**Quark exchange $NN$ interaction in the quark diquark model**

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One of the main interests of nuclear and hadron physics is to understand the hadron dynamics from the quark level. Especially, the chiral symmetry plays an important role.

Recently, Abu-Raddad *et al* derived a chiral meson-baryon lagrangian using the path-integral method for hadronization of a quark theory, the quark-diquark NJL model[1]. One advantage of the method is to maintain the symmetries of the underlying theory with incorporating internal structure of hadrons. They have verified that the Goldberger-Treiman relation for chiral symmetry and the Ward-Takahashi relation for gauge symmetry. Using the chiral and gauge symmetric lagrangian, physical quantities such as the nucleon mass, magnetic moments and axial couplings were studied. In this report, in addition to these one particle properties, we make a progress report on the calculation of the central part of the $NN$ interaction [1].

The meson-baryon lagrangian hadronized from the quark-diquark NJL model is given by

$$\mathcal{L} = -\frac{1}{\tilde{G}}\bar{B}B + i\mathrm{tr}\ln(1-\Box) + \cdots, \quad \Box = \begin{pmatrix} \mathcal{A} & \mathcal{F}_2 \\ \mathcal{F}_1 & \mathcal{S} \end{pmatrix} \tag{1}$$

$$\begin{aligned} \mathcal{A}^{\mu i,\nu j} &= \sin^2\theta \left(\tilde{\Delta}^T\right)^{\mu i,\rho k} \bar{B}\gamma_\rho\gamma^5\tau_k S\tau^j\gamma^\nu\gamma^5 B \\ \mathcal{S} &= \cos^2\theta\Delta^T\bar{B}SB \\ (\mathcal{F}_1)^{\mu i} &= \sin\theta\cos\theta\Delta^T\bar{B}S\tau^i\gamma^\mu\gamma^5 B \\ (\mathcal{F}_2)^{\nu j} &= \sin\theta\cos\theta(\tilde{\Delta}^T)^{\nu j,\rho k}\bar{B}\gamma_\rho\gamma^5\tau_k SB \end{aligned}$$

where $\theta$ is the scalar and axial-vector diquark mixing angle, and $\tilde{G}$ the quark diquark coupling constant. $S$, $\Delta$, and $\Delta^{\mu\nu ik}$ are quark, scalar diquark, and axial-vector diquark propagators, and $B$ is the nucleon field. The meson field is included in the quark propagator. The derivative expansion of the second term of lagrangian (1) gives the non-local $NN$ interaction $\Gamma(q,P)$ which is given by the one-loop diagram in Fig. 1, where $q = p' - p, P = (p+p')/2$. After the non-relativistic reduction of the $\Gamma(q,P)$, we obtained the $NN$ interactions as follows

$$\Gamma(q,P) = V_c(q,P) + V_{SS}(q,P)\ \mathbf{S}_1\cdot\mathbf{S}_2 + V_{LS}(q,P)\ \mathbf{S}\cdot(\mathbf{q}\times\mathbf{P})\cdots \tag{2}$$

where $V_c(q,P), V_{SS}(q,P)$ and $V_{LS}(q,P)$ are the central, spin-spin and spin-orbit part. We calculated the central part $V_c$ of the diagram in the local approximation. The parameters are used as given in Ref.[1], *i.e*, quark mass $m_q$=390 MeV, scalar diquark mass $M_s$=600 MeV, Pauli-Villars mass $\Lambda$=630 MeV and the quark diquark coupling constant $\tilde{G}$=159.1 GeV$^{-1}$.

So far, we have calculated the one-loop diagram only with the scalar diquark. The result is shown in the Fig. 2. The left panel of Fig. 2 shows that the interaction range is about $m_q$, and this process is considered as the quark exchange. The right panel of Fig. 2 shows that the interaction is strong attraction.

Experimentaly, $NN$ force has strong repulsion in the short range. With only the scalar diquark, our result did not agree with experiments. Possible sources are: Firstly, we neglected the axial-vector diquark contribution. Secondly, we carried out the calculation in

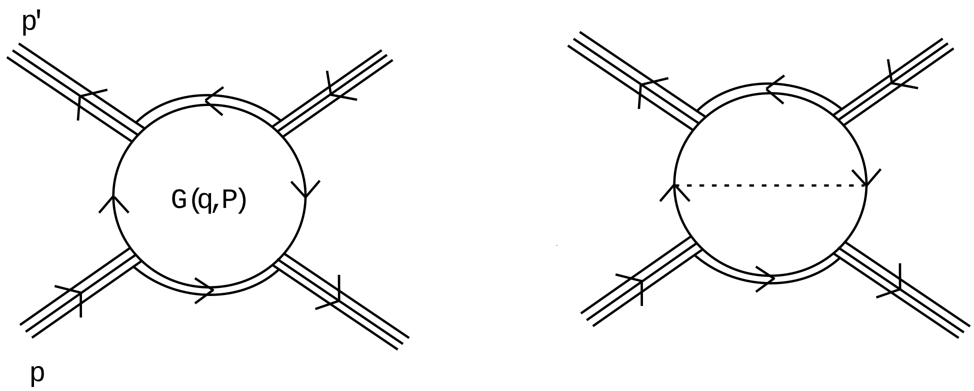


Figure 1: Feynman diagrams for the $NN$ interaction. Leading order(left) and next to order(right). Single, double, triple and dotted lines represent quark, scalar diquark, baryon and meson.

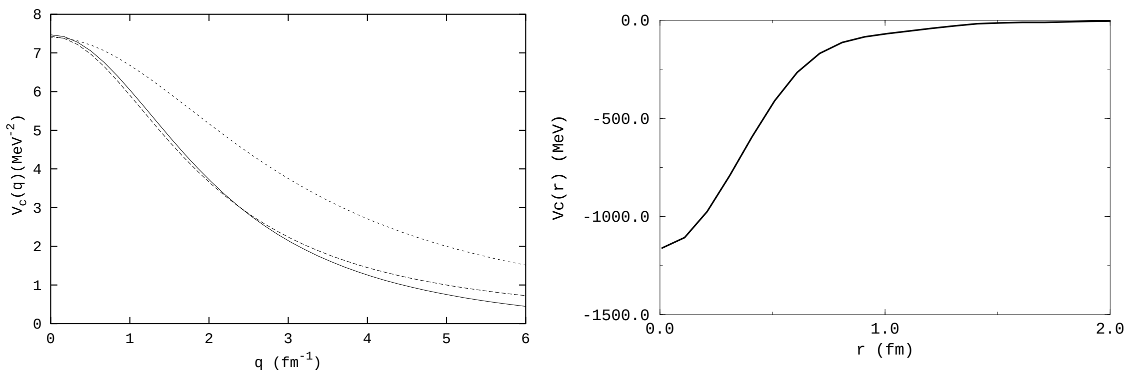


Figure 2: The central part $V_c$ of the potential in momentum(left) and coordinate(right) space. Solid lines are the numerical results, dashed and long-dashed lines are the fit by $a^2/(q^2+M_s^2), b^2/(q^2+m_q^2)$, where a=8.27, b=7.47.

the local approximation. Here, non-locality, which generated the repulsion, was neglected. Thirdly, RGM approch[2] suggests that the repulsive core is generated in the boson exchange diagram(the right panel of Fig. 1). We need to take into account these effects, which are in progress now.

# References


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