Comparison of GEANT4 Simulation of CMS ECAL Testbeam Experiments with Data and GEANT3 Simulation

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Motivation

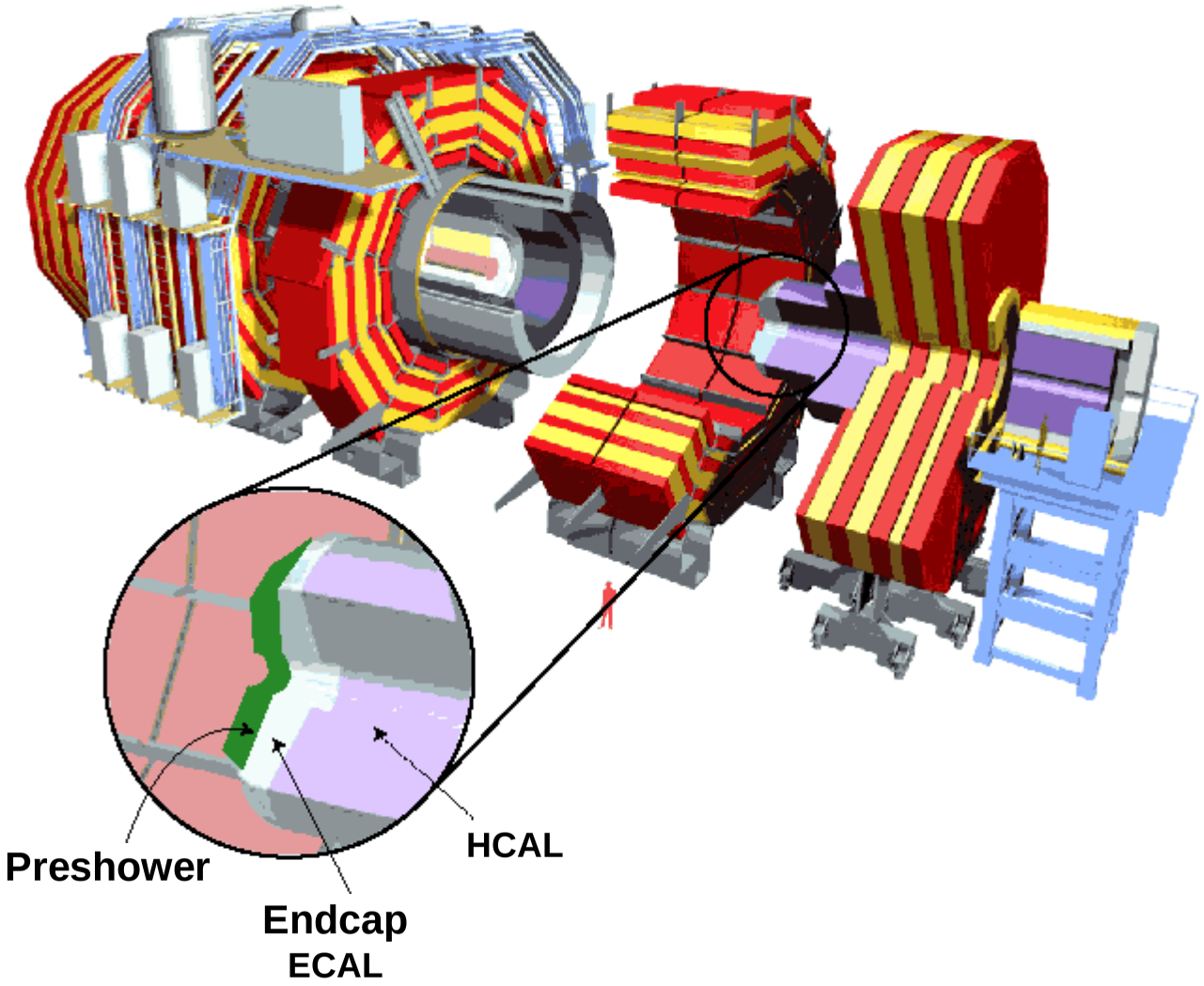
Comparison of Testbeam experiments with simulation

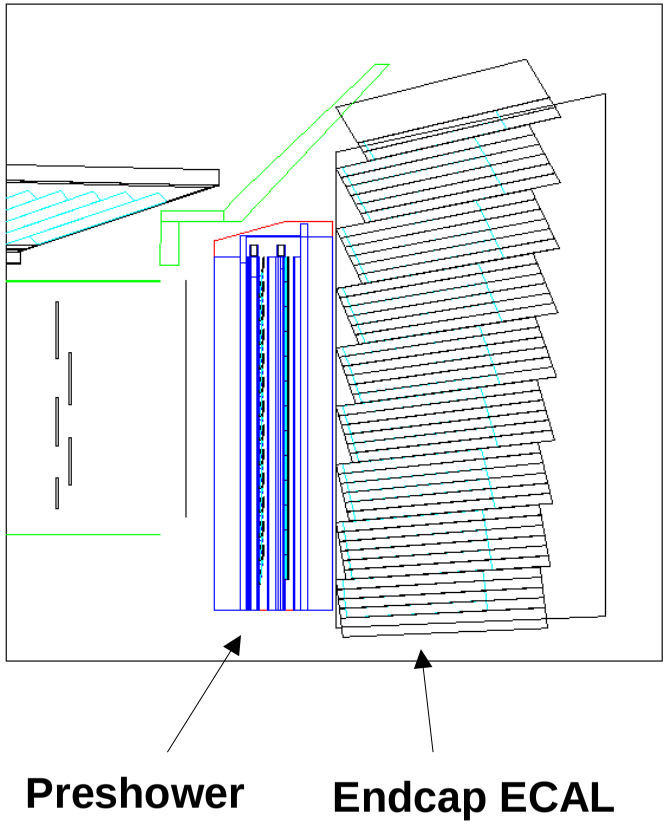
Future production system at CMS will use GEANT 4 for simulation (project OSCAR)

Gain confidence in GEANT 4

- Testbeam 1999, Ecal (PbWO4) Endcap Crystals and Preshower Prototype
  (Data + Geant 3 comparison: CMS Note 2000/001)

CMS Detector, Endcap ECAL





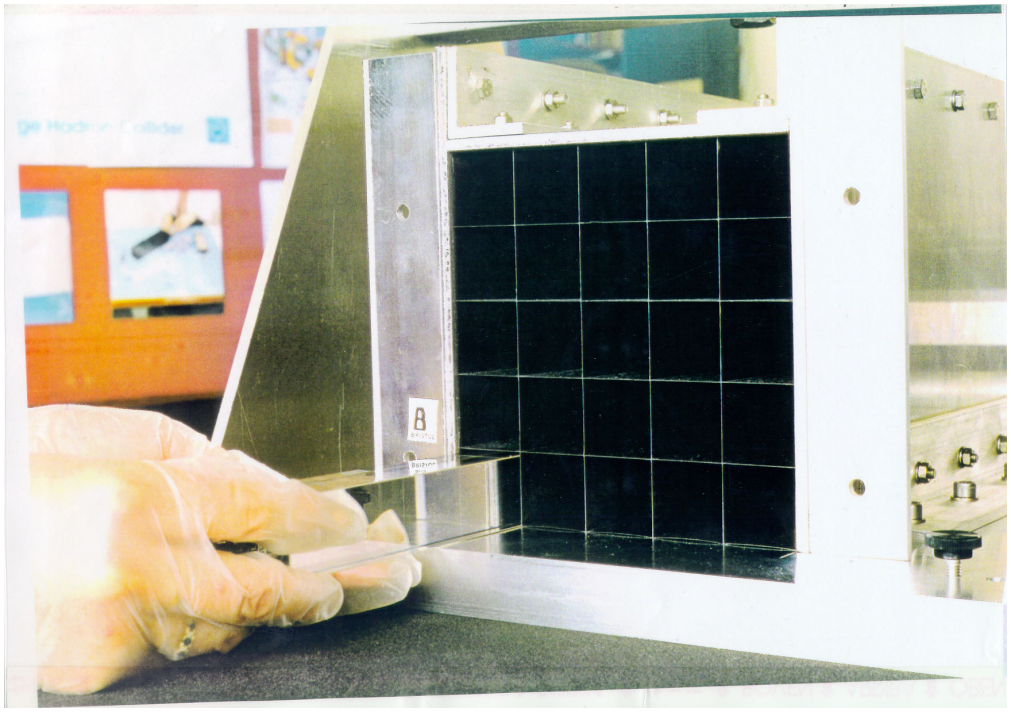
ECAL Endcap Crystals

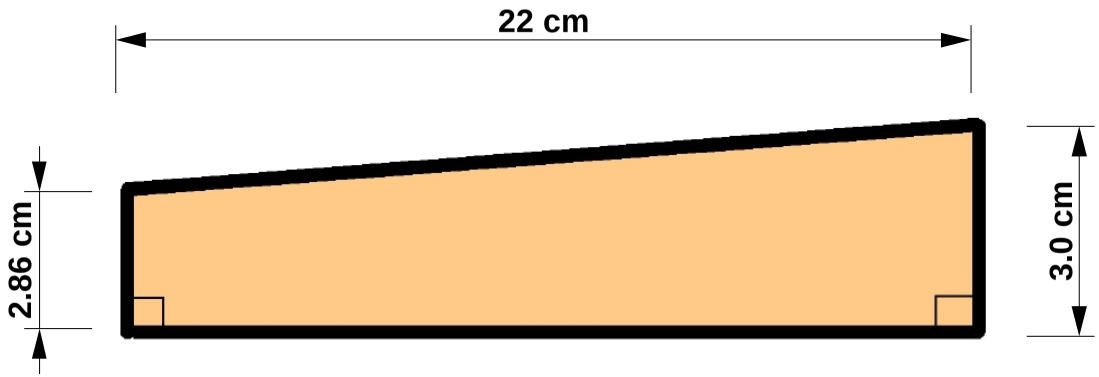
Crystals: $PbWO_4$

30x30mm rear face,
22cm long,
28.62x28.62mm front face

Radiation length: 24 Xo
Moliére radius: 2.2 cm

Energy containment on central hit: **~ 85 %**

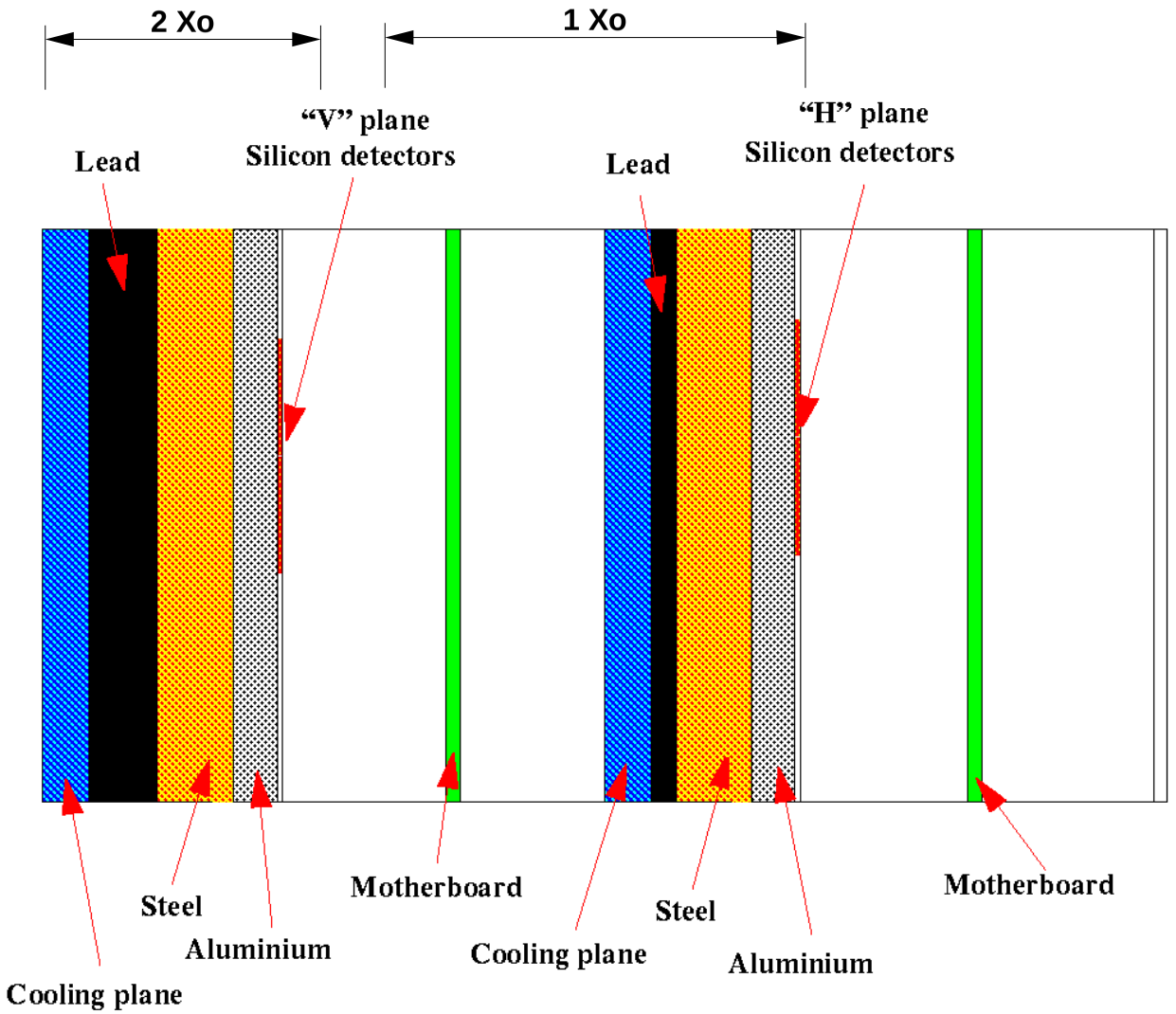




Preshower Prototype

Preshower:
radiation length 3.24 X_0

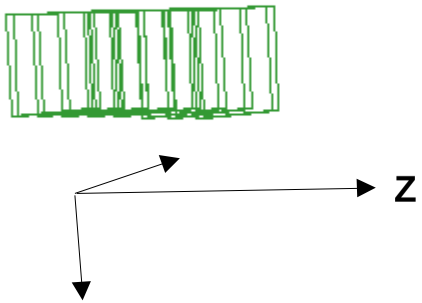
Silicon Strip Detectors:
57.7 x 57.7 x 0.3 mm
subdivided into 32 strips
(~ 1.9 mm strip)



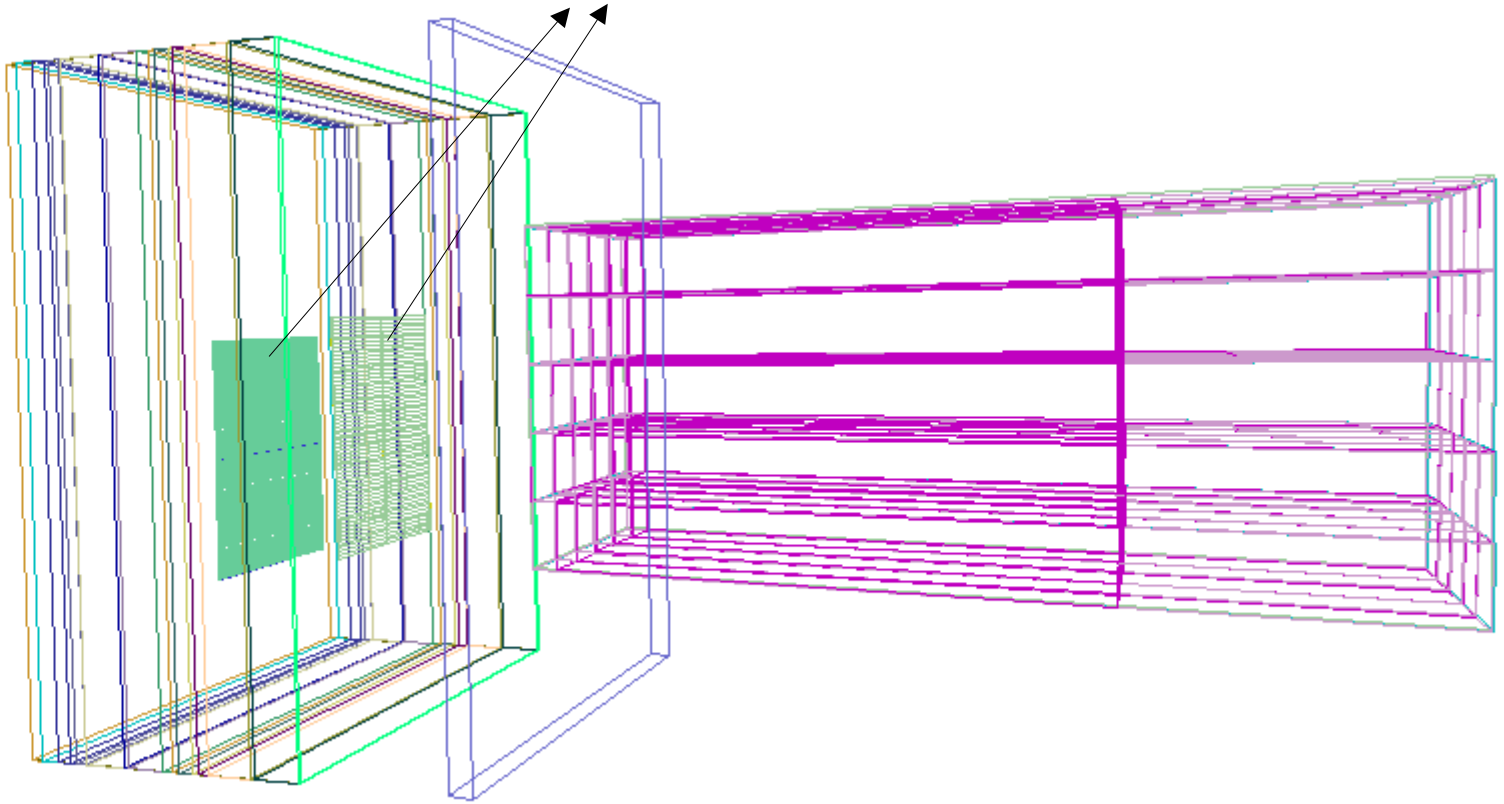
Testbeam Geometry

Silicon Strip Detectors

Scintillators



Beam along 'z'−axes
4x4mm^2 area
on center crystal



Preshower Prototype **5x5 matrix of $PbWO_4$ crystals**

G4 Simulation Setup

Cuts in GEANT4 (*production thresholds*)**:**

- 0.005 mm for every particle and material for preshower shower shape studies
- 0.5 mm for energy resolution studies
- GEANT 4.2.ref

Cuts in GEANT3

- 10 keV for e−/e+ and gamma in crystals and preshower
- Delta ray production turned off for energy resolution studies
- delta rays turned on for preshower shower profile

'Showershape' in Preshower (1)

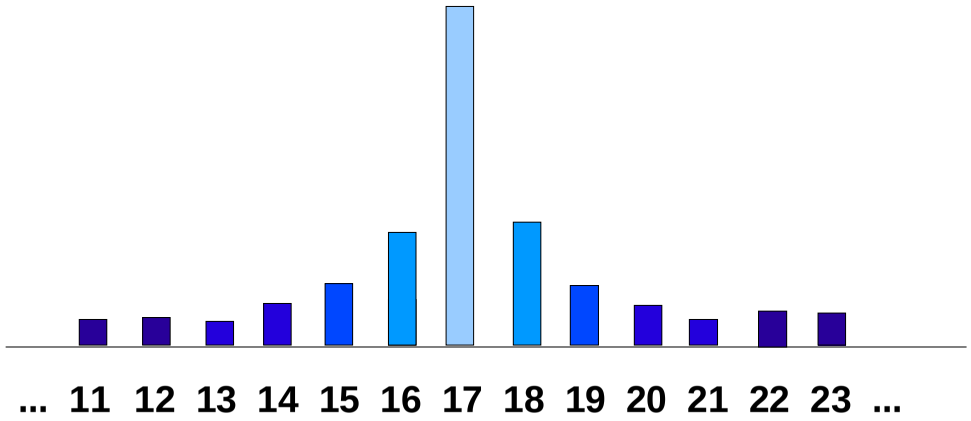
In the simulation:

- Find the strip with maximum energy deposit in the silicon detectors
- Take its (n) neighbours on both sides

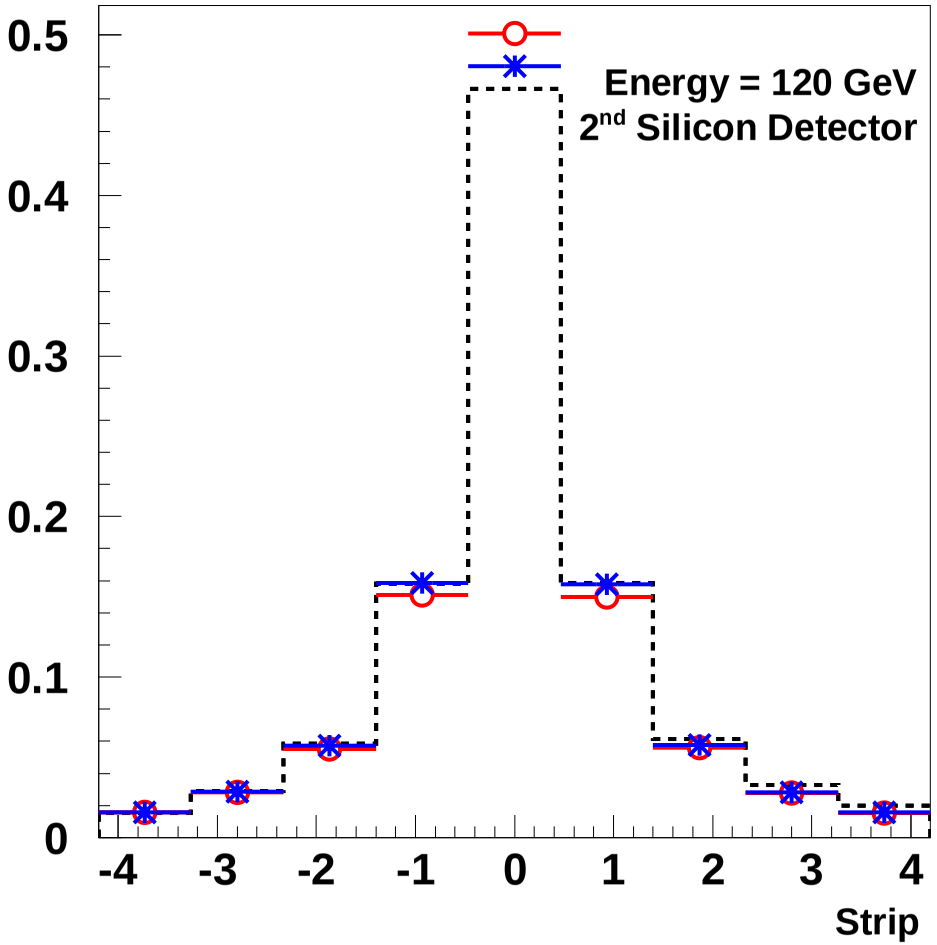
Additionally in the data:

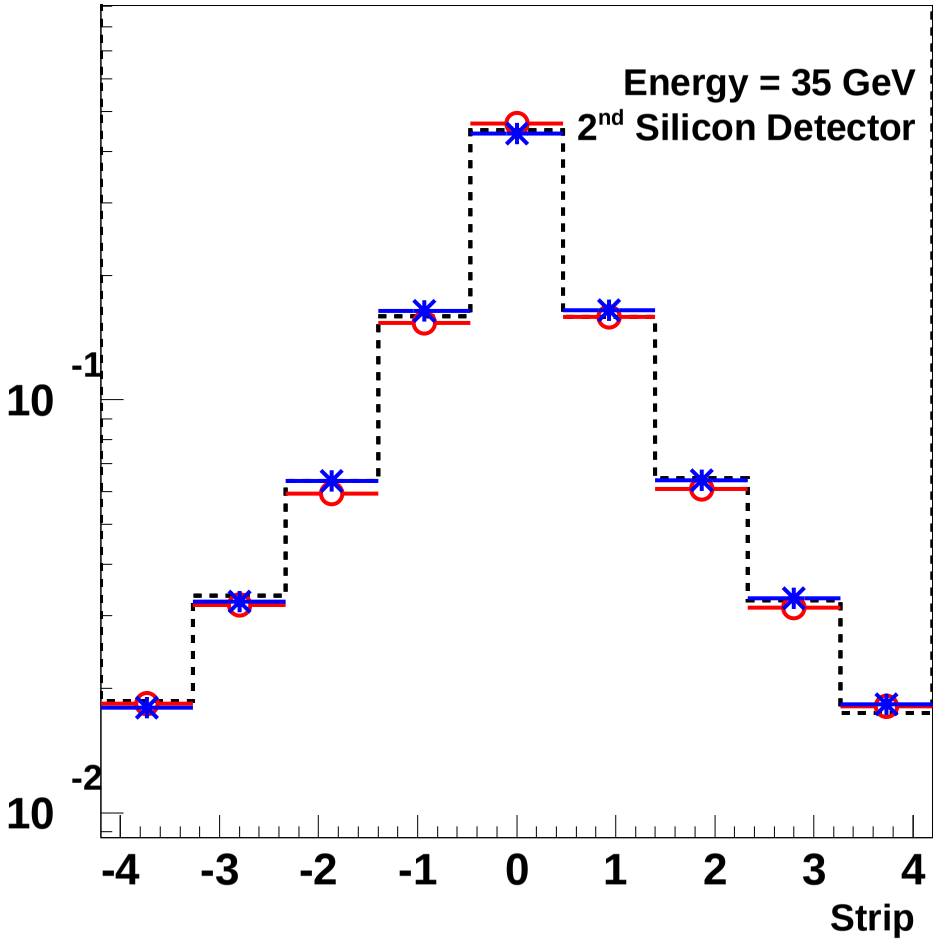
- Apply pedestal subtraction, common noise subtraction

Then: normalization of simulation & data histograms on same total energy



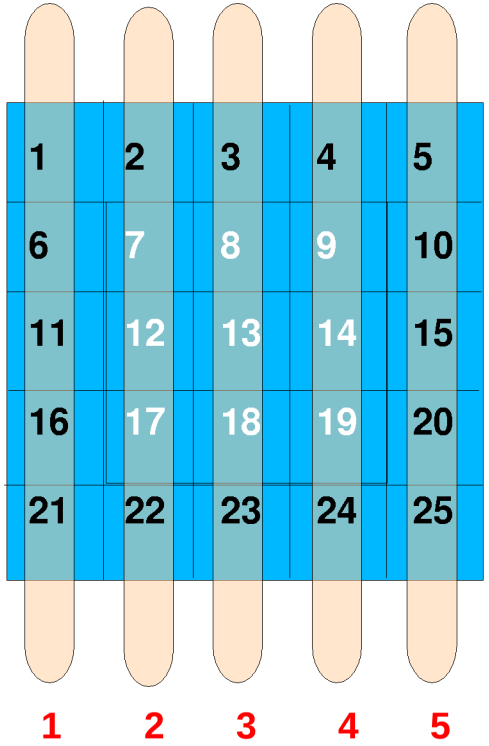
'Showershape' in Preshower (2)

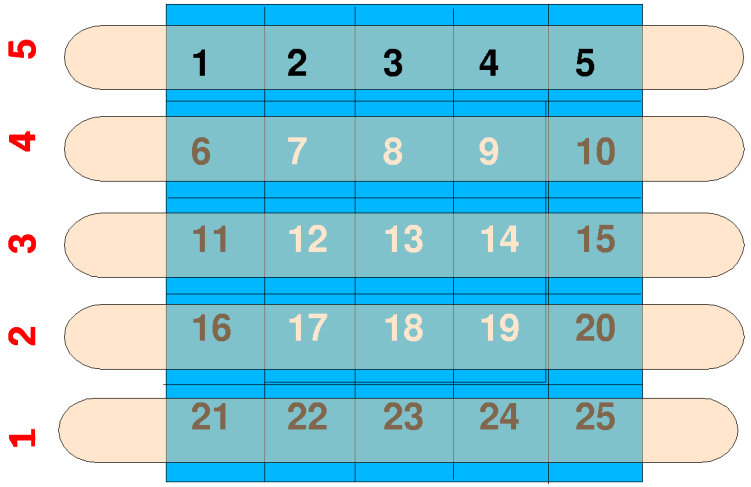




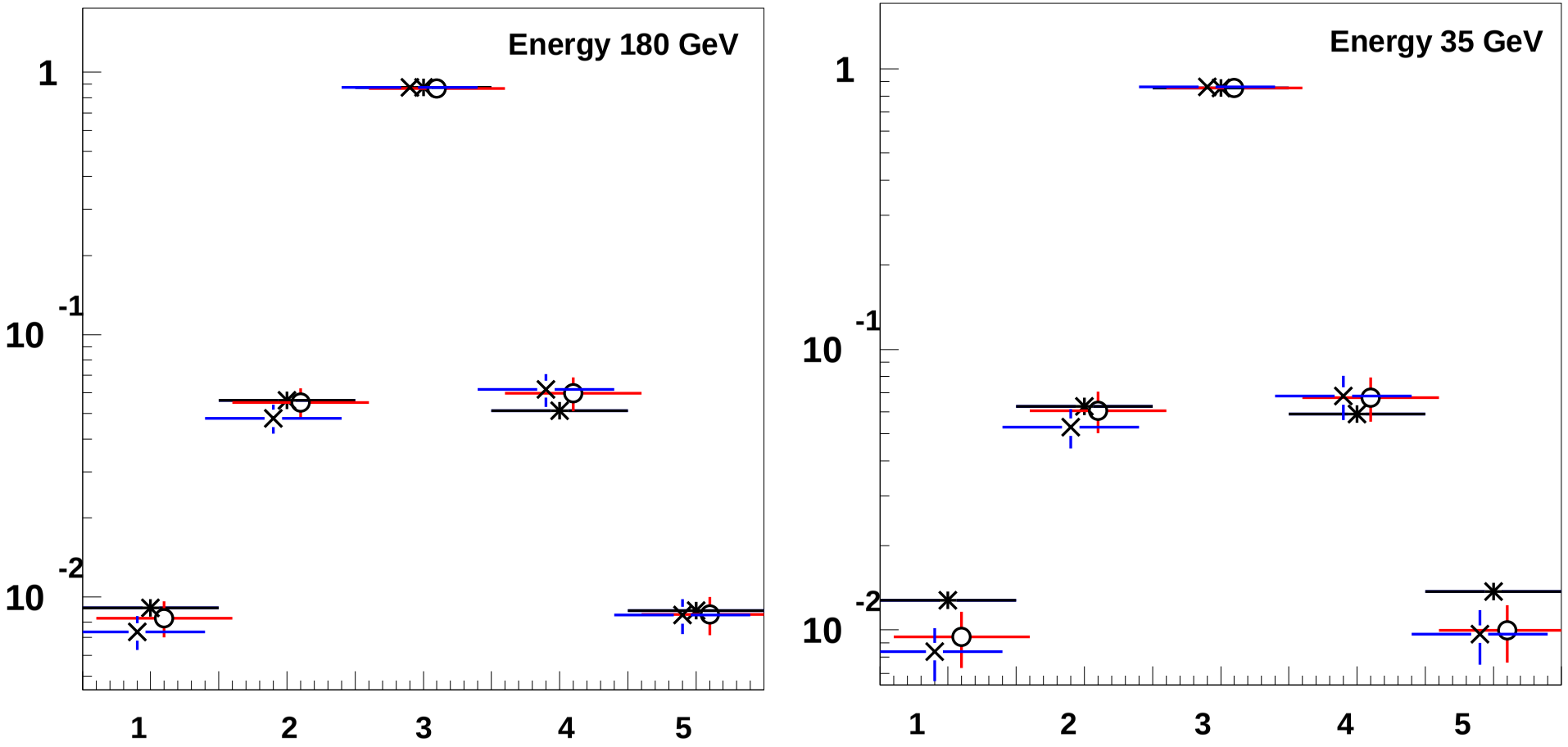
--- Data * Geant 4 o Geant 3

Profile in Crystal Columns





Profile in Crystal Columns (2)



*** Data** o **Geant 4** x **Geant 3**

Energy Resolution

Without preshower from 3x3 cluster of crystals:

Data: $\frac{\sigma}{E} = \frac{4.10}{\sqrt{E}}\% \oplus 0.25\%$

Geant 4: $\frac{\sigma}{E} = \frac{1.02}{\sqrt{E}}\% \oplus 0.25\% \Rightarrow \oplus \frac{4.0}{\sqrt{E}}\%$

Geant 3: $\frac{\sigma}{E} = \frac{1.40}{\sqrt{E}}\% \oplus 0.25\% \Rightarrow \oplus \frac{3.9}{\sqrt{E}}\%$

Photostatistics

Recalibration for Energy Resolution

Beam restricted to 4x4mm^2 centered on the centre crystal 13

Total energy: $E_{tot} = E_9 + E_{presh}$

$E_{presh} = a * (E_1 + b * E_2)$

1	2	3	4	5
6	7	8	9	10
11	12	13	14	15
16	17	18	19	20
21	22	23	24	25

E_{tot} .... total energy

E_9 ..... energy in 3x3 cluster of crystals

E_{presh}.. energy in preshower

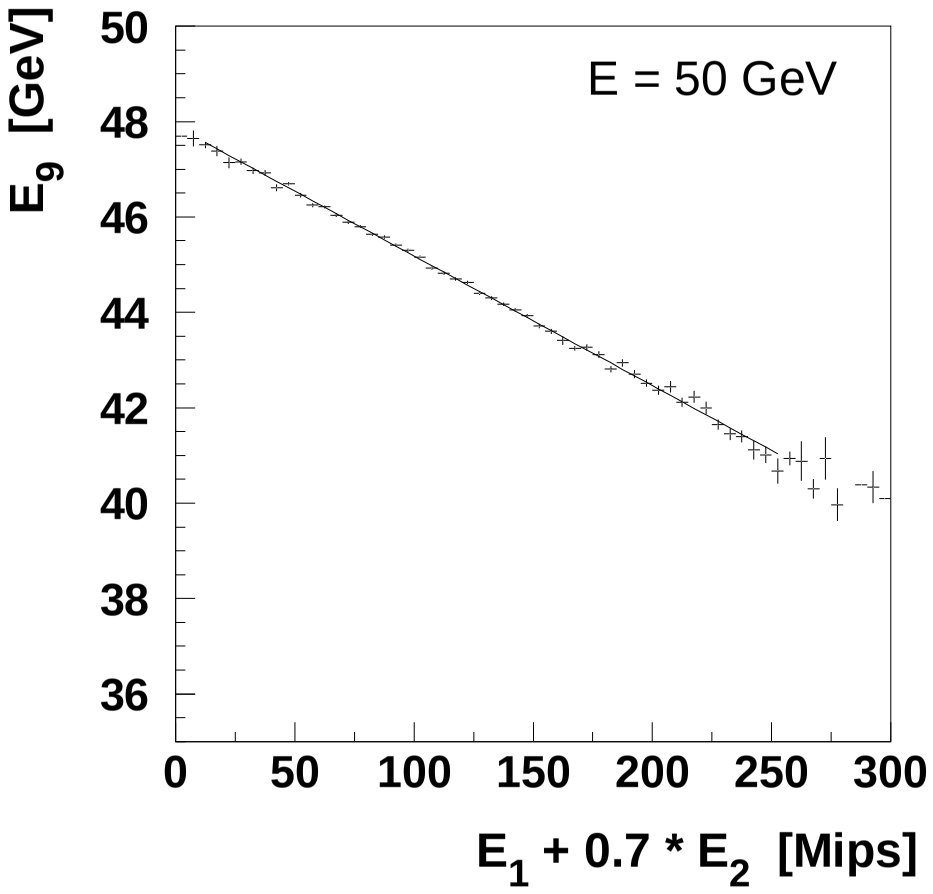
$E_{(i)}$ ..... energy in silicon detector of layer (i) (sum over 5 strips around max.)

a .. recalibration factor

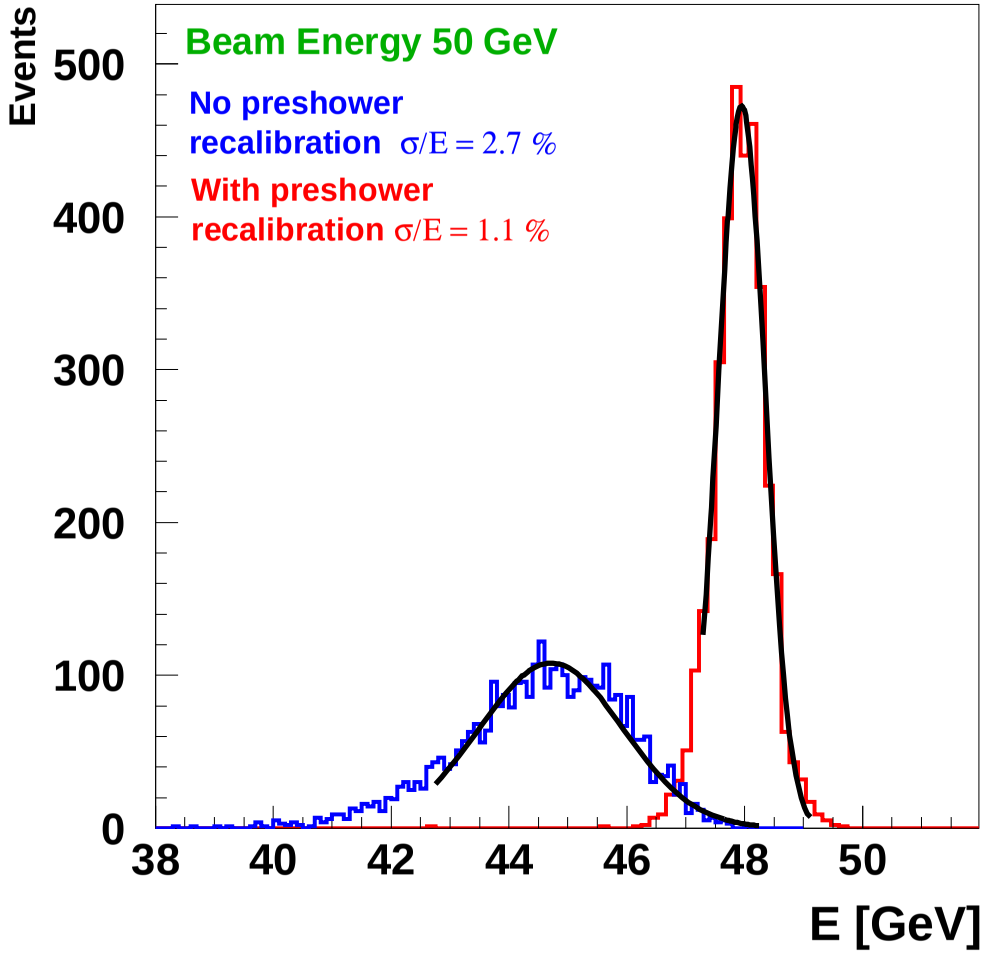
b .. weight of silicon plane 2, found to be 0.7

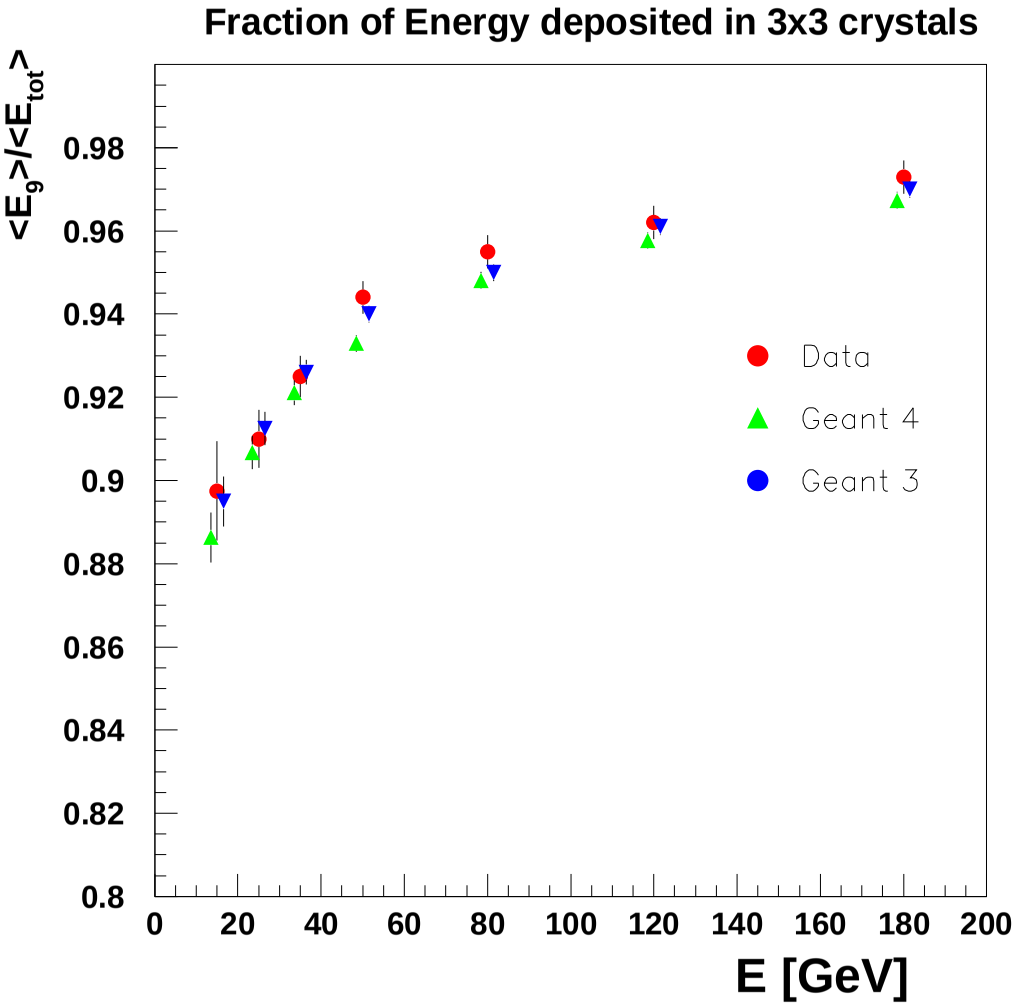
Slope of E_9 vs. E_1+0.7*E_2

Energy (GeV)	Data (+/− 5%)	G3	G4
15	0.026	0.028	0.027
25	0.027	0.027	0.027
35	0.027	0.027	0.027
50	0.027	0.027	0.027
80	0.027	0.025	0.025
120	0.026	0.025	0.024
180	0.023	0.024	0.023

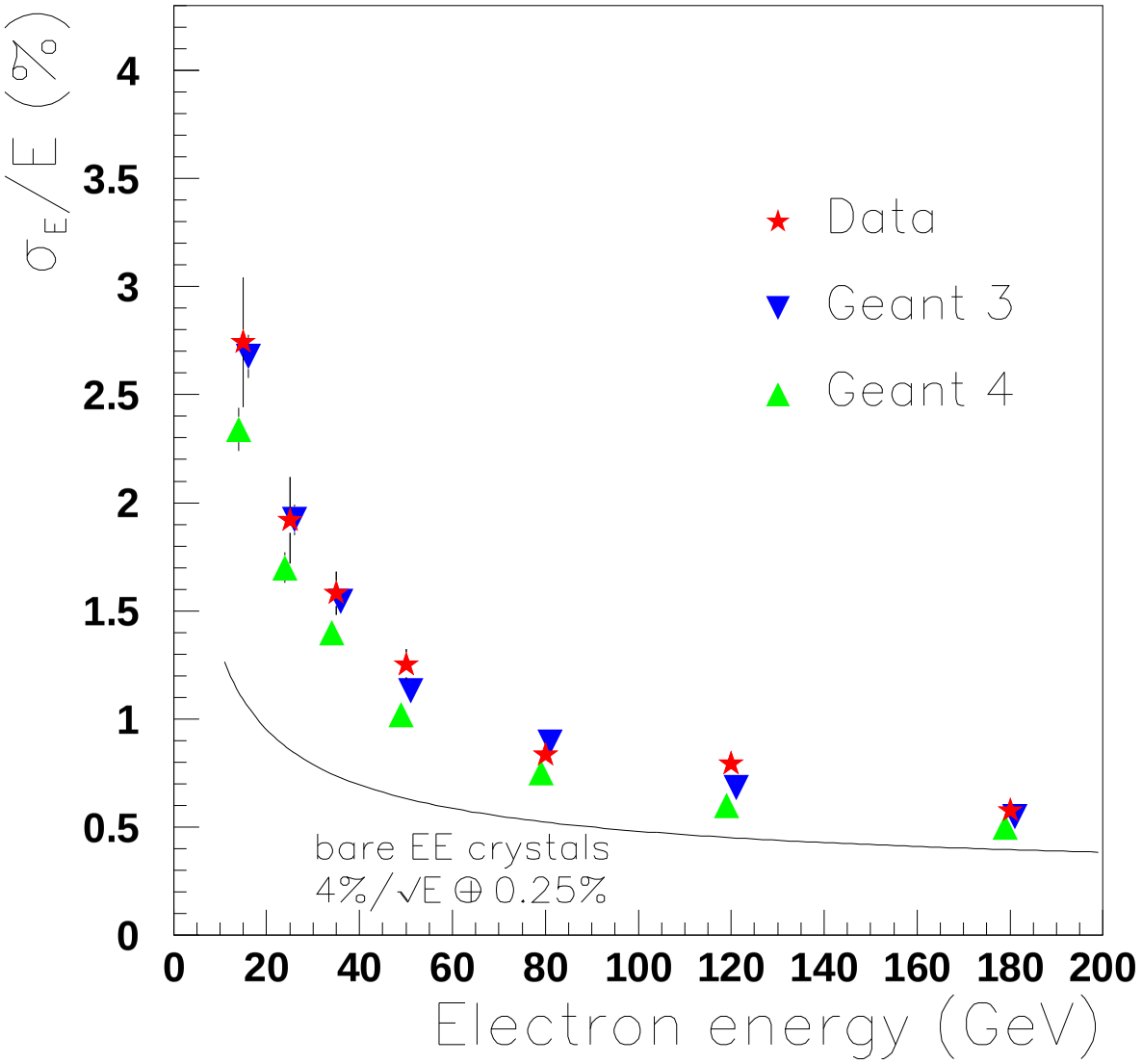


Results


Beam Energy 50 GeV
No preshower
recalibration σ/E = 2.7 %
With preshower
recalibration σ/E = 1.1 %
Events
500
400
300
200
100
0
38
40
42
44
46
48
50
E [GeV]


Fraction of Energy deposited in 3x3 crystals
<E_g>/<E_tot>
0.98
0.96
0.94
0.92
0.9
0.88
0.86
0.84
0.82
0.8
0
20
40
60
80
100
120
140
160
180
200
Data
Geant 4
Geant 3
E [GeV]

Energy Resolution



Conclusions

- Promising results achieved with GEANT4
- But need more understanding of certain differences to Data and well known GEANT3
- Compared to the quantities measured in this Testbeam, Simulations agree quite well
- But there are differences when we look closer on Simulations (e.g. absolute energy deps in simulated volumes, dependencies on G4 cuts)
- We have to proceed in a more systematic way in comparisons between Testbeams and G3 AND G4 simulations

G4 Simulation Setup (NTuple)

Name	Unit	Semantics
XC	cm	x-pos. of e- source
YC	cm	y- "
E_SCINT(8)	keV	energy in scint. (8=closest to presh)
E_ELSE	keV	energy escaped from simul.world
E_ALUM	MeV	energy in aluminium
E_TOT	MeV	energy deposited in every volume
E_XTAL(25)	MeV	energy in each xtal (numbering below)
E_SUM9	MeV	sum over 9 xtals around center xtal
E_SUM25	MeV	sum over all xtals
E_PRESH(19)	MeV	e./presh-layer (19=closest to xtals)
E_SI1(4,32)	keV	e. in 1st sil. (4 waver, 32 strips)
E_SI2(4,32)	keV	" 2nd "
NMIPS3(2)	-	sum 3 around max in sil. of 1st/2ndlayer
NMIPS5(2)	-	sum 5 "

G4 Simulation Setup (Hits)

Event Definition

- one e− being shot with defined energy
- Directed on center crystal along z−axes
- uniformly smeared over 2x2cm in x and y

Hit Definition

- simply total energy/event deposited in a sensitive volume
- sensitive volumes:
  - trigger scintilators
  - preshower layers (incl. every strip of the silicon detectors)
  - crystals

G4 Simulation Setup

Cuts in GEANT4 (*production thresholds*)**:**

- 0.005 mm for every particle and material
- GEANT 4.2 , em 'plus' processes

0.5mm	PbWO4 [keV]	Silicon [keV]
e−	640	335
Gamma	60	5

0.005mm	PbWO4 [keV]	Silicon [keV]
e−	34.3	6.6
Gamma	2.6	0.99

Cuts in GEANT3

- 10 keV for e−/e+ and gamma in crystals and preshower
- delta ray production turned off for energy resolution studies
- delta rays turned on for preshower shower profile