ECAL trigger performance in Run 2 and improvements for Run 3

Abraham Tishelman-Charny[1]
on behalf of the CMS Collaboration
[1]Northeastern University

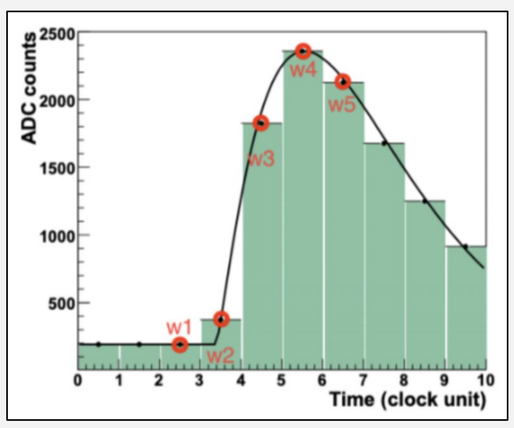
TIPP 2021 poster session (virtual), 27 May 2021

Introduction

- CMS ECAL precisely measures the energies of **photons** and **electrons**
- Composed of 75,848 $PbWO_4$ (Lead Tungstate) **crystals**. Barrel (EB): 61,200. Endcaps (EE): 14648
- Essential for **H → γγ** and many other **physics** studies
- ECAL trigger primitive:
  - Transverse **energy** value
- Sent with LHC **bunch crossing** information + feature bits to:
  - Identify **EM, τ, jet** energy sums
  - Reject **spikes** (anomalous signals)
- Sent to L1 trigger at **40 MHz**
- Spikes:
  - Anomalous signals caused by direct ionization of Avalanche Photo Diodes
  - Occur at high rates, need to **suppress** to keep trigger thresholds low

Energy reconstruction

- Transverse energy computed as:
  - Digis * weights
  - **Digis:** Digitized waveforms
  - **Weights:** Expected amplitude contributions
- Weights derived from signal **shapes** to identify expected signal waveforms

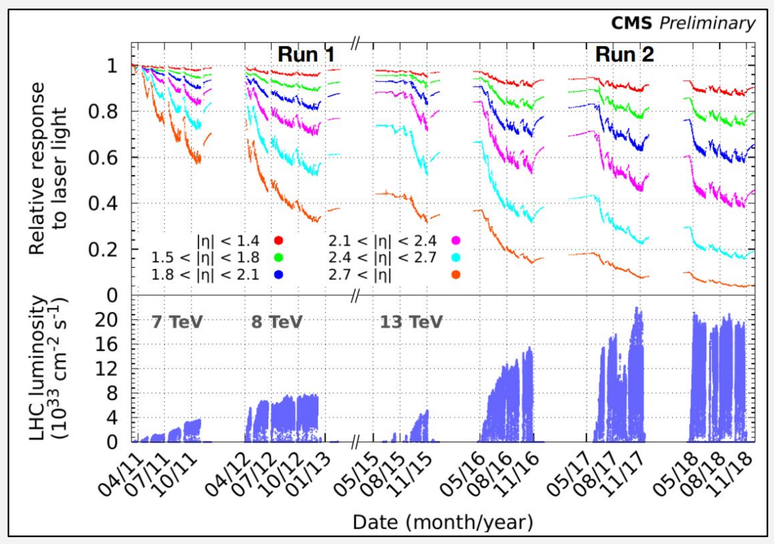


Digis * Weights

Run 2

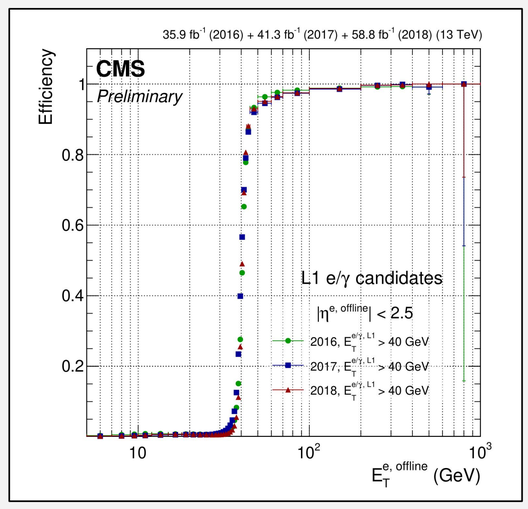
- At CMS ECAL: More **frequent** calibrations during Run 2 to **maintain** performance
- **Updated** spike killer settings, automasking to improve operational efficiency, less down time
- During Run 2, improved and maintained rate, stability, performance, and operational efficiency

- **Radiation** damage decreases crystal transparency
  - Run 2: Increased correction frequency from **once** to **twice** per week



Runs 1 and 2 crystal transparency

- Calibrations led to excellent trigger **efficiency**
  - Efficiently read out signals of desired **energy**
  - Stable e/γ **efficiency** & **resolution** over three years of Run 2 data-taking

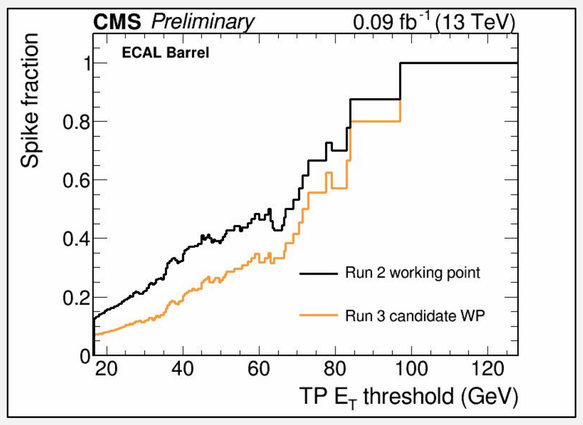


Run 2 L1 e/ɣ turn-on curve

Run 3

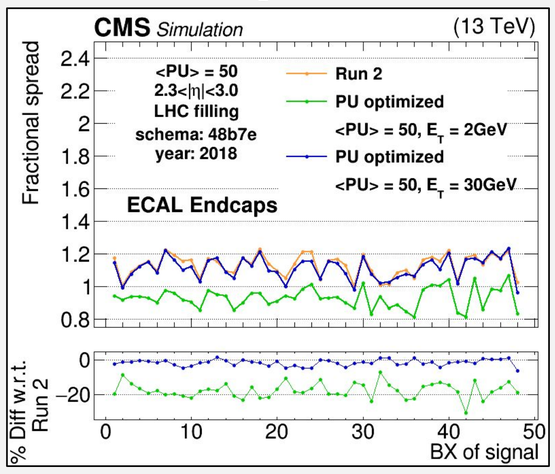
- LHC Run 3: Planned for 2022-24
- **Increased** noise and simultaneous interactions w.r.t. Run 2 (2016-18)
  - Planning **improvements** for more challenging running conditions
    - Spike Killer:
      - **Retune** thresholds in order to improve spike rejection
    - PU optimized weights:
      - Updating of weights to account for pileup **distortion** and crystal aging
    - Double Weights:
      - Testing of new feature to tag/reject **out-of-time** signals

- **Mitigate** anomalous signals with a topological cut
- Adjusting parameters to **improve** mitigation of anomalous signals



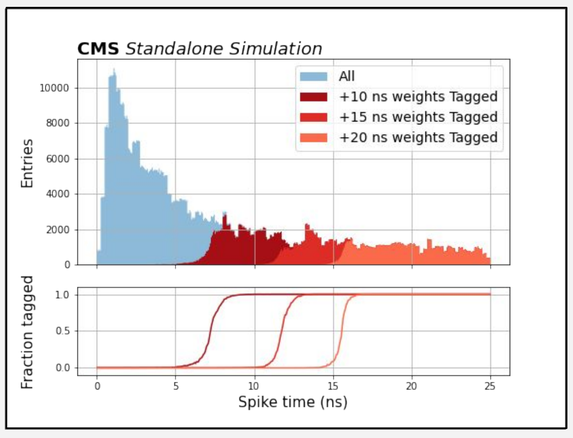
Expected Spike Killer improvement

- Weights **per strip** (5 channels) instead of per **EB/EE** partition
- **Reoptimized** for PU distortion and ageing
- Can bring significant TP **resolution** improvement in EE



Expected energy resolution improvement

- Can use double weights to **tag/reject** out-of-time signals
- Many spike **out-of-time** (see figure below)
- This method may further improve spike **rejection**



Out-of-time signal tagging with double weights mechanism

Conclusions

- LHC Run 2 (2015 - 2018):
  - Performance **depends** on frequent calibrations, optimized spike killer settings and improved treatment of problematic towers
  - **Minimum** ECAL downtime and excellent trigger performance achieved despite more challenging LHC conditions
- LHC Run 3 (2022 - 2024):
  - Expected **improvement** in trigger performance from reoptimized spike killer, weights and more frequent transparency corrections
  - Possible use of **new features** to tag and mitigate anomalous signals, or tag out-of-time physics from long lived particles

abraham.tishelman.charny@cern.ch