Three-nucleon reactions with chiral dynamics

H. Witała[1], J. Golak[1], R. Skibiński[1], K. Topolnicki[1]

[1] *M. Smoluchowski Institute of Physics, Jagiellonian University, PL-30059 Kraków, Poland*

Contact email: *henryk.witala@uj.edu.pl*

Comparison of theoretical predictions with data for elastic nucleon-deuteron (Nd) scattering and nucleon induced deuteron breakup clearly shows the importance of the three-nucleon force (3NF). Inclusion of semi-phenomenological 3NF models into calculations in many cases improves the data description. However, some serious discrepancies remain even when 3NF is included.

At low energies the prominent examples were found for the vector analyzing power in elastic Nd scattering and for the neutron-deuteron (nd) breakup cross sections in neutron-neutron (nn) quasi-free-scattering (QFS) and symmetric-space-star (SST) geometries [1]. Since both these configurations depend predominantly on the S-wave nucleon-nucleon (NN) force components, these cross section discrepancies have serious consequences for the nn ${}^1S_0$ force component. A stronger ${}^1S_0$ nn force is required to bring theory and nn QFS data to agreement. The increased strength of the ${}^1S_0$ nn interaction could make the nn system bound. However, even such a drastic modification of the ${}^1S_0$ nn force does not improve the SST data descritpion.

At energies above ≈ 100 MeV current 3NF's only partially improve the description of data for cross section and spin observables in elastic Nd scattering and breakup. The complex angular and energy behavior of analyzing powers and spin correlation and transfer coefficients fail to be explained by standard nucleon-nucleon interactions alone or combined with current 3NF's [2-3].

One of the reasons for the above disagreements could be a lack of consistency between 2N and 3N phenomenological potentials used or/and omission of important terms in the applied 3NF. The Chiral Effective Field Theory approach provides consistent two- and three-nucleon forces and 3NF occurs for the first time at next-to-next-to leading order (N^2LO) of chiral expansion. This force when used in 3N calculations provides the quality of data description comparable to that with realistic nuclear forces. Recently the chiral 3NF at N^3LO was derived. At this order 3NF consists of long range parts with the 2π-exchange, 1π-2π and ring terms [4] and a short-range contributions 2π-contact and relativistic corrections of order 1/m [5]. This is supplemented by 1π- and 3N- contact terms. Results obtained with these N^3LO forces for elastic Nd scattering and breakup will be presented.

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