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Investigation of the $\mathrm{D}^{\star}\mathrm{p}$ Resonance in the 3 GeV Region with HERAII Data

H1 Collaboration

Abstract

A possible resonance decaying into the $D^{\star}$-proton final state is investigated in deep inelastic scattering at HERA. The data were taken with the H1 detector in the years 2004 to 2007 and correspond to an integrated luminosity of $348\ \mathrm{pb}^{-1}$ thus increasing the available data significantly compared to the analysis of HERAI data.

1 Event Selection

The data sample corresponds to an integrated luminosity of $348\ \mathrm{pb}^{-1}$ and was recorded with the H1 experiment in the years 2004–2007, where either electrons or positrons at 27.6 GeV were collided with protons at 920 GeV.

variable	cut
energy of scattered electron E'_e	> 10 GeV
angle of scattered electron θ_e	< 3.09
photon virtuality Q^2	$2 < Q^2 < 100\ \mathrm{GeV}^2$
radius cut	$(x_{Sp} + 2.025\mathrm{cm})^2 + y_{Sp}^2 > (12.\ \mathrm{cm})^2$
inelasticity y	$0.05 < y < 0.7$

Table 1: Table of electron cuts adapted to the SpaCal geometry in HERAII.

$D^\star$ mesons are identified in their golden decay channel $D^{\star\pm} \to D^0\pi^\pm_{\mathrm{slow}} \to K^\mp\pi^\pm\pi^\pm_{\mathrm{slow}}$. The tracks of the decay particles are reconstructed by the CTD. The kaon, the pion and the slow pion must have a transverse momentum greater than 0.5 GeV, 0.3 GeV and 0.12 GeV, respectively. A cut on the scalar sum of the transverse momenta of the pion and kaon above 2.0 GeV is made in order to suppress background from the light quarks u,d and s. Due to these cuts the visible region, in which $D^\star$ mesons are reconstructed, is restricted to $p_t(D^\star) > 1.5$ GeV. In order to suppress the non-charm background further the pseudo-rapidity is restricted to $-1.5 < \eta(D^\star) < 1.0$ and the inelasticity of the $D^\star$ meson, $z(D^\star) = \frac{(E-p_z)_{D^\star}}{2yE_e}$, to $z(D^\star) > 0.2$.

In contrast to the published HERAI analysis, **no** particle identification by dE/dx requirements is used for the $D^\star$ selection.

2 Results

In order to show the sensitivity of the data to the decay of heavier charmed particles into a $D^\star$ meson and an additional particle, the decay of the $D_1(2420)^0$ and the $D_2^\star(2460)^0$ into a $D^\star$ and a pion is studied. The pion candidate is required to have the opposite charge than the $D^\star$ and a transverse momentum larger than 0.12 GeV. The resulting mass distribution, reconstructed by $M(D^\star\pi) = M(K\pi\pi_{\mathrm{slow}}\pi) - M(K\pi\pi_{\mathrm{slow}}) + M_{D^\star}$ with $M_{D^\star} = 2.010\,\mathrm{GeV}$, is shown in figure 2.

The selection of pentaquark candidates is kept close to the ”high proton momentum” selection of the published analysis. Central tracks with opposite charge than the $D^\star$ meson and a momentum $p(p) > 2\,\mathrm{GeV}$ are combined to form a pentaquark candidate. The invariant mass $M(D^\star p)$ is calculated with the assumption of the proton mass by $M(D^\star p) = M(K\pi\pi_{\mathrm{slow}}p) - M(K\pi\pi_{\mathrm{slow}}) + M_{D^\star}$. The resulting mass distribution is shown in figure 3 for HERAI and for HERAII data.

Under the assumption that a possible $D^\star p$ resonance has a Gaussian resolution of $12\,\mathrm{MeV}$ (in agreement with the resolution in HERAI data), **the** 95% **confidence limit for statistical**

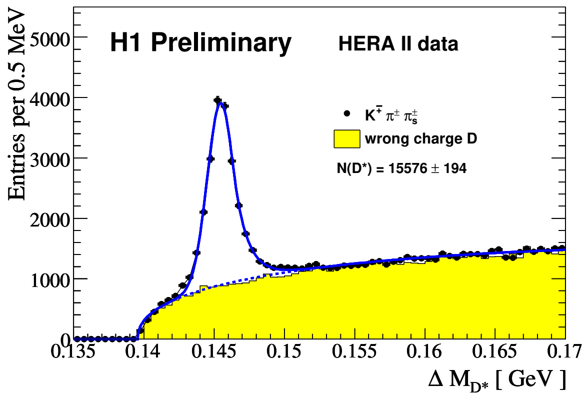

Figure 1: The distribution of $\Delta M = M(K\pi\pi_{\rm slow}) - M(K\pi)$ in the HERAII data sample. The signal data sample is shown as black points and the wrong charged D background as yellow histogram.

errors only is 16.3 events (H1 preliminary), corresponding to a ratio of $D^{\star}p$ to $D^{\star}$ of 1.0 per mille (H1 preliminary). The corresponding ratio in the HERAI data sample with the same kinematic cuts is 8.1 ± 2.1 per mille (H1 preliminary).

The ΔM distribution is shown in figure 5 for events in a $\pm 15\,\mathrm{MeV}$ window around the HERAI $D^{\star}p$ signal and a sideband region, 2.99 to 3.07 and 3.13 to $3.21\,\mathrm{GeV}$, scaled by a factor $3/16$ to account for the different widths. While for HERA1 the distributions differ around the expected value for $D^{\star}$ mesons, the signal and sideband distributions agree for HERAII data.

3 Conclusion

A study of the invariant mass spectrum of identified $D^{\star}$meson candidates with high momentum proton candidates similar to the HERAI search for a narrow charmed baryonic resonance has been performed with HERAII data. The selection is kept close to the "high proton momentum" selection of the published HERAI analysis to be independent from possible differences in the dE/dx calibration between the two datasets. The structure at $\sim 3.1\,\mathrm{GeV}$ in HERAI data is found again, also in the kinematic range accessible in HERAII. In the HERAII data sample, that is roughly 4 times larger, no significant peak structure is visible in HERAII data. The 95% confidence limit for statistical errors only is 16.3 events for HERAII, corresponding to a ratio of $D^{\star}p$ to $D^{\star}$ of 1.0 per mille. In the $\Delta M_{D^{\star}}$ distribution an enrichment at the expected value for $D^{\star}$ mesons is found in the $D^{\star}p$ "signal" region relative to the sidebands also only for HERAI data, not for HERAII.

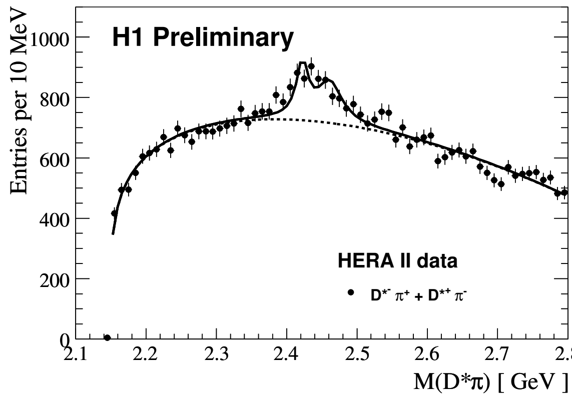

Figure 2: The distribution of $M(D^{\star}\pi) = M(K\pi\pi_{\text{slow}}\pi) - M(K\pi\pi_{\text{slow}}) + M_{D^{\star}}$ in the HERAII data sample. The data are fitted with the sum of two Breit-Wigner functions (with masses and widths fixed to the PDG values of the $D_1(2420)^0$ and $D_2^{\star}(2460)^0$) and a background function, which is parameterised as $p0 \cdot (M(D^{\star}\pi) - M_{D^{\star}} - M_{\pi})^{p1} \cdot (1. + p2 \cdot M(D^{\star}\pi) + p3 \cdot M(D^{\star}\pi)^2)$ with four free parameters.

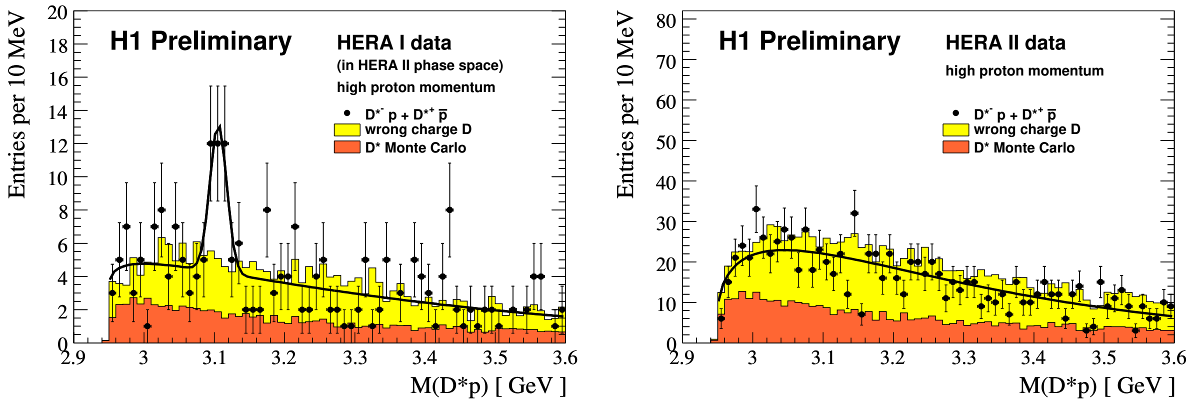

Figure 3: The distribution of $M(D^{\star}p) = M(K\pi\pi_{\text{slow}}p) - M(K\pi\pi_{\text{slow}}) + M_{D^{\star}}$ for the high proton momentum selection ($p(p) > 2\,\text{GeV}$) in the HERAI (left) and HERAII (right) data samples. The right charge data sample is shown as black points, the background from a $D^{\star}$ Monte Carlo and the wrong charged $D^{\star}$ background as orange and yellow histograms. The right charge data are fitted with a 3 parameter function $p0 \cdot (M(D^{\star}p) - M_{D^{\star}} - M_p)^{p1} \cdot \exp(p2 \cdot (M(D^{\star}p) - M_{D^{\star}} - M_p))$ (plus a Gaussian for the HERAI data).

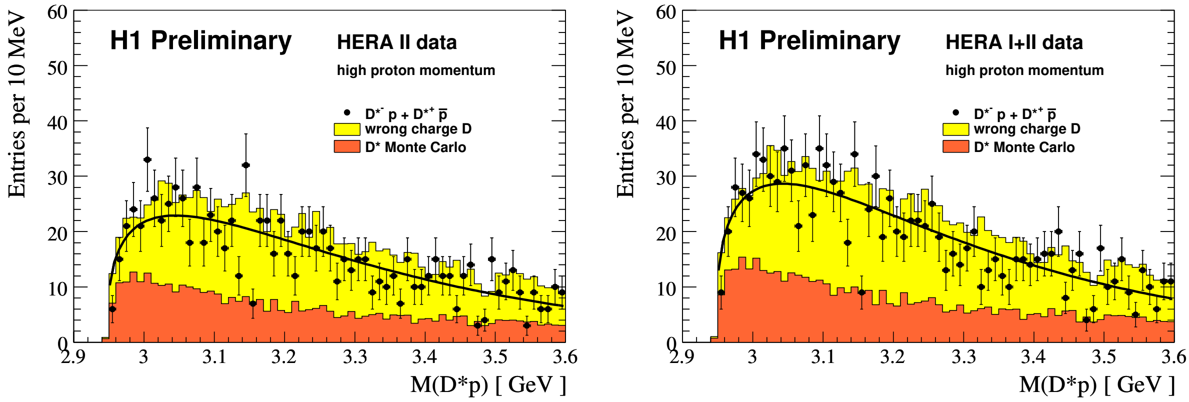

Figure 4: The distribution of $M(D^{\star}p)$ for the high proton momentum selection ($p(p) > 2\,\mathrm{GeV}$) in the HERAII (left) and the sum of HERAI and HERAII (right) data samples.

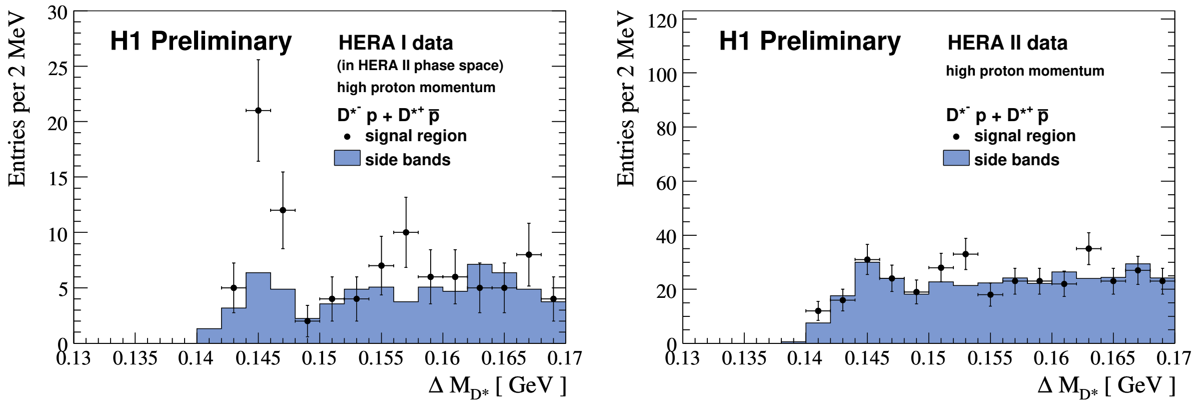

Figure 5: The ΔM distribution in the HERAI (left) and HERAII (right) data samples for events in a $30\,\mathrm{MeV}$ window around $3.1\,\mathrm{GeV}$ in $M(D^{\star}p)$ compared to the corresponding distribution from the side bands (2.99 to 3.07 and 3.13 to 3.21 GeV) in the $M(D^{\star}p)$ distribution, normalised according to the widths of the chosen sample regions.