

# Strange two-baryon interactions using chiral effective field theory

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**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  $SU(3)_f$  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 ( $\Xi N$ ) 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  $\Xi N$  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.

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## 2 Formalism

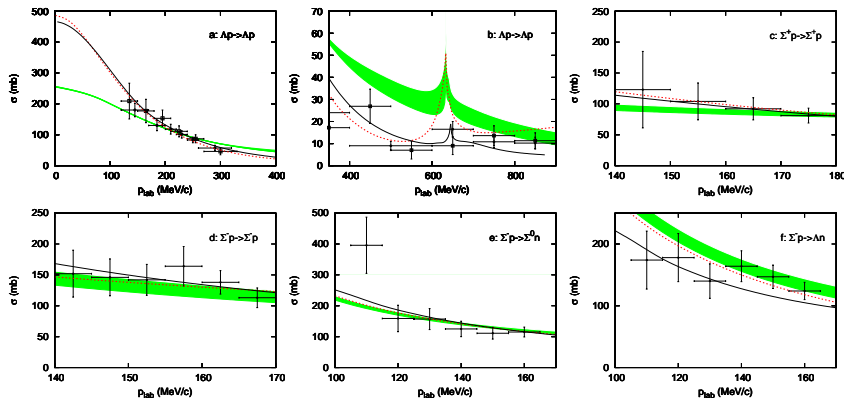
We have constructed the chiral potentials for the  $S = -1, -2$  sectors at LO using the Weinberg power counting, see [6]. The LO potential consists of four-baryon contact terms without derivatives and of one-pseudoscalar-meson exchanges. The LO  $SU(3)_f$  invariant contact terms for the octet baryon-baryon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

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

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  $\Xi N$  systems. The potentials in the LS equation are cut off with a regulator function,  $\exp[-(p'^4 + p^4)/\Lambda^4]$ , in order to remove high-energy components of the baryon and pseudoscalar meson fields.

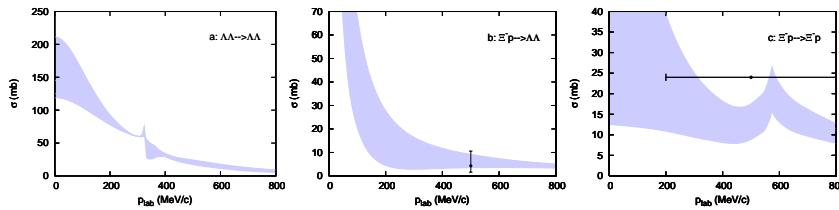
## 3 Results and discussion

Because of  $SU(3)_f$  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  $\Lambda = 550, \dots, 700$  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  $\Lambda$  separation energies for  ${}^4_\Lambda\text{H}$  have been predicted [6, 10].



**Figure 1.**  $YN$  integrated cross section  $\sigma$  as a function of  $p_{\text{lab}}$ . The band is the chiral EFT for  $\Lambda = 550, \dots, 700$  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  $\Xi N$  integrated cross section  $\sigma$  as a function of  $p_{\text{lab}}$ . 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  $2.0, \dots, -0.05$  times the natural value. Various cross sections for  $A = 600$  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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