TRANSVERSITY DISTRIBUTIONS AND SPIN ASYMMETRIES

S. HINO, M. HIRAI, S. KUMANO, M. MIYAMA

Department of Physics, Saga University
Saga 840-8502, Japan

We discuss transversity distributions and transverse spin asymmetries. First, Q^2 evolution results are shown for transversity and longitudinally polarized distributions. Second, the antiquark flavor asymmetry $\Delta_T\bar{u}/\Delta_T\bar{d}$ is discussed in two different descriptions, a meson-cloud model and an exclusion model. Both calculations produce a significant $\Delta_T\bar{d}$ excess over $\Delta_T\bar{u}$. Third, we explain general formalism of the polarized proton-deuteron Drell-Yan processes. This study is partly intended to find the asymmetry $\Delta_T\bar{u}/\Delta_T\bar{d}$ by the p-d asymmetry. However, the existence of tensor structure in the deuteron produces a number of new structure functions. There exist 108 structure functions and 22 ones even after integrating the cross section over the virtual-photon transverse momentum $\vec{Q}_T$.

1 Introduction

Using many experimental data on g_1, we have a rough idea on the longitudinally polarized parton distributions. However, the transversity distributions $\Delta_T q$ have not been measured at all because they do not contribute to the cross section of inclusive lepton-proton scattering. They are expected to be measured by the Drell-Yan process at RHIC. It is, therefore, important to predict the features of $\Delta_T q$ as many as we can before the RHIC experiment. There are three major reasons for studying the transversity distributions. First, our knowledge of proton spin should be tested by another observable. Second, the transversity Q^2 evolution is very different from the longitudinal one. It is a good test of perturbative QCD. Third, nonrelativistic quark models predict that transversity distributions are equal to the corresponding longitudinally polarized ones, so that the difference could shed light on the relativistic aspect of hadron structure.

We first discuss the Q^2 evolution of a transversity distribution.[1] Then, possible mechanisms are explained for producing the light antiquark flavor asymmetry $\Delta_T\bar{u}/\Delta_T\bar{d}$.[2,3] Obtained results are used for calculating the transverse double spin asymmetry at a RHIC energy.[3] The ratio $\Delta_T\bar{u}/\Delta_T\bar{d}$ could be extracted from the pp and pd Drell-Yan data. However, because there had been no available formalism for the polarized pd Drell-Yan, we explain various spin asymmetries for finding the structure functions of a spin-one hadron.[4]

2 Q^2 evolution and light antiquark flavor asymmetry

In order to test perturbative QCD, we have to rely on the Q^2 dependence of structure functions. Fortunately, the next-to-leading-order Q^2 evolution has been completed in the recent years not only for the longitudinally polarized distributions but also for the transversity ones. It was revealed that the transversity Q^2 evolution is very different from the longitudinal one because $\Delta_T q$ does not couple to the gluon distribution.[1] We show the singlet evolution results in Fig. 1 by using our program in Ref. 1.[a] The evolved distributions are significantly different even though the initial ones are identical. The difference should be an important test of perturbative QCD in spin physics.

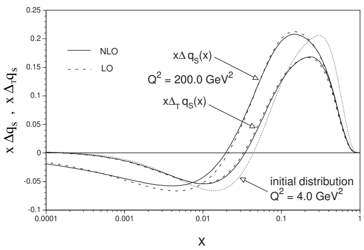

Figure 1: Q^2 evolution.

There are studies on the possible antiquark flavor asymmetry $\Delta\bar{u}/\Delta\bar{d}$ or $\Delta_T\bar{u}/\Delta_T\bar{d}$.[2,3] We have looked at two different descriptions, a meson-cloud model and an exclusion model.[3] The ρ-meson clouds could contribute to the polarized flavor asymmetries, for example, because ρ^+ contains the $\bar{d}$-valence quark. The exclusion principle is another approach. It produces the spin asymmetry, for example, because it is more difficult to create $u^\uparrow$ than to create $u^\downarrow$ due to the $u^\uparrow$ excess over $u^\downarrow$ in the SU(6) quark model. It is interesting to find that both models predict $\Delta_T\bar{d}$ excess over $\Delta_T\bar{u}$ although their magnitude could be different. We show the transverse double asymmetries calculated by using the flavor symmetric parton distributions and by the exclusion model in Fig. 2.[3] At this stage, the numerical analysis of the meson-cloud model is still preliminary so that its results are not shown here. The two curves are significantly different; however, the measurement of A_{TT} is not enough to find the ratio $\Delta_T\bar{u}/\Delta_T\bar{d}$. Although the longitudinal ratio $\Delta\bar{u}/\Delta\bar{d}$ should be found by the W production processes, the transversity ratio cannot be measured by the W. As the alternative, we propose to use the polarized proton-deuteron Drell-Yan process in combination with the polarized pp process.

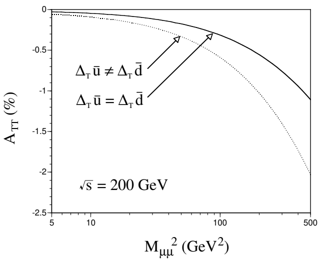

Figure 2: Transverse spin asymmetry.

[a] Our Q^2 evolution program could be obtained upon email request.
See http://www2.cc.saga-u.ac.jp/saga-u/riko/physics/quantum1/program.html.

3 Polarized proton-deuteron Drell-Yan processes

The major purpose for studying polarized proton-deuteron (pd) Drell-Yan processes is to investigate new spin-dependent structure functions for spin-one hadrons. However, the flavor asymmetry $\Delta_T\bar{u}/\Delta_T\bar{d}$ could be investigated as a byproduct. General formalism for the polarized pd reactions was completed recently.[4] Imposing Hermiticity, parity conservation, and time-reversal invariance, we have found that 108 structure functions exist in the pd Drell-Yan processes. The number reduces to 22 after integrating over the virtual-photon transverse momentum $\vec{Q}_T$ or after taking the limit $Q_T \rightarrow 0$. The following spin asymmetries could be investigated in the pd reactions:

$$
\begin{array}{l}
<\sigma>, \ A_{LL}, \quad A_{TT}, \quad A_{LT}, \quad A_{TL}, \quad A_{UT}, \quad A_{TU}, \\
A_{UQ_0}, \ A_{TQ_0}, \ A_{UQ_1}, \ A_{LQ_1}, \ A_{TQ_1}, \ A_{UQ_2}, \ A_{LQ_2}, \ A_{TQ_2},
\end{array}
$$

where the subscripts U, L, and T indicate unpolarized, longitudinally polarized, and transversely polarized states. The superscripts Q_0, Q_1, and Q_2 are quadrupole polarizations, and they are associated with the spherical harmonics Y_{20}, Y_{21}, and Y_{22}. Because the deuteron is a spin-one hadron, there are structure functions which cannot be studied in the proton-proton reactions. There are 11 new structure functions in addition to the 11 ones in the Drell-Yan processes of spin-1/2 hadrons, and they can be measured by the quadrupole polarization asymmetries. The deuteron reaction may be realized in the RHIC-Spin project and other future ones. Because the essential formalism is now completed, it is also possible to study the asymmetry $\Delta_T\bar{u}/\Delta_T\bar{d}$ by measuring the transverse asymmetry A_{TT} and then by taking the difference between the polarized pp and pd cross sections. However, we should be careful about the way to measure the transverse asymmetry in the sense that the tensor structure functions may contribute.[4]

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4. S. Hino and S. Kumano, preprints SAGA-HE-136-98, SAGA-HE-139-98.