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Short-range correlations of partons, and 3D nucleon structure

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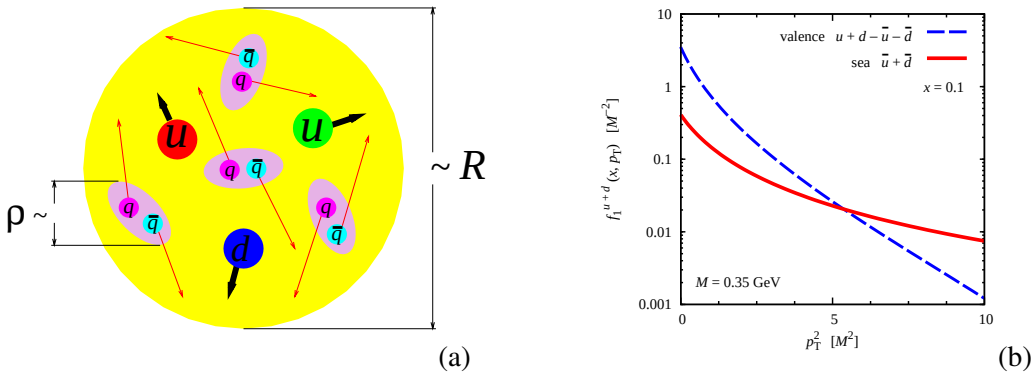
The dynamical breaking of chiral symmetry in QCD is caused by nonperturbative interactions on a scale $\rho \sim 0.3\,\text{fm}$ much smaller than the hadronic size $R \sim 1\,\text{fm}$, Fig. 1a. The non-perturbative short-distance scale ρ has critical impact on the intrinsic transverse momentum distributions of partons and their correlations at a low normalization point $\mu \sim \rho^{-1}$ [1]. This phenomenon is studied in an effective description of the low-energy strong interaction dynamics based on chiral constituent quark and Goldstone boson degrees of freedom, which is justified in the large-N_c limit of QCD. The nucleon is described in terms of constituent quarks and antiquarks bound in a self-consistent chiral field. This framework is realized in the chiral quark-soliton model, and allows to calculate the distributions of constituent quarks and antiquarks which can be identified with QCD parton distribution functions at low normalization scale μ [2].

The p_T distribution of valence quarks is roughly of Gaussian shape with a width of $p_T^2 \sim R^{-2}$. The sea quark distributions exhibit a power-like tail $\sim 1/p_T^2$ extending parametrically far beyond that up to the chiral symmetry-breaking scale ρ^{-1}, see Fig. 2b. The mechanism generating these high-momentum tails is due to short-range correlations between sea quarks in the nucleon's light-cone wave function [1]. This is in analogy to NN correlations in nuclei. The nucleon wave function contains correlated pairs of transverse size $\rho \ll R$ with σ- and π-like quantum numbers, whose internal wave functions become identical for $R^{-2} \ll p_T^2 \sim \rho^{-2}$. These features represent genuine, model-independent effects of dynamical chiral symmetry breaking on the nucleon's partonic structure. The results have important implications for the description of transverse momentum distributions of particles produced in hard scattering processes. The predicted nonperturbative parton correlations could be observed in particle correlations between the current and target fragmentation regions of DIS [1].



(a) (b)

Figure 1: *(a) The non-perturbative scales governing the nucleon structure: $R \sim 1\,\text{fm}$ sets the hadron size and describes valence quark effects, $\rho \ll R$ characterizes short-range correlations and determines the dynamics of sea quarks. (b) The distinct behavior of p_T-distributions of valence and sea quarks [1].*

[1] P. Schweitzer, M. Strikman and C. Weiss, JHEP **1301**, 163 (2013) [arXiv:1210.1267 [hep-ph]].
[2] D. Diakonov, V. Petrov, P. Pobylitsa, M. V. Polyakov and C. Weiss, Nucl. Phys. B **480**, 341 (1996).