EFT and Hypernuclear Decay

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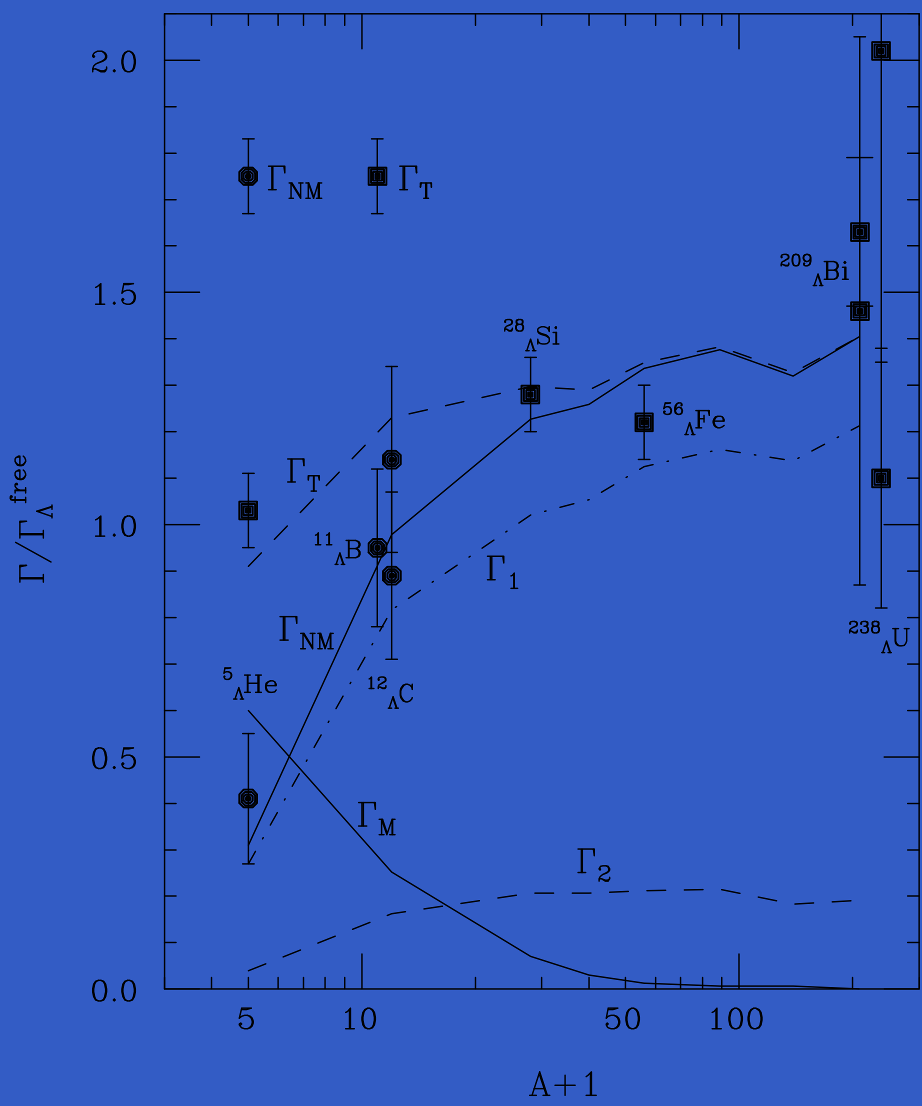
Motivation

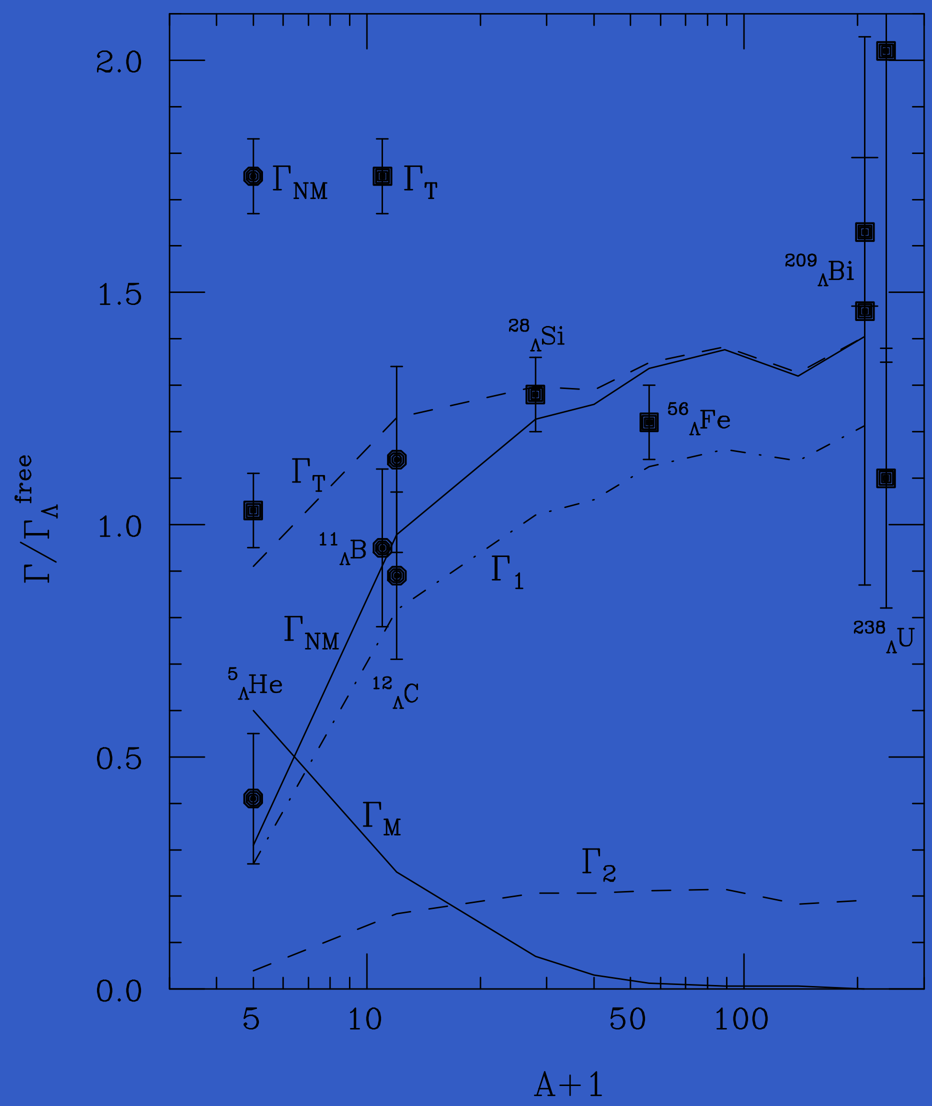
- Remarkable success in the SU(2) sector $\Rightarrow$ Successful extension to SU(3)?
- Is it possible to build a model independent (or at least a *less* model dependent) theory for the $|\Delta S| = 1$ ΛN interaction?
- Can a low order EFT describe the present available data for $\Lambda N \to NN$ (hypernuclear decay data)?
  $|\vec{p}| \sim 417$ MeV/c $\Longrightarrow$ Successful low-energy expansion?
  $\Rightarrow$ Systematic, stable (convergent) expansion
- Is this a valid scenario to learn something new on the $|\Delta S| = 1$ interaction?
  - $\Delta I = 3/2$ transitions?
  - SU(3) breaking?

Hypernuclear lifetimes – Decay rates



Hypernuclear lifetimes – Decay rates

$$\Gamma = \Gamma_M$$
$$= \Gamma_{\pi^-} + \Gamma_{\pi^0}$$
$$\Downarrow$$
$$\Lambda \to N\pi$$
(Δ I=1/2)



Hypernuclear lifetimes — Decay rates

$$\Gamma = \Gamma_M + \Gamma_{1N}$$
$$= \Gamma_{\pi^-} + \Gamma_{\pi^0} + \Gamma_{nn} + \Gamma_{np}$$
$$\Downarrow \qquad\qquad \Downarrow$$
$$\Lambda \to N\pi \qquad \Lambda N \to nN$$
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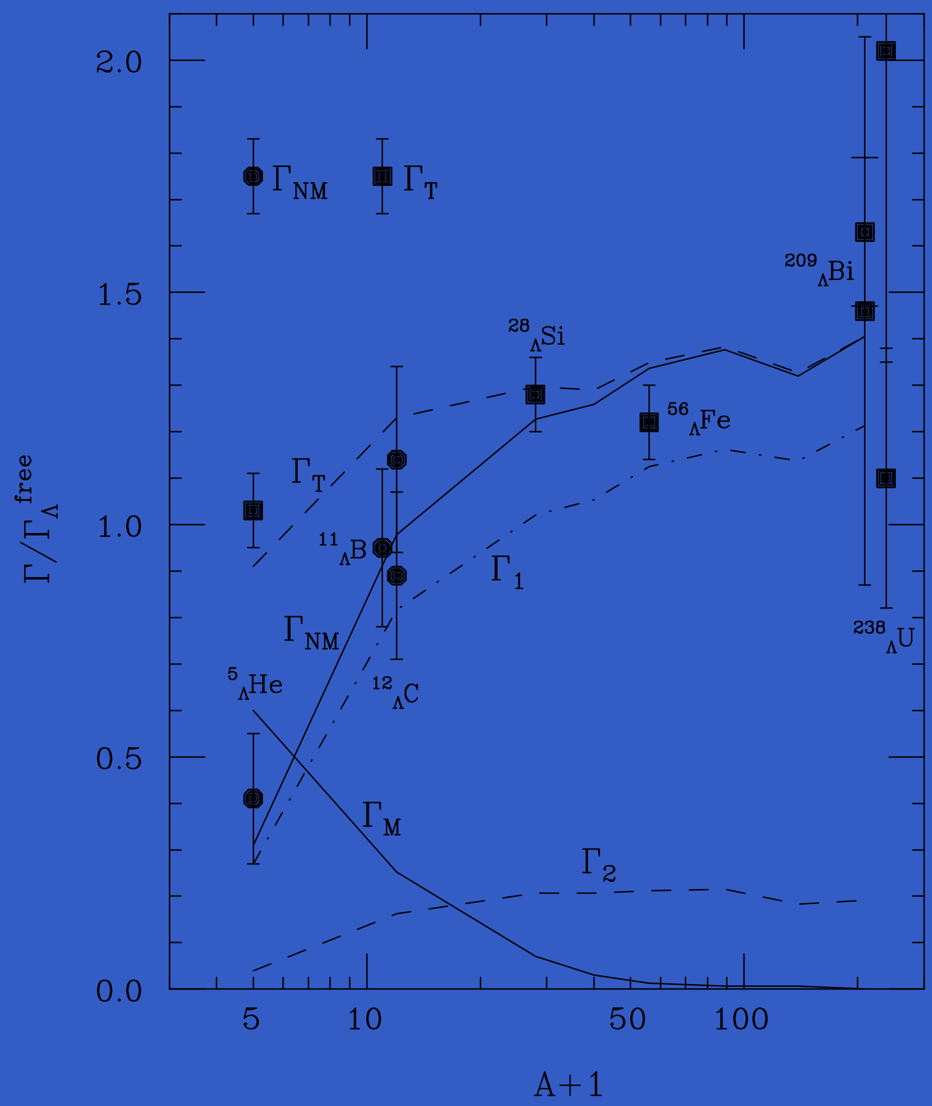

Hypernuclear lifetimes — Decay rates

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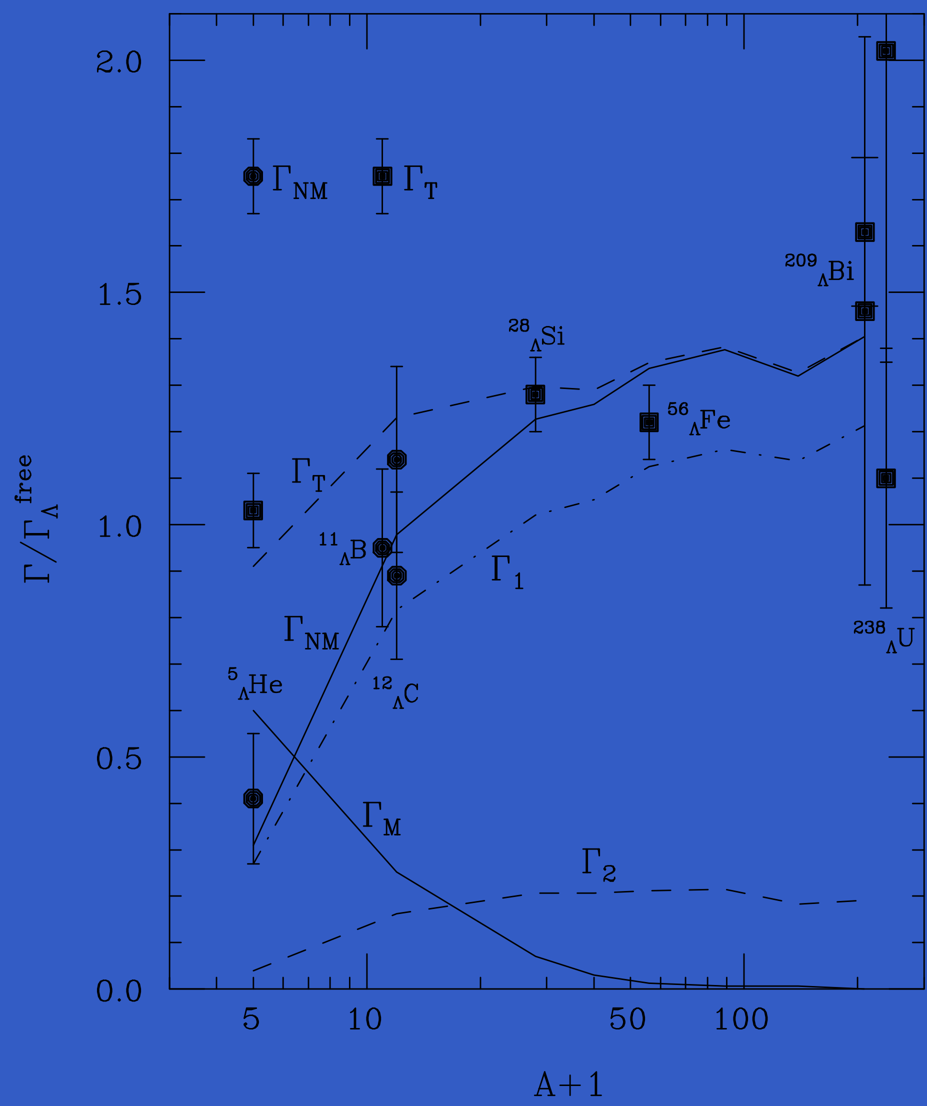

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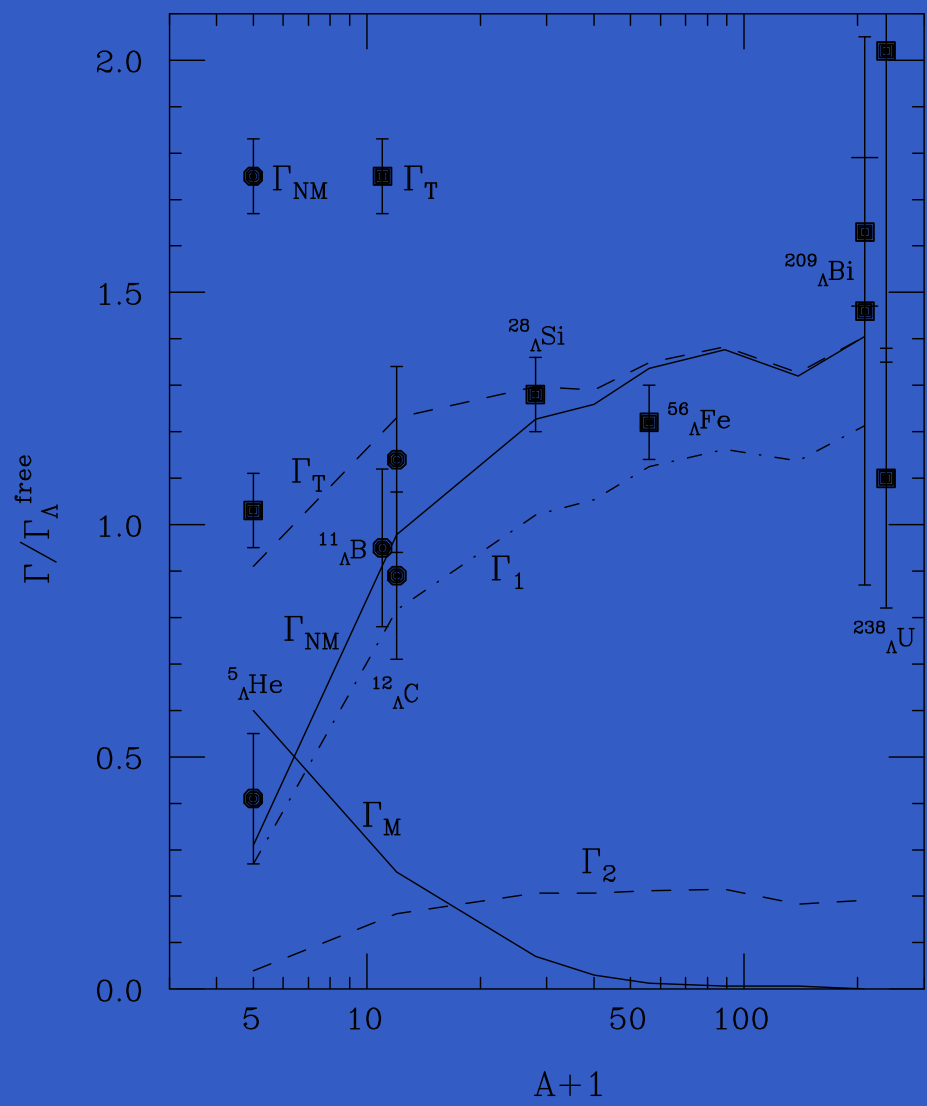
$$\Lambda \to N\pi \qquad \Lambda N \to nN \qquad \Lambda np \to nnp$$

(Δ I=1/2)

We will focus on the NM channel
for A = 5, 11, 12

$${}^{A}_{\Lambda}Z \to NN +^{(A-2)} Z'$$

$$|\vec{p}_N| \sim 417 \text{ MeV/c}$$



neutron-to-proton ratio

$$\frac{\Gamma_n}{\Gamma_p} = \frac{\Lambda n \to nn}{\Lambda p \to np} \longleftrightarrow \quad (FSI) \quad \frac{nn}{np}$$

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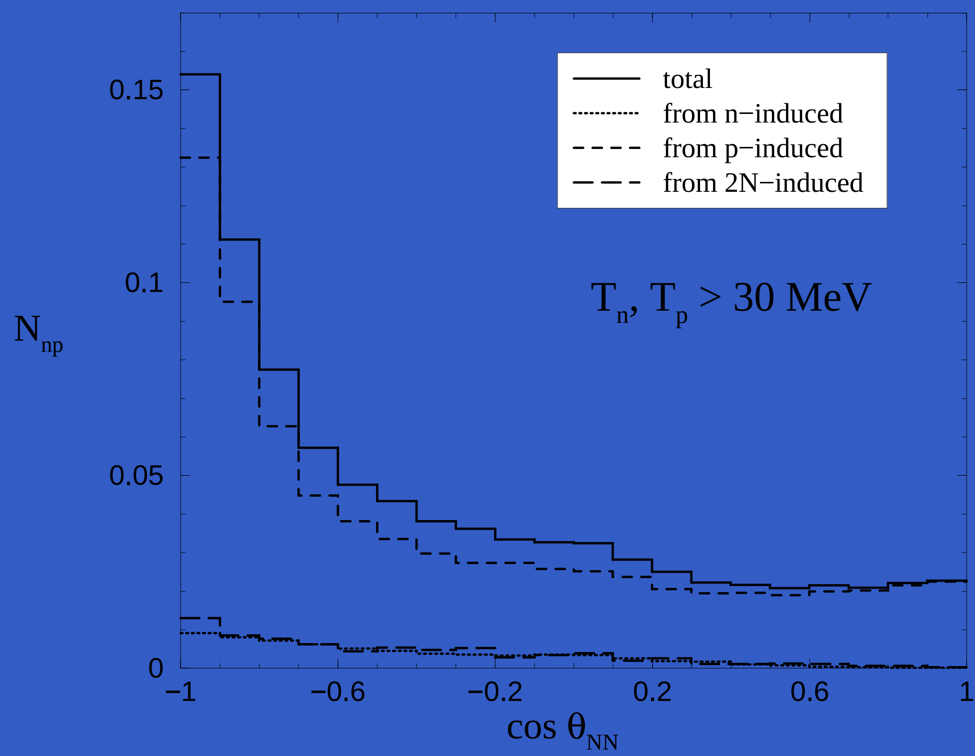
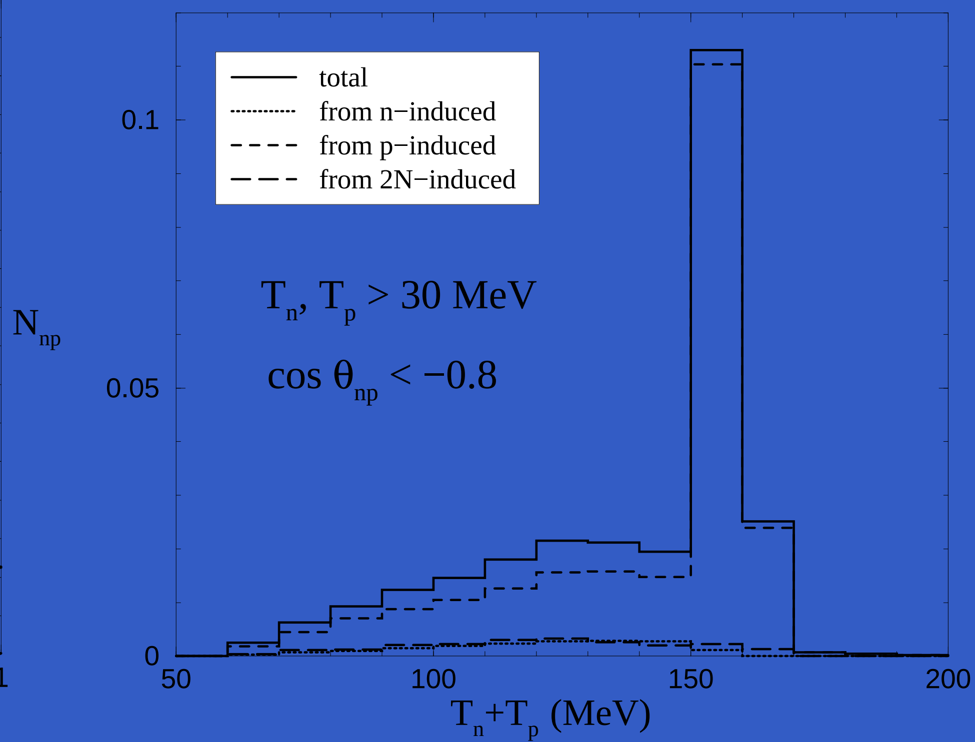
Study of double coincidence observables: KEK-E462

Garbarino, Parreño, Ramos, PRL 91 112501 (2003)



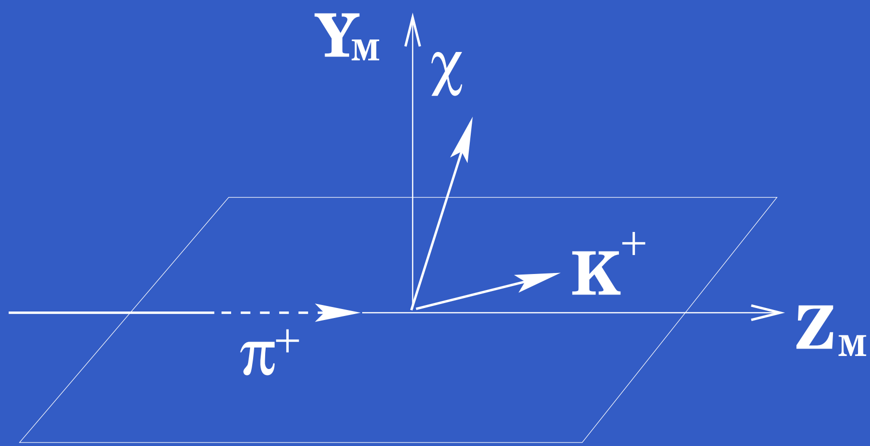


Parity Violating Asymmetry, $\mathcal{A}$

$$I(\chi) = Tr(\mathcal{M}\rho\mathcal{M}^\dagger), \qquad \rho = \frac{1}{2J+1}\left(1 + \frac{3}{J+1}P_y S_y\right)$$

$$I(\chi) = I_0\,(1+\mathcal{A}), \qquad I_0 = \frac{Tr(\mathcal{M}\mathcal{M}^\dagger)}{2J+1}$$

$$\mathcal{A} = P_y\,A_p, \qquad \mathcal{A} = P_y\,\frac{3}{J+1}\,\frac{Tr(\mathcal{M}S_y\mathcal{M}^\dagger)}{Tr(\mathcal{M}\mathcal{M}^\dagger)} = P_y\,\frac{3}{J+1}\,\frac{\sum_{M_i}\sigma(M_i)M_i}{\sum_{M_i}\sigma(M_i)}$$



KEK $n(\pi^+, K^+)\Lambda$

$p_\pi = 1.05\mathrm{GeV}$

$2^\circ \le \phi_K \le 15^\circ$

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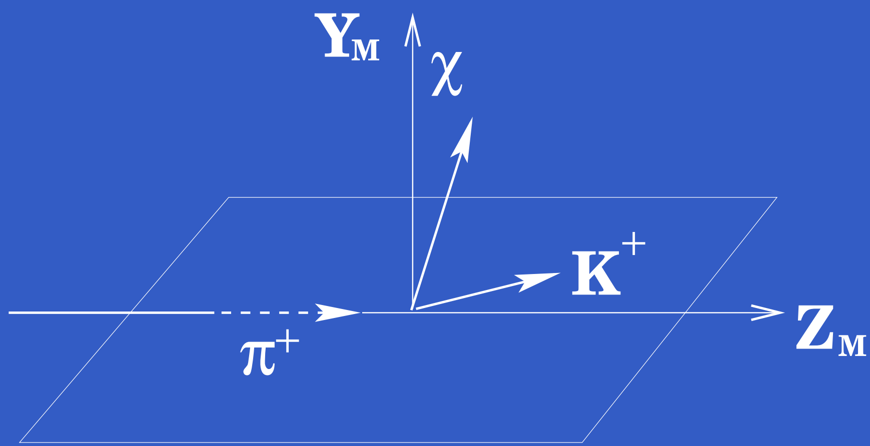

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$\mathcal{A}$

	Theory	Experiment
${}^5_\Lambda$He	~ -0.7	0.24 ± 0.22
${}^{12}_\Lambda$C	~ -0.07	-0.01 ± 0.10

Models and results for ${}^{5}_{\Lambda}\mathrm{He}$

from W.M. Alberico and G. Garbarino, Phys. Rep. 369 (2002) 1-109		
Work / Weak interaction model	$\Gamma_{1N}/\Gamma_{\Lambda}$	$\Gamma_{\mathrm{n}}/\Gamma_{\mathrm{p}}$
Parreño-Ramos-Bennhold (2001, 1997) $\pi+\rho+K+K^{*}+\eta+\omega$	$0.317 \div 0.425$	$0.343 \div 0.457$
Jun et al. (2001) $\mathrm{OPE}+4\mathrm{BPI}\ (\mathrm{V}-\mathrm{A})$	0.426	1.30
Sasaki et al. (2000) $\pi+K+\mathrm{DQ}$	0.519	0.70
Itonaga et al. (1998) $\pi+2\pi/\rho+2\pi/\sigma$	0.39	0.17
Dubach et al. (1996) OME (nuclear matter)	0.5	0.48
Oset Salcedo Usmani (1986) PPM	0.54	
Dalitz (1973) Phen. contact	0.5	
EXP BNL 1991	0.41 ± 0.14	0.93 ± 0.55
EXP KEK 1995	0.50 ± 0.07	(0.50 ± 0.10)

Finite nucleus calculation for ${}^{5}_{\Lambda}$He, ${}^{11}_{\Lambda}$B, ${}^{12}_{\Lambda}$C

$$\Gamma = \int \frac{d^3k_1}{(2\pi)^3} \int \frac{d^3k_2}{(2\pi)^3} \sum_{\substack{M_i\{R\} \\ \{1\}\{2\}}} (2\pi)\,\delta(M_H - E_R - E_1 - E_2) \frac{1}{(2J+1)} \mid \mathcal{M}_{fi} \mid^2$$

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$$\mathcal{M}_{fi} \sim \langle \vec{k}_1 m_1 \vec{k}_2 m_2 ; \Psi_{\mathrm{R}}^{A-2} \mid \hat{O}_{\Lambda\mathrm{N}\to\mathrm{NN}} \mid {}^{A}_{\Lambda} Z \rangle$$

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$|^{A}_{\Lambda} Z\rangle \to |\Lambda N\rangle \otimes |\Psi_{\mathrm{R}}^{A-2}\rangle$ Weak coupling scheme for the Λ:

- $$|^{A}_{\Lambda} Z\rangle^{J_I\ M_I}_{T_I\ T_{3_I}} = \mid \alpha_\Lambda\rangle \otimes \mid A-1\rangle$$
  $$= \sum \langle j_\Lambda m_\Lambda\ J_C M_C \mid J_I M_I\rangle \mid (n_\Lambda l_\Lambda s_\Lambda) j_\Lambda m_\Lambda\rangle \mid J_C M_C\, T_I T_{3_I}\rangle$$
- Technique of coefficients of fractional parentage:

$$\Psi_{\mathrm{as}}^{J_C T_C \alpha}(1....N) = \sum_{J_{R_0} T_{R_0} \alpha_0 j_{\mathrm{N}}} \langle J_C T_C \alpha \{\mid J_{R_0} T_{R_0} \alpha_0, j_{\mathrm{N}}\rangle$$
$$\times \quad [\Psi_{\mathrm{as}}^{J_{R_0} T_{R_0} \alpha_0}(1.\ldots N-1) \otimes \phi^{j_{\mathrm{N}}}(N)]^{J_C T_C} ,$$

Finite nucleus calculation for ${}^{5}_{\Lambda}$He, ${}^{11}_{\Lambda}$B, ${}^{12}_{\Lambda}$C

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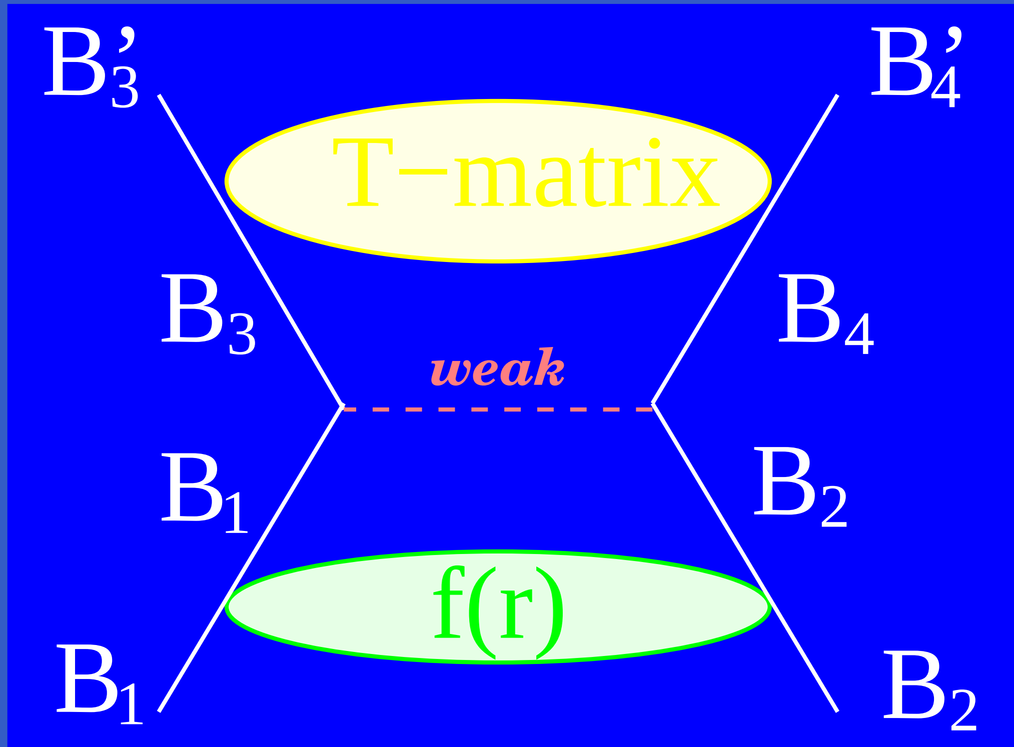
$$\mathcal{M}_{fi} \quad \sim \quad t_{\Lambda\mathrm{N}\to\mathrm{NN}}(S, M_S, T, T_3, S_0, M_{S_0}, T_0, T_{3_0}, l_\Lambda, l_{\mathrm{N}}, \vec{P}, \vec{k})$$

Incorporate the strong BB interaction



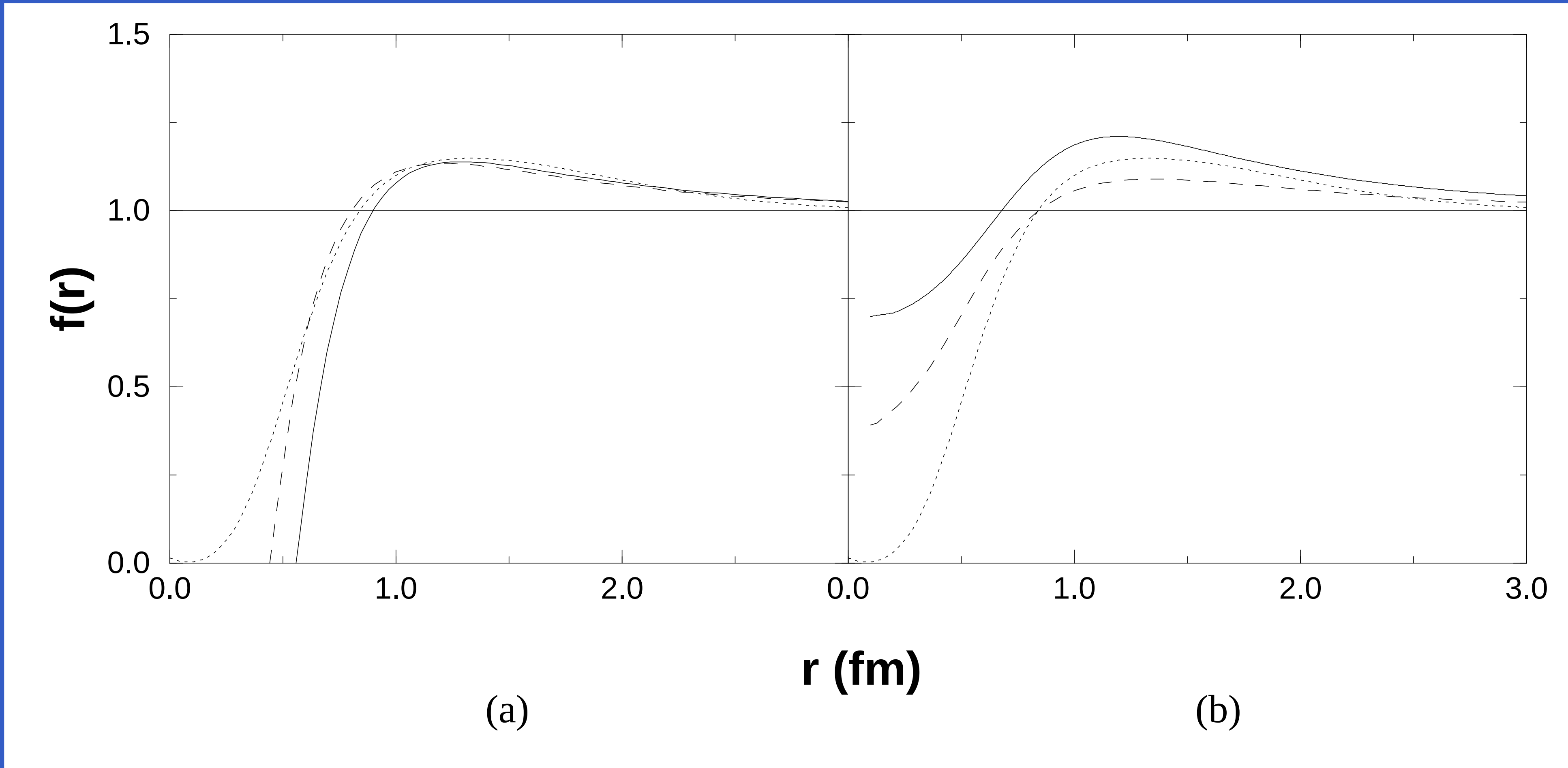
$$\Psi_{\Lambda N}(r) = \phi^{ho}_{\Lambda N}(r)\, f(r)$$

$$f(r) = \left(1 - \mathrm{e}^{-r^2/a^2}\right)^n + br^2\mathrm{e}^{-r^2/c^2}$$

$$\Psi_{NN}(r)$$

a=0.5 fm, b=0.25 fm^{-2}, c=1.28 fm, n=2

T-matrix $\Longleftrightarrow$ NSC97f



Correlation function for the ΛN channel $^1S_0$ (full line) and $^3S_1$ (dashed line) in the case of the hard-core D (a) and the soft-core (b) Nijmegen potential. The dotted line stands for the spin-independent parametrization $f(r)$ used in this work.

Theoretical Situation

- Different models for the weak $\Lambda N \to NN$ transition reproduce fairly well the NMD rates
  long range: π
  short range: Heavier mesons, QM, ...

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- Supplementing the decay process by Final Sate Interactions and looking to NN coincidence spectra, we get an agreement between theoretical and experimental Γ_n/Γ_p.
- Strong disagreement between experimental and theoretical PV Asymmetries
  This is a proton asymmetry $\Rightarrow$ FSI interactions should be properly implemented

- Model dependencies:
  - Weak interaction mechanism
  - Strong interaction:

    Shell model, Initial wave functions, Form Factors, Final wave functions...

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  - Weak interaction mechanism
  - Strong interaction:
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- Problems:
  - Significant degree of SU(3) breaking.
  - Problems facing SU(3) χPT:
    weak PC $Y \to N\pi$ amplitudes
  - Energy release in $(\Lambda N \to NN)_{\mathrm{th}} \sim$ 177 MeV
    ($|\vec{p}| \sim 417$ MeV/c)

Constructing the EFT for the $\Lambda N \to NN$ transition

- The long range behavior must be built into the EFT
  Include the π ($m_\pi \approx 138$ MeV) and the K ($m_K \approx 494$ MeV) as dynamical fields.

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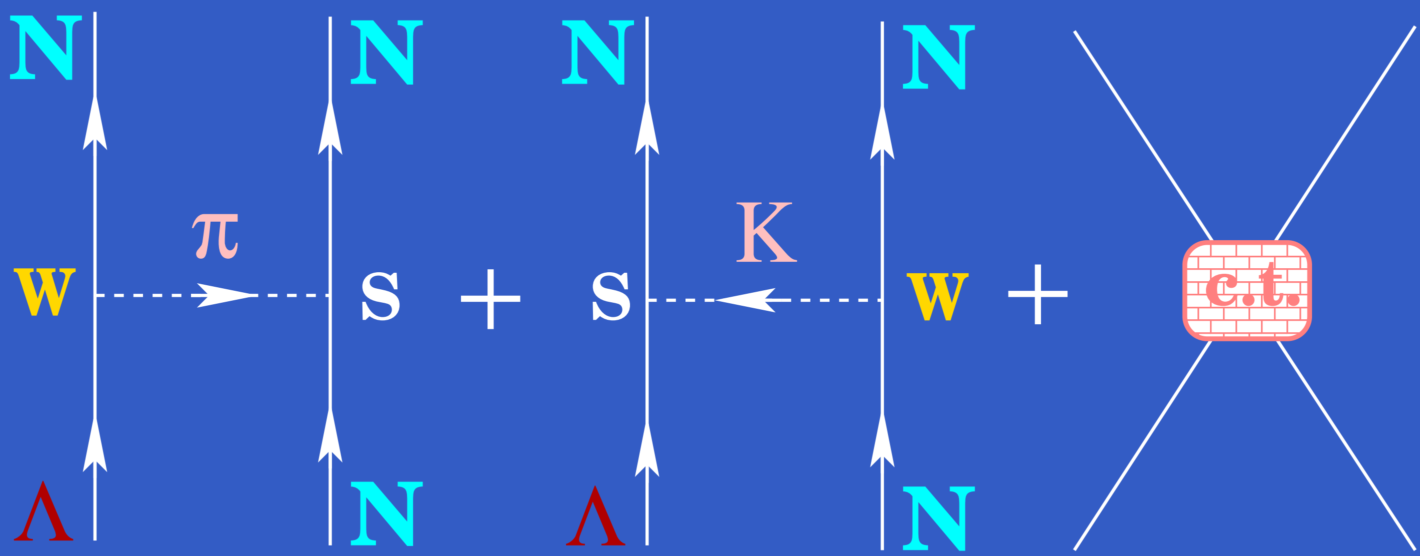
  SU(3) $\Rightarrow \eta$? Ignored due to the smaller ηNN coupling
- Add local correction terms to mimic the effect of excluded momenta
- At leading order: $\pi + K +$ LO contact terms



OPE and OKE potentials

$$
\begin{aligned}
\mathcal{L}^{\mathrm{W}}_{\Lambda\mathrm{N}\pi} &= -\mathrm{i}G_F m_\pi^2 \overline{\psi}_{\mathrm{N}}(A_\pi + B_\pi\gamma_5\gamma^\mu)\vec{\tau}\cdot\partial_\mu\vec{\phi}^{\pi}\psi_\Lambda \binom{0}{1} \\
\mathcal{L}^{\mathrm{S}}_{\mathrm{NN}\pi} &= -\mathrm{i}\, g_{\mathrm{NN}\pi}\,\overline{\psi}_{\mathrm{N}}\gamma_5\gamma^\mu\,\vec{\tau}\cdot\partial_\mu\vec{\phi}^{\pi}\psi_{\mathrm{N}} \\
V_{\mathrm{OPE}}(\vec{q}) &= -G_F m_\pi^2 \frac{g_{\mathrm{NN}\pi}}{2M_{\mathrm{S}}}\left(A_\pi + \frac{B_\pi}{2M_{\mathrm{W}}}\vec{\sigma}_1\,\vec{q}\right)\frac{\vec{\sigma}_2\,\vec{q}}{\vec{q}^{\,2}+\mu_\pi{}^2}\,\vec{\tau}_1\,\vec{\tau}_2
\end{aligned}
$$

OPE and OKE potentials

$$\mathcal{L}^{\mathrm{W}}_{\Lambda \mathrm{N}\pi} = -\mathrm{i} G_F m_\pi^2 \overline{\psi}_{\mathrm{N}} (A_\pi + B_\pi \gamma_5 \gamma^\mu) \vec{\tau} \cdot \partial_\mu \vec{\phi}^{\,\pi} \psi_\Lambda \binom{0}{1}$$

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$$V_{\mathrm{OPE}}(\vec{q}) = -G_F m_\pi^2 \frac{g_{\mathrm{NN}\pi}}{2M_{\mathrm{S}}} \left(A_\pi + \frac{B_\pi}{2M_{\mathrm{W}}} \vec{\sigma}_1 \vec{q} \right) \frac{\vec{\sigma}_2 \vec{q}}{\vec{q}^{\,2} + \mu_\pi{}^2} \vec{\tau}_1 \vec{\tau}_2$$

$$\begin{aligned} \mathcal{L}^{\mathrm{W}}_{\mathrm{NNK}} &= -\mathrm{i}\, G_F m_\pi^2 \left[\overline{\psi}_{\mathrm{N}} \binom{0}{1} (C^{\mathrm{PV}}_{\mathrm{K}} + C^{\mathrm{PC}}_{\mathrm{K}} \gamma_5 \gamma^\mu \partial_\mu)(\phi^{\mathrm{K}})^\dagger \psi_{\mathrm{N}} \right. \\ &\quad \left. + \overline{\psi}_{\mathrm{N}} \psi_{\mathrm{N}} (D^{\mathrm{PV}}_{\mathrm{K}} + D^{\mathrm{PC}}_{\mathrm{K}} \gamma_5 \gamma^\mu \partial_\mu)(\phi^{\mathrm{K}})^\dagger \binom{0}{1} \right] \\ \mathcal{L}^{\mathrm{S}}_{\Lambda \mathrm{NK}} &= -\mathrm{i}\, g_{\Lambda \mathrm{NK}} \overline{\psi}_{\mathrm{N}} \gamma_5 \gamma^\mu \partial_\mu \phi^{\mathrm{K}} \psi_\Lambda \end{aligned}$$

$$g_{\mathrm{NN}\pi} \to g_{\Lambda \mathrm{NK}} \; , \; \mu_\pi \to \mu_{\mathrm{K}}$$

$$\hat{A}_\pi \to \left(\frac{C^{\mathrm{PV}}_{\mathrm{K}}}{2} + D^{\mathrm{PV}}_{\mathrm{K}} + \frac{C^{\mathrm{PV}}_{\mathrm{K}}}{2} \vec{\tau}_1 \vec{\tau}_2 \right) \frac{M_{\mathrm{S}}}{M_{\mathrm{W}}}, \quad \hat{B}_\pi \to \left(\frac{C^{\mathrm{PC}}_{\mathrm{K}}}{2} + D^{\mathrm{PC}}_{\mathrm{K}} + \frac{C^{\mathrm{PC}}_{\mathrm{K}}}{2} \vec{\tau}_1 \vec{\tau}_2 \right)$$

Contact terms

- PV $\Lambda N \to NN$ transitions:

$${}^3S_1 \to {}^3P_1,$$

$${}^3S_1 \to {}^1P_1,$$
$${}^1S_0 \to {}^3P_0,$$

Contact terms

- PV $\Lambda N \to NN$ transitions:

$$^3S_1 \to ^3P_1, \quad A\,(\sigma_1+\sigma_2)\,\{p_1-p_2\,,\,\delta(\vec{r})\,\} + B\,(\sigma_1+\sigma_2)\,[\,p_1-p_2\,,\,\delta(\vec{r})\,]$$

$$^3S_1 \to ^1P_1, \quad C\,(\sigma_1-\sigma_2)\,\{p_1-p_2\,,\,\delta(\vec{r})\,\} + D\,(\sigma_1-\sigma_2)\,[\,p_1-p_2\,,\,\delta(\vec{r})\,]$$

$$^1S_0 \to ^3P_0, \quad +E\ \mathrm{i}\,(\sigma_1\times\sigma_2)\,\{p_1-p_2\,,\,\delta(\vec{r})\,\} + F\ \mathrm{i}\,(\sigma_1\times\sigma_2)\,[\,p_1-p_2\,,\,\delta(\vec{r})\,]$$

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- PC $\Lambda N \to NN$ transitions:

$$^1S_0 \to ^1S_0,$$
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- PC $\Lambda N \to NN$ transitions:

$$^1S_0 \to ^1S_0, \quad A'\,\hat{1}\,\delta(\vec{r}) + B'\,\sigma_1\sigma_2\,\delta(\vec{r})$$

$$^3S_1 \to ^3S_1, \quad \text{"}$$

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partial wave	operator	order	isospin
$^1S_0 \to ^1S_0$	$\hat{1},\ \vec{\sigma}_1\vec{\sigma}_2$	1	1
$^1S_0 \to ^3P_0$	$(\vec{\sigma}_1-\vec{\sigma}_2)\vec{q},\ (\vec{\sigma}_1\times\vec{\sigma}_2)\vec{q}$	q/M_N	1
$^3S_1 \to ^3S_1$	$\hat{1},\vec{\sigma}_1\vec{\sigma}_2$	1	0
$^3S_1 \to ^1P_1$	$(\vec{\sigma}_1-\vec{\sigma}_2)\vec{q},\ (\vec{\sigma}_1\times\vec{\sigma}_2)\vec{q}$	q/M_N	0
$^3S_1 \to ^3P_1$	$(\vec{\sigma}_1+\vec{\sigma}_2)\vec{q}$	q/M_N	1
$^3S_1 \to ^3D_1$	$(\vec{\sigma}_1\times\vec{q})(\vec{\sigma}_2\times\vec{q})$	$q^2/{M_N}^2$	0

4P potential

$$V_{4P}(\vec{q}) = \begin{cases} C_0^0 + C_0^1\, \vec{\sigma}_1\vec{\sigma}_2 \qquad \text{LO PC} \\ \\ \\ \\ \end{cases}$$

Isospin part for the 4-fermion interaction: $\hat{\mathcal{O}} \sim C_{IS}\,\hat{1} + C_{IV}\,\vec{\tau}_1\vec{\tau}_2$

Note that the $\Delta I = 1/2$ rule is assumed.

to LO PC: $2 + 2 = 4$ parameters

4P potential

$$V_{4P}(\vec{q}) = \begin{cases} C_0^0 + C_0^1\,\vec{\sigma}_1\vec{\sigma}_2 & \text{LO PC} \\ +C_1^0\,\dfrac{\vec{\sigma}_1\vec{q}}{2\overline{M}} + C_1^1\,\dfrac{\vec{\sigma}_2\vec{q}}{2M} + \mathrm{i}\,C_1^2\,\dfrac{(\vec{\sigma}_1\times\vec{\sigma}_2)\,\vec{q}}{2\tilde{M}} & \text{LO PV} \end{cases}$$

Isospin part for the 4-fermion interaction: $\hat{\mathcal{O}} \sim C_{IS}\,\hat{1} + C_{IV}\,\vec{\tau}_1\vec{\tau}_2$

Note that the $\Delta I = 1/2$ rule is assumed.

to LO PC: $2+2=4$ parameters

to LO PV: 7 parameters

4P potential

$$V_{4P}(\vec{q}\,) = \begin{cases} C_0^0 + C_0^1\ \vec{\sigma}_1\vec{\sigma}_2 & \text{LO PC} \\ +C_1^0\ \dfrac{\vec{\sigma}_1\vec{q}}{2\overline{M}} + C_1^1\ \dfrac{\vec{\sigma}_2\vec{q}}{2M} + \mathrm{i}\,C_1^2\ \dfrac{(\vec{\sigma}_1 \times \vec{\sigma}_2)\ \vec{q}}{2\tilde{M}} & \text{LO PV} \\ +C_2^0\ \dfrac{\vec{\sigma}_1\vec{q}\ \vec{\sigma}_2\vec{q}}{4M\overline{M}} + C_2^1\ \dfrac{\vec{\sigma}_1\vec{\sigma}_2\ \vec{q}^{\,2}}{4M\overline{M}} + C_2^2\ \dfrac{\vec{q}^{\,2}}{4M\tilde{M}} & \text{NLO PC} \end{cases}$$

Isospin part for the 4-fermion interaction: $\hat{O} \sim C_{IS}\,\hat{1} + C_{IV}\,\vec{\tau}_1\vec{\tau}_2$

Note that the $\Delta I = 1/2$ rule is assumed.

to LO PC: $2 + 2 = 4$ parameters

to LO PV: 7 parameters

to NLO PC: 10 parameters

(Method: Migrad minimizer (Minuit, CERN))

$V(\vec{q}) \Rightarrow \mathrm{F.T.} \Rightarrow V(\vec{r})$ at Lowest Order

$$\mathrm{OME}: V_\mu(\vec{r}) \quad = \quad \sum_{\mu\alpha} V_\mu^\alpha(r)\mathcal{O}^\alpha(\hat{r})\hat{I}_\mu$$

$$\mathcal{O}^\alpha(\hat{r}) = \begin{cases} \vec{\sigma}_1 \cdot \vec{\sigma}_2 \\ S_1{}^2(\hat{r}) = 3(\vec{\sigma}_1 \cdot \hat{r})(\vec{\sigma}_2 \cdot \hat{r}) - \vec{\sigma}_1 \cdot \vec{\sigma}_2 \\ \vec{\sigma}_2 \cdot \hat{r} \end{cases} \qquad \hat{I}_\mu = \begin{cases} \pi : \ \vec{\tau}_1 \cdot \vec{\tau}_2 \\ K : \ (\hat{1}, \vec{\tau}_1 \cdot \vec{\tau}_2) \end{cases}$$

$V(\vec{q}) \Rightarrow \mathrm{F.T.} \Rightarrow V(\vec{r})$ at Lowest Order

$$\mathrm{OME} : V_\mu(\vec{r}) = \sum_{\mu\alpha} V^\alpha_\mu(r)\mathcal{O}^\alpha(\hat{r})\hat{I}_\mu$$

$$\mathcal{O}^\alpha(\hat{r}) = \begin{cases} \vec{\sigma}_1 \cdot \vec{\sigma}_2 \\ S_{12}(\hat{r}) = 3(\vec{\sigma}_1 \cdot \hat{r})(\vec{\sigma}_2 \cdot \hat{r}) - \vec{\sigma}_1 \cdot \vec{\sigma}_2 \\ \vec{\sigma}_2 \cdot \hat{r} \end{cases} \qquad \hat{I}_\mu = \begin{cases} \pi : \ \vec{\tau}_1 \cdot \vec{\tau}_2 \\ K : \ (\hat{1}, \vec{\tau}_1 \cdot \vec{\tau}_2) \end{cases}$$

$$V_{4P}(\vec{r}) = \begin{cases} C^0_0 + C^1_0 \, \vec{\sigma}_1\vec{\sigma}_2 & \mathrm{LO\ PC} \\ + \dfrac{2r}{\delta^2}\left[C^0_1 \, \dfrac{\vec{\sigma}_1\hat{r}}{2\overline{M}} + C^1_1 \, \dfrac{\vec{\sigma}_2\hat{r}}{2M} + C^2_1 \, \dfrac{(\vec{\sigma}_1 \times \vec{\sigma}_2) \, \hat{r}}{2\tilde{M}}\right] & \mathrm{LO\ PV} \\ \times \ \dfrac{e^{-\frac{r^2}{\delta^2}}}{\delta^2\pi^{3/2}} \ \times \left[C_{IS} \, \hat{1} + C_{IV} \, \vec{\tau}_1 \cdot \vec{\tau}_2\right] & \end{cases}$$

$\delta \sim \rho$ meson range $\sqrt{2}m_\rho^{-1} \approx 0.36$ fm

Experimental data used in the fit (10 points)

	Γ	Γ_n/Γ_p	Γ_p	$\mathcal{A}$
${}^{5}_{\Lambda}$He	0.41 ± 0.14 [B91]	0.93 ± 0.55[B91]	0.21 ± 0.07 [B91]	0.24 ± 0.22 [K00]
	0.50 ± 0.07 [K95]	1.97 ± 0.67[K95]		
		0.50 ± 0.10 [K02]		
${}^{11}_{\Lambda}$B	0.95 ± 0.14 [K95]	$1.04^{+0.59}_{-0.48}$ [B91]	$0.30^{+0.15}_{-0.11}$[K95]	-0.20 ± 0.10[K92]
		$2.16 \pm 0.58^{+0.45}_{-0.95}$[K95]		
		$0.59^{+0.17}_{-0.14}$[B74]		
${}^{12}_{\Lambda}$C	0.83 ± 0.11 [K98]	$1.33^{+1.12}_{-0.81}$[B91]	$0.31^{+0.18}_{-0.11}$[K95]	-0.01 ± 0.10[K92]
	0.89 ± 0.15 [K95]	$1.87 \pm 0.59^{+0.32}_{-1.00}$[K95]		
	1.14 ± 0.2 [B91]	$0.59^{+0.17}_{-0.14}$[B74]		
		0.87 ± 0.23 [K02]		

RESULTS

	π	$+K$	$+$ LO PC	$+$ LO PC+PV	EXP:
$\Gamma(^5_\Lambda\mathrm{He})$	0.42	0.23	0.43	0.44	0.41 ± 0.14[B91]
					0.50 ± 0.07[K95]
$n/p(^5_\Lambda\mathrm{He})$	0.09	0.50	0.56	0.55	0.93 ± 0.55[B91]
					0.50 ± 0.10[K02]
$\mathcal{A}(^5_\Lambda\mathrm{He})$	-0.25	-0.60	-0.80	0.15	0.24 ± 0.22[K00]

RESULTS

	π	$+K$	+ LO PC	+ LO PC+PV	EXP:
$\Gamma({}^{5}_{\Lambda}\mathrm{He})$	0.42	0.23	0.43	0.44	0.41 ± 0.14[B91] 0.50 ± 0.07[K95]
$n/p({}^{5}_{\Lambda}\mathrm{He})$	0.09	0.50	0.56	0.55	0.93 ± 0.55[B91] 0.50 ± 0.10[K02]
$\mathcal{A}({}^{5}_{\Lambda}\mathrm{He})$	-0.25	-0.60	-0.80	0.15	0.24 ± 0.22[K00]
$\Gamma({}^{11}_{\Lambda}\mathrm{B})$	0.62	0.36	0.87	0.88	0.95 ± 0.14[K95]
$n/p({}^{11}_{\Lambda}\mathrm{B})$	0.10	0.43	0.84	0.92	$1.04^{+0.59}_{-0.48}$[B91]
$\mathcal{A}({}^{11}_{\Lambda}\mathrm{B})$	-0.09	-0.22	-0.22	0.06	-0.20 ± 0.10[K92]
$\Gamma({}^{12}_{\Lambda}\mathrm{C})$	0.74	0.41	0.95	0.93	1.14 ± 0.2[B91] 0.89 ± 0.15[K95] 0.83 ± 0.11[K98]
$n/p({}^{12}_{\Lambda}\mathrm{C})$	0.08	0.35	0.67	0.77	0.87 ± 0.23[K02]
$\mathcal{A}({}^{12}_{\Lambda}\mathrm{C})$	-0.03	-0.06	-0.05	0.02	-0.01 ± 0.10[K92]
$\hat{\chi}^2$			0.98	1.50	

RESULTS

	π	$+K$	+ LO PC	+ LO PC+PV	EXP:
$\Gamma({}^5_\Lambda\mathrm{He})$	0.42	0.23	0.43	0.44 (0.44)	0.41 ± 0.14[B91] 0.50 ± 0.07[K95]
$n/p({}^5_\Lambda\mathrm{He})$	0.09	0.50	0.56	0.55 (0.55)	0.93 ± 0.55[B91] 0.50 ± 0.10[K02]
$\mathcal{A}({}^5_\Lambda\mathrm{He})$	−0.25	−0.60	−0.80	0.15 (0.24)	0.24 ± 0.22[K00] $\Leftarrow$
$\Gamma({}^{11}_\Lambda\mathrm{B})$	0.62	0.36	0.87	0.88 (0.88)	0.95 ± 0.14[K95]
$n/p({}^{11}_\Lambda\mathrm{B})$	0.10	0.43	0.84	0.92 (0.92)	$1.04^{+0.59}_{-0.48}$[B91]
$\mathcal{A}({}^{11}_\Lambda\mathrm{B})$	−0.09	−0.22	−0.22	0.06 (0.09)	-0.20 ± 0.10[K92]
$\Gamma({}^{12}_\Lambda\mathrm{C})$	0.74	0.41	0.95	0.93 (0.93)	1.14 ± 0.2[B91] 0.89 ± 0.15[K95] 0.83 ± 0.11[K98]
$n/p({}^{12}_\Lambda\mathrm{C})$	0.08	0.35	0.67	0.77 (0.77)	0.87 ± 0.23[K02]
$\mathcal{A}({}^{12}_\Lambda\mathrm{C})$	−0.03	−0.06	−0.05	0.02 (0.03)	-0.01 ± 0.10[K92]
$\hat{\chi}^2$			0.98	1.50 (1.15)	

Low-Energy Coefficients

	+ LO PC	+LO PC+PV
C_0^0	-1.51 ± 0.38	-1.09 ± 0.36
C_0^1	-0.86 ± 0.24	-0.63 ± 0.35
C_1^0	$---$	-0.45 ± 0.42
C_1^1	$---$	0.17 ± 0.22
C_1^2	$---$	-0.48 ± 0.20
C_{IS}	5.08 ± 1.27	5.69 ± 0.74
C_{IV}	1.47 ± 0.39	1.49 ± 0.23
$\hat{\chi}^2$	0.98	1.50

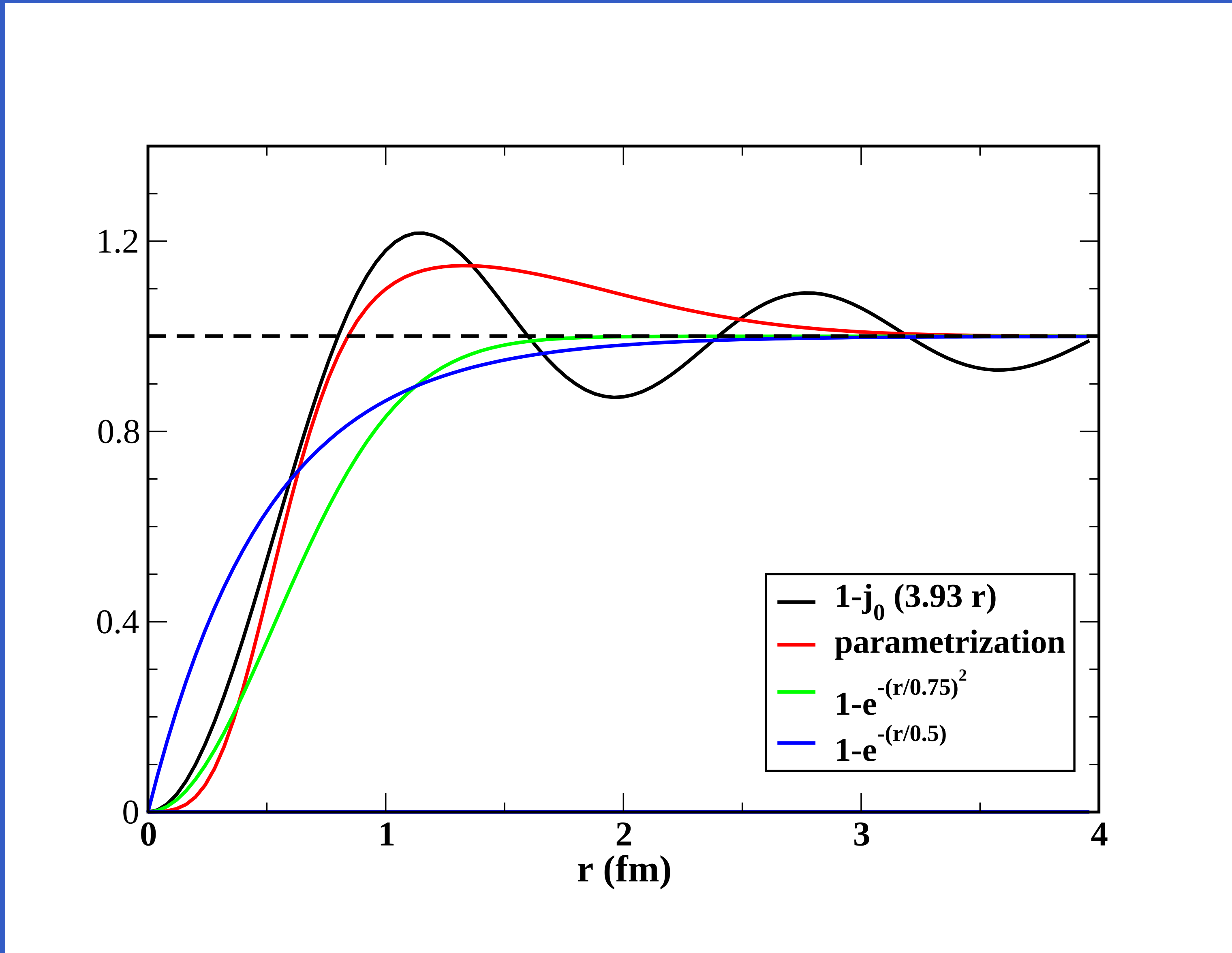
Low-Energy Coefficients

	$+$ LO PC	$+$LO PC+PV	
C_0^0	-1.51 ± 0.38	-1.09 ± 0.36	(-1.02 ± 0.35)
C_0^1	-0.86 ± 0.24	-0.63 ± 0.35	(-0.57 ± 0.29)
C_1^0	$---$	-0.45 ± 0.42	(-0.47 ± 0.17)
C_1^1	$---$	0.17 ± 0.22	(0.20 ± 0.19)
C_1^2	$---$	-0.48 ± 0.20	(-0.48 ± 0.22)
C_{IS}	5.08 ± 1.27	5.69 ± 0.74	(5.83 ± 0.82)
C_{IV}	1.47 ± 0.39	1.49 ± 0.23	(1.52 ± 0.24)
$\hat{\chi}^2$	0.98	1.50	(1.15)

Strong interaction model dependence: Final NN wf.

$\pi + K + \text{LO PC} + \text{LO PV}$		
	NSC97f	NSC97a
$\Gamma({}^{5}_{\Lambda}\text{He})$	0.44	0.44
$n/p({}^{5}_{\Lambda}\text{He})$	0.55	0.55
$\mathcal{A}({}^{5}_{\Lambda}\text{He})$	0.24	0.24
$\Gamma({}^{11}_{\Lambda}\text{B})$	0.88	0.88
$n/p({}^{11}_{\Lambda}\text{B})$	0.92	0.92
$\mathcal{A}({}^{11}_{\Lambda}\text{B})$	0.09	0.11
$\Gamma({}^{12}_{\Lambda}\text{C})$	0.93	0.93
$n/p({}^{12}_{\Lambda}\text{C})$	0.77	0.78
$\mathcal{A}({}^{12}_{\Lambda}\text{C})$	0.03	0.03
C_0^0	-1.02 ± 0.35	-0.87 ± 0.46
C_1^0	-0.57 ± 0.29	-0.53 ± 0.37
C_0^1	-0.47 ± 0.17	-0.53 ± 0.22
C_1^1	0.20 ± 0.19	0.25 ± 0.16
C_2^1	-0.48 ± 0.22	-0.57 ± 0.17
C_{IS}	5.83 ± 0.82	5.76 ± 0.74
C_{IV}	1.52 ± 0.24	1.50 ± 0.22
$\hat{\chi}^2$	1.15	1.15

Strong interaction model dependence: Initial Λ N wf.



Strong interaction model dependence: Initial Λ N wf.

$\pi + K + \mathrm{LO\ PC} + \mathrm{LO\ PV}$				
	bessel	parametrization	gaussian	exponential
$\Gamma({}^{5}_{\Lambda}\mathrm{He})$	0.44	0.44	0.44	0.44
$n/p({}^{5}_{\Lambda}\mathrm{He})$	0.55	0.55	0.54	0.54
$\mathcal{A}({}^{5}_{\Lambda}\mathrm{He})$	0.24	0.24	0.24	0.24
$\Gamma({}^{11}_{\Lambda}\mathrm{B})$	0.88	0.88	0.88	0.88
$n/p({}^{11}_{\Lambda}\mathrm{B})$	0.93	0.92	0.94	0.94
$\mathcal{A}({}^{11}_{\Lambda}\mathrm{B})$	0.09	0.09	0.07	0.08
$\Gamma({}^{12}_{\Lambda}\mathrm{C})$	0.93	0.93	0.93	0.93
$n/p({}^{12}_{\Lambda}\mathrm{C})$	0.78	0.77	0.80	0.80
$\mathcal{A}({}^{12}_{\Lambda}\mathrm{C})$	0.03	0.03	0.02	0.02
C^0_0	-0.94 ± 0.28	-1.02 ± 0.35	-1.44 ± 0.35	-0.94 ± 0.21
C^0_1	-0.52 ± 0.22	-0.57 ± 0.22	-0.75 ± 0.28	-0.50 ± 0.16
C^1_0	-0.43 ± 0.15	-0.47 ± 0.17	-0.50 ± 0.21	-0.37 ± 0.15
C^1_1	0.19 ± 0.19	0.20 ± 0.19	0.23 ± 0.31	0.17 ± 0.22
C^1_2	-0.43 ± 0.23	-0.48 ± 0.22	-0.49 ± 0.38	-0.36 ± 0.28
C_{IS}	5.68 ± 0.75	5.83 ± 0.82	6.10 ± 0.83	5.62 ± 0.65
C_{IV}	1.51 ± 0.23	1.52 ± 0.24	1.63 ± 0.25	1.54 ± 0.20
$\hat{\chi}^2$	1.14	1.15	1.13	1.12

Dependence on the smearing (δ) function

	$\delta \approx 0.3$fm (≈ 900MeV)	$\delta \approx 0.36$fm (≈ 770MeV)	$\delta \approx 0.4$fm (≈ 500MeV)
$\Gamma({}^{5}_{\Lambda}\mathrm{He})$	0.44	0.44	0.44
$n/p({}^{5}_{\Lambda}\mathrm{He})$	0.55	0.55	0.55
$\mathcal{A}({}^{5}_{\Lambda}\mathrm{He})$	0.24	0.24	0.24
$\Gamma({}^{11}_{\Lambda}\mathrm{B})$	0.88	0.88	0.88
$n/p({}^{11}_{\Lambda}\mathrm{B})$	0.93	0.92	0.94
$\mathcal{A}({}^{11}_{\Lambda}\mathrm{B})$	0.08	0.09	0.06
$\Gamma({}^{12}_{\Lambda}\mathrm{C})$	0.93	0.93	0.93
$n/p({}^{12}_{\Lambda}\mathrm{C})$	0.78	0.77	0.78
$\mathcal{A}({}^{12}_{\Lambda}\mathrm{C})$	0.02	0.03	0.02
C_0^0	-1.91 ± 0.56	-1.02 ± 0.35	-0.73 ± 0.19
C_0^1	-1.08 ± 0.52	-0.57 ± 0.29	-0.73 ± 0.16
C_1^0	-0.61 ± 0.28	-0.47 ± 0.17	-0.39 ± 0.26
C_1^1	0.24 ± 0.35	0.20 ± 0.19	0.17 ± 0.26
C_1^2	-0.60 ± 0.46	-0.48 ± 0.22	-0.25 ± 0.23
C_{IS}	6.45 ± 0.66	5.83 ± 0.82	5.83 ± 0.96
C_{IV}	1.79 ± 0.26	1.52 ± 0.24	1.48 ± 0.29
$\hat{\chi}^2$	1.15	1.15	1.15

Summary

- We have presented our study of the nonmesonic weak decay using an EFT framework to describe the weak interaction.
- The long-range components were described with pion and kaon exchange.
- The short-range part is parametrized in leading-order PV and PC contact terms.
- We find coefficients of natural size with significant error bars, reflecting the level of experimental uncertainty.
- The largest contact term corresponds to an isoscalar, spin-independent central operator.
- There is no indication of any contact terms violating the ΔI = 1/2 rule.

- We have not speculated on the dynamical origin of these contact contributions. Our aim was to ascertain their size and verify the validity of the EFT framework for the weak decay.
- The next generation of data from recent high-precision weak decay experiments currently under analysis holds the promise to provide much improved constraints for studies of this nature.
- Work in progress:

  ♣ Go to NLO? $\Longrightarrow$ 10 LEC's.

  Need of more independent data.

  ($np \to \Lambda p$, RCNP, Osaka, $\Rightarrow$ 2005-2007?)