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Multi-electron Events at HERA

H1 and ZEUS Collaborations

Abstract

A search for multi-electron events at high transverse momenta is performed on a data sample collected in $e^{\pm}p$ collisions with the H1 and ZEUS detectors at HERA during the period 1994–2007. This data sample corresponds to an integrated luminosity of 0.94 fb^{-1}. Yields of di-electron and tri-electron events are measured and in general a good agreement is found with the Standard Model (SM) predictions. Combining the two channels, six events are observed with a scalar sum of electron transverse momenta, $\sum P_T$, greater than 100 GeV, compared to a SM expectation of 3.0 $\pm$ 0.3. Five of those events are observed in e^+p collisions where the SM expectation is of 1.8 $\pm$ 0.2, whereas one event is observed in e^-p data for a SM prediction of 1.2 $\pm$ 0.1.

1 Introduction

Within the Standard Model (SM) the production of multi-electron events in ep collisions proceeds mainly via photon-photon interactions [1]. Cross-section measurements of both electron (e) and muon (μ) pair production at high transverse momentum (P_T) have already been performed by the H1 collaboration [2, 3] using HERA I data taken until 2000. At large di-electron masses, an excess of events is observed in both the di-electron and tri-electron samples [2]. New preliminary measurements in multi-lepton final states have been performed by the H1 Collaboration combining HERA I and HERA II data [4]. Preliminary measurements of the event yields of multi-electron events have also been done by the ZEUS Collaboration [5].

The present analysis covers multi-electron topologies and uses all available HERA data by combining results obtained by both H1 and ZEUS experiments. The integrated luminosity analysed amounts to 0.94 fb^{-1}.

2 Combined H1 and ZEUS multi-electron analysis

In order to coherently combine the results of both experiments a common phase space has been established. Electron candidates with energies above 10 and 5 GeV are identified in polar angle ranges $5° < \theta < 150°$ and $150° < \theta < 175°$, respectively. The final multi-electron selection requires that there be at least two central ($20° < \theta < 150°$) electron candidates, of which one must have $P_T^l > 10$ GeV and the other $P_T^l > 5$ GeV. The electron candidates are ordered according to decreasing P_T, with the highest P_T candidate first. The selected events are classified as belonging to the two electron sample (2e) if only two central electrons are identified, and to the three lepton sample (3e) if exactly one additional electron candidate is identified.

3 Results

The event yields observed in all channels are summarised in table 1. The observed event yields are in good agreement with SM expectations, which are dominated by pair production.

The distributions of the invariant mass of the two highest P_T electrons in the 2e and 3e samples are presented in figure 1. The agreement with the SM prediction is good. Invariant mass distributions are also shown separately for e^+p and e^-p data in figures 2 and 3, respectively. The event yields at high invariant mass ($M_{12} > 100$ GeV) are summarised in table 2.

The distributions of the scalar sum of P_T of all identified electrons for the combination of the 2e and 3e samples is shown in figure 4. For $\sum P_T > 100$ GeV, 6 events are observed in all channels combined while 3.0 ± 0.3 are expected from the SM.

The separation of the total HERA data sample between events taken in collisions with a positron or electron beam is also presented in figure 4 and in table 2. The majority of high invariant masses and $\sum P_T$ events have been recorded in e^+p collisions and only one event is observed in e^-p data. In e^+p collisions and for $\sum P_T > 100$ GeV, 5 events are observed in all channels combined while 1.8 ± 0.2 are expected from the SM (see table 3).

References

[1] J. A. M. Vermaseren, Nucl. Phys. B **229** (1983) 347.

[2] A. Aktas *et al.* [H1 Collaboration], Eur. Phys. J. C **31** (2003) 17 [hep-ex/0307015].

[3] A. Aktas *et al.* [H1 Collaboration], Phys. Lett. B **583** (2004) 28 [hep-ex/0311015].

[4] H1 Collaboration, contributed paper to EPS07, H1prelim-07-062.

[5] ZEUS Collaboration, contributed paper to EPS07, ZEUS-prel-07-011.

H1+ZEUS Multi-electron analysis HERA I+II (0.94 fb^{-1}, preliminary)

Selection	Data	SM	Pair Production	NC-DIS + Compton
2e	937	937 $\pm$ 67	756 $\pm$ 48	181 $\pm$ 39
3e	148	161 $\pm$ 10	160 $\pm$ 10	0.4 $\pm$ 0.01
All	1085	1098 $\pm$ 75	916 $\pm$ 58	182 $\pm$ 39

Table 1: Observed and predicted event yields for the 2e and 3e event classes and for the addition of both, for H1 and ZEUS data combined. The errors on the prediction include model uncertainties and experimental systematic errors added in quadrature.

H1+ZEUS Multi-electron analysis HERA I+II (preliminary)

M_{12} >100 GeV				
Selection	Data	SM	Pair Production	NC-DIS + Compton
e^+p collisions (0.56 fb^{-1})				
2e	4	1.97 $\pm$ 0.22	1.10 $\pm$ 0.21	0.87 $\pm$ 0.18
3e	4	1.10 $\pm$ 0.12	1.10 $\pm$ 0.12	—
e^-p collisions (0.38 fb^{-1})				
2e	1	1.44 $\pm$ 0.15	0.77 $\pm$ 0.10	0.67 $\pm$ 0.12
3e	0	0.75 $\pm$ 0.08	0.75 $\pm$ 0.08	—
$e^\pm$ collisions (0.94 fb^{-1})				
2e	5	3.41 $\pm$ 0.37	1.87 $\pm$ 0.25	1.54 $\pm$ 0.29
3e	4	1.85 $\pm$ 0.24	1.85 $\pm$ 0.24	—

Table 2: Yields for high di-electron masses, $M_{12} > 100$ GeV in all analysed samples, for H1 and ZEUS data combined. For the eee sample, M_{12} corresponds to the mass of the two highest P_T electrons. The errors on the prediction include model uncertainties and experimental systematic errors added in quadrature.

H1+ZEUS Multi-electron analysis HERA I+II (0.94 fb^{-1}, preliminary)

ΣP_T >100 GeV				
Data sample	Data	SM	Pair Production	NC-DIS + Compton
e$^+$p (0.56 fb^{-1})	5	1.82 $\pm$ 0.21	1.28 $\pm$ 0.16	0.54 $\pm$ 0.10
e$^-$p (0.38 fb^{-1})	1	1.19 $\pm$ 0.14	0.79 $\pm$ 0.09	0.40 $\pm$ 0.08
e$^\pm$p (0.94 fb^{-1})	6	3.00 $\pm$ 0.34	2.07 $\pm$ 0.24	0.94 $\pm$ 0.16

Table 3: Yields of events with $\sum P_T > 100$ GeV for the combination of di- and tri-electron events, for H1 and ZEUS data combined. The errors on the prediction include model uncertainties and experimental systematic errors added in quadrature.

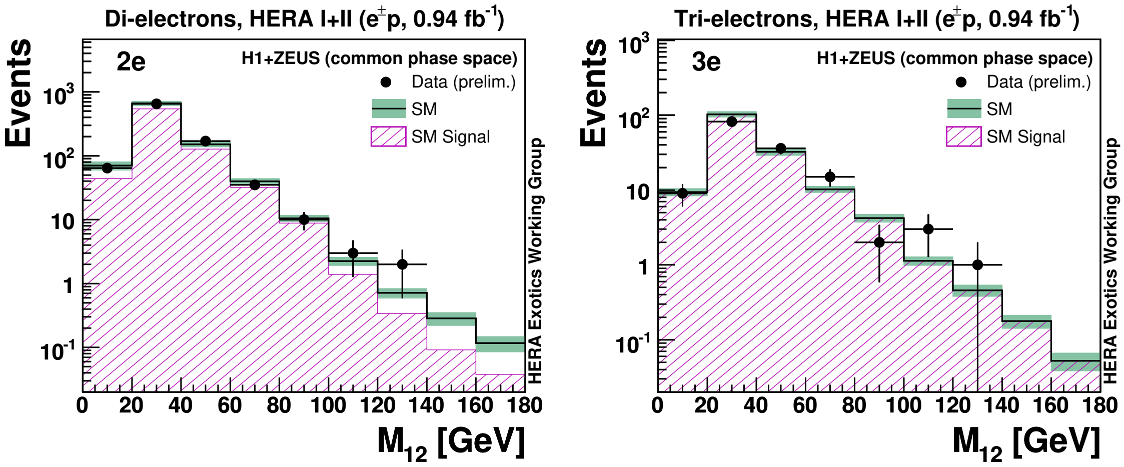

Figure 1: Distribution of the invariant mass M_{12} of the two highest P_T electrons for the 2e and 3e samples.

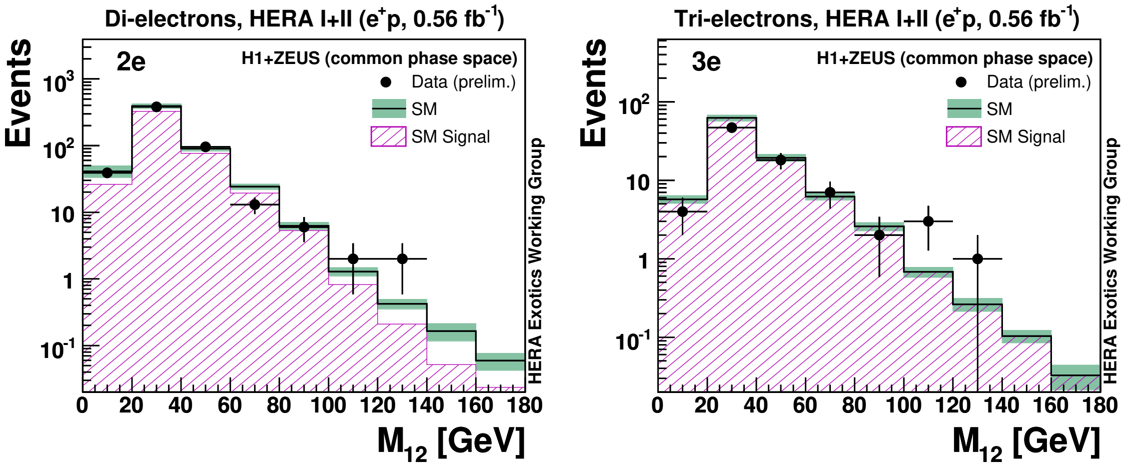

Figure 2: Distribution of the invariant mass M_{12} of the two highest P_T electrons for the 2e and 3e samples, using e^+p data only.

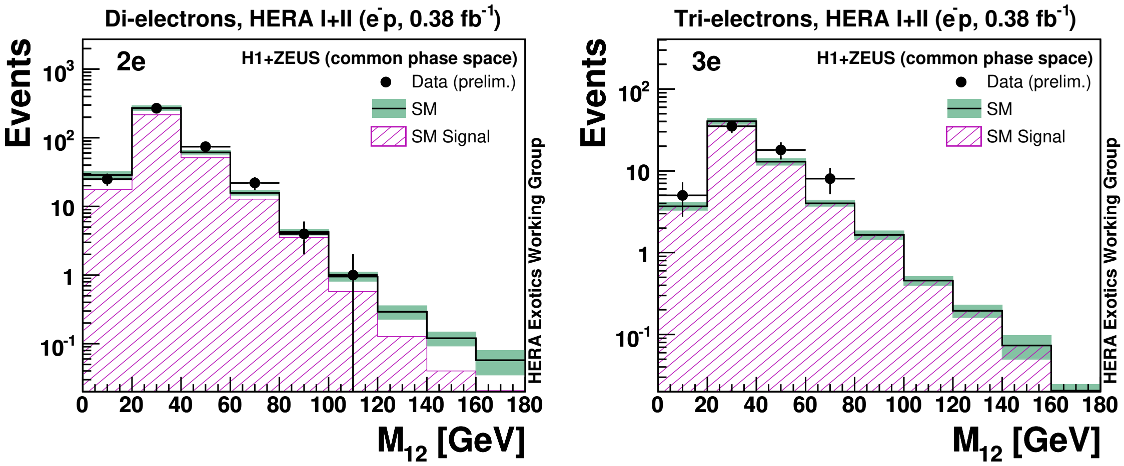

Figure 3: Distribution of the invariant mass M_{12} of the two highest P_T electrons for the 2e and 3e samples, using e^-p data only.

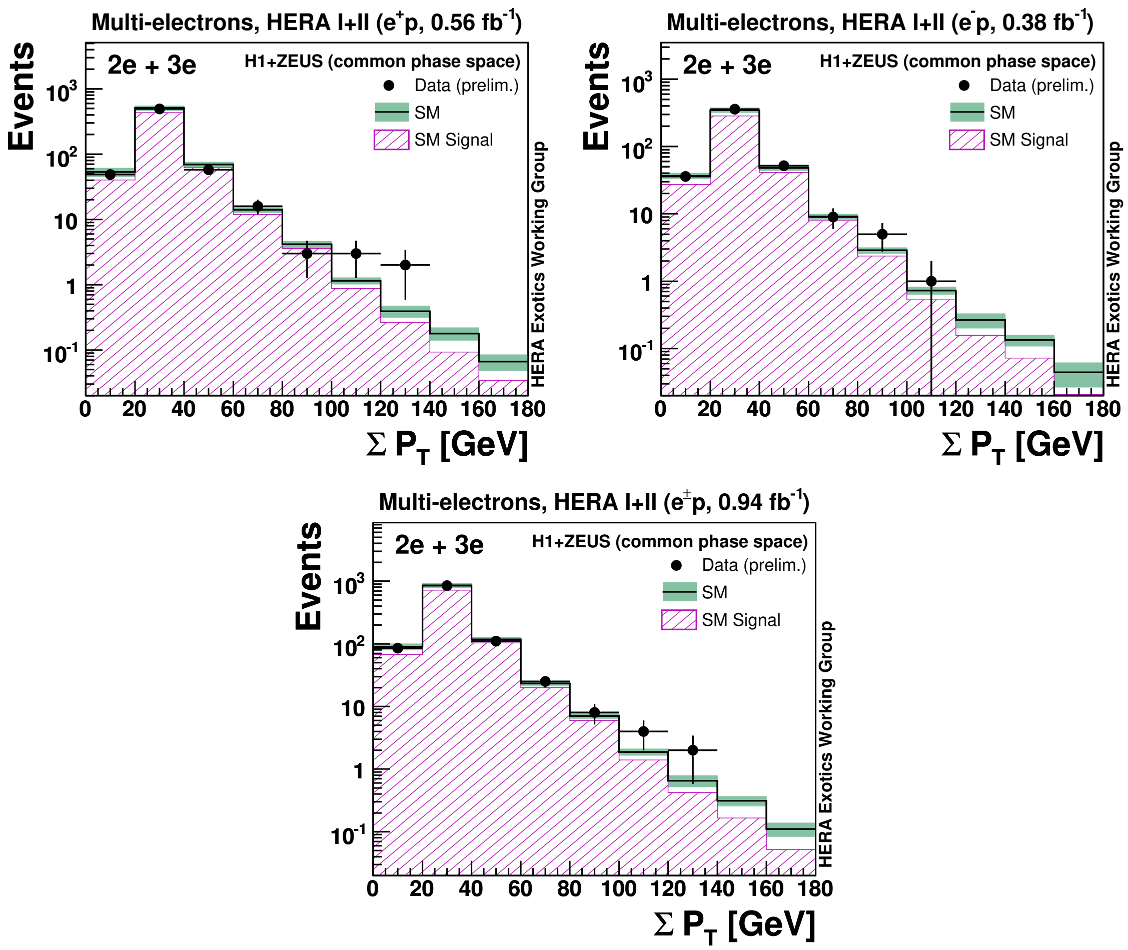

Figure 4: Distributions of the scalar sum of the transverse momenta of the combination of 2 and 3 electrons events compared to expectations for data taken in e^+p (upper left) and e^-p (upper right) collisions. The combination of all HERA data is shown in the bottom figure.