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Nucleon structure functions based on the relativistic Faddeev approach to the NJL model

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The valence (v) and sea quark distributions extracted from the experimental nucleon structure functions show an interesting flavor dependence: $d_v(x)$ is 'softer' than $u_v(x)$, i.e; it is more concentrated at smaller x, while $\overline{d}(x)$ is larger than $\overline{u}(x)$ in the whole region of x. The first feature can naturally be explained [1] as an effect of quark-quark (diquark) correlations in the scalar ($J^P = 0^+$, $T = 0$) channel, while the second feature is usually attributed to the pion cloud around the valence quarks.

In this work we investigate the influence of attractive quark-quark correlations in the axial vector ($J^P = 1^+$, $T = 1$) channel on the flavor dependence of the valence quark distributions. Our approach is based on the relativistic Faddeev approach [2] to the Nambu-Jona-Lasinio (NJL) model [3]. Any 4-fermi interaction of the NJL type can be characterized by the ratios $r_s = g_s/g_\pi$ and $r_a = g_a/g_\pi$ of the effective coupling constants in the scalar and axial vector qq channels to the one in the pionic $q\overline{q}$ channel [2]. We will use r_a as a free parameter to characterize the correlations in the axial vector diquark channel, and adjust r_s such as to reproduce the nucleon mass as the pole of the relativistic Faddeev equation in the 'static approximation' to the Faddeev kernel [4,5]. We use the constituent quark mass $M = 400MeV$, and employ the invariant mass regularization scheme [6]. We will consider the three parameter sets I, II, III shown in the upper part of table 1. The value of r_a used in case III reproduces also a bound state for the delta isobar.

In the lower part of table 1 we show some static properties of the nucleon, including corrections due to the pionic cloud. All the observables shown here seem to require the inclusion of the axial vector diquark channel. In fig.1 we show the ratio of structure functions F_2^n/F_2^p. [1] Effects of the pion cloud are taken into account by using the standard convolution formalism. We see that if r_a is large, the flavor dependence of the distributions is too weak to reproduce the data at large x. It seems that reasonable values of r_a are in the range between 0.0 and 0.25. The valence quark distributions for the case II are compared to the empirical distributions of ref. [8] in fig. 2. We note that for case I (strong scalar diquark correlations) the peak position of $x\, d_v(x)$ would move towards smaller x,

[1]These results are obtained by performing the Q^2 evolution up to the next-to-leading order [7] from a low energy scale $Q_0^2 = 0.16GeV^2$ to the experimental Q^2

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Table 1
Three different parameter sets for r_s, r_a, the corresponding scalar diquark masses (m_S), and some static properties of the nucleon

case	I	II	III	exp.
r_a	0	0.25	0.66	
r_s	0.73	0.63	0.50	
$M_S[MeV]$	600	684	766	
$g_A^{(3)}$	0.74	0.67	1.77	1.25
$g_A^{(0)}$	0.51	0.33	1.52	0.29 ± 0.06
μ_p	2.11	2.33	2.89	2.79
μ_n	-1.16	-1.51	-2.76	-1.91

but the overall shape (width and peak height) would become worse. We also show the difference of the sea quark distributions $\bar{d}-\bar{u}$ in fig.2. We see that the simple convolution formalism gives too less flavor asymmetry of the sea quark distributions, although the Gottfried sum is reproduced rather well ($S_G = 0.262$ compared to the experimental value 0.25 ± 0.026).

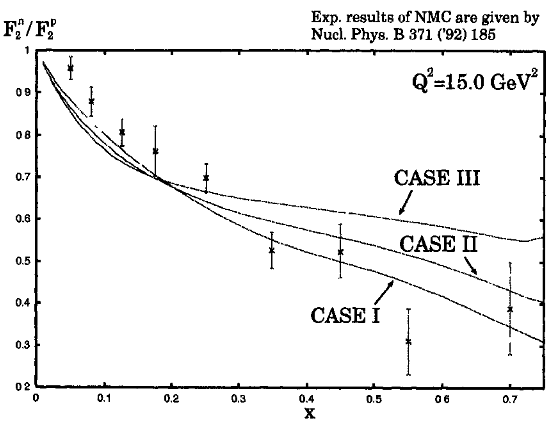

Figure 1. The ratio of structure functions F_2^n/F_2^p is shown for the three cases of table 1.

In conclusion, a reasonable description of the structure functions can be achieved with relatively weak correlations in the axial vector diquark channel. On the other hand, the static properties of the nucleon (except for the isoscalar spin sum $g_A^{(0)}$) seem to favor

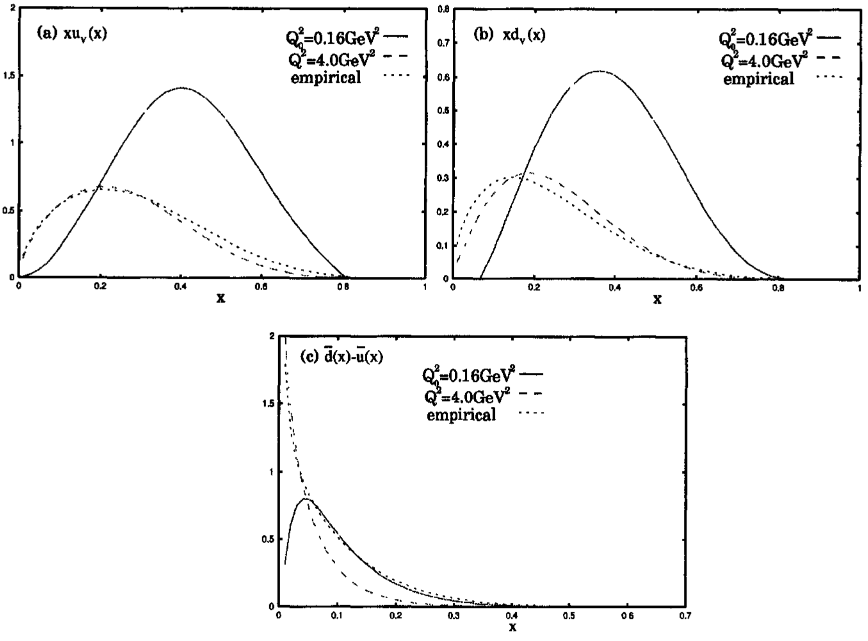

Figure 2. Valence u-quark distribution (a), d-quark distribution (b) and the difference of the sea quark distributions $\overline{d} - \overline{u}$ (c) including pionic cloud effects for case II of table 1. The result after the Q^2 evolution (dashed line) is compared to the empirical distribution (dotted line).

stronger correlations in this channel. Further investigations on this point are necessary.

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