CBPF-NF-021/97

Evaluation of higher twist corrections to Gottfried sum rule

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ABSTRACT

Higher twist corrections to the Gottfried sum rule are estimated in the framework of a quark-diquark model of the nucleon. The parameters of the model have been previously fixed by fitting the measured higher twist corrections to the proton unpolarized structure function $F_2^p(x, Q^2)$. The resulting corrections to the Gottfried sum rule turn out to be very small, as for the Bjorken sum rule, previously calculated. The physical features of the diquark model from which these results follow are discussed.

Key-words: Higher twist; Gottfried sum rule; Diquark.

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More and more accurate measurements of the neutron and proton structure functions $F_2(x, Q^2)$ allow a precise determination of the Gottfried sum rule integral (EISELE, 1995)

$$S_G \equiv \int_0^1 \frac{dx}{x}\,[F_2^p(x,Q^2) - F_2^n(x,Q^2)] = \frac{1}{3} + \frac{2}{3}\int_0^1 dx\,[\bar{u}(x,Q^2) - \bar{d}(x,Q^2)] \quad (1)$$

and a possible evaluation of the isospin symmetry violation of the sea which results from the measured value of $S_G \neq 1/3$.

However, in order to extract a reliable value of $\int dx\,[\bar{u}(x,Q^2) - \bar{d}(x,Q^2)]$ from Eq. (1) one should take into account all possible corrections, both perturbative QCD ones and higher twist ones. The former are known to be rather small, less than 1% (HINCHLIFFE & KWIATKOWSKI, 1996); we give here an estimate of the latter using a specific quark-diquark model of the nucleon recently used to compute higher twist corrections to $F_2^p(x,Q^2)$ (ANSELMINO *et al.*, 1996) and to Bjorken sum rule (ANSELMINO, CARUSO & LEVIN, 1995); they also will turn out to be negligibly small, so that Eq. (1) can be safely used to extract precise information on the isospin asymmetry of the nucleon sea.

Higher twist corrections induced by a quark-diquark structure of the valence component of the proton were already discussed in (ANSELMINO *et al.*, 1992), where it was shown that such corrections, at moderate Q^2 values, give positive contributions to S_G, thus increasing the value 1/3 obtained in case of equal contributions from u and d sea quarks. We compute here these actual numerical contributions by exploiting the parameters of the model as fixed in (ANSELMINO *et al.*, 1996), considering a most general derivation of diquark contributions to the nucleon structure functions that can be found in (ANSELMINO *et al.*, 1990).

According to the notations of (ANSELMINO *et al.*, 1996) and (ANSELMINO *et al.*, 1990) one has

$$\begin{aligned}\int_0^1 \frac{dx}{x}\,[F_2^p(x,Q^2) - F_2^n(x,Q^2)]_{q-D} &= \frac{1}{3} + \frac{2}{3}\int_0^1 dx\,[\bar{u}(x) - \bar{d}(x)] \\ &- \frac{4}{9}\sin^2\Omega\, D_1^2 + \frac{8}{27}\sin^2\Omega \int_0^1 dx\, f_{V_{uu}}(x)\times \qquad (2)\\ &\times \left\{\left[D_1 + Q^2\left(1 + \frac{Q^2}{4m_N^2x^2}\right)D_3\right]^2 + 2\left(1 + \frac{Q^2}{4m_N^2x^2}\right)D_1^2\right\},\end{aligned}$$

where the first line is the usual quark parton model result, the first term on the second line, with the negative sign, originates from the inelastic scattering off a diquark and the last term from the elastic scattering off a diquark (ANSELMINO *et al.*, 1996). Many diquark contributions cancel in the $p - n$ difference and one remains only with the contribution of vector diquarks made of uu quarks; $\sin^2\Omega$ is just the probability of having a vector diquark in the proton and the $D_{1,3}$ are form factors explicitely given in (ANSELMINO *et al.*, 1996) and (ANSELMINO, CARUSO & LEVIN, 1995) and in Eq. (4) below. The vector diquark distribution function $f_{V_{uu}}(x)$ integrates to 1.

The higher twist contributions to the Gottfried sum rule, as modeled by the quark-diquark model, are then positive and are given by the last two lines of Eq. (2), which can be rewritten as

$$\begin{aligned}[\delta S_G]_{q-D} = {} & \frac{4}{9}\sin^2\Omega\left[D_1^2 + \frac{4}{3}Q^2 D_1 D_3 + \frac{2}{3}Q^4 D_3^2\right] \\ & + \frac{8}{27}\sin^2\Omega\,\frac{Q^2}{2m_N^2}\left[D_1^2 + Q^2 D_1 D_3 + Q^4 D_3^2\right]\int_0^1 \frac{dx}{x^2} f_{V_{uu}}(x) \\ & + \frac{8}{27}\sin^2\Omega\,\frac{Q^8}{16m_N^4} D_3^2 \int_0^1 \frac{dx}{x^4} f_{V_{uu}}(x)\,;\end{aligned} \tag{3}$$

$[\delta S_G]_{q-D}$ vanishes at large Q^2 according to the form factor behaviours. We evaluate it here at $Q^2 = 4\ (\mathrm{GeV}/c)^2$ by using, from (ANSELMINO *et al.*, 1996), the same parameters which fit the higher twist corrections to $F_2(x, Q^2)$:

$$\begin{aligned}\sin^2\Omega &= 0.19 \\ f_{V_{uu}} &= N x^{7.93}(1-x)^{3.32} \\ D_1 &= \left(\frac{1.21}{1.21 + Q^2}\right)^2 \\ D_3 &= \frac{Q^2}{m_N^4} D_1^2\end{aligned} \tag{4}$$

where $N = 1/B(8.93;\, 4.32)$ is the normalization constant (B is the Euler beta function).

Eqs. (3) and (4) yield

$$[\delta S_G]_{q-D}\,(Q^2 = 4) \simeq 0.0061 \tag{5}$$

thus showing that such corrections are less than 1% at $Q^2 = 4$ (GeV/c)^2, which is the Q^2 value at which we have the most accurate data on S_G (EISELE, 1995). Eqs. (3) and (4) allow an explicit determination $[\delta S_G]_{q-D}$ at any Q^2 value and one sees that it decreases from 2% at $Q^2 = 1$ (GeV/c)^2 to 0.2% at $Q^2 = 10$ (GeV/c)^2. Fig. 1 shows the behaviour of $[\delta S_G]$ as a function of Q^2 in this range.

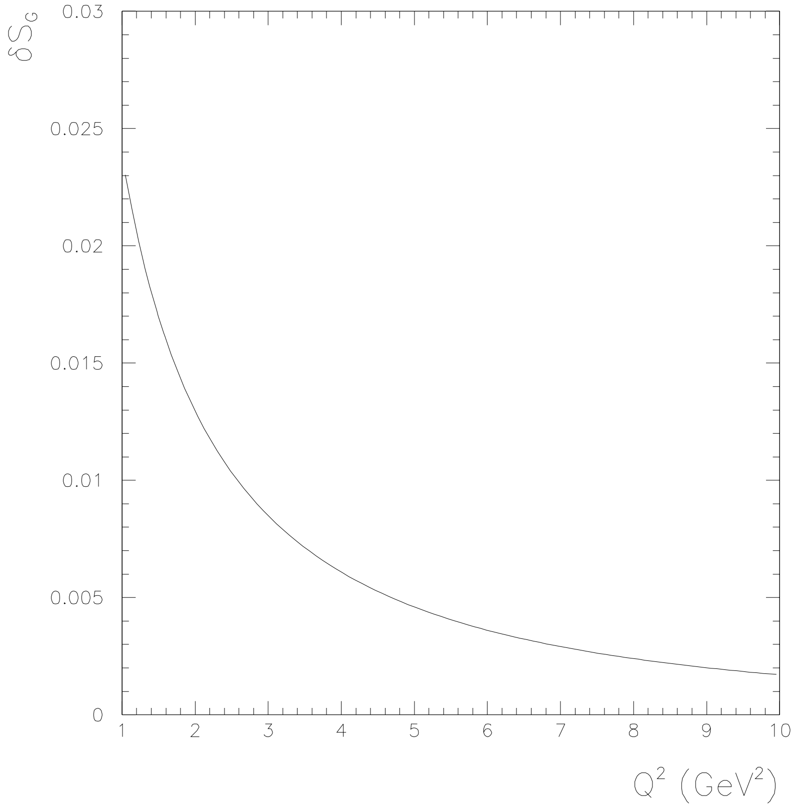

Fig. 1 *Behaviour of* $[\delta S_G]$ *as a function of* Q^2 *in a kinematical region where diquarks are relevant.*

In conclusion we have evaluated the higher twist corrections to Gottfried sum rule in an explicit phenomenological model which takes into account quark correlations and clustering; the concept of diquarks and its phenomenological importance is by now well established (ANSELMINO *et al.*, 1993) and this same model has been previously applied to a very accurate description of higher twist corrections to F_2^p so that its parameters are now fixed. We have shown that higher twist corrections to S_G are indeed very small (and comparable to the perturbative QCD ones) and one can safely use the experimental values to obtain information on the difference between the total amount of u and d quarks in the proton sea.

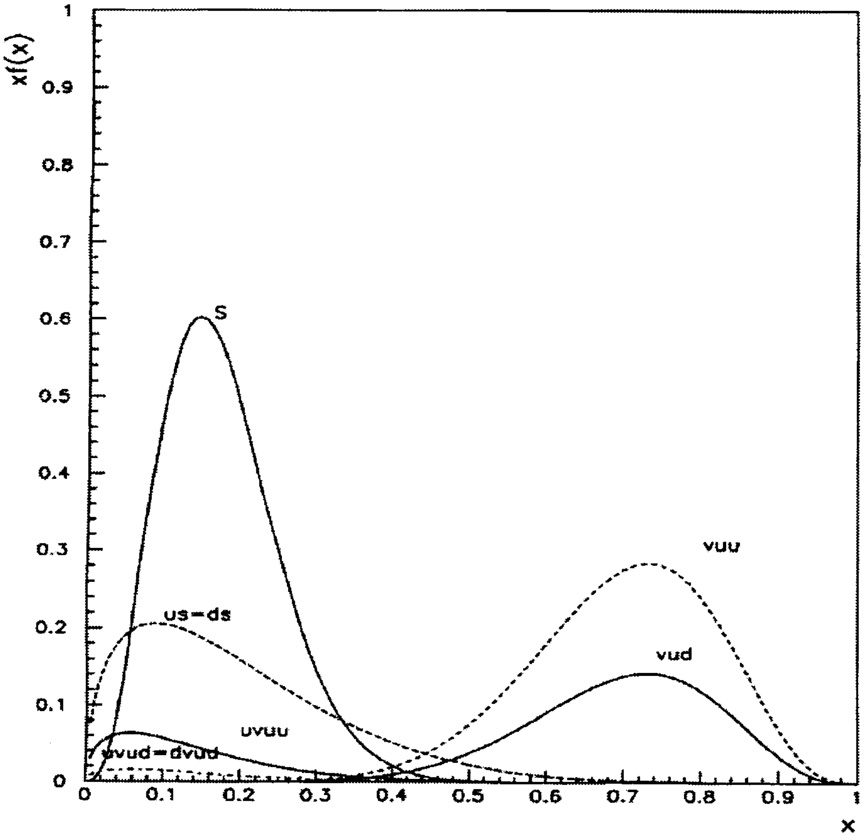

Fig. 2 *This figure shows the prediction of our model for the generalized partonic distributions* $xf_C(x)$, *as a function of* x, *for each constituent* $C = S, V, q$; *the quark and diquark distributions* $f_C(x)$ *and the values of their parameters are given in (ANSELMINO et al., 1996). The quark content of* S *is always* (ud) *while vector diquark* V *may be made of* (uu) *or* (ud) *system;* u_S *and* u_V *refer to* u *quarks inside a particular scalar and vector diquark, respectively.*

Why are diquark corrections to Gottfried and Bjorken sum rules so small? Considering that only vector diquarks contribute to these sum rules, one can easily conclude that the smallness of the diquark contributions to both of them is due to some intrinsic features of the quark-diquark model of the nucleon (ANSELMINO *et al.*, 1996), namely: the strong $SU(6)$ violation ($\sin^2 \Omega = 0.19$) favouring scalar diquarks; the mass scale of the vector diquark form factor which turns out to be small, $Q_V^2 = 1.21$ (GeV/c)^2, thus corresponding to a large size; and the vector diquark x distribution which is found to be peaked at $x \simeq 0.7$, suggesting that vector diquarks consist of two almost uncorrelated quarks (*Cf.* Fig. 2).

Acknowledgements - M.A. would like to thank the members of the LAFEX at CBPF, where most of this work was done, for the kind hospitality. Both authors are in debt with CNPq of Brazil for financial support.

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