Berkeley
UNIVERSITY OF CALIFORNIA

ATLAS EXPERIMENT

ACTS in ATLAS

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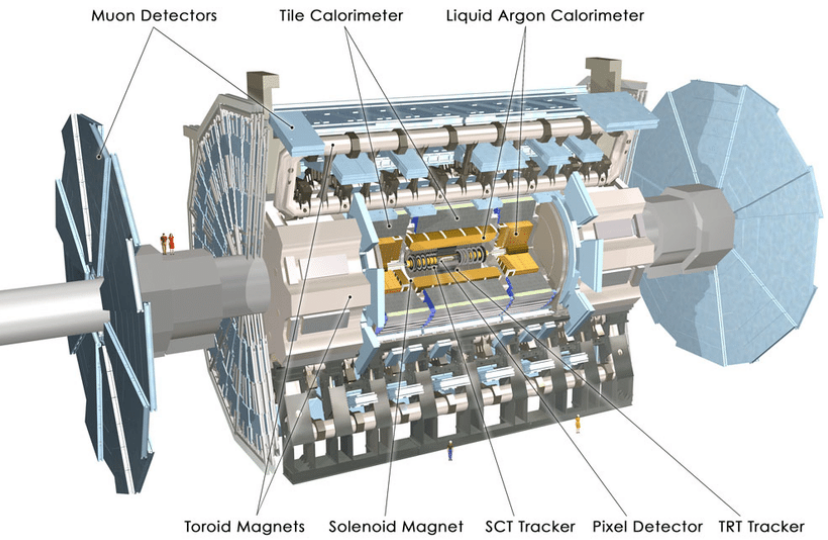
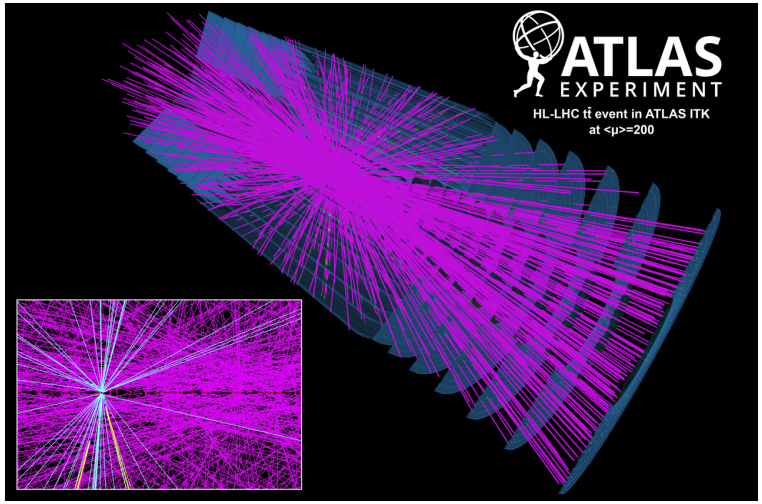
on behalf of ACTS developers in ATLAS

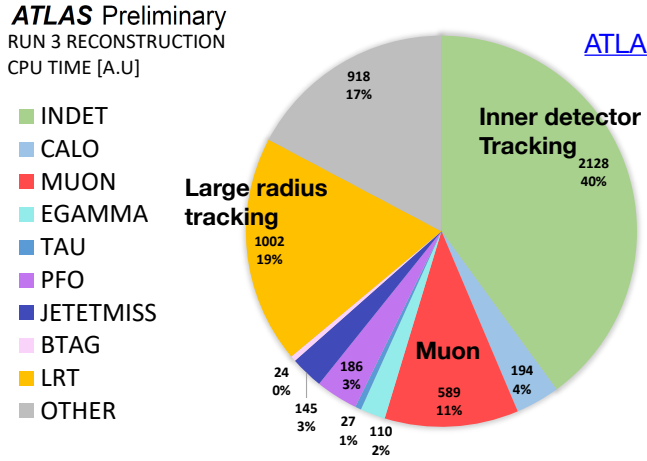
ACTS workshop
November 10th, 2023

ATLAS





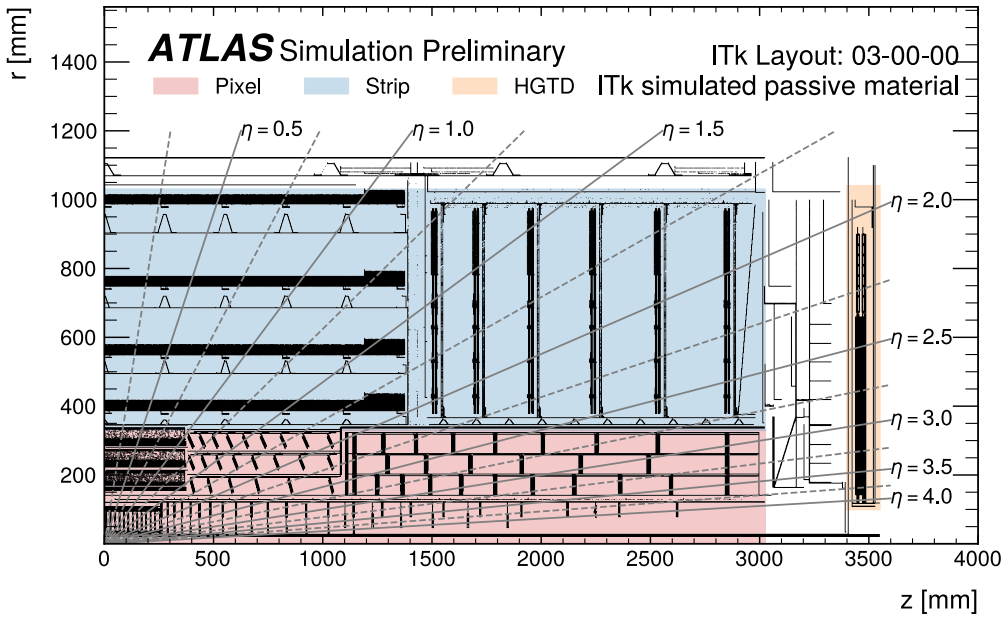
- Tracks are fundamental for ATLAS event reconstruction
- Significant portion of CPU time is used for tracking
- Tracking improvement is crucial for ATLAS reconstruction



[ATLAS Tracking SW performance]

- ATLAS plans to use ACTS for full tracking in HL-LHC (2029-)
- Not only because ACTS is advanced. Huge benefit in terms of the maintainability

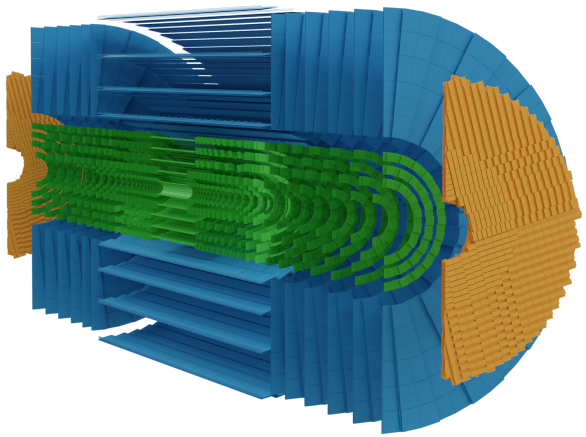
ITk



The current ATLAS tracker will be replaced with full silicon **Inner Tracker (ITk)** in HL-LHC

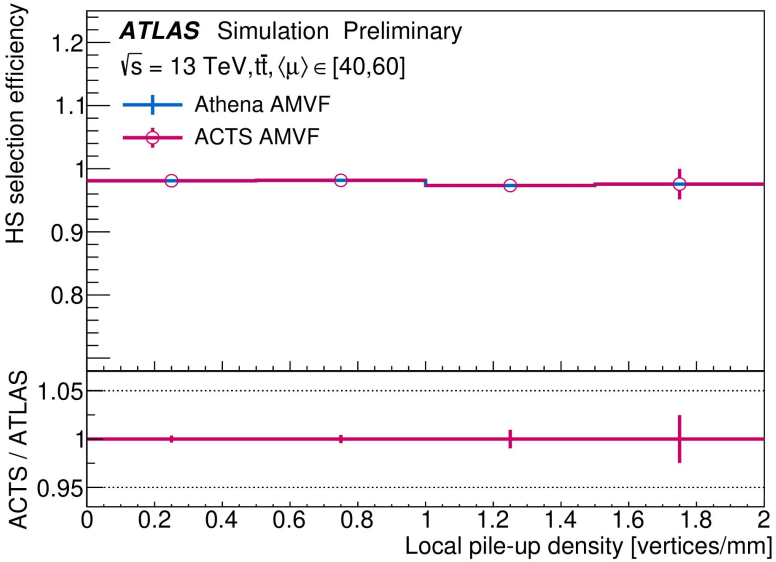
- ITk Pixel
  - 25 x 100 (innermost), 50x50 (others) μm^2
- ITk Strip
  - ~75 μm strip pitch
- HGTD (High Granularity Timing Detector)
  - 1.3x1.3 mm^2 pixel, 30 ps timing resolution

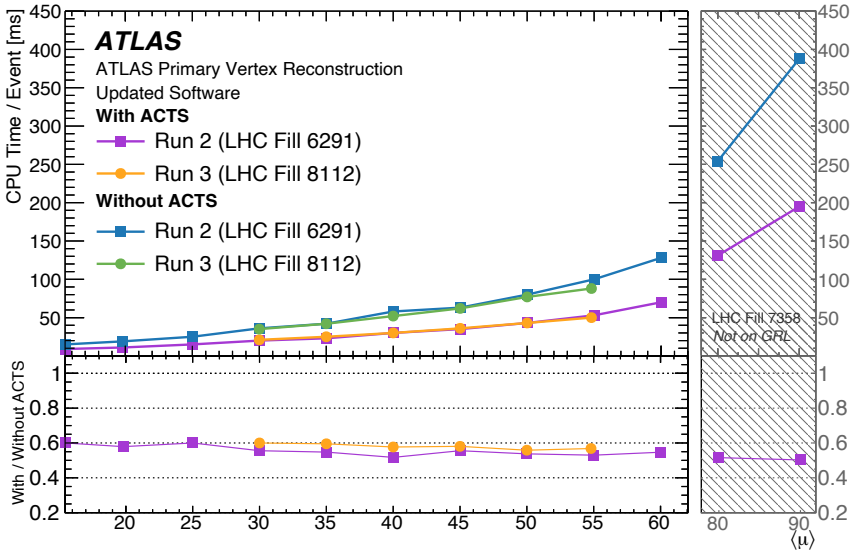
Two development lines available
- ACTS in the ATLAS reconstruction software (athena)
- Standalone ACTS with ITk geometry for R&D
  full_chain_itk.py (geometry is ATLAS internal)



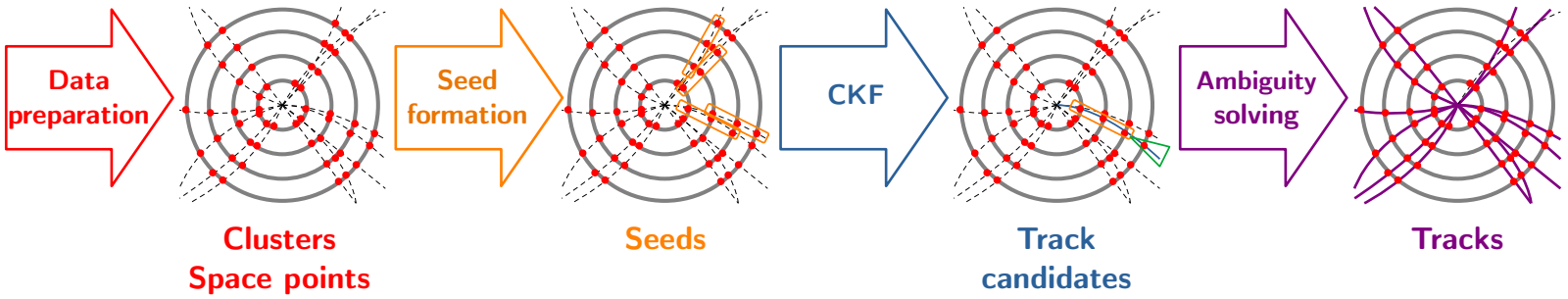
ACTS in ATLAS Run3

- ACTS AMVF primary vertex reconstruction is now fully integrated
- Already used in Run3 production (current data-taking)
  - Need to check changes due to ACTS version bumps (Carlo's talk)
- Identical physics performance
- 40% reduction of the CPU time compared to non-ACTS AMVF





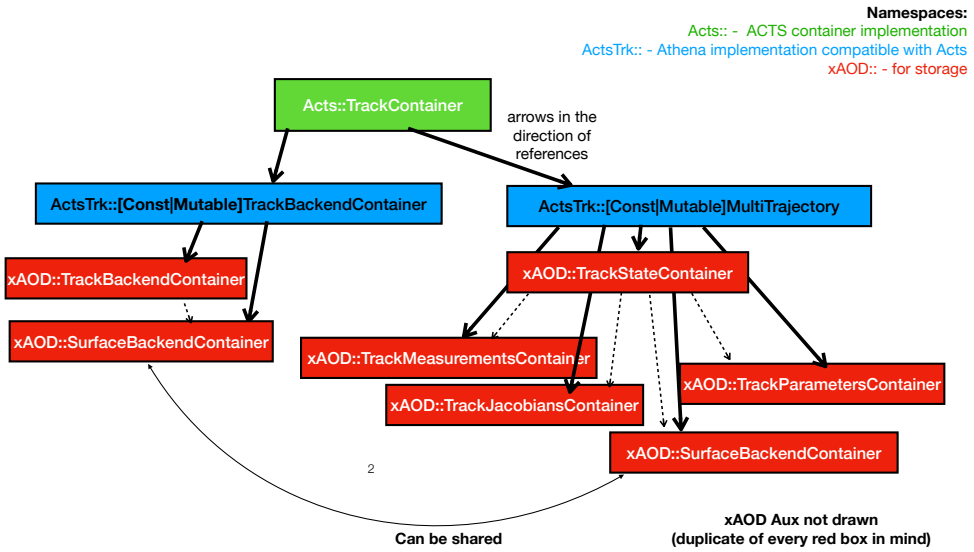
ACTS for ITk track reconstruction



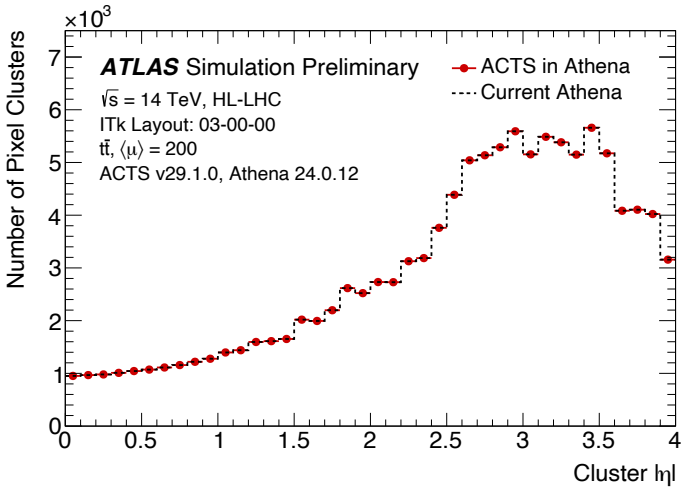
- ACTS integration into ATLAS reconstruction software (**athena**) is in progress
- Replacing old non-ACTS components with ACTS tracking tools
- At this time, the main tracking chain (clustering, SP formation, seeding, CKF, ambiguity solver) is available.
- Validation against non-ACTS algorithms, and optimization for further improvement ongoing
- Details on the ATLAS athena infrastructure in Carlo's talk

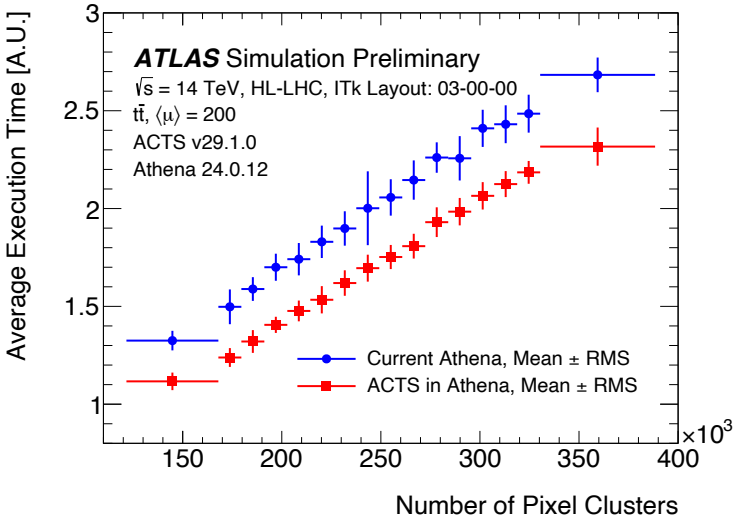
EDM

- Track and vertex EDMs for analyses and downstream customers remain
- New ATLAS EDMs (xAOD) for tracking inputs (designed with GPUs in mind, more memory efficient)
  - xAOD::UncalibratedMeasurement — base class for ATLAS specific measurements
  - xAOD::PixelCluster, xAOD::StripCluster, and more muon Measurements
  - xAOD::SpacePoint
  - ACTS-athena EDM converters available for validation
- Track EDM — Interface and memory backend are decoupled to avoid EDM conversion
  - Memory backend is fully ATLAS specific
  - Interface with dependencies on both ACTS and memory backend

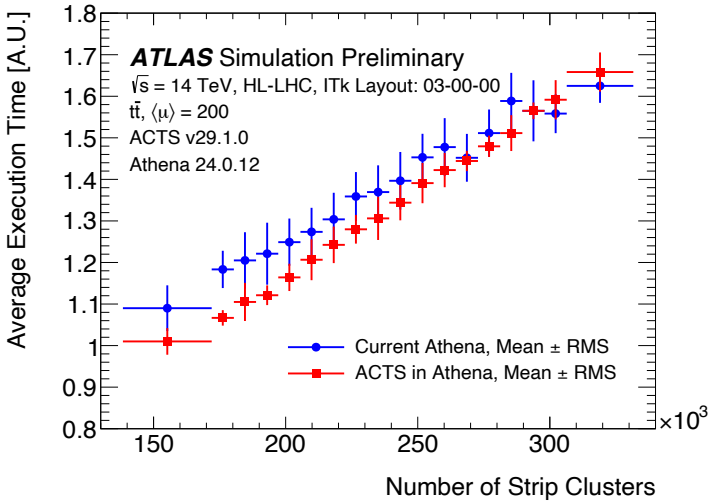


Clustering



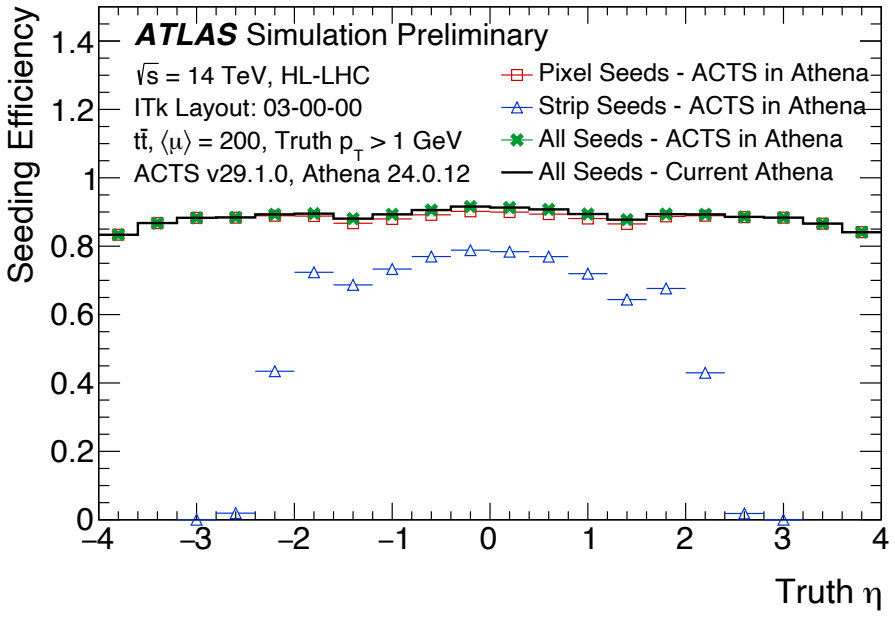


- ACTS clustering deployed in athena for both Pixels and Strips
- Algorithms are not exactly the same, but identical physics performance between ATLAS legacy and ACTS (deterministic problem)
- ACTS is 10-20% faster



Seeding

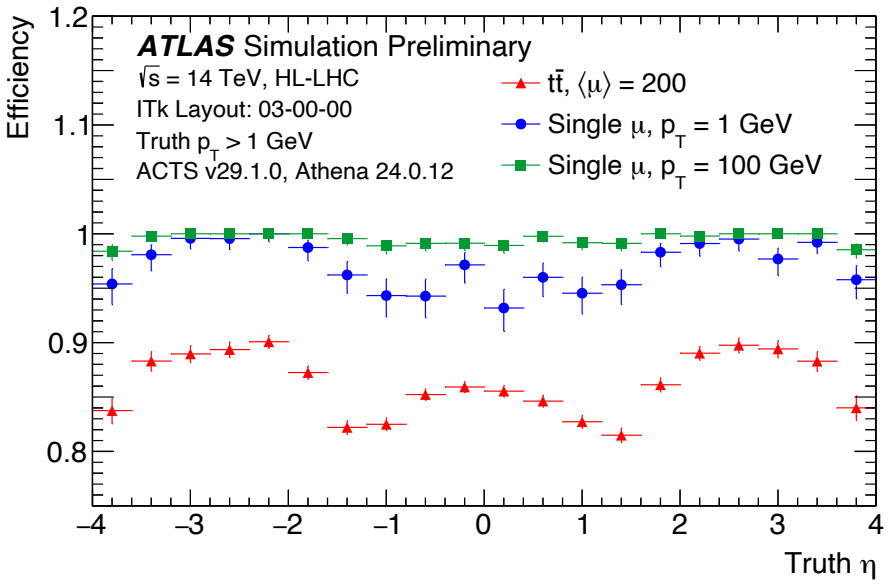
- Space Points
  - Strip SP formation deployed in athena.
  - No need for pixel SP (Just local → global transformation)

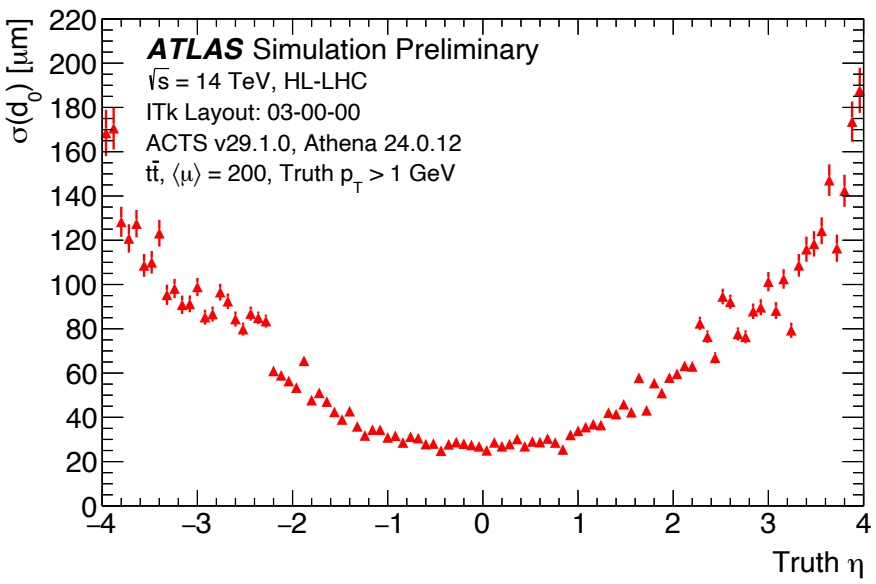


- Seeding
  - Nominal and orthogonal seeding algorithms deployed in athena.
  - Nominal seeding (originally from ATLAS) shows identical performance with compatible CPU performance
  - Orthogonal algorithm also being optimized.

- Seed selection
  - Seeding produces 5-15 seeds / track
  - Reduction of seeds processed by CKF is crucial to reduce CKF execusion time
  - Remove seeds if all measurements are already used for a trajectory previously found by the track finding
  - Another selection based on seed quality

ACTS Tracking performance





- ACTS CKF deployed in athena
  - Measurement calibration missing
  - Non-ACTS ambiguity solver used
- It is still under optimization but already shows promising physics performance
- ACTS KF validated against the ATLAS global chi2 fitter.

ACTS Tracking performance

- ACTS CKF produces more tracks than ATLAS legacy algorithm
  - The two algorithms are not equivalent and ACTS is still under developement
- ACTS CKF is still slower due to the large number of track candidates
  - Further reduction of branches required
- Post-CKF track selection based on p_T, η, and N_{hit}
- Will implement more complex ambiguity solver using track summary, eta, shared hits, cluster splitting.
- Inward propagation from starting point is missing
- KF-based seed refinement will be implemented to further reduce seeds (-30% expected)

	Legacy	ACTS
Seeds /event	31k	31k
CKF tracks /event		**41k**
Seleted tracks /event	5k	7k
Resolved tracks /event	2k	2k

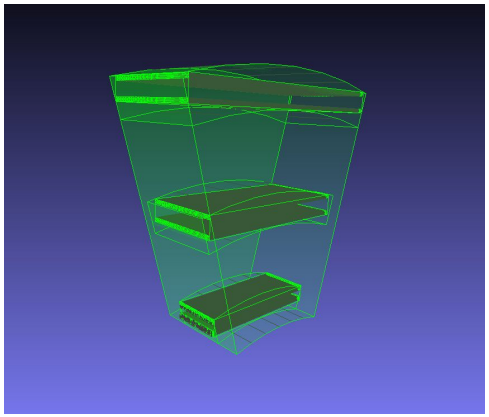
ttbar, 200 pileup

Muon

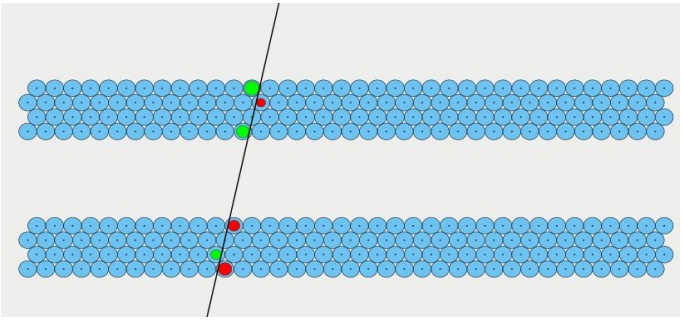
- Muon spectrometer (MS) is more complex than inner trackers
  - Different detector technologies (Drift tubes, RPC, Thin gap chambers, Micromegas)
  - Highly inhomogeneous magnetic field and large amount of material

- ACTS simplifies very complicated ATLAS MS navigation (800→200 lines of code)
  - Developed mockup MS geometries with the new ACTS geometry model for the navigation between MS chambers, and within chambers
  - Successfully tested the navigation using the navigation delegate schema of ACTS

- MS specific functionality needs to be added in ACTS
  - Gravitational wire sagging



Mock up muon sector spectrometer .
Every detector volume holds the navigation delegate



Closest approach to straw surfaces during propagation

More ongoing and future developments

- GSF for electron refitting
  - First prototype integrated. Electron refitting study planned
- Algorithms for online tracking
  - Hough transform, regional tracking, graph-based fast seeding
- ITk alignment with ACTS KF
- Tracking with HGTD
  - Extrapolate tracks to HGTD and associate HGTD hits for track time
  - ACTS track with time allows 4D-tracking
- Tracking in dense environments
  - ATLAS legacy tracking uses a dedicated neural network to deal with merged and shared clusters.
- Secondary vertex fitting is currently missing. Unification of primary and secondary vertexing is a future goal.

Summary

- ATLAS will use ACTS extensively for tracking in HL-LHC
  - ACTS PV is already used in Run3
- Finalizing the ACTS-based main tracking chain with ITk detector
  - Clustering, space point formation, seeding, CKF, and ambiguity solver deployed.
  - Despite some missing components, promising performance achieved.
  - Extensive validation campaign ongoing in both physics and CPU performance
- Develpments of ACTS tracking for dedicated reconstruction ongoing
  - Muon reconstruction
  - GSF for electrons
  - Tracking in dense environments
  - Online tracking
- Looking forward to discussing ways to boost performance with other experiments

Backup