Effect of Strong Coupling Constant on N-N Interaction

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Introduction

The problem of nucleon-nucleon (N-N) interaction has always remained a never ending challenge in nuclear physics. Study of N-N interaction using a relativistic harmonic model and with the inclusion of one pion exchange potential (OPEP) has been done successfully [1]. Also studies with a relativistic harmonic model by including instanton induced interaction (III) has also been done [2]. It is seen that OPEP gives a state independent repulsion and the III provides a net attraction upto 2 MeV. Study on finite size effect of quarks on the N-N interaction has been made in an earlier work [3]. There is a decrease in the magnitude and the range of short range repulsion as a result of smearing of the contact interaction.

The strong coupling constant (α_s) plays an important role in defining the interaction between nucleons. Khadkikar *et. al.* have studied the N-N interaction with a relativistic harmonic model including the σ and π exchange [4]. The variation in the value of α_s when the exchange of σ and π is included and when the exchange of σ and π is not included is studied.

In the present investigation the variation in the N-N interaction potential with variation of α_s is studied. The Resonating Group Method (RGM) technique in the framework of Relativistic Harmonic Model (RHM) has been used to calculate the N-N adiabatic potential for $^1S_0$ and $^3S_1$ states using Born approximation.

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Model

The full Hamiltonian used here is

$$H = K + V_{int} + V_{conf} - K_{CM} \tag{1}$$

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

The Confined Gluon Propagators (CGP) derived from a Current Confinement Model (CCM) are used to derive the COGEP [1]. The central part of the COGEP is given by

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

where

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

is the color electric part of the COGEP and

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

is the color magnetic part of the COGEP.

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.

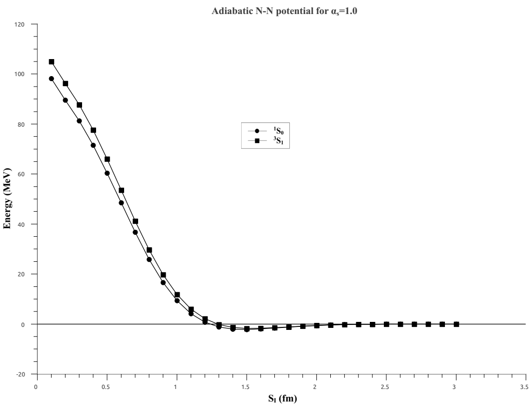

FIG. 1: Adiabatic N-N potential for $\alpha_s = 1.0$.

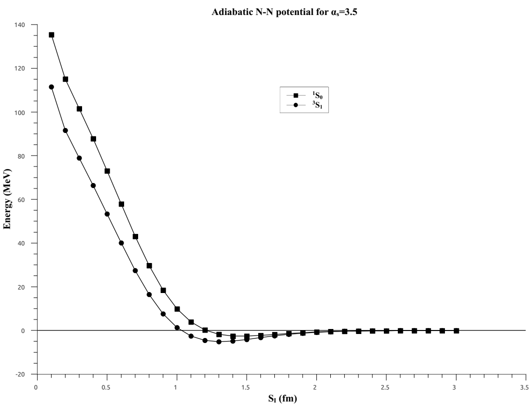

FIG. 2: Adiabatic N-N potential for $\alpha_s = 3.5$.

Results and Discussion

The overall N-N interaction potential has a short range repulsion, intermediate range attraction and long range saturation. The exchange part of the color magnetic interaction is responsible for the short range repulsion [4].

The exchange kernels of $\delta^3(\boldsymbol{r})$ dominates over the exchange kernels of $c^2 D_0(\boldsymbol{r})$ in the short range thus providing short range repulsion. In the intermediate and long range, the exchange kernels of $c^2 D_0(\boldsymbol{r})$ dominates over the exchange kernels of $\delta^3(\boldsymbol{r})$ thus providing intermediate and long range attraction [1, 4].

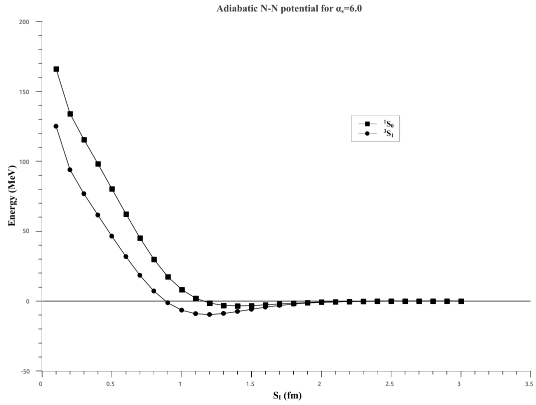

FIG. 3: Adiabatic N-N potential for $\alpha_s = 6.0$.

Thus it can be observed that increase in α_s results in an increase in the overall attraction.

References

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