Polarizations of hyperons produced in hadron-hadron, γ-hadron and e^+e^- collisions at high energies

K. Suzuki[a], N. Nakajima[a], H. Toki[a], K.-I. Kubo[b]

[a] *Research Center for Nuclear Physics (RCNP), Osaka University, Osaka 567-0047, Japan*
[b] *Department of Physics, Tokyo Metropolitan University, Tokyo 192-0397, Japan*

Against a naive expectation that the transverse spin effects are less important at high energies, significant polarizations of inclusively produced hyperons are observed in the unpolarized hadron-hadron collision at high $x_F(= 2p_L/\sqrt{s}$, p_L is the longitudinal momentum in CM.) and small transverse momentum p_T region. These data indicate some non-perturbative mechanism remains intact for the production of the polarization. To understand these phenomena, we construct a simple relativistic quark model for the hadronization[1, 2], in which the spin polarization is brought by the scalar confinement interaction between quarks.

Consider the inclusive Λ production by the unpolarized proton-proton collision, and the polarization of Λ in the final state. Experimentally, the spin polarization of the Λ, s_Λ, is defined perpendicular to a $(P_{beam} \times P_\Lambda)$ plane. Hence, the appearance of the polarization means the non-vanishing expectation value of $\langle (P_{beam} \times P_\Lambda) \cdot s_\Lambda \rangle$, which is not invariant under the T-reversal transformation, although QCD is T-invariant. Such phenomena are driven by the purely dynamical effect in the strong interacting system[3]. We assume here that the polarizations are brought by the final state interaction in the hadronization process. We shall show that the scalar confinement force between quarks does generate the non-trivial spin dependence of the cross section.

We focus on the large-x_F particle production, since observed polarizations are significant only at large x_F. To produce such a fast particle in the forward direction, Λ must contain the fast valence quarks from the incoming proton. Thus, the SU(6) spin-flavor symmetry tells us that a spin-0 ud quark-pair (diquark) from the beam nucleon picks up a strange quark s though the hadronization process to form Λ. Such a strange quark is assumed to be generated by the $q\bar{q}$ pair creation due to the flux-tube breaking in the hadronization process.

With this assumption and the scalar interaction between quarks, we calculate the polarization as

$$P_N(\Lambda) = R_0 \frac{\int [dx_i\, dy_i\, dz_i/x_i]\; \Psi_\Lambda^2(3,4)\; \sigma_{dep}\; f(2)\; G_{(ud)/p}(1)\; \Delta^4 \Delta^3}{\int [dx_i\, dy_i\, dz_i/x_i]\; \Psi_\Lambda^2(3,4)\; \sigma_{ind}\; f(2)\; G_{(ud)/p}(1)\; \Delta^4 \Delta^3}\ , \tag{1}$$

where the spin-dependent cross section is

$$\sigma_{dep} = -(x_F x_4 x_2) \left(\frac{x_F x_4 y_2 - x_2 y_4}{x_F x_3 x_1} \hat{p}_t \right)\ . \tag{2}$$

This term appears as the interference of the hadronization amplitudes. The spin-independent cross section as well as other details can be found in ref. [1]. If we took the vector interaction between quarks instead of the scalar, the polarization would vanish in the Infinite Momentum Frame.

Using the parton distributions of the incoming hadron and the wave function of the outgoing hyperon, we obtain the polarizations of various hyperons which are quite consistent with experiments (Fig.1). The polarization of Σ is also shown in Fig.2. Our model also accounts for the origin of the empirical rule suggested by DeGrand and Miettinen[4].

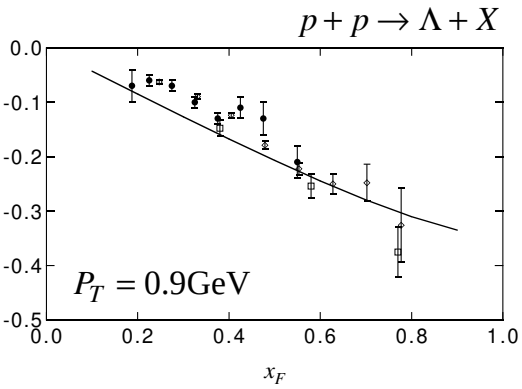

Figure 1: Λ polarization in pp collision

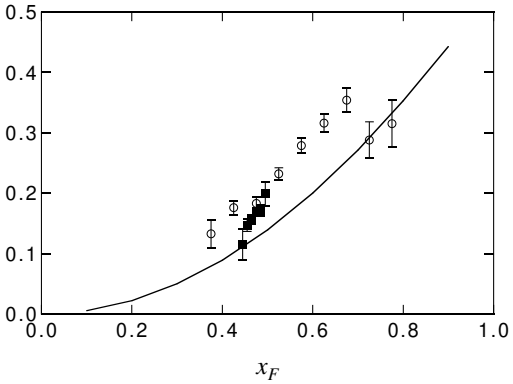

Figure 2: Σ polarizations in pp collision

From the viewpoint of our model, we definitely expect non-vanishing polarizations for photon induced reaction, because the hadronization process is independent of the beam. We study the photoproduction of $\Lambda(\Sigma)$, which can be accessible at future PEARL facility, using the quark distribution function of the photon. We show the quark distribution of the photon extracted from the deep inelastic scattering in Fig.3. As expected from the vector meson dominance principle, the u-quark plays a major role in the photon structure. Thus, the Λ photoproduction is dominated by the subprocess $u + ds \to \Lambda$, where a ds-diquark is picked up through the hadronization. This subprocess provides the negative polarization, and thus the total Λ polarization tends to be negative shown in Fig.4[5].

On the other hand, we find almost zero transverse polarization for $e^+e^- \to Z^0 \to \Lambda$ process which turns out to be consistent with the recent ALEPH data(Fig.4), because of a delicate cancellation between several subprocesses and the absence of the intrinsic transverse momentum of the incoming parton. These predictions will be tested by future experiments.

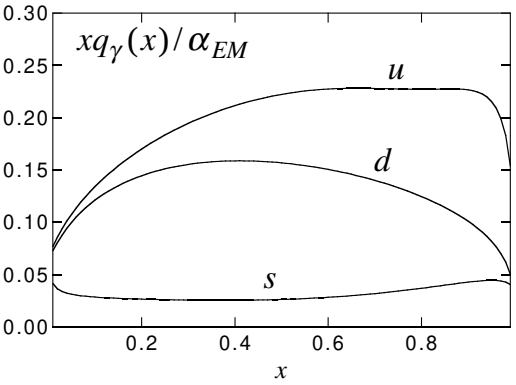

Figure 3: Photon structure function

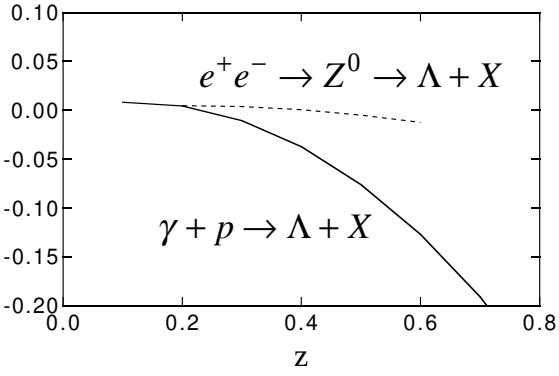

Figure 4: Λ polarizations in other reactions

References

[1] Y. Yamamoto, K.-I. Kubo, H. Toki, Prog. Theor. Phys. **98** (1997) 95
[2] K. Suzuki, N. Nakajima, H. Toki and K.-I. Kubo, preprint (1998)
[3] S. Gasiorowicz, Elementary Particle Physics (Wiely, New York, 1966)
[4] T.A. DeGrand and H.I. Miettinen, Phys. Rev. **D23** (1981) 1227
[5] K. Suzuki, talk presented at RCNP PEARL workshop (1999)
N. Nakajima, talk presented at APCTP workshop on Strangeness Nuclear Physics, Seoul, Korea, Feb. 1999