The CMS ECAL Calibration and Monitoring

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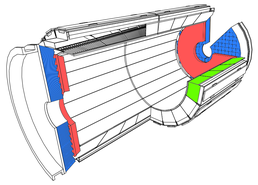
The Electromagnetic Calorimeter (ECAL)

- Primary instrument for measuring the energies of electrons and photons.
- Homogeneous and hermetic.
- Composed of scintillating lead tungstate ($PbWO_4$) crystals: $-61{,}200$ in the barrel and 14,648 in two endcaps
- Coverage: barrel ($|\eta| < 1.4442$) and endcaps ($1.566 < |\eta| < 3.0$)
- **Stability and uniformity of per-crystal response directly contributes to the ECAL energy resolution.**



The ECAL

$PbWO_4$ crystal

$$E_{e/\gamma} = \sum_i \left[S_i(t) \cdot c_i \cdot A_i \right] \cdot G(\eta) \cdot F_{e/\gamma}(\eta)$$

Laser Correction; ADC→GeV; Channel-to-Channel Response Correction; Pulse Amplitude; Clustering Correction

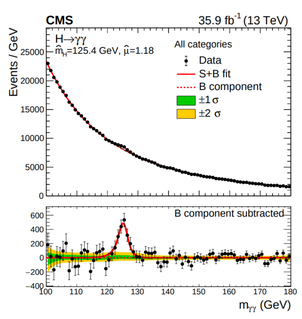
Need for High Resolution

Higgs Physics (precision measurement of mass, differential cross section, and couplings):

- $H \to \gamma\gamma$
- $H \to ZZ, \to 4e/2e+2\mu$
- $H \to WW \to 2e+2\nu/e+\mu+2\nu)$

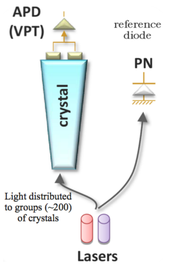
New Physics Searches

- SUSY (e/γ + MET)
- New resonances ($Z' \to ee$, $W' \to e\nu$)

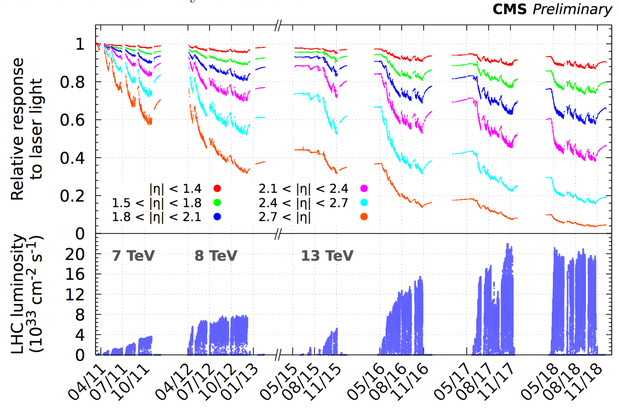


Laser Corrections for Crystal Response Variation

- During run, crystal response varies due to radiation-induced transparency loss.
- Laser monitoring system continuously records response variation during beam abort gaps and measures the corrections every 40 minutes.

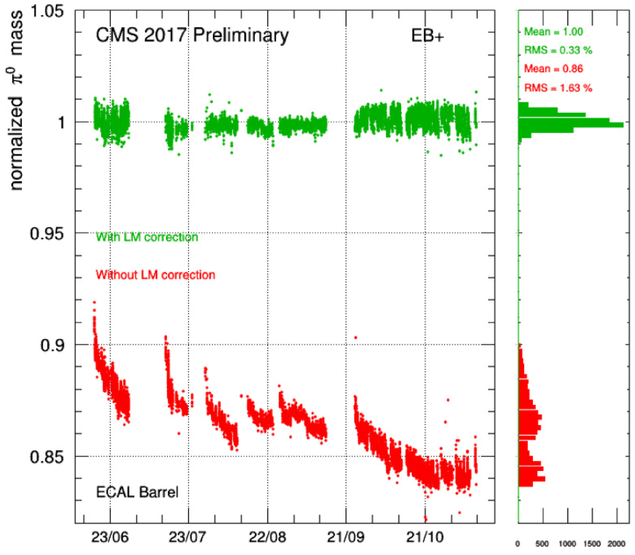


Laser Monitoring

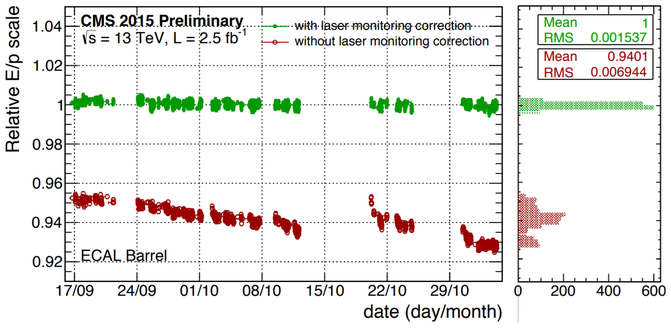


Monitoring

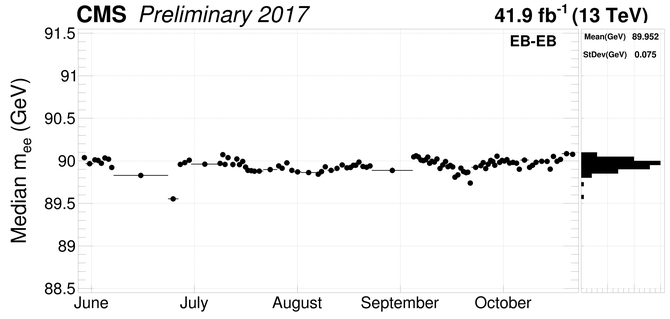
Peak $m_{\gamma\gamma}$ in $\pi^0 \to \gamma\gamma$ events



$E^{\mathrm{ECAL}}/p^{\mathrm{Tkr}}$ of e in $W \to e\nu$ events



Peak m_{ee} in $Z \to e^+e^-$ events



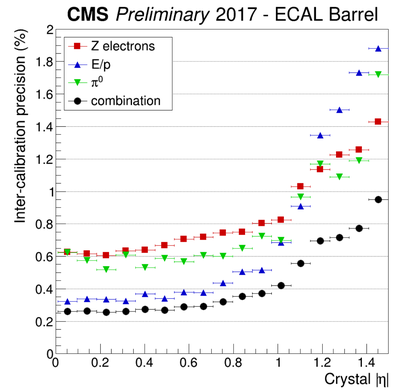
Equalizing Channel-to-Channel Response

Inter-Calibration Techniques

- **ϕ-symmetry**: For a large sample of minimum-bias events, the total deposited transverse energy should be the same in all crystals in a given η-ring.
- **$\pi^0 \to \gamma\gamma$ peak**: Iterative correction to have same fitted peak for every crystal.
- **$Z \to e^+e^-$ peak**: Iteratively minimize per-crystal spread of m_{ee}.
- **$E^{\mathrm{ECAL}}/p^{\mathrm{Tkr}}$ template**: Iteratively fit each crystal to the same underlying template.

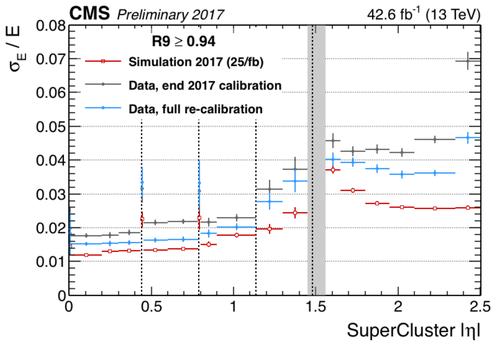
Combination

Use weighted mean of each technique to achieve highest precision.



Resolution Improvement

- Re-computation of inter-calibration gives up to **2% improvement in resolution**.
- Full Run II data will be reprocessed with finer time-binned corrections.



References

[1] The CMS Collaboration. "Energy calibration and resolution of the CMS electromagnetic calorimeter in pp collisions at $\sqrt{s} = 7$ TeV". In: *Journal of Instrumentation* 8.09 (2013), P09009–P09009.

[2] The CMS Collaboration. "Performance of photon reconstruction and identification with the CMS detector in proton-proton collisions at $\sqrt{s} = 8$ TeV". In: *Journal of Instrumentation* 10.08 (2015), P08010–P08010.

[3] The CMS Collaboration. "Performance of electron reconstruction and selection with the CMS detector in proton-proton collisions at $\sqrt{s} = 8$ TeV". In: *Journal of Instrumentation* 10.06 (2015), P06005–P06005.