The Muon Trigger at DØ

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Abstract

To cope with the high luminosity environment of the upgraded TeVatron p-$\bar{p}$ collider at Fermilab, the DØ collaboration has significantly improved the data acquisition system and the triggering capabilities of its detector. The new enhanced trigger combines information from individual sub-detectors to construct physics objects, in three major, consecutive levels of processing, gradually decreasing the 7 MHz input rate to a final accept rate of 20 Hz. In this talk I will discuss the design of the muon trigger.

Keywords: muon, trigger, D0

1 Introduction

The DØ detector in the RunII era is designed to operate in the challenging running conditions of the upgraded TeVatron p-$\bar{p}$ collider: withstand the radiation of a high luminosity environment (2×10^{32} cm^{-2} s^{-1}, a factor of ten increase since RunI), and rise the accept rate and collect data with a bunch crossing time of initially 396 ns (reduced to 132 ns or 7 MHz in phase RunIIb), much shorter than the 3.5 μs of RunI. New subdetectors (silicon tracker, fiber tracker, central and forward preshowers) have been added [1], an improved muon system (with trigger scintilator counters, mini-drift tubes and proportional drift tubes) is in place [2], the trigger system has been significantly enhanced [3] and new substantial shielding surrounds the beamlines.

In order of increasing radii, the detector physically contains a silicon tracker, a fiber tracker, a superconducting magnet, preshowers, a calorimeter and the muon detector system. The muon system consists of sets of tracking and scintillator plane counters divided into a central and a forward region.

The central part of the muon system (covering the $|\eta| < 1$ range [1]) includes 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 three or four 5-cm-thick drift cells per layer. A $\rho - \phi$ magnetic field lives in an iron toroid sandwiched between layers A and B of the PDT system. A p_T measurement is obtained from the kink of the muon in the toroid magnetic field with an average magnitude of 16.55 KGauss [4]. The A-PHI counters have nine segments in the z direction and 80 segments in the ϕ direction.

The forward muon system (located at both endcaps) is covering the $\eta \in [\pm 1, \pm 2]$ region of the DØ detector. It includes mini-drift tubes (MDT) and pixel scintillator counters (PIXEL). There are three layers of MDT's (A, B and C) with three or four decks of 1-cm square cells per layer. Iron toroids are located between the A and B layers of the MDT systems, similar to the one in the central region. The average magnitude of the field is 16.02 KGauss [4]. Three layers of PIXEL's have a 4.5° ϕ-segmentation and a 0.1 η-segmentation.

2 The Trigger

The upgraded DØ Trigger is organized in three major modules [3]. The first trigger level (L1) includes information from scintillators, tracking and calorimeter detectors and has an accept rate of 10 kHz. The second trigger level (L2) incorporates processing modules assigned to specific subdetectors and a single global processor. It identifies higher quality physics objects

[1] η, the pseudorapidity of a particle, is defined as $\eta \equiv -\log(\tan\theta/2)$, where θ is the polar angle of the particle direction with respect to the beam axis.

and seeks for correlations between L1 triggers. It has an output rate of 1 kHz and a maximum deadtime of 5%. The third level (L3) is a computer farm that reconstructs events. A set of physics tools and filters is used to identify interesting topologies and suppress the accept rate to about 20 Hz. A set of FIFO's throughout the system guarantees that the trigger decisions are made in the same order as the events arrive.

3 The Muon Trigger

3.1 L1 muon trigger (L1MU)

L1MU uses tracks from the central fiber tracker (CFT), and scintillator and wire hits from the muon system to form L1 objects. These objects contain the p_T of the formed centroids or "stubs" (± 2, ± 4, and 4, 7 or 11 GeV/c with undetermined sign), the η region ($|\eta| < 1.0$, 1.5, 2.0) and the object quality.

The input to L1MU is sent to hardware on a 1.3 Gbit/s ("G") serial link manufactured by AMCC [5]. The trigger logic is implemented on Altera FLEX 10k [6] and ACEX 1k series FPGA's. The central, north and south regions of the detector are divided into octants. The L1MU triggers are formed locally in each octant on two VME cards (MTC05 and MTC10). In effect, this translates into

- matching the p_T information carried by the CFT tracks with hits in the muon system (mainly for low p_T stubs),
- using patterns of wire and scintillator hits from the muon detectors; a low p_T trigger uses only the innermost tracking stubs, whereas a high p_T trigger uses correlations between stubs in more than one layers, and
- imposing a timing gate around the expected muon arrival time at the scintillator planes to suppress background and cosmic rays; this is necessary because the bunch crossing time is smaller than the proportional drift tube time (~ 600 ns).

For high p_T tracks penetrating the iron toroid, the cosmic ray veto scintillators are also used.

The identified formed stubs are collected by the muon trigger crate manager. The set of central, north and south stubs are picked up by the muon trigger manager, sent to the trigger framework and eventually included in the global physics triggers. L1MU is deadtimeless.

3.2 L2 muon trigger (L2MU)

The second level of the muon trigger uses calibration and more precision timing information to improve the quality of the muon candidates. L2MU receives the L1MU output, and approximately 150 front end data sources (from the PDT's and the scintillator counters). The identified muon candidates contain the track p_T, the η and ϕ coordinates of the muon, and quality and timing inforamtion of the muon component stubs.

L2MU uses the G-serial link for the front ends and a 160 MBit/s serial Hotlink on a coaxial cable for the L1MU output [7]. An analog Cable Input Converter (CIC) for the Hotlink data and a Fiber Input Converter (FIC) for the front end data are used to convert the inputs to proper physical formats. L2MU is more complex than any other L2 system: it has the largest number of inputs, does the heaviest processing job and involves one extra level of pre-processing in the stochastic pipeline sequence.

The first L2MU sub-level (unique to the muon system) incorporates 80 200-MHz Texas Instruments DSP's in a massively parallel scheme. Each DSP is responsible for the stub finding in a small region of the detector, and, therefore, the execution time of the ran algorithms is independent from the number of hits. The DSP's are geographically organized in eleven central and five forward boards (Second Level Input Computer, or SLIC [8]), with each SLIC containing four worker and one administrator DSP chips. The DSP/algorithms, characterized by the detector region (central or forward) and the input or subdetector plane (L1, A or BC), make use of the detector symetry to run the same basic code. Algorithms, data routing within the SLIC board, monitoring and error handling are all implemented in C.

A high-bandwidth 320 MByte/s 128-bit bus, called Magic Bus Tranceiver (MBT), sends the stubs found by the SLIC's to the next level of pre-processing. This is based on a 500 MHz Compaq Digital Alpha processor chip and is a common architectural element for all L2 modules. The Alpha board uses static C++ code to combine the track segments into integrated muon candidate tracks with an associated p_T, and quality and time masks.

The last sub-level of L2MU is the global processing, also implemented on an Alpha board. This is the first time in the trigger stream that trigger objects from different subsystems are combined and correlations between them are examined. The overall accept rate in L2MU is reduced by a factor of ten with respect to the L1MU output.

3.3 L3 muon trigger (L3MU)

Fast processors and a highly parallelized data pathway are the basis of L3MU. A set of physics tools controled by adjustable parameters examines the data for muons as well as other interesting event topologies. L3MU improves the resolution and the rejection efficiency of the L2MU candidates. This is accomplished by including more information from the drift chambers, by adding inputs from the calorimeter and the silicon micro-strop tracker (SMT) and by performing more analytical calculations on CFT tracks and PDT and A-PHI hits with the calibrated data. Once the physics tools have produced all the relevant information, a set of muon filters makes the decision for keeping or rejecting the event. Events satisfying the selection criteria are stored for off-line reconstruction. High level C++ subroutines are used for both the tool and filter implementation.

References

[1] DØ Collaboration, S. Abachi *et al.*, "The DØ Upgrade", DØ Note 2542.

[2] Documentation on the muon system upgrade can be found on `http://www-d0.fnal.gov/hardware/upgrade/muon_upgrade/muon_upgrade.html`

[3] Documentation of the trigger system for RunII can be found on `http://niuhep.physics.niu.edu/ blazey/upgrade.html`

[4] D. Denisov *et al.*, DØ Note 3874.

[5] Manufactured by AMCC, 6195 Lusk Boulevard, San Diego, CA 92121.

[6] Manufactured by Altera Corp., 2510 Orchard Parkway, San Jose, CA.

[7] Manufactured by Cypress Semiconductor, 3901 North First Street, San JOse, CA 95134.

[8] Documentation on the SLIC's can be found on `http://www.nevis.columbia.edu/ evans/L2mu/slic/slic.html`