By adopting two models of strange and antistrange quark distributions inside nucleon, the light-cone meson-baryon fluctuation model and the effective chiral quark model, we calculate the $D_s^+ - D_s^-$ asymmetry in photoproduction in the framework of heavy-quark recombination mechanism. We find that the effect of asymmetry of strange sea to the $D_s$ asymmetry is considerable and depending on the different models. Therefore, we expect that with the further study in electroproduction, e.g. at HERA and CEBAF, the experimental measurements on the $D_s^+ - D_s^-$ asymmetry may impose a strong restriction on the strange-antistrange distribution asymmetry models.

Keywords: strange-antistrange distribution asymmetry; $D_s^+ - D_s^-$ asymmetry; photoproduction.

1. Introduction

The production of charmed hadron at high-energy colliders has been the subject of considerable interest in recent years. Particularly, it is still controversial that fixed-target hadro- and photoproduction experiments have observed large production asymmetries between the charmed and anticharmed mesons. In fact, the experimental asymmetries of charm hadron production are very large compared with the predictions of perturbative QCD(pQCD). The charm hadrons are heavy enough that the cross section for their production can be factorized into a short-distance part, the cross section of the production of the $c\bar{c}$ pair, and a long-distance parameter, the nonperturbative fragmentation.
function. In the skeleton of pQCD, the charm-anticharm asymmetry comes only from the next-to-leading order (NLO), or higher, corrections and is relatively small.

Though many attempts try to resolve this problem,\textsuperscript{12,13} they all depend on the unknown distribution of partons in the remnant of the target nucleon or photon after the collider to a great extent.

Different from these, the heavy-quark recombination mechanism proposed by Braaten et al.\textsuperscript{14} can give a more quantitative and simple explanation to charm meson asymmetries. In their works,\textsuperscript{15} Braaten et al. consider that the light quark ($u, d$) that participates in the hard-scattering process may recombine with a heavy quark ($c, \bar{c}$) in the final state, provided the light quark has momentum of $O(\Lambda_{QCD})$ in rest frame of heavy quark. And the product of the recombination hadronize into the final state heavy meson ($D^+_s, D^-_s$) while the recoiling heavy quark ($\bar{c}, c$) fragments to $D^+_{s}, D^-_{s}$ meson. Because the strange sea of nucleon is symmetry in their assumption, the $D^+_s - D^-_s$ asymmetry is due to the excess of $u$ and $d$ over $\bar{u}$ and $\bar{d}$ in proton. The asymmetry of $D_s$ meson has the opposite sign as that of $D$ meson and is relatively small. However, we note that the striking strange sea asymmetry in the momentum distribution of the nucleon has been proposed.\textsuperscript{16,17} Based on this idea, we study the $D_s$ asymmetry in photoproduction with the heavy-quark recombination mechanism and expect the experimental measurements on this asymmetry will impose a restriction on the strange sea distribution in nucleon.

2. The $D_s$ production mechanism

The cross section of $D_s$ meson photoproduction takes the form in the heavy-quark recombination mechanism:

$$d\sigma[\gamma + N \rightarrow D_s + X] = f_{q/N} \otimes \sum d\tilde{\sigma}[\gamma + \bar{s} \rightarrow (c\bar{s})^n + \bar{c}] \rho[(c\bar{s})^n \rightarrow D_s],$$

Here $(c\bar{s})^n$ indicates the $s$ has very small momentum in the $\bar{c}$ rest frame, and $n$ is the color and angular momentum quantum numbers of $(c\bar{s})$ recombination. $d\tilde{\sigma}[\gamma + \bar{s} \rightarrow (c\bar{s})^n + \bar{c}]$ is the short-distance partonic subprocess. The factor $\rho[(c\bar{s})^n \rightarrow D_s]$ is the probability of the $(c\bar{s})^n$ state to hadronize into a the $D_s$ final state. The $D_s$ meson is produced by two schemes,

(a) \hspace{1cm} d\tilde{\sigma}[\gamma + \bar{s} \rightarrow (c\bar{s})^n + \bar{c}] \rho[(c\bar{s})^n \rightarrow D_s] ,

(b) \hspace{1cm} d\tilde{\sigma}[\gamma + q \rightarrow (c\bar{q})^n + \bar{c}] \sum_{\bar{D}} \rho[(c\bar{q})^n \rightarrow \bar{D}] \otimes D_{c\rightarrow D_s} ,

In process (a), the $(c\bar{s})^n$ recombines into the $D_s$ meson directly; in process (b), $(c\bar{q})^n$ recombines into the $D^-_{s}$, $D^-_{s}$ or $\bar{D}^0$ meson, and the recoiling $c$ quark fragments to the $D^+_s$ meson. Compare with Braaten’s work, we take into account the asymmetry effects due to the process (a).

To get the total cross section of $D_s$ production, it is important to quote the asymmetric distribution of strange sea. Here we adopt two distribution models of $s$ quark, i.e., the light-cone meson-baryon fluctuation model and the effective chiral
Fig. 1. The asymmetry $\alpha[D_s]$ versus $x_F$. The dotted and dash-dotted lines correspond to the results from the light-cone meson-baryon fluctuation model and the effective chiral quark model, respectively. The solid line from the Braaten’s result.

With the resultant production cross section, we can get the $D_s^+ - D_s^-$ Asymmetry in Photoproduction from the definition below,

$$\alpha[D_s] = \frac{\sigma_{D_s^+} - \sigma_{D_s^-}}{\sigma_{D_s^+} + \sigma_{D_s^-}}.$$  \hspace{1cm} (4)

Our prediction of $D_s^+ - D_s^-$ asymmetry, in comparison with Bratten’s result, are shown in Fig.1.

3. Summary

The detailed results of calculation and the selection of the relevant parameters can be found in Ref.18. As can be seen from Fig.1, the production asymmetry of $D_s$ by adopting the light-cone meson-baryon fluctuation model is about 1.2 times larger than Ref.15. While the result of the effective chiral quark model is only about 80% of the Braaten’s. In summary, the different models of the distribution of the strange sea give the obviously divergent curves of the asymmetry versus $x_F$. Though there is still some uncertainties, such as the breakdown of $SU(3)$ symmetry, the large $N_c$ limit and the NLO correction in pQCD, our results show that the effect of asymmetry of strange sea to the $D_s$ asymmetry is considerable and depending on the different models. Moreover, it is noted that the $D_s$ asymmetry experimental data are still limited and preliminary. We expect the more precise and new experimental data of $D_s$ asymmetry can impose a clear restriction on the strange and antistrange quark distribution.

Data from several recent experiments, including the HAPPEX, the SAMPLE experiment at MIT-Bates and the A4 experiment at the Mainz Laboratory in Ger-
many suggest that the strange quarks may contribute a positive value to the proton's magnetic moment. These stimulating experimental results are beginning to shed further light on the distribution of the strange quark. The next promising issues to be studied include confronting our theory predictions on the $D_s$ asymmetry with the corresponding experimental data in electroproduction. We also expect that the $D_s$ production asymmetry can be observed at HERA and CEBAF, which may give further information on the distribution of the strange quark inside the nucleon.

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