Quark-Model Baryon-Baryon Interaction and its Prospects in the Nuclear Matter Physics

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Contents

1. Introduction

Realistic nuclear force

・reproduces very accurately the deuteron properties and NN scattering data

(χ2 per datum ~ 1, essentially phase shift equivalent)

・**local potentials** Argonne potentials (V8, V14, V18)

underestiates the binding energy of few-nucleon systems

⇒ the necessity of three-body forces

・**nonlocal potentials** Meson-exchange (CD-Bonn), Chiral EFT ・・・

Nonlocal potentials often give more binding energies than local potential in few nucleons systems

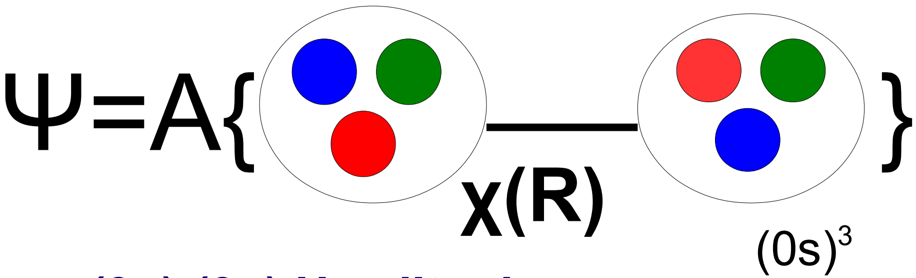
How the nuclear matter is described using the nonlocal potential?

We examined this problem using **Quark cluster model (regard nucleon as 3q)**

2.Quark-Model Baryon-Baryon (QM BB) Interactions

fss2 and FSS Y. Fujiwara Y. Suzuki and N. Nakamoto, Prog. Part. Nucl. Phys. 58, 439 (2007)

(3q)-(3q) resonating-group method (RGM)



solved in M. Oka, K. Yazaki PLB, 90, 41 (1980). PTP 66, 556, 572. (1981)

(3q)-(3q) Hamiltonian

$$H = \sum_i \left(m_i c^2 + \frac{p_i^2}{2\mathrm{m}} - T_G \right) + \sum_{i<j} \left(U_{ij}^{cf} + U_{ij}^{FB} + U_{ij}^{Meson} \right)$$

Confinement+Fermi-Breit (OGEP)+Effective meson exchange (EMEP)

short-range medium+ long-range

Parameters

QM i) width parameter for the $(0s)^3$ (3q)-clusters ii) m_{ud} iii) $\Lambda = m_s/m_{ud}$,

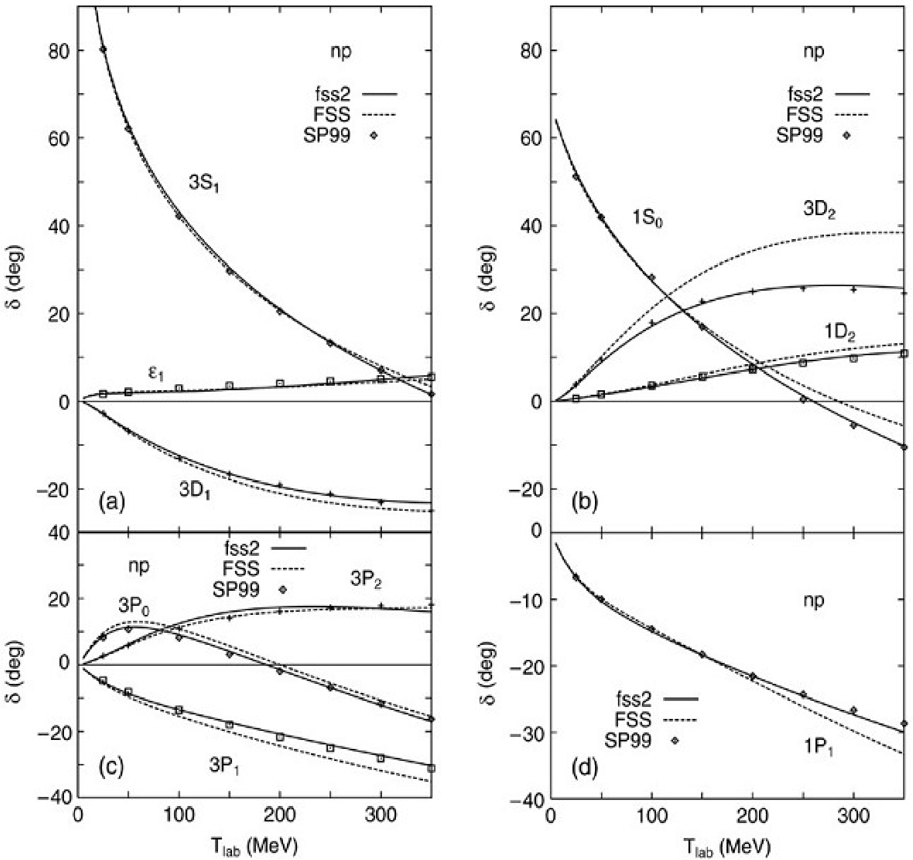
iv) quark-gluon coupling constant)

EMEP i) f1 ii) f8 and iii) θ for each S, PS, Ve,Vm type iv) meson mass

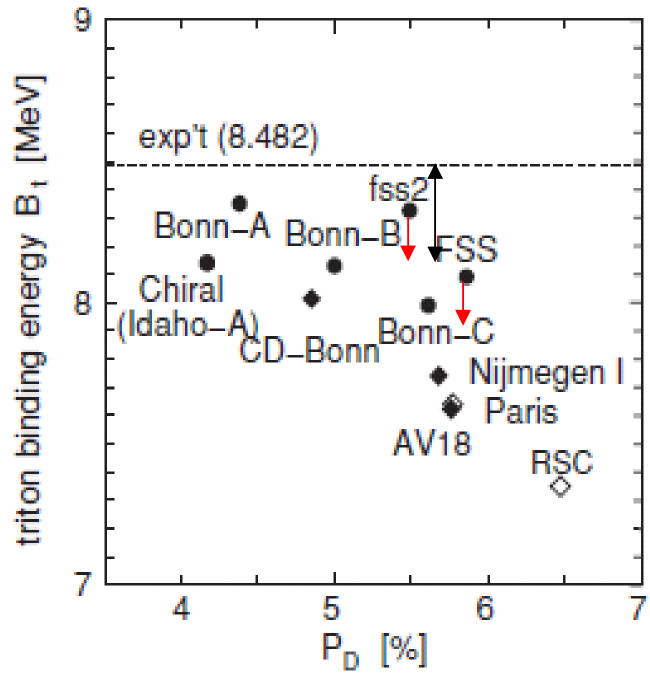
Other parameters to improve the fit of the NN phase shifts

NN phase shifts by fss2 (J≤2)

Y. Fujiwara, M. Kohno, C. Nakamoto and Y. Suzuki, Phys. Rev. C64, 054001 (2001).



Triton binding energy



Deuteron *D*-state probability

Y. Fujiwara et al. PRC77 (2008) 027001

◆ : take into account the charge dependence

● : do not take into account charge dependence ~200 keV

The energy deficiency of fss2 ~350 keV

3. Brueckner theory for nuclear matter

Effective G-matrix interaction based on realistic interactons

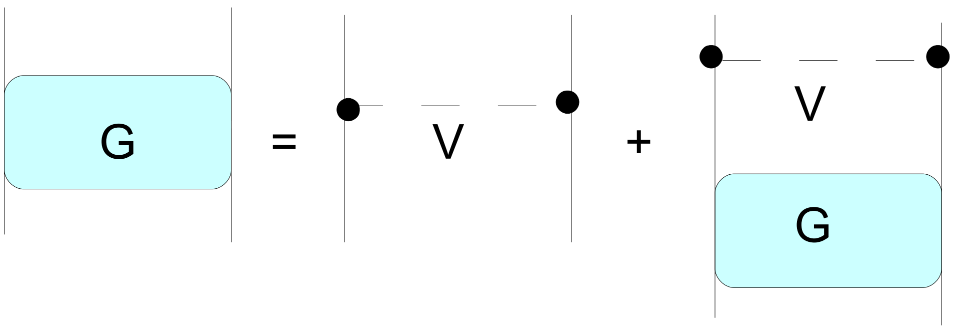
$$\langle k_1 k_2 | G(\omega) | k_3 k_4 \rangle = \langle k_1 k_2 | v | k_3 k_4 \rangle + \sum_{k'_3 k'_4} \langle k_1 k_2 | v | k'_3 k'_4 \rangle \frac{(1-\Theta_F(k'_3))(1-\Theta_F(k'_4))}{\omega - e_{k'3} - e_{k'4}} \langle k'_3 k'_4 | G(\omega) | k_3 k_4 \rangle$$

$$e_k = \frac{\hbar^2 k^2}{2\mathrm{m}} + U(k)$$ single particle energy   ω: starting energy

$$U(k) = \sum_{k' < k_F} \langle k k' | G(e_k + e_k{}') | k k' \rangle$$

Self-consistent

single particle potential ⟷ G-matrix

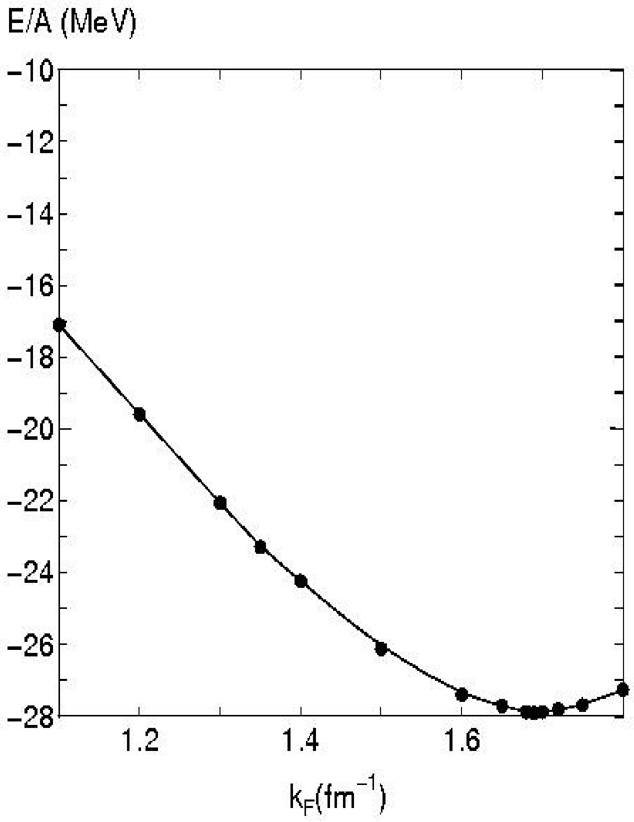


↓

binding energy E/A
single particle potentials   etc.

K. A. Brueckner and J. L. Gammel PR 109, 1023 (1958)

Saturation curve for nuclear symmetric matter



Saturation point
k_f ~ 1.7 fm^{-1}
E/A ~ -28 MeV

potential	AV14	fss2
k_f (fm^{-1})	1.36	1.35
1S0	-16.51	-17.12
3S1-3D1	-19.09	-26.33
3P0	-3.83	-3.17
3P1	10.56	9.97
1P1	3.94	4.12
1D2	-2.82	-2.24
3D2	-4.18	-3.82
3P2-3F2	-7.90	-8.60
....	....	....
kinetic	23.01	22.69
total	-15.47	-23.29

BHF calculation made in the continuous choice

AV14 result
M.Baldo et al. PRC 43, 2605 (1991)

3S1+3D1 channels makes SNM too deeply bound!!
← off shell effect of the QM BB interaction ?

4 Summary

We have applied the QM NN interaction fss2 to the syetric nuclear matter.

1. In few-nucleon systems, this model reproduces experimental values.
2. However, this model gives too large binding energy for the symmetric nuclear matter. The 3S1+3D1 channel makes SNM too deeply bound.

This is because of off-shell effect in the QM NN interaction.

Future works

1. including the phenomenological 3N force (under construction)
2. Calculations for pure neutron matter
3. including hyperons