Relation between the separable and one-boson-exchange potential for the covariant Bethe-Salpeter equation

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Relativistic approach of the nuclear physics becomes important for high momentum phenomena, in particular for those associated spin observables. Furthermore, the phenomena where pions appear as in many nuclear physics, the relativistic treatment is essential, since the fundamental chiral symmetry is related to the relativistic nature of particles.The starting point of the relativistically covariant theory is the Bethe-Salpeter equation for the two nucleon system. In order to overcome a difficulty of solving the integral equation, a separable interaction is often employed, primarily as a mathematical manipulation [2] .

In the present study, we investigate whether the parameters of the separable potential may be related to those of the OBEP, since the latter is considered to be physically more fundamental. . By doing this, we can make physics interpretation for the separable potential.

In order to determine parameters of separable interaction, we compare the one-boson-exchange potential of [3] with separable potential in the long wave length limit [1]. We have then calculated phase shifts using the BSE, which are compared with those obtained by solving the Schrödinger equation using the OBEP. Here we calculate various phase shifts using a term corresponding to σ- and ω-exchange potential. The resulting phase shifts are shown in Figs. 1.

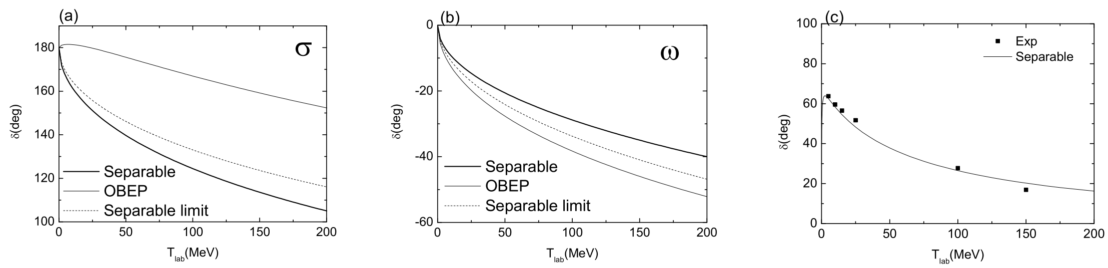

Figure 1: (a), (b): The phase shifts of $^1S_0$ channel calculated from the separable potential(thick solid line) and that from the OBEP(thin solid line). (c): The phase shifts of the $^1S_0$ channel calculated from the best fitted separable potential as a function of the kinetic energy in the laboratory frame as compared with the experimental data.

As a result, it turns out that the rank I separable potential can not reproduce the phase shift calculated from each component of the OBEP when we use the parameters determined in the long wave length limit. As for the σ channel, where the potential represents very strong attraction, we can not reproduce the phase shift of OBEP even if we take the coupling strength of the separable interaction infinity large. This limit is shown in Fig. 1 by the dashed lines. Similary as for the ω channel with strong repulsion, the separable potential can not reproduce again the phase shift of OBEP.

Despite the above fact, the rank I separable potential can reproduce the experimental data of the $^1S_0$ phase shift up to the energy $T_{lab} \gtrsim 200$ MeV where a mild attractive interaction dominates as shown in Fig. 1-(c).

These results show that the rank I separable potential is not suited to the description of very strong interactions separately. Rather, the separable potential can describe relatively mild interactions. In the nuclear force, such a mild strength is obtained by the sum of the σ-exchange and the ω-exchange potentials.

In the present study, we have demonstrated the simplest case where only one term for both the OBEP and separable interaction was compared. In principle, if we introduce more terms for the separable interaction, it is possible to reproduce the properties of the nuclear force better. In the Bethe-Salpeter equation, such a work is now in progress, where the use of the improved rank one anzats and of higher rank interactions are tested [4].

References

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