Search for Events with Isolated High P_T Leptons and Large $P_T^{\rm miss}$ using the H1 Detector at HERA

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A search for events with energetic isolated leptons and large transverse momentum imbalance produced at HERA using the H1 detector is presented [1]. The full H1 data set of $e^{\pm}p$ data collected in the period 1994 - 2007 at center of mass energies $\sqrt{s}$ of 300 to 320 GeV is employed, corresponding to a total integrated luminosity of 478 pb^{-1}. In the electron and muon channel, a good overall agreement with the Standard Model (SM) is found with 59 events observed where 58.9 $\pm$ 8.2 are expected. In the e^+p data at large hadronic transverse momentum P_T^X >25 GeV, 21 events are observed where only 8.9 $\pm$ 1.5 are expected. This corresponds to an excess of 3.0σ. In the tau channel 20 events are observed where 19.5 $\pm$ 3.2 are expected, in good agreement with the SM.

1 Introduction

The H1 and ZEUS experiments have previously reported [2, 3, 4, 5, 6] searches for events with an isolated lepton and large missing transverse momentum ($P_T^{\rm miss}$). In the electron (e) and muon (μ) channel, H1 has reported [4] a 3σ excess of data events over the SM expectation in the region of hadronic transverse momentum $P_T^X > 25$ GeV in HERA I data. The ZEUS Collaboration performed a similar analysis but could not confirm the excess [3].

H1 has updated [1, 7] its analysis which now includes the full HERA I+II data set at high energy[a]. The data corresponds to an integrated luminosity of 478 pb^{-1}, collected in the period 1994 - 2007: 184 pb^{-1} of e^-p and 294 pb^{-1} of e^+p data.

The search for isolated tau (τ) leptons has also been updated [1, 8] to include the full high energy data set. In addition the selection procedure has been improved.

2 The Search for Isolated Electrons and Muons

The signal topology in this channel consists of at least one isolated electron or muon with large transverse momentum (P_T) in the final state together with genuine large $P_T^{\rm miss}$. The main SM contribution to this topology is single W production where the W decays into an electron or muon and a neutrino, $e^{\pm}p \to eW\,(\to e/\mu + \nu)\,X$, where the hadronic system X typically has low P_T. The production via charged currents $e^{\pm}p \to \nu W\,(\to e/\mu + \nu)\,X$ is also considered. Both leptons from the W decay have a Jacobian peak around 40 GeV, corresponding to half the W mass. The neutrino of the W boson escapes undetected and accounts for the missing transverse momentum in the event. In the electron channel, the

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[a]The term 'high energy' refers to the period where the center of mass energy $\sqrt{s}$ was 300-320 GeV. HERA is currently running at lower energies for which the expected yield is considerably smaller.

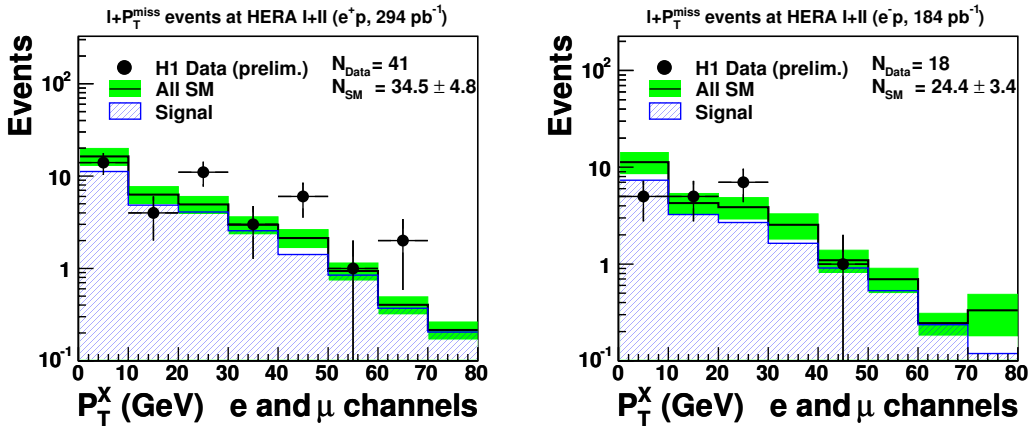

Figure 1: Distribution of the hadronic transverse momentum P_T^X in the electron and muon channel for HERA I+II data.

smaller contribution to the signal from Z^0 production, $ep \to eZ^0\,(\to \nu\bar{\nu})\,X$, is also taken into account.

The event selection is the same as used in the HERA I analysis [4]. The isolated lepton should have $P_T > 10$ GeV and polar angle $5^o < \theta < 140^o$. It should be isolated from jets and other tracks. The events are requiered to have a transverse momentum imbalance, measured in the calorimeter, of at least 12 GeV. Further cuts are applied to reduce the remaining SM background, whilst preserving a large signal purity.

The final sample contains 59 data events for 58.9 ± 8.2 expected from the SM. The SM signal purity is typically $\sim 70\%$. The P_T^X spectra for the e^-p and e^+p data are shown in Figure 1. The e^-p sample is in agreement with the SM with 18 events observed where 24.4 ± 3.4 are expected. In the e^+p data, 41 events are observed for 34.5 ± 4.8 expected, also in agreement with the SM. In the region $P_T^X > 25$ GeV, which is atypical for the SM signal processes, 21 events are observed where only 8.9 ± 1.5 are expected. This corresponds to an excess of 3.0σ. It should be noted that the excess is observed in both lepton channels.

The ZEUS Collaboration updated their analysis and reports [9] good agreement with the SM in all regions of phase space and cannot confirm the excess. A comparison between the H1 and ZEUS acceptances is shown in Figure 2. Both experiments observe events at high P_T^X. The H1 acceptance in P_T^X is larger due to the larger coverage in θ but it should be noted that most (not all) H1 events at high P_T^X are in the common phase space, visible for both H1 and ZEUS.

3 The Search for Isolated Tau Leptons

Events with isolated τ leptons and $P_T^{\rm miss}$ are searched for in the full data sample collected by H1 at HERA corresponding to an integrated luminosity of 471 pb^{-1} [1, 8].

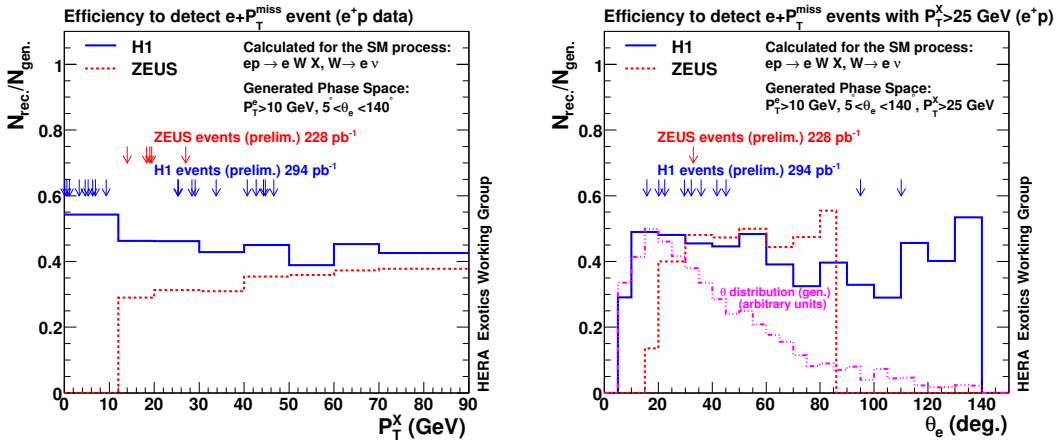

Figure 2: Comparison of the efficiencies of the H1 and ZEUS analyses to select events containing isolated electrons or muons and missing transverse momentum in the HERA e^+p data. Left: the efficiency, defined as N_{rec} / N_{gen}, as function of hadronic transverse momentum P_T^X in the electron channel. Right: the efficiency in the electron channel at large $P_T^X > 25$ GeV as a function of the electron polar angle θ. In both figures, the H1 (ZEUS) efficiency is given by the solid (dashed) line. The data events observed by each experiment are indicated by the arrows.

The only SM contribution to the signal topology originates from single W production followed by W decay into a τ and a ν_τ. The τ decay channel used for this analysis is the '1-prong' hadronic decay channel for which the branching ratio is 43%. The typical topology of this process consists of a pencil-like narrow jet with exactly one track and large $P_T^{\rm miss}$.

The event selection used in this preliminary analysis is based on the published HERA I analysis [6]. The τ lepton decay products are identified as narrow jets with a radius $R < 0.12$, in a data sample with $P_T^{\rm miss} > 12$ GeV. Cone radii and distances between tracks are in $\eta - \phi$ space. The track segment from the inner tracker chambers attributed to the jet should be inside a cone of radius 0.3 around the jet center.

A total of 20 events are observed for 19.5 ± 3.2 expected from the SM. Figure 3 shows the P_T^X spectra of the τ data sample, for the e^-p and e^+p data separately. In the e^-p sample 10 events are observed where 8.6 ± 1.5 are expected. In the e^+p sample 10 events are observed where 10.8 ± 1.8 are expected. At high P_T^X one event is observed where 0.99 ± 0.13 are expected. The contribution from SM single W production is below 10%, hence the sample is largely dominated by (Charged Current) background. All results in this channel are in good agreement with the SM.

4 Summary

A preliminary search for events with isolated high P_T leptons and large $P_T^{\rm miss}$ produced at HERA using the H1 detector is presented [1]. The full H1 data set of $e^\pm p$ data collected in the period 1994 - 2007 at center of mass energies $\sqrt{s}$ of 300 to 320 GeV is used corresponding to a total integrated luminosity of 478 pb^{-1}. In the electron and muon channels, 59 events

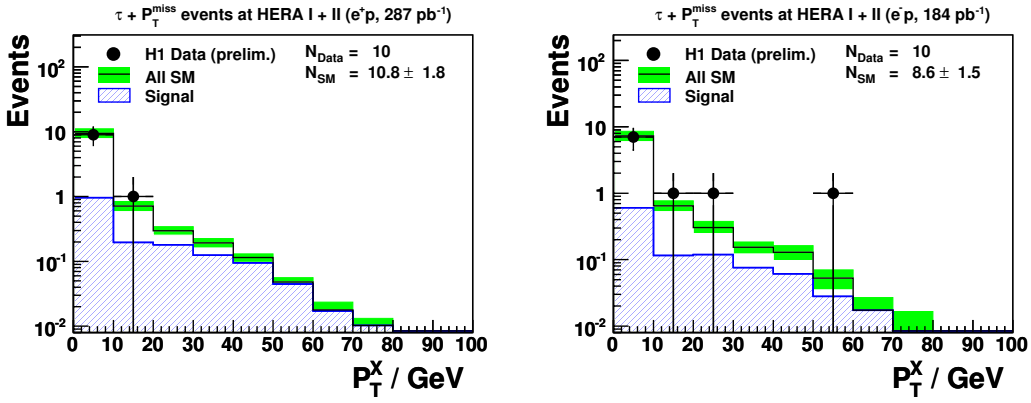

Figure 3: Distribution of the hadronic transverse momentum P_T^X of τ+$P_T^{\rm miss}$ events in HERA I+II data. The data are represented by the dots. The open histogram is the contribution from SM single W production and is given by the hatched histogram. N_{data} is the total number of events observed, N_{SM} is the total SM expectation. The total error on the SM expectation is given by the shaded band.

are observed for 58.9 ± 8.2 expected from the SM, dominated at 70% by single W production. However, in the e^+p data sample for the region $P_T^X > 25$ GeV, 21 events are observed where only 8.9 ± 1.5 are expected. Therefore, the 3σ fluctuation, previously observed using HERA I data, persists in the e^+p data after an increase of the luminosity by a factor of 3. In the isolated tau channel, 20 events are observed, in good agreement with the SM expectation of 19.5 ± 3.2. The separate e^-p and e^+p data sets display good agreement with the SM.

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