Bethe-Salpeter approach for the deuteron with the inclusion of negative energy states

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Traditionally, nuclear physics has been studied in a non-relativistic framework based on the Schrödinger equation with a one boson exchange potential. Using the nucleon-nucleon interaction determined through the fitting to scattering data, this framework has been applied to bound state problems for nuclei. Especially the application to deuteron problems is useful to test the framework. In a boson exchange picture, the moderate strength of the nuclear force is a consequence of large cancellation bteween strong scalar attractive and vector repulsive forces. If such strong interactions of order of several hundred MeV are essential, one would wonder the limitation of the non-relativistic Schrödinger approach.

With such a consideration, several attempts have been performed to formulate and apply relativistic methods base on the Bethe-Salpeter equation [1, 2]. Using a separable ansatz for the interaction kernel, the parameters were determined from the phase shifts, and some applications have been made to the investigation of deuteron properties. In spite of the strong motivation to extend to the relativistic framework, the former works have not been considered the inclusion of negative energy components in an explicit manner. Without negative energy effects, fully relativistic dynamics can not be discussed.

In this work, we attempt to include such negative energy components for the study of deuteron properties. The inclusion is very crucial to explain bound state properties such as electromagnetic form factors of the deuteron. We perform our analysis within the framework of the relativistic impulse approximation. Due to dynamical effects associated with negative energy components, we expect that some higher order effects due to exchange currents are automatically included in the present framework.

We calculate the form factors and tensor polarizations from the Bethe-Salpeter approach. The results are shown in the Fig. 1-(a), (b), (c), (d), (e) and (f). In all cases we find better agreements with experiments by including the negative energy components.

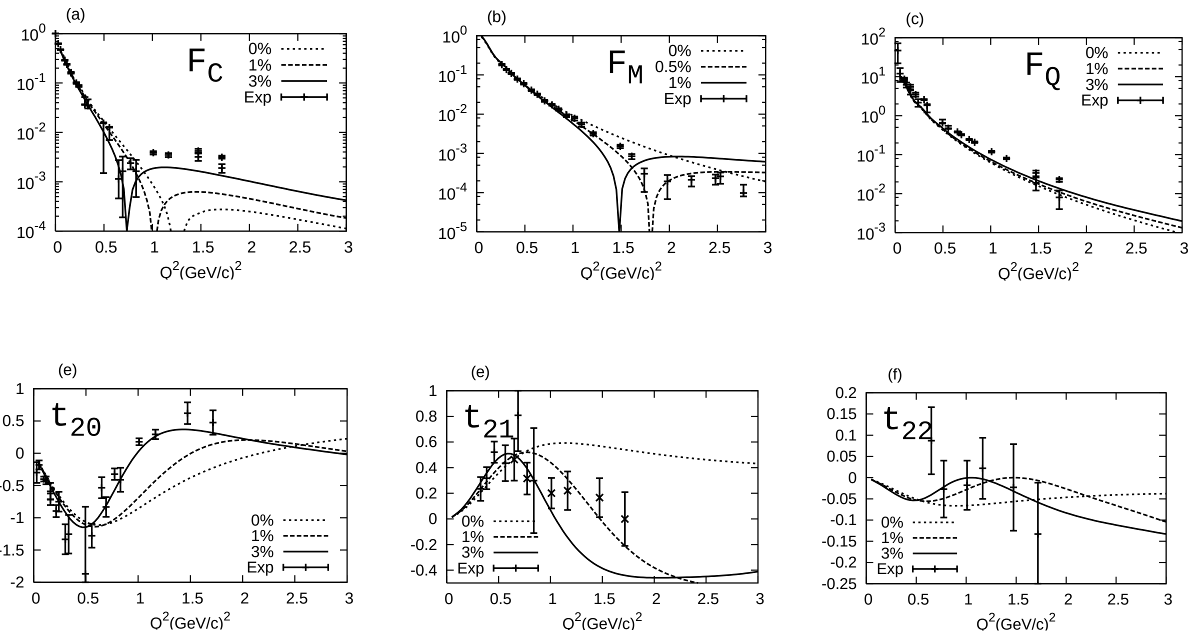

Figure 1: The form factors with negative energy components (a) Charge form factor. (b) Magnetic form factor. (c) Quadrupole form factor. (d) Tensor polarization t_{20}. (e) Tensor polarization t_{21}. (f) Tensor polarization t_{22}

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2. S. G. Bondarenko, V. V. Burov, A. V. Molochkov, G. I. Smirnov and H. Toki, Prog. Part. Nucl. Phys. **48**, 449 (2002)