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HIGH P_T MULTI-LEPTON PRODUCTION AT HERA

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Multi-electron and multi-muon production at high transverse momentum was measured in ep scattering at HERA. Good overall agreement is found with the Standard Model predictions, dominated by photon-photon interactions. Events are observed with a di-electron mass above 100 GeV, a domain where the Standard Model prediction is low. An extension of the multi-electron analysis to new HERA II data is also presented.

1 Multi-lepton processes

At HERA, two experiments (H1 and ZEUS) study electron-proton collisions with a centre-of-mass energy of up to 320 GeV. The first measurements of multi-electron and multi-muon production at high transverse momentum (P_T) in ep collisions have been carried out recently [2,3]. Within the Standard Model (SM) the production of multi-lepton events in ep collisions proceeds mainly via photon-photon interactions in which quasi-real photons radiated from the incident electron and proton interact to produce a pair of leptons: $\gamma\gamma \rightarrow l^+l^-$ [1]. For multi-electron final states, the background comes mainly from neutral current Deep Inelastic Scattering (DIS) or elastic Compton scattering, while for multi-muon final state the background is negligible.

2 Multi-electron measurements

The selection of multi-electron events is done by requiring at least two central electrons ($20° < \theta_e < 150°$) with $P_T^{e_1}(P_T^{e_2}) > 10(5)$ GeV. An isolated charged track has to be associated with the calorimeter energy deposit. A third electron is allowed to be present in a wider angular range ($5° < \theta_e < 175°$). The selected events are classified by the number of identified electrons into di- and tri-electron samples.

The H1 results and the preliminary ZEUS measurements are presented in Tab. 1. The di-electron sample is dominated by pair production with only a 15–20% contribution from other SM processes. In the tri-electron sample, the background contribution is negligible. Both the H1 and ZEUS observations are in good agreement with the predicted overall yields. The main difference between the H1 and ZEUS predictions for the signal is due to the different angular range allowed for the central electrons. A few events with invariant mass of the two highest P_T electrons $M_{12} > 100$ GeV are observed in a region in which the SM prediction is low (Fig. 1). Three di-electron events are measured by H1 where 0.3 are expected and 2 by ZEUS for an expectation of 0.77. In the tri-electron sample, 3 events are observed by H1 compared to an expectation of 0.23, while no events are observed by ZEUS where 0.37 are expected.

A constrained fit of the six high mass events observed by H1 was performed [2], imposing longitudinal and transverse momentum conservation. This corresponds to an adjustement of the particle energies, polar and azimuthal angles within experimental errors in order to achieve $E - P_z = 55.2$ GeV and $P_T^{miss} = 0$. The M_{12} values obtained from this procedure are consistent with the direct measurements, but the errors are reduced by more than a factor of two. The M_{12} values are incompatible with the interpretation that the six high mass electron pairs result from the decay of a single narrow resonance.

Selection	Data	SM	Pair Production	DIS+Compton
H1 (115 pb^{-1})				
"2e"	108	117.1 ± 8.6	91.4 ± 6.9	25.7 ± 5.2
"3e"	17	20.3 ± 2.1	20.2 ± 2.1	0.1 ± 0.1
"2e" $M_{12} > 100$ GeV	3	0.30 ± 0.04	0.21 ± 0.03	0.09 ± 0.02
"3e" $M_{12} > 100$ GeV	3	0.23 ± 0.04	0.23 ± 0.03	< 0.02 (95% C.L.)
ZEUS (preliminary, 130 pb^{-1})				
"2e"	191	213.9 ± 3.9	182.2 ± 1.2	31.7 ± 3.7
"3e"	26	34.7 ± 0.5	34.7 ± 0.5	–
"2e" $M_{12} > 100$ GeV	2	0.77 ± 0.08	0.47 ± 0.05	0.30 ± 0.07
"3e" $M_{12} > 100$ GeV	0	0.37 ± 0.04	0.37 ± 0.04	–

Table 1. Observed and predicted multi-electron event yields for all selected events and for events with masses $M_{12} > 100$ GeV.

This study of multi-electron events was recently extended to include the new HERA II data by H1. The additional integrated luminosity analysed amounts to 17 pb^{-1}. Ten "2e" events are observed for an expectation of 15.8±1.7 and 2 "3e" events where 3.0±0.4 are expected. The distributions of the invariant mass M_{12} of the events are presented in Fig. 2. No new events are observed with $M_{12} > 100$ GeV.

3 Measurement of multi-muon events

The production of muon pairs at high P_T was also studied by the H1 Collaboration [3]. Muons are identified using central tracker reconstructed tracks, calorimetric deposits and muon chamber signals. At least two muons with $P_T^{\mu_1} > 2$ GeV and $P_T^{\mu_2} > 1.75$ GeV in the angular range $20° < \theta_\mu < 160°$ and with an invariant mass $M_{\mu\mu} > 5$ GeV are required. With an analysed data sample corresponding to an integrated luminosity of 70 pb^{-1}, 1206 multi-muon events are observed in good agreement with the expectation of 1197±124. No events with two muons at high mass, $M_{\mu\mu} > 100$ GeV, are observed. The Fig. 3 presents the visible cross section measured as a function of the invariant mass of the muon pair compared to the SM prediction; very good agreement is observed up to 80 GeV. The integrated

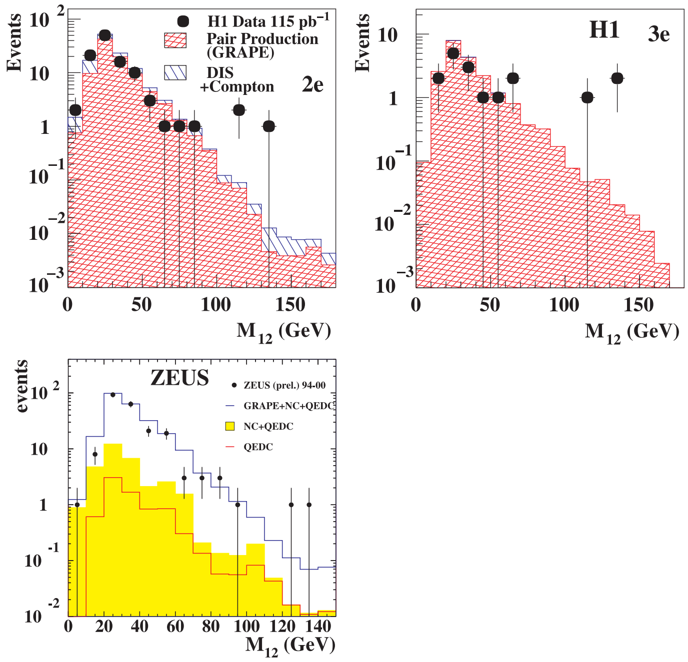

Figure 1. Distribution of the invariant mass M_{12} of the two highest P_T electrons for the H1 analysis (top figures). Events classified as di-electrons (left) and tri-electrons (right) are shown. The mass distribution from ZEUS analysis with di-electrons and tri-electrons samples combined is shown for comparison (bottom figure).

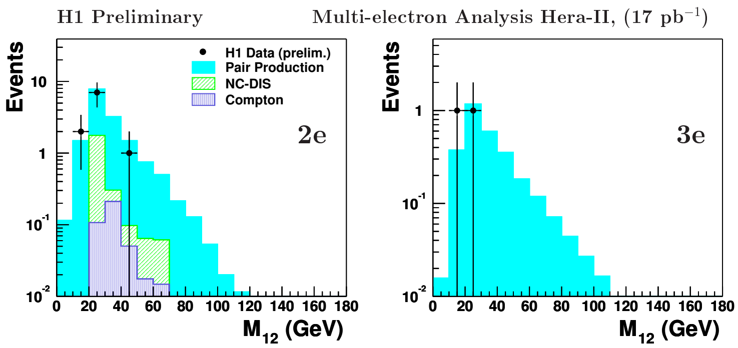

Figure 2. Distribution of the invariant mass M_{12} of the two highest P_T electrons for the H1 analysis on new HERA II data. Events classified as di-electrons (left) and tri-electrons (right) are shown.

cross section in the visible phase space is measured to be 46.4±1.3±4.5 pb, in good agreement with the prediction of 46.1±1.4 pb. In addition, events with two high P_T muons and possible additional leptons (muons or electrons) have been studied

[3]. The total integrated luminosity analysed was 113.7 pb^{-1}. To allow a comparison with the multi-electron analysis [2], at least two muons with $P_T^{\mu_1}(P_T^{\mu_2}) >$ 10(5) GeV in the angular range $20° < \theta_\mu < 150°$ are required. Forty data events with exactly two muons ($\mu\mu$ events) are found, while 39.9±4.2 events are expected. Sixteen events with one additional electron ($\mu\mu e$ events) are observed, compared with an expectation of 14.9±1.6. For invariant masses of the two highest P_T leptons $M_{12} > 100$ GeV, one $\mu\mu$ event is found while 0.08±0.01 are expected. No $\mu\mu e$ event with $M_{12} > 100$ GeV is observed for a prediction of 0.05±0.01. In view of the present limited statistics, these results at high di-lepton masses cannot be used to draw firm conclusions concerning the high mass excess observed for multi-electrons. For comparison, a preliminary analysis of di-muon events ($P_T^{\mu_1}, P_T^{\mu_2} > 5$ GeV, $20° < \theta_\mu < 160°$) was also carried out by the ZEUS experiment with an integrated luminosity of 105 pb^{-1} [4]. Two hundred events are detected where 213±11 are expected. No events with $M_{\mu\mu} > 100$ GeV are observed.

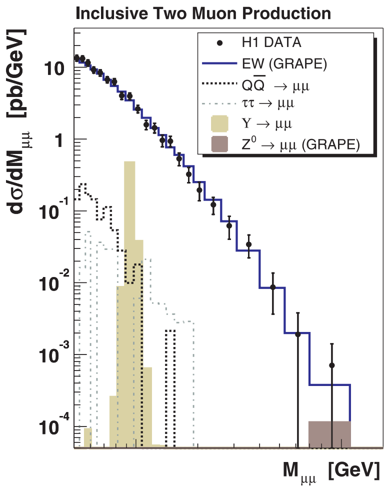

Figure 3. Differential muon pair production cross-section as a function of di-muon mass.

References

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