Comparisons between 2003 CMS ECAL TB data and a Geant 4 MC

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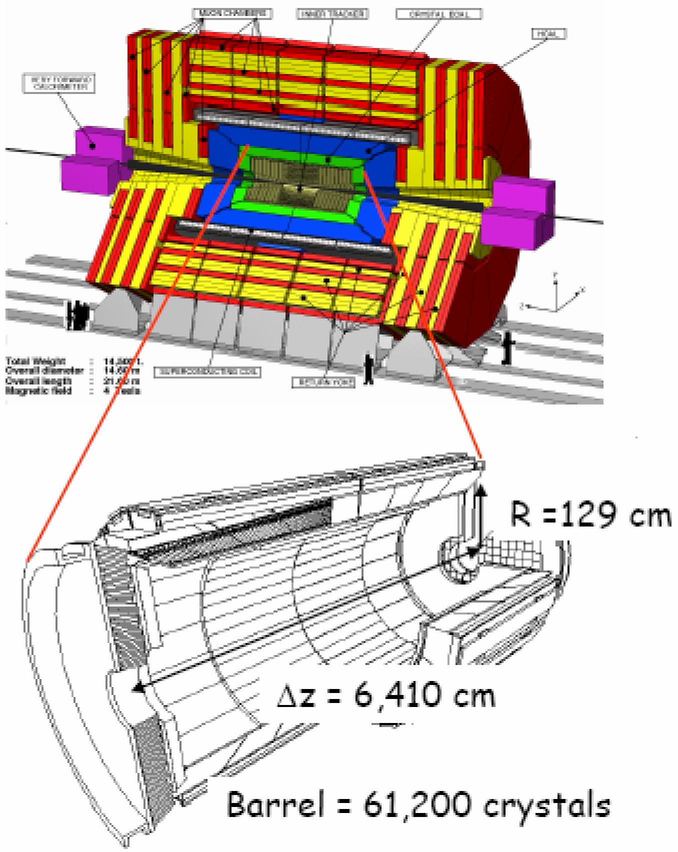
LCG Validation Meeting – 7th July 2004

Outline

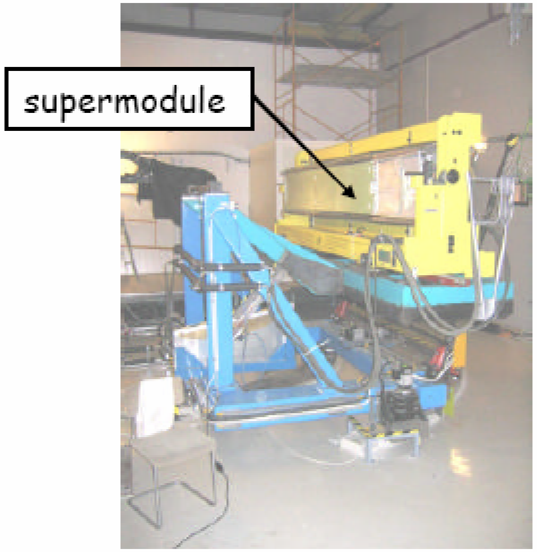
- CMS Electromagnetic calorimeter and 2003 TB
- h4sim http://cmsdoc.cern.ch/~h4sim/ (What's new?)
- Alignment between TB reference frame and MC reference frame
- Lateral shower development comparisons using different production cuts
- Energy resolution contributions and comparison
- Position resolution contributions and comparison
- This year test beam

CMS ECAL TB

The Compact Muon Solenoid dectector



The H4 Testbeam at CERN



Testbeam set-up in 2003:

- 2 supermodules (SM0/SM1) have been placed in the beam (electrons)
- Front-end electronics:

  FPPA(100) /MGPA(50) crystals equippe

h4sim

- Geant4 simulation of an entire ECAL supermodule in the H4 test beam configuration
  - Based on Geant 4 5.0p2
  - Supermodule geometry is read from the same Geometry XML files used in the official simulation OSCAR
  - Simulation of the electronics. Noise directly injected from test beam pedestal runs
  - Output of the simulation readable by the same framework used to analyse test beam data

h4sim Physics List

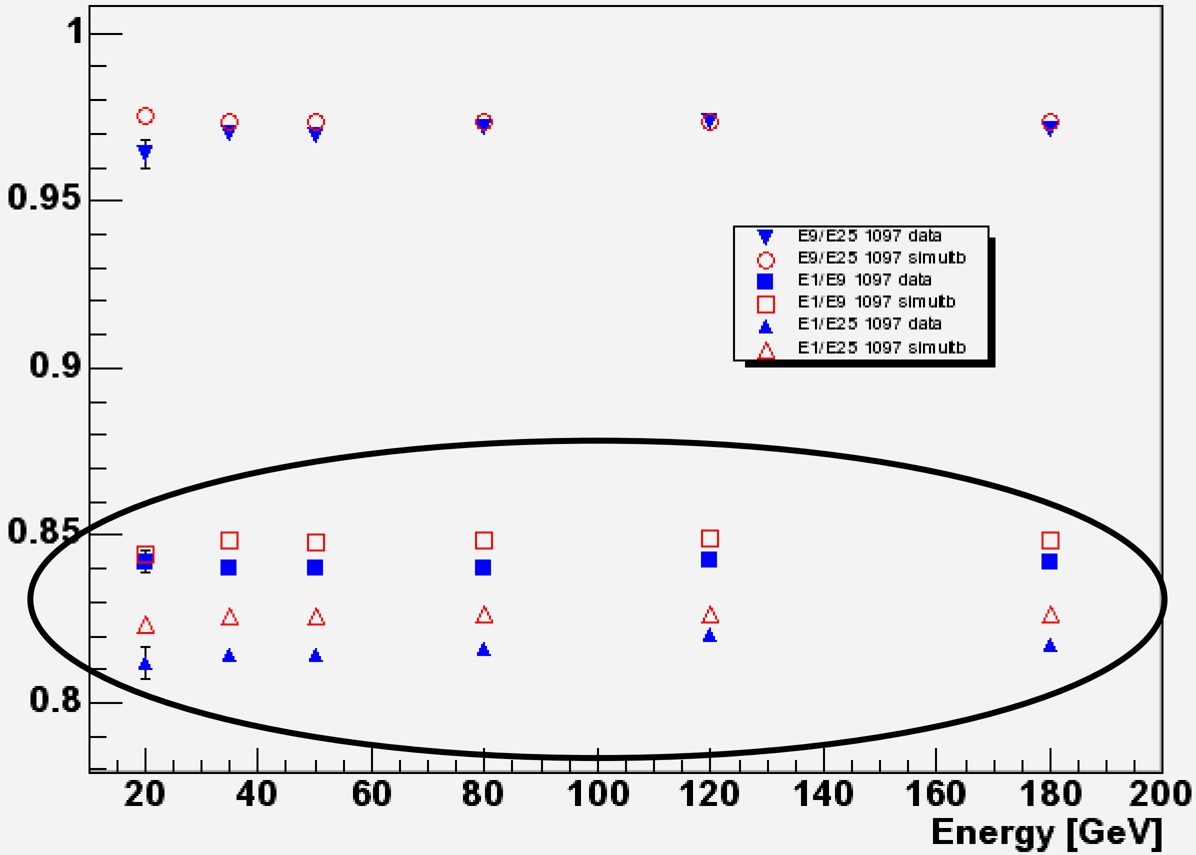
- Physics list includes only electromagnetic interactions of
  - Electrons, positrons
  - Gammas
  - Muons
- No magnetic field
- No hadronic interactions, hence no comparison is possible with pion data
- We tried two sets of production cuts
  - OSCAR production cuts in $PbWO_4$: 1mm for e-,e+ and γ
  - A greater cut for γ's: 100 mm which means a cut in energy at the same level of electrons ~1.15 MeV (we refer to them as h4sim cuts)

Alignment: TB data vs MC

- As the single crystal response varies with the impact point position an alignment procedure is needed to make absolute comparisons of the lateral shower development
- At H4 the supermodule is positioned such that @ 120 GeV center of the beam should be at the maximum containment point for each crystal (different from the crystal front face center due to a tilt angle between beam direction and crystal axis as will be in CMS)
- In the TB the “true” X & Y is given by the hodoscope
- We used MC data with the beam pointing to the “maximum containment point” @ 120 GeV
- We used two measured physical points to align the reference frames
  - maximum containment point
  - balance point

Containment vs Energy (OSCAR cuts)

Cut of +/- 2mm in X & Y around the position of the maximum

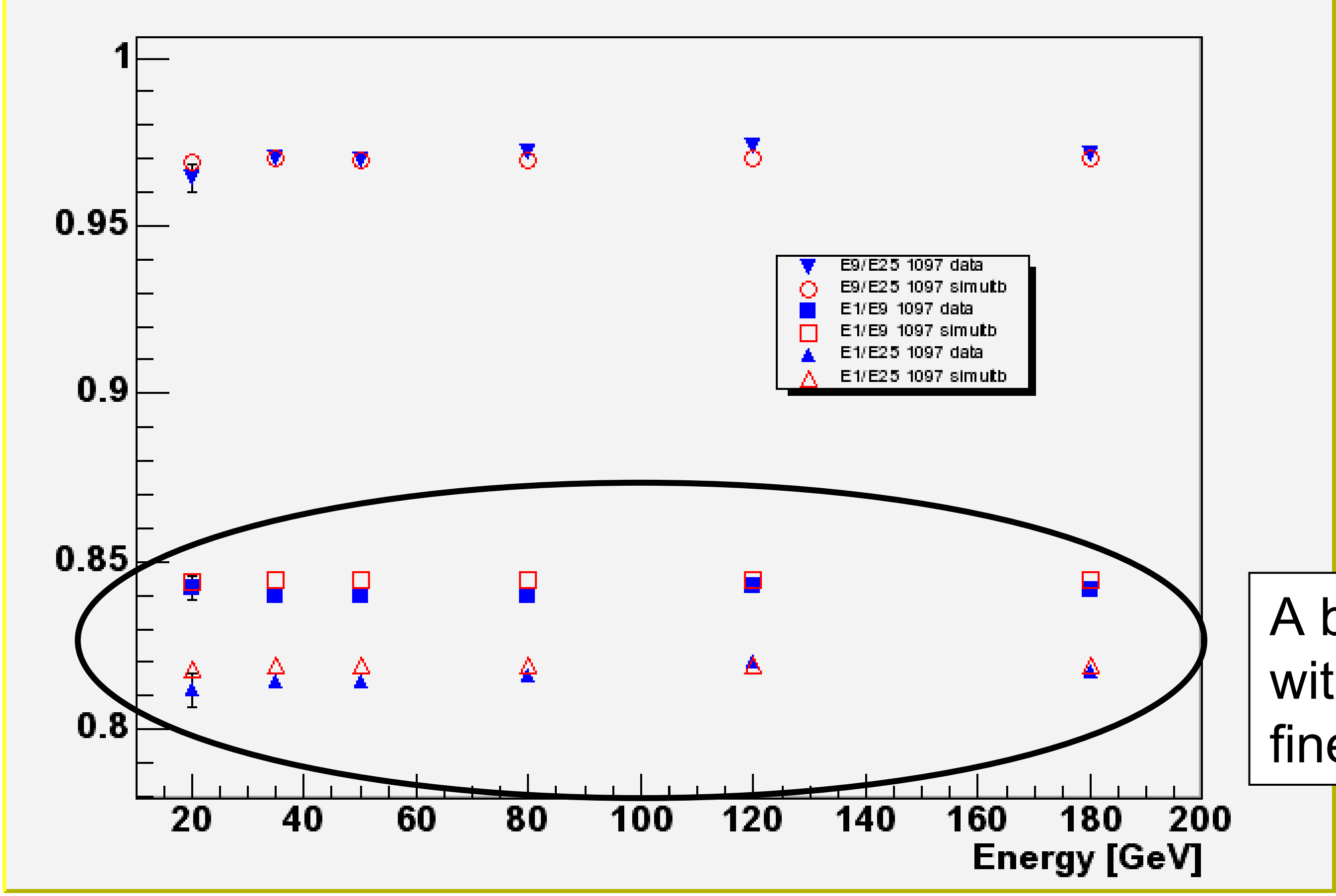


We compared the energy in ratios E1x1/E3x3, E1x1/E5x5 and E3x3/E5x5 which are important parametrization of the lateral shower development

Simulated shower is a bit narrower

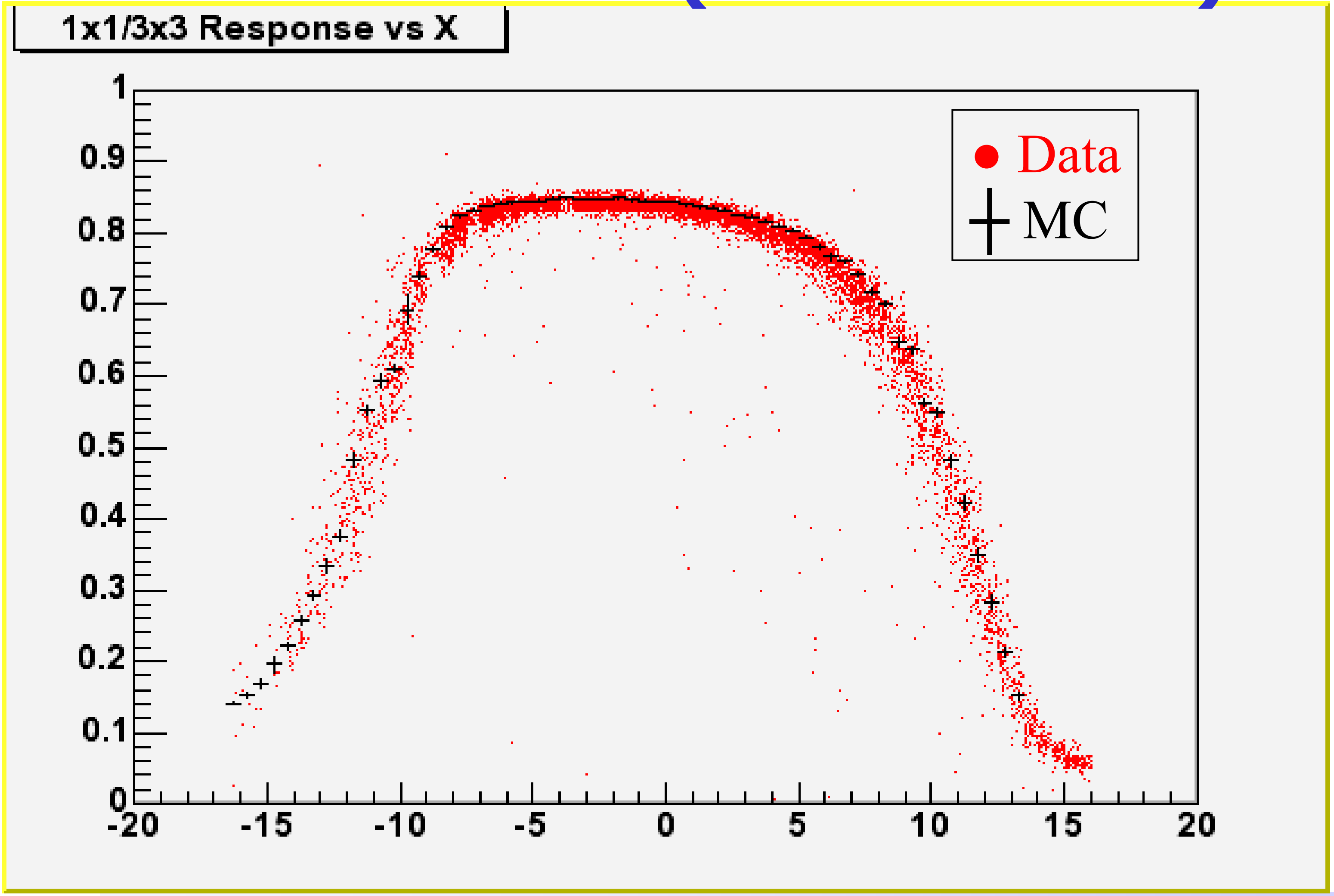
Containment vs Energy (h4sim cuts)

Cut of +/- 2mm in X & Y around the position of the maximum

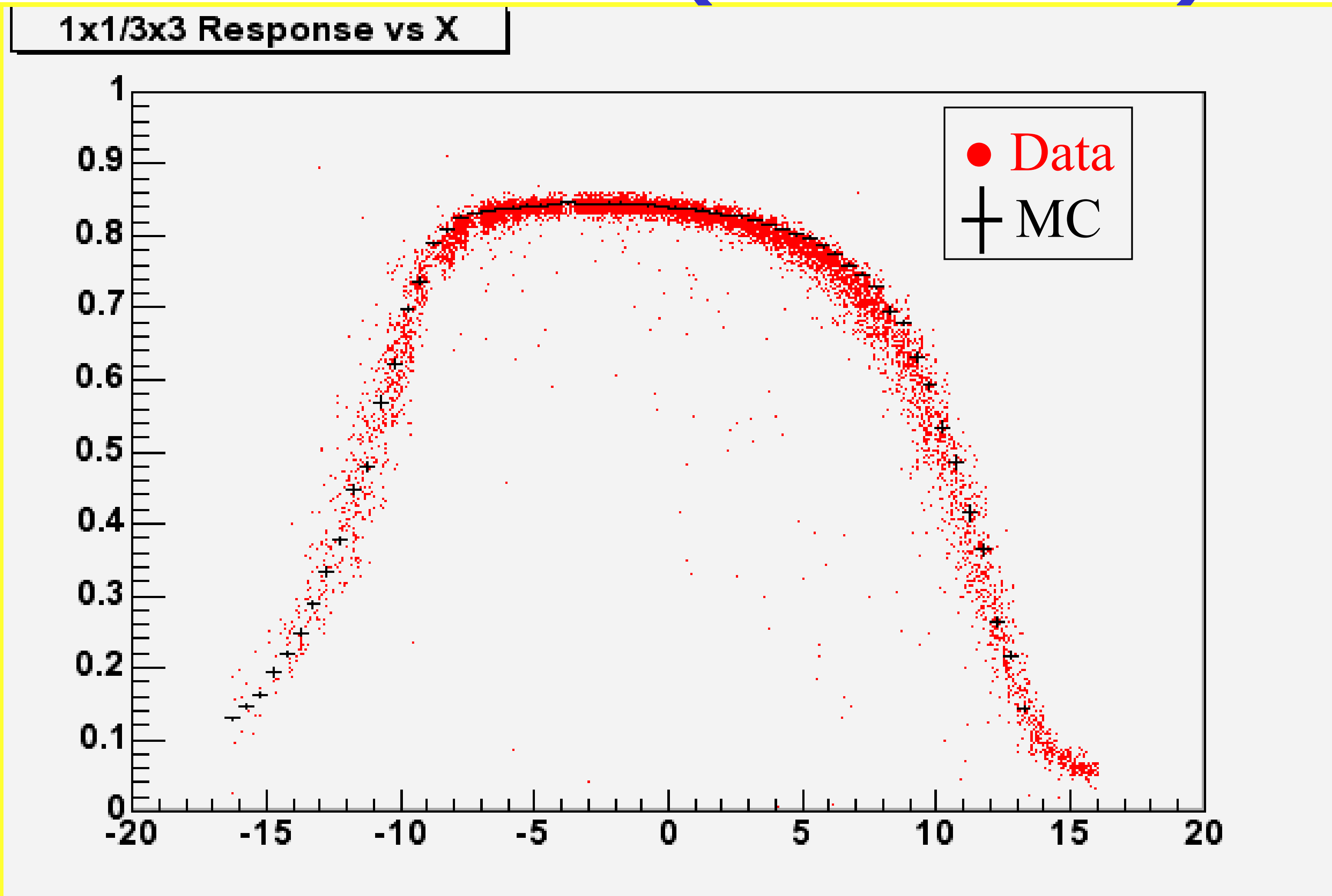


A better agreement is found with h4sim cuts. Possibility of fine tuning of the parameters

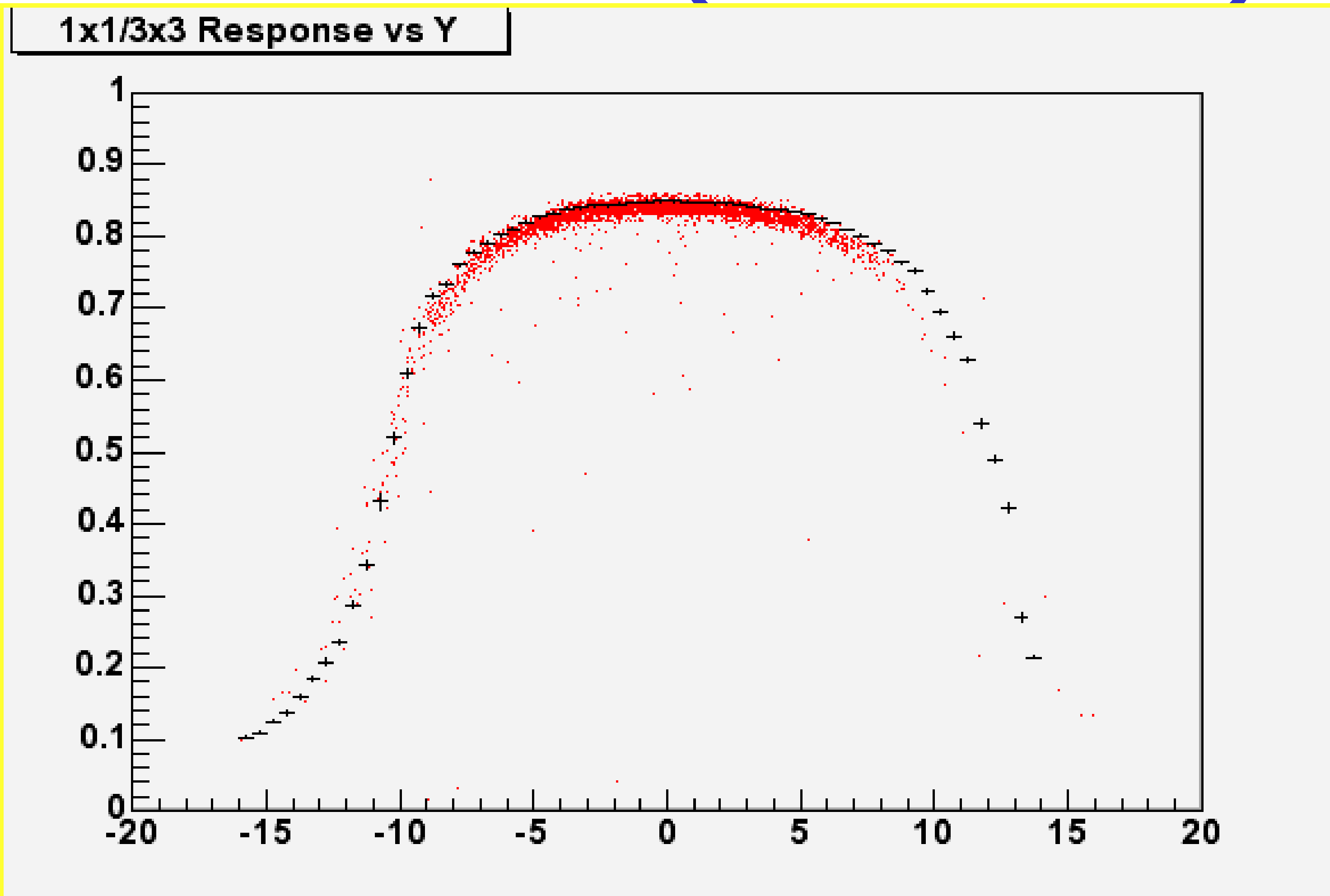
E1/E9 vs X @ 120 GeV (OSCAR cuts)



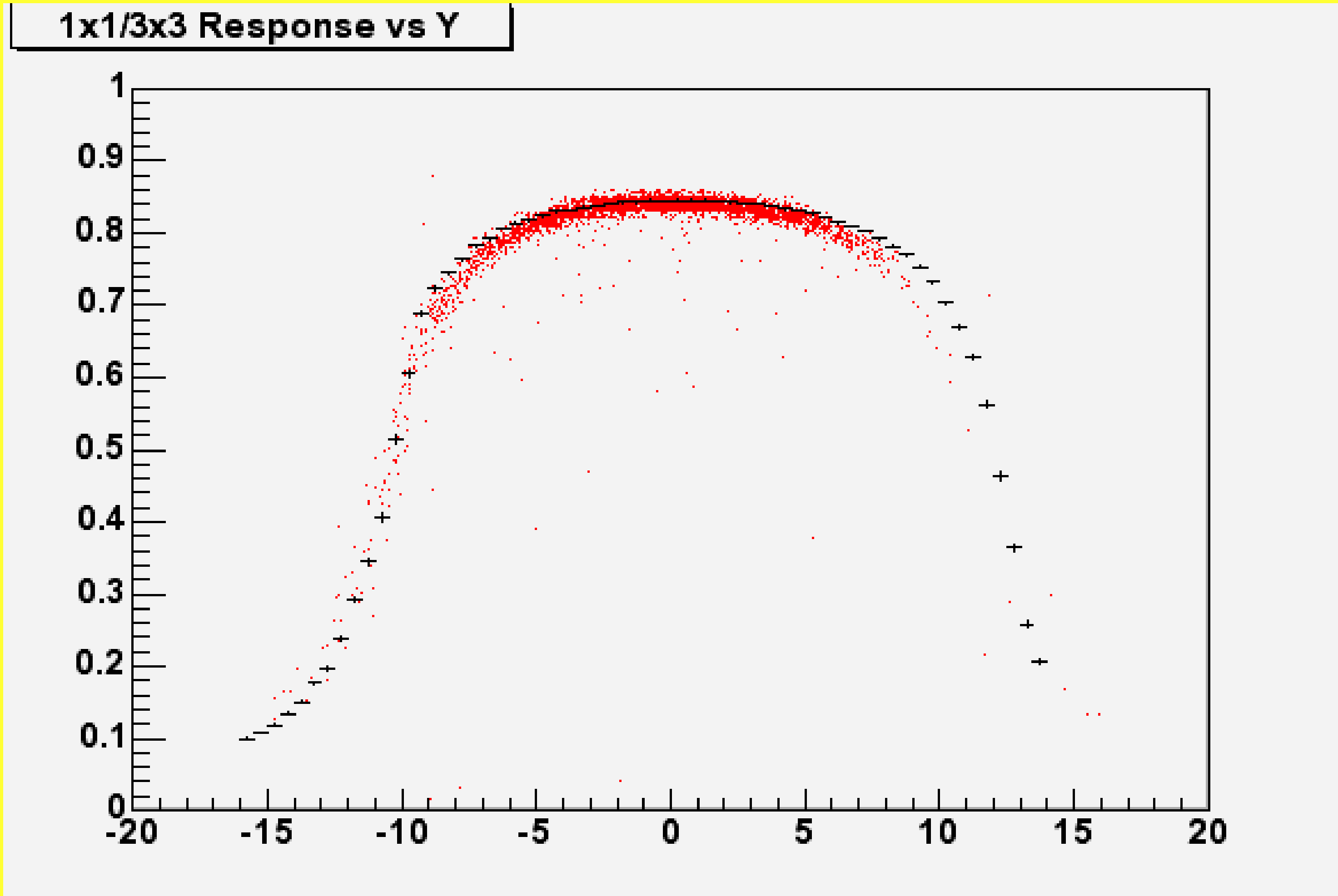
E1/E9 vs X @ 120 GeV (h4sim cuts)



E1/E9 vs Y @ 120 GeV (OSCAR cuts)

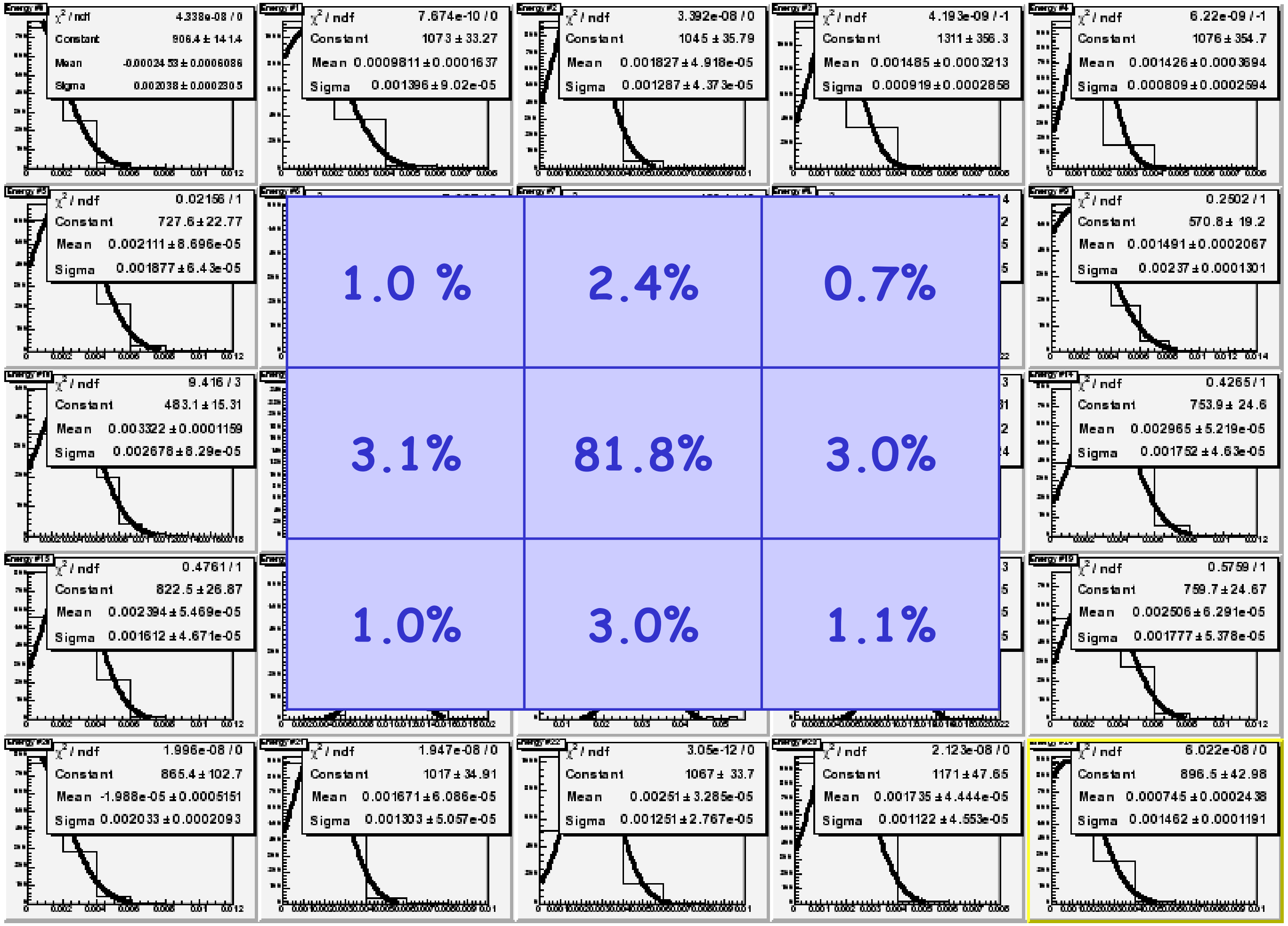


E1/E9 vs Y @ 120 GeV (h4sim cuts)



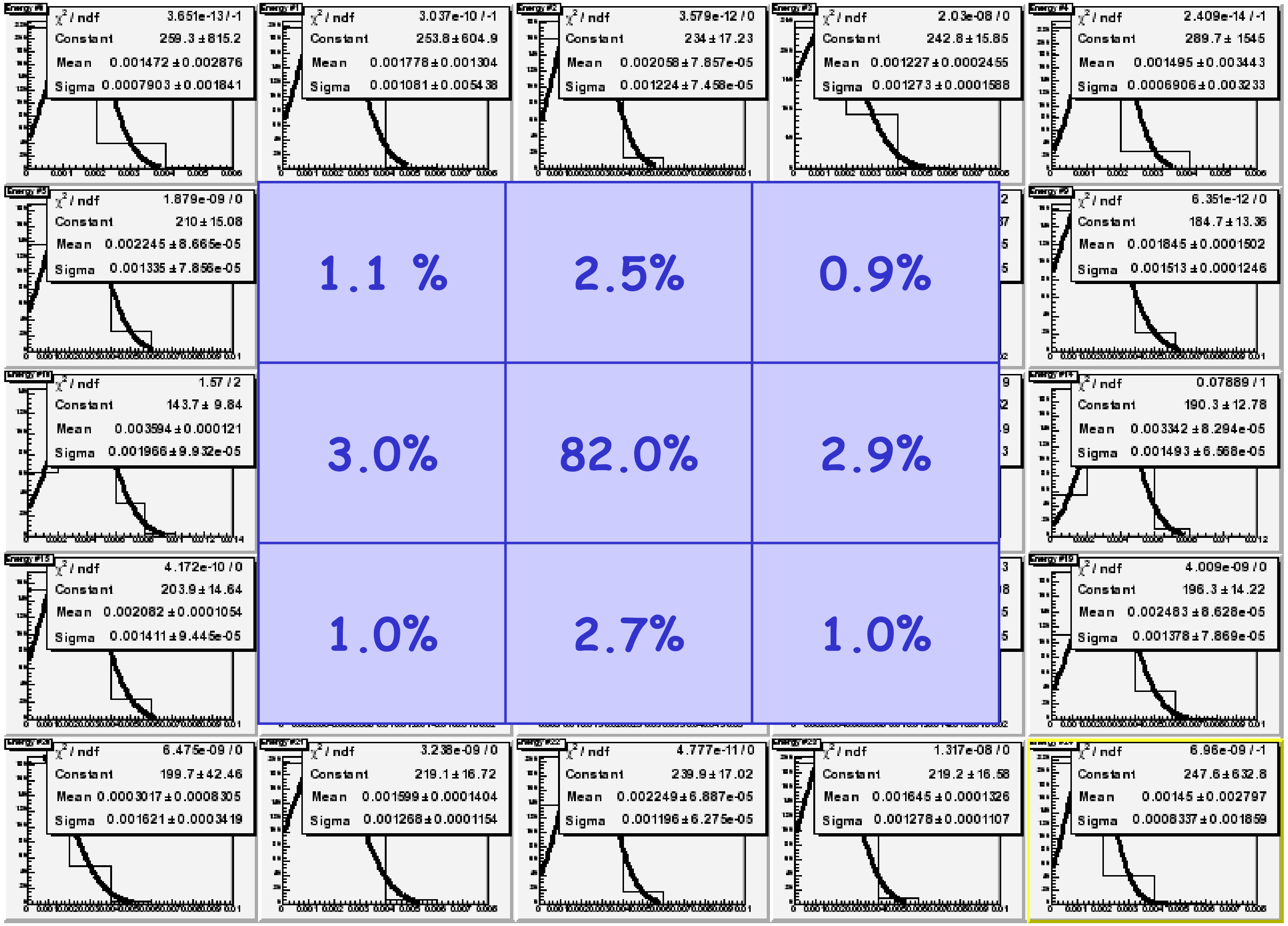
Energies in a 5x5 matrix @ 120 GeV

DATA



Energies in a 5x5 matrix @ 120 GeV

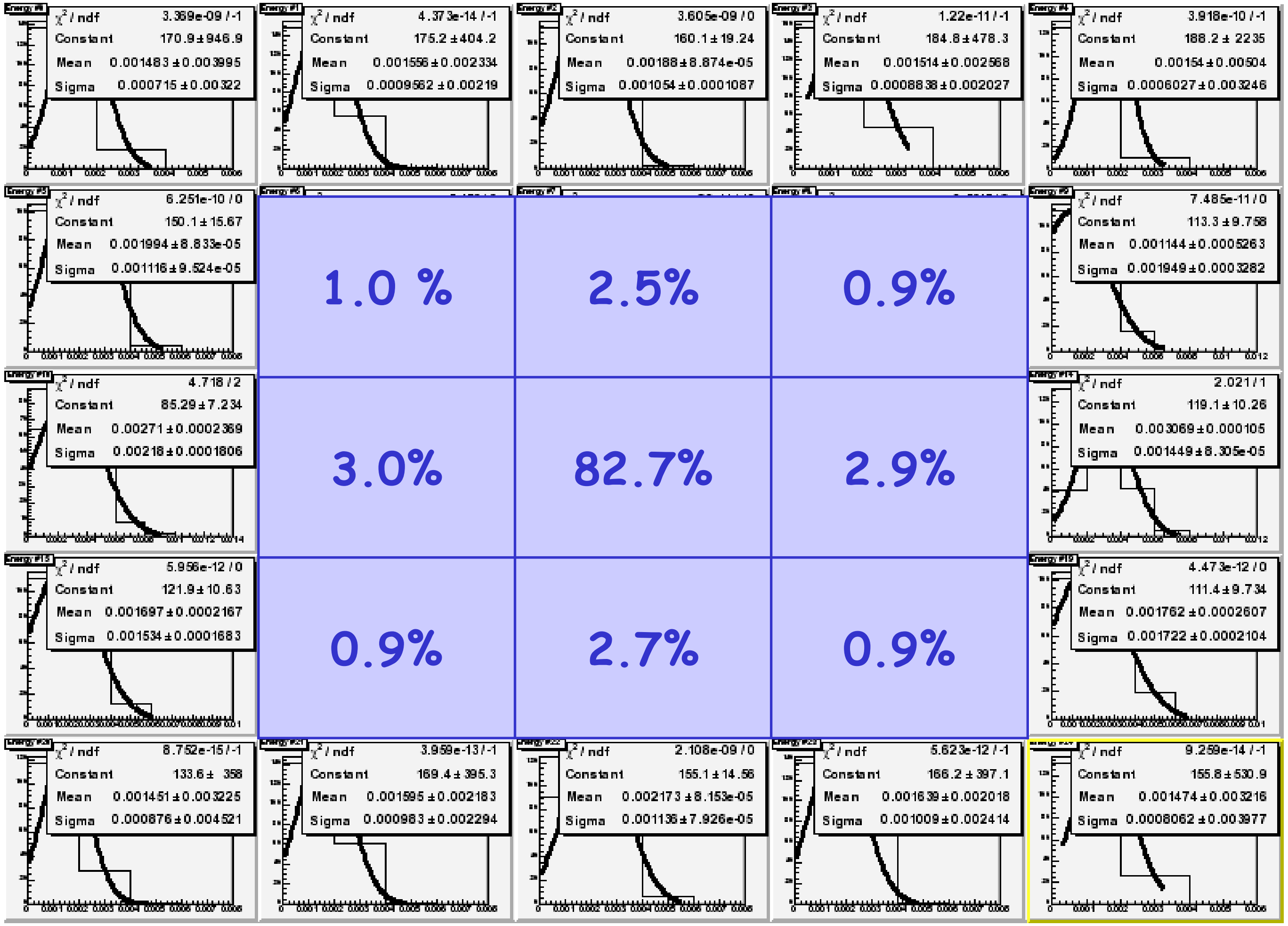
h4sim cuts



1.1 %	2.5%	0.9%
3.0%	82.0%	2.9%
1.0%	2.7%	1.0%

Energies in a 5x5 matrix @ 120 GeV

OSCAR cuts



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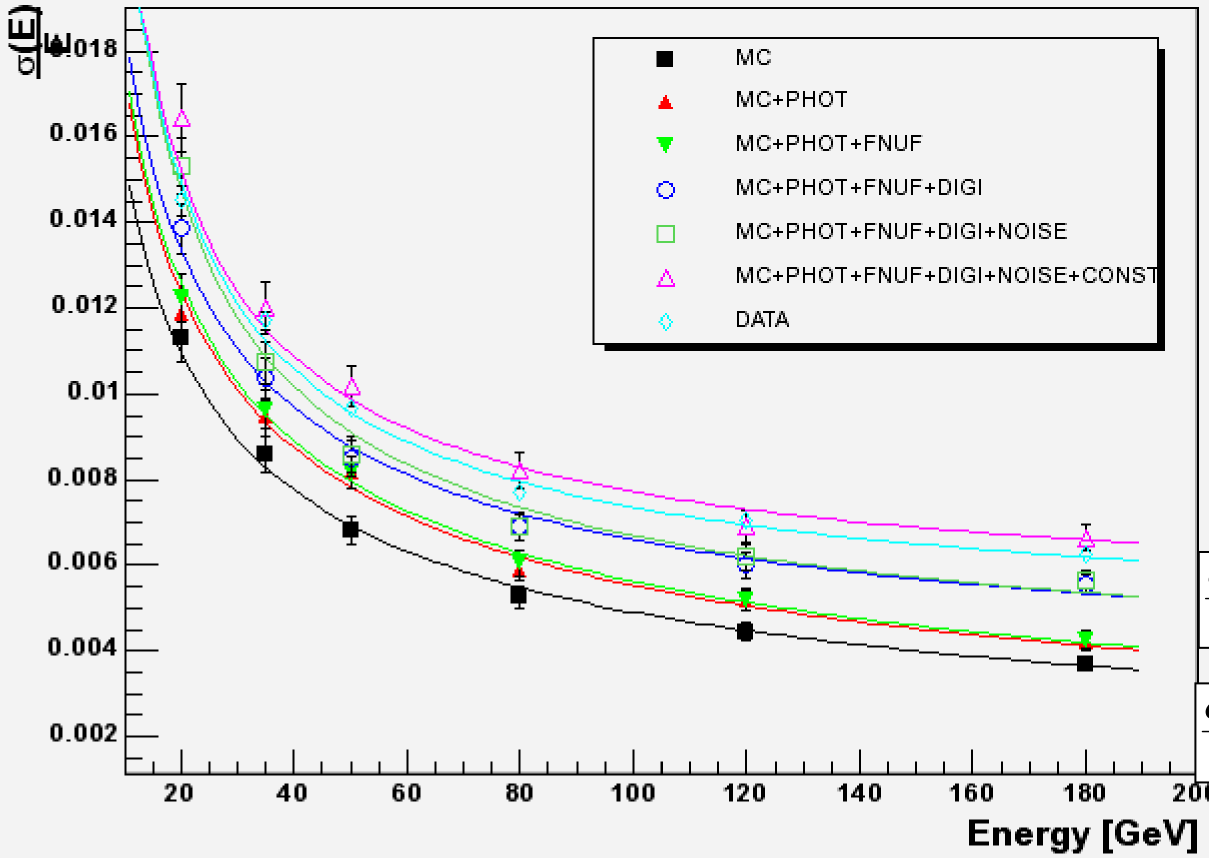
E1x1 resolution: different contributions

Cut of +/- 2mm around the position of the maximum



Contribution to stochastic term from lateral containment and shower fluctuactions

4.9± 0.1%

Old FPPA electronics

Single Crystal Noise

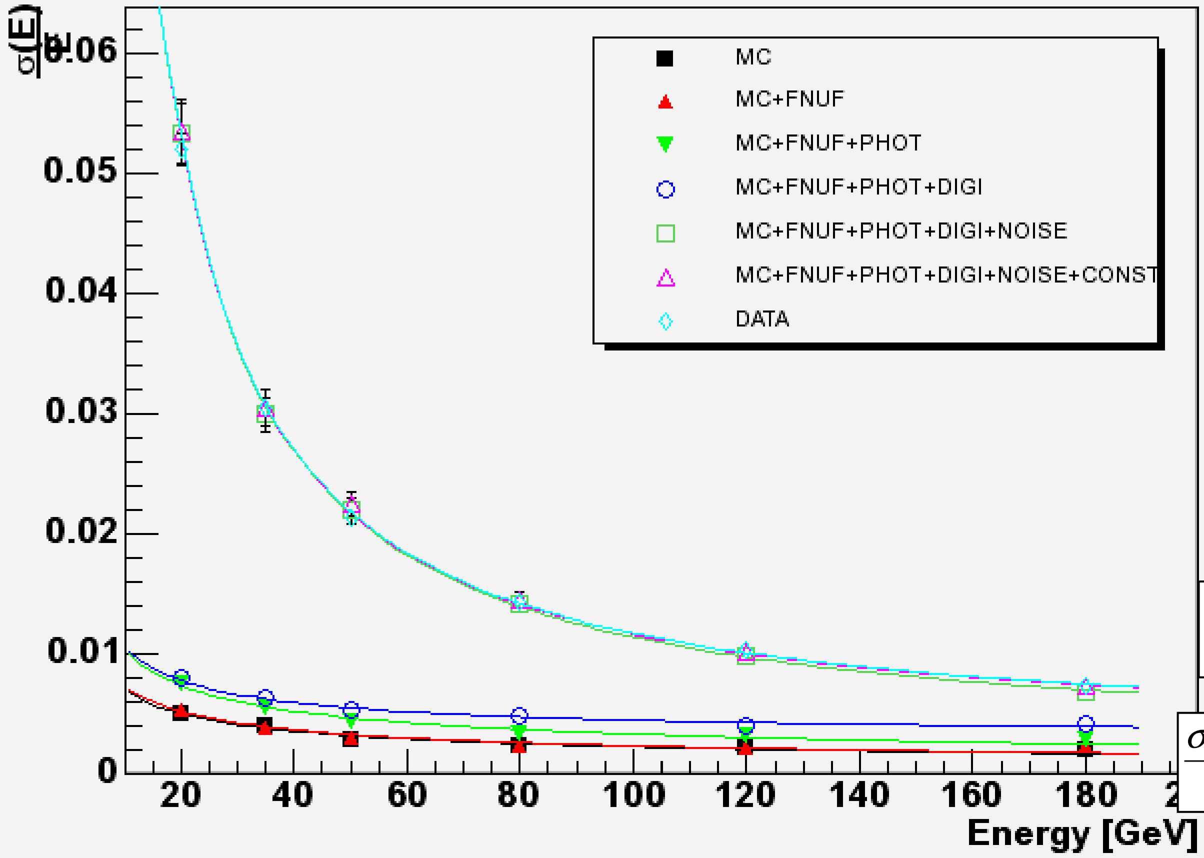
0.12± 0.02 GeV

$$\frac{\sigma_{DATA}(E)}{E} = \frac{(5.8 \pm 0.1)\%}{\sqrt{E}} \oplus \frac{(0.12 \pm 0.02)GeV}{E} \oplus (0.44 \pm 0.02)\%$$

$$\frac{\sigma_{MC}(E)}{E} = \frac{(5.6 \pm 0.2)\%}{\sqrt{E}} \oplus \frac{(0.12 \pm 0.02)GeV}{E} \oplus (0.49 \pm 0.03)\%$$

E3x3 resolution: different contributions

Cut of +/- 2mm around the position of the maximum



Contribution to stochastic term from lateral containment and shower fluctuactions

2.60± 0.05%

Old FPPA electronics

E3x3 Noise

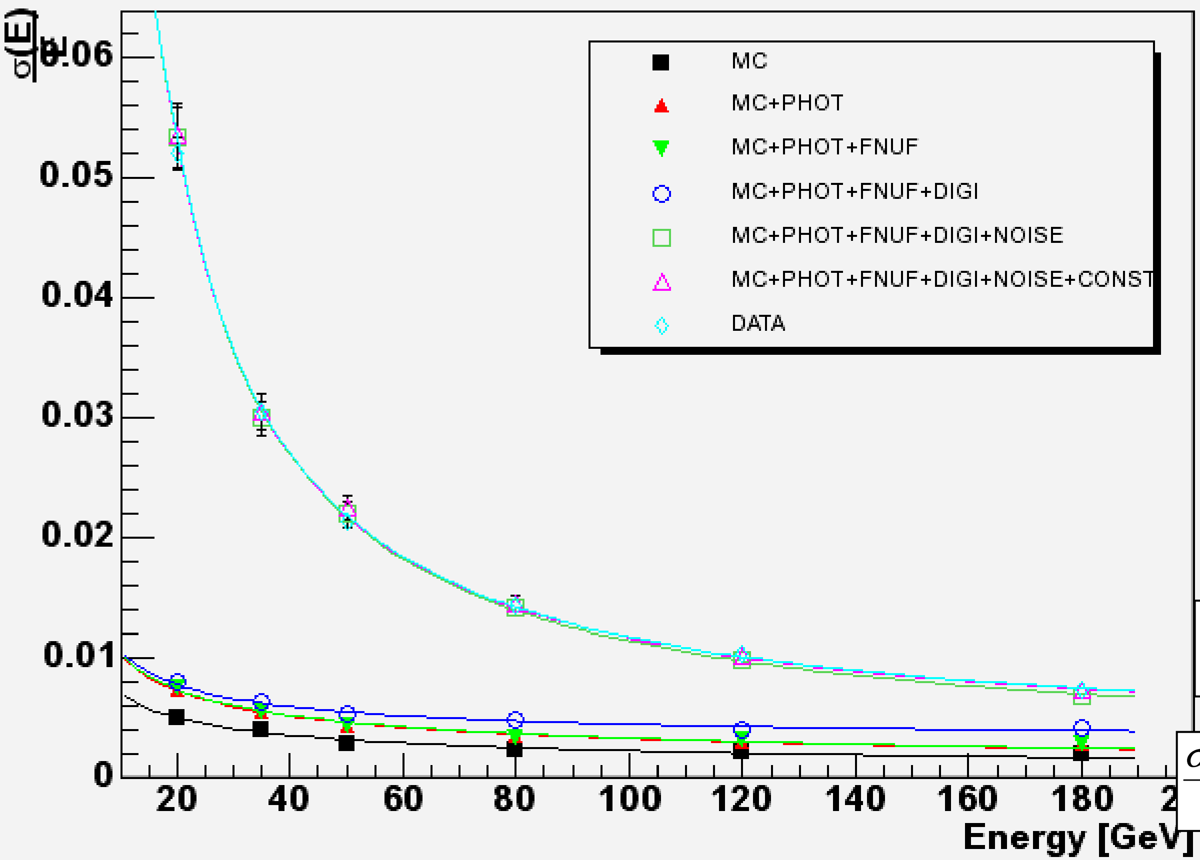
0.52± 0.02 GeV

$$\frac{\sigma_{DATA}(E)}{E} = \frac{(3.5 \pm 0.3)\%}{\sqrt{E}} \oplus \frac{(0.52 \pm 0.02)GeV}{E} \oplus (0.41 \pm 0.03)\%$$

$$\frac{\sigma_{MC}(E)}{E} = \frac{(3.47 \pm 0.07)\%}{\sqrt{E}} \oplus \frac{(0.52 \pm 0.02)GeV}{E} \oplus (0.42 \pm 0.03)\%$$

E5x5 resolution: different contributions

Cut of +/- 2mm around the position of the maximum



Contribution to stochastic term from lateral containment and shower fluctuactions

2.21± 0.04%

Old FPPA electronics

E5x5 Noise

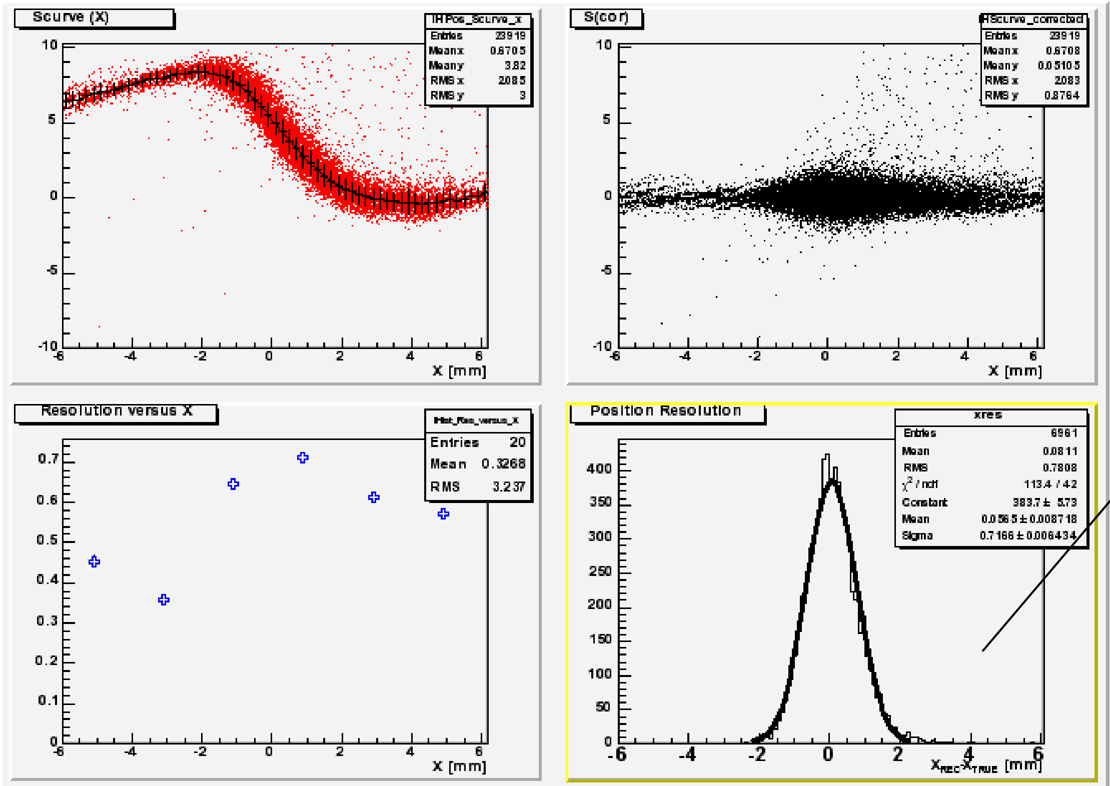
1.05± 0.02 GeV

$$\frac{\sigma_{DATA}(E)}{E} = \frac{(3.3 \pm 0.9)\%}{\sqrt{E}} \oplus \frac{(1.05 \pm 0.02) GeV}{E} \oplus (0.40 \pm 0.02)\%$$

$$\frac{\sigma_{MC}(E)}{E} = \frac{(3.27 \pm 0.06)\%}{\sqrt{E}} \oplus \frac{(1.05 \pm 0.02) GeV}{E} \oplus (0.40 \pm 0.03)\%$$

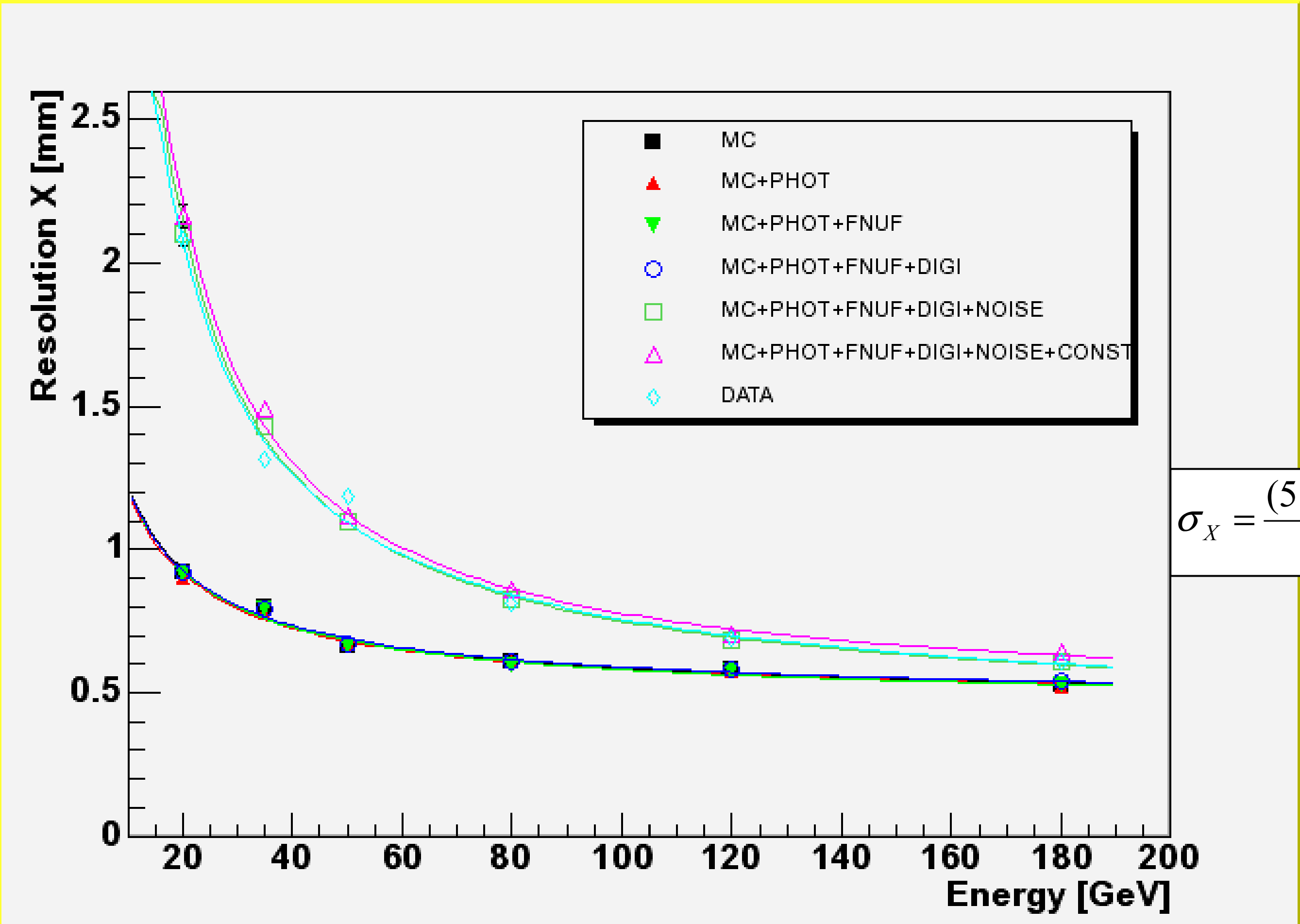
Position Resolution

- Impact point position reconstructed using the center of gravity method



Resolution (in the next plots) is given in the range [-2.2] mm around the maximum containment point (the worst resolution)

Position Resolution X



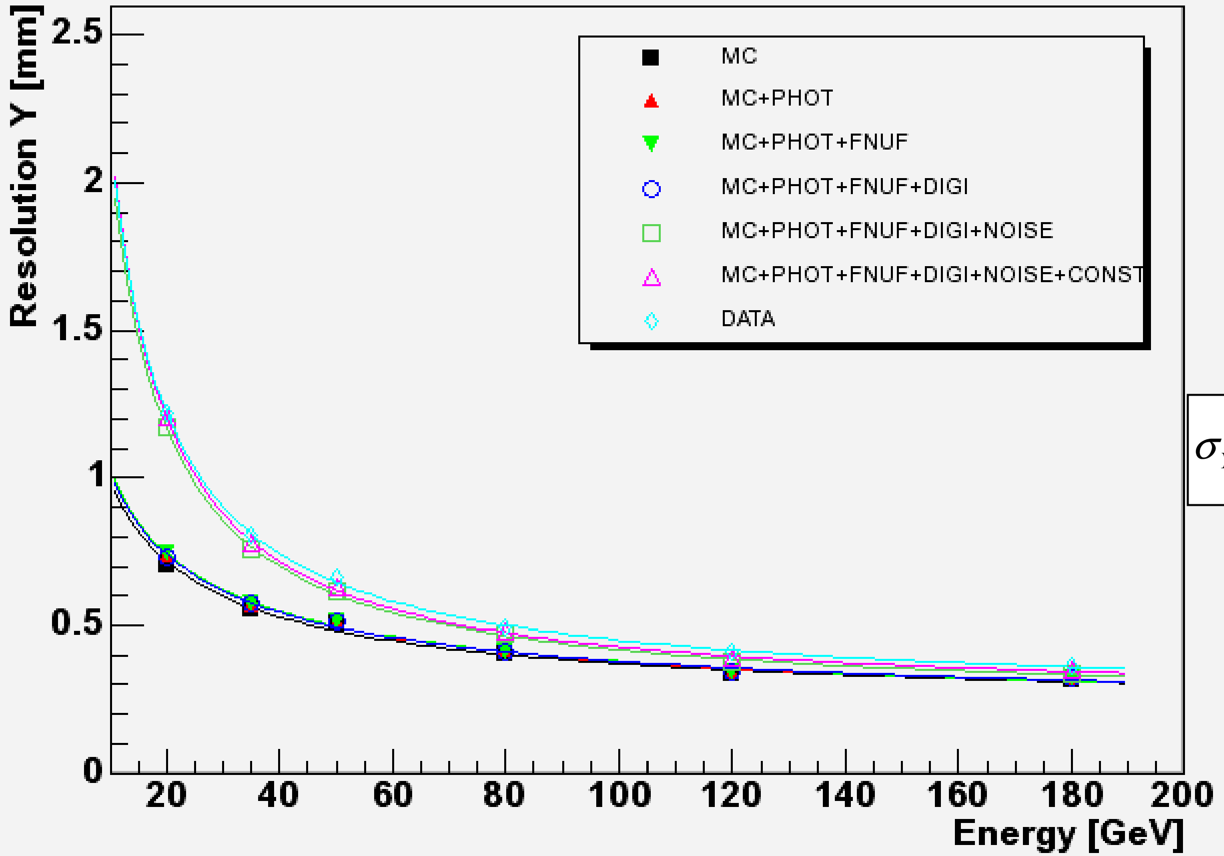
No Noise

$$\sigma_X = \frac{(3.58 \pm 0.09)mm}{\sqrt{E}} \oplus (0.47 \pm 0.01)mm$$

Data

$$\sigma_X = \frac{(5.0 \pm 0.5)mm}{\sqrt{E}} \oplus \frac{(3.6 \pm 0.2)cm}{E} \oplus (0.47 \pm 0.01)mm$$

Position Resolution Y



No Noise

$$\sigma_Y = \frac{(3.18 \pm 0.05)mm}{\sqrt{E}} \oplus (0.21 \pm 0.01)mm$$

Data

$$\sigma_Y = \frac{(3.3 \pm 0.5)mm}{\sqrt{E}} \oplus \frac{(1.9 \pm 0.6)cm}{E} \oplus (0.24 \pm 0.02)mm$$

New Test Beam

- An entire supermodule will be on the beam mid of September
  - 1700 crystals
  - New electronics (single crystal noise 40 MeV)
- A lot of comparison can be made with this extended set of data
  - Comparison of different crystal size – geometries
  - Intermodule gaps
  - Containment versus eta

Conclusions

- The agreement between Geant4 data and the h4sim simulation seems quite good
- “h4sim production cuts” (100 mm for gammas) seems to give a better agreement. Further check can be done with the inclusion of the upstream material in the simulation (hodoscope, scintillators...)
- Energy resolution contributions seems to be well understood and in good agreement with what expected.
- The new test beam (mid September-end October) should provide an extended set of data which will allow a more complete and refined comparison