LHCC Conference 2021

ATLAS Primary Vertex Reconstruction with ACTS

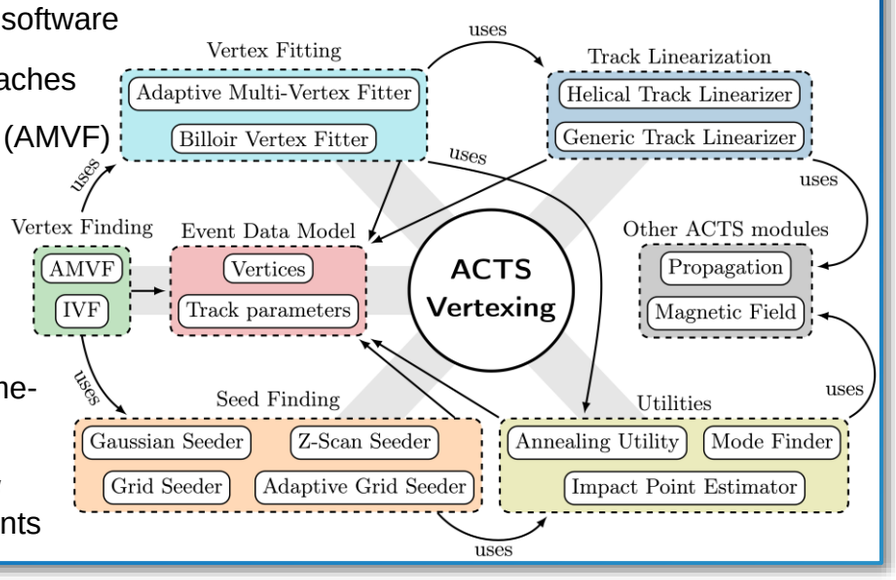
The ACTS Project

A Common Tracking Software (ACTS):

- **Detector-independent** track- and vertex-reconstruction software toolkit
- Inherently **thread-safe & highly optimized** algorithmic implementations
- Minimal external dependencies to allow easy integration and usage
- Already in use by multiple HEP experiments, e.g. ATLAS, sPHENIX, etc.

ACTS Vertexing

- Full **production-ready** vertexing software
- Two primary vertex finding approaches
  - **Adaptive Multi-Vertex Finder** (AMVF)
  - **Iterative Vertex Finder** (IVF)
- Compile-time polymorphism guarantees high modularity and optimal performance
- **4D event data model** to allow time-dependent vertex fitting
- Generic input track types to allow easy usage by different experiments

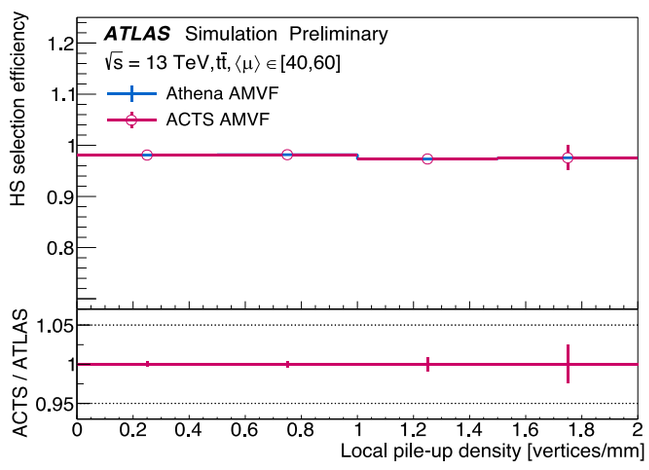


ACTS Primary Vertexing in ATLAS

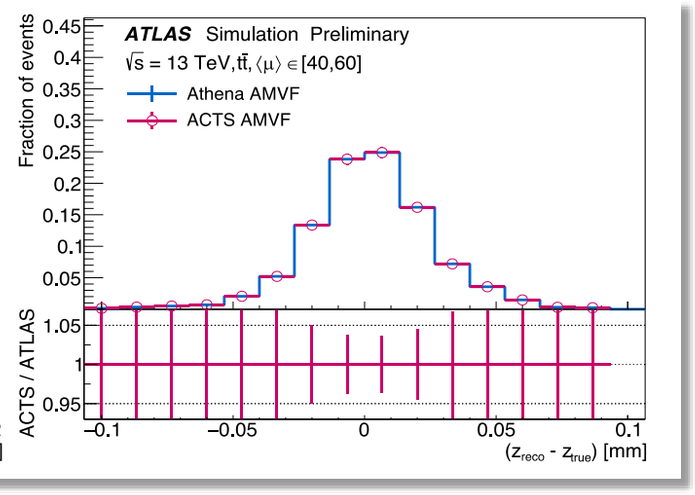
- **ACTS vertexing integrated in ATLAS** software Athena as external library
  - **Fully validated & commissioned** for single- and multithreaded execution
- ACTS AMVF to replace original Athena AMVF implementation for Run 3
- Validation of ACTS AMVF against original Athena implementations:
  - ACTS AMVF shows **identical physics performance** as Athena AMVF
  - ACTS AMVF is more than **2x faster** than Athena AMVF (see details on CPU performance below)

→ ACTS AMVF: **Default primary vertexing software in ATLAS Run 3**

Hard-scatter (HS) vertex selection efficiency



Longitudinal HS vertex position resolution



→ Identical physics performance observed in all tested conditions

New Primary Vertex Seed Finding for High Pile-up Environments

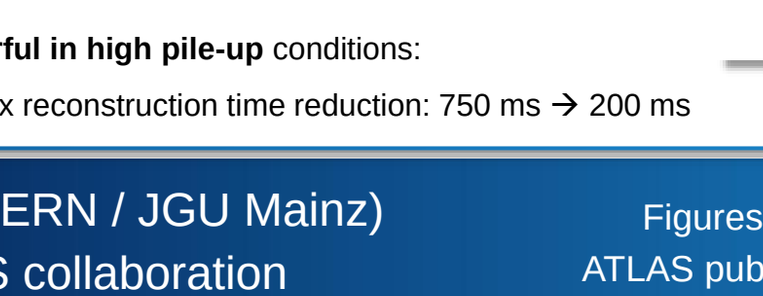
- Default Run 3 AMVF algorithm uses ”Gaussian Seeder” for vertex seed finding
  - Superb physics performance
  - But: very inefficient CPU usage in high pile-up conditions

→ **New vertex seed finder** developed & implemented in ACTS: Grid Seeder

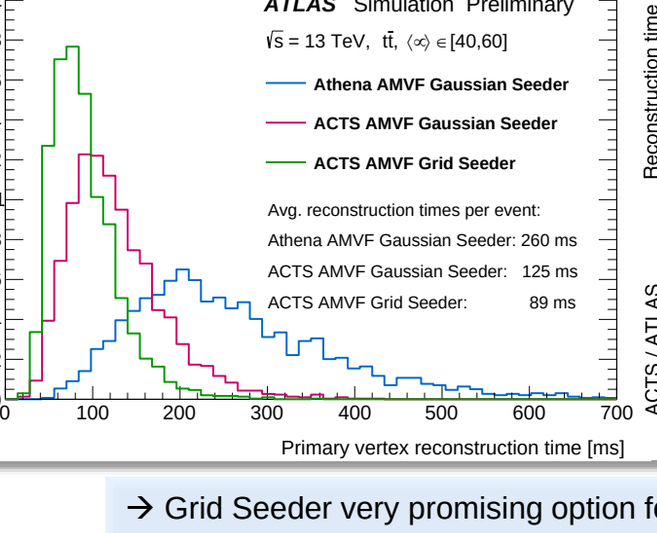
- Models tracks as 2D Gaussian track density grids
- Every track is represented by overlap vector of Gaussian grid with beam axis
- Calculates overall event track density only once and removes cached track information if track is removed from seed track collection

Example:

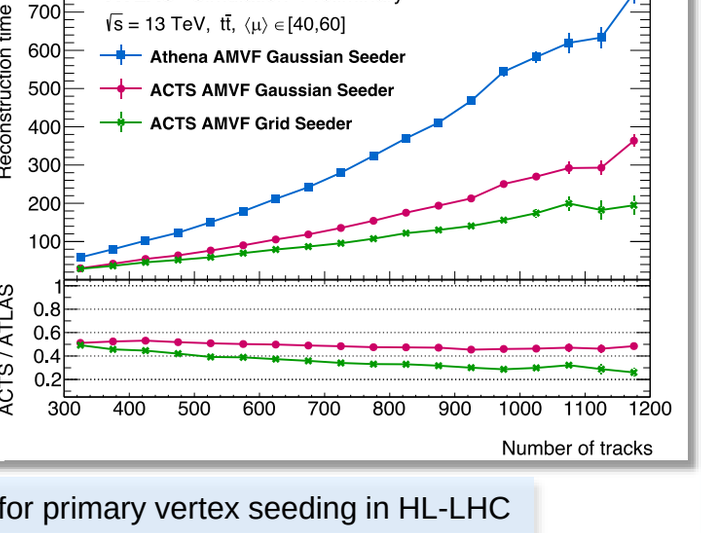
- 3 tracks represented as 2D Gaussian grids
- Only overlap vectors (red) with beam axis are calculated



HS vertex selection efficiency



HS vertex classification



- Grid Seeder in AMVF results in **similar physics performance** compared to Gaussian Seeder
- Improved HS quality: Grid Seeder results in **less contamination from pile-up** (PU) vertices

ACTS Primary Vertexing CPU Performance in ATLAS

- ACTS AMVF Gaussian Seeder (default for ATLAS Run 3) more than **twice as fast** as original Athena AMVF Gaussian Seeder implementation
- Execution time reduction per event: 260 ms → 125 ms
  - Note: Identical physics performance! (see above)
- ACTS AMVF with **Grid Seeder shows excellent CPU performance**
  - Execution time reduction: 260 ms → 89 ms in Run 3 conditions
  - Note: ~**3x faster with better physics performance**! (see above)
- Grid Seeder **very powerful in high pile-up** conditions:
  - Overall primary vertex reconstruction time reduction: 750 ms → 200 ms

Primary vertex reconstruction time per event

Reconstruction time vs. track multiplicity

→ Grid Seeder very promising option for primary vertex seeding in HL-LHC

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for the ATLAS collaboration

Figures are available in the ATLAS publication IDTR-2021-002