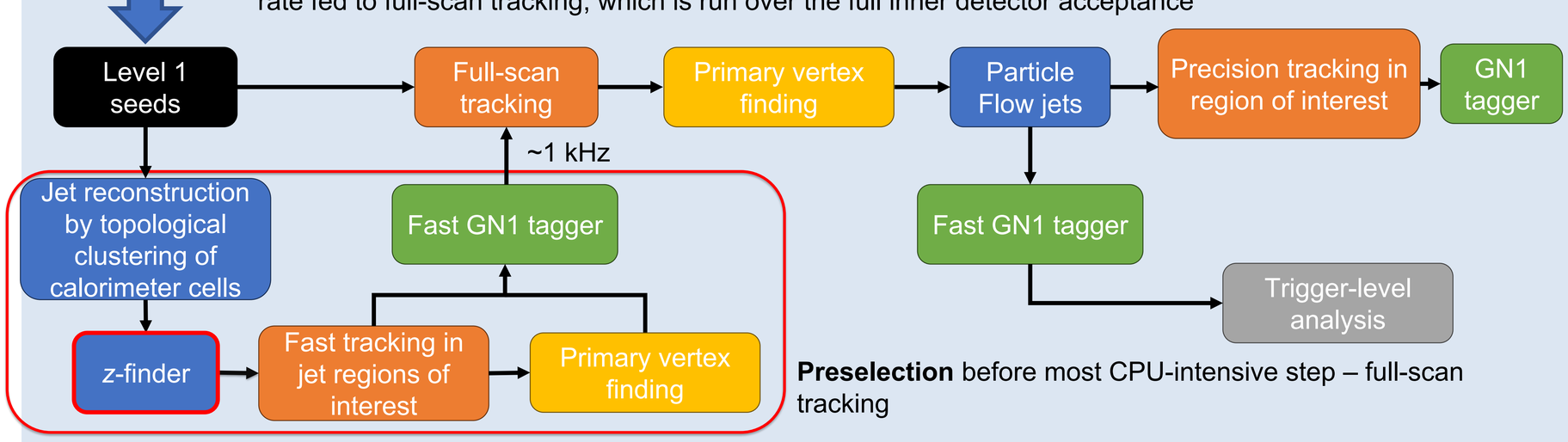
Fast determination of the primary vertex z-position prior to track reconstruction in the ATLAS b-jet trigger

Introduction

- Improving the trigger efficiency is particularly important for rare signatures such as $HH \to b\bar{b}b\bar{b}$
- b-tagging requires track reconstruction – most time-consuming part of the trigger
- **Reducing the CPU cost of tracking** early in the chain could allow loosening requirements to increase acceptance and running algorithms to further improve b-tagging

High-Level Trigger b-jet chains

- In 2023, primary vertex finding has been added to the preselection stage [1]
- Vertex information improves performance of neural-network-based tagger, (fast) **GN1** [2], and helps reduce the rate fed to full-scan tracking, which is run over the full inner detector acceptance

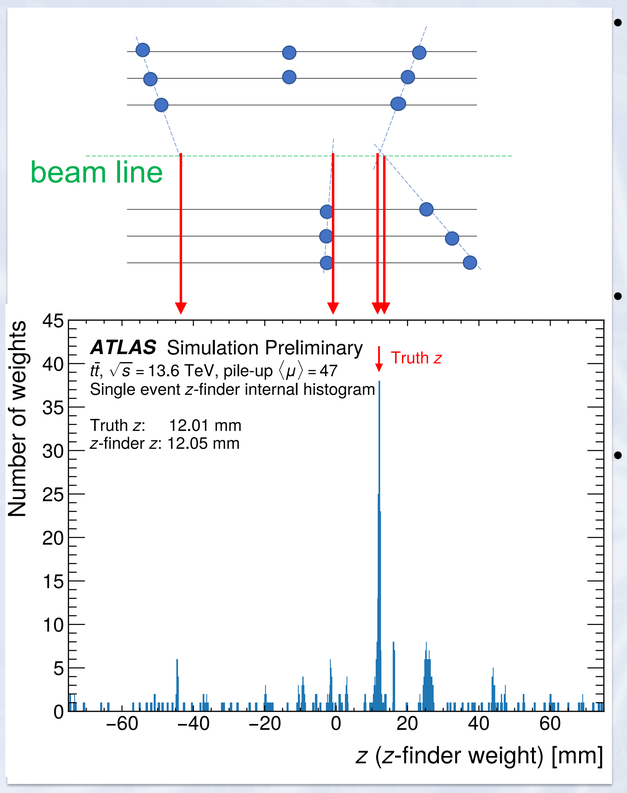


Preselection before most CPU-intensive step – full-scan tracking

- Proposed addition of ***z*-finder** [3] prior to track reconstruction to **reduces CPU cost of fast tracking** by almost a **factor of 2**

z-finder algorithm

- Finds z-coordinate of primary vertex prior to track reconstruction

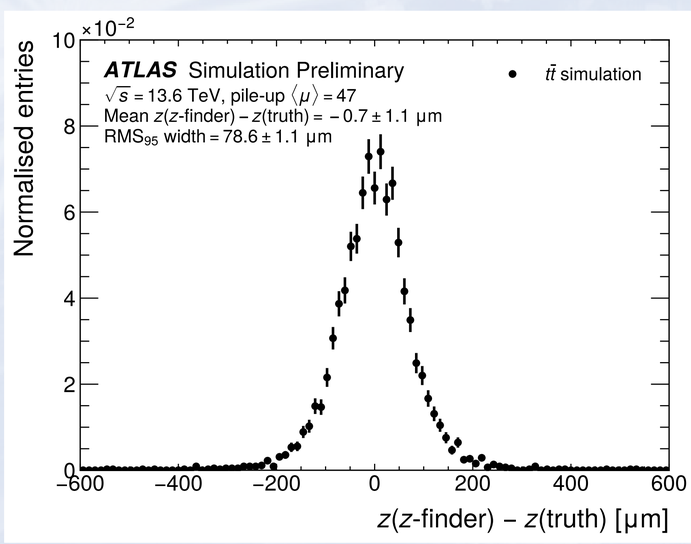


- Calculates z-positions by **extrapolating from pairs of space points** to beam line:

$$z_V = \frac{z_2\rho_1 - z_1\rho_2}{\rho_1 - \rho_2}$$

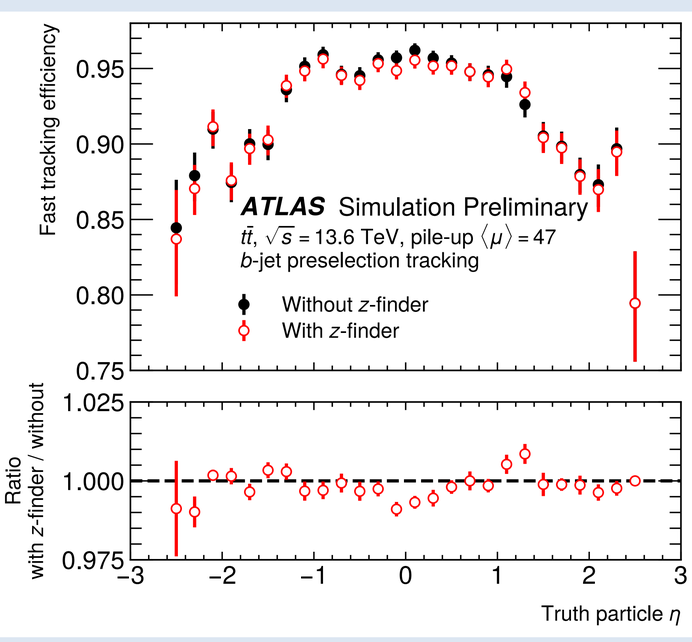
and creates a **histogram** of these, with z bin width 0.2 mm

- Only pairs that are **close together in ϕ**, and which are accompanied by a **third hit** consistent with being on the same track in a layer further out, are used
- Works best with only **barrel pixels**

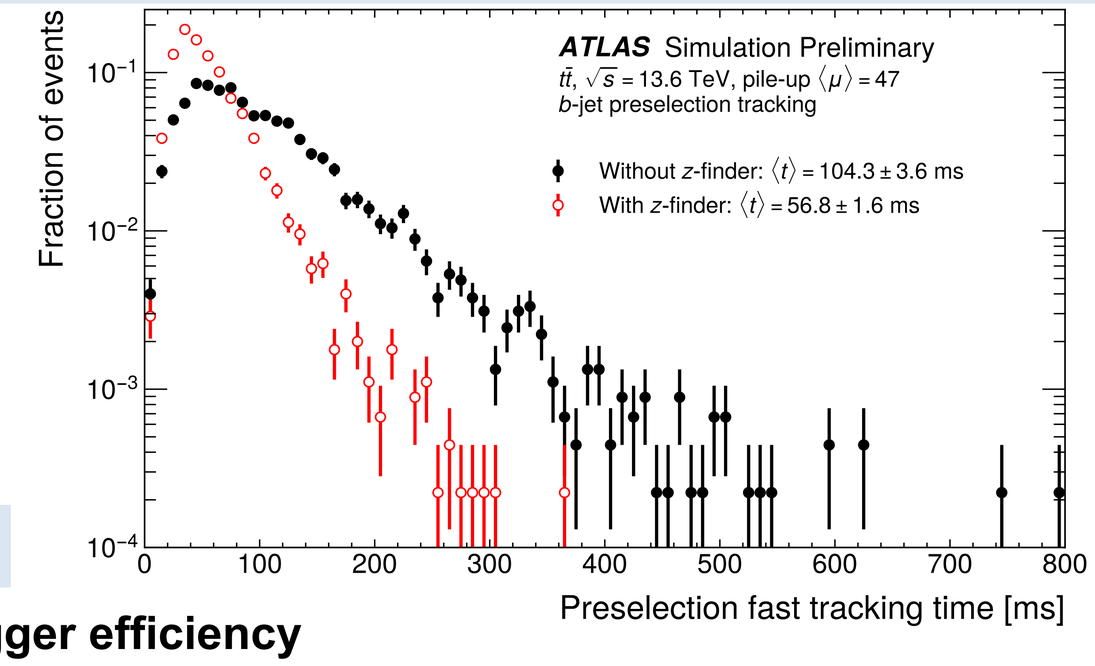


- z-position(s) calculated as the **weighted average** from 3 consecutive bins with the maximum number of entries in the z-histogram
- Correct generally to 0.4 mm

Preselection fast tracking performance

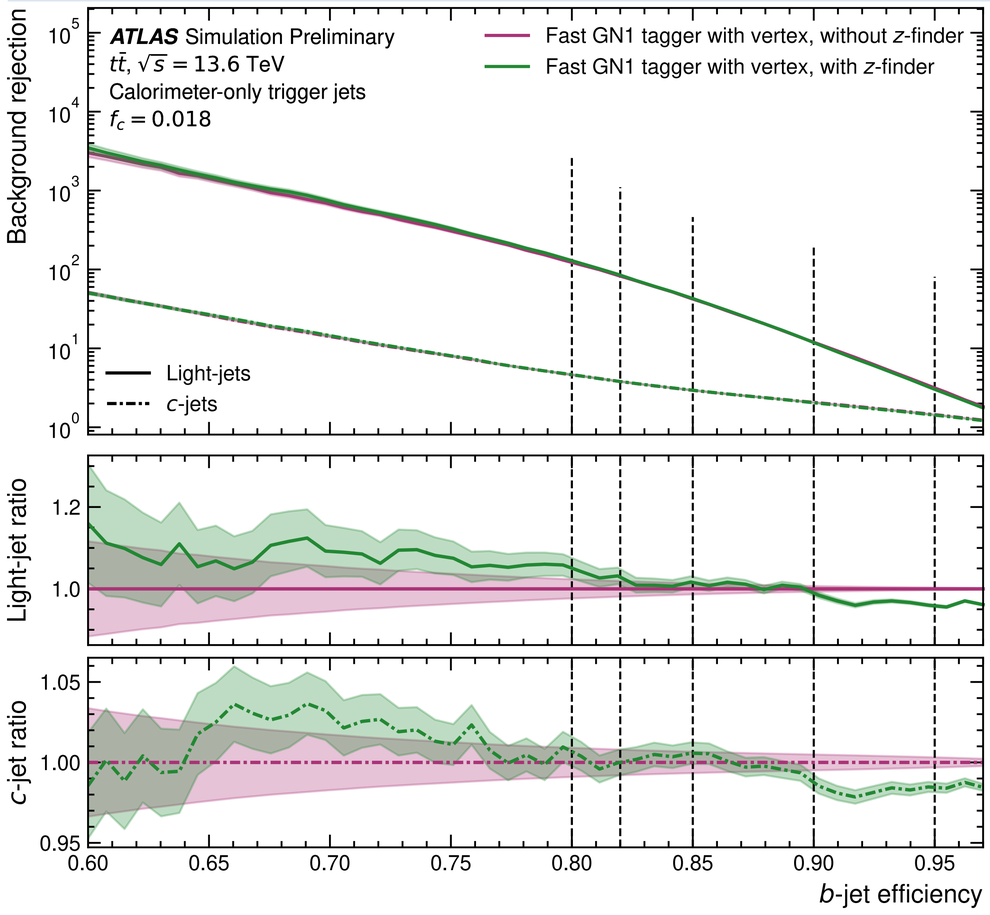


- Fast tracking in preselection currently performed in region of interest (ROI) restricted around calorimeter jets in pseudorapidity, η, and ϕ
- Further **restricting the ROI in z** to ± 20 mm around z-positions found by the z-finder for barrel layers leads to almost **no change in tracking efficiency**, but **reduces the tracking time** by almost a **factor of 2**
- Efficiency drops slightly around $\eta = 0$, but increases at $1.0 < \eta < 1.4$



Preselection b-tagging performance

- Fast GN1 tagger has **not yet been retrained** on tracks produced with the z-finder, but there is **almost no change** in performance



$HH \to b\bar{b}b\bar{b}$ trigger efficiency

- For trigger shown, **preselection** requires 2 b-tagged jets at **85% efficiency** and 2 more jets, all with $p_T > 20$ GeV
- **Almost no change** in full b-jet trigger efficiency when adding z-finder alone:

Without z-finder	With z-finder
54.43%	54.44%

- Likely possible to achieve improvements with simple changes such as tagger retraining, discriminant cut retuning
- Processing time saved with the z-finder will allow running preselection tracking in more events or with higher precision to improve the overall efficiency for b-tagged events

References

[1] *Fast b-tagging at the high-level trigger of the ATLAS experiment in LHC Run 3*, arXiv:2306.09738 [hep-ex]

[2] *Graph Neural Network Jet Flavour Tagging with the ATLAS Detector*, ATL-PHYS-PUB-2022-027

[3] *Determination of the z position of primary interactions in ATLAS*, ATL-SOFT-2002-007

Plots taken from the ATLAS public TWiki: https://twiki.cern.ch/twiki/bin/view/AtlasPublic/BJetTriggerPublicResults