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Triggering the DØ Experiment

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ABSTRACT

The DØ event selection consists of 3 levels of hardware trigger and one level of software trigger. Events passing the hardware trigger are read out to filtering processors, where the event is assembled in the multiported memory of the processor. Our trigger simulation runs from the same configuration files which specify the hardware and software trigger online. We outline the design and performance (rejection, efficiency, and throughput) of the trigger system for muons, electrons, photons, jets, and missing p_T.

1. Hardware Trigger

The Level 0 (valid beam-beam scintillator coincidence) and Level 1 decisions[1] are performed without deadtime in 3.5 μ sec. The present hardware runs with a pipeline step time of 135 nsec. There are 32 possible hardware triggers, each of which is the logical combination of 256 input terms. The input terms can be beam quality conditions (Level 0 vertex centered, Tevatron acceleration inactive, etc), counts of coarse muons, or counts above thresholds from the calorimeter Level 1 processor. The calorimeter processor presently extends to $|\eta| = 3.2$ in trigger towers of $\Delta\eta = .02$ by $\Delta\phi = 2\pi/32$. Electron (and jet) candidates are formed from the EM (EM + Hadronic) sections of single trigger towers exceeding one of 4 thresholds. Scalar E_T and missing E_T are calculated from vector sums of these towers.

In Level 1.5, the muon trigger is refined from a spatial resolution of 60 cm to 5 cm. Deadtime is incurred during the processing time of 5-40 μsec. If the event is rejected, a fast abort of digitization occurs. The trigger reports the number candidates above a single p_T threshold.

2. Software trigger and Trigger Simulator

Level 2 filtering takes place in one of 32 VAX 4000/60 nodes running FORTRAN filtering code under the ELN operating system. For each hardware trigger bit which fired, a specified sequence of "filter tools" is run. The trigger data block tags candidates by trigger bit, so a tool begins by refining the hardware trigger decision using the full detector information. Filter tools exist for jets, muons, electrons, photons, missing E_T, scalar E_T, and narrow jets (τ's). Higher level tools exist for selection on jet topology, or restricting the η range of various candidates.

The primary results of the filtering are 128 Level 2 bits which are used to steer events to data streams and online monitoring tasks. Detailed tool result banks are also attached to the events.

Each of these triggering levels incorporates considerable programmable flexibility. A good simulation is necessary not only to decide on triggering strategy, but also to comission and optimize the system. **ASCII** configuration files, easily read by humans, describe the configuration of the triggering system. The same files also drive the offline simulations. The hardware trigger simulator reproduces the trigger banks at the bit level, and is used for verification as well as physics simulation. Since the filter processors are VAX's, the Level 2 simulation also reproduces result banks bit for bit. The simulators operate on both real and Monte Carlo data.

3. Current Performance

The muon trigger[2] at Level 1 and Level 1.5 requires two or three hits in each of the three layers of the muon system. In addition, a scintillator roof rejects cosmic rays more than ±40ns out of time. The present muon trigger coverage ($|\eta| \leq 2$ is being extended to $|\eta| = 3$. The Level 1.5 trigger reaches 50% efficiency at 7 GeV p_T. The Level 2 muon filter is a subset of the offline code, with the addition of special cosmic ray rejection tests. The Level 2 muon trigger at a 15 GeV threshold typically has a rejection factor of about 50 and runs in 100-400 msec.

The electron trigger in Level 2 uses the full calorimeter information and better energy resolution to refine the Level 1 decision in several ways. It allows a candidate cluster to cross the single trigger towers used in Level 1. Use of the vertex z-coordinate from the Level 0 ($\sigma(z) \sim$ 5cm) is being implemented for the cluster E_T . At present the vertex smearing dominates the sharpness of our Level 2 thresholds, particularly as the crossings are presently not centered. We make cuts on longitudinal shape (energy fractions in the 4 EM layers (2, 2, 7, 10 X_0) and the first hadronic layer) and on the transverse shower shape using the $.05 \times .05$ segmentation in the third EM layer. After the Level 1 trigger, the transverse shape cut is most important. Some triggers add a requirement for isolation in the calorimeter. We are starting to use a track matching requirement (for $|\eta| < 1.0$) of $|\Delta\eta| < .03, |\Delta\phi| < .015$. Both the hardware and software trigger performance is well reproduced by the Monte Carlo simulations. The current Level 2 electron trigger with no track match runs with a threshold of 20 GeV and has a rejection factor of 25. Of this shape cuts give a factor or 4-5, isolation (15% extra energy in a cone of $\Delta R = .4$) gives a factor of 1.7, and raising the threshold from 12 to 20 GeV gives the rest. Processing in Level 2 requires less than 25 msec. An additional factor of 2-4 is expected for the track match for $|\eta| < 1$.

The jet Level 1 trigger requires a single trigger tower above threshold; its performance is well reproduced by a QCD Monte Carlo and our simulation program. In Level 2 the region of the jet definition is enlarged to a cone in $\Delta\eta - \Delta\phi$ space and as a result the threshold is raised typically by a factor of 3-4. The Level 2 code runs in 50-75 msec and provides a rejection of 10-50. Correction for vertex position to the jet p_T is under consideration.

The missing E_T uses the full calorimeter E_T information and continues to be developed. The Monte Carlo simulations agree well with the measured rates out to 15 GeV, beyond which some effects due to voltage-related isolated cells are visible. The Level 2 algorithm recalculates missing E_T using all calorimeter cells, since the present hardware trigger does not include $|\eta| = 3.2 - 4.0$ and the coarse section of the hadronic calorimeters. Current upgrades to the Level 2 trigger include correction for the vertex position, inclusion of energy from the detectors between the active calorimeter cells of the central and end calorimeters in the region around $|\eta| \sim 1$, and use of an algorithm to remove isolated noisy cells from the missing E_T calculation. Level 2 processing takes 50-100 msec. The present unprescaled trigger operates at 35-40 GeV without the improvements mentioned above.

4. Operations

Presently, Level 1 operates at 100-150 Hz (to be improved to 300-1000 Hz soon), which is reduced to 25-50 Hz (150-250 Hz) by Level 1.5. The Level 2 system passes 1-2 Hz (3-4 Hz) to be logged to tape. An express line immediately analyzes 0.2 Hz. Taken as a whole, the Level 2 system currently takes 200 $\pm$ 300 ms per event, compared with its budget of 250 msec. The current bandwidth limitations are in the transfer of the 450 KB events to the data logger and the digitization time for muon data; both are being improved. The Level 2 system will be upgraded to 50 processors on a similar time scale. With normal beam conditions, deadtime due to digitization is less than 10% and the Level 2 system less than 5%. The main ring traverses the detector and a deadtime of 17% is incurred for a 400 msec blanking of the main ring injection cycle and another 9% is lost to 1.6 msec blanking for bunches in the main ring coincident with Tevatron beam crossings. We are investigating changing the blankings to vetos based on beam loss monitor scintillators.

A trigger panel representing the physics groups of the collaboration decides when the trigger configurations are changed. A set of files is prepared to cover various luminosity conditions; these differ by variation of prescale factors or exclusion of certain triggers. The family of configuration files may change when a physics group requests different conditions, or when bandwidth needs to be reallocated. The trigger panel also approves code upgrades and additions for Level 2. New trigger setups are first tested by simulations on existing data. When required, we take special runs to measure rates and verify new setups offline. Some testing is also performed parasitically by a few nodes of the Level 2 system during regular running.

5. References

1. M. Abolins *et al.*, *IEEE Trans. Nuc. Sci 36, No 1* (1989) 384-389.
2. M. Fortner *et al.*, *IEEE Trans. Nuc. Sci 38, (1991), 480.*