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Title: Correlated Gamma and Neutron Emission in MCNP6

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Correlated Gamma and Neutron Emission in The MCNP Code

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¹XCP3: Monte Carlo Codes

Introduction

1. In the MCNP production of particles emitted from neutron reactions are sampled independently from the selection of the neutron reaction itself [1]
 - This prevents the conservation of energy for individual reactions
 - E.g., a 14 MeV particle can conceivably produce two 12 MeV particles in a single reaction
 - On net, over many particle interactions/reactions, the correct amount of energy is emitted
- For certain classes of problems this can result in simulation results which conflict with reality
 - E.g., Time coincident detector analysis, nuclear safeguards & nonproliferation
- Work is currently ongoing to implement and improve upon the existing capability
 - Goal of this presentation is to demonstrate preliminary results and discuss future improvements

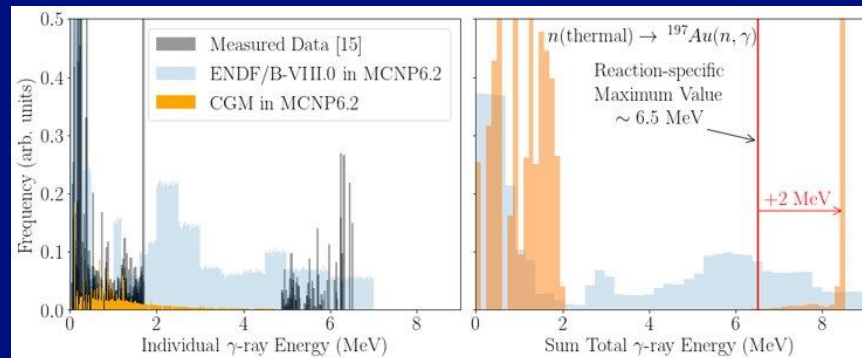
Background

- A method currently exists in the MCNP code to perform simulations with correlated emissions using the CGM code [2]
 - First introduced in MCNPX V2.7.0
 - Method has not been maintained in recent versions [3]
- A related code CGMF included in the MCNP6.2 release handles correlated decay of fission products [4]
 - Models decay via secondary neutron and γ emission
 - CGMF has been validated and shows impressive accuracy [5]

Background

- Existing Implementation of CGM is incomplete
 - The MCNP code doesn't report accurate Q-value to CGM
 - Emitted particle energies are binned instead of being reported exactly resulting in an unnatural energy spectrum
- A complete coupling of CGM with the MCNP code would allow for predictive modeling of neutron-photon interaction physics
 - Useful for nuclear data experiments such as the ongoing measurement campaign at LANCSE

Comparison of measured data and MCNP6.2 photon production options



Background

- CGM uses a Hauser-Feshbach [6] model to de-excite a nucleus after a neutron collision
 - This requires nuclear level data from the RIPL3 and ENSDF databases
 - Decays modeled this way conserve energy, spin, and parity providing a higher fidelity of nuclear reaction handling
 - In addition, angle and time information of the emissions can be included to allow for validation against gamma decay measurements
- Main drawback of this method is the computational cost incurred
 - Runtime costs incurred on the order of $\sim 3500\times$
 - Reduction of this cost are currently being investigated through refactoring and modernization

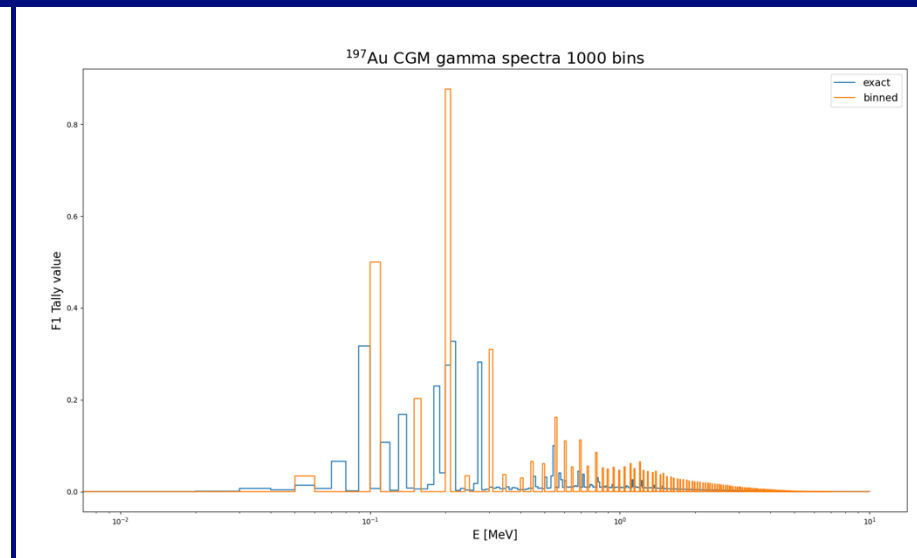
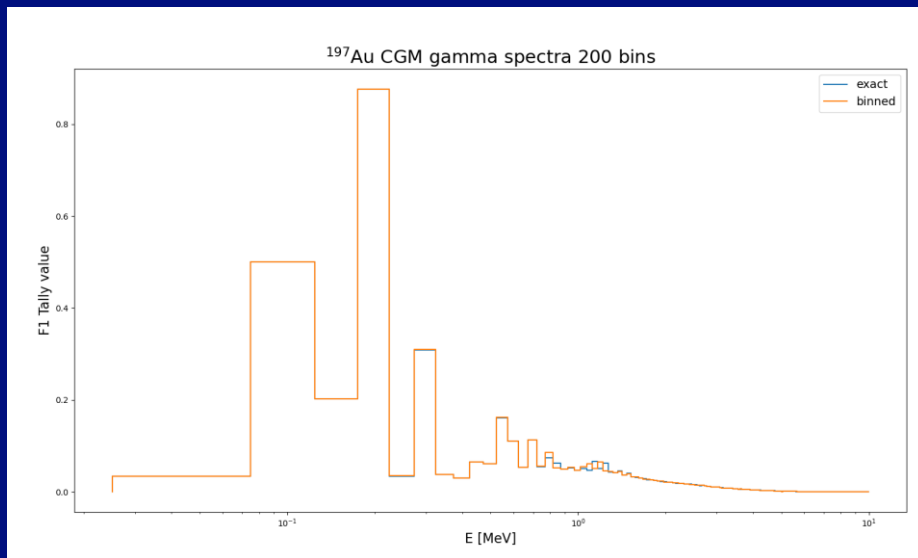
Goals

1. Update existing implementation of CGM to the standard of CGMF
 - a) Modernize Fortran interface and fix existing bugs
 - b) Remove energy binning from CGM
 - CGM bins energy of emitted particles rather than reporting exact energy
 - c) Report angle and time information to the MCNP code
2. V&V of CGM results
 - a) The DICEBOX code and ongoing experimental campaigns at LANCSE provide excellent candidates for this
3. Investigate potential for improved code performance through traditional methods and custom models
4. Use CGM to improve fidelity of how the MCNP code handles nuclear reactions more generally

Results

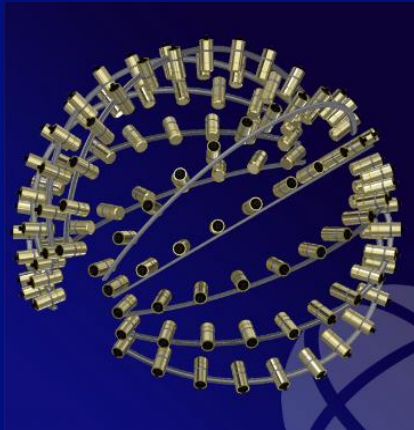
1. First Goal is nearly complete

- CGM interface has been updated and is now comparable to CGMF
- CGM now reports exact energies instead of the 50keV bins used previously

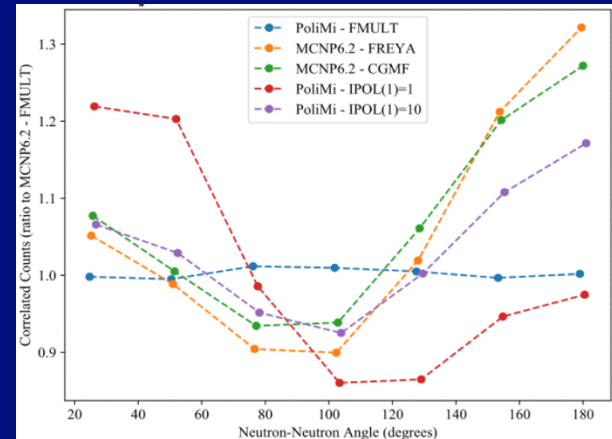


User Impact

1. This capability enables time-coincident detector modeling and improved simulation of gamma and neutron spectra measurements allowing for:
 - Simulation of characteristic signals for a wide variety of nuclides
 - Improved characterization of novel SMR's and micro-reactors for space applications



A rendering of the CoGNAC CLYC detector array [7]



Angle correlated neutron emission from fission products

Future work

1. Verification will be done using DICEBOX

- DICEBOX uses various photon strength function and level density functions to sample the widths of different level transitions.
- Both DICEBOX and CGM have the option to use the Phenomenological Generalized Lorentzian (GLO) model [5] for E1 transitions allowing for a fair comparison between the codes
- Similarly both codes use Brinx-Axel for M1 transitions
- Additional model must be added to DICEBOX to match E2 transition

2. Validation will be performed for a variety of isotopes

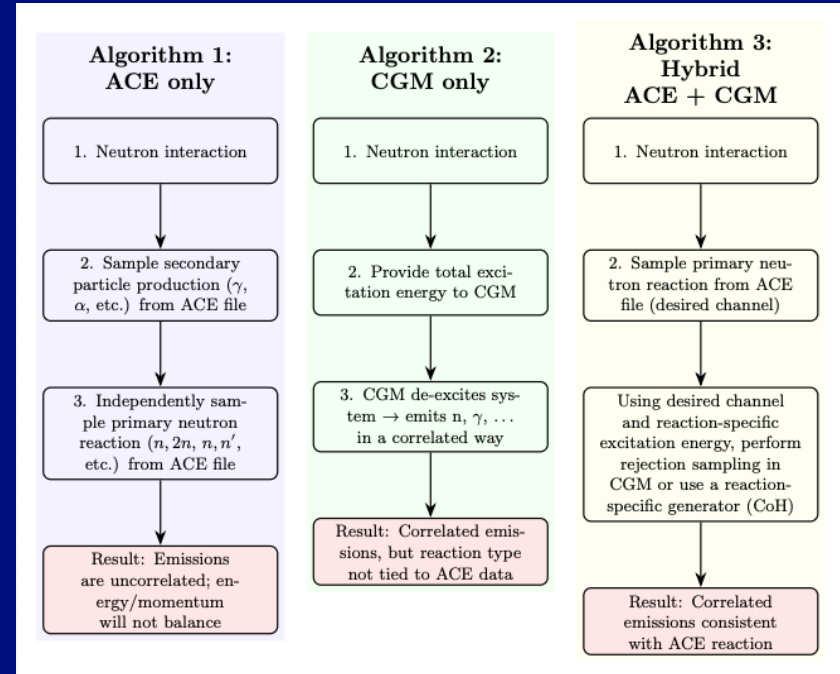
- Isotopes with $Z > 9$ will be the focus with lighter isotopes explored if valid

3. Modify CGM to include de-excitation via emission of light charged particles.

4. Increase efficiency of CGM via traditional and ML methods

Open Question

- How to maintain consistency with reaction types when de-excitation mode conflicts with the stated reaction type?
- If a (n,γ) reaction happens and the residual decays via a neutron wasn't the reaction actually (n,n') ?
- Similarly with other decay modes planned
- Currently the MCNP code only uses CGM with a small set of reactions
 - Handling more reactions (E.g., (n,p) , (n,α)) consistently would allow for greater applicability of the method.



Acknowledgements

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