Study of Confined One Gluon Exchange and Instanton-induced Interaction for Nucleon - Nucleon Interaction

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Introduction

In this paper, we investigate the effect of exchange of confined gluons among relativistically confined quarks for N-N interactions using Confined One-Gluon Exchange Potential (COGEP) [1] and Instanton-Induced Interaction (III) potential [3, 4] respectively. The Resonating Group Method (RGM) is used [2] to investigate the N-N adiabatic potential for the $^1S_0$ and $^3S_1$ states using Born-Oppenheimer approximation.

Model

The Hamiltonian for this problem is of the form:

$$H = K + V_{int} + V_{conf} - K_{CM}$$

where K is the kinetic energy, V_{int} is the interaction potential, V_{conf} is the harmonic confinement potential and K_{CM} is the kinetic energy of the center of mass. The interaction potentials considered here are COGEP and III.

The effect of exchange of confined gluons among relativistically confined quarks in NN scattering calculations are taken. For quarks, we use the relativistic harmonic oscillator Lorentz scalar plus vector (RHM) confinement model. For the confinement of gluons, we use the current confinement model (CCM). Using confined gluon propagators, we obtain the confined one-gluon-exchange potential (COGEP) between quarks [1]. The central part of COGEP is

$$\tilde{V}_{COGEP} = \frac{\alpha_s N^4}{4}\boldsymbol{\lambda}_i.\boldsymbol{\lambda}_j[D_0(\boldsymbol{r}) + \frac{1}{(E+M)^2} \times[4\pi\delta^3(\boldsymbol{r}) - c^4r^2D_1(\boldsymbol{r})][1-\frac{2}{3}\boldsymbol{\sigma}_i.\boldsymbol{\sigma}_j]]$$

where

$$\frac{\alpha_s N^4}{4}\boldsymbol{\lambda}_i.\boldsymbol{\lambda}_j[D_0(\boldsymbol{r}) + \frac{1}{(E+M)^2}(4\pi\delta^3(\boldsymbol{r}) - c^4r^2D_1(\boldsymbol{r}))]$$

is the color electric term of COGEP and

$$\frac{\alpha_s N^4}{4}\boldsymbol{\lambda}_i.\boldsymbol{\lambda}_j[\frac{1}{(E+M)^2}(4\pi\delta^3(\boldsymbol{r}) - c^4r^2D_1(\boldsymbol{r}))\times(1-\frac{2}{3}\boldsymbol{\sigma}_i.\boldsymbol{\sigma}_j)]$$

is the color magnetic term.

α_s is the strong coupling constant. $\boldsymbol{\lambda}_i$ and $\boldsymbol{\lambda}_j$ are the generators of the color SU(3) group for the i^{th} and j^{th} quarks, $\boldsymbol{\sigma}_i$ and $\boldsymbol{\sigma}_j$ are the Pauli spin operators.

The III is given by [4]

$$V_{III} = \frac{-W}{2}[\frac{16}{15} + \frac{2}{5}(\boldsymbol{\lambda}_i.\boldsymbol{\lambda}_j) + \frac{1}{10}(\boldsymbol{\lambda}_i.\boldsymbol{\lambda}_j)(\boldsymbol{\sigma}_i.\boldsymbol{\sigma}_j)]\times\delta^3(\boldsymbol{r}_{ij})$$

where W is the III strength parameter [3].

Results and Discussion

III has three terms - color independent, color electric and color magnetic. For short range, color independent part shows attractive nature for direct as well as exchange parts. The (direct part of) color electric term is slightly repulsive for short range and (exchange part is) attractive. The direct part of

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color magnetic term shows short range attraction which is state independent, while the exchange part is repulsive. Also, it distinguishes between singlet and triplet states which is lesser for the latter compared to the former. [3, 4].

The color magnetic terms of COGEP yields both short-range repulsion and intermediate-range attraction for the $^1S_0$ and $^3S_1$ states. The exchange kernels of $\delta(\boldsymbol{r})$ dominate over the exchange kernels of $c^4r^2D_1(\boldsymbol{r})$ at short range distances, thus producing short-range repulsion; whereas, the exchange kernels of $c^4r^2D_1(\boldsymbol{r})$ dominate over that of $\delta(\boldsymbol{r})$ at intermediate and long ranges. This reproduces the expected long range attraction. It is also observed that there's no significant contribution from the (quark) confinement potential and color electric terms [2].

Further work in this regard is in progress.

References

[1] P. C. Vinodkumar, K. B. Vijayakumar, S. B. Khadkikar, Pramana J. Phys. **39**, 47-70 (1991).

[2] S. B. Khadkikar and K. B. Vijayakumar, Phys. Lett. B, **254**, 3-4 (1991).

[3] M. Oka and S. Takeuchi, Phys. Rev. Lett. **63**, 1780 (1989).

[4] C. S. Vanamali and K. B. Vijaya Kumar, Phys. Rev. C **94**, 054002 (2016).