Hyperon-nucleon and hyperon-hyperon interactions in chiral effective field theory

Johann Haidenbauer

IAS & JCHP, Forschungszentrum Jülich, Germany

Bad Honnef, February 12-16, 2011

Outline

Why is the YN (YY) interaction interesting?

- study the role of strangeness in low and medium energy nuclear physics
- test $SU(3)_{flavor}$ symmetry
- H-dibaryon
  - Jaffe (1977) $\longrightarrow$ predicted a deeply bound 6-quark state with $I = 0$, $J = 0$, $S = -2$ from bag-model
  - many experimental searches for the H-dibaryon
    C.J. Yoon et al., PRC 75 (2007) 022201: No significant enhancements above levels of the model predictions were observed.
  - Lattice QCD (2010) $\rightarrow$ evidence for a bound H-dibaryon

    (S.R. Beane et al., arXiv:1012.3812 [hep-lat])

    (T. Inoue et al., arXiv:1012.5928 [hep-lat])

Introduction

- prerequisite for studies of (Λ, Σ) hypernuclei
- quest for $\Lambda\Lambda$ hypernuclei and Ξ hypernuclei
  $\longrightarrow$ J-PARC, FAIR
- implications for astrophysics
  $\longrightarrow$ hyperon stars
  stability/size of neutron stars

Experimental status

YN data [$S = -1$]

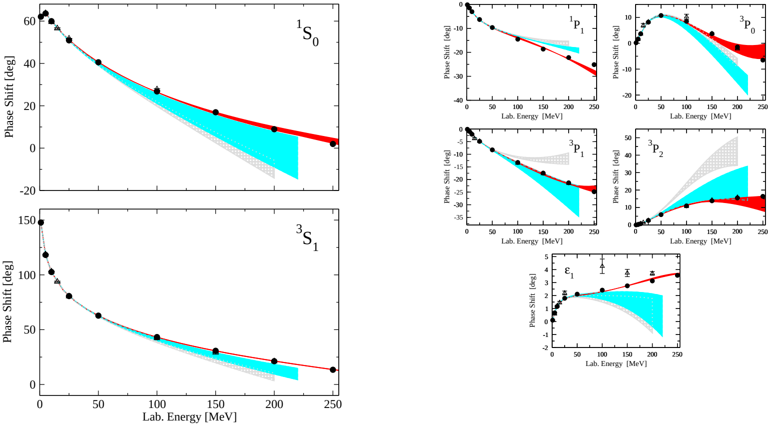
- about 35 data points, all from the 1960s
- 10 new data points, from the KEK-PS E251 collaboration (from $\approx$ 2000)
  (cf. $>$ 4000 NN data for $E_{lab} < 350$ MeV!)

YY data [$S = -2$]

- a few rough estimations of ΞN cross sections from the 1970s
- "more precise" cross sections (for $\Xi^- p$ and $\Xi^- p \to \Lambda\Lambda$) published in 2006

$S = -3, -4$: uncharted territory

Chiral Effective Field Theory for the *NN* interaction



NLO, *N²LO*, *N³LO*

(E. Epelbaum, W. Glöckle, Ulf-G. Meißner, NPA747 (2005) 362)

YN and YY in chiral effective field theory

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

Obstacle: YN data base is rather poor
practically no information on YY
($\rightarrow$ impose $SU(3)_f$ constraints)

few investigations so far (for YN only):

- C.K. Korpa et al., PRC 65 (2001) 015208
- S.R. Beane et al., NPA747 (2005) 55

pion-less theory; Kaplan-Savage-Wise resummation scheme

We follow the scheme of E. Epelbaum et al.

(E. Epelbaum, W. Glöckle, Ulf-G. Meißner, NPA747 (2005) 362)

Power counting

$$V_{\rm eff} \equiv V_{\rm eff}(Q, g, \mu) = \sum_{\nu} (Q/\Lambda)^{\nu} \, \mathcal{V}_{\nu}(Q/\mu, g)$$

- Q ... soft scale (baryon three-momentum, Goldstone boson four-momentum, Goldstone boson mass)
- Λ ... hard scale
- g ... pertinent low–energy constants
- μ ... regularization scale
- $\mathcal{V}_{\nu}$ ... function of order one
- $\nu \geq 0$ ... chiral power

Lowest order (LO): $\nu = 0$

a) non-derivative four-baryon contact terms

b) one-meson (Goldstone boson) exchange diagrams

Leading order (LO) contact term

The LO contact term for the BB interaction:

$$\mathcal{L} = C_i \left(\bar{N}\Gamma_i N\right)\left(\bar{N}\Gamma_i N\right) \quad \Rightarrow \quad \mathcal{L} = \tilde{C}_i \left\langle \bar{B}_a \bar{B}_b \left(\Gamma_i B\right)_a \left(\Gamma_i B\right)_b \right\rangle$$

$$\Gamma_1 = 1\,,\ \Gamma_2 = \gamma^\mu\,,\ \Gamma_3 = \sigma^{\mu\nu}\,,\ \Gamma_4 = \gamma^\mu\gamma_5\,,\ \Gamma_5 = \gamma_5$$

$a,\ b$ … Dirac indices of the particles

B is the usual irreducible octet representation of $\mathrm{SU}(3)_f$:

$$B = \begin{pmatrix} \frac{\Sigma^0}{\sqrt{2}} + \frac{\Lambda}{\sqrt{6}} & \Sigma^+ & p \\ \Sigma^- & \frac{-\Sigma^0}{\sqrt{2}} + \frac{\Lambda}{\sqrt{6}} & n \\ -\Xi^- & \Xi^0 & -\frac{2\Lambda}{\sqrt{6}} \end{pmatrix}$$

The LO contact term NN potential resulting from the interaction Lagrangian:

$$V^{NN\to NN} = C_S + C_T\,\boldsymbol{\sigma}_1\cdot\boldsymbol{\sigma}_2$$

C_S and C_T ... low-energy constants; to be determined in a fit to the experimental data.

Leading order contact terms for YN and YY

spin-momentum structure of the LO contact term potential resulting from the BB interaction Lagrangian:

$$V^{BB\to BB} = C_S^{BB\to BB} + C_T^{BB\to BB}\, \boldsymbol{\sigma}_1 \cdot \boldsymbol{\sigma}_2$$

$SU(3)$ structure for scattering of two octet baryons:
direct product:

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

There are only 6 independent low-energy constants for the BB interaction!
(8 independent spin-isospin channels in YN alone!)

C_S^i, C_T^i can be expressed by the coefficients corresponding to the $SU(3)_f$ irreducible representations:
C^1, C^{8_a}, C^{8_s}, C^{10^*}, C^{10}, C^{27}

BB contact interactions in terms of $SU(3)_f$ irreducible representations

	Channel	Isospin	$V_{^3S1}$
$S = 0$	$NN \to NN$	0	C^{10^*}
$S = -1$	$\Lambda N \to \Lambda N$	$\frac{1}{2}$	$\frac{1}{2}\left(C^{8_a} + C^{10^*}\right)$
	$\Lambda N \to \Sigma N$	$\frac{1}{2}$	$\frac{1}{2}\left(-C^{8_a} + C^{10^*}\right)$
	$\Sigma N \to \Sigma N$	$\frac{1}{2}$	$\frac{1}{2}\left(C^{8_a} + C^{10^*}\right)$
	$\Sigma N \to \Sigma N$	$\frac{3}{2}$	C^{10}
$S = -2$	$\Xi N \to \Xi N$	0	C^{8_a}
	$\Xi N \to \Xi N$	1	$\frac{1}{3}\left(C^{10} + C^{10^*} + C^{8_a}\right)$
	$\Xi N \to \Sigma\Lambda$	1	$\frac{\sqrt{6}}{6}\left(C^{10} - C^{10^*}\right)$
	$\Xi N \to \Sigma\Sigma$	1	$\frac{\sqrt{2}}{6}\left(C^{10} + C^{10^*} - 2C^{8_a}\right)$
	$\Sigma\Lambda \to \Sigma\Lambda$	1	$\frac{1}{2}\left(C^{10} + C^{10^*}\right)$
	$\Sigma\Lambda \to \Sigma\Sigma$	1	$\frac{\sqrt{3}}{6}\left(C^{10} - C^{10^*}\right)$
	$\Sigma\Sigma \to \Sigma\Sigma$	1	$\frac{1}{6}\left(C^{10} + C^{10^*} + 4C^{8_a}\right)$

$SU(3)$ content

	Channel	Isospin	$V_{^1S0}$
$S = \ \ 0$	$NN \to NN$	1	C^{27}
$S = -1$	$\Lambda N \to \Lambda N$	$\frac{1}{2}$	$\frac{1}{10}\left(9C^{27} + C^{8_s}\right)$
	$\Lambda N \to \Sigma N$	$\frac{1}{2}$	$\frac{3}{10}\left(-C^{27} + C^{8_s}\right)$
	$\Sigma N \to \Sigma N$	$\frac{1}{2}$	$\frac{1}{10}\left(C^{27} + 9C^{8_s}\right)$
	$\Sigma N \to \Sigma N$	$\frac{3}{2}$	C^{27}
$S = -2$	$\Lambda\Lambda \to \Lambda\Lambda$	0	$\frac{1}{40}\left(27C^{27} + 8C^{8_s} + 5C^{1}\right)$
	$\Lambda\Lambda \to \Xi N$	0	$\frac{-1}{40}\left(18C^{27} - 8C^{8_s} - 10C^{1}\right)$
	$\Lambda\Lambda \to \Sigma\Sigma$	0	$\frac{\sqrt{3}}{40}\left(-3C^{27} + 8C^{8_s} - 5C^{1}\right)$
	$\Xi N \to \Xi N$	0	$\frac{1}{40}\left(12C^{27} + 8C^{8_s} + 20C^{1}\right)$
	$\Xi N \to \Sigma\Sigma$	0	$\frac{\sqrt{3}}{40}\left(2C^{27} + 8C^{8_s} - 10C^{1}\right)$
	$\Sigma\Sigma \to \Sigma\Sigma$	0	$\frac{1}{40}\left(C^{27} + 24C^{8_s} + 15C^{1}\right)$
	$\Xi N \to \Xi N$	1	$\frac{1}{5}\left(2C^{27} + 3C^{8_s}\right)$
	$\Xi N \to \Sigma\Lambda$	1	$\frac{\sqrt{6}}{5}\left(C^{27} - C^{8_s}\right)$
	$\Sigma\Lambda \to \Sigma\Lambda$	1	$\frac{1}{5}\left(3C^{27} + 2C^{8_s}\right)$
	$\Sigma\Sigma \to \Sigma\Sigma$	2	C^{27}

five contact terms for the $S = -1$ channels

one additional contact term (C^1) for the $I = 0$, $S = -2$ channels

One pseudoscalar-meson exchange

LO $\mathrm{SU(3)}_f$-invariant pseudoscalar-meson-baryon interaction Lagrangian:

$$\mathcal{L} = -\left\langle \frac{g_A(1-\alpha)}{\sqrt{2}F_\pi}\bar{B}\gamma^\mu\gamma_5\{\partial_\mu P, B\} + \frac{g_A\alpha}{\sqrt{2}F_\pi}\bar{B}\gamma^\mu\gamma_5[\partial_\mu P, B]\right\rangle$$

g_A is the axial-vector strength: $g_A \simeq 1.26$
F_π is the weak pion decay constant: $F_\pi = 92.4$ MeV
$\alpha = F/(F+D)$ and $g_A = F + D$

$$P = \begin{pmatrix} \frac{\pi^0}{\sqrt{2}} + \frac{\eta}{\sqrt{6}} & \pi^+ & K^+ \\ \pi^- & \frac{-\pi^0}{\sqrt{2}} + \frac{\eta}{\sqrt{6}} & K^0 \\ -K^- & \bar{K}^0 & -\frac{2\eta}{\sqrt{6}} \end{pmatrix}$$

One pseudoscalar-meson exchange

$$
\begin{aligned}
\mathcal{L} \quad = \quad & -f_{NN\pi}\bar{N}\gamma^\mu\gamma_5\boldsymbol{\tau}N\cdot\partial_\mu\boldsymbol{\pi} + if_{\Sigma\Sigma\pi}\bar{\boldsymbol{\Sigma}}\gamma^\mu\gamma_5\times\boldsymbol{\Sigma}\cdot\partial_\mu\boldsymbol{\pi} \\
& -f_{\Lambda\Sigma\pi}\left[\bar{\Lambda}\gamma^\mu\gamma_5\boldsymbol{\Sigma} + \bar{\boldsymbol{\Sigma}}\gamma^\mu\gamma_5\Lambda\right]\cdot\partial_\mu\boldsymbol{\pi} - f_{\Xi\Xi\pi}\bar{\Xi}\gamma^\mu\gamma_5\boldsymbol{\tau}\Xi\cdot\partial_\mu\boldsymbol{\pi} \\
& -f_{\Lambda NK}\left[\bar{N}\gamma^\mu\gamma_5\Lambda\partial_\mu K + \bar{\Lambda}\gamma^\mu\gamma_5 N\partial_\mu K^\dagger\right] \\
& -f_{\Xi\Lambda K}\left[\bar{\Xi}\gamma^\mu\gamma_5\Lambda\partial_\mu K_c + \bar{\Lambda}\gamma^\mu\gamma_5\Xi\partial_\mu K_c^\dagger\right] \\
& -f_{\Sigma NK}\left[\bar{\boldsymbol{\Sigma}}\cdot\gamma^\mu\gamma_5\partial_\mu K^\dagger\boldsymbol{\tau}N + \bar{N}\gamma^\mu\gamma_5\boldsymbol{\tau}\partial_\mu K\cdot\boldsymbol{\Sigma}\right] \\
& -f_{\Sigma\Xi K}\left[\bar{\boldsymbol{\Sigma}}\cdot\gamma^\mu\gamma_5\partial_\mu K_c^\dagger\boldsymbol{\tau}\Xi + \bar{\Xi}\gamma^\mu\gamma_5\boldsymbol{\tau}\partial_\mu K_c\cdot\boldsymbol{\Sigma}\right] - f_{NN\eta_8}\bar{N}\gamma^\mu\gamma_5 N\partial_\mu\eta \\
& -f_{\Lambda\Lambda\eta_8}\bar{\Lambda}\gamma^\mu\gamma_5\Lambda\partial_\mu\eta - f_{\Sigma\Sigma\eta_8}\bar{\boldsymbol{\Sigma}}\cdot\gamma^\mu\gamma_5\boldsymbol{\Sigma}\partial_\mu\eta - f_{\Xi\Xi\eta_8}\bar{\Xi}\gamma^\mu\gamma_5\Xi\partial_\mu\eta
\end{aligned}
$$

$$
\begin{aligned}
f_{NN\pi} &= f & f_{NN\eta_8} &= \frac{1}{\sqrt{3}}(4\alpha-1)f & f_{\Lambda NK} &= -\frac{1}{\sqrt{3}}(1+2\alpha)f \\
f_{\Xi\Xi\pi} &= -(1-2\alpha)f & f_{\Xi\Xi\eta_8} &= -\frac{1}{\sqrt{3}}(1+2\alpha)f & f_{\Xi\Lambda K} &= \frac{1}{\sqrt{3}}(4\alpha-1)f \\
f_{\Lambda\Sigma\pi} &= \frac{2}{\sqrt{3}}(1-\alpha)f & f_{\Sigma\Sigma\eta_8} &= \frac{2}{\sqrt{3}}(1-\alpha)f & f_{\Sigma NK} &= (1-2\alpha)f \\
f_{\Sigma\Sigma\pi} &= 2\alpha f & f_{\Lambda\Lambda\eta_8} &= -\frac{2}{\sqrt{3}}(1-\alpha)f & f_{\Xi\Sigma K} &= -f
\end{aligned}
$$

One pseudoscalar-meson exchange

$$V^{B_1 B_2 \to B_1' B_2'} = -f_{B_1 B_1' P} f_{B_2 B_2' P} \frac{(\sigma_1 \cdot \mathbf{q})(\sigma_2 \cdot \mathbf{q})}{\mathbf{q}^2 + m_P^2}$$

$f_{B_1 B_1' P}$ ... coupling constants;
m_P ... mass of the exchanged pseudoscalar meson.

- assume SU(6) symmetry: $\alpha = 2/5$
- assume $\eta \simeq \eta_8$
- SU(3) 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) is taken into account.

Details:

(H. Polinder, J.H., U.-G. Meißner, NPA 779 (2006) 244)
(H. Polinder, J.H., U.-G. Meißner, PLB 653 (2007) 29)

Coupled channels Lippmann-Schwinger Equation

$$
\begin{aligned}
T_{\rho'\rho}{}^{\nu'\nu,J}(p',p) &= V_{\rho'\rho}{}^{\nu'\nu,J}(p',p) \\
&+ \sum_{\rho'',\nu''} \int_0^\infty \frac{dp'' p''^2}{(2\pi)^3} V_{\rho'\rho''}{}^{\nu'\nu'',J}(p',p'') \frac{2\mu_{\nu''}}{p^2 - p''^2 + i\eta} T_{\rho''\rho}{}^{\nu''\nu,J}(p'',p)
\end{aligned}
$$

$\rho', \ \rho = \Lambda N, \Sigma N$
$ = \Lambda\Lambda, \Sigma\Sigma, \Xi N, \Sigma\Lambda$

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

Coulomb interaction is included via the Vincent-Phatak method

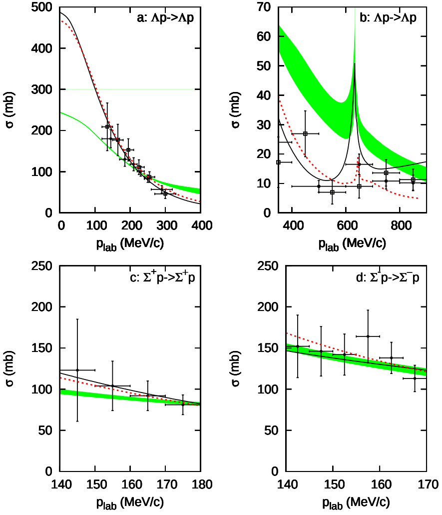
The potential in the LS equation is cut off with the regulator function:

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

consider values Λ = 550 - 700 MeV

(No $SU(3)$ constraints from the NN sector are imposed!)

YN integrated cross sections



EFT LO

(NPA 779 (2006) 244)

Jülich '04

(PRC 72 (2005) 044005)

Nijmegen NSC97f

(PRC 59 (1999) 21)

YN scattering lengths [fm]

	EFT LO				Jülich '04	NSC97f	experiment*
Λ [MeV]	550	600	650	700			
$a_s^{\Lambda p}$	-1.90	-1.91	-1.91	-1.91	-2.56	-2.51	$-1.8^{+2.3}_{-4.2}$
$a_t^{\Lambda p}$	-1.22	-1.23	-1.23	-1.23	-1.66	-1.75	$-1.6^{+1.1}_{-0.8}$
$a_s^{\Sigma^+ p}$	-2.24	-2.32	-2.36	-2.29	-4.71	-4.35	
$a_t^{\Sigma^+ p}$	0.70	0.65	0.60	0.56	0.29	-0.25	
$({}^3_\Lambda\mathrm{H})$ E_B	-2.35	-2.34	-2.34	-2.36	-2.27	-2.30	-2.354(50)

* A. Gasparyan et al., PRC 69 (2004) 034006 $\Rightarrow$ extract from final-state interaction:

$pp \to K^+\Lambda p$ (COSY, Jülich)

$\gamma d \to K^+\Lambda n$ (SPring-8)

YY channels

Strangeness S=-2 channels in the particle basis:

$$\begin{aligned} Q &= +2: \ \Sigma^+\Sigma^+ \\ Q &= +1: \ \Xi^0 p, \ \Sigma^+\Lambda, \ \Sigma^0\Sigma^+ \\ Q &= \ \ \ 0: \ \Lambda\Lambda, \ \Xi^0 n, \ \Xi^- p, \ \Sigma^0\Lambda, \ \Sigma^0\Sigma^0, \ \Sigma^-\Sigma^+ \\ Q &= -1: \ \Xi^- n, \ \Sigma^-\Lambda, \ \Sigma^-\Sigma^0 \\ Q &= -2: \ \Sigma^-\Sigma^- \end{aligned}$$

There is some experimental information on the $Q = 0$ channel:

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

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

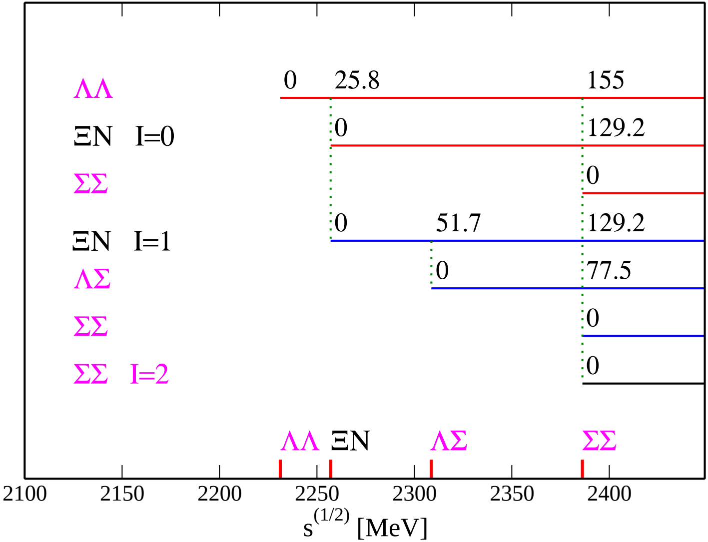
  0.67 ± 0.17 MeV

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

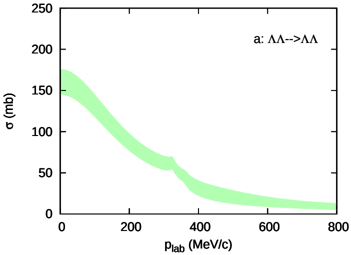
- $\Xi^- p$ scattering cross section at $p_{lab} = 500$ MeV/c

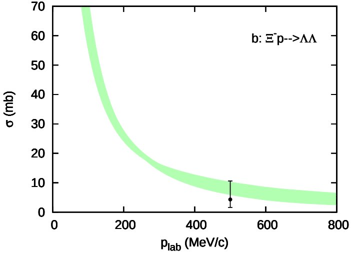
  (J.K. Ahn et al., Phys. Lett. B 633 (2006) 214)

YY kinematics



YY integrated cross sections





cut off Λ= 600 MeV

$a^{\Lambda\Lambda}_{^1S_0}$; $r^{\Lambda\Lambda}_{^1S_0}$ [in fm]

-1.52; 0.59 EFT LO

(PLB 653 (2007) 29)

-1.32; 4.40 ESC04d (Rijken)

(PRC 73 (2006) 044008)

-0.81; 3.80 fss2 (Fujiwara)

(Prog. Part. Nucl. Phys. 58 (2007) 439)

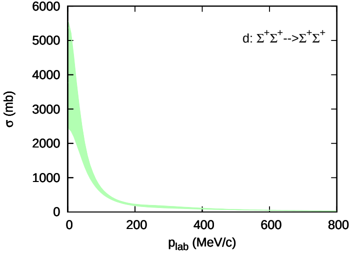
-2.54 (A.Valcarce et al.)

(PLB 693 (2010) 305)

$\sigma_{exp} = 4.3^{+6.3}_{-2.7}$ mb
at p_{lab} = 500 MeV/c

J.K. Ahn et al., 2006

YY integrated cross sections



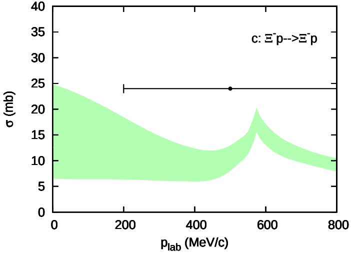
cut off Λ= 600 MeV

$a^{\Sigma^+\Sigma^+}_{^1S_0}$; $r^{\Sigma^+\Sigma^+}_{^1S_0}$ [in fm]

-7.76; 2.00 EFT LO

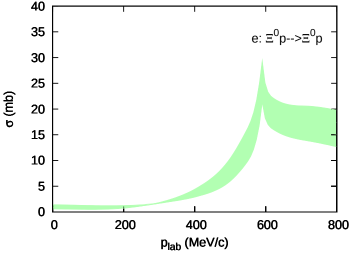
-63.7; 2.37 fss2 (Fujiwara)

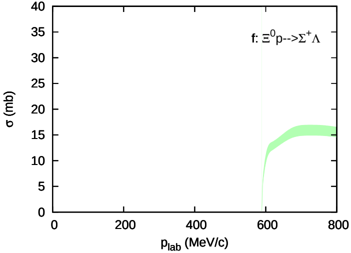
0.523 (A.Valcarce)



$\sigma^{exp} \leq 24$ mb

J.K. Ahn et al., 2006





cut off Λ= 600 MeV

$a^{\Xi^0 p}_{^1S_0}$; $r^{\Xi^0 p}_{^1S_0}$ [in fm]

0.19; -37.7 EFT LO

0.14; 4.67 ESC04d (Rijken)

0.33; -9.19 fss2 (Fujiwara)

-3.32 (A.Valcarce)

$a^{\Xi^0 p}_{^3S_1}$; $r^{\Xi^0 p}_{^3S_1}$ [in fm]

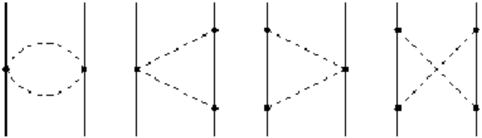
-0.003; – EFT LO

-0.203; 27.5 fss2 (Fujiwara)

18.69 (A.Valcarce)

YN interaction in NLO

- Two-pseudoscalar-meson exchange diagrams (V_{NLO}^{TBEP})
- *BB* contact terms with two derivatives ($V^{(2)}$)



$$
\begin{aligned}
V^{(2)} &= C_1\vec{q}^{\,2} + C_2\vec{k}^{\,2} + (C_3\vec{q}^{\,2} + C_4\vec{k}^{\,2})(\boldsymbol{\sigma}_1 \cdot \boldsymbol{\sigma}_2) \\
&+ iC_5(\boldsymbol{\sigma}_1 + \boldsymbol{\sigma}_2)\cdot(\vec{q}\times\vec{k}) + C_6(\vec{q}\cdot\boldsymbol{\sigma}_1)(\vec{q}\cdot\boldsymbol{\sigma}_2) + C_7(\vec{k}\cdot\boldsymbol{\sigma}_1)(\vec{k}\cdot\boldsymbol{\sigma}_2) \\
&+ iC_8(\boldsymbol{\sigma}_1 - \boldsymbol{\sigma}_2)\cdot(\vec{q}\times\vec{k})
\end{aligned}
$$

$$
V_{NLO} = V^{(2)} + V_{NLO}^{TBEP}
$$

$\vec{q} = \vec{p}\,' - \vec{p}$; $\vec{k} = (\vec{p}\,' + \vec{p})/2$

SU(3) symmetry

	Channel	I	V_{1S0}, $V_{3P0,3P1,3P2}$	V_{3S1}, $V_{3S1-3D1}$, V_{1P1}	$V_{1P1-3P1}$
$S = 0$	$NN \to NN$	1	C^{27}	C^{10^*}	–
$S = -1$	$\Lambda N \to \Lambda N$	$\frac{1}{2}$	$\frac{1}{10}\left(9C^{27} + C^{8_s}\right)$	$\frac{1}{2}\left(C^{8_a} + C^{10^*}\right)$	$\frac{-1}{\sqrt{20}} C^{8_s8_a}$
	$\Lambda N \to \Sigma N$	$\frac{1}{2}$	$\frac{3}{10}\left(-C^{27} + C^{8_s}\right)$	$\frac{1}{2}\left(-C^{8_a} + C^{10^*}\right)$	$\frac{3}{\sqrt{20}} C^{8_s8_a}$
					$\frac{-1}{\sqrt{20}} C^{8_s8_a}$
	$\Sigma N \to \Sigma N$	$\frac{1}{2}$	$\frac{1}{10}\left(C^{27} + 9C^{8_s}\right)$	$\frac{1}{2}\left(C^{8_a} + C^{10^*}\right)$	$\frac{3}{\sqrt{20}} C^{8_s8_a}$
	$\Sigma N \to \Sigma N$	$\frac{3}{2}$	C^{27}	C^{10}	–

Number of contact terms

	LO		NLO	
	NN	YN	NN	YN
$^1S_0$	1	1 + 1	1	1 + 1
$^3P_0$	0	0	1	1 + 1
$^3P_1$	0	0	1	1 + 1
$^3P_2$	0	0	1	1 + 1
$^3S_1$	1	1 + 2	1	1 + 2
$^3S_1 - {}^3D_1$	0	0	1	1 + 2
$^1P_1$	0	0	1	1 + 2
$^1P_1 - {}^3P_1$	0	0	0	1
Σ	2	2 + 3	7	7 + 11

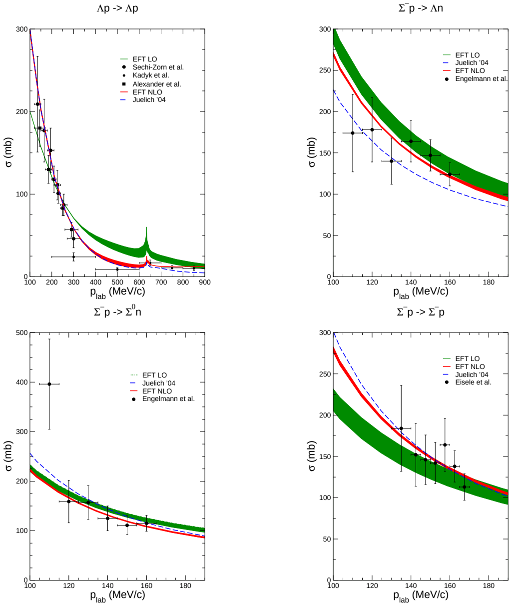
Preliminary (incomplete) NLO results

- Additional contact terms in S-waves are taken into account
- Contact terms in P-waves are not yet included
- Two-pseudoscalar-meson exchange diagrams are missing

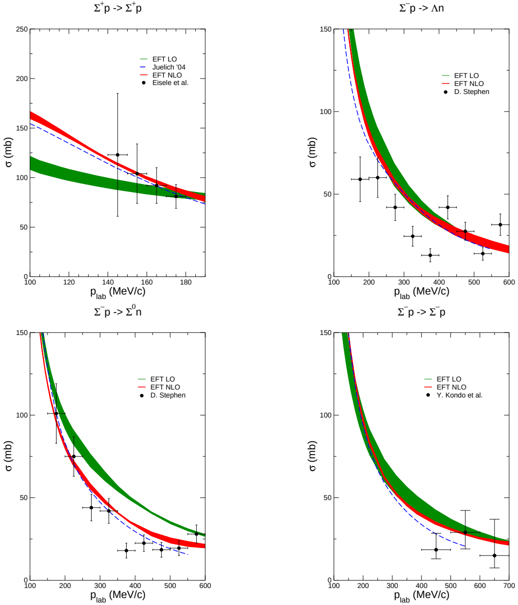
- no SU(3) constraints from the *NN* sector are imposed (SU(3) symmetry is used to relate ΛN and ΣN!)
- leading order SU(3) breaking in the one-boson exchange diagrams (coupling constants) is ignored

$\Rightarrow$ work in progress

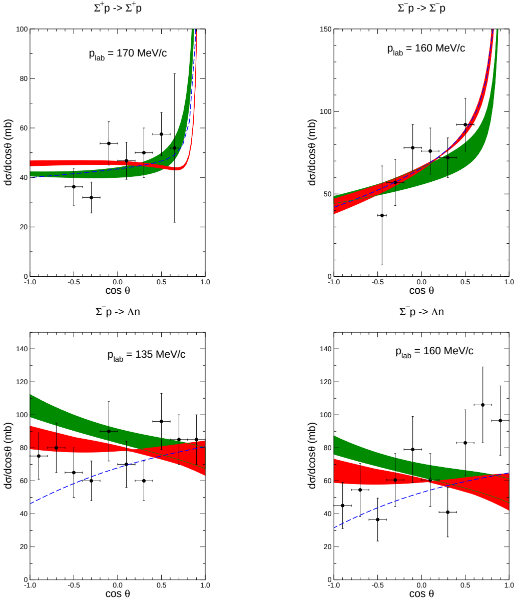
YN integrated cross sections



YN integrated cross sections



YN differential cross sections



YN effective range parameters [fm]

	EFT NLO				EFT LO	NSC97f	experiment
Λ [MeV]	550	600	650	700	550		
$a_s^{\Lambda p}$	−2.61	−2.61	−2.59	−2.63	−1.90	−2.51	$-1.8^{+2.3}_{-4.2}$
$r_s^{\Lambda p}$	2.67	2.56	2.37	2.36	1.44	3.03	
$a_t^{\Lambda p}$	−1.64	1.63	−1.62	−1.63	−1.22	−1.75	$-1.6^{+1.1}_{-0.8}$
$r_t^{\Lambda p}$	2.72	2.79	2.95	2.95	2.05	3.32	
$a_s^{\Sigma^+ p}$	−4.13	−4.11	−3.99	−3.97	−2.24	−4.35	
$r_s^{\Sigma^+ p}$	3.08	3.04	2.99	3.02	3.74	3.14	
$a_t^{\Sigma^+ p}$	−0.01	0.01	0.01	0.01	0.70	−0.25	
$r_t^{\Sigma^+ p}$	–	–	–	–	−2.14	−25.35	
χ^2	16.8	16.7	16.5	16.9	29.6	16.7	
$({}^3_\Lambda\mathrm{H})\ E_B$	−2.34	−2.34	−2.39	−2.38	−2.35	−2.30	−2.354(50)

Summary

YN and YY interactions based on *EFT*

- approach is based on a modified Weinberg power counting, analogous to the NN case
- LO potential (contact terms, one-pseudoscalar-meson exchange) is derived imposing $SU(3)_f$ constraints

- Good description of the empirical YN data was achieved (with only 5 free parameters!)
- Results compatible with the sparse empirical information on the YY interaction (1 free parameter)

- Preliminary (incomplete) YN results in next-to-leading order (NLO) look very promising

Outlook

Next tasks:

- A combined study of the NN and YN systems in chiral EFT, based on a complete NLO calculation
- A more thorough exploration of the interrelation between the elementary YN interaction and the properties of light hypernuclei
  - calculate the $YNNN$ bound states
  - consider YNN three-body forces