Baryon-baryon interactions from chiral effective field theory

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Outline

BB interaction in chiral effective field theory

- ΛN and ΣN scattering
  $\rightarrow$ Role of SU(3) flavor symmetry
- Few-body systems with hyperons: ${}^{3}_{\Lambda}\mathrm{H}$, ${}^{4}_{\Lambda}\mathrm{H}$, ${}^{4}_{\Lambda}\mathrm{He}$
  $\rightarrow$ Role of three-body forces
- (Λ, Σ) hypernuclei and hyperons in nuclear matter
  $\rightarrow$ very small spin-orbit splitting: weak spin-orbit force
  $\rightarrow$ repulsive Σ nuclear potential
- implications for astrophysics
  $\rightarrow$ hyperon stars
  stability/size of neutron stars

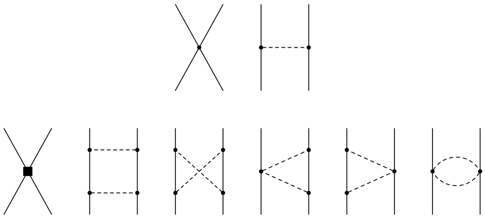
BB interaction in chiral effective field theory

Baryon-baryon interaction in SU(3) χEFT à la Weinberg (1990)

Advantages:

- Power counting
  systematic improvement by going to higher order
- Possibility to derive two- and three baryon forces and external current operators in a consistent way

- degrees of freedom: baryon octet, pseudoscalar Goldstone boson octet
- pseudoscalar-meson exchanges
- contact terms – represent unresolved short-distance dynamics



LO: H. Polinder, J.H., U. Meißner, NPA 779 (2006) 244

NLO: J.H., N. Kaiser, U. Meißner, A. Nogga, S. Petschauer, W. Weise, NPA 915 (2013) 24

Contact terms for BB – partial-wave projected

- spin-momentum structure up to NLO

$$
\begin{aligned}
V(S) &= \tilde{C}_S + C_S(p^2 + p'^2) & V(P) &= C_P\, p\, p' \\
V(^3D_1 - {}^3S_1) &= C_{^3S_1 - {}^3D_1}\, p'^2 & V(^1P_1 - {}^3P_1) &= C_{^1P_1 - {}^3P_1}\, p\, p' \\
V(^3S_1 - {}^3D_1) &= C_{^3S_1 - {}^3D_1}\, p^2 & V(^3P_1 - {}^1P_1) &= C_{^3P_1 - {}^1P_1}\, p\, p'
\end{aligned}
$$

$\tilde{C}_S$, C_S, etc., ... low-energy constants (LECs) that need to be fixed by a fit to data (or phase shifts)

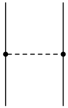
- $SU(3)$ structure for scattering of two octet baryons $\rightarrow$

$8 \otimes 8 = 1 \oplus 8_a \oplus 8_s \oplus 10^* \oplus 10 \oplus 27$

BB interaction can be given in terms of LECs corresponding to the $SU(3)_f$ irreducible representations: C^1, C^{8_a}, C^{8_s}, C^{10^*}, C^{10}, C^{27}, e.g.

$$
\begin{aligned}
V^{\Lambda N \rightarrow \Lambda N}_{^1S_0} &= \frac{1}{10}\left(9\tilde{C}^{27}_{^1S_0} + \tilde{C}^{8_s}_{^1S_0}\right) + \frac{1}{10}\left(9C^{27}_{^1S_0} + C^{8_s}_{^1S_0}\right)\left(p^2 + p'^2\right) \\
V^{\Sigma N \rightarrow \Sigma N}_{^1S_0} &= \tilde{C}^{27}_{^1S_0} + C^{27}_{^1S_0}\left(p^2 + p'^2\right) \quad [I = 3/2]
\end{aligned}
$$

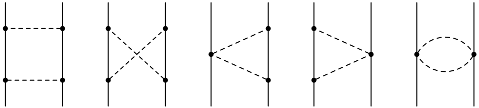
No. of contact terms: LO: 5 (YN) + 1 (YY) [2+1 in $^1S_0$ and 3 in $^3S_1$]
NLO: 18 (YN) + 4 (YY) [5+1 in the S waves; rest in P waves]



$$V^{OBE}_{B_1 B_2 \to B_1' B_2'} = -f_{B_1 B_1' P} f_{B_2 B_2' P} \frac{(\vec{\sigma}_1 \cdot \vec{q})\,(\vec{\sigma}_2 \cdot \vec{q})}{\vec{q}^{\,2} + m_P^2}$$

$f_{B_1 B_1' P}$ ... coupling constants fulfil standard SU(3) relations
m_P ... mass of the exchanged pseudoscalar meson

$SU(3)$ symmetry breaking due to the mass splitting of the ps mesons
(m_π = 138.0 MeV, m_K = 495.7 MeV, m_η = 547.3 MeV)
taken into account already at LO!



⇒ J.H., S. Petschauer, N. Kaiser, U.-G. Meißner, A. Nogga, W. Weise, NPA 915 (2013) 24

Coupled channels Lippmann-Schwinger Equation

$$
\begin{aligned}
T^{\nu'\nu,J}_{\rho'\rho}(p',p) &= V^{\nu'\nu,J}_{\rho'\rho}(p',p) \\
&+ \sum_{\rho'',\nu''}\int_0^\infty \frac{dp''p''^2}{(2\pi)^3}\, V^{\nu'\nu'',J}_{\rho'\rho''}(p',p'')\,\frac{2\mu_{\rho''}}{p^2-p''^2+i\eta}\, T^{\nu''\nu,J}_{\rho''\rho}(p'',p)
\end{aligned}
$$

ρ', ρ = ΛN, ΣN ($\Lambda\Lambda$, ΞN, $\Lambda\Sigma$, $\Sigma\Sigma$)

LS equation is solved for particle channels (in momentum space)

Coulomb interaction is included via the Vincent-Phatak method

The potential in the LS equation is cut off with the regulator function:

$$
V^{\nu'\nu,J}_{\rho'\rho}(p',p) \to f^\Lambda(p')\, V^{\nu'\nu,J}_{\rho'\rho}(p',p) f^\Lambda(p); \quad f^\Lambda(p) = e^{-(p/\Lambda)^4}
$$

consider values $\Lambda = 550$ - 700 MeV [LO]
500 - 650 MeV [NLO]

NLO calculation for ΛN, ΣN scattering

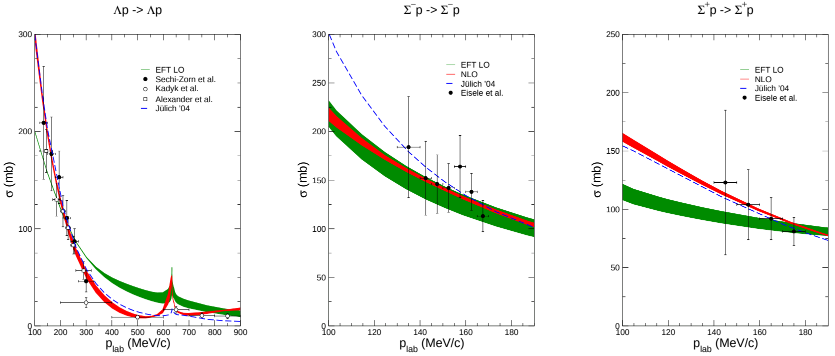
Pseudoscalar-meson exchange

- All one- and two-pseudoscalar-meson exchange diagrams are included
- $SU(3)$ symmetry is broken by using the physical m_π, m_K, and m_η
- $SU(3)$ breaking in the coupling constants is ignored
  $f_\pi = f_K = f_\eta = f_0 = 93$ MeV; $\alpha = F/(F+D) = 0.4$; $F + D = g_A = 1.26$
- Correction to V^{OBE} due to baryon mass differences are ignored

Contact terms

- $SU(3)$ symmetry is assumed
  (at NLO $SU(3)$ breaking corrections to the LO contact terms arise!)
- 10 contact terms in S-waves
  fixed from fit to ΛN and ΣN data
  no SU(3) constraints from the NN sector are imposed!
- 12 contact terms in P-waves and in ${}^3S_1 - {}^3D_1$
  SU(3) constraints from the NN sector are imposed!
- 1 contact term in ${}^1P_1 - {}^3P_1$ (singlet-triplet mixing)
  is fixed from considering Λ-nuclear spin-orbit force in medium

YN integrated cross sections



LO: H. Polinder, J.H., U. Meißner, NPA 779 (2006) 244

NLO: J.H., N. Kaiser, et al., NPA 915 (2013) 24

Jülich '04: J.H., U.-G. Meißner, PRC 72 (2005) 044005

Brueckner reaction-matrix formalism

conventional non-relativistic lowest order Brueckner theory:

$$\begin{aligned}\langle YN|G_{YN}(\zeta)|YN\rangle &= \langle YN|V|YN\rangle \\ &+ \sum_{Y'N} \langle YN|V|Y'N\rangle\, \langle Y'N|\frac{Q}{\zeta - H_0}|Y'N\rangle\, \langle Y'N|G_{YN}(\zeta)|YN\rangle\end{aligned}$$

Q ... Pauli projection operator

$$\zeta = E_Y(p_Y) + E_N(p_N)$$

$$E_\alpha(p_\alpha) = M_\alpha + \frac{p_\alpha^2}{2M_\alpha} + U_\alpha(p_\alpha), \qquad \alpha = Y,\ N$$

$$U_Y(p_Y) = \int_{p_N \le k_F} d^3p_N\, \langle YN|G_{YN}(\zeta(U_Y))|YN\rangle$$

$B_Y(\infty) = -U_Y(p_Y = 0)$ - evaluated at saturation point of nuclear matter

$\Rightarrow$ J.H, U.-G. Meißner, NPA 936 (2015) 29
S. Petschauer, et al., arXiv:1507.08808

Nuclear matter properties

$U_Y(p_Y = 0)$ [in MeV] at saturation density, $k_F = 1.35\ \mathrm{fm}^{-1}$

	EFT LO	EFT NLO	Jülich '04	Jülich '94
Λ [MeV]	$550 \cdots 700$	$500 \cdots 650$		
$U_\Lambda(0)$	$-38.0 \cdots -34.4$	$-28.2 \cdots -22.4$	-51.2	-29.8
$U_\Sigma(0)$	$28.0 \cdots 11.1$	$17.3 \cdots 11.9$	-22.2	-71.4

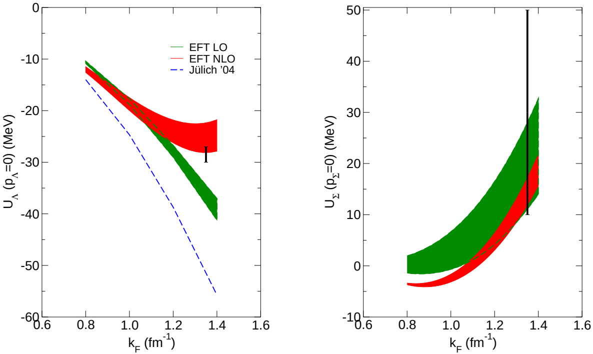
"Empirical" value for the Λ binding energy in nuclear matter:
≈ 30 MeV

ΣN (I=3/2): ${}^3S_1$–${}^3D_1$: decisive for Σ properties in nuclear matter

- A description of YN data is possible with an attractive as well as a repulsive ${}^3S_1$–${}^3D_1$ interaction
- adopt the repulsive solution in accordance with evidence from
  - level shifts and widths of Σ^- atoms
  - (π^-, K^+) inclusive spectra related to Σ^- formation in heavy nuclei
- Lattice QCD calculations support also a repulsive ${}^3S_1$–${}^3D_1$!
  S. Beane et al., PRL 109 (2012) 172001

Jülich '94: A. Reuber, K. Holinde, J. Speth, NPA 570 (1994) 543

k_F dependence of s.p. potentials



Spin-orbit interaction in Λ-hypernuclei

- Central potential: $U_\Lambda \approx \frac{1}{2} U_N$
- Spin-orbit potential: $U_\Lambda^{\ell s} \leq \frac{1}{20} U_N^{\ell s}$

  ${}^{13}_{\Lambda}\mathrm{C} \;\rightarrow\; E_\Lambda(p_{1/2^-}) - E_\Lambda(p_{3/2^-}) = (152 \pm 54 \pm 36)$ keV

  (S. Ajimura et al., PRL 86 (2001) 4255)

  ${}^{9}_{\Lambda}\mathrm{Be} \;\rightarrow\; E_\Lambda(p_{3/2^+}) - E_\Lambda(p_{5/2^+}) = (43 \pm 5)$ keV

  (H. Akikawa et al., PRL 88 (2002) 82501)

Strength of the spin-orbit potential is usually quantified in terms of the so-called Scheerbaum factor S_Λ:

$$U_\Lambda^{\ell s}(r) = -\frac{\pi}{2} S_\Lambda \frac{1}{r} \frac{d\rho(r)}{dr} \boldsymbol{\ell} \cdot \boldsymbol{\sigma}$$

$\rho(r)$ ... nucleon density distribution
ℓ ... single-particle orbital angular momentum operator

phenomenological analyses (Hiyama, Fujiwara, Kohno) of ${}^{9}_{\Lambda}$Be:

$\Rightarrow -4.6 \leq S_\Lambda \leq -3.0$ MeV fm^5

- aim at $S_\Lambda \approx -3.7$ MeV fm^5 (and fix $C_{{}^1P_1 \leftrightarrow {}^3P_1}$ accordingly)

Partial-wave contributions to S_Λ [MeV fm^5]

$$S_\Lambda(p_\Lambda) \propto \sum_J \int \Big\{ (J+2)\, G^J_{1\,J+1,\,1\,J+1}(p;p_\Lambda) + G^J_{1J,1J}(p;p_\Lambda) - (J-1)\, G^J_{1\,J-1,\,1\,J-1}(p;p_\Lambda)$$

$$- \sqrt{J(J+1)}\,\Big[G^J_{1J,0J}(p;p_\Lambda) + G^J_{0J,1J}(p;p_\Lambda) \Big] \Big\}\, W(p;p_\Lambda)\, dp$$

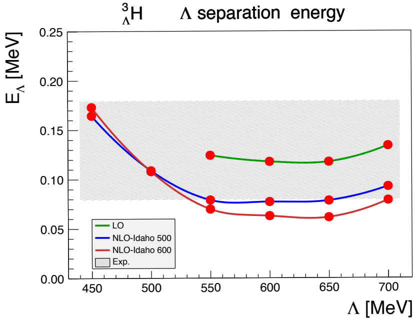
(notation: $G^J_{S\,L,S'L'}$)

	$^3P_0$	$^3D_1$	$^3P_1$	$^1P_1 \leftrightarrow {}^3P_1$	$^3P_2$	Total
LO (550)	8.7	−0.2	−5.2	0.0	−0.9	2.7
LO (700)	10.4	−0.2	−4.7	0.0	−1.4	4.4
NLO (500)	−5.9	−0.6	−3.3	8.9	−3.4	−3.7
NLO (650)	−4.4	−0.6	−2.0	5.8	−3.0	−3.7
NLO†(650)	−4.4	−0.6	−4.6	0.0	−3.0	−12.0
Jülich '04	4.0	0.5	−1.3	4.6	−9.2	−1.7
Jülich '94	−3.3	1.2	−3.8	8.4	−2.5	−0.4

NLO†(650) ... with $C_{^1P_1 \leftrightarrow {}^3P_1} = 0$

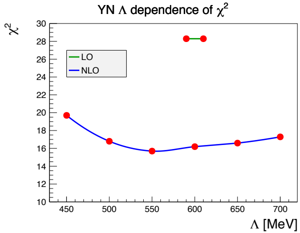
$\Rightarrow$ cancellation between spin-orbit and antisymmetric spin-orbit components

Hypertriton results (from Faddeev calculation)



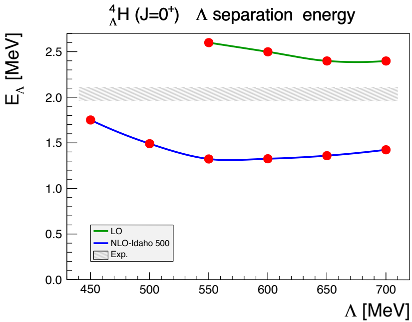
separation energies:

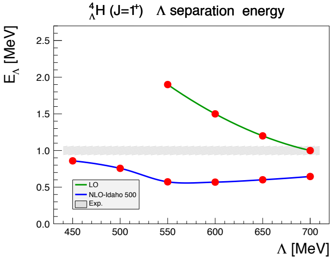
$$E_\Lambda = E(core) - E(hypernucleus)$$



- Λp $^1S_0$ / $^3S_1$ scattering lengths are chosen so that $^3_\Lambda$H BE is ok
- long range 3BFs need to be explicitly estimated
- cutoff variation:
  * $NNN \rightarrow$ is lower bound for magnitude of higher order contributions
  * ΛNN - correlation with χ^2 of YN interaction?

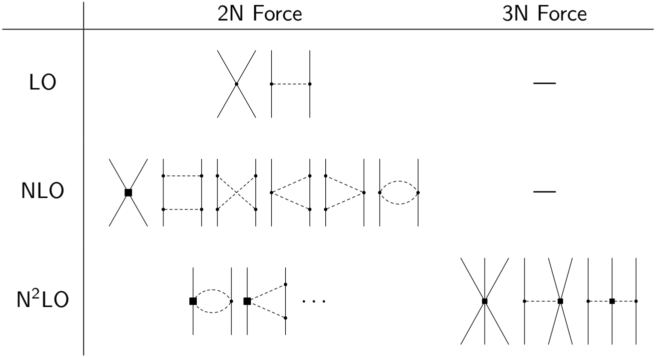
$^{4}_{\Lambda}$H results (from Faddeev-Yakubovsky calculation)





- LO: unexpected small cutoff dependence in 0^+ result
- NLO: underbinding $\rightarrow$ comparable to what is observed in calculations with phenomenological potentials (Jülich '04, NSC97f)
- long range 3BFs need to be explicitly estimated

Three-nucleon force in chiral EFT



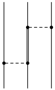
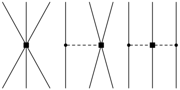
[van Kolck, Phys.Rev.C49, 1994]

[Epelbaum, Nogga, Glöckle, Kamada, Meißner, Witała, Phys.Rev.C66, 2002]

[Epelbaum, Hammer, Meißner, Rev.Mod.Phys.81, 2008]

new LECs in 3N force: c_D, c_E $\rightarrow$ have to be fixed in 3N sector

Three-nucleon force with Δ

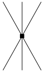
	3N Force with Δ isobar
LO	—
NLO	
N^2LO	 $+ \cdots$

[Epelbaum, Krebs and Meißner, Nucl.Phys.A806, 2008]
[Epelbaum, Hammer, Meißner, Rev.Mod.Phys.81, 2008]

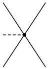
Three-baryon forces in SU(3) chiral EFT

Stefan Petschauer, PhD thesis:

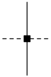
- symmetries of the effective Lagrangian:
  - chiral symmetry $\mathrm{SU}(3)_\mathrm{L} \times \mathrm{SU}(3)_\mathrm{R}$
  - C, P, T, Hermitian conjugation
  - Lorentz transformation
- degrees of freedom:
  - pseudoscalar Goldstone boson octet (π, K, η)
  - baryon octet $(N, \Lambda, \Sigma, \Xi)$
  - baryon decuplet $(\Delta, \Sigma^*, \Xi^*, \Omega)$
- antisymmetrized potential to respect generalized Pauli principle
- vertices:



18 low-energy constants (SU(3) symmetric)

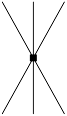


14 low-energy constants [Petschauer, Kaiser, Nucl.Phys.A916, 2013]



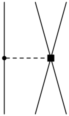
10 low-energy constants [Krause, Helv.Phys.Acta 63, 1990]

Potentials for leading three-baryon forces

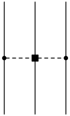


$$V^{\rm ct} = N_1 \mathbb{1} + N_2 \vec\sigma_1\cdot\vec\sigma_2 + N_3\vec\sigma_1\cdot\vec\sigma_3 + N_4\vec\sigma_2\cdot\vec\sigma_3 + N_5 \mathrm{i}\,\vec\sigma_1\times\vec\sigma_2\cdot\vec\sigma_3$$

example: $V^{\text{ct},\, I=0}_{\Lambda NN\to\Lambda NN} = c_1(\mathbb{1} + \frac{1}{3}\,\vec\sigma_2\cdot\vec\sigma_3) + c_2(\vec\sigma_1\cdot\vec\sigma_2 + \vec\sigma_1\cdot\vec\sigma_3)$



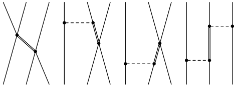
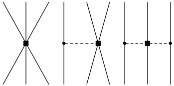
$$V^{1\phi} = -\frac{1}{2f_0^2}\frac{\vec\sigma_1\cdot\vec q_1}{\vec q_1^{\,2} + m_\phi^2}\left\{N_6\vec\sigma_2\cdot\vec q_1 + N_7\vec\sigma_3\cdot\vec q_1 + N_8 \mathrm{i}\,(\vec\sigma_2\times\vec\sigma_3)\cdot\vec q_1\right\}$$

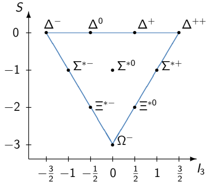


$$V^{2\phi} = \frac{1}{4f_0^2}\frac{\vec\sigma_1\cdot\vec q_1\;\vec\sigma_3\cdot\vec q_3}{(\vec q_1^{\,2} + m_{\phi_1}^2)(\vec q_3^{\,2} + m_{\phi_3}^2)} \times\left\{N_9 m_\pi^2 + N_{10} m_K^2 + N_{11}\vec q_1\cdot\vec q_3 + N_{12}\mathrm{i}\,\vec\sigma_2\cdot(\vec q_1\times\vec q_3)\right\}$$

$p_i(p_i')$ are initial (final) momenta of the baryon i and $\vec q_i \equiv \vec p_i\,' - \vec p_i$

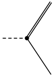
Three-baryon forces with decuplet baryons

	3B Force with decuplet baryons
LO	—
NLO	
N^2LO	 $+ \cdots$



Resonance saturation

- new vertices:

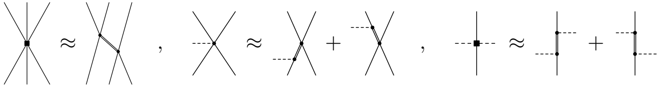


one constant ($C = \frac{3}{4} g_A \approx 1$ from $\Delta \to N\pi$)

two constants (Pauli-forbidden in nucleonic sector)

	tensor products in *flavor* space	and in *spin* space
final state	$\mathbf{10} \otimes \mathbf{8} = \mathbf{35} \oplus \mathbf{27} \oplus \mathbf{10} \oplus \mathbf{8}$	$\mathbf{3/2} \otimes \mathbf{1/2} = \mathbf{1} \oplus \mathbf{2}$
initial state	$\mathbf{8} \otimes \mathbf{8} = \underbrace{\mathbf{27} \oplus \mathbf{8_s} \oplus \mathbf{1}}_{\text{symmetric}} \oplus \underbrace{\mathbf{10} \oplus \overline{\mathbf{10}} \oplus \mathbf{8_a}}_{\text{antisymmetric}}$	$\mathbf{1/2} \otimes \mathbf{1/2} = \underbrace{\mathbf{0}}_{\text{a.sym.}} \oplus \underbrace{\mathbf{1}}_{\text{sym.}}$

- estimate chiral three-baryon forces via decuplet saturation:



- presently implemented into hypertriton calculations (A. Nogga)

Constraints on the $\Lambda\Lambda$ scattering length:

- $\Delta B_{\Lambda\Lambda} = B_{\Lambda\Lambda}({}^{6}_{\Lambda\Lambda}\mathrm{He}) - 2B_{\Lambda}({}^{5}_{\Lambda}\mathrm{He}) = 1.01 \pm 0.20^{+0.18}_{-0.11}$ MeV

  (H. Takahashi et al., Phys. Rev. Lett. 87 (2001) 212502)

  0.67 ± 0.17 MeV

  (K. Nakazawa, Nucl. Phys. A 835 (2010) 207)

  ${}^{6}_{\Lambda\Lambda}$He calculations (Filikhin; Fujiwara; Rijken; ...)

  $\Rightarrow -1.32 < a_{\Lambda\Lambda} < -0.73$ fm [based on 2001 value!]

- $a_{\Lambda\Lambda}$ = -1.2 $\pm$ 0.6 fm

  (A. Gasparyan et al., Phys. Rev. C 85 (2012) 0152047)

  deduced from $\Lambda\Lambda$ invariant mass spectrum of the reaction ${}^{12}C(K^-, K^+\Lambda\Lambda X)$

- $-1.25 < a_{\Lambda\Lambda} < -0.56$ fm

  (K. Morita et al., Phys. Rev. C 91 (2015) 024916)

  deduced from analyzing $\Lambda\Lambda$ correlations in relativistic heavy-ion collisions

Information on YY channels

Constraints on the ΞN interaction:

- data/limits for the range $200 < p_\Xi < 800$ MeV/c

  $\sigma_{\Xi^- p \to \Lambda\Lambda} < 12$ mb, at 90% confidence level
  $\sigma_{\Xi^- p \to \Xi^- p} < 24$ mb, at 90% confidence level
  $\sigma_{\Xi^- p \to \Lambda\Lambda} = 4.3^{+6.3}_{-2.7}$ mb, at $p_\Xi = 500$ MeV/c

  (J.K. Ahn et al., PLB 633 (2006) 214)

- in-medium cross sections:

  inelastic $\sigma_{\Xi^- N} = 12.7^{+3.5}_{-3.1}$ mb $(400 < p_\Xi < 600$ MeV/c)

  (S. Aoki et al., NPA 644 (1998) 365)

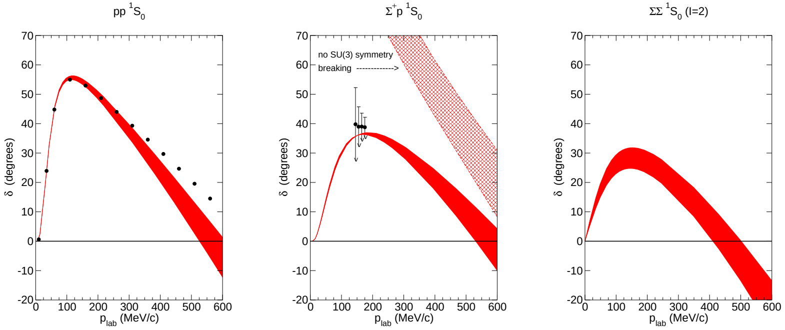
- older data at higher energies (Charlton, 1970; Muller, 1972):

  $\sigma_{\Xi^- p \to \Xi^- p} = 13 \pm 6$ mb $(p_\Xi = 1 - 4$ GeV/c)
  $\sigma_{\Xi^0 p \to \Xi^0 p} = 19 \pm 10$ mb $(p_\Xi = 1 - 4$ GeV/c)

  $\sigma_{\Xi^0 p \to \Xi^0 p} = 8$ mb
  $\sigma_{\Xi^0 p \to \Sigma^+ \Lambda} = 24$ mb $(p_\Xi \approx 2$ GeV/c)

$\Rightarrow$ ΞN cross sections are small $\rightarrow$
ΞN interaction cannot be very strong !

Breaking of SU(3) symmetry



$$V_{pp} = \tilde{C}^{27} + C^{27}(p^2 + p'^2) + \frac{1}{4} C_1^{\chi} (m_K^2 - m_\pi^2)$$

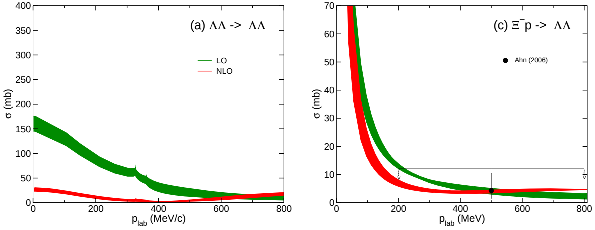
$$V_{\Sigma^+ p} = \tilde{C}^{27} + C^{27}(p^2 + p'^2)$$

$$V_{\Sigma^+\Sigma^+} = \tilde{C}^{27} + C^{27}(p^2 + p'^2) - \frac{1}{4} C_1^{\chi} (m_K^2 - m_\pi^2)$$

J.H., U.-G. Meißner, S. Petschauer, EPJA 51 (2015) 17:

$C_1^{\chi} < 0 \Rightarrow$ increasing repulsion for $S = 0 \rightarrow S = -1 \rightarrow S = -2$

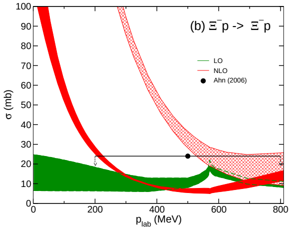
Preliminary results

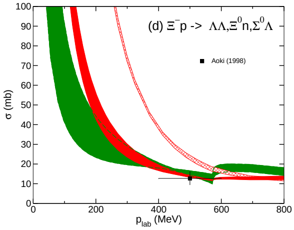


ΛΛ effective range parameters

	NLO				LO			
Λ	500	550	600	650	550	600	650	700
$a_{^1S0}$	−0.62	−0.61	−0.66	−0.70	−1.52	−1.52	−1.54	−1.67
$r_{^1S0}$	7.00	6.06	5.05	4.56	0.82	0.59	0.31	0.34

Preliminary results





hatched band: use $\tilde{C}^{i}_{3S1}$ as fixed in YN (*) filled band: $\tilde{C}^{8a}_{3S1}$ readjusted

		NLO				LO			
Λ		500	550	600	650	550	600	650	700
$\Xi^0 n$	a_{3S1}	11.39	5.15	4.78	4.74	-0.34	-0.25	-0.20	-0.15
	(*)	-0.25	-0.20	-0.26	-0.34				
$\Xi^0 p$	a_{1S0}	0.37	0.39	0.34	0.31	0.21	0.19	0.17	0.13
	a_{3S1}	-1.01	-0.85	-0.72	-0.66	0.02	0.00	0.02	0.03
	(*)	-0.20	-0.04	0.02	0.04				
$\Sigma^+\Sigma^+$	a_{1S0}	-2.19	-1.94	-1.83	-1.82	-6.23	-7.76	-9.42	-9.27

Summary

Baryon-baryon interactions constructed within chiral EFT

- Approach is based on a modified Weinberg power counting, analogous to the *NN* case
- The potential (contact terms, pseudoscalar-meson exchanges) is derived imposing $SU(3)_f$ constraints
- YN: Excellent results at next-to-leading order (NLO)
  low-energy data are reproduced with a quality comparable to phenomenological models
- Λ and Σ in nuclear matter:
  Λ single-particle potential at nuclear matter saturation density is in line with "empirical" value
  a repulsive Σ single-particle potential is achieved
  a weak Λ-nuclear spin-orbit potential is achieved
- Derivation of BBB forces within SU(3) chiral EFT is accomplished
  expect concrete results soon
- YY: Prelimary results look promising
  SU(3) symmetry breaking when going from NN to YN to YY!