Summer Student Report

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CERN Summer Student Report
ATLAS Trigger - Muon Trigger Optimisation Studies

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Abstract

The LHC is currently shutdown for upgrades and will restart in 2015 with a much higher luminosity and energy of 14 TeV. The offline Muon High Level Trigger algorithms are being optimized. The project focuses on comparing the performance of the newly developed high level muon trigger algorithms to the offline and the previous implementation of the muon trigger, with emphasis on efficiency and timing comparisons at the different stages of the high level trigger.

1 Introduction

The ATLAS Trigger is designed to have three main levels to achieve a high reducing rate and select interesting events for physics analysis. The trigger system selects a very small rate of physically interesting events (200 Hz) among about 40 million events per second. In the case of events containing muons, the hardware-based Level 1 Trigger, based on coarse muon and calorimeter information, selects the Regions of Interest (RoI) in the detector and reduces the event rate to 75 kHz with a maximum time of 2.5 s [1]. Such RoIs are used as the basis for the High Level Trigger (HLT), running on online computing farms which consists of two trigger levels (Level-2 and Event Filter). Level-2 reduces the total event rate to 3 kHz and the Event Filter finally reduces it to 200 Hz, with average processing times of 40 ms and 4 s, respectively [2]. According to the updated design parameters, the LHC will provide proton-proton collisions at a center of mass energy of 14 TeV leading to a higher bunch crossing and hence a higher rejection rate. Algorithms are being optimised to tackle the rejection rates. Two specific algorithms for muons will be mentioned in this report.

2 Algorithms-*TrigMuSuperEF, TrigMuonEF*

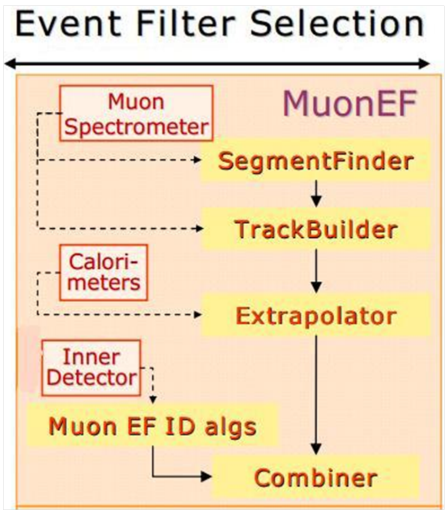


Figure 1: TrigMuonEF Algorithm Structure

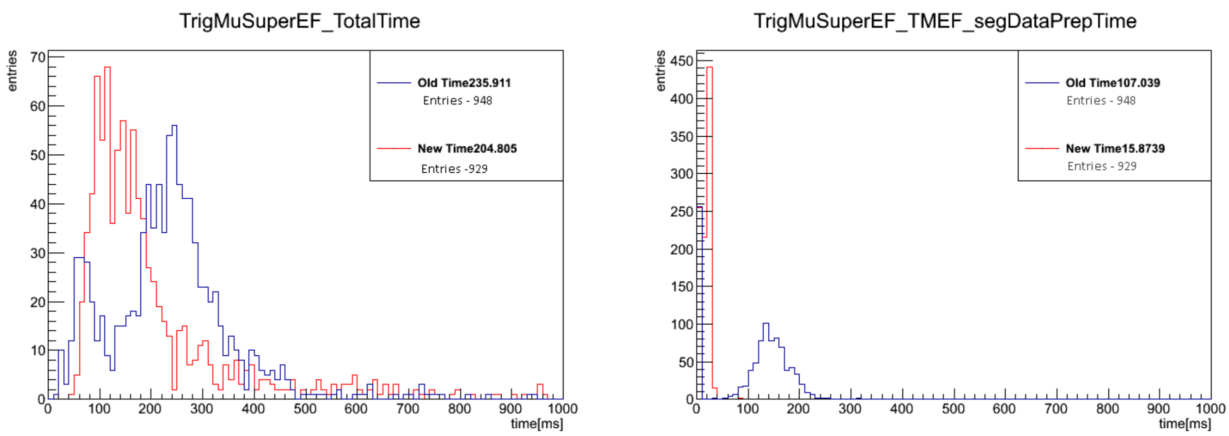
TrigMuonEF has three sections of code - SegmentFinder, TrackBuilder, Extrapolator and Combiner. Segments are made first, starting from Monitored Drift Tubes precision hits, then tracks are built from segments inside the Muon Spectrometer, adding information from the other muon detectors. In the following steps, the reconstructed tracks are extrapolated back to the Inner Detector taking into account the magnetic field the energy loss in the calorimeters and the effect of the multiple scattering through all the crossed materials **(StandAlone(SA) tracks)**. The **Combined tracks (CB tracks)** are formed by combining the muon spectrometer tracks and the inner detector tracks to give a better momentum resolution than the StandAlone(SA) tracks. The timing was monitored for the Segment Finder (segFinderTime),**Muon Spectrometer - MS tracks**, SA tracks and CB tracks. In addition to the track finder time for each kind of track, the data preparation time and the data output time were also recorded for the older and current release. The TrigMuSuperEF consists of the trigger timer flags and it monitors the algorithms which have to be executed in order to get the timing histograms.

3 Data and Analysis

3.1 Z$\longrightarrow\mu\mu$ events

Z$\mu\mu$ events was analysed using Monte-Carlo simulations at 8 TeV for 1000 events. Two ATLAS software releases with specific sets of Trigger Algorithms and ATHENA setup were used for timing comparison. Run 1 release (17.2.1.4) and the current release (19.2.0) were used. Proper clocks for the Timers were added in TrigMuonStandaloneTrackTool.cxx algorithm in the TrigMuonEF Package and respective jobOptions files were used for the two releases. Muon Signatures used in the jobOptions files were *mu24 imedium* for the current release and *mu24 itight* for the older release. Here, 24 refers to the cut-off energy of the muons - 24GeV and 'i' refers to isolated muons, tight and medium refer to the area taken into consideration around the muon hits. The number of entries depend on how many muons can cross the above -mentioned requirements. The following list of histograms were obtained (*Here the Old Time and New Time refer to the mean time taken by the older and current version*) :

- Total Time
- Segment Data Preparation Time, Segment Finder Time, Segment Data Output Time
- MS Data Preparation Time , MS Track Finder Time , MS Data Output Time
- SA Data Preparation Time, SA Track Finder Time , SA Data Output Time
- CB Track Finder Time , CB Data Output Time



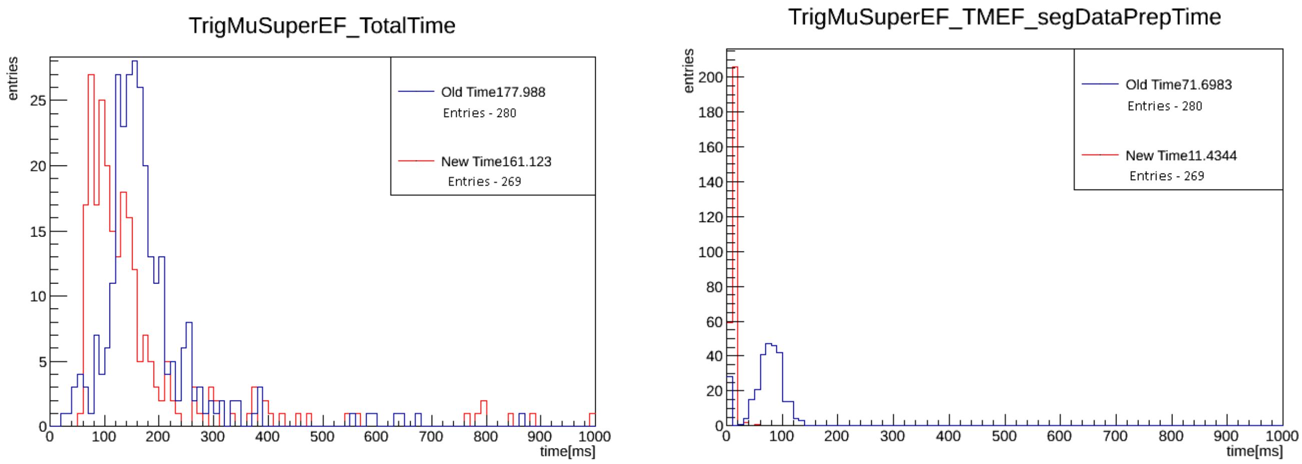
(a) Total Time

(b) Segment Data Prep Time

Figure 2: Timing Comparison for Z$\mu\mu$ events)

3.2 $t\bar{t}$ decay events

The timing difference in ttbar events was studied using the same two releases as the Z$\mu\mu$ events for 1000 events. The muon signatures used followed the same pattern as Z$\mu\mu$ decay and the type of histograms used for analysis were the same.



(a) Total Time

(b) Segment Data Prep Time

Figure 3: Timing Comparison for $t\bar{t}$ events

3.3 Comparison between Z$\mu\mu$ and $t\bar{t}$ events

Similarities

It can be observed in Figure 2 (a) and Figure 3(a)that the Total Time taken by the older algorithms is higher than the newer algorithms. A huge difference in timing is seen in the segDataPrepTime (Segment Data Preparation Time) plots shown in Figure 2 (b) and Figure 3 (b). The section of the code of segDataPrepTime calls to a number of functions which are used to decode the muon spectrometer. Before the update, the entire spectrometer was decoded, but in Run 2 only a section of the spectrometer would be decoded around the muon hits. This explains the drop in Timing in the current release.Both the pileup show similar behaviour in the remaining histograms.The data preparation time(apart from the segDataPrepTime)and data output time plots do not have much difference in terms of the two releases. The CB, MS, SA track finder time are higher in the newer algorithm than the older algorithms and the Total Time is higher in the older algorithm solely due to the contribution of the segDataPrepTime.

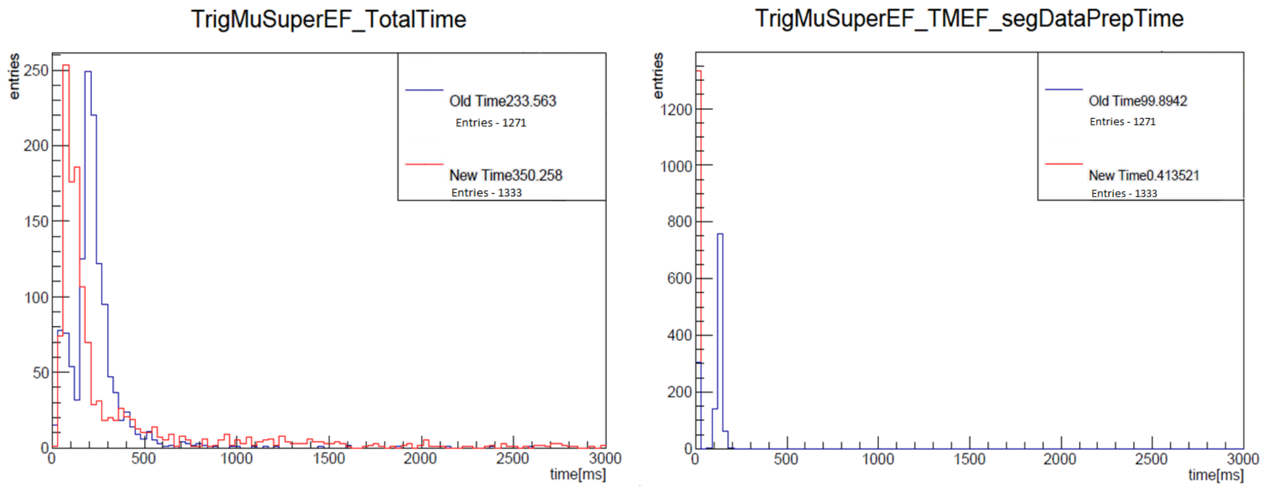
Differences

The number of entries in $t\bar{t}$ pileup is much lesser than Z$\mu\mu$ pileup. This may be due to the kind of decay the top quarks undergo resulting to only one muon per event or additional jets from the b-quarks. In this case, it is difficult for the muons to fulfill the isolation requirements mentioned in the type of trigger which was used for analysing(*mu24 imedium*, *mu24 itight*), whereas, a Z boson decays into two isolated muons which can be reconstructed by the offline algorthims . The overall time taken by Z$\mu\mu$ sample(235.911 ms) is higher than $t\bar{t}$ sample(177.988 ms). Moreover, the difference in Total Time in the former sample is higher (31.106 ms) than the latter sample (16.865 ms).

3.4 Comparison of data samples with different luminosities

The next data sets to be analysed were samples with different luminosities of Z$\mu\mu$ decay and hence different amounts of pileups. The program was run over 1000 events and the peak luminosities used were $7.3 \times 10^{35} cm^{-2} s^{-1} and$ $2.4 \times 10^{35} cm^{-2} s^{-1}$.

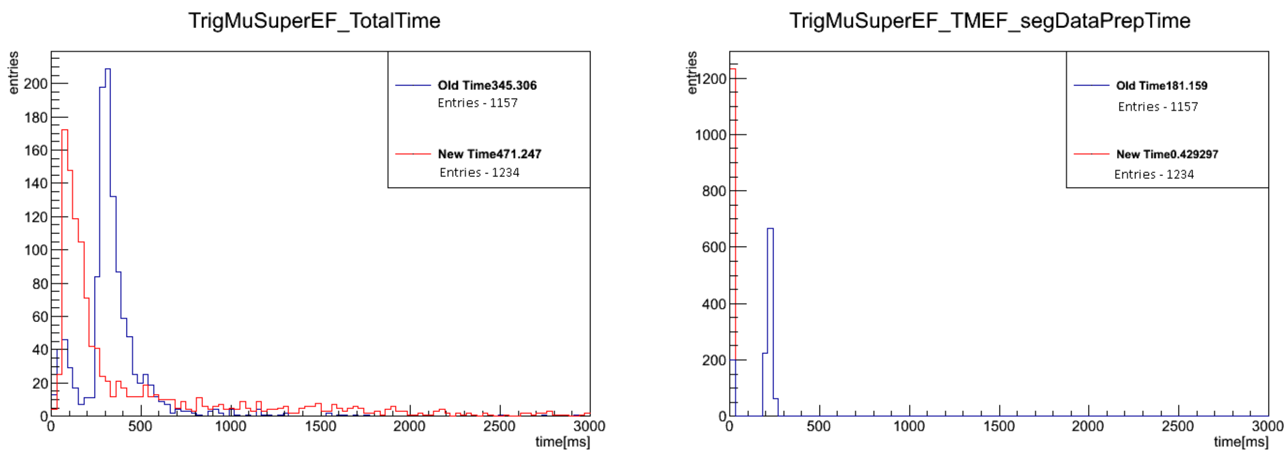
The jobOptions used was different from the other two discussed decay processes; two different trigger menus were used. Older Menu V4 was used in Release 17.2.1.4 and V5 was used in Release 19.2.0. The same list of histograms were obtained.



(a) Total Time

(b) Segment Data Prep Time

Figure 4: Timing Comparison for luminosity 2.4 × 10 $^{35}cm^{-2}s^{-1}$



(a) Total Time

(b) Segment Data Prep Time

Figure 5: Timing Comparison for luminosity 7.3× 10 $^{35}cm^{-2}s^{-1}$

It can be observed in Figure 4(a) and 5(a) that the total time in the high luminosity is greater than lower luminosity and the newer algorithms are slower than the older algorithms. The track finder timings (MS, SA, CB Tracks)are slower in the newer algorithms, but the time taken is proportional to the luminosity,i.e higher the luminosity, higher is the time taken by the algorithms, irrespective of the version.
In Figure 4(b) and 5(b), the Segment Finder Time shows a slightly different behaviour in terms of the comparison between the two versions. It produces almost the same value for the timing for the newer algorithm for different luminosities, but doubles when the older algorithm is used(99.89 ms and 181.16 ms for the low and high luminosity respectively).

4 Conclusion

In this report, three major timing comparisons were analysed using the Run 1 release - 17.2.1.4 and the current release - 19.2.0. The newer algorithms are generally slower in the finding the different tracks,

but the total time taken to process 1000 events is higher in the older version in $Z\mu\mu$ and $t\bar{t}$ events and this is mainly due to the timing difference in the Segment Data Preparation Time. Datasets with different luminosity were used under two trigger menus and the timing was compared. The Total Time taken by newer algorithms is higher than the older release, but the timing scales according to the luminosity. The Segment Data Prep Time shows some distinct behaviour when the two releases are used.
Future work would include optimising the current algorithms after analysing the time comparison histograms for different decays and luminosities. Offline Reconstruction algorithms do have the flexibility to run a bit slower than the online trigger system, but improving the set of codes to reduce the time taken to process the events is essential to discover new physics at higher energies during Run 2 of the Large Hadron Collider.

5 References

[1]Andrea Ventura,2010,The Muon High Level Trigger of the ATLAS, CERN

[2]Sandro Palestini,2002,The Muon Spectrometer of the ATLAS Experiment, CERN experiment