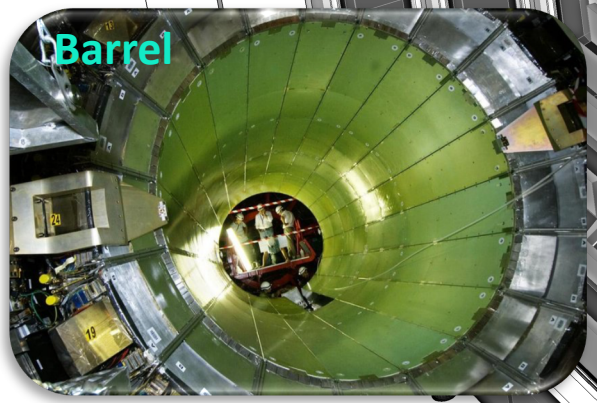
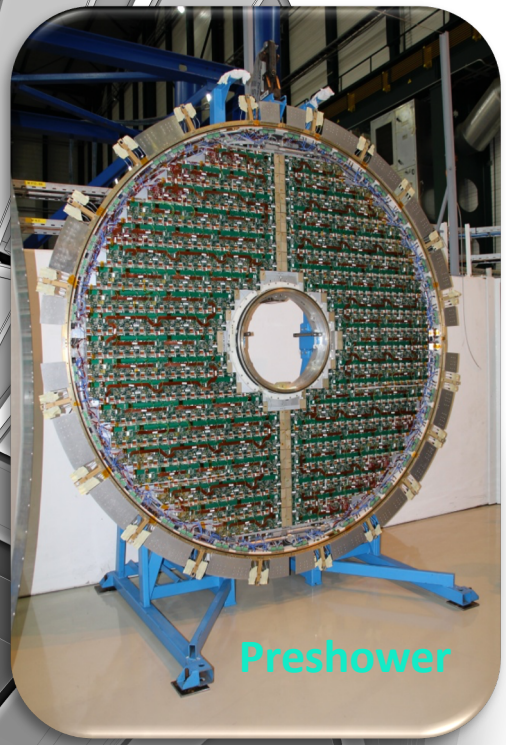
Calibration and Performance of the CMS Electromagnetic Calorimeter during LHC Run 2





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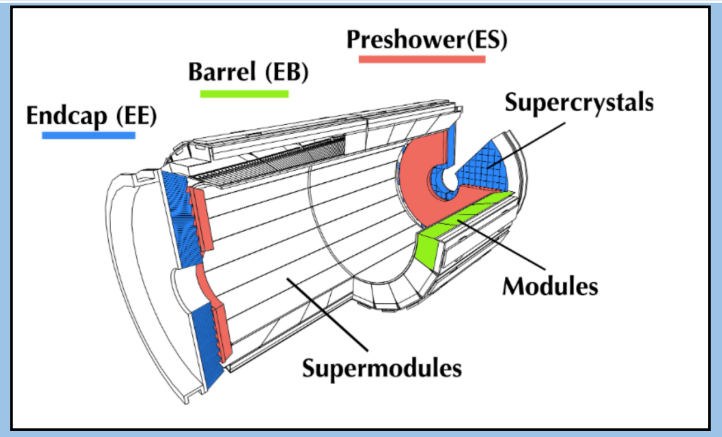
On behalf of the CMS collaboration

The Electromagnetic Calorimeter (ECAL)

The CMS ECAL is compact, hermetic, fine-grain and homogeneous:

- 75848 **$PbWO_4$** scintillating crystals
- **high** density – 8.28 g/cm^3
- **short** radiation length (0.89 cm)
- **small** Moliere radius (2.19 cm)
- **fast** light emission (80 % in 25 ns)

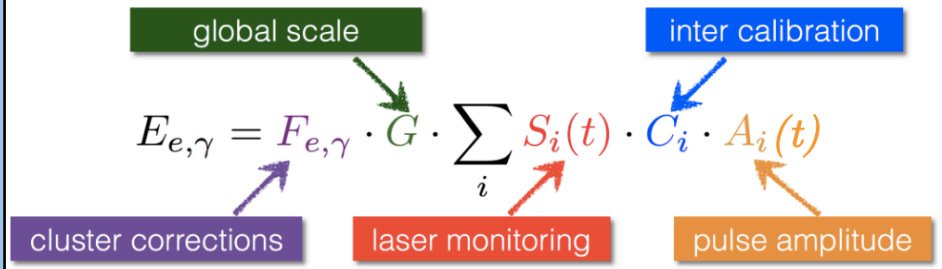


- Two regions:
  - barrel(EB) covers $|\eta| < 1.48$
  - endcap(EE) covers $1.48 < |\eta| < 3.0$
- Scintillation detected by APD (EB) and VPT (EE)

Challenges in LHC Run 2

- Harsher environment due to increasing luminosity: more pileup, larger noise
- Significant radiation damage (in particular in EE) requires a continuous monitoring of the detector response in order to maintain a stable energy scale)

e/γ reconstruction



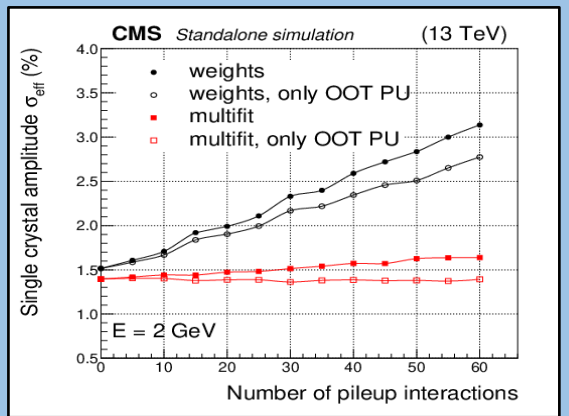
Signal Amplitude Reconstruction

1. Each pulse from APD/VPT is digitized in 10 samples ,

2.Run 1: Amplitude was a weighted sum of all 10 samples.

3.Run 2: "Multifit" method and frequent measurement of the pulse shape templates ***(new!)***

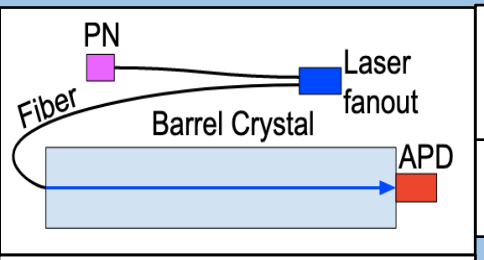
(mitigate out-of-time pileup)



"Multifit" reconstruction:
more robust to pileup increase

Correction of time-dependent effects to recover the stability of energy scale with time

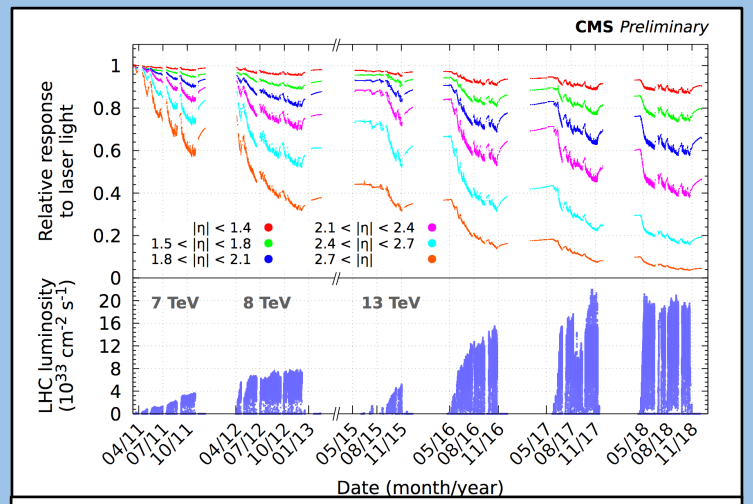
Laser Monitoring system records response to laser light recorded for each crystal every 40 minutes and the reconstructed energy is corrected accordingly



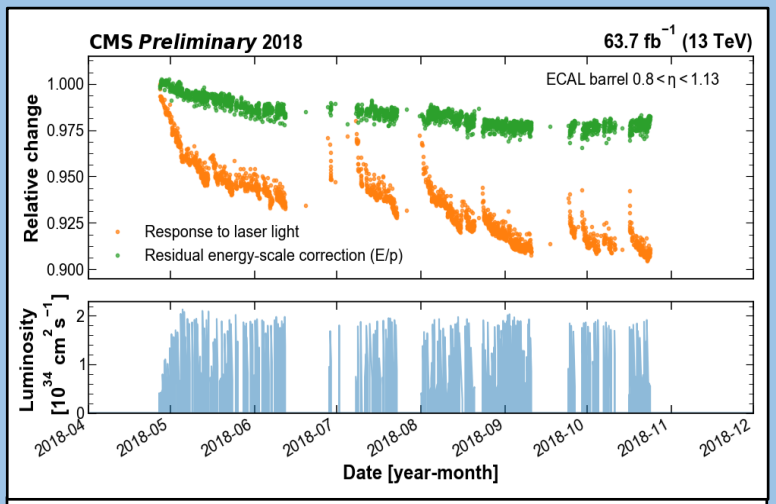
Schematic drawing of ECAL Laser monitoring

$$\frac{S}{S_0} = \left(\frac{R}{R_0}\right)^{\alpha}$$

Relation between laser and scintillation amplitudes



ECAL crystals relative response to laser light as afunction of time for different pseudorapidity regions.



Green – residual energy-scale correction from E/p ratio

Two new effects to be considered in laser corrections ***(new!)***

1. Observed drift of response for crystals in same EB regions sharing same laser PN). **New time-dependent correction – residual energy-scale correction**
2. **periodic re-computation of α parameter** which evolves with radiation damage

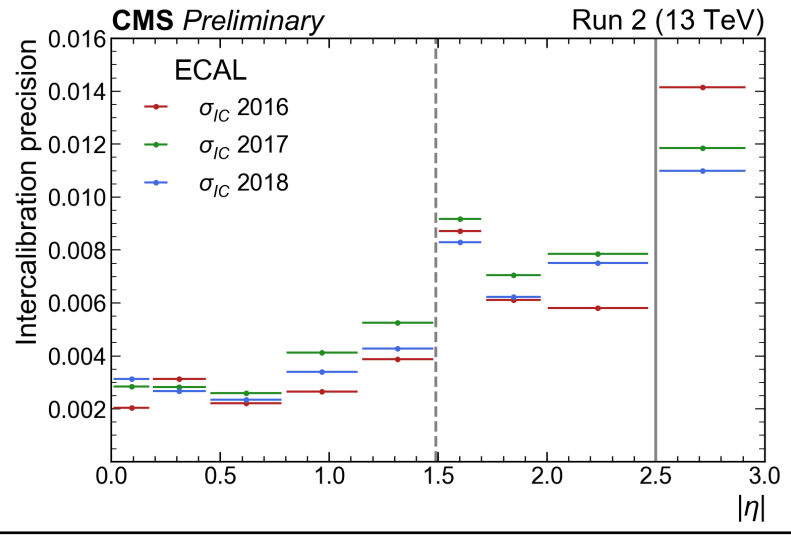
Crystal by crystal intercalibration (beg.)

to equalize the energy response at same η using different methods:

- $\pi^0 \to \gamma\,\gamma$: peak of π^0 invariant mass distribution equalized
- E/p: ratio of prompt electrons energy measured with ECAL and their momentum measured by the tracker detector
- $Z \to ee$: as for $\pi^0 \to \gamma\,\gamma$ but based on the Z-boson invariant mass peak

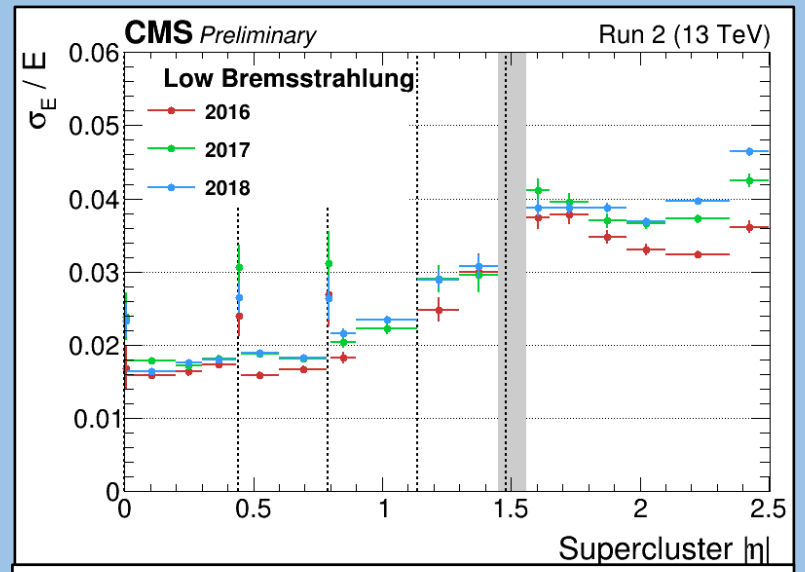
Combination: Each method is weighted by its energy resolution performance as measured in $Z \to ee$ decays to calculate the combined inter-calibration constants.

Crystal by crystal intercalibration (con.)

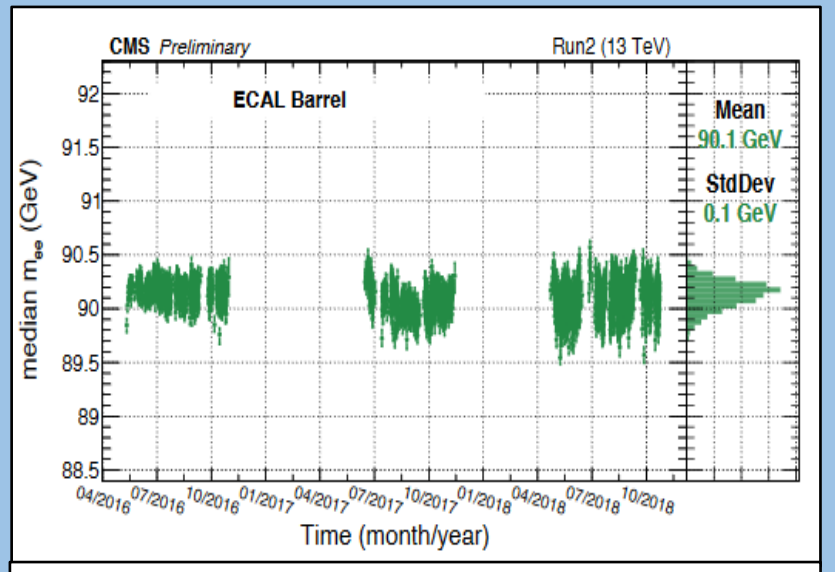


despite the increased radiation damage the same calibration precision level has been achieved for the entire Run2

Energy resolution and scale



resolution within 3% inner part (barrel) and 5% in endcaps



energy scale stable within 1% across three years of data taking

Conclusion

- *The electromagnetic calorimeter of CMS has demonstrated excellent performance during the LHC Run 2!*
- *And this is paramount for the Higgs boson physics program.*
- *The harsh radiation environment requires continuous effort of CMS ECAL team in the operation, monitoring, calibration and simulation of the calorimeter.*

Thank you for your attention.