Boosting the discovery potential for the LHC Run 3
Improved Track Reconstruction for prompt and long-lived particles in ATLAS

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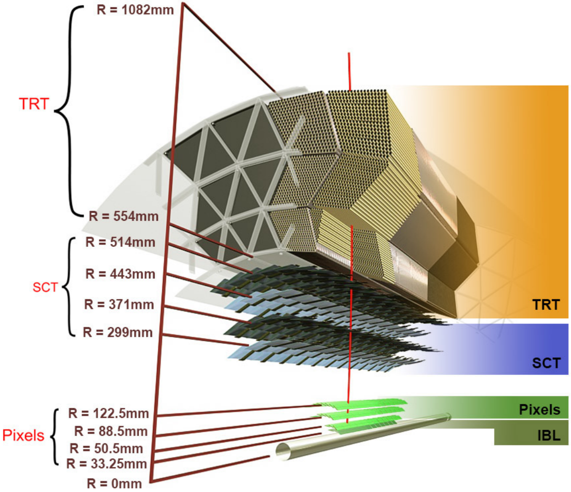
Introduction
The ATLAS Inner Detector

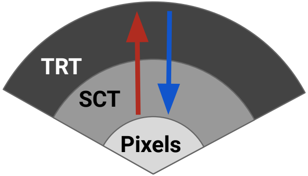
- Barrel:
  - TRT: Gaseous detector (straw tubes)
    → ~30 measurements/track
  - SCT: Silicon strip detectors
    → 8 measurements/track
  - Pixels and IBL: Silicon pixel detectors
    → 4 measurements/track
- End-caps on each side:
  - Pixels
  - SCT
  - TRT



Introduction
Tracking in ATLAS

ATLAS Primary Tracking

Space Point & Drift Circle Formation → Pixel & Strip Seed Finding → Track Finding → Ambiguity Resolution → TRT Extended Track Refit



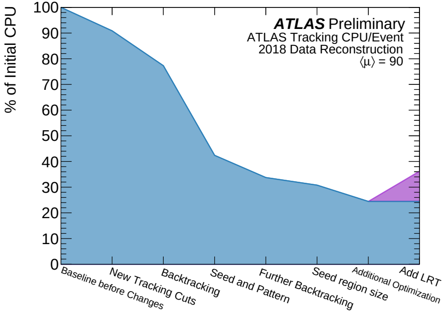
ATLAS Back-Tracking

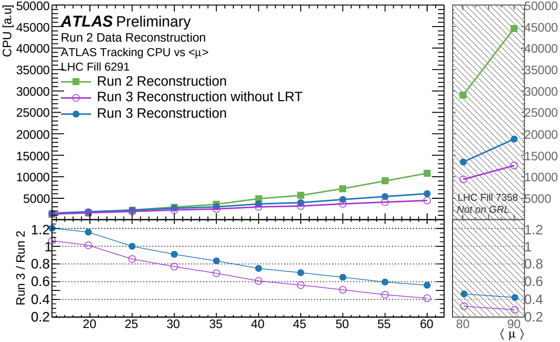
TRT Segment Finding in Calorimeter Regions of Interest → Track Finding → Ambiguity Resolution → TRT Extended Track Refit

Physics performance and software optimisation

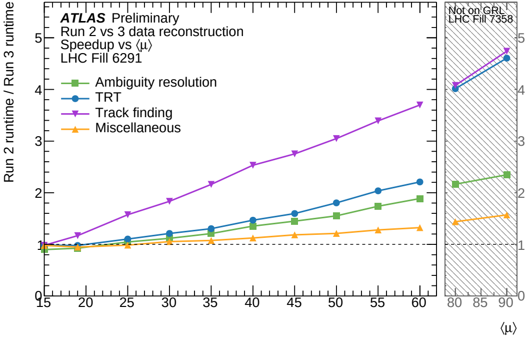
Changes with respect to Run 2 track reconstruction:

- Tighter cluster on track requirements ($7 \rightarrow 8$)
- Tighter impact parameter selection ($|d_0| < 10\,\text{mm} \rightarrow |d_0| < 5\,\text{mm}$)
- More selective backtracking
- Better seeding
- Confirmation space-point for falsely reconstructed track suppression
- New vertex finder (using ACTS implementation)
- Additional 'long radius tracking' pass in all events



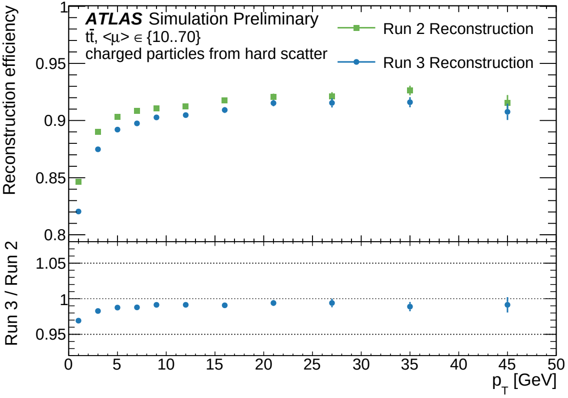


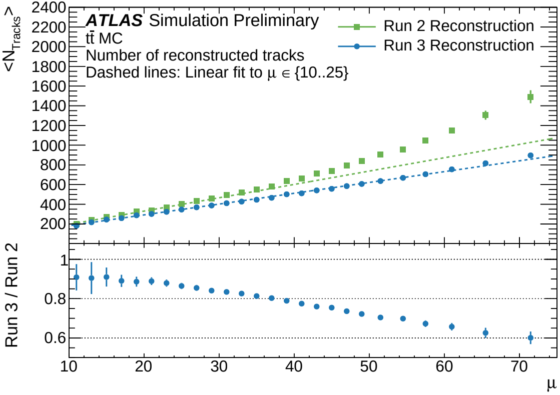
ATLAS Preliminary
Run 2 Data Reconstruction
ATLAS Tracking CPU vs <μ>
LHC Fill 6291
Run 2 Reconstruction
Run 3 Reconstruction without LRT
Run 3 Reconstruction
CPU [a.u]
Run 3 / Run 2
LHC Fill 7358
Not on GRL
⟨ μ ⟩



ATLAS Preliminary
Run 2 vs 3 data reconstruction
Speedup vs ⟨μ⟩
LHC Fill 6291
Ambiguity resolution
TRT
Track finding
Miscellaneous
Run 2 runtime / Run 3 runtime
Not on GRL
LHC Fill 7358
⟨μ⟩

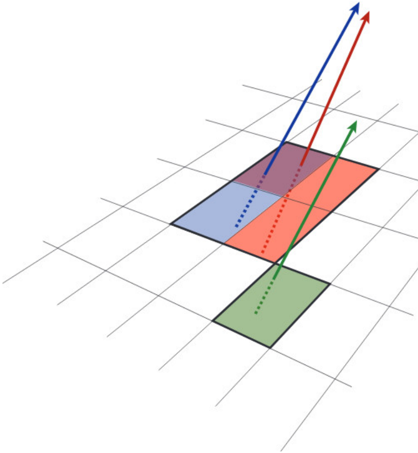
Physics performance and software optimisation



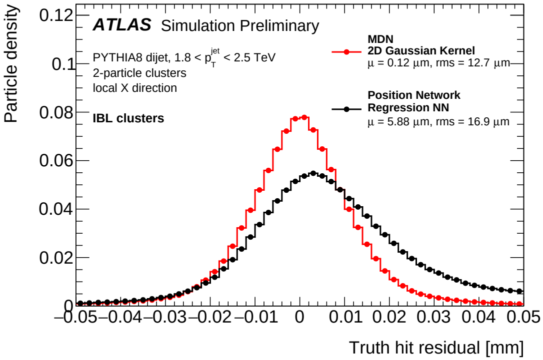


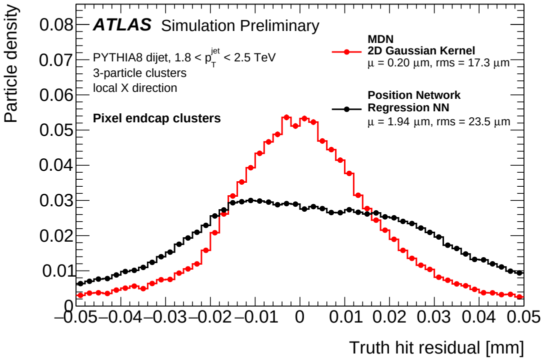
Pixel cluster splitting

- Separation of track smaller than sensitive elements size
  → clusters shared between tracks
  → lower track reconstruction efficiency with standard algorithms
- Neural network based cluster splitting
  → determine: number of particles → hit positions → hit position uncertainties
- Different NNs for 1, 2, ≥ 3 particle hits:
  - Old: 1 NN for position, 2 NNs for uncertainties (local x & y) each
  - New: 1 mixture density network each



Pixel cluster splitting

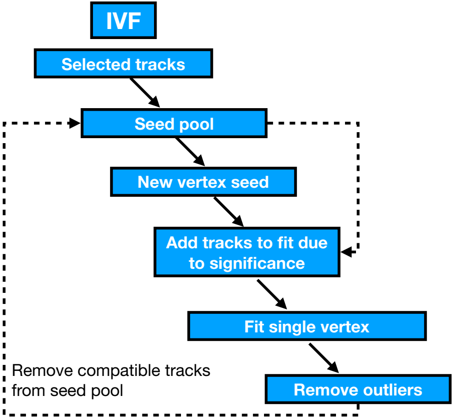




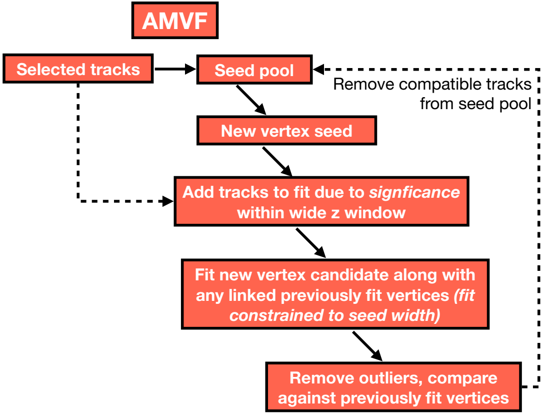
Primary vertexing

UCI

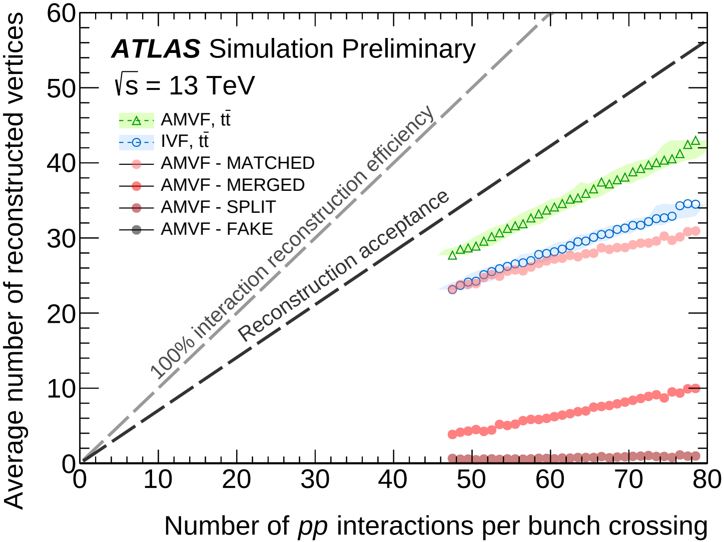
Iterative Vertex Fitter (old)



Adaptive Multi Vertex Finder/Fitter (new)

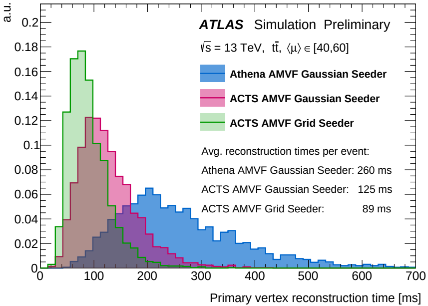


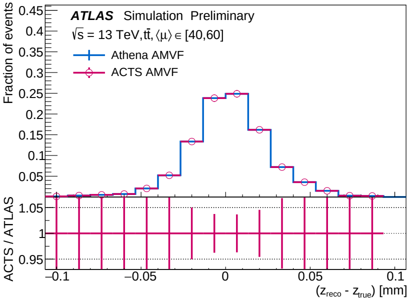
Primary vertexing

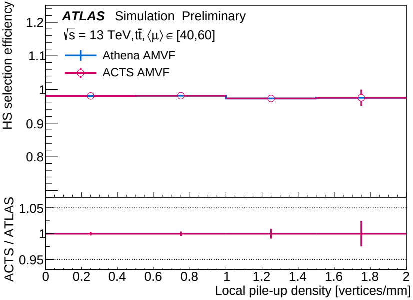


Primary vertexing

Athena → ACTS





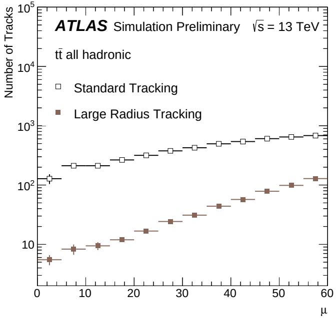


Large radius tracking

UCI

- Additional tracking pass after standard tracking
- Same reconstruction strategy as primary tracking:

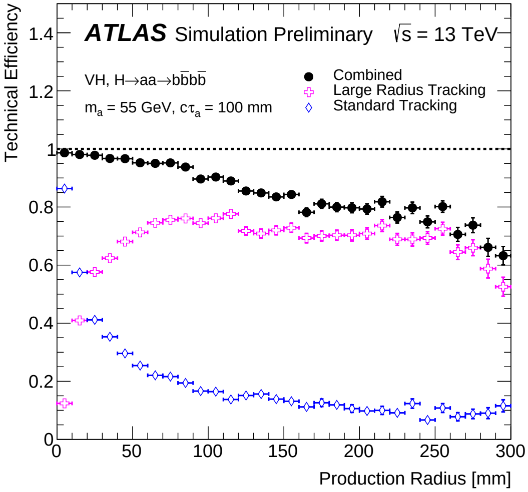
- Maximum $|d_0| \to 300\,\text{mm}$, $|z_0| \to 500\,\text{mm}$
- Old: optimised for high efficiency
  → large number of fakes
- New: optimised for fake reduction
  → 10–15 % reduction in efficiency, 95 % reduction in fakes
- Benchmark: signal models with secondary vertex topologies, $c\tau = 100\,\text{mm}$:
  - Pair-produced neutral pseudo-scalar a boson
    → hadronic displaced vertex
  - Heavy-neutral-lepton → di-lepton displaced vertex

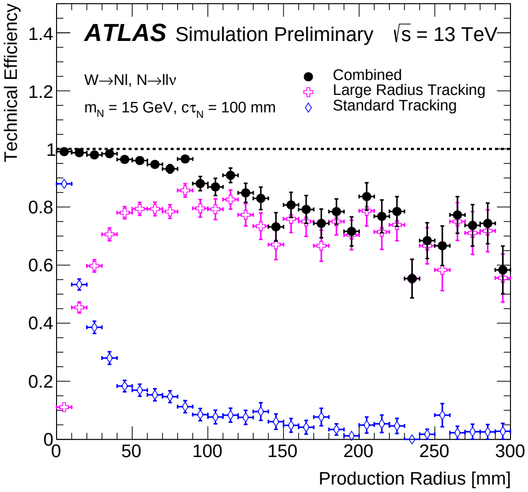


Large radius tracking

Performance vs. production radius

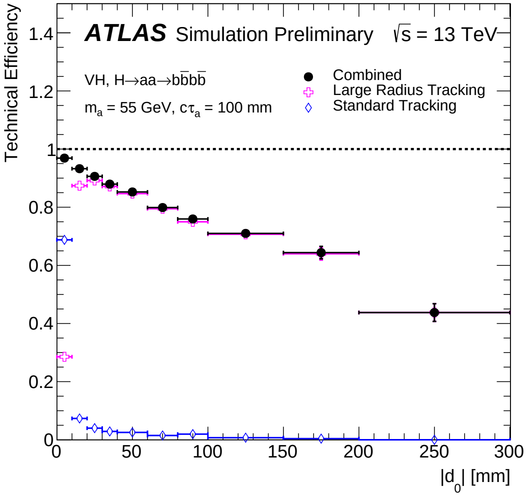
UCI

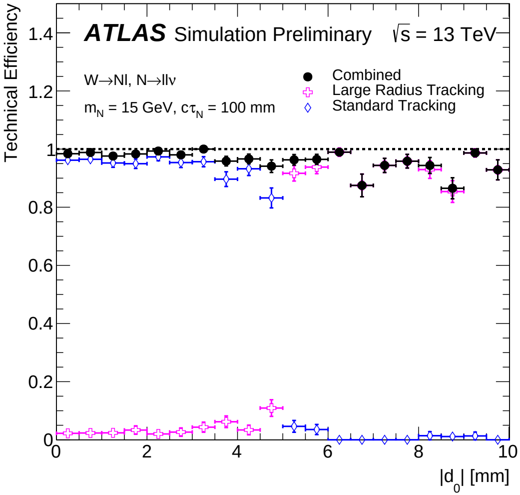




Large radius tracking

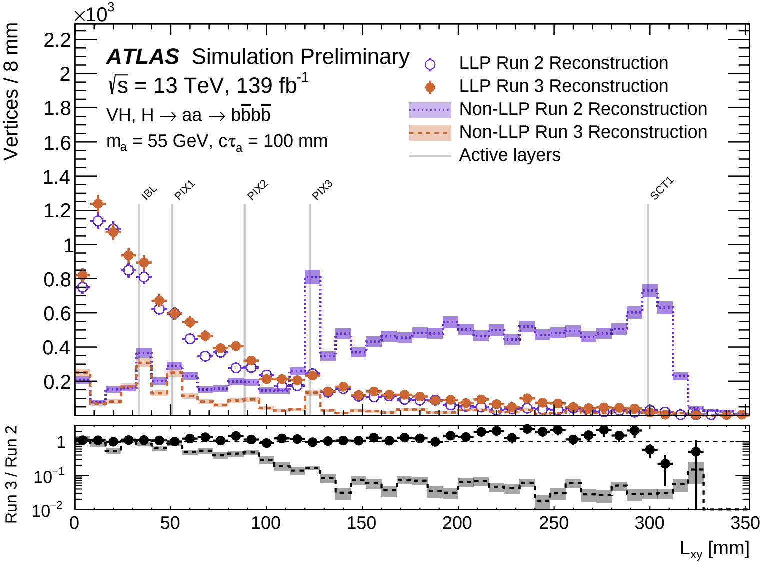
Performance vs. impact parameter





Large radius tracking

Performance



Conclusion

- Significant improvements over ATLAS Run 2 track reconstruction
- Factor 2–4 (pile-up dependent) reduction in processing time/event
- Retaining Run 2 reconstruction efficiency in standard tracking
- Additional 'standard' large radius tracking pass instead of special reconstruction for $\sim 10\,\%$ raw data