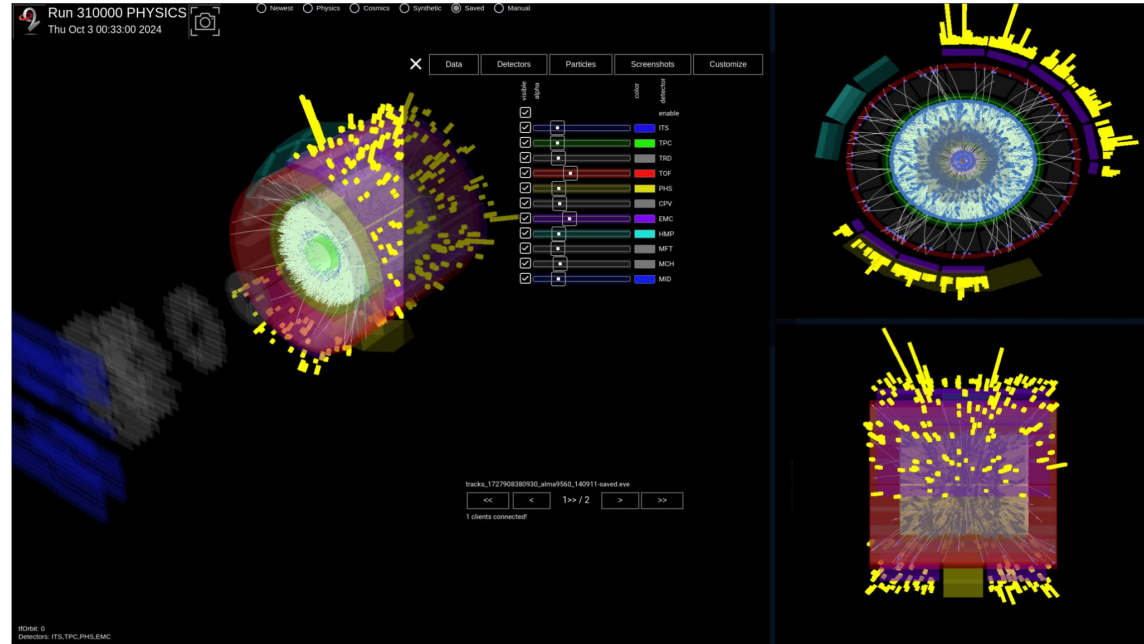

Track #2 summary: Online and real-time computing

CHEP 2024 - Krakow, Poland

C. Agapopoulou, M. Battaglia, K. Nagano, D. Rohr

Track #2: Online and real time computing

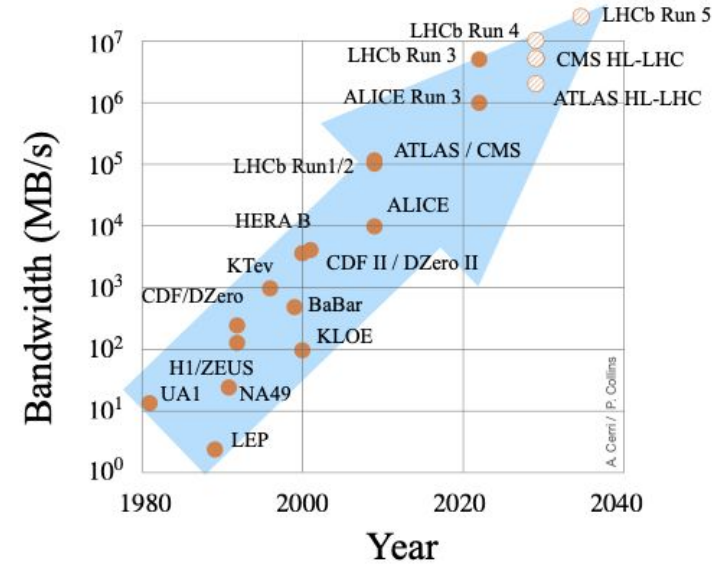
- 47 talks , 27 posters
- Conveners
 - Christina Agapopoulou (LHCb)
 - Marco Battaglieri (JLab)
 - Kunihiro Nagano (ATLAS)
 - David Rohr (ALICE)
- Topics
 - DAQ systems
 - Networks
 - Monitoring & slow control
 - Online reconstruction & AI
 - Accelerated & heterogeneous computing
 - Upgrade & Future prospects



An ALICE Run 3 event from the [new web-based ALICE event display](#) (no installation needed!)
from J. Myrcha

Online and real-time computing in every scale

- From [timepix](#) (1 ASIC) to LHC experiments (millions of channels)
- Talks from all around HEP: (HL-)LHC but also Dark matter, fixed target and nuclear physics experiments!
- And across the rate spectrum : from 3 kHz to the GHz (IR*PU of HL-LHC experiments)



Making hardware triggers smarter

ATLAS & CMS improving their L0 triggers to improve their efficiency:

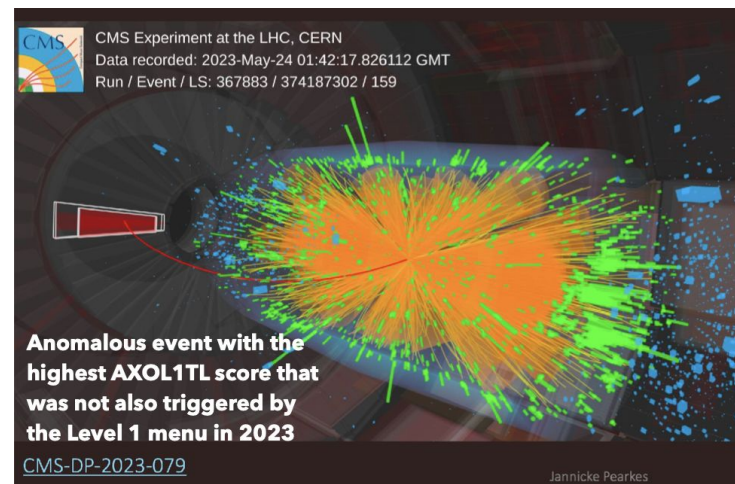
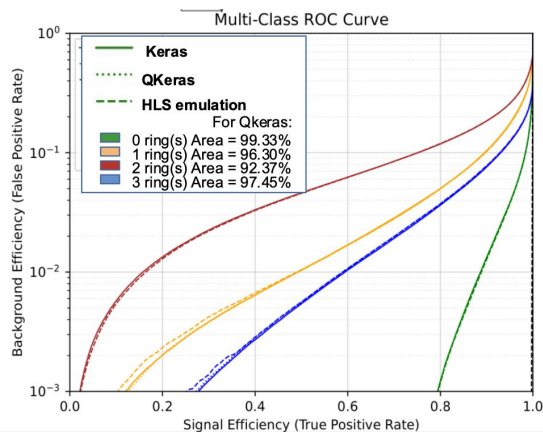
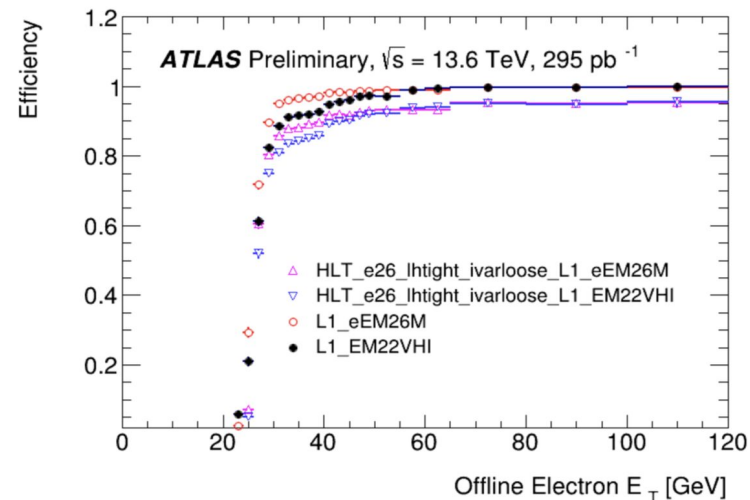
- ATLAS Trigger system [C. Merlassino](#)

Or to search for exotic New Physics

- CMS L1 Anomaly detection [M. Quinnan](#)

Not only an LHC game:

- NA62 L0TP+ [O. Frezza](#), RICH-FPGA [P. Perticalori](#)



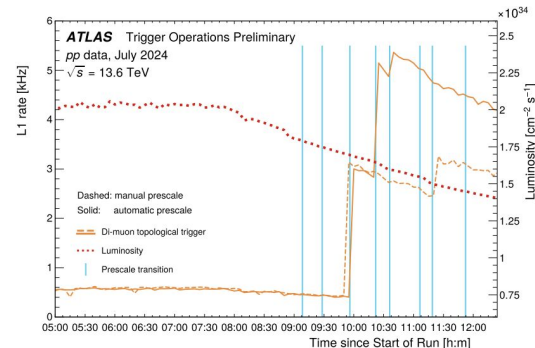
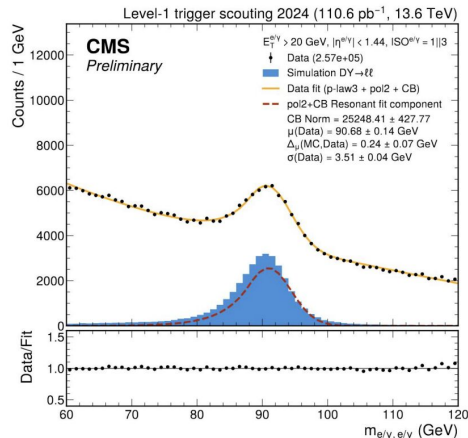
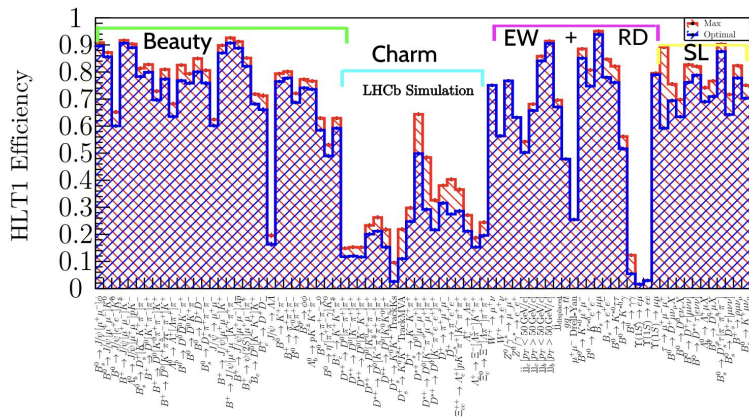
Maximising the physics output

CMS L1 scouting captures L1 reco objects at 40 MHz to ensure maximal coverage

- Run 3 demonstrator already saved 70 fb^{-1} of scouting data! [Talk from M. Migliorini](#)

ATLAS enabled an **end-of fill optimisation** to explore the extra available rate

- Being used for b-physics and HH triggers- checkout the [talk](#) from *C. Merlassino*



LHCb fully software trigger optimised for a **balanced BW distribution** among physics WGs

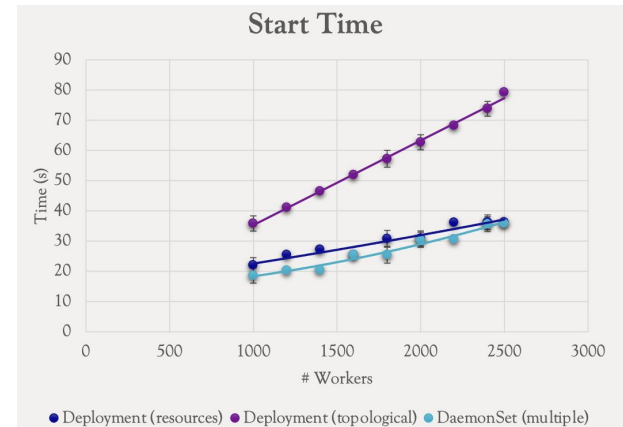
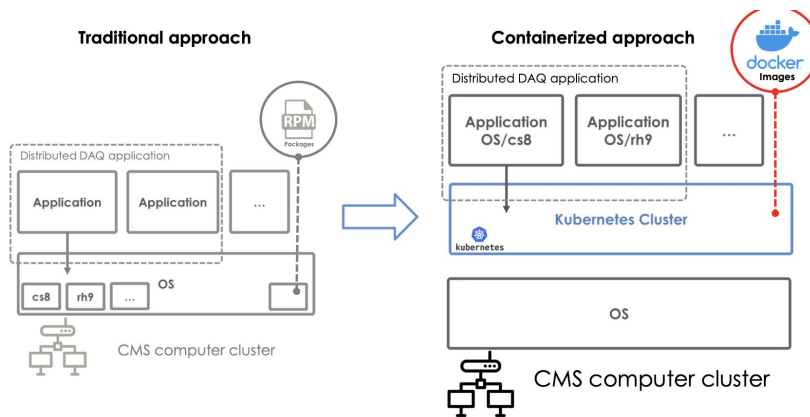
- HLT1 automatic method based on Adam algo - [J.E. Horswill](#)
- HLT2 regularly monitored to meet BW requirements in rapidly changing 2024 conditions - [R. J. Hunter](#)

+ **BSM LLP buffer scanner** based on HLT1 online monitoring - checkout the [talk from V. Kholoimov](#)

DAQ orchestration

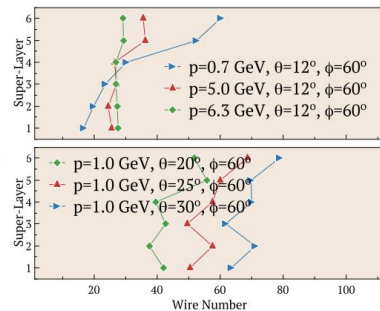
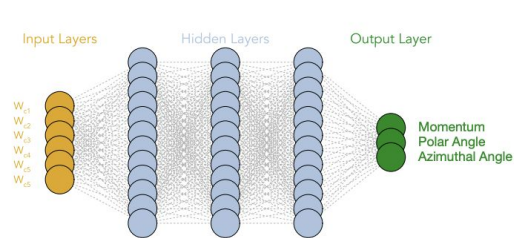
Well-validated large-scale frameworks are exploring optimised orchestration & containerisation:

- CMS has adapted XDAQ software framework to provide a built-in support for containerization and orchestration ([D. Šimelevičius](#))
- ATLAS is adopting Kubernetes in TDAQ to improve the scalability & resource utilisation ([A. C. Radu](#))

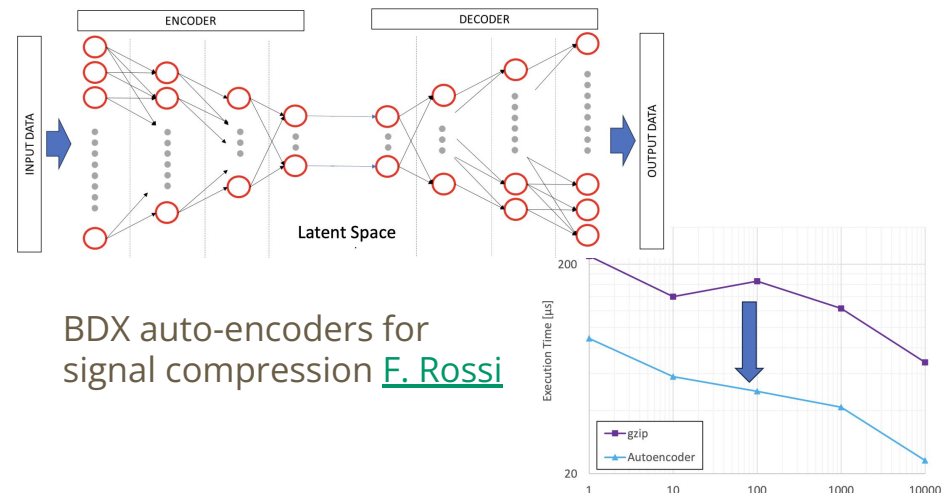


AI for online reconstruction

- Being widely explored by different experiments
- A lot of popularity with **GNNs** for tracking, but more local approaches also being explored
- AI being also explored for clusterization problems
- **Auto-encoders** very popular for compression & global/anomaly triggers



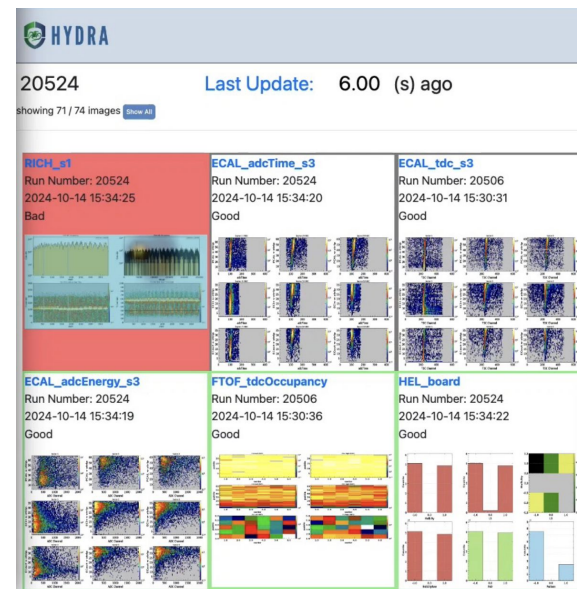
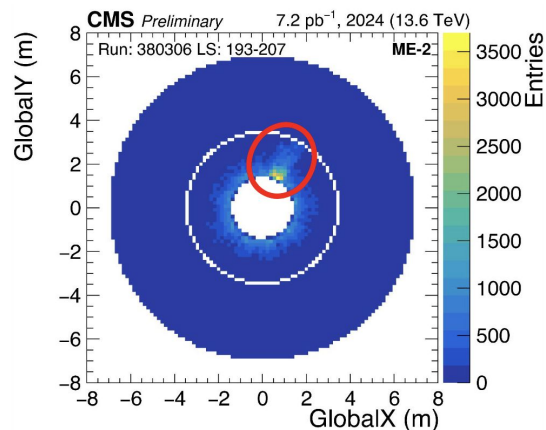
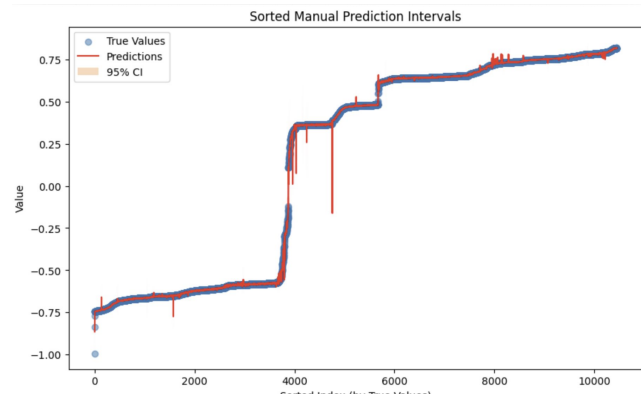
CLAS12 GNN-based tracking, [G.Gavalian](#)



AI also for the humans!

ML algorithms being explored as tools to detect anomalies in real-time monitoring and help shift crews with slow control tasks

- Anomaly detection in CMS muon detector DQ: [Talk by M. Buonsante](#)
- AI-based framework for portable DQ monitoring: [Hydra \(B. Sawatzky\)](#)
- ML for optimized polaritization at J-Lab: [Slides by T. Jeske](#)

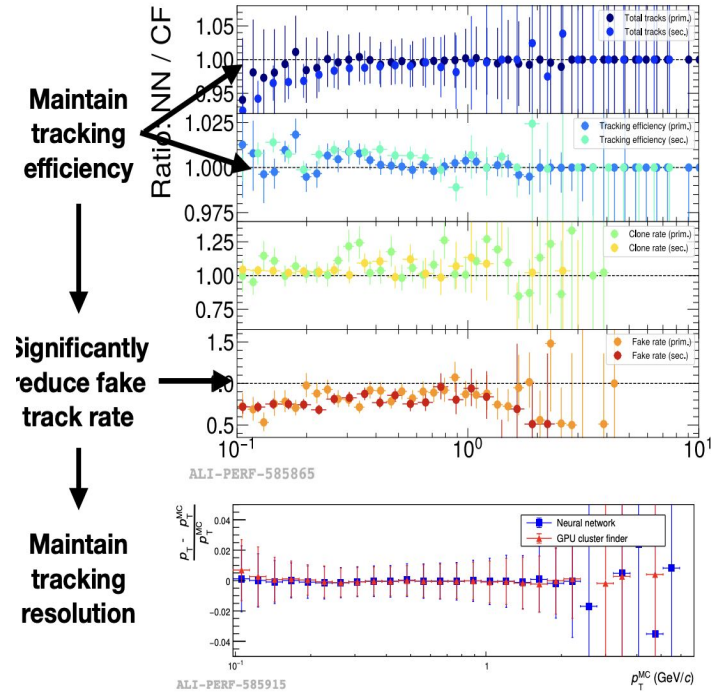
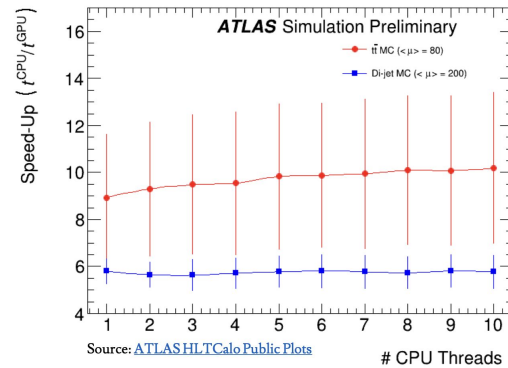
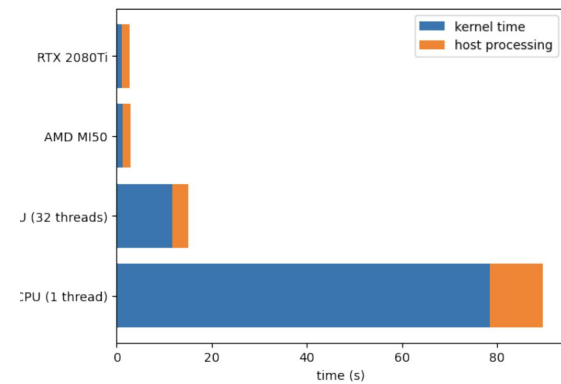


Acceleration with GPUs

Reconstruction advancements in GPUs to fit increasing DAQ online requirements

- **ALICE** is studying NN based TPC clusterisation: fake rate down by 30% - data rate reduction possible!
- **CBM** implemented its hit finding algorithm - running at 40GBps, more algorithms to follow (F. Weiglhofer, [slides](#))
- **ATLAS** Topo-Automaton CALO Clustering fully implemented - speedups of O(x10) (N. Fernandes, [talk](#))

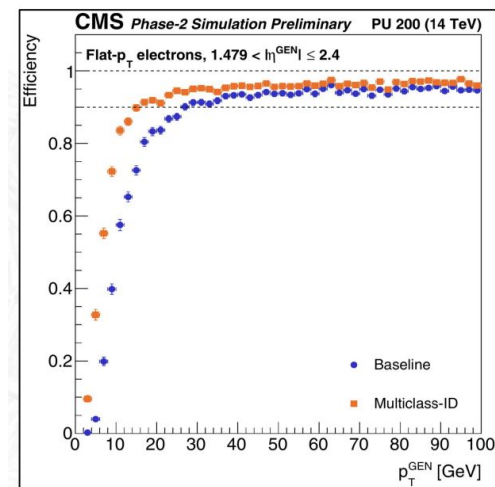
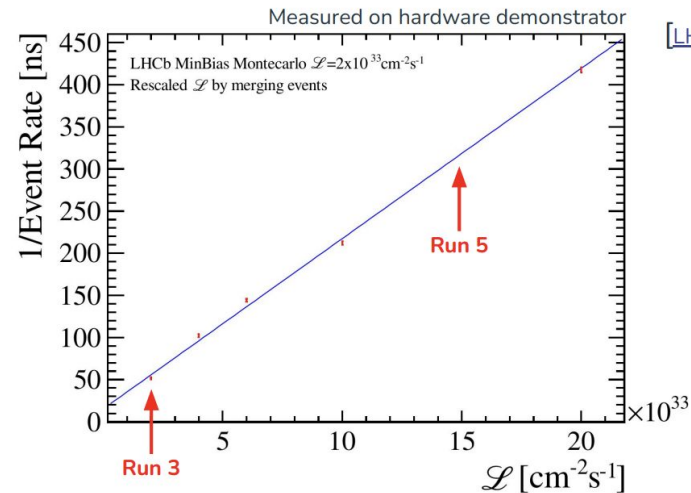
For more details on ALICE NN TPC clusterisation, checkout [talk from C. Sonnabend](#)



And FPGAs

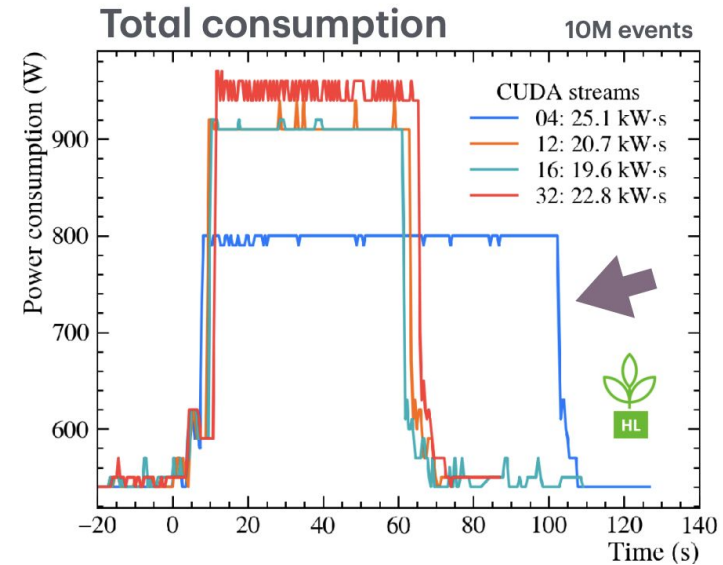
Creative solutions to fit within memory & latency requirements

- Offload part of the SW tracking to FPGAs - the **LHCb** approach
RETINA - [checkout talk from F. Lazzari](#):
 - VELO RETINA clustering already default in Run 3: data rate reduction and HLT throughput improvement
 - VELO tracking demonstrator also running, promising results for Run 5 scaling thanks to O(n) design
- **CMS** looking into FPGAs for a variety of tasks:
 - Electron tracking with AI: improved efficiencies at low-pT [P. Viscone](#)
 - Global trigger in HL-LHC: multiple ML approaches being investigated ([G. Bortolato](#))
- **ATLAS** is looking into upgrading to a heterogeneous Event Filter Farm for HL-LHC : Talks from [S. Ditmeier](#) & [Haider Abidi](#)
 - Tracking implementations on FPGAs started, both classical and GNN-based)
 - Work towards technology choice to be made next year



Towards the future

- Heterogeneous computing systems allow power consumption reduction but care must be taken to resource and SW optimisation
- Power / event should become a crucial metric
- Checkout [talk by V. Svintozelskyi](#)



The NextGen Triggers project ([A. Naumann](#))

- 4 years funding
- R&D for HL-LHC, focus on ML, FPGAs/GPUs
- investment in community



Technologies

- ▶ ML and classical algos: invent, optimize, benchmark
- ▶ Deploy on FPGAs: latency + throughput
- ▶ Employ GPUs, with focus on open source



Community

- ▶ Training to stay
- ▶ Educating the next generation
- ▶ Invest in open source to reduce vendor lock-in

Summary (of the summary)

- Track 2 had a very rich program with exciting new results
- We were happy to see first results of Run 3 with upgraded (or brand new) trigger systems
- And their plans for the HL-LHC era
- But also see many non-LHC experiments join the high-rate online & real-time world
- AI usage is becoming standard in online reconstruction & selection
- Acceleration with GPUs & FPGAs being further explored for the future
- Energy efficiency, a performance optimisation metric for the triggers of the future
- **Thanks to the organisers, all our speakers & all of you for a wonderful CHEP2024!**