ECAL TRIGGER PERFORMANCE IN RUN 2 AND IMPROVEMENTS FOR RUN 3

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On behalf of the CMS collaboration

Higgs Couplings
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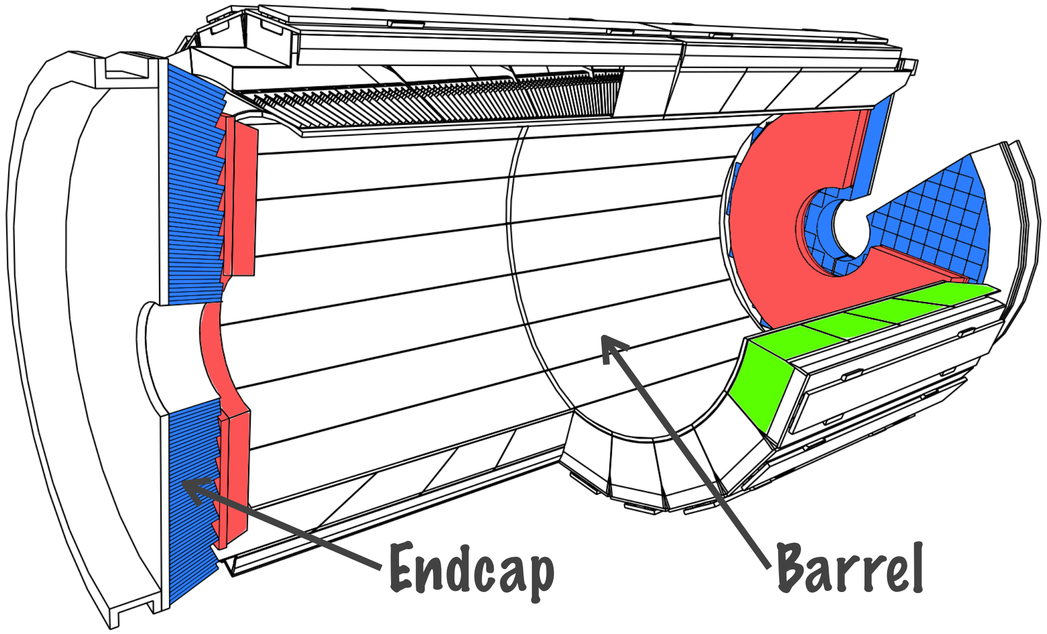
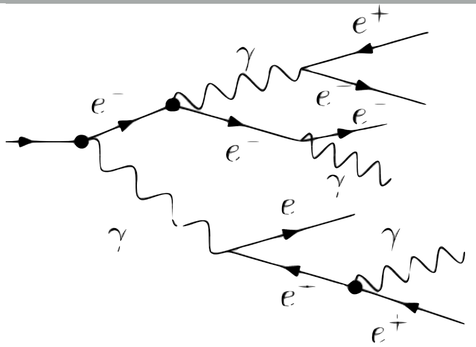
INTRODUCTION & TRIGGER PERFORMANCE DURING THE RUN 2

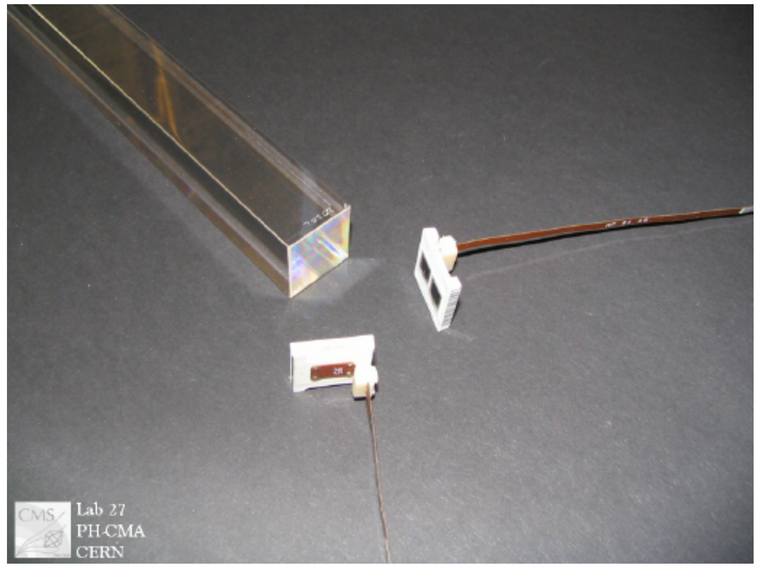
CMS & ECAL & ECAL Trigger in a nutshell

THE COMPACT MUON SOLENOID (CMS)

- General-purpose detector.
- Built around a huge solenoid magnet.







EM SHOWERS DETECTED BY

- APDs (Avalanche Photo Diodes) in EB
- VPTs (Vacuum Photo Triodes) in EE

THE CMS ECAL

- Made up of the Barrel (**EB**) and two Endcaps (**EE**)
- Consists of 75.848 $PbWO_4$ crystals - compact, fast, and radiation hard.
- Measures energies of electrons and photons, as well as the EM fractions of jets.

CMS & ECAL & ECAL Trigger in a nutshell

LHC collisions rate of 40 MHz

100 kHz of interesting events filtered-out by L1 trigger

1 kHz are written out by HLT.

The priority is to keep 100 kHz rate stable!

ECAL provides crystal energy sums i.e. Trigger Primitives (**TPs**).

The TCC transmits EB and EE TPs to the L1 calorimeter trigger.

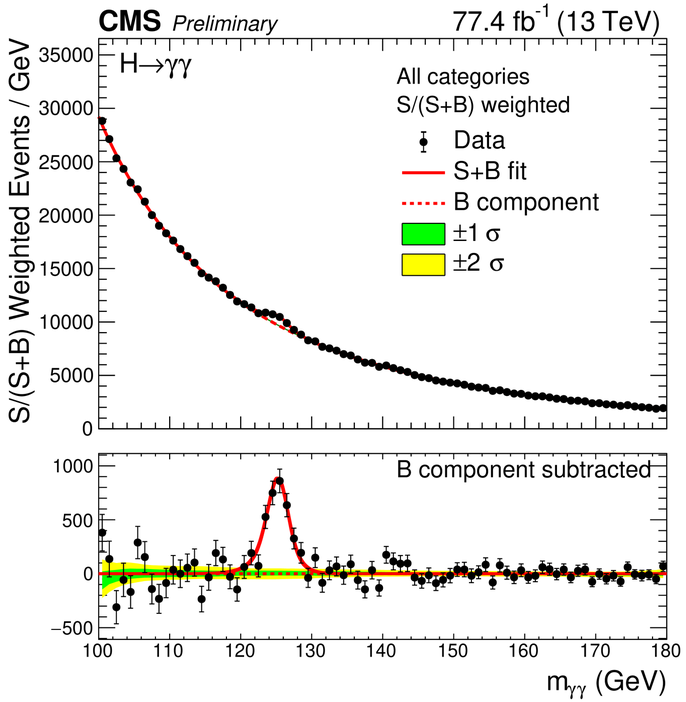
L1 trigger decision.

EB: 5x1 crystal strips are added into 5x5 Trigger Towers (**TT**).

EE: 5x1 strips are transmitted to the off-detector Trigger Concentrator Card (**TCC**).

ECAL TPs are combined with the HCAL TPs at the Global Calorimeter Trigger (**GCT**) level to form L1 e/γ, τ, jet candidates, and E_T sums.

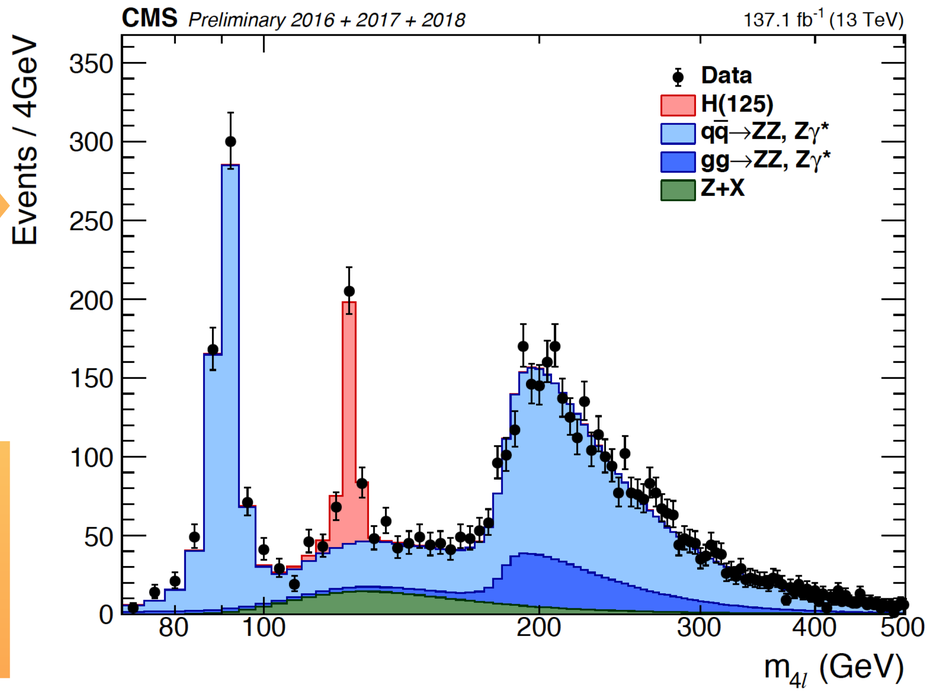
ECAL AND HIGGS PHYSICS



$H \rightarrow \gamma\gamma$ CMS PAS HIG-18-029

Low number of expected events. Robust trigger strategy needed to avoid any signal loss.

Asymmetric photon E_T thresholds of 30 (35) and 22 (25) GeV in 2016 (2017) data.



$H \rightarrow ZZ \rightarrow 4\ell$ CMS PAS HIG-19-001

- Important to maintain stable trigger rates and efficiencies, and provide the best achievable energy resolution of the related L1 objects, particularly **e/γ** candidates and **jets**.
- Excellent resolution and **e/γ** candidates identification were crucial in the discovery and characterisation of the 125 GeV Higgs Boson.
- The continued excellent performance of ECAL in the entire pseudo-rapidity range is a key component of Higgs Boson precision measurements and searches for new Physics.

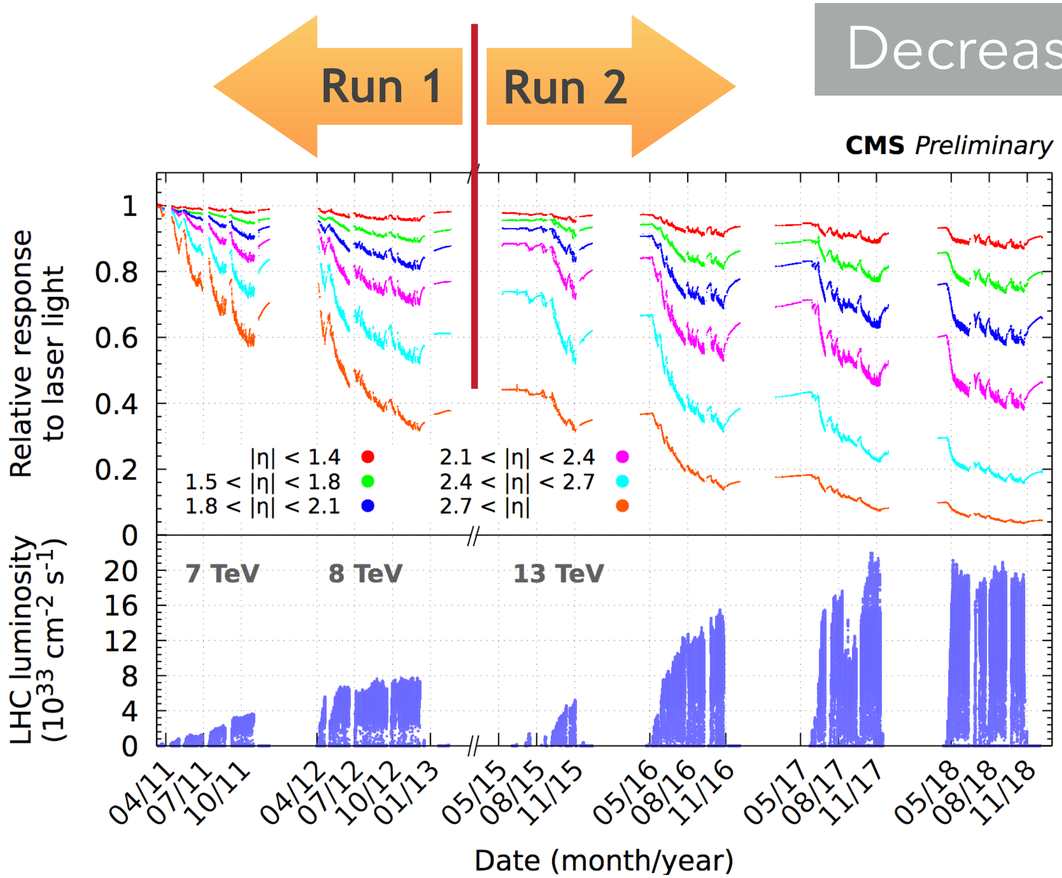
CALIBRATION: TRANSPARENCY CHANGES

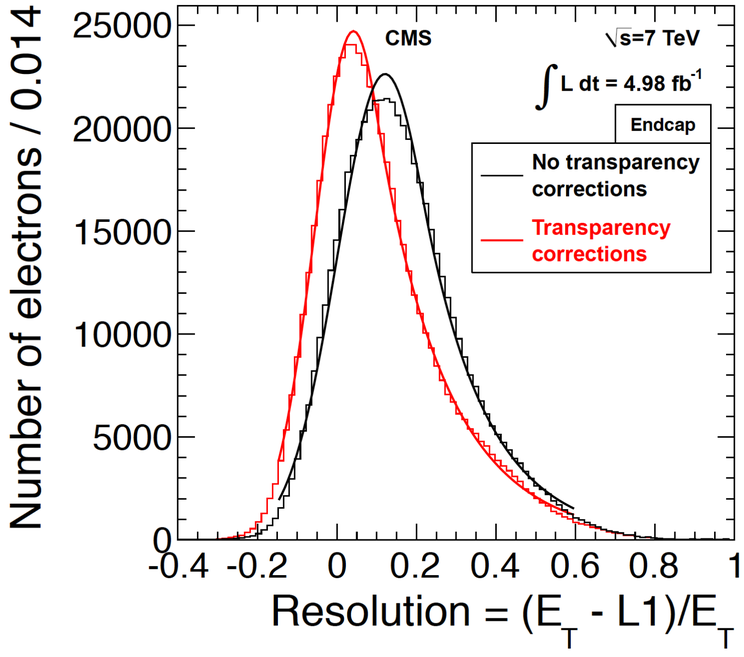
Crystal transparency decreases over time due to due to LHC irradiation.

Laser light with known amplitude is fired at all crystals every 40 minutes.

Decreases signal amplitude.

Twice per week validate laser data and apply laser corrections to maintain stable e/γ energy scale and resolution.



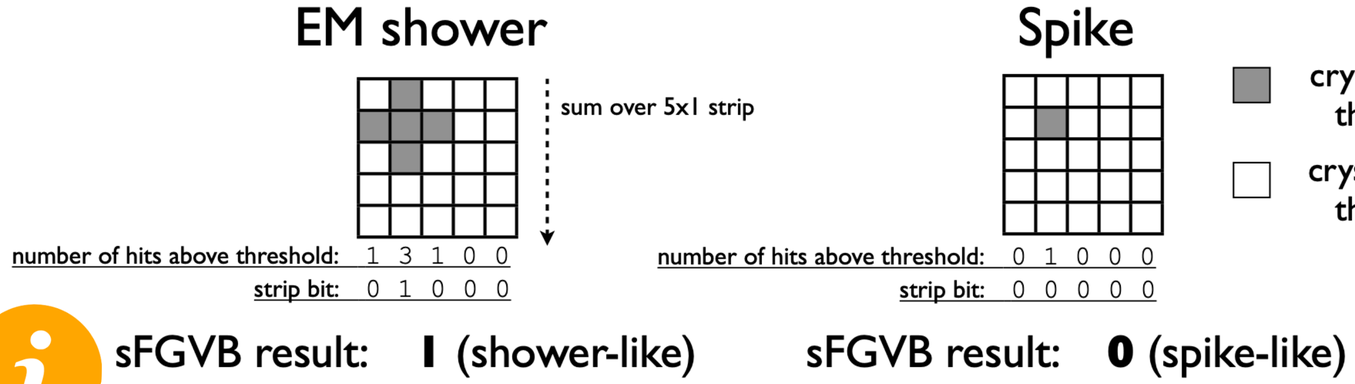


Corrections applied twice per week during Run 2, compared to Run 1 when corrections were applied once a week and only EE.

LARGE SIGNALS IN ECAL

- **Large signals (spikes) observed in the CMS ECAL:**
  - Direct energy deposition by particles in the APDs.
  - Occur at a rate proportional to the collision rate.
  - Can induce large trigger rates at both L1 and HLT.

At high luminosity spikes would be the dominant component of the 100 kHz CMS L1 trigger rate bandwidth!



sFGVB result: 1 (shower-like) **sFGVB result: 0 (spike-like)**

sFGVB (strip Fine-Grained Veto Bit) algorithm is computed in the on-detector electronics.

- The spike contamination for TPs with $E_T > 30$ GeV was maintained below 20% during the 2018 run.
- Better spike killing lowers the L1 rate and allows for lower EG seed thresholds to be used.

The sFGVB algorithm parameters have been retuned to deal with Run 2 conditions.

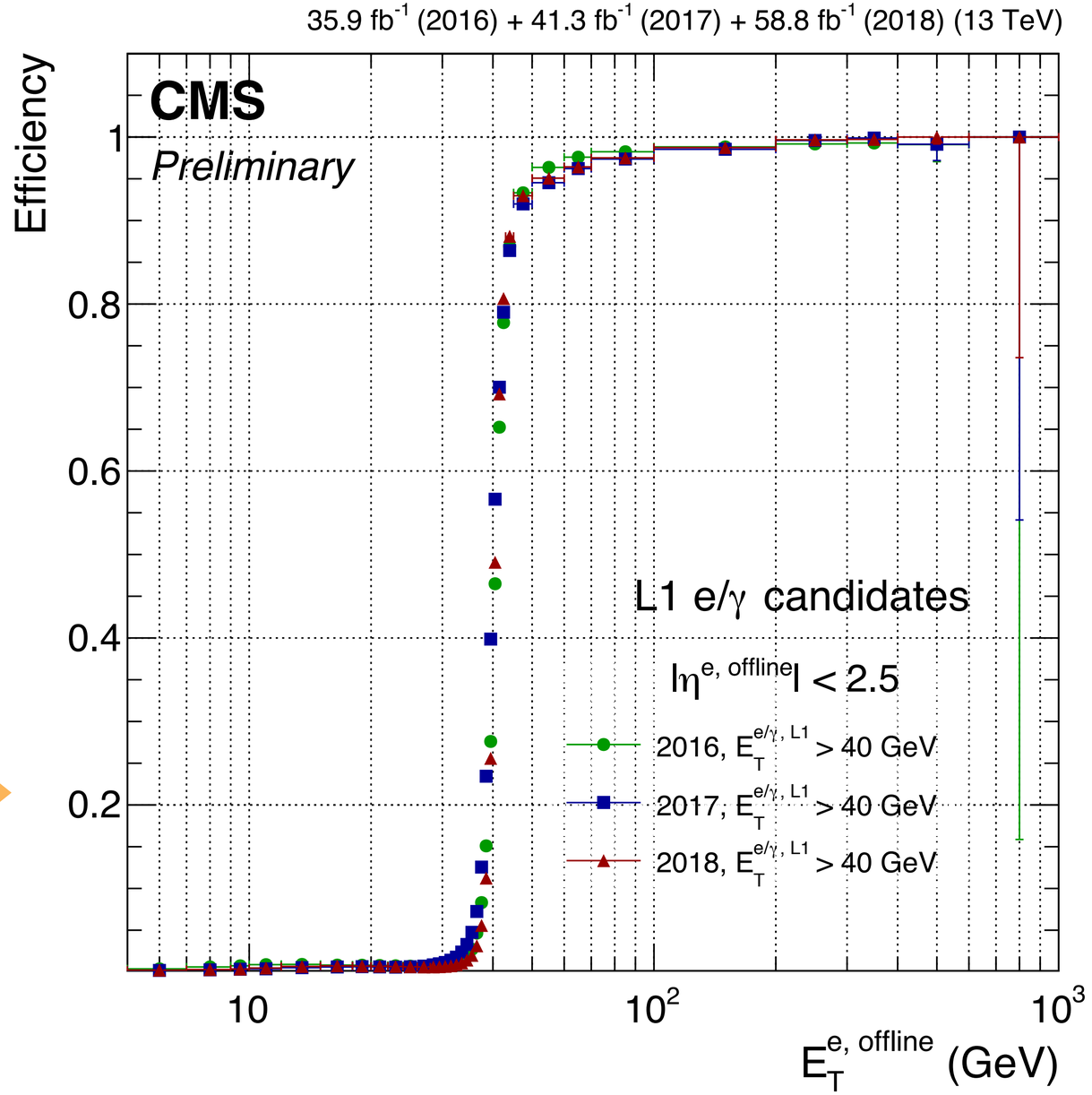
Single channel E_T threshold of about 450 MeV @ $\eta = 0$ + Killing threshold of 16 GeV =

Reduction of contamination caused by spikes in ECAL TPs with $E_T > 30$ GeV by a factor of two, with a negligible impact on the triggering of EM signals with $E_T > 20$ GeV.

RUN 2 OPERATIONS SUMMARY

- The ECAL trigger system operated with high, **99.9%** efficiency in Run 2.
- The fraction of ECAL channels that contributed to the trigger was larger than **99%**.
- Only a **few** problematic towers, strips and individual channels were permanently masked.

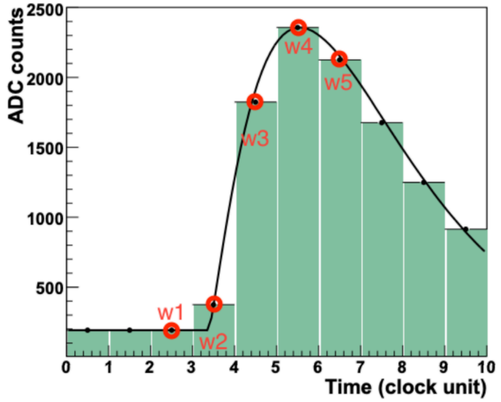
L1 e/γ trigger efficiency remained high in Run 2.



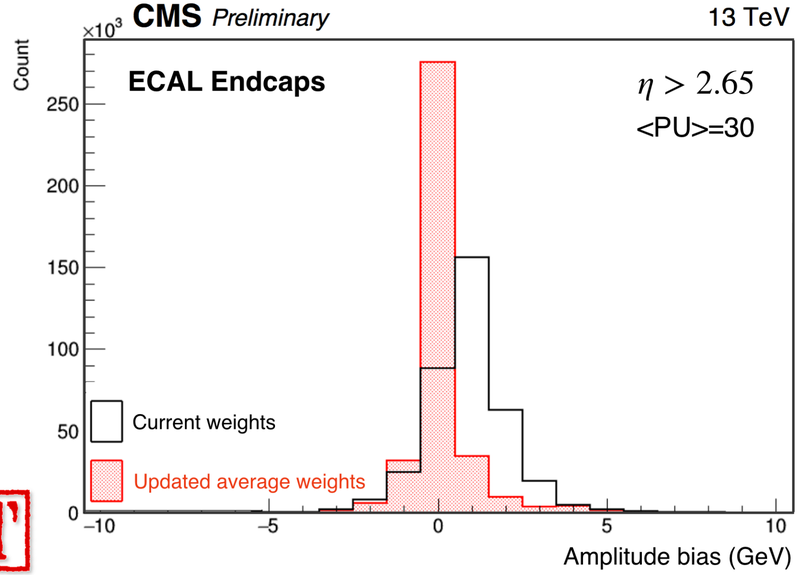
ALGORITHM IMPROVEMENTS FOR RUN 3 AND CONCLUSION

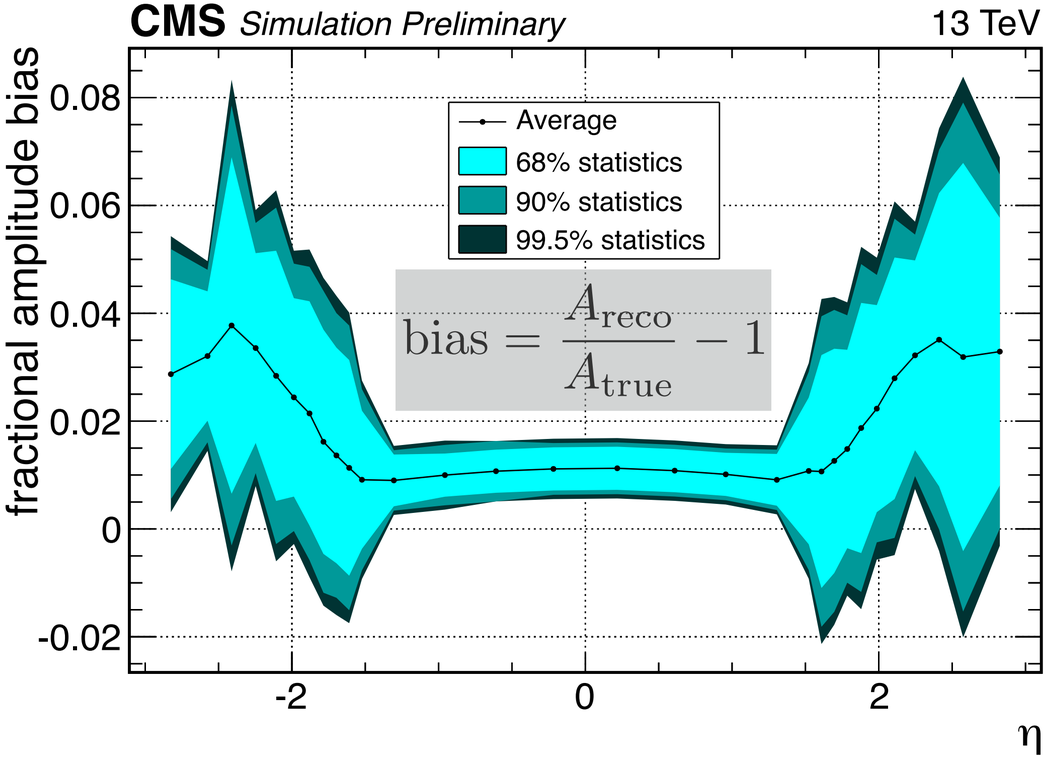
ALGORITHM IMPROVEMENTS FOR RUN 3

The main ideas for algorithm improvements in ECAL for Run 3:



- Update the current amplitude weights.
- Investigating the possibility of using a second set weights at L1.





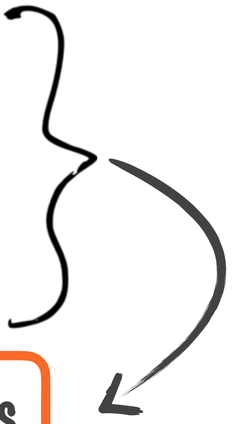
IMPORTANT

- The weights used for amplitude calculation can be improved for the high steady luminosity expected in Run 3
- The improvement can also deal with increased radiation damage in the forward region.

SUMMARY AND PROSPECTS

- **ECAL has operated smoothly and with excellent performance during Run 2**
  - Online and offline reconstruction has been adapted to meet the challenges of higher LHC luminosity and detector ageing.
  - Regular monitoring and updates of crystal response is performed to maintain stability of triggering and energy resolution.
  - Special attention is given to the high η region of EE, where the crystal response losses are greatest.

- **For Run 3, there are possible improvements to be made:**
  - Retune spike killer thresholds to reduce rate of spikes passing L1.
  - Optimise transparency validation and update procedure.
  - Optimise amplitude weights.
  - Use second set of weights at L1.



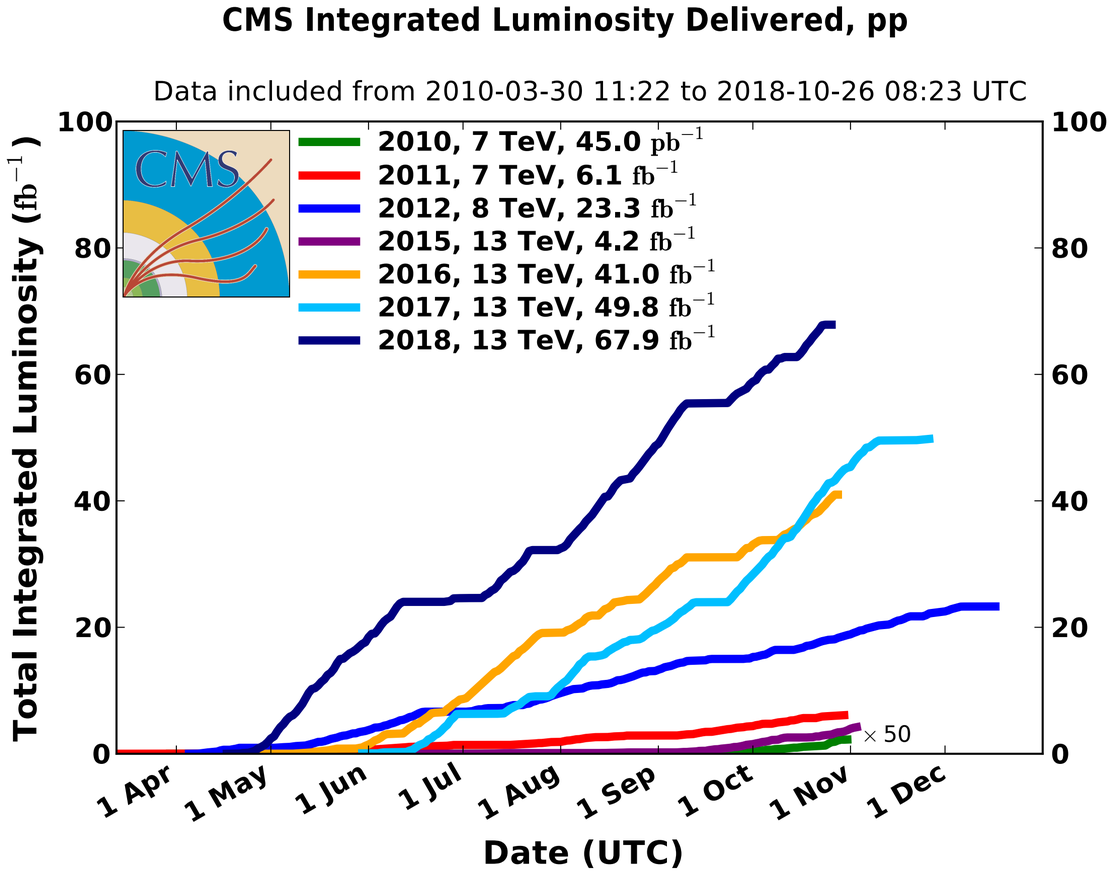
Keep excellent performance of the Higgs boson physics triggers.

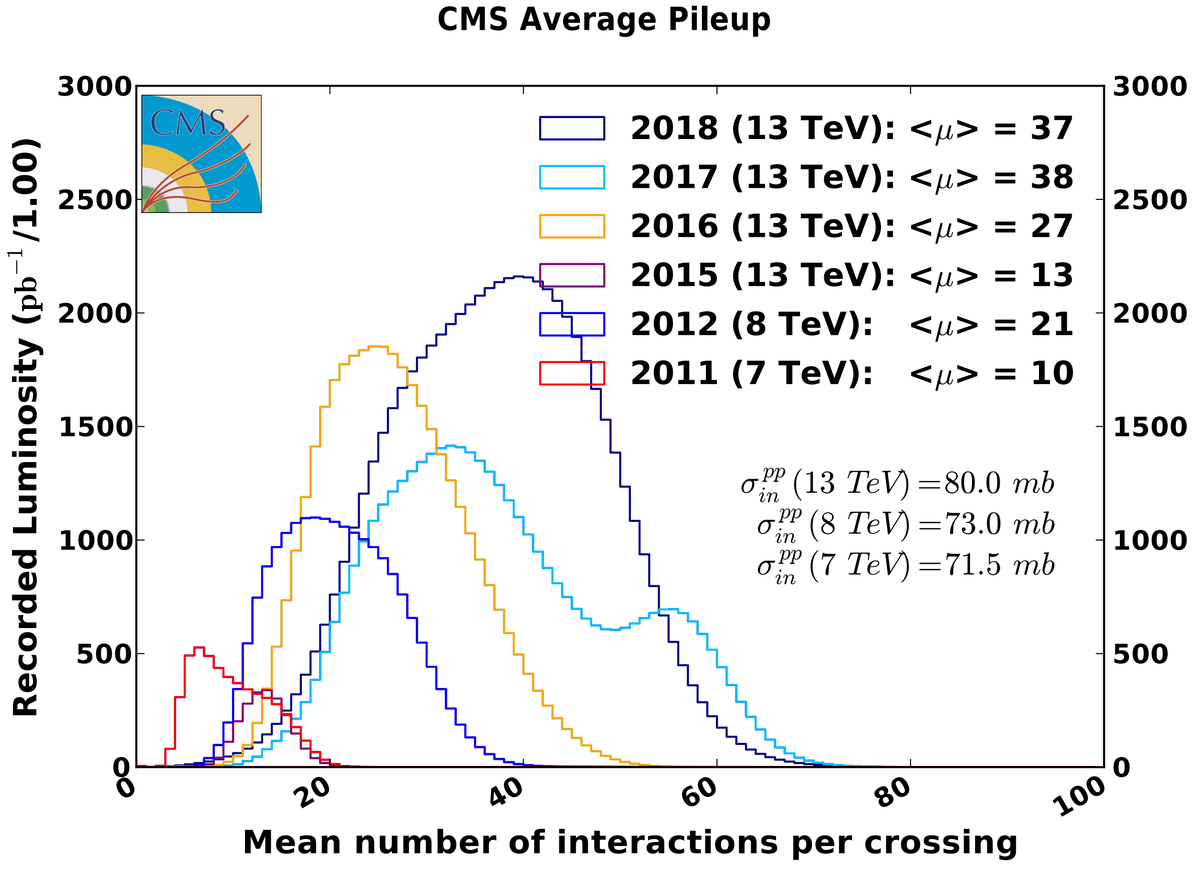
THANK YOU!


BACKUP

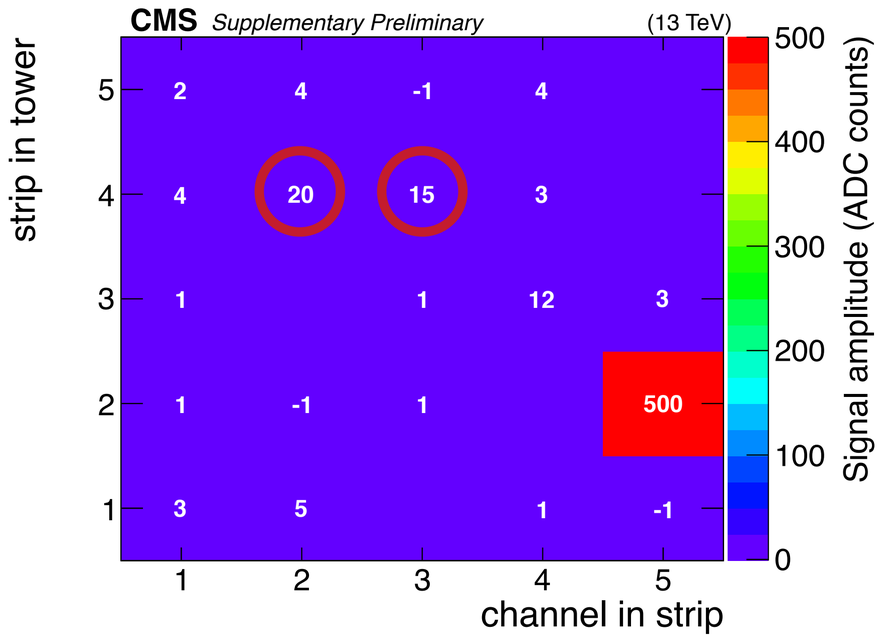
RUN 2 CONDITIONS SUMMARY - BACKUP

- Challenging beam conditions during LHC Run 2 with instantaneous luminosities of **2×10^{34} cm^{-2}s^{-1}** regularly experienced during LHC fills.
- **162.9 fb^{-1}** of data was collected, corresponding to ~6×10^{16} p-p collisions

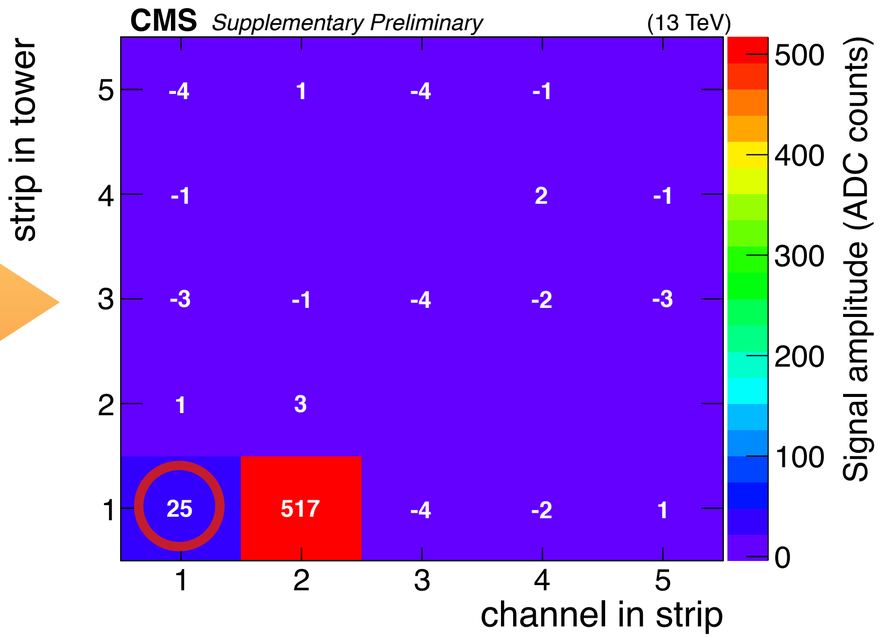




SPIKE KILLER INEFFICIENCIES

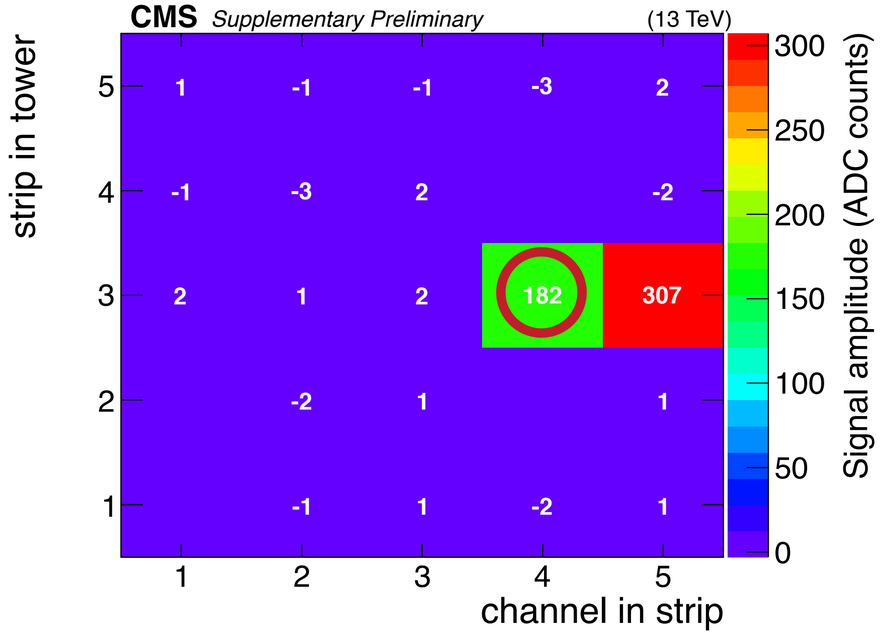


Two channels in strip 4 are above the threshold.

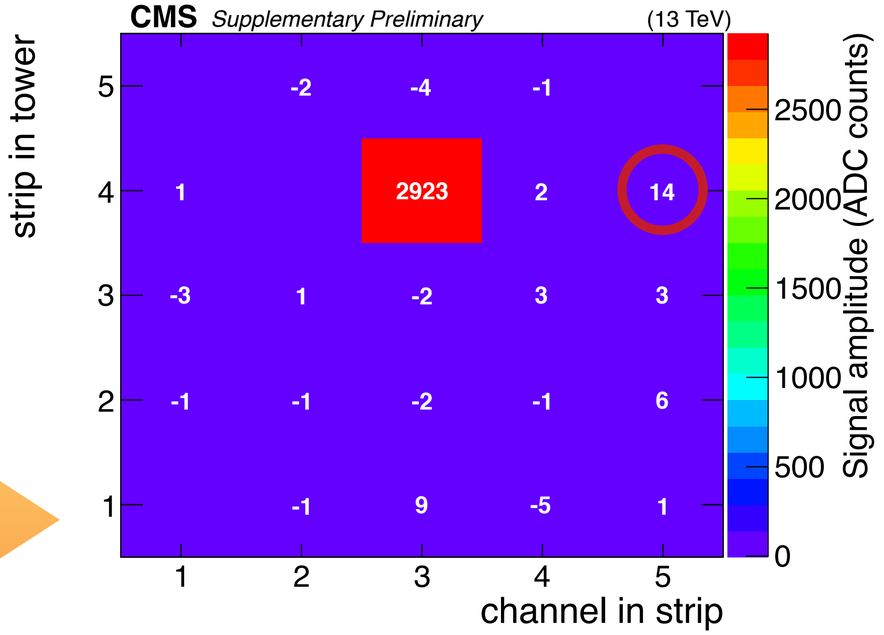


One channel in strip 1 is above the threshold.

THRESHOLD RETUNING FOR RUN 3 BEING EXPLORED TO REDUCE RATE OF SPIKES PASSING L1.



One channel in strip 3 is above the threshold.



One channel in strip 4 is above the threshold

RUN 3 - BACKUP OR MORE CHALLENGING CONDITIONS

- The LHC Run 3 is expected from 2021. - 2023.
- About **350 fb^{-1}** of integrated luminosity is expected with the PU of about **55 - 60**.