Finite size of constituent quarks and nucleon nucleon interaction.

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Introduction

We have investigated the effects of the finite size of the constituent quarks on the short range nucleon nucleon (NN) interaction in the framework of the nonrelativistic quark model (NRQM) using resonating group method (RGM).

Various studies of NN interaction in the NRQM suggest that the short range NN interaction is dominated by the color magnetic interactions. However, the color magnetic parts of the quark-quark interaction potentials derived from tree level one gluon exchange are singular due to the presence of the delta function. The orbital delta function potential also suggests a contact interaction between two constituent quarks. The term *constituent* is used to differentiate the current quarks that appear in the full theory of quantum chromodynamics from the nonrelativistic quasi-particles used in the NRQM. The constituent quarks are a complex potpourri of current quarks and quark-antiquark polarization [1]. The meson clouds that surround the current quarks provide an effective (dynamical) mass and hence an effective size to the constituent quarks. A previous approach suggested by Povh and Hufner, the constituent quarks were assumed to have a radius inversely proportional to their constituent mass [2].

In the present work, we have remodeled the color magnetic interactions by smearing the contact (delta function) interactions using a Gaussian function.

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Hamiltonian

The Hamiltonian used in the present study is given by,

$$H = K + V_{\rm Conf} + V_{\rm int} - K_{\rm cm}$$

The interaction potentials $V_{\rm int}$ contain two parts: One Gluon Exchange potential ($V_{\rm OGEP}$) and Instanton Induced Interaction ($V_{\rm III}$). The forms of potentials used and their need are given elsewhere [3]. Below, we list the color magnetic part of OGEP and III.

$$V_{\rm OGEP} = \frac{-2\pi\alpha_s}{12m_q^2}\frac{1}{\pi^{3/2}r_0^3}\sum_{i<j} e^{-r_{ij}^2/r_0^2}\boldsymbol{\sigma}_i.\boldsymbol{\sigma}_j\boldsymbol{\lambda}_i.\boldsymbol{\lambda}_j$$

and,

$$V_{\rm III} = -\frac{W}{20}\frac{1}{\pi^{3/2}r_0^3}\sum_{i<j} e^{-r_{ij}^2/r_0^2}\boldsymbol{\sigma}_i.\boldsymbol{\sigma}_j\boldsymbol{\lambda}_i.\boldsymbol{\lambda}_j$$

In the above potentials, we have replaced $\delta(|\boldsymbol{r}_i - \boldsymbol{r}_j|)$ by $\frac{1}{\pi^{3/2}r_0^3}e^{-r_{ij}^2/r_0^2}$, where r_0 represents the effective size of the quarks.

The smearing of the contact interactions is known to reproduce the rms charge radius of proton [1]. The heavy baryon and meson spectra have also been studied using the smeared color magnetic interactions [4].

Results and Discussion

The quark size parameter is varied from 0.1 fm to 0.6 fm. Fig.(1) shows the variation of the strength of repulsion of the short range part of the NN potential in the triplet channel ($^3S_1$) and fig.(2) shows the variation of the strength of repulsion of the short range part of the NN potential in the singlet channel ($^1S_0$). In both the cases, the strength of repulsion reduces as r_0 increases.

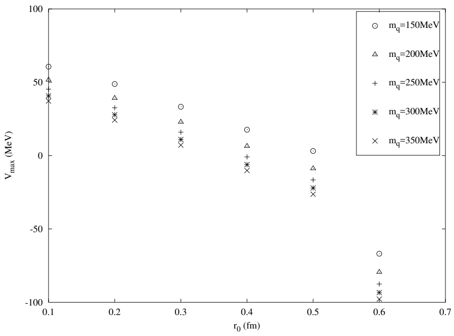

FIG. 1: Variation of the strength of repulsion of the short range part of the NN potential in the triplet channel ($^3S_1$).

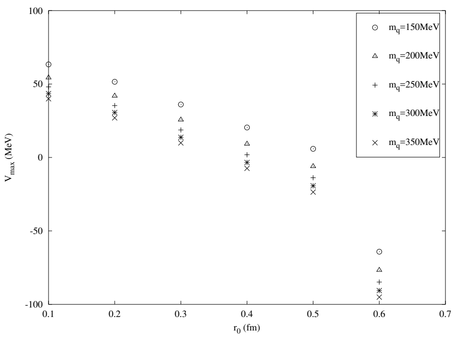

FIG. 2: Variation of the strength of repulsion of the short range part of the NN potential in the singlet channel ($^1S_0$).

The reduction in the repulsion can be attributed to the nature of smearing. The smearing of the contact interactions results in a model of constituent quarks that treats them as soft spheres. The extent of smearing is decide by r_0. Hence, as r_0 increases, the *sphere* becomes softer and softer resulting in reduced repulsion.

Conclusion and Outlook

In conclusion, we have probed the effect of the finite size of the constituent quarks on the short range repulsion of the NN interaction by smearing the contact interactions. We observe reduction in the strength of repulsion as the smearing is increased.

Investigations in to the effect of the finite size of the constituent quarks on the full NN potential and on the observables of NN scattering are in progress.

References

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