Geant4 hadronic physics validation with ATLAS Tile Calorimeter test-beam data

C. Alexa, S. Constantinescu and S. Diță,
IFIN, Bucharest

compare Geant4 and ATLAS Tile Calorimeter test-beam data for pions and protons

- test-beam data: 2002 and 2003 standalone setup
- simulations: GEANT 4.7.1 with QGSP_GN and GEANT 4.5.2 with QGSP 2.7

ATLAS Tile Calorimeter test beam data:

- Tile Calorimeter:
  - sampling calorimeter made out of iron and scintillating tiles (for details see Ilya Korolkov talk)

- H8 beam line at SPS-CERN:

  - Pion beams are contaminated with muons and protons:
    - at 50 GeV we have: ~60% pions, ~35% protons and ~5% muons
    - at 180 GeV we have: ~30% pions, ~60% protons and ~10% muons
    - muon identification (cut in energy deposition E < 10 GeV)
    - proton identification with Cherenkov Signal:
      - the pressure of the Cherenkov counter was set to a value lower than the proton threshold
      - a good efficiency of the proton - pion separation only in the interval 50 < Energy < 180 GeV
      - at 180 GeV the Cherenkov counter efficiency for pions is ~95%

  - Electron beams are contaminated with muons, pions and protons:
    - muon and proton identification as in pion beams
    - pion separation from electrons is done with a cut in the fraction of the total energy deposited in the first Tilecal sample of the central module:
      - the cut value was estimated using Geant simulations
      - the separation efficiency is higher than 95%

simulations:

- Tilecal geometry was implemented in Geant4 by A. Solodkov, V. Tsulaia, ATL-TILECAL-2003-002
- Geant4.5.2 with QGSP 2.7 and no leakage corrections, no noise and no Tilecal electronic signal response simulation
- Geant4.7.1 with QGSP_GN and noise, electronic signal response reconstruction and leakage corrections

9 GeV pion at η=-0.35			
no noise		with noise	
E_{mean}	σ	E_{mean}	σ
6.409	1.393	6.355	1.239

80 GeV pion at η=-0.35			
no electronics simulation		with electronics simulations	
E_{mean}	σ	E_{mean}	σ
66.21	6.205	64.87	6.475

Leakage correction: $(E_{first\ sampling}+E_{second\ sampling})/E_{tot} > 0.7$

	50 GeV pion		180 GeV pion		350 GeV pion	
	no correction	with correction	no correction	with correction	no correction	with correction
$E_{mean}^{simulation}$	39.67	39.98	148.6	149.2	293.1	294.3
$E_{mean}^{test-beam\_data}$	45.27	45.37	157.1	157.7		
$\sigma^{simulation}$	4.783	4.739	12.92	12.57	22.63	21.12
$\sigma^{test-beam\_data}$	4.312	4.117	11.85	11.32		

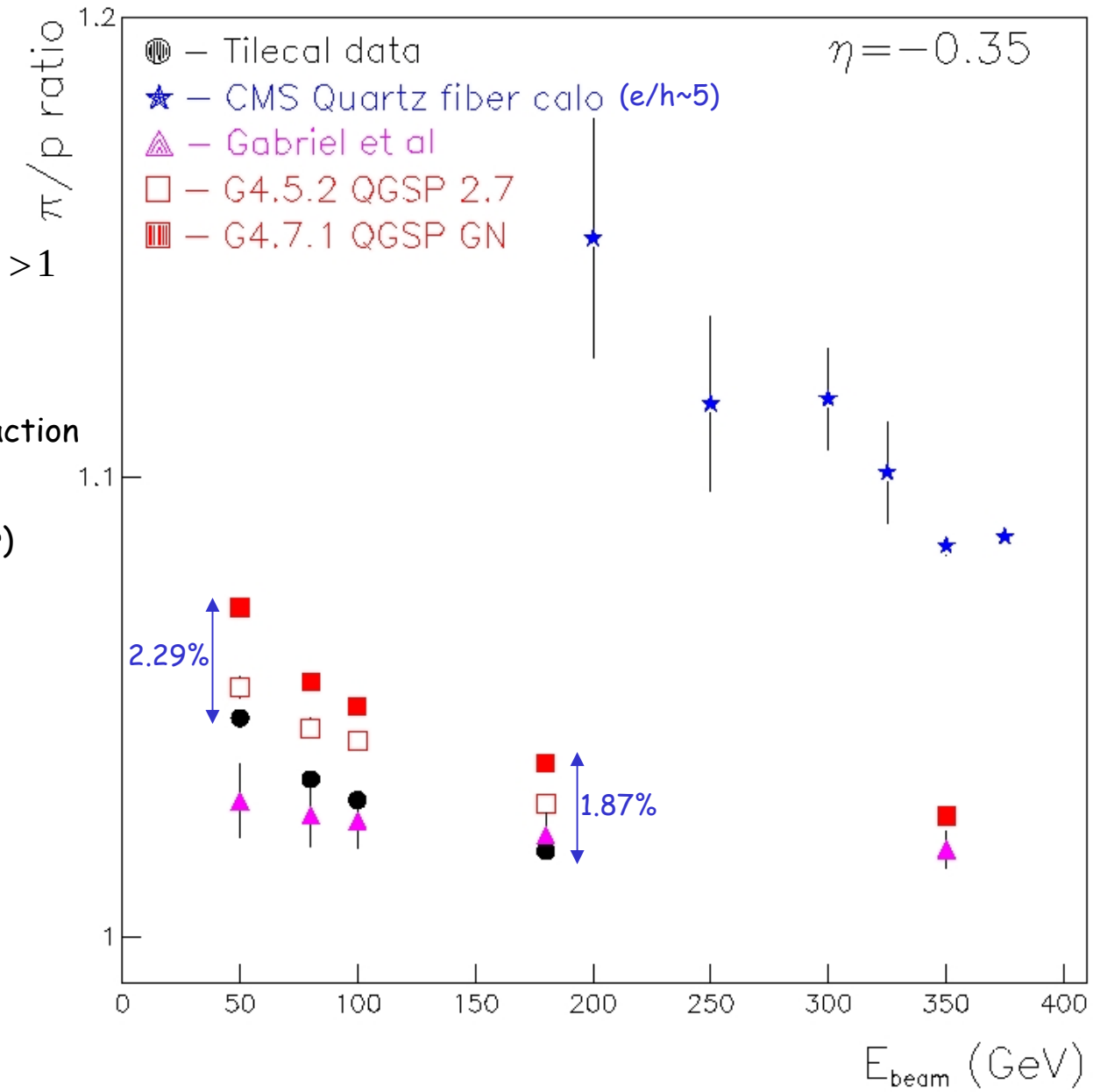
pion/proton:

G4.5.2 - no leakage corrections, no noise and electronic signal response simulation

The figure shows that the $E^{\pi}_{mean} / E^{p}_{mean} > 1$

This can be explained by:

- pions have a smaller pure hadronic fraction than protons
- e/h > 1 (non-compensating calorimeter)



CMS quartz fiber calorimeter data from:
NIM A 408 (1998) p380
Gabriel et al, NIM A 338 (1994) p336

pion/proton:

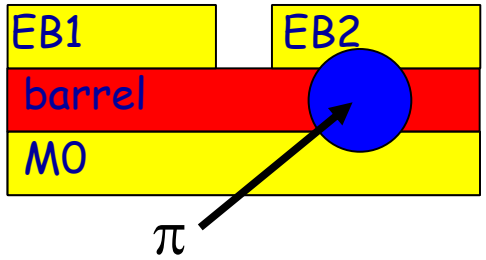
- predicted by T. A. Gabriel and coworkers, NIM A 338 (1994) p336 using G-Calor simulations
- observed experimentally, in the data taken with two non-compensating calorimeters :
  - a copper/quartz fiber calorimeter (Akchurin and coworkers, NIM A 408(1998) 380)
  - an iron/scintillating plates calorimeter TILECAL (prototype modules), ATL-TILECAL-2001-005
- both data were obtained using the contamination with proton of the positive pion beam from SPS-CERN

pion/proton:

The fraction of the energy deposited in the central tower as a function of energy:

- higher fraction values for pions than for protons in data as well as in simulations
- higher fraction values in simulations than in the data

The lateral shower profiles are wider for protons than for pions at the same energy.

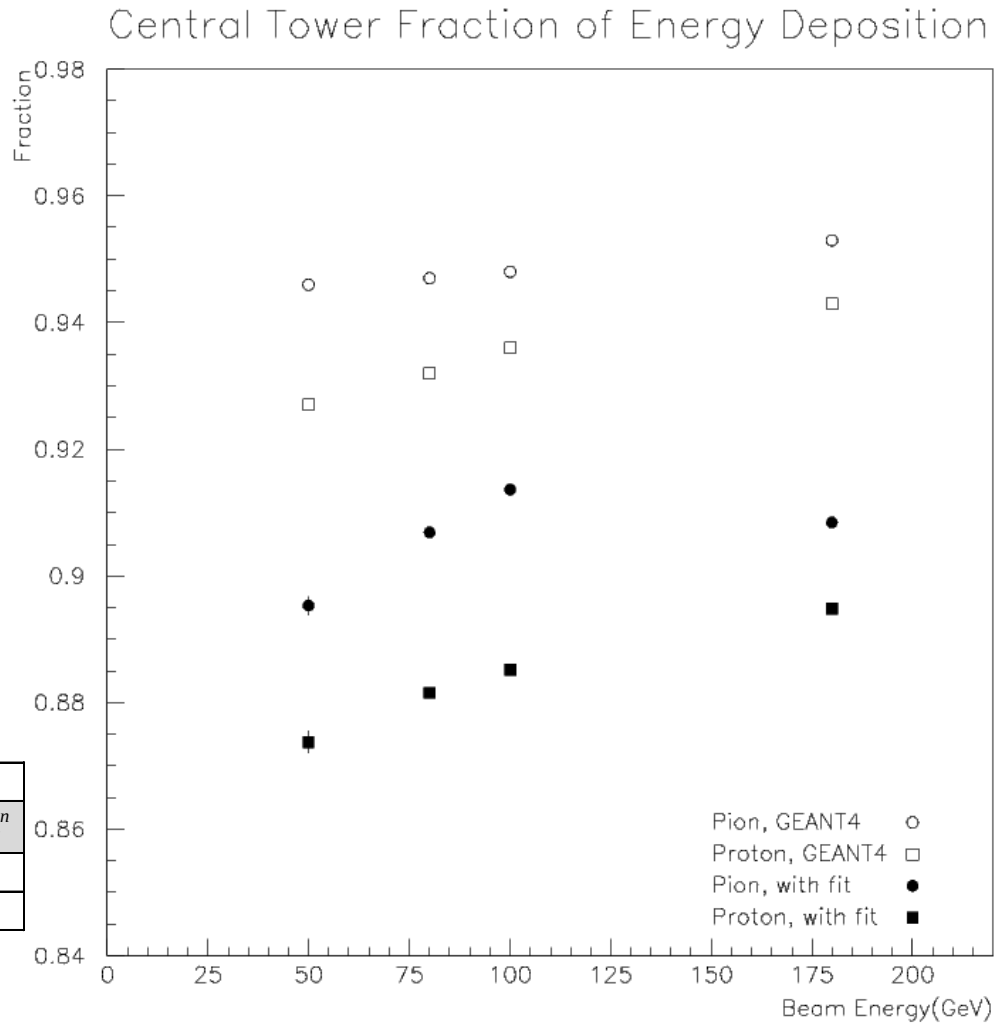


Sampling fractions from simulations

	$E_{S1}^{mean}/E_{total}^{mean}$	$E_{S2}^{mean}/E_{total}^{mean}$	$E_{S3}^{mean}/E_{total}^{mean}$
50 GeV pion	32.10%	63.26%	5.18%
50 GeV proton	36.48%	59.79%	4.43%
80 GeV pion	28.69%	65.61%	6.07%
80 GeV proton	34.04%	61.67%	4.64%
100 GeV pion	28.58%	65.55%	6.27%
100 GeV proton	33.65%	61.90%	4.85%
180 GeV pion	24.78%	68.31%	7.27%
180 GeV proton	31.21%	64.11%	5.0%

Sampling fractions

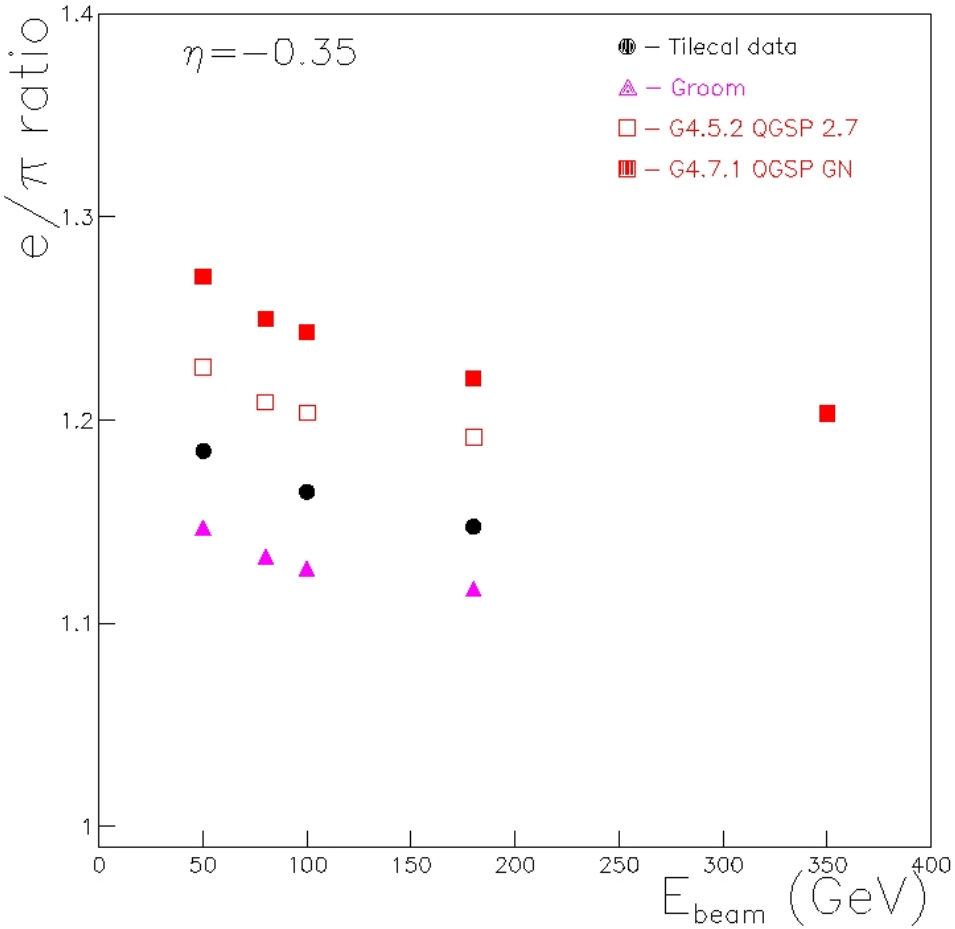
	50 GeV pion			180 GeV pion		
	$E_{S1}^{mean}/E_{total}^{mean}$	$E_{S2}^{mean}/E_{total}^{mean}$	$E_{S3}^{mean}/E_{total}^{mean}$	$E_{S1}^{mean}/E_{total}^{mean}$	$E_{S2}^{mean}/E_{total}^{mean}$	$E_{S3}^{mean}/E_{total}^{mean}$
data	37.36%	58.11%	5.55%	24.98%	69.51%	6.0%
sim	32.10%	63.26%	5.18%	24.78%	68.31%	7.27%

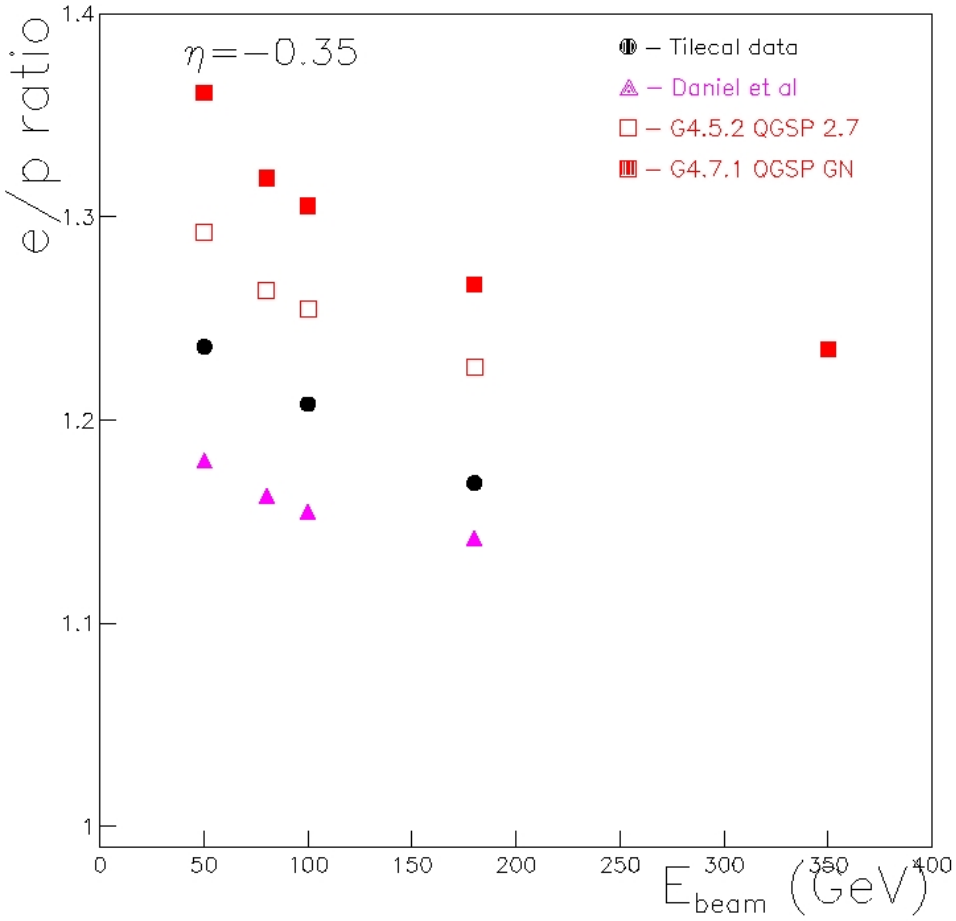


electron/pion and electron/proton:

- test beam data results were obtained from the same electron beams, that contains also pions and protons
- $(E^{e}_{mean}/E^{\pi}_{mean}) < (E^{e}_{mean}/E^{p}_{mean})$ because pions have a greater deposited energy than protons
- the decrease of these ratios with the beam energy are well described by the simulations

G4.5.2 - no leakage corrections, no noise and electronic signal response simulation



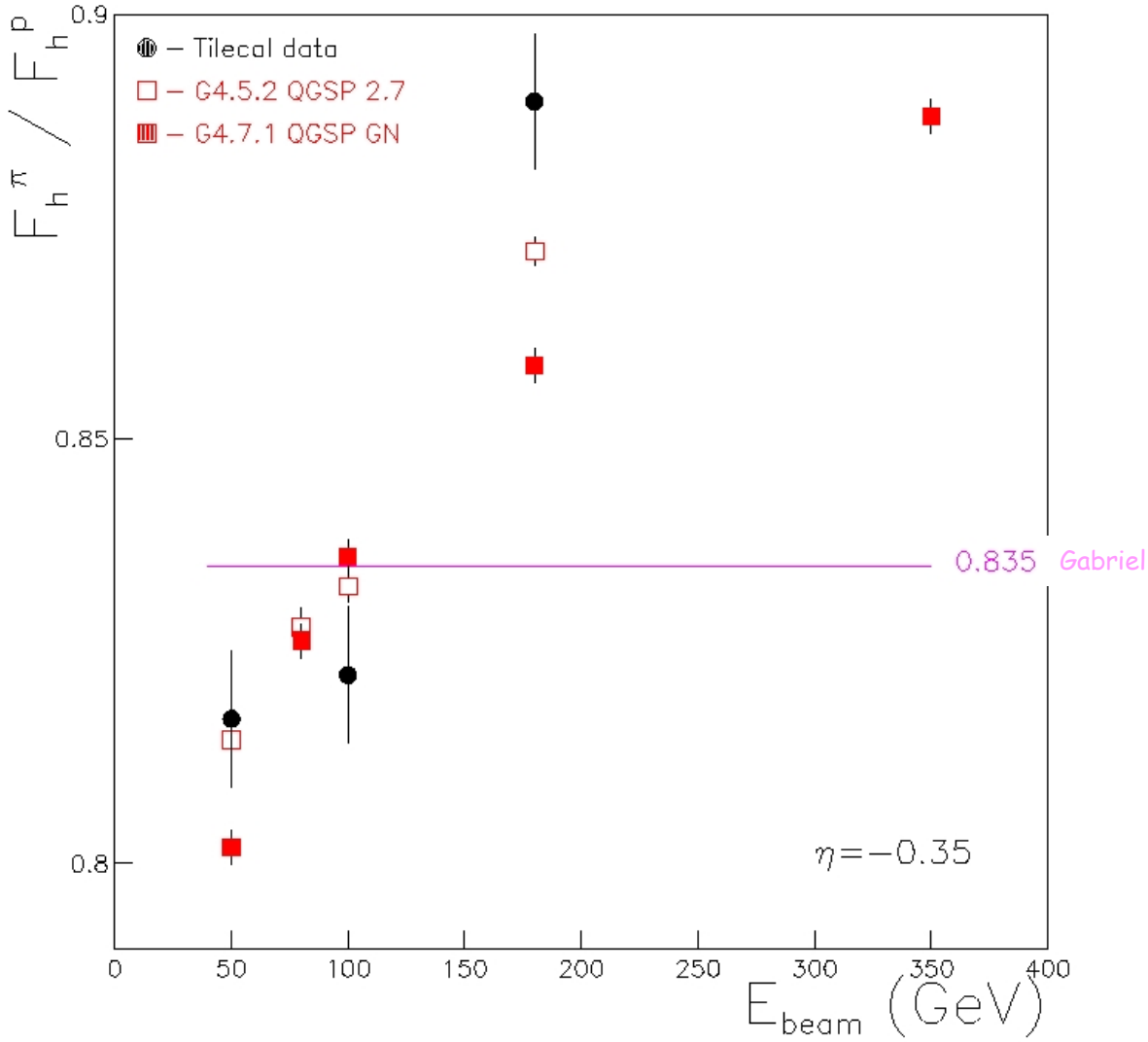


ratio between pion and proton pure hadronic fractions:

These results were obtained using energy deposition of electrons, pions and protons only from electron beams.

Both test beam data and simulations are showing an increase of the ration with the beam energy.

Gabriel et al results have no energy dependence.



conclusions:

• since different physics processes are involved in the showers initiated by pions and protons, the comparison of Geant4 predictions with the test beam data concerning the differences between pion and proton response, presents a special interest for the Geant4 physics validation.

• the main characteristics, observed in this comparison are the following:
  • the ratio π/p between the pion and proton Tilecal response has values greater than unity at all the incident energies for both test beam data and simulations
  • the decrease with the energy of the ratio π/p is observed in data and simulations
  • the decrease with the energy of the ratio π/p, given by Geant4 simulations, is in better agreement with the data than the simulations with G-Calor

• the values of the fraction of the energy deposited in the central tower are higher for pions than for protons in data and simulations (wider lateral shower profiles for protons)

• Geant4 gives higher values for the fraction of energy deposited in the central tower than the data (for pions as well as for protons) the fraction of the energy deposition in the central tower is increasing with the energy in data and simulations

• the decrease of the e/π and e/p ratios with the energy is well described by the Geant4 simulation

• values less than unity were obtained for the ratio between the pure hadronic fraction of pions and the pure hadronic fraction of protons in data and simulations, in agreement with Gabriel and al.

• the increase of this ratio with the energy, observed in the data and Geant4 simulations, is in contrast with the constant behavior predicted by Gabriel and al.

further analysis:

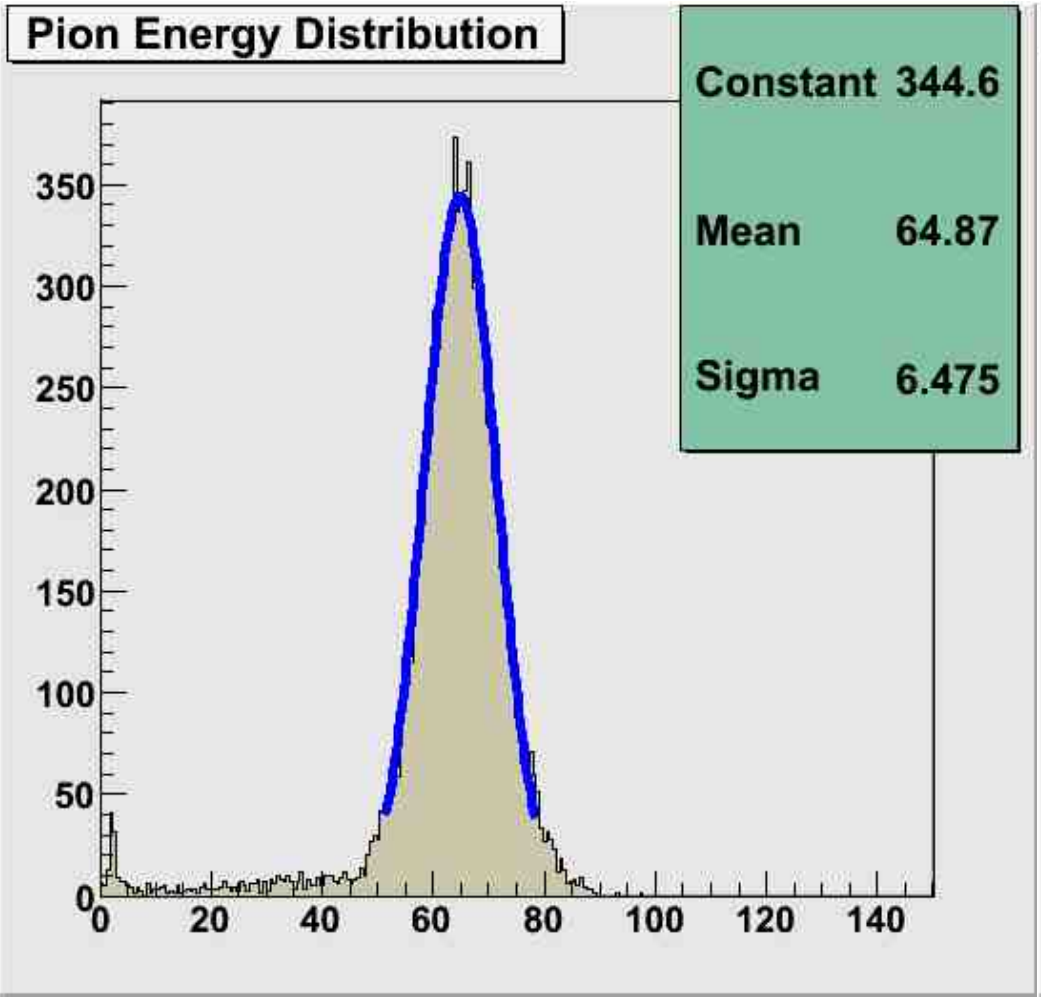
- new simulations with Geant4.8
- ATLAS Combined Test Beam data

backup slide 1:

with electronics simulation:

- bigger σ
- smaller E_{mean}

electronics simulation $\sigma / E_{mean} = 0.0998$



no electronics simulation $\sigma / E_{mean} = 0.0937$