Spectroscopy at HERA*

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Recent results on spectroscopy with special focus on searches for pentaquarks are presented from the H1 and ZEUS collaborations. Cross sections of observed states and upper limits on the production cross section of unobserved states are extracted in order to enable comparison between experiments. Measurements of the inclusive photoproduction of the neutral mesons η, ρ^0, $f_0(980)$ and $f_2(1270)$ in ep interactions at HERA at an average γp collision energy of 210 GeV are also presented.

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1. Introduction

Recently, some experiments have reported narrow signals in the vicinity of 1530 MeV in the nK^+ and pK^0_S invariant mass spectra which are consistent with the exotic pentaquark baryon state Θ^+ with quark content $uudd\bar{s}$ [1], while other experiments have searched for this state with negative results. The possible existence a charm pentaquark has also been discussed, with renewed theoretical interest in calculating their expected properties [2, 3] following the observation of strange pentaquarks.

The results of pentaquark searches by the H1 and the ZEUS collaboration are presented in this report. The analyses are based on data samples with an integrated luminosity of 75 pb^{-1} and 126 pb^{-1} taken by the H1 and the ZEUS collaborations in the years 1994-2000 when HERA collided electrons or positrons with 27.6 GeV and protons with 820 or 920 GeV.

Understanding the process whereby quarks and gluons convert to colourless hadrons is one of the outstanding problems in particle physics. The measurements of the inclusive photoproduction of the neutral mesons η, ρ^0, $f_0(980)$ and $f_2(1270)$ could contribute to resolving this problem.

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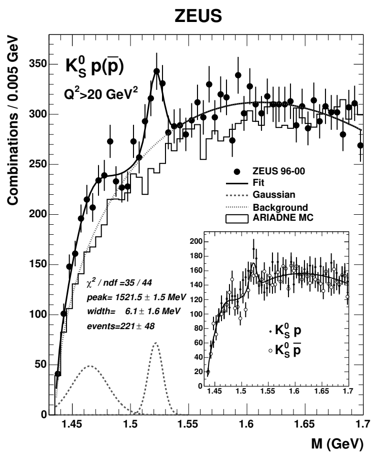

Fig. 1. Invariant mass spectrum for the $K^0_S p(\bar{p})$ channel for $Q^2 > 20$ GeV^2.

2. Pentaquarks

A strange pentaquark Θ^+ candidate was seen by the ZEUS collaboration. In this analysis deep inelastic scattering (DIS) events were selected by requiring an exchanged photon virtuality $Q^2 > 1$ GeV^2. The Θ^+ was reconstructed in the decay channel to pK^0_S. In Fig. 1, the invariant mass of proton and K^0_S is presented for events with $Q^2 > 20$ GeV^2. This distribution was fitted with a polynomial background and two Gaussians. The signal peak is observed with a mass of $1521.5 \pm 1.5^{+2.8}_{-1.7}$ MeV and the measured Gaussian width $6.1 \pm 1.6^{+2.0}_{-1.4}$ MeV which is consistent with the detector resolution. The significance of the signal is 4.6 sigma. The second Gaussian significantly improves the fit in the low mass region, and has a mass of about 1470 MeV and a width of 16 MeV and may correspond to the $\Sigma(1480)$ for which the evidence of existence is poor. The invariant-mass spectrum was investigated for the pK^0_S and $\bar{p}K^0_S$ separately. The signal has been seen in both charges with significance of 3 σ. If the signal corresponds to the Θ^+ pentaquark, this provides the first evidence for its antiparticle. The measured total cross section for the Θ^+ in the kinematic region $Q^2 > 20$ GeV^2, $p_T > 0.5$ GeV, $|\eta| < 1.5$ and $0.04 < y_e < 0.95$ is $125 \pm 27^{+37}_{-28}$ pb. The properties of the Θ^+ candidate were studied and it was found to be produced predominantly in the forward pseudorapidity region.

A similar analysis was done by the H1 collaboration and no peak is visible near 1520 MeV. The resulting upper limit on the Θ^+ production cross section was found to vary between 40 and 120 pb over the mass range of 1.48 to 1.7 GeV and does not exclude the previously measured cross section at ZEUS.

NA49 collaboration published results of double strange pentaquark $\Xi^{--}_{3/2}$

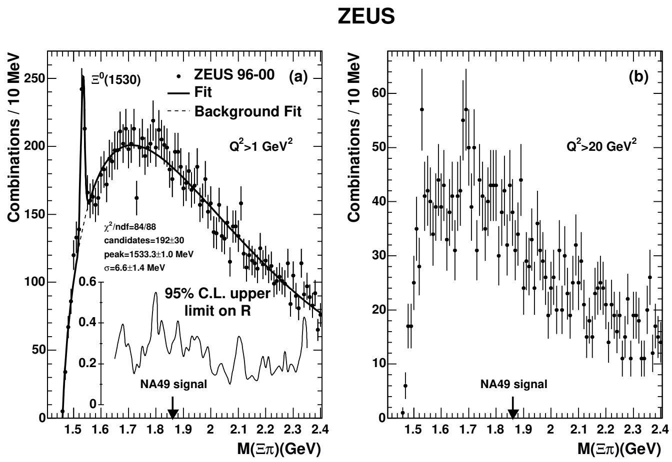

Fig. 2. The $\Xi\pi$ invariant-mass spectrum for: (a) $Q^2 > 1$ GeV^2 and, (b) $Q^2 > 20$ GeV^2 (all four charge combinations summed).

searches in the $\Xi\pi$ invariant mass spectrum [4]. They have observed a narrow peak with mass of about 1860 MeV. A similar analysis was repeated using ZEUS DIS data. The $\Xi^{--}_{3/2}$ was reconstructed from $\Xi^-\pi^-$ decay. ZEUS observed a clean signal of $\Xi^0(1530)$ in DIS events with $Q^2 > 1$ GeV^2, but no signal with a mass around 1860 MeV is observed (Fig. 2). A similar analysis was performed for $Q^2 > 20$ GeV^2, the kinematic region where the Θ^+ state was most clearly observed by ZEUS. Again no signal is observed near 1860 MeV. The number of $\Xi^0(1530)$ signal events reconstructed in this analysis is about the same as for NA49 data. However, it should be noted that NA49 is a fixed target experiment, which has good acceptance in the forward region. The non-observation of this signal in the central-fragmentation region in the ZEUS data does not necessarily contradict the observation of a signal predominantly produced in the forward region.

A search for a charm pentaquark Θ^0_c candidate was carried out by H1 using DIS data at $Q^2 > 1$ GeV^2. The Θ^0_c was reconstructed via its decay to D^*p, where the D^* is reconstructed using the decay channel $D^* \to D^0\pi \to K\pi\pi$. A clear and narrow resonance is observed for both $D^{*-}p$ and $D^{*+}\bar{p}$ combinations with an invariant mass of $M(D^*p) = 3099 \pm 3 \pm 5$ MeV (Fig. 3) with a significance of 5.4σ. The measured width of the resonance is 12 ± 3(stat.) MeV, consistent with the experimental resolution. A signal with compatible mass and width is also observed in an independent photoproduction data sample. An acceptance corrected ratio $R_{corr}(D^*p(3100)/D^*) = 1.59 \pm 0.33^{+0.33}_{-0.45}$ % was measured. When extrapolating to the full phase space of the decay products one observes a ratio of the visible cross section of $\sigma_{vis}(D^*p(3100))/\sigma_{vis}(D^*) = (2.48 \pm 0.52^{+0.85}_{-0.64})$ %.

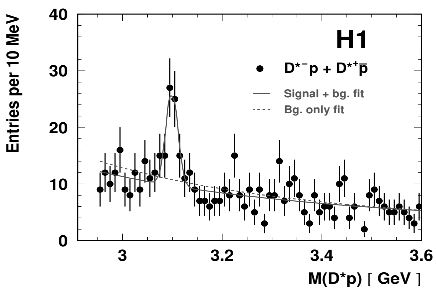

Fig. 3. $M(D^*p)$ distribution from opposite-charge D^*p combinations in DIS.

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 side bands in $M(D^*p)$. Compared to inclusive D^* production the $D^*p(3100)$ production seems to be suppressed in the close to central rapidity regions in laboratory and centre-of-mass frames.

A similar analysis was done by ZEUS using higher statistics and reconstructing D^* mesons in two channels $D^* \to D^0\pi \to K\pi\pi$ and $D^* \to D^0\pi \to K\pi\pi\pi\pi$. No signal near 3100 MeV is observed. ZEUS estimated the upper limit on the acceptance corrected ratio and it is equal 0.59 % (0.51 % for both D^* decay channels) in DIS.

3. Light Mesons (η, ρ^0, $f_0(980)$, $f_2(1270)$) Photoproduction

Besides exotic searches for particles the production of well-known hadrons such as pions, K^0_S, Λ, protons, charm mesons, J/ψ, *etc.* are measured by ZEUS and H1. A recent result is the cross section measurement of inclusive photoproduction of η, ρ^0, $f_0(980)$ and $f_2(1270)$ mesons at H1 in the central rapidity region. In this analysis a photoproduction data sample taken in the year 2000 corresponding to an integrated luminosity of 38.7 pb^{-1} and average $\sqrt{S_{\gamma p}}$ =210 GeV was used. The ρ^0, $f_0(980)$ and $f_2(1270)$ mesons were reconstructed though $\pi^+\pi^-$ decay, η meson though $\gamma\gamma$ decay.

In Fig. 4, the measured differential cross section $1/(2j+1)d^2\sigma/dydp_T^2$ of the resonances as a function of $m + p_T$, where j is a spin and m is a mass of measured particle, was compared with the cross section of charged pions. The resonances have a similar behavior as observed for long-lived hadrons [5].

4. Conclusions

The ZEUS collaboration observes a narrow baryonic state at a mass of about 1520 MeV that is interpreted as strange pentaquark Θ^+. H1 does not observe this state but the upper limit on the production cross section does

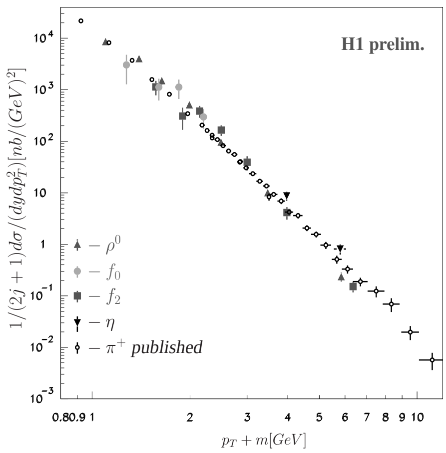

Fig. 4. The differential photoproduction cross section of η, ρ^0, $f_0(980)$ and $f_2(1270)$.

not exclude the ZEUS observation. A resonance search has been performed in the D^*p invariant-mass spectrum with the H1 and the ZEUS detector. H1 observes a Θ_c^0 candidate at mass of about 3100 MeV. ZEUS does not see any signal near this mass value. The upper limit on the Θ_c^0 production contradicts the H1 observation. More data from HERA*II* which are now being taken should resolve this contradiction.

The inclusive cross section for η, ρ^0, $f_0(980)$ and $f_2(1270)$ was measured and has the similar behavior as observed for long-lived hadrons [5].

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