HEC TB meeting
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Testbeam Data Analysis

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- **Electron and hadron TB data analysis: some new results**
- **LArg note outline**

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TB LArg note plan 14.03.99

Analysis of test-beam data obtained with HEC Module_0

1 Introduction

2 Test-beam Set-up

- general layout: cryostat, MWPC, scintillators, x and y movements;
- short module description, its orientation;
  Fig.T1 module + energy scan points;
- signal shaping, signal digitization - multiple samples;
- hardware calibration: gain equilization, non-linearity compensation, ADC to nA - absolute scale;
- apr98 and aug98 periods, beams, energy scan positions, statistics, HV problems;

3 Analysis Procedures

- only *procedure* description, but not their concrete implementation (software);
- TB analysis goals:
  - check linearity of response;
  - check spatial uniformity of response;
  - find *unbiased* α_{em} and α_{had}: nA to GeV;
  - extract the module performance characteristics (resolution - constant and sampling terms),

  which are different from experimental data analysis goal: most accurate reconstruction of the energy of each concrete particle or jet;
- lead to specific features of TB analysis procedure:
  - *fixed* tower to simplify interpretation of results;
  - *large* tower size to minimize the corrections, which are necessary to compensate the biases due to energy leakage out of the tower. The increase of electronic noise is a minor problem, *if* the noise can be reliably estimated and taken into account;
- criterion of a cell assignment to a tower - *mean* signal in the cell at some beam energy;
- signal amplitude finding - optimal filtering;

- **pedestal - mean run value is used. Pedestal drifting during a run exists but too small to noticeably increase the noise;**
  <u>Fig.A1</u> pedestal drift in some 4 channels;

- **noise estimate in a cell - the third sampling of a current signal multiplied with OF suppression factor, extracted from dedicated noise runs;**
  <u>Fig.A2</u> OF suppression factor: comparison noise and muon runs;

- **noise in a tower - just a sum of cell noise measurements for each physics event; coherence is taken into account automatically;**
  <u>Fig.A3</u> noise distribution for some hadron tower - illustrates its Gaussian shape;
  coherence illustration: real noise vs noise as square sum of cell noise;

- **correction factors:**
  - **factor of 2 for the third layer: coarser sampling**
  - **factor of 1.25 3rd layer, module 2, apr98, aug98: HV problem**
  - **factor of 1.16 2nd layer, module 1, aug98: HV problem**

  HV correction factor is ratio of biased and unbiased mean signals in the corresponding layers for 180 GeV pion beam;

- **Gaussian fit of an energy distribution in a limited interval $E^{reconstr} \pm 2\sigma$ is used to find the energy distribution width σ and maximum $E^{reconstr}$; the resolution is characterized with $\rho = \sigma / E^{reconstr}$;**

- **calibration factor (nA to GeV) calculation:**
  $\alpha = E^{beam}_{nominal} / E^{reconstr}_{nA}$,
  no any minimizations of any functionals;

- **Monte-Carlo samples, "spoiling", ideal MC, noise superimposed.**

4 Electron Data Analysis

- **Fig.E1** energy distributions at 4-6 energies;
- **Fig.E2** energy dependence of resolution, point D, apr98;
  MC - perfect coincidence;
- **Fig.E3** sampling term (apr+aug) vs spatial point number;
  difference between points and periods is rather small;
- **Fig.E4** constant term (apr+aug) vs spatial point number;
  everywhere is compatible with zero;
- **Fig.E5** linearity of response, apr98, 4 points;
  linear within $\pm 0.5\%$ *after* applying hw calibration;
- **Fig.E6** linearity of response, aug98, 4(?) points;
  worse linearity;
- **Fig.E7a,b** spatial uniformity of response apr (a) and aug (b): α_{em} vs spatial point number with/without hw calibration;
  deviations are within the band $\pm 1\%$ *after* applying hw calibration, i.e. σ is about 0.5% (?); Figs.5-7 are illustrating the quality of hw calibration;
- comparison of absolute calibration (table - α_{em} at all points) apr vs aug: the difference is about 2%.

5 Hadron Data Analysis

- **intrinsic energy resolution:** *no any adjustable correction factors*
- **fit of the energy dependence of the resolution with two parameter formula: sampling and constant terms, noise is presubtracted at each energy point separately;**
- **tables with fit results for different spatial points, apr and aug;**
- **Fig.H1 energy dependence of resolution at point I + 3MC, apr;**
- **point I: sampling term 76.4±2.4%, constant term 5.31±0.30%; these values can not be considered as the characteristics of the intrinsic HEC resolution because they are biased by energy leakage (∼5%);**
- **description of the correction procedure using MC;**
- **Fig.H2 correction factors obtained with GFLUKA, GCALOR, GHEISHA: they are very close;**
- **parameters of HEC intrinsic resolution: 70±4% and 4±0.4%**
- **ideal MC predictions:**
  - **GFLUKA - 43.7±1.1% and 2.34±0.23%**
  - **GCALOR - 62.6±1.6% and 3.67±0.31%**
  - **GHEISHA - 85.1±2.1% and 4.44±0.44%**

- **attempt to improve *intrinsic* resolution using energy independent adjustable multiplicative factors assigned to each of 3 longitudinal layers. The factors are found using only high energy data (120 and 180 GeV). Result at point I: no change in sampling term, constant term 5.31% → 4.72% (δ=0.6%);**

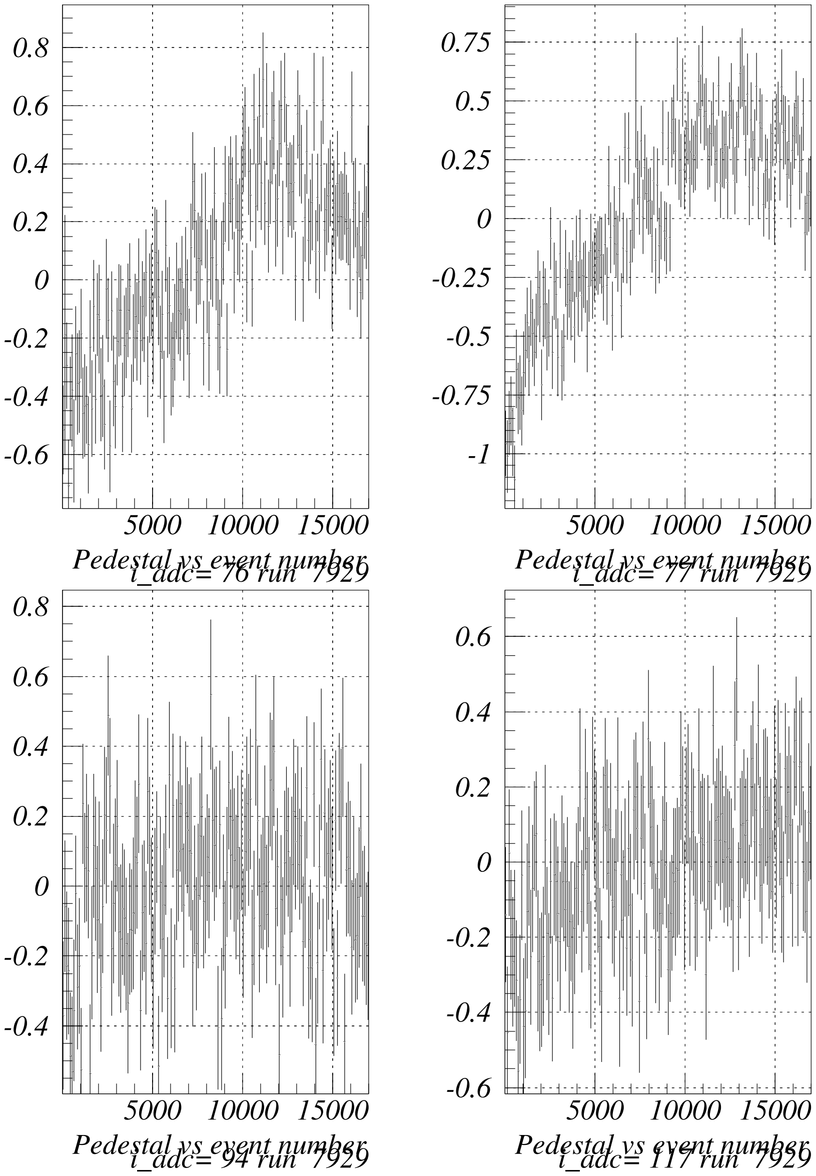
- **the same factors are found and applied at each energy separately. They works for noise suppression at low energies, but *after* noise subtraction the intrinsic resolution is approximately the same and even worse at the lowest energies. So, energy dependent adjustable correction factors are *unable to improve intrinsic resolution*;**

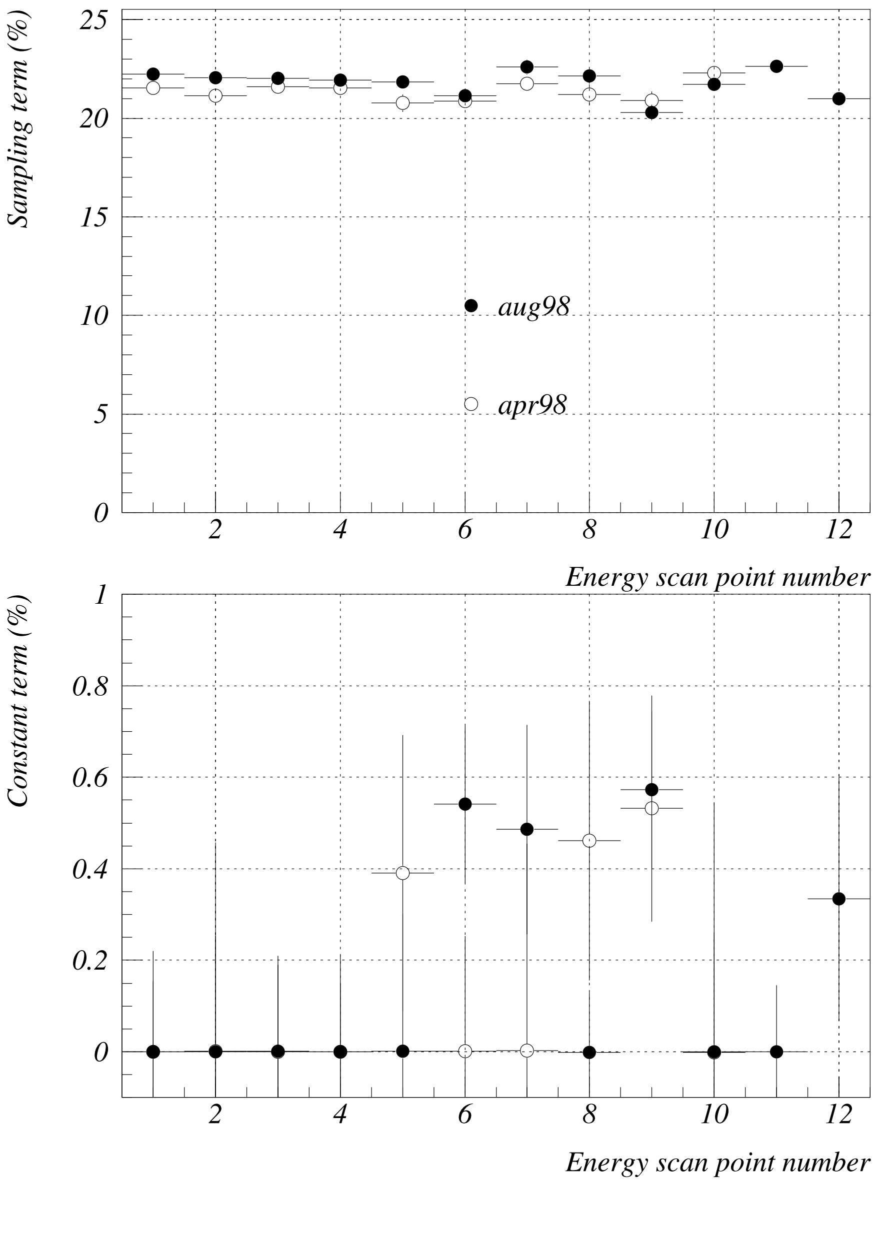
- **Fig.H3 normalized mean signal in all 3 layers vs E_beam in comparison with MC predictions. All three MC and exp are rather close to each other, i.e. no observable difference in longitudinal shower shapes;**

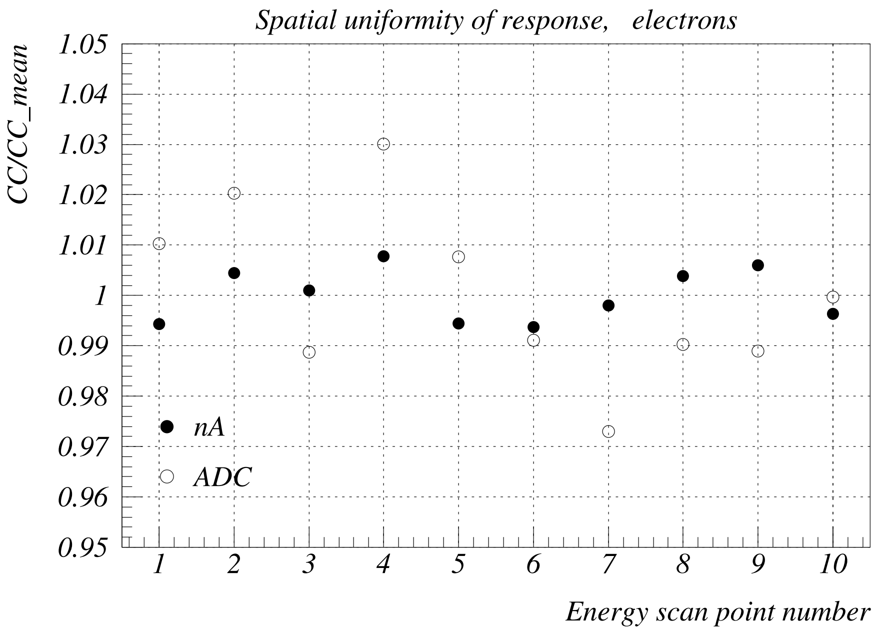
- **Fig.H4a-c horizontal scan with 120 GeV pions, mean signal in vertical strips for layers 1-3 (a-c). MC (GCALOR) predictions are rather close to exp data, i.e. no meaningful difference in lateral shower shapes;**

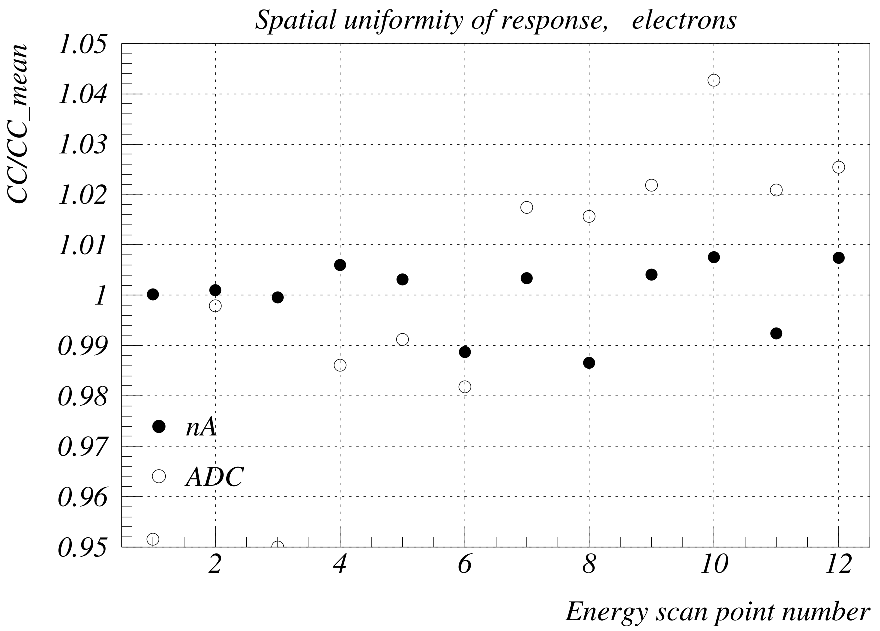
- **Fig.H5-? e/h ratio, MC correction, apr-aug comparison, MC predictions;**

6 Conclusions

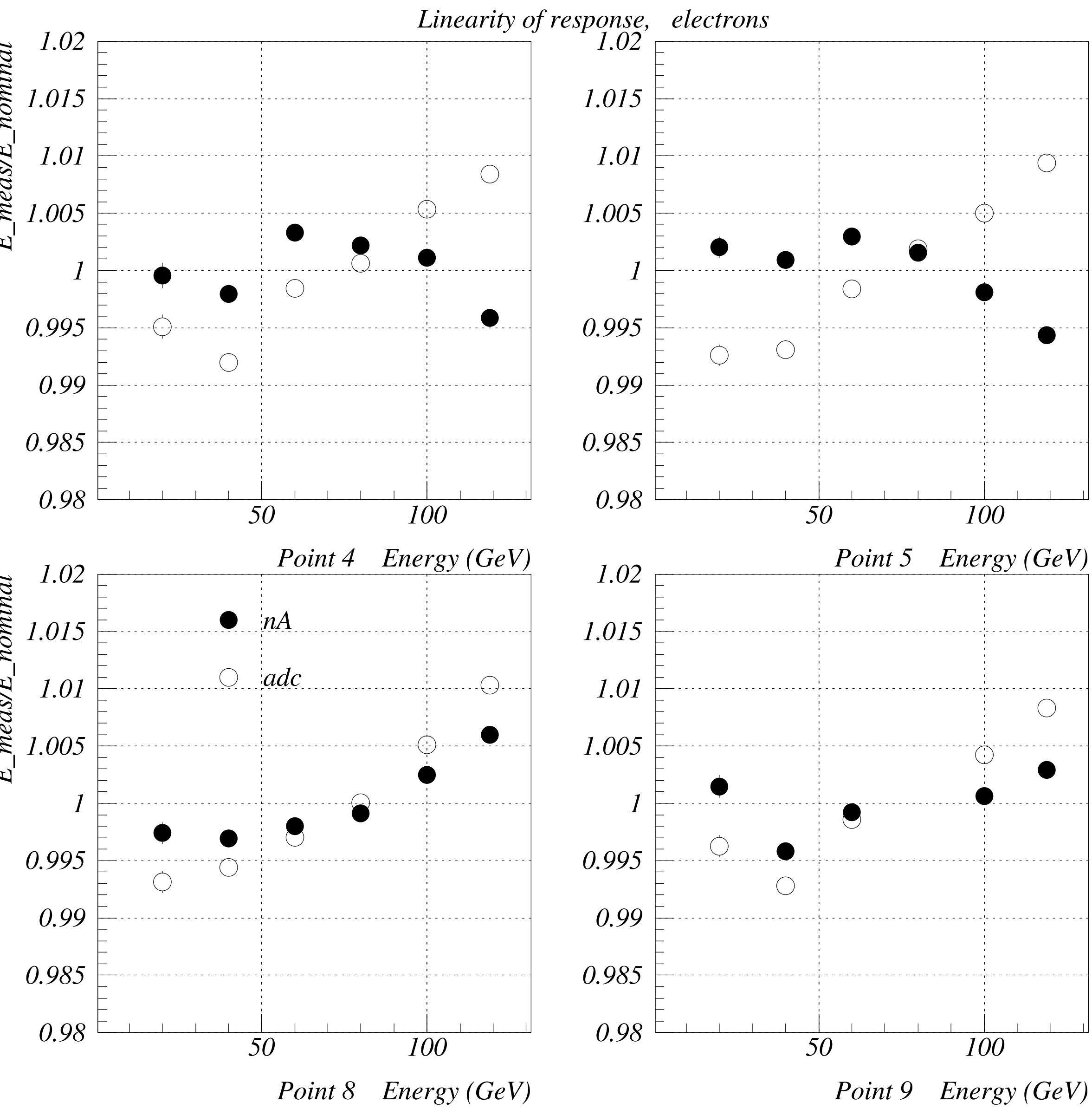

Pedestal vs event number
i_adc= 76 run 7929
Pedestal vs event number
i_adc= 77 run 7929
Pedestal vs event number
i_adc= 94 run 7929
Pedestal vs event number
i_adc= 117 run 7929
5000
10000
15000

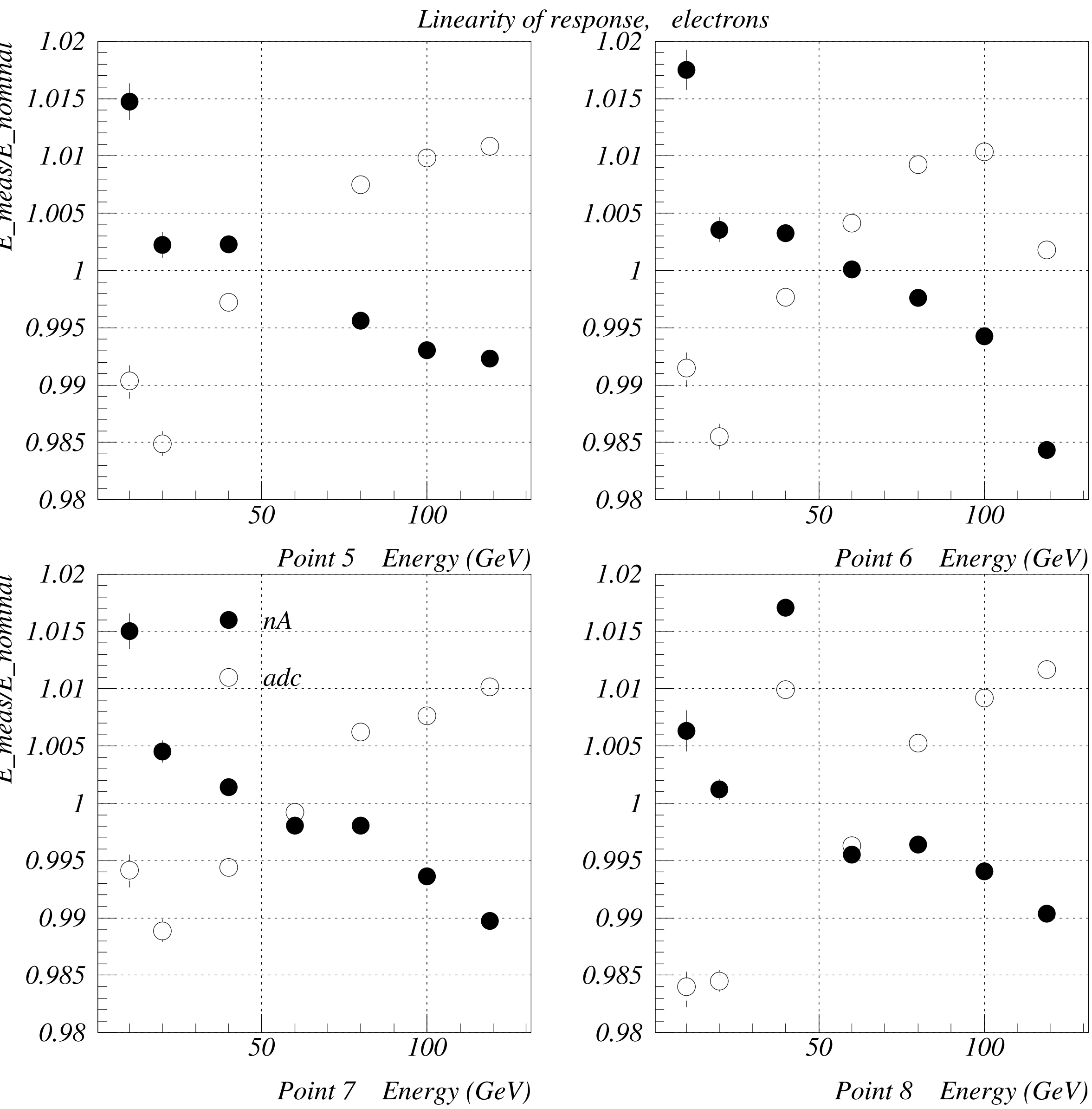

Sampling term (%)
25
20
15
10
5
0
2
4
6
8
10
12
aug98
apr98
Energy scan point number
Constant term (%)
1
0.8
0.6
0.4
0.2
0
2
4
6
8
10
12
Energy scan point number

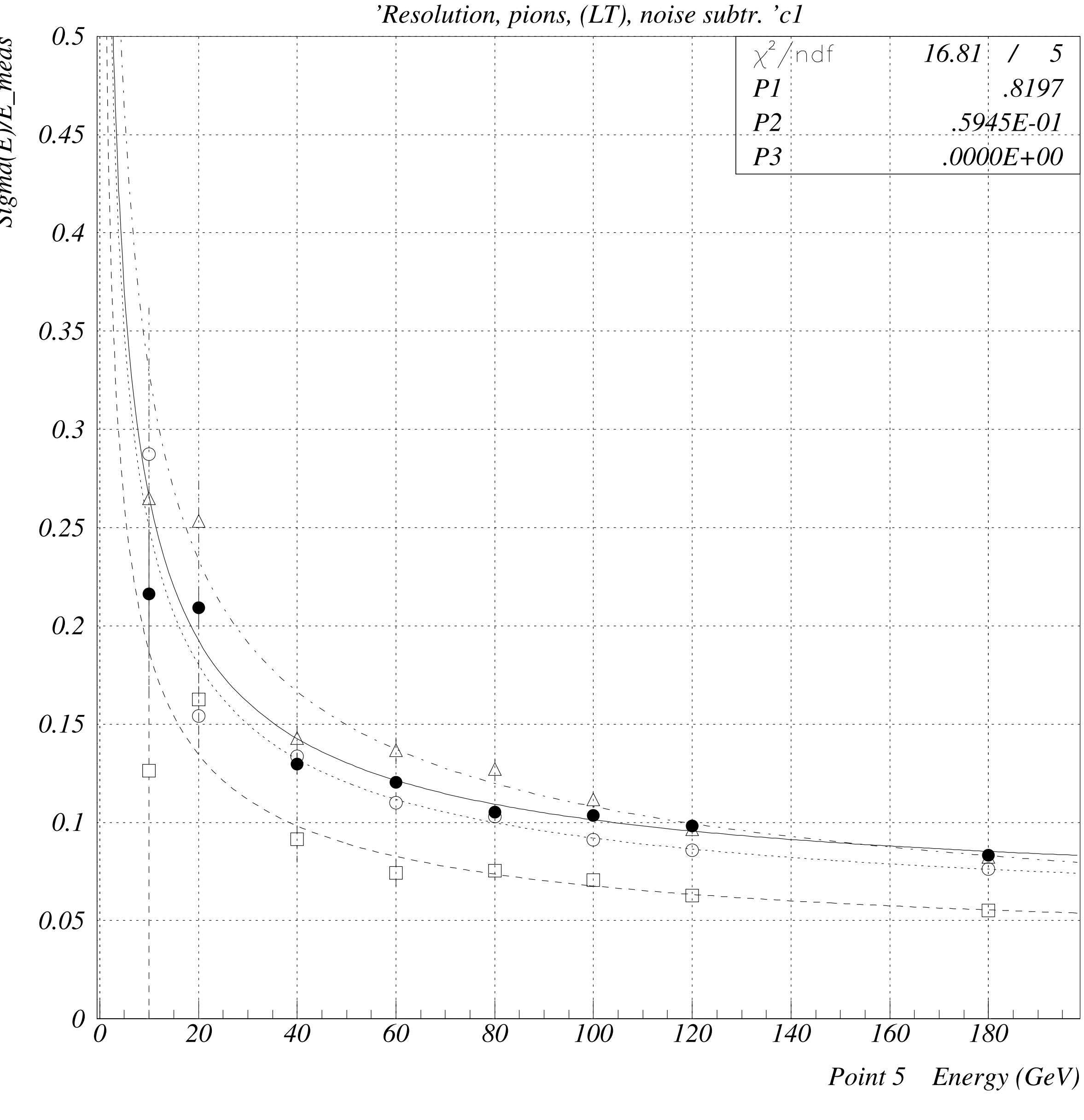

Spatial uniformity of response, electrons
CC/CC_mean
1.05
1.04
1.03
1.02
1.01
1
0.99
0.98
0.97
0.96
0.95
1
2
3
4
5
6
7
8
9
10
Energy scan point number
nA
ADC



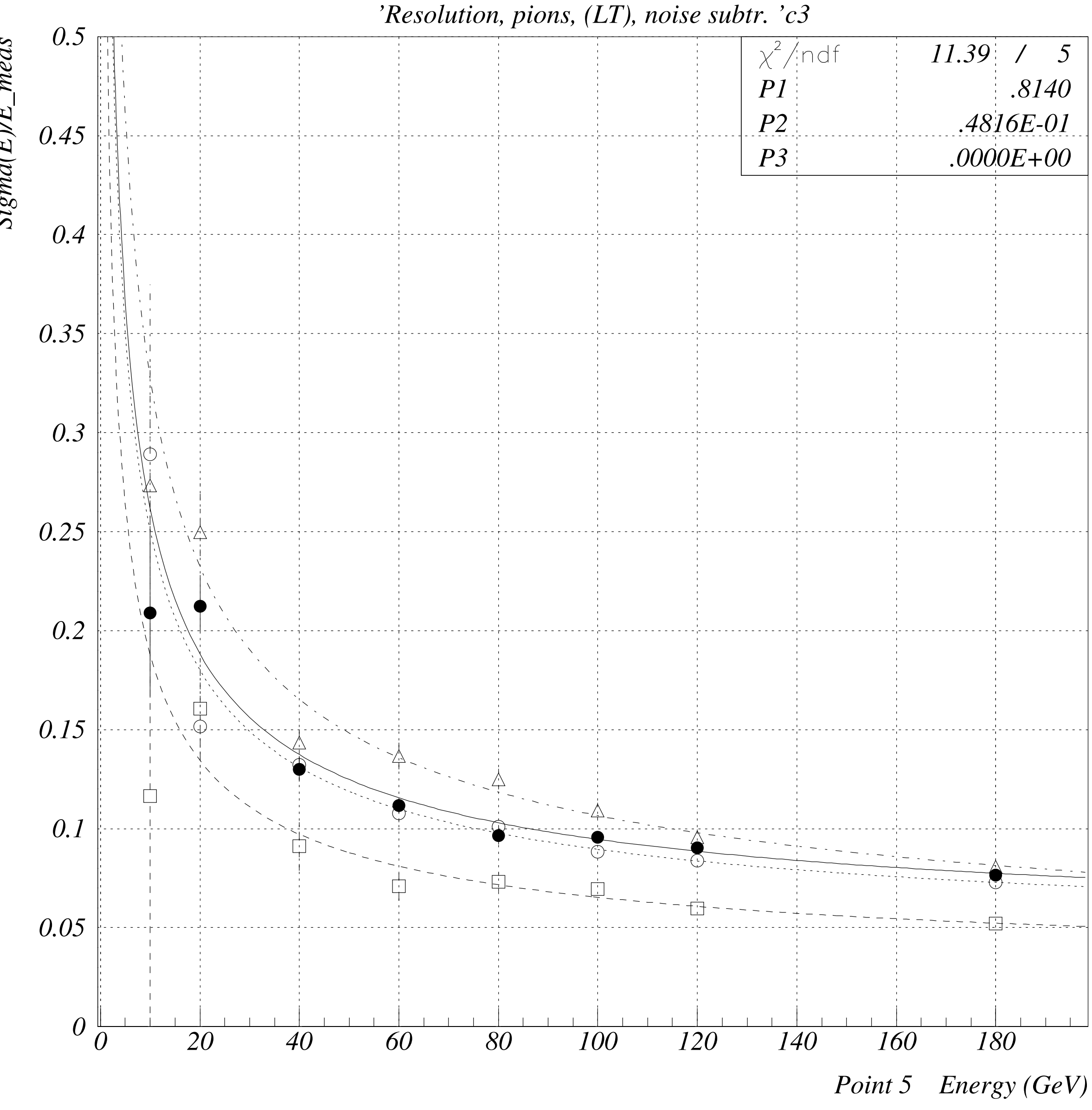
Spatial uniformity of response, electrons
CC/CC_mean
1.05
1.04
1.03
1.02
1.01
1
0.99
0.98
0.97
0.96
0.95
2
4
6
8
10
12
nA
ADC
Energy scan point number


Linearity of response, electrons
E_meas/E_nominal
1.02
1.015
1.01
1.005
1
0.995
0.99
0.985
0.98
50
100
Point 4 Energy (GeV)
Point 5 Energy (GeV)
nA
adc
Point 8 Energy (GeV)
Point 9 Energy (GeV)

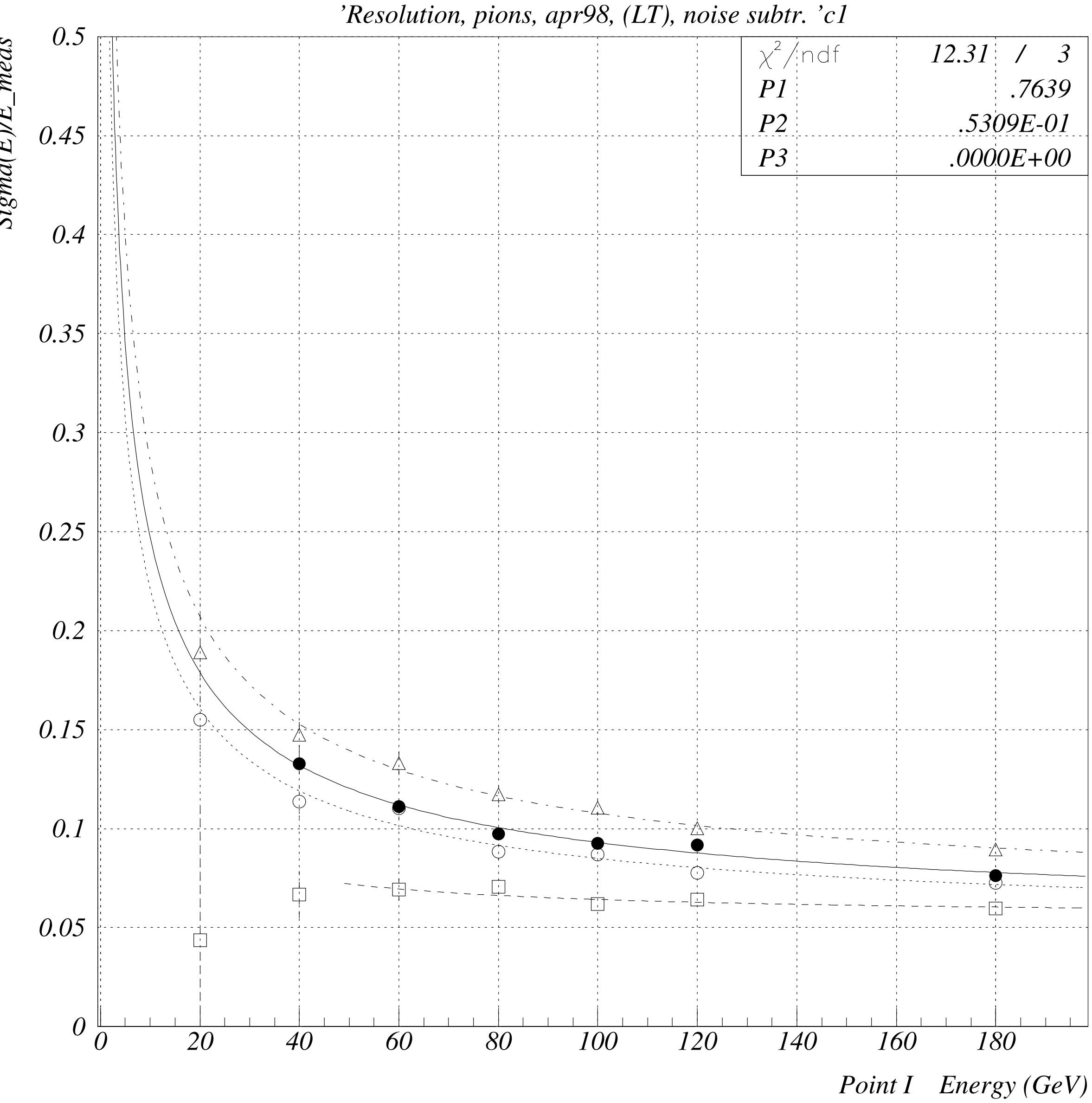

Linearity of response, electrons
E_meas/E_nominal
1.02
1.015
1.01
1.005
1
0.995
0.99
0.985
0.98
50
100
Point 5 Energy (GeV)
Point 6 Energy (GeV)
nA
adc
Point 7 Energy (GeV)
Point 8 Energy (GeV)

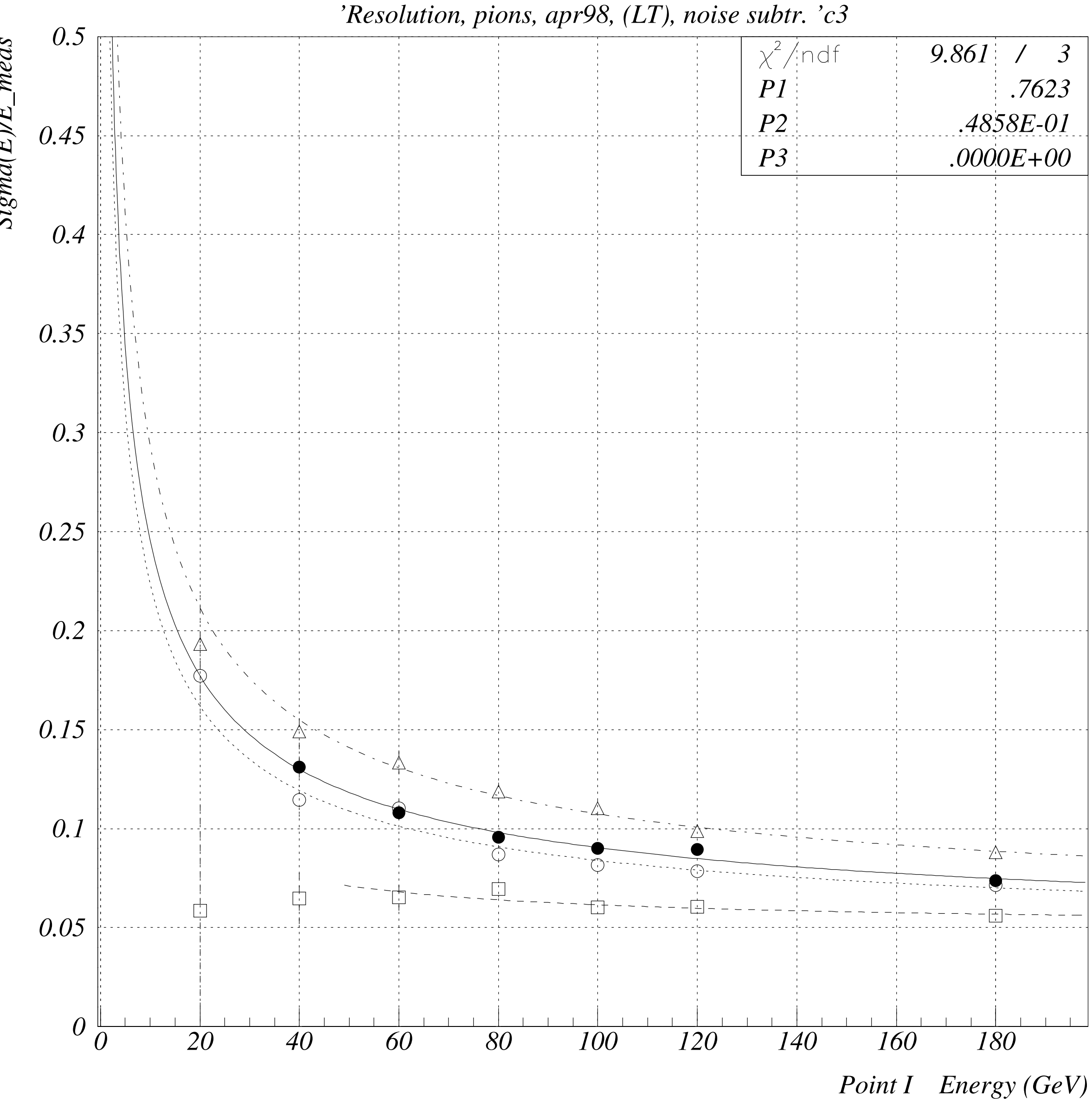


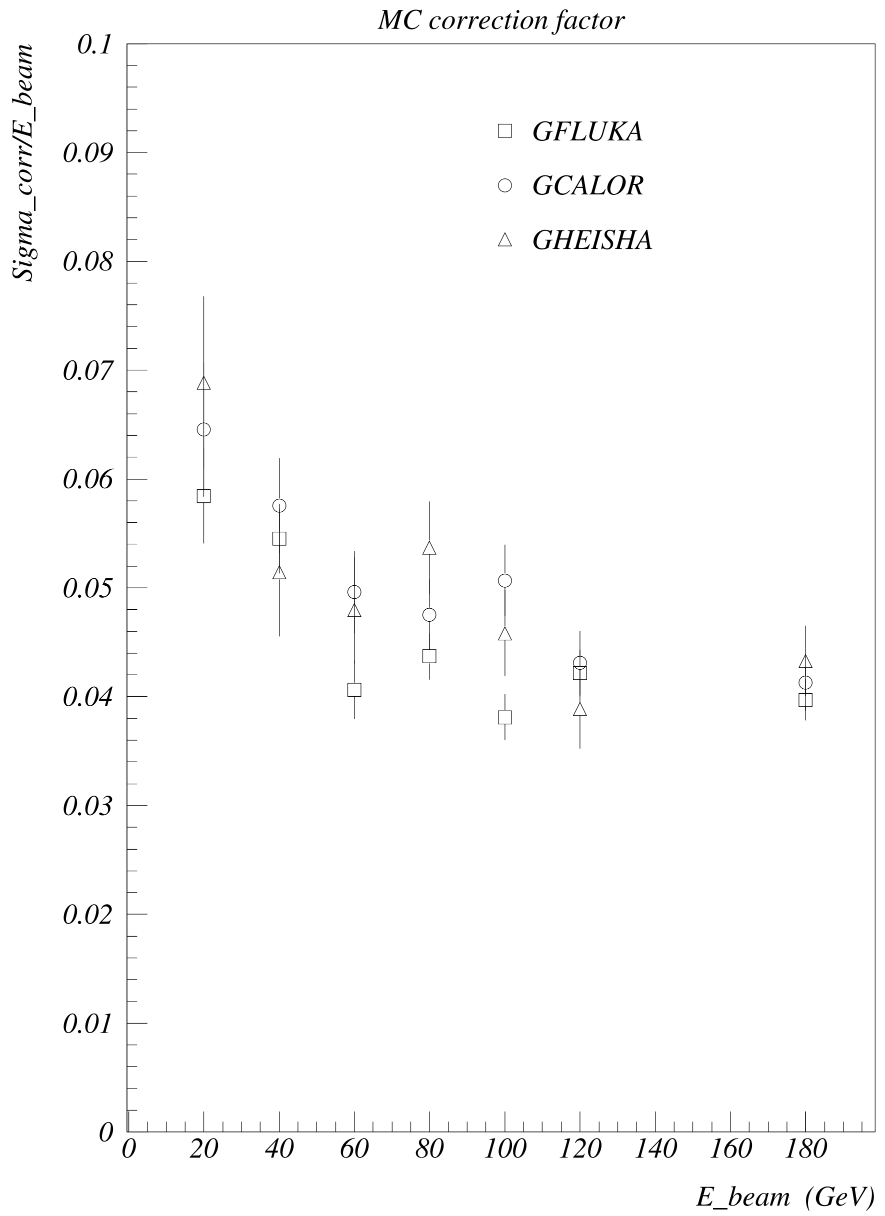
'Resolution, pions, (LT), noise subtr. 'c1
χ^2/ndf 16.81 / 5
P1 .8197
P2 .5945E-01
P3 .0000E+00
Sigma(E)/E_meas
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0 20 40 60 80 100 120 140 160 180
Point 5 Energy (GeV)

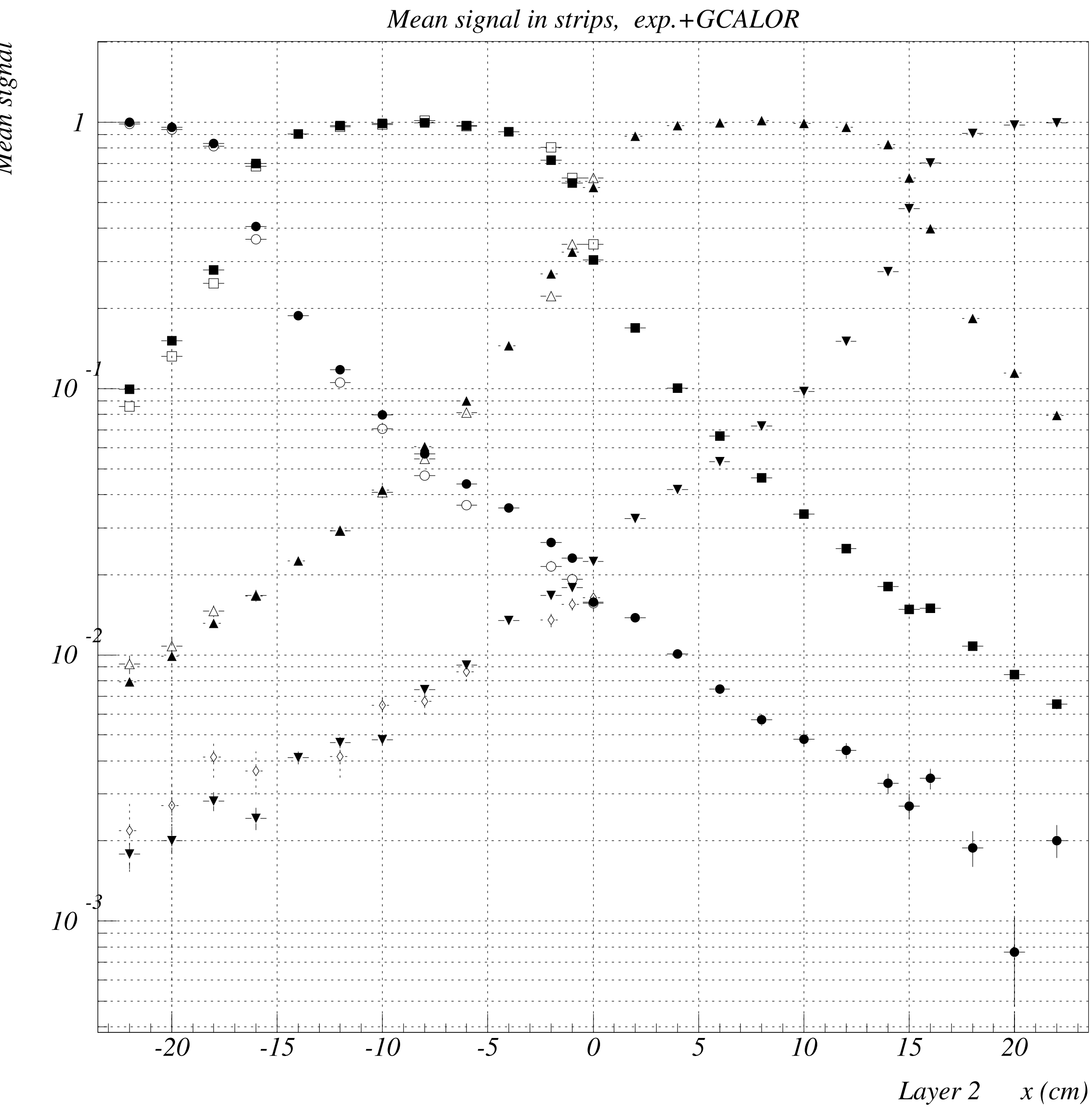


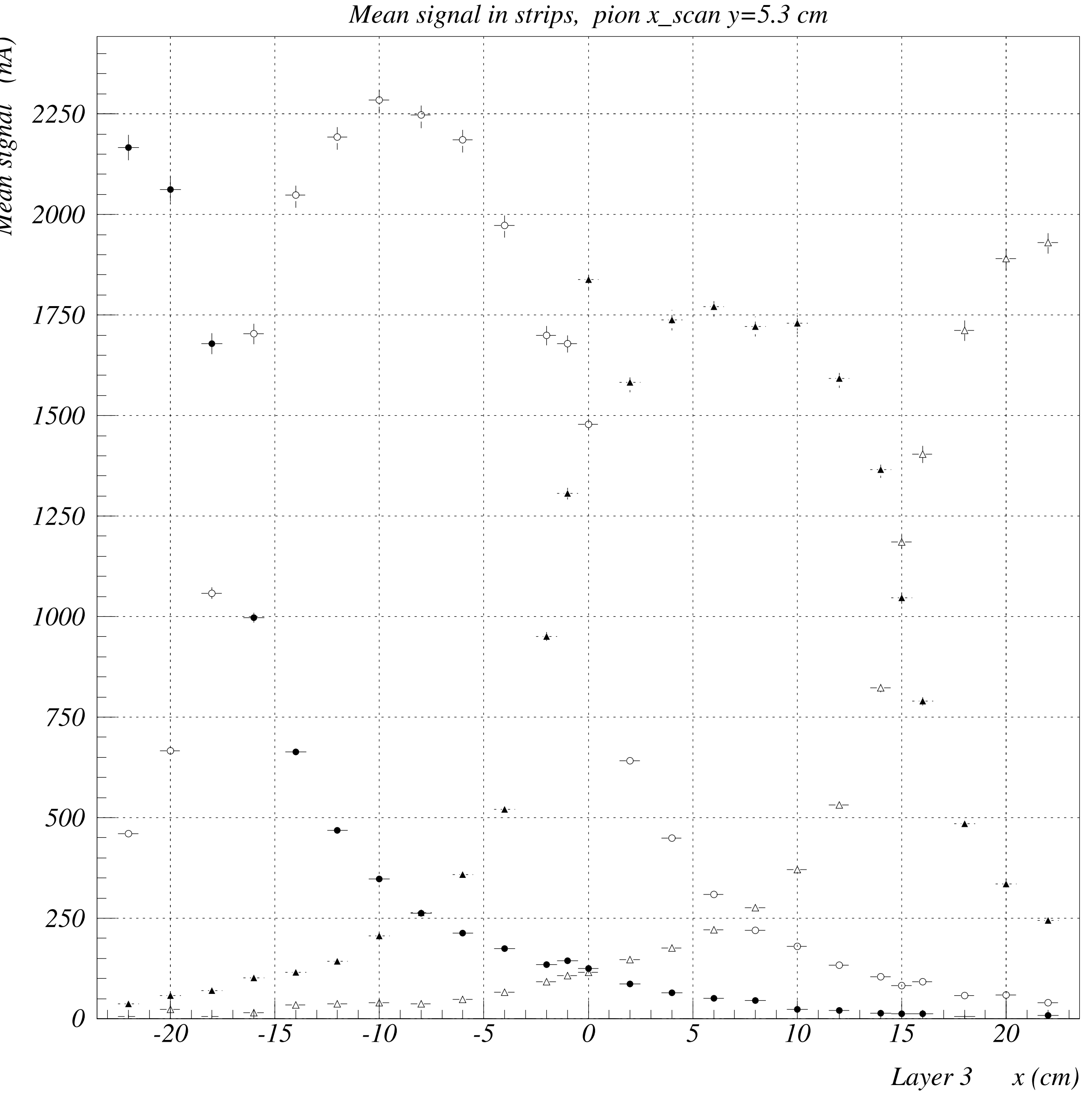
'Resolution, pions, (LT), noise subtr. 'c3
Sigma(E)/E_meas
χ²/ndf 11.39 / 5
P1 .8140
P2 .4816E-01
P3 .0000E+00
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
20
40
60
80
100
120
140
160
180
Point 5 Energy (GeV)


'Resolution, pions, apr98, (LT), noise subtr. 'c1
Sigma(E)/E_meas
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
χ^2/ndf 12.31 / 3
P1 .7639
P2 .5309E-01
P3 .0000E+00
0
20
40
60
80
100
120
140
160
180
Point I Energy (GeV)


'Resolution, pions, apr98, (LT), noise subtr. 'c3
Sigma(E)/E_meas
χ²/ndf 9.861 / 3
P1 .7623
P2 .4858E-01
P3 .0000E+00
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0 20 40 60 80 100 120 140 160 180
Point I Energy (GeV)


MC correction factor
Sigma_corr/E_beam
GFLUKA
GCALOR
GHEISHA
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
0
20
40
60
80
100
120
140
160
180
E_beam (GeV)


Mean signal in strips, exp.+GCALOR
Mean signal
1
10 -1
10 -2
10 -3
-20
-15
-10
-5
0
5
10
15
20
Layer 2
x (cm)

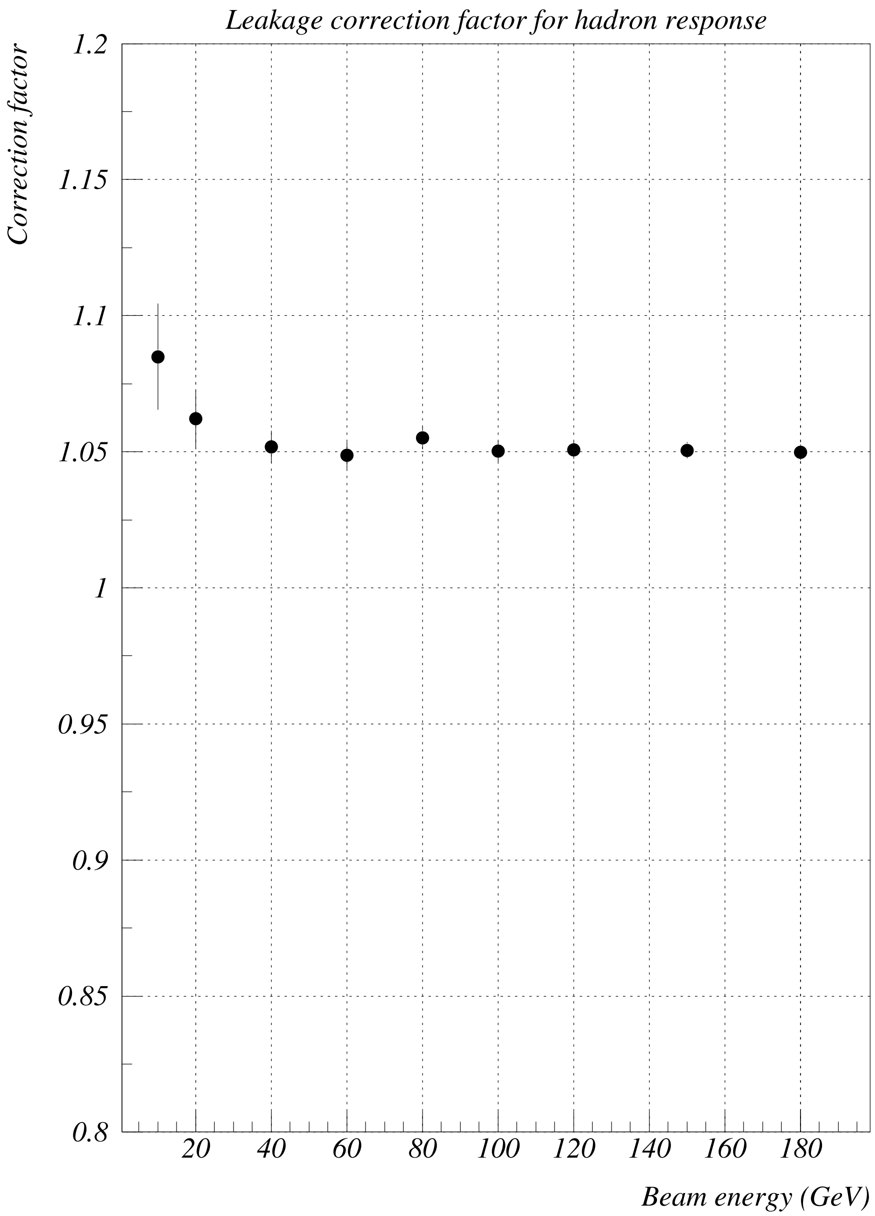

Mean signal in strips, pion x_scan y=5.3 cm
Mean signal (nA)
0
250
500
750
1000
1250
1500
1750
2000
2250
-20
-15
-10
-5
0
5
10
15
20
Layer 3
x (cm)

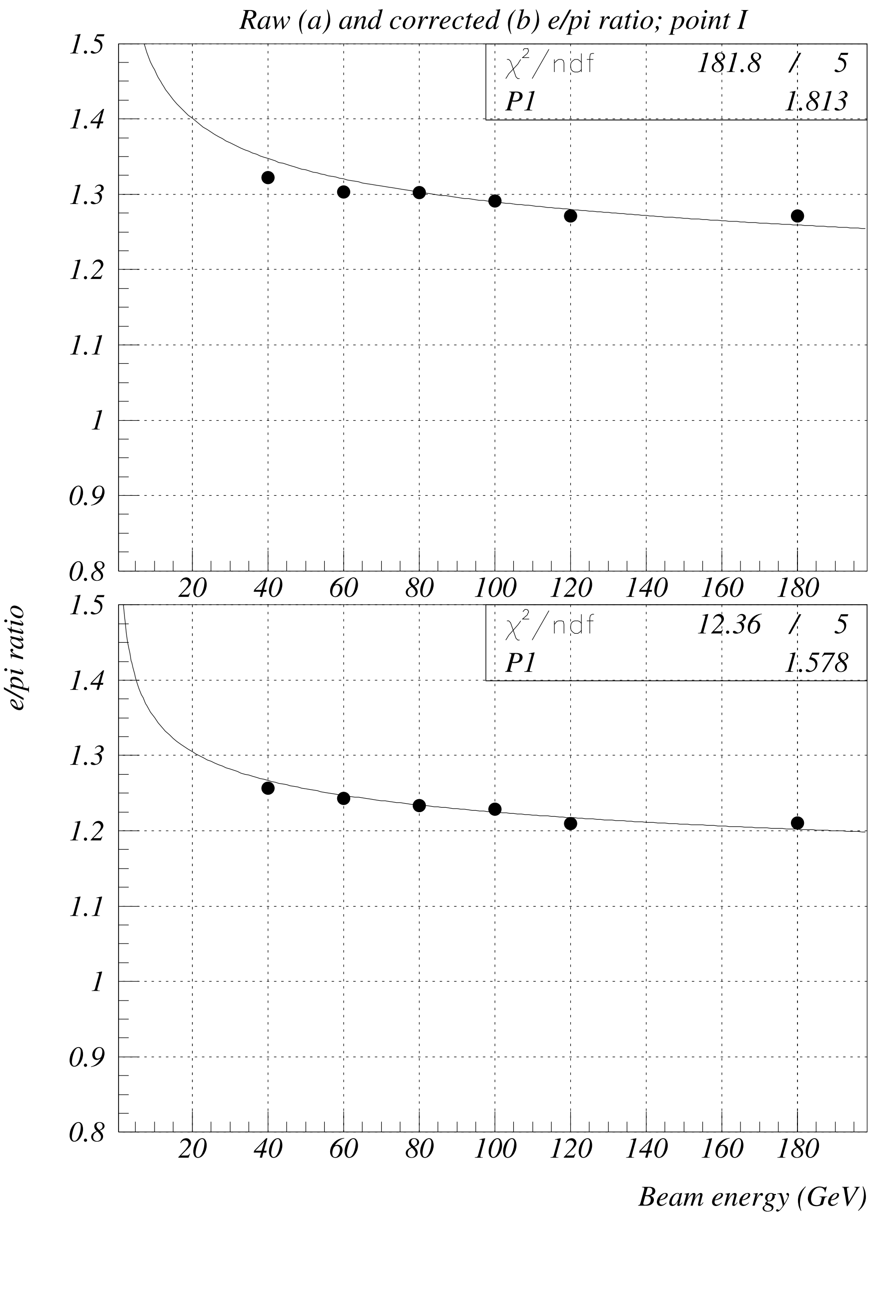
$$e/\pi = \frac{e/h}{1 + (e/h - 1) \cdot f_{\pi^0}} \tag{1}$$

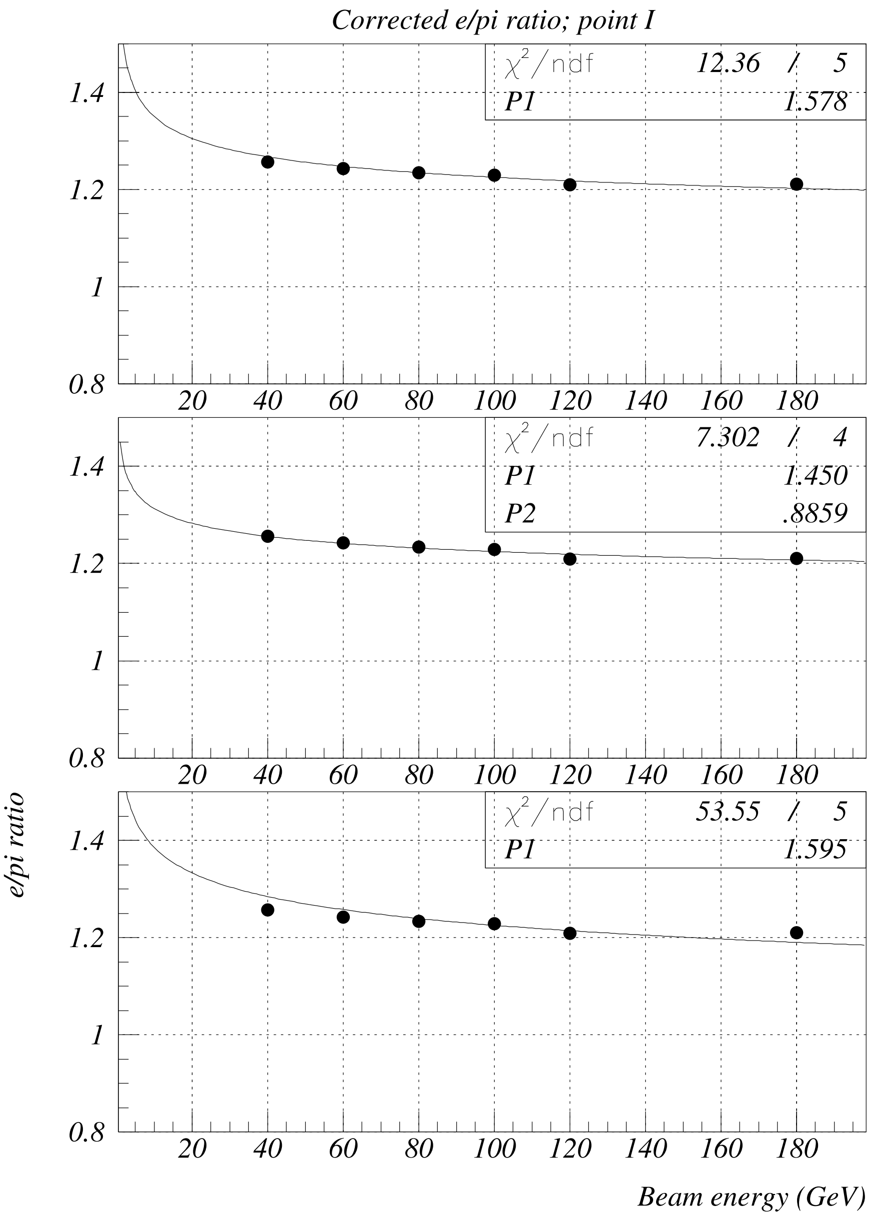
$$f_{\pi^0} = 1 - (E/E_0)^{1-m} \tag{2}$$

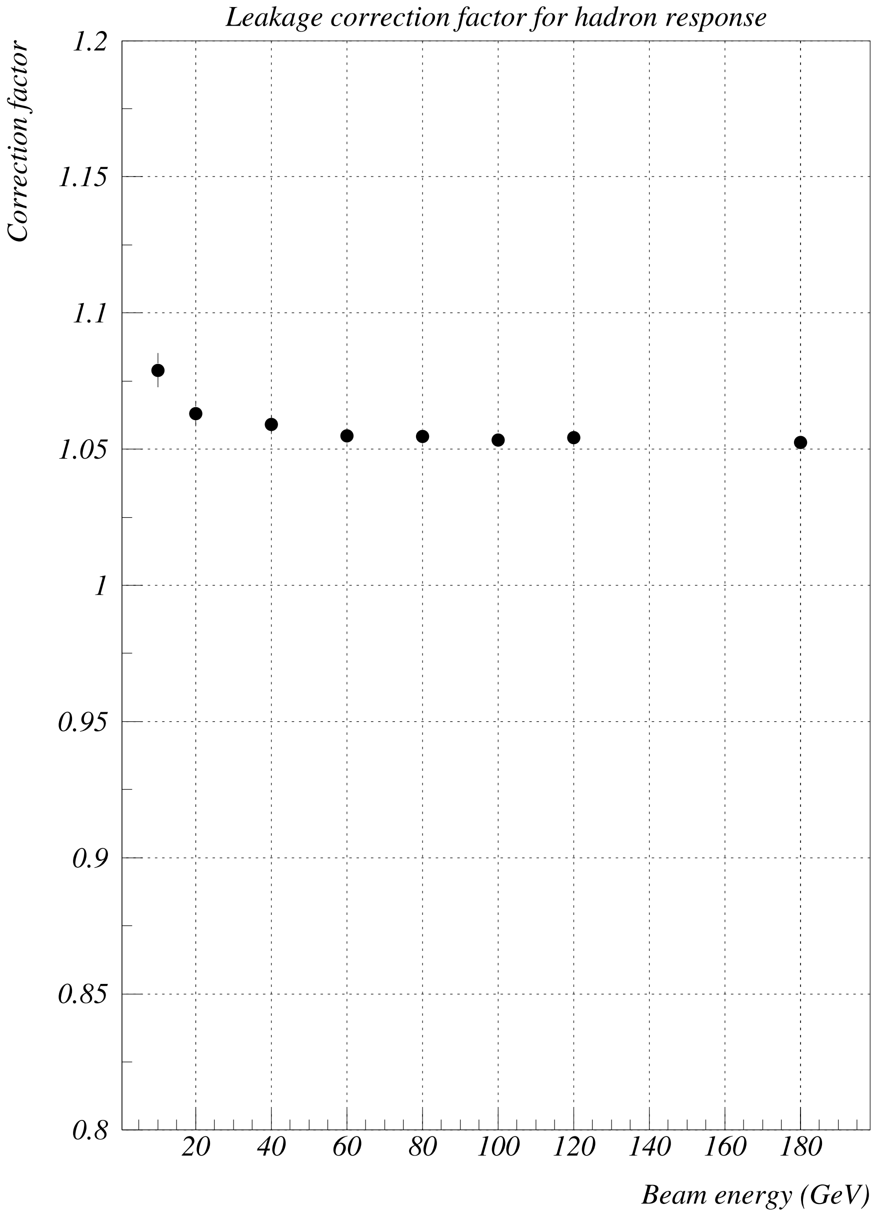
$$f_{\pi^0} = k \cdot \ln(E/E_0), \tag{3}$$

where E_0 =1 GeV, m=0.85 and k=0.11

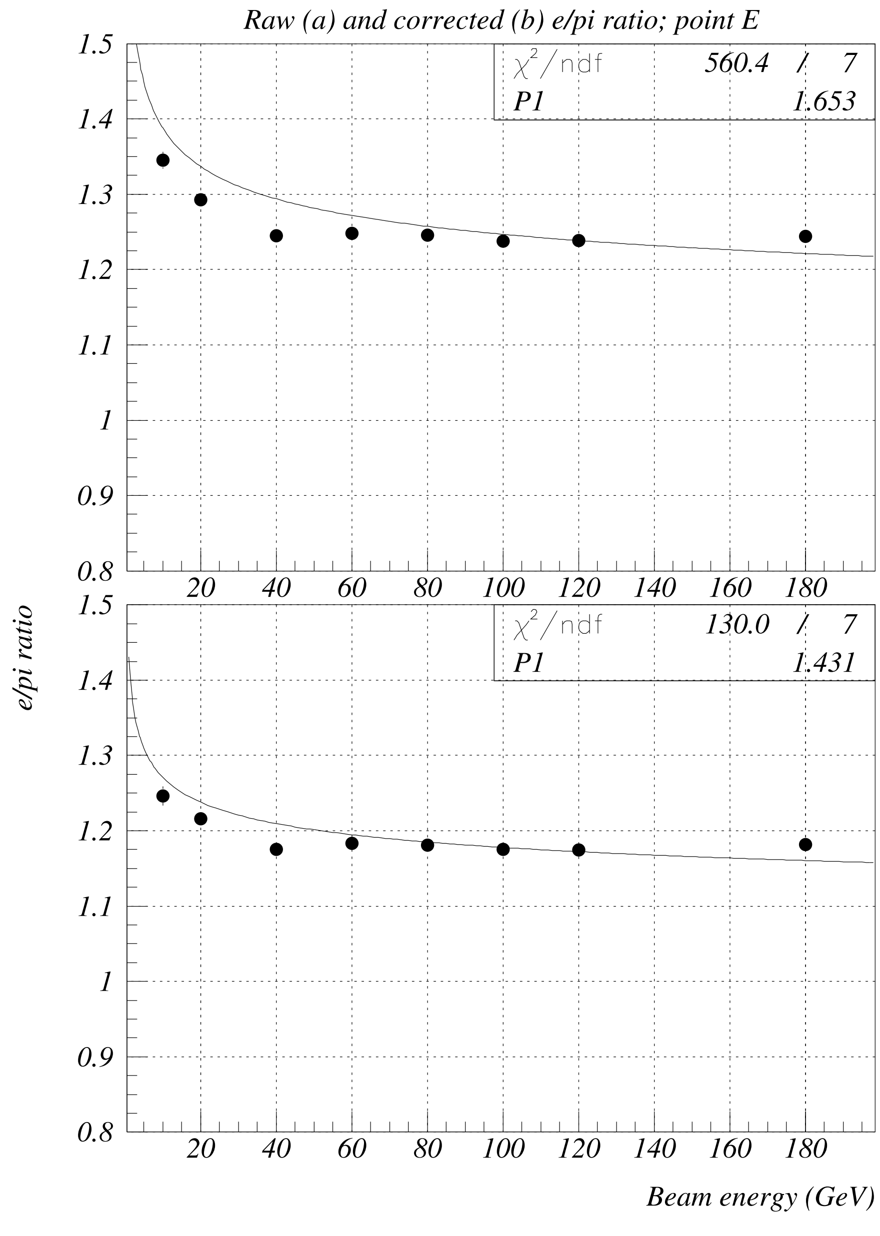

Leakage correction factor for hadron response
Correction factor
1.2
1.15
1.1
1.05
1
0.95
0.9
0.85
0.8
20
40
60
80
100
120
140
160
180
Beam energy (GeV)

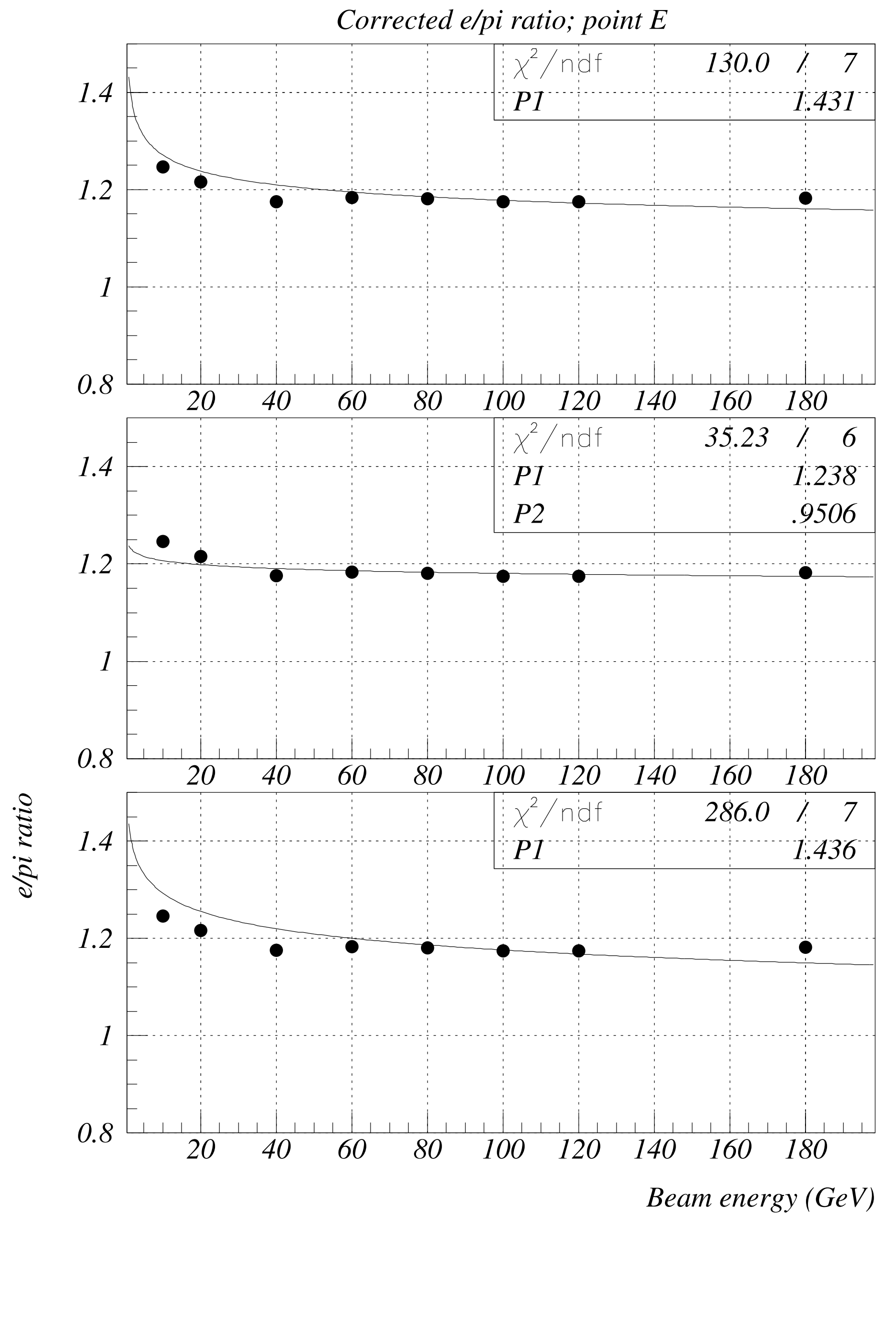

Raw (a) and corrected (b) e/pi ratio; point I
χ²/ndf 181.8 / 5
P1 1.813
χ²/ndf 12.36 / 5
P1 1.578
e/pi ratio
Beam energy (GeV)
0.8
0.9
1
1.1
1.2
1.3
1.4
1.5
20
40
60
80
100
120
140
160
180


Corrected e/pi ratio; point I
χ^2/ndf 12.36 / 5
P1 1.578
χ^2/ndf 7.302 / 4
P1 1.450
P2 .8859
χ^2/ndf 53.55 / 5
P1 1.595
e/pi ratio
Beam energy (GeV)

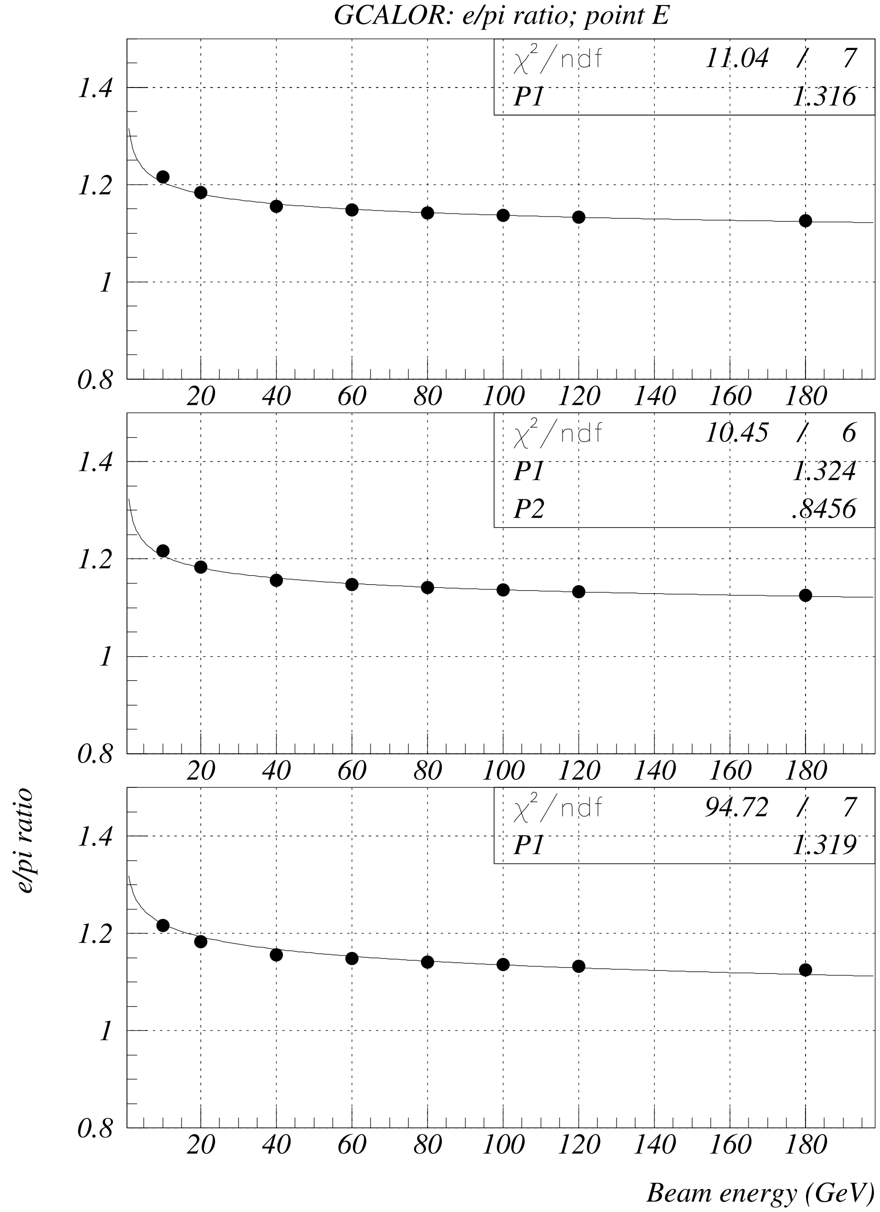


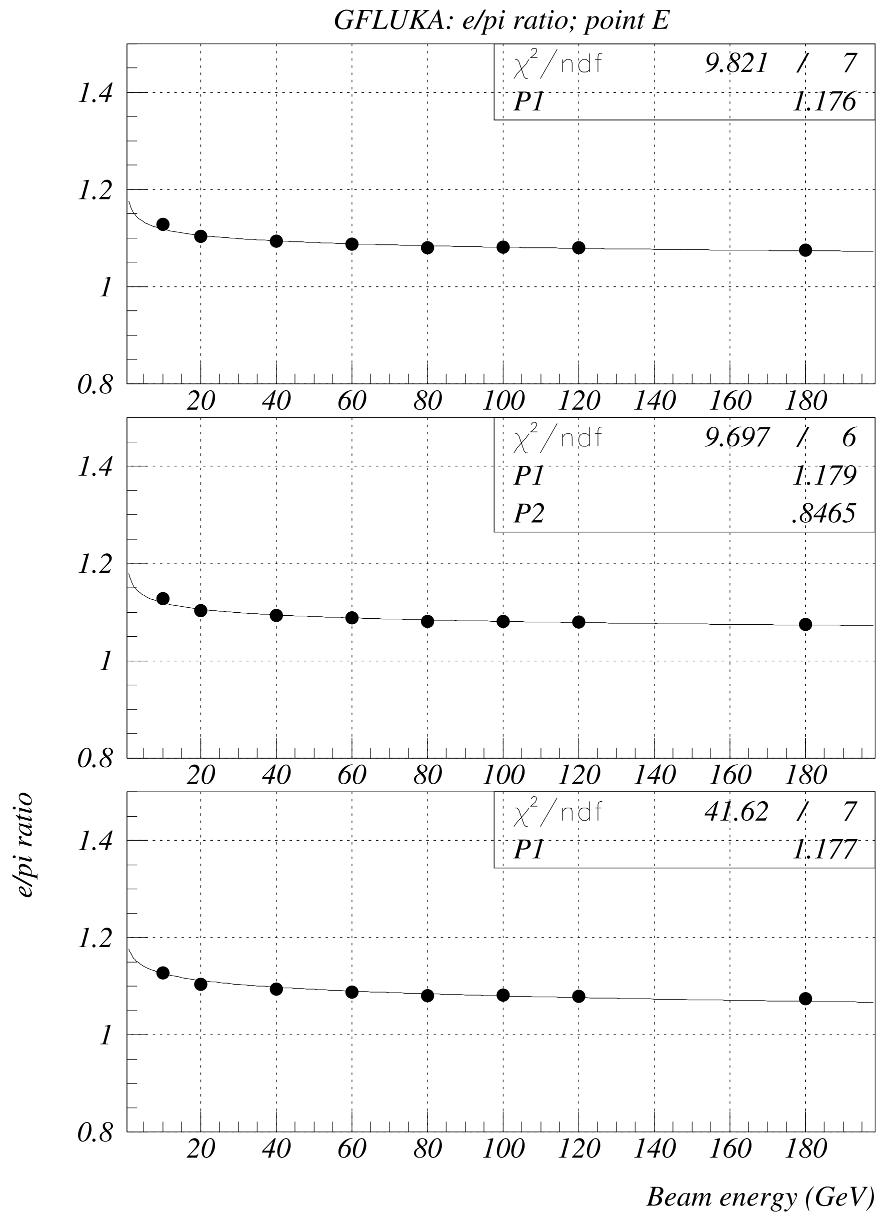
Leakage correction factor for hadron response
Correction factor
1.2
1.15
1.1
1.05
1
0.95
0.9
0.85
0.8
20
40
60
80
100
120
140
160
180
Beam energy (GeV)

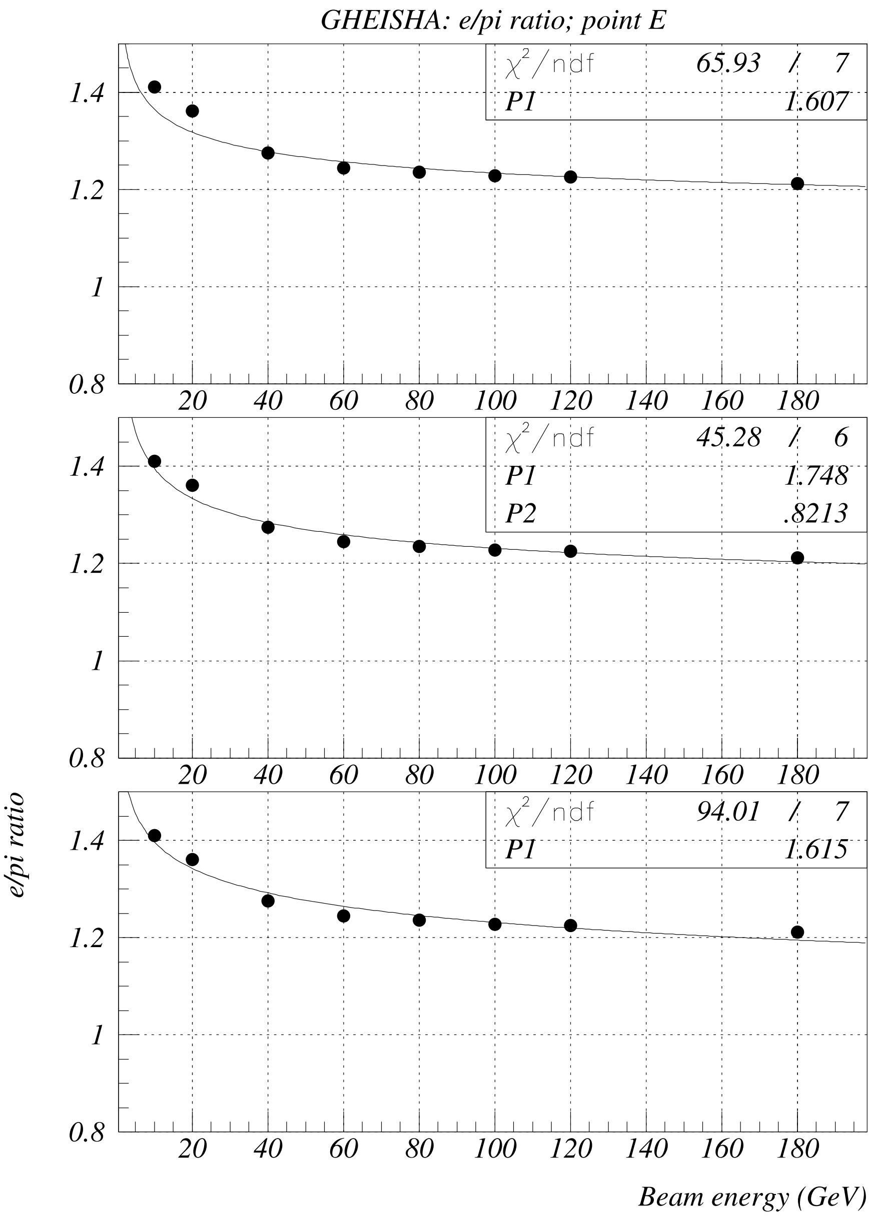

Raw (a) and corrected (b) e/pi ratio; point E
χ^2/ndf 560.4 / 7
P1 1.653
χ^2/ndf 130.0 / 7
P1 1.431
e/pi ratio
Beam energy (GeV)
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
20
40
60
80
100
120
140
160
180



Corrected e/pi ratio; point E
χ^2/ndf 130.0 / 7
P1 1.431
χ^2/ndf 35.23 / 6
P1 1.238
P2 .9506
χ^2/ndf 286.0 / 7
P1 1.436
e/pi ratio
1.4
1.2
1
0.8
20 40 60 80 100 120 140 160 180
Beam energy (GeV)


GCALOR: e/pi ratio; point E
χ^2/ndf 11.04 / 7
P1 1.316
χ^2/ndf 10.45 / 6
P1 1.324
P2 .8456
χ^2/ndf 94.72 / 7
P1 1.319
e/pi ratio
Beam energy (GeV)


GFLUKA: e/pi ratio; point E
χ^2/ndf 9.821 / 7
P1 1.176
χ^2/ndf 9.697 / 6
P1 1.179
P2 .8465
χ^2/ndf 41.62 / 7
P1 1.177
e/pi ratio
Beam energy (GeV)



GHEISHA: e/pi ratio; point E
χ²/ndf 65.93 / 7
P1 1.607
χ²/ndf 45.28 / 6
P1 1.748
P2 .8213
χ²/ndf 94.01 / 7
P1 1.615
e/pi ratio
Beam energy (GeV)