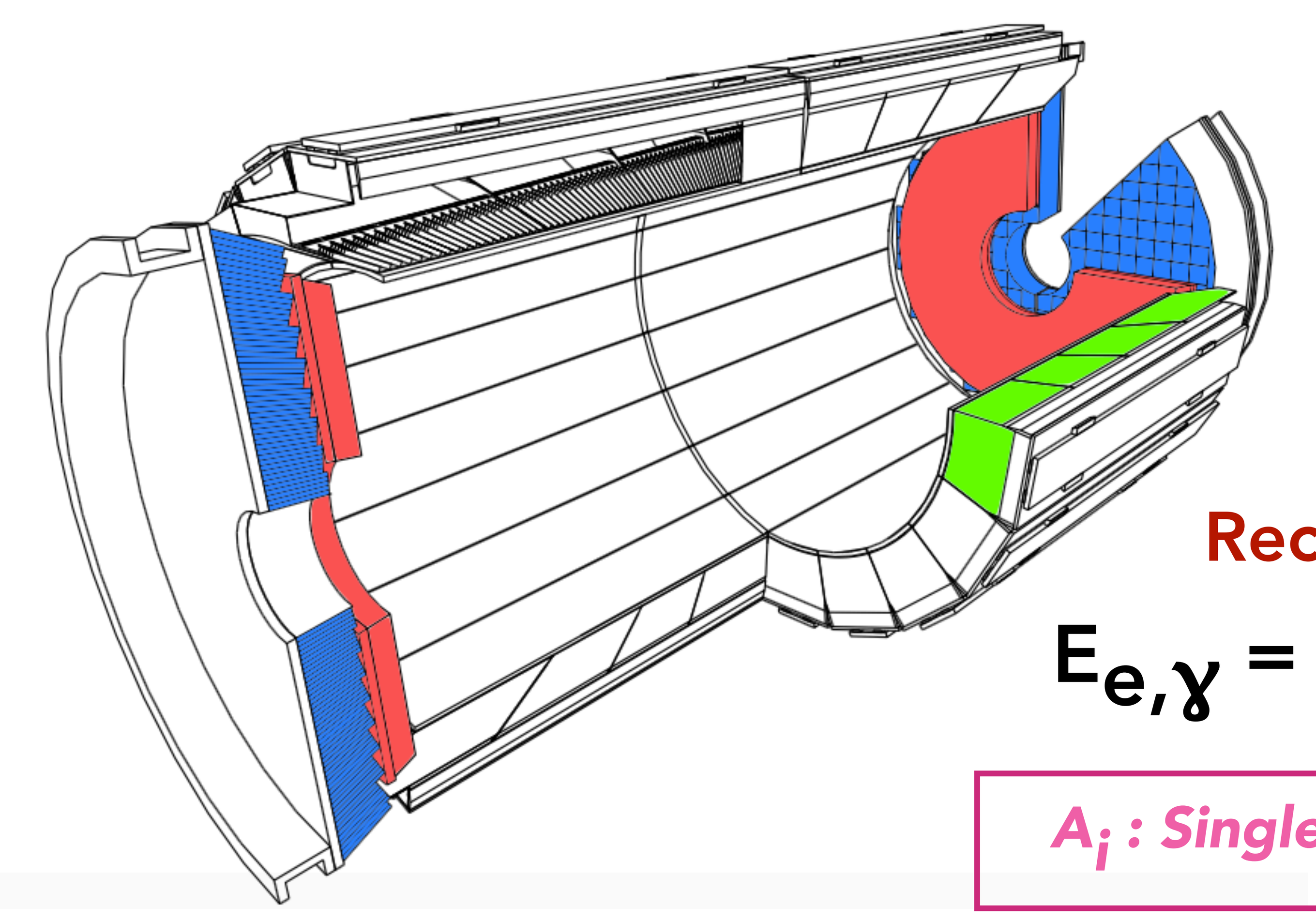
CMS Electromagnetic Calorimeter Calibration and Alignment

Tanvi Wamorkar, *on behalf of the CMS collaboration*
Northeastern University

PM2018 (14th Pisa Meeting on Advanced Detectors)



ECAL Barrel 61200 crystals
ECAL Endcap 14648 crystals
Preshower 137200 Pb/Si strips

Reconstructing energy with ECAL

$$E_{e,\gamma} = \sum_i [S_i(t) \times c_i \times A_i] \times G(\eta) \times F_{e,\gamma}$$

A_i : Single channel amplitude (Multifit reconstruction)

CMS ECAL must provide

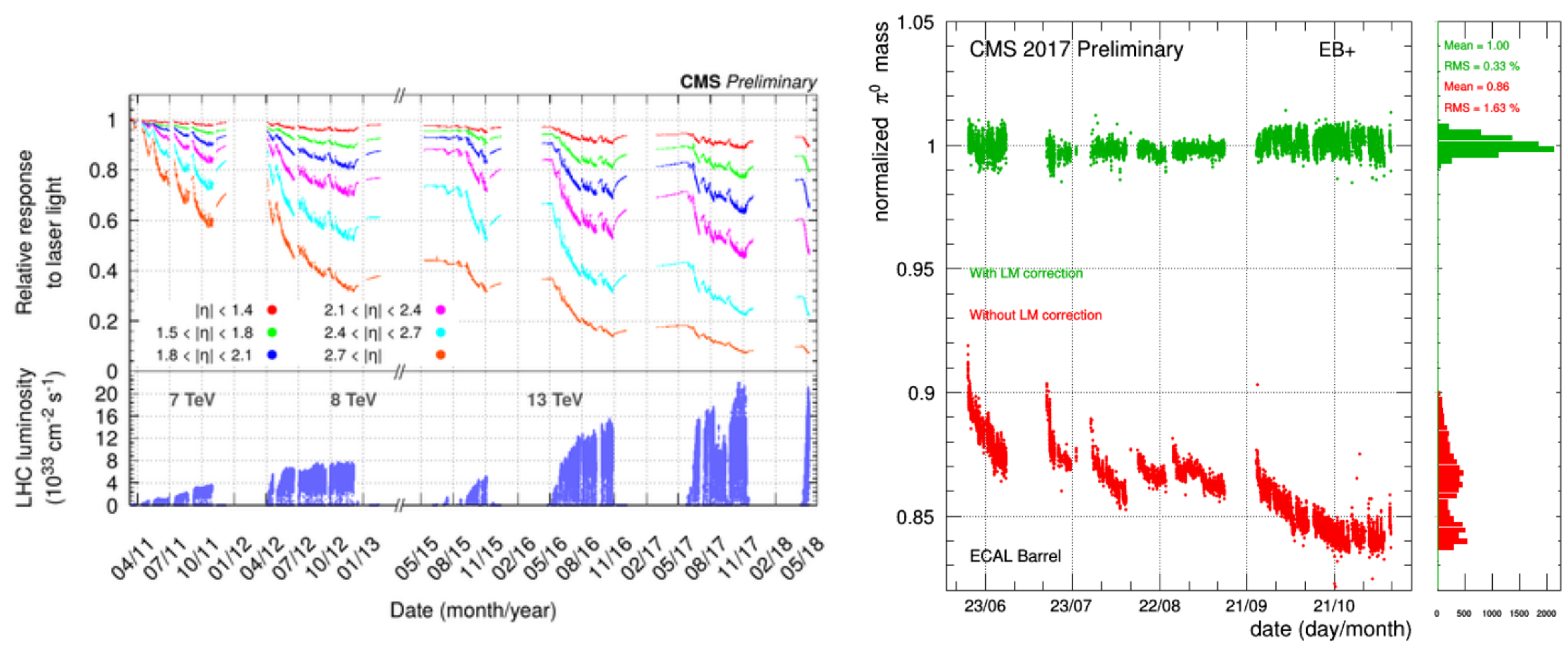
- Precise energy reconstruction resolution
- Precise position resolution for reconstructed deposits
- Fast and efficient readout for online selection

ECAL $PbWO_4$ crystals

- **Homogenous** medium
- Fast light emission : **~80% in 25 ns**
- Small radiation length : X_0 **= 0.89 cm**
- Small Moliere radius : R_M **= 2.10 cm**
- **Reasonable radiation resistance**

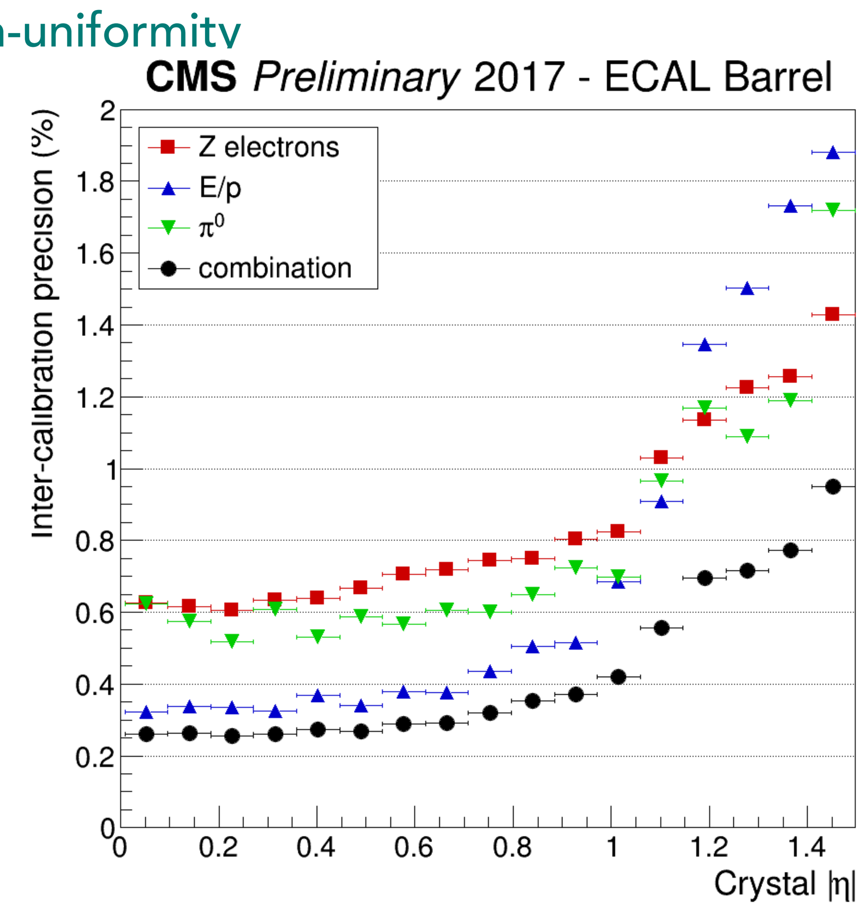
$S_i(t)$: Laser Monitoring

- **ECAL crystals change response** due to radiation exposure (time dependent)
- Response is **monitored with a laser system** injecting light in every ECAL crystal
- $PbWO_4$ **crystals partially recover** during periods with no exposure
- Monitoring **corrections obtained/applied promptly** (~48h)



c_i : Intercalibration

- **Equalizes the response of each single crystal** to the deposited energy
- **Φ symmetry:** energy flux around **Φ** rings (constant **η**) should be uniform - IC corrects for non-uniformity
- **π^0 /η→γγ:** In a **Φ** ring, use IC to improve M(**γγ**) resolution for **π^0** and **η** resonances
- **E/p:** compare isolated electron energy from ECAL and momentum tracker, calculate IC to correct discrepancies



G(η): Absolute calibration and η scale

- **Electrons from Z→ee events** are used to calibrate the **η dependence** of energy reconstruction and its **absolute scale**
- **Z mass peak is used to fix the overall absolute calibration (ADC to GeV)**, matching data to a detailed simulation of the detector
- Z mass peaks reconstructed with **electrons in a single Φ ring**, used to **correct the relative scale** between different **η** regions

$F_{e,\gamma}$: Particle energy corrections

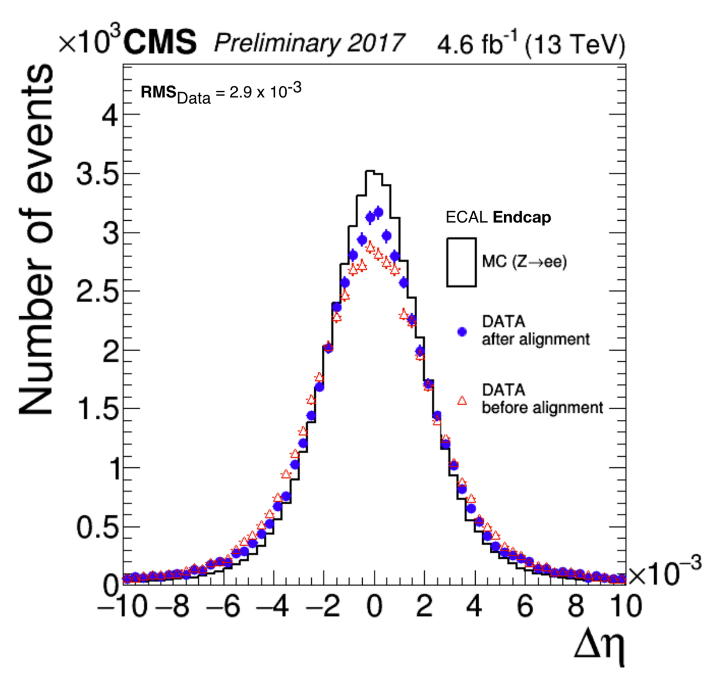
- Large amount of **material before ECAL** - high **probability of bremsstrahlung** emission for electrons **and conversion** of photons
- **Clustering algorithm gathers clusters of energy deposit into superclusters** to recover that information
- **Supercluster energy is corrected using a multivariate approach**
- For endcap e/**γ** , **energy deposited in preshower** is added to the supercluster

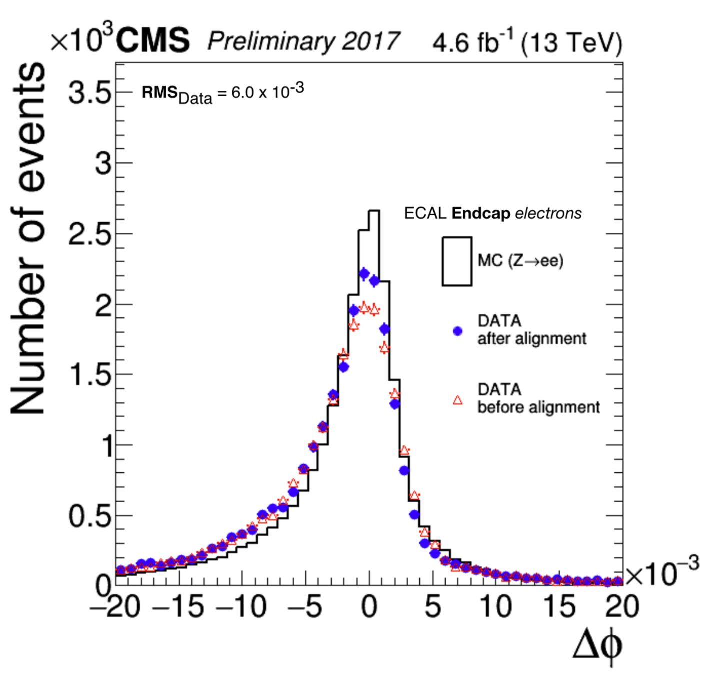
ECAL Alignment

- **Relative alignment of the ECAL crystals and CMS tracker,** measured using electrons from Z→ee events
- Alignment procedure uses **low bremsstrahlung electrons from Z→ee events** collected at the beginning of 2017 data taking period
- Angular distance between extrapolated track & cluster position is minimized for both e⁺ and e⁻ wrt to MC simulation

$$\chi^2_\pm = \sum_{leptons} \frac{(\Delta\varphi - \langle\Delta\varphi^{MC}_\pm\rangle)^2}{\varepsilon^2_\varphi} + \frac{(\Delta\eta - \langle\Delta\eta^{MC}_\pm\rangle)^2}{\varepsilon^2_\eta}$$

- Plots show **residual difference in Δη and ΔΦ** b/w position of the ECAL supercluster and the extrapolated track position, using the point of closest approach to the supercluster
- Relative ECAL-tracker precision of **3×10^{-3} in η units** and **6×10^{-3} in Φ units** achieved in the endcaps
- Meets the ECAL alignment goals of **4×10^{-3} in η units** and **20×10^{-3} in Φ** units for **electron-ID and di-photon resonance reconstruction**





- **Dielectron invariant mass distribution** (2017 data) using Z→ee events
- Only **low bremsstrahlung electrons** are considered
- Distributions show **improved invariant mass resolution** in both **ECAL barrel and endcap**