Angular dependence of FCal response to electrons and pions

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FCal response to 200 GeV test-beam electrons and pions was studied at four angles: 2.98^0, 1.61^0, 1.25^0 and 0.88^0. They correspond to pseudorapidities 3.65, 4.27, 4.52 and 4.87 respectively in real ATLAS setup. In accordance with [1], the average distance between test-beam impact point[1] at the front face of the FCal1 and its edge was only 4 cm for 0.88^0 and 7 cm for 1.25^0 so one would expect significant lateral shower leakage even for electrons. Note that some problems in the data and in the MC were observed during data analysis and simulation. They are listed after the main text in a separate Section.

1 Electrons at 200 GeV

FCal1 response to 200 GeV test-beam electrons is shown in Fig.1. Distributions have shapes close to gaussians in the region around the maxima. Low amplitudes are known due to residual pion and muon contamination. In addition, at small angles, lateral shower leakage becomes significant. It was observed that the average FCal response is reduced only by 8% with decreasing the angle from 2.98^0 to 0.88^0 due to this effect. This effect is well described by the ATHENA-based GEANT4 MC simulations (Fig.2, top plot) and has no sizeable energy dependence [2]. The observed behaviour of the FCal1 response with angle should be taken into account in the FCal calibrations for real ATLAS conditions. Energy resolution deteriorates almost twice in the same angular interval from 5.9% to 11.5% (Fig.2, bottom plot). Complete information can be found in Ref.[3].

Comment *Simulations were performed with real ATLAS setup described in ATHENA-based software release 10.0.1. Electrons were drawn at the front face of the FCal1, so passive material in front of the forward calorimeter was not taken into account here. The detailed description of the geometry of the test-beam setup is in progress [4]. In this setup about $2.7X_0$ of material was situated in front of the FCal1 irrespective of the beam impact angle, see Ref.[5]. For this reason, one would expect that angular dependence of the average FCal1 response is not affected by this material and results obtained with the MC are unbiased in this respect. However, it is not true for the energy resolution.*

2 Pions at 200 GeV

FCal response to 200 GeV test-beam pions is demonstrated in Fig.3.[2] As in the case of electrons, right parts of the spectra are better described by gaussians than left parts. However, non-gaussian tails towards large amplitudes are seen at any angle. Left tails at 2.98^0 and 1.61^0 are due to contaminating muons which result to (more or less angular-independent) fraction of events with very low amplitudes. At smaller angles, there is also a contribution from lateral shower leakage. Due to this effect, the average FCal response is reduced by $\approx$13% with decreasing the angle from 2.98^0 to 0.88^0. Energy resolution

[1] Let's remind that beam spot was a square with size 7x7 cm^2.

[2] Note that noise contribution is about 10 GeV and cannot be neglected.

deteriorates by a factor of 1.7 in the same angular interval. Both effects are qualitatively described by the MC (Fig.4).

Complete information can be found in Ref.[3].

Comment *Simulations were performed with and without passive material for the standard ATLAS setup. The amount of material which particle traverses depends on angle. In accordance with geantino scan, it corresponds to* $\approx 1.4X_0$ *at* 0.88^0, $\approx 0.9X_0$ *at* 1.25^0 *and* 1.61^0 *and* $3.1X_0$ *at* 2.98^0. *Let's remind that in the test-beam setup the material thickness was about* $2.7X_0$ *at any angle, see Ref.[5].*

3 Pions at different energies

In the test-beam data, energy dependence of the FCal response to pions was studied only in the range 5-200 GeV and at fixed angle 2.98^0. However, in real ATLAS conditions, interesting objects like jets from Higgs production via vector boson fusion [6] have much larger energies (~TeV) and wide angular range. With the validated MC, one can investigate the performance at any energies and angles.[3] Simulations were performed for 5, 25, 50, 100, 200, 400, 800 and 1600 GeV pions at different angles (excluding 0.88^0 and adding 4.3^0). Passive material in front of the FCal was NOT simulated here. MC predicts a few % non-linearity of the FCal response to pions with energy (above 25 GeV) irrespective of beam impact angle, see Fig.4. The situation can be improved if one excludes 25 GeV point from the fit. It is not a surprise as e/π ratio becomes (almost) constant at sufficiently high energies. FCal energy resolution varies with angle (Fig.5). The best constant term is achieved at 2.98^0, being $(6.1\pm0.2)\%$ while at 1.25^0 it increases to $(11.5\pm0.3)\%$ due to lateral shower leakage. The angular dependence of stochastic term of the FCal energy resolution is weaker.

Complete information can be found in Ref.[3].

Summarizing, FCal has reasonable performance up to η =4.5 for single electrons and pions. Predicted a few % non-linearity of the response is expected to be not crucial for successful jet reconstruction. Corrections to the average response due to lateral shower leakage, which are not large, can be easily applied during FCal calibration in real ATLAS setup.

4 Problems in the data and in the MC

Beloew there is a list of problems observed in the data and in the MC during analysis/simulation (with comments).

- **Difference in FCal responses in different runs in position 3 for pions**. There were two group of runs for 200 GeV pions in position 3: runs 1939-1973 and runs 3173-3189. In the last group of runs CEDAR was set to 200 GeV pions. Observation: gaussian energy resolutions are 14.5%±0.7% and 12.0±0.6% including systematic error. In the same situation for position 2 this problem is absent;

[3]Detailed data/MC comparisons for electrons and pions at 2.98^0 were made. Results can be found in Ref.[7], Ref.[8] and Ref.[9].

- **Difference in passive material thicknesses in real ATLAS (MC) and TB setup.**
  The problem is described in Section 4. One should decide how to take it into account when coming from test-beam simulations to real ATLAS simulations;

- **Possible absense of 1m-long polyethylene in ATLAS detector description for the MC.**
  This problem is under active investigation, key persons were notified, so no needs to describe it here;

- **FCal performance in G4.8.0 MC (sampling fraction and energy resolution)**
  There was a significant bug in GEANT4 which affects any calorimeter performance (mostly sampling fraction; but also energy resolution) for electrons. Some time ago a problem of calorimeter response variation with GEANT4 range cut especially at very strong cuts was observed). It was corrected very recently by GEANT4 team. From Ref.[10] one can conclude (see slides 4 and 5) that it would be desirable to resimulate our available FCal electron results (including those described in the memo!) with new GEANT4 version (G4.8.0). The expected effect due to bug correction is expected to be 30% for electron sampling fraction and maybe rather significant also for the energy resolution. One can hope that ratio SF1/SF2 for FCal, measured during 1998 test-beam electron exposure, will be described well by the new MC (to be checked).

References

[1] FCal 2003 test-beam logbook, not available electronically.

[2] I. Tsukerman, MC simulation of FCal 2003 beam tests with standalone LArG4 package, 6-Mar-2005

`http://atlas-fcaltb.web.cern.ch/atlas-fcaltb/Memos, analysis memo 12`

[3] I. Tsukerman, Angular dependence of FCal response to electrons and pions: data vs ATHENA G4 simulation, 29.12.05 (to be updated!)

`%/afs/cern.ch/user/z/zuckerma/public/LArG4doc/PG/fcanglenew.ps`

[4] M. Khakzad, private communications

[5] P. Gorbunov, private communications

[6] S. Asai et al., Eur.Phys.J.C32S2 (2004) 19.

[7] V. Epshteyn and P. Gorbunov, Analysis Note 10, 2004-09-07.

`http://atlas-fcaltb.web.cern.ch/atlas-fcaltb/Memos/Analysis/ITEP_Note10/tests_2003_Note10_eng_v3.pdf`

[8] M. Schram, FCal Calibration Test Beam Results

`http://agenda.cern.ch/fullAgenda.php?ida=a055759`

[9] A. Artamonov, Latest updates on FCal TB2003 analysis in ITEP

/afs/cern.ch/user/a/arzv5/public/doc/atl/jul05/prof_note_draft1.ps

[10] A. Rimoldi, presentation at Orsay ATLAS Software Workshop (Dec. 7, simulation parallel session)

http://agenda.cern.ch/askArchive.php?base=agenda&categ=a045110&id=a045110s14t1/transparencies

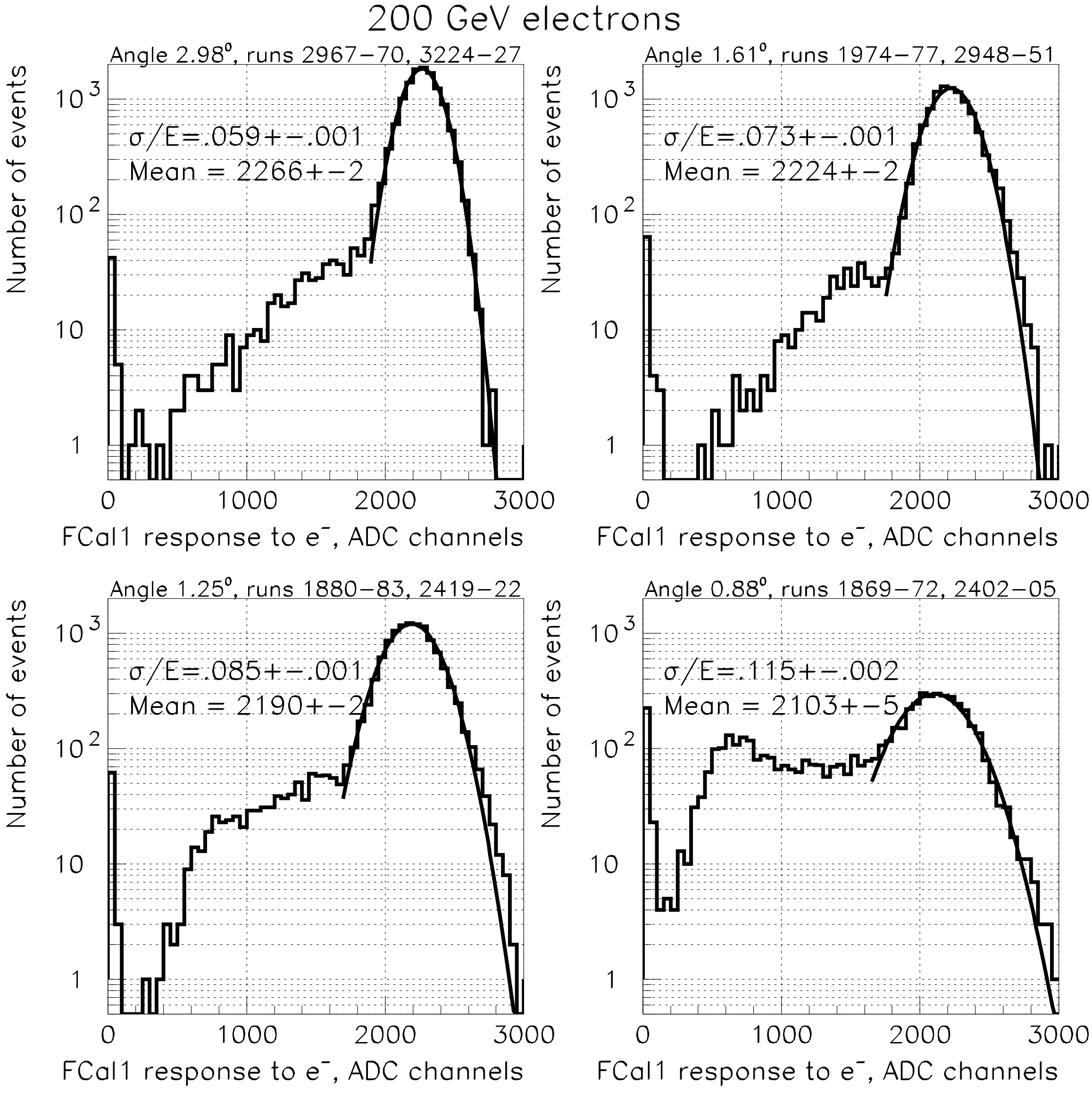

Figure 1: FCal response to 200 GeV test-beam electrons (solid histograms) with superimposed restricted gaussian fits (solid curves).

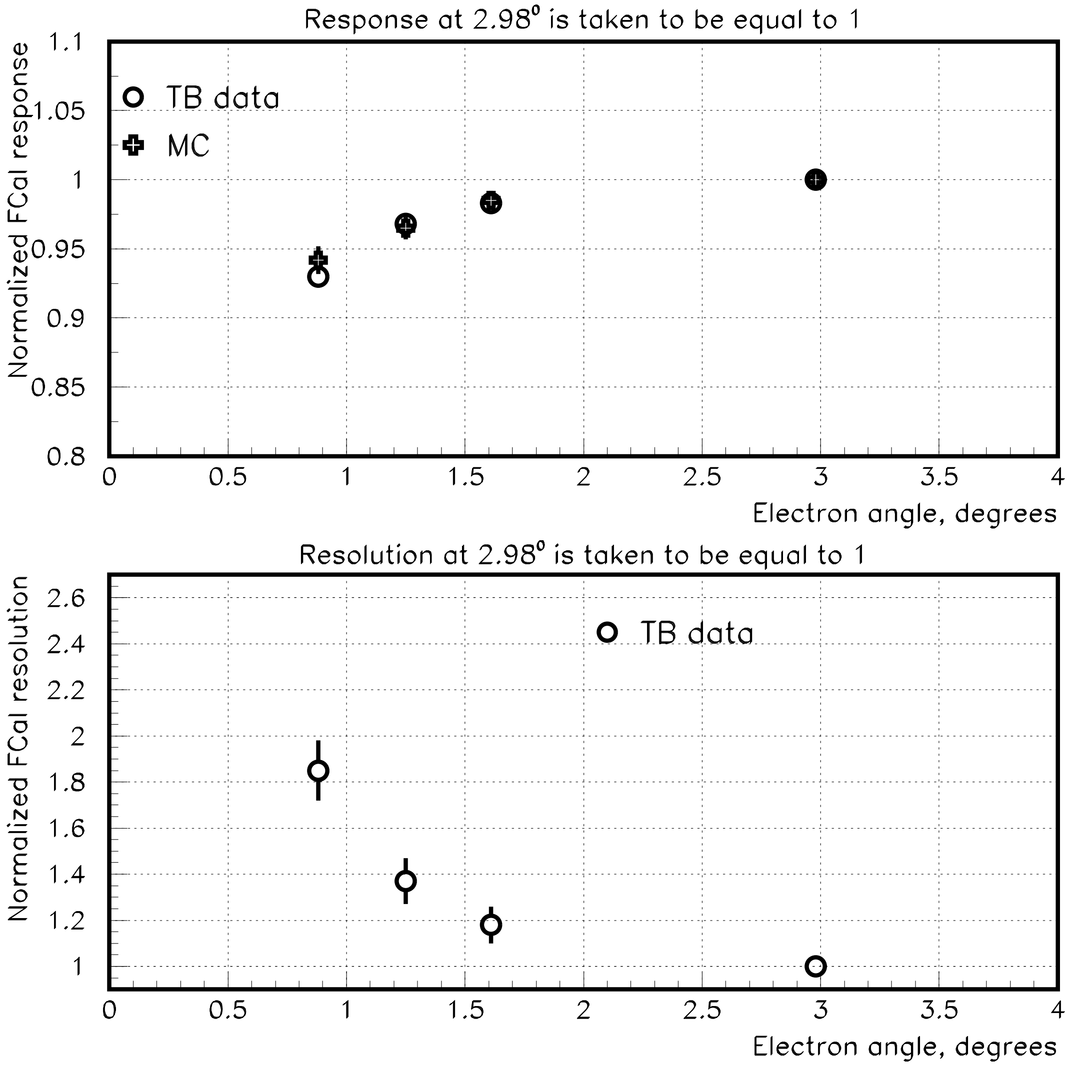

Figure 2: Angular dependence of the FCal response (top plot) and energy resolution (bottom plot) for electrons at 200 GeV. The response and resolution at 2.98^0 is taken to be 1. Systematic error of the average response (energy resolution) is estimated to be 0.5% (5%) respectively.

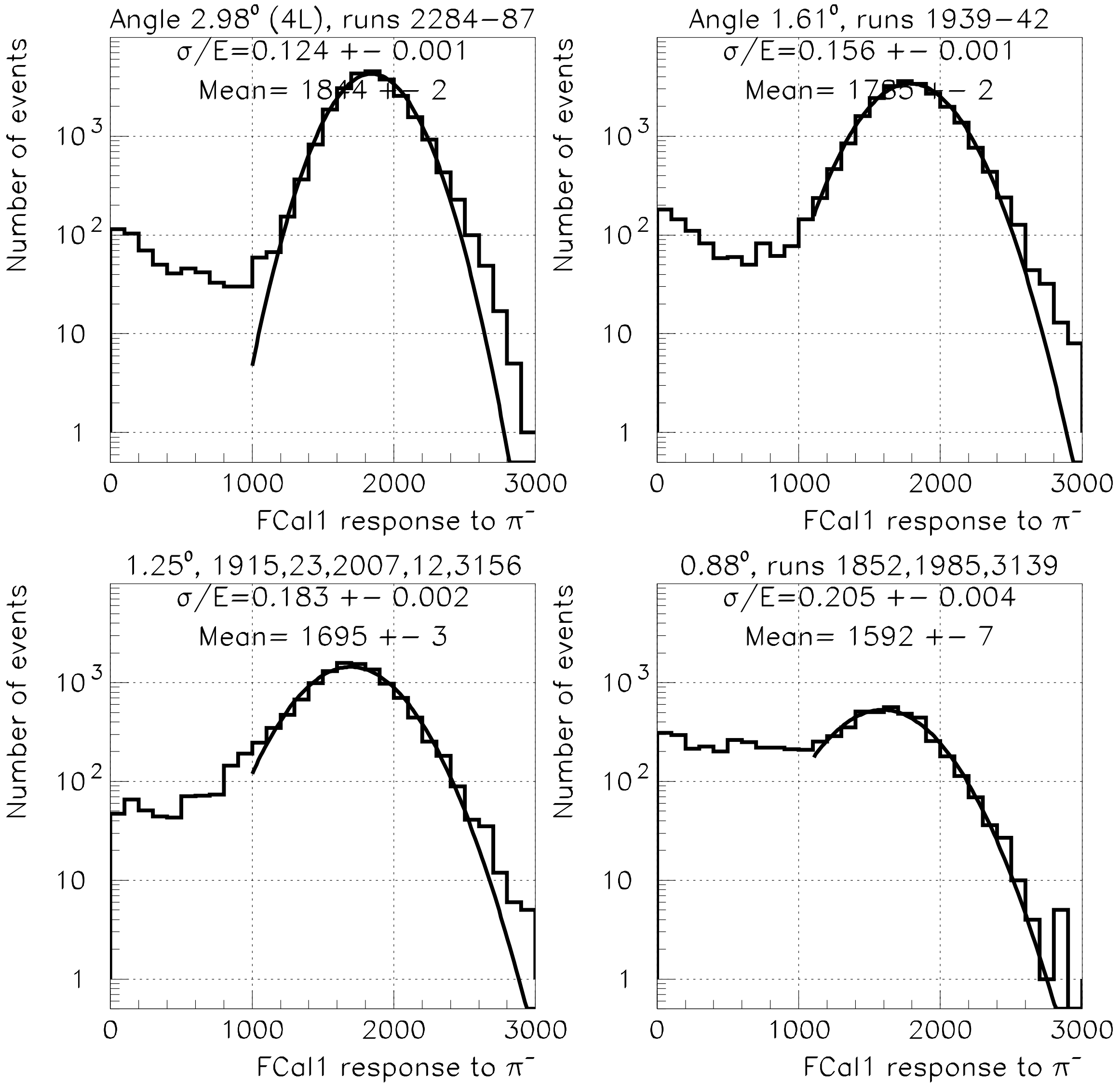

Figure 3: FCal response to 200 GeV test-beam pions (solid histograms) with superimposed restricted gaussian fits (solid curves).

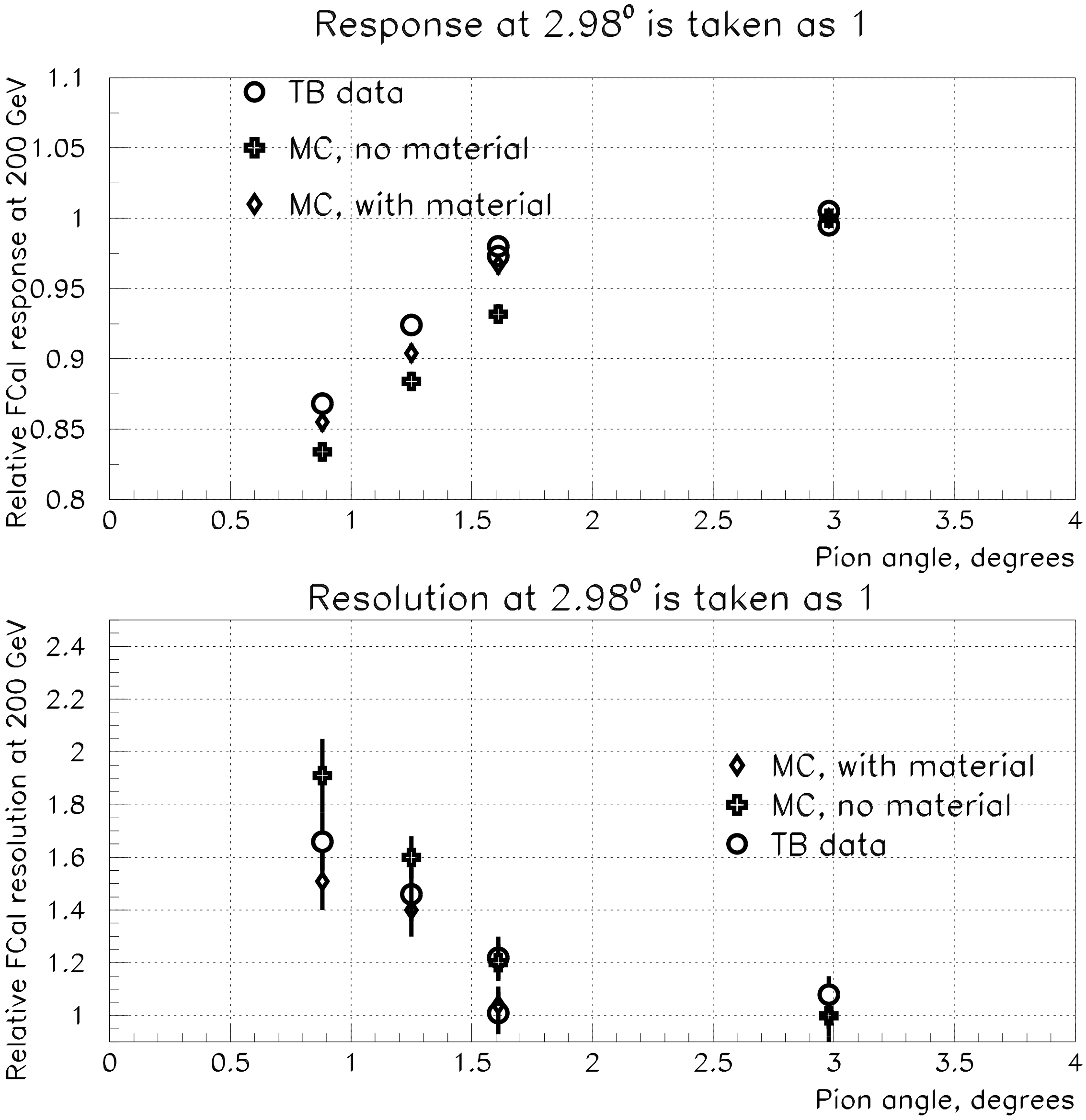

Figure 4: Angular dependence of the averaged gaussian response and energy resolution to pions in the MC. The response and resolution at 2.98^0 are taken to be equal to 1.

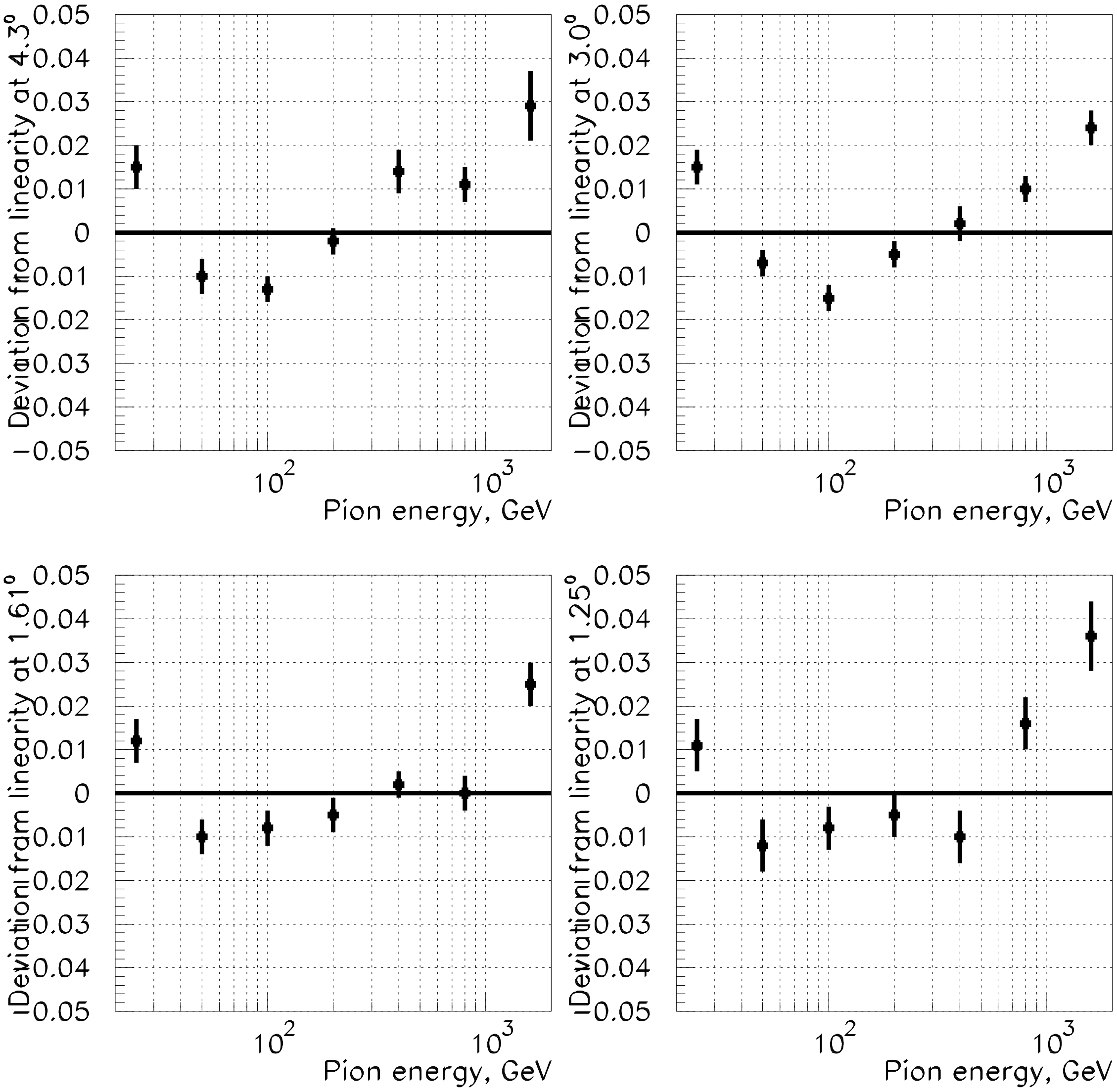

Figure 5: Deviation from linearity of the simulated FCal response to pions vs energy at different angles

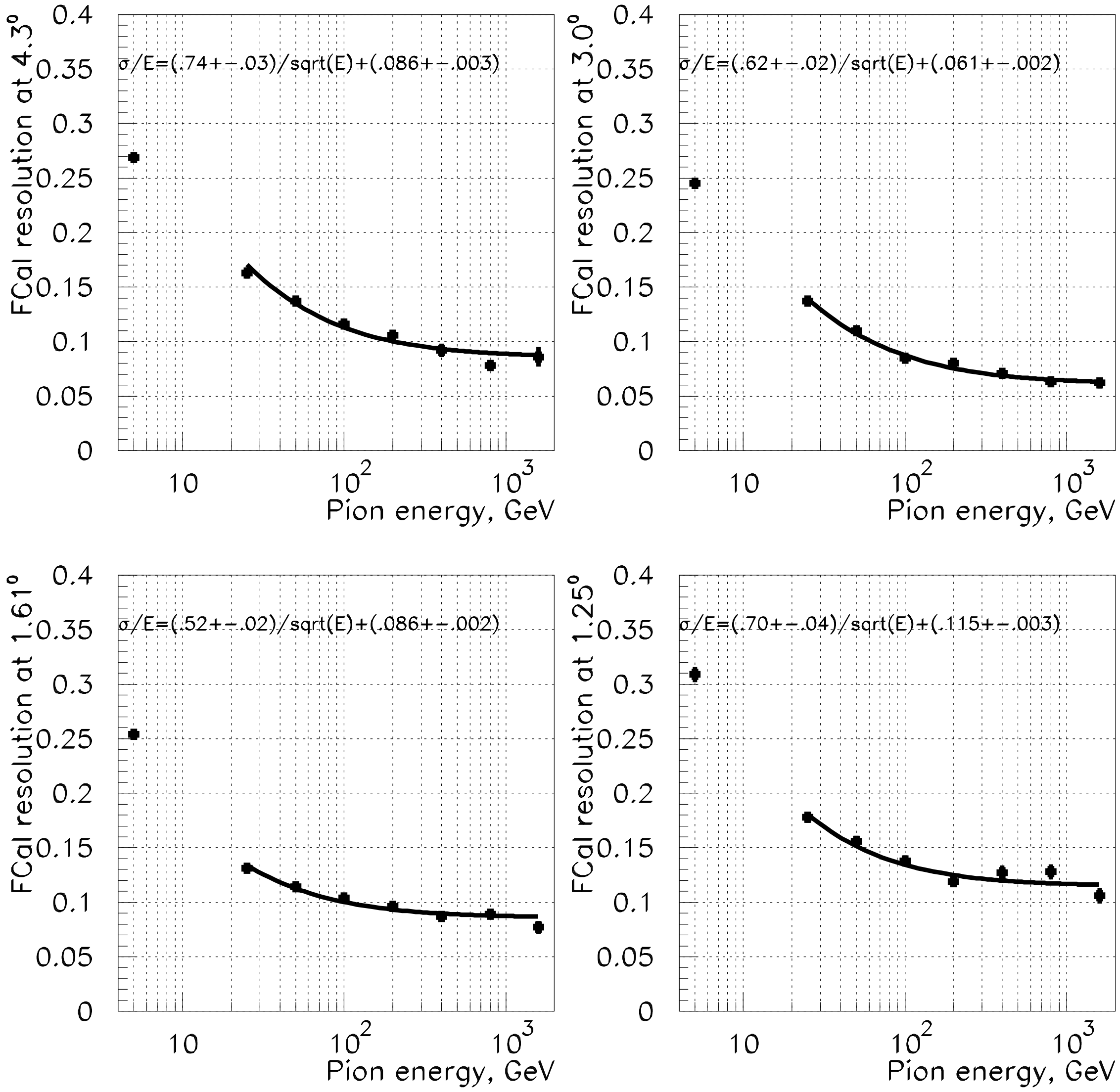

Figure 6: Angular dependence of stochastic and constant term of energy resolution to pions in the MC