Level 1 Central and Forward Tracking Trigger for the DØ Upgrade

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Abstract

The upgraded DØ detector will allow for a wide variety of physics with a peak instantaneous luminosity of $2\times10^{32}\mathrm{cm}^{-2}\mathrm{s}^{-1}$. Many of these physics topics heavily rely on the ability to trigger on electrons, photons and muons over a large region of phase space. The level 1 trigger at DØ is designed to handle an input data rate of 7.6 MHz and deliver an output data rate of 7 KHz. The tracking trigger, which forms a significant part of the DØ level 1 trigger uses data from a scintillating fiber tracker, central and forward preshower detectors, calorimeters and muon detectors. Tracks with transverse momentum greater than 1.5 GeV/c are found using the scintillating fiber tracker. The preshower detectors detect energy clusters above preprogrammed thresholds, left by electromagnetic particles. These information are sent to a level 1 trigger framework to be matched with information from the calorimeters to form a level 1 trigger. Large Field Programmable Gate Arrays (FPGA's) are used to code the complex trigger logic which also allow for extension and flexibility in trigger programming.

The upgraded Tevatron collider at Fermilab is expected to deliver an integrated luminosity of 2 fb^{-1} in the initial phase of RunII. The trigger for this collider run is divided into three levels. A hardware-based dead-timeless Level 1 (L1) trigger searches for signals and patterns consistent with electrons ($e^{\pm}$), photons (γ), muons ($\mu^{\pm}$) and jets to reduces the raw collision rate to $\sim$ 7 KHz. At a beam crossing rate of 7.6 MHz, the L1 trigger is designed to hold a new event every 132 ns; however a full L1 trigger decision can take as much as 4.2 μsec, requiring the system to have a pipeline that is 32 events deep. It also needs to send CFT tracks to be used as seeds by the L1 muon trigger in about 800 ns of the beam crossing. Upon L1 trigger accept, data are sent to level 2. Fully digitized data are also readout to level 3 and Offline system at this time. A Level 2 (L2) trigger based on 500 MHz DEC Alpha processors and Digital Signal Processors further reduce this rate to 1 KHz with a dead-time not exceeding 5%. A software based Level 3 (L3) trigger brings down the rate to $\sim$ 50 Hz. A Central Fiber Tracker (CFT), Central Preshower (CPS), Foward Preshower (FPS), Calorimeters and Muon detectors take part in DØ L1 trigger. Of these the first three are used in tracking at L1. More details in [1].

The CFT extending to $\pm 22^o$ in polar angle along with the CPS which extends to $\pm 30^o$ and follows the CFT surrounded by a 2 Tesla Solenoid magnet provides L1 tracking in the central part of DØ. CFT is made up of scintillating fibers contained in 16 cylindrical doublet layers. Eight of these with fibers parallel the z-axis take part in L1 trigger. The magnetic field bends charged tracks in a plane radial to CFT. The CPS has effectively 2 radiation thick ($2X_0$) material comprising the solenoid and lead (Pb) absorber in front of three layers of nested triangular strips made of scintillators. Only the inner most layer (axial) takes part in L1 trigger. Electromagnetic particles undergoing showering in the absorber leaves clusters of energies in the CPS that can be matched with CFT tracks to maximize signal efficiency and background rejection. Between X and Y of the North/South ends of the DØ detector, the FPS will provide additional position and energy information that can be spatially matched to the calorimeter for more precise L1 trigger. FPS has two layers of nested triangular strips at 22.5^o, separated from another two by a $2X_0$ thick Pb absorber. Mounted on the End Cap Calorimeters they are divided into 16 equal azimuthal sectors. Particle showers matched with minimum ionizing tracks (MIP) in layers in front of the absorber can separate $e^{\pm}$ and γ. More details in [1].

The CFT and CPS divided equally into 80 $r\phi$ sectors 4.5^o wide share the same front end boards for readout and trigger logic in the axial layers to facilitate track cluster matching. To account for track bending under magnetic field, for each track with H layer hit in a sector, hit information from neighboring sectors are also made available. The FPS has its own readout and trigger logic board which matches stereo clusters with MIPs to form L1 trigger.

Photons from the CFT, CPS and FPS scintillators are converted by Visible Light Photon

Counters (VLPCs) with 30,000 electrons per photoelectron [2] and discriminated by Scintillating Fiber Trigger chip (SIFT) for L1 trigger [3]. These are mounted on Analog Front End boards (AFE). Discriminated signals are sent to separate digital front end boards (DFE). There are 40 such boards for CFT and CPS L1 trigger while 16 for the FPS. Each of these DFEs have a number of Programmable Logic Devices (PLD) sitting on them where the trigger logic is programmed. PLDs are used as they are re-programmable and hence algorithms can be easily changed even when they are mounted on the detector. They are chosen from Xilinx Virtex 2.5 Volt Family having 400 I/O pins [4]. Standard VHIC Hardware Description Language (VHDL) is used for programming the chips.

The PLDs for the CFT execute pattern recognition code for track finding. Allowed trajectories for all charged tracks above 1.5 GeV/c p_T are computed analytically into equations and coded into the PLDs which are then matched to hit patterns in all 8 axial layers of the CFT. This amounts to 16000 logical equations for the CFT. Tracks are binned into 4 p_T thresholds of 1.5, 3.0, 5.0 and >10 GeV/c and 6 are reported in each bin. Cluster finding in CPS axial layer scans for contiguous strips above preset threshold and assigns a width. The logic resources taken are smaller compared to CFT track finding. CFT track matching with CPS cluster takes place in another PLD, where clusters with tracks are labeled as $e^{\pm}$'s and those with no tracks as γ like. A track with no neighbors in the home and neighboring sectors are tagged as isolated at this level. For the FPS, similar cluster finding algorithm is used in both layers behind the absorber and both are separately tagged with associated MIP signals. Hits in both layers together signal a charged particle ($e^{\pm}$, γ). Separate PLDs in boards following DFEs rearrange the data into geographical sectors before sending them into a L1 Trigger Framework. At the framework level information from different detectors are combined for final L1 trigger. This logic is also programmed in PLD's.

In summary, a fast dead-timeless L1 trigger system has been developed at DØ for central tracking (CFT/CPS) and forward triggering (FPS). Sophisticated readout through VLPC's, discrimination with SIFT's and extensive pipelining is used to achieve this. Large PLD's are used at all levels of L1 triggering providing us with desired flexibility for run time logic adjustments. A major improvement in RunII trigger is the use of multi detector trigger terms at a Trigger Framework level for L1 trigger decision.

References

[1] http://www-d0.fnal.gov/upgrade/upgrade.html

[2] M.Adams et. al. (DØ Collaboration), Nucl. Instrum and Meth., A366, pp.263-277, 1995.

[3] S. Mani et. al., Proc. of 5th. Int. Conf. on Electronics for Particle Physics, Chestnum Ridge, May 10-11, 1995.

[4] http://www.xilinx.com/products/virtex/ss_vir.html