Fermi National Accelerator Laboratory

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CDF

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Abstract

We have built and installed new electronics which brings the central shower max detector into the CDF Level-2 trigger. By matching a stiff track from the central fast track processor to an associated shower max cluster, this trigger improvement reduces the electron Level-2 cross section by approximately 50% while retaining greater than 85% of real electrons and allows us to lower our electron trigger threshold.

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1 Introduction

The Collider Detector at Fermilab (CDF) has made extensive use of an inclusive central electron trigger with a relatively low momentum threshold (typically 6 to 9 GeV/c.) This trigger is used for high-statistics studies of semileptonic B decays, high p_T physics, and overall detector calibration. The basic trigger, as used through 1993, requires a match between a central electromagnetic calorimeter (CEM) cluster and a stiff track from the central drift-chamber fast tracker (CFT). The CEM segmentation (15 deg in ϕ) allows only a rather coarse matching between the CFT track and the CEM cluster, and consequently, a large fraction of the triggers are due to overlaps of charged particles and photons. After full event readout, additional pulse height information is available from fine-grained shower maximum (CES) and preshower (CPR) detectors for electron identification in the Level-3 processor farm. Since the bandwidth for full detector readout into Level-3 is limited, it is desirable to improve the signal-to-noise in the Level-2 trigger, by tightening the track-shower match. As part of a trigger upgrade for CDF run 1b (1994), new electronics are used to bring the central shower max detector (CES) into the Level-2 electromagnetic (EM) cluster. The new trigger requires tracks to match to 2 degrees of the shower max channels.

2 The New Electronics

The trigger upgrade electronics include upgraded front end RABBIT electronics boards [1] (called XCES cards). Besides reading out the wire signals of the CES detector [2], these boards provide additional bits for those CES pulse heights above an adjustable threshold. Figure 1 shows schematically the features of CES detector and describes the XCES readout.

New surface mounted fastbus electronics (called the CERES board) receives the XCES signals along with track ϕ and signed P_t information from the CFT to form electron Level-2 triggers. Figure 2 shows the data flow with respect to these new electronics.

In addition to the electron Level-2 signal, the CERES board also provides 48 bits of information available for the photon triggers. The 8 XCES bits from each chamber are "ORed" together to provide one bit per CEM wedge, 24 bits each for east and west wedges. By requiring a CES pulse height in coincidence with a CEM cluster, it is possible to eliminate a significant background in the Level-2 photon triggers, namely noise "spikes" from single CEM phototubes.

3 Threshold and Efficiencies

3.1 Data Selection

To study the performance of the new electronics, we select electron events which have satisfied a Level-2 non-XCES trigger and which we refer to as the CEM8_CFT7.5 trigger. This trigger requires the calorimeter E_t >8GeV and the CFT P_t >7.5GeV/c. We also require that the electrons pass the Level-3 software trigger. In addition, to select a sample of good quality electrons, we require the electrons satisfy [3]:

- Longitudinal profile consistent with an electron shower, i.e., small leakage energy into the central hadronic calorimeter (CHA) E(CHA)/E(CEM)< 0.04
- Good lateral shower profiles measured with the CEM [4] and CES [5]
- Association of a single high P_t track with the calorimeter shower based on position matching ($\mid \Delta r\phi \mid <$ 3cm,$\mid \Delta z \mid <$ 5cm) and energy to momentum ratio ($.75 < E/P < 1.5$)

To measure the efficiency of the new track matching trigger, we use a sample of photon conversion electrons. The advantage of selecting conversion electrons is that the purity of this sample is high, and thus they serve as a good control sample to compare with the prompt electrons. To select conversion electrons, we require good quality electrons plus the additional cuts

- $\mid S \mid <$ 0.2 cm where S is the separation of the electron with a second track in the $r\phi$ plane at the point where they are tangent.
- $\mid \Delta \cot \theta \mid < .06$

3.2 Initial Determination of the ADC Threshold.

As a first attempt at selecting an ADC threshold that is highly efficient at selecting electrons, we use our understanding of the response of the shower max detector. We use the electron data from the 1993 run to parameterize the CES pulse height response as a function of the electron momentum and angle. We define a normalized CES pulse height as,

$$\text{CES(scaled)} = \text{CES(observed)}/\text{CES}(P, \theta) \tag{1}$$

where CES(observed) is the measured ADC pulse height in the CES and CES(P, θ) is a function which depends on the electron momentum (P) and angle (θ). The variable CES(scaled) is approximately gaussian with a mean on one and a sigma of .3, for electrons above 8 GeV/c. Figure 3 shows this distribution using the 1994 data for a) electrons passing level-3 cuts, b) conversion electrons and c) a sample enriched in hadrons faking electrons. The fake hadron sample is selected by requiring the good quality electron cuts with the exception of the E(CHA)/E(CEM) cut. Since hadrons have larger hadronic energy deposition, we require .04 <E(CHA)/E(CEM)< .12 to select a hadron enriched sample. The dashed curves show those events which have also passed the new track matching trigger with an ADC threshold of 3500 counts (a threshold of 3500 counts corresponds to an electron energy of approximately 6.75 GeV once gain corrections have been included.) A comparison of Figure 3b to Figure 3c shows the new trigger to be more efficient at selecting real electrons.

To determine the efficiency for a cut on the minimum CES ADC pulse height for real electrons, (such as from $B \rightarrow e\nu$), we can fit the inclusive electron E_t spectrum for $b + c$ electrons in the 1989 data to the form

$$dN/dP_t = E(P_t, \epsilon_E(\mathrm{L2}), \epsilon_P(\mathrm{L2})) * N * (P_t/10)^{a+bP_t} \tag{2}$$

where ϵ_E gives the Level-2 efficiency for calorimeter, E_t >8 GeV and ϵ_P gives the Level-2 efficiency for the CFT, P_t >7.5GeV/c. (We have assumed the actual electron $E_t = P_t$ and have fit the $(b + c) \rightarrow e\nu$ from the 1989 data and assumed b/(b+c)=.8, independent of E_t) [3].

The efficiency is then estimated by integrating over the electron spectrum and computing N'/N where N and N' are described by

$$N = \int (dN/dP_t) dP_t d\sin\theta \tag{3}$$

$$N' = \int (dN/dP_t * P(\mathrm{CES(minimum)}/\mathrm{CES}(P,\theta)) dP_t d\sin\theta \tag{4}$$

where CES(minimum) is the threshold ADC value and P(CES(minimum)/CES(P, θ)) is the probability that an electron will have a CES pulse height above the minimum. The distribution of the predicted efficiency is shown in Figure 4. From this figure, we would expect an ADC threshold of 3500 counts to be greater than 90% efficient at selecting prompt electrons given our Level-2 E_t and P_t thresholds.

Conversely, we can determine the efficiency of a minimum ADC cut using the 1994 data directly. Figure 5a shows the ADC distribution for conversion electrons. The integral of this spectrum is shown in Figure 5b. Using Figure 5b an ADC threshold of approximately 3500 counts is greater than 85% efficient at selecting conversion electrons with E_t >8GeV/c and P_t >7.5GeV/c. The measured efficiency is consistent with the predictions of the 1989 data shown in Figure 4. Differences are attributed to Level-2 trigger efficiency estimates made on the 1989 data to simulate a lower E_t and P_t turnon and due to the fact that Figure 4 predicts the efficiency for selecting background free prompt electrons and we have not subtracted the fake conversion background from our conversion signal.

3.3 Efficiency for Conversion Electrons

The efficiency of the XCES hardware is shown in Figure 6 for an ADC threshold of about 3500 counts. In this figure, the ADC plotted is for the XCES bit with the largest 4-wire sum for the triggered wedge. The curve through the points were fit to the form

$$\epsilon(\mathrm{ADC}) = \frac{1+b}{\exp^{a/\mathrm{ADC}} + b} \qquad (5)$$

where a=35100$\pm$1700 and b=133000$\pm$74000.

We use the conversion electron data to measure the E_t dependence of the new track matching trigger efficiency. (For the remainder of this paper, we refer to the new track matching trigger as the XCES trigger.) Figure 7 shows that at a threshold of E_t=8 GeV, the efficiency is about 86% efficient and slowly rises to 100% by about 16-18 GeV.

We also study the position dependence, both as a function of $r\phi$ within a wedge and as a function of detector z. Figure 8 shows the efficiency as a function of the electron $r\phi$ position where in this figure, $r\phi$ is expressed in terms of a local x position (-21cm to 21cm for each wedge). Figure 8a shows the distribution in local x for conversion electrons. Figure 8b shows the efficiency as a function of local x. Figure 9 shows the same distributions as a function of the local z coordinate. The dependence of the XCES efficiency on z reflects the fact that, for large z, the ionization path length for shower secondaries in CES increases as $1/sin(\theta)$, resulting in larger average pulse height.

3.4 Road Width and Threshold ADC Studies

The new trigger hardware has essentially two components which can be adjusted to maximize the yield of electrons while maintaining the allotted Level-2 bandwidth. These are the DAC threshold and the width of the road used to match the Level-2 track with the CES cluster. To optimize these parameters, we have studied data taken in a special Level-3 tagging run. We have required that the electrons satisfy the non XCES trigger, (CEM8_CFT7.55) and that the ϕ of the Level-2 electromagnetic cluster match the ϕ of the Level-3 electron. In addition, we have required that there be only one Level-2 track pointing to the ϕ of the EM cluster. Figure 10 shows the XCES triggered cross sections as a function of the road width, where the road width corresponds to the allowed distance between the Level-2 projected track and the CES cluster.

The main conclusion from this figure is that enlarging the road beyond 3 cm has little effect on the Level-3 rate. This is reasonable since this rate is just the fraction of good electrons passing the Level-3 software cuts, which include a matching cut of $| dx | < 3$ cm between the electron cluster and Level-3 track projection. An indication that the lookup algorithm is really doing the right thing is the fact that when the road width is set equal to 0, the Level-3 cross section is only reduced by about 20%. This is because a road width equal to 0 implies that only the XCES bit containing the wire the track projected to is allowed as a valid trigger. Figure 11 shows the distribution of the difference in the x position between the projected Level-2 track and the measured electron cluster in the CES.

With no road requirement, the Level-2 rate reduction is already down by a factor 1.4 as observed in Figure 10. This is due to the ADC requirement on the pulse height. Table 1 lists the XCES trigger Level-2 and Level-3 cross-sections as the ADC threshold is lowered. The numbers in this table should be compared to the non XCES trigger cross sections of Level-2 σ=840 nb and Level-3 σ=87 nb as determined from a run with average luminosity of $1.5x10^{30}(cm)^{-2}/\mathrm{sec}$

XCES ADC Threshold	XCES L2 σ (nb)	XCES L3 σ(nb)	XCES L3 σ/L2 σ	ϵ(L3) %
3500	402	73.2	.182	84.1
3000	452	76.6	.169	88.0
2500	505	80.0	.158	92.0
No XCES	840	87.0	.103	100.

Table 1: Table of Level-2 and Level-3 XCES trigger σs for different ADC thresholds.

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[5] F.Abe, et. al, Phys. Rev. Lett., 68, 2734 (1992). We use $\bar{\chi} < 10$.

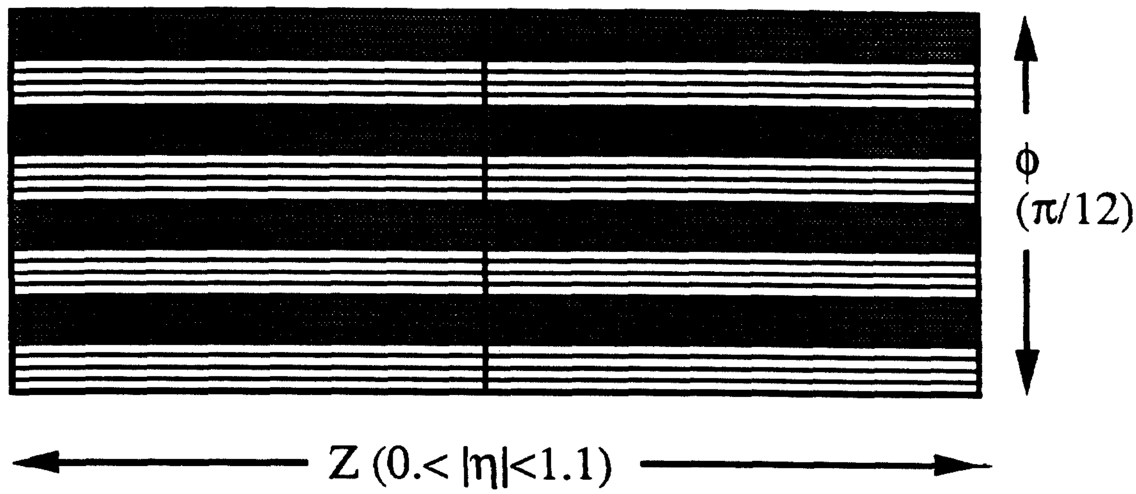

Figure 1. The CES module is a rectangular chamber of dimensions 48cm x 233.4cm which contains 32 wire channels approximately 1.45cm apart in the $r\phi$ view [2]. The wires are clipped at midpoint (z =121cm) and read out from both chamber ends. There is one chamber for each CEM wedge of the detector with a total of 48 wedges, 24 on the the east end of the detector and 24 on the west end. The XCES cards cluster the CES wire readouts into groups of 4, corresponding to the strips in the Figure above, and perform analog sums on the 4 clustered channels. A differential TTL high signal is generated if this sum is above an adjustable threshold. The XCES signals from the two ends of a given chamber are ORed together to provide 8 phi slices.

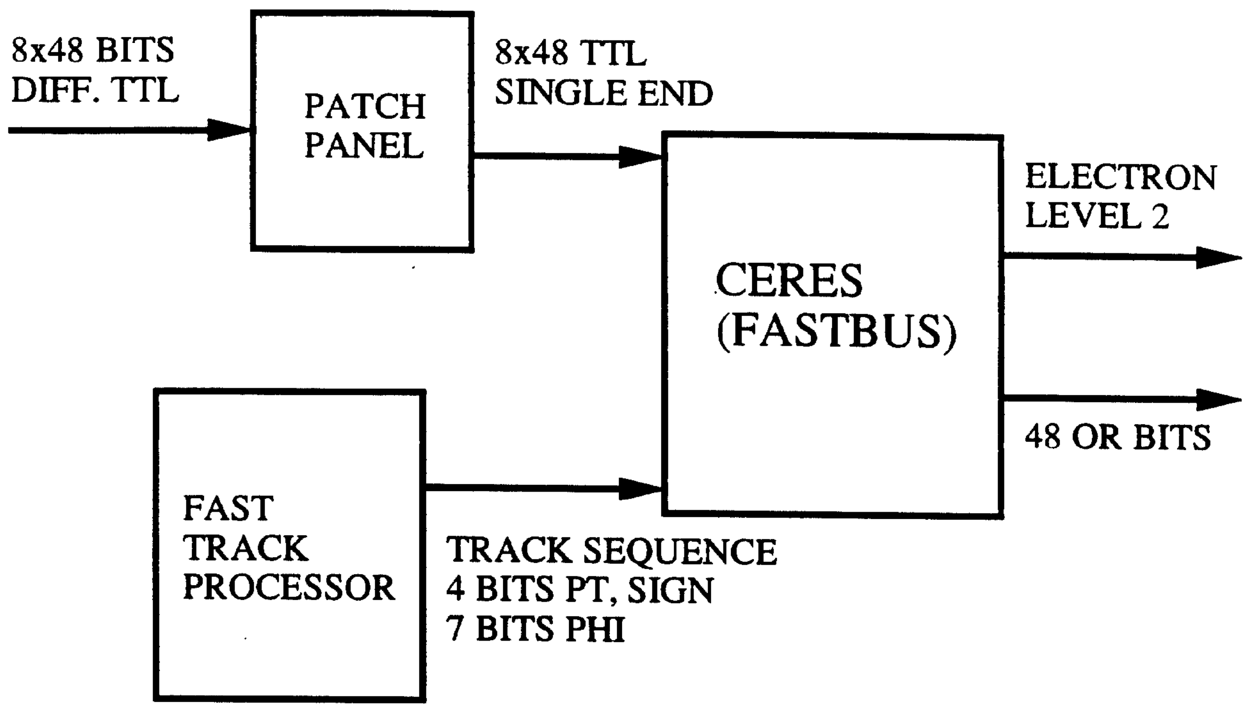

Figure 2. Schematic of the data flow for the new trigger electronics. The CERES board receives the 48x8 XCES signals along with track ϕ and signed P_t information from the central fast tracker processor. Lookup tables located on the CERES board match the different XCES bits with projected tracks. An electron Level-2 accept signal is generated if a match is found. In addition to the electron Level-2 signal, the CERES board also provides 48 bits of information available for the photon triggers. The 8 XCES bits for each detector phi are "ORed" together to provide one bit per phi, 24 bits for east phis and 24 bits for west phis.

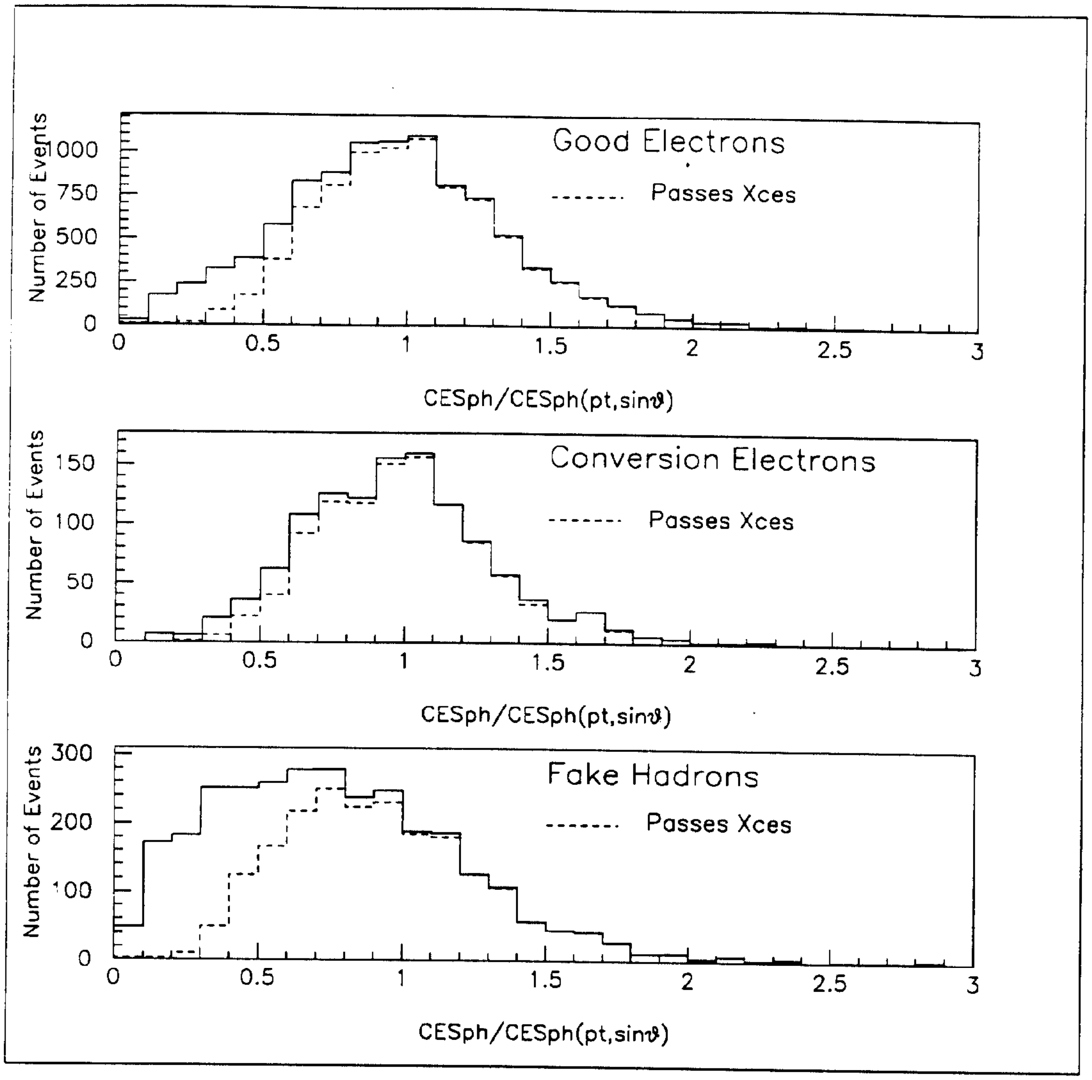

Figure 3. The scaled CES pulse height distribution using the 1994 data for a.) electrons passing level-3 cuts, b.) conversion electrons and c.) Fake hadrons. The dashed curves show those events which have also passed the XCES trigger with an ADC threshold of 3500 counts. A comparison of (b) to (c) demonstrates the XCES trigger is more efficient at selecting real electrons.

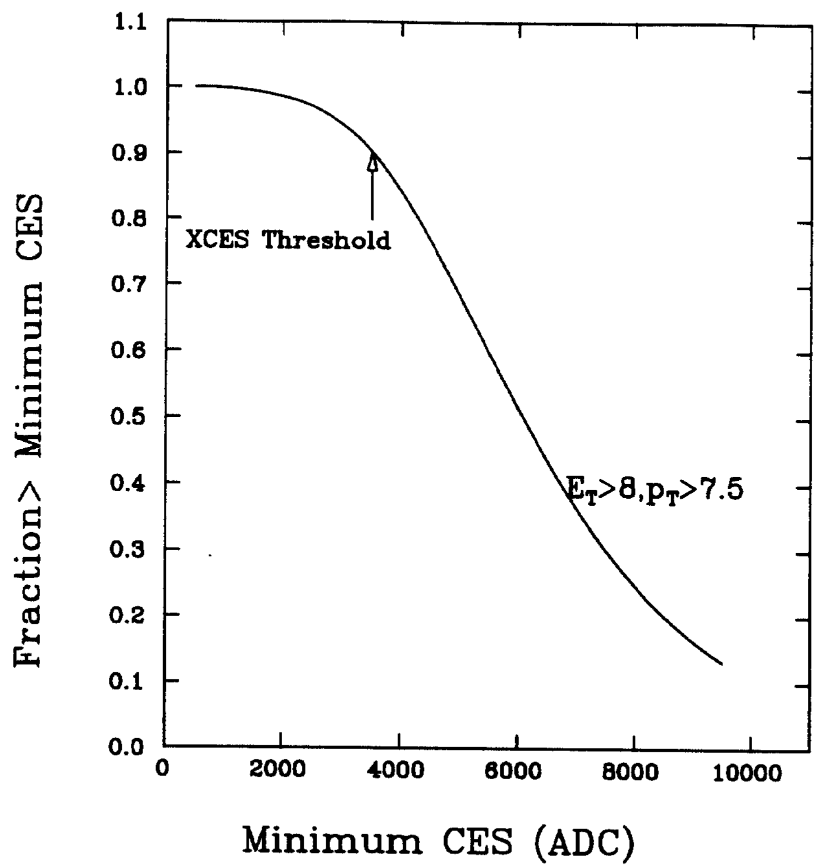

Figure 4. The predicted efficiency for selecting prompt electrons as a function of the minimum CES ADC using the 1993 data and assuming a Level-2 efficiency for E_t >8GeV and P_t >7.5GeV/c.

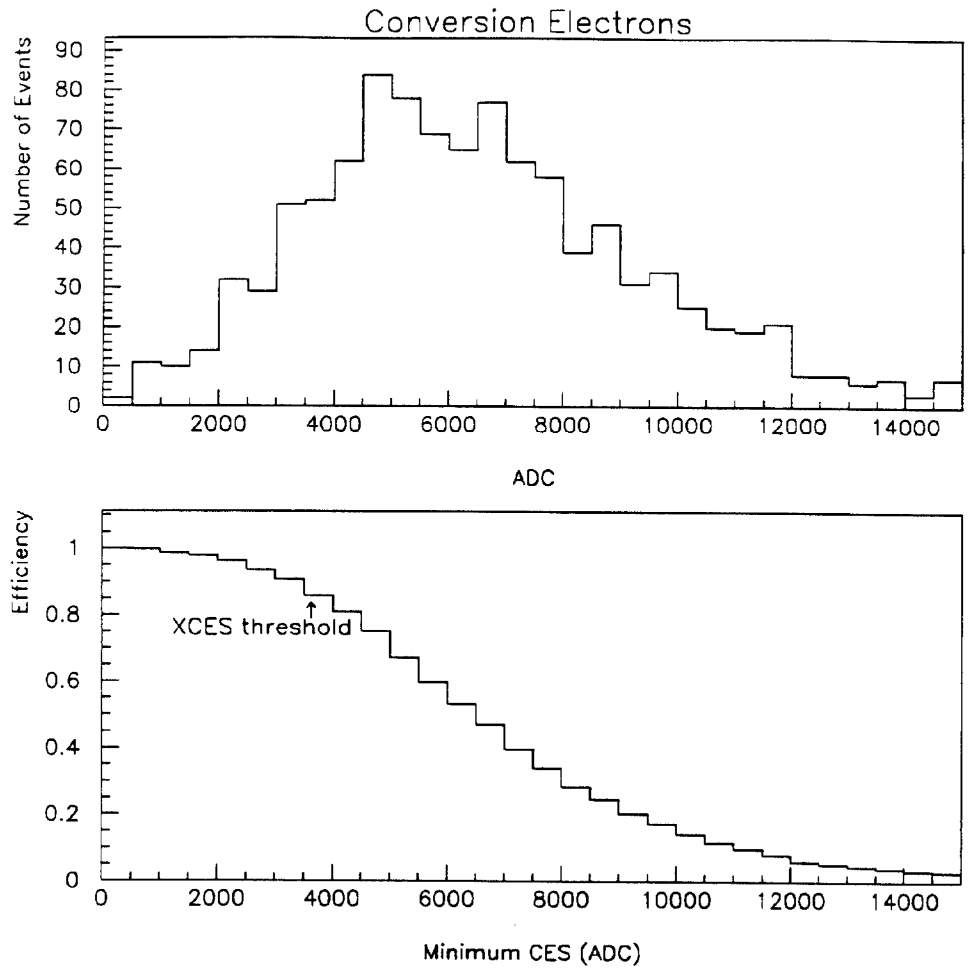

Figure 5. 5a.) The ADC distribution for conversion electrons where the ADC is the 4-channel sum of the XCES bit matched to the electron track. There is no XCES requirement for entries in this figure. 5b.) The integral ADC distribution for conversion electrons. From 5b, the efficiency for selecting conversion electrons above the XCES ADC threshold of 3500 would be greater that 85%.

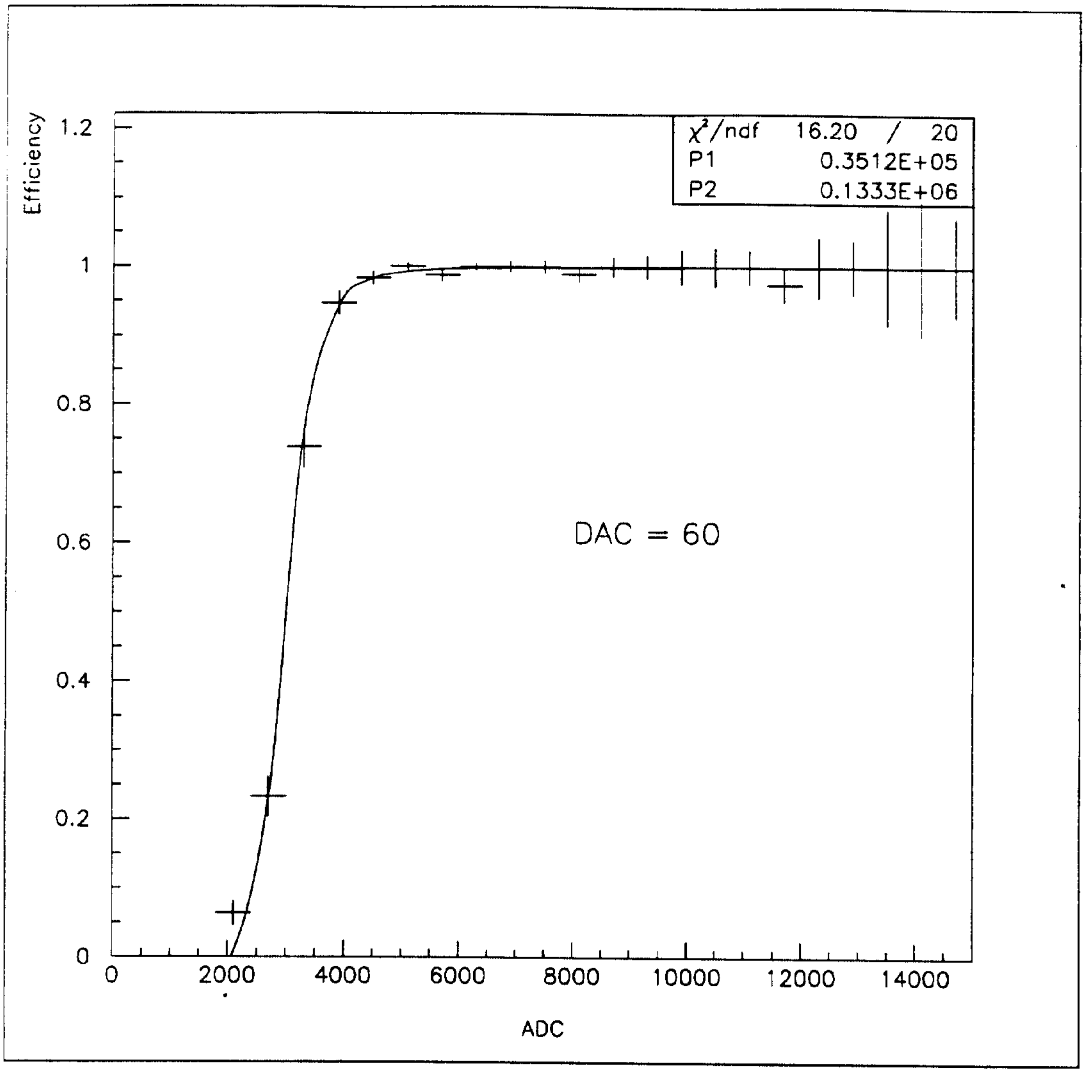

Figure 6. The XCES efficiency distribution as a function of the 4-channel ADC sum for the XCES bit with the largest ADC value. A DAC setting of 60 corresponds to an ADC sum of roughly 3500 counts.

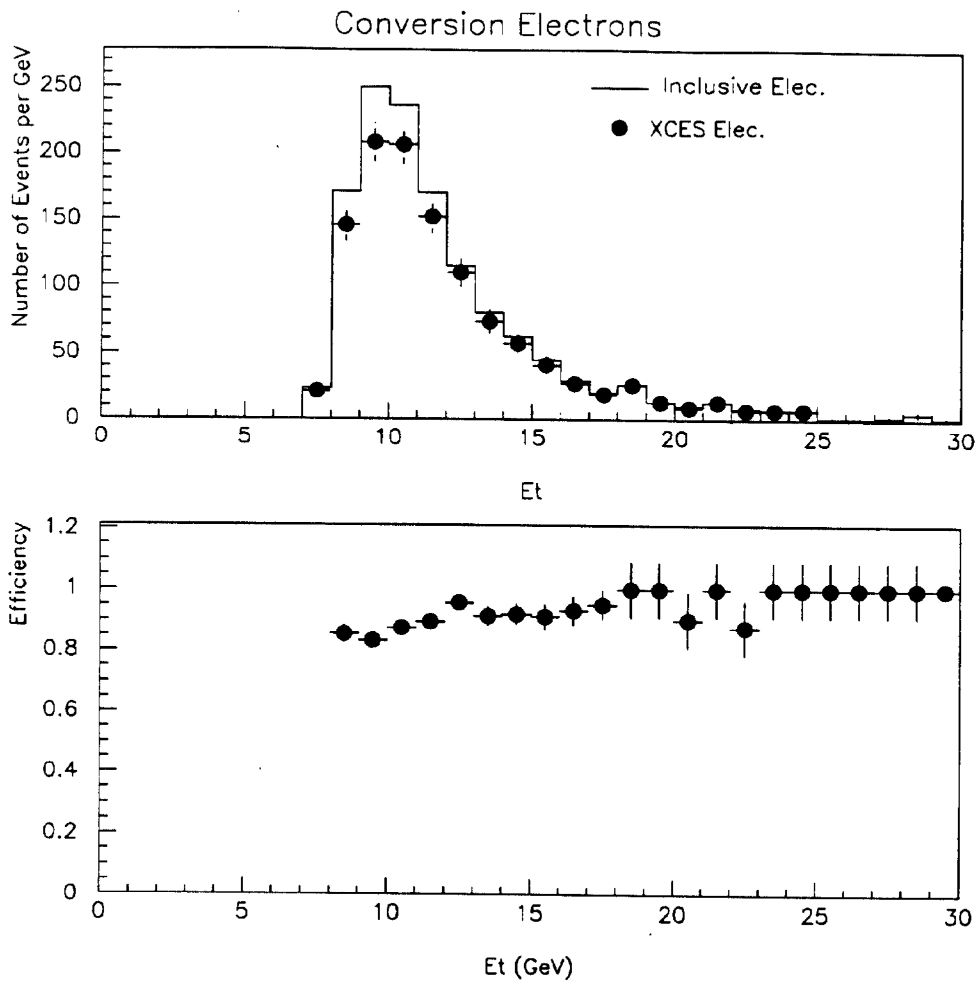

Figure 7. The XCES efficiency as a function of E_t using conversion electrons.

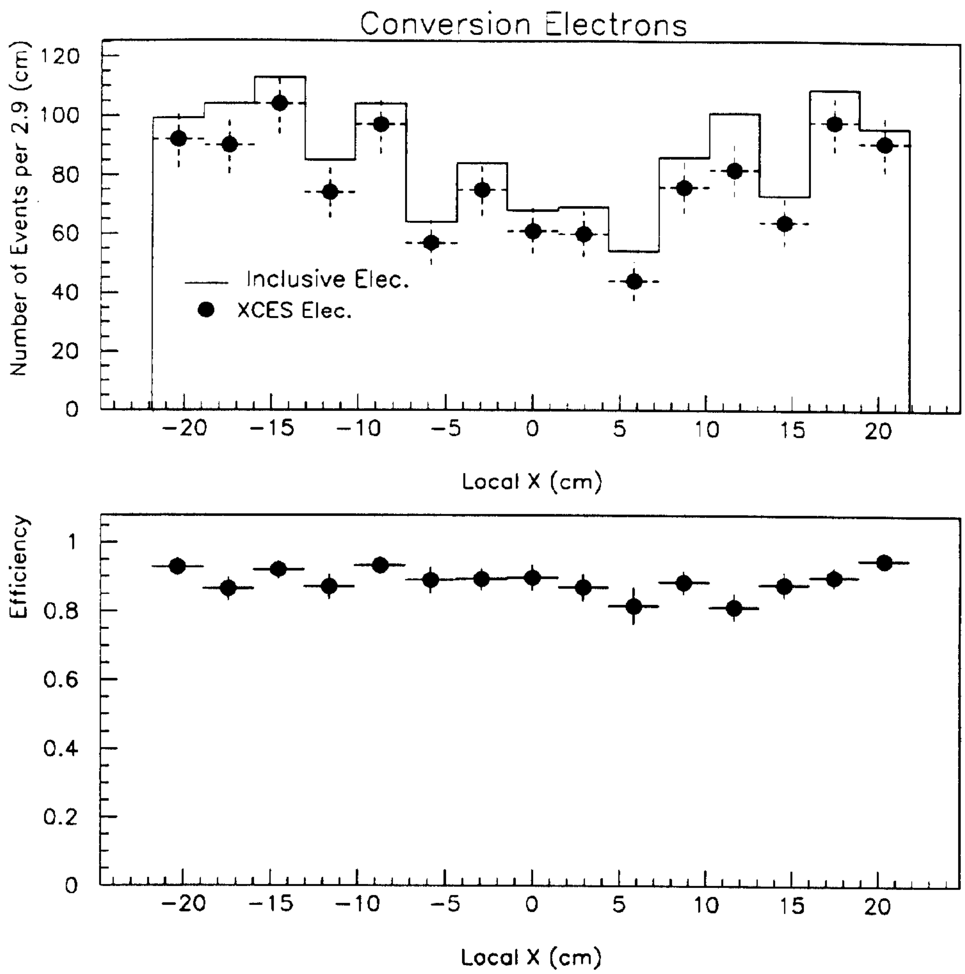

Figure 8. The XCES efficiency as a function of CES local x position using conversion electrons.

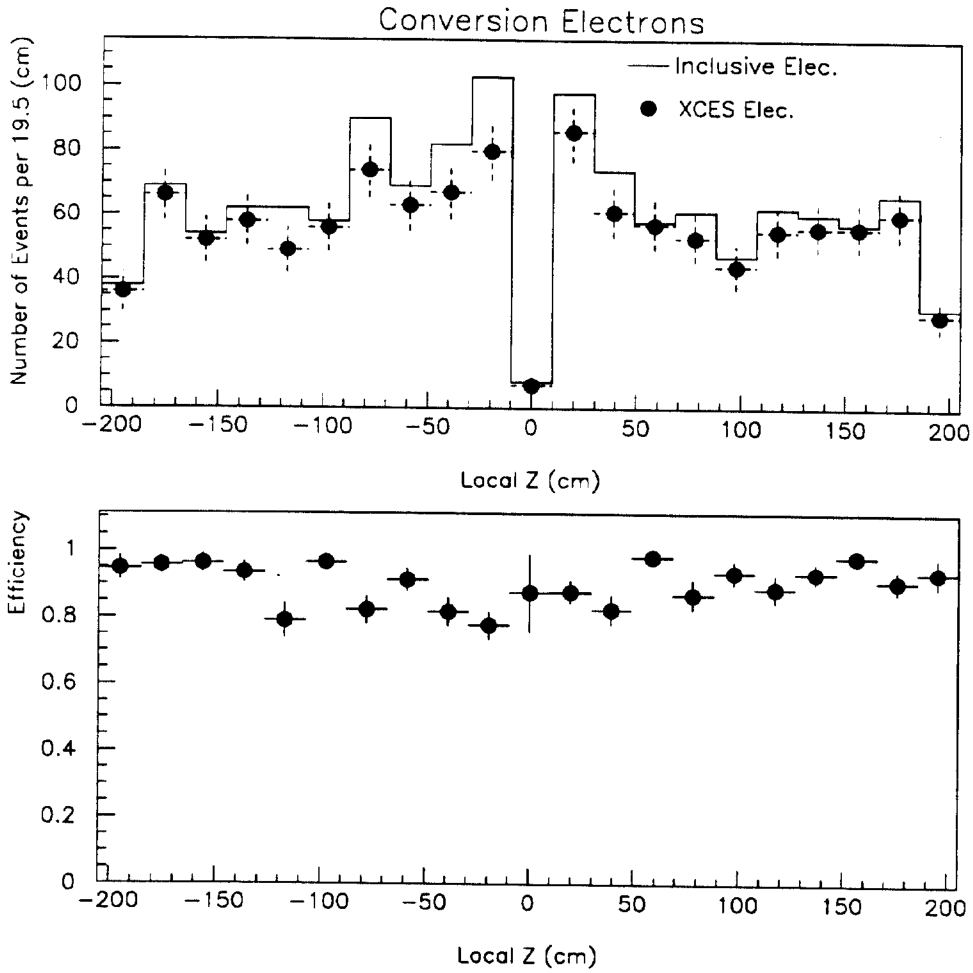

Figure 9. The XCES efficiency as a function of CES local z position using conversion electrons.

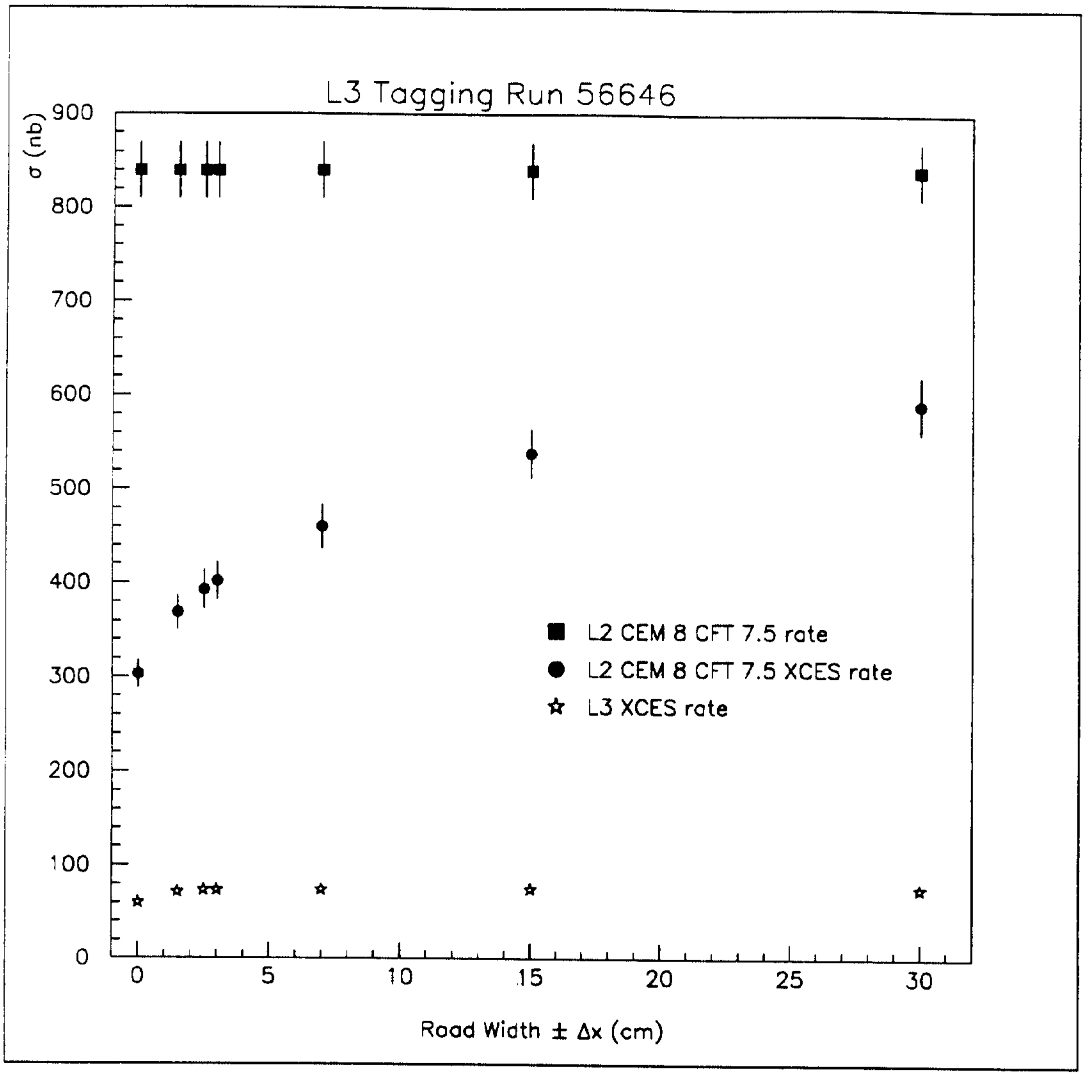

Figure 10. The Level-2 and Level-3 rate as a function of the road width used in the lookup table algorithm. These rates were determined using the Level-3 tagging run and making offline cuts on the data. The XCES threshold was 3500 for this data, i.e. DAC=60.

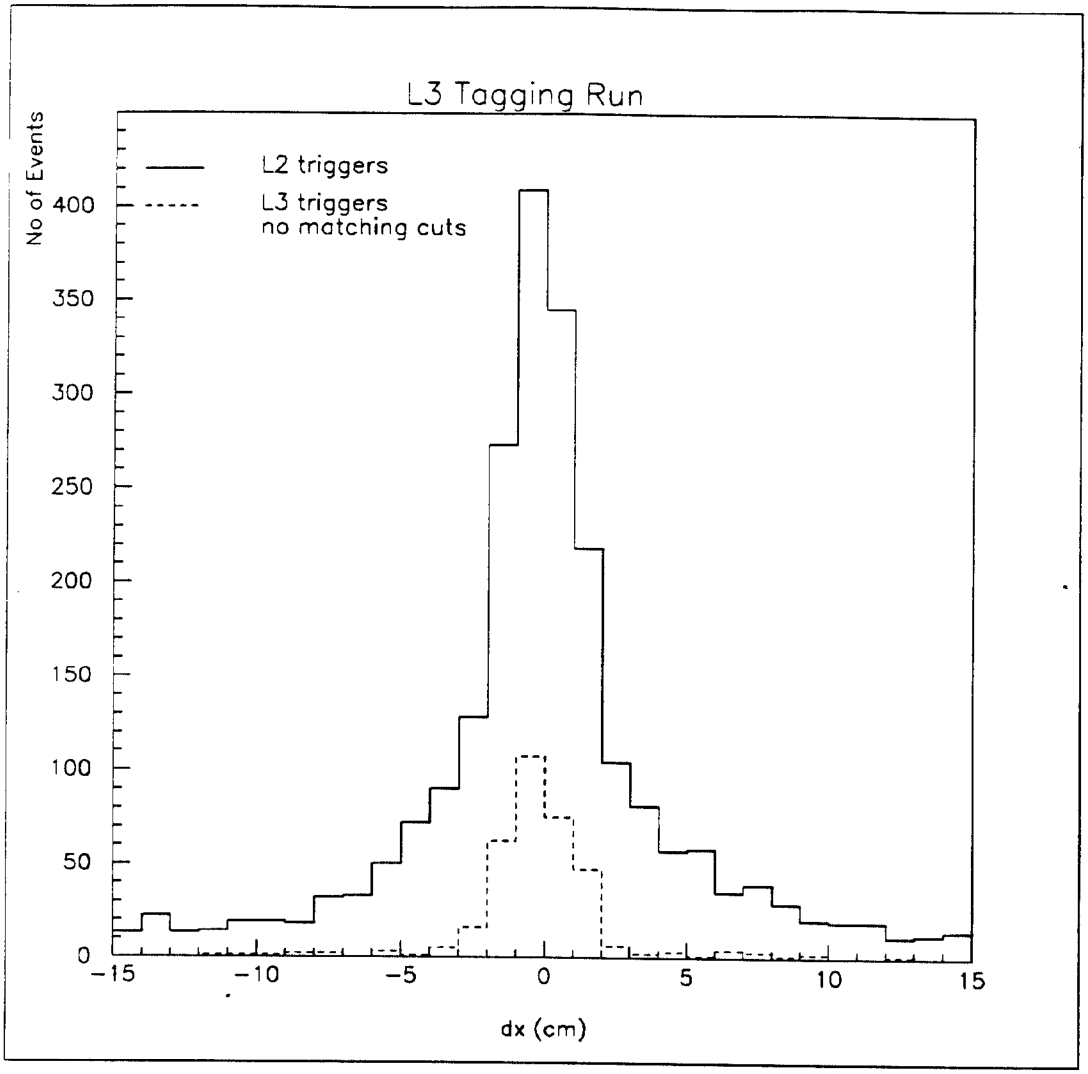

Figure 11. The difference between the projected Level-2 track x position and the CES cluster. The events in this distribution were required to have only one Level-2 track point to the wedge of the triggered electron and no XCES requirement.