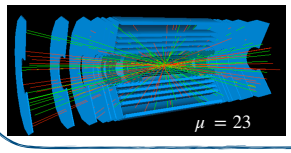
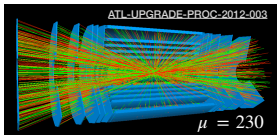
FPGA-based techniques to improve fast track finding in the ATLAS Trigger

Brookhaven National Laboratory

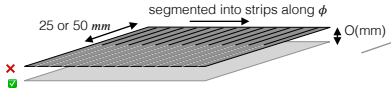
ATLAS EXPERIMENT

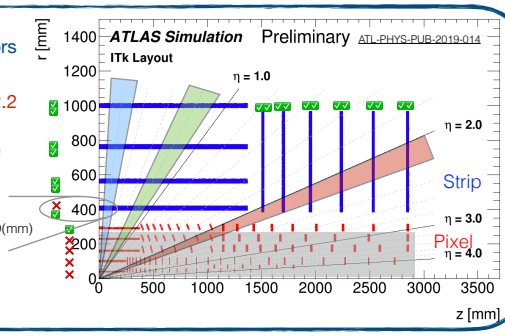
- High Luminosity LHC: ~50 -> ~200 pp interactions
- Tracking is key to identify different collision vertices and distinguish particles from each vertex
- Doing so in the trigger is vitally important to the physics program, to preserve bandwidth
- ATLAS will have a new inner tracker ("ITk"), and a new trigger system. Here: **how will we obtain tracks for use in the trigger?**

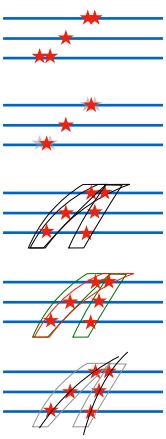




- Pixels: single-layer detectors, 50 x 50 μm^2 sensors
- Strips: **dual-layer** detectors, 20-50 mm x 75 μm
- Studies in three η regions: 0.1-0.3, 0.7-0.9, 2.0-2.2
- Here: considered outer pixel layer and all strip layers (though only inner side of inner strip layer) -> 8 layers for central η







Hit information from ITk

Clustering

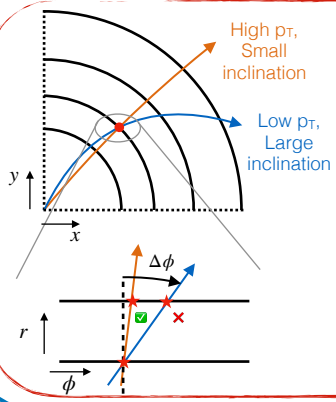
Pattern matching

Fake removal

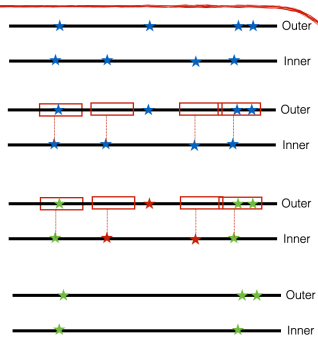
Track fitting

Final tracks for trigger

Filter clusters to reduce required pattern-matching throughput: "stub filtering"

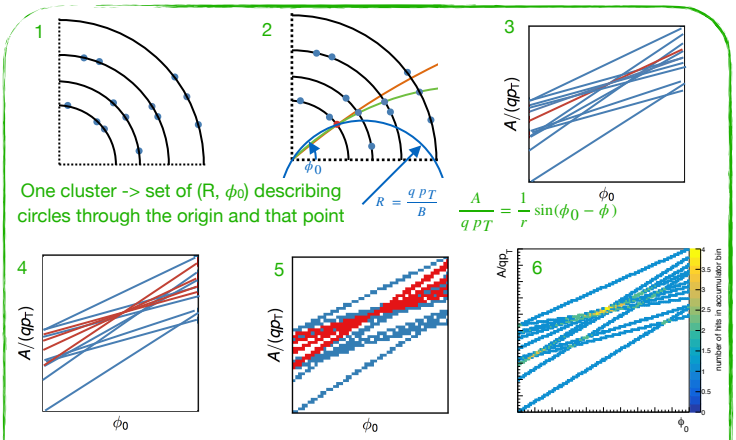


1. Read in all hit clusters in relevant modules
2. Look in $\Delta\phi$ window around each inner side cluster - window size varies across detector
3. Cluster in window? Pass : Fail
4. Send on only passing clusters



Simple algorithm, implemented in High Level Synthesis (much smaller and faster than Hough Transform)

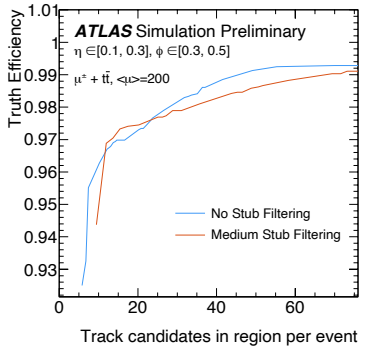
Hough Transform: image processing to find circles

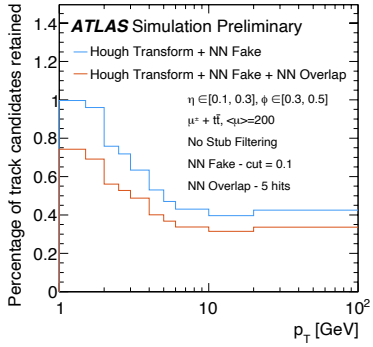


One cluster -> set of (R, ϕ_0) describing circles through the origin and that point

All clusters -> set of lines in Hough space, identify intersections as maxima in "accumulator" histogram. Intersection = circle compatible with all clusters, i.e. a set of track candidates

Use Machine Learning to aid fake removal

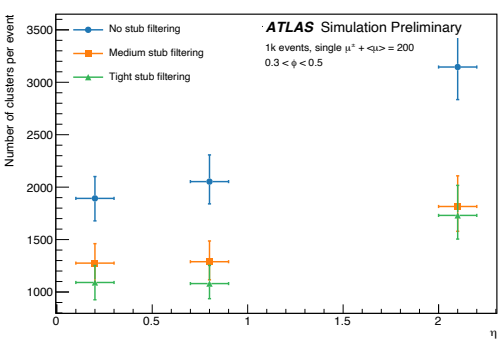


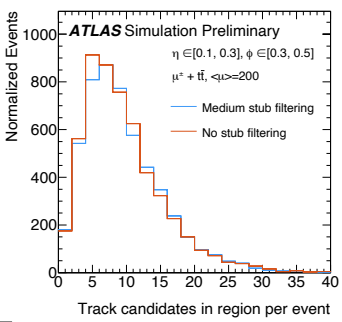


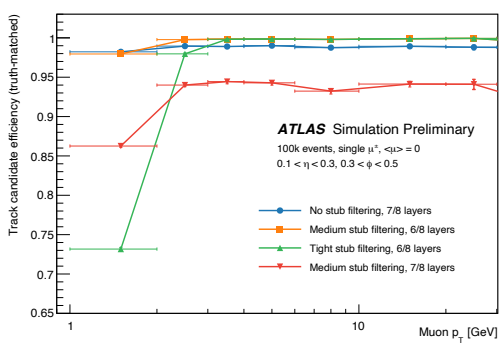
- Simple densely connected NN trained on the hit coordinates to reject fake track candidates
- NN score also used to remove overlaps among tracks sharing hits

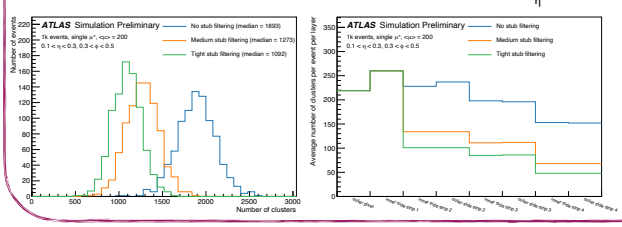
Some efficiency loss, but massive rejection -> **fewer precision track fits needed**

Stub + NN performance

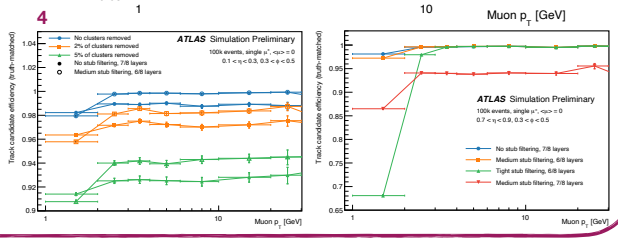








1. **Fewer clusters to process**
2. **Fewer precision track fits**
3. **Maintain track-finding efficiency**
4. **No additional sensitivity to radiation damage**



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