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Few-Body Systems

Strange two-baryon interactions using chiral effective field theory

H. Polinder *

Institut für Kernphysik (Theorie), Forschungszentrum Jülich, D-52425 Jülich, Germany

Abstract. We have constructed the leading order strangeness $S = -1, -2$ baryon-baryon potential in a chiral effective field theory approach. The chiral potential consists of one-pseudoscalar-meson exchanges and non-derivative four-baryon contact terms. The potential, derived using $\mathrm{SU(3)_f}$ symmetry constraints, contains six independent low-energy coefficients. We have solved a regularized Lippmann-Schwinger equation and achieved a good description of the available scattering data. Furthermore a correctly bound hypertriton has been obtained.

1 Introduction

The derivation of nuclear forces from chiral effective field theory (EFT) has been discussed extensively in the literature since the work of Weinberg [1]. An underlying power counting allows to improve calculations systematically by going to higher orders in a perturbative expansion. In addition, it is possible to derive two- and corresponding three-nucleon forces as well as external current operators in a consistent way. For reviews we refer the reader to [2]. Recently the nucleon-nucleon (NN) interaction was described to a high precision in chiral EFT [3, 4].

As of today, the strangeness $S = -1$ hyperon-nucleon (YN) interaction ($Y = \Lambda, \Sigma$) was not investigated extensively using EFT [5]. The strangeness $S = -2$ hyperon-hyperon (YY) and cascade-nucleon (ΞN) interactions had not been investigated using chiral EFT so far. In this contribution we show selected results for the recently constructed chiral EFT for the $S = -1, -2$ baryon-baryon (BB) channels [6, 7]. At leading order (LO) in the power counting, the YN, YY and ΞN potentials consist of four-baryon contact terms without derivatives and of one-pseudoscalar-meson exchanges, analogous to the NN potential of [4]. The potentials are derived using SU(3) constraints. We solve a coupled channels Lippmann-Schwinger (LS) equation for the LO potential and fit to the low-energy YN scattering data.

* *E-mail address:* h.polinder@fz-juelich.de

2 Formalism

We have constructed the chiral potentials for the $S = -1, -2$ sectors at LO using the Weinberg power counting, see [6]. The LO potential consists of four-baryon contact terms without derivatives and of one-pseudoscalar-meson exchanges. The LO $\mathrm{SU(3)_f}$ invariant contact terms for the octet baryon-baryon interactions that are Hermitian and invariant under Lorentz transformations were discussed in detail in [6]. The pertinent Lagrangians read

$$\begin{aligned} \mathcal{L}^1 &= C_i^1 \left\langle \bar{B}_a \bar{B}_b \left(\Gamma_i B\right)_b \left(\Gamma_i B\right)_a \right\rangle \ , \quad \mathcal{L}^2 = C_i^2 \left\langle \bar{B}_a \left(\Gamma_i B\right)_a \bar{B}_b \left(\Gamma_i B\right)_b \right\rangle \ , \\ \mathcal{L}^3 &= C_i^3 \left\langle \bar{B}_a \left(\Gamma_i B\right)_a \right\rangle \left\langle \bar{B}_b \left(\Gamma_i B\right)_b \right\rangle \ . \end{aligned} \tag{1}$$

As discussed in [6], in LO the Lagrangians give rise to six independent low-energy coefficients (LECs): C_S^1, C_T^1, C_S^2, C_T^2, C_S^3 and C_T^3, where S and T refer to the central and spin-spin parts of the potential respectively. The contribution of one-pseudoscalar-meson exchanges is discussed extensively in the literature. We do not discuss it here, instead we refer the reader to e.g. [6]. We solve the LS equation for the YN, YY and ΞN systems. The potentials in the LS equation are cut off with a regulator function, $\exp\left[-\left(p'^4 + p^4\right)/\Lambda^4\right]$, in order to remove high-energy components of the baryon and pseudoscalar meson fields.

3 Results and discussion

Because of $\mathrm{SU(3)_f}$ symmetry, only five of the LECs can be determined in a fit to the YN scattering data. A good description of the 35 low-energy YN scattering data has been obtained for cut-off values $\Lambda = 550, ..., 700$ MeV and for natural values of the LECs. The results are shown in Fig. 1. See [6] for more details. The YN interaction based on chiral EFT yields a correctly bound hypertriton, also reasonable Λ separation energies for ${}^4_\Lambda\mathrm{H}$ have been predicted [6, 10].

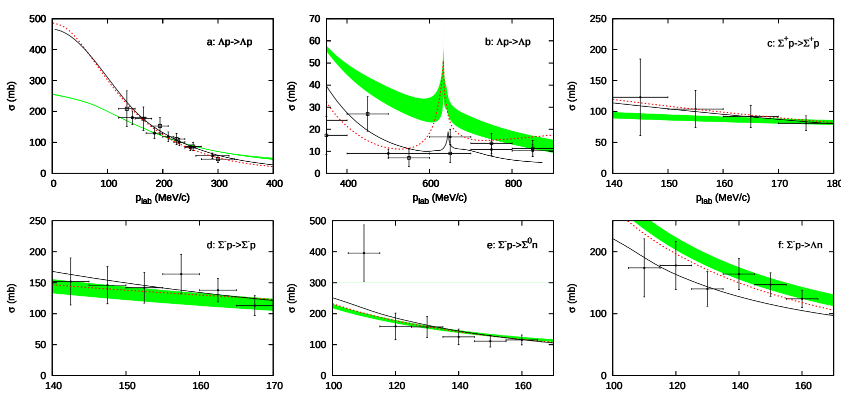

Figure 1. YN integrated cross section σ as a function of p_{lab}. The band is the chiral EFT for $\Lambda = 550, ..., 700$ MeV, the solid and dashed curves are the Jülich '04 meson-exchange model [8] and Nijmegen NSC97f meson-exchange model [9] respectively.

The sixth LEC is only present in the isospin zero $S = -2$ channels. There is scarce experimental knowledge in these channels. In the $\Lambda\Lambda$ system, we as-

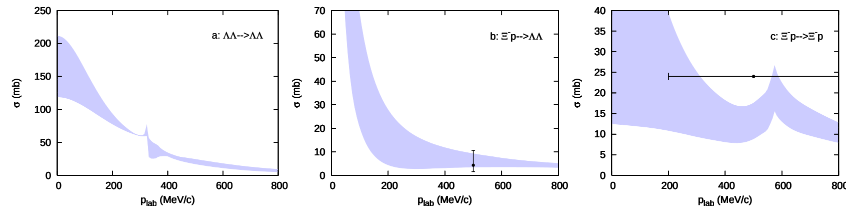

Figure 2. YY and ΞN integrated cross section σ as a function of $p_{\rm lab}$. The band shows the chiral EFT for variations of the sixth LEC, as discussed in the text.

sume a moderate attraction and exclude bound states or near-threshold resonances. Based on these considerations the sixth LEC was varied in the range of $2.0, ..., -0.05$ times the natural value. Various cross sections for $\Lambda = 600$ MeV are shown in Fig. 2. See [7] for more details.

Our findings have shown that the chiral EFT scheme, successfully applied in [4] to the NN interaction, also works well for the $S = -1, -2$ BB interactions in LO. It will be interesting to perform a combined NN and YN study in chiral EFT, starting with a next-to-leading order (NLO) calculation. Work in this direction is in progress.

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