Time will tell
Vertex seeding at high pile-up

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Motivations

- ★ One of the challenges in high-pile-up scenarios at the HL-LHC is the increased difficulty in reconstructing the locations of proton-proton interactions (**vertexing**).
- ★ We will look at how **hit-time information** can be used to improve the vertex-finding algorithms.

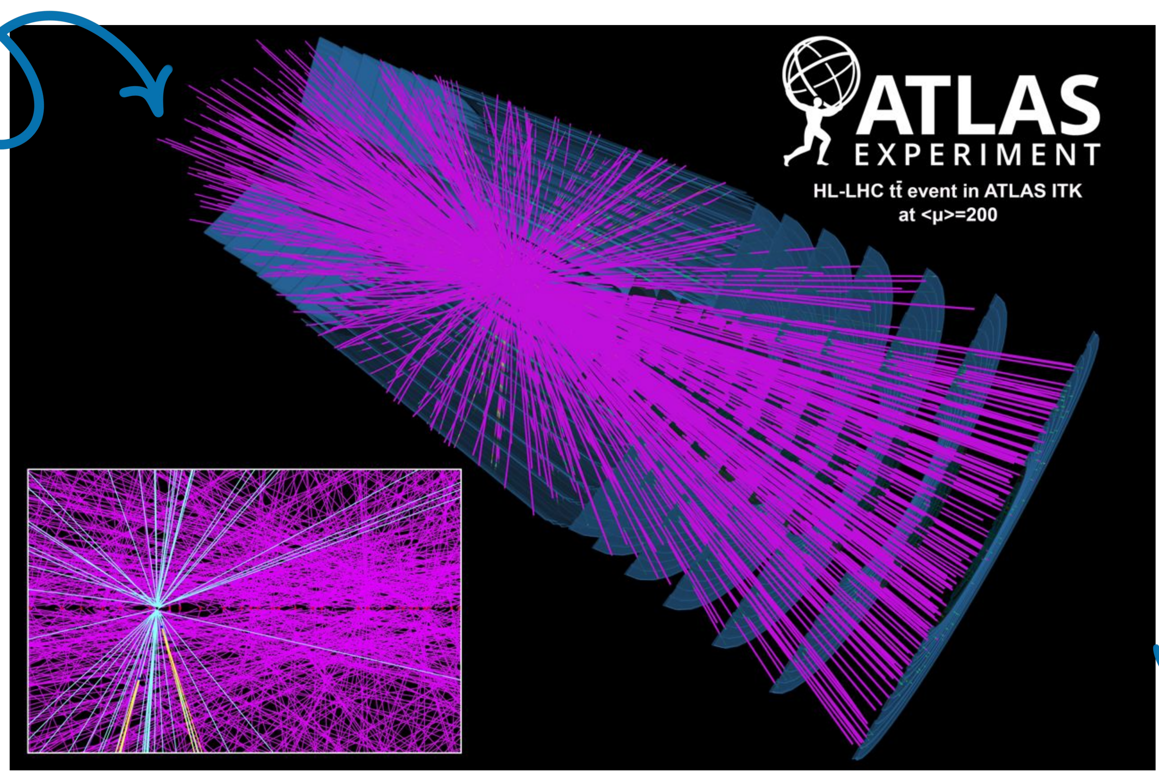


Fig 1:HL-LHC tt- event at <u>=200 showing charged particles in purple

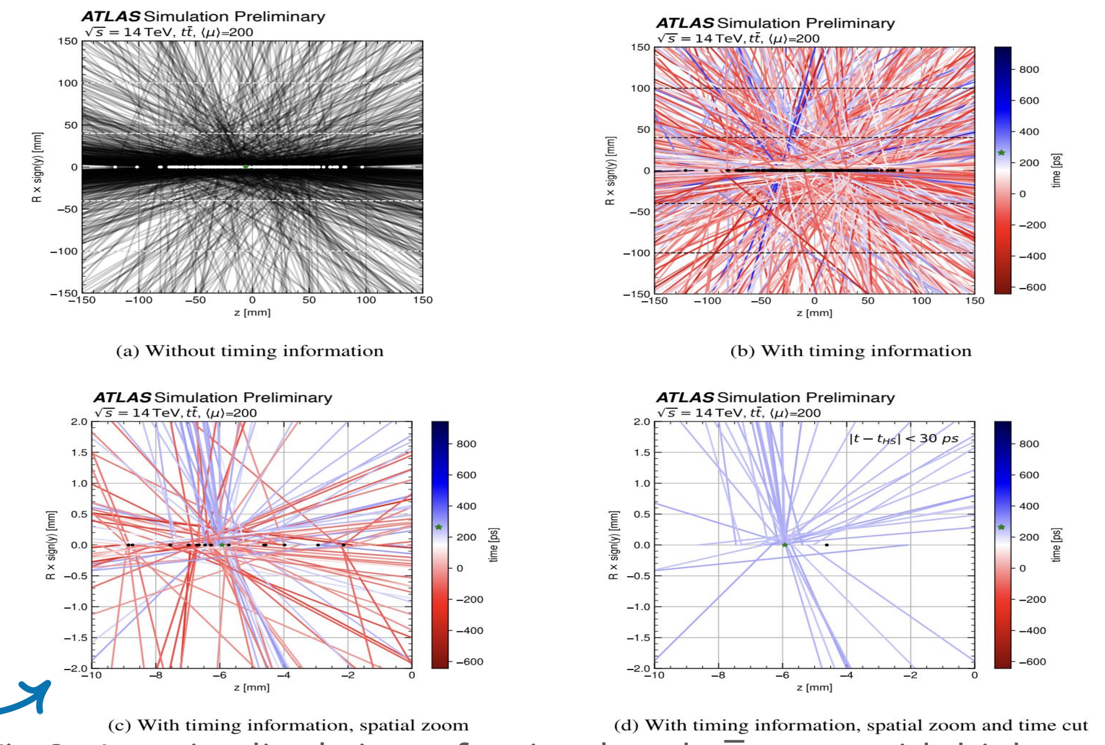


Fig 2: Longitudinal view of a simulated $t\bar{t}$ event with high μ = 200 with (1(a)) no track-timing compared to (1(b),1(c),1(d)) with track-timing information. Figure from ATLAS paper [1].

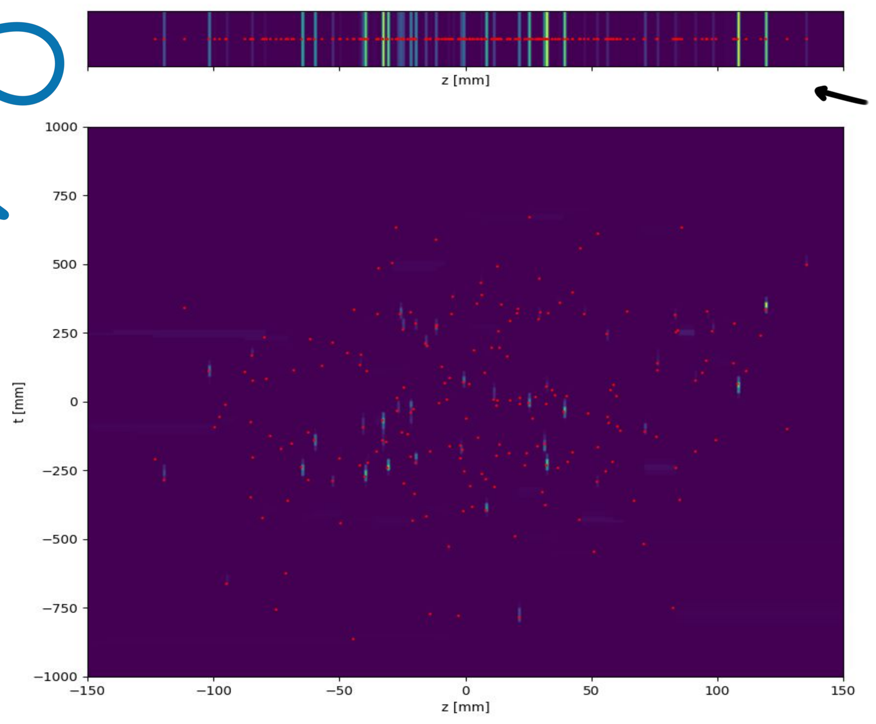
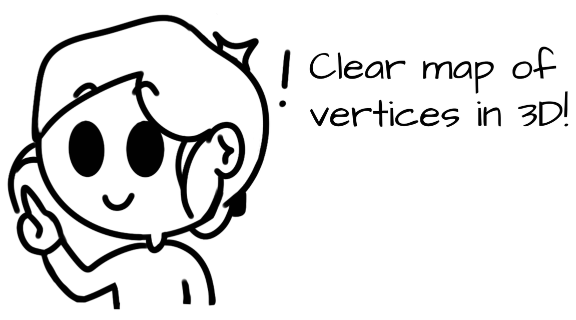


Fig 3: Seeder grid visualization in 2D (top) and 3D (bottom) to illustrate improvement of visibility of points.



Method

- ★ "Time" and "no time" algorithms use a **track density grid** to avoid recomputing Gaussians, while vertex finding algorithms use a **binned search** over high track density regions to reduce CPU time compared to the analytical Gaussian method computations.

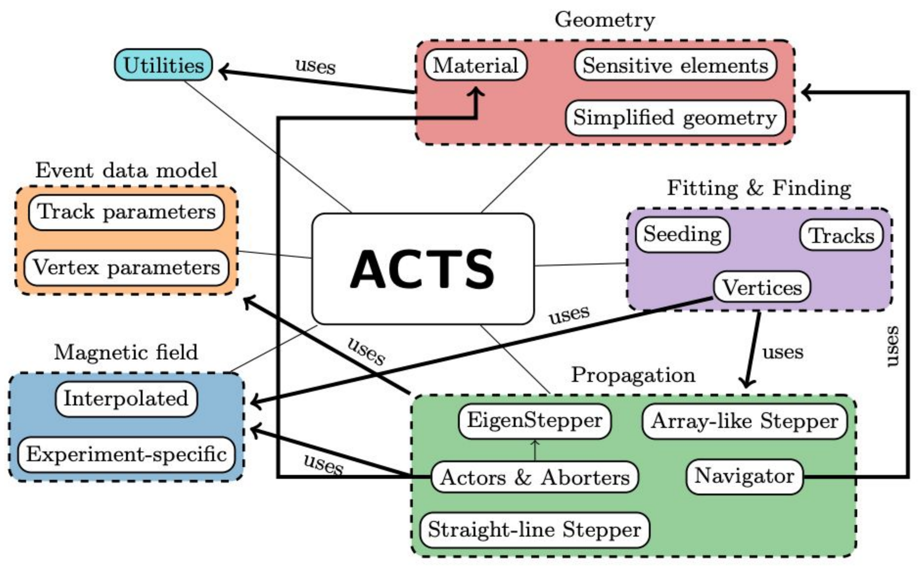


Fig 4: ACTS Project Components and their relations. Arrows show inter-module "use" relationships e.g. Steppers connect to the magnetic field module for information retrieval.

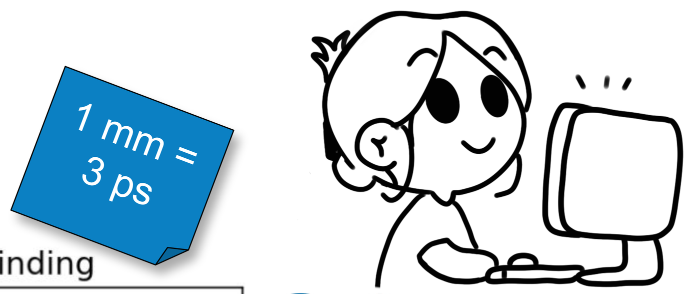


Fig 5: Performance metrics of various algorithms for multiple muon events with <100 pile-up options. Each event includes Y muons per vertex and up to X vertices per event. We studied reconstruction algorithms using the Open Data Detector (ODD) and ACTS Fatras simulation (refer to [2] de Moraes et al.; [3] Gonçalo et al.). Results show muon events, with blue lines for default parameters and orange lines for optimized parameters reducing CPU usage while maintaining clean vertices.

CPU

- ★ We investigated the effect of usage of time information on such search algorithms as well as the impact of their configuration parameters on **CPU usage and physics performance**
- ★ Most of the **improvement** comes from changes to the space parameter, though the time parameter also contributes significantly.

Vertices

- ★ It's crucial to identify the **hard scatter vertex** and keep it free from pile-up contamination.
- ★ Reconstruction algorithms must accurately determine vertex **locations** and correctly associate **tracks**.
- ★ We evaluated how different vertex finding configurations affect **accurate vertex reconstruction**.

Work in Progress

- ★ Understanding the algorithms and their configurations
- ★ Automating data collection process for the comparisons
- ★ Investigating memory consumption

Future Work

- ★ Extended parameter search for "AdaptiveGridDensityVertexFinder"
- ★ Implementation of "GaussianTrackDensityVertexFinder" with time information
- ★ Looking into alternative algorithms

Acknowledgements and Sources

I sincerely appreciate the invaluable support and contributions from the ATLAS/ ACTS contributors, the Summer Program, and my dedicated supervisors.

[1] ATLAS Collaboration. "Performance of the ATLAS Track Reconstruction Algorithms in Dense Environments." *ATLAS Public Note*, 2023, CERN

[2] de Moraes, A., et al. "Simulating the Response of a Particle Detector with FATRAS." *Journal of Physics: Conference Series*, vol. 2438, no. 1, 2023, p. 012110, IOP Publishing, doi:10.1088/1742-6596/2438/1/012110.

[3] Gonçalo, R., et al. "Performance Evaluation of the Open Data Detector with ACTS." Presented at CTD Workshop, 11 Oct. 2023