Beam Emittance and Energy Spectra for Hg and C Targets

J. Scott Berg
Brookhaven National Laboratory
MAP 2015 Spring Collaboration Meeting
May 19, 2015

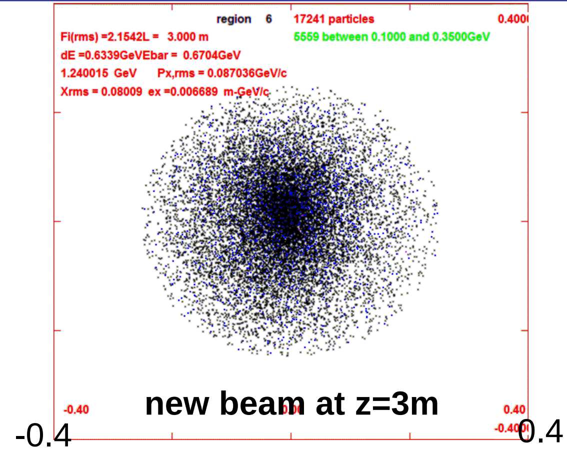
Motivation—Neuffer's Results

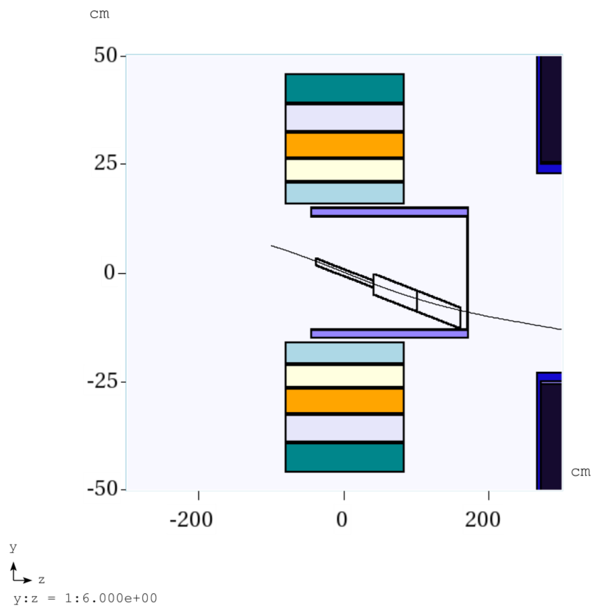
- Neuffer's talk at the MAP 2014 Winter Meeting, Dec. 4, 2014 (next 3 slides)
- Compared results from 8 GeV beam on Hg target to 6.75 GeV beam on C target
- C target had larger emittance by over a factor of 2
- Large increase in loss in first 6 m
- Performance reduction by about a factor of 2

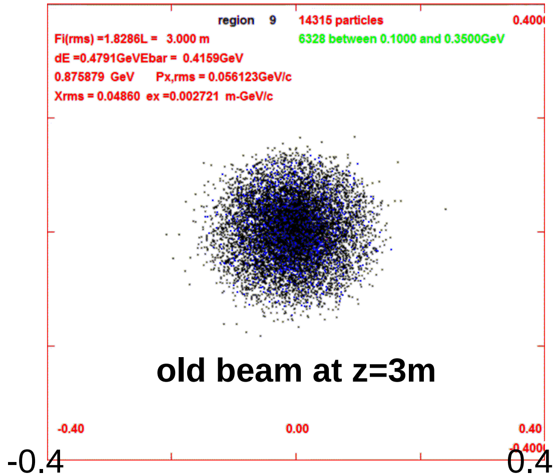
Motivation—Neuffer's Results

Use old FE with new initial beam

- New beam has too large initial size and divergence
  - initial transverse emittance >2X larger
    - 0.0027 → 0.0067 m-GeV/c
  - ~half of initial beam lost in <6m



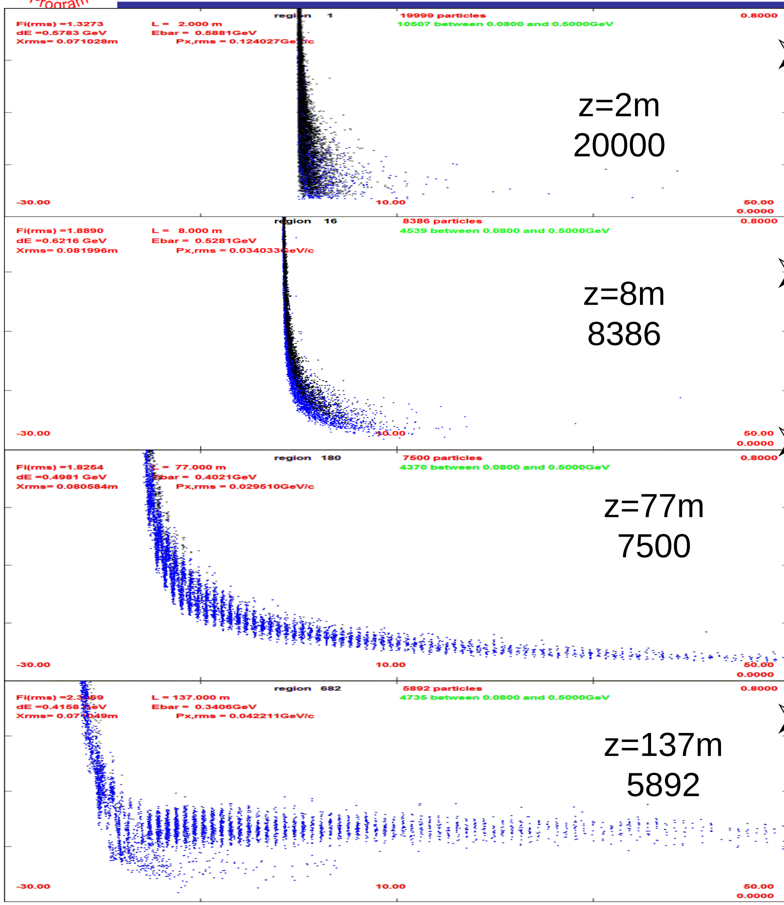




11

Motivation—Neuffer's Results

First simulations results



- ~60% of initial particles are lost in first 6m
  - previous front end lost ~20%
- Beam starts out very large
  - previous much smaller in
  - front end simulations
- μ/p reduced by factor ~ 2
  - → ~0.0545 μ^+/p
  - ~0.042 μ^-/p
    - μ^- less than μ^+
- Not fully reoptimized for new initial beam

12

6.75 GeV p/ C target – First Look

- Much worse than previous 8 GeV p / Hg target
- 6.75 (~25% less), Hg → C …
  - but initial beam has very large phase space
- Causes for early losses ???
  - Long C target not a good match to short taper ?
    - target should be within lens center …
  - "Beam dump" after target blows up π beam ??
- Bugs, errors?
  - Changes in Mars production code ??
  - normalization error ??
  - initialization errors
    - starts from z=2m rather than z=0
- After initial factor of 2 loss, very similar to old front end case
  - not yet reoptimized
- To investigate/debug/reoptimize ..

13

Scope of my Studies

- Determine reasons for the behavior that Neuffer saw
- Better understand behavior in front end
- Produce distributions, equivalent in some sense to what Neuffer worked with, that address any problems in the originals
- Parameters for optimized (X. Ding) target designs
  - Target in 20 T field, tapering down to 2 T in just under 5 m
  - Hg: 8 GeV beam
  - C: 6.5 GeV beam, 65 mrad tilt, no dump

Effect of Apertures

- Old target apertures
  - Mercury: square root taper aperture, starting at 7.5 cm at $z = 0.375$ m, growing to 30 cm at $z \approx 19$ m
  - Carbon: 13 cm aperture to $z = 1.7$ m, then 23 cm downstream
- Compare: maximum possible apertures near target for 20 T: 13 cm to $z = 85$ cm, then 23 cm downstream
- Compare distributions at 3 m to results with old apertures

Effect of Apertures

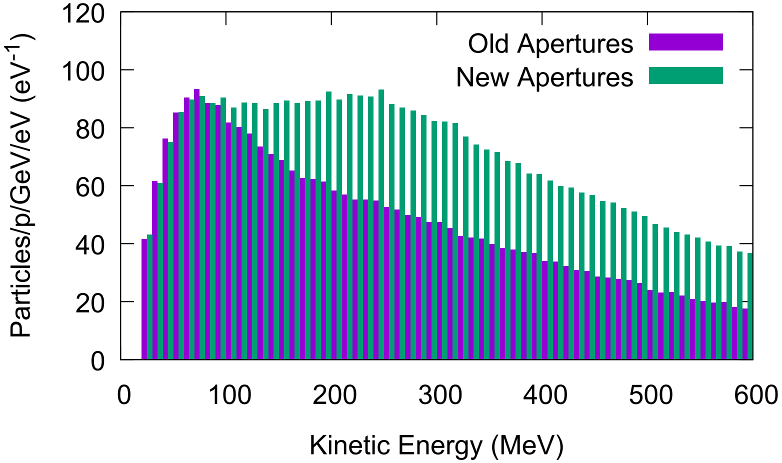
- Emittances are larger, and are identical for Hg and C: emittances determined by apertures!
  - Normalized canonical emittances in mm
  - Large sign is sort of helicity
  - Difference in emittances is angular momentum

	μ^-+	μ^--	μ^++	μ^+-	π^-+	π^--	π^++	π^+-
Hg old	30.7	13.4	35.2	15.1	21.0	14.4	21.9	15.1
Hg new	60.2	17.5	66.6	18.8	62.8	14.6	64.8	14.8
C old	51.5	22.1	52.7	23.9	36.5	26.0	36.6	27.4
C new	60.7	18.5	64.5	19.4	63.8	15.4	66.1	15.6

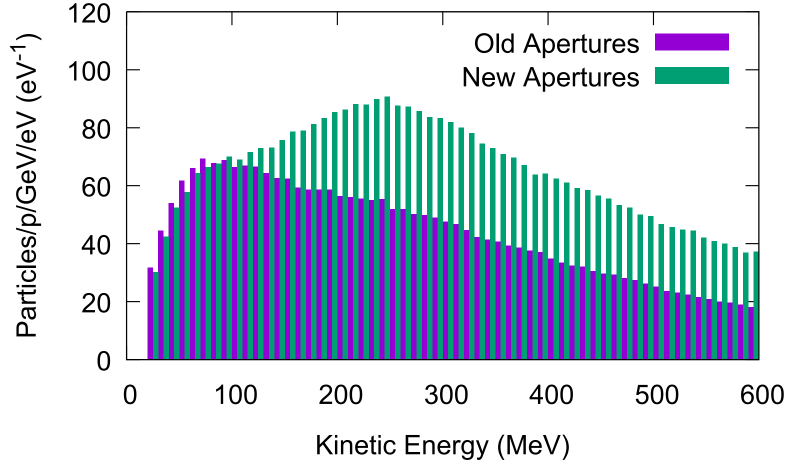
- Spectrum: widening apertures gives more particles at higher energy

Hg at 3 m

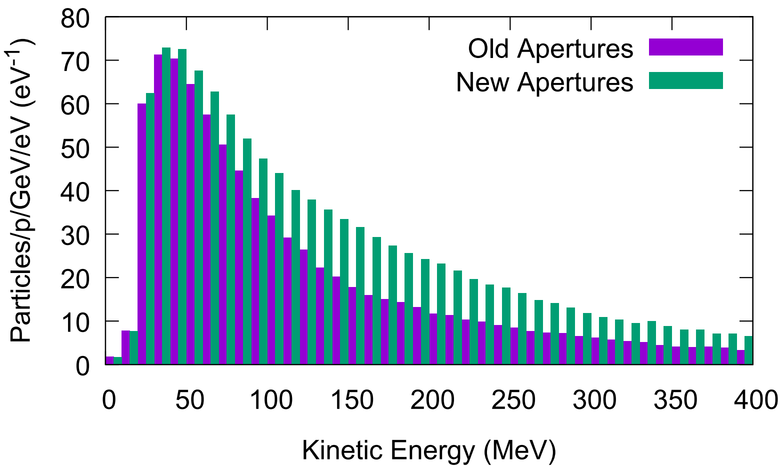
π^-



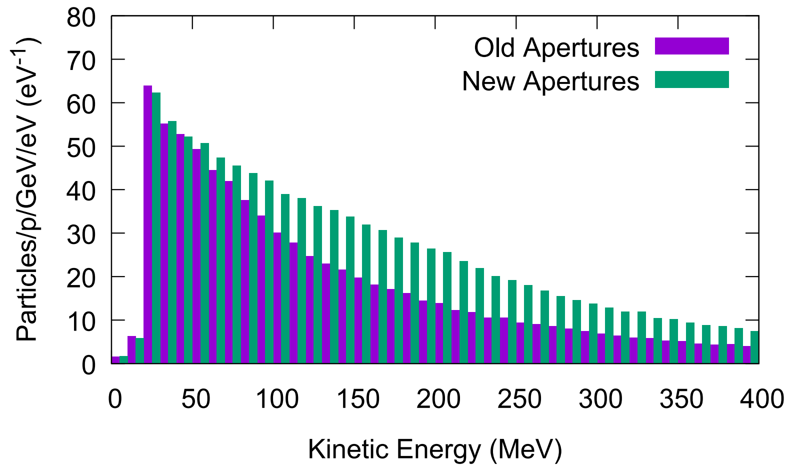
π^+



μ^-

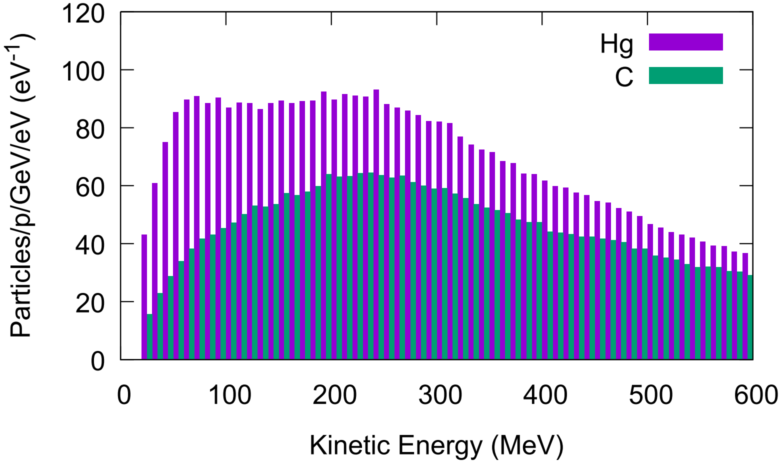


μ^+

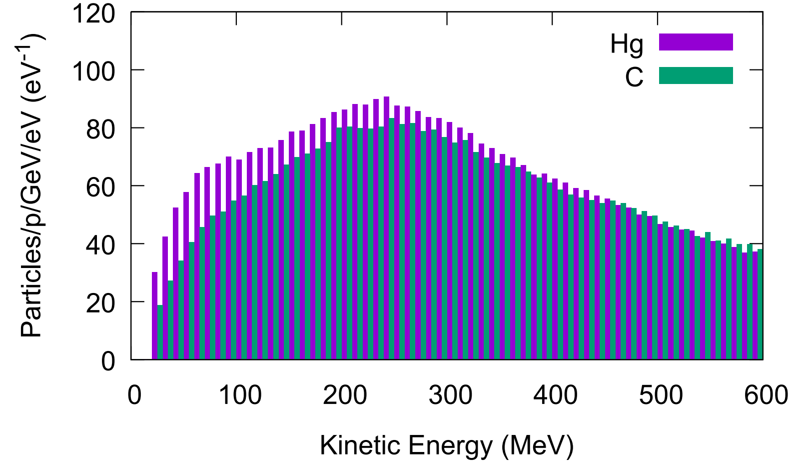


Hg vs. C at 3 m

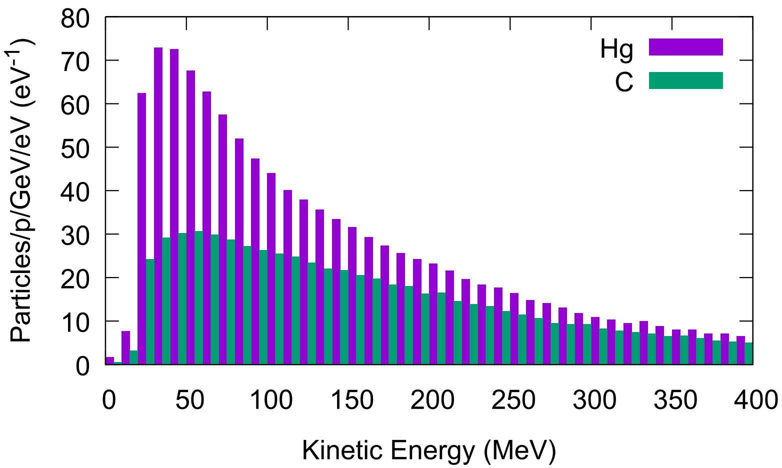
π^-



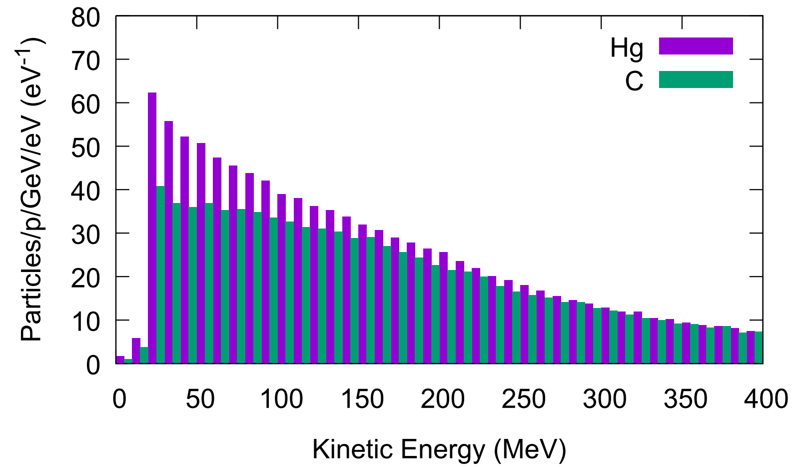
π^+



μ^-



μ^+

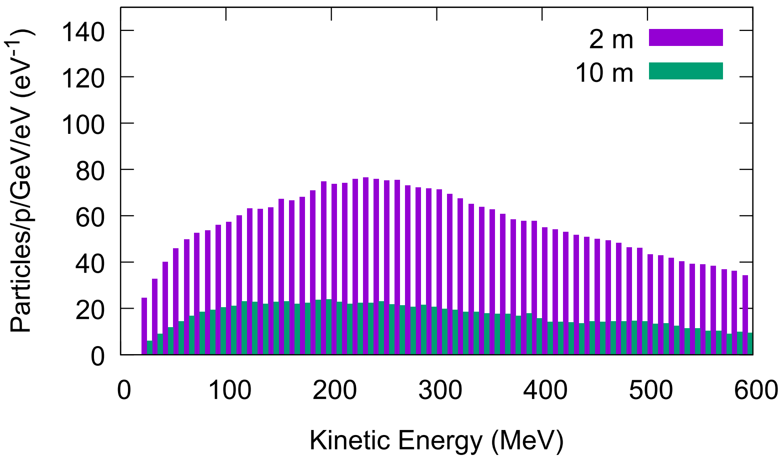


Hg vs. C at 3 m

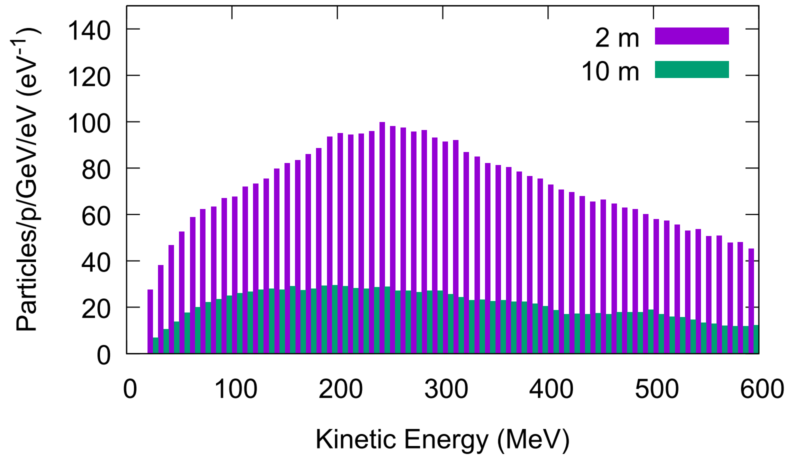
- Hg production per MW always higher than C
- Distributions (per MW!) get very similar at high energy, especially for positive charges
- Pion production peak at 250 MeV shows up in Hg as well as C
  - This peak may be related to geometry: higher fields may move this to higher energy
- C and Hg will require different NBPR
  - Note that NBPR will function differently for both signs (moreso in Hg): must be a compormise, designed simultaneously for both signs

Spectrum vs. Distance (C)

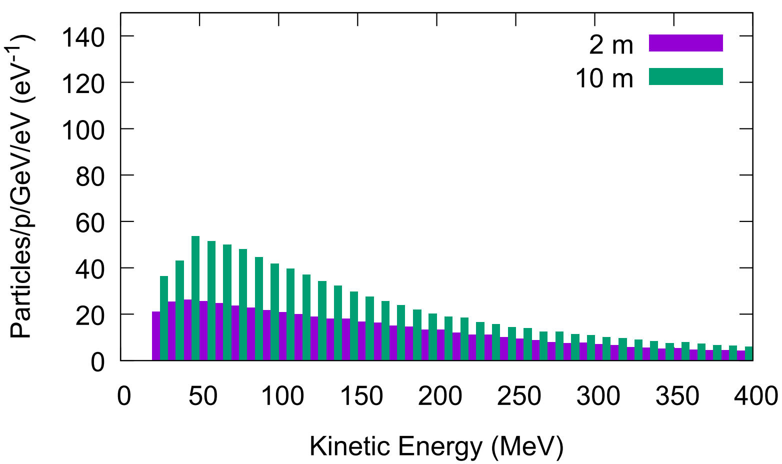
π^-



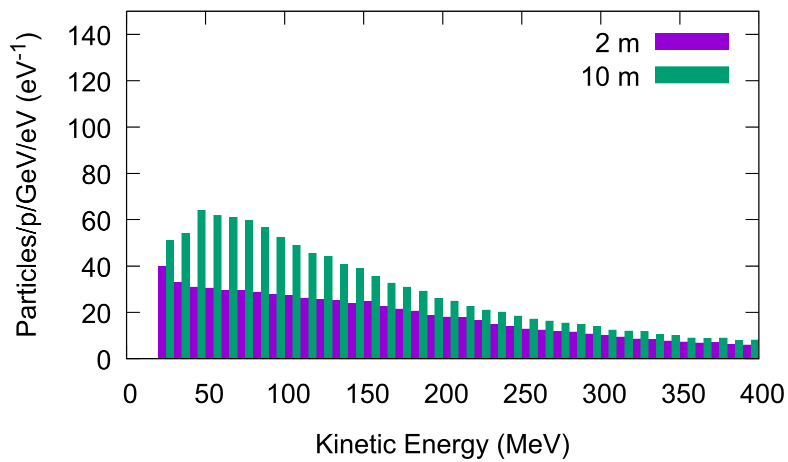
π^+



μ^-



μ^+



Spectrum vs. Distance

- Going down to 10 m, many more pions lost than muons created
- Peak at 250 MeV goes away
- Conclusion: many pions (and maybe some decay muons) lost on apertures
- Transmission would be improved by higher fields downstream
  - Consistent with Hisham's results
  - Spectrum would be weighted toward higher energy

IQGSM

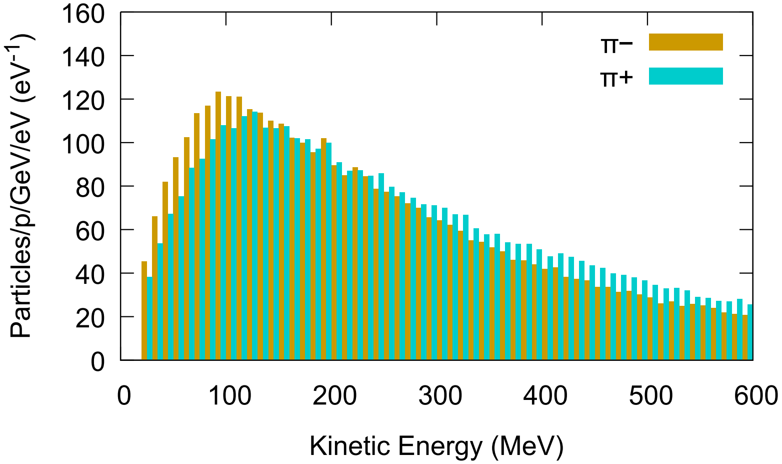
- IQGSM gives a “choice of inclusive and exclusive event generators at nuclear inelastic interactions”
- IQGSM=0: exclusive CEM (cascade exciton model?) for $E < 3$ GeV, MARS inclusive for $E > 5$ GeV, LAQGSM for some special cases. Old MARS default.
- IQGSM=1: CEM for $E < 0.3$ GeV, LAQGSM for 0.5 GeV $< E <$ 8 GeV, MARS inclusive for $E > 10$ GeV. New MARS default.

Distributions for Hg, IQGSM

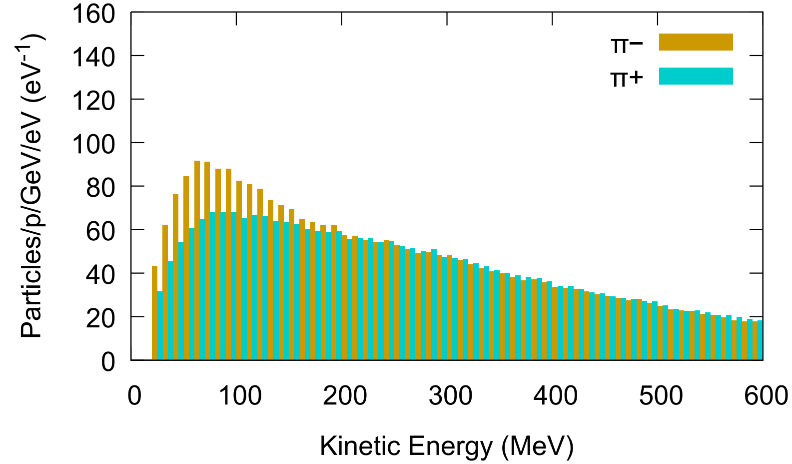
BROOKHAVEN NATIONAL LABORATORY

Muon Accelerator Program

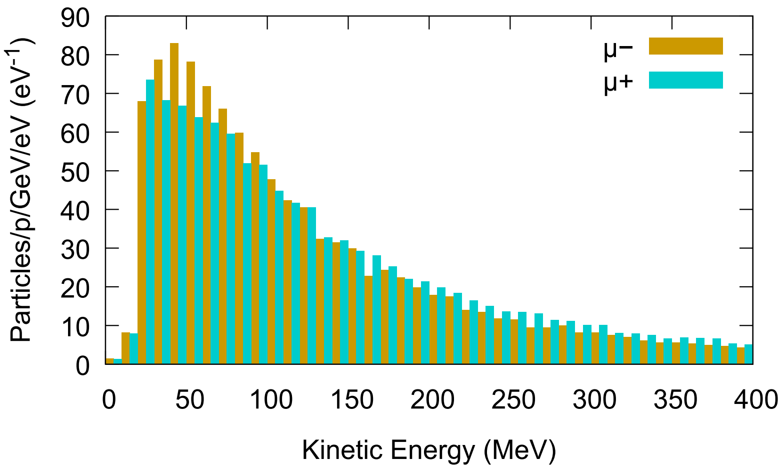
13-Jan-2015 IQGSM=0



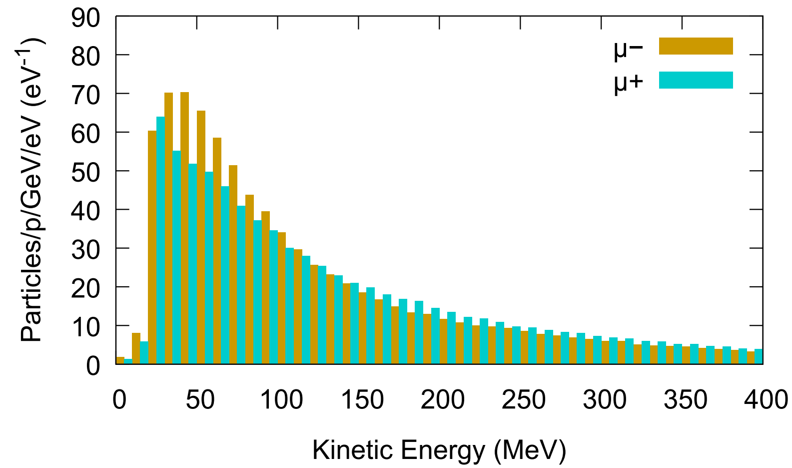
13-Jan-2015 IQGSM=1



13-Jan-2015 IQGSM=0



13-Jan-2015 IQGSM=1



IQGSM

- Significant performance hit for IQGSM=1 vs. IQGSM=0
- Energy spectrum also changes
- Emittance doesn't change
- C runs were all with IQGSM=1, earlier Hg were IQGSM=0

Conclusions

- I believe we more or less understand why David saw what he saw
- There were production differences due to differences in the nuclear inelastic model used (IQGSM)
- Emittances are determined primarily by apertures; Hg and C are the same
- High energy portion of spectrum clipped by apertures
- Spectrum shape differs for different signs

Conclusions

- Positive production similar for Hg and C
- Negative production differs significantly at low energy (< 150 MeV for μ^-)
  - Optimal NBPR will be different for Hg and C
- Higher fields downstream would increase number of captured particles, but likely raise energy of spectrum
- Hints that some early absorber may be beneficial, increasing lower-energy flux
  - In old days we had a “pre-cooler”
  - These results hint at a benefit from an “absorber horn”

Conclusions

- Finally: thanks to X. Ding for lots and lots of “ok, now run this configuration” MARS runs, which he completed very efficiently

Next Steps

- What does NBPR optimized for these distributions look like?
  - What portion of the distribution does it use?
  - What is the best compromise for both signs?
    - Is this different for collider and ν factory optimization?
  - Is there a significant difference for C and Hg?
- How does chicane change things?
- How does raising the field change things?
- Would an early absorber help?