HEAVY STABLE-PARTICLE PRODUCTION IN NC DIS WITH THE ZEUS DETECTOR

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The production of (anti)deuterons and (anti)protons was studied in deep inelastic ep scattering with the ZEUS detector at HERA. The data sample consists of deep inelastic ep scattering events at a center-of-mass energy of 300-318 GeV and $Q^2 >$ 1 GeV^2, and corresponds to 120 pb^{-1} integrated luminosity. No antitritons were found. The antideuteron production rate is three to four orders of magnitude smaller than the antiproton yield, which is in agreement with other measurements.

1. Introduction

Light-stable nuclei, such as deuterons (d) and tritons (t), are loosely bound states, and cannot be produced by the standard hadronization of quark and gluon jets. In collisions involving elementary particles, the underlying production mechanism of such states is poorly understood.

The production rate of antideuteron in $e^+e^- \rightarrow q\bar{q}$[1] is significantly lower than that measured in hadronic $\Upsilon(1S)$ and $\Upsilon(2S)$ decays[2], pA[4], pp collisions[5] and also in photonic collision with protons (γp) at HERA[3]. The production rates are also lower in nucleus-nucleus (AA) collisions[6]. Usually, coalescence model is used to explain the production of such light nuclei[7]. These subjects are also topical interests for possibly observed pentaquark states, since the coalescence model could be used to explain the formation of pentaquarks as in the case for the antideuteron[8].

At present, neither $\bar{d}$ nor $\bar{t}$ has been reported in deep inelastic scattering (DIS). This paper presents the first experimental results on the light nuclei production in DIS at HERA.

2. Antideuterons and (anti)protons in NC DIS

The data sample, collected with the ZEUS detector at HERA, corresponds to an integrated luminosity of 120 pb^{-1}, taken between 1996 and 2000. This sample is the sum of 39 pb^{-1} of $e^{+}p$ data taken at a center-of-mass energy of 300 GeV and 64 pb^{-1} taken at 318 GeV, plus 17 pb^{-1} of $e^{-}p$ data taken at 318 GeV. The search was performed using Neutral Current DIS with exchanged-photon virtuality $Q^2 \geq 1$ GeV^2.

The charged tracks were reconstructed in the central tracking detector(CTD) and required to have at least 40 CTD hits and transverse momenta $p_T \geq 0.15$ GeV. For each track, following variables are calculated: the distance, ΔZ, of the Z-component(beam direction) of the track helix to the interaction point given by Z_{vertex}; the distance of closest approach (DCA) of the track to the beam spot in the transverse plane. The energy-loss measurement in the CTD, dE/dx is also used in the selection of heavy stable-particles.

Figure 1(left) shows the dE/dx distribution as a function of the track momentum for negative tracks. To reduce the fraction of tracks coming from non-ep collisions, tracks are required to have $|\Delta Z| < 1$ cm and $|DCA| < 0.5$ cm. The requirement $dE/dx > 2.5$ mips enhances the fraction of heavy stable-particles such as protons and deuterons.

Figure 1(right) shows the reconstructed mass, M for different particle species. The mass was calculated from the track momentum and the most probable specific energy loss. The number of deuterons and antideuteron in the mass window $1.5 < M < 2.5$ GeV is 309 and 62, respectively. No antitritons were observed. Given the small number of triton candidates, no conclusive statement on the observation of t states in DIS can be made.

For protons and deuterons, observed candidates could be from beam gas and secondary interaction. The beam gas contribution is significantly reduced after the requirement of scattered lepton in the DIS trigger. The contribution of the secondary interaction is subtracted by using side band events of DCA distributions in Fig. 2(left).

The number of the reconstructed (anti)protons in data after the background subtraction is $1.61 \times 10^5 (1.75 \times 10^5)$. The number of antideuterons is 61 ± 8. The proton-antiproton asymmetry is mainly due to different dE/dx efficiencies. However, such a difference in the efficiencies cannot explain the case for the (anti)deuterons. Further studies are required for the backgrounds of deuterons. In this paper, we concentrate on the results of antideuterons and (anti)protons.

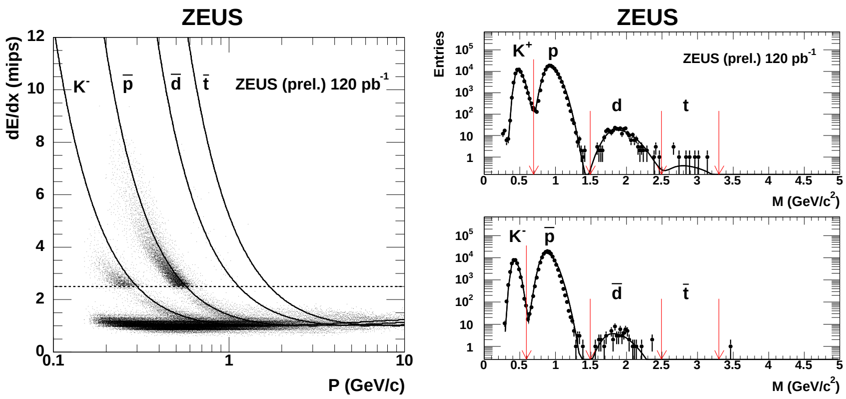

Figure 1. (Left) The dE/dx distributions a a function of the track momentum for negative charged tracks. The DIS events were accepted by requiring at least on track with $dE/dx > 2.5$ mips. The curves show the mean energy loss derived using the Bethe-Bloch equation for different particle species. (Right) The mass spectra for positive and negative charged particles. Tracks are selected with $dE/dx > 2.5$ mips. The arrows show the cuts for the each particle species.

For comparisons with other experiments, we measured the ratios of $\bar{d}/\bar{p}$ and $\bar{p}/p$ for $0.3 < p_T/M < 0.7$ (with 4 bin), in the central rapidity, $|y| < 0.4$. p_T is normalized with mass to match the kinematic region between antiproton and antideuteron in the coalescence. Raw ratio is corrected with tracking efficiency and efficiency of dE/dx cut. The tracking efficiency is estimated from Geant simulation and efficiency of dE/dx cut is estimated from (anti)proton sample in reconstructed $\Lambda \to p\pi$ decays. For (anti)protons, the weak decay contribution ($\sim 20\%$ from $\Lambda \to p\pi$) is also subtracted based on ARIADNE Monte Carlo simulation.

The detector-corrected $\bar{d}/\bar{p}$ ratio as a function of p_T/M is shown in Fig. 2(right, top). There is a good agreement with the H1 published data for photoproduction[3], as well as with pp data[5]. A similar ratio was also observed in hadronic $\Upsilon(1S)$ and $\Upsilon(2S)$ decays by the ARGUS Collaboration[2].

The $\bar{p}/p$ ratio as a function of p_T/M is shown in Fig. 2(right, bottom). For the given statistics, the $\bar{p}/p$ ratio is consistent with unity.

3. Conclusions

In conclusion, a first observation of antideuterons in ep collisions in the DIS regime at HERA is presented. No antitritons were observed. The production rate of antideuterons is about three to four orders of magnitude

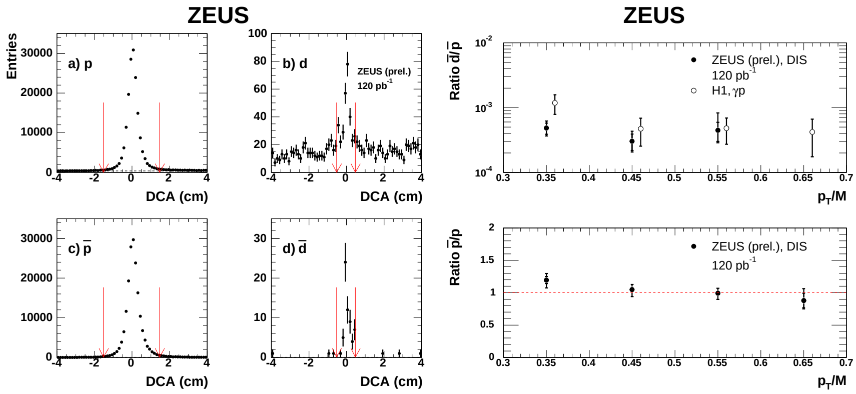

Figure 2. (Left) The distributions of the distance of closest approach for different particle species. The arrows show the signal region. (Right) The top plot shows the corrected $\bar{d}/\bar{p}$ production ratios as a function of p_T/M. The measurements are compared to the H1 photoproduction results. The bottom plot shows the $\bar{p}/p$ ratios.

smaller than that for antiprotons, which is in broad agreement with other experiments.

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