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The DØ Upgrade Trigger

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THE DØ UPGRADE TRIGGER

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ABSTRACT

The current trigger system for the DØ detector at Fermilab's Tevatron will need to be upgraded when the Main Injector is installed and the Tevatron can operate at luminosities exceeding 10^{32} $cm^{-2}s^{-1}$ and with a crossing time of 132 ns. We report on preliminary designs for upgrades to the trigger system for the Main Injector era.

1. Introduction

The Tevatron is a $p\ \bar{p}$ collider operating at a center-of-mass energy of $\sqrt{s}$=1.8 TeV, and currently runs with peak luminosities of 1.1x10^{31} $cm^{-2}s^{-1}$. The DØ detector[1] is optimized for measuring electrons, muons, jets and missing transverse energy ($\not{E}_T$), as these particles often signal the presence of new physics. DØ has a hermetic, compensating sampling calorimeter with fine longitudinal and transverse segmentation in pseudorapidity and azimuth. Muons within $|\ \eta\ |< 3.3$ are reconstructed using proportional drift tubes before and after magnetized iron toroids located outside the calorimeter. There is no central magnetic field.

Around 1997, the Tevatron will be upgraded to operate at luminosities exceeding 10^{32} $cm^{-2}s^{-1}$ and with a crossing time of 132 ns. At the same time, the DØ detector will add a magnetic field , a new fiber tracker, a silicon vertex chamber and a preshower detector.[2]

2. The Current DØ Trigger system

The current DØ trigger is typical of hadron-collider-detector triggers, and consists of a series of trigger "levels". Level 1 is a fast hardware trigger. Electron and Jet candidates are found at this level as calorimeter towers with E_T above a threshold. The L1 hardware also calculates $\not{E}_T$. The muon trigger uses crude measurements of the positions of hits in the muon chambers to search for muon candidates above a momentum threshold. Level 1 is dead-timeless. At L1.5, calorimeter tower clustering is done to allow a sharpened E_T threshold, and the energy in a cone around electron candidates is calculated, as a measure of their isolation. For muons, more precise muon hit locations are used to do a more precise momentum calculation. At Level 2, the detector is read-out at full precision into a computer farm, and the event is classified using offline-like cuts.

*Representing the DØ Collaboration

Signal	L1 (μb)	L1.5 (μb)	L2 (μb)
$W \rightarrow e\nu$ (20 GeV)	2.8	0.7	0.004
$Z^0 \rightarrow e^+e^-$ (20 GeV)	1.3	0.4	0.002
$W \rightarrow \mu\nu$ (15 GeV)	15	1.4	0.02
$Z^0 \rightarrow \mu^+\mu^-$ (15 GeV)	-	-	0.01
$t \rightarrow e, \mu$ (7,5 GeV)	0.1	0.1	0.002
$t \rightarrow e, jets$ (15 GeV)	1.7	0.4	0.01
$t \rightarrow \mu, jets$ (10 GeV)	0.2	0.2	0.01
$t \rightarrow jets$ (10 GeV)	0.3	0.3	0.01
$p\,\bar{p} \rightarrow jet, jet$ (115 GeV)	0.4	0.4	0.005
TOTAL	21.8	3.9	0.07
RATE: 15 x10^{30} $cm^{-2}s^{-1}$	330 Hz	60 Hz	1 Hz
RATE: 2 x10^{32} $cm^{-2}s^{-1}$	4400 Hz	780 Hz	14 Hz

Table 1. High P_T trigger menu for DØ

The hardware limitation on the rate into level 2 is 200 Hz for 5% dead time. Also, the maximum output rate from Level 2 is about 2 Mbytes/second. DØś event size is about 500 kbytes , leading to an event rate to tape of about 3-4 Hz.

Table 1 shows a typical high P_T physics trigger menu for run Ib, the current run, along with the rates.[3] The high P_T processes fit easily within our budgets, with room to spare for samples for b quark studies, QCD studies, etc.

3. DØ Trigger Upgrades

Table 1 also shows the projected rate for high P_T processes when using our current trigger system after the Tevatron upgrades. Obviously, the rate capability of the system needs to be increased. We would also like to improve the efficiency for high P_T muons. For run 1a, the trigger efficiency for muons from $W \rightarrow \mu\nu$ events, including prescales, was about 50%.[4] And, we would like to extend our physics reach at the same time, and trigger on the low P_T electrons and muons which come from b decay.

3.1. DØ Upgrade Parameters

Currently, several things constrain the rates achievable by an upgraded trigger. Firstly, the rate out of L1 is limited to be about 10 KHz by several things. Because the time between events will fluctuate according to a poisson distribution, running close to the theoretical rate limit for a system leads to substantial deadtime. Adding buffers before each trigger level can smooth out the fluctuations. Calculations[5] show that by adding 8 buffers at 10% deadtime one can obtain more than 90% of the maximum rate of the system, which corresponds to a factor of 9 total rate increase. The muon front-end electronics are being upgraded to include such buffers. However, the SVXII chip, designed by Fermilab as the readout chip for the CDF and DØ silicon trackers, has no L1.5 buffers. It has a pipeline to allow the L1 decision time to be longer than the time between beam-crossings. However, this pipeline is reset if the detector is readout. The electronics are also dead during readout. These conditions lead to a 10 KHz maximum L1 accept rate for 10% dead time. The upgraded calorimeter electronics will have a L1 accept rate limit of about 30 KHz.[6] The trigger frame work will need to be replaced. The upgraded frame work is expected to be able to operate at over 20 KHz.[5] Secondly, by doing only minor upgrades to the Level 2 system, it can have a maximum input rate of 1 KHz. If we do more major upgrades, it could achieve even higher rates.[7] So, our system is designed to 10 KHz L1 accepts, 1 KHz L1.5 accepts, and 5-10 Hz to tape.

3.2. New Trigger Elements

Our high P_T physics menu exceeds this event rate. Thus, we need to improve the purity of our sample. To do this, we will include new information into the L1 and L1.5 triggers from the new tracking chambers (Sci-Fi and Silicon), the new preshower, and some new fast muon trigger counters. The Sci-Fi trigger and the muon triggers are reasonably well-developed, and are described below. Information will be also be correlated between the muon chambers, new muon trigger counters, and the Sci-Fi at the L1 time-scale.[8]

3.3. Fast Tracking

The new trigger will include a fast hardware tracker[9].[10] The SciFi tracker consists of four superlayers. Each superlayers consists of four fiber double layers: 2 axial and 2 stereo. The stereo layers of the tracker will not be used at L1 time. They may be used at L1.5. For trigger purposes, the fiber detector will be divided into 80 sectors in ϕ, so that track processing can proceed in parallel. This segmentation is wide enough to allow a 1.5 GeV P_T threshold. Track identification is done in 3 steps, with data reduction at each step. The trigger first forms hits from the axial doublets. Then, it combines these hits into centroids for each super layer. In the current design, only ϕ information is used; no vectors are formed. The 4 ϕ layers are then combined together to find tracks. All triggers will be formed by the use of field programmable logic arrays. The time to form the trigger is much less than the time between beam-crossings. Rate simulations versus P_T threshold have been calculated using ISAJET[11] low P_T di-jet events plus GEANT[12] simulation.[9] The percent of tracks in a given P_T bin that come from smear-up of lower momentum tracks range from 9% at 1.5 GeV to 20% at 3 GeV for single vertex events. The percent from combinatorial fakes ranges from 9% at 1.5 GeV to 25% at 3 GeV.

3.4. Muons

Albedo, or particles from the showers of forward-going hadrons for which the direction has become randomized, is an unexpectedly severe problem in the DØ muon trigger system.[13] For example, for the muon chambers within $|\eta| < 1.0$ and inside the toroids, the probability per elastic collision of hits from albedo particles producing a trigger-like pattern is 10%. There are three solutions which should alleviate most of this problem. For chambers far from the albedo source, the albedo hits are out-of-time. Therefore, in this region, we will install scintillator counters with timing resolution of order 2 ns. Studies show that 96% of albedo hits can be removed this way, while maintaining 95% efficiency for real muons. These chambers should also allow us to lower our P_T threshold from about 3 GeV to about 1.5 GeV, thus increasing our

Signal	Rate (Hz)		
Level 1		Level 1.5	
Tracker+preshower e (10 GeV)	850	electron (10 GeV)	210
Tracker+muon (10 GeV)	120	Muon (10 GeV)	120
Jet (150 GeV)	80	Jet (150 GeV)	20
Tracker+muon (2 above 1.5 GeV)	2000	2 muons (1.5 GeV)	100-400

Table 2. Preliminary Main Injector era trigger menu and rates at 2x10^{32} $cm^{-2}s^{-1}$

acceptance for muons from b decay. For the muon chambers in the forward direction, close to the albedo source, we intend to install pixel counters, which provide true 3 dimensional space points to the trigger. Studies[14] have shown that this will alleviate the albedo problem in this region. We have also investigated installing shielding between the albedo source and the counters.

4. Rate Calculations

Preliminary rate calculations[15] have been done for this new system. ISAJET[11] low P_T dijet events were convoluted with parameterizations of the fake rates and rejections for the new systems, excluding the momentum smearing and fake track creation for the fast tracker. The calculation also included the effects of multiple interactions. The results are shown in Table 2. With our new system, our high P_T menu fits comfortably within budget.

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