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Spin structure of hadrons in supersymmetric quantum chromodynamics

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It is possible that the planned experiments at energies in the TeV region discover the supersymmetric nature of strong interactions. In such case hadrons display a richer structure as compared to the standard quantum chromodynamics (QCD). In addition to quarks (q) and gluons (G) new fields appear: the spin zero supersymmetric partners of quarks - squarks (s) and spin 1/2 partners of gluons - gluinos (λ). The spin structure of hadrons in supersymmetric QCD (SQCD) changes substantially due to these new degrees of freedom. To study it we use the standard procedure of Q^2-evolution of spin densities developed in QCD by Altarelli and Parisi[1]. The spin densities which depend on Bjorken x and momentum transfer Q^2 are defined as follows

$$\begin{aligned} \Delta q(x,Q^2) &= q_+(x,Q^2) - q_-(x,Q^2) \; ; \qquad \Delta\lambda(x,Q^2) = \lambda_+(x,Q^2) - \lambda_-(x,Q^2) \\ \Delta G(x,Q^2) &= G_+(x,Q^2) - G_-(x,Q^2) \; ; \qquad \Delta S(x,Q^2) = S_2(x,Q^2) - S_1(x,Q^2) \end{aligned} \tag{1}$$

where + (-) means spin parallel (antiparallel) to the hadron momentum and s_1, s_2 are two types of squarks. In general the squarks s_L (s_R) interacting with left (right) handed quarks can mix due to their non-diagonal mass matrix. We consider here only SQCD with parity conservation in which case $s_{1,2} = (s_R \pm s_L)/\,2$. The general form of the Q^2-evolution of the spin densities (1) reads

$$Q^2\frac{d}{dQ^2}\begin{bmatrix}\Delta G\\ \Delta\lambda\\ \Delta q\\ \Delta S\end{bmatrix} = \frac{\alpha(Q^2)}{2\pi}\begin{bmatrix}\Delta P_{GG} & \Delta P_{G\lambda} & \Delta P_{Gq} & \Delta P_{GS}\\ \Delta P_{\lambda G} & \Delta P_{\lambda\lambda} & \Delta P_{\lambda q} & \Delta P_{\lambda S}\\ \Delta P_{qG} & \Delta P_{q\lambda} & \Delta P_{qq} & \Delta P_{qS}\\ \Delta P_{SG} & \Delta P_{S\lambda} & \Delta P_{Sq} & \Delta P_{SS}\end{bmatrix} \otimes \begin{bmatrix}\Delta G\\ \Delta\lambda\\ \Delta q\\ \Delta S\end{bmatrix} \tag{2}$$

where the sign $\otimes$ stands for the convolution

$$\Delta P \otimes \Delta f = \int_x^1 \frac{dy}{y}\, \Delta P(y)\, \Delta f\left(\frac{x}{y}\right)$$

The evolution kernels are calculated using the vertices of SQCD

and are given in the Table. When integrated over z they give the anomalous dimensions $\Delta\gamma^{n}_{ba} = \int_0^1 dz\, z^{n-1}\Delta P_{ba}(z)$.
The equation (2) can be solved numerically when some initial quark and gluon spin densities are assumed. The evolution below the threshold for the production of supersymmetric partners goes according to the standard QCD, and above the threshold - with the use of ΔP_{ba} given in the Table. Various flavour channels, as well as all possible squark mixings were studied in our preceeding paper[2]. Here we present in Fig. 1 the resulting curves in the flavour singlet case at $\sqrt{Q^2} = 200$ GeV, compared with the standard QCD. The masses are chosen: $m_\lambda = 4$ GeV, $m_s = 46$ GeV.

A very important question is the spin sharing among the hadron constituents. To recall, the total spin carried by the constituent f is given by $S_f(Q^2) = \int_0^1 dz\, \Delta f(z,Q^2)$. This problem can be solved analytically in all channels. The most spectacular result which we obtained is the asymptotic vanishing of the spin carried by the valence quarks

$$S_q^{val}(Q^2) = S_q^{val}(Q_0^2)\, e^{-\frac{1}{2}C_F\cdot t} \xrightarrow[Q^2\to\infty]{} 0$$

where $C_F\cdot t = \frac{8}{3(9-N_f)} \ln \frac{\ln Q^2/\Lambda^2}{\ln Q_0^2/\Lambda^2}$ for SU(3) colour QCD with N_f flavours.

ΔP_{GG}	$C_A\left[\frac{1+z^4}{(1-z)_+} + \frac{1+z^4}{z} - \frac{(1-z)^3}{z}\right] + \frac{9C_A-3T_R}{6}\delta(1-z)$
ΔP_{Gq}	$C_F\,\frac{1-(1-z)^2}{z}$
$\Delta P_{G\lambda}$	$C_A\,\frac{1-(1-z)^2}{z}$
ΔP_{qG}	$T_R\,(z^2-(1-z)^2)$
ΔP_{qq}	$C_F\frac{1+z^2}{(1-z)_+} + C_F\,\delta(1-z)$
$\Delta P_{q\lambda}$	$-T_R(1-z)$
$\Delta P_{\lambda G}$	$C_A\left[z^2-(1-z)^2\right]$
$\Delta P_{\lambda q}$	$-C_F(1-z)$
$\Delta P_{\lambda\lambda}$	$C_A\frac{1+z^2}{(1-z)_+} + \frac{3C_A-T_R}{2}\delta(1-z)$
$\Delta P_{as} = \Delta P_{sa} = 0$	

Table. The evolution kernels P_{ba} in in SQCD with parity conservation.

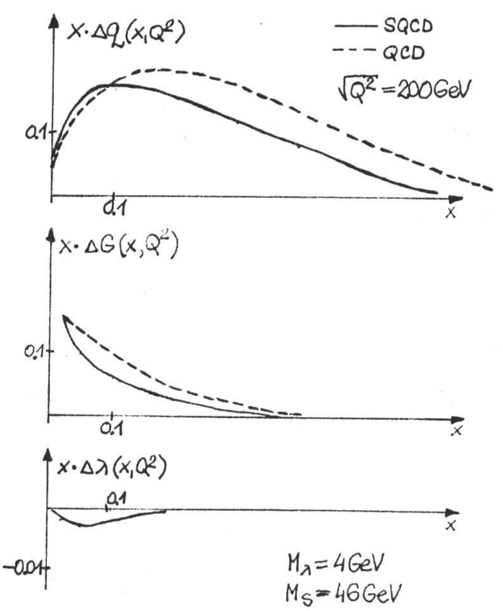

Fig.1. The spin densities in SQCD with parity conservation.

References.

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