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Non-relativistic Neutron Deuteron Scattering

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Abstract. We discuss the calculation of polarization observables, including A_y, in *nd* scattering to next-to-next-to-next-to-leading order in pionless effective field theory.

We present preliminary results of the first next-to-next-to-next-to-leading order (N^{3}LO) calculation of the *nd* scattering amplitude in the framework of nonrelativistic pionless effective field theory (EFT$_{\not\pi}$). In this theory, the typical momentum exchange in the scattering must be much smaller then the mass of the pion. The power counting parameter for EFT$_{\not\pi}$ is the ratio $\frac{Q}{\Lambda_{\not\pi}}$, where Q is the typical momentum exchange in the scattering and $\Lambda_{\not\pi}$ is the EFT$_{\not\pi}$ breakdown scale, $\Lambda_{\not\pi} \sim m_\pi$. The EFT$_{\not\pi}$ interaction terms in the two-body sector up to N^{3}LO are the two two-nucleon-to-dibaryon vertices (for the $^3S_1$ and $^1S_0$ channels) at LO, the effective range term at NLO, the SD-mixing interaction at N^{2}LO, and the shape parameter and two-body P-wave contact interaction terms at N^{3}LO. Three-body interaction terms enter first at LO and a new energy dependent term appears at N^{2}LO. The two-body interaction coefficients are matched onto NN scattering data. At LO the three-body interaction coefficient is matched onto the doublet S-wave *nd* scattering length and the N^{2}LO energy dependent three-body force to the triton binding energy.

The calculation of the amplitude for *nd* scattering requires summing an infinite set of diagrams. This sum does not factorize as it does in the two-body case; instead an integral equation must be solved numerically [1]. The n$^{\text{th}}$ order correction to the *nd* scattering amplitude is given by the integral equation shown in Fig. 1 [2–4]. An important part of this calculation is the two-body P-wave contact interaction diagram for *nd* scattering shown in Fig. 2. To solve the equation shown in Fig. 1 to a given order we project it onto different partial waves and then solve the projected equations numerically [5, 6]. After obtaining the numerical solution for the amplitude we are able to calculate any parity conserving observable of interest. One of the most important observables is A_y, which measures the asymmetry between the cross sections induced by nucleons of opposite transverse spin polarization on an unpolarized deuteron target [7]:

$$A_y = \frac{\frac{d\sigma}{d\Omega}|_\uparrow - \frac{d\sigma}{d\Omega}|_\downarrow}{\frac{d\sigma}{d\Omega}|_\uparrow + \frac{d\sigma}{d\Omega}|_\downarrow} \ . \tag{1}$$

Varying the N^{3}LO coefficients within the EFT$_{\not\pi}$ uncertainty gives the results in Fig 3, which shows good agreement with the differential cross section and reasonable agreement with A_y for a variety of energies. We can also pursue the calculation to higher orders to attempt to improve the agreement.

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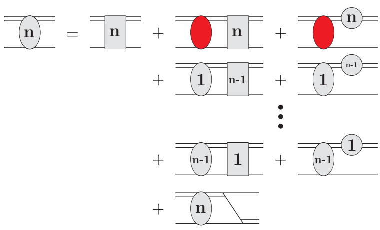

Figure 1. Thin line is nucleon propagator, double line is dibaryon propagator. For $m = 1, ..., n$ oval with an m is the m$^{\text{th}}$ order correction to the nd scattering amplitude, rectangle with an m is N^{m}LO corrections that involve all three-nucleons, and this includes three-body forces, circle with m is the m$^{\text{th}}$ order correction to the dibaryon propagator. The solid red oval is the LO nd scattering amplitude.

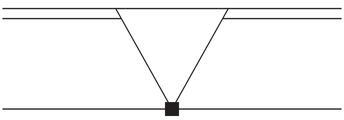

Figure 2. Diagram contributing at N^{3}LO. The square is a two-body P-wave interaction vertex. This diagram is included in Fig. 1 in the rectangle with $n = 3$.

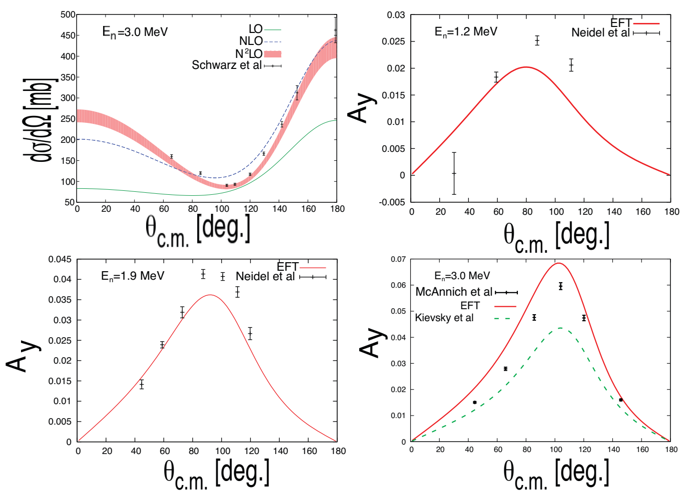

Figure 3. Top left is the EFT$_{\not\pi}$ results up to N^{2}LO and data [8] for the cross-section at a neutron lab energy of $E_n = 3.0$ MeV. The band on N^{2}LO result represents the estimated error of about 6%. On the other three figures the solid red line represents our preliminary N^{3}LO results for A_y at $E_n = 1.2$ and 1.9 MeV with data from [9] and at $E_n = 3.0$ MeV with data from [10] . On the bottom right figure the dashed green line comes from potential model calculations [11].

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