Particle Production at 3 GeV (update)

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Target Studies
Sept. 23, 2013
IDS120h and IDS120j Geometry
Fieldmap
**Target Setting**

- Simulation code: MARS15(2012) code (denoted as MARS15 below), FLUKA;
- Geometry setting: Nicholas (MARS15), John (FLUKA)
- Fieldmap: (IDS120j, 15T $\rightarrow$ 1.5T);
- Target parameters at 3 GeV (*from IDS120h*):
  
  Carbon: target radius/0.346 cm, beam radius/0.0865 cm, both beam and target angle/42 mrad, launch at $z$ = 100 cm, target length/72 cm along $z$ axis;
  
  Mercury: target radius/0.23 cm, beam radius/0.069 cm, beam angle/137 mrad, jet angle/155 mrad; launch at $z$ = -75 cm;
  
  Galium: target radius/0.34 cm, beam radius/0.102 cm, beam angle/114 mrad, jet angle/125 mrad; launch at $z$ = -75 cm;
Target Setting (cont’d)

- Target parameters for Mercury at 8 GeV *(from IDS120h)*:
  
  Mercury: target radius/0.4 cm, beam radius/0.12 cm, beam angle/117 mrad, jet angle/137.6 mrad; launch at $z = -75$ cm.

- Particle production collection: (0 m and 50 m downstream, $40 \text{ MeV} < \text{KE} < 180 \text{ MeV}$).

- Energy spectra at $z = 0$ m and $z = 50$ m.
MARS15(2012) Running Mode

• **Mode 1**: MARS15 default mode (without either LAQGSM or the MCNP tables)

• **Mode 2**: MARS15 with MCNPDATA (with the MCNP tables but without LAQGSM mode)

  An optional “MCNP mode” in MARS with it using the MCNPDATA x-section libraries for neutron interactions below 14 MeV.
MARS15(2012) Running Mode

• **Mode 3**: MARS15 in LAQGSM mode (with the LAQGSM mode but without the MCNP tables)
  A hybrid that includes the native inclusive model, Quark-Gluon String Model implementation in MARS15 and CEM (Cascade-Exciton Model).

• **Mode 4**: MARS15 in LAQGSM mode with MCNPDATA (with both the LAQGSM mode and the MCNP tables)
MARS15 in LAQGSM Mode

- ICEM C1CEM C2CEM EMODEL IQGSM NEVTYPE

Variables which control hadron event generator and use of cascade-exciton and quark-gluon string models, and evaporation scheme.

**IQGSM** An integer that globally switches between the inclusive and exclusive event generators at nuclear inelastic interactions.

For **IQGSM=0**, the default inclusive model is used at $E > 5$ GeV and the CEM model at lower energies.
For **IQGSM=1**, exclusive modeling with the LAQGSM is done at $E > E_{\text{CEMLQ}} = 1 + A/65$, or/and $A < 3$, and at all energies for $\bar{p}$, $K^\pm$, $d$, $t$, $^3\text{He}$, $^4\text{He}$, $\bar{n}$, hyperons and heavy ions; the CEM model is used otherwise. (ICEM 4=1)

For **IQGSM=2**, exclusive modeling with the LAQGSM code is always done for everything at all energies. IQGSM=1 and IQGSM=2 provide a theoretically consistent nuclear interaction modeling, but can be time-consuming. Default IQGSM=0 is more appropriate for shielding studies. (ICEM 4=2)
Incident Particle Energy and the threshold in matter for subsequent generated particles in MARS15

- **ENRG E0 EM EPSTAM EMCHR EMNEU EMIGA EMIEL**
  
  **E0:** The incident particle kinetic energy;
  **EM:** The hadron threshold energy (Default: 0.0145 GeV);
  **EPSTAM:** The star production threshold kinetic energy (Default: 0.03 GeV);
  **EMCHR:** The threshold energy applied collectively to muons, heavy ions and charged hadrons (Default: 0.001 GeV);
  **EMNEU:** The threshold energy for neutrons (Default: $10^{-4}$ GeV)
  **EMIGA:** The threshold energy for $\gamma$ (Default: $10^{-4}$ GeV);
  **EMIEL:** The threshold energy for $e^\pm$ (Default: $5\times10^{-4}$ GeV)

- **Default Setting:** ENRG E0
- **Non-default setting:** ENRG 1=E0 2=0.02 3=0.3 4=0.01 5=0.05 6=0.01 7=0.01
Particle Production from MARS15
(Unit: Yield/proton/GeV)

<table>
<thead>
<tr>
<th>Carbon/3GeV/ z = 0 m</th>
<th>Mode 1</th>
<th>Mode 2</th>
<th>Mode3 IQGSM=1</th>
<th>Mode4 IQGSM=1</th>
<th>Mode4 IQGSM=2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENRG (default)</td>
<td>0.034</td>
<td>0.034</td>
<td>0.030</td>
<td>0.030</td>
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<tr>
<td>ENRG (Non-default)</td>
<td>0.033</td>
<td>0.033</td>
<td>0.030</td>
<td>0.030</td>
<td>0.030</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Carbon/3GeV/ z = 50 m</th>
<th>Mode 1</th>
<th>Mode 2</th>
<th>Mode3 IQGSM=1</th>
<th>Mode4 IQGSM=1</th>
<th>Mode4 IQGSM=2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENRG (default)</td>
<td>0.026</td>
<td>0.025</td>
<td>0.028</td>
<td>0.027</td>
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<tr>
<td>ENRG (Non-default)</td>
<td>0.026</td>
<td>0.026</td>
<td>0.028</td>
<td>0.028</td>
<td>0.028</td>
</tr>
</tbody>
</table>
# Particle Production from MARS15

(Unit: Yield/proton/GeV)

<table>
<thead>
<tr>
<th>Mercury/3GeV/ z = 0 m</th>
<th>Mode 1</th>
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<th>Mode 4 IQGSM=1</th>
<th>Mode 4 IQGSM=2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENRG (default)</td>
<td>0.037</td>
<td>0.037</td>
<td>0.036</td>
<td>0.036</td>
<td>0.054</td>
</tr>
<tr>
<td>ENRG (Non-default)</td>
<td>0.034</td>
<td>0.034</td>
<td>0.033</td>
<td>0.033</td>
<td>0.052</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mercury/3GeV/ z = 50 m</th>
<th>Mode 1</th>
<th>Mode 2</th>
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<th>Mode 4 IQGSM=1</th>
<th>Mode 4 IQGSM=2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENRG (default)</td>
<td>0.020</td>
<td>0.020</td>
<td>0.020</td>
<td>0.020</td>
<td>0.039</td>
</tr>
<tr>
<td>ENRG (Non-default)</td>
<td>0.021</td>
<td>0.021</td>
<td>0.020</td>
<td>0.020</td>
<td>0.038</td>
</tr>
</tbody>
</table>
# Particle Production from MARS15

(Unit: Yield/proton/GeV)

<table>
<thead>
<tr>
<th>Gallium/3GeV/ ( z = 0 \text{ m} )</th>
<th>Mode 1</th>
<th>Mode 2</th>
<th>Mode 3 ( \text{IQGSM} = 1 )</th>
<th>Mode 4 ( \text{IQGSM} = 1 )</th>
<th>Mode 4 ( \text{IQGSM} = 2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENRG (default)</td>
<td>0.037</td>
<td>0.037</td>
<td>0.043</td>
<td>0.043</td>
<td>0.044</td>
</tr>
<tr>
<td>ENRG (Non-default)</td>
<td>0.035</td>
<td>0.035</td>
<td>0.042</td>
<td>0.042</td>
<td>0.042</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gallium/3GeV/ ( z = 50 \text{ m} )</th>
<th>Mode 1</th>
<th>Mode 2</th>
<th>Mode 3 ( \text{IQGSM} = 1 )</th>
<th>Mode 4 ( \text{IQGSM} = 1 )</th>
<th>Mode 4 ( \text{IQGSM} = 2 )</th>
</tr>
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<tr>
<td>ENRG (default)</td>
<td>0.023</td>
<td>0.023</td>
<td>0.034</td>
<td>0.033</td>
<td>0.034</td>
</tr>
<tr>
<td>ENRG (Non-default)</td>
<td>0.024</td>
<td>0.024</td>
<td>0.034</td>
<td>0.034</td>
<td>0.034</td>
</tr>
</tbody>
</table>
# Particle Production from MARS15

(Unit: Yield/proton/GeV)

<table>
<thead>
<tr>
<th>Mercury/8GeV/(z = 0) m</th>
<th>Mode 1</th>
<th>Mode 2</th>
<th>Mode 3 (IQGSM=1)</th>
<th>Mode 4 (IQGSM=1)</th>
<th>Mode 4 (IQGSM=2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENRG(default)</td>
<td>0.043</td>
<td>0.042</td>
<td>0.046</td>
<td>0.046</td>
<td>0.049</td>
</tr>
<tr>
<td>ENRG(Non-default)</td>
<td>0.040</td>
<td>0.042</td>
<td>0.045</td>
<td>0.045</td>
<td>0.049</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mercury/8GeV/(z = 50) m</th>
<th>Mode 1</th>
<th>Mode 2</th>
<th>Mode 3 (IQGSM=1)</th>
<th>Mode 4 (IQGSM=1)</th>
<th>Mode 4 (IQGSM=2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENRG(default)</td>
<td>0.042</td>
<td>0.041</td>
<td>0.036</td>
<td>0.036</td>
<td>0.037</td>
</tr>
<tr>
<td>ENRG(Non-default)</td>
<td>0.042</td>
<td>0.041</td>
<td>0.036</td>
<td>0.036</td>
<td>0.038</td>
</tr>
<tr>
<td></td>
<td>Yield/proton/GeV</td>
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</tr>
<tr>
<td>Carbon 3 GeV, z = 50 m</td>
<td>0.030 (neg: 0.012, pos: 0.018)</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon 3 GeV, z = 0 m</td>
<td>0.033 (neg: 0.014, pos: 0.020)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Mercury 3 GeV, z = 50 m</td>
<td>0.021 (neg: 0.011, pos: 0.010)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mercury 3 GeV, z = 0 m</td>
<td>0.025 (neg: 0.013, pos: 0.012)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Gallium 3 GeV, z = 50 m</td>
<td>0.026 (neg: 0.012, pos: 0.014)</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Gallium 3 GeV, z = 0 m</td>
<td>0.030 (neg: 0.014, pos: 0.016)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Mercury 8 GeV, z = 50 m</td>
<td>0.026 (neg: 0.014, pos: 0.013)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mercury 8 GeV, z = 0 m</td>
<td>0.029 (neg: 0.015, pos: 0.014)</td>
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<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Yield comparison between default and nondefault ENRG card

MARS15, Mode 4
Carbon at 3 GeV

Results are similar. However, the running speed with non-default ENRG card is about several times (~10) faster.
Yield comparison between default and nondefault ENRG card

Results are similar. However, the running speed with non-default ENRG card is about several times (~10) faster.

MARS15, mode 4
HG at 8 GeV
Yield comparison between mode 3 and mode 4 of MARS15 (C at 3 GeV)

Results are very similar. This means MCNP mode doesn’t play important role in particle production.
MARS15 (mode 1) vs. FLUKA
(Carbon target at 3 GeV)

Strange shape from Mode 1:
Higher peak of soft pions and shoulder
MARS15 (mode 4) vs. FLUKA
(Carbon target at 3 GeV)

1. No strange shape at mode 4 is not observed.
2. Energy spectra between MARS15 and FLUKA look similar.
Energy spectra (MARS15 vs. FLUKA)
(Carbon target at 3 GeV, z = 0 m)

1. Strange shape from MARS15 with default mode (IQGSM=0)
2. Results similar between MARS15 (mode 4) for IQGSM=1 or IQGSM=2 and FLUKA.
Energy spectra (MARS15)
(Carbon target at 3 GeV, \( z = 50 \) m)

1. Results similar between IQGSM=1 and IQGSM=2
2. Yield (pos) \( \approx 2 \times \) Yield (neg)
Positive and Negative Yield
(MARS15/mode 4/IQGSM=1)
(Carbon target at 3 GeV)

Yield (pos) \approx 2 \times \text{Yield (neg)}
Energy spectra (MARS15 vs. FLUKA) 
(Mercury target at 3 GeV, \( z = 0 \) m)

1. Narrow peak width from IQGSM=0 and IQGSM=1. 
2. Results different between MARS15 (mode 4) and FLUKA. 
3. MARS15 in LAQGSM mode (IQGSM=2) with MCNPDATA gives big peak width and almost double yield.
Energy spectra (MARS15)
(Mercury target at 3 GeV, z = 50 m)

1. Results much different between IQGSM=1 and IQGSM=2
2. Yield (neg) ≈ 1.1*Yield (pos) for IQGSM=2
Positive and Negative Yield
(MARS15/mode 4/IQGSM=2)
(Mercury target at 3 GeV)

Yield (neg) ≈ 1.1*Yield (pos)
Energy spectra (MARS15 vs. FLUKA)
(Gallium target at 3 GeV, $z = 0$ m)

1. Strange shape from MARS15 with default mode (IQGSM=0)
2. Results different between MARS15 (mode 4) and FLUKA.
MARS15 (mode 4)
(Gallium target at 3 GeV, z = 50 m)

1. Results similar between IQGSM=1 and IQGSM=2
2. Yield (pos) ≈ 1.3*Yield (neg)
Positive and Negative Yield
(MARS15/mode 4/IQGSM=1)
(Gallium target at 3 GeV)

\[ \text{Yield (pos)} \approx 1.3 \times \text{Yield (neg)} \]

- \( z = 0 \text{ m} \)
- \( z = 50 \text{ m} \)
SUMMARY

1. The setting of ENRG card with default and or non-default in MARS15 gives almost same particle production. However, the running speed with non-default ENRG is much faster.

2. Mode 3 and Mode 4 of MARS15 give almost same particle productions for carbon target at 3 GeV. So MCNP mode doesn’t play an important role in particle production.
SUMMARY (Cont’d)

3. Strange shape for Carbon or Gallium at 3 GeV with higher peak of soft pions and shoulder is observed for MARS15 default mode (IQGSM=0). It doesn’t exist with MARS15 in LAQGSM mode (IQGSM=1 or IQGSM=2). So MARS15 in LAQGSM mode is needed.

4. For Mercury at 3 GeV and for MARS15 in LAQGSM code, the setting of IQGSM=2 can give double particle production than that of IQGSM=1 or IQGSM=0.
SUMMARY (Cont’d)

5. For carbon target at 3 GeV, MARS15 in LAQGSM mode (IQGSM=1 or IQGSM=2) gives similar particle production with FLUKA. However, it’s much different for mercury or gallium target (FLUKA will give less than MARS15).

6. Carbon target (MARS15/mode 4):
   0.027 Yield/proton/GeV at $z = 50$ m
   Yield (pos) $\approx 2 \times$ Yield (neg)
   0.030 Yield/proton/GeV (from FLUKA) at $z = 50$ m
SUMMARY (Cont’d)

7. Mercury target (MARS15/Mode 4/IQGSM=2):
   0.039 Yield/proton/GeV at z = 50 m
   Yield (neg) \approx 1.1 \times \text{Yield (pos)}
   0.021 Yield/proton/GeV (from FLUKA)

8. Gallium target (MARS15, Mode 4):
   0.034 Yield/proton/GeV at z = 50 m
   Yield (pos) \approx 1.2 \times \text{Yield (neg)}
   0.026 Yield/proton/GeV (from FLUKA) at z = 50 m