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Measurement of Single W Production Cross Section and W Polarisation Fractions at HERA

H1 Collaboration

Abstract

A measurement of the production cross section of events with an energetic isolated electron or muon and missing transverse momentum is presented along with the measurement of the single W production cross section and the W polarisation fractions at HERA. The full HERA I+II data sample recorded with the H1 detector in the years 1994-2007 corresponding to an integrated luminosity of 482 pb^{-1} is used. The results are found to be in agreement with the Standard Model.

1 Introduction

Events with an energetic isolated electron (e) or muon (μ) and large missing transverse momentum ($\not{P}_T$) are selected in ep collisions in the full HERA I+II high-energy data sample. The data were collected in the period 1994 - 2007 with the H1 detector and correspond to an integrated luminosity of 482 pb^{-1}. In the e^+p data an excess of data events was observed at large hadronic transverse momentum [1], in a region of phase space which is atypical for W boson production. Presented here is a measurement of the production cross section of events with an energetic isolated electron or muon and large $\not{P}_T$ along with a measurement of the single W production cross section. Also presented here is the first measurement at HERA of the W polarisation fractions.

2 Cross Section Measurements

The selection used for the cross section measurements is identical to that used in [1]. The cross sections are calculated using the formula:

$$\sigma = \frac{N_{data} - N_{bkd}^{MC}}{\mathcal{L}\,\Gamma\,\mathcal{A}} \qquad \text{with} \qquad \mathcal{A} = \frac{N_{rec}^{MC}}{N_{gen}^{MC}},$$

where N_{data} is the number of data events, N_{bkd}^{MC} is the Monte Carlo (MC) estimate of number of background events, $\mathcal{L}$ is the total data luminosity, Γ is a branching ratio, and $\mathcal{A}$ is the acceptance. N_{rec}^{MC} and N_{gen}^{MC} are the number of reconstructed and generated events in the signal MC respectively.

For the isolated lepton cross section ($\sigma_{\ell+\not{P}_T}$), $\Gamma = 1$ and N_{gen}^{MC} is the number of events with an isolated electron or muon with polar angle $5^o < \theta_{e/\mu} < 140^o$, $P_T > 10$ GeV and isolated from any jet by at least one unit in $\eta - \phi$. In addition, the genuine missing transverse momentum in the event should be larger than 12 GeV. For the single W boson production total cross section (σ_W), Γ is the branching ratio of the leptonic W boson decay ($W \rightarrow e/\mu/\tau + \nu$) to any final state with an electron or muon $\Gamma_{W\rightarrow e/\mu+X} = 0.24$. Furthermore, N_{gen}^{MC} is defined as $\sigma_W^{SM} \cdot \mathcal{L} \cdot \Gamma_{W\rightarrow e/\mu+\nu}$, where σ_W^{SM} is the the Standard Model (SM) prediction for σ_W.

For the generation of events with isolated leptons and $\not{P}_T$ in ep collisions (signal), the EPVEC generator [2] is used. The two main contributions to the SM signal are single W and Z^0 production $e^{\pm}p \rightarrow W/Z^0 + eX$. The latter contributes only in the electron channel with the invisible decay $Z^0 \rightarrow \nu\nu$. The EPVEC is reweighted to a NLO calculation [3] for W production at HERA. The resulting theoretical uncertainty on the cross section is 15%. It should be noted that the small SM contribution to N_{rec}^{MC} from Z^0 production is signal for $\sigma_{\ell+\not{P}_T}$, whereas it is considered background for σ_W.

The results are shown in table 1. Both cross sections are in agreement with the SM, where it should be noted, that σ_W is measured with a 5σ significance. The quoted systematic errors on the measured cross sections include experimental and theoretical uncertainties. An extra model uncertainty is included for $\sigma_{\ell+\not{P}_T}$, which is assessed using the exotic model of anomalous single top production via Flavour Changing Neutral Current (FCNC) [4]. For the calculations in this model, the ANOTOP generator [5] is used.

H1	HERA I+II Data	SM
$\sigma_{\sigma_{\ell+\not{P}_T}}$	0.24 ± 0.05 (stat) ± 0.05 (sys)	0.26 ± 0.04 (th.sys)
σ_W	1.23 ± 0.25 (stat) ± 0.22 (sys)	1.31 ± 0.20 (th.sys)

Table 1: The measured cross section for events with an energetic isolated lepton and large missing transverse momentum ($\sigma_{\ell+\not{P}_T}$) and the measured cross section for single W boson production (σ_W) with statistical (stat) and systematic (sys) uncertainties. The results are compared to the SM predictions which are quoted with a theoretical systematic error (th.sys) of 15%.

3 Measurement of W Boson Polarisation Fractions

The measurement of W boson polarisation fractions makes use of the $\cos\,\theta^*$ distributions in the decay $W \rightarrow e/\mu{+}\nu$. θ^* is defined as the angle between the W boson momentum in the lab frame and that of the charged decay lepton in the W boson rest frame. For the left handed polarisation fraction F_-, the longitudinal fraction F_0 and the right handed fraction $F_+ \equiv 1 - F_- - F_0$, the $\cos\,\theta^*$ distributions for W^+ bosons are given [6] by:

$$
\begin{aligned}
\frac{dN}{dcos\,\theta^*} \quad \propto \quad & (1 - F_- - F_0) \cdot \frac{3}{8}\,(1 + cos\,\theta^*)^2 \\
+ \quad & F_0 \cdot \frac{3}{4}\left(1 - cos^2\theta^*\right) \\
+ \quad & F_- \cdot \frac{3}{8}\,(1 - cos\,\theta^*)^2\,.
\end{aligned} \tag{1}
$$

For W^- bosons, the $\cos\,\theta^*$ distributions have opposite values. To allow for combination of both channels, $\cos\,\theta^*$ is weighted with the sign of the lepton charge $q_\ell = \pm 1$. Events in the electron or muon channel originating from W boson to tau decay, $W \rightarrow \tau\,(\rightarrow e/\mu + \nu) + \nu$, are considered background, since for these events the $\cos\,\theta^*$ distributions are not expected to be described by relation 1.

Starting from the sample in [1], events are selected for which a W boson can be successfully reconstructed. The reconstruction of the missing neutrino kinematics and the W boson rest frame is based on a method employed in [4]. To ensure a reliable charge measurement, only leptons in the central region, $\theta_{e/\mu} > 20^o$, are considered. Furthermore, the 'charge significance', $\kappa/d\kappa$, should be larger than 1, where κ is the curvature of the associated track and $d\kappa$ the uncertainty on κ. In the electron channel, the P_T measured from the associated track ($P_T^{\rm track}$) is required to match the calorimetric measurement ($P_T^{\rm calo}$) with $1/P_T^{\rm track} + 1/P_T^{\rm calo} < 0.04$ [7]. With these requirements the charge misidentification is well below 1%. The final sample consists of 21 electron events and 10 muon events with an overall signal purity of 83%.

The measured $q_\ell \cos\,\theta^*$ distribution is corrected for acceptance and detector effects. The resulting differential cross section is fit to the model defined in relation 1 as shown in Figure 1. In the fit, the optimal values for F_- and F_0 are simultaneously extracted. The result is shown in Figure 2 and found to be in good agreement with the SM and compatible with anomalous single top production via FCNC within one 1σ confidence level (CL). F_- and F_0 are also extracted in fits where one parameter is fixed to its SM value. The results are presented in table 2 and display good agreement with the SM. The quoted systematic uncertainties are propagated from the cross section calculations. In addition, the systematic effects on the shape of the differential cross section from uncertainties on the background estimates and charge misidentification are taken into account.

H1	HERA I+II Data	SM
F_-	$0.58 \pm 0.15\,(\text{stat}) \pm 0.12\,(\text{sys})$	$0.61 \pm 0.01\,(\text{stat})$
F_0	$0.15 \pm 0.21\,(\text{stat}) \pm 0.09\,(\text{sys})$	$0.19 \pm 0.01\,(\text{stat})$

Table 2: One parameter fit results with statistic (stat) and systematic (sys) errors. The central values are obtained by fixing one parameter to its SM prediction and fitting the other. The SM prediction is obtained from a two parameter fit to the SM $q_\ell \cos\theta^*$ distribution where the quoted error is purely statistical.

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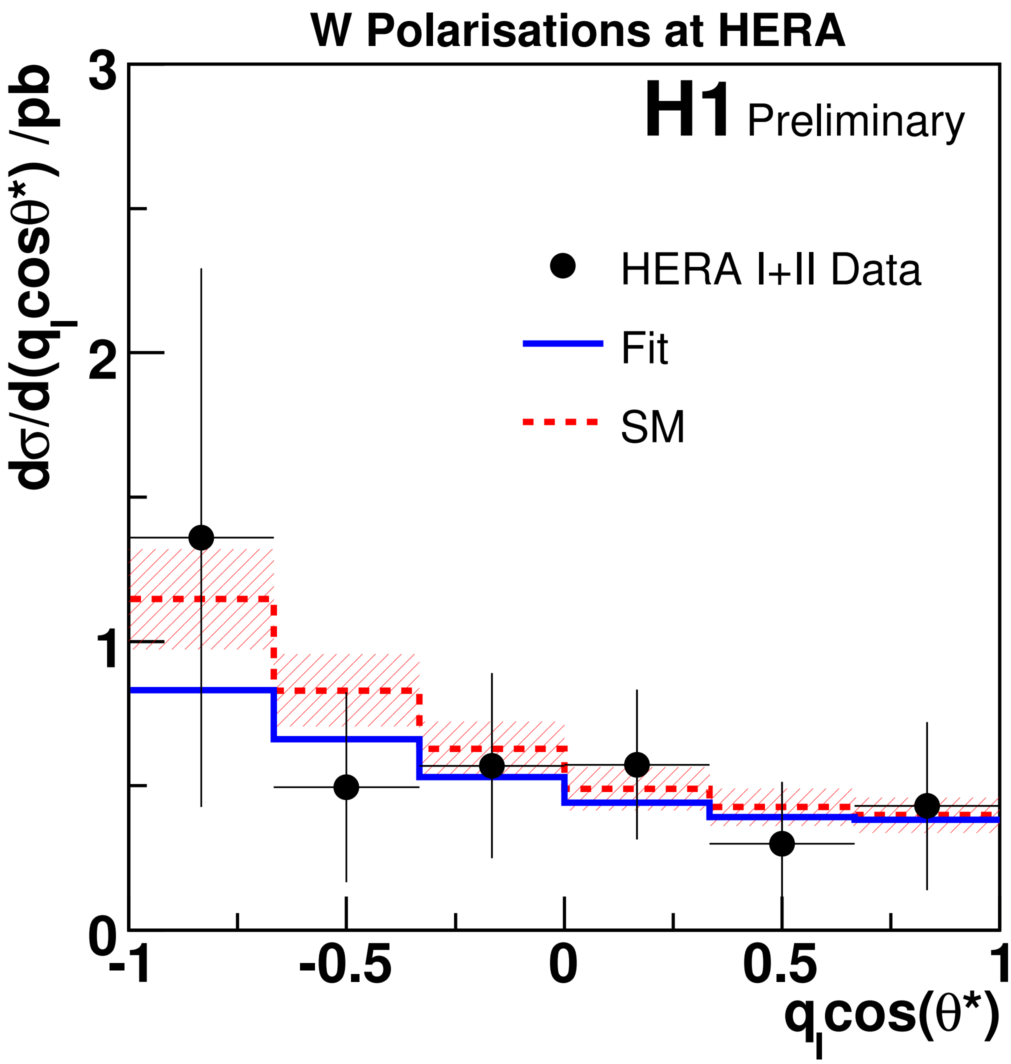

Figure 1: The simultaneous fit (open histogram) of F_- and F_0 to the differential cross section $d\sigma/d\,(q_\ell \cos\theta^*)$ (points) where the error bars denote the statistical uncertainty only. The SM prediction is also shown (dashed histogram) with a 15% theoretical systematic error (hatched area).

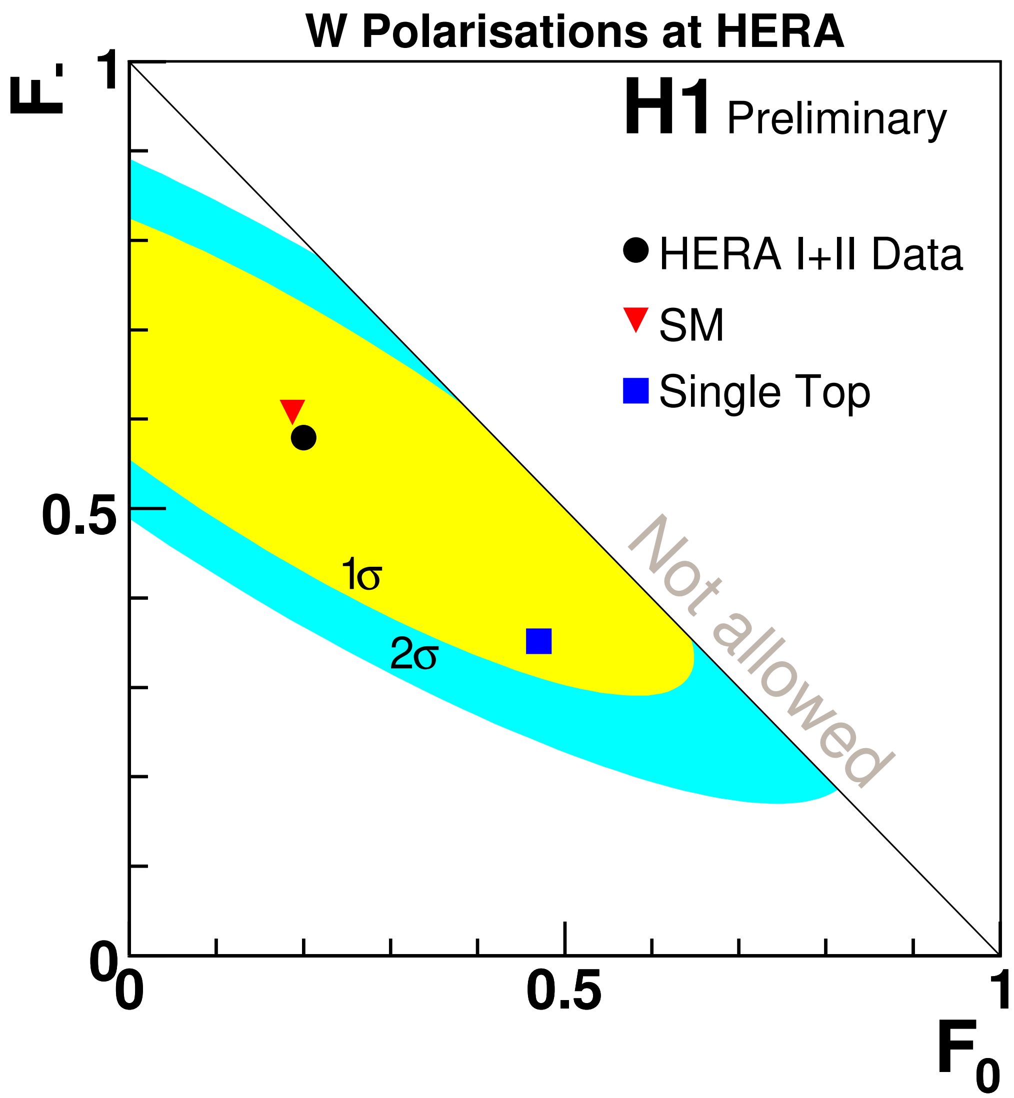

Figure 2: The fit result for the simultaneously extracted left handed (F_-) and longitudinal (F_0) W boson polarisation fractions (point) at 1 and 2σ CL (contours). Also shown are the values for the SM prediction (triangle) and anomalous single top production via FCNC (square).