Bertini Nucleus Parameters

Michael H. Kelsey
SLAC GEANT4 Group

GEANT4 Collaboration Meeting
13 Sep 2012

Introduction

Several new features still require validation

- Physical units in the nuclear structure model
- Final-state nucleon coalescence (clustering)
- Trailing effect (shadowing)
- Low-energy nucleon-nucleon cross-sections (for SATIF)

Want thin and thick target validations completed to activate by default in 9.6

Nuclear Structure

Current code has mismatch of length and cross-section ($h-N$ total) units in nuclear structure model

$$r \sim 2.8179 \times \text{fm} \qquad \sigma \sim \text{mb} \ (\times\ 10\ \text{fm}^2)$$

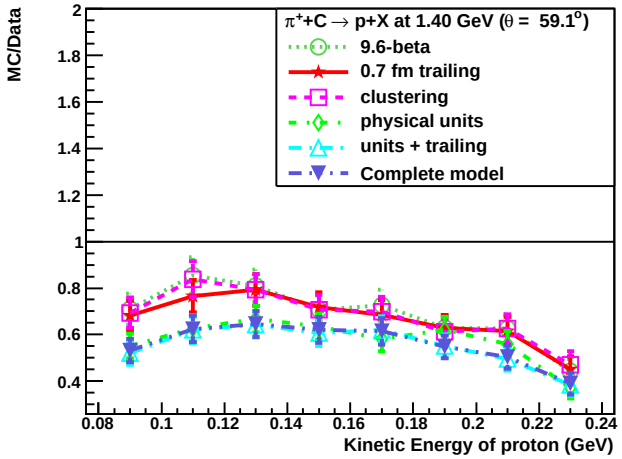
True physical units (fm, fm^2, $1/\text{fm}^3$) changes thin-target and calorimeter performance noticeably

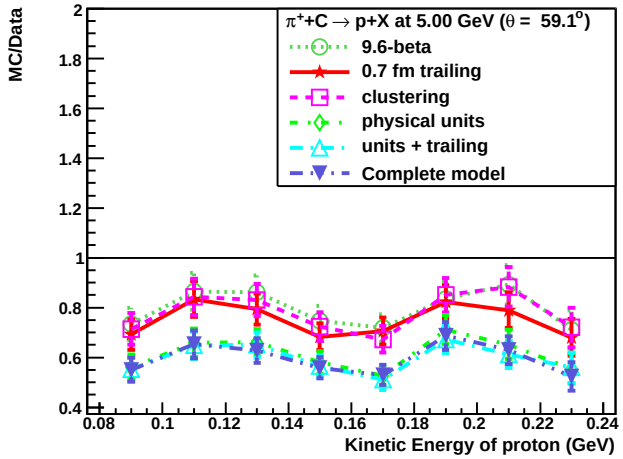
- Thin-target response reduced by factor of 2
- Calorimeter visible energy increased by 10–15%

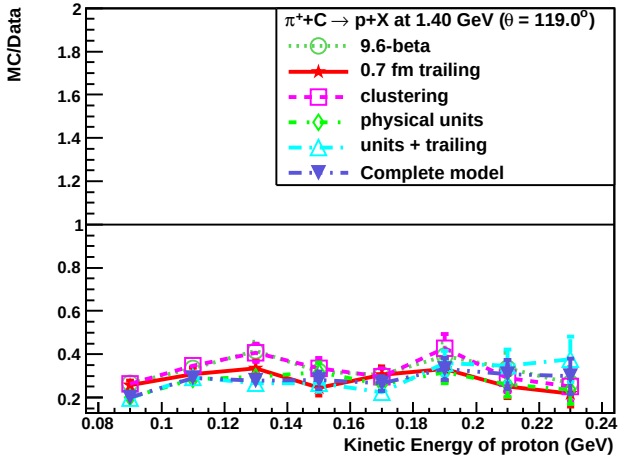
Scaling up total cross-sections $\times 3$ restores data-MC comparison

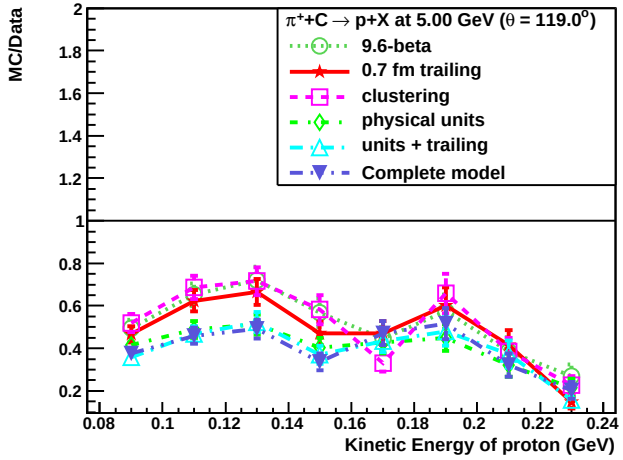
Thin-target Validation

Test47: π^- on carbon target, outgoing proton spectra



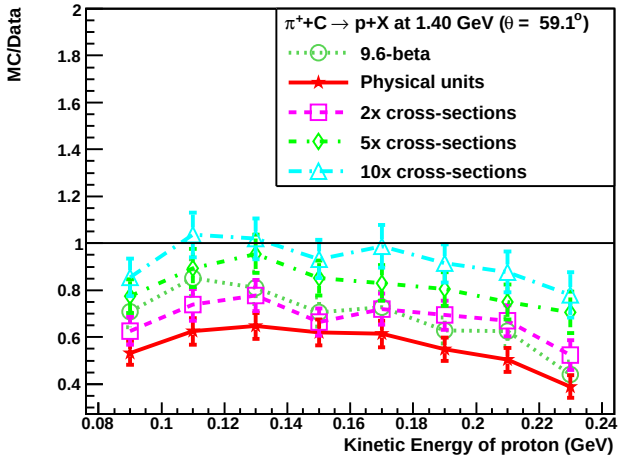


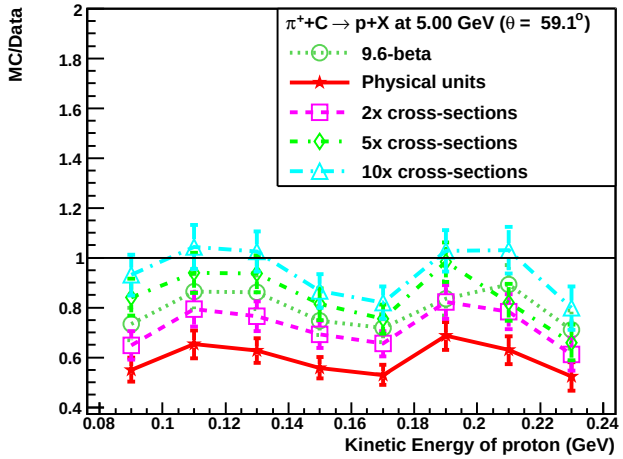


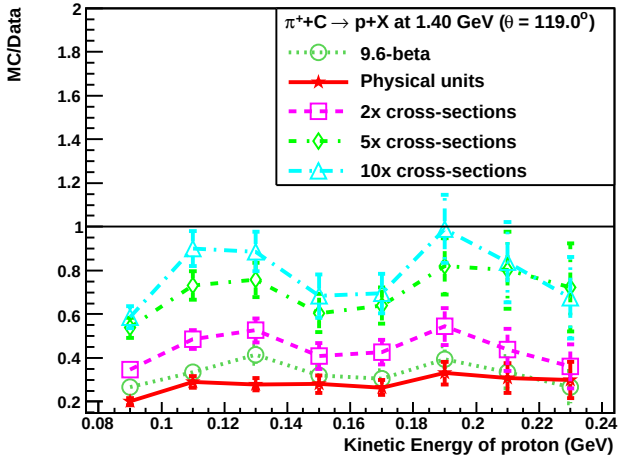


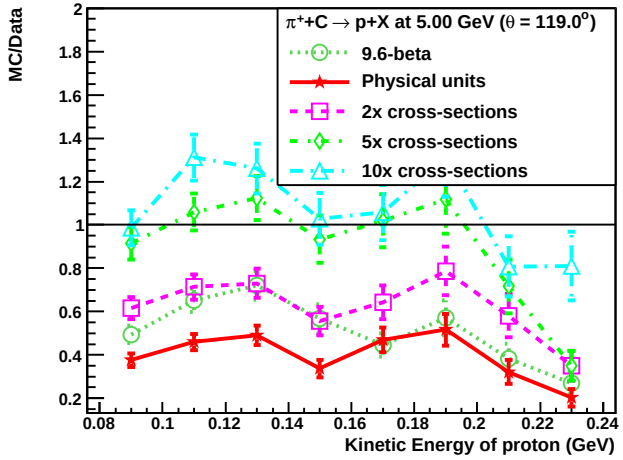
Thin-target Validation

Test47: π^- on carbon target, outgoing proton spectra



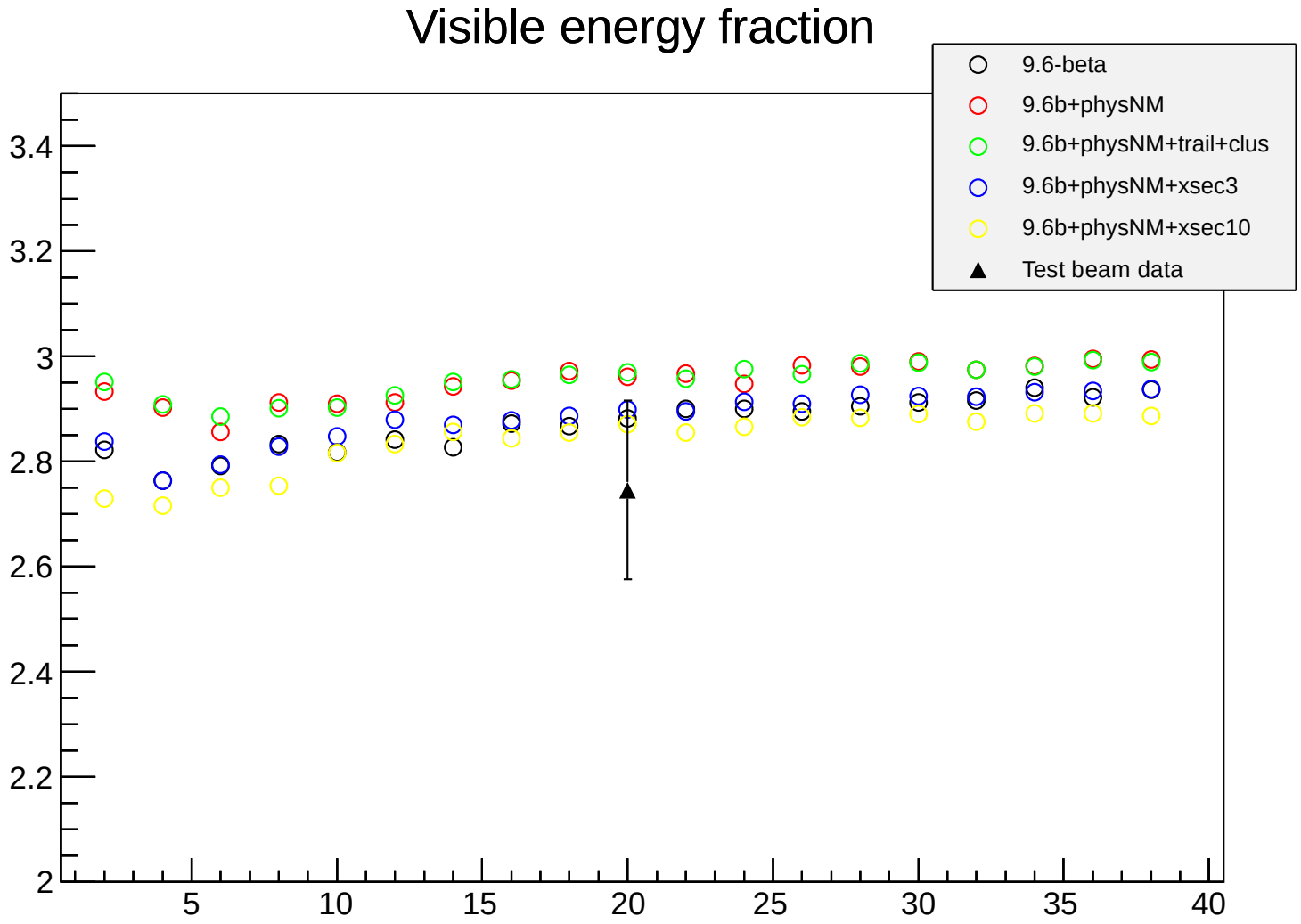






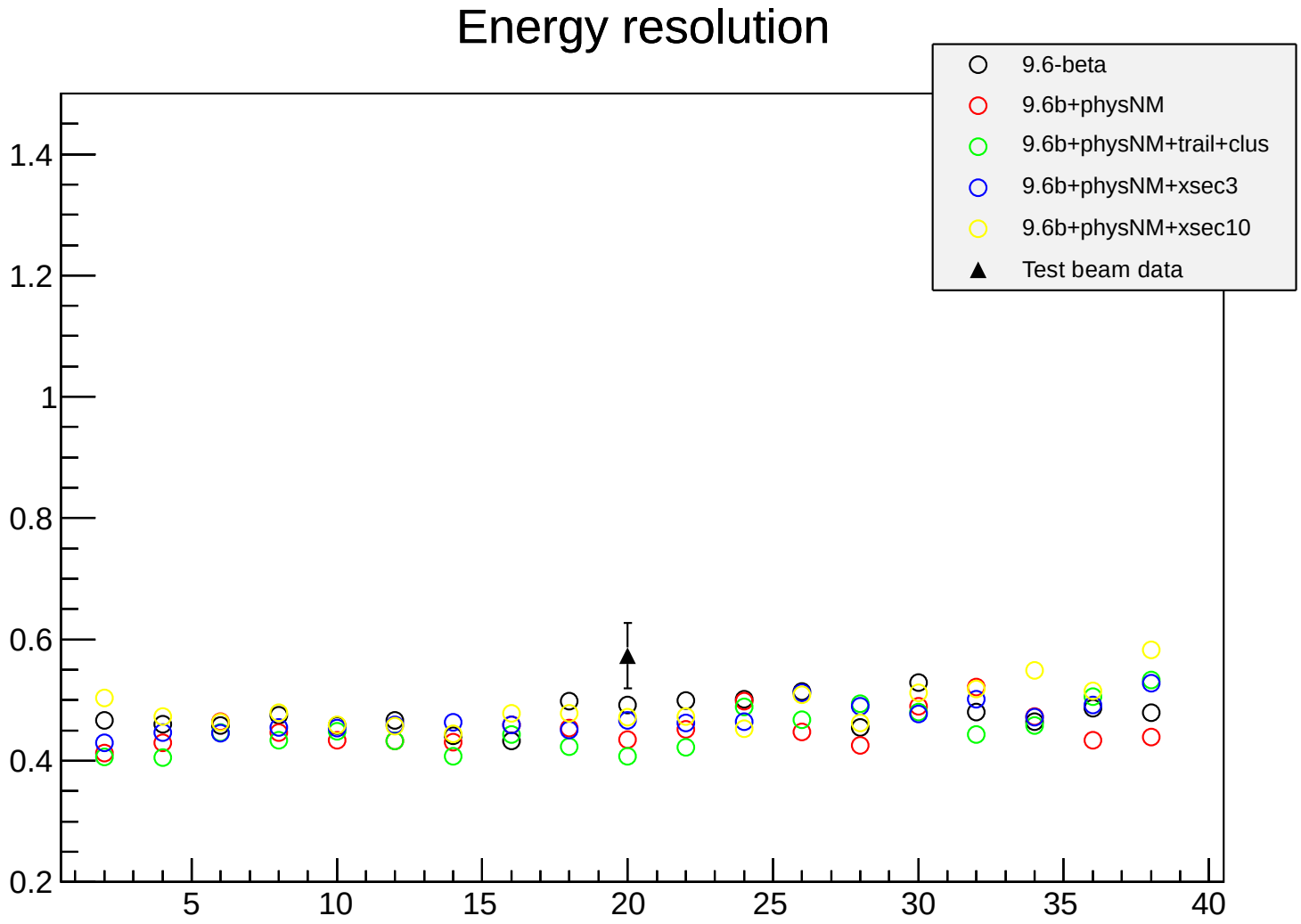
Calorimeter Validation

SimplifiedCalorimeter: π^- on iron-scintillator stack



Calorimeter Validation

SimplifiedCalorimeter: π^- on iron-scintillator stack



Final-state Coalescence

Bertini generally understimates light ions (D, T, ^{3}He, α)

Only produced in non-equilibrium evaporation or breakup

New optional code (envvar `G4CASCADE_DO_COALESCENCE`) finds clusters of final-state nucleons which can be bound

Momentum spread in cluster below thresholds:

$pn \Rightarrow$	D	90 MeV
$pnn \Rightarrow$	T	108 MeV
$ppn \Rightarrow$	^{3}He	108 MeV
$ppnn \Rightarrow$	^{4}He	115 MeV

Other light-ion sources (collective states within cascade, nucleon-induced "evaporation") not implemented

Trailing Effect

Also known as "shadowing"

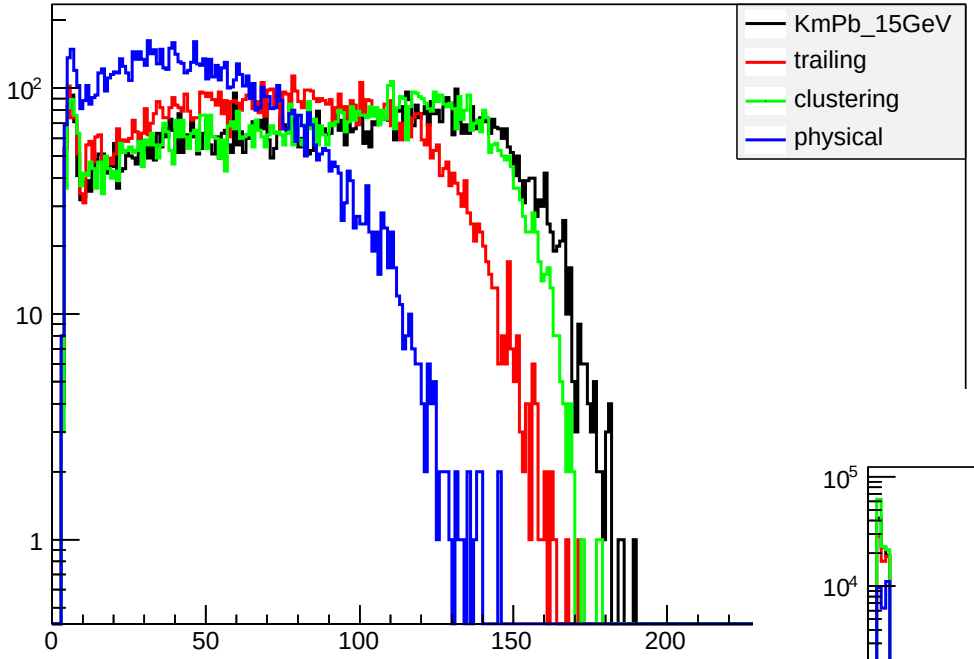
Emulates true time-dependent cascade by skipping interactions at locations of previously hit nucleons

Enabled by setting non-zero effective radius of nucleon (envvar `G4NUCMODEL_RAD_TRAILING`)

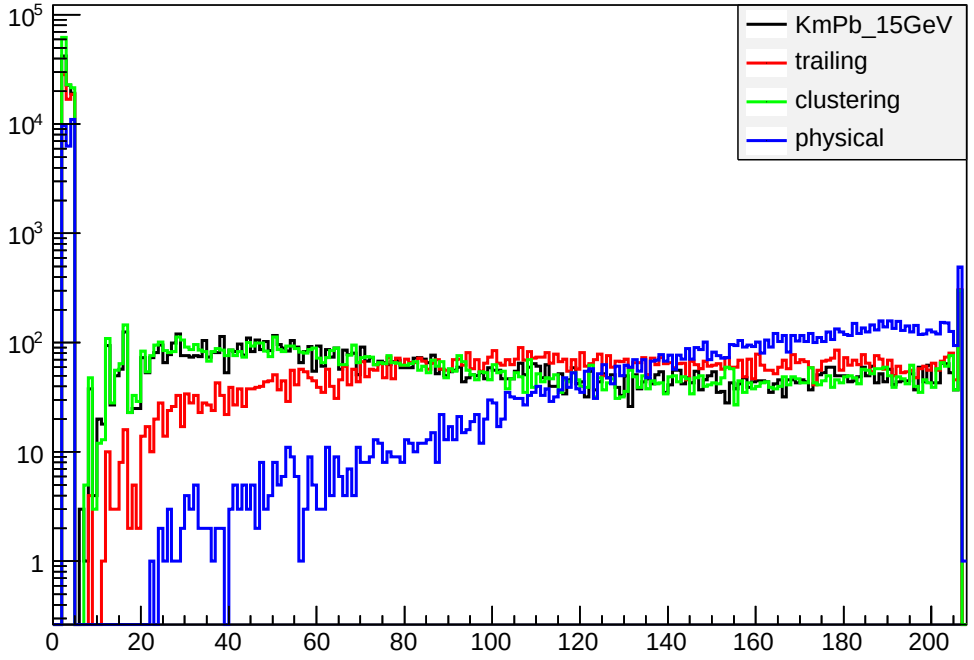
Comparison with data suggests small radius, 0.7 fm

15 GeV K^- Pb

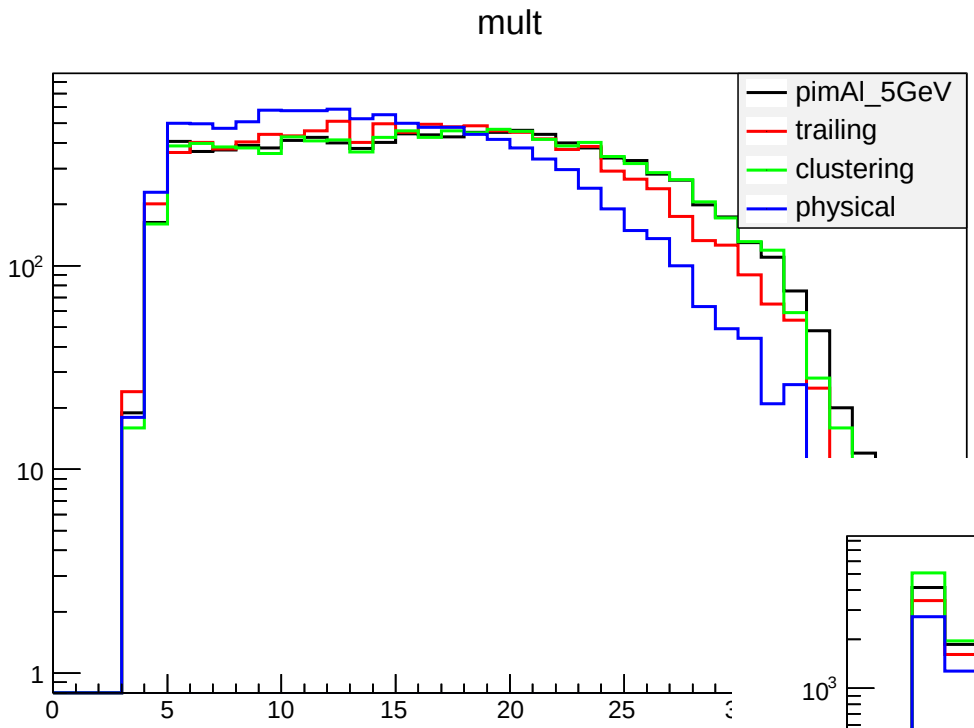
mult

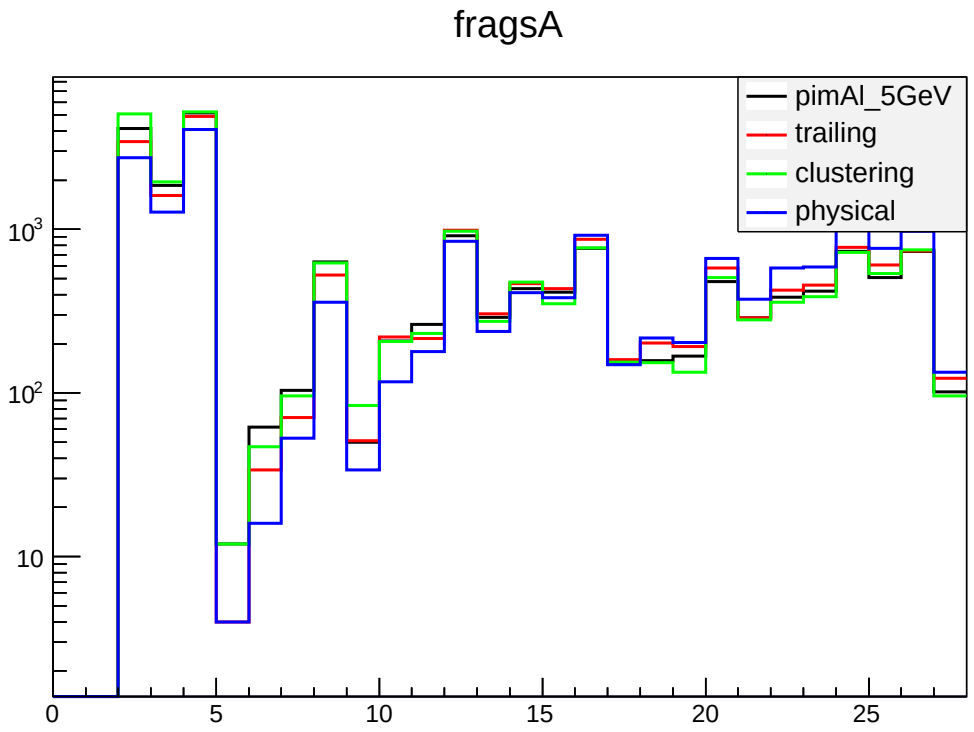


fragsA



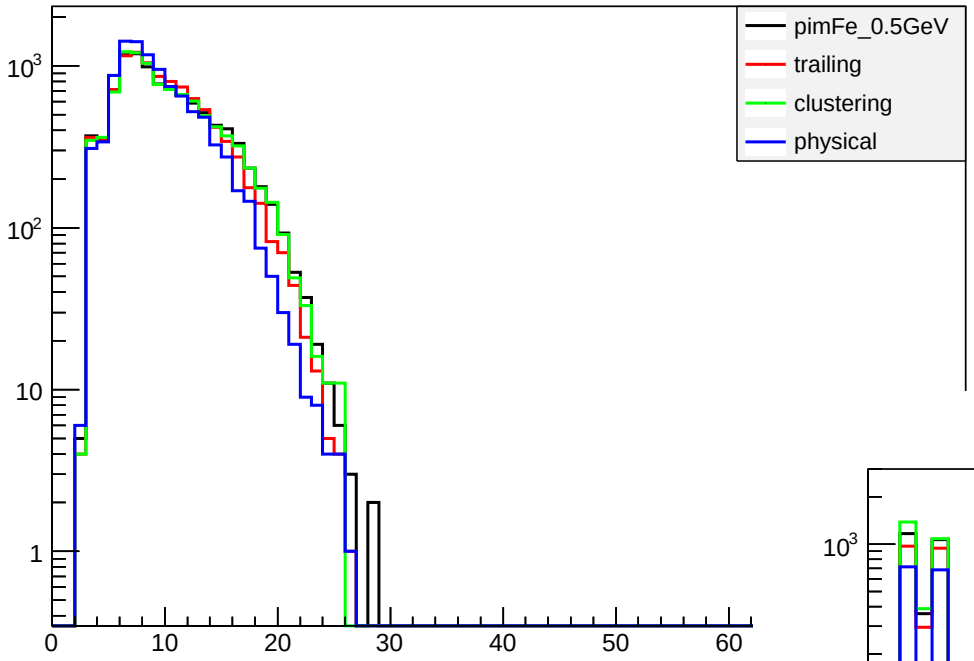
5 GeV π^- Al


mult
pimAl_5GeV
trailing
clustering
physical
10^2
10
1
0
5
10
15
20
25

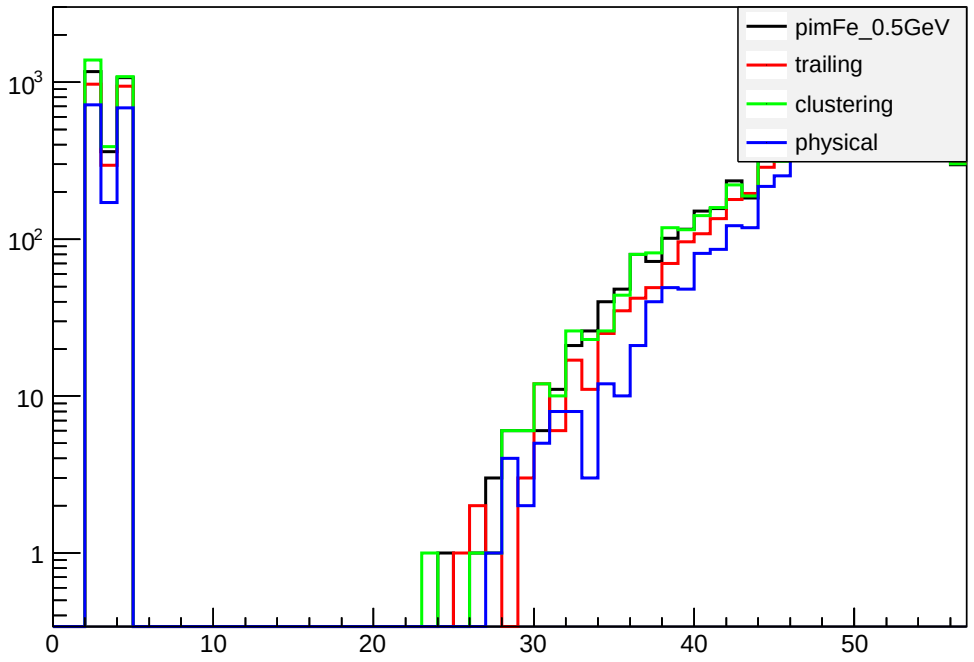

fragsA
pimAl_5GeV
trailing
clustering
physical
10^3
10^2
10
0
5
10
15
20
25

500 MeV π^- Fe

mult



fragsA



NN Cross Sections

Degradation in Bertini-related performance on SATIF benchmarks (neutron spallation)

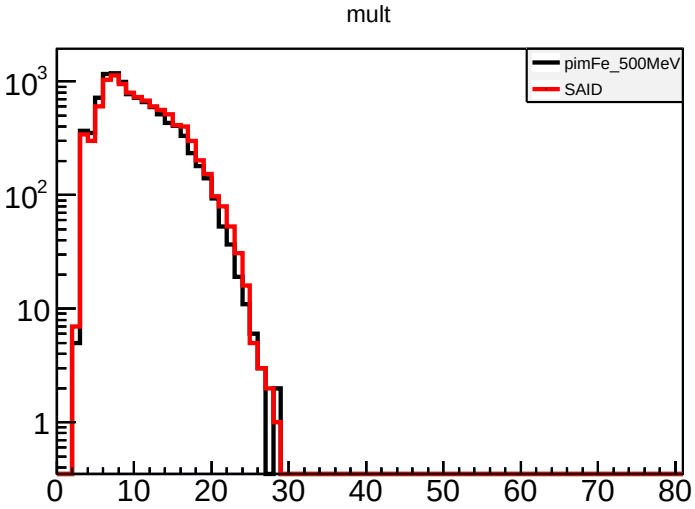
Could be related to changes in pp, nn, pn cross-section tables

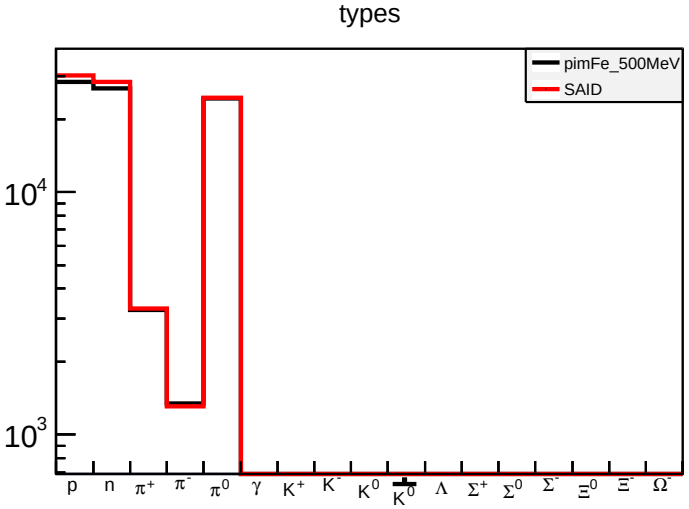
New low-energy SAID calculations for total and elastic provided by GWU collaborators

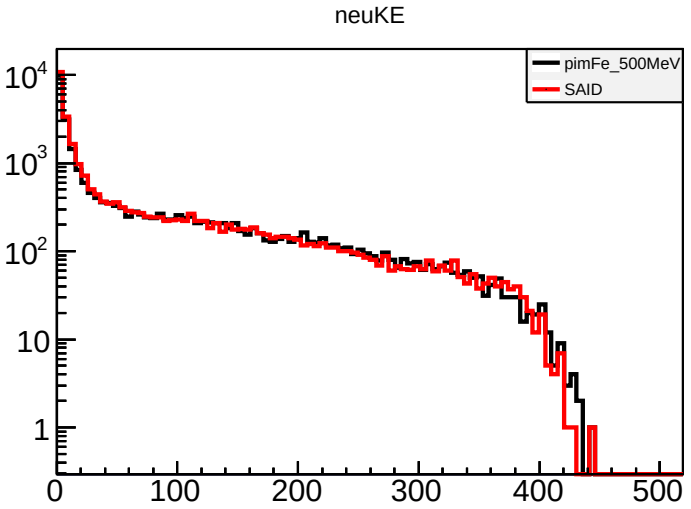
- pp and np calculated for 0 to 320 MeV
- nn calculated using pp with Coulomb interactions turned off (in progress)
- PDG values used above 320 MeV
- Analytic functions for 0–20 MeV, replacing interpolation
  $\sigma(pp) \sim 1/T$ $\qquad$ $\sigma(np) \sim \frac{a}{bT+(1-cT)^2} + \frac{d}{eT+(1-fT)^2}$

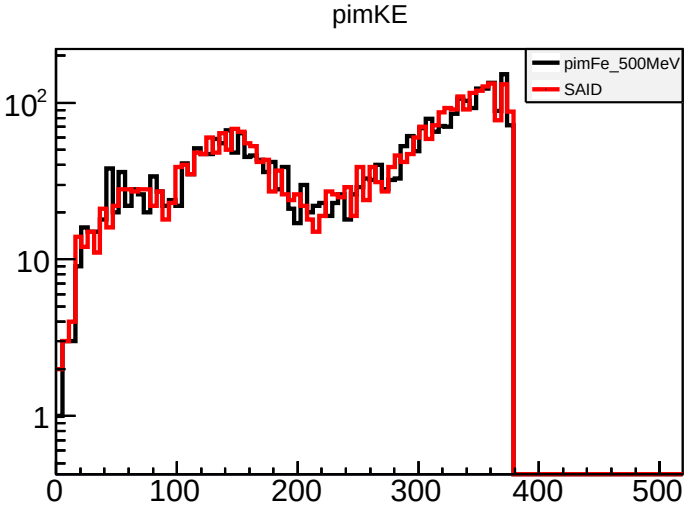
Thin Target Results

Bertini unit test: 500 MeV π^- on iron



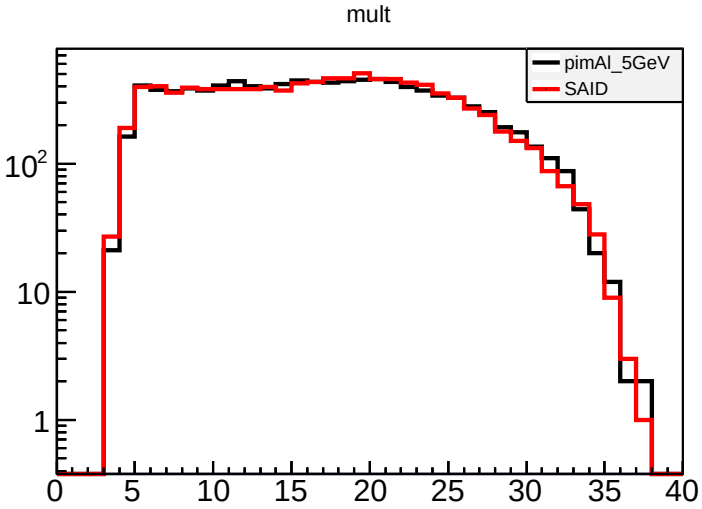


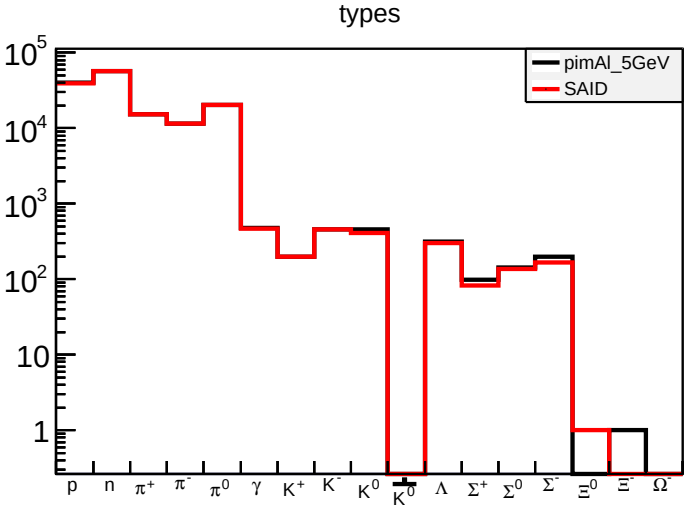


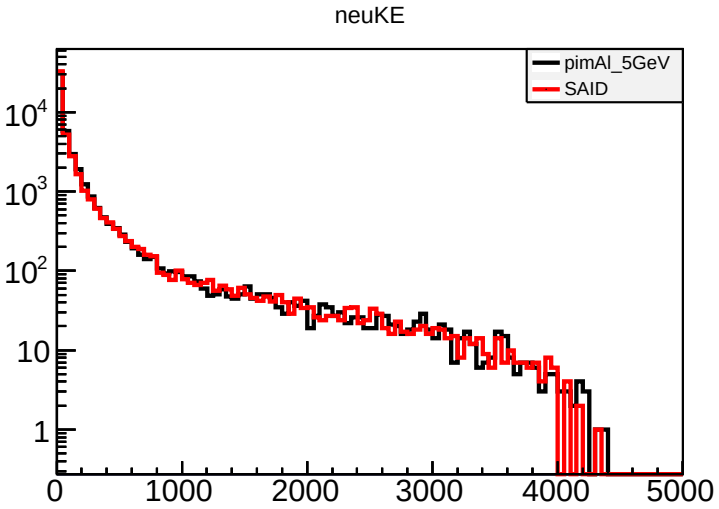


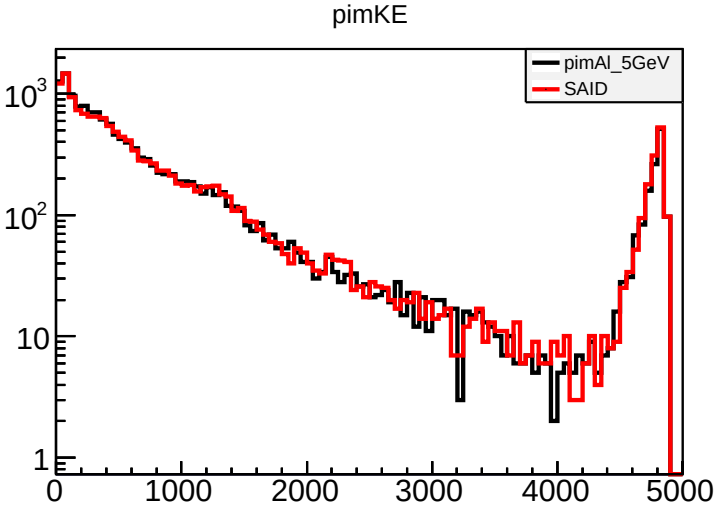
Thin Target Results

Bertini unit test: 5 GeV π^- on aluminum



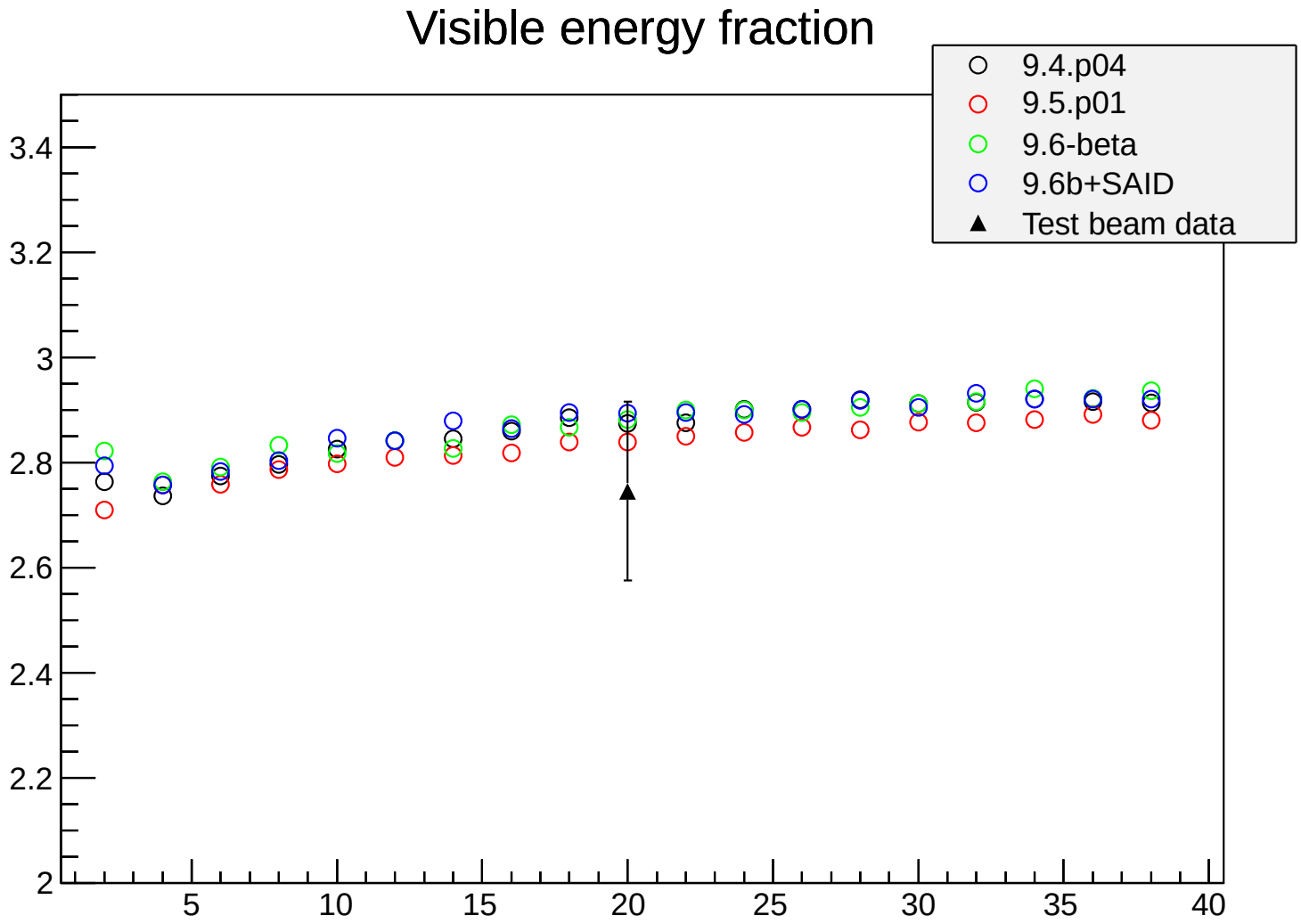






Thick Target Results

SimplifiedCalorimeter: π^- on iron-scintillator stack



Thick Target Results

SimplifiedCalorimeter: π^- on iron-scintillator stack