CERN Summer Student Report
Primary Vertex Reconstruction in ATLAS

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Abstract

The project is to implement a new algorithm for primary vertex reconstruction (vertexing) and test its performance with Monte Carlo simulation. Properties of the vertices are being studied to chacterized and improve the performance.

1 Introduction

Vertex fitting serves two purposes. The first is to estimate the position of the point of interaction and the momentum vectors of the tracks emerging from this point. The second is to check the association of tracks to a vertex [1]. Figure 1 shows the vertex topologies in ATLAS: primary and pile up vertices (multiple proton-proton interactions per brunch crossing) and vertices from decay chains [2]. Therefore an accurate primary vertexing algorithm is of fundamental importance for physics analysis.

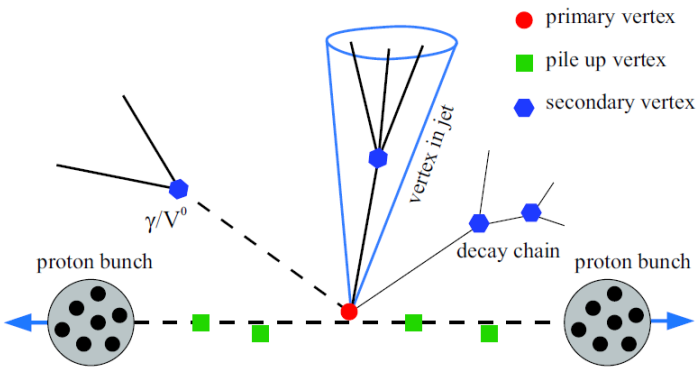


Figure 1: Vertex topologies

2 Medical Imaging Vertexer

ATLAS now uses a new algorithm, Medical Imaging Vertexer (MIV), inspired by techniques used in Positron Emission Tomography (PET). It is the seeding algorithm which approximates the primary vertex positions.

Figure 2 shows the collaboration diagram of the algorithm. The seeding algorithm (MIV) filters the noise and produces the approximated primary vertex positions (seeds). The cluster finding process identifies the clusters with high track density.

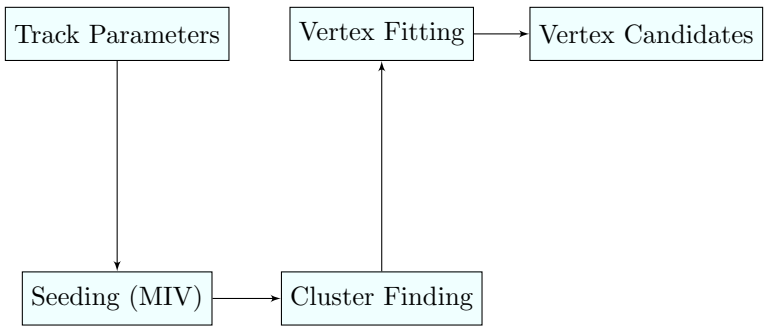


Figure 2: Collaboration diagram showing the idea of vertexing

3 Algorithm Performance

The algorithm of truth matching to proton-proton interactions is useful in studying vertexing in a high pile-up environment. Each reconstructed vertex can be categorized as either Matched, Merged, Split, or Fake. This categorization is based on the number and types of interactions matched and on the relative weight: [4]

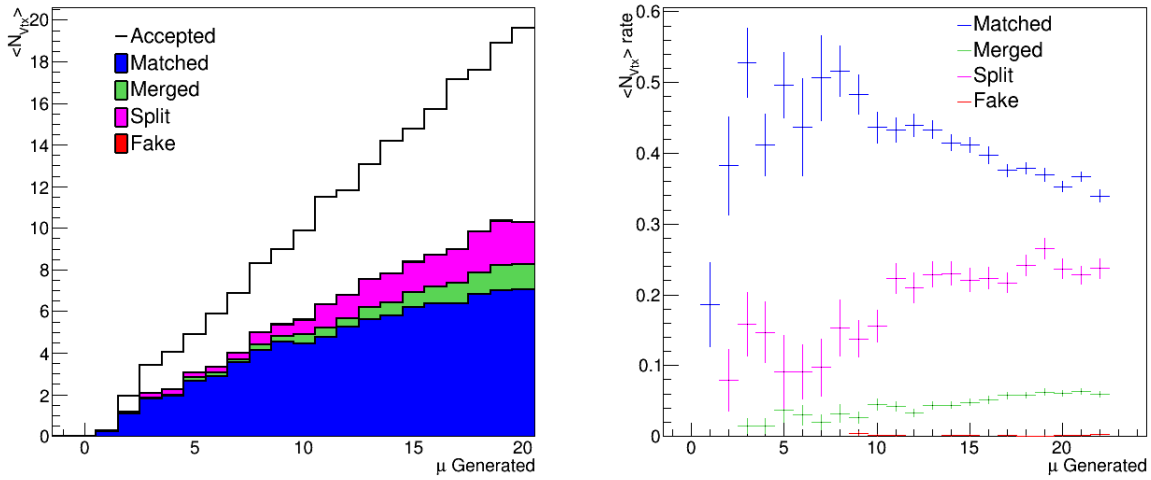
Matched - 70% of weight from one single generated interaction

Merged - Two or more interactions (counting fake contribution as one) contribute to one reconstructed vertex

Split - Generated interaction with largest contribution is also the largest contributor to one or more other reconstructed vertices; the highest $\sum p_T^2$ vertex is denoted the main split. The lower $\sum p_T^2$ vertex is denoted the sub split.

The algorithm performance was studied with a $\sqrt{s} = 8$ TeV Monte Carlo sample. Figure 3a shows the number of recostructed primary vertices as a function of the number of interactions generated in Monte Carlo. An accepted vertex is a primary vertex with at least two tracks with the beam constraint. The number of split and merged vertices increases with the number of interactions.

Figure 3b shows the corresponding reconstructed rate. The matched rate is decreasing significantly for high pile-up. It can be shown that the splitting is a dominant effect. Therefore, it is necessary to look for some criteria to re-merge the split vertices as Run 2 in 2015 is expected to have a much higher pile-up.



(a) Number of reconstructed vertex

(b) Rate of reconstructed vertex

Figure 3: Vertexing performance

4 Method to Re-merge a Split Vertex

In order to identify the split vertex in the experiment, the following scheme is being developed by computing the reconstructed primary vertex separation in the z coordinate.

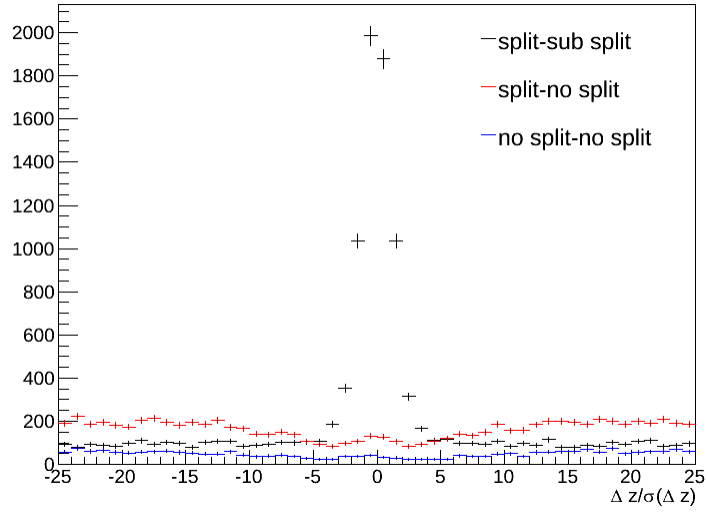


Figure 4: Vertex separation distribution in z coordinate

Figure 4 shows the primary vertex separation in the z coordinate. The separation (pull) is defined as the distance between vertex pairs in the z coordinate normalized by the error coming from the vertexing algorithm. The split-sub split distribution peaks sharply at zero. It is possible to re-merge most of the split vertex which has the pull close to zero.

5 Conclusion

The vertex separation is a good criteria to re-merge the split vertex. Other quantities like $\sum p_T^2$ and χ^2 are under investigation to identify split vertices. The method will be verified using high pile-up Monte Carlo samples.

References

[1] R. FRÜHWIRTH et al. Data Analysis Technique for High-Energy Physics Second Edition (Cambridge University Press, 2000), Chapter 3.4

[2] E. Bouhova-Thacker et al. Vertex Reconstruction in the ATLAS Experiment at the LHC, ATL-INDET-PROC-2008-003

[3] S Hageböck and E von Toerne, Medical Imaging Inspired Vertex Reconstruction at LHC, Journal of Physics: Conference Series 396 (2012) 022021

[4] K. Grimm et al., Reconstruction of primary vertices in Run 1 pp collisions at the LHC, ATLAS NOTE