Statistical Quark Model for the Nucleon Structure Function

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Abstract. A statistical quark model, with quark energy levels given by a central linear confining potential is used to obtain the light sea-quark asymmetry, $\bar{d}/\bar{u}$, and also for the ratio d/u, inside the nucleon. After adjusting a temperature parameter by the Gottfried sum rule violation, and chemical potentials by the valence up and down quark normalizations, the results are compared with experimental data available.

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We report results for the light sea-quark asymmetry, $\bar{d}/\bar{u}$ and also for the ratio d/u obtained in a statistical quark model [1], where the quark energy levels are given by a central linear confining potential [2]. The model is parameterized by experimental data, with the Gottfried sum rule (GSR) violation [3] being adjusted by a temperature parameter, and with two chemical potentials to fix the flavor normalization inside the nucleon. From the analysis of the E866 experiments [4], the value for the violation of the GSR is $I_{GSR} = \int_0^1 [\bar{d}(x) - \bar{u}(x)]dx = 0.118 \pm 0.012$. The up and down sea quarks are assumed to be massless, with levels given by a linear scalar plus vector potential [2]. The statistical quark model is outlined in Ref. [5]. In this reference, the model was shown to give a good description of the strangeness content of the nucleon [5] when compared with experimental data.

In Fig. 1, we report the results we have obtained by the model for the ratios $\bar{d}/\bar{u}$ [in the left frame of Fig. 1] and d/u [right frame of Fig.1], as functions of the Bjorken scale x. Initially, in spite of the fact that we fit the GSR violation with such a model, we obtain a constant ratio between the proton and neutron structure functions [constant dashed line of Fig.1]. Next, we incorporate in the model contributions from gluonic splitting processes, which is represented by the parameter α_s. This is shown in the left frame of Fig.1 by the small dashed curve, and in the right panel by the solid line. In the results shown for $\bar{d}/\bar{u}$, in the left panel of Fig.1, we also verify how the substructure of the constituent quarks can affect the results. Such substructure is obtained from a model for the structure function of a valence quark in the pion, given by the following parametrization [1]: $q_\pi(x) = N_\pi x^{a-1}(1 + A\sqrt{x} + Bx)(1-x)^D$, where: $N_\pi \equiv 1.212 + 0.498s + 0.009s^2, A \equiv -0.037 - 0.578s, a \equiv 0.517 - 0.020s, B \equiv 0.241 + 0.251s$, $D \equiv 0.383 + 0.624s$, with $s \equiv ln[ln(Q^2/0.204^2)/ln(\mu^2/0.204^2)]$ evaluated at $\mu^2 = 0.26$ GeV^2 [6]. Using this prescription, the constituent structure of the quark (antiquark) in

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the nucleon is given by $q(x) = -\int_x^1 \frac{\partial}{\partial z} q_\pi(z, Q^2)|_{z=x/y} q_{model}(y)dy$, where $q_{model}(y)$ is the quark structure function given by the statistical model. In Fig.1, the experimental data are from Refs. [7, 8]; in the right panel we also show on- and off-shell results given in Ref. [9].

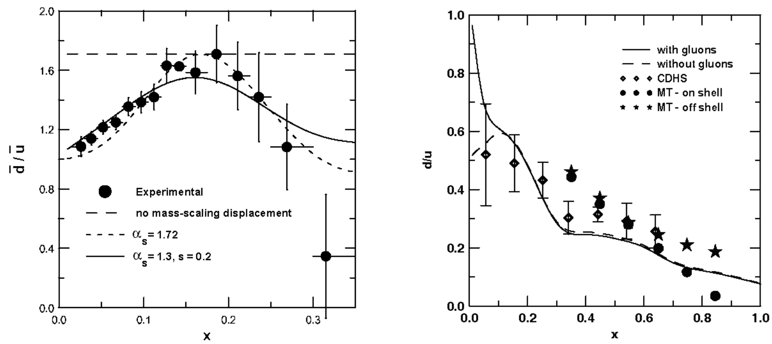

FIGURE 1. *Left panel*: Model results for $\bar{d}/\bar{u}$, as a function of x, compared with data [7]. Without mass-scaling displacement, we have the constant (long-dashed line) results. With the small-dashed-line and solid-line curves, we consider gluonic contributions, without quark substructure (small-dashed-line, for $\alpha_s = 1.72$); and with quark substructure (solid-line, with $\alpha_s = 1.3$ and $s = 0.2$). *Right panel*: d/u distribution inside the proton as a function of x. The results, considering the mass-scaling displacement, without gluon splitting (dashed line) and with gluon splitting (solid line), are compared with experimental data [8]. We also show on-shell (solid circles) and off-shell (stars) calculations of Ref. [9].

Finally, with the statistical model parametrization reproducing the Δ resonance, we should note that instanton induced interactions between quarks [10] are responsible for the mass shift between nucleon and Δ. The qualitative difference between the structure functions comes from the fact that light quarks with different flavors (u and d and corresponding antiparticles) also have different current masses. So, a simple mathematical trick, based in the Dirac's delta distribution, was used in Ref. [1] to obtain the shift of the given structure functions (which are equal a priori). At the end, after considering the contributions from gluon splitting processes [11], a quite good fit is obtained for the ratios $d(x)/u(x)$ and $\bar{d}(x)/\bar{u}(x)$ in the proton.

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