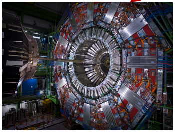
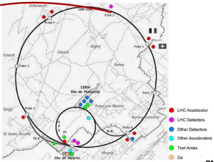
The ultimate CMS ECAL calibration and performance for the legacy reprocessing of LHC Run 2 data

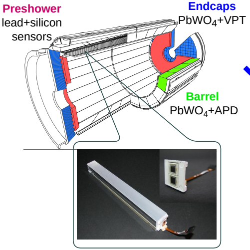
Simone Pigazzini
On behalf of the CMS collaboration

CALOR-2022
Brighton, 16-20 May 2022

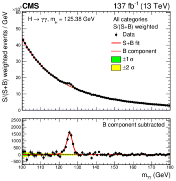
From scintillation light to the Higgs boson







10.1007/JHEP07(2021)027



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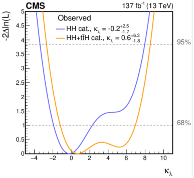
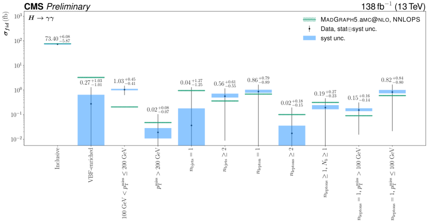
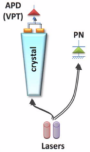
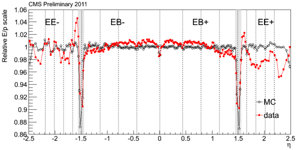
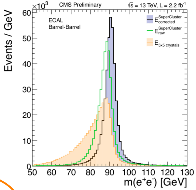




e/γ reconstruction and calibration in CMS







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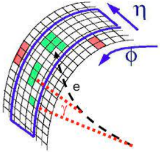
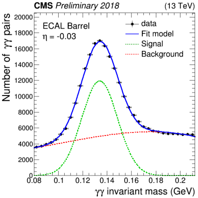
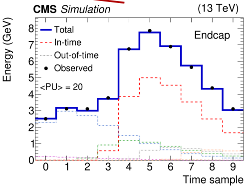
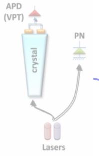
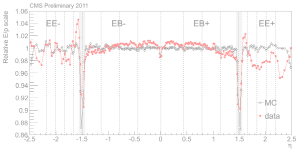


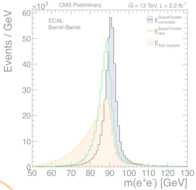




Signal amplitude reconstruction







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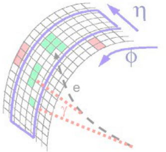
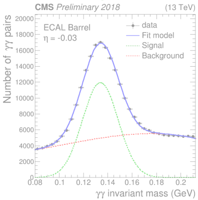
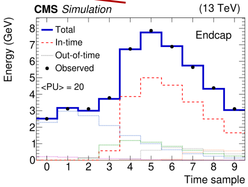


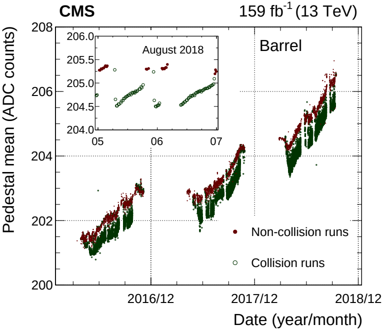
ECAL+Preshower clustering

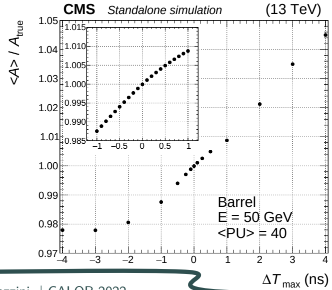


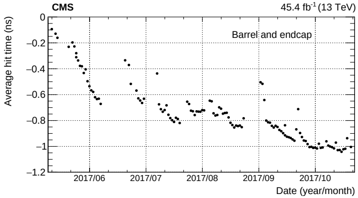


Signal amplitude reconstruction 10.1088/1748-0221/15/10/p10002

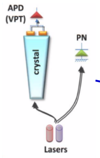
- The **signal pedestal and phase are inputs** to the amplitude reconstruction algorithm
- Pedestal measured from laser events every 40 minutes.
- Time shift corrected every year, **dirft during datataking absorbed in the templates** used by the algorithm (1 per channel).

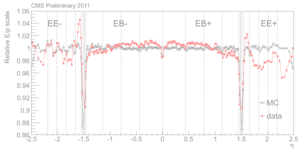


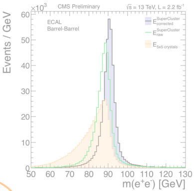




Transparency loss correction







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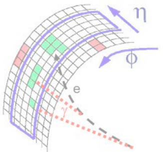
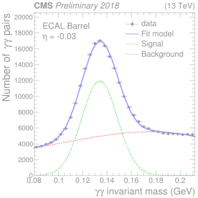
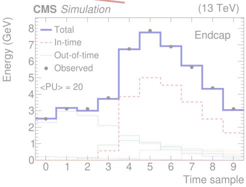


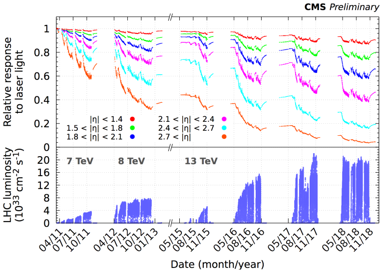
ECAL+Preshower clustering

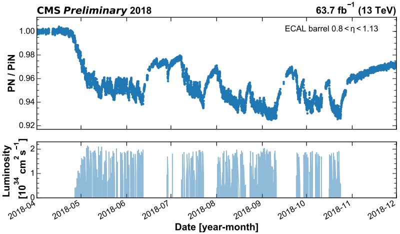


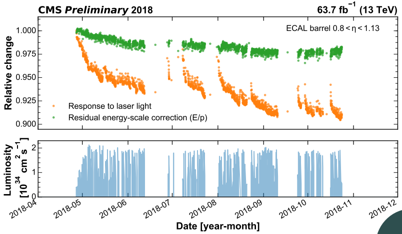


Transparency loss correction

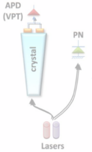
- Continuous operation of the laser monitoring system has allowed a costant monitoring: **all crystals measured every 40 minutes**.
- **Run2 challenge**: sizable radiation damage in laser transmission fibers and reference diode.
  - → **corrected using electrons from W/Z boson decays** and relative measurement w.r.t tracker.

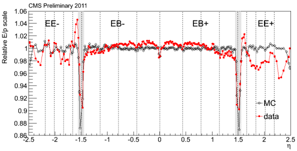


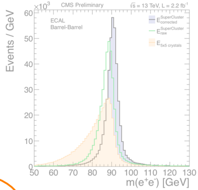




Channel intercalibration and energy scale







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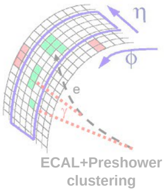
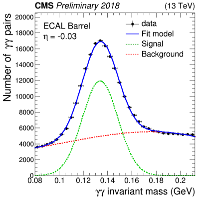
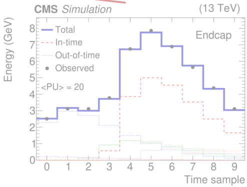
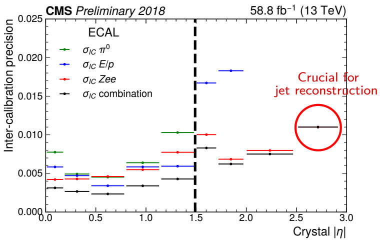


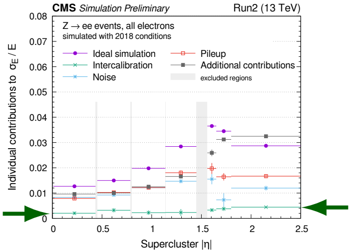


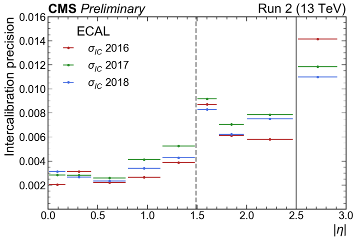


Channel intercalibration and energy scale

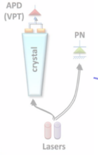
- **Equalize response of channels at same η** combining different methods: $Z \to e^+e^-$, E/p and $\pi^0 \to \gamma\gamma$ (in practice: **reduce peak width**).
- **Energy scale vs η** corrected in data to match MC using $Z \to e^+e^-$ mass peak (in practice: **adjust peak position**).
- **Negligible impact on the energy resolution from intercalibration precision.**

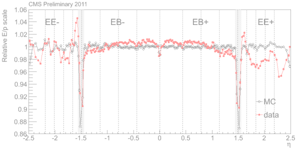


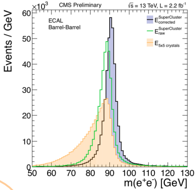




Clustering and object level correction







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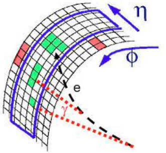
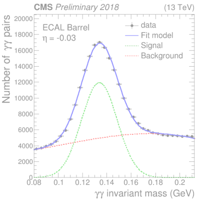
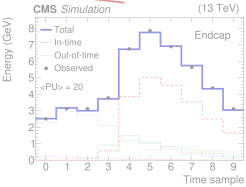


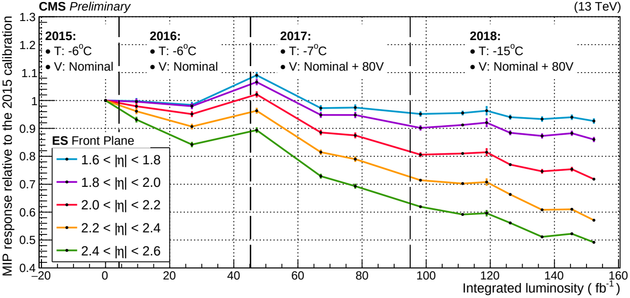
ECAL+Preshower clustering





Clustering and object level correction

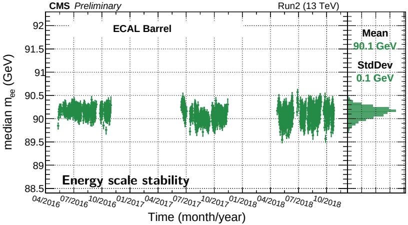
- **Energy thresholds** for hits clustering re-tuned to mitigate **pile-up** and **noise** contamination. Preshower operation adjusted to cope with irradiation.
- Energy measurment in the **preshower** crucial for particle ID (photon/neutral hadron separation) and EM-shower energy measurement (in the endcaps):
  - ➔ Regular response corrections derived using short, **dedicated runs with gain adjusted for m.i.p sensitivity**.

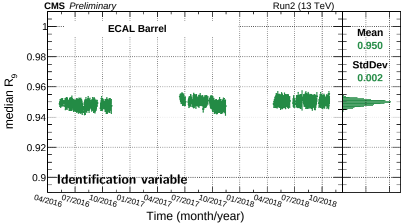


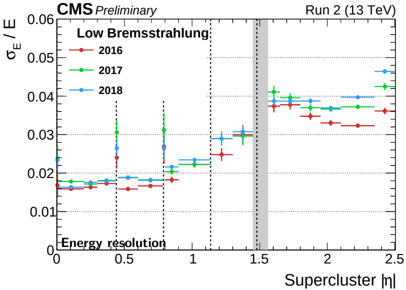
- Object energy corrected for leakage, material effects using a **semiparametric BDT to provide the ultimate performance for physics analysis**.

ECAL performance in Run2

- **Excellent energy scale stability crucial in different aspect of the CMS reconstruction:**
  - ➔ Photon/electron **energy resolution** and **identification** (shower description)
  - ➔ Jet EM-component measurement.



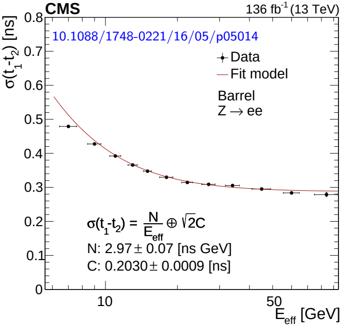


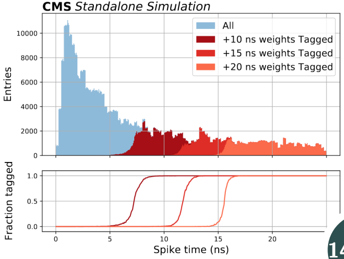


Run3 outlook

Precision timing

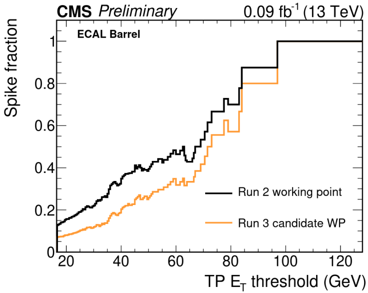
- Inclusion of **precise time of flight** **($\sim 20 - 30$ps)** information in the event reconstruction is a goal for the CMS **HL-LHC upgrade** (Charlotte's talk).
- **ECAL time information will play a crucial role in HL-LHC but not only:**
  - → An excellent time resolution already achieved in Run1+Run2, **exploited in LLP searches**.
  - → **Run3, Level-1 trigger**: reduction of anomalous signals (APD direct ionization, a.k.a. "spikes") rate exploiting redundancy feature of existing trigger ASIC.



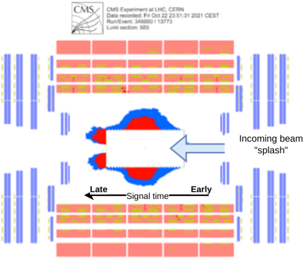


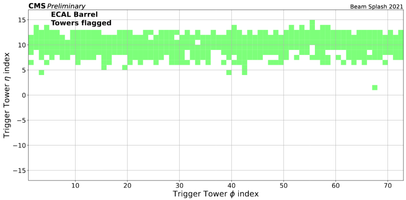
Encouraging tests of L1 developments

- **Topological spike tagger** re-optimized using a set of Run2 data with PU conditions close to the **Run3 expected ones**.

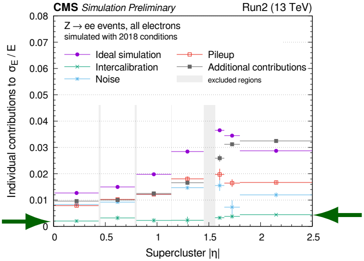


Time-based spike tagging working in CMS, tested using LHC beam splashes.



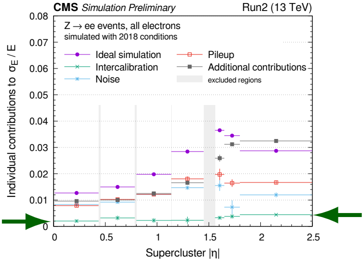


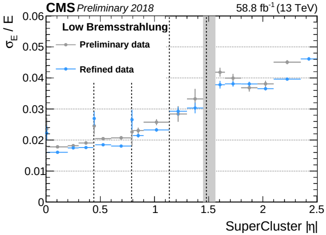
Calibration of prompt reconstruction in Run3



- The **main focus in Run3** will be to improve the mitigation of **noise** and **pile-up** related effects ➔ML-based algorithm (more in Polina's talk).
- **But there's a catch...**

Calibration of prompt reconstruction in Run3





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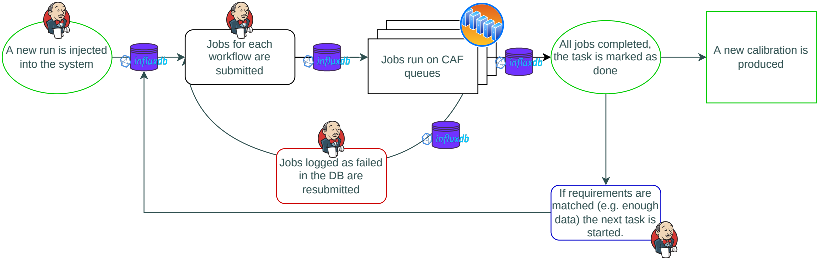
- **But there's a catch...**

- Ultimate performance ∼ 40% (= **1 year of work**) better than the one with "prompt" calibration.
- **Run3 goal: automatize the calibration procedures that rely on collision data** to provide the highest quality calibration possible within few days from data-taking.

Calibration of prompt reconstruction in Run3

- Implement each calibration workflow as a **finate state machine**.
- Execute jobs regularly updating conditions when predefined conditions are met.
- Exploit tools from industry deployed by CERN IT: **Openshift, influxdb, Jenkins, HTCondor**.



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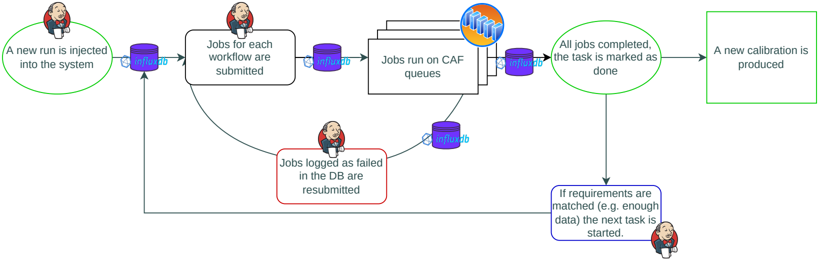
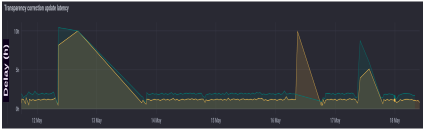
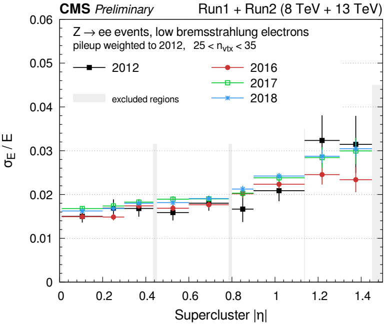




- ➔ The system is being commissioned with data from cosmics runs.
- ➔ Execution monitoring through webpages and dedicated **Mattermost alerts and slash commands**.

Summary

- **Achieving and maintaining an excellent energy resolution on e/γ** in CMS has required a constant re-calibration of several inputs to the reconstruction.
- Main challenges: radiation induced **aging of the PbWO crystals and monitoring system**.



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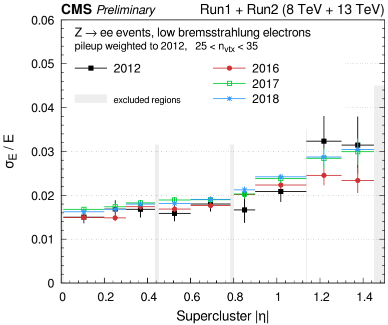

Moving forward with **Run3**:

➔ More challenges coming from **increasing noise and pile-up levels**, new **ML techniques** being explored to cope with them.

➔ The ECAL community is constantly working to squeeze any bit of performance out of the detector: **new developments being tested to improve the L1 trigger.**

➔ **A crucial objective for Run3 will be to deploy all calibrations promptly during the data-taking**.