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Non-perturbative studies of the three-boson system using the Bethe-Salpeter equation

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Generally speaking, improving our understanding of the interaction in terms of the fundamental degrees of freedom is very important for nuclear and particle non-perturbative physics. As it is very involved problem, simple models are of great value for understanding the basic qualitative features of the solution for more realistic kernels. Unraveling the properties of relativistic three-body systems is also important, in particular, for the perspective of hadron physics, e.g. for the modeling of the nucleon and its dynamics. Moreover, it is well-established that in the non-relativistic approach the binding energy of this system is not bounded from below, what is known as Thomas collapse. As it was discovered in the light-front dynamics (LFD) [1,2], the relativistic repulsion prevents the Thomas collapse in the non-relativistic sense.

The Bethe-Salpeter (BS) equation constitutes a convenient approach to perform non-perturbative studies of few-body systems in Minkowski space. Calculations of that type is important in order to access dynamical observables, such as space-like and time-like form factors, which are defined exclusively in Minkowski space. In this contribution we will discuss the solutions of the bound-state Bethe-Salpeter equation (BSE) for a system of three bosons interacting through a zero-range interaction. This equation was solved in Minkowski space by Frederico in Ref. [1], and later improved by Carbonell and Karmanov in [2]. However, in these calculations the projection onto the light-front was adopted, retaining only the valence component of the BS amplitude. Recently, in Ref. [3], we solved the full three-body BS equation in Euclidean space, and it was found that contributions from higher Fock components have a dramatic effect, both on binding energies and transverse amplitudes. Even more recently, in Ref. [4], we solved the three-body BS equation in Minkowski space, by direct integration of the equation, similarly to the method introduced in [5] for the two-body system.

We compare the computed results for the three-body binding energies and transverse amplitudes, with the ones obtained in Euclidean space.

Our results show that, at least for moderate three-body binding energies, a fair agreement is found between the two methods, both for the binding energy and the modulus of the transverse amplitude. This is encouraging since the calculations based on direct integration of the BSE present many challenges, both from analytical and numerical points of view, due to the singularities of the kernel and the Bethe-Salpeter amplitude. To improve the numerical accuracy, one possibility could be to represent the three-body BS amplitude by the Nakanishi Integral Representation, and thus produce a non-singular equation. This is still work in progress, and will be briefly discussed.

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