Overview of validations at LHC

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http://lcgapp.cern.ch/project/simu/validation/

Physics Validation

- First cycle of electromagnetic physics validation completed at the percent level. We will focus here only on the (most difficult!) hadronic physics validation.
- As for the choice of the Geant4 Physics List, the validation should be targeted to each considered application domain: e.g. for high-energy physics one should consider different observables than, for instance, medical physics, or space science, or background radiation applications.
- The criteria to consider a simulation "good" or "bad" should be based on the particular application: e.g., for LHC experiments, the main requirement is that the dominant systematic uncertainties for all physics analyses should not be due to the imperfect simulation.

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Validation setups

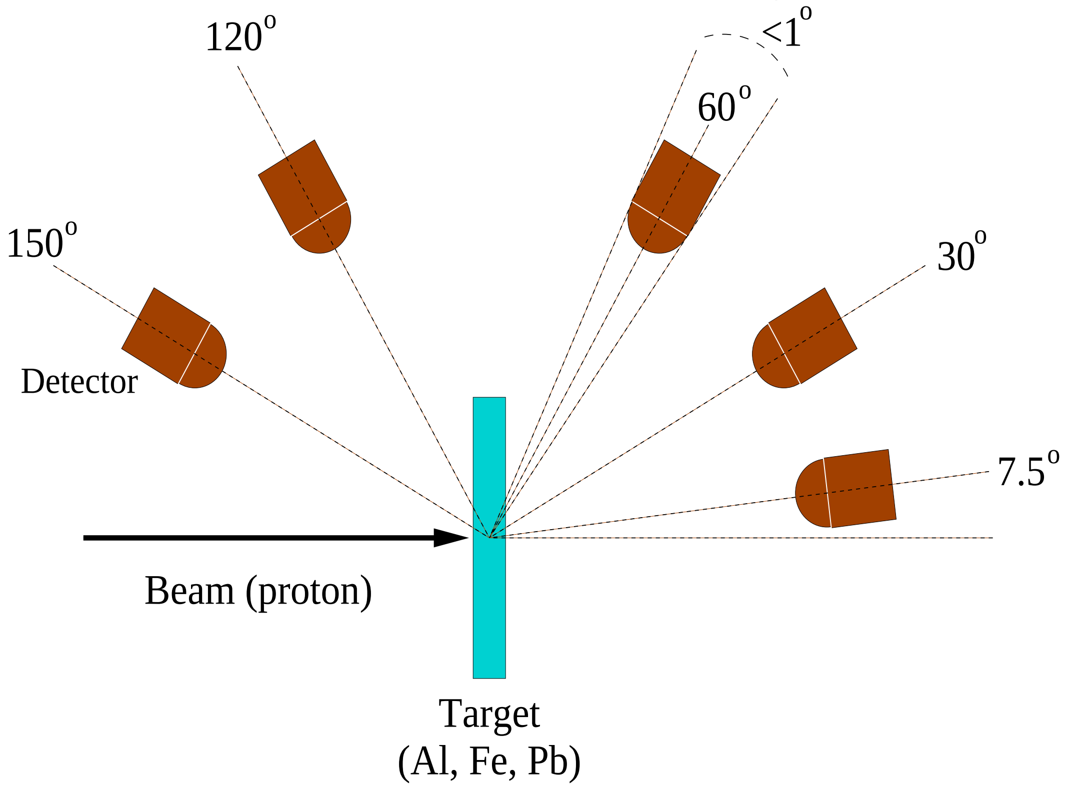
Two main types of test-beam setups:

1. Calorimeters: the typical test-beams (made mainly for detector purposes).
   The observables are the convolution of many effects and interactions. In other words, one gets a macroscopic test.

2. Simple benchmarks: typical thin-target setups with simple geometry (made, very often, for validation purposes).
   It is possible to test at microscopic level a single interaction or effect.

➔ These two kinds of setups provide **complementary** information.

Double-differential neutron production (p,xn)



Proton beam energies: 113, 256, 597, 800 MeV

Neutron detectors (TOF, scintillators) at 5 angles

Study of the neutron production spectrum (kinetic energy) at fixed angles.

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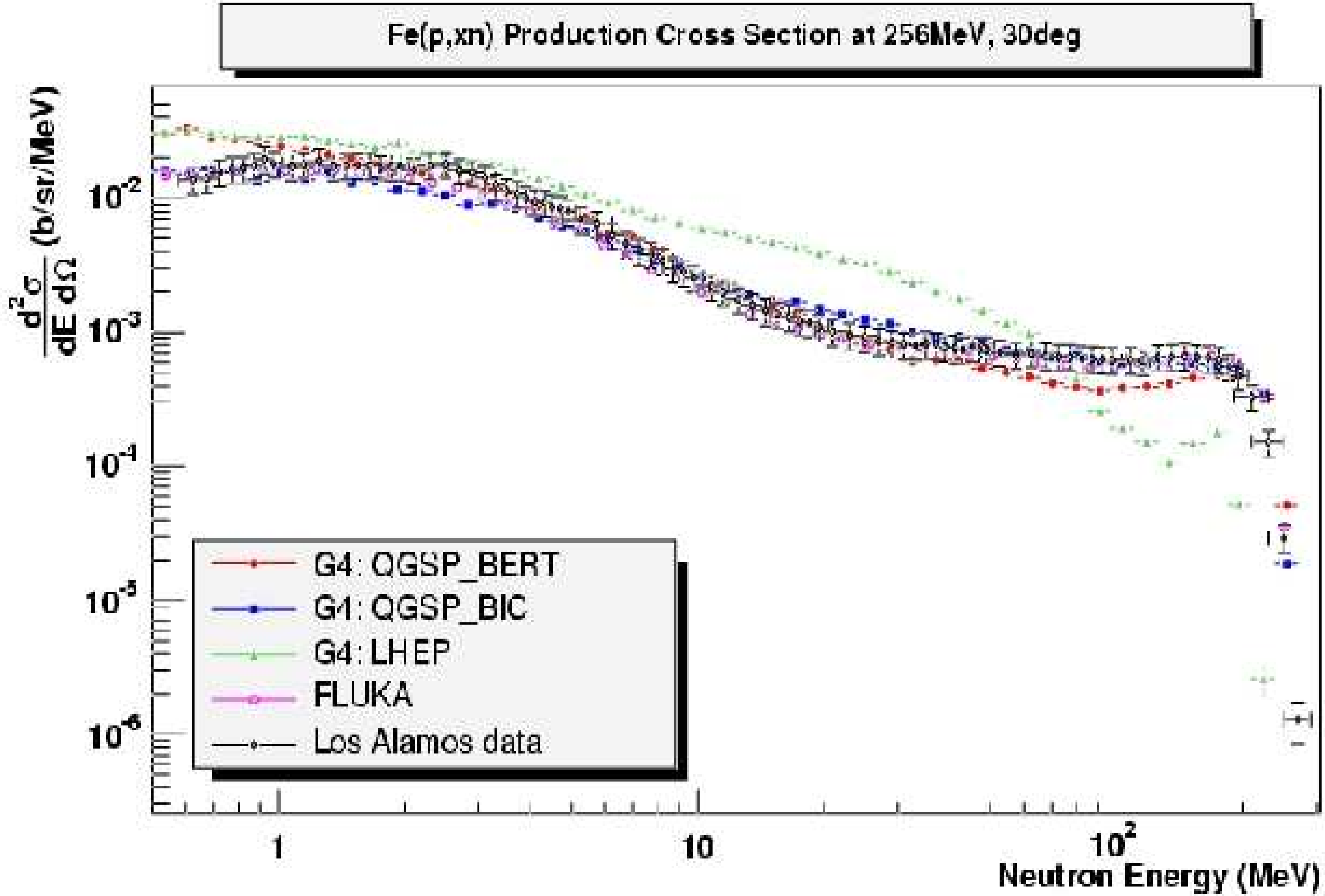

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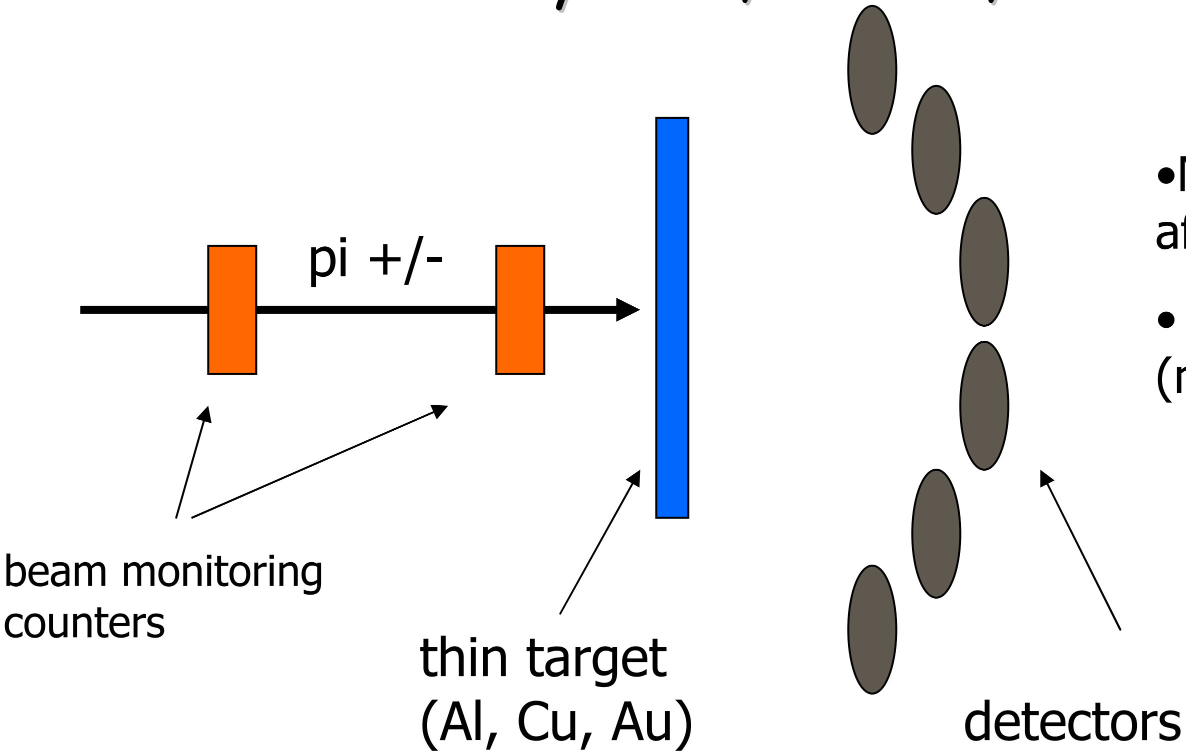
Pion absorption – experiments

- K. Nakai at al., PRL 44, 1446 (1980)
- D. Ashery et al, PR C23, 2173 (1991)



- Nakai – look for gammas emitted after pion absorption
- Ashery – look for transmitted (not absorbed) pions

pi+/- beams of energies between 23 - 315 MeV

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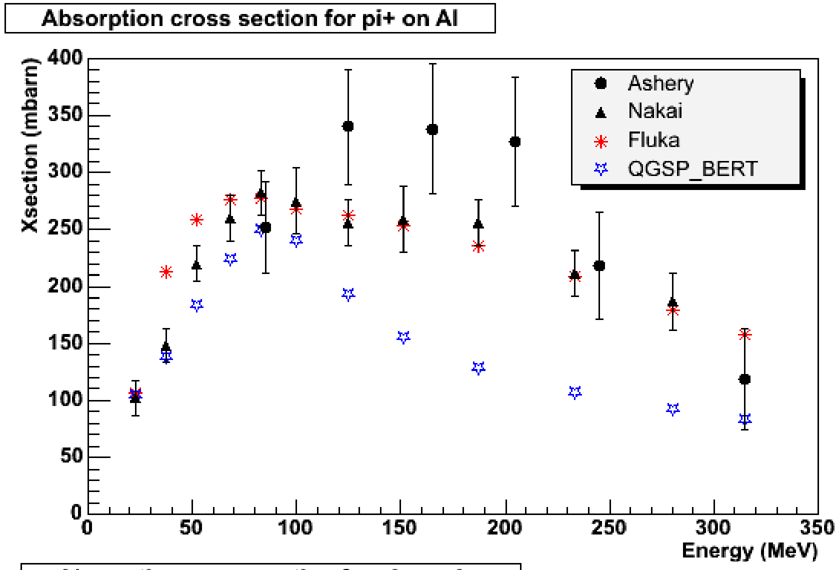
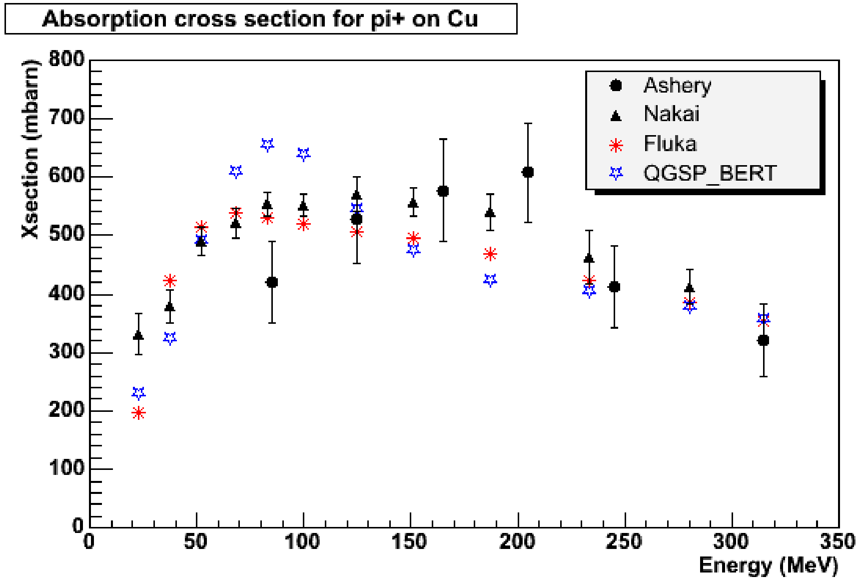
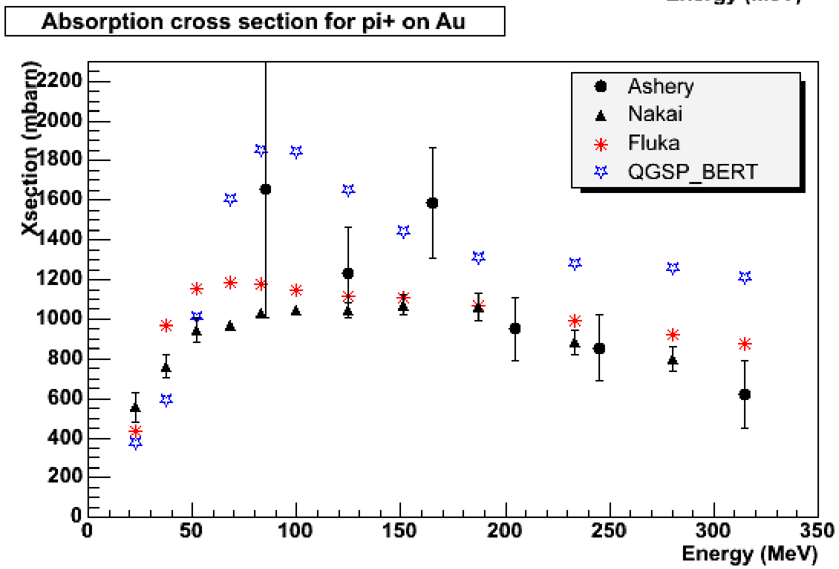
Absorption Xsection for pi+







- both G4 and Fluka show reasonable agreement
- in some cases Fluka seems to be a bit better
- difficult to make more conclusions because of big uncertainties in the experimental data

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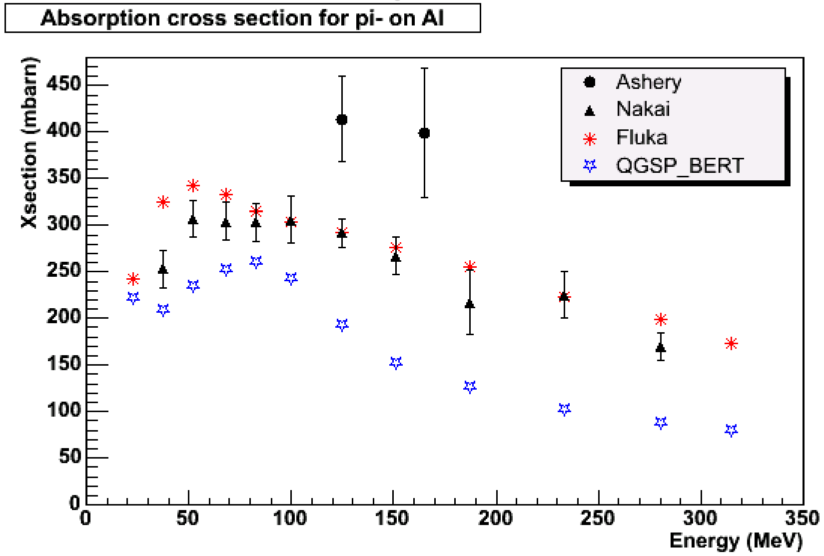
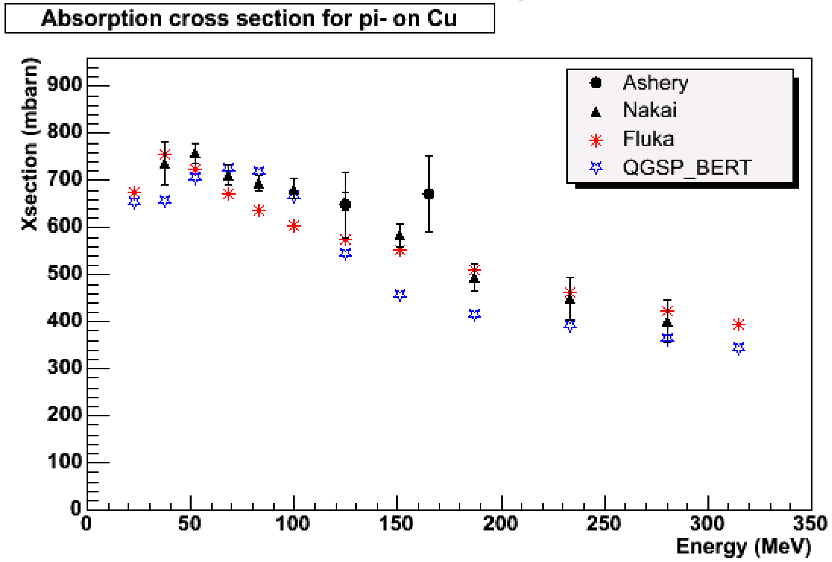
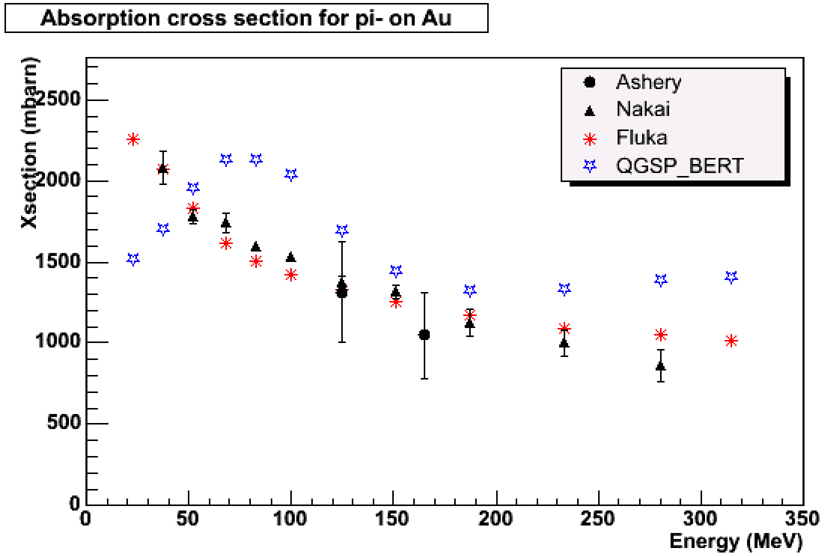
Absorption Xsection for pi-







- same remarks as for pi+
- for heavy material (Au) the shape of the QGSP_BERT quite different
- G4: best agreement for 'medium-weight' materials

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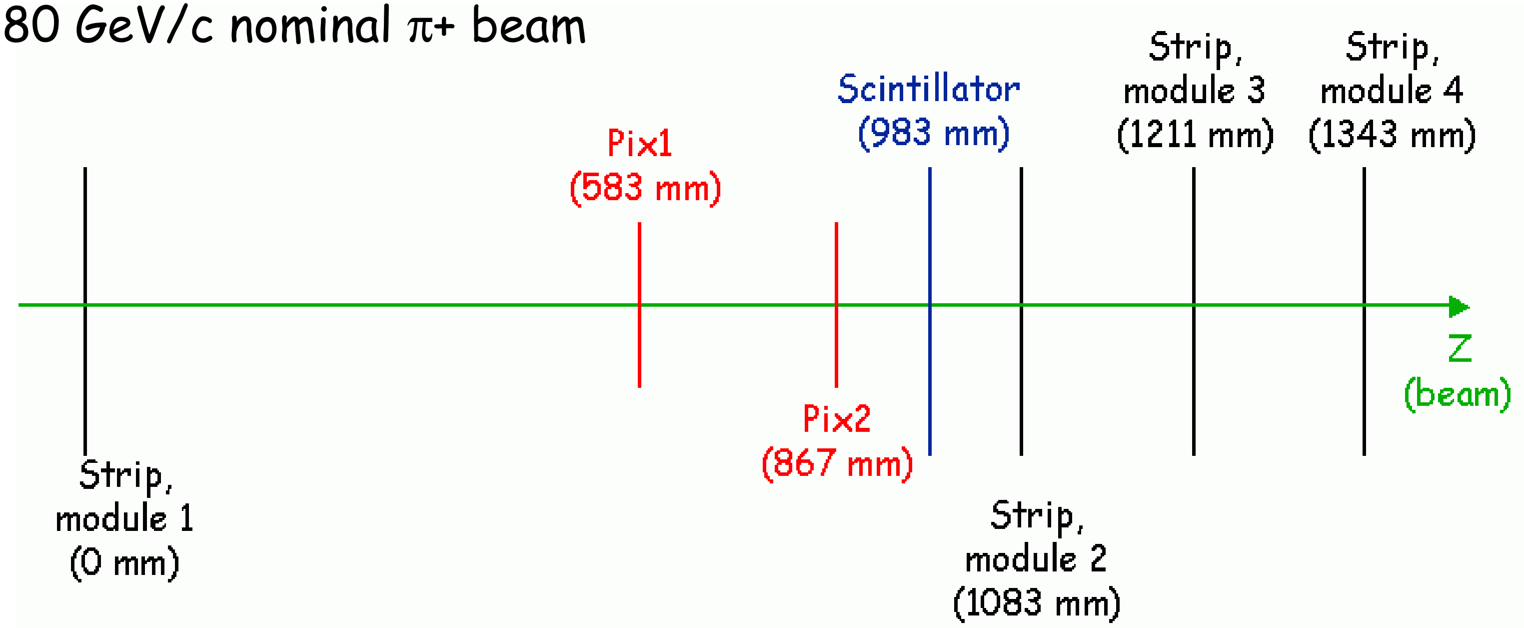
Hadronic interactions in ATLAS pixel test-beam

180 GeV/c nominal π+ beam



Geant4 Geometry. Use the same Geometry also with Fluka, using FLUGG (interface between the Transportation and Physics of Fluka and Geant4 Navigation of the Geometry).

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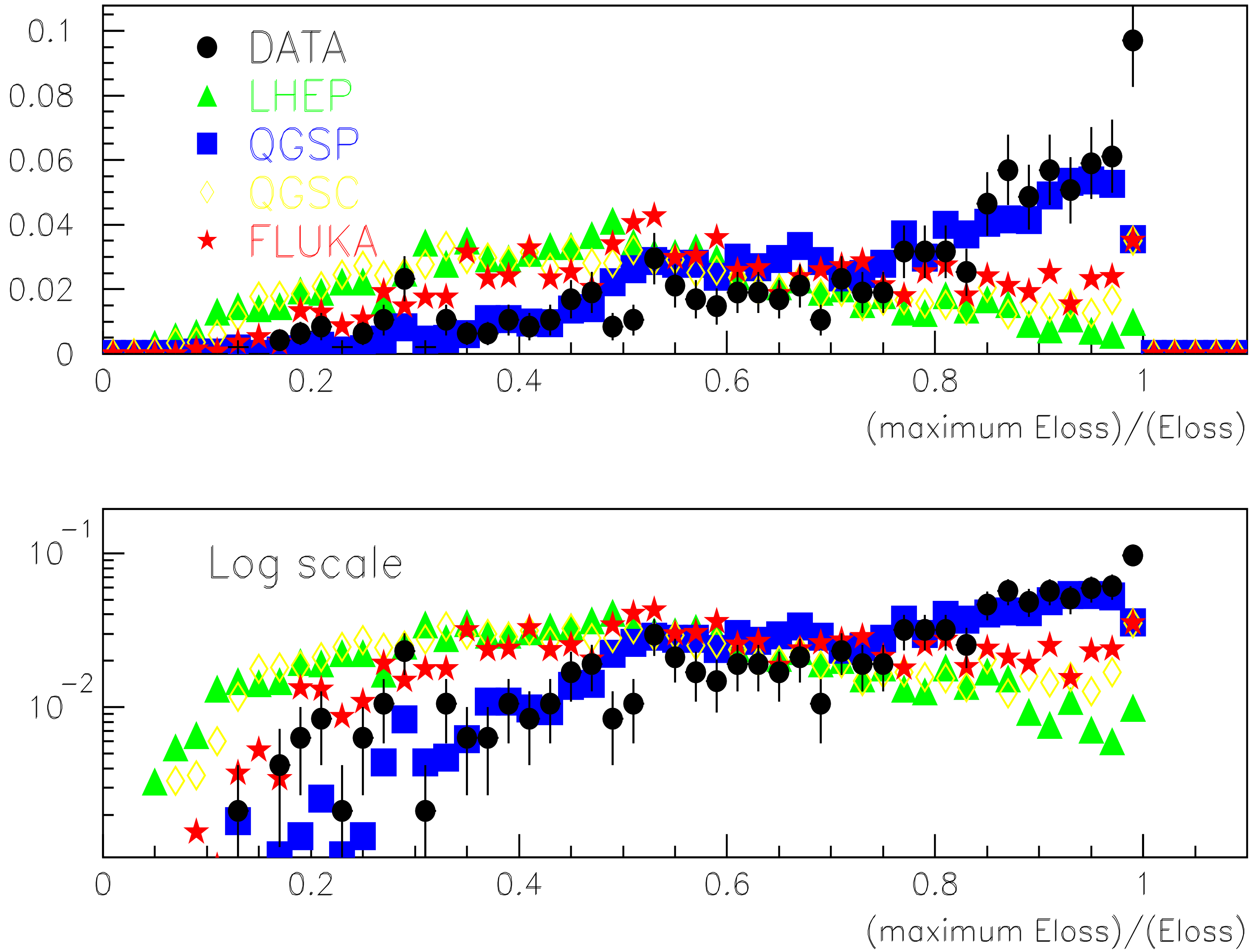
Ratio max Eloss / total Eloss



QGSP is in excellent agreement with data.

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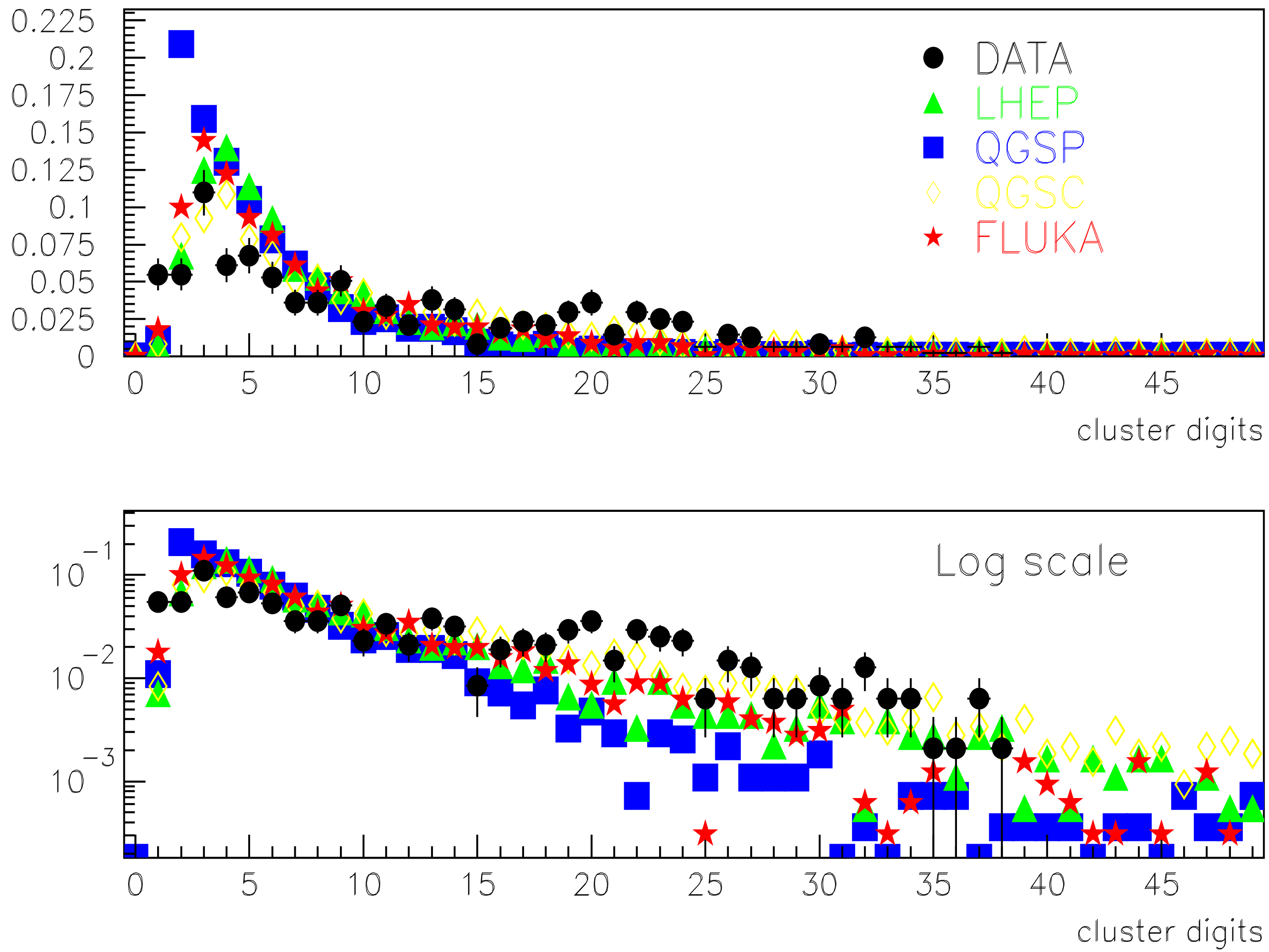
Cluster size



QGSP produces too narrow clusters. FLUKA, LHEP and QGSC are in good agreement with data.

In conclusion, FLUKA, Geant4 are in reasonable good agreement with the data, but some observables can be improved.

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Pion production at 100 GeV/c

- J.J. Whitmore et al. Z. Phys. C 62 (1994), 199.

Inclusive pion+/pion- production in hadron-nucleus

Interactions at 100 GeV/c .

Beam particles: $\pi^{+/-}$, $K^{+/-}$, p, pbar

Target: thin foils of Mg, Ag, Au

Observables: y_{lab} , laboratory rapidity distributions;

p^2_T , transverse momentum square dist.

Work in progress.

Future: extend to different beam energies, target materials, and observables.

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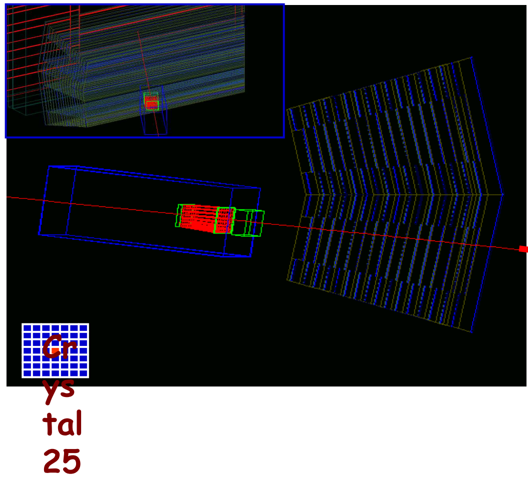
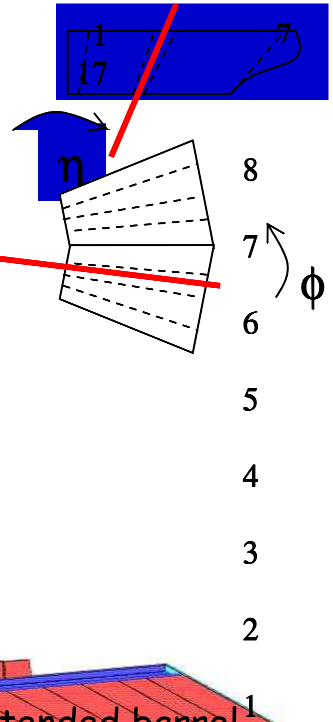
LHC hadronic calorimeter test-beams (before 2004)

- ATLAS:
  - HEC : copper + LAr
    HEC1 + HEC2, 4 longitudinal compartments
    6-150 GeV for electrons;
    10-200 GeV for charged pions;
    120, 150, 180 GeV for muons.
  - Tilecal : iron + scintillator tile
    2 extended barrel + 1 barrel + barrel 0 modules
    20-180 GeV electrons and charged pions;
    1, 2, 3, 5, 9 GeV charged pions.
- CMS:
  - combined ECAL + HCAL :
    ECAL : prototype of 7 x 7 $PbWO_4$ crystals
    HCAL : copper + scintillator tile
    each tile is read out independently
    Max magnetic field of 3 T
    10-300 GeV muons, electrons, and hadrons.

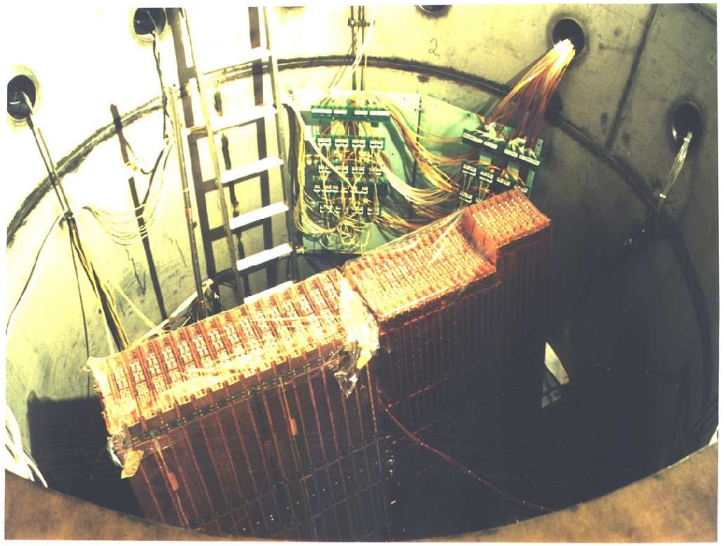
Calorimeter test-beams

CMS HCAL & ECAL

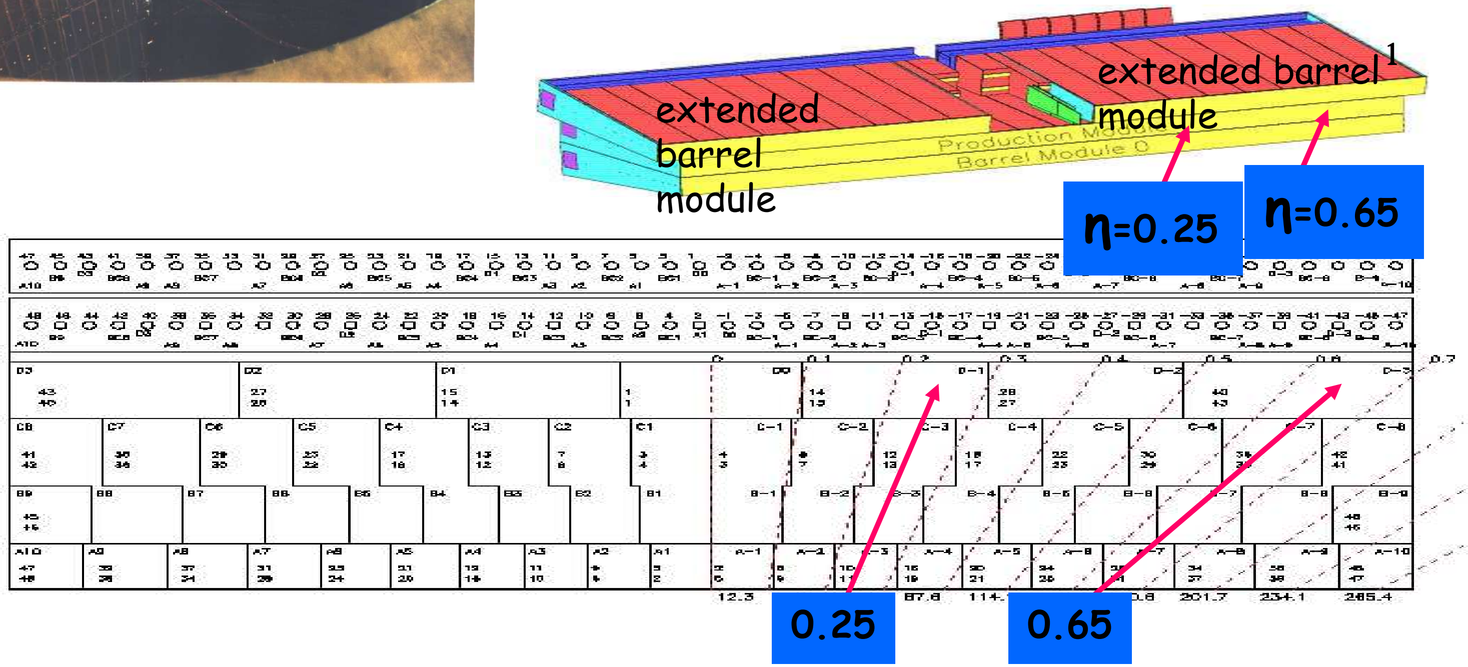




ATLAS HEC



ATLAS TileCal



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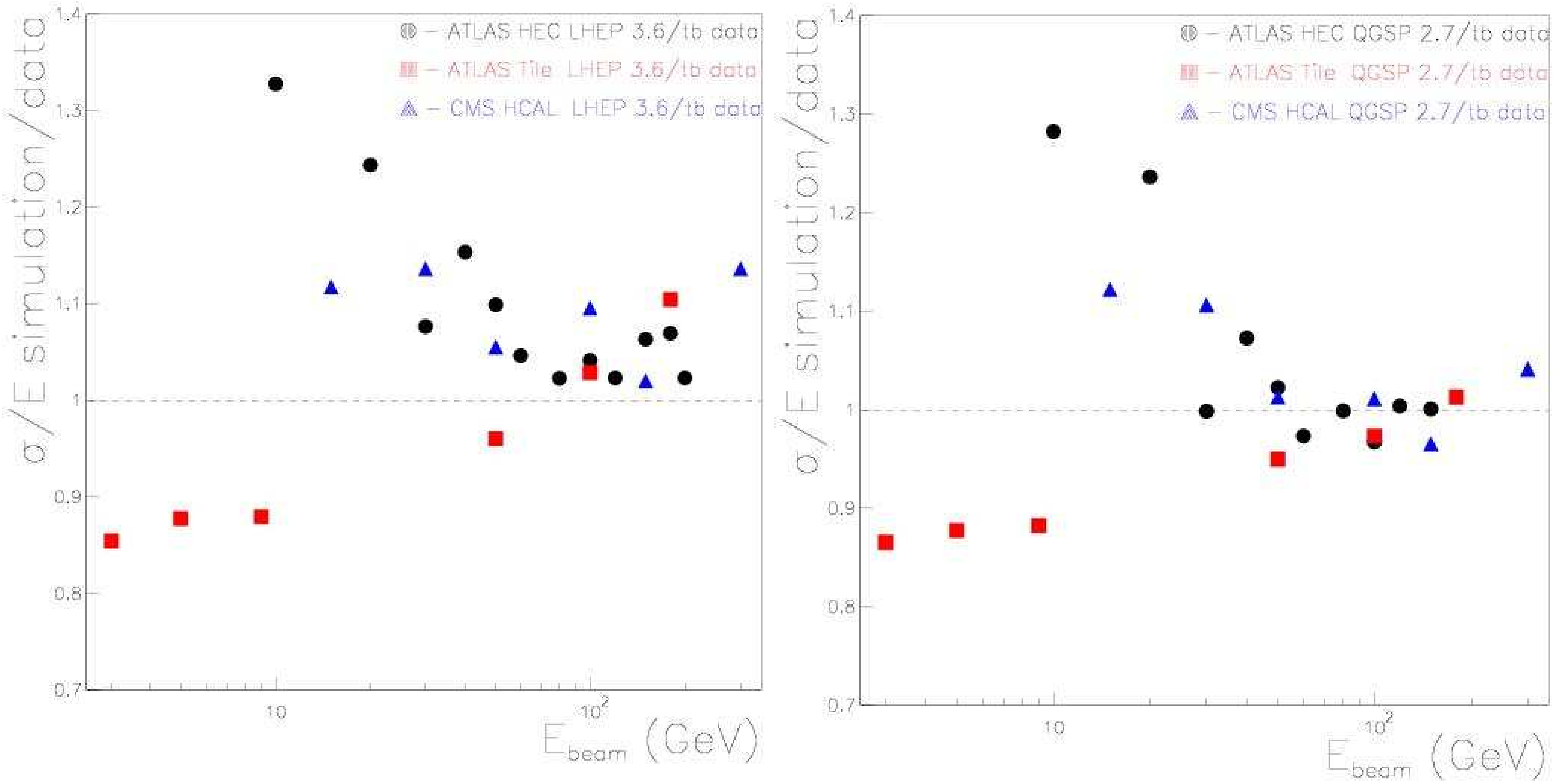
energy resolution of pions

$$\left(\frac{\sigma}{\langle E\rangle}\right)_{simulation} \Big/ \left(\frac{\sigma}{\langle E\rangle}\right)_{test-beam}$$



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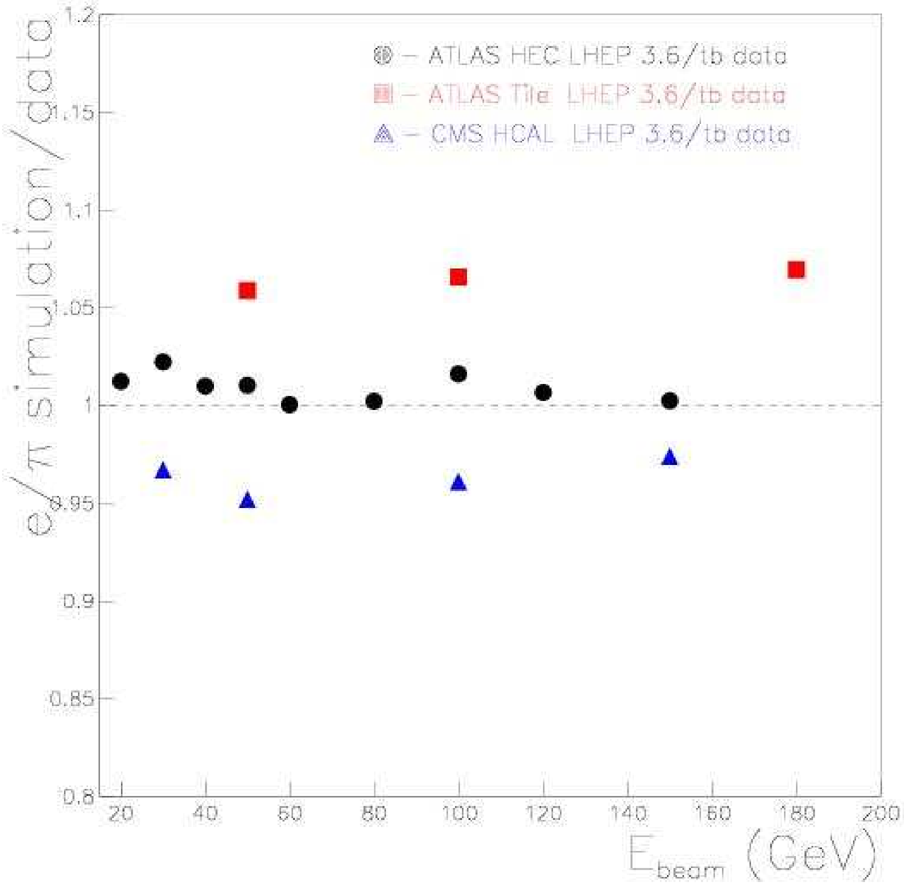
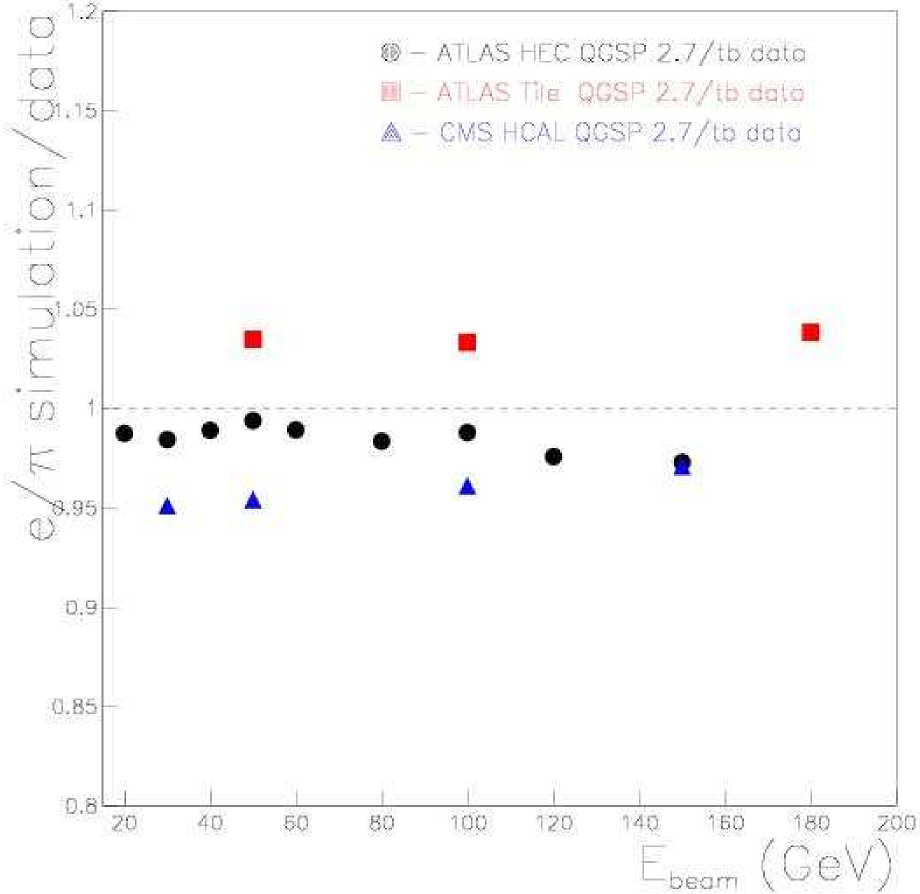
<u>e/π ratio</u>

$$\left(\frac{e}{\pi}\right)_{simulation} \Big/ \left(\frac{e}{\pi}\right)_{test-beam}$$





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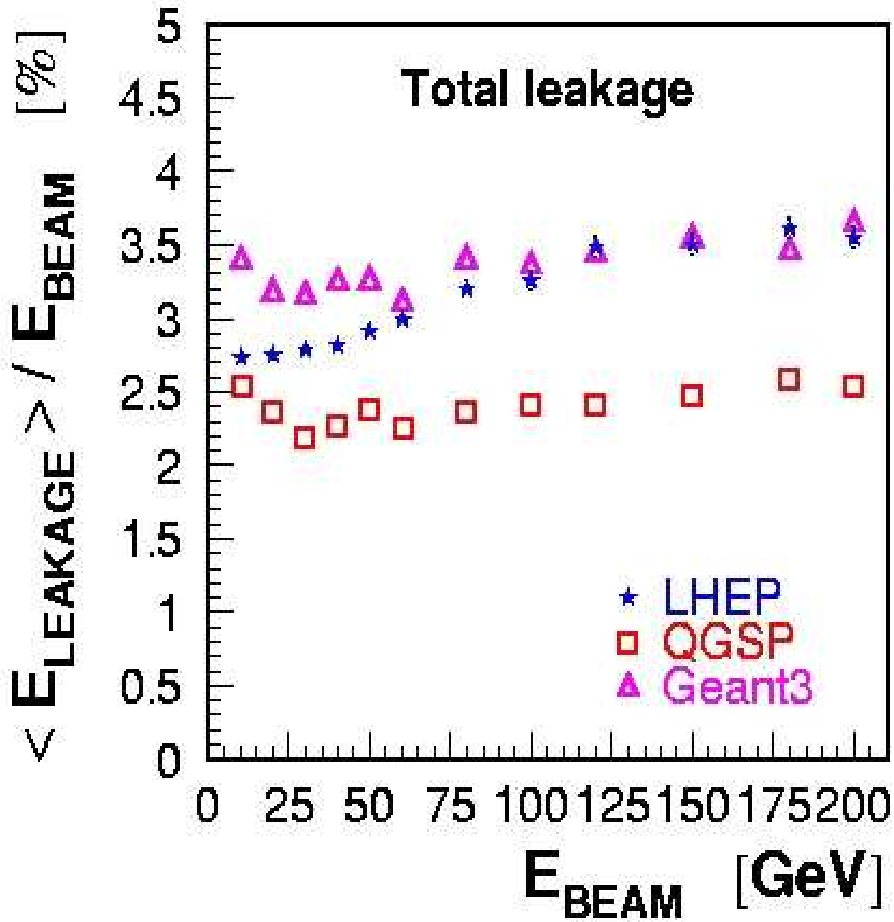
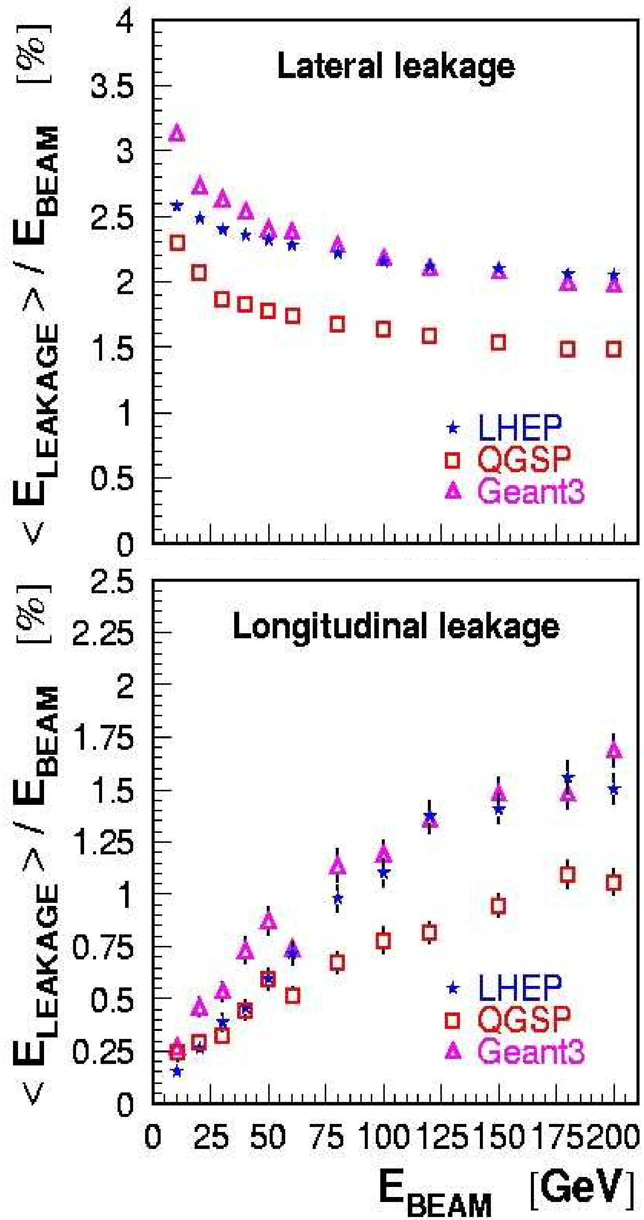
ATLAS HEC: leakage

G4
5.2p02





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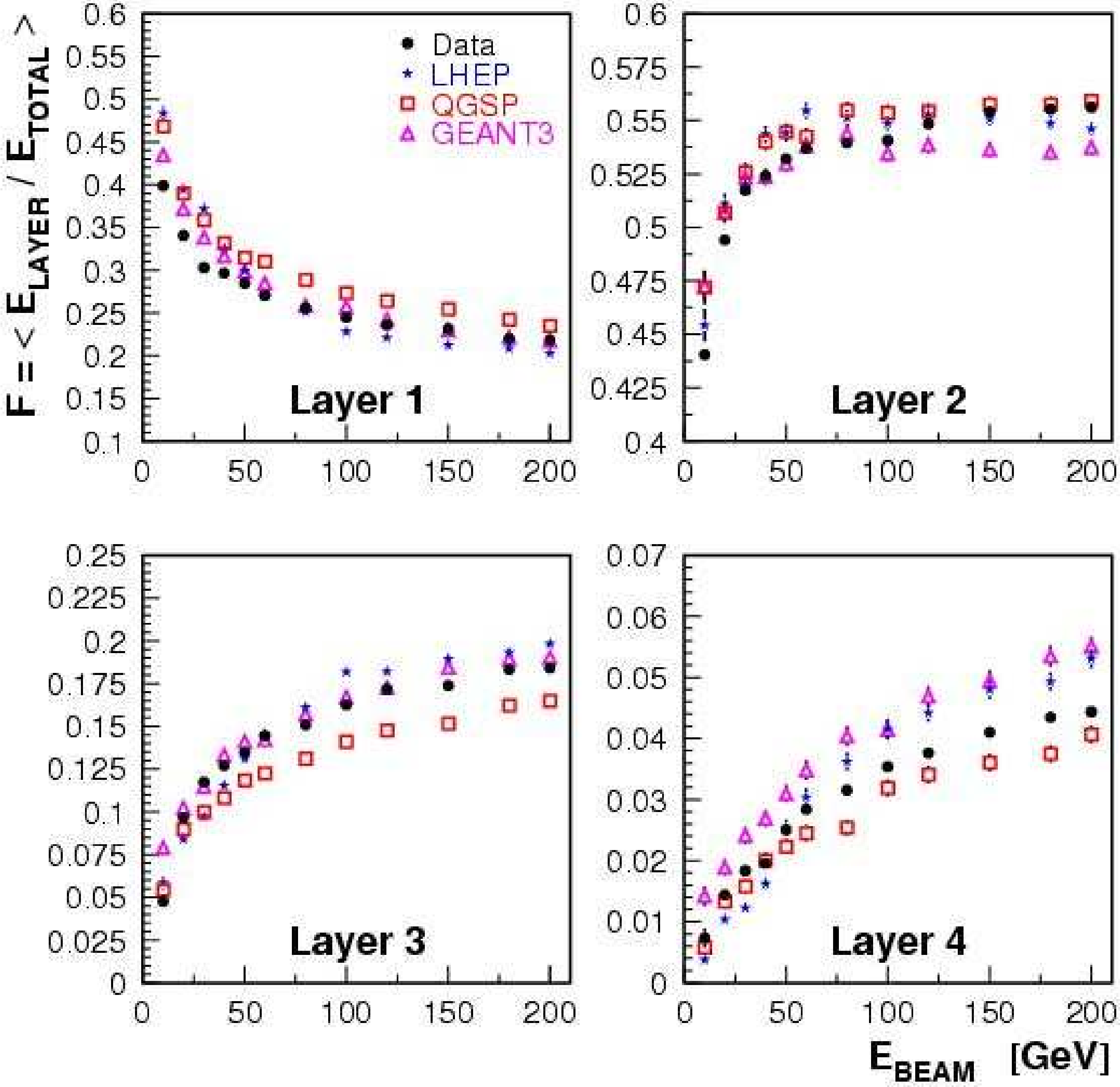
ATLAS HEC:

G4 5.2p02



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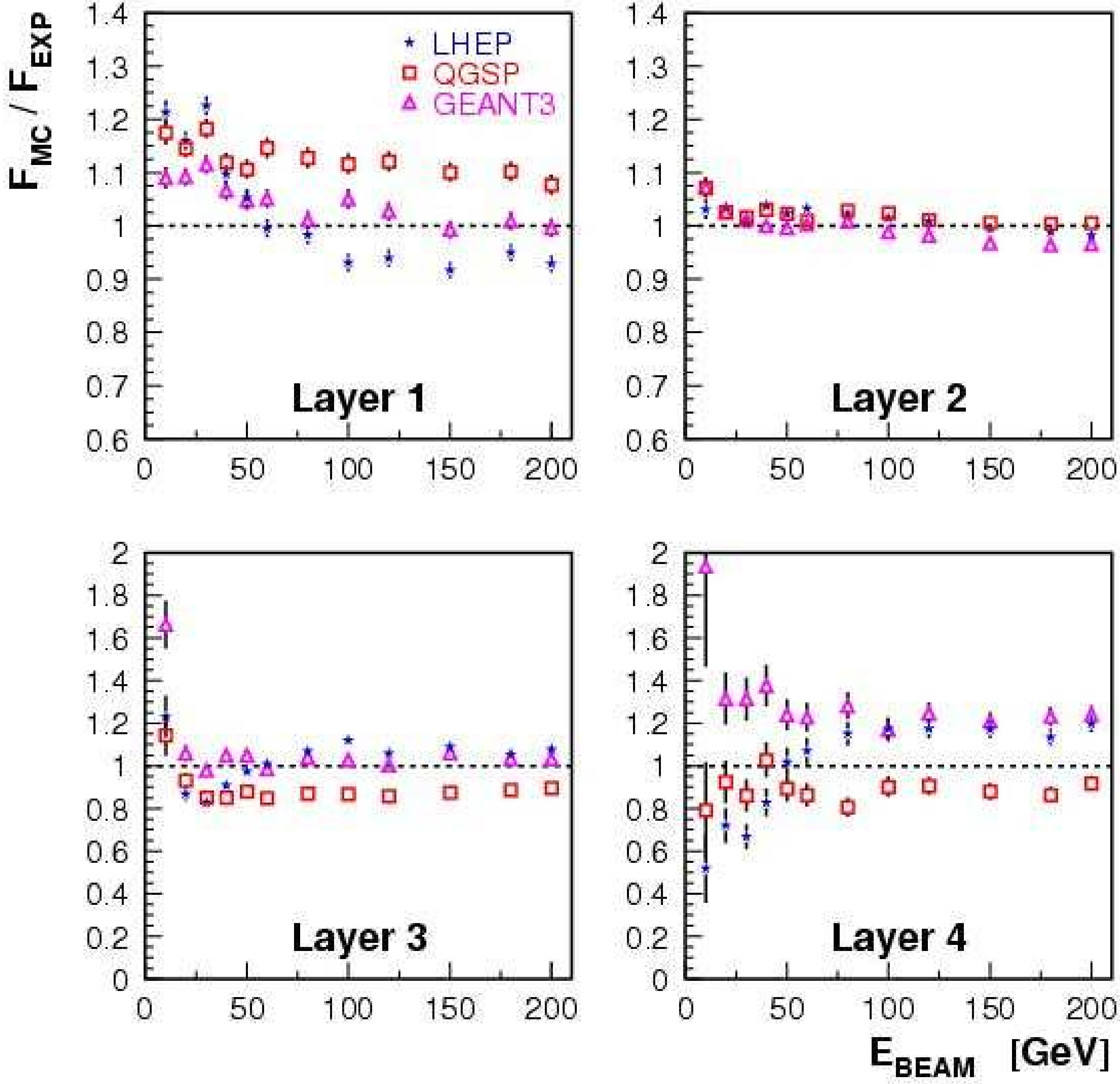
ATLAS HEC:



G4 5.2p02

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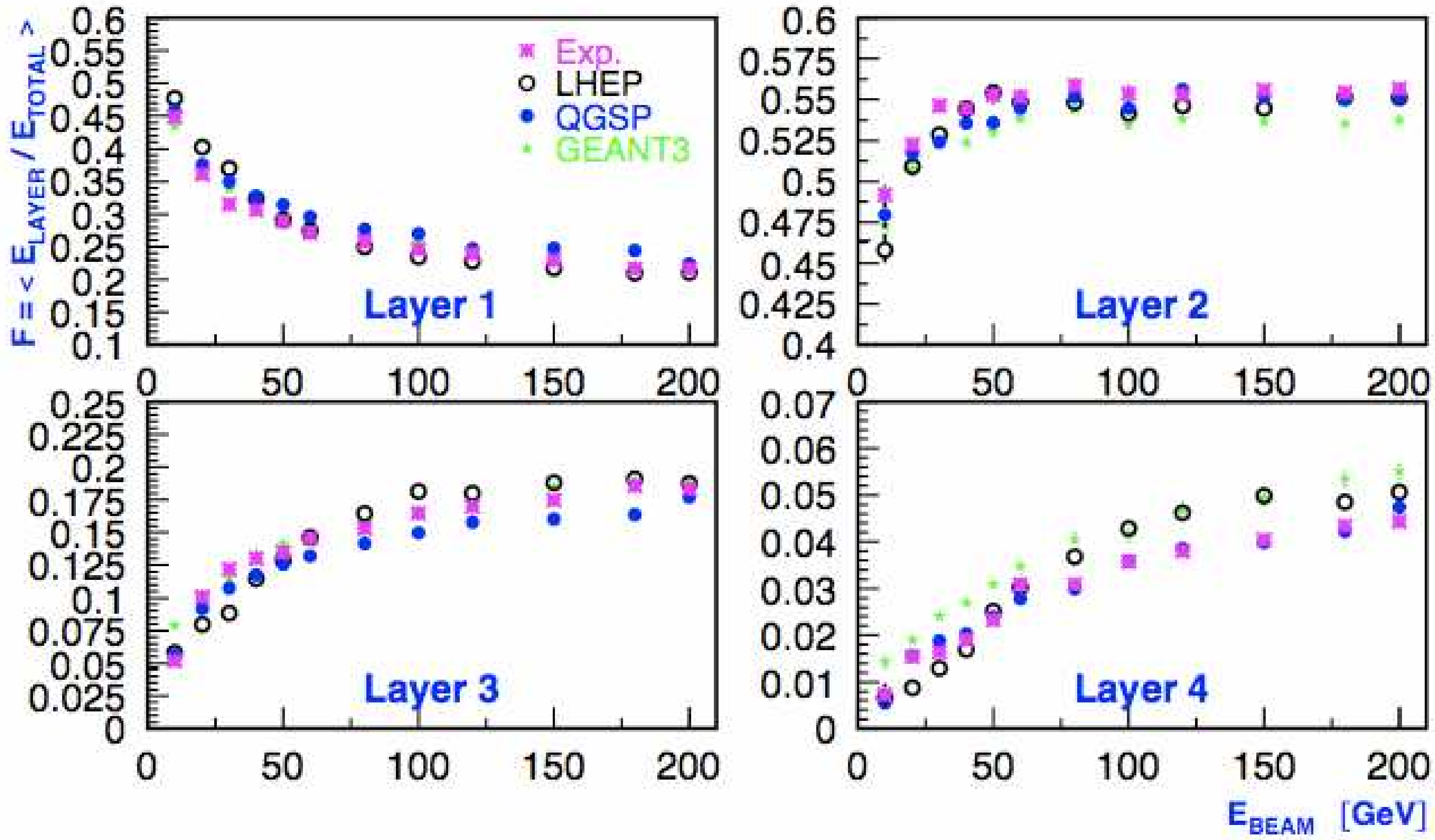
ATLAS HEC:

G4 7.0p01

PRELIMINARY



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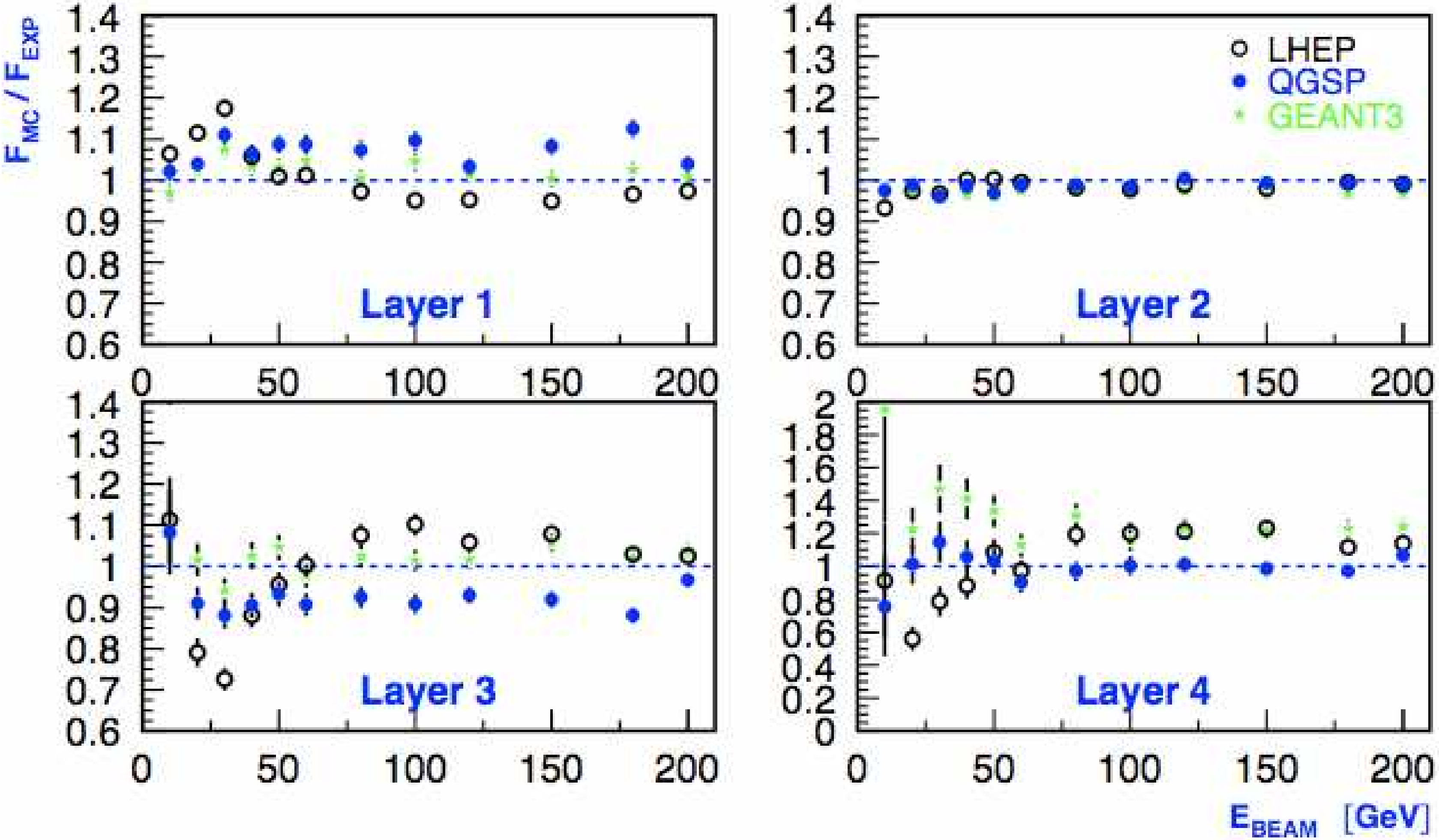
ATLAS HEC:

G4 7.0p01

PRELIMINARY



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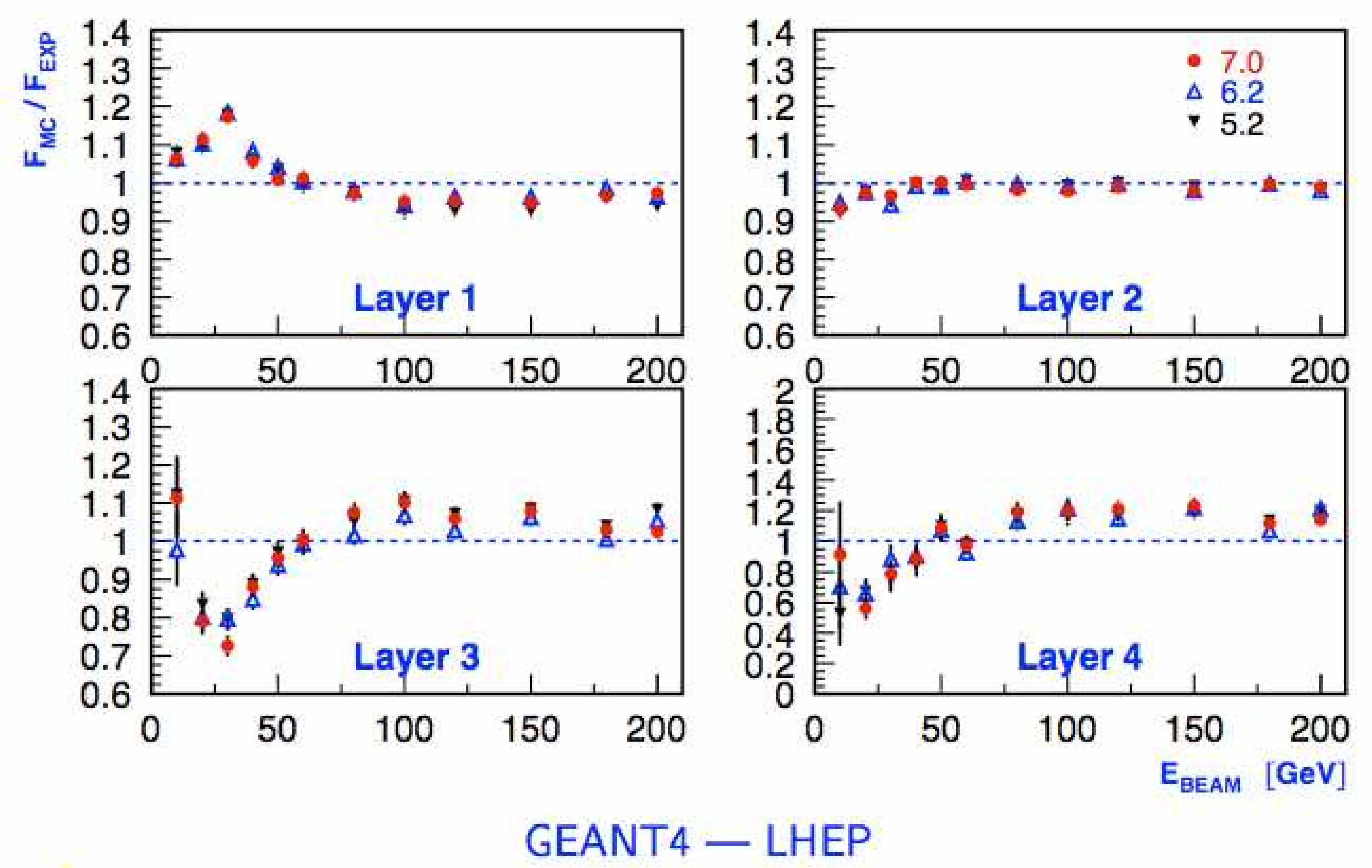
ATLAS HEC:

G4 7.0p01

PRELIMINARY



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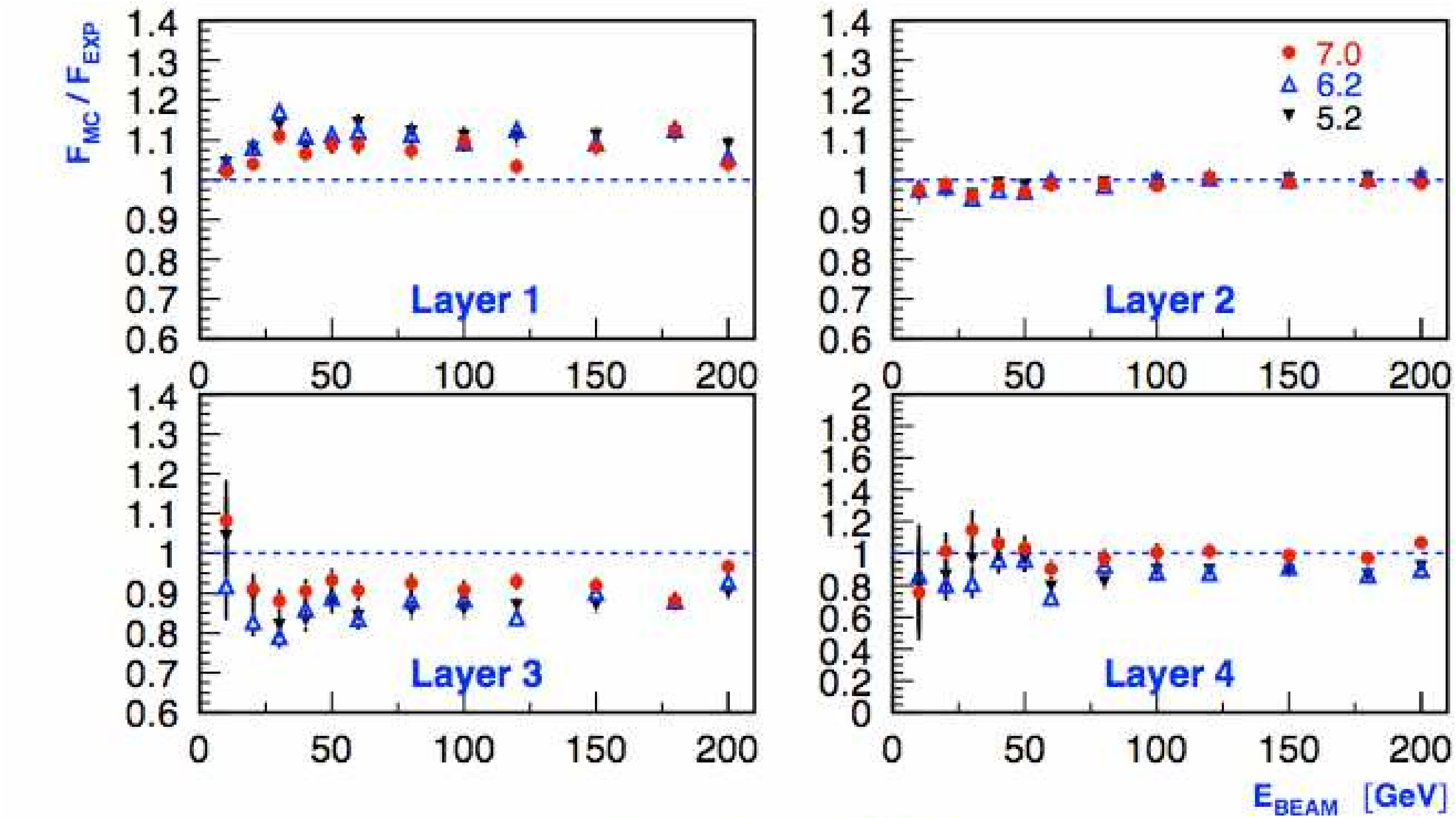
ATLAS HEC:

G4 7.0p01 PRELIMINARY



GEANT4 — QGSP

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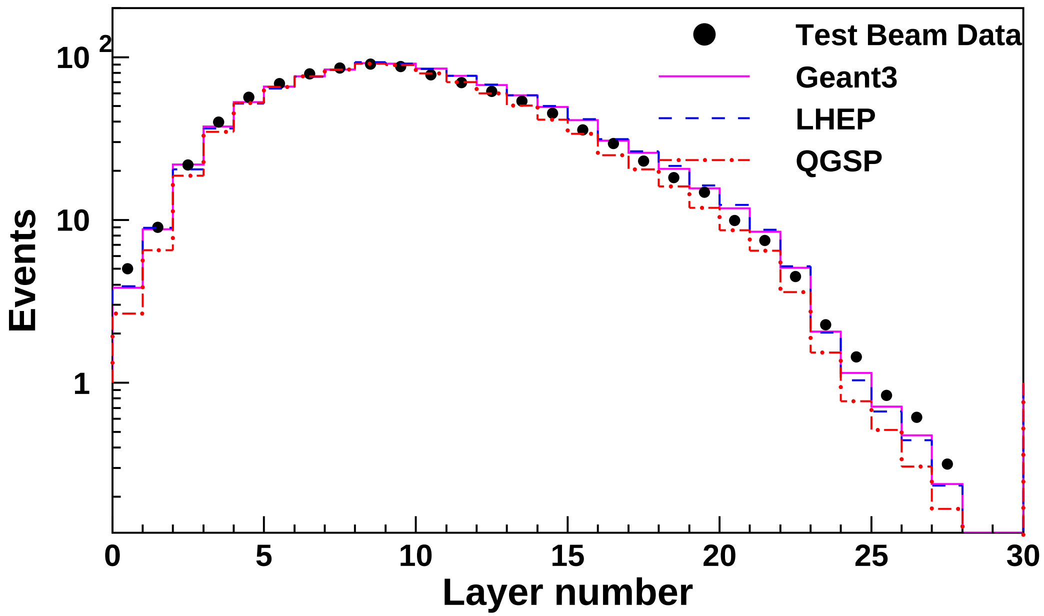
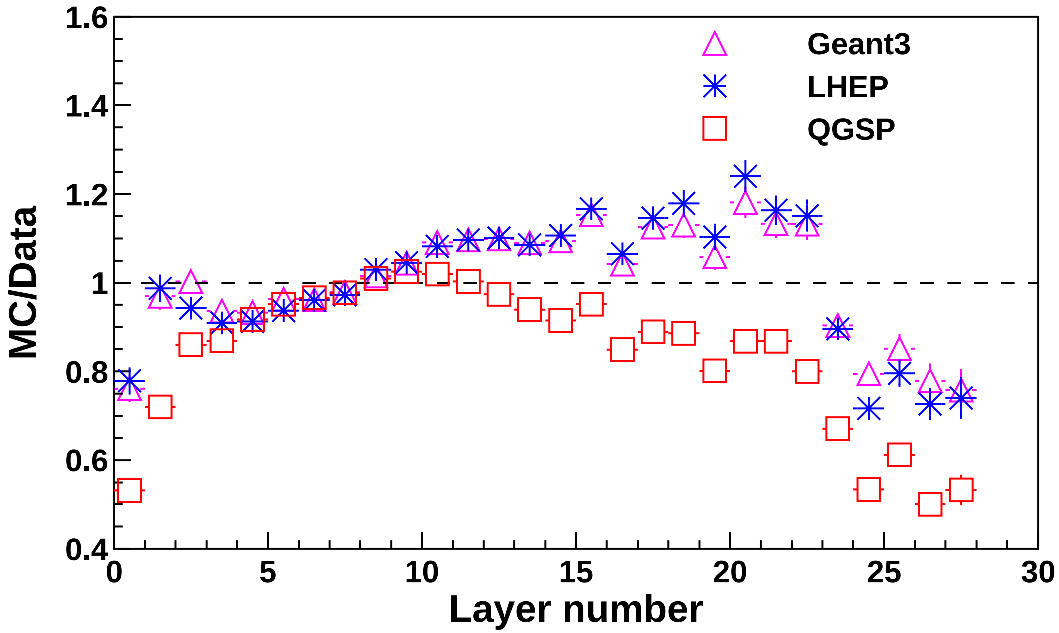
CMS longitudinal shower profile in HCAL for 100 GeV pions



G4 5.2p02

TB 2002



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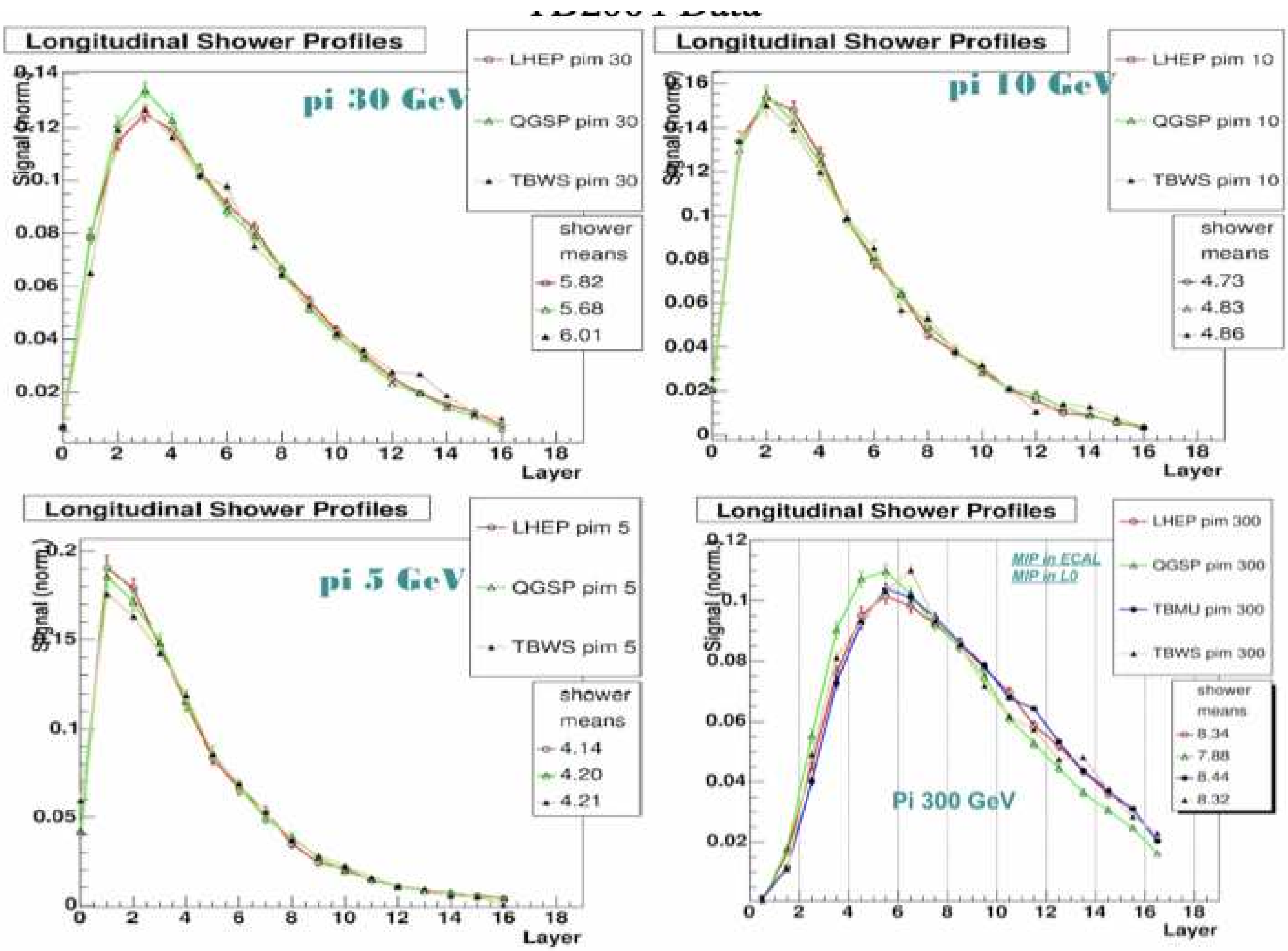
TB 2004 G4 6.2p02 : PRELIMINARY



Albert
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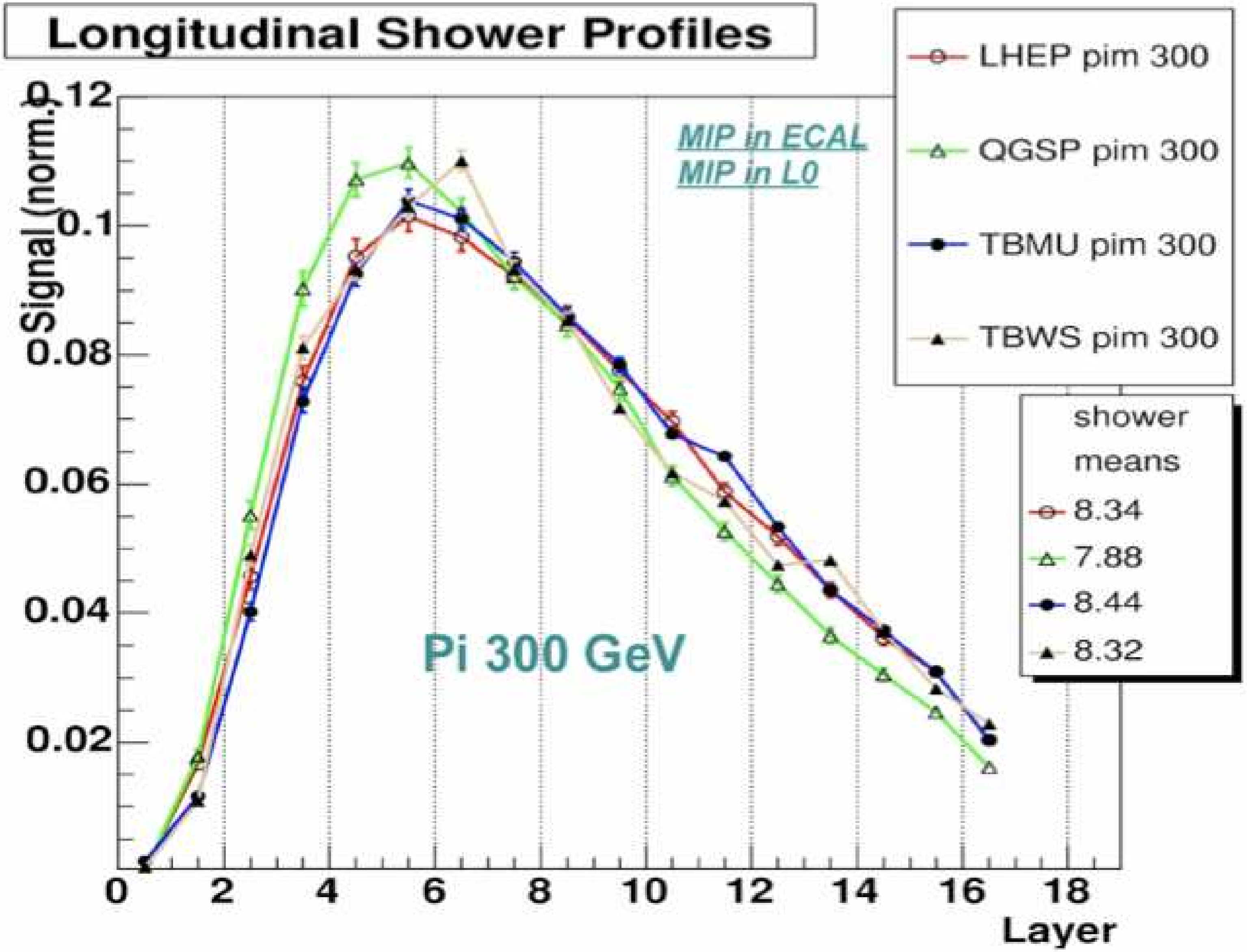
TB 2004 G4 6.2p02 : PRELIMINARY



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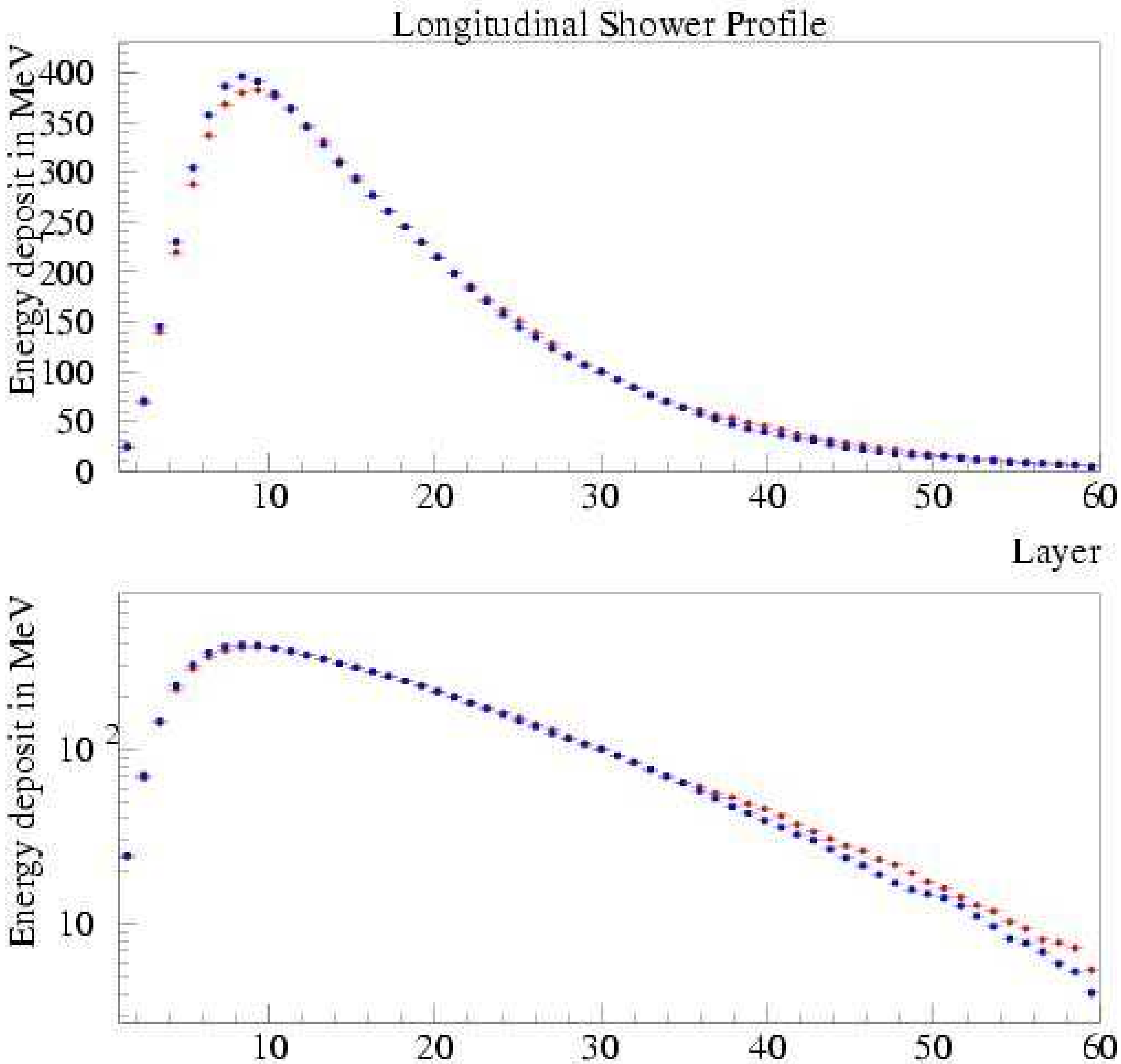
Studies in simplified calorimeter setups (I)

"Atlas HEC"
π^- 200 GeV
Cu-LAr
10 λ 60 layers
(25 mm Cu)
8.5 LAr
5000 events
QGSP
G4 7.1p01
G4 6.2p02



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Studies in simplified calorimeter setups (II)

"CMS HCAL"

π^- 150 GeV

Cu-Sci

10 λ 25 layers

(6 cm Cu)

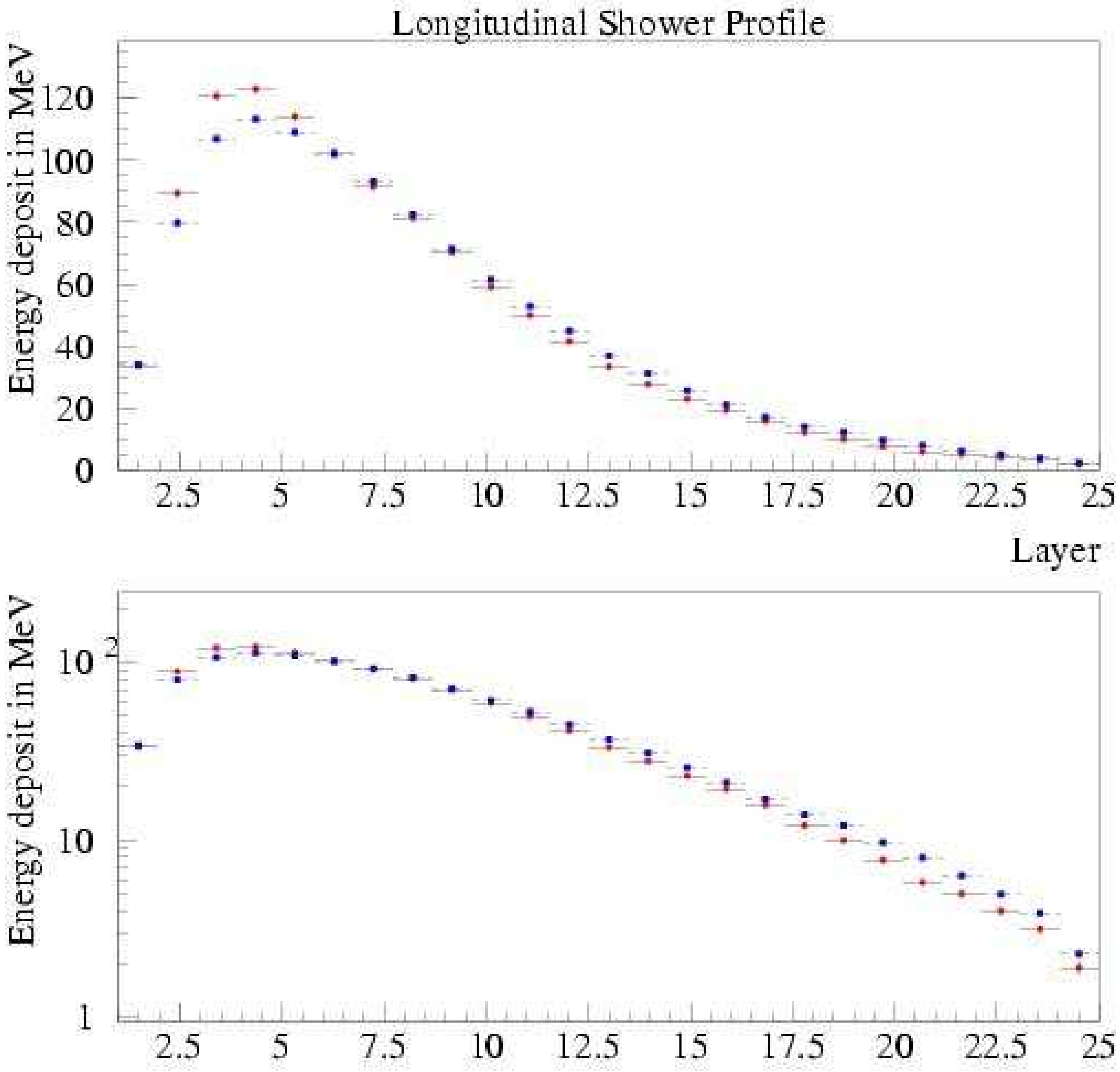
4 mm Sci

5000 events

G4 7.1p01

QGSP

LHEP



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Studies in simplified calorimeter setups (III)

"CMS HCAL"

π^- 150 GeV

Cu-Sci

10 λ 25 layers

(6 cm Cu)

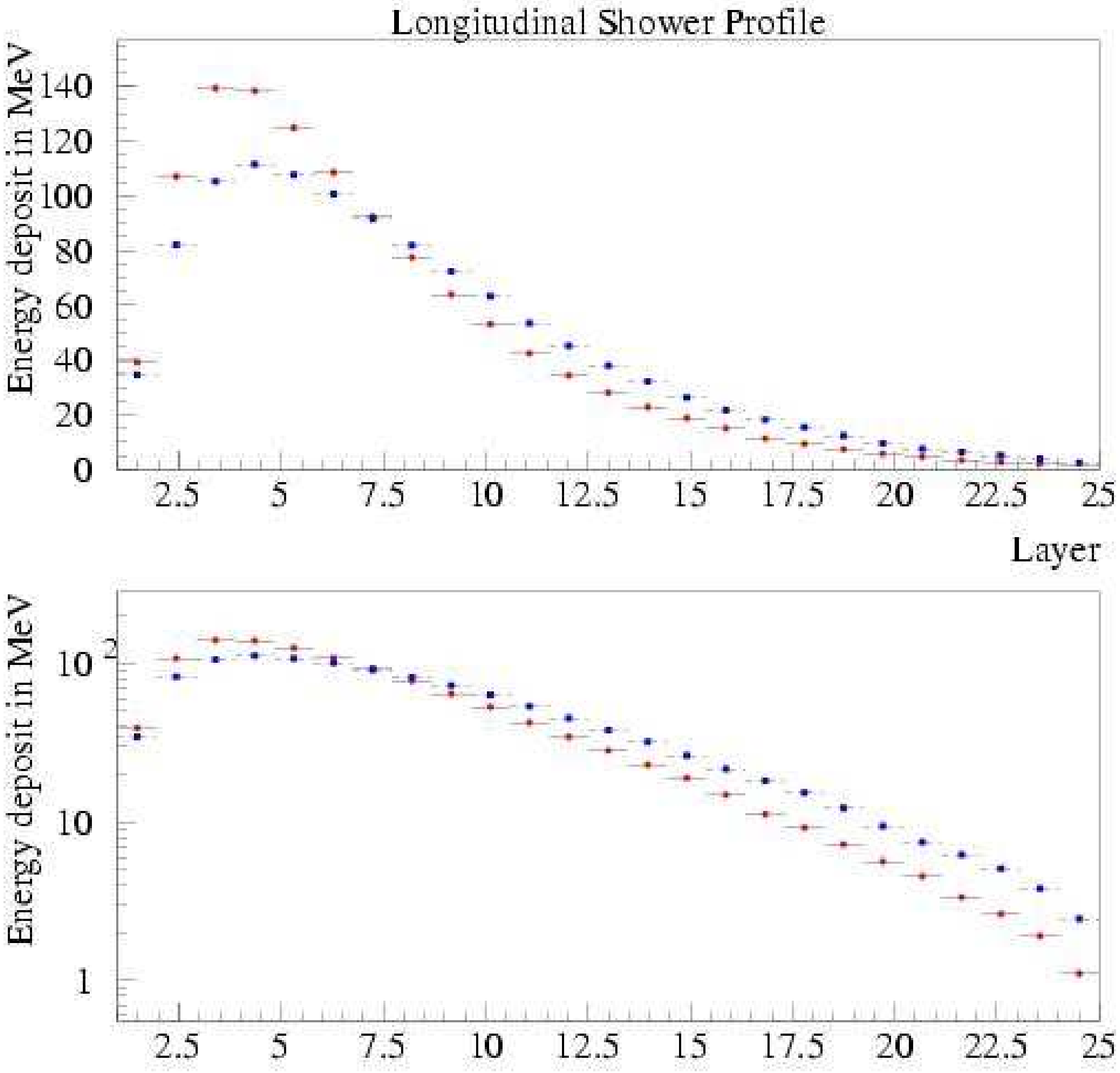
4 mm Sci

5000 events

G4 7.1p01

QGSP forced Xsec

LHEP



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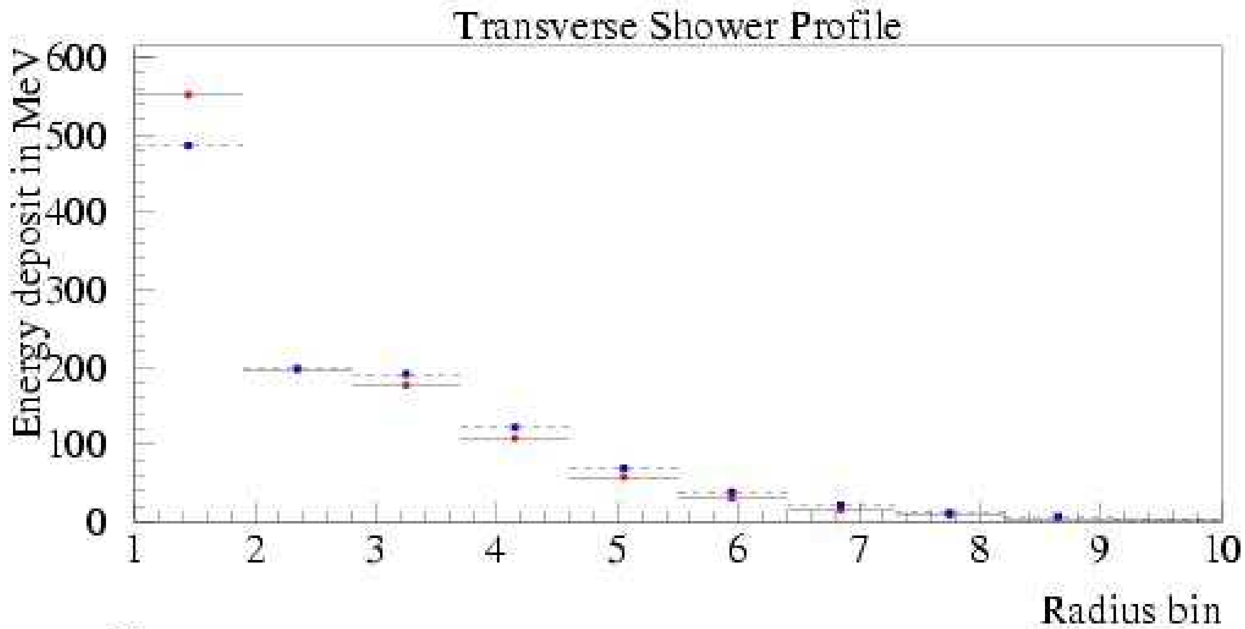
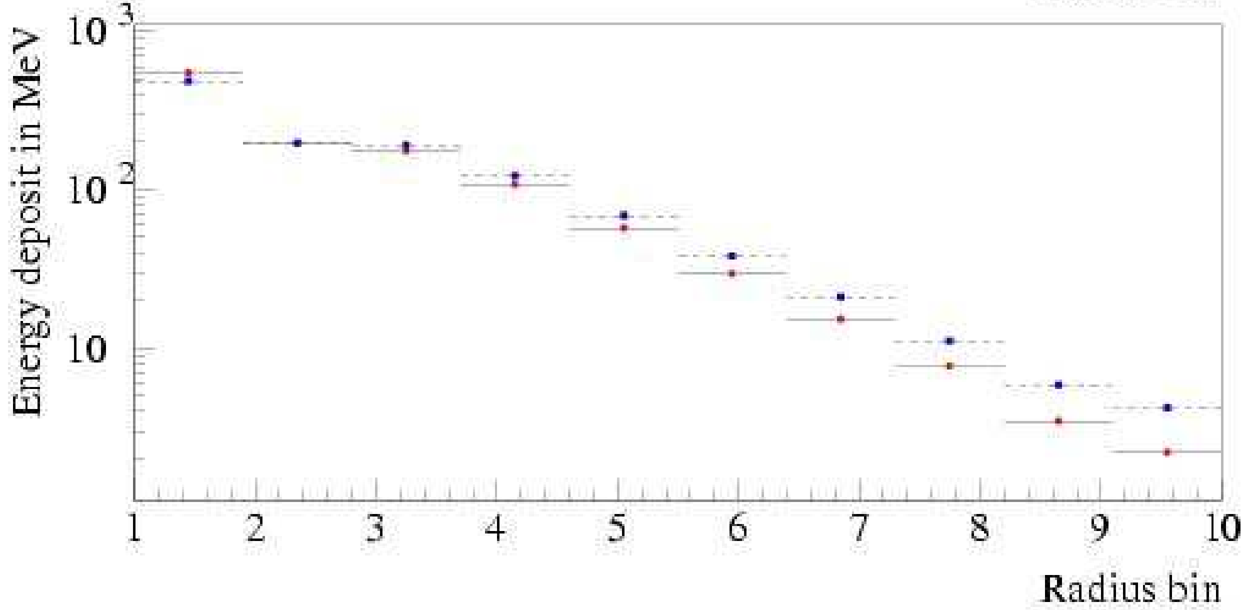
Studies in simplified calorimeter setups (IV)

"CMS HCAL"
π^- 150 GeV
Cu-Sci
10 λ 25 layers
(6 cm Cu)
4 mm Sci
5000 events
G4 7.1p01
QGSP
LHEP





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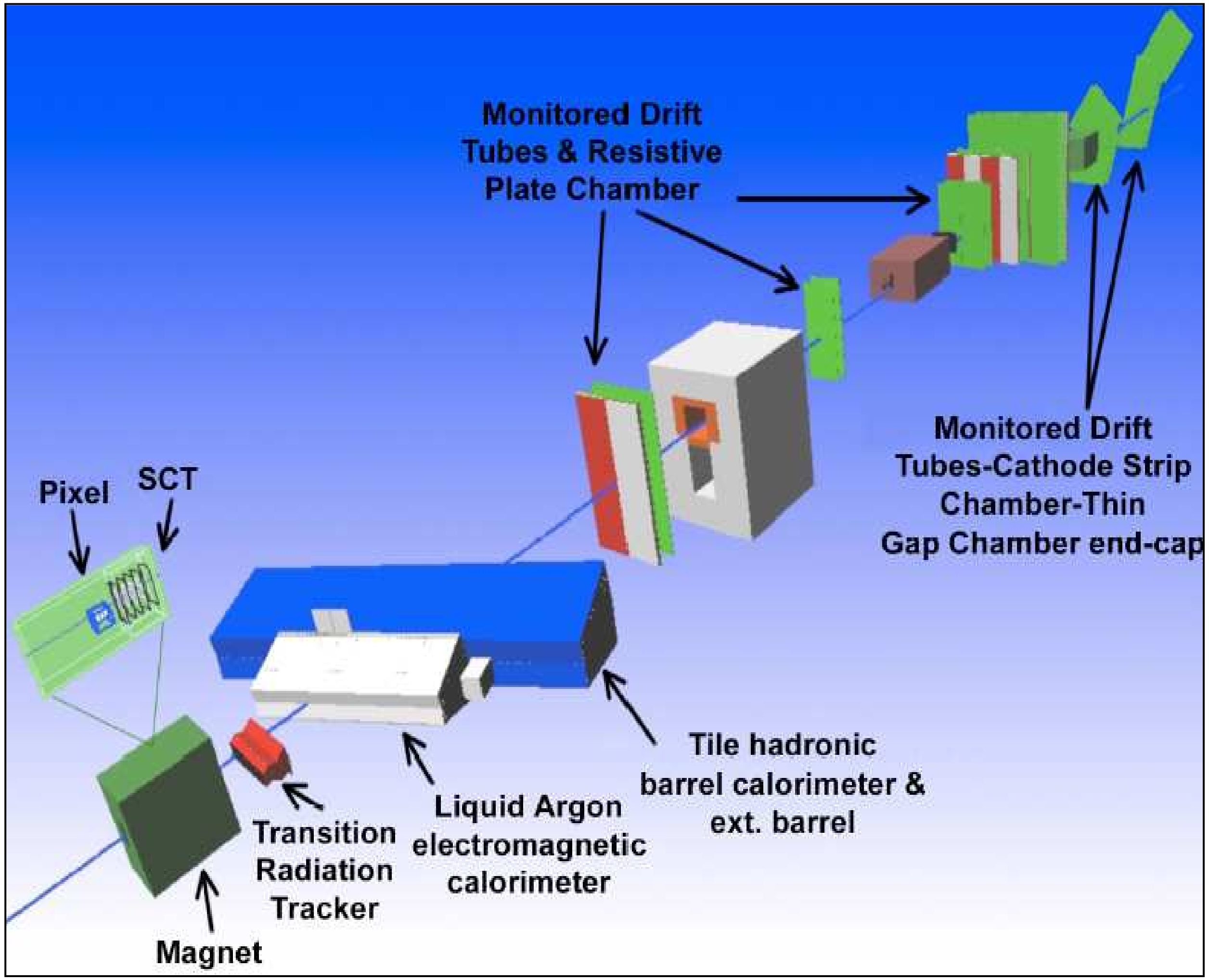
ATLAS Combined Test-Beam



ATLAS barrel slide 85 m long
from May to October 2004
1-350 GeV, e, π, p, μ, γ

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Radiation studies with Geant4

Knowledge of particle fluences, their energy spectra and absorbed doses is necessary for radiation protection, and to estimate the damage probability of detectors and electronics, and therefore for shielding design.

Background radiation studies for LHC experiments have been done mainly with Fluka . It is very interesting to compare them with Geant4, which offers a precise treatment of low energy neutrons with some Physics Lists.

Work is in progress in LHCb.

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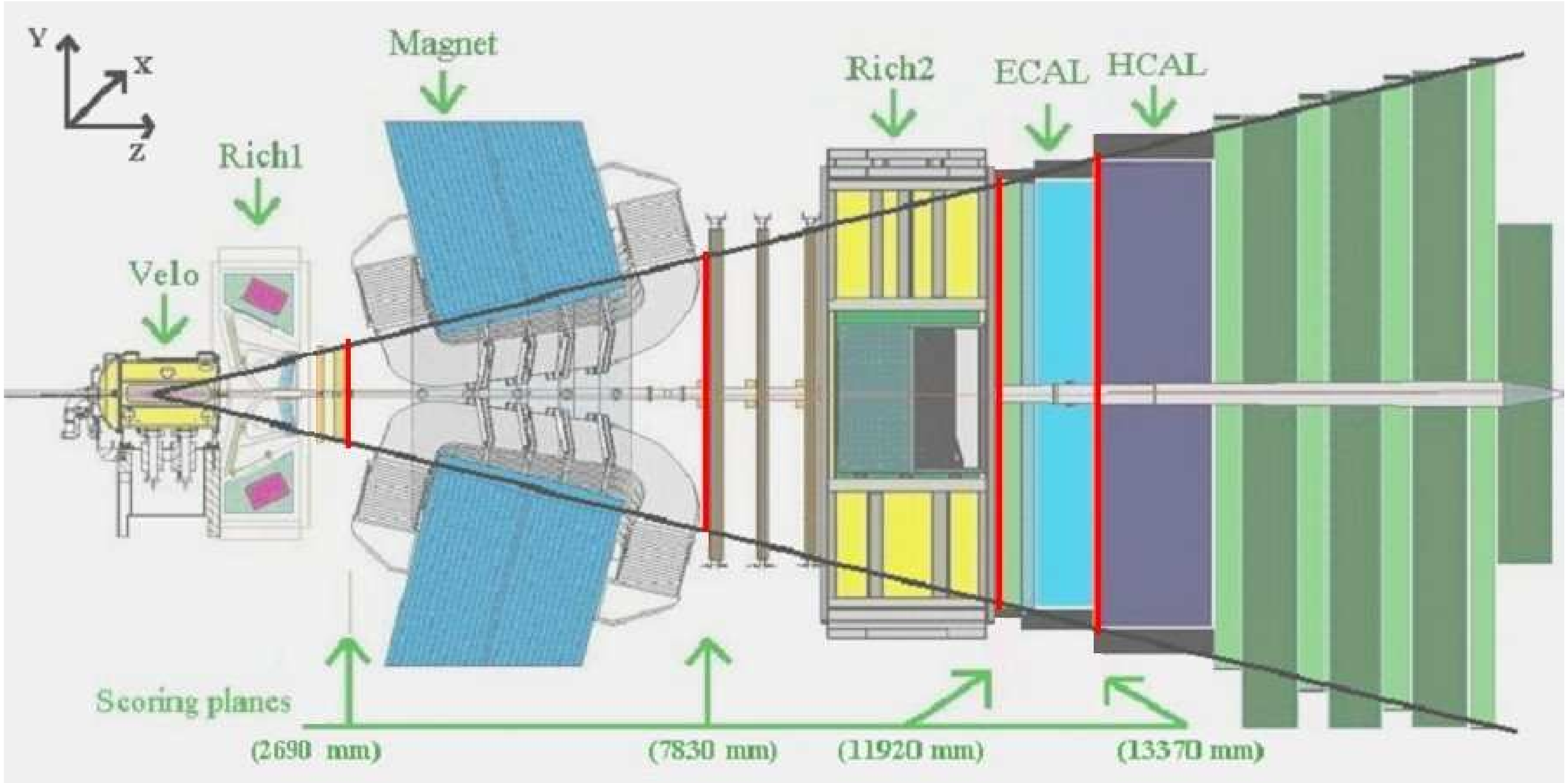
LHCb layout



4 scoring planes

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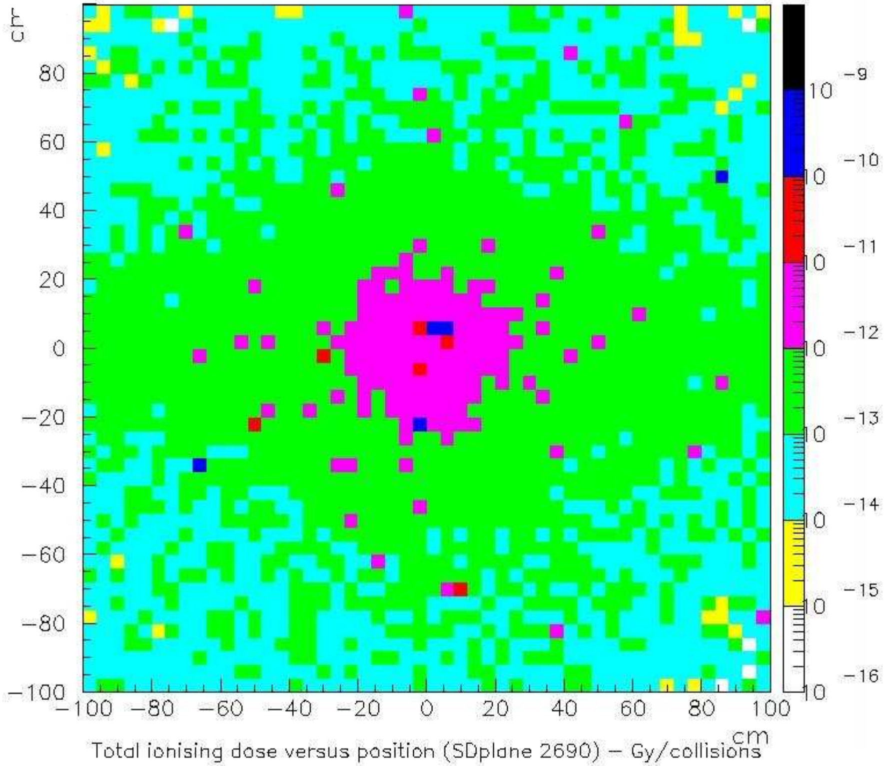
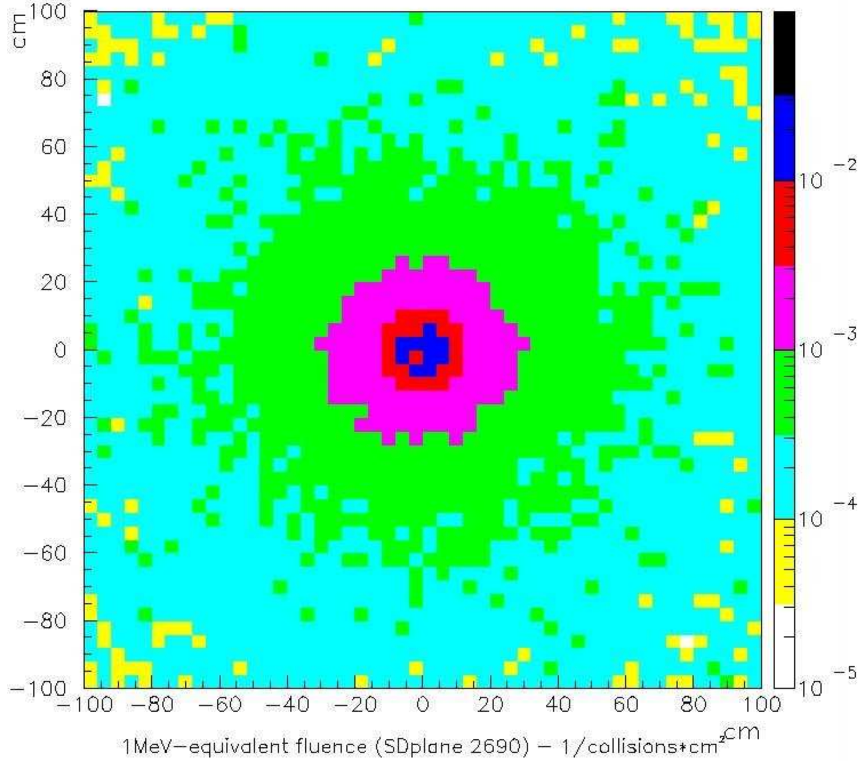
QGSP_BERT_HP

Scoring plane @ 2960



Total ionising dose



1 MeV neutron equivalent fluence

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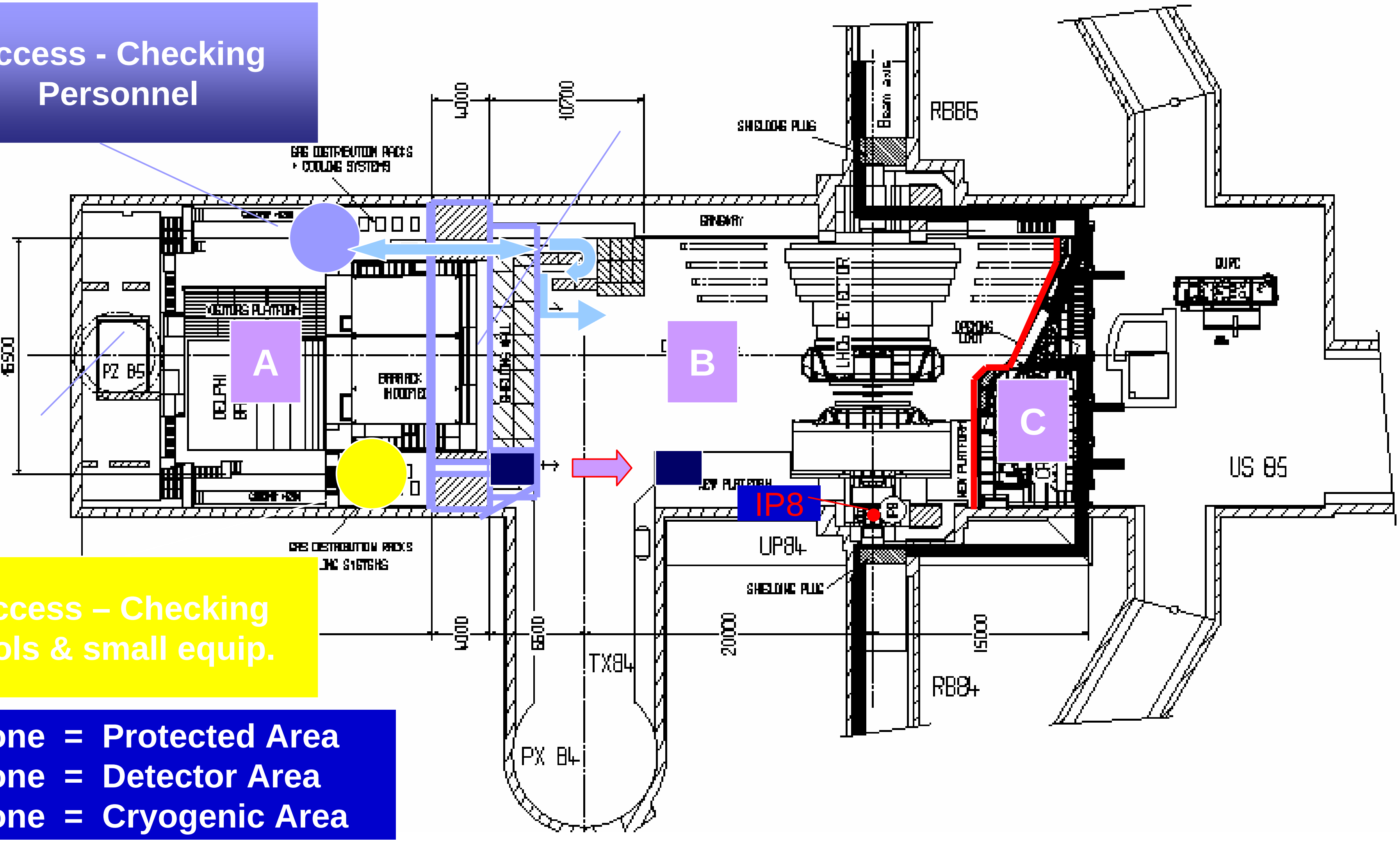
Including the cavern in the simulation

Access - Checking Personnel



Access – Checking Tools & small equip.

A Zone = Protected Area
B Zone = Detector Area
C Zone = Cryogenic Area

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Conclusions

- Geant4 electromagnetic physics has been already validated at percent level. Work is in progress to improve it further.
- First round of hadronic physics validation has been completed, with good results.

  For the simple benchmark observables that we have checked so far there is a reasonable agreement between data and both Geant4 and Fluka, more or less at the same level.

  For the calorimeter test-beams, Geant4 describes well the pion energy resolution, σ/E, and the ratio e/π.

  The shape of hadronic showers still needs further improvements.
- ATLAS and CMS 2004 test-beam data will provide several other validation tests for Geant4 EM and HAD physics.
- Radiation background studies in Geant4 are in progress.