# 1 - 23 On Gauge Invariant Nucleon Spin Decomposition

Zhang Pengming and D. G. Pak[1]

It has been a long-standing problem of gauge invariant definition of gluon spin and orbital angular momentum. Recently a gauge invariant decomposition of the total nucleon angular momentum into quark and gluon constituents has been proposed[1], and subsequently other possible gauge invariant decompositions for nucleon spin have been suggested[2]. Despite this progress there are still principal controversies on the fundamental conceptual level in determining a consistent notion for gluon spin and orbital angular momentum.

In this letter we revise the problem of nucleon spin decomposition and the existence of a consistent gauge invariant concept of spin in the non-Abelian gauge theory. We find that there is a wide number of possible gauge invariant spin decompositions suggested in[2]. In general they lead to gauge nonequivalent gluon spin operators. The Poincare and conformal invariance selects a unique Lorentz invariant decomposition with the Lorentz-type constraint for physical field. However, since this decomposition is not well defined on mass-shell, its physical meaning is unclear. For most of Lorentz non-invariant decompositions the definition of spin operator is frame dependent. We have shown that there is a class of gauge equivalent spin decompositions leading to gauge invariant gluon spin operators consistent with the helicity notion, so that such definitions of spin operators are frame independent. In general, the gauge invariant spin densities represent spatially and temporally non-local functionals. However, this non-locality has no physical meaning

1 Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, Dubna, Moscow Region, 141980, Russia.

since it can be removed in a special gauge resulting in a standard local expression for the canonical spin decomposition. The corresponding definitions for the spin operator are gauge equivalent and lead to the same matrix elements. Notice, that the notion of such defined gauge invariant spin operator with using a non-local operator function for the physical field is similar to the notion of the quantum effective action which is gauge invariant but has a different operator form depending on a chosen gauge.

As is known, there are two principal issues in the nucleon spin decomposition problem. The first one is how to separate contributions of nucleon constituents. Another one is related to the problem of observability in experiment. In QED the photon spin and orbital angular momentum are measurable quantities, and they correspond to the canonical decomposition. In QCD, since hadrons represent strongly bound states, other schemes of nucleon spin decomposition with dynamic quark momentum might be more relevant.

## References

[1] X. S. Chen, X. F. Lu, W. M. Sun, et al., Phys. Rev. Lett., 100(2008)232002; Phys. Rev. Lett., 103(2009)062001.
[2] Y. M. Cho, M. L. Ge, P. M. Zhang, arXiv:1010.1080; Y. M. Cho, M. L. Ge, D. G. Pak, et al., arXiv: 1102.1130.