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Observation of $e^+p \rightarrow \mu^+X$ and $e^+p \rightarrow e^-X$ Events with High Transverse Momenta at HERA

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Abstract

At the HERA electron-proton collider two events have been observed in the H1 detector which show an isolated e^- or μ^+ of high transverse momentum recoiling against a hadronic system. A possible interpretation is W production with subsequent leptonic decay.

Introduction

In 1994 two events of unusual topology and signature have been observed in the H1 detector at the HERA electron-proton storage ring. The total data sample analysed corresponds to an accumulated luminosity of $2.70\,\mathrm{pb}^{-1}$ in positron (27.6 GeV) - proton (820 GeV) collisions and of $0.36\,\mathrm{pb}^{-1}$ in electron-proton collisions.

In the Charged Current (CC) analysis [1] of the 1994 data the selection (main criterion is an apparent imbalance in the total observed transverse momenta, $P_t^{miss} \geq 25\,\mathrm{GeV}$) resulted in 88 CC candidates. In a scan this data sample has been identified to consist of

- 53 CC events
- 33 events identified as non $e-p$ events or badly measured neutral current events.
- 2 events with an isolated high P_t charged lepton of 'wrong signature' : $e^+p \rightarrow \mu^+X$ and $e^+p \rightarrow e^-X$. Both events were recorded when HERA was colliding positrons with protons. No event of this type was recorded when HERA was operated with electrons on protons.

  In the following we give details of the latter two events and discuss a possible interpretation.

The $e^+p \rightarrow e^-X$ event

The event is shown in figure 1. At first sight the event looks like a Neutral Current (NC) event but the kinematics and the lepton charge measurement make this interpretation unlikely.

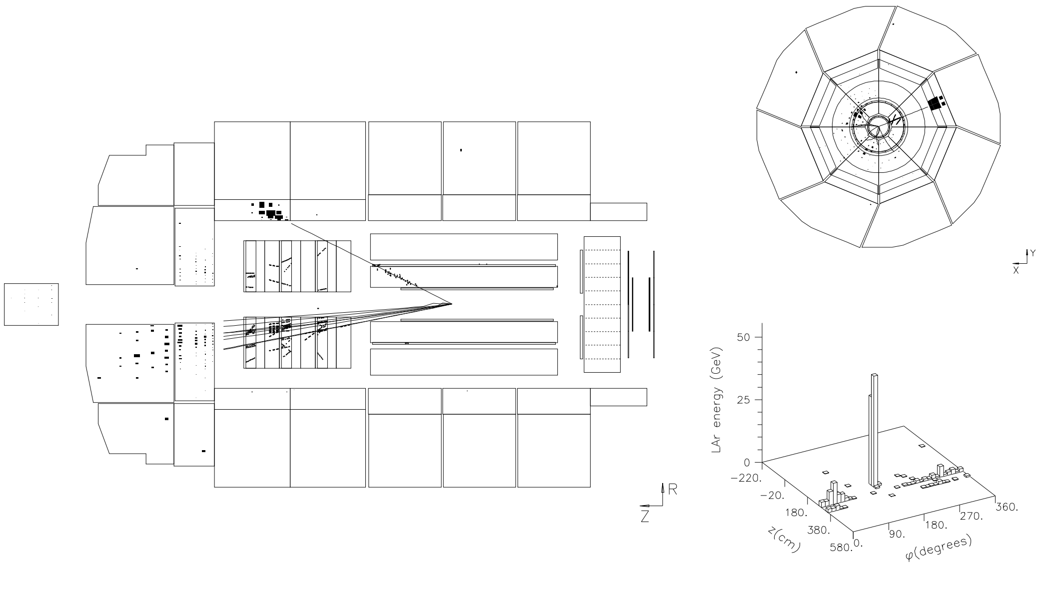

Figure 1: Display of the $e^+p \rightarrow e^-X$ event

The event shows an isolated track measured in the central jet chamber (CJC) pointing towards a high energy electromagnetic shower in the Liquid Argon calorimeter. The track is recoiling opposite in azimuth (ϕ) against the system of hadrons measured in the forward (proton direction, +z) track detector and in the inner forward LAr calorimeter.

The isolated track shows in the CJC a specific ionization well compatible with a minimum ionizing particle. The track is linked to an energetic cluster (E=82 GeV,E_t=37 GeV) in the electromagnetic part of the calorimeter. The shower pattern is as expected for a shower of electromagnetic origin. The curvature measured for the track is well compatible with a track of transverse momentum P_t=37 GeV with negative charge, whereas a positive charge is ruled out by 5 standard deviations.

The event shows a hadronic shower in the very forward direction with a transverse energy of 8 GeV measured in the LAr calorimeter.

The momentum balance has been calculated from the electron energy and the total hadronic energy deposition. The total missing transverse momentum amounts to $P_t^{miss} = |\vec{P}_t^e + \vec{P}_t^{had}| =$ 30 GeV. This suggests that particles carrying transverse momentum have escaped detection. There is also a deficit seen in the value of $\delta = \sum(E - P_z)$, where the sum runs over all detected particles. For an event where only longitudinal momentum along the proton direction is undetected one would expect $\delta = 2E_e = 55\,\mathrm{GeV}$, with E_e being the energy of the incident positron. The event shows a value of $\delta = 10\,\mathrm{GeV}$.

The detector resolutions in P_t^{miss} and δ have been investigated using a sample of candidates fulfilling a neutral current preselection where the transverse momentum of the scattered lepton exceeds 20 GeV. In this case the lepton and the recoiling hadronic shower are measured in the detector. These NC events are intrinsically balanced in P_t^{miss} and δ assumes a value of $2E_e$ for non-radiative events. Fig. 2 shows the event distribution in the $P_t^{miss} - \delta$ plane. The NC candidates with $P_t^{miss} > 14\,\mathrm{GeV}$ or $\delta < 20\,\mathrm{GeV}$ have been scanned in order to identify background. Some events are not of NC type. These are marked by squares (CC), stars (cosmic) and crosses (QED e^+e^- events). Events marked by triangles are identified as NC events, however the lepton track points to a crack in the calorimeter resulting in badly measured kinematics. It is thus evident that most of the events in the tails are either due to background or badly reconstructed NC events. In the event under consideration the electron is registered far away from a crack region.

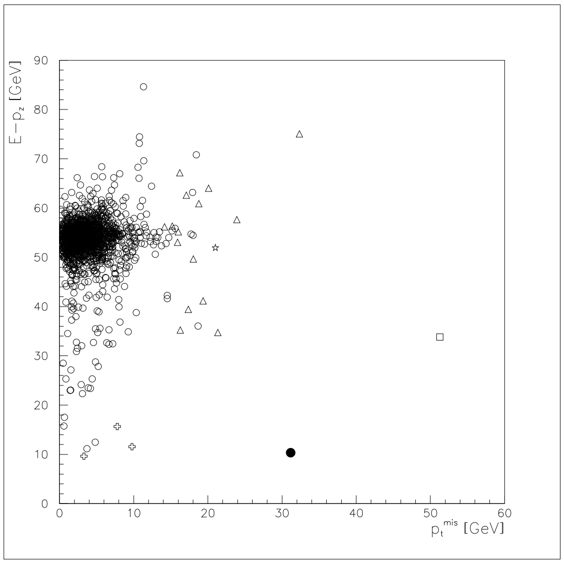

Figure 2: Event distribution of NC candidates (open circles) in P_t^{miss} and $\delta = \sum(E - P_z)$. For events marked by crosses, stars, squares or triangles see text. The event marked with full circle is the e^-event under consideration.

The measured values of P_t^{miss} and δ in the event (marked by a full circle in fig. 2) are found to be far off compared to the NC sample. This fact and the wrong charge of the lepton renders the NC interpretation of the event very unlikely.

The $e^+p \rightarrow \mu^+ X$ event

Fig. 3 shows a display of the event [2]. It exhibits an isolated penetrating track recoiling against a hadronic system. The isolated track is identified in the CJC as a minimum ionizing particle of

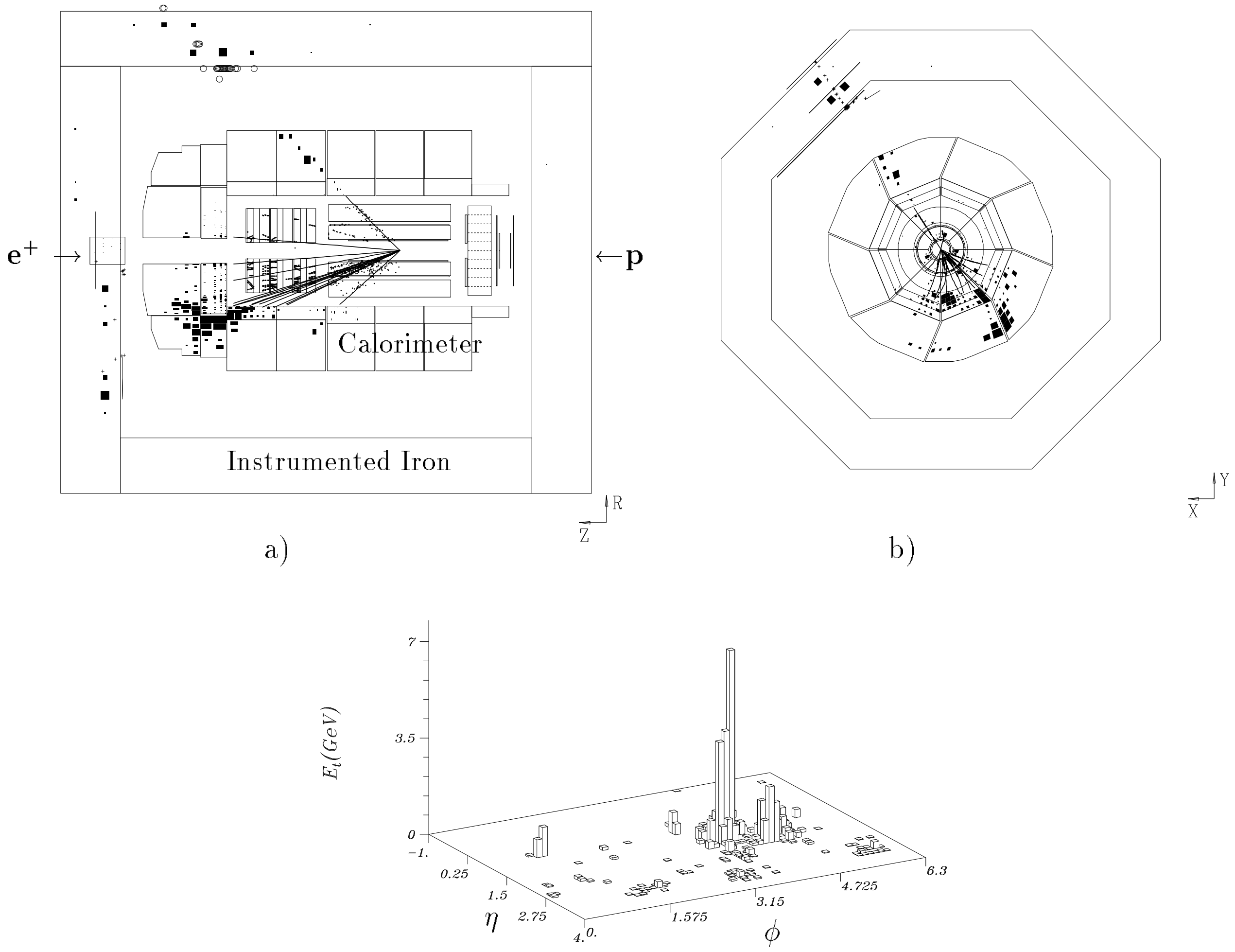

Figure 3: Display of the $e^+p \rightarrow \mu^+ X$ event

transverse momentum $P_t = 23.4 \pm 2.4^{+7}_{-5}$ GeV. It traverses the LAr calorimeter with an energy release characteristic for a muon and penetrates the instrumented iron with a hit and energy pattern as expected for a muon. The event shows a large energy deposition in the forward calorimeter. The spatial distribution of this energy deposition agrees with the expectation for a shower of hadronic origin. The transverse energy of the total hadronic system is measured to $E_t = 42.1 \pm 3.0$ GeV.

The total missing transverse momentum amounts to $P_t^{miss} = |\vec{P}_t^{\mu} + \vec{P}_t^{had}| = 18.7 \pm 4.8^{+5}_{-7}$ GeV. Again, this suggests that particles carrying transverse momentum have escaped detection.

There is also a deficit seen in the value of $\delta = \sum(E - P_z)$. The event shows a value of $\delta = 19.2 \pm 1.6^{+3.0}_{-2.1}$ GeV.

Discussion

Both events show an isolated high P_t lepton of 'wrong type', and an event imbalance in P_t as well as in longitudinal momentum δ.

These features rule out an interpretation as a high Q^2 Neutral Current event. The probability that the events are due to a photoproduction process, where one jet fluctuates into an isolated lepton, is also negligible. This has been shown for the muon event in a detailed background investigation [2]. The interpretation as a flavour changing process is also unlikely since one expects these events to be balanced in P_t and δ.

The features seen in both events are expected in processes where a W is produced with subsequent leptonic decay ($e^+p \rightarrow e^+WX, W \rightarrow e^-\nu$ or $W \rightarrow \mu^+\nu$). This photoproduction process (the outgoing e^+ is undetected) 'naturally' explains the imbalance in δ and the neutrino accounts for P_t^{miss} (and also δ). Both events fit kinematically to this hypothesis.

The production of W bosons is expected within the standard electroweak theory. An estimate of the W production rate was made using a Monte Carlo calculation based on the cross section of reference [3]. The total cross section for W production of a specific charge decaying into a specific leptonic channel is of the order 40 fb. Assuming 100 % acceptance one would then expect ≈ 0.1 events per leptonic decay channel for the given luminosity , which is to be compared to the one event observed in each channel.

The cross section is expected to be dominated by low transverse momenta of the W and thus also of the recoiling hadronic system. In the e^- event the W is produced with relatively small transverse momentum, whereas in the μ^+ event the transverse momentum of the W exeeds 40 GeV (only 20% of MC events are above this value).

In general the lepton from the W decay is not expected to have a strong correlation in azimuth with the recoiling hadronic system. Both events show a pattern where the lepton seems to recoil more or less 'back to back' in ϕ w.r.t the measured hadronic system.

Summary

In the 1994 data taken with the H1 detector two events of unusual topology have been recorded. A possible explanation is the production of W bosons decaying leptonically.

References

[1] H1 Collaboration, DESY preprint DESY 95-102, accepted for publication in Zeitschrift für Physik.

[2] H1 Collaboration, DESY preprint DESY 94-248.

[3] U.Baur, J.A.M. Vermaseren, D. Zeppenfeld, Nucl. Phys. B375 (1992) 3.