# EGamma algorithm for CMS Phase-2 Level-1 Calorimeter Trigger

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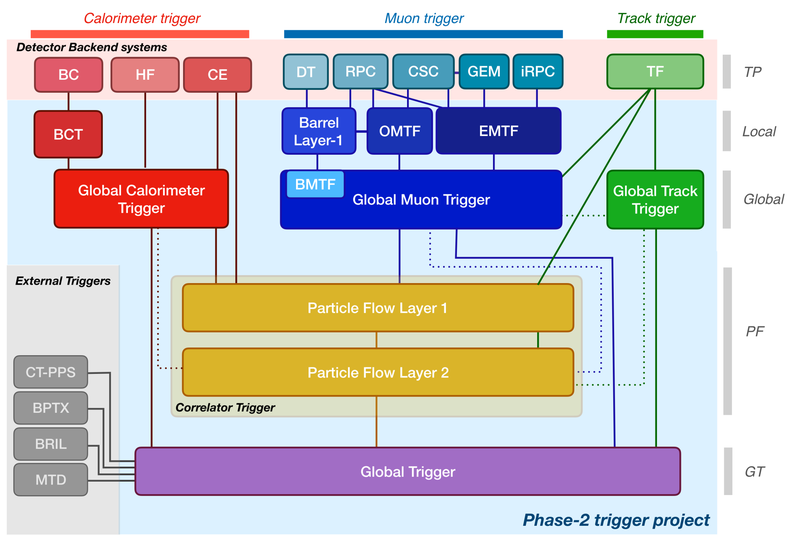
**Abstract:** In order to achieve robust triggering in the intense pileup conditions of the High-Luminosity LHC, the Phase-2 upgrade of the CMS Level-1 (L1) Trigger has been proposed. In the barrel region, it will enable improved particle reconstruction and identification by providing electromagnetic calorimeter (ECAL) trigger primitives with crystal-level granularity (5x5 in one tower), compared to tower-level primitives in the current Phase-1 trigger. We present a summary of the new electron and photon (EGamma) reconstruction algorithm based on crystal ECAL granularity.

## Phase-2 Level-1 Trigger

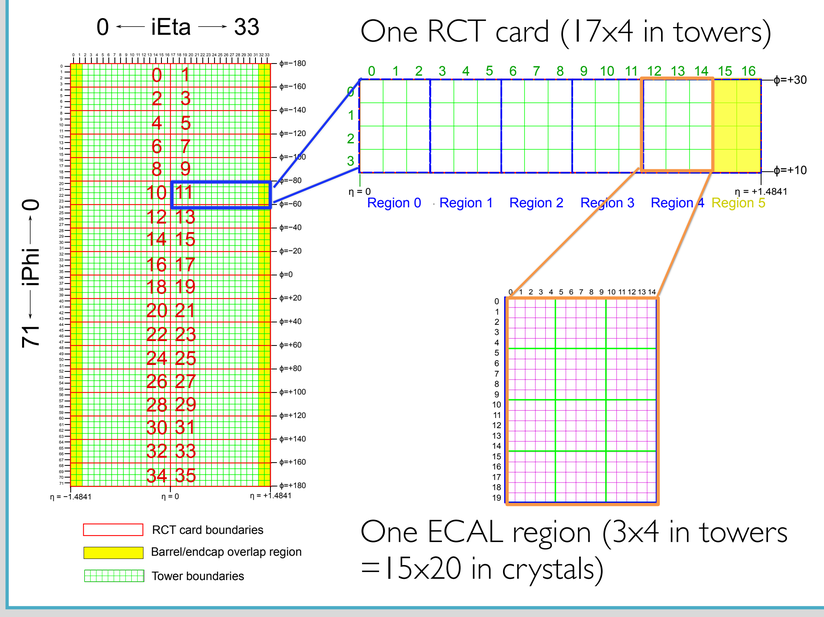
To efficiently select events with low background rate, the Phase-2 Level-1 Trigger will use calorimeter, muon, and track triggers that will provide both standalone and combined decisions:

Total latency of L1 Trigger will increase to 12.5 μs, and the maximum bandwidth will be 750 kHz, compared to 3.8 μs and 100 kHz in Phase-1.




## Barrel Calorimeter Trigger Geometry

In the barrel region, granularity of ECAL inputs will be increased from tower-level, to single-crystal granularity (x25 increase in data volume):



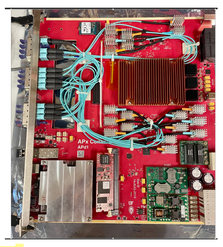

Data is processed in Regional Calorimeter Trigger (RCT) cards. Each RCT card produces up to 8 EGamma clusters and 17x4 towers, giving a total of 288 clusters and 2448 towers in the barrel.

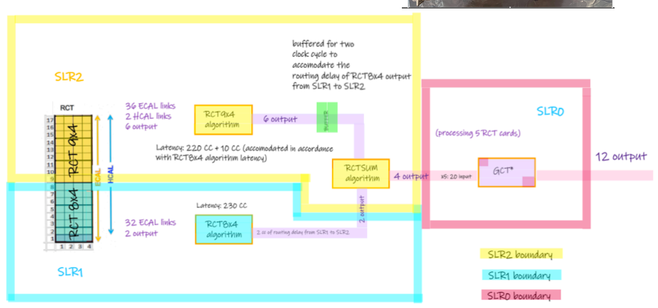
This data is sent to three Global Calorimeter Trigger (GCT) cards, where clusters are combined across RCT card edges (if applicable), and further processing of EGamma information is performed.

## Phase-2 L1T Hardware

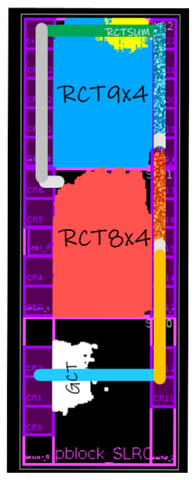
For testing, the RCT and GCT algorithms are implemented in three SLRs (super logic regions) of one advanced processor demonstrator (APd1) board:

Prototype APd1 demonstrator board with high-speed optical links, hosting a Xilinx XCVU9P FPGA






One RCT card is handled in SLR1 and 2; GCT is in SLR0

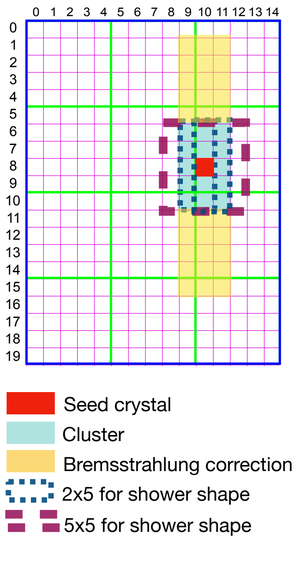



Resource utilization of SLRs

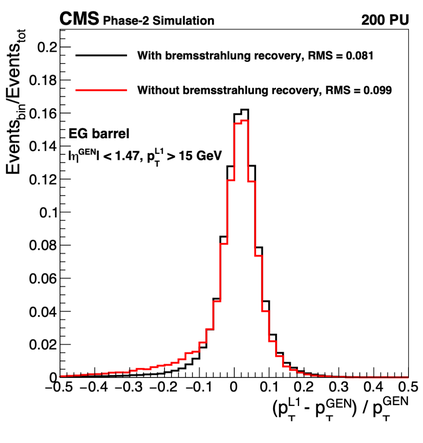
## Electrons/Photons Algorithm

The RCT and GCT reconstruct and identify EGamma clusters using ECAL crystal information:

One ECAL region

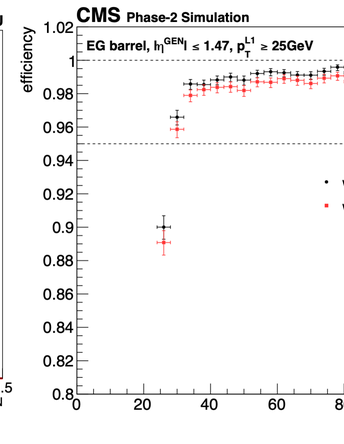


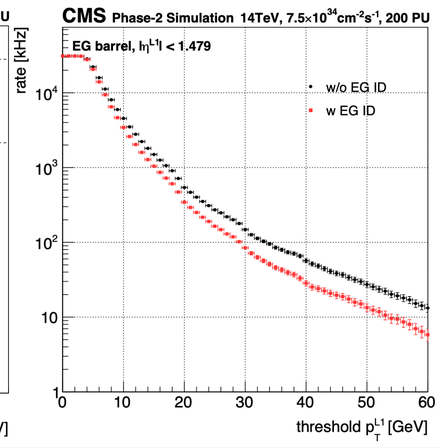

Cluster resolution with bremsstrahlung recovery (CMS-TDR-021):




Rates and efficiencies with identification (ID) flags, consisting of (CMS-TDR-021):

- isolation around seed cluster
- shower shape based on ratio of energies in 2x5/5x5 windows

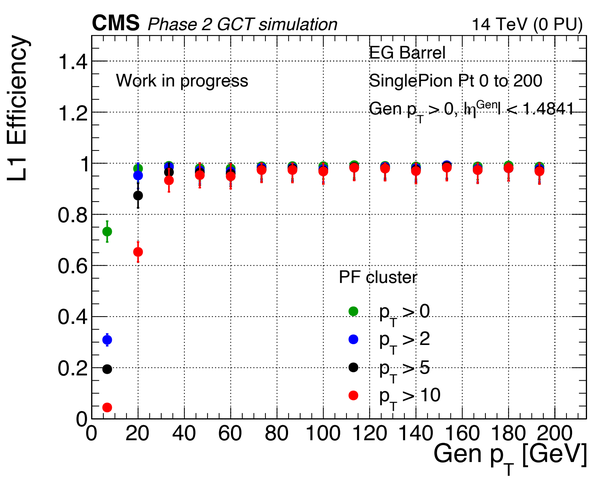


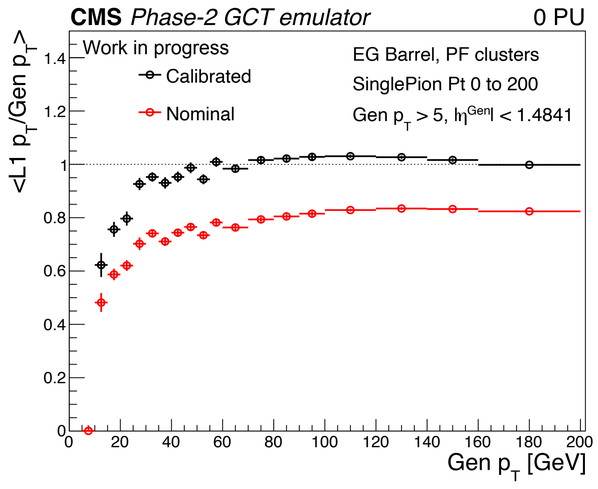

## ParticleFlow Algorithm

In addition, the GCT produces towers (ECAL+HCAL) for the calorimeter-based PF algorithm. PF clusters are built using regions of 3x3 towers:

PF Cluster efficiencies (work in progress)




PF Cluster response with and without calibration on cluster pT (work in progress)




## Conclusions and Future Work

- The Phase-2 Level-1 Regional and Global Calorimeter Triggers in the barrel will use crystal-granularity ECAL hits to produce:
  - Electron/photon clusters with corrections and ID
  - Inputs to the calorimeter-based ParticleFlow algorithms for EGamma, jets, and taus.
- In progress: Development of firmware and realistic firmware-based emulator of these algorithms.

## References

1. CMS TDR 021, The CMS Collaboration, EGamma simulation performance plots.
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3. Poster by P. Kumar on behalf of the CMS Collaboration at ICFAST-2022 at the University of Hyderabad, Hardware algorithm figures.
4. Kumar, P.; Gomber, B., on behalf of the CMS Collaboration. The CMS Level-1 Calorimeter Trigger for the HL-LHC. Instruments 2022, 6, 64.
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6. Poster template by Nikki Marinsek

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