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Magnetic moments of baryons

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One-gluon corrections to baryon magnetic moments calculated within the framework of the MIT bag model by different authors are compared. The coincidence of the results is emphasized. Further improvement of the experimental data on the magnetic moments of Δ^{++} and Ω^- is very desirable.

The discrepancy between predictions for baryon magnetic moments of the additive SU(6) quark scheme and the experimental data can apparently be removed within the framework of QCD-inspired models by taking into account effects of gluon and pion interaction of quarks. The most popular model concerning that subject is the MIT bag model and its modifications. The problem of calculation of gluon corrections to the baryon magnetic moments is analogous to the calculation of QED corrections to the magnetic moment of the hydrogen atom.[1] This problem has been discussed for several years by many authors.[2–10] Nevertheless, up to this moment there is no generally accepted final result for the gluon corrections. Recently Hogassen and Myhrer[10] repeated calculations by Ushio[6] and reproduced his result. It was pointed out also that their result for the gluon corrections to the magnetic moments is a factor 4 greater than ours (Ref. 7). This remark is erroneous, the results of Refs. 6, 10, and 7 agree with each other and with the earlier published paper.[5] According to our works, the magnetic moment of a hadron with α_c corrections taken into account takes the form

$$\boldsymbol{\mu}=\sum_i C_i\boldsymbol{\mu}_{0i}+(-\tfrac{3}{8}\alpha_c R)\sum_{i\neq j}\lambda_i^a\lambda_j^a e_i\boldsymbol{\sigma}_j A_{ij} \ , \qquad (1)$$

where $\boldsymbol{\mu}_{0i}$ is the magnetic moment of the ith quark in zeroth α_c approximation, the coefficient $C_i=1+O(\alpha_c)$ includes one-gluon corrections to the magnetic moment of the ith quark, $\alpha_c=g^2/4\pi$ is the coupling constant of strong interactions, which corresponds to the color-quark current definition $j_\mu^a=g\bar{\psi}\gamma_\mu\lambda^a\psi$, e_i is the quark charge, and R is the bag radius.

The most important contribution is described by the second term in Eq. (1), because just that term is responsible for deviations from predictions of the additive SU(6) quark scheme. For massless quarks[5] $A_{ij}=A=0.0406$. In particular, using parameters $\alpha_c=0.55$ and $R=1$ fm adopted in Ushio's paper,[6] we get the gluon correction to the neutron magnetic moment $\Delta\mu_n=0.14\ \mu_N$ which coincides with Ushio's result. In Refs. 5–7 and 10 different approaches for calculation of α_c corrections are used. In Ref. 5, for instance, where the result (1) was originally presented, correction to the quark wave function due to presence of the external magnetic field is found. Such a correction leads to the disturbance of color-quark currents, gluon field created by the quarks, and hence to an additional contribution to the one-gluon-exchange energy. The derivative of the gluon interaction energy on the external magnetic field gives desirable correction to the magnetic moment of a hadron.

In Refs. 6 and 10 the expansion of the gluon corrections to the quark wave function in unperturbed modes is found, the contribution of each of the modes to the magnetic moment of the system is presented, and the rapid convergence of the sum over the modes is emphasized.

In Ref. 7 the diagram technique of noncovariant perturbation theory is used and the discrete character of gluon levels in the bag is taken into account explicitly. It is shown that the summation of diagrams allows us to reproduce the result obtained in Ref. 5. Besides it is pointed out that the main contribution corresponds to the exchange by gluons with $J^P=1^+$ in the ground state.

There is, therefore, theoretical proof of equivalence of different approaches to the calculation of gluon corrections. It is not surprising that numerical results also coincide.

The inclusion of α_c corrections cannot still remove deviations from the experimental data; pions also contribute to the magnetic moments.[11–14] Fit to the magnetic moments with account taken of both gluon and pion corrections is given within the framework of the chiral bag model in Refs. 8 and 10. Predictions of Refs. 8 and 10 for magnetic moments of octet baryons practically coincide and agree with experimental data with accuracy better than 5%.

In Ref. 8 the magnetic moment of Δ^{++} is found to be $\mu(\Delta^{++})=6.54\ \mu_N$. The Particle Data Group gives[15] $\mu(\Delta^{++})^{\rm expt}=5.7\pm1.0\ \mu_N$. Recently detailed analysis of the πN scattering data was made[16] and a new value of the magnetic moment of Δ^{++} was extracted with the use of the Kondratyuk-Ponomarev method to be $\mu(\Delta^{++})^{\rm expt}=8.4\pm1.4\ \mu_N$. Preliminary results were also reported on the magnetic moment of the Ω^- hyperon[17] $\mu(\Omega^-)^{\rm expt}=-2.0\pm0.2\ \mu_N$. This value does not contain systematic errors. Reference 8 gives $\mu(\Omega^-)=-2.52\ \mu_N$.

Some of the models give predictions for magnetic moments of the decuplet essentially different from predictions of the bag models. Sum rules[18] give, for instance, $\mu(\Delta^{++})=2.7\pm0.4\ \mu_N$ and $\mu(\Omega^-)=-0.95\pm0.2\ \mu_N$ (Ref. 19). Further improvement of the experimental data would be very desirable.

It has to be noted that there is a real discrepancy in calculation of gluon corrections to the neutron charge radius (see Refs. 20 and 21). New calculations would help to resolve this puzzle.

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