A Statistical approach for Flavor Decomposition of the Polarized Quark Distribution

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Introduction

The spin asymmetries of semi-inclusive [1] cross sections for the production of positively and negatively charged hadrons has been measured in deep-inelastic scattering of polarized positrons on polarized hydrogen and ^{3}He targets. The polarized quark and antiquark distribution is extracted as a function of x for up and down flavors. The up quark polarization is positive and the down quark polarization is negative in the measured range [2]. The flavor decomposition of polarized quark distributions are evaluated within the range 0.033 < x < 0.465 at an average Q^2=5GeV^2 by using Thermodynamical Bag Model (TBM) and results have been compared with experimental values obtained in the Deep Inelastic Scattering (DIS) by HERMES Collaboration[3].

Thermodynamical Bag Model

Thermodynamical Bag Model is a modified form of MIT Bag Model. The distribution function of u and d quarks has been studied separately. In the Infinite Momentum Frame (IMF), the nucleon is a bound state of three constituent quarks and gluons [4]. The mean number of quarks in the volume d^3p of the stationary
bag is given by

$$q_i = (6V/8\pi^3)[1+\exp(\in -\mu_i/T)]^{-1}$$ where

T is the temperature of the quark
gluon gas in the bag, V is the volume of the bag in the rest frame and i is the quark flavor. Considering the nucleon to be in the IMF, where quarks and gluon are treated as Fermions and Bosons respectively the number densities of up (u) and down (d) quarks [5] inside a proton can be expressed as

$$\varepsilon(T)V + BV = M$$
$$6(n_u - n_u^-) = 2/V = \mu_u T^2 + \mu_u^3/\pi^2$$
$$6(n_d - n_d^-) = 1/V = \mu_d T^2 + \mu_d^3/\pi^2$$
$$P = (1/3)\varepsilon(T) - B = 0$$

where $\varepsilon(T)$ is the energy density of the system and the chemical potential μ are obtained as a function of temperature T. M is the mass of the nucleon, P is the nucleon pressure. The bag constant is denoted by B and μ_u and μ_d are the chemical potential of u and d quarks. The flavor decomposition of polarized quark distributions are evaluated within the range 0.033<x<0.465 at an average Q^2=5GeV^2 by using TBM.

The up and down quark distribution functions expressed in terms of temperature and chemical potential is given by

$$u(x) = (\frac{6V}{4\pi^2})M^2 Tx \ln[1+\exp\{(\frac{1}{T})(\mu_u - \frac{Mx}{2})\}]$$
$$d(x) = (\frac{6V}{4\pi^2})M^2 Tx \ln[1+\exp\{(\frac{1}{T})(\mu_d - \frac{Mx}{2})\}]$$

The antiquark distribution functions $\bar{u}(x)$ and $\bar{d}(x)$ can be obtained by changing the sign of the chemical potentials μ_u and μ_d where u(x) and d(x) are the unpolarized distribution functions and Δu(x) and Δd(x) are the polarized distribution functions[6] which can be written as

$$\Delta u(x) = \cos 2\theta(x)[u(x) - 2/3(d(x))]$$
$$\Delta\bar{u}(x) = \cos 2\theta(x)[\bar{u}(x) - 2/3(\bar{d}(x))]$$
$$\Delta d(x) = -\cos 2\theta(x)[d(x)]/3$$
$$\Delta\bar{d}(x) = -\cos 2\theta(x)[\bar{d}(x)]/3$$

where

$$\cos 2\theta(x) = [1 + H_0/\sqrt{x}(1-x)^2]^{-1}$$

is known as the spin dilution factor. Here H_0 is a free parameter H_0 is chosen as -0.075 so that the Bjorken sum rule may be satisfied.

Polarized Quark Distribution

The flavor decomposition of polarized u quark distributions are evaluated by using the relation $\left[(\Delta u + \Delta\bar{u})/(u + \bar{u}) \right]$

similarly for d quarks, the flavour decomposition is

$$\left[\left(\Delta d + \Delta\bar{d}\right)/\left(d + \bar{d}\right)\right]$$

Where u and d are the unpolarised up and down quark distribution functions. Δu and Δd are the polarized distribution functions.

Result and Discussions

The flavor decomposition of the u and d quark polarization as a function of x has been studied using TBM and is shown in Fig.1 and Fig.2 respectively. In the case of inclusive deep-inelastic scattering (DIS) that only a fraction of the nucleon spin can be attributed to the quark spins and that the strange quark sea seems to be negatively polarized. But in the semi-inclusive polarized deep–inelastic scattering which separate spin contributions of quark and antiquark flavor to the total spin of the nucleon can be determined as a function of the Bjorken scaling variable x. It is evident that the flavor decomposition of polarized quark distribution in the nucleon in the range 0.033<x<0.465 at an average Q^2=5Gev^2 by using TBM. The evaluated values are shows good agreement with the experimental data from The HERMES Collaboration.

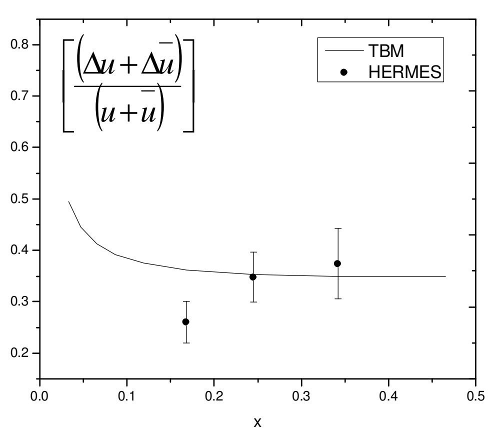

Fig 1: flavor decomposition of the u quark polarization as a function of x TBM (solid line) and The HERMES Collaboration data (solid circle).

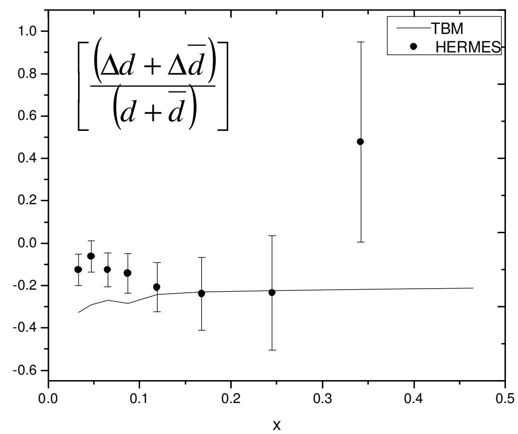

Fig 2: flavor decomposition of the d quark polarization as a function of x TBM (solid line) and The HERMES Collaboration data (solid circle).

References

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