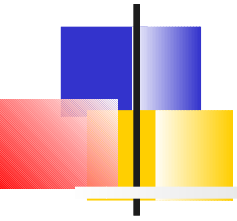
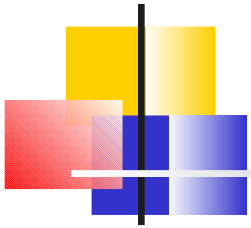


Recent Developments in Geant4 Hadronics

Geant4/Spenvis Workshop at JPL

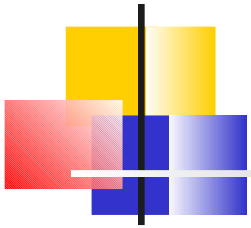
6 November 2006

Dennis Wright



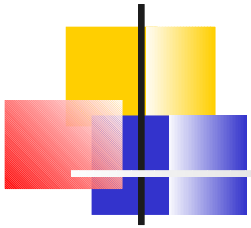
Outline

- Treatment of isotopes (abundance,masses,PDG code)
- Cross section improvements
- Elastic scattering
- Capture reactions
- Neutrons
- INCL/ABLA
- "Grand Validation" at FNAL Hadronic Shower Simulation Workshop
- Shower shapes/energy deposition



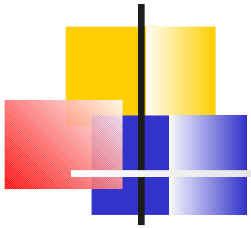
Treatment of Isotopes in Geant4 (1)

- G4 hadronic processes currently recognize only natural isotope abundances in elements
  - User-defined abundances ignored (except for HP neutrons and CHIPS models)
- G4HadronicProcess must calculate a cross section for the MFP, and choose an isotope from the abundance to pass to the relevant model
  - in both cases the approximation: $_{Z}$ $_{0}/\langle A\rangle^{2/3})\cdot$ $_{A}\mathrm{abund}_{A}\cdot A^{2/3}$ is used
  - should be: $_{Z}$ $_{A}\mathrm{abund}_{A}\cdot$ $_{Z,A}\cdot$
- Many cross-section sets do not have isotope-wise cross sections or temperature dependence
- Above problems to be fixed for default cross sections in V8.2
- Need methods to access isotope-specific cross sections
- Need a common system for all cross section data sets



Treatment of Isotopes in Geant4 (2)

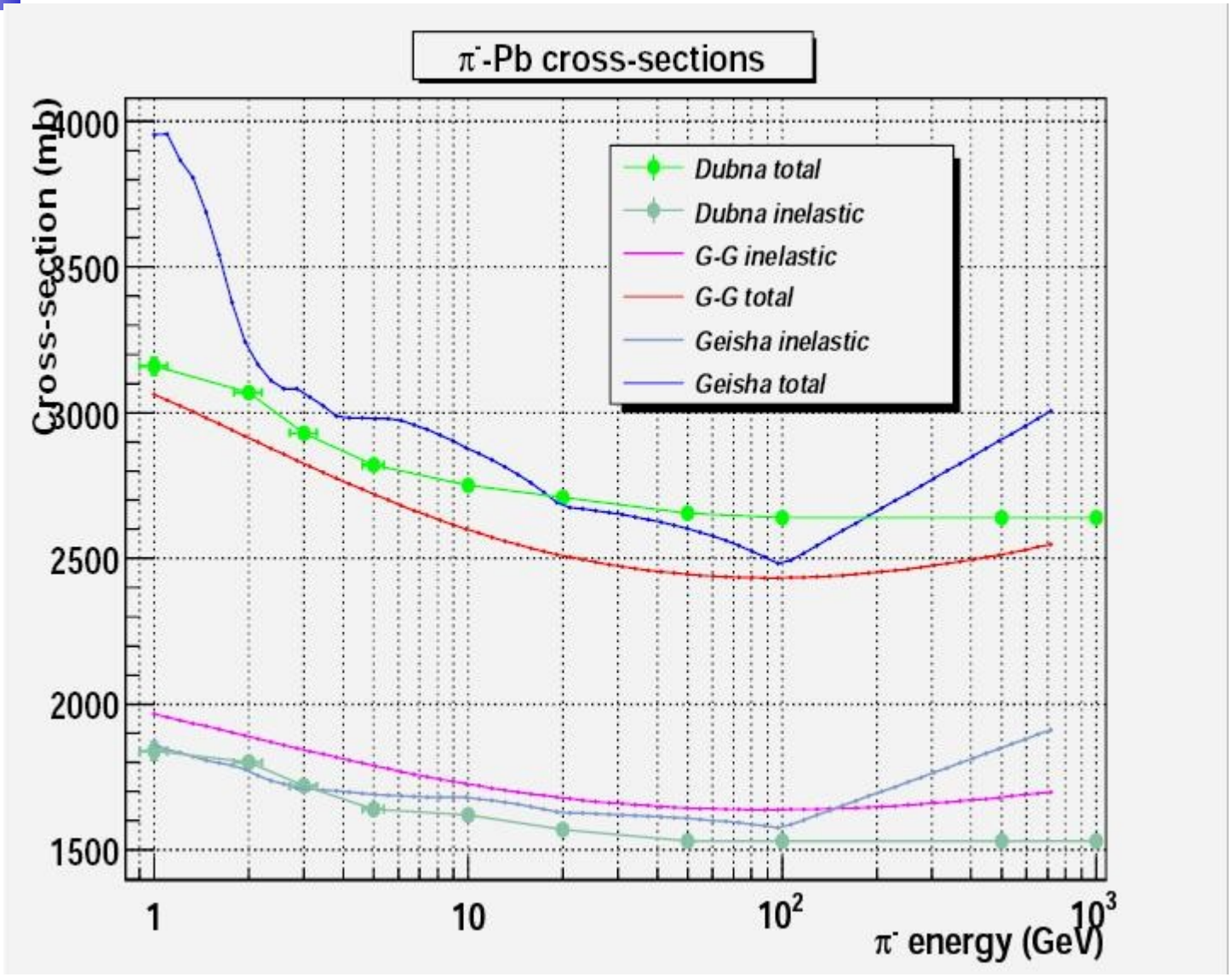
- Nuclei produced in reaction currently have PDG code = 0
  - Non-zero PDG code to be returned in V 8.2
- At various places in Geant4 physics, three different isotope mass tables have been used in the past
  - now reduced to 2
- Long-term goal: a unified atomic/nuclear mass table which will have:
  - All long-lived isotopes, isomers, hypernuclei (>4500 entries)
  - Updated nuclear masses
  - Known and predicted decay channels
  - Updated interpolation function for unmeasured nuclei



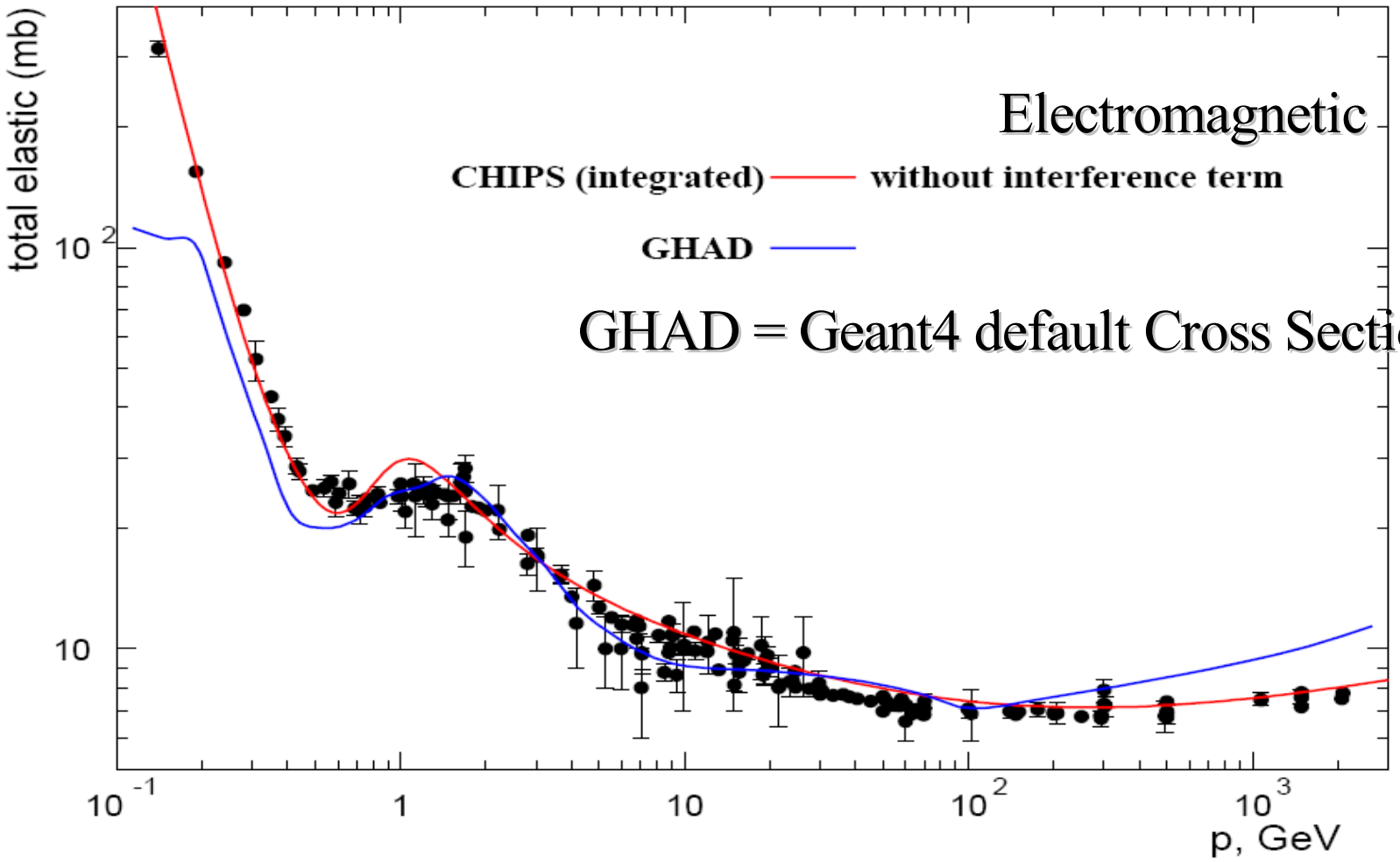
Cross Sections

- Geant4 hadronic cross sections being reviewed and improved
- Glauber-Gribov cross sections available in V 8.2
  - parameterizations of elastic and inelastic hadron-nucleus cross sections for E > 1 GeV
  - tuning/improvements still being made
- Elastic/charge exchange
  - p-p, n-p cross sections improved
  - elastic, charge exchange cross sections to be separated into separate data sets

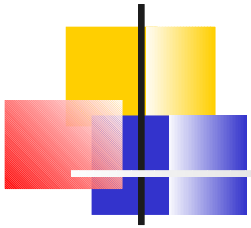
Glauber-Gribov Cross Sections



pp Elastic Cross Section



GHAD = Geant4 default Cross Sections

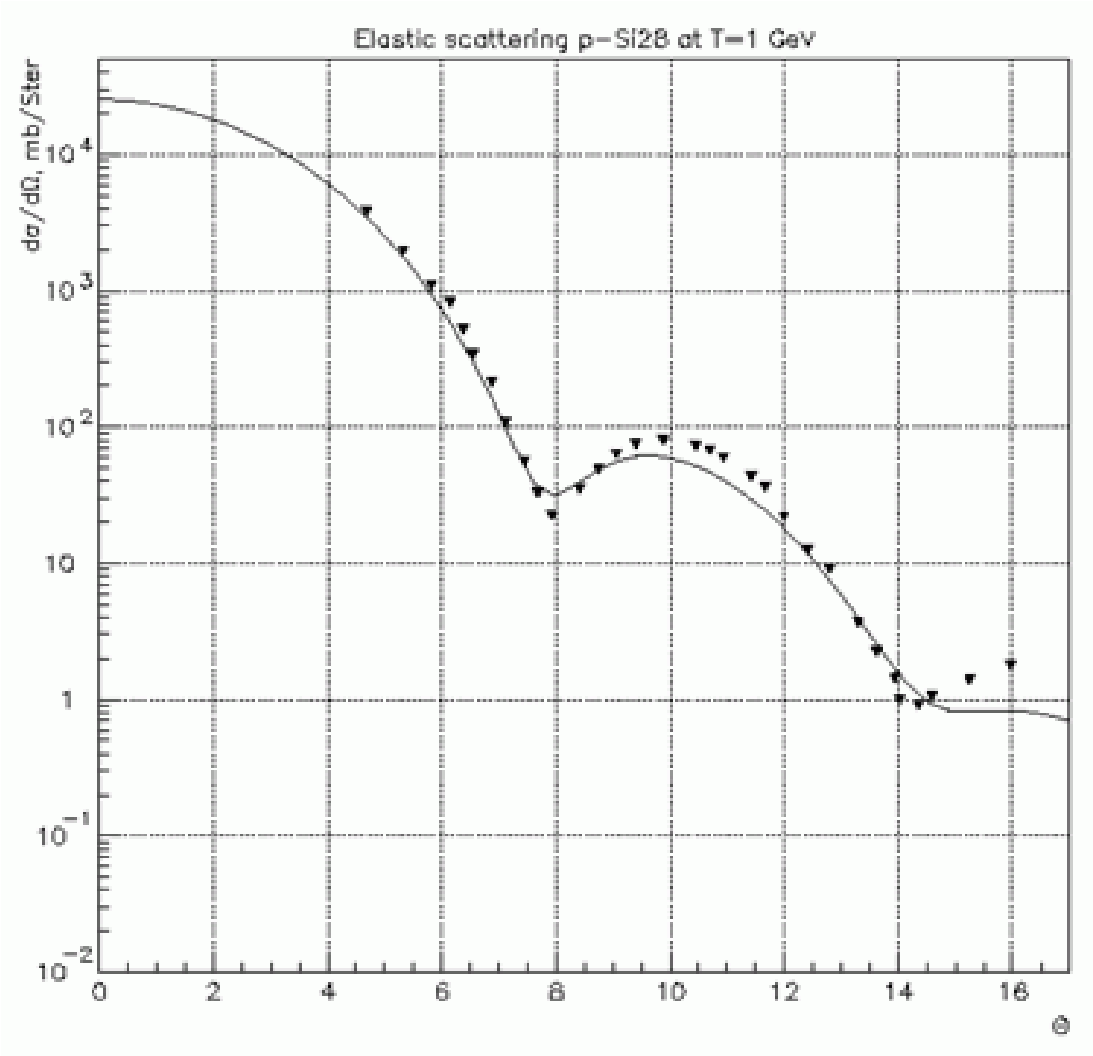


Coherent Elastic Scattering

- Coherent elastic hadron-nucleus scattering for E > 1 GeV
  - Currently process uses large look-up table
  - In V 9.0 data will be parameterized and internal to model

Coherent Elastic Model: 1GeV p on ^{28}Si

mb/sr

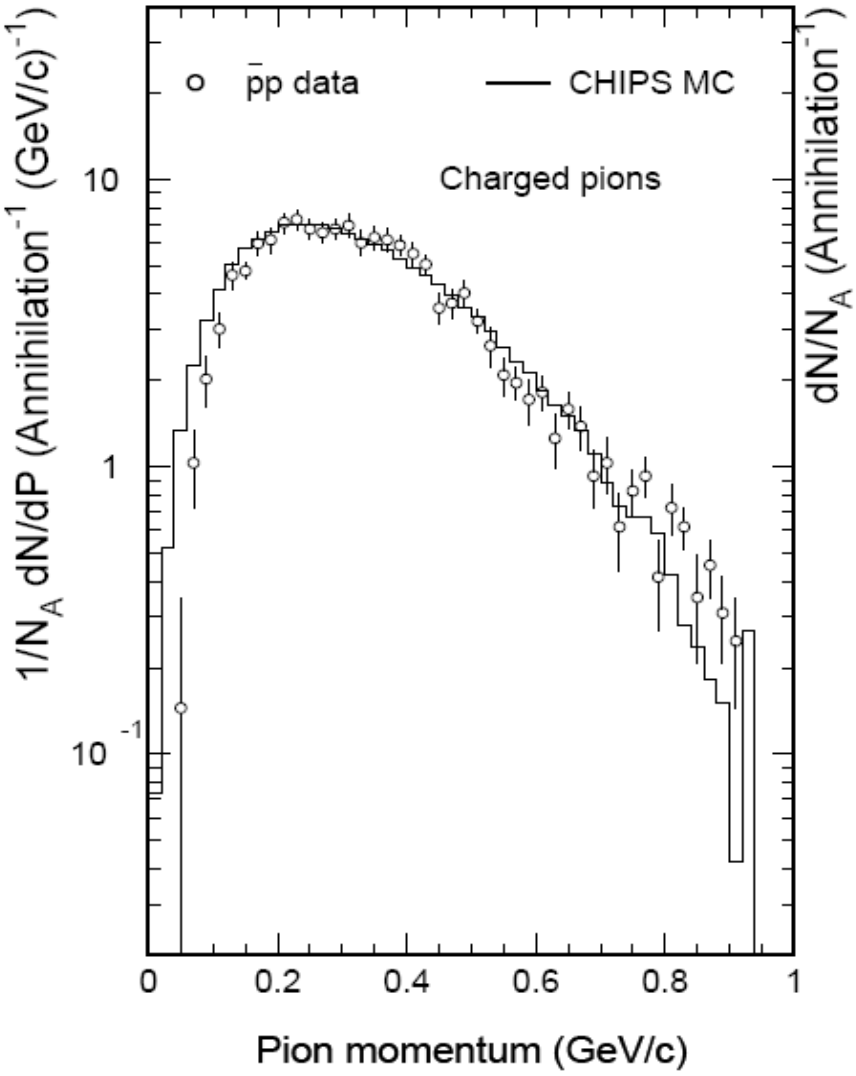


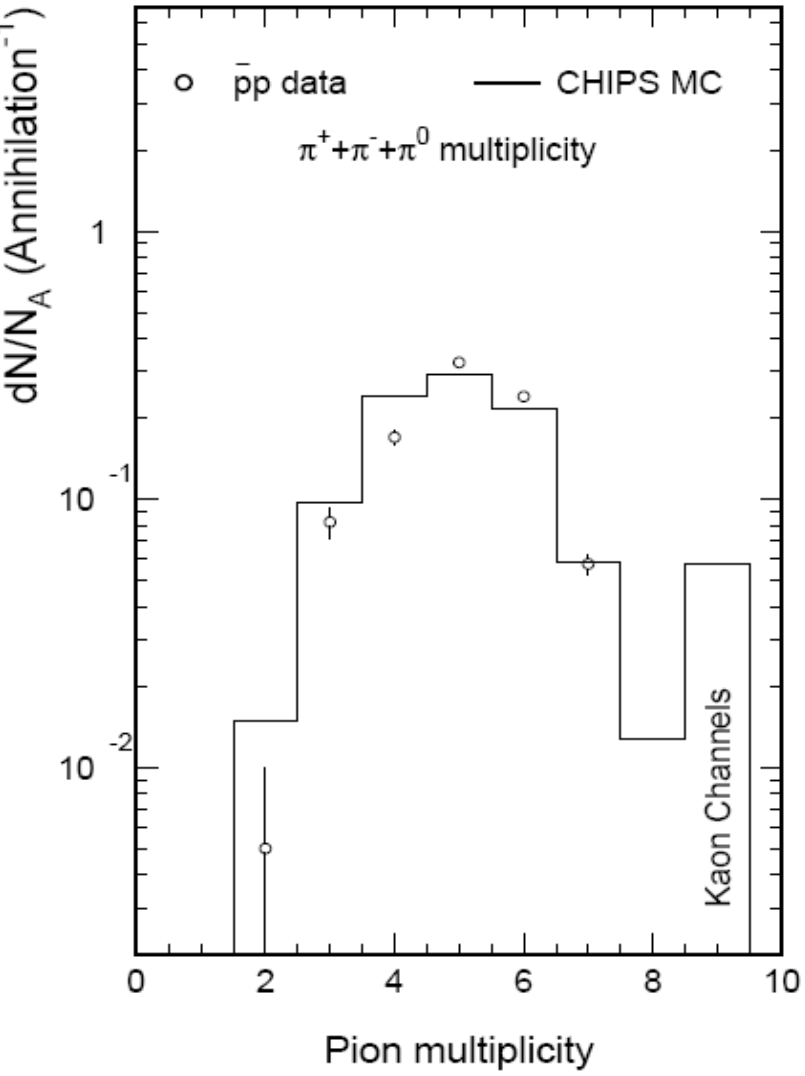
degrees

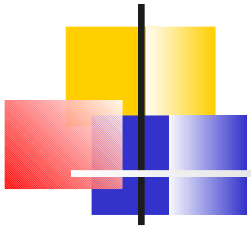
Improved Capture Reactions

- Before V 8.0 most capture reactions were handled by GHEISHA-like (parameterized) models
- New option since V 8.0: CHIPS-based capture for:
  - K^- ,p-bar, -bar
- Theory-based with a few parameters
- Slower, but more accurate than the GHEISHA-like models
- n, n-bar capture still GHEISHA-like or in high precision neutron models
  - CHIPS version planned

Anti-proton capture at rest (CHIPS)

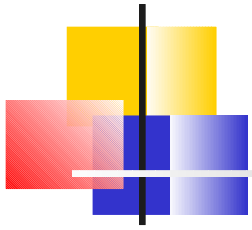






Neutrons

- High precision (HP) neutron package
  - Neutron data library G4NDL recently upgraded to 3.9
  - Support for the 0.2 version (without thermal cross sections) to be dropped after December
  - Plans for simplifying G4NDL: will depend only on ENDF and JENDL databases -> no evaluation by Geant4
  - Possible extension of HP neutron energies to 150 MeV
  - Since V 8.0, alternate versions of the HP processes have been available for elastic, inelastic, capture and fission: if no isotope entry is available in G4NDL, process defaults to parameterized (less accurate) models



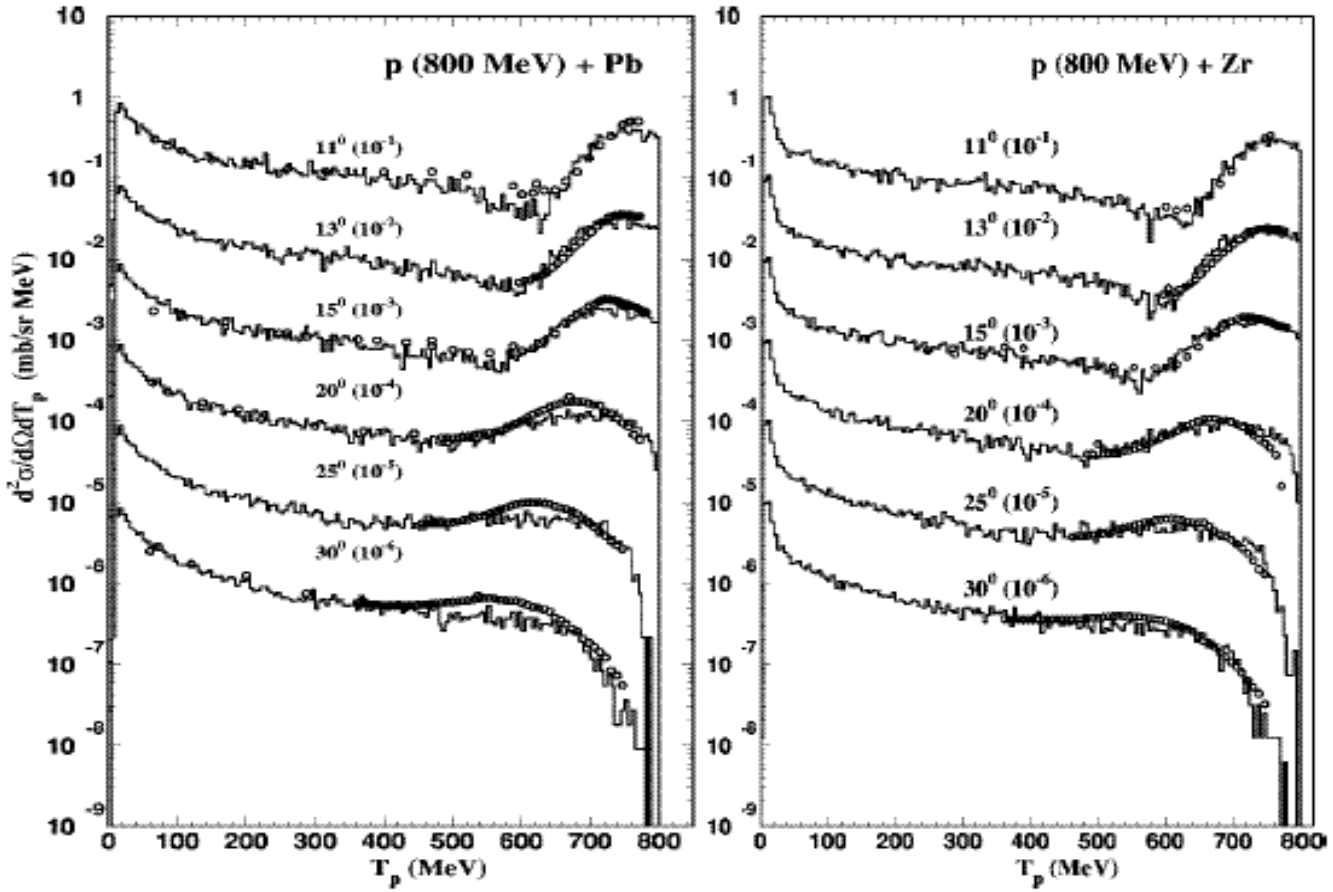
INCL/ABLA Model

- Intra-nuclear cascade Liege + Ablation model
  - for ~100 MeV to 3 GeV pion, nucleon, light ion beams
  - uses resonance formation and decay, Weisskopf-Ewing evaporation
  - less phenomenology, more predictive power
  - currently used successfully in LAHET and MCNPX
  - currently in FORTRAN, project underway to cast into C++ and include with Geant4
- Planned improvements:
  - INCL5 already extended down to 50 MeV
  - using 2- and 3-pion exchange may extend up to 10 GeV

INCL4 + ABLA Results

R. Chrien et al, Phys. Rev. C21 (1980) 1014

J. McGill et al Phys. Rev. C29 (1984) 204

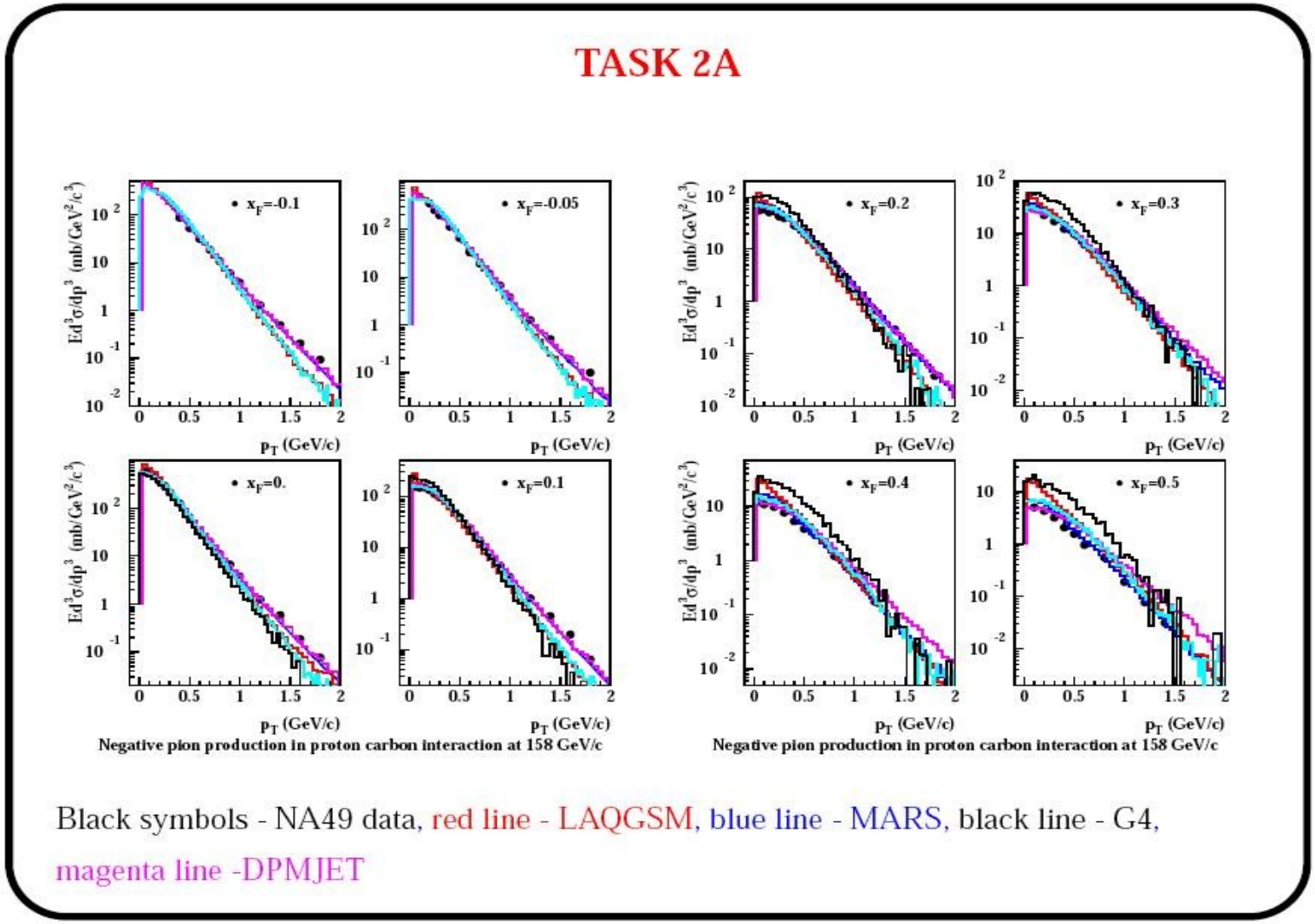


Proton production

Grand Validation

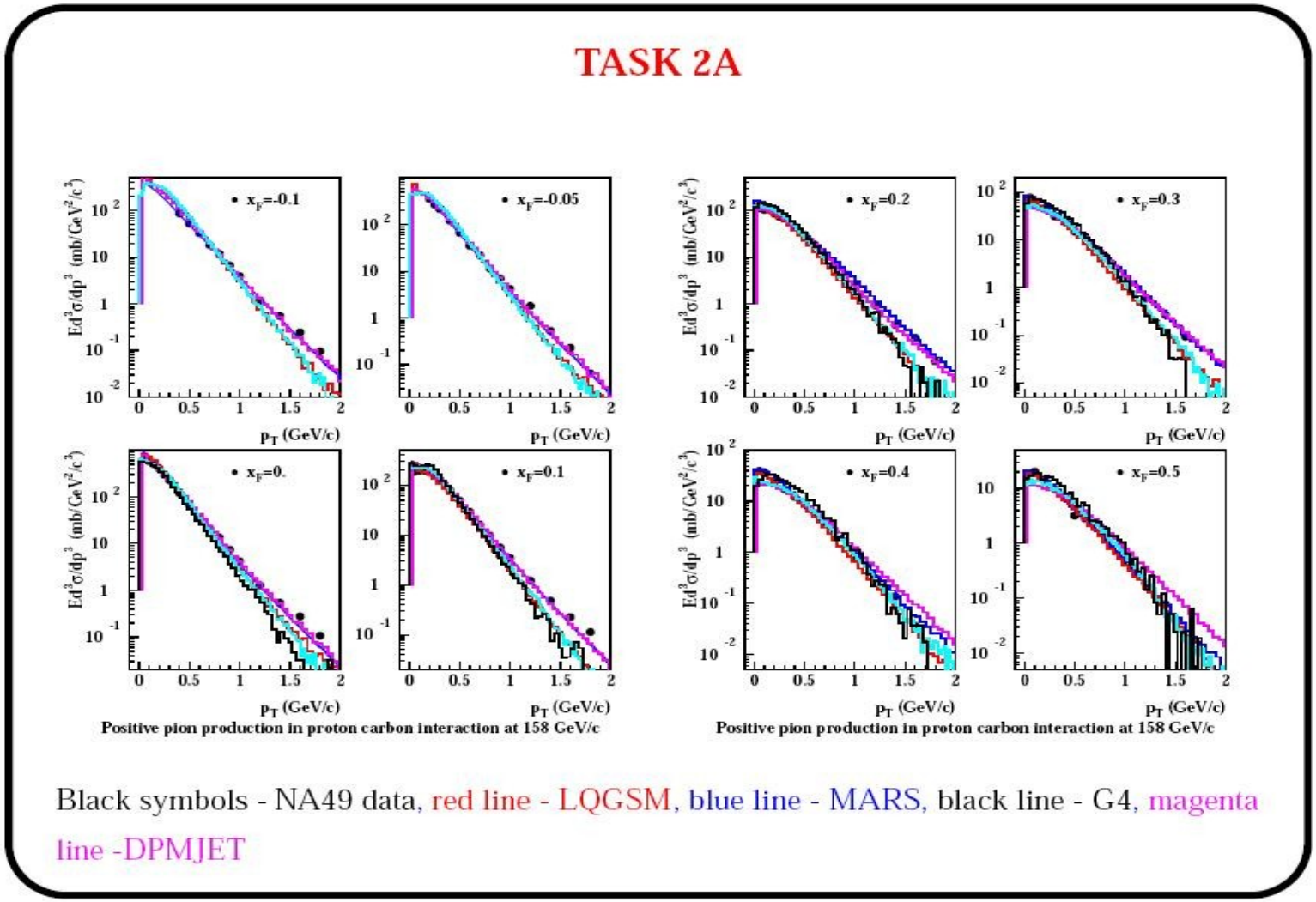
- 7 validation tests proposed for Hadronic Shower Simulation Workshop at FNAL in September
  - covered wide energy range
  - head-to-head comparison of (5-6) simulation codes for each test
  - data sets agreed upon beforehand
  - voluntary participation
- Due to short time scale, not all tasks could be completed
- Agreed to make this a regular exercise
  - repeat once every 18 months

Task2a: from 158 GeV/c p on C



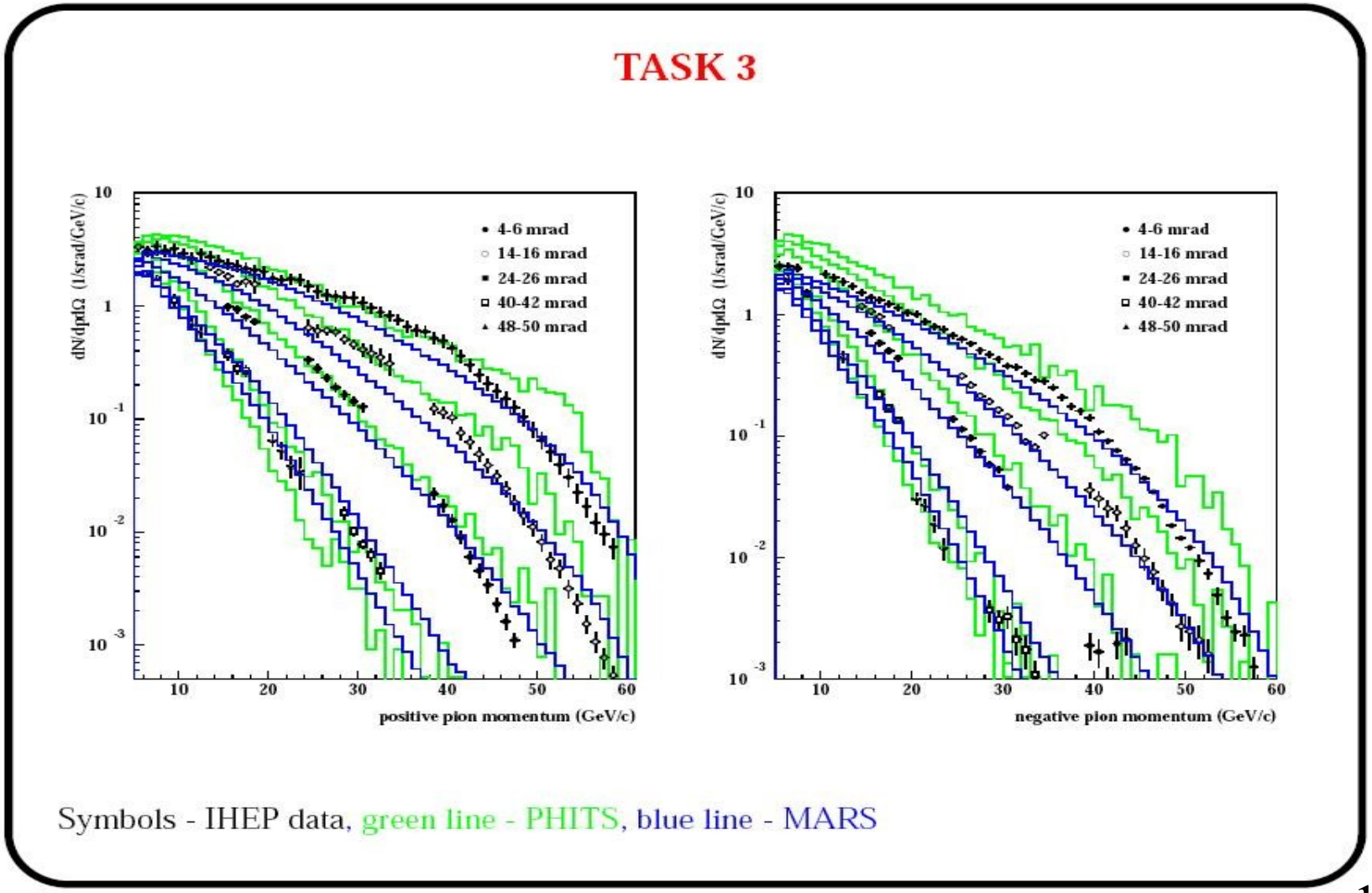
Black symbols - NA49 data, red line - LAQGSM, blue line - MARS, black line - G4, magenta line -DPMJET

Task2a: $^{+}$ from 158 GeV/c p on C

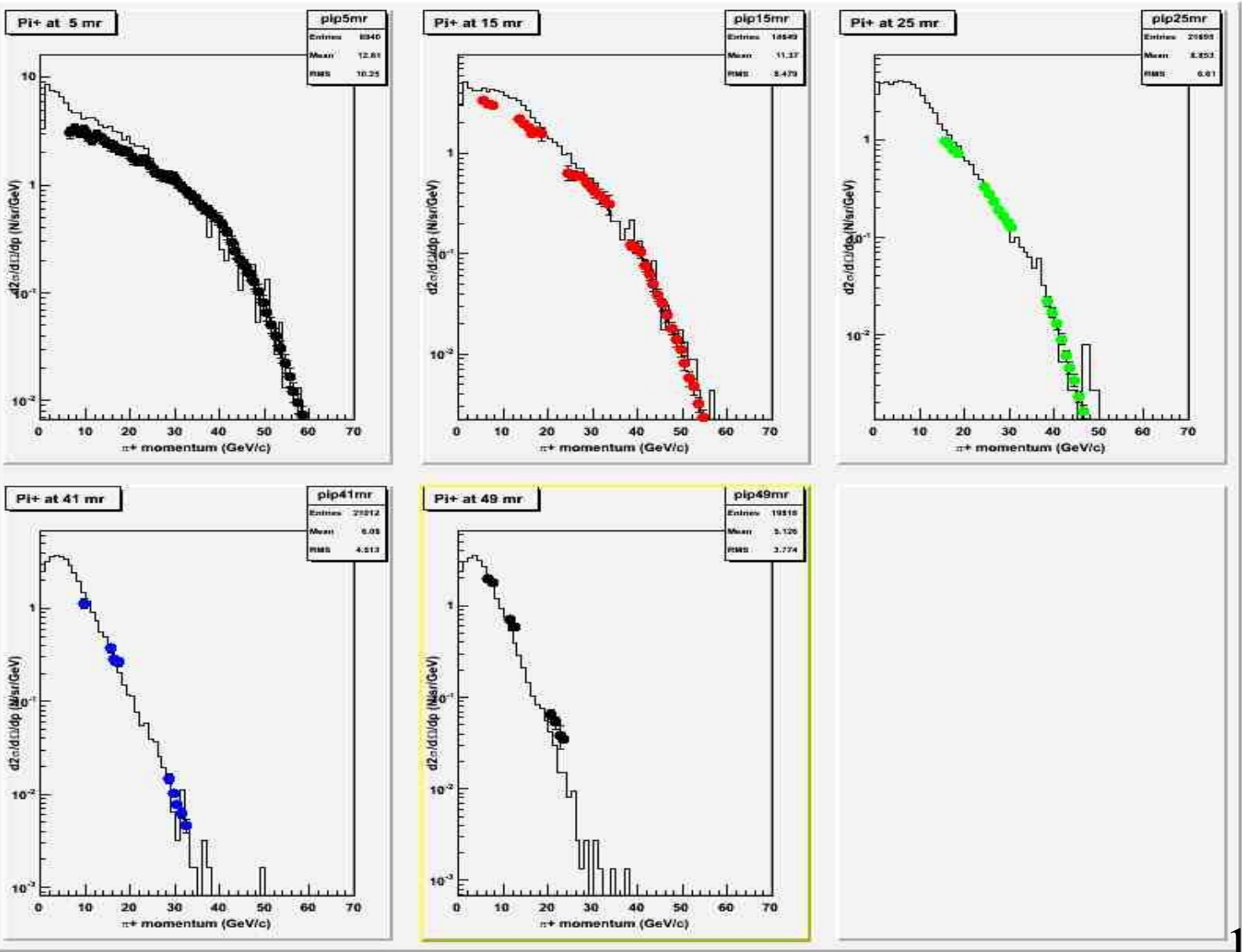


Black symbols - NA49 data, red line - LQGSM, blue line - MARS, black line - G4, magenta line -DPMJET

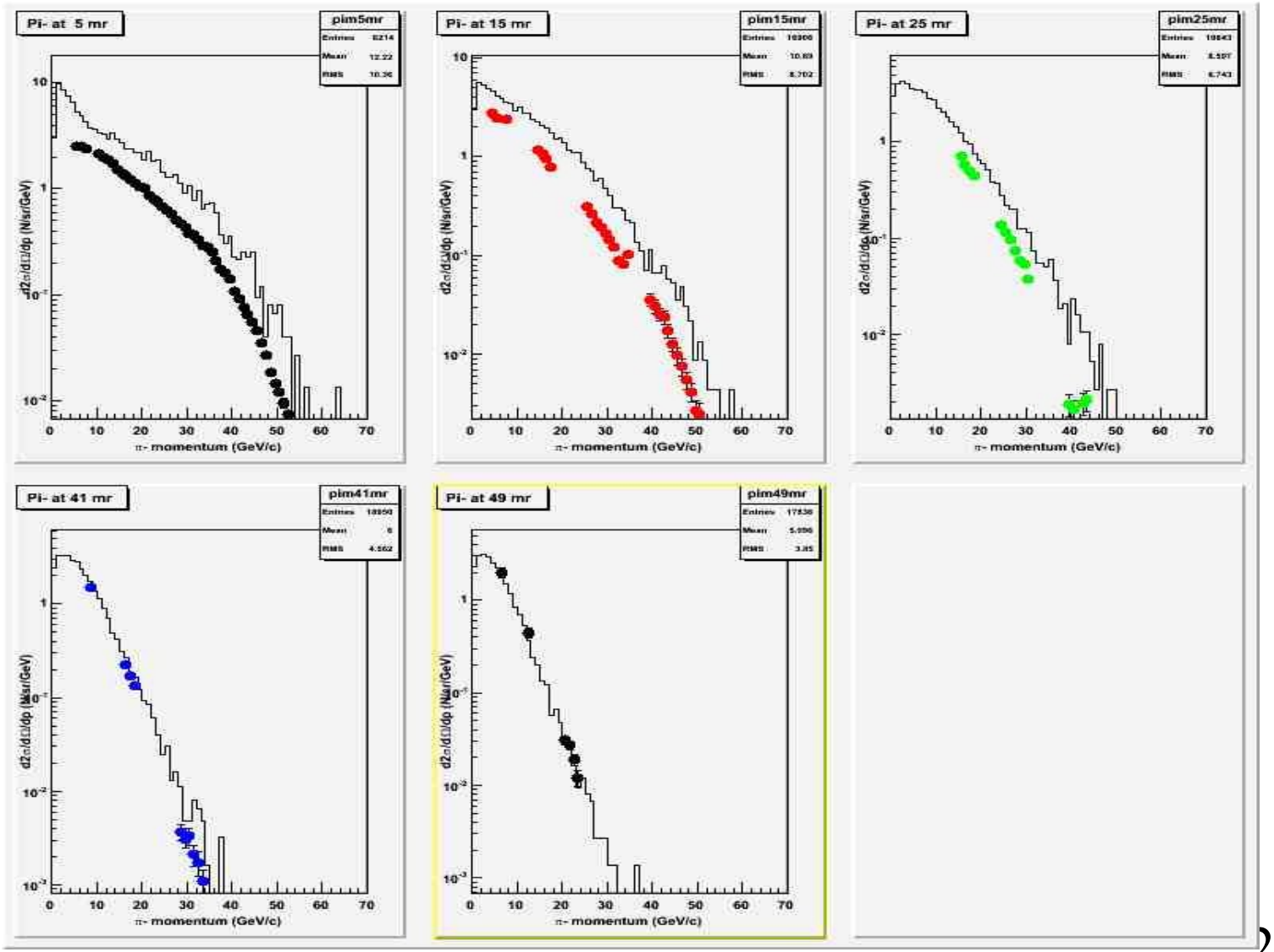
Task 3: $^{+}$ $^{-}$ from 67 GeV/c p on Al



$^{+}$ from 67 GeV/c p on Al



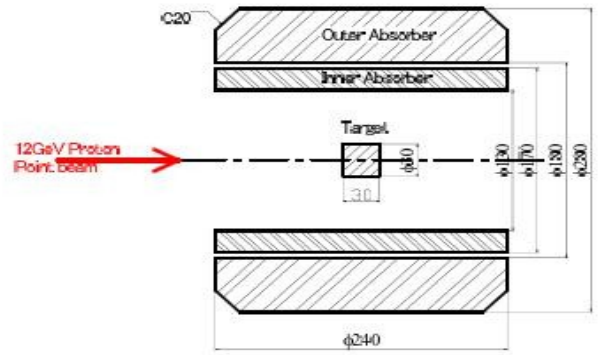
from 67 GeV/c p on Al



Task 5: Total Energy in a Cu Absorber

TASK 5

計算条件メモ



単位：(mm)

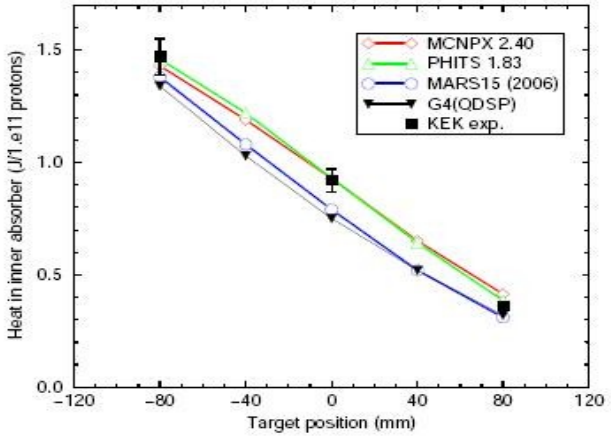
outer absorberはC20だけ面取りしてある。

材料：Target、inner absorber、outer absorber は銅板。

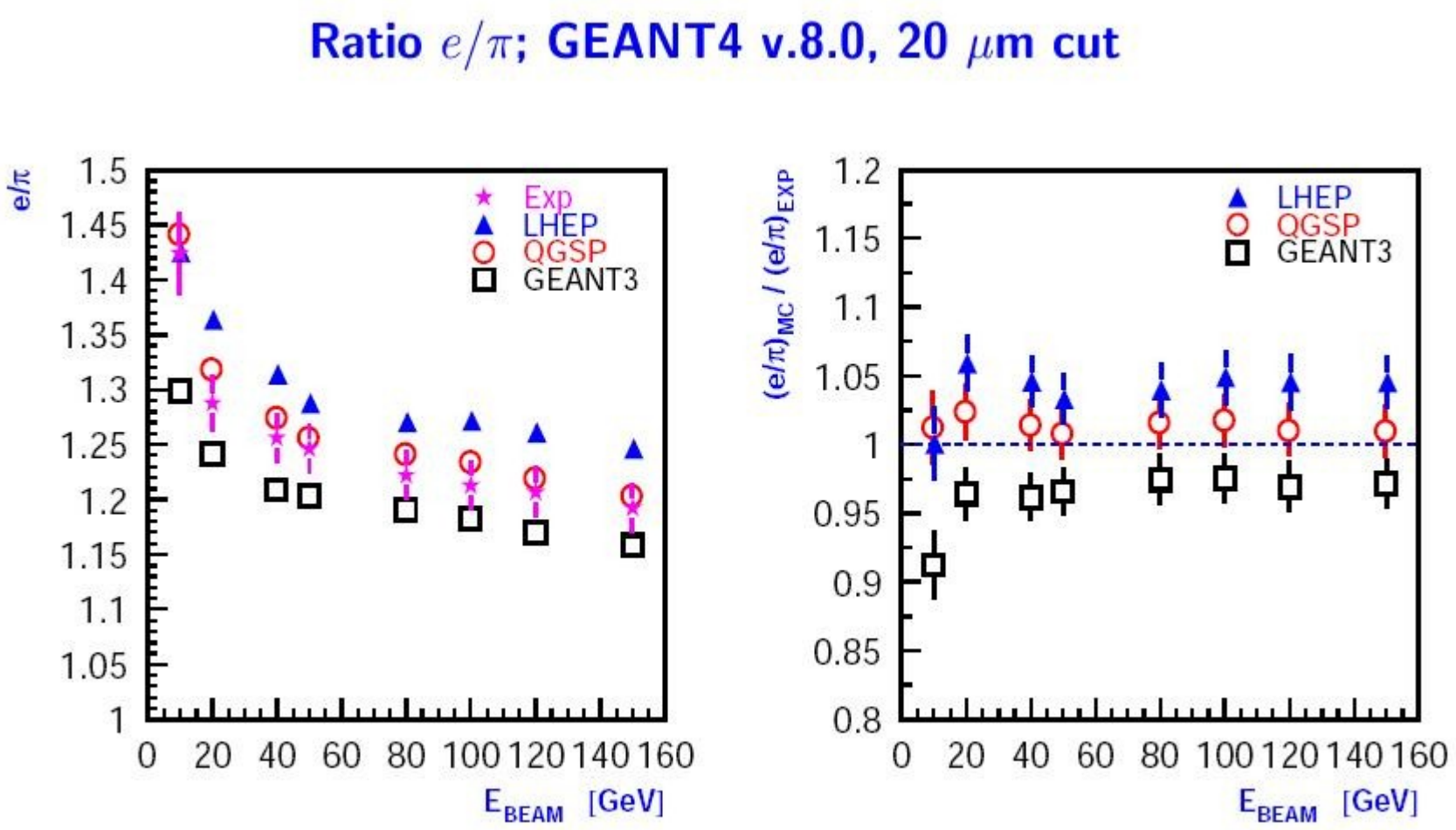
63Cu -6.19 $69.1 % density of 63Cu in natural copper

65Cu -2.77 $30.9 % density of 65Cu in natural copper

入熱分布を計算する。

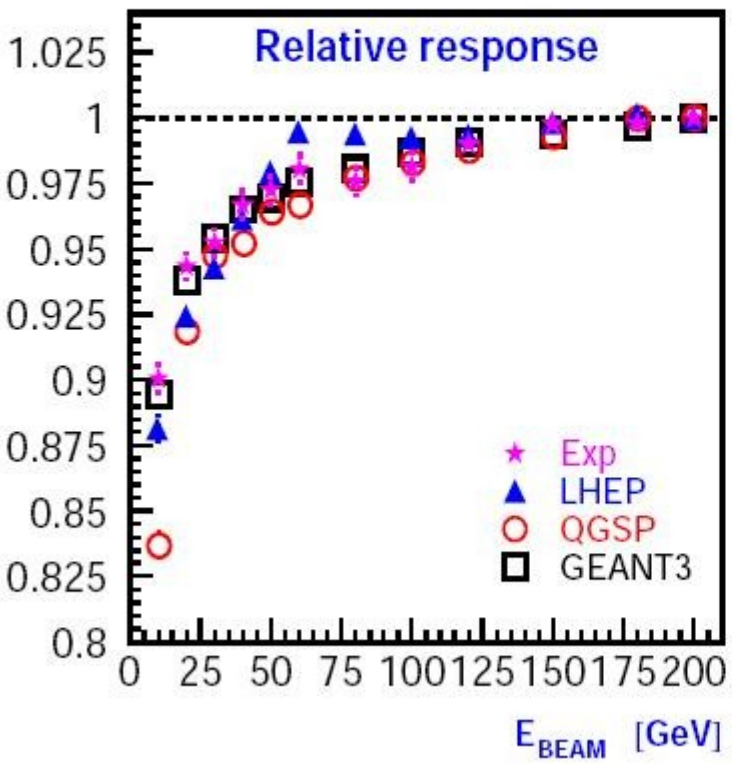


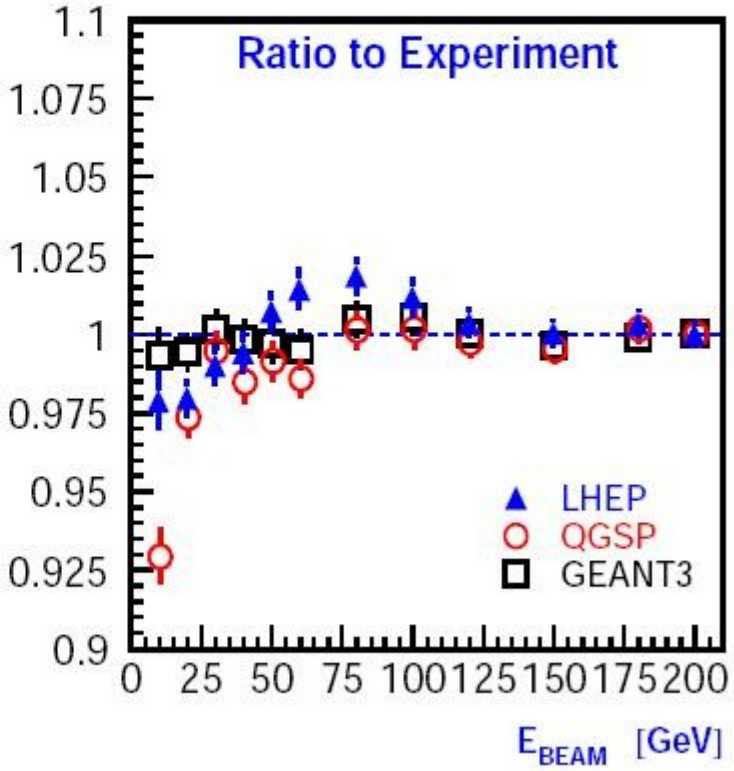
Atlas (HEC)


Ratio e/π; GEANT4 v.8.0, 20 μm cut
e/π
Exp
LHEP
QGSP
GEANT3
E_BEAM [GeV]
(e/π)_MC / (e/π)_EXP
LHEP
QGSP
GEANT3
E_BEAM [GeV]

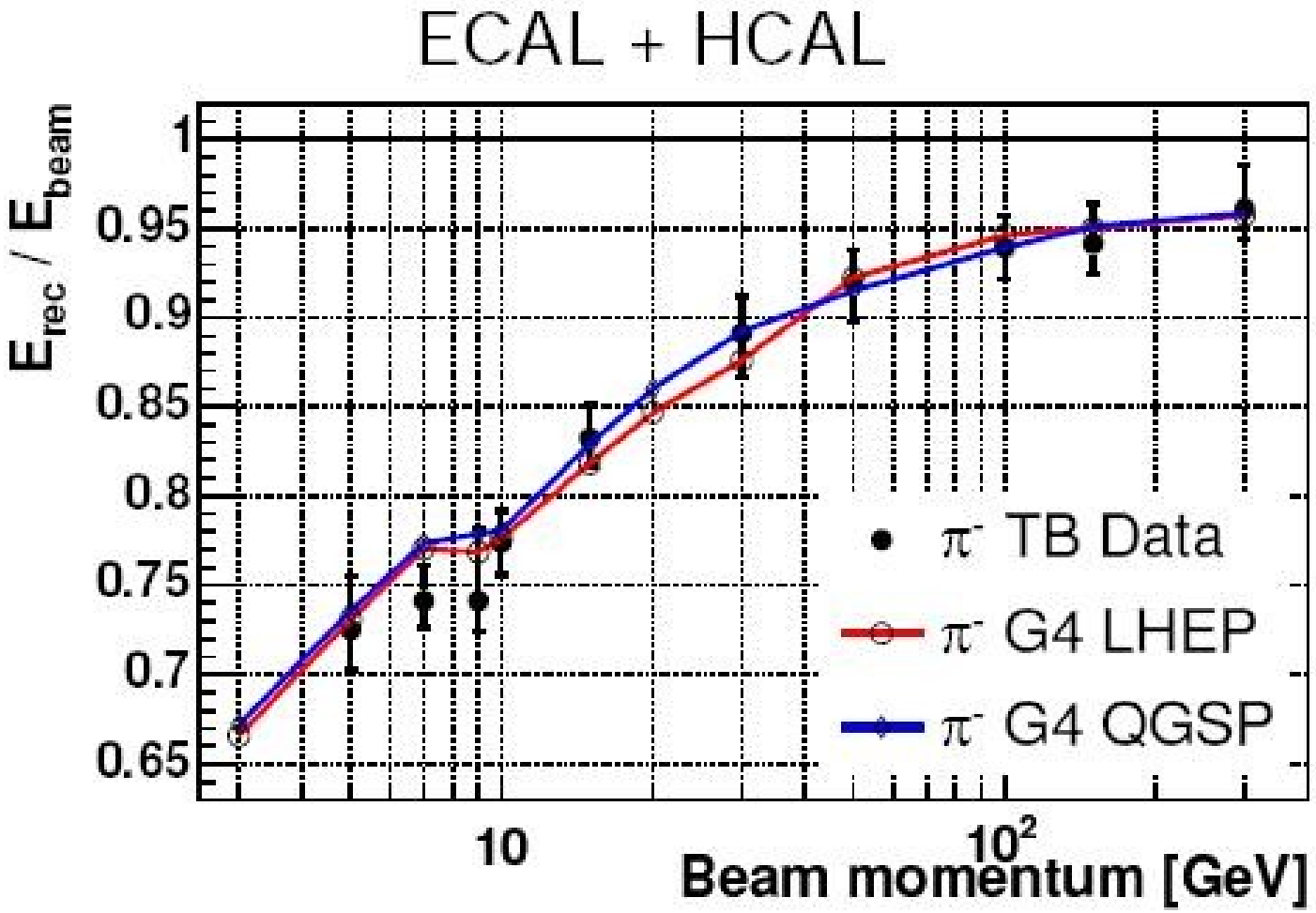
Atlas (HEC)

Relative response, GEANT4 v.8.0, 20 μm cut

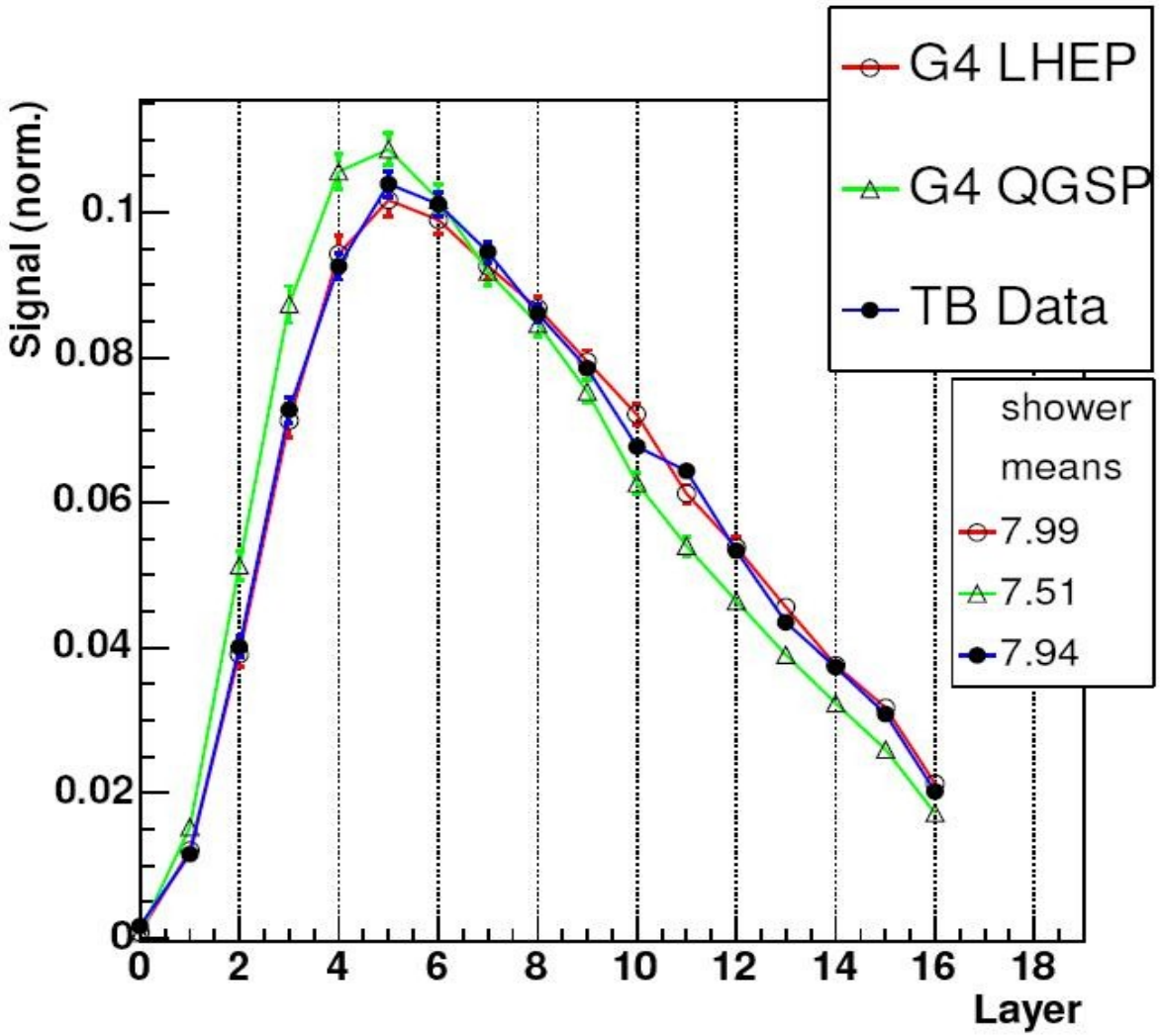




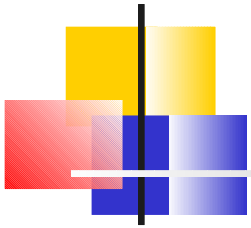
CMS


ECAL + HCAL
E_{rec} / E_{beam}
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
10
10^2
Beam momentum [GeV]
π^- TB Data
π^- G4 LHEP
π^- G4 QGSP

CMS



300 GeV pions, leaving MIP in ECAL and L0.



Summary

- User defined isotope abundances will be used, PDG code assigned to final state nuclei
- Hadronic cross sections being reviewed and improved
- Improved elastic scattering at medium/high energies
- Improved capture reactions based on CHIPS model
- New high precision neutron models added, G4 neutron data library improved
- INCL/ABLA cascade-ablation model to be added to Geant4
- “Grand Validation” at FNAL Hadronic Shower Simulation Workshop provides opportunities for inter-code comparisons
- In test beam calorimeters G4 energy deposits are good, but shower shapes have some problems due to QGS model