Nucleon spin decomposition and Non-forward parton distributions of the nucleon studied by wide-angle Compton scattering

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The spin structure of the nucleon has attracted considerable experimental and theoretical interests during the last decade. Naive quark model assumes that three spin-1/2 constituent quarks in the nucleon provides the nucleon's spin-1/2 according to the successful SU(6) spin-flavor symmetry. However, the experimental findings tell us that about 20% of the nucleon spin originates from the quark spin, and remaining dominant parts are coming from other contributions such as gluon spin and orbital angular momentum of constituents. In general, one can decompose the nucleon spin as[1]

$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + L_q + \Delta G + L_g \tag{1}$$

The first term represents the quark spin contribution $\Delta\Sigma = \Delta u + \Delta d + \Delta s \sim 0.2$. ΔG is the gluon spin contribution, and L_q and L_g the orbital angular momentum contributions of quarks and gluons, respectively. Corresponding operators for $\Delta\Sigma, L_q, \Delta G, L_g$ can be explicitly written from QCD Lagrangian[1].

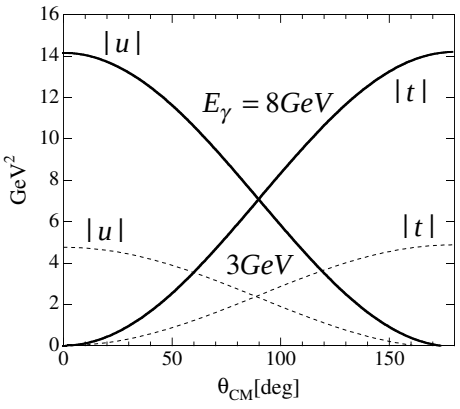

Figure 1: Kinematics of WACS

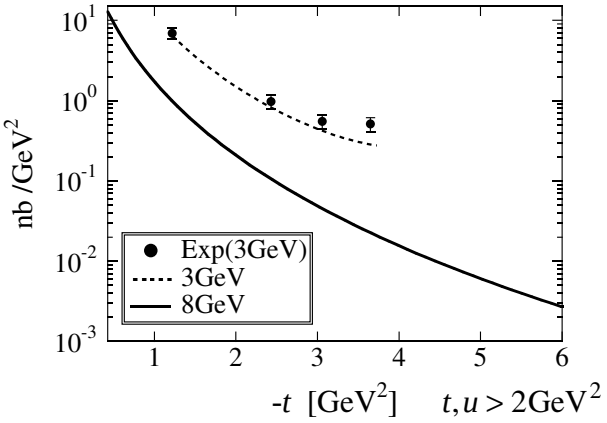

Figure 2: Unpolarized cross section for WACS

At the present we extract $\Delta\Sigma$ from the polarized deep inelastic lepton-nucleon scattering, and in near future polarized proton-proton collision will serve constraints on ΔG at RHIC-SPIN or HERA-$\vec{N}$. Apparently, we need more general framework to deal with the nucleon spin structure. Formalism to handle them has been developed very recently, that is, *non-forward* parton distribution functions of the nucleon (off-forward, off-diagonal, skewed etc.). The non-forward parton distribution (NFPD) can be defined by the light-cone correlation function in analogy with the normal parton distributions.

$$M^{\mu\nu} = i \int d^4z \, e^{i\bar{q}\cdot z} \left\langle p', s' \left| T \; \bar{\psi} Q \, \gamma^\mu \psi \left(-\frac{z}{2}\right) \quad \bar{\psi} Q \, \gamma^\nu \psi \left(\frac{z}{2}\right) \right| p, s \right\rangle \tag{2}$$

Note that the momentum and the spin of the final state p', s' could be different from the initial state p, s in contrast with the normal parton distribution, namely $\Delta_\mu = p - p' \neq 0$.

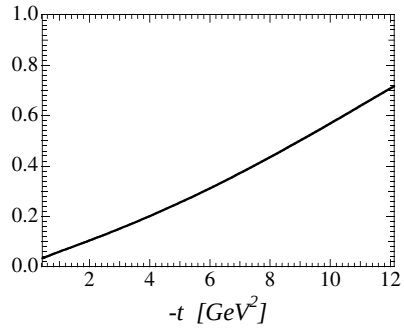

Figure 3: A_{LL} in WACS at $E = 8$GeV

This correlator can be parametrized into the following form;

$$\begin{aligned} \sim \quad & R_V(x,\Delta)\bar{U}(p')\gamma^+ U(p) + R_T(x,\Delta)\frac{i}{2M}\bar{U}(p')\sigma^{+\nu}\Delta_\nu U(p) \\ & + R_A(x,\Delta)\bar{U}(p')\gamma^+\gamma_5 U(p) + R_P(x,\Delta)\frac{\Delta^+}{2M}\bar{U}(p')\gamma_5 U(p) \ , \end{aligned}$$

where R_i are the non-forward parton distributions of the nucleon, which depend on the momentum transfer to the target Δ_μ in addition to the light-cone momentum fraction x. As for a relation with the nucleon spin structure, one can see $\Delta\Sigma/2 + L_q = \int x dx/2[R_V(x,0) + R_T(x,0)]$ [1].

Measurement of this correlator may be possible by the deeply virtual Compton scattering (DVCS). However, the absolute value of the DVCS cross section is strongly suppressed compared with DIS, and also DVCS gets huge background from the Bethe-Heitler process, in which the real photon of the final state comes from the radiation of the beam lepton.

We here consider alternative process, wide-angle Compton scattering (WACS) off the nucleon[2, 3]. Strictly speaking, whole process appeared in the real photon-nucleon scattering is non-perturbative and the factorization cannot be applied. Here, we stress the very large angle scattering, namely the large momentum transfer process, $|t|, |u| \geq 2 \sim 3\text{GeV}^2$. In this case we expect dominance of the single quark scattering may be realized, if the nucleon wave function does not involve anomalously high momentum components. Based on this assumption we calculate the WACS cross section using NFPD. In Fig.1 we show the kinematics of this process with the incident photon energy being 3 and 8GeV/c.

To provides a first guess for the cross section, we assume the factorized form for $R_V(x,t) = \exp\left[\frac{(1-x)}{4\beta^2 x}t\right]\sum_i e_i^2(q_i(x) + \bar{q}_i(x))$ with $t = -\Delta^2$. Here, $q_i(x)$ are the standard parton distributions. We note again that our approximation is valid for only the large t events. Magnitude and behavior of the calculated cross section in Fig.2 are rather consistent with the experiments at $E = 3$GeV, although the agreement depends on the choice of the model parameters. We also show in Fig.3 the double spin asymmetry A_{LL}, in which both the photon and the target nucleon are polarized. Calculations of the spin-dependent cross section which include the helicity-flip non-forward parton distribution are now in progress.

References

[1] X. Ji, Phys. Rev. Lett **78** (1997) 610
[2] A.V. Radyushkin, Phys. Rev. **D58** (1998) 114008
[3] K. Suzuki, to be published, talk presented at JSPS annual meeting, March 1999