Meson Production at HERA: From $\gamma I\!\!P$ via $\gamma\gamma$ towards $\gamma I\!\!O$ Processes

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Abstract. A first search for exclusive production of C=+1 mesons at HERA using data taken with the H1 detector in 1996 is presented. The process is expected to be dominated by photon-photon fusion, but may also be induced by Odderon ($I\!\!O$) exchange. Utilizing its backward calorimeter SPACAL, H1 is able to measure mesons decaying into multi-photon final states and to investigate these for exclusive production.

Properties of soft hadron-hadron interactions at high energies are known to be well described by Regge theory provided that the exchange of a trajectory with the quantum numbers of the vacuum and an intercept $\alpha(t=0) \approx 1$ and C parity +1 (called "Pomeron" – $I\!\!P$) is introduced. However, no direct evidence has been found at high energies (where subleading trajectories do no longer contribute) for an exchange with $\alpha(t=0) \approx 1$ but with $C = -1$ (called "Odderon" – $I\!\!O$).

At HERA the existence of an Odderon trajectory could result, as suggested by Schäfer, Nachtmann, and Mankiewicz [1], in the production of pseudoscalar mesons with $C = +1$ in addition to their production via the two photon fusion process. Figure 1 (a) shows the two processes, taking as an example the η_c meson. Schäfer et al. suggest to measure the cross section ratio for exclusive production of η's and η''s, since in their model, the sensitivity to the Odderon induced process differs for η and η'.

The data used were taken in 1996 with the H1 detector at HERA (27.5 GeV positrons on 820 GeV protons) and amount to an integrated luminosity of about 5 pb^{-1}. The data are based on a trigger demanding a signal in the positron calorimeter of the H1 luminosity system and a localized energy

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deposit in the backward calorimeter (SPACAL) of more than 1.5 GeV. This corresponds to a kinematic range of $0.3 < y < 0.7$ and $Q^2 < 0.01$ GeV$^2/c^2$.

The lead/scintillating fibre calorimeter SPACAL [2] has a sampling term of $7\%/\sqrt{E/\mathrm{GeV}}$ and, due to its fine granularity, a position resolution of about 5 mm at 1 GeV. This allows for a precise measurement of mesons decaying into multi-photon final states, e.g. of π^0 and η mesons in their 2γ decay mode, as shown in Figure 1 (b) and (c). Here the invariant mass spectra of inclusively produced photon pairs are shown, yielding clear signals of π^0 (Fig. 1 b) and η (Fig. 1 c) mesons. The measured width of the invariant mass distribution is $\sigma \approx 13$ MeV/c^2 for π^0 and $\sigma \approx 31$ MeV/c^2 for η, demonstrating the good performance of the detector. No inclusive signal of $\eta' \to \gamma\gamma$ has been found.

Selecting events which are compatible with exclusive η (and η') production, where the meson is detected via its two photon decay, leads to the invariant mass spectrum of photon pairs as shown in Figure 2 (a). No signal of exclusively produced η and η' mesons is observed with the available data, neither an exclusive π^0 signal. However, a resonance-like structure at an invariant mass of about 800 MeV/c^2 is visible which is interpreted as being due to elastic photoproduction of ω mesons and their subsequent decay into the $\gamma\pi^0$ final

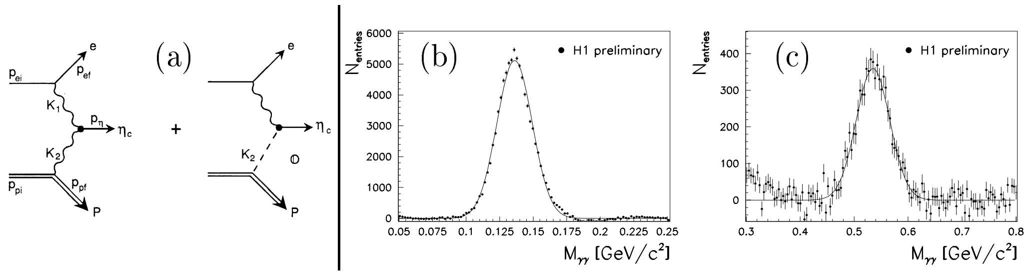

FIGURE 1. (a): Production of $C = +1$ mesons at HERA (taken from ref. [1]) via photon-photon fusion (left part) and photon-Odderon fusion (right part). (b) and (c): Invariant mass spectra of inclusively produced γ-γ pairs (after background subtraction): in the π^0 mass region (b) and in the η mass region (c).

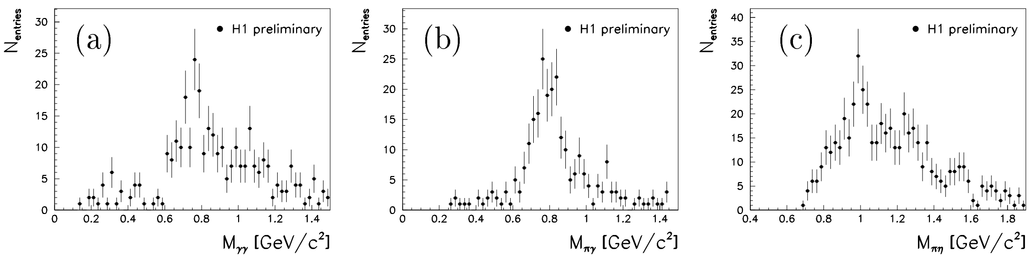

FIGURE 2. Invariant mass spectra of candidates for exclusively mesons: (a): γ-γ pairs, (b): γ-π^0 pairs, and (c): η-π^0 pairs.

state, where only two out of the three photons are detected.

Figure 2 (b) shows the invariant mass spectra of γ-π^0 pairs (i.e. final states with three photon out of which two form a π^0), after applying a mass constrained fit to the reconstructed π^0. A clear signal of the ω meson is observed, confirming the contribution from ω mesons to the two photon invariant mass spectrum. The data will be used in the future to measure the photoproduction cross section for ω mesons at high values of W ($140 < W < 250$ GeV/c^2).

The non-observation of η mesons is compatible with the expectation from a pure two photon fusion process, given the small acceptance of the detector. This excludes a large contribution from Odderon induced processes with cross sections substantially larger than the two photon fusion cross section. The magnitude of the observed ω signal supports these findings, since the acceptance is expected to be similar and the cross section for ω photoproduction due to Pomeron exchange is two to three orders of magnitude larger than the one for η mesons due to two photon fusion. In the case of the η' the small branching ratio of 2.12% further reduces the expected number of events by about one order of magnitude.

Figure 2 (c) shows the invariant mass spectra of η-π^0 pairs, where for both mesons a mass constrained fit has been applied. A signal of the $a_0(980)$ meson is observed. With tightened cuts, an indication of the $a_2(1320)$ is found. These mesons can also be used to search for Odderon induced processes at HERA.

In conclusion, a first search for contributions from Odderon induced production of $C = +1$ mesons at HERA has been performed. No signal for exclusive production of η and η' mesons has been obtained with the available statistics. The capability of the H1 detector to perform such a search has been demonstrated utilizing the new backward calorimeter which allows the detection of resonances decaying into multi-photon final states.

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