

# RUN3 CMS HIGH LEVEL TRIGGER PERFORMANCE

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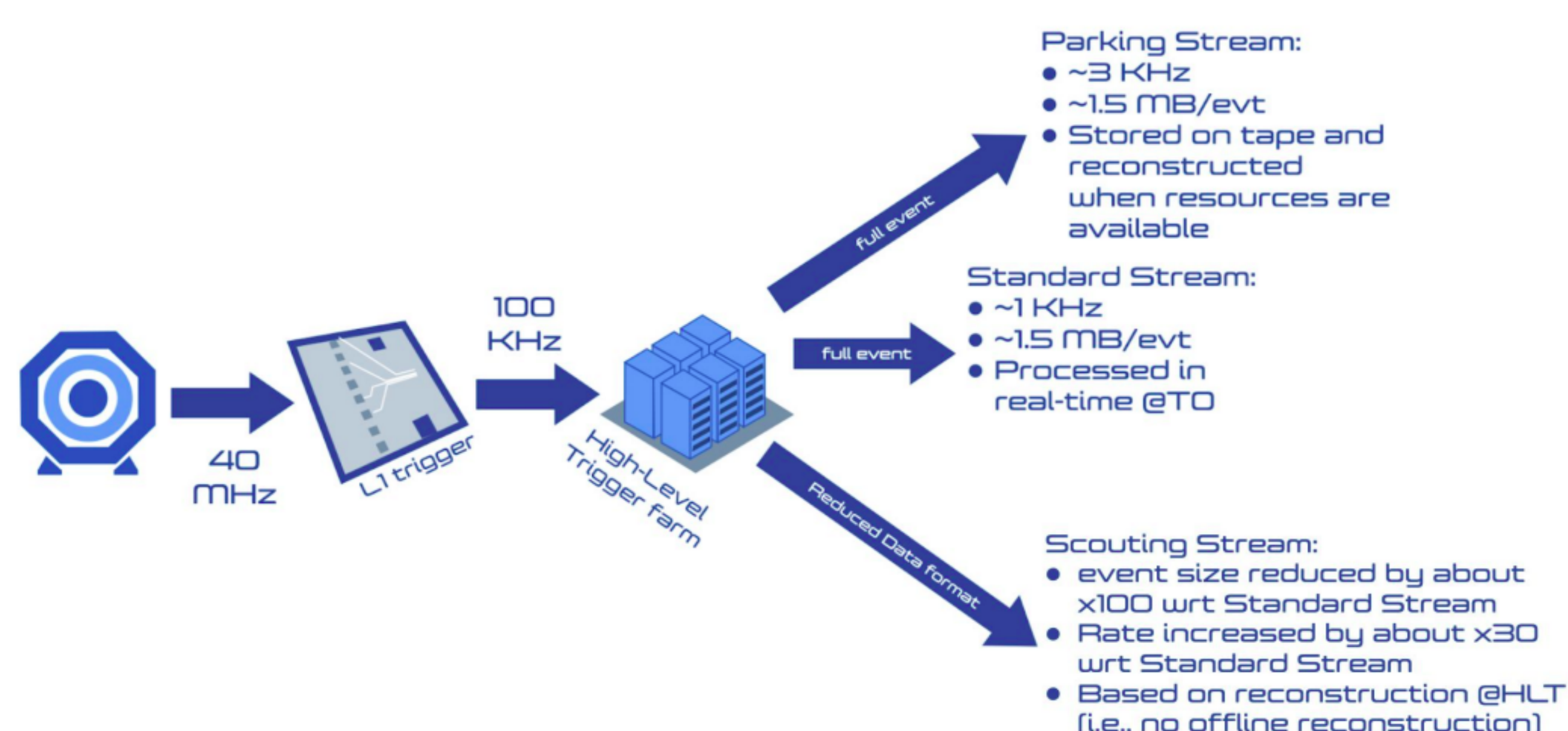
<sup>1</sup>IOP and NISER, Bhubaneswar



## CMS Trigger System

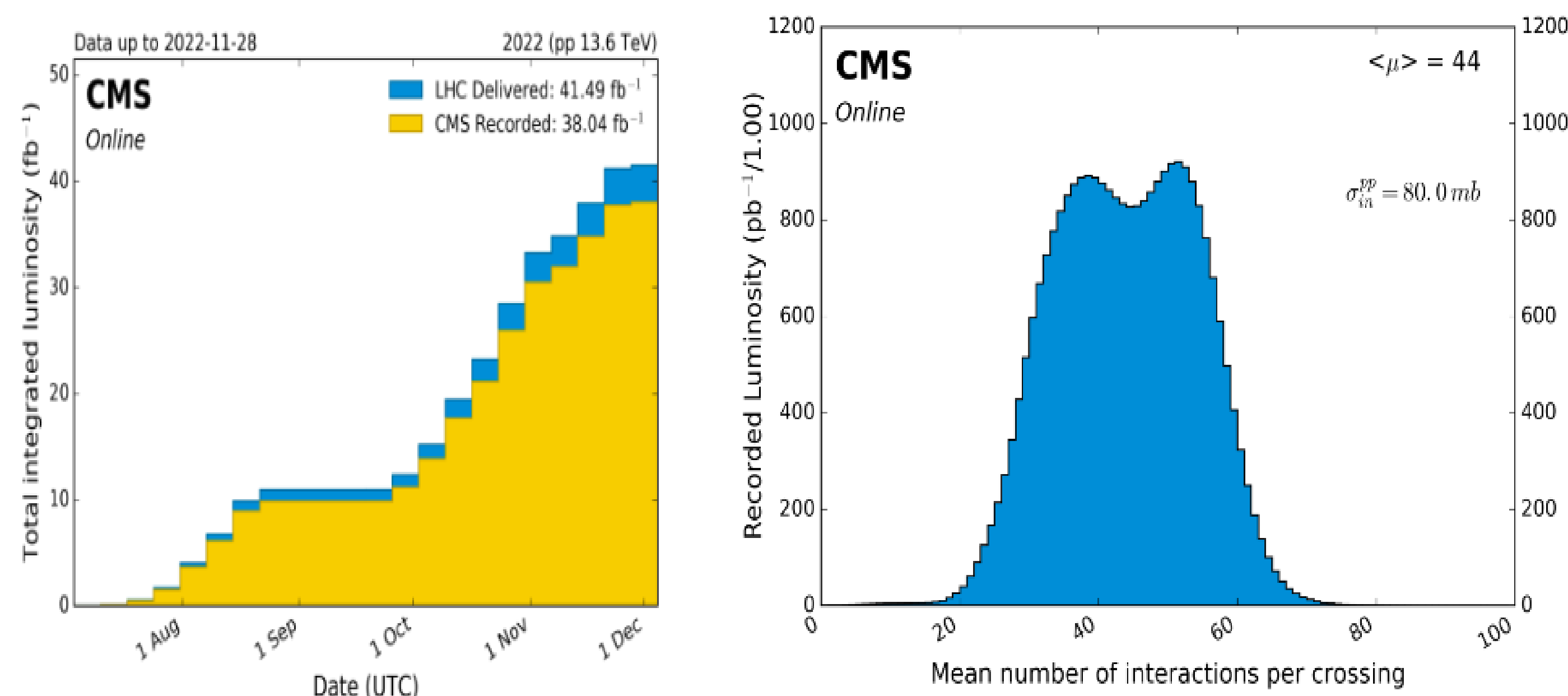
LHC collisions happen at a rate of 40 MHz, impossible to save all events. The CMS experiment uses a two level Trigger system to save events of physics importance.

- Level 1 Trigger (L1):** Based on FPGA's and fast electronics which reduces the event rate to 100 kHz. The accept/reject decision must be made within 4 micro seconds.
- High Level Trigger (HLT):** Software based trigger which runs on computer farms with an average output rate of around 2 kHz. The accept/reject decision should be made at an average time of less than 500 ms using full event information. Strategies to gain additional output rate include delaying reconstruction (parking) or outputting only trigger level information (scouting).



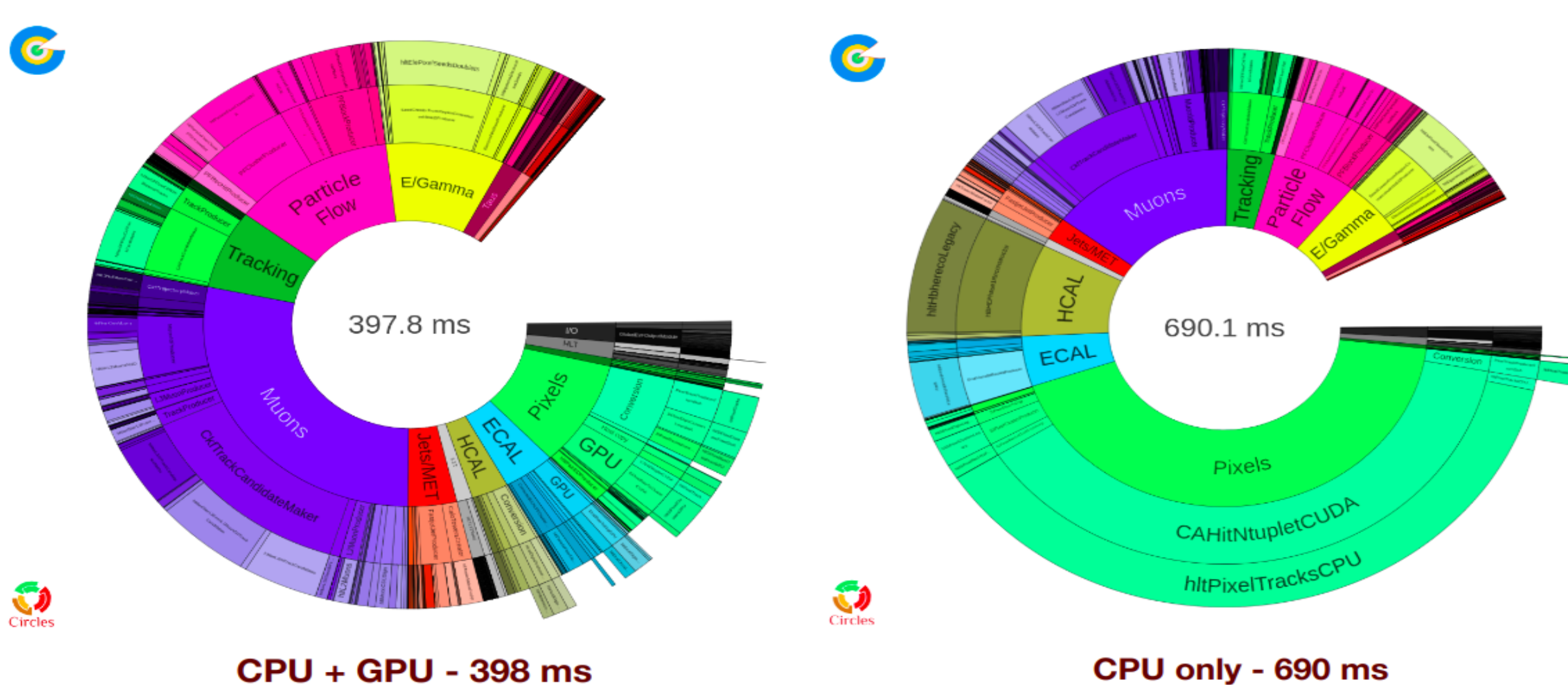
## 2022: First Year of Run3

After a long shutdown of more than 3 years, LHC restarted its operations on July 5, 2022 at an increased centre of mass energy of 13.6 TeV. By the end of the year, around  $38 fb^{-1}$  of p-p collision data has been recorded by CMS.



## Run3 HLT Farm

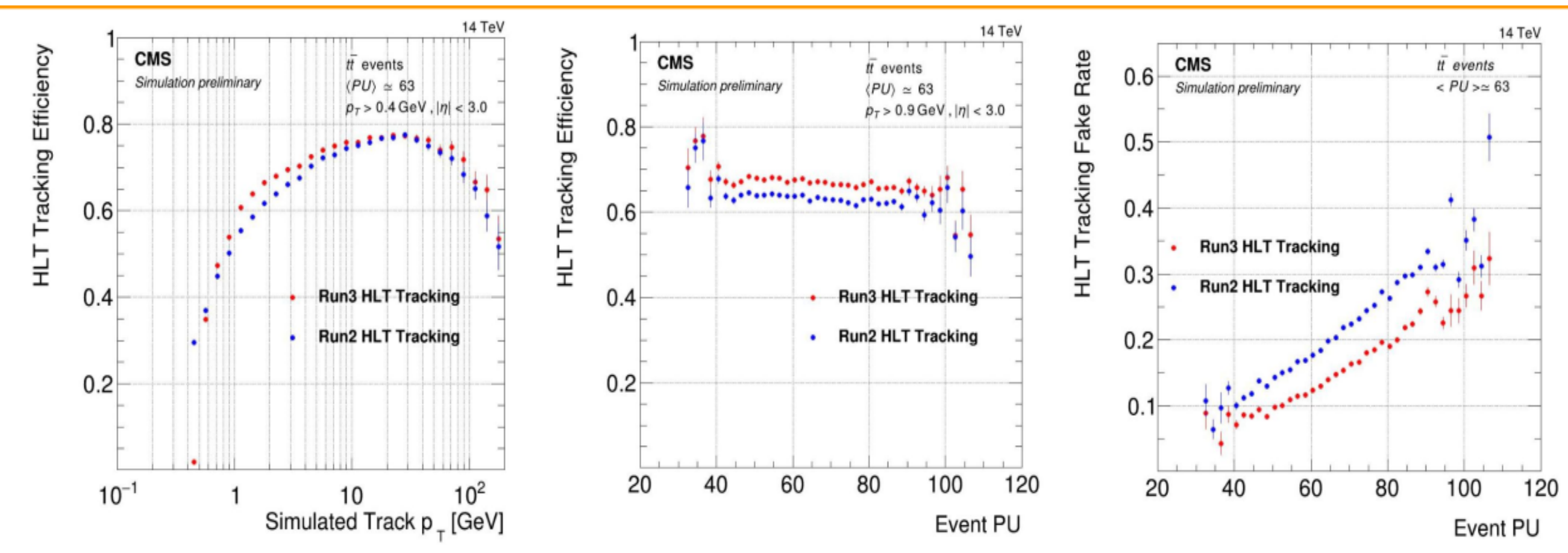
- The new HLT farm consists of 200 machines with 2 sockets each equipped with AMD EPYC 7763 "Milan" 64-core processors as well as 2 Nvidia T4 GPU's (25600 CPU cores + 400 GPU's in total)
- In service since the start of run 3 (July 5)
- Currently, the GPU code is running at 90kHz (pixel reconstruction is run on 88% of events, ECAL on 70% and HCAL on 65%)
- The execution time per event of the HLT step was reduced on average by a factor 1.7 (measured with a run taken in October 2022 with an average pileup of 56)



## HLT Developments for Run3

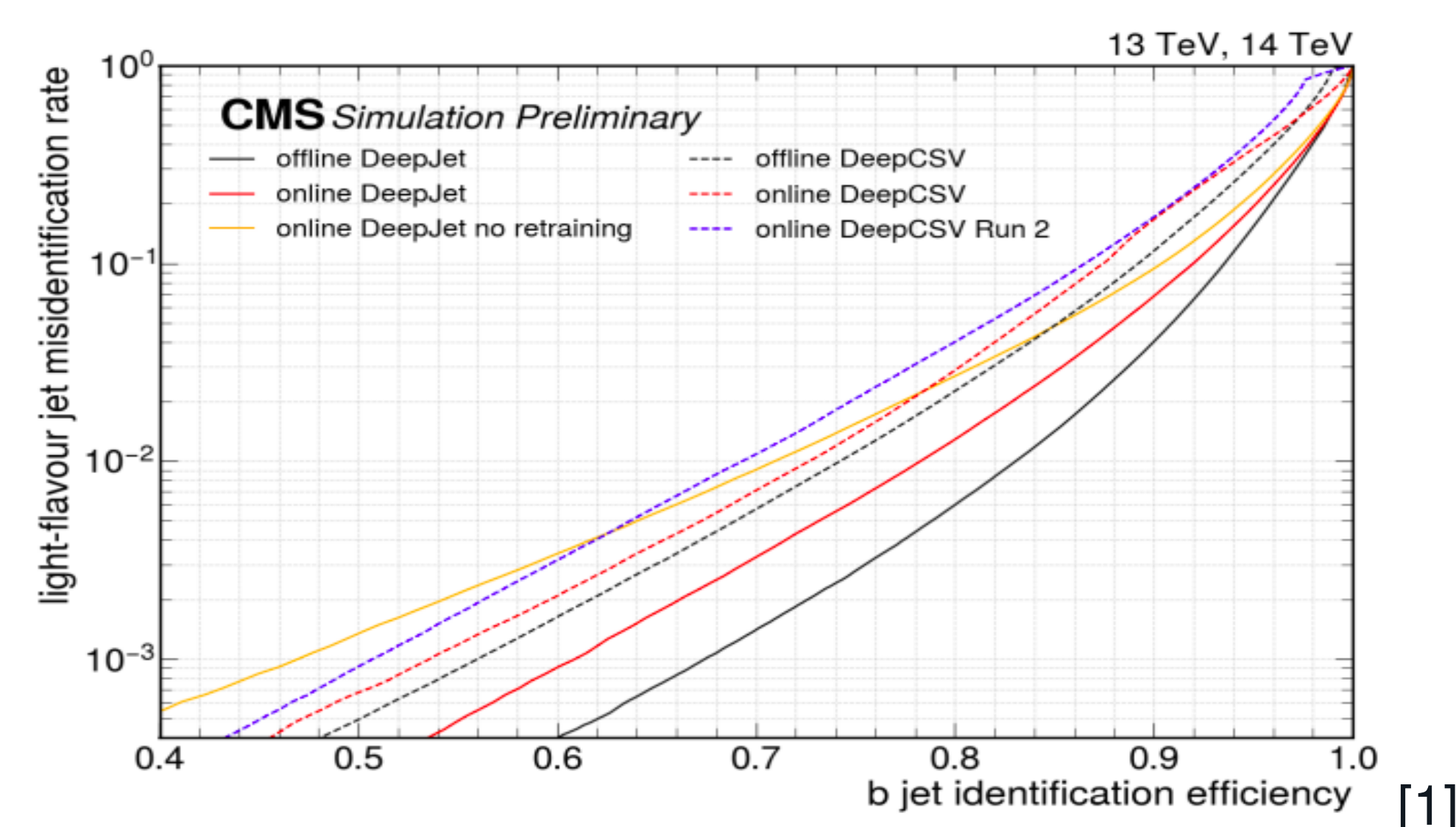
### Run3 Tracking

- New tracking based on the optimized pixel track (= Patatrack) reconstruction
- It allows to run the HLT tracking in a single iteration
- pixel tracks can be offloaded to GPUs: improvement in reconstruction speed



### New Neural Network based Reconstruction Algorithms

- New Convolutional Neural Network (CNN) based DeepJet and DeepTau algorithms for Heavy flavour Jet/ Tau identification.
- Graph Neural Network (GNN) based ParticleNet triggers for  $H \rightarrow$  (boosted) and  $H \rightarrow bb$  (boosted and resolved) and for  $VBF + \tau\tau, \tau\tau + jet, HH \rightarrow b\tau\tau$  searches

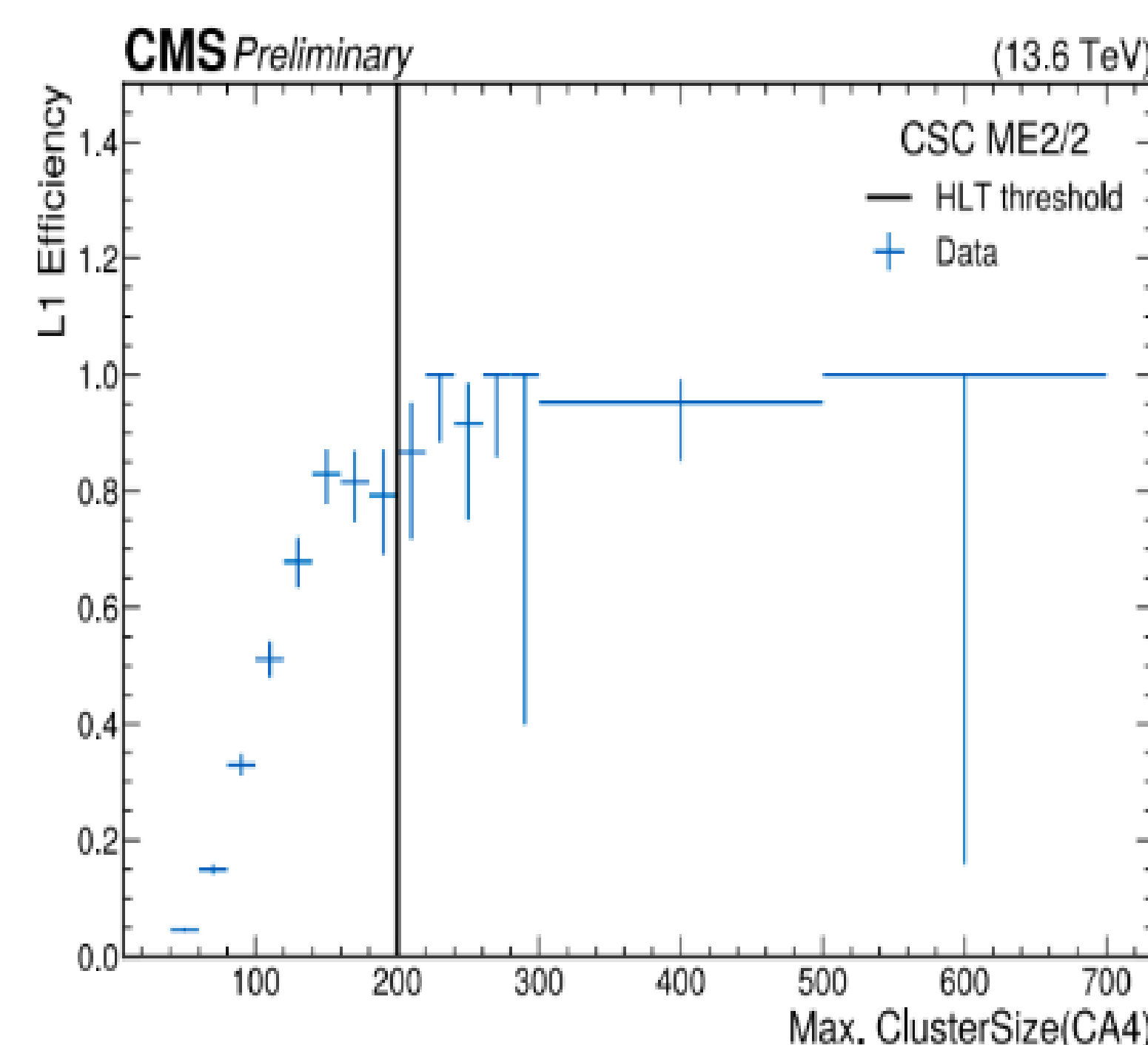


### New Triggers for B Physics and Long Lived Particle (LLP) Searches.

- New Di-electron and inclusive Di-muon Parking Triggers targeting lepton flavour universality violation tests ( $R_k$  measurement), precision tests of  $B_s \rightarrow \mu\mu$  and lepton flavour violating  $\tau \rightarrow 3\mu$  searches.
- New dedicated triggers targeting displaced/delayed signatures (eg displaced muons/taus/ jets/photons) for Long Lived Particle searches.

These new dedicated triggers have been shown to significantly improve the signal sensitivity of their respective searches.

As an example, a dedicated trigger (called High Multiplicity Trigger (HMT), searching for exotic long lived signatures by triggering on Hadronic showers developing in the CMS muon detector called Muon Detector Shower (MDS) increases the signal acceptance by more than 20 times[3] with respect to the previous Run2 triggers.



**L1 efficiency of CSC High Multiplicity Trigger(HMT) as a function of the largest CSC rechit cluster size, which is a reconstructed quantity used at HLT. The L1 efficiency is evaluated as the fraction of events in which the HMT is fired, given the above cluster selections are satisfied. A data sample of around 2M events triggered with zero bias triggers is used.**

## Conclusion

The new developments of HLT system for Run3 promises much and is expected to significantly improve the potential for finding new physics. The first year of data-taking was very successful and 3 more years of data-taking is ahead of us.

## References

- [1] CMS Collaboration. *Expected Performance of Run-3 HLT b-quark jet identification*, CMS-DP-2022/062.
- [2] CMS Collaboration. *High Level Trigger Tracking*, CMS-DP-2022/014.
- [3] CMS Collaboration. *High Multiplicity Trigger in Run 3*, CMS-DP-2022/062.