# Vertex Reconstruction and Performance in ATLAS

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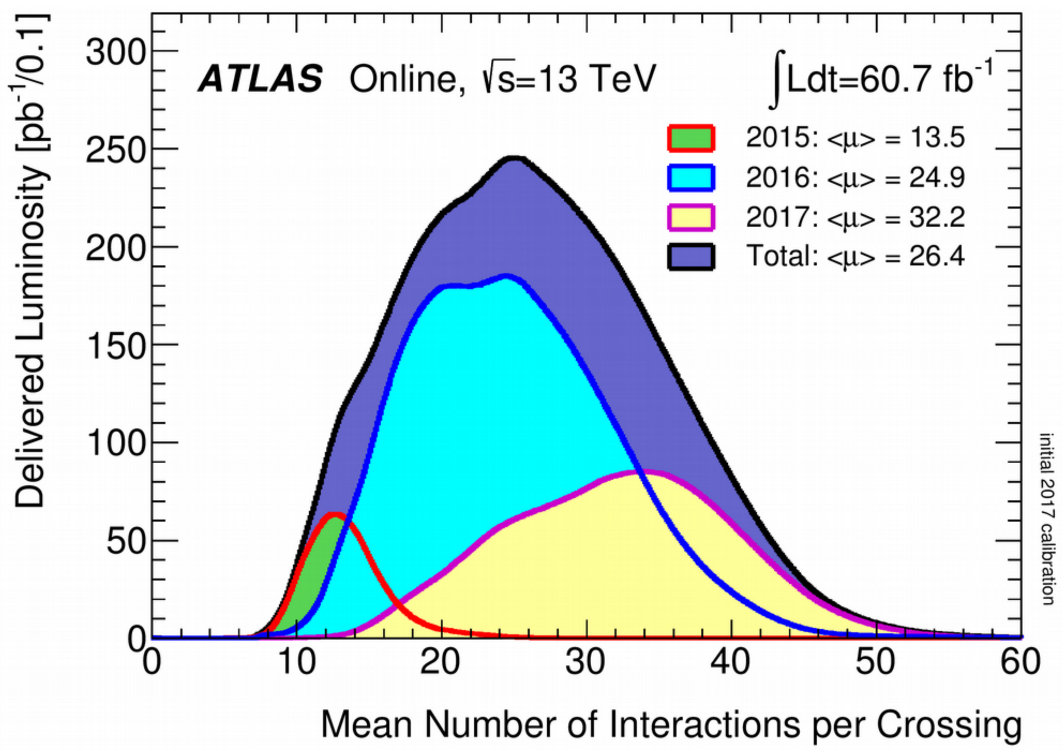
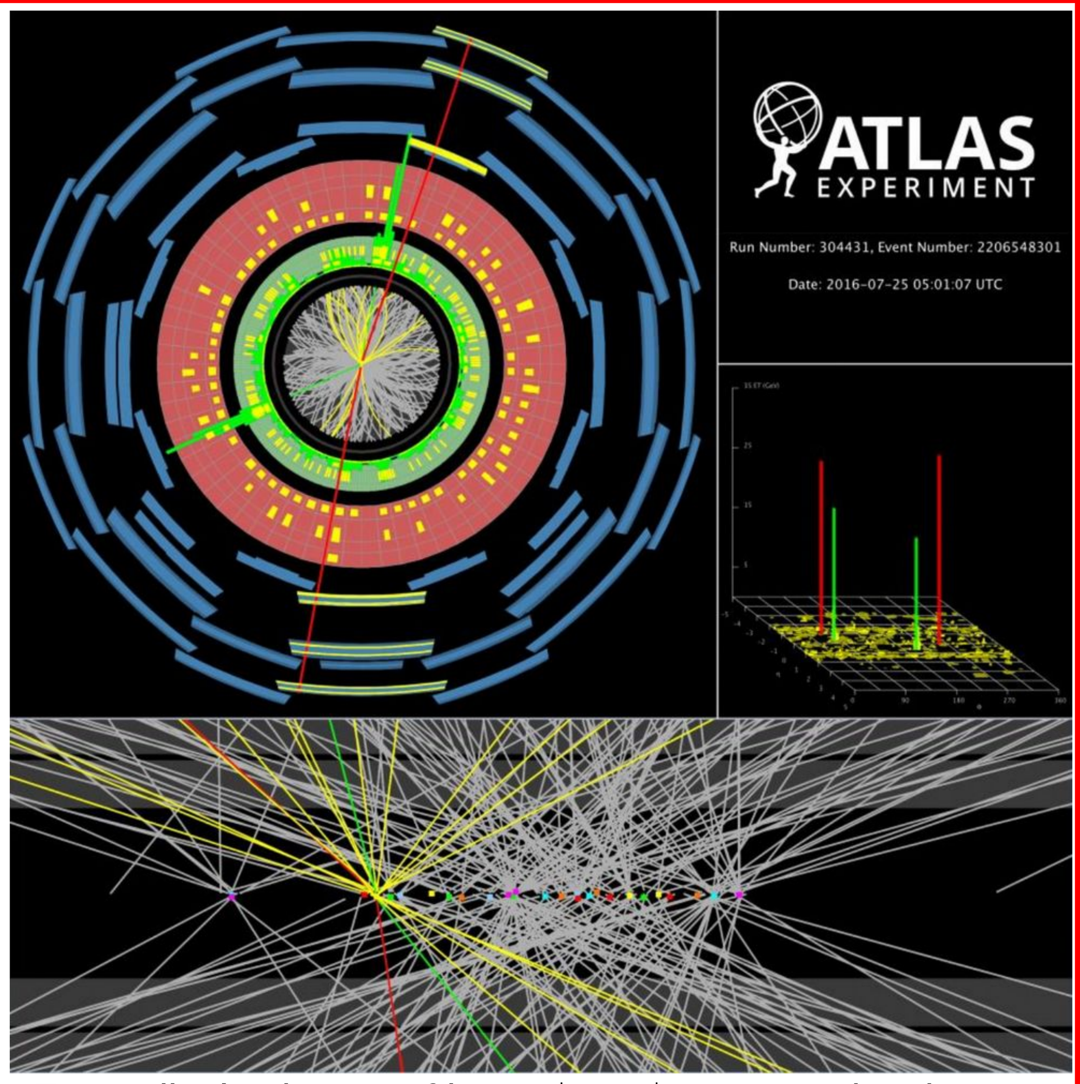
## Vertex Reconstruction Overview



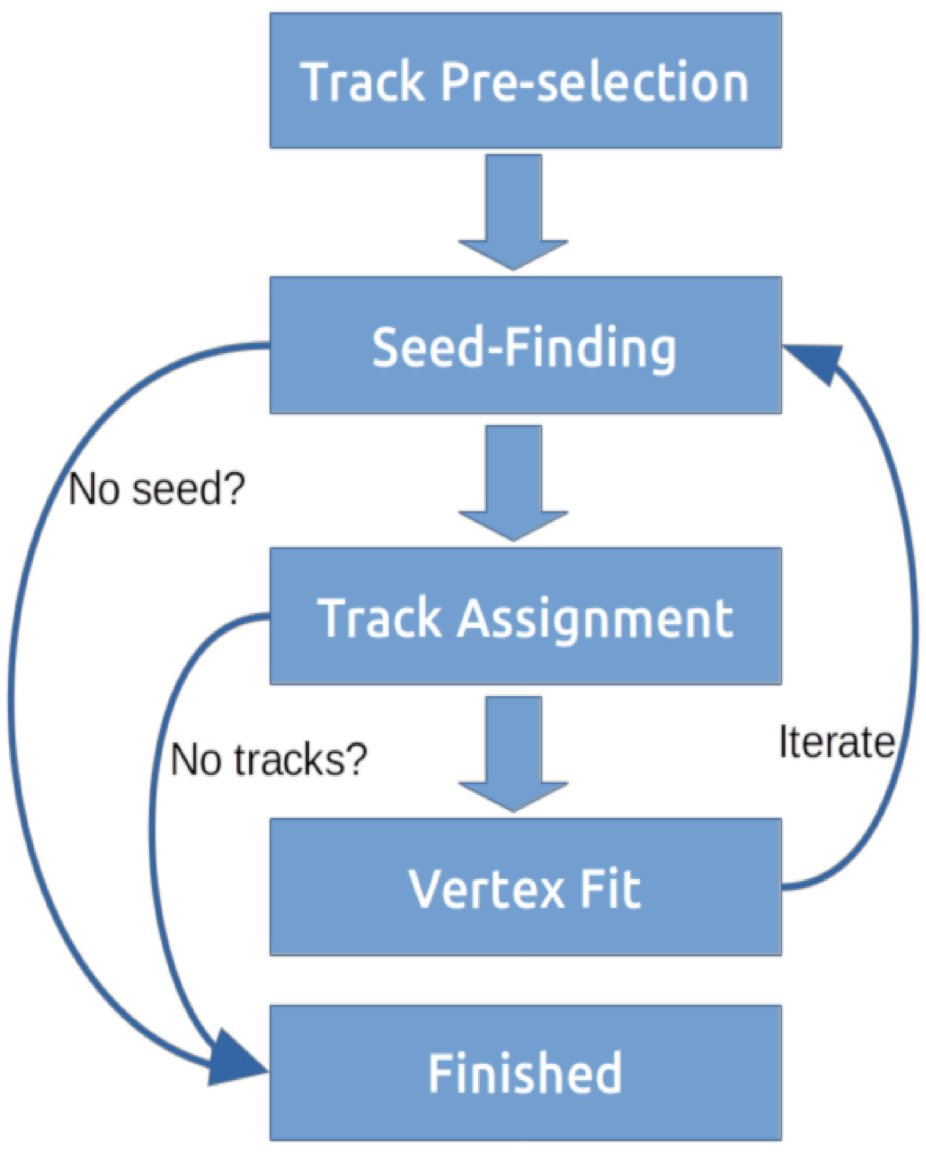

- Rare searches and precision measurements benefit from increased luminosity.
- Increasing luminosity means more collisions per beam crossing → pileup ($\mu$).
- Pileup tracks may contaminate hard-scatter vertices
  - Hard-scatter tracks may be split between multiple reconstructed vertices.
  - Nearby pp interactions may be merged into a single reconstructed vertex.
- Vertices are reconstructed with high efficiency, but merging increases with pileup.
- Contamination by pileup tracks can degrade vertex resolution.
- Vertex position resolution is calculated with MC, or with data-driven Split-Vertex method [2].

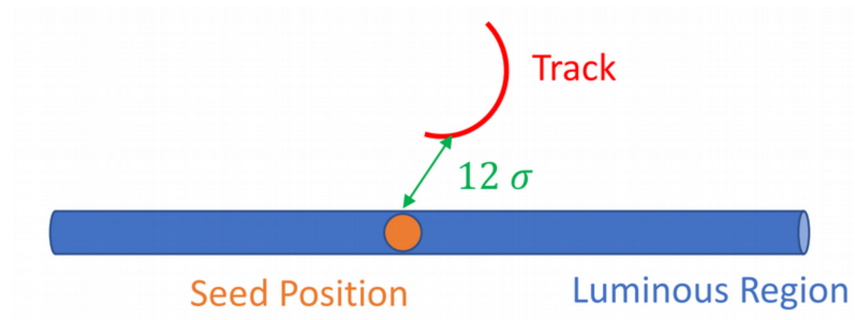



Event display image of $h \to \mu^+ \mu^- e^+ e^-$ event showing additional pielup vertices.

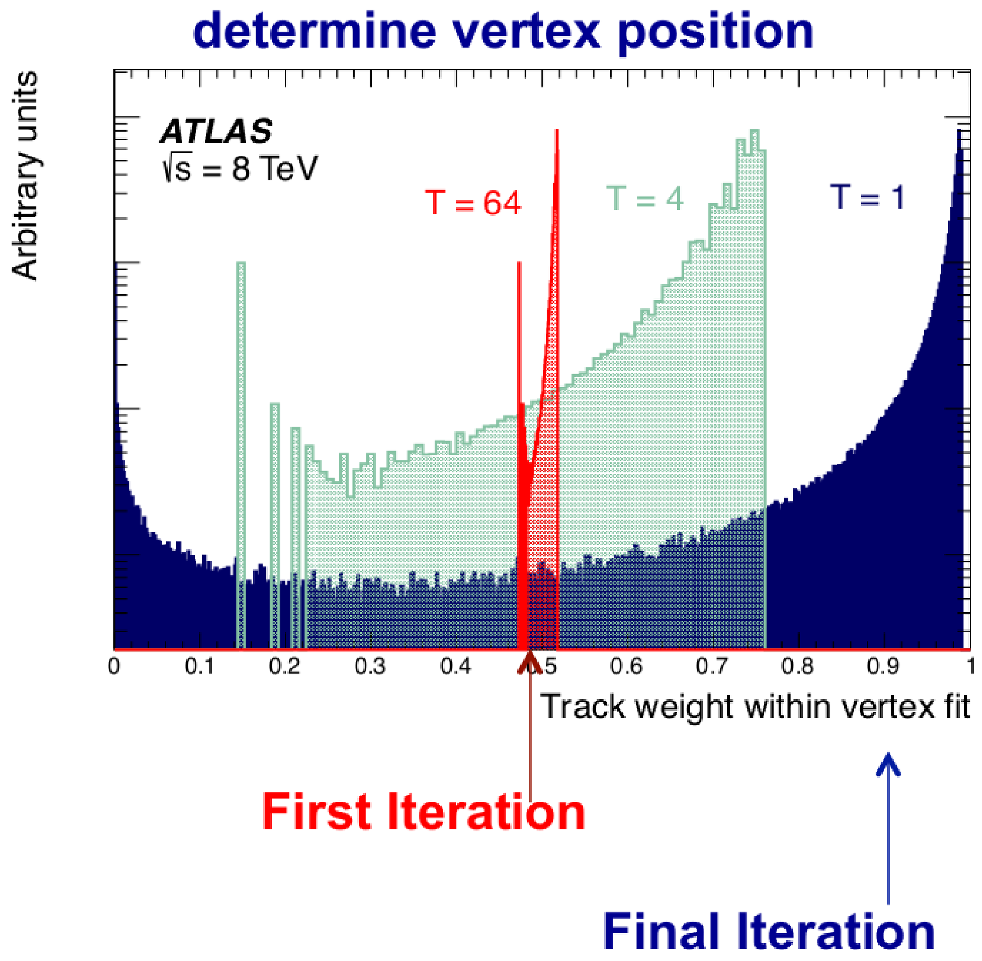
## Vertex Fitting

- **Tracks:** A set of tracks satisfying vertex track selection criteria is defined.
- **Seed** position for the first vertex is selected. Seed is placed at the (x,y) centre of the beam spot and the estimated mode in Z, considering the track points of closest approach to the beam spot centre.
- **Track Assignment:** Tracks within 12 σ (calculated from track measurement errors only) of the seed are selected for fitting.
- **Fit:** Use tracks and seed to estimate the best vertex position with a fit → an iterative procedure: in each iteration less compatible tracks are down-weighted and the vertex position is recomputed. An "adaptive" vertex fit, based on the Kalman filter, is used. Each track's weight is determined by its consistency with the previous iteration of fitting.




**Distributions of progressive track weights used to determine vertex position**




- Outliers are gradually de-weighted according to an annealing schedule.
- After final iteration most tracks have weight close to 1 (inlier) or 0 (outlier).
- After vertex position is Determined, far outliers (weight < 0.01 and $\chi^2 > 36$) are removed from the vertex and available to future vertices.
- The procedure is repeated with the remaining tracks in the event.

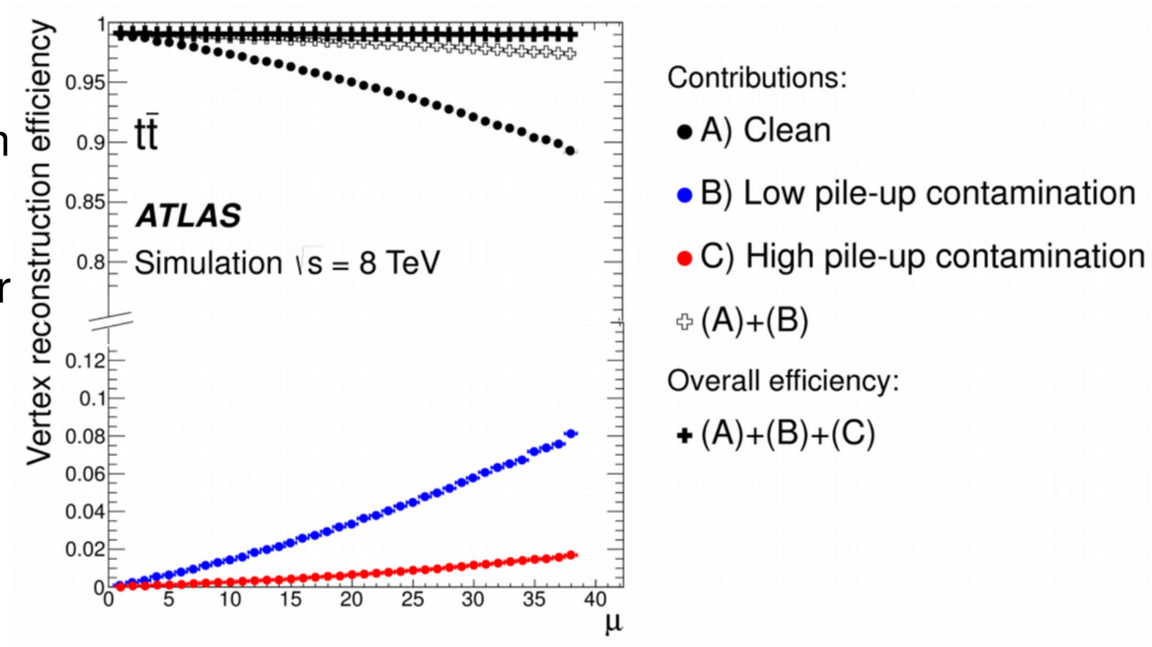
## Reconstruction Efficiency

- Because of merging of vertices, the number of reconstructed vertices does not track the number of pp interactions ($\mu$) perfectly.
- However, hard scatter vertices with reconstructed tracks in the detector have nearly 100 % efficiency for pileup in Run 2.
- Although efficiency is not affected strongly by pileup, increased contamination degrades vertex resolution.

**Clean**: The hard scatter contributes at least 70% of the track weight to one reconstructed vertex, and does not contribute more than 50% of the weight of any other reconstructed vertex

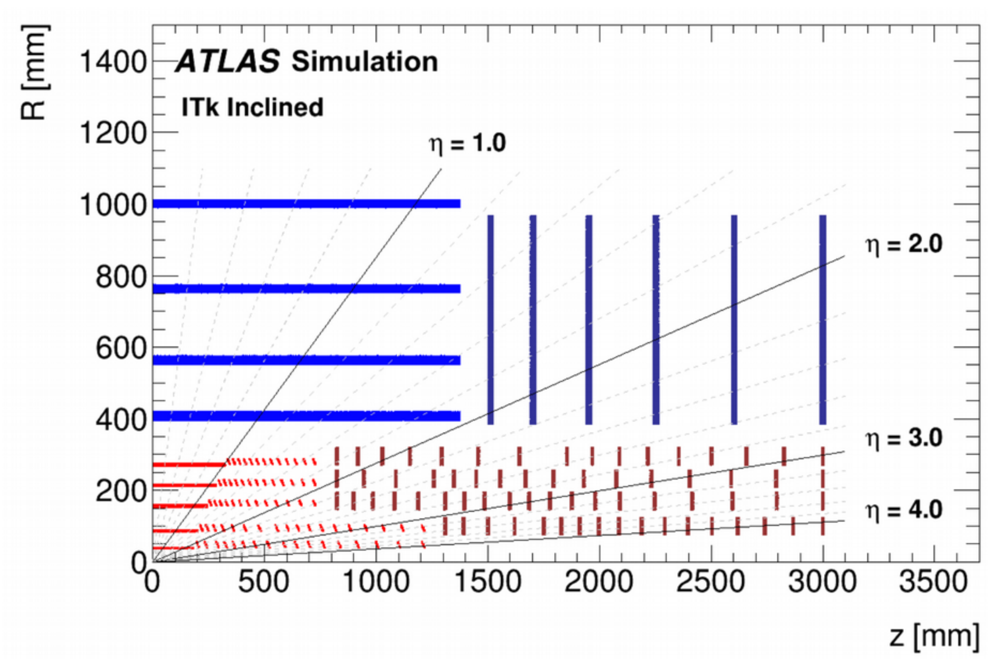
**Low pileup**: The hard scatter contributes at least 50% of the weight to one merged vertex

**High pileup**: The hard scatter contributes 1-50% of the weight to one merged vertex. [2]




## High Luminosity and ITk

- High-Luminosity LHC will produce ≥ 3000 fb$^{-1}$ of 14 TeV pp data by ~2035.
- Will improve precision of Higgs/SM measurements and searches for BSM physics.
- **Upgraded Inner Tracker (ITk)** will replace current ATLAS tracker:
- All-silicon, hermetic tracking in $|\eta|<4.0$, increased from $|\eta|<2.5$ for Run 2.
- Designed to cope with high radiation doses, bandwidth, and <μ> = 200 pileup.
- Strip and Inclined Pixel detectors modeled with GEANT4 simulation.
- Preliminary optimization of tracker layout performed.
- Track reconstruction: Silicon hits → clusters → tracks.
- Simulation and tracking documented in recent ITk Strip TDR [1].
- Order of magnitude Improvement in track resolution.




ATLAS EXPERIMENT

References
[1] ATLAS Collaboration. "Technical Design Report for the ATLAS Inner Tracker Strip Detector". ATLAS-TDR-025, CERN-LHCC-2017-005 (2017)
[2] Eur. Phys. J. C 77 (2017) 332