UNIVERSITÉ DE GENÈVE

ATLAS EXPERIMENT

Real Time Analysis in ATLAS Trigger with Machine Learning

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SMARTHEP
REAL-TIME ANALYSIS FOR SCIENCE AND INDUSTRY

MARIE CURIE ACTIONS

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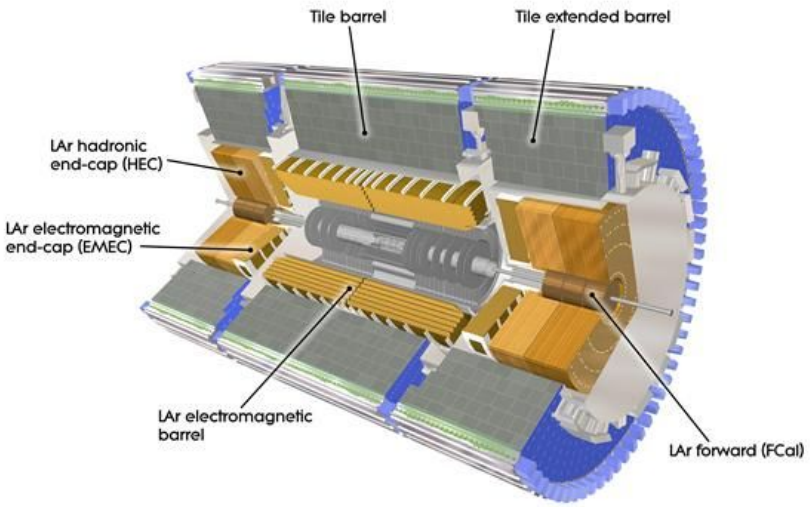
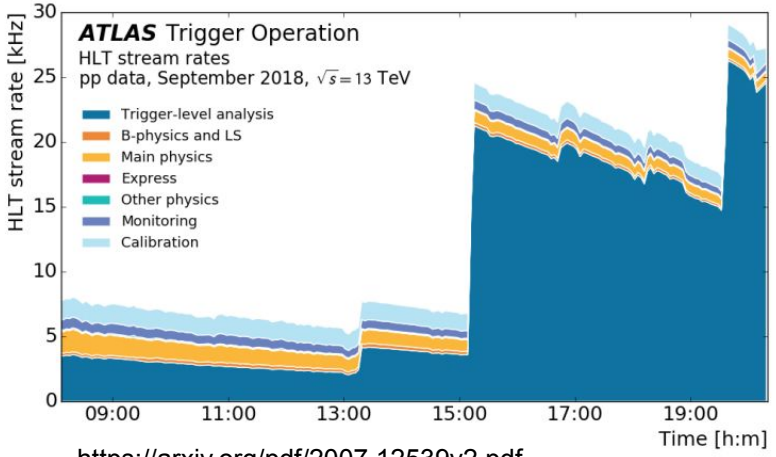
ATLAS Trigger

Raw Data → 40 MHz → **L1 Trigger** → 100 kHz → **HLT** → 1 kHz →

Hardware based (FPGA/ASIC).
Calorimeter and muon systems only.
Latency 2.5μs

Software based (ATHENA).
Seeded by L1.
40k CPU cores.
Full detector output.
Average execution time 300ms.





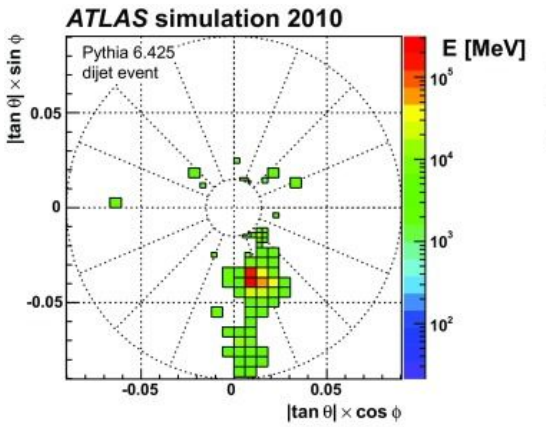
https://arxiv.org/pdf/2007.12539v2.pdf

What is TopoClustering?

Cluster Formation:

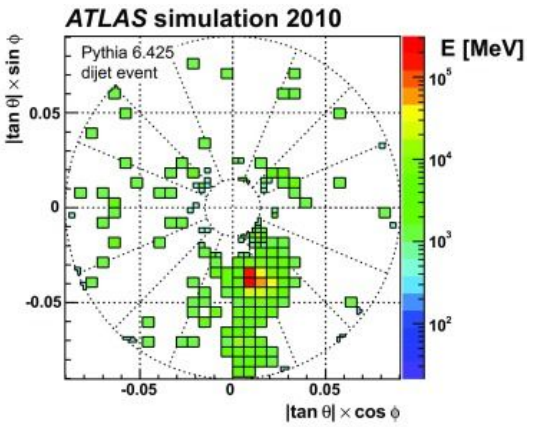
- Cluster Seeding
  - Cell signal significance > 4**σ**.
  - Initialise highly significant “seed” cells.
- Cluster Growth
  - Cell signal significance > 2**σ**.
  - Neighbours of seed cells extend cluster.
- Cluster Boundary Cells
  - Cell signal significance > 0.
  - Add all neighbouring cells to existing cluster.

> 4σ

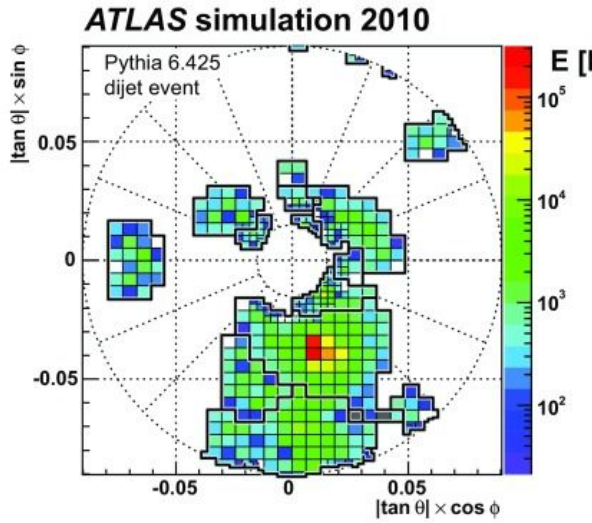


(a) Cells passing selection in Eq. (3)

> 2σ



(b) Cells passing selection in Eq. (4)



(c) All clustered cells

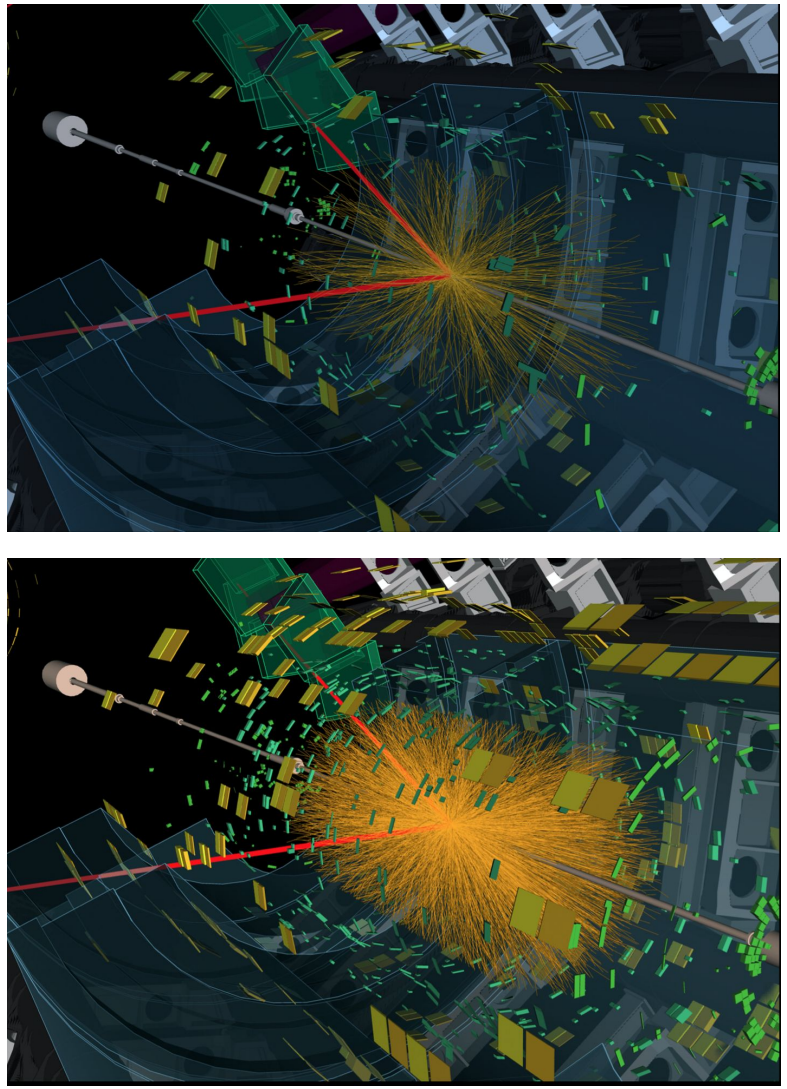
Final clusters

https://arxiv.org/abs/1603.02934

Problem Statement

- ➔ **Topoclustering** is one of the most **resource intensive** algorithms in use in HLT.
- ➔ Crucial role in **jet** and **MET** reconstruction.
- ➔ Far worse **pile-up** conditions in HL-LHC.
- ➔ We pursue **faster** solutions with (at least) similar performance**.**

Work already underway to migrate current Topocluster to GPUs, and starting up on FPGA at present.

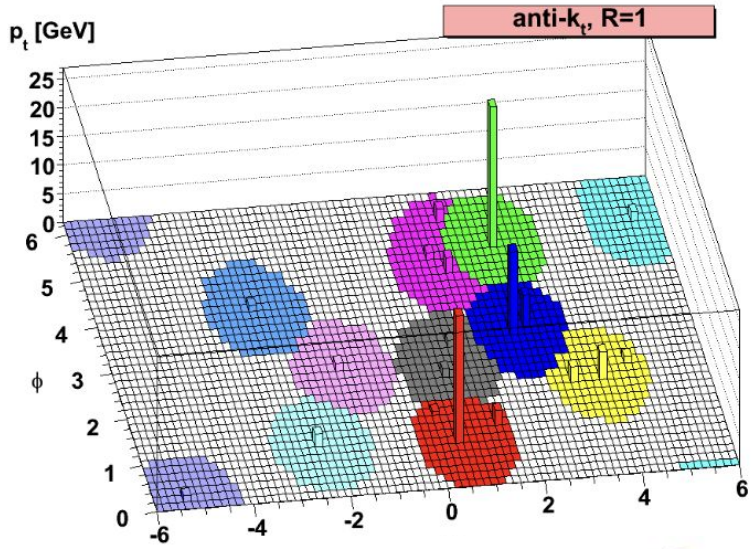


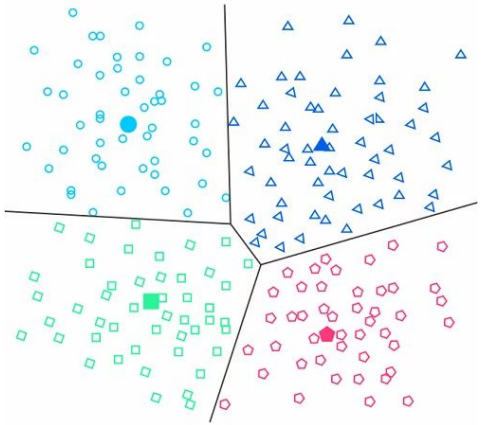
50 vs 200 p-p collisions per bunch crossing.

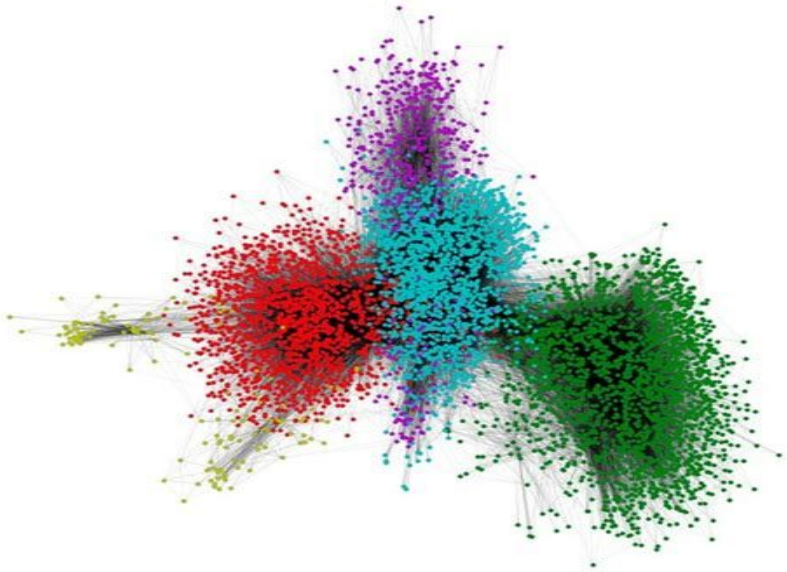
Proposal Solution

Any solution should address:

- Permit arbitrary **cluster topology**, shape and size.
- **Detector geometry -** barrel/end-cap, EM/HAD calorimeter.
- Adjacent calorimeter layers **granularity** and **irregularity**.
- Robust to **noise** and **cluster overlap**.
- **Variable number** of clusters to find.
- **Speed** of execution.



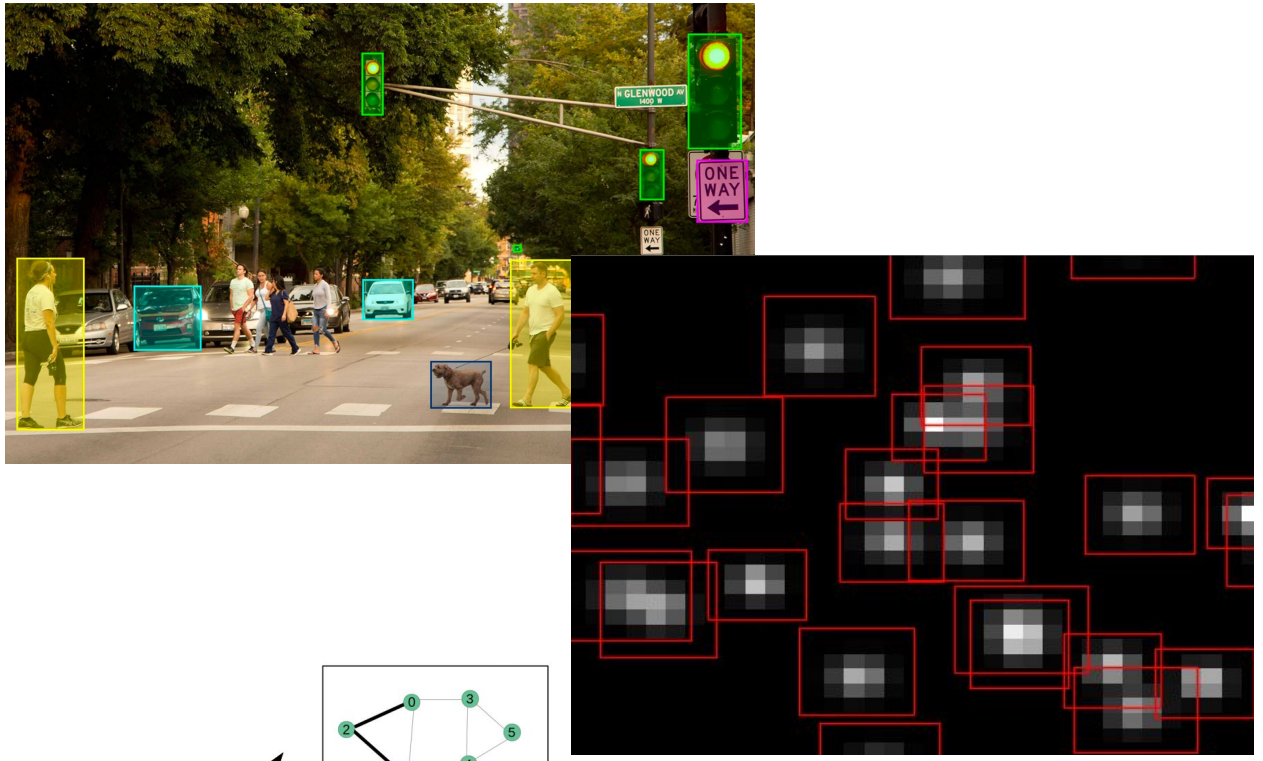


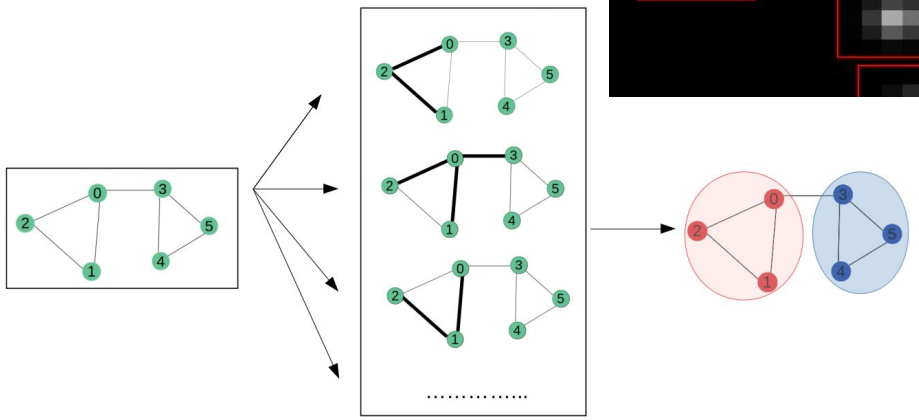


Proposal Solution

Two-step CNN + GNN

1. Transform detector response into **eta-phi projection** of calorimeter.
2. Use lightweight **Region Proposal Network** to identify Regions of Interest (ROIs).
3. Pass ROIs to **GNN** in original calorimeter coordinates.
4. **Classify nodes** in the graph as noise or members of a cluster.
5. (Incorporate splitter decisions, cluster classification and energy regression.)



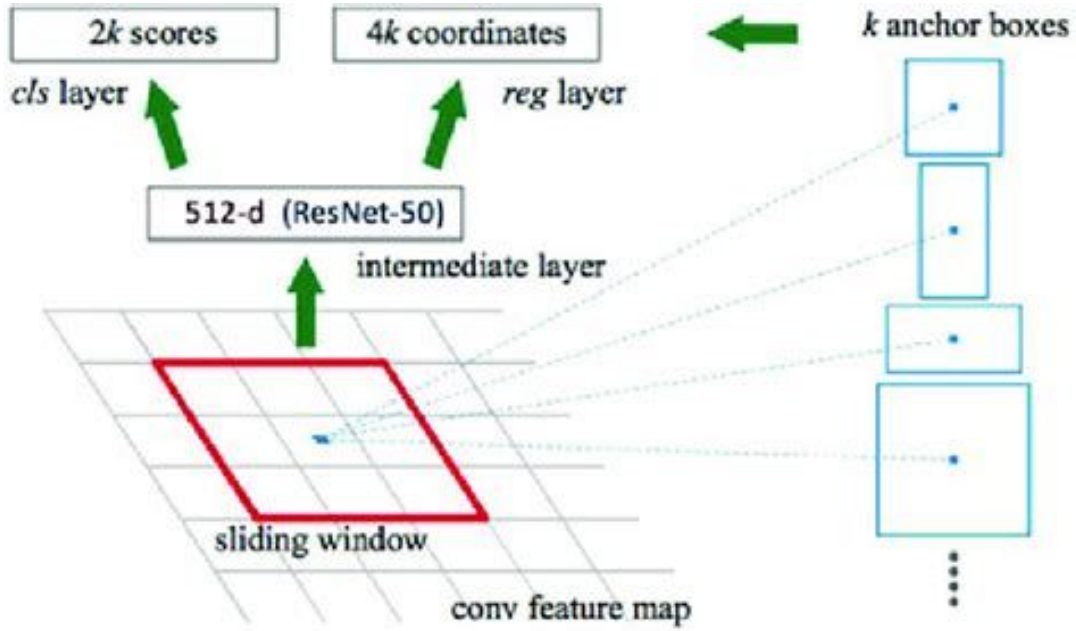


https://arxiv.org/abs/1603.02934

ML Proposal

Benefits of the approach

- Eta-phi projection simplifies problem of irregular detector geometry for CNN.
- Use of CNN to reduce search area from full calorimeter readout.
- GNN preserves detector geometry, preserving causal relationships between cells.
- Permit clusters of arbitrary shape and topology.
- Speed of GNN node classification within RoI.
- Potential cluster regression using graph level prediction.



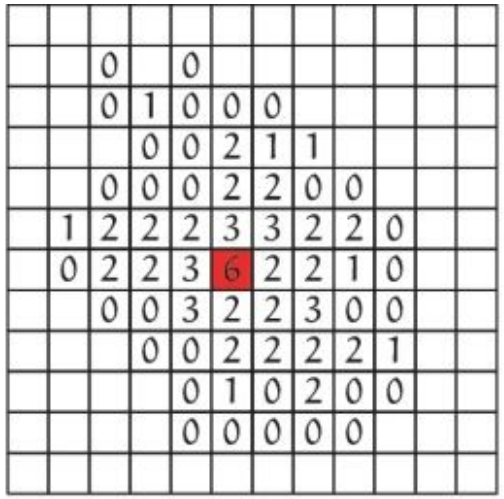
Thanks for listening

Backup

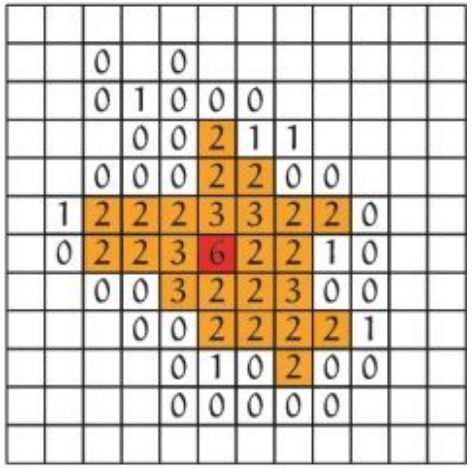
TopoCluster Algorithm

TopoCluster Algorithm:

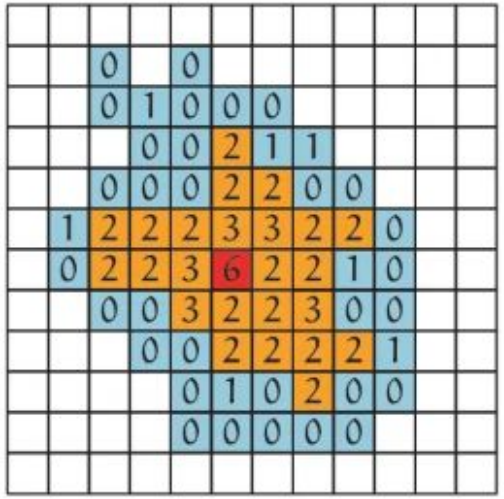
- Cluster formation is then later refined to jets and physics objects
- Base clusters from cell energy significance
  - Seed clusters
  - Grow protoclusters
  - Merge protoclusters
  - Splitting algorithm into clusters
- Calculation of cluster kinematics/moments
- Local hadronic cell weighting calibration



(a) Clustering of $|\epsilon^{\text{EM}}_{\text{cell}}| > 4$ cells.



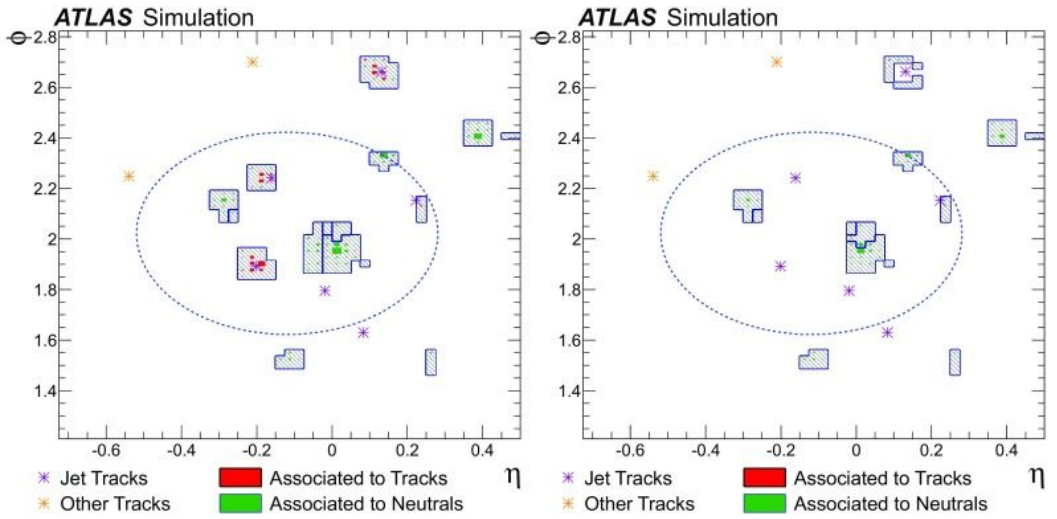
(b) Clustering of $|\epsilon^{\text{EM}}_{\text{cell}}| > 2$ cells.



(c) Clustering of $|\epsilon^{\text{EM}}_{\text{cell}}| > 0$ cells.

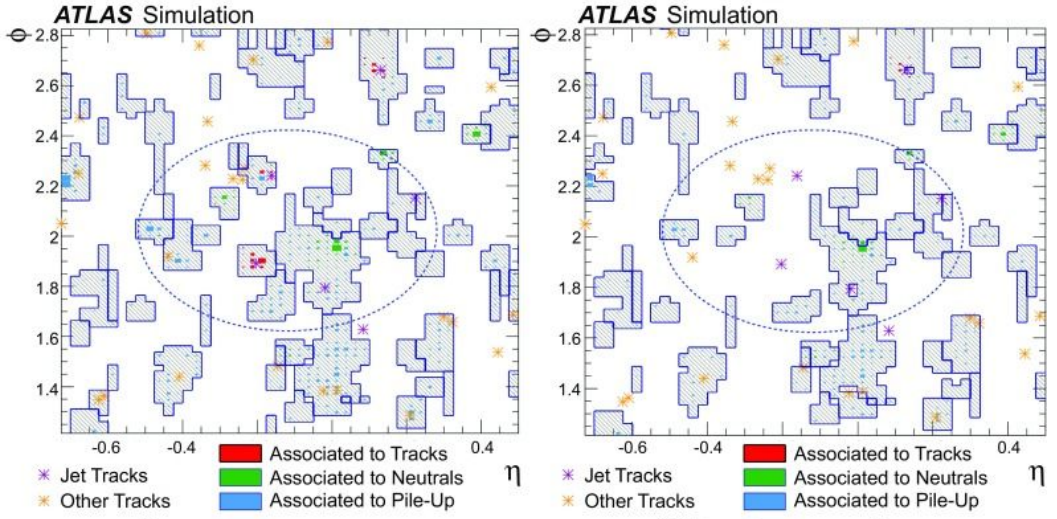
https://arxiv.org/abs/1603.02934

TopoCluster Algorithm



(a) Before subtraction, no pile-up.

(b) After subtraction, no pile-up.

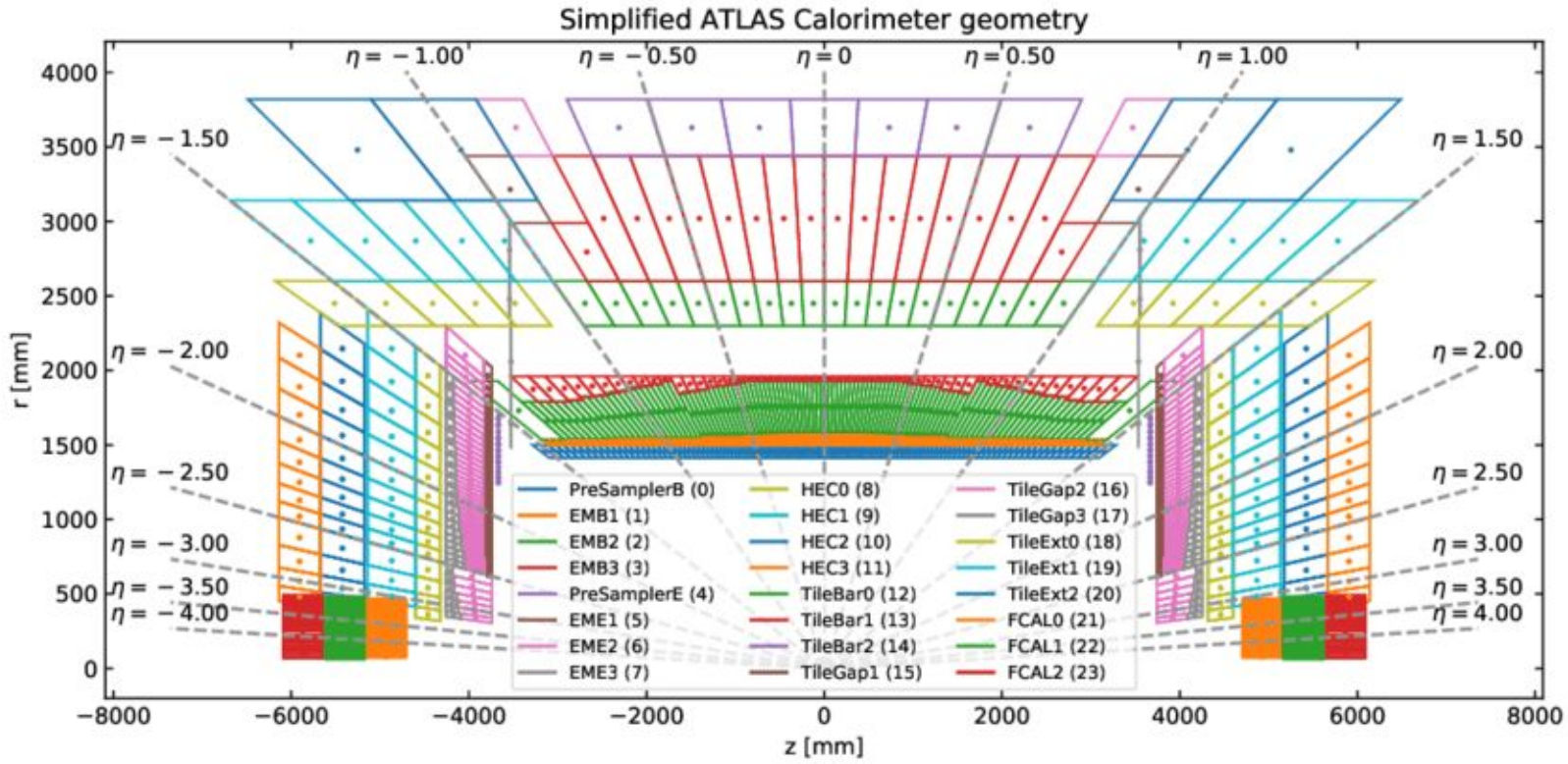


(c) Before subtraction, $\mu = 40$.

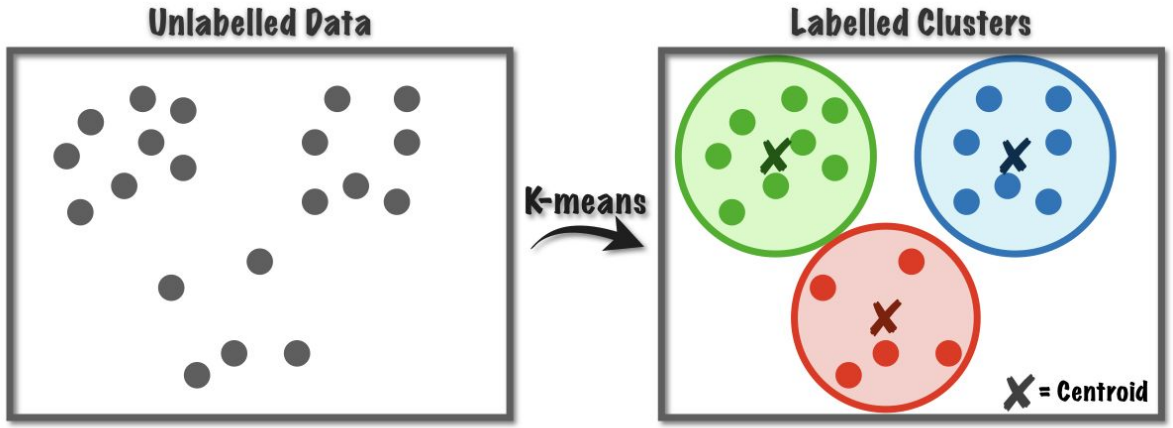
(d) After subtraction, $\mu = 40$.

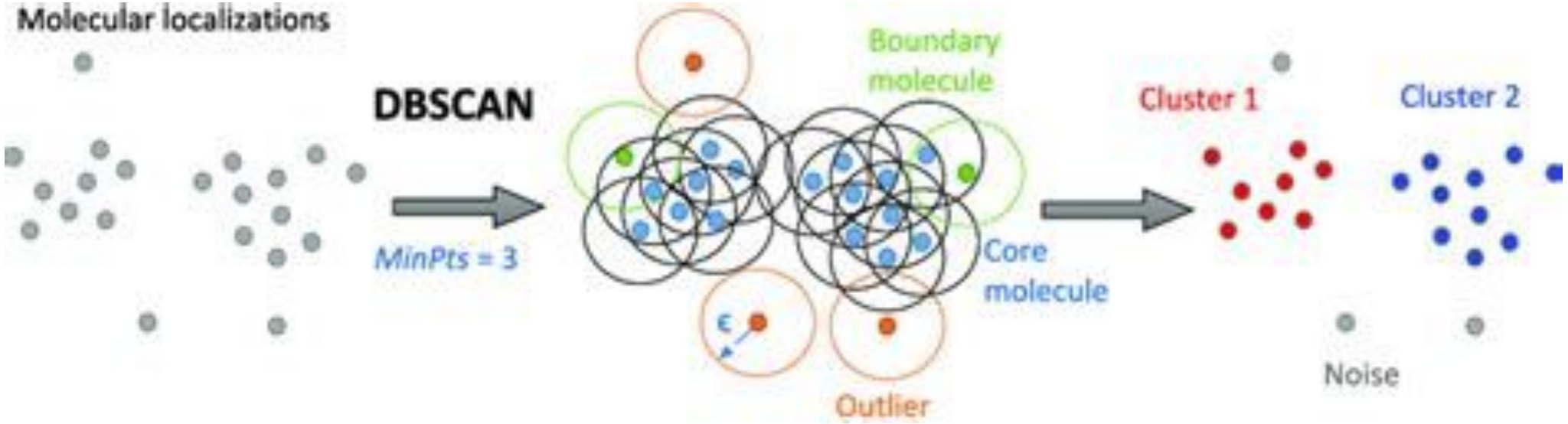
https://arxiv.org/abs/1703.10485

Calorimeter Granularity



Learning Paradigm





Project Objectives

- ➔ Investigate ML **clustering substitutes** for **TopoCluster** algorithm in trigger
- ➔ Deal with calorimeter **granularity**, **complexity** and **irregularity**
- ➔ Benchmark tests **performance** + **speed**
- ➔ Potential extension to **parallel computing** structure / **GPUs**
- ➔ [Additional functionality - cluster classification, energy/momentum regression]

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