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The 4He spectrum

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In this contribution, we present some recent studies of the excited states of 4He nucleus, performed by accurately solving the four body scattering problem in the framework of the ab-initio hyperspherical harmonic method. The considered nuclear Hamiltonians include modern two- and three-nucleon interactions, derived using the chiral effective field theory approach.

First of all, we study the first excited state, which energy is slightly above the threshold for p+3H breakup, but below that of n+3He (this state is unbound due to the effect of the Coulomb repulsion between the protons [1]). Recently, an electron scattering experiment has allowed the extraction of accurate monopole transition form factor F(q) data from the 4He ground state to this first excited state [2]. Previous theoretical studies have shown that F(q) is very sensitive to the adopted nuclear interaction [3,4]. We will present new results for this observable obtained using the calculated four-body continuum wave functions.

Second, we present a study of the second excited state (a 0- resonance). For such a study, we exploit a recent measurement of the 3He(n,p)3H Ay observable using cold neutrons performed at ORNL [5]. In fact, the energy of the process is close to the expected position of the 0- resonance. We found that the theoretical predictions for such observable are very sensitive to the interaction, in particular to the three-nucleon force.

Finally, we study the processes d(d,p)3H and d(d,n)3He at energies of interest for energy production and for big-bang nucleosinthesis [6]. In this case, we are sensitive to the presence of 1- resonant states in the 4He spectrum. We will present new results for the cross section and polarization observables of these processes and study the sensitivity to the position of 1- resonances.

These studies show that the spectrum of 4He is still poorly understood and that more accurate interactions between the nucleons are needed to quantitatively describe it.

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