LCG Physics Validation

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CERN PH/SFT

Outline

- Goals & Strategy
- Summary previous activities

- Activities since the last review
  April 2005 - August 2006

- Man power situation and
  Planned activities

For more information

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

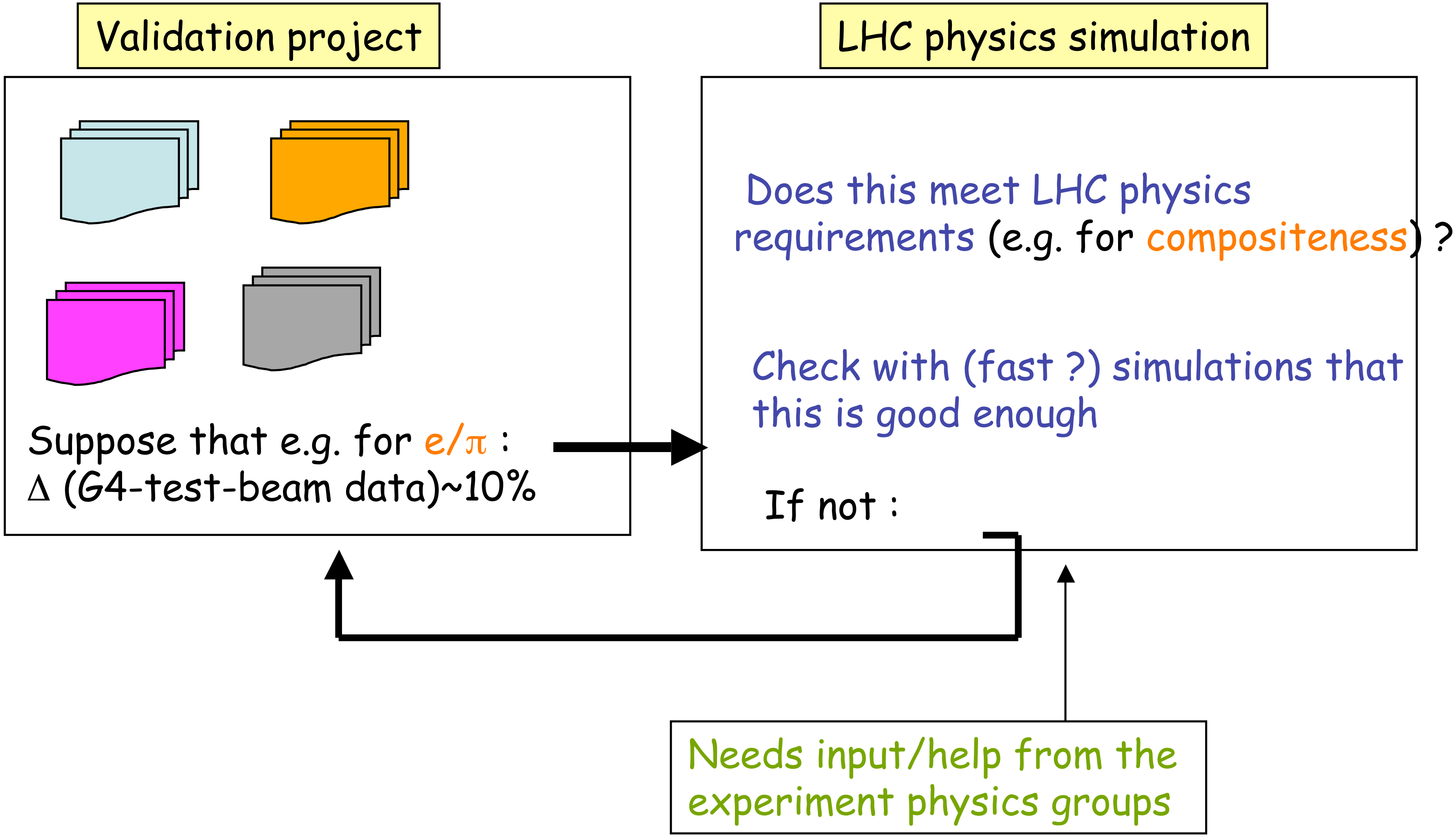
Project Goals

- Compare Geant4 and Fluka with the LHC test-beam data.
- Test coherence of results across experiments and sub-detector technologies.
- Study simple benchmarks relevant to LHC.
- "Certify" that simulation packages and framework are ready and functional for LHC physics.
- Weaknesses and strengths of the packages.

Strategy

- Physics validation should be targeted to a specific application domain: e.g. for high-energy physics one should consider different observables than, for instance, medical physics, or space science.

- The criteria to consider a simulation "good" or "bad" should also be application specific: for LHC experiments, the main requirement is that the dominant systematic uncertainties for all physics analyses should not be due to the imperfect simulation.


Validation project
Suppose that e.g. for e/π :
Δ (G4-test-beam data)~10%
LHC physics simulation
Does this meet LHC physics requirements (e.g. for compositeness) ?
Check with (fast ?) simulations that this is good enough
If not :
Needs input/help from the experiment physics groups

Validation setups

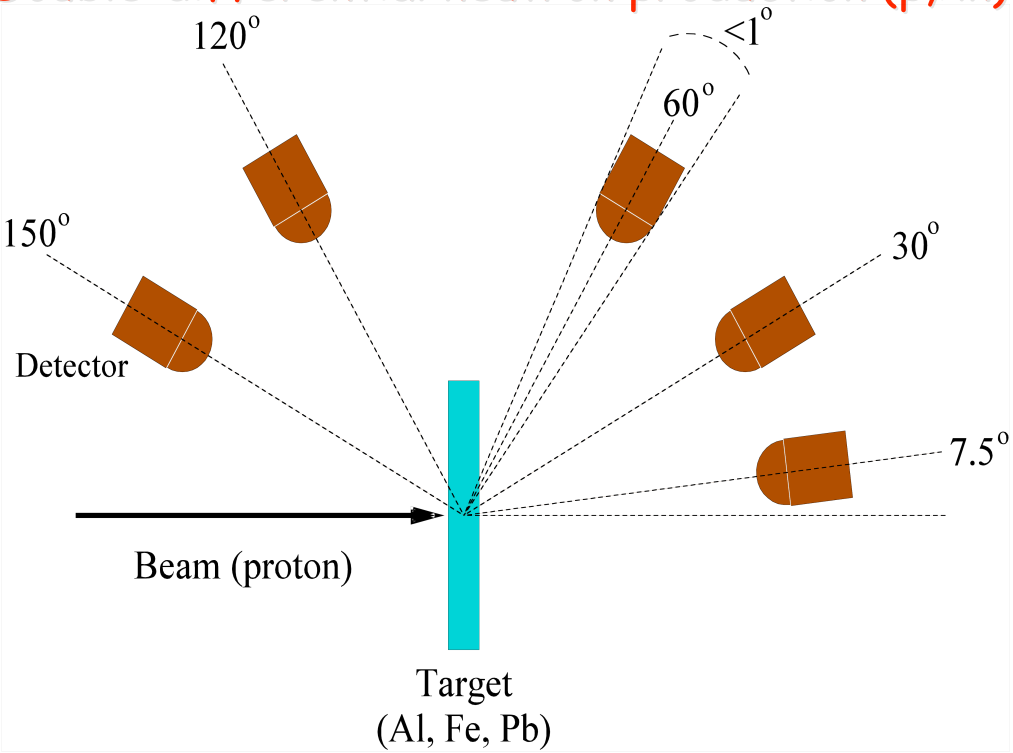
Two main types of test-beam setups:

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.

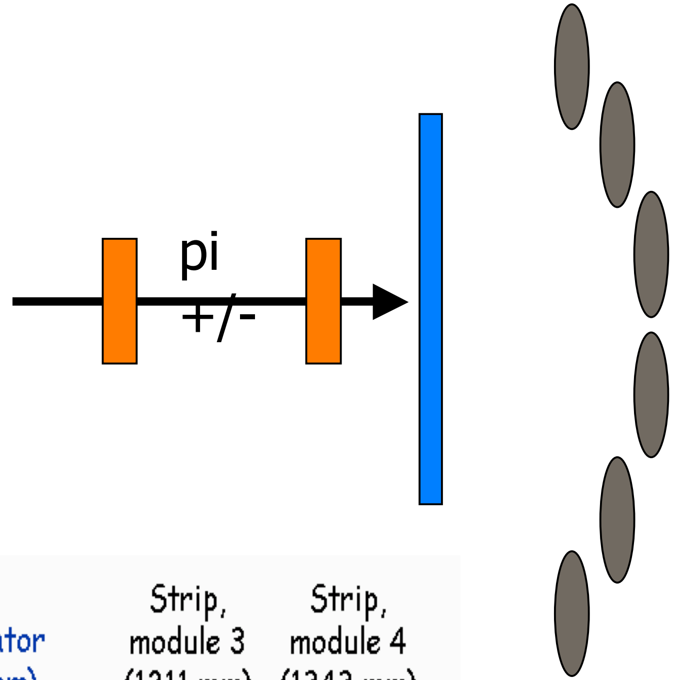
2. Simple benchmarks: typical thin-target setups with simple geometries (made, very often, for validation purposes).
   It is possible to test at microscopic level a single interaction or effect.

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

Double-differential neutron production (p,xn)

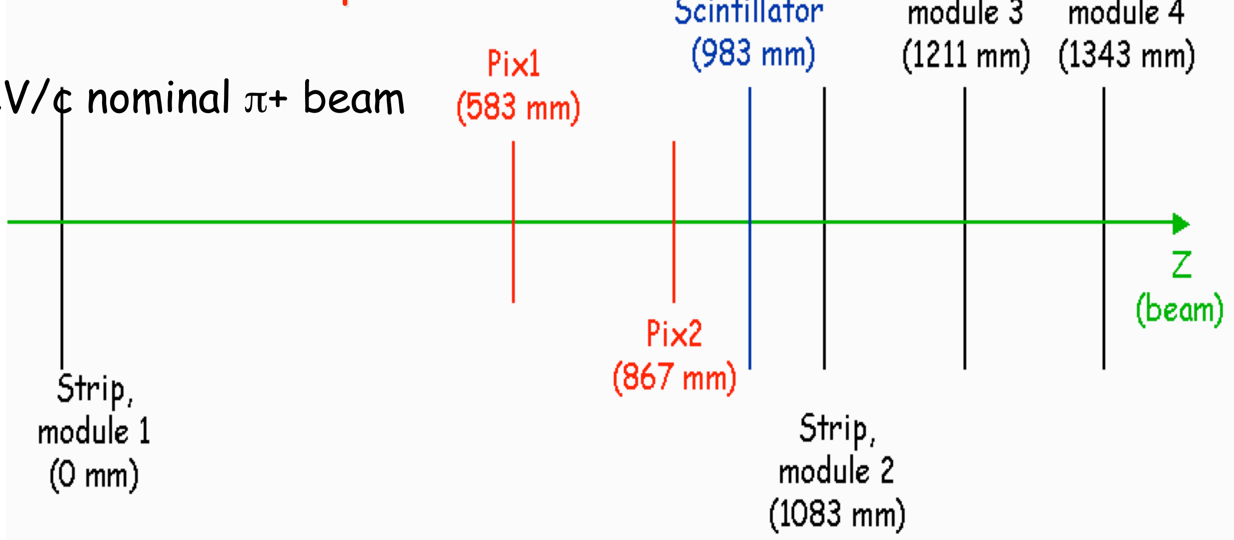


Pion absorption in flight



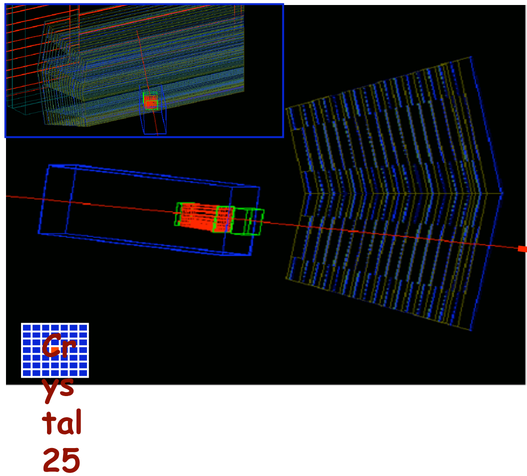
Hadronic interactions in ATLAS pixel test-beam

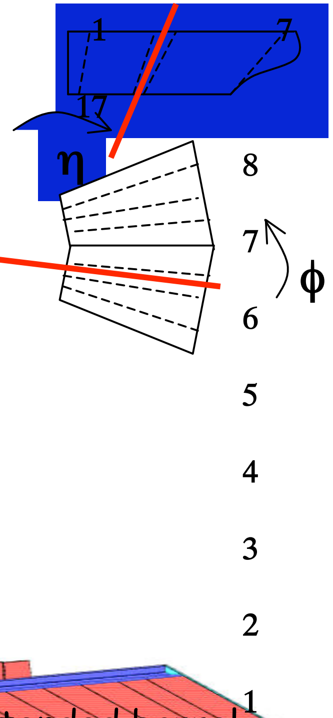
180 GeV/c nominal π+ beam



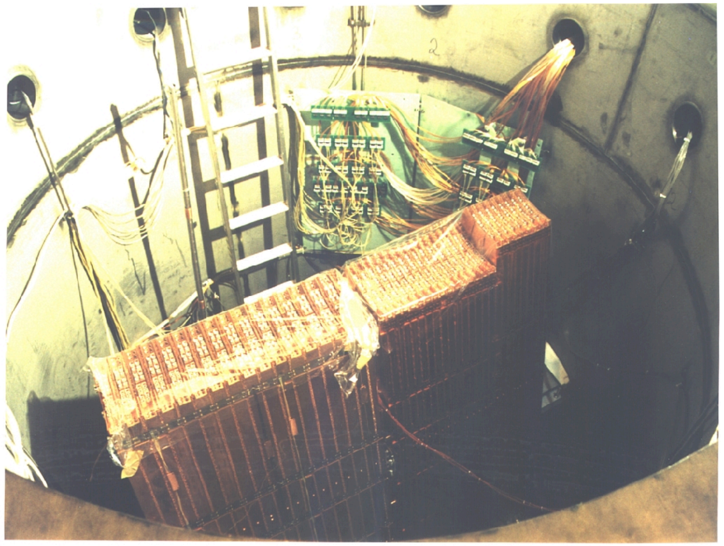
Calorimeter test-beams

CMS HCAL & ECAL

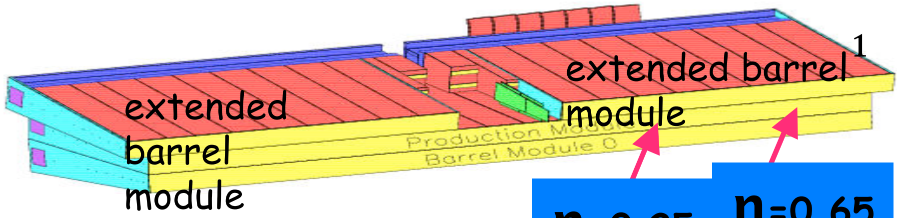


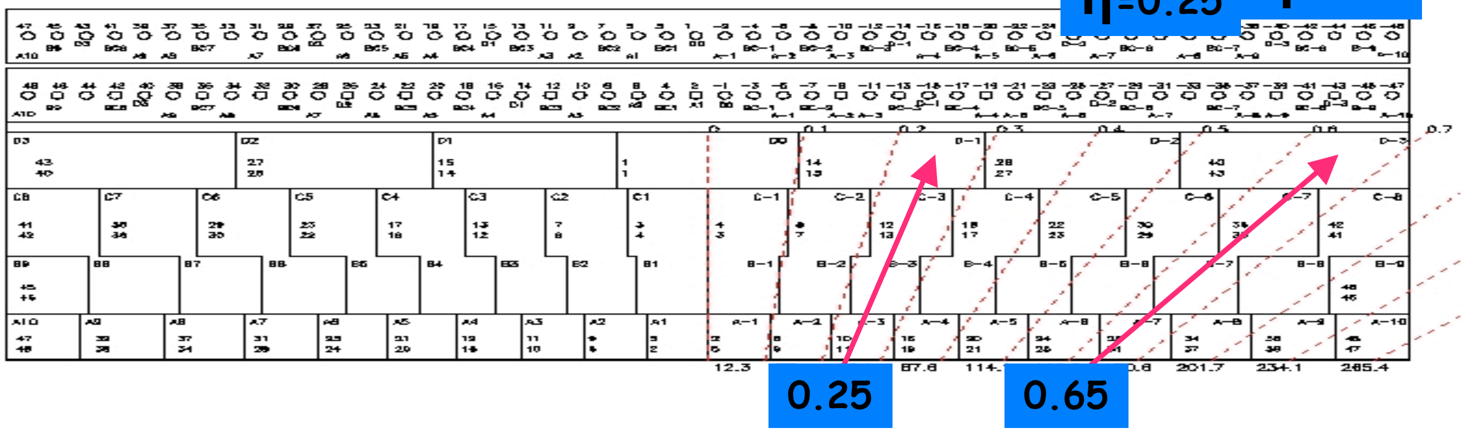


ATLAS HEC



ATLAS TileCal





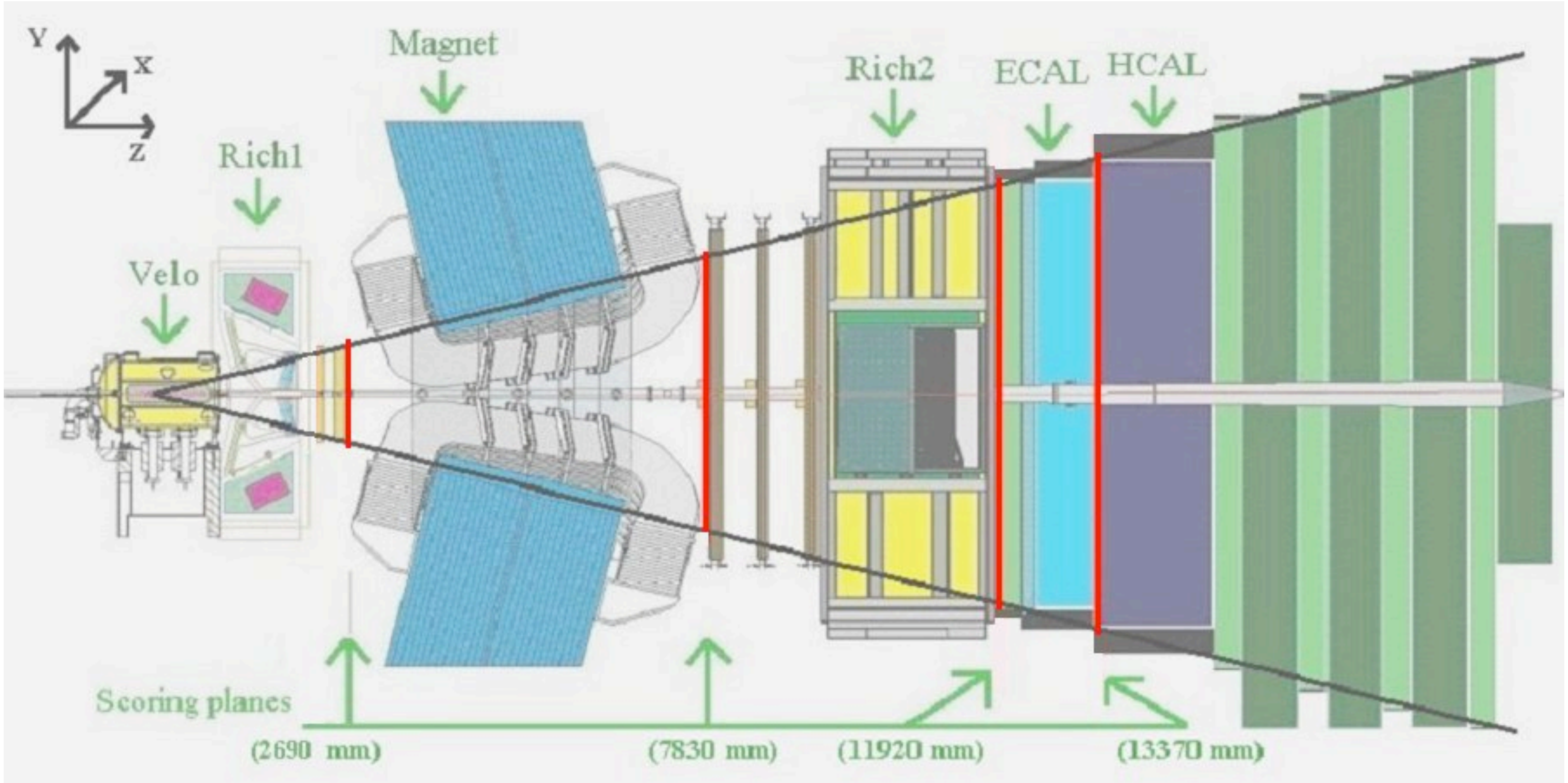
Radiation studies with Geant4

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 like QGSP_BERT_HP .

- Radiation studies in LHCb : Alex Howard (LCG) is continuing the work started by G. Daquino.
- Radiation studies in CMS : Pedro Arce (CMS) is working on similar radiation studies for CMS.

Connected to these studies, a new benchmark test for neutrons has been introduced: TARC.

LHCb layout



4 scoring planes

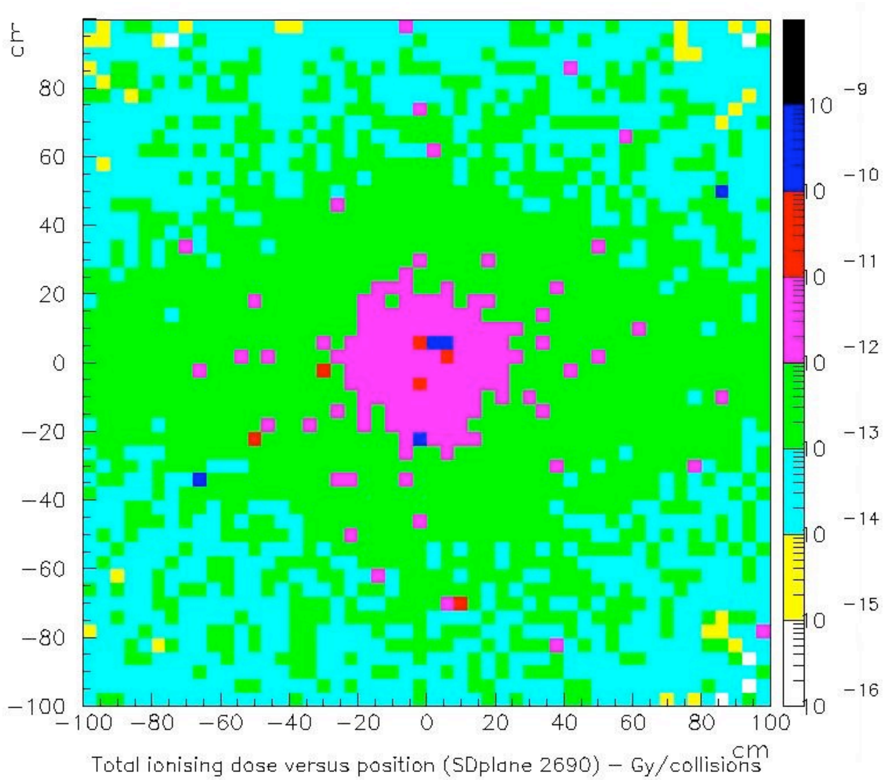
Milestone UD508 ✓

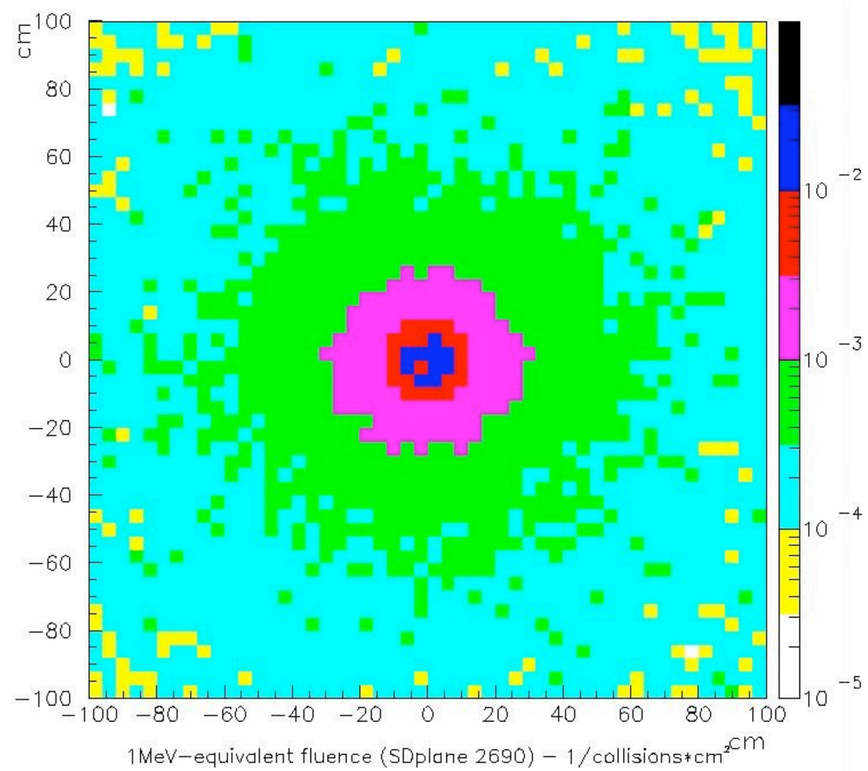
PRELIMINARY

G. Daquino Physics Validation meeting, 4 May 2005

QGSP_BERT_HP

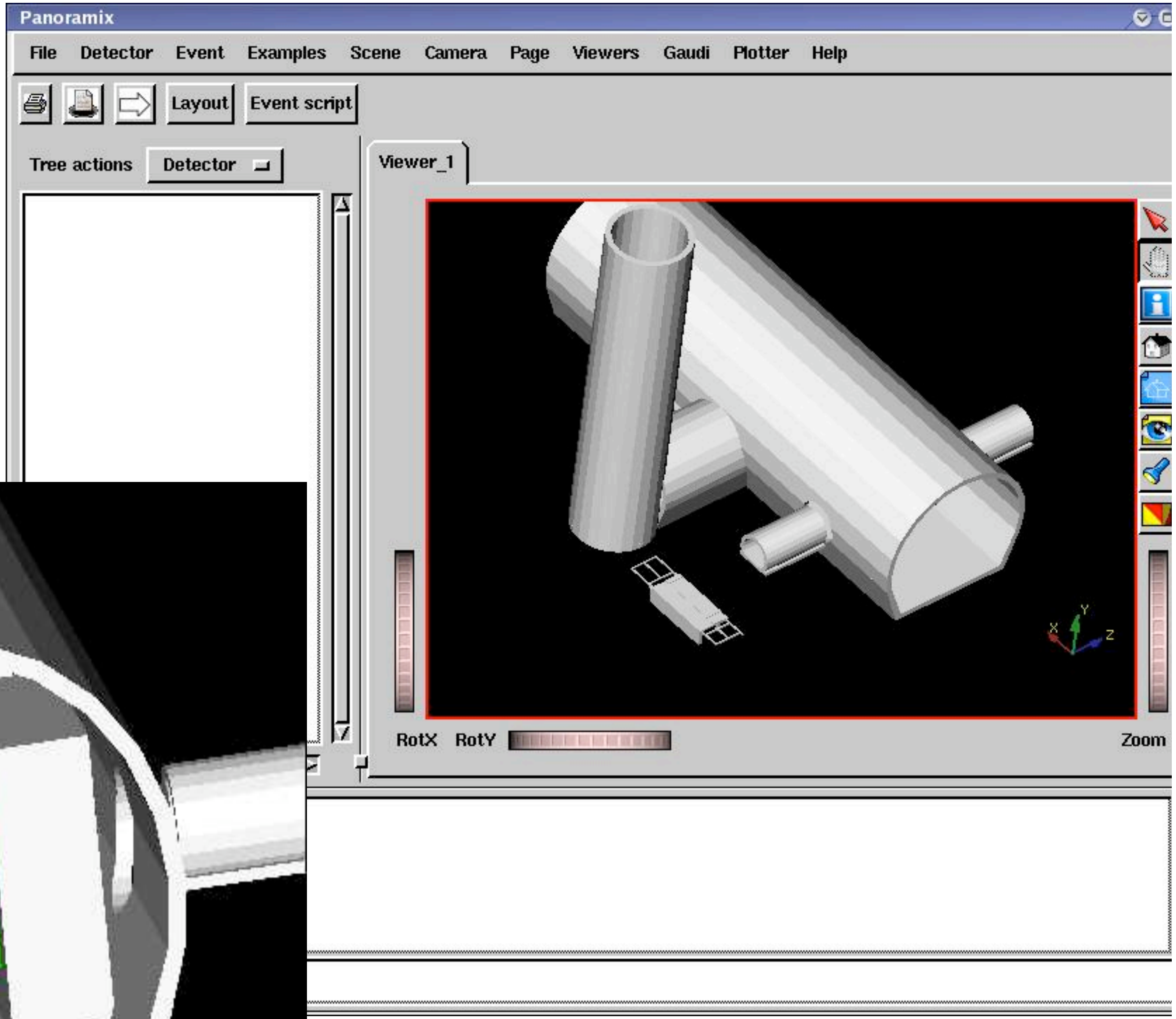
Scoring plane @ 2960

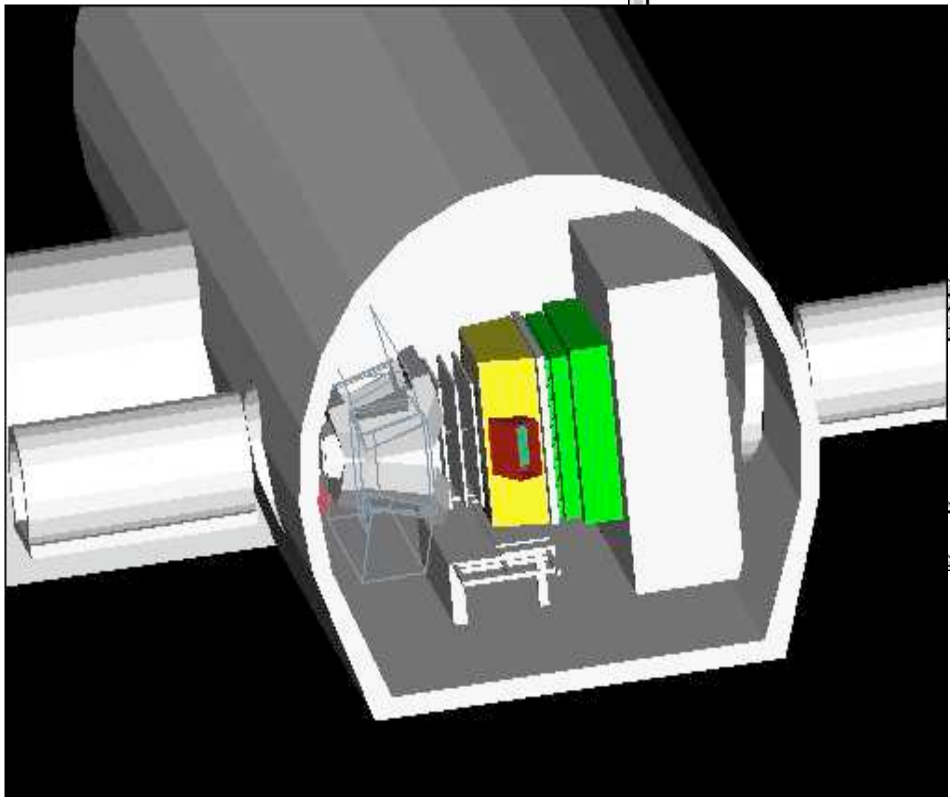




Total ionising dose **1 MeV neutron equivalent fluence**

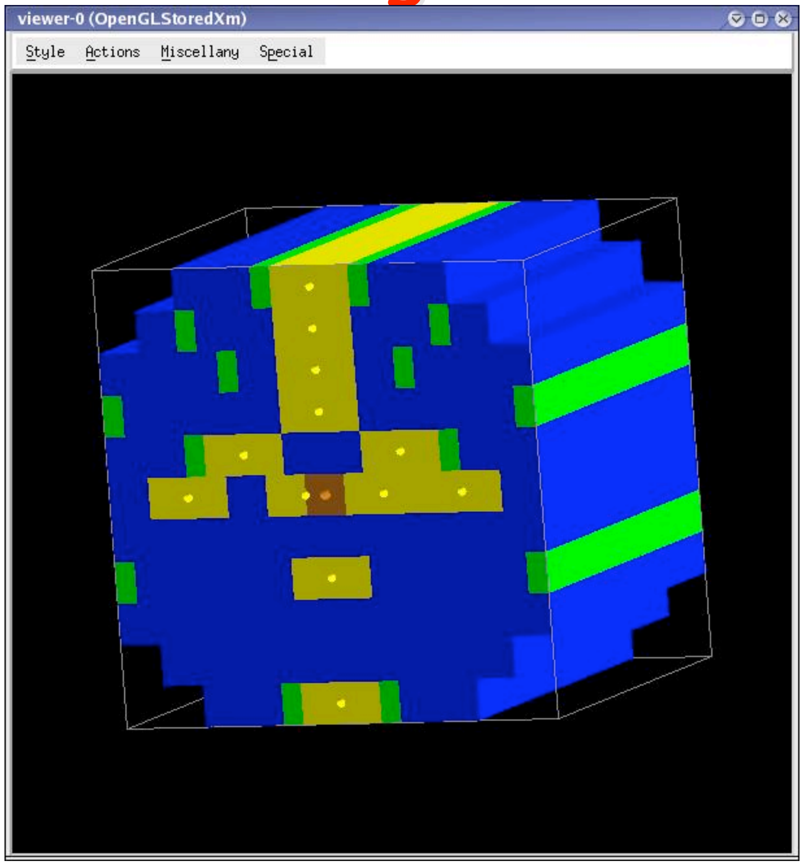
A. Howard extension of G4 LHCb simulation: cavern and tunnel.





Neutron benchmark for Geant4 using TARC

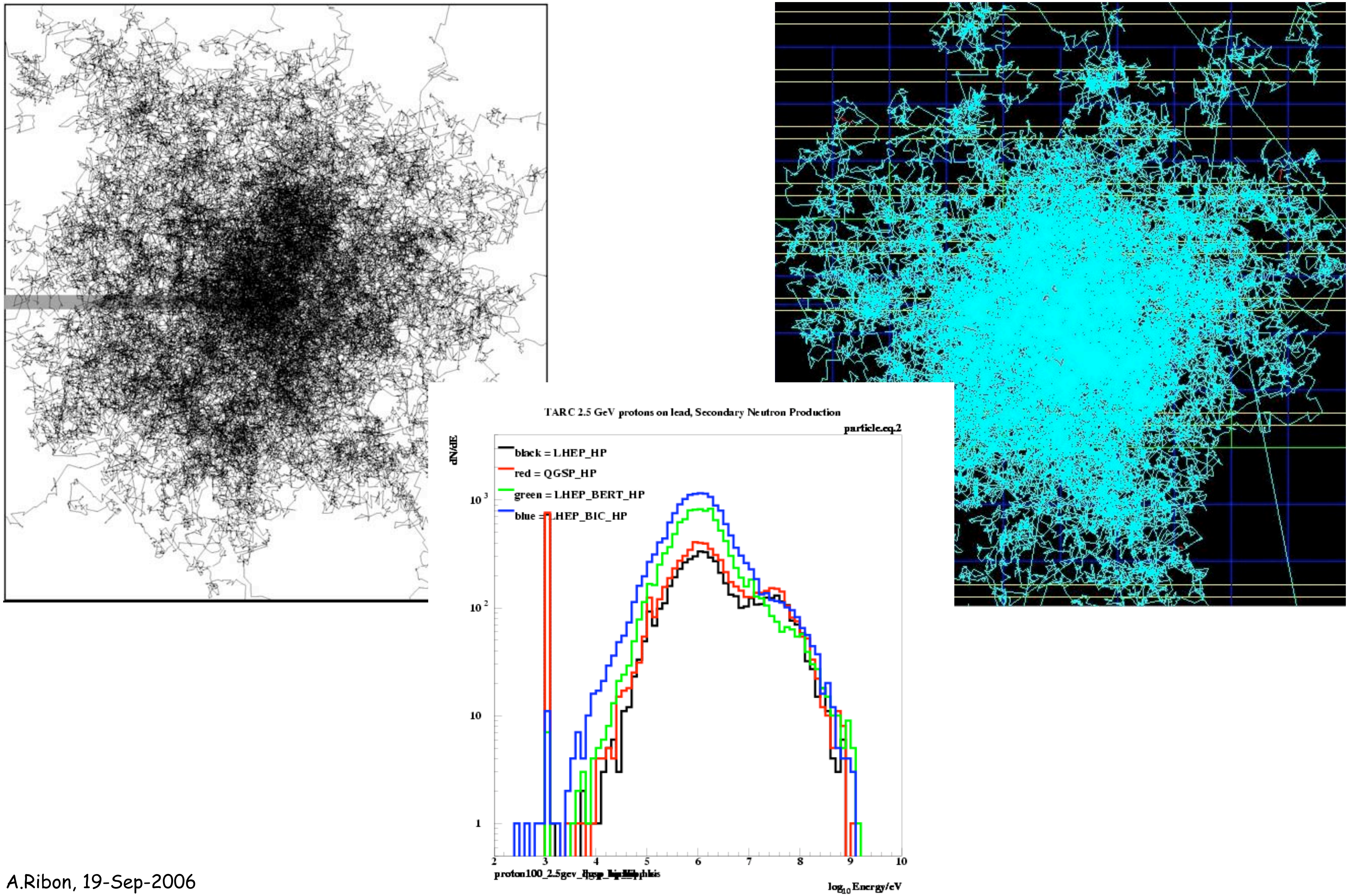
- Neutron Driven Nuclear Transmutation by Adiabatic Resonance Crossing (Cern 96-97)
- 334 tons of pure Pb in cylindrical 3.3m x 3.3m x 3m block.
- 12 sample holes are located inside the volume to measure capture cross-sections on some isotopes.
- 2.5 or 3.5 GeV/c proton beam.



It allows to validate spallation neutron production for GeV protons on pure lead, and neutron transportation down to thermal energies. Observables: neutron fluence spectrum, energy-time relationship, capture cross-sections.
Fluka used for both the analysis and benchmark (2002).

TARC simulation in Geant4

A. Howard,Physics Validation meeting, 10 May 2006

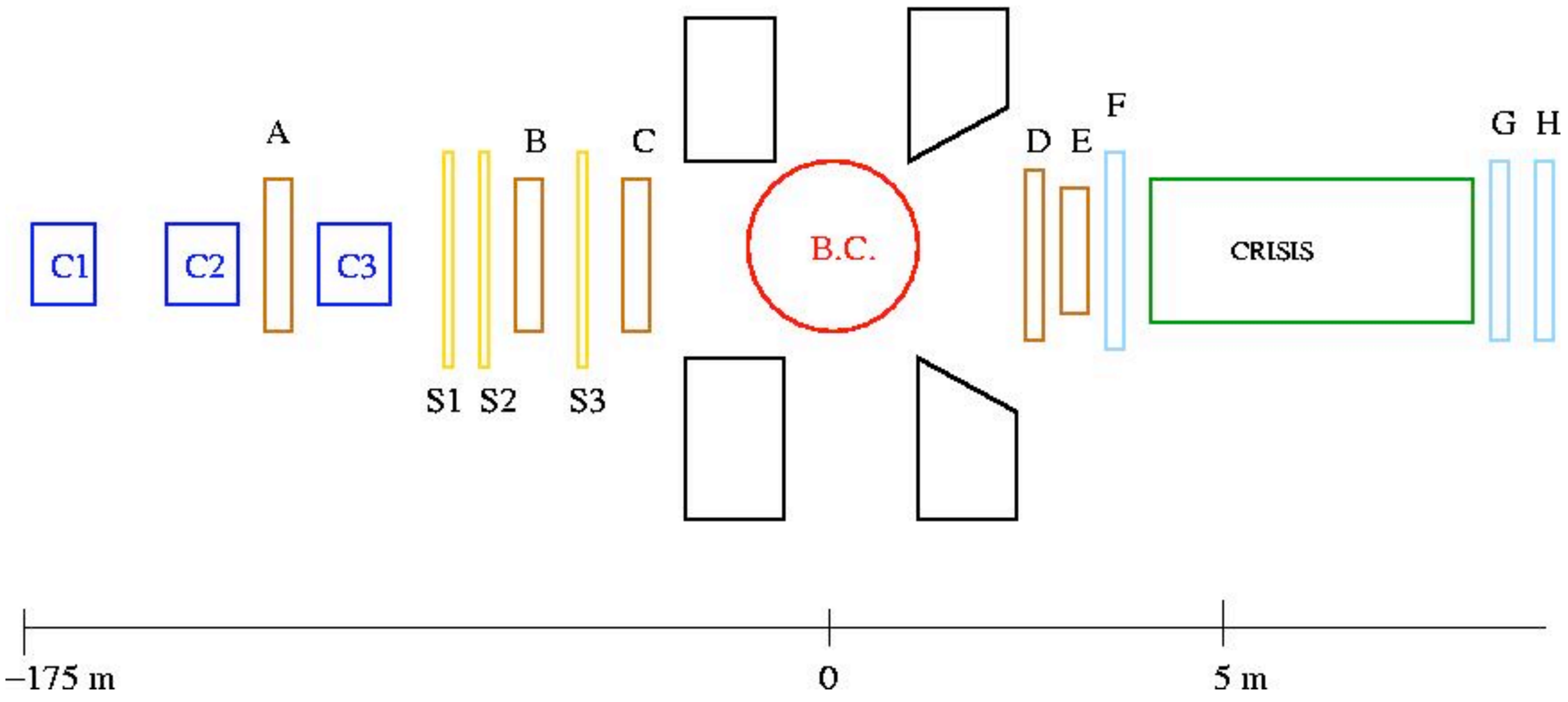


Milestone UD522

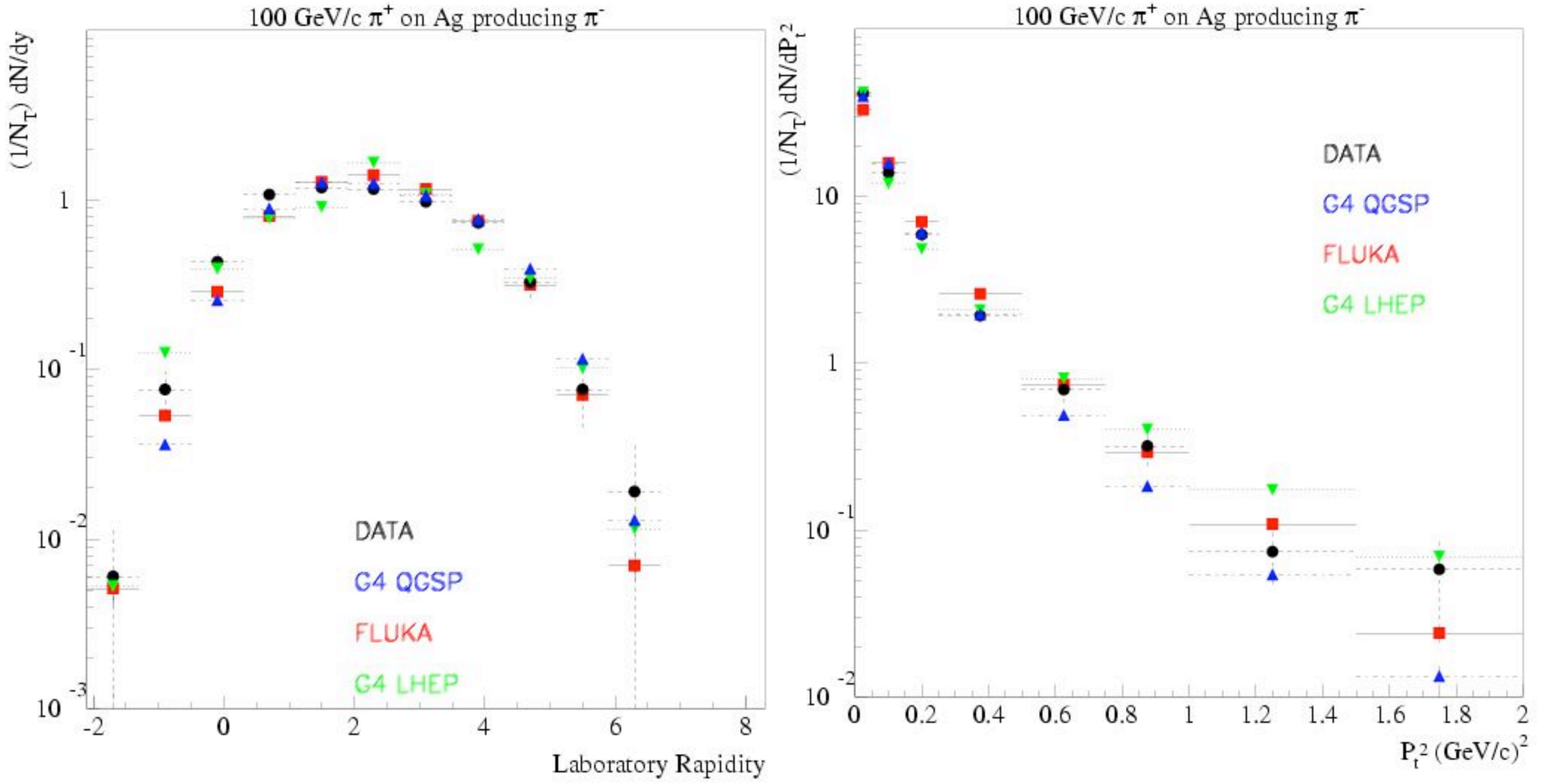
3rd simple benchmark:

inclusive $\pi^{\pm}$ production in $\pi^{\pm}$,K^{+},p,$\bar{p}$ interactions on **Mg**, **Ag**, **Au**, at **100** and **320** (π^{-}) ***GeV/c***

A.R.



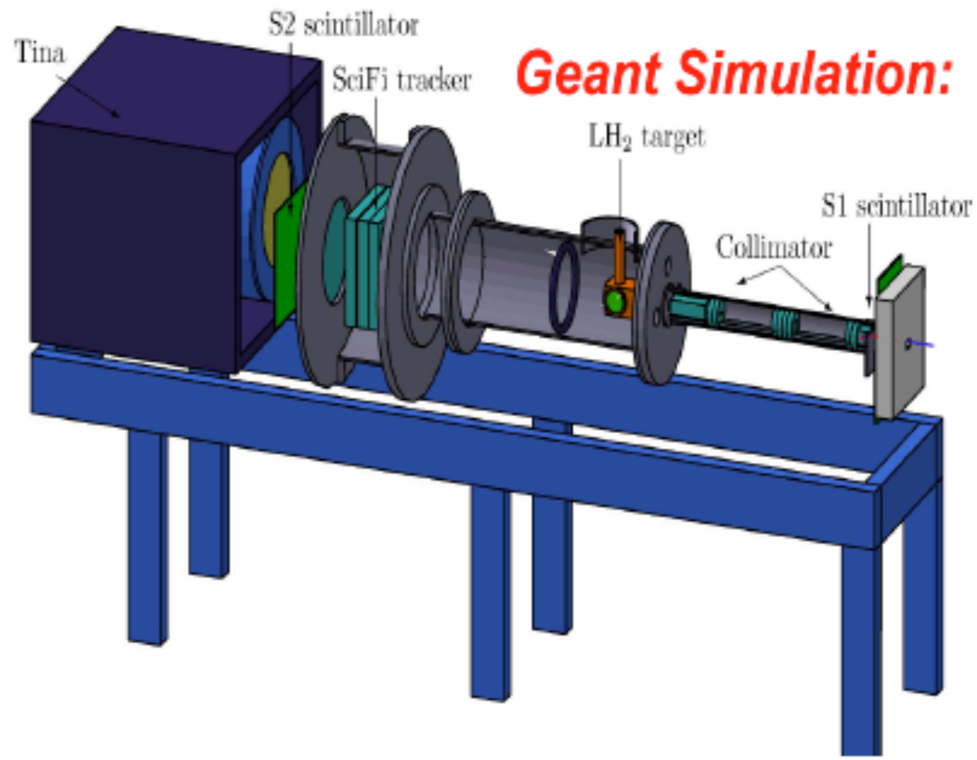
3rd simple benchmark: y and P_t^2 distributions



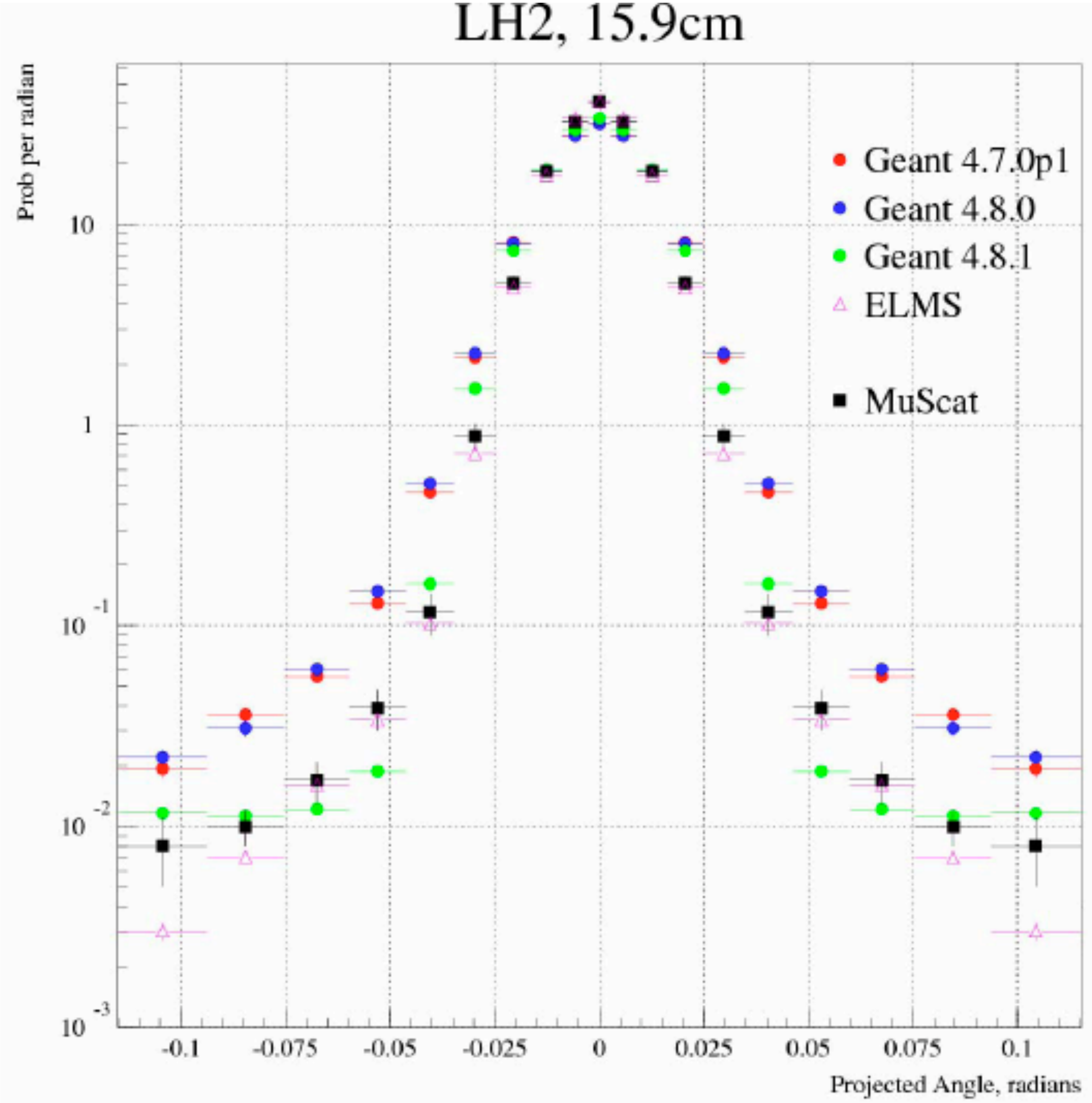
MuScat (Ionisation Cooling for muon colliders)

172 MeV/c μ on different targets (TRIUMF, 2003)

Target	Thickness, mm	X0, %	Events, Millions
Lithium 2	12.78	0.82	2.0
Lithium 1	6.43	0.41	3.0
Lithium 1	6.4	0.41	2.1
Lithium 2	12.72	0.81	3.0
Beryllium	0.98	0.28	3.4
Beryllium	3.73	1.06	3.8
Polyethylene	4.74	0.99	2.0
Carbon	2.5	1.53	2.0
Aluminium	1.5	1.69	3.0
None			6.0
Iron	0.24	1.36	2.2
Iron	5.05	28.68	3.4
Long, empty	150		4.8
Long, full	150	1.53	5.2
short, empty	100		9.5
short, full	100	1.02	6.0

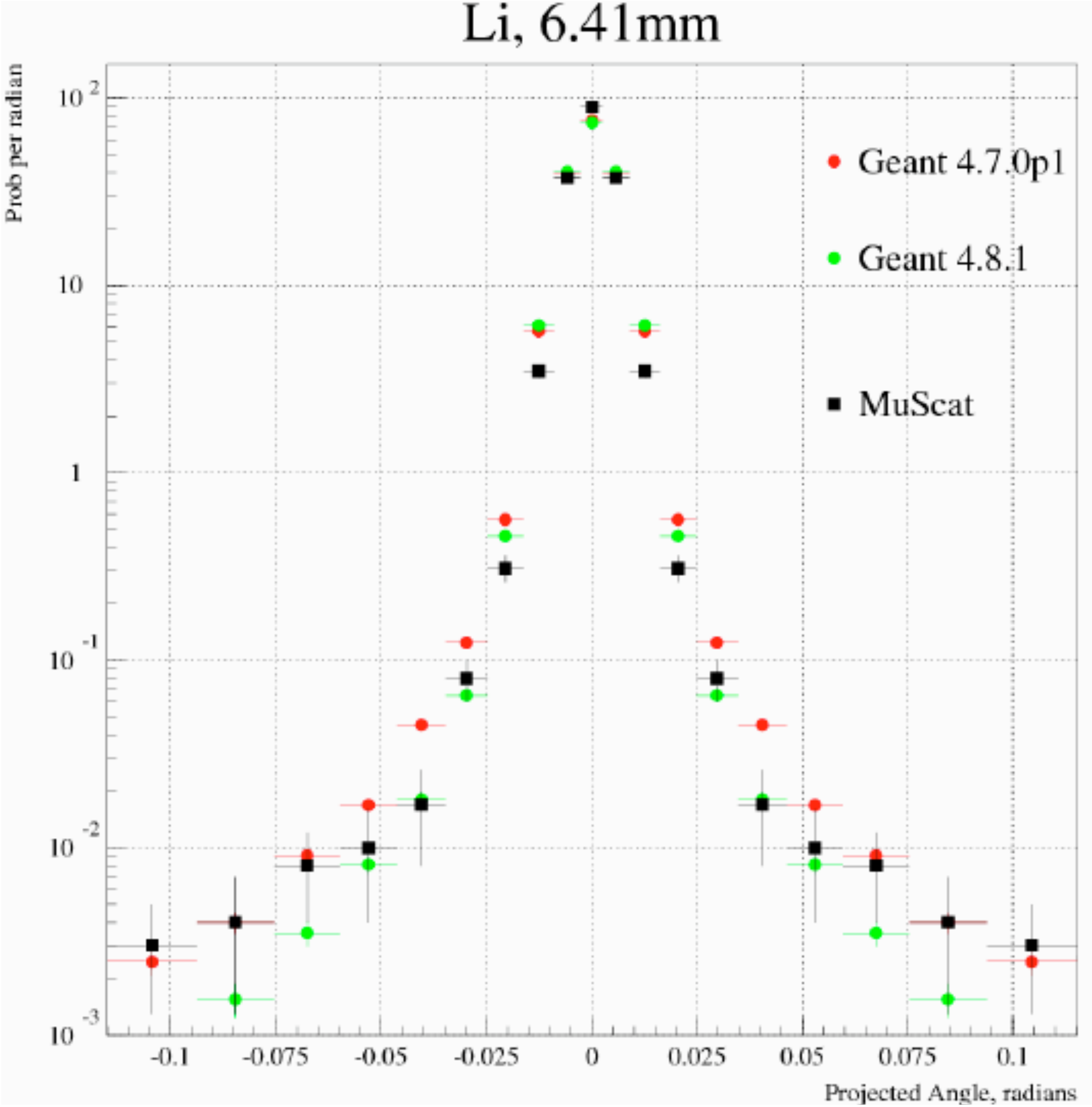


MuScat



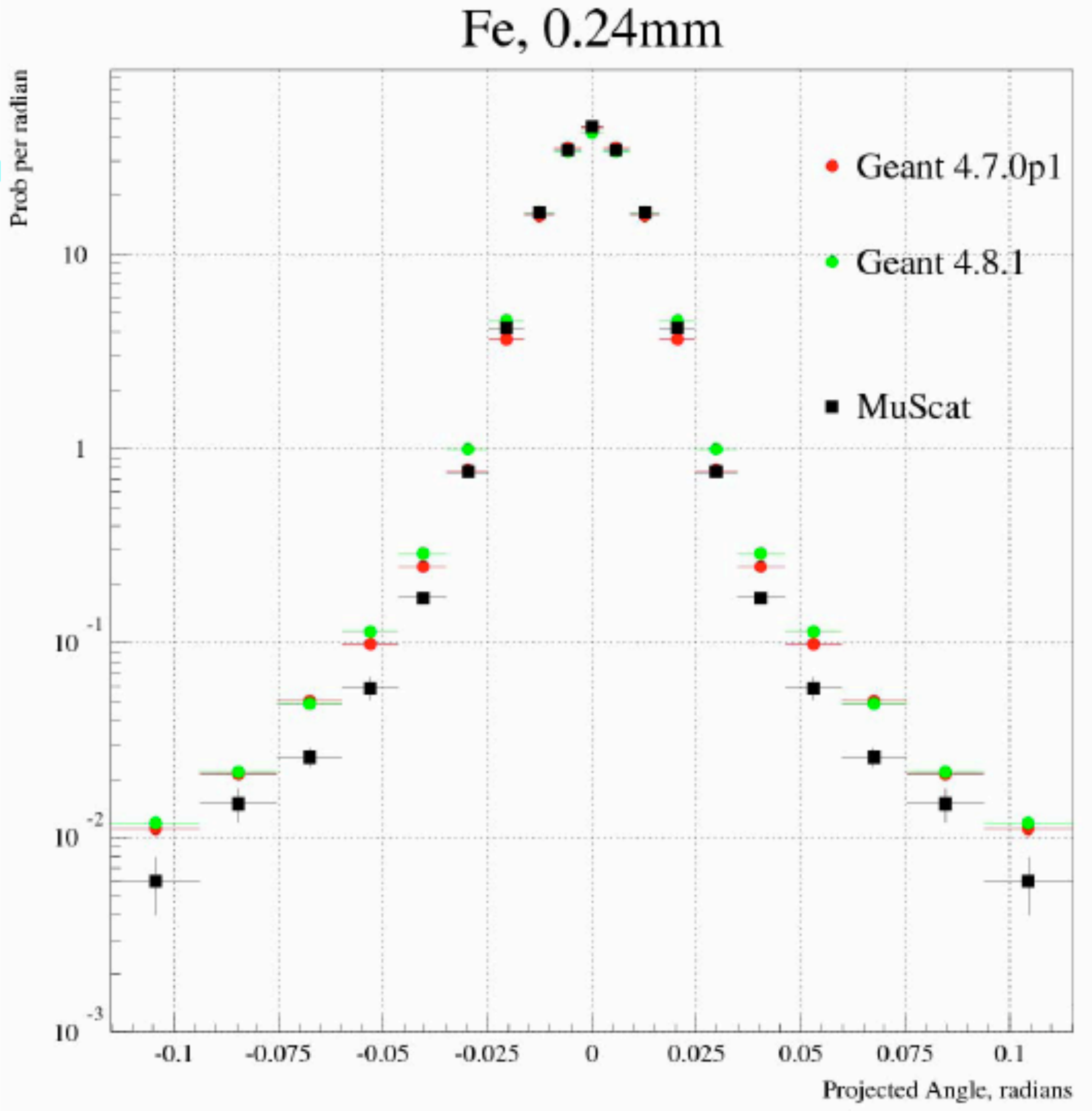
A.Ribon, 19-Sep-2006

MuScat



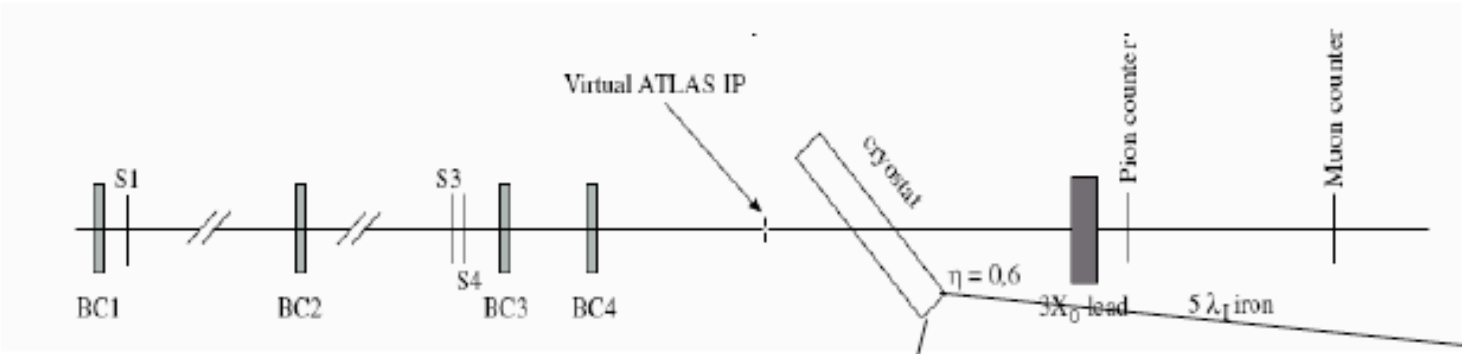
Li, 6.41mm
Prob per radian
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
-0.1
-0.075
-0.05
-0.025
0
0.025
0.05
0.075
0.1
Projected Angle, radians
Geant 4.7.0p1
Geant 4.8.1
MuScat

MuScat



A.Ribon, 19-Sep-2006

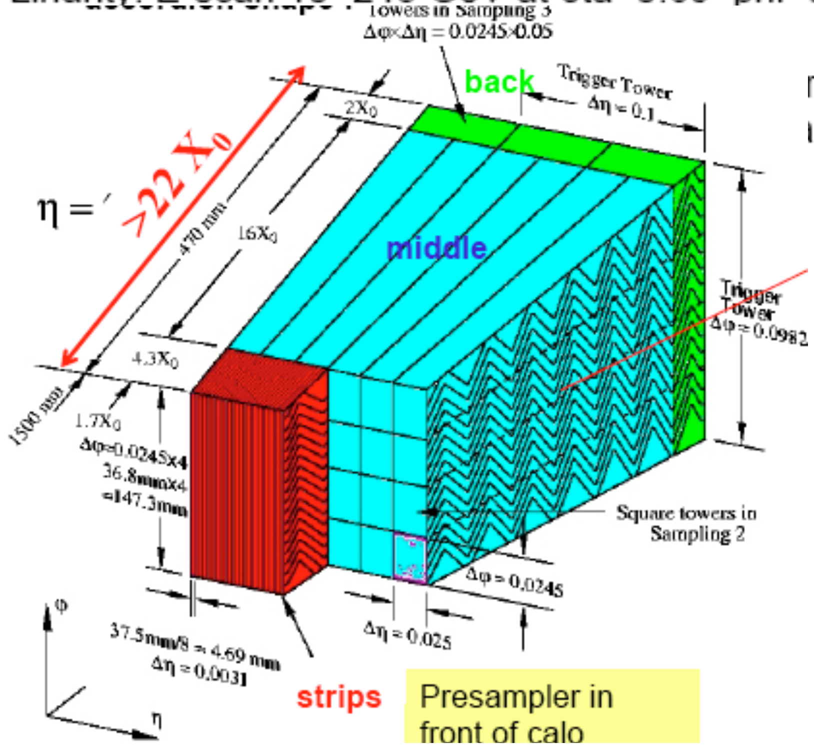
EM Barrel Test-Beam 2002

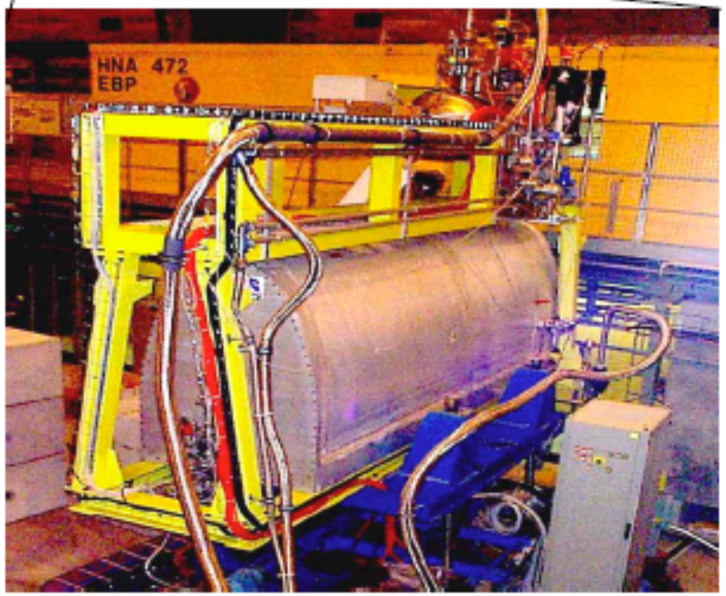


Test-beam 2002:

Uniformity: 3 production modules η/ϕ scan

Linarity: E-scan 10 -245 GeV at eta=0.69 phi=0.28

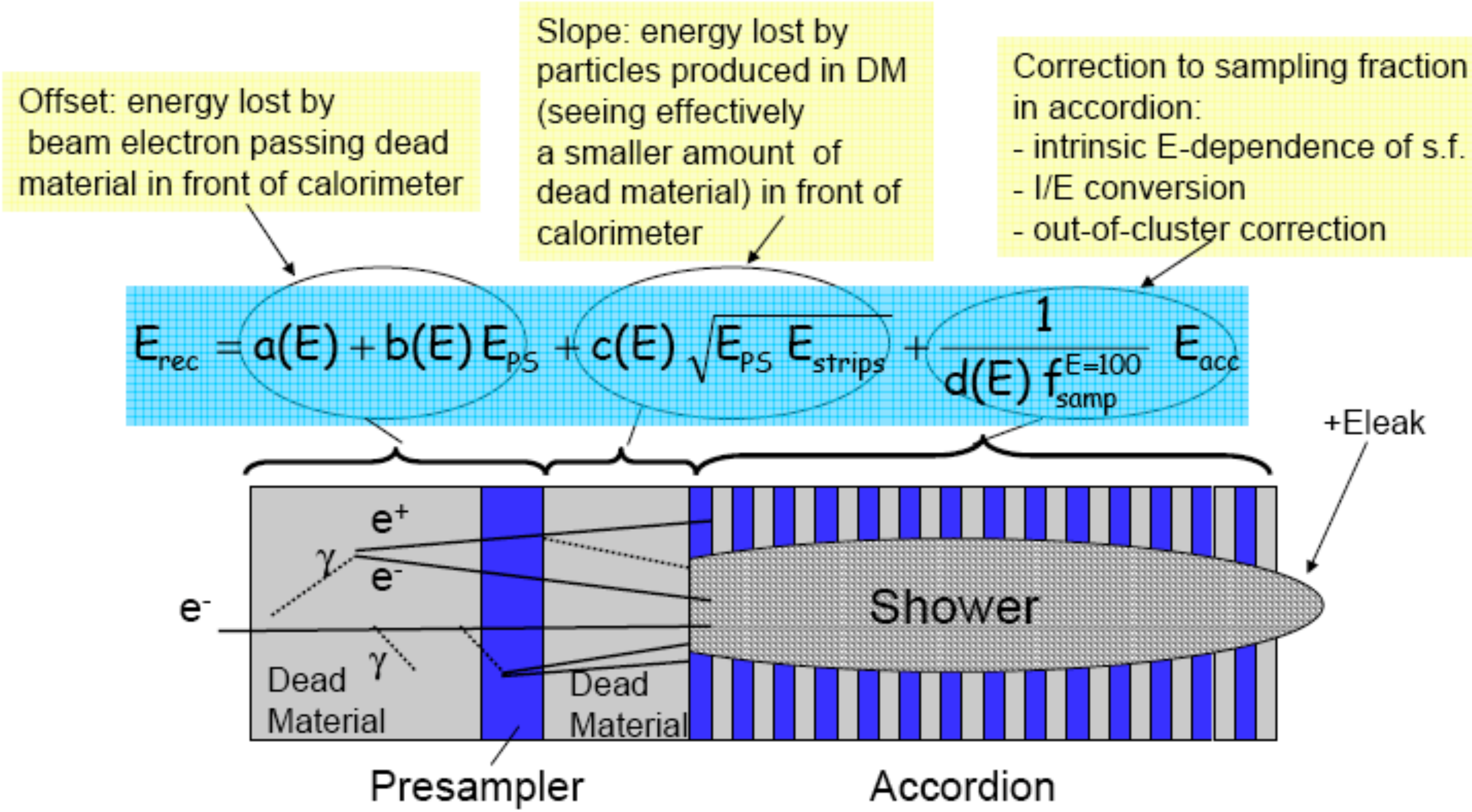




Tancredi Carli

ATLAS EM Barrel

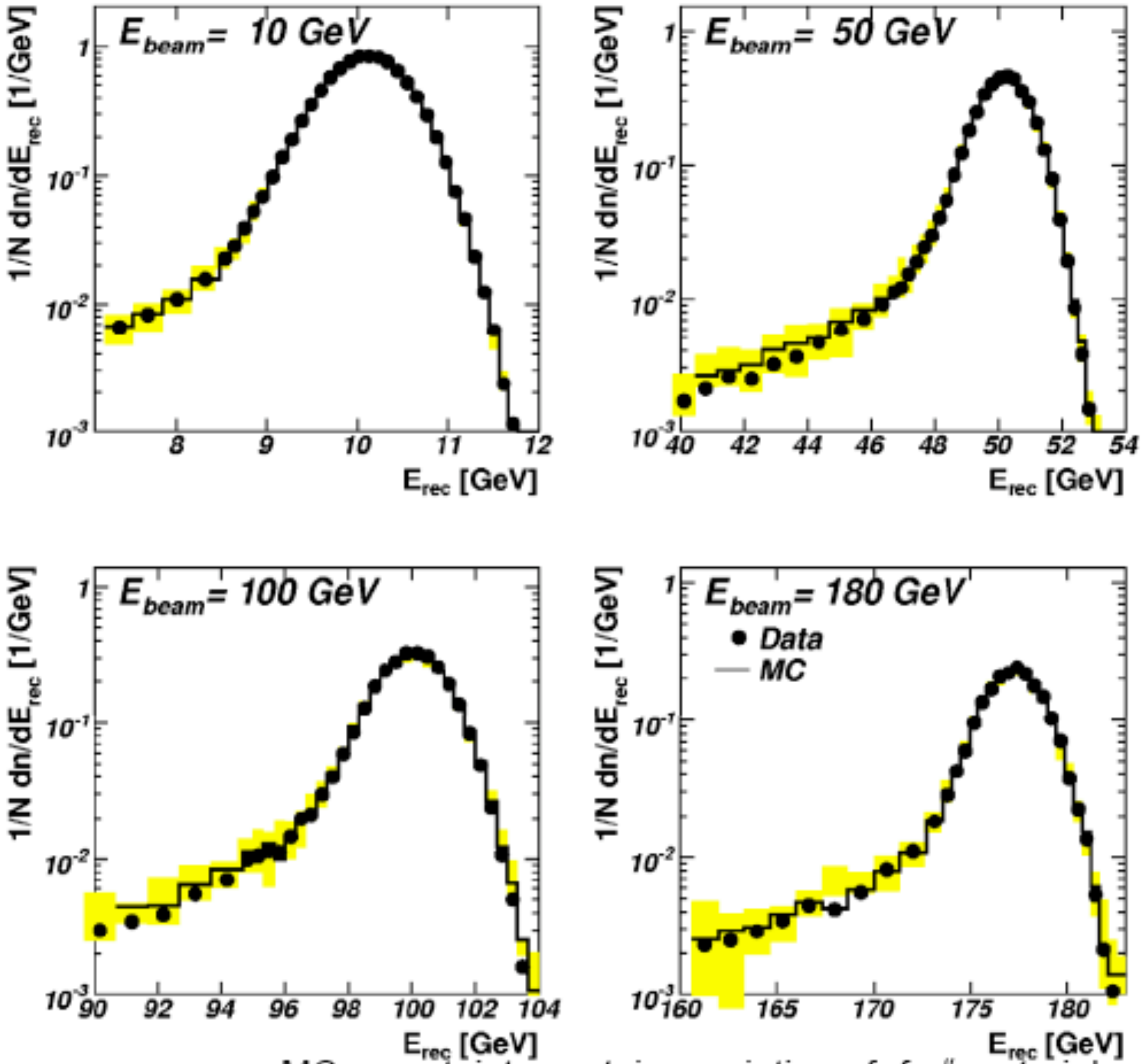
Final Calibration Formula



- Good linearity and resolution achieved
- Constants depend on impact point (upstream material) and on the energy.
  - Can be parameterized.
- Constants are derived from a MC simulation of the detector setup.

ATLAS EM Barrel

Electron: Data/MC Comparisons – Total Energy

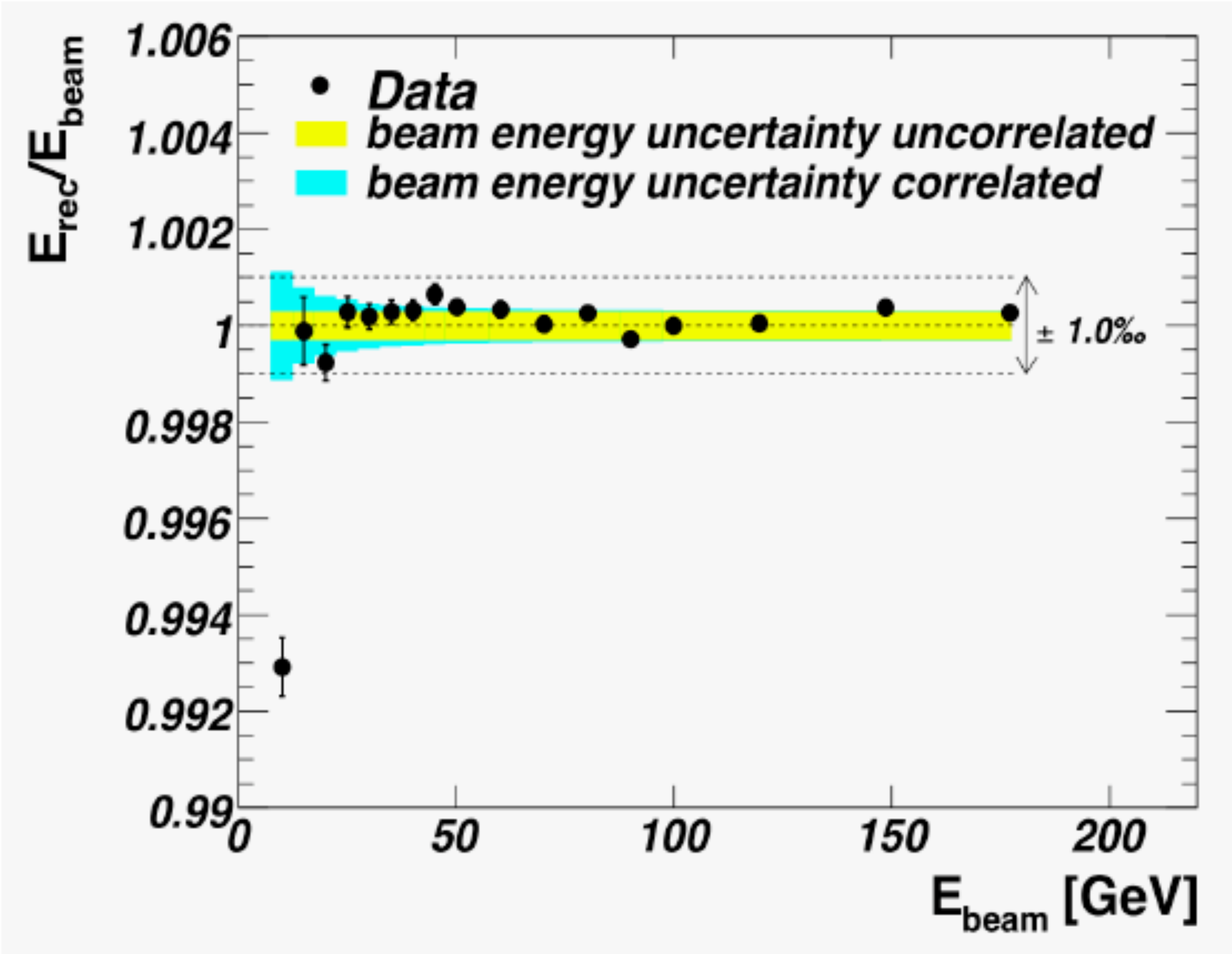


MC uncertainty contains variation of „far" material

Need to fold in acceptance correctic for electrons having lost large energy in „far" material (from beam-line simulation)

mean visible energy is reproduced within 0.1% (energy linearity)

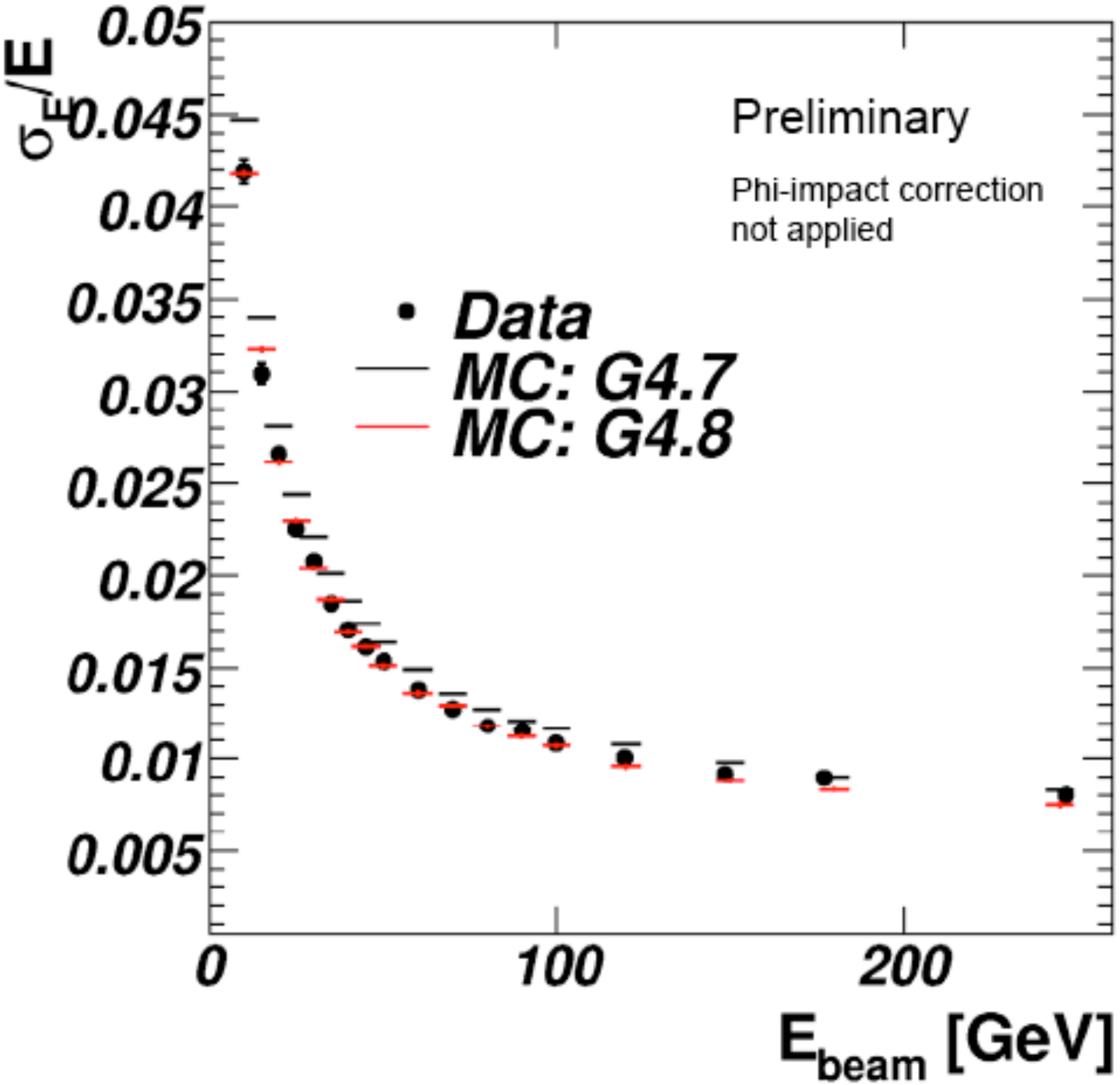
Linearity Result



within 1% for 15-180 GeV, E=10 GeV 4 per mil too low, reason unclear…

ATLAS EM Barrel

Electron: Data MC Comparison - Resolution

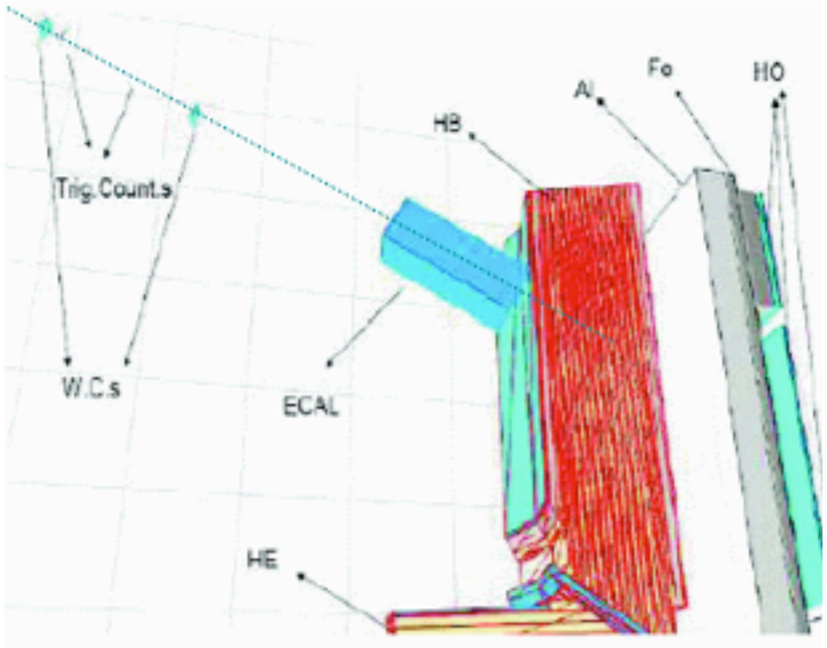


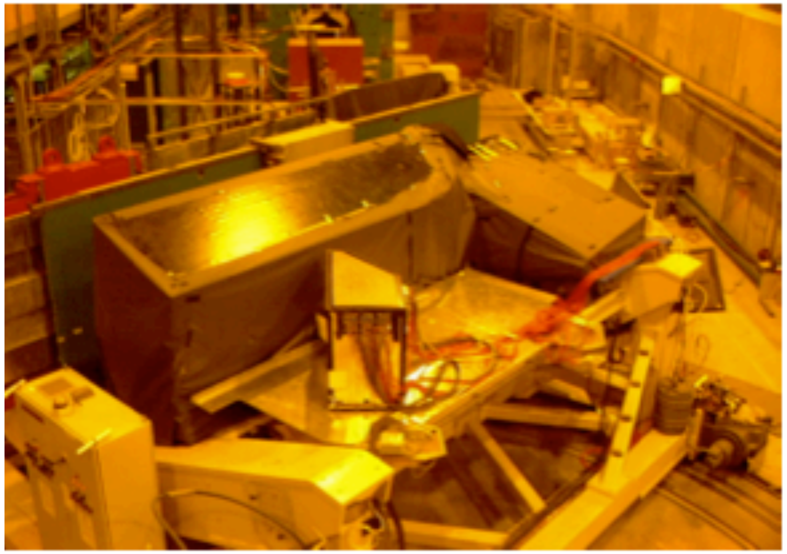
Resolution is much better described in new G4 version !

G4.8 has completely revised multiple-scattering

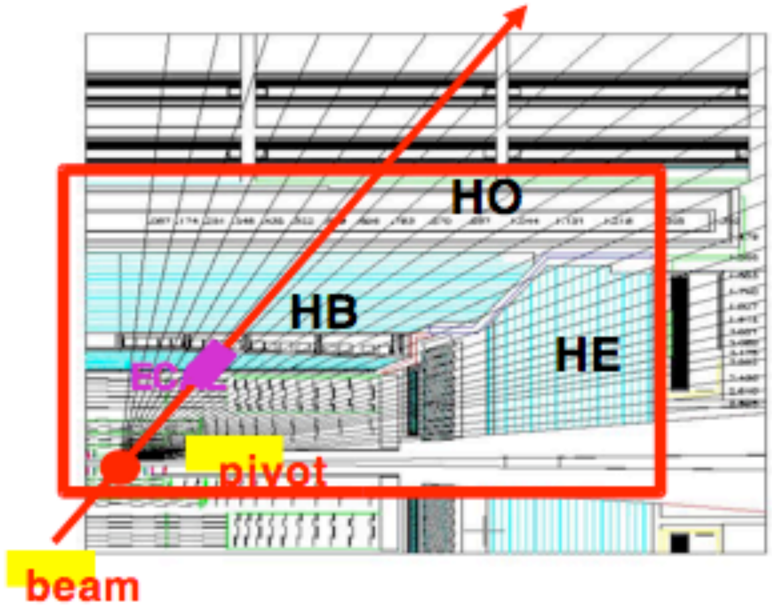
GEANT4 validation with HCAL TB2004 data

J. Damgov (INRNE/FNAL),
S. Piperov (INRNE/FNAL),
S. Kunori (U. of Maryland) et al.

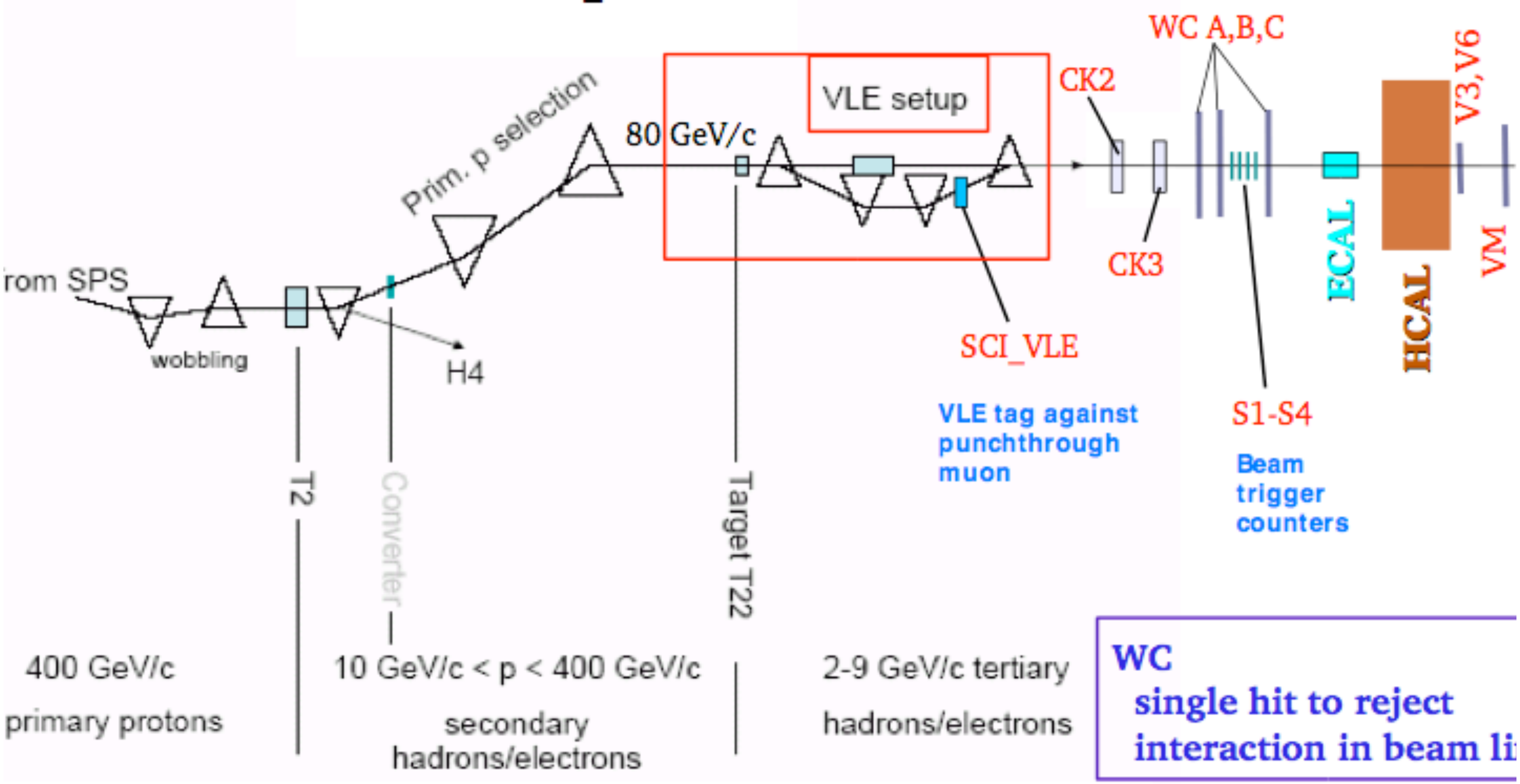




April 2006



Beam line with particle identification



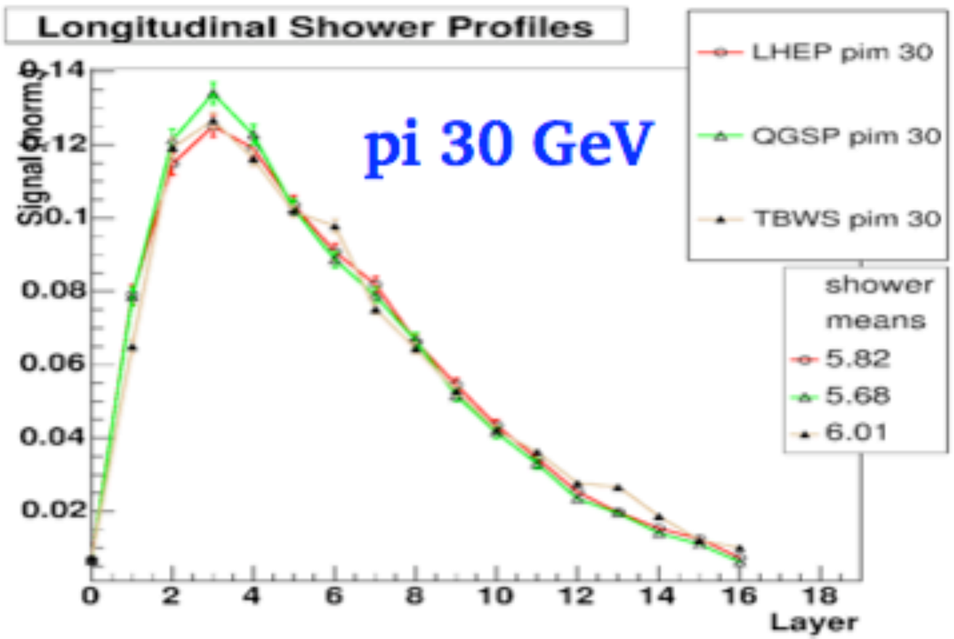
WC
single hit to reject
interaction in beam li

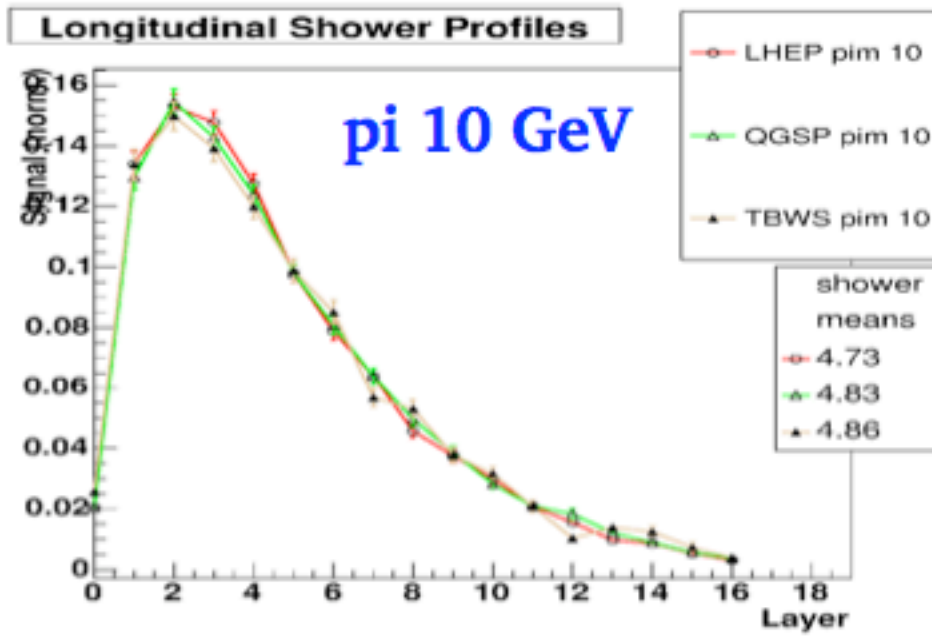
Available beam tunes:
- pions 2-300 GeV
- electrons 9-100 GeV
- muons 80/150 GeV

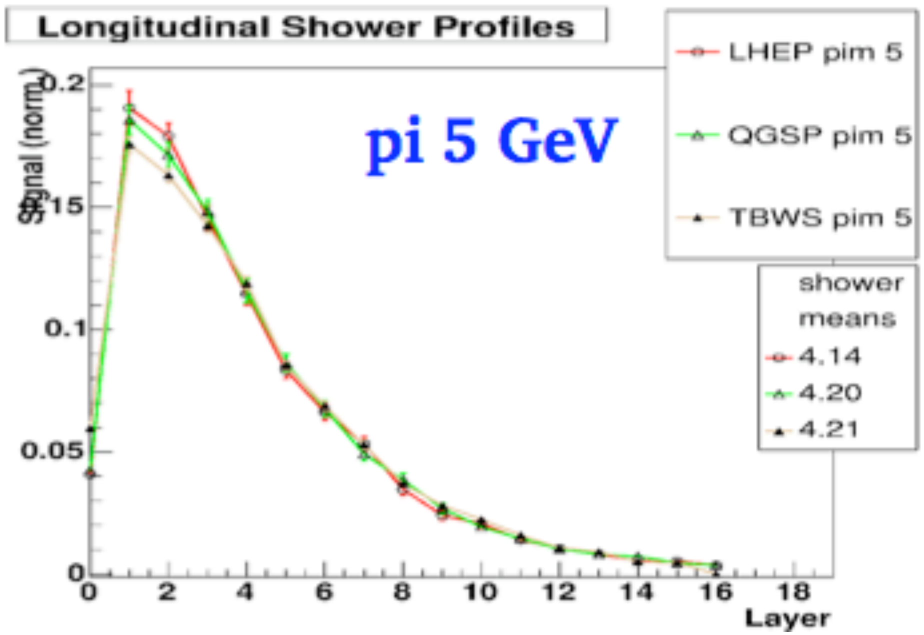
P-ID:
- CK2- electron
- CK3- pion / kaon / proton
- V3, V6, VM – muon

Longitudinal shower profiles (

CMS HCAL



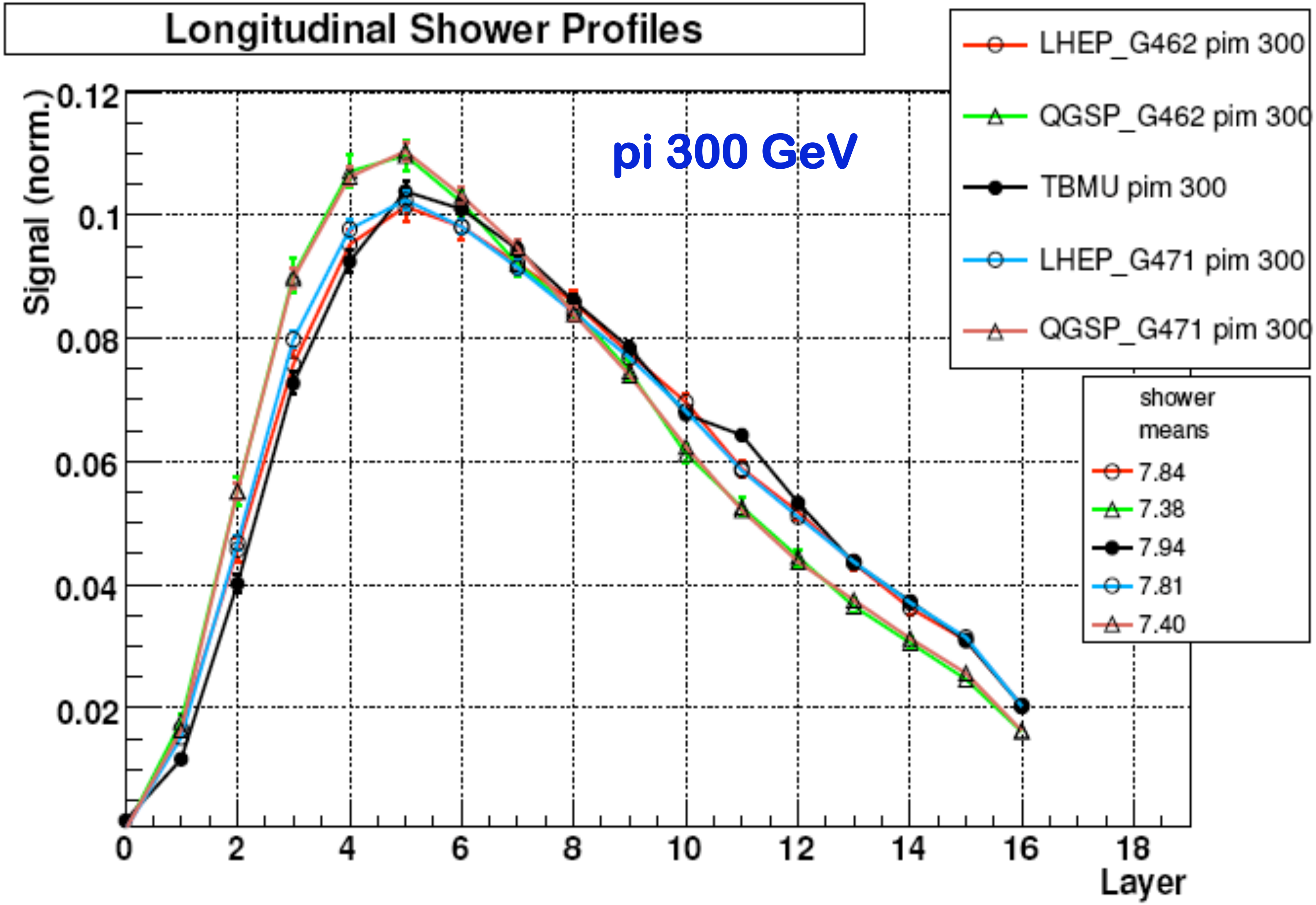




LHEP and QGSP show good agreement with test beam data at low and intermediate energies

Milestone UD512 ✓

CMS HCAL



A.Ribon, 19-Sep-2006

GEANT4 Physics Validation with ATLAS HEC Testbeam Data

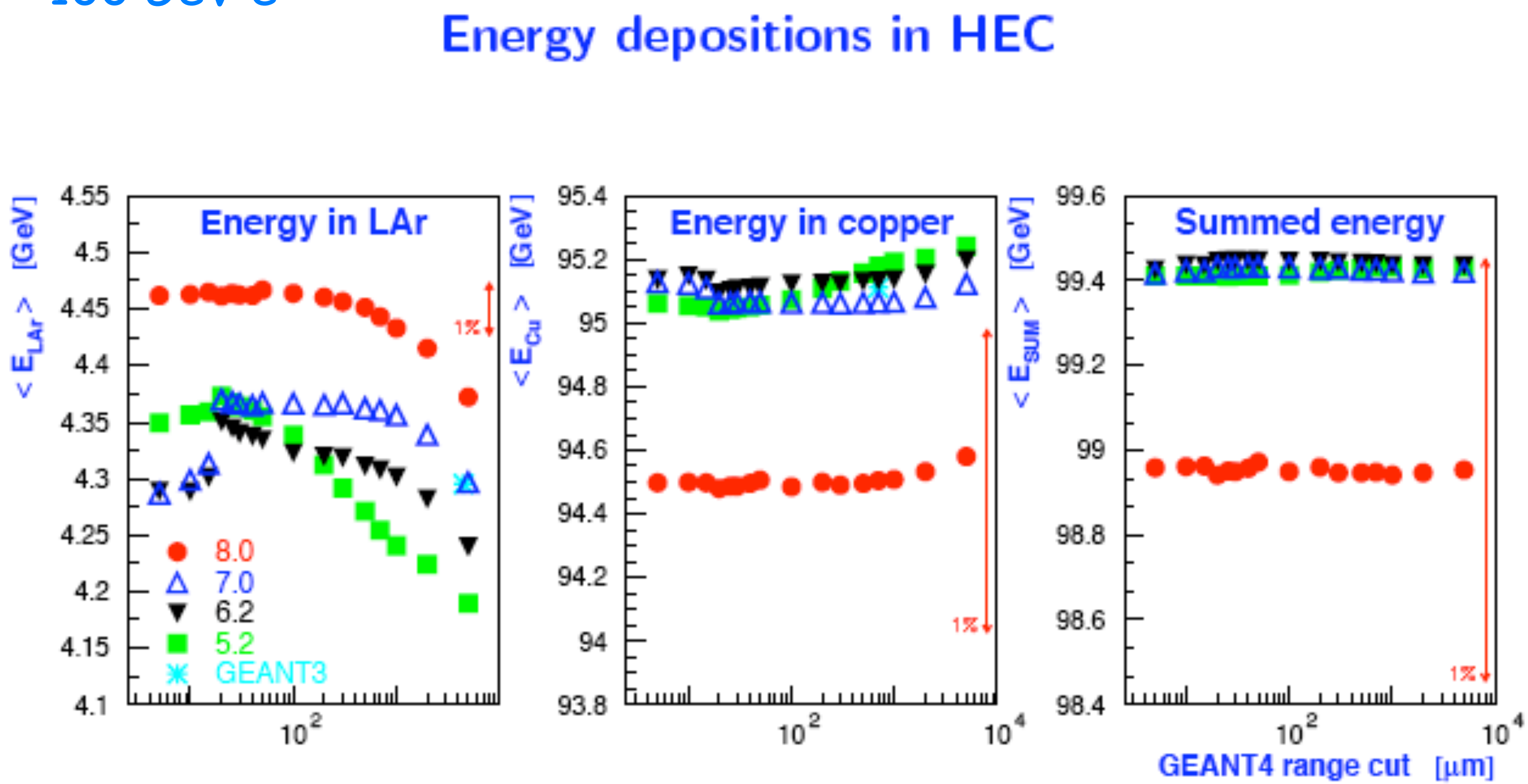
A. Kiryunin (MPI Munich)

- GEANT4

Version	5.2p02	6.2p02[1)]	7.0p01	8.0p01
Physics lists	LHEP 3.6 QGSP 2.7	LHEP 3.7 QGSP 2.8	LHEP 3.7 QGSP 2.8	LHEP 4.0 QGSP 3.0
Packaging library	PACK 2.3	PACK 2.4	PACK 2.4	PACK 5.0
Release date	October 2003	October 2004	February 2005	February 2006

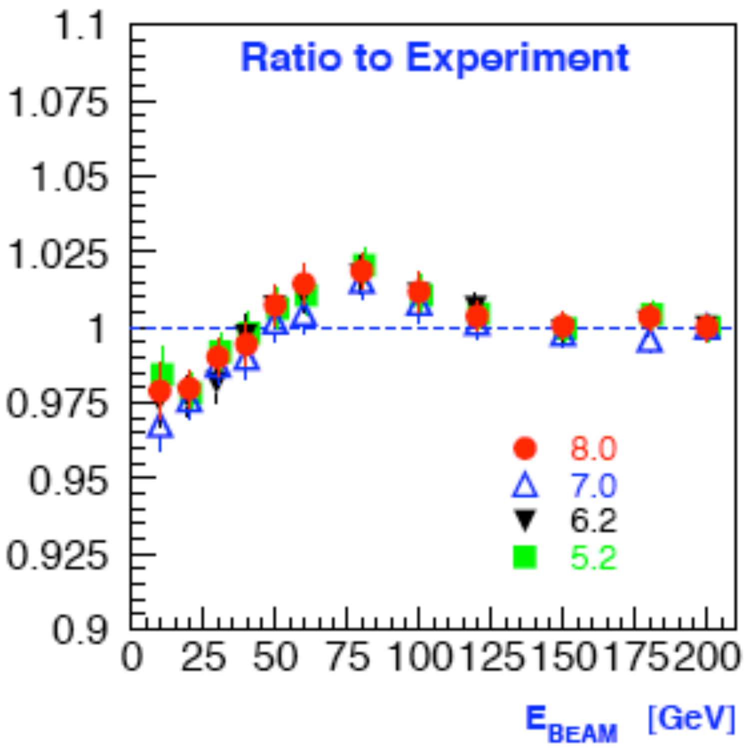
- GEANT3
  - Version 3.21
  - G-CALOR (hadronic shower code)
  - 100 keV transport cuts and 1 MeV process cuts

100 GeV e-

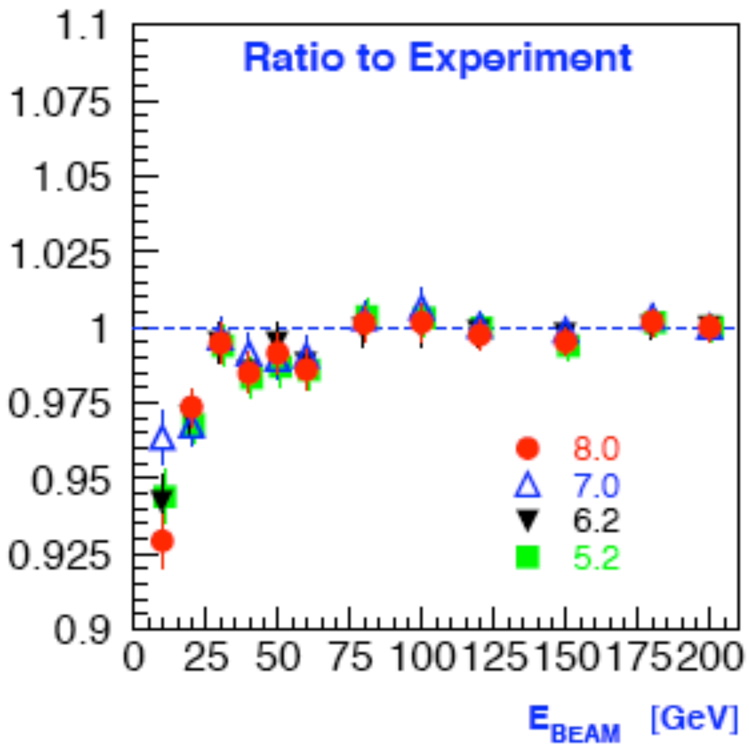

Energy depositions in HEC
Energy in LAr
< E_LAr > [GeV]
8.0
7.0
6.2
5.2
GEANT3
1%
Energy in copper
< E_Cu > [GeV]
1%
Summed energy
< E_SUM > [GeV]
1%
GEANT4 range cut [μm]

Energy scans with pions

Relative response: ratio to experimental data



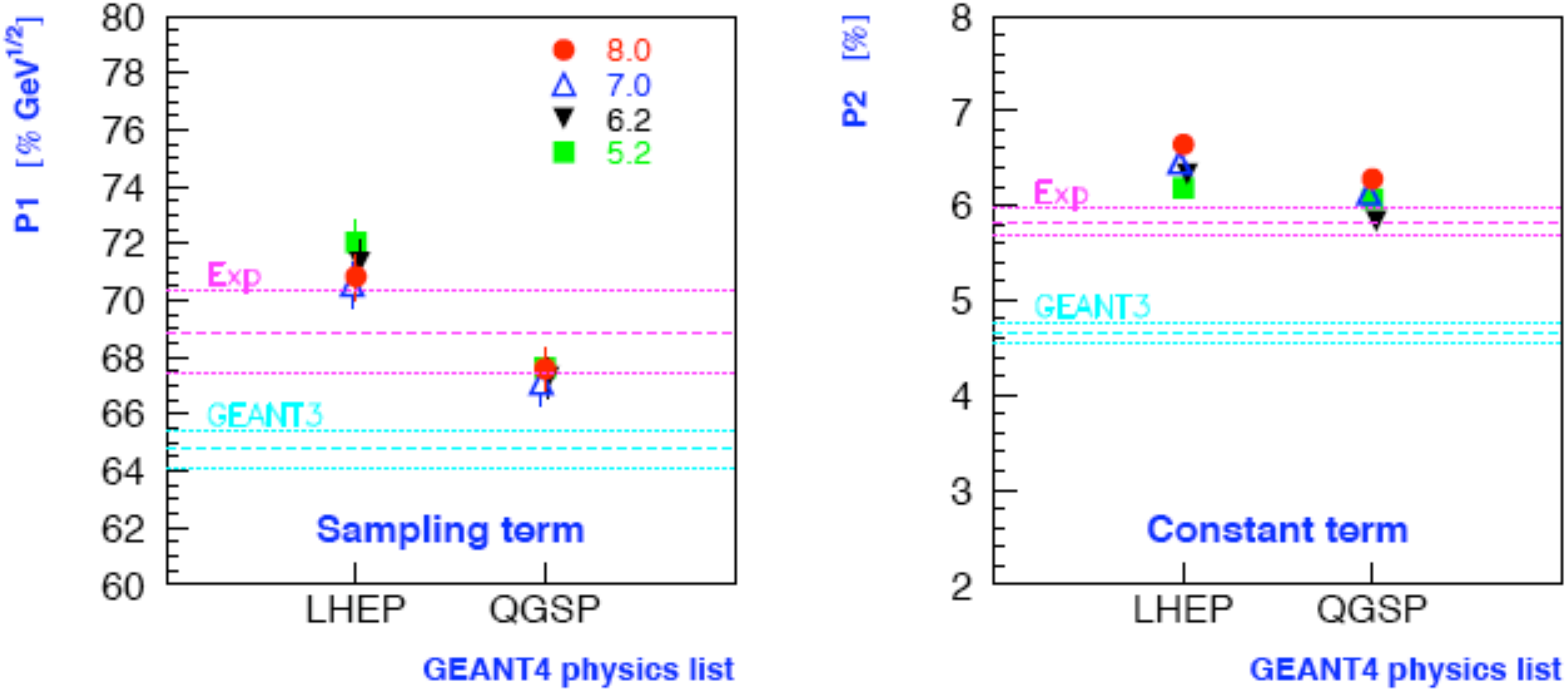
LHEP, 20 μm cut



QGSP, 20 μm cut

Energy scans with pions

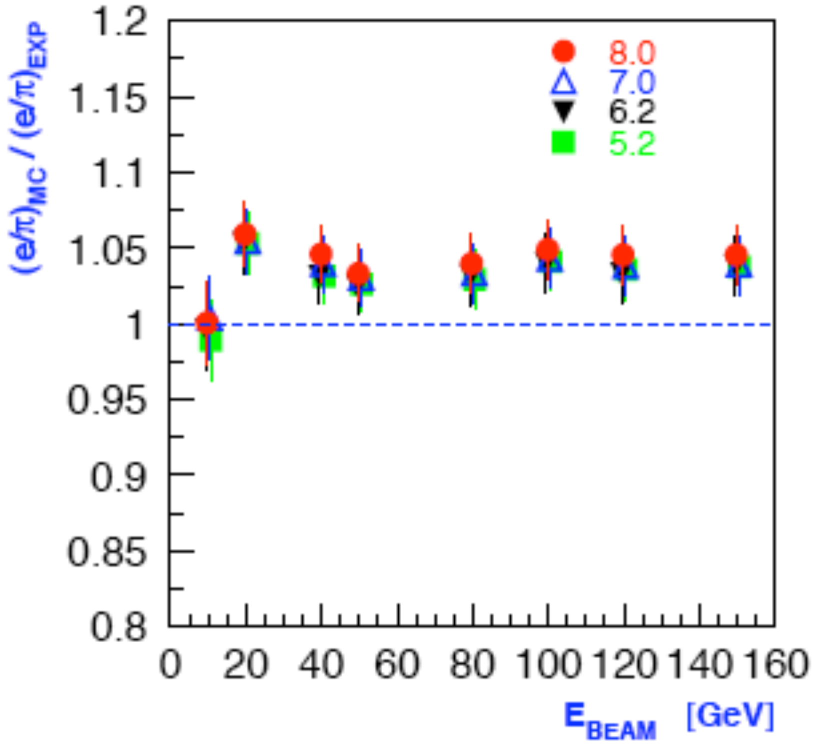
Energy resolution: $\sigma/E_0 = P1/\sqrt{E_{BEAM}} \oplus P2$



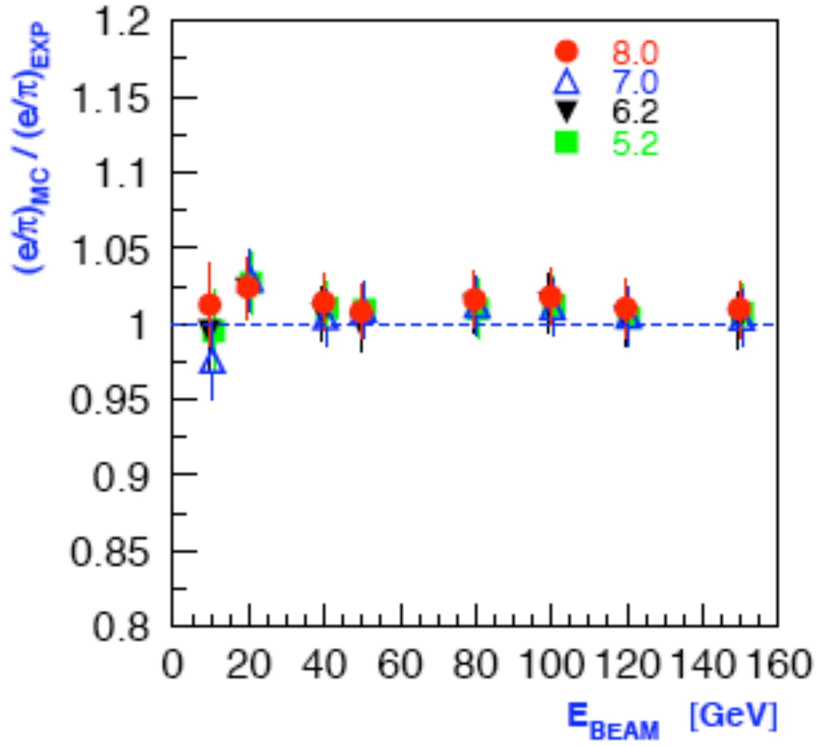
20 μm cut

Energy scans with pions

e/π: ratio to experimental data



LHEP, 20 μm cut



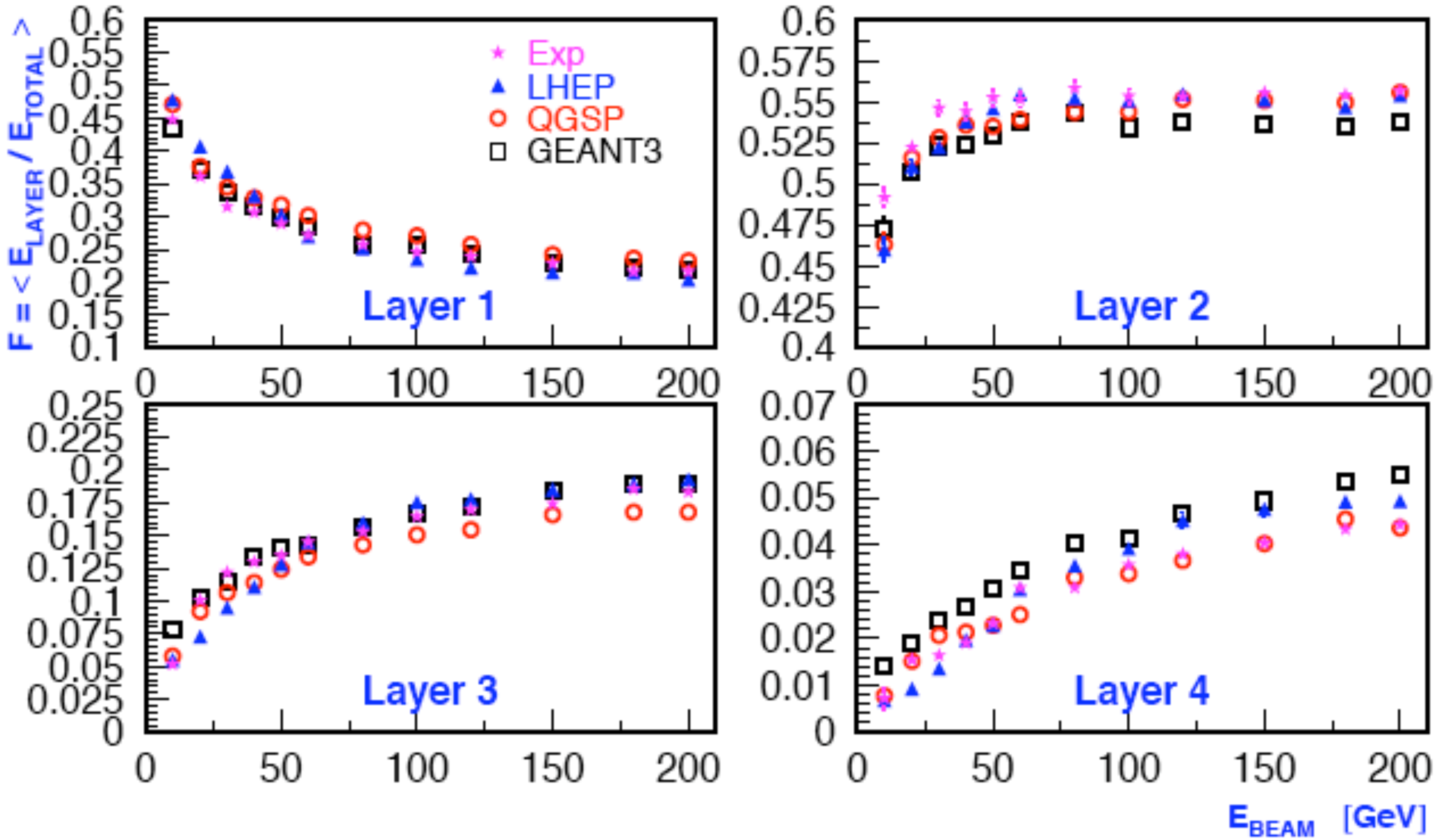
QGSP, 20 μm cut

Milestone UD512 ✓

ATLAS HEC

Energy scans with pions

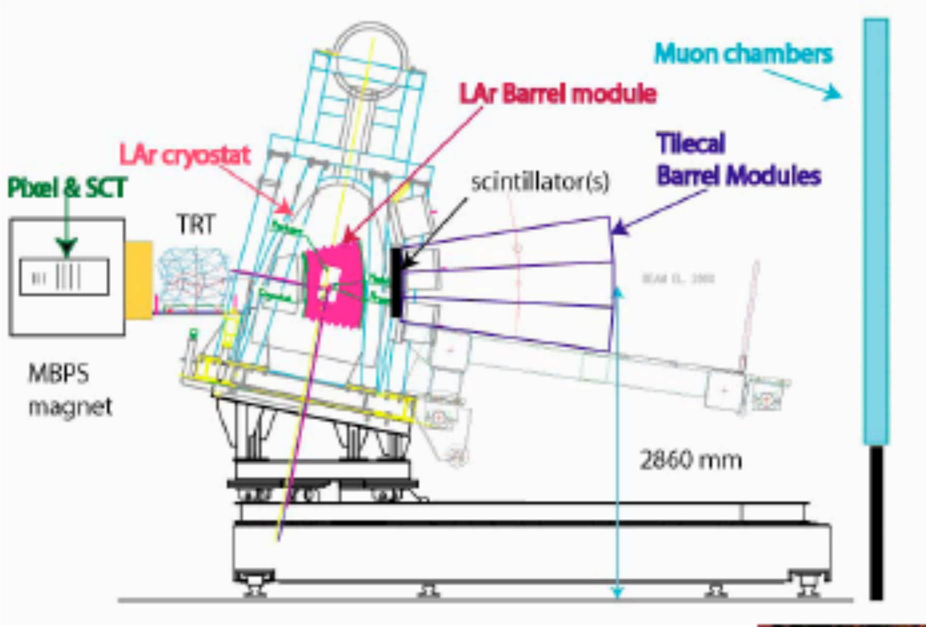
Fraction of energy in longitudinal layers



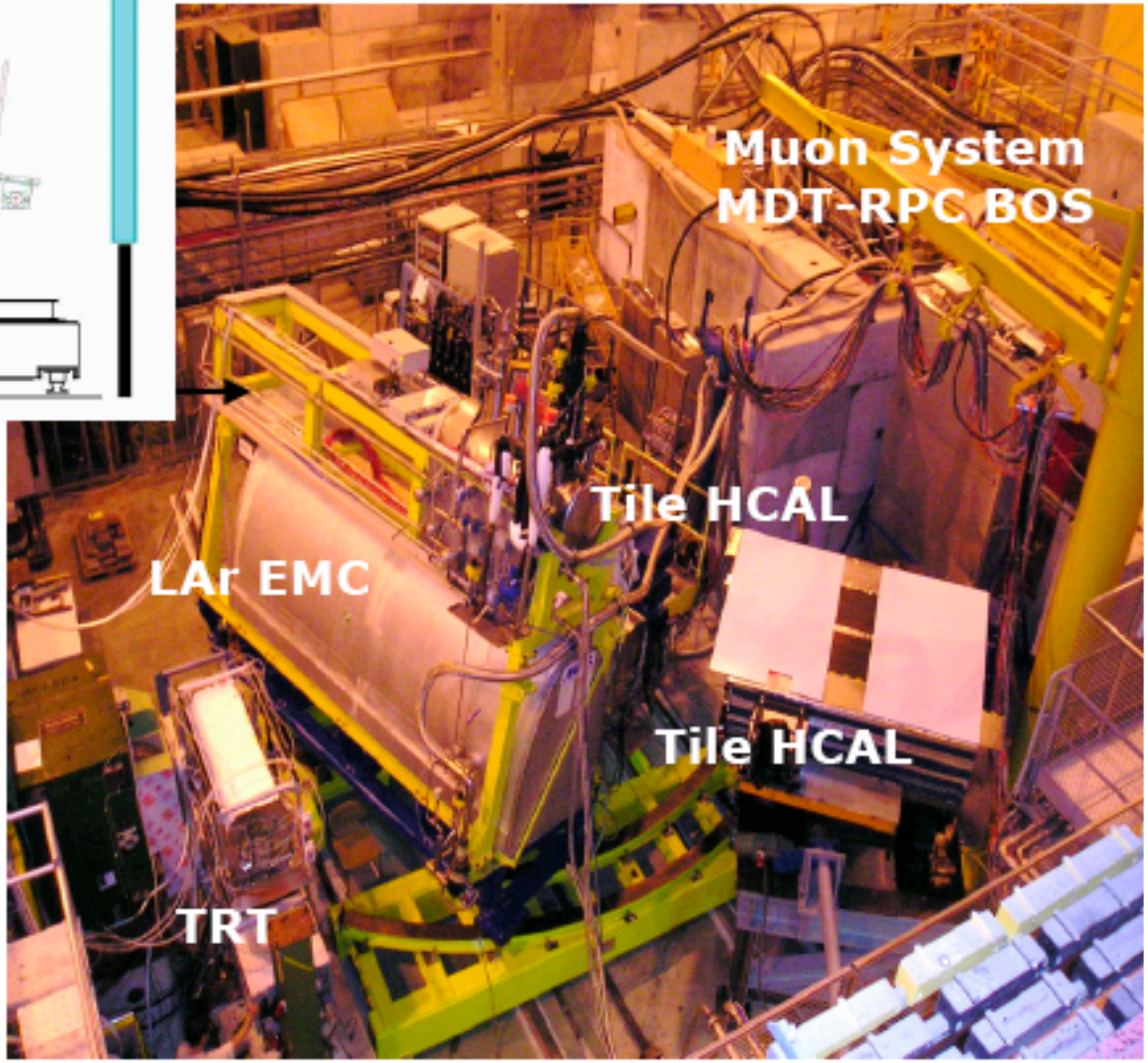
GEANT4 version 8.0, 20 μm cut

Milestone UD532

ATLAS Barrel Combined Test-beam 2004

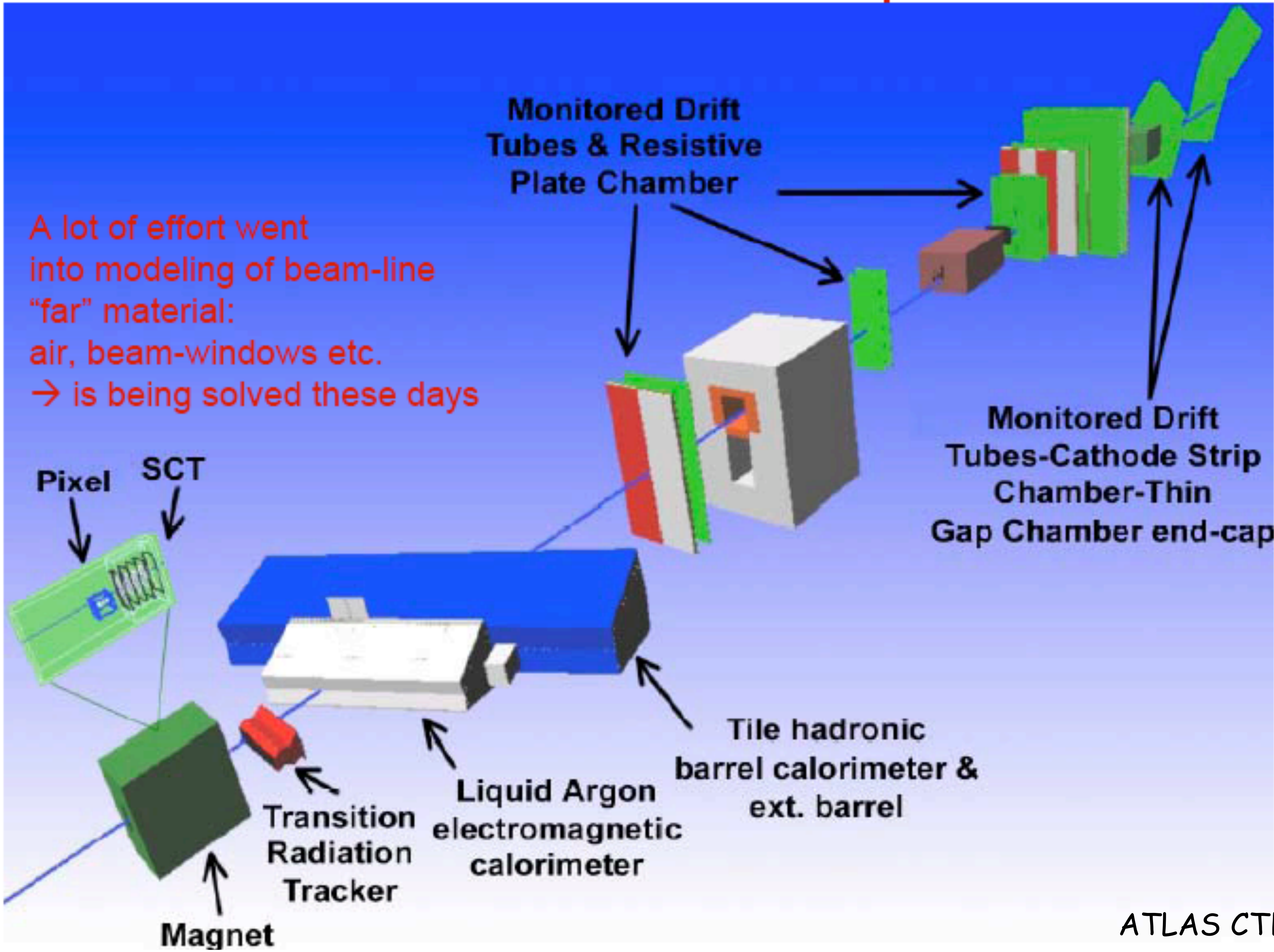


Full η -slice of ATLAS detector



- Drift chambers: beam position
- Scintillators: trigger
- Calorimeters on η moving table
- H8 beam: e, γ, μ, π and p
- Energy: 1 to 350 GeV

H8 G4 Simulation Setup



ATLAS CTB

MC Validation

1) Detector geometry and test-beam set-up
   (cables, electronics, air in beam-line)

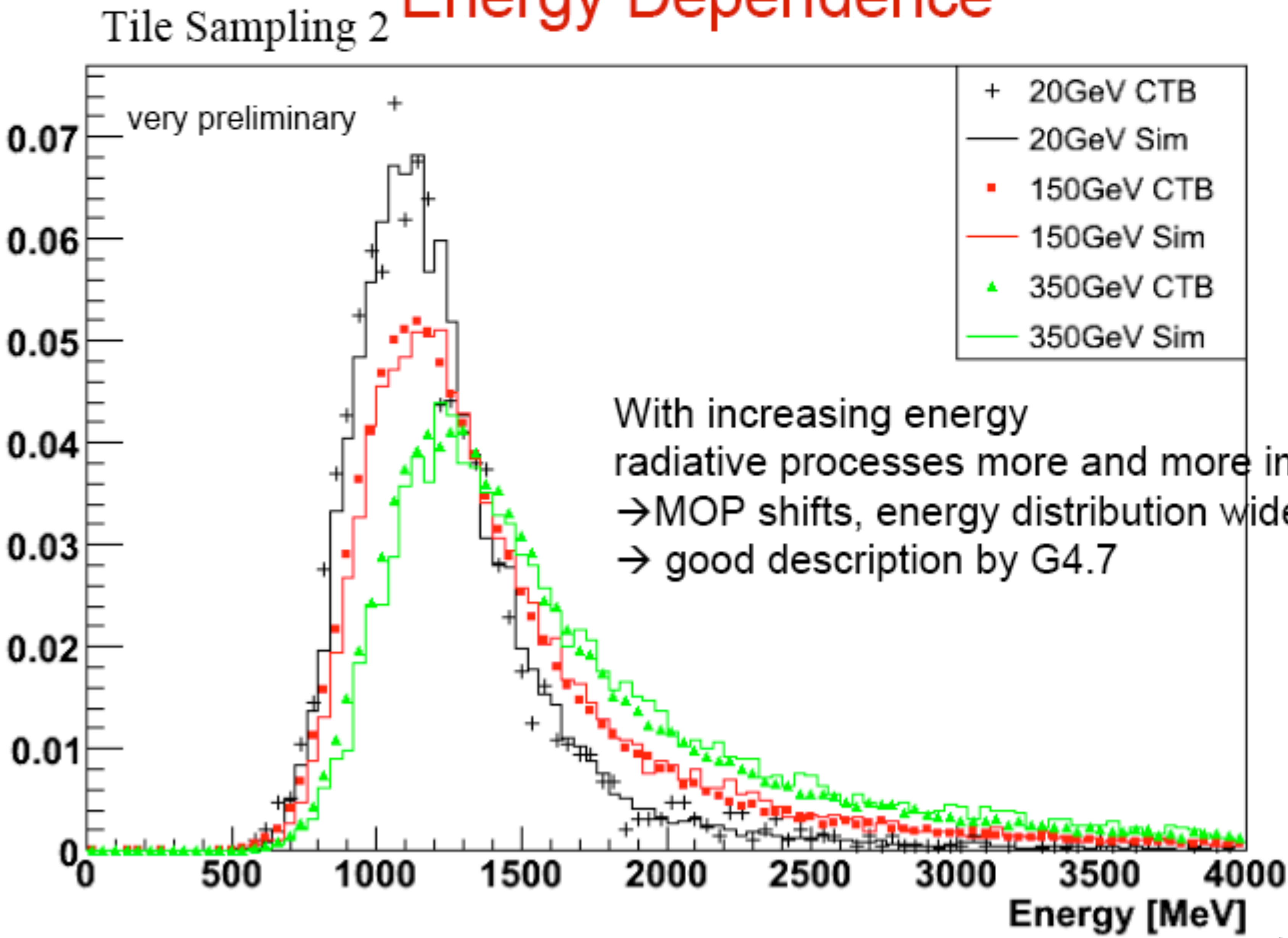
2) Detector response: physics processes in detector
   (charge collection in complicated E-fields, recombination, photostatistics, light attenuation, Birk's law)

3) Electronic signal modeling and noise

For the moment we are mostly busy with this… and start to work on 4)

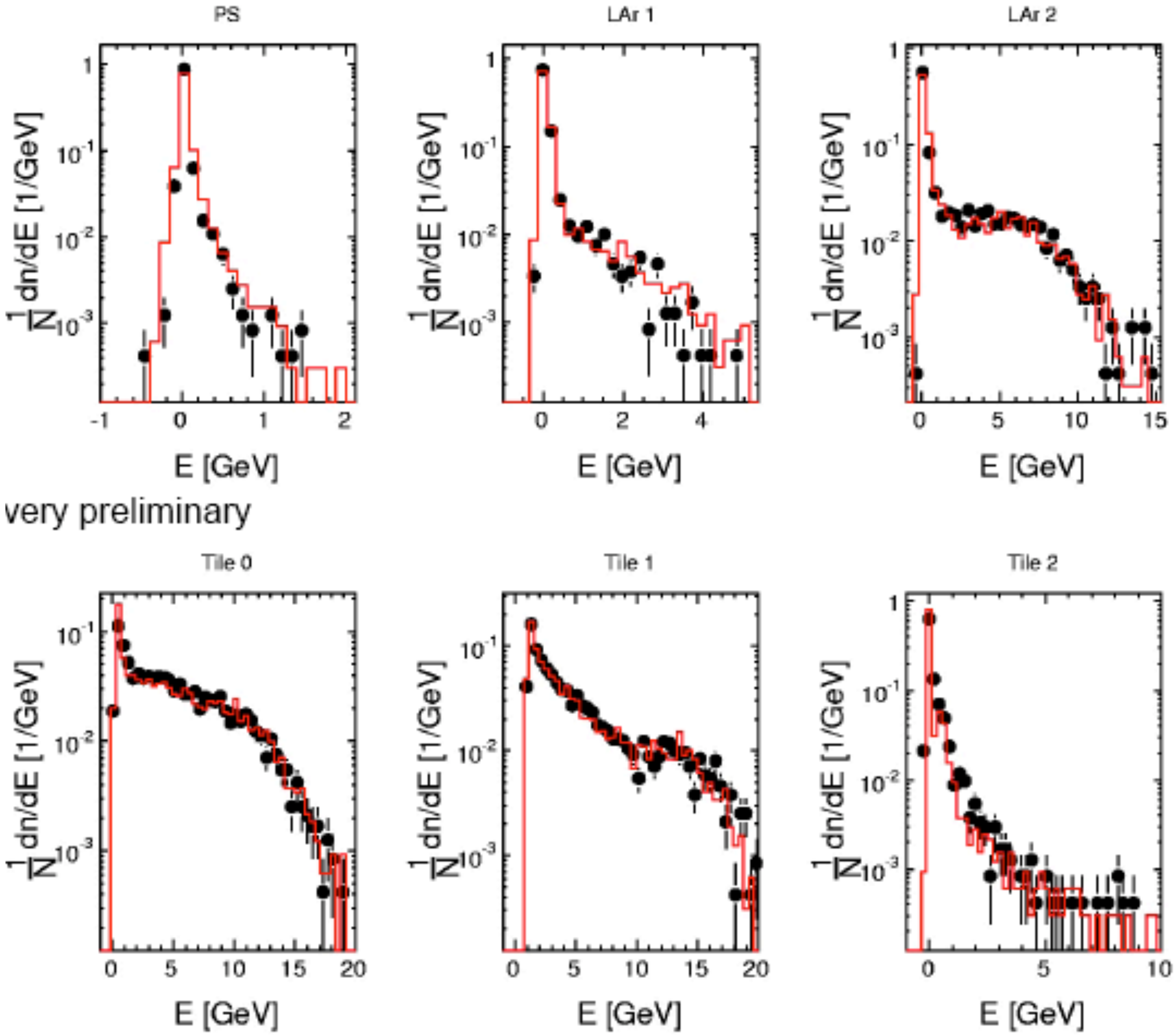
4) Physics processes: Interaction of particles with detector

Muon: MC/CTB Comparison – Energy Dependence



With increasing energy
radiative processes more and more important
→MOP shifts, energy distribution widens
→ good description by G4.7

Pion: MC/CTB Comparison – E=20 GeV



MC

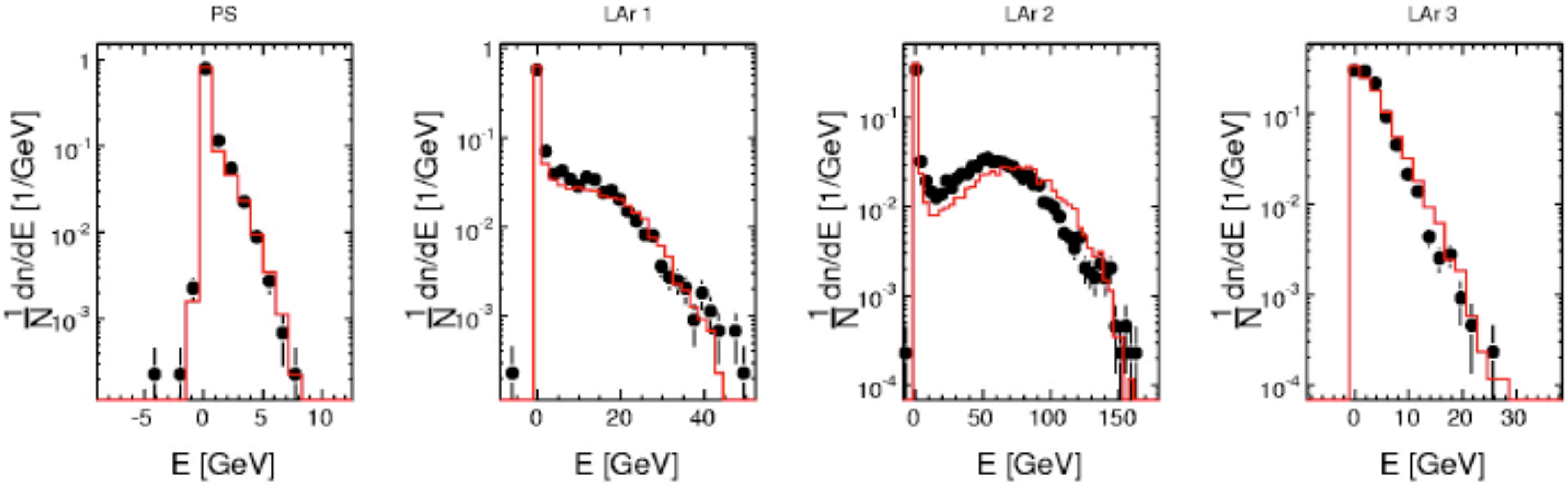
Data

MC: G4.7 QGSP

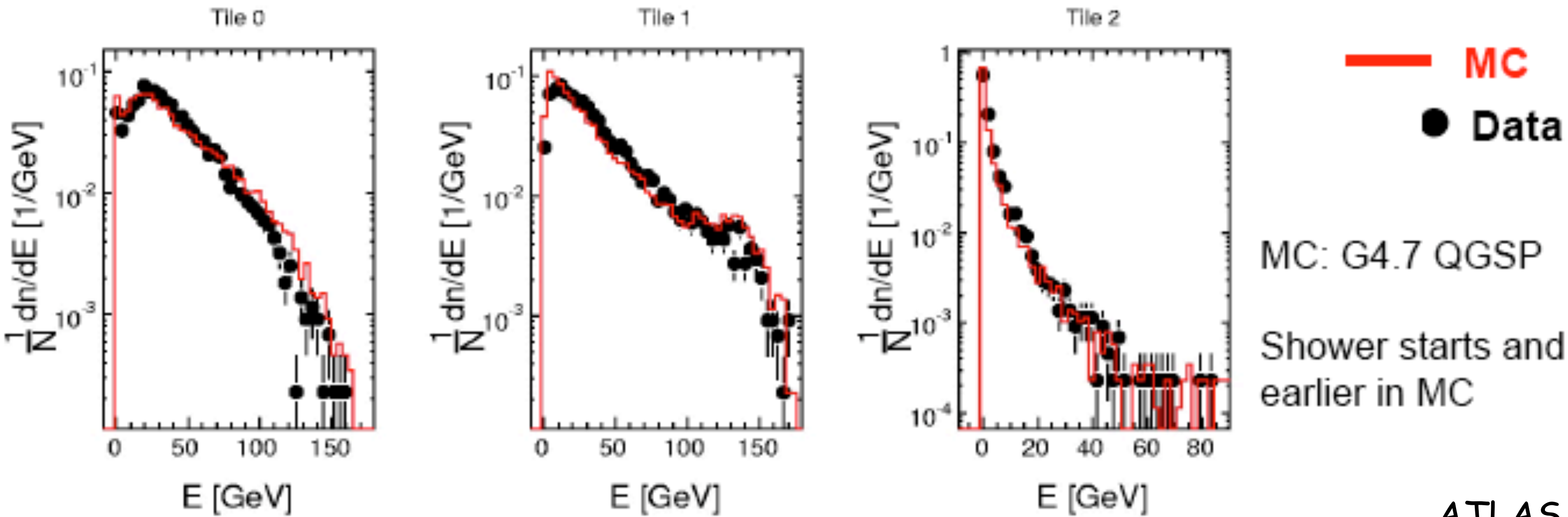
describes data well
(to be quantified)

ATLAS CTB

Pion: MC/CTB Comparison – E=180 GeV



very preliminary



MC: G4.7 QGSP

Shower starts and ends earlier in MC

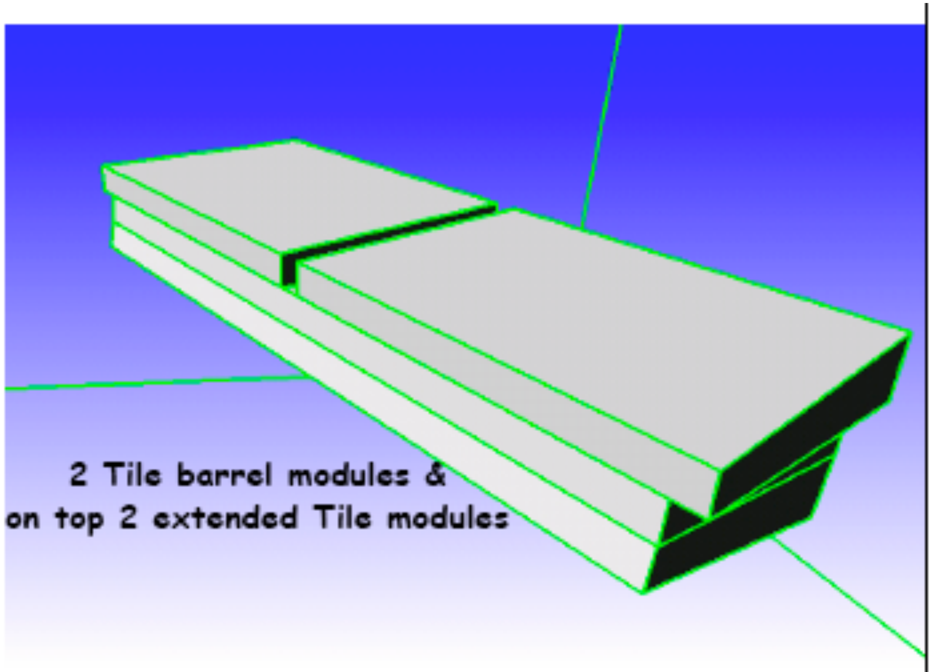
Milestone UD524

Comparing Fluka and Geant4 against ATLAS TileCal 2002 test-beam data

M.Gallas, W.Pokorski, A.R.

(see Witek's talk for more details!)

- Motivation: compare Fluka and Geant4 in a calo setup; study the shower shapes in Fluka.
- We want to use the same geometry, digitization, and analysis: only the physics engines should be different!
- Use this as an example for other LHC calorimeter test-beam setups.



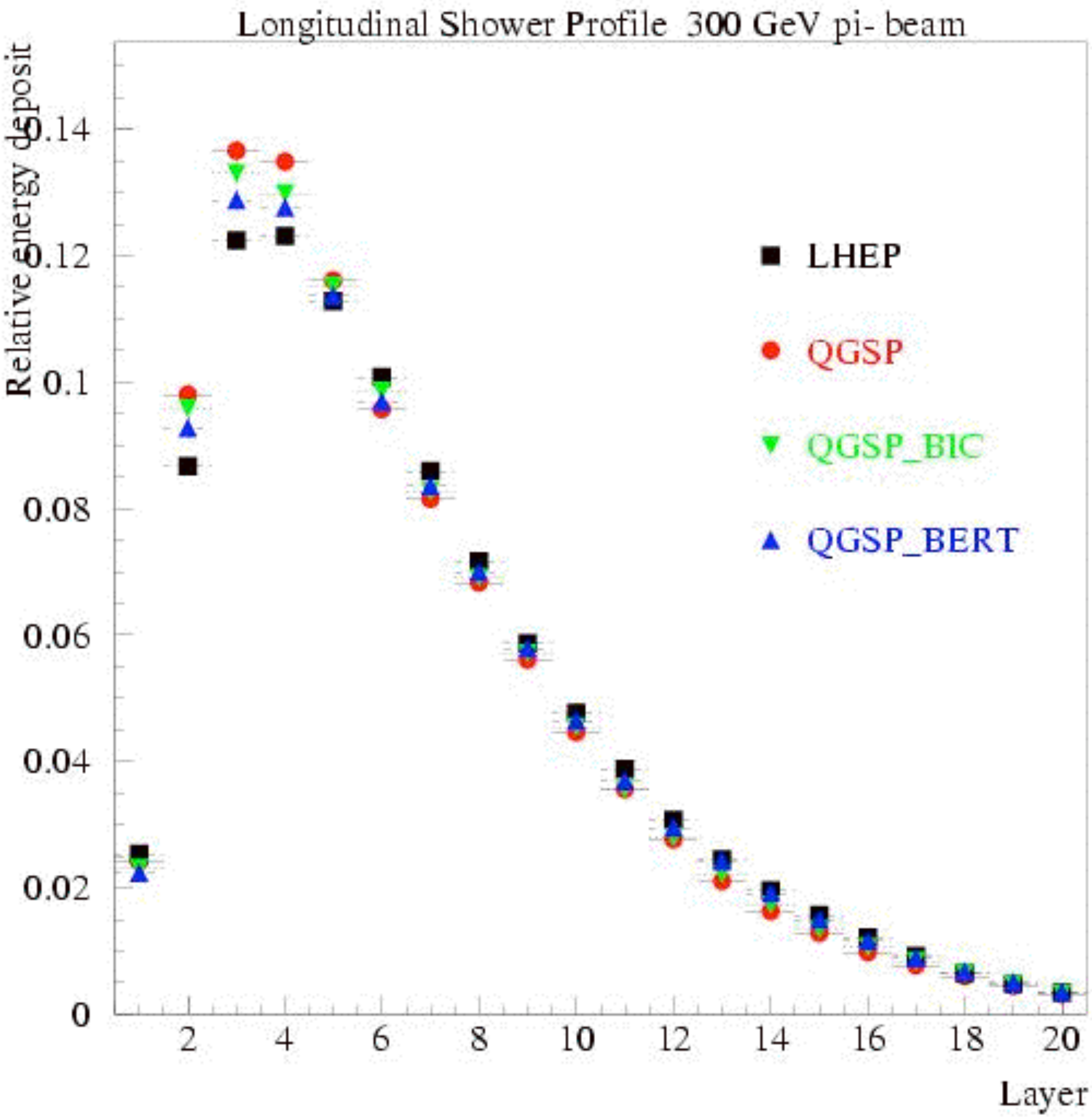
* 2002 data: pions and electrons 20-180Gev

Shower shape studies in Geant4

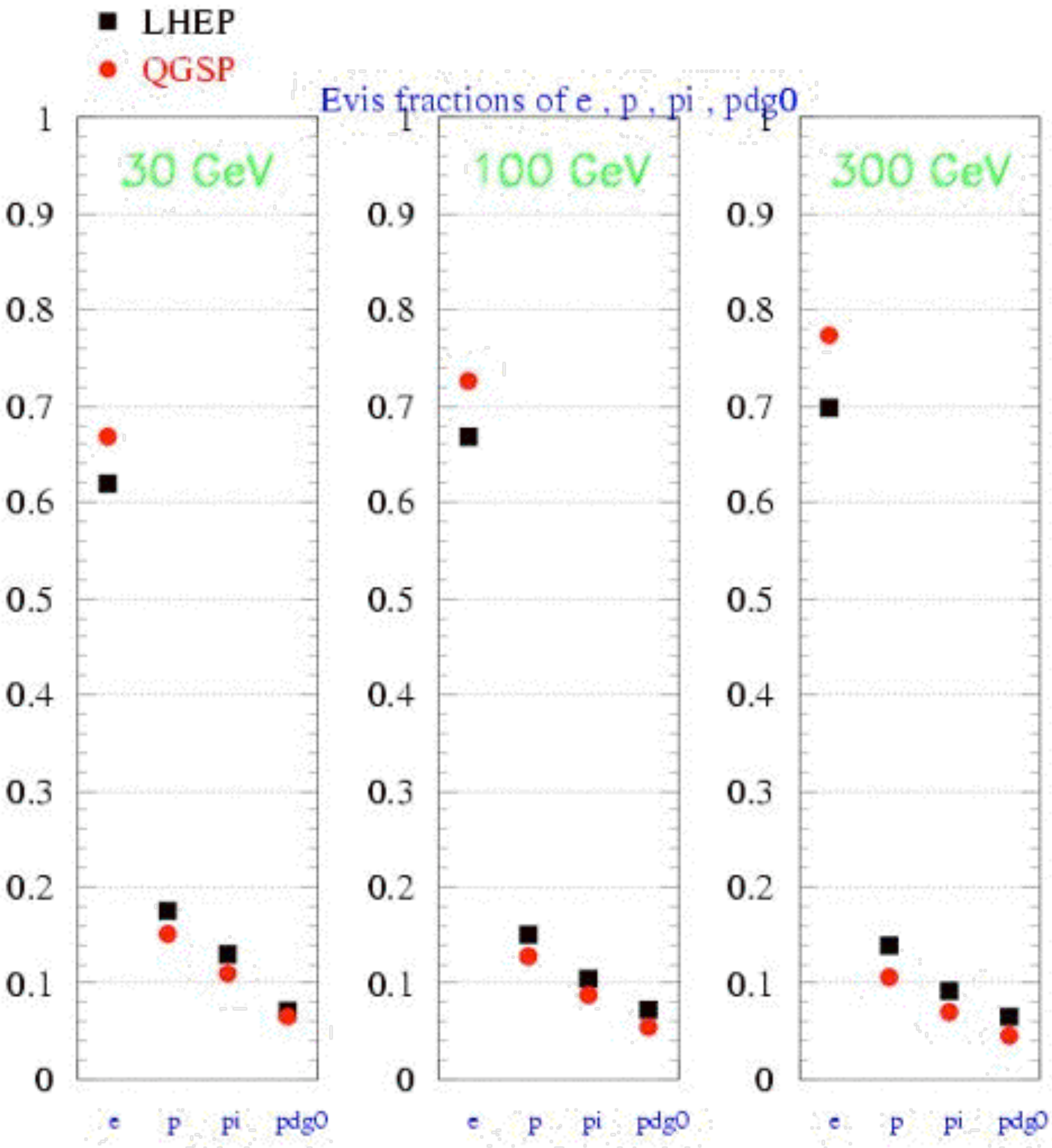
The goal is to understand the impact of the various physics processes on the development of hadronic showers, in order to improve the longitudinal (and lateral) shower profiles.

To tackle this complex problem we use two complementary approaches:

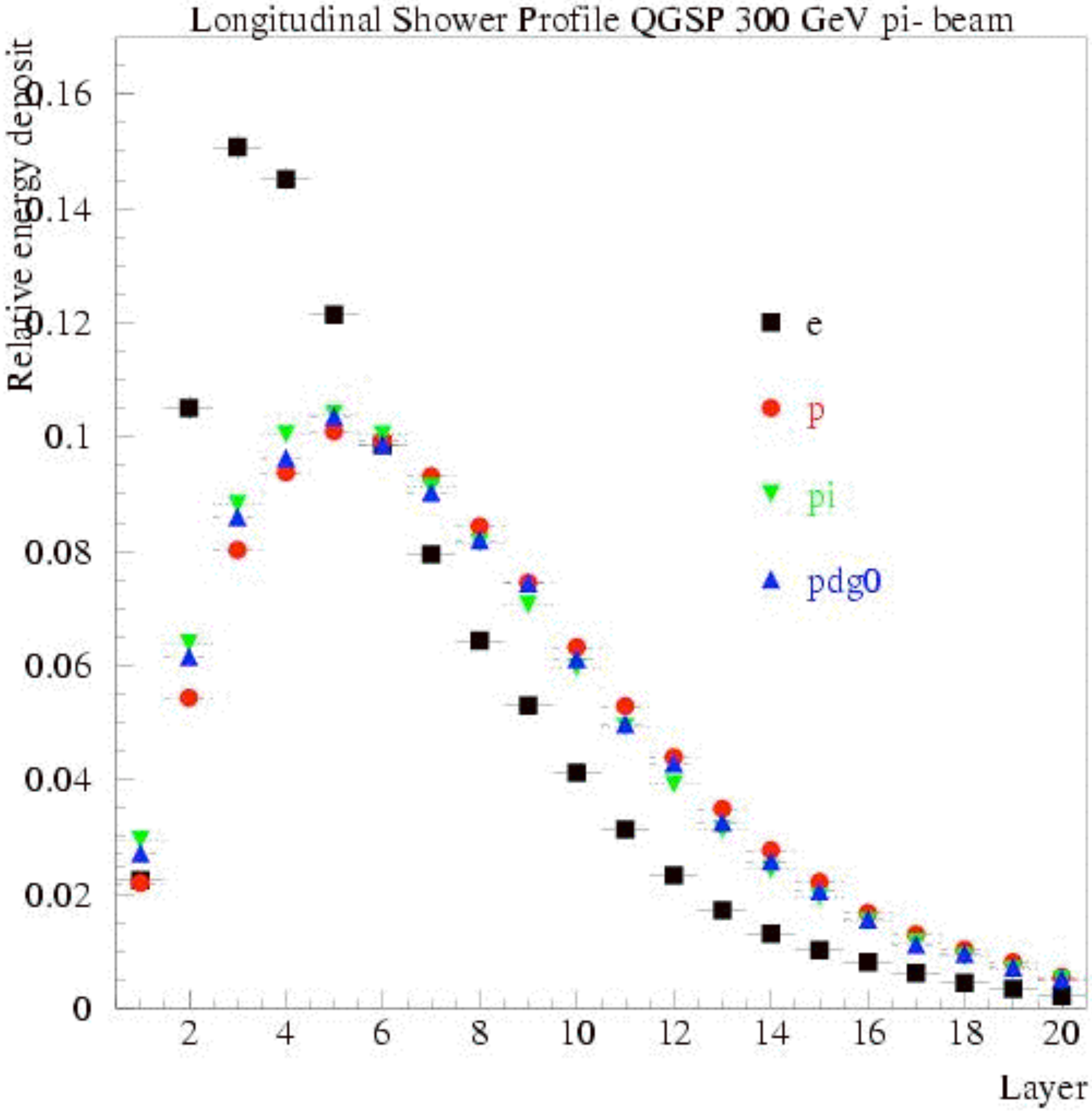
1. "microscopic" : study for instance:
   - elastic scattering
   - neutron production and transportation
   - pion inelastic cross-sections
   - multiplicity and spectra.
2. "macroscopic" : monitor the observables of a simplified sampling calorimeter setup to compare different physics simulations.



Visible energy fractions per layer, for 4 Geant4 Physics Lists.
Cu-LAr calorimeter,
10 λ



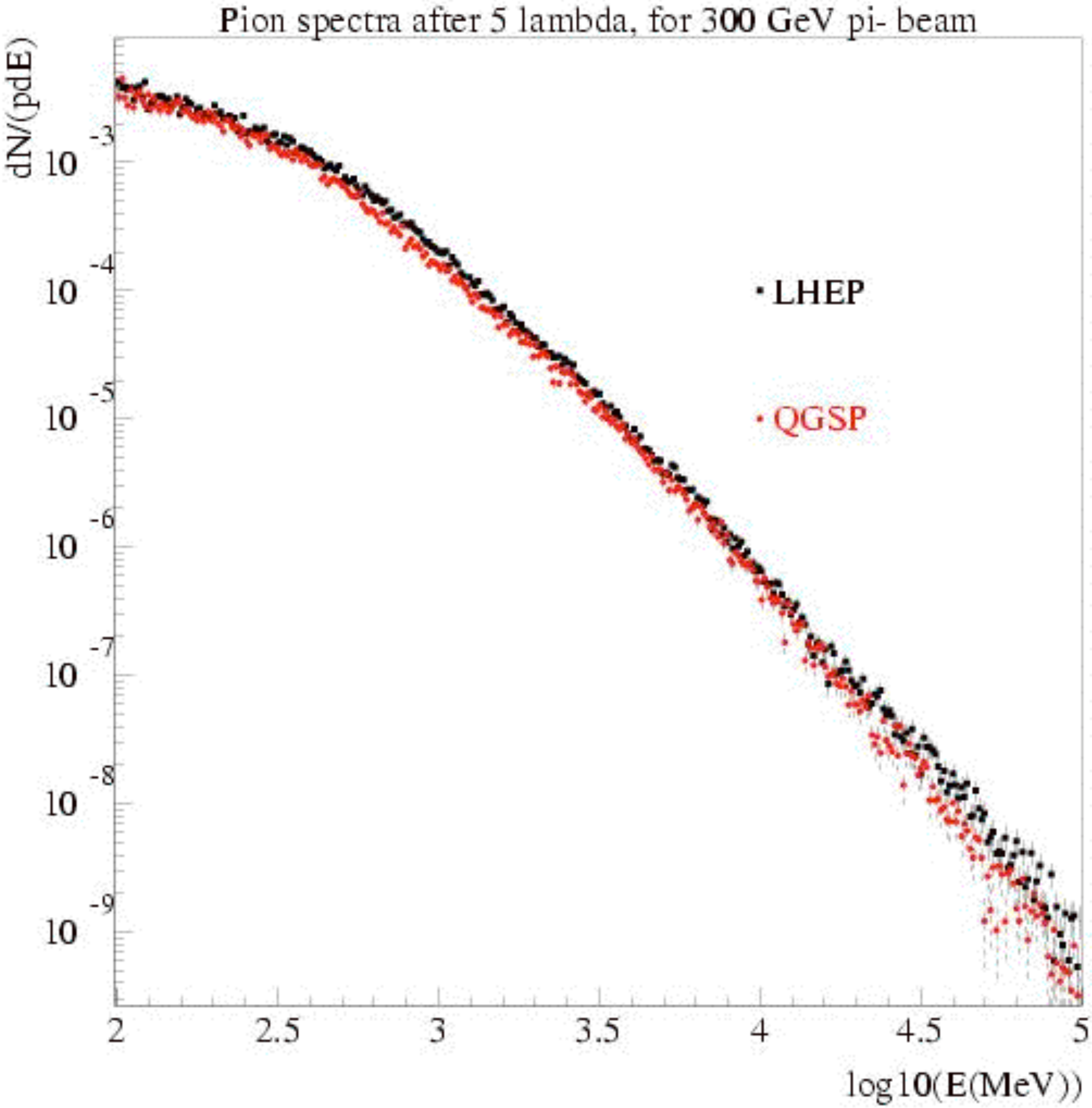
Visible energy fractions per particle type, for different beam energies. Cu-LAr calorimeter, 10 λ



Visible energy fractions per layer, for some particle types.

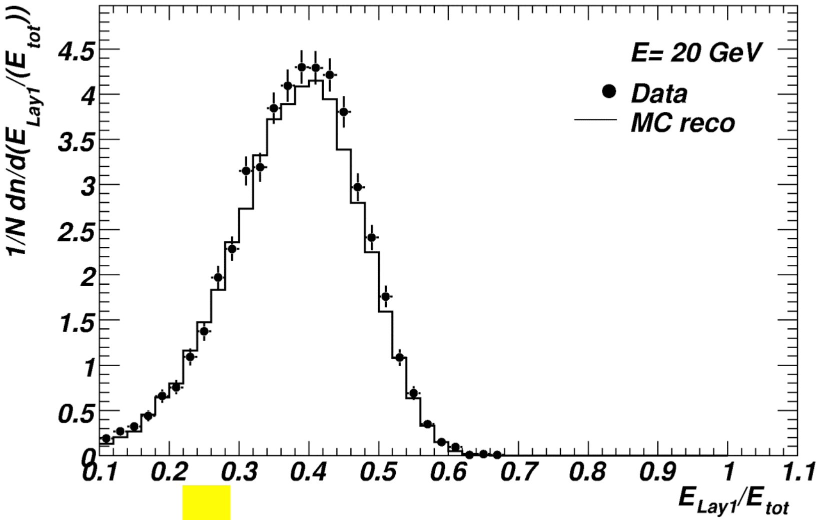
Cu-LAr calorimeter,

10 λ



Kinetic energy distribution, between 100 MeV and 100 GeV, for charged pions in middle of a 10 λ Cu-LAr calorimeter.

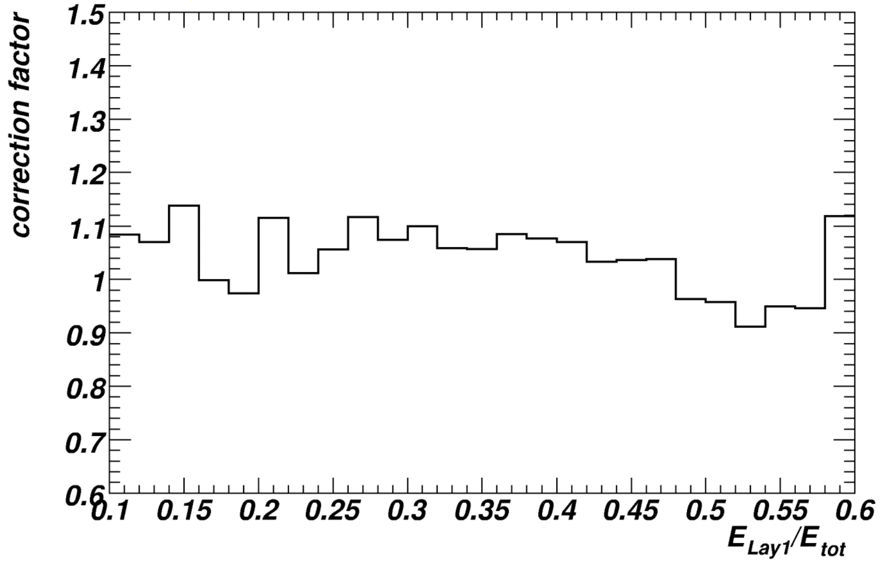
Test-bench Prototype for TB02 LAr Data (T.Carli, AR)

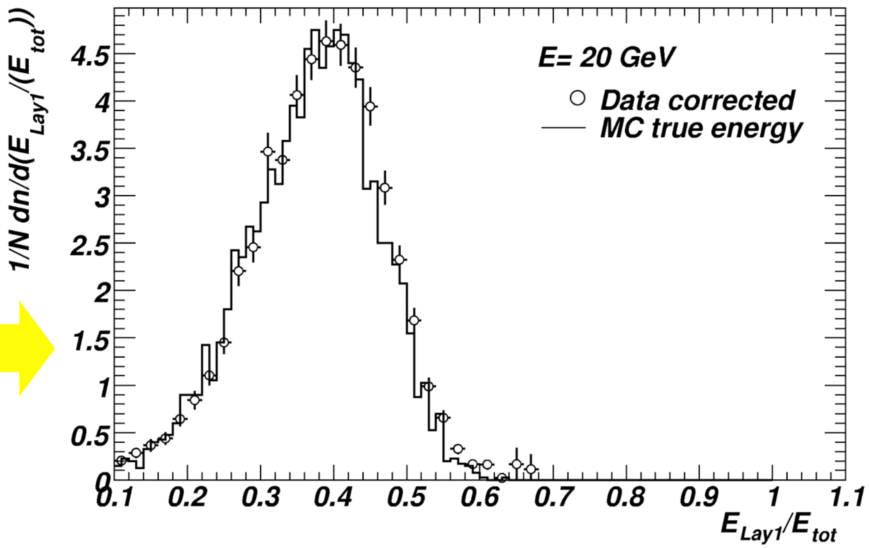


Goal: let Geant4 and Fluka developers to use directly the calorimeter test-beam data for validation purposes.

Method: correct the data, as it is done for cross-sections measurements:

1) Get observables from detector simulation
2) Get observable from calibration hits
3) Divide the two, to obtain corrected data
4) Provide detector geometry via xml-file





Current LCG man-power: 2.3 FTE

- M. Gallas : 75% F.T.E. dedicated to the extension to Fluka of the ATLAS calorimeter test beam setups, and support for the CTB.

- A. Howard: 75% F.T.E. dedicated to TARC neutron benchmark and LHCb radiation studies with G4.

- W. Pokorski : 30% F.T.E. dedicated to simple benchmarks, and extension to Fluka of the calorimeter test beam setups.

- A. Ribon : 50% F.T.E. dedicated to coordination, simple benchmarks, and extension to Fluka of the calorimeter test beam setups.

Proposed work activities in 2007

- Conclusion of the on-going LHC test-beam analyses, and final report of the results.

- New simple benchmark tests.

- Extension to Fluka of some LHC test-beam analyses, following the ATLAS TileCal example.

- Apply corrections to LHC test-beam data, following the ATLAS Barrel electron analysis example, in order to allow stand-alone setups to be used for Geant4 (or Fluka) validation at each release.

Summary

- Still important test-beam analyses to complete.
- So far, Geant4 gives good results, but hadronic shower shapes need improvements.
- Investigations in various directions are undergoing in Geant4 to address the shower shape issue:
  - cross-sections (elastic and inelastic);
  - model of the hadronic elastic scattering;
  - neutron production;
  - production (multiplicities), rapidity and spectra in h-A;
  - diffraction.
- Relation between simulation developers and experiments has improved, and it is now very good!
- Progress has been slower than anticipated, due to different reasons (complexity of the setups, detailed description of instrumental effects, other commitments…).