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Search for Events with an Isolated High Energy Lepton and Missing Transverse Momentum in e$^-$p collisions at HERA

H1 Collaboration

Abstract

At the HERA electron-proton collider a search for events with a high energy lepton and an imbalance in transverse momentum has been performed in the e^-p data collected in 1998 and early 1999. Within the Standard Model the only known source with a significant rate for this kind of topology is the production of W bosons with subsequent leptonic decay. Using the same method as in the published analysis of the e^+p data, no event with such properties is observed in 13.6 pb^{-1} of e^-p data.

Abstract: 157s
Parallel sessions: 6,7
Plenary sessions: 6,7,8

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1 Introduction

The H1 collaboration had recently reported [1] the observation of events with high P_T isolated leptons and missing transverse momentum in their positron-proton data collected in 1994-1997. Within 35.6 pb^{-1} of e^+p data, H1 has observed 1 electron e^- event for 2.4 ± 0.5 expected and 5 muon events for 0.8 ± 0.2 expected. Three muon events show atypical kinematic properties compared to the Standard Model contributions.

In this paper we report on a search for similar events in the data collected in 1998 and early 1999, when HERA collided 27.5 GeV electrons on 920 GeV protons. The increased center of mass system energy compared to earlier data provides a higher sensitivity to new phenomena and the change of lepton beam polarity allows a complementary insight into the studied processes.

2 Data Analysis

2.1 Experimental Conditions

This analysis is based on e^-p collisions recorded by the H1 experiment in the 1998-1999 period. It is restricted to periods where the central drift chambers, the liquid argon calorimeter and the luminosity system are active and fully operational. The corresponding integrated luminosity is 13.6 ± 0.4 pb^{-1}.

A detailed description of the H1 detector can be found in [2]. Only components essential for this analysis are shortly described here. A tracking system of central and forward drift chambers is used to measure the charged particle trajectories and to determine the interaction vertex. Particle transverse momenta are determined from the curvature of the trajectories in a magnetic field of 1.15 Tesla.

Hadronic and electromagnetic final state particles are absorbed in a highly segmented calorimeter [3], which is 5 to 8 interaction lengths deep depending on the polar angle of the particle. The calorimeter is surrounded by a superconducting coil and an iron yoke instrumented with streamer tubes. Leakage of hadronic showers outside the calorimeter is measured from an analogue charge sampling of the streamer tubes (Tail Catcher). Tracks of penetrating charged particles, such as muons, escaping the calorimeter are reconstructed from their hit pattern in the streamer tubes with an efficiency higher than 90%.

The trigger condition for high transverse energy interactions is based on calorimeter signals. The trigger efficiency is higher than 95% for events with a scattered electron with an energy above 10 GeV, and higher than 85% for events with a calorimetric missing transverse momentum greater than 25 GeV.

2.2 Event Selection

The event selection is based on the same requirements as those used in the published analysis of the 1994-1997 e^+p data [1] and is summarized in the following. The two basic conditions are:

- A calorimetric missing transverse momentum, P_T^{calo} greater than 25 GeV.
- The presence of at least one well measured track with a polar angle greater than 10° and a transverse momentum higher than 10 GeV.

Cosmic and halo muons or beam-gas interactions are removed using a set of topological and timing requirements and demanding a reconstructed vertex in the ep interaction region. Neutral Current events with a badly measured energy deposition originating from hadron or electron deposits can show a significant P_T^{calo} imbalance. Therefore events containing an electron are rejected if δ is above 45 GeV (here δ is the $E - P_z$ sum over all visible particles) or the electron is balanced in azimuth by the hadronic system within $\Delta\Phi = 5°$.

The event sample selected by this procedure consists of 93 events and is referred to as the *inclusive sample*. Within this sample the isolation of high-P_T tracks with respect to other tracks in the event or with respect to jets is quantified using:

- Their distance D_{jet} to the closest hadronic jet in the pseudorapidity-azimuth plane $(\eta - \phi)$, defined by $D_{jet} = \sqrt{(\Delta\eta_{track-jet})^2 + (\Delta\phi_{track-jet})^2}$. Jets are identified with the cone algorithm ($R < 1$, $E_T > 5$ GeV) [4].
- Their distance D_{track} to the closest track in $\eta - \phi$, defined in an analogous way to D_{jet}. Here all well measured tracks with a polar angle greater than $5°$ are considered.

Figure 1 shows the correlation between D_{track} and D_{jet} for the high P_T tracks in the inclusive event sample. The high P_T tracks all show small values for the isolation variables, typical for genuine Charged Current events. No high P_T track with $D_{track} > 0.5$ and $D_{jet} > 1.0$ is observed. Therefore no event with an isolated lepton and missing transverse momentum is observed in the analyzed data sample. [1]

3 Standard Model Processes

In this section we quantify the Standard Model expectation for events of the searched topology. In addition to the requirements presented above, a loose lepton identification criteria is applied together with the isolation condition $D_{track} > 0.5$ and $D_{jet} > 1.0$. The contributions are already described in detail in the H1 published paper [1]. The main difference with respect to the previous analysis is the cross-sections increase, due to the change in the center of mass energy and to the lepton polarity. The predicted rates for the Standard Model processes are summarized in table 1.

[1] In an additional data sample, corresponding to a luminosity of 2.7 pb^{-1}, for which the innermost track detectors were not fully operational because of adverse beam conditions, one event has been found with P_T^{calo} =57 $\pm$ 5 GeV and an isolated electron e^- with a calorimetric visible P_T of 32 ± 3 GeV .

	Electron Channel	Muon Channel
Data	0	0
W production	0.63 ± 0.19	0.23 ± 0.05
Charged Current	0.08 ± 0.02	0.01 ± 0.01
Neutral Current	0.22 ± 0.05	0.03 ± 0.02
Photoproduction	< 0.02	< 0.02
Photon-Photon	0.05 ± 0.02	$0.09^{+0.09}_{-0.05}$
Total SM	1.0 ± 0.2	0.4 ± 0.1

Table 1: Observed and predicted event rates in 13.6 pb^{-1} integrated luminosity of e^-p collisions. The limits given correspond to 95% confidence level. Quoted numbers refer to the summed production of both lepton charged states.

- **W production**
  The main contribution is due to W-boson production with subsequent decay into a high P_T lepton and a neutrino. The cross section of W production at HERA for the analysis period is higher by about 10-15% with respect to the 1994-1997 period due to the center of mass energy increase. The contribution has been calculated using the EPVEC generator [5] based on leading order calculation including a resolved photon contribution. The cascade decay $W \to \tau \to e, \mu$ is taken into account.

- **High Q^2 CC processes**
  These events are intrinsically imbalanced in transverse momentum. A lepton candidate can be due to fluctuations in the hadronic final state. The generator DJANGO [6] is used to simulate this contribution.

- **High Q^2 NC processes**
  The scattered e^- constitutes the isolated lepton whereas the $P_T^{\rm calo}$ above the required threshold of 25 GeV can only be produced by fluctuations in the electron or hadron shower development and the detector response. The rate of such events is reduced by the selection criteria on δ and $\Delta\Phi$. The generator DJANGO [6] is used to simulate this contribution.

- **Photoproduction**
  The rate of photoproduction events where a high P_T hadron is misidentified as a lepton is calculated as explained in [1]. The rate of heavy quarks photoproduction events has been calculated using the AROMA generator [7].

- **Photon-Photon lepton pair production:** $\gamma\gamma \to \ell^+\ell^-$
  The e^+e^- production channel yields events with $P_T^{\rm calo} \sim 0$ and does not contribute. The $\mu^+\mu^-$ channel can contribute due to the $P_T^{\rm calo}$ deposited by the scattered electron in the elastic production or by the hadronic jet in the inelastic production case. The $\tau^+\tau^-$ events contribute mainly if one tau decays into a μ while the $P_T^{\rm calo}$ is due to the hadronic decay of the second τ. The generator LPAIR [8] is used to simulate these contributions.

4 Summary

A search for events containing high energy isolated leptons and missing transverse momentum has been performed in $e^- p$ data. In a data sample corresponding to an integrated luminosity of 13.6 pb^{-1}, no event with an isolated high P_T lepton (electron or muon) has been found using the same analysis method as published with the $e^+ p$ data [1]. The expected rates from the various Standard Model contributions are 1.0$\pm$0.2 and 0.4$\pm$0.1 events in the electron and muon channel, respectively.

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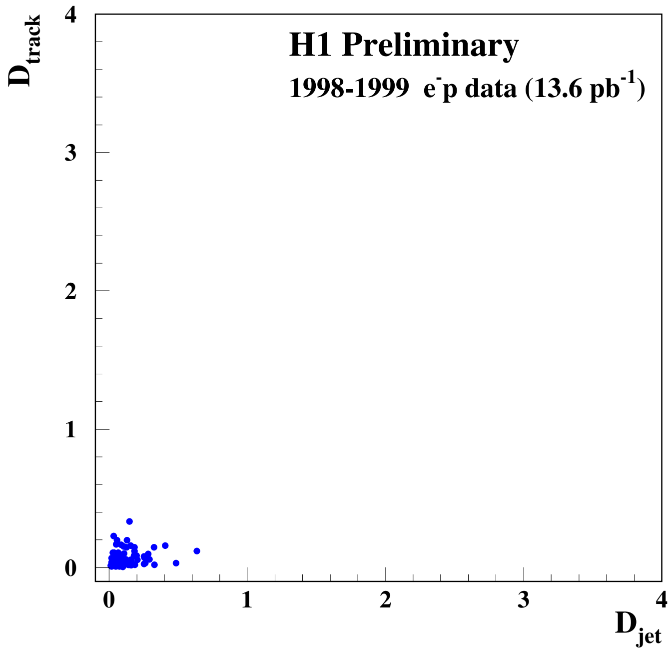

Figure 1: Correlation between the distances D_{jet} and D_{track} of high P_T tracks to its closest hadronic jet and closest track. No isolated track with $D_{jet} > 1.0$ and $D_{track} > 0.5$ is observed.