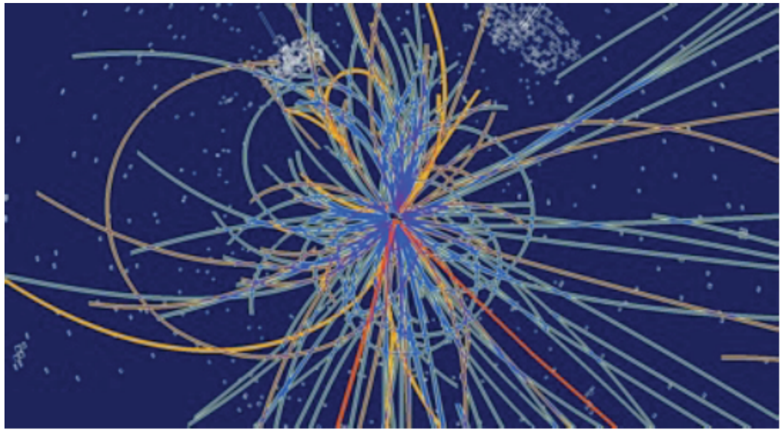
Kruger2010: Workshop on Discovery Physics at the LHC

Operation and performance of the CMS electromagnetic calorimeter

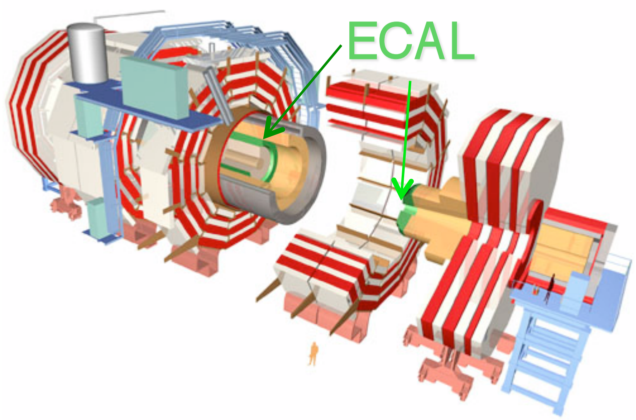
M. Malberti, Univ. & INFN Milano Bicocca
On behalf of the CMS Collaboration

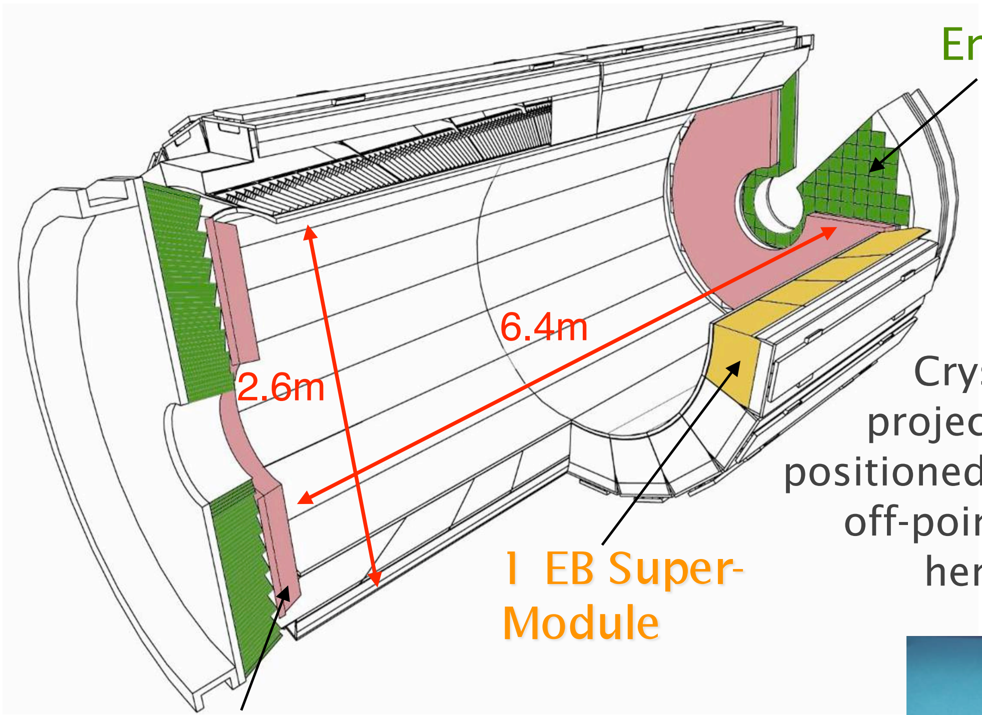


Outline

- The CMS electromagnetic calorimeter: description and performance target
- Status and stability
- Reconstruction and performance on low level observables
- Calibration strategy
- Electrons, photons

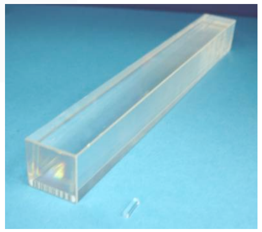
CMS Electromagnetic calorimeter





Homogenous $PbWO_4$ Crystal Calorimeter + Pb-Si Preshower

Crystals are projective and positioned slightly off-pointing for hermeticity



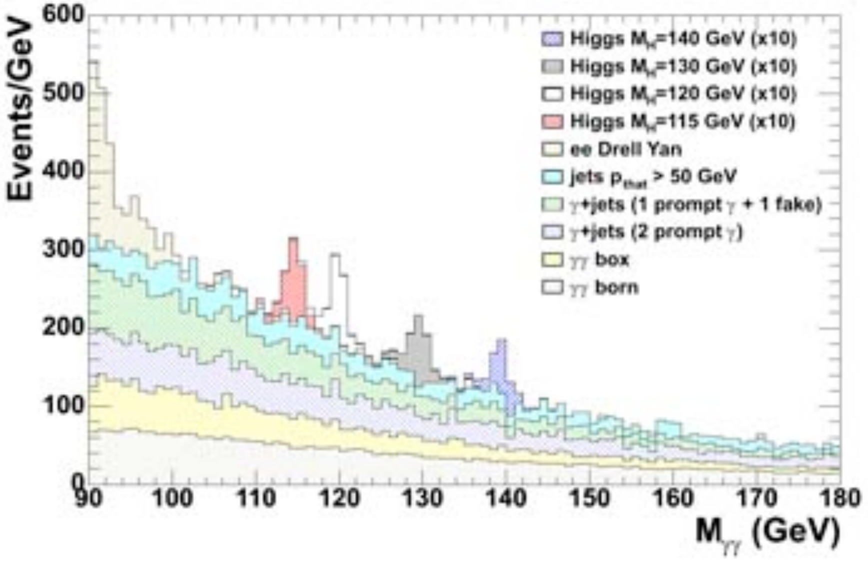
BARREL (EB) $\lvert\eta\rvert<1.48$	ENDCAP (EE) $1.48 <\lvert\eta\rvert< 3.0$	PRESHOWER (ES) $1.6<\lvert\eta\rvert<2.6$
61200 crystal	4 Dee's	4 Planes
($2.2 \times 2.2 \times 23$ cm^3) - $26X_0$	14648 crystals	Total of 137216 Si strips
36 Super Modules	($3 \times 3 \times 22$ cm^3) – $25X_0$	Pb/Si - $3X_0$
Avalanche Photo Diodes	Vacuum Photo Triodes	

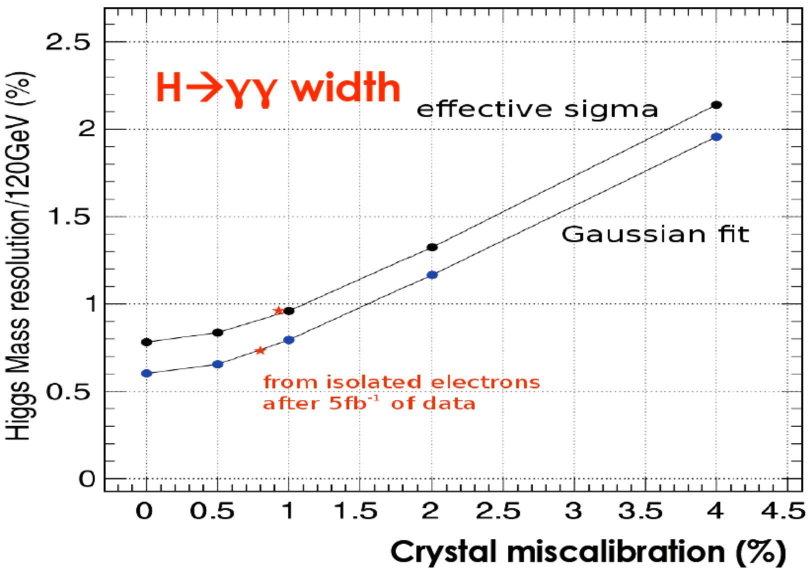
ECAL performance target

- Excellent energy (and position) resolution for photons and electrons crucial for studying interesting physics channels ($H\rightarrow\gamma\gamma$, $H\rightarrow ZZ\rightarrow 4e$, $Z'\rightarrow ee$ …)
- Benchmark physics process $H\rightarrow\gamma\gamma$
- Energy resolution target
  - 0.5% for unconverted photons

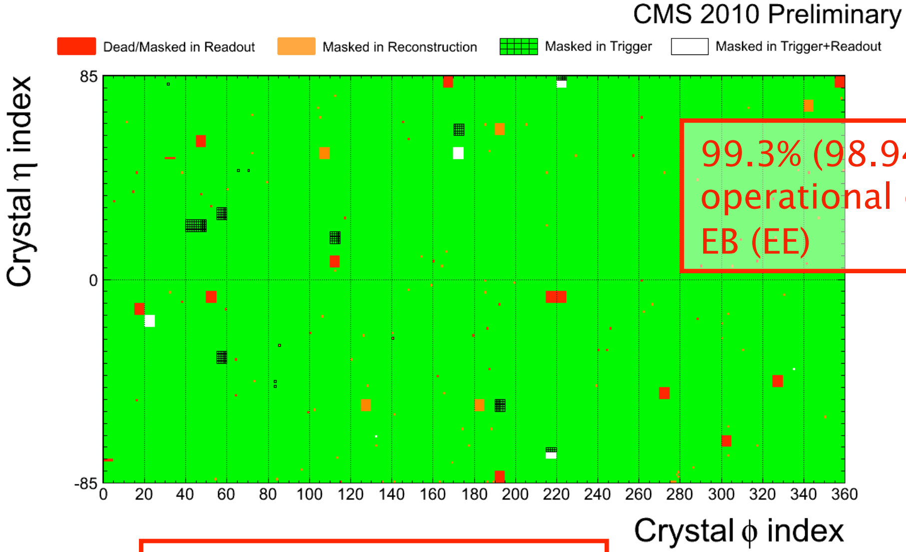
$$\frac{\sigma}{E} = \frac{a}{\sqrt{E}} \oplus \frac{b}{E} \oplus \boxed{c}$$

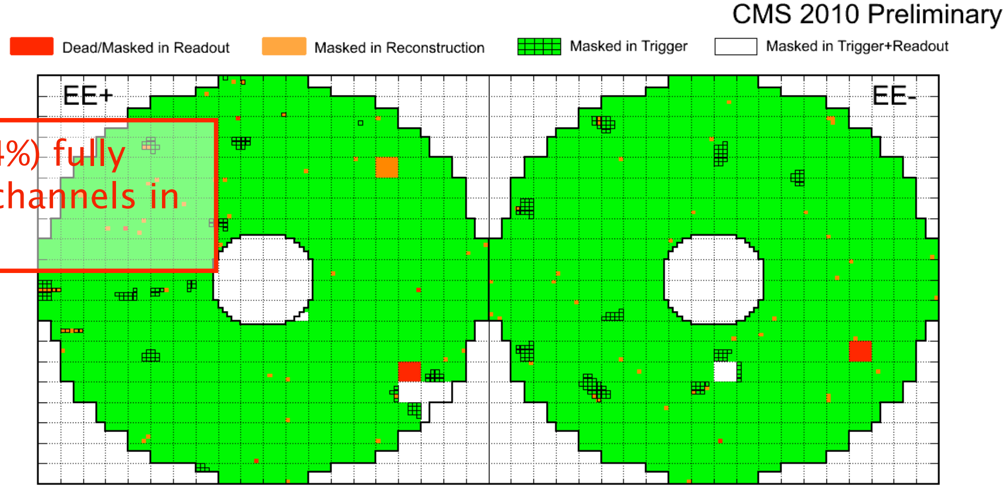
Constant term
- temperature/HV stability
- accuracy of intercalibration constants
- non uniformity of longitudinal light collection
- dominates at high energy





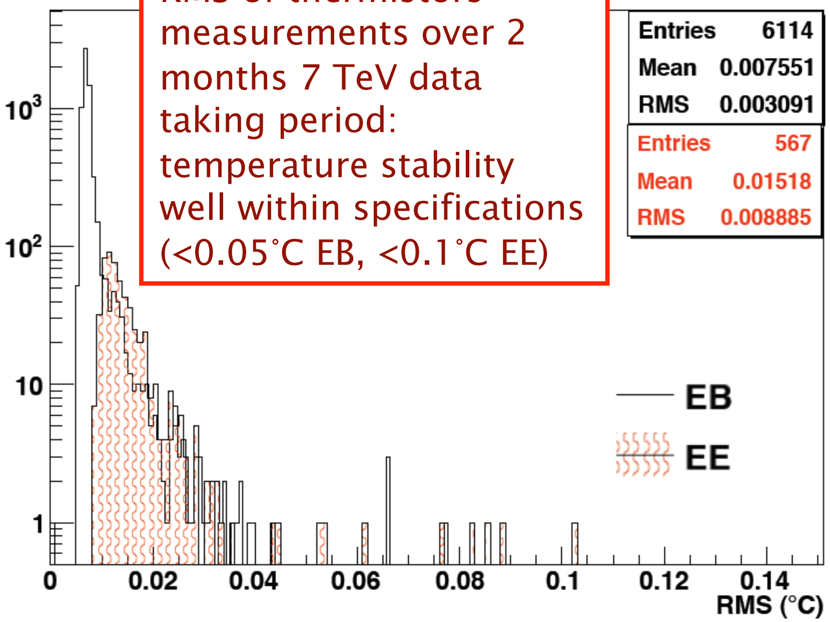
ECAL status and stability



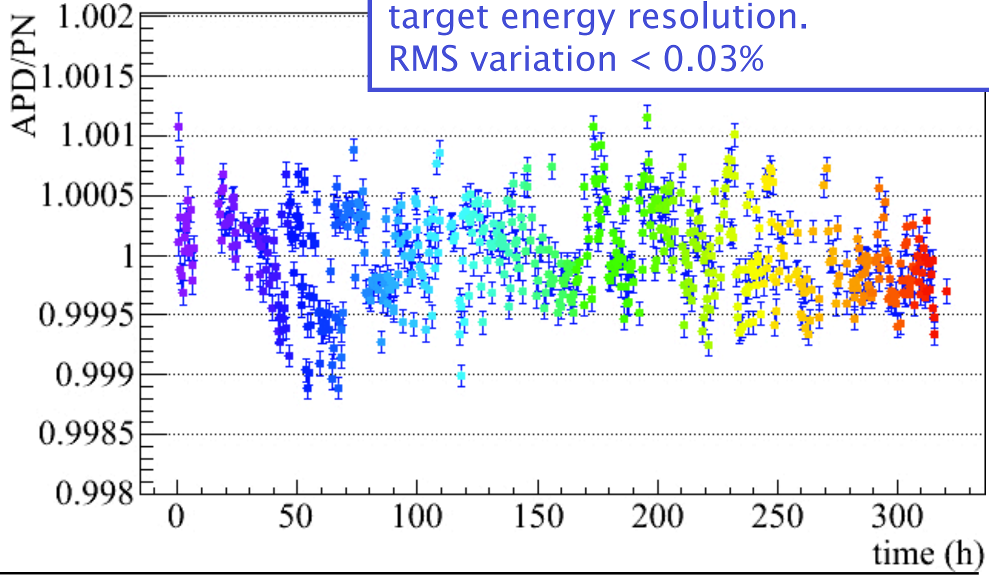


99.3% (98.94%) fully operational channels in EB (EE)

RMS of thermistors measurements over 2 months 7 TeV data taking period: temperature stability well within specifications (<0.05˚C EB, <0.1˚C EE)

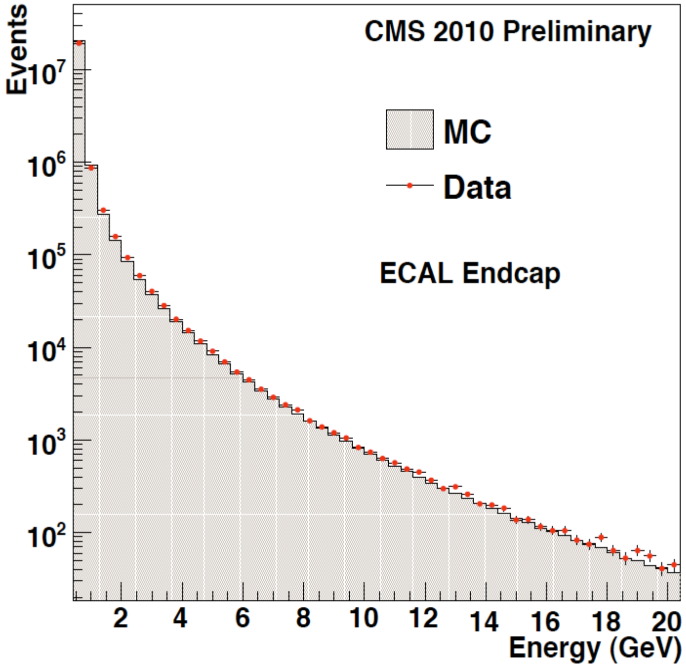


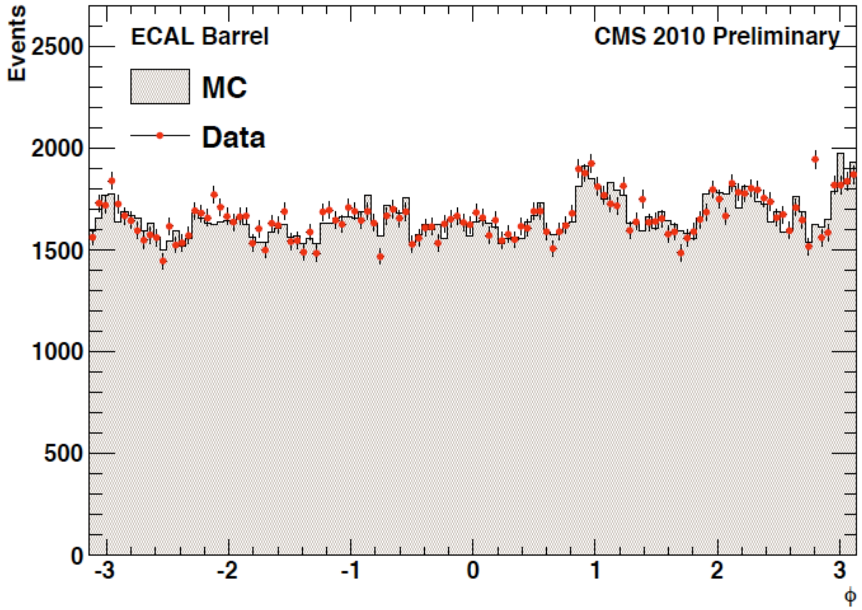
Light monitoring system stability: required better than 0.2% for the target energy resolution.
RMS variation < 0.03%



ECAL low level variables

7 TeV Minimum bias collison events
Good agreement data/MC

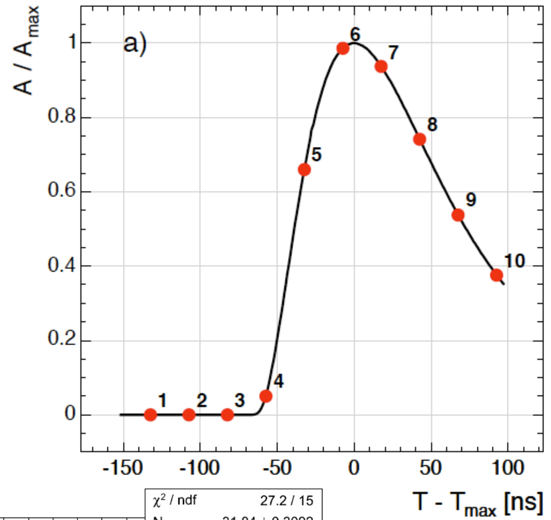


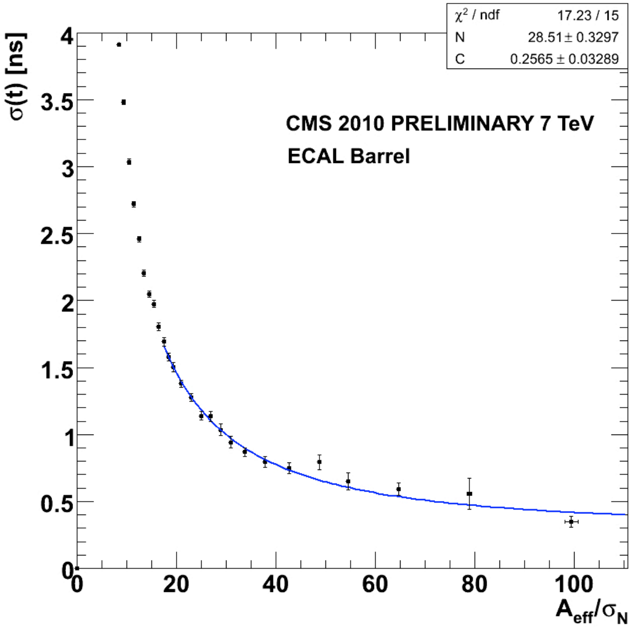


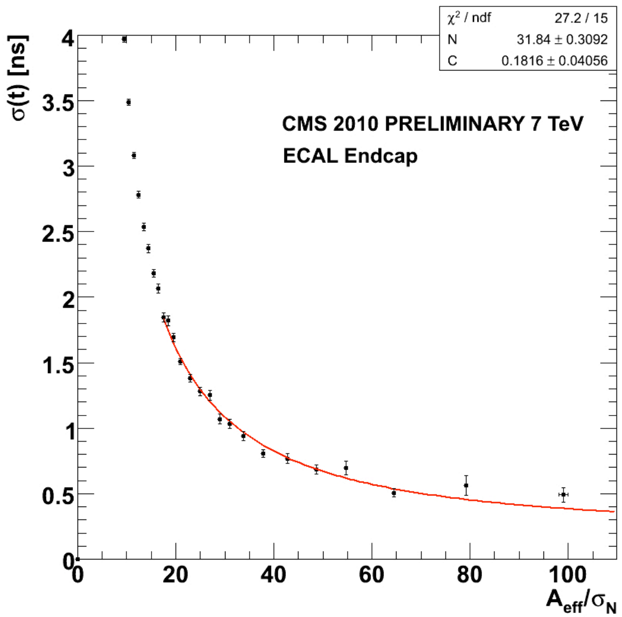
- Energy spectrum of the individual channels
- Azimuthal distribution of the channel with the highest reconstructed energy

ECAL time measurement

- Precision time measurement and synchronization
  - backgrounds (cosmics, beam halo, noise...) rejection
  - particle ID (e.g. slow heavy charged R-hadrons)
- time reconstruction obtained comparing digitized 25 ns amplitude samples with known pulse shape
- measurement of time resolution from the spread of time difference between adiacent crystals
  - sub-nanosecond resolution at high energy



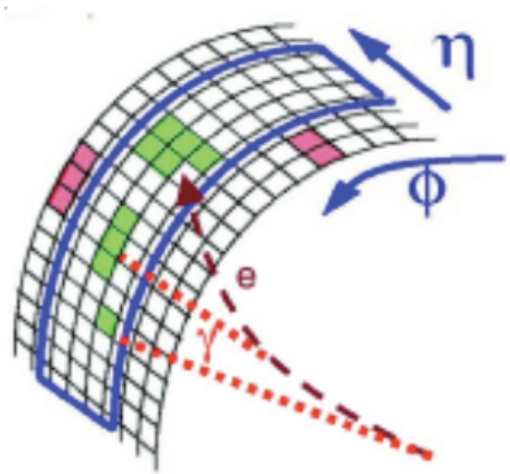




Energies range up to 4.5 GeV (EB) and 18 GeV (EE).

ECAL calibration

- Calibration aims at the best estimate of the energy of electrons/photons
- Energy of electrons and photons spread over several crystals



$$E_{e/\gamma} = F_{e/\gamma} \sum_{\substack{cluster \\ crystals}} G(GeV/ADC) \cdot C_i \cdot A_i$$

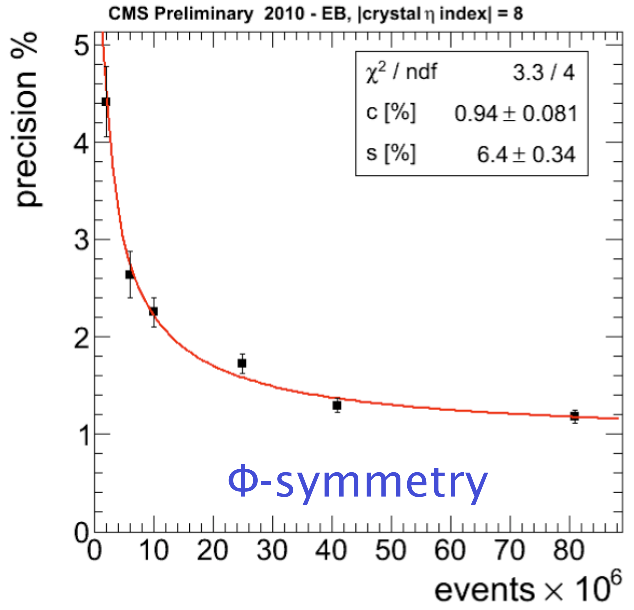
- A_i amplitude in ADC counts
- C_i intercalibration constants
- G global energy scale
- F particle specific corrections (containment, clustering for e/γ)

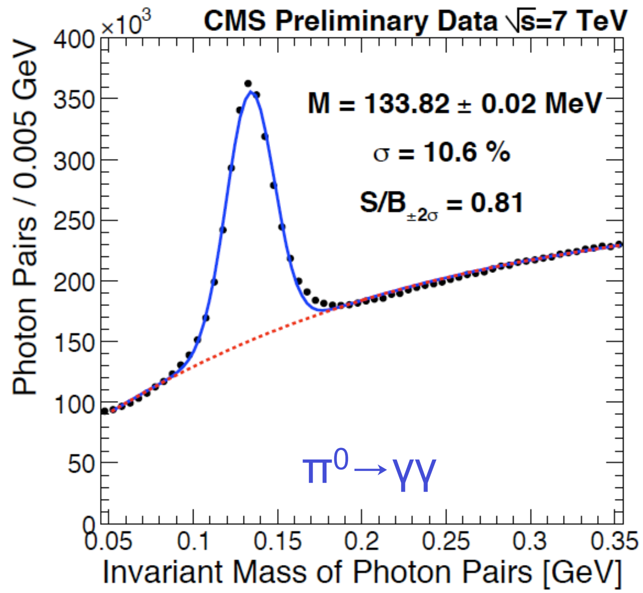
- ECAL pre-calibrated prior to LHC collisions
  - *intercalibration*: from Test Beams, Cosmics, Beam Dumps and Lab measurements overall precision ~0.5%-2% (EB), ~5%(EE)
  - *energy scale*: set at Test Beam, verified with cosmics
- Improving calibration *in-situ* using LHC collisions data
  - Φ-symmetry, $\pi^0(\eta)\rightarrow\gamma\gamma$, isolated electrons from $W\rightarrow e\nu$, $Z\rightarrow ee$

In-situ calibration strategies

Several methods to calibrate *in-situ*:

- ***Φ-symmetry***
  - fast calibration method
  - based on invariance around the beam axis of the energy flow in minimum bias
  - intercalibration of crystals in a ring at the same pseudorapidity
  - inhomogenities limit the precision to ~1.5-3%
- ***π^0 and η***
  - mass peak of photon pairs selected as $\pi^0(\eta)\to\gamma\gamma$ candidates
  - useful at start-up to investigate the ECAL energy scale
- ***isolated electrons*** from $W\to e\nu$, $Z\to e^+e^-$:
  - E/P measurement
  - main tool for several fb^{-1}
- di-electrons resonances and $Z\to e^+e^-$ and $J/\psi\to e^+e^-$ to monitor and correct the absolute energy scale

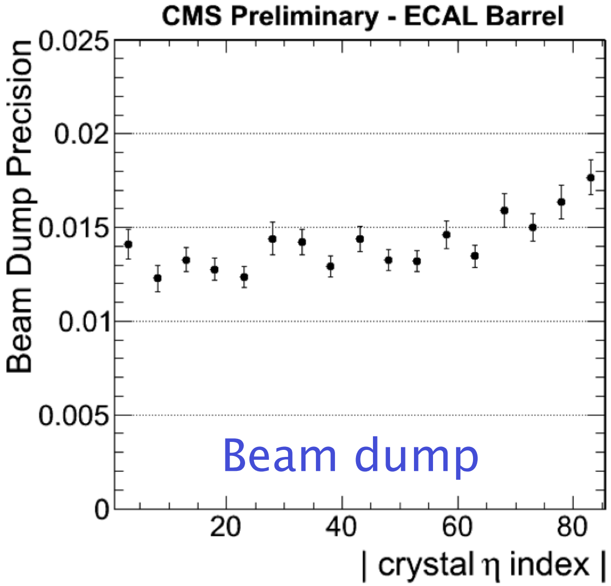


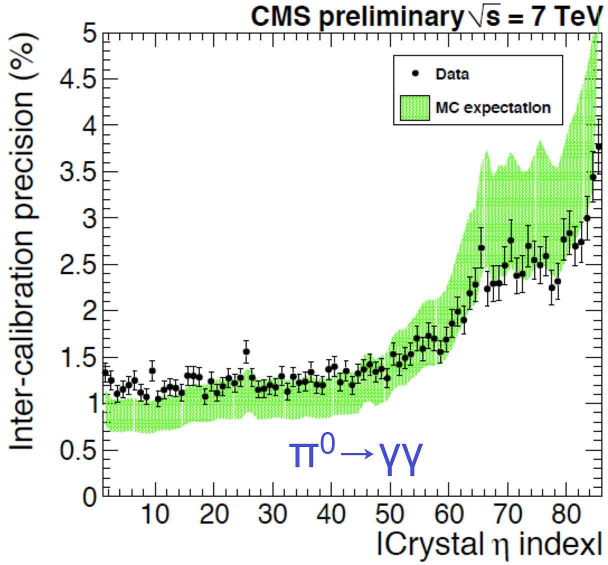


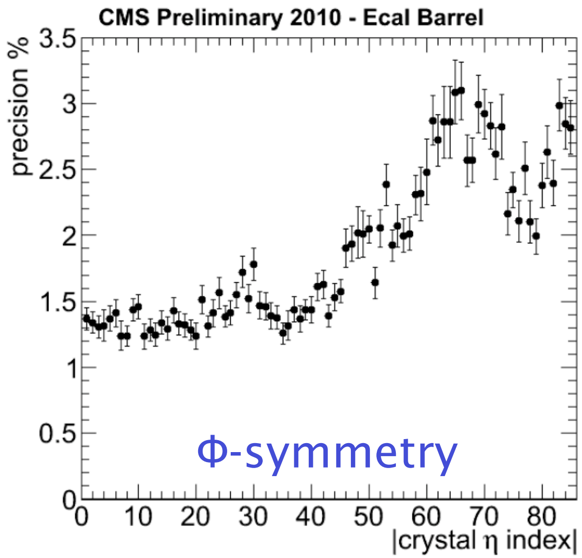
Intercalibration results

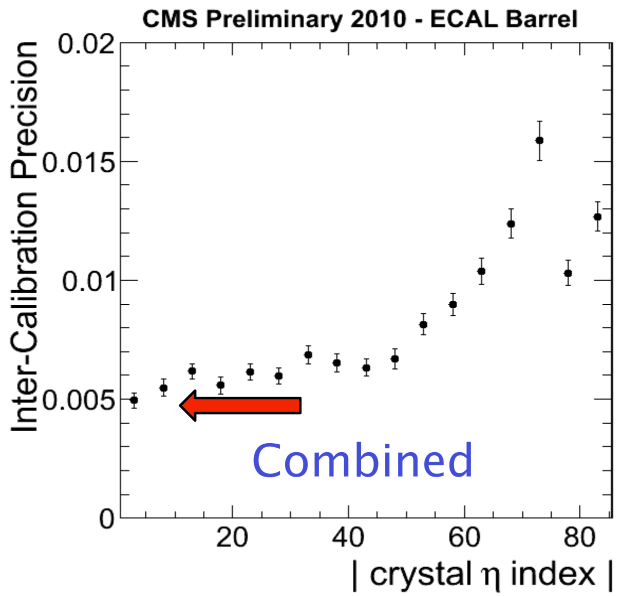
- Combination of Φ-symmetry, $\pi^0 \rightarrow \gamma\gamma$ and beam dump calibrations gives a precision of 0.6% in the central region with only *250 nb^{-1}*

- already close to the 0.5% goal for $H \rightarrow \gamma\gamma$ discovery!



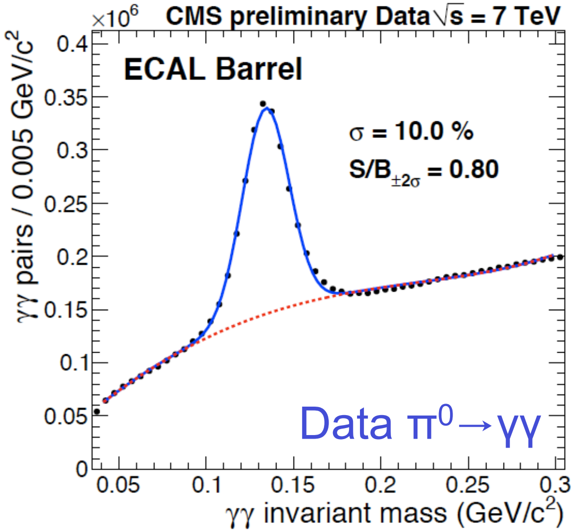


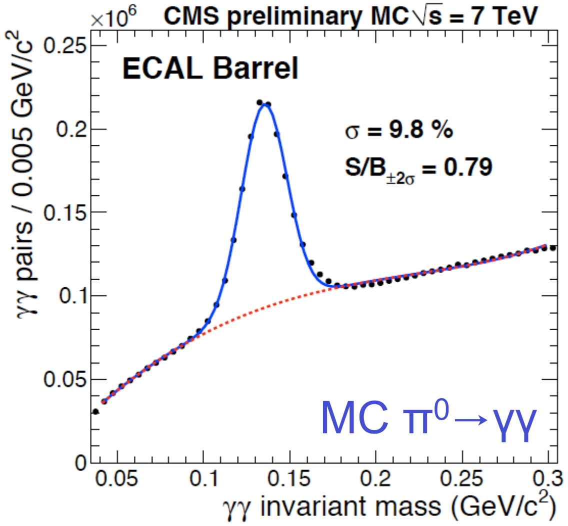




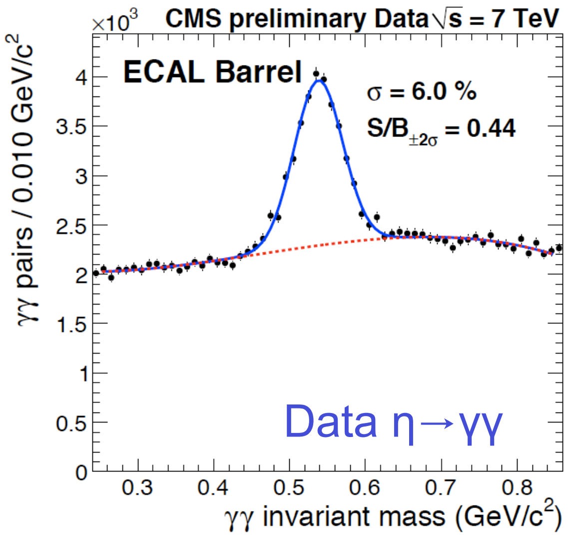
Low mass resonances–energy scale

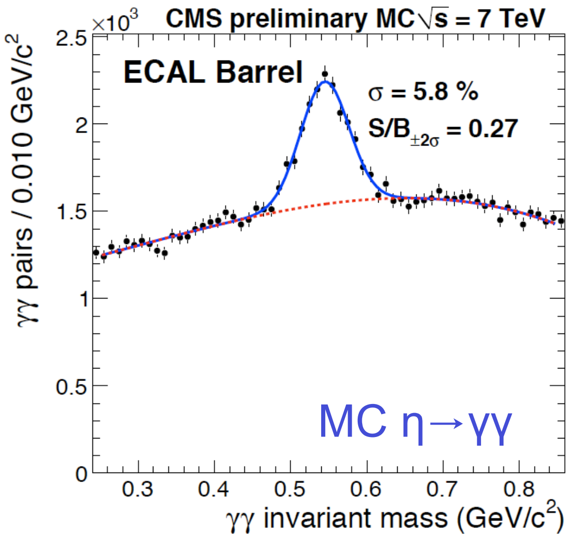
- Absolute energy scale measured in Test Beam using electrons of known energy
- In collision events, a first indication from $\pi^0 \to \gamma\gamma$ and $\eta \to \gamma\gamma$, comparing data and MC: agreement at the ***1%*** (***3%***) level in EB (EE)
- In the long term: J/ψ and Z decays ($Z \to ee$, $Z \to \mu\mu\gamma$)



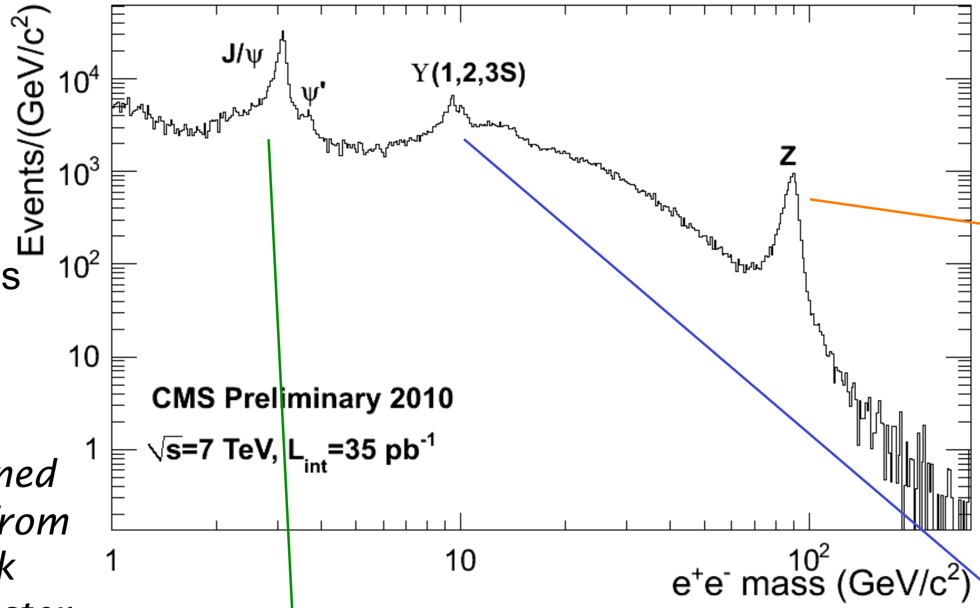


π^0 peak	Data (MeV/c^2)	MC (MeV/c^2)	Data/MC - 1
EB−	134.53 ± 0.03	135.14 ± 0.02	(-0.45 ± 0.03) %
EB+	133.78 ± 0.03	134.94 ± 0.02	(-0.86 ± 0.03) %
EB	134.16 ± 0.02	135.07 ± 0.02	(-0.68 ± 0.02) %
EE−	138.5 ± 0.3	134.8 ± 0.3	$(+2.8 \pm 0.3)$ %
EE+	137.0 ± 0.3	134.2 ± 0.3	$(+2.1 \pm 0.3)$ %
EE	137.8 ± 0.2	134.5 ± 0.2	$(+2.5 \pm 0.2)$ %
η peak	Data (MeV/c^2)	MC (MeV/c^2)	Data/MC - 1
EB−	539.4 ± 0.9	543.3 ± 0.7	(-0.7 ± 0.2) %
EB+	536.5 ± 1.0	543.7 ± 0.7	(-1.3 ± 0.2) %
EB	537.8 ± 0.6	543.3 ± 0.5	(-1.0 ± 0.1) %



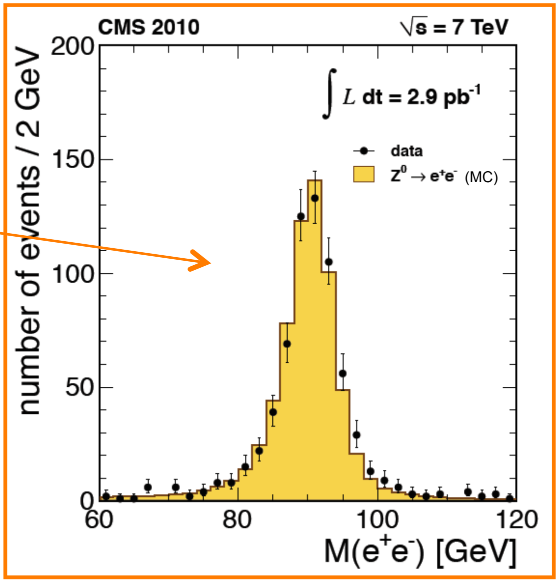


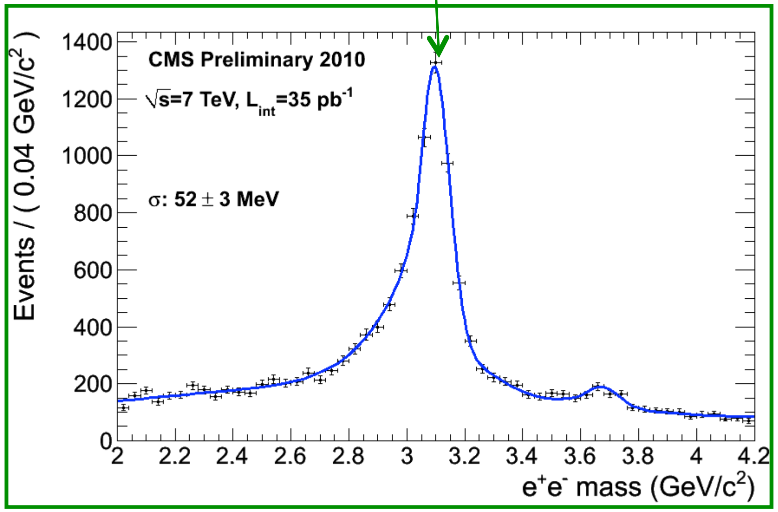
Electrons

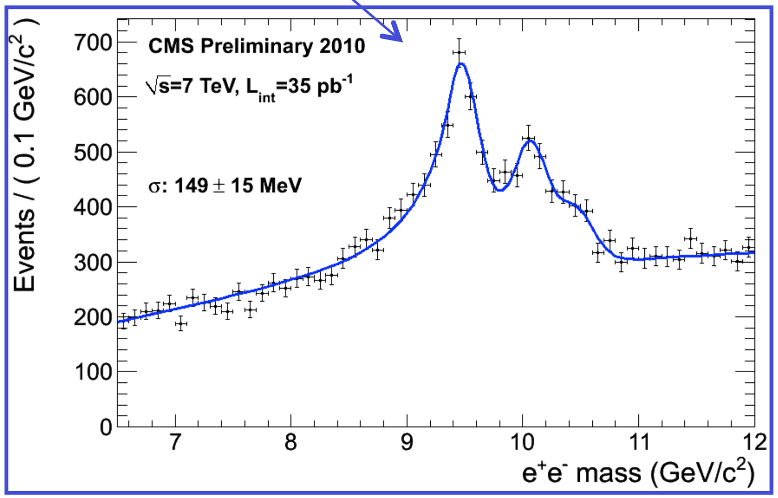


Invariant mass spectrum for opposite sign electron pairs

- used combined momentum from electron track and ECAL cluster energy

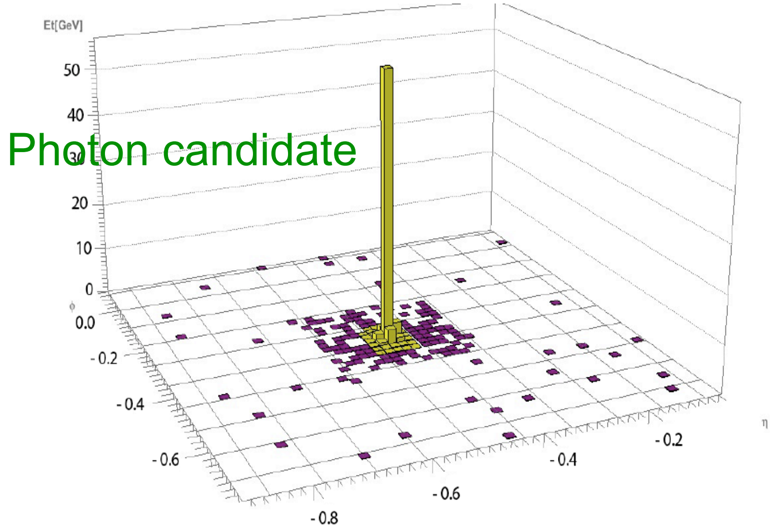


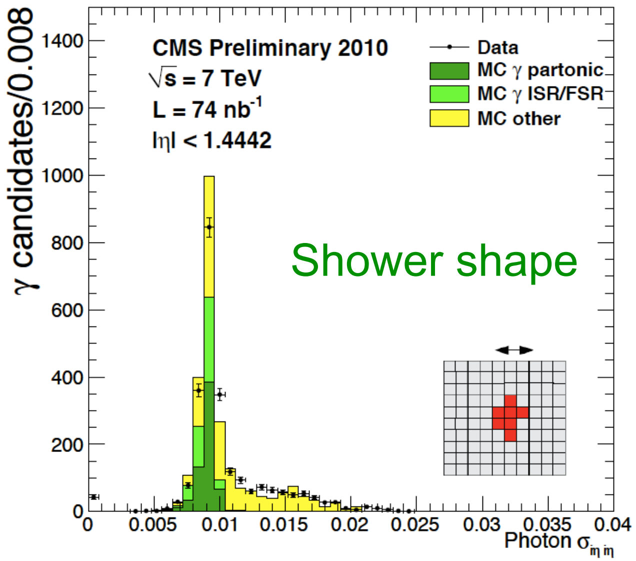


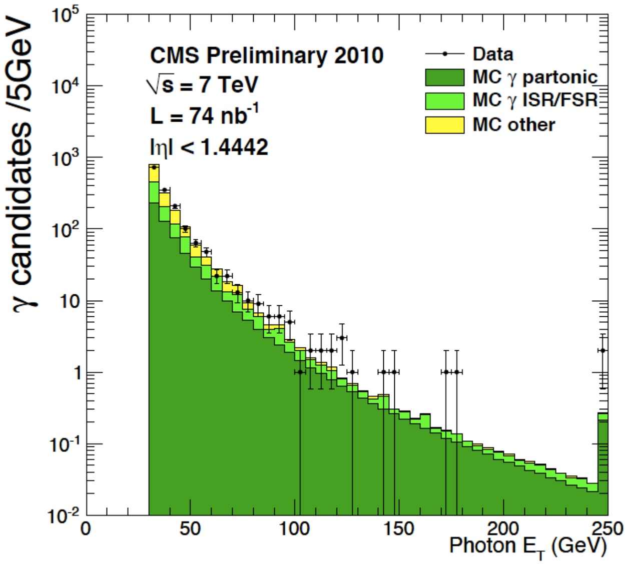


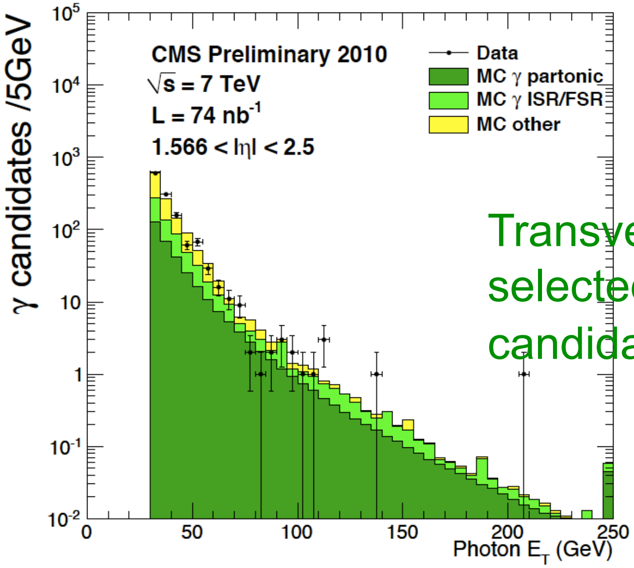
Photons

Photon candidate









Transverse energy of selected photon candidates

Summary

- The CMS ECAL performances in 2010 collisions have been shown.
- ECAL stability is within specifications and constantly monitored
- First collisions provided the opportunity to test our understanding of basic observables
- *In-situ* calibration procedures are being carried out
- Channel-to channel calibration precision at 0.6% level in the central EB region (target for $H\rightarrow\gamma\gamma$)
- Global energy scale in agreement with expectations within 1% in EB and 3% in EE
- The ECAL calibration is being improved using the most recent data
- Good performances in the electromagnetic objects (electrons and photons) reconstruction

Backup slides

ECAL reconstruction

- Signal reconstruction aimed at the best estimate of energy and time in each channel
- Signal quality checked and detector anomalies dealt with
- Among these, direct ionization of the APD efficiently identified and removed at the reconstruction level, exploiting:
  - energy pattern inconsistent with electromagnetic showers
  - timing distribution