0  9.811E-02 +/- 9.81E-02 0.000E+00 +/- 0.00E+00 9.811E-02 +/- 9.81E-02 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  48.0-  50.0  9.811E-02 +/- 9.81E-02 0.000E+00 +/- 0.00E+00 9.811E-02 +/- 9.81E-02 0.000E+00 +/- 0.00E+00
  50.0-  52.0  9.811E-02 +/- 9.81E-02 0.000E+00 +/- 0.00E+00 9.811E-02 +/- 9.81E-02 0.000E+00 +/- 0.00E+00

 Integrated:   2.158E+00 +/- 6.51E-01 0.000E+00 +/- 0.00E+00 2.158E+00 +/- 6.51E-01 0.000E+00 +/- 0.00E+00

 ------------------------ Angular Distributions [mb/sr] ------------------------

  Ang.He3         Total               Coalescence             Precompound         Total Evaporation
  [deg.]
    5.0   2.056E+00 +/- 2.06E+00 0.000E+00 +/- 0.00E+00 2.056E+00 +/- 2.06E+00 0.000E+00 +/- 0.00E+00
   35.0   6.247E-01 +/- 4.42E-01 0.000E+00 +/- 0.00E+00 6.247E-01 +/- 4.42E-01 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   95.0   1.798E-01 +/- 1.80E-01 0.000E+00 +/- 0.00E+00 1.798E-01 +/- 1.80E-01 0.000E+00 +/- 0.00E+00
  115.0   1.977E-01 +/- 1.98E-01 0.000E+00 +/- 0.00E+00 1.977E-01 +/- 1.98E-01 0.000E+00 +/- 0.00E+00

 Integ.   2.158E+00 +/- 6.51E-01 0.000E+00 +/- 0.00E+00 2.158E+00 +/- 6.51E-01 0.000E+00 +/- 0.00E+00

 ********************************   alphas   ********************************

 --------------------------- Energy Spectrum [mb/MeV] --------------------------
     Energy spectrum from   0.0 to   64.0 MeV (zero values suppressed).

    THe4[MeV]           Total               Coalescence            Precompound         Total Evaporation
  19.0-  20.0  5.887E-01 +/- 3.40E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 5.887E-01 +/- 3.40E-01
  20.0-  21.0  5.887E-01 +/- 3.40E-01 0.000E+00 +/- 0.00E+00 1.962E-01 +/- 1.96E-01 3.924E-01 +/- 2.78E-01
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  50.0-  52.0  9.811E-02 +/- 9.81E-02 0.000E+00 +/- 0.00E+00 9.811E-02 +/- 9.81E-02 0.000E+00 +/- 0.00E+00
  56.0-  58.0  9.811E-02 +/- 9.81E-02 0.000E+00 +/- 0.00E+00 9.811E-02 +/- 9.81E-02 0.000E+00 +/- 0.00E+00

 Integrated:   1.746E+01 +/- 1.85E+00 0.000E+00 +/- 0.00E+00 1.472E+01 +/- 1.70E+00 2.747E+00 +/- 7.34E-01

 ------------------------ Angular Distributions [mb/sr] ------------------------

  Ang.He4         Total               Coalescence             Precompound         Total Evaporation
  [deg.]
    5.0   6.167E+00 +/- 3.56E+00 0.000E+00 +/- 0.00E+00 4.111E+00 +/- 2.91E+00 2.056E+00 +/- 2.06E+00
   15.0   1.384E+00 +/- 9.79E-01 0.000E+00 +/- 0.00E+00 1.384E+00 +/- 9.79E-01 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  155.0   1.272E+00 +/- 7.34E-01 0.000E+00 +/- 0.00E+00 4.239E-01 +/- 4.24E-01 8.479E-01 +/- 6.00E-01
  165.0   2.077E+00 +/- 1.20E+00 0.000E+00 +/- 0.00E+00 1.384E+00 +/- 9.79E-01 6.922E-01 +/- 6.92E-01

 Integ.   1.746E+01 +/- 1.85E+00 0.000E+00 +/- 0.00E+00 1.472E+01 +/- 1.70E+00 2.747E+00 +/- 7.34E-01
```

```
Double differential cross sections [mb/MeV/sr];
Lab. angle =  22.5 to  27.5 degrees.

   THe4[MeV]           Total               Coalescence            Precompound         Total Evaporation
  28.0-  30.0  4.235E-01 +/- 4.24E-01 0.000E+00 +/- 0.00E+00 4.235E-01 +/- 4.24E-01 0.000E+00 +/- 0.00E+00
  42.0-  44.0  4.235E-01 +/- 4.24E-01 0.000E+00 +/- 0.00E+00 4.235E-01 +/- 4.24E-01 0.000E+00 +/- 0.00E+00
  50.0-  52.0  4.235E-01 +/- 4.24E-01 0.000E+00 +/- 0.00E+00 4.235E-01 +/- 4.24E-01 0.000E+00 +/- 0.00E+00

 Integrated:   2.541E+00 +/- 1.47E+00 0.000E+00 +/- 0.00E+00 2.541E+00 +/- 1.47E+00 0.000E+00 +/- 0.00E+00

Double differential cross sections [mb/MeV/sr];
Lab. angle =  52.5 to  57.5 degrees.

   THe4[MeV]           Total               Coalescence            Precompound         Total Evaporation
  22.0-  24.0  2.185E-01 +/- 2.19E-01 0.000E+00 +/- 0.00E+00 2.185E-01 +/- 2.19E-01 0.000E+00 +/- 0.00E+00
  26.0-  28.0  2.185E-01 +/- 2.19E-01 0.000E+00 +/- 0.00E+00 2.185E-01 +/- 2.19E-01 0.000E+00 +/- 0.00E+00
  30.0-  32.0  2.185E-01 +/- 2.19E-01 0.000E+00 +/- 0.00E+00 2.185E-01 +/- 2.19E-01 0.000E+00 +/- 0.00E+00
  32.0-  34.0  4.370E-01 +/- 3.09E-01 0.000E+00 +/- 0.00E+00 4.370E-01 +/- 3.09E-01 0.000E+00 +/- 0.00E+00

 Integrated:   2.185E+00 +/- 9.77E-01 0.000E+00 +/- 0.00E+00 2.185E+00 +/- 9.77E-01 0.000E+00 +/- 0.00E+00

Double differential cross sections [mb/MeV/sr];
Lab. angle =  72.5 to  77.5 degrees.

   THe4[MeV]           Total               Coalescence            Precompound         Total Evaporation
  24.0-  26.0  1.853E-01 +/- 1.85E-01 0.000E+00 +/- 0.00E+00 1.853E-01 +/- 1.85E-01 0.000E+00 +/- 0.00E+00
  28.0-  30.0  1.853E-01 +/- 1.85E-01 0.000E+00 +/- 0.00E+00 1.853E-01 +/- 1.85E-01 0.000E+00 +/- 0.00E+00

 Integrated:   7.412E-01 +/- 5.24E-01 0.000E+00 +/- 0.00E+00 7.412E-01 +/- 5.24E-01 0.000E+00 +/- 0.00E+00

Double differential cross sections [mb/MeV/sr];
Lab. angle =  92.5 to  97.5 degrees.

   THe4[MeV]           Total               Coalescence            Precompound         Total Evaporation
  20.0-  21.0  3.593E-01 +/- 3.59E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 3.593E-01 +/- 3.59E-01
  22.0-  24.0  1.797E-01 +/- 1.80E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.797E-01 +/- 1.80E-01
  32.0-  34.0  1.797E-01 +/- 1.80E-01 0.000E+00 +/- 0.00E+00 1.797E-01 +/- 1.80E-01 0.000E+00 +/- 0.00E+00

 Integrated:   1.078E+00 +/- 6.22E-01 0.000E+00 +/- 0.00E+00 3.593E-01 +/- 3.59E-01 7.187E-01 +/- 5.08E-01

Double differential cross sections [mb/MeV/sr];
Lab. angle = 112.5 to 117.5 degrees.

   THe4[MeV]           Total               Coalescence            Precompound         Total Evaporation
  26.0-  28.0  1.975E-01 +/- 1.97E-01 0.000E+00 +/- 0.00E+00 1.975E-01 +/- 1.97E-01 0.000E+00 +/- 0.00E+00

 Integrated:   3.950E-01 +/- 3.95E-01 0.000E+00 +/- 0.00E+00 3.950E-01 +/- 3.95E-01 0.000E+00 +/- 0.00E+00

Double differential cross sections [mb/MeV/sr];
Lab. angle = 152.5 to 157.5 degrees.

   THe4[MeV]           Total               Coalescence            Precompound         Total Evaporation
  24.0-  26.0  4.235E-01 +/- 4.24E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 4.235E-01 +/- 4.24E-01

 Integrated:   8.471E-01 +/- 8.47E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 8.471E-01 +/- 8.47E-01

Elapsed cpu time  =  0. min and 29.940 sec.
```

CEM03.01 Output Example 7

```
 Sun Aug 21 12:17:56 2005

Example No. 7: xsec and kinetic energy of all products measued
at GSI in inverse kinematics for 800 MeV p + Au197; 10,000 events
 Number of types of evaporated particles =  6

    M      T0     A    Z   Q  B   limc   idel
 0.9383 0.8000  197.  79.  1  1   10000   1

 dt0 =  -20.0, t0max = 1000.5, dteta = 10.0

  nnnp  mspec mpyld  mchy  misy mdubl mang  ipar1 ipar2
    0     0     1     0     1     0     0     2     2

 r0m =  1.2, & cevap = 12.0.

 lim =     100000 .

 Geometrical cross section = 2394.46 mb.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   Inelastic cross section used here = 1629.65 mb
 Monte Carlo inelastic cross section = 1594.82 mb

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               800.0 MeV (Z =  1, A = 1) + (Z = 79., A = 197.)

 Number of inelastic interactions =    10000,
 Number of elastic interactions   =     5014,

 Reaction cross section = 1629.65 mb, Elastic cross section =  817.11 mb.

  The mean excitation energy, charge, mass, and angular momentum
  of the    10000 nuclei after the
  cascade and before preequilibrium decay are:
  E*av = 228.5 +/-148.0 MeV;  E*min =  -1.0;  E*max = 727.4
   Zav =  78.6 +/-  1.1;       Zmin =  73.;    Zmax =  82.
   Aav = 192.7 +/-  2.6;       Amin = 181.;    Amax = 198.
   Lav =  12.7 +/-  7.4 h-bar; Lmin =   0.;    Lmax =  47.

  The mean charge, mass, and angular momentum
  of the     197 residual nuclei with less than
  3 MeV of excitation energy after the cascade are:
   Zav =  79.1 +/-  0.3;       Zmin =  79.;   Zmax =  80.
   Aav = 196.1 +/-  0.4;       Amin = 195.;   Amax = 197.
   Lav =   3.7 +/-  2.2 h-bar; Lmin =   0.;   Lmax =  12.

  The mean excitation energy, charge, mass, and angular momentum
  of the    9803 nuclei after preequilibrium
  decay and before the start of statistical decay are:
  E*av = 183.6 +/- 126.6 MeV; E*min =   0.9;  E*max = 679.5
   Zav =  77.7 +/-  1.7;       Zmin =  68.;   Zmax =  82.
   Aav = 190.6 +/-  4.1;       Amin = 169.;   Amax = 197.
   Lav =  14.9 +/-  9.0 h-bar; Lmin =   0.;   Lmax =  68.

  The mean kinetic energy, charge, mass, and angular momentum
  of the    9552 residual nuclei are:
  Ekav =   2.1 +/-  2.6 MeV;  Ekmin =  0.0;  Ekmax =  27.1
   Zav =  74.8 +/-  3.8;       Zmin =  60.;   Zmax =  82.
   Aav = 175.6 +/- 13.1;       Amin = 136.;   Amax = 197.
   Lav =  14.5 +/-  9.1 h-bar; Lmin =   0.;   Lmax =  68.

  The mean excitation energy, charge, mass, angular momentum, and
  fission barrier height of the     448 fissioning nuclei are:
  E*av = 248.6 +/-106.4 MeV; E*min =  38.7; E*max =  575.2
   Zav =  76.7 +/- 2.6;        Zmin =  66.;  Zmax =  82.
   Aav = 183.9 +/- 6.6;        Amin = 160.;  Amax = 196.
   Lav =  17.1 +/- 8.0 h-bar;  Lmin =   2.;  Lmax =  47.
  Bfav =  16.1 +/- 2.7 MeV;   Bfmin =  7.7; Bfmax = 27.8

 The mean total fission product kinetic energy after neutron emission is 167.92 MeV.

              Direct Monte Carlo Simulation Method:
 Fissility =  0.0448 +/-  0.0021,
 Fission cross section = 7.30083E+01 +/- 3.45E+00 mb.

              Statistical Weight Functions Method:
 Fissility =  0.0434,
 Fission cross section = 7.06993E+01 mb.

 Number of coalesced d, t, He3, He4 =     3717    1131     191     288

 Mean multiplicities, yields, and mean energies of ejected particles:
 (Notation: T - all production mechanisms, C - cascade, P - preequilibrium,
 Sp - from spallation residues, Pf - from nuclei before fission,
 F - from fission fragments, E - total evaporation = Sp + Pf + F,
 Co - Coalescence from cascade;
 Values which are identically zero are not printed.

 Part.     Multiplicities           Yields [mb]     <TKE> [MeV]
 ****************************************************************
 T  n    14.5496 +/- 0.0381   23710.740 +/-  62.161     20.39
 C  n     3.2178 +/- 0.0179    5243.884 +/-  29.233     75.54
 P  n     0.5958 +/- 0.0077     970.945 +/-  12.579     19.33
```

```
 Sp n     9.9679 +/- 0.0316   16244.177 +/-  51.451      3.84
 Pf n     0.1258 +/- 0.0035     205.010 +/-   5.780      6.55
 F  n     0.6423 +/- 0.0080    1046.723 +/-  13.061      4.74
 E  n    10.7360 +/- 0.0328   17495.911 +/-  53.397      3.92
 ************************************************************
 T  p     2.3858 +/- 0.0154    3888.016 +/-  25.172     79.75
 C  p     0.8876 +/- 0.0094    1446.476 +/-  15.353    187.42
 P  p     0.3509 +/- 0.0059     571.844 +/-   9.654     28.60
 Sp p     1.0689 +/- 0.0103    1741.932 +/-  16.849     12.16
 Pf p     0.0200 +/- 0.0014      32.593 +/-   2.305     15.35
 F  p     0.0584 +/- 0.0024      95.171 +/-   3.938      9.54
 E  p     1.1473 +/- 0.0107    1869.696 +/-  17.456     12.08
 ************************************************************
 T  d     1.0844 +/- 0.0104    1767.191 +/-  16.970     36.45
 P  d     0.2560 +/- 0.0051     417.190 +/-   8.245     30.74
 Sp d     0.4235 +/- 0.0065     690.156 +/-  10.605     13.28
 Pf d     0.0161 +/- 0.0013      26.237 +/-   2.068     14.85
 F  d     0.0176 +/- 0.0013      28.682 +/-   2.162     10.85
 E  d     0.4572 +/- 0.0068     745.075 +/-  11.019     13.24
 Co d     0.3712 +/- 0.0061     604.926 +/-   9.929     68.97
 ************************************************************
 T  t     0.3831 +/- 0.0062     624.318 +/-  10.087     26.62
 P  t     0.0827 +/- 0.0029     134.772 +/-   4.686     37.34
 Sp t     0.1715 +/- 0.0041     279.485 +/-   6.749     13.95
 Pf t     0.0065 +/- 0.0008      10.593 +/-   1.314     15.41
 F  t     0.0096 +/- 0.0010      15.645 +/-   1.597     11.73
 E  t     0.1876 +/- 0.0043     305.722 +/-   7.058     13.88
 Co t     0.1128 +/- 0.0034     183.824 +/-   5.473     39.93
 ************************************************************
 T He3    0.0921 +/- 0.0030     150.091 +/-   4.946     44.53
 P He3    0.0557 +/- 0.0024      90.771 +/-   3.846     43.53
 SpHe3    0.0158 +/- 0.0013      25.748 +/-   2.048     23.43
 PfHe3    0.0010 +/- 0.0003       1.630 +/-   0.515     27.90
 F He3    0.0005 +/- 0.0002       0.815 +/-   0.364     22.02
 E He3    0.0173 +/- 0.0013      28.193 +/-   2.143     23.64
 CoHe3    0.0191 +/- 0.0014      31.126 +/-   2.252     66.34
 ************************************************************
 T He4    0.6188 +/- 0.0079    1008.427 +/-  12.819     25.08
 P He4    0.0299 +/- 0.0017      48.727 +/-   2.818     54.52
 SpHe4    0.5206 +/- 0.0072     848.395 +/-  11.758     23.13
 PfHe4    0.0102 +/- 0.0010      16.622 +/-   1.646     24.78
 F He4    0.0293 +/- 0.0017      47.749 +/-   2.790     17.61
 E He4    0.5601 +/- 0.0075     912.766 +/-  12.196     22.87
 CoHe4    0.0288 +/- 0.0017      46.934 +/-   2.766     37.39
 ************************************************************
 pi-      0.1109 +/- 0.0033     180.728 +/-   5.427     75.67
 pi0      0.1839 +/- 0.0043     299.692 +/-   6.989     83.19
 pi+      0.0870 +/- 0.0029     141.779 +/-   4.807    111.42
 ************************************************************

 ************** Nuclide yields [mb]  (zero values suppressed) *****************

                 Z =  84.               Z =  83.               Z =  82.
 A = 188 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.630E-01 +/- 1.63E-01
 S =   1 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.630E-01 +/- 1.63E-01

                 Z =  81.               Z =  80.               Z =  79.
 A = 197 0.000E+00 +/- 0.00E+00 6.193E+00 +/- 1.00E+00 2.444E+00 +/- 6.31E-01
 A = 196 0.000E+00 +/- 0.00E+00 7.007E+00 +/- 1.07E+00 4.253E+01 +/- 2.63E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A = 184 0.000E+00 +/- 0.00E+00 8.148E-01 +/- 3.64E-01 8.148E-01 +/- 3.64E-01
 A = 183 0.000E+00 +/- 0.00E+00 3.259E-01 +/- 2.30E-01 1.630E-01 +/- 1.63E-01
 S =  15 4.889E-01 +/- 2.82E-01 7.170E+01 +/- 3.42E+00 1.946E+02 +/- 5.63E+00

                 Z =  78.               Z =  77.               Z =  76.
 A = 196 4.889E-01 +/- 2.82E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 195 1.043E+01 +/- 1.30E+00 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A = 169 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 3.259E-01 +/- 2.30E-01
 A = 168 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.630E-01 +/- 1.63E-01
 S =  29 2.412E+02 +/- 6.27E+00 1.377E+02 +/- 4.74E+00 1.649E+02 +/- 5.18E+00

                 Z =  75.               Z =  74.               Z =  73.
 A = 185 1.630E-01 +/- 1.63E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 184 4.889E-01 +/- 2.82E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A = 163 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.630E+00 +/- 5.15E-01
 A = 162 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 6.519E-01 +/- 3.26E-01
 S =  24 1.014E+02 +/- 4.06E+00 1.401E+02 +/- 4.78E+00 8.735E+01 +/- 3.77E+00

                 Z =  72.               Z =  71.               Z =  70.
 A = 176 3.259E-01 +/- 2.30E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 174 1.630E-01 +/- 1.63E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A = 153 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 3.259E-01 +/- 2.30E-01
 A = 152 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.630E-01 +/- 1.63E-01
 S =  24 9.648E+01 +/- 3.97E+00 9.093E+01 +/- 3.85E+00 8.246E+01 +/- 3.67E+00

                 Z =  69.               Z =  68.               Z =  67.
 A = 166 1.630E-01 +/- 1.63E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 165 1.630E-01 +/- 1.63E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A = 149 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 8.148E-01 +/- 3.64E-01
 A = 148 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 3.259E-01 +/- 2.30E-01
 S =  19 3.129E+01 +/- 2.26E+00 4.970E+01 +/- 2.85E+00 1.711E+01 +/- 1.67E+00
```

```
                Z =  66.              Z =  65.              Z =  64.
 A = 157 1.630E-01 +/- 1.63E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 156 1.630E-01 +/- 1.63E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A = 143 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.467E+00 +/- 4.89E-01
 A = 142 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.630E-01 +/- 1.63E-01
 S =  15 1.972E+01 +/- 1.79E+00 1.059E+01 +/- 1.31E+00 1.076E+01 +/- 1.32E+00

                Z =  63.              Z =  62.              Z =  61.
 A = 146 1.630E-01 +/- 1.63E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 145 9.778E-01 +/- 3.99E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A = 137 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.630E-01 +/- 1.63E-01
 A = 136 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.630E-01 +/- 1.63E-01
 S =  11 3.585E+00 +/- 7.64E-01 2.282E+00 +/- 6.10E-01 1.793E+00 +/- 5.40E-01

                Z =  60.
 A = 137 1.630E-01 +/- 1.63E-01
 A = 136 3.259E-01 +/- 2.30E-01
 A = 135 1.630E-01 +/- 1.63E-01
 S =   3 6.519E-01 +/- 3.26E-01

                Z =  57.              Z =  56.              Z =  55.
 A = 122 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.630E-01 +/- 1.63E-01
 S =   1 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.630E-01 +/- 1.63E-01

                Z =  54.              Z =  53.              Z =  52.
 A = 123 0.000E+00 +/- 0.00E+00 1.630E-01 +/- 1.63E-01 0.000E+00 +/- 0.00E+00
 A = 121 0.000E+00 +/- 0.00E+00 1.630E-01 +/- 1.63E-01 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A = 116 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.630E-01 +/- 1.63E-01
 A = 115 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 3.259E-01 +/- 2.30E-01
 S =   7 0.000E+00 +/- 0.00E+00 3.259E-01 +/- 2.30E-01 9.778E-01 +/- 3.99E-01

                Z =  51.              Z =  50.              Z =  49.
 A = 120 1.630E-01 +/- 1.63E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 117 1.630E-01 +/- 1.63E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A = 108 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.630E-01 +/- 1.63E-01
 A = 105 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.630E-01 +/- 1.63E-01
 S =  10 1.304E+00 +/- 4.61E-01 1.304E+00 +/- 4.61E-01 8.148E-01 +/- 3.64E-01

                Z =  48.              Z =  47.              Z =  46.
 A = 117 1.630E-01 +/- 1.63E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 115 1.630E-01 +/- 1.63E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A = 100 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 4.889E-01 +/- 2.82E-01
 A =  98 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.630E-01 +/- 1.63E-01
 S =  16 5.378E+00 +/- 9.36E-01 2.119E+00 +/- 5.88E-01 4.889E+00 +/- 8.93E-01

                Z =  45.              Z =  44.              Z =  43.
 A = 109 1.630E-01 +/- 1.63E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 106 1.630E-01 +/- 1.63E-01 1.630E-01 +/- 1.63E-01 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  94 0.000E+00 +/- 0.00E+00 1.630E-01 +/- 1.63E-01 3.259E-01 +/- 2.30E-01
 A =  93 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.630E-01 +/- 1.63E-01
 S =  15 4.563E+00 +/- 8.62E-01 6.356E+00 +/- 1.02E+00 3.422E+00 +/- 7.47E-01

                Z =  42.              Z =  41.              Z =  40.
 A = 100 1.630E-01 +/- 1.63E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  98 3.259E-01 +/- 2.30E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  87 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 4.889E-01 +/- 2.82E-01
 A =  86 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.630E-01 +/- 1.63E-01
 S =  14 5.704E+00 +/- 9.64E-01 4.889E+00 +/- 8.93E-01 7.985E+00 +/- 1.14E+00

                Z =  39.              Z =  38.              Z =  37.
 A =  91 1.630E-01 +/- 1.63E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  90 6.519E-01 +/- 3.26E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  79 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.630E-01 +/- 1.63E-01
 A =  78 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.630E-01 +/- 1.63E-01
 S =  14 7.659E+00 +/- 1.12E+00 9.289E+00 +/- 1.23E+00 7.496E+00 +/- 1.11E+00

                Z =  36.              Z =  35.              Z =  34.
 A =  85 3.259E-01 +/- 2.30E-01 1.630E-01 +/- 1.63E-01 0.000E+00 +/- 0.00E+00
 A =  84 1.630E-01 +/- 1.63E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  74 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.141E+00 +/- 4.31E-01
 A =  73 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 3.259E-01 +/- 2.30E-01
 S =  13 1.027E+01 +/- 1.29E+00 9.126E+00 +/- 1.22E+00 5.867E+00 +/- 9.78E-01

                Z =  33.              Z =  32.              Z =  31.
 A =  81 1.630E-01 +/- 1.63E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  79 1.630E-01 +/- 1.63E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  68 0.000E+00 +/- 0.00E+00 1.630E-01 +/- 1.63E-01 1.141E+00 +/- 4.31E-01
 A =  67 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 9.778E-01 +/- 3.99E-01
 S =  14 6.356E+00 +/- 1.02E+00 6.356E+00 +/- 1.02E+00 3.748E+00 +/- 7.82E-01

                Z =  30.              Z =  29.              Z =  28.
 A =  73 1.630E-01 +/- 1.63E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  70 1.630E-01 +/- 1.63E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  60 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.304E+00 +/- 4.61E-01
 A =  59 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.630E-01 +/- 1.63E-01
```

```
 S =  13 6.356E+00 +/- 1.02E+00 4.237E+00 +/- 8.31E-01 4.237E+00 +/- 8.31E-01

                Z =  27.              Z =  26.              Z =  25.
 A =  63 1.630E-01 +/- 1.63E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  62 1.630E-01 +/- 1.63E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  54 0.000E+00 +/- 0.00E+00 1.630E-01 +/- 1.63E-01 4.889E-01 +/- 2.82E-01
 A =  53 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 3.259E-01 +/- 2.30E-01
 S =  11 2.607E+00 +/- 6.52E-01 1.467E+00 +/- 4.89E-01 2.282E+00 +/- 6.10E-01

                Z =  24.              Z =  23.              Z =  22.
 A =  53 6.519E-01 +/- 3.26E-01 1.630E-01 +/- 1.63E-01 0.000E+00 +/- 0.00E+00
 A =  52 6.519E-01 +/- 3.26E-01 3.259E-01 +/- 2.30E-01 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  47 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 3.259E-01 +/- 2.30E-01
 A =  46 0.000E+00 +/- 0.00E+00 1.630E-01 +/- 1.63E-01 1.630E-01 +/- 1.63E-01
 S =   8 2.119E+00 +/- 5.88E-01 1.793E+00 +/- 5.40E-01 1.630E+00 +/- 5.15E-01

                Z =  21.              Z =  20.              Z =  19.
 A =  48 1.630E-01 +/- 1.63E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  47 1.630E-01 +/- 1.63E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  41 0.000E+00 +/- 0.00E+00 1.630E-01 +/- 1.63E-01 0.000E+00 +/- 0.00E+00
 A =  39 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.630E-01 +/- 1.63E-01
 S =   7 6.519E-01 +/- 3.26E-01 6.519E-01 +/- 3.26E-01 1.630E-01 +/- 1.63E-01

                Z =  18.              Z =  17.              Z =  16.
 A =  42 1.630E-01 +/- 1.63E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  38 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.630E-01 +/- 1.63E-01
 A =  37 0.000E+00 +/- 0.00E+00 1.630E-01 +/- 1.63E-01 0.000E+00 +/- 0.00E+00
 S =   3 1.630E-01 +/- 1.63E-01 1.630E-01 +/- 1.63E-01 1.630E-01 +/- 1.63E-01

                Z =  15.              Z =  14.              Z =  13.
 A =  32 0.000E+00 +/- 0.00E+00 1.630E-01 +/- 1.63E-01 0.000E+00 +/- 0.00E+00
 A =  31 1.630E-01 +/- 1.63E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  28 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.630E-01 +/- 1.63E-01
 A =  27 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.630E-01 +/- 1.63E-01
 S =   4 1.630E-01 +/- 1.63E-01 1.630E-01 +/- 1.63E-01 3.259E-01 +/- 2.30E-01

                Z =   3.              Z =   2.              Z =   1.
 A =   4 0.000E+00 +/- 0.00E+00 1.008E+03 +/- 1.28E+01 0.000E+00 +/- 0.00E+00
 A =   3 0.000E+00 +/- 0.00E+00 1.501E+02 +/- 4.95E+00 6.243E+02 +/- 1.01E+01
 A =   2 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.767E+03 +/- 1.70E+01
 A =   1 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 3.888E+03 +/- 2.52E+01
 S =   4 0.000E+00 +/- 0.00E+00 1.159E+03 +/- 1.37E+01 6.280E+03 +/- 3.20E+01

                Z =   0.
 A =   1 2.371E+04 +/- 6.22E+01
 S =   1 2.371E+04 +/- 6.22E+01

 End of nuclide yields.

Mass yield [mb] and the mean and variance of the kinetic energy [MeV]
 of residual nuclei:
 A = 197 8.637E+00 +/- 1.19E+00  1.146E-01 +/- 8.21E-02
 A = 196 5.003E+01 +/- 2.86E+00  6.661E-02 +/- 7.69E-02
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =   2 1.767E+03 +/- 1.70E+01  3.645E+01 +/- 5.20E+01
 A =   1 2.760E+04 +/- 6.71E+01  2.875E+01 +/- 8.42E+01
 S = 154 3.285E+04 +/- 7.32E+01  2.797E+01 +/- 7.86E+01

Charge yield [mb] and the mean and variance of the  kinetic energy [MeV]
 of residual nuclei:
 Z = 82 1.630E-01 +/- 1.63E-01  3.137E+00 +/- 0.00E+00
 Z = 81 4.889E-01 +/- 2.82E-01  1.285E+00 +/- 1.06E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 Z =  2 1.159E+03 +/- 1.37E+01  2.760E+01 +/- 1.88E+01
 Z =  1 6.280E+03 +/- 3.20E+01  6.228E+01 +/- 1.16E+02
 Z =  0 2.371E+04 +/- 6.22E+01  2.039E+01 +/- 6.76E+01
 S = 68 3.285E+04 +/- 7.32E+01  2.797E+01 +/- 7.86E+01

 Elapsed cpu time  =  0. min and 48.400 sec.
```

CEM03.01 Output Example 8

```
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Example No. 8: yields, mean kinetic energy, angle of emission,
and much more (the most complete output) of all products measured
at GSI in inverse kinematics for 1000 MeV p  + Fe56; 10,000 events
 Number of types of evaporated particles =  6

    M      T0     A    Z   Q  B   limc   idel
 0.9383 1.0000   56.  26.  1  1   10000   1

 dt0 =  -20.0, t0max = 1000.5, dteta = 10.0

  nnnp  mspec mpyld  mchy  misy mdubl mang  ipar1 ipar2
    0     0     1     0     3     0     0     2     2

 r0m =  1.2, & cevap = 12.0.

 lim =     100000 .

 Geometrical cross section = 1367.65 mb.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   Inelastic cross section used here =  735.39 mb
 Monte Carlo inelastic cross section =  741.36 mb

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              1000.0 MeV (Z =  1, A = 1) + (Z = 26., A =  56.)

 Number of inelastic interactions =    10000,
 Number of elastic interactions   =     8448,

 Reaction cross section =  735.39 mb, Elastic cross section =  621.25 mb.

  The mean excitation energy, charge, mass, and angular momentum
  of the    10000 nuclei after the
  cascade and before preequilibrium decay are:
  E*av = 146.9 +/-119.5 MeV;  E*min =  -3.8;  E*max = 654.4
   Zav =  24.7 +/-  1.4;       Zmin =  18.;    Zmax =  28.
   Aav =  52.1 +/-  2.8;       Amin =  41.;    Amax =  56.
   Lav =   6.6 +/-  4.3 h-bar; Lmin =   0.;    Lmax =  30.

  The mean charge, mass, and angular momentum
  of the     313 residual nuclei with less than
  3 MeV of excitation energy after the cascade are:
   Zav =  26.1 +/-  0.3;       Zmin =  26.;   Zmax =  27.
   Aav =  55.1 +/-  0.4;       Amin =  53.;   Amax =  56.
   Lav =   2.2 +/-  1.2 h-bar; Lmin =   0.;   Lmax =   7.

  The mean excitation energy, charge, mass, and angular momentum
  of the    9687 nuclei after preequilibrium
  decay and before the start of statistical decay are:
  E*av = 126.8 +/- 108.4 MeV; E*min =   0.6;  E*max = 633.8
   Zav =  24.2 +/-  1.8;       Zmin =  15.;   Zmax =  28.
   Aav =  51.1 +/-  3.4;       Amin =  35.;   Amax =  56.
   Lav =   7.7 +/-  5.0 h-bar; Lmin =   0.;   Lmax =  33.

  The mean kinetic energy, charge, mass, and angular momentum
  of the   10000 residual nuclei are:
  Ekav =   4.4 +/-  5.7 MeV;  Ekmin =  0.0;  Ekmax =  58.6
   Zav =  19.8 +/-  4.9;       Zmin =   2.;   Zmax =  27.
   Aav =  41.8 +/- 10.6;       Amin =   4.;   Amax =  56.
   Lav =   7.5 +/-  5.0 h-bar; Lmin =   0.;   Lmax =  33.

 Number of coalesced d, t, He3, He4 =     4403     907     577     575

 Mean multiplicities, yields, and mean energies of ejected particles:
 (Notation: T - all production mechanisms, C - cascade, P - preequilibrium,
 Sp - from spallation residues, Pf - from nuclei before fission,
 F - from fission fragments, E - total evaporation = Sp + Pf + F,
 Co - Coalescence from cascade;
 Values which are identically zero are not printed.

 Part.     Multiplicities            Yields [mb]     <TKE> [MeV]
 ********************************************************************
 T  n     4.6774 +/- 0.0216    3439.694 +/-  15.904     67.54
 C  n     1.9034 +/- 0.0138    1399.734 +/-  10.146    155.80
 P  n     0.1426 +/- 0.0038     104.866 +/-   2.777     20.31
 Sp n     2.6314 +/- 0.0162    1935.095 +/-  11.929      6.25
 E  n     2.6314 +/- 0.0162    1935.095 +/-  11.929      6.25
 ********************************************************************
 T  p     3.8332 +/- 0.0196    2818.882 +/-  14.398     85.04
 C  p     1.5456 +/- 0.0124    1136.613 +/-   9.142    195.40
 P  p     0.1502 +/- 0.0039     110.455 +/-   2.850     23.90
 Sp p     2.1374 +/- 0.0146    1571.814 +/-  10.751      9.54
 E  p     2.1374 +/- 0.0146    1571.814 +/-  10.751      9.54
 ********************************************************************
 T  d     1.2426 +/- 0.0111     913.791 +/-   8.197     34.12
 P  d     0.1102 +/- 0.0033      81.040 +/-   2.441     25.89
 Sp d     0.6930 +/- 0.0083     509.622 +/-   6.122     11.61
 E  d     0.6930 +/- 0.0083     509.622 +/-   6.122     11.61
 Co d     0.4394 +/- 0.0066     323.129 +/-   4.875     71.67
 ********************************************************************
 T  t     0.2649 +/- 0.0051     194.804 +/-   3.785     27.99
 P  t     0.0446 +/- 0.0021      32.798 +/-   1.553     33.35
```

```
 Sp t     0.1299 +/- 0.0036      95.527 +/-   2.650     12.36
 E  t     0.1299 +/- 0.0036      95.527 +/-   2.650     12.36
 Co t     0.0904 +/- 0.0030      66.479 +/-   2.211     47.79
 ********************************************************************
 T He3    0.2202 +/- 0.0047     161.932 +/-   3.451     30.58
 P He3    0.0468 +/- 0.0022      34.416 +/-   1.591     34.29
 SpHe3    0.1158 +/- 0.0034      85.158 +/-   2.502     16.02
 E He3    0.1158 +/- 0.0034      85.158 +/-   2.502     16.02
 CoHe3    0.0576 +/- 0.0024      42.358 +/-   1.765     56.83
 ********************************************************************
 T He4    0.7205 +/- 0.0085     529.846 +/-   6.242     15.29
 P He4    0.0374 +/- 0.0019      27.503 +/-   1.422     44.19
 SpHe4    0.6258 +/- 0.0079     460.205 +/-   5.817     12.12
 E He4    0.6258 +/- 0.0079     460.205 +/-   5.817     12.12
 CoHe4    0.0573 +/- 0.0024      42.138 +/-   1.760     30.99
 ********************************************************************
 pi-      0.1359 +/- 0.0037      99.939 +/-   2.711    112.85
 pi0      0.2635 +/- 0.0051     193.774 +/-   3.775    123.36
 pi+      0.1860 +/- 0.0043     136.782 +/-   3.172    147.89
 ****************************************************************

 *************** Nuclide yields [mb]  (zero values suppressed) *****************

                 Z =  28.              Z =  27.              Z =  26.
 A =  56 0.000E+00 +/- 0.00E+00 3.824E+00 +/- 5.30E-01 5.442E+00 +/- 6.33E-01
 A =  55 0.000E+00 +/- 0.00E+00 1.618E+00 +/- 3.45E-01 3.228E+01 +/- 1.54E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  52 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 2.942E-01 +/- 1.47E-01
 S =   5 0.000E+00 +/- 0.00E+00 5.736E+00 +/- 6.49E-01 5.729E+01 +/- 2.05E+00

                 Z =  25.              Z =  24.              Z =  23.
 A =  55 1.588E+01 +/- 1.08E+00 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  54 1.353E+01 +/- 9.98E-01 1.103E+00 +/- 2.85E-01 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  46 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.618E+00 +/- 3.45E-01
 S =  10 8.229E+01 +/- 2.46E+00 7.817E+01 +/- 2.40E+00 5.008E+01 +/- 1.92E+00

                 Z =  22.              Z =  21.              Z =  20.
 A =  50 1.030E+00 +/- 2.75E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  49 2.721E+00 +/- 4.47E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  40 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 5.515E+00 +/- 6.37E-01
 S =  11 6.060E+01 +/- 2.11E+00 4.089E+01 +/- 1.73E+00 4.846E+01 +/- 1.89E+00

                 Z =  19.              Z =  18.              Z =  17.
 A =  45 7.354E-02 +/- 7.35E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  44 2.942E-01 +/- 1.47E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  33 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 7.354E-02 +/- 7.35E-02
 S =  13 3.934E+01 +/- 1.70E+00 3.898E+01 +/- 1.69E+00 3.677E+01 +/- 1.64E+00

                 Z =  16.              Z =  15.              Z =  14.
 A =  37 7.354E-02 +/- 7.35E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  36 1.177E+00 +/- 2.94E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  27 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.471E-01 +/- 1.04E-01
 S =  11 3.912E+01 +/- 1.70E+00 3.221E+01 +/- 1.54E+00 3.633E+01 +/- 1.63E+00

                 Z =  13.              Z =  12.              Z =  11.
 A =  30 1.471E-01 +/- 1.04E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  29 1.618E+00 +/- 3.45E-01 7.354E-02 +/- 7.35E-02 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  21 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 2.942E-01 +/- 1.47E-01
 S =  10 2.169E+01 +/- 1.26E+00 2.169E+01 +/- 1.26E+00 1.235E+01 +/- 9.53E-01

                 Z =  10.              Z =   9.              Z =   8.
 A =  23 7.354E-02 +/- 7.35E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  22 3.383E+00 +/- 4.99E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  15 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 4.412E-01 +/- 1.80E-01
 S =   9 1.441E+01 +/- 1.03E+00 5.442E+00 +/- 6.33E-01 6.398E+00 +/- 6.86E-01

                 Z =   7.              Z =   6.              Z =   5.
 A =  16 7.354E-02 +/- 7.35E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  15 1.397E+00 +/- 3.21E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  10 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.471E-01 +/- 1.04E-01
 S =   7 3.603E+00 +/- 5.15E-01 2.353E+00 +/- 4.16E-01 2.942E-01 +/- 1.47E-01

                 Z =   4.              Z =   3.              Z =   2.
 A =   7 0.000E+00 +/- 0.00E+00 7.354E-02 +/- 7.35E-02 0.000E+00 +/- 0.00E+00
 A =   6 0.000E+00 +/- 0.00E+00 7.354E-02 +/- 7.35E-02 0.000E+00 +/- 0.00E+00
 A =   4 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 5.298E+02 +/- 6.24E+00
 A =   3 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.619E+02 +/- 3.45E+00
 S =   4 0.000E+00 +/- 0.00E+00 1.471E-01 +/- 1.04E-01 6.918E+02 +/- 7.13E+00

                 Z =   1.              Z =   0.
 A =   3 1.948E+02 +/- 3.78E+00 0.000E+00 +/- 0.00E+00
 A =   2 9.138E+02 +/- 8.20E+00 0.000E+00 +/- 0.00E+00
 A =   1 2.819E+03 +/- 1.44E+01 3.440E+03 +/- 1.59E+01
 S =   3 3.927E+03 +/- 1.70E+01 3.440E+03 +/- 1.59E+01

 End of nuclide yields.

Mass yield [mb] and the mean and variance of the kinetic energy [MeV]
 of residual nuclei:
```

```
 A =  56 9.266E+00 +/- 8.25E-01  3.374E-01 +/- 3.13E-01
 A =  55 4.979E+01 +/- 1.91E+00  2.243E-01 +/- 3.40E-01
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =   1 6.259E+03 +/- 2.15E+01  7.542E+01 +/- 1.63E+02
 S =  53 8.794E+03 +/- 2.54E+01  5.970E+01 +/- 1.41E+02

Charge yield [mb] and the mean and variance of the  kinetic energy [MeV]
 of residual nuclei:
 Z = 27 5.736E+00 +/- 6.49E-01  5.467E-01 +/- 5.86E-01
 Z = 26 5.729E+01 +/- 2.05E+00  3.519E-01 +/- 5.32E-01
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 Z =  0 3.440E+03 +/- 1.59E+01  6.754E+01 +/- 1.56E+02
 S = 27 8.794E+03 +/- 2.54E+01  5.970E+01 +/- 1.41E+02

 ********** Nuclide yields [mb] in forward direction (theta_lab < 90) **********
           (zero values suppressed)

                Z =  28.              Z =  27.              Z =  26.
 A =  56 0.000E+00 +/- 0.00E+00 3.824E+00 +/- 5.30E-01 5.442E+00 +/- 6.33E-01
 A =  55 0.000E+00 +/- 0.00E+00 1.250E+00 +/- 3.03E-01 1.949E+01 +/- 1.20E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  52 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 2.206E-01 +/- 1.27E-01
 S =   5 0.000E+00 +/- 0.00E+00 5.368E+00 +/- 6.28E-01 3.809E+01 +/- 1.67E+00

                Z =  25.              Z =  24.              Z =  23.
 A =  55 1.022E+01 +/- 8.67E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  54 8.310E+00 +/- 7.82E-01 7.354E-01 +/- 2.33E-01 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  46 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.250E+00 +/- 3.03E-01
 S =  10 5.567E+01 +/- 2.02E+00 5.699E+01 +/- 2.05E+00 3.861E+01 +/- 1.68E+00

                Z =  22.              Z =  21.              Z =  20.
 A =  50 8.089E-01 +/- 2.44E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  49 1.838E+00 +/- 3.68E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  40 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 4.265E+00 +/- 5.60E-01
 S =  11 4.618E+01 +/- 1.84E+00 3.177E+01 +/- 1.53E+00 3.853E+01 +/- 1.68E+00

                Z =  19.              Z =  18.              Z =  17.
 A =  45 7.354E-02 +/- 7.35E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  44 7.354E-02 +/- 7.35E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  33 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 7.354E-02 +/- 7.35E-02
 S =  13 3.081E+01 +/- 1.51E+00 3.052E+01 +/- 1.50E+00 2.875E+01 +/- 1.45E+00

                Z =  16.              Z =  15.              Z =  14.
 A =  37 7.354E-02 +/- 7.35E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  36 1.030E+00 +/- 2.75E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  27 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.471E-01 +/- 1.04E-01
 S =  11 3.155E+01 +/- 1.52E+00 2.780E+01 +/- 1.43E+00 2.993E+01 +/- 1.48E+00

                Z =  13.              Z =  12.              Z =  11.
 A =  30 1.471E-01 +/- 1.04E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  29 1.177E+00 +/- 2.94E-01 7.354E-02 +/- 7.35E-02 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  21 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.471E-01 +/- 1.04E-01
 S =  10 1.838E+01 +/- 1.16E+00 1.816E+01 +/- 1.16E+00 1.022E+01 +/- 8.67E-01

                Z =  10.              Z =   9.              Z =   8.
 A =  23 7.354E-02 +/- 7.35E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  22 2.574E+00 +/- 4.35E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  15 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 2.942E-01 +/- 1.47E-01
 S =   9 1.177E+01 +/- 9.30E-01 4.118E+00 +/- 5.50E-01 5.221E+00 +/- 6.20E-01

                Z =   7.              Z =   6.              Z =   5.
 A =  16 7.354E-02 +/- 7.35E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  15 1.177E+00 +/- 2.94E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  10 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 7.354E-02 +/- 7.35E-02
 S =   7 3.236E+00 +/- 4.88E-01 1.912E+00 +/- 3.75E-01 1.471E-01 +/- 1.04E-01

                Z =   4.              Z =   3.              Z =   2.
 A =   7 0.000E+00 +/- 0.00E+00 7.354E-02 +/- 7.35E-02 0.000E+00 +/- 0.00E+00
 A =   6 0.000E+00 +/- 0.00E+00 7.354E-02 +/- 7.35E-02 0.000E+00 +/- 0.00E+00
 A =   4 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 3.114E+02 +/- 4.79E+00
 A =   3 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.065E+02 +/- 2.80E+00
 S =   4 0.000E+00 +/- 0.00E+00 1.471E-01 +/- 1.04E-01 4.179E+02 +/- 5.54E+00

                Z =   1.              Z =   0.
 A =   3 1.320E+02 +/- 3.12E+00 0.000E+00 +/- 0.00E+00
 A =   2 5.846E+02 +/- 6.56E+00 0.000E+00 +/- 0.00E+00
 A =   1 1.877E+03 +/- 1.17E+01 2.254E+03 +/- 1.29E+01
 S =   3 2.594E+03 +/- 1.38E+01 2.254E+03 +/- 1.29E+01

 End of nuclide yields (forward direction).

 Mass yield [mb] and the mean and variance of the kinetic energy [MeV]
 of residual nuclei in the forward direction:
 A =  56 9.266E+00 +/- 8.25E-01  3.374E-01 +/- 3.13E-01
 A =  55 3.096E+01 +/- 1.51E+00  2.714E-01 +/- 4.06E-01
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =   1 4.131E+03 +/- 1.74E+01  1.059E+02 +/- 1.92E+02
 S =  53 5.830E+03 +/- 2.07E+01  8.227E+01 +/- 1.68E+02
```

```
Charge yield [mb] and the mean and variance of the kinetic energy [MeV]
 of residual nuclei in the forward direction:
 Z = 27 5.368E+00 +/- 6.28E-01  5.506E-01 +/- 9.42E-01
 Z = 26 3.809E+01 +/- 1.67E+00  4.199E-01 +/- 1.06E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 Z =  0 2.254E+03 +/- 1.29E+01  9.535E+01 +/- 9.29E+01
 S = 27 5.830E+03 +/- 2.07E+01  8.227E+01 +/- 1.68E+02

 ********** Nuclide yields [mb] in backward direction (theta_lab > 90) *********
           (zero values suppressed)

                 Z =  28.              Z =  27.              Z =  26.
 A =  55 0.000E+00 +/- 0.00E+00 3.677E-01 +/- 1.64E-01 1.280E+01 +/- 9.70E-01
 A =  54 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 5.442E+00 +/- 6.33E-01
 A =  53 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 8.825E-01 +/- 2.55E-01
 A =  52 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 7.354E-02 +/- 7.35E-02
 S =   4 0.000E+00 +/- 0.00E+00 3.677E-01 +/- 1.64E-01 1.919E+01 +/- 1.19E+00

                 Z =  25.              Z =  24.              Z =  23.
 A =  55 5.662E+00 +/- 6.45E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  54 5.221E+00 +/- 6.20E-01 3.677E-01 +/- 1.64E-01 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  46 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 3.677E-01 +/- 1.64E-01
 S =  10 2.662E+01 +/- 1.40E+00 2.118E+01 +/- 1.25E+00 1.147E+01 +/- 9.18E-01

                 Z =  22.              Z =  21.              Z =  20.
 A =  50 2.206E-01 +/- 1.27E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  49 8.825E-01 +/- 2.55E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  40 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.250E+00 +/- 3.03E-01
 S =  11 1.441E+01 +/- 1.03E+00 9.119E+00 +/- 8.19E-01 9.928E+00 +/- 8.54E-01

                 Z =  19.              Z =  18.              Z =  17.
 A =  44 2.206E-01 +/- 1.27E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  43 7.354E-02 +/- 7.35E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  34 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 2.206E-01 +/- 1.27E-01
 S =  11 8.530E+00 +/- 7.92E-01 8.457E+00 +/- 7.89E-01 8.016E+00 +/- 7.68E-01

                 Z =  16.              Z =  15.              Z =  14.
 A =  36 1.471E-01 +/- 1.04E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  35 2.942E-01 +/- 1.47E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  28 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.471E+00 +/- 3.29E-01
 S =   9 7.574E+00 +/- 7.46E-01 4.412E+00 +/- 5.70E-01 6.398E+00 +/- 6.86E-01

                 Z =  13.              Z =  12.              Z =  11.
 A =  29 4.412E-01 +/- 1.80E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  28 5.883E-01 +/- 2.08E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  21 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.471E-01 +/- 1.04E-01
 S =   9 3.309E+00 +/- 4.93E-01 3.530E+00 +/- 5.09E-01 2.133E+00 +/- 3.96E-01

                 Z =  10.              Z =   9.              Z =   8.
 A =  22 8.089E-01 +/- 2.44E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  21 4.412E-01 +/- 1.80E-01 7.354E-02 +/- 7.35E-02 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  15 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.471E-01 +/- 1.04E-01
 S =   7 2.647E+00 +/- 4.41E-01 1.324E+00 +/- 3.12E-01 1.177E+00 +/- 2.94E-01

                 Z =   7.              Z =   6.              Z =   5.
 A =  15 2.206E-01 +/- 1.27E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  14 1.471E-01 +/- 1.04E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  10 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 7.354E-02 +/- 7.35E-02
 S =   6 3.677E-01 +/- 1.64E-01 4.412E-01 +/- 1.80E-01 1.471E-01 +/- 1.04E-01

                 Z =   4.              Z =   3.              Z =   2.
 A =   4 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 2.184E+02 +/- 4.01E+00
 A =   3 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 5.545E+01 +/- 2.02E+00
 S =   2 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 2.739E+02 +/- 4.49E+00

                 Z =   1.              Z =   0.
 A =   3 6.280E+01 +/- 2.15E+00 0.000E+00 +/- 0.00E+00
 A =   2 3.292E+02 +/- 4.92E+00 0.000E+00 +/- 0.00E+00
 A =   1 9.419E+02 +/- 8.32E+00 1.185E+03 +/- 9.34E+00
 S =   3 1.334E+03 +/- 9.90E+00 1.185E+03 +/- 9.34E+00

 End of nuclide yields (backward direction).

 Mass yield [mb] and the mean and variance of the kinetic energy [MeV]
 of residual nuclei in the backward direction:
 A =  55 1.883E+01 +/- 1.18E+00  1.469E-01 +/- 1.60E-01
 A =  54 1.103E+01 +/- 9.01E-01  3.156E-01 +/- 3.89E-01
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =   1 2.127E+03 +/- 1.25E+01  1.624E+01 +/- 2.72E+01
 S =  49 2.964E+03 +/- 1.48E+01  1.530E+01 +/- 2.47E+01

 Charge yield [mb] and the mean and variance of the kinetic energy [MeV]
 of residual nuclei in the backward direction:
 Z = 27 3.677E-01 +/- 1.64E-01  4.903E-01 +/- 4.57E-01
 Z = 26 1.919E+01 +/- 1.19E+00  2.169E-01 +/- 2.74E-01
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 Z =  0 1.185E+03 +/- 9.34E+00  1.462E+01 +/- 2.66E+01
 S = 26 2.964E+03 +/- 1.48E+01  1.530E+01 +/- 2.47E+01
```

******** Nuclide average kinetic energies [MeV] (zero yield suppressed) ********

```
                Z =  28.              Z =  27.              Z =  26.
 A =  56 0.000E+00 +/- 0.00E+00 4.146E-01 +/- 3.53E-01 2.832E-01 +/- 2.69E-01
 A =  55 0.000E+00 +/- 0.00E+00 6.183E-01 +/- 5.05E-01 2.591E-01 +/- 3.74E-01
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  52 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.129E+00 +/- 1.13E+00
 S =   5 0.000E+00 +/- 0.00E+00 5.467E-01 +/- 5.86E-01 3.519E-01 +/- 5.32E-01

                Z =  25.              Z =  24.              Z =  23.
 A =  55 1.134E-01 +/- 1.46E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  54 3.504E-01 +/- 3.60E-01 3.117E-01 +/- 2.84E-01 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  46 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 3.328E+00 +/- 3.44E+00
 S =  10 5.262E-01 +/- 7.56E-01 1.178E+00 +/- 1.39E+00 1.884E+00 +/- 1.97E+00

                Z =  22.              Z =  21.              Z =  20.
 A =  50 1.388E+00 +/- 1.68E+00 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  49 2.056E+00 +/- 1.56E+00 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  40 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 4.453E+00 +/- 3.71E+00
 S =  11 2.732E+00 +/- 2.42E+00 3.342E+00 +/- 2.88E+00 4.392E+00 +/- 3.79E+00

                Z =  19.              Z =  18.              Z =  17.
 A =  45 1.913E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  44 1.797E+00 +/- 3.19E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  33 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 6.434E+00 +/- 0.00E+00
 S =  13 5.188E+00 +/- 4.51E+00 5.753E+00 +/- 4.81E+00 6.609E+00 +/- 5.70E+00

                Z =  16.              Z =  15.              Z =  14.
 A =  37 9.657E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  36 8.417E+00 +/- 8.94E+00 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  27 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 3.112E+00 +/- 1.83E+00
 S =  11 7.564E+00 +/- 5.88E+00 7.922E+00 +/- 6.42E+00 8.752E+00 +/- 6.84E+00

                Z =  13.              Z =  12.              Z =  11.
 A =  30 7.844E+00 +/- 1.61E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  29 5.701E+00 +/- 4.70E+00 8.359E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  21 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 7.789E+00 +/- 5.98E+00
 S =  10 9.743E+00 +/- 8.11E+00 1.021E+01 +/- 8.06E+00 1.126E+01 +/- 8.19E+00

                Z =  10.              Z =   9.              Z =   8.
 A =  23 1.448E+01 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  22 9.206E+00 +/- 7.50E+00 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  15 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 8.855E+00 +/- 6.63E+00
 S =   9 1.120E+01 +/- 9.27E+00 1.225E+01 +/- 9.02E+00 1.159E+01 +/- 7.73E+00

                Z =   7.              Z =   6.              Z =   5.
 A =  16 2.872E+01 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  15 1.080E+01 +/- 7.07E+00 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  10 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 2.002E+01 +/- 7.67E+00
 S =   7 1.086E+01 +/- 7.01E+00 1.054E+01 +/- 7.75E+00 1.506E+01 +/- 9.50E+00

                Z =   4.              Z =   3.              Z =   2.
 A =   7 0.000E+00 +/- 0.00E+00 5.884E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =   6 0.000E+00 +/- 0.00E+00 4.818E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =   4 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.529E+01 +/- 1.50E+01
 A =   3 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 3.058E+01 +/- 3.64E+01
 S =   4 0.000E+00 +/- 0.00E+00 5.351E+00 +/- 5.33E-01 1.887E+01 +/- 2.29E+01

                Z =   1.              Z =   0.
 A =   3 2.799E+01 +/- 3.86E+01 0.000E+00 +/- 0.00E+00
 A =   2 3.412E+01 +/- 5.96E+01 0.000E+00 +/- 0.00E+00
 A =   1 8.504E+01 +/- 1.70E+02 6.754E+01 +/- 1.56E+02
 S =   3 7.036E+01 +/- 1.49E+02 6.754E+01 +/- 1.56E+02

 End of nuclide average kinetic energies.

 Mass yield [mb] and the mean and variance of the emission angle [deg.]
 of residual nuclei:
 A =  56  9.266E+00 +/- 8.25E-01   8.263E+01 +/- 1.94E+00
 A =  55  4.979E+01 +/- 1.91E+00   8.346E+01 +/- 3.46E+01
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =   1  6.259E+03 +/- 2.15E+01   7.353E+01 +/- 4.06E+01
 S =  53  8.794E+03 +/- 2.54E+01   7.374E+01 +/- 3.99E+01

 The mean and variance of the z velocity [v/c] of residual nuclei,
 and the forward/backward ratio:
 A =  56  4.158E-04 +/- 2.18E-04   1.000E+00 +/- 0.00E+00
 A =  55  2.945E-04 +/- 1.19E-03   1.645E+00 +/- 1.83E-01
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =   1  1.113E-01 +/- 2.26E-01   1.942E+00 +/- 1.96E-02
 S =  53  8.722E-02 +/- 2.00E-01   1.967E+00 +/- 1.68E-02

 Charge yield [mb] and the mean and variance of the emission angle [deg.]
 of residual nuclei:
 Z = 27  5.736E+00 +/- 6.49E-01   8.209E+01 +/- 1.19E+01
 Z = 26  5.729E+01 +/- 2.05E+00   8.219E+01 +/- 3.26E+01
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 Z =  0  3.440E+03 +/- 1.59E+01   7.391E+01 +/- 4.06E+01
 S = 27  8.794E+03 +/- 2.54E+01   7.374E+01 +/- 3.99E+01
```

The mean and variance of the z velocity [v/c] of residual nuclei,
and the forward/backward ratio:

Z = 27	6.596E-04 +/- 1.38E-03	1.640E+01 +/- 1.31E+01
Z = 26	5.461E-04 +/- 1.61E-03	3.841E+00 +/- 7.71E-01
Z = 0	1.017E-01 +/- 2.17E-01	1.241E+01 +/- 3.28E-02
S = 27	8.722E-02 +/- 2.00E-01	1.967E+00 +/- 1.68E-02

Mass distributions of nuclei:

	after cascade	after preeq	at start of evap, which: evap.\ only	fission	just prior to fission
A = 56	3.870E-02	3.100E-02	3.100E-02	0.000E+00	0.000E+00
A = 55	1.919E-01	1.509E-01	1.509E-01	0.000E+00	0.000E+00
A = 35	0.000E+00	3.000E-04	3.000E-04	0.000E+00	0.000E+00
<A> =	5.201E+01	5.104E+01	5.104E+01	0.000E+00	0.000E+00
St Dv A =	2.769E+00	3.447E+00	3.447E+00	0.000E+00	0.000E+00
norm =	1.000E+00	1.000E+00	1.000E+00	0.000E+00	0.000E+00

Charge distributions of nuclei:

	after cascade	after preeq	at start of evap, which: evap.\ only	fission	just prior to fission
Z = 28	2.800E-03	1.800E-03	1.800E-03	0.000E+00	0.000E+00
Z = 27	5.860E-02	4.190E-02	4.190E-02	0.000E+00	0.000E+00
Z = 15	0.000E+00	1.000E-04	1.000E-04	0.000E+00	0.000E+00
<Z> =	2.466E+01	2.417E+01	2.417E+01	0.000E+00	0.000E+00
St Dv Z =	1.440E+00	1.754E+00	1.754E+00	0.000E+00	0.000E+00
norm =	1.000E+00	1.000E+00	1.000E+00	0.000E+00	0.000E+00

Excitation energy distributions [1/MeV] of nuclei:

E*(MeV)	after cascade	after preeq	at start of evap, which: evap.\ only	fission	just prior to fission
0.- 10.	4.450E-03	5.020E-03	5.020E-03	0.000E+00	0.000E+00
10.- 20.	4.380E-03	5.890E-03	5.890E-03	0.000E+00	0.000E+00
630.- 640.	2.000E-05	2.000E-05	2.000E-05	0.000E+00	0.000E+00
<E*> =	1.474E+02	1.266E+02	1.266E+02	0.000E+00	0.000E+00
St dev E* =	1.147E+02	1.081E+02	1.081E+02	0.000E+00	0.000E+00
norm =	1.000E+00	1.000E+00	1.000E+00	0.000E+00	0.000E+00

Linear momentum distributions [1/MeV/c] of nuclei:

P(MeV/c)	after cascade	after preeq	at start of evap, which: evap.\ only	fission	just prior to fission
0.- 20.	7.000E-05	5.000E-05	5.000E-05	0.000E+00	0.000E+00
20.- 40.	3.100E-04	2.950E-04	2.950E-04	0.000E+00	0.000E+00
1940.-1960.	5.000E-06	5.000E-06	5.000E-06	0.000E+00	0.000E+00
<P> =	5.076E+02	5.039E+02	5.039E+02	0.000E+00	0.000E+00
St dev P =	3.428E+02	3.399E+02	3.399E+02	0.000E+00	0.000E+00
norm =	1.000E+00	1.000E+00	1.000E+00	0.000E+00	0.000E+00

Angular momentum distributions [1/hbar] of nuclei:

L	after cascade	after preeq	at start of evap, which: evap.\ only	fission	just prior to fission
0.- 1.	6.100E-03	5.400E-03	5.400E-03	0.000E+00	0.000E+00
1.- 2.	5.170E-02	4.450E-02	4.450E-02	0.000E+00	0.000E+00
33.- 34.	0.000E+00	1.000E-04	1.000E-04	0.000E+00	0.000E+00
<L> =	6.740E+00	7.665E+00	7.665E+00	0.000E+00	0.000E+00
St dv L =	4.251E+00	5.015E+00	5.015E+00	0.000E+00	0.000E+00
norm =	1.000E+00	1.000E+00	1.000E+00	0.000E+00	0.000E+00

Neutron-multiplicity probability:

Nn	Total	Cascade	Preequil.	Evap.\ res.	Pre-fiss.	Post-fiss.
0	3.330E-02	1.608E-01	8.723E-01	1.452E-01	0.000E+00	0.000E+00
1	9.480E-02	3.275E-01	1.147E-01	1.970E-01	0.000E+00	0.000E+00
16	1.000E-04	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
<n> =	4.677E+00	1.903E+00	1.426E-01	2.631E+00	0.000E+00	0.000E+00
St dv n =	2.712E+00	1.557E+00	3.961E-01	2.043E+00	0.000E+00	0.000E+00
norm =	1.000E+00	1.000E+00	1.000E+00	1.000E+00	0.000E+00	0.000E+00

Elapsed cpu time = 0. min and 32.430 sec.

CEM03.01 Output Example 9

```
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Example No. 9: p spectra from monochromatic 300 MeV gamma + 64Cu;
10,000 events
 Number of types of evaporated particles =  6

    M      T0     A    Z   Q  B   limc   idel
 0.0000 0.3000   64.  29.  0  0   10000   1

 dt0 =   -5.0, t0max =  300.5, dteta = 10.0

  nnnp  mspec mpyld  mchy  misy mdubl mang  ipar1 ipar2
    0     0     1     0     0     1     0     2     2

 r0m =  1.2, & cevap = 12.0.

    Theta1     Theta2     Theta3     Theta4     Theta5     Theta6
  42.5  47.5  87.5  92.5 132.5 137.5 -55.0 165.0  55.0  65.0  75.0  85.0

    Theta7     Theta8     Theta9    Theta10
  95.0 105.0 115.0 125.0 135.0 145.0 155.0 165.0


 Tmin, Tmax, dT{1};Tmin, Tmax, dT{2};Tmin, Tmax, dT{3};Tmin, Tmax, dT{4}.
   0.0   22.0  1.00  22.0 120.0  2.00  120.  400.  10.0  400. 1000.   20.

 lim =    6000000 .

 Geometrical cross section = 1445.99 mb.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   Inelastic cross section used here =   26.58 mb
 Monte Carlo inelastic cross section =   27.40 mb

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                300.0 MeV (Z =  0, A = 0) + (Z = 29., A =  64.)

 Number of inelastic interactions =        10000,
 Number of elastic interactions   =       517695,

 Reaction cross section =   26.58 mb, Elastic cross section = 1376.12 mb.

  The mean excitation energy, charge, mass, and angular momentum
  of the    10000 nuclei after the
  cascade and before preequilibrium decay are:
  E*av =  85.5 +/- 52.3 MeV;  E*min =   1.7;  E*max = 299.1
   Zav =  28.2 +/-  0.9;       Zmin =  24.;    Zmax =  30.
   Aav =  61.8 +/-  1.4;       Amin =  56.;    Amax =  64.
   Lav =   4.3 +/-  2.5 h-bar; Lmin =   0.;    Lmax =  17.

  The mean charge, mass, and angular momentum
  of the       9 residual nuclei with less than
  3 MeV of excitation energy after the cascade are:
   Zav =  28.0 +/-  0.0;       Zmin =  28.;   Zmax =  28.
   Aav =  61.8 +/-  0.6;       Amin =  60.;   Amax =  62.
   Lav =   4.8 +/-  3.6 h-bar; Lmin =   1.;   Lmax =  12.

  The mean excitation energy, charge, mass, and angular momentum
  of the    9991 nuclei after preequilibrium
  decay and before the start of statistical decay are:
  E*av =  65.4 +/-  43.6 MeV; E*min =   0.3;  E*max = 287.7
   Zav =  27.8 +/-  1.1;       Zmin =  23.;   Zmax =  30.
   Aav =  60.9 +/-  1.9;       Amin =  51.;   Amax =  64.
   Lav =   5.4 +/-  3.4 h-bar; Lmin =   0.;   Lmax =  29.

  The mean kinetic energy, charge, mass, and angular momentum
  of the   10000 residual nuclei are:
  Ekav =   1.6 +/-  1.8 MeV;  Ekmin =  0.0;  Ekmax =  18.1
   Zav =  25.9 +/-  2.1;       Zmin =  16.;   Zmax =  30.
   Aav =  55.6 +/-  4.6;       Amin =  34.;   Amax =  63.
   Lav =   5.4 +/-  3.4 h-bar; Lmin =   0.;   Lmax =  29.

 Number of coalesced d, t, He3, He4 =      754      98      25       9

 Mean multiplicities, yields, and mean energies of ejected particles:
 (Notation: T - all production mechanisms, C - cascade, P - preequilibrium,
 Sp - from spallation residues, Pf - from nuclei before fission,
 F - from fission fragments, E - total evaporation = Sp + Pf + F,
 Co - Coalescence from cascade;
 Values which are identically zero are not printed.

 Part.     Multiplicities            Yields [mb]     <TKE> [MeV]
 ********************************************************************
 T  n     4.0854 +/- 0.0202     108.597 +/-   0.537     18.70
 C  n     1.3215 +/- 0.0115      35.128 +/-   0.306     47.34
 P  n     0.2523 +/- 0.0050       6.707 +/-   0.134     17.00
 Sp n     2.5116 +/- 0.0158      66.762 +/-   0.421      3.80
 E  n     2.5116 +/- 0.0158      66.762 +/-   0.421      3.80
 ********************************************************************
 T  p     1.9705 +/- 0.0140      52.379 +/-   0.373     29.43
 C  p     0.7133 +/- 0.0084      18.961 +/-   0.225     64.63
 P  p     0.1841 +/- 0.0043       4.894 +/-   0.114     21.61
 Sp p     1.0731 +/- 0.0104      28.525 +/-   0.275      7.37
 E  p     1.0731 +/- 0.0104      28.525 +/-   0.275      7.37
```

```
 ***************************************************************
 T  d     0.3555 +/- 0.0060       9.450 +/-   0.158     16.50
 P  d     0.1088 +/- 0.0033       2.892 +/-   0.088     23.01
 Sp d     0.1719 +/- 0.0041       4.569 +/-   0.110      8.97
 E  d     0.1719 +/- 0.0041       4.569 +/-   0.110      8.97
 Co d     0.0748 +/- 0.0027       1.988 +/-   0.073     24.33
 ***************************************************************
 T  t     0.0711 +/- 0.0027       1.890 +/-   0.071     17.12
 P  t     0.0315 +/- 0.0018       0.837 +/-   0.047     26.02
 Sp t     0.0298 +/- 0.0017       0.792 +/-   0.046      8.99
 E  t     0.0298 +/- 0.0017       0.792 +/-   0.046      8.99
 Co t     0.0098 +/- 0.0010       0.260 +/-   0.026     13.23
 ***************************************************************
 T He3    0.0386 +/- 0.0020       1.026 +/-   0.052     23.12
 P He3    0.0223 +/- 0.0015       0.593 +/-   0.040     29.84
 SpHe3    0.0139 +/- 0.0012       0.369 +/-   0.031     13.09
 E He3    0.0139 +/- 0.0012       0.369 +/-   0.031     13.09
 CoHe3    0.0024 +/- 0.0005       0.064 +/-   0.013     18.68
 ***************************************************************
 T He4    0.3299 +/- 0.0057       8.769 +/-   0.153     13.12
 P He4    0.0146 +/- 0.0012       0.388 +/-   0.032     39.42
 SpHe4    0.3144 +/- 0.0056       8.357 +/-   0.149     11.88
 E He4    0.3144 +/- 0.0056       8.357 +/-   0.149     11.88
 CoHe4    0.0009 +/- 0.0003       0.024 +/-   0.008     19.01
 ***************************************************************
 pi-      0.1182 +/- 0.0034       3.142 +/-   0.091     56.05
 pi0      0.2230 +/- 0.0047       5.928 +/-   0.126     57.99
 pi+      0.0805 +/- 0.0028       2.140 +/-   0.075     48.64
 ***************************************************************

 ********************************  protons   *******************************

 Double differential cross sections [mb/MeV/sr];
 Lab. angle =  42.5 to  47.5 degrees.

    Tp  [MeV]            Total                Cascade               Precompound         Total Evaporation
    2.0-   3.0  2.057E-02 +/- 1.19E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 2.057E-02 +/- 1.19E-02
    3.0-   4.0  1.715E-01 +/- 3.43E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.715E-01 +/- 3.43E-02
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  210.0- 220.0  2.743E-03 +/- 1.37E-03 2.743E-03 +/- 1.37E-03 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
  230.0- 240.0  1.372E-03 +/- 9.70E-04 1.372E-03 +/- 9.70E-04 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00

  Integrated:   4.684E+00 +/- 1.79E-01 1.982E+00 +/- 1.17E-01 4.732E-01 +/- 5.70E-02 2.229E+00 +/- 1.24E-01

 Double differential cross sections [mb/MeV/sr];
 Lab. angle =  87.5 to  92.5 degrees.

    Tp  [MeV]            Total                Cascade               Precompound         Total Evaporation
    2.0-   3.0  2.910E-02 +/- 1.19E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 2.910E-02 +/- 1.19E-02
    3.0-   4.0  1.746E-01 +/- 2.91E-02 0.000E+00 +/- 0.00E+00 9.699E-03 +/- 6.86E-03 1.649E-01 +/- 2.83E-02
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  200.0- 210.0  4.849E-04 +/- 4.85E-04 4.849E-04 +/- 4.85E-04 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
  210.0- 220.0  4.849E-04 +/- 4.85E-04 4.849E-04 +/- 4.85E-04 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00

  Integrated:   3.623E+00 +/- 1.33E-01 1.057E+00 +/- 7.16E-02 3.928E-01 +/- 4.36E-02 2.173E+00 +/- 1.03E-01

 Double differential cross sections [mb/MeV/sr];
 Lab. angle = 132.5 to 137.5 degrees.

    Tp  [MeV]            Total                Cascade               Precompound         Total Evaporation
    2.0-   3.0  4.115E-02 +/- 1.68E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 4.115E-02 +/- 1.68E-02
    3.0-   4.0  3.018E-01 +/- 4.55E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 3.018E-01 +/- 4.55E-02
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  130.0- 140.0  2.743E-03 +/- 1.37E-03 2.057E-03 +/- 1.19E-03 6.858E-04 +/- 6.86E-04 0.000E+00 +/- 0.00E+00
  140.0- 150.0  6.858E-04 +/- 6.86E-04 6.858E-04 +/- 6.86E-04 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00

  Integrated:   3.470E+00 +/- 1.54E-01 8.367E-01 +/- 7.58E-02 3.635E-01 +/- 4.99E-02 2.270E+00 +/- 1.25E-01

 Elapsed cpu time  =  1. min and 16.120 sec.
```

CEM03.01 Output Example 10

```
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Example No. 10: yields, mean kinetic energy, emission andle,
neutron multiplicities, Forward/Backward ratios, and much more
(the most complete output) of all products from E_max = 1000 MeV
bremsstrahlung gammas + 197Au; 10,000 events
 Number of types of evaporated particles =  6

    M      T0     A    Z   Q  B   limc   idel
 0.0000 0.0301  197.  79.  0  0   10000   1

 dt0 =  -20.0, t0max = 1000.0, dteta = 10.0

  nnnp  mspec mpyld  mchy  misy mdubl mang  ipar1 ipar2
    0     0     1     0     3     0     0     2     2

 r0m =  1.2, & cevap = 12.0.

 lim =    6000000 .

 Geometrical cross section = 2394.46 mb.
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  Number of equivalent gamma quanta =  3.235206E-01
  Inelasic cross section per eqqv   =  1.381499E+02
  Averaged absorption cross section =  4.469434E+01
  Results are normalized to eqqv.

   Inelastic cross section used here =  138.15 mb
 Monte Carlo inelastic cross section =   36.17 mb

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                30.1 MeV (Z =  0, A = 0) + (Z = 79., A = 197.)

 Number of inelastic interactions =        10000,
 Number of elastic interactions   =       652030,

 Reaction cross section =  138.15 mb, Elastic cross section = 9007.79 mb.

  The mean excitation energy, charge, mass, and angular momentum
  of the    10000 nuclei after the
  cascade and before preequilibrium decay are:
  E*av = 127.7 +/-105.3 MeV;  E*min =   1.7;  E*max = 767.7
   Zav =  78.6 +/-  0.8;       Zmin =  74.;    Zmax =  81.
   Aav = 194.7 +/-  2.2;       Amin = 183.;    Amax = 197.
   Lav =   6.0 +/-  4.7 h-bar; Lmin =   0.;    Lmax =  37.

  The mean charge, mass, and angular momentum
  of the       2 residual nuclei with less than
  3 MeV of excitation energy after the cascade are:
   Zav =  79.0 +/-  0.0;       Zmin =  79.;   Zmax =  79.
   Aav = 194.5 +/-  1.5;       Amin = 193.;   Amax = 196.
   Lav =   2.0 +/-  2.0 h-bar; Lmin =   0.;   Lmax =   4.

  The mean excitation energy, charge, mass, and angular momentum
  of the    9998 nuclei after preequilibrium
  decay and before the start of statistical decay are:
  E*av =  93.3 +/-  86.0 MeV; E*min =   0.3;  E*max = 729.8
   Zav =  78.1 +/-  1.2;       Zmin =  69.;   Zmax =  81.
   Aav = 193.4 +/-  3.3;       Amin = 168.;   Amax = 197.
   Lav =   8.3 +/-  6.2 h-bar; Lmin =   0.;   Lmax =  53.

  The mean kinetic energy, charge, mass, and angular momentum
  of the    9840 residual nuclei are:
  Ekav =   0.7 +/-  1.1 MeV;  Ekmin =  0.0;  Ekmax =  17.1
   Zav =  77.2 +/-  2.5;       Zmin =  60.;   Zmax =  80.
   Aav = 185.1 +/-  9.5;       Amin = 132.;   Amax = 196.
   Lav =   8.2 +/-  6.1 h-bar; Lmin =   0.;   Lmax =  53.

  The mean excitation energy, charge, mass, angular momentum, and
  fission barrier height of the     160 fissioning nuclei are:
  E*av = 187.4 +/- 92.5 MeV; E*min =  38.2; E*max =  549.0
   Zav =  77.3 +/- 2.6;        Zmin =  66.;  Zmax =  80.
   Aav = 187.2 +/- 7.6;        Amin = 155.;  Amax = 196.
   Lav =  10.9 +/- 6.8 h-bar;  Lmin =   0.;  Lmax =  36.
  Bfav =  18.1 +/- 2.1 MeV;   Bfmin = 11.1; Bfmax = 23.2

 The mean total fission product kinetic energy after neutron emission is 163.57 MeV.

               Direct Monte Carlo Simulation Method:
 Fissility =  0.0160 +/-  0.0013,
 Fission cross section = 2.21040E+00 +/- 1.75E-01 mb.

               Statistical Weight Functions Method:
 Fissility =  0.0168,
 Fission cross section = 2.31715E+00 mb.

 Number of coalesced d, t, He3, He4 =     1072     372      41      44

 Mean multiplicities, yields, and mean energies of ejected particles:
 (Notation: T - all production mechanisms, C - cascade, P - preequilibrium,
 Sp - from spallation residues, Pf - from nuclei before fission,
 F - from fission fragments, E - total evaporation = Sp + Pf + F,
 Co - Coalescence from cascade;
```

Values which are identically zero are not printed.

Part.	Multiplicities	Yields [mb]	<TKE> [MeV]
T n	9.1965 +/- 0.0303	1270.496 +/- 4.189	10.78
C n	1.6140 +/- 0.0127	222.974 +/- 1.755	41.47
P n	0.5663 +/- 0.0075	78.234 +/- 1.040	19.65
Sp n	6.7728 +/- 0.0260	935.662 +/- 3.595	2.94
Pf n	0.0433 +/- 0.0021	5.982 +/- 0.287	5.91
F n	0.2001 +/- 0.0045	27.644 +/- 0.618	4.22
E n	7.0162 +/- 0.0265	969.287 +/- 3.659	3.00
T p	1.0023 +/- 0.0100	138.468 +/- 1.383	42.73
C p	0.3456 +/- 0.0059	47.745 +/- 0.812	85.72
P p	0.3018 +/- 0.0055	41.694 +/- 0.759	29.97
Sp p	0.3402 +/- 0.0058	46.999 +/- 0.806	11.75
Pf p	0.0042 +/- 0.0006	0.580 +/- 0.090	14.06
F p	0.0105 +/- 0.0010	1.451 +/- 0.142	10.08
E p	0.3549 +/- 0.0060	49.029 +/- 0.823	11.72
T d	0.3534 +/- 0.0059	48.822 +/- 0.821	29.54
P d	0.1227 +/- 0.0035	16.951 +/- 0.484	31.34
Sp d	0.1171 +/- 0.0034	16.177 +/- 0.473	12.70
Pf d	0.0048 +/- 0.0007	0.663 +/- 0.096	15.44
F d	0.0032 +/- 0.0006	0.442 +/- 0.078	11.86
E d	0.1251 +/- 0.0035	17.283 +/- 0.489	12.78
Co d	0.1056 +/- 0.0032	14.589 +/- 0.449	47.30
T t	0.1162 +/- 0.0034	16.053 +/- 0.471	24.38
P t	0.0263 +/- 0.0016	3.633 +/- 0.224	37.18
Sp t	0.0491 +/- 0.0022	6.783 +/- 0.306	13.86
Pf t	0.0020 +/- 0.0004	0.276 +/- 0.062	14.48
F t	0.0021 +/- 0.0005	0.290 +/- 0.063	11.66
E t	0.0532 +/- 0.0023	7.350 +/- 0.319	13.80
Co t	0.0367 +/- 0.0019	5.070 +/- 0.265	30.54
T He3	0.0273 +/- 0.0017	3.771 +/- 0.228	40.13
P He3	0.0194 +/- 0.0014	2.680 +/- 0.192	44.32
SpHe3	0.0037 +/- 0.0006	0.511 +/- 0.084	23.17
PfHe3	0.0002 +/- 0.0001	0.028 +/- 0.020	31.01
F He3	0.0001 +/- 0.0001	0.014 +/- 0.014	13.24
E He3	0.0040 +/- 0.0006	0.553 +/- 0.087	23.31
CoHe3	0.0039 +/- 0.0006	0.539 +/- 0.086	36.49
T He4	0.1856 +/- 0.0043	25.641 +/- 0.595	23.75
P He4	0.0085 +/- 0.0009	1.174 +/- 0.127	49.24
SpHe4	0.1669 +/- 0.0041	23.057 +/- 0.564	22.56
PfHe4	0.0020 +/- 0.0004	0.276 +/- 0.062	25.23
F He4	0.0040 +/- 0.0006	0.553 +/- 0.087	18.10
E He4	0.1729 +/- 0.0042	23.886 +/- 0.574	22.48
CoHe4	0.0042 +/- 0.0006	0.580 +/- 0.090	24.22
pi-	0.1168 +/- 0.0034	16.136 +/- 0.472	103.23
pi0	0.1357 +/- 0.0037	18.747 +/- 0.509	91.33
pi+	0.0502 +/- 0.0022	6.935 +/- 0.310	127.77

********** Nuclide yields [mb] (zero values suppressed) **********

	Z = 81.	Z = 80.	Z = 79.
A = 196	0.000E+00 +/- 0.00E+00	0.000E+00 +/- 0.00E+00	3.730E-01 +/- 7.18E-02
A = 195	0.000E+00 +/- 0.00E+00	1.520E-01 +/- 4.58E-02	3.136E+00 +/- 2.08E-01
A = 183	0.000E+00 +/- 0.00E+00	1.381E-02 +/- 1.38E-02	0.000E+00 +/- 0.00E+00
S = 14	0.000E+00 +/- 0.00E+00	3.633E+00 +/- 2.24E-01	4.124E+01 +/- 7.55E-01

	Z = 78.	Z = 77.	Z = 76.
A = 196	3.592E-01 +/- 7.04E-02	0.000E+00 +/- 0.00E+00	0.000E+00 +/- 0.00E+00
A = 195	1.492E+00 +/- 1.44E-01	0.000E+00 +/- 0.00E+00	0.000E+00 +/- 0.00E+00
A = 169	0.000E+00 +/- 0.00E+00	0.000E+00 +/- 0.00E+00	2.763E-02 +/- 1.95E-02
S = 28	4.216E+01 +/- 7.63E-01	1.598E+01 +/- 4.70E-01	1.196E+01 +/- 4.07E-01

	Z = 75.	Z = 74.	Z = 73.
A = 188	2.763E-02 +/- 1.95E-02	0.000E+00 +/- 0.00E+00	0.000E+00 +/- 0.00E+00
A = 187	1.381E-02 +/- 1.38E-02	0.000E+00 +/- 0.00E+00	0.000E+00 +/- 0.00E+00
A = 163	0.000E+00 +/- 0.00E+00	0.000E+00 +/- 0.00E+00	1.381E-02 +/- 1.38E-02
S = 26	5.208E+00 +/- 2.68E-01	4.739E+00 +/- 2.56E-01	2.749E+00 +/- 1.95E-01

	Z = 72.	Z = 71.	Z = 70.
A = 173	2.763E-02 +/- 1.95E-02	0.000E+00 +/- 0.00E+00	0.000E+00 +/- 0.00E+00
A = 172	1.381E-02 +/- 1.38E-02	1.381E-02 +/- 1.38E-02	0.000E+00 +/- 0.00E+00
A = 154	0.000E+00 +/- 0.00E+00	0.000E+00 +/- 0.00E+00	2.763E-02 +/- 1.95E-02
S = 20	2.031E+00 +/- 1.67E-01	1.948E+00 +/- 1.64E-01	1.409E+00 +/- 1.40E-01

	Z = 69.	Z = 68.	Z = 67.
A = 165	1.381E-02 +/- 1.38E-02	0.000E+00 +/- 0.00E+00	0.000E+00 +/- 0.00E+00
A = 163	1.381E-02 +/- 1.38E-02	0.000E+00 +/- 0.00E+00	0.000E+00 +/- 0.00E+00
A = 149	0.000E+00 +/- 0.00E+00	0.000E+00 +/- 0.00E+00	1.381E-02 +/- 1.38E-02
S = 16	6.217E-01 +/- 9.27E-02	8.013E-01 +/- 1.05E-01	3.177E-01 +/- 6.63E-02

	Z = 66.	Z = 65.	Z = 64.
A = 153	1.381E-02 +/- 1.38E-02	0.000E+00 +/- 0.00E+00	0.000E+00 +/- 0.00E+00

```
 A = 152 6.907E-02 +/- 3.09E-02 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A = 144 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02
 S =  10 4.697E-01 +/- 8.06E-02 1.520E-01 +/- 4.58E-02 2.901E-01 +/- 6.33E-02

                Z =  63.              Z =  62.              Z =  61.
 A = 145 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 143 2.763E-02 +/- 1.95E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A = 136 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02
 S =   8 6.907E-02 +/- 3.09E-02 2.763E-02 +/- 1.95E-02 4.144E-02 +/- 2.39E-02

                Z =  60.
 A = 136 4.144E-02 +/- 2.39E-02
 A = 135 1.381E-02 +/- 1.38E-02
 A = 134 1.381E-02 +/- 1.38E-02
 A = 132 1.381E-02 +/- 1.38E-02
 S =   4 8.289E-02 +/- 3.38E-02

                Z =  57.
 A = 130 1.381E-02 +/- 1.38E-02
 A = 129 1.381E-02 +/- 1.38E-02
 A = 123 1.381E-02 +/- 1.38E-02
 S =   3 4.144E-02 +/- 2.39E-02

                Z =  54.              Z =  53.              Z =  52.
 A = 124 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 118 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02
 A = 116 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02
 S =   3 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 2.763E-02 +/- 1.95E-02

                Z =  51.              Z =  50.              Z =  49.
 A = 111 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02
 S =   1 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02

                Z =  48.              Z =  47.              Z =  46.
 A = 112 2.763E-02 +/- 1.95E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 111 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A = 102 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02
 S =  11 1.243E-01 +/- 4.14E-02 1.381E-01 +/- 4.37E-02 1.381E-01 +/- 4.37E-02

                Z =  45.              Z =  44.              Z =  43.
 A = 108 1.381E-02 +/- 1.38E-02 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00
 A = 105 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  94 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00
 S =  12 1.658E-01 +/- 4.79E-02 1.796E-01 +/- 4.98E-02 1.658E-01 +/- 4.79E-02

                Z =  42.              Z =  41.              Z =  40.
 A = 101 2.763E-02 +/- 1.95E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 100 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  88 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02
 S =  13 2.763E-01 +/- 6.18E-02 1.934E-01 +/- 5.17E-02 2.763E-01 +/- 6.18E-02

                Z =  39.              Z =  38.              Z =  37.
 A =  93 4.144E-02 +/- 2.39E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  92 1.381E-02 +/- 1.38E-02 1.381E-02 +/- 1.38E-02 1.381E-02 +/- 1.38E-02
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  79 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 4.144E-02 +/- 2.39E-02
 S =  14 3.592E-01 +/- 7.04E-02 3.454E-01 +/- 6.91E-02 2.763E-01 +/- 6.18E-02

                Z =  36.              Z =  35.              Z =  34.
 A =  85 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  84 2.763E-02 +/- 1.95E-02 2.763E-02 +/- 1.95E-02 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  75 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02 2.763E-02 +/- 1.95E-02
 S =  11 2.487E-01 +/- 5.86E-02 3.039E-01 +/- 6.48E-02 1.658E-01 +/- 4.79E-02

                Z =  33.              Z =  32.              Z =  31.
 A =  78 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 2.763E-02 +/- 1.95E-02
 A =  77 2.763E-02 +/- 1.95E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  67 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02 2.763E-02 +/- 1.95E-02
 S =  11 8.289E-02 +/- 3.38E-02 1.658E-01 +/- 4.79E-02 1.658E-01 +/- 4.79E-02

                Z =  30.              Z =  29.              Z =  28.
 A =  72 2.763E-02 +/- 1.95E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  71 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  60 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 2.763E-02 +/- 1.95E-02
 S =  10 1.243E-01 +/- 4.14E-02 6.907E-02 +/- 3.09E-02 6.907E-02 +/- 3.09E-02

                Z =  27.              Z =  26.              Z =  25.
 A =  59 4.144E-02 +/- 2.39E-02 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00
 A =  58 0.000E+00 +/- 0.00E+00 2.763E-02 +/- 1.95E-02 0.000E+00 +/- 0.00E+00
 A =  57 2.763E-02 +/- 1.95E-02 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00
 A =  56 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02 1.381E-02 +/- 1.38E-02
 S =   4 6.907E-02 +/- 3.09E-02 6.907E-02 +/- 3.09E-02 1.381E-02 +/- 1.38E-02

                Z =  24.              Z =  23.              Z =  22.
 A =  52 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  50 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00
 A =  49 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00
 A =  48 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02
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```
 S =   4 1.381E-02 +/- 1.38E-02 2.763E-02 +/- 1.95E-02 1.381E-02 +/- 1.38E-02

                Z =  21.              Z =  20.              Z =  19.
 A =  47 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  46 2.763E-02 +/- 1.95E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  45 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02
 A =  40 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02
 S =   4 5.526E-02 +/- 2.76E-02 0.000E+00 +/- 0.00E+00 2.763E-02 +/- 1.95E-02

                Z =   3.              Z =   2.              Z =   1.
 A =   4 0.000E+00 +/- 0.00E+00 2.564E+01 +/- 5.95E-01 0.000E+00 +/- 0.00E+00
 A =   3 0.000E+00 +/- 0.00E+00 3.771E+00 +/- 2.28E-01 1.605E+01 +/- 4.71E-01
 A =   2 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 4.882E+01 +/- 8.21E-01
 A =   1 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.385E+02 +/- 1.38E+00
 S =   4 0.000E+00 +/- 0.00E+00 2.941E+01 +/- 6.37E-01 2.033E+02 +/- 1.68E+00

                Z =   0.
 A =   1 1.270E+03 +/- 4.19E+00
 S =   1 1.270E+03 +/- 4.19E+00

 End of nuclide yields.

Mass yield [mb] and the mean and variance of the kinetic energy [MeV]
 of residual nuclei:
 A = 196 7.322E-01 +/- 1.01E-01  1.533E-01 +/- 7.94E-02
 A = 195 4.780E+00 +/- 2.57E-01  1.576E-01 +/- 1.40E-01
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =   1 1.409E+03 +/- 4.41E+00  1.392E+01 +/- 3.31E+01
 S = 137 1.644E+03 +/- 4.77E+00  1.373E+01 +/- 3.17E+01

Charge yield [mb] and the mean and variance of the  kinetic energy [MeV]
 of residual nuclei:
 Z = 80 3.633E+00 +/- 2.24E-01  3.128E-01 +/- 3.05E-01
 Z = 79 4.124E+01 +/- 7.55E-01  1.799E-01 +/- 2.50E-01
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 Z =  1 2.033E+02 +/- 1.68E+00  3.812E+01 +/- 4.89E+01
 Z =  0 1.270E+03 +/- 4.19E+00  1.078E+01 +/- 2.80E+01
 S = 57 1.644E+03 +/- 4.77E+00  1.373E+01 +/- 3.17E+01

 ********** Nuclide yields [mb] in forward direction (theta_lab < 90) **********
           (zero values suppressed)

                Z =  81.              Z =  80.              Z =  79.
 A = 196 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.520E-01 +/- 4.58E-02
 A = 195 0.000E+00 +/- 0.00E+00 1.520E-01 +/- 4.58E-02 1.312E+00 +/- 1.35E-01
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A = 184 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 2.763E-02 +/- 1.95E-02
 S =  13 0.000E+00 +/- 0.00E+00 3.219E+00 +/- 2.11E-01 2.517E+01 +/- 5.90E-01

                Z =  78.              Z =  77.              Z =  76.
 A = 196 8.289E-02 +/- 3.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 195 4.835E-01 +/- 8.17E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A = 169 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 2.763E-02 +/- 1.95E-02
 S =  28 2.342E+01 +/- 5.69E-01 1.007E+01 +/- 3.73E-01 8.027E+00 +/- 3.33E-01

                Z =  75.              Z =  74.              Z =  73.
 A = 188 2.763E-02 +/- 1.95E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 186 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A = 164 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02 2.763E-02 +/- 1.95E-02
 S =  24 3.675E+00 +/- 2.25E-01 3.606E+00 +/- 2.23E-01 1.879E+00 +/- 1.61E-01

                Z =  72.              Z =  71.              Z =  70.
 A = 172 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00
 A = 171 6.907E-02 +/- 3.09E-02 2.763E-02 +/- 1.95E-02 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A = 154 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 2.763E-02 +/- 1.95E-02
 S =  19 1.368E+00 +/- 1.37E-01 1.423E+00 +/- 1.40E-01 9.670E-01 +/- 1.16E-01

                Z =  69.              Z =  68.              Z =  67.
 A = 163 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 162 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A = 149 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02
 S =  15 4.697E-01 +/- 8.06E-02 5.664E-01 +/- 8.85E-02 2.072E-01 +/- 5.35E-02

                Z =  66.              Z =  65.              Z =  64.
 A = 153 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 152 2.763E-02 +/- 1.95E-02 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A = 144 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02
 S =  10 3.316E-01 +/- 6.77E-02 1.381E-01 +/- 4.37E-02 2.210E-01 +/- 5.53E-02

                Z =  63.              Z =  62.              Z =  61.
 A = 145 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 143 2.763E-02 +/- 1.95E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A = 136 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02
 S =   7 6.907E-02 +/- 3.09E-02 1.381E-02 +/- 1.38E-02 2.763E-02 +/- 1.95E-02

                Z =  60.
 A = 136 4.144E-02 +/- 2.39E-02
 A = 134 1.381E-02 +/- 1.38E-02
 A = 132 1.381E-02 +/- 1.38E-02
 S =   3 6.907E-02 +/- 3.09E-02
```

```
                Z =  54.
 A = 124 1.381E-02 +/- 1.38E-02
 S =   1 1.381E-02 +/- 1.38E-02

                Z =  48.              Z =  47.              Z =  46.
 A = 112 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 110 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02 1.381E-02 +/- 1.38E-02
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A = 103 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02 1.381E-02 +/- 1.38E-02
 S =   8 8.289E-02 +/- 3.38E-02 8.289E-02 +/- 3.38E-02 6.907E-02 +/- 3.09E-02

                Z =  45.              Z =  44.              Z =  43.
 A = 108 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00
 A = 104 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  94 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00
 S =   9 8.289E-02 +/- 3.38E-02 1.105E-01 +/- 3.91E-02 9.670E-02 +/- 3.66E-02

                Z =  42.              Z =  41.              Z =  40.
 A = 101 2.763E-02 +/- 1.95E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 100 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  89 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 4.144E-02 +/- 2.39E-02
 S =  10 9.670E-02 +/- 3.66E-02 6.907E-02 +/- 3.09E-02 1.658E-01 +/- 4.79E-02

                Z =  39.              Z =  38.              Z =  37.
 A =  93 4.144E-02 +/- 2.39E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  92 1.381E-02 +/- 1.38E-02 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  79 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 2.763E-02 +/- 1.95E-02
 S =  12 1.934E-01 +/- 5.17E-02 1.934E-01 +/- 5.17E-02 1.520E-01 +/- 4.58E-02

                Z =  36.              Z =  35.              Z =  34.
 A =  84 1.381E-02 +/- 1.38E-02 2.763E-02 +/- 1.95E-02 0.000E+00 +/- 0.00E+00
 A =  83 1.381E-02 +/- 1.38E-02 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  75 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02
 S =  10 1.243E-01 +/- 4.14E-02 1.796E-01 +/- 4.98E-02 5.526E-02 +/- 2.76E-02

                Z =  33.              Z =  32.              Z =  31.
 A =  78 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02
 A =  77 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  67 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02 1.381E-02 +/- 1.38E-02
 S =  10 5.526E-02 +/- 2.76E-02 8.289E-02 +/- 3.38E-02 8.289E-02 +/- 3.38E-02

                Z =  30.              Z =  29.              Z =  28.
 A =  72 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  71 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  60 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 2.763E-02 +/- 1.95E-02
 S =   7 8.289E-02 +/- 3.38E-02 2.763E-02 +/- 1.95E-02 2.763E-02 +/- 1.95E-02

                Z =  27.              Z =  26.
 A =  59 2.763E-02 +/- 1.95E-02 1.381E-02 +/- 1.38E-02
 A =  58 0.000E+00 +/- 0.00E+00 2.763E-02 +/- 1.95E-02
 A =  57 1.381E-02 +/- 1.38E-02 1.381E-02 +/- 1.38E-02
 S =   3 4.144E-02 +/- 2.39E-02 5.526E-02 +/- 2.76E-02

                Z =  24.              Z =  23.
 A =  50 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02
 S =   1 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02

                Z =  21.              Z =  20.              Z =  19.
 A =  47 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  46 2.763E-02 +/- 1.95E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  40 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02
 S =   3 4.144E-02 +/- 2.39E-02 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02

                Z =   3.              Z =   2.              Z =   1.
 A =   4 0.000E+00 +/- 0.00E+00 1.377E+01 +/- 4.36E-01 0.000E+00 +/- 0.00E+00
 A =   3 0.000E+00 +/- 0.00E+00 2.224E+00 +/- 1.75E-01 9.325E+00 +/- 3.59E-01
 A =   2 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 2.905E+01 +/- 6.34E-01
 A =   1 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 8.498E+01 +/- 1.08E+00
 S =   4 0.000E+00 +/- 0.00E+00 1.600E+01 +/- 4.70E-01 1.234E+02 +/- 1.31E+00

                Z =   0.
 A =   1 6.766E+02 +/- 3.06E+00
 S =   1 6.766E+02 +/- 3.06E+00

 End of nuclide yields (forward direction).

 Mass yield [mb] and the mean and variance of the kinetic energy [MeV]
 of residual nuclei in the forward direction:
 A = 196 2.349E-01 +/- 5.70E-02  1.979E-01 +/- 8.30E-02
 A = 195 1.948E+00 +/- 1.64E-01  1.792E-01 +/- 1.70E-01
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =   1 7.616E+02 +/- 3.24E+00  1.763E+01 +/- 4.06E+01
 S = 118 9.032E+02 +/- 3.53E+00  1.693E+01 +/- 3.85E+01

Charge yield [mb] and the mean and variance of the kinetic energy [MeV]
 of residual nuclei in the forward direction:
 Z = 80 3.219E+00 +/- 2.11E-01  3.207E-01 +/- 7.12E-01
 Z = 79 2.517E+01 +/- 5.90E-01  2.033E-01 +/- 7.54E-01
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
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```
 Z =  0 6.766E+02 +/- 3.06E+00  1.338E+01 +/- 8.85E+00
 S = 51 9.032E+02 +/- 3.53E+00  1.693E+01 +/- 3.85E+01

 ********** Nuclide yields [mb] in backward direction (theta_lab > 90) *********
          (zero values suppressed)

               Z =  81.              Z =  80.              Z =  79.
 A = 196 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 2.210E-01 +/- 5.53E-02
 A = 195 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.824E+00 +/- 1.59E-01
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A = 183 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00
 S =  13 0.000E+00 +/- 0.00E+00 4.144E-01 +/- 7.57E-02 1.607E+01 +/- 4.71E-01

               Z =  78.              Z =  77.              Z =  76.
 A = 196 2.763E-01 +/- 6.18E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 195 1.008E+00 +/- 1.18E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A = 172 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 6.907E-02 +/- 3.09E-02
 S =  25 1.875E+01 +/- 5.09E-01 5.913E+00 +/- 2.86E-01 3.937E+00 +/- 2.33E-01

               Z =  75.              Z =  74.              Z =  73.
 A = 187 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 185 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A = 163 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02
 S =  23 1.533E+00 +/- 1.46E-01 1.133E+00 +/- 1.25E-01 8.703E-01 +/- 1.10E-01

               Z =  72.              Z =  71.              Z =  70.
 A = 173 2.763E-02 +/- 1.95E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 172 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  A = 156 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 5.526E-02 +/- 2.76E-02
 S =  18 6.631E-01 +/- 9.57E-02 5.250E-01 +/- 8.52E-02 4.421E-01 +/- 7.81E-02

               Z =  69.              Z =  68.              Z =  67.
 A = 165 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 162 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A = 150 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00
 S =  13 1.520E-01 +/- 4.58E-02 2.349E-01 +/- 5.70E-02 1.105E-01 +/- 3.91E-02

               Z =  66.              Z =  65.              Z =  64.
 A = 152 4.144E-02 +/- 2.39E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 151 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A = 146 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 2.763E-02 +/- 1.95E-02
 S =   7 1.381E-01 +/- 4.37E-02 1.381E-02 +/- 1.38E-02 6.907E-02 +/- 3.09E-02

               Z =  63.              Z =  62.              Z =  61.
 A = 141 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00
 A = 139 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02
 S =   2 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02 1.381E-02 +/- 1.38E-02

               Z =  60.
 A = 135 1.381E-02 +/- 1.38E-02
 S =   1 1.381E-02 +/- 1.38E-02

               Z =  57.
 A = 130 1.381E-02 +/- 1.38E-02
 A = 129 1.381E-02 +/- 1.38E-02
 A = 123 1.381E-02 +/- 1.38E-02
 S =   3 4.144E-02 +/- 2.39E-02

               Z =  54.              Z =  53.              Z =  52.
 A = 118 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02
 A = 116 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02
 S =   2 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 2.763E-02 +/- 1.95E-02

               Z =  51.              Z =  50.              Z =  49.
 A = 111 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02
 S =   1 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02

               Z =  48.              Z =  47.              Z =  46.
 A = 112 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 111 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  A = 102 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02
 S =   9 4.144E-02 +/- 2.39E-02 5.526E-02 +/- 2.76E-02 6.907E-02 +/- 3.09E-02

               Z =  45.              Z =  44.              Z =  43.
 A = 108 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 105 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  95 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02
 S =  10 8.289E-02 +/- 3.38E-02 6.907E-02 +/- 3.09E-02 6.907E-02 +/- 3.09E-02

               Z =  42.              Z =  41.              Z =  40.
 A =  98 1.381E-02 +/- 1.38E-02 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00
 A =  97 2.763E-02 +/- 1.95E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  88 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02
 S =  11 1.796E-01 +/- 4.98E-02 1.243E-01 +/- 4.14E-02 1.105E-01 +/- 3.91E-02

               Z =  39.              Z =  38.              Z =  37.
 A =  92 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02
 A =  91 2.763E-02 +/- 1.95E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
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- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  79 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02
 S =  12 1.658E-01 +/- 4.79E-02 1.520E-01 +/- 4.58E-02 1.243E-01 +/- 4.14E-02

               Z =  36.               Z =  35.               Z =  34.
 A =  85 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  84 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  75 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02 1.381E-02 +/- 1.38E-02
 S =  11 1.243E-01 +/- 4.14E-02 1.243E-01 +/- 4.14E-02 1.105E-01 +/- 3.91E-02

               Z =  33.               Z =  32.               Z =  31.
 A =  78 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02
 A =  77 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  67 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02
 S =   9 2.763E-02 +/- 1.95E-02 8.289E-02 +/- 3.38E-02 8.289E-02 +/- 3.38E-02

               Z =  30.               Z =  29.               Z =  28.
 A =  72 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  67 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  61 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02
 S =   7 4.144E-02 +/- 2.39E-02 4.144E-02 +/- 2.39E-02 4.144E-02 +/- 2.39E-02

               Z =  27.               Z =  26.               Z =  25.
 A =  59 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  57 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  56 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02 1.381E-02 +/- 1.38E-02
 S =   3 2.763E-02 +/- 1.95E-02 1.381E-02 +/- 1.38E-02 1.381E-02 +/- 1.38E-02

               Z =  24.               Z =  23.               Z =  22.
 A =  52 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  49 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00
 A =  48 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02
 S =   3 1.381E-02 +/- 1.38E-02 1.381E-02 +/- 1.38E-02 1.381E-02 +/- 1.38E-02

               Z =  21.               Z =  20.               Z =  19.
 A =  45 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02
 S =   1 1.381E-02 +/- 1.38E-02 0.000E+00 +/- 0.00E+00 1.381E-02 +/- 1.38E-02

               Z =   3.               Z =   2.               Z =   1.
 A =   4 0.000E+00 +/- 0.00E+00 1.187E+01 +/- 4.05E-01 0.000E+00 +/- 0.00E+00
 A =   3 0.000E+00 +/- 0.00E+00 1.547E+01 +/- 1.46E-01 6.728E+00 +/- 3.05E-01
 A =   2 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.977E+01 +/- 5.23E-01
 A =   1 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 5.349E+01 +/- 8.60E-01
 S =   4 0.000E+00 +/- 0.00E+00 1.341E+01 +/- 4.30E-01 7.999E+01 +/- 1.05E+00

               Z =   0.
 A =   1 5.939E+02 +/- 2.86E+00
 S =   1 5.939E+02 +/- 2.86E+00

 End of nuclide yields (backward direction).

 Mass yield [mb] and the mean and variance of the kinetic energy [MeV]
 of residual nuclei in the backward direction:
 A = 196 4.973E-01 +/- 8.29E-02  1.323E-01 +/- 6.82E-02
 A = 195 2.832E+00 +/- 1.98E-01  1.428E-01 +/- 1.13E-01
- - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =   1 6.474E+02 +/- 2.99E+00  9.548E+00 +/- 2.03E+01
 S = 119 7.405E+02 +/- 3.20E+00  9.827E+00 +/- 1.99E+01

 Charge yield [mb] and the mean and variance of the kinetic energy [MeV]
 of residual nuclei in the backward direction:
 Z = 80 4.144E-01 +/- 7.57E-02  2.516E-01 +/- 3.06E-01
 Z = 79 1.607E+01 +/- 4.71E-01  1.433E-01 +/- 1.68E-01
- - - - - - - - - - - - - - - - - - - - - - - - - - - -
 Z =  0 5.939E+02 +/- 2.86E+00  7.806E+00 +/- 1.79E+01
 S = 55 7.405E+02 +/- 3.20E+00  9.827E+00 +/- 1.99E+01

******** Nuclide average kinetic energies [MeV] (zero yield suppressed) ********

               Z =  81.               Z =  80.               Z =  79.
 A = 196 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.417E-01 +/- 6.19E-02
 A = 195 0.000E+00 +/- 0.00E+00 3.395E-01 +/- 2.24E-01 1.202E-01 +/- 7.90E-02
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A = 183 0.000E+00 +/- 0.00E+00 1.549E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 S =  14 0.000E+00 +/- 0.00E+00 3.128E-01 +/- 3.05E-01 1.799E-01 +/- 2.50E-01

               Z =  78.               Z =  77.               Z =  76.
 A = 196 1.654E-01 +/- 9.27E-02 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 195 2.177E-01 +/- 1.86E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A = 169 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 2.536E+00 +/- 2.08E+00
 S =  28 3.942E-01 +/- 4.23E-01 6.699E-01 +/- 6.57E-01 1.004E+00 +/- 9.03E-01

               Z =  75.               Z =  74.               Z =  73.
 A = 188 5.925E-01 +/- 4.50E-01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 187 5.707E-01 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A = 163 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.152E+00 +/- 0.00E+00
 S =  26 1.287E+00 +/- 1.05E+00 1.481E+00 +/- 1.25E+00 1.628E+00 +/- 1.40E+00

               Z =  72.               Z =  71.               Z =  70.
 A = 173 1.866E+00 +/- 1.00E+00 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 172 1.401E-01 +/- 0.00E+00 9.192E-01 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
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- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A = 154 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.244E+00 +/- 1.01E+00
 S =  20 2.098E+00 +/- 1.67E+00 2.353E+00 +/- 1.67E+00 2.700E+00 +/- 2.29E+00

                Z =  69.                Z =  68.                Z =  67.
 A = 165 4.011E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 163 2.490E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A = 149 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.392E+00 +/- 0.00E+00
 S =  16 4.044E+00 +/- 3.58E+00 3.057E+00 +/- 2.43E+00 3.166E+00 +/- 2.38E+00

                Z =  66.                Z =  65.                Z =  64.
 A = 153 1.879E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 152 4.726E+00 +/- 3.94E+00 2.398E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A = 144 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 3.020E+00 +/- 0.00E+00
 S =  10 3.642E+00 +/- 3.41E+00 3.378E+00 +/- 2.13E+00 4.337E+00 +/- 2.39E+00

                Z =  63.                Z =  62.                Z =  61.
 A = 145 3.455E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 143 3.536E+00 +/- 2.63E+00 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A = 136 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.104E+01 +/- 0.00E+00
 S =   8 3.862E+00 +/- 2.54E+00 8.001E+00 +/- 6.18E+00 7.623E+00 +/- 4.45E+00

                Z =  60.
 A = 136 6.679E+00 +/- 4.65E+00
 A = 135 3.594E+00 +/- 0.00E+00
 A = 134 1.421E+01 +/- 0.00E+00
 A = 132 2.869E+00 +/- 0.00E+00
 S =   4 6.784E+00 +/- 4.92E+00

                Z =  57.
 A = 130 1.261E+01 +/- 0.00E+00
 A = 129 2.981E+01 +/- 0.00E+00
 A = 123 4.729E+01 +/- 0.00E+00
 S =   3 2.990E+01 +/- 1.42E+01

                Z =  54.                Z =  53.                Z =  52.
 A = 124 3.255E+01 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 118 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 3.372E+01 +/- 0.00E+00
 A = 116 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 4.080E+01 +/- 0.00E+00
 S =   3 3.255E+01 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 3.726E+01 +/- 3.54E+00

                Z =  51.                Z =  50.                Z =  49.
 A = 111 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 3.470E+01 +/- 0.00E+00
 S =   1 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 3.470E+01 +/- 0.00E+00

                Z =  48.                Z =  47.                Z =  46.
 A = 112 4.534E+01 +/- 1.85E+00 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 111 0.000E+00 +/- 0.00E+00 5.507E+01 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A = 102 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 4.867E+01 +/- 0.00E+00
 S =  11 4.446E+01 +/- 7.87E+00 5.259E+01 +/- 8.96E+00 4.990E+01 +/- 6.38E+00

                Z =  45.                Z =  44.                Z =  43.
 A = 108 5.430E+01 +/- 0.00E+00 5.201E+01 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 105 5.019E+01 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  94 0.000E+00 +/- 0.00E+00 3.782E+01 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 S =  12 5.456E+01 +/- 6.71E+00 4.971E+01 +/- 6.29E+00 5.824E+01 +/- 1.23E+01

                Z =  42.                Z =  41.                Z =  40.
 A = 101 5.561E+01 +/- 5.28E+00 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A = 100 5.528E+01 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  88 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 6.047E+01 +/- 0.00E+00
 S =  13 5.676E+01 +/- 1.23E+01 5.879E+01 +/- 6.48E+00 5.907E+01 +/- 1.30E+01

                Z =  39.                Z =  38.                Z =  37.
 A =  93 6.691E+01 +/- 3.10E+00 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  92 8.277E+01 +/- 0.00E+00 7.347E+01 +/- 0.00E+00 6.107E+01 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  79 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 6.674E+01 +/- 8.18E+00
 S =  14 6.283E+01 +/- 1.23E+01 5.847E+01 +/- 1.27E+01 6.684E+01 +/- 9.88E+00

                Z =  36.                Z =  35.                Z =  34.
 A =  85 7.146E+01 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  84 5.580E+01 +/- 1.94E+01 6.887E+01 +/- 6.38E-01 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  75 0.000E+00 +/- 0.00E+00 4.203E+01 +/- 0.00E+00 6.347E+01 +/- 1.06E+01
 S =  11 6.591E+01 +/- 1.20E+01 6.517E+01 +/- 1.13E+01 6.786E+01 +/- 9.65E+00

                Z =  33.                Z =  32.                Z =  31.
 A =  78 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 7.416E+01 +/- 1.62E-01
 A =  77 7.024E+01 +/- 3.55E+00 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  67 0.000E+00 +/- 0.00E+00 4.560E+01 +/- 0.00E+00 6.920E+01 +/- 2.46E+01
 S =  11 6.935E+01 +/- 5.49E+00 7.237E+01 +/- 1.29E+01 7.317E+01 +/- 1.43E+01

                Z =  30.                Z =  29.                Z =  28.
 A =  72 5.600E+01 +/- 1.44E+01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
 A =  71 7.910E+01 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =  60 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 6.464E+01 +/- 1.48E-01
 S =  10 6.918E+01 +/- 1.10E+01 5.859E+01 +/- 1.00E+01 7.258E+01 +/- 7.34E+00
```

```
                Z =  27.              Z =  26.              Z =  25.
A =  59 7.085E+01 +/- 2.09E+01 6.337E+01 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
A =  58 0.000E+00 +/- 0.00E+00 8.900E+01 +/- 1.69E+01 0.000E+00 +/- 0.00E+00
A =  57 7.233E+01 +/- 1.21E+01 8.656E+01 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
A =  56 0.000E+00 +/- 0.00E+00 9.326E+01 +/- 0.00E+00 6.543E+01 +/- 0.00E+00
S =   4 7.144E+01 +/- 1.79E+01 8.424E+01 +/- 1.51E+01 6.543E+01 +/- 0.00E+00

                Z =  24.              Z =  23.              Z =  22.
A =  52 8.528E+01 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
A =  50 0.000E+00 +/- 0.00E+00 6.047E+01 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
A =  49 0.000E+00 +/- 0.00E+00 7.149E+01 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
A =  48 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 4.742E+01 +/- 0.00E+00
S =   4 8.528E+01 +/- 0.00E+00 6.598E+01 +/- 5.51E+00 4.742E+01 +/- 0.00E+00

                Z =  21.              Z =  20.              Z =  19.
A =  47 9.897E+01 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
A =  46 8.836E+01 +/- 1.38E+01 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00
A =  45 4.543E+01 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 5.407E+01 +/- 0.00E+00
A =  40 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 1.002E+02 +/- 0.00E+00
S =   4 8.028E+01 +/- 2.28E+01 0.000E+00 +/- 0.00E+00 7.714E+01 +/- 2.31E+01

                Z =   3.              Z =   2.              Z =   1.
A =   4 0.000E+00 +/- 0.00E+00 2.375E+01 +/- 9.14E+00 0.000E+00 +/- 0.00E+00
A =   3 0.000E+00 +/- 0.00E+00 4.013E+01 +/- 2.15E+01 2.438E+01 +/- 2.15E+01
A =   2 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 2.954E+01 +/- 3.04E+01
A =   1 0.000E+00 +/- 0.00E+00 0.000E+00 +/- 0.00E+00 4.273E+01 +/- 5.54E+01
S =   4 0.000E+00 +/- 0.00E+00 2.585E+01 +/- 1.27E+01 3.812E+01 +/- 4.89E+01

                Z =   0.
A =   1 1.078E+01 +/- 2.80E+01
S =   1 1.078E+01 +/- 2.80E+01

 End of nuclide average kinetic energies.

 Mass yield [mb] and the mean and variance of the emission angle [deg.]
 of residual nuclei:
 A = 196  7.322E-01 +/- 1.01E-01   1.054E+02 +/- 4.00E+01
 A = 195  4.780E+00 +/- 2.57E-01   9.797E+01 +/- 4.29E+01
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =   1  1.409E+03 +/- 4.41E+00   8.608E+01 +/- 4.02E+01
 S = 137  1.644E+03 +/- 4.77E+00   8.527E+01 +/- 4.03E+01

 The mean and variance of the z velocity [v/c] of residual nuclei,
 and the forward/backward ratio:
 A = 196 -2.246E-04 +/- 7.99E-04   4.722E-01 +/- 1.93E-01
 A = 195 -9.069E-05 +/- 8.46E-04   6.878E-01 +/- 1.06E-01
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 A =   1  1.695E-02 +/- 1.04E-01   1.176E+00 +/- 1.04E-02
 S = 137  1.574E-02 +/- 9.91E-02   1.220E+00 +/- 1.00E-02

 Charge yield [mb] and the mean and variance of the emission angle [deg.]
 of residual nuclei:
 Z = 80  3.633E+00 +/- 2.24E-01   4.869E+01 +/- 3.30E+01
 Z = 79  4.124E+01 +/- 7.55E-01   7.972E+01 +/- 4.24E+01
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 Z =  0  1.270E+03 +/- 4.19E+00   8.692E+01 +/- 3.99E+01
 S = 57  1.644E+03 +/- 4.77E+00   8.527E+01 +/- 4.03E+01

 The mean and variance of the z velocity [v/c] of residual nuclei,
 and the forward/backward ratio:
 Z = 80  1.076E-03 +/- 9.26E-04   9.899E+00 +/- 4.75E+00
 Z = 79  2.418E-04 +/- 8.98E-04   2.223E+00 +/- 2.88E-01
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 Z =  0  1.207E-02 +/- 9.11E-02   1.953E+00 +/- 5.78E-03
 S = 57  1.574E-02 +/- 9.91E-02   1.220E+00 +/- 1.00E-02

                  Mass distributions of nuclei:
                                        at start of evap, which:  just prior to
            after cascade after preeq   evap.\ only    fission      fission
   A = 197    2.122E-01    8.790E-02    8.780E-02    1.000E-04    0.000E+00
   A = 196    2.574E-01    2.214E-01    2.203E-01    1.100E-03    2.000E-04
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   A = 155    0.000E+00    0.000E+00    0.000E+00    0.000E+00    1.000E-04
    <A> =     1.947E+02    1.934E+02    1.934E+02    1.917E+02    1.872E+02
St Dv A =     2.241E+00    3.266E+00    3.255E+00    3.446E+00    7.572E+00
   norm =     1.000E+00    1.000E+00    9.840E-01    1.600E-02    1.600E-02

                  Charge distributions of nuclei:
                                        at start of evap, which:  just prior to
            after cascade after preeq   evap.\ only    fission      fission
   Z =  81    5.000E-04    2.000E-04    2.000E-04    0.000E+00    0.000E+00
   Z =  80    5.200E-02    3.520E-02    3.350E-02    1.700E-03    9.000E-04
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
   Z =  66    0.000E+00    0.000E+00    0.000E+00    0.000E+00    3.000E-04
    <Z> =     7.857E+01    7.806E+01    7.806E+01    7.824E+01    7.728E+01
St Dv Z =     7.915E-01    1.241E+00    1.240E+00    1.322E+00    7.678E+01
   norm =     1.000E+00    1.000E+00    9.840E-01    1.600E-02    1.600E-02

           Excitation energy distributions [1/MeV] of nuclei:
                                        at start of evap, which:  just prior to
    E*(MeV)   after cascade after preeq   evap.\ only    fission      fission
    0.-  10.    3.100E-04    2.450E-03    2.450E-03    0.000E+00    0.000E+00
   10.-  20.    2.630E-03    6.610E-03    6.610E-03    0.000E+00    0.000E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  760.- 770.    1.000E-05    0.000E+00    0.000E+00    0.000E+00    0.000E+00
```

```
     <E*> =     1.273E+02    9.332E+01    9.087E+01    2.440E+02    1.874E+02
St dev E* =     1.050E+02    8.599E+01    8.310E+01    1.199E+02    9.246E+01
     norm =     1.000E+00    1.000E+00    9.840E-01    1.600E-02    1.600E-02

          Linear momentum distributions [1/MeV/c] of nuclei:
                                          at start of evap, which:  just prior to
    P(MeV/c)  after cascade after preeq   evap.\ only    fission      fission
    0.-  10.    4.000E-05    3.000E-05    3.000E-05    0.000E+00    0.000E+00
   10.-  20.    5.000E-05    3.000E-05    3.000E-05    0.000E+00    0.000E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 1920.-1930.    0.000E+00    1.000E-05    1.000E-05    0.000E+00    0.000E+00
      <P> =     3.022E+02    3.378E+02    3.347E+02    5.308E+02    5.607E+02
 St dev P =     2.237E+02    2.311E+02    2.288E+02    2.853E+02    3.406E+02
     norm =     1.000E+00    1.000E+00    9.840E-01    1.600E-02    1.600E-02

             Angular momentum distributions [1/hbar] of nuclei:
                                      at start of evap, which:  just prior to
      L     after cascade after preeq   evap.\ only    fission      fission
   0.-  1.    2.400E-02    1.360E-02    1.350E-02    1.000E-04    1.000E-04
   1.-  2.    1.393E-01    7.940E-02    7.930E-02    1.000E-04    1.000E-04
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  53.- 54.    0.000E+00    1.000E-04    1.000E-04    0.000E+00    0.000E+00
    <L> =     6.049E+00    8.269E+00    8.226E+00    1.087E+01    1.087E+01
St dv L =     4.671E+00    6.153E+00    6.134E+00    6.772E+00    6.772E+00
   norm =     1.000E+00    1.000E+00    9.840E-01    1.600E-02    1.600E-02

   Distribution of fission-fragment opening angles [1/deg.] (lab.sys.) in different
                              bins of neutron multiplicity:
 theta(deg.) All events  n = 0-5   n = 6-8  n = 9-12  n = 13-15 n = 16-19   n > 20
 146. - 147.  6.250E-03 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 6.250E-03
 150. - 151.  6.250E-03 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 6.250E-03
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 179. - 180.  2.500E-02 0.000E+00 0.000E+00 1.250E-02 0.000E+00 6.250E-03 6.250E-03
    <thet> =  1.716E+02 0.000E+00 1.779E+02 1.755E+02 1.738E+02 1.726E+02 1.692E+02
St dv thet =  5.897E+00 0.000E+00 0.000E+00 2.417E+00 3.024E+00 4.517E+00 6.979E+00
     norm. =  1.000E+00 0.000E+00 6.250E-03 8.750E-02 1.625E-01 3.063E-01 4.375E-01


                    Neutron-multiplicity probability:

     Nn      Total      Cascade    Preequil.   Evap.\ res.  Pre-fiss.   Post-fiss.
      0    3.300E-03   2.916E-01   5.897E-01   1.260E-02   3.800E-03   0.000E+00
      1    1.480E-02   3.124E-01   2.918E-01   4.870E-02   3.800E-03   0.000E+00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
     32    3.000E-04   0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
    <n> =  9.197E+00   1.614E+00   5.663E-01   6.883E+00   2.706E+00   1.251E+01
St dv n =  5.844E+00   1.725E+00   8.096E-01   4.473E+00   2.794E+00   4.504E+00
   norm =  1.000E+00   1.000E+00   1.000E+00   9.840E-01   1.600E-02   1.600E-02

 Elapsed cpu time  =  1. min and 50.800 sec.
```

Appendix 3

Example 1

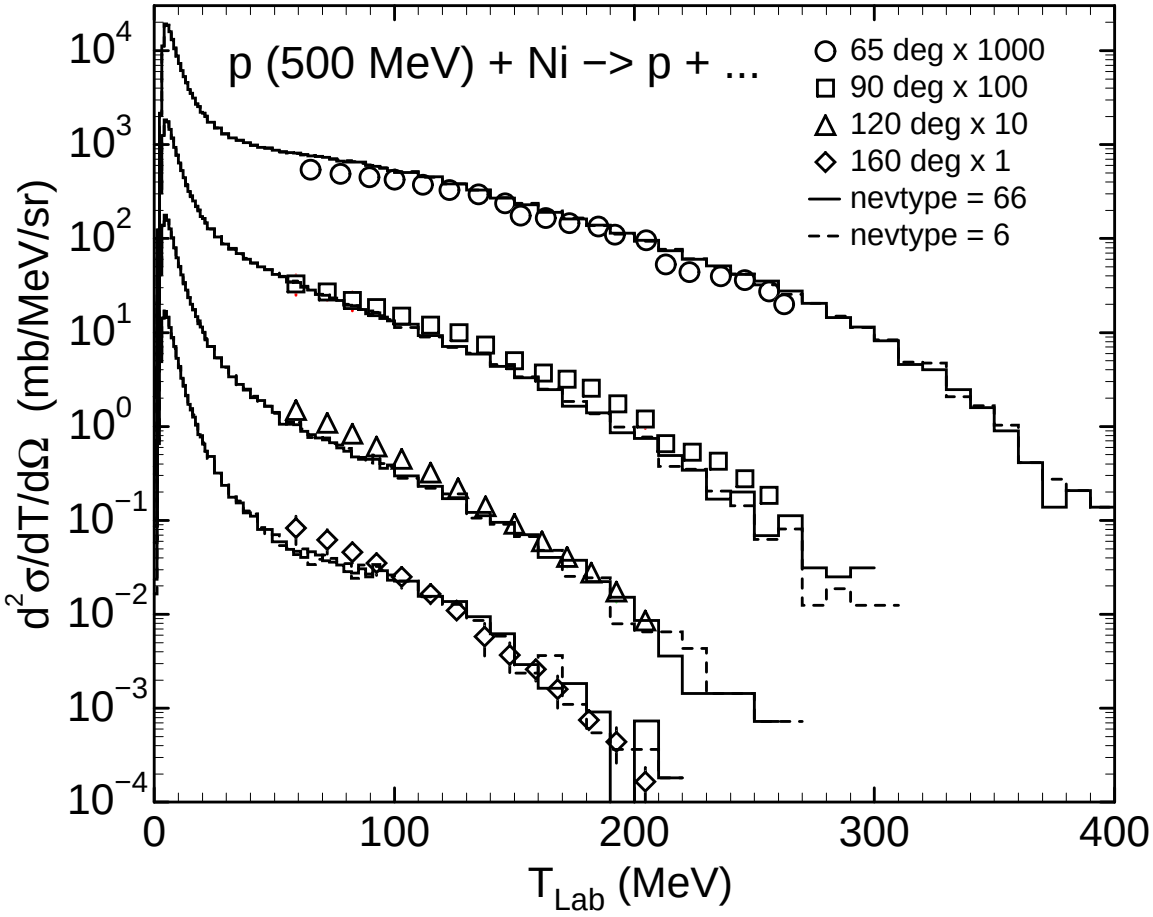

Figure 1: Experimental proton spectra from 500 MeV p + Ni [115] compared with CEM03.01 results obtained using the input shown in Example 1 of Appendix 1 (the corresponding output is shown in Example 1 of Appendix 2). The results shown in this figure are for one million simulated inelastic events (**limc=1000000**). The option considering 66 types of possible evaporated particles (**nevtype=66**) requires 1 hr 31 min 59 sec of computing time on a SunBlade 100, 500 MHz computer, while the **nevtype=6** option requires only 33 min 38 sec, providing almost the same results.

Example 2

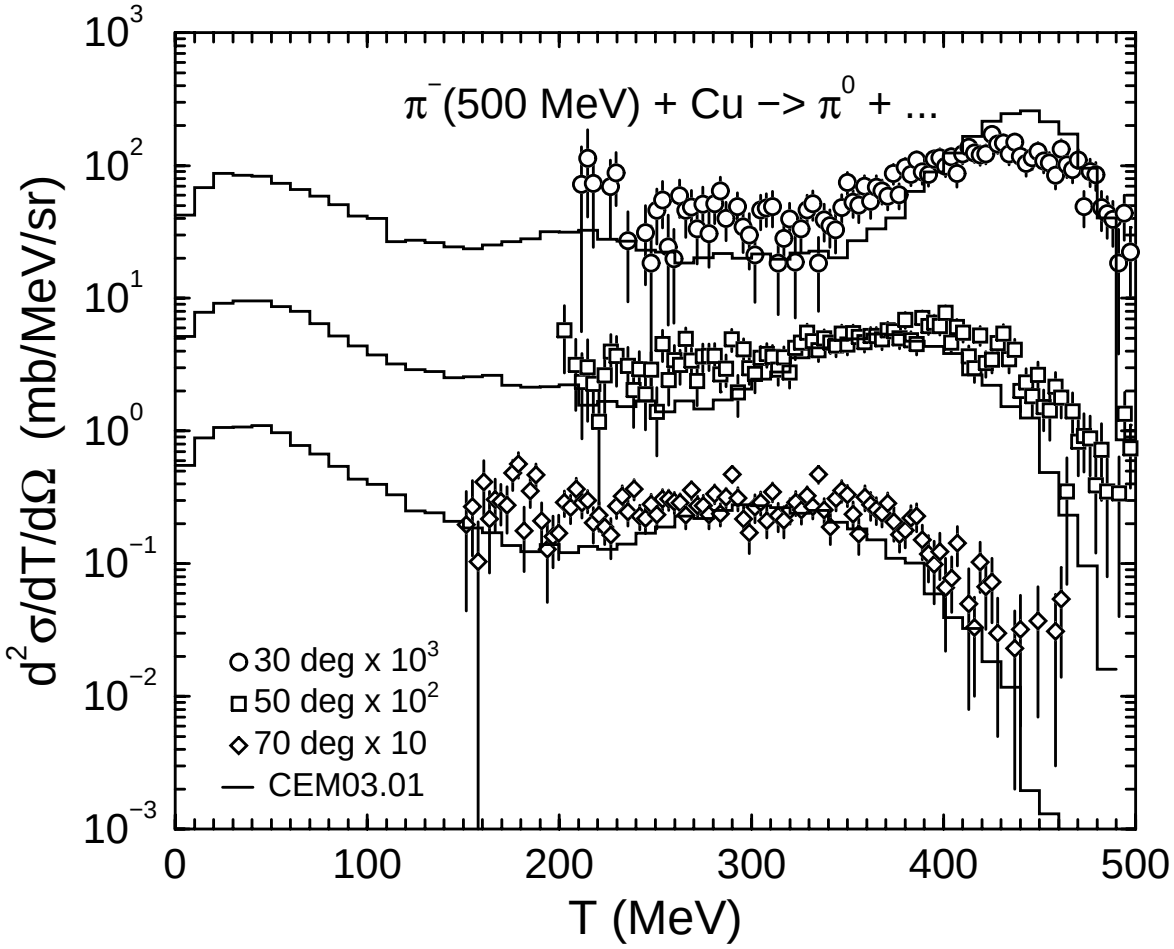

Figure 2: Experimental π^0 spectra from 500 MeV π^- + Cu [116, 23] compared with CEM03.01 results obtained using the input shown in Example 2 of Appendix 1 (the corresponding output is shown in Example 2 of Appendix 2). The results shown in this figure are for one million simulated inelastic events (**limc=1000000**). As pions are produced by CEM03.01 only at the INC stage of reactions, calculated pion spectra do not depend on the value of **nevtype**; this calculation was done using only the **nevtype=6** option in the input and it took 43 min 28 sec on a SunBlade 100, 500 MHz computer.

Example 3

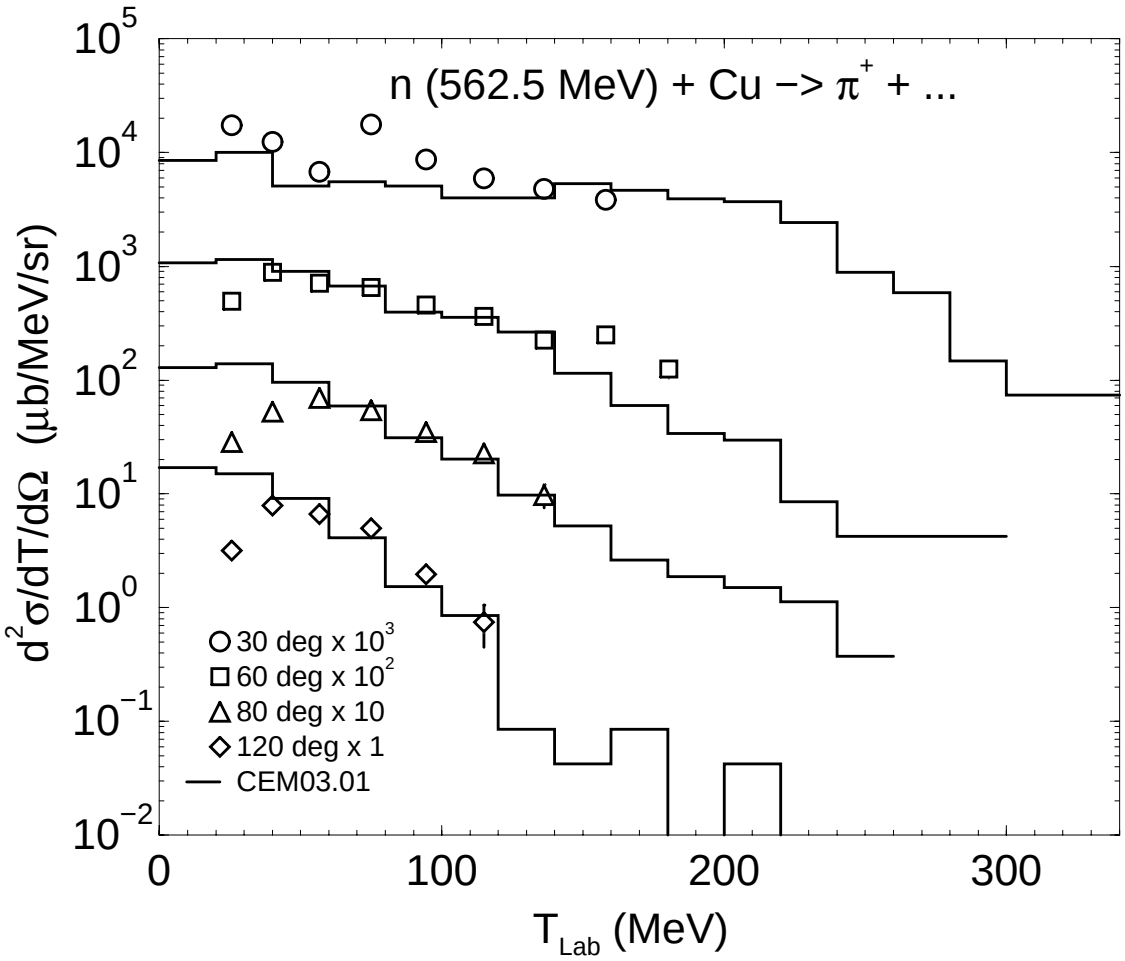

Figure 3: Experimental π^+ spectra from 562.5 MeV n + Cu [117] compared with CEM03.01 results obtained using the input shown in Example 3 of Appendix 1 (the corresponding output is shown in Example 3 of Appendix 2). The results shown in this figure are for one million simulated inelastic events (**limc=1000000**). This calculation was done using only the **nevtype=6** option in the input, for the same reason as discussed for Example 2, and it took 39 min 33 sec on a SunBlade 100, 500 MHz computer.

Example 4

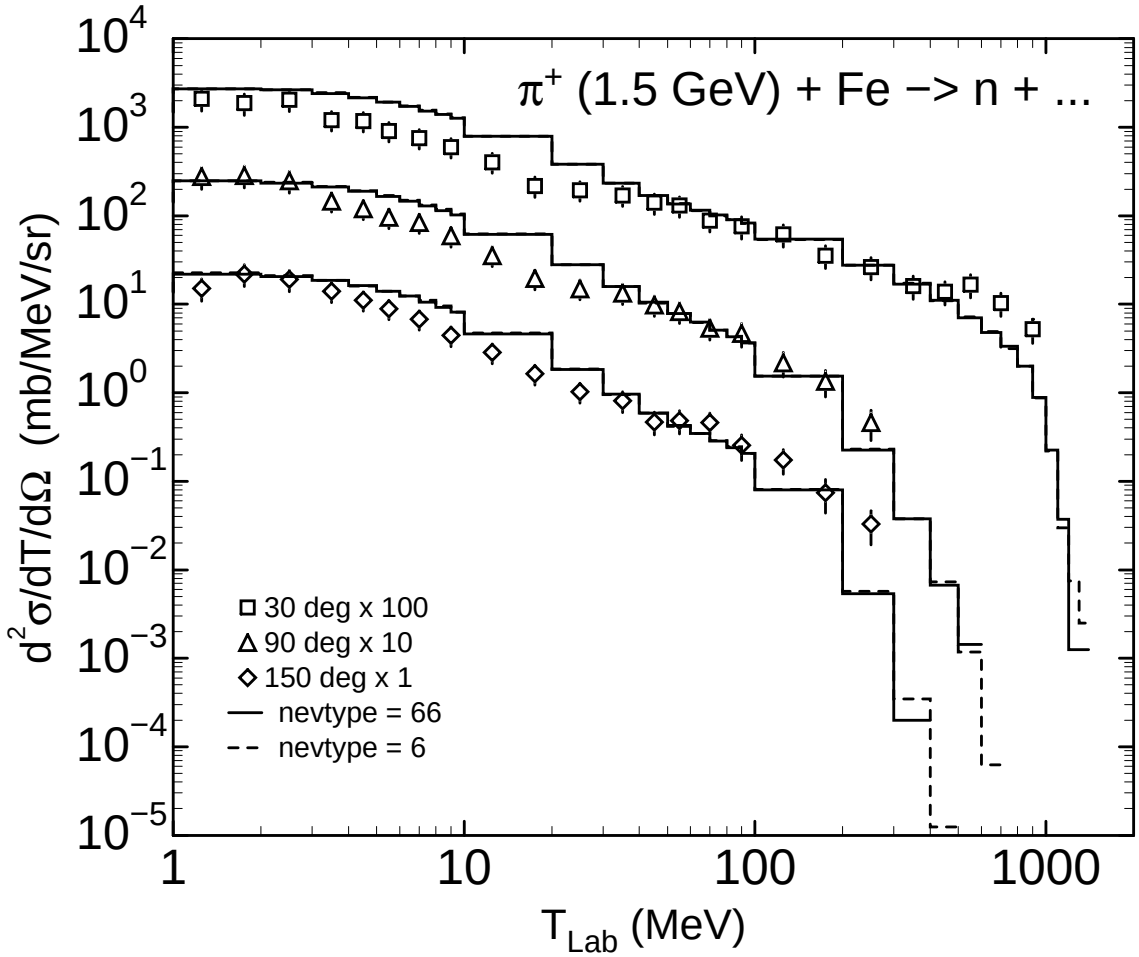

Figure 4: Experimental neutron spectra from 1.5 GeV π^+ + Fe [118] compared with CEM03.01 results obtained using the input shown in Example 4 of Appendix 1 (the corresponding output is shown in Example 4 of Appendix 2). The results shown in this figure are for one million simulated inelastic events (**limc=1000000**). The **nevtype=66** option requires 3 hr 30 min 52 sec of computing time on a SunBlade 100, 500 MHz computer, while the **nevtype=6** option requires only 1 hr 51 min 58 sec, providing almost the same results.

Example 5

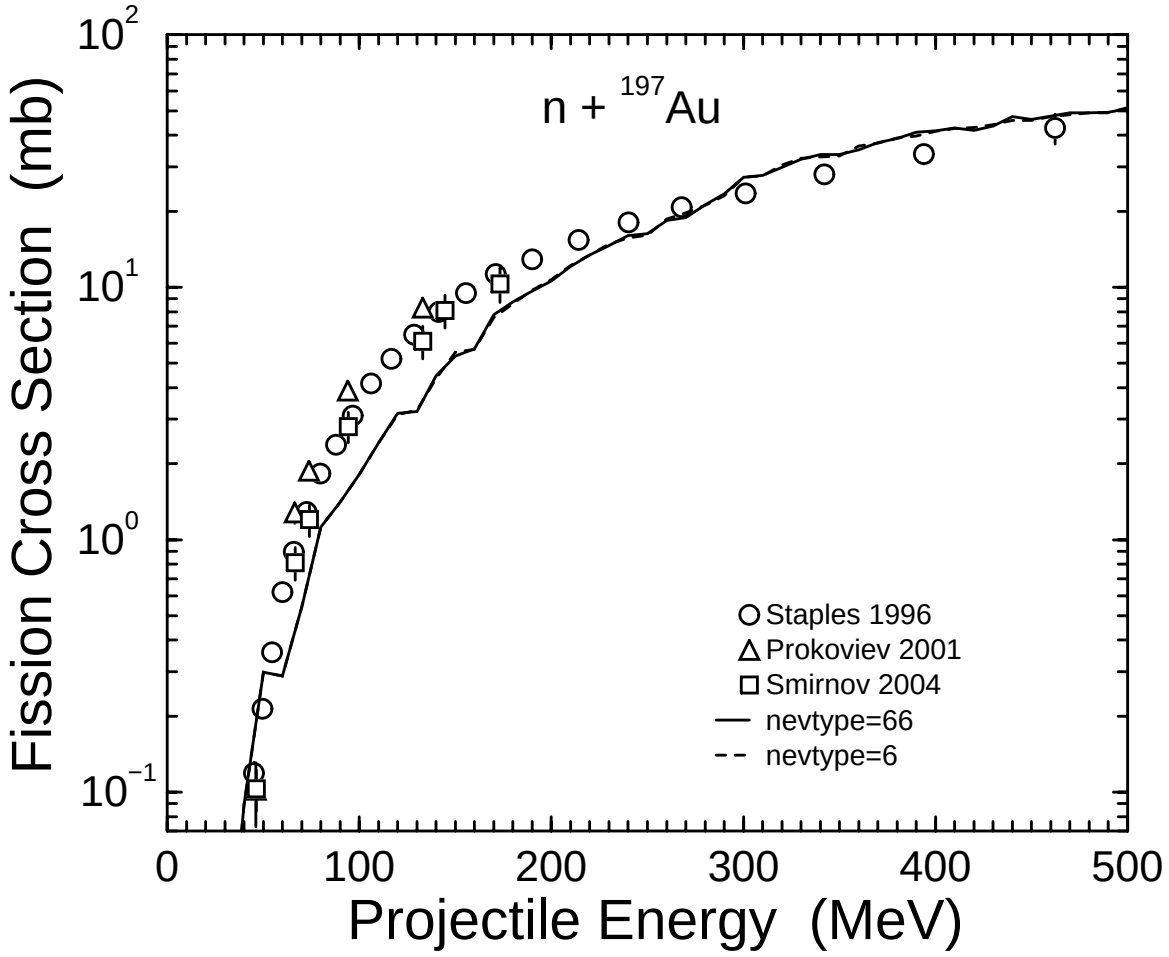

Figure 5: Experimental neutron-induced fission cross section of ^{197}Au [119]–[121] compared with CEM03.01 results obtained using the input shown in Example 5 of Appendix 1 (the corresponding output is shown in Example 5 of Appendix 2). The results shown in this figure are the **Direct Monte Carlo Simulation Method** fission cross sections from the CEM03.01 output. These calculations were done at neutron energies from 30 MeV (**t0mev=30.0**) to 500 MeV (**t0max=500.5**) with a step of 10 MeV (**dt0=10.0**), 100000 simulated inelastic events for each energy point (**limc=100000**). The **nevtype=66** option requires 9 hr 22 min 38 sec of computing time on a SunBlade 100, 500 MHz computer, while the **nevtype=6** option requires only 4 hr 12 min 21 sec, providing almost the same results.

Example 6

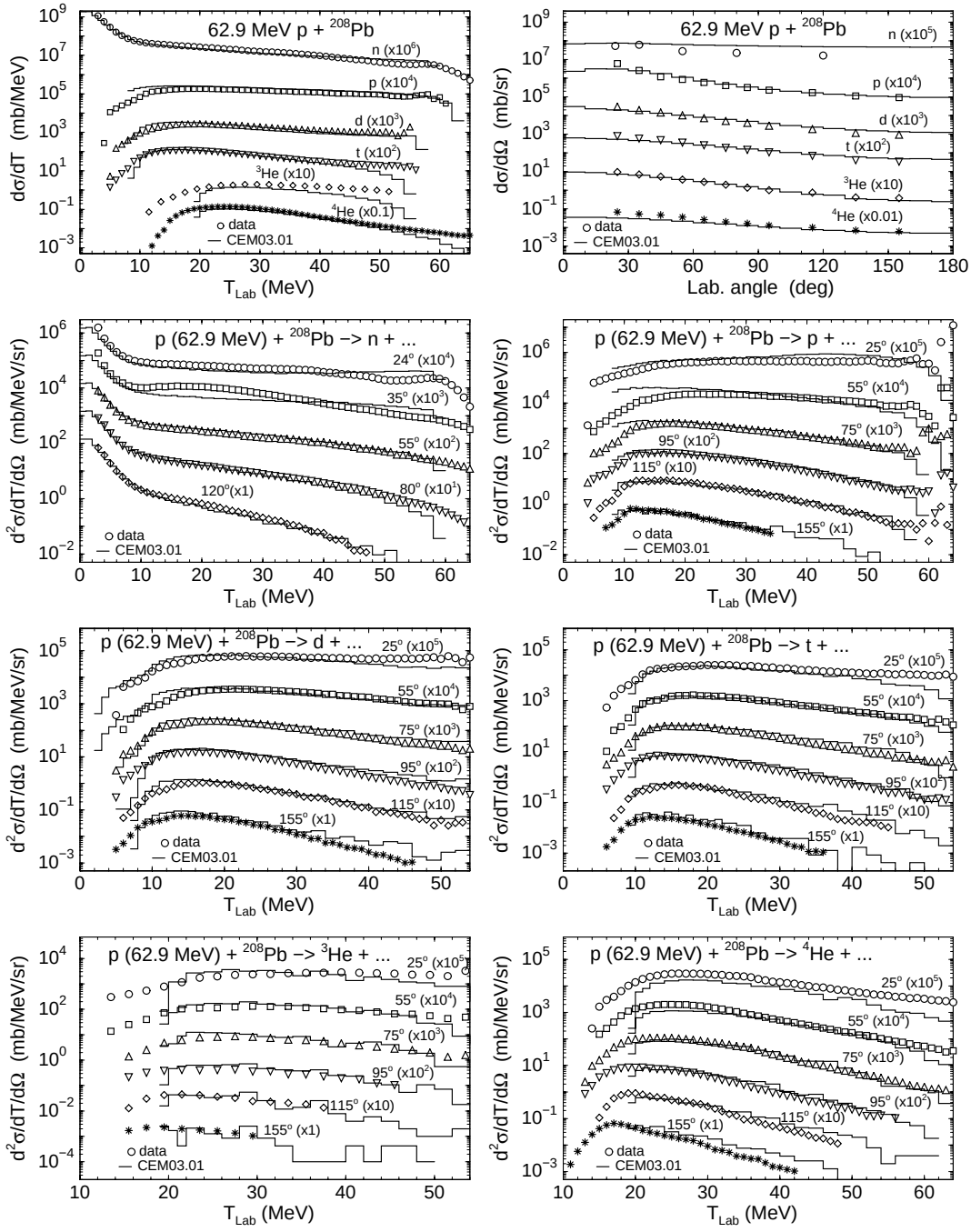

Figure 6: Experimental angle-integrated energy spectra (upper left plot), energy-integrated angular distributions (upper right plot), and double-differential spectra of nucleons and complex particles [122] compared with CEM03.01 results obtained using the input shown in Example 6 of Appendix 1 (the corresponding output is shown in Example 6 of Appendix 2). The results shown in this figure are for ten million simulated inelastic events (**limc=10000000**). The **nevtype=66** option requires 10 hr 28 min 23 sec of computing time on a SunBlade 100, 500 MHz computer, while the **nevtype=6** option requires only 7 hr 44 min 54 sec, providing practically the same results, indistinguishable within the scale of this figure.

Example 7

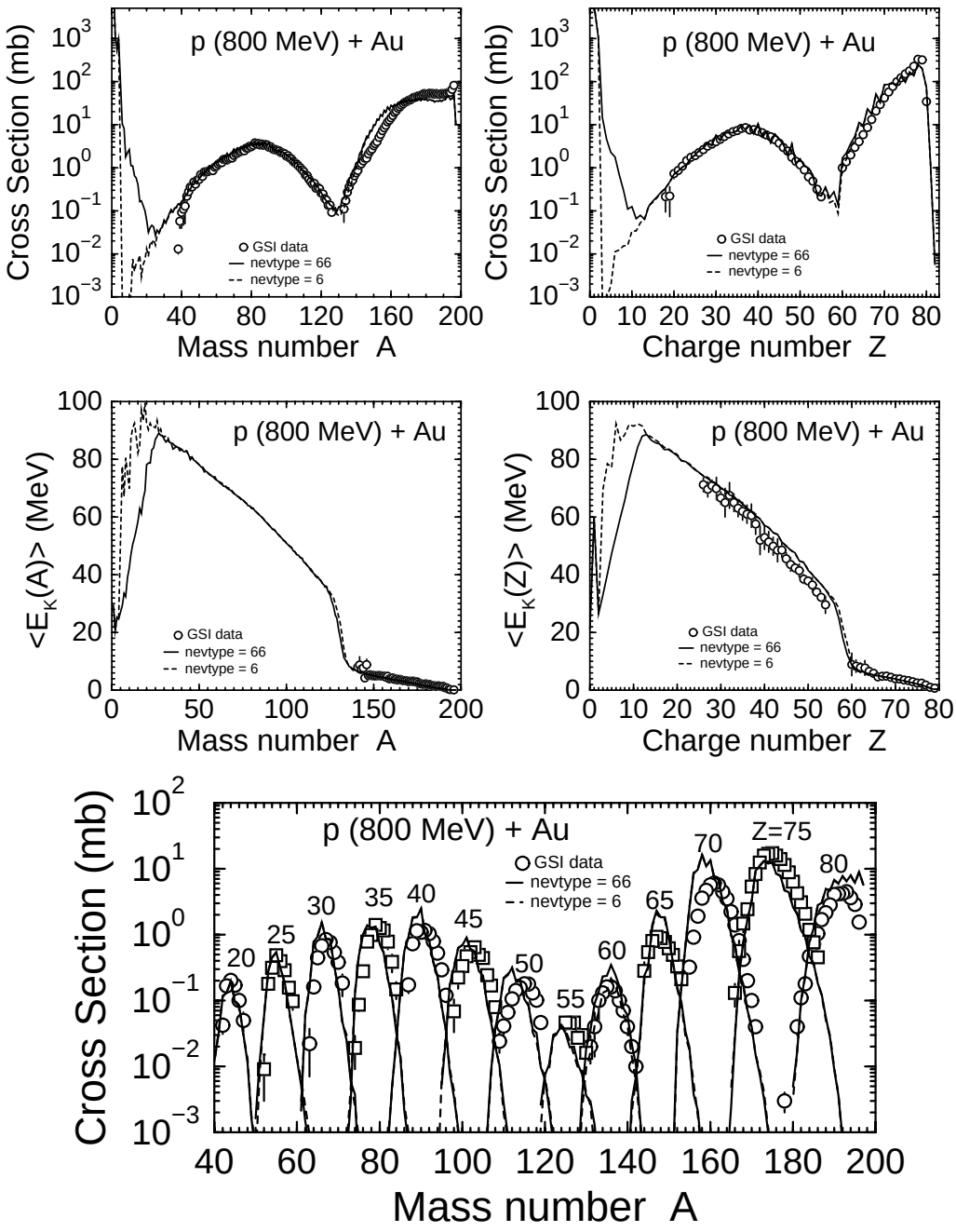

Figure 7: The measured [123] mass and charge distributions of the product yields from the reaction 800 MeV/A ^{197}Au+p and of the mean kinetic energy of these products, and the mass distributions of the cross sections for the production of thirteen elements with the charge Z from 20 to 80 (open symbols) compared with CEM03.01 results obtained using the input shown in Example 7 of Appendix 1 (the corresponding output is shown in Example 7 of Appendix 2). The results shown in this figure are for ten million simulated inelastic events (**limc=10000000**). The **nevtype=66** option requires 53 hr 34 min 31 sec of computing time on a SunBlade 100, 500 MHz computer, while the **nevtype=6** option requires only 12 hr 48 min 3 sec, providing almost the same results for the spallation and fission products. The fragment ($2 < Z < 13$, $6 < A < 29$) results are very different, therefore we need to use the option **nevtype=66** when we are interested in fragment production.

Example 8

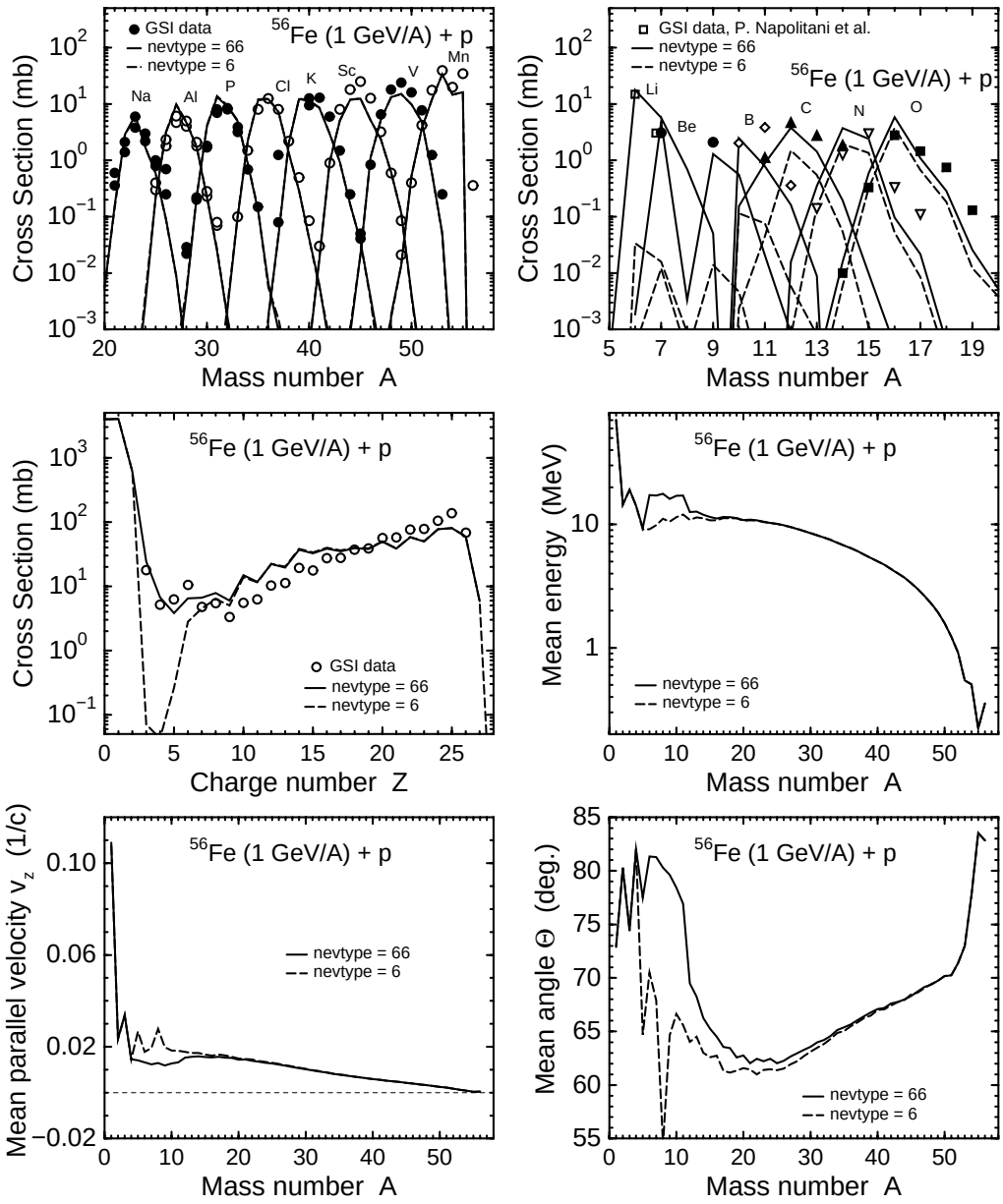

Figure 8: Experimental mass distributions of the yields of eight isotopes from Na to Mn [124] and of all light fragments from Li to O [125] from the reaction 1 GeV/A ^{56}Fe+p and the charge distribution of the product yield compared with CEM03.01 results obtained using the input shown in Example 8 of Appendix 1 (the corresponding output is shown in Example 8 of Appendix 2). Predictions of CEM03.01 for the mean kinetic energy, mean parallel velocity v_z, and the mean production angle Θ of all products in the laboratory system are given as well. The results shown in this figure are for ten million simulated inelastic events (**limc=10000000**). The **nevtype=66** option requires 27 hr 38 min 37 sec of computing time on a SunBlade 100, 500 MHz computer, while the **nevtype=6** option requires only 8 hr 27 min 48 sec, providing almost the same results for the spallation products. The yields of light fragments, especially of Li and Be, differ by several orders of magnitude, therefore we need to use the option **nevtype** $>$ **6** when we are interested in light-fragment production.

Example 9

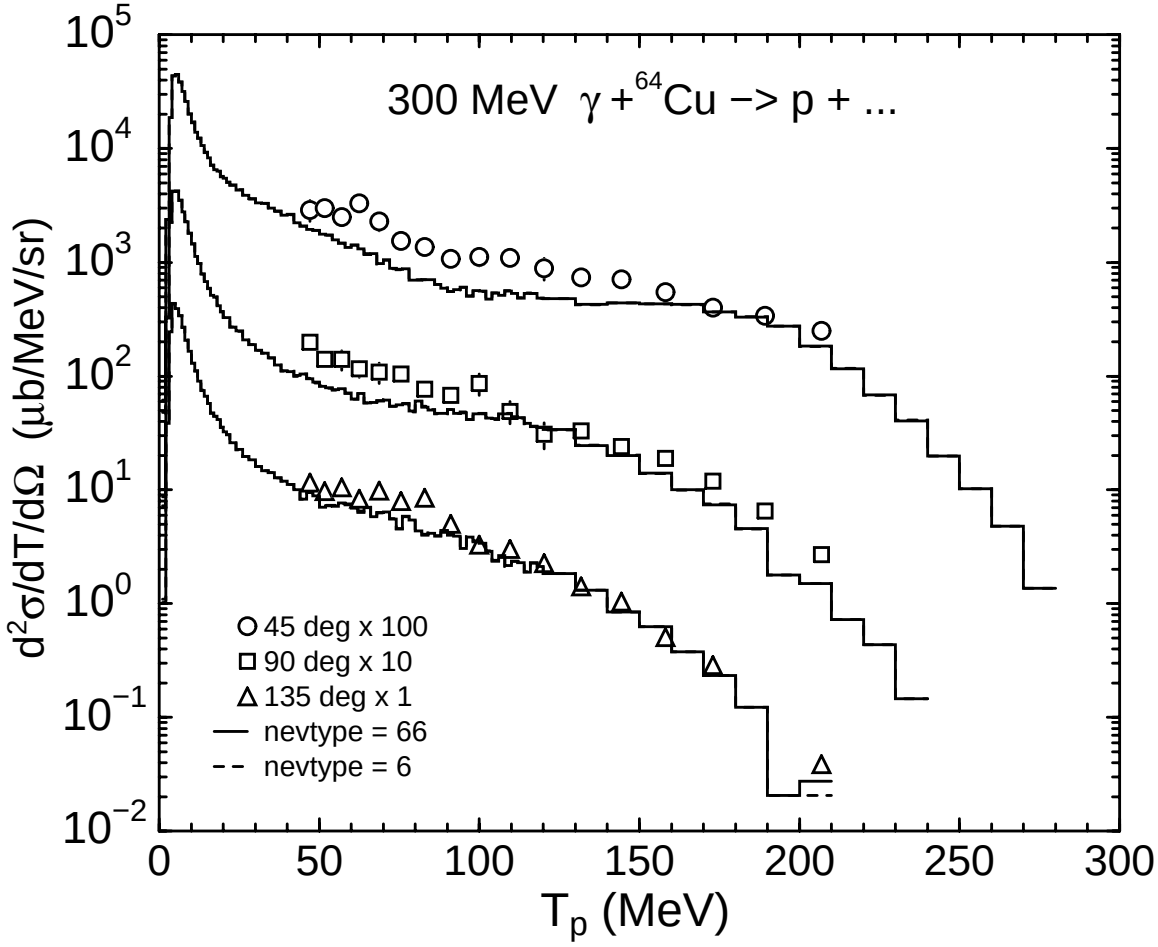

Figure 9: Proton spectra at 45°, 90°, and 135° from the reaction 300 MeV γ + Cu. Symbols are experimental data from [126] and histograms are CEM03.01 results obtained using the input shown in Example 9 of Appendix 1 (the corresponding output is shown in Example 9 of Appendix 2). The results shown in this figure are for one million simulated inelastic events (**limc=1000000**). The **nevtype=66** option requires 2 hr 48 min 28 sec of computing time on a SunBlade 100, 500 MHz computer, while the **nevtype=6** option requires only 2 hr 0 min 22 sec, providing almost the same results.

Example 10

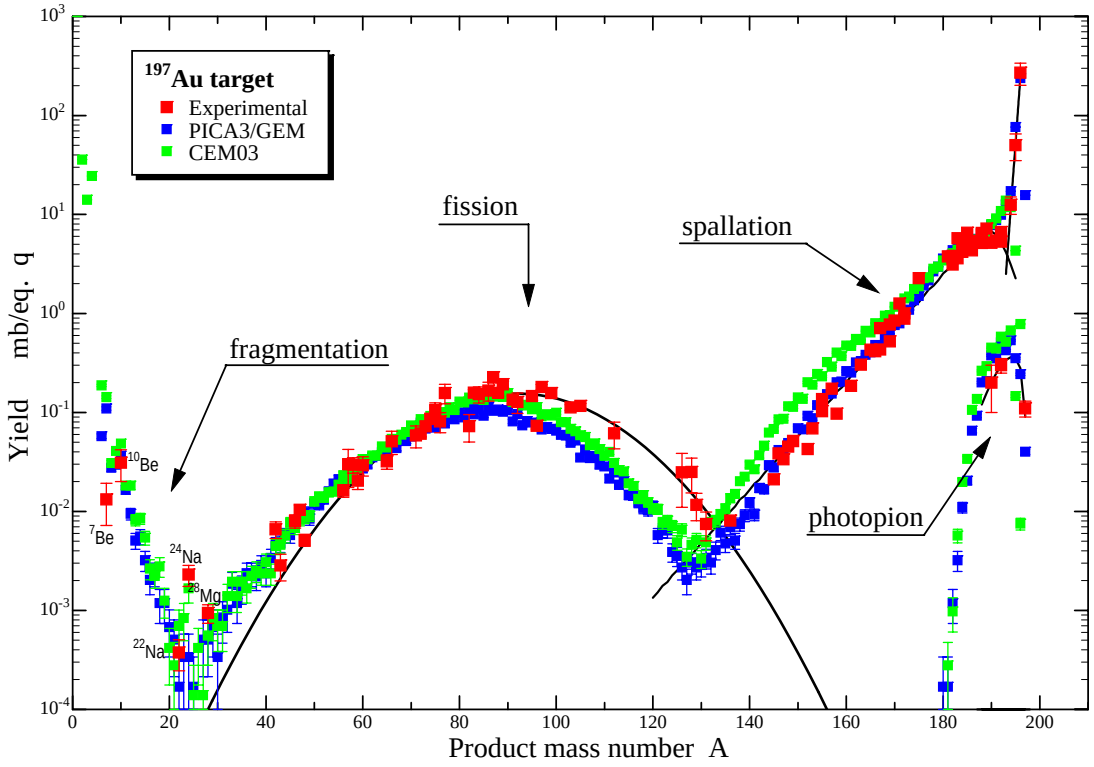

Figure 10: Comparison of CEM03.01 results (green symbols) obtained using the input shown in Example 10 of Appendix 1 with the option **nevtype=66** and one million simulated inelastic events (**limc=1000000**) (the corresponding output is shown in Example 10 of Appendix 2) for the isotopic yields of products produced by bremsstrahlung reactions on ^{197}Au with the end-point energy E_0 = 1 GeV (**t0mev=30.0**, **t0max=1000.0**) with experimental data (red symbols) from the review [127] and calculations by PICA3/GEM (blue symbols); the PICA3/GEM results are from several publications and are presented in Fig. 18 of Ref. [127] with the corresponding citations. The mass yields for the fission products shown by black curves represent approximations based on experimental data by Prof. Sakamoto's group. This figure was made for us by Dr. Hiroshi Matsumura by adding our results to Fig. 18 of the review [127].

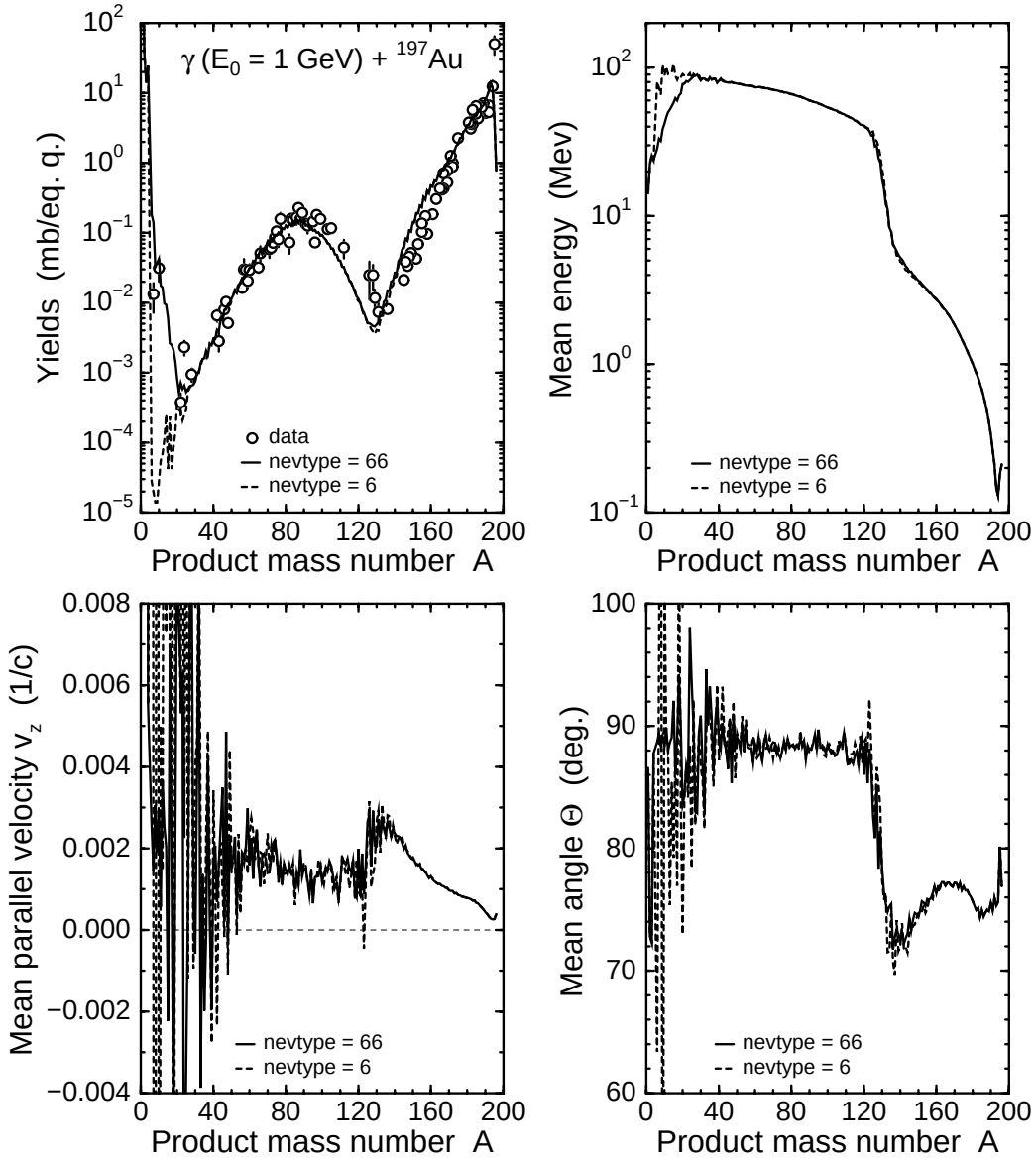

Figure 11: Results from CEM03.01 for the mass yield of all products, their mean laboratory kinetic energy, mean laboratory velocity v_z in the beam direction, and mean laboratory angle Θ as functions of the product mass A from interactions of 1 GeV bremsstrahlung gammas with Au. The input shown in Example 10 of Appendix 1 with the options **nevtype=66** and **nevtype=6** for ten million simulated inelastic events (**limc=10000000**) (the corresponding output is shown in Example 10 of Appendix 2) was used in these calculations. The **nevtype=66** option requires 45 hr 0 min 31 sec of computing time on a SunBlade 100, 500 MHz computer, while the **nevtype=6** option requires only 30 hr 11 min 58 sec, providing almost the same results for the spallation and fission products but underestimating the yields of light fragments by more than two orders of magnitude. The experimental cross sections shown for comparision by open circles are the same as in Fig. 10. The big fluctuations in the values of v_z and Θ for masses around $A = 20$ and 130 do not provide real physical information, as they are related to the limited statistics of our Monte-Carlo simulation caused by the very low yield of isotopes at the border between spallation and fission, and at that between fission and fragmentation. Our calculation provides only a few (or even one) isotopes of a given A in these mass regions, and mean values for such events do not have any significance.

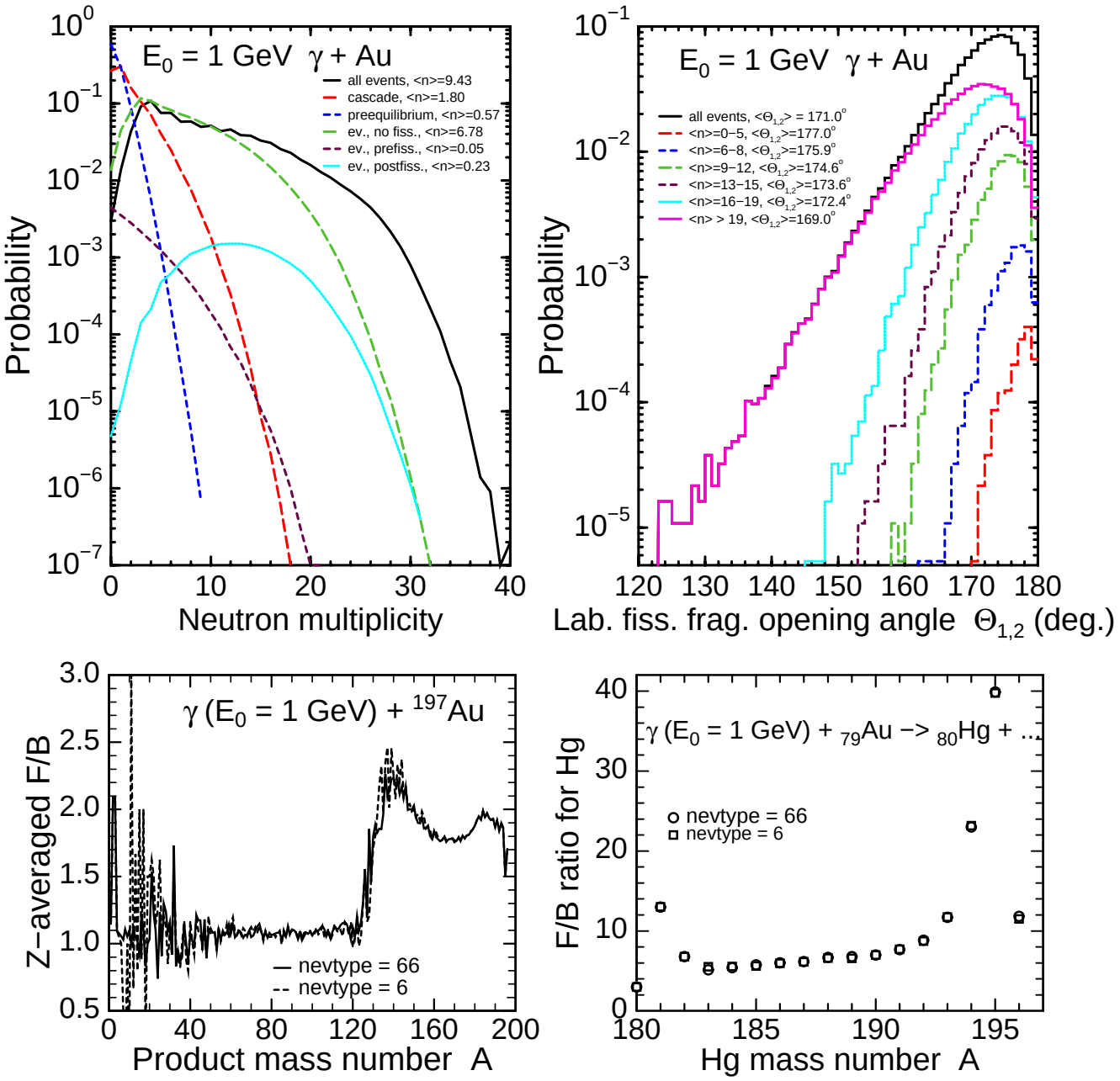

Figure 12: More CEM03.01 results for the same reaction, inputs, and outputs as shown in Fig. 11. **Upper left plot:** distributions of multiplicity of neutrons emitted during the INC, preequilibrium, evaporation from compound nuclei that do not fission, pre-fission evaporation from compound nuclei that will fission, evaporation from fission fragments, and for the sum of all reaction mechanisms, labeled as "all events". The mean values of neutron multiplicity, $< n >$, for all these reaction mechanisms, printed in the output at the end of the corresponding distribution tables, are listed in the legend. **Upper right plot:** distributions of laboratory angle between two fission fragments for events with mean neutron multiplicity from 0 to 5, 6 to 8, 9 to 12, 13 to 15, 16 to 19, more than 19, and for all events, respectively; the mean angle $< \Theta_{1,2} >$ for all these types of events are printed in the output and listed in the legend. **Lower left plot:** Z-averaged A-dependence of the F/B ratio of the forward product cross sections to the backward ones. **Lower right plot:** The F/B ratio of the Hg isotopes produced in the same reaction as a function of the mass number of the Hg nuclei. Results shown in both upper plots are for the **nevtype=66** option.

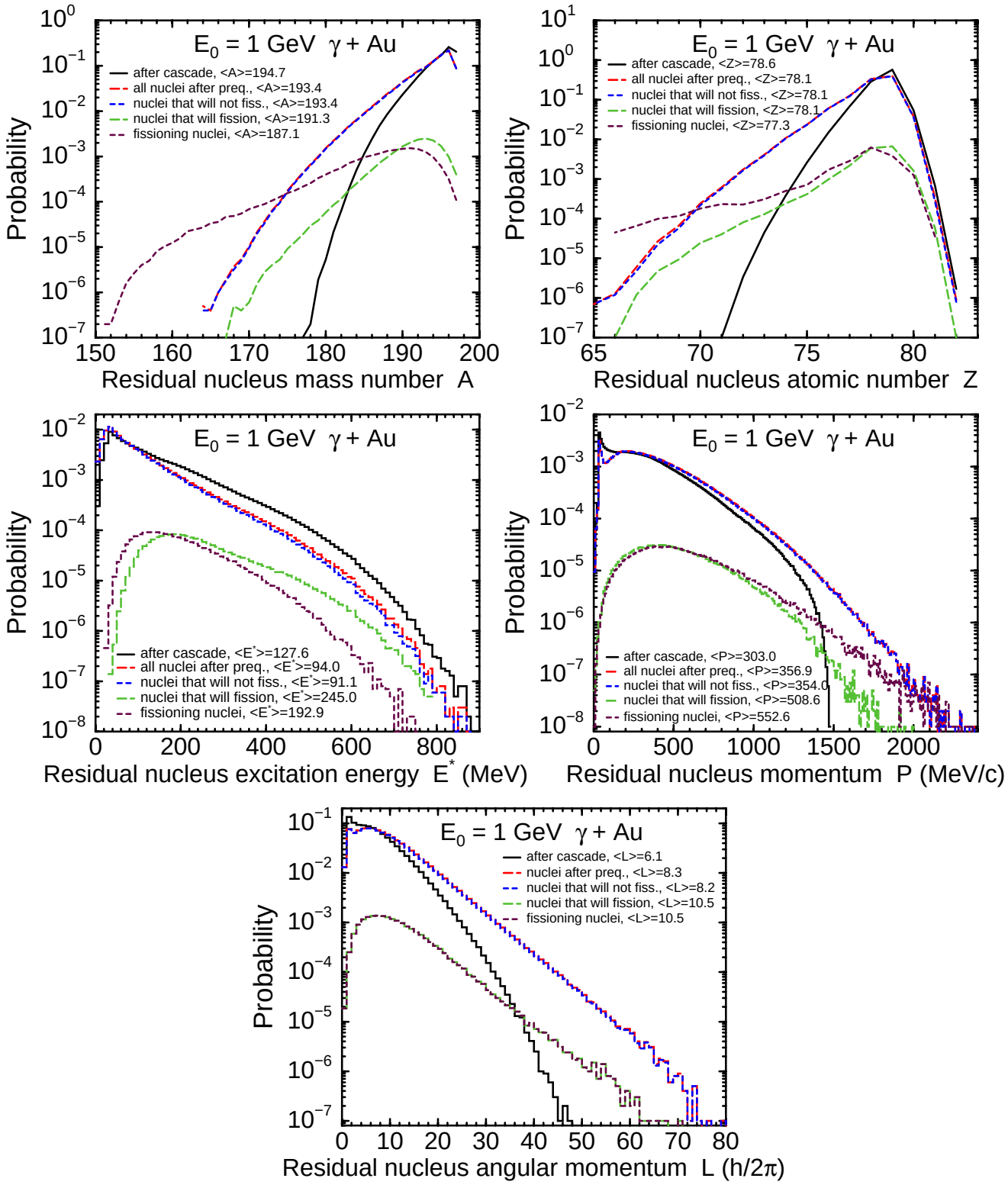

Figure 13: More CEM03.01 results for the same reaction, input, and output as shown in Fig. 11 for the option **nevtype=66**: Mass A and charge Z numbers, excitation energy E^*, linear P and angular L momentum distributions of residual nuclei formed after the INC and preequilibrium stages of reactions, for compound nuclei that will not fission, for compound nuclei that will fission after evaporation of several pre-fission particles, and for fissioning nuclei just before their fission. The mean values of all quantities, for the corresponding type of events, are printed in the output and listed in the legends of the subplots.

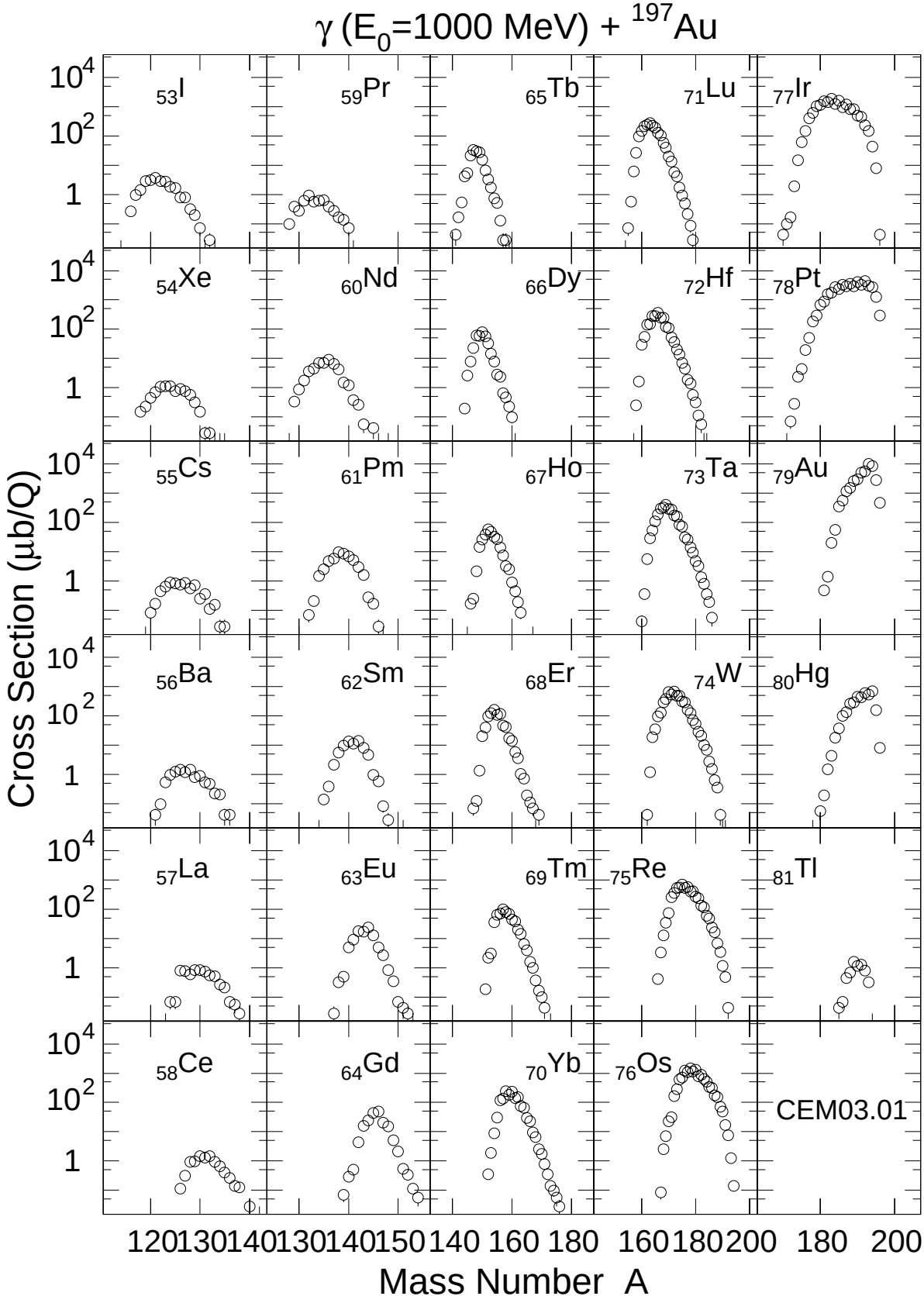

Figure 14: More CEM03.01 results for the same reaction, input, and output as shown in Fig. 11 for the option **nevtype=66**: Predicted cross sections of the spallation products from Iodine to Thallium.

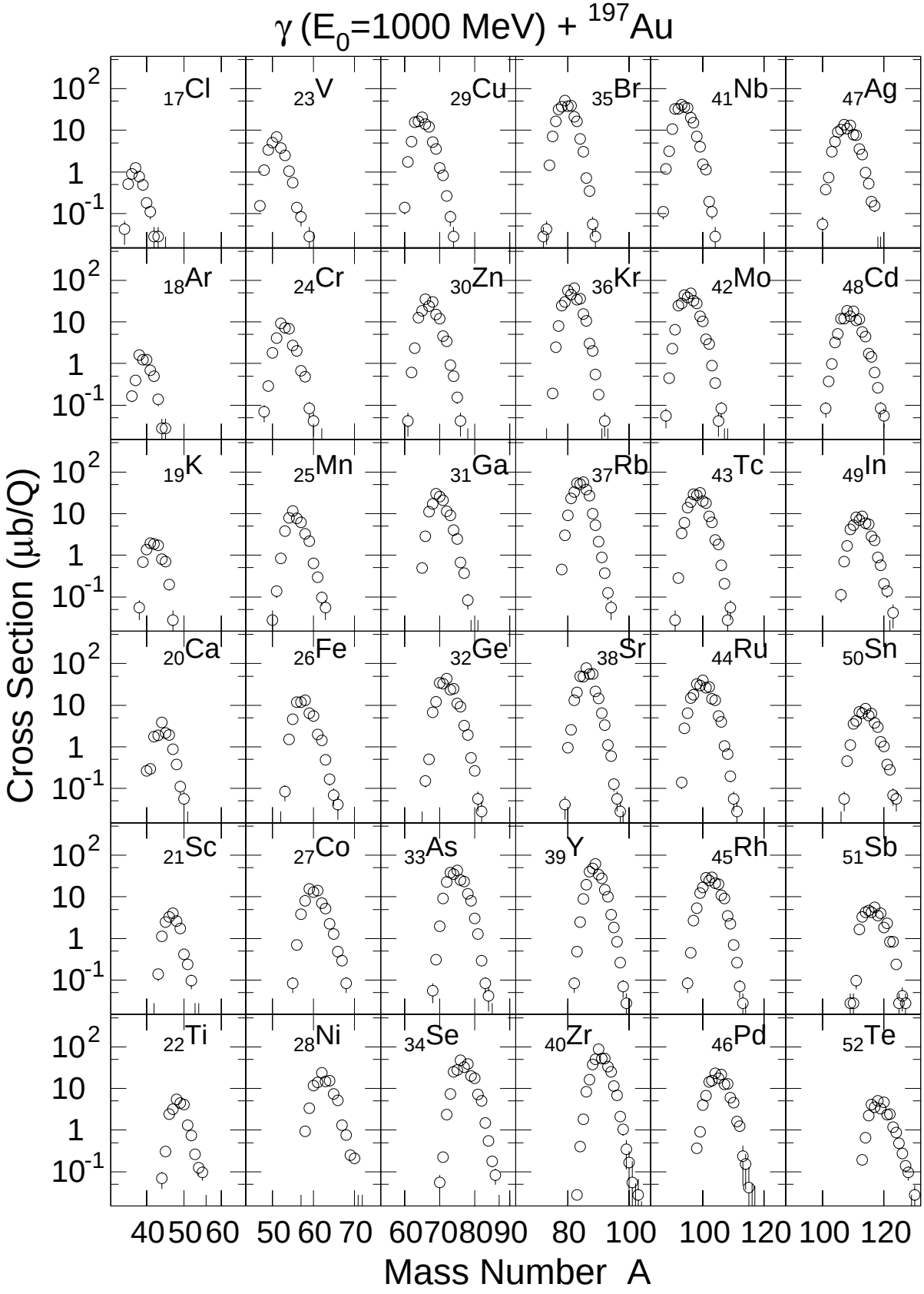

Figure 15: The same as Fig. 14, but for fission and fragmentation products from Chlorine to Tellurium.

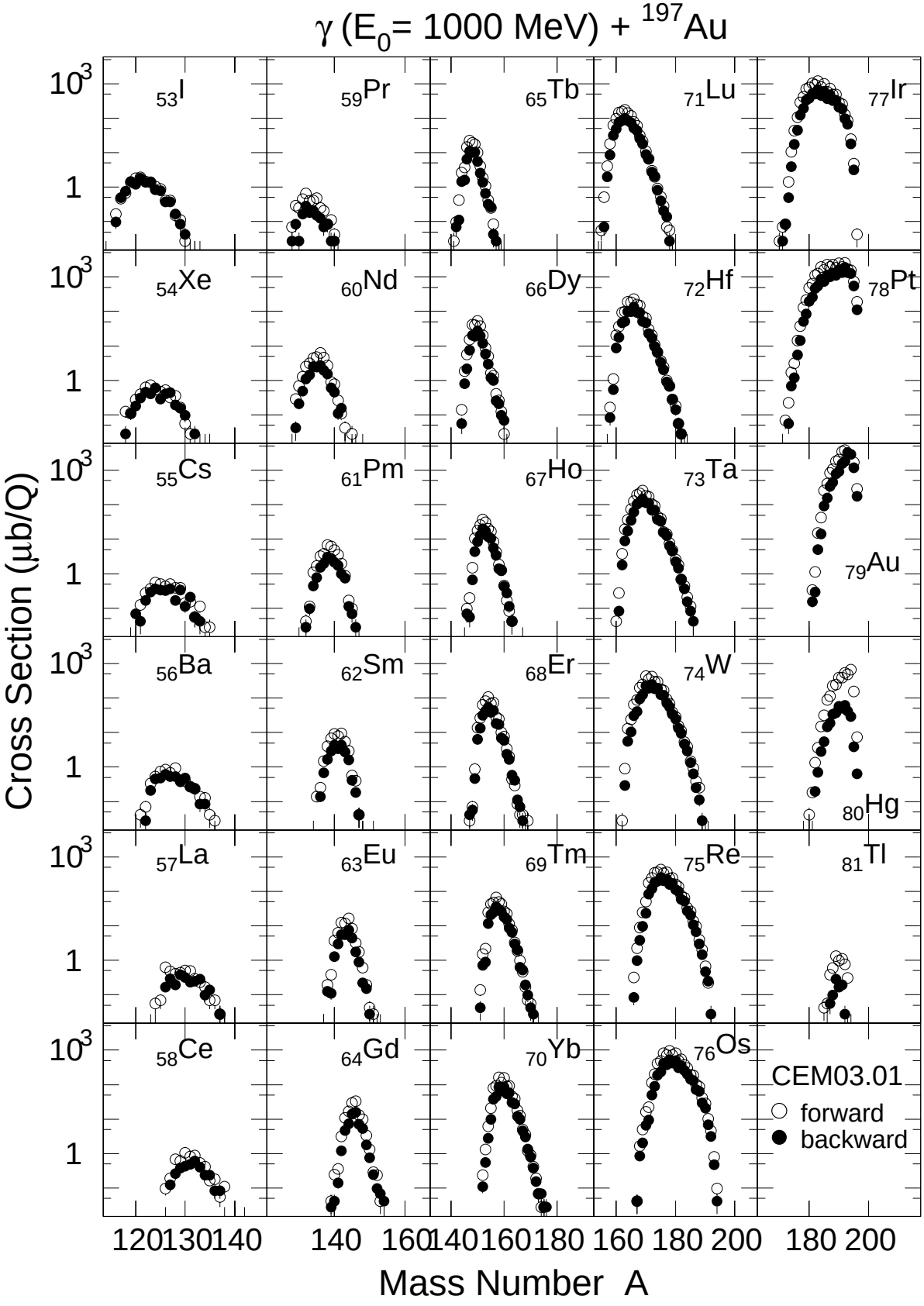

Figure 16: The same as Fig. 14, but separately for forward and backward products.

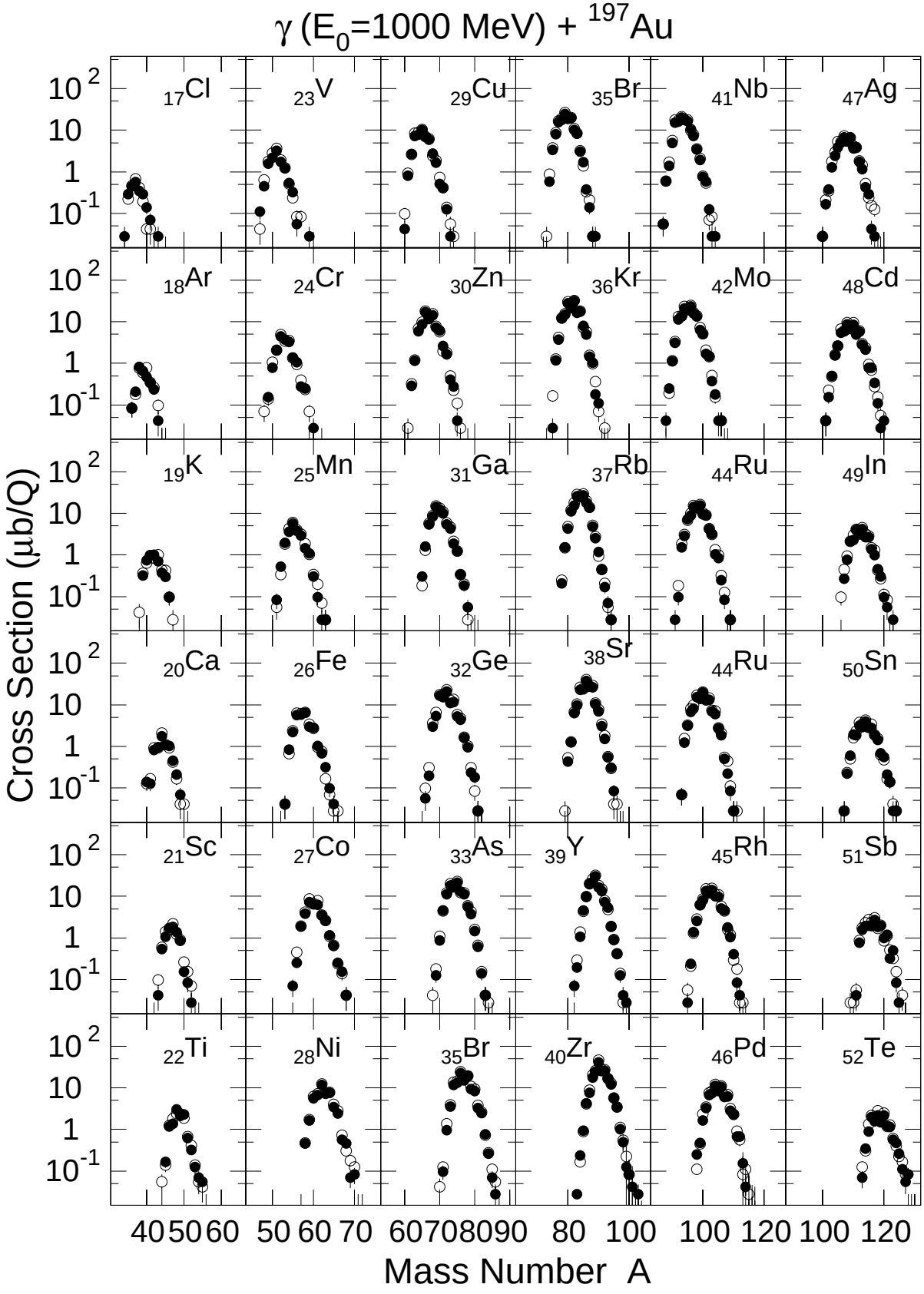

Figure 17: The same as Fig. 15, but separately for forward and backward products.

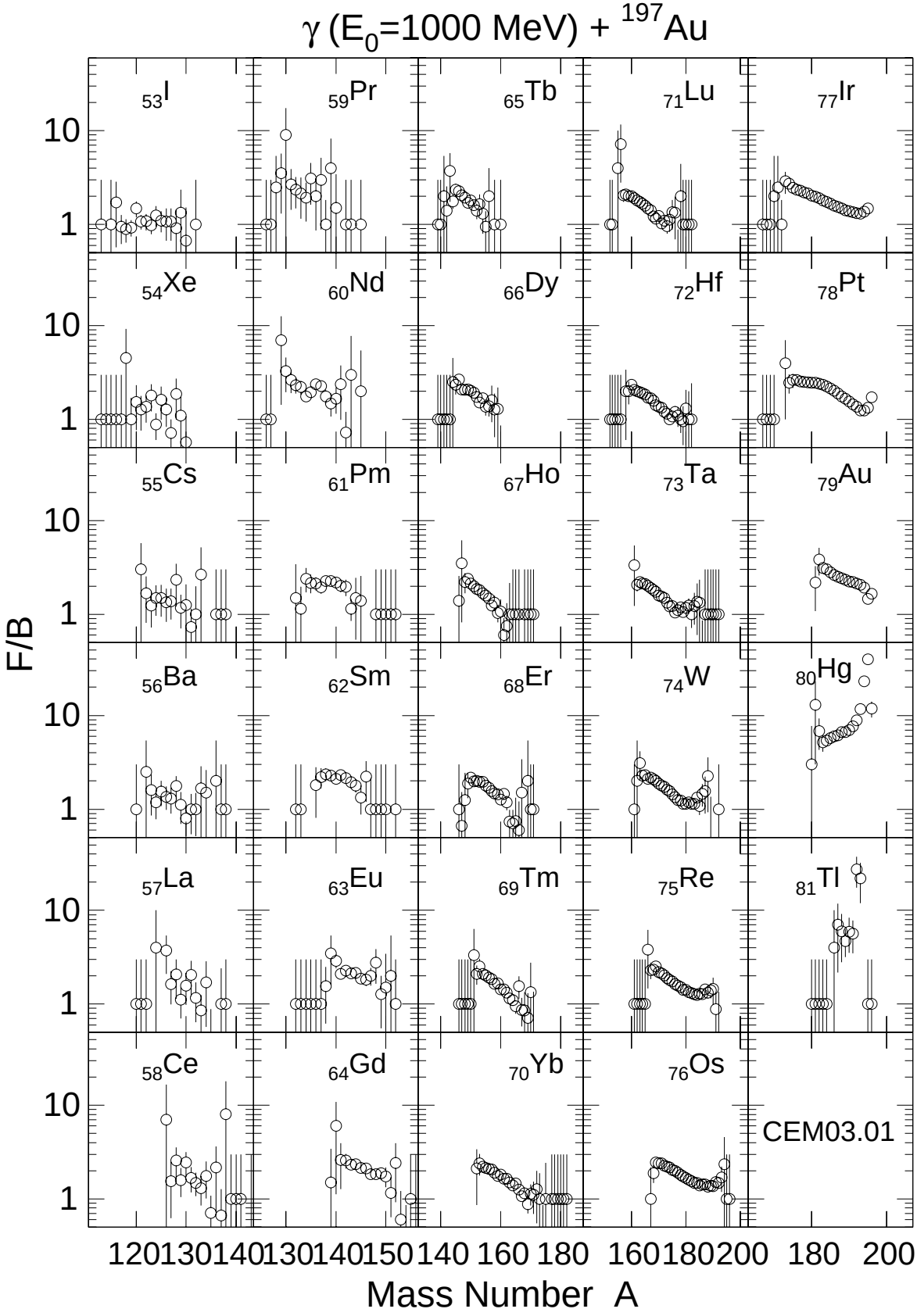

Figure 18: The F/B ratios for spallation products calculated from the cross sections shown in Fig. 16.

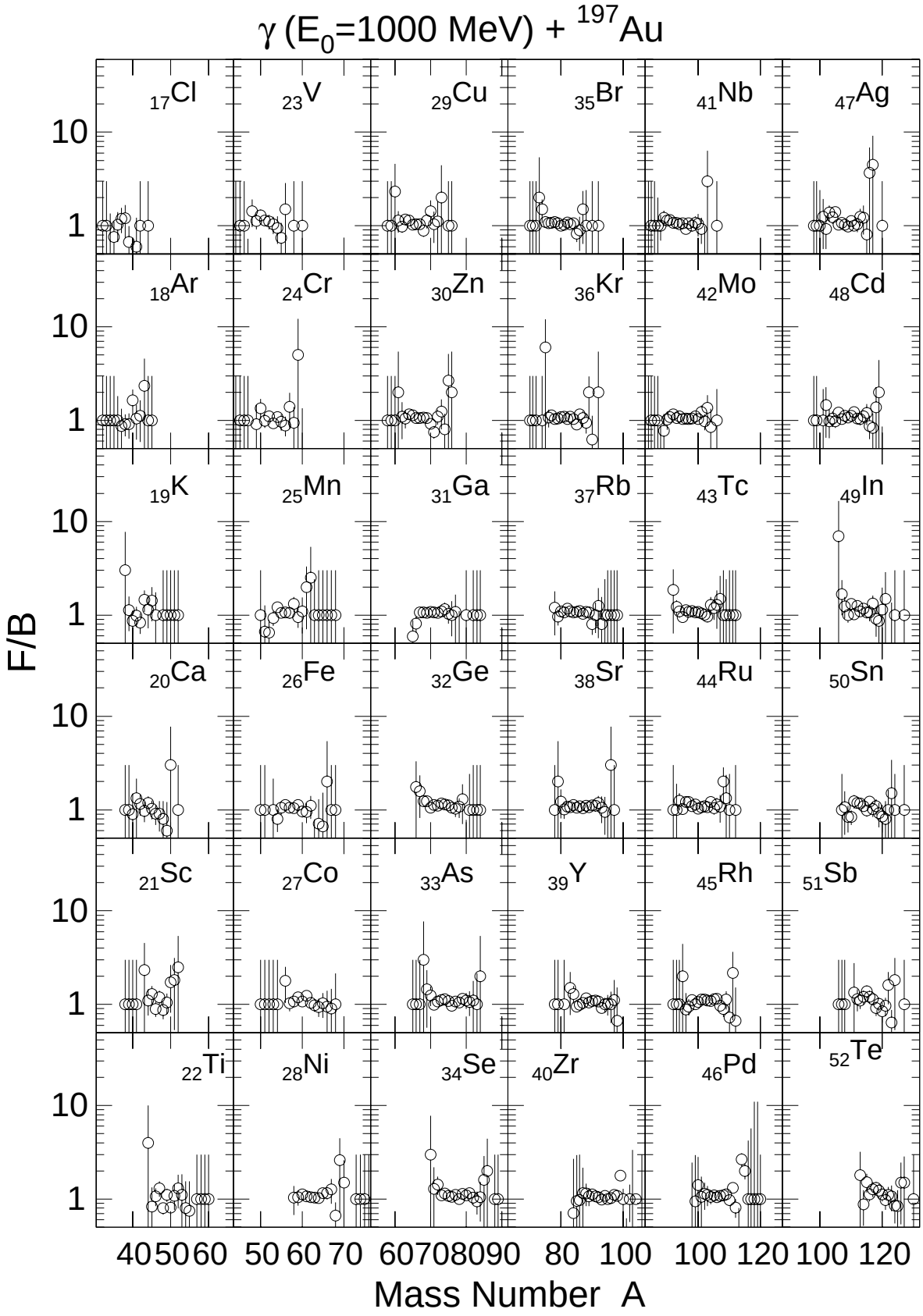

Figure 19: The F/B ratios for fission and fragmentation products calculated from the cross sections shown in Fig. 17.

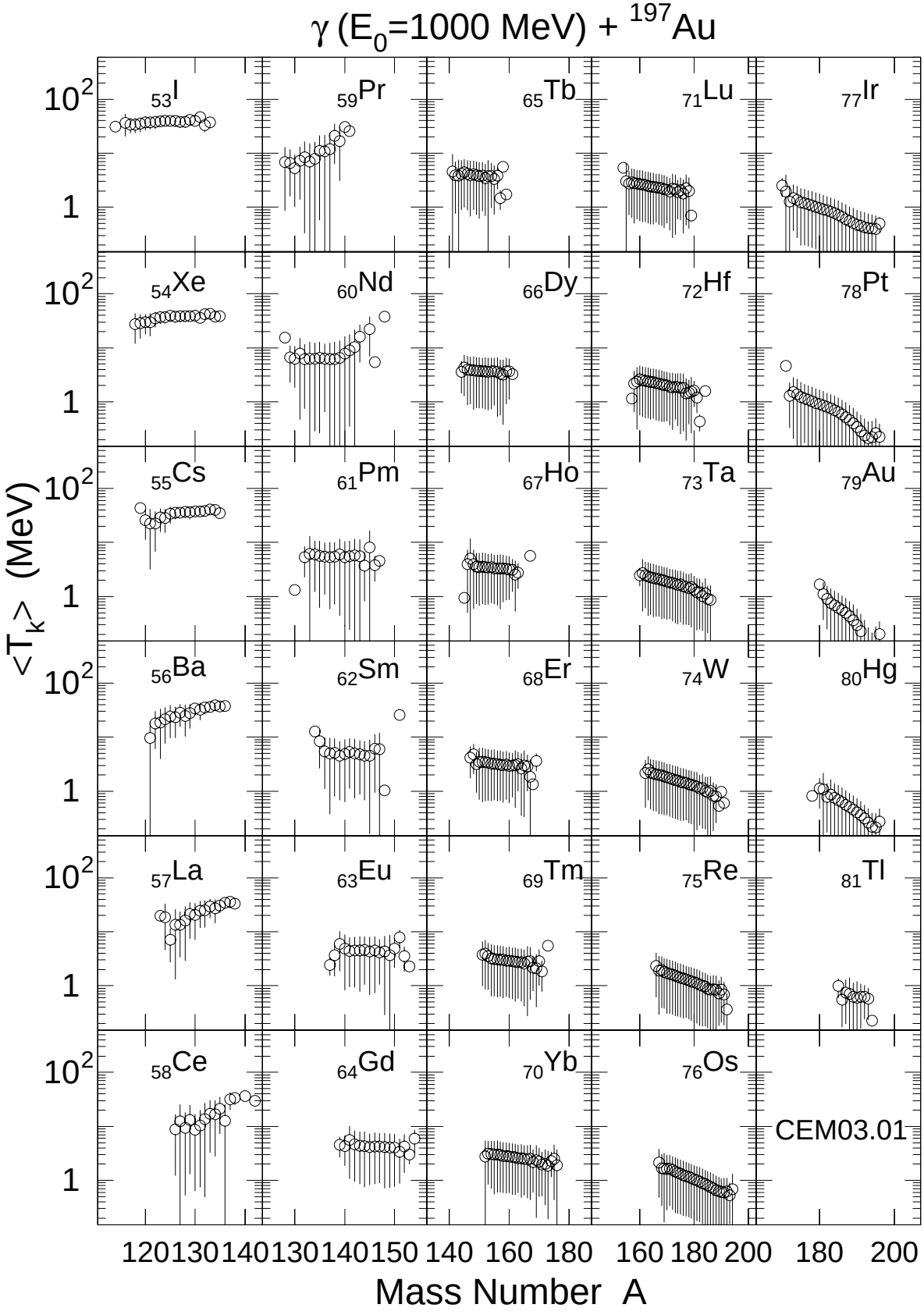

Figure 20: Mean laboratory kinetic energy of all spallation products from Iodine to Thallium.

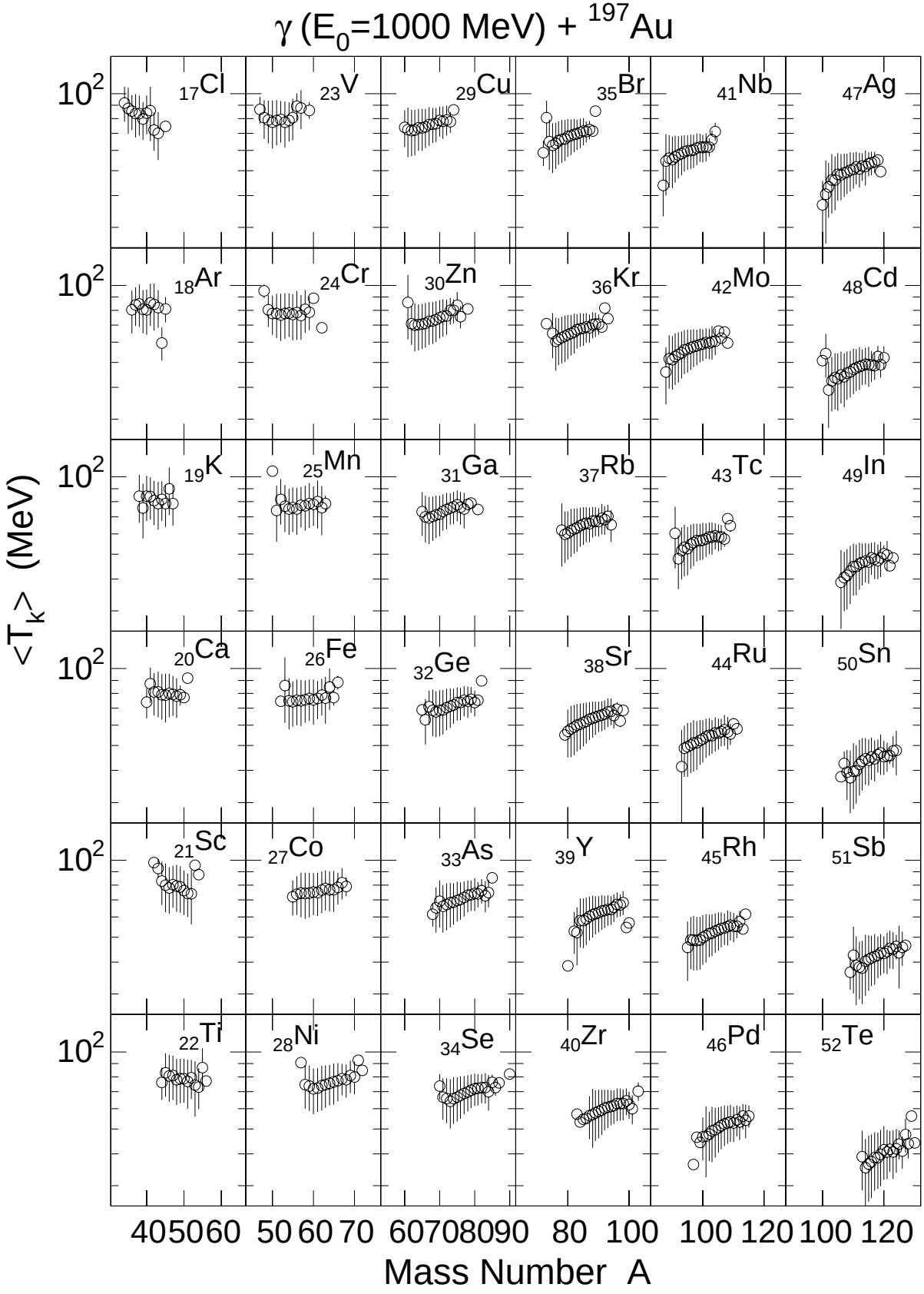

Figure 21: Mean laboratory kinetic energy of all fission and fragmentation products from Chlorine to Tellurium.