Proceedings of the DIS'2004, Štrbské Pleso, Slovakia

EVIDENCE FOR A NARROW EXOTIC ANTI-CHARMED BARYON STATE

SCHMIDT SEBASTIAN
ON BEHALF OF THE H1 COLLABORATION
Max-Planck-Institut für Physik, München
Föhringer Ring 6, 80805 München, Germany
E-mail: sschmidt@mppmu.mpg.de

Evidence for a narrow resonance in the $D^{*-}p$ and $D^{*+}\bar{p}$ invariant mass distributions, observed by H1 in deep inelastic ep-collisions (DIS) at HERA, is presented. The resonance has a mass of 3099 ± 3 (stat.) ± 5 (syst.) MeV and a Gaussian width of 12 ± 3 (stat.) MeV, compatible with the experimental resolution. It is interpreted as an anti-charmed baryon with a minimal constituent quark composition $uudd\bar{c}$, together with its charge conjugate.

1 Experimental Procedure

The analysis [1] is based on the DIS data taken in 1996 – 1997 and in 1999 – 2000 with a center-of-mass energy of $\sqrt{s} = 300\,\text{GeV}$ and $\sqrt{s} = 320\,\text{GeV}$, respectively, corresponding to a total luminosity of 75 pb^{-1}. The kinematic range is defined by the virtuality of the exchanged boson $1 < Q^2 < 100\,\text{GeV}^2$ and the inelasticity $0.05 < y < 0.7$, both reconstructed using the scattered electron.

The decay channel $D^{*+} \to D^0\pi_s^+ \to K^-\pi^+\pi_s^+$ + c.c. is used to reconstruct D^* mesons. The particle selection criteria, transverse momentum cuts and dE/dx requirements on the decay products are very similar to those used in a previous H1 analysis [2]. The D^* candidates are required to have a transverse momentum $p_t > 1.5\,\text{GeV}$, pseudorapidity $-1.5 < \eta < 1$ and production elasticity $z = (E - p_z)_{D^*}/2yE_e > 0.2$, where E_e is the electron beam energy. The resulting ΔM_{D^*} distribution, $M(K\pi\pi_s) - M(K\pi)$, is shown in Fig. 1 (left). Those candidates having a ΔM_{D^*} value in a window $\pm$ 2.5 MeV around the nominal $M(D^*) - M(D^0)$ mass difference are subsequently combined with proton candidates.

The proton candidates are selected with dE/dx requirements based on normalised likelihoods to suppress the background mainly due to pions. Fig. 1 (right) shows the measured dE/dx values as a function of the momentum p. The average dE/dx resolution of the central tracking system is about 8%.

2 Analysis of D^*p combinations

The mass of the D^*p state is calculated as

$$M(D^*p) = m(K\pi\pi_s p) - m(K\pi\pi_s) + M_{PDG}(D^*), \tag{1}$$

where $m(K\pi\pi_s p)$ and $m(K\pi\pi_s)$ are the invariant masses of the corresponding particle combinations to which the D^* mass [3] $M_{PDG}(D^*)$=2010.0 MeV is added. A

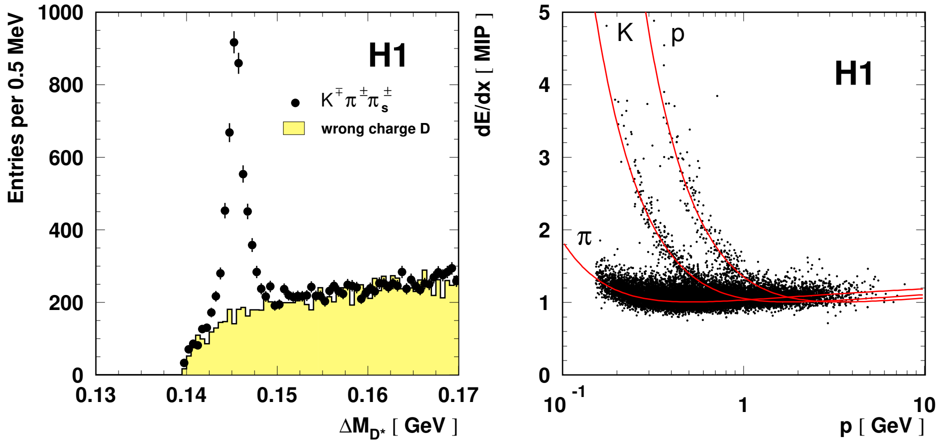

Figure 1. Left: ΔM_{D^*} distribution for $K^{\mp}\pi^{\pm}\pi_s^{\pm}$ combinations. For comparison, the distribution from "wrong charge D" combinations where K and π yielding the D^0 mass have the same charge, is also shown. Right: Specific ionisation energy loss relative to that of a minimally ionising particle, plotted against momentum, of all tracks in events with a selected D^* candidate yielding a mass $M(D^*p) < 3.9\,\mathrm{GeV}$. The curves indicate parameterisations of the most probable responses of the tracking system for pions, kaons and protons.

clear narrow peak is observed in the mass distribution shown in Fig. 2 (left). The data are compared with D^*p events using a D^* Monte-Carlo (MC) simulation and data using "wrong charge D" combinations, where the K and π have the same

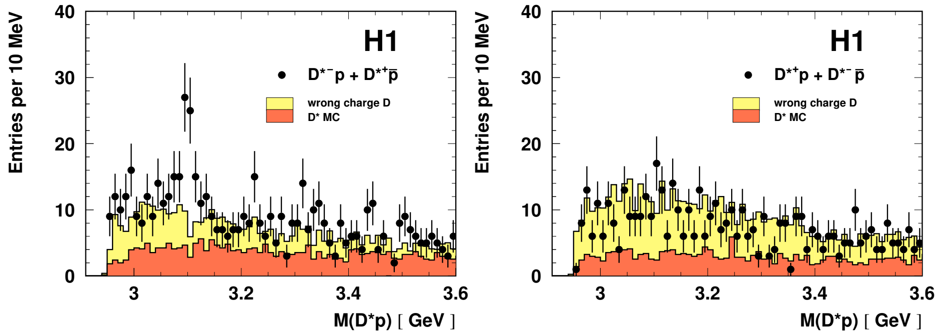

Figure 2. Distributions in $M(D^*p)$ for (left) opposite and (right) same charge D^*p combinations. The data are compared with a two-component background model in which data with "wrong charge D" $K^{\pm}\pi^{\mp}$ combinations with a proton candidate and a D^* MC simulation are used to describe non-charm and charm related background respectively.

charge but nevertheless give the D^0 mass, and which are combined with a proton candidate. No enhancement is seen either in MC or in the non-charm background from data, while the combination of these two background sources describes well the $M(D^*p)$ distribution except in the signal region. The signal is seen separately in $D^{*-}p$ and $D^{*+}\bar{p}$ combinations with compatible significance, mass position and width. As shown in Fig. 2 (right) no significant enhancement is observed in like-charge D^*p combinations.

Possible kinematic reflections that could fake the signal have been ruled out by studying invariant mass distributions and correlations involving the K, π, π_s and proton candidates under various particle mass hypotheses. All events in the M(D^*p) distribution have been scanned visually. No anomalies are observed in the reconstruction of the candidate tracks.

Studies were performed to test the D^* and proton content of the signal. Fig. 3 (left) shows that the D^*p signal region is enriched with D^* in comparison to its side bands. Furthermore, the signal is visible for low momentum proton candidates, where protons can be unambiguously identified using dE/dx.

It is expected that the kinematics of the D^* and the proton from the decay of a resonance differ from those of the background distribution. Such a difference is observed in the momentum distribution of the proton candidates, without any dE/dx requirement, shown in Fig. 3 (right). It reveals a significantly harder spectrum in the D^*p signal region compared to the sidebands.

The signal is observed likewise in an independent photoproduction sample as shown in Fig. 4 (left).

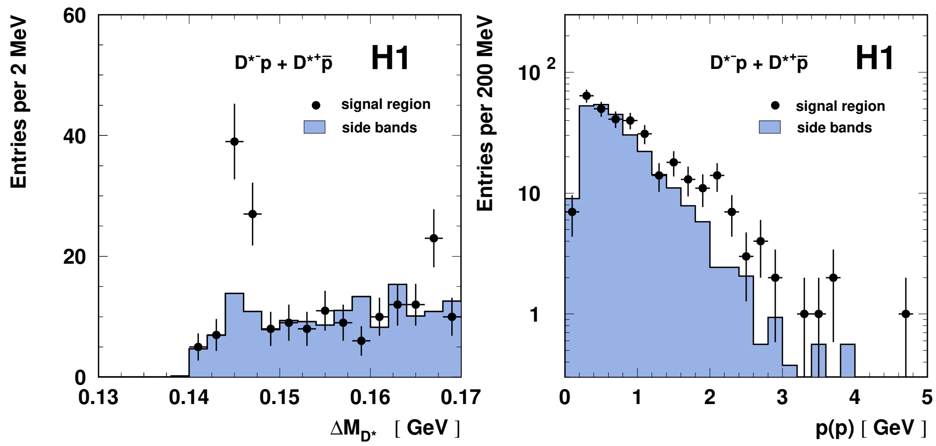

Figure 3. Left: ΔM_{D^*} distribution for events in the signal region of the $M(D^*p)$ distribution without any requirement on ΔM_{D^*} compared with the corresponding distribution from the side bands. The distributions are normalised according to the widths of the respective sample region. Right: Momentum distributions of the proton candidates yielding $M(D^*p)$ values falling in the signal and side band regions when combined with D^* candidates of opposite charge.

3 Signal Assessment

Fig. 4 (right) shows fits to the M(D^*p) distribution in DIS. The signal is described by a Gaussian distribution, the background is parameterised with a power law. The fit to the signal yields a resonance mass of 3099 ± 3 (stat.) ± 5 (syst.) MeV, with a root-mean-square width of 12 ± 3 (stat.) MeV, compatible with the experimental resolution. The signal consists of 50.6 ± 11.2 events.

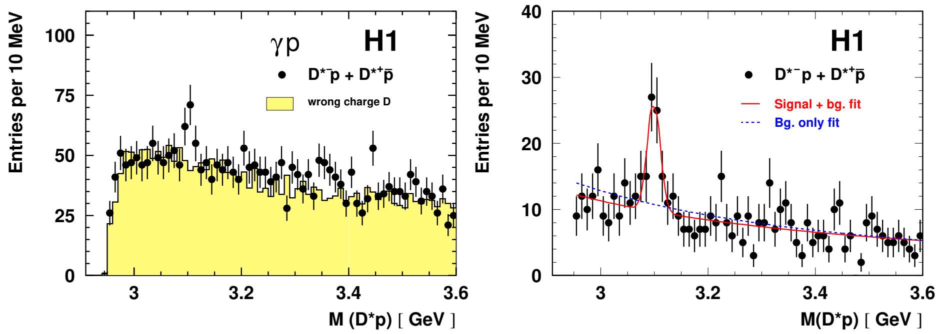

Figure 4. Left: $M(D^*p)$ distribution from the photoproduction analysis compared with a background model derived from "wrong charge D" combinations. Right: $M(D^*p)$ distribution for opposite-charge combinations in DIS compared with the results of fits modelling signal plus background (solid line) and background only (dashed line).

From the background-only hypothesis – displayed by a dashed line in Fig. 4 (right) – the Poissonian probability to observe a background fluctuation of at least the size of the signal is found to be 4×10^{-8}, which corresponds to 5.4 σ in terms of Gaussian standard deviations.

A state decaying strongly to $D^{*-}p$ must have baryon number +1 and charm -1 and thus has a minimal constituent quark composition of $uudd\bar{c}$, making it a candidate for a charmed pentaquark state.

References

1. H1 Collab., A. Aktas *et al.*, Phys. Lett. **B588** (2004) 17-28 [hep-ex/0403017].
2. H1 Collab., C. Adloff *et al.*, Phys. Lett. **B528** (2002) 199 [hep-ex/0108039].
3. Particle Data Group, H. Hagiwara *et al.*, Phys. Rev. **D66** (2002) 010001.