SPECTROSCOPIC MEASUREMENTS USING THE H1 AND ZEUS DETECTORS

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Results on spectroscopy from the H1 and ZEUS collaborations are presented. The main focus is to search for baryon states which could be interpreted as pentaquarks. This includes states decaying to $K^0_s p$ and $K^0_s \bar{p}$, $\Xi\pi$ and $D^* p$. In addition an analysis of $K^0_s K^0_s$ resonances is covered.

1 Introduction

At the ep-collider HERA, interactions are studied at a centre-of-mass energy of 300–320 GeV by the H1 and ZEUS multi-purpose detectors. The virtuality, Q^2, of the exchanged photon allows to distinguish two kinematical regimes: photoproduction ($Q^2 < 1\,\mathrm{GeV}^2$) and deep-inelastic-scattering (DIS) ($Q^2 > 1\,\mathrm{GeV}^2$). As recent results from fixed-target experiments have evidence for a narrow baryon resonance decaying to $K^+ n$ [1] and $K^0_s p$ [2], interpreted as a pentaquark, spectroscopic measurements covering this and related topics have been performed at HERA.

2 Evidence for a narrow baryonic state decaying to $K^0_s p$ and $K^0_s \bar{p}$ in DIS

A resonance search[3] has been made in the $K^0_s p$ and $K^0_s \bar{p}$ invariant-mass spectrum measured with the ZEUS detector using an integrated luminosity of 121 pb^{-1}. The search was performed in the central rapidity region of inclusive DIS for Q^2 above $1\,\mathrm{GeV}^2$. The results support the existence of a state like those observed by the fixed-target experiments, with a mass of 1521.5 ± 1.5 (stat.) $^{+2.8}_{-1.7}$ (syst.) MeV and a Gaussian width consistent with the experimental resolution of 2 MeV. The signal is visible at moderate Q^2 and, for $Q^2 > 20\,\mathrm{GeV}^2$, contains 221 ± 48 events (Fig. 1 (a)). The probability of a similar signal anywhere in the range 1500–1560 MeV arising from fluctuations of the background is below 6×10^{-5}.

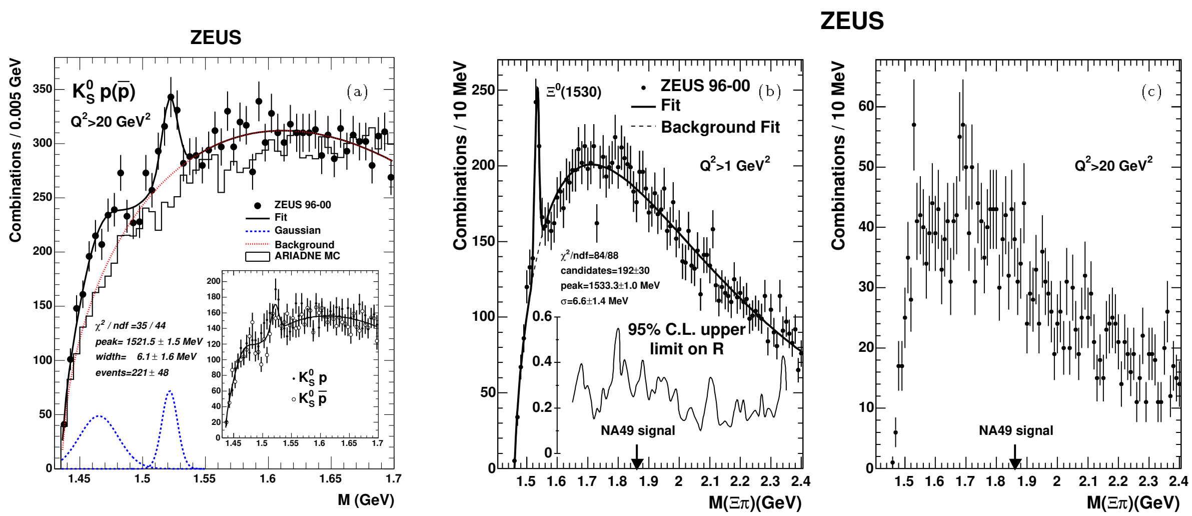

Figure 1: (a) Invariant-mass spectrum for the $K^0_s p(\bar{p})$ channel for $Q^2 > 20\,\mathrm{GeV}^2$. The solid line is the result of a fit using two Gaussians plus background parametrisation. The histogram shows the prediction of the ARIADNE Monte Carlo, the inset the charge separated samples. (b) The $\Xi\pi$ invariant-mass spectrum for $Q^2 > 1\,\mathrm{GeV}^2$ and (c) for $Q^2 > 20\,\mathrm{GeV}^2$. All four charge combinations have been summed up. The solid line in (b) is the result of a fit to the data using a Gaussian and a parametrised background. Also shown is the 95% C.L. upper limit on R, the ratio of the $\Xi^{--}_{3/2}(\Xi^0_{3/2})$ signal to $\Xi^0(1530)$ as a function of the invariant mass for $Q^2 > 1\,\mathrm{GeV}^2$. The arrows show the location of the signal observed by NA49.

3 Search for pentaquarks decaying to $\Xi\pi$ in DIS

The ZEUS collaboration has also performed a search[5] for pentaquarks decaying to $\Xi^-\pi^-$ ($\Xi^-\pi^+$) and corresponding antiparticles using the same data sample as in the previous analysis, to investigate the observation of the NA49 experiment[4]. A clear signal for $\Xi^0(1530) \to \Xi^-\pi^+$ was observed. However, no signal for any new baryonic state was observed at higher masses in either the $\Xi^-\pi^-$ or $\Xi^-\pi^+$ channels (Fig. 1 (b) and (c)). The searches in the antiparticle channels were also negative. Upper limits on the ratio of a possible $\Xi^{--}_{3/2}$ ($\Xi^0_{3/2}$) signal to the $\Xi^0(1530)$ signal were set in the mass range 1650–2350 MeV.

4 Evidence for a narrow anti-charmed baryon state by H1

The H1 collaboration observed[6] a narrow resonance in $D^{*-}p$ and $D^{*+}\bar{p}$ invariant-mass combinations in a data sample corresponding to an integrated luminosity of $75\,\mathrm{pb}^{-1}$ in DIS. The decay channel $D^{*+} \to D^0\pi^+_s \to (K^-\pi^+)\pi^+_s$ (and the corresponding antiparticle decay) was used to identify the D^{*+} mesons, the (anti-)proton candidates were selected using particle identification based on the differential energy loss. The resonance has a mass of $M(D^*p) = 3099 \pm 3\,(\mathrm{stat.}) \pm 5\,(\mathrm{syst.})\,\mathrm{MeV}$ and a measured Gaussian width of $12 \pm 3\,(\mathrm{stat.})\,\mathrm{MeV}$, compatible with the experimental resolution (Fig. 2 (a)). The probability for a background fluctuation to produce a signal as large as observed is less than 4×10^{-8}. The region of $M(D^*p)$ in which the signal is observed contains a richer yield of D^* mesons and exhibits a harder proton candidate momentum distribution than is the case for the side bands in $M(D^*p)$. The fraction of D^* mesons originating from the resonance decay is found to be $1.46 \pm 0.32\%$. A signal with compatible mass and width is also observed in an independent photoproduction sample.

The resonance is interpreted as an anti-charmed baryon with a minimal constituent quark

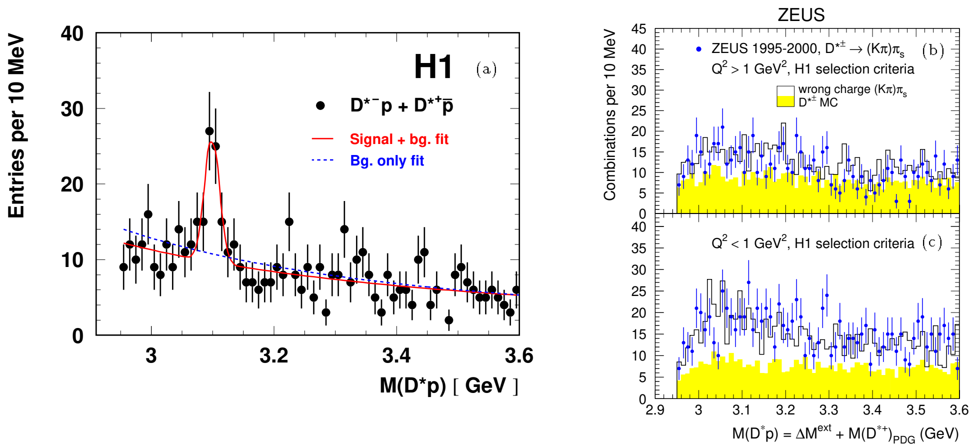

Figure 2: (a) $M(D^*p) = \Delta M + M(D^*)_{\mathrm{PDG}}$ distribution from opposite-charge D^*p combinations in DIS obtained by H1, compared with the results of a fit in which both signal and background components are included (solid line) and with the results of a fit in which only background is assumed (dashed line). (b) The distribution of $M(D^*p)$ for opposite-charge D^*p combinations (points) obtained by ZEUS using H1-like selection criteria in DIS with $Q^2 > 1\,\mathrm{GeV}^2$ and (c) in photoproduction with $Q^2 < 1\,\mathrm{GeV}^2$. The histograms show a two-component model in which the wrong charge $(K\pi)\pi_s$ combinations are used to describe the non-charm contribution and the inclusive $D^{*\pm}$ Monte Carlo simulation (shaded area) describes the contribution of real $D^{*\pm}$ mesons. The mass difference ΔM is defined as $M(K\pi\pi_s p) - M(K\pi\pi_s)$ and $M(D^*)_{\mathrm{PDG}}$ is the nominal D^* mass.

composition of $uudd\bar{c}$, together with its charge conjugate.

5 Search for a narrow anti-charmed baryonic state decaying to $D^{*\pm}p^{\mp}$ by ZEUS

A similar search[7] has been performed by the ZEUS collaboration in the $D^{*\pm}p^{\mp}$ invariant-mass spectrum using an integrated luminosity of $126\,\mathrm{pb}^{-1}$. The decay channels $D^{*+} \to D^0\pi_s^+ \to (K^-\pi^+)\pi_s^+$ and $D^{*+} \to D^0\pi_s^+ \to (K^-\pi^+\pi^+\pi^-)\pi_s^+$ (and the corresponding antiparticle decays) were used to identify D^{*+} mesons in a combined DIS and photoproduction sample. No resonance structure was observed in the mass spectrum in DIS as well as in photoproduction. The upper limit on the fraction of D^* mesons originating from such a resonance decay is found to be 0.23% (95% C.L.); the upper limit for DIS with $Q^2 > 1\,\mathrm{GeV}^2$ is 0.35% (95% C.L.). To guarantee the highest possible comparability between the measurements of the H1 and the ZEUS collaborations the analysis has been repeated with requirements as close as possible to those of the H1 collaboration (Fig. 2 (b) and (c)); no signal was observed. The results of the two collaborations are incompatible.

6 Observation of $K_s^0K_s^0$ resonances in DIS

Inclusive $K_s^0K_s^0$ production has been studied[8] by the ZEUS collaboration in DIS using an integrated luminosity of $120\,\mathrm{pb}^{-1}$. Two states are observed at masses of $1537^{+9}_{-8}\,\mathrm{MeV}$ and $1726 \pm 7\,\mathrm{MeV}$, as well as an enhancement around $1300\,\mathrm{MeV}$ (Fig. 3). The state at $1537\,\mathrm{MeV}$ is consistent with the well established f'. The state at $1726\,\mathrm{MeV}$ may be the glueball candidate $f_0(1710)$. However, its width of $38^{+20}_{-14}\,\mathrm{MeV}$ is narrower than the $125 \pm 10\,\mathrm{MeV}$ observed by previous experiments for the $f_0(1710)$.

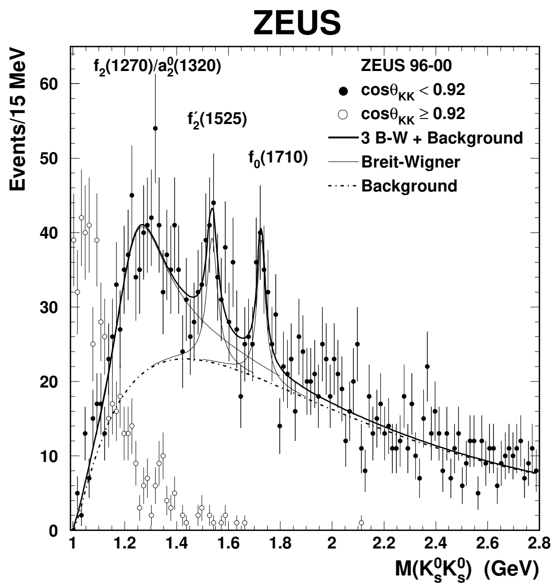

Figure 3: The $K^0_sK^0_s$ invariant-mass spectrum for K^0_s pair candidates with $cos\theta_{K^0_sK^0_s} < 0.92$ (black points). The thick line represents a fit using three Breit-Wigners and a background parametrisation.

7 Conclusions

Most of the recent spectroscopic measurements using the H1 and ZEUS detectors cover exotic resonances. The ZEUS collaboration has observed a resonance in $K^0_sp(\bar{p})$ which could be the Θ^+ which has been observed recently by several other experiments. The H1 collaboration has observed a narrow resonance in D^*p which could be a candidate for a charmed pentaquark. However, this observation is not been confirmed by the ZEUS collaboration.

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