M. Fujiwara & A. Titov

ASRC, JAERI
RCNP, Osaka-U.
JINR

Parity Non-Conservation in Reaction

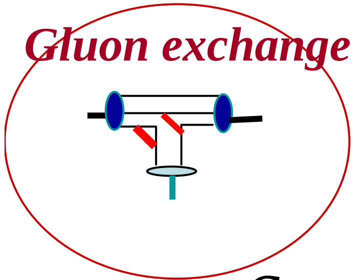
$$\gamma D \rightarrow np$$

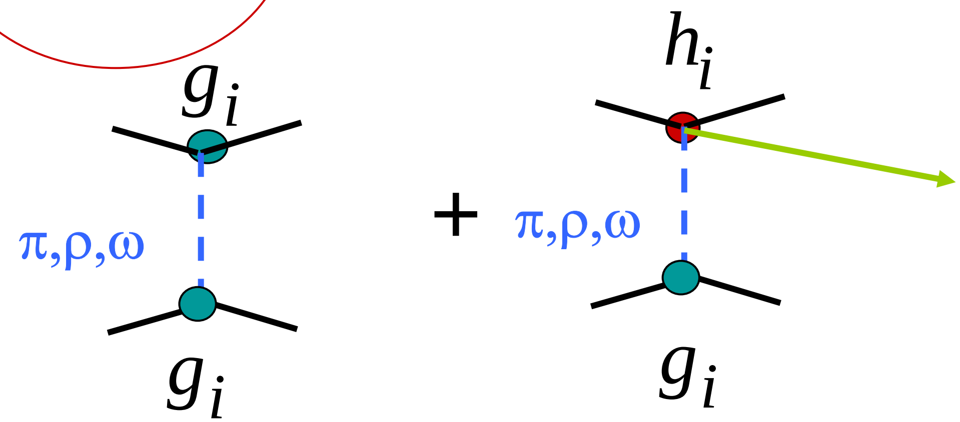
Outline

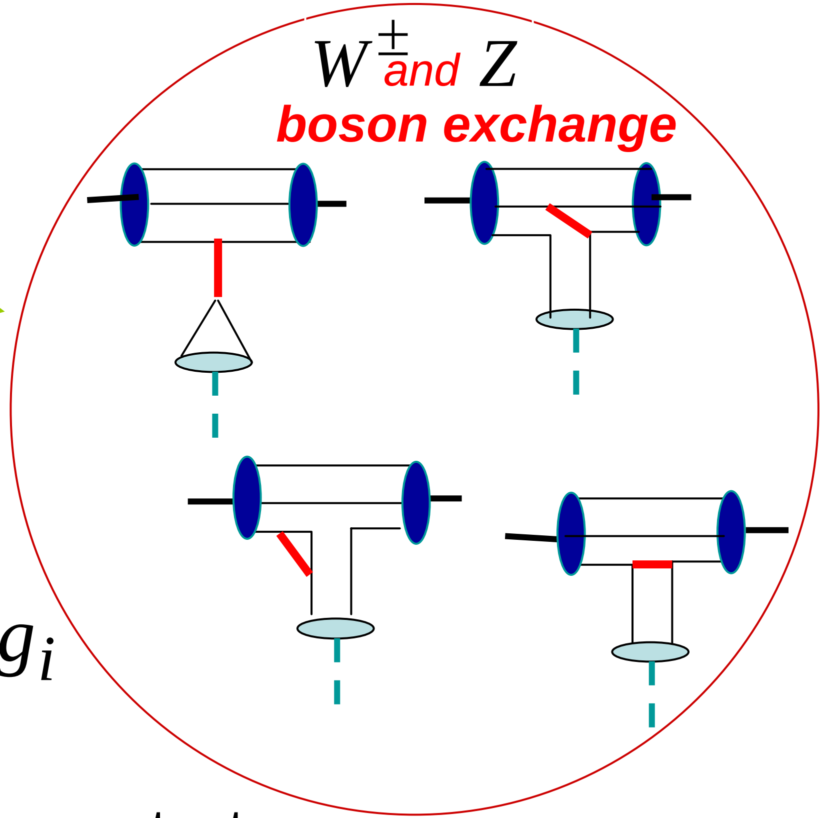
1. Motivation
2. Odd-parity admixtures in pn-wave functions
3. Parity-non-conserving asymmetries
4. Summary

Motivation

Parity non-conservation in NN interaction







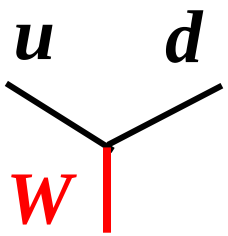
Strong $= g_i \otimes g_i$ Weak $= h_i^j \otimes g_i$

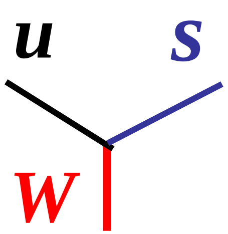
Goal: Weak Parity violated coupling constants

$$h_\rho^0, h_\rho^1, h_\rho^{1'}, h_\rho^2, h_\omega^0, h_\omega^1, f_\pi^1 \rightarrow$$ **Weak interaction** $\otimes$ **NP-QCD**

Weak Interaction and PNC-forces

Charge current





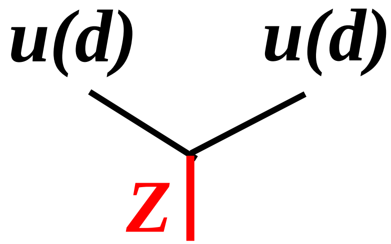
$\Delta I = 1$

$\Delta S = 0$

$\Delta I = 1/2$

$\Delta S = -1$

Neutral current



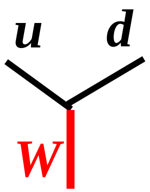
$\Delta I = 0,1$

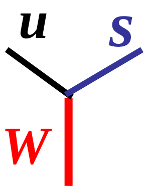
$\Delta S = 0$

$$J_W = \cos\vartheta_C J_W^1 + \sin\vartheta_C J_W^{1/2}$$

$$J_Z = J_Z^0 + J_Z^1$$

Weak Interaction and PNC-forces



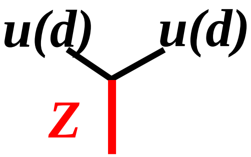


$$L \propto \overbrace{\cos^2 \vartheta_C J_W^{1*} J_W^{1}}^{\Delta I = 0,2} + \overbrace{\sin^2 \vartheta_C J_W^{1/2*} J_W^{1/2}}^{\Delta I = 1}$$

Charge current

$$\sin^2 \vartheta_C \approx \frac{1}{25}$$

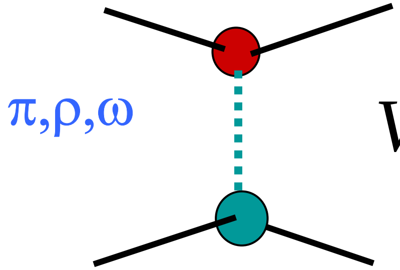
$$+ \overbrace{J_Z^{1*} J_z^{1} + J_Z^{0*} J_Z^{0}}^{\Delta I = 0,2} + \overbrace{J_Z^{0*} J_z^{1} + J_Z^{1*} J_Z^{0}}^{\Delta I = 1} + h.c.$$



Neutral current

Parity non-conserving (PNC) potential

$$L_{weak} + L_{QCD} \Rightarrow L^{PNC}_{MNN}(h^{0,1,2}_{\rho,\omega}, f_\pi)$$

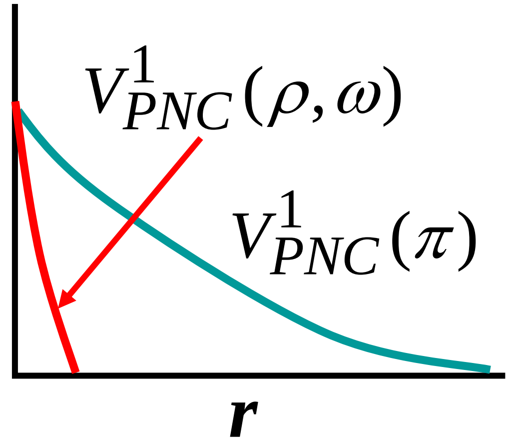


$$V_{PNC}(r) \propto (\vec{\sigma}_1 \pm \vec{\sigma}_2)\cdot\vec{r} \otimes e^{-m_i r}$$

$$L^{PC}_{MNN}(g_\rho, g_\omega, g_\pi)$$

$$V^{\Delta I=0,2}_{PNC}(r) \propto g_V h^{0,2}_V \otimes e^{-m_\rho r}; V=\rho,\omega$$

$$V^{\Delta I=1}_{PNC}(r) \propto g_V h^1_V \otimes e^{-m_\rho r} + g_\pi f_\pi \otimes e^{-m_\pi r}$$



Theory

$h_V^{0,2},\ f_\pi\quad(10^{-7})$

	MW	DZ	DDH	HHK	*RR of* DDH
f_π	$0.8 \to 1.3$	1.30	4.54	3.0	$+0.00 \to +11.4$
h_ρ^0	-3.70	-8.30	-11.4	$-$	$-30.8 \to +11.4$
h_ρ^2	-3.30	-6.70	-7.06	$-$	$-11.0 \to -7.6$
h_ω^0	-6.20	-3.90	-1.90	$-$	$-10.3 \to +5.7$

MW: Meissner, Weigel, Phys. Lett.B 447, '99 **(Skyrmion model)**

DZ: Dubovik, Zenkin, Ann. Phys. 172, '86 **(Soft pions + Bag model)**

DDH: Desplanques, Donoghue, Holstein, Ann. Phys. 124, '80 **(SU(6) + QCD)**

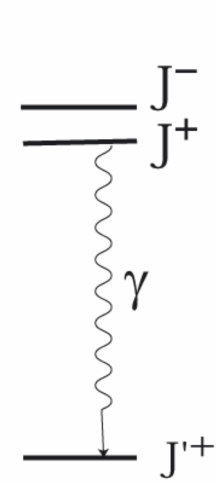
HHK: Henley, Hwang, Kisslinger, Phys. Lett.B 440,'98 **(QCD SR)**

***RR* of DDH: Reasonable Range of DDH**

Experiment: study of parity doublets

PNC–observable: asymmetry of circularly polarized photons

$$\lambda = \vec{S}_\gamma \cdot \vec{n}_\gamma$$



$$\left|\Psi_{J^+}\right\rangle = \cos\alpha\left|\Phi_{J^+}\right\rangle + \sin\alpha\left|\Phi_{J^-}\right\rangle$$

$$\left|\Psi_{J^-}\right\rangle = \cos\alpha\left|\Phi_{J^-}\right\rangle - \sin\alpha\left|\Phi_{J^+}\right\rangle$$

Weak coupling constants

Nuclear matrix elements

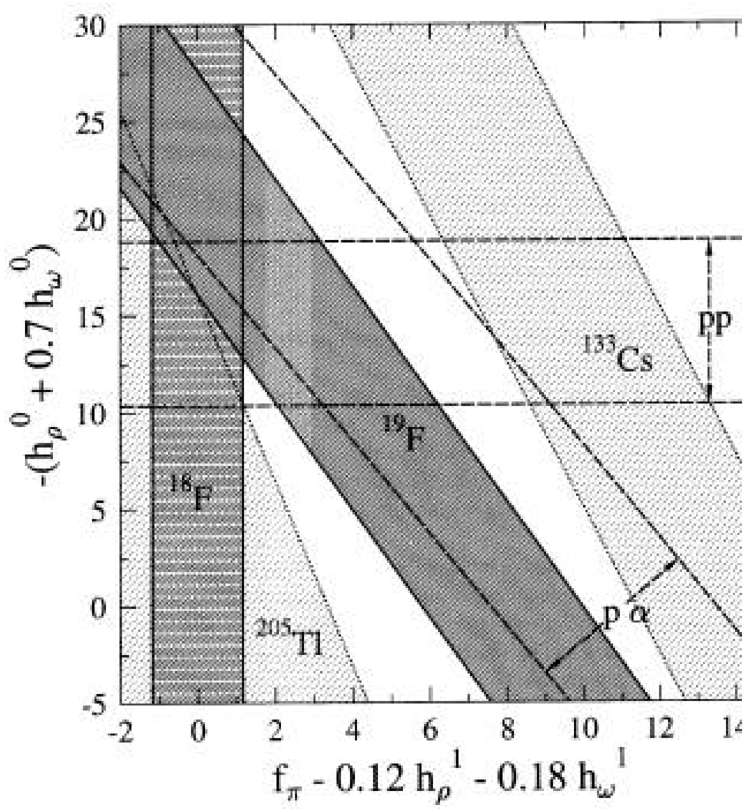
$$\alpha \approx \frac{\left\langle\Phi_{J^-}\left|H_{PNC}\right|\Phi_{J^+}\right\rangle}{E_+ - E_-} \approx \frac{\sum h_i N^i_{J^-J^+}}{E_+ - E_-}$$

$$P_\gamma \approx 2\alpha \frac{M_L E_L}{E_L^2 + \alpha^2 M_L^2} \approx 2 \cdot \frac{\sum h_i N_i}{E_+ - E_-} \cdot \frac{M_L}{E_L} \sim 10^{-2} \dots 10^{-6}$$

Experiment

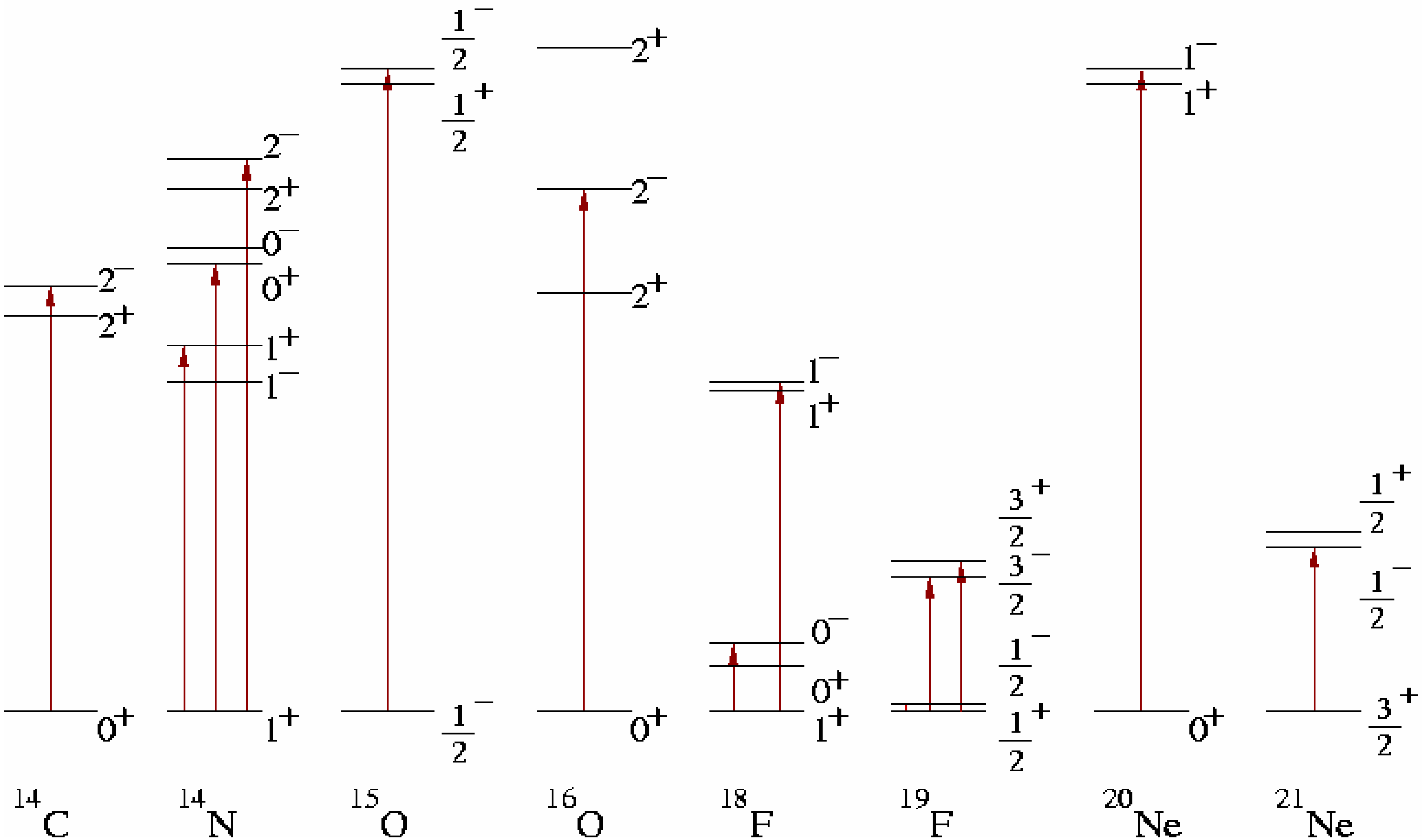
constraints for PNC coupling constants

Haxton, Liu, Ramsei-Musolf, Phys. Rev. C 65, '02



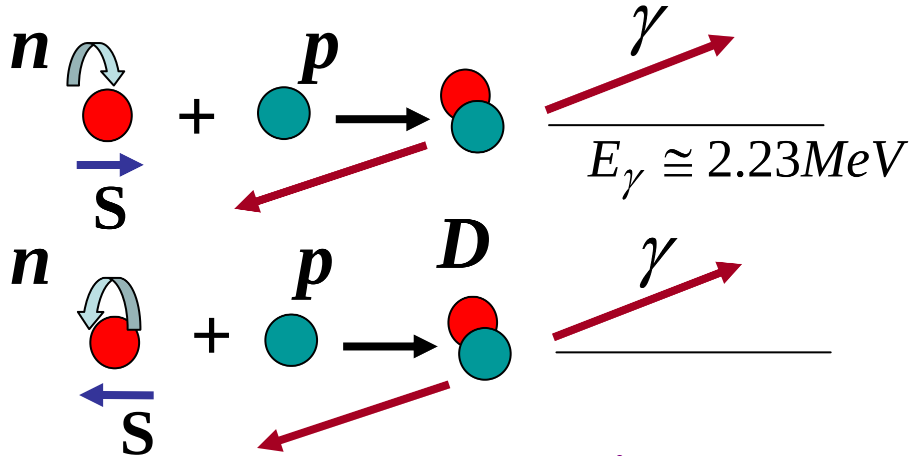
Future experiment at Spring-8?

absorption of circularly polarized photons by “parity doublets” (M. Fujiwara)



Capture of thermal neutron by proton

(i) polarized neutron and unpolarized γ



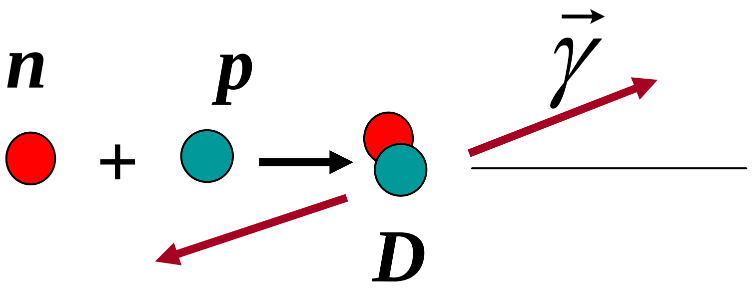
LANL project

$$W \propto 1 + 2A_\gamma^{PNC} \vec{S}_n \cdot \vec{n}_\gamma$$

$$A_\gamma^{PNC} = (6 \pm 21) \cdot 10^{-8}$$

$$A_\gamma^{PNC}(theor) \sim 5 \cdot 10^{-8}$$

(ii) unpolarized neutron and polarized γ

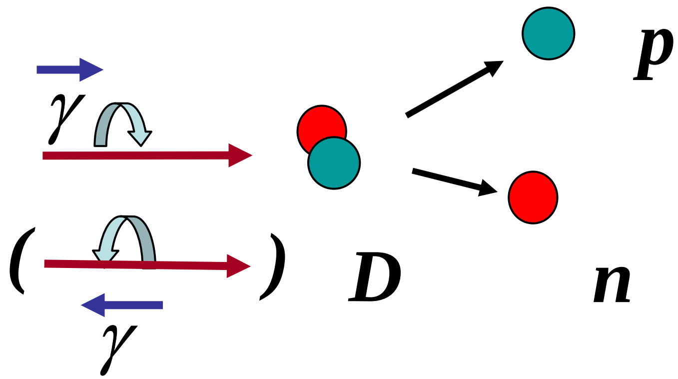


$$P_\gamma^{PNC} = (18 \pm 18) \cdot 10^{-8}$$

$$P_\gamma^{PNC}(theor) = (1 \sim 6) \cdot 10^{-8}$$

Deuteron photo-disintegration

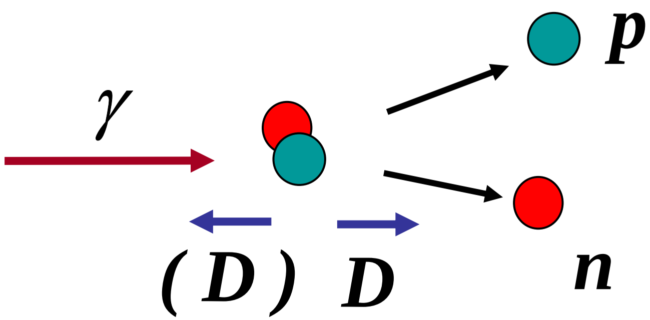
(i) circularly polarized γ and unpolarized deuteron



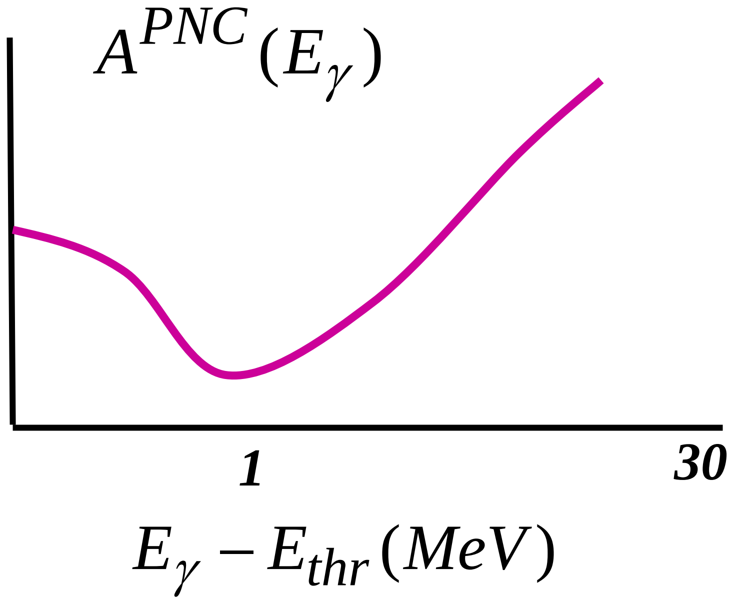
$$A_{RL}^{PNC}(E_\gamma) = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L}$$

$$A_{RL}^{PNC}(E_\gamma \approx 2.23) = P_\gamma^{PNC}$$

(ii) unpolarized γ and polarized deuteron

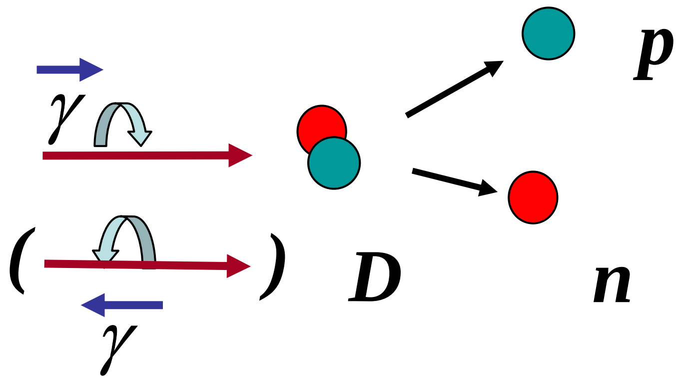


$$A_D^{PNC}(E_\gamma) = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$$

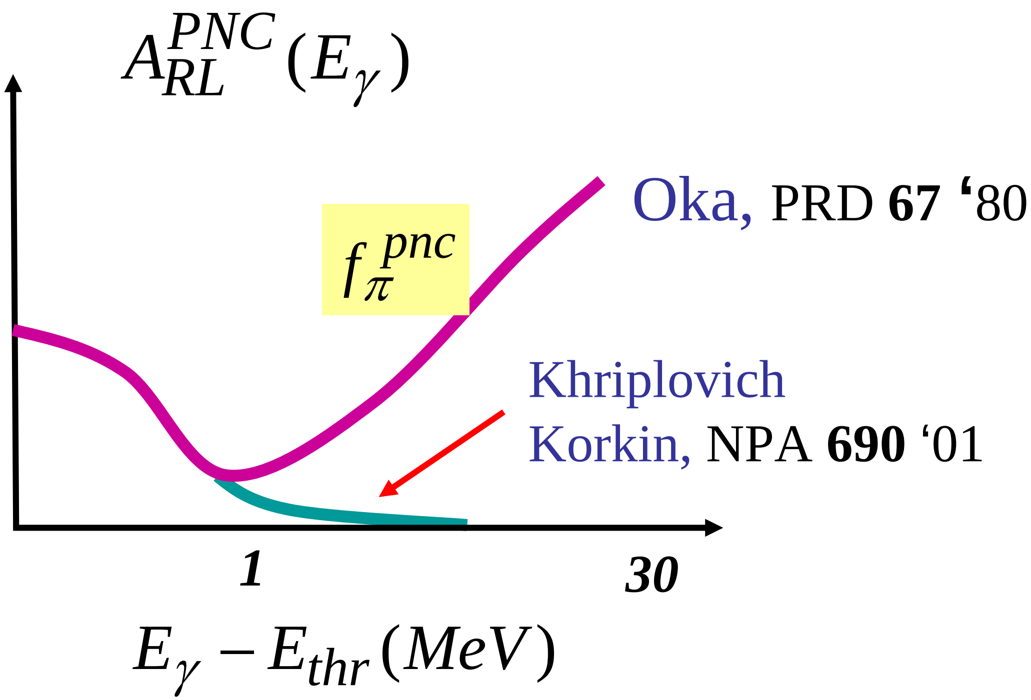


Deuteron photo-disintegration

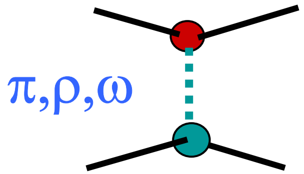
circularly polarized γ and unpolarized deuteron



$$A_{RL}^{PNC}(E_\gamma) = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L}$$



Parity non-conserving (PNC) potential



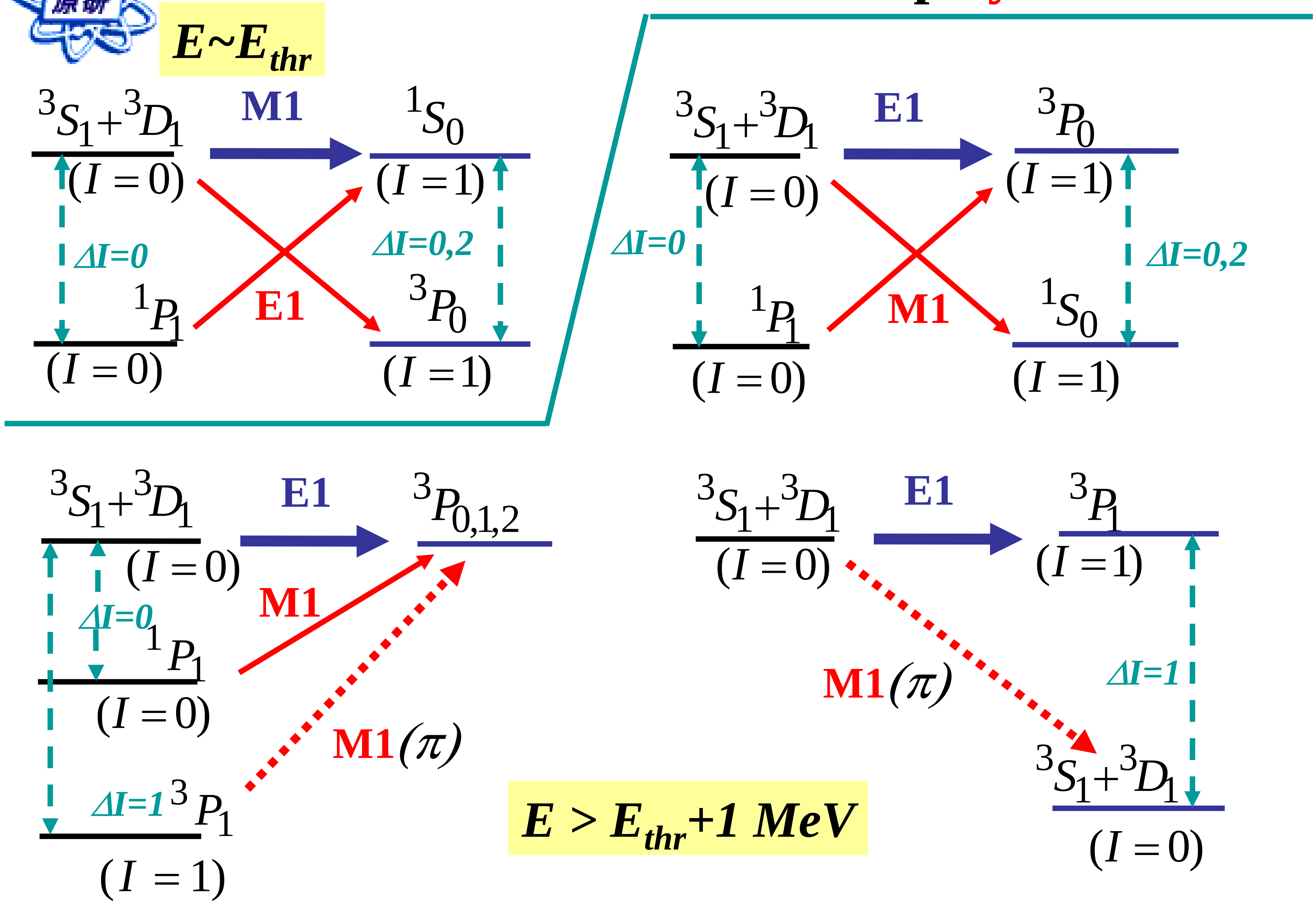
$$
\begin{aligned}
V_{\rm PNC} = \; & \frac{2ig_\rho}{M}\left\{\left[h_\rho^0\tau_1\tau_2 + \frac{1}{2}h_\rho^1(\tau_1^z+\tau_2^z) + \frac{1}{2\sqrt{6}}h_\rho^2(3\tau_1^z\tau_2^z - \tau_1\tau_2)\right]\right. \\
\times \; & \left(\Sigma\{\nabla, f_\rho(r)\} + (1+\chi_\rho)\,\Omega\nabla f_\rho(r)\right) \\
- \; & \left.\frac{1}{2}h_\rho^1(\tau_1^z-\tau_2^z)\,\mathbf{S}\,\{\nabla, f_\rho(r)\} + ih_\rho^{1'}\left[\frac{\tau_1\times\tau_2}{2}\right]^z \mathbf{S}\,\nabla\, f_\rho(r)\right\} \qquad \rho \\
& \frac{2ig_\omega}{M}\left\{\left[h_\omega^0 + \frac{1}{2}h_\omega^1(\tau_1^z+\tau_2^z)\right]\left(\Sigma\{\nabla, f_\omega(r)\} + (1+\chi_\omega)\,\Omega\nabla f_\omega(r)\right)\right\} \\
+ \; & \left.\frac{1}{2}h_\omega^1(\tau_1^z-\tau_2^z)\,\mathbf{S}\,\{\nabla, f_\omega(r)\}\right\} \qquad \omega \\
+ \; & \frac{2g_\pi f_\pi}{\sqrt{2}M}\left\{\left[\frac{\tau_1\times\tau_2}{2}\right]^z \mathbf{S}\,\nabla f_\pi(r)\right\}, \qquad \pi
\end{aligned}
$$

where

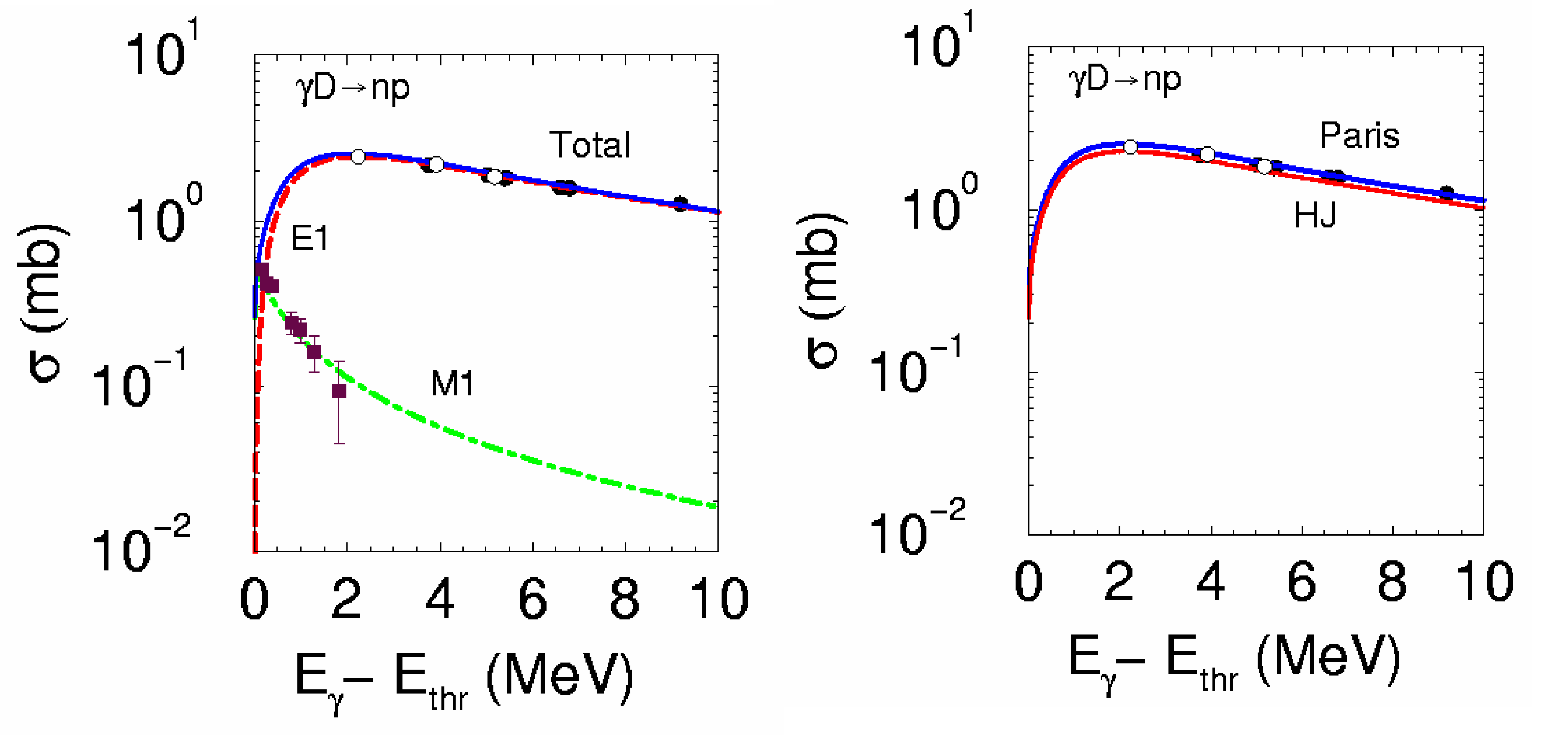
$$\vec{S} = \frac{1}{2}(\vec{\sigma}_1 + \vec{\sigma}_2) \qquad \vec{\Sigma} = \frac{1}{2}(\vec{\sigma}_1 - \vec{\sigma}_2)$$

$$f_\rho(r) = f_\omega(r) = \frac{e^{-m_\rho r}}{4\pi r}, \qquad f_\pi(r) = \frac{e^{-m_\pi r}}{4\pi r}, \qquad \Omega = \frac{i}{2}[\sigma_1\times\sigma_2].$$

PNC transitions in np-system



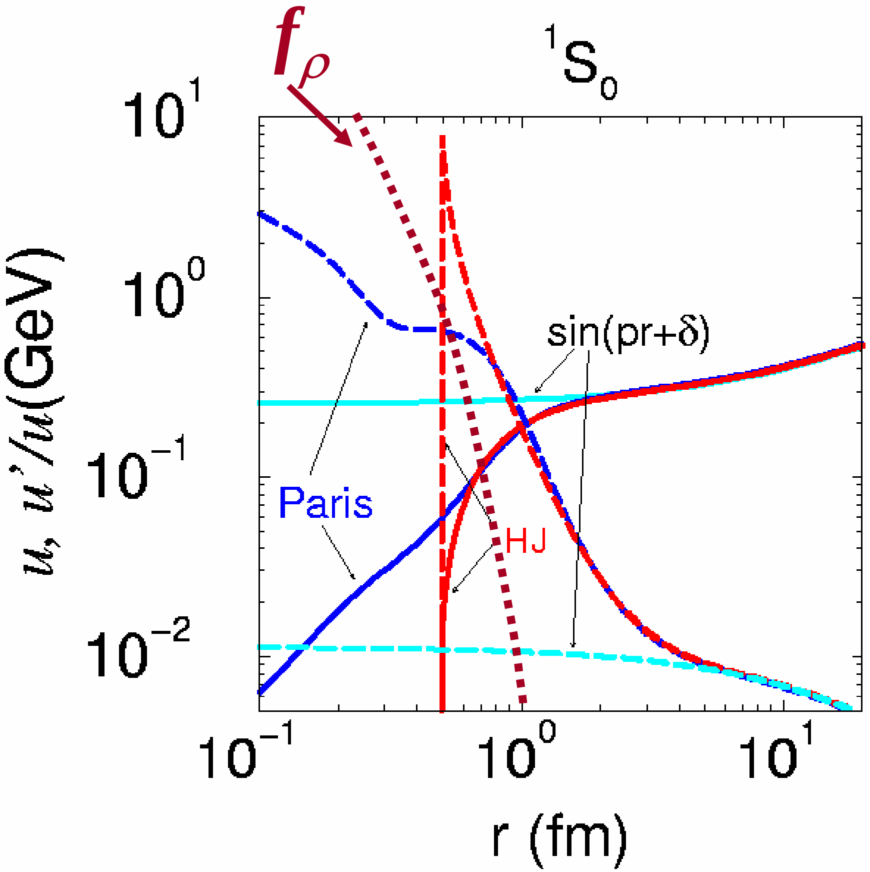
Total cross section of deuteron photo-disintegration



Structure of PNC matrix elements

$$^1\tilde{P}_1 \sim \sum_{i=\rho,\omega} g_i \hat{h}_i \cdot \int dr' G(r,r')[-\chi_i f_i' + 2 f_i (\frac{\partial}{\partial r'} - \frac{1}{r'})] \cdot u(r') + O(w)$$

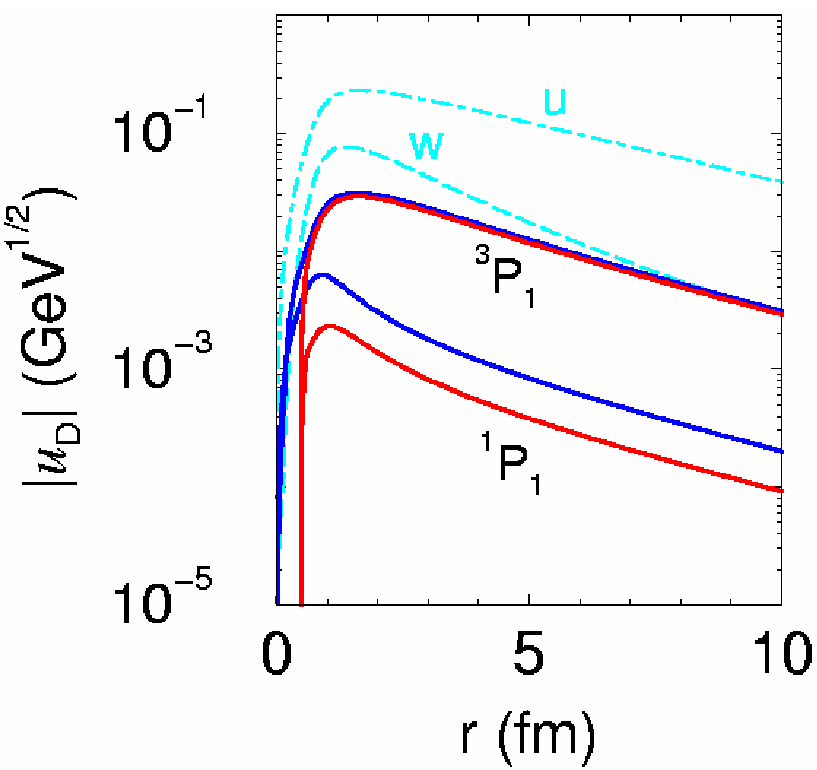
$$^3\tilde{P}_0 \sim \sum_{i=\rho,\omega} g_i \hat{h}_i \cdot \int dr' G(r,r')[(2+\chi_i) f_i' + 2 f_i (\frac{\partial}{\partial r'} - \frac{1}{r'})] \cdot u(^1S_0 : r')$$

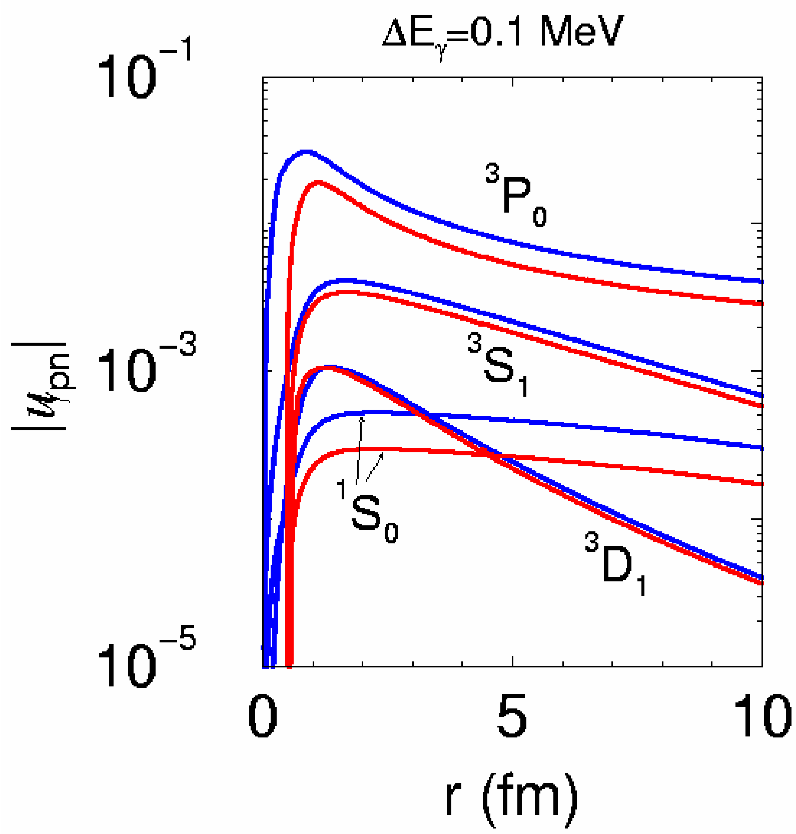


Odd-parity admixture in np-states

$$(E - T - V_{PC})\tilde{\Psi}_{PNC} = V_{PNC}\Psi; \qquad \Psi = \Psi_D, \Psi_{np}$$

$V_{PC} = V(S, L, I)$ **Paris, Hamada Johnston**



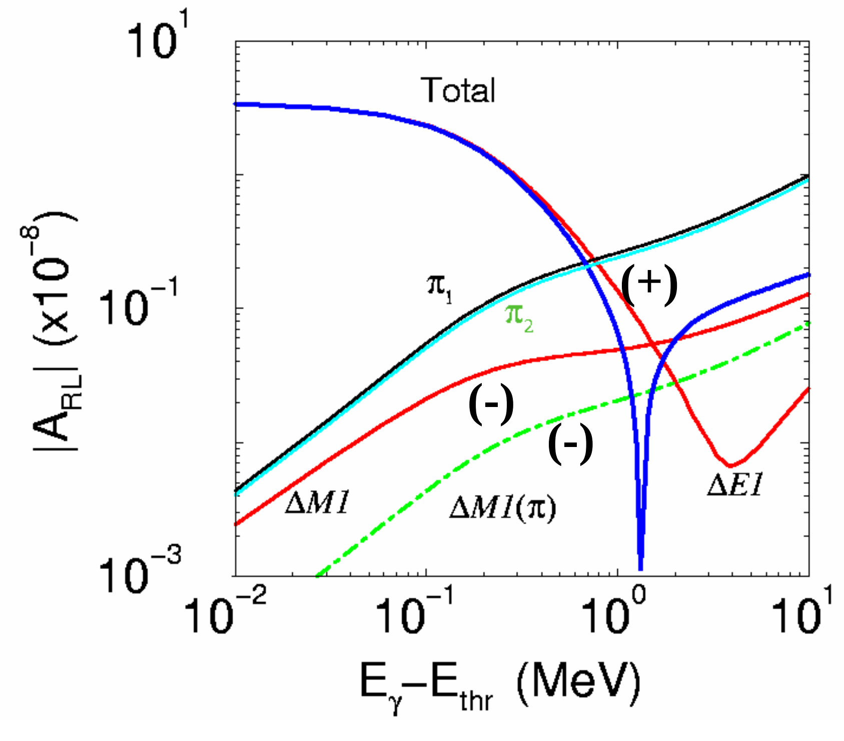


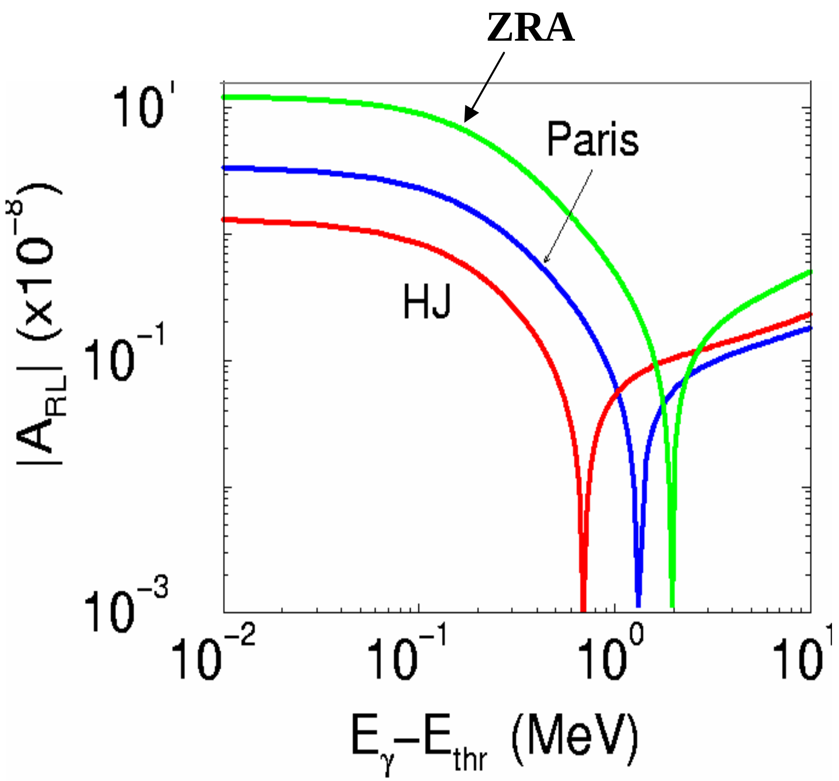
$\tilde{\Psi}$ ***are shown in units*** 10^{-6}

PNC asymmetry: polarized beam and unpolarized target

$$A_{RL}^{PNC}(E_\gamma) = 2\frac{M1 \otimes \Delta E1_V + E1 \otimes \Delta M1_V + E1 \otimes \Delta M1_\pi}{M1^2 + E1^2}$$

$$|\Delta M1(\pi)| = |\pi_1 + \pi_2| << |\pi_{1,2}|$$

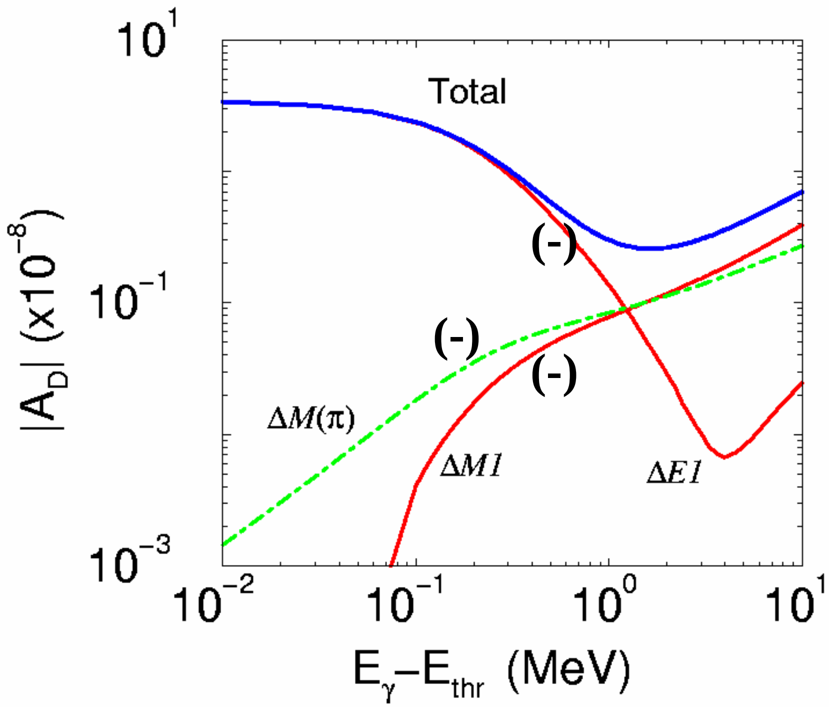


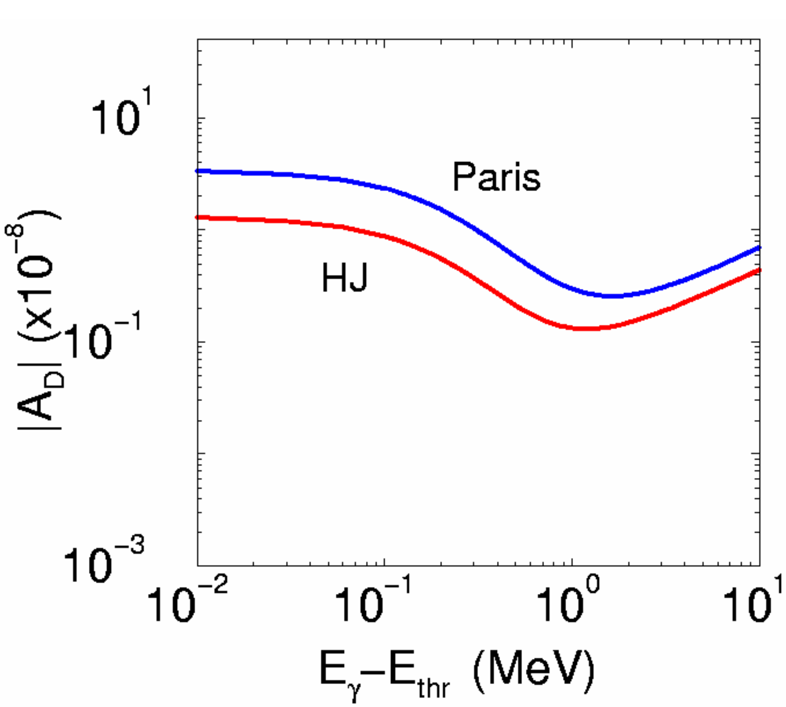


PNC asymmetry:
unpolarized beam and polarized target

$$A_D^{PNC}(E_\gamma) = 2\frac{M1\tilde{\otimes}\Delta E1_V + E1\tilde{\otimes}\Delta M1_V + E1\tilde{\otimes}\Delta M1_\pi}{M1^2 + E1^2}$$

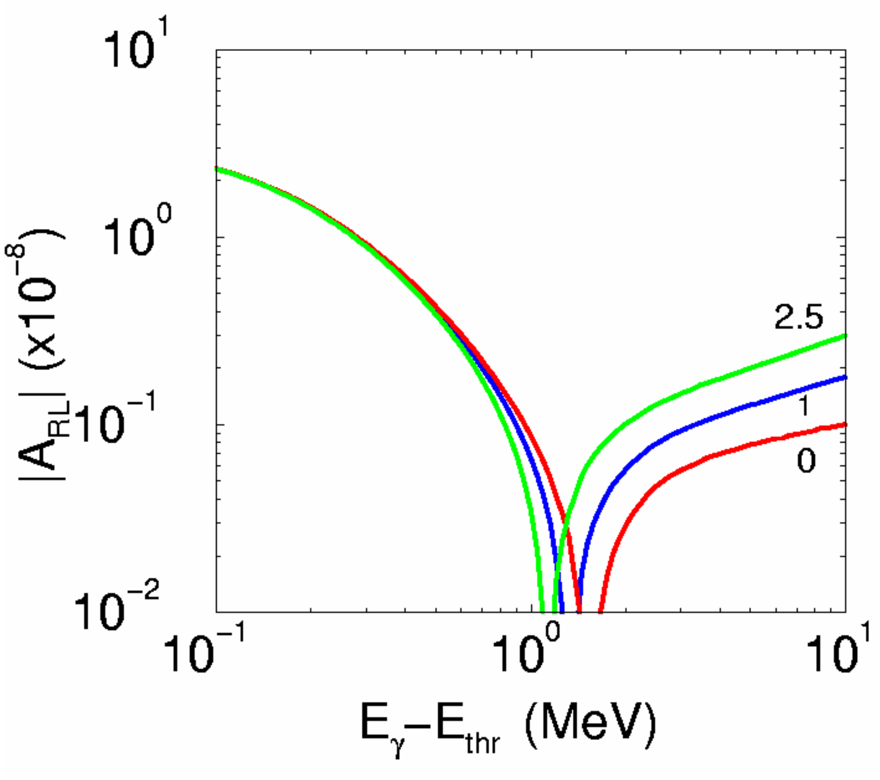
$$|\Delta M1(\pi)/\pi_2| = (2\mu_s - 1)/\mu_s \approx 0.86$$

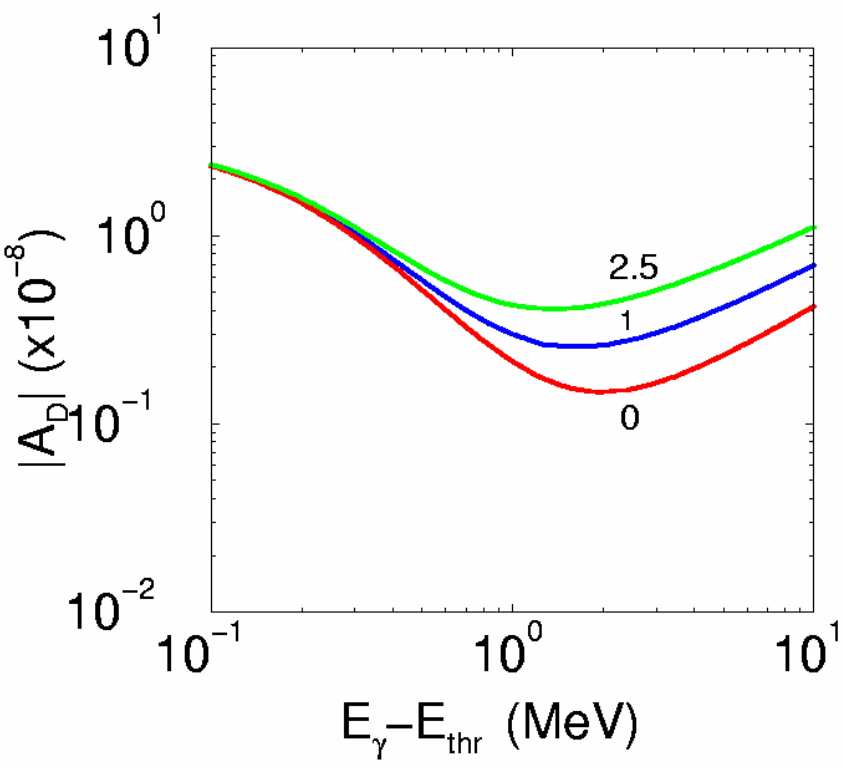




PNC asymmetries: and f_π - coupling constant

$$R_\pi = \frac{f_\pi}{f_\pi^{best}(DDH)};\ f_\pi^{best} = 4.6 \cdot 10^{-7}$$

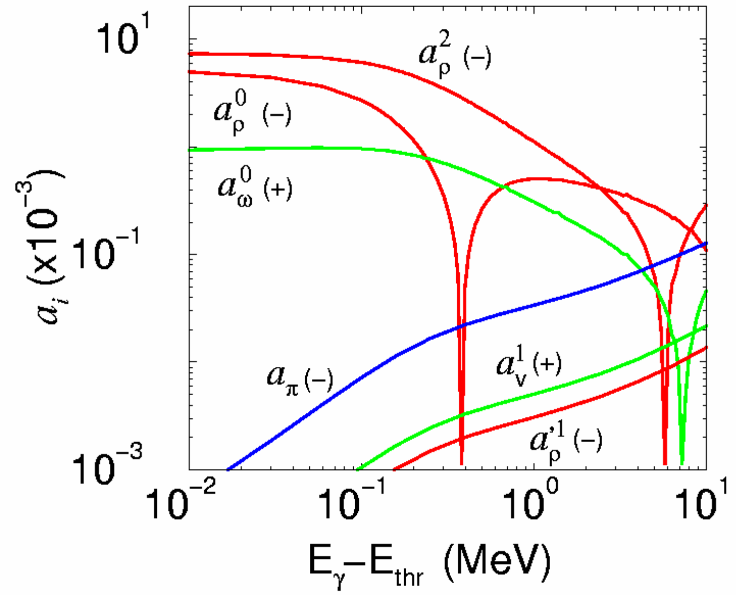


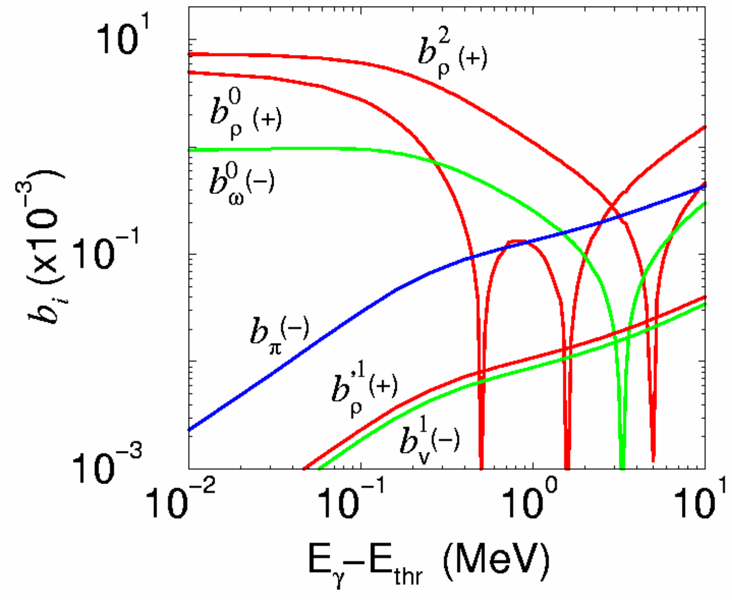


Constraints for PNC coupling constants

$$A_{RL} = a_\rho^0 g_\rho h_\rho^0 + a_\rho^2 g_\rho h_\rho^2 + a_\omega^0 g_\omega h_\omega^0 + a_v^1 (g_\omega h_\omega^1 - g_\rho h_\rho^1) + a'^1_\rho g_\rho h'^1_\rho + a_\pi g_\pi f_\pi$$

$$A_D = b_\rho^0 g_\rho h_\rho^0 + b_\rho^2 g_\rho h_\rho^2 + b_\omega^0 g_\omega h_\omega^0 + b_v^1 (g_\omega h_\omega^1 - g_\rho h_\rho^1) + b'^1_\rho g_\rho h'^1_\rho + b_\pi g_\pi f_\pi$$





$$A_{RL}(\Delta E_\gamma \to 0) \approx -(4.95 g_\rho h_\rho^0 + 2.32 g_\rho h_\rho^2 - 0.94 g_\omega h_\omega^0) \cdot 10^{-3}; A_D = -A_{RL}$$

$$A_D(\Delta E_\gamma \approx 10 MeV) \approx (1.54 g_\rho h_\rho^0 - 0.47 g_\rho h_\rho^2 + 0.30 g_\omega h_\omega^0 - 0.43 g_\pi f_\pi) \cdot 10^{-3}$$

Summary: *we found a principle possibility to obtain constraints for PNC coupling constants using only the simplest nuclear object: np-system*