Multi-Lepton Production in ep Collisions at ZEUS

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Multi-electron and di-tau production at high transverse momentum have been studied in ep collisions using the ZEUS detector at HERA. The data collected during the years 1996-2006 were used in the analysis, corresponding to an integrated luminosity of approximately 450 pb^{-1}. The results are compared with the Standard Model prediction.

1 Introduction

At HERA, multi-lepton production with high transverse momentum can be explored up to invariant masses of the order of 100 GeV. The dominant process is the two-photon process, $\gamma\gamma \to l^+l^-$, well understood in the Standard Model (SM) [2]. Therefore any excess over the SM prediction, especially in the high mass region, would be a sign of new phenomena. The H1 Collaboration has reported the observation of an excess in both di-electron ("ee") and tri-electron ("eee") samples in the high mass region for an integrated luminosity of $\mathcal{L}$=115 pb^{-1} [3]. The present analysis was performed with the ZEUS detector using a higher interated luminosity, combining the HERA-I data ($\mathcal{L}$=121 pb^{-1}) with the new HERA-II data ($\mathcal{L}$=325 pb^{-1}), collected during the years 2003-2006.

2 Event Selection

2.1 Multi-electron

Electron candidates were reconstructed as electromagnetic (EM) clusters in the Uranium-Scintillator Calorimeter (CAL). Depending on the angle θ_e, the electron candidates were classified into three regions; central ($20^\circ < \theta_e < 150^\circ$), forward ($5^\circ < \theta_e < 20^\circ$) and backward ($150^\circ < \theta_e < 175^\circ$). The electrons in the central region were required to be matched to a track from the central tracking detector (CTD). The following energy thresholds were required : E_e>10 GeV for electrons in the forward and the central regions, and E_e>5 GeV for those in the backward region. The events were required to have at least two electrons in the central region, one with transverse momentum calculated from the CAL P_T>10 GeV, and the other with P_T>5 GeV.

2.2 Di-tau

We looked for a topology in which a di-tau decays into an electron and the other into a muon. The selection criteria for electrons and muons were as follows :

- Electron identification - Similar to the multi-electron analysis, EM clusters were required to have energy greater than 4 GeV, and if found in the range $17^\circ < \theta_e < 150^\circ$, they were required to be matched to a track from the CTD;

*on behalf of the ZEUS collaboration

- Muon identification - the tracks from the CTD were required to be matched to a minimum ionizing particle (MIP) cluster in the CAL or to tracks from the muon chamber. The transverse momentum of the muon candidate ($P_{T,\mu}$) was required to be greater than 2 GeV.

The final selection was designed to further suppress the di-muon background. The quantity $E - P_z$ which was defined as $(E - P_z)_{CAL} + (E - P_z)_{\mu,track}$ was required to be below 45 GeV [a] and events which had an additional calorimeter deposit consistent with a MIP but not found by the muon algorithm were rejected. Additionally, events with a measured electron charge equal to -1 were required to have $\theta_e <$ 1 rad.

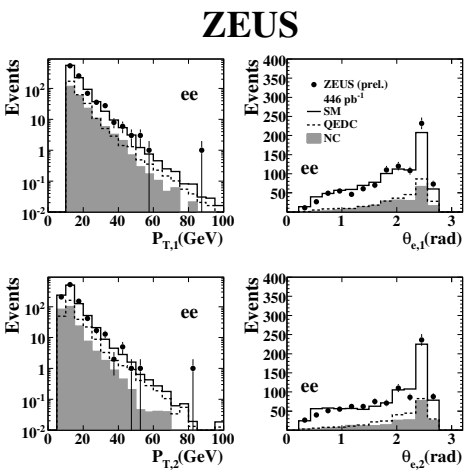

Figure 1: Comparison of the transverse momentum and polar angle distributions of the two highest P_T electrons with the SM expectations in the di-electron ("ee") sample.

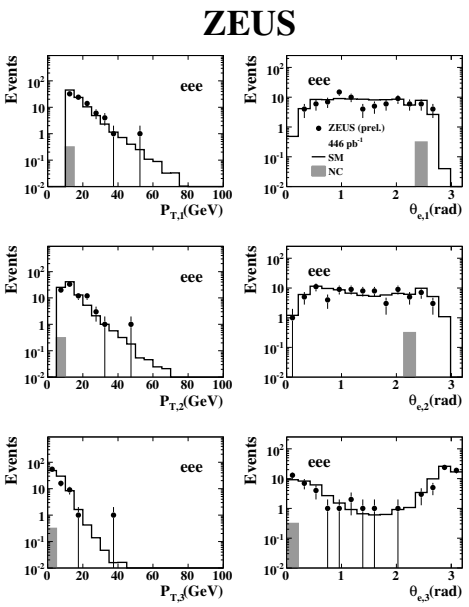

Figure 2: Comparison of the transverse momentum and polar angle distributions of the three highest P_T electrons with the SM expactations in the tri-electron ("eee") sample.

3 Results

The distributions of the transverse momentum, $P_{T,i}$, and polar angle, $\theta_{e,i}$, of the i^{th} highest-P_T electron in the final state of the di-electron ("ee") and of the tri-electron ("eee") events are shown in Fig.1 and Fig.2, respectively.

The event yield observed in the di-electron and tri-electron samples, with the SM predictions are summarised in Table.1. The data yields are in good agreement with the SM

[a] E and P_z are the energy and the longitudinal momentum, respectively. $(E-P_z)_{CAL}$ means the quantity $E - P_z$ measured by the CAL and $(E - P_z)_{\mu,track}$ is the one measured by the CTD for muons.

Topology	DATA	SM	GRAPE	QEDC	NC
ee M_{12}>80GeV	15	14.0±1.1	5.7±0.6	6.0±0.6	2.2±0.4
eee M_{12}>80GeV	3	$3.4^{+0.5}_{-0.1}$	3.4±0.3	<0.2	<0.5
ee M_{12}>100GeV	5	4.3±1.1	1.1±0.2	2.3±1.1	0.9±0.2
eee M_{12}>100GeV	1	$1.1^{+0.5}_{-0.1}$	1.1±0.1	<0.02	<0.5

Table 1: The observed and predicted multi-electron event yield for the ee and eee samples. The quoted uncertainties include MC statistics, luminosity measurement and electron enegy scale. Upper limit of 68% CL are given in case no MC event was remained after selection cuts.

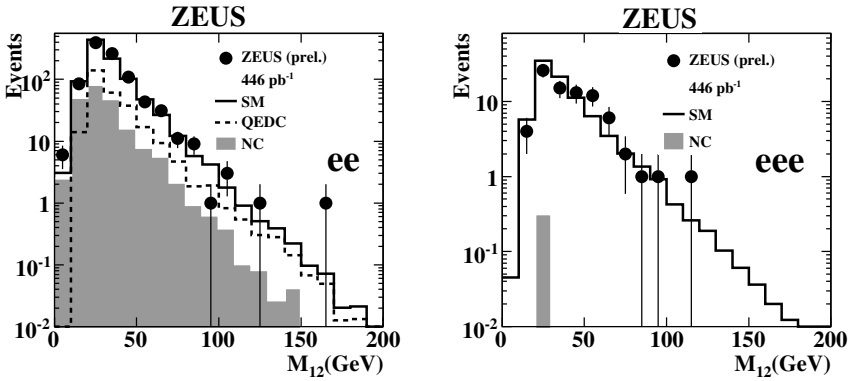

Figure 3: Distribution of the invariant mass M_{12} of the two highest P_T electrons compared with the SM expectations.

expectations, where the uncertainties on the SM expectation include the MC statistics, luminosity measurement and the electron energy scale uncertainty. If no MC event remained after the event selection, the upper limit of 68% CL is given.
The distributions of the invariant mass M_{12} of the di-electron samples and of the two highest P_T electrons from the tri-electron samples are presented in Fig.3.

In the di-tau search, three events remained after selection cuts compared with 2.0 ± 0.8 expected from the SM di-tau process. The expected number of events from di-muon background was found to be less than 0.2. The distributions of the polar angle and of the transverse momentum of the electron and muon coming from the decays of the tau candidates are shown in Fig.4.

4 Conclusions

A search for multi-electrons production with high transverse momentum was performed with HERA-I and HERA-II data, corresponding to a total integrated luminosity of 446 pb^{-1}.

The measured event yields in di-electron and tri-electron production in the final state

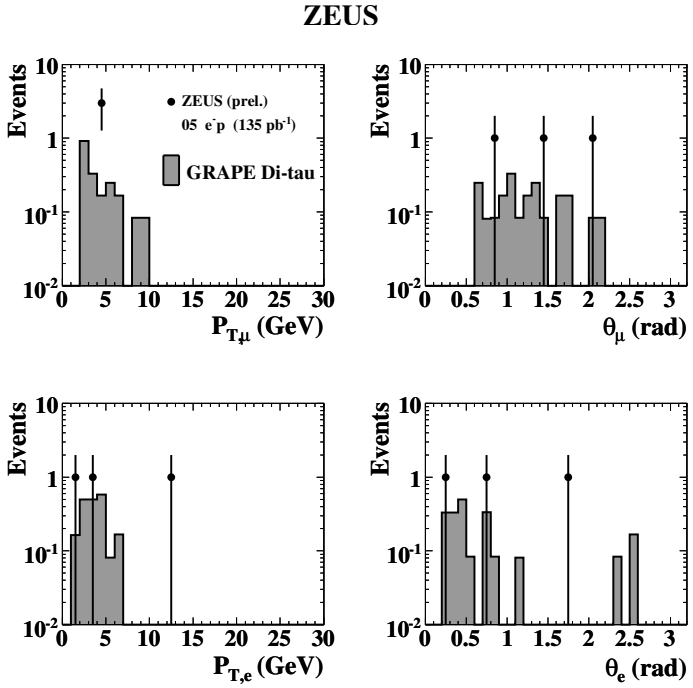

Figure 4: Comparison of the measured distribution of polar angles θ_μ and θ_e and transverse momenta $P_{T,\mu}$ and $P_{T,e}$ of the final state electron and muon with the SM expectations.

were found to be in good areement with the SM predictions and in particuler no excess was found in the high invariant mass region.

As for the di-tau search, the leptonic decay modes were analyzed with the 2005 data, corresponding to 135 pb^{-1}, yielding results compatible with the SM expectations. Three events were found in the final sample where no background is expected.

References

[1] Slides:
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[2] J.A.M Vermaseren, Nucl. Phys. **B229**, 347 (1983).

[3] H1 Collaboration, *Multi-Electron Production at High Transverse Momenta in ep Collisions at HERA*, Eur. Phys. J. **C31**, 17-29 (2003).