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Color Screening Effect and Baryon Spectra

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By using the color confinement potential which includes the color screening effect obtained from the lattice gauge calculation, we studied the structure of the baryons, and calculated the baryon spectra and the square root radii of the corresponding states.

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1. INTRODUCTION

As a strong interaction theory, the Quantum Chromodynamics theory has a key issue, i.e., how to treat the non-perturbative part. In recent years, one of the non-perturbative technique developed from the lattice gauge calculation provides a phenomenological potential between the quark and antiquark, in which the short range part is like a coulomb interaction and the long range part is a linear potential [1]. This potential has been successfully used in the research on the heavy meson spectra; it seems that the linear potential as a confinement potential of the QCD inspired model is more reliable. In 1986, E. Laermann et al. [2] considered the virtual fermion loop diagrams in the lattice gauge calculation. They found that when the distance between the quark and antiquark is large enough, the potential is obviously lower than the linear one (Fig.1). In Fig.1, the dashed curve represents the linear potential and the solid curve represents the potential which includes the virtual fermion loop effects. This means that the color screening effects from the quark sea can influence the color confinement, i.e., when the distance between two valence quarks increases, the importance of the interactions between the valance quark and the sea quark grows, and this effect reduces the color confinement interactions between the valance quarks. Thus, the color screening effect should be an important physical mechanism for studying the structure of hadrons and the hadron-hadron interactions.

Let us start from an examination about the baryon spectra. From the baryon spectra data, we see that a group of states with $N = 2$ is very close to the state of $N = 1$. In principle, for a quantum system, a narrow potential has energy spectra with large energy gap, and when the width of the potential grows, the energy gap becomes smaller. The color screening effect makes the color

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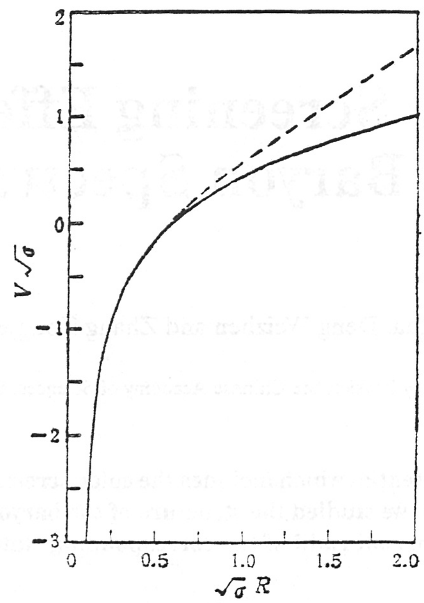


Fig.1
Interaction between quark and anti-quark
from lattice gauge calculation.

confinement potential wider for large r region, and this would reduce the energy gap of $N = 1$ and 2 states. In this sense, it is qualitatively consistent with the feature of the baryon spectra data. On the other hand, in the study of the baryon-baryon interactions of the quark potential model, although it is successful in explaining the short range repulsive core, an unreasonable color Van der Waals force appears when the color hidden states are included either for the quadratic confinement potential or for the linear confinement potential. It is a serious shortcoming of the quark potential model, and this is caused by the linear (or quadratic) confinement potential which is proportional to the distance of two quarks r or r^2. So the color Van der Waals force problem might be solved, when the confinement potential has linear (or quadratic) behavior only for the region of $r < r_0$ and stops its increase for the large r region. Such kind of the confinement potential may be obtained if the color screening effect is considered.

In Ref.[2], a phenomenological expression of the color confinement potential with the color screening effect is given as:

$$V_{ij}^{\mathrm{CONF}(1)} = -(\lambda_i \cdot \lambda_j)\frac{\sigma}{\mu}(1 - e^{-\mu r_{ij}}).$$

It is named exponential confinement potential and its asymptotic behaviors are

$$V_{ij}^{\mathrm{CONF}(1)} \xrightarrow{r_{ij}\ \text{small}} -(\lambda_i \cdot \lambda_j)\sigma r_{ij},$$

$$V_{ij}^{\mathrm{CONF}(1)} \xrightarrow{r_{ij}\ \text{large}} -(\lambda_i \cdot \lambda_j)\frac{\sigma}{\mu}.$$

i.e:, when r_{ij} is small, it is like a linear potential; when r_{ij} is large, it tends to be a constant. According to the numerical calculation of the lattice gauge theory, we also propose a phenomenological expression of the color confinement potential called error function confinement potential,

$$V_{ij}^{\mathrm{CONF}(2)} = -(\lambda_i \cdot \lambda_j)a_c\mathrm{erf}(\mu r_{ij}).$$

It has similar asymptotic behavior as

$$V_{ij}^{\mathrm{CONF}(2)} \xrightarrow{r_{ij}\ \mathrm{small}} -(\lambda_i \cdot \lambda_j)a_c \frac{2}{\sqrt{\pi}} r_{ij},$$

$$V_{ij}^{\mathrm{CONF}(2)} \xrightarrow{r_{ij}\ \mathrm{large}} -(\lambda_i \cdot \lambda_j)a_c.$$

and in the small r_{ij} region this potential is more like a linear one.

In this paper, we calculate the baryon spectra and the square root radii of the corresponding states in the frame work of non-relativistic quark potential model by using the two kinds of confinement potential with the color screening effect, exponential form and error function form, respectively. The results are compared with the linear confinement potential calculation, and the parameters of the model are discussed.

2. THEORETICAL FRAME WORK

In the non-relativistic quark potential model, baryon is regarded as consisting of three quarks, and between each two of them there is color confinement interaction and one gluon exchange interactions. The Hamiltonian of the system can be written as

$$H = \sum_{i=1}^{3}\left(m_i + \frac{p_i^2}{2m_i} + B_i\right) - T_G + \sum_{i<j=1}^{3} (V_{ij}^{\mathrm{OGE}} + V_{ij}^{\mathrm{CONF}}). \tag{1}$$

Here m_i is the quark mass, B_i the zero point energy, T_G the kinetic energy of the center of mass motion, and V_{ij}^{OGE} the one gluon exchange interactions [3], including coulomb term, color electric term color magnetic term and tensor term (we ignore the spin-orbit term in the calculation).

$$V_{ij}^{\mathrm{OGE}} = (\lambda_i \cdot \lambda_j)\frac{\alpha_s}{4}\left\{\frac{1}{r_{ij}} - \frac{\pi}{2}\delta(r_{ij}) \cdot \left[\frac{1}{m_i^2} + \frac{1}{m_j^2} + \frac{4}{3m_im_j}\sigma_i \cdot \sigma_j\right]\right.$$
$$\left. - \frac{3}{4m_im_jr_{ij}^3}\left[\frac{(\sigma_i \cdot r_{ij})(\sigma_j \cdot r_{ij})}{r_{ij}^2} - \frac{1}{3}(\sigma_i \cdot \sigma_j)\right]\right\}. \tag{2}$$

For the color confinement potential V_{ij}^{CONF}, two kinds of confinement potential with color screening effect, the exponential form $V_{ij}^{\mathrm{CONF}(1)}$ and the error function form $V_{ij}^{\mathrm{CONF}(2)}$, are used.

$$V_{ij}^{\mathrm{CONF}(1)} = -(\lambda_i \cdot \lambda_j)a_c^{(1)}(1 - e^{-\mu_1 r_{ij}}). \tag{3a}$$

$$V_{ij}^{\mathrm{CONF}(2)} = -(\lambda_i \cdot \lambda_j)a_c^{(2)}\mathrm{erf}(\mu_2 r_{ij}). \tag{3b}$$

For comparison, we also considere two kinds of confinement potential without color screening effect, the linear form $V_{ij}^{\mathrm{CONF}(3)}$ and the quadratic form $V_{ij}^{\mathrm{CONF}(4)}$.

$$V_{ij}^{\mathrm{CONF}(3)} = -(\lambda_i \cdot \lambda_j)a_c^{(3)}r_{ij}, \tag{3c}$$

$$V_{ij}^{\mathrm{CONF}(4)} = -(\lambda_i \cdot \lambda_j)a_c^{(4)}r_{ij}^2. \tag{3d}$$

For a three-quark system, the internal coordinates of the orbital space are ρ and λ,

$$\begin{cases} \rho = \sqrt{\frac{1}{2}}(r_1 - r_2), \\ \lambda = \sqrt{\frac{1}{6}}(r_1 + r_2 - 2r_3). \end{cases} \tag{4}$$

We take the harmonic oscillator wave functions as the basic wave functions. Some orbital wave functions of the low lying states are given as follows [4]:

$$\psi([3]N = 0, 0^+) = \psi_0(\rho, \lambda, b) = (\pi b^2)^{-\frac{3}{2}} \exp\left(-\frac{\rho^2 + \lambda^2}{2b^2}\right), \tag{5a}$$

$$\psi_{(12)}([21]N = 1, 1^-) = \sqrt{\frac{8\pi}{3}} \frac{\lambda}{b} \psi_0(\rho, \lambda, b) Y_{1m}(\hat{\lambda}), \tag{5b}$$

$$\psi_{[12]}([21]N = 1, 1^-) = \sqrt{\frac{8\pi}{3}} \frac{\rho}{b} \psi_0(\rho, \lambda, b) Y_{1m}(\hat{\rho}), \tag{5c}$$

$$\begin{aligned} \psi([3]N = 2, 0^+) &= \psi_2'(\rho, \lambda, b) \\ &= \sqrt{\frac{1}{3}}\left(3 - \frac{\rho^2 + \lambda^2}{b^2}\right)\psi_0(\rho, \lambda, b). \end{aligned} \tag{5d}$$

The symbol (12) of $\psi_{(12)}$ in (5b) and the symbol [12] of $\psi_{[12]}$ in (5c) mean that $\psi_{(12)}$ has symmetric property and $\psi_{[12]}$ has anti-symmetric property, respectively, when particles 1 and 2 are permitted. It should be mentioned that ψ_0 and ψ_2 are not orthogonal when they have different size parameter b. In the baryon spectra calculation, the size parameters are determined by the energy variation conditions and each state has its own size parameter b. Therefore, we have to make them orthogonalized.

$$\psi_2(\rho, \lambda, b_2, b_0) = \alpha[\psi_2'(\rho, \lambda, b_2) - \beta\psi_0(\rho, \lambda, b_2)]. \tag{5e}$$

with

$$\begin{cases} \beta = \sqrt{3}\left(\frac{b_2^2 - b_0^2}{b_2^2 + b_0^2}\right), \\ \alpha = \frac{1}{\sqrt{1 + \beta^2}}. \end{cases}$$

is orthogonal to $\psi_0(\rho, \lambda, b_0)$. In our calculation, we take ψ_2 instead of ψ_2'.

In the calculation of the baryon energies, only the confinement potential is different compared with the previous calculation. The energy expectative values of the different kinds of confinement potentials for some low lying states are shown in Eqs. (6), (7) and (8).

For $\psi([3]N = 0, 0^+)$ state:

$$\begin{aligned} &3_0\langle -(\lambda_1 \cdot \lambda_2) a_c^{(1)} (1 - \exp(-\mu_1 r_{12})) \rangle_0 \\ &= 8a_c^{(1)}[1 - 4I_1(\mu, b)], \end{aligned} \tag{6a}$$

$$3_0\langle -(\lambda_1 \cdot \lambda_2) a_c^{(2)} \mathrm{erf}(\mu_2 r_{12}) \rangle_0$$
$$= \frac{16 a_c^{(2)}}{\pi}\left(\mathrm{tg}^{-1}(\sqrt{2}\,\mu_2 b) + \frac{\sqrt{2}\,\mu_2 b}{1 + 2\mu_2^2 b^2} \right), \tag{6b}$$

$$3_0\langle -(\lambda_1 \cdot \lambda_2) a_c^{(3)} r_{12} \rangle_0 = \frac{32 a_c^{(3)} b}{\sqrt{2\pi}}, \tag{6c}$$

$$3_0\langle -(\lambda_1 \cdot \lambda_2) a_c^{(4)} r_{12}^2 \rangle_0 = 24 a_c^{(4)} b^2. \tag{6d}$$

For $\psi([21], N = 1, 1^-)$ state:

$$3_1\langle -(\lambda_1 \cdot \lambda_2) a_c^{(1)} (1 - \exp(-\mu_1 r_{12})) \rangle_1$$
$$= a_c^{(1)} \left[8 - 16 I_1(\mu, b) - \frac{32}{3} I_2(\mu, b) \right], \tag{7a}$$

$$3_1\langle -(\lambda_1 \cdot \lambda_2) a_c^{(2)} \mathrm{erf}(\mu_2 r_{12}) \rangle_1$$
$$= \frac{16 a_c^{(2)}}{\pi}\left(\mathrm{tg}^{-1}(\sqrt{2}\,\mu_2 b) + \frac{\sqrt{2}\,\mu_2 b}{1 + 2\mu_2^2 b^2}\left(1 + \frac{1}{3}\,\frac{1}{1 + 2\mu_2^2 b^2}\right) \right), \tag{7b}$$

$$3_1\langle -(\lambda_1 \cdot \lambda_2) a_c^{(3)} r_{12} \rangle_1 = \frac{112 a_c^{(3)} b}{3\sqrt{2\pi}}, \tag{7c}$$

$$3_1\langle -(\lambda_1 \cdot \lambda_2) a_c^{(4)} r_{12}^2 \rangle_1 = 32 a_c^{(4)} b^2. \tag{7d}$$

For $\psi([3], N = 2, 0^+)$ state:

$$3_2\langle -(\lambda_1 \cdot \lambda_2) a_c^{(1)} (1 - \exp(-\mu_1 r_{12})) \rangle_2$$
$$= a_c^{(1)} \left[8 - 40 I_1(\mu, b) + 32 I_2(\mu, b) - \frac{32}{3} I_3(\mu, b) \right], \tag{8a}$$

$$3_2\langle -(\lambda_1 \cdot \lambda_2) a_c^{(2)} \mathrm{erf}(\mu_2 r_{12}) \rangle_2$$
$$= \frac{16 a_c^{(2)}}{\pi}\left(\mathrm{tg}^{-1}(\sqrt{2}\,\mu_2 b) + \frac{\sqrt{2}\,\mu_2 b}{1 + 2\mu_2^2 b^2} \times\left(1 - \frac{1}{6(1 + 2\mu_2^2 b^2)} + \frac{2}{3}\,\frac{1}{(1 + 2\mu_2^2 b^2)^2}\right)\right), \tag{8b}$$

$$3_2\langle -(\lambda_1 \cdot \lambda_2) a_c^{(3)} r_{12} \rangle_2 = \frac{40 a_c^{(3)} b}{\sqrt{2\pi}}, \tag{8c}$$

$$3_2\langle -(\lambda_1 \cdot \lambda_2) a_c^{(4)} r_{12}^2 \rangle_2 = 40 a_c^{(4)} b^2. \tag{8d}$$

Here, the expressions of I_0, I_1, I_2, I_3 are:

$$I_0(\mu, b) = \frac{1}{2}\exp\left(\frac{\mu^2 b^2}{2}\right)\left[1 - \mathrm{erf}\left(\frac{\mu b}{\sqrt{2}}\right)\right],$$

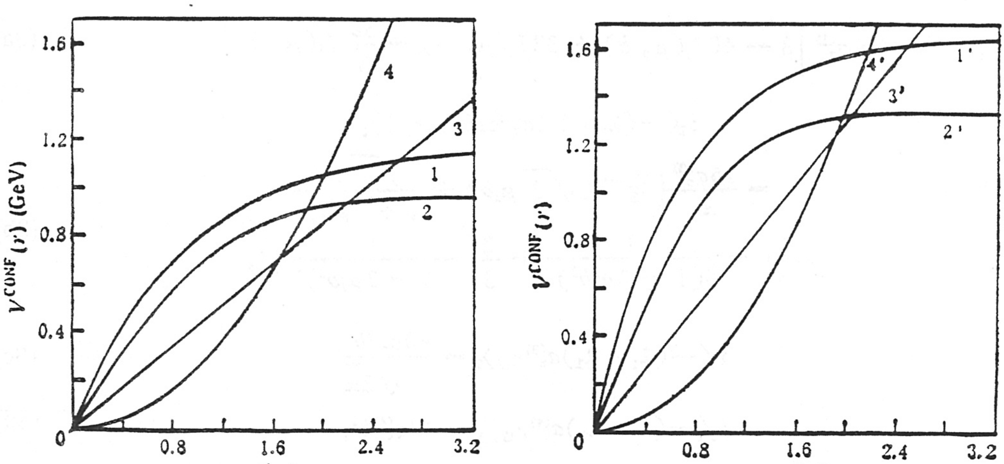
$$I_1(\mu, b) = \left(\frac{1}{2} + \frac{\mu^2 b^2}{2}\right) I_0(\mu, b) - \frac{\mu b}{2\sqrt{2\pi}},$$

$$I_2(\mu, b) = \left(\frac{1}{2} + \mu^2 b^2\right) I_0(\mu, b) + \left(\frac{1}{2} + \frac{\mu^2 b^2}{2}\right) I_1(\mu, b) - \frac{\mu b}{\sqrt{2\pi}},$$

$$I_3(\mu, b) = (1 + 3\mu^2 b^2) I_0(\mu, b) + (1 + 2\mu^2 b^2) I_1(\mu, b) + \left(\frac{1}{2} + \frac{\mu^2 b^2}{2}\right) I_2(\mu, b) - \frac{3\mu b}{\sqrt{2\pi}}.$$

Before doing the quantitative calculation, we would like to have a qualitative discussion first. For simplicity, we assume that the different energy levels have the same size parameter b. The energy gaps from the confinement potential are named ΔE_1 for $N = 0$ and $N = 1$ states and ΔE_2 for $N = 1$ and $N = 2$ states. Apparently, for the quadratic confinement potential, $\Delta E_2 = \Delta E_1 = 8a_c^{(4)} b^2$. The linear confinement potential can reduce ΔE_2 by a factor of 1/2, i.e., $\Delta E_2 = \frac{1}{2}\Delta E_1 = \frac{16 a_c^{(3)} b}{3\sqrt{2\pi}}$. The error function confinement potential can make ΔE_2 smaller, i.e., $\Delta E_2 < 1/2\,\Delta E_1$, and the exponential potential, when $\mu_1 b$ is smaller than 1.5, can also have $\Delta E_2 < 1/2\,\Delta E_1$. From this simple analysis, we can see that both of the confinement potentials with the color screening effect can improve the results by reducing the energy gap ΔE_2. Furthermore, for comparison with the experimental data, we calculate the baryon spectra quantitatively. In the calculation, there are several parameters to be determined, such as the quark mass m, the size parameters b of $N = 0, 1, 2$ states, zero point energy B, the coupling constant of one gluon exchange interaction α_s, the strength of confinement potential a_c and the length of color screening effect μ^{-1}. The quark mass and the size parameter of the ground state b_0 should first be selected from a reasonable range, i.e.,

$$\begin{cases} m = 0.300 - 0.350 \text{ GeV}, \\ b_0 = 0.45 - 0.55 \text{ fm}. \end{cases} \tag{9}$$



(A) Without color electric force (B) With color electric force

Fig.2
Color confinement potential. 1. 1′ exponential form; 2. 2′ error function form; 3. 3 linear form; 4. 4′ quadrtic form.

Table 1
Parameters.

(A) Without color electric force

parameters	erf	exp	lin	qua
M(GeV)	0.300	0.300	0.300	0.300
μ(fm^{-1})	0.7500	1.1250	0.0000	0.0000
α_s	0.746	0.746	0.822	0.578
a_c	0.3595(GeV)	0.4418(GeV)	0.1615(GeV/fm)	0.0975(GeV/fm^2)
B(GeV)	−0.598	−0.712	−0.376	−0.290

(B) With color electric force

parameters	erf	exp	lin	qua
M(GeV)	0.325	0.325	0.325	0.300
μ(fm^{-1})	0.9000	1.5000	0.0000	0.0000
α_s	0.876	0.876	0.931	0.695
a_c	0.4987(GeV)	0.6197(GeV)	0.2440(GeV/fm)	0.1255(GeV/fm^2)
B(GeV)	−0.958	−0.1186	−0.607	−0.395

Note: M: quark mass; μ: length of color screening effect; α_s: OGE coupling constant; a_c: strength of color confinement potential; B: zero point energy.

After giving a group of values of m and b_0, we can determine the other parameters by fitting the variation conditions for N = 0, 1, 2 states and energy difference conditions:

$$\begin{cases} M_\Delta - M_N = 0.296 \text{ GeV}, \\ E(N=1) - E(N=0) \simeq 0.5 \text{ GeV}, \\ E(N=0) \simeq 1.080 \text{ GeV}. \end{cases} \tag{10}$$

Here, we should mention that in the quark potential model, the interactions between two quarks are taken to be $V_{ij}^{\rm OGE} + V_{ij}^{\rm CONF}$ and this is a phenomenological treatment. In order to acquire more information about the short range interaction between the two quarks, in our calculation we consider two kinds of $\delta(r_{ij})$ term in the one gluon exchange interactions: one, designated as (A), omits the color electric interaction $-(\lambda_i \cdot \lambda_j)\frac{\alpha_s}{4} \cdot \frac{\pi}{m^2}\delta(\boldsymbol{r}_{ij})$ in expression (2) and only maintains the color magnetic term, and the other, designated as (B), includes the color electric term. The parameters for case (A) and case (B) are all listed in Table 1, and the corresponding confinement potentials are given in Fig.2. The length of the color screening effect μ^{-1} of the exponential confinement potential is 0.89 fm for case (A) and 0.67 fm for case (B), both being consistent with the value 0.8 ± 0.2 fm obtained from the lattice gauge calculation [2]. From these parameters, we calculate the energies and the square root radii of N = 0, 1, 2 states, and then take into account the color magnetic force and the tensor force to obtain the fine structure baryon spectra and compare the results with the experimental data.

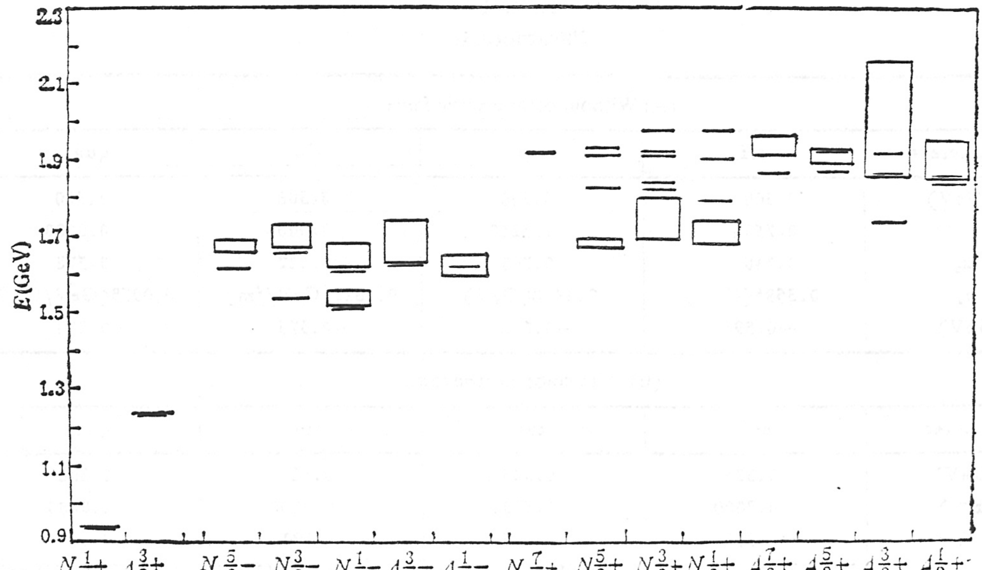


Fig.3
Fine structure baryon spectra.

3. RESULTS AND DISCUSSION

For studying the color screening effect on the baryon spectra, the results of only central force are shown in Table 2. Tables 2(A) and 2(B) are for the cases without and with color electric force, respectively. Four kinds of confinement potential are considered altogether, and for each kind of confinement potential, the energies, the square root radii and the corresponding size parameters b are all listed in the table. According to Table 2:

(1) The color screening effect does improve the result of the baryon spectra. The error function confinement potential and the exponential confinement potential both have smaller energy gap $N = 2$ and $N = 1$, compared with the linear confinement potential. The energy gap of $N = 2$ and $N = 1$ states is reduced about 0.1 – 0.25 GeV for various cases, and the result of the error function confinement potential is about 0.020 GeV better than that of the exponential confinement potential. Even that the states of $N = 2$ are still 0.1 – 0.15 GeV higher than the experimental data (Fig.3).

(2) After including the color screening effect, the square root radii for $N = 2$ state become much larger than the case of the linear confinement potential. For example, for the error function confinement potential, the square root radius of $N = 2$ state is about 1.05 fm, a factor 2.2 times that of the $N = 0$ state. But for the linear confinement potential, the square root radius of $N = 2$ state is only 1.5 times that of the $N = 0$ state. This means that the wave functions of the $N = 2$ states are quite different for different confinement potential cases, and that the wave function distribution of $N = 2$ state becomes much wider when the color screening effect is considered. This feature can be further studied by calculating the baryon decay processes.

(3) By comparing the cases of with and without color electric force, the color electric force makes the energy gap of $N = 2$ and $N = 1$ states larger, and even the color screening effect can improve the result by reducing 0.25 GeV, the energies of the $N = 2$ states are still about 0.2 GeV higher than experimental data.

Finally, we take into account the color magnetic force and tensor force of the one gluon exchange in order to obtain the fine structure of the baryon spectra. As an example, Fig.3 shows one

Table 2
Energies and square root radii of baryons.

(A) Without color electric force

state		erf			exp		
		E(GeV)	$\sqrt{\overline{r^2}}$(fm)	b(fm)	E(GeV)	$\sqrt{\overline{r^2}}$(fm)	b(fm)
$n = 0$	[56,0+]	1.080	0.4900	0.4900	1.081	0.4900	0.4900
$n = 1$	[70,1−]	1.580	0.6928	0.6000	1.581	0.6900	0.5976
$n = 2$	[56,0+]	1.717	0.9762	0.6904	1.737	0.9148	0.6486
	[70,0+]	1.816	1.0308	0.7984	1.843	0.9260	0.7174
	[56,2+]	1.847	1.0382	0.8042	1.873	0.9282	0.7190
	[70,2+]	1.908	1.0586	0.8200	1.932	0.9322	0.7222
	[20,1+]	1.969	1.0904	0.8446	1.992	0.9370	0.7258

state		lin			qua		
		E(GeV)	$\sqrt{\overline{r^2}}$(fm)	b(fm)	E(GeV)	$\sqrt{\overline{r^2}}$(fm)	b(fm)
$n = 0$	[56,0+]	1.081	0.5060	0.5060	1.081	0.4500	0.4500
$n = 2$	[70,1−]	1.583	0.6412	0.5554	1.546	0.5996	0.5194
$n = 2$	[56,0+]	1.864	0.7644	0.5622	1.995	0.7108	0.5168
	[70,0+]	1.953	0.7604	0.5890	2.036	0.6772	0.5246
	[56,2+]	1.974	0.7606	0.5892	2.045	0.6778	0.5250
	[70,2+]	2.016	0.7608	0.5892	2.062	0.6792	0.5260
	[20,1+]	2.059	0.7612	0.5896	2.080	0.6806	0.5272

(B) With color electric force

state		erf			exp		
		E(GeV)	$\sqrt{\overline{r^2}}$(fm)	b(fm)	E(GeV)	$\sqrt{\overline{r^2}}$(fm)	b(fm)
$n = 0$	[56,0+]	1.081	0.4900	0.4900	1.080	0.4900	0.4900
$n = 1$	[70,1−]	1.581	0.6180	0.5352	1.580	0.6168	0.5342
$n = 2$	[56,0+]	1.799	0.9100	0.6458	1.821	0.8532	0.6090
	[70,0+]	1.877	0.9260	0.7174	1.902	0.8448	0.6544
	[56,2+]	1.910	0.9142	0.7080	1.932	0.8340	0.6460
	[70,2+]	1.976	0.8828	0.6838	1.990	0.8114	0.6286
	[20,1+]	2.039	0.8370	0.6484	2.046	0.7848	0.6078

state		lin			qua		
		E(GeV)	$\sqrt{\overline{r^2}}$(fm)	b(fm)	E(GeV)	$\sqrt{\overline{r^2}}$(fm)	b(fm)
$n = 0$	[56,0+]	1.081	0.5000	0.5000	1.080	0.4700	0.4700
$n = 1$	[70,1−]	1.573	0.5768	0.4996	1.554	0.5776	0.5002
$n = 2$	[56,0+]	2.045	0.7066	0.5302	2.151	0.6938	0.5136
	[70,0+]	2.057	0.6812	0.5276	2.119	0.6520	0.5050
	[56,2+]	2.060	0.6744	0.5224	2.106	0.6486	0.5024
	[70,2+]	2.065	0.6600	0.5112	2.080	0.6414	0.4968
	[20,1+]	2.066	0.6444	0.4992	2.053	0.6338	0.4910

Note: E: baryon energies; $\sqrt{\overline{r^2}}$: square root radii; b: size parameters.

of the results, which is for the case of the error function confinement potential and without color electric force in the OGE interaction. In Fig.3, the thick line represents the experimental data [5] and the thin line denotes the theoretical results. N and Δ represent the baryons with isospin 1/2 and 3/2, respectively. J^{π} denotes the total spin and the parity of the baryon. For the isospin 1/2 particles, the energies of the $N = 2$ states are about 0.1-0.15 GeV higher than the experimental data; for the isospin 3/2 particles, the energies of the $N = 2$ states are almost consistent with the experimental data. Furthermore, the spin-orbit force and some sea-quark effect should be considered to improve the result. In any event, we start from the simple non-relativistic quark potential model, including the color screening effect in the phenomenological confinement potential, to analyze and calculate the baryon spectra and the square root radii, respectively. We think that all the results are significant for understanding the influence of the color screening effect on the baryon spectra, and also for studying the mechanism of the color confinement.

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