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Search for Events with Isolated Leptons And Missing Transverse Momentum at HERA

H1 Collaboration

Abstract

The search for isolated leptons (electrons or muons) and missing transverse momentum is performed in $e^{\pm}p$ collisions with the H1 detector at HERA in the period 1994–2005. The analysed data sample corresponds to an integrated luminosity of 192 pb^{-1}, which includes 53 pb^{-1} of $e^{+}p$ data and 21 pb^{-1} of $e^{-}p$ data recently taken in the new HERA II phase.

Nine events in the electron channel and one event in the muon channel are observed in the 2003-04 HERA II $e^{+}p$ data sample, compared to Standard Model (SM) predictions of 4.8 $\pm$ 0.8 and 1.3 $\pm$ 0.2 repectively. Five events in the electron channel and no events in the muon channel are observed in the new 2004-05 HERA II $e^{-}p$ data sample compared to SM predictions of 2.2 $\pm$ 0.3 and 0.6 $\pm$ 0.1 respectively.

In the combined electron and muon channel of the complete HERA data set 34 events are observed, compared to a SM prediction of 23.3 $\pm$ 3.2. At large hadronic transverse momentum 17 events are observed, compared to a SM prediction of 5.8 $\pm$ 1.1. Events with large transverse momentum are observed in both the HERA I and II samples. Further details of the analysis may be found in [1].

1 Introduction

The H1 Collaboration has reported the observation of events with energetic isolated electrons or muons associated with missing transverse momentum [1]. The analysis included the full HERA I data sample corresponding to an integrated luminosity of 118 pb^{-1}. Presented here is an update of the published analysis, including the new $e^{\pm}p$ data sample accumulated at HERA II from October 2003 to April 2005, corresponding to an integrated luminosity of 74 pb^{-1}.

Standard Model (SM) "signal" processes are defined as those events which contain a prominent high P_T isolated lepton accompanied by genuine, large missing transverse momentum. The dominant SM process that may produce events with this topology is the production of real W bosons with subsequent leptonic decay. In the SM W bosons are mainly produced in the photoproduction regime.

In the HERA I data, the H1 Collaboration observe 11 electron events and 8 muon events compared to a SM expectation of 11.5 $\pm$ 1.5 and 2.9 $\pm$ 0.5 respectively. At large hadronic transverse momentum $P_T^X > 25$ GeV, 5 electron events and 6 muon events are observed compared to a SM expectation of 1.8 $\pm$ 0.3 and 1.7 $\pm$ 0.3 respectively. The dominant contribution to the SM expectation arises from signal processes.

2 Event Selection

The HERA II event selection is identical to that used in the HERA I analysis and is detailed in table 1. The main selection requirements are as follows: The lepton should have high transverse momentum P_T^l, be observed in the central region of the detector, defined by the polar angle θ_l and be isolated with respect to jets and other tracks in the event. The isolation of the lepton is quantified using the distances in $\eta-\phi$ space to the nearest jet D_{jet} and nearest track D_{track}. The event should contain a large transverse momentum imbalance, both measured in the calorimeter, P_T^{calo} and over the complete event, P_T^{miss}. In order to reduce background contributions, further cuts are then applied using variables sensitive to the presence of high energy undetected particles in the event: The azimuthal balance of the event $\frac{V_{ap}}{V_p}$, the difference in azimuthal angle between the lepton and the hadronic system, $\Delta\phi_{l-X}$ and the longitudinal momentum imbalance δ_{miss}. Further details on these variables and the event selection can be found in [1].

3 Analysis of HERA II Data

The analysis of the HERA II e^+p data yields nine electron events and one muon event for an expectation of 4.8 $\pm$ 0.8 and 1.3 $\pm$ 0.2 respectively. The SM prediction is dominated by signal processes, where the majority is due to real W production. Table 2 summarises the results obtained from the analysis of the HERA II e^+p data sample. The P_T^X distribution in the electron and muon channel for this data sample is displayed in figure 1. In the electron channel an excess of events is observed in the data compared to the SM expectation for $P_T^X > 25$ GeV. The observation of one muon event in the data is in agreement with the SM event yield.

Variable	Electron	Muon
θ_l	$5^\circ < \theta_l < 140^\circ$	
P_T^l	> 10 GeV	
$P_T^{\rm calo}$	> 12 GeV	
$P_T^{\rm miss}$	> 12 GeV	
P_T^X	–	> 12 GeV
D_{jet}	> 1.0	
D_{track}	> 0.5 for $\theta_e \geq 45^\circ$	> 0.5
ζ_l^2	> 5000 GeV^2 for $P_T^{\rm calo} < 25$ GeV	–
$\frac{V_{ap}}{V_p}$	< 0.5 (< 0.15 for $P_T^e < 25$ GeV)	< 0.5 (< 0.15 for $P_T^{\rm calo} < 25$ GeV)
$\Delta\phi_{l-X}$	$< 160^\circ$	$< 170^\circ$
# isolated μ	0	1
$\delta_{\rm miss}$	> 5 GeV †	–

† *if only one e candidate is detected, which has the same charge as the beam lepton.*

Table 1: Selection requirements for the electron and muon channels in the search for events with isolated leptons and missing transverse momentum.

Figure 2 displays one of the HERA II e^+p electron events. It shows a high P_T electron and large missing transverse momentum. The absence of any reconstructed hadronic system X makes this event a candidate for elastic W production. Figure 3 shows a HERA II e^+p electron event with high P_T^X. The same features are visible as in figure 2, a high P_T electron and large missing transverse momentum. However, also present in this event is a prominent hadronic jet, giving rise to the large P_T^X.

The analysis of the HERA II e^-p data yields five electron events and no muon events for an expectation of 2.2 ± 0.3 and 0.6 ± 0.1 respectively. As for the HERA II e^+p data the SM prediction is dominated by signal processes, where the majority is due to real W production. However, as expected from the SM, the charged current background is observed to be higher. Table 3 summarises the results obtained from the analysis of the HERA II e^-p data sample. The P_T^X distribution in the electron and muon channel for this data sample is displayed in figure 4. The data excess observed at high P_T^X in the HERA II e^+p electron channel is not present in the e^-p data, although a similar level of agreement is seen across the whole phase space. The observation of no muon events in the data is in agreement with the SM event yield.

4 Summary

Table 4 shows the combined results for the HERA I and HERA II searches for events containing isolated electrons or muons and large missing transverse momentum, corresponding to an integrated luminosity of 192 pb^{-1}. In both channels the SM expectation is dominated by signal processes, the main contribution arising from real W production. Combining the electron and muon channels, 34 events are observed in the data sample, for an expectation from SM processes of 23.3 ± 3.2. At large hadronic momentum $P_T^X > 25$ GeV, 17 events are observed in the data for an expectation of 5.8 $\pm$ 1.1. The probability for the SM expectation to fluctuate to the observed number of events or more is 0.0005 for $P_T^X > 25$ GeV, compared to 0.0015 for the HERA I data. The P_T^X distribution in the electron and muon channels combined for the HERA I and HERA II searches is displayed in figure 5.

The continued increase in luminosity expected from the HERA II programme in the coming years will improve the precision of the measurement of events with isolated leptons and missing transverse energy and will hopefully clarify the excess observed at large hadronic transverse momentum.

References

[1] V. Andreev *et al.* [H1 Collaboration], Phys. Lett. B **561** (2003) 241 [hep-ex/0301030].

H1 Preliminary, HERA II $e^{+}p$ data $\mathcal{L} = 53$ pb^{-1}

Electron	H1 Data	SM Expectation	SM Signal
Total	9	4.75 ± 0.76	3.11 ± 0.47
P_T^X >25 GeV	5	0.84 ± 0.19	0.58 ± 0.09

Muon	H1 Data	SM Expectation	SM Signal
Total	1	1.33 ± 0.19	1.03 ± 0.16
P_T^X >25 GeV	0	0.85 ± 0.13	0.63 ± 0.10

Combined	H1 Data	SM Expectation	SM Signal
Total	10	6.08 ± 0.92	4.14 ± 0.62
P_T^X >25 GeV	5	1.69 ± 0.28	1.21 ± 0.18

Table 2: The results of the search for events with isolated electrons or muons and missing transverse momentum in the HERA II $e^{+}p$ data ($\mathcal{L}$=53 pb^{-1}): observed and predicted numbers of events in the electron channel, the muon channel and the sum of electron and muon channels. The signal component of the SM expectation, dominated by real W production, is also given. The quoted errors contain statistical and systematic uncertainties added in quadrature.

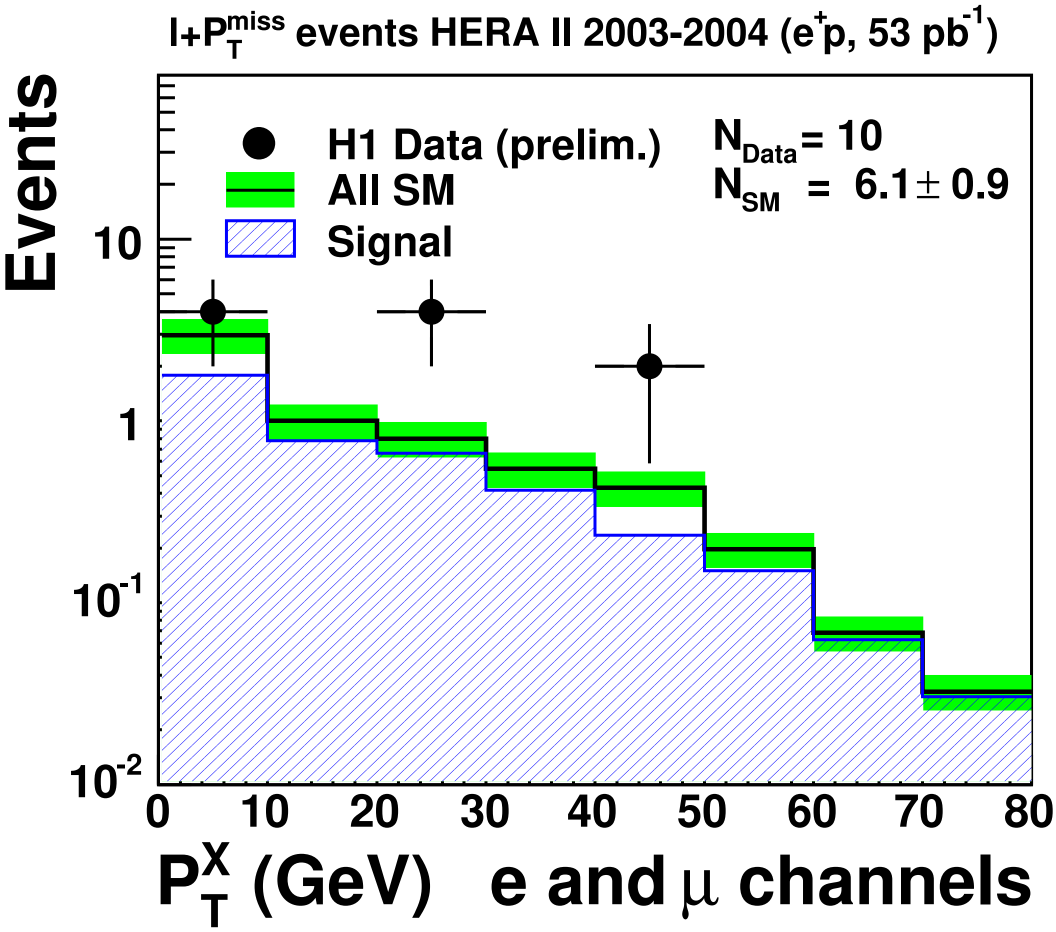

Figure 1: The hadronic transverse momentum distribution in the electron and muon channels combined: data (HERA II e^+p, $\mathcal{L} = 53$ pb^{-1}) is compared to the SM expectation (open histogram). The signal component of the SM expectation, dominated by real W production, is given by the hatched histogram. $\mathrm{N_{Data}}$ is the total number of data events observed, $\mathrm{N_{SM}}$ is the total SM expectation. The total error on the SM expectation is given by the shaded band.

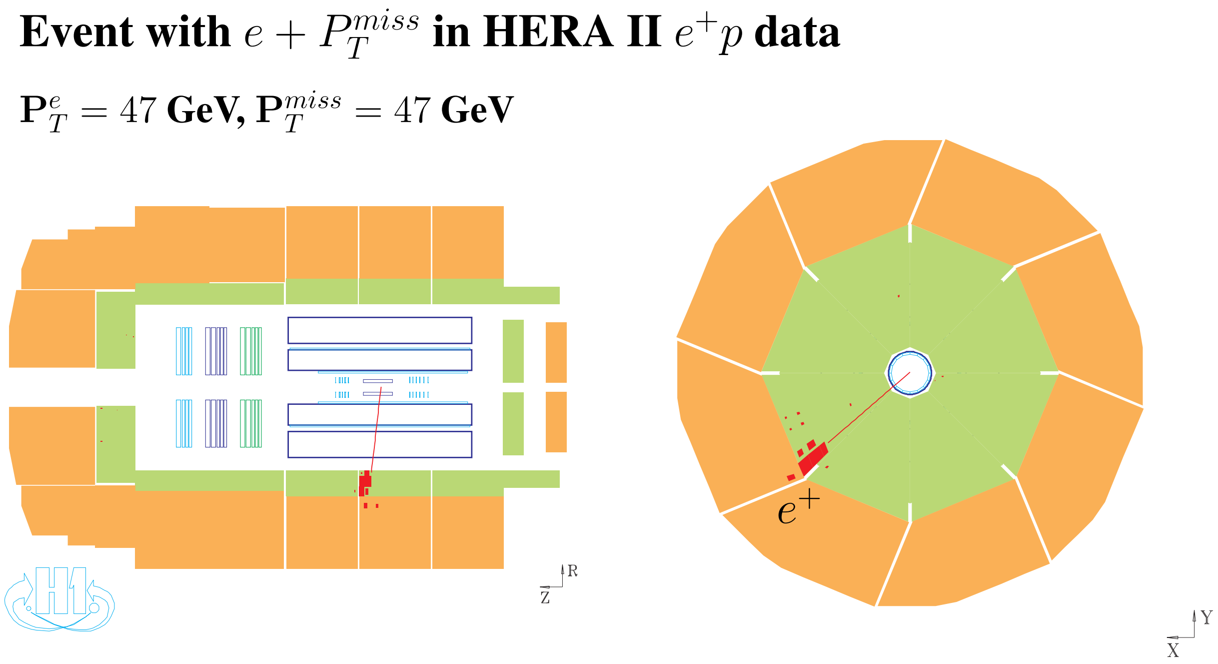

Figure 2: Display of an event with an isolated electron and missing transverse momentum: a candidate for elastic W production.

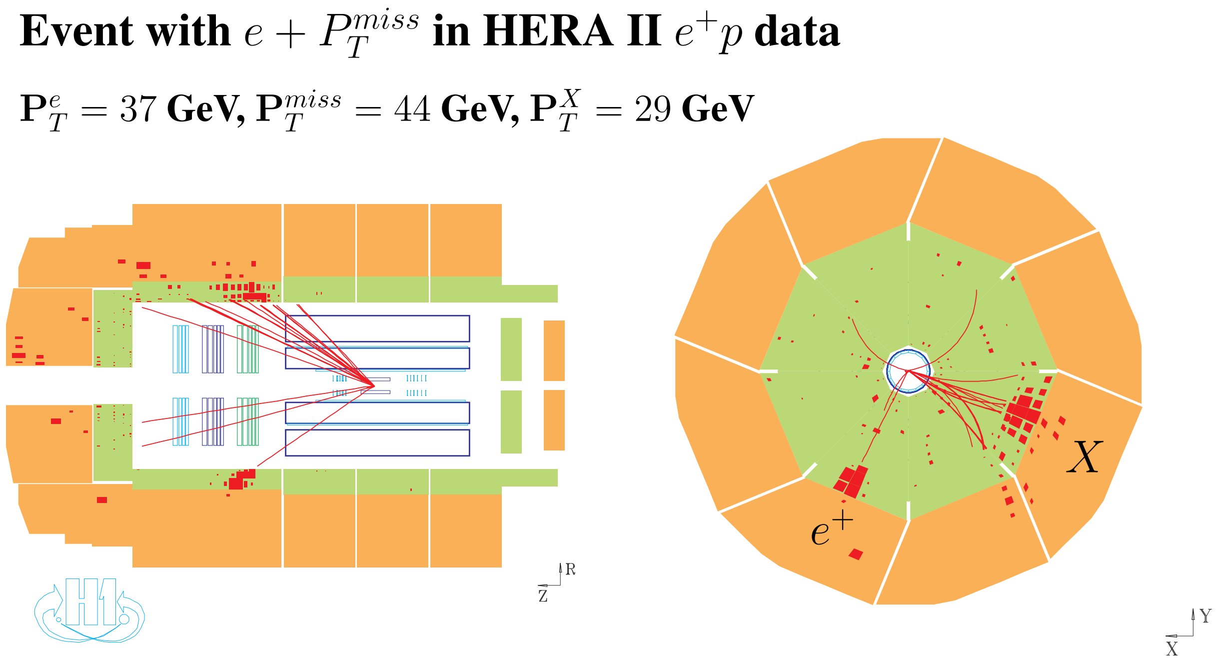

Figure 3: Display of an event with an isolated electron, missing transverse momentum and a prominent hadronic jet.

H1 Preliminary, HERA II $e^{-}p$ data $\mathcal{L} = 21$ pb^{-1}

Electron	H1 Data	SM Expectation	SM Signal	SM Background
Total	5	2.15 ± 0.33	1.36 ± 0.22	0.79 ± 0.25
P_T^X >25 GeV	1	0.30 ± 0.05	0.23 ± 0.04	0.07 ± 0.03

Muon	H1 Data	SM Expectation	SM Signal	SM Background
Total	0	0.59 ± 0.09	0.45 ± 0.07	0.14 ± 0.05
P_T^X >25 GeV	0	0.36 ± 0.06	0.26 ± 0.04	0.10 ± 0.04

Combined	H1 Data	SM Expectation	SM Signal	SM Background
Total	5	2.75 ± 0.40	1.81 ± 0.27	0.94 ± 0.30
P_T^X >25 GeV	1	0.66 ± 0.10	0.50 ± 0.08	0.17 ± 0.06

Table 3: The results of the search for events with isolated electrons or muons and missing transverse momentum in the HERA II $e^{-}p$ data ($\mathcal{L}$=21 pb^{-1}): observed and predicted numbers of events in the electron channel, the muon channel and the sum of electron and muon channels. The signal (dominated by real W production) and background components of the SM expectation are also given. The quoted errors contain statistical and systematic uncertainties added in quadrature.

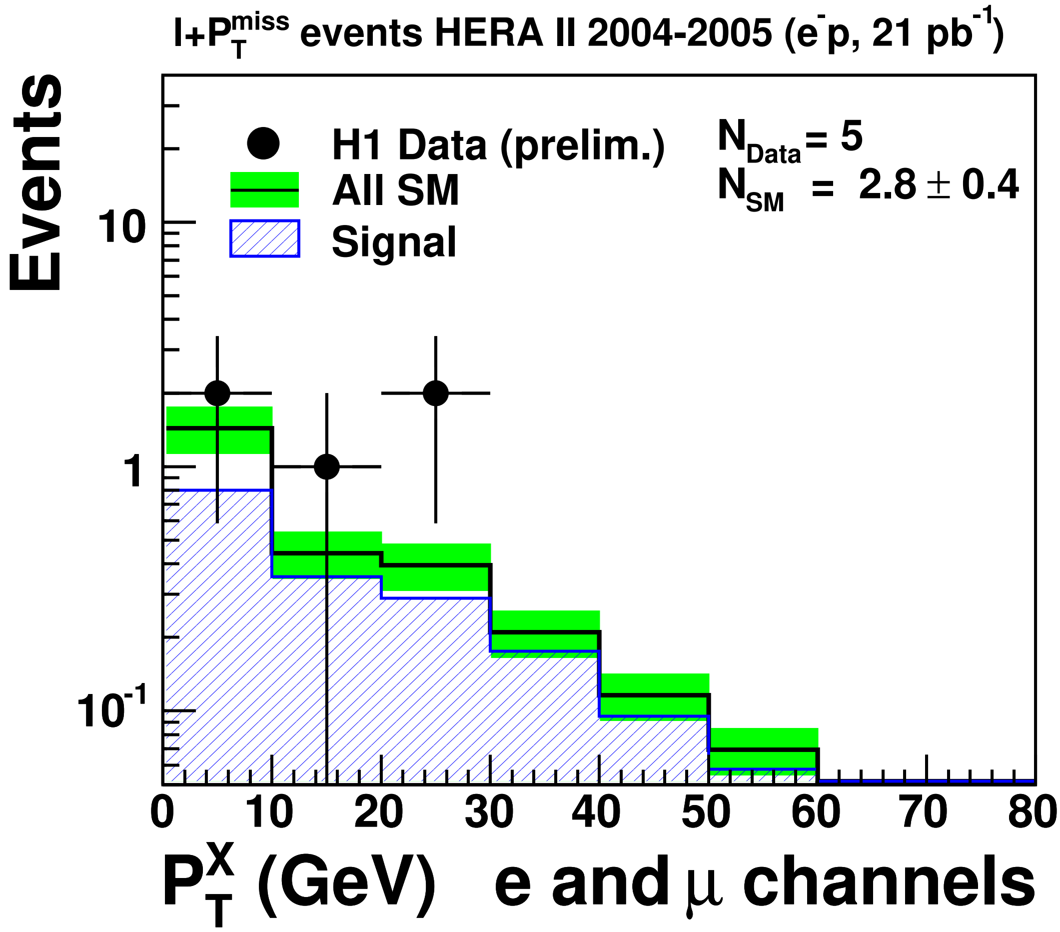

Figure 4: The hadronic transverse momentum distribution in the electron and muon channels combined: data (HERA II e^-p, $\mathcal{L} = 21$ pb^{-1}) is compared to the SM expectation (open histogram). The signal component of the SM expectation, dominated by real W production, is given by the hatched histogram. $\mathrm{N_{Data}}$ is the total number of data events observed, $\mathrm{N_{SM}}$ is the total SM expectation. The total error on the SM expectation is given by the shaded band.

H1 Preliminary 1994-2005 $e^{\pm}p$ 192 pb^{-1}	Electron obs./exp. (Signal contribution)	Muon obs./exp. (Signal contribution)	Combined obs./exp. (Signal contribution)
Total	25 / 18.4 $\pm$ 2.5 (70%)	9 / 4.9 $\pm$ 0.8 (85%)	34 / 23.3 $\pm$ 3.2 (73%)
$P_T^X > 25$ GeV	11 / 2.9 $\pm$ 0.6 (81%)	6 / 2.9 $\pm$ 0.6 (86%)	17 / 5.8 $\pm$ 1.1 (84%)

Table 4: Summary of the H1 results of searches for events with isolated electrons or muons and missing transverse momentum in the full HERA data set ($\mathcal{L}$=192 pb^{-1}). The results are shown for the full selected sample and for the subsample at large $P_T^X > 25$ GeV. The number of observed events is compared to the SM prediction. The signal component of the SM expectation, dominated by real W production, is given as a percentage in parentheses. The quoted errors contain statistical and systematic uncertainties added in quadrature.

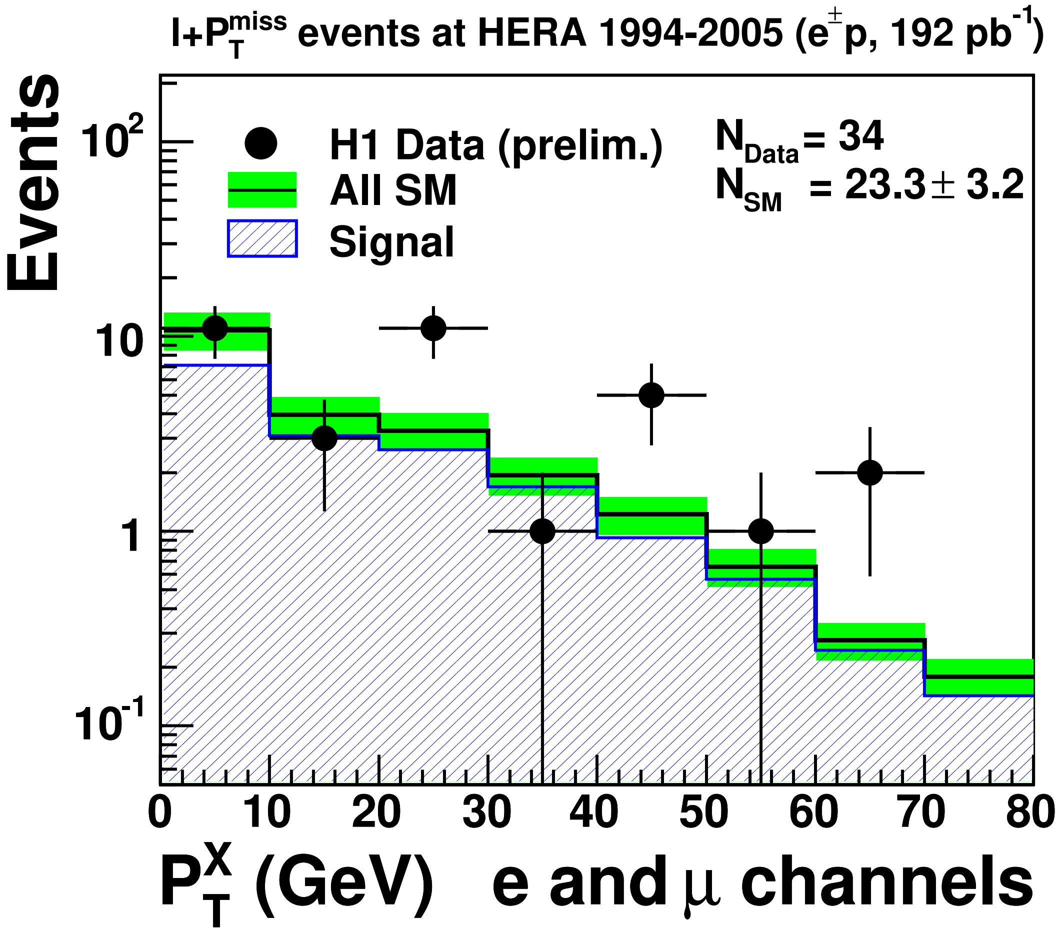

Figure 5: The hadronic transverse momentum distribution in the electron and muon channels combined: data (full HERA data set, $\mathcal{L} = 192$ pb^{-1}) is compared to the SM expectation (open histogram). The signal component of the SM expectation, dominated by real W production, is given by the hatched histogram. $\mathrm{N}_{\mathrm{Data}}$ is the total number of data events observed, N_{SM} is the total SM expectation. The total error on the SM expectation is given by the shaded band.