Particle Production at 3 GeV (update)

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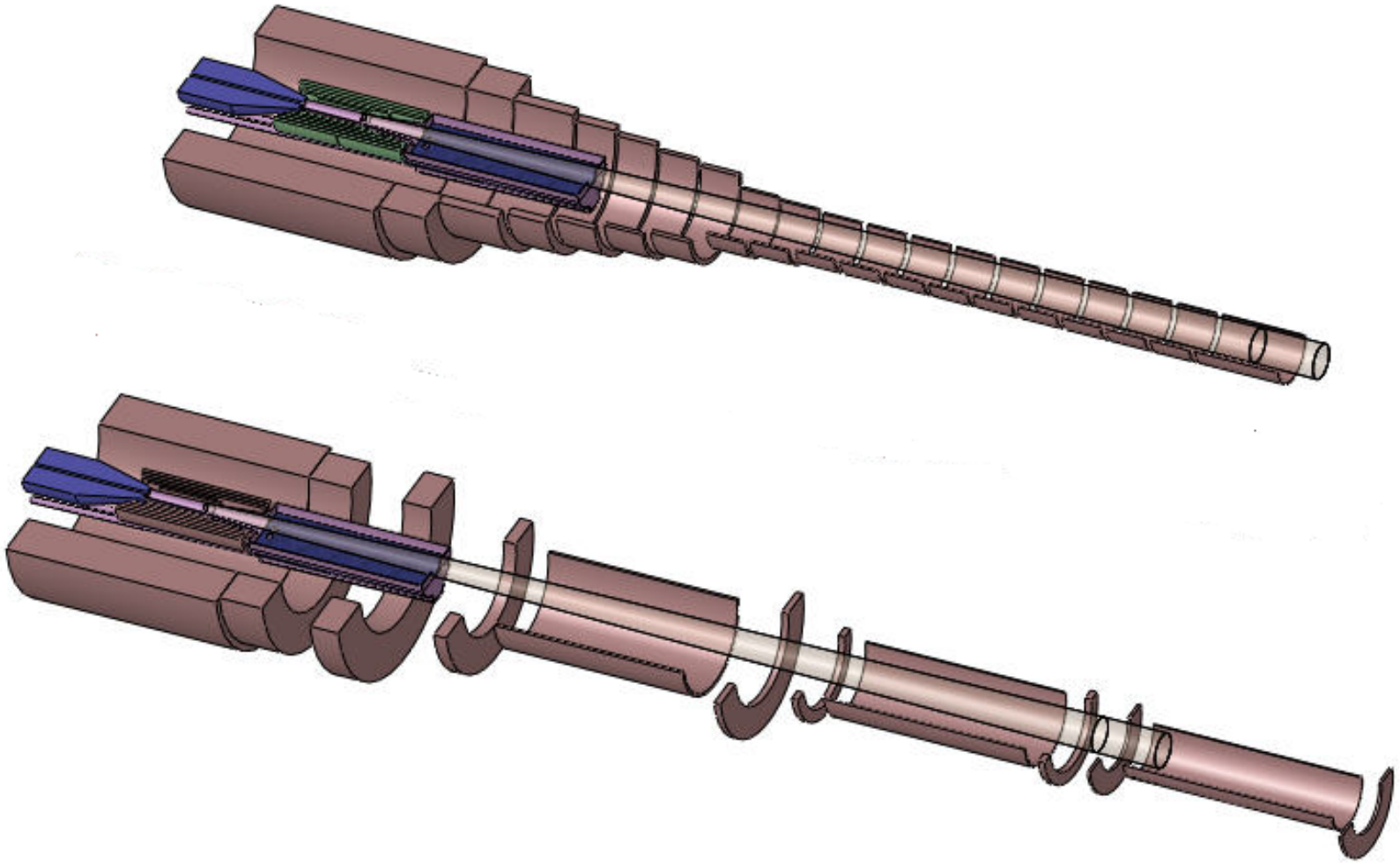
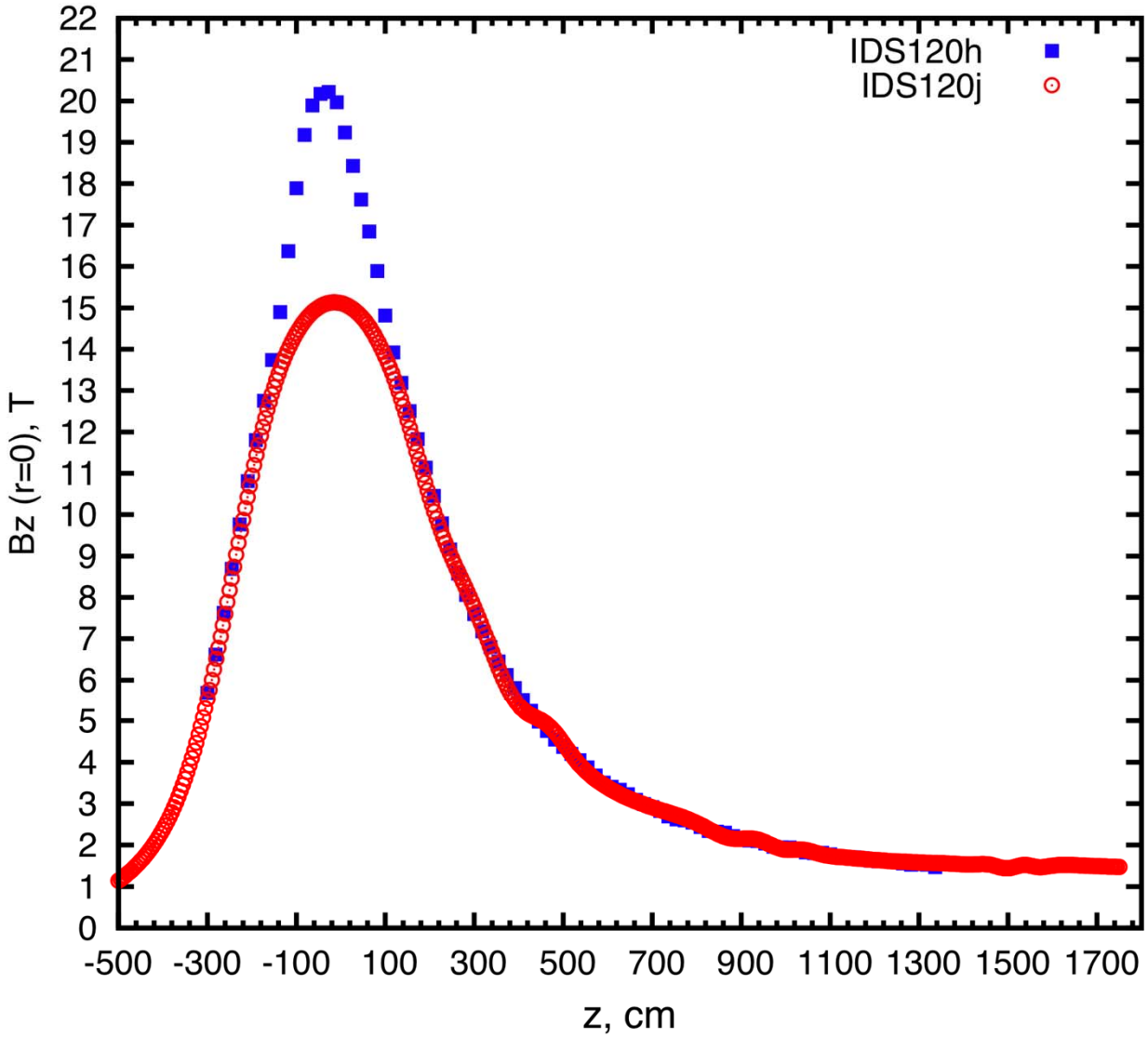
Target Studies
Sept. 23, 2013

IDS120h and IDS120j Geometry



Fieldmap


IDS120h
IDS120j
Bz (r=0), T
z, cm
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-500
-300
-100
100
300
500
700
900
1100
1300
1500
1700

Target Setting

- Simulation code: MARS15(2012) code (denoted as MARS15 below), FLUKA;
- Geometry setting: Nicholas (MARS15), John (FLUKA)
- Fieldmap: (IDS120j, 15T➔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 MeV < KE < 180 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.

MARS15 in LAQGSM Mode (Cont'd)

For IQGSM=1, exclusive modeling with the LAQGSM is done at E > ECEMLQ = 1 + A/65, or/and A < 3, and at all energies for $\overline{p}$, $K^{\pm}$, d, t, ^{3}He, ^{4}He, $\overline{n}$, hyperons and heavy ions; the CEM model is used otherwise. (ICEM 4=1)

For IQGSM=2, exclusive modeling with the LAQGSMcode 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 γ (Default: 10^{-4} GeV);

  EMIEL: The threshold energy for $e^{\pm}$ (Default: $5*10^{-4}$ 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)

Carbon/3GeV/ z = 0 m	Mode 1	Mode 2	Mode3 IQGSM=1	Mode4 IQGSM=1	Mode4 IQGSM=2
ENRG (default)	0.034	0.034	0.030	0.030	0.030
ENRG (Non-default)	0.033	0.033	0.030	0.030	0.030

Carbon/3GeV/ z = 50 m	Mode 1	Mode 2	Mode 3 IQGSM=1	Mode4 IQGSM=1	Mode4 IQGSM=2
ENRG (default)	0.026	0.025	0.028	0.027	0.027
ENRG (Non-default)	0.026	0.026	0.028	0.028	0.028

Particle Production from MARS15

(Unit: Yield/proton/GeV)

Mercury/3GeV/ z = 0 m	Mode 1	Mode 2	Mode 3 IQGSM=1	Mode 4 IQGSM=1	Mode 4 IQGSM=2
ENRG (default)	0.037	0.037	0.036	0.036	0.054
ENRG (Non-default)	0.034	0.034	0.033	0.033	0.052

Mercury/3GeV/ z = 50 m	Mode 1	Mode 2	Mode 3 IQGSM=1	Mode 4 IQGSM=1	Mode 4 IQGSM=2
ENRG (default)	0.020	0.020	0.020	0.020	0.039
ENRG (Non-default)	0.021	0.021	0.020	0.020	0.038

Particle Production from MARS15

(Unit: Yield/proton/GeV)

Gallium/3GeV/ z = 0 m	Mode 1	Mode 2	Mode 3 IQGSM=1	Mode 4 IQGSM=1	Mode 4 IQGSM=2
ENRG (default)	0.037	0.037	0.043	0.043	0.044
ENRG (Non-default)	0.035	0.035	0.042	0.042	0.042

Gallium/3GeV/ z = 50 m	Mode 1	Mode 2	Mode 3 IQGSM=1	Mode 4 IQGSM=1	Mode 4 IQGSM=2
ENRG (default)	0.023	0.023	0.034	0.033	0.034
ENRG (Non-default)	0.024	0.024	0.034	0.034	0.034

Particle Production from MARS15

(Unit: Yield/proton/GeV)

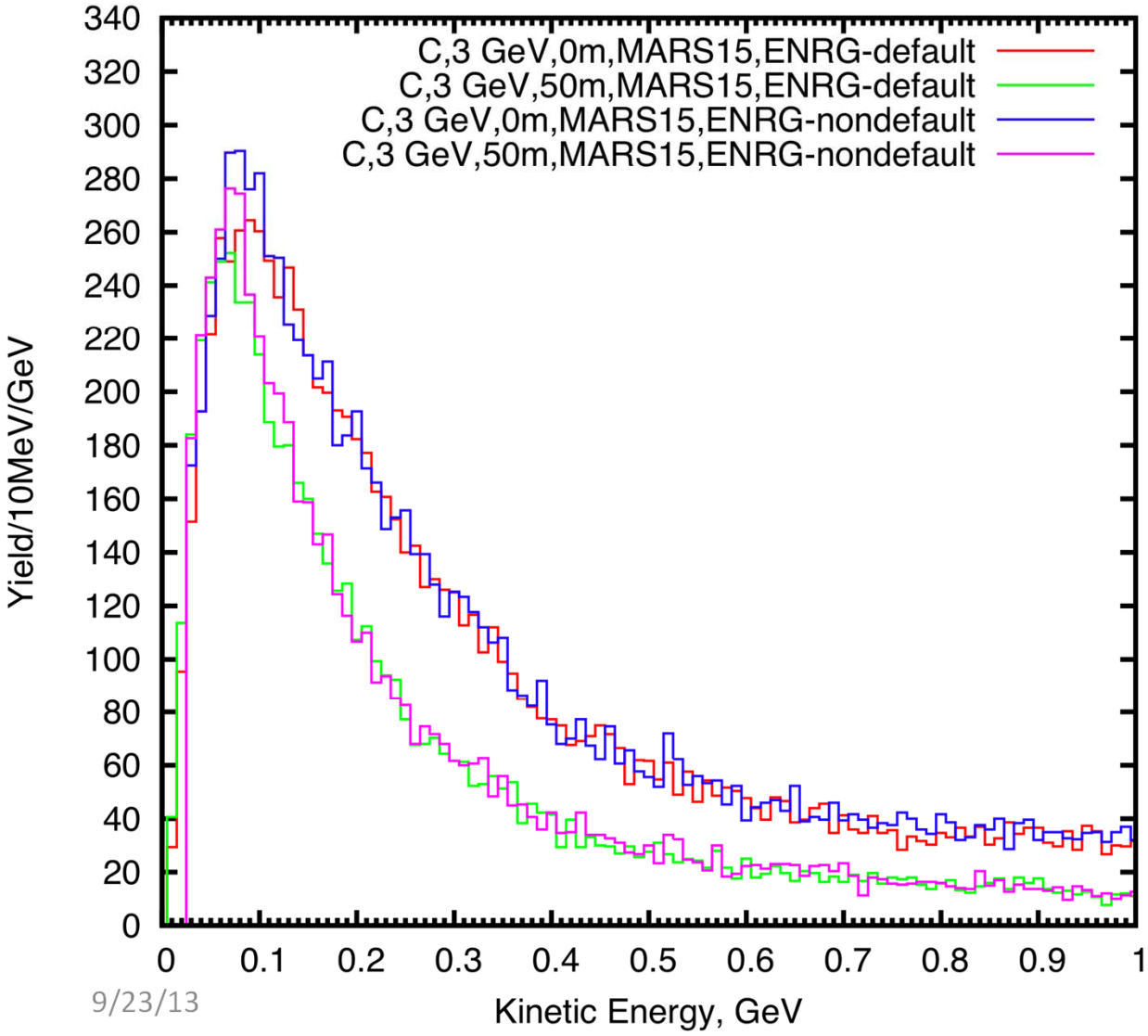
Mercury/8GeV/ z = 0 m	Mode 1	Mode 2	Mode 3 IQGSM=1	Mode 4 IQGSM=1	Mode 4 IQGSM=2
ENRG(default)	0.043	0.042	0.046	0.046	0.049
ENRG(Non-default)	0.040	0.042	0.045	0.045	0.049

Mercury/8GeV/ z = 50 m	Mode 1	Mode 2	Mode 3 IQGSM=1	Mode 4 IQGSM=1	Mode 4 IQGSM=2
ENRG(default)	0.042	0.041	0.036	0.036	0.037
ENRG(Non-default)	0.042	0.041	0.036	0.036	0.038

Particle Production from FLUKA

		Yield/proton/GeV
Carbon	3 GeV, z = 50 m	0.030 (neg: 0.012, pos: 0.018)
Carbon	3 GeV, z = 0 m	0.033 (neg: 0.014, pos: 0.020)
Mercury	3 GeV, z = 50 m	0.021 (neg: 0.011, pos: 0.010
Mercury	3 GeV, z = 0 m	0.025 (neg: 0.013, pos: 0.012)
Gallium	3 GeV, z = 50 m	0.026 (neg: 0.012, pos: 0.014)
Gallium	3 GeV, z = 0 m	0.030 (neg: 0.014, pos: 0.016)
Mercury	8 GeV, z = 50 m	0.026 (neg: 0.014, pos: 0.013)
Mercury	8 GeV, z = 0 m	0.029 (neg: 0.015, pos: 0.014)

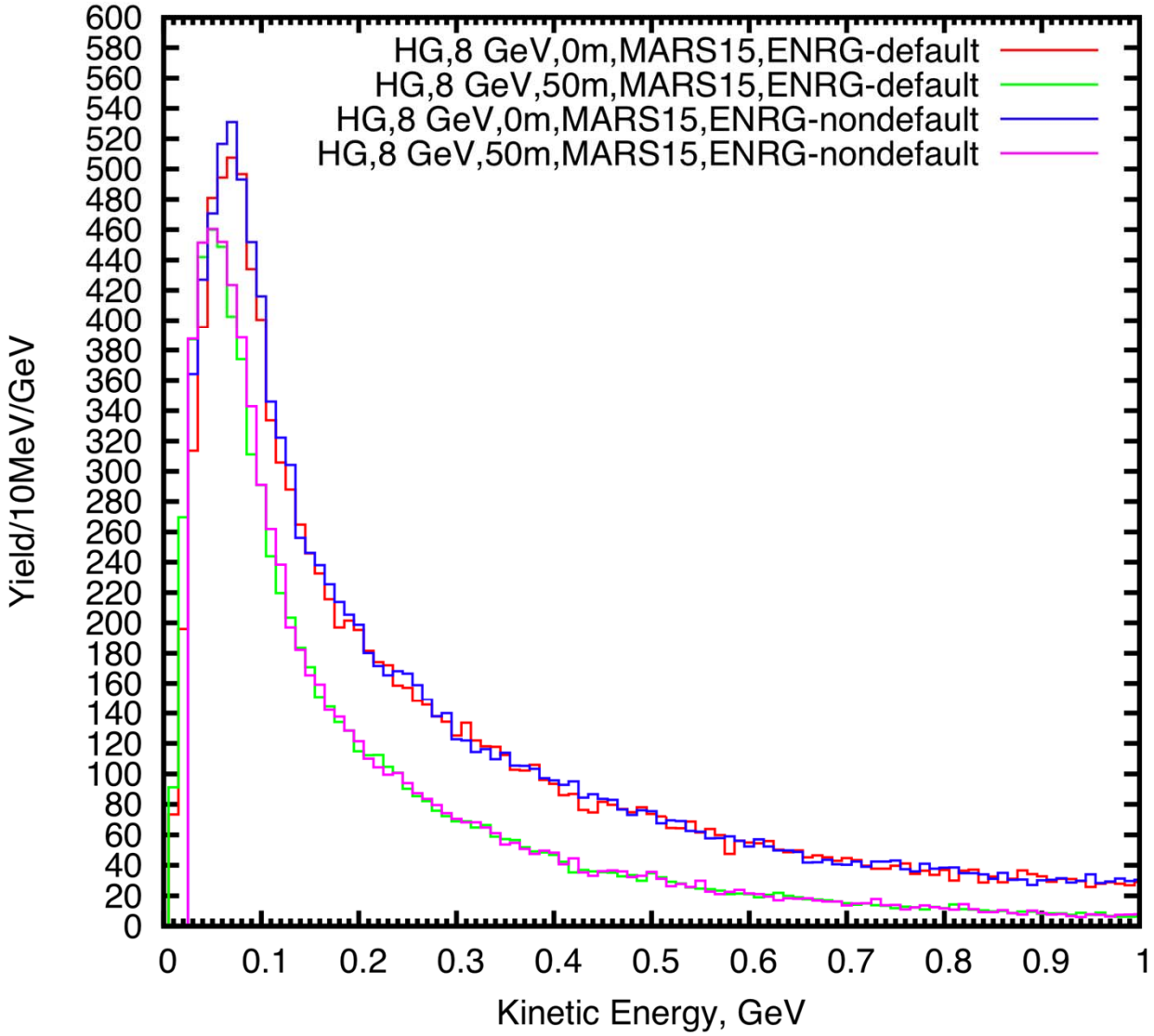
Yield comparison between default and nondefault ENRG card



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.

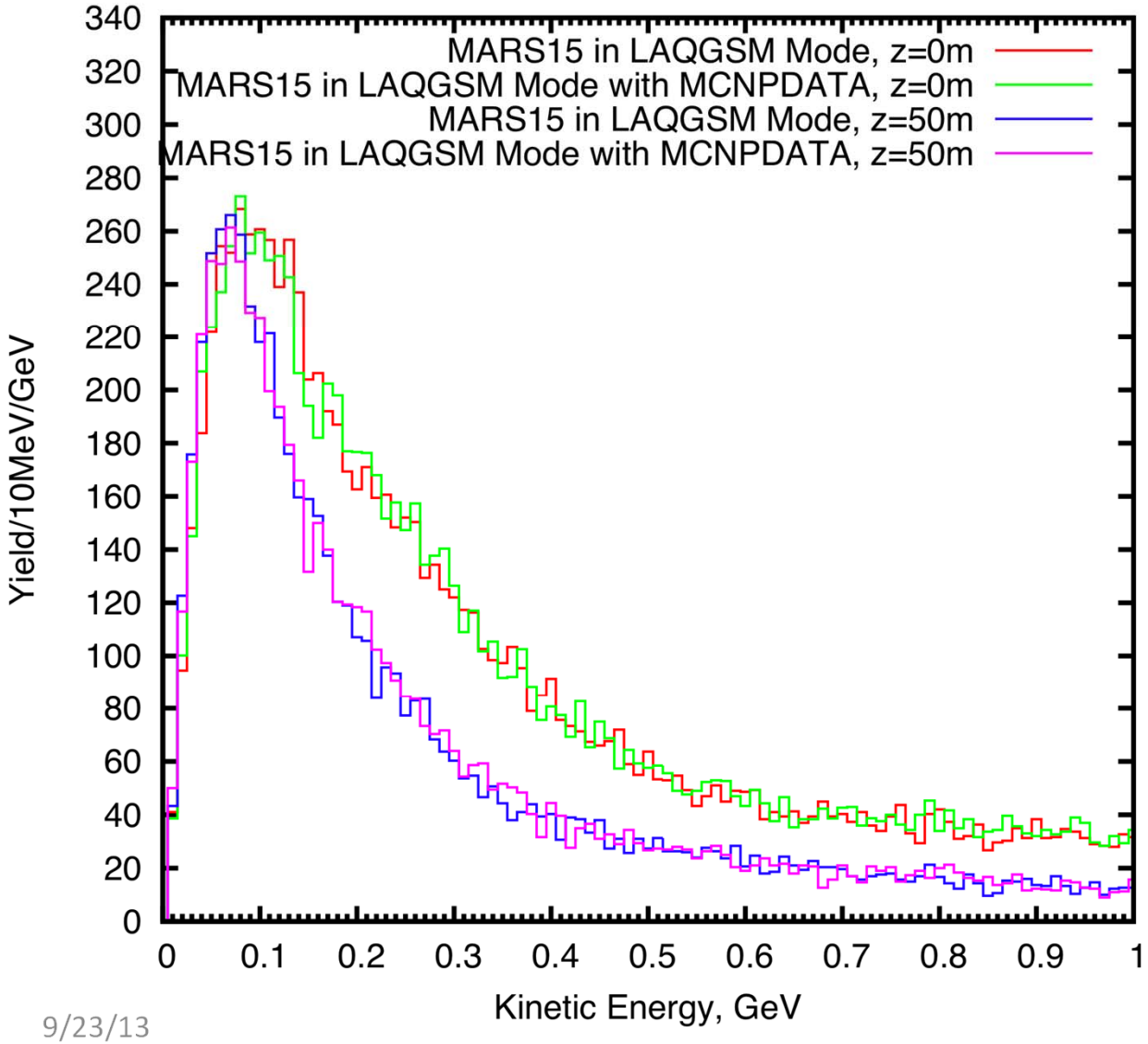
Yield comparison between default and nondefault ENRG card



MARS15, mode 4
HG at 8 GeV

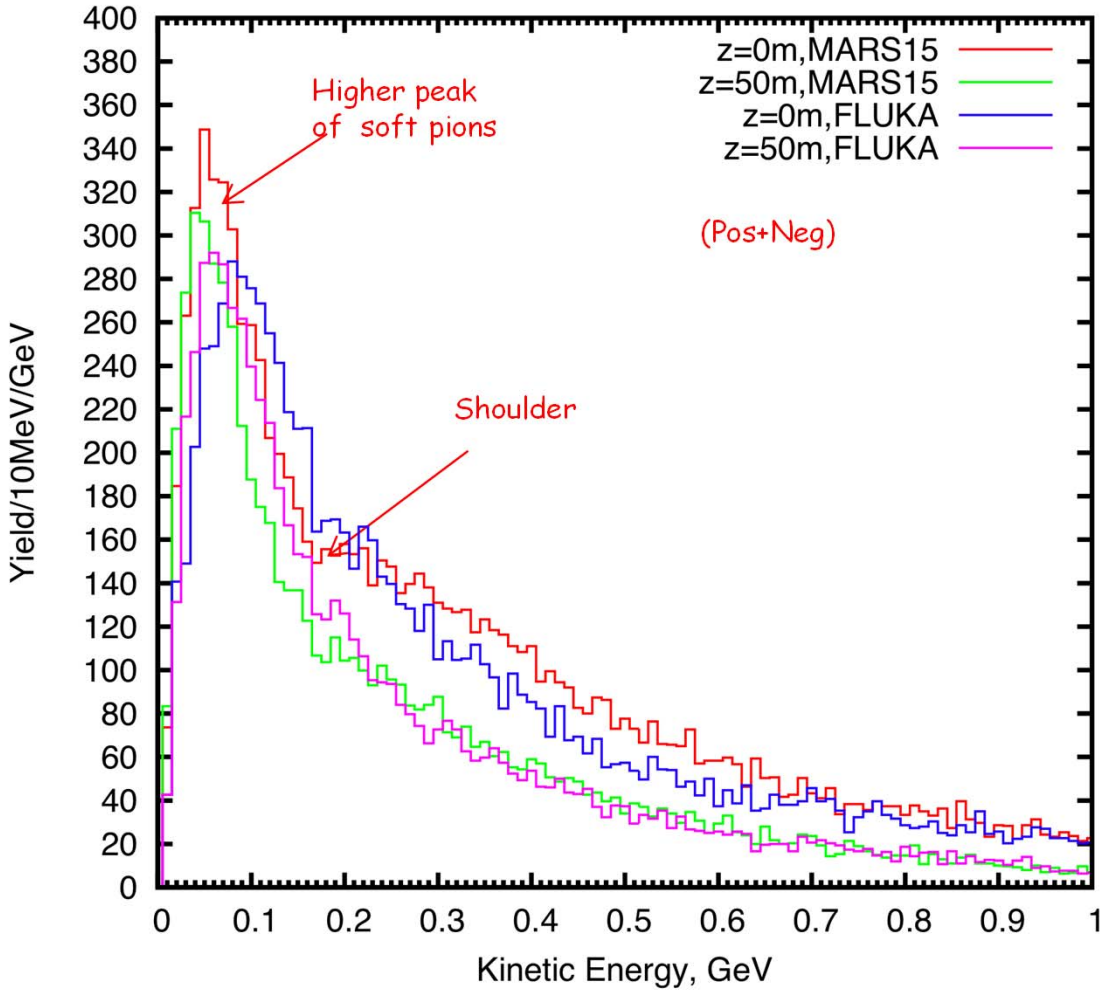
Results are similar.
However, the running speed with non-default ENRG card is about several times (~10) faster.

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



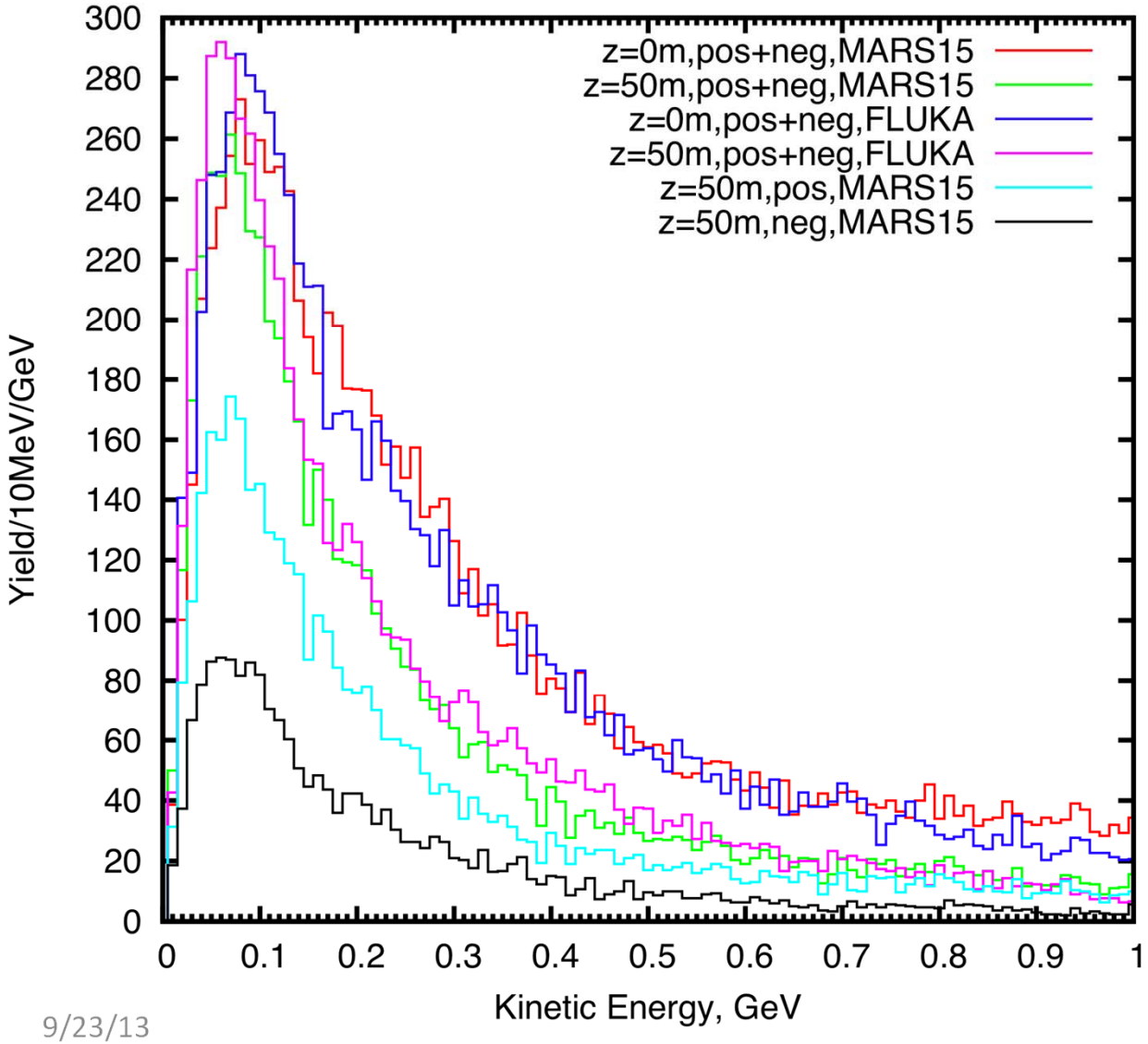
Results are very similar. This means MCNP mode doesn't play important role in particle production.

MARS15 (mode 1) vs. FLUKA (Carbon target at 3 GeV)



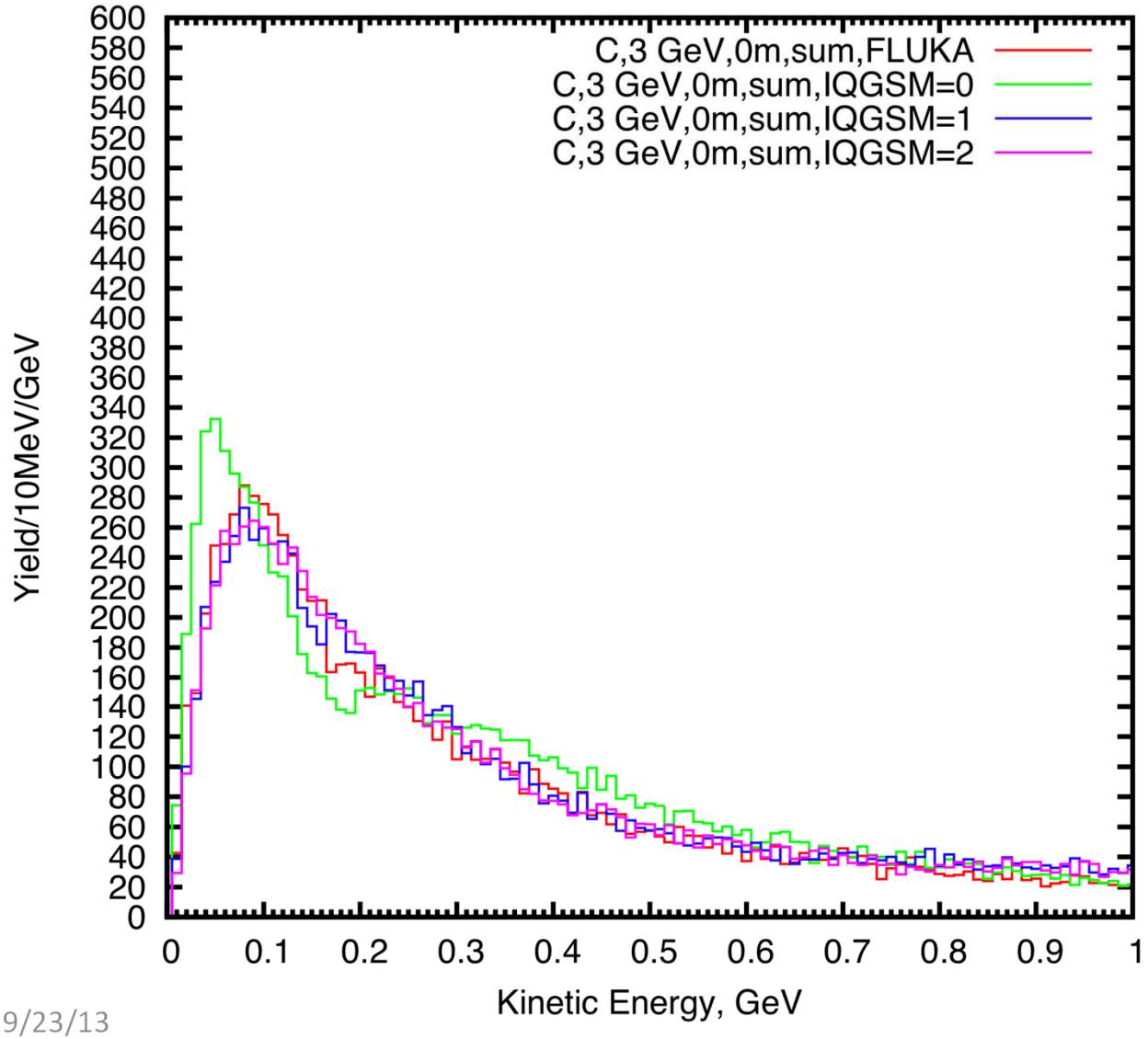
Strange shape from Mode 1: Higher peak of soft pions and shoulder

MARS15 (mode 4) vs. FLUKA
(Carbon target at 3 GeV)



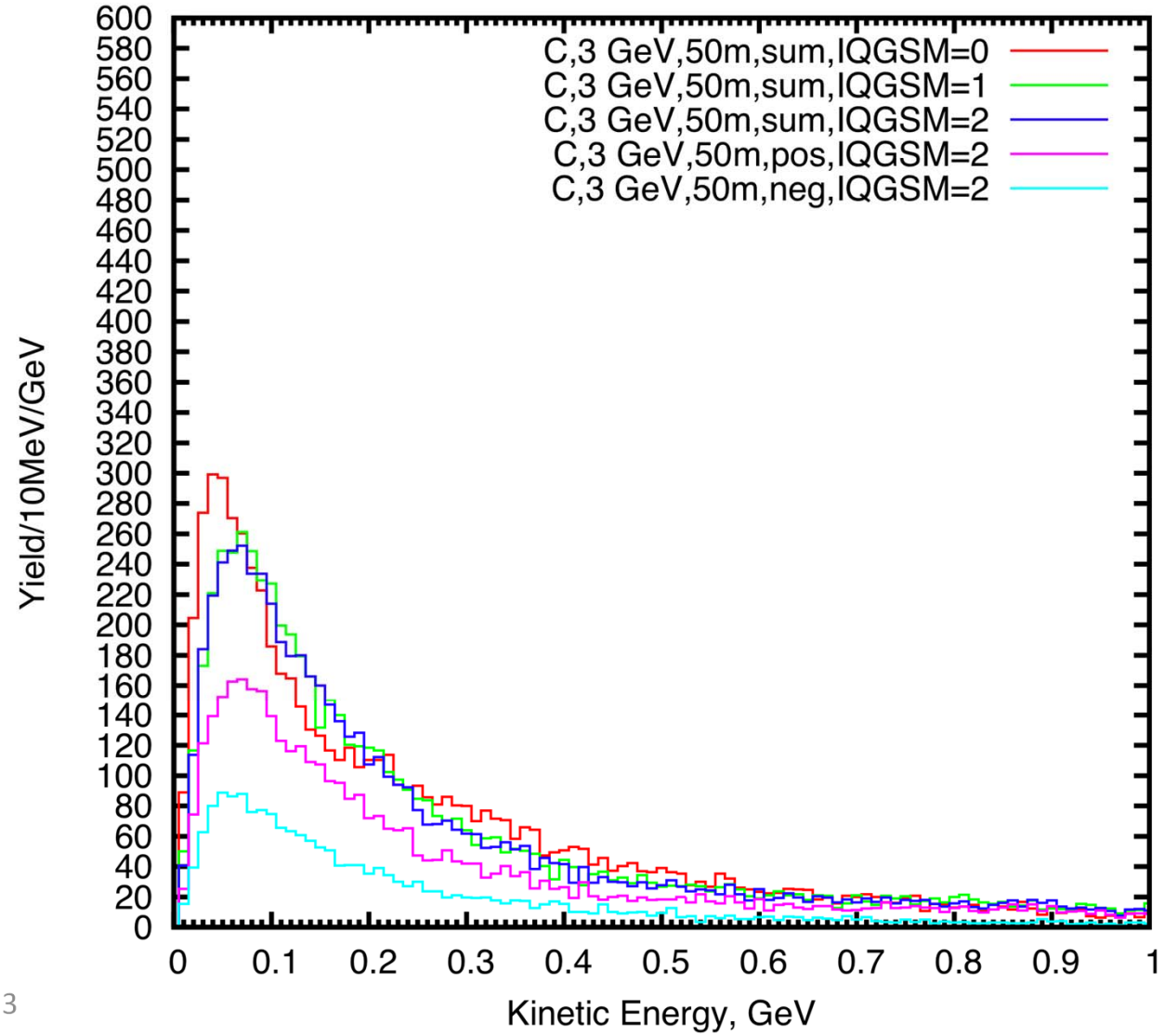
1. No strange shape at mode 4 is not observed.
2. Energy spectra between MARS15 and FLUKA look similar.

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)



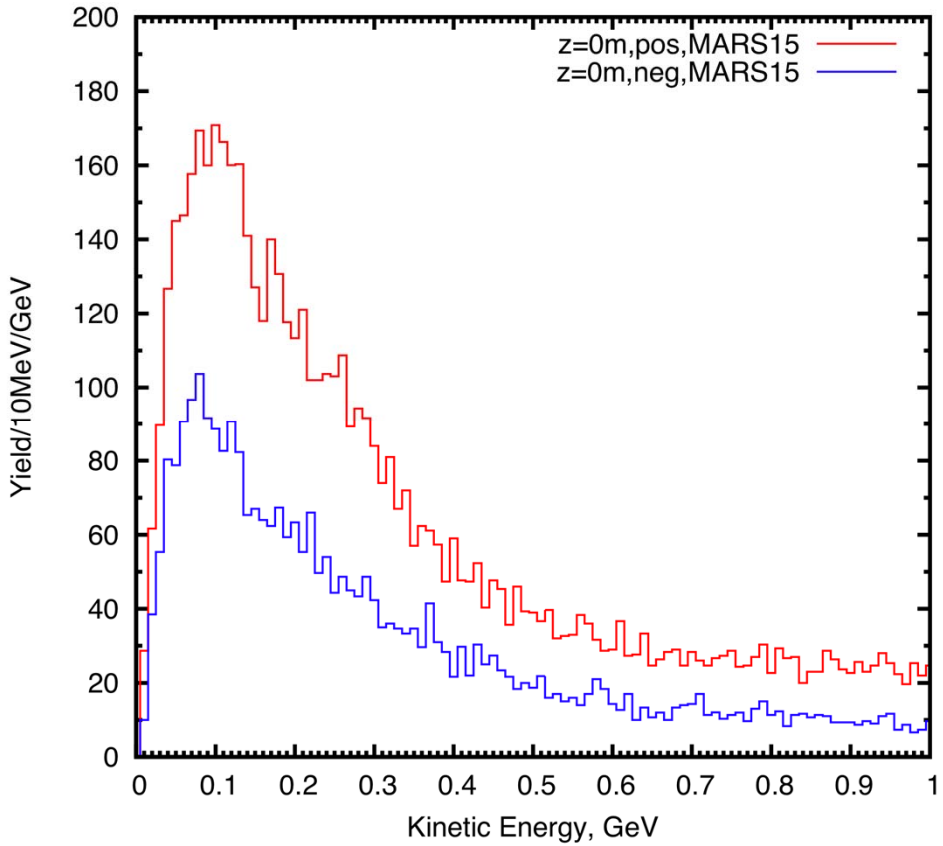
1. Results similar between IQGSM=1 and IQGSM=2
2. Yield (pos) ≈ 2*Yield (neg)

Positive and Negative Yield

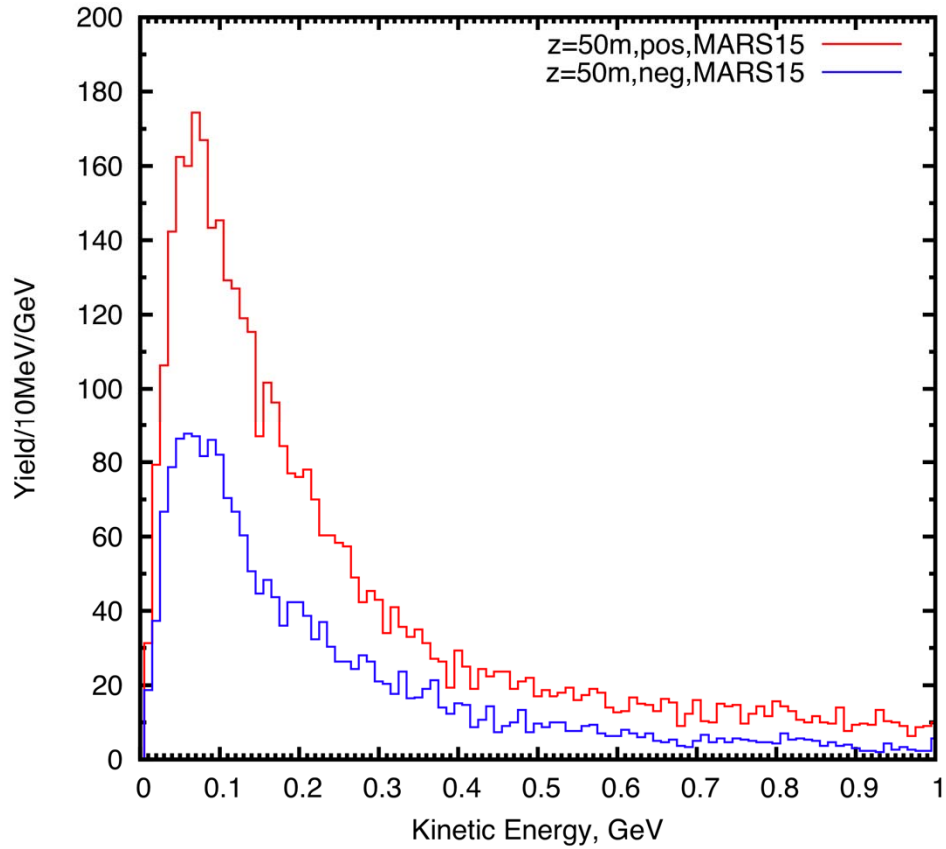
(MARS15/mode 4/IQGSM=1)

(Carbon target at 3 GeV)

Yield (pos) ≈ 2*Yield (neg)

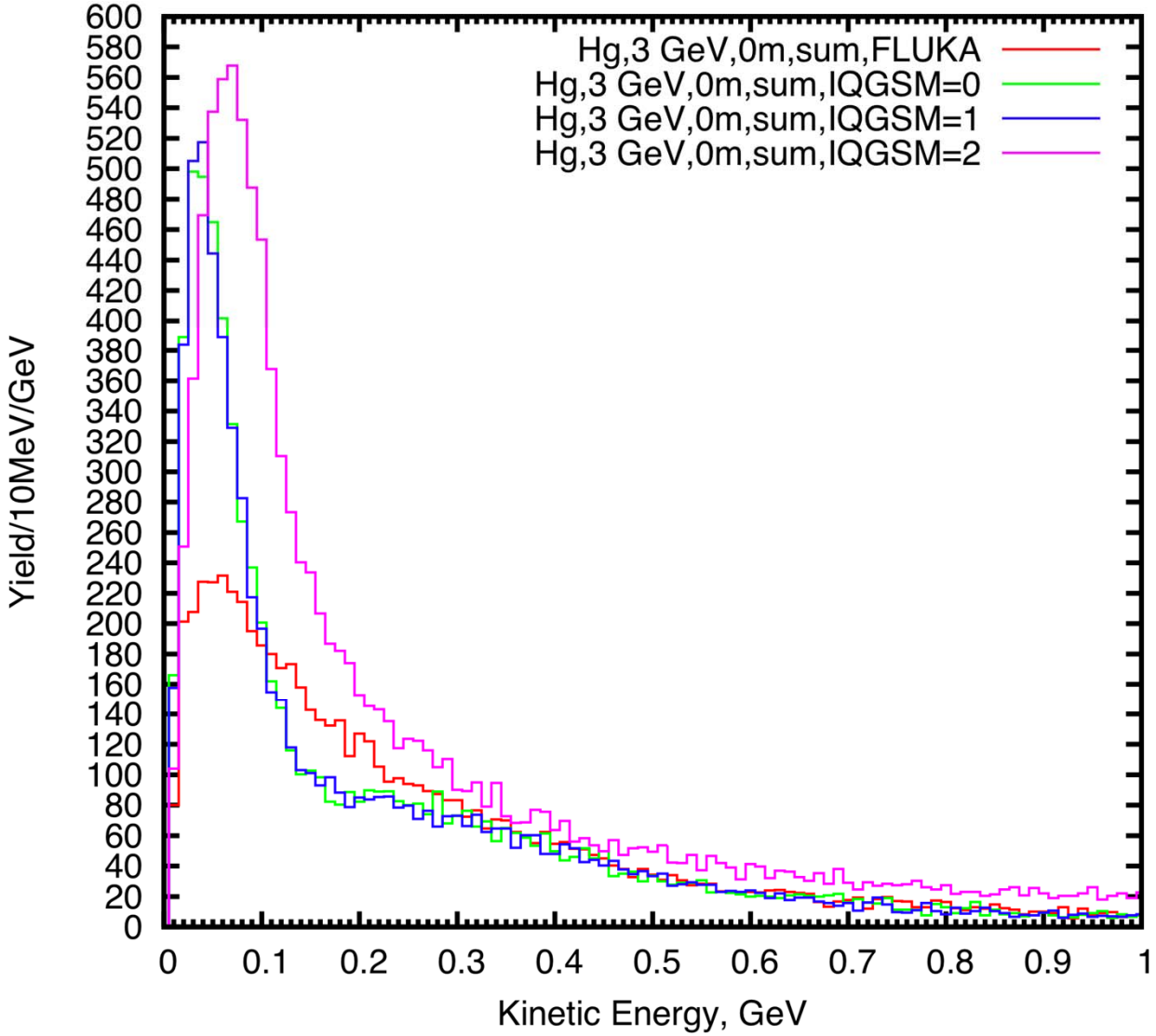


z = 0 m



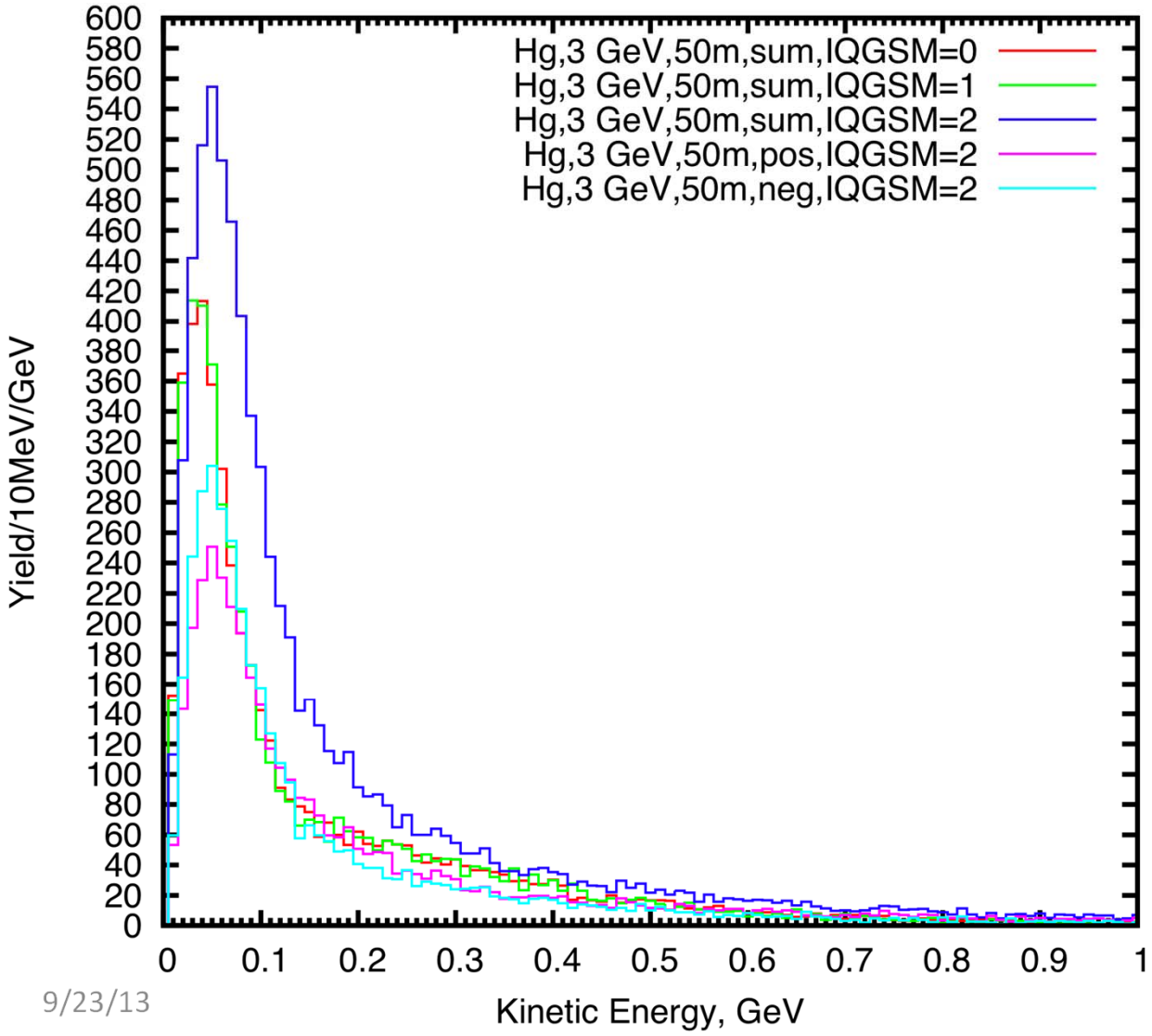
z = 50 m

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)



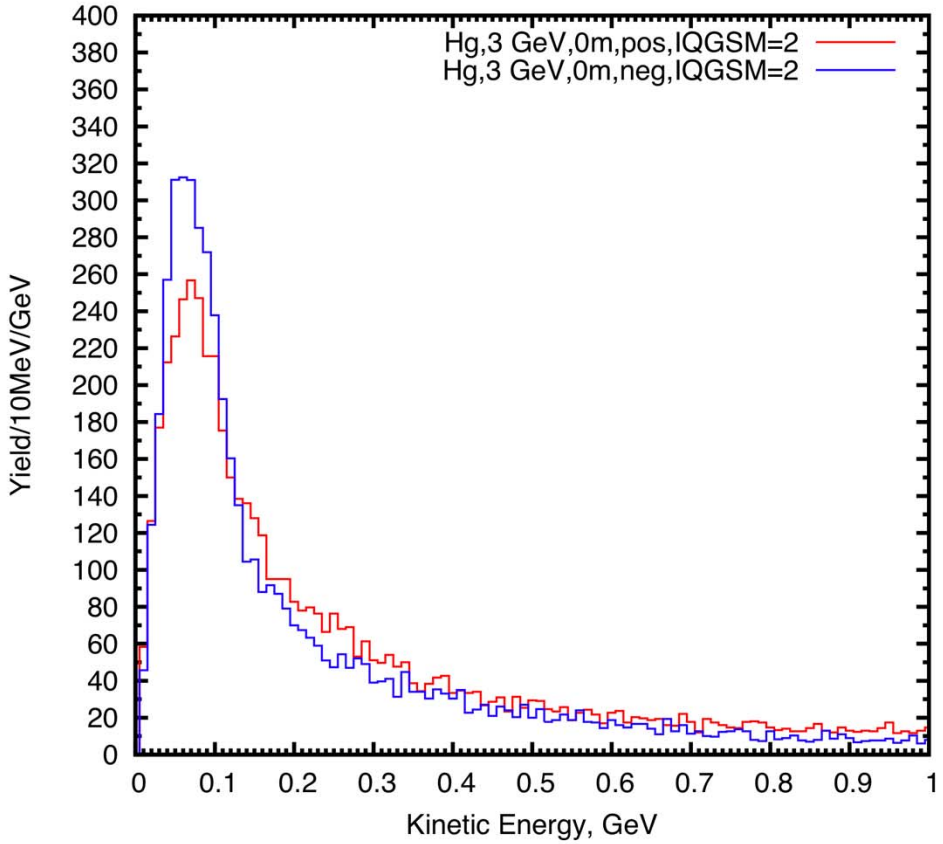
1. Results much different between IQGSM=1 and IQGSM=2
2. Yield (neg) ≈ 1.1*Yield (pos) for IQGSM=2

Positive and Negative Yield

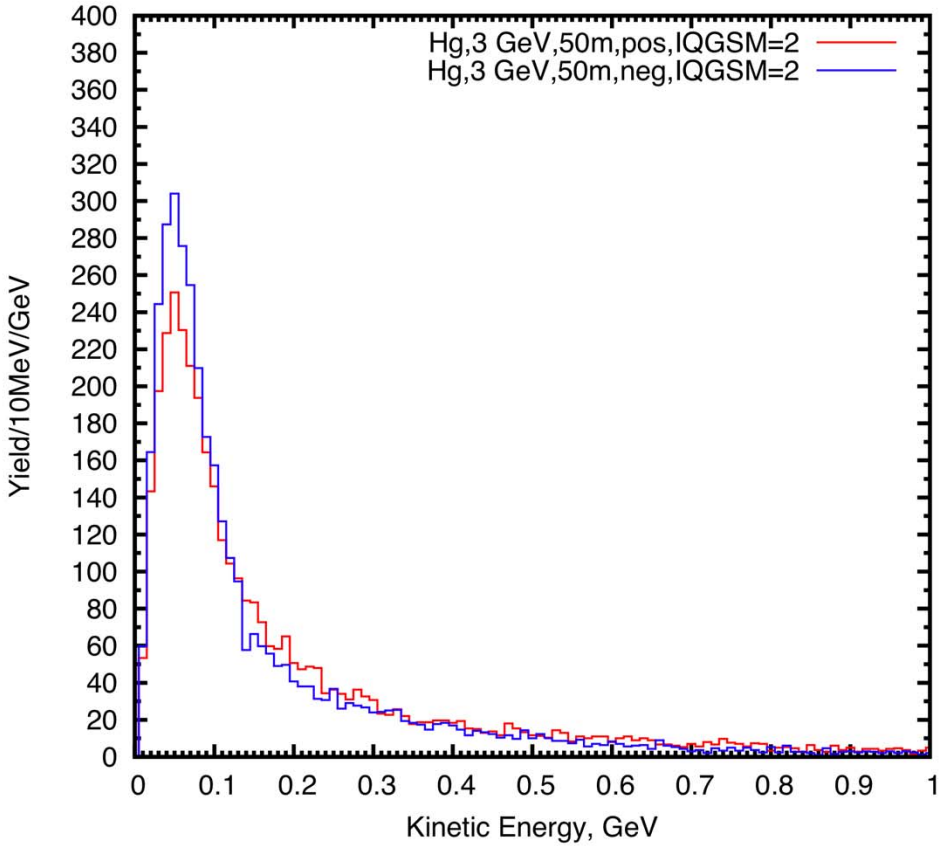
(MARS15/mode 4/IQGSM=2)

(Mercury target at 3 GeV)

Yield (neg) ≈ 1.1*Yield (pos)

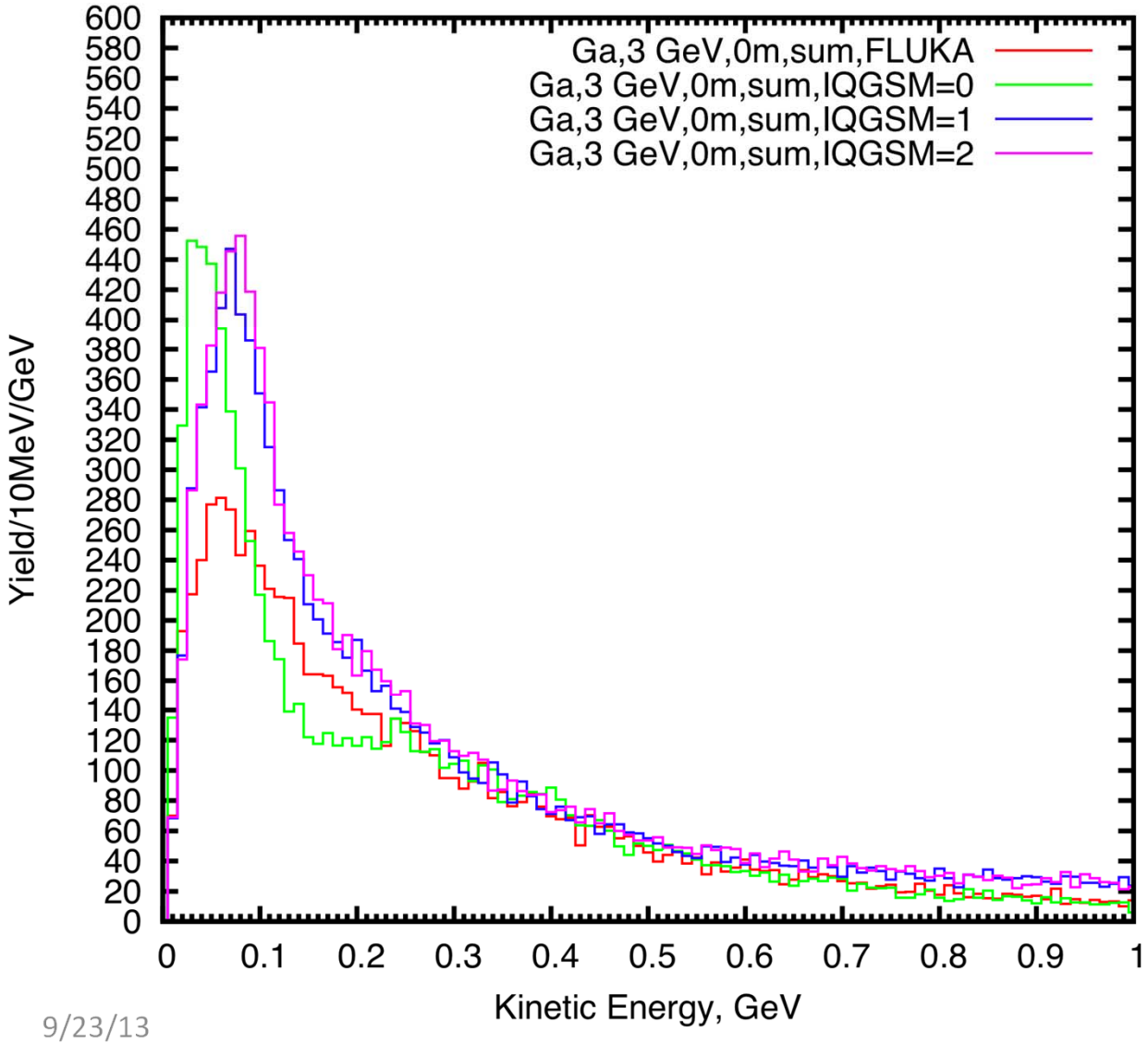


z = 0 m



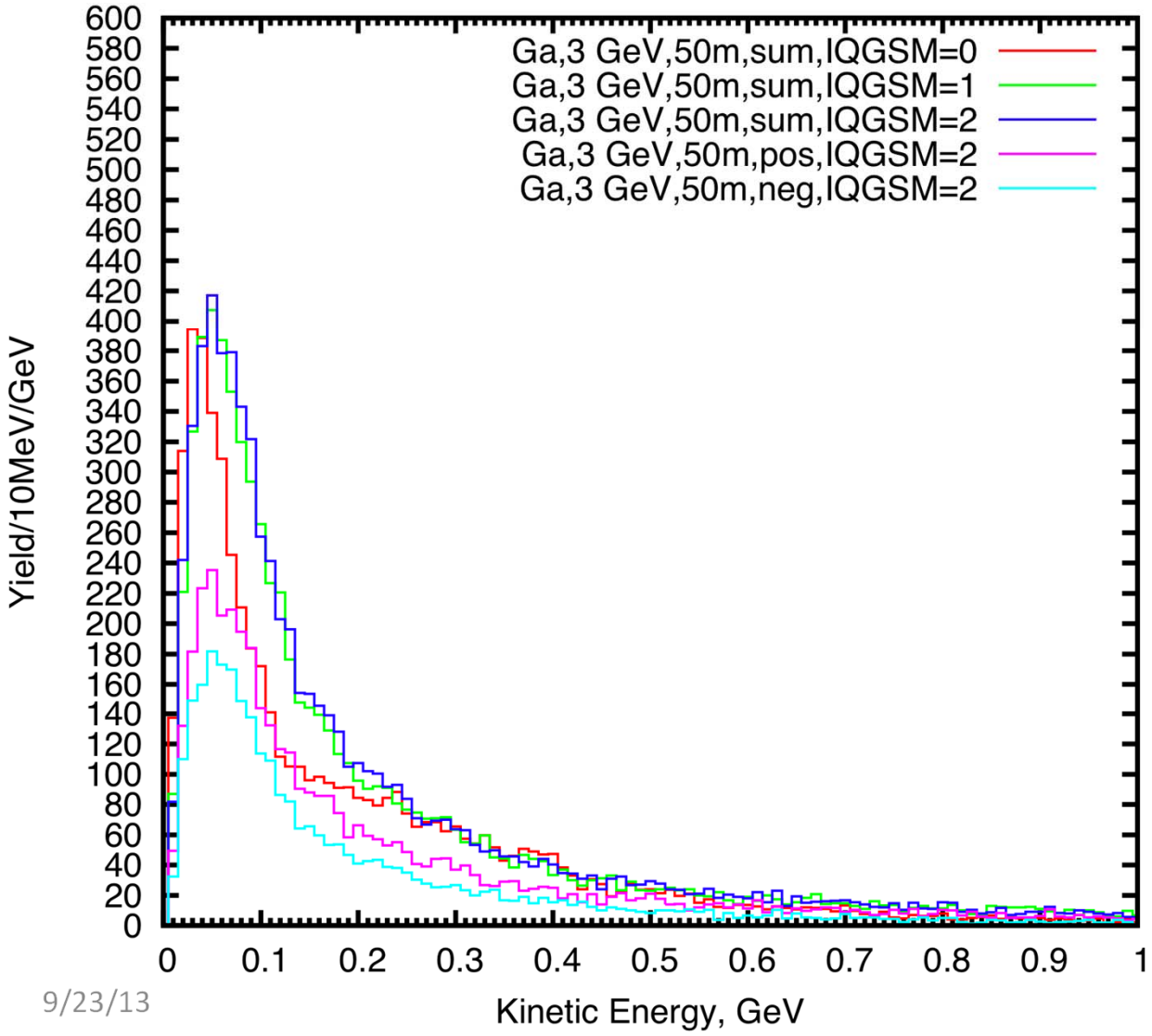
z = 50 m

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)



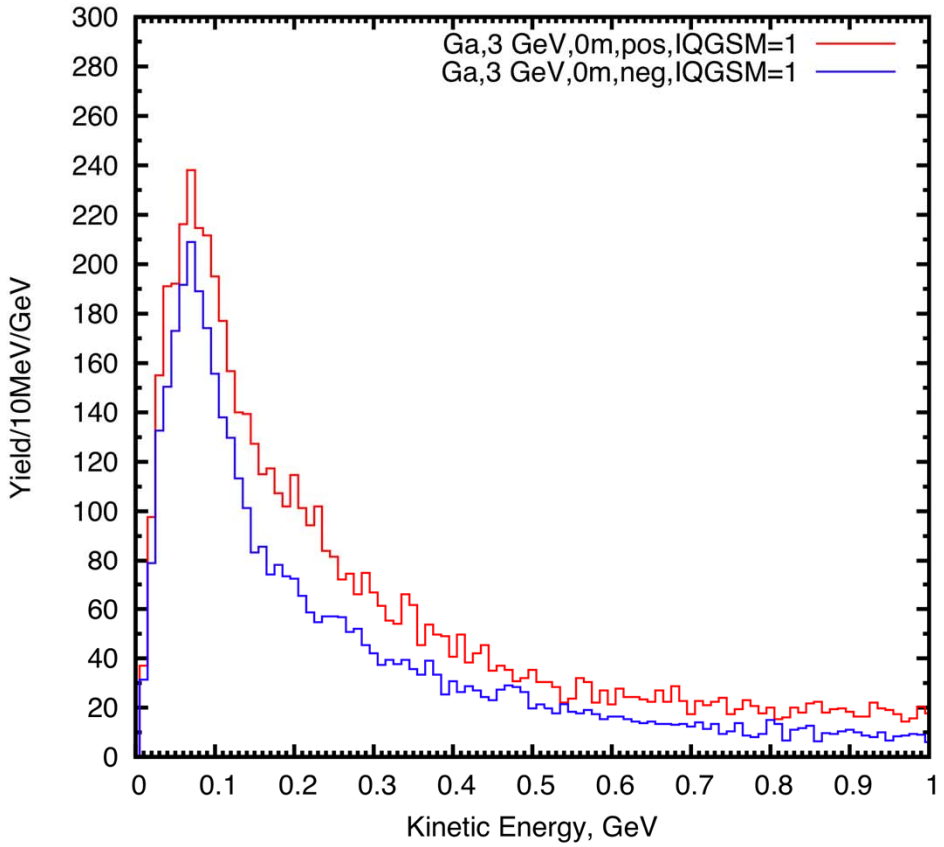
1. Results similar between IQGSM=1 and IQGSM=2
2. Yield (pos) ≈ 1.3*Yield (neg)

Positive and Negative Yield

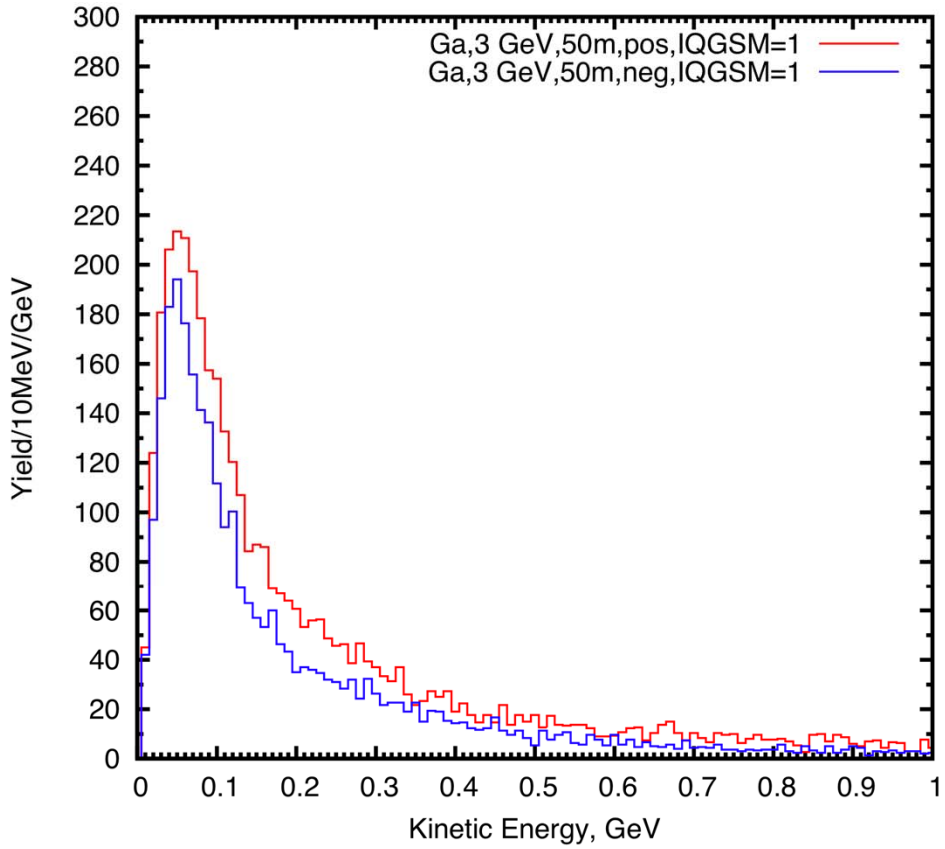
(MARS15/mode 4/IQGSM=1)

(Gallium target at 3 GeV)

Yield (pos) ≈ 1.3*Yield (neg)



z = 0 m



z = 50 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) ≈ 2*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) ≈ 1.1*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) ≈ 1.2*Yield (neg)

   0.026 Yield/proton/GeV (from FLUKA) at z = 50 m