Symmetry violations in few-body reactions: old and new approaches

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Why a few-body?

- DDH cannot reliably describe the available experimental data:
  - it is not adequate for descriptions of PV
  - “wrong” experimental data
  - new physics
- EFT - a model independent parametrization of PV effects
  - Two-body – solved
  - Few-body – as a bridge to light nuclei

B. Desplanques, J. F. Donoghue, and B. R. Holstein, Ann. Phys. (NY) **124**, 449 (1980).
S.-L. Zhu, C. M. Maekawa, B. R. Holstein, M. J. Ramsey-Musolf, and U. van Kolck, Nucl. Phys. A **748**, 435 (2005).
M. J. Ramsey-Musolf and S. A. Page, Annu. Rev. Nucl. Part.Sci. **56**, 1 (2006).
C. P. Liu, Phys. Rev. C **75**, 065501 (2007).

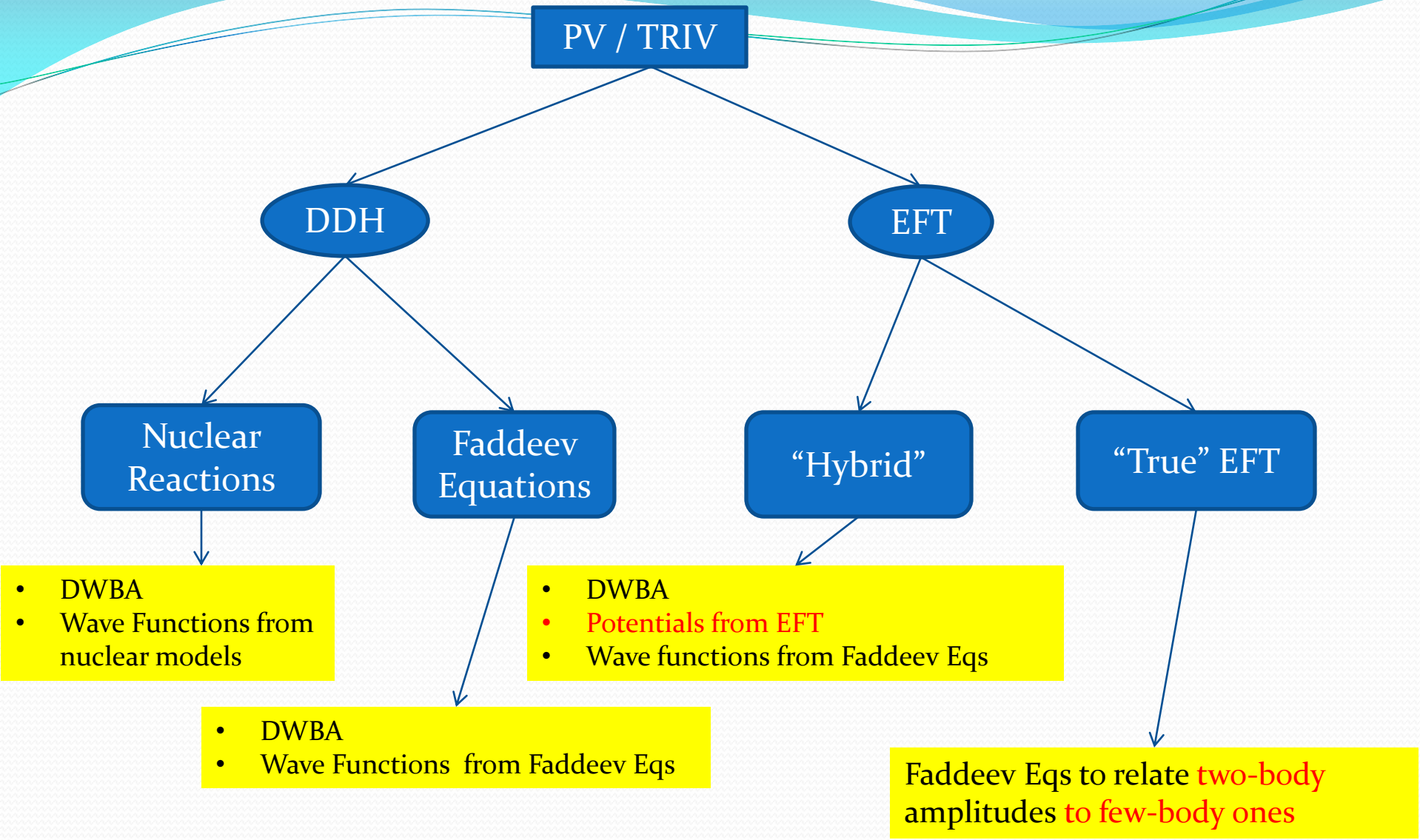
First order effects

$$f = f_{PC} + f_{PV}$$

$$w \sim |f_{PC} + f_{PV}|^2 = |f_{PC}|^2 + 2\Re e(f_{PC} f_{PV}^*) + |f_{PV}|^2$$

$$\alpha \sim \frac{\Re e(f_{PC} f_{PV}^*)}{|f_{PC}|^2} \sim \frac{|f_{PV}|}{|f_{PC}|}$$

$$\alpha \sim G_F m_\pi^2 \sim 2 \cdot 10^{-7}$$


PV / TRIV
DDH
EFT
Nuclear Reactions
Faddeev Equations
"Hybrid"
"True" EFT
• DWBA
• Wave Functions from nuclear models
• DWBA
• Wave Functions from Faddeev Eqs
• DWBA
• Potentials from EFT
• Wave functions from Faddeev Eqs
Faddeev Eqs to relate two-body amplitudes to few-body ones

"True" EFT

AGS equation:

$$U_{\beta\alpha} = \bar{\delta}_{\alpha\beta} G_0^{-1} + \sum_{\gamma} \bar{\delta}_{\gamma\beta} t_\gamma G_0 U_{\gamma\alpha}$$

interaction is small $\Rightarrow$

$$t_\gamma = t_\gamma^s + t_\gamma^w$$

$$U_{\beta\alpha} = U_{\beta\alpha}^s + U_{\beta\alpha}^w$$

Symmtry is violated $\Rightarrow$

$$U_{\beta\alpha}^s = \bar{\delta}_{\alpha\beta} G_0^{-1} + \sum_{\gamma} \bar{\delta}_{\gamma\beta} t_\gamma^s G_0 U_{\gamma\alpha}^s$$

$$U_{\beta\alpha}^w = \sum_{\gamma} \bar{\delta}_{\gamma\beta} t_\gamma^s G_0 U_{\gamma\alpha}^w + \sum_{\gamma} \bar{\delta}_{\gamma\beta} t_\gamma^w G_0 U_{\gamma\alpha}^s$$

V.G. & Y.-H. Song, Phys. Rev. C 82, 028502 (2010)

Configuration Space

$$(E - H_0 - V_i^s)\psi_i^s = V_i^s(\psi_j^s + \psi_k^s)$$

$$(E - H_0 - V_i^s)\psi_i^w = V_i^s(\psi_j^w + \psi_k^w) + V_i^w(\psi_i^s + \psi_j^s + \psi_k^s)$$

“Hybrid” method

- n-D scattering

$$\frac{1}{N}\frac{d\phi}{dz}=\frac{2\pi}{9p^2}\mathrm{Im}\left[R^{\frac{1}{2}}_{1\frac{1}{2},0\frac{1}{2}}+R^{\frac{1}{2}}_{0\frac{1}{2},1\frac{1}{2}}-2\sqrt{2}R^{\frac{1}{2}}_{1\frac{3}{2},0\frac{1}{2}}-2\sqrt{2}R^{\frac{1}{2}}_{0\frac{1}{2},1\frac{3}{2}}+4R^{\frac{3}{2}}_{1\frac{1}{2},0\frac{3}{2}}+4R^{\frac{3}{2}}_{0\frac{3}{2},1\frac{1}{2}}-2\sqrt{5}R^{\frac{3}{2}}_{1\frac{3}{2},0\frac{3}{2}}-2\sqrt{5}R^{\frac{3}{2}}_{0\frac{3}{2},1\frac{3}{2}}\right]$$

$$P=\frac{1}{3}\mathrm{Re}\left[R^{\frac{1}{2}}_{1\frac{1}{2},0\frac{1}{2}}+R^{\frac{1}{2}}_{0\frac{1}{2},1\frac{1}{2}}-2\sqrt{2}R^{\frac{1}{2}}_{1\frac{3}{2},0\frac{1}{2}}-2\sqrt{2}R^{\frac{1}{2}}_{0\frac{1}{2},1\frac{3}{2}}+4R^{\frac{3}{2}}_{1\frac{1}{2},0\frac{3}{2}}+4R^{\frac{3}{2}}_{0\frac{3}{2},1\frac{1}{2}}-2\sqrt{5}R^{\frac{3}{2}}_{1\frac{3}{2},0\frac{3}{2}}-2\sqrt{5}R^{\frac{3}{2}}_{0\frac{3}{2},1\frac{3}{2}}\right]/$$

$$/\mathrm{Re}\left[R^{\frac{1}{2}}_{0\frac{1}{2},0\frac{1}{2}}+2R^{\frac{3}{2}}_{0\frac{3}{2},0\frac{3}{2}}\right]$$

$$R^{J}_{l'_yS',l_yS}\simeq 4i^{-l'_y+l_y+1}\mu p\,{}^{(-)}_{pc}\langle\Psi,(l'_yS')JJ^z|V_{pv}|\Psi,(l_yS)JJ^z\rangle^{(+)}_{pc}$$

- R. Schiavilla, M. Viviani, L. Girlanda, A. Kievsky, and L. E. Marcucci, Phys. Rev. **C78**, 014002 (2008).
- Y.-H. Song, R. Lazauskas, and V.G. , (2010) in preparation.

TABLE I: Parameters and operators of parity violating potentials. πNN coupling $g_{\pi NN}$ can be represented by g_A by using Goldberger-Treiman relation, $g_\pi = g_A m_N/F_\pi$ with $F_\pi = 92.4$ MeV. $\mathcal{T}_{ij} \equiv (3\tau_i^z\tau_j^z - \tau_i\cdot\tau_j)$. Scalar function $\tilde{L}_\Lambda(r) \equiv 3L_\Lambda(r) - H_\Lambda(r)$.

n	c_n^{DDH}	$f_n^{DDH}(r)$	$c_n^{\not\pi}$	$f_n^{\not\pi}(r)$	c_n^{π}	$f_n^{\pi}(r)$	$O_{ij}^{(n)}$
1	$+\frac{g_\pi}{2\sqrt{2}m_N}h_\pi^1$	$f_\pi(r)$	$\frac{2\mu^2}{\Lambda_\chi^3}C_6^{\not\pi}$	$f_\mu^{\not\pi}(r)$	$+\frac{g_\pi}{2\sqrt{2}m_N}h_\pi^1$	$f_\pi(r)$	$(\tau_i\times\tau_j)^z(\boldsymbol{\sigma}_i+\boldsymbol{\sigma}_j)\cdot\boldsymbol{X}_{ij,-}^{(1)}$
2	$-\frac{g_\rho}{m_N}h_\rho^0$	$f_\rho(r)$	0	0	0	0	$(\tau_i\cdot\tau_j)(\boldsymbol{\sigma}_i-\boldsymbol{\sigma}_j)\cdot\boldsymbol{X}_{ij,+}^{(2)}$
3	$-\frac{g_\rho(1+\kappa_\rho)}{m_N}h_\rho^0$	$f_\rho(r)$	0	0	0	0	$(\tau_i\cdot\tau_j)(\boldsymbol{\sigma}_i\times\boldsymbol{\sigma}_j)\cdot\boldsymbol{X}_{ij,-}^{(3)}$
4	$-\frac{g_\rho}{2m_N}h_\rho^1$	$f_\rho(r)$	$\frac{\mu^2}{\Lambda_\chi^3}(C_2^{\not\pi}+C_4^{\not\pi})$	$f_\mu^{\not\pi}(r)$	$\frac{\Lambda^2}{\Lambda_\chi^3}(C_2^{\pi}+C_4^{\pi})$	$f_\Lambda(r)$	$(\tau_i+\tau_j)^z(\boldsymbol{\sigma}_i-\boldsymbol{\sigma}_j)\cdot\boldsymbol{X}_{ij,+}^{(4)}$
5	$-\frac{g_\rho(1+\kappa_\rho)}{2m_N}h_\rho^1$	$f_\rho(r)$	0	0	$\frac{2\sqrt{2}\pi g_A^3\Lambda^2}{\Lambda_\chi^3}h_\pi^1$	$L_\Lambda(r)$	$(\tau_i+\tau_j)^z(\boldsymbol{\sigma}_i\times\boldsymbol{\sigma}_j)\cdot\boldsymbol{X}_{ij,-}^{(5)}$
6	$-\frac{g_\rho}{2\sqrt{6}m_N}h_\rho^2$	$f_\rho(r)$	$-\frac{2\mu^2}{\Lambda_\chi^3}C_5^{\not\pi}$	$f_\mu^{\not\pi}(r)$	$-\frac{2\Lambda^2}{\Lambda_\chi^3}C_5^{\pi}$	$f_\Lambda(r)$	$\mathcal{T}_{ij}(\boldsymbol{\sigma}_i-\boldsymbol{\sigma}_j)\cdot\boldsymbol{X}_{ij,+}^{(6)}$
7	$-\frac{g_\rho(1+\kappa_\rho)}{2\sqrt{6}m_N}h_\rho^2$	$f_\rho(r)$	0	0	0	0	$\mathcal{T}_{ij}(\boldsymbol{\sigma}_i\times\boldsymbol{\sigma}_j)\cdot\boldsymbol{X}_{ij,-}^{(7)}$
8	$-\frac{g_\omega}{m_N}h_\omega^0$	$f_\omega(r)$	$\frac{2\mu^2}{\Lambda_\chi^3}C_1^{\not\pi}$	$f_\mu^{\not\pi}(r)$	$\frac{2\Lambda^2}{\Lambda_\chi^3}C_1^{\pi}$	$f_\Lambda(r)$	$(\boldsymbol{\sigma}_i-\boldsymbol{\sigma}_j)\cdot\boldsymbol{X}_{ij,+}^{(8)}$
9	$-\frac{g_\omega(1+\kappa_\omega)}{m_N}h_\omega^0$	$f_\omega(r)$	$\frac{2\mu^2}{\Lambda_\chi^3}\tilde{C}_1^{\not\pi}$	$f_\mu^{\not\pi}(r)$	$\frac{2\Lambda^2}{\Lambda_\chi^3}\tilde{C}_1^{\pi}$	$f_\Lambda(r)$	$(\boldsymbol{\sigma}_i\times\boldsymbol{\sigma}_j)\cdot\boldsymbol{X}_{ij,-}^{(9)}$
10	$-\frac{g_\omega}{2m_N}h_\omega^1$	$f_\omega(r)$	0	0	0	0	$(\tau_i+\tau_j)^z(\boldsymbol{\sigma}_i-\boldsymbol{\sigma}_j)\cdot\boldsymbol{X}_{ij,+}^{(10)}$
11	$-\frac{g_\omega(1+\kappa_\omega)}{2m_N}h_\omega^1$	$f_\omega(r)$	0	0	0	0	$(\tau_i+\tau_j)^z(\boldsymbol{\sigma}_i\times\boldsymbol{\sigma}_j)\cdot\boldsymbol{X}_{ij,-}^{(11)}$
12	$-\frac{g_\omega h_\omega^1-g_\rho h_\rho^1}{2m_N}$	$f_\rho(r)$	0	0	0	0	$(\tau_i-\tau_j)^z(\boldsymbol{\sigma}_i+\boldsymbol{\sigma}_j)\cdot\boldsymbol{X}_{ij,+}^{(12)}$
13	$-\frac{g_\rho}{2m_N}h_\rho'^1$	$f_\rho(r)$	0	0	$-\frac{\sqrt{2}\pi g_A\Lambda^2}{\Lambda_\chi^3}h_\pi^1$	$L_\Lambda(r)$	$(\tau_i\times\tau_j)^z(\boldsymbol{\sigma}_i+\boldsymbol{\sigma}_j)\cdot\boldsymbol{X}_{ij,-}^{(13)}$
14	0	0	0	0	$\frac{2\Lambda^2}{\Lambda_\chi^3}C_6^{\pi}$	$f_\Lambda(r)$	$(\tau_i\times\tau_j)^z(\boldsymbol{\sigma}_i+\boldsymbol{\sigma}_j)\cdot\boldsymbol{X}_{ij,-}^{(14)}$
15	0	0	0	0	$\frac{3\sqrt{2}\pi g_A^3\Lambda^2}{2\Lambda_\chi^3}h_\pi^1$	$\tilde{L}_\Lambda(r)$	$(\tau_i\times\tau_j)^z(\boldsymbol{\sigma}_i+\boldsymbol{\sigma}_j)\cdot\boldsymbol{X}_{ij,-}^{(15)}$

L. Girlanda, Phys. Rev. **C77**, 067001 (2008)

R. Schiavilla, M. Viviani, L. Girlanda, A. Kievsky, and L. E. Marcucci, Phys. Rev. **C78**, 014002 (2008).

Y.-H. Song, R. Lazauskas, and V.G. , (2010) in preparation.

TABLE IV: Coefficients I_n^{DDH} for AV18 and AV18+U9 strong potentials, and DDH-I and DDH-II parameter sets for parity violating potentials. $I_{6,7}^{DDH} = 0$.

n	DDH-I/AV18	DDH-I/AV18U9	DDH-II/AV18	DDH-II/AV18U9
1	-.555D+02	-.541D+02	-.558D+02	-.544D+02
2	-.604D+00	-.659D+00	-.103D+01	-.112D+01
3	0.118D+01	0.120D+01	0.192D+01	0.196D+01
4	-.827D+00	-.848D+00	-.119D+01	-.122D+01
5	-.889D+00	-.900D+00	-.139D+01	-.141D+01
8	0.114D+01	0.118D+01	0.145D+01	0.151D+01
9	0.558D+00	0.564D+00	0.713D+00	0.723D+00
10	-.906D+00	-.929D+00	-.112D+01	-.115D+01
11	-.101D+01	-.102D+01	-.133D+01	-.135D+01
12	-.899D+00	-.892D+00	-.127D+01	-.127D+01
13	-.131D+01	-.130D+01	-.205D+01	-.204D+01

Preliminary results (Y.-H. Song, R. Lazauskas, and V.G.)

TABLE V: Coefficients $I_n^{\not\pi}$ for AV18 and AV18+U9 strong potentials, and $\not\pi$EFT-I and $\not\pi$EFT-II parameter sets for parity violating potentials. $I^{\not\pi}_{2,3,5,6,7,10,11,12,13} = 0$.

n	$\not\pi$EFT-I/AV18	$\not\pi$EFT-I/AV18U9	$\not\pi$EFT-II/AV18	$\not\pi$EFT-II/AV18U9
1	-.558D+02	-.544D+02	-.879D+00	-.879D+00
4	-.550D+02	-.534D+02	-.453D+00	-.467D+00
8	0.690D+02	0.686D+02	0.614D+00	0.643D+00
9	0.858D+01	0.601D+01	0.309D+00	0.315D+00

TABLE VI: Coefficients I_n^{π} for AV18 and AV18+U9 strong potentials, and πEFT-I and πEFT-II parameter sets for parity violating potentials. $I^{\pi}_{2,3,6,7,10,11,12} = 0$.

n	πEFT-I/AV18	πEFT-I/AV18U9	πEFT-II/AV18	πEFT-II/AV18U9
1	-.558D+02	-.544D+02	-.558D+02	-.544D+02
4	-.138D+01	-.129D+01	-.498D+00	-.443D+00
5	-.395D+01	-.168D+01	-.112D+01	-.600D-01
8	0.167D+01	0.162D+01	0.710D+00	0.679D+00
9	0.744D+00	0.663D+00	0.308D+00	0.261D+00
13	-.205D+02	-.198D+02	-.880D+01	-.849D+01
14	-.308D+01	-.302D+01	-.160D+01	-.158D+01
15	-.594D+02	-.572D+02	-.248D+02	-.239D+02

Preliminary results (Y.-H. Song, R. Lazauskas, and V.G.)

TABLE X: DDH PV coupling constants in units of 10^{-7}. Strong couplings are $\frac{g_\pi^2}{4\pi} = 13.9$, $\frac{g_\rho^2}{4\pi} = 0.84$, $\frac{g_\omega^2}{4\pi} = 20$, $\kappa_\rho = 3.7$, and $\kappa_\omega = 0$, h'_ρ contribution is neglected.

DDH Coupling	DDH 'best'	4-parameter fit[]	3-parameter fit[]
h_π^1	$+4.56$	-0.456	-0.5
h_ρ^0	-11.4	-43.3	-33
h_ρ^2	-9.5	37.1	41
h_ω^0	-1.9	13.7	0
h_ρ^1	-0.19	-0.19	-0.19
h_ω^1	-1.14	-1.14	-1.14

[] J.D. Bowman, INT Workshop on Electric Dipole Moments and CP Violations, March 19-23, 2007

TABLE XI: Neutron spin rotation in 10^{-7} rad-cm^{-1} for the case of DDH-II potential with AV18+U9 strong potential for a liquid deuteron density $N = 0.4 \times 10^{23}$ atoms per cm^3.

	DDH 'best'	4-parameter fit[]	3-parameter fit[]
1	-0.976E-01	0.976E-02	0.107E-01
2	-0.350E-02	-0.133E-01	-0.101E-01
3	0.288E-01	0.109E+00	0.833E-01
4	-0.316E-04	-0.316E-04	-0.316E-04
5	-0.136E-03	-0.136E-03	-0.136E-03
8	0.383E-02	-0.276E-01	-0.000E+00
9	0.183E-02	-0.132E-01	0.000E+00
10	-0.878E-03	-0.878E-03	-0.878E-03
11	-0.103E-02	-0.103E-02	-0.103E-02
12	-0.930E-03	-0.930E-03	-0.930E-03
total	-0.697E-01	0.619E-01	0.809E-01

Preliminary results (Y.-H. Song, R. Lazauskas, and V.G.)

TABLE XII: Neutron spin asymmetry for the case of DDH-II potential twith AV18+U9 strong potential (the total cross section $\sigma_{tot} = 3.35$ b at $E = 15\ keV$).

	DDH 'best'	4-parameter fit[]	3-parameter fit[]
1	-.848D-08	0.848D-09	0.930D-09
2	-.222D-09	-.845D-09	-.644D-09
3	0.664D-09	0.252D-08	0.192D-08
4	-.274D-12	-.274D-12	-.274D-12
5	-.124D-11	-.124D-11	-.124D-11
8	0.828D-10	-.597D-09	-.000D+00
9	-.543D-11	0.391D-10	0.000D+00
10	-.760D-11	-.760D-11	-.760D-11
11	-.936D-11	-.936D-11	-.936D-11
12	-.714D-10	-.714D-10	-.714D-10
total	-0.805D-08	0.188D-08	0.212D-08

Preliminary results (Y.-H. Song, R. Lazauskas, and V.G.)

Nuclear Reactions

- Pros:
  - “Easy” to calculate
  - Energy dependency
- Cons:
  - Model dependent

n-^{3}He →^{3}H-p

$$E_n \sim 0.01\, eV \qquad E_p = 0.764\, MeV$$

$$k_n \sim 2.19 \cdot 10^{-5}\, fm^{-1} \qquad k_p = 0.19\, fm^{-1}$$

$$R \sim 1.97\, fm$$

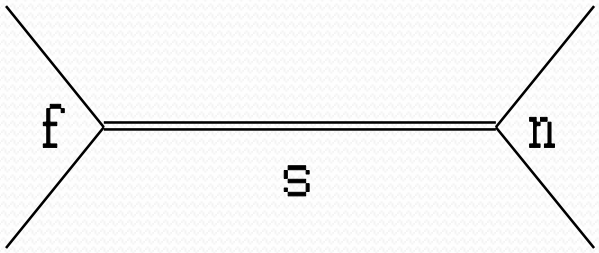
$$(k_n R) \sim 4 \cdot 10^{-5} \quad \Rightarrow \quad l = 0$$

$$(k_p R) \sim 0.4 \quad \Rightarrow \quad l' = 0,1,2(?)$$

*(For calculations at zero energy see: M. Viviani, R. Schiavilla, L. Girlanda, A. Kievsky, and L. E. Marcucci, (2010), arXiv:1007.2052.)

Correlations for n-^{3}He

PV	PC
$(\vec{\sigma}\cdot\vec{k}_p)$	$(\vec{k}_n\cdot\vec{k}_p)$
$(\vec{\sigma}\cdot\vec{k}_n)$	$\vec{\sigma}\cdot[\vec{k}_n\times\vec{k}_p]$
$(\vec{I}\cdot\vec{k}_p)$	$(\vec{\sigma}\cdot\vec{I})$
$(\vec{I}\cdot\vec{k}_n)$	$\vec{I}\cdot[\vec{k}_n\times\vec{k}_p]$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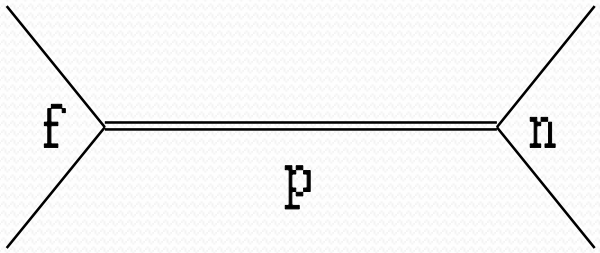
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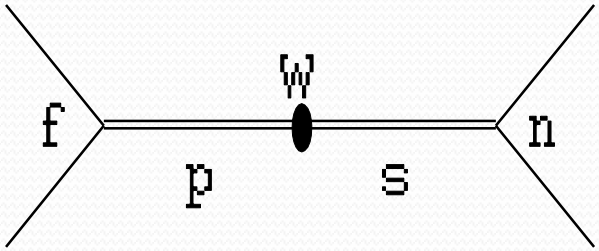
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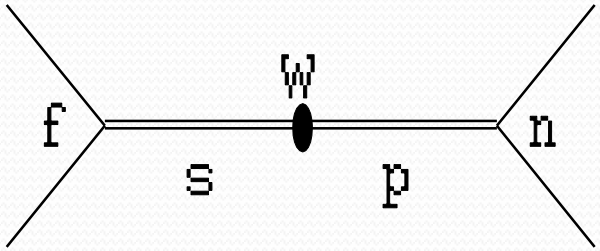
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DWBA

$$T_{if} = < \Psi_f^- | W | \Psi_i^+ >$$

$$\Psi_{i,f}^{\pm} = \sum_k a_{k(i,f)}^{\pm}(E)\phi_k + \sum_m \int b_{m(i,f)}^{\pm}(E,E')\chi_m^{\pm}(E')dE'$$

$$a_{k(i,f)}^{\pm}(E) = \frac{\exp(\pm i\delta_{i,f})}{\sqrt{2\pi}} \frac{(\Gamma_k^{i,f})^{1/2}}{E - E_k \pm i\Gamma_k / 2}$$

$$(\Gamma_k^i)^{1/2} = \sqrt{2\pi} < \chi_i(E') | V | \phi_k >$$

$$b_{m,\alpha}^{\pm}(E,E') = \exp(\pm i\delta_\alpha)\delta(E - E') + a_{k,\alpha}^{\pm} \frac{< \phi_k | V | \chi_m(E') >}{E - E' \pm i\varepsilon}$$

$$P = -\frac{\mathrm{Re}\,[<00|R^0|11> + <11|R^0|00>]}{\mathrm{Re}\,[<00|R^0|00> + 3<10|R^1|10>]} + \sqrt{3}\,\frac{\mathrm{Re}\,[<10|R^1|01> + <01|R^1|10>]}{\mathrm{Re}\,[<00|R^0|00> + 3<10|R^1|10>]}$$

$$+\sqrt{6}\,\frac{\mathrm{Re}\,[<10|R^1|11> + <11|R^1|10>]}{\mathrm{Re}\,[<00|R^0|00> + 3<10|R^1|10>]}$$

$$<s'l'|R^J|s\,l> \;= -\frac{i\,w\,(\,\Gamma_l^n(s)\Gamma_{l'}^p(s')\,)^{\frac{1}{2}}}{(E - E_l + i\Gamma_l/2)(E - E_{l'} + i\Gamma_{l'}/2)}\,e^{i(\delta_l^n + \delta_{l'}^p)}$$

$$<s'l'|R^J|s\,l> \;= \frac{i(\,\Gamma_l^n(s)\Gamma_{l'}^p(s')\,)^{\frac{1}{2}}}{(E - E_l + i\Gamma_l/2)}\,e^{i(\delta_l^n + \delta_{l'}^p)}$$

D.R. Tilley et al. / Energy levels of light nuclei A = 4

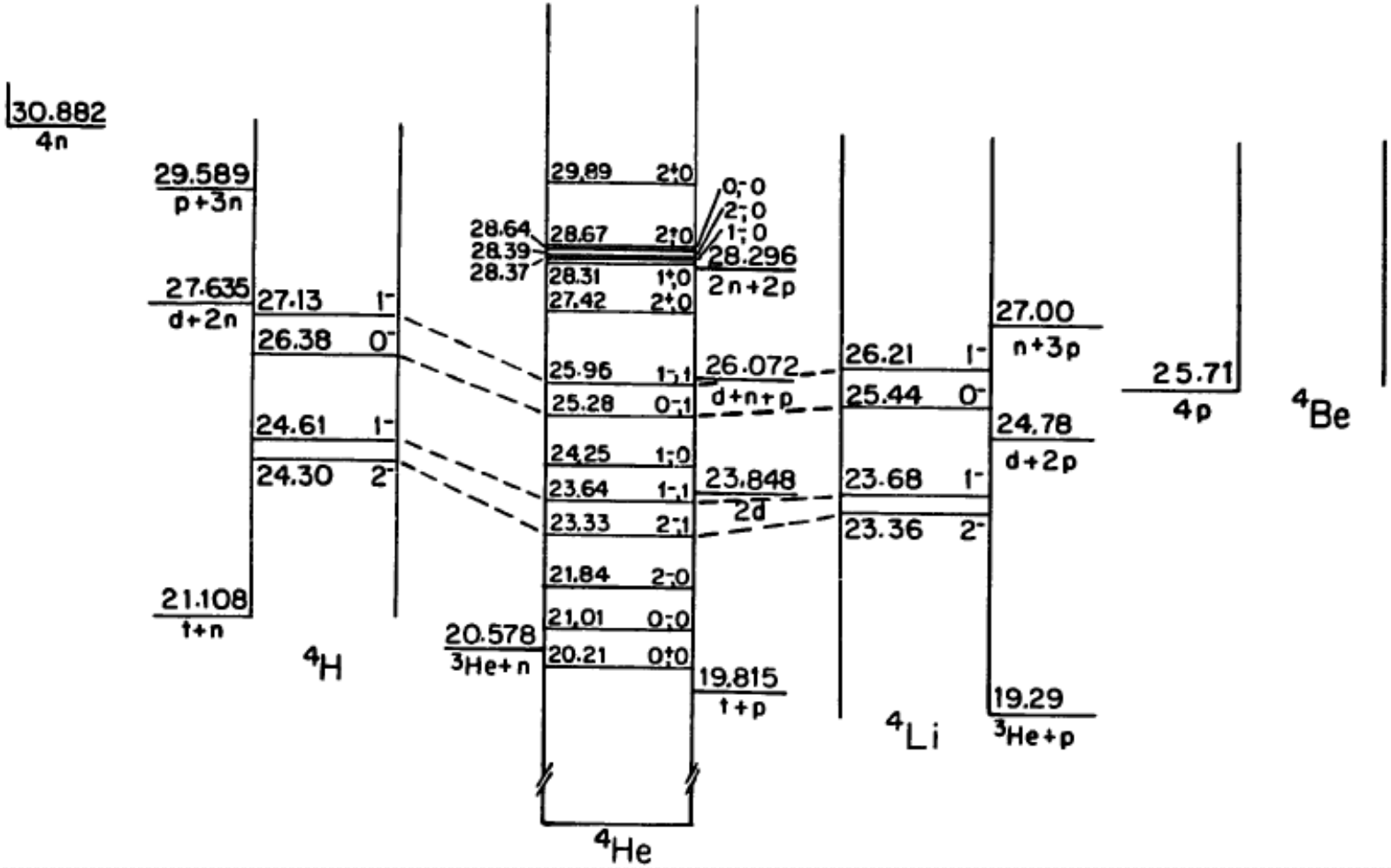

TABLE II. Resonance parameters (Set 1). Here E_r is a resonance energy; T and J^π are resonance isospin and the total resonance spin with parity; Γ and Γ_p are total and proton widths; Γ_n, Γ_n^0 and l are neutron width, reduced width, and angular momentum, correspondingly; α_{PV} (%) and P (%) are normalized contribution of the resonance to α_{PV} and P, correspondingly.

$E_r(MeV)$	J^π	l	T	$\Gamma_n(MeV)$	$\Gamma_n^0(eV)$	$\Gamma_p(MeV)$	$\Gamma(MeV)$	α_{PV} (%)	P (%)
-0.211	0+	0	0		954.4	1.153	1.153		
0.430	0-	1	0	0.48		0.05	0.05	3.1	100
3.062	1-	1	1	2.76		3.44	6.20	100±26	2±1
3.672	1-	1	0	2.87		3.08	6.10	75±24	1±1
4.702	0-	1	1	3.85		4.12	7.97	20	3
5.372	1-	1	1	6.14		6.52	12.66	79±18	1
7.732	1+	0	0	4.66		4.725	9.89		
7.792	1-	1	0	0.08		0.07	3.92	2±1	0
8.062	0-	1	0	0.01		0.01	4.89	14	0

TABLE III. Resonance parameters (Set 2). Here E_r is a resonance energy; T and J^π are resonance isospin and the total resonance spin with parity; Γ and Γ_p are total and proton widths; Γ_n, Γ_n^0 and l are neutron width, reduced width, and angular momentum, correspondingly; α_{PV} (%) and P (%) are normalized contribution of the resonance to α_{PV} and P, correspondingly.

$E_r(MeV)$	J^π	l	T	$\Gamma_n(MeV)$	$\Gamma_n^0(eV)$	$\Gamma_p(MeV)$	$\Gamma(MeV)$	α_{PV} (%)	P (%)
-0.211	0+	0	0		954.4	1.153	1.153		
0.430	0-	1	0	0.20		0.640	0.84	100	100
3.062	1-	1	1	2.76		3.44	6.20	82±27	4±3
3.672	1-	1	0	2.87		3.08	6.10	62±20	3±2
4.702	0-	1	1	3.85		4.12	7.97	16	8
5.372	1-	1	1	6.14		6.52	12.66	65±15	2±1.5
7.732	1+	0	0	4.66		4.725	9.89		
7.792	1-	1	0	0.08		0.07	3.92	2±1	0
8.062	0-	1	0	0.01		0.01	4.89	1	0.5

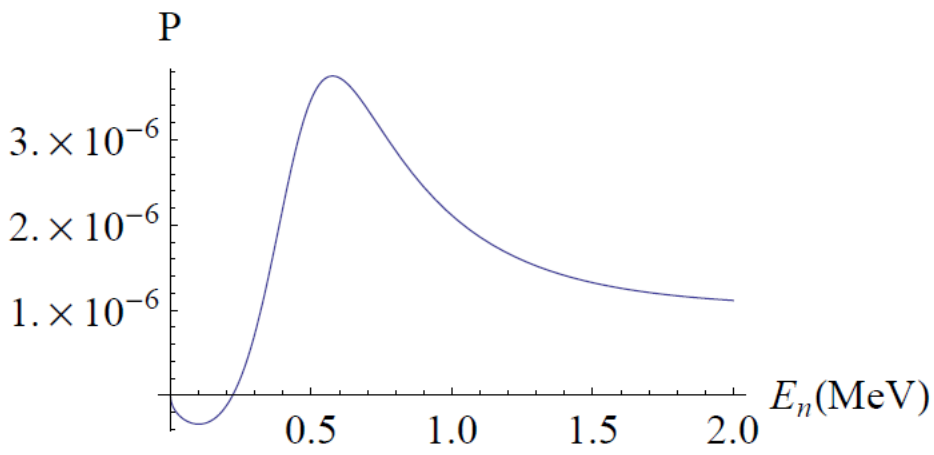

FIG. 2. Resonance enhancement of of the P parameter.

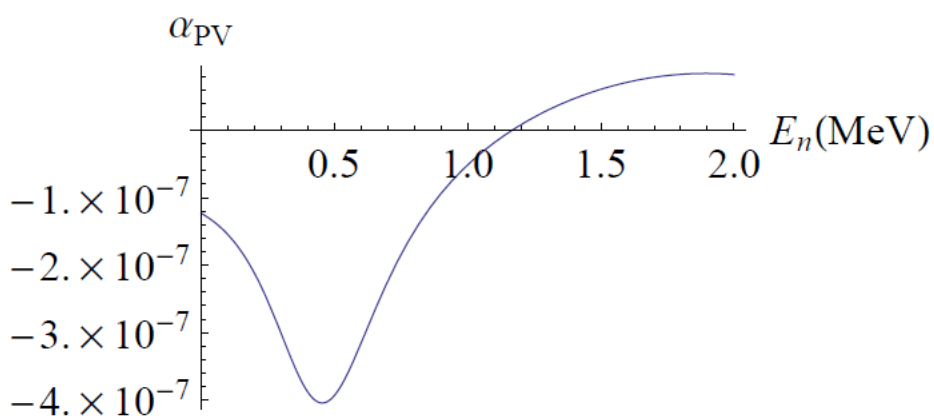

FIG. 3. Resonance enhancement of of the α_{PV} asymmetry (for the first set of parameters).

Summary

- "True" EFT few-body calculations: theoretical approach is developed, and computational algorithms are on the way
- "Hybrid" calculations are available, but they probably will not resolve the "PV-puzzle" completely
- "Nuclear reaction" approach is still useful (energy dependencies, fast estimates)