Preliminary comparison between GEANT4, Fluka and the TileCal 2002 Test Beam data

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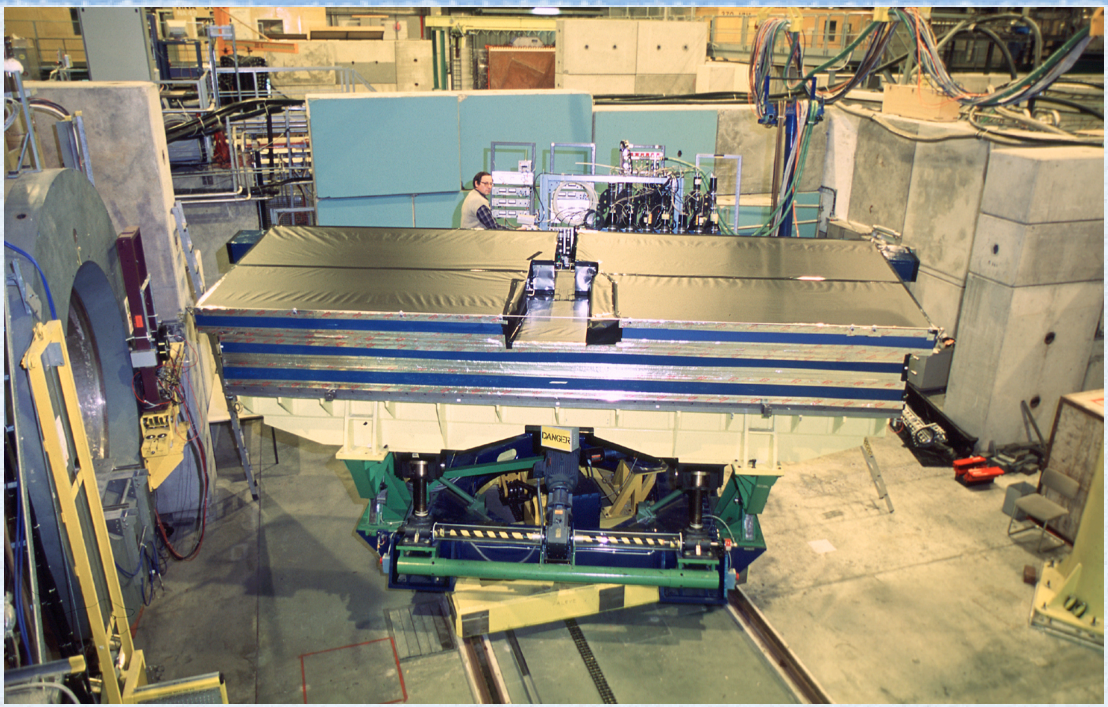
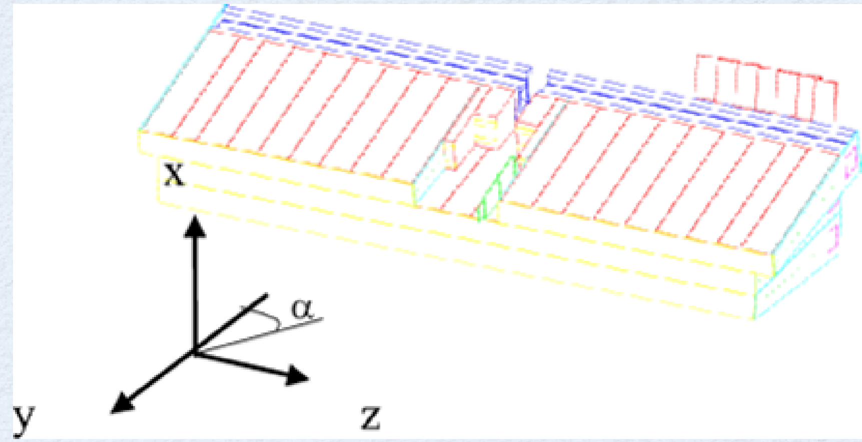
INTRODUCTION

- integration of Fluka in the test beam Monte Carlo machinery
- Some details on the analysis
- Total energy distribution
  - 20 GeV
  - 50 GeV
- Shower shape (at 20 GeV)
  - lateral end longitudinal shape
  - longitudinal shape correlations

The 2002 Test Beam





- 4 TileCal modules stacked together
- projective particle beam
  - electrons, pions, muons and protons
  - wide range of energies 2-350 GeV

Goal and Motivation

- Be able to compare simulations results from Geant4 and FLUKA with data in the context of the ATLAS Tile 2002 test beam.

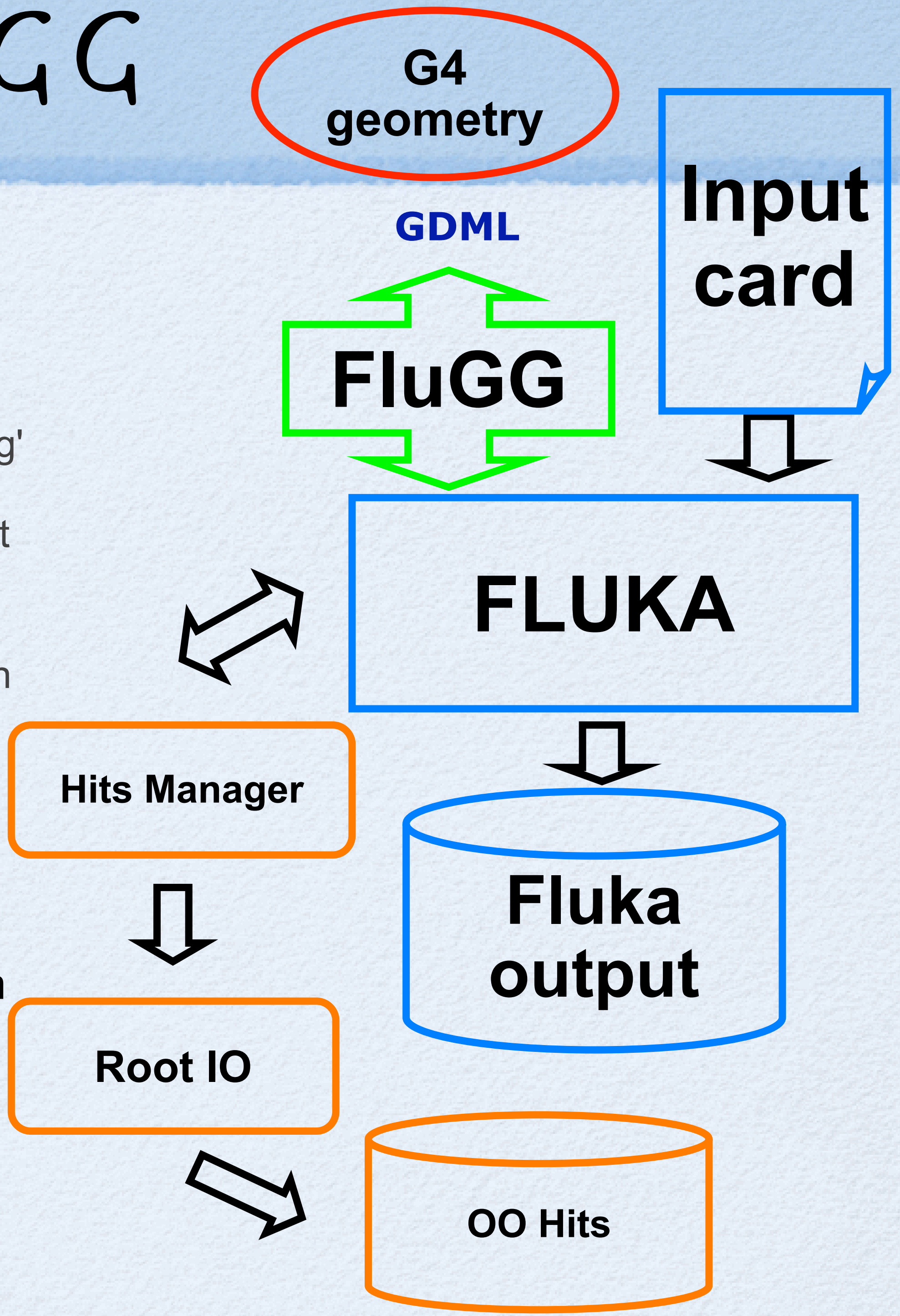
- To come up with a reusable machinery which is as much as possible application-independent:
  - In order to reduce implementation effort (and number of possible bugs) the maximum number of elements should be common to both G4 and FLUKA applications:
    - ✓ common source of geometry
    - ✓ same format of the simulation output allowing common digitization/analysis
  - ✓ Main principles:
    - ✓ Use GDML+FluGG+FLUKA to create FLUKA-hits with the material & geometry extracted from the G4 simulation of the TB.
    - ✓ Re-use as much as possible the work done for the Geant4 and data comparison: re-create the same ntuples, use the same macros for the analysis.

FLUGG

Fluka Geant4 Geometry Interface (FluGG) developed by P.Sala and S.Vanini

- allows running FLUKA with Geant4 geometry
  - FORTRAN - C++ interface allowing to 'plug' Geant4 geometry into FLUKA
- all the steering still done through FLUKA input cards
- all the output as in native FLUKA
  - configurable through input cards, based on FLUKA 'user routines'

- very useful tool, but a few things need to be added for the purpose of G4 - FLUKA validation:
  - Geometry is not always available in form of G4Classes (=> GDML)
  - Mimic of the G4 sensitive detectors
  - HitsManager
  - Root I/O hit persistency

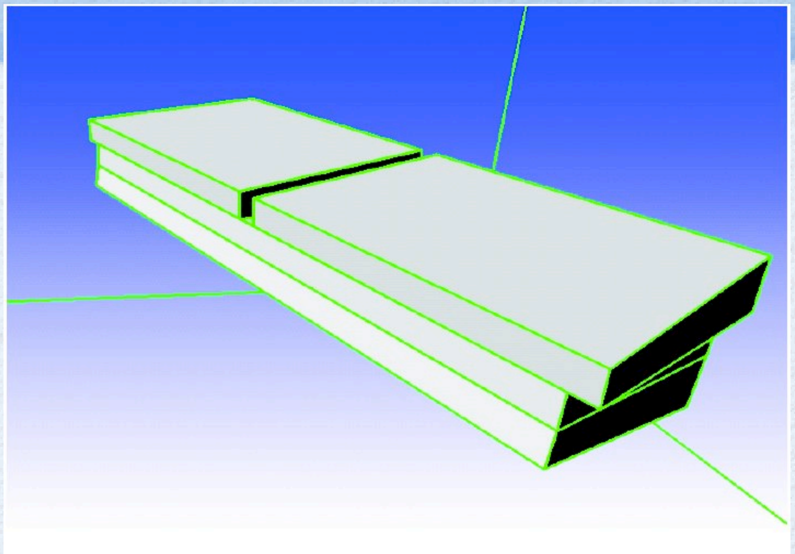


Geant4 Simulations and FLUKA hit analysis

- G4 simulations:
  - The geometry in use by the old Tile 2002 TB was ported (V. Tsulaia) to the ATHENA framework (ATLAS framework for event processing).
  - A G4Atlas application was assembled: the easiest way to use the latest G4 versions and (if needed) access to the digitization and reconstruction in use by the ATLAS exp.
- Geometry exportation:
  - Once the geometry is loaded into the Atlas G4 application it can be exported in xml format using the GDML writers.Fluka+Flugg can read the GDML geometry using the GDML readers
  - Any mismatch in between the geometries used by G4 and FLUKA will be detected at the time the FLUKA hits are processed.
- The read-out geometry (complex) implemented in the G4 SD is not exported.
  - The FLUKA-hits (pre/post step, PDG, energy, time) are read into the G4Atlas application and processed using the G4SD.
  - The process of FLUKA or G4 produces always the same TileHitVector container ---> we can use the same digitization, reconstruction and analysis
- Analysis:
  - Can be done at the step level, hit level or after digit+reconstruction
  - To reproduce the Tile2002 analysis a specific G4UserAction was created. It produces paw tuple information at the level of the energy-hit.

More information can be found in W. Pokorski and M. Gallas presentations at LCG Physics Validation Meeting 25 Jnauary 2006:
http://indico.cern.ch/conferenceDisplay.py?confId=a06408

Monte Carlo Data



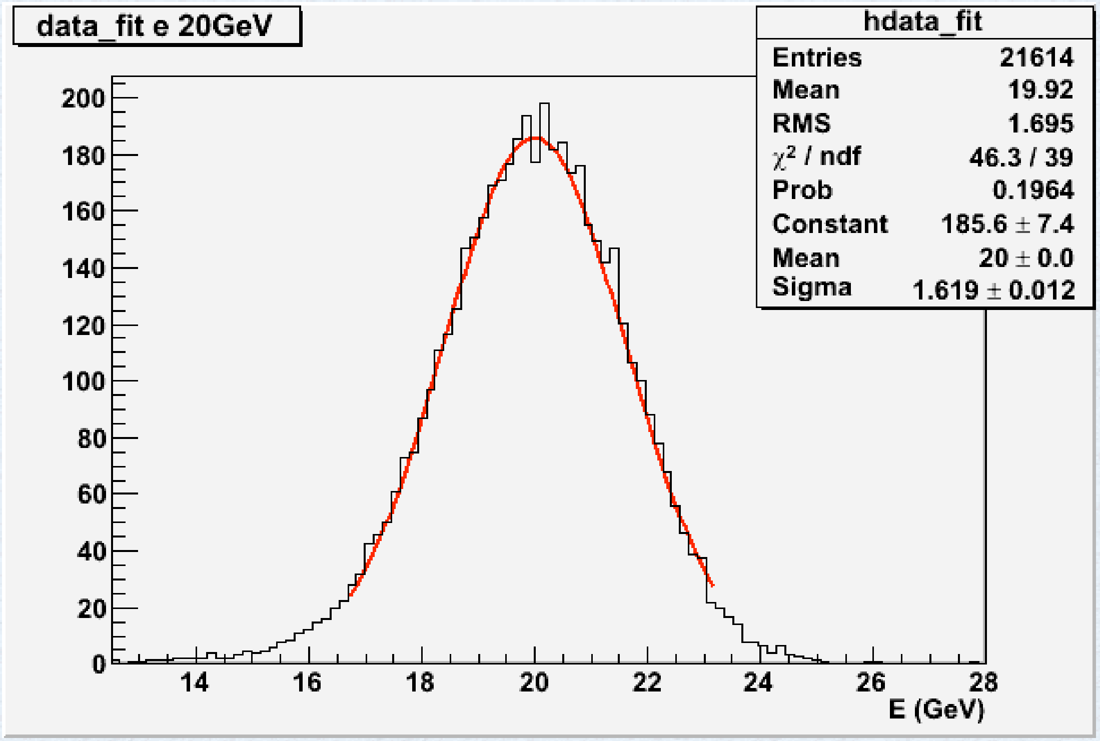
- One position of the Tile calorimeter at eta=0.35
- The coordinate system has (0,0,0) at the center of the central barrel module 1, below we have the module0 and on top two extended barrels.
- Particle gun:
  - PDGs: +11, -211, +211, 2212, +13
  - beam spot flat at -3000 mm (z and y in [-16,9,16,9] mm)
  - beam smearing in theta and phi
  - constant energies: 20-350 Gev.

- **Geant4**
  - Two versions:
    - geant4-07-patch-01 (25 Oct 2005)
    - geant4-08-01-patch-01 (27 Jul 2006)
  - Two physics lists: QGSP, QGSP_BERT
  - ATLAS standard cuts of 1mm.
  - Birks' law implemented in the G4 sensitive detector.
  - Time cut in the hit collection 200ns

- **FLUKA**
  - One version:
    - FLUKA-2006.3
  - Configuration card: CALORIMEter
  - Cuts suggested by Paola Sala (100kev for e+- and 5 kev for gammas)
  - Birks' law (quenching) implemented in FLUKA.
  - Time cut in the hit collection 200ns

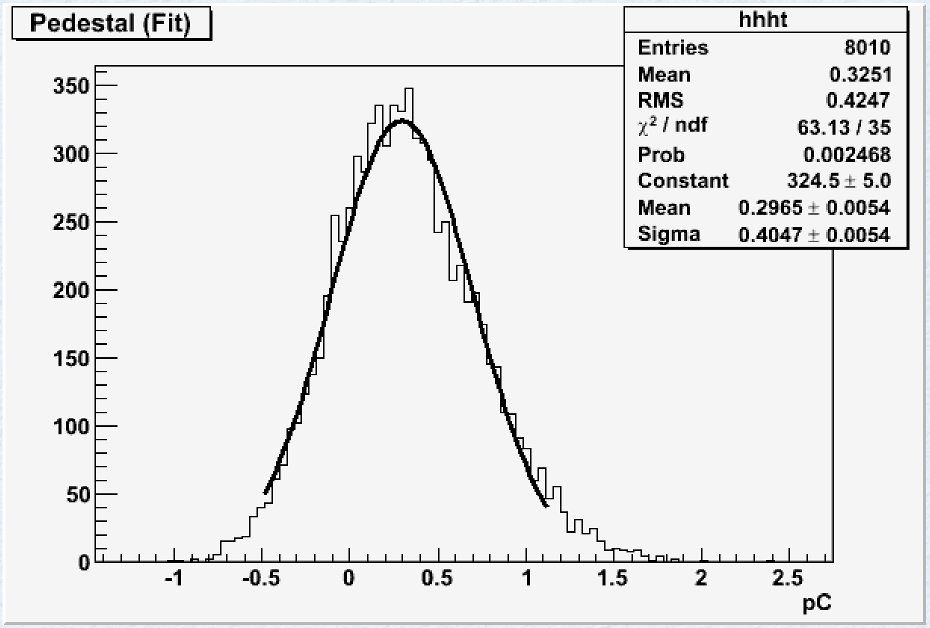
CALIBRATION

- Energy measured summing over 3 half-modules ($-0.7<\eta<0$)
- residual pedestal (small) subtracted from data



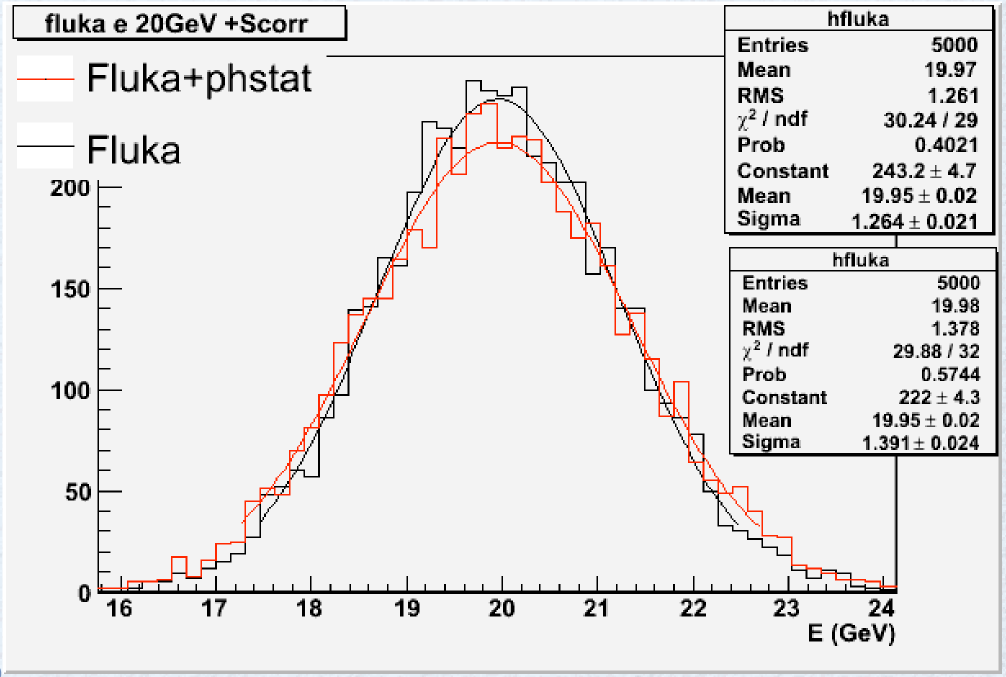
- data and MonteCarlo are both calibrated at nominal beam energy (20 GeV electrons)

CORRECTIONS

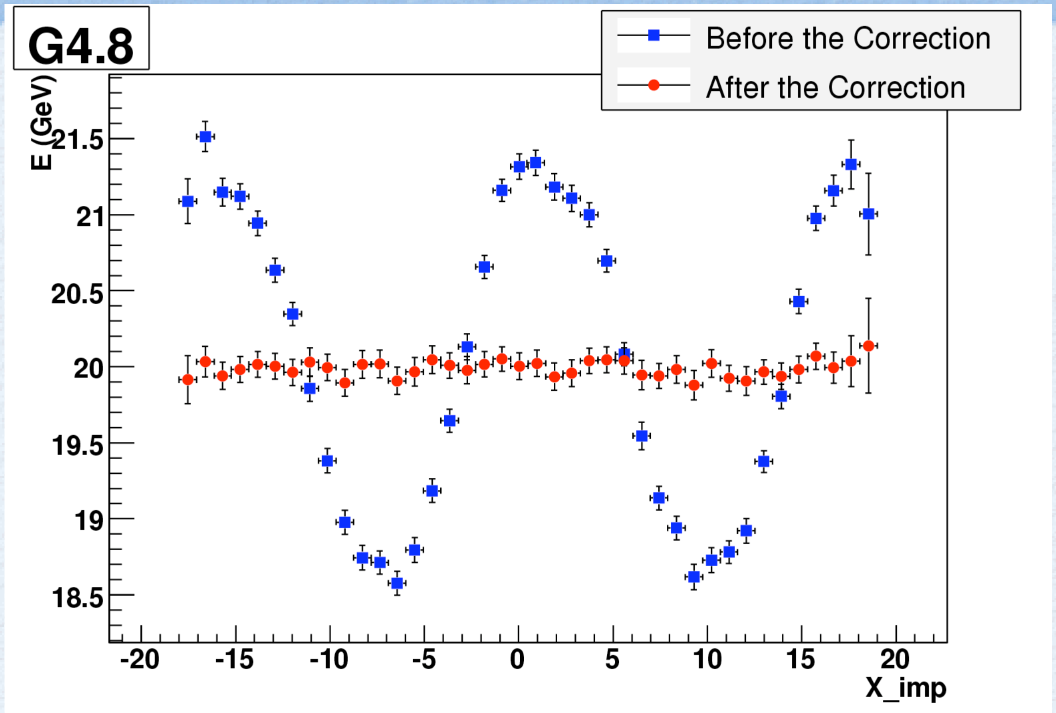


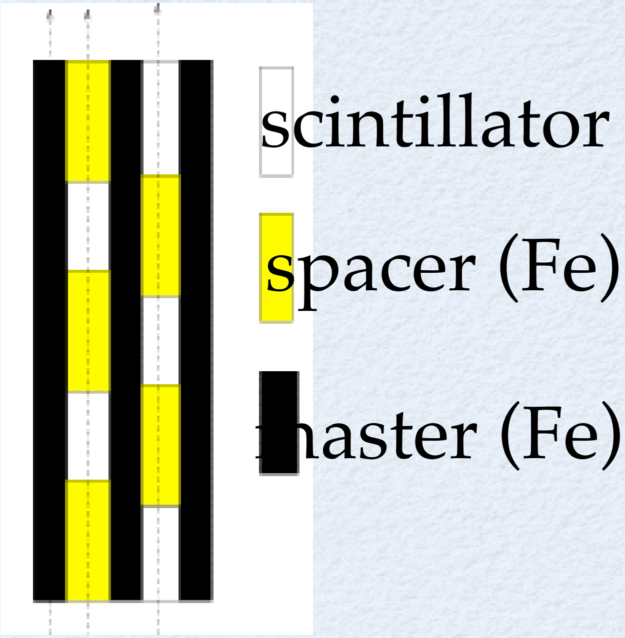
electronic noise is measured on data and a correspondent gaussian noise is added to the simulations

to account for the effect of photostatics we also add a poissonian fluctuation to the MC (70.7 photoelectrons per GeV).



Corrections: S-shape



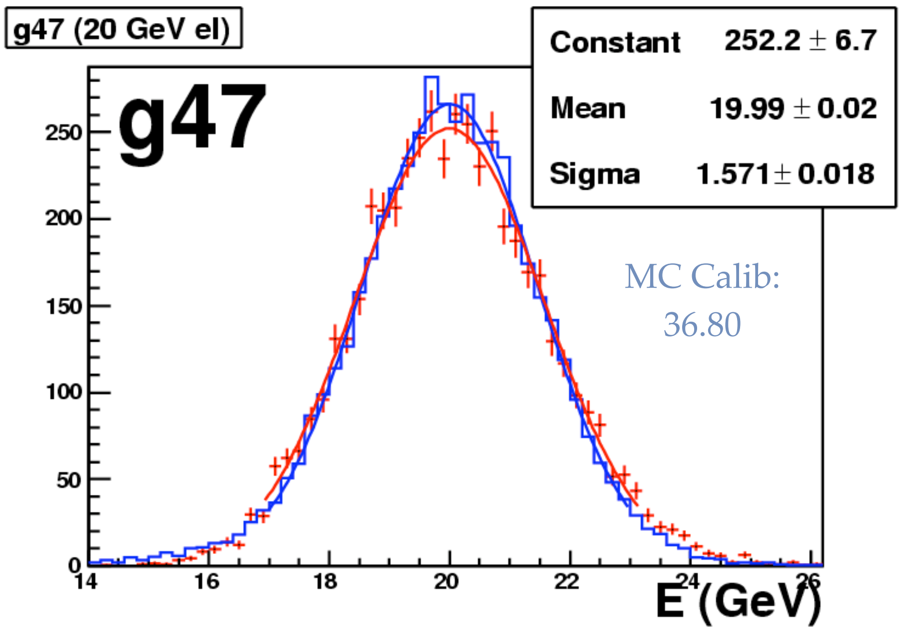


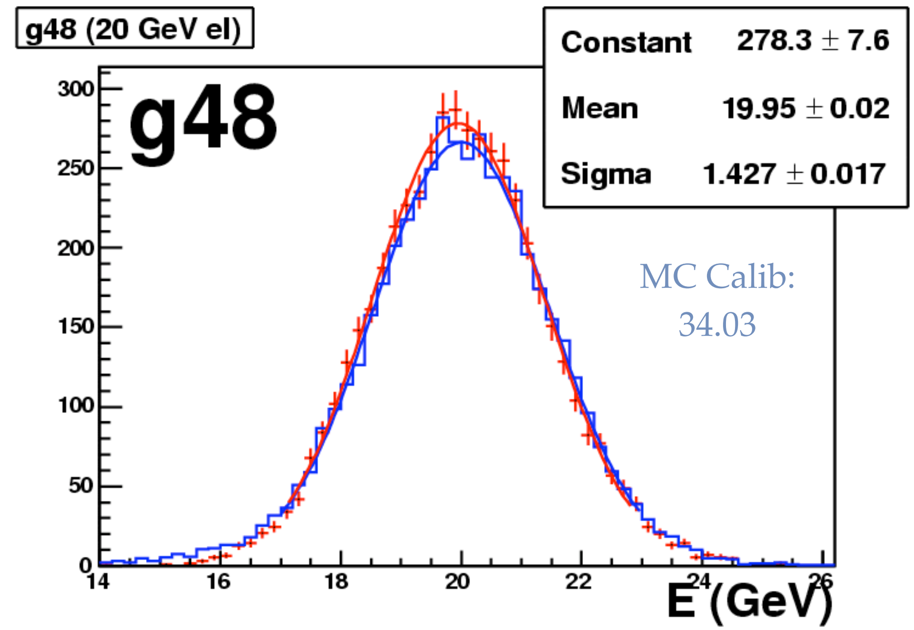
the total energy depends (~5%) on the impact point due to the periodic TileCal structure. Electron data and simulations are both corrected (pions do not suffer from this effect since their shower is larger)

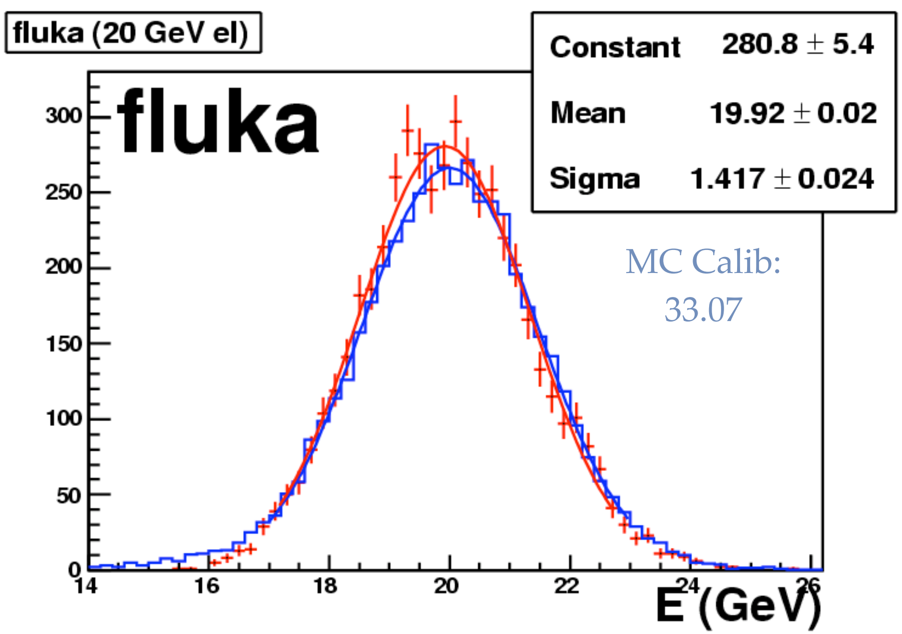
Particle Selection

- 20 GeV (π^- run)
  - Cherenkov counter to separate e/pi (4.9% residual electron contamintation in pions)
  - anti-proton contamination is negligible
  - muon are easily removed (calorimetric cut)
- 50 GeV (π^+ run) preliminary results
  - Cherenkov used to identify protons
  - we use two variables related to the shower shape (C_{long} and C_{tot}) to separate e/pi

20 GeV Electrons





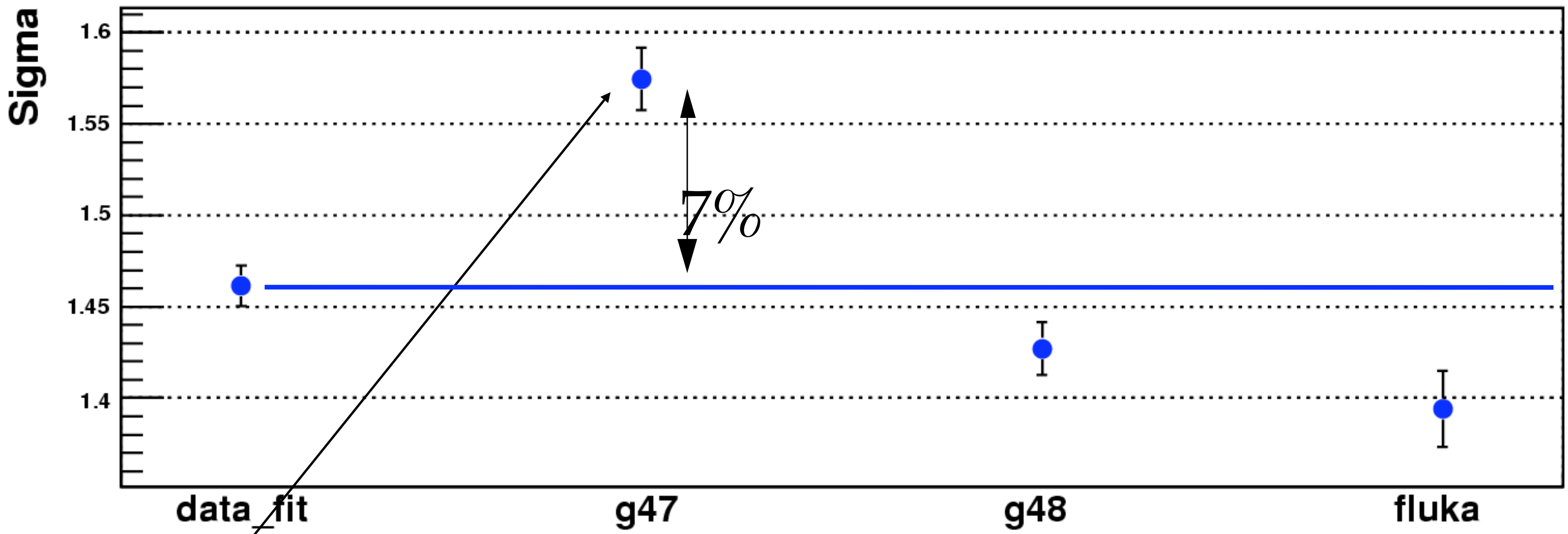


- Data

- MC simulation

mean values at 20 GeV are fixed by the calibration

20 GeV electrons



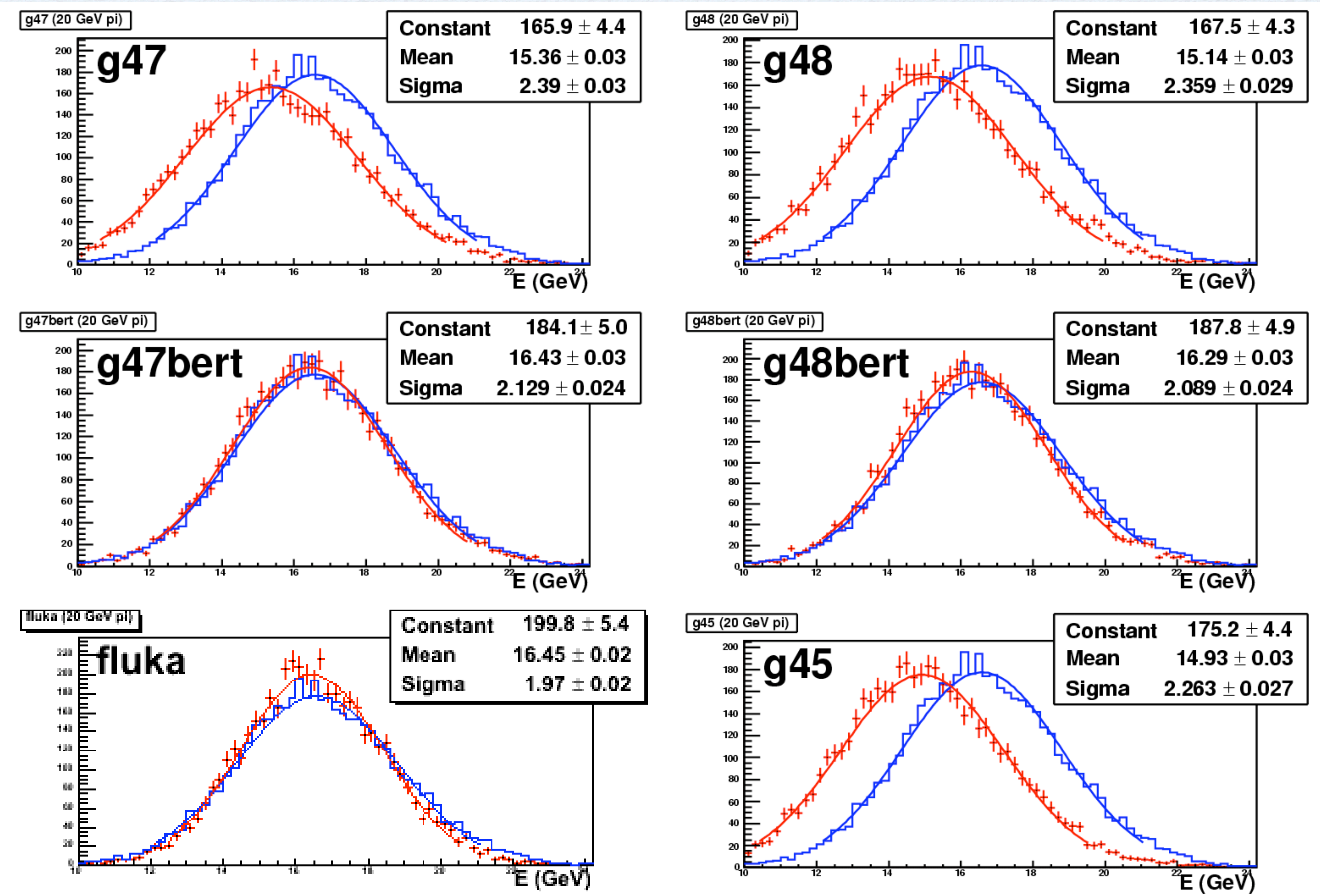
statistical errors only

No residual pion contamination in electron run considered

GEANT 4.8 has the better agreement with our data

20 GeV PIONS

20 GeV Pions: Total Energy

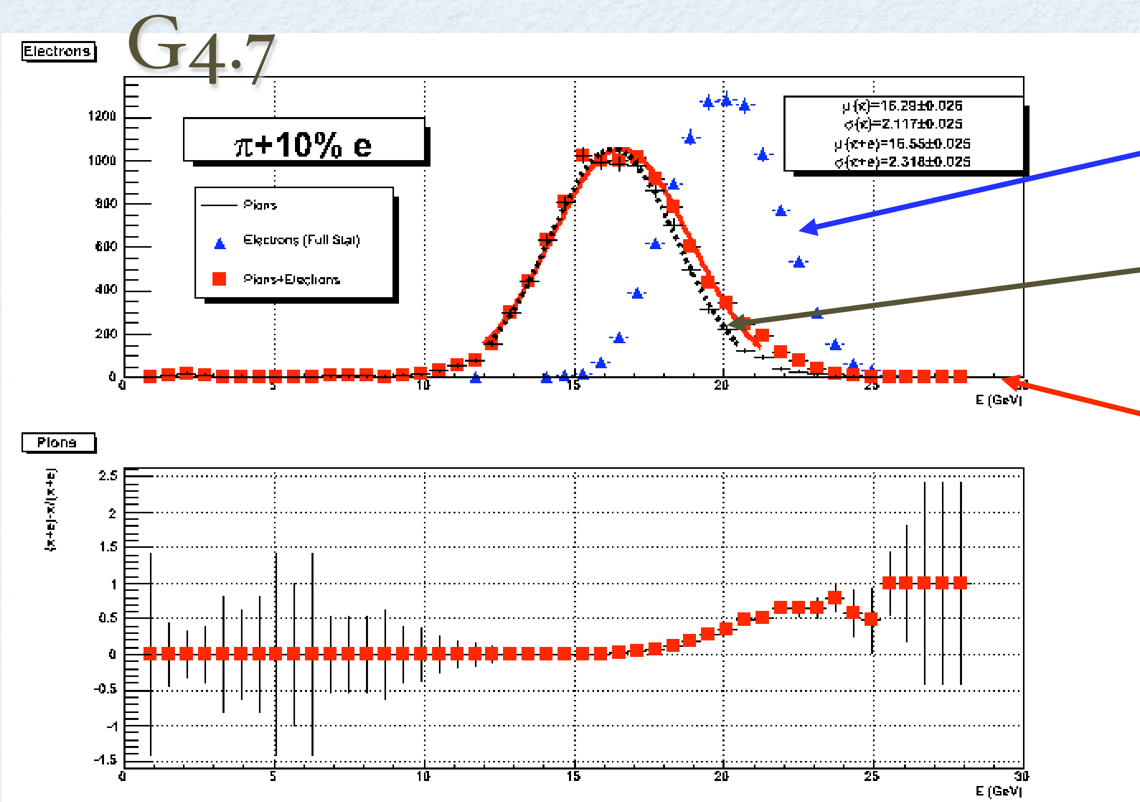


Residual electron contamination

- we can study the residual contamination of electrons in pion beams using combination of calorimetric (C_{long} and C_{tot}) and Cherenkov cuts
- Residual electrons in pion runs
  - using C_{long} and C_{tot}: 2.7%
  - using Cherenkov gives: 4.9%
- At 20 GeV beam polarity is negative (very few anti-protons expected)

EFFECT OF THE ELECTRON CONTAMINATION

- We study the effect of contamination on mean and sigma of the pion energy distribution adding the expected fraction of electrons to the correspondent pion sample



electrons

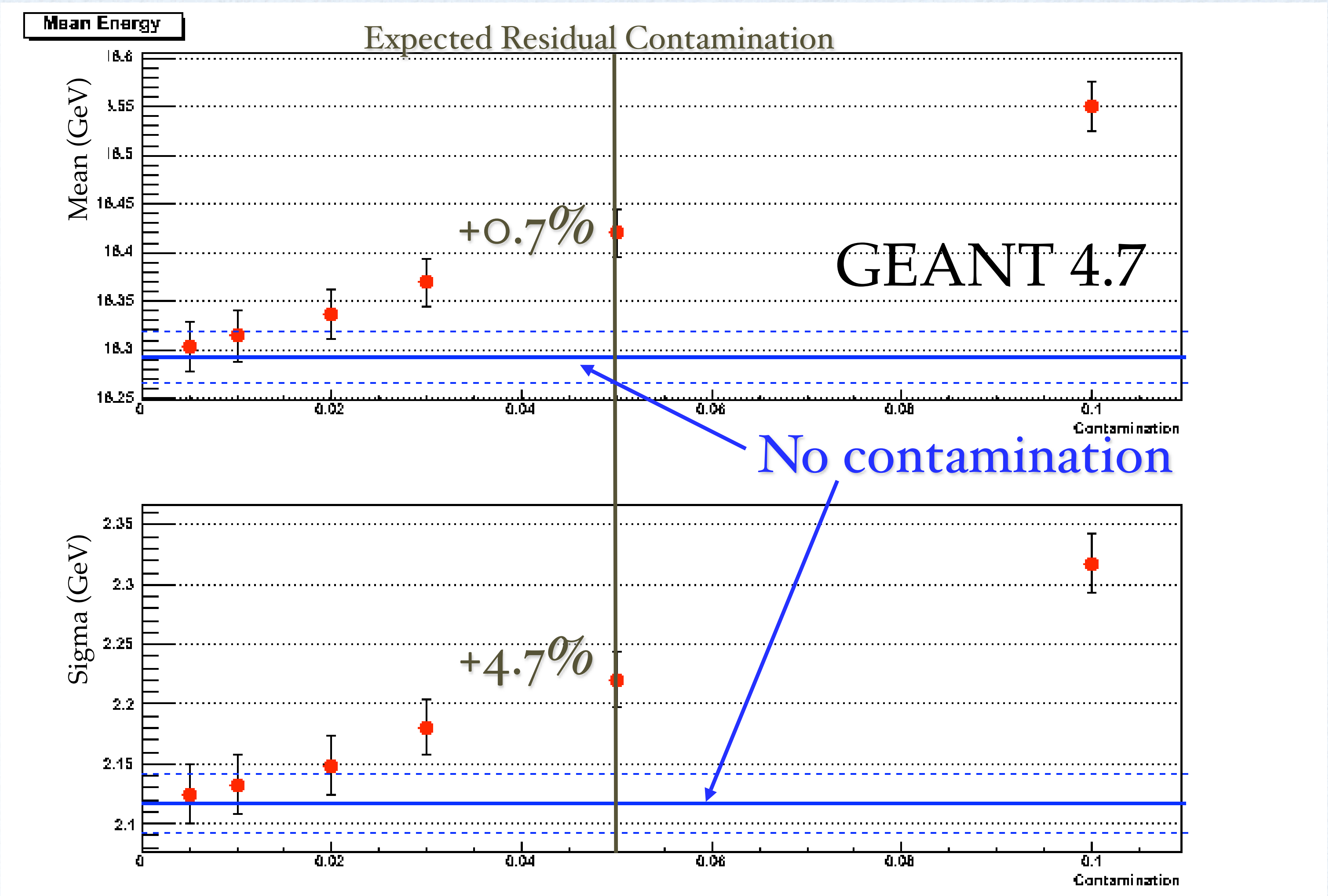
pions

10k pi + 1k e-

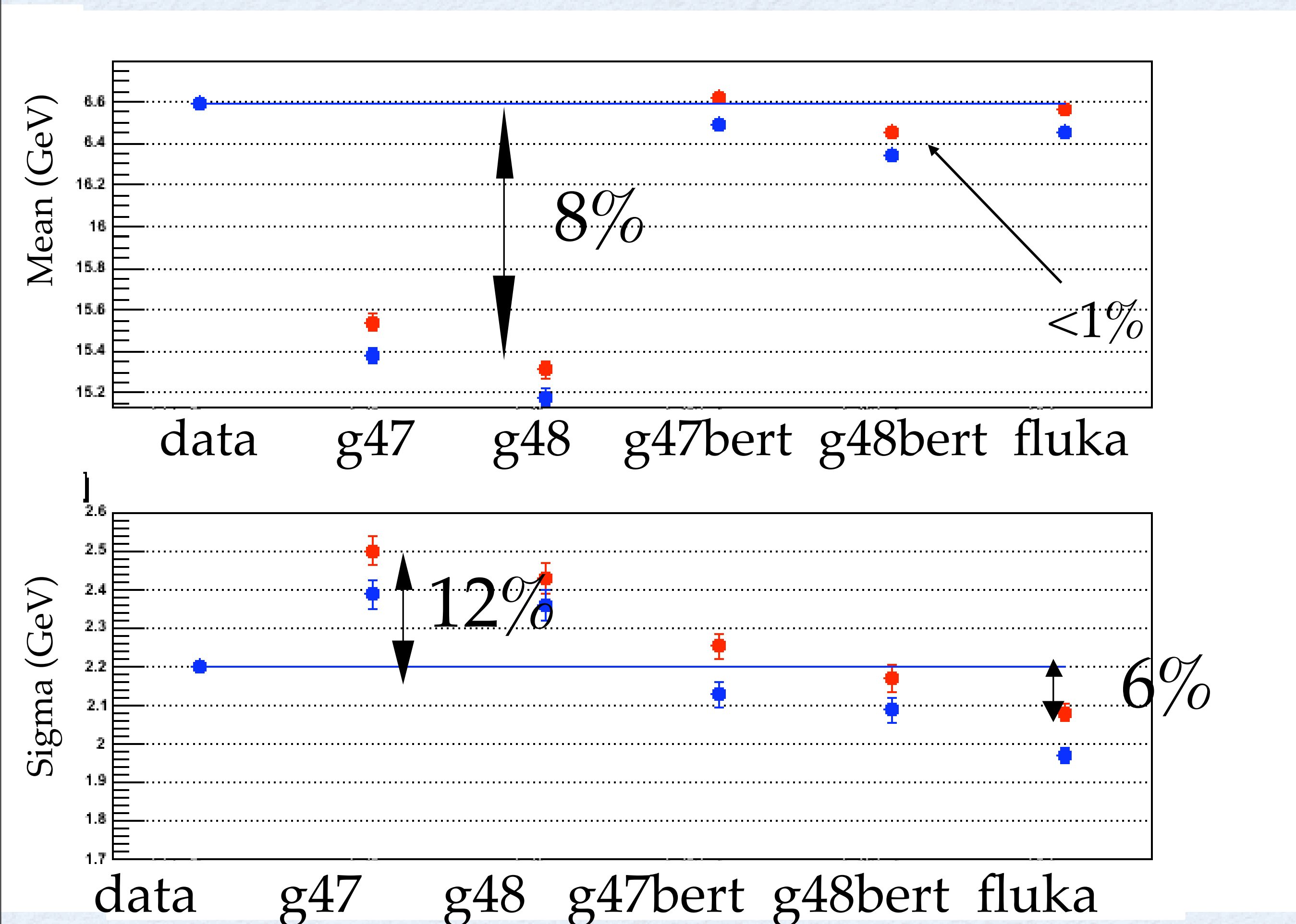
Example:

effect of a 10% electron contamination

Electron Contamination



Comparison with the data



- Mean value is increased, we get a better MC/data agreement
- Sigma becomes larger, resulting in better or comparable agreement for GEANT+Bertini and Fluka

Before and after adding the electron contamination

50 GeV Pions

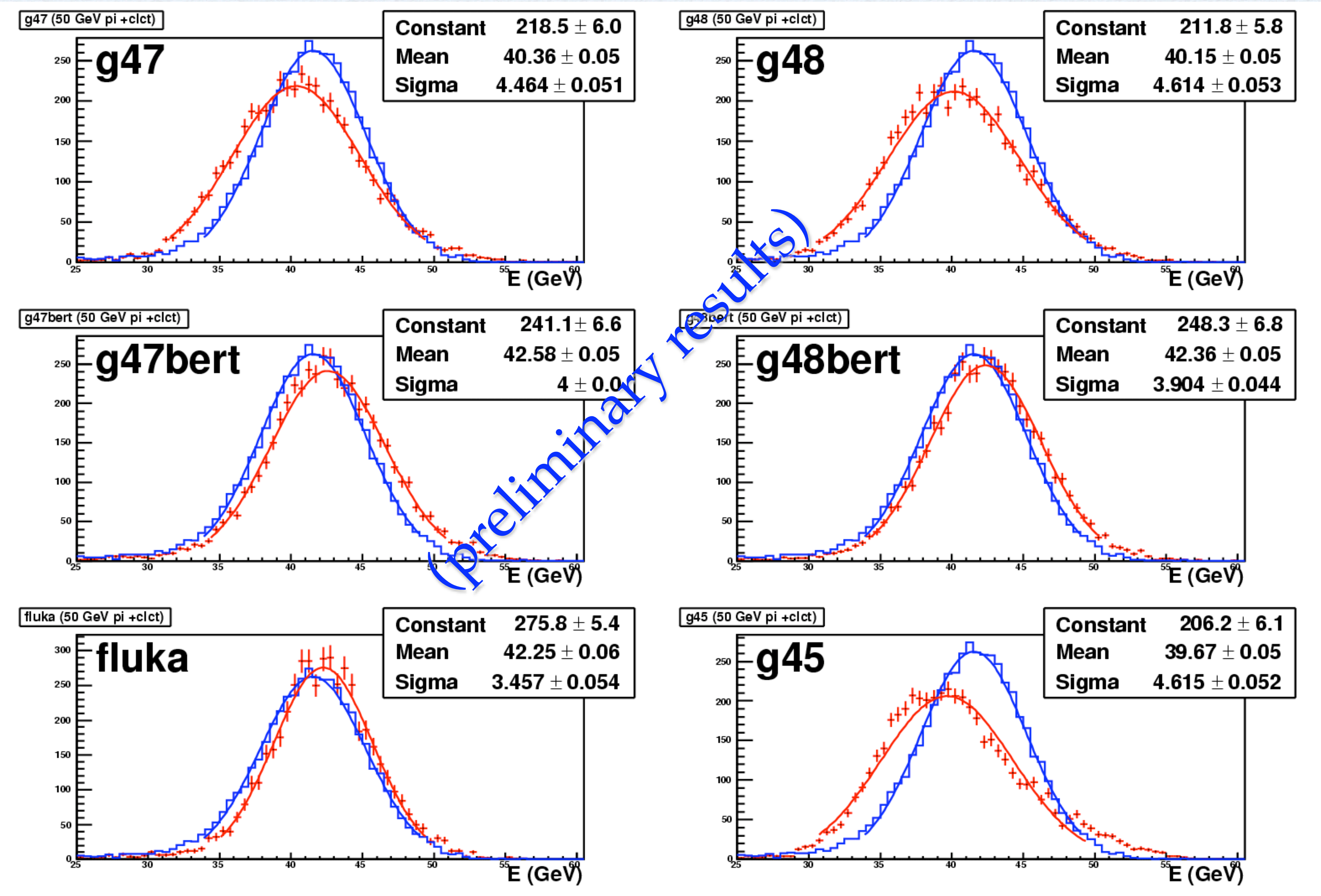
(Preliminary Results)

Experimental issues

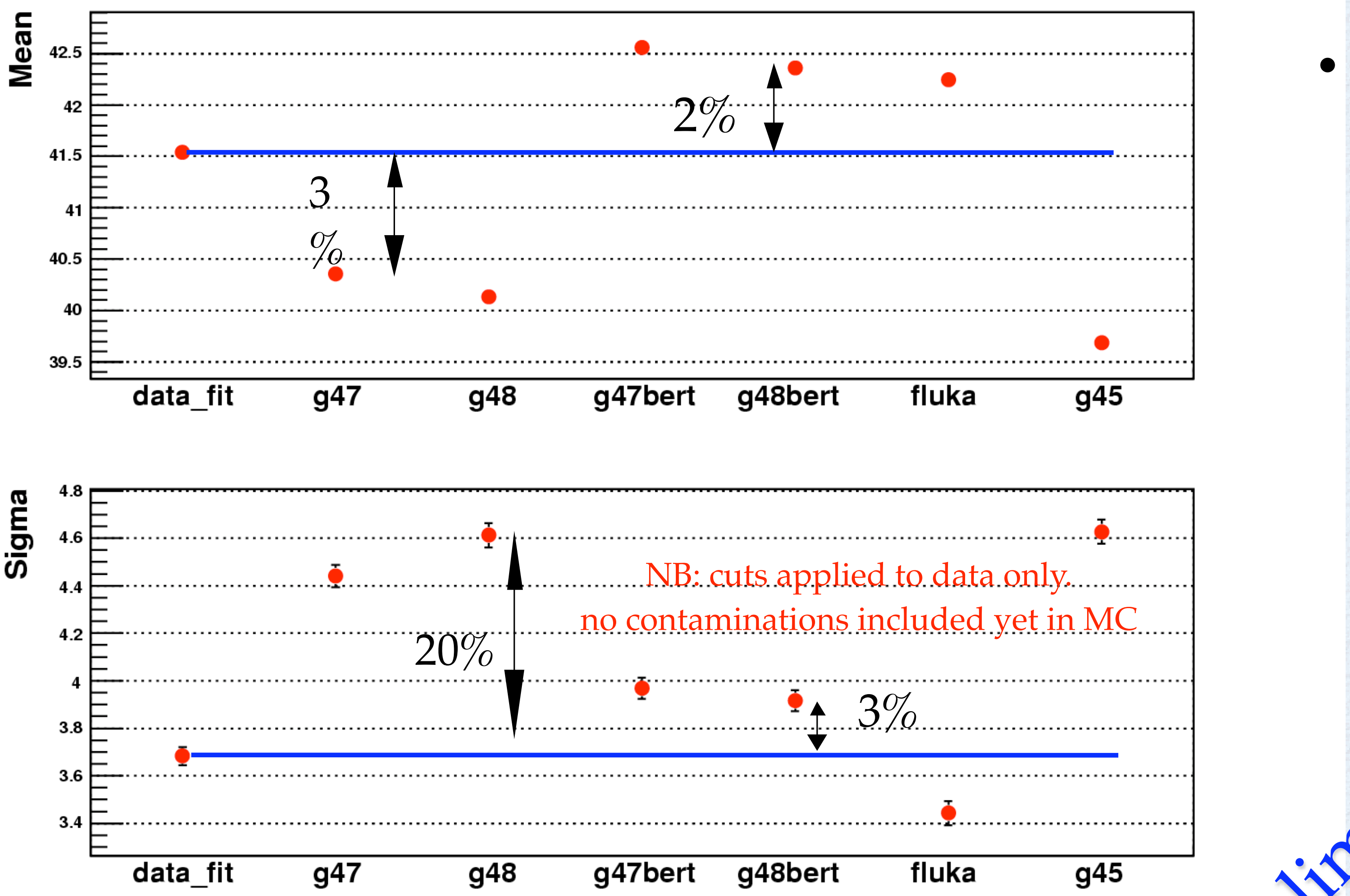
- Cherenkov used to reject protons -> variables related to the shower shape are used to separate pions from positrons
  - mean value affected at 1% level
  - 5% uncertainty over the width
  - positron residual contamination (~2.7%)
  - Caveat: the cut is not applied to MC (would induce a bias dependent on the how well the shape is reproduced, need a more detailed study)

Preliminary evaluations

50 GeV pions


g47 (50 GeV pi +clct)
g47
Constant 218.5 ± 6.0
Mean 40.36 ± 0.05
Sigma 4.464 ± 0.051
E (GeV)
g48 (50 GeV pi +clct)
g48
Constant 211.8 ± 5.8
Mean 40.15 ± 0.05
Sigma 4.614 ± 0.053
E (GeV)
g47bert (50 GeV pi +clct)
g47bert
Constant 241.1 ± 6.6
Mean 42.58 ± 0.05
Sigma 4 ± 0.0
E (GeV)
g48bert
Constant 248.3 ± 6.8
Mean 42.36 ± 0.05
Sigma 3.904 ± 0.044
E (GeV)
fluka (50 GeV pi +clct)
fluka
Constant 275.8 ± 5.4
Mean 42.25 ± 0.06
Sigma 3.457 ± 0.054
E (GeV)
g45 (50 GeV pi +clct)
g45
Constant 206.2 ± 6.1
Mean 39.67 ± 0.05
Sigma 4.615 ± 0.052
E (GeV)
(preliminary results)

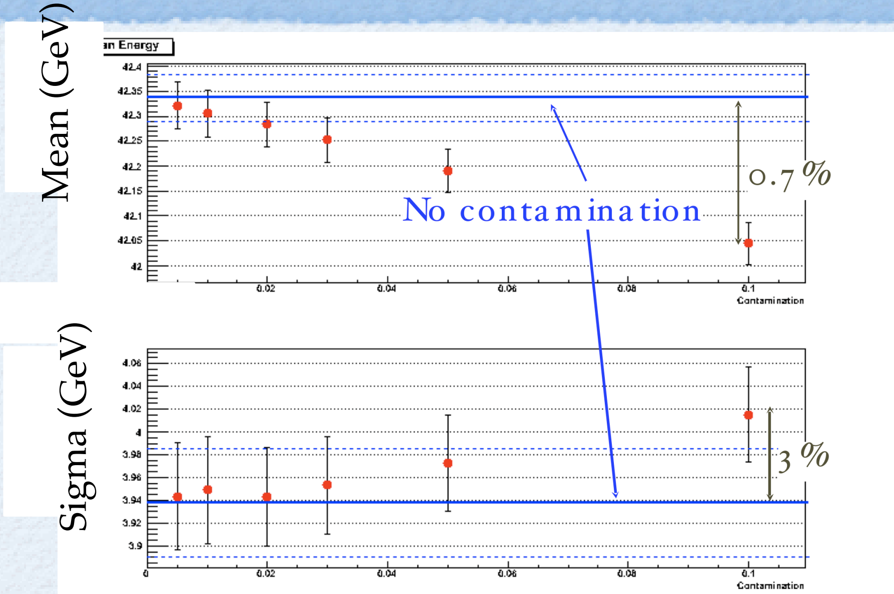
50 GeV pions mean and sigma

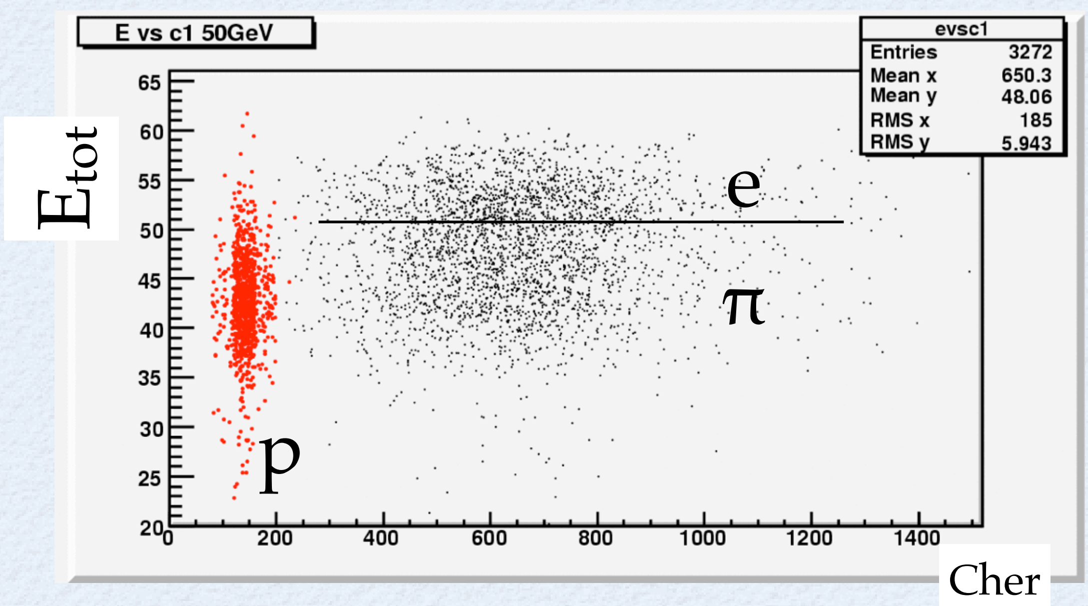


- the mean values for G4 +Bertini and Fluka are in agreement with our data within 2%

(preliminary results)

Preliminary studies on the proton contaminations

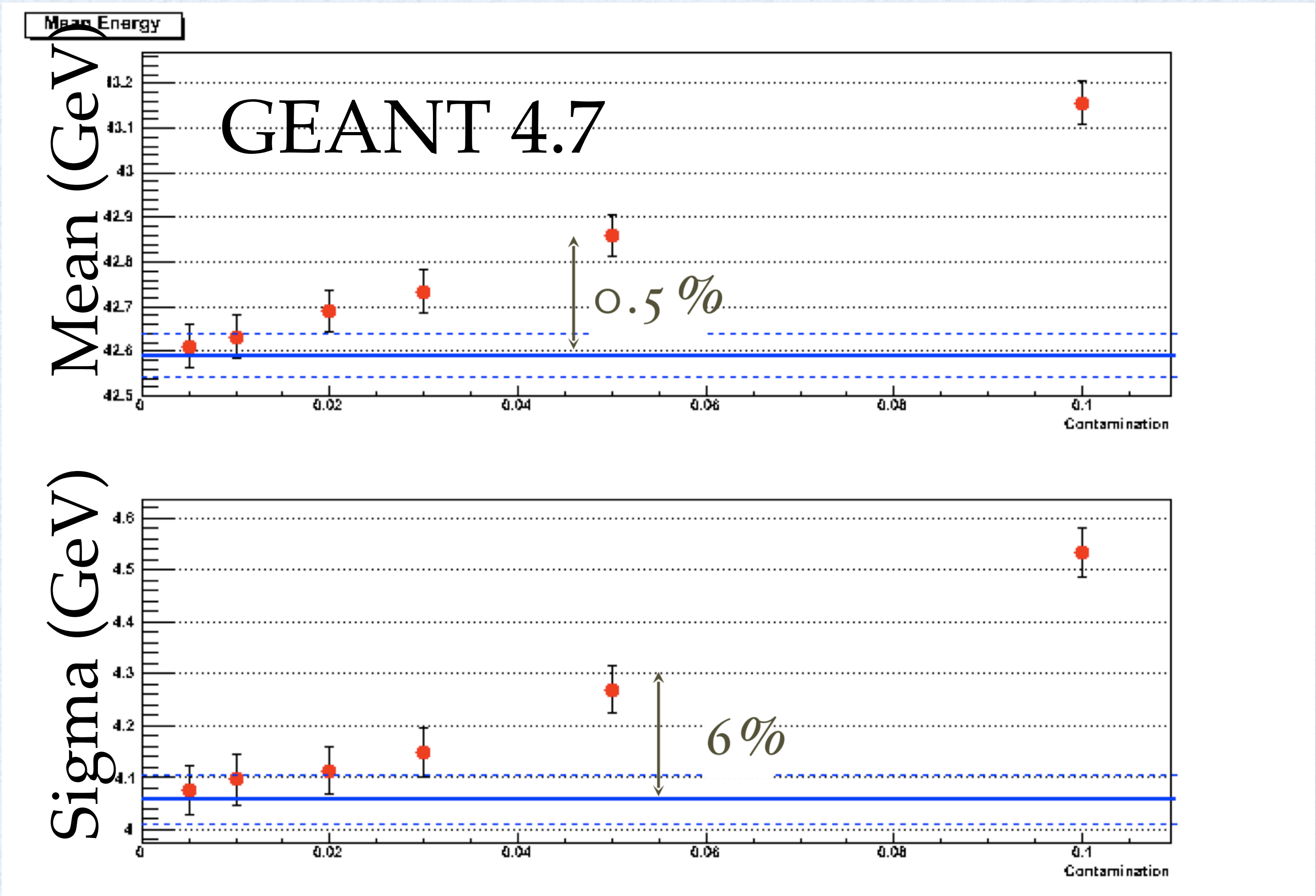




if the residual proton contamination is <5% the effect can be safely neglected at this level of analysis

cherenkov pedestal well separated from signal.
Proton residual (after Cher cuts) contamination neglected

Preliminary studies on the positrons contaminations



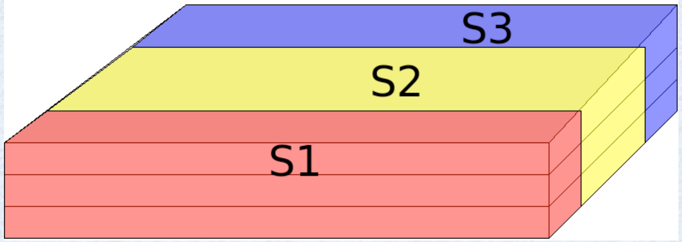
In addition the effect of the calorimetric cut still needs to be understood in detail

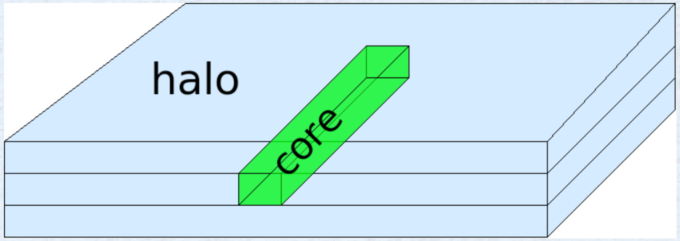
The Shower Shape

(E = 20 GeV)

Longitudinal and lateral segmentation

- TILECAL's longitudinal segments
  - S1 ~ A cells ~ 1.7 λ_I
  - S2 ~ BC cells ~ 4.8 λ_I
  - S3 ~ D cells ~ 2.2 λ_I





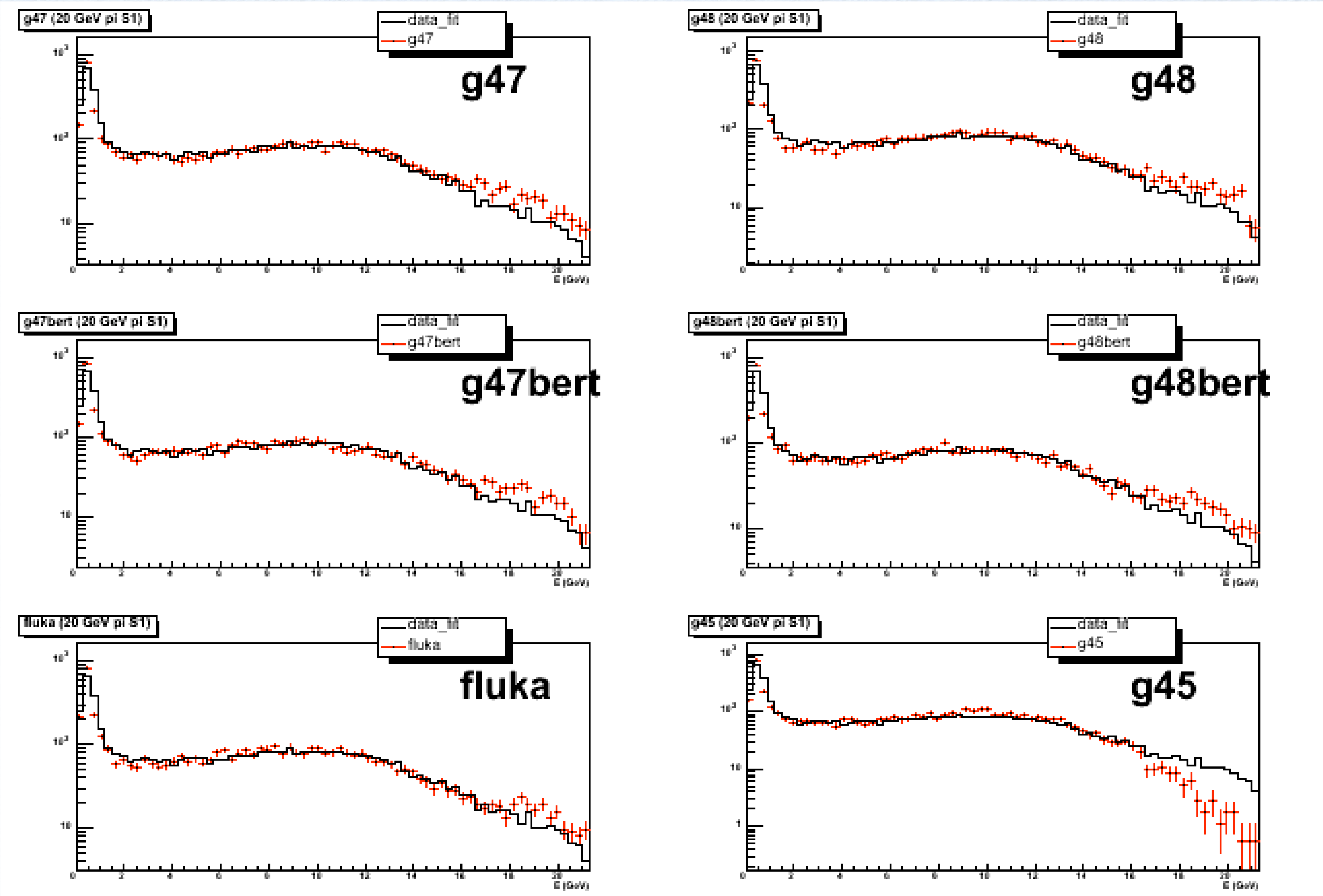
- the core is defined as the projective tower crossed by the beam line ~25x25x150 cm^3
- the halo is the external volume

Experimental issues

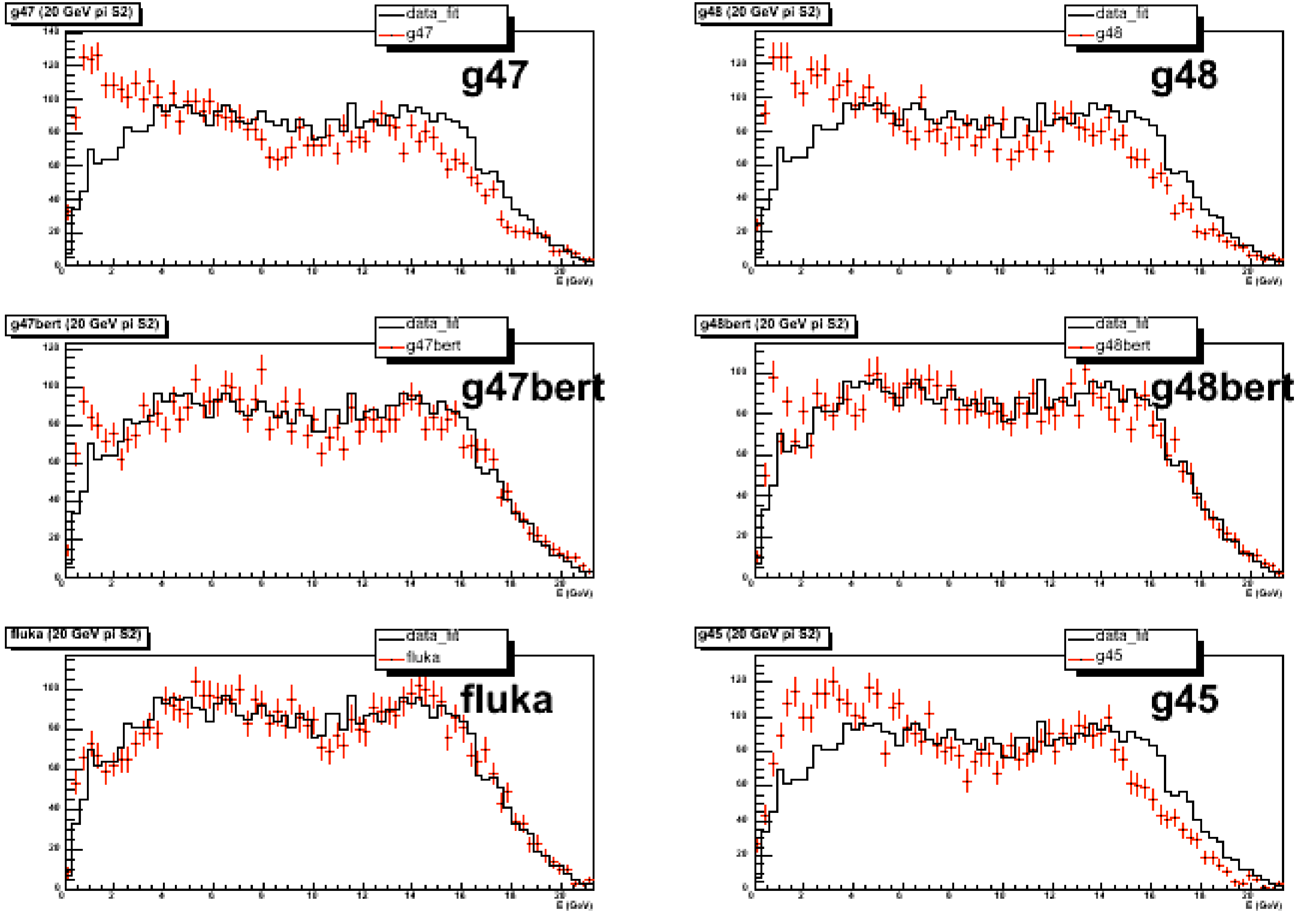
- Electron contamination has been included in MC simulations (4.9%)
- To get rid of residual muons and out-of-axis events an energy release of at least 5 GeV is requested in the central tower

Longitudinal Shower Shape

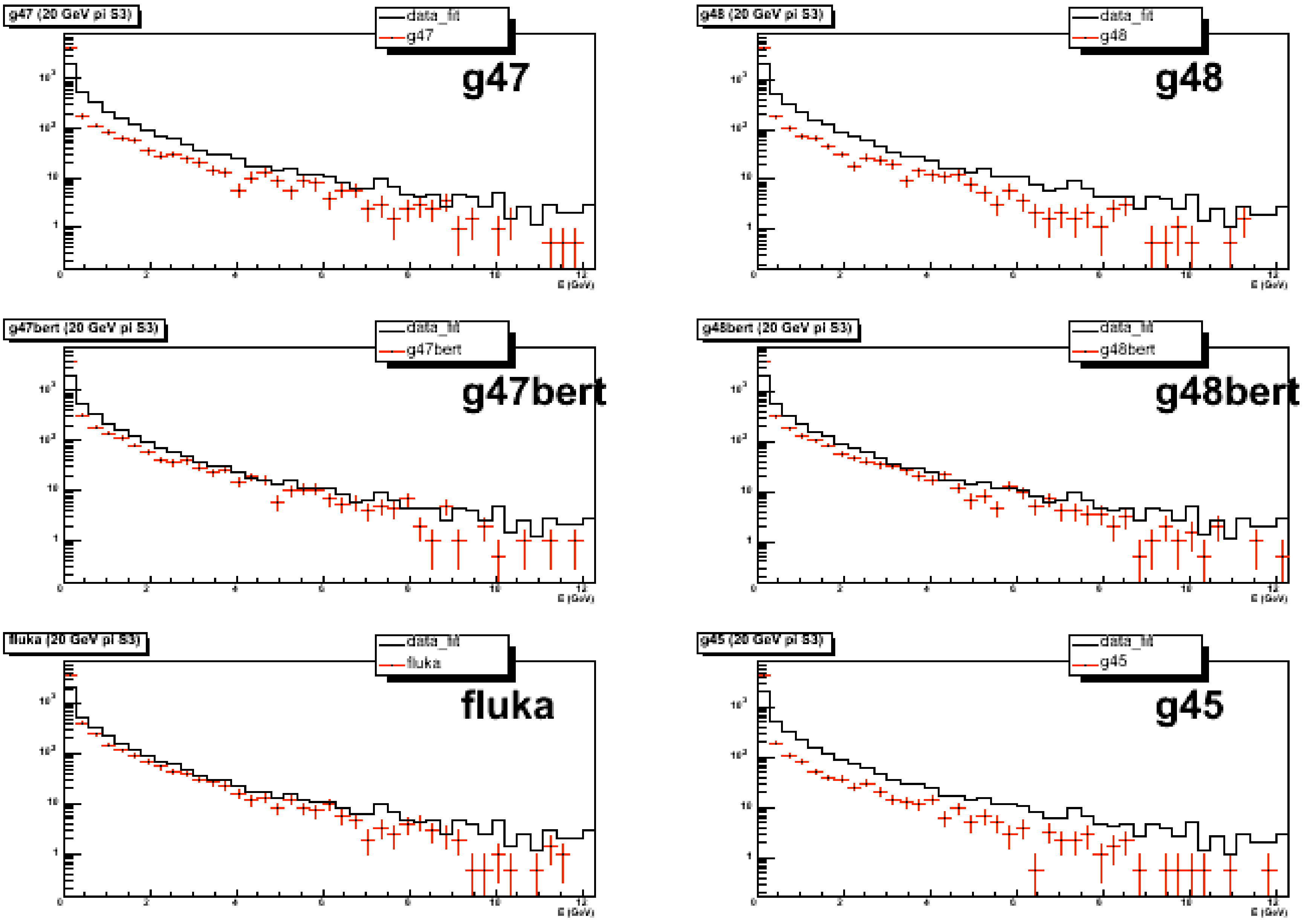
ENERGY IN SAMPLE 1



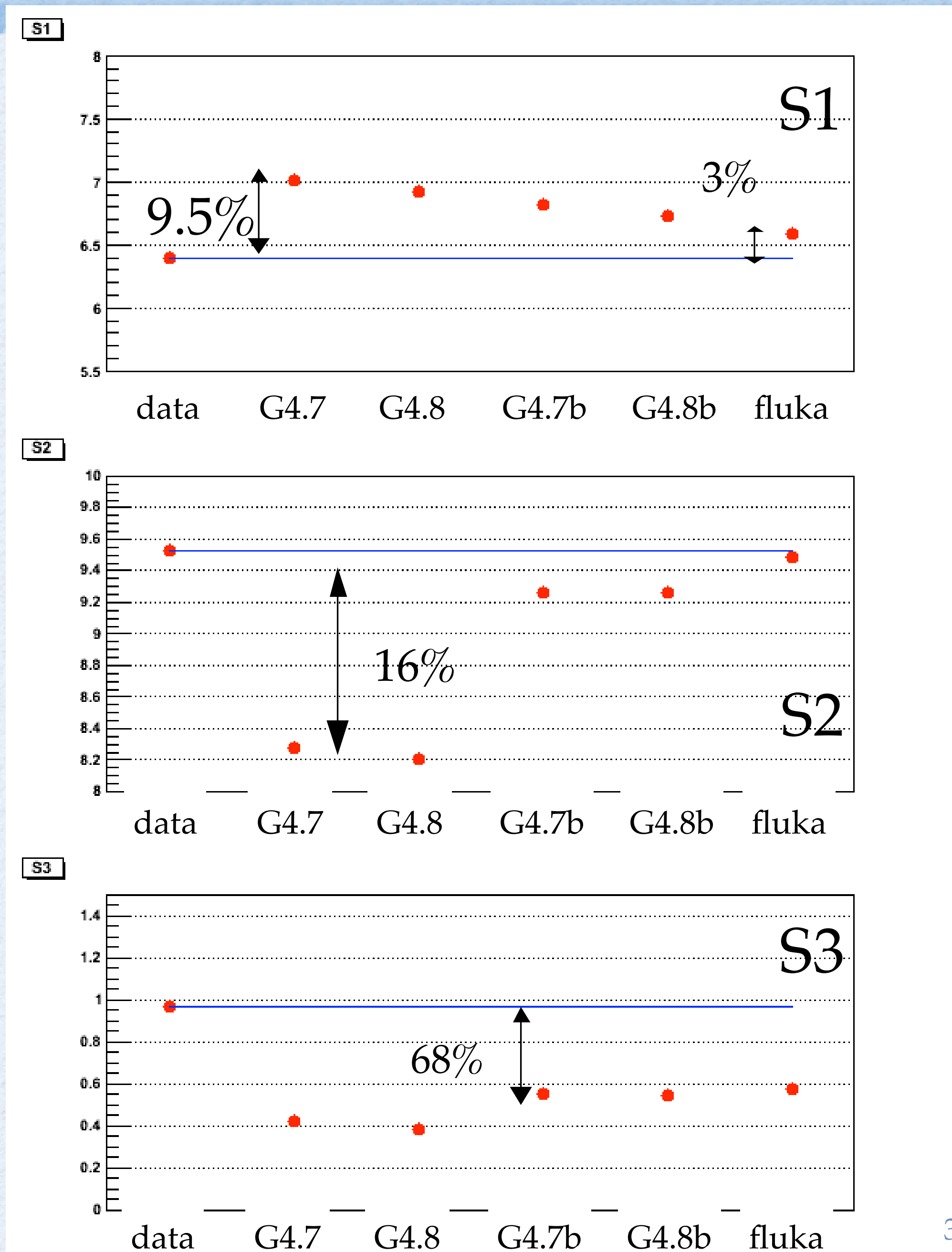
ENERGY IN SAMPLE 2



Energy in sample 3



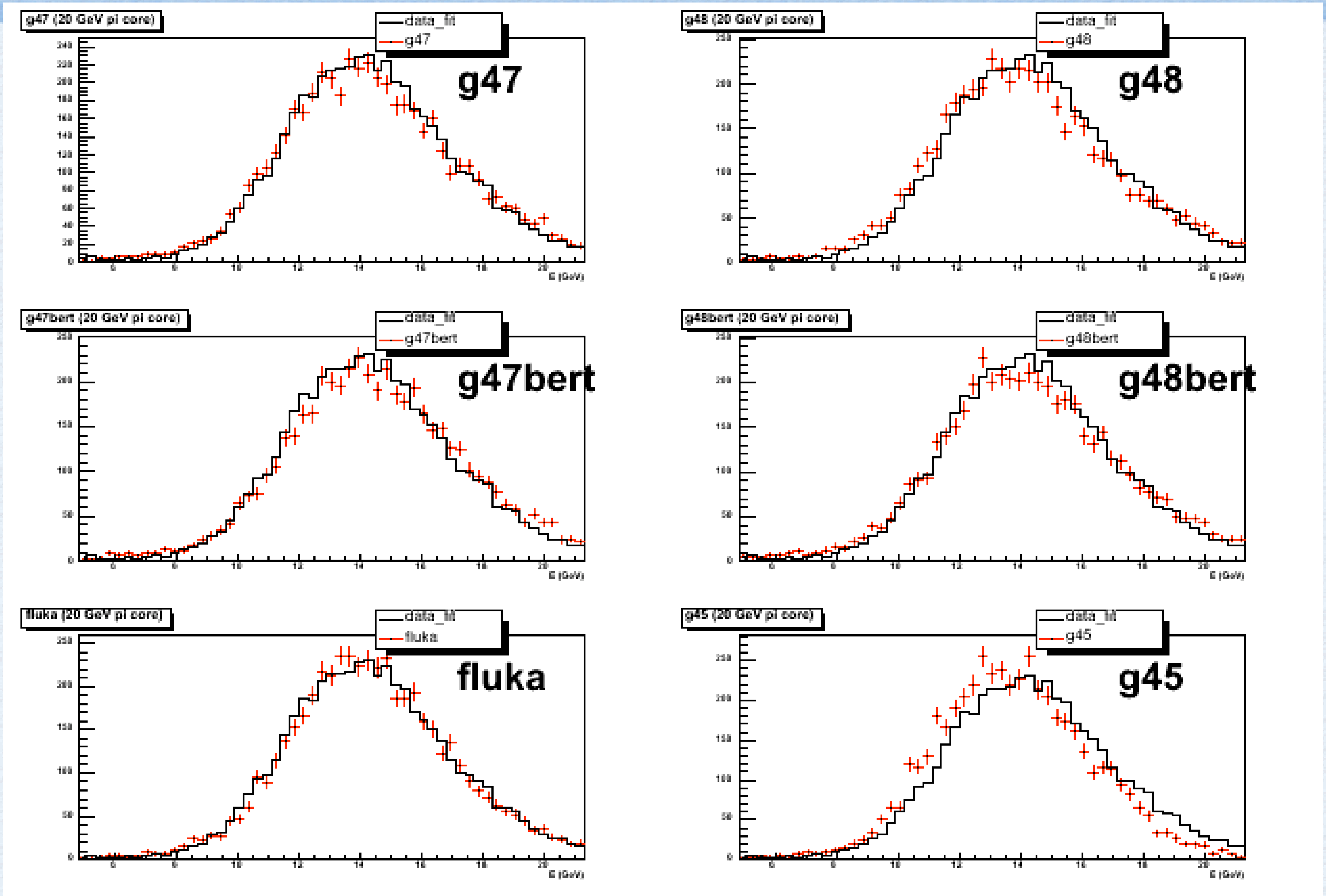
The Longitudinal Shower Shape (20 GeV Pion)



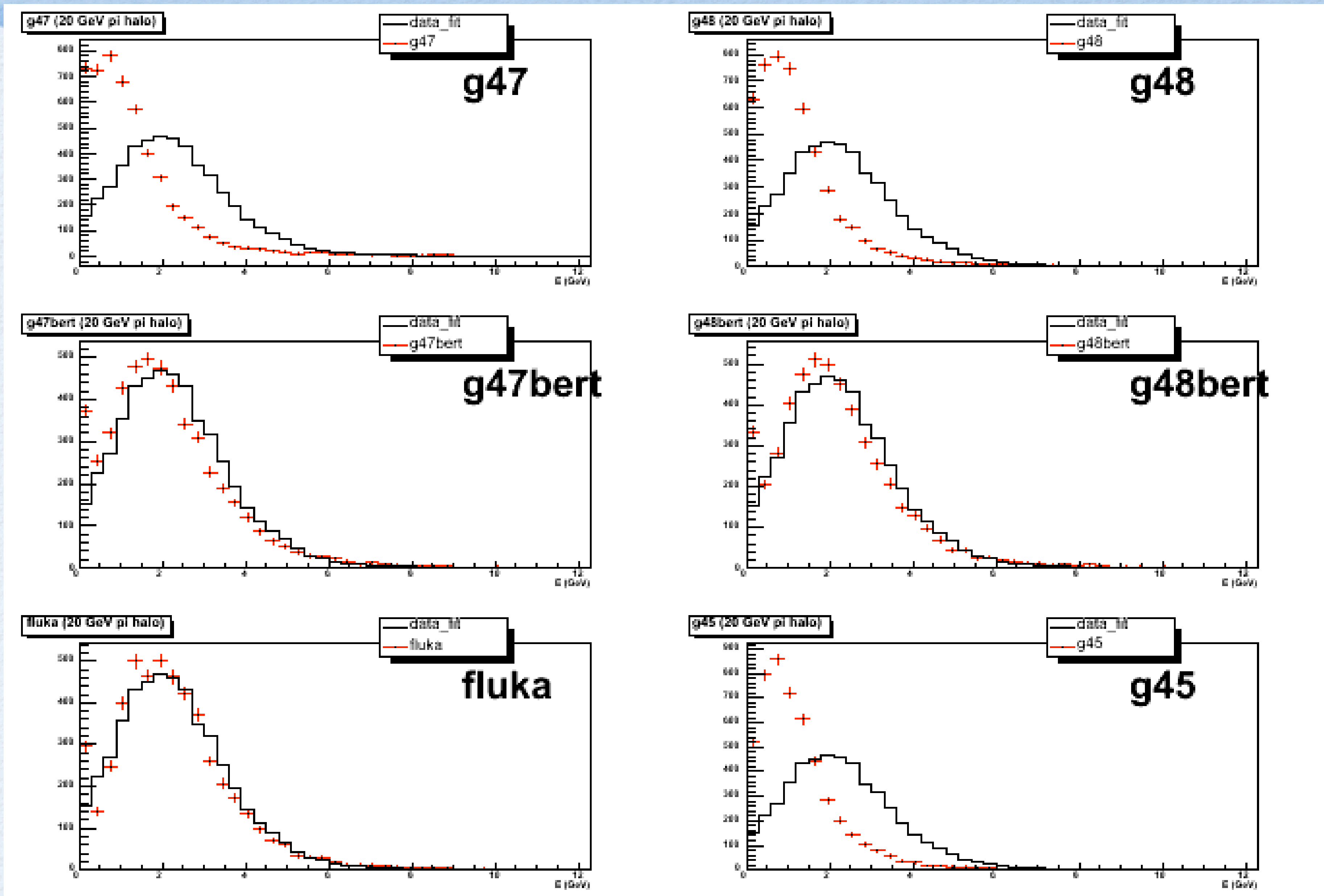
- All simulations give more energy in the first sample
- the tendency is reversed in Sample 2 and 3
- Fluka and G4+Bertini give reasonable agreement at this level of the analysis
- Fluka is the closest to data

Lateral Shower Shape

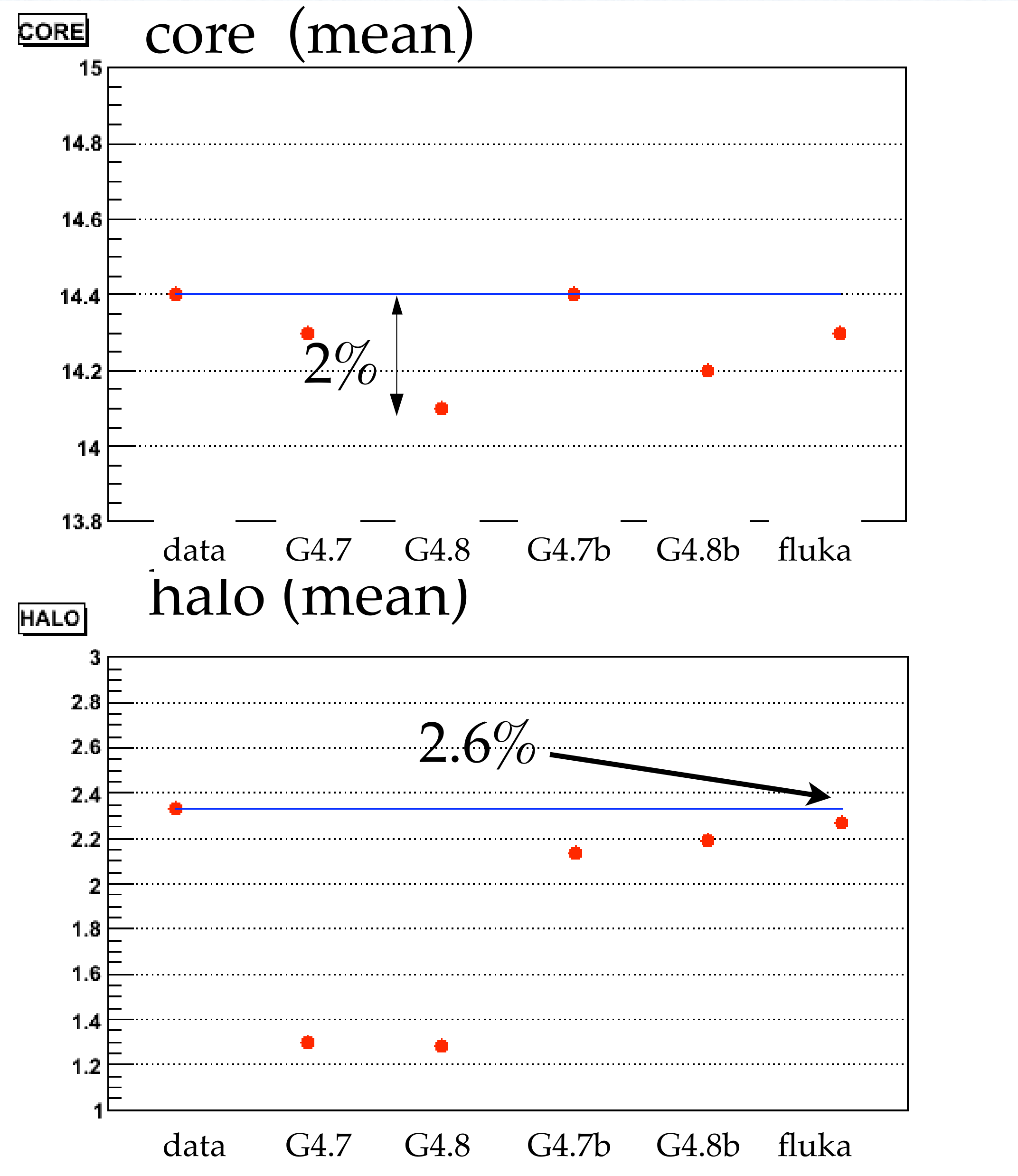
Energy release in the core



Energy release in the halo



The Lateral Shower Shape (20 GeV pion)



- GEANT with the Bertini list and Fluka are closer to the data
- GEANT without Bertini has significantly less energy in the shower halo

CONCLUSIONS

Conclusions

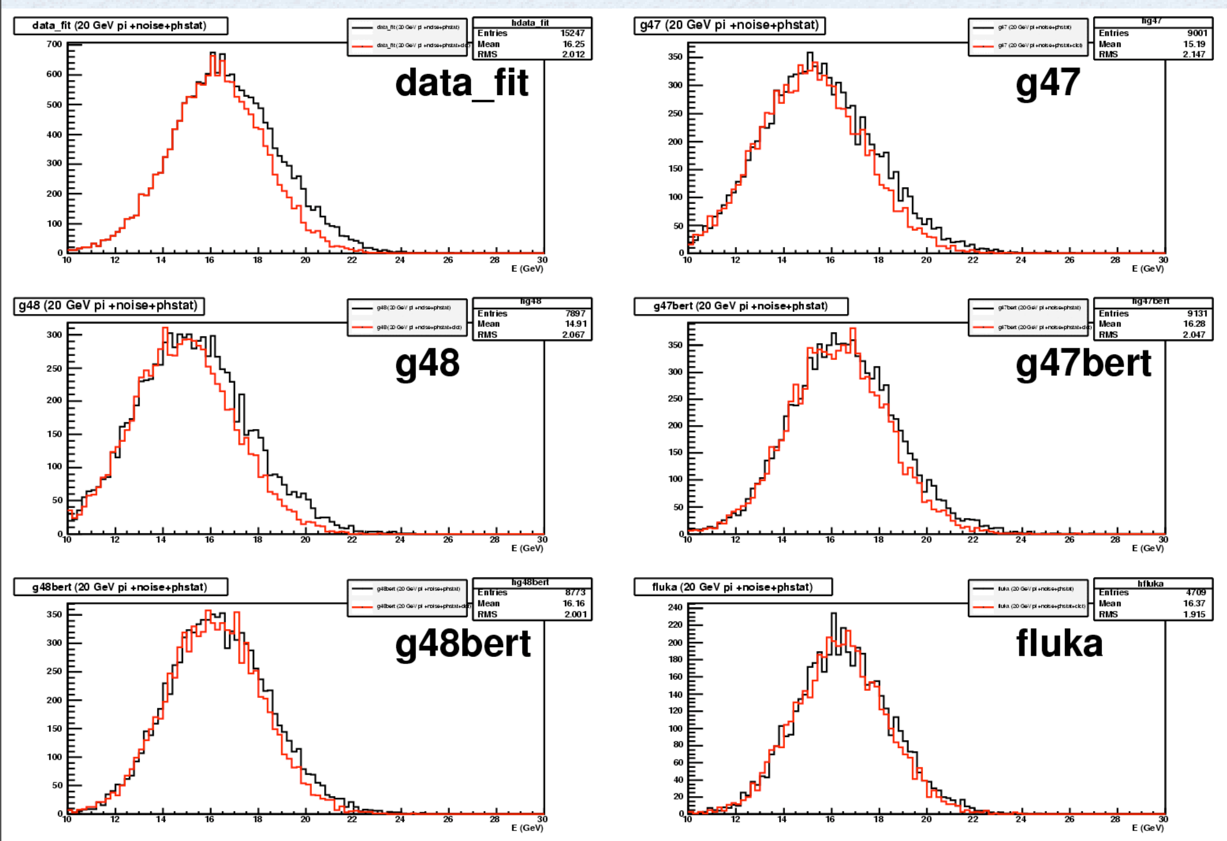
- GEANT4 QGSP has a lower energy response and the resulting shower shape is shorter and narrower than the data
  - GEANT4 needs Bertini to reproduce the characteristics of hadronic shower
- Overall acceptable agreement between data GEANT+Bertini and Fluka
- For 50 GeV need to take into account correct beam residual contaminations and effect of calorimetric cuts to improve comparison
- Big improvement on both simulation accuracy and on understanding of the data with respect to previous studies

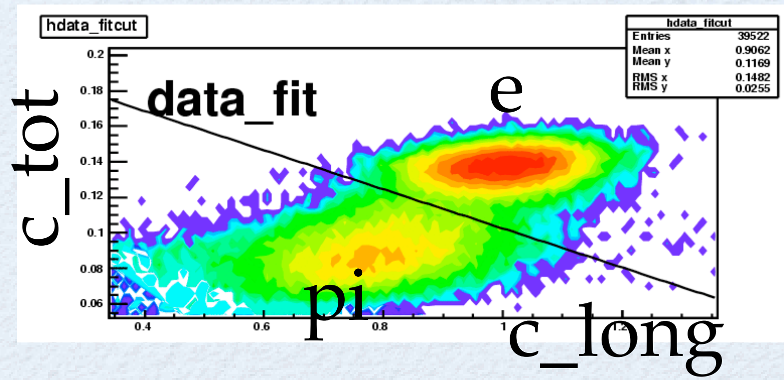
Open issues and work in progress

- better control of contaminations and calorimetric cuts to extend the analysis on the total energy distributions at E_{beam}= 100, 180, 350 GeV
- expand our work on the shower shapes to higher energies.

Backup slide

Electron cuts





- we use two variables related to the shower shape (C_{long} and C_{tot}) to get rid of the residual electrons

$$C_{\mathrm{long}} = \sum_i \sum_{j=1}^{2} E_{ij}/E_{\mathrm{beam}}$$

$$C_{\mathrm{tot}} = \frac{1}{\sum_c E_c^\alpha} \sqrt{\sum_c \frac{\left(E_c^\alpha - \sum_c E_c^\alpha / N_{\mathrm{cell}}\right)^2}{N_{\mathrm{cell}}}}$$