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CDF

New Shower Maximum Trigger for Electrons and Photons at CDF

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NEW SHOWER MAXIMUM TRIGGER FOR ELECTRONS AND PHOTONS AT CDF*

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ABSTRACT

For the 1994 Tevatron collider run, CDF has upgraded the electron and photon trigger hardware to make use of shower position and size information from the central shower maximum detector. For electrons, the upgrade has resulted in a 50% reduction in backgrounds while retaining approximately 90% of the signal. The new trigger also eliminates the background to photon triggers from single-phototube discharge.

Inclusive electron triggers have provided CDF with a rich stream of data. Studies of the W and Z bosons, as well as the search for and study of the top quark, are carried out in part using electron triggers with a threshold of typically 12-16 GeV. Topics in b physics, including production properties, the identification of exclusive decays, lifetime studies, and in particular the search for rare processes, demand a lower trigger threshold. In addition, the low-threshold electron trigger provides important calibration samples. In the 1988-89 and 1992-93 Tevatron collider runs, this threshold varied between 6 and 9 GeV, and the lower-threshold trigger was prescaled. With the long-anticipated, and now realized,[1] high-luminosity conditions of the 1994-95 collider run, a means for reducing the cross section of this trigger without raising the threshold was necessary in order to keep the rate of accepted events from becoming unmanageably high. We have solved this problem by making shower position and size information from the central strip chambers (CES) available for use in the trigger decision.

The CDF detector and trigger system have been described in detail elsewhere.[2,3] The detector components of interest for this discussion are the central tracking chamber (CTC), the central electromagnetic and hadronic calorimeters (CEM and CHA), and the CES. The CTC, which is located inside a 1.4-T solenoidal magnetic field, is a cylindrical drift chamber with 84 layers, grouped into five axial and four stereo superlayers. Fast timing information from the axial layers is used by a hardware track finder, the Central Fast Tracker (CFT), which has a transverse momentum resolution

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of $\delta P_T/P_T = 3.5\% \times P_T$. The CEM and CHA, located outside the solenoid, cover the pseudorapidity region $|\eta| < 1.1$, and are organized into projective towers in η-ϕ space of size $0.1 \times 15°$, where ϕ is the azimuthal angle. Fast analog outputs on these calorimeters make the energy in "trigger towers" of size $0.2 \times 15°$ available for immediate use by the trigger. The CES, located inside the CEM near EM shower maximum at a depth of six radiation lengths, provides shower position and amplitude information in both the r-ϕ and z views. Until the present upgrade, this information was not available to the hardware triggers.

The hardware electron trigger consists of two levels. Level-1 operates without deadtime in the 3.5 μsec window between beam crossings, and requires at least 8 GeV of transverse energy, E_T, in a CEM trigger tower. This requirement also serves as the photon trigger at Level-1. At level-2, a hardware cluster-finder identifies clusters with at least 87.5% electromagnetic energy, and a CFT track is sought that matches this cluster in momentum and azimuth. (The photon trigger works similarly, but with an independent threshold and no track-match requirement.) Events that satisfy these requirements are accepted as electron candidates, and are passed to the third level of the trigger, which is a software trigger that uses the full detector information. The rate of events into Level-3 is bandwidth-limited, hence the desirability of reducing the rate out of Level-2.

Fewer than 10% of events that pass the Level-2 electron trigger actually contain good primary electrons. The remaining events consist of conversions, hadronic showers that fluctuate into predominantly electromagnetic energy, and π^0-$\pi^\pm$ overlaps (where the neutral pion provides the electromagnetic shower and the charged pion provides the track). While conversions constitute a valuable control sample, the remaining backgrounds can be significantly reduced by making use of shower position information from the CES. This is because the default trigger can make only a 15° match between the track and the EM cluster, much too loose to reject overlaps. In addition, the default trigger does not know the depth in the CEM at which energy was deposited, so it cannot reject early hadronic showers that take place in the back portion of the CEM, after EM shower maximum. Similarly, the background to photon triggers from single-phototube discharges, which average approximately 1 Hz out of the overall 25-50 Hz allotted for all level-2 accepts, can be rejected by requiring energy in the CES.

We have therefore constructed new front-end readout cards[4] (known as XCES boards) for the CES that make the shower position information available in Level-2, for CES clusters above a selectable threshold. The XCES boards perform sums of the energy on groups of four adjacent CES wires, corresponding to a 2° ϕ segment, and compare them to a threshold (typically ≈ 4 GeV) supplied by an on-board adjustable DAC. The resulting on/off bits, eight bits for each of the 24 15° wedges in each half of the detector, for a total of $8 \cdot 24 \cdot 2 = 384$ bits, are latched by additional new trigger hardware (the CERES board) following a level-1 accept. The turn-on curve for the XCES bits, as a function of the energy deposited on the four wires, is shown in Figure 1.

The CERES board, a double-width, surface-mounted Fastbus board, receives the XCES bits along with track ϕ and signed P_T information from the CFT. A large lookup table is used to identify tracks that match to a CES cluster, and these tracks are flagged

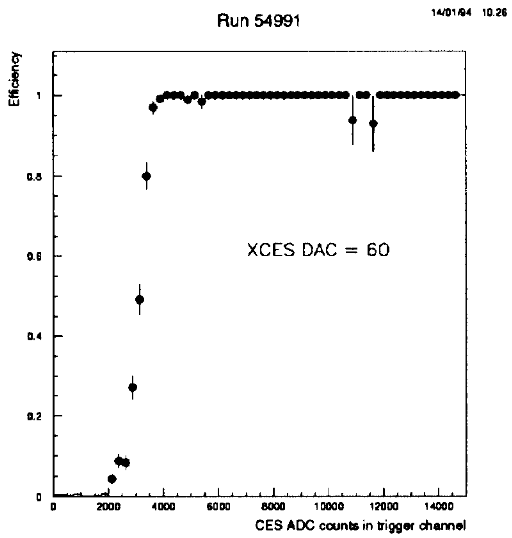

Fig. 1. The turn-on efficiency for XCES bits as a function of the CES energy deposition in a 4-wire strip, expressed here in ADC counts. 1 GeV $\approx$ 800 counts. The DAC threshold that determines the turn-on point is adjustable and is shown here at its nominal value.

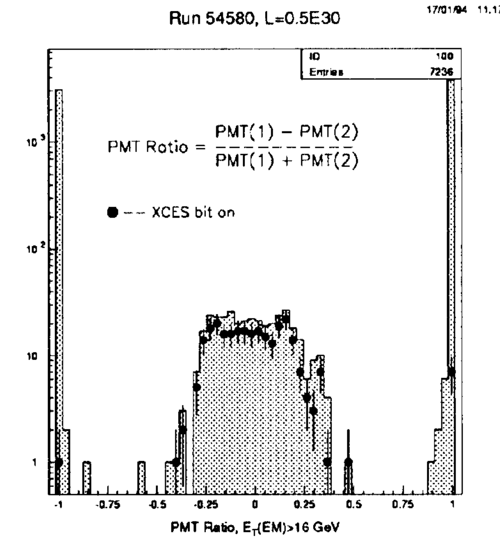

Fig. 2. The phototube ratio R, defined as the difference between the two phototube energies in a tower divided by their sum. Single-phototube discharges show up at ± 1, and dominate the physics rate in this low-luminosity run. The points show R for towers with an OR-bit turned on.

for use in the electron trigger. The electron trigger then operates as before, with the additional requirement that the track associated to the EM cluster must have been flagged by the XCES/CERES system. The CERES board also performs an OR of the eight XCES bits from each wedge. The resulting 48 bits are used to reject the single-phototube background to the photon trigger by requiring that the CEM tower that gave the trigger also have the relevant "OR-bit" set. Figure 2 shows the near-total rejection obtained by this requirement.

As implemented in the CDF trigger for the current collider run, the XCES-based electron trigger requires an EM cluster with $E_T > 8$ GeV, associated to a CFT track with $P_T > 7.5$ GeV that is required to match to a CES cluster. At luminosities above $10^{31}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ the trigger is prescaled by a factor of 2. This trigger has two adjustable parameters: the CES threshold at which XCES bits are set, and the road width used in the CERES lookup table to define a track-cluster match. We have varied these parameters in a series of studies in which the Level-3 trigger was operated in tagging mode.

The cross section for the 8 GeV trigger is shown in Figure 3 as a function of the road size used in the lookup table. The nominal CES threshold of 3500 ADC counts (see Figure 1) was used for this study. For comparison, the cross section for this trigger with no XCES requirement is also shown. Even with a very wide road the rate is reduced by a factor of 1.4, indicating the effect of requiring a CES cluster above threshold anywhere in the wedge. For the nominal road size of 3 cm the trigger cross

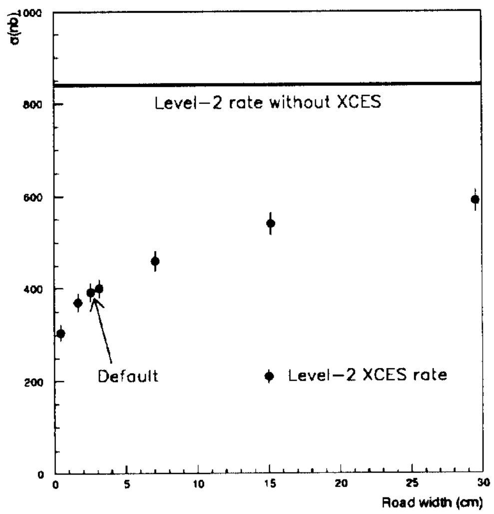

Fig. 3. Cross section for the 8 GeV electron trigger as a function of the road size used to match tracks to CES clusters.

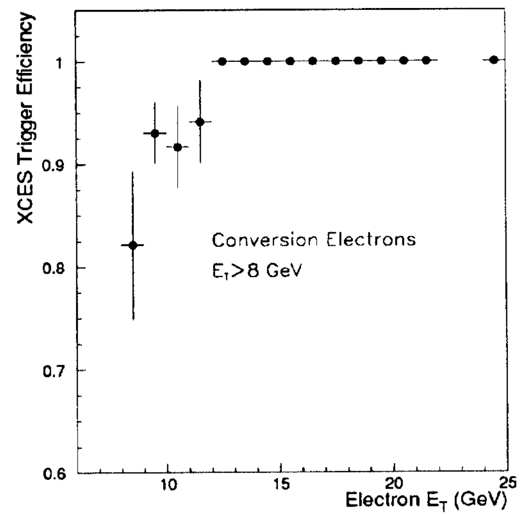

Fig. 4. Efficiency of the 8 GeV XCES electron trigger as a function of electron E_T, as measured in a conversion sample.

section is reduced by more than a factor of two, from 840 nb to 400. The efficiency for the nominal threshold and road sizes, measured using a control sample of electrons from photon conversions, is shown in Figure 4. The efficiency is $\approx$ 85% at the trigger threshold, and rises to 100% for $E_T \gtrsim 13$ GeV. We find little gain in efficiency for larger road sizes, and attribute the increase in the cross section to π^0-$\pi^\pm$ overlaps.

In conclusion, we have built and commissioned a shower maximum trigger that has allowed us to reduce the Level-2 electron trigger cross section by a factor of two while remaining highly efficient for good electrons. Compared to the alternative of prescaling the old electron trigger, this trigger will allow CDF to collect an additional 1-2 million electrons from b decays in the 100 pb^{-1} of luminosity expected in 1994-95.

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References

1. As this article was being prepared, a world-record $\bar{p}p$ luminosity of $1.28\times10^{31}\text{cm}^{-2}\text{sec}^{-1}$ was achieved at the Tevatron on July 23, 1994.
2. F. Abe *et al.*, Nucl. Instrum. Methods Phys. Res. **A271**, 387 (1988) and references therein.
3. D. Amidei *et al.*, Nucl. Instrum. Methods Phys. Res. **A269**, 51 (1988).
4. The CDF front-end system is described in G. Drake *et al.*, Nucl. Instrum. Methods Phys. Res. **A269**, 68 (1988).