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Upgrade and Operation of the DØ Central Track Trigger (CTT)

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Abstract- The DØ experiment at the Fermilab Tevatron collider (Batavia, IL, USA) has undergone significant upgrades in anticipation of high luminosity running conditions. As part of the upgrade, the capabilities of the Central Track Trigger (CTT) to make trigger decisions based on hit patterns in the Central Fiber Tracker (CFT) have been much improved. We report on the implementation, commissioning and operation of the upgraded CTT system.

I. INTRODUCTION

Currently, the highest energy collider accelerator in operation, the Tevatron, collides protons and antiprotons with a bunch-spacing of 396 ns at a center of mass energy of $\sqrt{s}$ = 1.96 TeV. This bunch-spacing corresponds to a crossing frequency of 1.7MHz, of which the DØ detector can only record 100Hz for further analysis. The tracking trigger provides a handle to lower our rates by selecting physics events containing high momentum tracks in the central region of the detector.

One important part of the tracking system is the Central Fiber Tracker (CFT) (Fig. 1) [1]. The CFT is composed of 80,000 scintillating fibers 1mm in diameter. As a charged particle passes through a fiber, it deposits energy, some of which is converted into light. The light is converted into an electrical signal through Visible Light Photon Counters (VLPCs), cryogenic semiconductor devices with low noise, high gain and high quantum efficiency. [2,3].

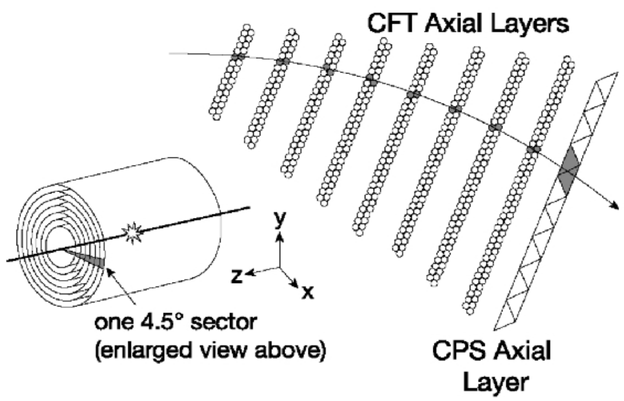

Fig.1: Schematic view of the axial part of the Central Fiber Tracker (CFT). It consists of 8 concentric doublet layers of scintillating fibers and a pre-shower detector (CPS) surrounding the interaction point. One of the 80 trigger sectors used by the CTT is shown with a hypothetical track overlaid.

Discriminator signals for all axial fibers are fed to the Central Track Trigger (CTT) [4]. The CTT provides a trigger decision every 132 ns based on the number of tracks found using logic implemented in field programmable gate arrays (FPGAs) which compare fiber hit inputs to a predefined list of track equations. For trigger purposes the fiber tracker is divided into 80 sectors, where each sector corresponds to 4.5 degrees in azimuth.

The CTT takes the hit fibers for a sector and its two neighboring sectors and compares the hits to predefined hit patterns. Tracks are found in four different momentum bins of 1.5 to 3.0 GeV, 3 to 5 GeV, 5 to 10 GeV, and greater than 10 GeV. In addition to delivering counts of tracks to the hardware Level 1 trigger, the CTT also provides the six highest momentum tracks for each sector for further processing at trigger level 2.

II. HIGH LUMINOSITY CHALLENGE

High luminosity data taking (Run IIb) is well underway, with initial luminosities reaching over 2.8 x $10^{32}cm^{-2}s^{-1}$. With higher luminosity, the number of fake high momentum tracks increases at an unacceptable rate (Fig. 2). As a result, the CTT system needed to be upgraded, particularly the CTT track-finding FPGAs which reside on 40 Digital Front End Axial boards (DFEA2) [5, 6]. Prior to the upgrade, the CTT did not take advantage of the full CFT granularity due to limits in FPGA resources. A doublet scheme was used where pairs of neighboring fibers in each of the eight CFT double layers were combined. The upgraded CTT can now take advantage of the 'singlet' granularity due to larger FPGA resources. (Fig. 3)

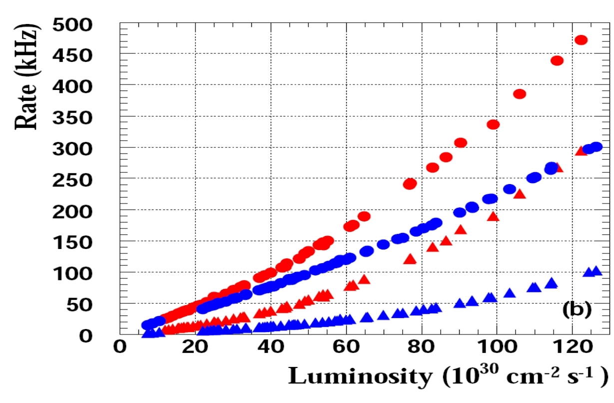

Fig. 2: Trigger rates for single (circle) and double (triangle) track triggers as a function of luminosity for doublet equations (red) and singlet equations (blue) for tracks with pT > 3 GeV.

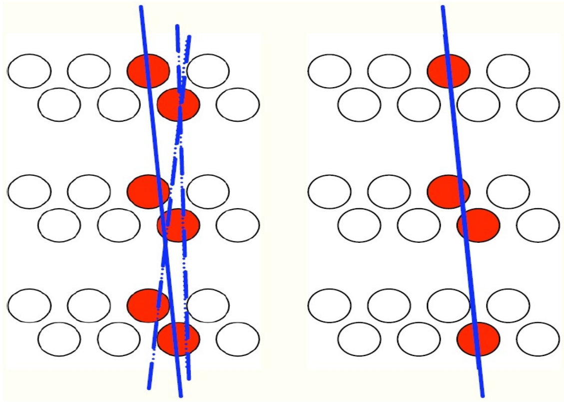

Fig. 3: Schematic view of 3 doublet layers. On the left, the doublet scheme is depicted, showing that beside from the correct track (solid blue line) other tracks (dashed blue lines) can trigger the same equation. With the singlet equation shown on the right, only the correct track fires the trigger

III. CTT UPGRADE

Two 6U crates each containing 20 DFEA2 boards and a redesigned crate controller (DFEC) have been installed during the upgrade. The DFECs provide a high bandwidth Gigabit Ethernet communication path which allows firmware to be downloaded much faster than with the previously used 1553 bus. All I/O and cabling is routed through the back plane of each crate to facilitate easy DFEA2 maintenance access, leaving the front of the board available for diagnostics. There have been no CTT failures since installation.

With the FPGA upgrade, the CTT has a much improved background rejection. and a similar if not better efficiency than before to detect a track of a given momentum. Additionally, we have improved our monitoring of the system to make the CTT more robust and to make it easier for shifters to detect and handle problems. Our monitoring is EPICS based. In addition to feeding information to our monitoring GUIs, the system is also directly tied into the DØ alarm system. Online, we also run a data simulator which compares data in real time with a trigger simulation that processes upstream CTT data inputs from the same event.

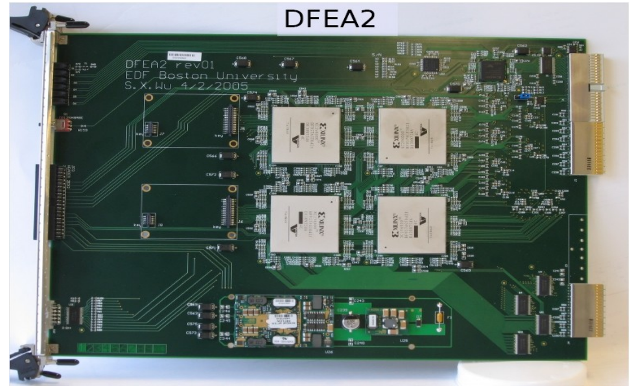

Fig. 4 DFEA2 board with 4 Xilinx Virtex 2 FPGAs in the center. Two boards were installed in a parallel chain in the DØ detector prior to full installation.

IV. SUMMARY

In its current implementation, the upgraded DØ CTT is well able to cope with the increased luminosity delivered by the Tevatron despite the fact that the tracking system was conceived for peak luminosities of 2.0 x $10^{32}cm^{-2}s^{-1}$. With further luminosity increases beyond 3.0 x $10^{32}cm^{-2}s^{-1}$, we must look into new ways to keep our data acquisition rates low. We are currently investigating refining the track finding algorithms and possibly implementing high occupancy trigger vetoes.

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