

CHARM SPECTROSCOPY AND EXOTICS AT ZEUS

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Light and charmed hadrons are produced copiously in ep collisions with a centre-of-mass energy of 318 GeV at HERA. Results of the ZEUS Collaboration on pentaquark searches, deuteron and antideuteron production and charmed-meson spectroscopy, obtained using the HERA I data, are summarised.

Keywords: spectroscopy; pentaquarks; deuterons.

1. Introduction

Light and charmed mesons and baryons are produced copiously in ep collisions with a centre-of-mass energy of 318 GeV at HERA. During the first phase of the HERA operation (1992-2000), the ZEUS Collaboration accumulated a data sample corresponding to an integrated luminosity of $\sim 120 \text{ pb}^{-1}$. Results on pentaquark searches, deuteron and antideuteron production and charmed-meson spectroscopy, obtained by the ZEUS Collaboration using the HERA I data, are summarised in this note.

2. Strange pentaquarks

A peak in the $K_s^0 p(\bar{p})$ invariant mass spectrum around 1520 MeV was observed in deep inelastic scattering (DIS) by the ZEUS Collaboration¹. In Fig. 1, the spectrum is shown for $Q^2 > 20 \text{ GeV}^2$, where Q^2 is the exchanged-photon virtuality. The statistical significance of the signal varies between 3.9σ and 4.6σ depending upon the treatment of the background. The candidate Θ^+ signal was found to be produced predominantly in the forward (proton) direction in the laboratory frame². This is unlike the case for the $\Lambda(1520)$ and can indicate that Θ^+ may have an unusual production mechanism related to the proton-remnant fragmentation. Using a smaller integrated luminosity, the H1 Col-

laboration did not observe the candidate Θ^+ signal and set an upper limit on its production³. The production cross section for the Θ^+ candidate, measured by the ZEUS Collaboration⁴, is $125 \pm 27(\text{stat.})_{-28}^{+37}(\text{syst.}) \text{ pb}$ for $Q^2 > 20 \text{ GeV}^2$. The value is larger than, but consistent with, the upper limit obtained by the H1 Collaboration.

The ZEUS Collaboration performed also a search for two strange pentaquarks, re-

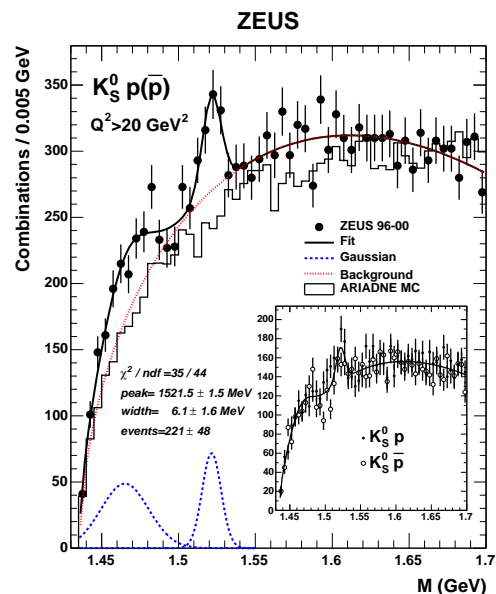


Fig. 1. Invariant mass spectrum for the $K_s^0 p(\bar{p})$ combinations obtained by the ZEUS Collaboration.

ported by the NA49 Collaboration ⁵, and observed no signal in the $\Xi\pi$ invariant mass spectrum ⁶. Upper limits on the ratio of a possible $\Xi_{3/2}^-(\Xi_{3/2}^0)$ signal to the $\Xi^0(1530)$ signal were set in the mass range 1.65 – 2.35 GeV.

3. Deuterons and antideuterons

A first observation of deuteron and antideuteron production in ep collisions in the DIS regime has been recently reported by the ZEUS collaboration ⁷. To identify the particles, the measurement of the energy losses, dE/dx , in the central tracking detector has been used.

Figure 2 shows the mass spectra for positive and negative tracks with $dE/dx > 2.5$ mips (minimum ionising particles) in DIS events with $Q^2 > 1 \text{ GeV}^2$. For each track, the mass has been calculated from the track momentum and dE/dx value using a parametrisation based on the Bethe-Bloch equation. The number of deuteron and antideuteron candidates in the mass window $1.5 < M < 2.5 \text{ GeV}$ is 309 and 62, respectively. No antitritons have been observed. Given the small number of the triton candi-

dates, no statement on the triton observation in DIS has been made.

Small contributions to the observed signals from the secondary interactions in the beam-pipe and detector material have been subtracted using side bands of the distribution on the distance of the closest approach of a track to the beam spot in the transverse plane. Possible contamination of the observed deuteron signal due to interactions of the proton or electron beam with the residual gas in the beam-pipe has been found to be below 20%.

Figure 3 shows the \bar{d}/\bar{p} and \bar{p}/p production ratios, corrected for the detector and trigger effects, as a function of p_T/M . The measured \bar{p}/p ratio is consistent with unity. The \bar{d}/\bar{p} ratios are in fair agreement with those obtained in pp interactions ⁸, in hadronic Υ decays ⁹, and by the H1 Collaboration at HERA in the photoproduction regime ($Q^2 < 1 \text{ GeV}^2$) ¹⁰.

No antideuteron candidates have been found in the current region of the Breit frame ¹¹. Since the region is similar to a single hemisphere of the e^+e^- annihilation process, the antideuteron observation in DIS

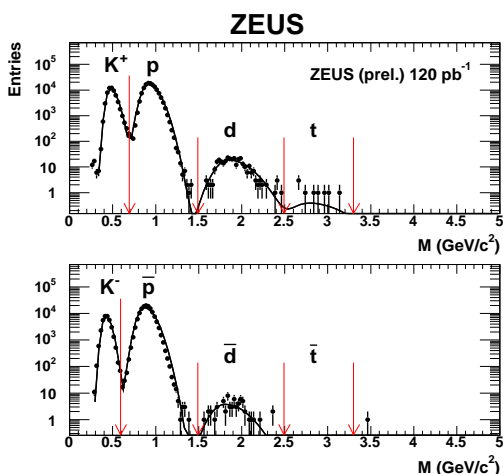


Fig. 2. The mass spectra for positive and negative tracks with $dE/dx > 2.5$ mips. The arrows show cuts applied for selection of (anti)proton and (anti)deuteron candidates.

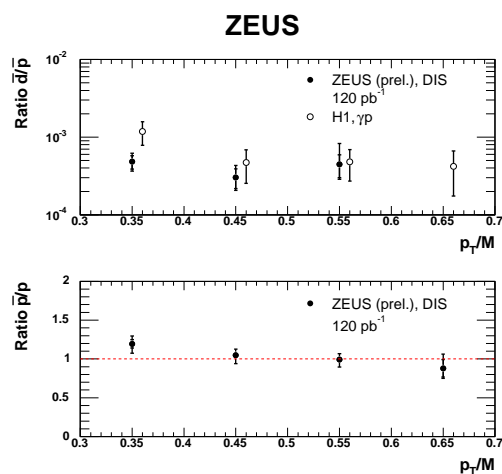


Fig. 3. The corrected (top) \bar{d}/\bar{p} and (bottom) \bar{p}/p production ratios as a function of p_T/M . Open circles show the \bar{d}/\bar{p} ratios obtained by the H1 Collaboration in the photoproduction regime.

does not contradict to the small antideuteron rates observed at LEP ¹².

4. Charmed pentaquark

An observation of a candidate for the charmed pentaquark state, $\Theta_c^0 = uud\bar{d}\bar{c}$, decaying to $D^{*\pm}p^\mp$ was reported by the H1 Collaboration ¹³. A fit of the signal in DIS yielded 50.6 ± 11.2 signal events and the mass of $3099 \pm 3(\text{stat.}) \pm 5(\text{syst.})$ MeV. The observed resonance was reported to contribute $(1.46 \pm 0.32)\%$ of the $D^{*\pm}$ production rate in the kinematic range studied in DIS ¹⁴. The measured differential distributions were found to be consistent with the fragmentation modelling of the candidate Θ_c^0 production.

The observation of the H1 Collaboration was challenged by the ZEUS Collaboration ¹⁵. 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. 4. The Monte Carlo Θ_c^0 signals normalised to 1% of the number of reconstructed $D^{*\pm}$ mesons are shown on top

of the fitted backgrounds. The upper limit on the fraction of $D^{*\pm}$ mesons originating from Θ_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.).

5. Studies of excited D mesons

Sizeable production of the excited charmed, D_1^0 and D_2^{*0} , and charmed-strange, D_{s1}^+ , mesons has been observed in ep interactions by the ZEUS collaboration ^{16,17}. Figure 5 shows the distribution of the $M(D^{*\pm}K_s^0)$ for the $D^{*\pm}$ candidates. A clear signal is seen at the nominal value of $M(D_{s1}^+)$. The measured D_1^0 , D_2^{*0} and D_{s1}^+ rates were converted to the fractions of c quarks hadronising as a particular excited charmed meson. These fragmentation fractions agree with previous measurements in e^+e^- annihilations.

The helicity angular distribution of the D_{s1}^\pm signal was fitted to a form $1 + R \cos^2 \alpha$, where R is a helicity parameter and the helicity angle (α) is defined as the angle between the K_s^0 and π_S momenta in the $D^{*\pm}$ rest

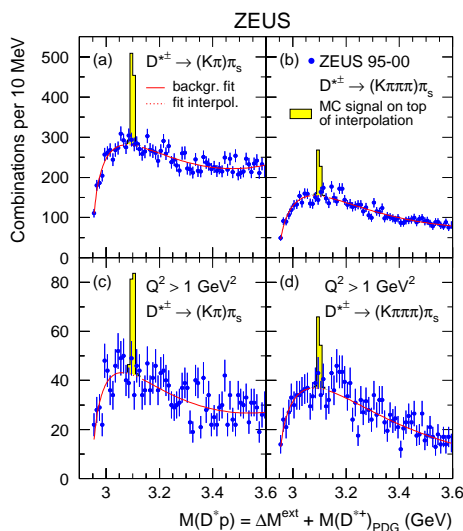


Fig. 4. The distributions of $M(D^{*\pm}p^\mp)$ obtained by the ZEUS Collaborations.

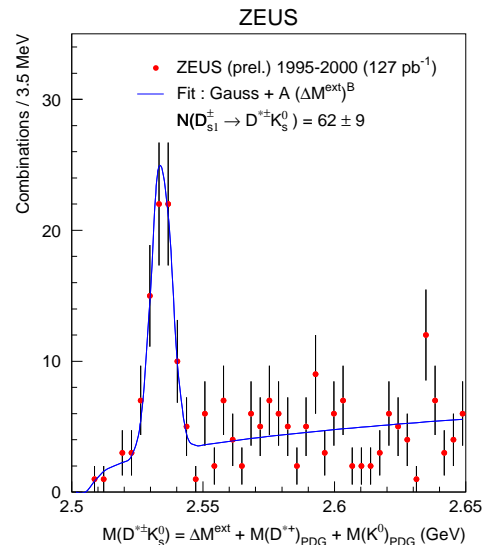


Fig. 5. The distributions of the $M(D^{*\pm}K_s^0)$ for the $D^{*\pm}$ candidates.

frame. The unbinned likelihood fit yielded the value $R = -0.53 \pm 0.32(\text{stat.})_{-0.14}^{+0.05}(\text{syst.})$. This value is consistent with the helicity parameter value $-0.23_{-0.32}^{+0.40}$ obtained by the CLEO Collaboration for D_{s1}^{\pm} meson in the $D^{*0}K^{\pm}$ final state¹⁸. The present measurement does not contradict the conclusion of the CLEO Collaboration that $R = 0$ and, thus, the spin-parity of the D_{s1}^+ is 1^+ . However, this measurement is also consistent with $R = -1$, expected for spin-parities 1^- and 2^+ ¹⁹. Recently, a precise measurements of the D_{s1}^+ helicity parameter, $R = -0.70 \pm 0.03$, has been reported by the Belle Collaboration²⁰. The measured value has been interpreted as a result of the D and S waves mixture due to an interference of the D_{s1}^+ meson with the recently discovered $D_{sJ}(2460)^+$ meson.

The ZEUS search for the radially excited $D^{*\pm}$ meson, reported by the DELPHI Collaboration²¹, revealed no signal¹⁶. The upper limit on the product of the fraction of c quarks hadronising as a D^{*+} meson and the branching ratio of the D^{*+} decay to $D^{*+}\pi^+\pi^-$ was estimated to be 0.7% (95% C.L.). This limit is somewhat stronger than the 0.9% limit obtained by the OPAL Collaboration²².

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