HEC TB meeting
20.09.2000

Analysis of June_00 HEC Test-Beam data

A.Minaenko[1]

Max-Planck-Institut für Physik, Werner-Heisenberg-Institut
München, Germany

- **Calibration problems**
- **Electron data & comparison with MC**
- **Pion data & comparison with MC**
- **Summary**

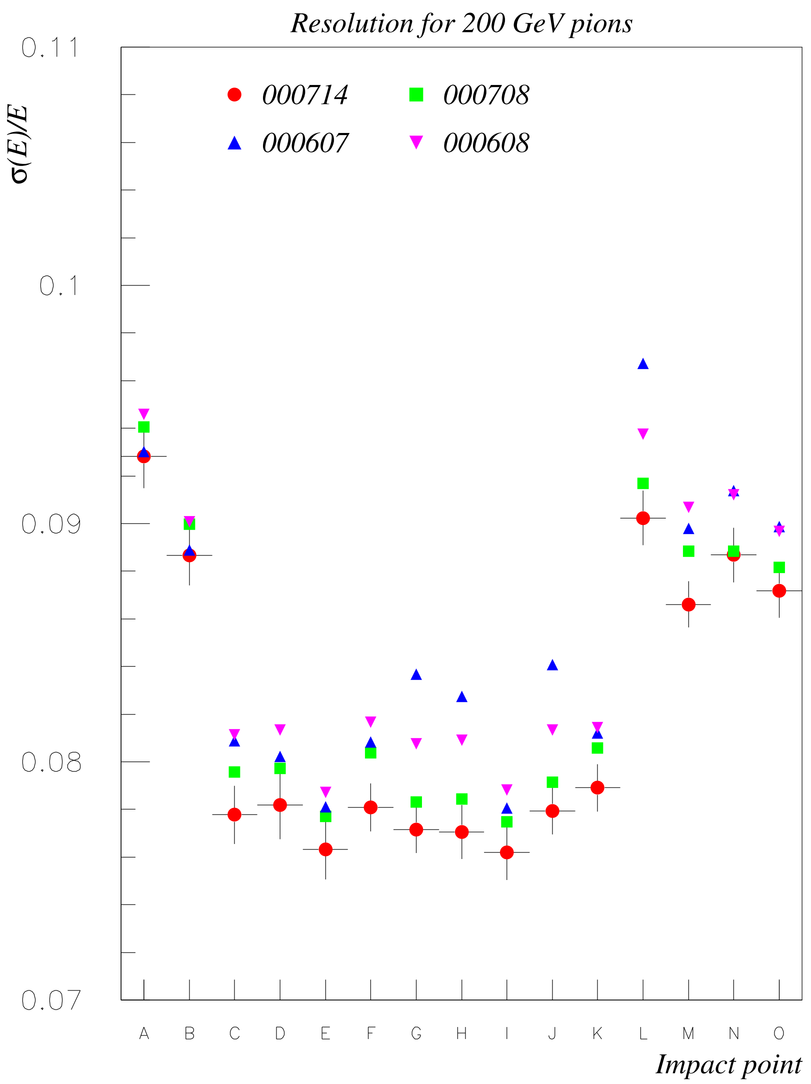
~minaenko/public/trans_Sept00

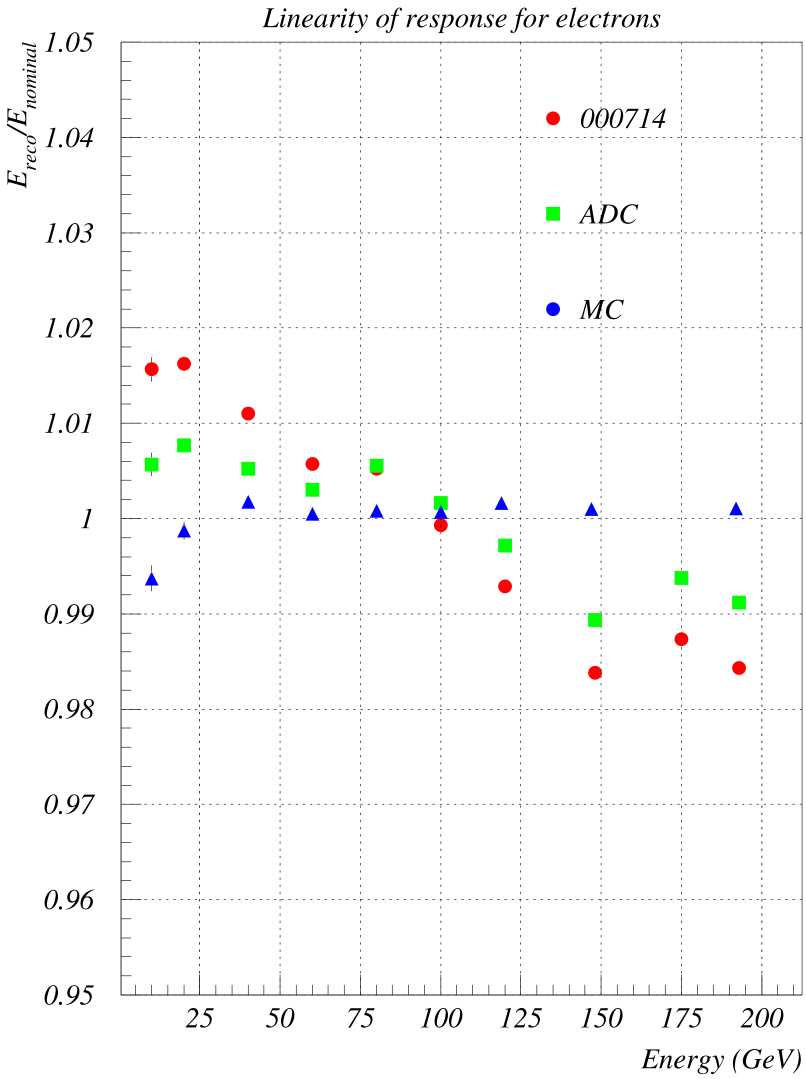
[1]Permanent address: Institute for High Energy Physics, Protvino, Russia

Calibration problems

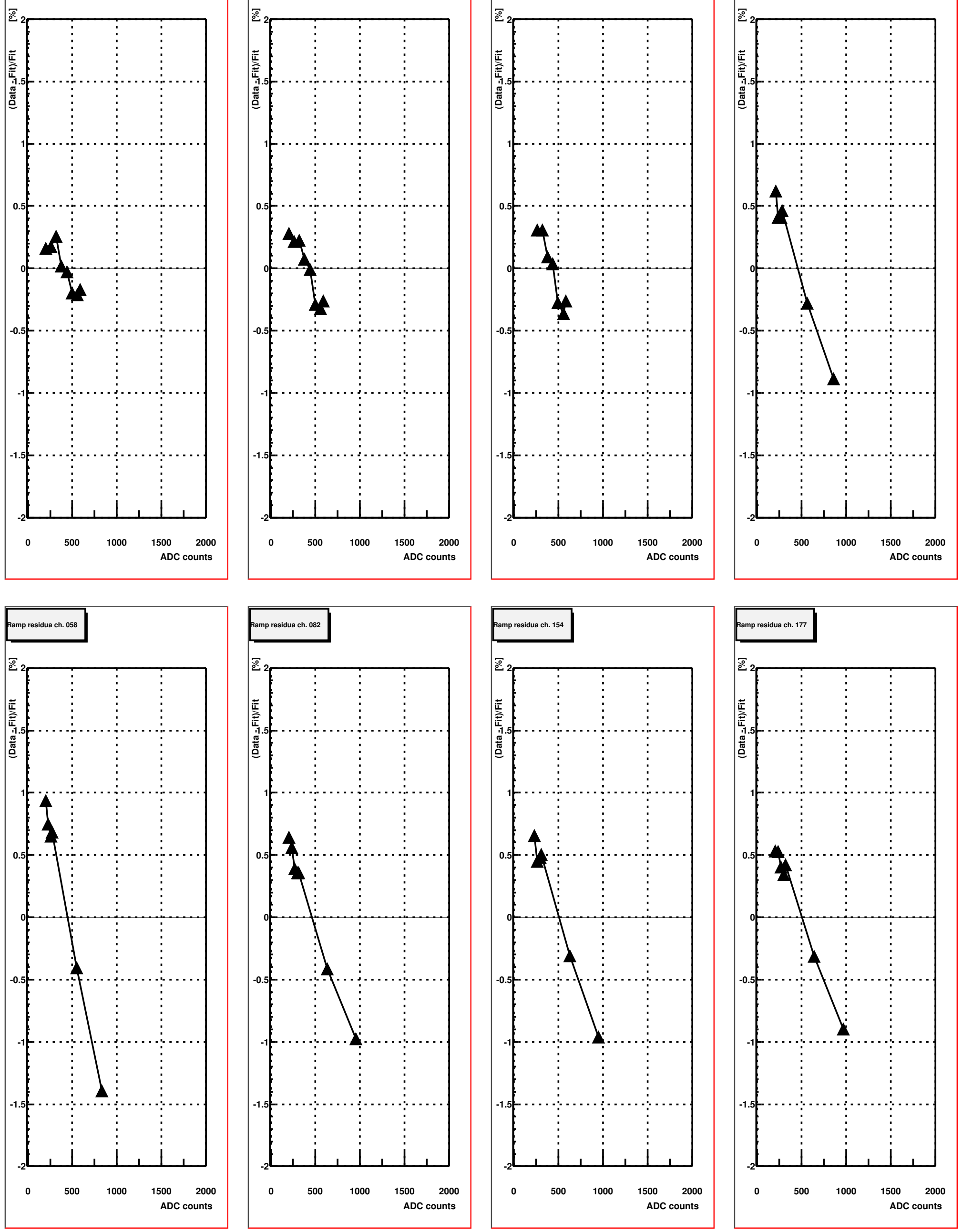
- **Calib. signal $\sim$ DAC$*\alpha + X_0$, where DAC - integer number, α - known constant (nA), X_0 - some offset**
- **Clock feedthrough $\sim const$**
- **Clock feedthrough and X_0 are presubtracted out of raw calibration data**
- **Calibration function: y $= a_1 * x + a_2 * x^2 + a_3 * x^3$, where x(y) is an amplitude in ADC counts (nA).**
- **New calibration coeffs (ver. 000714) improves the resolution for high energy pions (Fig.1). Pion's constant term decreases from 6.7% to 6.0%.**
- **The residuals for 000714 demonstarte some irregular structure at the lowest DAC levels (deviations upto 5%).**
- **The non-linearity of electron response in the range from 10 to 193 GeV (Fig.2) amounts $\sim$2%, if calibration is not used (ADC). The 000714 not compensates it but increases upto $\sim$3%. The electron data requires a POSITIVE non-linear term in the calibration coeffs, but it is really negative.**
- **The residuals for the linear coeffs (000731) clearly require NEGATIVE non-linear term to describe properly the calibration data (Fig.3). So, distinctive contradiction between the calibration and the electron particle data exists: the linearity of calibration hw should be checked.**

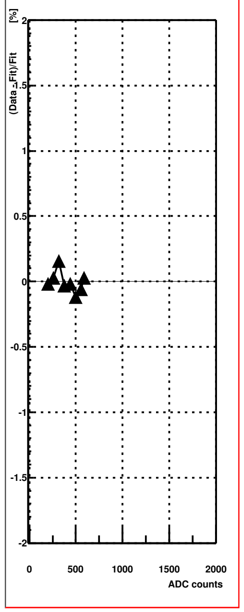
- **Possible source of electron response non-linearity (without calibration) can be a variation of a signal shape in dependence on amplitude. But it is not so, as can be seen in Fig.5: no noticeable difference in the quality of the amplitude reconstruction for 20 and 193 GeV electrons.**

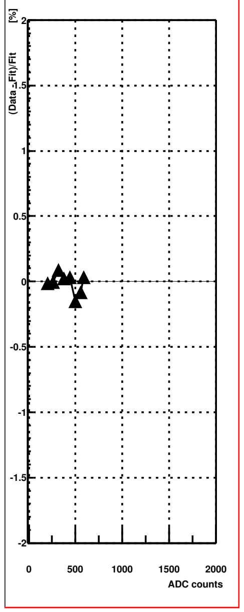

Resolution for 200 GeV pions
σ(E)/E
0.11
0.1
0.09
0.08
0.07
000714
000708
000607
000608
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
Impact point

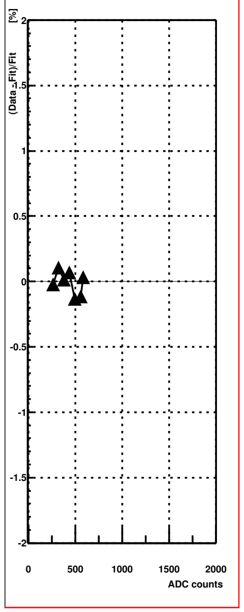


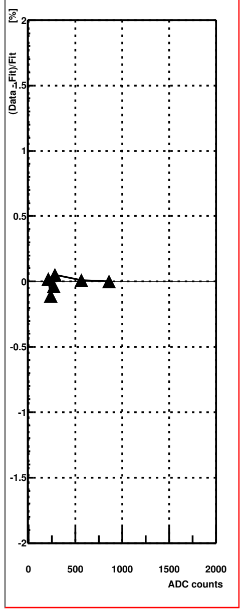
Linearity of response for electrons
$E_{reco}/E_{nominal}$
1.05
1.04
1.03
1.02
1.01
1
0.99
0.98
0.97
0.96
0.95
000714
ADC
MC
25
50
75
100
125
150
175
200
Energy (GeV)

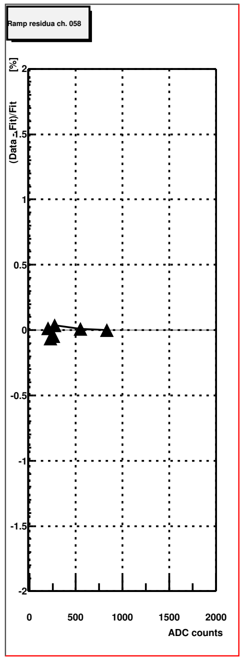

Ramp residua ch. 058
Ramp residua ch. 082
Ramp residua ch. 154
Ramp residua ch. 177
(Data - Fit)/Fit [%]
ADC counts

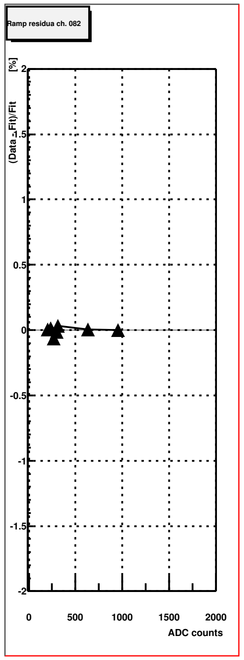

[%]
(Data - Fit)/Fit
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
500
1000
1500
2000
ADC counts

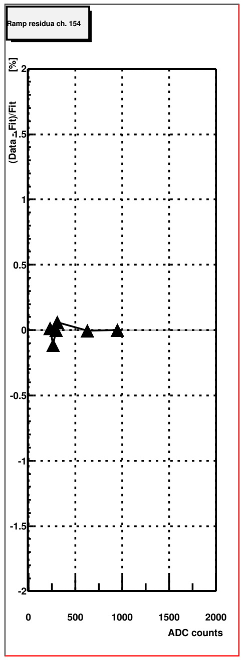

[%]
(Data - Fit)/Fit
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
500
1000
1500
2000
ADC counts

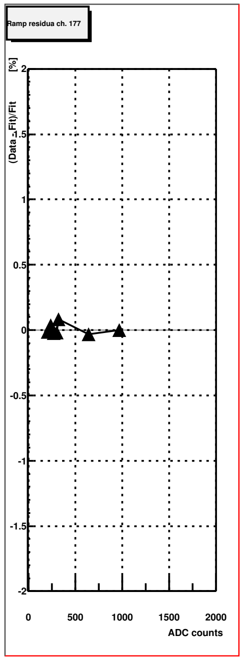

[%]
(Data - Fit)/Fit
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
500
1000
1500
2000
ADC counts

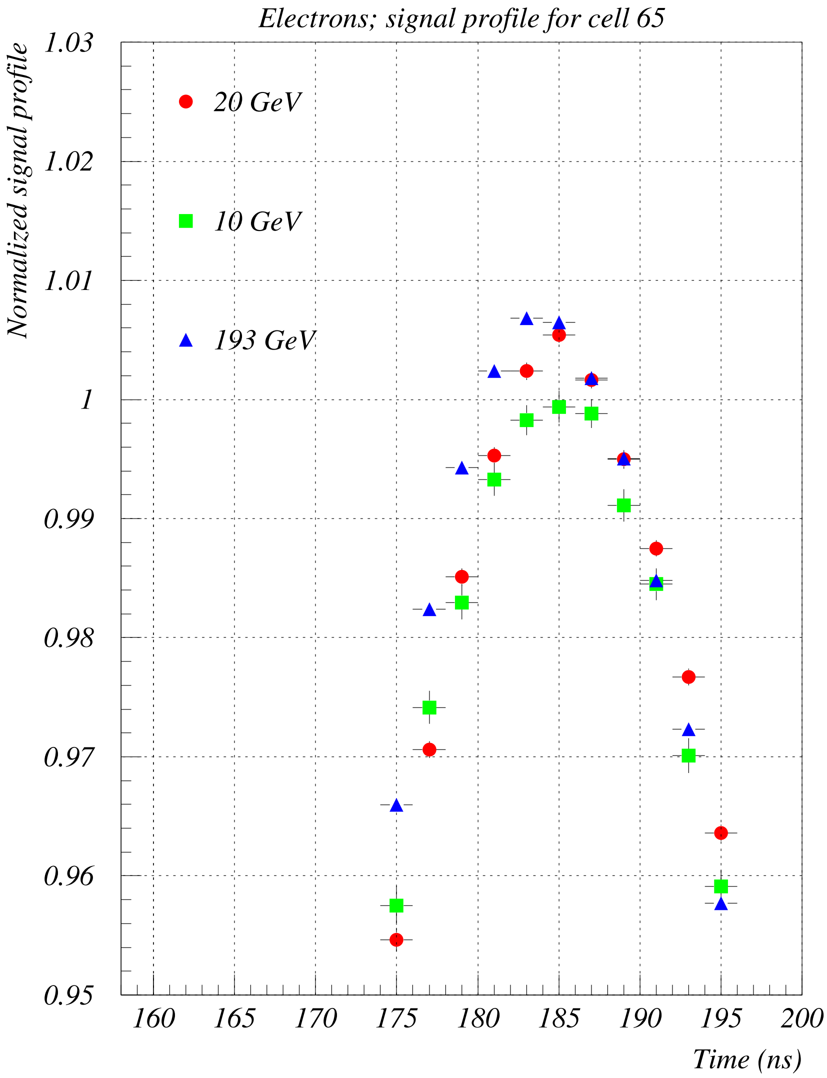

[%]
(Data - Fit)/Fit
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
500
1000
1500
2000
ADC counts


Ramp residua ch. 058
[%]
(Data - Fit)/Fit
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
500
1000
1500
2000
ADC counts


Ramp residua ch. 082
[%]
(Data - Fit)/Fit
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
500
1000
1500
2000
ADC counts


Ramp residua ch. 154
[%]
(Data - Fit)/Fit
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
500
1000
1500
2000
ADC counts

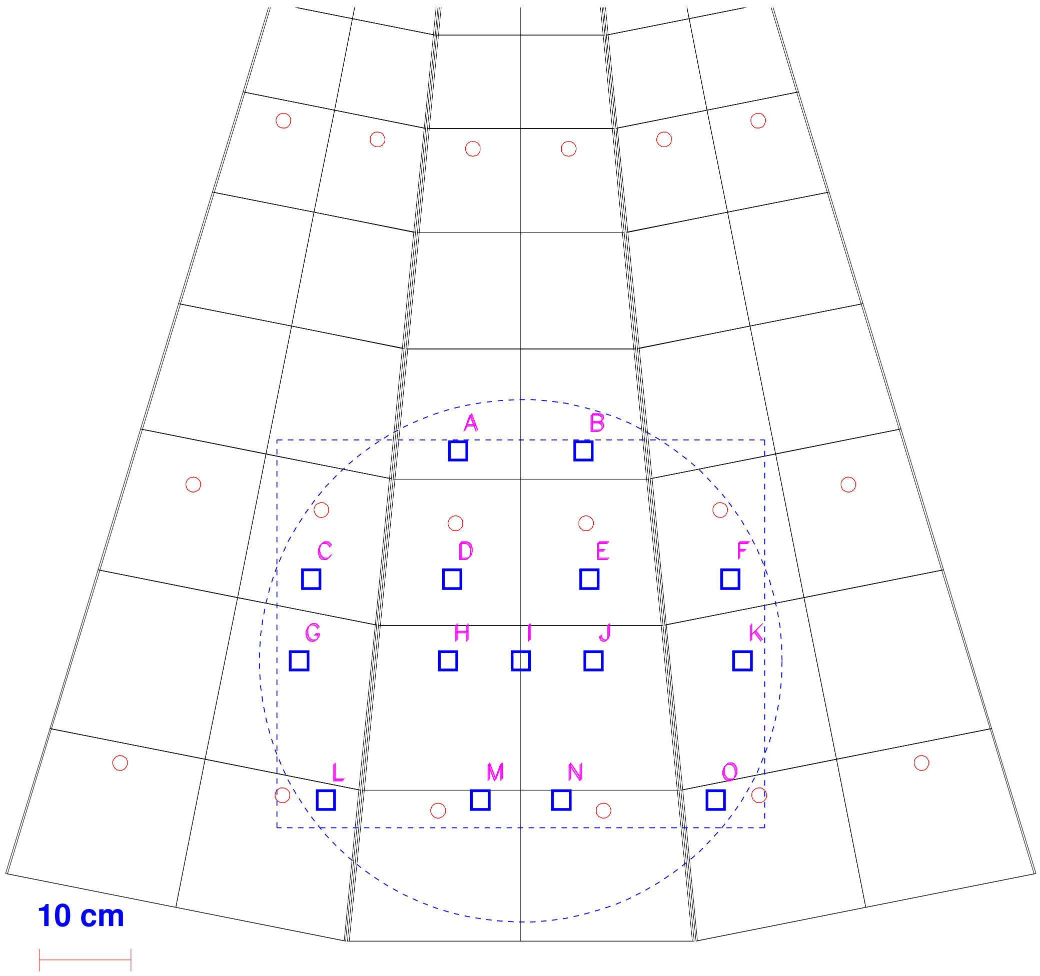

Ramp residua ch. 177
[%]
(Data - Fit)/Fit
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
500
1000
1500
2000
ADC counts



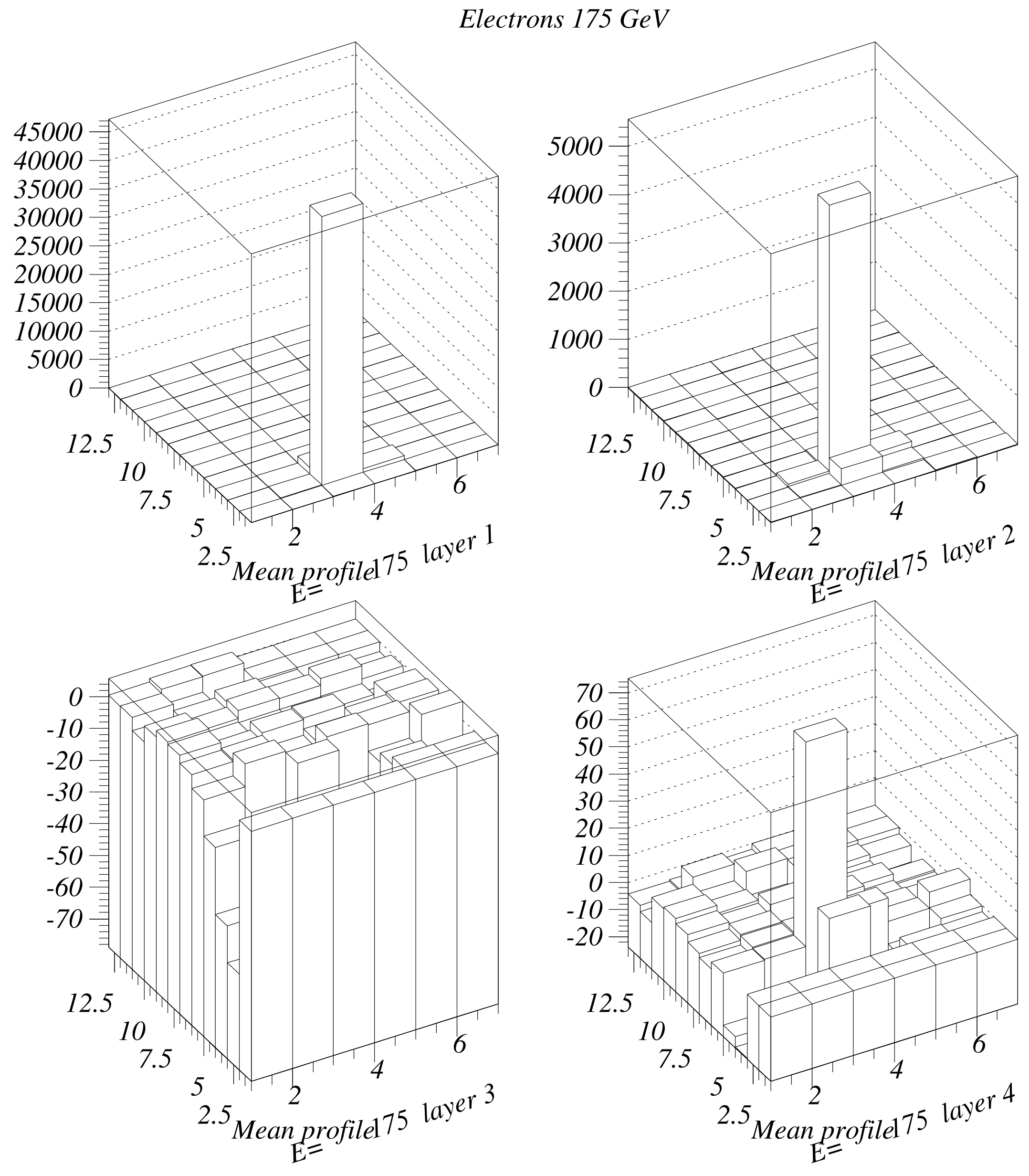
Electrons; signal profile for cell 65
Normalized signal profile
20 GeV
10 GeV
193 GeV
1.03
1.02
1.01
1
0.99
0.98
0.97
0.96
0.95
160
165
170
175
180
185
190
195
200
Time (ns)

TB June00: electron data

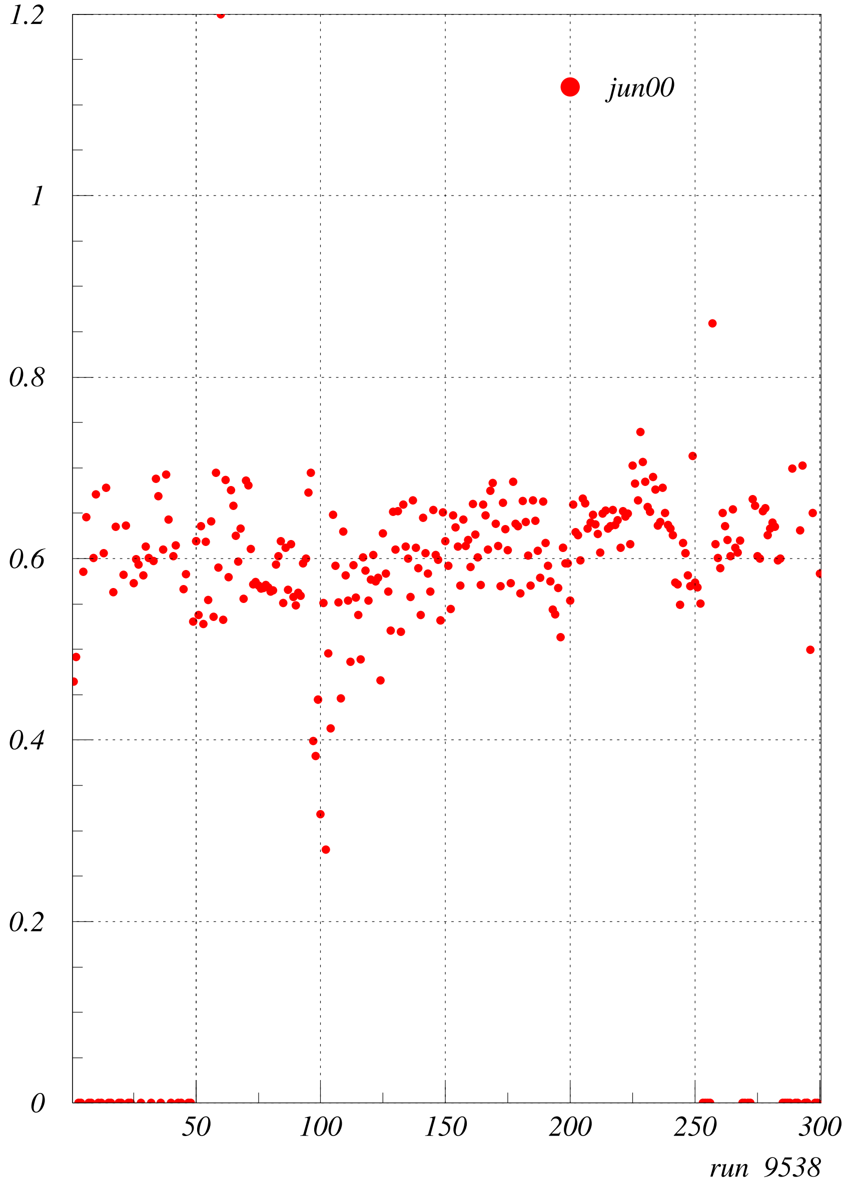
- **Electrons at 15 points: A-O (Fig.1)**
- **10 energies: 10, 20, 40, 60, 80, 100, 119.1, 147.8, 175.4, 193.1**
- **175 and 193 GeV - e/pi trigger; e/pi*C for the others**
- **only points G, J and K have full set of energies**
- **Cluster size is fixed for each impact point and does not depend on the beam energy**
- **Claster selection: mean cell signal greater 200 nA at 175 GeV - cluster size 5-6 cells (3-4 in the 1st layer, 2 in the 2nd) (Fig.2)**
- **Noise:**
  - **first 5 samples are used**
  - **OF for each event**
  - **sum of cell signals through the selected cluster**
- **OF noise suppression factor as for 1998 data: ~0.6 (Fig.3)**
- **noticeable variation of noise for different runs (Fig.4)**
- **one energy independent calibration coefficient α_{em} is used: averaging through all the energies**



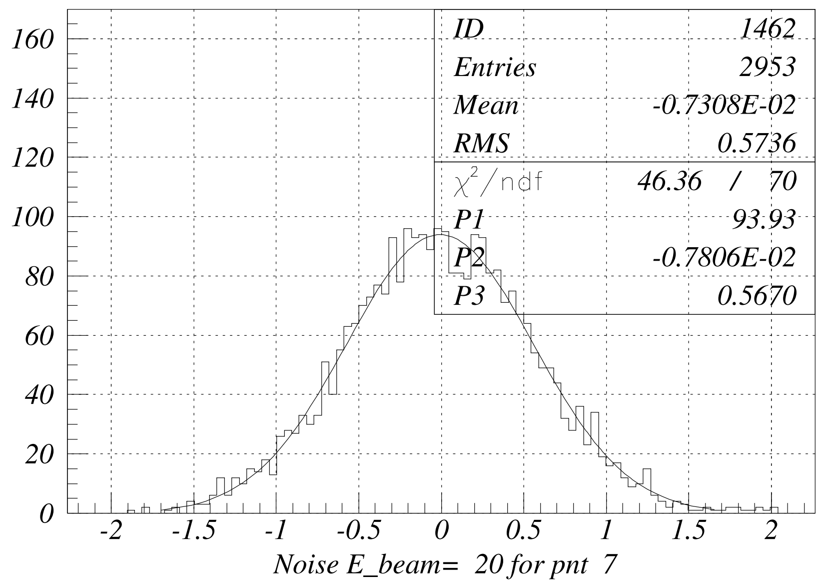
Projection on the front face of the HEC module

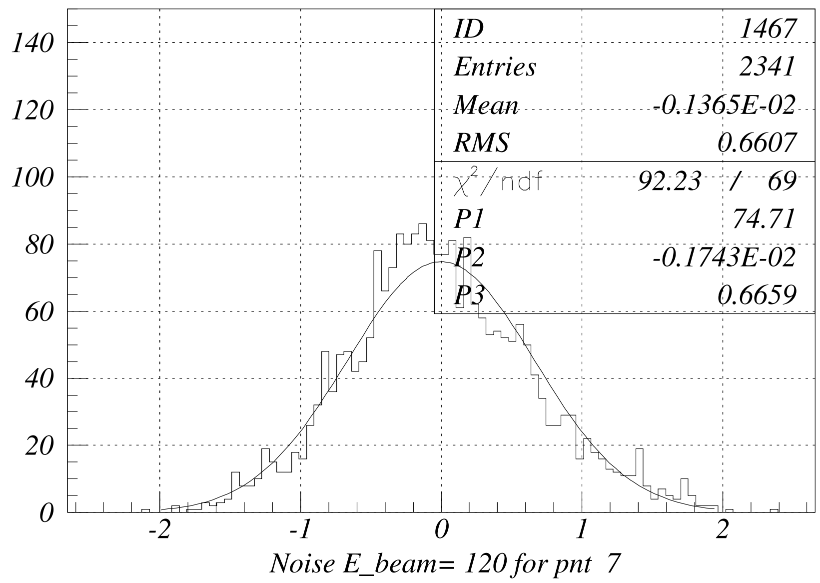


Electrons 175 GeV
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
12.5
10
7.5
5
2.5
2
4
6
Mean profile E=175 layer 1
5000
4000
3000
2000
1000
0
Mean profile E=175 layer 2
0
-10
-20
-30
-40
-50
-60
-70
Mean profile E=175 layer 3
70
60
50
40
30
20
10
0
-10
-20
Mean profile E=175 layer 4

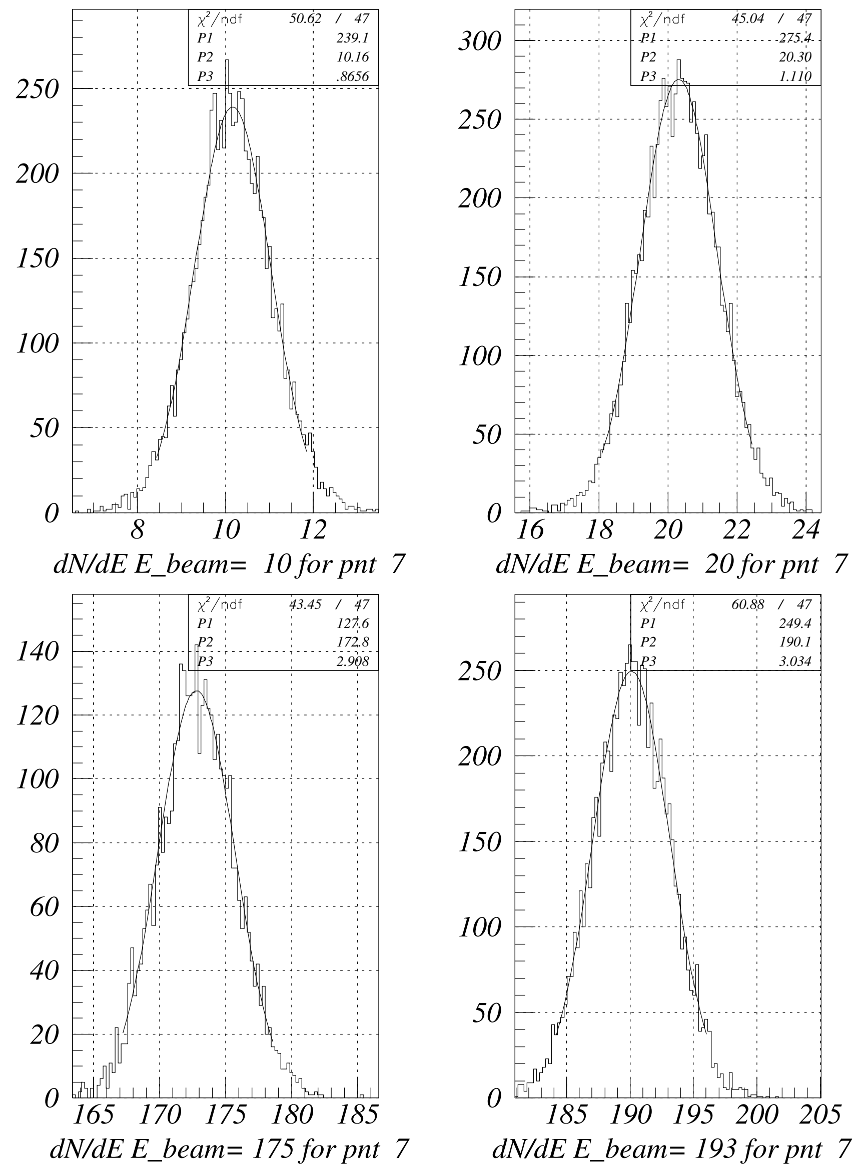


OF noise suppression factor

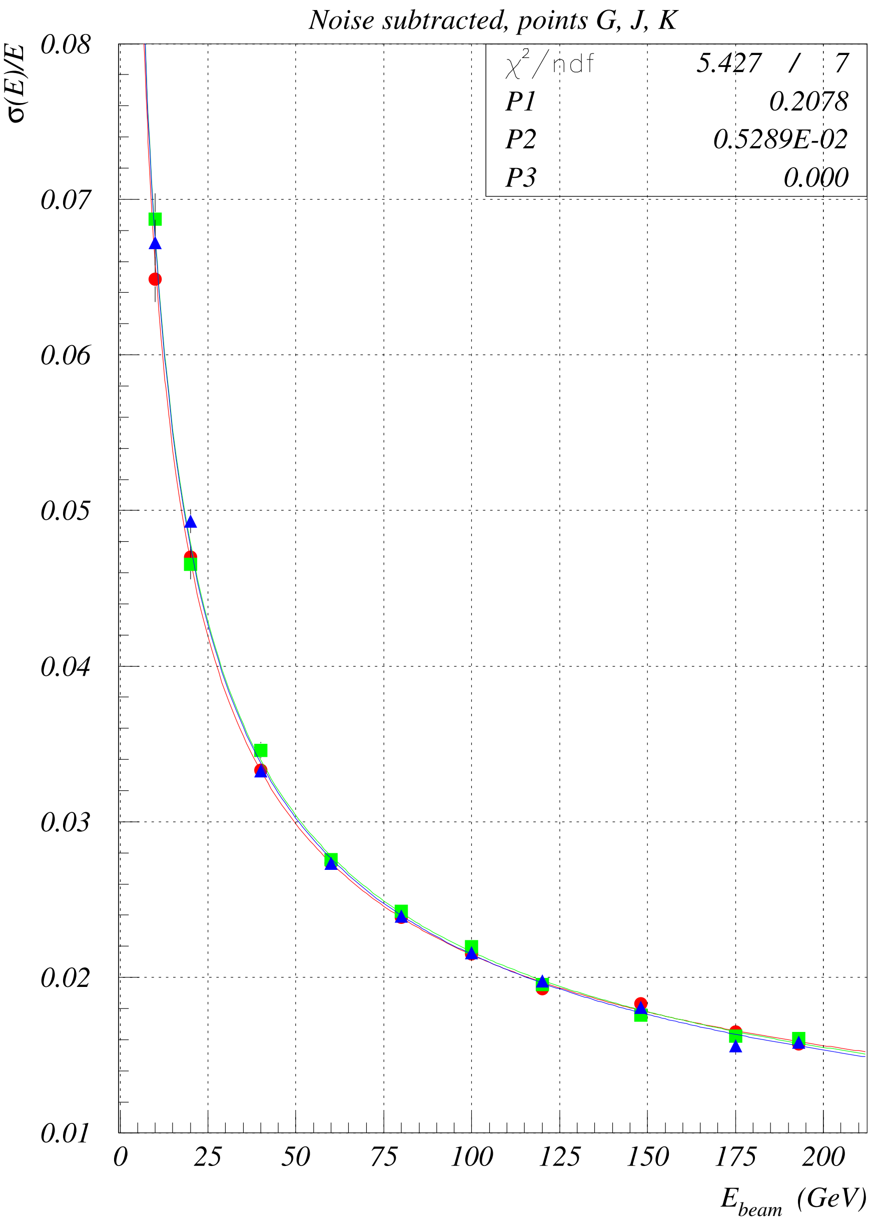

ID 1462
Entries 2953
Mean -0.7308E-02
RMS 0.5736
χ²/ndf 46.36 / 70
P1 93.93
P2 -0.7806E-02
P3 0.5670
Noise E_beam= 20 for pnt 7


ID 1467
Entries 2341
Mean -0.1365E-02
RMS 0.6607
χ²/ndf 92.23 / 69
P1 74.71
P2 -0.1743E-02
P3 0.6659
Noise E_beam= 120 for pnt 7

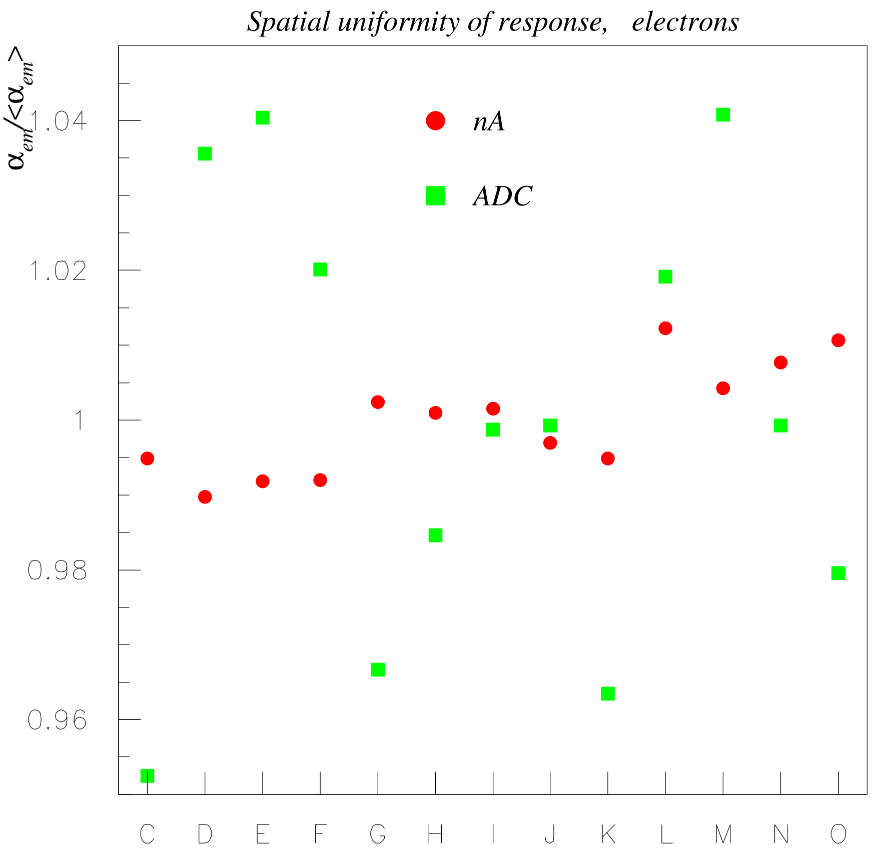
Point G

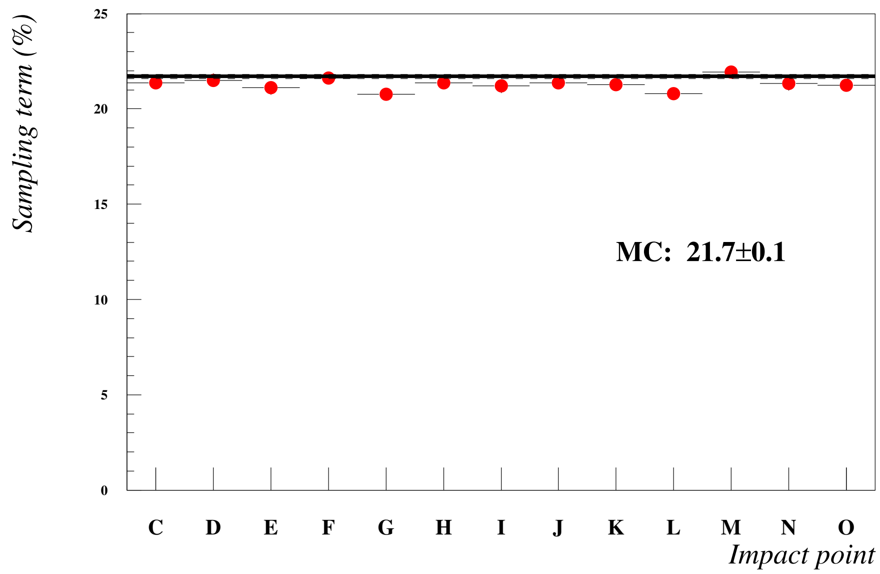


χ²/ndf 50.62 / 47
P1 239.1
P2 10.16
P3 .8656
dN/dE E_beam= 10 for pnt 7
χ²/ndf 45.04 / 47
P1 275.4
P2 20.30
P3 1.110
dN/dE E_beam= 20 for pnt 7
χ²/ndf 43.45 / 47
P1 127.6
P2 172.8
P3 2.908
dN/dE E_beam= 175 for pnt 7
χ²/ndf 60.88 / 47
P1 249.4
P2 190.1
P3 3.034
dN/dE E_beam= 193 for pnt 7

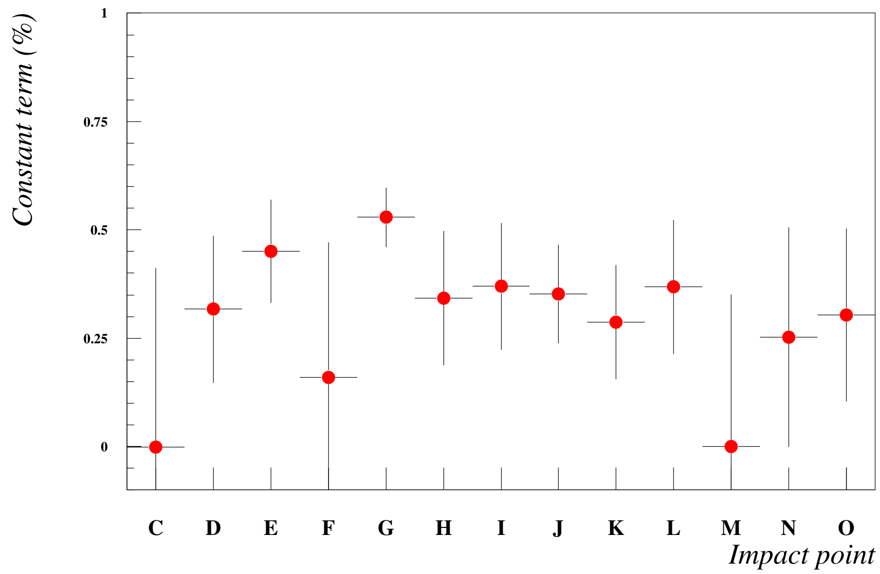


Noise subtracted, points G, J, K
σ(E)/E
χ²/ndf 5.427 / 7
P1 0.2078
P2 0.5289E-02
P3 0.000
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
25
50
75
100
125
150
175
200
E_beam (GeV)


Spatial uniformity of response, electrons
$\alpha_{em}/\langle\alpha_{em}\rangle$
nA
ADC
1.04
1.02
1
0.98
0.96
C D E F G H I J K L M N O



Sampling term (%)
25
20
15
10
5
0
MC: 21.7±0.1
C D E F G H I J K L M N O
Impact point



Constant term (%)
1
0.75
0.5
0.25
0
C D E F G H I J K L M N O
Impact point

TB June00: pion data

- Pions at 15 points: A-O
- 9 energies: 10, 20, 60, 80, 100, 120, 150, 180, 200
- 200 GeV - e/pi trigger; e/pi*C for the others
- only points G, J and K have full set of energies
- Claster selection: mean cell signal greater 15 nA at 180 GeV - more than 50 cells (Fig.1)
- no large deviations for the time positions of signals (table 1)
- acceptable quality of OF amplitude reconstruction ($\sim$0.5%) (table 2)
- Noise: as for electrons
- noticeable influence of coherent noise; considerable variation of noise for different runs (Fig.2-3)
- one energy independent calibration coefficient α_{had} is used: averaging through the largest energies 120-200 GeV.

- **1 CC $->$ 4 CC (one per layer): constant term 5.5±0.2%.**
- **GCALOR: M99(8.0, -1.0) $<->$ J00(8.4, 0.0)**
- **energy dependence of resolution (point J):**

	sampling term (%)	constant term (%)
exp.	**70.6±2.1**	**6.0±0.2**
GCALOR	**65.2±0.9**	**5.0±0.1**
GCALOR(corr)	**59.7±0.8**	**4.0±0.1**

- **e/h ratio**

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

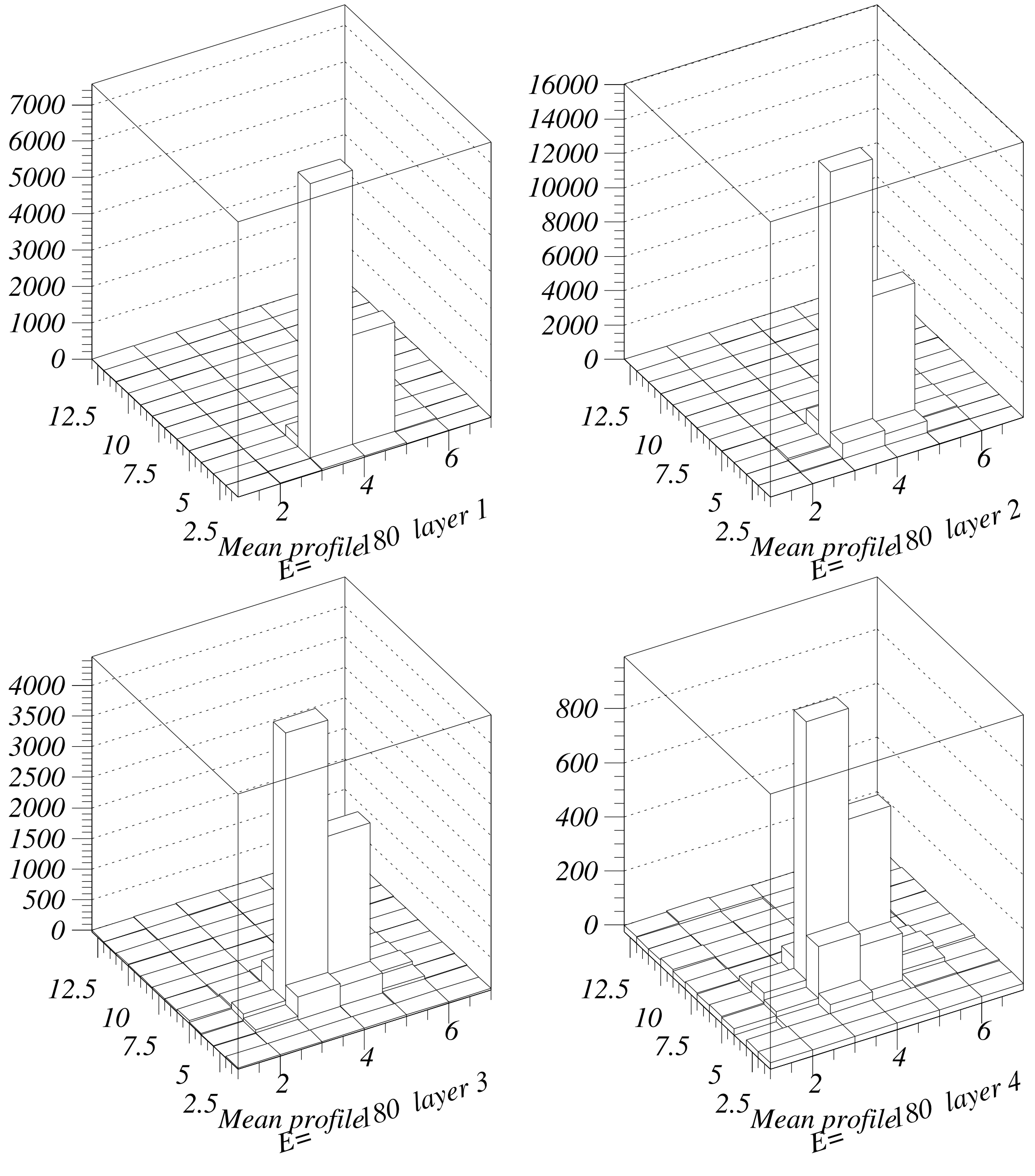
where f_{π^0} is the mean fraction of the initial pion energy deposited through electromagnetic cascades. f_{π^0} is a slowly rising function of the pion energy, which can be parametrized as

$$f_{\pi^0} = 1 - \left(\frac{E}{E_0'}\right)^{m-1}, \tag{2}$$

where E_0' ≈1 GeV for pions and m ≈0.85.

- **MC correction for leakage is important**
- e/h **ratio ∼1.5±0.05, but very bad** χ^2

Pions 180 GeV



Layer 1			
	85	*81*	
	0.3	**0.1**	
65	*61*	*57*	*53*
-0.2	**-0.8**	**-1.1**	**-0.7**
41	*37*	*33*	*29*
0.3	**0.3**	**0.1**	**0.3**
17	*13*	*9*	*5*
0.5	**0.3**	**0.3**	**0.5**

Layer 2			
	110	*106*	
	-0.4	**-0.6**	
90	*86*	*82*	*78*
-1.2	**-1.3**	**-1.5**	**-1.3**
66	*62*	*58*	*54*
-1.6	**-1.7**	**-1.7**	**-1.7**
42	*38*	*34*	*30*
-0.9	**-1.0**	**-1.0**	**-0.9**

Layer 3			
	135	*131*	
	—	**2.4**	
115	*111*	*107*	*103*
2.0	**2.2**	**1.8**	**2.2**
91	*87*	*83*	*79*
2.8	**1.9**	**2.4**	**2.5**
67	*63*	*59*	*55*
3.2	**2.8**	**2.9**	**3.1**

Layer 4			
	136	*132*	
	1.2	**0.8**	
116	*112*	*108*	*104*
0.8	**0.8**	**0.5**	**1.1**
92	*88*	*84*	*80*
1.2	**0.5**	**0.8**	**0.9**

Table 1. The deviation of a particle signal position (in ns) out of the expected (from calibration) position. Mean deviations for the layers are: -**0.3**, -**1.1**, +**2.5** and +**0.8** ns.

Layer 1			
	85	*81*	
	+0.3	**+0.2**	
65	*61*	*57*	*53*
-0.4	**-0.4**	**-0.4**	**-0.4**
41	*37*	*33*	*29*
-0.6	**-0.8**	**-0.7**	**-0.8**
17	*13*	*9*	*5*
-0.7	**-0.6**	**-0.3**	**-0.5**

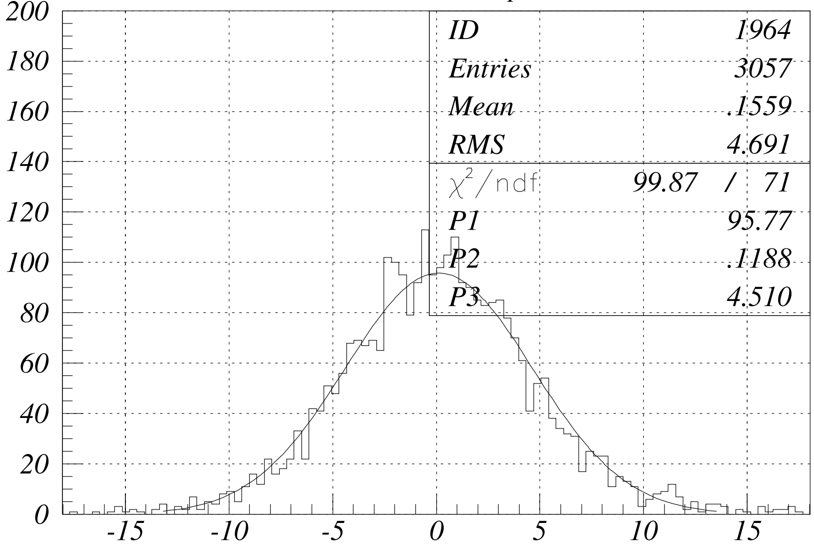
Layer 2			
	110	*106*	
	+1.0	**+1.0**	
90	*86*	*82*	*78*
+0.8	**+0.7**	**+0.6**	**+0.7**
66	*62*	*58*	*54*
-0.4	**-0.5**	**-0.5**	**-0.4**
42	*38*	*34*	*30*
+0.6	**+0.3**	**0.0**	**+0.3**

Layer 3			
	135	*131*	
	—	**-2.0**	
115	*111*	*107*	*103*
+0.3	**0.0**	**+0.3**	**0.0**
91	*87*	*83*	*79*
0.0	**0.0**	**-0.4**	**-0.5**
67	*63*	*59*	*55*
+0.6	**+0.4**	**0.0**	**-0.1**

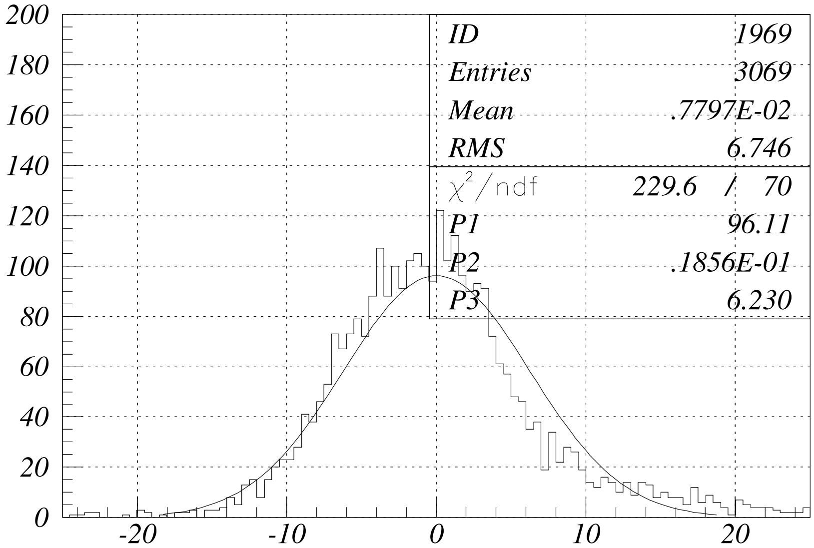
Layer 4			
	136	*132*	
	+0.4	**+0.4**	
116	*112*	*108*	*104*
-0.6	**-0.6**	**-0.2**	**-0.8**
92	*88*	*84*	*80*
+0.5	**+0.3**	**+0.5**	**-0.2**

Table 2. The deviation of an OF reconstructed amplitude (in %) out of the true value: A_{OF} - A_{true}.

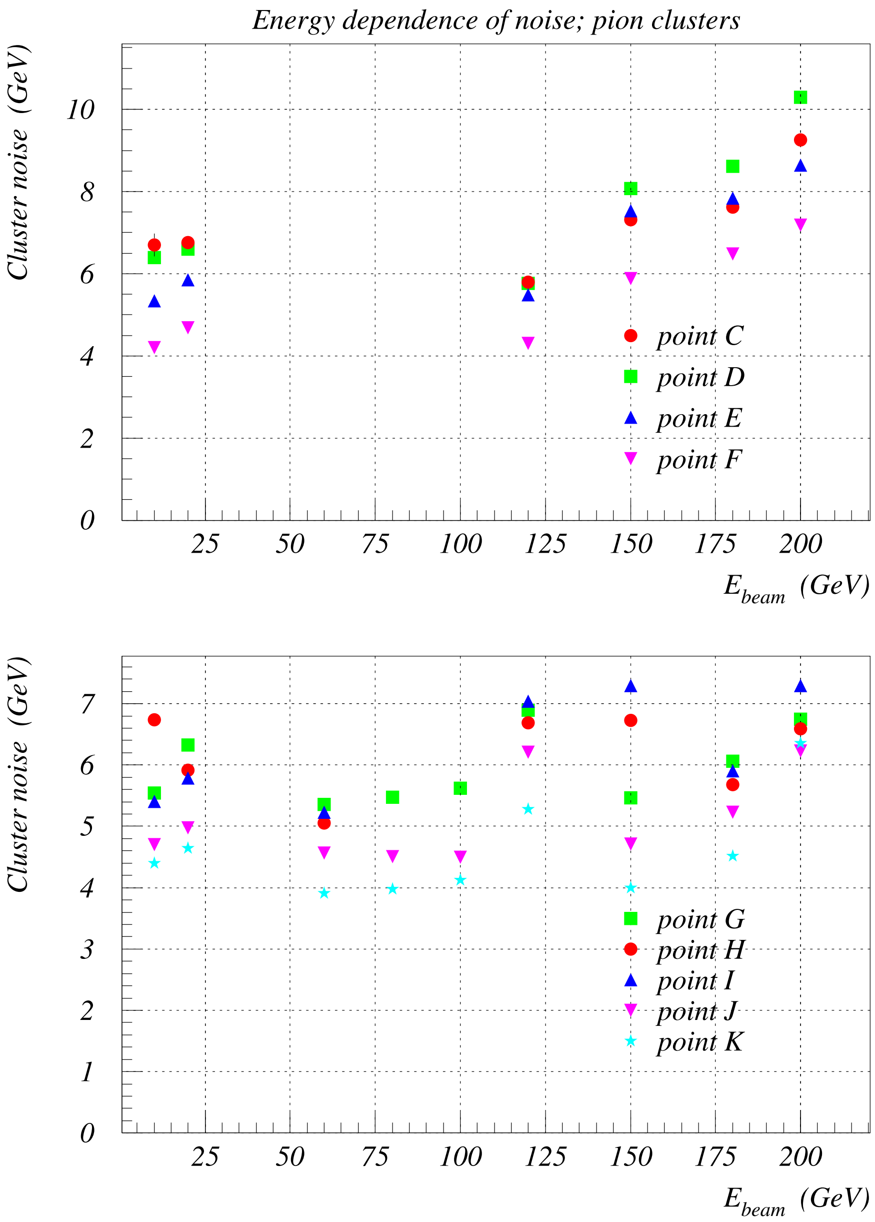
Pion cluster noise; point J



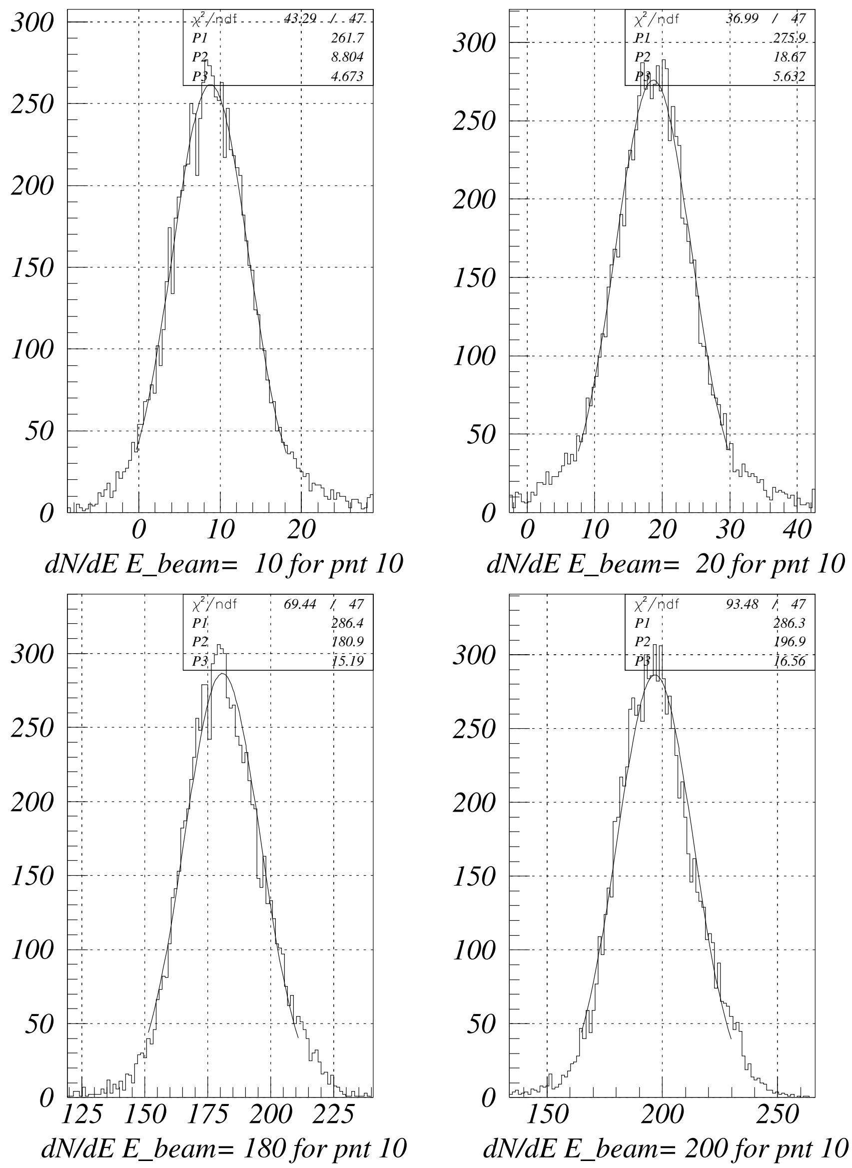
Noise E_beam= 80 for pnt 10



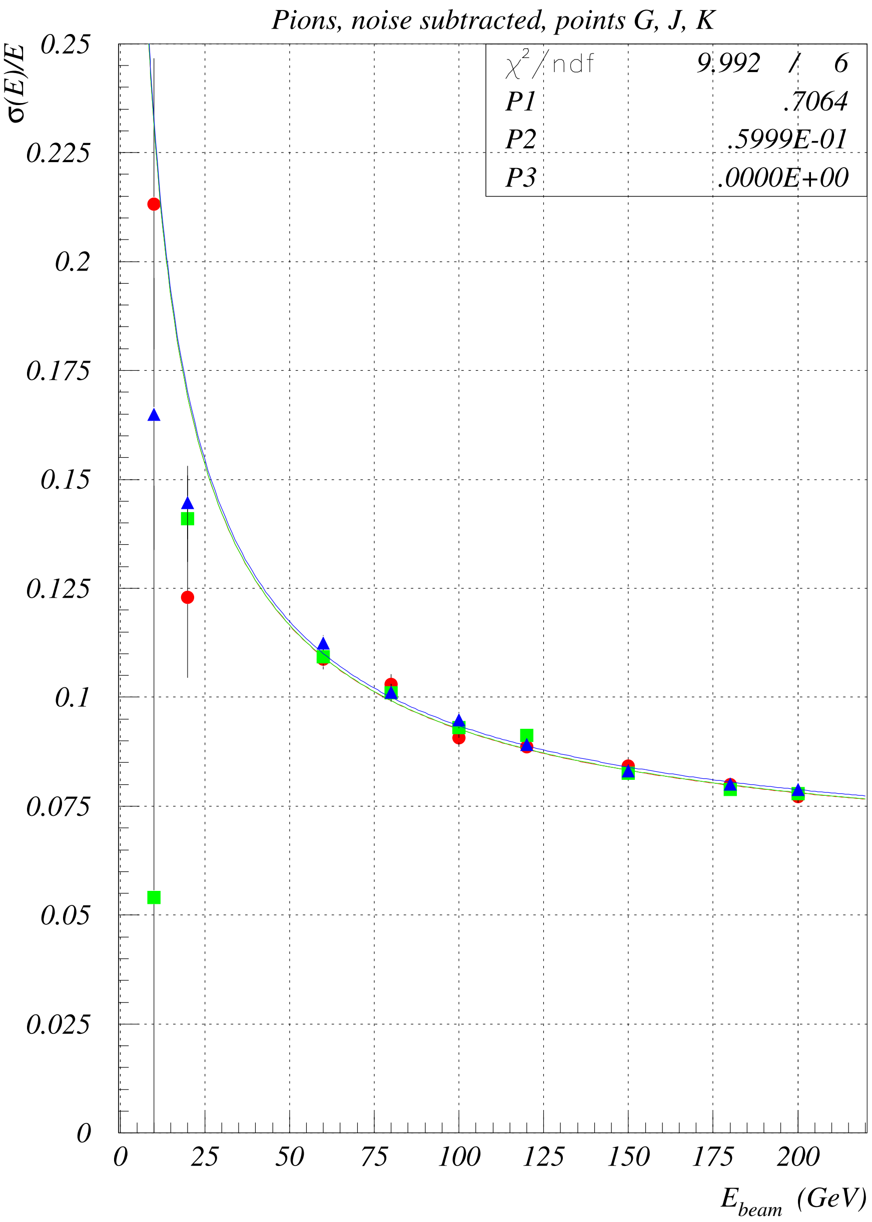
Noise E_beam= 200 for pnt 10

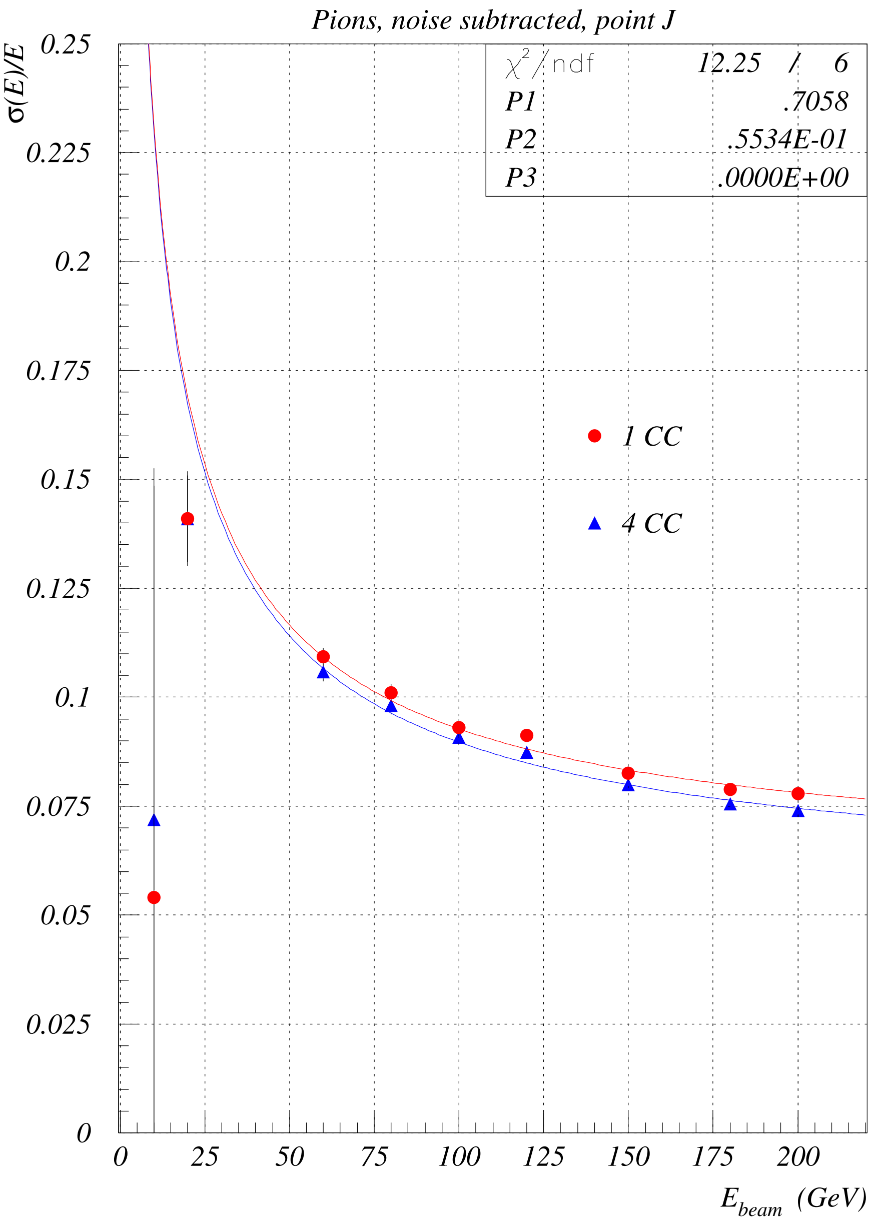

Energy dependence of noise; pion clusters
Cluster noise (GeV)
E_{beam} (GeV)
point C
point D
point E
point F
Cluster noise (GeV)
E_{beam} (GeV)
point G
point H
point I
point J
point K

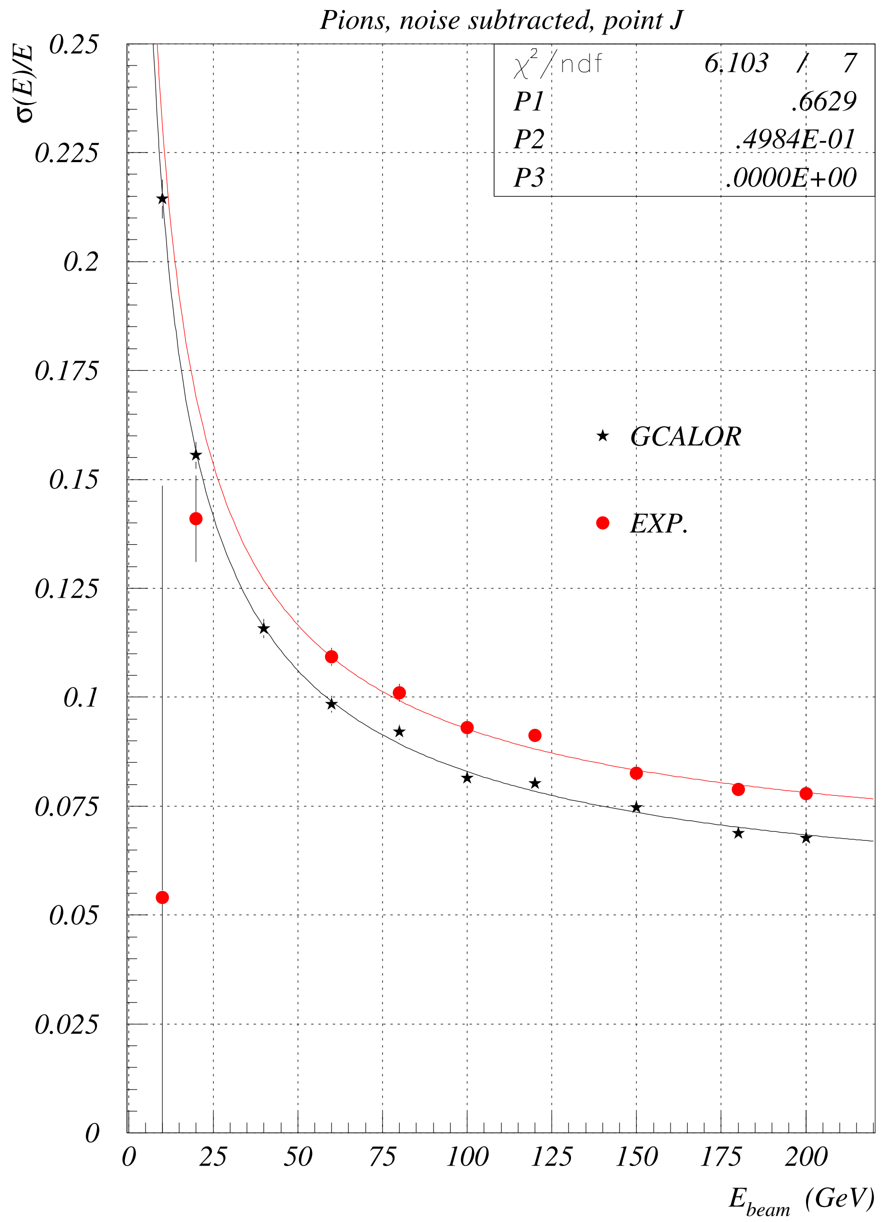
Point J



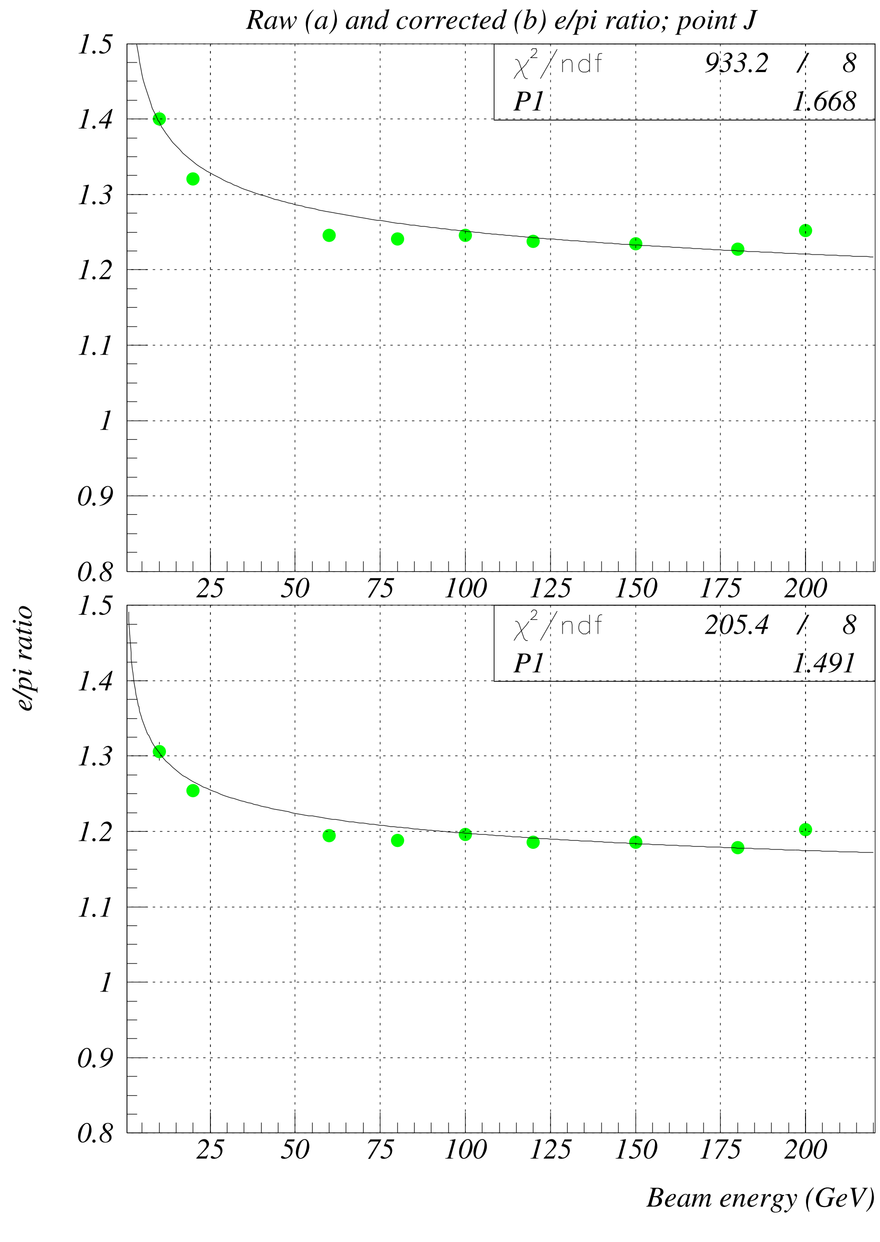
χ²/ndf 43.29 / 47
P1 261.7
P2 8.804
P3 4.673
dN/dE E_beam= 10 for pnt 10
χ²/ndf 36.99 / 47
P1 275.9
P2 18.67
P3 5.632
dN/dE E_beam= 20 for pnt 10
χ²/ndf 69.44 / 47
P1 286.4
P2 180.9
P3 15.19
dN/dE E_beam= 180 for pnt 10
χ²/ndf 93.48 / 47
P1 286.3
P2 196.9
P3 16.56
dN/dE E_beam= 200 for pnt 10


Pions, noise subtracted, points G, J, K
σ(E)/E
χ²/ndf 9.992 / 6
P1 .7064
P2 .5999E-01
P3 .0000E+00
0.25
0.225
0.2
0.175
0.15
0.125
0.1
0.075
0.05
0.025
0
0
25
50
75
100
125
150
175
200
E_beam (GeV)

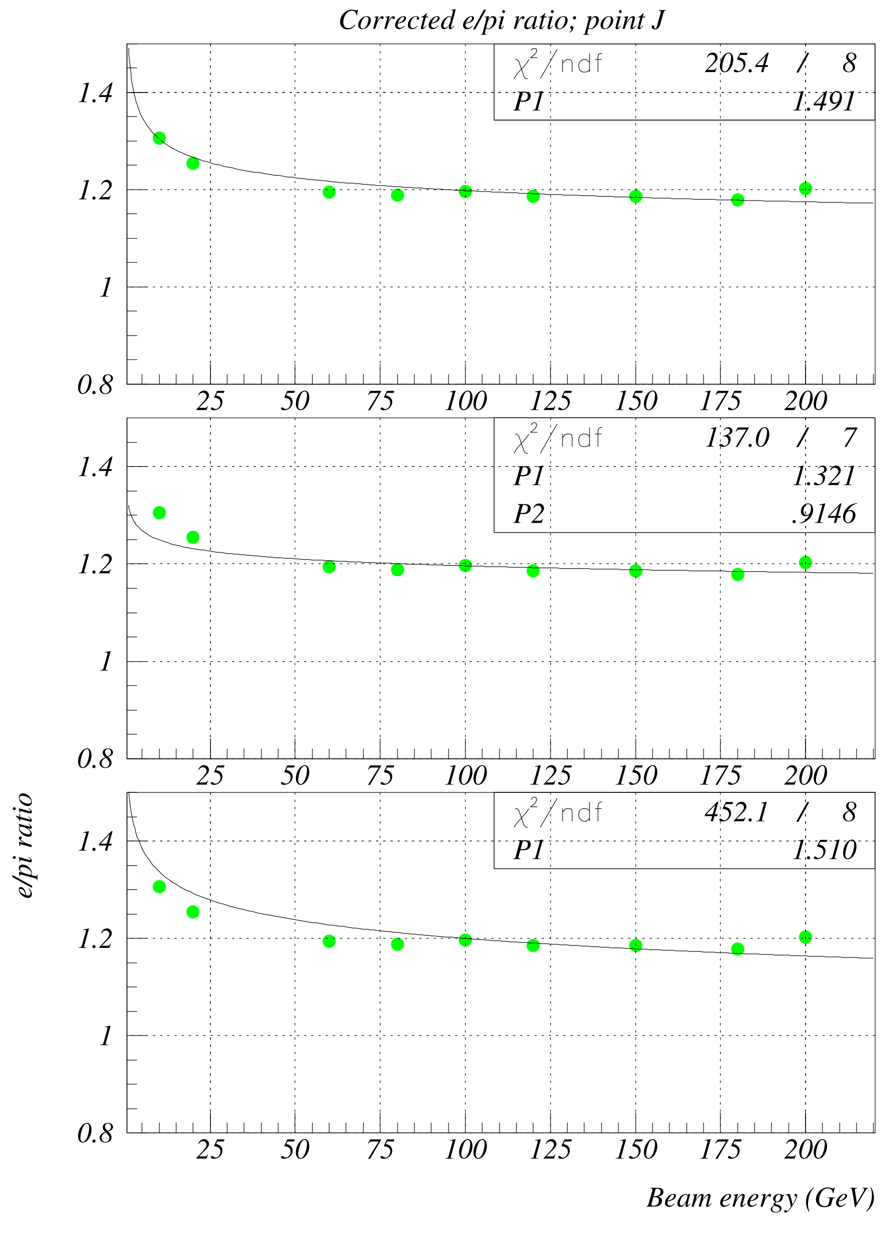

Pions, noise subtracted, point J
σ(E)/E
χ²/ndf 12.25 / 6
P1 .7058
P2 .5534E-01
P3 .0000E+00
1 CC
4 CC
0.25
0.225
0.2
0.175
0.15
0.125
0.1
0.075
0.05
0.025
0
0 25 50 75 100 125 150 175 200
E_beam (GeV)

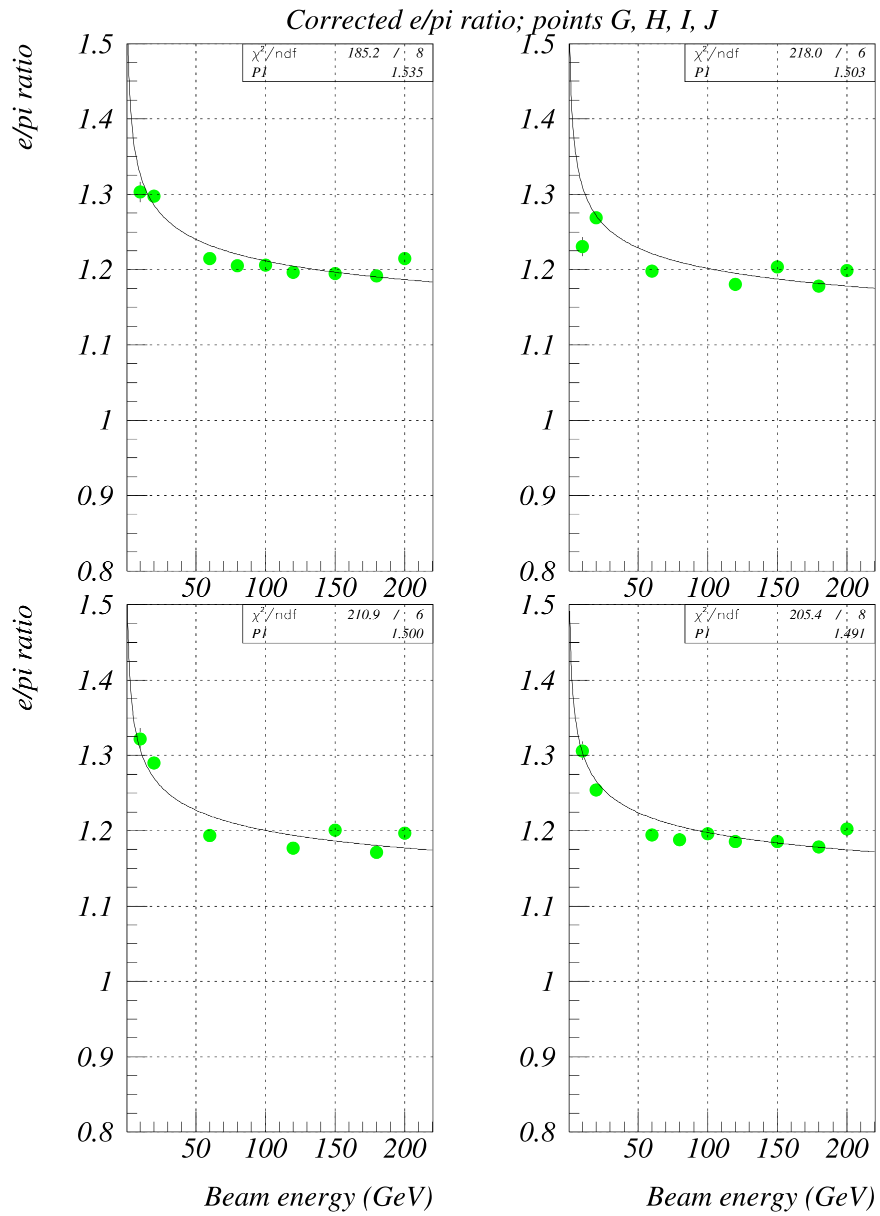


Pions, noise subtracted, point J
σ(E)/E
χ²/ndf 6.103 / 7
P1 .6629
P2 .4984E-01
P3 .0000E+00
GCALOR
EXP.
0.25
0.225
0.2
0.175
0.15
0.125
0.1
0.075
0.05
0.025
0
0 25 50 75 100 125 150 175 200
E_beam (GeV)



Raw (a) and corrected (b) e/pi ratio; point J
χ^2/ndf 933.2 / 8
P1 1.668
χ^2/ndf 205.4 / 8
P1 1.491
e/pi ratio
Beam energy (GeV)


Corrected e/pi ratio; point J
χ^2/ndf 205.4 / 8
P1 1.491
χ^2/ndf 137.0 / 7
P1 1.321
P2 .9146
χ^2/ndf 452.1 / 8
P1 1.510
e/pi ratio
Beam energy (GeV)
0.8
1
1.2
1.4
25
50
75
100
125
150
175
200


Corrected e/pi ratio; points G, H, I, J
e/pi ratio
Beam energy (GeV)
χ²/ndf 185.2 / 8
P1 1.535
χ²/ndf 218.0 / 6
P1 1.503
χ²/ndf 210.9 / 6
P1 1.500
χ²/ndf 205.4 / 8
P1 1.491
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
50
100
150
200

Summary

- **Calibration procedure equalizes channel responses with 0.5% accuracy**
- **Calibration data at the region of small level signals looks biased: some irregularity takes place**
- **The calibration coefficients have "wrong" sign non-linearity. They do not compensate properly the non-linearity of a HEC module response to electrons.**
- **Electronic noise varies noticeably from run to run. The contribution of coherent noise is considerable.**
- **The deviations of a particle signal position out of the expected position (from calibration) are -0.3, -1.1, +2.5 and +0.8 ns for HEC layers 1-4. The layer by layer time correction is necessary in the hec_adc sw package.**
- **The accuracy of the signal amplitude reconstruction by OF procedure is at the level of 0.5%.**
- **Spatial uniformity of response to electrons is in the limits of ±0.5% for points C-K. α_{em}=0.00292 GeV/nA.**
- **Energy dependence of resolution for electrons: sampling term ≃21.5±0.5% and constant term ≃0.3pm0.1%. Good agreement with MC prediction: 21.7±0.1% and 0.0pm0.3%.**
- **The observed non-linearity of the HEC response to electrons is about 2% (ADC) or 3% (calib.) in the energy range from 10 upto 193 GeV.**

- **α_{had}=0.00362 GeV/nA (averaged through 120-200 GeV)**
- **Energy dependence of resolution for pions: sampling term 71±2% and constant term 6.0±0.2%.**
- **GCALOR prediction is 65.2±0.9% and 5.0±0.1%, correspondingly**
- **1 CC $->$ 4 CC (one per layer): constant term 5.5±0.2%.**
- **e/h ratio 1.5±0.05, but the quality of the fit is very bad**