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Electron Identification in the CDF§ Central Calorimeter†

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ABSTRACT

Efficient identification of electrons both from W decay and QCD heavy flavour production has been achieved with the CDF Central Calorimeter, which is a lead - scintillator plate calorimeter incorporating tower geometry. The fine calorimetry granularity (0.1 x 0.26 in η, ϕ space) allows identification of electrons well within the typical jet cone and is wholly sufficient for the measurement of the isolation of electrons from W decay. With minor improvements, such a detector is a realistic option for electron identification in the central rapidity region at the SSC.

1. INTRODUCTION

The CDF Detector is a large 4π general purpose detector built to study proton-antiproton collisions at $\sqrt{s}$ = 2 TeV at the Fermilab Tevatron. Event reconstruction is based on charged particle tracking, their momentum analysis and fine grained calorimetry. Only the salient features relating to electron identification in the central region ($|\eta|$ < 1.1) will be discussed here, further details of the detectors may be obtained in Reference 1 and references therein.

§ The Collider Detector at Fermilab is a collaboration of: Argonne National Laboratory; Brandeis University; University of Chicago; Fermi National Accelerator Laboratory, INFN, Laboratori Nazaionali di Frascati, Italy; Harvard University; University of Illinois; KEK, Japan; Lawrence Berkeley Laboratory, University of Pennsylvania; INFN, University and Scuola Normale Superiore of Pisa, Italy; Purdue University; Rockefeller University; Rutgers University; Texas A&M University; University of Tsukuba, Japan; University of Wisconsin.

The CDF central calorimeter covers the range $|\eta| < 1.1$ in pseudorapidity with fine grained calorimetry: lead/scintillator calorimetry (18 r.l.) for the measurement of electromagnetic showers (CEM) followed by iron/scintillator ($\sim 5\ \lambda_o$) for the containment of hadronic showers (CHA). It is constructed in wedges 0.26 radians in azimuth x 1.1 units of rapidity long. Within a wedge, in both depth segments, the scintillator is viewed by waveshifters on two sides to form projective towers of 0.1 units in rapidity, which are read out by photomultiplier tubes. A gas proportional chamber (CES) is incorporated in the electromagnetic section of the calorimeter, approximately at shower maximum, to give accurate reconstuction of the impact point of the shower in the calorimeter. All wedges in the detector were calibrated in a testbeam. The energy resolution of the calorimeter for electromagnetic showers is $\sigma_E/E \sim 14\%/\sqrt{E}$.

Charged particle tracking and momentum reconstruction is provided by the Central Tracking Chamber (CTC), embedded in a 1.5 Tesla magnetic field. The chamber has 84 sense layers with radii between 31 and 132 cm and allows measurement of charged tracks at angles greater than 30° to the beam. Stereo reconstruction is obtained from sense wires rotated $\pm$ 3° relative to the axial wires. Hit resolutions of order 200 μm have been obtained with a resultant momentum resolution $\sigma P_T/P_T \sim 0.2\% P_T$. Testbeam measurements yield a pion rejection factor of 10^3 for the combined calorimeter energy and track momentum measurement.

The innermost detector required in electron identification is the Vertex Time Projection Chamber System (VTPC) covering the radii 5 to 28 cm. This is optimised to provide good r-z reconstruction in the rapidity region $|\eta| < 3.5$ and is used to determine the location of the primary event vertex with an accuracy of ~ 3mm rms (the luminosity profile at the Tevatron is approximately 30cm wide). In addition, this detector is used to discriminate electrons from photon conversions in the beampipe and walls of the VTPC itself.

2. ELECTRON IDENTIFICATION CRITERIA

The objective of the central electron identification criteria in CDF is to use the fine granularity of the detector system to obtain a sample of minimally isolated electrons from an event sample dominated by backgrounds (e.g. π^{o} $\pi^{\pm}$ overlaps, γ conversions). This is achieved by associating the energy deposition profile in the calorimeter with the shower measured in the proportional chamber, the reconstructed track and the primary event vertex. This is shown schematically in Fig. 1. The corresponding detector variables can be summarised as follows:

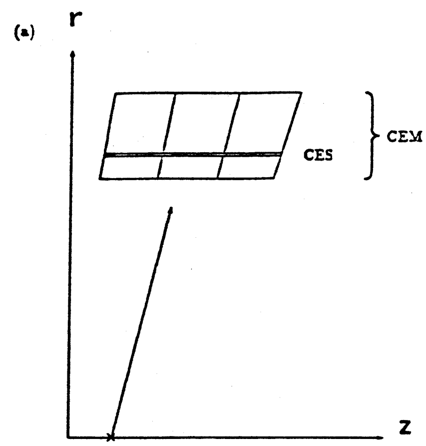

Fig. 1 Schematic geometry of shower energy deposition in the CDF central calorimeter.

- 2 depth measurements in the calorimeter yielding a measurement of the ratio of hadronic to total energy deposition: HAD/ETOT
- 0.1 x 0.26 (η, ϕ) projective towers clustered according to transverse energy about a seed tower to form 3-tower segments and yielding a measurement of the lateral shower profile: LSHR (by construction electron showers do not cross wedge boundaries)
- geometrical matching of the shower measured in the proportional chamber with tracks reconstructed in the tracking detectors: DZ,DrØ
- a χ^2 comparison of the shower profile measured in the proportional chamber with testbeam electron showers: CHISQ
- the ratio of the calorimeter energy in the 3-tower segment to the matched track momentum: E/P

Of the above, only the calculation and use of the lateral shower profile in the calorimeter requires futher discussion as it is this selection which mainly determines the local isolation of electron candidates. The lateral shower profile is defined as

$$\mathrm{LSHR} = 0.14 \sum_{k} \frac{M_K - P_K}{\sqrt{0.14^2\, E + (\Delta P_K)^2}}$$

where the sum is over the towers adjacent to the seed tower, M_K is the measured energy in the adjacent tower, P_K is the expected energy in the adjacent tower predicted using the impact point z in the proportional chamber (CES) the event vertex and a shower profile parameterisation obtained from testbeam measurements, E is the electromagnetic energy in the 3-tower segment and ΔP_K is the error in P associated with a 1cm variation in the impact point. The factor $0.14 \sqrt{E}$ is chosen to normalise the energy difference $M_k - P_k$ relative to the statistical fluctuations inherent in the energy measurement of electromagnetic showers. For most events ΔP_K is small since the CEM has full containment (> 99%) for showers more than 2 cm away from a boundary (the cell size is typically 24 cm long in z). The isolation implicit in this selection can be characterised by considering the effect of the standard CDF electron cut of LSHR < 0.2. This then demands that for a 50 GeV electron in the centre of a tower, for which the expected energy in each adjacent tower is ~ 250 MeV, the summed excess energy measured in the adjacent towers be less than 1.4 GeV.

The electron identification characteristics are best demonstrated from a sample of "golden W" events selected solely on missing transverse energy in the event being greater than 30 GeV and the event containing a central electromagnetic cluster with transverse energy greater than 30 GeV matched to a reconstructed track. Figure 2 shows the hadronic energy fraction HAD/ETOT for these events compared to 50 GeV electron and pion showers. Fair agreement is observed between the testbeam electrons and the W

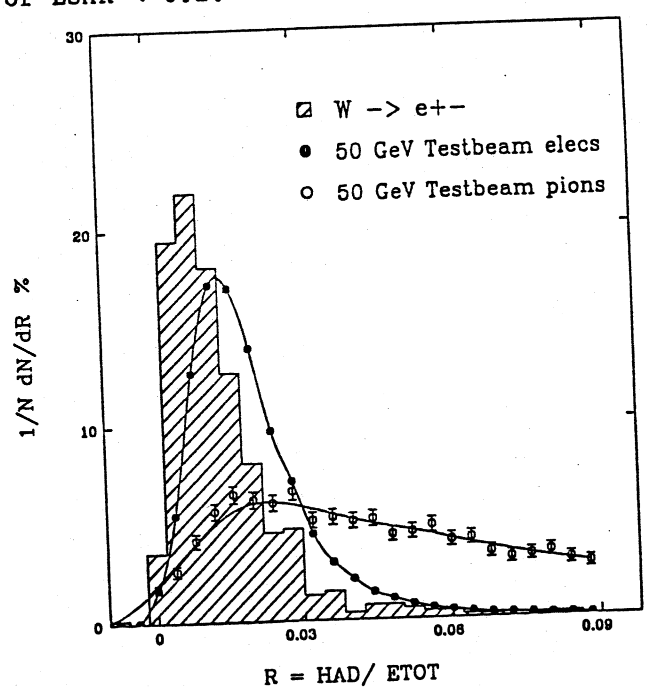

Fig. 2 Hadronic energy fraction measured for 50 GeV testbeam electron and pion showers compared with electrons in a W sample selected to have E/P > 0.9.

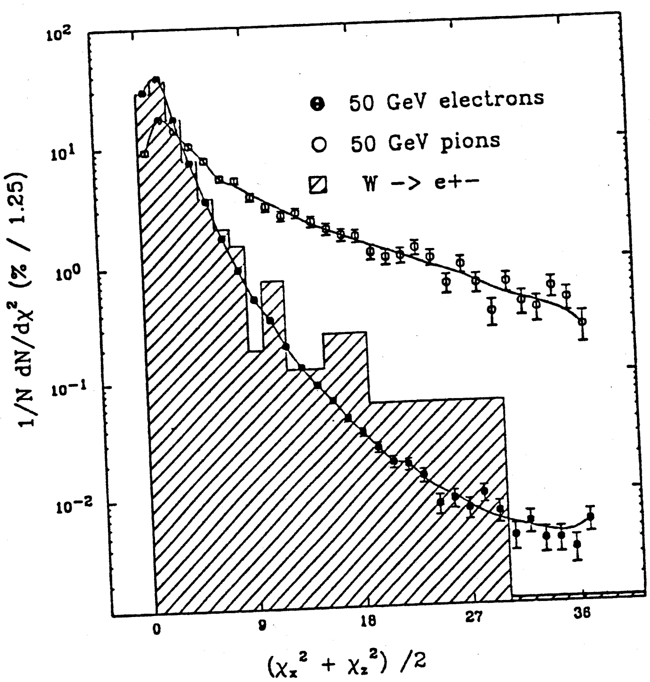

Fig. 3 Proportional chamber χ^2 distribution for 50 GeV testbeam and pion showers compared with electrons in a W sample selected to have E/P > 0.9.

detailed alignment corrections are shown in Fig. 4 and yield resolutions of ~ 2mm in $r\phi$ and ~ 4mm in the z (beam) direction, which are consistent with those measured in testbeam data. The observed LSHR distribution is shown in Fig. 5 and demonstrates that electrons from W decay are well isolated in the 3-tower cell and the standard CDF selection of LSHR < 0.2 is not a significant bias to this sample. Finally, the E/P distribution for this event sample is shown in

electrons. A standard CDF cut in this variable is HAD/ETOT < 0.04 which is seen to be efficient for electrons and has good rejection against pion backgrounds. A comparison of the shower profile χ^2 measured in the proportional chamber (CHISQ) in these events with that measured in 50 GeV testbeam electron and pion showers is shown in Fig. 3. Again the agreement with the electron data is good and shows good efficiency with high rejection power for a cut of CHISQ < 10.0 (the standard CDF electron cut). The observed track match distributions in the z and $r\phi$ planes after

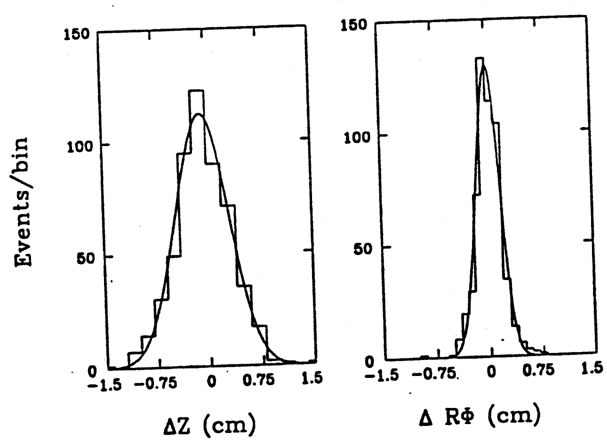

Fig. 4 Z and $r\phi$ matching distributions between the reconstructed track and shower position measured in the proportional chamber at shower maximum.

Fig. 6, and for a sample of inclusive electrons having a transverse energy > 12 GeV, selected using the the above standard cuts and a track match cut of 5 cm in Fig. 7. The systematics of this distribution are still under study, however, it is evident that the resolution at high energy is very good (~ 6%). Some background is clearly present in the inclusive sample. This has been studied using the correlation between the proportional chamber shower χ^2 and the fractional hadronic energy measurement (EHAD/ETOT). Roughly 15% of the events in the peak region can be attributed to charged pion backgrounds. It is important to note that this rate was not observed to change significantly if additional isolation cuts on energy surrounding the electron were applied. Reconstruction code to measure the rate of conversion photon pairs is being developed and current results indicate that some $\lesssim$ 25% of the electron signal comes from this source.

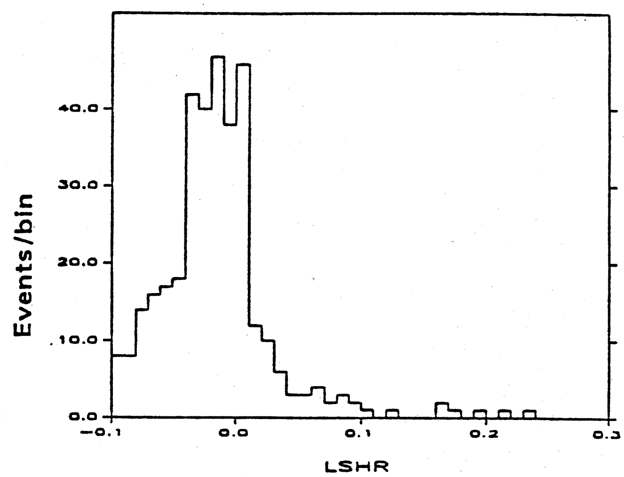

Fig. 5 Calorimeter shower profile, LSHR, for W electrons as described in text.

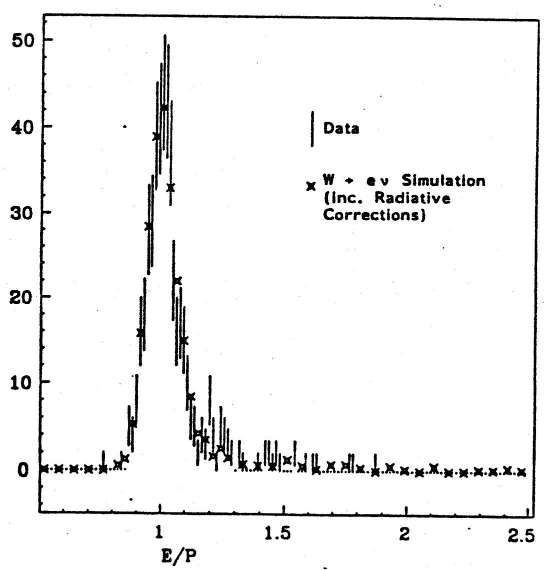

Fig. 6 E/P/ for electrons in W sample, compared to a Monte Carlo simulation of W → eν including

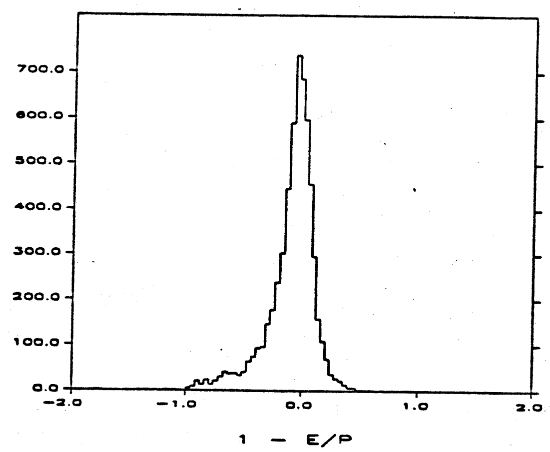

Fig. 7 1 - E/P for exclusive electrons selected using cuts on track matching, shower χ^2 and lateral shower profile as described in the text.

3. CONCLUSION

The CDF central calorimeter and tracking detectors can efficiently identify electrons contained well within the solid angle of a typical jet cone in addition to the relatively isolated electrons from W decay. The electron isolation implicit in the 3-tower segment analysis described here is not a significant bias to the identification of electrons from W decay, which are an essential ingredient of many of the processes to be studied at the SSC. As was discussed in this Workshop a decrease in cell size may however still be desirable in order to reduce background trigger and event rates from neutral jets and further minimise isolation bias. Since the above electron identification relies primarily on the fact that most of the time a single electron will deposit almost all of its energy to a single tower, the results of the analysis should remain approximately valid if one were to halve the cell size (as is presently being considered for SSC detectors at this workshop). However, the accuracy of the essential analysis ingredients must be maintained: low noise readout to allow measurement of energy levels down to 50 MeV for profile and isolation measurements, accurate spatial location of the electromagnetic shower and momentum reconstruction for high momentum tracks. Results presented at this workshop indicate that radiation damage to scintillator is expected to be manageable down to 30 degrees to the beam direction and therefore a scintillator plate calorimeter, which is known to work, is a very realistic option for electron identification in the central rapidity region at the SSC.

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REFERENCES

1) Abe, F. et al., Nucl. Inst. and Meth. A271, 387 (1988).