

# Results from ATLAS Tile Calorimeter: a comparison between data and Geant 4 simulation

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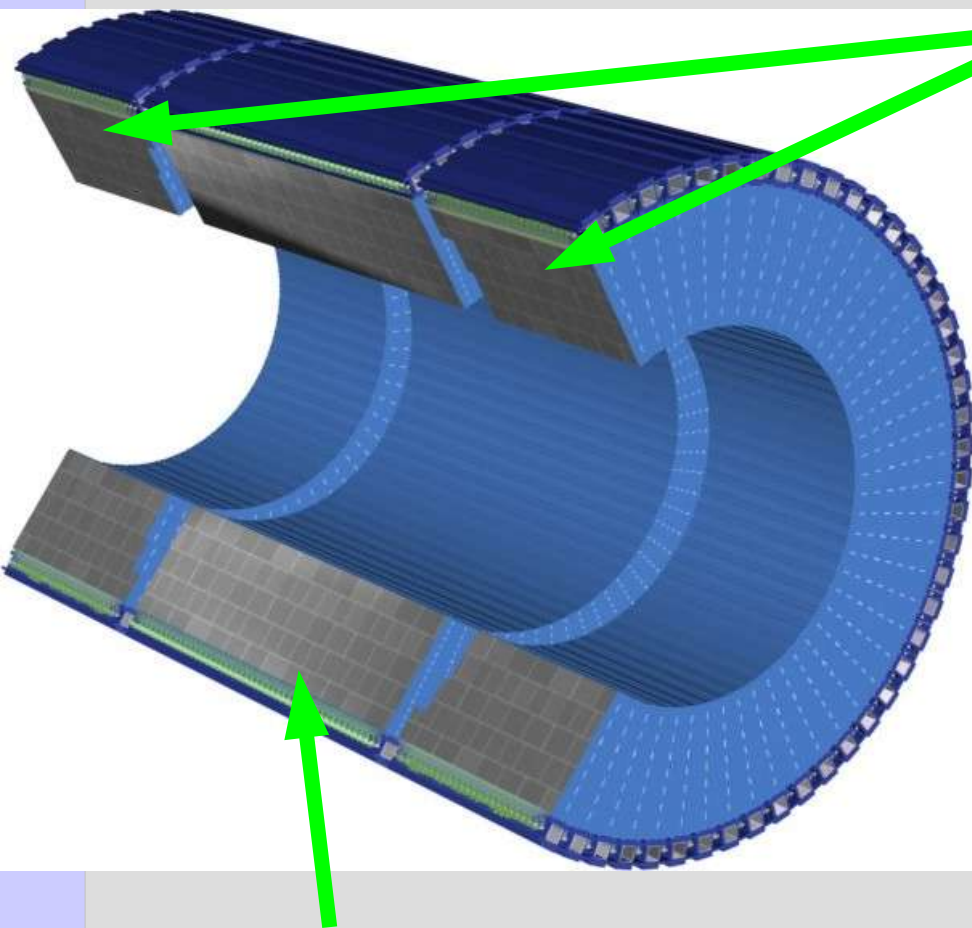
9<sup>th</sup> Topical Seminar on Innovative Particle and Radiation Detectors  
Siena, 23 – 26 May 2004



# Introduction

- Calorimeter description and setup at Test Beam
- Geant 4 Simulation
- Results for electrons at high and Very Low Energy at different geometries (linearity and resolution)
- Results for pions at high and Very Low Energy at different geometries ( $e/\pi$ , resolution and partial shower profile)
- Conclusions

# ATLAS Hadronic Calorimeter: TileCal



Extended Barrel Modules

**TileCal**: The central ATLAS Hadronic Calorimeter. Divided in 3 Sections, 64 phy modules each.

Pseudorapidity coverage :  $|\eta| < 1.7$

Sampling Calorimeter: Fe(82%)-Sci(18%)

3 Longitudinal Sections for a total of  $7.2 \lambda$

Segmentation:  $\Delta\eta \times \Delta\phi = 0.1 \times 0.1$

Design Resolution:  $\sigma/E \approx 50\%/\sqrt{E}$

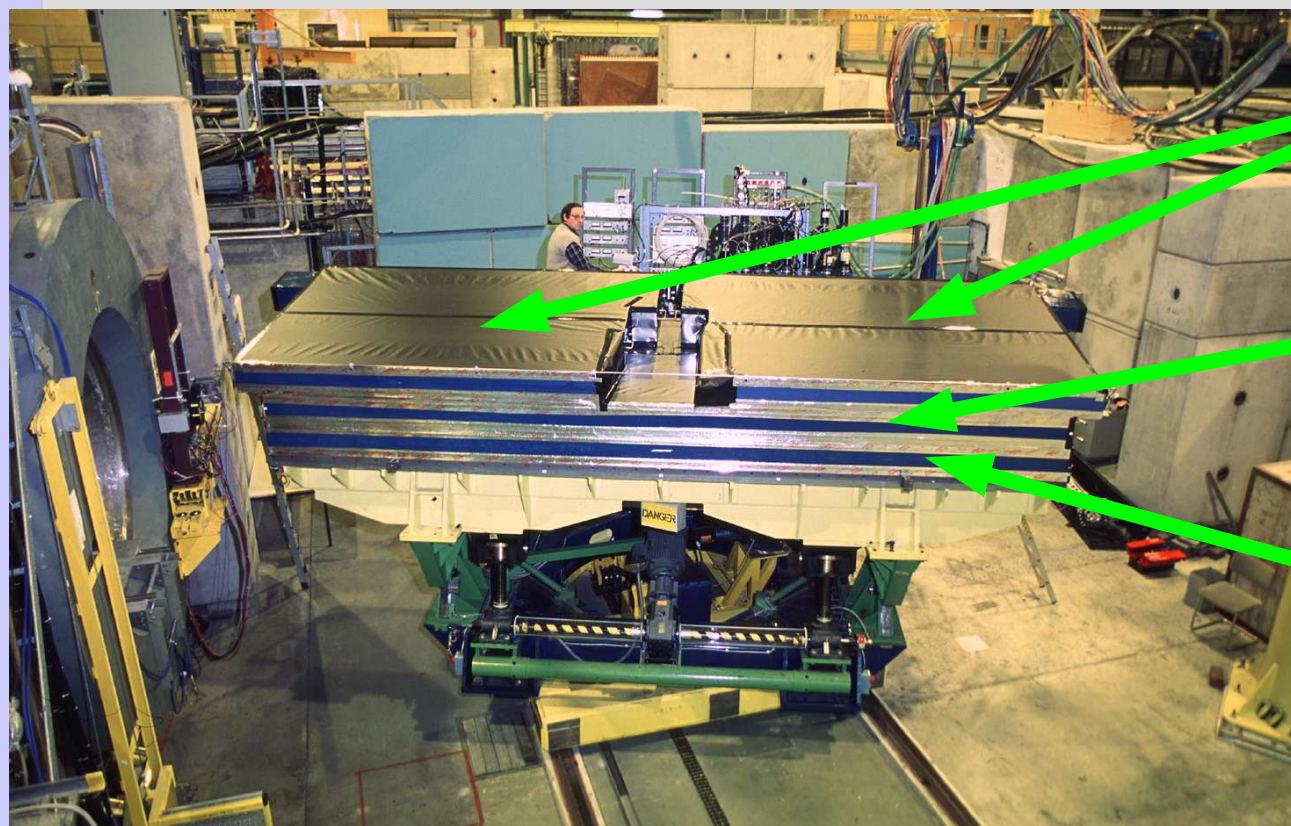
Barrel Modules

# Test Beam Activity

In the Period 2001 – 2003 an extensive Test Beam Calibration Program has been developed at CERN. 14 EB and 9 B modules have been calibrated with electrons, pions and muons of different energies (10 – 180 GeV), a special session (Very Low Energy: 1 – 9 GeV) has been carried out in 2003.

Different beam impinging geometries have been used (projective and 90 degree: simpler geometry to study uniformity)

# Test Beam Setup



Extended Barrel Modules

Barrel Module

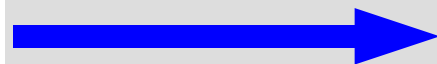
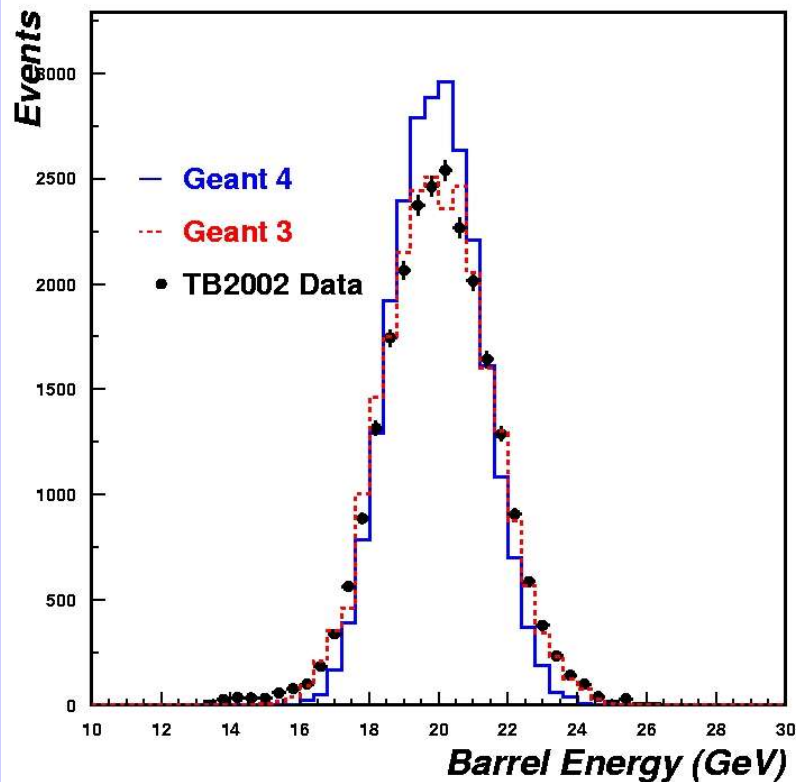
Reference Barrel  
Module (Module 0)

A special version of Geant 4 simulation Package (FADS/Goofy by V. Tsulaya) has been developed to simulate Test Beam setup. Electrons and pions real data have been compared to simulated data to tune G4.

# Geant 4 for TestBeam

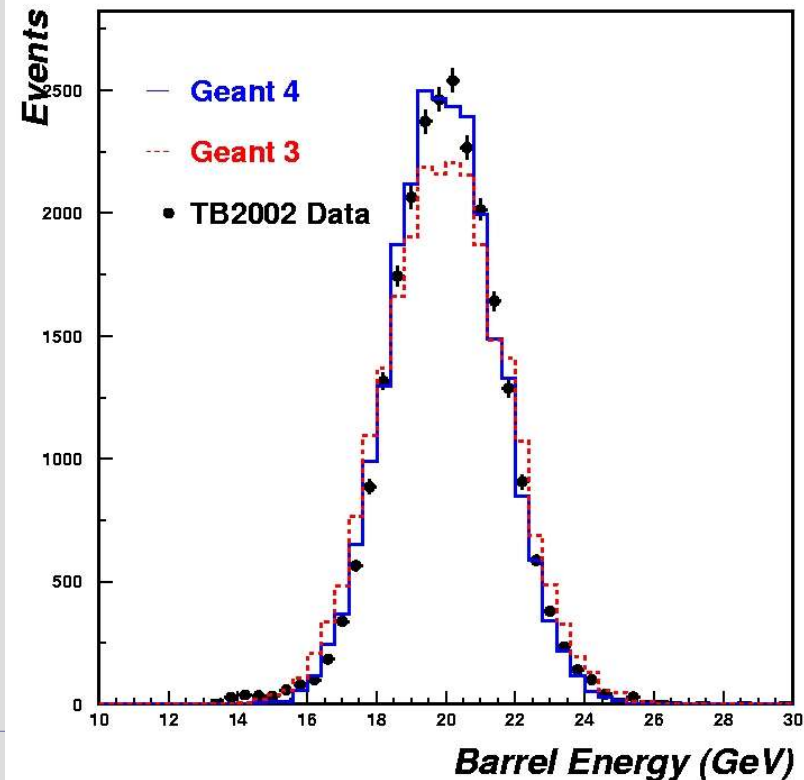
- Two hadronic physic lists have been compared: LHEP 2.7 parametrized models for inelastic scattering; QGSP 3.6 theory driven modeling for hadronic interactions
- Simulated response is treated as in Test Beam:  $E(\text{GeV}) = c * R$ , where  $c$  is the electromagnetic calibration constant  
 $c = E_{\text{beam}}(e) / E_{\text{vis}}(e)$  and  $R$  is the response of the calorimeter (in GeV)
- In the simulation electronic noise and photo statistic fluctuations (measured from real data) have been added introducing a gaussian smearing

20 GeV electrons,  $\eta=0.65$  (Data Run r0210612)



Improvement  
achieved adding  
noise sources

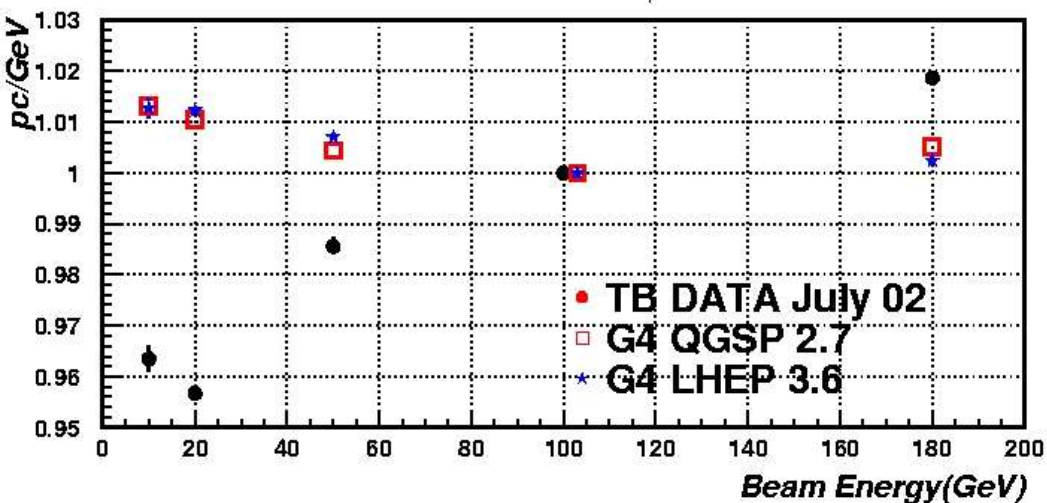
20 GeV electrons,  $\eta=0.65$  (Data Run r0210612)



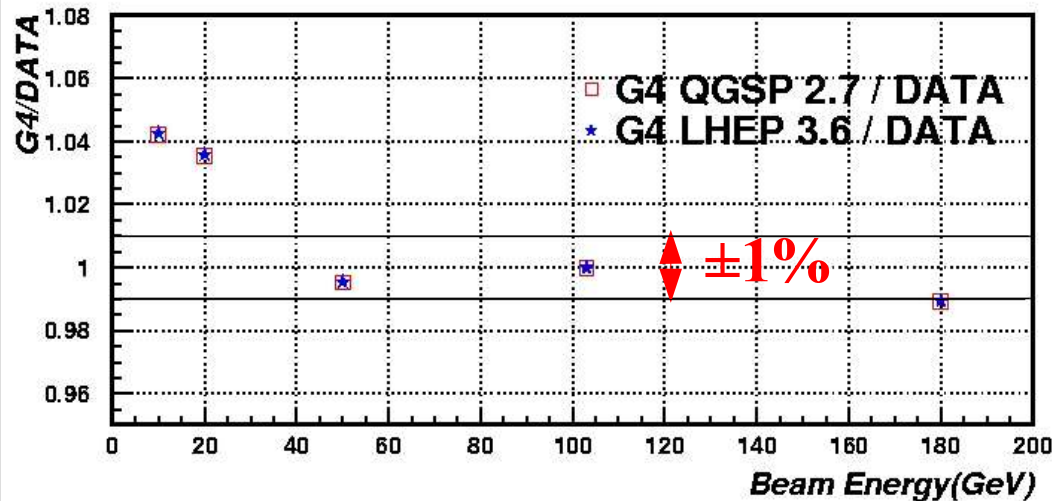
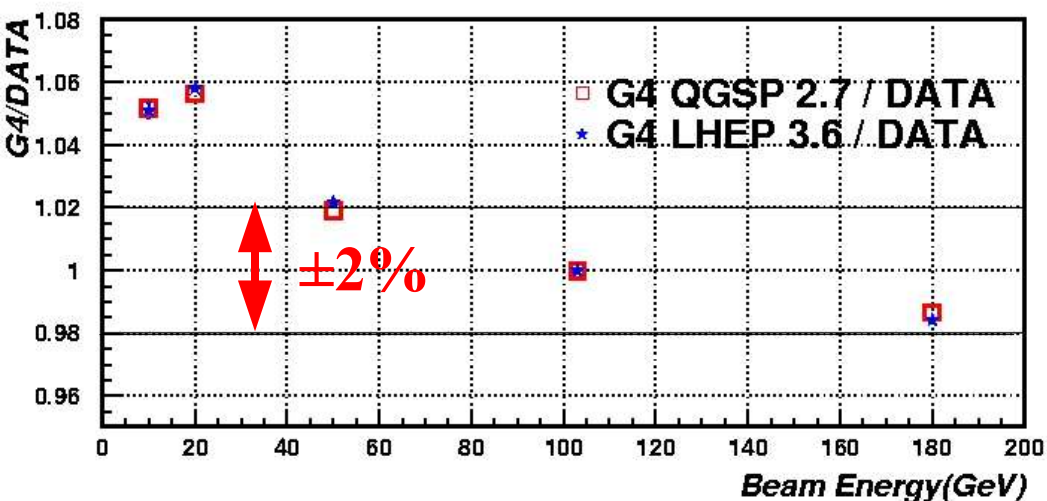
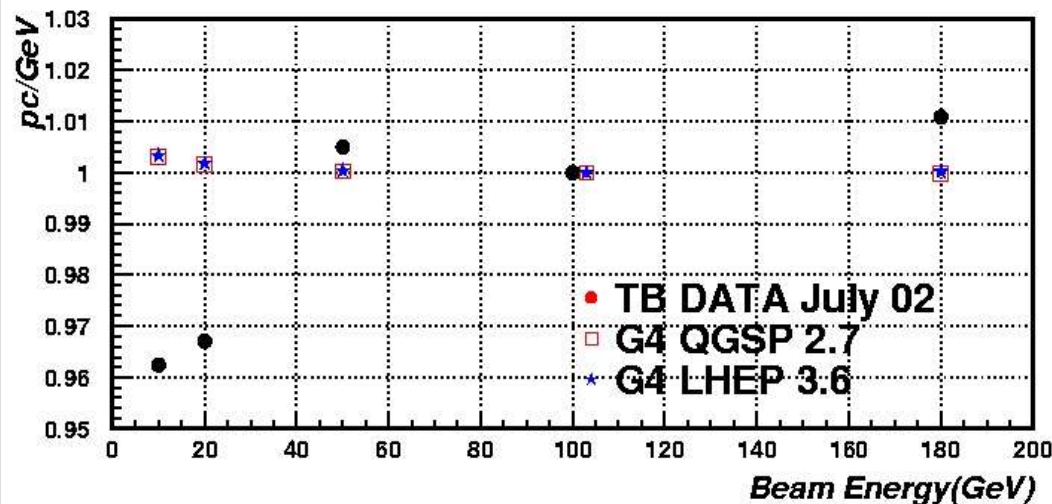
# Results for electrons: linearity

A dependence on E in real data is visible ( $\sim 6\%$ ) that is not present in G4. The problem is related to the energy calculation algorithm and electronic gain, more detailed studies are in progress.

electrons with  $\eta = -0.65$

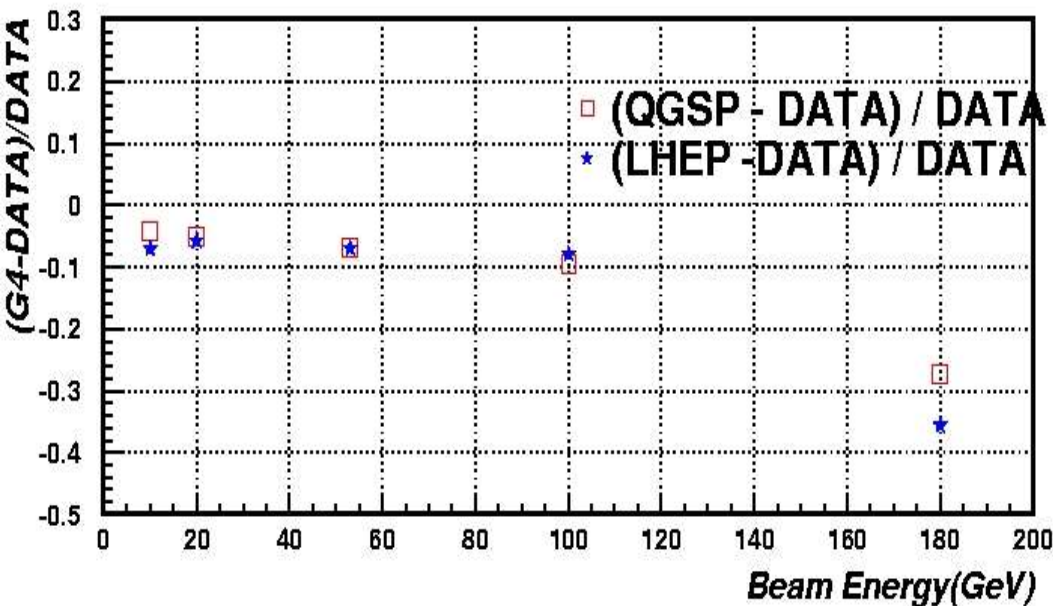
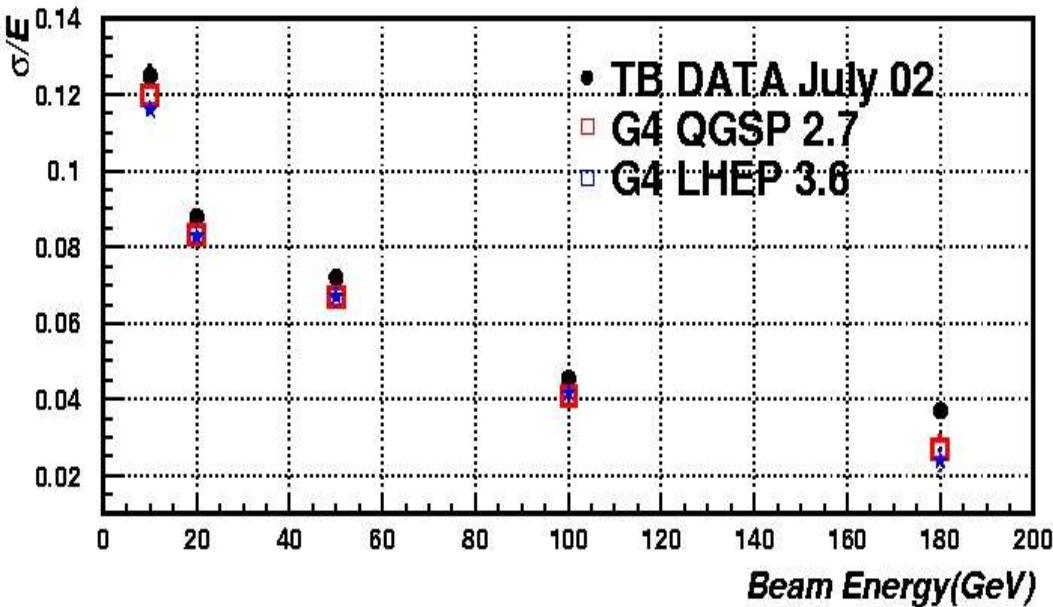


electrons with  $\vartheta = -90$ , tr5



# Results for electrons: resolution

electrons with  $\eta = -0.65$



The resolution is in good agreement between data and simulation. The data have been fitted with:

$$\sigma/E = a/\sqrt{E} \oplus b$$

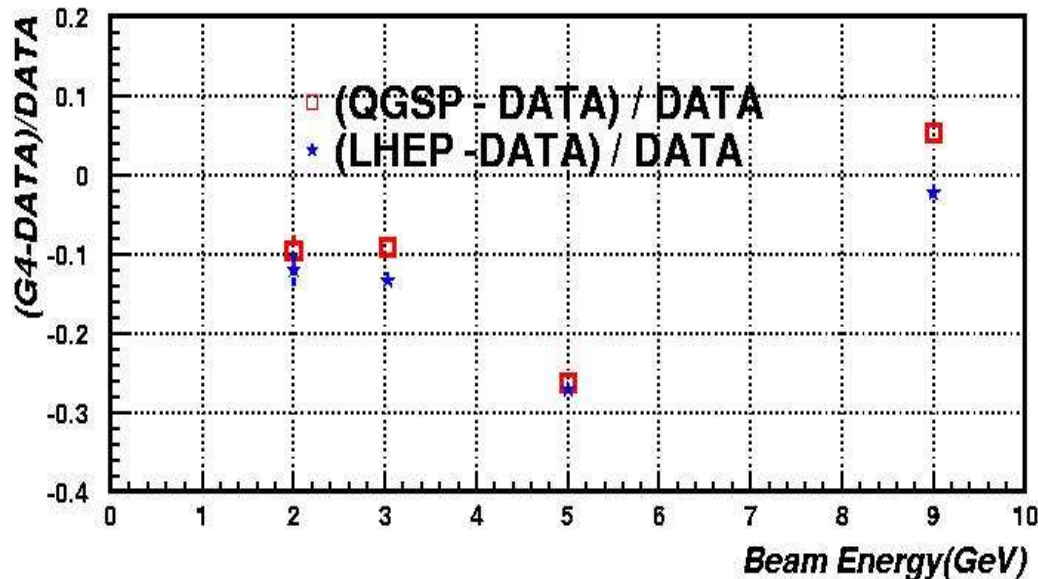
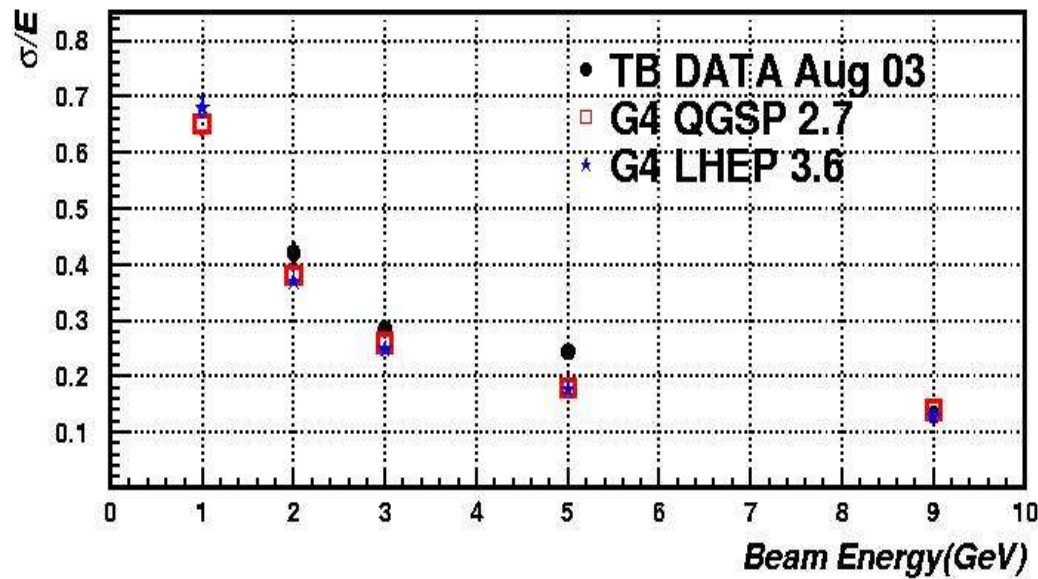
$a/\sqrt{E}$

$b$

	$a/\sqrt{E}$	$b$
QGSP	$(34 \pm 1)\%$	$(0.9 \pm 0.2)\%$
LHEP	$(34.5 \pm 0.8)\%$	$(0.7 \pm 0.1)\%$
DATA	$(35 \pm 1)\%$	$(1.1 \pm 0.1)\%$

# Results for electrons: resolution for VLE

electrons with  $\eta = -0.35$



- At 1 GeV is not possible in data to separate e from  $\pi$
- Agreement is  $\pm 10\%$  (except point at 5 GeV)
- The fit has been performed with only  $a/\sqrt{E}$  as b is difficult to extract at these low values

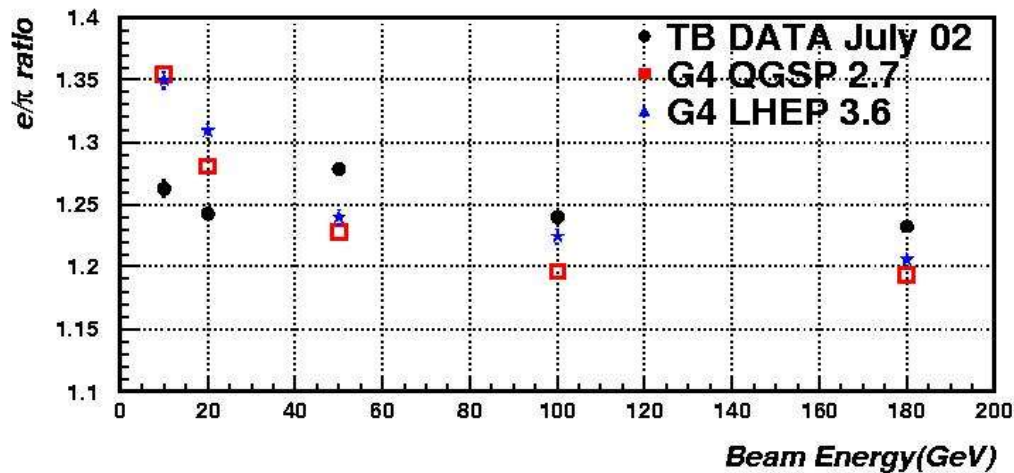
$a/\sqrt{E}$

QGSP	$(62 \pm 2)\%$
LHEP	$(63 \pm 2)\%$
DATA	$(72 \pm 2)\%$

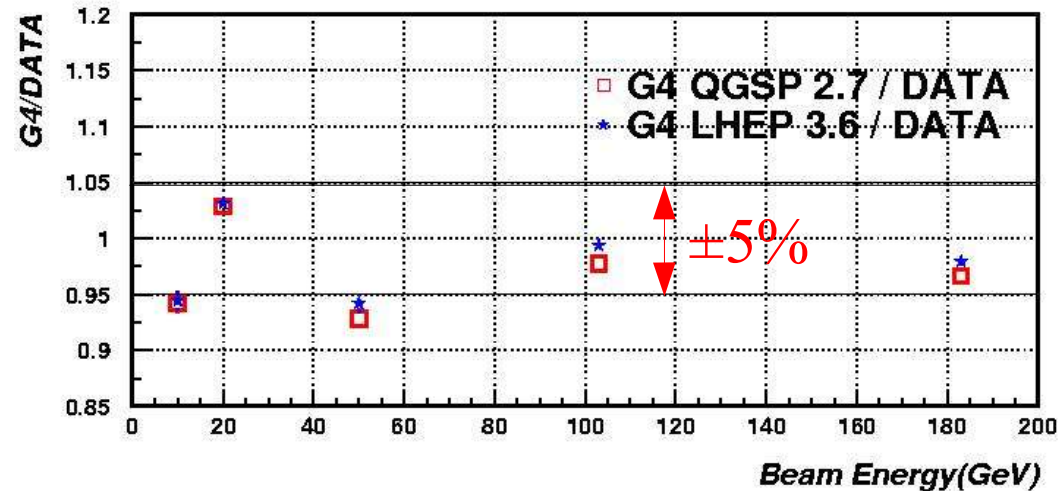
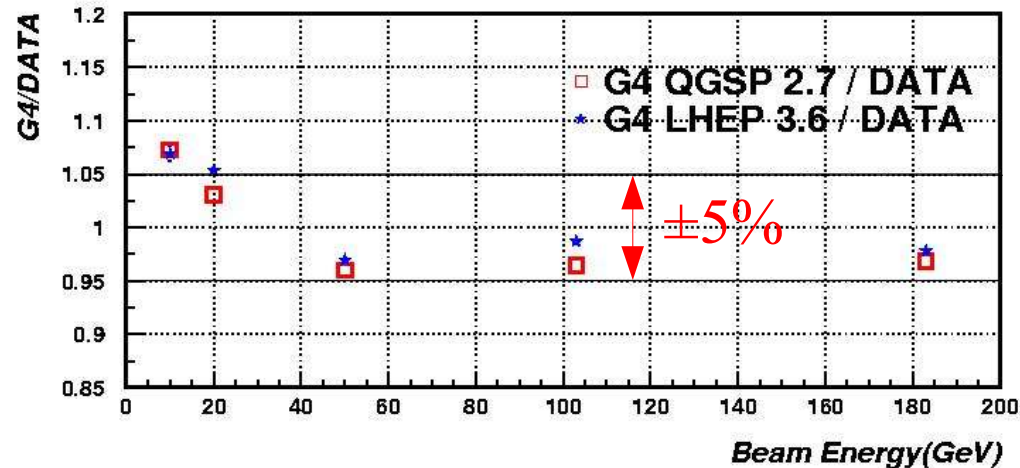
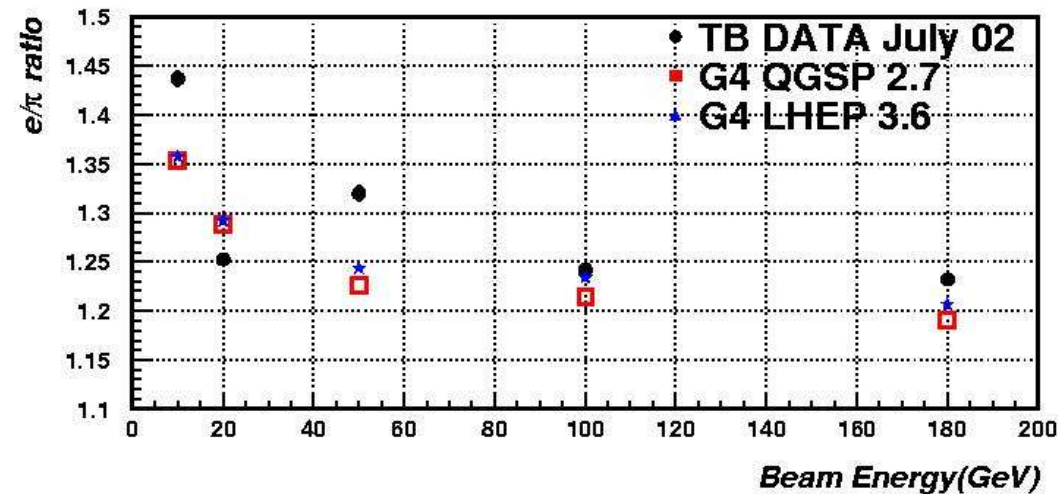
# Results for pions: $e/\pi$ ratio

- General agreement is  $\pm 5\%$  at the two different impinging geometries
- There are no major differences in the two physics lists LHEP and QGSP

TB DATA JULY02,  $\eta = -0.65$



TB DATA JULY02,  $\vartheta = -90$ , tr 5



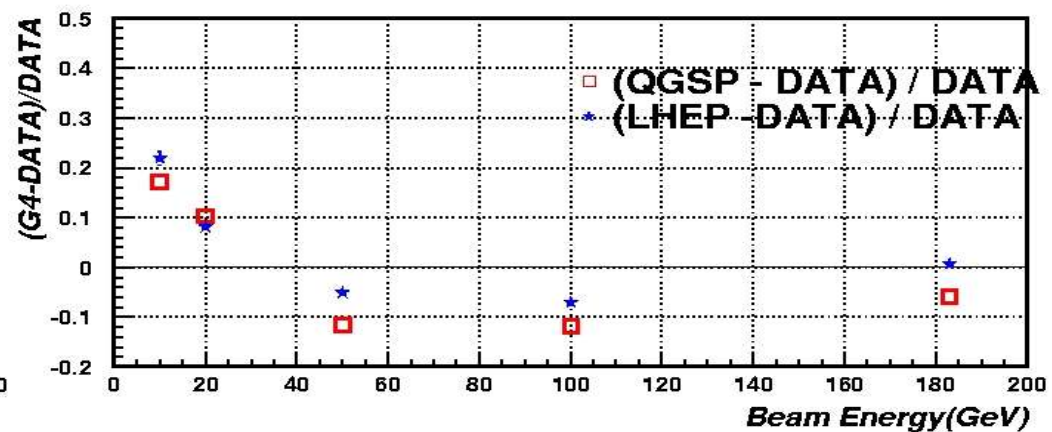
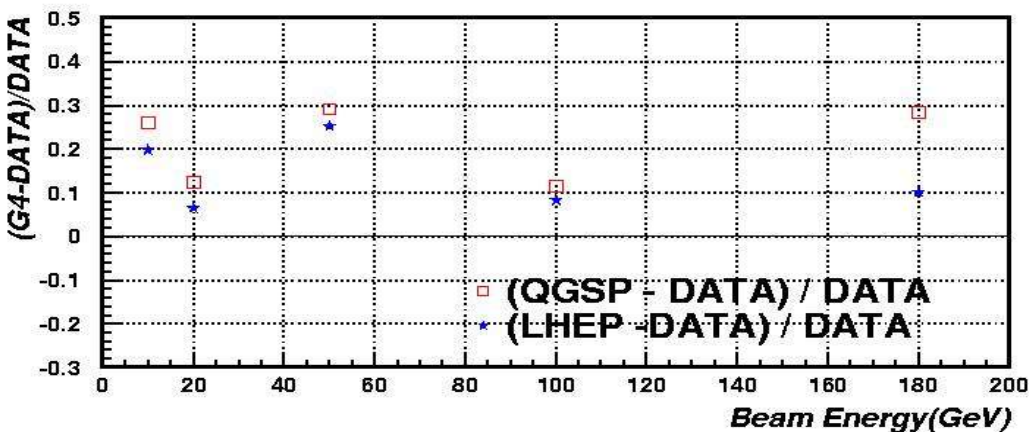
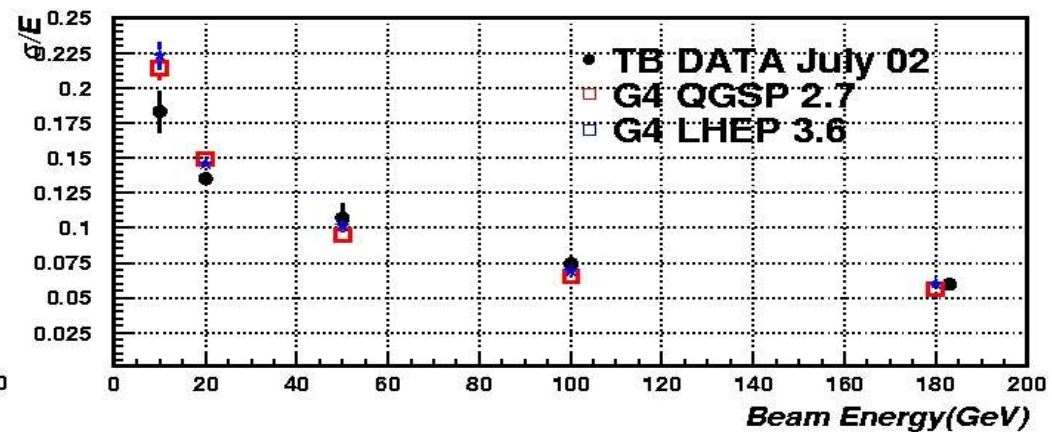
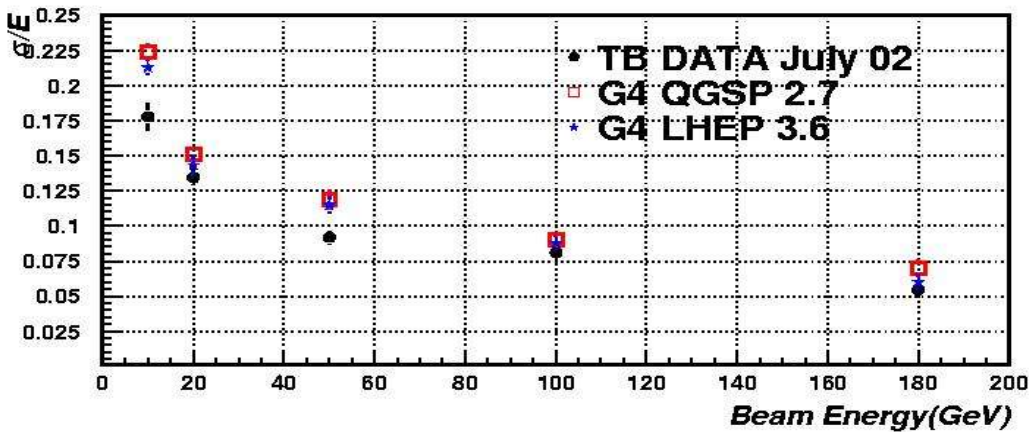
# Results for pions: resolution

	$a/\sqrt{E}$	$b$
QGSP	$(58 \pm 3)\%$	$(2.9 \pm 0.5)\%$
LHEP	$(59 \pm 3)\%$	$(2.4 \pm 0.5)\%$
DATA	$(53 \pm 2)\%$	$(2.0 \pm 0.2)\%$

	$a/\sqrt{E}$	$b$
QGSP	$(61 \pm 2)\%$	$(7.0 \pm 0.2)\%$
LHEP	$(60 \pm 1)\%$	$(1.3 \pm 0.2)\%$
DATA	$(51 \pm 2)\%$	$(2.1 \pm 0.2)\%$

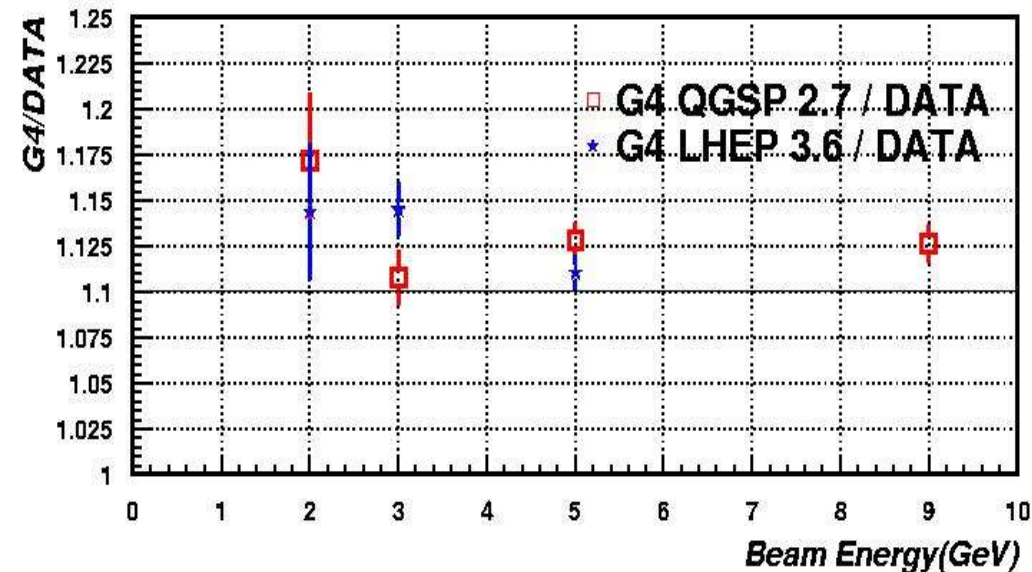
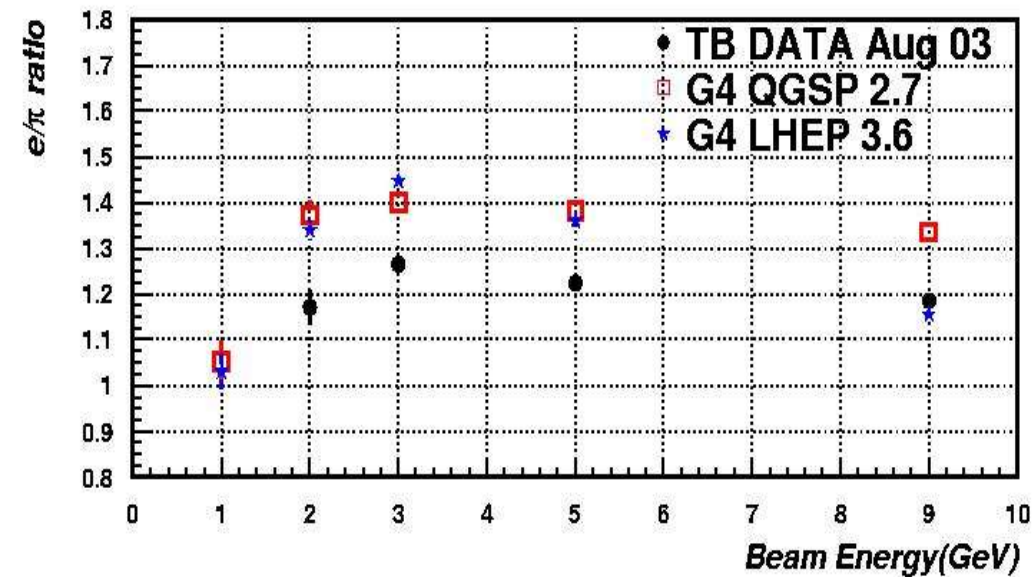
pions with  $\eta = -0.65$

pions with  $\vartheta = -90$ , tr5



# Results for pions: $e/\pi$ for VLE

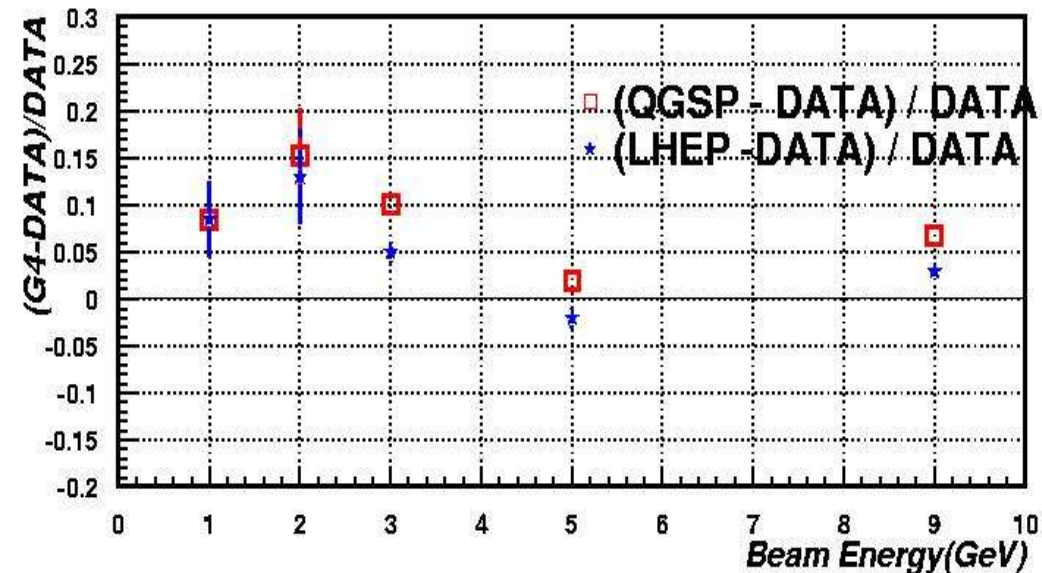
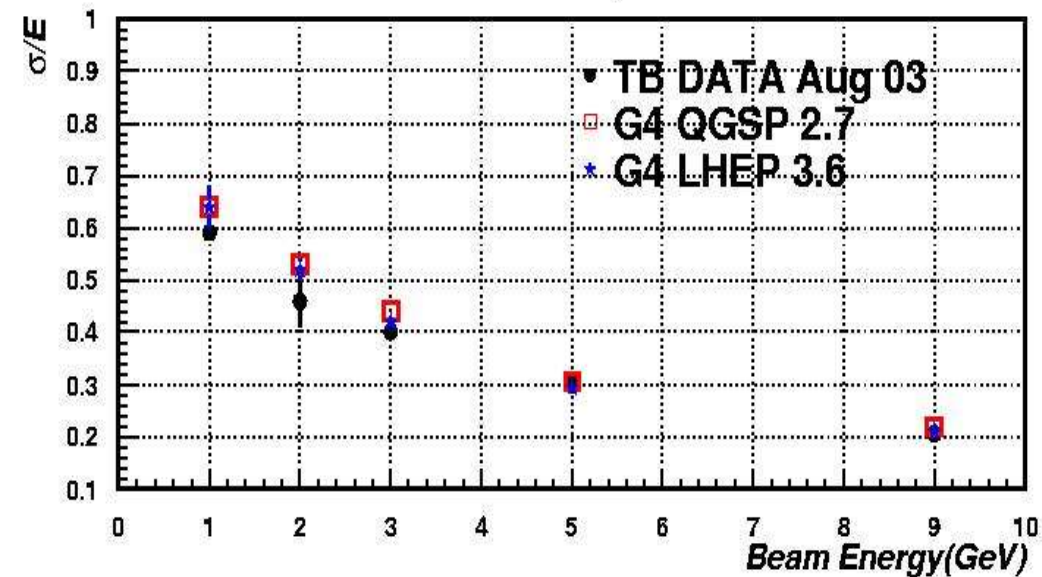
TB DATA AUG03,  $\eta=-0.35$



- For  $E < \sim 5 \text{ GeV}$   $e/\pi$  begins to become smaller both for TB data and MC and doesn't follow anymore the usual parametrizations
- In real data is not possible to separate  $e$  and  $\pi$  at 1 GeV (MC gives  $e/\pi=1.05$ , TileCal granularity is not enough high to distinguish using shape profile methods)
- No main differences between LHEP and QGSP

# Results for pions: resolution for VLE

*pions with  $\eta = -0.35$*

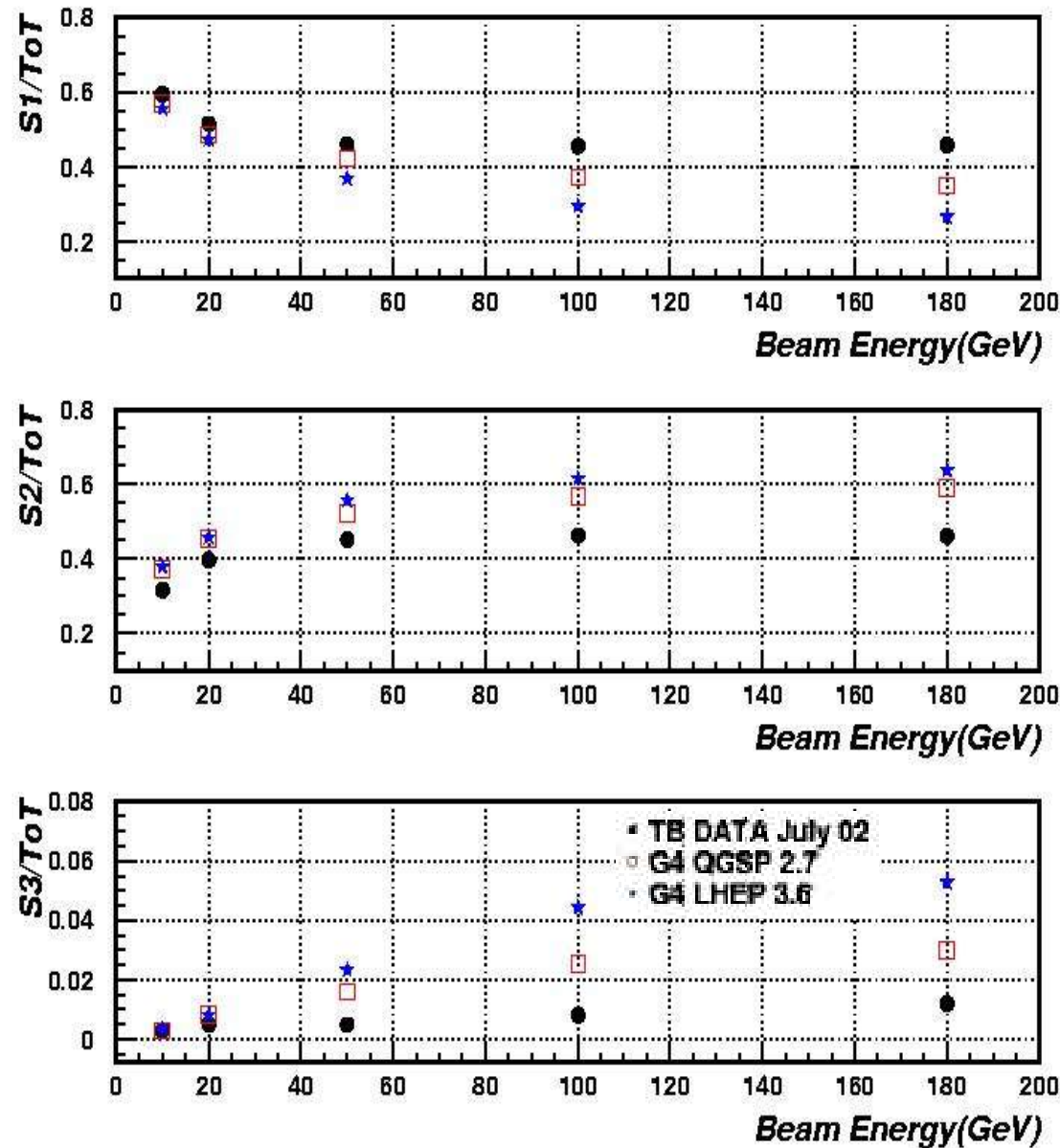


- For 1 GeV point all the data have been considered pions:  $e/\pi \approx 1$ ,  $\sigma/E(e) \approx \sigma/E(\pi)$
- Also in this case no major differences between the two physic lists

$a/\sqrt{E}$

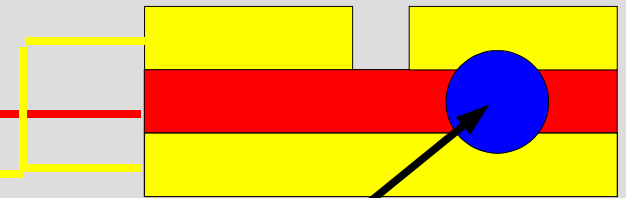
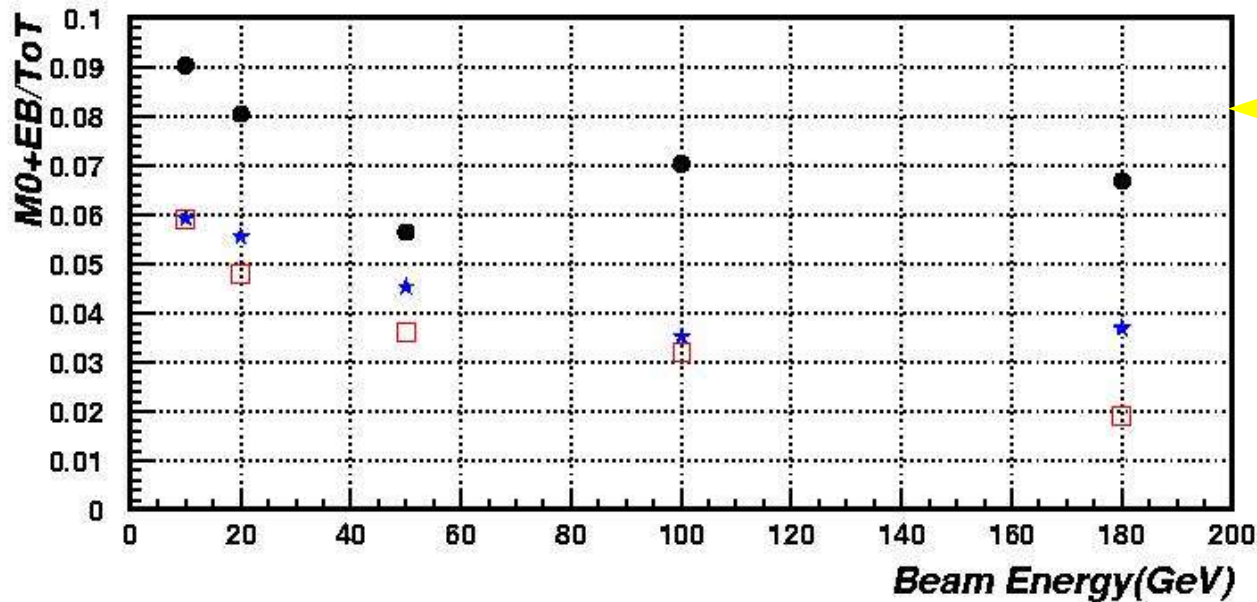
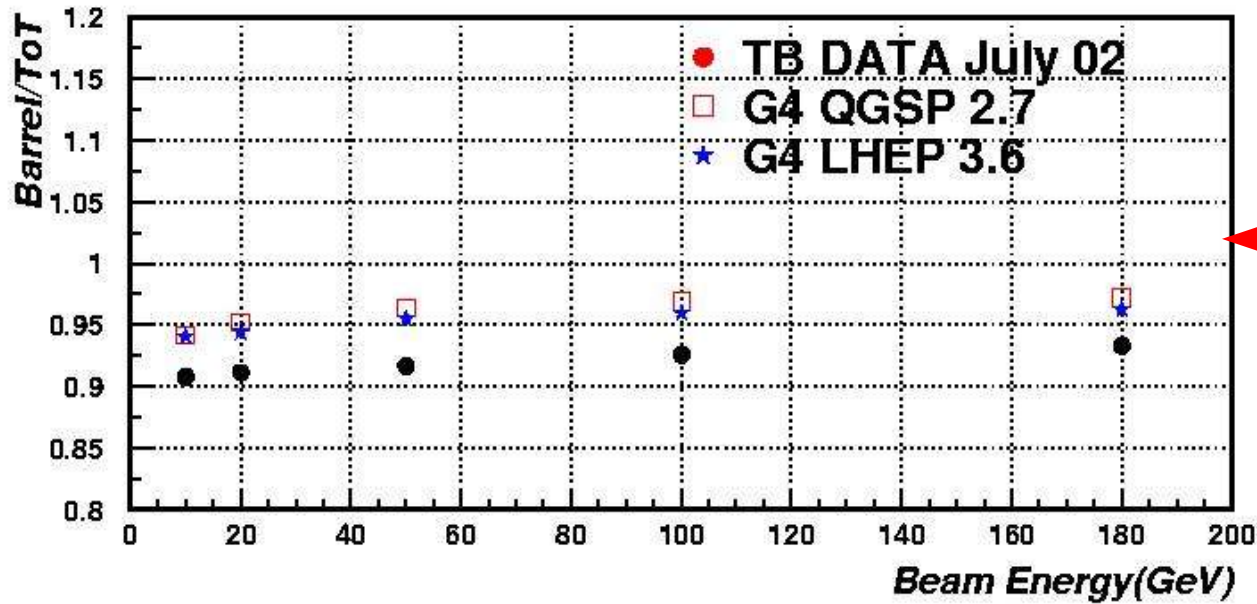
QGSP	$(81 \pm 3)\%$
LHEP	$(80 \pm 2)\%$
DATA	$(72 \pm 3)\%$

# Results for pions: longitudinal shower profile



- Energy deposit in one sample over the total energy deposit in the module is shown
- Geant 4 produces longer showers at high energy, especially in outer sample where MC gives  $\sim 5\%$  of Energy deposit and real data only 1%
- QGSP, however, better reproduces data

# Results for pions: partial transverse shower profile



- Only lateral deposit in Extended barrels and module 0 is considered
- G4 produces more compact shower, in particular QGSP
- ~7% of signal from data is in EBs+M0, while for G4 is ~3%

# Conclusions (1/3)

- Linearity is well described at all geometries ( $\pm 1-2\%$ ) excluding points at 10 and 20 GeV (electronic gain and energy calculation algorithm problems? work is undergoing)
- Electromagnetic resolution is in good agreement for high energy, and is  $\pm 10\%$  for VLE
- $\pi$  resolution is in sufficient agreement at all energies and geometries (some problems at  $\eta = -0.65$ : MC gives systematic higher values than real data)

# Conclusions (2/3)

- $e/\pi$  ratio is in agreement at the level of 5% for high energy, at VLE MC simulation gives too higher values, for  $E < 5\text{GeV}$   $e/\pi$  goes down to 1 ( $e/\pi(1\text{GeV})=1.05$ )
- Geant4 predicts too long  $\pi$  showers, while seems to simulate too compact showers in transverse dimension. QGSP better simulates the first, while LHEP the second. This is the most significant difference between the two physic lists

# Conclusions (3/3)

- This work is part of the “LCG Simulation Physics Validation Project” aiming to validate G4 physic for the future LHC experiments. The results are being compared to other experimental TB results (ATLAS Cu-LArg hadronic end cap, CMS brass-scintillator HCAL). A note is in preparation.