Contribution ID: **56** Type: **Poster**

Precision Studies of Few-Nucleon System Dynamics

Tuesday, 12 October 2010 17:00 (0 minutes)

A basic step towards a full understanding of nuclear interaction is a proper modeling of all details of the few-nucleon system dynamics. Systems composed of three nucleons (3N) are the simplest non-trivial environment to explore details of the nucleon-nucleon (NN) potential models and to investigate limits of a just two-nucleon based description of the interaction dynamics. In particular, data obtained for the elastic and breakup channels of the nucleon-deuteron (N-d) reaction have proven to be especially well suited to study subtle effects of suppressed degrees of freedom, described by means of three-nucleon forces (3NF). Effects of 3NF, although small, are very important and have far-reaching consequences in various fields of physics.

Precise experimental results have shown, however, that also further dynamical ingredients are indispensable to correctly describe the data. The theoretical calculations, based on rigorous solutions of the Faddeev equations with the physical input taken e.g. as realistic NN potentials combined with model 3NF, as the two- and three-nucleon interactions obtained with the explicit treatment of the Delta-isobar excitation or as forces derived within Chiral Perturbation Theory methods, have to take into account also, for a long-time neglected, effects induced by the long-range Coulomb interaction and influences of relativity.

In the elastic N-d channel numerous evidences of the 3NF effects have been found in the cross section data at intermediate energies. The polarization observables lead to a more complicated picture, indicating certain imperfections in construction of 3NF models, especially in their spin part. Precise measurements of the breakup process are experimentally very demanding, but fortunately the recent activities has been able to meet the requirements of providing rich and precise data sets. The results at every energy comprise several hundreds data points for each vector and/or tensor analyzing power, and a few thousands for cross sections. Their comparisons with predictions using nuclear interactions generated in various ways provided important insight into details of the few-body system dynamics. Just the cross-section data from the first new generation experiment at KVI allowed to establish a clear evidence of importance of the 3N forces in the breakup process. Moreover, the results confirmed predictions of sizable Coulomb force influences in certain phase space regions of this reaction, confirmed later in a dedicated experiment researching specially selected phase space regions. The outcome from the analysis of polarization observables is not-so-unambiguous. Therefore further studies are planned at several laboratories, which will investigate also the next more complicated system of four nucleons, also with respect to charge symmetry violation aspects of the NN interaction.

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Session Classification: Poster Session