A3D3 HEP activities

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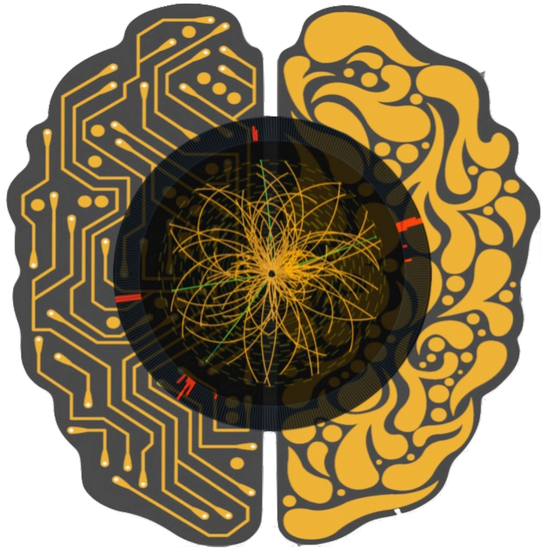
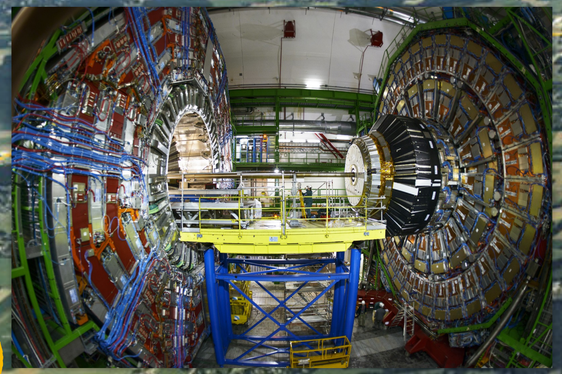
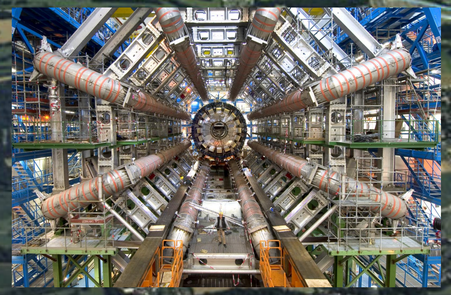


Accelerated AI Algorithms for Data-Driven Discovery

THE LARGE HADRON COLLIDER





LHCb

ATLAS

CERN Meyrin

CERN Prévessin

SPS 7 km

SUISSE

FRANCE

CMS

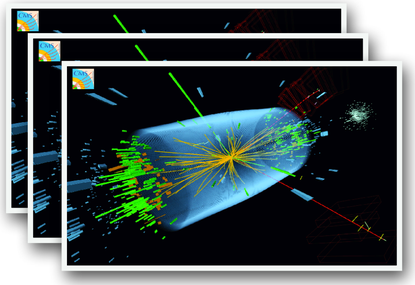
ALICE

Proton → 40MHZ ← Proton

LHC 27 km

7/8/13 TeV

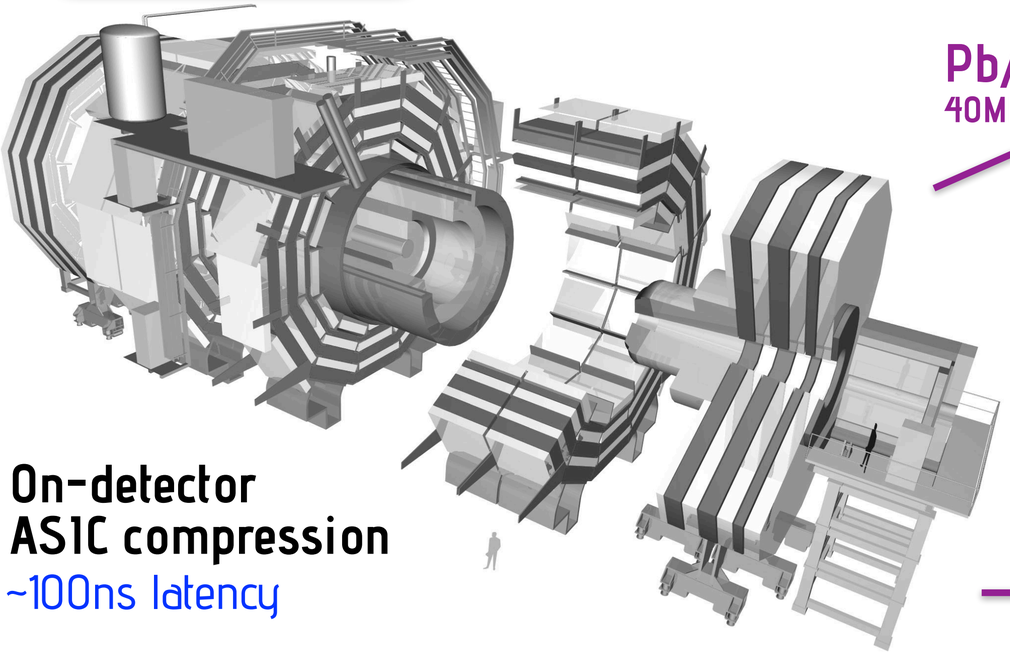
ATLAS and CMS at the LHC



CMS Experiment

40MHz collision rate

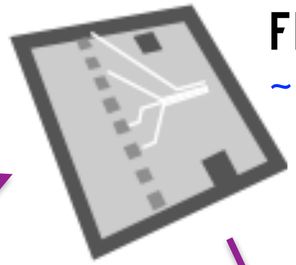
~1B detector channels



On-detector ASIC compression

~100ns latency

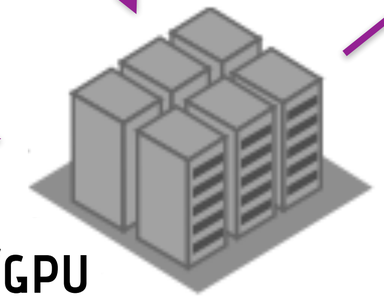
Pb/s
40MHz



FPGA filter stack

~µs latency

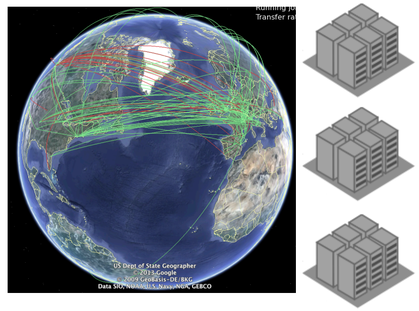
10s Tb/s
100s kHz



On-prem CPU/GPU filter farm

~100 ms latency

10s Gb/s
~5 kHz



Worldwide computing grid

Exabyte-scale datasets

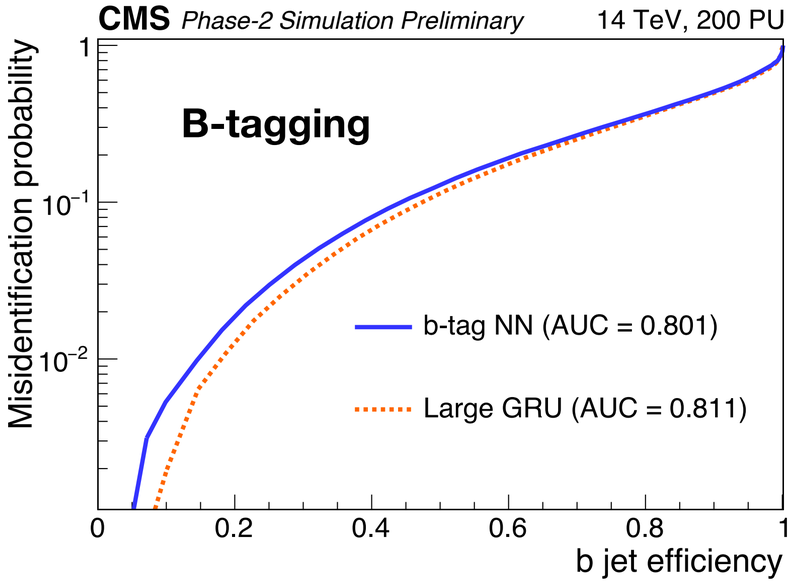
ML in 3 tiers of data processing

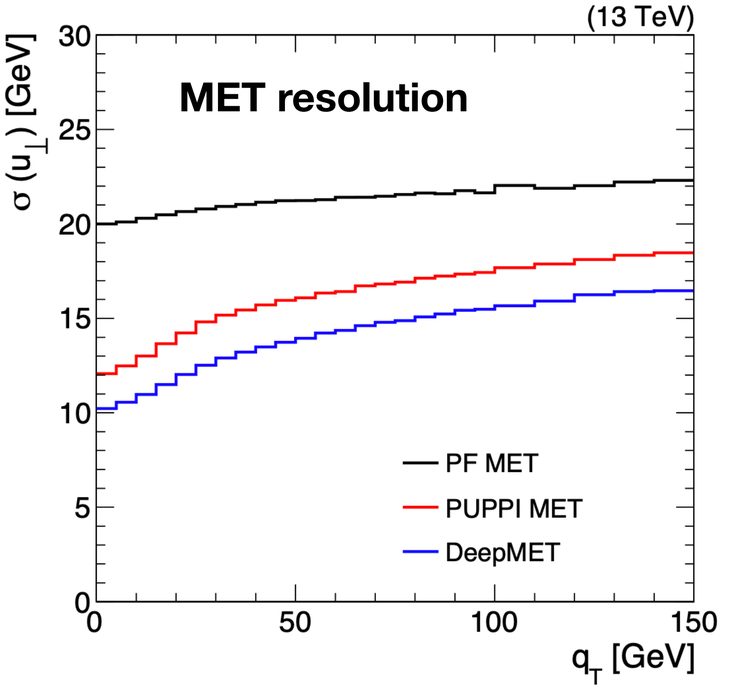
Overview of HEP activities

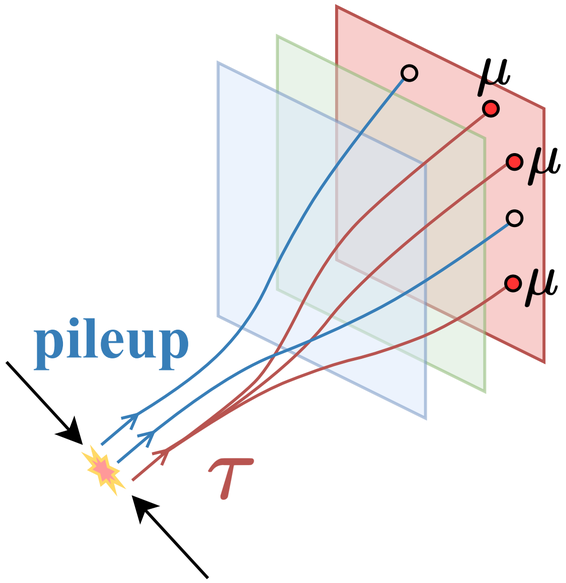
- We aim to deploy machine learning algorithms combined with heterogeneous computing within each of the three reconstruction tiers at the LHC, the L1 Trigger, the High Level Trigger, and offline reconstruction.
  - Triggering critical physics
  - Lower level reconstruction: tracking, calorimetry
  - Unconventional approaches: anomaly detection
  - Heterogeneous computing as-a-service deployment

- Develop and maintain software toolkits that enable the deployment of these algorithms into the existing software and hardware systems of the main experiments.
  - HLS4ML: deployment of ML on FPGAs for low latency,
  - SONIC : asynchronous use of ML on coprocessors respectively.

Triggering critical physics

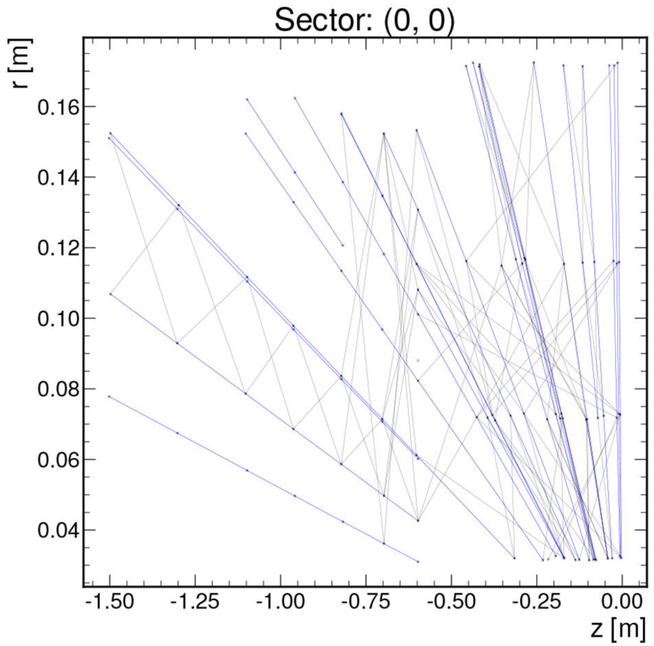




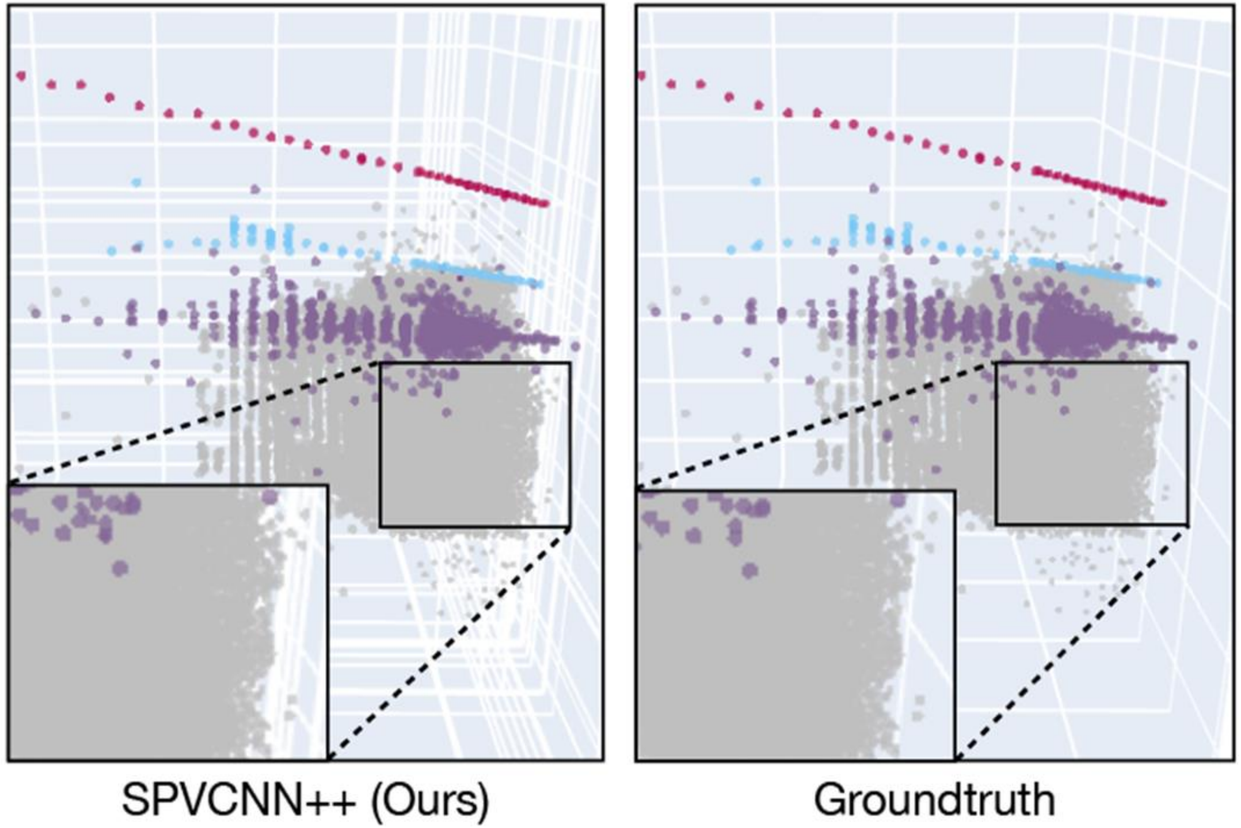


- Improve triggering capability of signatures crucial for CMS physics program in high luminosity operational conditions: higher rate, pileup, more granular detectors (talk1, talk2 at fast ml workshop)
  - B-tagging, Missing transverse energy, tau leptons
- Design and develop algorithms for signatures challenging for traditional methods
  - Long lived particles: LLP jet tagging in the CMS Level-1 trigger
  - Low momentum: e.g tau3mu GNN tagger, potential of orders of magnitude improvement in signal efficiency Pan's talk in fast ml.

Tracking and Calorimeter Clustering

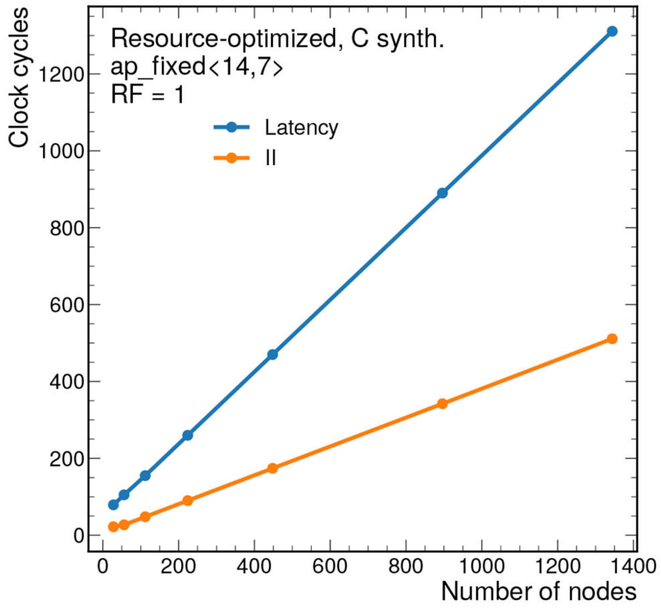


GNN tracking



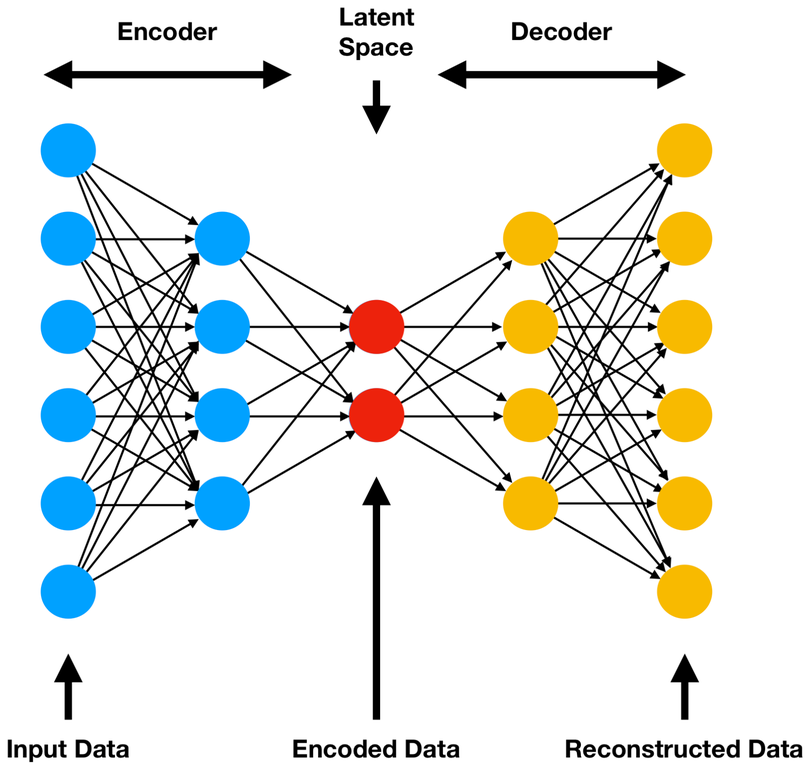
Left – predicted clusters from SPVCNN.
Right – event display from HGCAL.

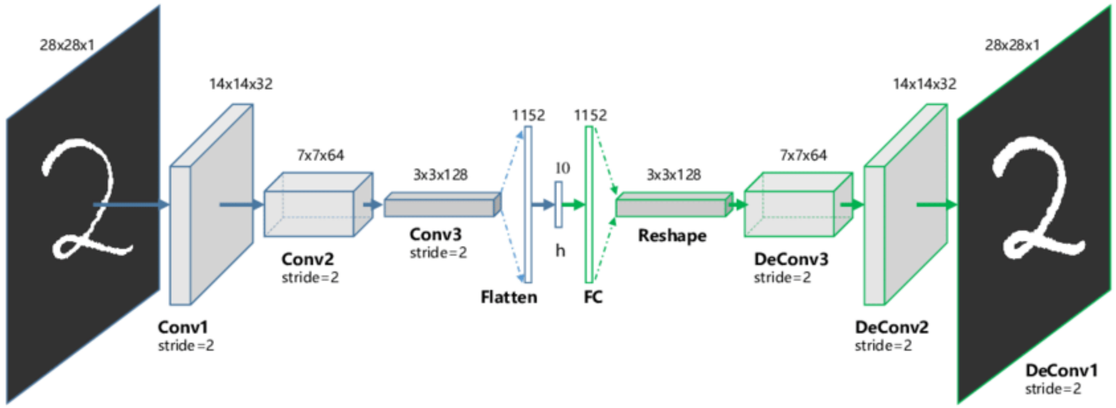
fast ml workshop Talk



Talk at Fast ML workshop

Anomaly detection

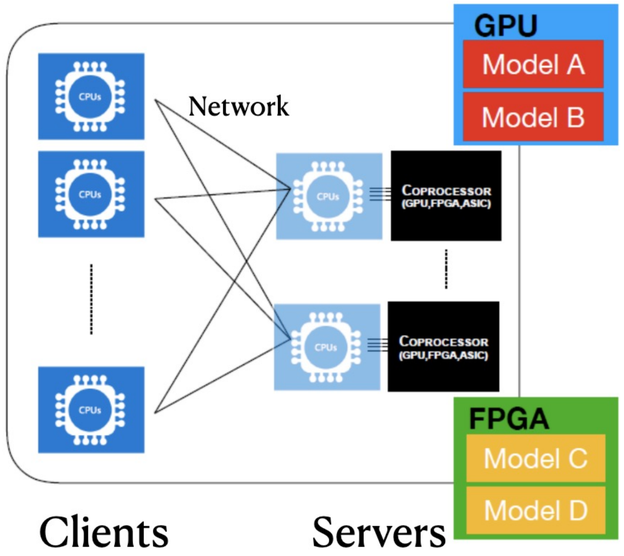


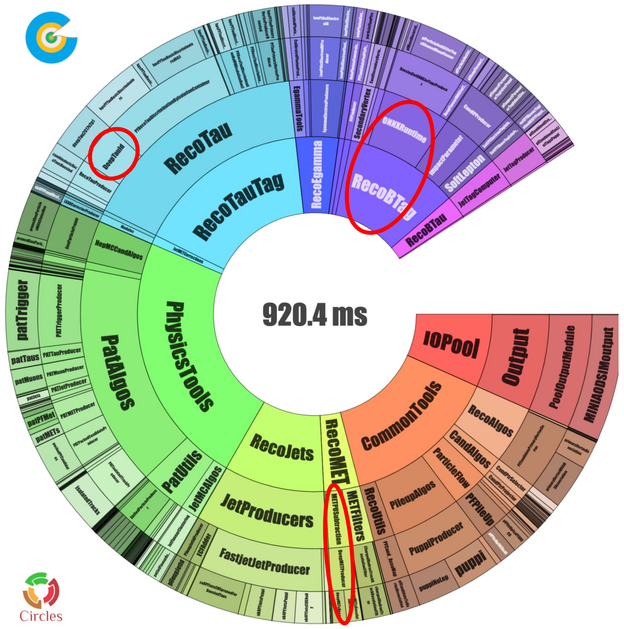


- Unbiased model agnostic approach with encoded latent space of auto-encoder. **E.g.**: physics objects (electrons, muons, jets, MET) momenta, train on Standard Model events (ttbar, QCD, W/Z+jets etc) (talk1, talk2 at fast ml workshop)

- Challenging though worthwhile: design to detect new physics signature, inclusive trigger for ultra-rare SM processes?

Heterogeneous computing as-a-service





- Heterogeneous computing as-a-service:
  - Resource usage/scalability/flexibility
- Significant progress towards integration of SONIC in CMS:
  - Developed and tested a miniAOD (one step in CMS data processing) workflow: offloading 3 ML algorithms with SONIC: scaling, throughput etc with GPU in cloud/ T2 (Purdue). (Talk at fast ml workshop)
  - Important step going beyond ‘proof of concept’ demonstration, develop HEP data specific support with industry partners.
- Adapt/enhance commercial service’s support for HEP: graphCore, ragged batching for irregular data patterns in NVIDIA triton. (Talk at fast ml workshop)

Next year

- Continue to make progress in existing efforts:
  - Hardware L1 trigger: HLS4ML support/implementation, board implementation, emulator
  - Demonstration of SONIC in CMS production, and in HPC, working closely with USCMS O&C operations program.
- Close collaboration with other areas in A3D3:
  - Develop and maintain HLS4ML support: general, scalable support of various GNN architectures.
  - Graph generation in GNN needs new mathematical formulation for edge device implementations.
- Brainstorm new ideas: tau3mu anomaly detection with GNNs—> inclusive trigger for low momentum signature.
- As the number of projects grow, will improve the HEP area organization with e.g. sub-areas.
  - Opportunity in integrating postdocs and students.