SPIN-DEPENDENT QUARK-QUARK INTERACTION AND ELECTROMAGNETIC STRUCTURE OF Λ^0 (1115) HYPERON

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Lambda Λ^0 (1115) hyperon is the first baryon which contains the hard strange quark. So, this hyperon is the worth notice object in several aspects. It's interesting (i) to establish the influence of s-quark on the calculations of Λ structure together with the light quarks (ii) to compare Λ radius with (unusual in hadron's physics) the negative value of neutron mean-square charge radius (MSCR) $< r_n^2 >< 0$ and (iii) to outline the perspectives of experimental determination of $< r_\Lambda^2 >$ Λ MSCR.

Previous investigations (see e.g. [1]) of Λ structure clearly demonstrate that in nonrelativistic constituent quark model (NRCQM) and in many other quark models the values of Λ MSCR $< r_\Lambda^2 >$ may oscillate near zero value, but (as it was naturally expected) the absolute values are not very large. So, after determination of the limits for $| < r_\Lambda^2 > |$ the natural question immediately arises: how much may be the various corrections to nonrelativistic value of $< r_\Lambda^2 >$? In this thesis we'll consider one of the most important correction.

HYPERFINE SPIN-DEPENDENT INTERACTION (HSDI)

Many years ago it was established in refs. [2, 3, 4] that one gluon $(1g)$ exchange between two quarks leads to the appearance of spin-dependent qq (or $q\overline{q}$) interaction. From the theory of atomic spectra this interaction was named as hyperfine (hyp) interaction.

For the low-lying states of mesons and baryons in case of light quarks the nonrelativistic reduction of $1g$-exchange may be used in proper modified form. Following [2, 3, 4] we surely consider that for any two quarks in a baryon HSDI has the following structure:

$$H_{hyp} = \sum_{i<j} \frac{2\alpha_s(r_{ij})}{3m_i m_j} [\frac{8\pi}{3} \vec{s}_i \cdot \vec{s}_j \cdot \delta(\vec{r}_{ij}) + + \frac{1}{r_{ij}^3} (\frac{3(\vec{s}_i \cdot \vec{r}_{ij})(\vec{s}_j \cdot \vec{r}_{ij})}{r_{ij}^2} - (\vec{s}_i \cdot \vec{s}_j))], \qquad (1)$$

where α_s is a QCD coupling constant and $\vec{r}_{ij} = \vec{r}_i - \vec{r}_j$.

HSDI in eq. (1) contains two terms: the first one is the spin-spin contact part $(\sim \vec{s}_i \cdot \vec{s}_j \cdot \delta(\vec{r}_{ij}))$ and the second term describes the tensor part of interaction. But if we consider only the properties of ground states baryons, it's completely straightforward to calculate the diagonal part of HSDI contribution to these states, which comes from contact $\vec{s}_i \cdot \vec{s}_j \cdot \delta(\vec{r}_i - \vec{r}_j)$ interaction.

Finally to take into account the additional contribution $< \delta r_\Lambda^2 >_{SDI}$ to Λ MSCR we'll use the SDI in the form of contact Fermi-Breit potential (FBP)

$$U_{FB} = A \sum_{i<j} \frac{\vec{s}_i \cdot \vec{s}_j}{m_i m_j} \delta(\vec{r}_i - \vec{r}_j), \qquad (2)$$

with the new renormalized coupling constant A. It's reasonable tacitly to suppose that realistic determination of this value will (with effective quark masses) incorporate (at least partially) the omitted contributions of other effects without altering the FBP.

PERTURBATIVE POTENTIAL

Let's suppose [5] that (together with the potential of harmonic oscillator model (HOM)) the additional perturbative auxiliary potential

$$V = \beta \sum_{i=1}^{3} e_i \left(\vec{r}_i - \vec{R}\right)^2 \qquad (3)$$

also acts on the quarks inside baryon. In eq. (3) β is a small parameter ($\beta/m_q^3 \ll 1$).

SPIN-DEPENDENT CONTRIBUTION TO Λ MSCR

Now let's define the new Hamiltonian:

$$H_I \to H_\beta = H_I + V =$$
$$= \frac{1}{2} m_\rho \omega_\rho^2 \cdot \vec{\rho}^2 + \frac{1}{2} m_\lambda \omega_\lambda^2 \cdot \vec{\lambda}^2 + \beta \sum_{i=1}^{3} e_i \left(\vec{r}_i - \vec{R}\right)^2. \qquad (4)$$

The ground state wave function $\psi_\beta(\rho, \lambda)$ of the Hamiltonian (4) has the well-known form

$$\psi_\beta\left(\vec{\rho}, \vec{\lambda}\right) = \left(\frac{m_\rho \omega_\rho'}{\pi}\right)^{\frac{3}{4}} \left(\frac{m_\lambda \omega_\lambda'}{\pi}\right)^{\frac{3}{4}} \times$$
$$\times exp\left(-\frac{1}{2} m_\rho \omega_\rho' \vec{\rho}^2 - \frac{1}{2} m_\lambda \omega_\lambda' \vec{\lambda}^2\right), \qquad (5)$$

where

$$\omega_\rho' = \omega_\rho + \frac{\beta}{6 m_\rho \omega_\rho},$$
$$\omega_\lambda' = \omega_\lambda - \frac{\beta}{2 m_\lambda \omega_\lambda} \cdot \frac{(2m - m_s)}{(2m + m_s)}.$$

Now we can obtain the final formula for calculation of SDI-contribution to Λ MSCR:

$$< \delta r_\Lambda^2 >_{SDI} = \frac{d}{d\beta} < \psi_\beta | U_{FB} | \psi_\beta > |_{\beta=0} =$$
$$= A \sum_{i<j} \frac{\vec{s}_i \cdot \vec{s}_j}{m_i m_j} \frac{d}{d\beta} < \psi_\beta | \delta(\vec{r}_i - \vec{r}_j) | \psi_\beta > |_{\beta=0}. \qquad (6)$$

For Λ hyperon $\vec{s}_1 \cdot \vec{s}_2 = -3/4$ and $\vec{s}_1 \cdot \vec{s}_3 = -\vec{s}_2 \cdot \vec{s}_3$.

The result is

$$< \delta r_\Lambda^2 >_{SDI} = -A \cdot 0.006 fm^2. \qquad (7)$$

Now to complete the calculations it's necessary to define the normalization constant A in FBP potential (2). Here we'll propose the new method of how to do it. The value of constant A in baryon sector may be exactly defined by means of reliably established experimental value of neutron MSCR: $< r_n^2 >= -0.1161 \pm 0.0022 fm^2$. Really due to equality $< r_n^2 >= 0$ in NRCQM the nonzero value $< r_n^2 >< 0$ is fully defined by the SDI (2). So, for the neutron we have the equation $-0.1161 fm^2 = \frac{d}{d\beta} < \psi_\beta | U_{FB} | \psi_\beta > |_{\beta=0}$ .From this equation the constant A is defined as

$$A = 9.58 \,, \tag{8}$$

and $< \delta r_\Lambda^2 >_{SDI} = -0.057 fm^2$.

The "total" (t) Λ MSCR $< r_\Lambda^2 >_t$ is defined as:

$$< r_\Lambda^2 >_t = 0.117 - 0.057 = 0.06 fm^2. \tag{9}$$

Looking at the eqs. (8) and (9) we can made the following remarks:

(i) the value $|< \delta r_\Lambda^2 >_{SDI}|$ is two times smaller than the proper neutron value $|< \delta r_n^2 >| = 0.1161 fm^2$. Such tendency seems to be natural due to the presence of hard *s*-quark inside Λ^0 (1115) hyperon.

(ii) the total value of Λ MSCR $< r_\Lambda^2 >_t = 0.06 fm^2$ remains positive in spite of the very essential negative SDI-contribution. For Λ the neutron phenomenon $< r_n^2 >< 0$ is not repro.

(iii) Duced.

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