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The Three-Nucleon Analyzing Power Puzzle - The Past 20 Years[1]

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The three-nucleon (3N) analyzing power $A_y(\theta)$ puzzle (3NAPP) refers to the failure of rigorous 3N calculations to account for the magnitude of the measured nucleon-deuteron $A_y(\theta)$ in the angular region of the A_y maximum (30% underprediction). The 3NAPP is a low-energy phenomenon and does not refer to $A_y(\theta)$ in the energy range above 100 MeV, where standard 3N forces contribute significantly to $A_y(\theta)$ in the angular region of the cross-section minimum. The 3NAPP was discovered by Witała, Glöckle and Cornelius in 1987 when they compared their rigorous 3N calculations to the neutron-deuteron (n-d) data of the Tübingen/TUNL group, although some evidence of a possible problem with describing $A_y(\theta)$ was already reported in 1986 by Koike and Haidenbauer. Before 1995 the 3NAPP was solely a n-d scattering phenomenon. However, with the Coulomb problem solved in 3N calculations by Kievsky, Viviani and Rosati in 1995 for energies below, and in 1999 for energies above the deuteron breakup threshold, the 3NAPP entered a new stage and included $A_y(\theta)$ in proton-deuteron (p-d) scattering as well as the vector analyzing power $iT_{11}(\theta)$ in d-p scattering. Although p-d phase-shift analyses and their comparison to theoretical phase shifts provided some insight into the physics of the 3NAPP, the accurate p-d data initially created a new problem at energies below about 5 MeV, until the theoretical treatment of the magnetic moment interaction by Witała et al. and Kievsky et al. provided a uniform picture. The recent inclusion of relativity in 3N calculations by Witała et al. has increased the 3NAPP at low energies considerably (by about 25% at 5 MeV). Furthermore, the new n-d $A_y(\theta)$ data obtained by Weisel et al. at TUNL confirmed our conjecture that the transition region between 20 MeV and about 35 MeV, above which the 3NAPP disappears, is poorly understood. Here, p-d data are needed to make progress. Currently, the hope is that the 3N force terms predicted by Chiral Effective Filed Theory in N3LO will eventually provide the correct explanation of the 3NAPP. However, the range of the required 3N force terms has to be about 3 fm in order to describe the $A_y(\theta)$ and $iT_{11}(\theta)$ data at $E_{c.m.}$=432 keV.

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