The CMS ECAL Pre-calibration with Cosmic Rays

- Introduction
- Pre-calibration with cosmic rays
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  - results
- Conclusions

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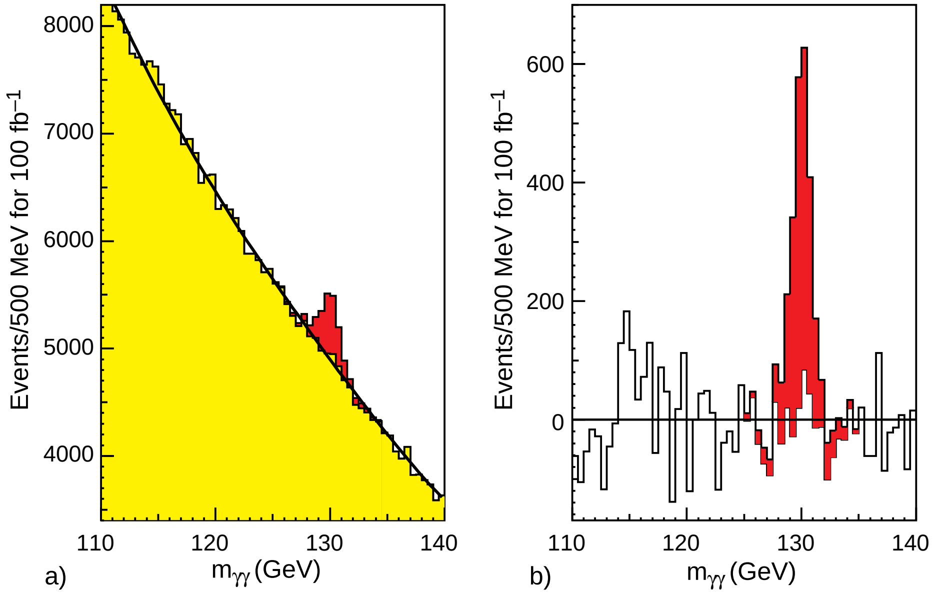
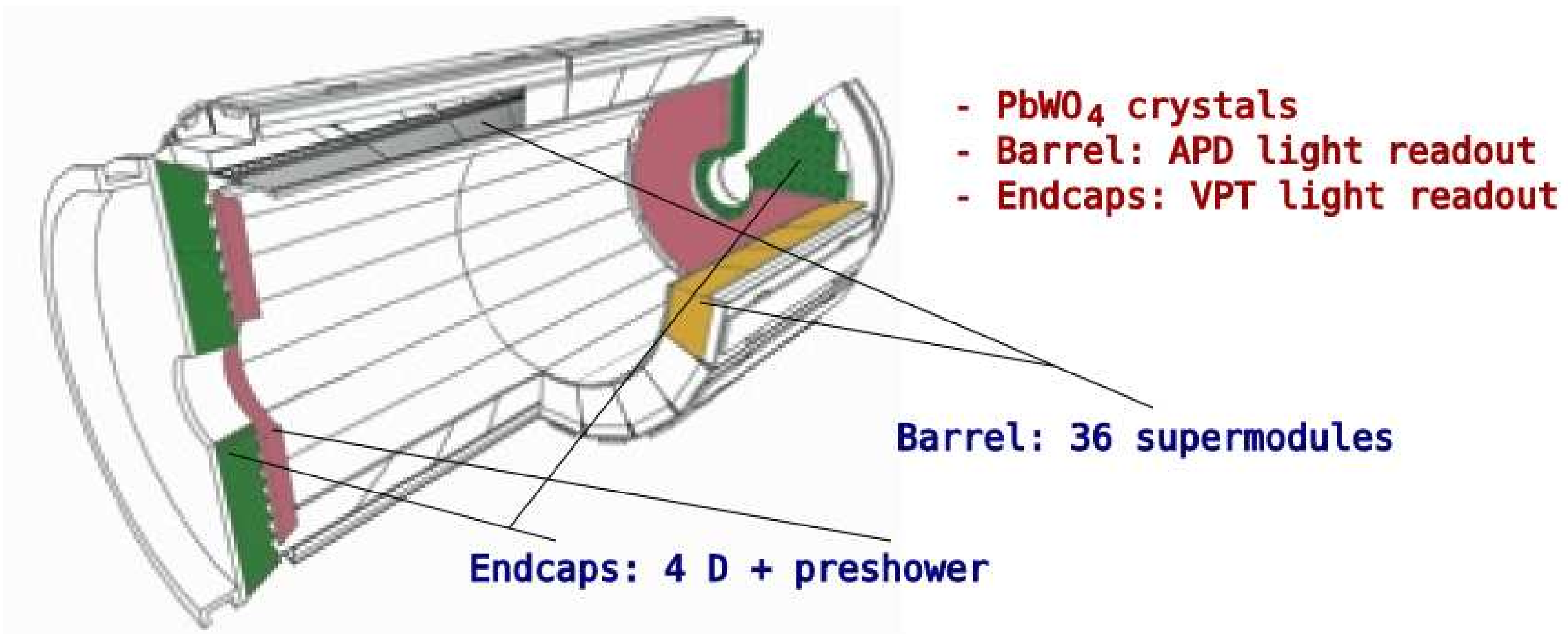
on the behalf of the CMS Collaboration

Higgs Hunt: the ECAL Benchmark

- Main channel: $H \longrightarrow \gamma\gamma$
  - "golden" for $m_H < 150$ GeV$/c^2$
  - excellent invariant mass resolution required to detect the peak ($\Gamma_H \sim$ MeV$/c^2$)
  - $\Rightarrow$ ECAL energy and angular resolutions are crucial

mass resolution required at 1%





The ECAL Calibration

Energy resolution goal: 0.5% @ high energies

- Initial (inter)calibration:
  - electrons from test beam: $< 0.5\%$ (fraction of the calorimeter)
  - laboratory Light-Yield measurements: 4% (all supermodules)

- *In situ* (inter)calibration:
  - ϕ symmetry (minimum bias and jet triggers): rings at $\sim 2\%$ within a few days
  - $Z \to e^+e^-$: rings at 0.5% in 1 day low lumi, absolute scale
  - $W \to e\nu$ using E/p from tracker: 0.5% (all crystals in $\mathcal{O}(1$ month$)$)
  - other methods under study ($\pi^0 \to \gamma\gamma$, $\eta^0 \to \gamma\gamma$, $Z \to \mu^+\mu^-\gamma$, m.i.p. ...)

!! Large material budget in front of ECAL ($\sim 1X_0$) due to the tracker material

Pre-calibration with cosmic rays for the ECAL barrel (goal 2%):

- **Acceptable ECAL performance at start-up**
- **Good starting point for calibration with physics events**

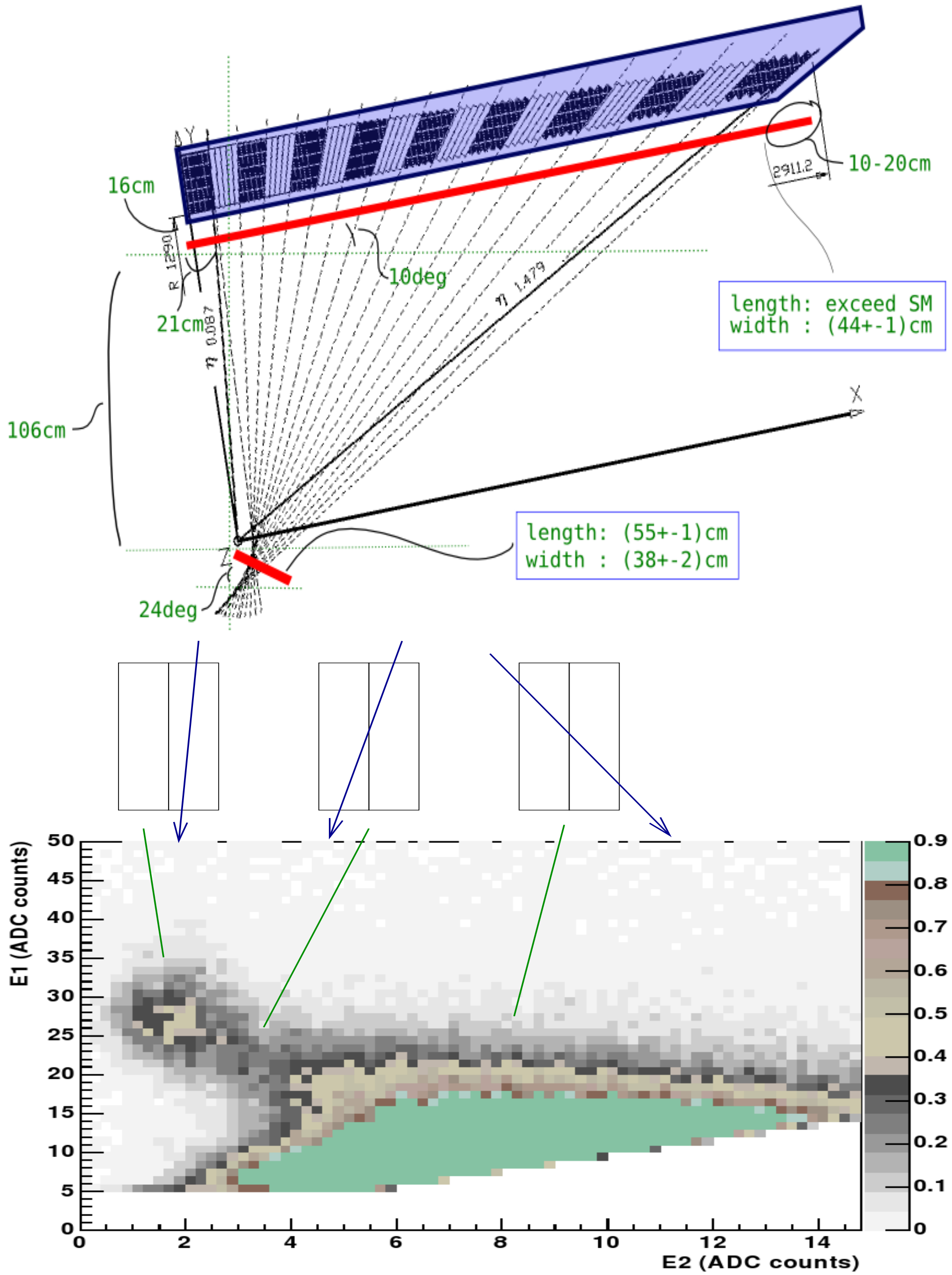
The Pre-calibration with Cosmic Rays

- cosmic ray muons (m.i.p.) aligned to a crystal provide a reference signal of ~ 250 MeV for calibration
- First selection of quasi "pointing" muons: trigger geometry
- APD gain at 200 enables vetoing on neighbours to discard non-aligned muons
  - $\times 4$ w.r.t. CMS final setup
  - measured with a laser-based light injection system
- Supermodule inclined by $10°$ to increase flux in module 4

Notation for crystal energies:

E1 = muon candidate

E2 = highest among the neighbours



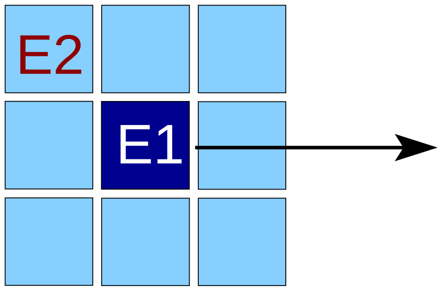
The Pre-calibration with Cosmic Rays

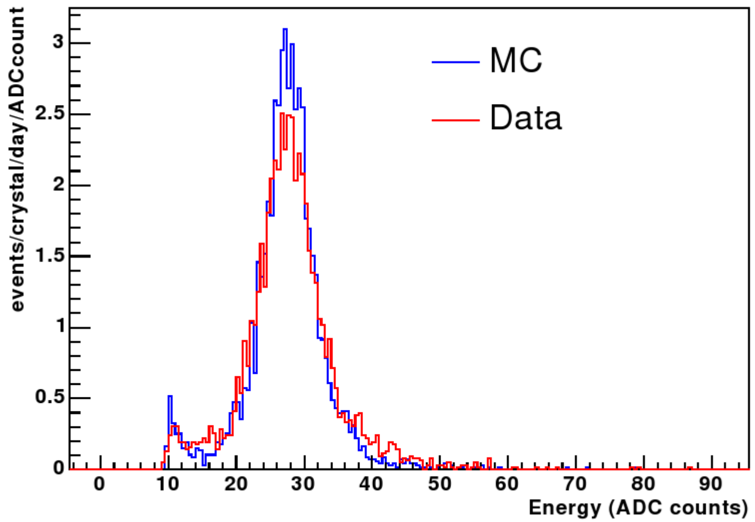
- Monte Carlo description of the experimental setup as well as of the cosmics muon flux (energetic and angular spectrum)
- Aligned muons:

E1 > 10 ADC counts

E2 < 3 ADC counts

(electronic noise:
1 ADC count)

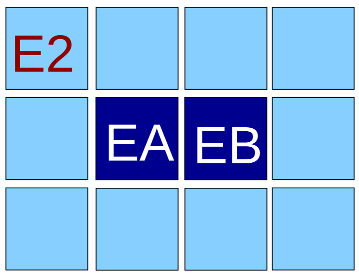




- Muons crossing two crystals:

EA + EB > 12 ADC counts

E2 < 3 ADC counts

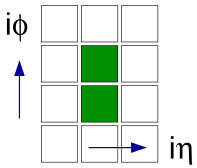


Results focus on internal crystals.

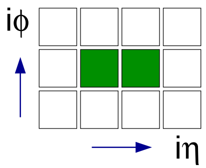
Independent Data Samples

Vetoing on the neighbours allows to identify three independent data samples:

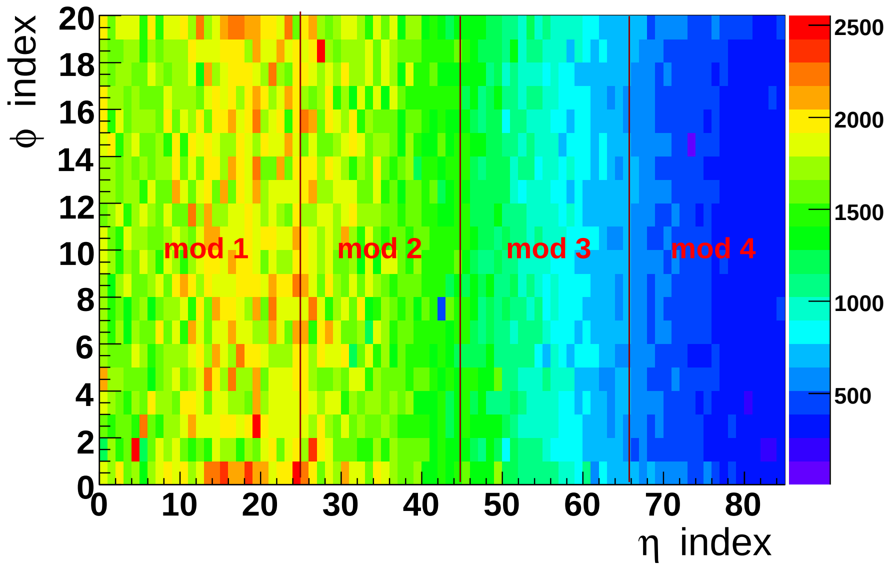
- single crystal events: muons aligned with 1 crystal
- double crystal events: muons crossing 2 crystals
  - in the same $i\eta$ ring



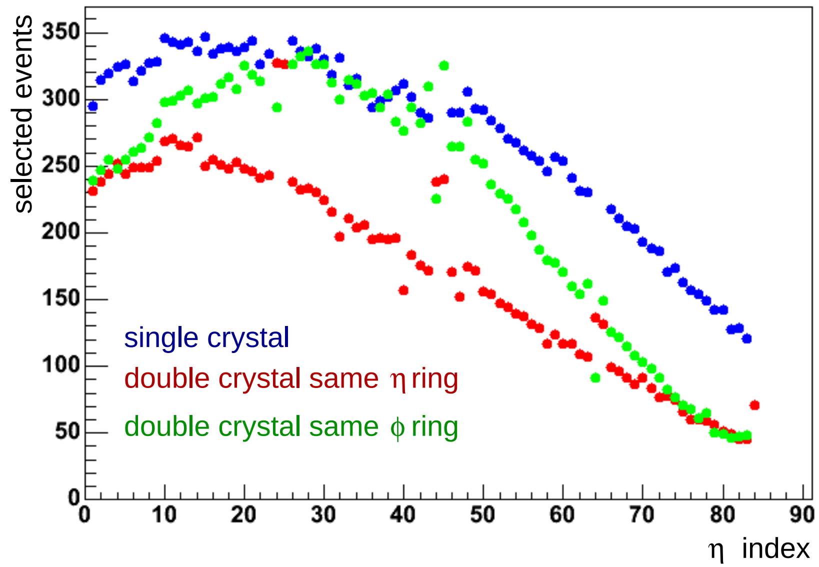
  - in the same $i\phi$ ring



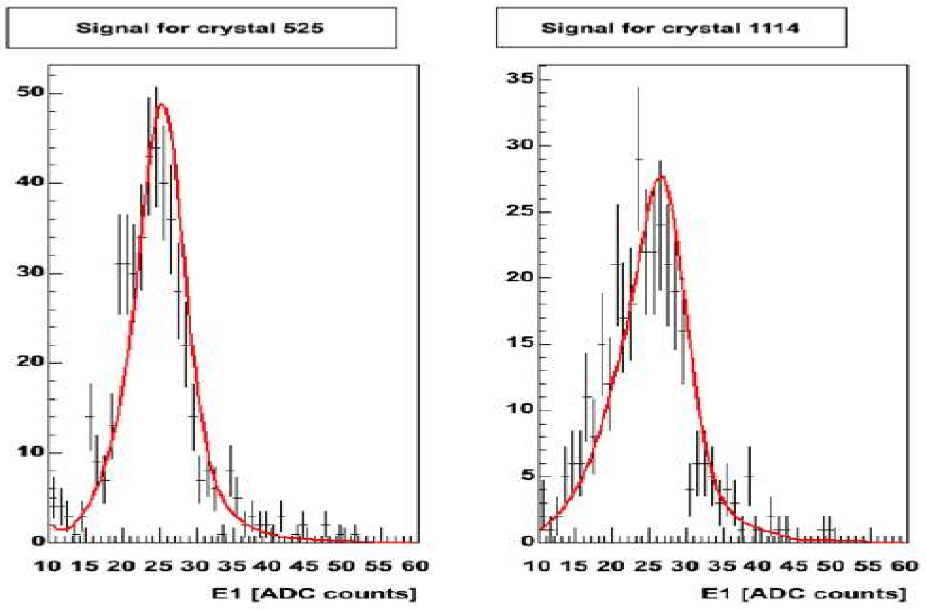
Events before selections



Useful events for calibration



Single Crystal Method

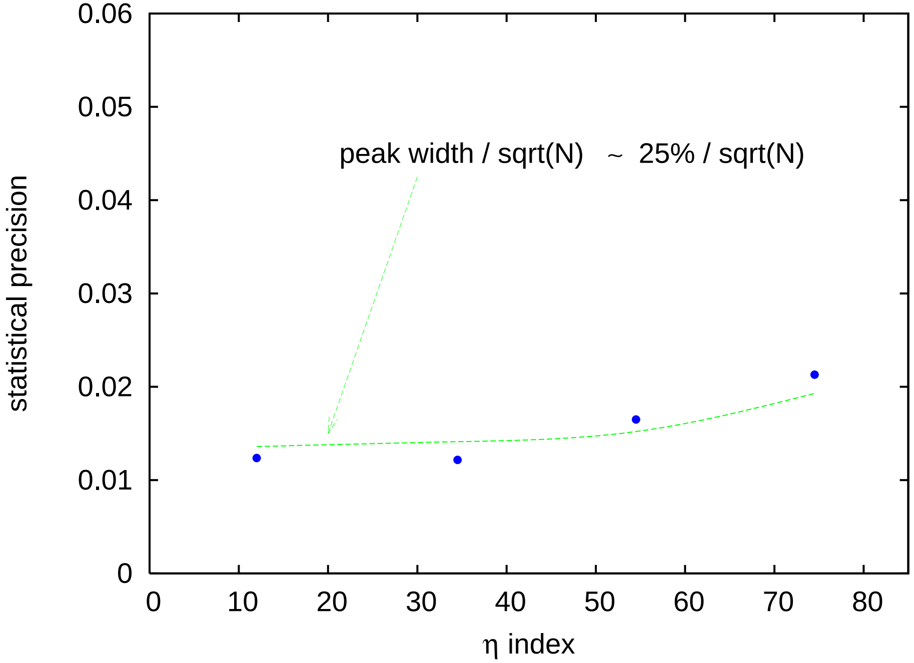


- unbinned maximum likelihood fit to data of $i\eta$ dependent reference MC distributions (red lines)

$$\mathcal{L} = \Pi_i \; pdf(c \cdot E_i)$$

  - c, the scale of the reference, gives the intercalibration coefficient

- method robust with the statistics provided by a week of data (live-time)
  - useful events: ~ 600 kevt/day
- statistical precision varies inside a supermodule according to the muon flux
  - agreement with the expected behaviour given the width of the distributions ($\sim 25\%$)

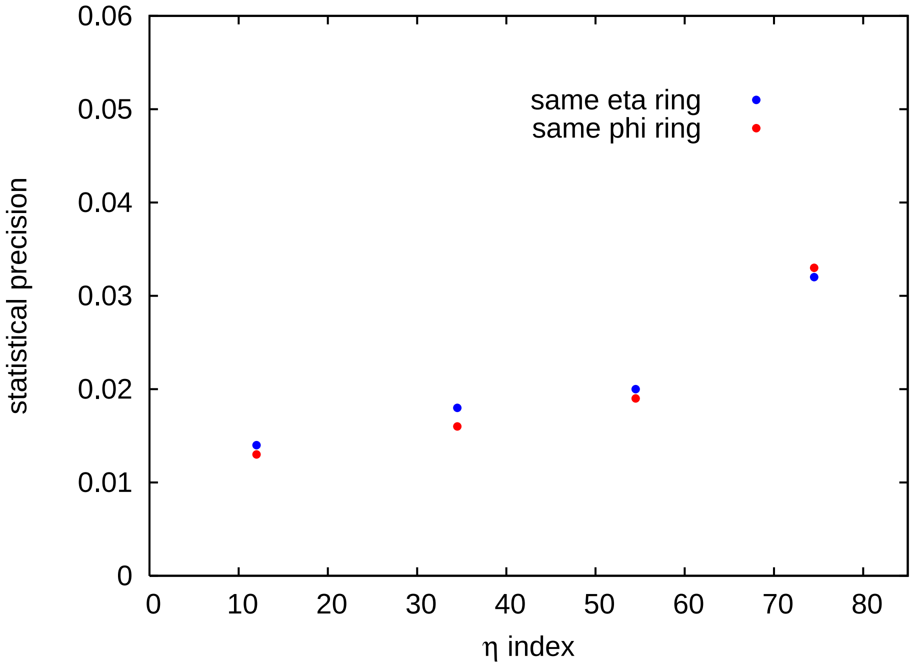


Double Crystal Method

- Matrix inversion technique:
  - Total muon energy deposited in a pair of crystals:
    $E_{tot} = c_A \cdot E_A + c_B \cdot E_B$
  - On the average, it holds
    $\langle E_{tot} \rangle = \langle c_A \cdot E_A + c_B \cdot E_B \rangle = \langle E_{true} \rangle$
  - Minimize a χ^2 for each calibration constant c_i:
    $\chi^2 = \sum_i \frac{(E_{true} - E_{tot})^2}{\sigma_E^2}$

- only input needed is the expected $\langle E_{true} \rangle$ from Monte Carlo
- two independent data samples (same $i\eta$ ring and same $i\phi$ ring)

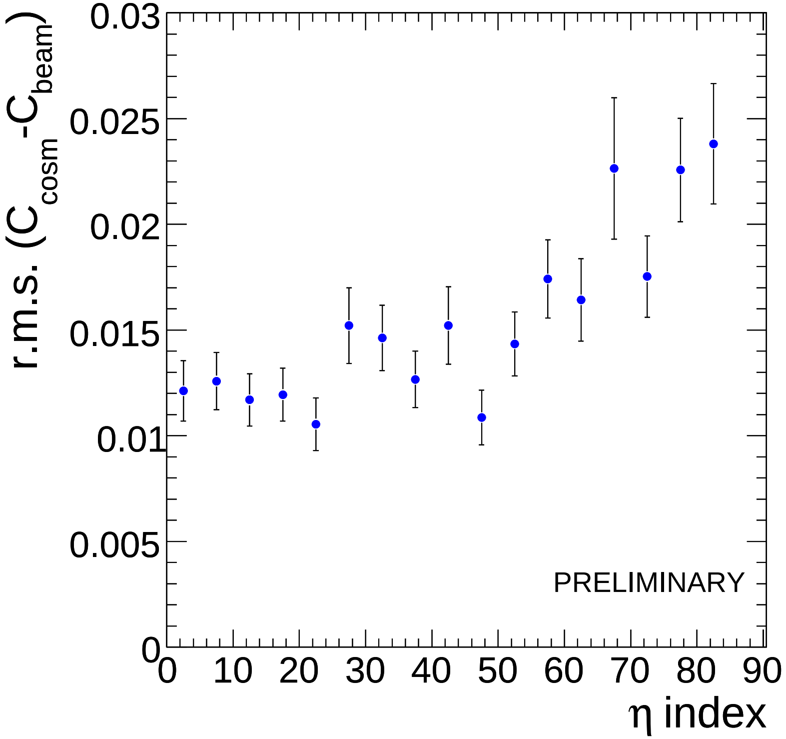
$\Rightarrow$ possibility to combine them



Comparison with Electron Beam Calibration

This slide only: focus on single crystal analysis

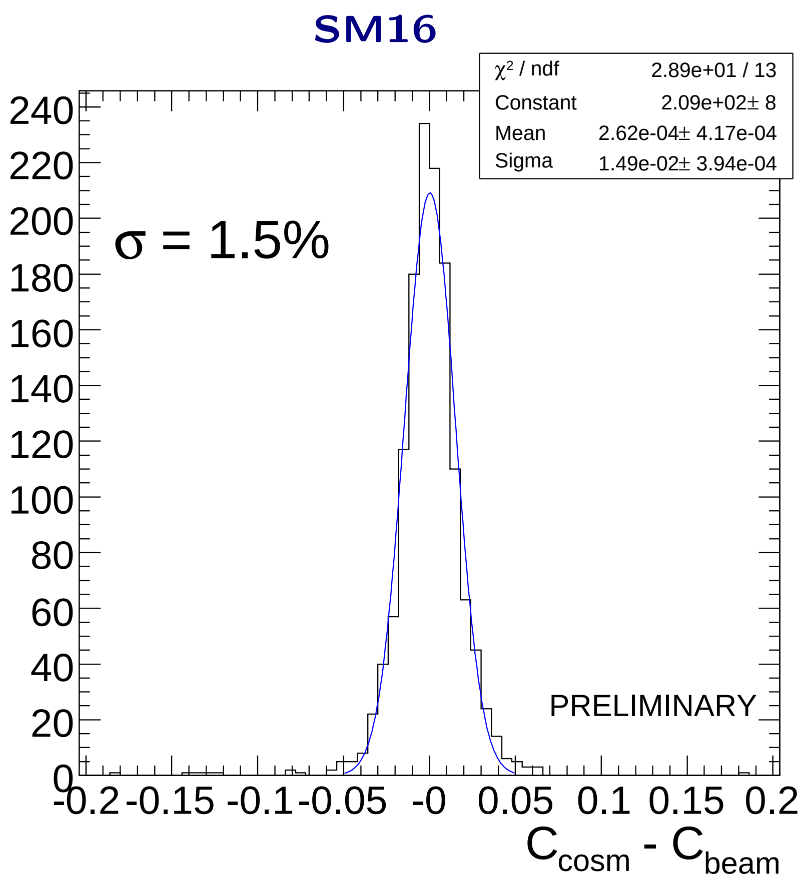
- Test Beam is using a 120 GeV electron beam reproducing final CMS geometry and setup (see W. Funk talk)
  - coefficients obtained from the energy deposited in the single hitted crystal
- APD gain ratio gain200/gain50 measured at 0.1% with a laser monitoring system
  - spread of the distribution: 2.5%
- Preliminary results already available for 2 supermodules (SM16 and SM18)

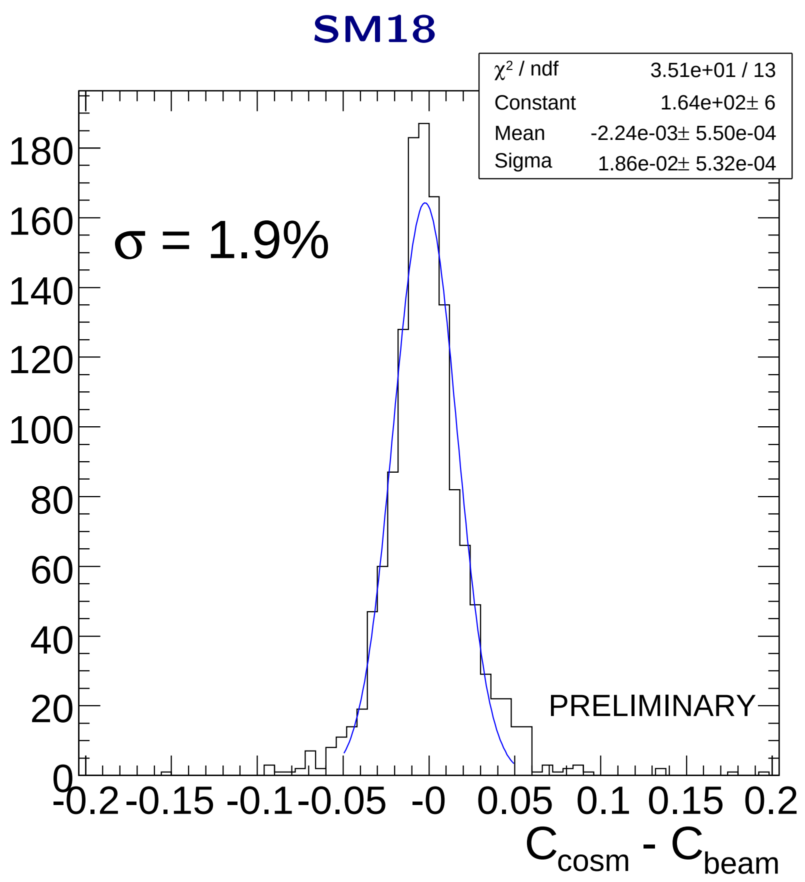


SM16
each point accounts
for ~ 90 crystals

Combined Results

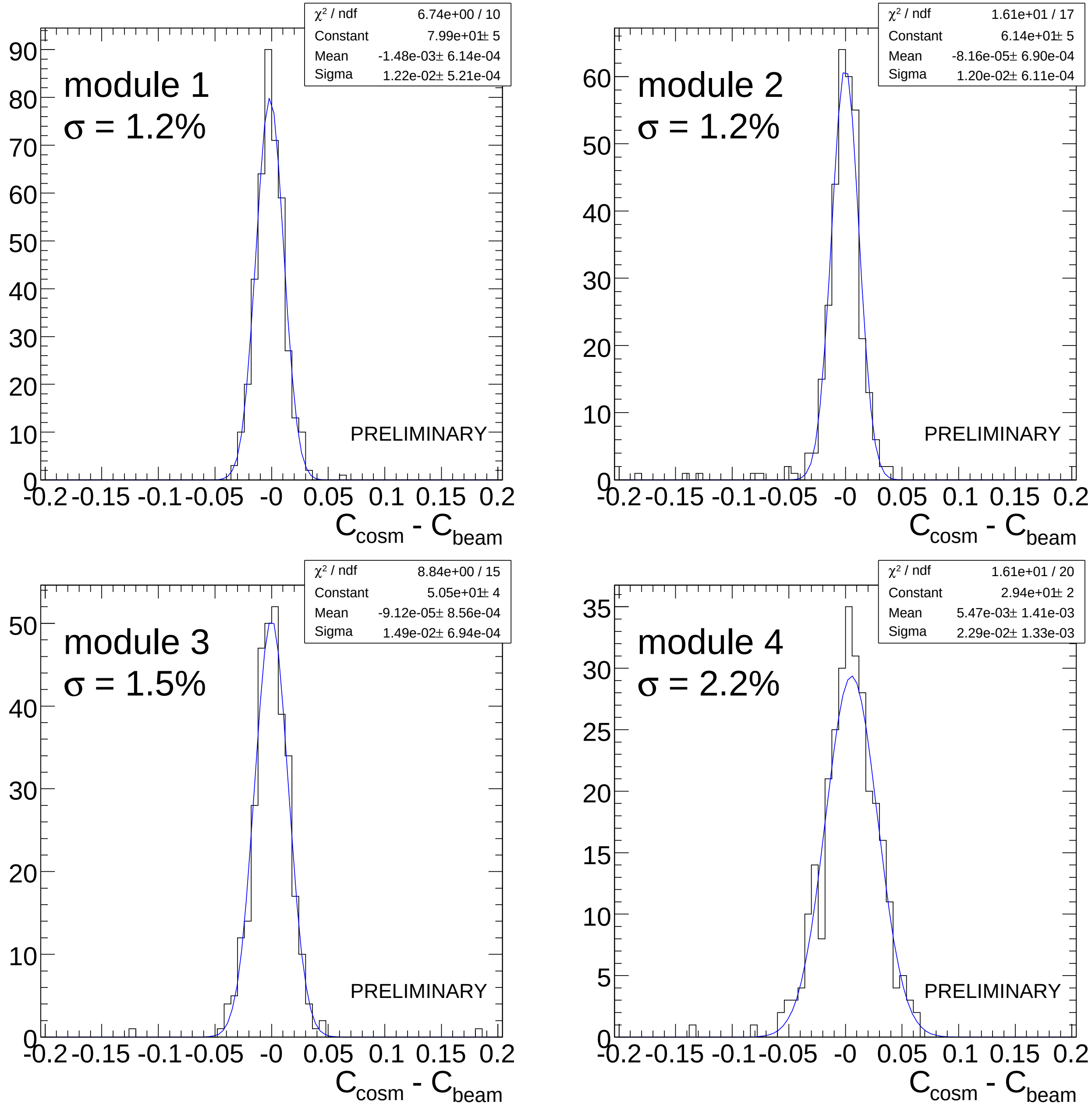
The results from the three independent data samples are combined with a weighted mean according to their statistical precision along $i\eta$:





Systematic uncertainties are evaluated by comparison to electron data on a few supermodules

Combined Results: detail for SM16



Conclusions

- So far 22 supermodules of the CMS ECAL barrel have been exposed to cosmic rays and calibrated $\Rightarrow$ important test for commissioning
- The pre-calibration with cosmic muons proves to be the most accurate one that can be performed for all the channels of the ECAL barrel
- ~ 5 million triggers collected in ~ 10 days ensure a statistical accuracy at the level of 2% or better
- Detailed comparisons with test beam results preliminarily show an overall agreement of 2%
- Systematic uncertainties are under detailed study
- The data taking schedule will allow to have all the ECAL barrel supermodules exposed to cosmic rays before the final installation in CMS, which will start on November

Reference: CMS NOTE 2005/023