Testing the Muon Detecting Algorithm at DØ

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ABSTRACT

In this note I describe studies with the L2 muon code used in the DØ experiment. The initial analysis reviews the efficiency of the L2MU trigger system as a function of a pt. This helps to describe the faults and virtues of the algorithm. The next step in analysis describes the qualities of the dimuon algorithm. By studying various properties of the dimuon algorithm, I was able to attribute inefficiences to a number of the cuts used in the dimuon algorithm.

Contents

1 The Importance of a Muon

The detection of muons is important in understanding interesting physics. Muons result in the decay of vector bosons ($W^- \to \mu^- \nu_\mu$ and $Z^0 \to \mu^+ \mu^-$) and b physics ($B \to c\mu^- \nu_\mu$) and top physics (t $\to bW^+ \to \mu^- \nu_\mu X + \mu^+ \nu_\mu$) decays. Thus, an efficient muon detector is a necessity in any modern particle detector.

2 DØ's Muon Trigger

2.1 Hardware

The muon system is divided into a central and forward region. The central region covers an area of $\eta \in$ [-1,1]. This region consists of proportional drift tubes (PDT), barrel scintillator counters (A-PHI), and cosmic ray veto scintillator counters. There are three PDT layers (A, B, and C) with a toroid magnet in between the A and B layers. The kink that the magnet induces is used to determine the p_T of the muon that passes through the PDT. Nine segments of the A-PHI counters are in the z direction and 80 in the ϕ direction. [1]

The forward region sweeps out $\eta \in$ [-2,-1]$\cap$[1,2]. This part of the detector includes mini-drift tubes (MDT) and pixel scintillator counters. As in the central region, there are three MDTs with a toroid in between the A and B layer. [1]

2.2 Software

There are three major parts to the trigger system. The first of these parts is the level 1 trigger (L1) recieves information from scintillators, tracking and calorimeter detectors. It has an input rate of 5 MHz and an output rate of 10 kHz. The second level (L2) refines the quality of the muons by using information from subdetectors, a single global processor, and input from the L1 trigger to output at a rate of 1 kHz. At the third level of the the trigger (L3), reconstruction algorithms consisting of physics tools and filters further reduces the output rate to 20 Hz. [1]

3 L2 Muon Efficiency

The efficiency of the L2 muon system is dependent on what constitutes a muon and how efficiency is defined. By using different combinations of qualities, efficiencies can vary greatly.

3.1 Quality

Whether a muon exists or not depends on its quality. There are four classifications of quality: no quality, loose, medium, or tight. These descriptions of quality are based on the track that is found in the A and BC PDTs and MDTs. A loose muon is an object that could be a muon. If the muon is described as having a medium quality, then there is a good chance that the object found is a muon. When a medium object is defined as tight then this object is almost surely a muon.

3.2 Efficiency

The efficiency in this study is defined as $\frac{L1 \times L2 \times RECO}{L1 \times RECO}$. This means that it cycles through the events in an ntuple and looks for those events with L1 and RECO muons. For each event that it finds, it adds one to the L1-RECO counter. When it finds such an event, the algorithm checks to see if there are any L2 muons. If there are, it adds one to the L1-L2-RECO counter. The efficiency is then defined by the L1-L2-RECO counter divided by the L1-RECO counter. Because L3 is very good at finding muons, the objects that it defines as muons can be assumed to really be muons. Thus, the efficiency is essentially defined as the the percent of events with real muons that the L2 muon trigger correctly defines.

However as stated before, the efficiency also depends on quality. As the quality of the accepted L2 and L3 muons changes, so does the efficiency of the trigger. When only loose L2 muons are accepted there is a huge pile of possible muons, of which only some are real. If this is being compared to RECO muons of tight quality, the efficiency will be very high because there are so many L2 muon events that most of the RECO events will correspond to an L2 event.

The reason why we do not always use the highest efficiency possible is to increase another parameter called rejection. The rejection is defined as $\frac{L1}{L2}$. This means that the higher the smaller the sample of L2 events, the larger the rejection. By having a larger rejection, many of the events that are thought to be muons by the L1 trigger are removed by L2 trigger. For this reason, it is sometimes better to be strict on the quality of the accepted muons.

The results of these permutations and resultant change in efficiency can be seen on Figure 1 in the appendix. The set of graphs along the top are of loose RECO muon events and the set of graphs on the left are of loose L2 muon events. By moving right and down on this set of graphs, the quality of the muons is increased. As seen from the graphs, the average efficiency of the L2 muon trigger ranges from 99% to 82%, excluding the graphs above the diagonal. These graphs do not make sense because they are comparing RECO events of quality worse than the quality of the L2 events.

4 Dimuon Efficiency

4.1 Need for a Dimuon Trigger

The purpose of the L2 muon trigger is to detect multimuon events. The L1 dimuon trigger has no prescale. This means that the data the L1 trigger sends to the L2 dimuon trigger will be better than from the L1MU trigger. The L2 dimuon trigger is perfect for B physics applications ($B \rightarrow J/\psi(\mu\mu) + X$).

4.2 Algorithm Cuts

There are two cuts that are made in the dimuon algorithm. The first of these is requiring that there are two muons in the event, one of loose quality and one of medium quality. This insures finding objects that are probably muons, while still taking into account muons that are slow enough to be candidates from a J/ψ decay.

A $\Delta\eta$ and $\Delta\phi$ cut is the second step in refinement of the muon data. This cut dismissed muons that were too close in η and ϕ because occasionally one muon is mistaken for two muons. If it is mistaken, then the η and ϕ will be relatively close together. In the final algorithm $\Delta\eta > 0.15$ or $\Delta\phi > 13.5$ for the muon to pass this cut.

4.3 Hardware Inefficiencies

Unlike the L2 muon trigger, the L2 dimuon trigger has not yet been incorporated into the detector. Thus, only Monte Carlo simulations could be used to test the trigger. However, the Monte Carlo does not take into account geometric holes in the detector or incorrect detection of particles by the hardware. In order to determine the efficiencies of the dimuon algorithm, the inefficiencies of the above to effects must be eliminated. To remove geometric holes, made a two dimensional histogram of η versus ϕ of the RECO muons in a real run. All of the Monte Carlo events that have a muon in a place that the RECO histogram does not, were removed. This elimination of geometric holes resulted in the removal of 37.5% of the the events.

To remove the biassing of inefficient hardware, I used a $\Delta\eta$ and $\Delta\phi$ cut to make sure that the Monte Carlo muons are the same as the muons seen by the detector. If they appear to be in different places, the event is rejected because the detector incorrectly identified the existance of a muon. When this cut is made, another 8.67% of the Monte Carlo events are eliminated.

4.4 Algorithm Inefficiency

After all the hardware ineffiecies are taken into account, the focus can be placed on the inefficiencies of the algorithm. After taking the one loose and one medium cut on the data, 83.79% of the events with dimuons are remain. This means that the algorithm is inefficient by 16.21%. When the $\Delta\eta$ and $\Delta\phi$ cuts are made in addition to the first, only 75.79% of the events remain; resulting in an 8% inefficiency of the second cut.

5 Conclusions

5.1 Results

The results of the L2 Muon trigger efficiency is as expected from previous tests. Although an 82% efficiency is consistent with other results, there is still room for improvement.

The same can be said about the dimuon trigger. Although an efficiency of 75% is acceptable, it is possible to obtain a better efficiency.

5.2 Future Work

Future work on this project would be continuing the study of the dimuon trigger. The algorithms that are used are rather simple and have not been well studied. By testing different algorithms besides a $\Delta\eta$ and $\Delta\phi$ cut, a better efficiency should be obtained.

References

[1] C. Leonidopoulos, "The Muon Trigger at DØ ", *DØ note xxxx, 2001*

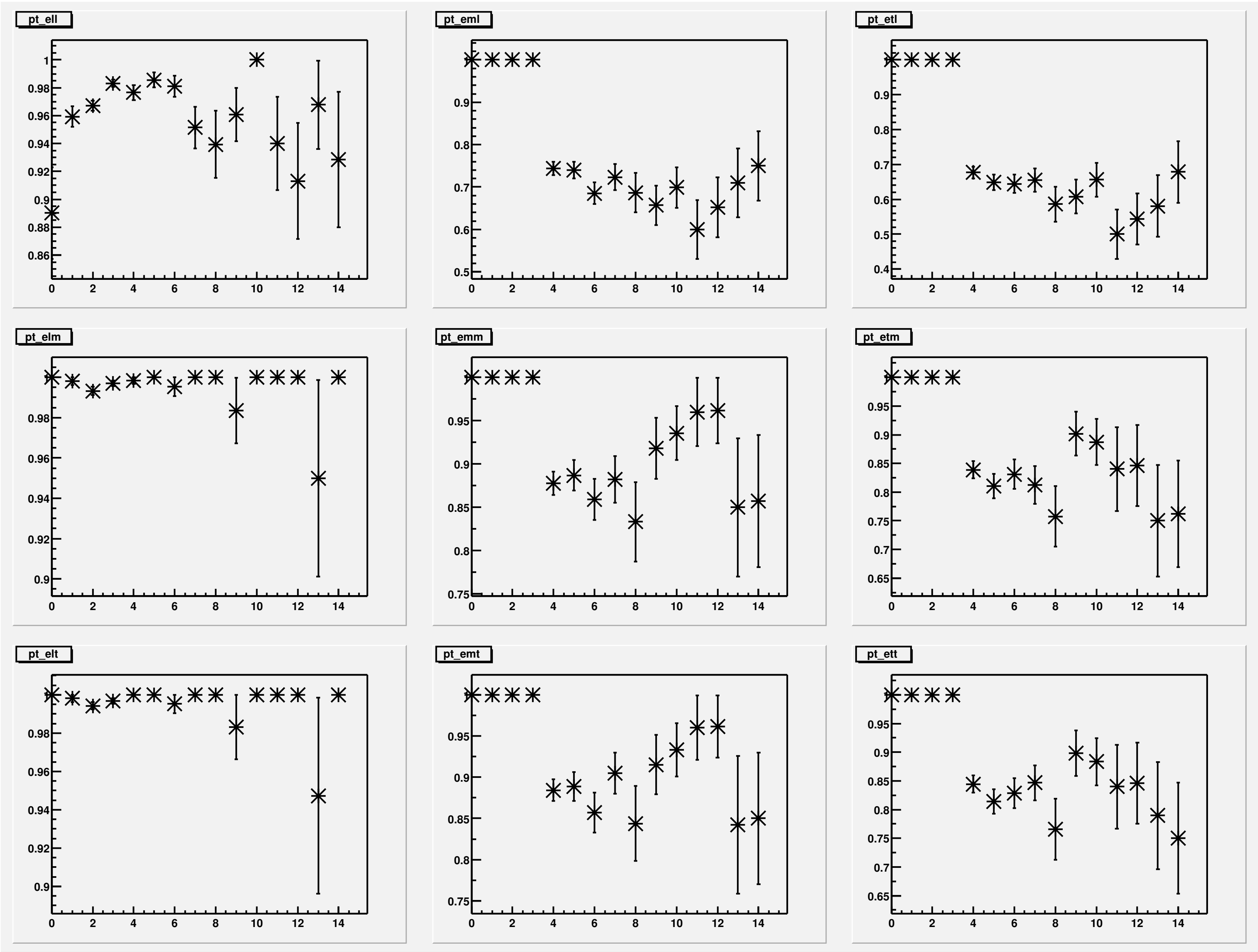

Figure 1: Permutations of loose, medium, and tight qualities of L2 muon efficiencies as a function of p_T .