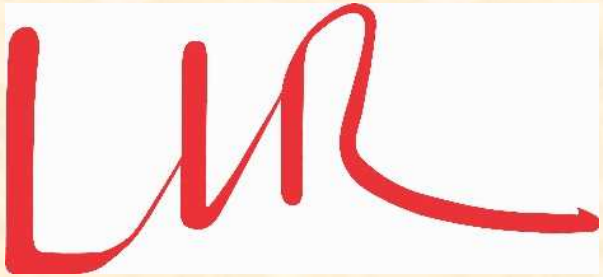

H4sim, a Geant4 simulation program for the CMS ECAL supermodule

Philippe Miné, on behalf of the CMS collaboration

Laboratoire Leprince-Ringuet, École polytechnique, IN2P3-CNRS, Palaiseau, France
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Outline

The CMS electromagnetic calorimeter

Geant4 implementation

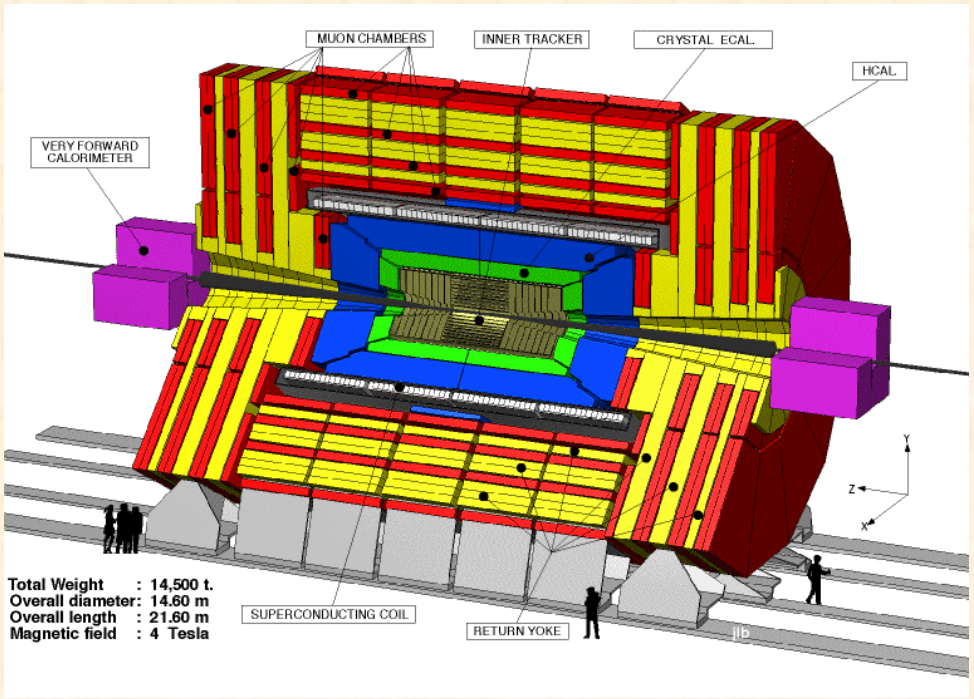
Comparison with test beam data : electrons

Comparison with test beam data : pions

Precalibration with cosmic muons

The CMS electromagnetic calorimeter

Compact Muon Solenoid at CERN LHC (2007)
7+7 TeV p-p, heavy ions



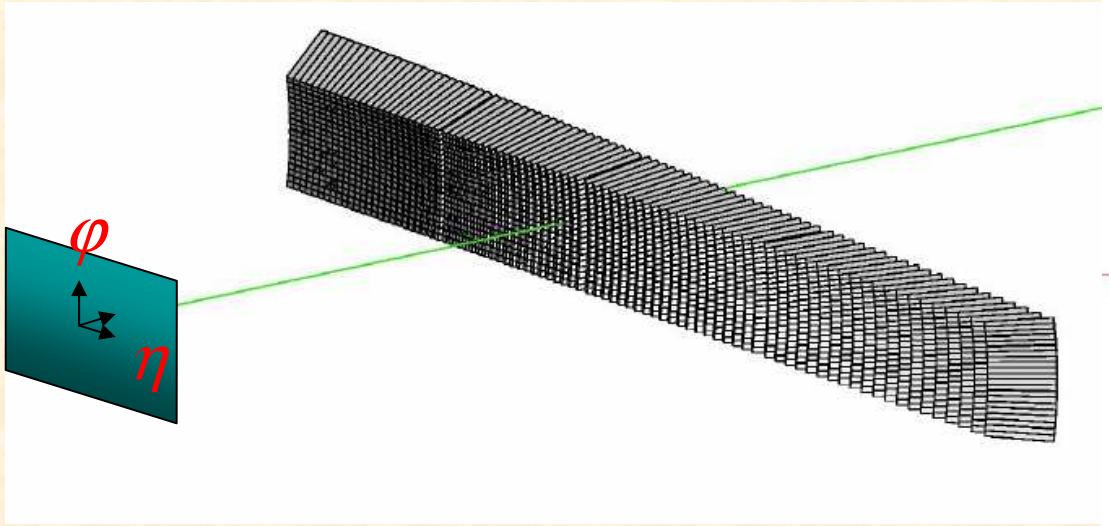
ECAL : 75848 lead tungstate crystals

$22 \times 23 \times 230$ mm^3
Density = 8.28 g/cm^3
X_0 = 0.89 cm
R_M = 2.10 cm

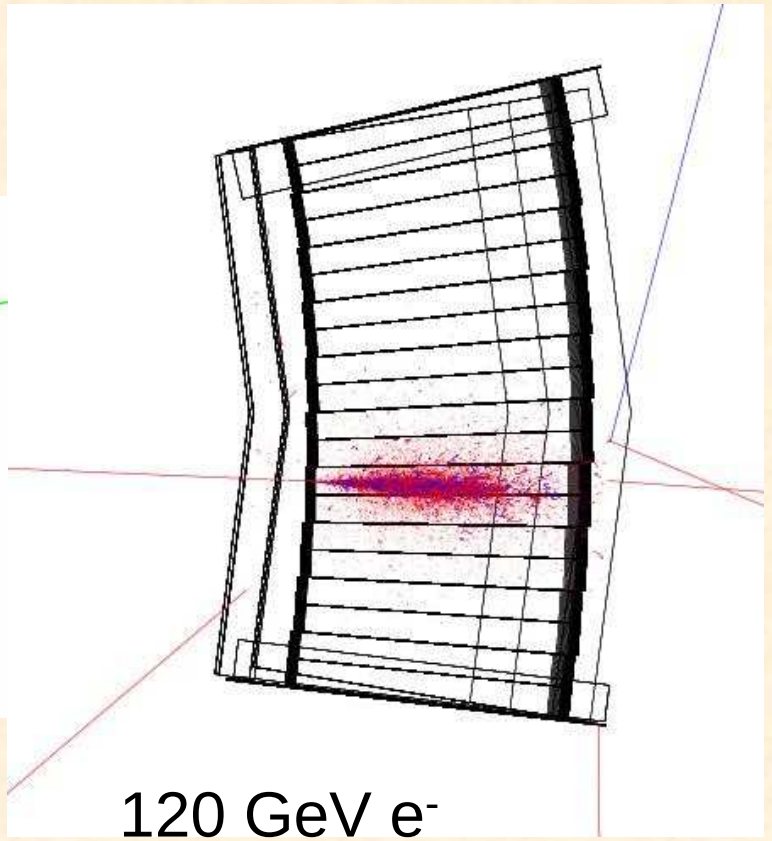
Fast < 15 ns
Radiation hard
20 interactions/25 ns

The CMS electromagnetic calorimeter

Barrel 36 supermodules,
2 end-caps

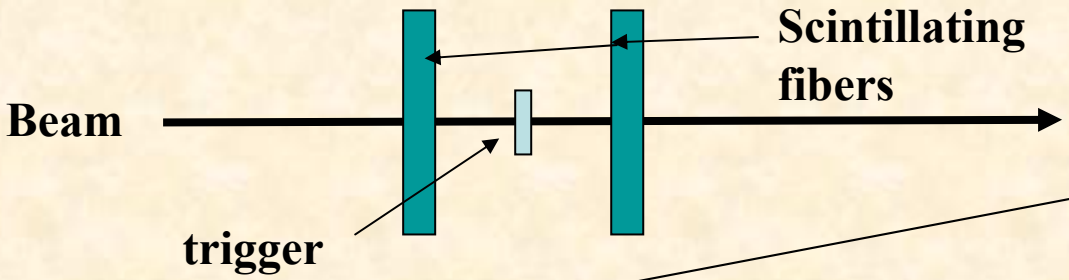


Non-pointing geometry 3° in η (beam axis) and in φ



120 GeV e^-

The CMS electromagnetic calorimeter



Movable table:
Used to reproduce for the impinging particle the same almost pointing geometry of CMS

Readout Electronics: 2 avalanche photodiodes + MGPA (multi gain pre-amplifier) 3 gains (12,6,1), 10 samples

4 photoelectrons / MeV 35.6 MeV / ADC count

The CMS electromagnetic calorimeter

Test in the H4 beam at CERN SPS since 1997 : electrons 20 to 250 GeV, pions, muons, laser light

Energy and position resolution, containment, cracks, irradiation recovery

Precalibration with electrons in the H4 beam : 2004 - 2006

Precalibration with cosmic muons : 2004 - 2006

In situ monitoring with laser

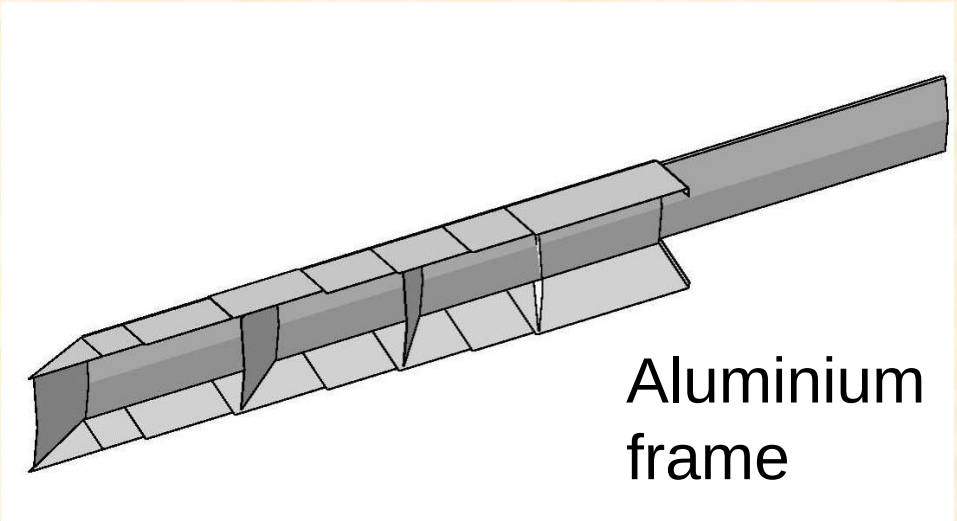
In situ calibration with electrons from Z, W, …

Geant4 implementation

CMS has a Geant4 simulation program, OSCAR, for the complete detector, interfaced with the reconstruction

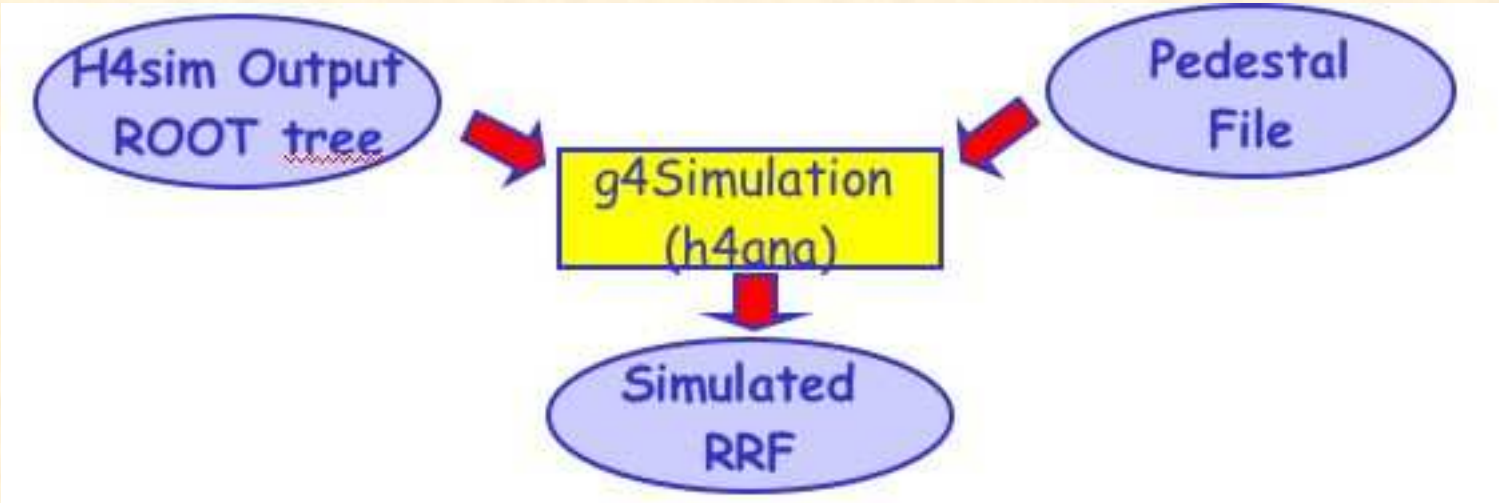
H4sim is a standalone simulation of one supermodule in H4

Geometry description by Geant4 data cards with a text file DDD (Detector Description Database) in XML format

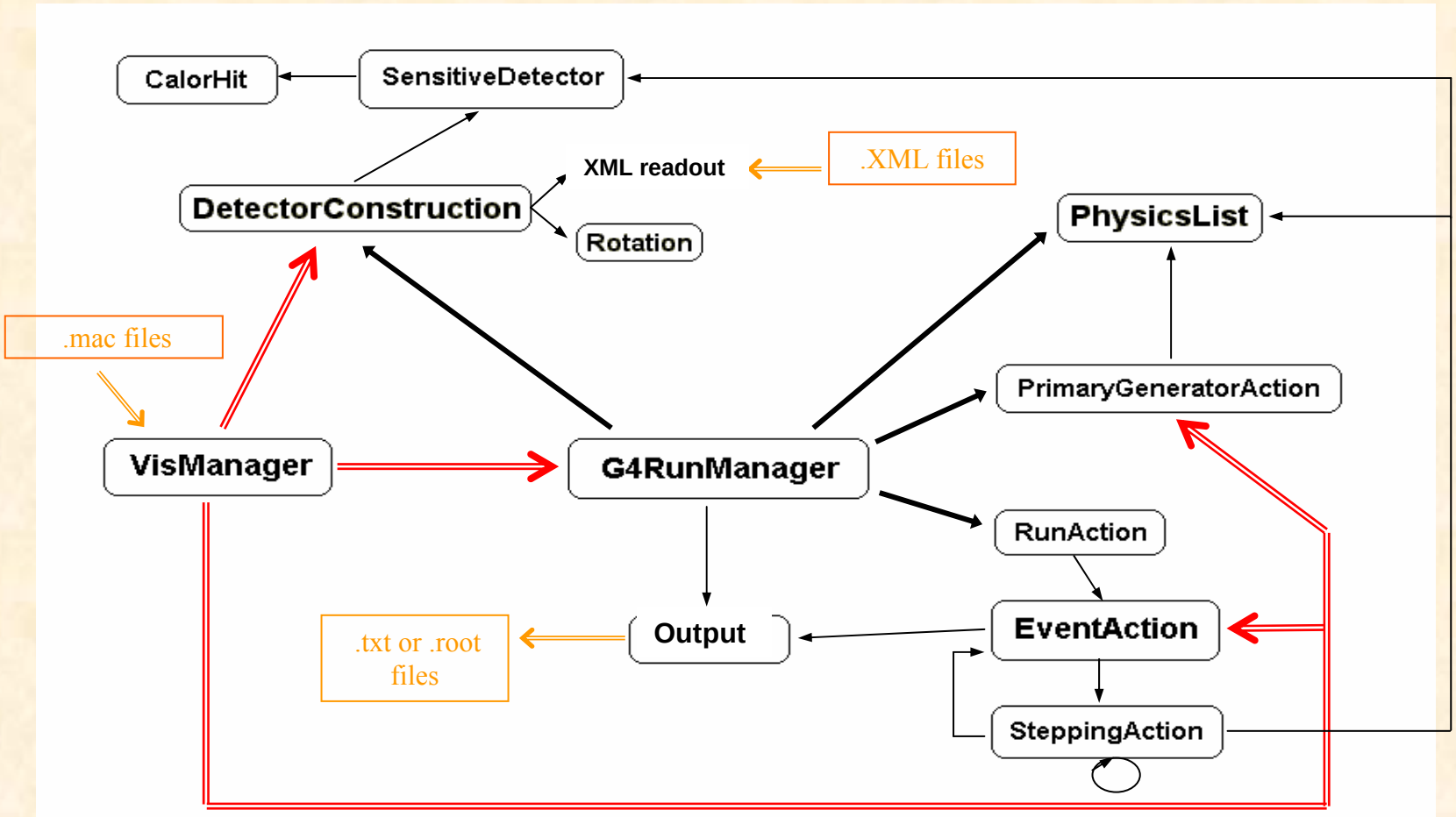


Geant4 implementation

No magnetic field (time consuming tracking)
No matter behind the crystals
Can add specific H4 devices, e.g. hodoscopes
Output of the crystal energies in a ROOT file, interface to RRF (Raw Root File) to simulate beam data



Geant4 implementation



Geant4 implementation

Version 6.2. p 02

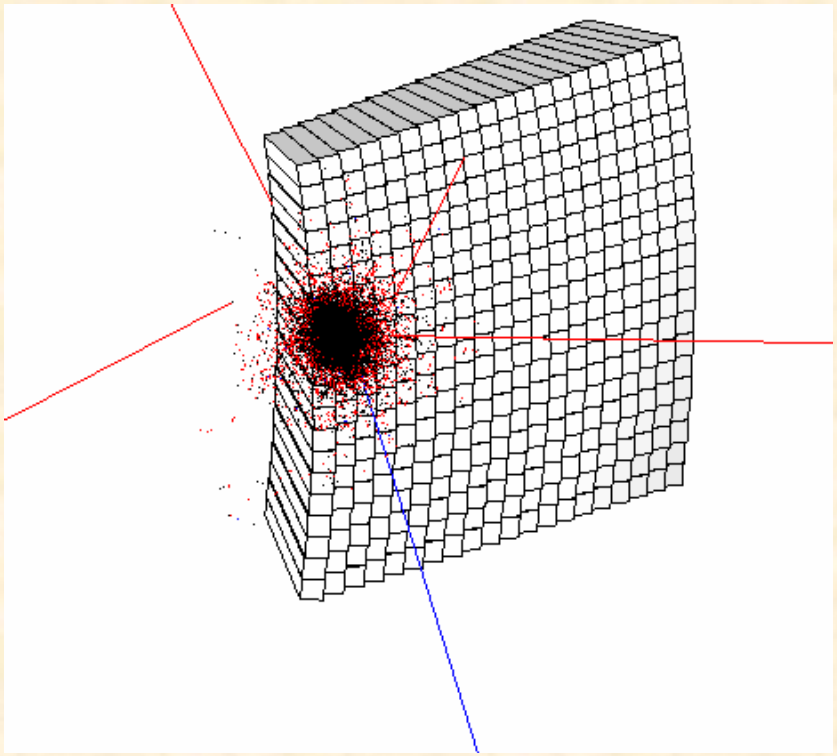
Production cuts :

1mm for e-,e+ and γ

correspond to :

~ 1.15 MeV for electrons in $PbWO_4$

~ 0.59 MeV in Al

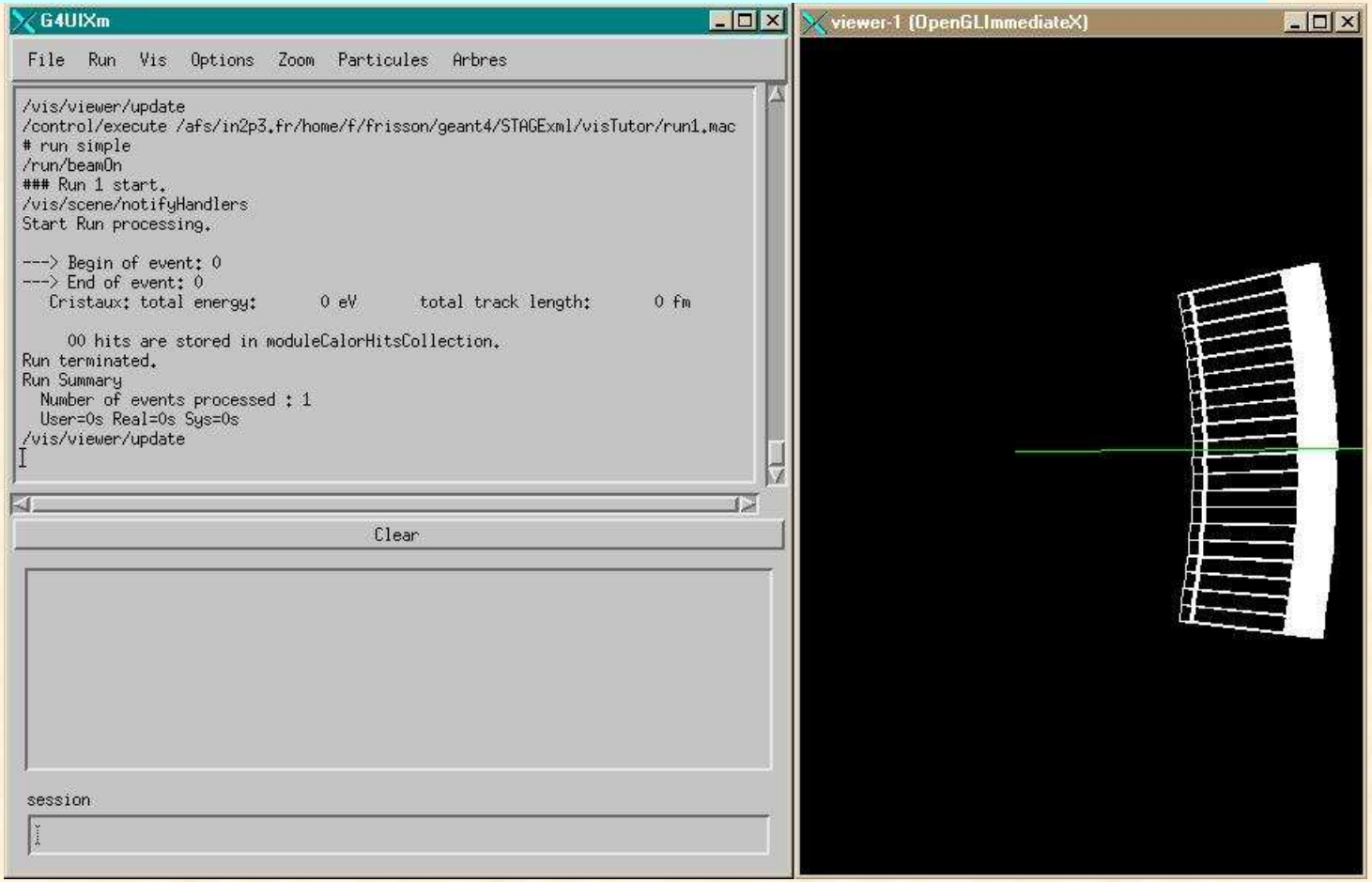


Execution time : 1.4 s for 50 GeV on 2 GHz

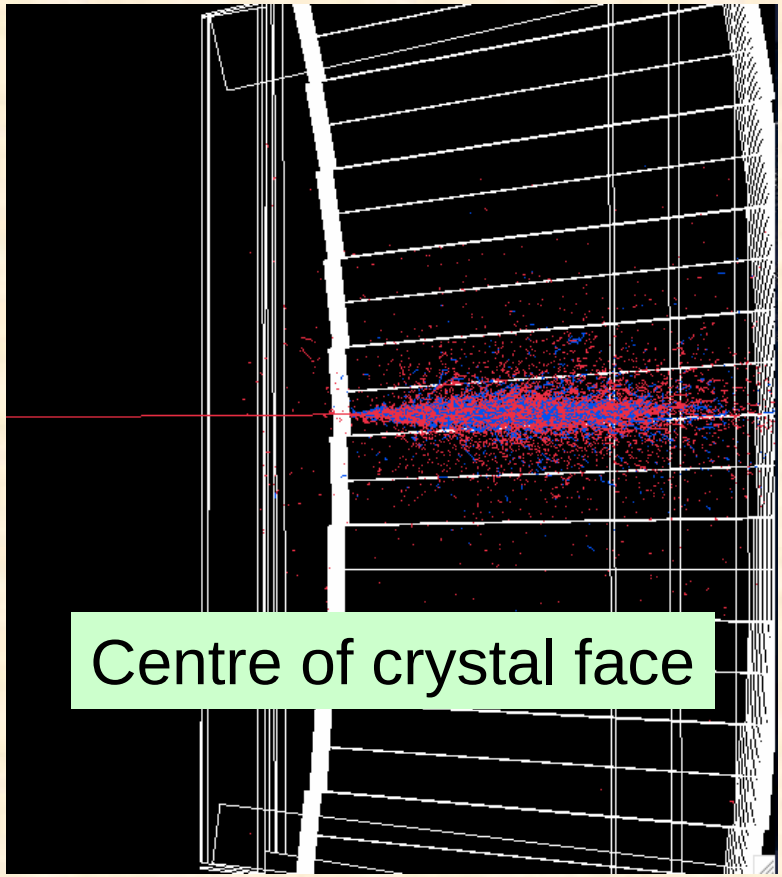
Geant4 implementation

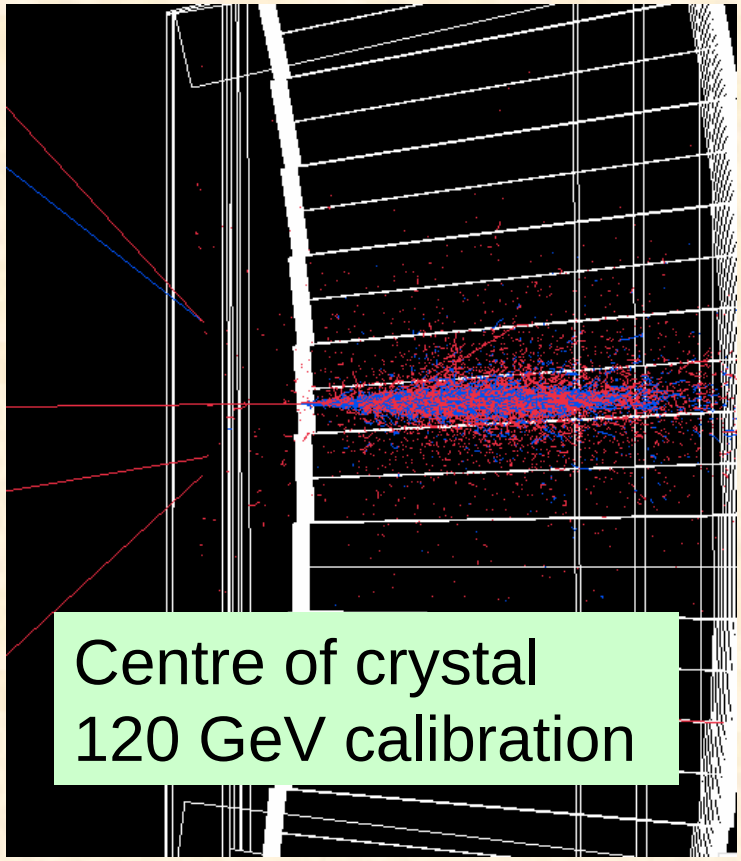
- Interactive version graphical interface & visualization
- Batch version

Special H4sim commands

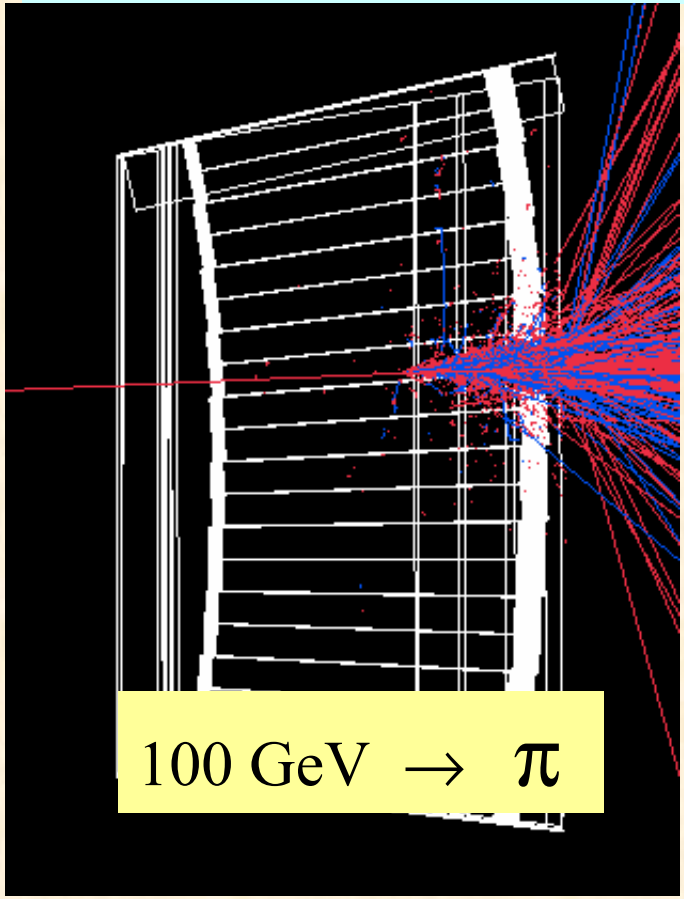


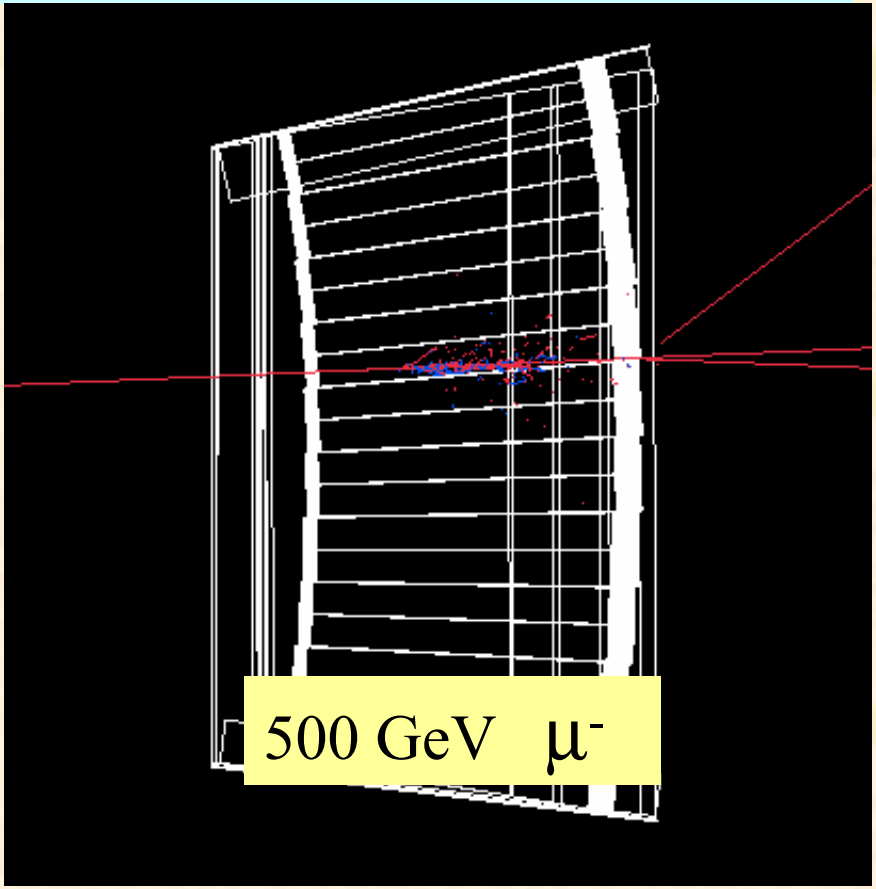
Geant4 implementation



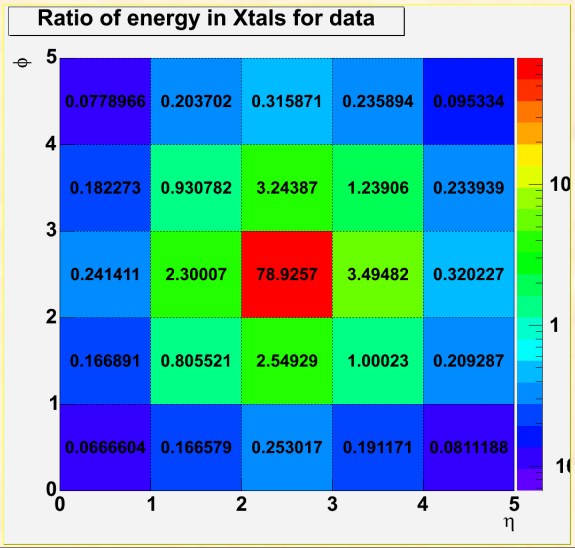


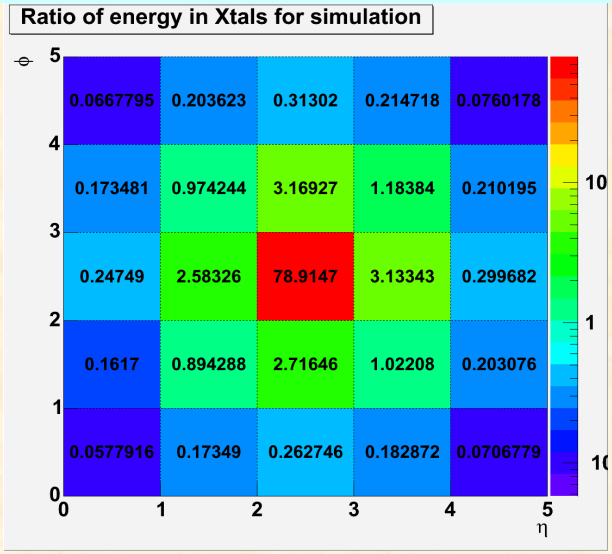
Geant4 implementation





Electron beam data





TEST BEAM

E25 = 97,5 %

E9 = 94,5 %

E1 = 78,9 %

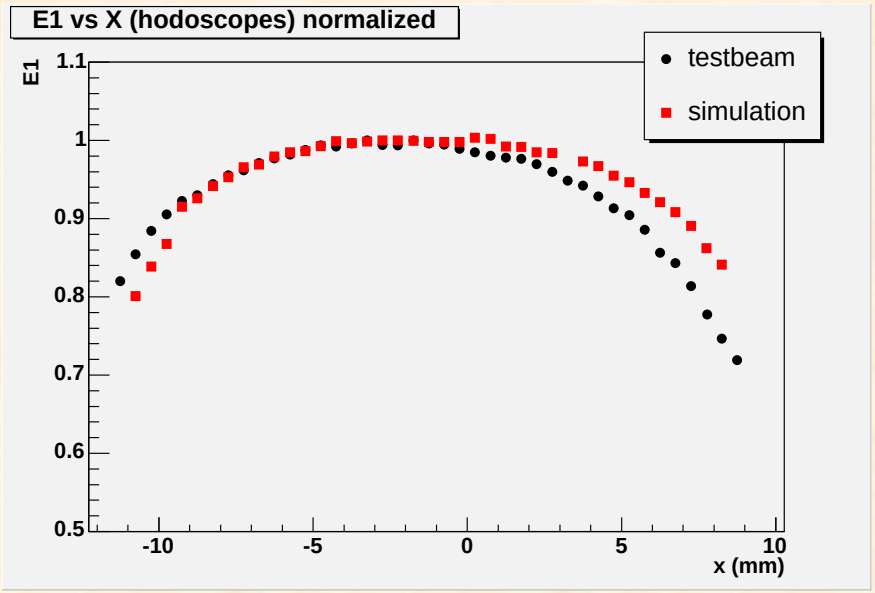
MONTE CARLO

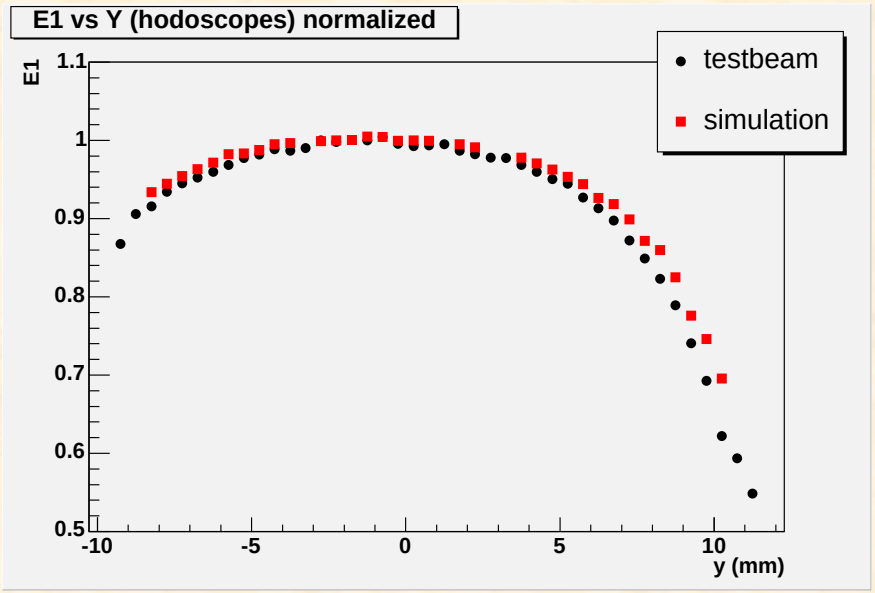
E25 = 97,5 %

E9 = 94,6 %

E1 = 78,9 %

Electron beam data





X (mm)

Test beam

Simulation

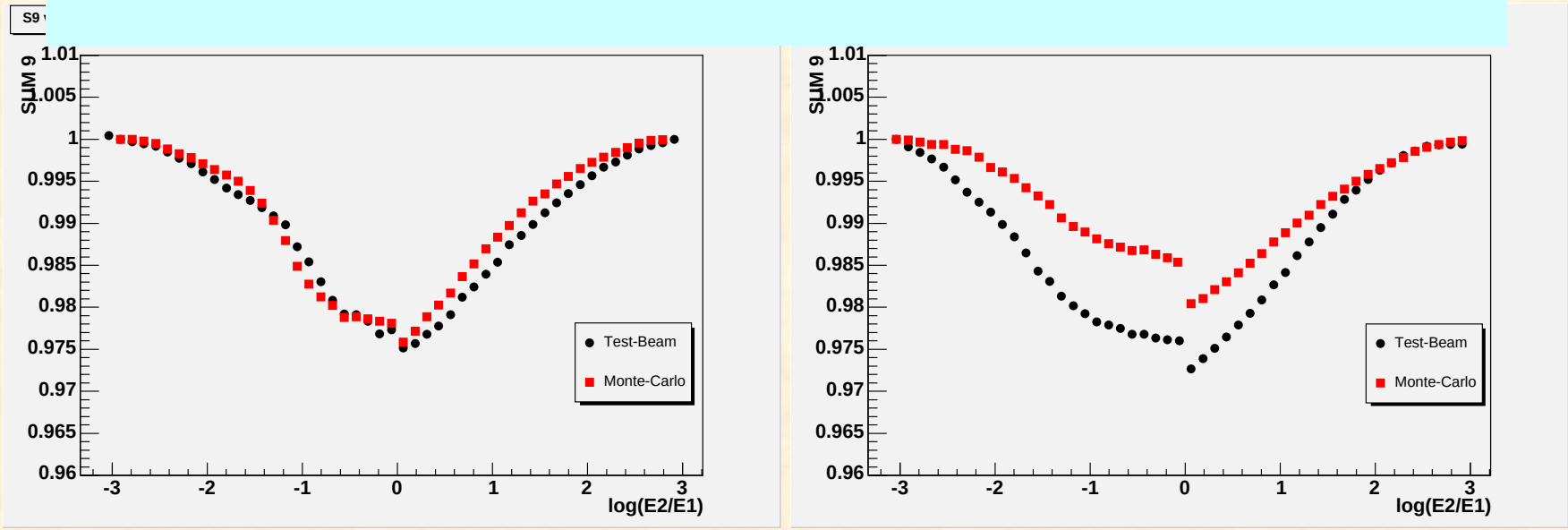
Y (mm)

Position scan at centre of crystal 204

Y good

X ~ 2 %

Electron beam data



Phi

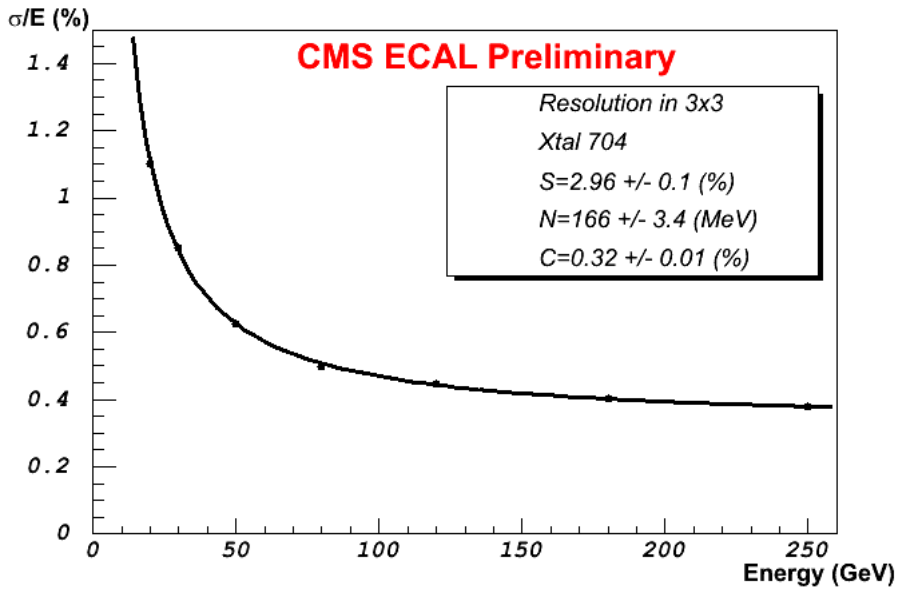
Data

Simulation

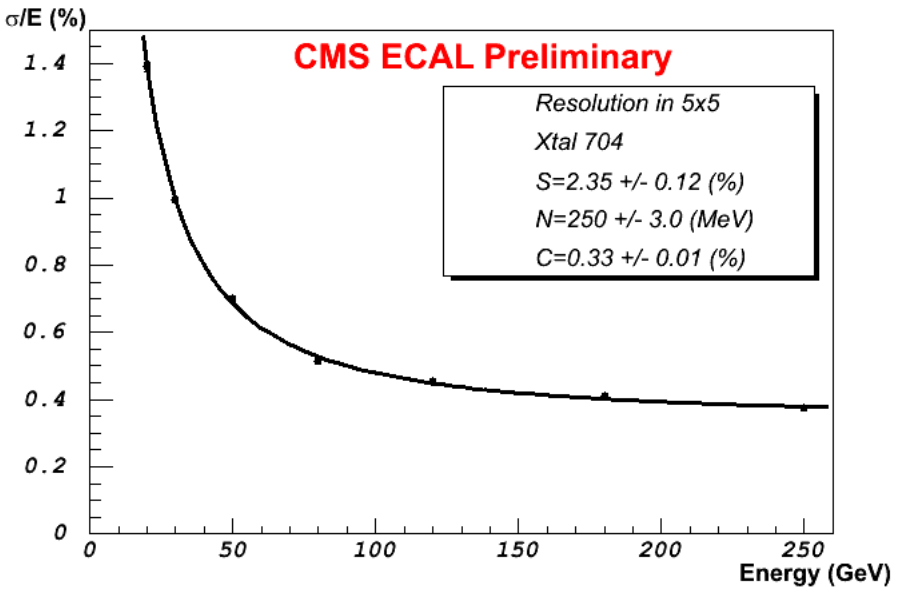
Eta

3x3 crystals impact position measured by log(*E2*/*E*1) function

Electron beam data



3X3



5X5

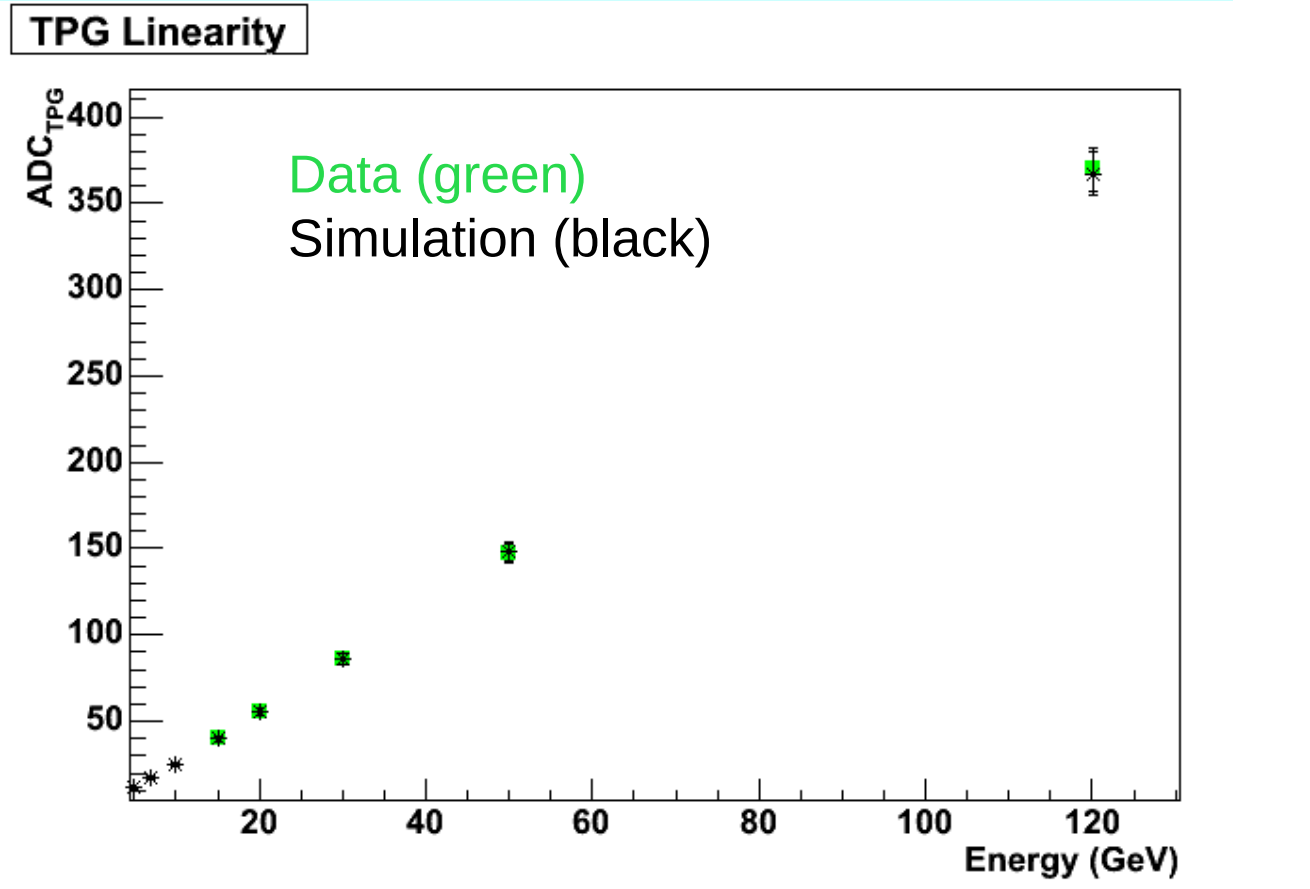
$$\left(\frac{\sigma}{E}\right)^2 = \left(\frac{S}{\sqrt{E}}\right)^2 + \left(\frac{N}{E}\right)^2 + C^2$$

S = stochastic
N = noise
C = constant

Electron beam data

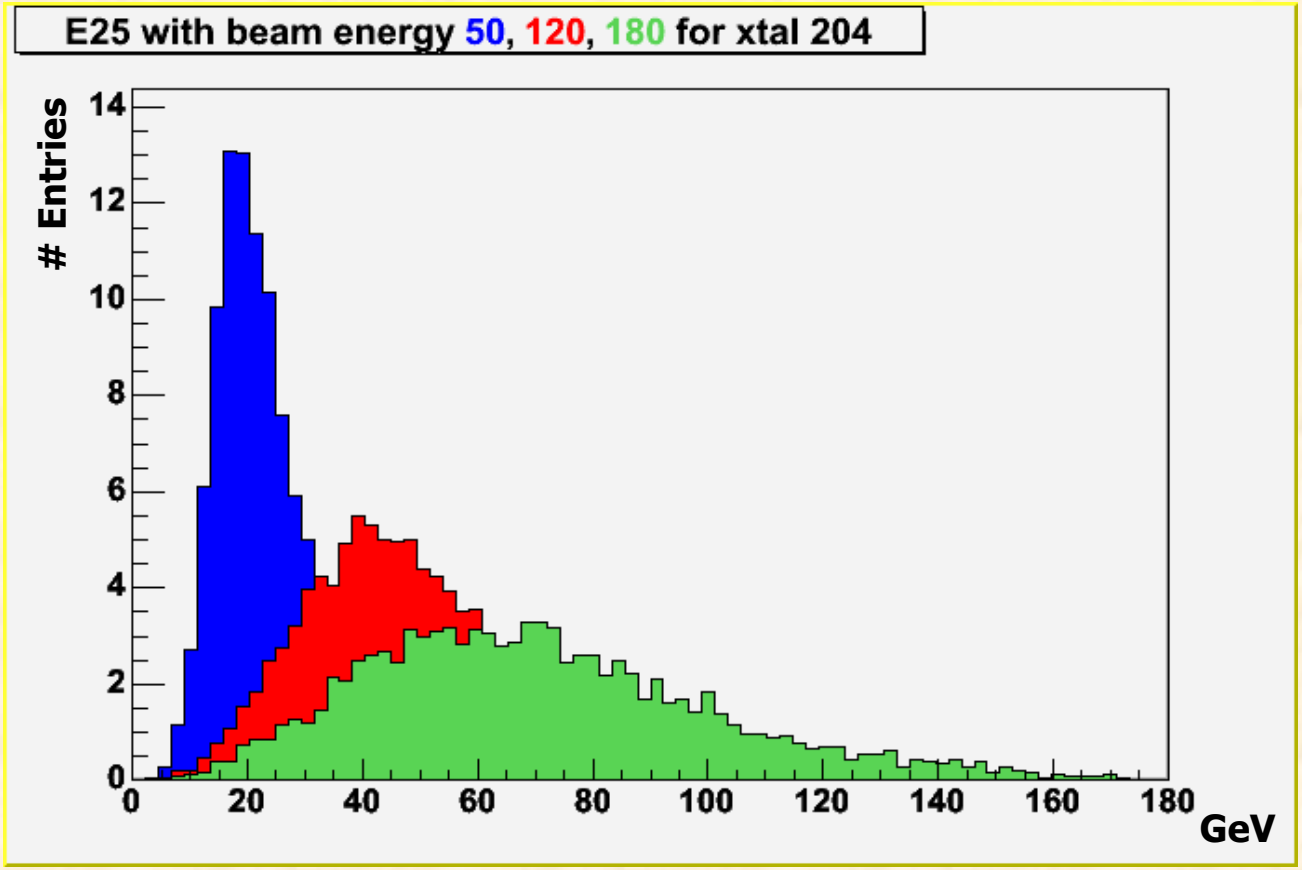
ECAL used in trigger

Simulation of the TPG linearity (Trigger Primitive Generator)



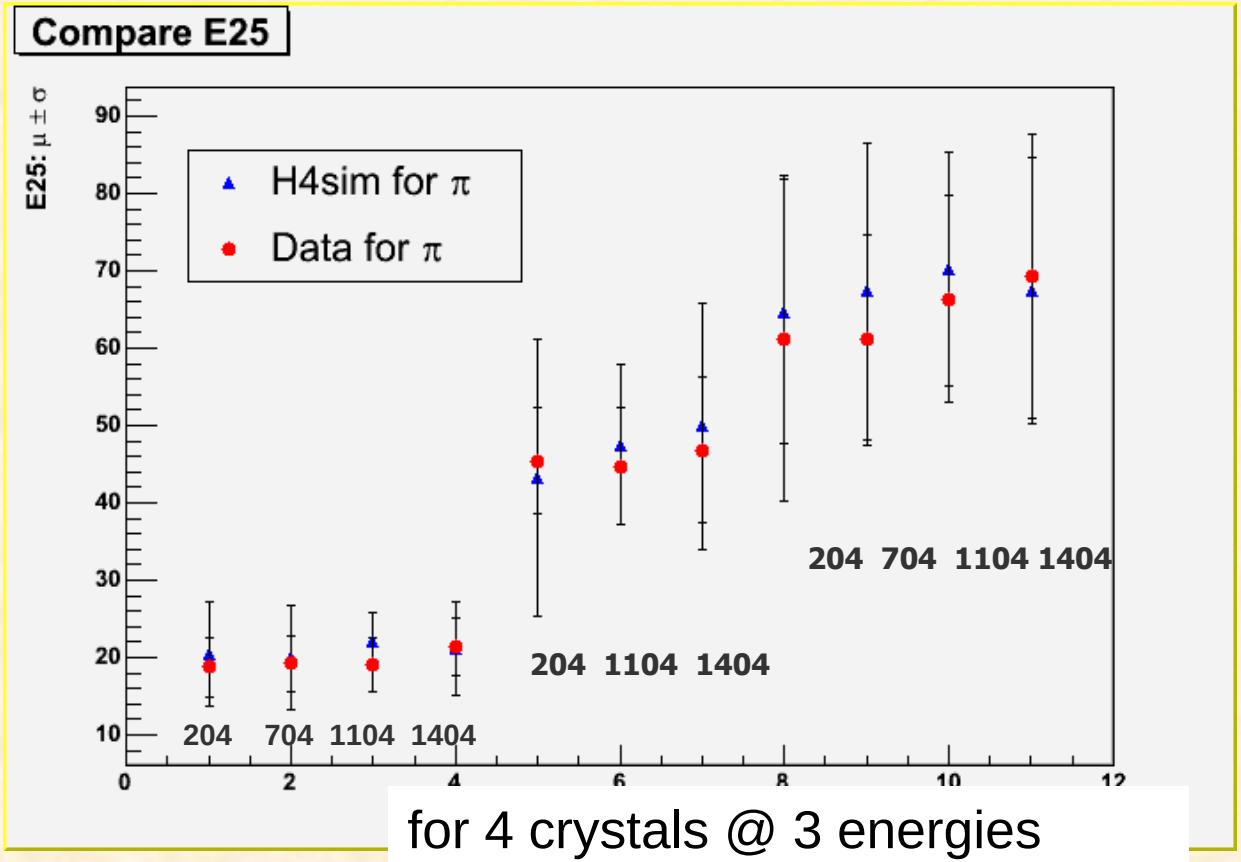
Pion beam data

5x5 energy for 50, 120 & 180 GeV pions



Pion beam data

Compare the mean values $\mu \pm \sigma$ of Landau-fit for 4 crystals @ 3 energies



for 4 crystals @ 3 energies

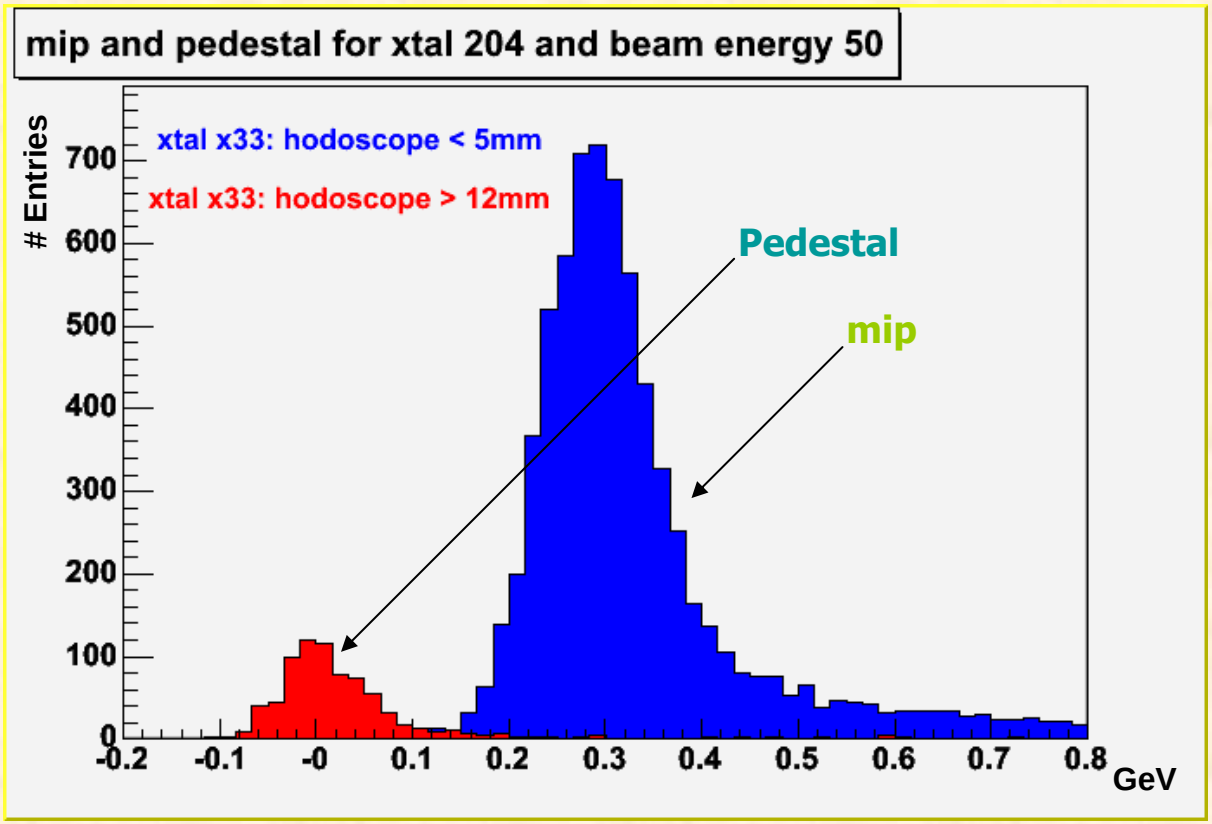
Pion beam data

Minimum ionizing particle (mip) are visible

50 GeV

$\lambda \sim 23$ cm

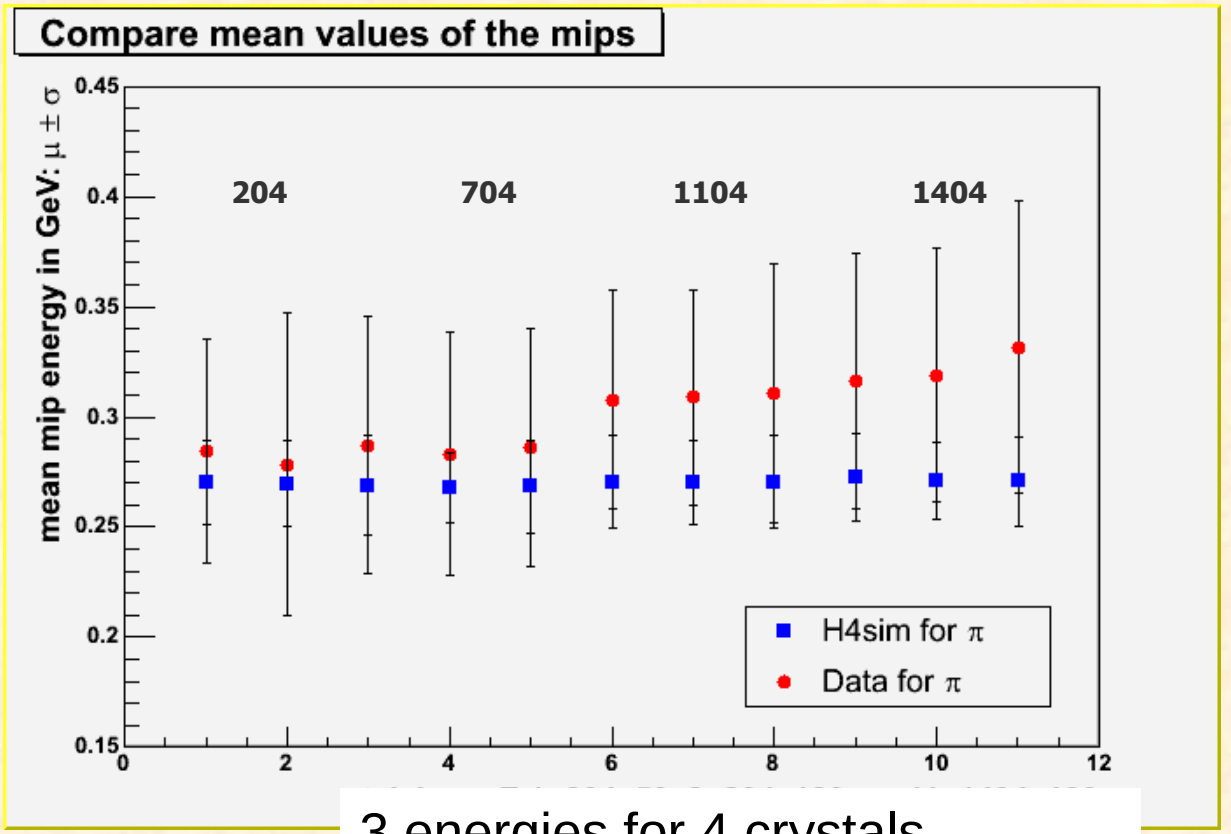
$E = 270$ MeV



Pion beam data

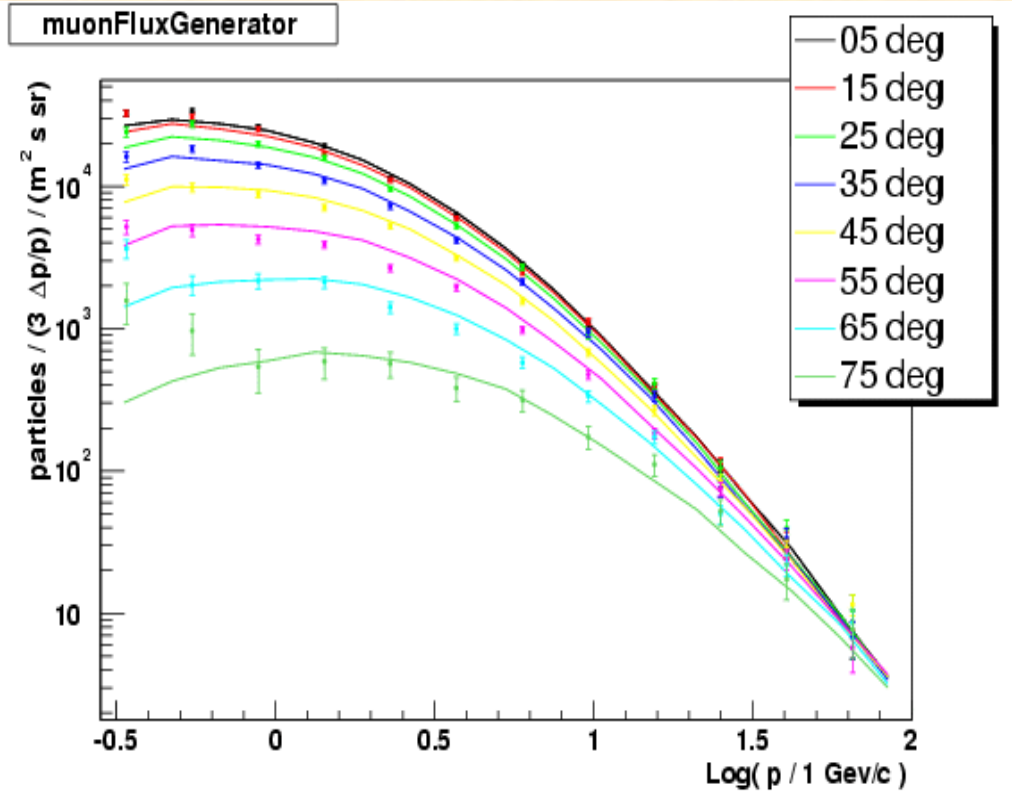
Almost constant, as it should be for mips

Less good agreement for crystals 1104 & 1404



3 energies for 4 crystals

Precalibration by cosmic muons

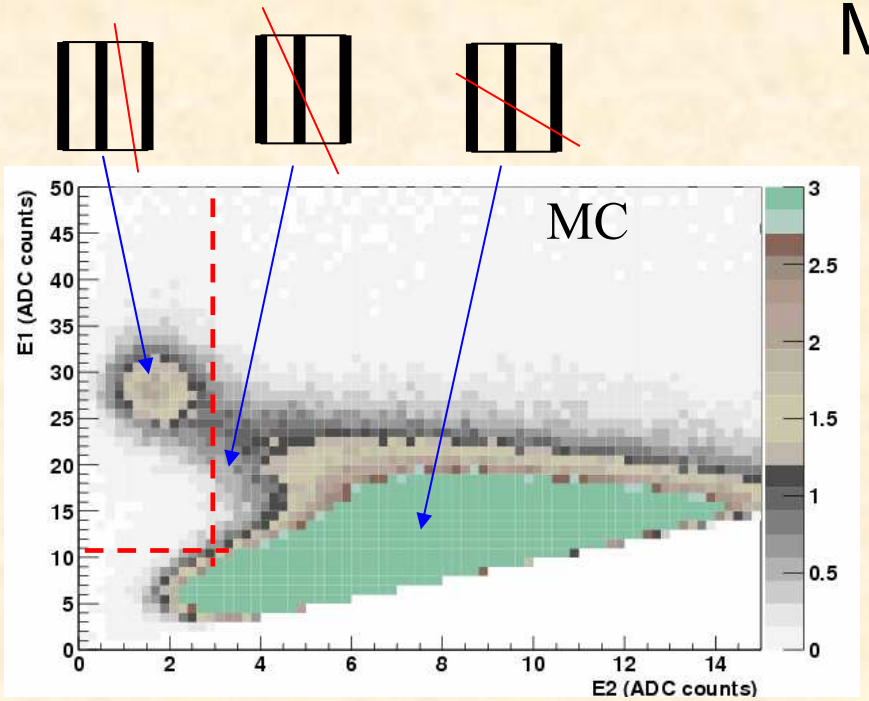


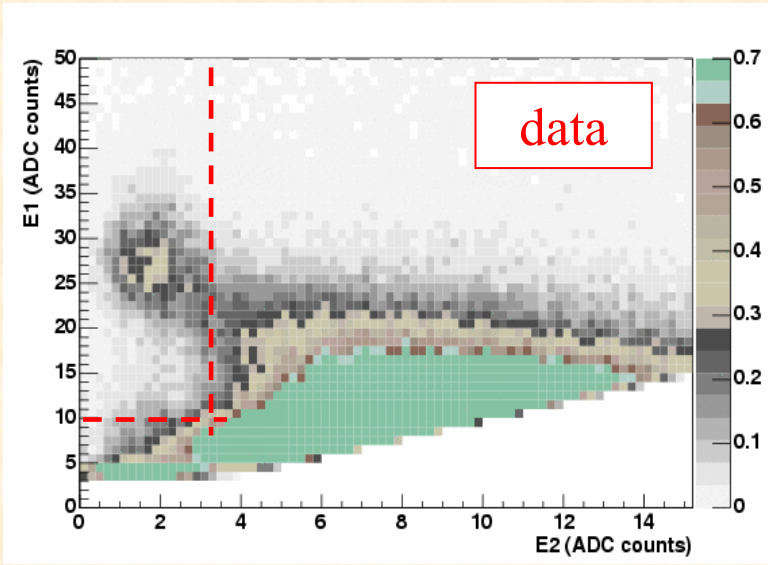
Raise the APD gain by a factor 4

Select the muons parallel to the crystal axis
Veto neightbouring crystals

Precalibration by cosmic muons

Module 1

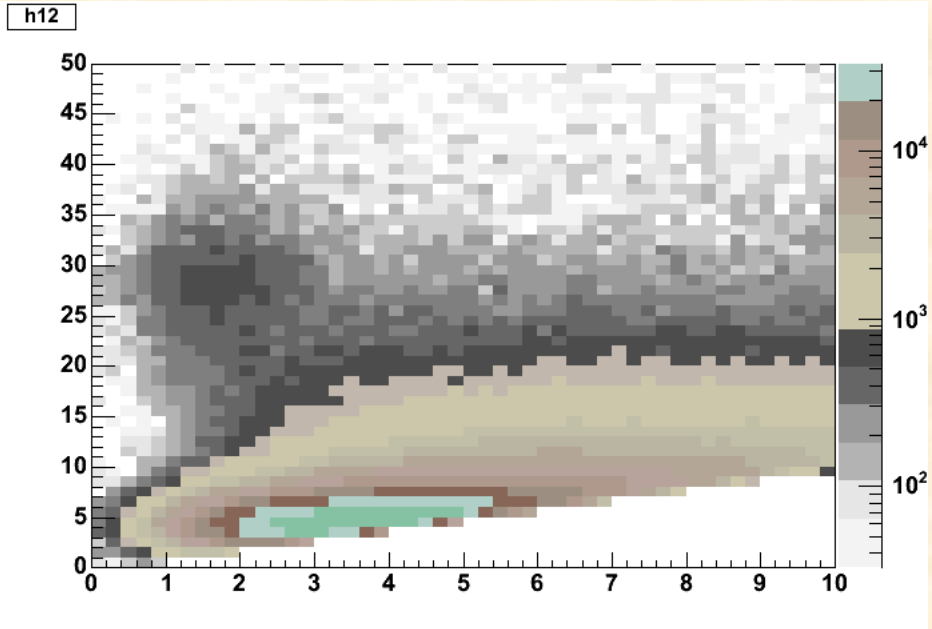




Event selection: E1 > 10 ADC counts & E2 < 3 ADC counts

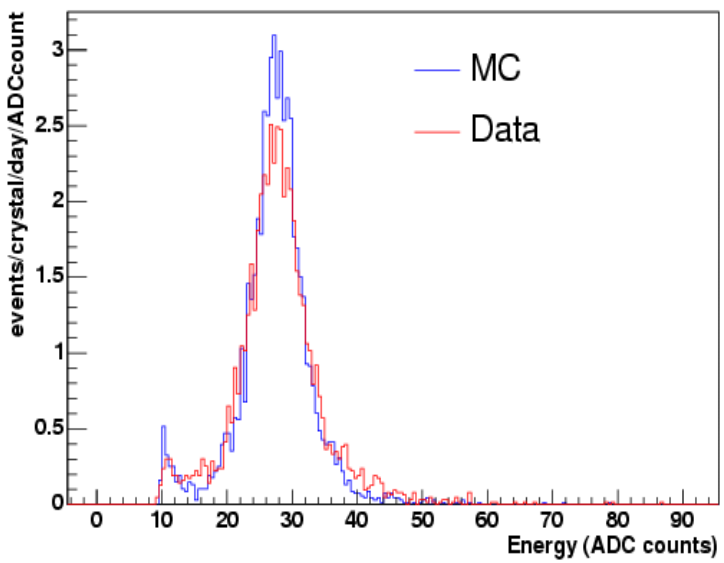
Precalibration by cosmic muons

More difficult for module 4 (eta angle)
$\Rightarrow$ incline the supermodule by 10 degrees



Intercalibration precision of 2-3% can be reached with 1 week of continuous cosmic ray data taking

Precalibration by cosmic muons



Peak after final selection:

good agreement between data (after calibration) and MC

Data: <evts/xtal/day> = 55±2 MC: <evts/xtal/day> = 61±2

Disagreement ~ 10% due to trigger inefficiency and uncertainty on the overall normalization

Conclusion

Geant4 based H4sim is widely used by the ECAL CMS community
Interpretation of test beam data
Test of algorithms and cosmic precalibration

Acknowledgments to :
T. Frisson, J. Gilly, P. Mora de Freitas, S. Bimbot, P. Paganini, P. Meridiani, R. Salerno, P. Jarry, J. Descamps, A. Ghezzi, S. Vigano, C. Marchica, A. Holzner, P. Bloch, A.Zabi and the ECAL group