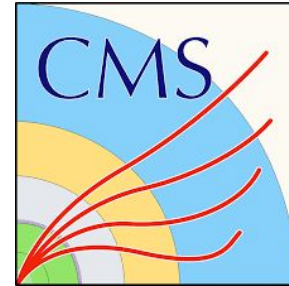


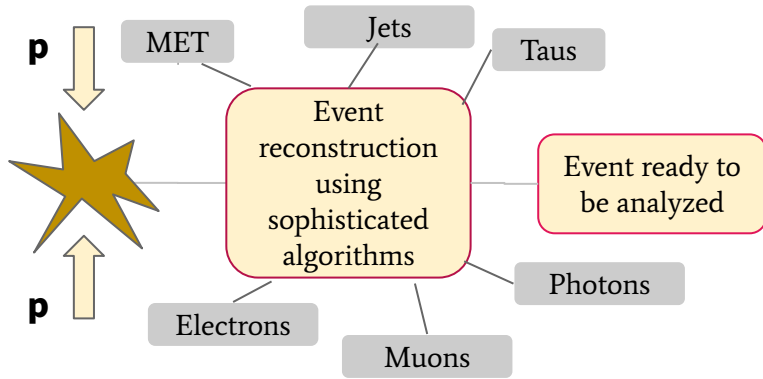
GPUS AT CMS



Thematic CERN School of Computing 2022

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CMS EVENT RECONSTRUCTION

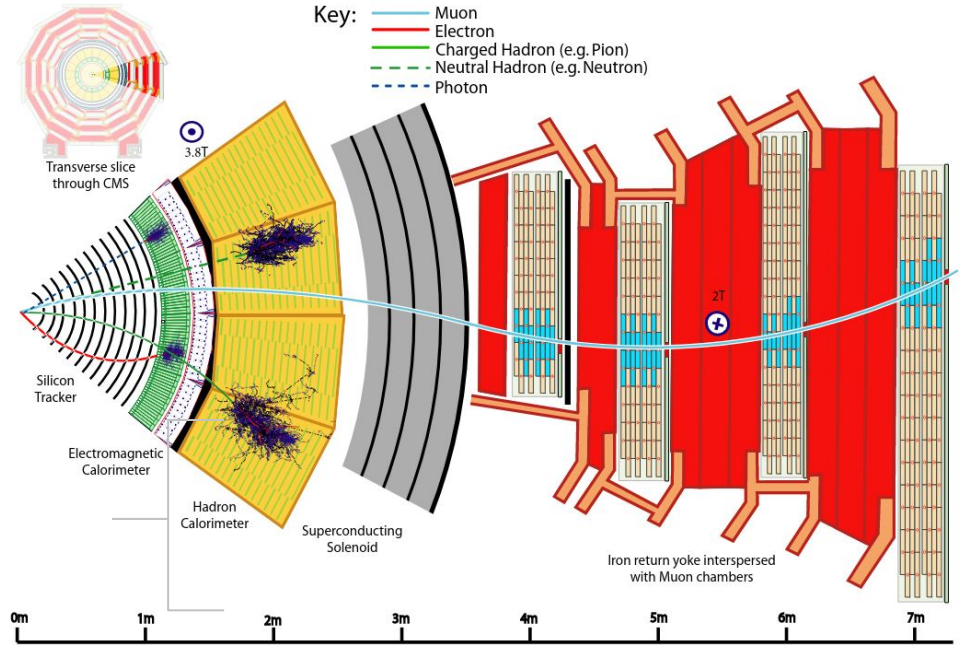


Online reconstruction at the HLT :

- Fast
- Runs on computing farm@CERN

Offline reconstruction :

- Can be more sophisticated
- Runs on computing centers worldwide



COMPUTING AT THE HL-LHC

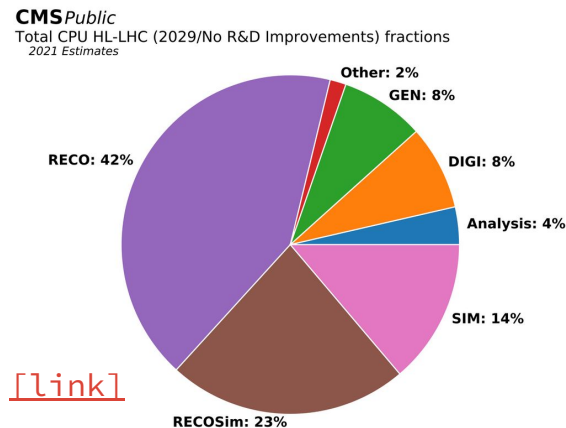
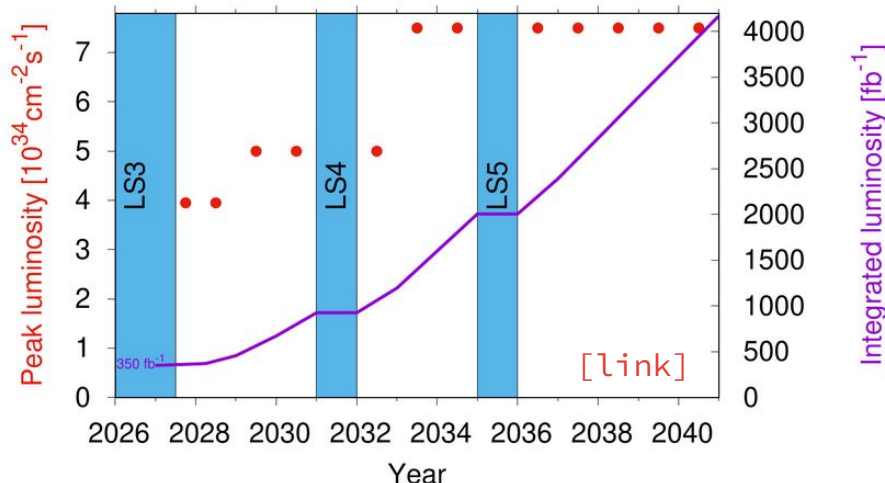
- 2-3 times greater instantaneous luminosity compared to Run-2
- Up to ~200 PU interactions
- Much larger event processing rate

Unprecedented challenge for online and offline event reconstruction.

Imperative to take advantage of new hardware technologies → **Heterogeneous computing**

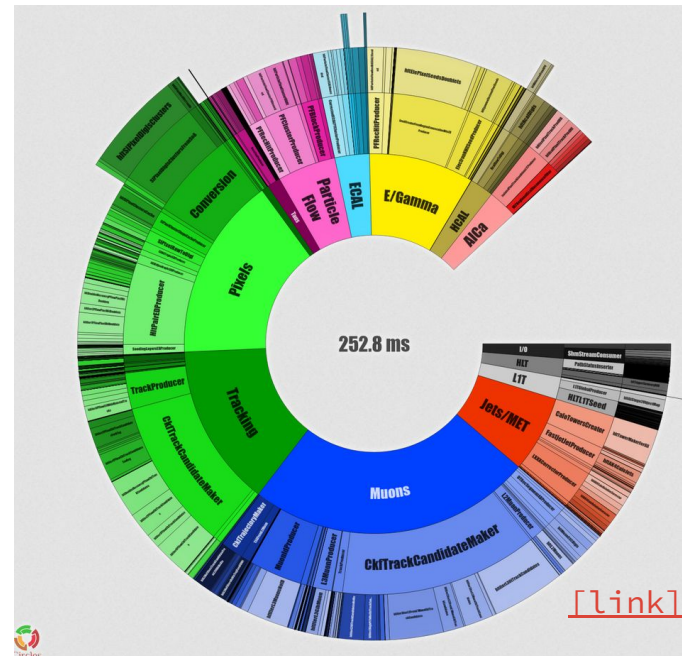
- Use of different co-processors designed to handle specific tasks in parallel
- Current software should be adapted to run on such systems

Heterogeneous software has been already developed and **will be used for HLT reconstruction in Run-3 !**



USE OF GPUS AT THE CMS HLT

- Pixel tracks (patatrack), ECAL & HCAL local reconstruction able to run on GPUs.
- Use of GPUs allows introduction of more computer intensive tasks using the same processing time.
- New track reconstruction@HLT showed significant improvement in the performance with respect to legacy pixel tracks.



GPUS @ THE WORLDWIDE LHC COMPUTING GRID

Offline event reconstruction :

- Can use more sophisticated algorithms → higher latency
- Enormous amount of data & simulated events expected to be reconstructed for the HL-LHC

Efforts are being made within CMS to adapt different parts of the reconstruction software to run on heterogeneous computing systems:

- ~20% of reconstruction software already ported → Goal to reach 70-80%
- My focus → Electron/photon reconstruction with GPUs

One of the first GPU clusters dedicated to CMS was set up at T2_US_Wisconsin :

- Has been extensively tested and is now integrated with the LCG.



ELECTRON & PHOTON RECONSTRUCTION @ CMS - 1

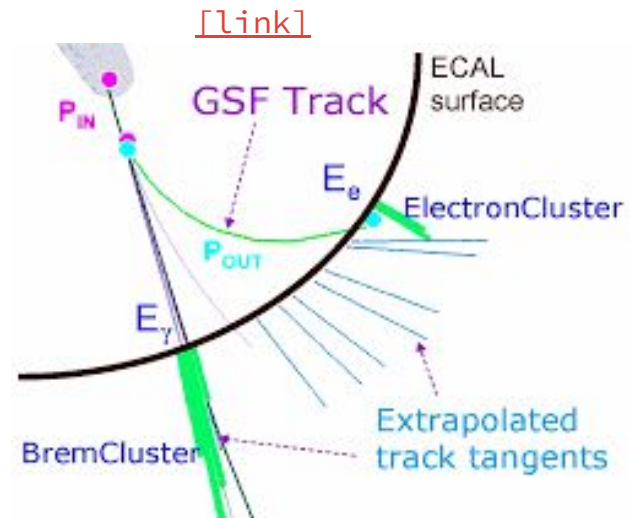
Performed by a dedicated tracking algorithm (GSF) that takes into account energy losses due to bremsstrahlung:

- CPU-intensive \rightarrow does not run on all reconstructed hits of the detector.

Instead \rightarrow identification of a hit pattern that might lie on an electron trajectory (“seeding”):

- ECAL-driven
- Tracker-driven

GSF tracking algo runs on all ECAL & tracker-driven seeds



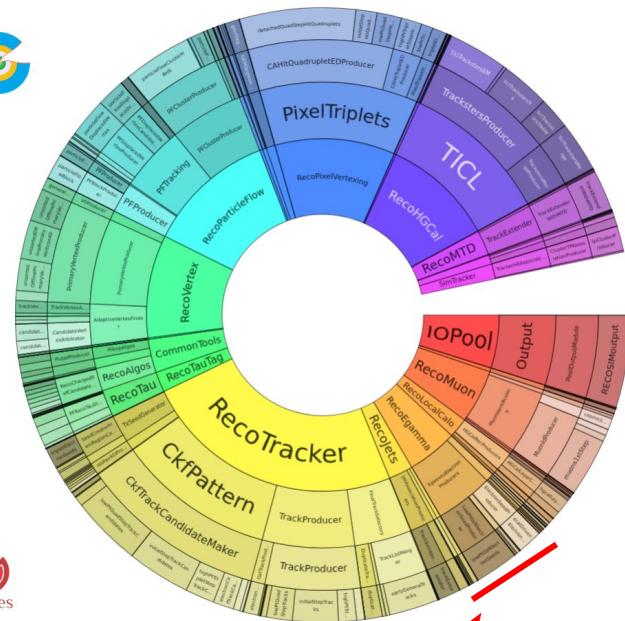
ELECTRON & PHOTON RECONSTRUCTION @ CMS -2

Electron & photon reconstruction takes up ~5-7% of total event reconstruction CPU time

- Electron seeding modules have the largest contribution

Goal is to be able port the e/g reconstruction on GPUs while:

- Making sure that the performance & reconstruction efficiency is similar or better than the current CPU implementation
- The timing is improved



Electron/photon reconstruction (PU~200)

SUMMARY

- HL-LHC will present an unprecedented challenge for both online and offline event reconstruction
 - The required processing power will be of orders of magnitude larger than today
 - Use solely of conventional CPUs will not be enough
- Heterogeneous computing systems can provide the solution
 - Need to explore/adapt current CMS software to run on GPUs
- CMS already deployed heterogeneous reconstruction of tracks at the HLT

Looking forward to learning about new concepts & tools for heterogeneous computing at the tCSC!

THANK YOU!!