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HIGH-$P_{\rm T}$ MULTI-ELECTRON PRODUCTION AT HERA*

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Multi-electron production has been measured at high transverse momentum in 115 pb^{-1} of positron- and electron–proton collisions collected by the H1 experiment at HERA. A good overall agreement is found with the Standard Model predictions, dominated by photon–photon interactions. Six events are observed with a di-electron mass above 100 GeV, a domain where the Standard Model prediction is low.

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1. Standard model processes for multi-electron production

At HERA, the dominant contribution to multi-electron production is the interaction of two photons [1] radiated from the incident electron and proton. In comparison, the contribution of the Cabibbo–Parisi process, involving the interaction of the incident electron with a second electron issued from a photon radiated from the proton, is one order of magnitude lower. Drell–Yan contributions are negligible [2].

Multi-electron production is simulated with the GRAPE generator [3], based on the symbolic graphs calculation system GRACE [4], and interfaced to a simulation of the H1 detector. GRAPE includes the full $2 \to 4$ electroweak matrix elements at tree level, except for the negligible Drell–Yan contribution, for production of 3 leptons plus hadrons in the final state. It was checked that the GRAPE prediction agrees with that from the LPAIR generator [5] at the percent level for the dominant two-photon process.

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The main experimental backgrounds to multi-electron production are Neutral Current (NC–DIS) and elastic Compton interactions where, in addition to the true electron, fake electrons may be misidentified from final state hadrons or photons. These processes are simulated with the DJANGO and WABGEN generators, respectively.

The Monte Carlo predictions of all processes are attributed theoretical and experimental errors added in quadrature, reflecting the accuracy at which the generator inputs and the experimental effects are controlled.

2. Multi-electron event selection

The electron identification is designed to minimize the contributions of fake electrons, while keeping a high efficiency for true electrons and a reliable control of the overall selection performance. It includes a calorimetric identification of isolated electromagnetic clusters in the polar angular range $5^\circ < \theta < 175^\circ$, complemented in the region of overlap between the central tracker and the liquid argon calorimeter ($20^\circ < \theta < 150^\circ$) by tight requirements on the electron track. The track association efficiency is described by the simulation with an accuracy ranging from 3% in the central region, to 15% at the edges of the angular acceptance of the central tracker. Fake electron background is understood within 20%.

The selection of the multi-electron events requires two central electron candidates ($20^\circ < \theta < 150^\circ$) with transverse momenta P_{T} above 10 and 5 GeV, respectively. Additional electron candidates are identified in the forward, central or backward regions ($5^\circ < \theta < 175^\circ$) with no explicit P_{T} cut. The selected events are classified as di-electrons ("2e") in the case where only the two central electrons are visible, and tri-electrons ("3e") in the case where exactly one additional electron is identified. No event is observed with more than one additional electron. In order to measure the photon–photon cross-section in a well defined phase space with low background, a subsample of the "2e" sample, labeled "$\gamma\gamma$", is selected requiring two electrons of opposite charges and a significant deficit, compared to the initial state, in the difference $E - P_z$ between the visible total energy and longitudinal momentum. This ensures that the incident electron is lost in the beam pipe after radiating a quasi-real photon.

3. Results

The observed event yields (Table I) and distributions of global event variables (Fig. 1) are in agreement with the Standard Model (SM) expectations. The "3e" events show the expected accumulation at $E - P_z$ values equal to twice the incident electron energy, whereas "2e" events show a tail at lower

TABLE I

Observed and predicted multi-electron event rates for the samples described in the text.

H1 Preliminary 115 pb^{-1}			**Multi-electron analysis**	
Selection	DATA	SM	GRAPE	NC–DIS + Compton
Visible 2e	105	118.2 ± 12.8	93.3 ± 11.5	25.0 ± 5.5
Visible 3e	16	21.6 ± 3.0	21.5 ± 3.0	0.1 ± 0.1
Visible 4e or more	0	0.1 ± 0.0	0.1 ± 0.0	0.0 ± 0.0
$\gamma\gamma \to e^+e^-$ (subsample)	41	48.3 ± 6.1	46.4 ± 6.1	1.9 ± 0.9

$E - P_z$, corresponding to the $\gamma\gamma$ topology described above. All events are balanced in transverse momentum $P_{\rm T}^{\rm miss}$ within resolution. The hadronic transverse momentum $P_{\rm T}^{\rm hadrons}$ is also well described [1].

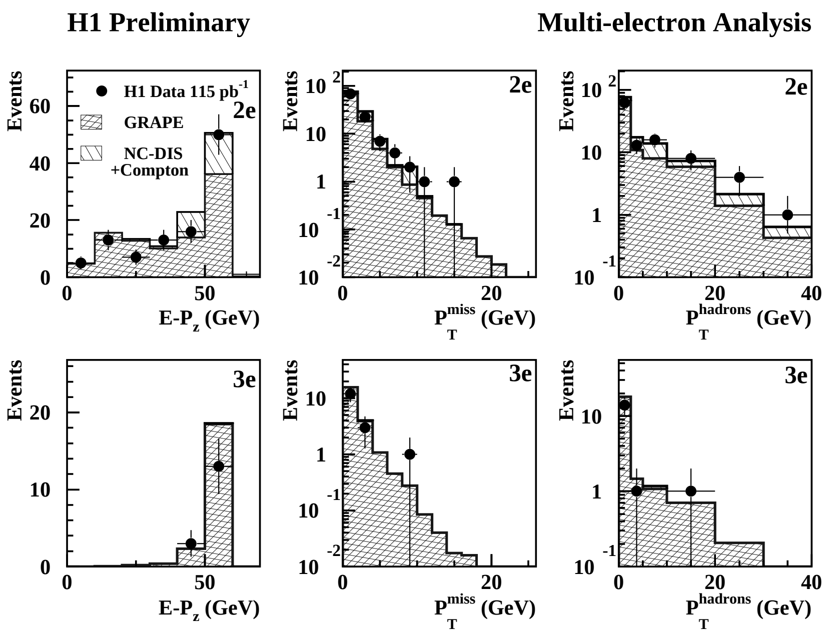

Fig. 1. Gloabal event variable distributions (see text) for events classified as di-electrons (top) and tri-electrons (bottom).

[1] This confirms our understanding of the SM expectation for the excess of events with a high $P_{\rm T}$ lepton and missing transverse momentum $P_{\rm T}^{\rm miss}$ observed at high $P_{\rm T}^{\rm hadrons}$ by H1 in a separate analysis [6].

The distributions of the mass M_{12} of the 2 highest-P_T electrons (Fig. 2 left) are in agreement with the SM at low M_{12}. However three "2e" events and three "3e" events are observed with M_{12} above 100 GeV, a domain where the SM prediction is low (Table II). Five out of these six high mass events

TABLE II

Observed and predicted multi-electron event rates for masses $M_{12} > 100$ GeV.

H1 Preliminary 115 pb^{-1}			**Multi-electron analysis**	
Selection	DATA	SM	GRAPE	NC–DIS + Compton
Visible 2e $M_{12} > 100$ GeV	3	0.25 ± 0.05	0.21 ± 0.04	0.04 ± 0.03
Visible 3e $M_{12} > 100$ GeV	3	0.23 ± 0.04	0.23 ± 0.04	0.00 ± 0.00

have a configuration of activity in the detector characteristic of an elastically scattered proton (Fig. 3). The "2e" and "3e" events have different topologies, with the highest mass pairs made of either two central high-P_T electrons (figure 2 top right) or one forward and one central electron of intermediate P_T's (figure 2 bottom right).

Finally, the two-photon differential cross-sections measured with the "$\gamma\gamma$" sample in a restricted kinematical domain agree with the SM.

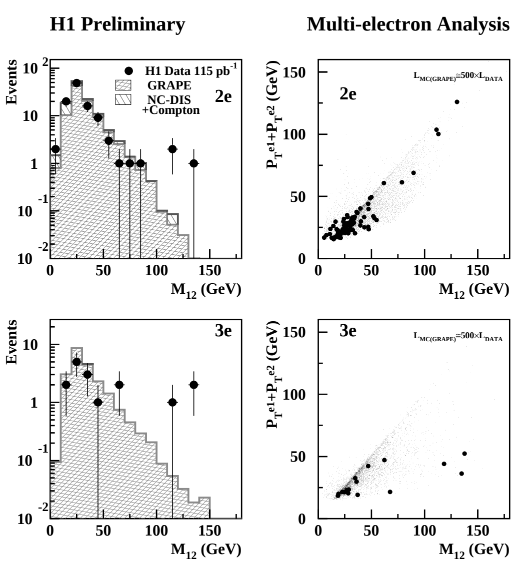

Fig. 2. Distribution of the invariant mass M_{12} of the two highest P_T electrons (left) and its correlation with the sum of the electron P_T's (right), for events classified as di-electrons (top) and tri-electrons (bottom).

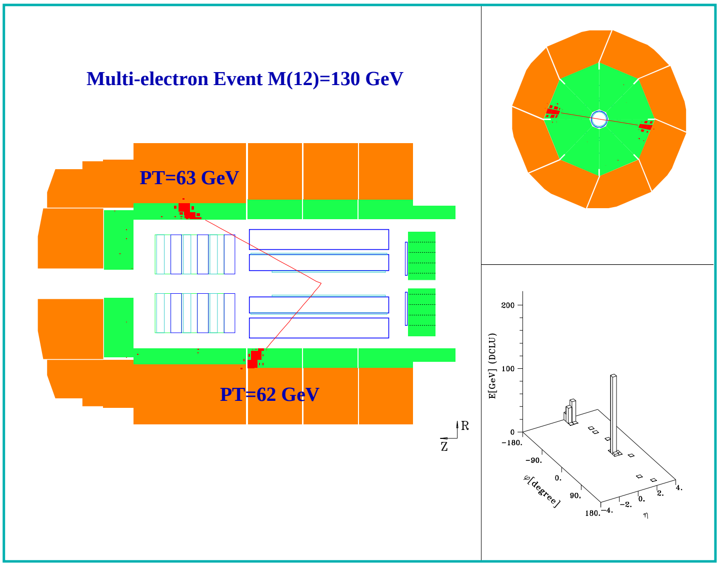

Fig. 3. Example event display of a high M_{12} event classified as "2e".

4. Conclusion

High-$P_{\rm T}$ multi-electron production has been measured for the first time in *ep* scattering at HERA, and found to be in general agreement with the Standard Model expectation. For masses of the highest $P_{\rm T}$ electron pair above 100 GeV, three events classified as di-electrons, and three events classified as tri-electrons are seen, compared to SM expectations of 0.25 ± 0.05 and 0.23 ± 0.04, respectively. This observation needs confirmation with independent data samples.

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