Analysis of the Anti-charmed Baryon State at H1

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Abstract. The measurement of acceptance corrected ratios $\sigma(D^*p(3100))/\sigma(D^*)$ for electroproduction of the anti-charmed baryon state $D^*p(3100)$ decaying into D^* and p is presented. The analysis based on the 1996-2000 data is performed in the deep inelastic scattering region $1 < Q^2 < 100$ GeV^2, $0.05 < y_e < 0.7$.

Keywords: deep-inelastic scattering, charmed pentaquark
PACS: 12.39.Mk

INTRODUCTION

Recently the H1 experiment has reported the observation of a narrow resonance decaying to $D^{*-}p$ [2] with a mass of 3099 MeV in deep inelastic ep scattering at HERA [1]. This resonance is a candidate for the charmed pentaquark Θ_c^0. Subsequent searches by other high energy physics experiments did not confirm this observation [2]. To facilitate further comparisons of experimental results and to investigate the production mechanism of the $D^*p(3100)$ resonance[3] its production phase space is explored in this paper. The data presented here include acceptance corrections assuming pentaquark production as part of the fragmentation process.

ANALYSIS OF $D^{*-}P$ COMBINATIONS

The data were collected with the H1 detector in the years 1996 to 2000 and corresponds to an integrated luminosity of $76\,\mathrm{pb}^{-1}$. A detailed description of the H1 detector is given in [3]. DIS events are selected by requiring a reconstructed scattered electron in the backward calorimeter of H1 in the kinematic range $Q^2 > 1\,\mathrm{GeV}^2$ and $0.05 < y < 0.7$. The selection of D^* mesons and proton candidates is the same as in [1]. The decay channel $D^* \to D^0\pi_s \to K\pi\pi_s$ is used to reconstruct D^* mesons. D^* candidates in the visible region $p_T(D^*) > 1.5$ GeV, $-1.5 < \eta(D^*) < 1$ and $z(D^*) > 0.2$ having a mass difference $\Delta M_{D^*} = m(K\pi\pi_s) - m(K\pi)$ within ± 2.5 MeV of the nominal value $\Delta M_{D^*} = 145.4$ MeV are combined with oppositely charged proton candidates selected according to the proton likelihood based on the particles energy loss $\mathrm{d}E/\mathrm{d}x$ in the central trackers.

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[2] The charge conjugate state is always implied if not otherwise stated explicitly.
[3] Since the spin of the resonance is unknown the term $D^*p(3100)$ is used through out this paper.

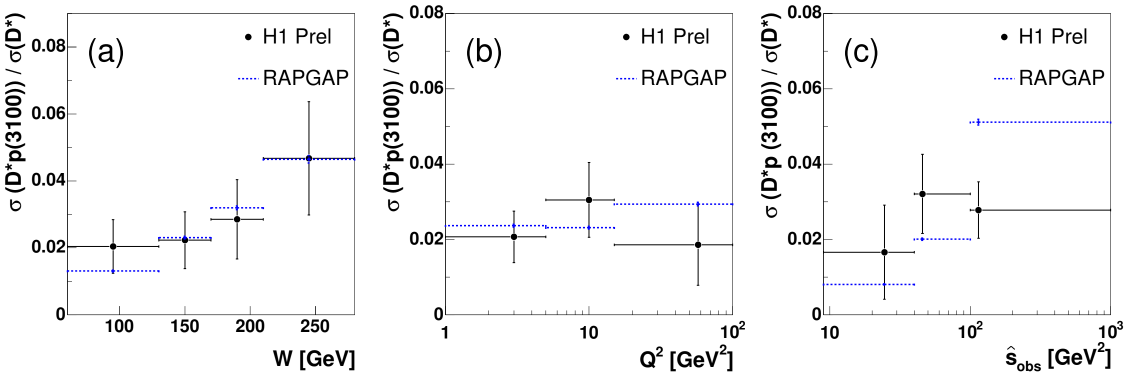

FIGURE 1. $\sigma_{vis}(D^*p(3100))/\sigma_{vis}(D^*)$ as a function of the kinematic variables (a) W, (b) Q^2 and (c) $\hat{s}_{obs}$. Data (closed symbols) are compared with the expectation (dashed line) of RAPGAP 3.1 which assumes the same mechanism for D^* and $D^*p(3100)$ production. Only statistical errors are shown.

The acceptances for the D^* meson and for the $D^*p(3100)$ baryon are calculated by Monte Carlo methods using the RAPGAP 3.1 [4] event generator incorporating fragmentation according to the Lund string model [5] implemented in PYTHIA 6.1 [6]. Pentaquarks are assumed to be produced by fragmentation. The generated events are passed through the full detector simulation using GEANT 3.15 [7] and are subsequently subjected to the same reconstruction and analysis chain as the data.

For the visible range of the $D^*p(3100)$: $p_t(D^*p(3100)) > 1.5$ GeV, $-1.5 < \eta(D^*p(3100)) < 1.0$ and of the D^* meson: $p_t(D^*) > 1.5$ GeV, $-1.5 < \eta(D^*) < 1.0$, $z(D^*) > 0.2$ a total acceptance corrected yields ratio of

$$R_{cor}(D^*p(3100)/D^*) = \left(1.59 \pm 0.33(stat.)^{+\,0.33}_{-\,0.45}(syst.)\right)\ \% \tag{1}$$

has been observed. The same D^* visibility cuts are required for the D^* meson originating from $D^*p(3100)$ baryon decay and for those from the inclusive D^* mesons sample. If acceptance corrections to the $D^*p(3100)$ signal are applied by extrapolating to the full D^* phase space from $D^*p(3100)$ decay the visible cross section ratio is

$$\sigma_{vis}(D^*p(3100))/\sigma_{vis}(D^*) = \left(2.48 \pm 0.52(stat.)^{+0.85}_{-0.64}(syst.)\right)\ \%. \tag{2}$$

In figure 1 the acceptance corrected ratio $\sigma_{vis}(D^*p(3100))/\sigma_{vis}(D^*)$ is shown as a function of the hadronic mass W, the four momentum transfer squared of the virtual photon Q^2 and the invariant mass of the $c\bar{c}$ system, $\hat{s}_{obs}$ in comparison with the expectations of the fragmentation production model. Since the absolute normalization of the $D^*p(3100)$ rate is not fixed in the model, the $D^*p(3100)$ yield is normalized such to reproduce the ratio R_{cor} in (1). The observed dependence on W and on Q^2 is well described by this model, while it is significantly above the data at large $\hat{s}_{obs}$.

In order to investigate the properties of the D^* mesons contributing to the $D^*p(3100)$ resonance the ratio $\sigma_{vis}(D^*p(3100))/\sigma_{vis}(D^*)$ is shown in figure 2 as a function of the pseudorapidity $\eta(D^*)$ and the transverse momentum $p_t(D^*)$, both in the laboratory frame, the inelasticity $z(D^*)$ and the pseudorapidity $\eta^*(D^*)$ in the hadronic centre-of-mass system. Also shown are the expectations from the model. The most striking feature

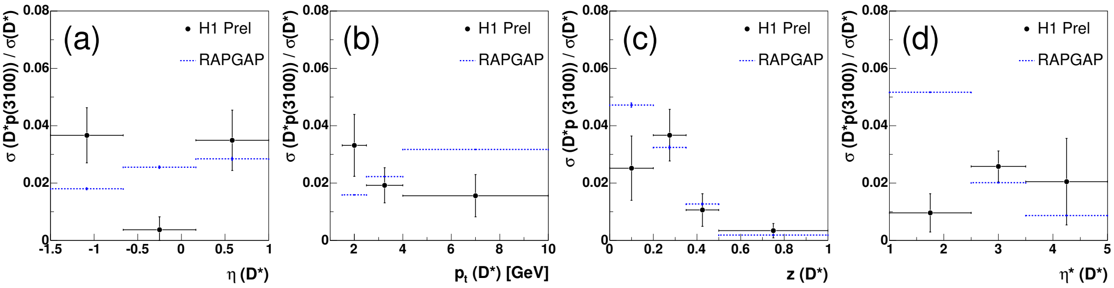

FIGURE 2. $\sigma_{vis}(D^*p(3100))/\sigma_{vis}(D^*)$ as a function of D^* variables (a) $\eta(D^*)$ and (b) $p_t(D^*)$ both in the laboratory frame, (c) $z(D^*)$ and (d) $\eta^*(D^*)$ in the hadronic centre-of-mass system. See fig.1 for details.

in the data is the suppression of the $D^*p(3100)$ baryon relative to D^* meson production in the near to central region in both frames. Such a dependence is not predicted by the fragmentation production model. The data indicate that $D^*p(3100)$ baryon production is closer to the photon direction than normal D^* meson production.

In figure 3 $D^*p(3100)$ differential cross sections are presented as a function of $\eta(D^*p)$, $p_t(D^*p)$, $z(D^*p)$ and $\eta^*(D^*p)$. The $D^*p(3100)$ production cross section shows the same features as a function of $\eta(D^*p)$ and $\eta^*(D^*p)$ than observed for the ratio $\sigma_{vis}(D^*p(3100))/\sigma_{vis}(D^*)$ as a function of the D^* variables. Within the quite large statistical errors the shapes of the $z(D^*p)$ and of the $p_t(D^*p)$ distributions are consistent with the fragmentation production model. These two distributions are suggesting that boson gluon fusion is the source for the production of $D^*p(3100)$ baryons while the pseudorapidity distributions are not evidently supporting this picture.

Finally, information on the $D^*p(3100)$ fragmentation process and the D^* hadronization of D^* mesons from $D^*p(3100)$ decay has been extracted from the data. In figure 4 the cross section ratio $\sigma_{vis}(D^*p(3100))/\sigma_{vis}(D^*)$ as a function of the D^* hadronization variable $x_{obs}(D^*)$ and the differential $D^*p(3100)$ cross section as a function of fragmentation variable $x_{obs}(D^*p)$ are shown together with the predictions from the model. The ratio $\sigma_{vis}(D^*p(3100))/\sigma_{vis}(D^*)$ increases with decreasing $x_{obs}(D^*)$ value which means that D^* mesons originating from $D^*p(3100)$ decay are significantly softer than inclusive D^* mesons. This is expected in decay of a real $D^*p(3100)$ particle. In figure 4b the differential cross section $d\sigma_{vis}(D^*p(3100))/dx_{obs}(D^*p)$ is shown as a function of $x_{obs}(D^*p)$.

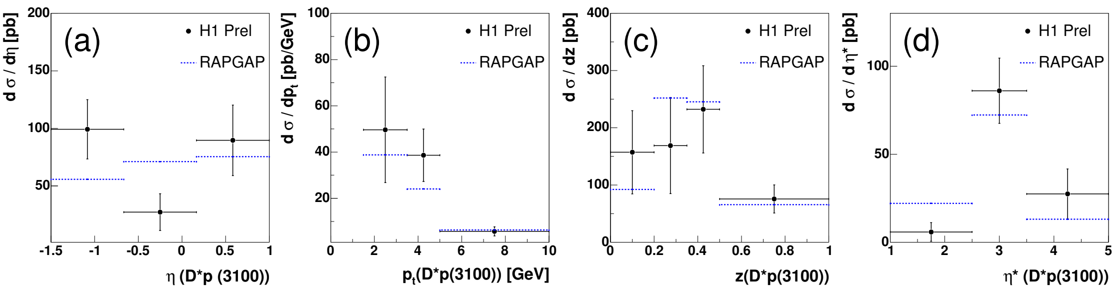

FIGURE 3. Differential $(D^*p(3100))$ cross sections as a function of D^*p variables (a) $\eta(D^*p)$ and (b) $p_t(D^*p)$, (c) $z(D^*p)$ and (d) $\eta^*(D^*p)$. See fig.1 for details.

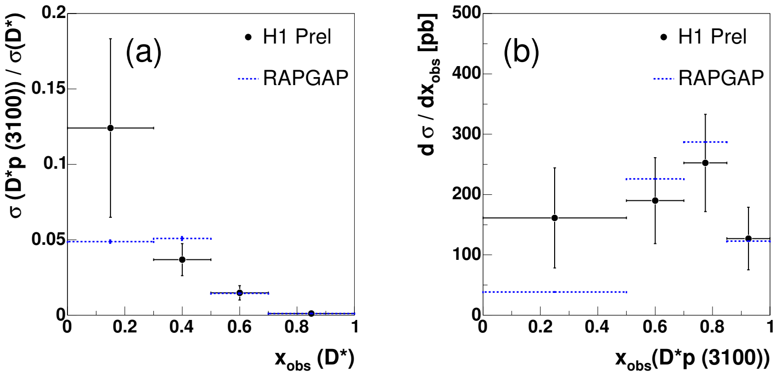

FIGURE 4. $\sigma_{vis}(D^*p(3100))/\sigma_{vis}(D^*)$ as a function of the D^* hadronization fraction $x_{obs}(D^*)$ in (a) and $d\sigma_{vis}(D^*p(3100))/dx_{obs}(D^*p)$ in (b). See fig.1 for details.

The $D^*p(3100)$ fragmentation function is very hard compared to the D^* hadronization function of figure 4a. Such hard fragmentation is expected for charmed hadrons.

CONCLUSION

A detailed analysis of the exotic $D^*p(3100)$ baryon has been presented. An acceptance corrected yields ratio $R_{cor}(D^*p(3100)/D^*) = \left(1.59 \pm 0.33(stat.)^{+\,0.33}_{-\,0.45}(syst.)\right)$ % for the visible $D^*p(3100)$ and D^* range has been observed.

Differential distributions of $\sigma_{vis}(D^*p(3100))/\sigma_{vis}(D^*)$ as a function of event kinematics and D^* quantities as well as differential $D^*p(3100)$ cross sections as a function of $D^*p(3100)$ variables have been presented. In general the fragmentation production model leads to a reasonable description of the data with some exceptions. Compared to inclusive D^* production the $D^*p(3100)$ production seems to be suppressed in the close to central rapidity region. The $D^*p(3100)$ fragmentation function is hard, as expected for charmed hadrons. The hadronization function of D^* mesons from the $D^*p(3100)$ resonance is much softer than observed in inclusive D^* mesons production.

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