Preparing ATLAS Reconstruction for LHC's Run 2

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Introduction

Run 2 of the LHC will be a challenging software environment for the ATLAS detector [1]:

i. The HLT accept rate will be 1 kHz, instead of 400Hz prompt and about 150Hz delayed as in Run 1.

ii. Increased pile-up: the software should be prepared for higher pile-up, though the plan is to keep pile-up low this year. Fig. 1 shows the per-event execution time as a function of the average interactions per bunch crossing.

iii. Physics performance must not be compromised, but improved.

iv. Flat computing budget: cannot buy our way out.

Meeting these goals requires a factor of three reduction in processing time. This poster will briefly mention the reconstruction software improvements for Run 2, both in computing and in physics performance.

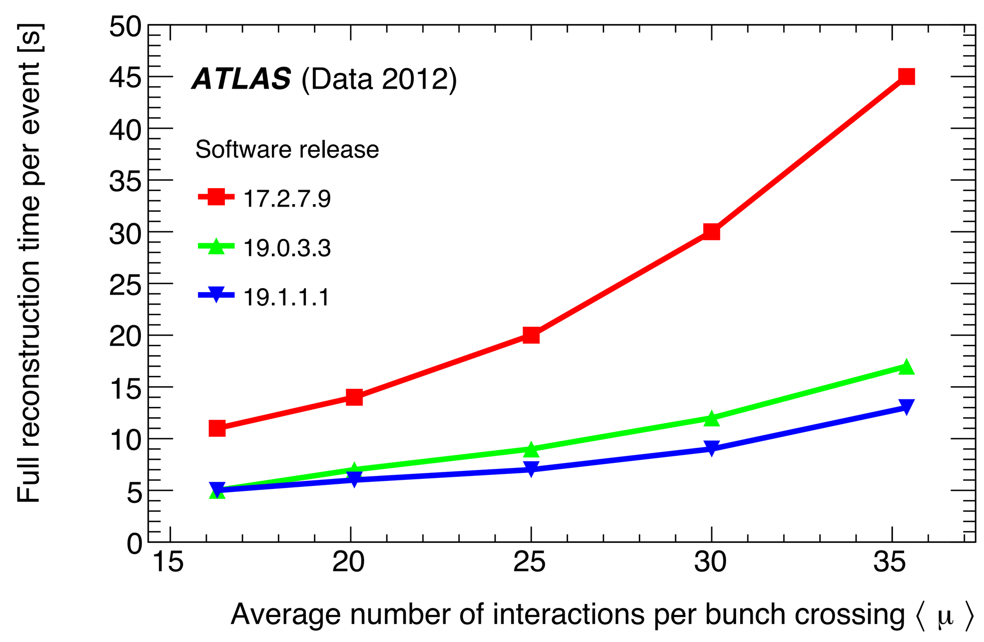


Figure 1: The time per event to reconstruct data events triggered by the presence of jets, missing transverse momentum, or tau leptons at the end of 2012 as a function of the average number of interactions per bunch crossing and software release. Release 17.2.7.9 was used in Run 1, while releases 19.0.3.3 and 19.1.1.1 incorporate some improvements. Plot from Ref [2].

General Improvements

A number of general improvements in the software were performed to speed up the reconstruction [2, 3, 4]:

i. The method to access the magnetic field strength was rewritten, reducing the call depth, reducing the unit conversions, and caching recent results.

ii. The CLHEP linear algebra library was replaced by Eigen, which by using expression templates significantly improves the performance.

iii. Replaced GNU libm with the Intel math library.

iv. Updated the compiler, and moved to 64-bit architecture.

To improve the usability of the software for performing physics analyses, a new event data model (EDM) was created for analysis-level objects (see talk by S. Snyder, #182). This required many changes to the reconstruction software. Simplicity and harmonization were major themes in the new EDM, which we also strived to follow in the reconstruction software. For example, we now have one code to do isolation for electrons and muons.

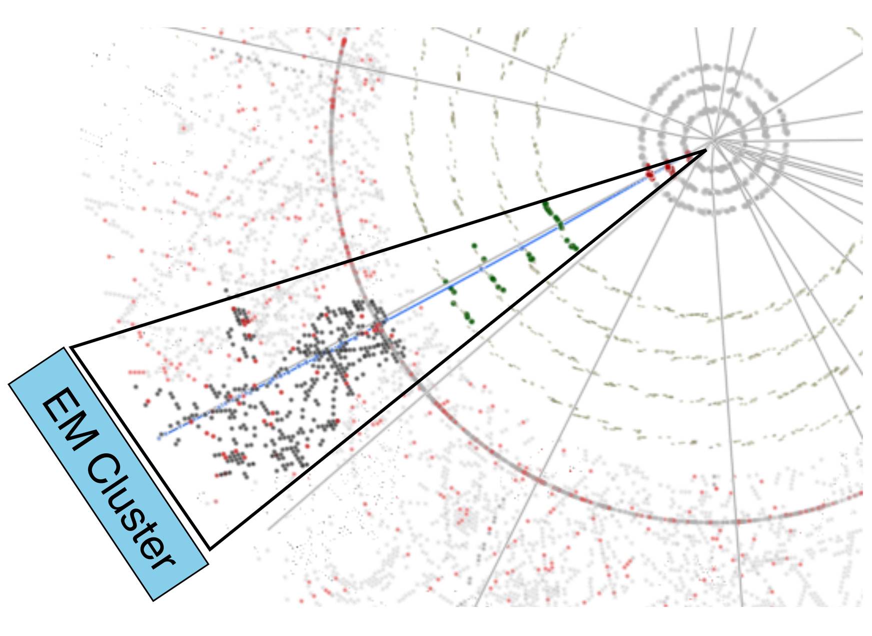


Figure 2: An EM calorimeter cluster creating an ROI for tracking.

Improvements in Domains

1. Tracking and Vertexing

Tracking and vertexing changes are covered in more detail in a talk by A. Salzburger (#209) and a poster by M. Rudolf (#163). Some improvements:

i. The tracking EDM was greatly simplified, reducing the call depth and reducing the number of dynamic casts.

ii. Optimized the track seeding for high pileup and including IBL [5].

iii. TRT-seeded tracking only in e/γ regions of interest (ROIs), as shown in Fig. 2.

iv. Improved ambiguity resolution for tracking in dense environments, improving flavor tagging and tau reconstruction.

v. Use dense volume description of calorimeter.

vi. Cached extrapolation to the calorimeter.

vii. New seeding algorithm for vertexing based on imaging techniques.

2. Electron/Photon

The main changes to the electron and photon reconstruction software:

i. Simplify the code and configuration, harmonizing with offline

ii. Incorporate MVA-based calibration

iii. Design to tolerate various TRT gas mixture scenarios

3. Muon

The muon system had a few new chambers installed for Run 2. The main changes to the muon software:

i. Run a unified reconstruction chain, with simplified steering / configuration

ii. New pattern recognition, with new Hough transform tuning and TGC-seeded segment finding.

iii. Improved energy loss tuning in the calorimeter: goal of 10 MeV precision to the energy loss. Use improved calorimeter geometry description and energy loss parametrization

iv. More support for "exotic" reconstruction, like displaced vertices, more information for low-β particles

v. New identification for high-p_T muons

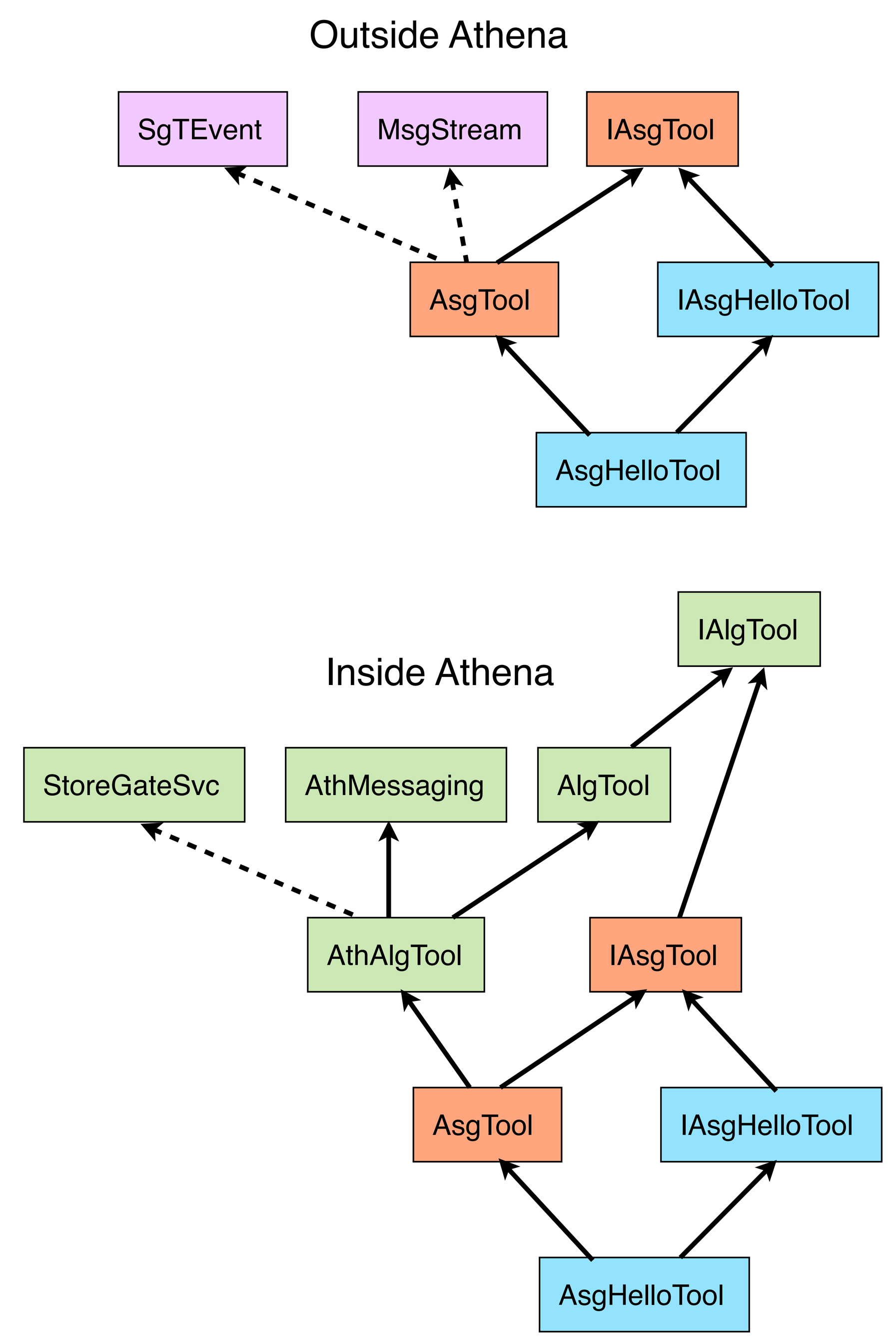


Figure 3: The "dual-use" tool class diagram.

4. Jet

Jet software is now "dual-use," meaning that it can run both within and outside of Athena (see poster by S. Farrell, #177). Fig. 3 gives a diagram of how this works. Other improvements:

i. Newer FastJet 3 version for improved performance.

ii. Ghost association is now integrated in the reconstruction flow and EDM to easily ghost-associate any particle of interest.

iii. Substructure calculations, including subjets, are well integrated in the software for easier analysis.

5. Missing Transverse Momentum

Missing transverse momentum is calculated as:

$$\vec{E}_T^{\rm miss} = \vec{E}_T^{\rm miss}(e) + \vec{E}_T^{\rm miss}(\gamma) + \vec{E}_T^{\rm miss}(\tau) + \vec{E}_T^{\rm miss}({\rm jet}) + \vec{E}_T^{\rm miss}(\mu) + \vec{E}_T^{\rm miss}({\rm soft})$$

Double-counting by treating an object as multiple objects must be avoided. This overlap is now encoded in one structure per jet type, allowing easier customization. Analysis users can easily and efficiently compute the MET terms with an arbitrary object selection.

At the end of Run 1, there was significant effort devoted to pile-up suppression. The methods continue to be refined. Fig. 4 shows the good pile-up performance.

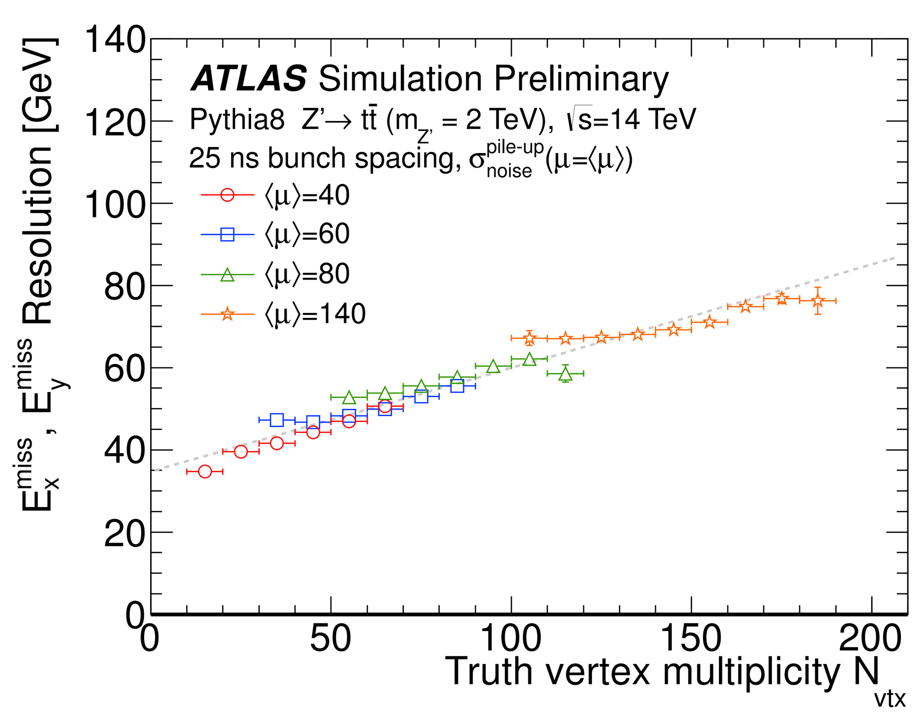


Figure 4: The $E_T^{\rm miss}$ resolution as a function of the vertex multiplicity for simulated Z' events.

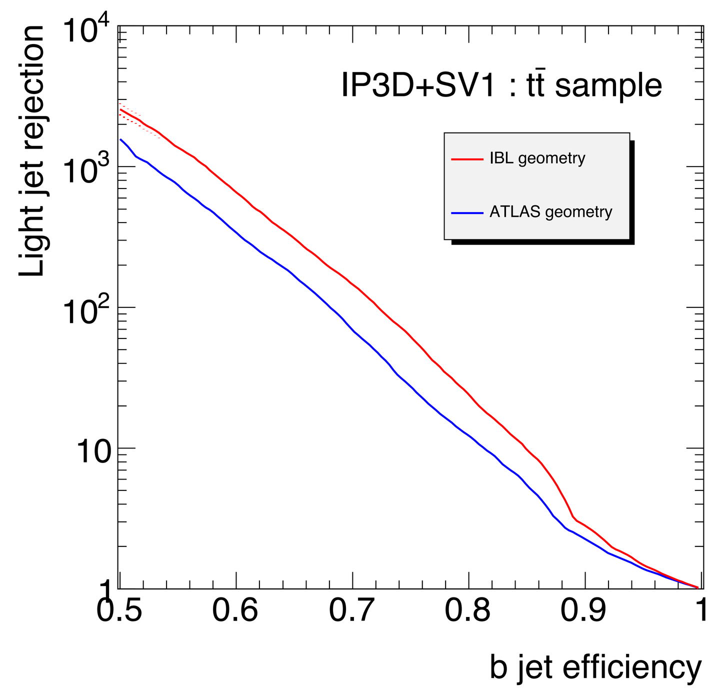
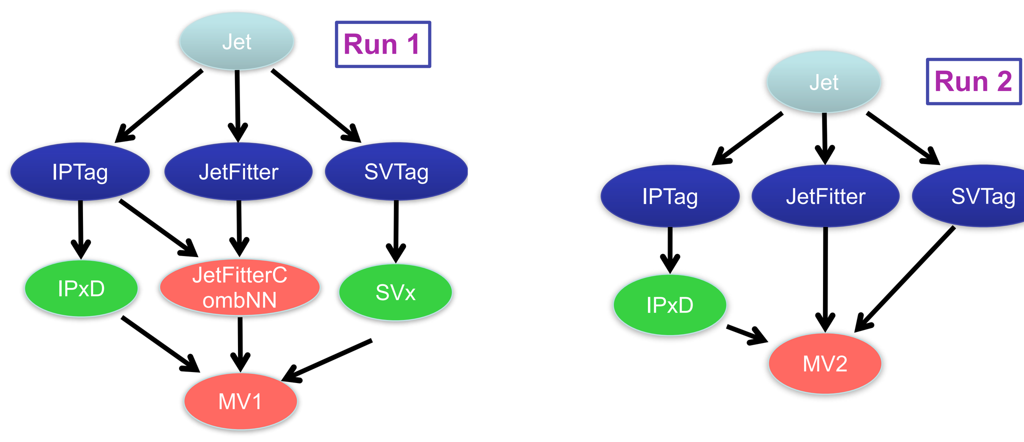


Figure 5: Light jet rejection vs. b-tagging efficiency with and without the IBL. Plot from Ref [5].

6. Flavor Tagging

Flavor tagging benefits from the new IBL, as can be seen by Fig 5. Other improvements:

i. New mulitvariate MV2 tagger, 30-50% better light jet rejection, while simpler in structure than MV1 used in Run 1.



ii. High-p_T tagging based on b-tagging track-jets and matching to jets [6].

iii. New mulitvariate MVb tagger for boosted scenarios [7].

iv. Harmonize with trigger b-tagging.

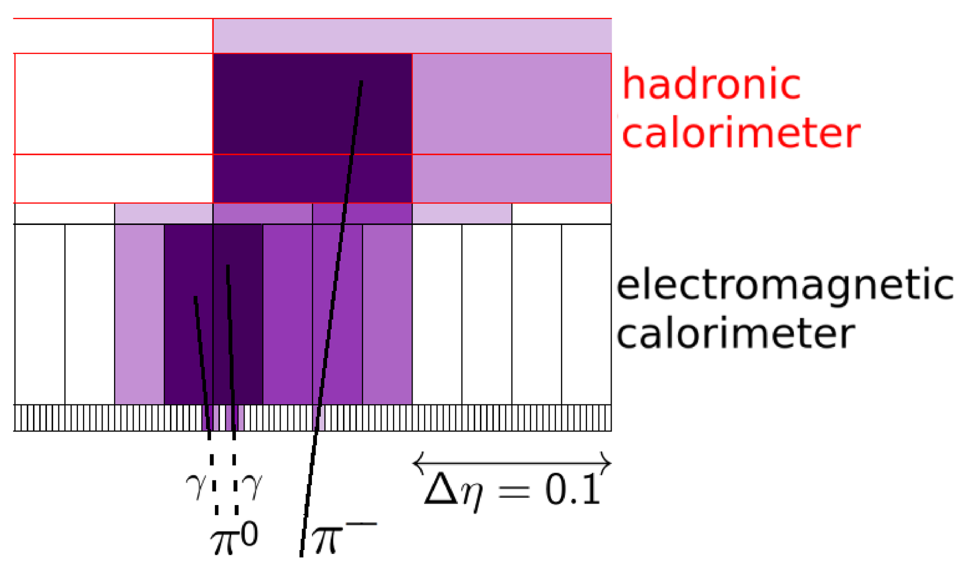


Figure 6: A diagram of a tau signal in the detector.

7. Tau

There has been work in the reconstruction of individual decay products (substructure reconstruction) as a way to improve the energy resolution, position resolution, and identification efficiency of hadronic taus. Fig. 6 shows the components of a tau signal. Both tracking and calorimeter information is used to identify and measure the charged and neutral pions.

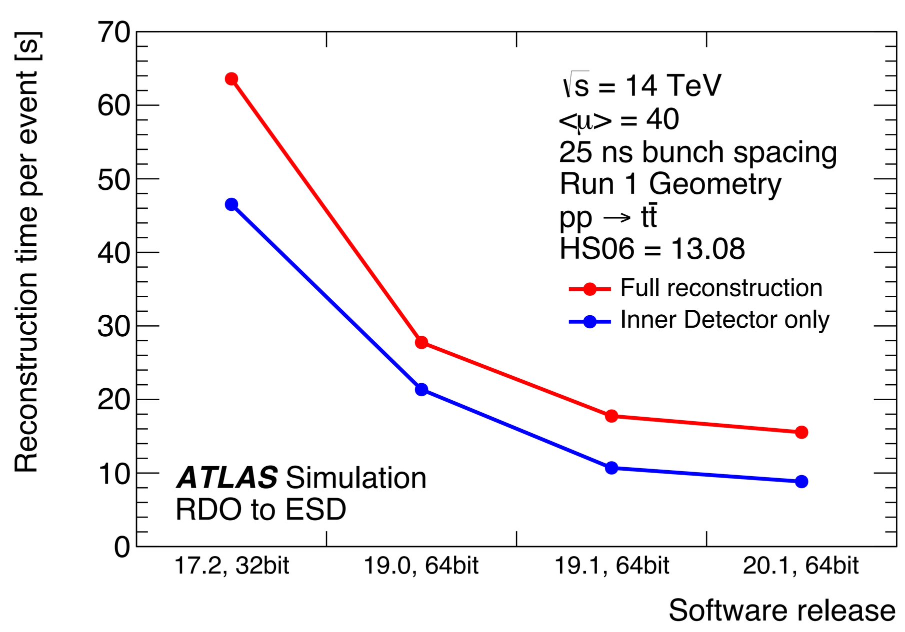


Figure 7: The time per event to reconstruct $t\bar{t}$ MC events as a function of the software release.

Conclusion

As can be seen in Fig. 7, the reconstruction execution time improved by a factor of four. Physics performance has also improved.

References

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

[2] ATLAS Collaboration, ATLAS offline reconstruction timing improvements for run-2, ATL-SOFT-PUB-2014-004, 2014.

[3] R. Langenberg et al., Preparing the track reconstruction in ATLAS for a high multiplicity future, J. Phys.: Conf. Ser. **513** 022018 (2014).

[4] N Chauhan et al., ATLAS offline software performance monitoring and optimization, J. Phys.: Conf. Ser. **513** 052022 (2014).

[5] M. Capeans et al., ATLAS Insertable B-Layer Technical Design Report, CERN-LHCC-2010-013 / ATLAS-TDR-019, 2010.

[6] ATLAS Collaboration, Flavor tagging with track jets in boosted topologies with the ATLAS detector, ATL-PHYS-PUB-2014-013, 2014.

[7] ATLAS Collaboration, b-tagging in dense environments, ATL-PHYS-PUB-2014-014, 2014.