PROCEEDINGS OF SCIENCE

B hadron reconstruction in early ATLAS Run 3 data

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The ATLAS B physics program will exploit data from Run 3 of the LHC. Aspects such as new hardware and software triggers, and updated reconstruction code necessitate a recommissioning of the reconstruction and analysis chain. The performance of B hadron triggering and reconstruction in the 2022 data will be shown.

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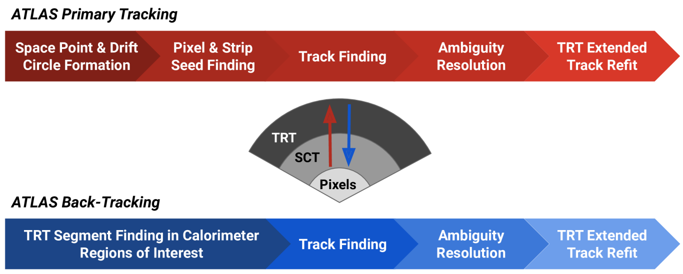


Figure 1: ATLAS Run-3 Track finding process [2].

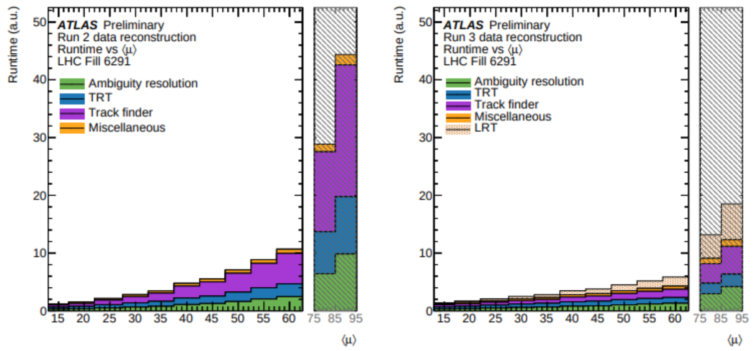


Figure 2: CPU time of Run 2 vs Run 3 track finding against pileup [2].

1. The ATLAS Detector and Run 3 upgrades

The ATLAS Detector [1] is a general purpose detector with nearly complete coverage in solid angle. It is built from 4 main detector subsystems; the Inner Detector (ID), the Liquid Argon calorimeter (LAr), the Hadronic calorimeter (HCal), and the Muons Systems (MS), linked together by the ATLAS Trigger and Data Acquisition system (TDAQ). Many hardware and software improvements were made to ATLAS for Run 3. Major upgrades were made to the LAr trigger and readout systems, producing higher granularity and additional topological information. Valuable to B-Physics studies is the inclusion of the New Small Wheels (NSW) and the Thin Gap Chambers (TGC) into the MS, providing advanced tracking and improved muon information in the L1 triggers, aiding offline reconstruction and improving rate reduction and pileup rejection in the endcaps.

2. Track and Vertex Reconstruction in Run 3

Along with improvements to tracking for the trigger, reconstruction of tracks and vertices for physics analysis has been improved [2]. For tracks, the process is shown in Figure 1. Signal clusters from ID are converted into 3D points, tracks are seeded from three of these, and the trajectories are used to build search roads; sets of clusters compatible with the seeds. A combinatorial Kalman filter extends the track into the compatible clusters and an ambiguity resolution procedure is applied for track purity and to remove low quality candidates and overlaps. An extension to the TRT is

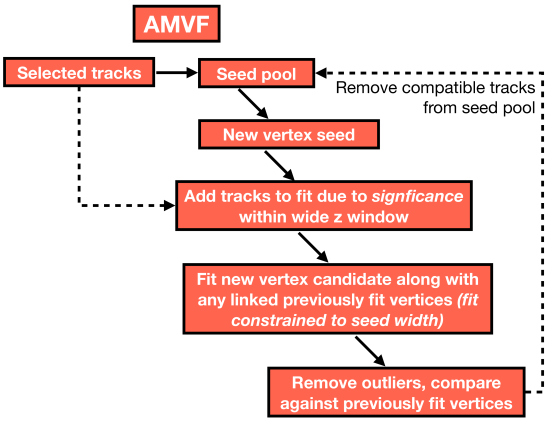


Figure 3: ATLAS Run-3 vertex finder algorithm [3].

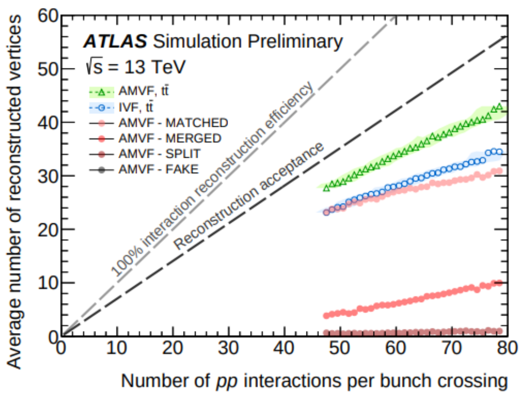


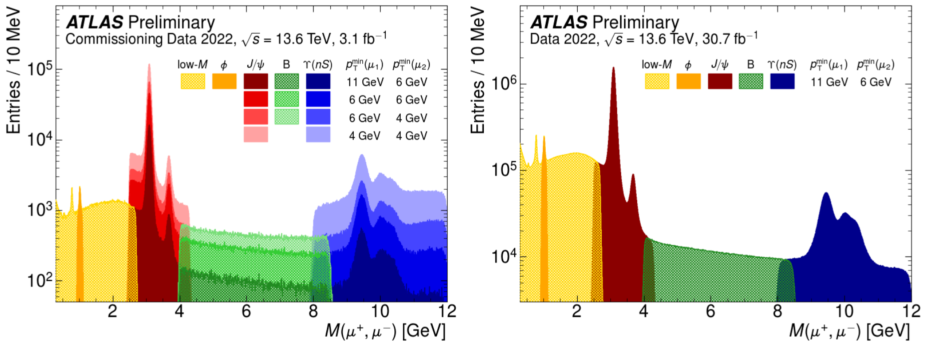
Figure 4: Average number of reconstructed vertices against pp interactions per crossing [3].

attempted, prompting a refit of the full track, and the procedure is conducted in reverse using seeds selected from the TRT using RoI's generated from the Electromagnetic Calorimeter. This produces multiple improvements to track reconstruction: failing tracks abort earlier, track candidates are of a higher standard, and there is improved performance at high pileup. In general, the algorithm runs with half the CPU time of the previous Run 2 version.

Tracks are passed to the new Adaptive Multi-Vertex Fitter (AMVF) algorithm [3], detailed in Figure 3. The Track Density along the beam axis is modelled and vertex candidates are identified using density peaks. *All* eligible tracks, those assigned and previously unassigned to a vertex, can be assigned to a nearby vertex. The Run 2 approach used only previously unassigned tracks. Tracks are then fit to vertices using a weighted Kalman filter and any new fits to a vertex prompt a full refit. Refits propagate to all vertices sharing a track. Verticies are accepted based on their track compatibility, separation, and sufficient weighting. There are marked improvements in tracking performance in Run 3 leading to a recovery of 35-50% of reconstructable vertices missed by the

Run 2 method, as shown in Figure 4.

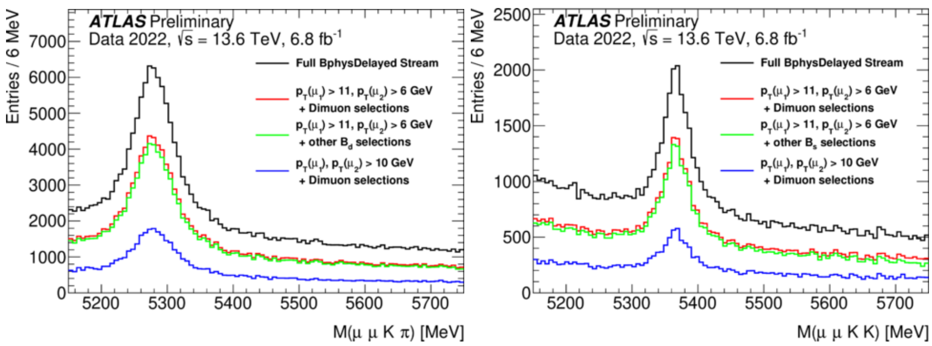
3. B-hadron reconstruction results



(a) Run 3 2022 Commissioning data.

(b) Run 3 2022 Data.

Figure 5: Invariant mass distribution of offline-selected di-muon candidates passing the thresholds of di-muon B-physics triggers [5].



(a) Reconstructed B_d mass.

(b) Reconstructed B_s mass.

Figure 6: B Hadrons reconstructed using early Run-3 data [4].

New Run 3 methods have been applied to the reconstruction of B-Hadrons. Figure 5 shows reconstructed di-muons across mass regions of interest to ATLAS B-physics [5], produced with early run commissioning data before data quality requirements, and data from runs with full quality requirements. Figure 6 shows reconstructed mass for B_d and B_s [4]. Figure 6a focusses on $B \to J/\psi K^*$ decay, a di-muon pair is constrained to the mass of the J/ψ, while the $K\pi$ candidates from the K^* decay are constrained to a 100 MeV wide window around 894 MeV. Figure 6b, covers an identical process for $B_s \to J/\psi\phi$, except the $\phi \to KK$ are constrained to 1008 MeV $< m(KK) <$ 1030 MeV.

References

[1] ATLAS Collaboration *The ATLAS Experiment at the CERN Large Hadron Collider*, JINST 3 (2008) S08003

[2] ATLAS Collaboration *Software Performance of the ATLAS Track Reconstruction for LHC Run 3*, ATL-PHYS-PUB-2021-012 CERN, Geneva (2021)

[3] ATLAS Collaboration *Development of ATLAS primary vertex reconstruction for LHC Run 3*, ATL-PHYS-PUB-2019-015 CERN, Geneva (2019)

[4] ATLAS Collaboration *ATLAS Early Run 3 B_d and B_s candidate mass spectra* Tech. Rep. BPHY-2022-001 CERN, Geneva (2022)

[5] ATLAS Collaboration *ATLAS B physics Trigger Public Results* Tech Rep. ATL-COM-DAQ-2023-003 CERN, Geneva (2023)