Precision measurements of the n-p, n-d, and n-^{3}He coherent neutron scattering lengths

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Recent advances in effective field theories and Monte Carlo calculation techniques for two-body and three-body interactions among nucleons now make it possible to attempt to calculate neutron scattering lengths in low-A nuclei from first principles with experimental input from the NN system. We used the new neutron interferometer facility at NIST (see Fig. 1) to conduct high precision measurements of coherent scattering lengths to test these theories in the

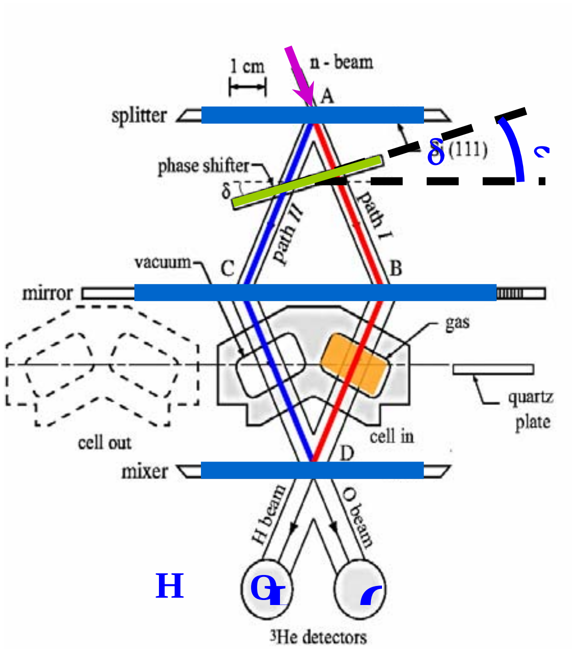

Figure 1 . *Schematic of the apparatus used to measure the coherent neutron scattering lengths. The gas introduces an extra phase shift in one arm of the neutron interferometer that is simply related to the scattering length.*

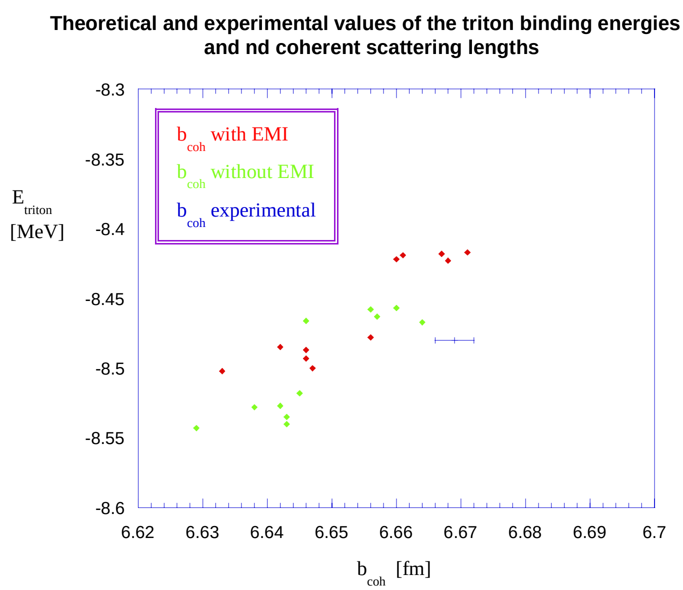

Figure 2 . *Calculations of the triton binding energy and the n-d coherent neutron scattering length with a variety of modern NN and 3N potentials and with and without electromagnetic effects (EMI). None of the models match the data (horizontal error bar) from Refs. [1,2].*

low-energy limit. The results from measurements at NIST of the n-p (b_{np}= −3.738±0.002 fm) and n-d (b_{nd}=6.665±0.004 fm) coherent scattering lengths [1,2] showed that almost all existing n-d calculations are in serious disagreement with experiment (see Fig. 2) and that present measurements are sufficiently precise to sense possible three-body force and charge symmetry-breaking effects. This work has motivated new theoretical calculations [3] and a new experiment to measure the spin-dependence of the n-d scattering length [4] to sharpen comparison to theory, and has established this parameter as an observable of comparable importance to the triton binding energy for understanding the A=3 system. The precision of the recent NIST n-^{3}He coherent scattering length measurement, b_{n3He}=5.857±0.007 fm [5], is an improvement over previous measurements of almost an order of magnitude and is also sensitive to 3N forces in the A=4 system [6]. In combination with a recent measurement of the n-^{3}He spin-dependence [7] we determined the scattering lengths in the two spin channels: b_0=9.949±0.027 fm and b_1=4.488±0.017 fm. Again the results disagree with the best existing calculations [6]. Slightly improved constraints also follow from our recently published measurement of the n-^{3}He total cross section, which achieved 0.1% absolute accuracy over 3 decades of neutron energy [8].

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