Evaluation of Nachtmann Moments for Structure functions in Thermodynamical Bag Model

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Introduction

The Thermodynamical Bag Model (TBM) is a successful model in explaining the nuclear phenomena and by applying TBM, Nachtmann moments for proton structure function are evaluated in the interval $1 \leq Q^2 \leq 100\ \mathrm{GeV}^2$ and compared with data extracted from structure function measurements with the CLAS detector. Also the ratio of neutron to proton moments and the difference in moments are evaluated at $Q^2 = 4\mathrm{GeV}^2$.

Moments of Structure function

The connection between the partonic structure of hadrons in QCD approach is made through *moments*, or x-*weighted integrals*, of structure functions. A very powerful tool for analyzing in QCD the Q^2 dependence of the moments $M_n(Q^2)$ is represented by the Operator Product Expansion (OPE) and the *moments* are given as a series expansion in terms of matrix elements of local operators [1], namely

$$M_n(Q^2) = \sum_{\tau=2}^{\infty} E_{n\tau}(Q^2, \mu) O_{n\tau} \left(\frac{1}{Q^2}\right)^{\frac{1}{2}(\tau-2)} \quad (1)$$

where μ is the renormalization scale, $O_{n\tau}$ is the reduced matrix element of local operators with a definite spin 'n' and twist 'τ' and $E_{n\tau}$ is a short-distance coefficient calculable in pQCD. The first term of the series (1) is the Leading Twist (LT) and is determined by single parton distributions in the target and the following terms are Higher Twists (HT) that depend on multi-parton correlations. The two standard moments of structure functions used are Cornwall-Norton and Nachtmann moments. Here Nachtmann definition of moments is chosen instead of Cornwall-Norton moments just for the reason that the effects arising from target-mass corrections are cancelled out.

Nachtmann moment $M_n(Q^2)$ of the structure function F_2 is given by

$$M_n(Q^2) = \int_0^1 dx \frac{\xi^{n+1}}{x^2} F_2(x,Q^2) \frac{3+3(n+1)r+n(n+2)r^2}{(n+2)(n+3)} \quad (2)$$

where 'n' is the order of the moment, $\xi = 2x/(1+r)$ is Nachtmann variable with M being the nucleon mass and $r = \sqrt{1+4M^2x^2/Q^2}$. Using Nachtmann moments dynamical HTs can be extracted for multi-parton correlations. The structure function F_2 is evaluated from the statistical distribution of TBM.

Thermodynamical Bag Model [TBM]

TBM is a modified form of MIT Bag model. Here the quarks and gluons are treated as fermions and bosons, respectively. Considering the thermodynamical bag as an unpolarized nucleon and restricting the consideration to u and d valence quarks, the equations [2-4] defining quarks and antiquarks are

$$q(x) = \left(\frac{6V}{4\pi^2}\right)M^2 Tx.\ln[1 + \exp\{(\frac{1}{T})(\mu_q - \frac{Mx}{2})\}] \quad (3)$$

$$\bar{q}(x) = \left(\frac{6V}{4\pi^2}\right)M^2 Tx.\ln[1 + \exp\{(\frac{1}{T})(-\mu_q - \frac{Mx}{2})\}] \quad (4)$$

where V is the volume of the bag, B the bag constant, M the mass of the nucleon and ν the energy transfer, μ_q is the chemical potential. In the parton model, the distribution function of the quark momenta is denoted by $q_i(x)$ and the momentum distribution of antiquarks is denoted by $\bar{q}_i(x)$. Instead of parameterized structure function F_2, we are using the sum of the momentum distributions weighted by x and z_i^2 and hence

$$F_2(x) = x\sum_i z_i^2[q_i(x) + \overline{q}_i(x)] \qquad (5)$$

Now the moments of proton and neutron structure functions are evaluated using the equations (3) to (5) in (2).

Results and Discussion

Figure 1 compares the evaluated proton moments of order n=2 in the interval $1 \leq Q^2 \leq 100$ GeV^2 using TBM with the evaluated moments along with statistical and systematic uncertainties of the CLAS data [5]. The values show a good agreement almost over the entire range of Q^2. Figure 2 shows the ratio of neutron to proton moments versus 'n'. Full triangles and open dots correspond to the results obtained with and without nuclear corrections, respectively [5]. The ratio is slightly higher than the value of 3/7, suggested by perturbative QCD arguments. Also figure 3 shows (p-n) moments of the nucleon F_2 structure function evaluated from TBM compared with data [5] and lattice QCD simulations at $Q^2 = 4$GeV^2. The deviations at higher orders of 'n' show the requirements of multiparton correlation.

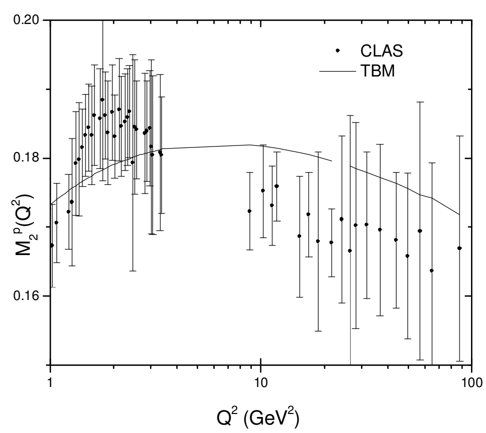

Fig 1: $M_2^p(Q^2)$ as a function Q^2. The calculated TBM values compared with CLAS data including uncertainties.

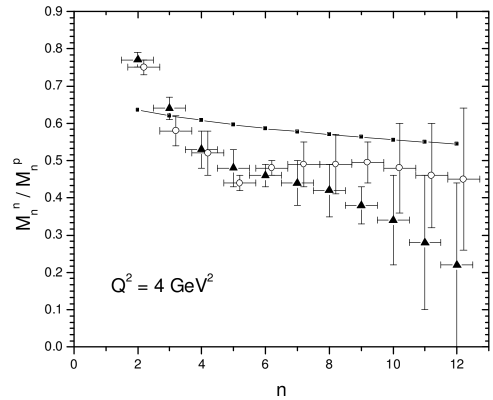

Fig 2: Ratio of neutron to proton moments versus 'n': TBM values compared with results of [5] with (full triangles) and without (open dots) nuclear corrections, evaluated at $Q^2 = 4$ GeV^2

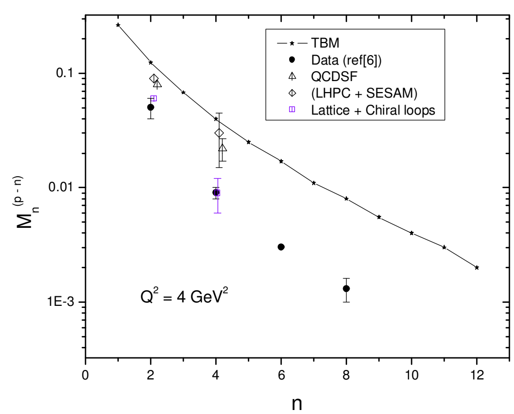

Fig 3: Calculated TBM values compared with other measurements evaluated at $Q^2 = 4$ GeV^2.

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