Detection of muons at 150 GeV/c and absolute energy calibration of a CMS Preshower Prototype

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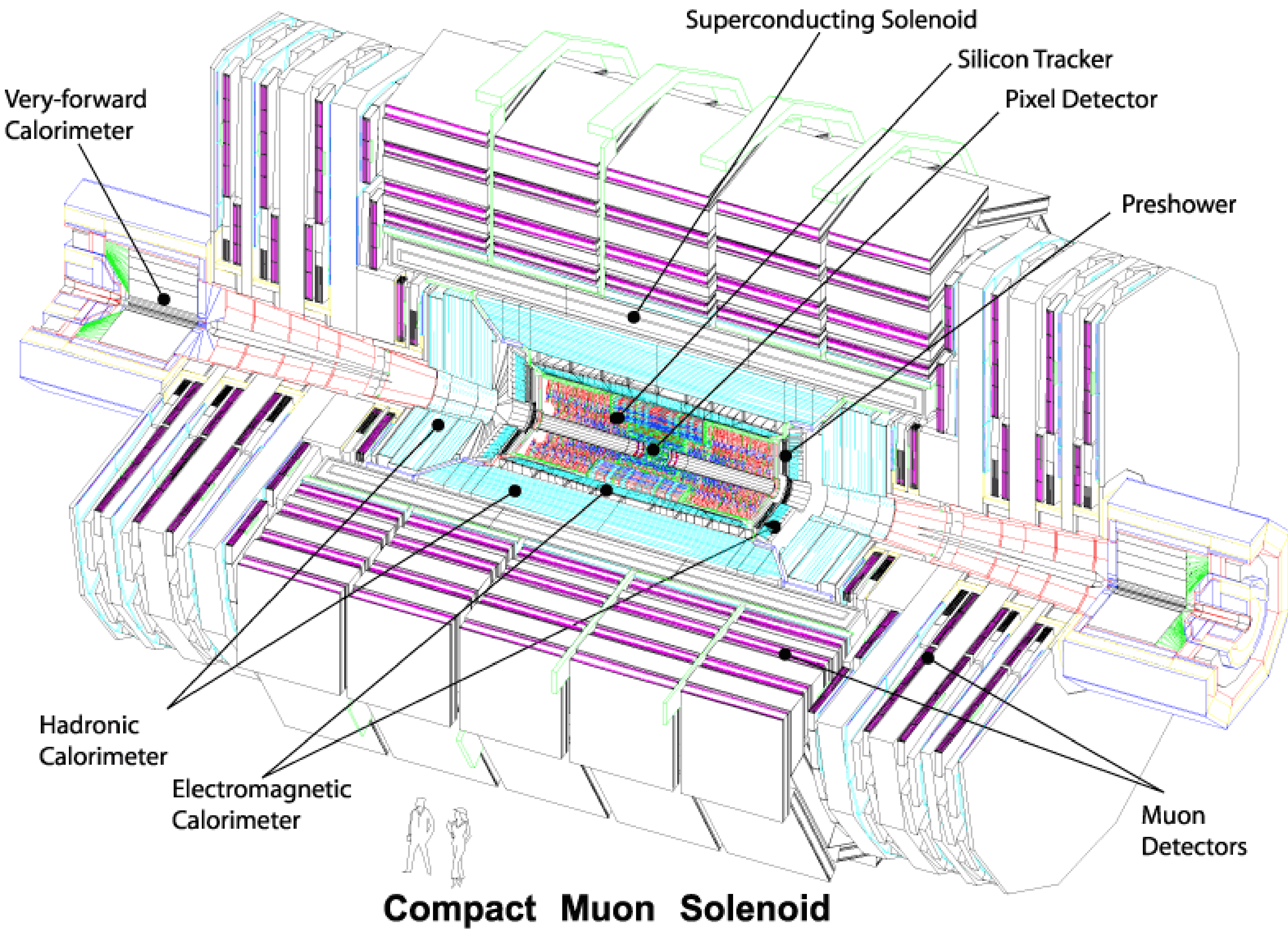
Talk Overview

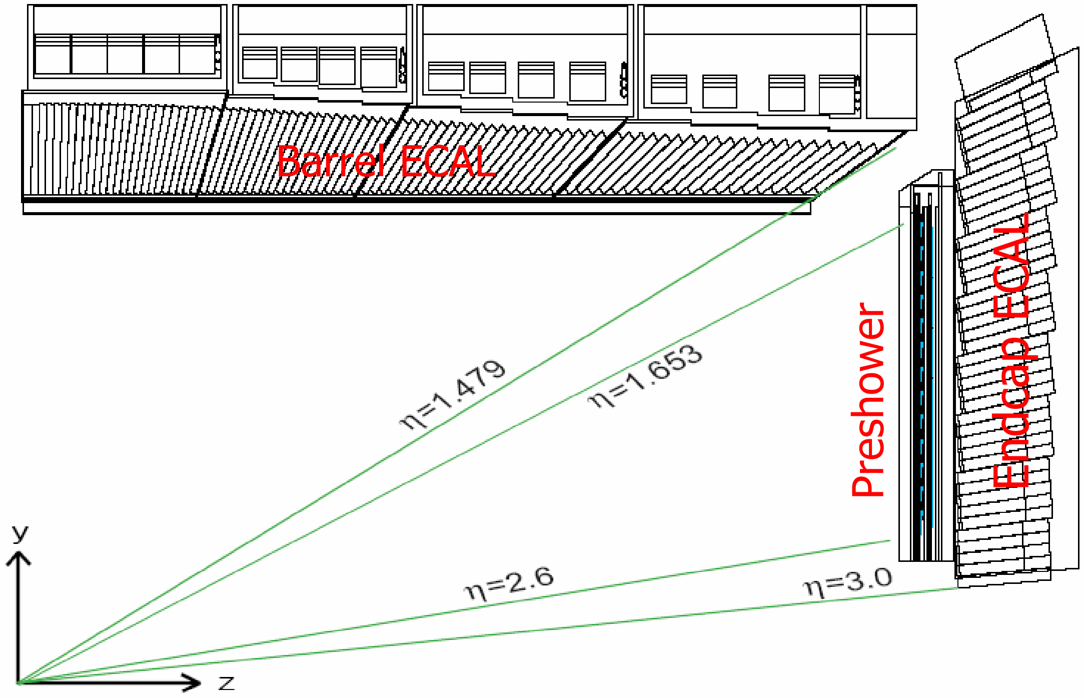
- The Preshower detector in CMS.
- Preshower calibration (why?)
- Test Beam Setup
- Muon Data Analysis
  - Pedestal Subtraction
  - Common Mode correction
  - Single strip signal extraction
  - Total signal extraction
  - GEANT 4 simulation
  - Energy calibration
  - Data over MC
- Electron Analysis
- Summary

The Preshower Detector in CMS



The Preshower Detector

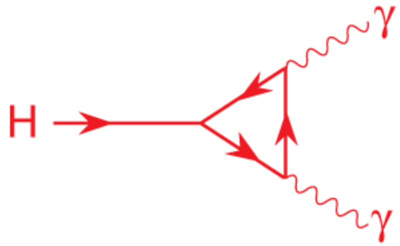
Preshower fiducial coverage:
$1.653<\eta<2.6$ or $10^\circ<\theta<20^\circ$



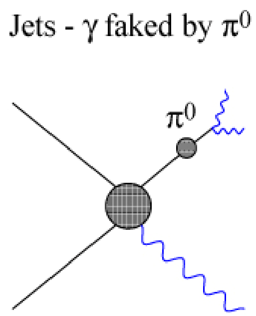
- The Preshower is a sandwich of two orthogonal layers of silicon strip sensors positioned behind two planes of lead absorbers.
- Provides the position of the foot of the shower in the endcap ECAL.
- Main task is to identify the photons from $\pi^0 \rightarrow \gamma\ \gamma$ and distinguish them from single photons (π^0/γ separation).

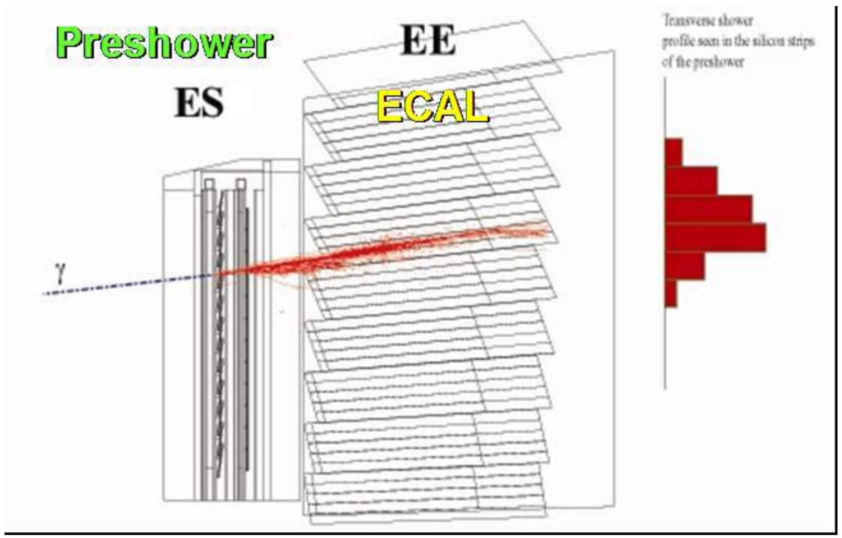
The Preshower Detector

Signal : Higgs decay to two gammas

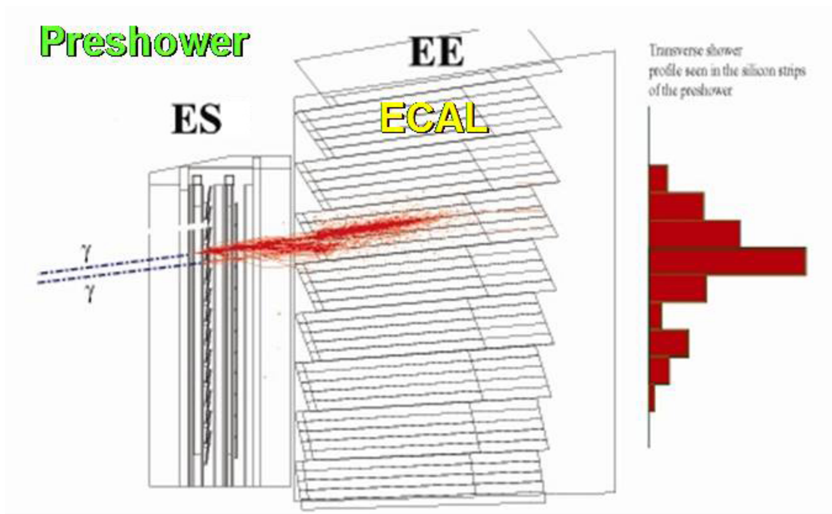


Background : one gamma faked by π^0 decay





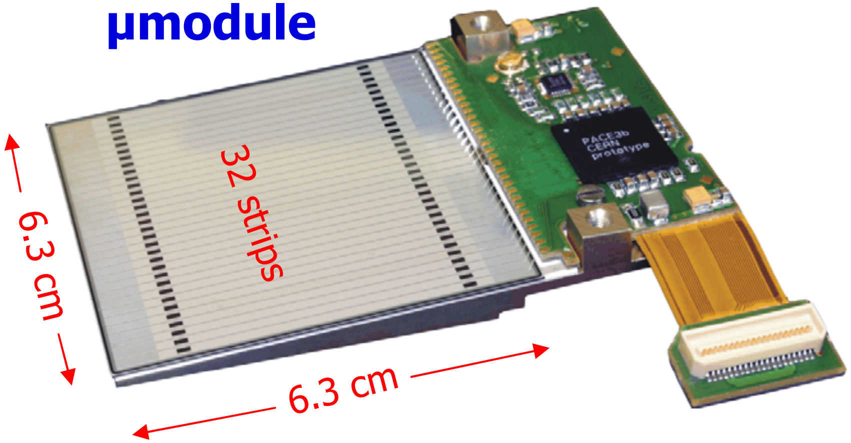
Single γ detection



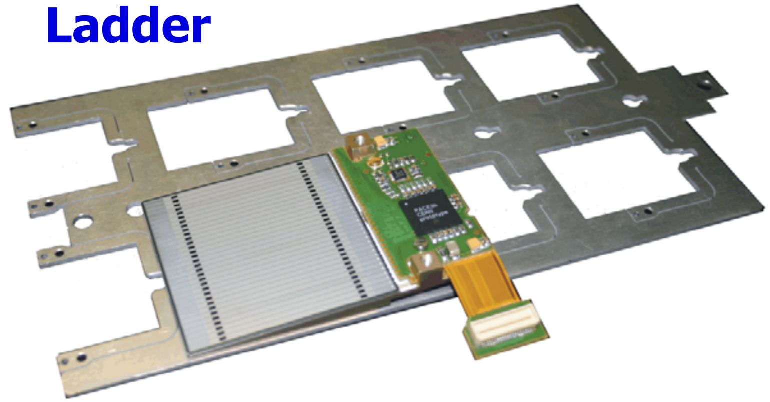
Double γ detection from π^0 decay

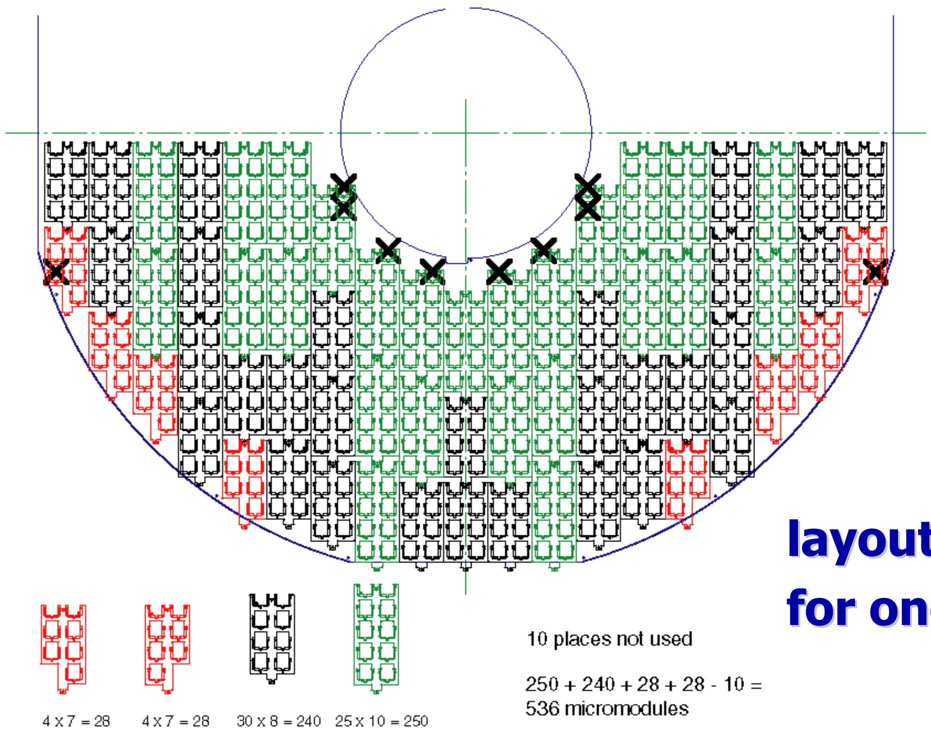
The Preshower Detector

µmodule



Ladder





layout of the ladders for one half of an ES plane

Preshower calibration (Why?)

- Total Energy Deposition in ECAL:

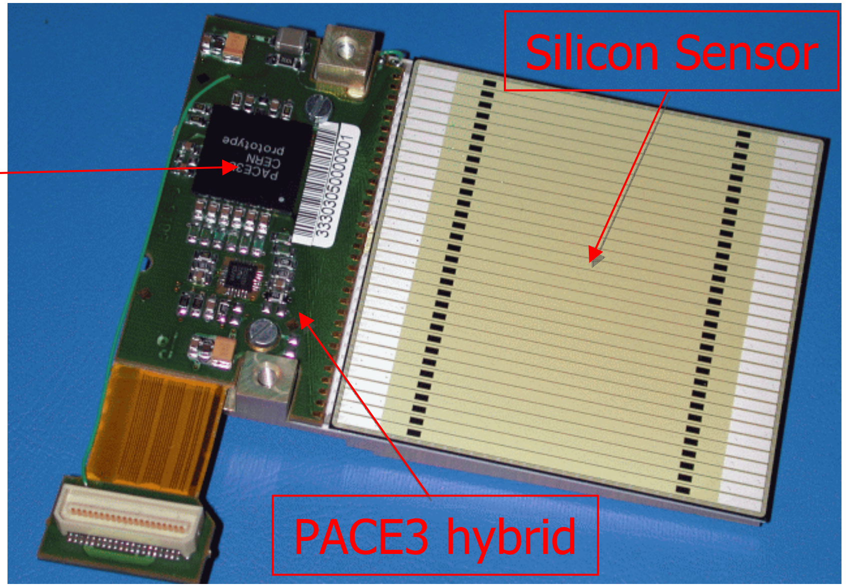
$$E_{Total} = E_{Crystals} + E_{Preshower}$$

- Preshower should provide $E_{Preshower}$ with an accuracy of ~5%.

- Signal produced by the sensors depends on:
  - Incident particle type and energy.
  - Angle of incidence (varies with η).
  - Sensor capacitance (vary by ±5% due to variation of thickness 320±15 μm).
  - Charge collection efficiency of the sensors, which decreases with neutron - proton fluence (10 y for High Luminosity ~$1.6x10^{14}cm^{-2}$ neutrons and ~$0.4x10^{14}cm^{-2}$ protons for large η).
  - Intrinsic gain of pre-amplifier (PACE3).

Preshower calibration

- PACE 3:
  - 32 channel Preamplifier shaper
  - 32x192 analogue memory for event pipelining

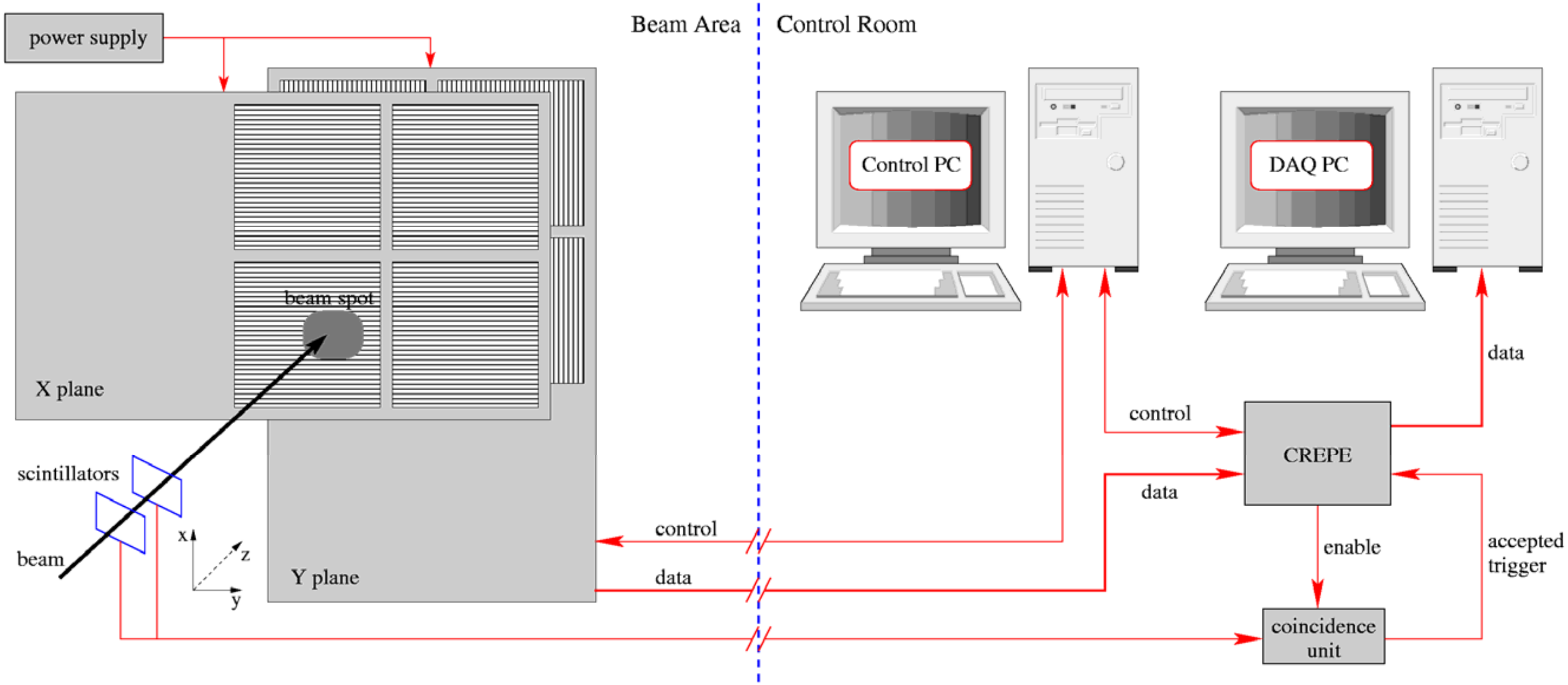


PACE 3 modes of operation:

- "Calibration mode": average gain ~ 20 mV /mip
- "Normal mode": average gain ~ 3.2 mV /mip

  (1 mip = 83.7 KeV = 3.7 fC for a 320 μm thick sensor)

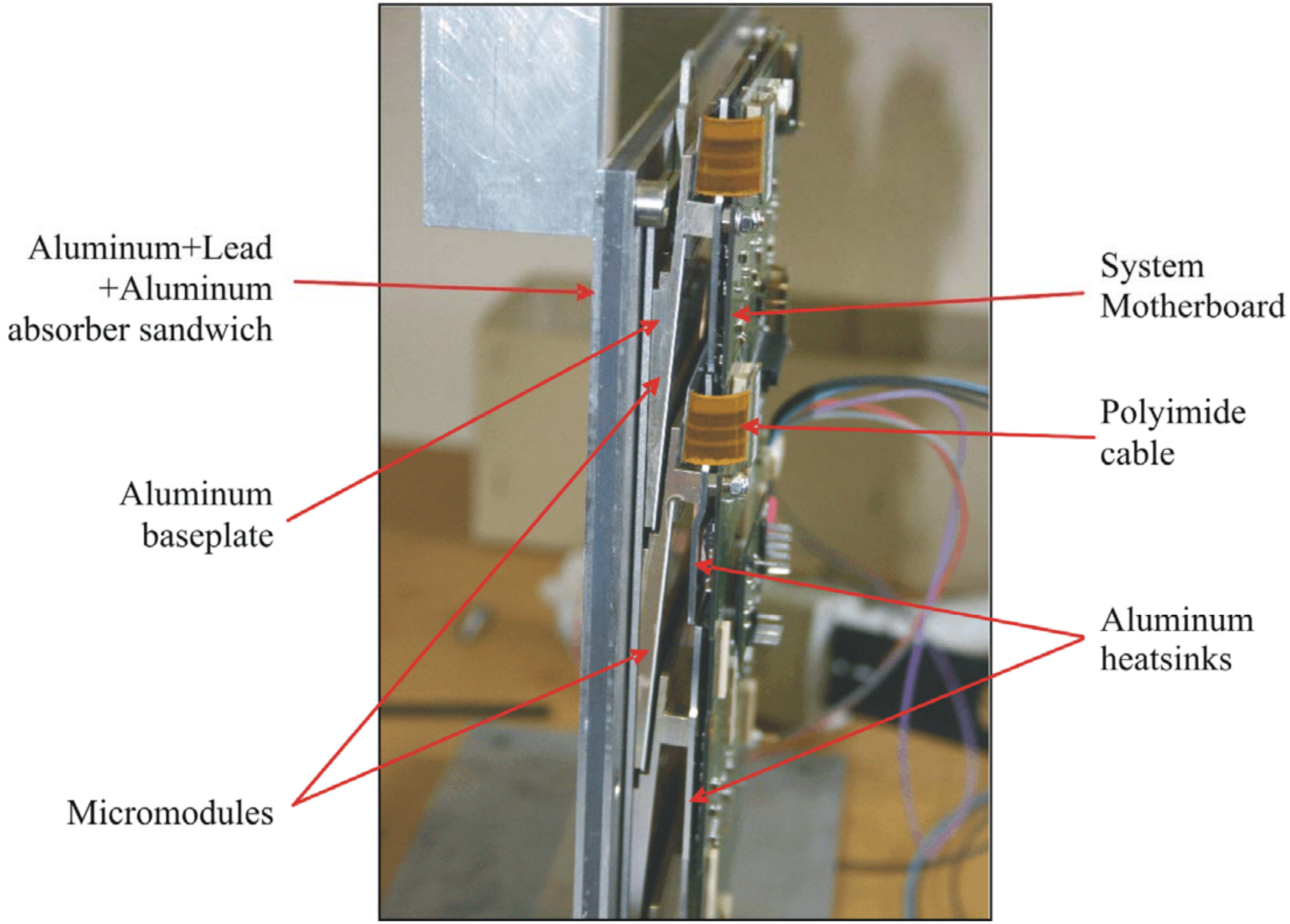
Test Beam Setup



CERN H4 experimental hall.

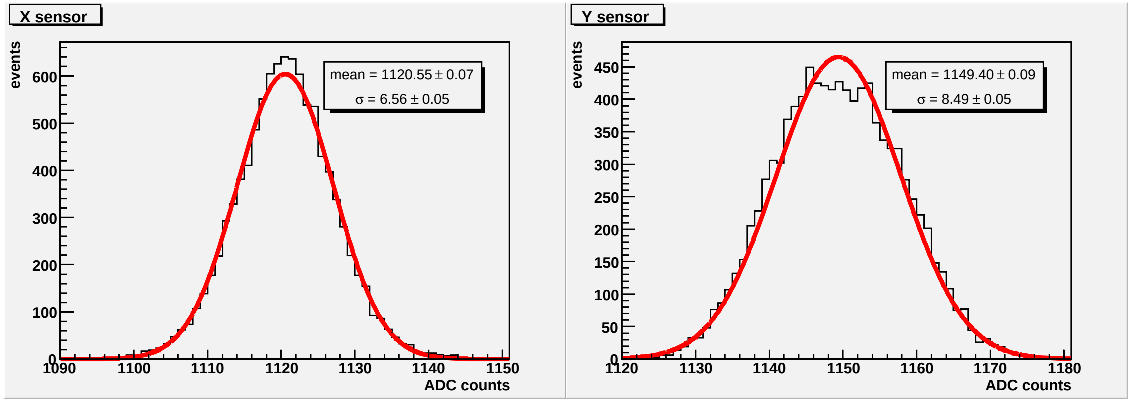
- Muon data at 150 GeV/c
- Electron data at 20, 35, 50, 80 and 120 GeV/c
- Pion data at 20, 30, 50, 80 and 120 GeV/c

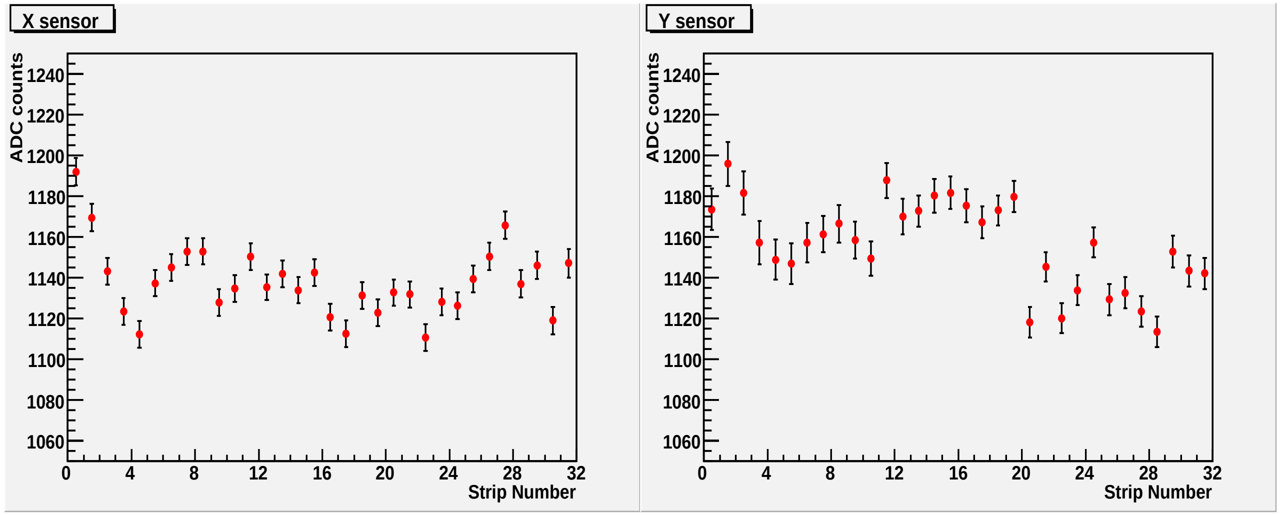
One Plane of the Preshower Prototype



Pedestal Subtraction

- Use of dedicated pedestal runs.
- Pedestal evaluation per strip.
- For every channel raw values fitted to a Gaussian distribution.
- Extraction of central values and sigmas.

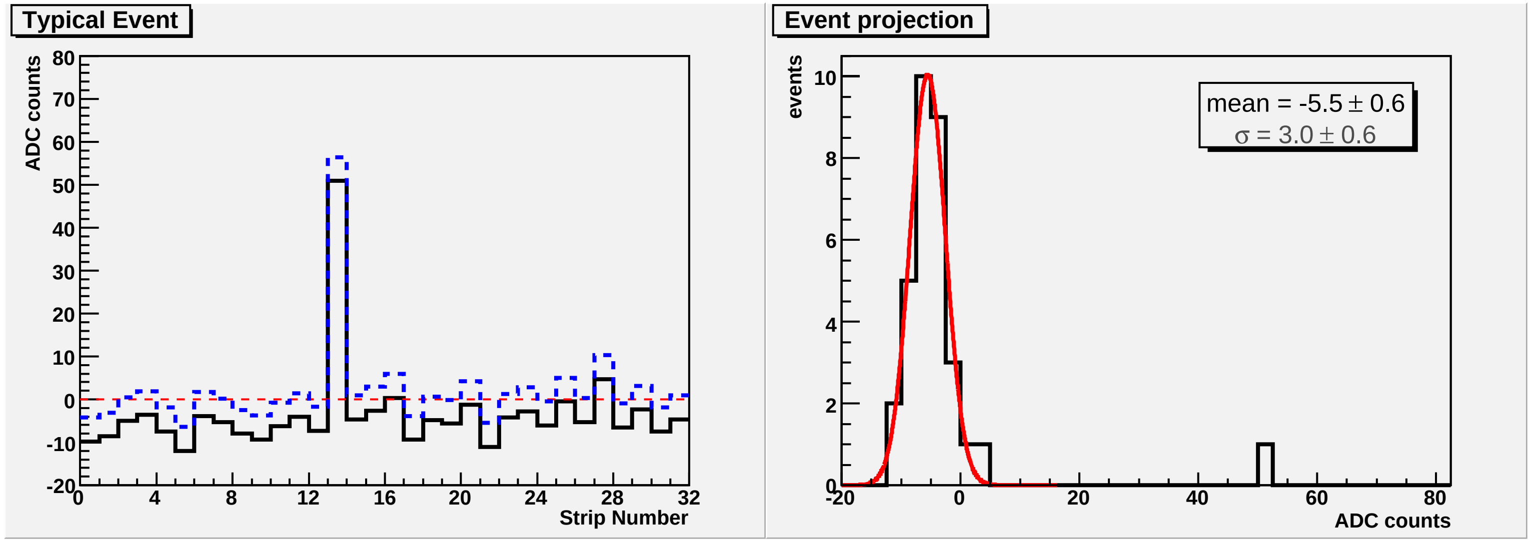




$\overline{\sigma}_X = 6.6\ ADCcounts\ (2.9mV)$ $\overline{\sigma}_Y = 8.5\ ADCcounts\ (3.7mV)$

Common Mode correction

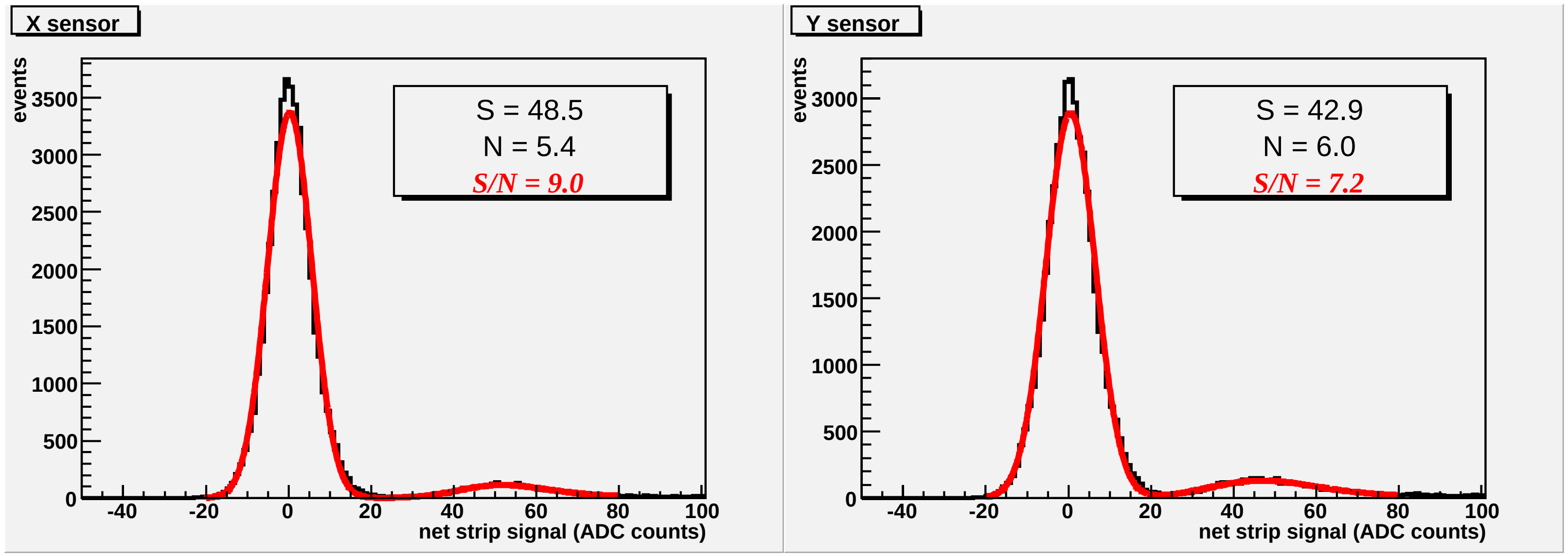
- Small displacement of base line, differing on an event by event basis, due to external sources of noise.
- Correction on an event by event basis.
- Method: Projection of the event on the y axis. Fitting of the peak to a Gaussian distribution. Evaluation of common mode.



Single strip signal extraction

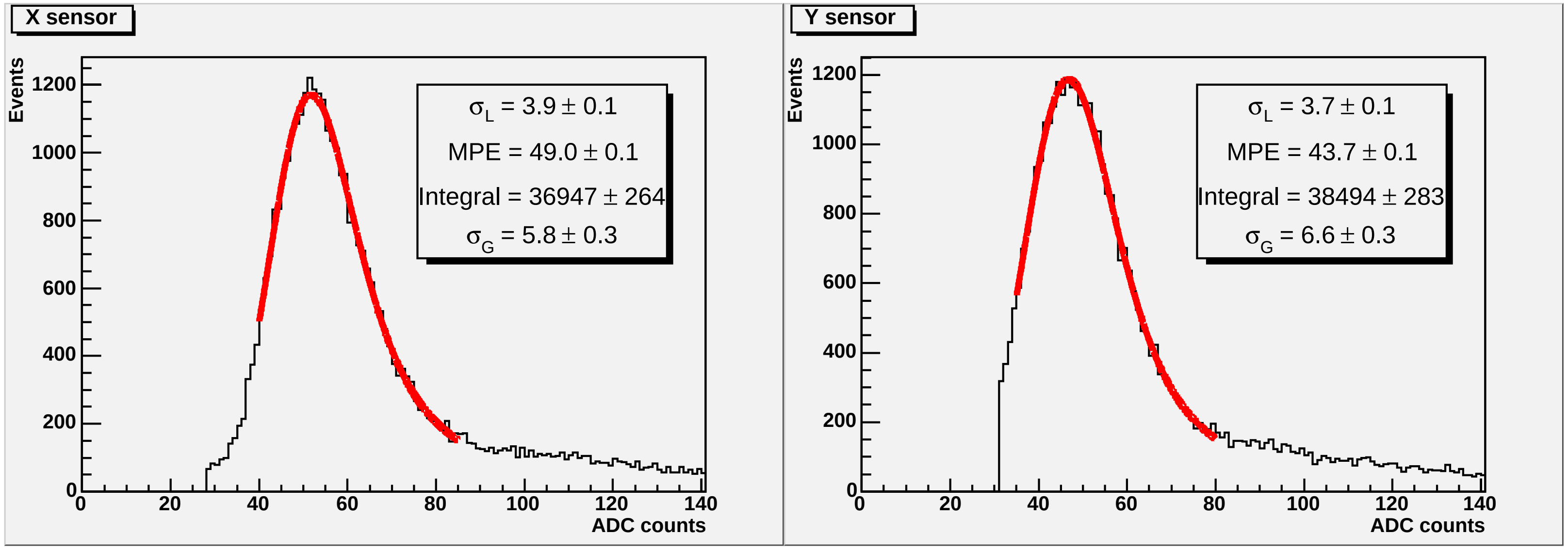
- Pedestal region fitted to a Gaussian Distribution (sigma = noise N).
- Signal region fitted to a Landau distribution convoluted with a Gaussian one (MPE = signal S).

X sensor : S/N≈9 Y sensor : S/N≈7

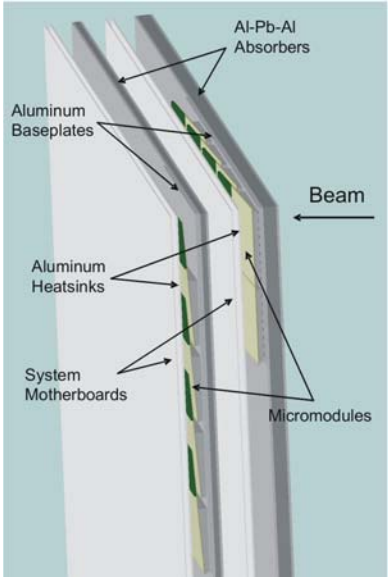


Total signal extraction

- Total signal (ADC counts) = The sum of all strips after cutting 5σ (pedestal σ) on every strip.
- Fitting data to a Landau distribution convoluted by a Gaussian:
  - σ_L : Width parameter of Landau density
  - MPE : Most Probable Energy of Landau density
  - Integral : Normalization constant
  - σ_G : Width of convoluted Gaussian distribution

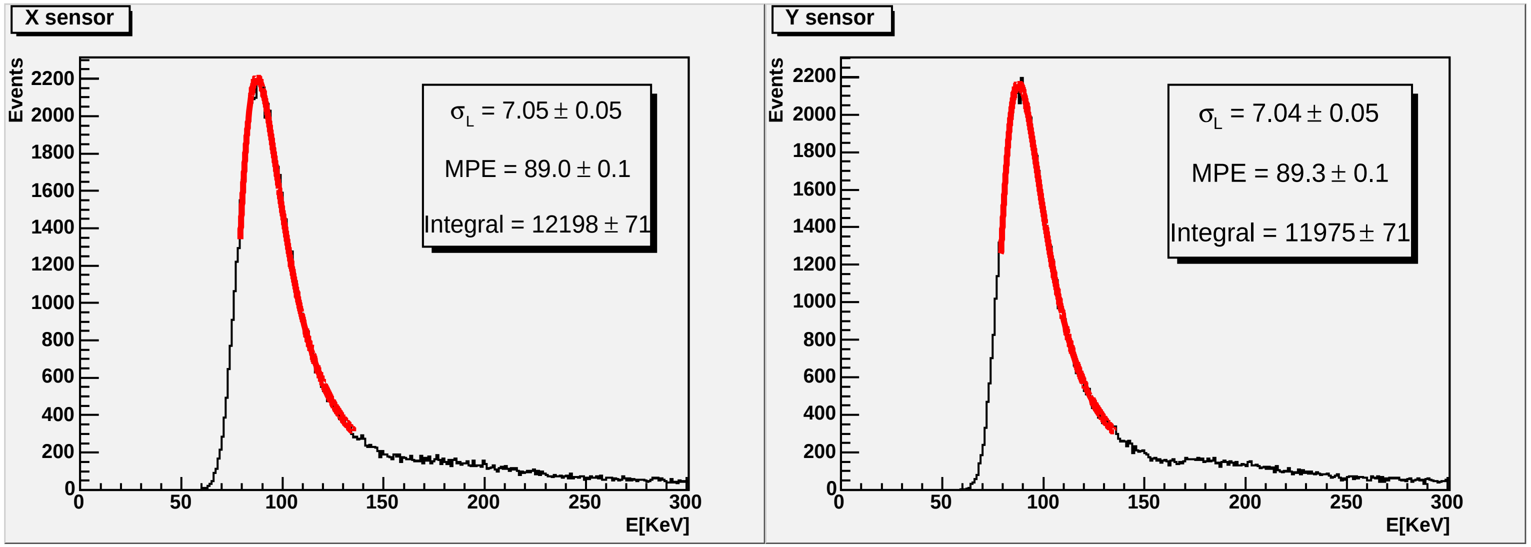


GEANT 4 simulation



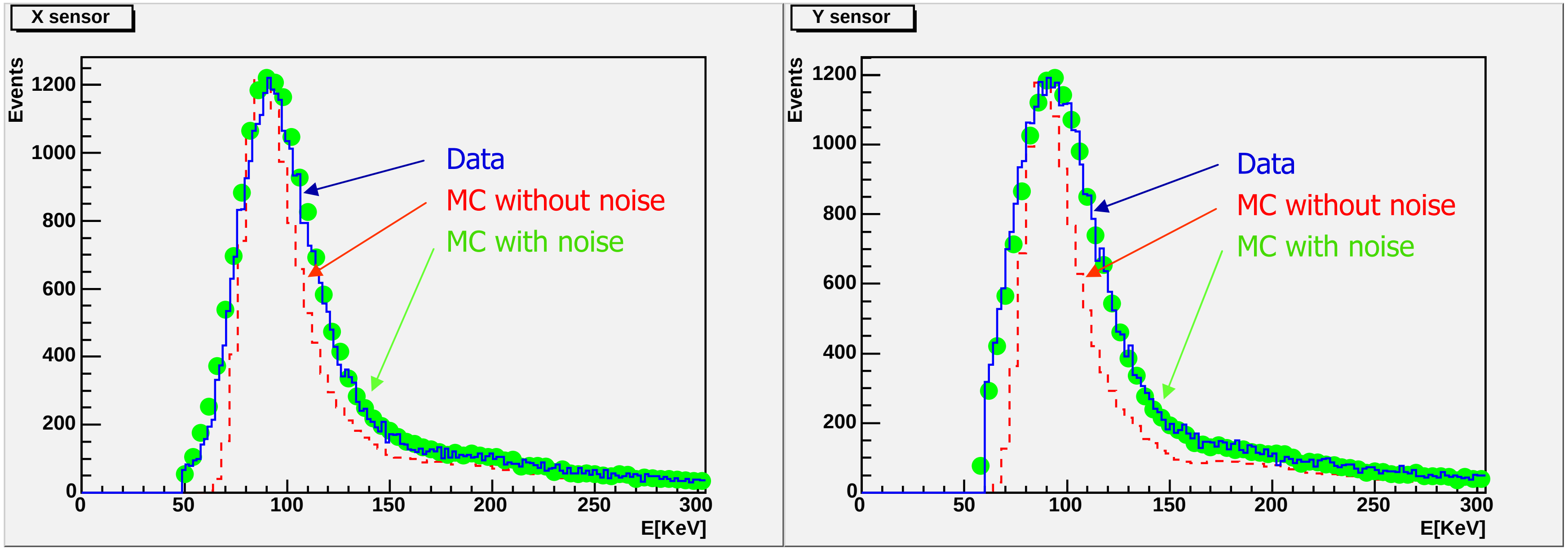
- For the analysis of the Test Beam Data a Monte Carlo was developed based on Geant 4.
- Fit MC data on a Landau distribution.

	Simulation (keV)	DATA (ADC counts)
Sensor X (MPE)	89.0±0.1	49.0±0.1
Sensor Y (MPE)	89.3±0.1	43.7±0.1



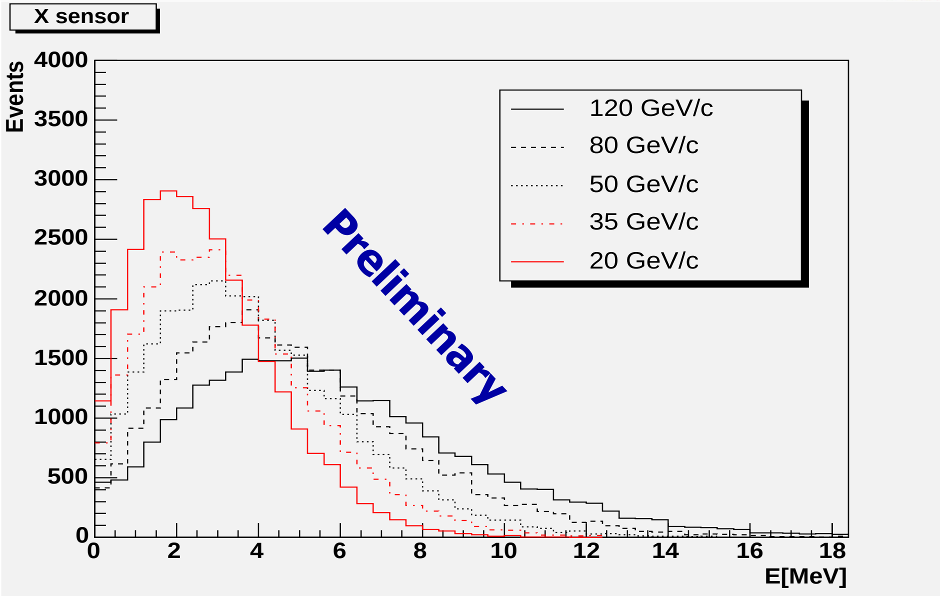
Data over MC

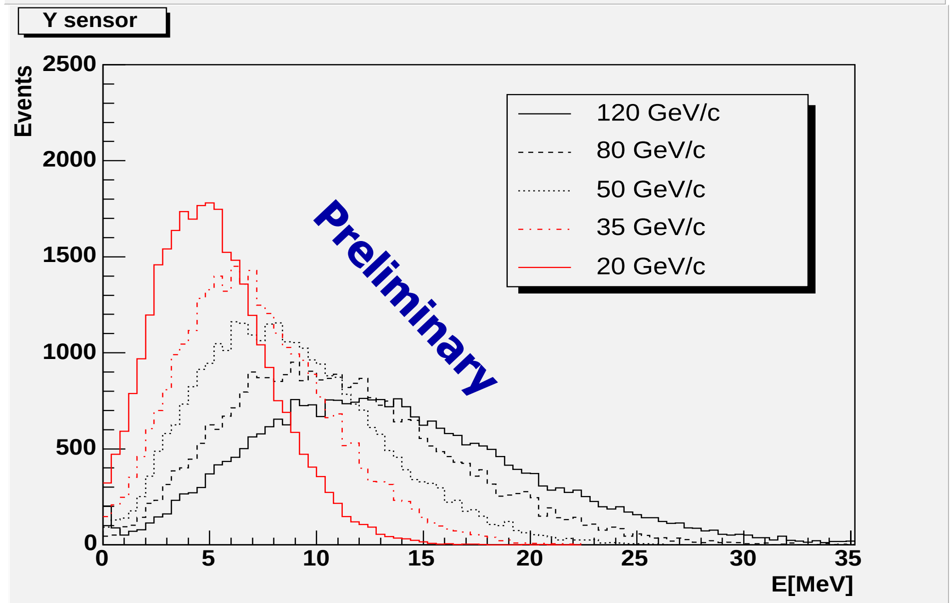
- Electronic noise added in MC in the form of a Gaussian distribution with widths:
  - X sensor: 5.4 ADC counts correspond to 9.8 keV
  - Y sensor: 5.9 ADC counts correspond to 12.1 keV



Electron Detection

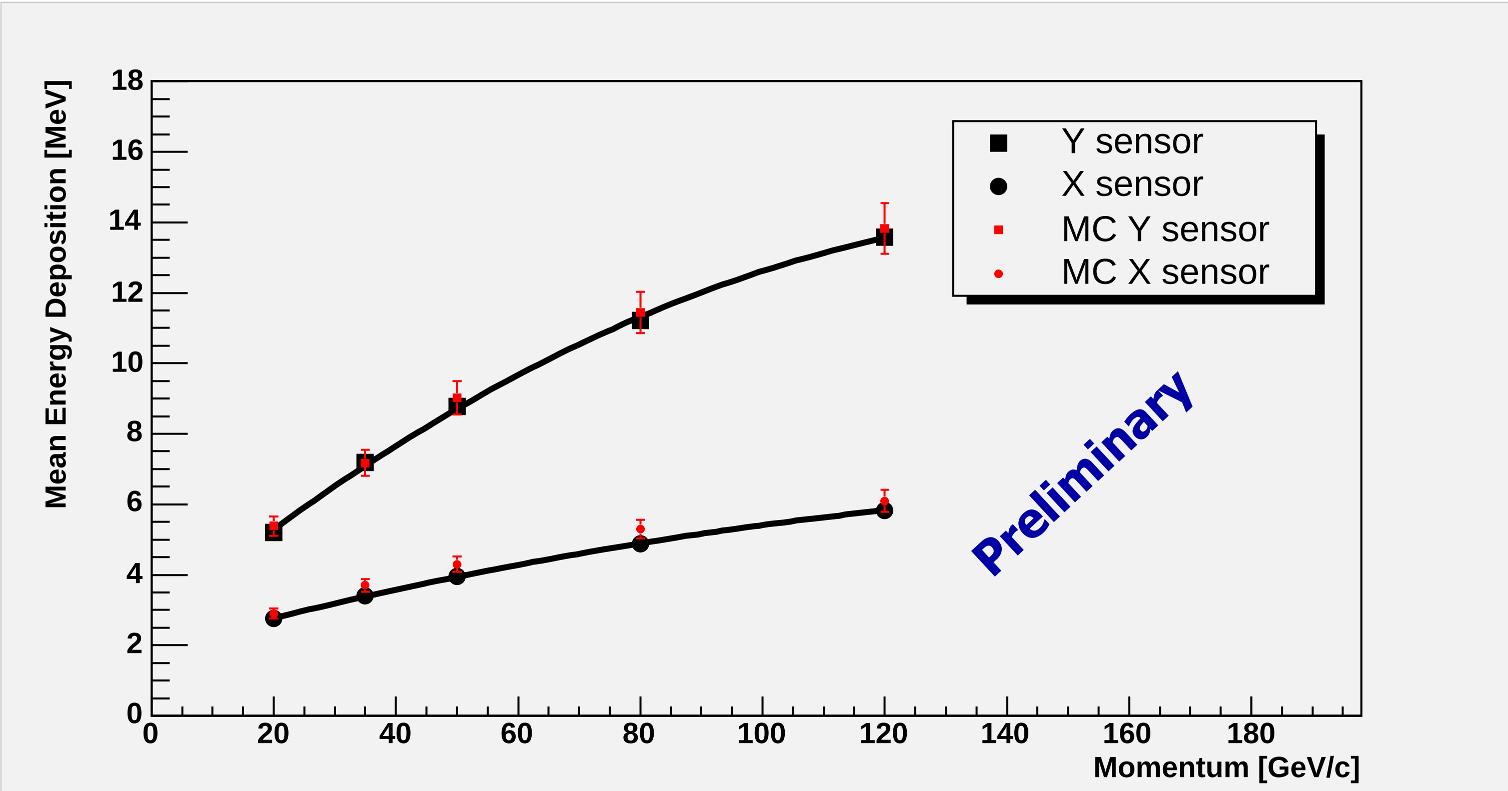
- Analysis of electron Data.
- Pedestal Subtraction.
- Common Mode correction.
- Total signal (ADC counts) = The sum of all strips after cutting 5σ (pedestal σ) on every strip.
- Use Absolute Energy Calibration (muons).
- Going from “calibration” to “normal” mode.
- Plot electron Energy Deposition in X and Y sensor.





Electron Detection

- Electrons Mean Energy Deposition per sensor and for the various momentum.
- Red points Monte Carlo.



Summary

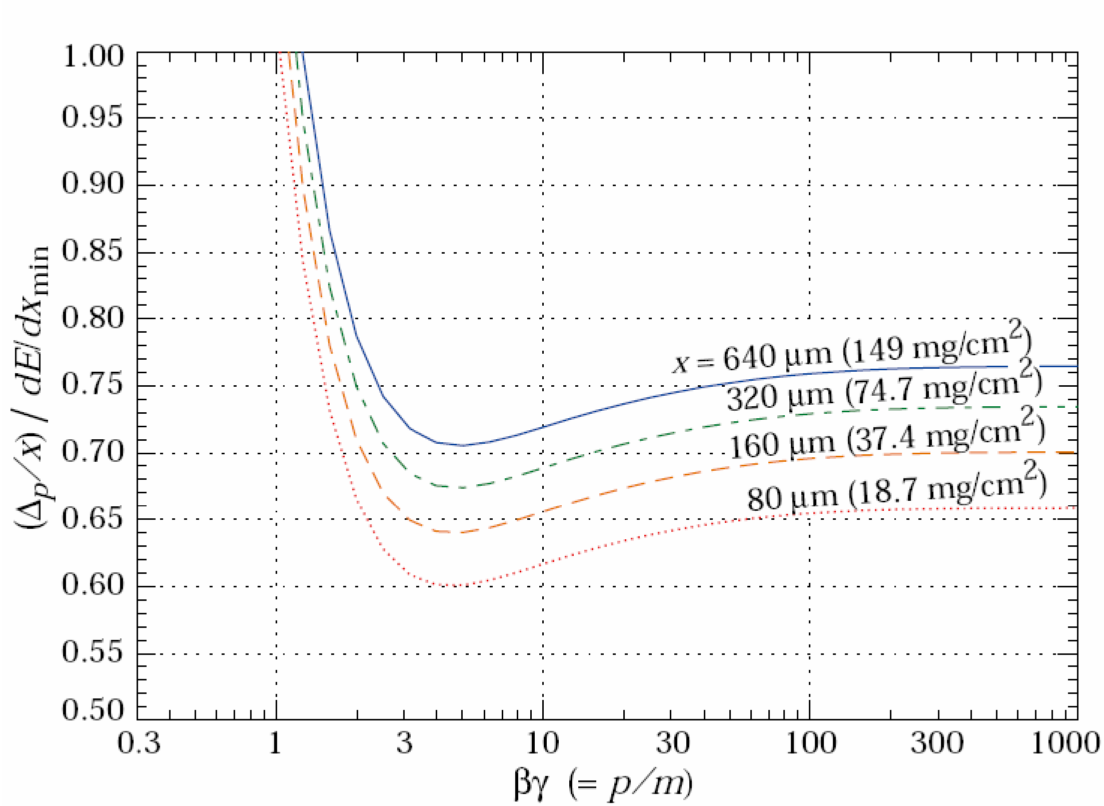
- The Muon signal per silicon sensor is extracted, after pedestal subtraction and common mode correction.
- The absolute calibration of the Preshower sensors is demonstrated.
- MC in excellent agreement with data.
- Electron – pion analysis in progress.

- Calibration before detector construction.
  - Calibration during construction of the ladders using cosmic muons.
- Calibration during data taking.
  - An absolute calibration will be performed at regular intervals in-situ in CMS using muons or even pions.

Spare Transparencies

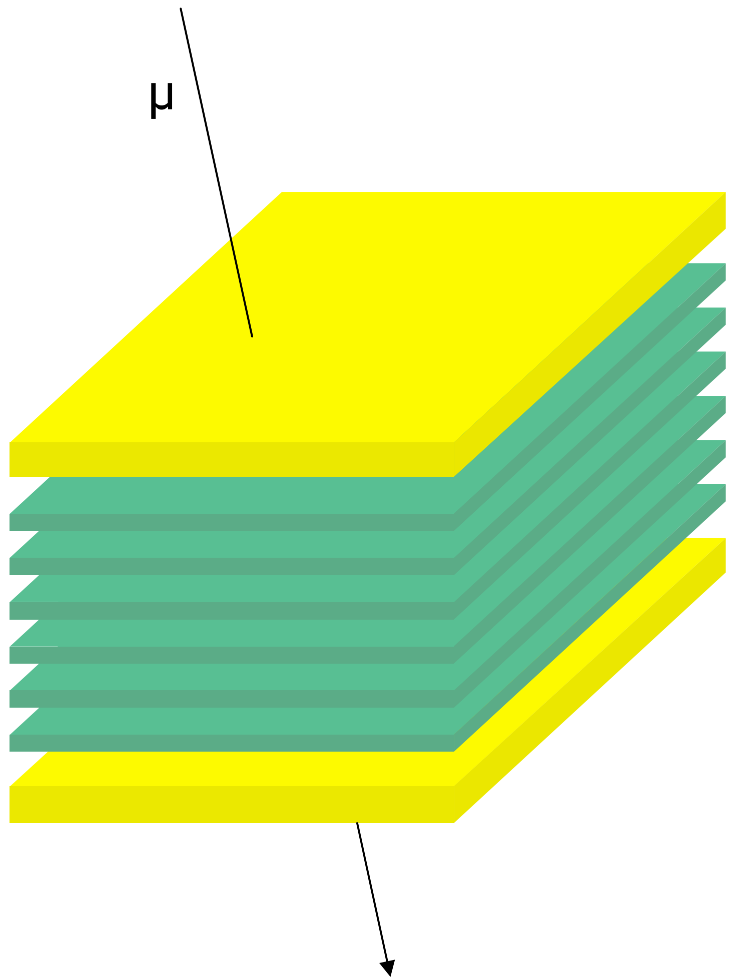
Preshower calibration

Muons with momentum ~150 GeV/c are on the most probable energy loss plateau. Energy deposition ~91 KeV for a 320μm thick sensor.



Most probable energy loss in silicon, scaled to the mean loss of a minimum ionising particle, 388 eV/μm (1.66 MeV g^{-1} cm^2) (PDG 2004)

Calibration using cosmic muons

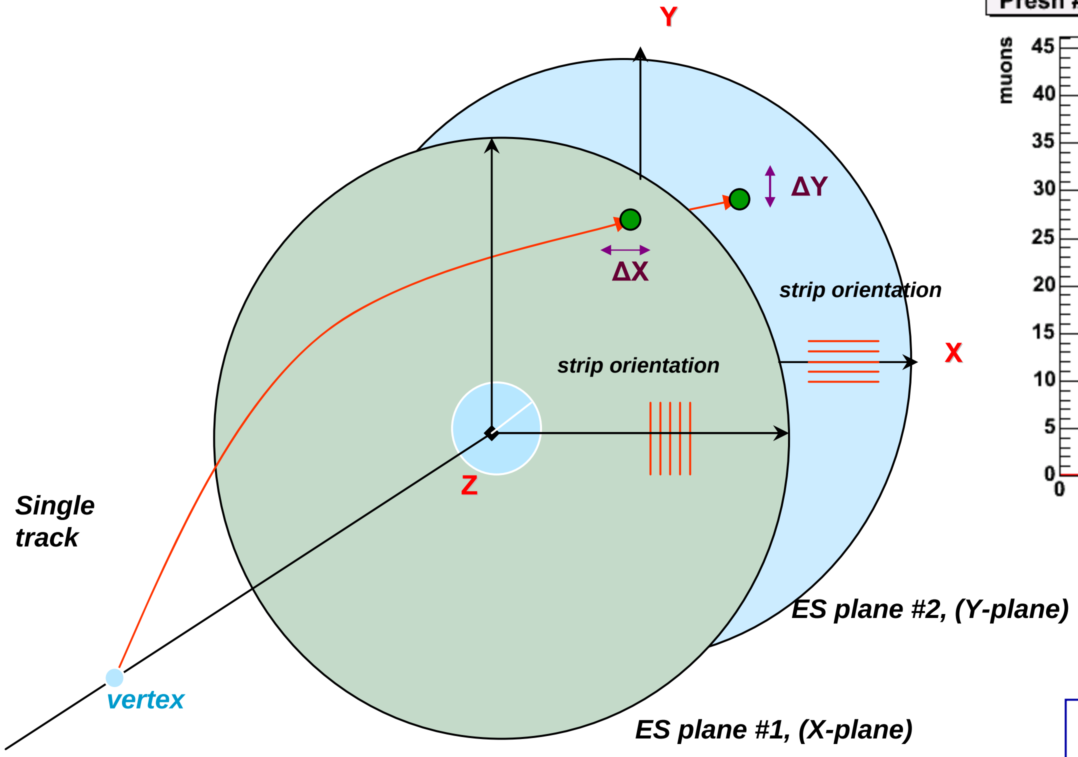


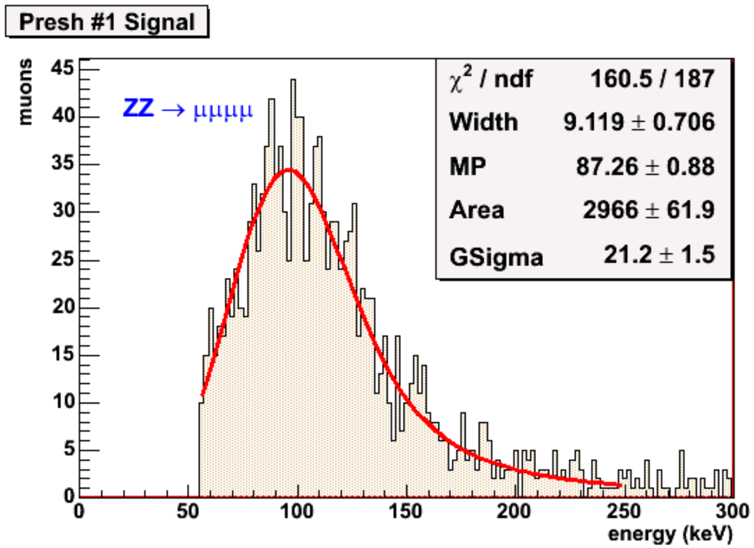
- Stack of 6 ladders.
- Two scintillators for triggering.
- Trigger rate ~1Hz.
- ~1 week data taking.

- One year operation for 536 ladders (4300 μmodules).

In-situ Absolute Calibration

- Using muon or jet events.
- Use tracker/muon system to predict ES strips that have been traversed.





<2 weeks needed for calibration at low luminosity