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Energy Reconstruction Algorithms for the ATLAS Tile Calorimeter

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Tilecal subsystem of ATLAS collaboration.

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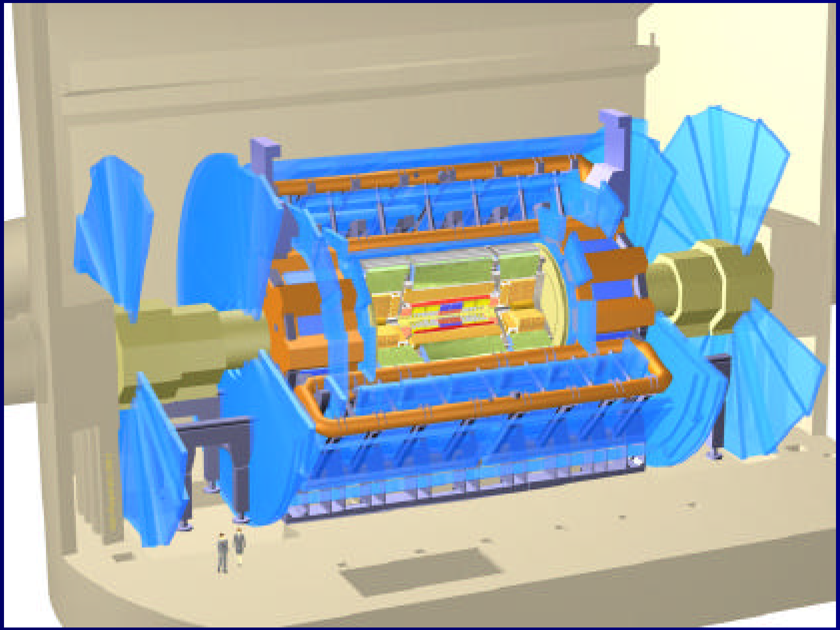
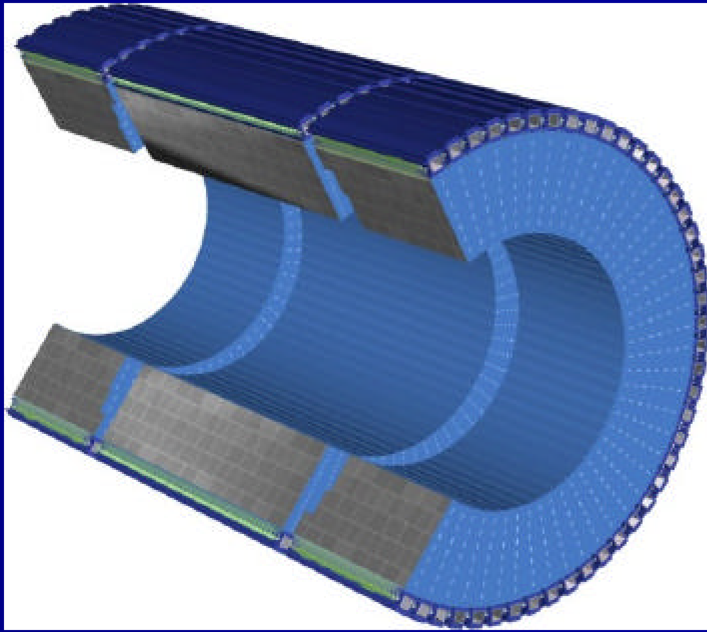
Summary

- Tile Calorimeter
- Test beam calibration
- Energy reconstruction algorithms
- Energy resolution under Pions
- Energy resolution under electrons
- Linearity
- Conclusions

Tile Calorimeter

Tile Calorimeter inside ATLAS





3 Barrels: 64 modules / barrel

R_i: 2280 mm R_o: 4320 mm

L: 5640 mm + 2910 mm

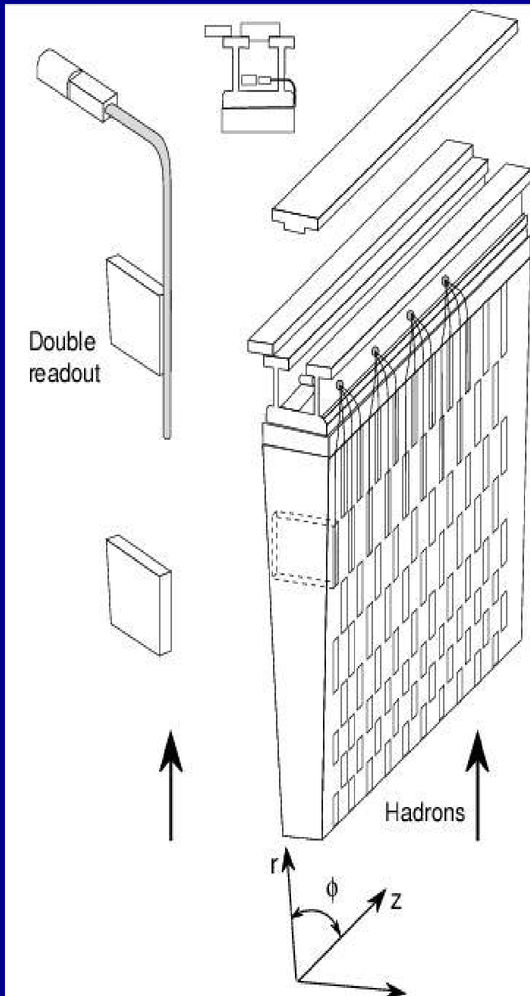
Passive Medium: Iron

Active Medium: Scintillators

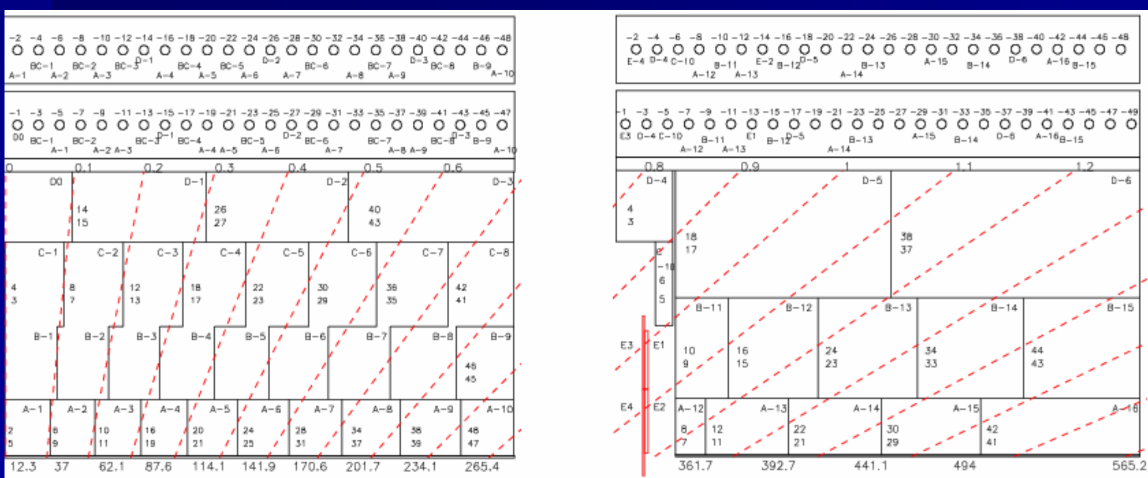
Weight: 2900 T

Tilecal

- •Staggered in Scintillator Tiles and iron
- •Tiles perpendicular to beam direction and read out by two WLS fibres
- •Segmented in cells defined as groups of fibres.
- •Each cell is read by two photomultiplier
- •Front-End electronics placed inside the module.

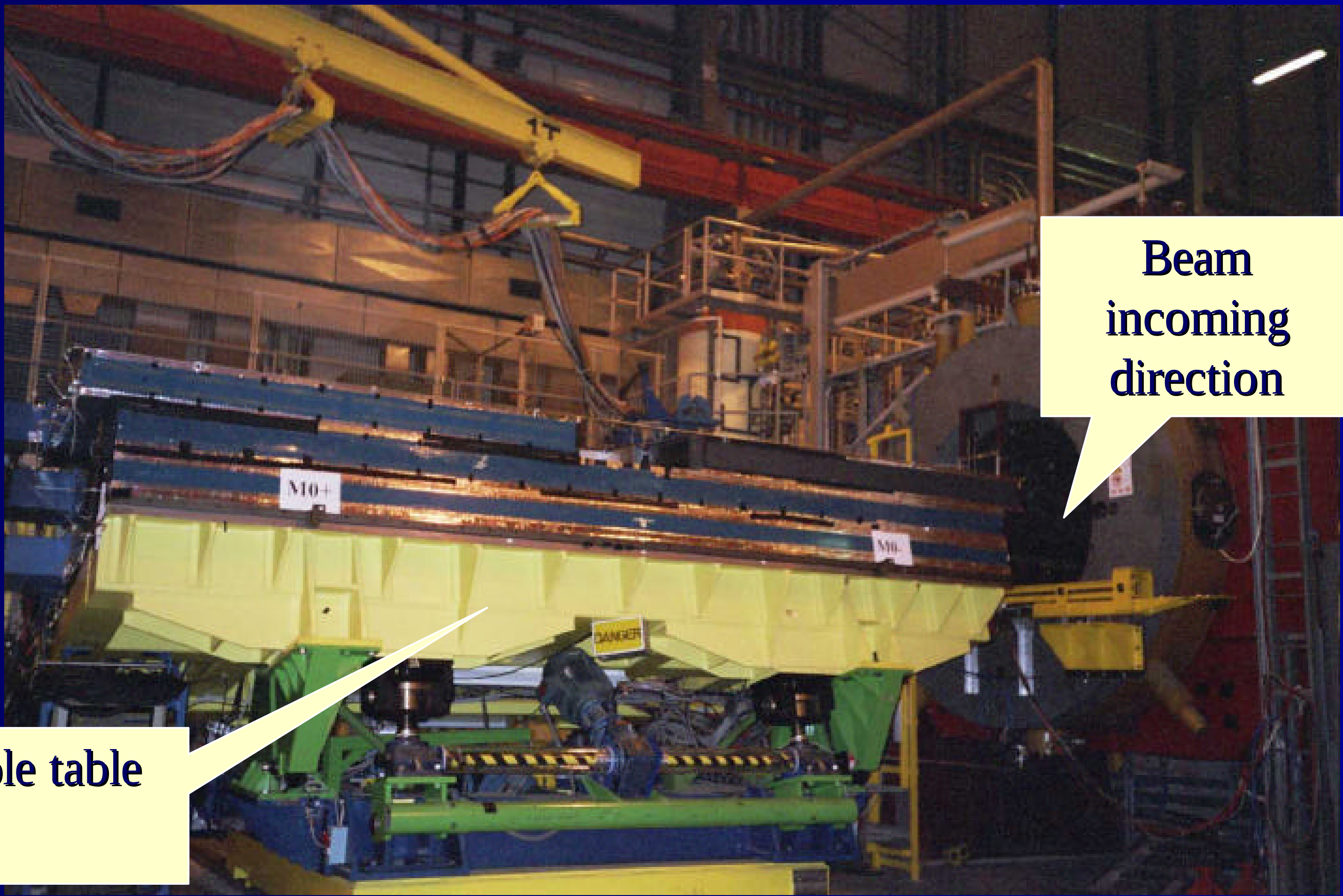


1.8?
4.0?
1.4?



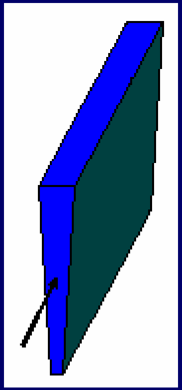
Test Beam Calibration

Test beam setup

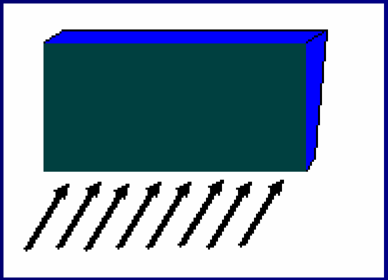


Test beam features

- 8% of the modules calibrated under particles of known energy
- Pion, electron and muon response
- Energies from 350 GeV to 1 GeV
- Three angles of incidence:



90º

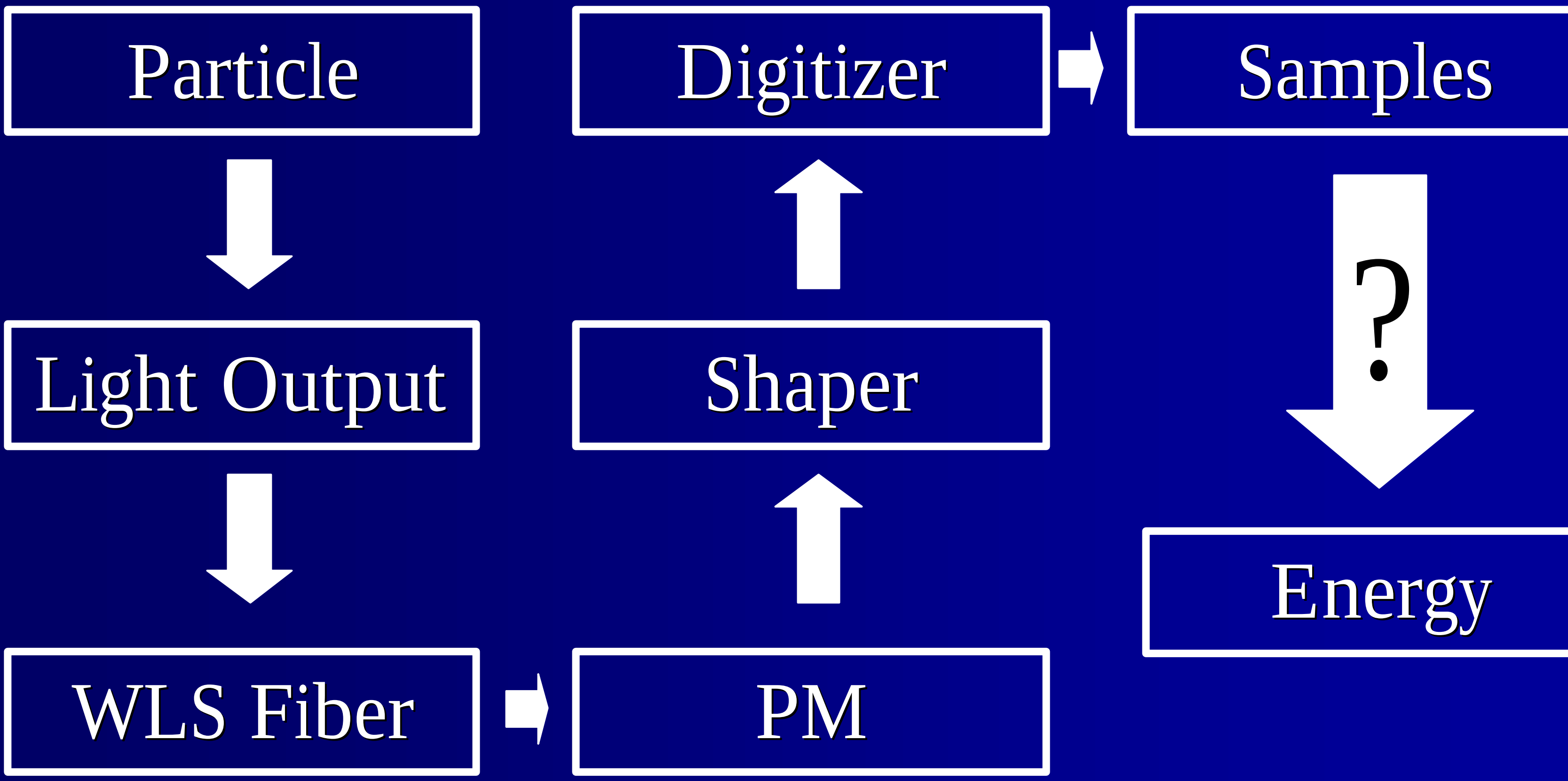


20º

Eta projective

Energy reconstruction algorithms

Introduction



Most simple algorithms

- Area Based Algorithms
  - Flat Filtering
- Amplitude Based Algorithms
  - Maximum Sample
  - Optimal Filtering

Flat Filtering (FF)

Samples: S_i → **Pedestal Subtraction**: $S_i' = S_i - Ped$ → **Energy Calculation**: $E = \sum_{i=1}^{n} S_i'$

Maximum Sample

Samples: S_i ⇒

Pedestal Subtraction

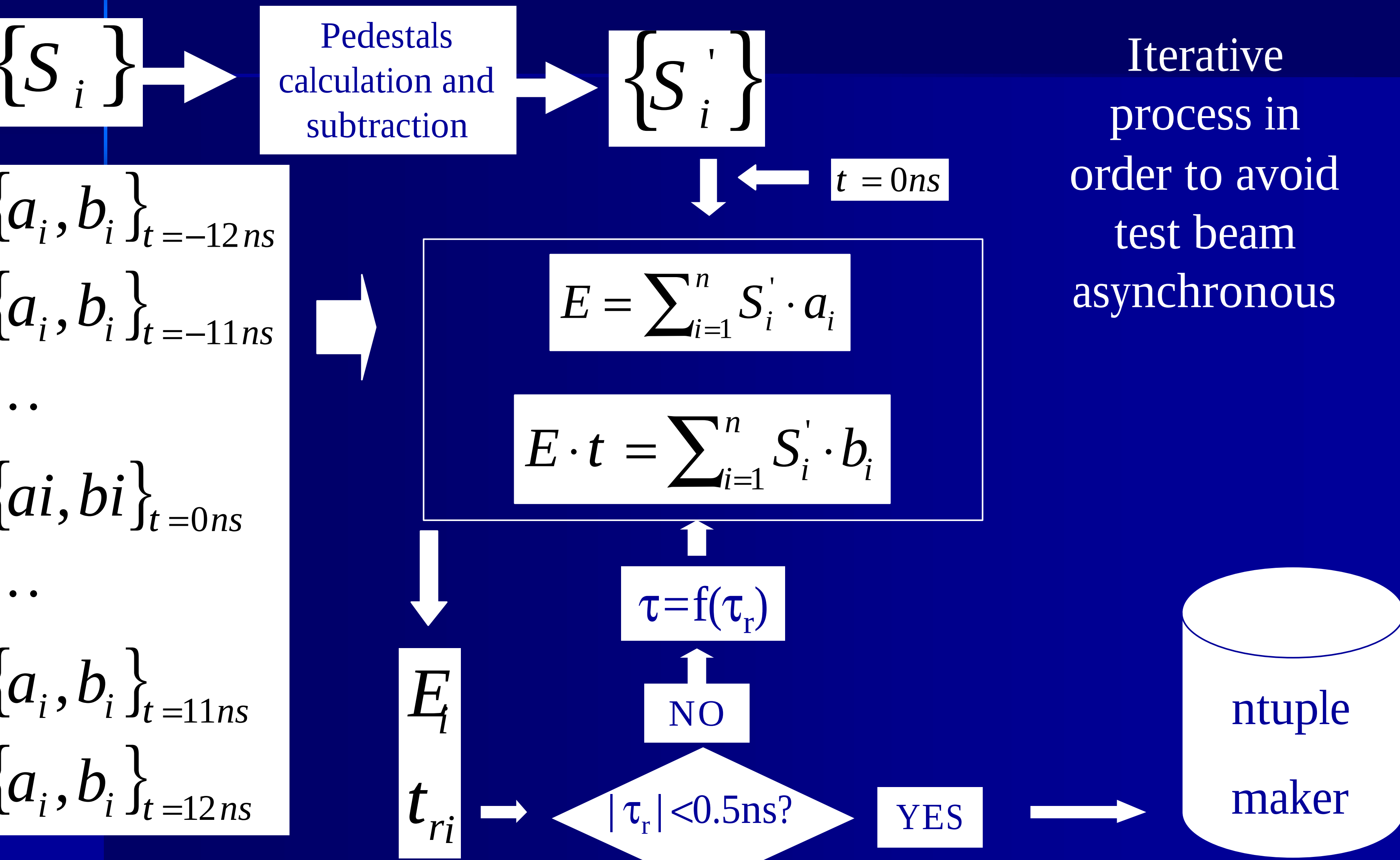
$$S_i' = S_i - Ped$$

⇒

Energy Calculation

$$E = Max\{S_i'\}$$

Optimal Filtering (OF)



Weights calculation

Noise autocorrelation matrix

Values of the PM shape form function

Values of the PM shape form function derivative

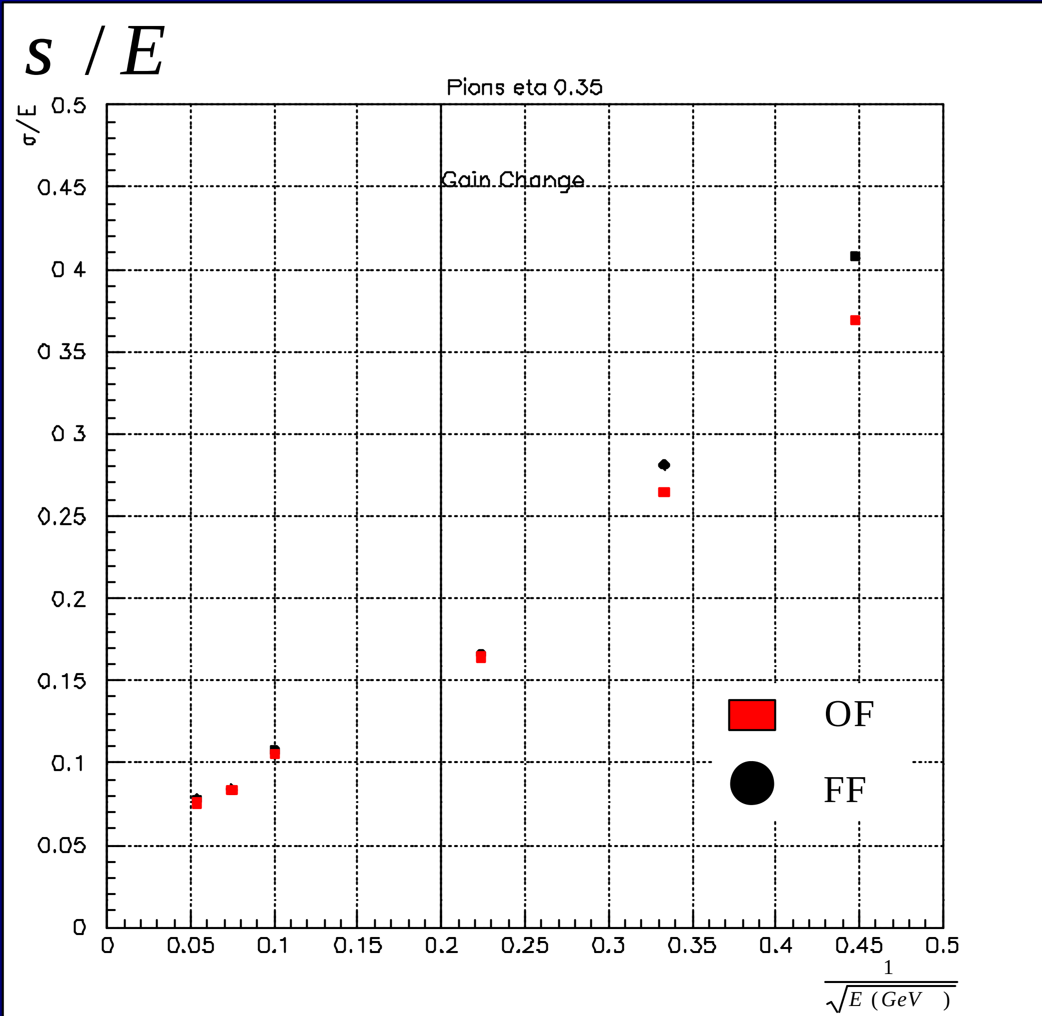
Result → Weights

$$\begin{vmatrix} R_{11} & R_{12} & R_{13} & R_{14} & R_{15} & R_{16} & R_{17} & G_1 & dG_1 \\ R_{21} & R_{22} & R_{23} & R_{24} & R_{25} & R_{26} & R_{27} & G_2 & dG_2 \\ R_{31} & R_{32} & R_{33} & R_{34} & R_{35} & R_{36} & R_{37} & G_3 & dG_3 \\ R_{41} & R_{42} & R_{43} & R_{44} & R_{45} & R_{46} & R_{47} & G_4 & dG_4 \\ R_{51} & R_{52} & R_{53} & R_{54} & R_{55} & R_{56} & R_{57} & G_5 & dG_5 \\ R_{61} & R_{62} & R_{63} & R_{64} & R_{65} & R_{66} & R_{67} & G_6 & dG_6 \\ R_{71} & R_{72} & R_{73} & R_{74} & R_{75} & R_{76} & R_{77} & G_7 & dG_7 \\ G_1 & G_2 & G_3 & G_4 & G_5 & G_6 & G_7 & 0 & 0 \\ dG_1 & dG_2 & dG_3 & dG_4 & dG_5 & dG_6 & dG_7 & 0 & 0 \end{vmatrix} * \begin{vmatrix} A_1 \\ A_2 \\ A_3 \\ A_4 \\ A_5 \\ A_6 \\ A_7 \\ \chi \\ \zeta \end{vmatrix} = \begin{vmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 1 \\ 0 \end{vmatrix}$$

Energy resolution under pions

Pions eta projective 0.35

Energy (GeV)	FF	OF
350	7.8%	7.6%
180	8.4%	8.4%
100	10.8%	10.5%
20	16.6%	16.4%
9	28.1%	26.5%
5	40.8%	36.9%



Pions Resolution

1

$$\frac{s}{E} = \frac{a}{\sqrt{E}} \oplus \frac{b}{E} \oplus c$$

	FF	OF
a (√GeV)	0.64	0.66
b (GeV)	1.43	1.07
c	0.073	0.070
χ^2	0.008	0.006

2

$$\frac{s}{E} = \frac{a}{\sqrt{E}} \oplus c$$

	FF	OF
a (√GeV)	0.86	0.79
c	0.055	0.060
χ^2	0.056	0.023

3

$$\frac{s}{E} = \frac{a}{\sqrt{E}} + \frac{b}{E} + c$$

	FF	OF
a (√GeV)	0.22	0.32
b (GeV)	1.24	0.86
c	0.064	0.058
χ^2	0.007	0.005

4

$$\frac{s}{E} = \left(\frac{a}{\sqrt{E}} + c\right) \oplus \frac{b}{E}$$

	FF	OF
a (√GeV)	0.46	0.50
b (GeV)	1.59	1.27
c	0.053	0.049
χ^2	0.008	0.006

Pions eta projective 0.35 Fit 2

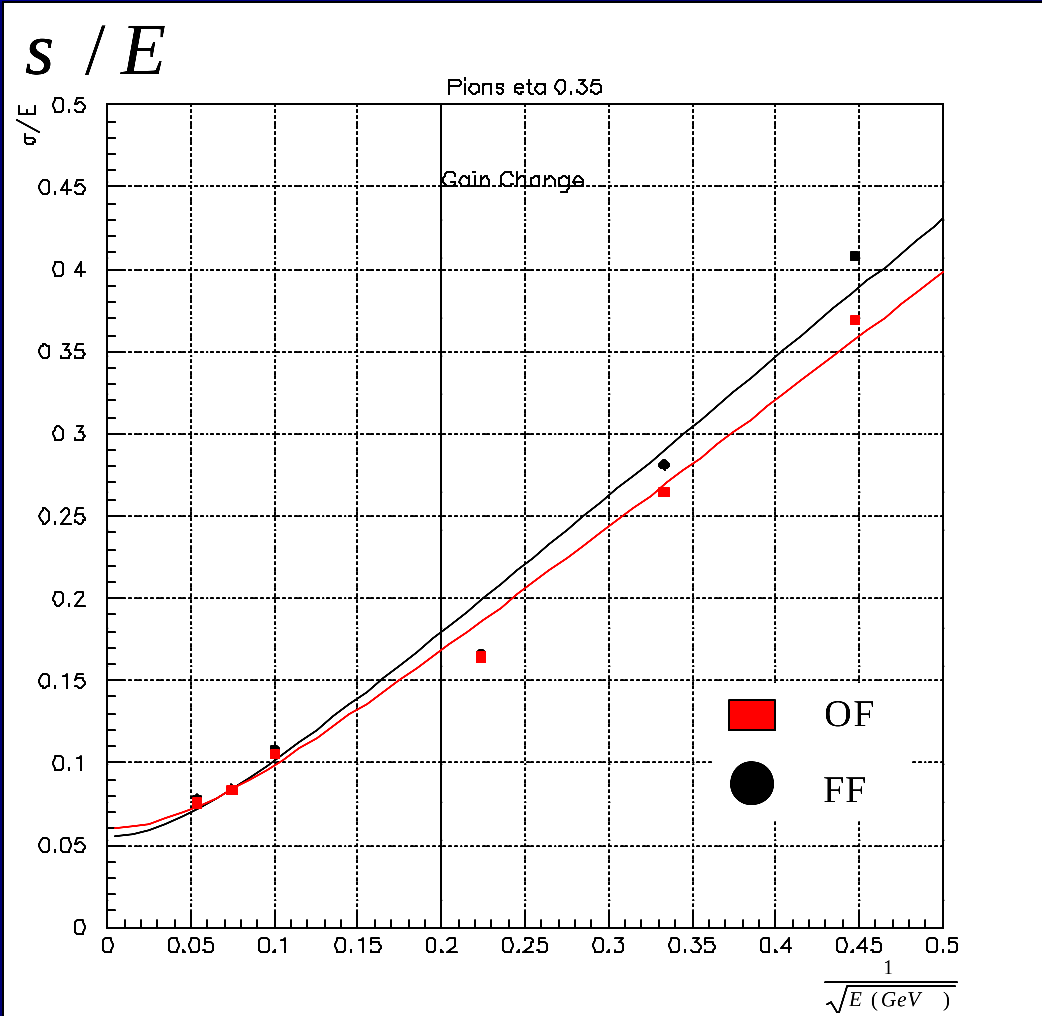
2

FF

$$\frac{s}{E} = \frac{0.86}{\sqrt{E}} \oplus 0.055$$

OF

$$\frac{s}{E} = \frac{0.79}{\sqrt{E}} \oplus 0.060$$

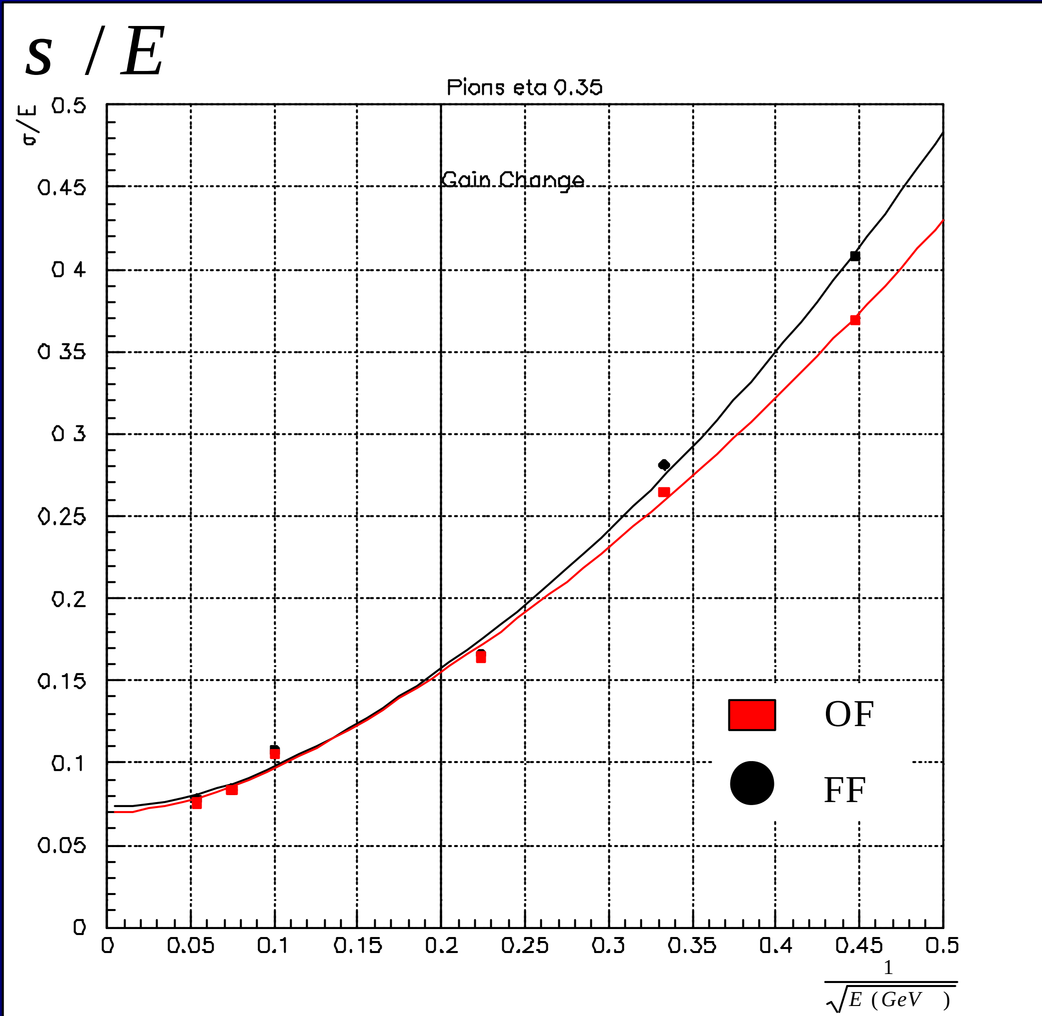


Pions eta projective 0.35 Fit 1

1

FF $$\frac{s}{E} = \frac{0.64}{\sqrt{E}} \oplus \frac{1.43}{E} \oplus 0.073$$

OF $$\frac{s}{E} = \frac{0.66}{\sqrt{E}} \oplus \frac{1.07}{E} \oplus 0.070$$



Pions eta projective 0.35 Fit 3

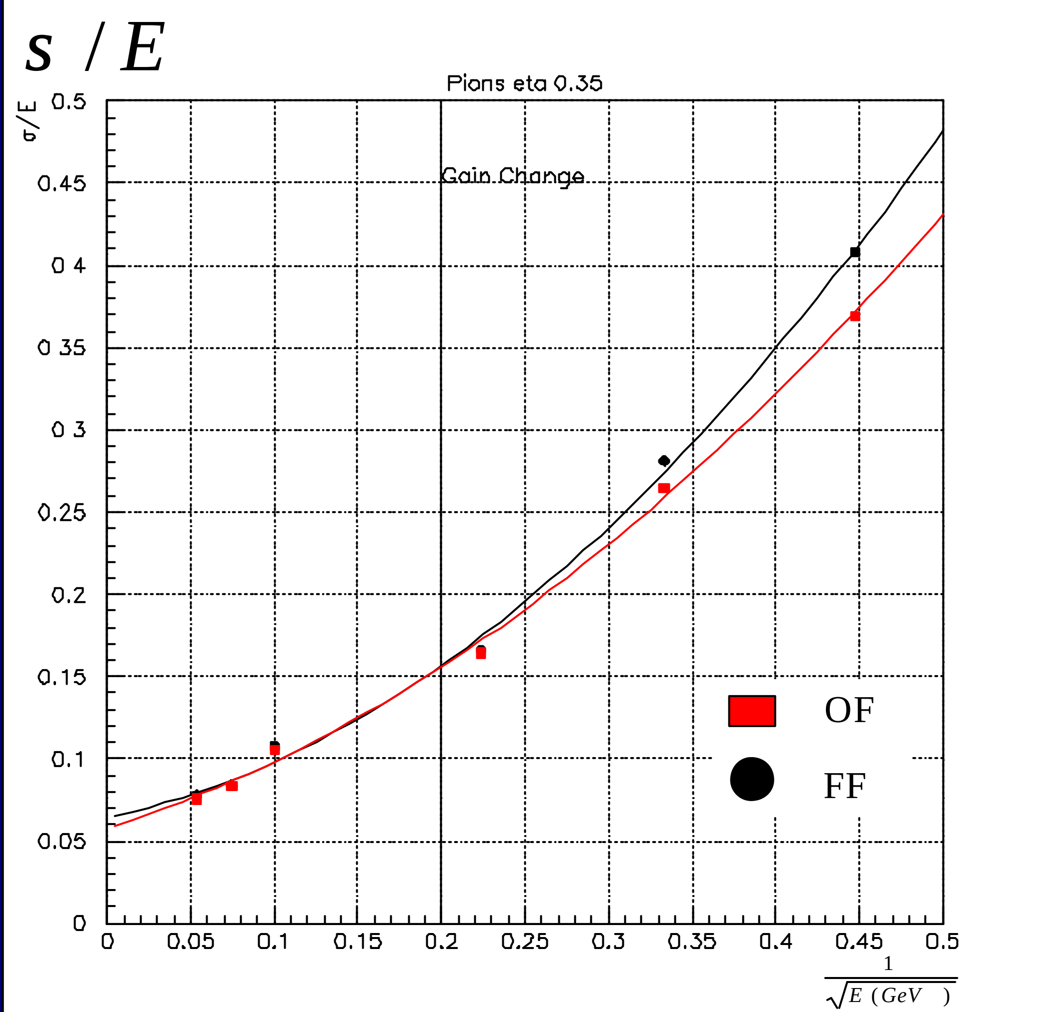
3

FF

$$\frac{s}{E} = \frac{0.22}{\sqrt{E}} + \frac{1.24}{E} + 0.064$$

OF

$$\frac{s}{E} = \frac{0.32}{\sqrt{E}} + \frac{0.86}{E} + 0.058$$



Pions eta projective 0.35 Fit 4

4

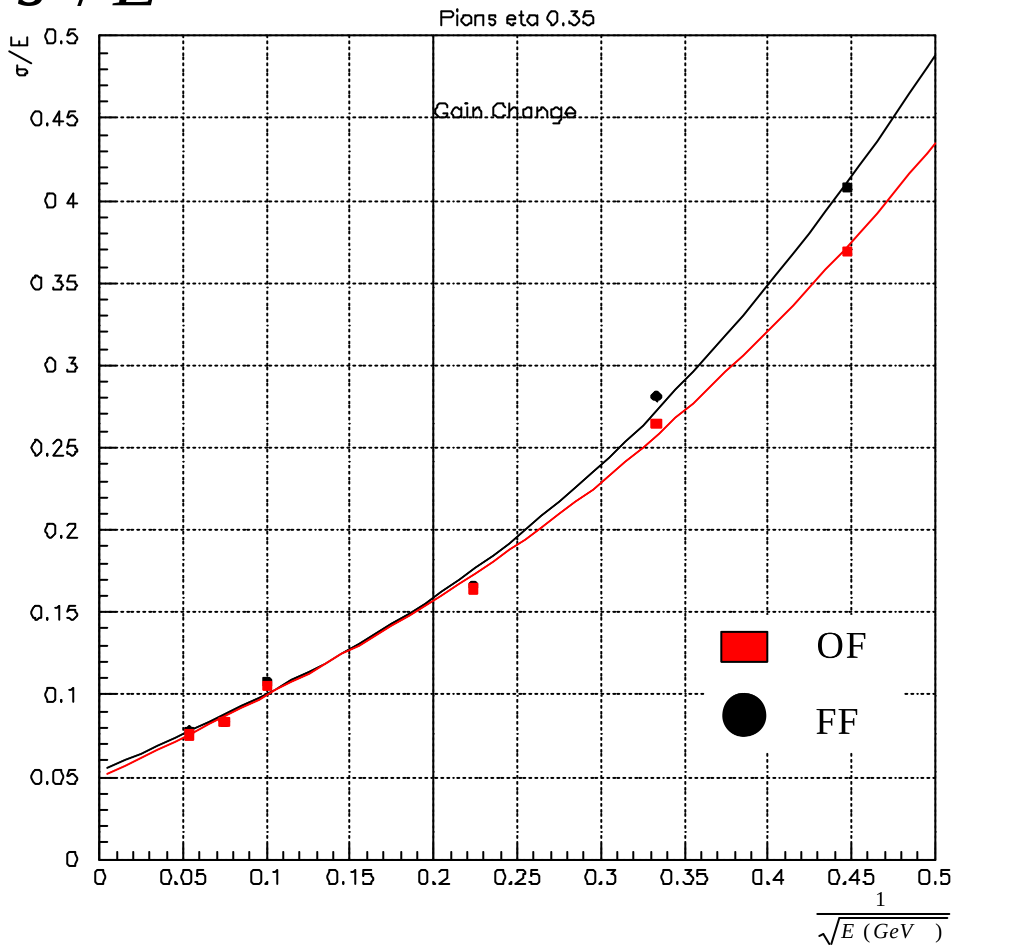
FF

$$\frac{s}{E} = \left(\frac{0.46}{\sqrt{E}} + 0.053\right) \oplus \frac{1.59}{E}$$

OF

$$\frac{s}{E} = \left(\frac{0.50}{\sqrt{E}} + 0.049\right) \oplus \frac{1.27}{E}$$

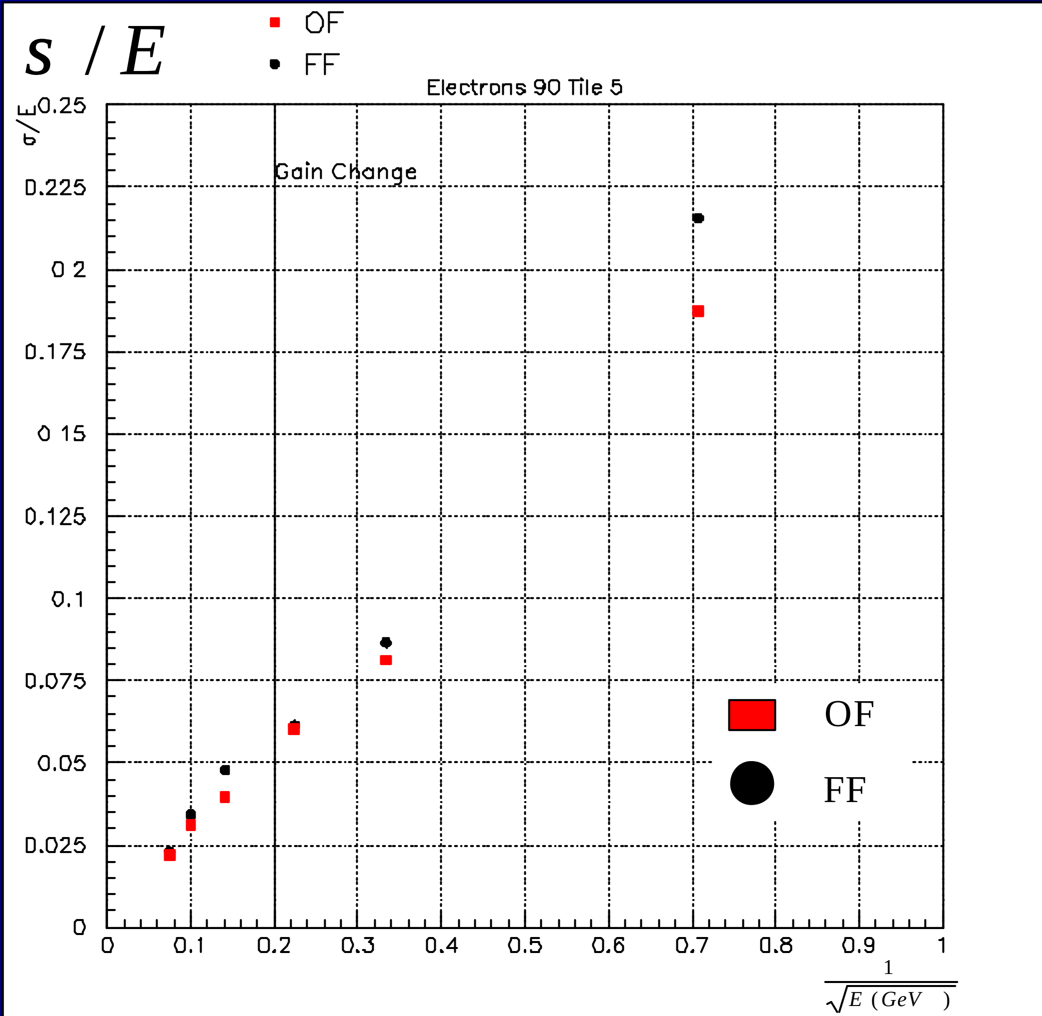
s / E



Energy resolution under Electrons

Electrons 90º

Energy (GeV)	FF	OF
180	2.3%	2.2%
100	3.4%	3.1%
50	4.8%	4.0%
20	6.1%	6.0%
9	8.7%	8.1%
2	21.6%	18.7%



e Resolution

1

$$\frac{s}{E} = \frac{a}{\sqrt{E}} \oplus \frac{b}{E} \oplus C$$

	FF	OF
a (√GeV)	0.23	0.26
b (GeV)	.271	.007
c	.028	.002
χ^2	.001	.003

2

$$\frac{s}{E} = \frac{a}{\sqrt{E}} \oplus c$$

	FF	OF
a (√GeV)	0.29	0.26
c	.018	.012
χ^2	.010	.002

3

$$\frac{s}{E} = \frac{a}{\sqrt{E}} + \frac{b}{E} + c$$

	FF	OF
a (√GeV)	0.13	0.20
b (GeV)	.202	.074
c	.022	.009
χ^2	.001	.001

4

$$\frac{s}{E} = \left(\frac{a}{\sqrt{E}} + c\right) \oplus \frac{b}{E}$$

	FF	OF
a (√GeV)	0.30	0.26
b (GeV)	.004	.021
c	0.0	0.0
χ^2	0.013	[illegible]

e Resolution Fit 2

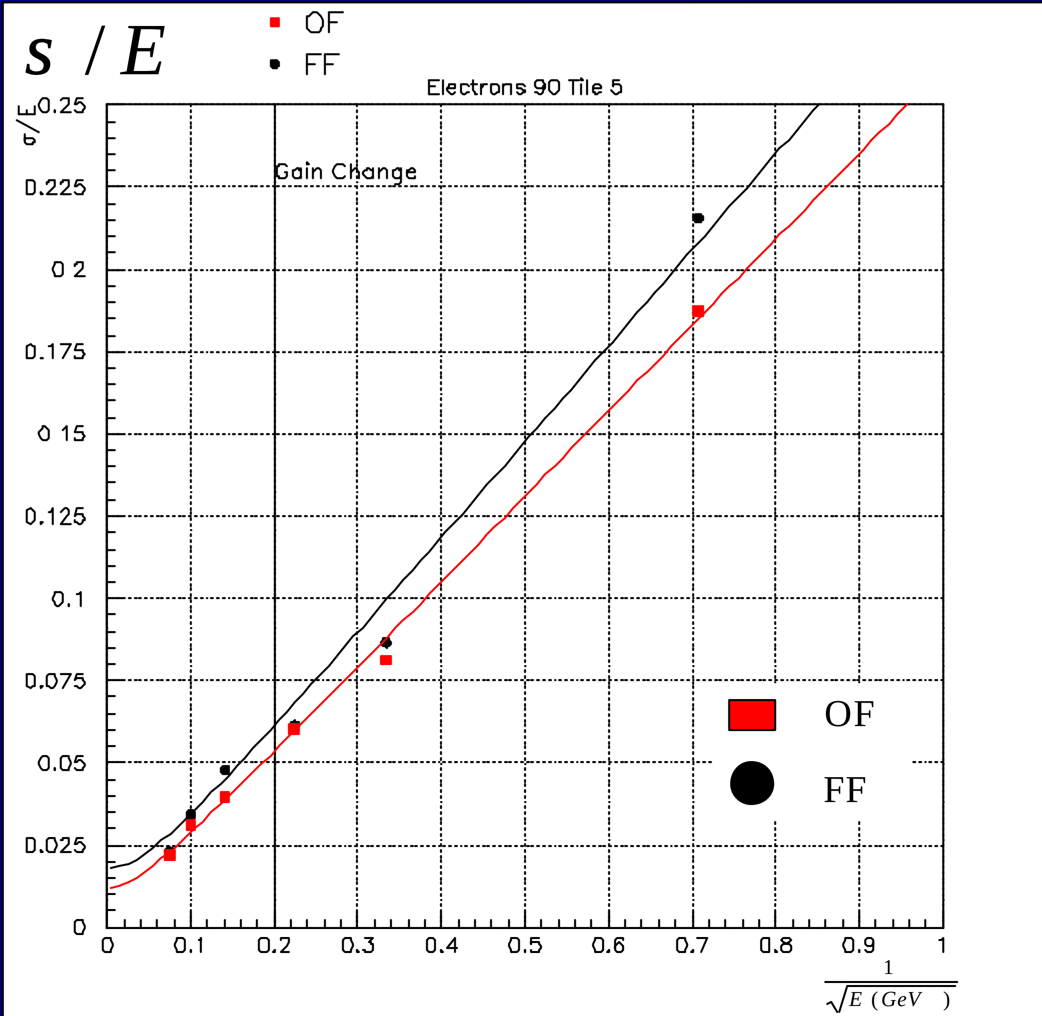
2

FF

$$\frac{s}{E} = \frac{0.29}{\sqrt{E}} \oplus 0.018$$

OF

$$\frac{s}{E} = \frac{0.26}{\sqrt{E}} \oplus 0.012$$

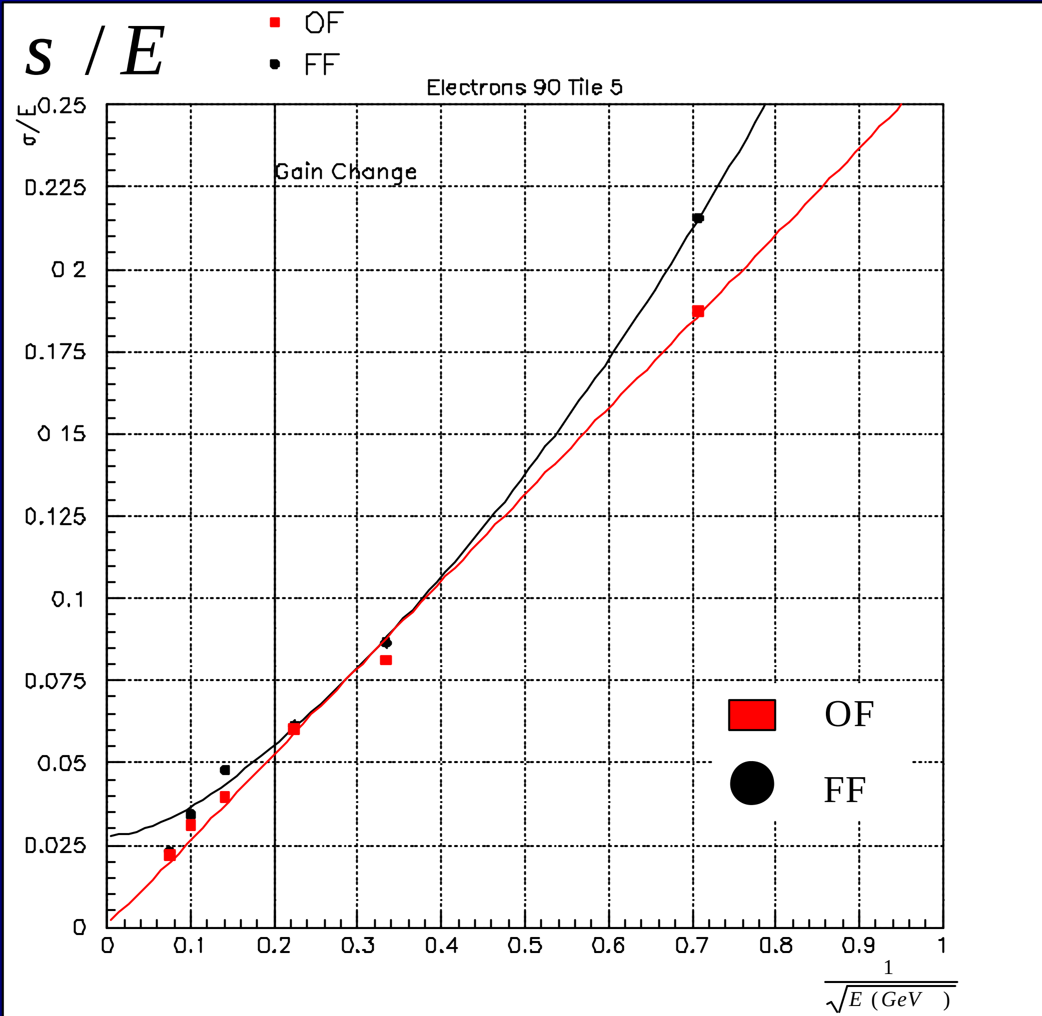


e Resolution Fit 1

1

FF $\frac{s}{E} = \frac{0.23}{\sqrt{E}} \oplus \frac{.271}{E} \oplus 0.028$

OF $\frac{s}{E} = \frac{0.26}{\sqrt{E}} \oplus \frac{.007}{E} \oplus 0.002$



e Resolution Fit 3

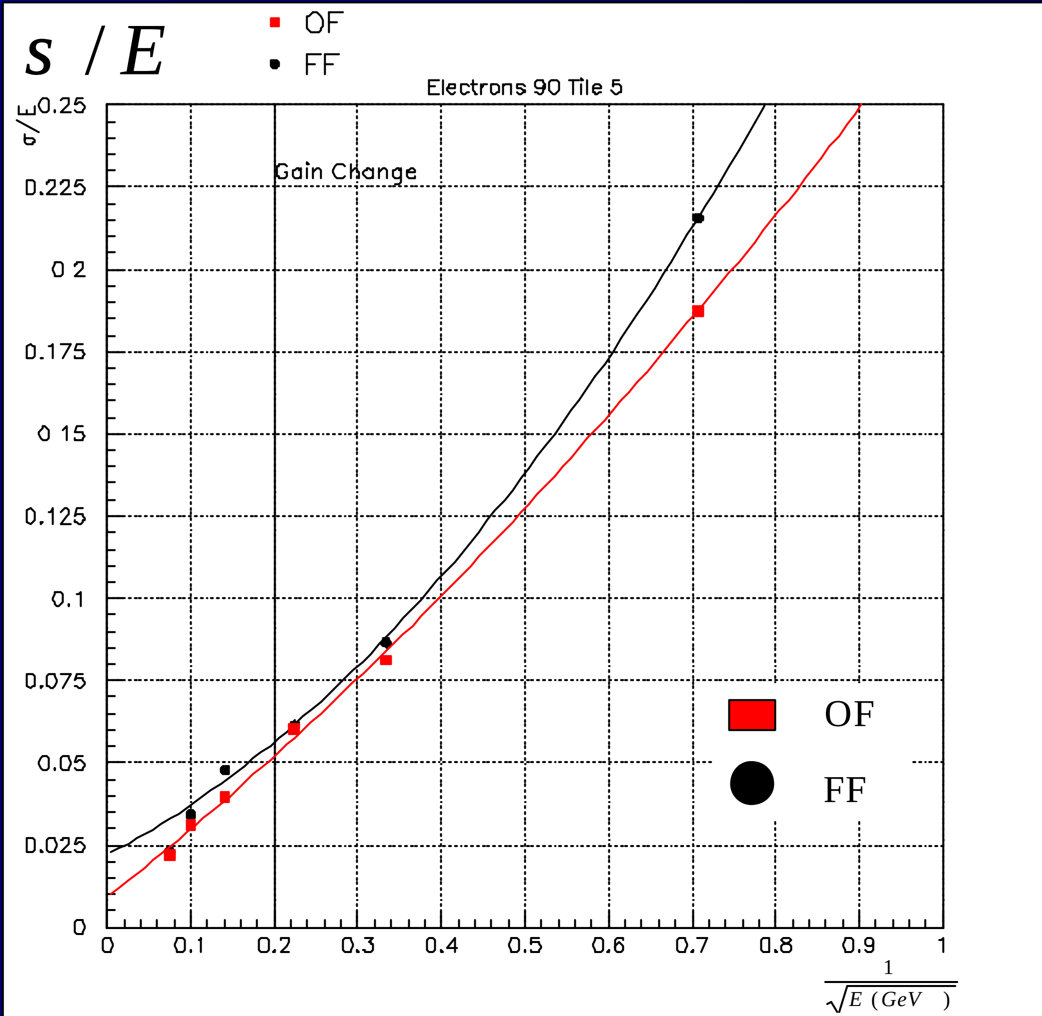
3

FF

$$\frac{s}{E} = \frac{0.13}{\sqrt{E}} + \frac{.202}{E} + 0.022$$

OF

$$\frac{s}{E} = \frac{0.20}{\sqrt{E}} + \frac{.074}{E} + 0.009$$



e Resolution Fit 4

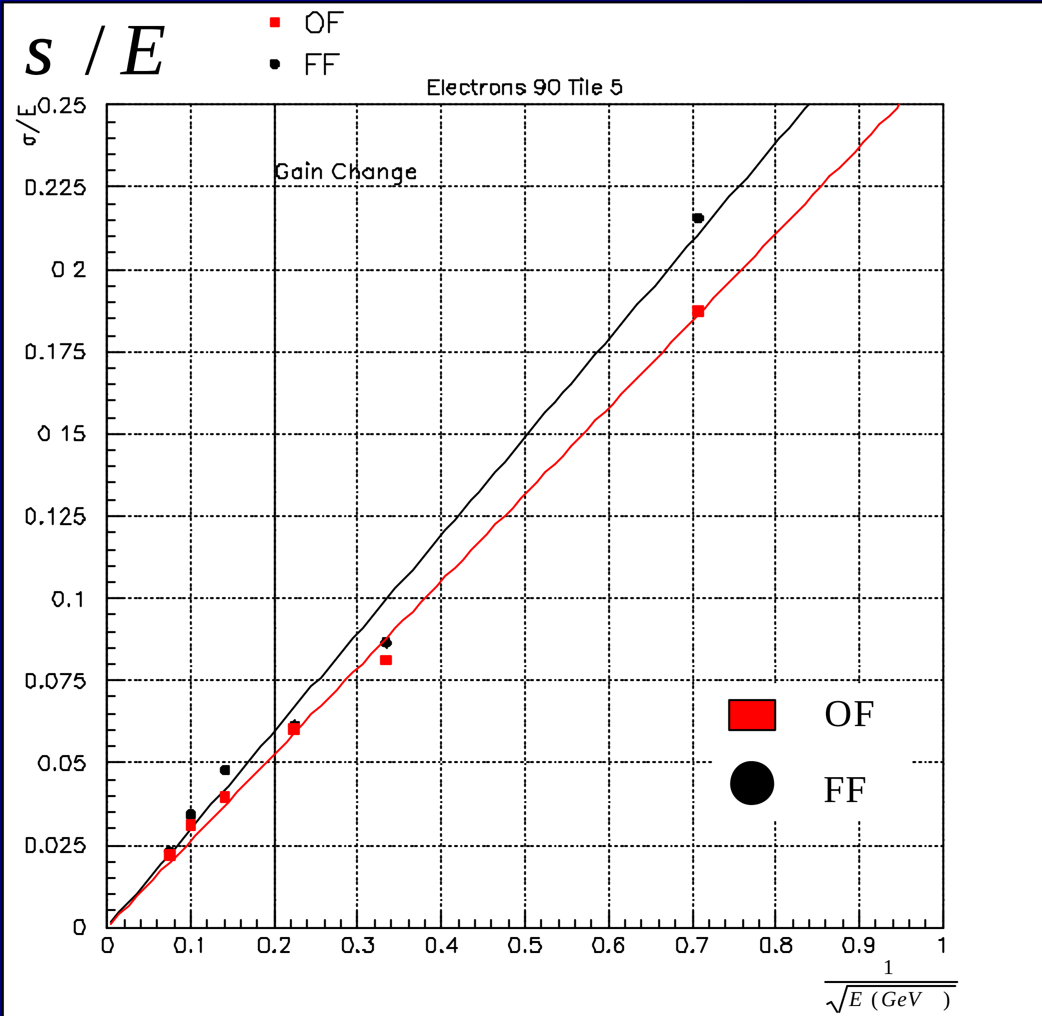
4

FF

$$\frac{s}{E} = \left(\frac{0.30}{\sqrt{E}}\right) \oplus \frac{.004}{E}$$

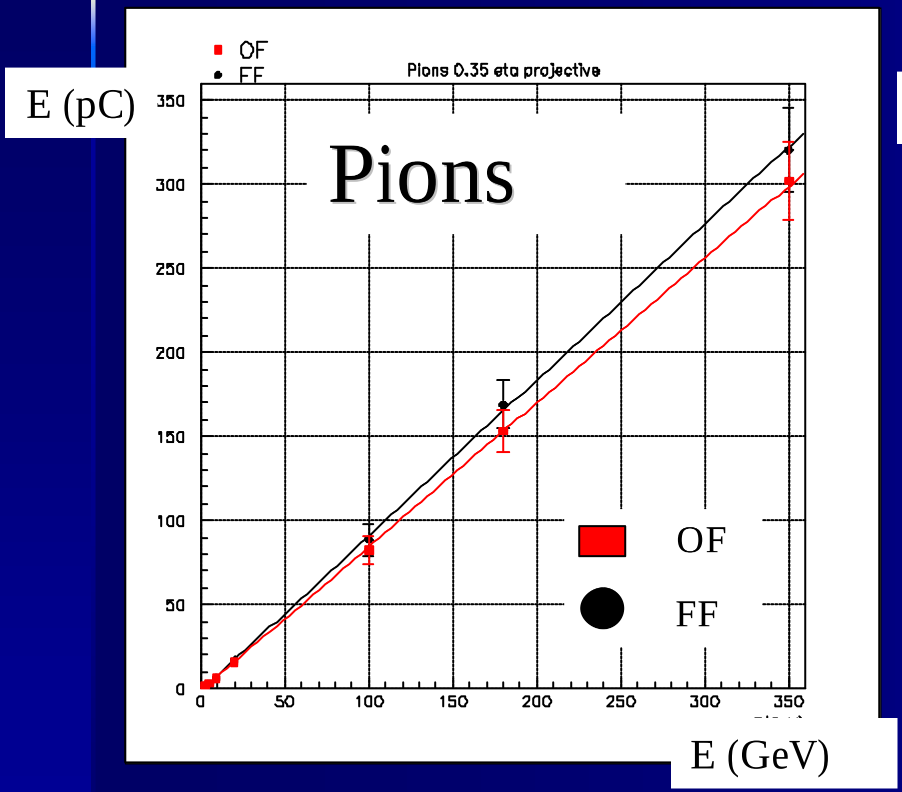
OF

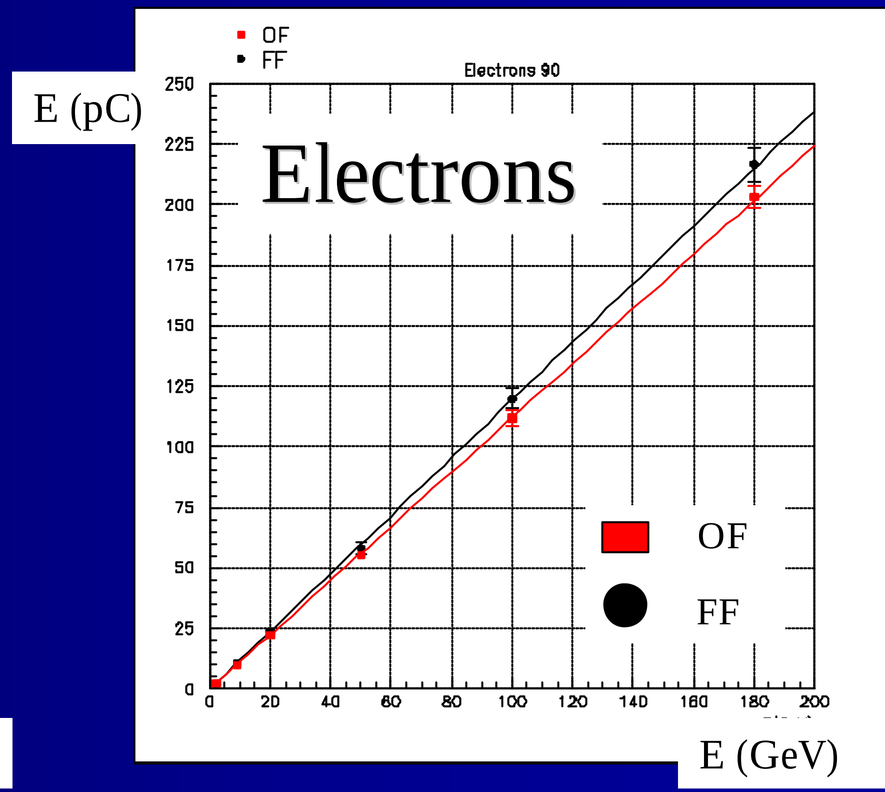
$$\frac{s}{E} = \left(\frac{0.26}{\sqrt{E}}\right) \oplus \frac{.021}{E}$$



Linearity

Linearity

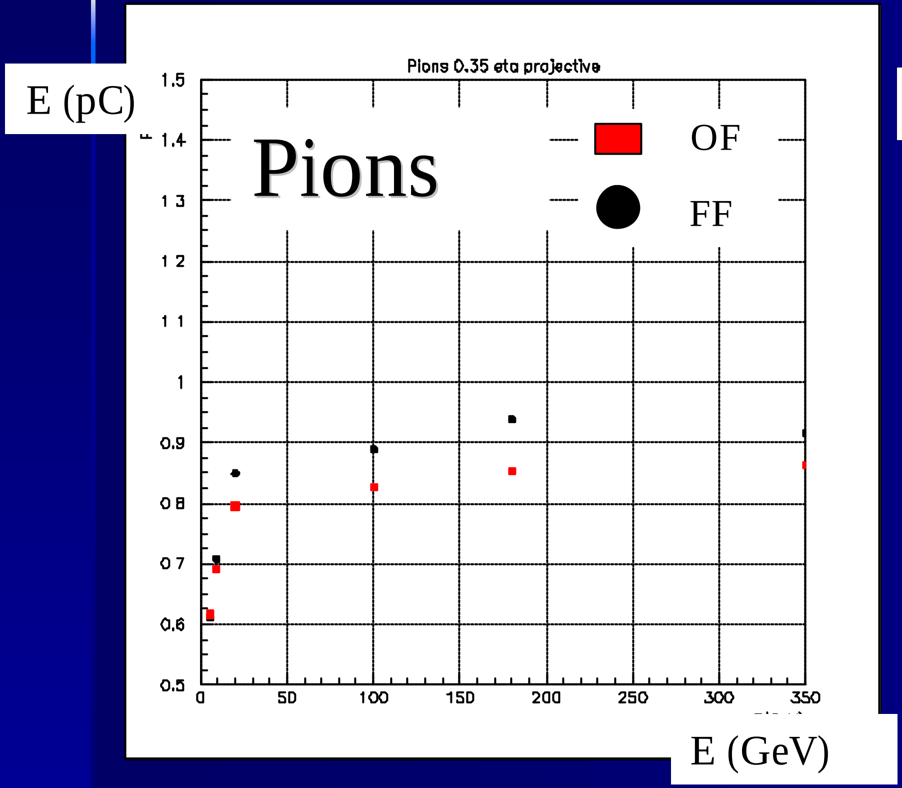


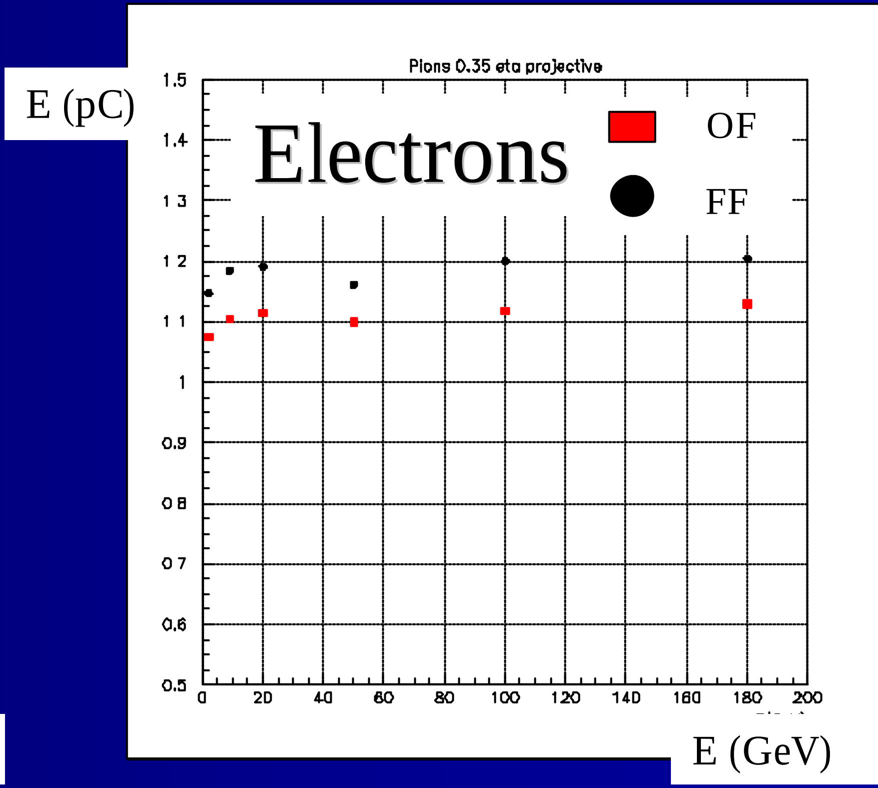


OF: $E(pC) = (0.93 \pm 0.05)E(GeV) + (-1.7 \pm 1.1)$ $E(pC) = (1.20 \pm 0.03)E(GeV) + (-0.1 \pm 0.$

FF: $E(pC) = (0.86 \pm 0.04)E(GeV) + (-1.3 \pm 1.0)$ $E(pC) = (1.12 \pm 0.02)E(GeV) + (-0.1 \pm 0.$

Linearity


E (pC)
Pions 0.35 eta projective
Pions
OF
FF
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0
50
100
150
200
250
300
350
E (GeV)


E (pC)
Pions 0.35 eta projective
Electrons
OF
FF
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0
20
40
60
80
100
120
140
160
180
200
E (GeV)

Conclusions

Conclusions

- Energy reconstruction algorithms can change significantly the resolution in energy regions where sampling fluctuations are not dominant
- Respecting FF vs. OF, OF improves the resolution in energy regions when the ratio (electronic noise)/(PM signal) is important
- Using FF or OF does not affect compensation