6. SU(3) Cloudy Bag Model による8重項重粒子の磁気能率

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Abstract The magnetic moment of all members of the octet baryons are calculated using the volume-type SU(3) cloudy bag model (CBM).

Motivation The calculation of octet baryon magnetic moment by the volume-type SU(2) CBM has been practiced.[1] However this calculation includes only the pion cloud and the kaon and η-meson effects are not considered at all.But it is not clear whether their effects are negligible.So we hope to extend the volume-type SU(2) CBM to SU(3),and apply it to the magnetic moment of the octet baryon.Whether the introduction of the kaon- and η -cloud improves the result or not ----- it interests us greatly.

Properties of the Model The properties of CBM are the following: (A)It incorporates the symmetry-breaking effects via quark mass differences in a natural way. (B)Quarks (three Dirac particles) are confined permanentry inside a static spherical cavity called the "bag",whose radius R fixes the scale for the whole model. (C)Its Lagrangian satisfies the current algebra[2],and obeys the chiral symmetry[3](if quark mass term is neglected).These are the constraints from QCD. (D)This model is suitable for the linearization because the meson fields are assumed to be small. (E)The meson fields are quantized.

Volume-type CBM There are two versions in CBM. One is the surface-type[4),5)],and the other is the volume-type[1),6)].Volume-type CBM is obtained from the surface-type CBM, via the unitary transformation on the quark field q(x)[7],

$$q_s(x) \xrightarrow{\quad U \quad} q_v(x) \quad ; \quad U \equiv e^{i\vec{\lambda}\cdot\vec{\phi}\,\gamma_5/2f_\pi}, \qquad (1)$$

where the suffix s,v is surface-type,volume-type respectively. $\lambda_i (i=1\sim 8)$ are Gell-Mann matricies, $\vec{\phi}$ is the meson field,and f_π is the pion-decay constant with $|f_\pi| \cong 93$ Mev. Using (1),the Lagrangian density of the volume-type SU(3) CBM in the absence of the gluon fields is given by,

$$\mathcal{L}(x) = \mathcal{L}_q + \mathcal{L}_\phi + \mathcal{L}_{q\text{-}\phi} \qquad (2)$$

$$\mathcal{L}_q = (\bar{q}(x)\, i\gamma\cdot\partial q(x) - B)\theta_v - \frac{1}{2}\bar{q}(x)q(x)\Delta_s - m_q\bar{q}(x)U^{\dagger}U^{\dagger}q(x)\theta_v \qquad (2-a)$$

$$\mathcal{L}_\phi = \frac{1}{2}\partial_\mu\vec{\phi}(x)\cdot\partial^\mu\vec{\phi}(x) - \frac{1}{2}m_\phi^2\vec{\phi}^{\,2}(x) \qquad (2-b)$$

$$\mathcal{L}_{q\text{-}\phi} = \frac{1}{2f_\pi}\bar{q}(x)\gamma^\mu\gamma^5(\vec{\lambda}q(x)\cdot\partial_\mu\vec{\phi}(x))\cdot\theta_v - \frac{1}{4f_\pi^2}\bar{q}(x)\vec{\lambda}\gamma^\mu\cdot(\vec{\phi}(x)\times\partial_\mu\vec{\phi}(x))q(x)\theta_v \qquad (2-c)$$

where θ_V is the function such that one inside the bag volume and zero outside, and Δ_S is a surface delta function. B is the constant "vacuum pressure". m_q is the quark mass and m_ϕ is the meson mass. The second term on the right-hand side in (2-c) is the WEINBERG-TOMOZAWA(W-T) term[8], responsible for low-energy s-wave pion-nucleon scattering. Whereas, this W-T term does not exist in the surface-type CBM. From (2-a)-(2-c), we extract the hamiltonian and the conserved electromagnetic (e.m) current $\vec{j}^\mu$, and then calculate the matrix elements:

(A) $\langle A|\frac{1}{2}\int d^3r\,\vec{r}\times\vec{j}_q\,|A\rangle$; (B) $\langle A|\frac{1}{2}\int d^3r\,\vec{r}\times\vec{j}_\phi\,|A\rangle$; (C) $\langle A|\frac{1}{2}\int d^3r\,\vec{r}\times\vec{j}_{q-\phi}\,|A\rangle$;

for the magnetic moments of octet baryons. $\vec{j}_\alpha$, $|A\rangle$ is the e.m. currents and the physical baryon state respectively,

$$\left.\begin{aligned}\vec{j} &= \vec{j}_q + \vec{j}_\phi + \vec{j}_{q-\phi}\\ \vec{j}_q &= \bar{q}\gamma^\mu\tfrac{1}{2}(\lambda_3+\tfrac{1}{\sqrt{3}}\lambda_8)q, \qquad \vec{j}_\phi = (f_{3ij}+\tfrac{1}{\sqrt{3}}f_{8ij})\phi^i\partial_\mu\phi^j,\\ \vec{j}_{q-\phi} &= -\frac{1}{2f_\pi}\bar{q}\lambda^i\gamma_\mu\gamma_5 q\,(f_{3ij}+\tfrac{1}{\sqrt{3}}f_{8ij})\phi^j .\end{aligned}\right\} \qquad (3)$$

$$\left.\begin{aligned}|A\rangle &= \sqrt{Z_2^A}\left\{1+(m_A-H_0-\Lambda H_{int}\Lambda)^{-1}H_{int}\right\}|A_0\rangle,\\ \Lambda &\equiv 1-\sum_{B\in 56}|B_0\rangle\langle B_0| ,\end{aligned}\right\} \qquad (4)$$

where the bare bag probability is Z_2^A, the bare baryon state $|A_0\rangle$, the physical mass m_A of the baryon $|A\rangle$, and the interaction hamiltonian H_{int}.

The theoretical result (TABLE 1) is in good agreement with the experimental value within about 7% except Ξ^-.

TABLE 1

	p	n	Σ^+	Σ^0	Σ^-	Ξ^0	Ξ^-	Λ^0
Theo.	2.65	−2.03	2.43	0.64	−1.15	−1.31	−0.48	−0.60
Exp.	2.79	−1.91	2.38 ±0.02		−1.14 ±0.05	−1.25 ±0.01	−0.69 ±0.04	−0.613

input data
$R = 1.0\,fm$
$R_\pi = 0.48\,fm$

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