Investigation of Adaptive Multi Vertex Finding for Secondary Vertexing

The Adaptive Multi Vertex Finder will replace the Iterative Vertex Finder in the primary vertex reconstruction chain in Run 3 of the LHC. Performance analysis showed an improvement in reconstruction efficiency in high pile-up conditions. This prompted an interest in implementing this approach to secondary vertexing in hopes of reproducing the increase in performance.

Adaptive Multi and Inclusive Vertex Finding

AMVF flow (Remove compatible tracks from seed pool):

1. Selected tracks
2. Seed pool
3. New vertex seed
4. Add tracks to fit due to significance
5. Fit vertex along with any other vertices sharing tracks
6. Remove outliers

IVF flow (Remove compatible tracks from seed pool):

1. Selected tracks
2. Seed pool
3. New vertex seed
4. Add tracks to fit due to significance
5. Fit single vertex
6. Remove outliers

- Same adaptive estimator to calculate weights of tracks in the vertex fit
- Same deterministic annealing procedure to progressively de-weight and reject outlier tracks
- AMVF uses a global track pool to select tracks for new vertex candidates
- IVF uses only tracks not compatible to the previously fit vertices
- In AMVF, the tracks can have weights to multiple vertices
- In AMVF all vertices sharing tracks with the current vertex candidate are fit simultaneously

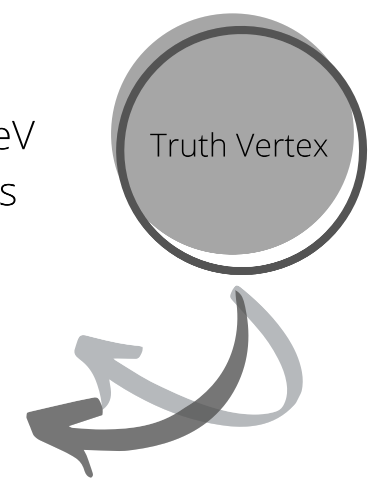
Validation method [1]

- New validation package has been written to validate and compare the tools for the fisrt time
- It tests the finder's ability to reconstruct a given MC event record truth vertex

Clean Reconstructed Vertex:

- Labeled as Secondary Vertex
- Has => 2 tracks
- Tracks have weight at vertex
- Tracks have links to truth particles
- Truth particles are traced to desired truth vertex

Reconstructable Truth Vertex:



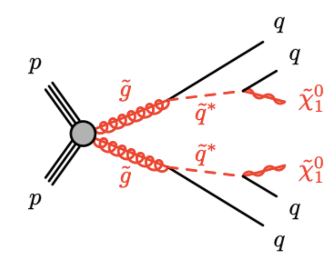
- Is in Inner Detector region
- Has => 2 tracks with pT > 1GeV
- Has => 2 reconstructed tracks that pass track selection

- Evaluation metric is not precision, but purity of reconstructed vertices

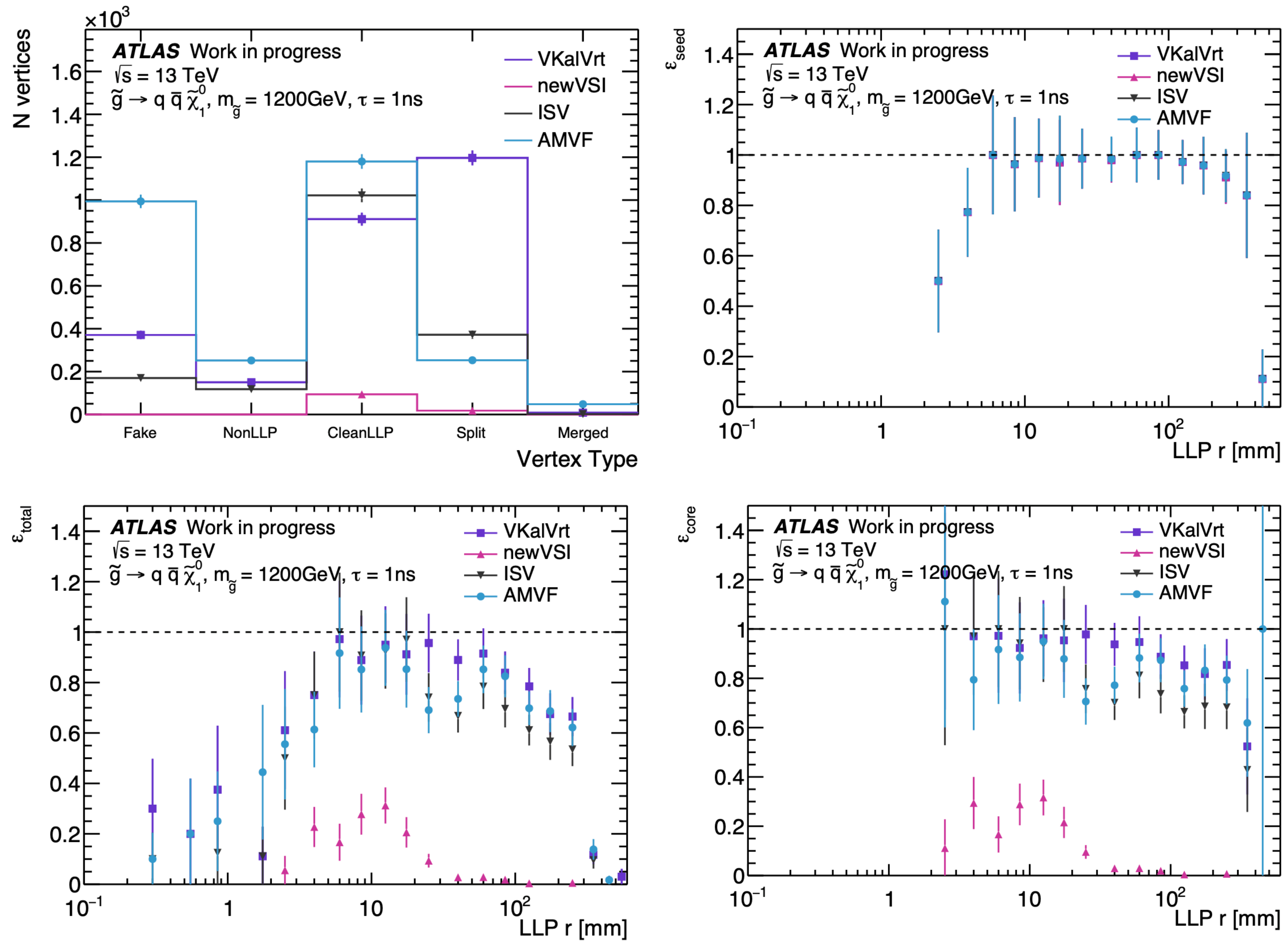
$$match\ score(v,l) = \frac{\sum_{i \in trk \in v} (pT^{(i)} | descendant\ of\ decay\ l)}{\sum_{i \in trk \in v} (pT^{(i)})}$$

Analysis strategy and results

- Analysis on 1K split SUSY gluino sample, the gluino is Long-Lived (LLP): [2]
- The same track reconstruction and track selection tools were implemented into vertex finders



- Seed efficiency is fully dependant on track reconstruction and selection efficiency, seeing overlap gives confidence in an "apples-to-apples" comparison
- AMVF shows signifantly larger number of clean vertices, but lacks any mechanism for fake rejection
- Total efficiency accounts for detector acceptance and both tracking efficiencies, core efficiency is decoupled from the later and probes pure vertex reconstruction efficiency
- Our capability to reconstruct secondaries is high, but degrades at higher R due to degradation of tracks reconstruction efficiency and due to collimation of decay products at higher R, creating difficult topologies to reconstruct



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References:
1 ATLAS Collaboration, Search for long-lived, massive particles in events with displaced vertices and missing transverse momentum, Phys. Rev. D., (2018)
2 ATLAS Collaboration, Performance of vertex reconstruction algorithms for detection of new long-lived particle decays within the ATLAS inner detector, ATL-COM-PHYS-2017-205, 2019