Commissioning and performance of the CMS calorimeter systems with proton-proton collisions at the LHC

Philippe Gras[1]
On behalf of CMS collaboration

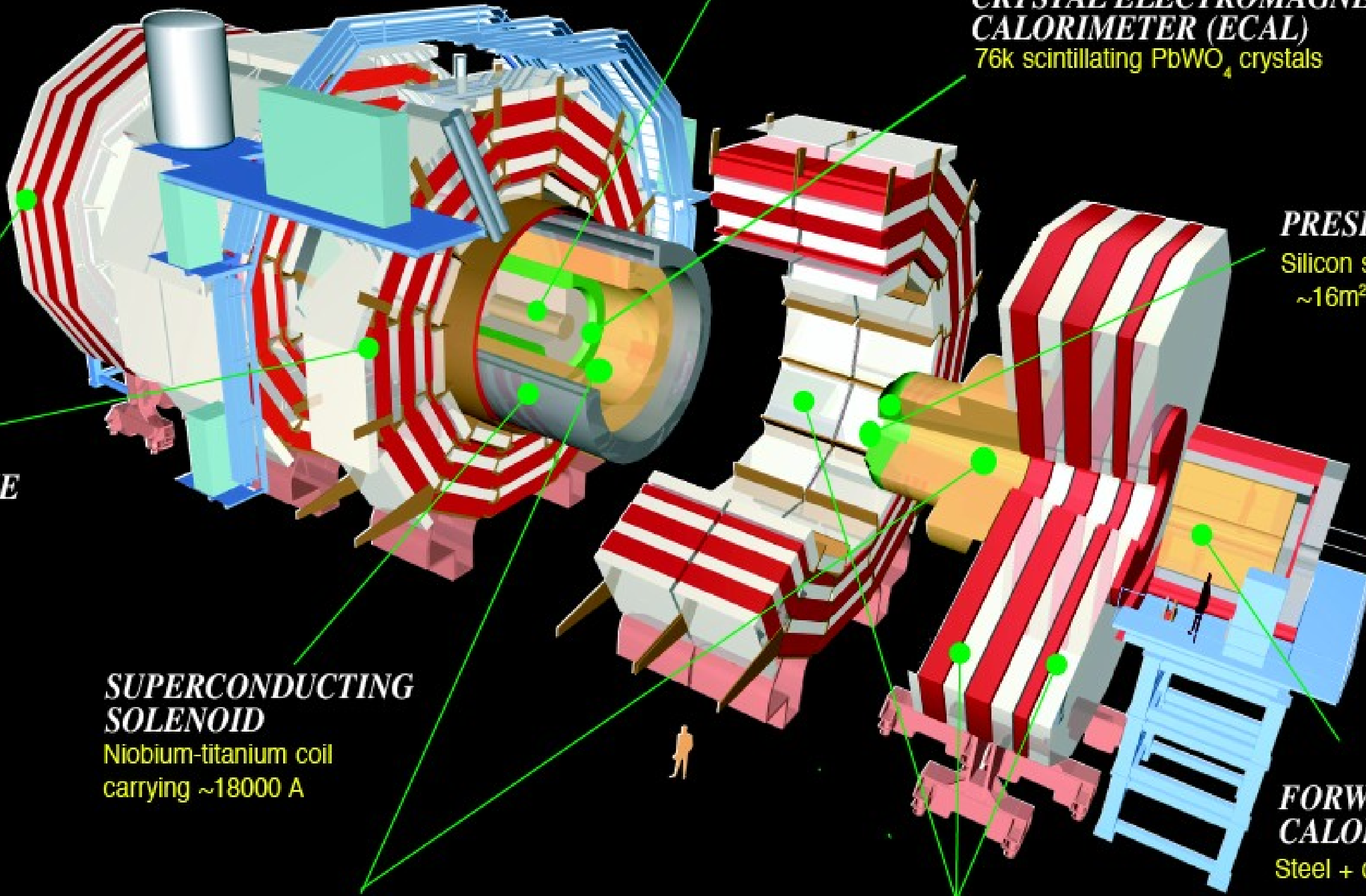
[1] CEA/IRFU - Saclay

- Overview
- Start-up conditions
- Detector performance
- Physics object performance
- Conclusions

CMS Detector

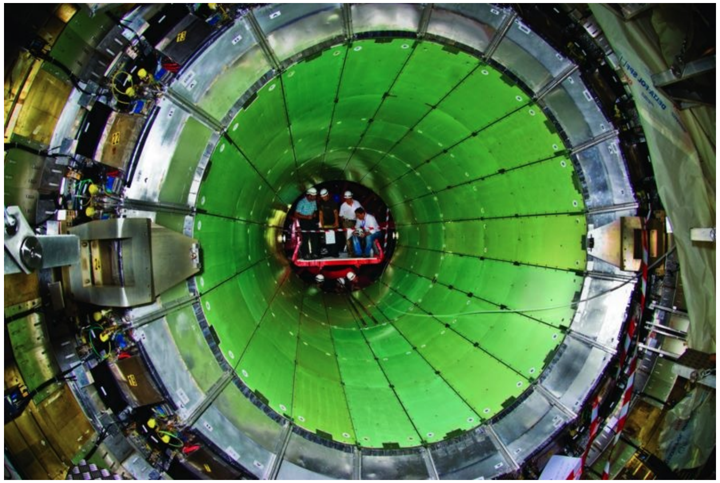
HCAL |η| < 5
ECAL |η| < 3.0
Tracker |η| < 2.5
Muons |η| < 2.4

Pixels
Tracker
ECAL
HCAL
Solenoid
Steel Yoke
Muons



Total weight	**: 14000 tonnes**
Overall diameter	**: 15.0 m**
Overall length	**: 28.7 m**
Magnetic field	**: 3.8 T**

The CMS calorimeters

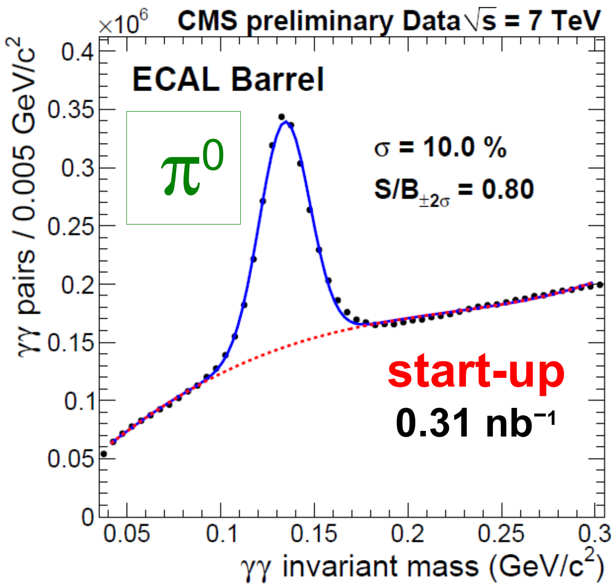


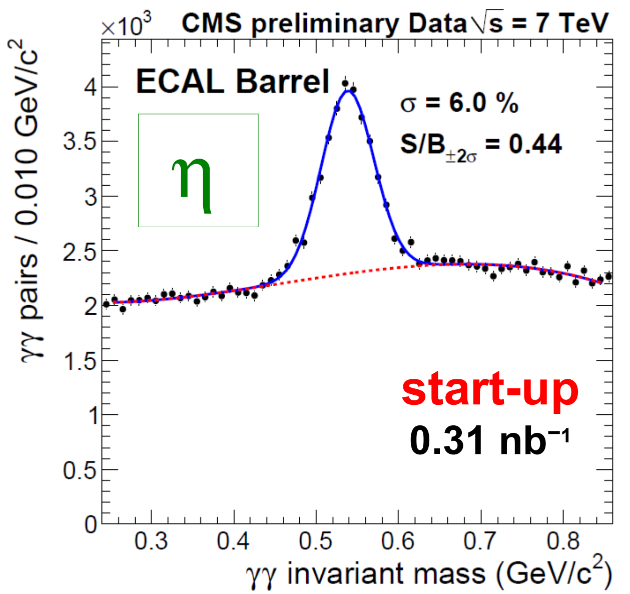
- Electromagnetic calorimeter, ECAL:
  Homogeneous $PbWO_4$ crystal calorimeter
  - Barrel (EB): $PbWO_4$
    - $26X_0$. $\Delta\eta x\Delta\varphi = 0.0174x0.0174$
  - Endcap (EE):$PbWO_4$
    - $25X_0$. $\Delta\eta x\Delta\varphi = 0.021x0.021 \sim 0.050x0.050$
  - Preshower in endcap (ES): $3X_0$ lead with 2 planes of 61mm x 1.9mm Si strips
  - Target resolution: 0.5% at high energy
  - > 99% working channels (EB: 99.3, EE: 98.94, ES: 99.8)
  - stable conditions: temp. RMS 0.003°C (EE: 0.015°C). Laser response stability < 0.02%.

- Hadronic calorimeter, HCAL:
  - Barrel (HB): Brass + Scintillators
    - $\Delta\eta x\Delta\varphi = 0.087x0.087$
  - Barrel tail catcher (HO): Scintillators
  - Endcap (HE): Brass + Scintillators
    - $\Delta\eta x\Delta\varphi = 0.087x0.087...0.35x0.087$
  - Forward (HF): Steel + quartz fibre (Čerenkov)
    - $\Delta\eta x\Delta\varphi = 0.349x(0.175 \text{ or } 0.35)$
  - > 99.75% working channels (100% in HB/HE/HF)

ECAL start-up conditions

- Synchronization
  - All channels synchronized.
  - Providing a time measurement precision better than 1ns.
- Calibration
  - Start-up calibration uses results from a 10-year campaign of test-beam and cosmics rays precalibation, in-situ "splash" events and π^0 calibration.
  - Precision of start-up calibration:
    - EB: 0.5% ~ 2.2% *(1.2% in central region with first 120 nb^{-1})*
    - EE: 5%
    - ES: 2.2% *(better than design goal)*
  - Target with 10 pb^{-1}: 0.5% in EB; 1%~2% in EE
- Alignment
  - ES vs EE:
    - misalignment < 0.5mm (+/- 0.2mm)
  - Tracker vs ES/EE:
    - Δy = 7~8mm for + and – side
    - Δx ~ 5mm for + side
  - Possible small displacement in EB. Will be measured with the increased integrated luminosity





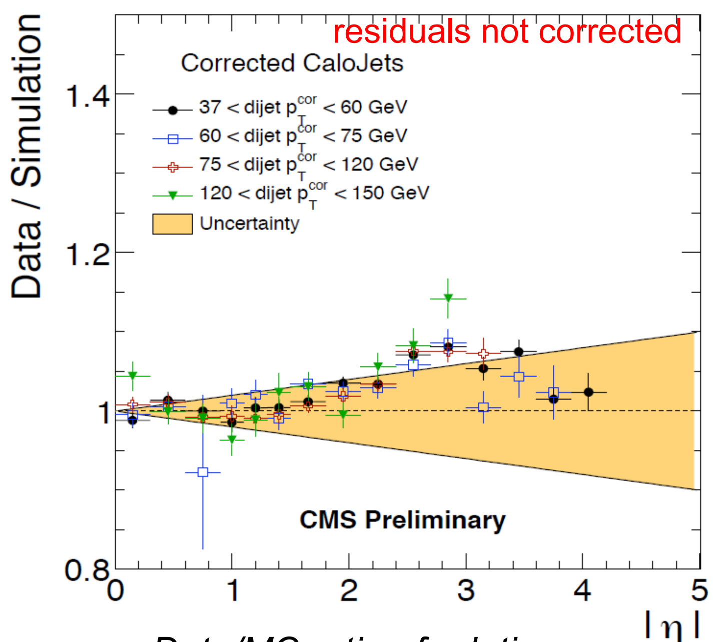
More details in posters #824 (Y. Yang), #507 (Z.-K. Liu), #477 (Y.-M. Tzeng)

HCAL start-up conditions

- All channels synchronized
  - Providing a time measurement precision in HB and HE better than 2ns.
- Precalibration
  - Absolute scale set in test beam
  - Intercalibration made in-situ with Co^{60} source
  - Cosmic rays and “splash” events *(beam dumped on a collimator 150 m from IP)*
- Data-driven calibrations
  - Target: 5% on absolute scale, 0.5% (2%) on relative scale for barrel (endcap)
  - Requires ~10 pb^{-1}. With available data, set limit on systematic uncertainties.
  - Single particle response: E_{calo}/p_{track}
    - barrel: agreement with Monte Carlo within 3%
    - endcap: response ≤ 8% higher than Monte Carlo. It will be adjusted with more data when performing the actual calibration.
  - Jet energy scale: from dijet balance
    - Uncertainties currently used in analyses,

      $$10\% + 2\% |\eta|$$

      is confirmed within the statistics errors (71 nb^{-1}, but with trigger prescale)



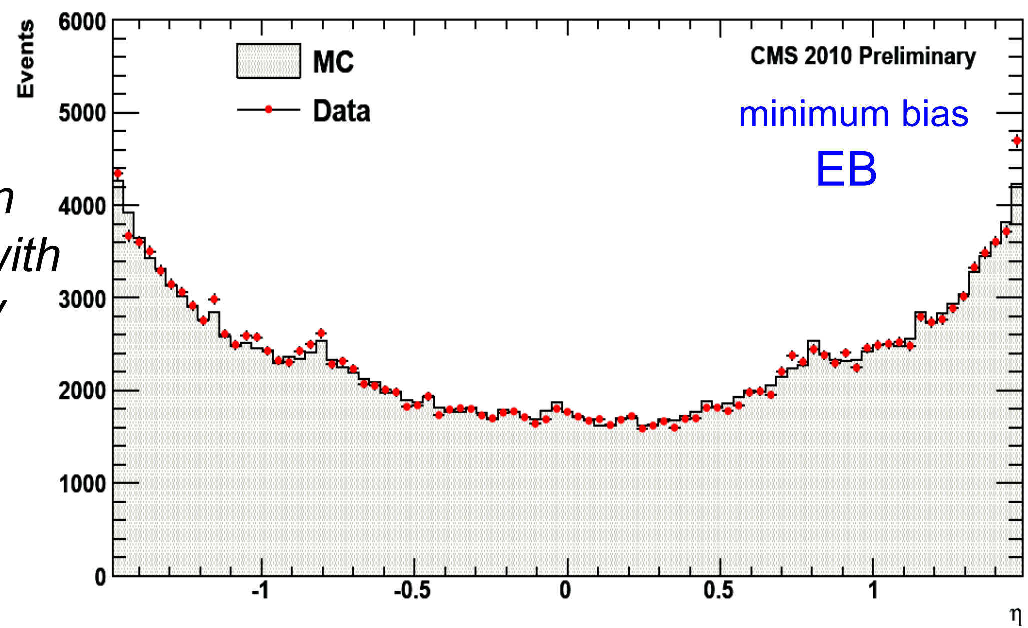
Data/MC ratio of relative response from dijet balance

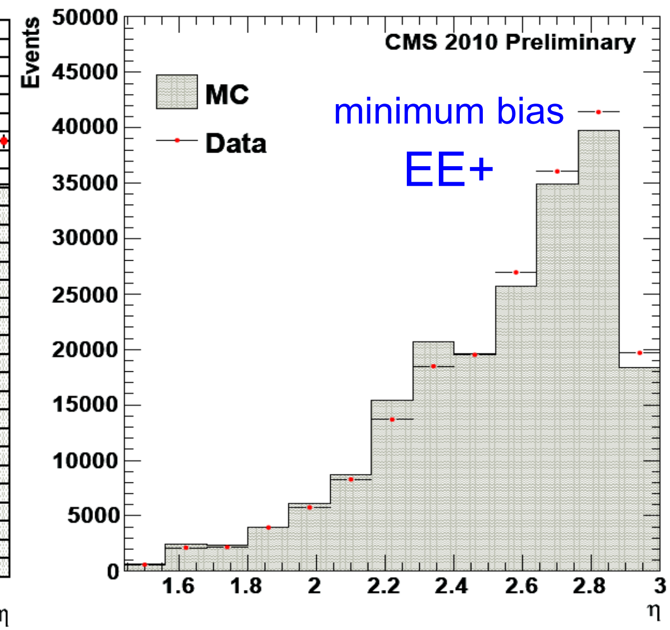
More details in P. De Barbaro's poster #854

Detector response comprehension, ECAL

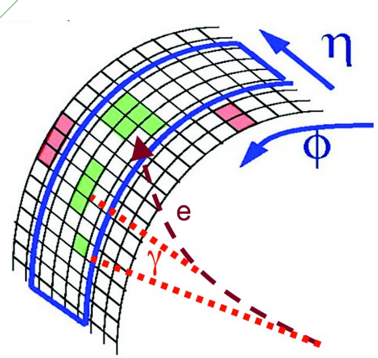
- Data and Monte Carlo in very good agreement without any Monte Carlo tuning

η distribution of channel with max. energy

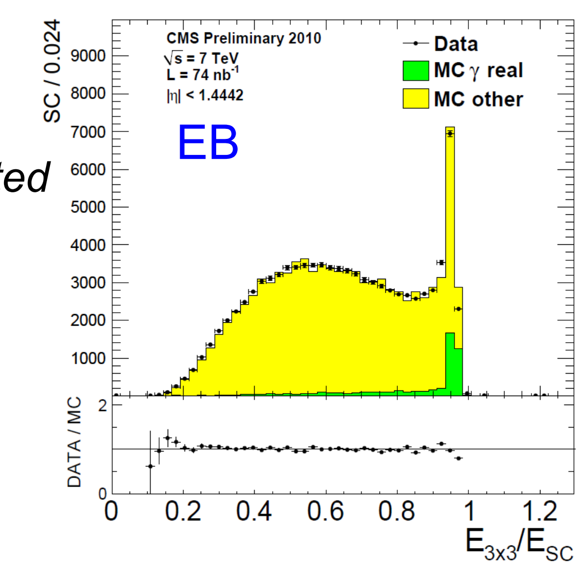




“out-of-the-box” Monte Carlo

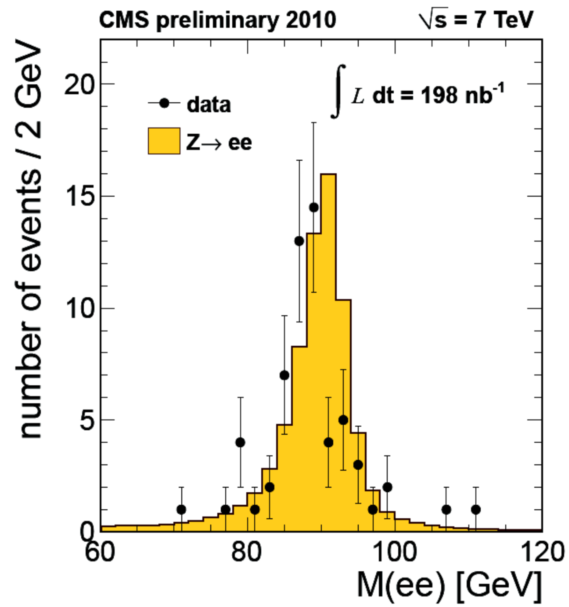


Ratio of energy deposited in 3x3 crystal matrix to cluster energy.

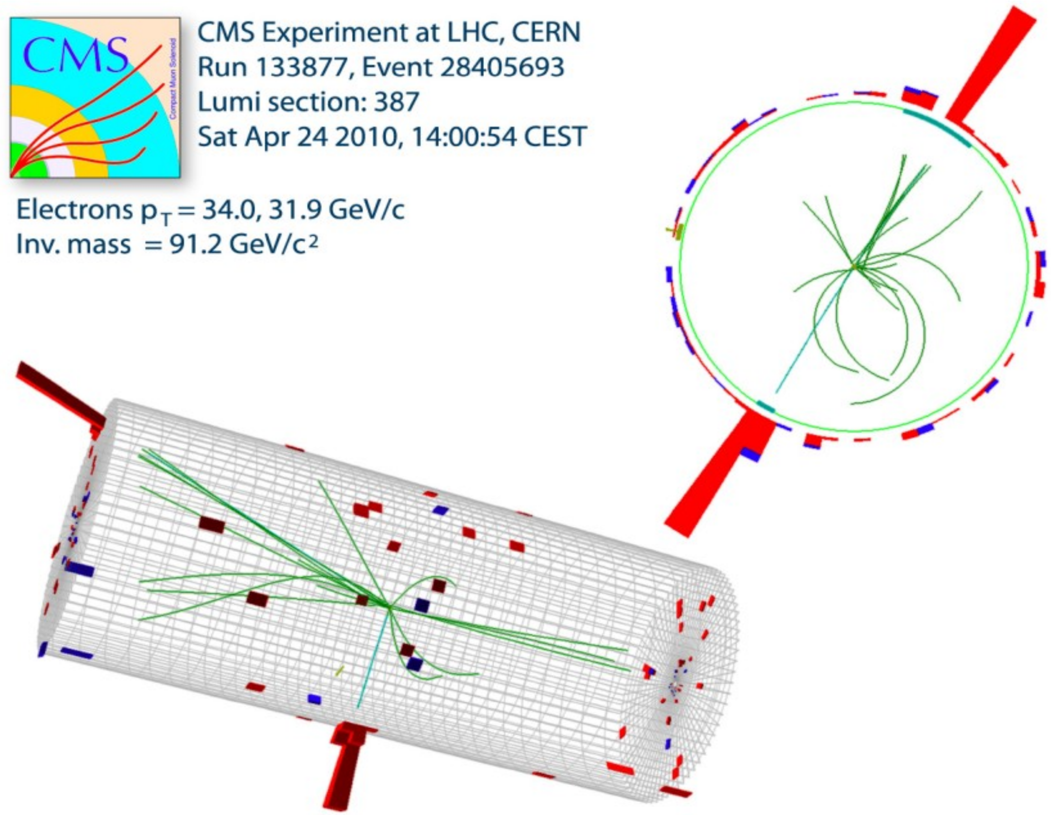


See R. Salerno's talk on electron and photon reconstruction

Z→e⁺e⁻



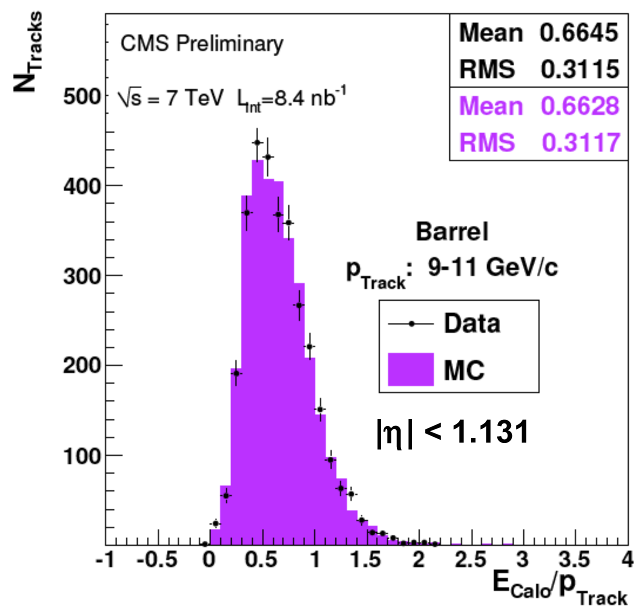
Distribution of M_{ee} of selected $Z \to e+e-$ candidates

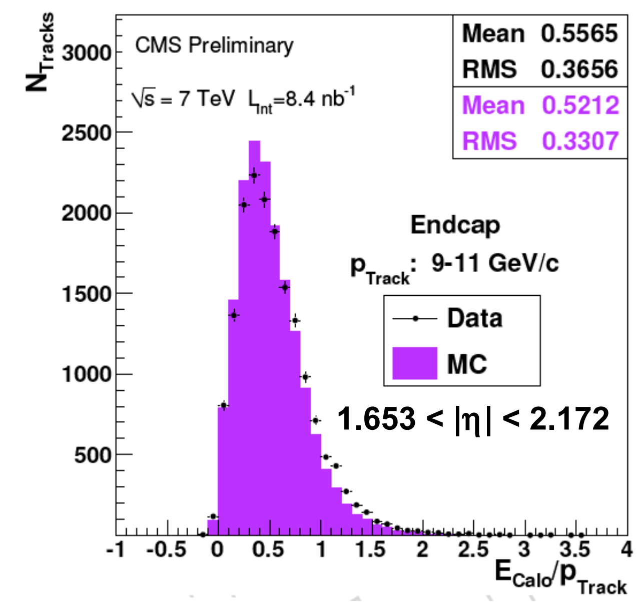


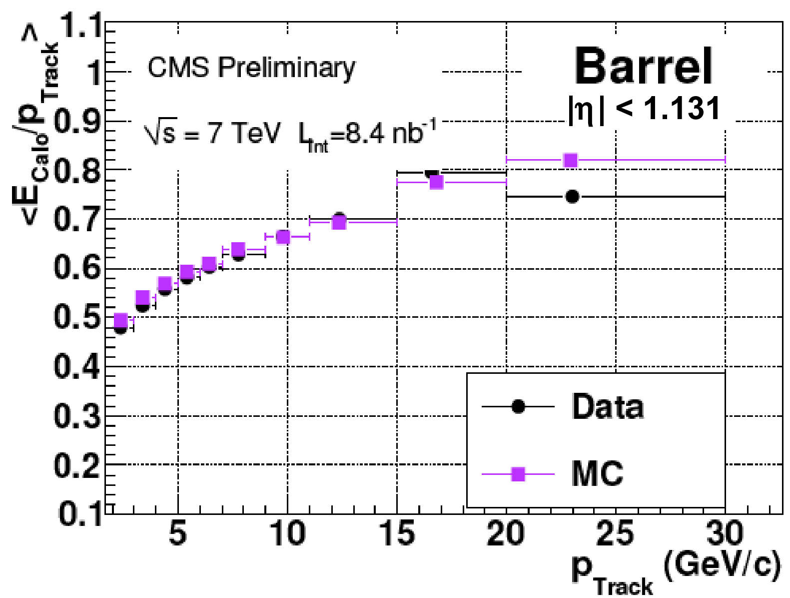
See J. Mans' talk and M. Cepeda's talk

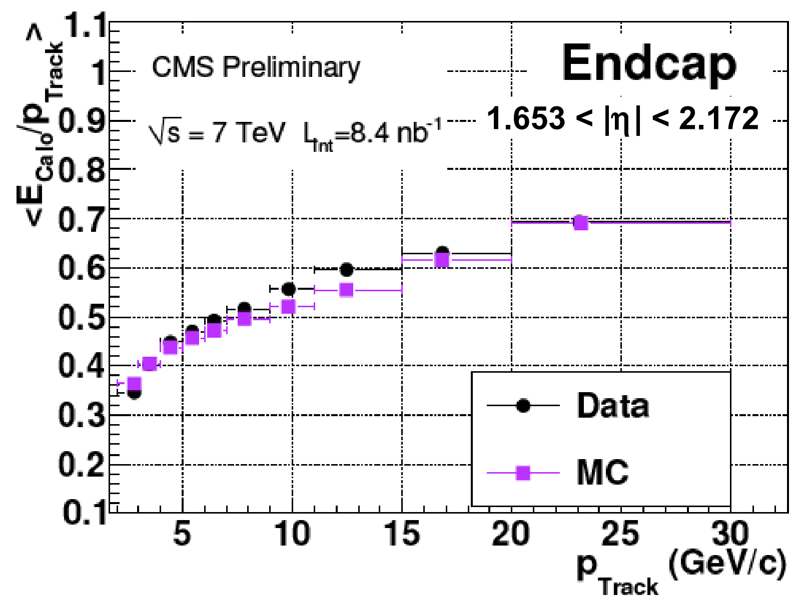
Detector response comprehension, HCAL

- Single particle response measurement as function of the track momentum. Selecting isolated charged particles with low deposit in ECAL (< 500MeV).





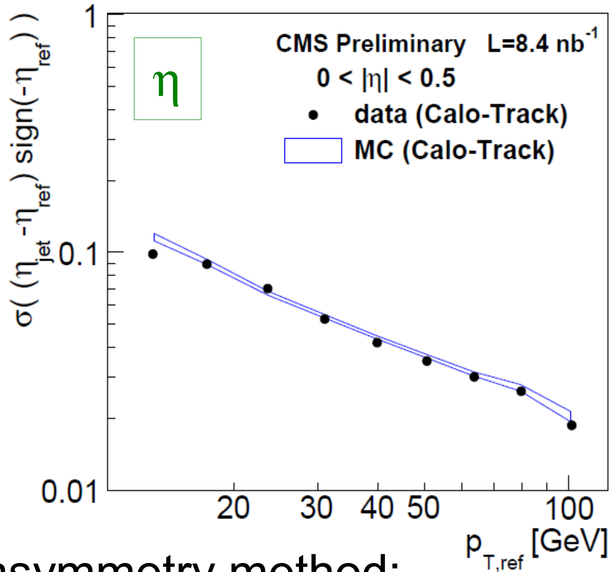


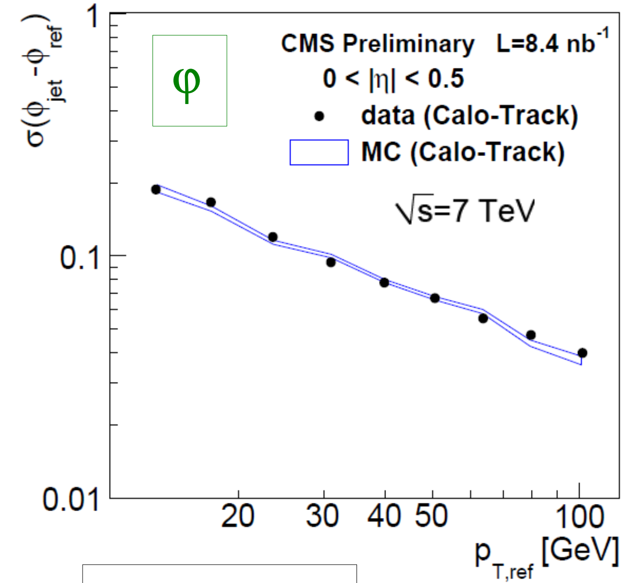


Jet measurement resolution

- Position resolution estimated by comparing tracker and calorimeter based measurements

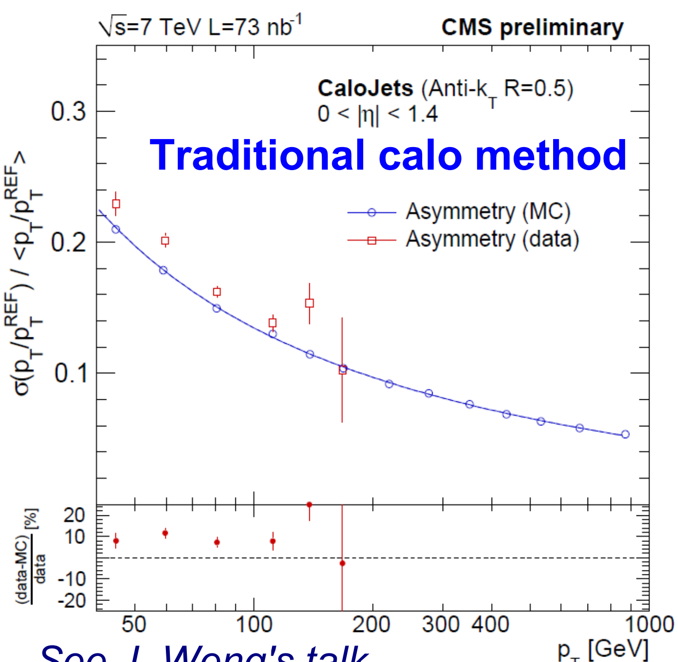
"out-of-the-box" Monte Carlo

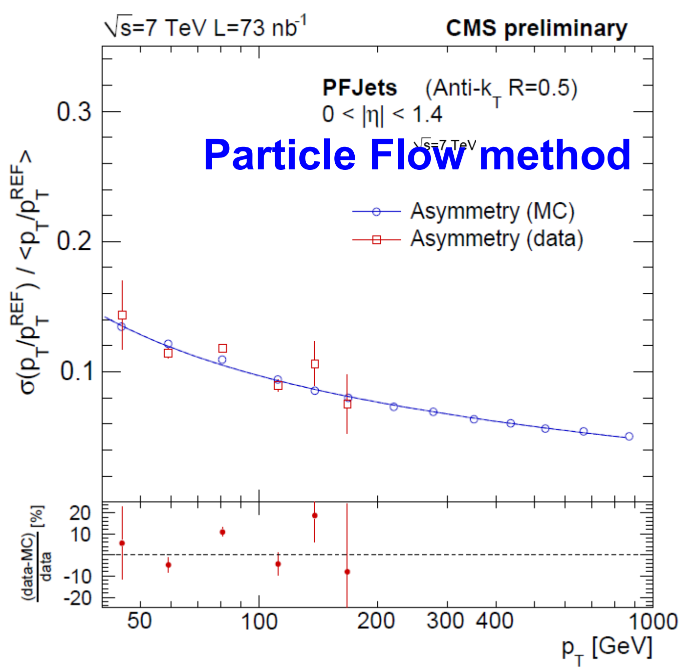




anti-k$_t$ algo

- P_T resolution estimated with dijet asymmetry method:



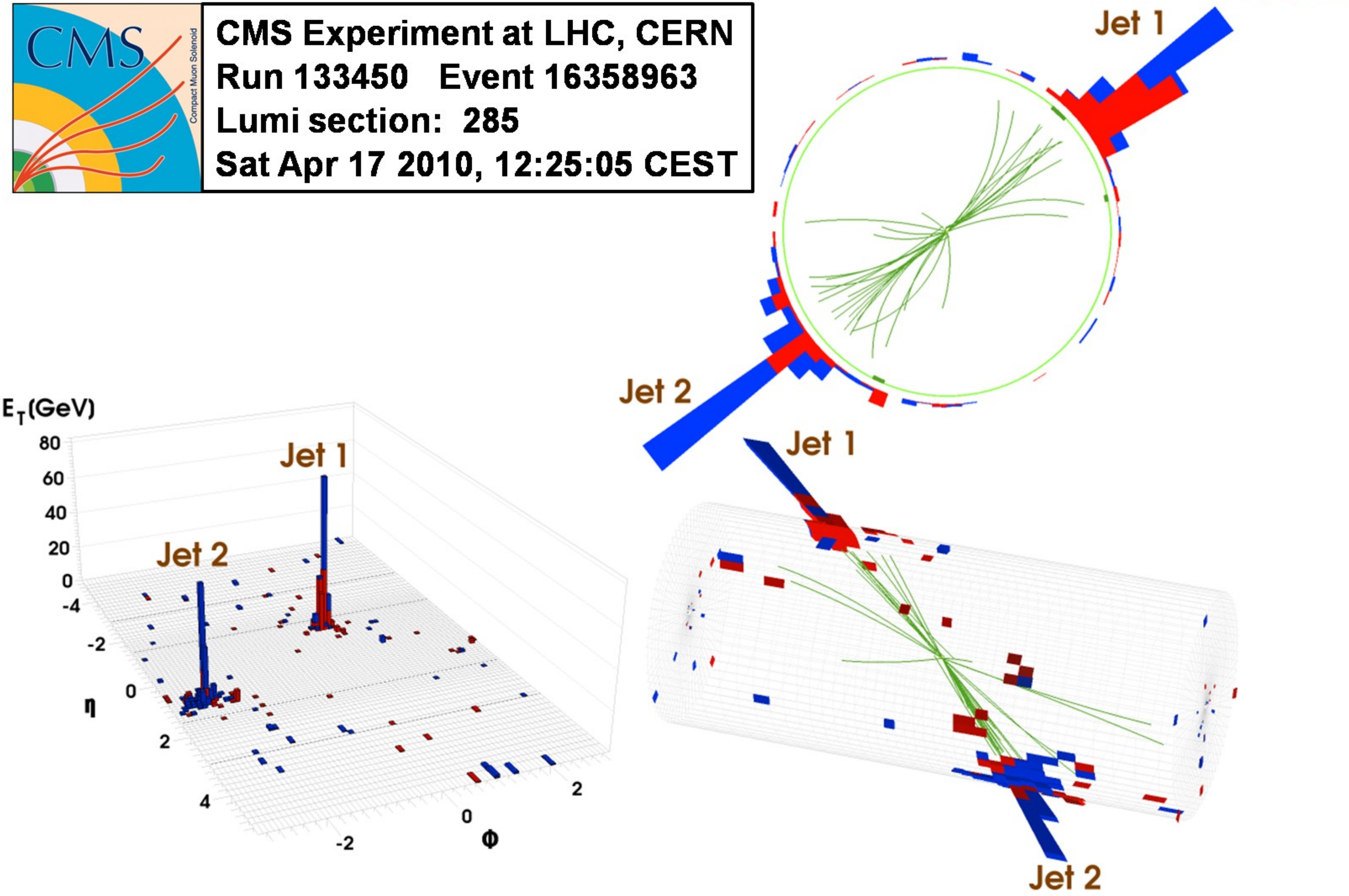


See J. Weng's talk

Particle flow technique strongly improves resolution in low P_T range

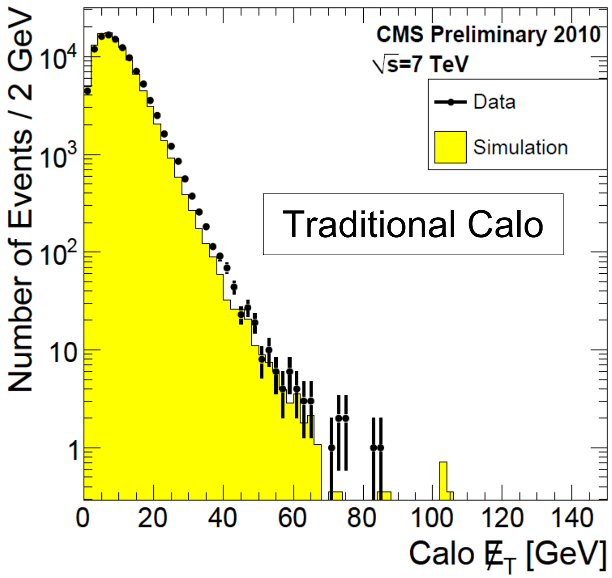
Already better than design resolution (100%/√E⊕5%)

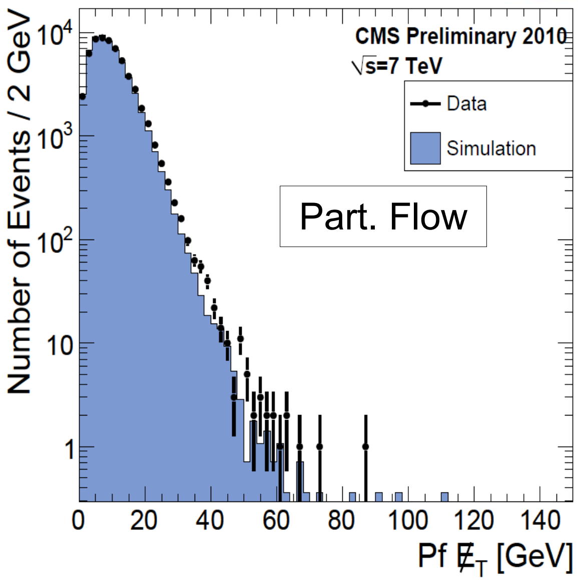
High mass dijet event



Missing Et measurement performance

Missing E_T for Dijet events measured with two methods.
$p_T > 25$ *GeV/c*

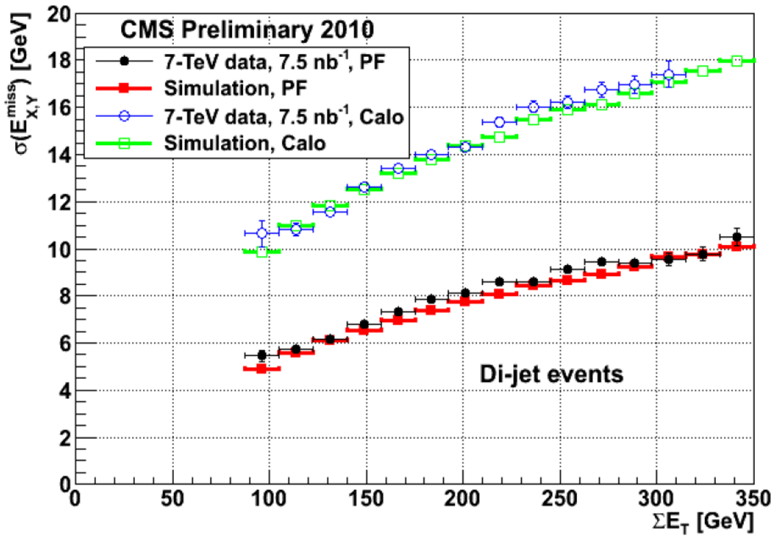




Monte Carlo describes the data well over 3 orders of magnitude without tuning.

Missing Et Gaussian core resolution:

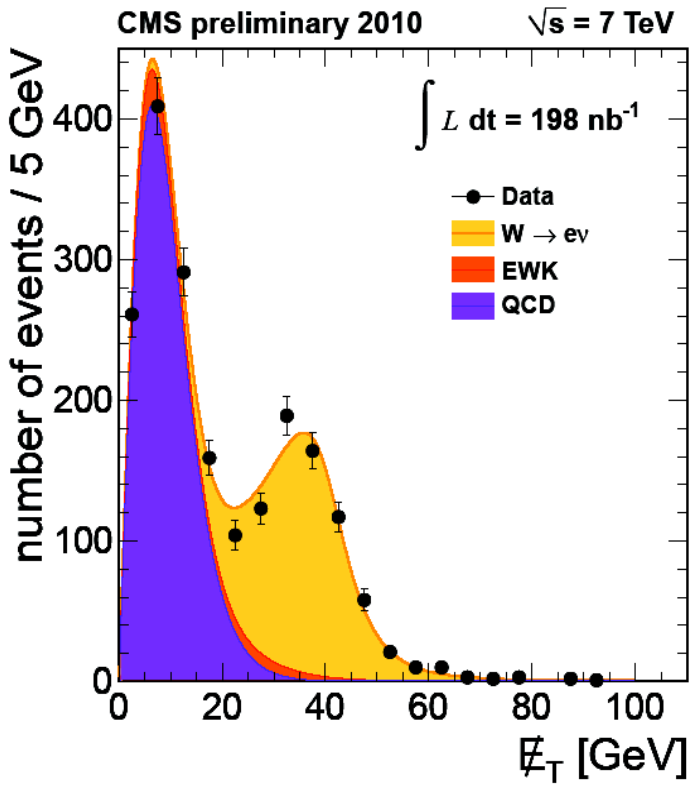
- < 10 GeV on whole $\sum E_T$ range up to 350GeV.
- Factor 2 improvement from Particle Flow technique.



See particle flow algorithm F. Beaudette's talk this afternoon

Conclusions

- Excellent detector performance since the very beginning of data taking.
- Commissioning is essentially finished. It has fully exploited the (limited!) amount of available data.
- Calibration will advance very fast with the LHC luminosity ramp-up.
- First physics analyses with excellent results.



Missing E_T distribution in $W \to e\nu$ candidate events

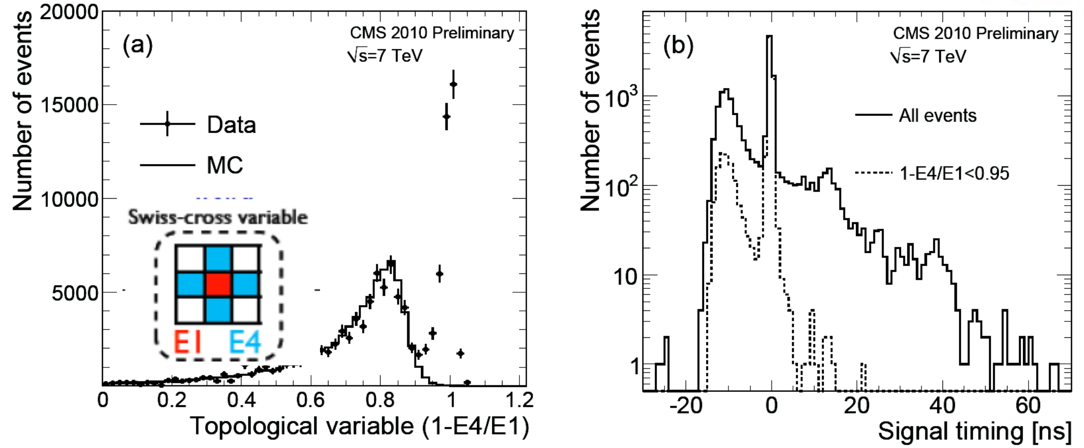
Backup

Anomalous signal

CMS NOTE 2010-012

ECAL barrel

- **origin**: heavily ionizing particles deposit energy in the Avalanche Photodiode
- **characteristic**: large signal on an isolated channel. Signal shape ~1 in 10^3 minimum bias events.
- **filtering**: topological cut + timing



EB discriminating variables plot for the highest energy hit (E_T>3GeV)

2010 JINST 5 T03014

HCAL barrel - endcap

- **origin**: ion feedback, noise & discharges in HPDs
- **characteristic**: Random, ~ 10-20 Hz (E>20 GeV). .
- **filtering**: topology + timing

HCAL forward

- **origin**: Čerenkov light by particles going through PMT glass
- Appear mostly in one channel in time with collisions
- **filtering**: based on energy sharing between long and short fibers + timing