Effects of Fermi-motion and pion exchanges on proton-deuteron Drell-Yan processes

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Since the asymmetry between the anti-up ($\bar{u}$) and anti-down ($\bar{d}$) quark distributions in the proton was revealed by the New Muon Collaboration [1] (NMC), a number of experiments on the di-muons ($\mu^+\mu^-$) production from the Drell-Yan [2] (DY) processes in pp and pd collisions had been performed at Fermi National Accelerator Laboratory (Fermilab). The objective was to extract the $\bar{d}/\bar{u}$ ratio of the parton distribution functions (PDFs) in the proton. Combined with the information from the measurements of deep inelastic scattering (DIS) of leptons from the nucleon, it has been confirmed that the NMC's finding, $\bar{d}/\bar{u} > 1$, is satisfied only in the region of low Bjorken $x \lesssim 0.35$. The ratio $\bar{d}/\bar{u} > 1$ signals the nonperturbative nature of the sea of the proton. Its dynamical origins have been investigated rather extensively with various models. Precise experimental determination of $\bar{d}/\bar{u}$ for higher $x > 0.35$ is needed to distinguish more decisively these models and to develop a deeper understanding of the sea of the proton. This information will soon become available from a forthcoming experiment [3] at Fermilab.

In analyzing the DY data on the deuteron and nuclei, it is common to neglect the nuclear effects that are known to be important in analyzing the DIS data. It is well established that the nuclear effect due to the nucleon Fermi motion (FM) can influence significantly the DIS cross sections, in particular in the large x region. It is also known that the contributions from the virtual pions in nuclei must be considered for a quantitative understanding of the parton distributions in nuclear medium. Thus it is interesting and also important to develop an approach to investigate these two nuclear effects on the pd DY process.

In Ref. [4], we have developed such an approach and computed the ratio

$$R_{pd/pp} = \frac{d\sigma^{dp}}{dx_1 dx_2} \Bigg/ \left(2\frac{d\sigma^{pp}}{dx_1 dx_2} \right), \tag{1}$$

where σ^{pd} (σ^{pp}) is the pd (pp) DY cross section, and x_1 (x_2) is the Bjorken variable for the incident proton (the target proton or the nucleon in the target deuteron). The calculated $R_{pp/pd}$ at the incident proton momentum of 800 (GeV/c) is compared with the available data from [5] (left panel of Fig. 1). Also, we make predictions for the forthcoming experiment at 120 (GeV/c) [3] (right panel of Fig. 1). At 800 (GeV/c) our result agrees well with the available data. It is the observation that the Fermi-motion and the pion-exchange effects in the deuteron is small at 800 (GeV/c), while those effects produce sizable differences in $R_{pp/pd}$ at large $x_2 > 0.3$. This clearly shows that it is necessary to include the Fermi-motion and the pion-exchange effects to extract the ratio $\bar{d}/\bar{u}$ in the proton from the data of $R_{pd/pp}$ in the large x_2 region.

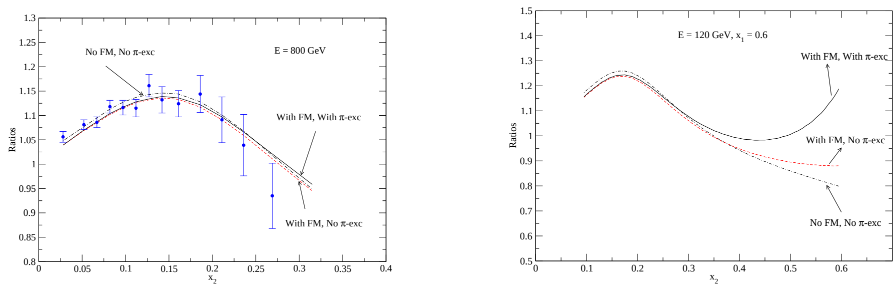

Figure 1: [Left panel] Ratio $R_{pd/pp}$ at 800 (GeV/c). Data are from Ref. [5]. With (No) FM denotes that Fermi motion is included (not included). With (No) π-exc denotes that pion-exchange is included (not included). [Right panel] Ratio $R_{pd/pp}$ at 120 (GeV/c) and $x_1 = 0.6$. The meaning of each curve is same as the left panel.

References

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