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Green's Function Monte Carlo Calculations with Two- and Three-Nucleon Interactions from Chiral Effective Field Theory

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Abstract. I discuss our recent work on Green's function Monte Carlo (GFMC) calculations of light nuclei using local nucleon-nucleon interactions derived from chiral effective field theory (EFT) up to next-to-next-to-leading order (N^2LO). I present the natural extension of this work to include the consistent three-nucleon (3N) forces at the same order in the chiral expansion. I discuss our choice of observables to fit the two low-energy constants which enter in the 3N sector at N^2LO and present some results for light nuclei.

1 Introduction

Accurate predictions of properties of light nuclei require at least two ingredients: (1) validated nuclear interactions and (2) accurate many-body computational methods. While quantum Chromodynamics is known to be the ultimate source of the first, arguably the best current path to validated nuclear interactions is through chiral effective field theory (EFT) [1, 2]. The second may come in many forms – hyperspherical harmonics, the no-core shell model, and Green's function Monte Carlo (GFMC) to name a few – but among the most accurate of these is the GFMC method. Recently we have demonstrated the powerful effect of combining these two ingredients (which was not possible before) [3] by studying properties of the lightest nuclei $A = 3, 4$ with chiral interactions up to N^2LO, neglecting however, the corresponding three-nucleon (3N) interaction which enters at N^2LO. Now we include the consistent 3N interaction arising at N^2LO in the chiral expansion, fitting the two low-energy constants which enter at this order to the ^{4}He binding energy and to n-α P-wave elastic scattering phase shifts [4].

2 The Fits

We fit the two low-energy constants c_D and c_E to ^{4}He binding energy Fig. 1a and to P-wave n-α scattering phase shifts Fig. 1b. Details about the various 3N interactions $V_C + V_D^{(i)} + V_E^{(j)}$, with $i = 1, 2, 3$ and $j = \tau, \mathbb{1}, P$, which amount to different operator choices for the terms proportional to c_D and c_E are available in [4]. It is significant that chiral interactions at N^2LO have sufficient freedom to fit both properties of light nuclei (Fig. 1a and Table 1) and the splitting of the P-wave n-α scattering phase shifts (Fig. 1b). See [4] for more details.

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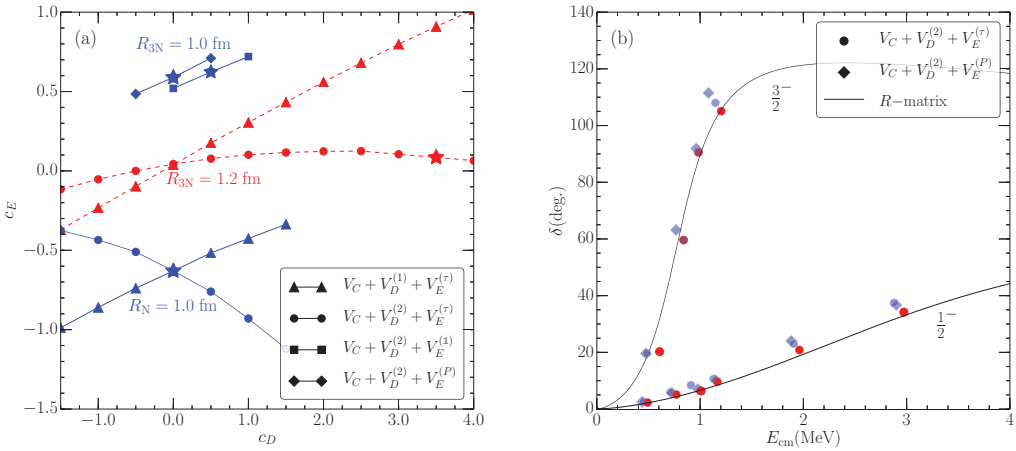

Figure 1. Fitting c_D and c_E. The GFMC statistical uncertainties are the size of the symbols or smaller. Blue (Red) symbols correspond to R_{3N} = 1.0 fm (R_{3N} = 1.2 fm), with R_{3N} a 3N cutoff parameter. (a) Curves of c_E vs. c_D obtained by fitting the ^{4}He binding energy. The fits were obtained at the points: The lines are a guide to the eye. The stars correspond to the values of c_D and c_E which fit both the ^{4}He binding energy and the n-α P-wave phase shifts. No fit to both observables can be obtained for the case with R_{3N} = 1.2 fm and $V_D^{(1)}$. See Ref. [4] for details. (b) P-wave n-α elastic scattering phase shifts compared with an R-matrix analysis of the data.

Table 1. Comparison of results for A = 3 in this work with experimental values. The values in parenthesis are the GFMC statistical errors.

	R_0 [fm]	E_B [MeV]		$\sqrt{\langle r_{pt}^2 \rangle}$ [fm]	
		GFMC	Exp.	GFMC	Exp.
^{3}H	1.0	-8.33(1)	-8.48	1.55(3)	1.59
	1.2	-8.35(4)		1.55(4)	
^{3}He	1.0	-7.66(1)	-7.72	1.77(2)	1.76
	1.2	-7.63(4)		1.77(1)	

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