The experimental search for CHARM pentaquarks in the ZEUS detector at HERA[1]

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Abstract. Using the full 1996 - 2000 ZEUS data at HERA (121 pb^{-1}) we have searched for the $\Theta_c^0(3100)$ pentaquark in the photoproduction and DIS regime. The search has yielded negative results. The 95% C.L. upper limits on the visible rate $R(\Theta_c^0 \to D^* p/D^*)$ is 0.23% (0.35% for DIS).

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INTRODUCTION: PENTAQUARKS

Observation of a narrow exotic baryon with strangeness $+1$ around 1530 MeV decaying into K^+n was reported during the last 2 years by a few low energy experiments [1]. It was suggested that these are due to the $\Theta^+ = uudd\bar{s}$ pentaquark candidate predicted by Diakonov et al. [2], at the top of a $SU(3)$ spin $1/2$ anti-decuplet of baryons. Narrow peaks were also seen at a similar mass in the final state $K_S^0 p$, which is exotic if the K_S^0 strangeness is +1. In high energy experiments ZEUS searched for the $\Theta^+(1530) \to K_S^0 p$ [3] in the DIS regime ($Q^2 > 20$ GeV^2) and reported observation of the $\Theta^+(1530)$.

It should be noted however that other high energy experiments at LEP, BaBar, CDF and FOCUS searched and have not seen the $\Theta^+(1530)$ pentaquark [5]. Recently some theoretical arguments have been presented [6] suggesting possible reasons why the $\Theta^+(1530)$ can be seen only in very specific experiments.

SEARCH FOR CHARM PENTAQUARK DECAYING TO $D^{*\pm}P^{\mp}$

The existence of the strange pentaquark Θ^+ suggests that charmed pentaquarks, $\Theta_c^0 = uudd\bar{c}$, may also exist.

The H1 Collaboration reported [9] observation of a narrow signal in the $D^{*\pm}p^{\mp}$ at 3.1 GeV with a width consistent with the detector resolution. The signal was seen in a DIS sample of ≈ 3400 $D^{*\pm} \to D^0\pi^{\pm} \to (K^{\mp}\pi^{\pm})\pi^{\pm}$ with a rate of $\approx 1.5\%$ of the visible

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D^* production. A less clean signal of a comparable rate was seen also in the H1 PHP sample (see previous talk by K.Daum in this session)

The Θ_c^0 search of ZEUS in the $D^{*\pm}p^{\mp}$ mode was performed with the full HERA-I data [10]. Clean $D^{*\pm}$ signals were seen in the $\Delta M = M(D^{*\pm}) - M(D^0)$ plots (Fig. 1 left). Two $D^{*\pm} \to D^0\pi^{\pm}$ decay channels were used with $D^0 \to K^{\mp}\pi^{\pm}$ and $D^0 \to K^{\mp}\pi^{\pm}\pi^+\pi^-$. The Θ_c^0 search was performed in the kinematic range $|\eta(D^*)| < 1.6$ and $p_T\ (D^*) > 1.35\ (2.8)$ GeV and with ΔM values between $0.144 - 0.147 (0.1445 - 0.1465)$ GeV for the $K\pi\pi$ ($K\pi\pi\pi\pi$) channel. The shaded bands in Fig.1a,b contains a total of ≈ 62000 D^*'s after subtracting wrong-charge combinations with charge ± 2 for the D^0 candidate. Selecting DIS events with $Q^2 > 1$ GeV^2 yielded smaller, but cleaner D^* signals with a total of ≈ 13500 D^*'s (Fig. 1c-d left).

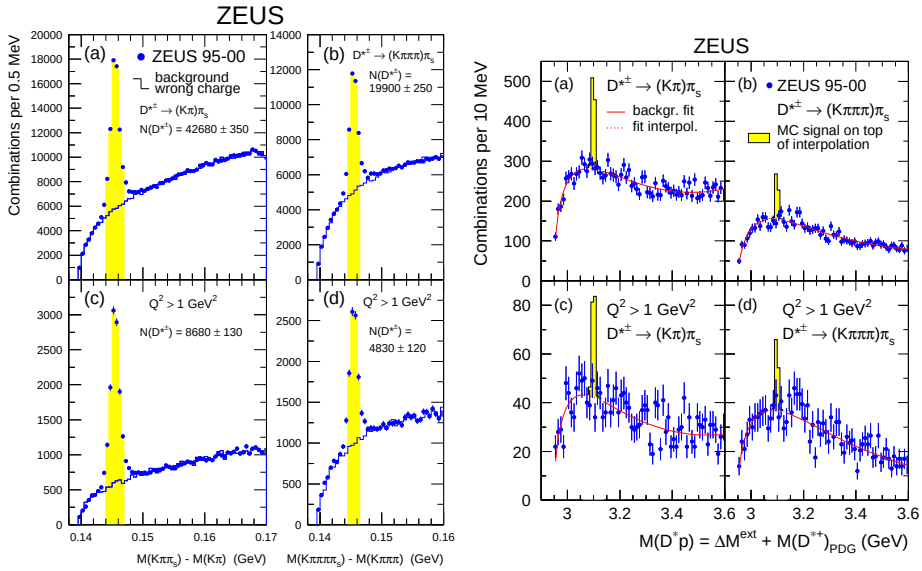

FIGURE 1. Left: ΔM distributions (dots) for (a) $D^* \to K\pi\pi$ and (b) $D^* \to K\pi\pi\pi\pi$ candidates. Events with $Q^2 > 1$ GeV^2 for the two channels, respectively, are shown in (c) and (d). The histograms are for wrong charge combinations. Right: $M(D^{*\pm}p^{\mp})$ distributions (dots) for the same samples. Solid curves are fi ts to a background function (see text). Shaded historgams are MC Θ_c^0 signals, normalised to $\Theta_c^0/D^* = 1\%$, on top of the background fi t.

Protons were selected with $p_T(p) > 0.15$ GeV. To reduce the pion and kaon background, a parameterisation of the expected dE/dx as a function of P/m was obtained using tagged protons from Λ decays and tagged pions from K_S^0 decays. The χ^2 probability of the proton hypothesis was required to be above 0.15. Fig. 2 shows the $M(D^*p) = M(K\pi\pi p) - M(K\pi\pi) + M(D^*)_{PDG}$ distributions for the $K\pi\pi$ channel for the full (left) and the DIS (right) samples, where $M(D^*)_{PDG}$ is the $D^{*\pm}$ mass [4]. In the low-P selection (Fig. 2b), a clean proton sample separated from the π and K dE/dx bands was obtained by taking only tracks with $P < 1.35$ GeV and $dE/dx > 1.3$ mips. In the high-P selection (Fig. 2c) only tracks with $P(p) > 2$ GeV were used. The latter selection was prompted by the H1 observation [9] of a better Θ_c^0 signal-to-background ratio for high proton momenta. No narrow signal is seen in the $K\pi\pi$ (Fig. 2) as well as in the $K\pi\pi\pi\pi$ (Fig. 1b,d right,Fig.3a,b left) channel. The $K\pi\pi$ analysis was repeated using very similar selection criteria as in the H1 analysis [9]. No indication of a narrow

resonance was found in either the DIS or the PHP event sample [10].

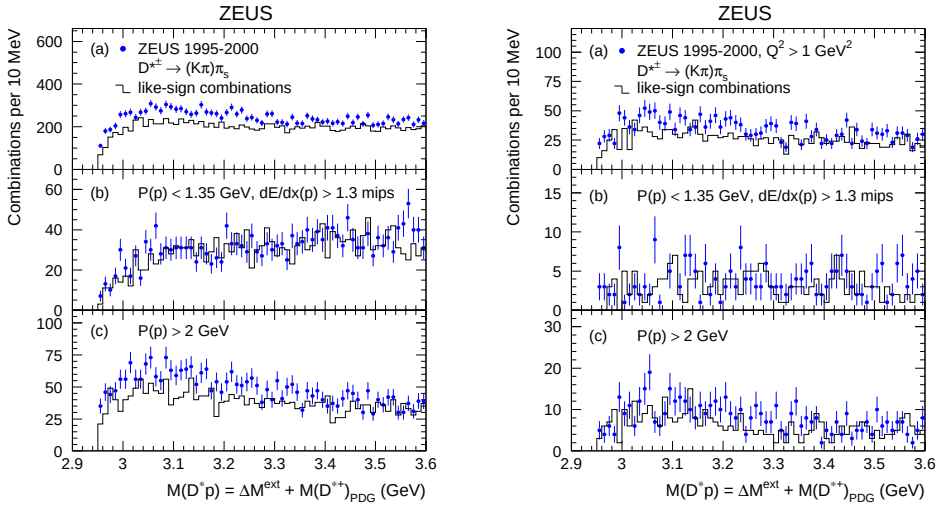

FIGURE 2. Left: $M(D^{*\pm}p^{\mp})$ distributions for the $K\pi\pi$ channel (dots) with (a) all proton candidates, (b) candidates with $P(p) < 1.35$ GeV and $dE/dx > 1.3$, and (c) candidates with $P(p) > 2$ GeV. Histograms show the $M(D^{*\pm}p^{\pm})$ like-sign combinations. Right: Same for DIS events with $Q^2 > 1$ GeV^2.

95% C.L. upper limits on the fraction of D^* mesons originating from Θ_c^0 decays, $R(\Theta_c^0 \to D^*p/D^*)$, were calculated in a signal window $3.07 < M(D^*p) < 3.13$ GeV for the $K\pi\pi$ and $K\pi\pi\pi\pi$ channels. A visible rate of 1% for this fraction (Fig. 1 right), as claimed by H1 [9], is excluded by 9σ (5σ) for the full (DIS) combined sample. The $M(D^*p)$ distributions were fitted to the form $x^a e^{-bx+cx^2}$, where $x = M(D^*p) - M(D^*) - m_p$ (Fig. 1 right). The number of reconstructed Θ_c^0 baryons was estimated by subtracting in the signal window the background function from the observed number of events, yielding $R(\Theta_c^0 \to D^*p/D^*) < 0.23\%$ and $< 0.35\%$ for the full and DIS combined two channels. The acceptance-corrected rates are, respectively, 0.37% and 0.51%. The 95% C.L. upper limit on the fraction of charm quarks fragmenting to Θ_c^0 times the branching ratio $\Theta_c^0 \to D^*p$ for the combined two channels is $f(c \to \Theta_c^0) \cdot B_{\Theta_c^0 \to D^*p} < 0.16\%$ ($< 0.19\%$) for the full (DIS) sample.

We conclude that the ZEUS data are not compatible with the H1 result of $\approx 1.5\%$ rate of $\Theta_c^0 \to D^*p/D^*$. Such a rate is excluded by more then 9σ for the full data and 5σ for the ZEUS DIS data. Further experiments perhaps with HERA II may help resolve this discrepancy. No other experiment reported the observation of Θ_c^0 [5].

REFERENCES

1. CLAS Coll., V. Kubarovsky et al, Phys. Rev. Lett. 92, 032001 (2004); SAPHIR Coll., J.Narth et al, Phys. Lett. B572,127 (2003).
2. D. Diakonov, V. Petrov and M.V. Polyakov, *Z. Phys.* **A359**, 305 (1997).
3. ZEUS Coll., S. Chekanov et al., *Phys. Lett.* **B591**, 7 (2004). See update in the talk of Zhenhai Ren ,on behalf of ZEUS at this conference.
4. Particle Data Group, K. Hagiwara et al., *Phys. Rev.* **D66**, 10001 (2002).
5. See reports in this conference: Christiane Risler DESY H1 results; Eric Eckhart, BaBar results; Marco Battaglieri, Pentaquark at JLab: new results from CLAS. Aleph Coll.,S. Schael et al, Phys. Lett. B

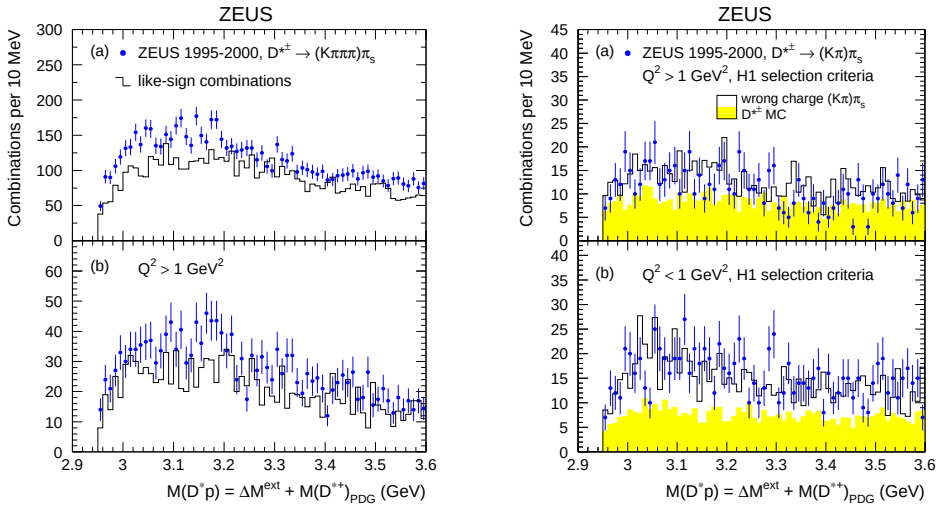

FIGURE 3. Left: $M(D^{*\pm}p^{\mp})$ distributions for the $K\pi\pi\pi\pi$ channel (dots) with (a) full sample, (b) DIS sample, $Q^2 > 1GeV^2$. Right: same distributions for the $K\pi\pi$ channel for DIS ($Q^2 > 1$ GeV^2) and photoproduction using the H1 event selection criteria.

599,1 (2004); CDF Coll., I. V. Gorelov Preprint (hep-ex/0408025). See also references in K.Hicks,hep-ex//0504027 and C. Risler talk,this session

6. M. Karliner and H. J .Lipkin, preprint (hep=ph/0506084)
7. A. Jaffe and F. Wilczek, , *Phys. Rev. Lett.* **91**, 232003 (2003).
8. M. Karliner and H.J. Lipkin, Preprint hep-ph/0307343 (2003).
9. H1 Coll., C. Atkas et al., , *Phys. Lett.* **B588**, 17 (2004).
10. ZEUS Coll., S. Chekanov et al., *Eur.Phys. J.* **C38** (2004)29 .