The CMS Electromagnetic Calorimeter workflow

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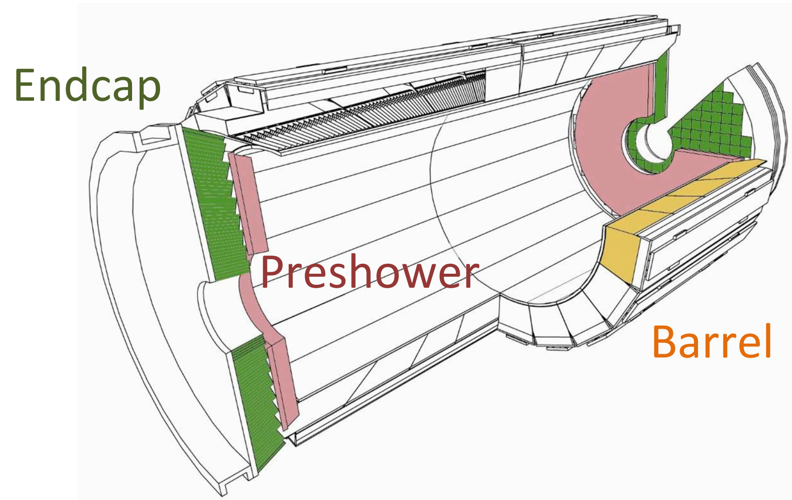
on behalf of the CMS Collaboration

CHEP2019, Adelaide, 4-8 Nov. 2019

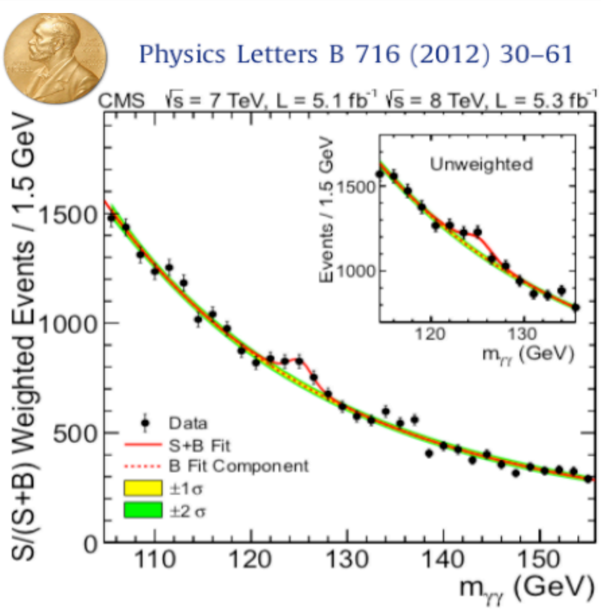
The CMS Electromagnetic Calorimeter

Homogeneous, high granularity, hermetic
$PbWO_4$ crystals calorimeter + Lead/Si Preshower

	coverage	channels	readout
Barrel (EB)	|η|<1.48	61200	APD
Endcaps (EE)	1.48<|η|<3	14648	VPT
Preshower	1.65<|η|<2.6	137216	



Largest crystal calorimeter ever built for a high energy physics experiment

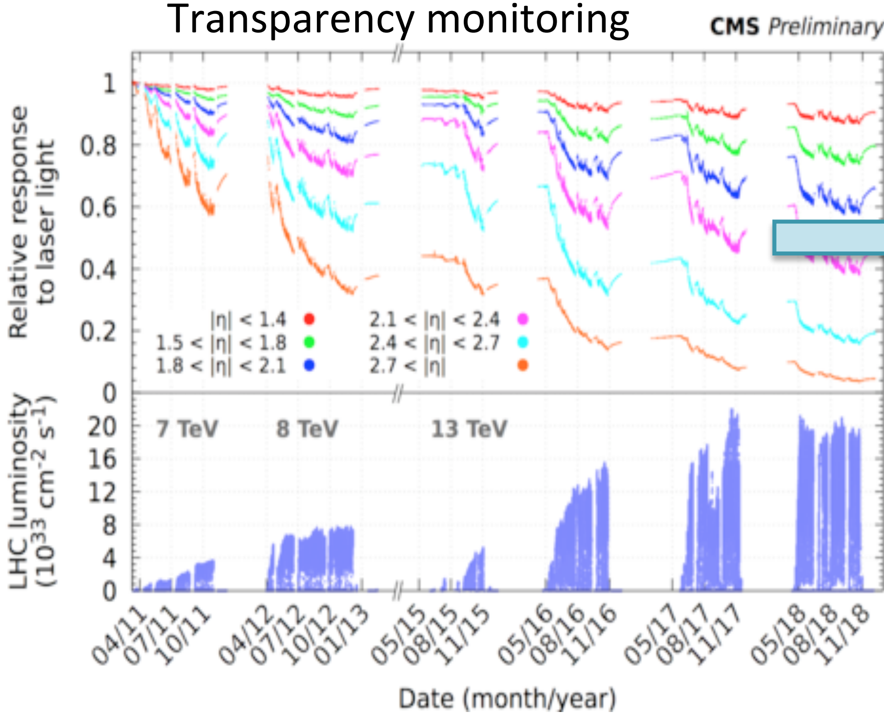


ECAL plays a crucial role for the CMS physics program

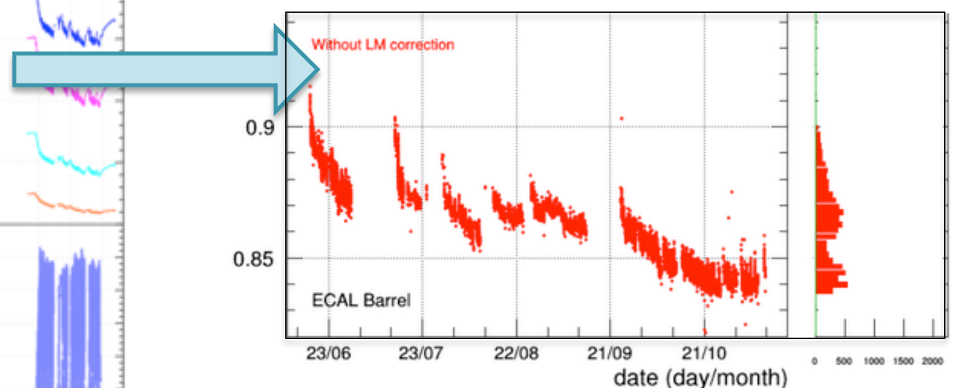
Goal: precise (%-level) e/γ energy measurement
−> stability and uniformity in situ must be <<1%

Challenges

Transparency monitoring



Normalized π^0 mass (wo corrections)



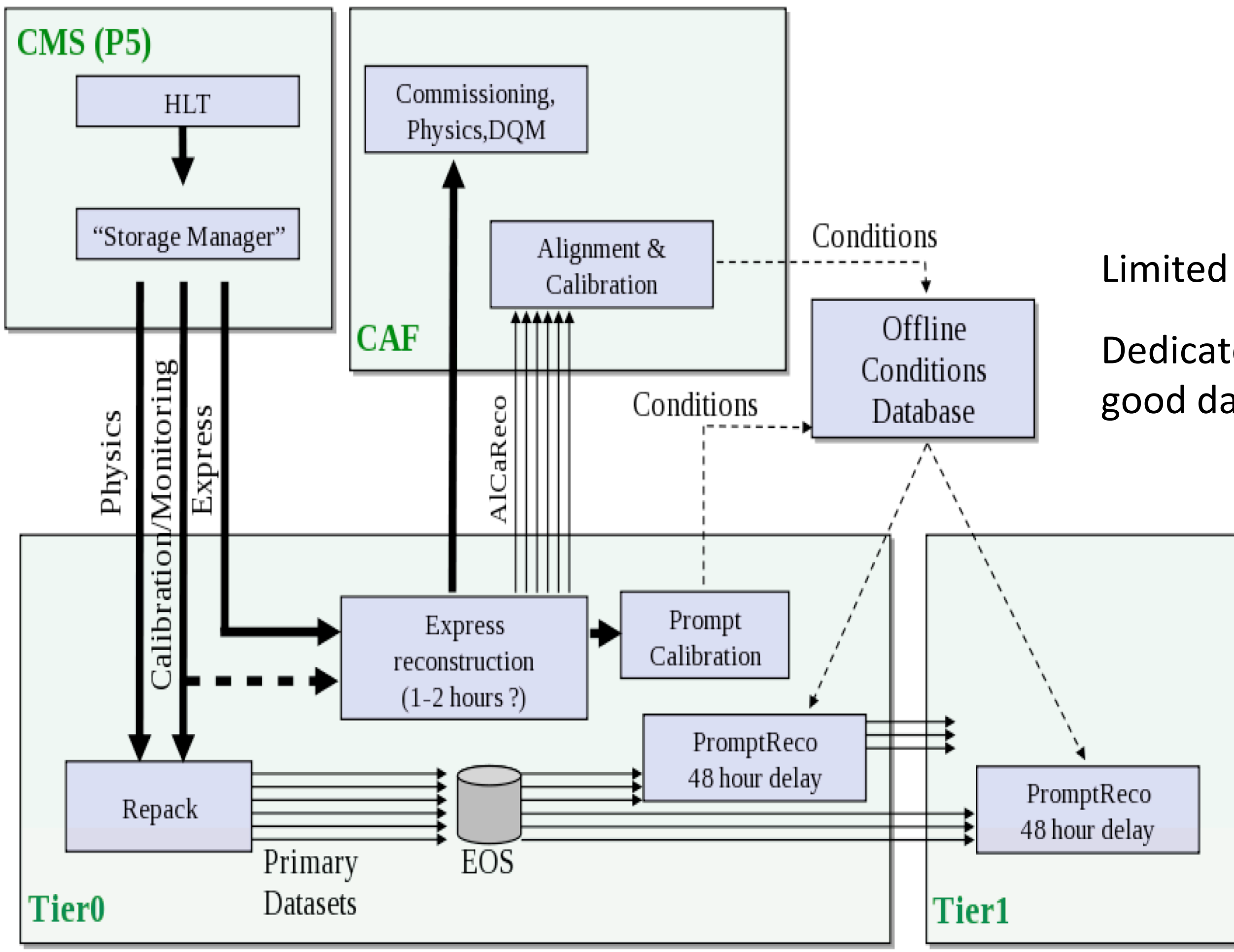
ECAL goal is in-situ stability <<1%, but response variation is >>1%

Crystal calorimeters require constant monitoring to correct for environment effects and radiation induced light output change, and periodic channel-to-channel calibration

⇒ Dedicated streams
⇒ Dedicated monitoring workflow

To have frequent and high granularity corrections

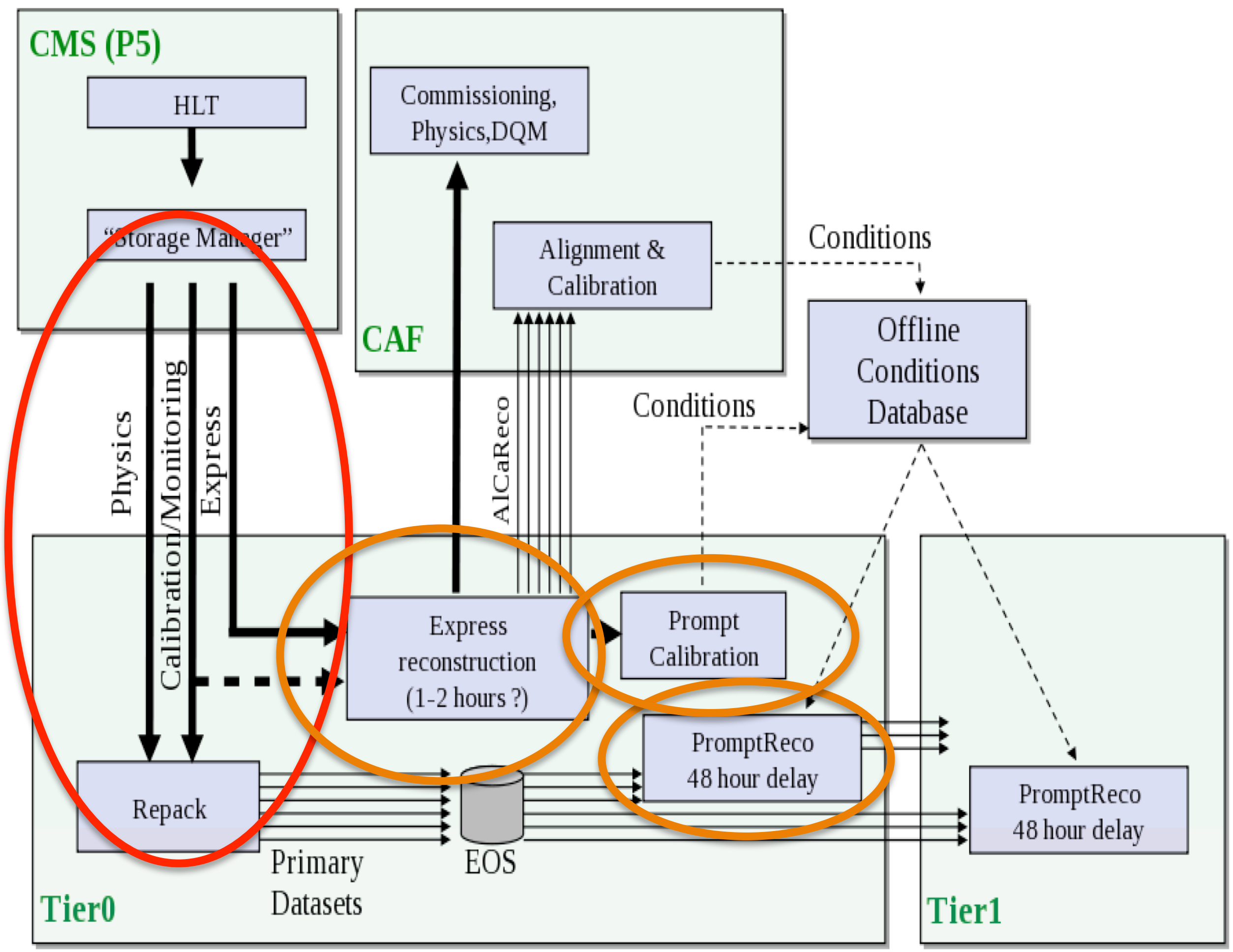
CMS Calibration workflow



Limited number of data reprocessings /year

Dedicated workflows to ensure good data quality since the beginning

CMS Calibration workflow



Trigger selecting good events (L1 hardware + HLT software)

3 data streams

Express

- Prescaled
- Prompt feedback and calibrations

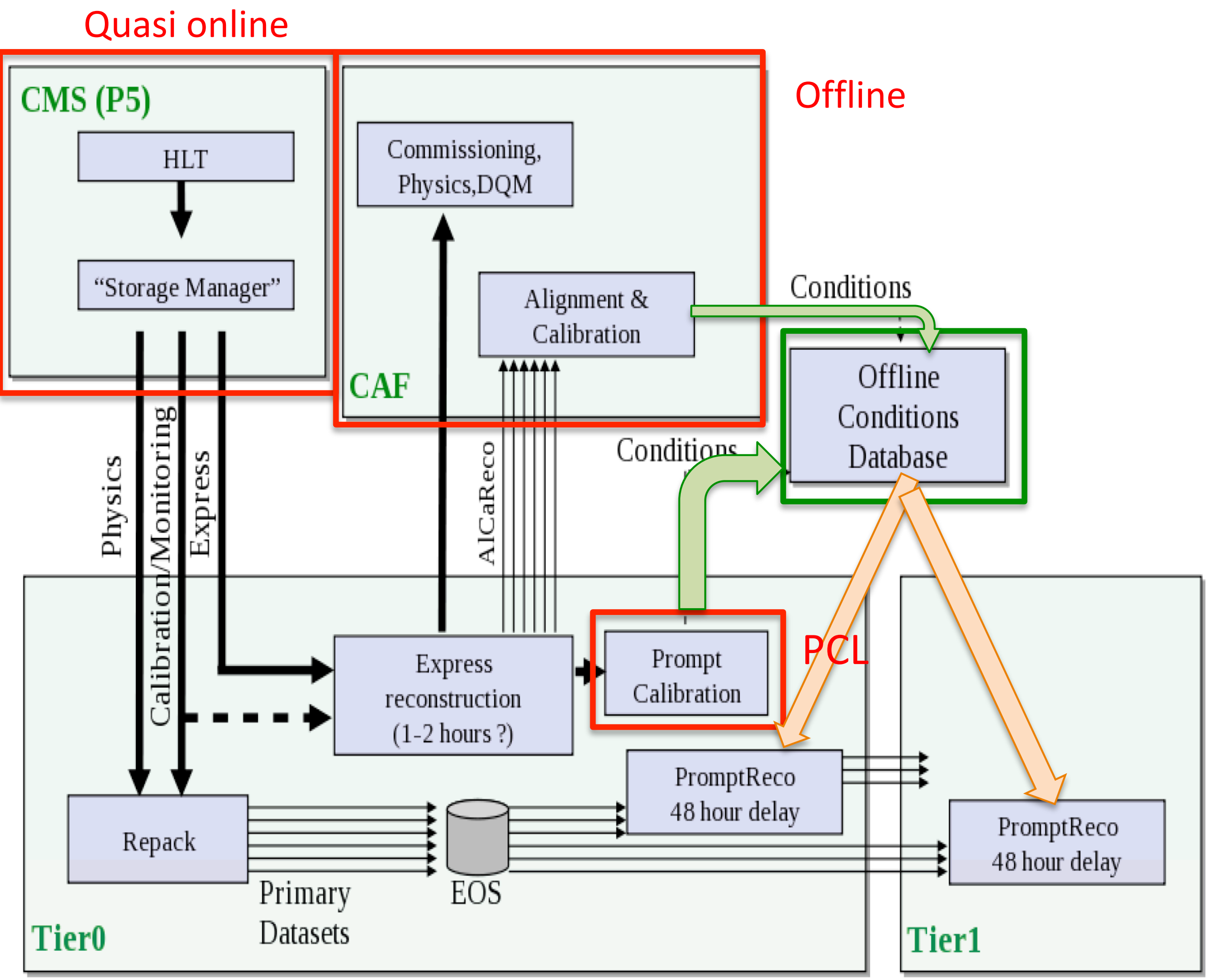
Alignment and calibration streams produced at HLT:

- Low CPU usage
- Reduced event content

Prompt reconstruction:

- Delayed 48h to get updated calibrations from a *Prompt Calibration Loop (PCL)*

CMS Calibration workflow



Calibrations computed quasi online, in PCL and offline

⇩

Uploaded to Conditions Database

⇩

Used in prompt reco

ECAL calibration streams @HLT

Online streams to accumulate millions of events for calibration even if the relevant triggers are normally heavily prescaled

- Smaller size -> reduced event content -> higher rate allowed

More frequent,
more granular updates

ϕ-symmetry stream

For calibration and local reconstruction tuning

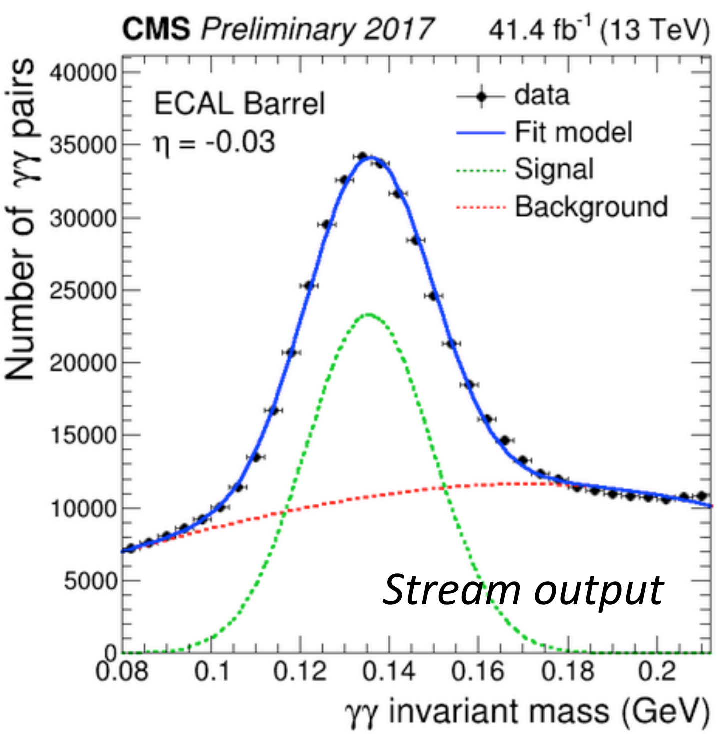
- HLT output: filtered ECAL digis above noise
- Rate fixed by L1 prescale

π^0 and $\eta \to \gamma\gamma$ stream

For calibration and response stability monitoring

- Unpack only ECAL regions around L1 relevant seeds
- HLT output: filtered ECAL digis,
  in regions with a π/η candidates

Stream	Rate	Event Size
ϕ-symmetry	~3 kHz	Few kBs
π^0, η	~7 kHz	~2kB



Monitoring ECAL response

Automatic

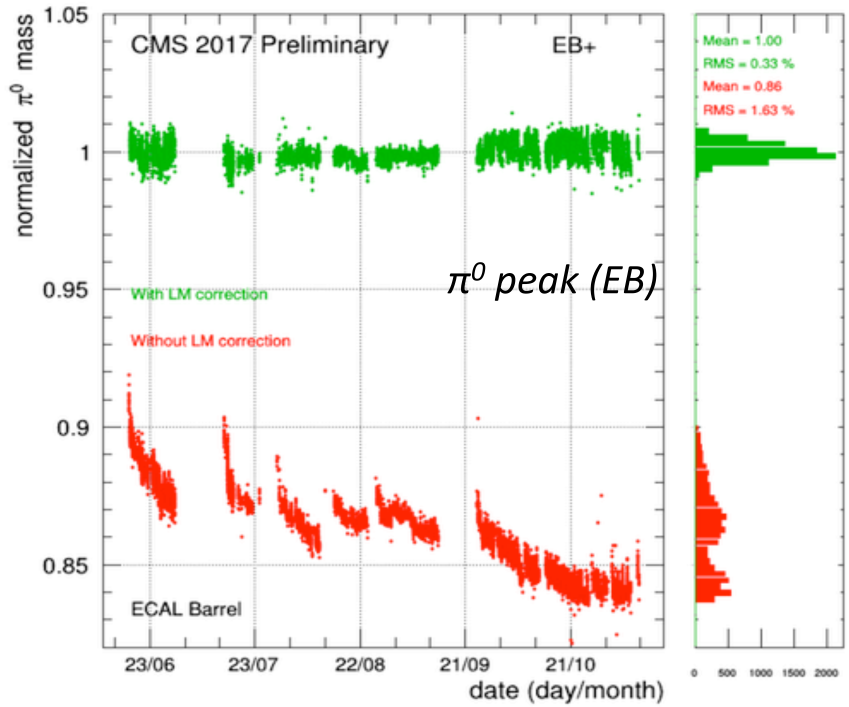
Scintillation mechanism in ECAL crystals radiation hard, but crystal transparency affected

Crystals response monitored event by event with a laser system

Laser light injected in each crystal during LHC abort gap @100Hz

- Blue (447 nm) and green (527 nm)
- 1 point / crystal every 40 min (entire detector)

Data processing @laser monitoring farm



Offline corrections computed in PCL

- Run unattended just after data taking
- Uploaded to the condition database in time for prompt-reconstruction

Online conditions (L1/HLT) updated 2/week

- Stabilize energy scale, resolution, efficiency

Monitoring pedestals

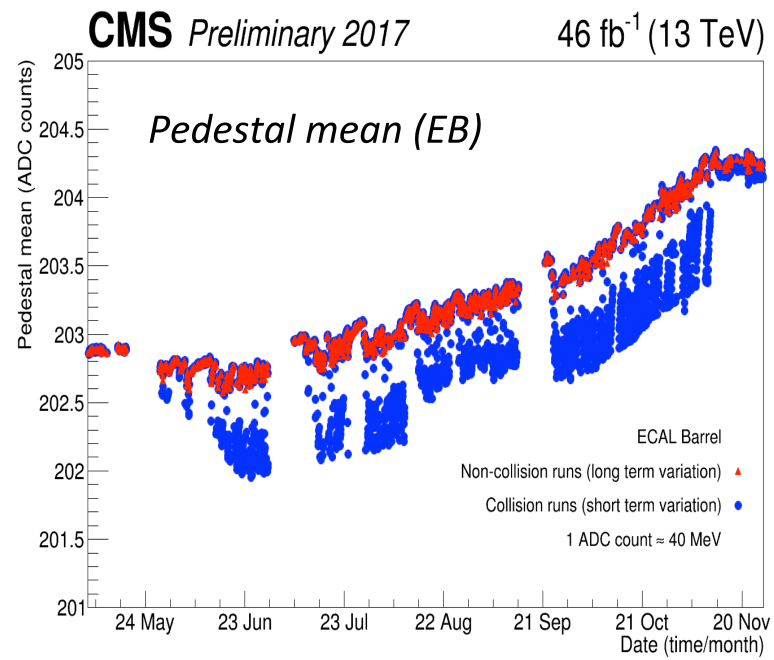
Automatic

Electronic pedestals drift with time

Input to local reconstruction, needs monitoring
- Data processing @Tier-0
- Laser stream data used

Offline corrections computed in PCL
- 1 point / crystal per run
- Uploaded to the condition database in time for prompt-reconstruction

Online conditions (L1/HLT) updated 2/week
- Stabilize rate
- Reduce impact of spikes (direct APD ionization) at L1



Other conditions

Manual

Other conditions computed offline and updated manually after validation

Timing-related quantities

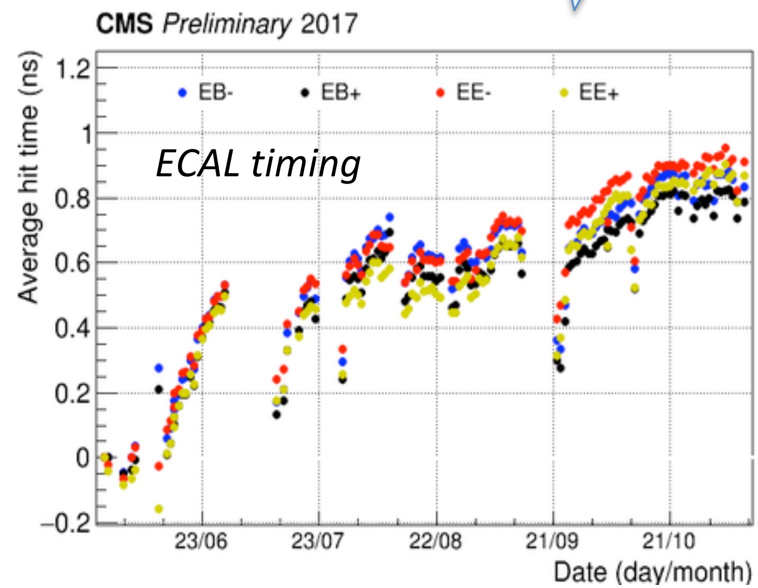
- From φ-symmetry stream
- Updated when amplitude bias ~1% (~1ns drift)

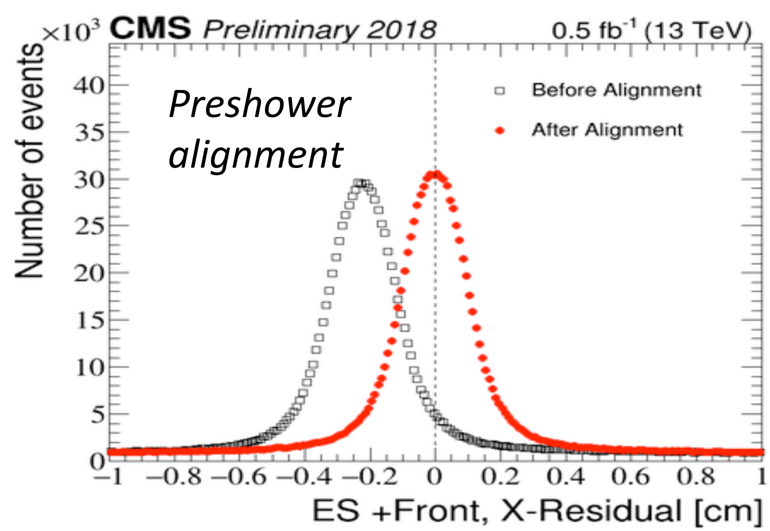
Energy scale

- From Z−>ee events in prompt-reco data
- Updated when relevant scale drift (~1-2%)

Alignment

- Updated at data-taking startup (tracker movements during shutdown)
- No further updates during year
- From Z−>ee (ECAL) and charged tracks (preshower)





Computing intercalibrations

Offline

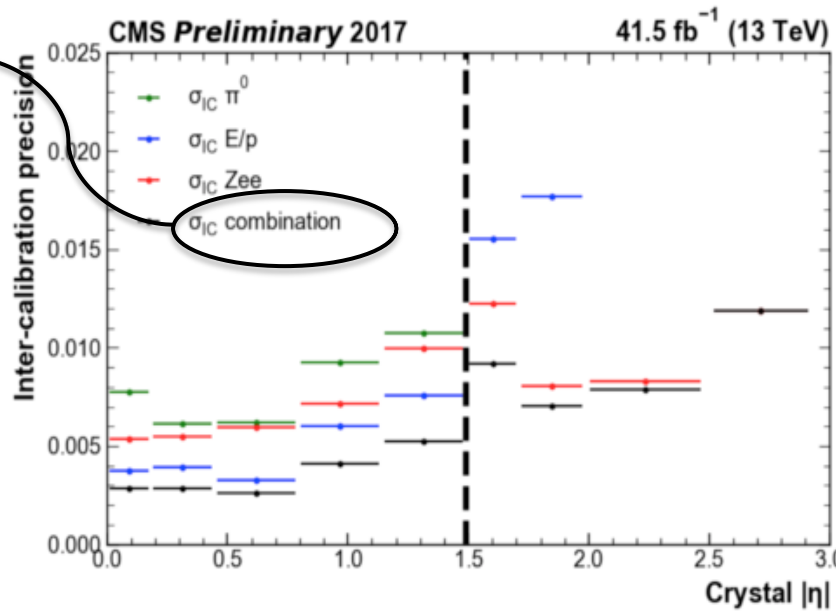
Crystals intercalibration precision directly affects ECAL energy resolution

Complementary techniques, gain from combination

Method	Frequency / year	HLT stream	Data-format
ϕ-symmetry	several	yes	yes
$\pi^0/\eta \to \gamma\gamma$	1	yes	yes
Electron E/p	1	no	yes
Z->ee mass	1	no	yes

Reduced format: regional and electrons infos.

ECAL-only 1y data processings take 3-4 days on LSF or HT condor.



Manual

- Minor updates, if any, during data-taking
- Recalibration performed at the end of the year and used the year after

See F.Cavallari's poster in T2

Data reprocessing

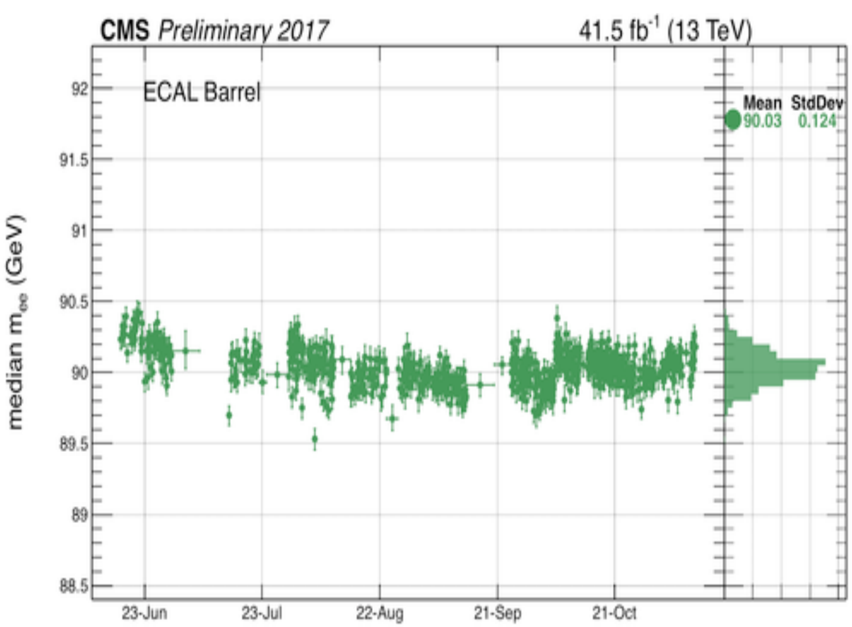
Offline

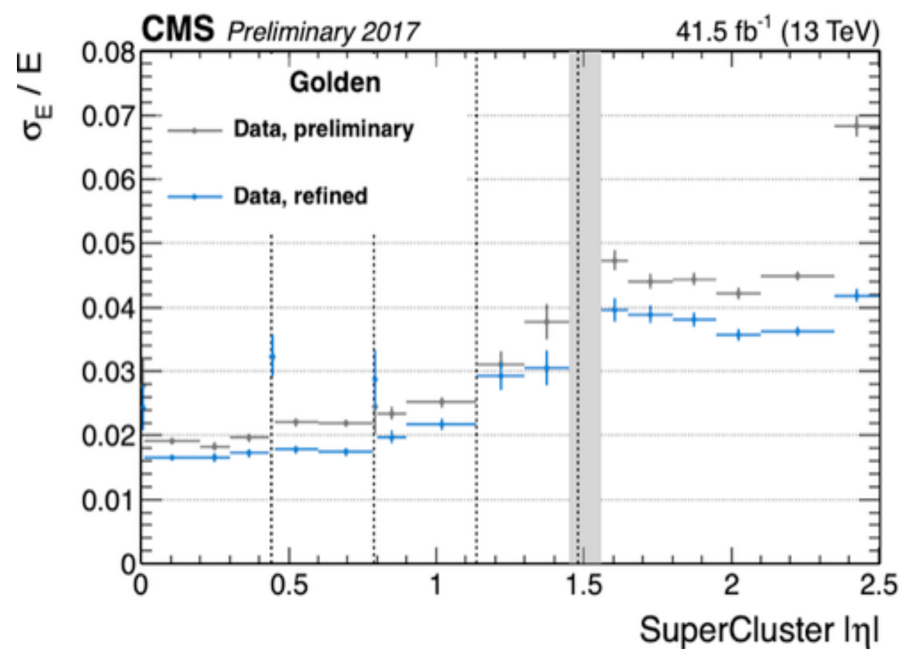
During Run2 CMS re-processed data at the end-of-the year
to provide improved conditions for analysis.
Further full re-processing of Run2 data ongoing to achieve optimal performance

About 2months / year
for recalibration

ECAL: offline re-derivation of ALL conditions
exploiting full statistics and with better granularity

- e.g. several pedestals IOVs / run (1 IOV/run in prompt-reconstruction)





Summary

Keeping high performance for a crystal calorimeter at hadron colliders is a real challenge and requires novel techniques

The CMS ECAL exploits a complex workflow for monitoring and calibration

During LHC Run1 and Run2 it proved to be well designed

- Capability of providing results timely to ensure high quality of prompt reconstruction within 48h

Plans for increasing automation of described workflows in Run3, minimizing manual intervention

Goal is to have the full calibration chain up and running at the beginning of Run3 to contribute to high quality CMS publications

Backup

Energy reconstruction

Electrons and photons deposit their energy in several crystals (~70% in 3x3 array) collected by a clustering algorithm

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

- A_i: Pulse amplitude
- $S_i(t)$: Time dependent response correction
- c_i: intercalibration
- $G(\eta)$: Global scale
- $F_{e,\gamma}$: Cluster corrections (multivariate)

Energy resolution from test-beam
(no irradiation, no material in front, no magnetic field)

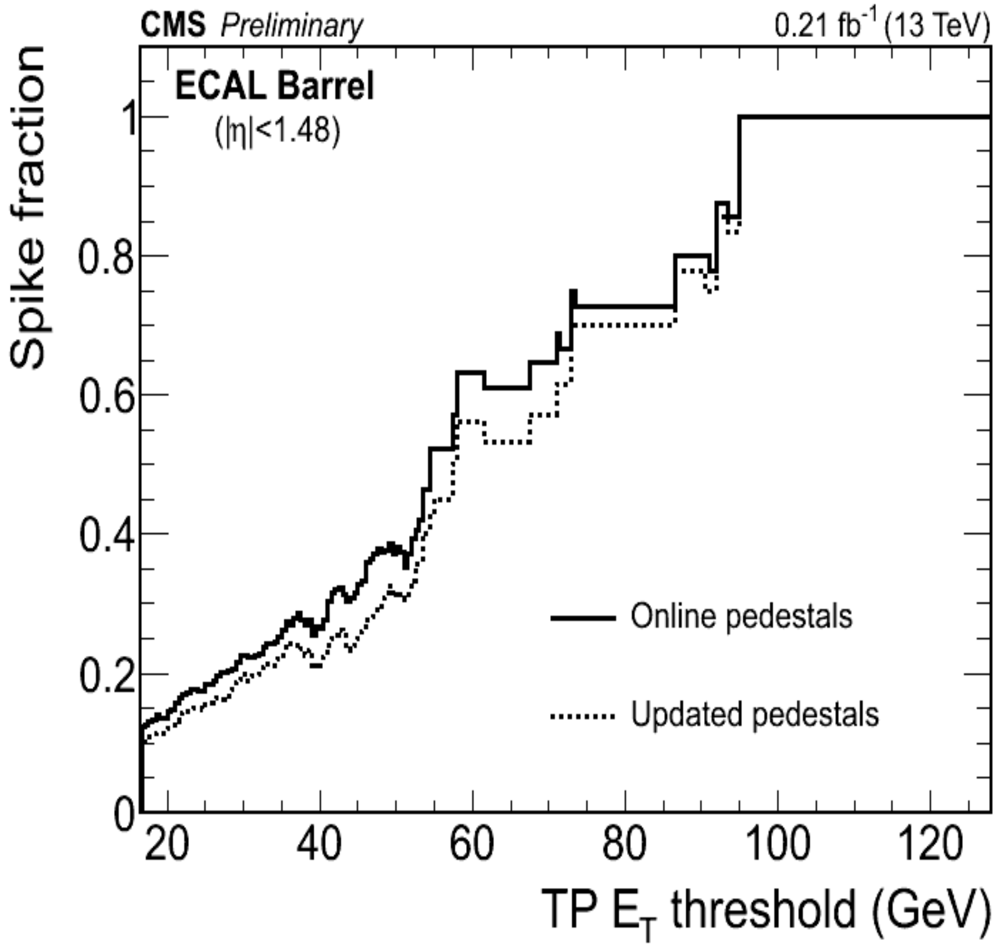
$$\sigma(E) = \frac{2.8\%}{\sqrt{E(GeV)}} \oplus \frac{41.5MeV}{E(GeV)} \oplus 0.3\%$$

Stability and uniformity in situ required <<1%

All terms to be carefully monitored and updated

Complex and dedicated workflows in place

ECAL conditions @trigger



Spikes: caused by direct ionization of APDs and removed at L1 identifying isolated hits above threshold

ECAL data validation

ECAL workflows complexity requires robust validation

Several stages of Data Quality Monitoring (DQM):

Online DQM: monitor detector performance during data-taking

- Dedicated event stream (sampling)

Offline DQM: monitor performance

- Run on full statistics available for analysis

CMS centrally-coordinated effort

Several semi-automatic checks:

- Prompt and reliable derivation of conditions in PCL
- Energy scale stability in prompt reco
- Any other issue

ECAL-specific effort, involving experts and shifters

Two efforts combination => ECAL data-certification,
to provide a list of good runs/events for physics