Recalling Zakopane 1989 School

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50 Cracow School of Theoretical Physics, Zakopane, June 9-19, 2010

The most important event during 1989 School

High noon
4 June 1989

First (quasi) free election in Poland after WWII

Beginning of the end of communism in Europe

Polarized Structure Functions

or

Where Does the Proton Spin Come From

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ABSTRACT

The 1987 data of the European Muon Collaboration (EMC) on the spin-dependent proton structure function $g_p^1(x)$ suggest that only a very small fraction of the proton helicity is due to the helicity of the current quarks inside it. We review the experimental situation and discuss some recent interesting theoretical developments resulting from the attempt to understand the data through the use of effective Lagrangians and via anomalous contribution of gluons to the g_1^p structure functions. On the phenomenological level, the data suggest that the nucleon wave-function at low Q^2 contains a substantial sea of $\bar{s}s$ quark pairs. The strange sea is polarized, with the average helicity being negative, almost exactly cancelling the net positive helicity carried by the valence and sea u and d quarks. The presence of $\bar{s}s$ pairs in the proton signals a strong violation of the OZI rule in baryon physics. Experimental consequences of such a violation are examined and some new predictions are discussed.

$$\frac{1}{2}\sum_q \Delta q + \Delta G + \langle L_z \rangle = \frac{1}{2}.$$

$$\left.\begin{aligned} \Delta u &= 0.75 \pm 0.06 \\ \Delta d &= -0.50 \pm 0.06 \\ \Delta s &= -0.22 \pm 0.06 \end{aligned}\right\} \Delta u + \Delta d + \Delta s = 0.03 \pm 0.18$$

$$\widetilde{\Delta u} = \Delta u - (\alpha_s/2\pi)\Delta G$$

$$\widetilde{\Delta d} = \Delta d - (\alpha_s/2\pi)\Delta G$$

$$\widetilde{\Delta s} = \Delta s - (\alpha_s/2\pi)\Delta G$$

Initially some physicists have hoped[16] that these radiative corrections could rescue the NQM model, by making $\Delta s = 0$ compatible with experiment. In principle, this is possible, as the experiment only tells us the value of $\widetilde{\Delta s}$. As it turns out, however, this is a rather unlikely possibility.[13,50] At $Q^2 \sim 10$ GeV^2 $\alpha_s \sim 0.2$. It follows from eqs. (14) and (15) that having $\Delta s = 0$, while keeping $\widetilde{\Delta s}$ at its experimental value, would require $\Delta G \sim 7 \pm 2$, a prohibitively large value. Such to that of $g_1^p(x)$, i.e. x^δ with $\delta \sim 0$. Thus a large value of ΔG is ruled out. In the literature there have been several proposals for the possible values of ΔG and Δs. As we have just seen, the most extreme in one direction, $\Delta s = 0$, is ruled out. The other extreme, $\Delta G = 0$ appears naturally[13] in a certain class of Skyrme-type models, to be discussed shortly. An intermediate case has been advocated in Ref. 50, where the observed value of $\widetilde{\Delta s}$ is attributed to roughly equal contributions from Δs and ΔG. The actual value of ΔG is something that will have to be determined by experiment.

The next priority is to measure the gluon polarization, ΔG. The basic idea is to measure an asymmetry in a process in which a major part of the cross-section is due to gluon-photon or gluon-gluon fusion and where the amplitude is highly sensitive to the relative polarization of the two gauge bosons. If the gluons in a proton are substantially polarized, then changing the polarization of a proton target will have a strong effect on the cross-section. The measured asymmetry is given by a convolution of the gluon polarization distribution with the polarization-dependent amplitude.

The are several experimental setups in which this idea can be realized:*

(a) Measurement of J/ψ production and decay properties in deep inelastic muon scattering off polarized targets;[34,49]

(b) Measurement of $\chi_2(3555)$ production and decay properties in hadronic collisions[35]

(c) Measurements of charm distributions in deep inelastic scattering off a polarized target using dimuon events from $c(\bar{c}) \to \mu^+(\mu^-) + X$ decays;

(d) Hadronic jet asymmetries in polarized pp collisions;[36,48]

(e) Direct photon production at large p_T by polarized protons;[36,48]

(f) Hyperon production at large p_T in polarized pp collisions;[37] †

(g) Higher order effects in polarized ep collisions;[38]

(h) Drell-Yan l^+l^- production with polarized beams;[39]

(i) Large p_T hadron production in photoproduction off polarized targets.[40]