Fermi National Accelerator Laboratory

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CDF

A Study of Events with the Highest Total Transverse Energy in CDF

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Abstract

The properties of proton-antiproton interactions in which the total transverse energy exceeds 320 GeV are described. The events have been recorded at the Fermilab Tevatron collider operating at a center-of-mass energy of 1.8 TeV. The differential cross-section is in good agreement with the QCD predictions.

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1 INTRODUCTION

The Collider Detector at Fermilab[1] (CDF) has recently completed a data taking run at the Fermilab Tevatron Collider which operates at a center-of-mass energy of 1.8 TeV. This is the highest $p\bar{p}$ collision energy currently available in the laboratory. In this paper we describe some of the properties of the events recorded by CDF that have the highest observed total transverse energies:

$$\sum E_T \equiv \sum E_T^{cluster>10GeV} > 300\text{GeV}$$

where the sum is over calorimeter energy clusters with $E_T > 10$ GeV as defined by the CDF jet clustering algorithm[2]. The data sample corresponds to an integrated luminosity of 22 pb^{-1}. The properties of the events will be compared with the predictions of quantum chromodynamics (QCD) as embodied in the leading-order parton shower Monte Carlo HERWIG[3].

2 THE $\sum E_T$ TRIGGER

The trigger hardware performs clustering in $\eta - \phi$ space. A cluster is initiated by a "seed" tower with E_T above 3 GeV and consists of all contiguous towers in η and ϕ above an E_T of 1 GeV. The $\sum E_T$ trigger is formed by summing over these clusters and asking that the sum be greater that 175 GeV. A subset of these events is selected by an online computer farm by requiring that the $\sum E_T$ summed over jet clusters with $E_T > 10$ GeV is larger than 300 GeV. The high-$\sum E_T$ in many of these events can be attributed to a high-energy cosmic-ray interaction in one of the calorimeters. These cosmic-rays tend to deposit their energy either in the electromagnetic calorimeter or the hadronic calorimeter but not both. This produces events that have an electromagnetic energy (EM) fraction of zero or one (see Fig. 5 of Ref.[4]. In addition these events are expected to generate large missing transverse energy. We define the missing transverse energy significance[5],

$$S \equiv \not{E}_T / \left(\sum E_T\right)^{1/2}$$

where the missing transverse energy is given by

$$\not{E}_T \equiv \left|\sum_i \vec{E}_{T_i}\right|$$

and $\sum_i \vec{E}_{T_i}$ is a vector which points from the interaction point to the calorimeter cell and has a magnitude equal to the cell E_T . We have shown previously that events with large missing transverse energy and EM fraction close to zero are well identified cosmic-ray interactions[4]. Based on this study, we remove events if they have $S > 10$ *and* EM fraction < 0.2.

3 THE MONTE CARLO SAMPLE

A detailed discussion of the relevant features of the HERWIG Monte Carlo program were given in Ref. [4] along with a description of the CDF detector simulation. We have used HERWIG 5.6 to generate the Monte Carlo sample and then applied the CDF detector simulation. We have used the CTEQ1M structure function and $Q^2 = stu/2(s^2 + t^2 + u^2)$. HERWIG generates $2 \to 2$ processes above a specified p_T^{hard} where p_T^{hard} is the p_T of the outgoing partons from the hard scatter before any radiation has occurred. We have set the minimum p_T^{hard} to 60 GeV/c. This relatively low value of p_T^{hard} is necessary to obtain an unbiased Monte Carlo sample in which adequate account is taken of events in which the detector response has fluctuated upwards by several standard deviations and/or the spectator system, including the initial-state radiation, makes an unusually large contribution to the $\sum E_T$. This low value necessitates generating a large number of events in order to get one event that has $\sum E_T > 300$ GeV (0.2% of the events generated actually have $\sum E_T > 300$ GeV). The Monte Carlo sample corresponds to 10 pb^{-1} of integrated luminosity.

4 THE DATA SAMPLE SELECTION

The initial sample consists of 18322 events which pass the trigger described above with $\sum E_T$ > 300 GeV. The sample still contains some cosmic-ray interactions and events with noise in the gas calorimeters. Events are rejected if they have energy deposited in the central hadron calorimeter that is out of time with the proton-antiproton collision. We also reject events that have total energy greater than 2000 GeV. We then apply a $\sum E_T$ cut of 320 GeV. This cut is required because in the online computer farm we calculate the $\sum E_T$ using the center of the detector as the vertex position whereas offline we use the reconstructed event vertex. This introduces a small inefficiency near the trigger threshold. We are left with 8942 events after these cuts. Only those events that have a reconstructed vertex are retained, this removes 35 events. To ensure good energy containment we require that the primary event vertex be within 60 cm of the center of the detector, this removes 350 events. The distribution of S (see above) for the 8557 events is shown in Fig 1. The distribution is reasonably well described by the Monte Carlo program for events with $S < 6$. However in the region $S > 6$ where we predict 8 events from the Monte Carlo and we see 50. We remove events with $S > 6$. The $\not{E}_T$ distribution for the surviving 8507 events is shown in Fig. 2 and is reasonably well described by the Monte Carlo prediction. The predicted distribution reflects the experimental resolution on the measurement of the $\not{E}_T$. There is no evidence for any significant contribution to the $\sum E_T$ sample from events in which high-p_T neutrinos or other non-interacting particles are emitted.

In our previous analysis[4] of 1988/89 data we removed multiple interactions, i.e., events that had more that one clearly identified vertex in the vertex tracking chamber. This was necessary because the previous $\sum E_T$ trigger was defined as

$$\sum_i E_T \equiv \sum E_i \sin\theta_i$$

where the sum is over all calorimeter cells in the detector, E_i is the energy deposition recorded by the ith cell, and the angle θ_i is the angle between the p$\bar{\text{p}}$ collision axis and a vector pointing from the interaction vertex to the energy deposition in the ith cell. This method of defining the $\sum E_T$ biases the trigger towards selecting multiple interactions. We demonstrated in our previous analysis[4] that the additional interactions in the high-$\sum E_T$ events are predominately minumum bias and about 1.8% of these interactions would produce a jet with $p_T > 10$ GeV/c. Calculations made for a luminosity of $L = 2 \times 10^{31}\text{cm}^{-2}\text{s}^{-1}$ predict that the mean $\sum E_T$ contributed from minimum bias interactions is 1.5% if the $\sum E_T$ is computed using a cluster threshold of 10 GeV. This is why we chose to define $\sum E_T$ as shown above. This 1.5% is a very small bias and so we choose not to remove events with more than one vertex.

5 THE $\sum E_T$ DISTRIBUTION

The uncorrected $\sum E_T$ spectrum for the high-$\sum E_T$ sample is compared in Fig. 3 with the leading order QCD prediction using the CTEQ1M structure function and $Q^2 = stu/2(s^2 + t^2 + u^2)$. The measured cross-section is 387 pb and the prediction from the Monte Carlo is

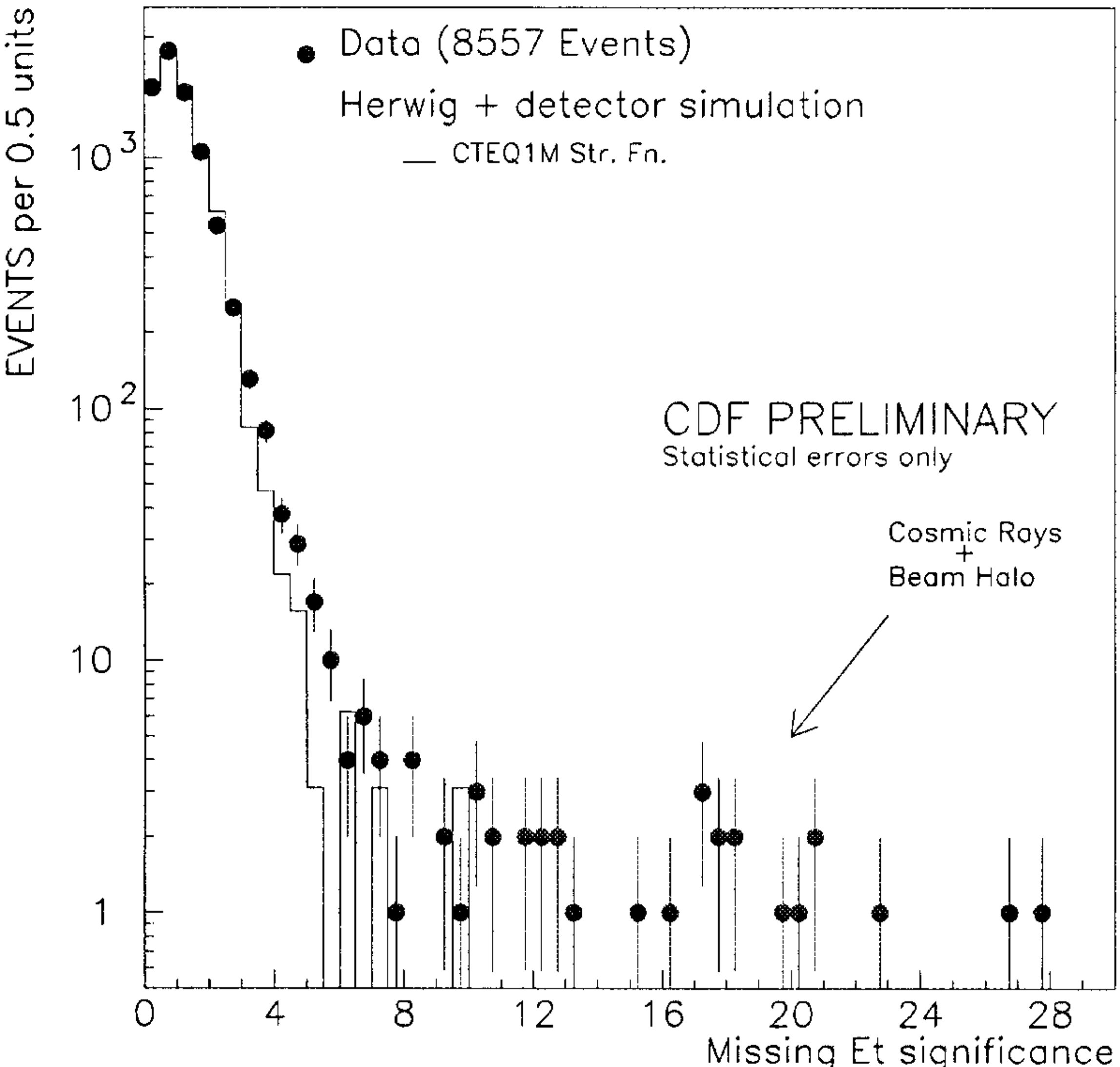

Figure 1: The distribution of missing-E_T significance (S) (solid circles) for the high-$\sum E_T$ events before the S cut compared with the expectation for QCD jet events based on the CDF detector simulation program.

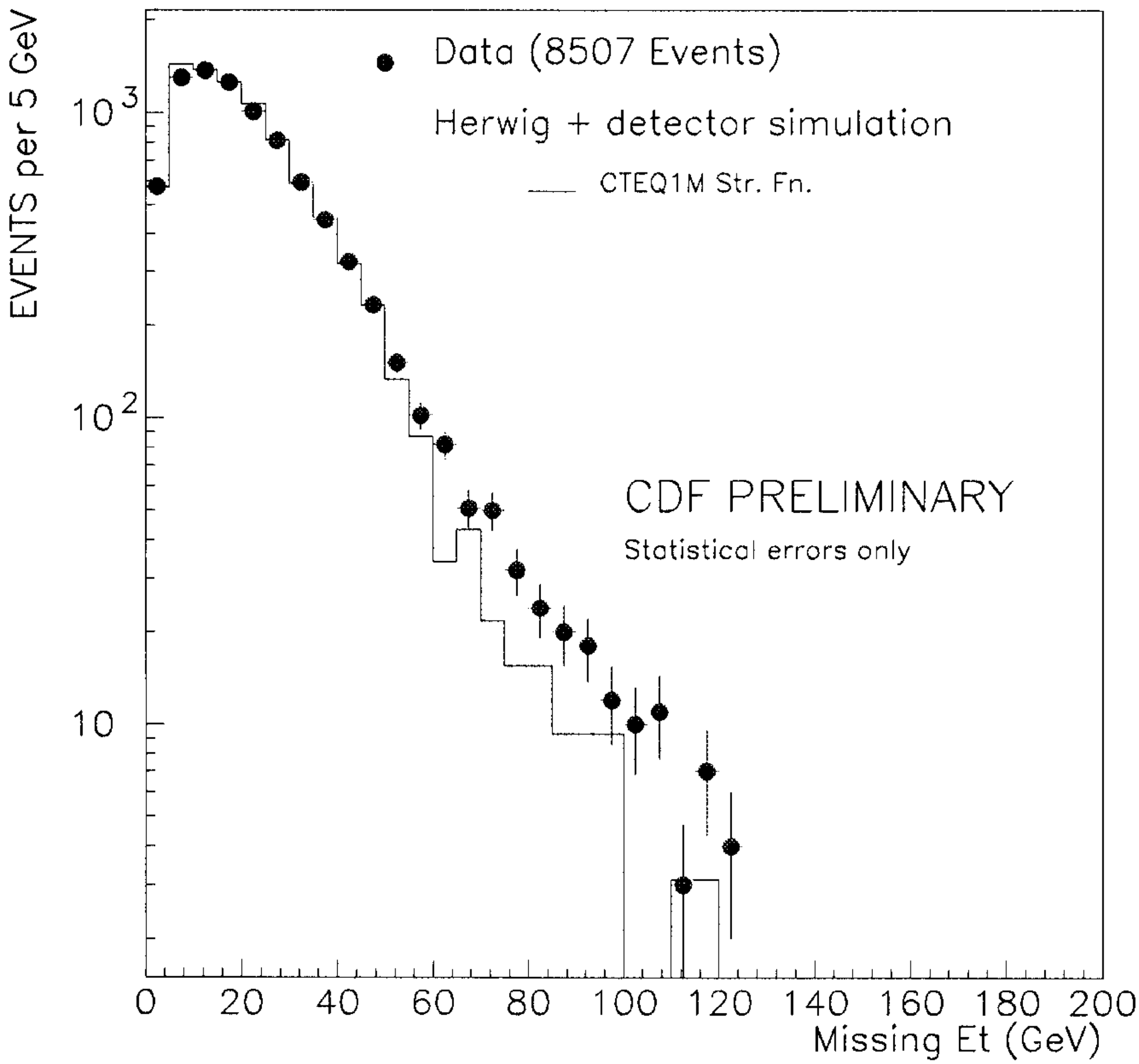

Figure 2: The missing-transverse energy distribution for events with $\sum E_T > 320$ GeV and $S < 6$ (points) compared with expectations based on HERWIG and the CDF detector simulation.

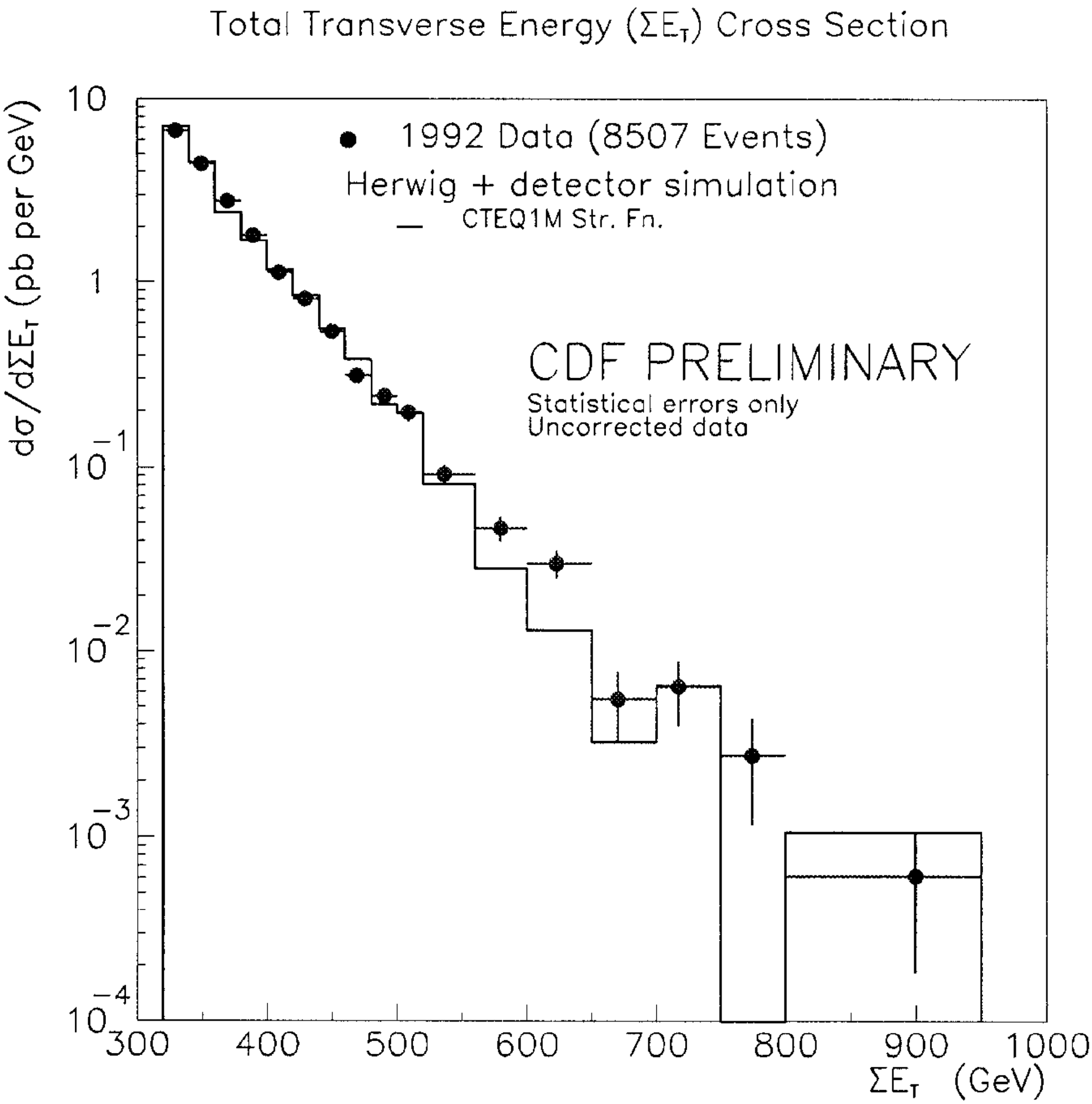

Figure 3: The $\sum E_T$ distribution compared to the prediction of the HERWIG Monte Carlo program.

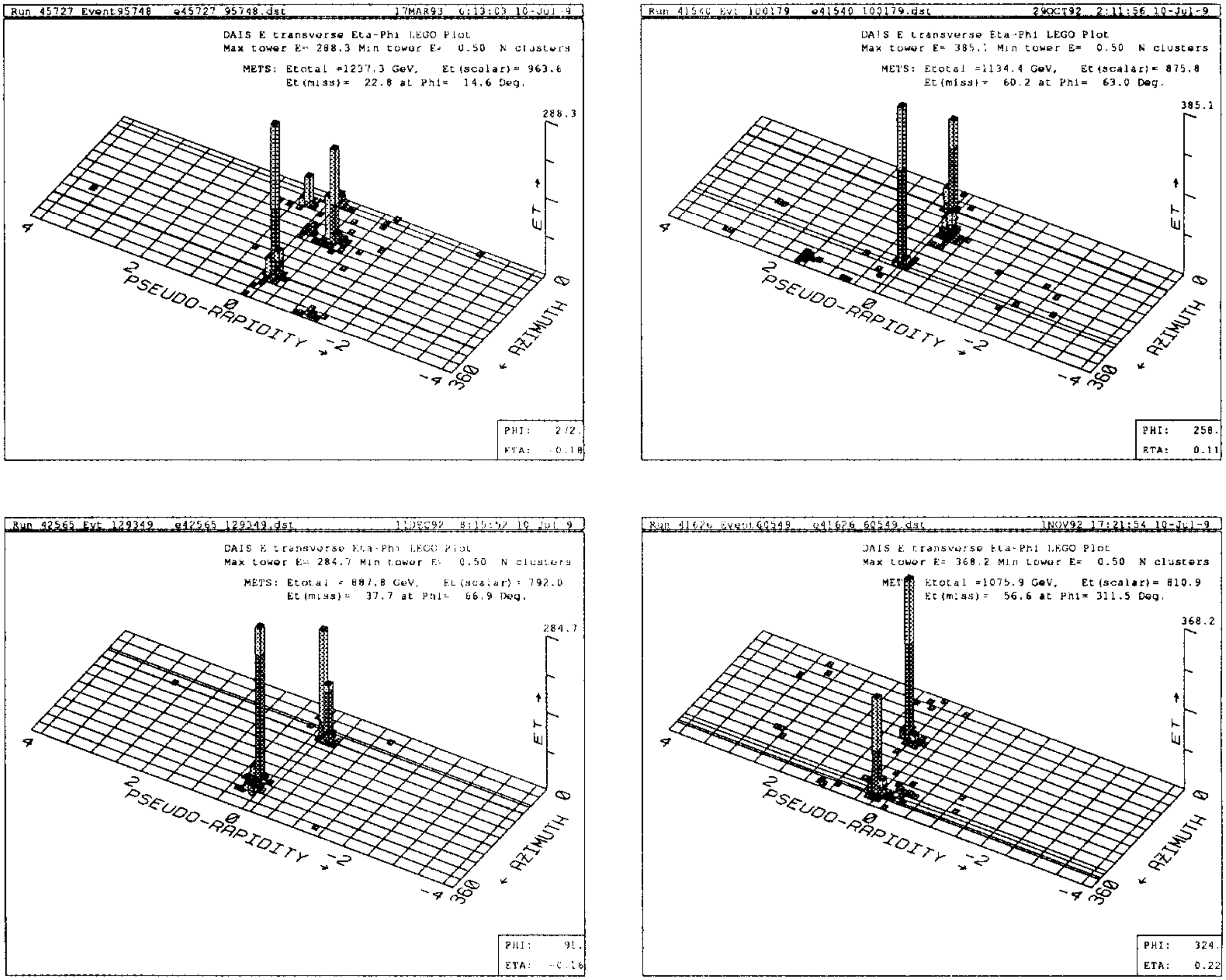

Figure 4: The four events with the highest total transverse energy.

263 pb which implies a K-factor of 1.5. The Monte Carlo curve has been normalized upwards by this factor. The data is well described by the Monte Carlo.

In Fig. 4 we show the four events with the highest $\sum E_T$. They all have high-p_T central jets and a well defined 2-jet or 3-jet topology.

6 CONCLUSIONS

We have compared the events with $\sum E_T > 320$ GeV to the predictions of the HERWIG Monte Carlo program. For the distributions we have studied we find good agreement between the data and the Monte Carlo.

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