THE RUN 2 DØ MUON SYSTEM AT THE FERMILAB TEVATRON

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The Run 2 DØ muon detector at the Fermilab Tevatron has three subsystems: Proportional Drift Tubes (PDTs), Mini-Drift Tubes (MDTs) and trigger scintillation counters. The PDTs were used in the 1992-1996 data taking run and provide tracking coverage for pseudorapidity $|\eta| \leq 1.0$. The forward muon tracking system, new for Run II, uses planes of mini-drift tubes and extends muon detection to $|\eta| = 2.0$. Scintillation counters are used for triggering and for cosmic muon and accelerator backgrounds rejection. Toroidal magnets and special shielding complete the muon system. All subsystems interact with 3 levels of triggers. Level 1 generates trigger information synchronously with the beam crossing. Level 2 operates asynchronously with a maximum decision time of 0.1msec. All three muon detector subsystems use a common readout system based on a 16-bit fixed point digital signal processor, which buffers the data from the front-end, re-formats the data if accepted by Level 2 and sends it to the Level 3 trigger system, which is a farm of Linux workstations running software trigger filters. Muon triggers accepted by Level 3 are written to tape for offline reconstruction.

1 Introduction

The recent upgrade of the Tevatron Proton-Antiproton Collider at Fermilab near Chicago for increased luminosity up to $2\times10^{32} cm^{-2} s^{-1}$ and smaller beam bunch spacing of 396 ns requires a corresponding upgrade of the DØ detector [1,2]. The Run 2 DØ muon system will enable DØ to trigger, identify and measure muons in the new high rate environment[3]. The central muon system has been supplemented with additional scintillator layers for triggering, cosmic ray rejection, and low momentum muon measurements. The Run I forward muon system has been completely replaced with scintillator pixels and mini-drift tube chambers. New shielding has been added to decrease background rates. The muon trigger has been redone to accommodate the high trigger rate and increased number of interactions per beam crossing. The upgraded central tracking system consisting of the Central Fiber Tracker and the Silicon Microstrip Tracker improves the momentum measurement of muons as well as other charged particles.

The detection of leptons (muons and electrons) is very important for physics at the energy frontier. The study of intermediate vector bosons decaying into leptons will give precise measurement of the mass of the W, results on forward backward asymmetry and the measurement of anomalous gauge boson couplings. Multileptons are a signature of supersymmetric particles in many models. The search for leptoquarks and heavy vector bosons uses lepton final states. Massive stable particles can appear as slowly moving muon-like objects. Muons are also used to tag b-jets for B physics, top physics and higgs searches.

2 Central Muon Detectors

The central muon tracking system, with pseudorapidity coverage $|\eta| \leq 1.0$, consists of 94 proportional drift tube chambers built for Run I [4]. The A layer is between the calorimeter cryostat and the 2 Tesla muon toroid magnet. The A layer chambers on the top and sides have 4 decks to help in rejecting backgrounds, while those on the bottom only have 3 decks due to space constraints. The B and C layers outside the toroid have three decks each. See figure 1 for the layout. The chambers are rectangular aluminum tubes with 5.7 cm by 10 cm cells. The drift distance resolution is about 1mm. The momentum resolution from the PTDs is $\sim 30\%$ for muons with $p_T = 100$ GeV/c, where p_T is the momentum transverse to the beam direction. But when the muon track is matched with tracks from the D0 central tracking system, the resolution is improved for all central muons. For muons with p_T=100 GeV/c, the resolution using central tracking is $\sim 15\%$.

Layers of scintillator, called the Cosmic Cap, on the top and upper sides of the central muon detector were used in Run 1 to help reject cosmic rays. Coverage was completed for Run 2 with the addition of the Cosmic Bottom counters. A new layer of scintillators, called the Aϕ counters, was added between the A layer and the calorimeter [5]. These counters have ϕ segmentation of 4.5 degrees. The Aϕ counters are used for muon triggering, rejection of out-of-time scattered particles and identifying low p_T muons.

3 Forward Muon System

The Forward Angle Muon Detection System, which consists of mini-drift tubes (MDTs) and pixel scintillators, is entirely new for Run 2. The Run 1 forward toroids are used, and new shielding has been added. The MDT system covers the region $1.0 \leq |\eta| \leq 2.0$ [6]. The mini-drift tubes have 8 cells of 1 cm x 1 cm cross-section, and are made of aluminum extruded combs and plastic sleeves. The A-layer chambers are in front of the forward toroid magnet and the B

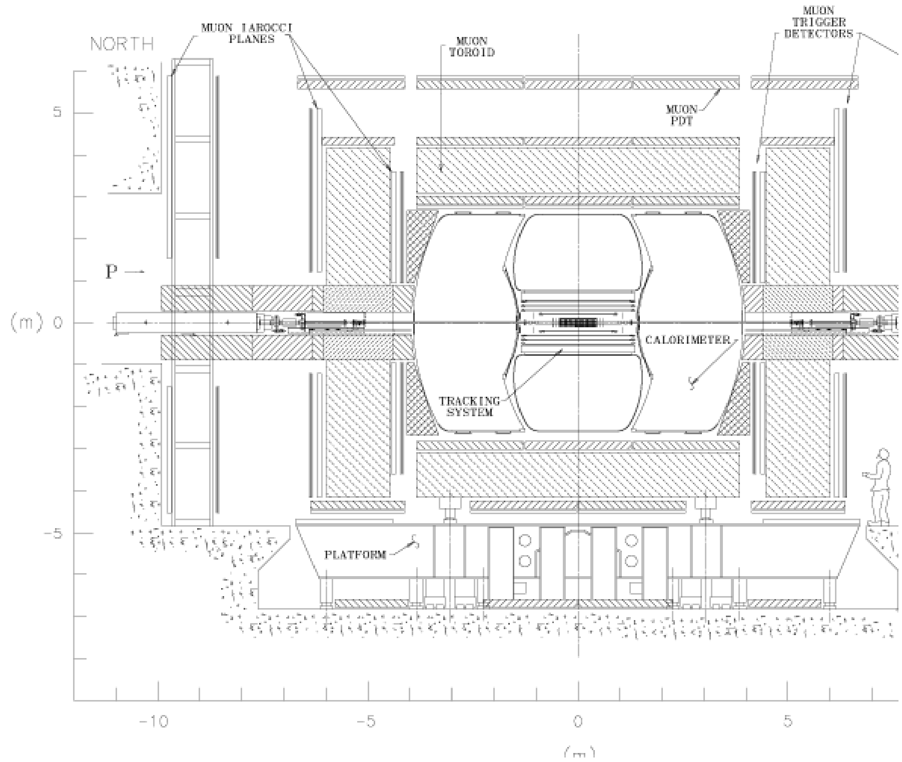

Figure 1. The Run 2 DØ Muon Detector

and C layers are behind it (see figure 1.).The layers are divided into octants with the length of the tube depending on its position in the octant. As in the central region, the MDT A-Layer has four decks of drift tubes and the B and C Layers have three decks each. The coordinate resolution is 0.7 mm/deck. The momentum resolution is 20% for low momentum tracks.

The Muon Forward Scintillator Pixel system covers the same eta region [7]. The ϕ segmentation of 4.5 degrees matches the segmentation of the Central Fiber Tracker. The η segmentation is 0.1. The typical size is 20 cm x 30 cm. The counters are made out of Bicron 404A scintillator. Kumarin WLS bars are used for light collection into PMTs. The scintillators are used for triggering and track reconstruction.

Large backgrounds in the forward direction in Run I were, in general, due to the interaction of beam jets with the forward elements of the D0 detector and the accelerator hardware. For Run 2 shielding was built in several large moveable sections. These extend from the endcap calorimeters and contain the low beta quadrupole magnet inside a case of 20 inches of iron, six inches of polyethylene and two inches of lead.

4 Triggers and Electronics Upgrades

The D0 Run 2 Trigger System consists of 3 levels [8]. Level 1 is a pipelined hardware stage. It processes information from individual subdetectors in Field Programmable Gate Arrays (FPGAs) in a decision time of 4.2 μs. The trigger accept rate, output from Level 1, input to Level 2, is 10KHz. Level 2 is a second hardware stage which uses Dec Alphas. It refines Level 1 information and adds more information if available with preprocessors for each subdetector. A global processor combines information from the subdetectors. Level 2 has a maximum decision time of 100 microseconds. The accept rate out of Level 2 is 1 KHz. Level 3 has two stages: a custom-built data acquisition system and a Linux farm of processors which makes the final trigger decisions. The farm does partial online event reconstruction and uses filters to accept or reject events. The decision time depends on the number of farm nodes, and is about 50 msec for the beginning of the run. The sustained trigger rate out of Level 3 is 20 Hz, with an output event size of 250 Kilobytes.

In order to handle the high input data rate, the front end electronics of all the muon subsystems was upgraded. Digital signal processors (DSPs) are used to buffer and reformat the data [9]. The DSPs make muon stubs from hits and buffer the Level 1 accepted data from the front-end readout, while a Level 2 decision is pending. If the trigger is accepted by Level 2, the DSPs reformat the data and send it to the Level 3 trigger system.

The muon trigger has 3 levels plus an extra trigger level between Level 1 and Level 2 called SLICs (Second Level Input Computers). [10]. Level 1 triggers uses wire positions, scintillator hits in the A, B and C layers and central, north and south octants to define and/or trigger terms. The SLICs use 80 DSPs to find muon stubs in from nearby hits in a single layer. Level 2 combines muons, calorimeter and central tracks. Timing, p_T, eta, phi and quality values are calculated for all muon candidates. Level 3 uses muon hits, makes muon segments and combines them into muon tracks which are matched with central tracks and calorimeter information. Events passing the triggers requirements are written to tape.

5 Conclusions

Run 2 of the Tevatron has started. The upgraded DØ Muon System is well-matched to the upgraded Tevatron. It should do an excellent job of triggering, measuring and identifying muons. Very exciting physics with muons is just around the corner.

Acknowledgments

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References

1. D0 Collaboration, S. Abachi *et al*, "The DØ Upgrade - the Detector and its Physics", FERMILAB-PUB-96-357-E (Oct. 1997)
2. T. LeCompte and H.T. Diehl, *Annu. Rev. Part. Sci.*, **50**, 71 (2000).
3. D0 Collaboration, "The DØ Upgrade - Forward Preshower, Muon System and Level 2 Trigger", DØ Note 2894, FERMILAB-FN-641.
4. D0 Collaboration, S. Abachi *et al*, *Nucl. Instrum. Methods* A **338**, 185 (1994).
5. D0 Collaboration, B. Baldin *et al*, "Technical Design of the Central Muon System", DØ Note 3365.
6. D0 Collaboration, G. Alexeev *et al*, "Technical Design of the Forward Muon Tracking Detector Based On Mini-drift Tubes", DØ Note 3366.
7. D0 Collaboration, V. Abramov *et al*, "Technical Design of the DØ Forward Trigger Scintillation Counters", DØ Note 3237.
8. G. C. Blazey (DØ Collaboration), "The DØ Run II Trigger", Xth IEEE Real Time Conference, Beaune, France, 22-26 September 1997, Editor C.E. Vandoni, pg 83-87.
9. N. Parashar *et al*, "Real-Time Data Processing in the Muon System of the DØ Detector", IEEE Trans. Nucl. Sci, **47**, 276, (2000), FERMILAB-Conf-01-083-E (Jul. 2001)
10. C. Leonidopoulos, "The Muon Trigger at DØ", to be published in *the Proceedings of CHEP2001*, Beijing, China, Sept. 3-7, 2001.