Spectroscopy and pentaquarks at HERA
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Abstract.
Results of the H1 and ZEUS Collaborations on spectroscopy of light and charmed mesons and on pentaquark searches, obtained using the HERA I data, are summarised.

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INTRODUCTION

Light and charmed hadrons are produced copiously in ep collisions with a centre-of-mass energy of 318 GeV at HERA. During first phase of HERA operation (1992-2000), the H1 and ZEUS Collaborations accumulated data samples corresponding to \( \sim 120 \text{pb}^{-1} \) each. The H1 and ZEUS results on hadron spectroscopy and pentaquark searches are summarised in this note.

SPECTROSCOPY OF LIGHT AND CHARMED MESONS

Inclusive photoproduction of \( \eta, \rho^0, f_0(980) \) and \( f_2(1270) \) mesons was measured at an average photon-proton centre-of-mass energy \( W = 210 \text{GeV} \) \cite{1}. The differential cross sections for those mesons and for charged pions as a function of \( p_T + m \), where \( m \) is the meson’s nominal mass, show similar power-law behaviour. The results suggest a similar mechanism of the mesons production in fragmentation processes.

Measurement of inclusive \( K_s^0 K_s^0 \) production in deep inelastic scattering (DIS) revealed a state at 1537 MeV, consistent with \( f_2'(1525) \), and another at 1726 MeV \cite{2}. The state at 1726 MeV has a mass consistent with \( f_0(1710) \), and is found in a gluon-rich region of phase space. This observation indicates that \( f_0(1710) \) has a sizeable gluonic component.

The production of excited charmed and charmed-strange mesons was studied using their decays to final states involving \( D^{*\pm} \) \cite{3}. The measured rates of c quarks hadronising as \( D_0^0, D_2^0 \) and \( D_{s1}^\pm \) mesons agree with those obtained in \( e^+e^- \) annihilations. The measured value of the helicity parameter for \( D_{s1}^\pm \) mesons is consistent with the observation of the CLEO Collaboration that the spin-parity of the \( D_{s1}^\pm \) is 1\(^+\). A search for the radially excited \( D^{*\pm} \) meson revealed no signal. The upper limit on the product of the fraction of c quarks hadronising as a \( D^{*\pm} \) meson and the branching ratio of the \( D^{*\pm} \) decay to \( D^{\pm} \pi^+\pi^- \) was estimated to be 0.7% (95% C.L.).
A peak in the \( K_0^+ p(\bar{p}) \) invariant mass spectrum around 1520 MeV was observed in DIS by the ZEUS Collaboration [4]. In Fig. 1(left), the spectrum is shown for exchanged photon virtuality \( Q^2 > 20 \text{GeV}^2 \). The statistical significance of the signal varies between 3.9\( \sigma \) and 4.6\( \sigma \) depending upon the treatment of the background. The signal is seen in both \( K_0^+ p \) and \( K_0^+ \bar{p} \) samples. If the signal corresponds to the pentaquark \( \Theta^+ \), this provides the first evidence for an anti-pentaquark with a quark content \( \bar{u}u\bar{d}d\bar{s} \). A ratio of the \( \Theta^+ \) and \( \Lambda^0 \) production cross sections was measured to be \( 4.2 \pm 0.9 \text{(stat.)} \pm 1.2 \text{(syst.)} \% \) [5].

The ZEUS Collaboration performed also a search for two other pentaquarks, reported by the NA49 Collaboration, and observed no signal in the \( \Xi \pi \) invariant mass spectrum [6]. In Fig. 1(right), the spectrum is shown for \( Q^2 > 1 \text{GeV}^2 \). A clear peak with more than 160 \( \Xi^0(1530) \) baryons indicates that the statistical sensitivity of the search is similar to that of the NA49 Collaboration.

**CHARMED PENTAQUARKS**

An observation of a candidate for the charmed pentaquark state, \( \Theta_c^0 = uudd\bar{c} \), decaying to \( D^{*\pm} p^\mp \) was reported by the H1 Collaboration [7]. Fig. 2(left) shows the \( D^{*\pm} p^\mp \) invariant-mass distributions in DIS with \( Q^2 > 1 \text{GeV}^2 \) and in photoproduction with smaller \( Q^2 \) values. A fit of the signal in DIS yielded 50.6 \( \pm \) 11.2 signal events and the mass of 3099 \( \pm \) 3(stat.) \( \pm \) 5(syst.) MeV. The observed resonance was reported to contribute roughly 1\% of the \( D^{*\pm} \) production rate in the kinematic range studied in DIS.

The observation of the H1 Collaboration was challenged by the ZEUS collaboration [8]. Using a larger sample of \( D^{*\pm} \) mesons, ZEUS observed no signature of the narrow resonance in the \( M(D^{*\pm} p^\mp) \) spectra shown in Fig. 2(right). The Monte Carlo
FIGURE 2. The distributions of $M(D^\mp p^-)$ obtained by the H1 Collaboration (left) and by the ZEUS Collaborations (right).

$\Theta_c^0$ signals normalised to 1% of the number of reconstructed $D^{\mp}$ mesons are shown on top of the fitted backgrounds. The upper limit on the fraction of $D^{\mp}$ mesons originating from $\Theta_c^0$ decays was evaluated to be 0.23% (95% C.L.). The upper limit for DIS with $Q^2 > 1\text{ GeV}^2$ is 0.35% (95% C.L.).

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