PROCEEDINGS OF SCIENCE

Contribution of Vector Mesons to F_2 Structure Function

Farid Zamani*
Villanova University
E-mail: farid.zamani@villanova.edu

In recent years we have used meson cloud to investigate polarized and unpolarized nucleon structure functions [1-6]. Here we present the contribution of vector mesons along with their baryon octets and decuplets counterparts to the meson cloud [1]. For the bare nucleon we use a quark-diquark model. Our work has shown that it is necessary for the core nucleon to have a spin-1 diquark component. In this work we will use superposition of spin-0 and spin-1 diquarks as the core nucleon to calculate quark distribution functions. Then, using pQCD, an initial gluon distribution is generated inside the core nucleon. The physical nucleon is assumed to be a superposition of the bare nucleon plus the virtual light-cone Fock states of the baryon-meson pairs. The initial distributions are evolved using DGLAP equations. The F_2 structure functions calculated from the evolved distributions are compared with NMC and Zeus results along with a CTEQ fits. Also, we will show that the meson cloud is a contributing factor to sea quark asymmetry and one needs both pseuoscalar mesons and vector mesons to account fully for the Gottfried sum-rule violation.

8th Conference Quark Confinement and the Hadron Spectrum
September 1-6 2008
Mainz, Germany

*Speaker.

PoS(Confinement8)091

1. Formulation

1.1 Proton Wavefunction:

We start with writing the wave function of the nucleon as $\Psi = \Phi\chi\phi$, where Φ, χ and ϕ are the flavor, spin and momentum distributions, respectively. We are going to consider three different wave functions for the core nucleon. Set-1 and Set-3 are quark-diquark system. For set-1 we assume that the nucleon is a quark-diquark system with spin-0 diquark and for Set-3 a superposition of spin-0 and spin-1 diquarks [1]:

$$\begin{aligned}
\Psi_1 = \tfrac{A}{\sqrt{2}}[\ & uud(\chi^{\rho 1}\phi_1^{\lambda 1} + \chi^{\rho 2}\phi_1^{\lambda 2}) - udu(\chi^{\rho 1}\phi_1^{\lambda 1} - \chi^{\rho 3}\phi_1^{\lambda 3}) - \\
& duu(\chi^{\rho 2}\phi_1^{\lambda 2} + \chi^{\rho 3}\phi_1^{\lambda 3})] + \\
\tfrac{B}{\sqrt{6}}[\ & uud(\chi^{\rho 1}\phi_1^{\rho 1} + \chi^{\rho 2}\phi_1^{\rho 2} - 2\chi^{\rho 3}\phi_1^{\rho 3}) + \\
& udu(\chi^{\rho 1}\phi_1^{\rho 1} - 2\chi^{\rho 2}\phi_1^{\rho 2} + \chi^{\rho 3}\phi_1^{\rho 3}) + \\
& duu(-2\chi^{\rho 1}\phi_1^{\rho 1} + \chi^{\rho 2}\phi_1^{\rho 2} + \chi^{\rho 3}\phi_1^{\rho 3})] + \\
\tfrac{C}{\sqrt{2}}[\ & uud(\chi^{\lambda 1}\phi_1^{\rho 1} + \chi^{\lambda 2}\phi_1^{\rho 2}) - udu(\chi^{\lambda 1}\phi_1^{\rho 1} - \chi^{\lambda 3}\phi_1^{\rho 3}) - \\
& duu(\chi^{\lambda 2}\phi_1^{\rho 2} + \chi^{\lambda 3}\phi_1^{\rho 3})] + \\
\tfrac{D}{\sqrt{6}}[\ & uud(\chi^{\lambda 1}\phi_1^{\lambda 1} + \chi^{\lambda 2}\phi_1^{\lambda 2} - 2\chi^{\lambda 3}\phi_1^{\lambda 3}) + \\
& udu(\chi^{\lambda 1}\phi_1^{\lambda 1} - 2\chi^{\lambda 2}\phi_1^{\lambda 2} + \chi^{\lambda 3}\phi_1^{\lambda 3}) + \\
& duu(-2\chi^{\lambda 1}\phi_1^{\lambda 1} + \chi^{\lambda 2}\phi_1^{\lambda 2} + \chi^{\lambda 3}\phi_1^{\lambda 3})].
\end{aligned} \tag{1.1}$$

For Set-2, we assume that there is no clustering of the quarks inside the nucleon [7]:

$$\Psi_2 = \frac{-1}{\sqrt{3}}(uud\chi^{\lambda 3} + udu\chi^{\lambda 2} + duu\chi^{\lambda 1})\phi_2. \tag{1.2}$$

For Set-1 we use $A = .9798$, $B = -.2$, $C = 0.0$ and $D = 0.0$ in Eq.(1). Equation (2) is used for set-2. For Set 3 we choose $A = -0.7874$, $B = 0.0$, $C = 0.0$, and $D = -0.6164$ in Eq.(1). Also, in Eqs. (1) and (2), u and d represent the up and down flavor. χ^{ρ_i}, and χ^{λ_i} with $i = 1,2,3$ represent the Melosh transformed spin wave functions.

1.2 Radiative Gluons:

Having constructed the wavefunction for the core nucleon, we know introduce gluons inside the nucleon. Following the work done by Barone and collaborators [8], one can consider a transition $v(x) \to q(x) + g(x)$, where $v(x)$ is the initial valence quark distribution in quark model and g(x) is the gluon distribution generated in the process. Knowing $v(x)$, one can calculate $q(x)$ and $g(x)$. This procedure can be repeated in small steps until one reaches the desired final Q^2, which in our case is 0.5 GeV^2. In our case, at this stage we have introduced about six gluons that carry about 27% of the nucleon's momentum. From here on we identify the sets as set-1g, set-2g and set-3g, to highlight the fact the gluons have been introduced in the core nucleon. The next step is to introduce meson cloud at this momentum transfer and evolve the distributions to the final momentum transfer.

1.3 Meson cloud model in light-cone frame:

Using the convolution model, one can decompose the physical nucleon in terms of the core nucleon and intermediate, virtual meson-baryon states [1-6, and the references therein]:

$$| N\rangle = Z^{1/2}[| N\rangle_{bare} + \sum_{BM} \beta_{BM} | BM\rangle], \tag{1.3}$$

where Z is the probability of the physical nucleon being in the core state, BM stands for a virtual baryon-meson state and β_{BM} is the probability amplitude for the physical nucleon being in BM state. The summation in Eq. (1.3), in general, includes all physically possible pairs from the meson octet and baryon octet and decuplet. In terms of the quark distributions one can write:

$$q_N(x) = Z[q_{N,core}(x) + \sum_{MB} \alpha_{MB}(\int_x^1 n_{MB} q_M(\frac{x}{y})\frac{dy}{y} + \int_x^1 n_{BM} q_B(\frac{x}{y})\frac{dy}{y})], \tag{1.4}$$

where x is the fraction of the total momentum of the nucleon being carried by the quark, q, α_{MB} are spin-flavor Clebsch-Gordan coefficients, n_{MB} and n_{BM} ,the splitting functions, are the probabilities of the nucleon being in state of MB or BM respectively, y is the fraction of the momentum being carried by the meson(baryon) in $n_{MB}(y)(n_{BM}(y))$. We have evaluated the splitting functions for vector mesons-baryon octet pairs[1]:

$$\begin{aligned}
n_{MB}(y) = {} & \frac{1}{64\pi^2 m_M^2}\frac{1}{y^4(1-y)^2}\int_0^\infty dk_\perp^2 \frac{| \Gamma_{MB}(M_{MB}^2) |^2}{(M_{MB}^2 - m_N^2)^2} \times (f_{NMB}^2(4m_M^4 y^2 \times \\
& ((1-y)^2(m_B - m_N y)^2 + (1+y)^2\mathbf{k_\perp^2}) + 4((1-y)(m_B^2 - m_N^2 y) + \mathbf{k_\perp^2})^2 \times \\
& ((1-y)^2(m_B - m_N y)^2 + 8m_M^2 y((1-y)^2(m_B - m_N)^2(8m_B m_N y + m_N^2 \times \\
& (5-y)y - m_B^2(1-5y)) + (1-y)(10m_B m_N(1-y)y - m_N^2(5-y)y \times \\
& (1-2y) + m_B^2(2-y)(1-5y))\mathbf{k_\perp^2} - (1-(6-y)y)\mathbf{k_\perp^4}))) + f_{NMB} g_{NMB} \times \\
& (4m_M^4(1-y)y^3(m_B - m_N y) + 4(1-y)y((1-y)(m_B^2 - m_N^2 y) - \mathbf{k_\perp^2}) \times \\
& (m_B m_N (1-y)^2(m_B - m_N y) - (m_B + 2m_B y - m_N(2+y))\mathbf{k_\perp^2}) + \\
& 4m_M^2(1-y)y^2(-9(m_B - m_N)(1-y)(m_B - m_N y)^2 - 2(m_N(5-4y) + \\
& m_B(4-5y)\mathbf{k_\perp^2}))) + g_{NMB}^2(m_M^4 y^4 + 2m_m^2 y^2((1-y)^2 + (4m_B^2 - 9m_B m_N y + \\
& 4m_N^2 y^2) + (4-y(1-4y))\mathbf{k_\perp^2}) + y^2(m_B^2 m_N^2(1-y)^4 + 2 \times \\
& (2m_B^2 - 3m_B m_N + 2m_N^2)(1-y)^2 y^2 + y^4))),
\end{aligned} \tag{1.5}$$

and vector mesons-baryon decuplet pairs[1]:

$$\begin{aligned}
n_{MB}(y) = {} & \frac{f_{NMB}^2}{48\pi^2}\frac{1}{y(1-y)}\int_0^\infty dk_\perp^2 \frac{| \Gamma_{MB}(M_{MB}^2) |^2}{(M_{MB}^2 - m_N^2)^2}\frac{1}{6m_B^2 y^3(1-y)^2} \times \\
& (m_B^4(y-1)^4(m_B^2 + 3m_N^2 y^2 + m_B^2(y-1)^2(3+y(-2+3y))) \times \\
& \mathbf{k_\perp^2} + (m_N^2 y^2 + m_B^2(3+4(y-1)y))\mathbf{k_\perp^2} + \mathbf{k_\perp^6} + m_M^4 y^4(3m_B^2 + \\
& m_N^2 y^2 + \mathbf{k_\perp^2}) + 2m_M^2 y^2(m_B^2(y-1)^2(m+B^2 - 6m_B m_N + m_N^2 y^2) + \\
& (m+B^2 - 6m_B m_N + m_n^2 y^2) + (m_N^2 y^2 + m_B^2(y^2-1))\mathbf{k_\perp^2} + \mathbf{k_\perp^4})).
\end{aligned} \tag{1.6}$$

where $V_{IMF}(y, k_\perp^2)$ is the vertex function and $\Gamma_{BM}(y, k_\perp^2)$ is the vertex form factor. Having the splitting function one can calculate the initial dressed polarized quark distributions. These distributions can be evolved using the DGLAP equations [9-11]. Using the evolved distributions we can calculate F_2 structure functions for proton and neutron and evaluate the Gottfried sum rule (GSR), which is [12]:

$$\int_0^1 \frac{dx}{x}[F_{2p}(x,Q^2) - F_{2n}(x,Q^2)] = \frac{1}{3}. \tag{1.7}$$

2. Results and discussion

In Figs. 1 and 2 we present evolved xu-valence distribution and F_{2p} structure function, respectively. All data have been evolved to $Q_f^2 = 70GeV^2$. In Fig. 1 one can observe that the distribution with spin-1 diquark and vector meson cloud has the best agreement with CTEQ6M [13] and Zeus [14-16]. Fig. 2 demonstrates that our model calculation of the structure function agrees reasonably well with CTEQ6M[13], NMC[17,18] and ZEUS[14-16], down to x about 0.02. For x less that 0.02 the all versions of our models overestimate

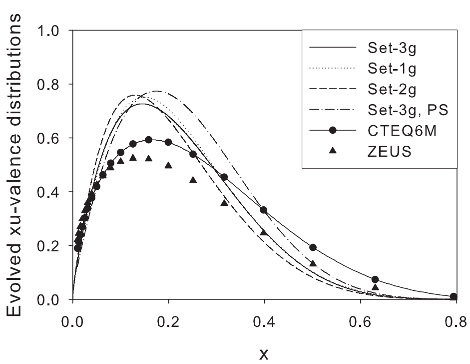

FIG.1. Evolved xu-valence distributions for Set-3g(spin-0 and spin-1 diquark), Set-1g (only spin 0 diquark), Set-2g (no diquark), Set-3g, PS (no vector mesons, only pseudoscalar mesons), CTEQ6M, and ZEUS.

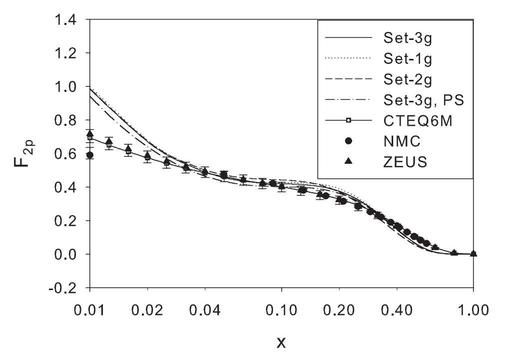

Fig. 2. F_2 structure function for proton. The lines are the results of our models Set-3g (spin-0 and spin-1 diquark), Set-1g (only spin-0 diquark), Set-2g (no diquark) and Set-3g, PS (no vector mesons, only pseudoscalar mesons). Circles and triangles are NMC and ZEUS fits, respectively, at $Q^2 = 70$ GeV^2. The line-symbol is the CTEQ6M fit.

the observation, indicating the break down of the model for that range.

Table 1: GSR results for this work, NMC [17], ZEUS [14,15], and CTEQ6M 5-flavor [13] at $Q^2 = 70\ GeV^2$.

	Set-3g	Set-2g	Set-1g	Set-3g, PS	NMC	ZEUS	CTEQ6M-5f
GSR	0.207	0.209	0.219	0.265	0.212	0.232	0.236

In Table 1 we present our results along with the NMC, ZEUS and CTEQ6M. As can be seen if we use only pseudoscalar mesons the GSR violation is not as pronounce as observation. However, inclusion of the vector mesons rectifies the situation and we can fully account for the GSR violation.

To summarize, we used a quark-diquark model for the core nucleon. We considered three different wavefunctions for the core nucleon. Two were two variations of quark-diquark model and the third represented a case with no diquark inside the nucleon. The two diquark cases considered were one with only spin-0 diquark and the other a superposition of spin-0 and spin-1 diquark. We introduced gluons through a radiative process. In the final step the meson cloud was introduced and the distributions were evolved to the final momentum transfer. Both diquark models had a reasonably good agreement with experimental results for F_2 structure functions down to x about 0.02 specially the case with spin-1 diquark was considered. Our calculations also showed that the meson cloud is a source of sea quark asymmetry which leads to the GSR violation and to fully account for GSR violation one should include both pseudoscalar and vector mesons in the meson cloud.

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