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| Title:        | MCNP6 calculations of secondary particle production in a thick Line C exit window for proton radiography (U) |
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| Author(s):    | John D. Zumbro<br>XCP-7, Transport Applications<br>Los Alamos National Laboratory                            |
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research note

Computation Physics Division Transport Applications

Group XCP-7, MS F663 Los Alamos, New Mexico 87545

Fax: 505-665-2879

To/MS: Distribution From/MS: John D. Zumbro / XCP-7, MS F663 Phone/Email: 5-1009 / zumbro@lanl.gov Thru/MS: Avneet Sood / XCP-7, MS F663 Phone/Email: 7-2119 / sooda@lanl.gov Symbol: XCP-7:11-011 [LA-UR-11-04562] Date: 2 August 2011

# SUBJECT: MCNP6 calculations of secondary particle production in a thick Line C exit window for proton radiography (U)

#### Abstract

In a recent JOWOG 32P talk (2011 May 20) results were presented for MCNP6 calculations of the production of secondary particles in an exit window used for dynamic proton radiography experiments. In this note the quantitative numbers from those calculations are presented along with a description of the model.

### I. Introduction with a bit of history

The Clinton P. Anderson Meson Physics Facility at Los Alamos (LAMPF) [the facility is now call LANSCE, Los Alamos Neutron Scattering CEnter] was built over four decades ago to, among other things, make beams of secondary particle (specifically beams of mesons, i.e. pions and muons). This was accomplished by running the high-intensity 800-MeV proton beam from the accelerator through 'pion' production targets. Beams at forward angles (at  $35^{\circ}$  for EPICS [Energetic PIon Channel and Spectrometer], at  $45^{\circ}$  for LEP [Low Energy Pion], at  $20^{\circ}$  for P<sup>3</sup> [Pion Particle Physics] and at  $60^{\circ}$  for SMC [Stopped Muon Channel]; not all that forward) were directed to secondary target area for experiments. The first two beam channels (EPICS and LEP) viewed a common 3-cm thick graphite target and the latter two channels (P<sup>3</sup> and SMC) were designed to view a 6-cm thick graphite target.

In proton radiography the image is generated by focusing particle trajectories from an object onto an image plane with a magnetic lens at forward angles (i.e. in the range from 0 degrees to  $\sim$ 1 degree). The detector at the image plane, while not necessarily, has generally been an ionizing radiation-to-light converter (i.e. a fast scintillator) and a camera system is arranged to take optical pictures of this scintillator.

Because the transport of the protons through the magnetic lens is in vacuum there is a window immediately upstream of the scintillator. In the case of dynamic experiments (i.e. experiments involving the detonation of high explosives) this typical window might be 1/8" of glass followed by 1/8" of aluminum. The bottom line is that this window (1.27 cm of material) could be a particle production target at 0 degrees, and in this note the results of MCNP6 calculations looking at the production on secondary particles are presented.

MCNP6 is a developmental version<sup>1</sup> of MCNP which, in addition to neutrons, photons, and electrons, can transport twenty-four (24) additional particles. Particle production on nuclear targets is currently accomplished using the CEM (Cascade Exciton Model).<sup>2</sup> While trying to do transport runs (for protons, muons, pions, deuterons, tritons, <sup>3</sup>He, and alphas) through the whole Line C proton radiography system (diffuser to image plane) it was noticed that the object to diffuser times for all particles, regardless of particle energy, was highly correlated. This indicated that the protons were producing secondary particles near the image plane, hence the study reported here.

### II.The MCNP6 Model # 1

The MCNP6 model, for which results will be presented, was quite simple and a sample input is presented in Appendix I. Simply a line beam of mono-energetic protons along the z-axis (starting at -100 cm) was incident on a window as described above (1/8" of

glass followed by 1/8'' of aluminum). The window extended from -0.3175-cm to 0.0-cm (SiO<sub>2</sub> with density 2.65 grams per cc) and from 0.0-cm to +0.3175-cm (Al with density 2.70 grams per cc); this was followed by a drift from 0.3175 cm to 100 cm in void (i.e. vacuum); from 100 cm to 100.2 cm there was LSO (Lu<sub>2</sub>SiO<sub>5</sub> with density 7.36 gram per cc).

Results for various particles were tallied in fmesh (track length) tallies that were from -7 cm to +7 cm in both dimensions transverse to the z-axis and from 100.0 cm to 100.2 cm along the z-axis. There were separate fmesh tallies for protons,  $\pi^+$ ,  $\pi^-$  (charged pions), deuterons, tritons, helions (<sup>3</sup>He) and alphas. There is the possibility of other particles or recoiling nuclei but in this study we present results for only these particles.

In addition to the results for the fmesh tallies, results are also presented for a different set of fmesh tallies where an energy dependent multiplier is used for the various particle tallies. In this case the multiplier for a given particle is the dE/dx in LSO at a given energy divided by the value of dE/dx in LSO for a 1-GeV proton. It is thought that this should account for differences in a given particles ionization energy in the LSO scintillator the tallies are overlaid on. The MCNP input for these multipliers can be found in the sample input deck in Appendix I.

### III. Results for Model #1

| Energy | $\pi^+$ |        | π -    |        | d      |        | t      |        | <sup>3</sup> He |        | α      |        |
|--------|---------|--------|--------|--------|--------|--------|--------|--------|-----------------|--------|--------|--------|
| (MeV)  |         | Error  |        | Error  |        | Error  |        | Error  |                 | Error  |        | Error  |
| 800    | 1.73E-  | 1.85E- | 1.34E- | 1.63E- | 3.76E- | 2.73E- | 8.56E- | 1.30E- | 2.11E-          | 6.46E- | 2.88E- | 7.56E- |
|        | 03      | 05     | 03     | 05     | 03     | 05     | 04     | 05     | 04              | 06     | 04     | 06     |
| 750    | 1.55E-  | 1.75E- | 1.16E- | 1.52E- | 3.46E- | 2.62E- | 7.74E- | 1.24E- | 1.90E-          | 6.13E- | 2.58E- | 8.35E- |
| , 00   | 03      | 05     | 03     | 05     | 03     | 05     | 04     | 05     | 04              | 06     | 04     | 06     |
| 700    | 1.35E-  | 1.63E- | 9.82E- | 1.40E- | 3.17E- | 2.51E- | 6.93E- | 1.17E- | 1.69E-          | 5.79E- | 2.28E- | 6.73E- |
|        | 03      | 05     | 04     | 05     | 03     | 05     | 04     | 05     | 04              | 06     | 04     | 06     |
| 650    | 1.13E-  | 1.50E- | 8.06E- | 1.26E- | 2.87E- | 2.38E- | 6.12E- | 1.10E- | 1.48E-          | 5.40E- | 1.99E- | 6.3E-  |
|        | 03      | 05     | 04     | 05     | 03     | 05     | 04     | 05     | 04              | 06     | 04     | 06     |
| 600    | 8.96E-  | 1.33E- | 6.47E- | 1.13E- | 2.56E- | 2.30E- | 5.33E- | 1.00E- | 1.29E-          | 5.10E- | 1.71E- | 5.8E-  |
| 000    | 04      | 05     | 04     | 05     | 03     | 05     | 04     | 05     | 04              | 06     | 04     | 06     |
| 550    | 6.71E-  | 1.15E- | 4.91E- | 9.88E- | 2.28E- | 2.10E- | 4.64E- | 9.59E- | 1.10E-          | 4.68E- | 1.45E- | 5.4E-  |
|        | 04      | 05     | 04     | 06     | 03     | 05     | 04     | 06     | 04              | 06     | 04     | 06     |
| 500    | 4.62E-  | 9.58E- | 3.49E- | 8.33E- | 1.99E- | 1.99E- | 3.94E- | 8.85E- | 9.31E-          | 4.30E- | 1.21E- | 4.91E- |
| 200    | 04      | 06     | 04     | 06     | 03     | 05     | 04     | 06     | 05              | 06     | 04     | 06     |

The results of the MCNP6 fmesh tallies are given in Table I as a ration to the proton fmesh tally. These results are also plotted in Figure 1a. Table II gives (plotted in Figure 1b) the results when an energy dependent multiplier (that is different for each particle) is applied. The protons are also multiplied by an energy dependent multiplier.

Table I – The values of the fmesh for the indicated particle as a ratio to the value for protons is given.

| Energy | $\pi^+$ |        | $\pi^{-}$ |        | d      |        | t      |        | <sup>3</sup> He |        | α      |        |
|--------|---------|--------|-----------|--------|--------|--------|--------|--------|-----------------|--------|--------|--------|
| (MeV)  |         | Error  |           | Error  |        | Error  |        | Error  |                 | Error  |        | Error  |
| 800    | 2.54E-  | 2.11E- | 2.03E-    | 1.89E- | 4.55E- | 8.93E- | 1.57E- | 5.24E- | 1.28E-          | 4.74E- | 3.15E- | 7.43E- |
|        | 03      | 05     | 03        | 05     | 02     | 05     | 02     | 05     | 02              | 05     | 02     | 05     |
| 750    | 2.27E-  | 1.97E- | 1.74E-    | 1.73E- | 4.11E- | 8.40E- | 1.39E- | 4.89E- | 1.14E-          | 4.42E- | 2.78E- | 1.08E- |
|        | 03      | 05     | 03        | 05     | 02     | 05     | 02     | 05     | 02              | 05     | 02     | 04     |
| 700    | 1.97E-  | 1.82E- | 1.45E-    | 1.56E- | 3.67E- | 7.84E- | 1.22E- | 4.53E- | 9.95E-          | 4.09E- | 2.42E- | 6.38E- |
|        | 03      | 05     | 03        | 05     | 02     | 05     | 02     | 05     | 03              | 05     | 02     | 05     |
| 650    | 1.71E-  | 1.70E- | 1.21E-    | 1.43E- | 3.33E- | 7.48E- | 1.09E- | 4.3E-  | 8.82E-          | 3.85E- | 2.14E- | 6.00E- |
|        | 03      | 05     | 03        | 05     | 02     | 05     | 02     | 05     | 03              | 05     | 02     | 05     |
| 600    | 1.38E-  | 1.51E- | 9.70E-    | 1.26E- | 2.93E- | 6.9E-  | 9.34E- | 3.9E-  | 7.55E-          | 3.5E-  | 1.82E- | 5.5E-  |
|        | 03      | 05     | 04        | 05     | 02     | 05     | 03     | 05     | 03              | 05     | 02     | 05     |
| 550    | 1.04E-  | 1.30E- | 7.35E-    | 1.09E- | 2.54E- | 6.4E-  | 7.96E- | 3.6E-  | 6.35E-          | 3.20E- | 1.52E- | 4.9E-  |
|        | 03      | 05     | 04        | 05     | 02     | 05     | 03     | 05     | 03              | 05     | 02     | 05     |
| 500    | 7.30E-  | 1.07E- | 5.21E-    | 9.02E- | 2.18E- | 5.83E- | 6.61E- | 3.21E- | 5.26E-          | 2.86E- | 1.25E- | 4.41E- |
| - • •  | 04      | 05     | 04        | 06     | 02     | 05     | 03     | 05     | 03              | 05     | 02     | 05     |

Table II – The values of the fmesh for the indicated particle as a ratio to the value for protons is given. This is for the case where each tally has an energy dependent multiplier that is dE/dx over dE/dx of a 1-GeV proton. Note that these tally multipliers are different for each particle type.

One sees by comparing Figures 1 and 2 that there is other an order of magnitude increase in this signal for the case of the energy dependent multiplier. The ratios of the sums are given in Table III, and these figures are those that were presented at the recent JOWOG32P.



**Figure 1a** (left) – Ratio of the raw produced particle count (track length) to the proton count (track length) in an fmesh tally that overlays the LSO "detector". This "detector" is one pixel that is  $14\text{-cm} \times 14\text{-cm} \times 0.2\text{-mm}$  thick in beam direction located at 100 cm from the center of the window (Mode # 1). The particle type is indicated in the legend and sum is the sum of all particles excluding the protons. **Figure 1b** (right) is the same as 1a but the signal (track length) is multiplied by an energy dependent term. This term is the particles dE/dx as a function of energy divided by dE/dx for 1-GeV (1000-MeV) protons. The particle type is indicated in the legend and sum is the sum of all particles excluding the protons.

| Energy | Sum w   | vithout | Sum with | multiplier | Ratio of sum with to |       |  |
|--------|---------|---------|----------|------------|----------------------|-------|--|
|        | mult    | iplier  |          |            | sum without          |       |  |
| (MeV)  |         | Error   |          | Error      |                      | Error |  |
| 800    | 0.00818 | 0.00004 | 0.11013  | 0.00014    | 13.46                | 0.07  |  |
| 750    | 0.00740 | 0.00004 | 0.09817  | 0.00015    | 13.27                | 0.07  |  |
| 700    | 0.00659 | 0.00004 | 0.08649  | 0.00012    | 13.12                | 0.07  |  |
| 650    | 0.00576 | 0.00003 | 0.07725  | 0.00011    | 13.42                | 0.08  |  |
| 600    | 0.00494 | 0.00003 | 0.06666  | 0.00010    | 13.49                | 0.09  |  |
| 550    | 0.00416 | 0.00003 | 0.05676  | 0.00010    | 13.66                | 0.10  |  |
| 500    | 0.00341 | 0.00003 | 0.04736  | 0.00009    | 13.88                | 0.11  |  |

Table III – The sum of the values in Table I (without multiplier) are compared to the sum in Table II (with multiplier), and the ratio of the two sums is given.

#### IV. The MCNP6 Model # 2

In preparing this document it was realized that the MCNP6 model with the LSO at 100 cm from the window center did not represent the real situation with the LSO as the detector. The problem was re-run for a more realistic case. In this case the LSO material starts 1-cm downstream of the center of the glass-Al window interface and is otherwise the same as Model #1. A MCNP geometry plot for this second case is shown in Figure 2.



Figure 2 – MCNP geometry for the Model # 2 geometry (dimensions on the plot are in centimeters), note the aspect ratio of the plot is not 1-to-1. Protons are incident on the window (SiO<sub>2</sub> and Al) from the left (indicated by the arrow).

As in the case of Model # 1 results, various particles were tallied in fmesh (track length) tallies that were from -7 cm to +7 cm in both dimensions transverse to the z-axis and from 1.0 cm to 1.2 cm along the z-axis. There were separate fmesh tallies for protons,  $\pi^+$ ,  $\pi^-$  (charged pions), deuterons, tritons, helions (<sup>3</sup>He) and alphas, with and without the energy dependent multiplier.

#### V. Results for Model #2

The results of the MCNP6 fmesh tallies are given in Table IV as a ratio to the proton fmesh tally for the Model # 2 (Figure 2) geometry. These results are also plotted in Figure 3a. Table V gives (plotted in Figure 3b) the results when an energy dependent multiplier (that is different for each particle) is applied. These multipliers were the same as the multipliers used for the Model # 1 results.

| Energy | $\pi^+$ |        | π-     |        | d      |        | t      |        | <sup>3</sup> He |        | α      |        |
|--------|---------|--------|--------|--------|--------|--------|--------|--------|-----------------|--------|--------|--------|
| (MeV)  |         | Error  |        | Error  |        | Error  |        | Error  |                 | Error  |        | Error  |
| 800    | 4.51E-  | 3.93E- | 2.37E- | 3.07E- | 6.32E- | 3.45E- | 1.07E- | 1.11E- | 2.82E-          | 4.26E- | 2.95E- | 2.82E- |
|        | 03      | 06     | 03     | 06     | 03     | 06     | 03     | 06     | 04              | 07     | 04     | 07     |
| 750    | 4.01E-  | 3.72E- | 2.03E- | 2.85E- | 5.88E- | 3.27E- | 9.63E- | 1.04E- | 2.54E-          | 4.02E- | 2.64E- | 4.17E- |
|        | 03      | 06     | 03     | 06     | 03     | 06     | 04     | 06     | 04              | 07     | 04     | 07     |
| 700    | 3.48E-  | 3.45E- | 1.69E- | 2.60E- | 5.43E- | 3.08E- | 8.66E- | 9.71E- | 2.28E-          | 3.77E- | 2.33E- | 2.39E- |
|        | 03      | 06     | 03     | 06     | 03     | 06     | 04     | 07     | 04              | 07     | 04     | 07     |
| 650    | 2.90E-  | 3.13E- | 1.37E- | 2.33E- | 4.95E- | 2.88E- | 7.64E- | 8.94E- | 2.01E-          | 3.49E- | 2.03E- | 2.17E- |
|        | 03      | 06     | 03     | 06     | 03     | 06     | 04     | 07     | 04              | 07     | 04     | 07     |
| 600    | 2.30E-  | 2.77E- | 1.08E- | 2.07E- | 4.44E- | 2.68E- | 6.67E- | 8.21E- | 1.75E-          | 3.23E- | 1.74E- | 1.95E- |
|        | 03      | 06     | 03     | 06     | 03     | 06     | 04     | 07     | 04              | 07     | 04     | 07     |
| 550    | 1.72E-  | 2.36E- | 8.02E- | 1.77E- | 3.93E- | 2.47E- | 5.78E- | 7.52E- | 1.49E-          | 2.93E- | 1.48E- | 1.74E- |
|        | 03      | 06     | 04     | 06     | 03     | 06     | 04     | 07     | 04              | 07     | 04     | 07     |
| 500    | 1.19E-  | 1.94E- | 5.58E- | 1.46E- | 3.41E- | 2.25E- | 4.89E- | 6.77E- | 1.24E-          | 2.61E- | 1.23E- | 1.54E- |
|        | 03      | 06     | 04     | 06     | 03     | 06     | 04     | 07     | 04              | 07     | 04     | 07     |

Table IV – The values of the fmesh for the indicated particle as a ratio to the value for protons is given for the indicated proton energy.

| Energy | $\pi^+$ |        | $\pi^{-}$ |        | d      |        | t      |        | <sup>3</sup> He |        | α      |        |
|--------|---------|--------|-----------|--------|--------|--------|--------|--------|-----------------|--------|--------|--------|
| (MeV)  |         | Error  |           | Error  |        | Error  |        | Error  |                 | Error  |        | Error  |
| 800    | 5.49E-  | 5.20E- | 3.18E-    | 4.18E- | 5.88E- | 3.03E- | 1.70E- | 1.47E- | 1.42E-          | 1.67E- | 3.00E- | 2.24E- |
|        | 03      | 06     | 03        | 06     | 02     | 05     | 02     | 05     | 02              | 05     | 02     | 05     |
| 750    | 4.90E-  | 4.92E- | 2.70E-    | 3.85E- | 5.35E- | 2.82E- | 1.52E- | 1.36E- | 1.27E-          | 1.55E- | 2.65E- | 3.25E- |
|        | 03      | 06     | 03        | 06     | 02     | 05     | 02     | 05     | 02              | 05     | 02     | 05     |
| 700    | 4.28E-  | 4.57E- | 2.24E-    | 3.48E- | 4.83E- | 2.61E- | 1.34E- | 1.26E- | 1.12E-          | 1.43E- | 2.32E- | 1.86E- |
| ,      | 03      | 06     | 03        | 06     | 02     | 05     | 02     | 05     | 02              | 05     | 02     | 05     |
| 650    | 3.69E-  | 4.28E- | 1.85E-    | 3.19E- | 4.41E- | 2.46E- | 1.19E- | 1.19E- | 9.94E-          | 1.34E- | 2.05E- | 1.71E- |
|        | 03      | 06     | 03        | 06     | 02     | 05     | 02     | 05     | 03              | 05     | 02     | 05     |
| 600    | 3.00E-  | 3.84E- | 1.47E-    | 2.82E- | 3.91E- | 2.25E- | 1.03E- | 1.03E- | 8.57E-          | 1.23E- | 1.75E- | 1.5E-  |
|        | 03      | 06     | 03        | 06     | 02     | 05     | 02     | 05     | 03              | 05     | 02     | 05     |
| 550    | 2.29E-  | 3.31E- | 1.10E-    | 2.42E- | 3.42E- | 2.05E- | 8.83E- | 9.67E- | 7.24E-          | 1.11E- | 1.47E- | 1.3E-  |
|        | 03      | 06     | 03        | 06     | 02     | 05     | 03     | 06     | 03              | 05     | 02     | 05     |
| 500    | 1.62E-  | 2.74E- | 7.70E-    | 2.00E- | 2.94E- | 1.84E- | 7.34E- | 8.57E- | 6.00E-          | 9.83E- | 1.20E- | 1.17E- |
|        | 03      | 06     | 04        | 06     | 02     | 05     | 03     | 06     | 03              | 06     | 02     | 05     |

Table V – The values of the fmesh for the indicated particle as a ratio to the value for protons is given. This is for the case where each tally has an energy dependent multiplier that is dE/dx over dE/dx of a 1-GeV proton. Note that these tally multipliers are different for each particle type.

One sees in general that the values in Tables IV and V (Model # 2) are greater that the values in Tables I and II (Model # 1) but the ratios of the sum with multiplier to sum without multiplier for Model # 2 (Table VI) are less than the values for Model # 1 (Table III). There are at least two effects: one is the fact that the solid angle for particles off the window getting to the LSO will be greater for Model # 2 than for Model # 1. A second effect is that the energy spectrum of the particles getting to the LSO in the two cases could be and probably is different.

While we have not tabulated the results here, there is a number of charged muons getting to the LSO in the Model # 2 case (these were not recorded in the Model #1 case) – these muons presumably coming from charged-pion decay and are 5% to 8% of the  $\pi^+/p$  ratios and ~0.2% of the  $\pi^-/p$  ratios.

| Energy | Sum     | without   | Sum with        | n multiplier | Ratio of sum with |        |  |
|--------|---------|-----------|-----------------|--------------|-------------------|--------|--|
|        | mul     | tiplier   |                 |              | to sum without    |        |  |
| (MeV)  |         | Error     |                 | Error        |                   | Error  |  |
| 800    | 0.01485 | 0.00001   | 0.12868         | 0.00004      | 8.67              | < 0.01 |  |
| 750    | 0.01340 | 0.00001   | 0.11550         | 0.00005      | 8.62              | 0.01   |  |
| 700    | 0.01193 | 0.00001   | 0.10252 0.00004 |              | 8.59              | 0.01   |  |
| 650    | 0.01038 | < 0.00001 | 0.09203         | 0.00004      | 8.87              | 0.01   |  |
| 600    | 0.00884 | < 0.00001 | 0.07989         | 0.00003      | 9.04              | 0.01   |  |
| 550    | 0.00732 | < 0.00001 | 0.06831         | 0.00003      | 9.33              | 0.01   |  |
| 500    | 0.00589 | < 0.00001 | 0.05714         | 0.00003      | 9.70              | 0.01   |  |

Table VI – The sum of the values in Table IV (without multiplier) are compared to the sum in Table V (with multiplier), and the ratio of the two sums is given. This is for the MCNP geometry Model # 2 case.

For Model # 2 we have also calculation the image of the particles in the LSO with a mesh that is 1400 pixels -by- 1400 pixels -by- 1 pixel thick covering 14-cm × 14-cm × 0.2-cm. These images divided by the summed image (protons +  $\pi^+ + \pi^- + \mu^+ + \mu^- + deuterons + tritons + 3He + \alpha$ ) are shown in Figure 4a-i, respectively, on plots that cover two orders of magnitude in the intensity scale; and in Figure 5a-i where the lower bound of the intensity is auto scaled for each plot.



Figure 3a and 3b (left) – Caption is the same as Figure 1a and 1b except that runs were with MCNP Model #2 (see text) with LSO detector 1 cm from the center of the window.



Protons from 800-MeV protons with SiO2-AI window and LSO

Figure 4a – Ratio of the proton image to the summed image (see text).



Pi-plus from 800-MeV protons with SiO2-AI window and LSO

Figure 4b – Ratio of the  $\pi^+$  image to the summed image (see text).





Figure 4c – Ratio of the  $\pi^{-}$  image to the summed image (see text).

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# Mu-plus from 800-MeV protons with SiO2-Al window and LSO

Figure 4d – Ratio of the  $\mu^+$  image to the summed image (see text).





Figure 4e – Ratio of the  $\mu^{-}$  image to the summed image (see text).

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# Deuterons from 800-MeV protons with SiO2-AI window and LSO

Figure 4f – Ratio of the deuteron image to the summed image (see text).





Figure 4g – Ratio of the triton image to the summed image (see text).



3He from 800-MeV protons with SiO2-AI window and LSO

Figure 4h – Ratio of the <sup>3</sup>He image to the summed image (see text).



Alphas from 800-MeV protons with SiO2-Al window and LSO

Figure 4i - Ratio of the alpha particle image to the summed image (see text).



## Protons from 800-MeV protons with SiO2-AI window and LSO

Figure 5a - Ratio of the proton image to the summed image with the lower limit of the intensity scale auto scaled by the plotting program. This is the same data is in Figure 4a.



Pi-plus from 800-MeV protons with SiO2-AI window and LSO

Figure 5b – Ratio of the  $\pi^+$  image to the summed image with the lower limit of the intensity scale auto scaled by the plotting program. This is the same data is in Figure 4b.





Figure 5c – Ratio of the  $\pi^{-}$  image to the summed image with the lower limit of the intensity scale auto scaled by the plotting program. This is the same data is in Figure 4c.



Mu-plus from 800-MeV protons with SiO2-Al window and LSO

Figure 5d – Ratio of the proton image to the summed image with the lower limit of the intensity scale auto scaled by the plotting program. This is the same data is in Figure 4d.

Mu-minus from 800-MeV protons with SiO2-AI window and LSO



Figure 5e - Ratio of the proton image to the summed image with the lower limit of the intensity scale auto scaled by the plotting program. This is the same data is in Figure 4e.



## Deuterons from 800-MeV protons with SiO2-AI window and LSO

Figure 5f - Ratio of the proton image to the summed image with the lower limit of the intensity scale auto scaled by the plotting program. This is the same data is in Figure 4f.





Figure 5g – Ratio of the proton image to the summed image with the lower limit of the intensity scale auto scaled by the plotting program. This is the same data is in Figure 4g.



3He from 800-MeV protons with SiO2-AI window and LSO

Figure 5h - Ratio of the proton image to the summed image with the lower limit of the intensity scale auto scaled by the plotting program. This is the same data is in Figure 4h.





Figure 5i - Ratio of the proton image to the summed image with the lower limit of the intensity scale auto scaled by the plotting program. This is the same data is in Figure 4i.

### VI. Conclusions

Monte Carlo calculations with MCNP6 of a protons incident of a thick window (similar to the window used in some proton radiography experiments at Line C) and subsequently transported to a LSO detector show a significant number of secondary particles in the LSO. If a model that accounts for the relative energy loss of the particles in the LSO is applied one sees that the summed signal from the secondary particles is 5% to 12% of the proton signal depending on the incident proton energy.

The effects of these secondary particles should cancel out when the experimenters calculate a transmission by taking the ratio of an object-in run to an object-out run. However, one must be careful since there appears to be energy dependence to the secondary contribution, and the protons energies for the object-in run and the object-out run will probably be different.

The secondary production in the window and subsequent spreading of signal in the LSO scintillator (Figures 4b through 4i) might lead to the effect that has been called "long range blur". The effect of long range blur has been discussed in a couple of documents.<sup>3</sup> These documents discuss the effect at LANSCE Line C (800-MeV protons) and at the Brookhaven AGS (24-GeV/c protons), respectively, and the latter points out that the long range blur is reduced by approximately an order of magnitude at the energy higher energy. If it is secondary particle production causing the effect then the forward peaking at energy proton energies might explain the effect. We intend to perform similar MCNP6 calculations at the higher energy when the cross sections become available in the code – the cross sections currently stop at ~5-GeV proton energy.

It should be noted that the calculations presented in this note do not include delta rays (i.e. fast electrons produced by the energetic charged particles knocking orbiting electrons out of atoms), or heavy ions (i.e. ions heavier than alpha particles that could be produced primarily by the protons interacting with the nuclei of the window material(s). Both of these processes would modify the scintillator signal, but neither process is included in MCNP6 at the moment.

### VII. References

1. "Initial MCNP6 Release Overview", T. Goorley et al., LA-UR-11-01766 -- states: "While MCNP6 is simply and accurately described as the merger of MCNP5 and MCNPX capabilities, it is also the result of 4 years of meticulous effort by the MCNP5 and MCNPX code development teams."

The merger is cited is being or nearing completion, but this author will believe this when it is seen at RSICC (Radiation Safety Information Computational Center).

2. "CEM03.03 and LAQGSM03.03 Event Generators for the MCNP6, MCNPX, and MARS15 Transport Codes", S. G. Mashnik, K. K. Gudima, R. E. Prael, A. J. Sierk, M. I. Baznat, and N. V. Mokhov, Joint ICTP-IAEA Advanced Workshop on Model Codes for Spallation Reactions, February 4-8, 2008, ICTP, Trieste, Italy; LA-UR-08-2931; E-print: arXiv:0805.0751v2 [nucl-th]; IAEA Report INDC(NDS)-0530, Distr. SC, Vienna, Austria, August 2008, p. 51.

3. "Long Range Blur correction to Proton Radiography Data", N. S. P. King, K. B. Morley, C. L. Morris and Pete Pazuchanics, Los Alamos National Laboratory (no date and no LA number); "Tile Glow Correction" Chris Morris et al., LANL, LLNL, and Bechtel Nevada (no date and no LA number).

### VIII. Acknowledgements

Thanks to my fellow transporters in XCP-7 "Transport Applications" for the occasional discussion of this and similar topics. And also to XCP-3 "Monte Carlo Codes" for the implementation of the new features that allow proton radiography simulations with MCNP6, and in advance for features that are yet to be implemented.

JDZ:jdz

#### Appendix I — MCNP6 input for Model # 2 geometry

```
file: .../Rprad/LineC/minusI/particle_production/035/pp035-700.inp
c from .../Rprad/LineC/minusI/particle_production/034/pp034-700.inp
c from .../Rprad/LineC/minusI/particle_production/018/pp018.inp
С
c to 1400x1400-pixel LSO detector that is 14-cm by 14-cm by 0.2-cm thick
c location 1-cm to 1.2-cm downstream of center of window
С
c particle production with 700-MeV protons
с with 'tropt' card
c and proton cutoff set to 10-MeV
c DF cards are dE/dX(E) to proton stopping power at 1-GeV
с
c start cell cards
С
 101
       0
                      -50
                           101 -102
                                         imp:h=1
 102
      14
          -2.65
                       -50 102 -103
                                         imp:h=1
                       -50
                           103 -104
 103
     13
          -2.70
                                         imp:h=1
 104
       0
                       -50
                            104 -105
                                         imp:h=1
 105
      71
           -7.36
                       -50
                            105 -106
                                         imp:h=1
                            106 -107
 106
       0
                       -50
                                         imp:h=1
С
  75
        0
                       50:-101:+107
                                         imp:h=0
 -----
С
c end of cell cards
c start surface cards
   50
        сz
              95
С
  101
        pz
             -100
  102
              -0.3175
        pz
  103
               0.0000
        pz
        pz
  104
               0.3175
  105
        pz
               1
  106
        pz
               1.2
  107
        pz
              100
                      -----
с -----
c end of surface cards
c start physics cards
c mode h
 mode h
             / * | !
                         dtsa
c phys:n 1000
 phys:h 1000
 phys:/ 1000
 phys:* 1000
 phys:| 1000
 phys:! 1000
 phys:d 1000
 phys:t 1000
 phys:s 1000
 phys:a 1000
с
c cut:n j
          1.00
 cut:h j
          5.
 cut:/ j
          5.
 cut:* j
          5.
 cut:| j
          5.
 cut:! j
          5.
 cut:d j
          5.
 cut:t j
          5.
 cut:s j
          5.
 cut:a j
          5.
с
 tropt nreact=on nescat=on mcscat=fnal1 eloss=strag1
c void
                     -----
с -----
```

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XCP-7:11-011 / LA-UR-11-04562

sdef erg=700. part=5 sur=101 x=0 y=0 z=-100 vec=0 0 1 dir=1 с -----rand gen=2 print -160 -30 с -----..... nps 100000000 prdmp j 10000000 1 2 10000000 c ----m13 13027 1. \$ aluminum 08016 2. 14028 1. 8016 5. m14 14028 1. Si02 == glass (rho=2.64 g/cc)m71 71175 2. \$ LSO (rho=7.36 g/cc) c end of material cards -----С С fc021 exit of problem f021:h 105 e021 0 001 800i 802 С ----fc031 exit of problem f031:n 105 e031 0 001 800i 802 с ----fc411 pi+ at exit of problem f411:/ 105 e411 00 99i 1000 c ----fc511 pi- just after object energy f511:\* 105 e511 00 99i 1000 c ----fc611 mu+ just after object energy f611:! 105 e611 00 99i 1000 C -----fc711 mu- just after object energy f711:| 105 e711 00 99i 1000 C -----fc811 deuterons just after object energy f811:d 105 e811 00 99i 1000 с ----fc911 tritons just after object energy f911:t 105 e911 00 99i 1000 c ----fc1011 3He just after object energy f1011:s 105 e1011 00 99i 1000 с ----fc1111 alphas just after object energy f1111:a 105 e1111 00 99i 1000 C ----с ----с ----------С fc154 proton image at IL1 fmesh154:h geom=rec origin=-7 -7 +1.0 imesh 7 iints 1400 jmesh 7 jints 1400 kmesh +1.2 out=cf 5.06578 5.52427 6.02426 6.56950 8.51959 9.29068 10.13160 11.04850 DE154 LIN 7.16409 7.81250 11.04850 12.04850 13.13900 14,32820 15,62500 17,03920 18,58140 20,26310 22,09710 24.09700 26.27800 28.65640 31.25000 34.07840 37.16270 40.52620 44.19420 48.19410 52.55600 57.31280 62.50000 68.1567074.3254081.0525088.3883096.38820105.11200114.62600125.00000136.31300148.65100162.10500176.77699 192.77600 210.22400 229.25101 250.00000 272.62701 297.30200 324.20999 353.55301 385.55301 420.44800 458.50201 500.00000 An Equal Opportunity Employer / Operated by Los Alamos Nuclear Security, LLC

|   | 545.25403  | 594.60400  | 648.41998   | 707.10699  | 771.10498   | 840.89600   |  |
|---|--|--|---|--|---|---|--|
|   | 917.00403  | 1000.00000   | ~~ ~~~  | ~~~~~~   | 00 50500  | 10 00000  |  |
| DF154 LIN   | 26.08269   | 24.42458   | 23.06607  | 23.06607   | 20.53502  | 19.36003  |  |
|   | 10.24370   | 11 00020   | 10.1/801  | 10.17801   | 14.32089  | 13.4/228  |  |
|   | 8 67966  | 8 14202  | 7 63895   | 7 63895  | 9.85550   | 9.24000   |  |
|   | 5 91134  | 5 54462  | 5 20113   | 5 20113  | 4 57863   | 4 20743   |  |
|   | 4 03476  | 3 78938  | 3 56046   | 3 56046  | 3 14812   | 2 96289   |  |
|   | 2.79043  | 2,63060  | 2.48150   | 2.48150  | 2.21463   | 2.09555   |  |
|   | 1.98528  | 1.88349  | 1.78915   | 1.78915  | 1.62186   | 1.54794   |  |
|   | 1.48000  | 1,41767  | 1.36058   | 1.36058  | 1.26090   | 1.21772   |  |
|   | 1.17860  | 1.14331  | 1.11163   | 1.11163  | 1.05821   | 1.03608   |  |
|   | 1.01673  | 1.00000  |   |  |   |   |  |
| c   |  |  |   |  |   |   | -  |
| fc454 pi  | ⊦ image  | e at IL1   |   |  |   |   |  |
| fmesh454:/  | geom=rec   | origin=-7  | -7 +1.0   |  |   |   |  |
| imes  | sh 7 iints 1   | 1400   |   |  |   |   |  |
| jmes  | sh 7 jints 1   | 1400 kme   | esh +1.2  | out=cf   |   |   |  |
| DE454 LIN   | 5.06578  | 5.52427  | 6.02426   | 6.56950  | 7.16409   | 7.81250   |  |
|   | 14 20000   | 9.29008  | 17 02020  | 10 50140   | 12.04850  | 13.13900  |  |
|   | 24 00700   | 26 27800   | 28 65640  | 31 25000   | 20.20310  | 22.09710  |  |
|   | 40 52620   | 20.27800   | 28.05040  | 52 55600   | 57 31280  | 62 50000  |  |
|   | 68 15670   | 74 32540   | 81 05250  | 88 38830   | 96 38820  | 105 11200   |  |
|   | 114.62600  | 125.00000  | 136.31300   | 148.65100  | 162,10500   | 176.77699   |  |
|   | 192.77600  | 210.22400  | 229.25101   | 250.00000  | 272.62701   | 297.30200   |  |
|   | 324,20999  | 353.55301  | 385.55301   | 420.44800  | 458.50201   | 500.00000   |  |
|   | 545.25403  | 594,60400  | 648,41998   | 707.10699  | 771.10498   | 840.89600   |  |
|   | 917.00403  | 1000.00000   |   |  |   |   |  |
| DF454 LIN   | 6.71911  | 6.30202  | 5.91054   | 5.91054  | 5.20051   | 4.87881   | <pre>\$ ratio of pion dE/dx values</pre>                               |
|   | 4.57813  | 4.29698  | 4.03435   | 4.03435  | 3.56011   | 3.34675   | \$ to proton dE/dx at 1-GeV  |
|   | 3.14781  | 2.96259  | 2.79015   | 2.79015  | 2.48122   | 2.34276   |  |
|   | 2.21435  | 2.09526  | 1.98498   | 1.98498  | 1.78884   | 1.70182   |  |
|   | 1.62152  | 1.54759  | 1.47963   | 1.47963  | 1.36017   | 1.30801   |  |
|   | 1.26047  | 1.21727  | 1.17812   | 1.17812  | 1.11110   | 1.08277   |  |
|   | 1.05764  | 1.03548  | 1.01609   | 1.01609  | 0.98504   | 0.97297   |  |
|   |  |  |   |  |   |   |  |
|   | 0.96294  | 0.95483  | 0.94849   | 0.94849  | 0.94066   | 0.93894   |  |
|   | 0.96294<br>0.93854   | 0.95483<br>0.93936   | 0.94849<br>0.94129  | 0.94849<br>0.94129   | 0.94066   | 0.93894   |  |
|   | 0.96294<br>0.93854<br>0.95829  | 0.95483<br>0.93936<br>0.96445  | 0.94849<br>0.94129<br>0.97121   | 0.94849<br>0.94129<br>0.97121  | 0.94066<br>0.94811<br>0.98629   | 0.93894<br>0.95282<br>0.99448   |  |
| c   | 0.96294<br>0.93854<br>0.95829<br>1.00303   | 0.95483<br>0.93936<br>0.96445<br>1.01189   | 0.94849<br>0.94129<br>0.97121   | 0.94849<br>0.94129<br>0.97121  | 0.94066<br>0.94811<br>0.98629   | 0.93894<br>0.95282<br>0.99448   | _  |
| c   | 0.96294<br>0.93854<br>0.95829<br>1.00303   | 0.95483<br>0.93936<br>0.96445<br>1.01189   | 0.94849<br>0.94129<br>0.97121   | 0.94849<br>0.94129<br>0.97121  | 0.94066<br>0.94811<br>0.98629   | 0.93894<br>0.95282<br>0.99448   | -  |
| c<br>fc554 pi<br>fmesh554:*                                   | 0.96294<br>0.93854<br>0.95829<br>1.00303<br>   | 0.95483<br>0.93936<br>0.96445<br>1.01189<br>e at IL1<br>origin=-7  | 0.94849<br>0.94129<br>0.97121   | 0.94849<br>0.94129<br>0.97121  | 0.94066<br>0.94811<br>0.98629   | 0.93894<br>0.95282<br>0.99448   | -  |
| c<br>fc554 pi<br>fmesh554:*<br>imes                           | 0.96294<br>0.93854<br>0.95829<br>1.00303<br>   | 0.95483<br>0.93936<br>0.96445<br>1.01189<br>e at IL1<br>origin=-7  | 0.94849<br>0.94129<br>0.97121<br>-7 +1.0  | 0.94849<br>0.94129<br>0.97121  | 0.94066<br>0.94811<br>0.98629   | 0.93894<br>0.95282<br>0.99448   | -  |
| c<br>fc554 pi<br>fmesh554:*<br>imes<br>jmes                   | 0.96294<br>0.93854<br>0.95829<br>1.00303<br>   | 0.95483<br>0.93936<br>0.96445<br>1.01189<br>e at IL1<br>origin=-7<br>1400 kme  | 0.94849<br>0.94129<br>0.97121<br>-7 +1.0<br>esh +1.2  | 0.94849<br>0.94129<br>0.97121  | 0.94066<br>0.94811<br>0.98629   | 0.93894<br>0.95282<br>0.99448   | -  |
| c<br>fc554 pi<br>fmesh554:*<br>imes<br>jmes<br>DE554 LIN      | 0.96294<br>0.93854<br>0.95829<br>1.00303<br>   | 0.95483<br>0.93936<br>0.96445<br>1.01189<br>e at IL1<br>origin=-7<br>1400<br>1400 kme<br>5.52427   | 0.94849<br>0.94129<br>0.97121<br>-7 +1.0<br>esh +1.2<br>6.02426   | 0.94849<br>0.94129<br>0.97121<br>out=cf<br>6.56950   | 0.94066<br>0.94811<br>0.98629<br>7.16409  | 0.93894<br>0.95282<br>0.99448<br>7.81250  | -  |
| c<br>fc554 pi<br>fmesh554:*<br>imes<br>jmes<br>DE554 LIN      | 0.96294<br>0.93854<br>0.95829<br>1.00303<br>geom=rec<br>sh 7 iints 1<br>5.06578<br>8.51959   | 0.95483<br>0.93936<br>0.96445<br>1.01189<br>e at IL1<br>origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068  | 0.94849<br>0.94129<br>0.97121<br>-7 +1.0<br>esh +1.2<br>6.02426<br>10.13160   | 0.94849<br>0.94129<br>0.97121<br>out=cf<br>6.56950<br>11.04850   | 0.94066<br>0.94811<br>0.98629<br>7.16409<br>12.04850  | 0.93894<br>0.95282<br>0.99448<br>7.81250<br>13.13900  | -  |
| c<br>fc554 pi<br>fmesh554:*<br>imes<br>jmes<br>DE554 LIN      | 0.96294<br>0.93854<br>0.95829<br>1.00303<br>   | 0.95483<br>0.93936<br>0.96445<br>1.01189<br>e at IL1<br>origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068<br>15.62500  | 0.94849<br>0.94129<br>0.97121<br>-7 +1.0<br>esh +1.2<br>6.02426<br>10.13160<br>17.03920   | 0.94849<br>0.94129<br>0.97121<br>out=cf<br>6.56950<br>11.04850<br>18.58140   | 0.94066<br>0.94811<br>0.98629<br>7.16409<br>12.04850<br>20.26310  | 0.93894<br>0.95282<br>0.99448<br>7.81250<br>13.13900<br>22.09710  | -  |
| C<br>fc554 pi<br>fmesh554:*<br>imes<br>jmes<br>DE554 LIN      | 0.96294<br>0.93854<br>0.95829<br>1.00303<br>   | 0.95483<br>0.93936<br>0.96445<br>1.01189<br>e at IL1<br>origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800  | 0.94849<br>0.94129<br>0.97121<br>-7 +1.0<br>esh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640   | 0.94849<br>0.94129<br>0.97121<br>out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000   | 0.94066<br>0.94811<br>0.98629<br>7.16409<br>12.04850<br>20.26310<br>34.07840  | 0.93894<br>0.95282<br>0.99448<br>7.81250<br>13.13900<br>22.09710<br>37.16270  | -  |
| C<br>fc554 pi<br>fmesh554:*<br>imes<br>jmes<br>DE554 LIN      | 0.96294<br>0.93854<br>0.95829<br>1.00303<br>   | 0.95483<br>0.93936<br>0.96445<br>1.01189<br>e at IL1<br>origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420  | 0.94849<br>0.94129<br>0.97121<br>-7 +1.0<br>esh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410   | 0.94849<br>0.94129<br>0.97121<br>out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600   | 0.94066<br>0.94811<br>0.98629<br>7.16409<br>12.04850<br>20.26310<br>34.07840<br>57.31280  | 0.93894<br>0.95282<br>0.99448<br>7.81250<br>13.13900<br>22.09710<br>37.16270<br>62.50000  | -  |
| C<br>fc554 pi<br>fmesh554:*<br>imes<br>jmes<br>DE554 LIN      | 0.96294<br>0.93854<br>0.95829<br>1.00303<br>   | 0.95483<br>0.93936<br>0.96445<br>1.01189<br>e at IL1<br>origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420<br>74.32540  | 0.94849<br>0.94129<br>0.97121<br>-7 +1.0<br>esh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410<br>81.05250   | 0.94849<br>0.94129<br>0.97121<br>out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600<br>88.38830   | 0.94066<br>0.94811<br>0.98629<br>7.16409<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820  | 0.93894<br>0.95282<br>0.99448<br>7.81250<br>13.13900<br>22.09710<br>37.16270<br>62.50000<br>105.11200   | -  |
| C<br>fc554 pi<br>fmesh554:*<br>imes<br>jmes<br>DE554 LIN      | 0.96294<br>0.93854<br>0.95829<br>1.00303<br>   | 0.95483<br>0.93936<br>0.96445<br>1.01189<br>e at IL1<br>origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420<br>74.32540<br>125.00000   | 0.94849<br>0.94129<br>0.97121<br>-7 +1.0<br>esh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410<br>81.05250<br>136.31300  | 0.94849<br>0.94129<br>0.97121<br>out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600<br>88.38830<br>148.65100  | 0.94066<br>0.94811<br>0.98629<br>7.16409<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500   | 0.93894<br>0.95282<br>0.99448<br>7.81250<br>13.13900<br>22.09710<br>37.16270<br>62.50000<br>105.11200<br>176.77699  | -  |
| C<br>fc554 pi<br>fmesh554:*<br>imes<br>jmes<br>DE554 LIN      | 0.96294<br>0.93854<br>0.95829<br>1.00303<br>   | 0.95483<br>0.93936<br>0.96445<br>1.01189<br>e at IL1<br>origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420<br>74.32540<br>125.00000<br>210.22400  | 0.94849<br>0.94129<br>0.97121<br>-7 +1.0<br>esh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410<br>81.05250<br>136.31300<br>229.25101   | 0.94849<br>0.94129<br>0.97121<br>out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600<br>88.38830<br>148.65100<br>250.00000   | 0.94066<br>0.94811<br>0.98629<br>7.16409<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500<br>272.62701  | 0.93894<br>0.95282<br>0.99448<br>7.81250<br>13.13900<br>22.09710<br>37.16270<br>62.50000<br>105.11200<br>176.77699<br>297.30200   | -  |
| C<br>fc554 pi<br>fmesh554:*<br>imes<br>jmes<br>DE554 LIN      | 0.96294<br>0.93854<br>0.95829<br>1.00303<br>   | 0.95483<br>0.93936<br>0.96445<br>1.01189<br>e at IL1<br>origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420<br>74.32540<br>125.00000<br>210.22400<br>353.55301   | 0.94849<br>0.94129<br>0.97121<br>-7 +1.0<br>esh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410<br>81.05250<br>136.31300<br>229.25101<br>385.55301  | 0.94849<br>0.94129<br>0.97121<br>out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600<br>88.38830<br>148.65100<br>250.00000<br>420.44800  | 0.94066<br>0.94811<br>0.98629<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500<br>272.62701<br>458.50201  | 0.93894<br>0.95282<br>0.99448<br>7.81250<br>13.13900<br>22.09710<br>37.16270<br>62.50000<br>105.11200<br>176.77699<br>297.30200<br>500.00000  | -  |
| C<br>fc554 pi<br>fmesh554:*<br>imes<br>jmes<br>DE554 LIN      | 0.96294<br>0.93854<br>0.95829<br>1.00303<br>   | 0.95483<br>0.93936<br>0.96445<br>1.01189<br>e at IL1<br>origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420<br>74.32540<br>125.00000<br>210.22400<br>353.55301<br>594.60400  | 0.94849<br>0.94129<br>0.97121<br>-7 +1.0<br>esh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410<br>81.05250<br>136.31300<br>229.25101<br>385.55301<br>648.41998   | 0.94849<br>0.94129<br>0.97121<br>out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600<br>88.38830<br>148.65100<br>250.00000<br>420.44800<br>707.10699   | 0.94066<br>0.94811<br>0.98629<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500<br>272.62701<br>458.50201<br>771.10498   | 0.93894<br>0.95282<br>0.99448<br>7.81250<br>13.13900<br>22.09710<br>37.16270<br>62.50000<br>105.11200<br>176.77699<br>297.30200<br>500.00000<br>840.89600   | -  |
| C<br>fc554 pi<br>fmesh554:*<br>imes<br>jmes<br>DE554 LIN      | 0.96294<br>0.93854<br>0.95829<br>1.00303<br>   | 0.95483<br>0.93936<br>0.96445<br>1.01189<br>e at IL1<br>origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420<br>74.32540<br>125.00000<br>210.22400<br>353.55301<br>594.60400<br>1000.00000<br>6.20202   | 0.94849<br>0.94129<br>0.97121<br>-7 +1.0<br>esh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410<br>81.05250<br>136.31300<br>229.25101<br>385.55301<br>648.41998   | 0.94849<br>0.94129<br>0.97121<br>out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600<br>88.38830<br>148.65100<br>250.00000<br>420.44800<br>707.10699   | 0.94066<br>0.94811<br>0.98629<br>7.16409<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500<br>272.62701<br>458.50201<br>771.10498  | 0.93894<br>0.95282<br>0.99448<br>7.81250<br>13.13900<br>22.09710<br>37.16270<br>62.50000<br>105.11200<br>176.77699<br>297.30200<br>500.00000<br>840.89600   | • stip of pion dE/dx values  |
| C<br>fc554 pi<br>fmesh554:*<br>imes<br>jmes<br>DE554 LIN      | 0.96294<br>0.93854<br>0.95829<br>1.00303<br>   | 0.95483<br>0.93936<br>0.96445<br>1.01189<br>e at IL1<br>origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420<br>74.32540<br>125.00000<br>210.22400<br>353.55301<br>594.60400<br>1000.00000<br>6.30202<br>4.29698  | 0.94849<br>0.94129<br>0.97121<br>-7 +1.0<br>esh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410<br>81.05250<br>136.31300<br>229.25101<br>385.55301<br>648.41998<br>5.91054<br>4 03435   | 0.94849<br>0.94129<br>0.97121<br>out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600<br>88.38830<br>148.65100<br>250.00000<br>420.44800<br>707.10699<br>5.91054<br>4 03435   | 0.94066<br>0.94811<br>0.98629<br>7.16409<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500<br>272.62701<br>458.50201<br>771.10498<br>5.20051<br>3.56011  | 7.81250<br>13.13900<br>22.09710<br>37.16270<br>62.50000<br>105.11200<br>176.77699<br>297.30200<br>500.00000<br>840.89600<br>4.87881<br>3.34675  | <pre>- \$ ratio of pion dE/dx values \$ to proton dE/dx at 1.6eV</pre> |
| C<br>fc554 pi<br>fmesh554:*<br>jmes<br>DE554 LIN              | 0.96294<br>0.93854<br>0.95829<br>1.00303<br>   | 0.95483<br>0.93936<br>0.96445<br>1.01189<br>e at IL1<br>origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420<br>74.32540<br>125.00000<br>210.22400<br>353.55301<br>594.60400<br>1000.00000<br>6.30202<br>4.29698<br>2.96258   | 0.94849<br>0.94129<br>0.97121<br>-7 +1.0<br>esh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410<br>81.05250<br>136.31300<br>229.25101<br>385.55301<br>648.41998<br>5.91054<br>4.03435<br>2 79015  | 0.94849<br>0.94129<br>0.97121<br>out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600<br>88.38830<br>148.65100<br>250.00000<br>420.44800<br>707.10699<br>5.91054<br>4.03435<br>2 79015  | 0.94066<br>0.94811<br>0.98629<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500<br>272.62701<br>458.50201<br>771.10498<br>5.20051<br>3.56011<br>2.48122  | 0.93894<br>0.95282<br>0.99448<br>   | -<br>\$ ratio of pion dE/dx values<br>\$ to proton dE/dx at 1-GeV      |
| C<br>fc554 pi<br>fmesh554:*<br>imes<br>jmes<br>DE554 LIN      | 0.96294<br>0.93854<br>0.95829<br>1.00303<br>image<br>geom=rec<br>sh 7 iints 1<br>5.06578<br>8.51959<br>14.32820<br>24.09700<br>40.52620<br>68.15670<br>114.62600<br>192.77600<br>324.20999<br>545.25403<br>917.00403<br>6.71911<br>4.57813<br>3.14781<br>2.21435 | 0.95483<br>0.93936<br>0.96445<br>1.01189<br>e at IL1<br>origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420<br>74.32540<br>125.00000<br>210.22400<br>353.55301<br>594.60400<br>1000.00000<br>6.30202<br>4.29698<br>2.96259<br>2.09526  | 0.94849<br>0.94129<br>0.97121<br>-7 +1.0<br>esh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410<br>81.05250<br>136.31300<br>229.25101<br>385.55301<br>648.41998<br>5.91054<br>4.03435<br>2.79015<br>1.98498   | 0.94849<br>0.94129<br>0.97121<br>out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600<br>88.38830<br>148.65100<br>250.00000<br>420.44800<br>707.10699<br>5.91054<br>4.03435<br>2.79015<br>1.98498   | 0.94066<br>0.94811<br>0.98629<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500<br>272.62701<br>458.50201<br>771.10498<br>5.20051<br>3.56011<br>2.48122<br>1.78884   | 0.93894<br>0.95282<br>0.99448<br>   | -<br>\$ ratio of pion dE/dx values<br>\$ to proton dE/dx at 1-GeV      |
| C<br>fc554 pi<br>fmesh554:*<br>jmes<br>DE554 LIN              | 0.96294<br>0.93854<br>0.95829<br>1.00303<br>   | 0.95483<br>0.93936<br>0.96445<br>1.01189<br>e at IL1<br>origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420<br>74.32540<br>125.00000<br>210.22400<br>353.55301<br>594.60400<br>1000.00000<br>6.30202<br>4.29698<br>2.96259<br>2.09526<br>1.54759   | 0.94849<br>0.94129<br>0.97121<br>-7 +1.0<br>esh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410<br>81.05250<br>136.31300<br>229.25101<br>385.55301<br>648.41998<br>5.91054<br>4.03435<br>2.79015<br>1.98498<br>1.47963  | 0.94849<br>0.94129<br>0.97121<br>out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600<br>88.38830<br>148.65100<br>250.00000<br>420.44800<br>707.10699<br>5.91054<br>4.03435<br>2.79015<br>1.98498<br>1.47963  | 0.94066<br>0.94811<br>0.98629<br>7.16409<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500<br>272.62701<br>458.50201<br>771.10498<br>5.20051<br>3.56011<br>2.48122<br>1.78884<br>1.36017   | 0.93894<br>0.95282<br>0.99448<br>   | -<br>\$ ratio of pion dE/dx values<br>\$ to proton dE/dx at 1-GeV      |
| C<br>fc554 pi<br>fmesh554:*<br>jmes<br>DE554 LIN              | 0.96294<br>0.93854<br>0.95829<br>1.00303<br>   | 0.95483<br>0.93936<br>0.96445<br>1.01189<br>e at IL1<br>origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420<br>74.32540<br>125.00000<br>210.22400<br>353.55301<br>594.60400<br>1000.00000<br>6.30202<br>4.29698<br>2.96259<br>2.09526<br>1.54759<br>1.21727  | 0.94849<br>0.94129<br>0.97121<br>-7 +1.0<br>esh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410<br>81.05250<br>136.31300<br>229.25101<br>385.55301<br>648.41998<br>5.91054<br>4.03435<br>2.79015<br>1.98498<br>1.47963<br>1.17812   | 0.94849<br>0.94129<br>0.97121<br>out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600<br>88.38830<br>148.65100<br>250.00000<br>420.44800<br>707.10699<br>5.91054<br>4.03435<br>2.79015<br>1.98498<br>1.47963<br>1.47963<br>1.17812                                  | 0.94066<br>0.94811<br>0.98629<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500<br>272.62701<br>458.50201<br>771.10498<br>5.20051<br>3.56011<br>2.48122<br>1.78884<br>1.36017<br>1.11110   | 0.93894<br>0.95282<br>0.99448<br>   | -<br>\$ ratio of pion dE/dx values<br>\$ to proton dE/dx at 1-GeV      |
| C<br>fc554 pi<br>fmesh554:*<br>jmes<br>DE554 LIN              | 0.96294<br>0.93854<br>0.95829<br>1.00303<br>   | 0.95483<br>0.93936<br>0.96445<br>1.01189<br>e at IL1<br>origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>27.22400<br>27.22400<br>27.22400<br>27.22400<br>27.226259<br>2.09526<br>1.54759<br>1.21727<br>1.03548 | 0.94849<br>0.94129<br>0.97121<br>-7 +1.0<br>esh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410<br>81.05250<br>136.31300<br>229.25101<br>385.55301<br>648.41998<br>5.91054<br>4.03435<br>2.79015<br>1.98498<br>1.47963<br>1.17812<br>1.01609                                  | 0.94849<br>0.94129<br>0.97121<br>out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600<br>88.38830<br>148.65100<br>250.00000<br>420.44800<br>707.10699<br>5.91054<br>4.03435<br>2.79015<br>1.98498<br>1.47963<br>1.17812<br>1.01609                                  | 0.94066<br>0.94811<br>0.98629<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500<br>272.62701<br>458.50201<br>771.10498<br>5.20051<br>3.56011<br>2.48122<br>1.78884<br>1.36017<br>1.11110<br>0.98504                                  | 0.93894<br>0.95282<br>0.99448<br>   | -<br>\$ ratio of pion dE/dx values<br>\$ to proton dE/dx at 1-GeV      |
| C<br>fc554 pi<br>fmesh554:*<br>jmes<br>DE554 LIN              | 0.96294<br>0.93854<br>0.95829<br>1.00303<br>   | 0.95483<br>0.93936<br>0.96445<br>1.01189<br>e at IL1<br>origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>125.00000<br>210.22400<br>353.55301<br>594.60400<br>1000.00000<br>6.30202<br>4.29698<br>2.96259<br>2.09526<br>1.54759<br>1.21727<br>1.03548<br>0.95483  | 0.94849<br>0.94129<br>0.97121<br>-7 +1.0<br>esh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>28.65640<br>81.05250<br>136.31300<br>229.25101<br>385.55301<br>648.41998<br>5.91054<br>4.03435<br>2.79015<br>1.98498<br>1.47963<br>1.17812<br>1.01609<br>0.94849                       | 0.94849<br>0.94129<br>0.97121<br>out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>88.38830<br>148.65100<br>250.00000<br>420.44800<br>707.10699<br>5.91054<br>4.03435<br>2.79015<br>1.98498<br>1.47963<br>1.17812<br>1.01609<br>0.94849                                   | 0.94066<br>0.94811<br>0.98629<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500<br>272.62701<br>458.50201<br>771.10498<br>5.20051<br>3.56011<br>2.48122<br>1.78884<br>1.36017<br>1.11110<br>0.98504<br>0.94066                       | 0.93894<br>0.95282<br>0.99448<br>   | -<br>\$ ratio of pion dE/dx values<br>\$ to proton dE/dx at 1-GeV      |
| C<br>fc554 pi<br>fmesh554:*<br>jmes<br>DE554 LIN<br>DF554 LIN | 0.96294<br>0.93854<br>0.95829<br>1.00303<br>   | 0.95483<br>0.93936<br>0.96445<br>1.01189<br>e at IL1<br>origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>125.00000<br>210.22400<br>353.55301<br>594.60400<br>1000.00000<br>6.30202<br>4.29698<br>2.96259<br>2.09526<br>1.54759<br>1.21727<br>1.03548<br>0.95483<br>0.93936   | 0.94849<br>0.94129<br>0.97121<br>-7 +1.0<br>esh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410<br>81.05250<br>136.31300<br>229.25101<br>385.55301<br>648.41998<br>5.91054<br>4.03435<br>2.79015<br>1.98498<br>1.47963<br>1.17812<br>1.01609<br>0.94849<br>0.94129            | 0.94849<br>0.94129<br>0.97121<br>out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>88.38830<br>148.65100<br>250.00000<br>420.44800<br>707.10699<br>5.91054<br>4.03435<br>2.79015<br>1.98498<br>1.47963<br>1.17812<br>1.01609<br>0.94849<br>0.94129                        | 0.94066<br>0.94811<br>0.98629<br>12.04850<br>20.26310<br>34.07840<br>96.38820<br>162.10500<br>272.62701<br>458.50201<br>771.10498<br>5.20051<br>3.56011<br>2.48122<br>1.78884<br>1.36017<br>1.11110<br>0.98504<br>0.94066<br>0.94811                        | 0.93894<br>0.95282<br>0.99448<br>   | -<br>\$ ratio of pion dE/dx values<br>\$ to proton dE/dx at 1-GeV      |
| C<br>fc554 pi<br>fmesh554:*<br>jmes<br>DE554 LIN<br>DF554 LIN | 0.96294<br>0.93854<br>0.95829<br>1.00303<br>   | 0.95483<br>0.93936<br>0.96445<br>1.01189<br>e at IL1<br>origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>125.00000<br>210.22400<br>353.55301<br>594.60400<br>1000.00000<br>6.30202<br>4.29698<br>2.96259<br>2.09526<br>1.54759<br>1.21727<br>1.03548<br>0.93936<br>0.96445   | 0.94849<br>0.94129<br>0.97121<br>-7 +1.0<br>esh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410<br>81.05250<br>136.31300<br>229.25101<br>385.55301<br>648.41998<br>5.91054<br>4.03435<br>2.79015<br>1.98498<br>1.47963<br>1.17812<br>1.01609<br>0.94849<br>0.94129<br>0.97121 | 0.94849<br>0.94129<br>0.97121<br>out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>88.38830<br>148.65100<br>250.00000<br>420.44800<br>707.10699<br>5.91054<br>4.03435<br>2.79015<br>1.98498<br>1.47963<br>1.17812<br>1.01609<br>0.94849<br>0.94129<br>0.97121             | 0.94066<br>0.94811<br>0.98629<br>12.04850<br>20.26310<br>34.07840<br>96.38820<br>162.10500<br>272.62701<br>458.50201<br>771.10498<br>5.20051<br>3.56011<br>2.48122<br>1.78884<br>1.36017<br>1.11110<br>0.98504<br>0.94066<br>0.94811<br>0.98629             | 0.93894<br>0.95282<br>0.99448<br>.99448<br>   | -<br>\$ ratio of pion dE/dx values<br>\$ to proton dE/dx at 1-GeV      |
| C<br>fc554 pi<br>fmesh554:*<br>jmes<br>DE554 LIN<br>DF554 LIN | 0.96294<br>0.93854<br>0.95829<br>1.00303<br>   | 0.95483<br>0.93936<br>0.96445<br>1.01189<br>e at IL1<br>origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>125.00000<br>210.22400<br>353.55301<br>594.60400<br>1000.00000<br>6.30202<br>4.29698<br>2.96259<br>2.09526<br>1.54759<br>1.21727<br>1.03548<br>0.95483<br>0.93936<br>0.96445<br>1.01189   | 0.94849<br>0.94129<br>0.97121<br>-7 +1.0<br>esh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410<br>81.05250<br>136.31300<br>229.25101<br>385.55301<br>648.41998<br>5.91054<br>4.03435<br>2.79015<br>1.98498<br>1.47963<br>1.17812<br>1.01609<br>0.94849<br>0.94129<br>0.97121 | 0.94849<br>0.94129<br>0.97121<br>out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>88.38830<br>148.65100<br>250.00000<br>420.44800<br>707.10699<br>5.91054<br>4.03435<br>2.79015<br>1.98498<br>1.47963<br>1.17812<br>1.01609<br>0.94849<br>0.94129<br>0.97121             | 0.94066<br>0.94811<br>0.98629<br>12.04850<br>20.26310<br>34.07840<br>96.38820<br>162.10500<br>272.62701<br>458.50201<br>771.10498<br>5.20051<br>3.56011<br>2.48122<br>1.78884<br>1.36017<br>1.11110<br>0.98504<br>0.94066<br>0.94811<br>0.98629             | 0.93894<br>0.95282<br>0.99448<br>.99448<br>   | -<br>\$ ratio of pion dE/dx values<br>\$ to proton dE/dx at 1-GeV      |
| C<br>fc554 pi<br>fmesh554:*<br>jmes<br>DE554 LIN<br>DF554 LIN | 0.96294<br>0.93854<br>0.95829<br>1.00303<br>   | 0.95483<br>0.93936<br>0.96445<br>1.01189<br>e at IL1<br>origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>125.00000<br>210.22400<br>353.55301<br>594.60400<br>1000.00000<br>6.30202<br>4.29698<br>2.96259<br>2.09526<br>1.54759<br>1.21727<br>1.03548<br>0.95483<br>0.93936<br>0.96445<br>1.01189   | 0.94849<br>0.94129<br>0.97121<br>-7 +1.0<br>esh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410<br>81.05250<br>136.31300<br>229.25101<br>385.55301<br>648.41998<br>5.91054<br>4.03435<br>2.79015<br>1.98498<br>1.47963<br>1.17812<br>1.01609<br>0.94849<br>0.94129<br>0.97121 | 0.94849<br>0.94129<br>0.97121<br>out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>88.38830<br>148.65100<br>250.00000<br>420.44800<br>707.10699<br>5.91054<br>4.03435<br>2.79015<br>1.98498<br>1.47963<br>1.17812<br>1.01609<br>0.94849<br>0.94129<br>0.97121             | 0.94066<br>0.94811<br>0.98629<br>12.04850<br>20.26310<br>34.07840<br>96.38820<br>162.10500<br>272.62701<br>458.50201<br>771.10498<br>5.20051<br>3.56011<br>2.48122<br>1.78884<br>1.36017<br>1.11110<br>0.98504<br>0.94066<br>0.94811<br>0.98629             | 0.93894<br>0.95282<br>0.99448<br>7.81250<br>13.13900<br>22.09710<br>37.16270<br>62.50000<br>105.11200<br>176.77699<br>297.30200<br>500.00000<br>840.89600<br>4.87881<br>3.34675<br>2.34276<br>1.70182<br>1.30801<br>1.08277<br>0.97297<br>0.93894<br>0.95282<br>0.99448 | -<br>\$ ratio of pion dE/dx values<br>\$ to proton dE/dx at 1-GeV<br>- |
| C<br>fc554 pi<br>fmesh554:*<br>jmes<br>DE554 LIN<br>DF554 LIN | 0.96294<br>0.93854<br>0.95829<br>1.00303<br>   | 0.95483<br>0.93936<br>0.96445<br>1.01189<br>e at IL1<br>origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>125.00000<br>210.22400<br>353.55301<br>594.60400<br>1000.00000<br>6.30202<br>4.29698<br>2.96259<br>2.09526<br>1.54759<br>1.21727<br>1.03548<br>0.95483<br>0.93936<br>0.96445<br>1.01189<br>e at IL1   | 0.94849<br>0.94129<br>0.97121<br>-7 +1.0<br>esh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410<br>81.05250<br>136.31300<br>229.25101<br>385.55301<br>648.41998<br>5.91054<br>4.03435<br>2.79015<br>1.98498<br>1.47963<br>1.17812<br>1.01609<br>0.94849<br>0.94129<br>0.97121 | 0.94849<br>0.94129<br>0.97121<br>out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>88.38830<br>148.65100<br>250.00000<br>420.44800<br>707.10699<br>5.91054<br>4.03435<br>2.79015<br>1.98498<br>1.47963<br>1.17812<br>1.01609<br>0.94849<br>0.94129<br>0.97121             | 0.94066<br>0.94811<br>0.98629<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500<br>272.62701<br>458.50201<br>771.10498<br>5.20051<br>3.56011<br>2.48122<br>1.78884<br>1.36017<br>1.11110<br>0.98504<br>0.94066<br>0.94811<br>0.98629 | 0.93894<br>0.95282<br>0.99448<br>.99448<br>   | -<br>\$ ratio of pion dE/dx values<br>\$ to proton dE/dx at 1-GeV<br>- |
| C<br>fc554 pi<br>fmesh554:*<br>jmes<br>DE554 LIN<br>DF554 LIN | 0.96294<br>0.93854<br>0.95829<br>1.00303<br>   | 0.95483<br>0.93936<br>0.96445<br>1.01189<br>e at IL1<br>origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>26.27800<br>26.27800<br>26.27800<br>125.00000<br>210.22400<br>353.55301<br>594.60400<br>1000.00000<br>6.30202<br>4.29698<br>2.96259<br>2.09526<br>1.54759<br>1.21727<br>1.03548<br>0.95483<br>0.93936<br>0.96445<br>1.01189<br>e at IL1<br>origin=-7  | 0.94849<br>0.94129<br>0.97121<br>-7 +1.0<br>esh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>88.19410<br>81.05250<br>136.31300<br>229.25101<br>385.55301<br>648.41998<br>5.91054<br>4.03435<br>2.79015<br>1.98498<br>1.47963<br>1.17812<br>1.01609<br>0.94849<br>0.94129<br>0.97121 | 0.94849<br>0.94129<br>0.97121<br>out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>82.35800<br>83.38830<br>148.65100<br>250.00000<br>420.44800<br>707.10699<br>5.91054<br>4.03435<br>2.79015<br>1.98498<br>1.47963<br>1.17812<br>1.01609<br>0.94849<br>0.94129<br>0.97121 | 0.94066<br>0.94811<br>0.98629<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500<br>272.62701<br>458.50201<br>771.10498<br>5.20051<br>3.56011<br>2.48122<br>1.78884<br>1.36017<br>1.11110<br>0.98504<br>0.94066<br>0.94811<br>0.98629 | 0.93894<br>0.95282<br>0.99448<br>7.81250<br>13.13900<br>22.09710<br>37.16270<br>62.50000<br>105.11200<br>176.77699<br>297.30200<br>500.00000<br>840.89600<br>4.87881<br>3.34675<br>2.34276<br>1.70182<br>1.30801<br>1.08277<br>0.97297<br>0.93894<br>0.95282<br>0.99448 | -<br>\$ ratio of pion dE/dx values<br>\$ to proton dE/dx at 1-GeV<br>- |

| imes       | sh 7 iints <sup>-</sup> | 1400             |             |                      |             |            |   |
|------------|-------------------------|------------------|-------------|----------------------|-------------|------------|---|
| jmes       | sh 7 jints <sup>.</sup> | 1400 kme         | esh +1.2    | out=cf               |             |            |   |
| DE654 LIN  | 5.06578                 | 5.52427          | 6.02426     | 6.56950              | 7.16409     | 7.81250    |   |
|            | 8.51959                 | 9.29068          | 10.13160    | 11.04850             | 12.04850    | 13.13900   |   |
|            | 14.32820                | 15.62500         | 17.03920    | 18.58140             | 20.26310    | 22.09710   |   |
|            | 24.09700                | 26.27800         | 28.65640    | 31.25000             | 34.07840    | 37.16270   |   |
|            | 40.52620                | 44.19420         | 48.19410    | 52.55600             | 57.31280    | 62.50000   |   |
|            | 68.15670                | 74.32540         | 81.05250    | 88.38830             | 96.38820    | 105.11200  |   |
|            | 114.62600               | 125.00000        | 136.31300   | 148.65100            | 162.10500   | 176.77699  |   |
|            | 192.77600               | 210.22400        | 229.25101   | 250.00000            | 272.62701   | 297.30200  |   |
|            | 324.20999               | 353.55301        | 385.55301   | 420.44800            | 458.50201   | 500.00000  |   |
|            | 545.25403               | 594.60400        | 648.41998   | 707.10699            | 771.10498   | 840.89600  |   |
|            | 917.00403               | 1000.00000       |             |                      |             |            |   |
| DF654 LIN  | 5.46768                 | 5.12906          | 4.81208     | 4.81208              | 4.23864     | 3.97987    | <pre>\$ ratio of muon dE/dx values</pre>                              |
|            | 3.73813                 | 3.51271          | 3.30252     | 3.30252              | 2.92424     | 2.75446    | \$ to proton dE/dx at 1-GeV   |
|            | 2.59712                 | 2.45038          | 2.31414     | 2.31414              | 2.07065     | 1.96219    |   |
|            | 1.86209                 | 1.76934          | 1.68382     | 1.68382              | 1.53230     | 1.46558    |   |
|            | 1.40439                 | 1.34837          | 1.29722     | 1.29722              | 1.20832     | 1.17001    |   |
|            | 1.13548                 | 1.10451          | 1.07689     | 1.07689              | 1.03084     | 1.01203    |   |
|            | 0.99580                 | 0.98199          | 0.97036     | 0.97036              | 0.95301     | 0.94702    |   |
|            | 0.94266                 | 0.93981          | 0.93837     | 0.93837              | 0.93926     | 0.94139    |   |
|            | 0.94451                 | 0.94855          | 0.95341     | 0.95341              | 0.96525     | 0.97210    |   |
|            | 0.97946                 | 0.98728          | 0.99551     | 0.99551              | 1.01294     | 1.02205    |   |
|            | 1.03136                 | 1.04084          |             |                      |             |            |   |
| с          |                         |                  |             |                      |             |            |   |
| fc754 mu   | - image                 | e at IL1         |             |                      |             |            |   |
| fmesh754:  | geom=rec                | origin=-7        | -7 +1.0     |                      |             |            |   |
| imes       | sh 7 iints '            | 1400             |             |                      |             |            |   |
| jmes       | sh 7 jints '            | 1400 kme         | esh +1.2    | out=cf               |             |            |   |
| DE754 LIN  | 5.06578                 | 5.52427          | 6.02426     | 6.56950              | 7.16409     | 7.81250    |   |
|            | 8.51959                 | 9.29068          | 10.13160    | 11.04850             | 12.04850    | 13.13900   |   |
|            | 14.32820                | 15.62500         | 17.03920    | 18.58140             | 20.26310    | 22.09710   |   |
|            | 24.09700                | 26.27800         | 28.65640    | 31.25000             | 34.07840    | 37.16270   |   |
|            | 40.52620                | 44.19420         | 48.19410    | 52.55600             | 57.31280    | 62.50000   |   |
|            | 68.15670                | 74.32540         | 81.05250    | 88.38830             | 96.38820    | 105.11200  |   |
|            | 114.62600               | 125.00000        | 136.31300   | 148.65100            | 162.10500   | 176.77699  |   |
|            | 192.77600               | 210.22400        | 229.25101   | 250.00000            | 272.62701   | 297.30200  |   |
|            | 324.20999               | 353.55301        | 385.55301   | 420.44800            | 458.50201   | 500.00000  |   |
|            | 545.25403               | 594.60400        | 648.41998   | 707.10699            | 771.10498   | 840.89600  |   |
|            | 917.00403               | 1000.00000       |             |                      |             |            |   |
| DF754 LIN  | 5.46768                 | 5.12906          | 4.81208     | 4.81208              | 4.23864     | 3.97987    | \$ ratio of muon dE/dx values   |
|            | 3.73813                 | 3.51271          | 3.30252     | 3.30252              | 2.92424     | 2.75446    | \$ to proton dE/dx at 1-GeV   |
|            | 2.59712                 | 2.45038          | 2.31414     | 2.31414              | 2.07065     | 1.96219    |   |
|            | 1.86209                 | 1.76934          | 1.68382     | 1.68382              | 1.53230     | 1.46558    |   |
|            | 1.40439                 | 1.34837          | 1.29722     | 1.29722              | 1.20832     | 1.17001    |   |
|            | 1.13548                 | 1.10451          | 1.07689     | 1.07689              | 1.03084     | 1.01203    |   |
|            | 0.99580                 | 0.98199          | 0.97036     | 0.97036              | 0.95301     | 0.94702    |   |
|            | 0.94266                 | 0.93981          | 0.93837     | 0.93837              | 0.93926     | 0.94139    |   |
|            | 0.94451                 | 0.94855          | 0.95341     | 0.95341              | 0.96525     | 0.97210    |   |
|            | 0.97946                 | 0.98728          | 0.99551     | 0.99551              | 1.01294     | 1.02205    |   |
| _          | 1.03136                 | 1.04084          |             |                      |             |            |   |
| C          |                         |                  |             |                      |             |            |   |
| TC854 det  | iteron image            | e at ILI         | a's are the | e largest tr         | action of o | ther stuff |   |
| Tmesn854:0 | geom=rec                | origin=-7        | -7 +1.0     |                      |             |            |   |
| Intes      | SN 7 IINLS              | 1400<br>1400 kma | ab 110      | out-of               |             |            |   |
|            |                         | 1400 Kille       | e 00406     |                      | 7 16400     | 7 01050    |   |
| DE834 LIN  | 5.00578                 | 5.52427          | 0.02420     | 0.00900              | 7.10409     | 7.81250    |   |
|            | 8.01909                 | 9.29008          | 17 02000    | 10 50140             | 12.04850    | 13.13900   |   |
|            | 14.32820                | 10.02000         | 11.00920    | 10.00140             | 20.20310    | 22.09/10   |   |
|            | 24.09/00                | 20.2/800         | 20.00040    | 31.23000<br>50 55600 | 54.0/840    | 37.102/U   |   |
|            | 40.52620                | 44.19420         | 40.19410    | 02.00000             | 06 20000    | 105 11000  |   |
|            | 11/ 60600               | 105 00000        | 126 21200   | 140 65400            | 30.3002U    | 176 77600  |   |
|            | 102 77600               | 210 22400        | 220 251000  | 250 00000            | 102.10000   | 1/0.//099  |   |
|            | 192.//000               | 210.22400        | 229.20101   | 200.00000            | 212.02/UI   | 291.30200  |   |
|            | 324.20999               | 333.55301        | 383.55301   | 420.44800            | 438.50201   | 500.00000  |   |
|            | 017 00400               | 1000 00000       | 040.41998   | 101.10099            | //1.10498   | 040.89000  |   |
|            | 917.00403               | 1000.00000       | 40 00010    | 40 06040             |             | 00 00004   | ¢ notio of doutones dride   |
| UF854 LIN  | 40.99316                | 43.849/4         | 40.80316    | 40.80310             | 33.35503    | 32.83821   | $\varphi$ ratio or deuteron dE/dX<br>$\Phi$ to proton dE/dy at 1 Call |
|            | 00.40042                | 20.19230         | 20.0/328    | 20.0/320             | 20.00004    | <1. (000)  |   |
|            | 20 50005                | 10 25507         | 10 00000    | 10 00000             | 16 17406    | 15 01000   |   |
|            | 20.52985                | 19.35507         | 18.23888    | 18.23888             | 16.17406    | 15.21982   |   |

|  | 14.32294   | 13.46847  | 12.66044  | 12.66044  | 11.17413  | 10.49369  |   |
|--|--|---|---|---|---|---|---|
|  | 9.85235  | 9.24588   | 8.67708   | 8.67708   | 7.63658   | 7.16322   |   |
|  | 6.71806  | 6.30098   | 5.90950   | 5.90950   | 5.19951   | 4.87786   |   |
|  | 4.57721  | 4.29610   | 4.03353   | 4.03353   | 3.55937   | 3.34606   |   |
|  | 3.14/18  | 2.96202   | 2.78962   | 2.78962   | 2.48081   | 2.34240   |   |
|  | 2.21404  | 2.09500   | 1.98478   | 1.98478   | 1.78873   | 1.70176   |   |
|  | 1.02150  | 1.54/01   | 1.4/9/0   | 1.4/9/0   | 1.36034   | 1.30822   |   |
| 0  | 1.20072  | 1.21750   |   |   |   |   | _   |
| fc954 tr   | iton image   | at TI 1   |   |   |   |   |   |
| fmesh954:t   | deom=rec   | origin=-7   | -7 +1.0   |   |   |   |   |
| ime  | sh 7 iints 1   | 1400  |   |   |   |   |   |
| ime  | sh 7 jints 1   | 1400 kme  | sh +1.2   | out=cf  |   |   |   |
| DE954 LÍN  | 5.06578  | 5.52427   | 6.02426   | 6.56950   | 7.16409   | 7.81250   |   |
|  | 8.51959  | 9.29068   | 10.13160  | 11.04850  | 12.04850  | 13.13900  |   |
|  | 14.32820   | 15.62500  | 17.03920  | 18.58140  | 20.26310  | 22.09710  |   |
|  | 24.09700   | 26.27800  | 28.65640  | 31.25000  | 34.07840  | 37.16270  |   |
|  | 40.52620   | 44.19420  | 48.19410  | 52.55600  | 57.31280  | 62.50000  |   |
|  | 68.15670   | 74.32540  | 81.05250  | 88.38830  | 96.38820  | 105.11200   |   |
|  | 114.62600  | 125.00000   | 136.31300   | 148.65100   | 162.10500   | 176.77699   |   |
|  | 192.77600  | 210.22400   | 229.25101   | 250.00000   | 272.62701   | 297.30200   |   |
|  | 524.20999  | 504 60400   | 383.33301   | 420.44800   | 438.30201   | 500.00000   |   |
|  | 917 00403  | 1000 00000  | 040.41990   | 707.10099   | //1.10496   | 640.69000   |   |
| DF954 LIN  | 63.82817   | 59,91015  | 56,16025  | 56,16025  | 49,15790  | 45,91025  | \$ ratio of triton dE/dx  |
| DI SOF LIN   | 42.82045   | 39.88614  | 37.11004  | 37.11004  | 32.01544  | 29.66841  | \$ to proton dF/dx at 1-GeV                                       |
|  | 27.46039   | 25.38572  | 23.95152  | 23.95152  | 21.33982  | 20.12637  |   |
|  | 18.97208   | 17.87300  | 16.83272  | 16.83272  | 14.91396  | 14.02916  |   |
|  | 13.18993   | 12.39757  | 11.64733  | 11.64733  | 10.27243  | 9.64296   |   |
|  | 9.04943  | 8.49191   | 7.96623   | 7.96623   | 7.00925   | 6.57388   |   |
|  | 6.16580  | 5.78267   | 5.42411   | 5.42411   | 4.77385   | 4.47999   |   |
|  | 4.20520  | 3.94859   | 3.70890   | 3.70890   | 3.27715   | 3.08300   |   |
|  | 2.90226  | 2.73404   | 2.57816   | 2.57816   | 2.29787   | 2.17273   |   |
|  | 2.05674  | 1.94937   | 1.85027   | 1.85027   | 1.67385   | 1.59580   |   |
|  | 1.52399  | 1.45801   |   |   |   |   |   |
| 0  |  |   |   |   |   |   |   |
| C  | <br>   | <br>at TI 1   |   |   |   |   | -   |
| c<br>fc1054 31<br>fmesh1054:   | He imag<br>s geom=reg  | ge at IL1<br>c origin=-7  |   |   |   |   | -   |
| c<br>fc1054 31<br>fmesh1054:<br>ime:   | He imag<br>s geom=rec<br>sh 7 iints 1  | ge at IL1<br>c origin=-7<br>1400  | -7 +1.0   |   |   |   | -   |
| c<br>fc1054 31<br>fmesh1054:<br>ime:<br>jme:   | He imag<br>s geom=rec<br>sh 7 iints 1<br>sh 7 jints 1  | ge at IL1<br>c origin=-7<br>1400<br>1400 kme  |   | out=cf  |   |   | -   |
| c<br>fc1054 31<br>fmesh1054::<br>ime:<br>jme:<br>DE1054 LIN  | He imag<br>s geom=rec<br>sh 7 iints 1<br>sh 7 jints 1<br>5.06578   | ge at IL1<br>c origin=-7<br>1400<br>1400 kme<br>5.52427   | -7 +1.0<br>sh +1.2<br>6.02426   | out=cf<br>6.56950   | 7.16409   | 7.81250   | -   |
| C<br>fc1054 31<br>fmesh1054:<br>ime:<br>jme:<br>DE1054 LIN   | He imag<br>s geom=rec<br>sh 7 iints 1<br>sh 7 jints 1<br>5.06578<br>8.51959  | ge at IL1<br>c origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068  | -7 +1.0<br>sh +1.2<br>6.02426<br>10.13160   | out=cf<br>6.56950<br>11.04850   | 7.16409<br>12.04850   | 7.81250<br>13.13900   | -   |
| C<br>fc1054 31<br>fmesh1054:<br>ime:<br>jme:<br>DE1054 LIN   | He imag<br>s geom=red<br>sh 7 iints 1<br>sh 7 jints 1<br>5.06578<br>8.51959<br>14.32820  | ge at IL1<br>c origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068<br>15.62500  | -7 +1.0<br>sh +1.2<br>6.02426<br>10.13160<br>17.03920   | out=cf<br>6.56950<br>11.04850<br>18.58140   | 7.16409<br>12.04850<br>20.26310   | 7.81250<br>13.13900<br>22.09710   | -   |
| C<br>fc1054 31<br>fmesh1054:<br>ime:<br>jme:<br>DE1054 LIN   | He imag<br>s geom=red<br>sh 7 iints 1<br>sh 7 jints 1<br>5.06578<br>8.51959<br>14.32820<br>24.09700  | ge at IL1<br>c origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800  | -7 +1.0<br>sh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640   | out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000   | 7.16409<br>12.04850<br>20.26310<br>34.07840   | 7.81250<br>13.13900<br>22.09710<br>37.16270   | -   |
| C<br>fc1054 31<br>fmesh1054:<br>ime:<br>jme:<br>DE1054 LIN   | He imag<br>s geom=red<br>sh 7 iints 1<br>sh 7 jints 1<br>5.06578<br>8.51959<br>14.32820<br>24.09700<br>40.52620  | ge at IL1<br>c origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420  | -7 +1.0<br>sh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410   | out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600   | 7.16409<br>12.04850<br>20.26310<br>34.07840<br>57.31280   | 7.81250<br>13.13900<br>22.09710<br>37.16270<br>62.50000   | -   |
| C<br>fc1054 31<br>fmesh1054:<br>ime:<br>jme:<br>DE1054 LIN   | He imag<br>s geom=red<br>sh 7 iints 1<br>sh 7 jints 1<br>5.06578<br>8.51959<br>14.32820<br>24.09700<br>40.52620<br>68.15670  | ge at IL1<br>c origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420<br>74.32540  | -7 +1.0<br>sh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410<br>81.05250   | out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600<br>88.38830   | 7.16409<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820   | 7.81250<br>13.13900<br>22.09710<br>37.16270<br>62.50000<br>105.11200  | -   |
| C<br>fc1054 31<br>fmesh1054:<br>ime:<br>jme:<br>DE1054 LIN   | He imag<br>s geom=red<br>sh 7 iints 1<br>5.06578<br>8.51959<br>14.32820<br>24.09700<br>40.52620<br>68.15670<br>114.62600   | ge at IL1<br>c origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420<br>74.32540<br>125.00000   | -7 +1.0<br>sh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410<br>81.05250<br>136.31300  | out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600<br>88.38830<br>148.65100  | 7.16409<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500  | 7.81250<br>13.13900<br>22.09710<br>37.16270<br>62.50000<br>105.11200<br>176.77699   | -   |
| C<br>fc1054 31<br>fmesh1054:<br>ime<br>jme<br>DE1054 LIN   | He imag<br>s geom=red<br>sh 7 iints 1<br>sh 7 jints 1<br>5.06578<br>8.51959<br>14.32820<br>24.09700<br>40.52620<br>68.15670<br>114.62600<br>192.77600<br>224.20000   | ge at IL1<br>c origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420<br>74.32540<br>125.00000<br>210.22400<br>2530  | -7 +1.0<br>sh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410<br>81.05250<br>136.31300<br>229.25101<br>285.65401  | out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600<br>88.38830<br>148.65100<br>250.00000<br>420 44800  | 7.16409<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500<br>272.62701   | 7.81250<br>13.13900<br>22.09710<br>37.16270<br>62.50000<br>105.11200<br>176.77699<br>297.30200<br>500.00000   | -   |
| C<br>fc1054 31<br>fmesh1054:<br>ime<br>jme<br>DE1054 LIN   | He imag<br>s geom=red<br>sh 7 iints 1<br>sh 7 jints 1<br>5.06578<br>8.51959<br>14.32820<br>24.09700<br>40.52620<br>68.15670<br>114.62600<br>192.77600<br>324.20999<br>545 25403  | ge at IL1<br>c origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420<br>74.32540<br>125.00000<br>210.22400<br>353.55301<br>594 60400  | -7 +1.0<br>sh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410<br>81.05250<br>136.31300<br>229.25101<br>385.55301<br>648.41998   | out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600<br>88.38830<br>148.65100<br>250.00000<br>420.44800<br>707 10699   | 7.16409<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500<br>272.62701<br>458.50201<br>771.10498   | 7.81250<br>13.13900<br>22.09710<br>37.16270<br>62.50000<br>105.11200<br>176.77699<br>297.30200<br>500.00000<br>840.89600  | -   |
| C<br>fc1054 31<br>fmesh1054:<br>ime<br>jme<br>DE1054 LIN   | He imag<br>s geom=red<br>sh 7 iints 1<br>5.06578<br>8.51959<br>14.32820<br>24.09700<br>40.52620<br>68.15670<br>114.62600<br>192.77600<br>324.20999<br>545.25403<br>917.00403   | ge at IL1<br>c origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420<br>74.32540<br>125.00000<br>210.22400<br>353.55301<br>594.60400<br>1000.00000  | -7 +1.0<br>sh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410<br>81.05250<br>136.31300<br>229.25101<br>385.55301<br>648.41998   | out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600<br>88.38830<br>148.65100<br>250.00000<br>420.44800<br>707.10699   | 7.16409<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500<br>272.62701<br>458.50201<br>771.10498   | 7.81250<br>13.13900<br>22.09710<br>37.16270<br>62.50000<br>105.11200<br>176.77699<br>297.30200<br>500.00000<br>840.89600  | -   |
| C<br>fc1054 31<br>fmesh1054:<br>jme<br>DE1054 LIN  | He imag<br>s geom=rec<br>sh 7 iints 1<br>5.06578<br>8.51959<br>14.32820<br>24.09700<br>40.52620<br>68.15670<br>114.62600<br>192.77600<br>324.20999<br>545.25403<br>917.00403<br>251.35355  | ge at IL1<br>c origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420<br>74.32540<br>125.00000<br>210.22400<br>353.55301<br>594.60400<br>1000.00000<br>236.69599   | -7 +1.0<br>sh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410<br>81.05250<br>136.31300<br>229.25101<br>385.55301<br>648.41998<br>222.48483  | out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600<br>88.38830<br>148.65100<br>250.00000<br>420.44800<br>707.10699<br>222.48483  | 7.16409<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500<br>272.62701<br>458.50201<br>771.10498<br>195.55695  | 7.81250<br>13.13900<br>22.09710<br>37.16270<br>62.50000<br>105.11200<br>176.77699<br>297.30200<br>500.00000<br>840.89600<br>182.91138   | -<br>\$ ratio of helion dE/dx                                     |
| C<br>fc1054 31<br>fmesh1054:<br>jme<br>DE1054 LIN<br>DE1054 LIN  | He imag<br>s geom=red<br>sh 7 iints 1<br>5.06578<br>8.51959<br>14.32820<br>24.09700<br>40.52620<br>68.15670<br>114.62600<br>192.77600<br>324.20999<br>545.25403<br>917.00403<br>251.35355<br>170.79847   | ge at IL1<br>c origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420<br>74.32540<br>125.00000<br>210.22400<br>353.55301<br>594.60400<br>1000.00000<br>236.69599<br>159.23402  | -7 +1.0<br>sh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410<br>81.05250<br>136.31300<br>229.25101<br>385.55301<br>648.41998<br>222.48483<br>148.24679   | out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600<br>88.38830<br>148.65100<br>250.00000<br>420.44800<br>707.10699<br>222.48483<br>148.24679   | 7.16409<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500<br>272.62701<br>458.50201<br>771.10498<br>195.55695<br>127.99319   | 7.81250<br>13.13900<br>22.09710<br>37.16270<br>62.50000<br>105.11200<br>176.77699<br>297.30200<br>500.00000<br>840.89600<br>182.91138<br>118.63409  | <pre>- \$ ratio of helion dE/dx \$ to proton dE/dx at 1-GeV</pre> |
| C<br>fc1054 31<br>fmesh1054:<br>jme:<br>DE1054 LIN<br>DE1054 LIN   | He imag<br>s geom=red<br>sh 7 iints 1<br>5.06578<br>8.51959<br>14.32820<br>24.09700<br>40.52620<br>68.15670<br>114.62600<br>192.77600<br>324.20999<br>545.25403<br>917.00403<br>251.35355<br>170.79847<br>109.81699  | ge at IL1<br>c origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420<br>74.32540<br>125.00000<br>210.22400<br>353.55301<br>594.60400<br>1000.00000<br>236.69599<br>159.23402<br>101.52535   | -7 +1.0<br>sh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410<br>81.05250<br>136.31300<br>229.25101<br>385.55301<br>648.41998<br>222.48483<br>148.24679<br>95.79416   | out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600<br>88.38830<br>148.65100<br>250.00000<br>420.44800<br>707.10699<br>222.48483<br>148.24679<br>95.79416   | 7.16409<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500<br>272.62701<br>458.50201<br>771.10498<br>195.55695<br>127.99319<br>85.34892   | 7.81250<br>13.13900<br>22.09710<br>37.16270<br>62.50000<br>105.11200<br>176.77699<br>297.30200<br>500.00000<br>840.89600<br>182.91138<br>118.63409<br>80.49541  | -<br>\$ ratio of helion dE/dx<br>\$ to proton dE/dx at 1-GeV      |
| C<br>fc1054 31<br>fmesh1054:<br>jme<br>DE1054 LIN<br>DE1054 LIN  | He imag<br>s geom=red<br>sh 7 iints 1<br>5.06578<br>8.51959<br>14.32820<br>24.09700<br>40.52620<br>68.15670<br>114.62600<br>192.77600<br>324.20999<br>545.25403<br>917.00403<br>251.35355<br>170.79847<br>109.81699<br>75.87840  | ge at IL1<br>c origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420<br>74.32540<br>125.00000<br>210.22400<br>253.55301<br>594.60400<br>1000.00000<br>236.69599<br>159.23402<br>101.52535<br>71.48250   | -7 +1.0<br>sh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410<br>81.05250<br>136.31300<br>229.25101<br>385.55301<br>648.41998<br>222.48483<br>148.24679<br>95.79416<br>67.32202   | out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600<br>88.38830<br>148.65100<br>250.00000<br>420.44800<br>707.10699<br>222.48483<br>148.24679<br>95.79416<br>67.32202   | 7.16409<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500<br>272.62701<br>458.50201<br>771.10498<br>195.55695<br>127.99319<br>85.34892<br>59.64778   | 7.81250<br>13.13900<br>22.09710<br>37.16270<br>62.50000<br>105.11200<br>176.77699<br>297.30200<br>500.00000<br>840.89600<br>182.91138<br>118.63409<br>80.49541<br>56.10900  | -<br>\$ ratio of helion dE/dx<br>\$ to proton dE/dx at 1-GeV      |
| C<br>fc1054 31<br>fmesh1054:<br>jme<br>DE1054 LIN<br>DE1054 LIN  | He imag<br>s geom=red<br>sh 7 iints 1<br>5.06578<br>8.51959<br>14.32820<br>24.09700<br>40.52620<br>68.15670<br>114.62600<br>192.77600<br>324.20999<br>545.25403<br>917.00403<br>251.35355<br>170.79847<br>109.81699<br>75.87840<br>52.75274  | ge at IL1<br>c origin=-7<br>1400<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420<br>74.32540<br>125.00000<br>210.22400<br>353.55301<br>594.60400<br>1000.00000<br>236.69599<br>159.23402<br>101.52535<br>71.48250<br>49.58344   | -7 +1.0<br>sh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410<br>81.05250<br>136.31300<br>229.25101<br>385.55301<br>648.41998<br>222.48483<br>148.24679<br>95.79416<br>67.32202<br>46.58300   | out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600<br>88.38830<br>148.65100<br>250.00000<br>420.44800<br>707.10699<br>222.48483<br>148.24679<br>95.79416<br>67.32202<br>46.58300   | 7.16409<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500<br>272.62701<br>458.50201<br>771.10498<br>195.55695<br>127.99319<br>85.34892<br>59.64778<br>41.08420   | 7.81250<br>13.13900<br>22.09710<br>37.16270<br>62.50000<br>105.11200<br>176.77699<br>297.30200<br>500.00000<br>840.89600<br>182.91138<br>118.63409<br>80.49541<br>56.10900<br>38.56652  | -<br>\$ ratio of helion dE/dx<br>\$ to proton dE/dx at 1-GeV      |
| C<br>fc1054 31<br>fmesh1054:<br>jme<br>DE1054 LIN<br>DE1054 LIN  | He imag<br>s geom=rec<br>sh 7 iints 1<br>5.06578<br>8.51959<br>14.32820<br>24.09700<br>40.52620<br>68.15670<br>114.62600<br>192.77600<br>324.20999<br>545.25403<br>917.00403<br>251.35355<br>170.79847<br>109.81699<br>75.87840<br>52.75274<br>36.19267  | ge at IL1<br>c origin=-7<br>400<br>400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420<br>74.32540<br>125.00000<br>210.22400<br>253.55301<br>594.60400<br>1000.00000<br>236.69599<br>159.23402<br>101.52535<br>71.48250<br>49.58344<br>33.96295   | -7 +1.0<br>sh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410<br>81.05250<br>136.31300<br>229.25101<br>385.55301<br>648.41998<br>222.48483<br>148.24679<br>95.79416<br>67.32202<br>46.58300<br>31.86046   | out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600<br>88.38830<br>148.65100<br>250.00000<br>420.44800<br>707.10699<br>222.48483<br>148.24679<br>95.79416<br>67.32202<br>46.58300<br>31.86046   | 7.16409<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500<br>272.62701<br>458.50201<br>771.10498<br>195.55695<br>127.99319<br>85.34892<br>59.64778<br>41.08420<br>28.03308   | 7.81250<br>13.13900<br>22.09710<br>37.16270<br>62.50000<br>105.11200<br>176.77699<br>297.30200<br>500.00000<br>840.89600<br>182.91138<br>118.63409<br>80.49541<br>56.10900<br>38.56652<br>26.29187  | -<br>\$ ratio of helion dE/dx<br>\$ to proton dE/dx at 1-GeV      |
| C<br>fc1054 31<br>fmesh1054:<br>jme<br>DE1054 LIN<br>DE1054 LIN  | He imag<br>s geom=rec<br>sh 7 iints 1<br>5.06578<br>8.51959<br>14.32820<br>24.09700<br>40.52620<br>68.15670<br>114.62600<br>0192.77600<br>324.20999<br>545.25403<br>917.00403<br>251.35355<br>170.79847<br>109.81699<br>75.87840<br>52.75274<br>36.19267<br>24.65978   | ge at IL1<br>c origin=-7<br>400<br>400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420<br>74.32540<br>125.00000<br>210.22400<br>253.55301<br>594.60400<br>1000.00000<br>236.69599<br>159.23402<br>101.52535<br>71.48250<br>49.58344<br>33.96295<br>23.12746   | -7 +1.0<br>sh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410<br>81.05250<br>136.31300<br>229.25101<br>385.55301<br>648.41998<br>222.48483<br>148.24679<br>95.79416<br>67.32202<br>46.58300<br>31.86046<br>21.69341   | out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600<br>88.38830<br>148.65100<br>250.00000<br>707.10699<br>222.48483<br>148.24679<br>95.79416<br>67.32202<br>46.58300<br>31.86046<br>21.69341  | 7.16409<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500<br>272.62701<br>458.50201<br>771.10498<br>195.55695<br>127.99319<br>85.34892<br>59.64778<br>41.08420<br>28.03308<br>19.09277                                   | 7.81250<br>13.13900<br>22.09710<br>37.16270<br>62.50000<br>105.11200<br>176.77699<br>297.30200<br>500.00000<br>840.89600<br>182.91138<br>118.63409<br>80.49541<br>56.10900<br>38.56652<br>26.29187<br>17.91749  | -<br>\$ ratio of helion dE/dx<br>\$ to proton dE/dx at 1-GeV      |
| C<br>fc1054 31<br>fmesh1054:<br>jme<br>DE1054 LIN<br>DF1054 LIN  | He imag<br>s geom=red<br>sh 7 iints 1<br>5.06578<br>8.51959<br>14.32820<br>24.09700<br>40.52620<br>68.15670<br>114.62600<br>192.77600<br>324.20999<br>545.25403<br>917.00403<br>251.35355<br>170.79847<br>109.81699<br>75.87840<br>52.75274<br>36.19267<br>24.65978<br>16.81848  | ge at IL1<br>c origin=-7<br>400<br>400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420<br>74.32540<br>125.00000<br>210.22400<br>253.55301<br>594.60400<br>1000.00000<br>236.69599<br>159.23402<br>101.52535<br>71.48250<br>49.58344<br>33.96295<br>23.12746<br>15.79222   | -7 +1.0<br>sh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410<br>81.05250<br>136.31300<br>229.25101<br>385.55301<br>648.41998<br>222.48483<br>148.24679<br>95.79416<br>67.32202<br>46.58300<br>31.86046<br>21.69341<br>14.83359   | out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600<br>88.38830<br>148.65100<br>250.00000<br>420.44800<br>707.10699<br>222.48483<br>148.24679<br>95.79416<br>67.32202<br>46.58300<br>31.86046<br>21.69341<br>14.83359   | 7.16409<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500<br>272.62701<br>458.50201<br>771.10498<br>195.55695<br>127.99319<br>85.34892<br>59.64778<br>41.08420<br>28.03308<br>19.09277<br>13.10683                       | 7.81250<br>13.13900<br>22.09710<br>37.16270<br>62.50000<br>105.11200<br>176.77699<br>297.30200<br>500.00000<br>840.89600<br>182.91138<br>118.63409<br>80.49541<br>56.10900<br>38.56652<br>26.29187<br>17.91749<br>12.33043  | -<br>\$ ratio of helion dE/dx<br>\$ to proton dE/dx at 1-GeV      |
| C<br>fc1054 31<br>fmesh1054:<br>jme<br>DE1054 LIN<br>DE1054 LIN  | He imag<br>s geom=rec<br>sh 7 iints 1<br>5.06578<br>8.51959<br>14.32820<br>24.09700<br>40.52620<br>68.15670<br>114.62600<br>192.77600<br>324.20999<br>545.25403<br>917.00403<br>251.35355<br>170.79847<br>109.81699<br>75.87840<br>52.75274<br>36.19267<br>24.65978<br>16.81848<br>11.60751  | ge at IL1<br>c origin=-7<br>400<br>400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420<br>74.32540<br>125.00000<br>210.22400<br>253.55301<br>594.60400<br>1000.00000<br>236.69599<br>159.23402<br>101.52535<br>71.48250<br>49.58344<br>33.96295<br>23.12746<br>15.79222<br>10.93476   | -7 +1.0<br>sh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410<br>81.05250<br>136.31300<br>229.25101<br>385.55301<br>648.41998<br>222.48483<br>148.24679<br>95.79416<br>67.32202<br>46.58300<br>31.86046<br>21.69341<br>14.83359<br>10.31132   | out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600<br>88.38830<br>148.65100<br>250.00000<br>707.10699<br>222.48483<br>148.24679<br>95.79416<br>67.32202<br>46.58300<br>31.86046<br>21.69341<br>14.83359<br>10.31132  | 7.16409<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500<br>272.62701<br>458.50201<br>771.10498<br>195.55695<br>127.99319<br>85.34892<br>59.64778<br>41.08420<br>28.03308<br>19.09277<br>13.10683<br>9.19032            | 7.81250<br>13.13900<br>22.09710<br>37.16270<br>62.50000<br>105.11200<br>176.77699<br>297.30200<br>500.00000<br>840.89600<br>182.91138<br>118.63409<br>80.49541<br>56.10900<br>38.56652<br>26.29187<br>17.91749<br>12.33043<br>8.68987<br>20255                                      | -<br>\$ ratio of helion dE/dx<br>\$ to proton dE/dx at 1-GeV      |
| C<br>fc1054 31<br>fmesh1054:<br>jme:<br>DE1054 LIN<br>DF1054 LIN   | He images geom=recessors of 7 iints 1<br>sh 7 jints 1<br>5.06578<br>8.51959<br>14.32820<br>24.09700<br>40.52620<br>68.15670<br>114.62600<br>324.20999<br>545.25403<br>917.00403<br>251.35355<br>170.79847<br>109.81699<br>75.87840<br>52.75274<br>36.19267<br>24.65978<br>16.81848<br>11.60751<br>8.22594  | ge at IL1<br>c origin=-7<br>400<br>400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420<br>74.32540<br>125.00000<br>210.22400<br>353.55301<br>594.60400<br>1000.00000<br>236.69599<br>159.23402<br>101.52535<br>71.48250<br>49.58344<br>33.96295<br>23.12746<br>15.79222<br>10.93476<br>7.79659<br>5 22140   | -7 +1.0<br>sh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>84.19410<br>81.05250<br>136.31300<br>229.25101<br>385.55301<br>648.41998<br>222.48483<br>148.24679<br>95.79416<br>67.32202<br>46.58300<br>31.86046<br>21.69341<br>14.83359<br>10.31132<br>7.40023  | out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600<br>88.38830<br>148.65100<br>250.00000<br>420.44800<br>707.10699<br>222.48483<br>148.24679<br>95.79416<br>67.32202<br>46.58300<br>31.86046<br>21.69341<br>14.83359<br>10.31132<br>7.40023  | 7.16409<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500<br>272.62701<br>458.50201<br>771.10498<br>195.55695<br>127.99319<br>85.34892<br>59.64778<br>41.08420<br>28.03308<br>19.09277<br>13.10683<br>9.19032<br>6.69472 | 7.81250<br>13.13900<br>22.09710<br>37.16270<br>62.50000<br>105.11200<br>176.77699<br>297.30200<br>500.00000<br>840.89600<br>182.91138<br>118.63409<br>80.49541<br>56.10900<br>38.56652<br>26.29187<br>17.91749<br>12.33043<br>8.68987<br>6.38256                                    | -<br>\$ ratio of helion dE/dx<br>\$ to proton dE/dx at 1-GeV      |
| C<br>fc1054 31<br>fmesh1054:<br>jme:<br>DE1054 LIN<br>DF1054 LIN   | He images geom=recessors of the second secon | ge at IL1<br>c origin=-7<br>1400<br>kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420<br>74.32540<br>125.00000<br>210.22400<br>353.55301<br>594.60400<br>1000.00000<br>236.69599<br>159.23402<br>101.52535<br>71.48250<br>49.58344<br>33.96295<br>23.12746<br>15.79222<br>10.93476<br>7.79659<br>5.83149  | -7 +1.0<br>sh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410<br>81.05250<br>136.31300<br>229.25101<br>385.55301<br>648.41998<br>222.48483<br>148.24679<br>95.79416<br>67.32202<br>46.58300<br>31.86046<br>21.69341<br>14.83359<br>10.31132<br>7.40023  | out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600<br>88.38830<br>148.65100<br>250.00000<br>420.44800<br>707.10699<br>222.48483<br>148.24679<br>95.79416<br>67.32202<br>46.58300<br>31.86046<br>21.69341<br>14.83359<br>10.31132<br>7.40023  | 7.16409<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500<br>272.62701<br>458.50201<br>771.10498<br>195.55695<br>127.99319<br>85.34892<br>59.64778<br>41.08420<br>28.03308<br>19.09277<br>13.10683<br>9.19032<br>6.69472 | 7.81250<br>13.13900<br>22.09710<br>37.16270<br>62.50000<br>105.11200<br>176.77699<br>297.30200<br>500.00000<br>840.89600<br>182.91138<br>118.63409<br>80.49541<br>56.10900<br>38.56652<br>26.29187<br>17.91749<br>12.33043<br>8.68987<br>6.38256                                    | -<br>\$ ratio of helion dE/dx<br>\$ to proton dE/dx at 1-GeV      |
| C<br>fc1054 31<br>fmesh1054:<br>jme:<br>DE1054 LIN<br>DF1054 LIN   | He images geom=recessors of 7 iints 1<br>sh 7 jints 1<br>5.06578<br>8.51959<br>14.32820<br>24.09700<br>40.52620<br>68.15670<br>114.62600<br>324.20999<br>545.25403<br>917.00403<br>251.35355<br>170.79847<br>109.81699<br>75.87840<br>52.75274<br>36.19267<br>24.65978<br>16.81848<br>11.60751<br>8.22594<br>6.09534   | ge at IL1<br>c origin=-7<br>1400<br>kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420<br>74.32540<br>125.00000<br>210.22400<br>353.55301<br>594.60400<br>1000.00000<br>236.69599<br>159.23402<br>101.52535<br>71.48250<br>49.58344<br>33.96295<br>23.12746<br>15.79222<br>10.93476<br>7.79659<br>5.83149  | -7 +1.0<br>sh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>81.05250<br>136.31300<br>229.25101<br>385.55301<br>648.41998<br>222.48483<br>148.24679<br>95.79416<br>67.32202<br>46.58300<br>31.86046<br>21.69341<br>14.83359<br>10.31132<br>7.40023  | out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600<br>88.38830<br>148.65100<br>250.00000<br>420.44800<br>707.10699<br>222.48483<br>148.24679<br>95.79416<br>67.32202<br>46.58300<br>31.86046<br>21.69341<br>14.83359<br>10.31132<br>7.40023  | 7.16409<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500<br>272.62701<br>458.50201<br>771.10498<br>195.55695<br>127.99319<br>85.34892<br>59.64778<br>41.08420<br>28.03308<br>19.09277<br>13.10683<br>9.19032<br>6.69472 | 7.81250<br>13.13900<br>22.09710<br>37.16270<br>62.50000<br>105.11200<br>176.77699<br>297.30200<br>500.00000<br>840.89600<br>182.91138<br>118.63409<br>80.49541<br>56.10900<br>38.56652<br>26.29187<br>17.91749<br>12.33043<br>8.68987<br>6.38256                                    | -<br>\$ ratio of helion dE/dx<br>\$ to proton dE/dx at 1-GeV<br>- |
| C<br>fc1054 31<br>fmesh1054::<br>jme:<br>DE1054 LIN<br>DF1054 LIN<br>DF1054 LIN  | He images geom=red<br>s geom=red<br>sh 7 iints 1<br>5.06578<br>8.51959<br>14.32820<br>24.09700<br>40.52620<br>68.15670<br>114.62600<br>08.15670<br>114.62600<br>192.77600<br>324.20999<br>545.25403<br>917.00403<br>251.35355<br>170.79847<br>109.81699<br>75.87840<br>52.75274<br>36.19267<br>24.65978<br>16.81848<br>11.60751<br>8.22594<br>6.09534  | ge at IL1<br>c origin=-7<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420<br>74.32540<br>125.00000<br>210.22400<br>353.55301<br>594.60400<br>1000.00000<br>236.69599<br>159.23402<br>101.52535<br>71.48250<br>49.58344<br>33.96295<br>23.12746<br>15.79222<br>10.93476<br>7.79659<br>5.83149<br>ce at IL1<br>c origin=-7   | -7 +1.0<br>sh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>81.05250<br>136.31300<br>229.25101<br>385.55301<br>648.41998<br>222.48483<br>148.24679<br>95.79416<br>67.32202<br>46.58300<br>31.86046<br>21.69341<br>14.83359<br>10.31132<br>7.40023<br>-7 +1.0   | out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600<br>88.38830<br>148.65100<br>250.00000<br>420.44800<br>707.10699<br>222.48483<br>148.24679<br>95.79416<br>67.32202<br>46.58300<br>31.86046<br>21.69341<br>14.83359<br>10.31132<br>7.40023  | 7.16409<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500<br>272.62701<br>458.50201<br>771.10498<br>195.55695<br>127.99319<br>85.34892<br>59.64778<br>41.08420<br>28.03308<br>19.09277<br>13.10683<br>9.19032<br>6.69472 | 7.81250<br>13.13900<br>22.09710<br>37.16270<br>62.50000<br>105.11200<br>176.77699<br>297.30200<br>500.00000<br>840.89600<br>182.91138<br>118.63409<br>80.49541<br>56.10900<br>38.56652<br>26.29187<br>17.91749<br>12.33043<br>8.68987<br>6.38256                                    | -<br>\$ ratio of helion dE/dx<br>\$ to proton dE/dx at 1-GeV<br>- |
| C<br>fc1054 31<br>fmesh1054::<br>jme:<br>DE1054 LIN<br>DF1054 LIN<br>C<br>fc1154 a:<br>fmesh1154::<br>ime:                             | He images geom=red<br>s geom=red<br>sh 7 iints 1<br>5.06578<br>8.51959<br>14.32820<br>24.09700<br>40.52620<br>68.15670<br>114.62600<br>08.15670<br>114.62600<br>192.77600<br>324.20999<br>545.25403<br>917.00403<br>251.35355<br>170.79847<br>109.81699<br>75.87840<br>52.75274<br>36.19267<br>24.65978<br>16.81848<br>11.60751<br>8.22594<br>6.09534<br>Ipha image<br>a geom=red<br>sh 7 iints 1  | ge at IL1<br>c origin=-7<br>400<br>400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420<br>74.32540<br>125.00000<br>210.22400<br>353.55301<br>594.60400<br>1000.00000<br>236.69599<br>159.23402<br>101.52535<br>71.48250<br>49.58344<br>33.96295<br>23.12746<br>15.79222<br>10.93476<br>7.79659<br>5.83149<br>   | -7 +1.0<br>sh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>81.05250<br>136.31300<br>229.25101<br>385.55301<br>648.41998<br>222.48483<br>148.24679<br>95.79416<br>67.32202<br>46.58300<br>31.86046<br>21.69341<br>14.83359<br>10.31132<br>7.40023<br>-7 +1.0   | out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600<br>88.38830<br>148.65100<br>250.00000<br>420.44800<br>707.10699<br>222.48483<br>148.24679<br>95.79416<br>67.32202<br>46.58300<br>31.86046<br>21.69341<br>14.83359<br>10.31132<br>7.40023  | 7.16409<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500<br>272.62701<br>458.50201<br>771.10498<br>195.55695<br>127.99319<br>85.34892<br>59.64778<br>41.08420<br>28.03308<br>19.09277<br>13.10683<br>9.19032<br>6.69472 | 7.81250<br>13.13900<br>22.09710<br>37.16270<br>62.50000<br>105.11200<br>176.77699<br>297.30200<br>500.00000<br>840.89600<br>182.91138<br>118.63409<br>80.49541<br>56.10900<br>38.56652<br>26.29187<br>17.91749<br>12.33043<br>8.68987<br>6.38256                                    | -<br>\$ ratio of helion dE/dx<br>\$ to proton dE/dx at 1-GeV<br>- |
| C<br>fc1054 31<br>fmesh1054::<br>jme:<br>DE1054 LIN<br>DF1054 LIN<br>C<br>fc1154 a:<br>fmesh1154:<br>ime:<br>jme:                      | He images geom=red<br>s geom=red<br>sh 7 iints 1<br>5.06578<br>8.51959<br>14.32820<br>24.09700<br>40.52620<br>68.15670<br>114.62600<br>192.77600<br>324.20999<br>545.25403<br>917.00403<br>251.35355<br>170.79847<br>109.81699<br>75.87840<br>52.75274<br>36.19267<br>24.65978<br>16.81848<br>11.60751<br>8.22594<br>6.09534<br>Ipha image<br>a geom=red<br>sh 7 iints 1   | ge at IL1<br>c origin=-7<br>400<br>400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420<br>74.32540<br>125.00000<br>210.22400<br>353.55301<br>594.60400<br>1000.00000<br>236.69599<br>159.23402<br>101.52535<br>71.48250<br>49.58344<br>33.96295<br>23.12746<br>15.79222<br>10.93476<br>7.79659<br>5.83149<br>   | -7 +1.0<br>sh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>81.05250<br>136.31300<br>229.25101<br>385.55301<br>648.41998<br>222.48483<br>148.24679<br>95.79416<br>67.32202<br>46.58300<br>31.86046<br>21.69341<br>14.83359<br>10.31132<br>7.40023<br>-7 +1.0<br>sh +1.2  | out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600<br>88.38830<br>148.65100<br>250.00000<br>420.44800<br>707.10699<br>222.48483<br>148.24679<br>95.79416<br>67.32202<br>46.58300<br>31.86046<br>21.69341<br>14.83359<br>10.31132<br>7.40023  | 7.16409<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500<br>272.62701<br>458.50201<br>771.10498<br>195.55695<br>127.99319<br>85.34892<br>59.64778<br>41.08420<br>28.03308<br>19.09277<br>13.10683<br>9.19032<br>6.69472 | 7.81250<br>13.13900<br>22.09710<br>37.16270<br>62.50000<br>105.11200<br>176.77699<br>297.30200<br>500.00000<br>840.89600<br>182.91138<br>118.63409<br>80.49541<br>56.10900<br>38.56652<br>26.29187<br>17.91749<br>12.33043<br>8.68987<br>6.38256                                    | -<br>\$ ratio of helion dE/dx<br>\$ to proton dE/dx at 1-GeV<br>- |
| C<br>fc1054 31<br>fmesh1054::<br>jme:<br>DE1054 LIN<br>DF1054 LIN<br>DF1054 LIN<br>C<br>fc1154 a:<br>fmesh1154:<br>jme:<br>DE1154 LIN  | He images geom=red<br>s geom=red<br>sh 7 iints 1<br>5.06578<br>8.51959<br>14.32820<br>24.09700<br>40.52620<br>68.15670<br>114.62600<br>192.77600<br>324.20999<br>545.25403<br>917.00403<br>251.35355<br>170.79847<br>109.81699<br>75.87840<br>52.75274<br>36.19267<br>24.65978<br>16.81848<br>11.60751<br>8.22594<br>6.09534<br>Ipha image<br>a geom=red<br>sh 7 iints 1<br>5.06578  | ge at IL1<br>c origin=-7<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420<br>74.32540<br>125.00000<br>210.22400<br>353.55301<br>594.60400<br>1000.00000<br>236.69599<br>159.23402<br>101.52535<br>71.48250<br>49.58344<br>33.96295<br>23.12746<br>15.79222<br>10.93476<br>7.79659<br>5.83149<br>ge at IL1<br>c origin=-7<br>1400 kme<br>5.52427                        | -7 +1.0<br>sh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410<br>81.05250<br>136.31300<br>229.25101<br>385.55301<br>648.41998<br>222.48483<br>148.24679<br>95.79416<br>67.32202<br>46.58300<br>31.86046<br>21.69341<br>14.83359<br>10.31132<br>7.40023<br>-7 +1.0<br>sh +1.2<br>6.02426                         | out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600<br>88.38830<br>148.65100<br>250.00000<br>420.44800<br>707.10699<br>222.48483<br>148.24679<br>95.79416<br>67.32202<br>46.58300<br>31.86046<br>21.69341<br>14.83359<br>10.31132<br>7.40023  | 7.16409<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500<br>272.62701<br>458.50201<br>771.10498<br>195.55695<br>127.99319<br>85.34892<br>59.64778<br>41.08420<br>28.03308<br>19.09277<br>13.10683<br>9.19032<br>6.69472 | 7.81250<br>13.13900<br>22.09710<br>37.16270<br>62.50000<br>105.11200<br>176.77699<br>297.30200<br>500.00000<br>840.89600<br>182.91138<br>118.63409<br>80.49541<br>56.10900<br>38.56652<br>26.29187<br>17.91749<br>12.33043<br>8.68987<br>6.38256                                    | -<br>\$ ratio of helion dE/dx<br>\$ to proton dE/dx at 1-GeV<br>- |
| C<br>fc1054 31<br>fmesh1054::<br>jme:<br>DE1054 LIN<br>DF1054 LIN<br>C<br>fc1154 a.<br>fmesh1154:<br>jme:<br>DE1154 LIN                | He images geom=red<br>s geom=red<br>sh 7 iints 1<br>5.06578<br>8.51959<br>14.32820<br>24.09700<br>40.52620<br>68.15670<br>114.62600<br>192.77600<br>324.20999<br>545.25403<br>917.00403<br>251.35355<br>170.79847<br>109.81699<br>75.87840<br>52.75274<br>36.19267<br>24.65978<br>16.81848<br>11.60751<br>8.22594<br>6.09534<br>Ipha image<br>a geom=red<br>sh 7 iints 1<br>5.06578<br>8.51959   | ge at IL1<br>c origin=-7<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420<br>74.32540<br>125.00000<br>210.22400<br>353.55301<br>594.60400<br>1000.00000<br>236.69599<br>159.23402<br>101.52535<br>71.48250<br>49.58344<br>33.96295<br>23.12746<br>15.79222<br>10.93476<br>7.79659<br>5.83149<br>ge at IL1<br>c origin=-7<br>1400 kme<br>5.52427<br>9.29068             | -7 +1.0<br>sh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410<br>81.05250<br>136.31300<br>229.25101<br>385.55301<br>648.41998<br>222.48483<br>148.24679<br>95.79416<br>67.32202<br>46.58300<br>31.86046<br>21.69341<br>14.83359<br>10.31132<br>7.40023<br>-7 +1.0<br>sh +1.2<br>6.02426<br>10.13160             | out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600<br>88.38830<br>148.65100<br>250.00000<br>420.44800<br>707.10699<br>222.48483<br>148.24679<br>95.79416<br>67.32202<br>46.58300<br>31.86046<br>21.69341<br>14.83359<br>10.31132<br>7.40023  | 7.16409<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500<br>272.62701<br>458.50201<br>771.10498<br>195.55695<br>127.99319<br>85.34892<br>59.64778<br>41.08420<br>28.03308<br>19.09277<br>13.10683<br>9.19032<br>6.69472 | 7.81250<br>13.13900<br>22.09710<br>37.16270<br>62.50000<br>105.11200<br>176.77699<br>297.30200<br>500.00000<br>840.89600<br>182.91138<br>118.63409<br>80.49541<br>56.10900<br>38.56652<br>26.29187<br>17.91749<br>12.33043<br>8.68987<br>6.38256<br>7.81250<br>13.13900             | -<br>\$ ratio of helion dE/dx<br>\$ to proton dE/dx at 1-GeV<br>- |
| C<br>fc1054 31<br>fmesh1054::<br>jme:<br>DE1054 LIN<br>DF1054 LIN<br>DF1054 LIN<br>C<br>fc1154 a:<br>fmesh1154::<br>jme:<br>DE1154 LIN | He images geom=red<br>s geom=red<br>sh 7 iints 1<br>5.06578<br>8.51959<br>14.32820<br>24.09700<br>40.52620<br>68.15670<br>114.62600<br>192.77600<br>324.20999<br>545.25403<br>917.00403<br>251.35355<br>170.79847<br>109.81699<br>75.87840<br>52.75274<br>36.19267<br>24.65978<br>16.81848<br>11.60751<br>8.22594<br>6.09534<br>Lpha image<br>a geom=red<br>sh 7 iints 1<br>5.06578<br>8.51959<br>14.32820   | ge at IL1<br>c origin=-7<br>1400 kme<br>5.52427<br>9.29068<br>15.62500<br>26.27800<br>44.19420<br>74.32540<br>125.00000<br>210.22400<br>353.55301<br>594.60400<br>1000.00000<br>236.69599<br>159.23402<br>101.52535<br>71.48250<br>49.58344<br>33.96295<br>23.12746<br>15.79222<br>10.93476<br>7.79659<br>5.83149<br>ge at IL1<br>c origin=-7<br>1400 kme<br>5.52427<br>9.29068<br>15.62500 | -7 +1.0<br>sh +1.2<br>6.02426<br>10.13160<br>17.03920<br>28.65640<br>48.19410<br>81.05250<br>136.31300<br>229.25101<br>385.55301<br>648.41998<br>222.48483<br>148.24679<br>95.79416<br>67.32202<br>46.58300<br>31.86046<br>21.69341<br>14.83359<br>10.31132<br>7.40023<br>-7 +1.0<br>sh +1.2<br>6.02426<br>10.13160<br>17.03920 | out=cf<br>6.56950<br>11.04850<br>18.58140<br>31.25000<br>52.55600<br>88.38830<br>148.65100<br>250.00000<br>420.44800<br>707.10699<br>222.48483<br>148.24679<br>95.79416<br>67.32202<br>46.58300<br>31.86046<br>21.69341<br>14.83359<br>10.31132<br>7.40023<br>out=cf<br>6.56950<br>11.04850<br>18.58140 | 7.16409<br>12.04850<br>20.26310<br>34.07840<br>57.31280<br>96.38820<br>162.10500<br>272.62701<br>458.50201<br>771.10498<br>195.55695<br>127.99319<br>85.34892<br>59.64778<br>41.08420<br>28.03308<br>19.09277<br>13.10683<br>9.19032<br>6.69472 | 7.81250<br>13.13900<br>22.09710<br>37.16270<br>62.50000<br>105.11200<br>176.77699<br>297.30200<br>500.00000<br>840.89600<br>182.91138<br>118.63409<br>80.49541<br>56.10900<br>38.56652<br>26.29187<br>17.91749<br>12.33043<br>8.68987<br>6.38256<br>7.81250<br>13.13900<br>22.09710 | -<br>\$ ratio of helion dE/dx<br>\$ to proton dE/dx at 1-GeV<br>- |

|            | 24.09700  | 26.27800   | 28.65640  | 31.25000  | 34.07840  | 37.16270  |   |
|------------|-----------|------------|-----------|-----------|-----------|-----------|---|
|            | 40.52620  | 44.19420   | 48.19410  | 52.55600  | 57.31280  | 62.50000  |   |
|            | 68.15670  | 74.32540   | 81.05250  | 88.38830  | 96.38820  | 105.11200 |   |
|            | 114.62600 | 125.00000  | 136.31300 | 148.65100 | 162.10500 | 176.77699 |   |
|            | 192.77600 | 210.22400  | 229.25101 | 250.00000 | 272.62701 | 297.30200 |   |
|            | 324.20999 | 353.55301  | 385.55301 | 420.44800 | 458.50201 | 500.00000 |   |
|            | 545.25403 | 594.60400  | 648.41998 | 707.10699 | 771.10498 | 840.89600 |   |
|            | 917.00403 | 1000.00000 |           |           |           |           |   |
| DF1154 LIN | 301.14149 | 285.98364  | 270.49441 | 270.49441 | 240.57549 | 226.23997 | <pre>\$ ratio of alpha dE/dx values</pre> |
|            | 212.38032 | 199.03174  | 186.25032 | 186.25032 | 162.27752 | 151.12927 | \$ to proton dE/dx at 1-GeV               |
|            | 140.61071 | 130.57880  | 121.09534 | 121.09534 | 103.69260 | 97.26703  |   |
|            | 91.85572  | 86.69168   | 81.76917  | 81.76917  | 72.63794  | 68.41291  |   |
|            | 64.41078  | 60.62861   | 57.03621  | 57.03621  | 50.41296  | 47.37011  |   |
|            | 44.49215  | 41.78218   | 39.22719  | 39.22719  | 34.54728  | 32.40993  |   |
|            | 30.40391  | 28.51857   | 26.74653  | 26.74653  | 23.52734  | 22.06799  |   |
|            | 20.70093  | 19.42070   | 18.22400  | 18.22400  | 16.05998  | 15.08374  |   |
|            | 14.17299  | 13.32413   | 12.53271  | 12.53271  | 11.10994  | 10.47421  |   |
|            | 9.88132   | 9.33070    | 8.82005   | 8.82005   | 7.90815   | 7.50345   |   |
|            | 7.12849   | 6.78267    |           |           |           |           |   |
| с          |           |            |           |           |           |           |   |
| c          |           |            | -         |           |           |           |   |