



Next Generation Triggers

for the ATLAS and CMS Experiments

Cristina Botta

on behalf of the **Next Generation Trigger Project**
and the CMS & ATLAS Collaborations



ACAT. September 8-12 2025

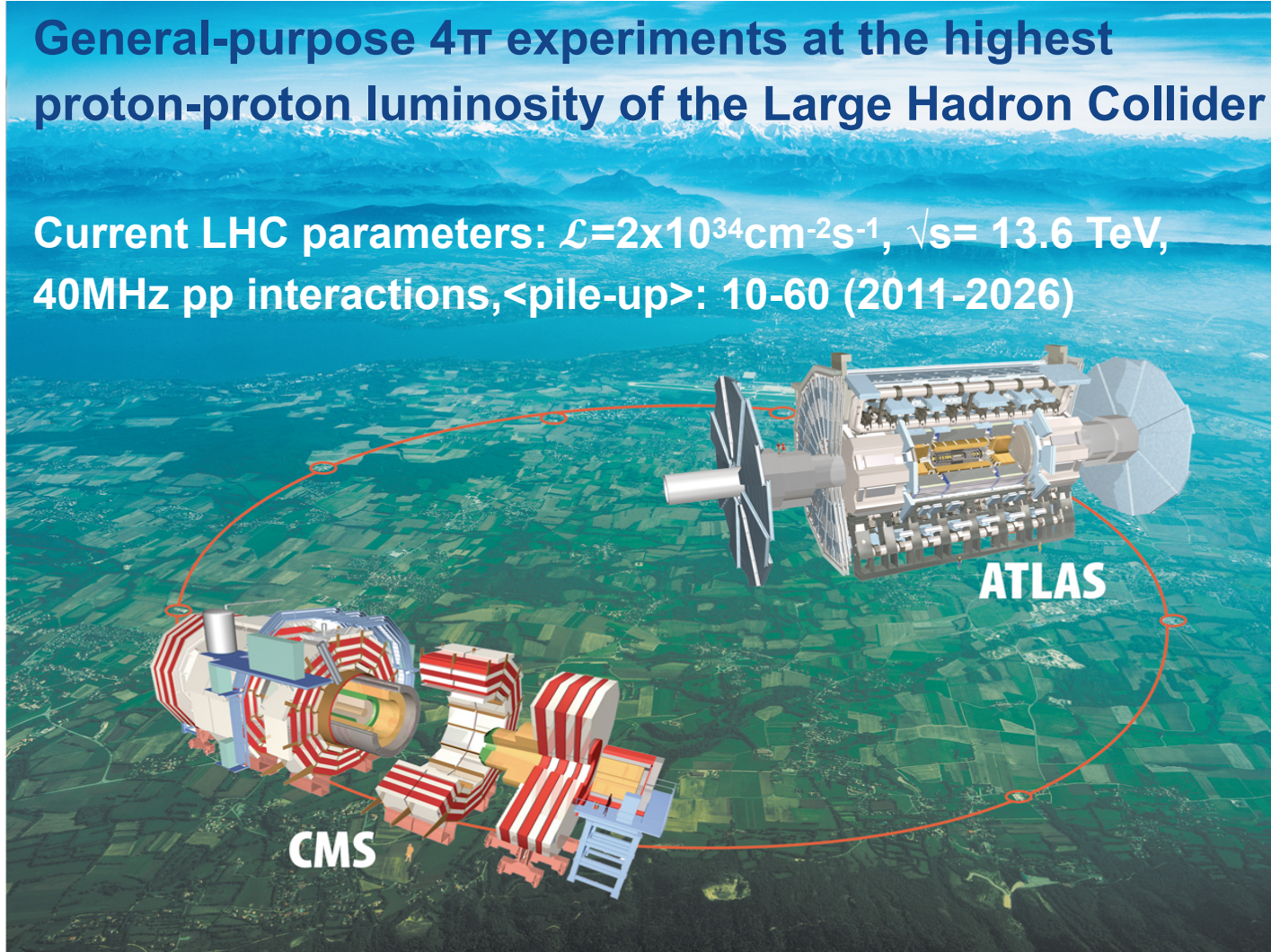


NextGen

ATLAS and CMS @ LHC: setting the stage

General-purpose 4π experiments at the highest proton-proton luminosity of the Large Hadron Collider

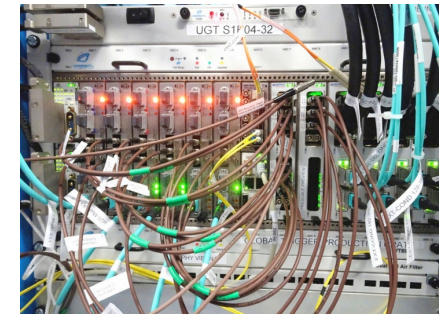
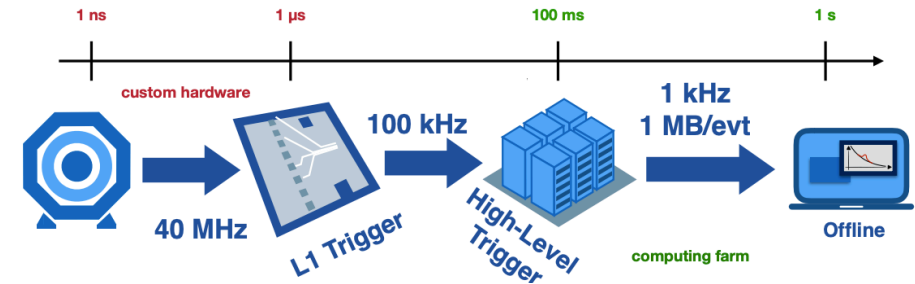
Current LHC parameters: $\mathcal{L}=2\times 10^{34}\text{cm}^{-2}\text{s}^{-1}$, $\sqrt{s}=13.6\text{ TeV}$,
40MHz pp interactions, $\langle\text{pile-up}\rangle: 10\text{-}60$ (2011-2026)



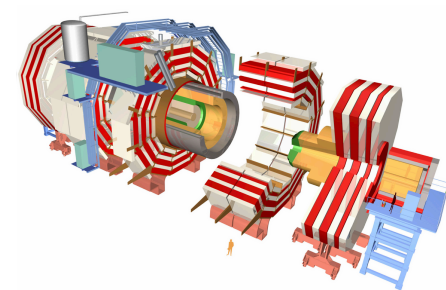
- Online selection (Triggers) necessary to reduce data rate & volume
 - 1-2 MB/event @ 40 MHz $\rightarrow$ 500 Tbps, ~ 300 EB/year
- Initial goal (LHC Run-1/2): find the Higgs boson and New Physics (NP) at $O(100\text{-}1000)$ GeV scale with ewk-like cross sections
 - Higgs boson search driven by $H\rightarrow WW, ZZ, \gamma\gamma$ decays
 - $\rightarrow O(10)$ GeV lepton (μ, e) & photon triggers
 - BSM search in tails of hadronic/missing-transverse-energy distributions
 - $\rightarrow$ Hadronic Triggers at High Energy

ATLAS and CMS Triggers: Original Design

- **Hardware trigger (L0/L1→L1), limited detector readout @40 MHz**
 - uses reduced granularity of calorimeters and muon spectrometer
 - runs on FPGAs, $\sim 2.5\text{--}3.8\mu\text{s}$ latency, **max output rate $\sim 100\text{ kHz}$** (hard limits, from readout pipeline size & link throughput)
- **Software trigger (EF/HLT→HLT), incremental processing of full readout**
 - runs on local server farm, $O(100)$ ms/event processing
 - **output rate 1-3 kHz**, limited mostly by downstream computing and storage cost
- **Perfect compromise between technological limitations and theory motivated objectives:**
 - **99.75% events rejected at L1T, 98% rejected at HLT**



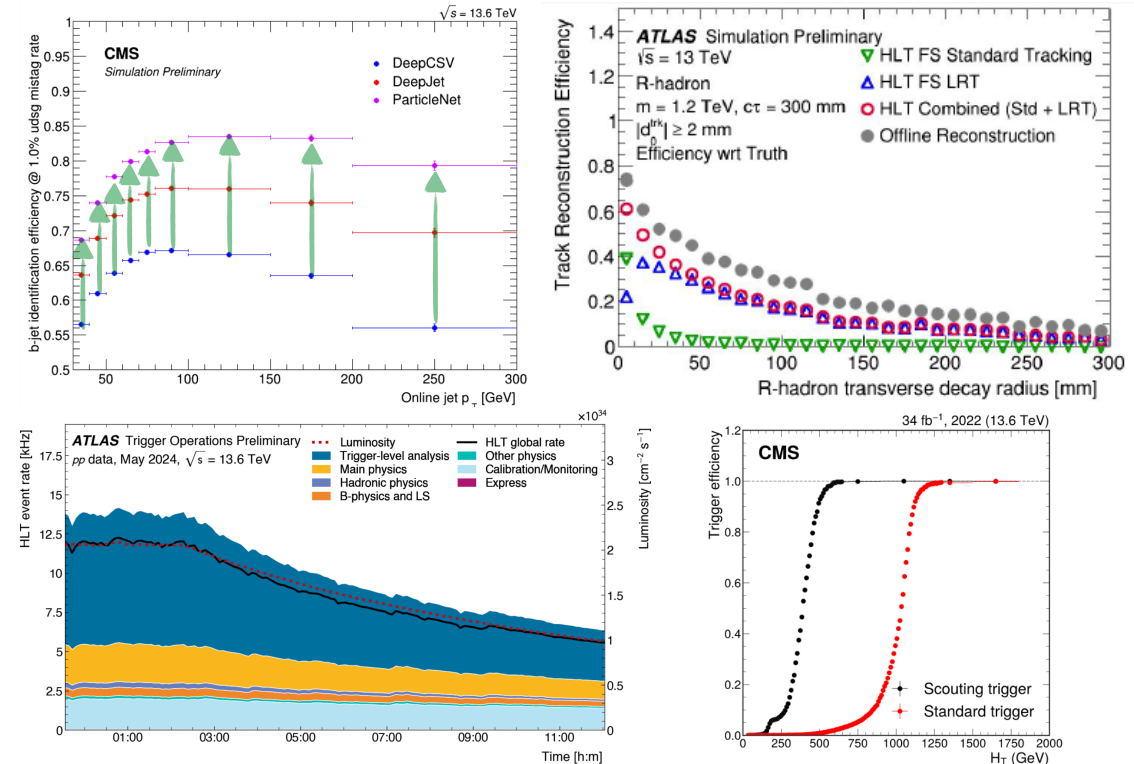
CMS L1 Trigger



CMS High Level Trigger

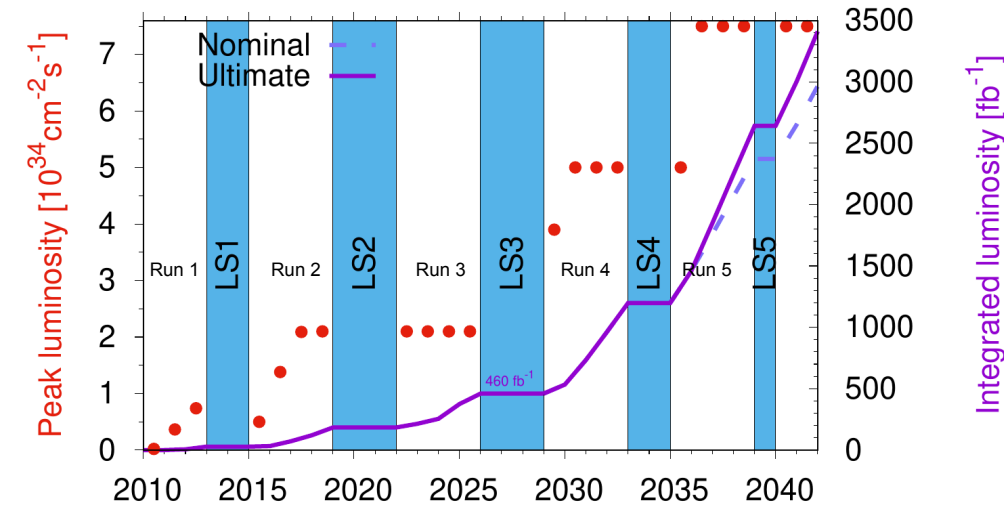
ATLAS and CMS Triggers: Evolving Goals

- After Higgs boson discovery and null results of searches during LHC Run 1 and 2: characterize the Higgs boson further and search for hidden (not behaving as expected!) NP
 - ➔ need new triggers for: lower p_T (b)-jets and taus, final state with multiple soft objects for compressed mass spectra, alternative reconstructions for long-lived particles (LLP)...
- Several updates for Run-(2)3
 - **@L1**: new hardware (Xilinx UltraScale+ FPGAs @ ATLAS) and better calorimeter reconstruction
 - **@HLT**: better reconstruction algos (aligned with latest offline reco) with **more usage of inner tracking and ML taggers**: used more computing power, improved code, heterogeneous computing
 - **CMS**: ~34% of reco on GPUs (eg. Patatrack pixel tracks with [Alpaka](#))
 - **Data Parking** (delayed availability for analysis): **up to 5 kHz @CMS** in 2024
 - **TriggerLevelAnalysis/Scouting** (reduced data format, HLT objects): **up to 27/8 kHz @CMS/ATLAS** in 2024

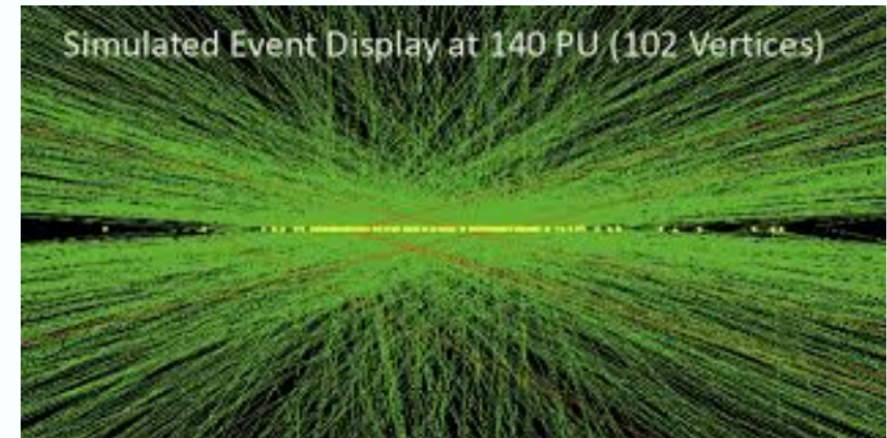


ATLAS and CMS preparing for HL-LHC

- Have to keep (at least) the same physics acceptance up to 200 pile-up interactions: **challenge!**
- ATLAS & CMS invested in upgrading most of their sub-detectors to provide more granular information to L1
 - CMS example: input data from 2 Tb/s to 63 Tb/s (**$\sim 1/10$ of the internet traffic**): for the first time **tracking at 40MHz** ($p_T > 2$ GeV) (no pixels!) & higher granularity from Calo/Muon
- Upgraded sub-detectors backends with newer technologies we can afford higher L1 Latency ($2.5\text{-}3.8\mu\text{s} \rightarrow 10\text{-}12\mu\text{s}$) and L1 rate up to 750-1000 kHz
 - **Still can't afford to read everything**; even disregarding cost, it would need too many links, i.e. more cables, power, cooling: all passive material degrading physics performance & hermeticity

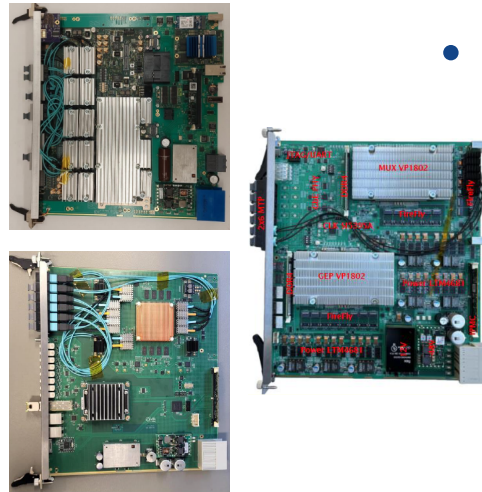
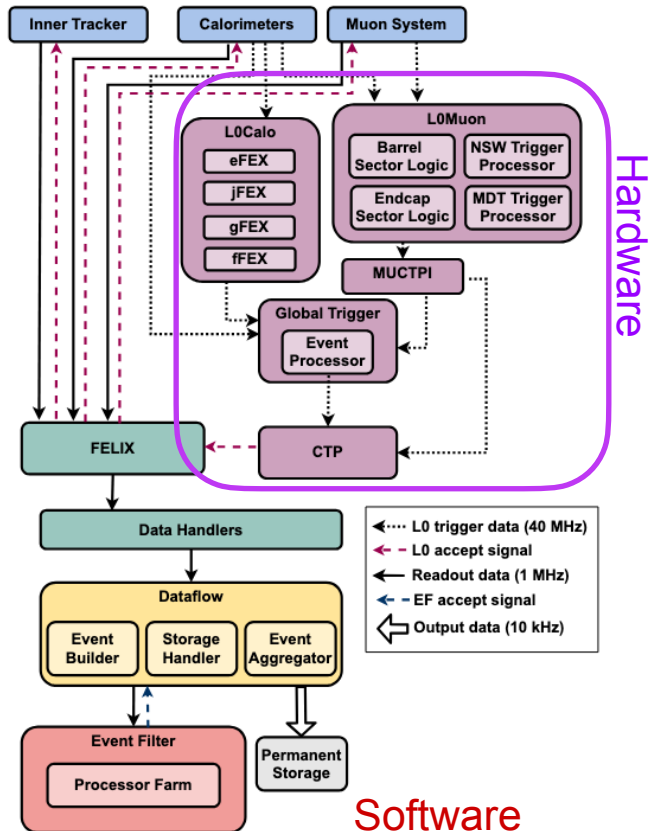
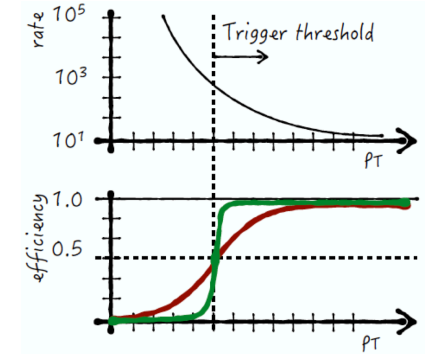


↓ 140 pileup vertices



ATLAS and CMS Trigger strategies for HL-LHC

- Hardware & Software Triggers are being upgraded to profit from all this:
the LHC physics acceptance can be maintained with full trigger-chain up to ~10 kHz



• ATLAS Hardware Trigger

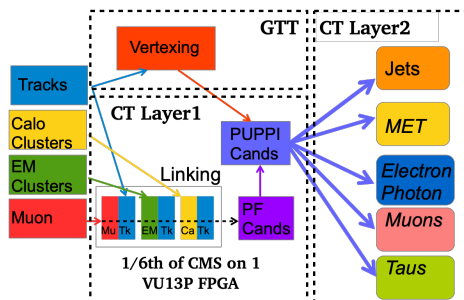
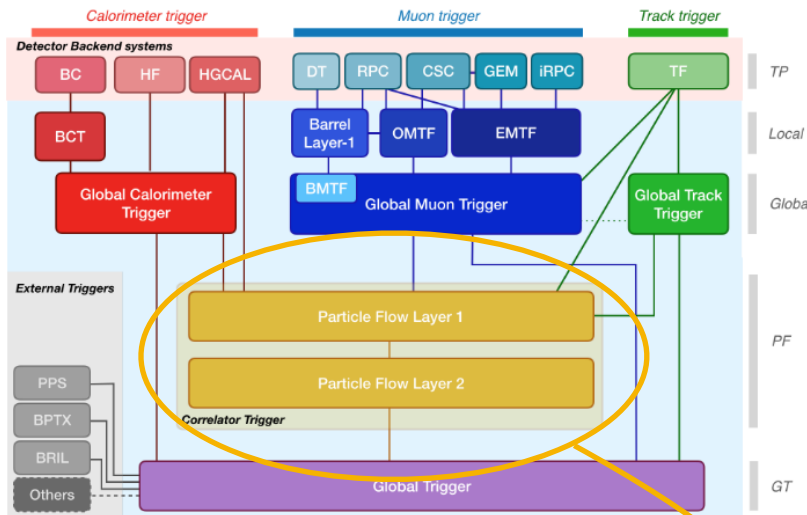
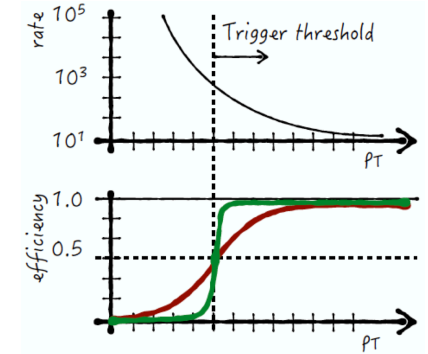
- ATCA boards, Xilinx FPGAs, in many flavours
 - Some parts of the L1 trigger already upgraded for Run-3
- FPGAs: VU13P and also newer and bigger Versal
- **New Global Trigger with big FPGAs** and access to both low-& high-level info to allow more advanced reconstruction

• ATLAS Software Trigger

- commercial CPUs processors and classical CPU fast tracking as baseline, possibly with accelerators

ATLAS and CMS Trigger strategies for HL-LHC

- Hardware & Software Triggers are being upgraded to profit from all this:
the LHC physics acceptance can be maintained with full trigger-chain up to **~10 kHz**



• CMS Hardware Trigger

- ATCA boards, AMD Xilinx FPGAs, in many flavours
- FPGAs: VU13P mostly
- Tracker Tracks available! Together with bigger FPGAs & more latency: **allow Particle-Flow reconstruction at L1**
- **Vertexing allow PUPPI** (PileUp-Per-Particle Identification)

• CMS Software Trigger

- New fast and parallel algorithms for tracking (LST) and HGCAL clustering (TICL) to allow offloading to GPUs up to 50%

The Next Generation Trigger Project



NexTGen

- But what if New Physics doesn't look as expected and it is buried under the bulk of the background events that we are still throwing away?
- **Five years project** (2024-2028) supported by an external donation, combining **ATLAS and CMS Collaborations, CERN's Theory & IT departments, CERN's Experimental Physics Software group**
- To leverage innovative computing technologies for data acquisition and processing and see **how far we can expand trigger acceptance?**
- Opportunities for wider R&D: **Heterogeneous computing, FastML tools, workflows for ML in Trigger systems, Event generators, Physics signatures benchmarking...**

WP1(19M\$):

Infrastructure,
Algorithms and
Theory

01

WP4(3M\$):

Education
Programmes
and Outreach

04

02

WP2(13M\$):

Enhancing the
ATLAS Trigger
and Data
Acquisition

03

WP3(13M\$):

Rethinking the
CMS Real Time
Data Processing



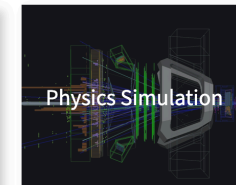
Experiment Trigger
Systems



Heterogeneous
Computing



Artificial
Intelligence



Physics Simulation



Education and
Training

[Full proposal](#)

NGT core structure

Enhancing the ATLAS Trigger and Data Acquisition

- 2.1 Optimal real-time event selection in the L1 GT
- 2.2 Enhancing the L1 Muon Trigger
- 2.3 High Throughput Data-Collection
- 2.4 HLT Tracking
- 2.5 Optimised HLT Muon Trigger Selection
- 2.6 Common Tracking HLT infrastructure
- 2.7 Enhance Reconstruction acceptance for HLT

First Technical Workshop (Nov 2024)

Rethinking the CMS Real Time Data Processing

- 3.1.1 R³ Faster Reconstruction for HLT
- 3.1.2 Optimized data structures for HLT
- 3.2 Towards a distributed HLT architecture
- 3.3 Reduction of the RAW data size for HLT
- 3.4 Optimal calibrations for HLT
- 3.5 Enhancing L1T Scouting for HL-LHC
- 3.6 Practical real-time AI for L1T
- 3.7 L1T anomaly detection & data compression

First year evaluation report

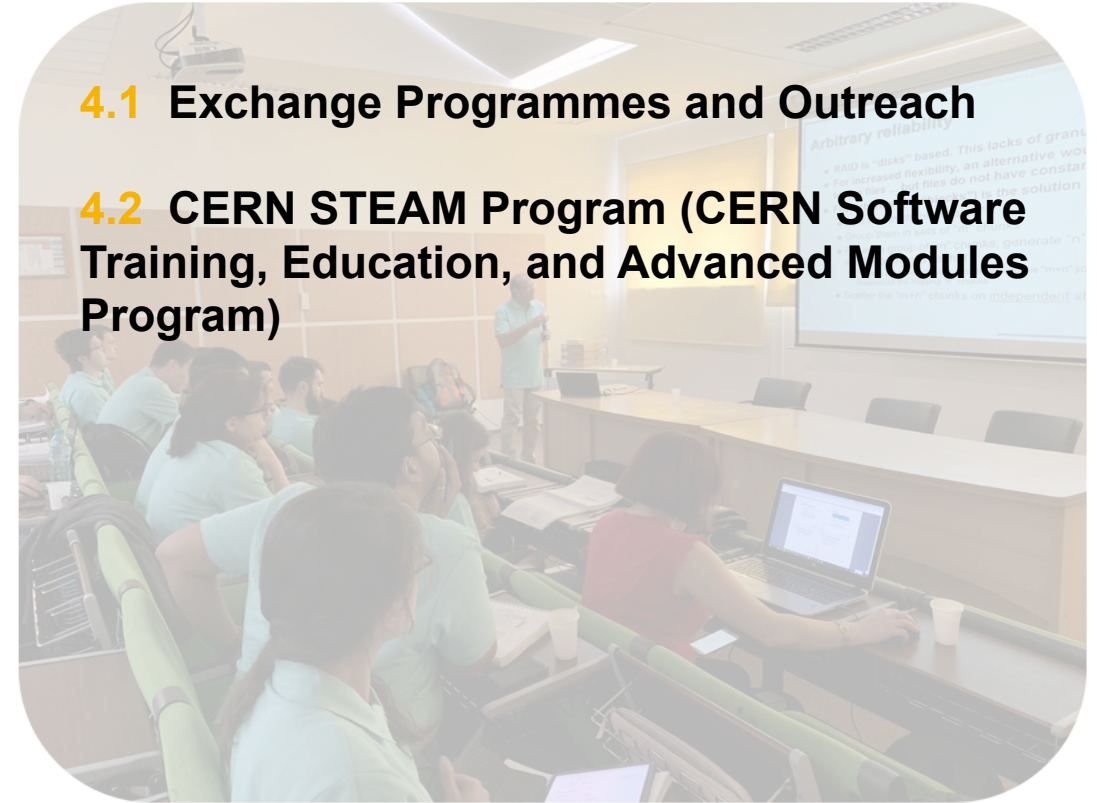
NGT infrastructure

Infrastructure Algorithms and Theory

- 1.1 Procurement of hardware and services
- 1.2 Development framework towards fast inference of complex network architectures on LHC online systems
- 1.3 Hardware-aware AI optimisation
- 1.4 Tensor Networks for Quantum Systems
- 1.5 New computing strategies for data modelling and interpretations
- 1.6 New physics scenarios & SM properties as trigger benchmarks
- 1.7 Common software developments for heterogeneous architectures

Working Package 4

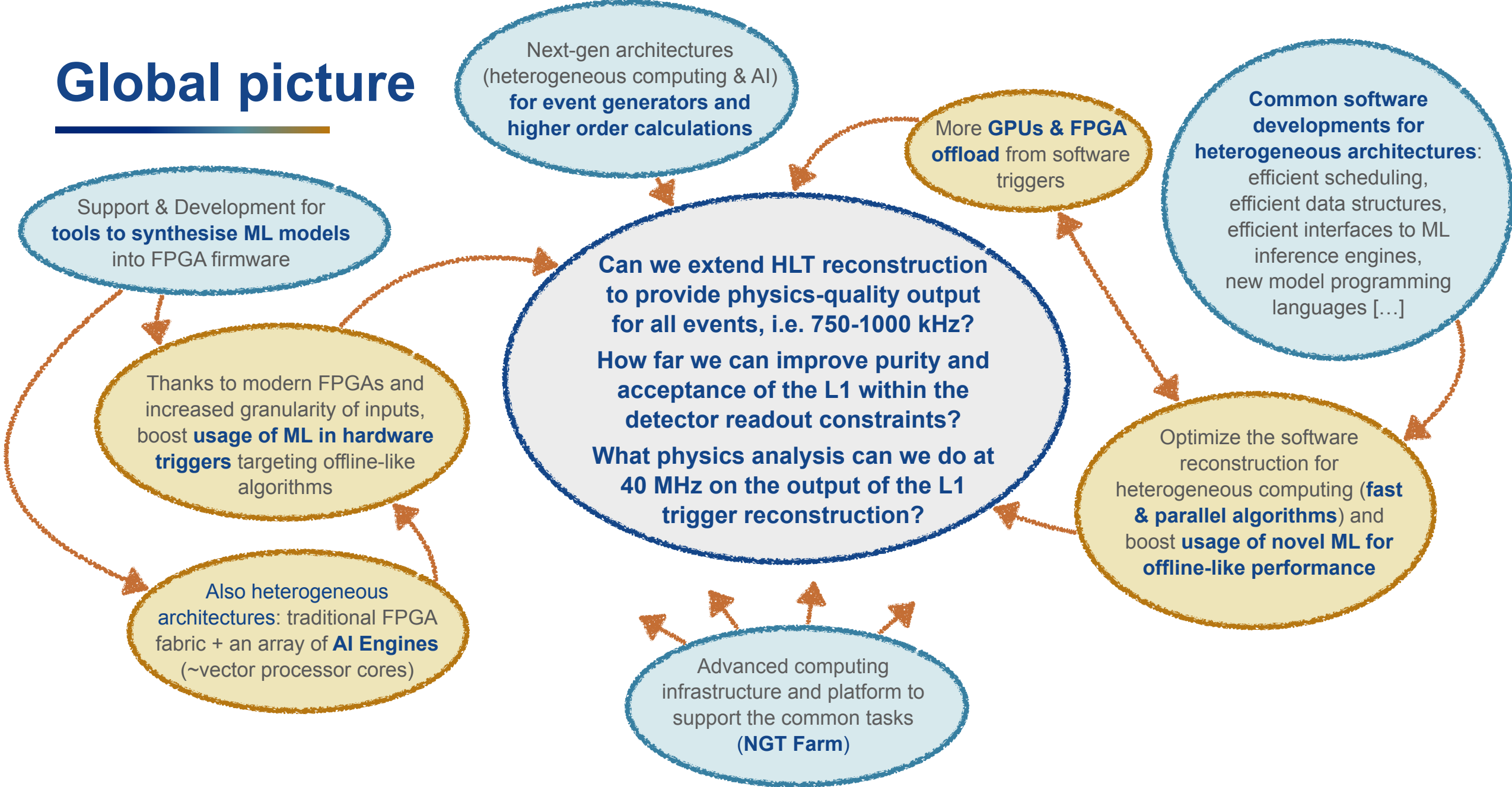
- 4.1 Exchange Programmes and Outreach
- 4.2 CERN STEAM Program (CERN Software Training, Education, and Advanced Modules Program)

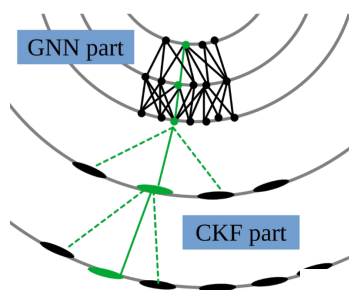
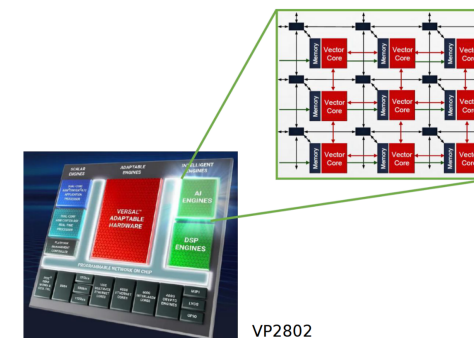
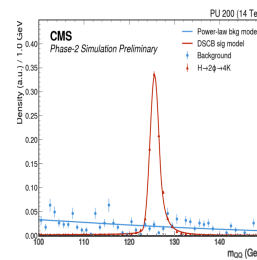
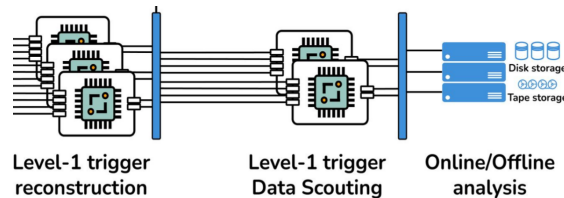
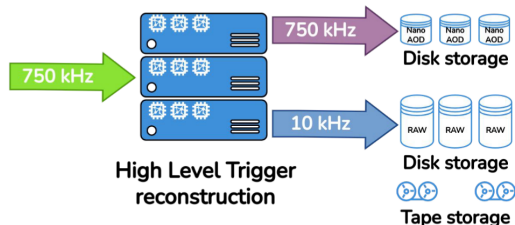


First Technical Workshop (Nov 2024)

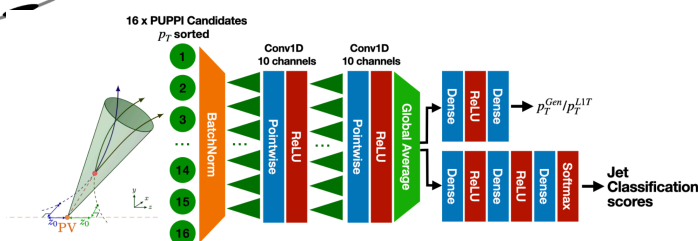
First year evaluation report

Global picture

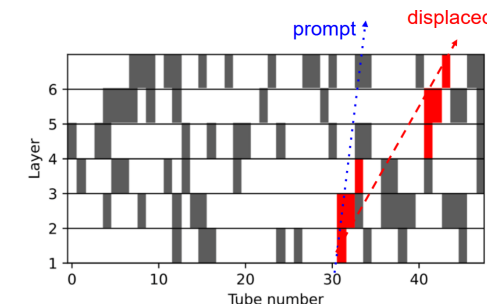




Let's explore *some* of the ongoing developments



ATLAS Software Athena running on CPU

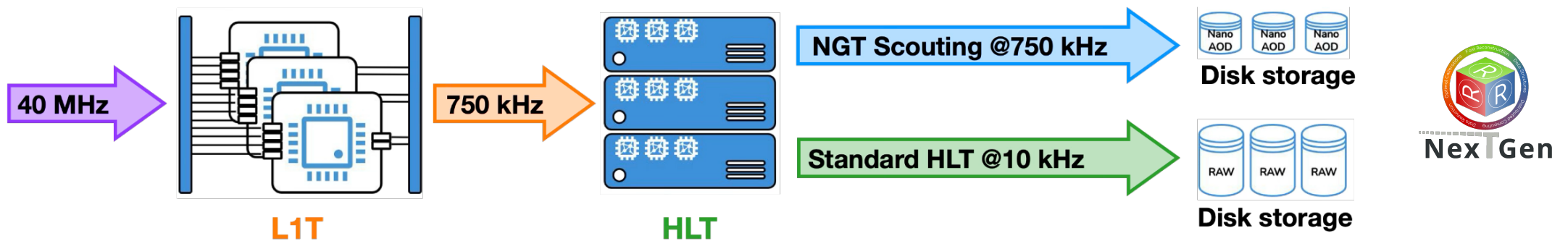


Many Talks/Poster this week or last week at FastML conference



CMS NGT @ HLT: Real-time Reconstruction Revolution (R³)

- **Goal: reconstruct all events selected by the L1 eventually with “offline-like” quality, assuming single chance to reconstruct data, and saving physics-oriented data-format**
 - **Need to overcome the main limitations of HLT**
 - quality of the online reconstruction → limited by the processing capacity (timing/throughput)
 - HLT output rate → limited by the storage capacity and processing power of the offline computing infrastructure



- **First milestone: assessment of speed-up factors (considering a fixed budget for the HL-LHC HLT farm)**
 - Assume ~50% code runs on GPU by Run-4 and 80% on GPU by Run-5
 - Assume flat +20% improvements in performance per year from hardware and cost (CPUs & GPUs)
 - Compare current Phase-2 online Reco with Phase-2 offline Reco
 - **need a factor x2 speedup on current online reco by Run 4**
 - **need a factor x2-8 more (from simply removing filters, or wanting offline-like quality) for NGT goal**

CMS NGT @ HLT: R³ developments

- **How? More efficient GPU-friendly cut-based/ML reconstruction algorithms**

- Following the paradigm and building on top of mature projects:

- LST with DNN for fake-tracks rejections and for duplicate removals
- DNN clustering in TICL for electrons and photons



[Talk by Mario Masciovecchio](#)

- **Extend to pixel tracks, particle flow, muons, tau leptons, jets/MET... Exciting results from NGT expected soon!**

- **How? Use optimised data structure**

- Algorithms designed in tandem with the corresponding data structures: extends the **SoA (Structure of Array)** approach vs standard object-based programming (AoS, Array of Structures)

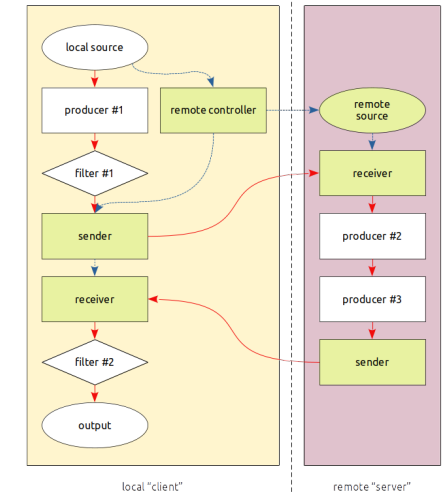
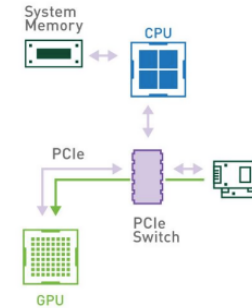
- **data structures in heterogeneous environments might become the bottleneck when high cost of sequential copies and conversions**



[Talk by Jolly Chen from WP1](#)

- **How? Facilitate heterogeneous computing**

- Design and implement the CMS Software (CMSSW) as a **distributed application** in order to exploit **remote accelerators**
 - prototype based on the Message Passing Interface (MPI): 10% of HLT runs on remote GPUs
- Expand fast inference on GPU, **minimizing the need to transfer data** between CPU and GPU for improved efficiency
 - ex. running inference directly on the GPU without moving data back to the CPU



[Poster by Christine Zeh from WP1](#)

ATLAS NGT @ HLT: Tracking with ML & accelerators

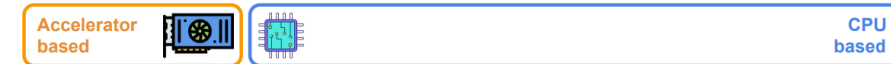
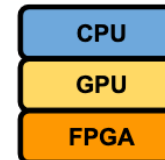
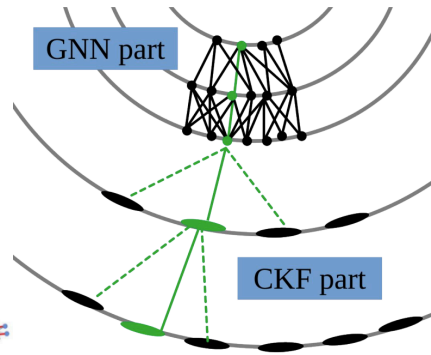
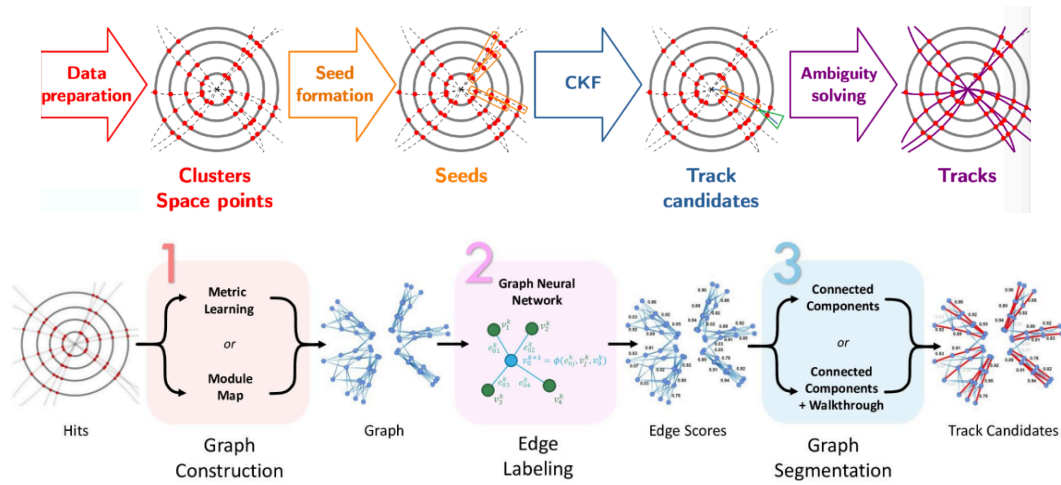
- Big effort towards decisions on best technology solutions for boosting HLT Tracking towards offline-like performance

- **TDR baseline based on CPU fast tracking**

- combines regional tracking on the majority of the events, with full-scan tracking at a reduced rate

- **With NGT contributing to investigate and compare several different pipelines**

- a classical graph-based track finder for seeding (GBTS)
 - throughput porting full or partial chain on GPUs or FPGAs
 - GNN based track reconstruction when deployed on accelerators



Sliding window which can be optimized for FPGA solution

Code and name of pipeline	Clustering	Seeding	Track Finding	Ambiguity & fake resolution	Track fitting
C-100 ACTS-based Fast Tracking					
C-230 C-100 w/ Graph-Based Track Seeding		GBTS			CKF
G-200 End-to-end GPU Tracc					
G-400 G-200 with GBTS		GBTS			CKF
G-300 G-200 with GNN patt rec			GNN		
G-100 Tracc clustering & seeding rest C-100					CKF
F-100 FPGA clustering rest C-100					
F-610 End-to-end FPGA + CPU KF					KF
F-410 F-610 except with GNN patt rec			GNN		

ATLAS NGT @ HLT: Tracking with ML & accelerators

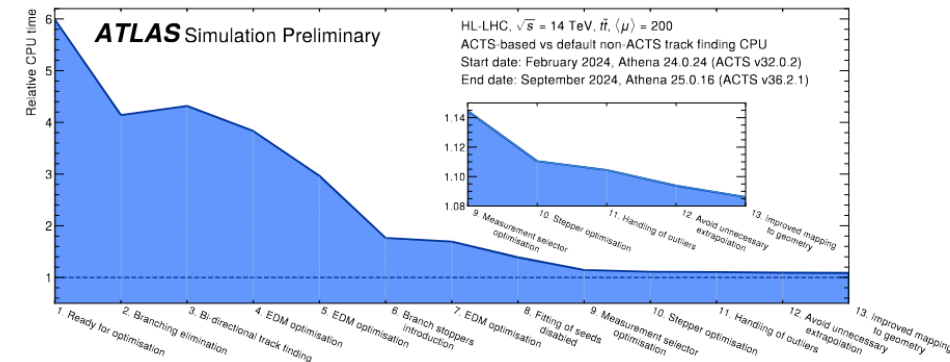
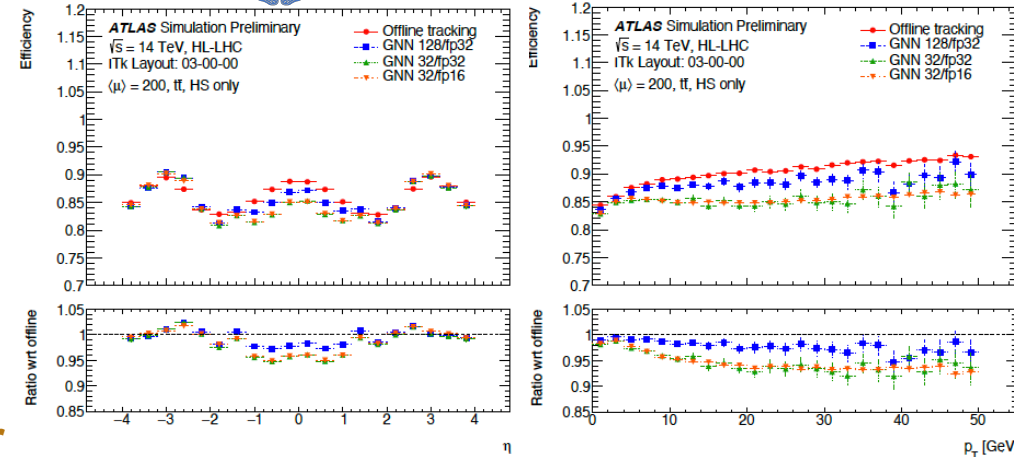
- First performance of the GNN based pipeline on GPU are compared with offline tracking
 - details on resources usage in [ATL-COM-DAQ-2025-071](#)
- Important support from a dedicated team devoted to develop common core algorithm and infrastructure
 - Integration of **ACTS** (A Common Tracking Software), an experiment-independent track reconstruction toolkit in the ATLAS software for HL-LHC operations
 - CPU fast tracking chain fully integrated and [on-going work on improving physics/CPU performance](#)
- Provide infrastructure support for various prototypes within ACTS
 - including geometry, material, magnetic field and event data model support/integration
- Improve and optimise integration of CPU/GPU/FPGA-based demonstrators
 - optimize data structure (in collaboration with WP1)
- Help with interfacing ML pipelines in ACTS



[Talk by Andreas Stefl](#)



[Poster by Benjamin Huth](#)

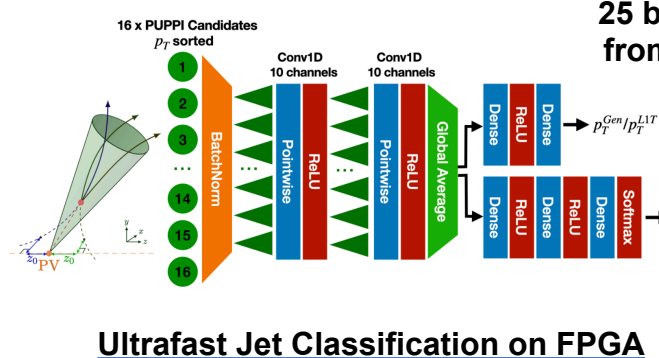
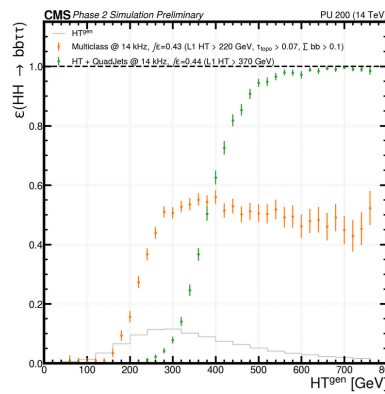
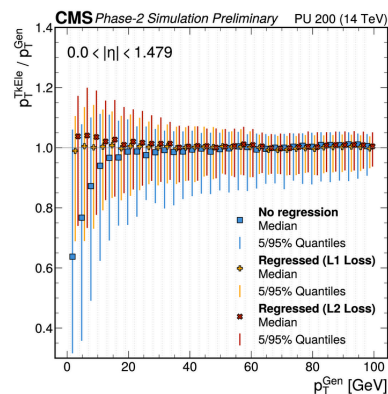
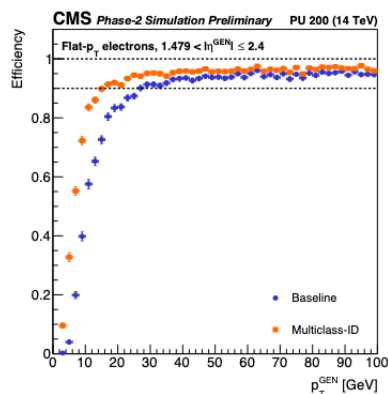
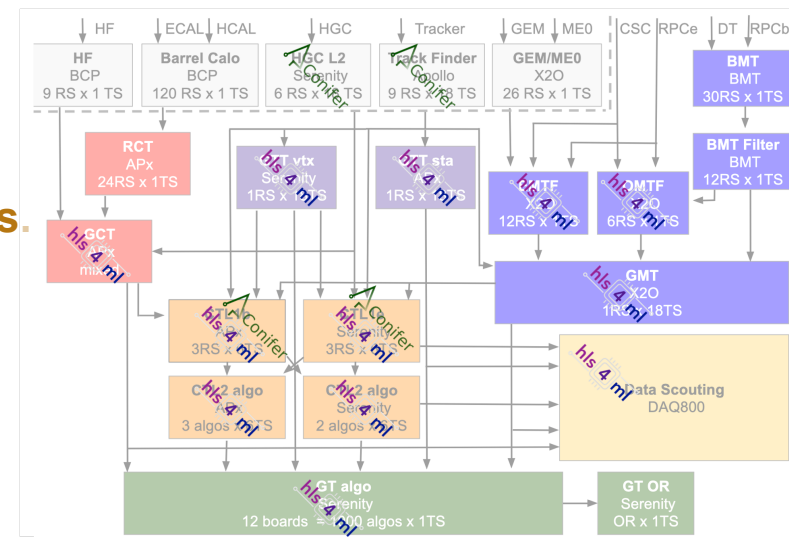


CMS NGT @ L1: Boosting performance with ML

- **Boost usage of advance ML algorithms for improving the L1T reco**
 - **From clustering ID, to Particle-Flow and Pile-up mitigation methods (vertexing, track-to-vertex association), to jet-tagging and event topologies.**

Already developed:

- Multiclass ID for HGCal Cluster: improves e/ γ identification at low pT (**BDT**)
- Electron pT regression to improve resolution (**BDT**)
- Multiclass jet tagging trained on a variety of target classes: b jets, c jets, $\tau_{h(+/-)}$, gluon jets, muon, electron, and light quark (uds) jets (**DeepSet**)



25 billion inference/second estimated from known projects in development

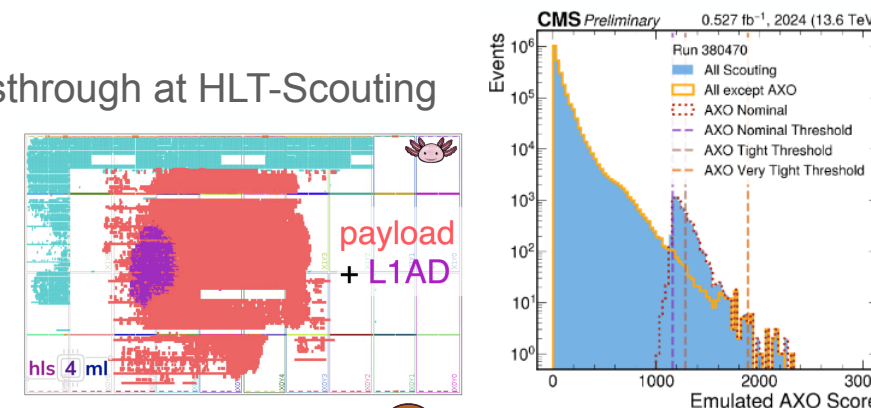
Poster by Piero Viscone

Talk by Chris Brown

- **Next: develop setup for complex trainings of multiple algorithms** (e.g implemented in different subsystems, only limited amount of information is propagated between subsystems)

CMS NGT @ L1: New paradigm with Anomaly Detection

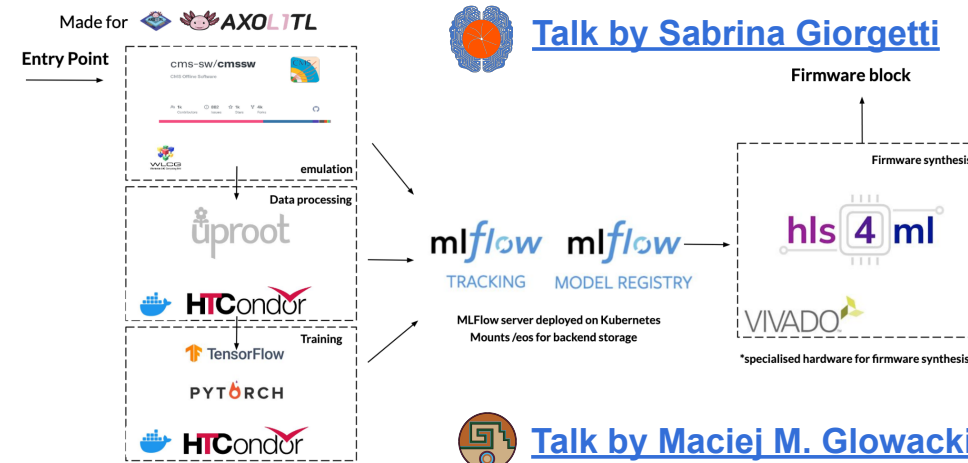
- Another way: trigger on “anomalous” events using ML unsupervised models
 - In spring 2024 CMS established a new trigger paradigm with the first sub- μ s variational autoencoder for anomaly detection: AXOL1TL deployed in L1 Global Trigger
 - $\sim 100 \text{ fb}^{-1}$ collected by AXOL1TL, L1T pure rate of $\sim 300\text{Hz}-1100 \text{ Hz}$, passthrough at HLT-Scouting
 - Many AXOL1TL events are unique vs existing triggers
- NGT aims at pushing this novel technology to its frontier
 - Designed more robust model based on contrastive learning
 - new model introduces contrastive block upstream of AXOL1TL to produce robust representations of events
 - MLOps: Developed first infrastructure to automate steps of the model training and deployment pipeline
 - for current AD, but also for all Phase-2 models (in collaboration with WP1 and ATLAS)
 - Phase 2 Preparation: Developing an upgraded model tailored to the Phase 2 trigger system
 - designing novel point-cloud based AD algo that takes as input all reconstructed particles from L1 PF ([arxiv.2311.17162](https://arxiv.org/abs/2311.17162))



[Poster by Maciej M. Glowacki](#)



[Talk by Sabrina Giorgetti](#)



[Talk by Maciej M. Glowacki](#)

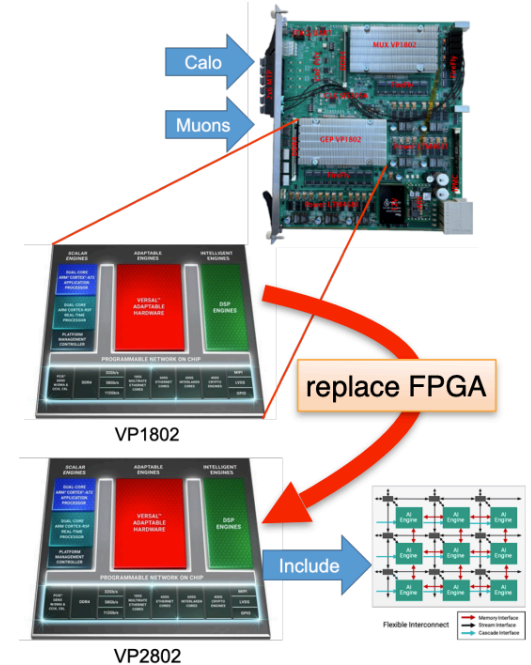
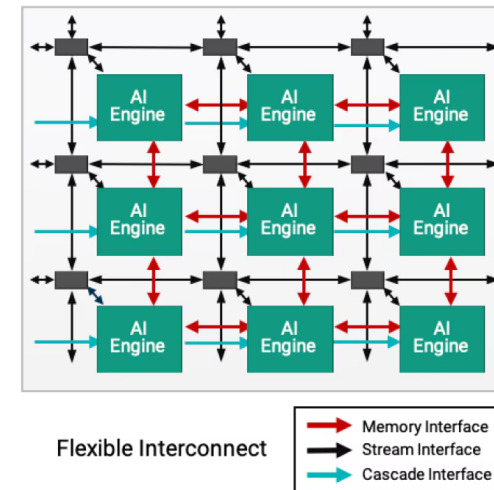
ATLAS NGT @ L1: Optimal selection in the Global Trigger

- Exploring new industry technologies:

- AMD released a pin-compatible FPGA with current target which includes the AI-Engines (VP2802)
 - Heterogeneous architecture: traditional FPGA fabric + an array of AI Engine tiles.
 - Each tile: a vector processor, a scalar processor, and a local memory bank, enabling efficient parallel execution of ML workloads.

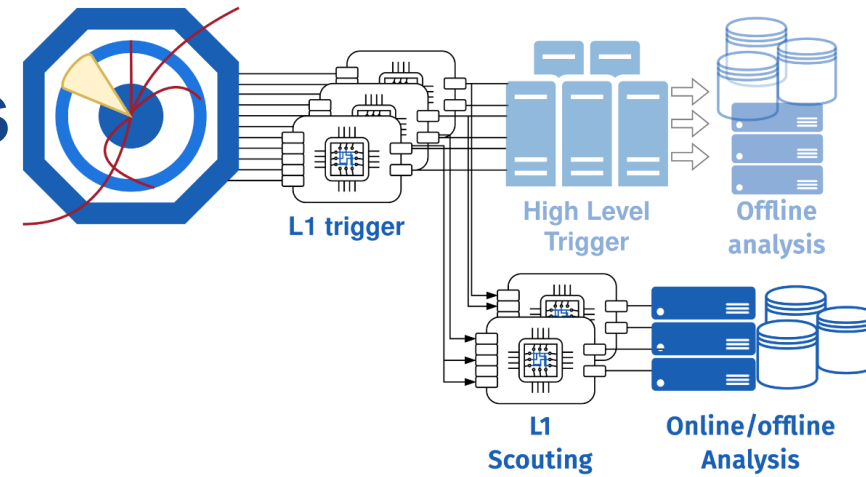
- Evaluation of this new technology on going :

- Characterise the performance of those devices
- Provide some generic implementation for specific ML models
 - interplay with WP1 for AI-engines support of hls4ml!
- Explore the feasibility of deploying them in the harsh environment of a mission critical system



 [Talk by Ioannis Xiotidis](#)

CMS NGT @ L1: Triggerless analysis

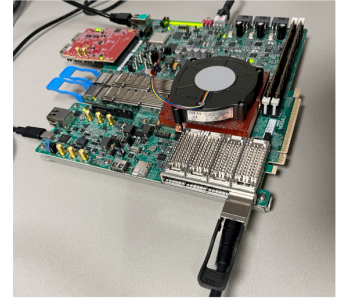


- **L1T Data Scouting: acquire and analyse the L1 Trigger information for all events (at 40 MHz)**
 - **Look for physics signatures identifiable with just L1 information but that would evade the L1T → HLT → Offline chain, e.g.:**
 - Too large “irreducible” backgrounds, e.g. narrow resonances of low and unknown mass
 - Signal identification requires an algorithm that can’t fit the L1 fixed latency and resource budget, e.g. has too complex combinatorics
 - Signal identifications requires time-correlation across several BXs, beyond what allowed by GT, e.g. slow or long-lived BSM
- **FPGA-equipped boards that receive L1 data via optical links and transfer it to PCs via standard high-speed networking (e.g. TCP/IP over 100GbE)**
 - Run-3 demonstrator up and running (coarse muons and calo information)
 - **At HL-LHC: can profit from much improved L1T object reconstruction quality**
 - L1 Tracker Tracks, Particle-flow linking, Pile-up per particle identification (PUPPI)
- **With NGT: investigate different analyses of increasing complexity in terms of data processing and bandwidth**
 - **From di-lepton resonances to soft hadronic final states with NN taggers, multi-BX signatures, to ML algorithms for soft objects (e/γ/jet) reconstruction & tagging**

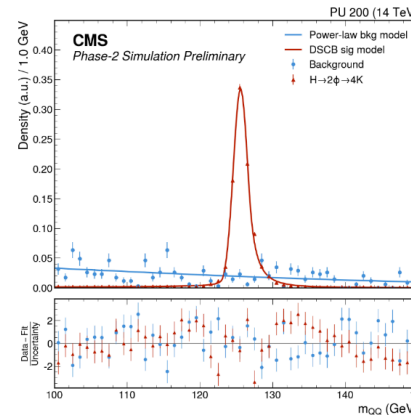
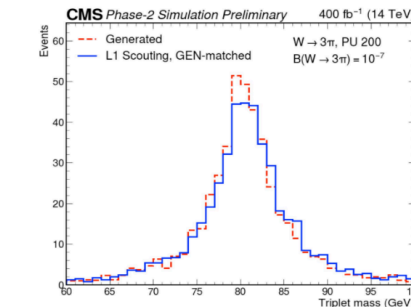
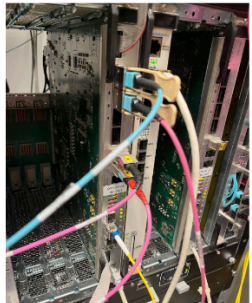
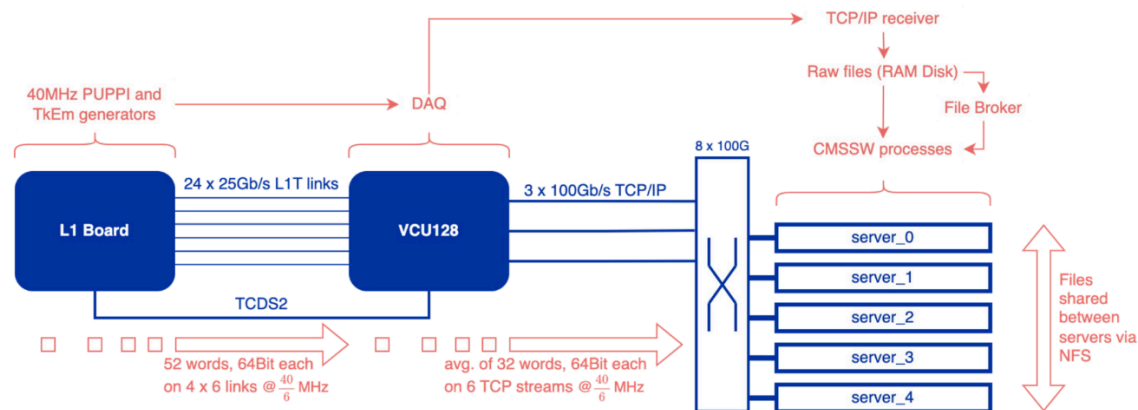
CMS NGT @ L1: Triggerless analysis

- **How: Incrementally build a test system of increasing bandwidth & processing power to run benchmarks**

- Investigate running algorithms on CPU / GPU / FPGA / AI engines
- investigate different approaches for data acquisition from DAQ board: protocols (e.g. TCP/IP vs RoCE vs direct fpga-fpga links), networking (400GbE links, NIC vs accelerators cards), workflows
- prototype a Scouting DAQ board with newer technology (e.g. large Versal devices) to have more links on the same FPGA and more on-board resources



Versal devkits available: VHK158, VPK180



- **First Demonstrator built in 2024**

- Successfully demonstrated receiving and processing 6 stream of L1 PUPPI and e/y candidates (**~40MHz**), **data rate of ~18 GB/s**
- unpackers and **10 analyses for rare Higgs/W decays, $X \rightarrow ee$: ~1.3μs per BX**



Talk by Efe Yiğitbaşı

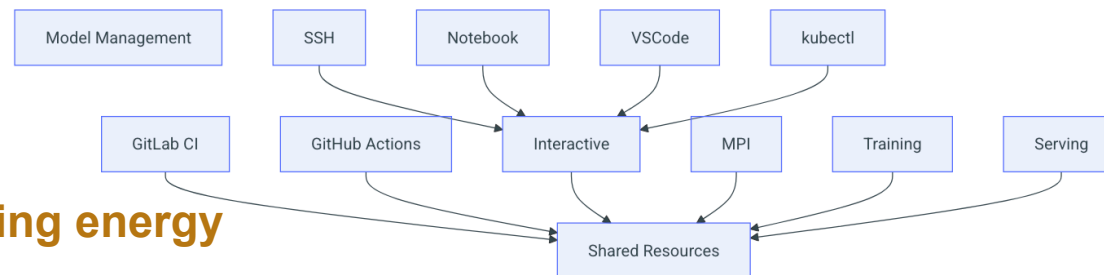
The NGT farm

- **Goal: advanced computing infrastructure and platform to support the common tasks in WP1** (hardware-aware NN training workflows and next-generation physics simulations) **and the specific activities in WP2 and WP3** (MLOps pipelines, compiling firmware...)

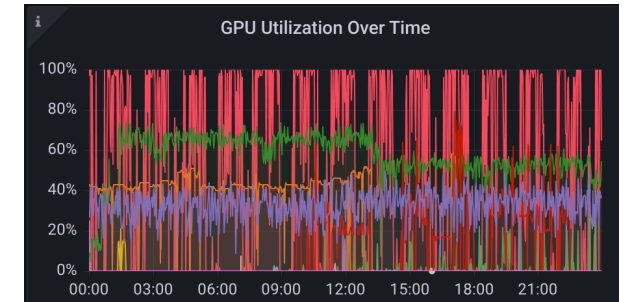
- Almost all resources procured and installed in the new CERN Data Center.

Various setup for different R&D:

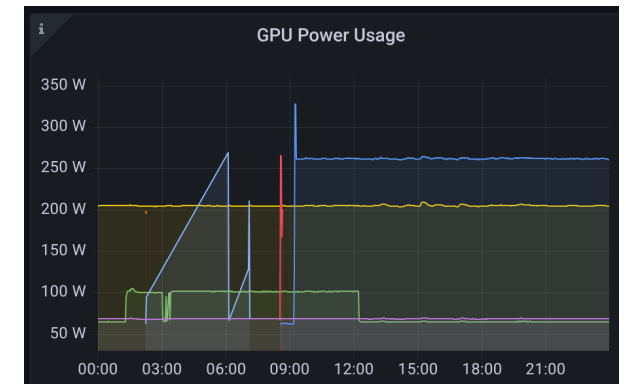
- 33 nodes with hundreds of GPUs (H100s, AMD MI300X, etc.); connected by 200Gbit RoCEv2 or Infiniband
- 6 CPU specialized nodes (memory-heavy, high-core count, fast single core)
- **Service platform based on kubernetes:** GitLab / GitHub CI, ML Training, ML Serving, Model management (MLFlow)



- **Monitoring set up, including energy**
- **Hardware validated with dedicated benchmarks**



NGT Farm GPU Utilization Example (24h)



The NGT tools: FastML for hardware triggers

- **Goal: facilitate extensive ML use in hardware-level triggers (FPGAs)**

- work with existing community of experts that developed **hls4ml** to allow **model synthesis into FPGAs** and with WP2 and WP3 to understand specific needs

- **hls4ml: translation of trained ML models to optimized HLS code**

- currently supporting common ML architectures - MLP, CNN, RNN
- already widely explored at CERN

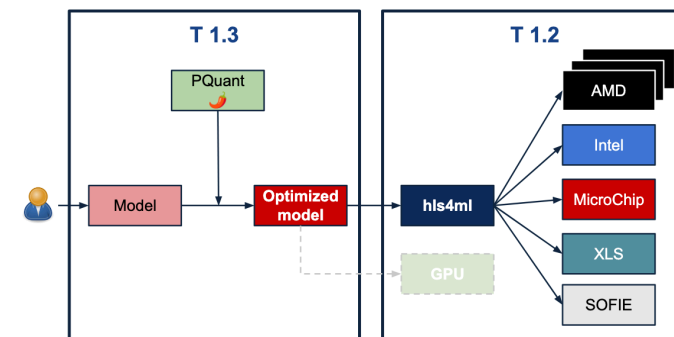
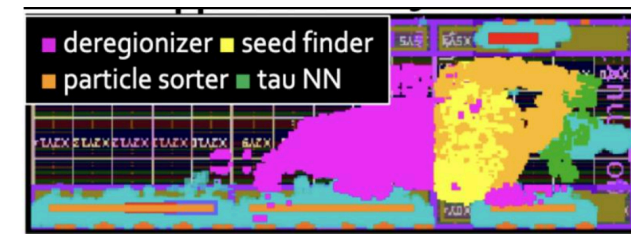
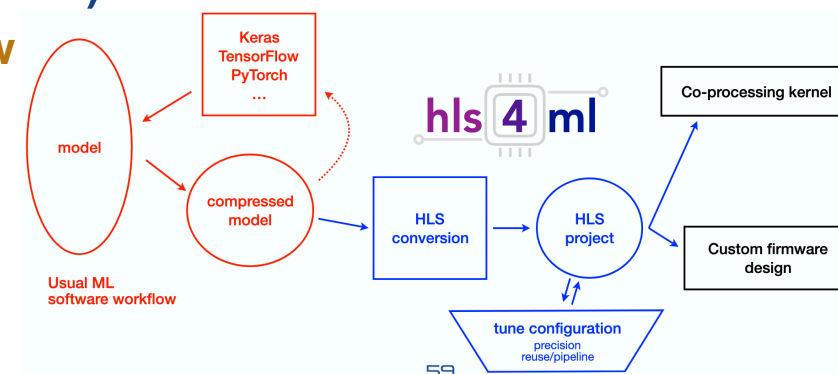
- **First NGT focus (1.2): maintain & improve hls4ml for WP2/3 needs**

- support new model architectures (GNNs, Transformers, SSM...)
- Enhancements to internals to support more deployment options (beyond Xilinx FPGAs to Versal AI engines, Microchip FPGAs, etc.)

- **Second NGT focus (1.3): enable hardware-aware neural network training workflows**

- building a library of model compression techniques to make the NNs cheaper in the FPGAs (pruning, quantisation...) with a unified interface

<https://fastmachinelearning.org/hls4ml/>



Talk by Roope Niemi



Talk by Dimitrios Danopoulos



Talk by Dimitrios Danopoulos



ACAT25: Next Generation Triggers for the ATLAS and CMS Experiments

NGT for Physics Theory

- NGT R&D extremely important for another key ingredient of the HL-LHC success: speed up MC generators and higher-order perturbative calculations
 - Porting and optimization of **event-generation codes and perturbative calculations to GPUs**
 - Development of **AI strategies for phase-space sampling** and matrix element estimation
 - **AI-driven modelling of non-perturbative aspects** of proton collisions (underlying event, hadronization)
 - Development of SW and algos to best exploit next-gen architectures in **LQFT simulations on extreme-scaling low-latency/high-bandwidth accelerator-based clusters**
- New Physics models benchmarking for new triggers developments
 - Identify **Beyond the SM scenarios and signatures to be used as benchmarks for the assessment of the new triggers strategies** in collaboration with the experiments

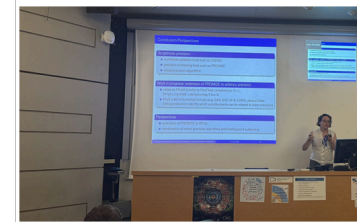


12 December 2024

Lattice QCD on Exascale Computing: The NGT Algorithm Workshop Recap

This week, from December 9th to 11th, 2024, CERN played host to the NGT Algorithm Workshop – Lattice QCD at the large scale on exascale computing facilities, a dynamic three-day event bringing together leading experts in physics and computing...

[Explore](#)

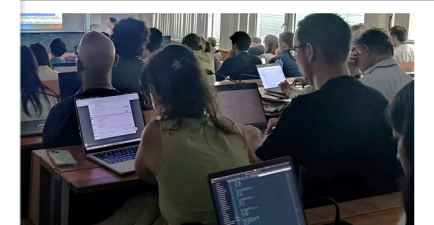


15 July 2025

Precision Matters: Unlocking the Future of Floating Point at CERN

Precision Matters: Unlocking the Future of Floating Point at CERN On 1–2 July 2025, the “Optimising Floating Point Precision” Workshop, co-organized by Next Generation Triggers and CERN Openlab, took place at CERN, gathering experts to explore how...

[Explore](#)



14 July 2025

From Theory to Trigger: First NGT Workshop on BSM Benchmarks

From Theory to Trigger: First NGT Workshop on BSM Benchmarks On 4 July 2025, the first NGT workshop dedicated to BSM benchmarks for Next Generation Triggers took place at CERN's Theory Department, bringing over 100 participants both in person and...

[Explore](#)

Conclusions and Prospects

- NGT is opening up new frontiers on several fronts for HL-LHC
 - ultimate goal: **expanding the event selection acceptance of ATLAS and CMS to unveil potentially hidden new physics**
 - by product R&D on Heterogeneous computing, FastML tools, workflows for ML in Trigger systems, Event generators, Physics signatures benchmarking...
- One year and a half into the project
 - **strong teams in place, steady technical progress, and on track!**
- Stay tuned, we are organizing the second Technical Workshop with many new updates!



NexTGen
Next Generation Triggers

Next Generation Triggers

2nd Technical Workshop

November 19-21, 2025

80/1-001 - CERN Globe of Science and Innovation - 1st Floor

REGISTER NOW!

contact nextgen-info@cern.ch



NextGen
Next Generation Triggers

CMS NGT @ HLT: R³ developments

• How? Compression of raw data size

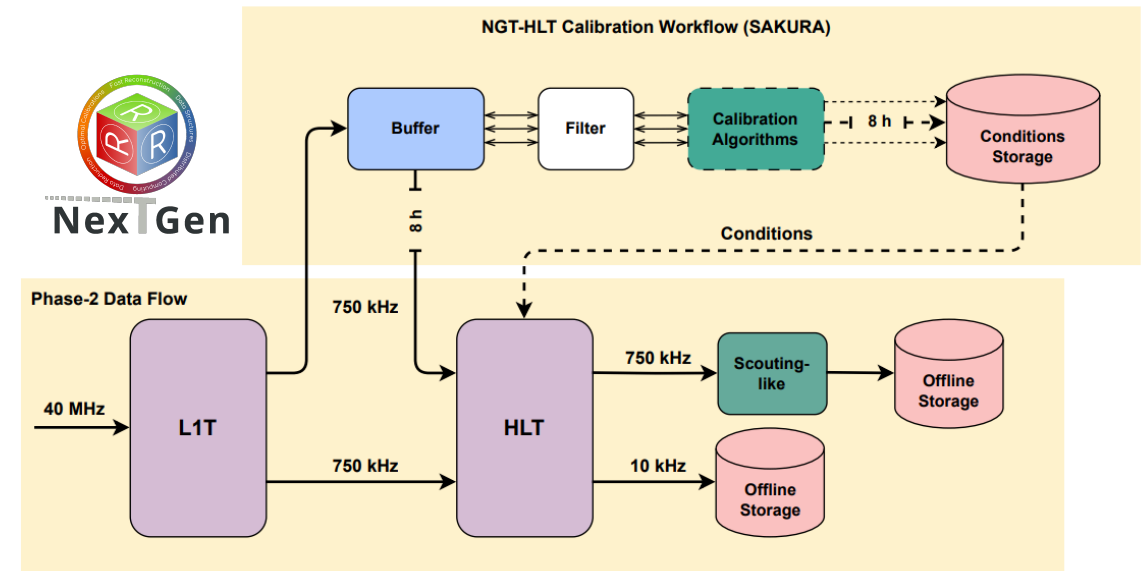
- Phase-2 event size of CMS is expected to be around 10 MB/event: **not possible to store all events accepted from the L1T in RAW data format (7.5 TB/s)**
- Goal: increase the maximum available bandwidth by reducing the size of events saved by CMS
 - **Lossy compression:** replacing raw data with reconstructed hit positions and energies (RAW'), possible to re-reconstruct high-level objects with newer algorithm or calibrations
 - **Lossless compression:** testing and benchmarking current and new compression algorithms (eg. LZMA, ZLIB, ZSTD, LZ4)



[Poster by Simone Rossi Tisbeni](#)

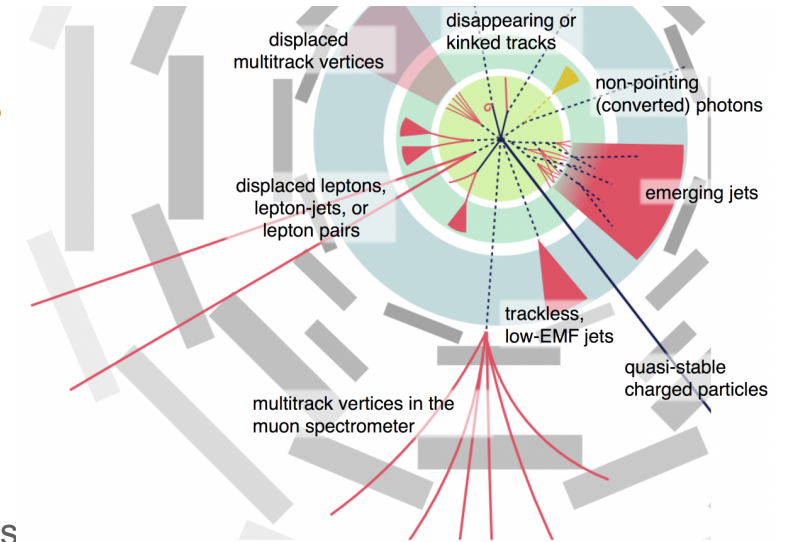
• How? Optimal Calibrations

- Design **accelerated calibration workflows** at HLT to achieve the same accuracy as the prompt calibrations for offline reconstruction
 - **Inspired by existing LS-based beamspot workflow at HLT and LHCb real-time alignment and calibrations**
 - buffer *all* input data, over several (8 - 12) hours: expected buffer size ~200-300 PB
 - Run-3 demonstrator ready by end of 2025

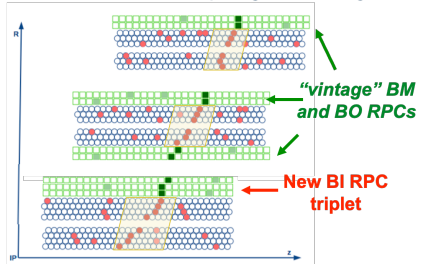


ATLAS NGT @ L1: Enhancing the Muon Trigger

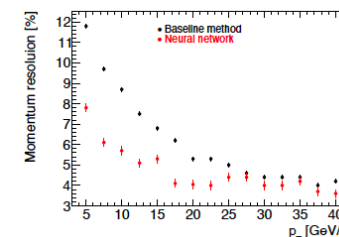
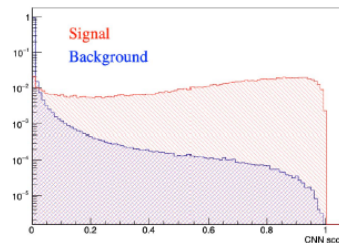
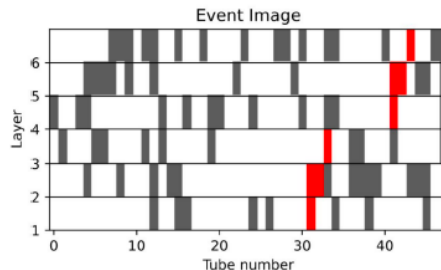
- Important upgrades for HL-LHC of the L1 Muon Trigger
 - Precision measurements from monitored drift tube (MDT) chambers
 - Improved efficiency with additional layer of RPCs in barrel
 - New electronics including modern FPGAs for trigger and readout
- Opportunities to design novel ML-based algorithms for pattern recognition and momentum estimation
 - Explore algorithms more suitable for sparse data such as CNN/RNN
 - Improve robustness and acceptance
 - Baseline algorithms relies on fast trigger detectors: want to improve robustness in case of reduced RPC performance



Hit Extraction
RPCs provide seeds to identify MDT hits from a muon & set up segment fitting



Pattern recognition algorithms to identify the regions of interest with only MDT hits



- ML-based algorithms can be more easily extended to non standard-topologies
 - Work on going targeting displaced-muons
 - for decays before the Muon Spectrometer very non-pointing tracks
 - for decays in the Muon Spectrometer: diverging patterns of hits
 - Want to extend also to: quasi-stable charged particles, signatures with high muon hits