The CMS ECAL ϕ-symmetry calibration

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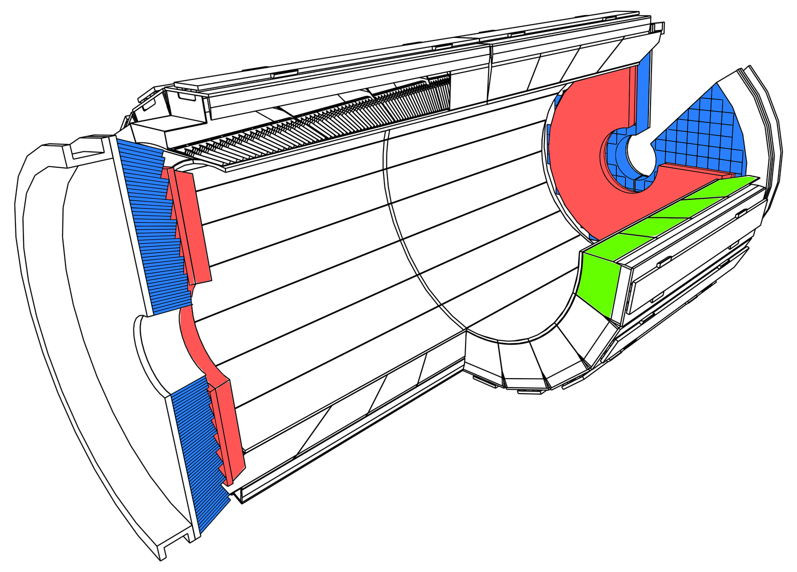
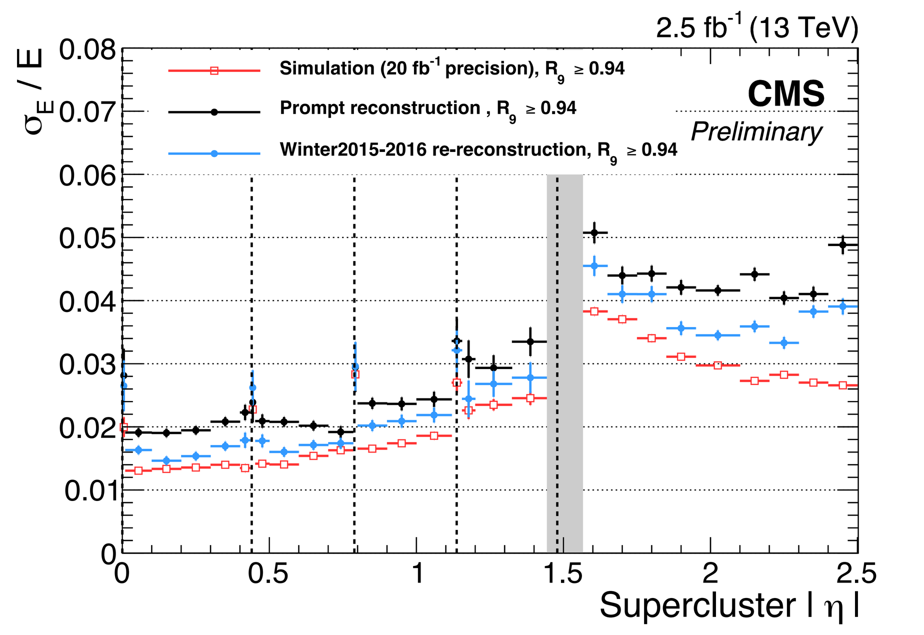


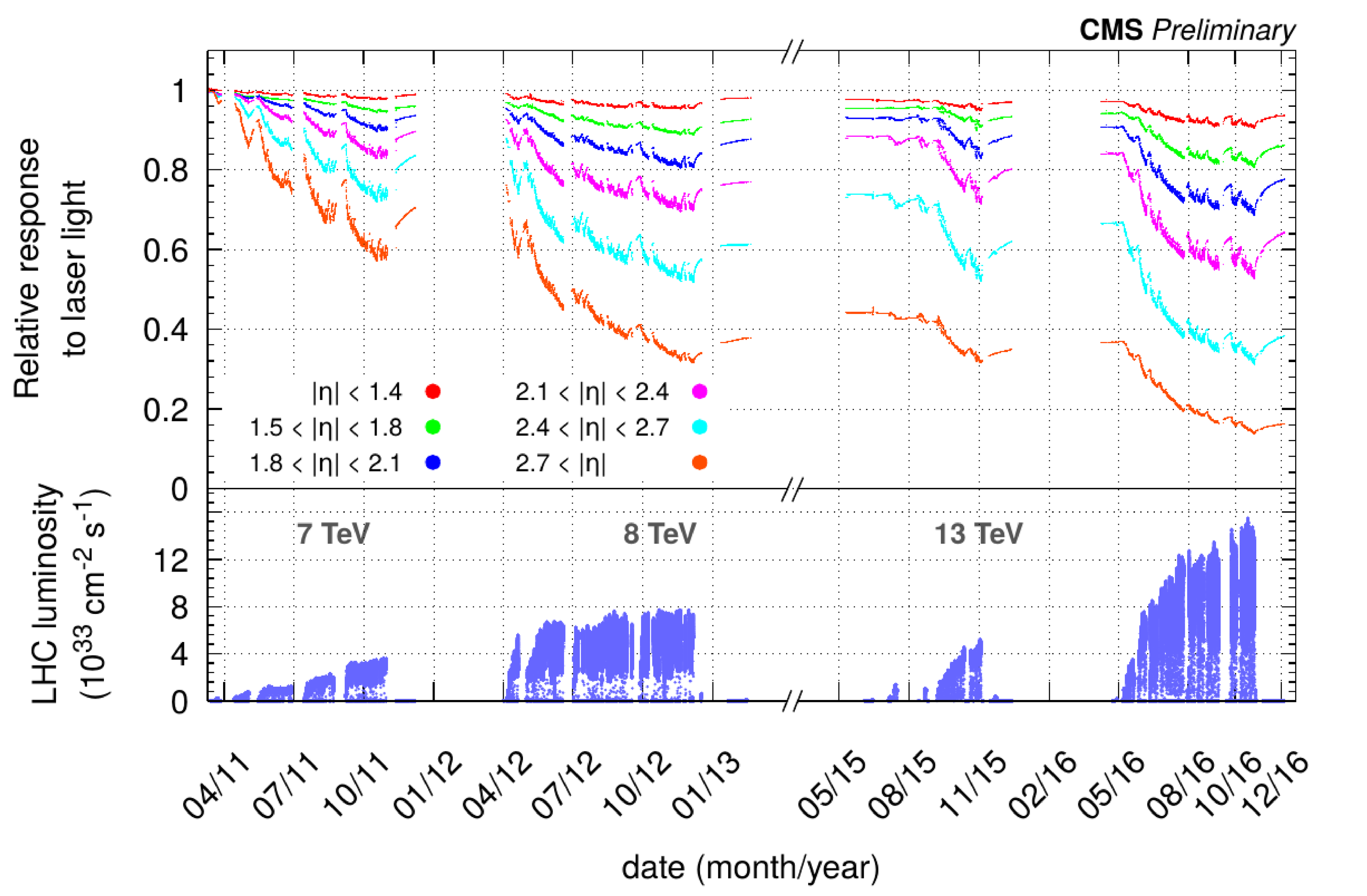
The CMS ECAL barrel, endcaps and preshower.

The CMS Electromagnetic Calorimeter

- The CMS ECAL is an homogeneous calorimeter made of 75848 $PbWO_4$ scintillating crystals.
- **The purpose of the energy intercalibration is:**
  - → Achieve an excellent resolution on high energy electrons and photons.
  - → The ultimate goal is to measure the properties of the standard model Higgs bosons and search for particles predicted by new models of fundamental interactions.



Relative electron (ECAL) energy resolution unfolded in bins of pseudo-rapidity η. Electrons from $Z \rightarrow e^+e^-$ decays are used. **Black points** refer to 2015 data with 2012 calibration while azure points show the improvement brought by a dedicated 2015 ECAL calibration.



Relative response to blue laser light injected in the ECAL crystals, measured by the ECAL laser monitoring system, averaged over all crystals in bins of pseudo-rapidity. **The system provide a measurement every 40 minutes.**

Energy measurement with ECAL

Laser monitoring · Intercalibration · Global scale · Cluster corrections · Pulse amplitude

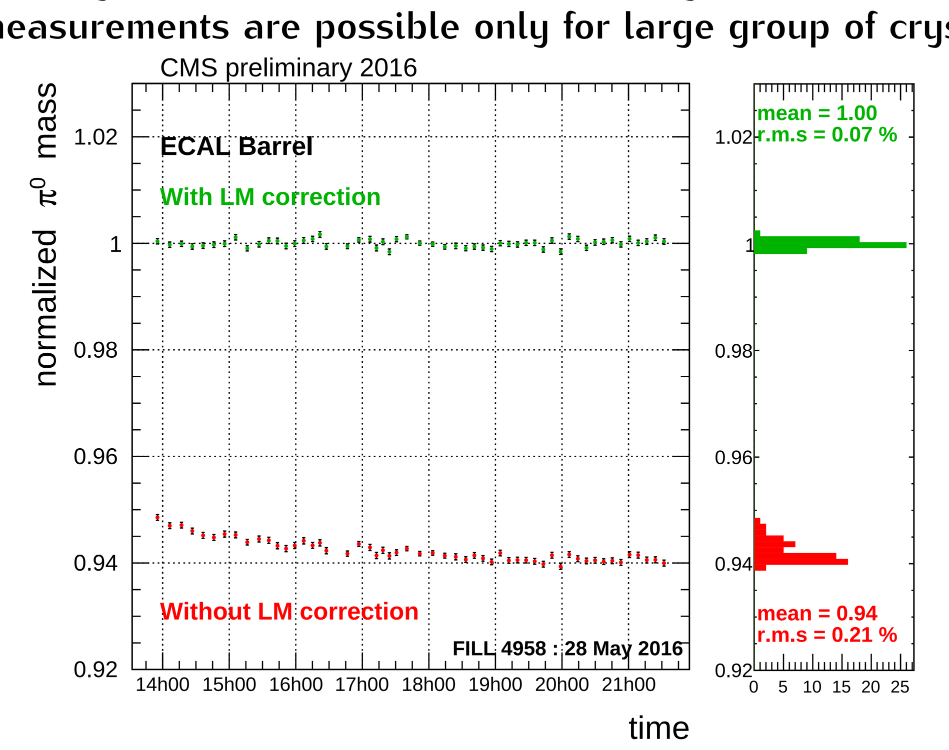
$$E_{e,\gamma} = \Sigma_i [S_i(t) \cdot c_i \cdot A_i] \cdot G(\eta) \cdot F_{e,\gamma}$$

- Intercalibrations with **isolated electrons** from W and Z bosons decays are based on the comparison of the energy measured in the ECAL to the track momentum measured in the silicon tracker.
- The π^0 and η^0 calibration uses the invariant mass of photon pairs from these mesons to intercalibrate the channel response.
- **The ϕ-symmetry method is based on the expectation that, for a large sample of minimum bias events, the total deposited transverse energy should be the same in all crystals at the same pseudorapidity η. The intercalibration coefficients (IC) are then computed such that the average for crystals at the same η is one.**

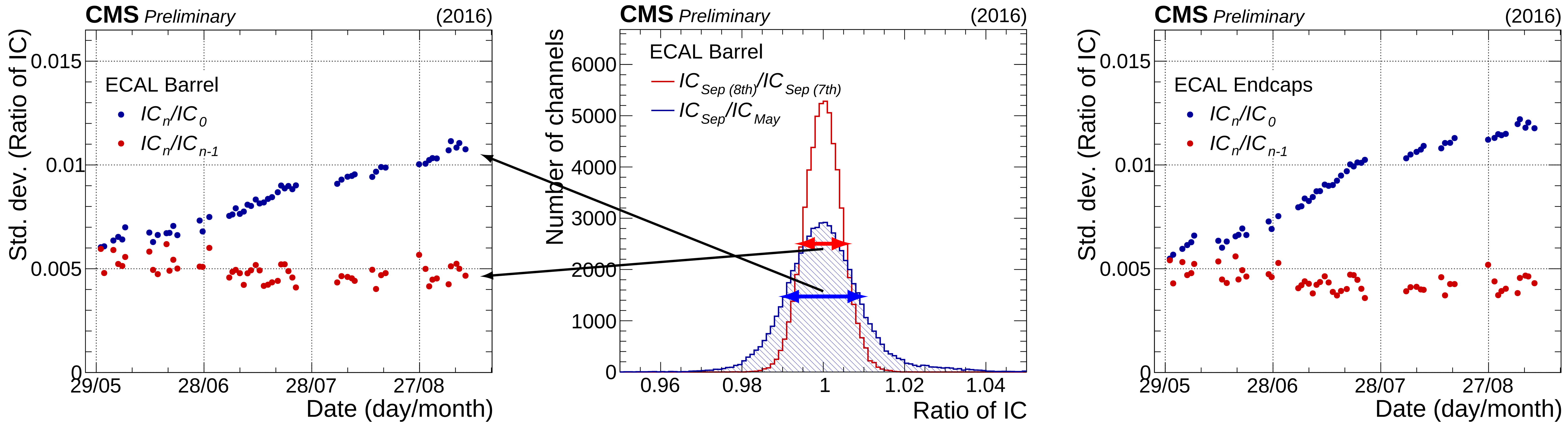
Monitoring and calibration with ϕ-symmetry

- **The ϕ-symmetry provides both a method to derive channel IC and a way to monitor each crystal response with collision data and a fine time granularity of typically 1-2 days (that correspond to about 80 million minimum bias events).**
- In 2016 a variation of the IC over time has been observed, as show from the plots at the bottom.
- The response change (R_{change}) measured with the laser monitoring system is used to correct the energy measured by each crystal. The correction factor is $(1/R_{change})^{\alpha}$, where the parameter α takes into account the different response of the detector to the laser light and scintillation light produced by electromagnetic showers. The α parameter value is known (from test beam measurements) only for few crystals of the CMS ECAL with an uncertainty of about 10%.
- **The variation over time of the IC can be corrected using the ϕ-symmetry method, improving in this way the stability of the ECAL response vs time.**

The improvement on the energy reconstruction provided by the correction derived from the laser data is observed looking at the stability in time of the π^0 invariant mass and E/p ratio for high energy electrons.
Although these methods track changes over the course of few hours, the measurements are possible only for large group of crystals.



The plot shows, for a typical LHC fill in 2016, the stability of the relative energy scale measured from the invariant mass distribution of π^0 decays in the ECAL barrel. Each point is obtained from a fit to approximately 8 minutes of data taking.



The plots show the relative variation of the intercalibration coefficients (IC) of the CMS ECAL during 2016 data taking. The left plot includes channels in the barrel ($\eta < 1.5$) while the right one in the endcaps ($\eta > 1.5$). For each channel and for each point in time two ratios are computed: IC_n/IC_{n-1} and IC_n/IC_0 being n, n-1 and 0 the current, previous and first point of the year. Example distribution are shown in the center plot