Level 1 Muon Trigger for the DØ Upgrade

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DØ Collaboration

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Motivation for the Upgraded Muon Detector at DØ

- Meet Run II Physics Goals of DØ
  
  **Top Physics**
  - Top mass (± 5 GeV/c²), decay properties, and cross-section
  
  **B-Physics**
  - \(B_s\) and \(B_d\) Mixing - Constrain CKM parameters
  - Searches for CP violation in the neutral B system

  **Electroweak Physics and Precision Tests of SM**
  - Precision measurement of W Boson mass (± 50 MeV/c²)
  - W and Z Asymmetry measurements

  **Search for New Phenomena**
  - Supersymmetry
  - Search for additional vector bosons

- Operate within 132 ns bunch crossing time

- Endure higher event and background rates for luminosities up to \(L = 2 \cdot 10^{32}\) cm\(^{-2}\)/s

- Replace radiation damaged proportional drift tubes in end region
Muon Detector for the DØ Upgrade

Addition of central solenoidal field

Central Fiber Tracker

Wide Angle Muon System ($|\eta|<1$)

- CMSC A Counters (AP111 Barrel Counters)
  \[ \Delta\phi = 4.5^\circ \text{ to match CFT and 9 segments in } \phi \]

- CMSC B/C Counters
  Cosmic ray veto scintillation counters

- Proportional Drift Tubes (PDT's)
  Three layers provide independent momentum measurement

Forward Angle Muon System ($1<|\eta|<2$)

- Pixel Counters
  \[ \Delta\phi = 4.5^\circ \text{ to match CFT and } \Delta\eta = 0.1 \]

- Mini Drift Tubes
  Three layers provide independent momentum measurement

Shielding

- Thick shielding (iron, lead, and polyethylene) around the beam pipe and low $\beta$ quads in forward region.

- Polyethylene shielding between calorimeter and CMSC A counters.
Trigger Hierarchy for Run II

L1 4.2 μs

5-10 kHz

L2 ~100 μs

1 kHz

L3 25 ms

10 Hz

Custom hardware-based triggers for L1 objects consistent with tracks, muons, electrons, and jets.

Processor-based triggers which combine L1 objects into muons, electrons, and jets.

L3 computer farm uses offline algorithms for particle/jet identification.
Elements of the L1 Muon Trigger

- Transmission of data to the MTCXX cards from the CFT and muon front end electronics via AMCC Gbit/s serial links over copper (16 inputs per card)

- One MTC05 and MTC10 card per octant

- One MTCM per region forms a regional trigger decision based on octant trigger decisions

- The MTM forms a global trigger decision based on the regional trigger decisions of the three MTCM's

- Trigger logic implemented in Altera's Flex 10K series of FPGA's

- Buffering of muon trigger data pending L1 and L2 trigger decisions, resulting in deadtimeless operation

- Communication, FPGA programming, and error monitoring performed via 1553 interface on MTCM
MTC05 Logic Detail

10 cables each with up to 6 CTT tracks per crossing

Combinatorial Logic
Determine A or A.B.C
PIXEL coincidences

Memory lookup
Determine pT threshold, sign, and CFT centroid

Combinatorial Logic
Match CTT tracks and PIXEL coincidences

Summing Logic
Output consists of 2-bit counters for 4 different pT thresholds and phi information for triggers

To MTCM

All logic implemented in less than 10 Flex 10K devices with a total time of under 396 ns.
MTC10 Logic Detail

Scientific hits for A, B, C layers

Combinatorial Logic
Form anemoids ("stubs") in each layer of PDT/MDT's.

Combinatorial Logic
Confirm stubs with scintillator information

Summing Logic
Output consists of 2 bit counters for four types of triggers: A, AB, AC, or BC, AB and BC

To MTCM

All logic implemented in less than 10 Flex 10K devices with a total time of under 100 ns.
Results from GEANT Simulations

- Full GEANT simulation of all muon upgrade detector elements
- FPCA logic simulated by Fortran routines
- Single muon events used for finding trigger efficiencies
- Minimum bias events with 1, 2, 4, 6, and 8 interactions used for estimating background rates

Figure 1: Efficiency curves for $1.1 < |\eta^{\mu}| < 1.5$ for four $p_T$ thresholds
Muon Level 1 Trigger

- Results
  - 400 Hz for single $\mu$, $p_T > 7$ GeV
  - 900 Hz for dimuons, $p_T > 2$ GeV
- Uncertainties: shielding factors & statistics
- Agrees with calculations based on Run I data plus $n_A^*n_B^*n_C$ scaling and shielding calculations
Conclusions

- We have designed and are building a new L1 muon trigger for Run II of DØ.

- Highlights of the muon trigger system include:
  
  Use of all upgrade muon detector elements in the muon trigger
  
  Muon triggers are searched for locally (in octants) and combined to form global trigger decisions
  
  Muon trigger logic implemented in FPGA's
  
  Deep buffering for deadtimeless operation.
  
  Use of Gbit/s serial links to minimize cable plant

- Full GEANT simulations for $\mathcal{L} = 2 \cdot 10^{32}$/cm$^2$/s and 132 ns bunch crossing

  High $p_T$ (7 GeV/c) single muon trigger rate = 400 Hz
  
  Low $p_T$ (2 GeV/c) dimuon trigger rate = 900 Hz