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Estimation of Polarized Parton distribution at low order momentum transfer

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Abstract

The polarized quark distribution $x\Delta u(x), x\Delta\bar{u}(x), x\Delta d(x)$ and $x\Delta\bar{d}(x)$ are evaluated in the kinematic range 0.001< x < 1.0 at Q^2 = 3 Gev^2 using Thermodynamical Bag Model (TBM). The evaluated results are compared with experimental results and are in good agreement with experimental results.

Keyword: DIS, Polarized distribution function, TBM

INTRODUCTION

Still now the internal structure of the nucleon is an open question. To study the nucleon spin, many polarized lepton nucleon deep inelastic scattering experiments are demonstrated by SLAC, EMC and CERN. In1960s the internal structure of the nucleon could be studied with electron beam[1]. From this experiment, a hypothesis that inside nucleon there are point-like object is called partons. At earlier, 1970s the first DIS experiment with polarized beams experiments to investigate the spin of the nucleon [2-3] and since four decades, polarized lepton nucleon scattering experiments used to investigate the spin of the nucleon[4-8].

EMC discovered that Elli-Jaffe sum rule [9] is violated, a fact as a "spin crisis". In simplest approach of the Quark Patron Model(QPM), there are three valence quark inside a nucleon which have spin equal to ½. The spin of two quark is parallel to the nucleon spin and one quark has its spin anti parallel. In the simplest approach the quantity which measures a fraction of the nucleon spin carried by the quarks. The spin of the nucleon is carried by quarks, gluon and orbital momentum of quarks and gluon[10],

$$S_z^N = S_z^q + L_z^q + J_z^g = \frac{1}{2}$$

Where S_Z^N is nucleon spin, S_Z^q is quark spin, L_Z^q is orbital angular momentum of quark and J_Z^g is the total angular momentum of the gluon. The spin distribution of valence quark carries approximately 75% of proton spin and the remaining 25% spin is carried by the orbital angular momentum. In this paper, we evaluated spin distribution of polarized quarks using thermodynamical bag model at $Q^2 = 3\ GeV^2$ is compared with COMPASS experimental results[11].

THERMODYNAMICAL BAG MODEL (TBM):

The DIS of lepton on nucleon indicate the nucleon consists of three valance quark, sea quark and gluon confined within a small volume. TBM is modified form of MIT Bag Model treat quark as fermions and gluon as Bosons, the invariant mass(W) the final hadron and the equation of states are[12-16]:

$$\left[\varepsilon(T)V + BV\right]^2 = W^2 = M^2 + 2M\nu - Q^2 \tag{1}$$

$$6(\mathrm{n_u} - n_{\bar{u}}) = \frac{2}{V} = \mu_u T^2 + \frac{\mu_u^3}{\pi^2} \tag{2}$$

$$6(\mathrm{n_d} - n_{\bar{d}}) = \frac{2}{V} = \mu_d T^2 + \frac{\mu_d^3}{\pi^2} \tag{3}$$

Where ε(T)is energy densities of the system at a temperature T, V volume of the Bag, B Bag constant, W-mass of excited nucleon at temperature T, ν energy transfer, Q^2 is the square of four momentum transfer, M nucleon mass at ground state $(n_u - n_{\bar{u}})$ number density of up quark $(n_d - n_{\bar{d}})$ number density of down quark, μ_u chemical potential of up quark and μ_d chemical potential of down quark, ε(T) is obtained energy densities of up quark, down quark and gluon as follows

$$\varepsilon_{\mathrm{u}} + \varepsilon_{\bar{\mathrm{u}}} = \left(\frac{1}{8\pi^2}\right)\mu_u^4 + \left(\frac{1}{4}\right)\mu_u^2 T^2 + \left(\frac{7\pi^2}{120}\right)T^4 \tag{4}$$

$$\varepsilon_{\mathrm{d}} + \varepsilon_{\bar{\mathrm{d}}} = \left(\frac{1}{8\pi^2}\right)\mu_d^4 + \left(\frac{1}{4}\right)\mu_d^2 T^2 + \left(\frac{7\pi^2}{120}\right)T^4 \tag{5}$$

$$\varepsilon_g = \frac{\pi^2 T^4}{30} \tag{6}$$

since each flavor of quark and antiquark has 6 degrees of freedom of the energy of the system consisting of u, $\bar{u}$, d and $\bar{d}$ and the gluon has 16. The total energy density ε(T) of the Bag comprised of gluon can be written as in terms of energy density of the consistent by

$$\varepsilon(\mathrm{T}) = \mathrm{d_q}(\varepsilon_{\mathrm{u}} + \varepsilon_{\bar{\mathrm{u}}}) + d_q(\varepsilon_{\mathrm{d}} + \varepsilon_{\bar{\mathrm{d}}}) + d_g\varepsilon_{\mathrm{g}} \tag{7}$$

The pressure balance condition for the energy reduced condition with respect to the nucleon volume consideration equation (1) relate the invariant mass of the nucleon obtain from DIS kinematic variables and TBM.

The invariant mass in TBM is obtained by considering the energy transfer to the nucleon result in heating up the constituent of nucleon the temperature and two chemical potential are not free parameter evaluate in accordance with x and Q^2 either with fixed Q^2 (or) fixed x at very low Q^2 i.e. as Q^2 tends to zero and only the valance quark dominate when T~0 Mev the variant mass is equal to the mass of the nucleon at rest. As Q^2 increases the temperature of the bag increases and in turn more sea quark and gluon are generated and invariant mass corresponds to the excited state of nucleon for T > 0 Mev. The unpolarized up and down quark distribution are expressed as

$$u(x,Q^2)=\left(\frac{6V}{4\pi^2}\right)M^2Tx\ln\left\{1+\exp\left[\left(\frac{1}{T}\right)\left(\mu_u-\frac{Mx}{2}\right)\right]\right\} \tag{8}$$

$$d(x,Q^2)=\left(\frac{6V}{4\pi^2}\right)M^2Tx\ln\left\{1+\exp\left[\left(\frac{1}{T}\right)\left(\mu_d-\frac{Mx}{2}\right)\right]\right\} \tag{9}$$

The antiquark distribution can be obtained by putting μ>-μ

$$\bar{u}(x,Q^2)=\left(\frac{6V}{4\pi^2}\right)M^2Tx\ln\left\{1+\exp\left[\left(\frac{1}{T}\right)\left(-\mu_u-\frac{Mx}{2}\right)\right]\right\} \tag{10}$$

$$\bar{d}(x,Q^2)=\left(\frac{6V}{4\pi^2}\right)M^2Tx\ln\left\{1+\exp\left[\left(\frac{1}{T}\right)\left(-\mu_d-\frac{Mx}{2}\right)\right]\right\} \tag{11}$$

μ is the chemical potential of a quark with u(x, Q^2) and d(x,Q^2) include both valance and intrinsic sea quark.

POLARIZED QUARK DISTRIBUTION FUNCTION:

The polarized distribution function $\Delta u(x), \Delta\bar{u}(x), \Delta d(x)$ and $\Delta\bar{d}(x)$ which can be obtained by multiplying the unpolarized distribution by spin dilution factor,

$$\Delta\mathrm{u}(\mathrm{x})=\left[(\mathrm{u}(\mathrm{x})+\bar{\mathrm{u}}(\mathrm{x}))-\frac{2}{3}(d(x)+\bar{d}(x))\right]\cos 2\theta(x) \tag{12}$$

$$\Delta\bar{\mathrm{u}}(\mathrm{x})=\left[(\bar{\mathrm{u}}(\mathrm{x})-\frac{2}{3}\bar{d}(x)\right]\cos 2\theta(x) \tag{13}$$

$$\Delta\mathrm{d}(\mathrm{x})=\left[-\frac{1}{3}(d(x)+\bar{d}(x))\right]\cos 2\theta(x) \tag{14}$$

$$\Delta\bar{d}(x) = \left[-\frac{1}{3}\bar{d}(x) \right] \cos 2\theta(x) \tag{15}$$

Where

$$\cos 2\theta(x) = \frac{1}{1 + \left(\frac{H_0}{\sqrt{x}(1-x^2)} \right)}$$

is known as spin dilution factor[17] which vanishes as x→0 and becomes unity as x→1 characterizing the valence quark helicity contribution of proton. Since the spin dilution factor is derived from the first principles it is adjusted to satisfy the Bjorken sum rule which is considered as the fundamental test of QCD, this enable to determine explicitly. Here Ho is only free parameter which is used to satisfy the Bjorken sum rule.

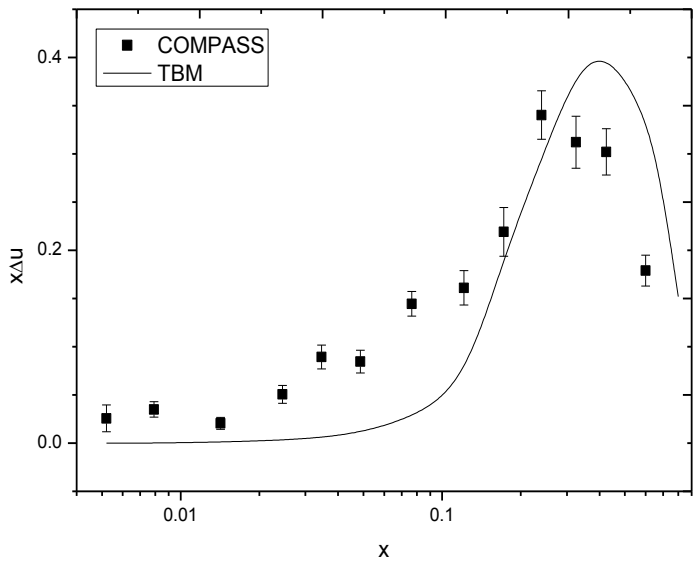

Figure I: The up quark helicity distribution $x\Delta u$ at Q^2 = 3 GeV^2 as a function of x. TBM results(solid line) are compared with COMPASS experimental data(shaded square).

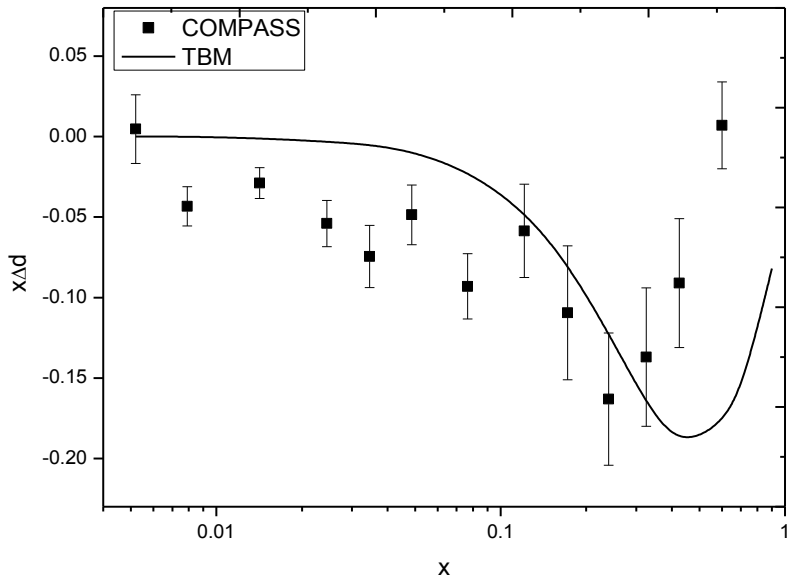

Figure II: The down quark helicity distribution $x\Delta d$ at $Q^2 = 3\ GeV^2$ as a function of x. TBM results(solid line) are compared with COMPASS experimental data(shaded square).

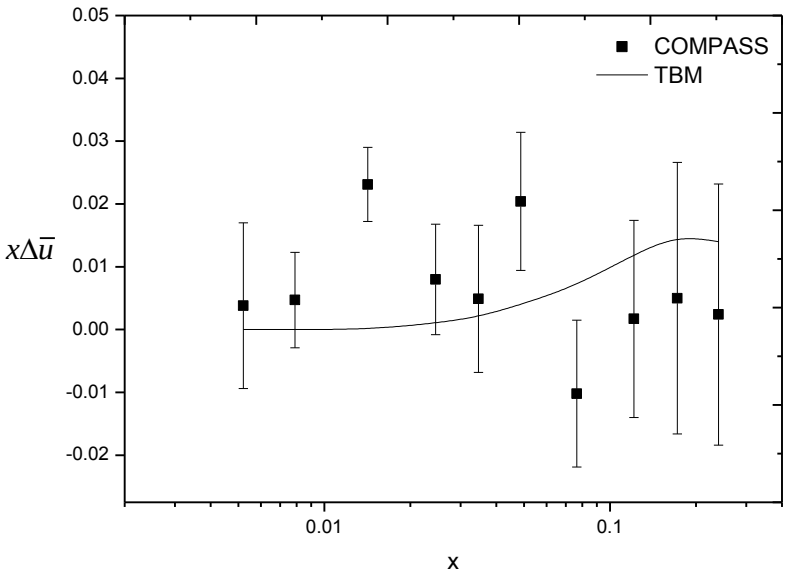

Figure III: The anti-up quark helicity distribution $x\Delta\bar{u}$ at $Q^2 = 3\ GeV^2$ as a function of x. TBM results(solid line) are compared with COMPASS experimental data(shaded square).

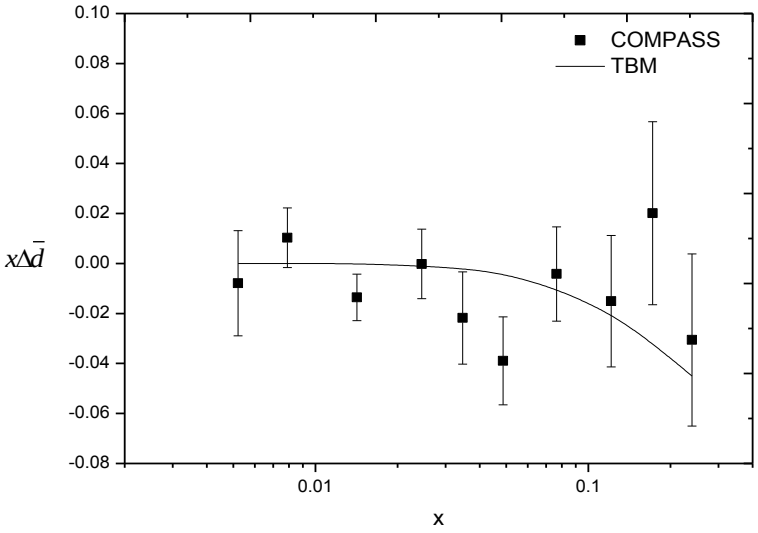

Figure IV: The anti-down quark helicity distribution $x\Delta\bar{d}$ at Q^2 = 3 GeV^2 as a function of x. TBM results(solid line) are compared with COMPASS experimental data(shaded square).

RESULTS AND DISCUSSIONS:

In the present work, the polarized distribution functions have been evaluated based on TBM. In figure I, the polarized distribution function increases with Bjorken variable x and then reaches the maximum value. Further increasing x value, the polarized up quark distribution functions decreases. In figure II, the polarized down quark distribution increases the negative value and then it decreases. In figure III, the polarized $x\Delta\bar{u}$ distribution is positive. $x\Delta d(x)$ and $x\Delta\bar{d}(x)$ negative distribution entire the whole kinematic region. This is due to the up quark has the positive charge and down quark has negative charge.

Table I: First moment of quark distributions at Q^2 = 3GeV^2 are given below in the table.

	0.004 < x < 0.3		0.004 < x < 0.7	
	COMPASS	TBM	COMPASS	TBM
Δu	$0.47 \pm 0.02 \pm 0.03$	0.41	$0.69 \pm 0.02 \pm 0.03$	0.628
Δd	$-0.27 \pm 0.03 \pm 0.02$	-0.36	$-0.33 \pm 0.04 \pm 0.03$	-0.443
$\Delta\bar{u}$	$0.02 \pm 0.02 \pm 0.01$	0.037	-	-
$\Delta\bar{d}$	$-0.05 \pm 0.03 \pm 0.02$	-0.074	-	-
Δu_v	$0.46 \pm 0.03 \pm 0.03$	0.132	$0.67 \pm 0.03 \pm 0.03$	0.77
Δd_v	$-0.23 \pm 0.05 \pm 0.02$	-0.034	$-0.28 \pm 0.06 \pm 0.03$	-0.19

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