Cosmic ray calibration of the CMS $PbWO_4$ crystal electromagnetic calorimeter

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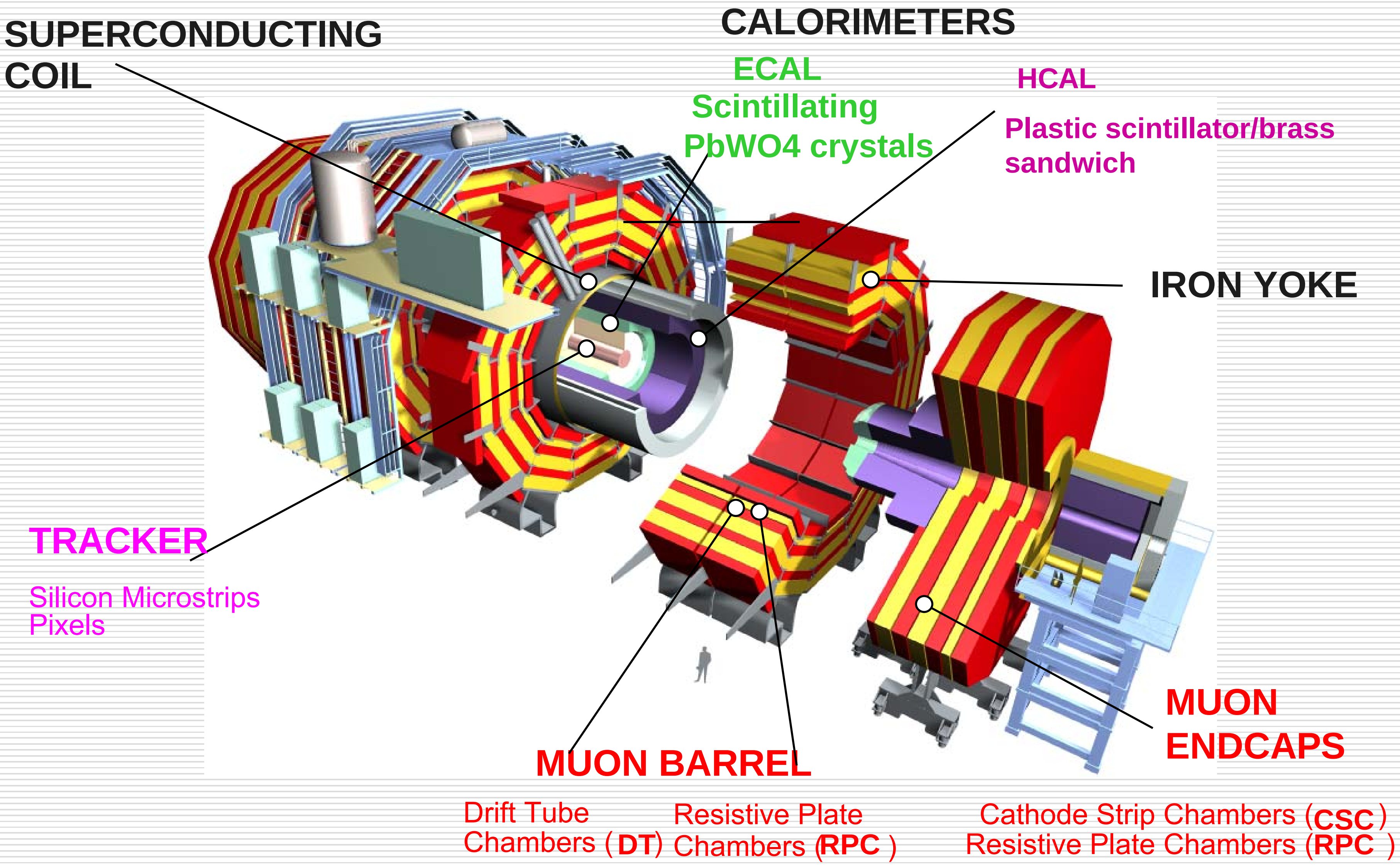
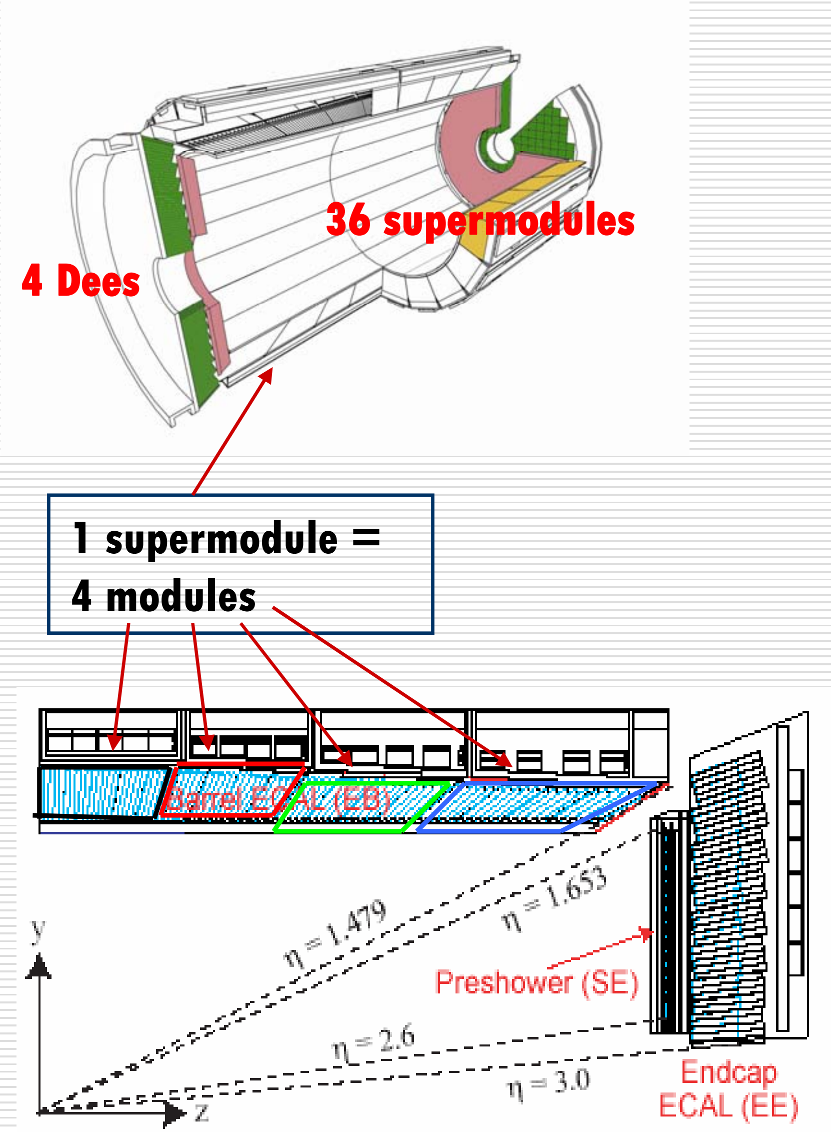
Outline

- CMS and ECAL
- The setup and muon data sample
- How muons look like in ECAL
- The intercalibration method based on aligned muons
- Achievable precision
- Conclusions

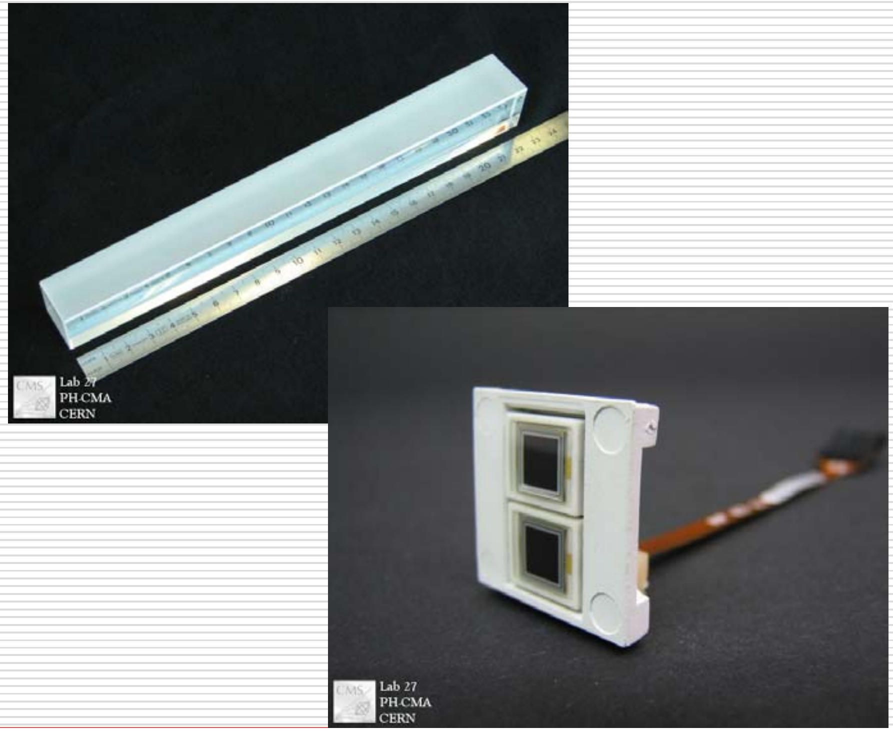
CMS Overview



CMS ECAL reminders



- CMS ECAL: scintillating crystal $PbWO_4$ (see R. Paramatti's talk)
- Barrel photodetectors: Avalanche Photo Diodes operated at gain=50



ECAL inter-calibration

- Each crystal is calibrated in the lab with an automated procedure before being inserted in the ECAL modules C_{lab} (see R. Paramatti's talk).

  Measurements of:
  - light transmission spectrum
  - light yield from ^{60}Co

  are and used to predict a calibration constant
- Comparison to test beam shows an agreement of 4.2% between C_{lab} and $C_{test\ beam}$

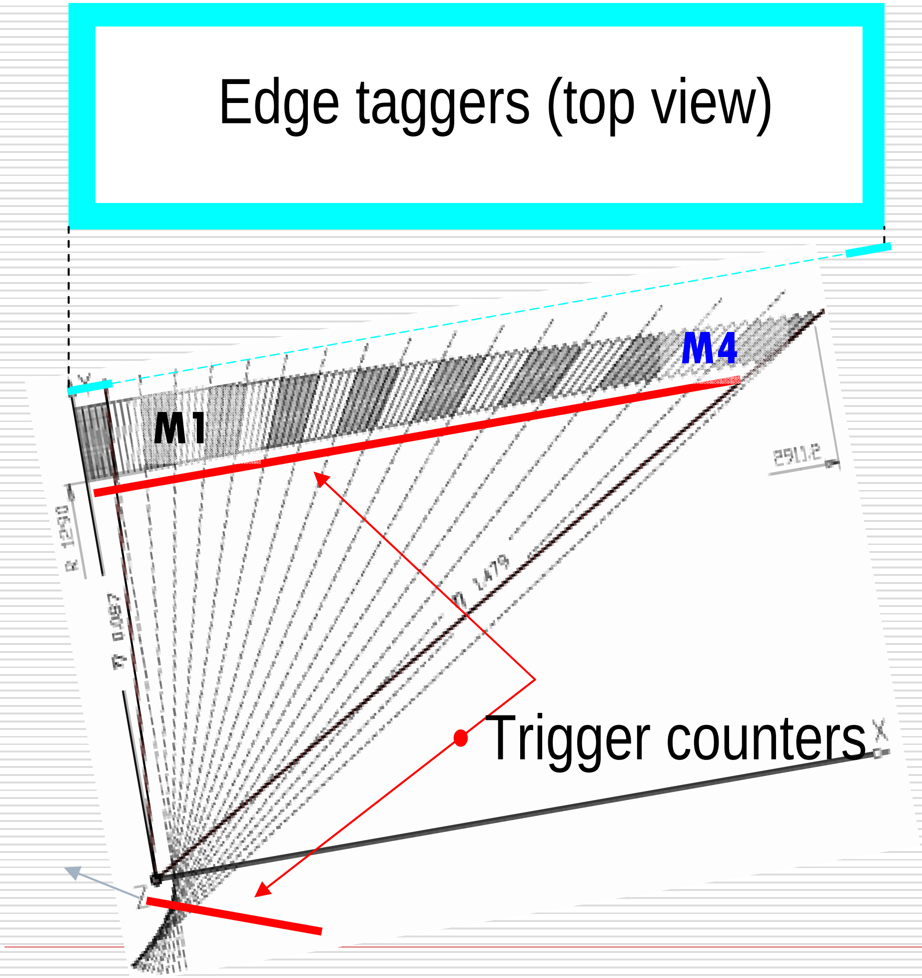
- Goals of cosmic muons calibration:
  - Providing an intercalibration method alternative to the laboratory measurements which can give information for all the 61200 channels of the CMS ECAL barrel and have a better precision.

    Only few of the supermodules will be calibrated with electrons at the test beam this summer.
  - Taking cosmics data with each supermodule is an excellent complement of the burn-in and test procedure (see P.Rumerio's talk).

The Setup

Setup and Data sample

- SM inclined by 10°
- Quasi-pointing trigger with additional edge taggers

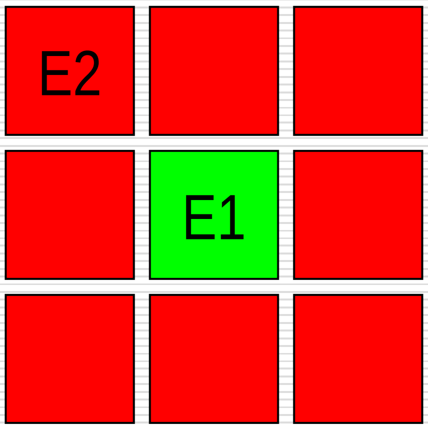


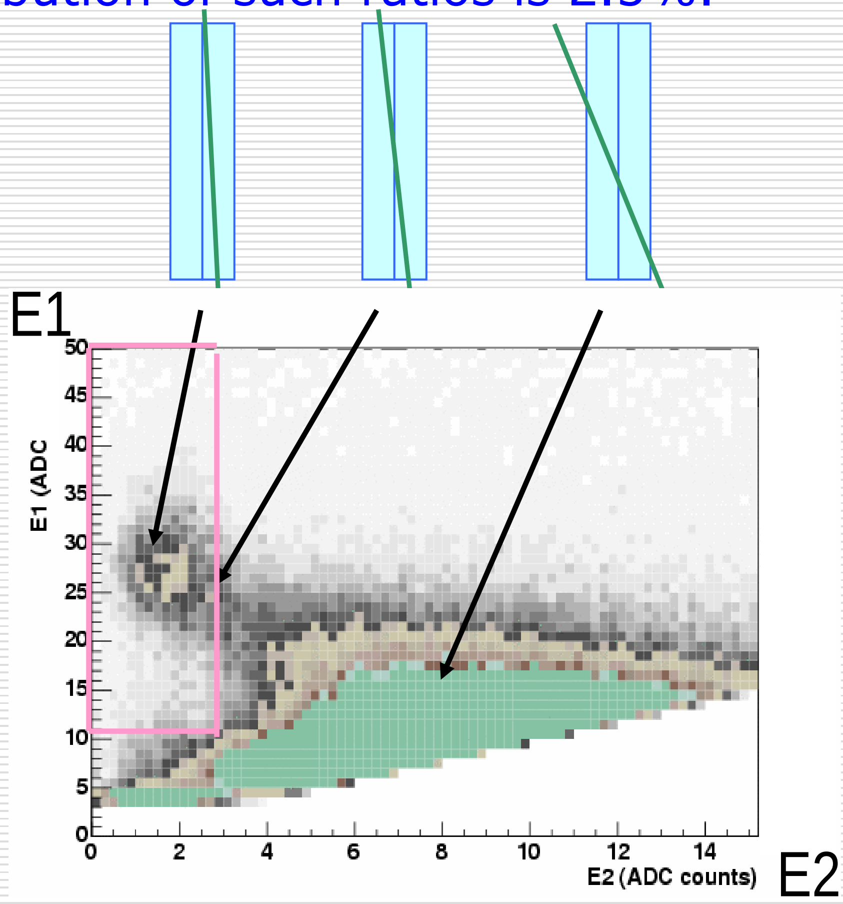
- 10 supermodules have been exposed so far to cosmic rays at the stand by the CERN North Area.
- They came to the cosmics stand after the 1 week of tests which follows the mounting of the electronics

- One supermodule has very large statistics, over 34M triggers
- All the others range between 4 and 7M, corresponding to 10-15 days of live time

Muons in ECAL

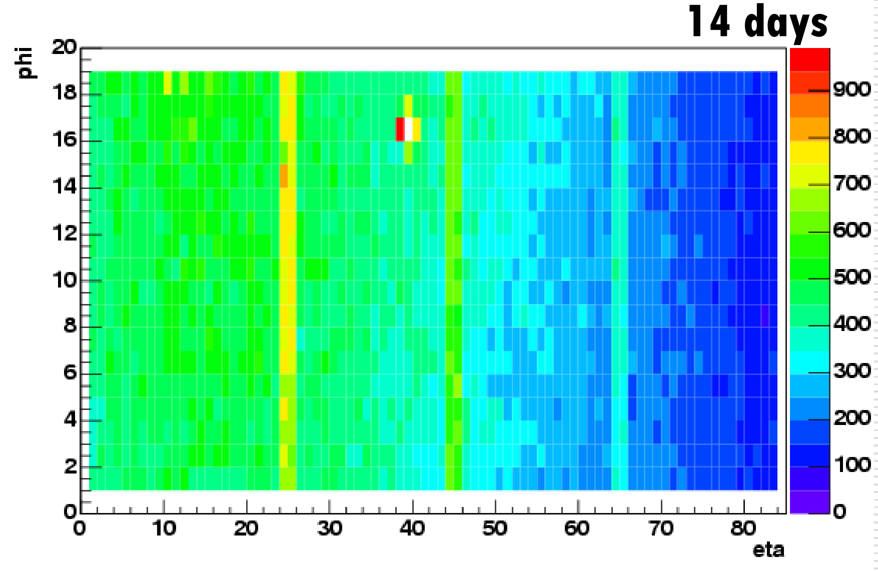
- Cosmic muons aligned to the crystal axis provide a reference signal for calibration, depositing 250 MeV of energy in the $PbWO_4$.
- APD's are operated at gain 200 =X4 w.r.t. CMS
- The ratio gain200/gain50 is measured very accurately using laser events - the spread of the distribution of such ratios is 2.5%.
- Signal to noise ratio: 15
- Pointing muons selected, vetoing on neighbours
  - E1>10 ADC counts
  - E2< 3 ADC counts





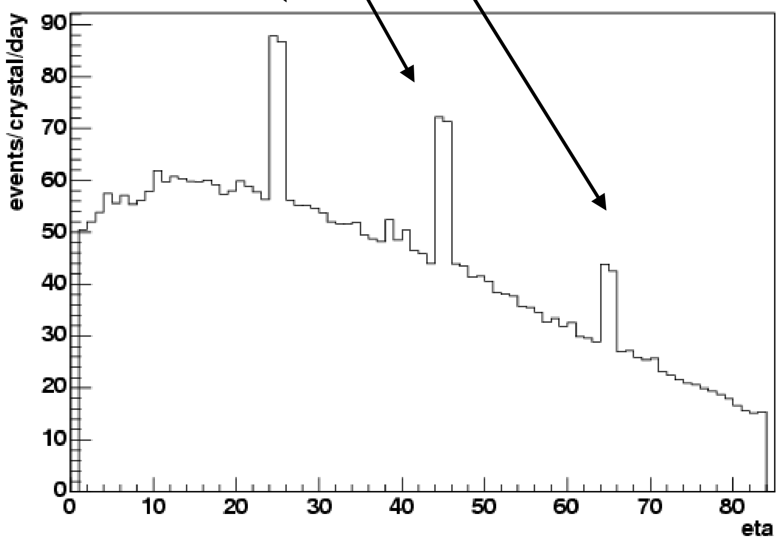
Single crystals muon candidates

- Number of single muon candidates VS ηφ:



- module1 ~60 evts/cry/day
- module4 ~15 evts/cry/day

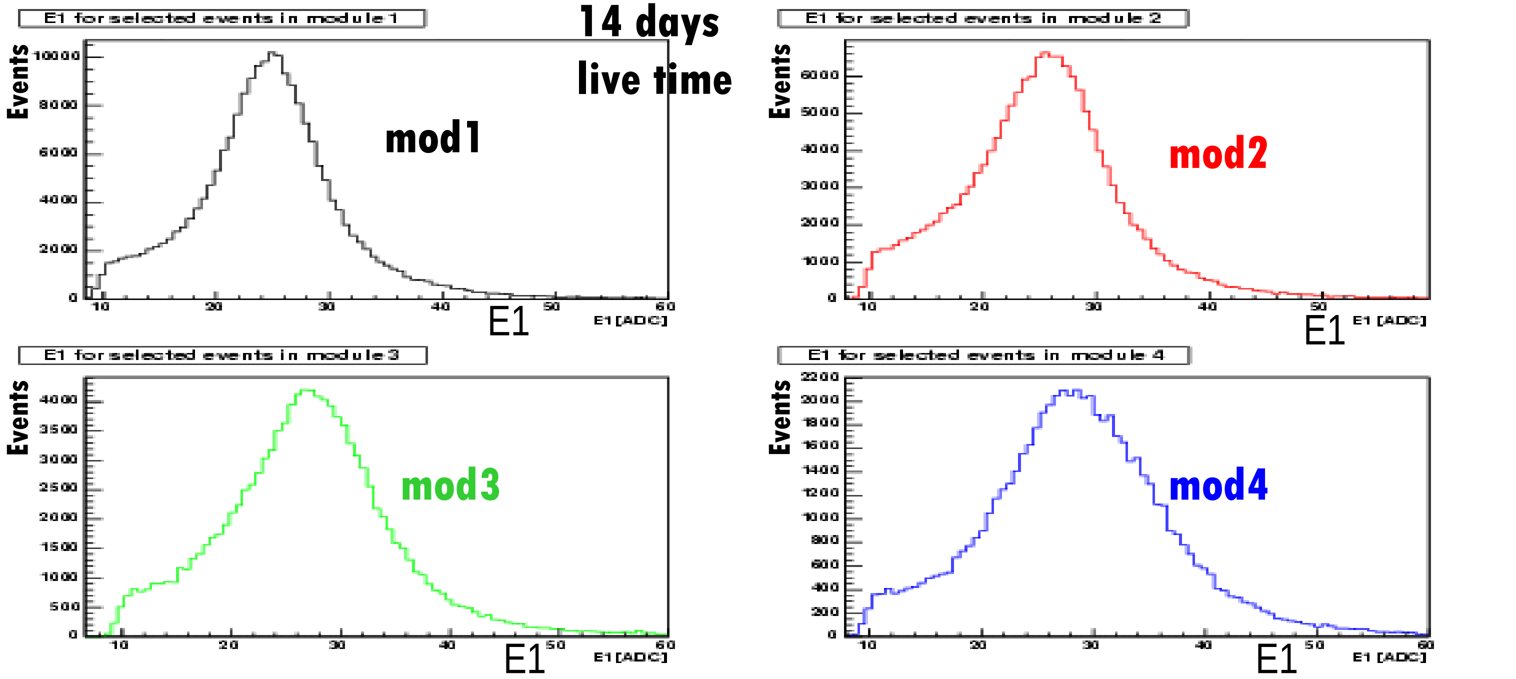
Larger inter-crystal spacing between modules makes veto on neighbours less efficient



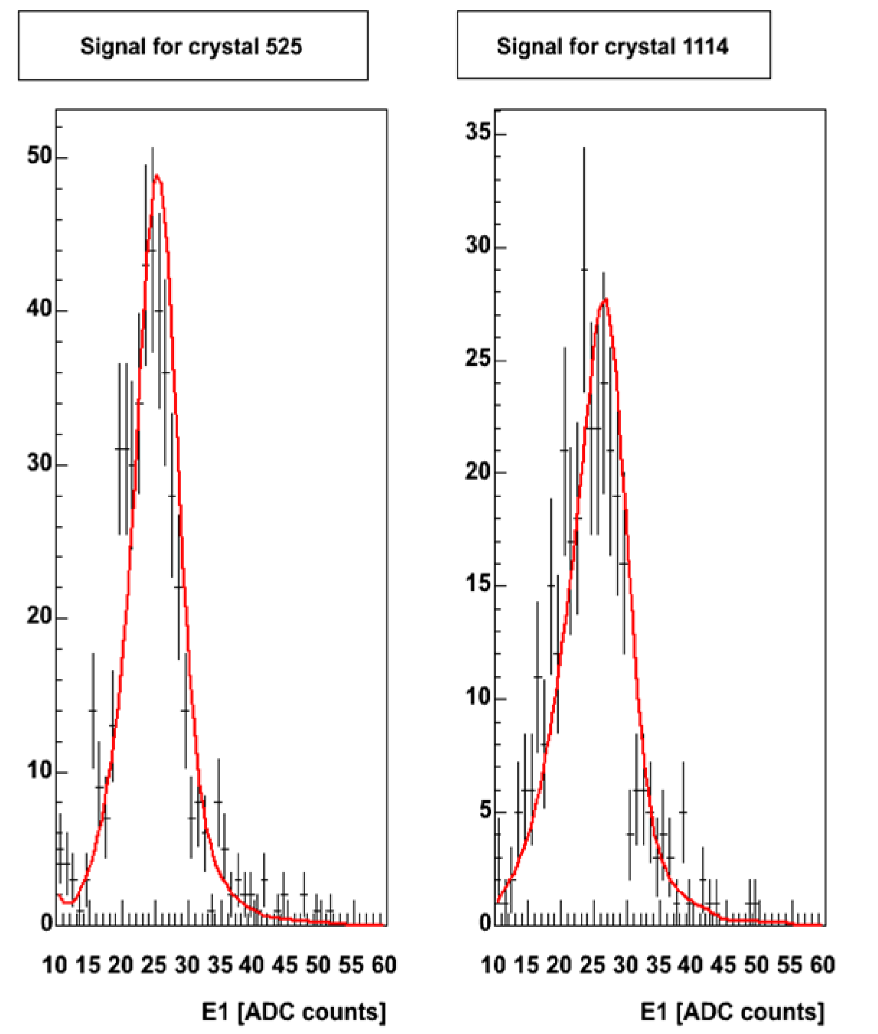
- Cosmic rays flux at sea level: ~130 $m^{-2}s^{-1}$. First selection made by the trigger geometry
- 7% of the triggers are single crystal muon candidates

Single crystal analysis (1)

- The intercalibration coefficients are determined from position of the peak of E1 distribution.
- The shape of the E1 distribution mildly depends on the η coordinate of the crystal. Thus η-dependent reference distributions are built from MC merging the events of 5 rings in η.



Single crystal analysis (2)



- Unbinned maximum likelihood fit to data of η dependent reference MC distributions (red lines)
  - Scale calibration coefficient c as free parameter

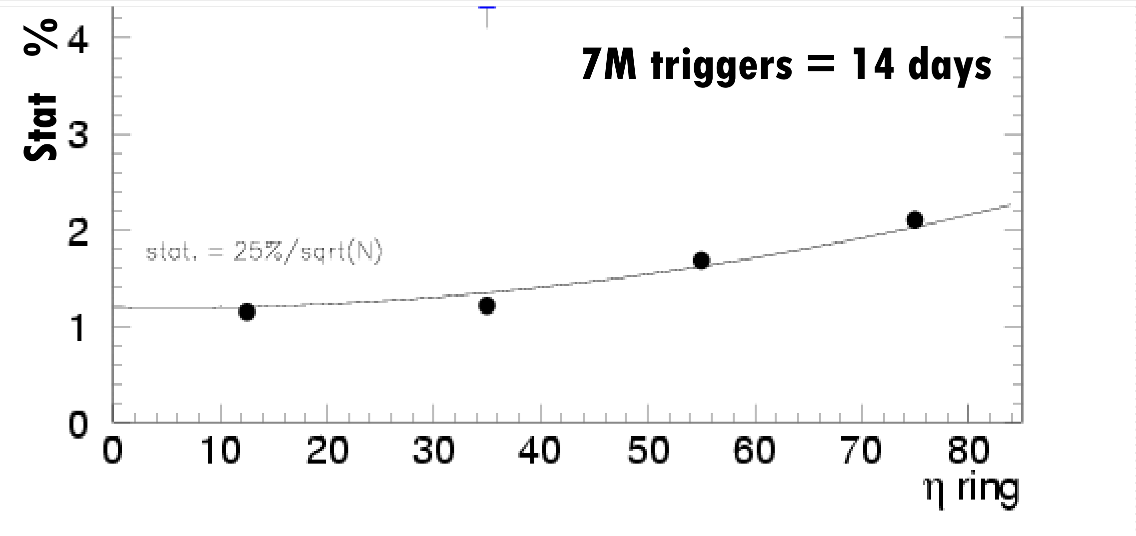
    $$\mathcal{L} = \Pi_i \, \mathrm{pdf}\,(c\, E_i)$$

- The method proves robust with the available statistics
- calibration of edge crystals using scintillator tags: studies on going – not presented here

Statistical precision

- The statistical precision of the intercalibration varies inside a supermodule with η due to the different number of single crystal muon candidates.
- Statistical precision follows semi-empirical law:

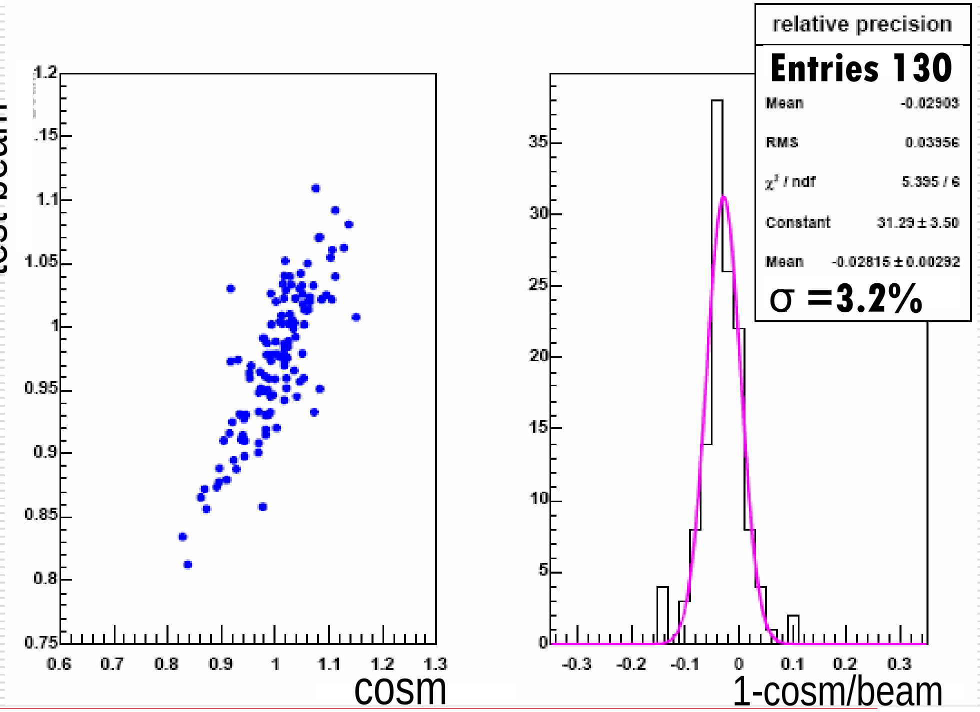
$$\frac{peak \quad width}{\sqrt{entries}} \approx \frac{25\%}{\sqrt{entries}}$$



Systematic uncertainty

- Direct comparison to test beam results of several supermodules will be possible in the summer (test beam is starting late July).
- One supermodule was exposed to cosmic rays just after the last test beam 2004, using a prototype trigger telescope. 41 hours of data taking.
- The comparison of the comics to test beam intercalibration was performed for 130 channels in module1 (boundaries excluded).
- That analysis shows that systematic differences between cosmics and test beam intercalibrations are within 2%

- $\sigma = \sigma_{stat} \oplus \sigma_{gain} \oplus \sigma_{sys}$
  $3.2\% = 1.8\% \oplus 2.5\% \oplus \sigma_{sys}$
- $\sigma_{sys} \approx 1.7\%$
  - Ascribed to the MC description of the E1 typical distributions
  - Test beam 2006 will supply calibrated supermodules, hence typical distributions will be obtained from data



Conclusions

→ 10 supermodules of the CMS ECAL barrel have been exposed to cosmic rays so far.

→ The precalibration with cosmic muons proves to be the most accurate one which can extend to all the channels of the ECAL barrel.

Furthermore, it complements the burn in procedure of the ECAL supermodules.

→ Triggers collected in 2 weeks ensure a statistical accuracy of 1.2% for module 1&2 and ~2% for module 4.

→ Comparison of $C_{cosmics}$ to 2004 test beam results (130 channels module1) shows the systematic uncertainty for module 1 to be within 2%.

→ The plan is to intercalibrate with cosmics all the supermodules, thus having ~10 days of cosmics data taking per supermodule.

→ Test beam 2006 will start at the end of July and will provide further understanding on the systematics

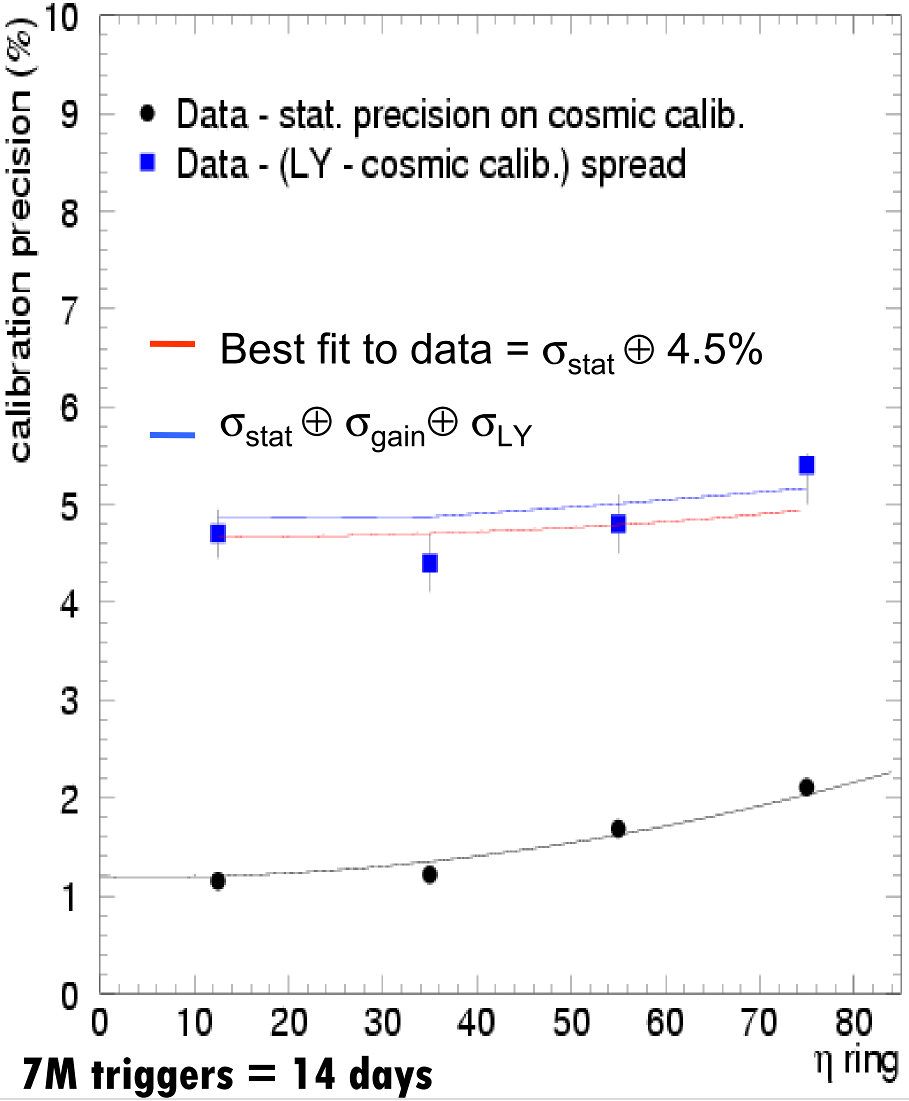
Complementary slides

Consistency: C_{cosm} agaist C_{lab}

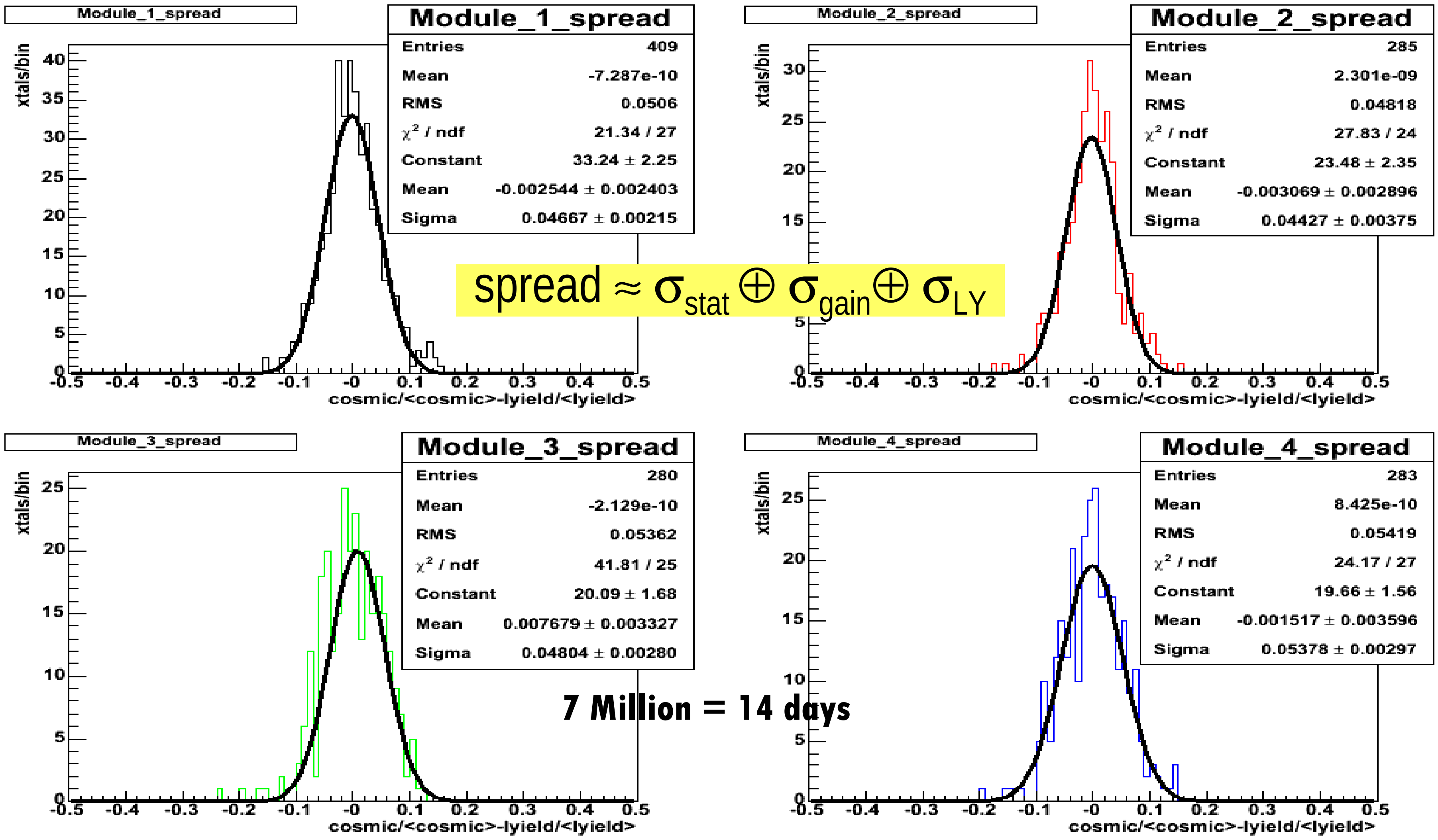
- For all supermodules calibrated in 2005-06 comparison to C_{lab} (4.2% precise) has been performed:

$$\frac{comics}{\langle comics \rangle} - \frac{C_{lab}}{\langle C_{lab} \rangle}$$

- For the four modules, spread interpreted accounting for:
  - spread on APD gain ratio
    - RMS<g200/g50> = 2.5%
  - $C_{cosmics}$ statistic uncertainty
  - Accuracy of C_{lab}



Comparisong: $C_{cosmics}$ - C_{lab}



$\text{spread} \approx \sigma_{stat} \oplus \sigma_{gain} \oplus \sigma_{LY}$

7 Million = 14 days

Eta dependencies