Improved track reconstruction for prompt and long-lived particles in ATLAS for the LHC Run 3

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on behalf of the ATLAS collaboration

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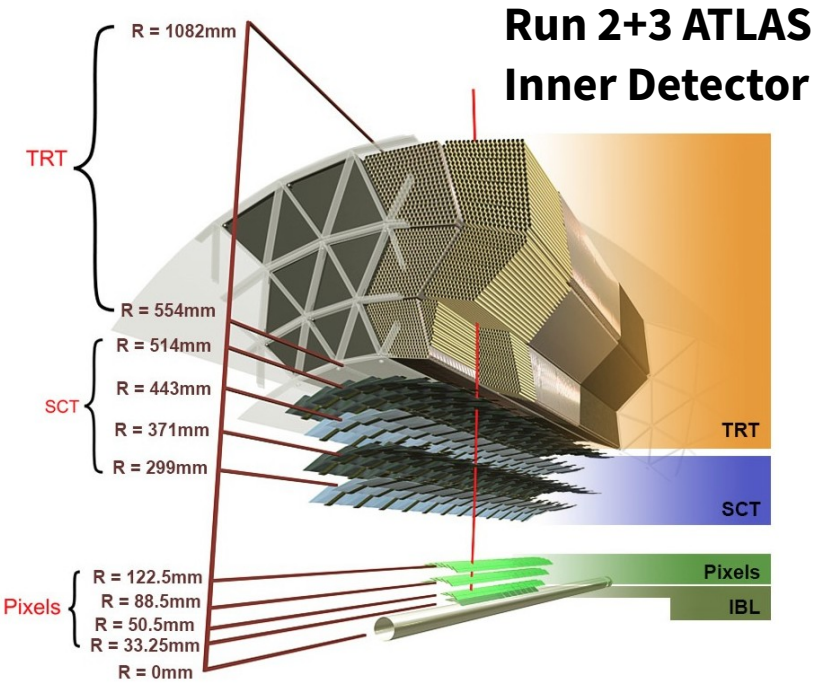
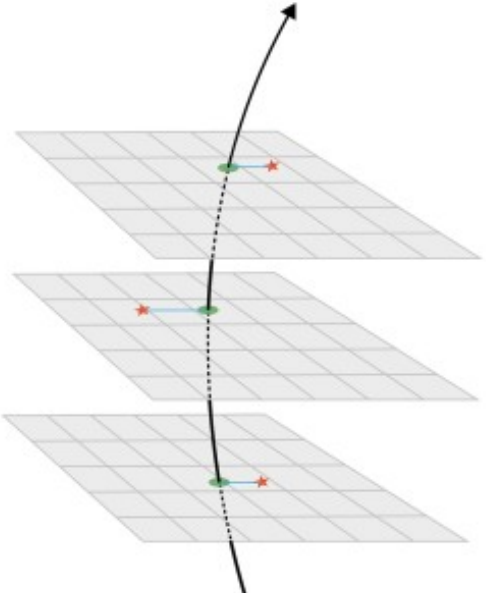
Track Reconstruction in ATLAS

Track reconstruction is important!

- aka reconstructed **trajectory of charged particles** in a **magnetic field**
- Pile-up suppression, b-tagging, single particle ID, jet substructure resolution, long lived particle searches



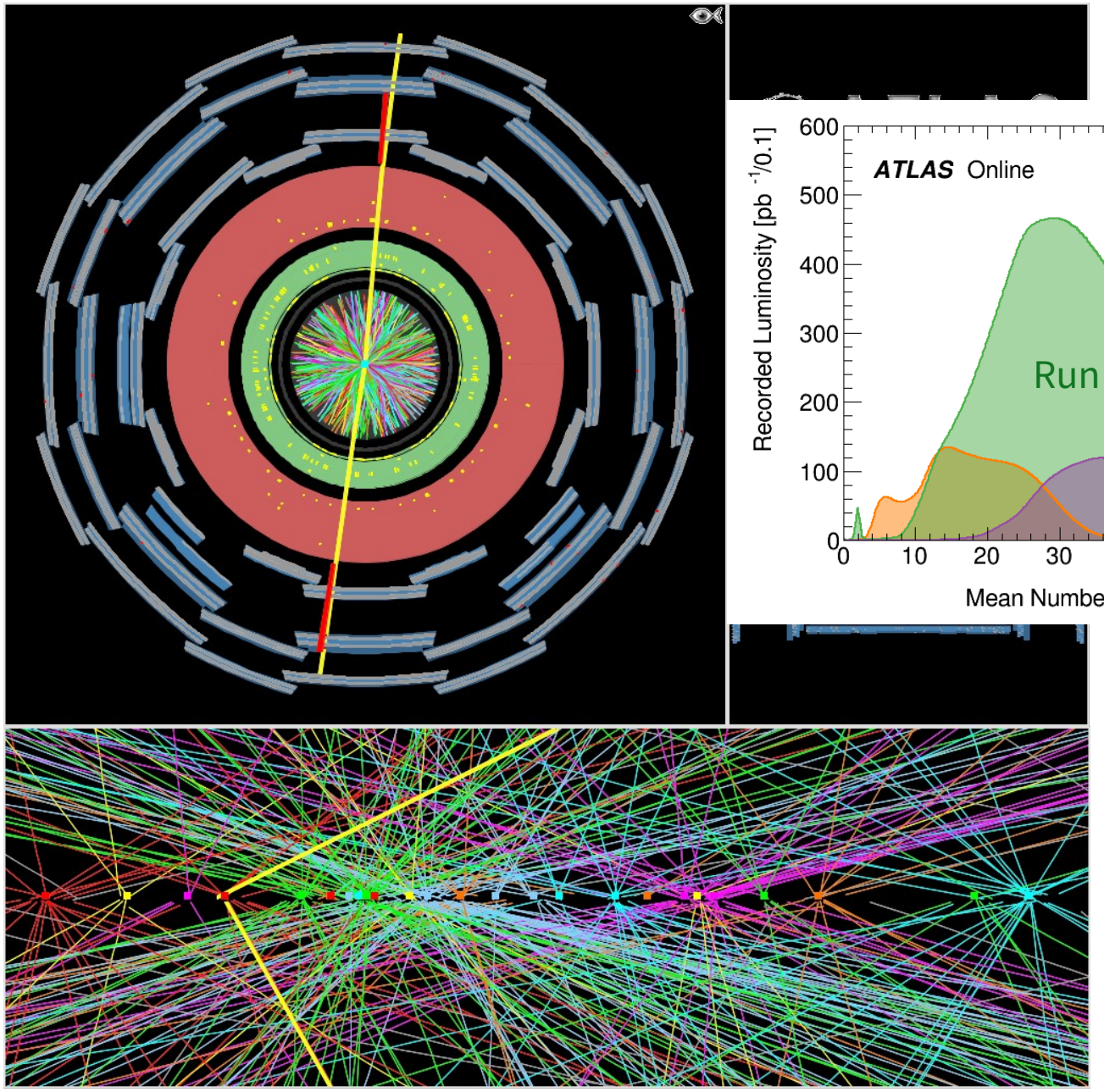


Track reconstruction is hard!

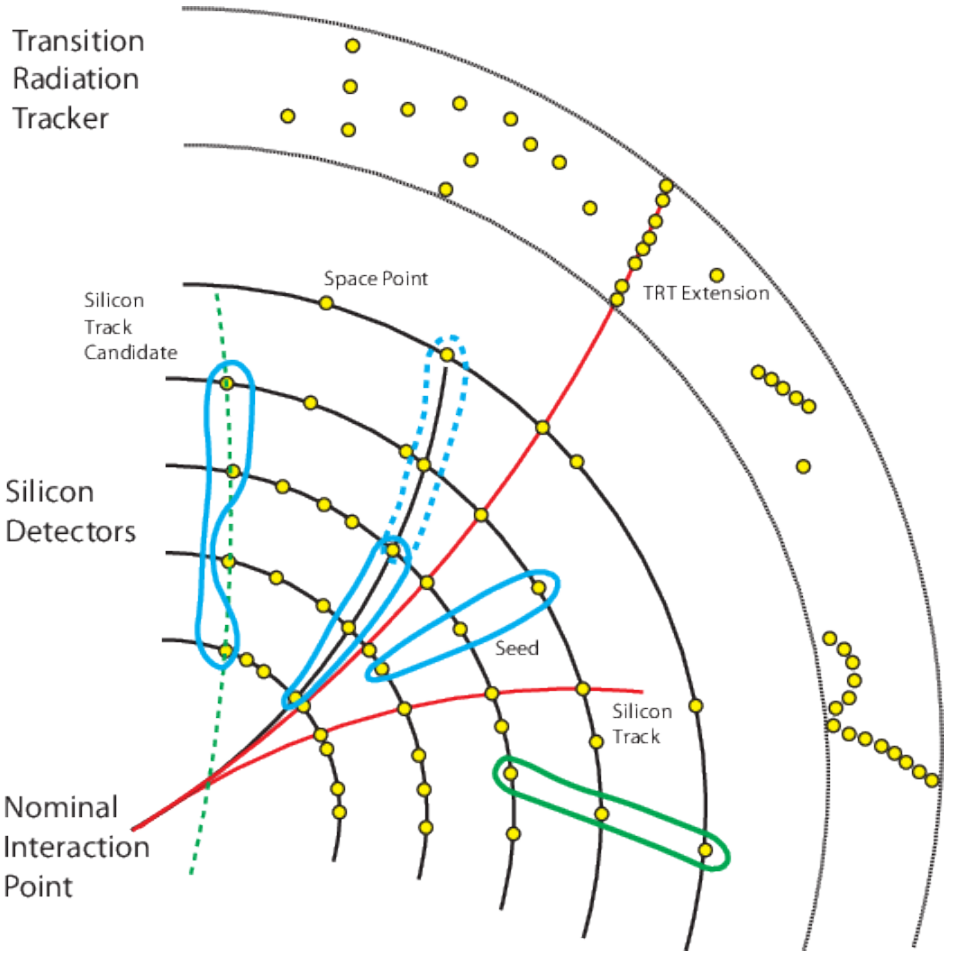
- Huge combinatorics in pattern recognition
- Radiation damage degrades detector performance
- Both gets worse with increased pile-up.

Pile-Up

Event display with 20 reconstructed vertices



Track Reconstruction Algorithm



Simplified picture of the different track reconstruction stages.

Selection applied at each stage to reduce track candidates.

Space-Point formation
Pixel clusters, Strip intersection, TRT radii

Seed Finding
3/4 hit combinations, separately in Pix and SCT

Track Following
Combinatorial Kalman Filter with silicon SP's

Track Fitting
Done using a *Global χ^2 Fitter*

Ambiguity Resolution
Assign shared clusters to tracks in dense environments.

TRT Extension
Add hits in the TRT compatible with the track.

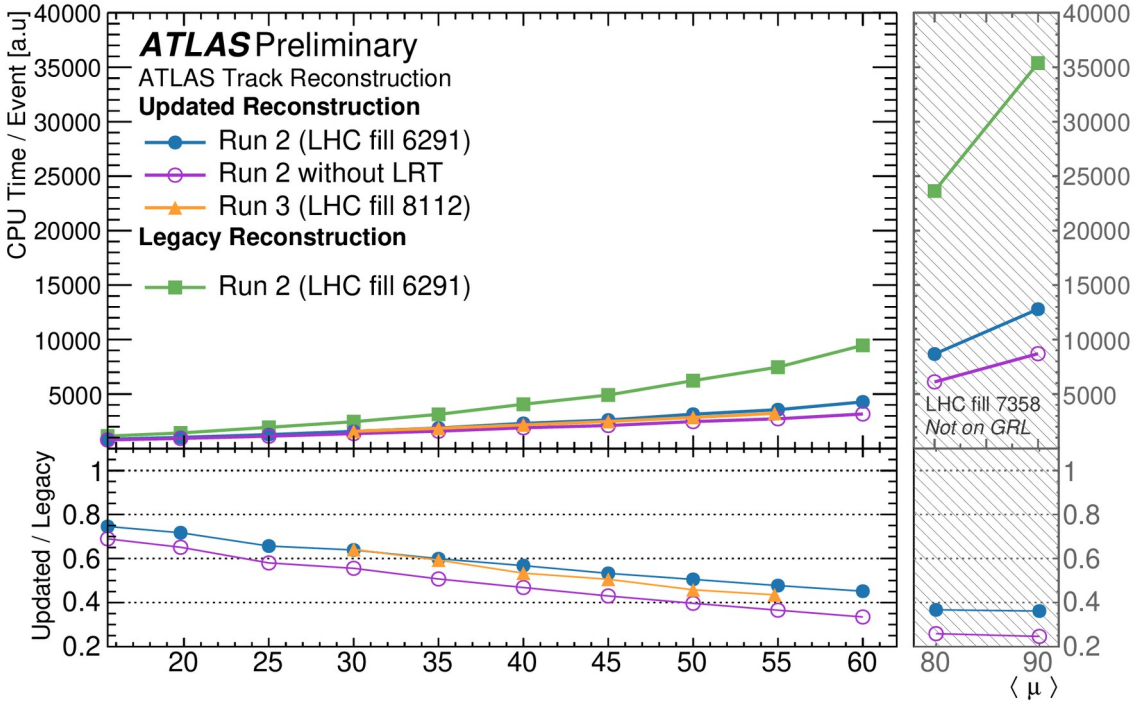
Back-Tracking
Use unassigned hits for TRT-seeded track finding.

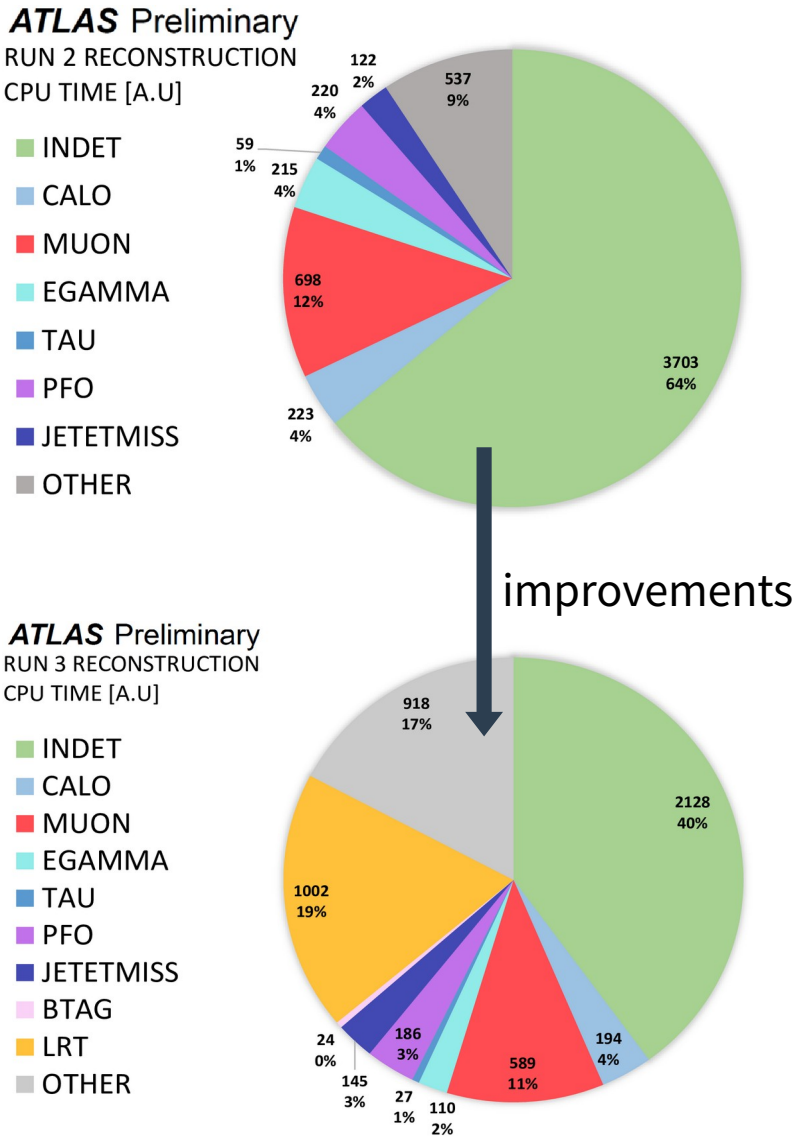
Dedicated Track-Finding Setups
Rerun* tweaked algorithm on unassigned hits.
ie: low-p_T tracks, large radius tracks

* Not all run by default.

Note on Computation

ATL-PHYS-PUB-2021-012

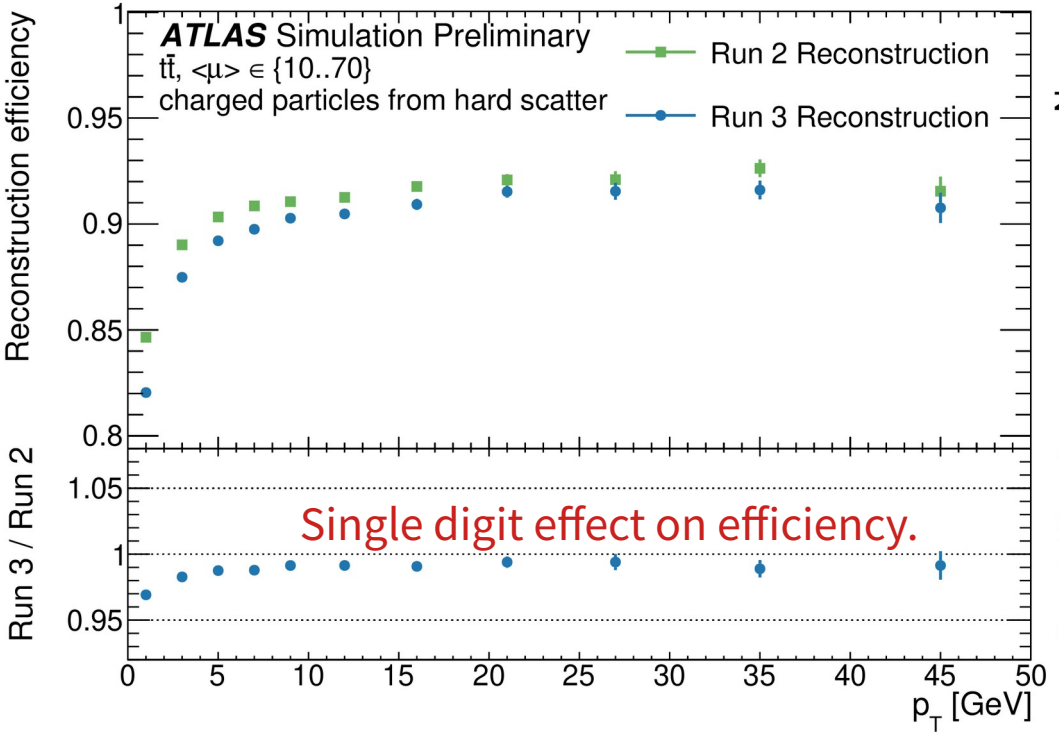


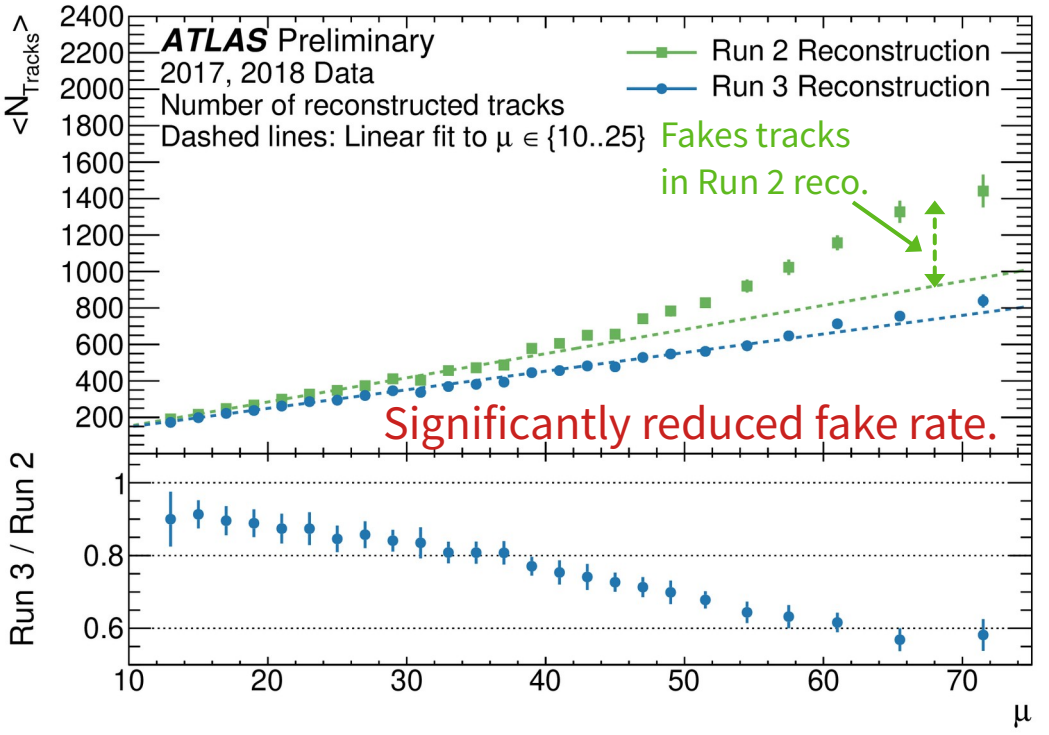


- **General algorithm optimizations**
- **Abort track finding ASAP for fake tracks**
  - Tighten cuts on seeds and tracks
  - Back-tracking requires an ECal deposits

Overall Performance

ATL-PHYS-PUB-2021-012

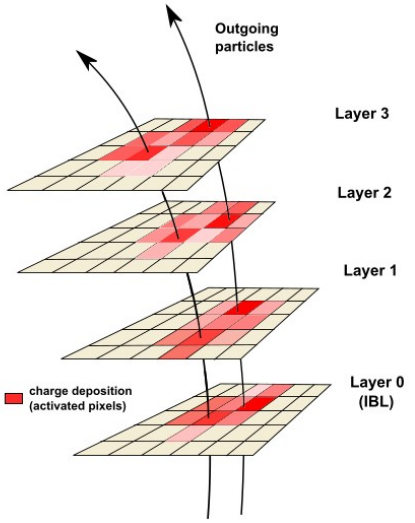




Note: This is performance before final track quality cuts.

Ambiguity Resolution

Ambiguity: Cluster assigned to two tracks. Who owns it?



Classifier NN
Determine number of hits inside cluster.

↓

Regression NN
Determine position of hits inside cluster

Improves resolution of **hit position** → improves resolution of track parameters

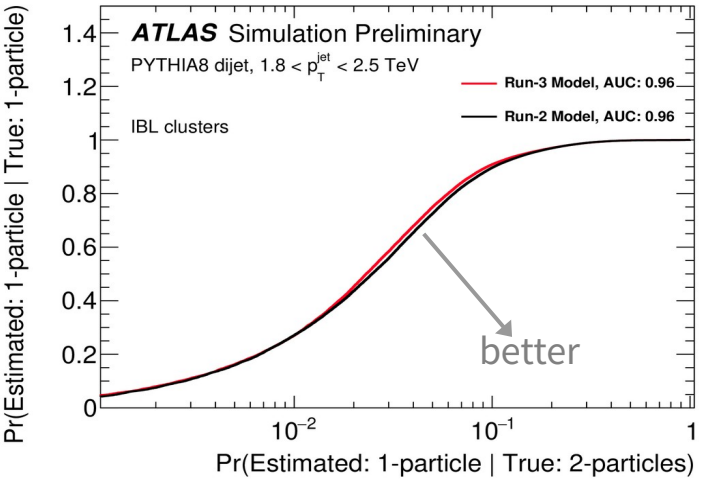
Important for **dense environments** (ie: energetic jets).

Run 2: separate regression NN's for position and uncertainty

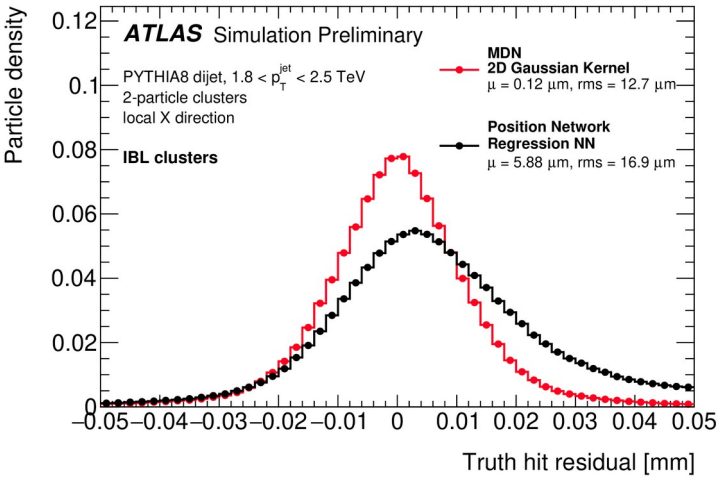
Run 3: **single** regression **NN** for **position and uncertainty**

- Mixed Density Network

Classifier NN



Regression NN

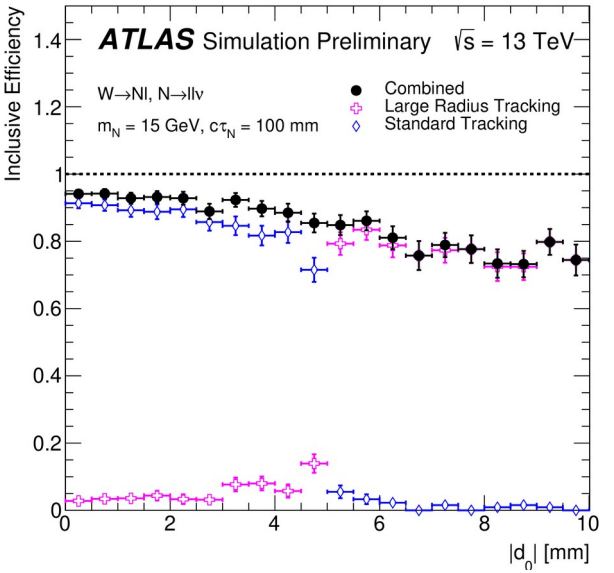


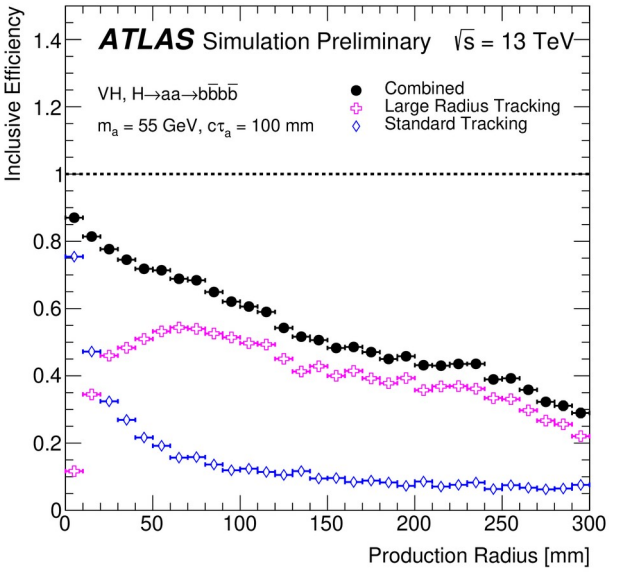
Large Radius Tracking

IDTR-2021-003

Second pass on “left-over clusters” optimized charged particles produced at a large radius.

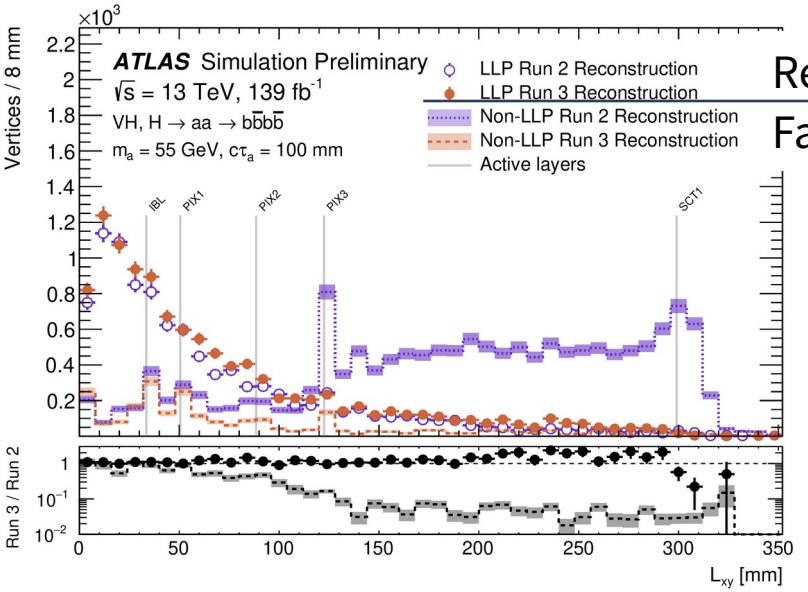
Important for long-lived particle searches.





Run 2: High signal efficiency and only run on specific events.

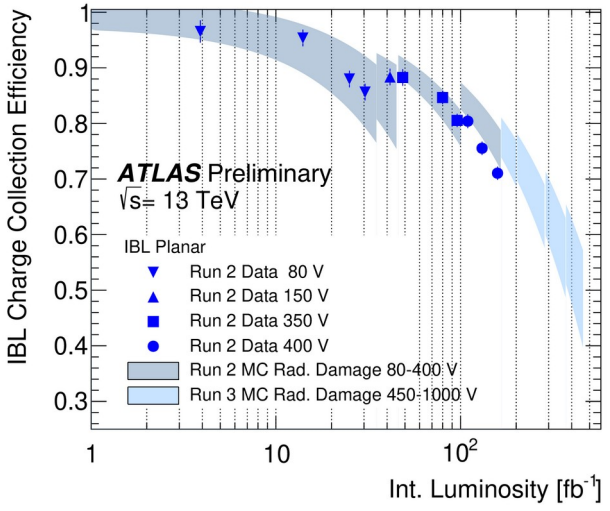
Run 3: Low fake rate and run as part of standard reconstruction.



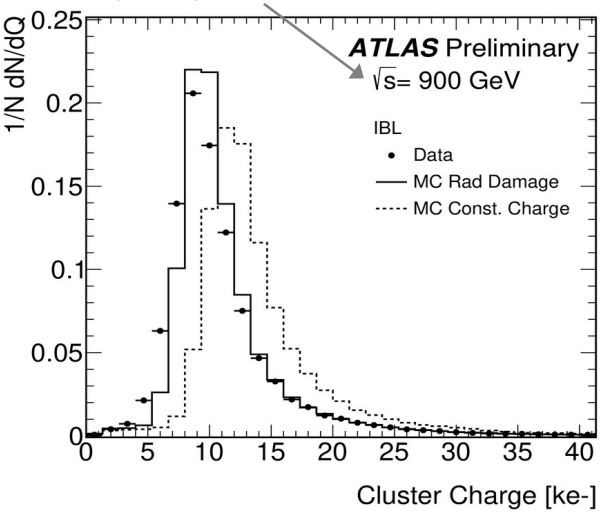
Radiation Damage

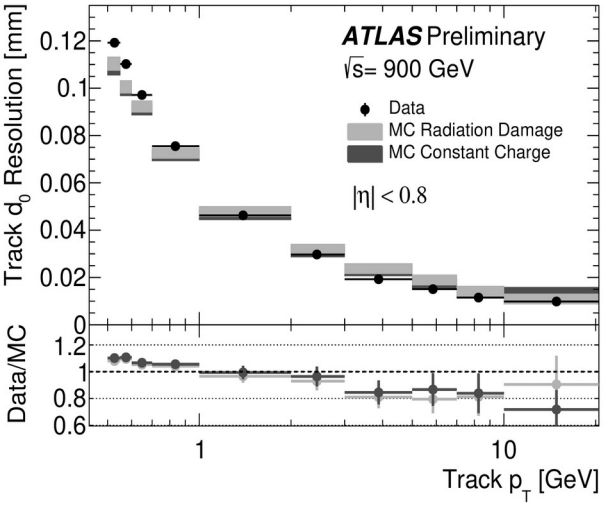
ATL-PHYS-PUB-2022-033

Radiation damage is now standard part of detector simulation.



Very early Run 3 result!





Efficiency of silicon sensors decreases with fluence.

Fairly well modeled by simulation w/ differences understood.

No significant effect on track reconstruction.

Conclusion

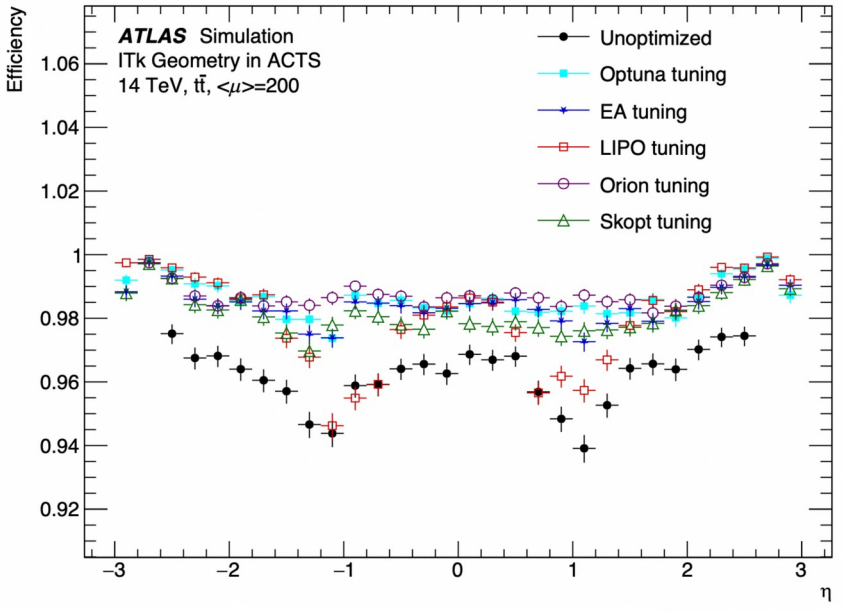
ATLAS track reconstruction ready for Run 3!

- **Track selection optimized for low fake rate.**
  - Significant effect on reducing computational time.
  - Negligible effect on efficiency.
- **New ambiguity network (Mixed Density Network) improves hit position resolution.**
- **Large Radius Tracking now part of standard track reconstruction.**
- **Radiation Damage part of simulation.**
  - Fairly well modeled, but limited impact on track parameters.

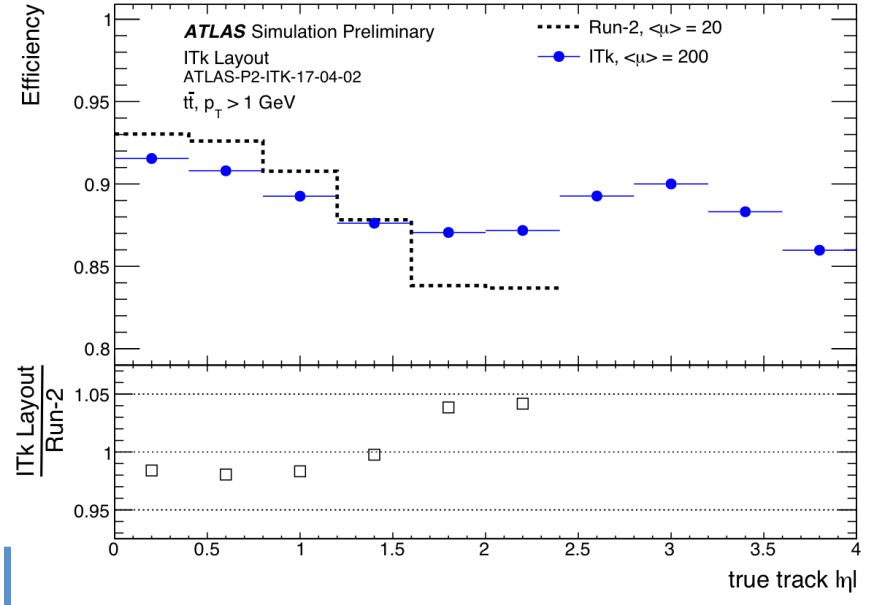
BACKUP

Lots of R&D too!

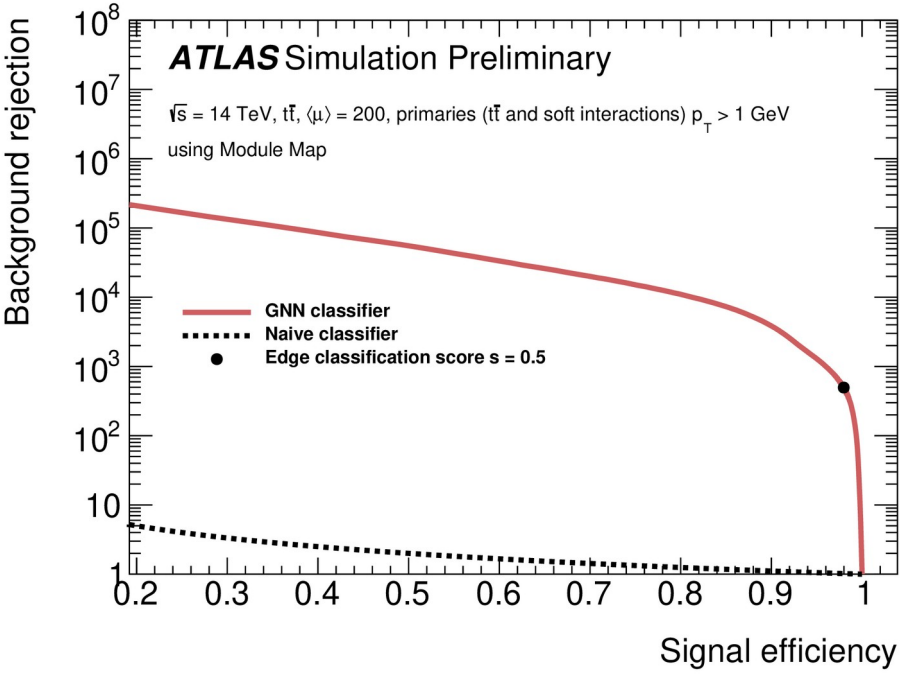
Automated optimization



Getting ready for HL-LHC



Track Finding Using Graph Neural Networks



Tracking Performance in MC