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Search for baryonic resonances

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Search for Baryonic Resonances

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Abstract. A search for narrow baryonic resonances produced in deep inelastic scattering and decaying to $K_s^0 p$ ($K_s^0 \bar{p}$) or $\Xi^- \pi^-$ ($\Xi^- \pi^+$ and their antiparticles) is carried out with the H1 detector at HERA. No signal is observed for a new baryonic state. Upper limits on $\sigma(ep \rightarrow e\Theta^+ X) \times BR(\Theta^+ \rightarrow K^0 p)$ and on the ratio of the production rates of hypothetical baryonic states relative to the $\Xi(1530)^0$ baryonic state are obtained at the 95% confidence level.

1. Introduction

Various theoretical approaches [1, 2, 3] based on Quantum Chromodynamics predict the existence of exotic baryonic states composed of four valence quarks and an anti-quark, commonly known as “pentaquarks”. Such states are expected to form a flavour anti-decuplet and are not explicitly forbidden within the Standard Model. Recently several fixed target experiments have published evidence for the production of a narrow baryonic resonance, which can be interpreted as the strange pentaquark Θ^+ [4], with a minimal quark content of $uudd\bar{s}$, observed in the decay channels $K^+ n$ and $K_s^0 p$. The NA49 Collaboration [5] reported the observation of two baryonic resonances, which are interpreted as the candidate doubly strange pentaquarks members of the anti-decuplet. Many non-observations of these states have also been reported [4]. The experimental situation is thus controversial and further data are needed to establish the existence of these resonances.

2. Search for the strange pentaquark Θ^+

A search for the strange pentaquark Θ^+ using 74 pb^{-1} of deep inelastic ep scattering data taken with the H1 detector in the years 1996-2000 is presented [6]. A narrow resonance is searched for in the $K_s^0 p$ or $K_s^0 \bar{p}$ decay channel in the mass range from 1.48 to 1.7 GeV and in the range of the negative four-momentum transfer squared, Q^2 , from 5 to 100 GeV^2 and of the inelasticity, y , from 0.1 to 0.6.

The mass distributions of the $K_s^0 p$ system are shown in Fig. 1(a)-(c) for three bins in Q^2 . The shape of the invariant mass distributions is found to be reproduced by a background Monte Carlo simulation of inclusive DIS events using the DJANGO event generator and the H1 detector simulation based on GEANT (not shown). The data are well described by a phenomenological threshold function. No narrow resonance is observed in any of the Q^2 bins. Since the mass of the Θ^+ is not well established, mass dependent limits are derived in the range from 1.48 to 1.7 GeV. An upper limit at 95% confidence level (C.L.) on the number of expected $K_s^0 p$ combinations due to Θ^+ production, N_{UL} , is obtained from the observed, the background and the signal $M_{K_s^0 p}$ distributions using a modified frequentist approach based on likelihood ratios [7]. This takes into

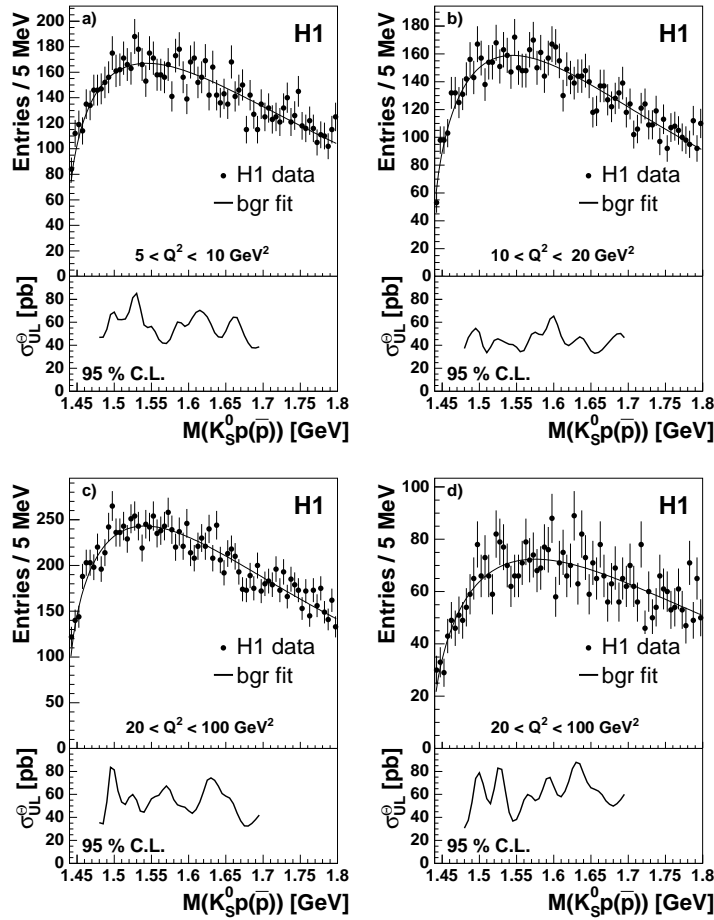


Figure 1. (a)-(c) Invariant $K_s^0 p(\bar{p})$ mass spectra in bins of Q^2 and d) for $20 < Q^2 < 100 \text{ GeV}^2$ for proton candidates with momenta below 1.5 GeV. The full line shows the result from the fit of the background function to the data. The upper limits on the cross section σ_{UL}^Θ at 95% confidence level are shown below the mass spectra.

account statistical and systematic uncertainties of the signal and of the background number of $K_s^0 p$ combinations. The $M_{K_s^0 p}$ distribution for signal combinations is taken to be a Gaussian with a width corresponding to the experimental mass resolution as obtained in the Θ^+ Monte Carlo simulations. The background $M_{K_s^0 p}$ distribution is taken to be the fitted threshold function. The upper limit on the cross section, σ_{UL}^Θ , is then calculated from N_{UL} using the integrated luminosity, acceptances of the DIS and the Θ^+ event selections and the branching ratio for the transition of K^0 to K_s^0 and its decay into charged pions. The limits vary between 30 and 90 pb for different Q^2 bins and over the mass range from 1.48 to 1.7 GeV. The invariant mass spectra for positive $K_s^0 p$ and negative $K_s^0 \bar{p}$ combinations are also studied separately and no narrow resonance is observed.

The ZEUS experiment has reported[8] a positive Θ^+ observation at a mass of 1.522 GeV in DIS for $Q^2 > 20 \text{ GeV}^2$ and $0.04 < y < 0.95$ using a data sample corresponding to an integrated luminosity of 121 pb^{-1} . Since the proton momentum in the ZEUS analysis was restricted to be below 1.5 GeV, the H1 analysis described above has been repeated using protons with the same requirement on the momentum. The resulting invariant $K_s^0 p(\bar{p})$ mass spectra are shown in Fig. 1(d) for $20 < Q^2 < 100 \text{ GeV}^2$ and $0.1 < y < 0.6$. Also in this low momentum proton selection no significant pentaquark signal is observed. At a Θ^+ mass of 1.52 GeV an upper limit on the cross section of 72 pb at 95% C.L. is found. Assuming the same y -dependence of the production cross section of the Θ^+ as of ordinary strange baryons, the limit on the cross section is 100 pb at 95% C.L., when extrapolated to the ZEUS y -range. This can be compared with the reported[9] preliminary cross section for ZEUS signal, $125 \pm 27(\text{stat})_{-28}^{+36}(\text{sys}) \text{ pb}$.

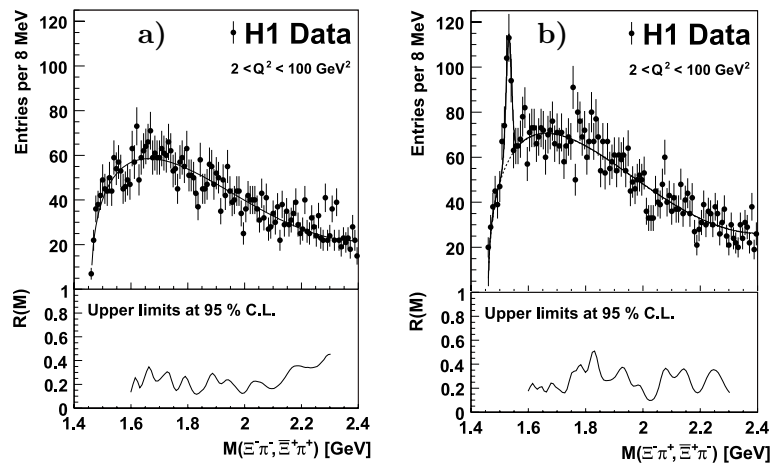


Figure 2. The invariant mass spectrum for the doubly charged combinations $\Xi^- \pi^-$ and $\bar{\Xi}^+ \pi^+$ (a) and neutral combinations $\Xi^- \pi^+$ and $\bar{\Xi}^+ \pi^-$ (b). The solid line shows the result of a fit to the data using a background function (in (b) a Gaussian in addition fits the $\Xi(1530)^0$). The lower part shows the 95% C.L. upper limit on the ratio $R(M)$ as a function of the mass M .

3. Search for a doubly strange pentaquark

A search for new narrow baryonic resonances decaying into $\Xi^- \pi^-$ and $\Xi^- \pi^+$ and their charge conjugate states is performed[10] with the H1 detector using a DIS data sample in the kinematic region $2 < Q^2 < 100 \text{ GeV}^2$ and $0.05 < y < 0.7$, corresponding to a total integrated luminosity of 101 pb^{-1} . The hypothetical doubly charged X^{--} and the neutral X^0 baryon states are identified by complete reconstruction of their respective decay chains through Ξ^- and Λ baryons into pions and protons. The baryon selection is chosen to optimise the signal for the well known standard baryon $\Xi(1530)^0$, which is observed in both neutral spectra ($\Xi^- \pi^+$, $\bar{\Xi}^+ \pi^-$). No signal of a new baryonic state is observed above the $\Xi(1530)^0$ mass in either the neutral or the doubly charged mass spectra (Fig. 2). A mass-dependent upper limit at 95% C.L. on the ratio, $R(M)$, of the hypothetical baryonic state relative to the $\Xi(1530)^0$ is obtained from the observed invariant mass spectra using a modified frequentist approach based on likelihood ratios [7].

The results reported here are similar to the limits measured[11] by the ZEUS Collaboration. The overall H1 statistics in the Ξ^- samples is comparable to the data of NA49 Collaboration. The limits obtained by H1 at HERA do not confirm the NA49 observation of potential pentaquark states.

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