Cluster formation, calibration, & splitting: A Discussion

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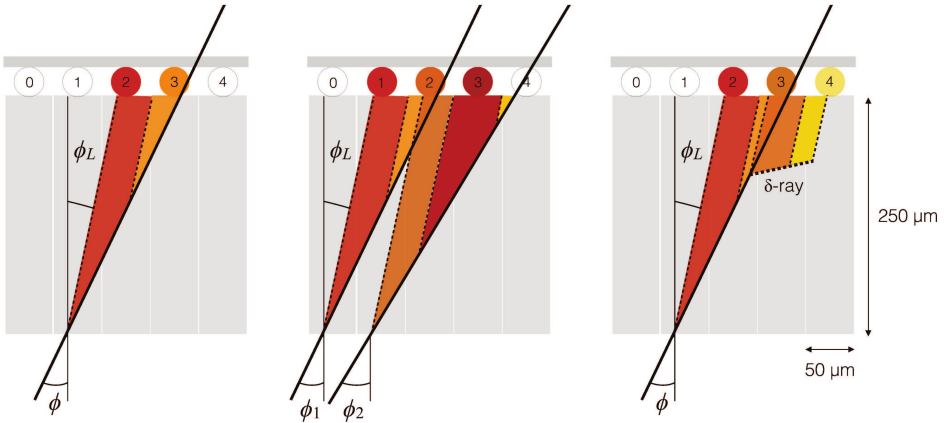
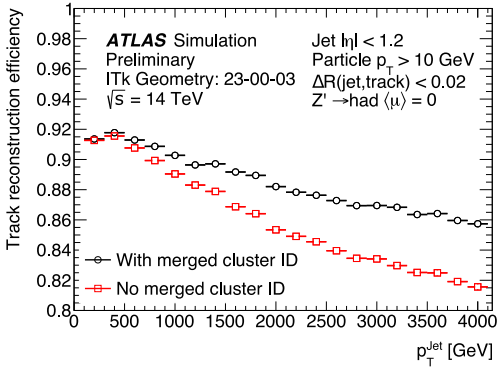
Introduction: Charge clusters

- In Si Pixel detector, charge often deposited in ≥ 1 pixel



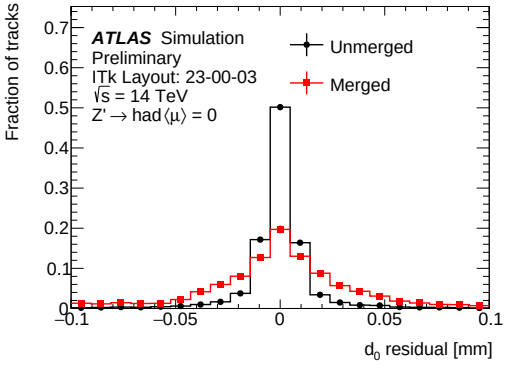
- Center: multiple particle in same cluster!

Introduction: Why should we care?



- HL-LHC is a discovery machine
- BSM often features new heavy resonances
- Heavy → light decay:
  - Decay products can be highly boosted
  - → relativistic angle contraction
- Clusters inside such jets can merge
- Left: **This lowers the tracking efficiency**
- Downstream impact on on jet reconstruction, flavor tagging, . . .

Introduction: Why should we care?



- HL-LHC is a discovery machine
- BSM often features new heavy resonances
- Heavy → light decay:
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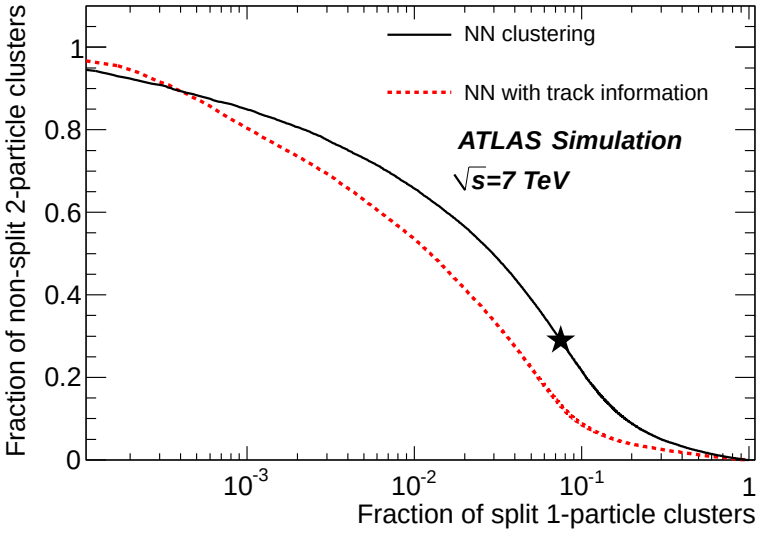
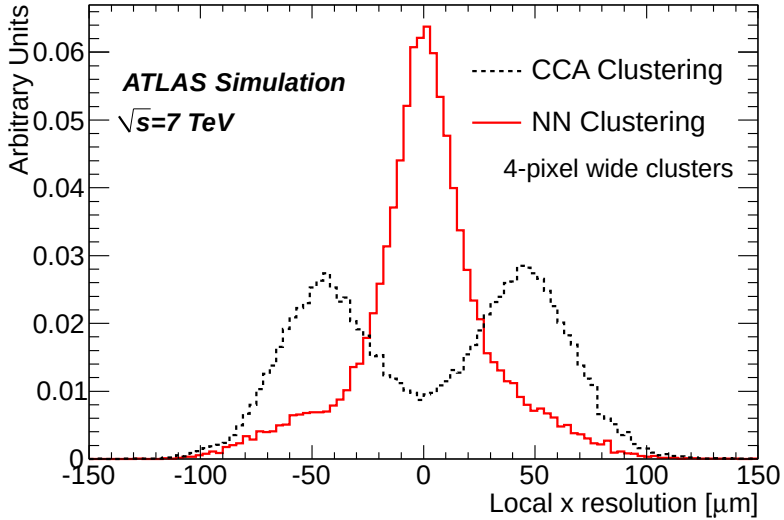
  - → relativistic angle contraction
- Clusters inside such jets can merge
- Left: **The parameter resolution is degraded**
- Downstream impact on on jet reconstruction, flavor tagging, . . .

Introduction: What can we do?

1. Split the clusters

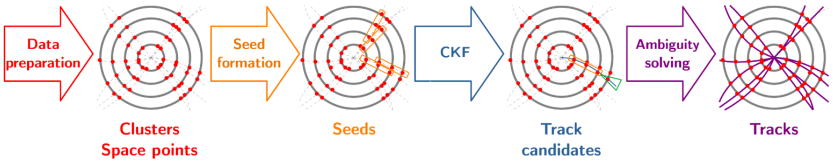


2. Re-calibrate the positions



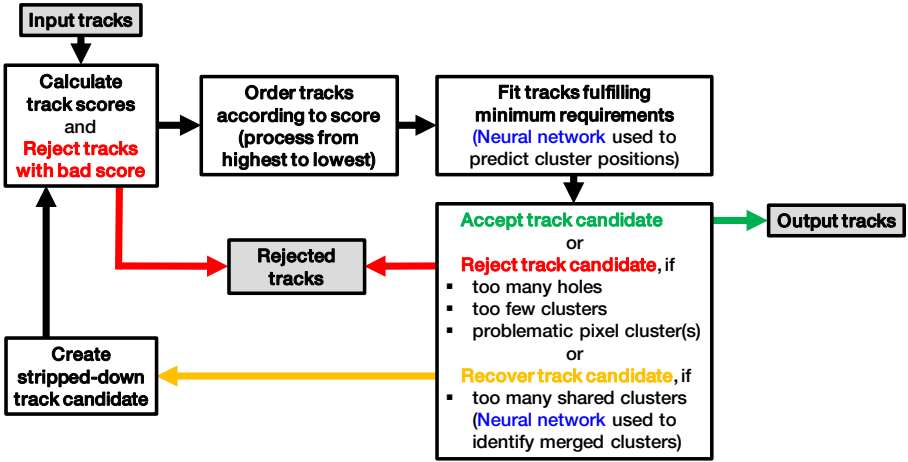
What about ACTS?

- Typical ACTS-based CKF track finding pipeline:



- Where cluster splitting?
- Where cluster re-calibration?

How it's done in ATLAS



⚠ Non-trivial coupling between **splitting**, **calibration**, **(re-)fitting**, and **ambiguity resolution**

How can we incorporate this in ACTS?

1. Splitting at cluster formation time?

Pros

- Requires modification to cluster formation code only
- Clusters already split before CKF: No recovery needed for efficiency
- No special calibration needed to recover resolution

Cons

- No information on track direction $\implies$ splitting not optimal
- Spend time splitting clusters from particles not in acceptance
  - e.g. ATLAS ITk has min. pT cut of 1 GeV $\implies$ there's a *ton* of low pT particle not in acceptance

How can we incorporate this in ACTS?

2. Implement Athena-style splitting?
i.e. Do splitting & refit in a loop inside ambiguity solver

Pros

- Well understood, proven design
- Efficient: Can concentrate on tracks rejected because of shared measurements

Cons

- To recover resolution: Needs to be able to refit tracks with split clusters
- Introduce tight coupling between Splitting, Ambiguity solving, Refitting
- Introduce specific requirements on ambi solver
  - e.g. might need way to tell it rejects a track because of shared measurements
  - Straightforward for a "greedy"-type solver, less so for ML solver ...

How can we incorporate this in ACTS?

3. Splitting as intermediate stage between CKF & Ambiguity Solving
(or ≈ equivalently, 2-stage ambiguity solving)

Pros

- No need to tightly coupled (final) ambiguity solving and splitting, refitting
- Can also be made efficient by not checking all tracks
  - e.g. check tracks with $\geq N$ shared measurements
  - or do track-jet clustering & only run in core of track-jets

Cons

- Still needs to support refitting to recover resolution
- Might still be slower than tightly-coupled ambi solver paradigm

How can we incorporate this in ACTS?

4. Splitting in CKF measurement calibrator

- I.e., implement calibrator for use during track finding that:
  - Outputs optimal position for measurement for the current track
  - Outputs probability that measurement arises from >1 particle

Pros

- No need to split! The Calibrator knows how to deal with multi-particle clusters
- No need to refit! The Calibrated measurement is *always* optimal
- Can use number probability to mark "shareable" measurement & use during ambiguity solving

Cons

- Calibrator model would get more complex → slower
- Non-trivial blue-sky R&D project... Looks good on paper, but no idea how well this would work

In Conclusion

- Measurement Splitting & Calibration is completely missing from ACTS
- Currently designed ACTS CKF-based pipeline do not easily support this
- Need to take decision & start real work: every option requires non-trivial work
- Support for re-fitting is needed for most options
- Anyone interested in helping?
- Let's discuss!