Generalized Form Factors, Generalized Parton Distributions and the Spin Contents of the Nucleon

Masashi Wakamatsu and Yoshihiko Nakakoji
Department of Physics, Faculty of Science, Osaka University, Toyonaka, Osaka 560-0043, JAPAN

With a special intention of clarifying the underlying spin contents of the nucleon, we investigate the generalized form factors of the nucleon, which are defined as the x-moments of the generalized parton distribution functions, within the theoretical framework of the chiral quark soliton model [1]. A particular emphasis is put on the pion mass dependence of final predictions, which we shall compare with the predictions of lattice QCD simulations carried out in the so-called heavy pion region around $m_\pi \simeq (700 \sim 900)\,\mathrm{MeV}$. We find that some observables are very sensitive to the variation of the pion mass. This explains the reason why the negligible importance of the quark orbital angular momentum indicated by the LHPC and QCDSF lattice collaborations might be true in the unrealistic heavy pion world, but it is probably not true in our real world close to the chiral limit.

An interesting common prediction of the CQSM and the LHPC and QCDSF lattice simulations is that the net quark contribution to the *anomalous gravitomagnetic moment* of the nucleon is identically *zero* or at least *very small*, i.e., $B_{20}^Q(0) \simeq 0$. (See Figure 1.) Once we accept this indication as a theoretical postulate, we are necessarily led to a surprisingly simple relations, $J^Q = \frac{1}{2}\langle x \rangle^Q$ and $J^g = \frac{1}{2}\langle x \rangle^g$, i.e., the proportionality of the linear and angular momentum fractions carried by the quarks and the gluons. Using these relations, together with the existing empirical information for the unpolarized and the longitudinally polarized PDFs, we can give *model-independent predictions* for the quark and gluon contents of the nucleon spin. For instance, with combined use of the MRST2004 fit for the unpolarized PDFs and the DNS2005 fit for the longitudinally polarized PDFs, we obtain $2\,J^Q \simeq 0.58$, $\Delta\Sigma^Q \simeq 0.31$, and $2\,L^Q \simeq 0.27$ at $Q^2 = 4\,\mathrm{GeV}^2$ in the standard $\overline{\mathrm{MS}}$ scheme. Since L^Q (as well as J^Q) is a rapidly decreasing function of the energy scale, while the scale dependence of $\Delta\Sigma^Q$ is very weak, we must therefore conclude that L^Q is even more dominant over $\Delta\Sigma^Q$ at the scale below $Q^2 \simeq 1\,\mathrm{GeV}^2$, where any low energy models are supposed to hold.

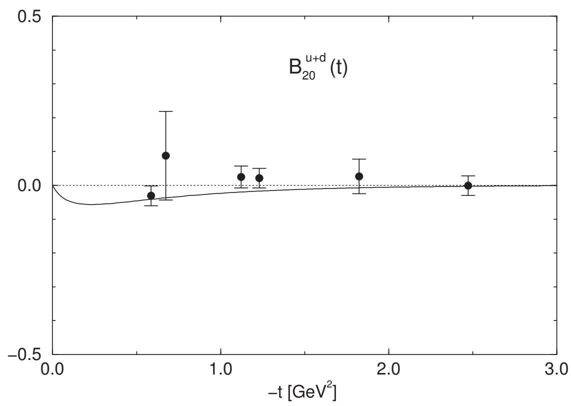

Figure 1: The predictions of the CQSM for the generalized form factor $B_{20}(t)$ of the nucleon, in comparison with the corresponding prediction of the lattice QCD by LHPC collaboration [2].

References

[1] M. Wakamatsu and Y. Nakakoji. *hep-ph/0605279.*

[2] Ph. Hägler, J.W Negele, D.B. Renner, W. Schroers, Th. Lippert and K. Schilling. *Eur. Phys. J.*, A24:29, 2005.