NOP-T
New approach to CP-violation search

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Neutrons for CP-violation search

T-odd correlation in compound nuclei

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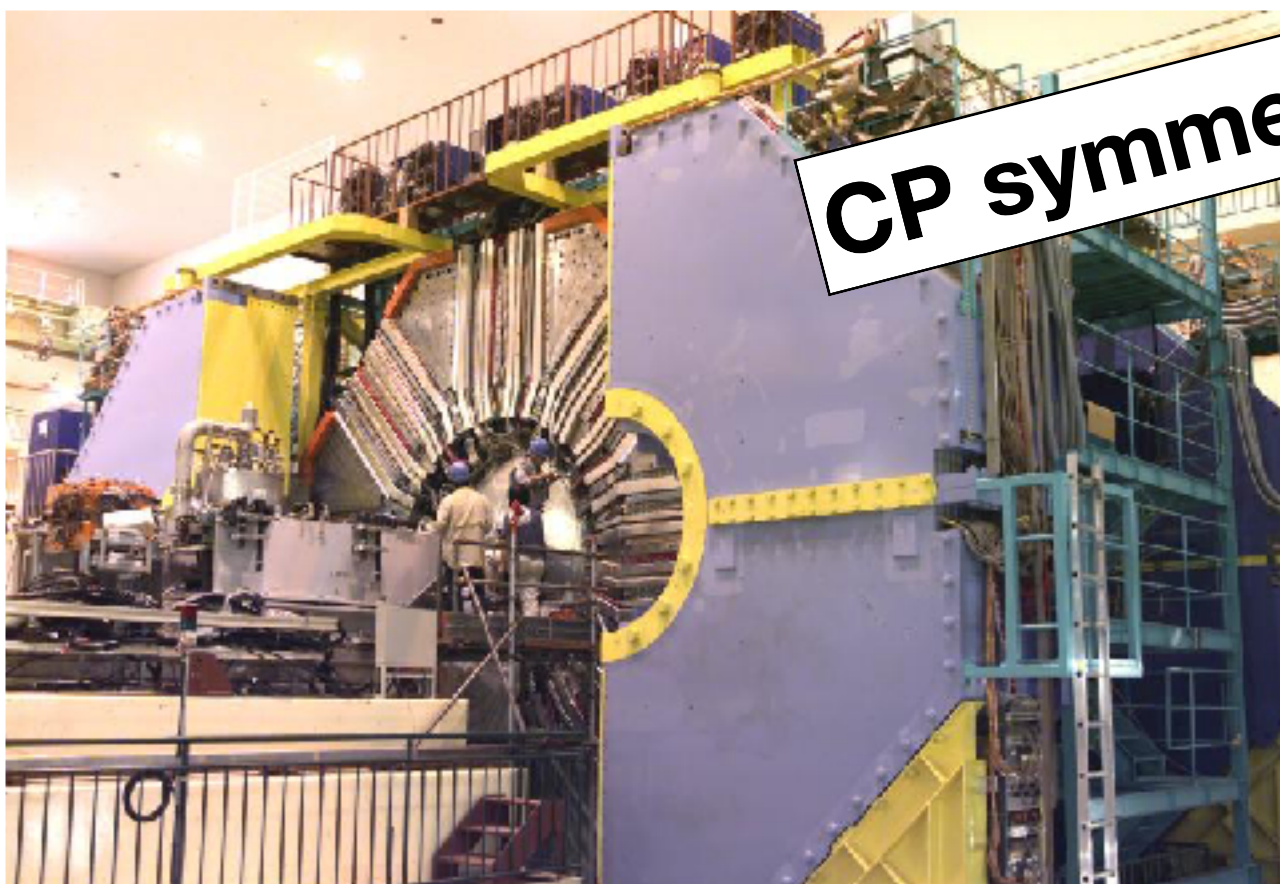
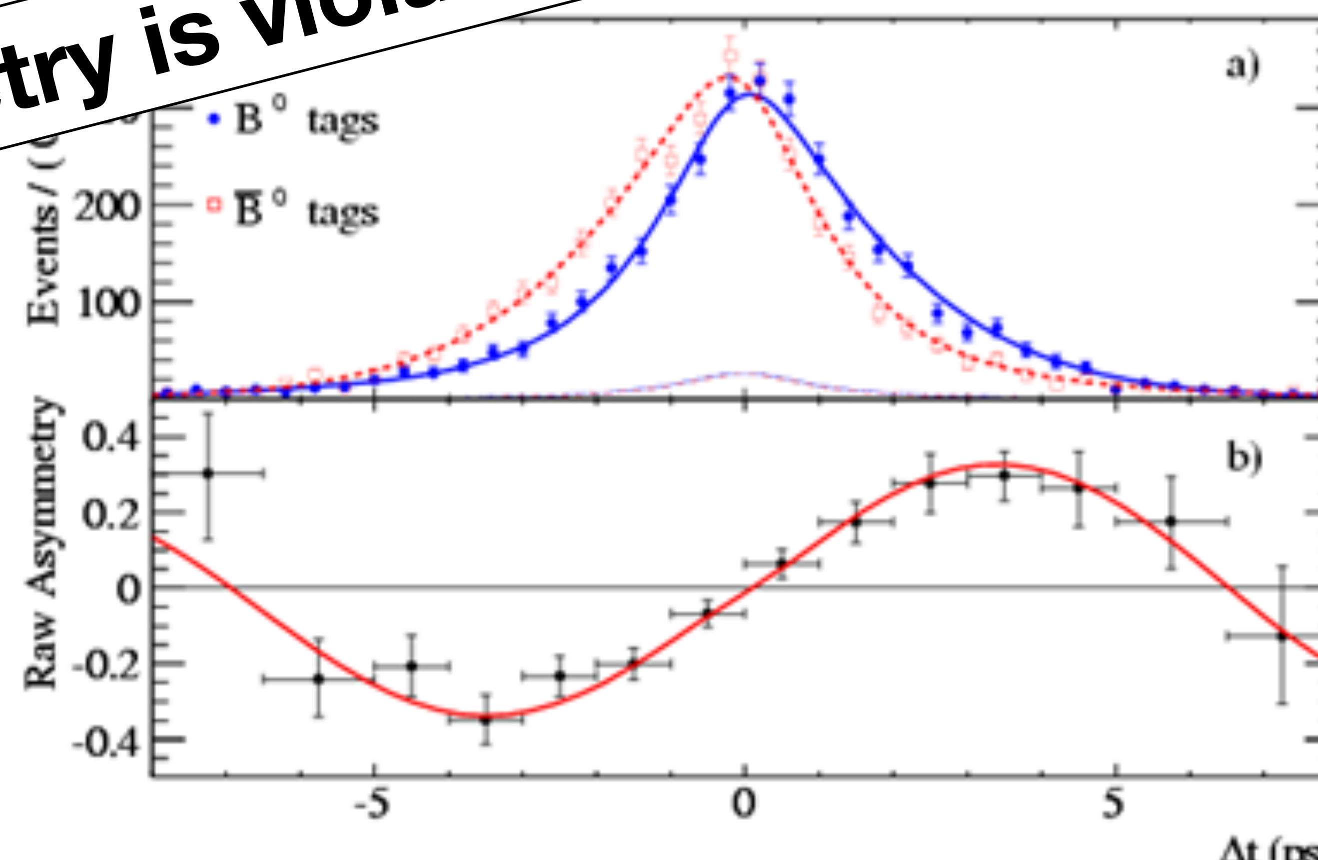
CP invariance

The laws of physics should be the same
if a particle is interchanged with its antiparticle (C symmetry), and
when its spatial coordinates are inverted (P symmetry).

This means physics is NOT the same between 'particle and antiparticle'

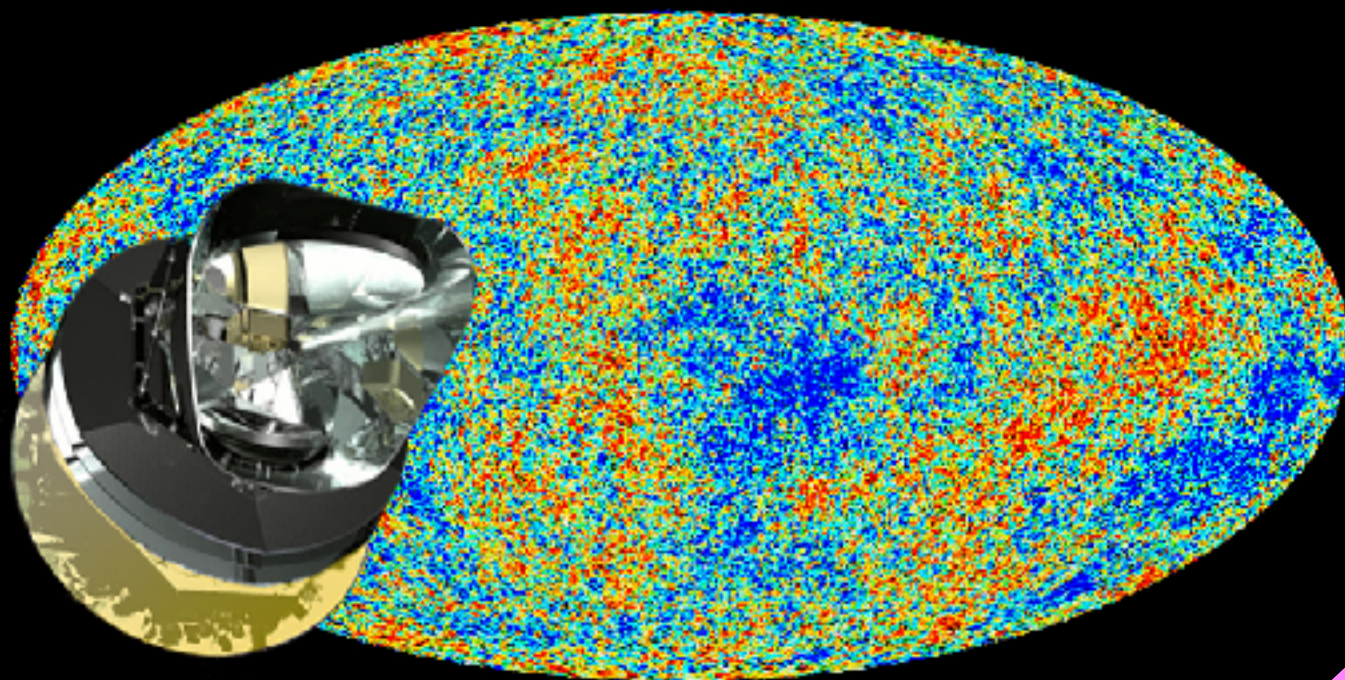
CP symmetry is violated!





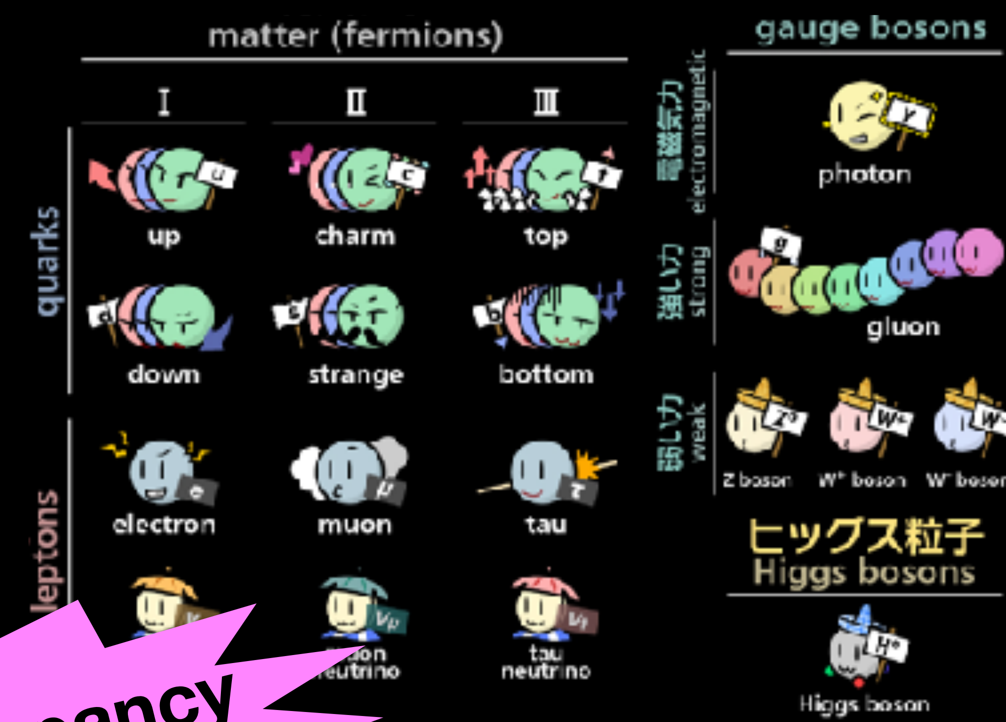
More large CP violation !

Cosmological observation



$n_b/n_\gamma=(0.61\pm0.02)\times10^{-9}$

Standard Model of particle physics

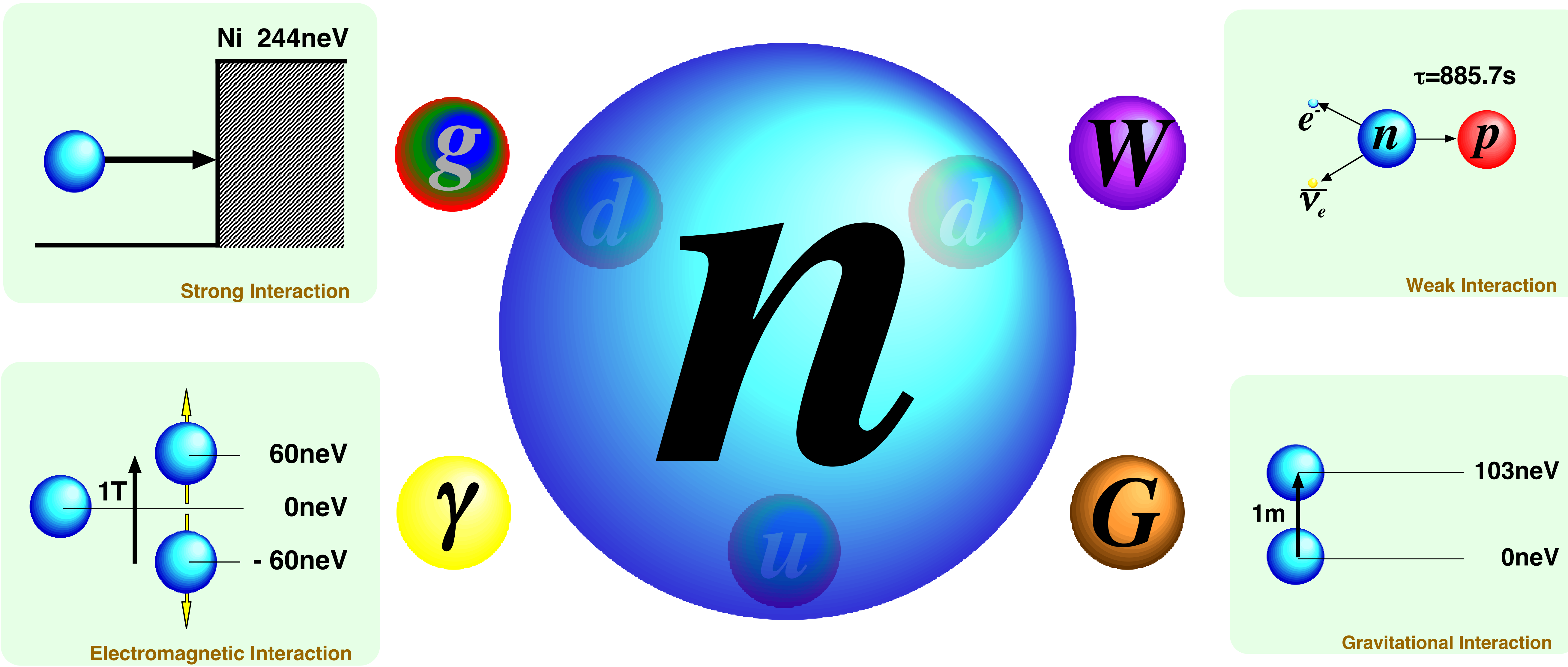


$n_b/n_\gamma=10^{-18}$

Large discrepancy 10^9

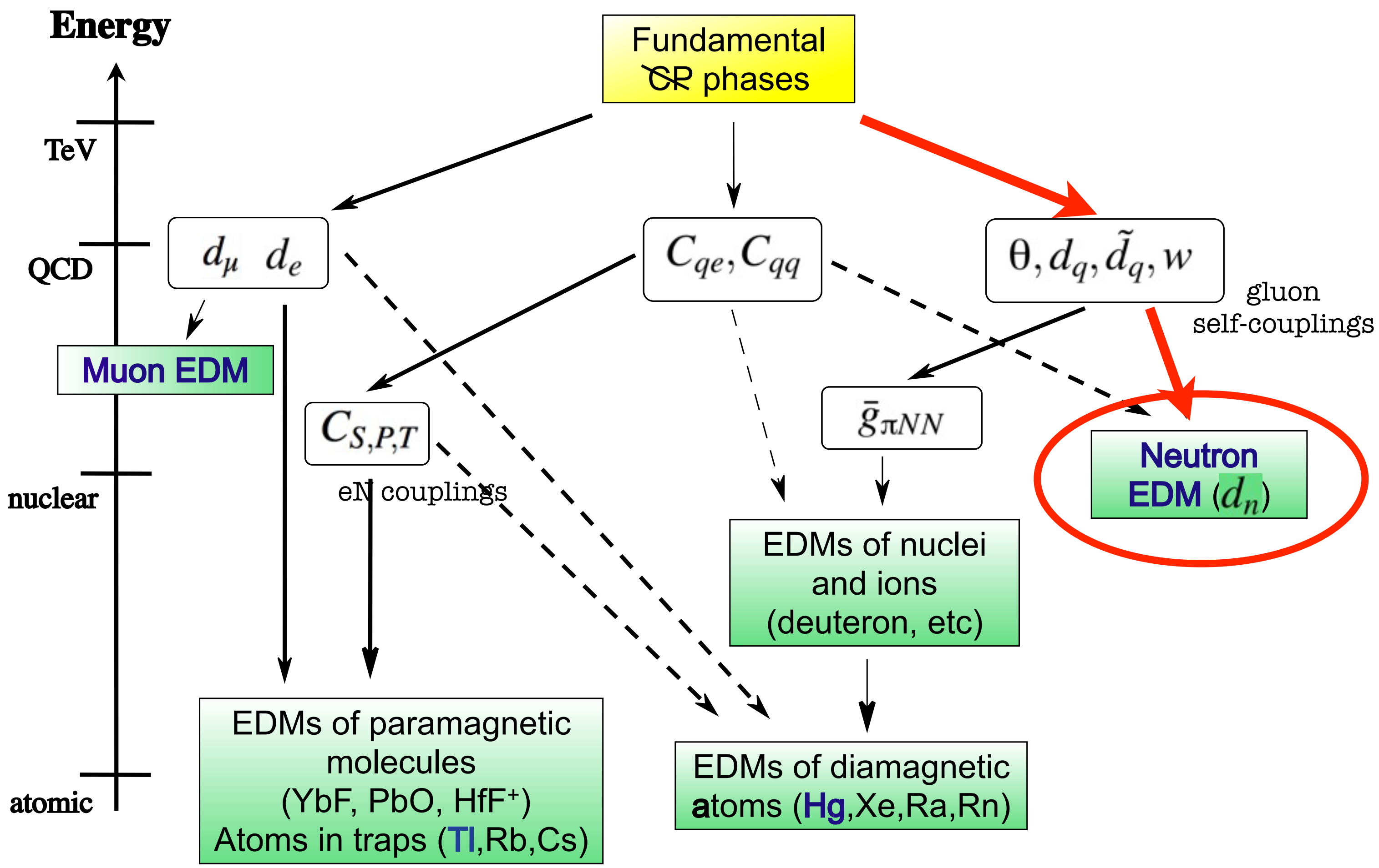
Larger CP violation (from unknown source) is required !

Fundamental Physics with Neutrons



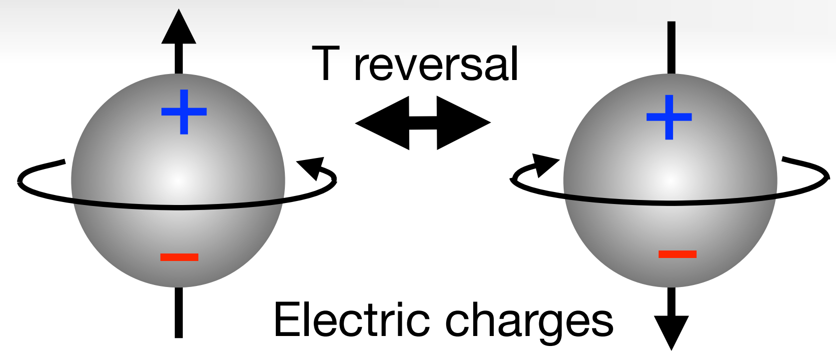
suitable for precision measurement

Neutron EDM

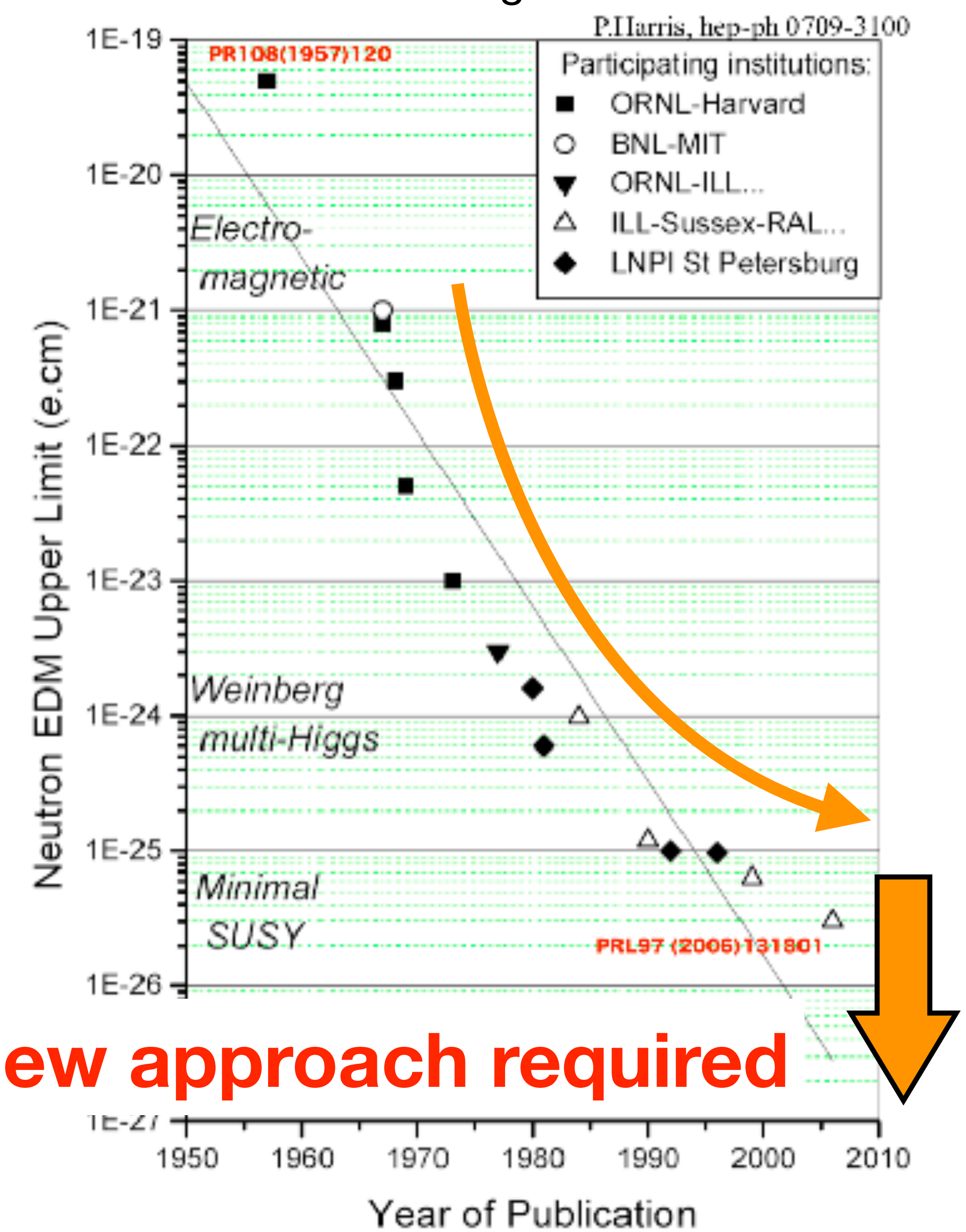


Pospelov Ritz, Ann Phys 318 (05) 119

Spin is reversed.



Electric charges
don't change.



Present upper limit $|d_n| < 2.9 \times 10^{-26}\ e$ cm

is approaching to the predictions of some physics beyond the standard model of particle physics.

New approach required

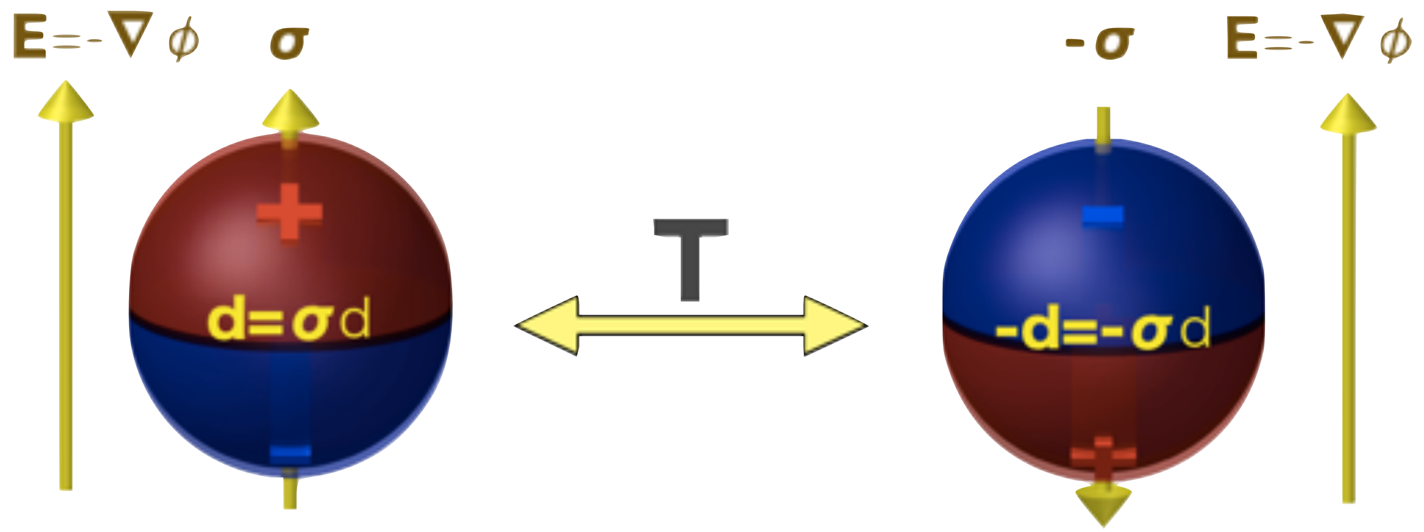
Standerd Model : $|d_n| \sim 10^{-32}\ e$ cm

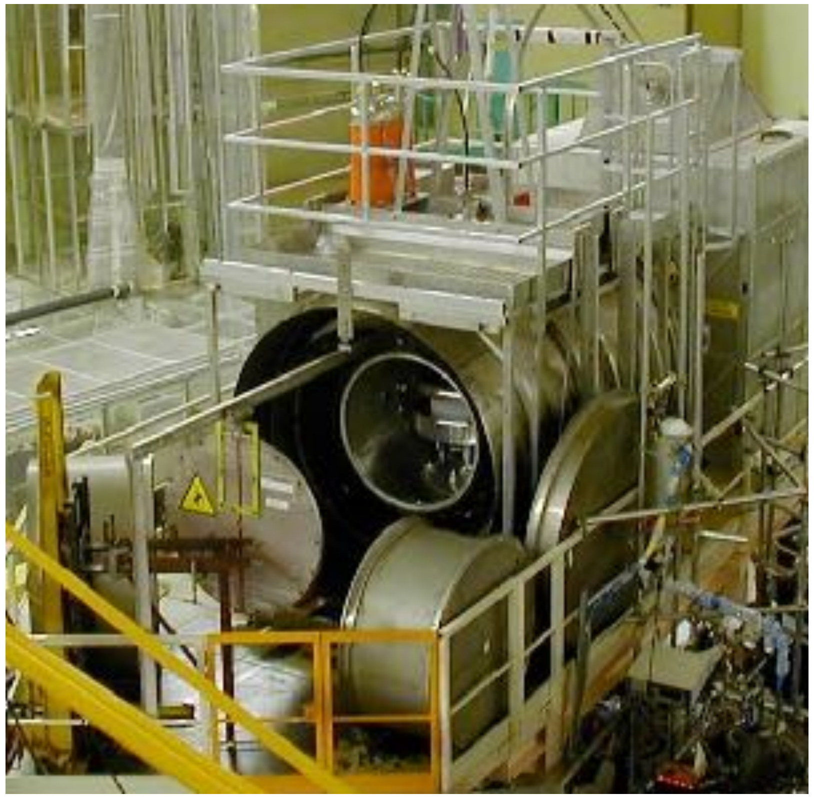
New Physics (SUSY ...) : $|d_n| \sim 10^{-27 \sim -28}\ e$ cm

Neutron Electric Dipole Moment search

CPT theorem says **CP violation is equivalent to T violation.**

EDM signals T violation.





ILL-Sasex experiment with UCNs

Present upper limit $|d_n| < 3.0 \times 10^{-26}\ e\ \mathrm{cm}$

is close to beyond standard model.

Intense UCN sources are now constructing at PSI, TRIUMF, SNS,…

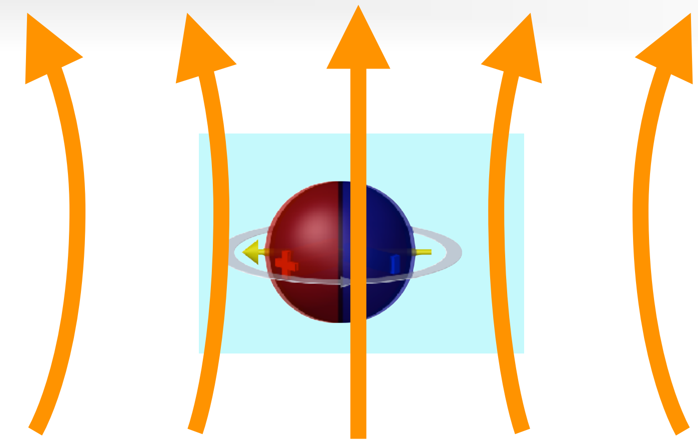
Neutron EDM

Dense UCNs

Precessions of stored UCNs are measured.

$$\frac{\omega_\pm}{2\pi} = 3\times 10^{1}\frac{B}{1\mu T} \pm 5\times 10^{-8}\frac{d_n}{10^{-26}\mathrm{e}\cdot\mathrm{cm}}\frac{E}{10\mathrm{kV/cm}}$$

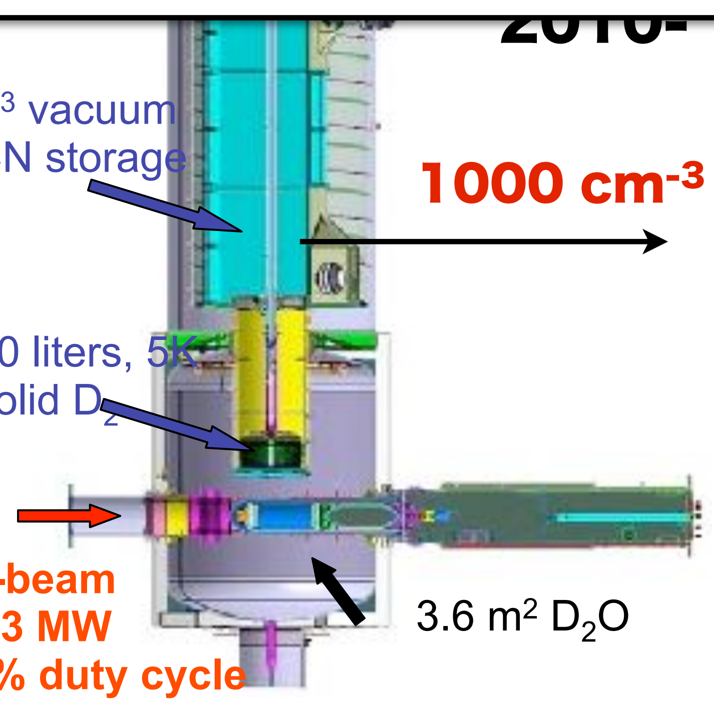
1 μT   1fT equiv.



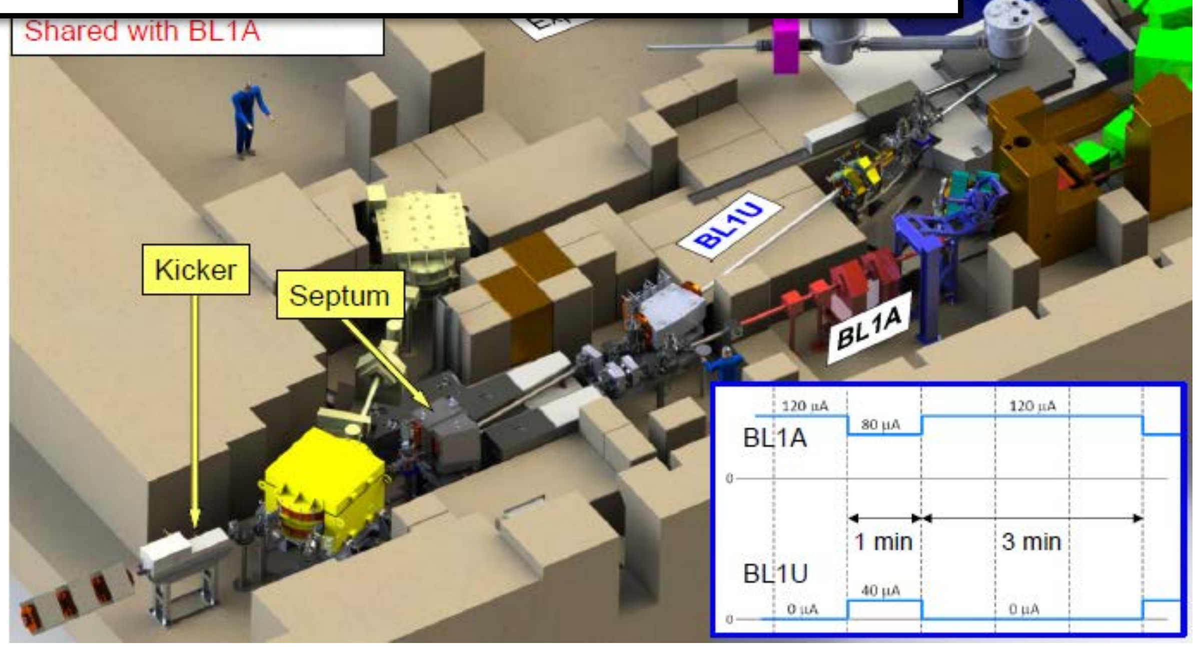
Use int

Challenge to improve the sensitivity

RCNP-
UMF



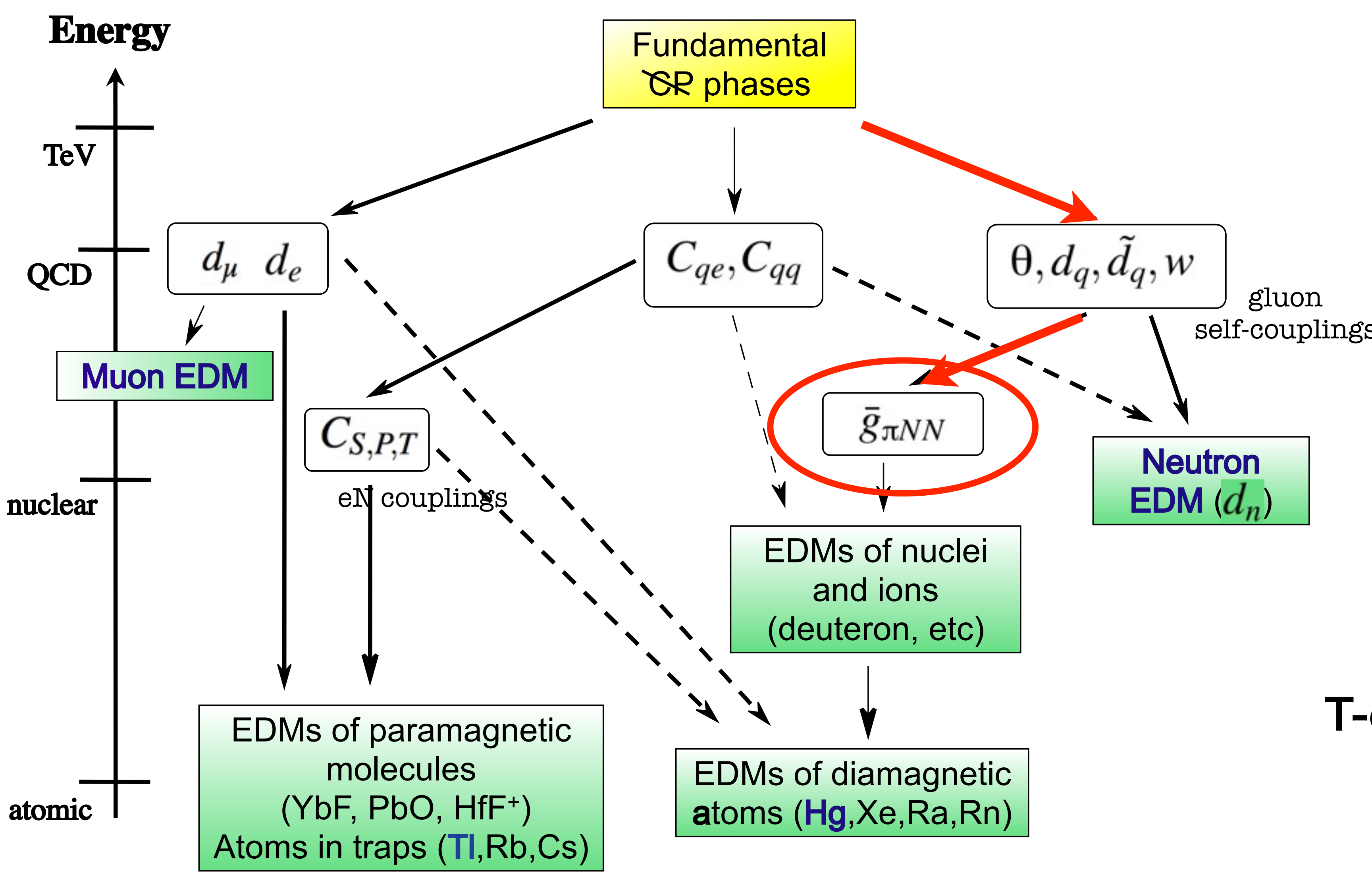
average = 13kW
max. peak power = 1.3MW



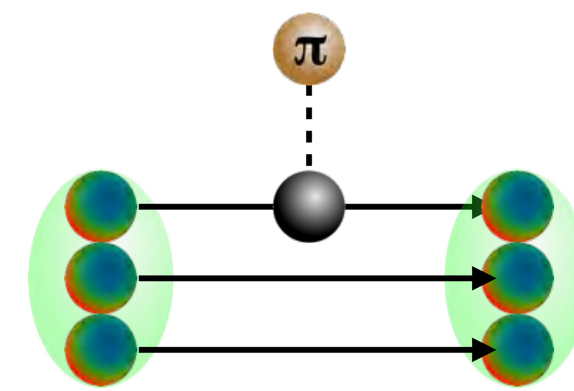
average=20kW
max. peak power = 200kW

T-odd correlation in compound nuclei

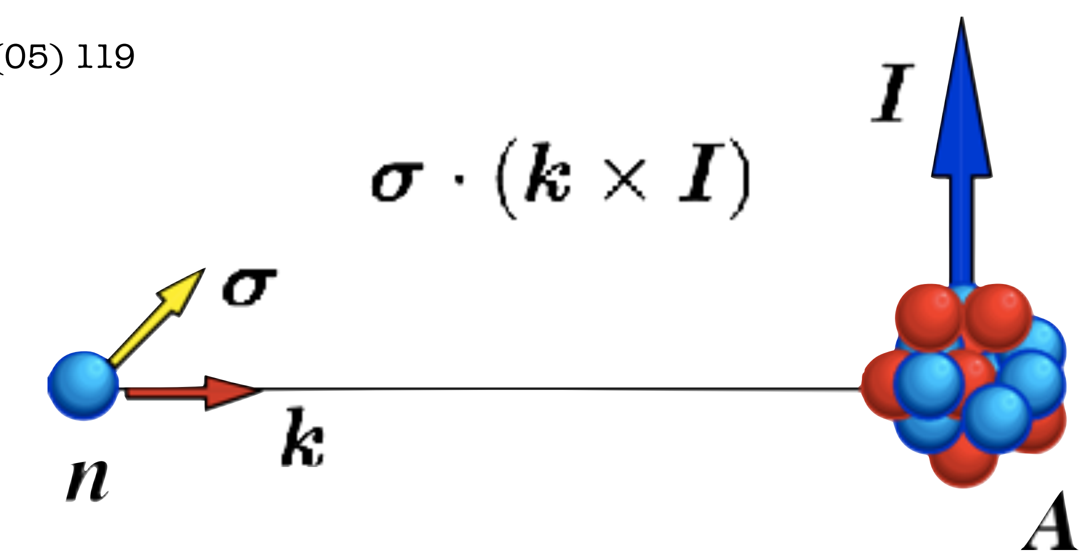
T-odd Correlation in Compound Nuclei



Pospelov Ritz, Ann Phys 318 (05) 119

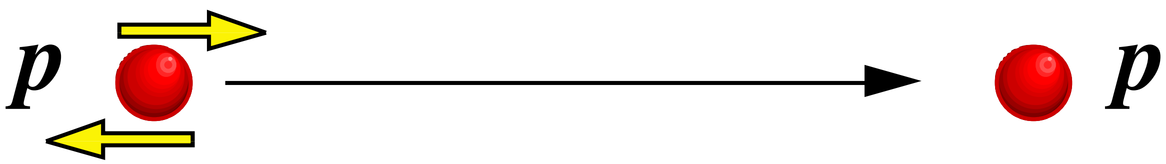


T-odd P-odd pion-nucleon coupling



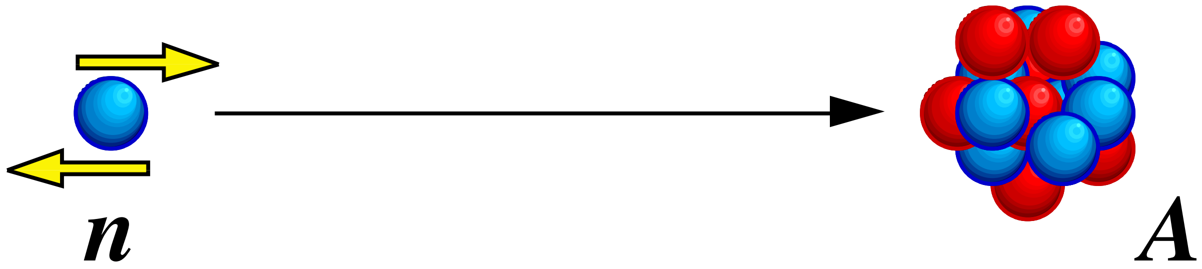
P-violation in compound nuclei

P-violation in nucleon

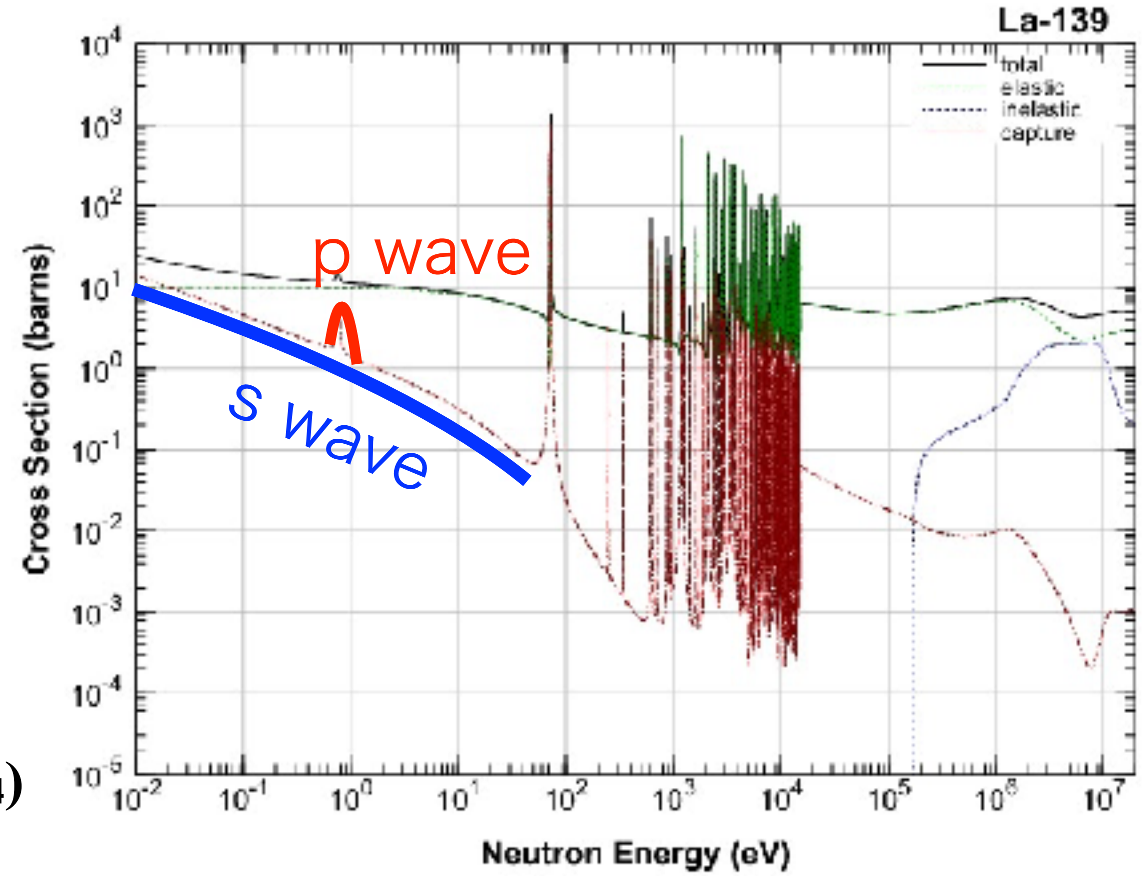


15MeV	$-(1.7\pm0.8)\times10^{-7}$
45MeV	$-(2.3\pm0.8)\times10^{-7}$
800MeV	$-(2.4\pm1.1\pm0.1)\times10^{-7}$

P-violation in neutron-nuclei reaction



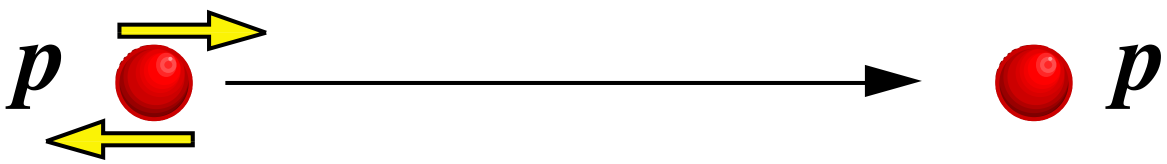
^{139}La	$E_n = 0.734$ eV	0.097 ± 0.003
^{81}Br	$E_n = 0.734$ eV	0.021 ± 0.001
^{111}Cd	$E_n = 4.53$ eV	$-(0.013^{+0.007}_{-0.004})$



P-violation is enhanced in p-wave resonance of compound nuclei

P-violation in compound nuclei

P-violation in nucleon



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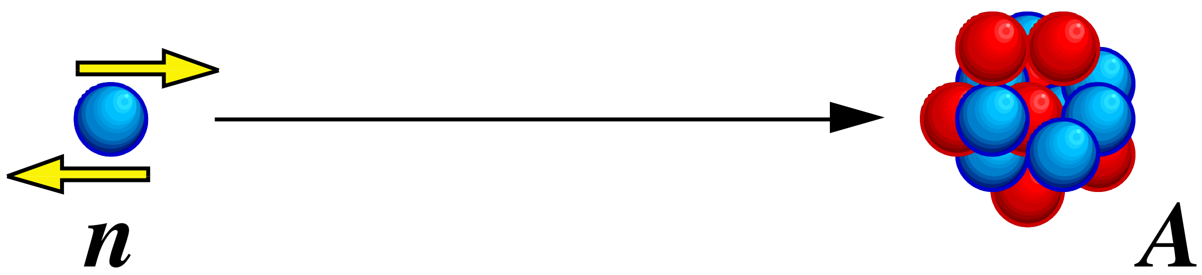

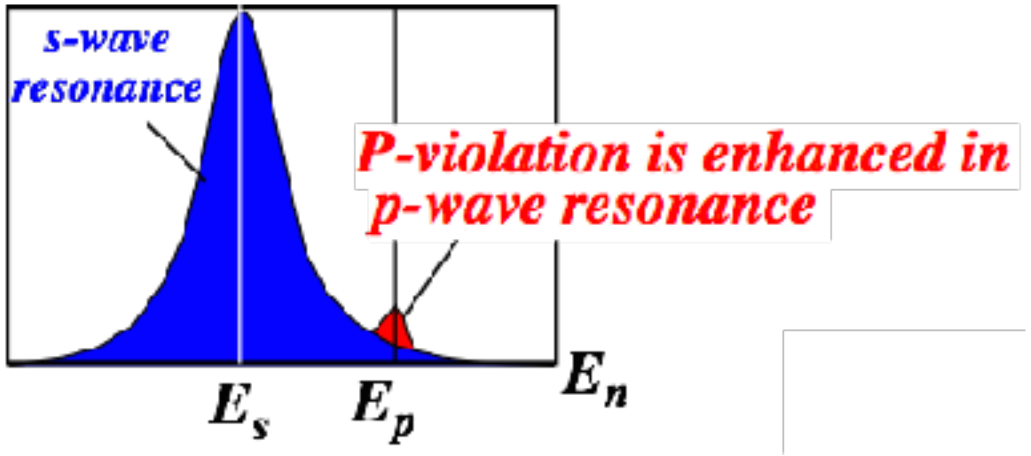

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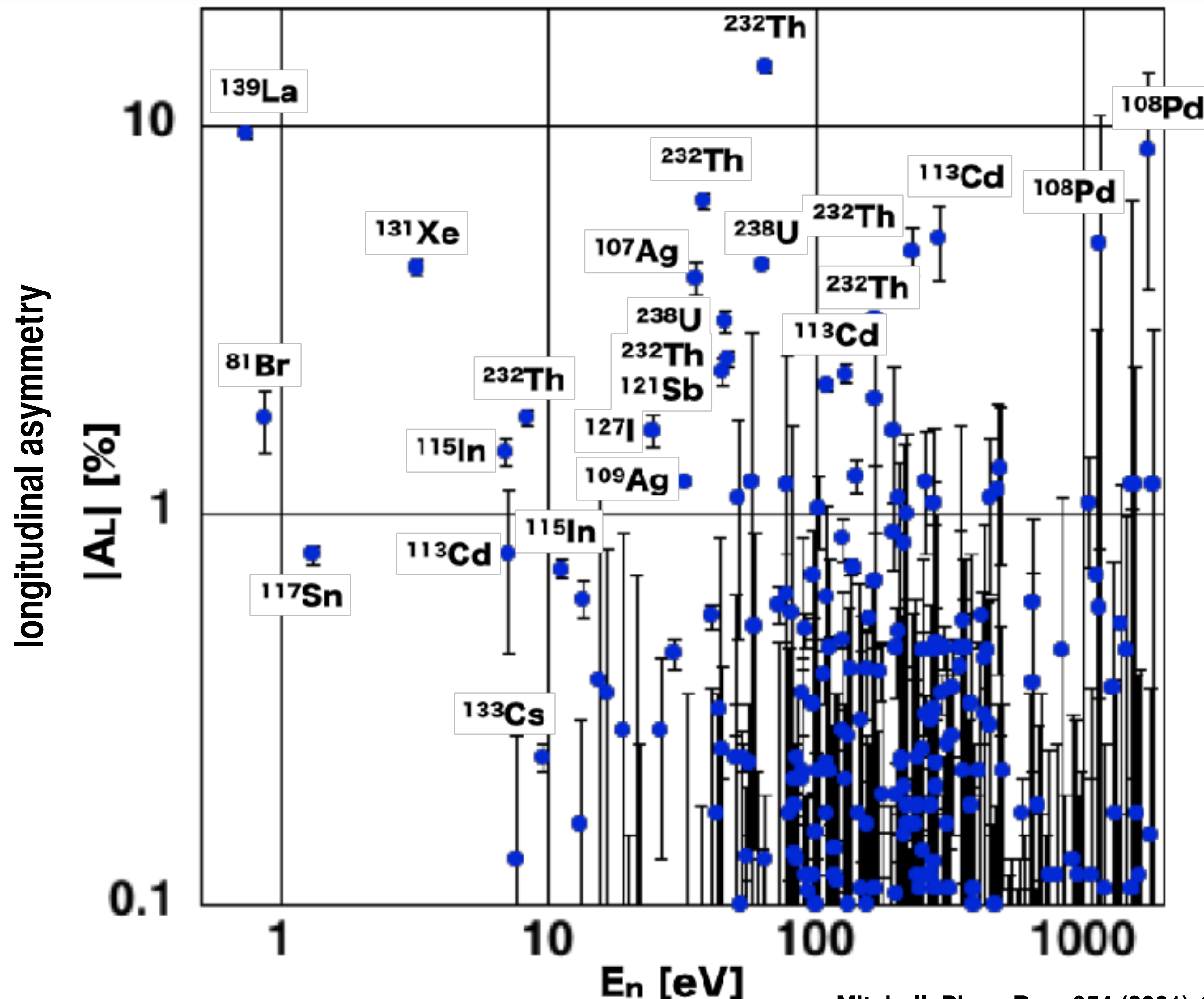
2% of p-wave total cross section

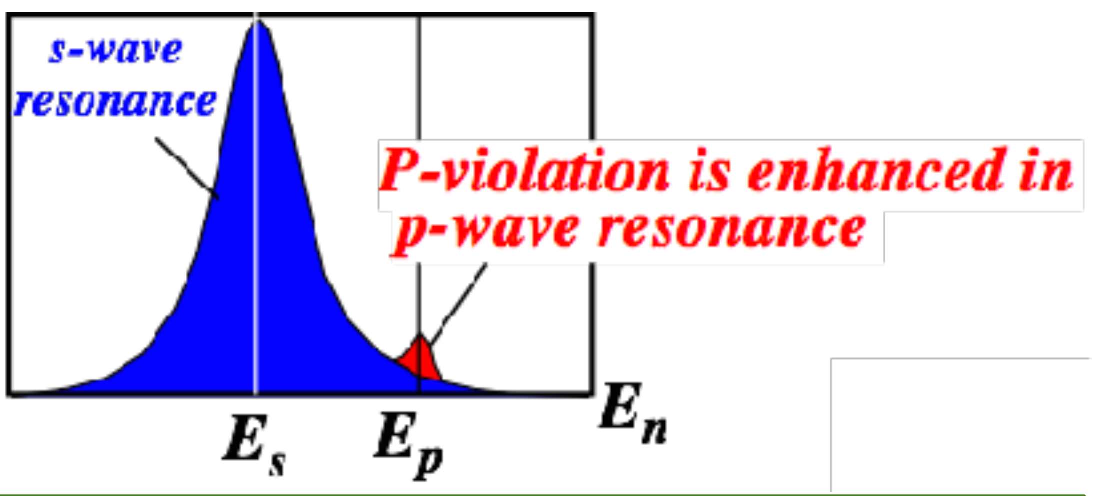
P-violation is enhanced in p-wave resonance of compound nuclei

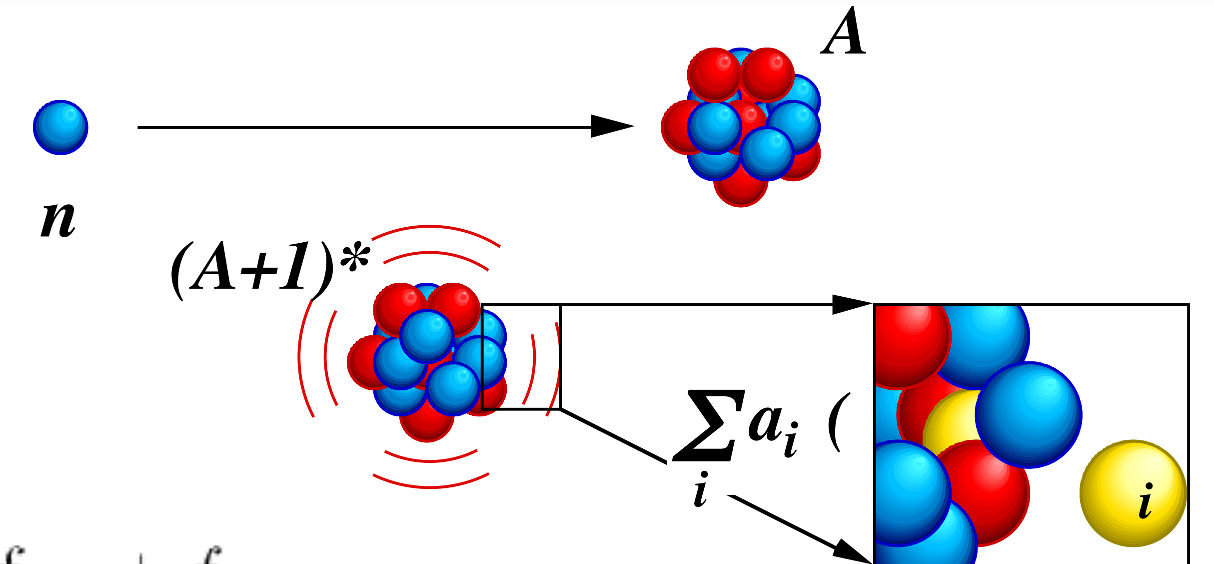
P-violation in compound nuclei



Mitchell, Phys. Rep. 354 (2001) 157

P-violation in compound nuclei





$$J = I + j \qquad j = l + s$$

- J: Resonance spin
- I: target spin
- j: neutron total angular momentum

$l = 0$ **s-wave resonance** s

$1/kR \sim 10^{-3}$

$l = 1$ **p-wave resonance**

$j = 1/2 \quad p_{1/2}$

$j = 3/2 \quad p_{3/2}$

interference

J is good quantum number

$$f = f_{\rm PC} + f_{\rm PNC}$$

$$\Rightarrow |f|^2 = |f_{\rm PC}|^2 + 2{\rm Re}\, f_{\rm PC} f_{\rm PNC} + |f_{\rm PNC}|^2$$

$$\alpha = \frac{2{\rm Re}\, f_{\rm PC} f_{\rm PNC}}{|f_{\rm PC}|^2} \sim 2\frac{|f_{\rm PNC}|}{|f_{\rm PC}|}$$

Dynamic Enhancement | Structural Enhancement

$$\xrightarrow[E = E_p]{} \frac{2W}{|E_p - E_s|}\sqrt{\frac{\Gamma^n_s}{\Gamma^n_p}}$$

10^2 - 10^3 $\sim 10^3$

T-violation in compound nuclei

The interference between s-wave and p-wave results in the interference between partial waves with different channel spin.

Gudkov, Phys. Rep. 212 (1992) 77.

$$\Delta\sigma_{\mathrm{CP}} = \kappa(J)\frac{w}{v}\Delta\sigma_{\mathrm{P}}$$

T-violation

$$\kappa(I-\frac{1}{2}) = (-1)^{2I}\left(1+\frac{1}{2}\sqrt{\frac{2I-1}{I+1}}\frac{y}{x}\right)$$

$$\kappa(I-\frac{1}{2}) = (-1)^{2I+1}\frac{I}{I+1}\left(1-\frac{1}{2}\sqrt{\frac{2I+3}{I}}\frac{y}{x}\right)$$

$$x^2 = \frac{\Gamma^n_{p,1/2}}{\Gamma^n_p} \qquad y^2 = \frac{\Gamma^n_{p,3/2}}{\Gamma^n_p}$$

Unknown parameter

$$x^2 + y^2 = 1$$

$$x = \cos\phi \qquad y = \sin\phi$$

T-violation in compound nuclei

The interference between s-wave and p-wave results in the interference between partial waves with different channel spin.

Gudkov, Phys. Rep. 212 (1992) 77.

$$\boldsymbol{J} = \boldsymbol{l} + \boldsymbol{s} + \boldsymbol{I}$$

$$\boldsymbol{j} = \boldsymbol{l} + \boldsymbol{s}$$

$$\boldsymbol{S} = \boldsymbol{s} + \boldsymbol{I}$$

$$P : |lsI\rangle \to (-1)^l |lsI\rangle$$

$$T : |lsI\rangle \to (-1)^{i\pi S_y} K |lsI\rangle$$

$$\begin{aligned} |((Is)S,l)J\rangle &= \sum_j \langle (I,(sl)j)J|((Is)S,l)J\rangle \, |(I,(sl)j)J\rangle \\ &= \sum_j (-1)^{l+s+I+J} \sqrt{(2j+1)(2S+1)} \left\{ \begin{matrix} I & s & l \\ J & S & j \end{matrix} \right\} |(I,(sl)j)J\rangle \end{aligned}$$

$$x = \sqrt{\frac{\Gamma_p^n(j=1/2)}{\Gamma_p^n}} \quad y = \sqrt{\frac{\Gamma_p^n(j=3/2)}{\Gamma_p^n}} \quad x_S = \sqrt{\frac{\Gamma_p^n(S=I-1/2)}{\Gamma_p^n}} \quad y_S = \sqrt{\frac{\Gamma_p^n(S=I+1/2)}{\Gamma_p^n}}$$

$$z_j = \left\{ \begin{matrix} x & (j=1/2) \\ y & (j=3/2) \end{matrix} \right. , \quad \tilde{z}_S = \left\{ \begin{matrix} x_S & (S=I-1/2) \\ y_S & (S=I+1/2) \end{matrix} \right. \quad \tilde{z}_S = \sum_j (-1)^{l+I+j+S} \sqrt{(2j+1)(2S+1)} \left\{ \begin{matrix} l & s & j \\ I & J & S \end{matrix} \right\} z_j$$

T-odd Correlation in Compound Nuclei

Gudkov, Phys. Rep. 212 (1992) 77.

T-violation is also enhanced?

$$\Delta\sigma_{\mathrm{CP}} = \kappa(J)\frac{w}{v}\Delta\sigma_{\mathrm{P}}$$

T-violation

g_{CP}/g_P P-violation

10^{-3} $10^{-2}\,\sigma_{tot}$

compare with EDM 

$$d_n = \frac{e}{m_N}\frac{g_\pi(\bar{g}_\pi^{(0)} - \bar{g}_\pi^{(2)})}{4\pi^2}\ln\frac{m_N}{m_\pi}$$

$$\simeq 0.14(\bar{g}_\pi^{(0)} - \bar{g}_\pi^{(2)})$$

from upper limit of EDM

$$|d_n| < 2.9\times10^{-26}\,\mathrm{e\,cm}$$

$$\rightarrow \bar{g}_\pi^{(0)} < 2.5\times10^{-10}$$

Estimation in effective field theory

Y.-H.Song et al., Phys. Rev. C83 (2011) 065503

$$|\Delta\sigma_{\mathrm{T}}^{nA}| \le 10^6\times\kappa(J)\left[\bar{g}_\pi^{(0)} + 0.26\bar{g}_\pi^{(1)} - 0.0012\bar{g}_\eta^{(0)} + 0.0034\bar{g}_\eta^{(1)}\right.$$
$$\left. -0.0071\bar{g}_\rho^{(0)} + 0.0035\bar{g}_\rho^{(1)} + 0.0019\bar{g}_\omega^{(0)} - 0.00063\bar{g}_\omega^{(1)}\right]$$

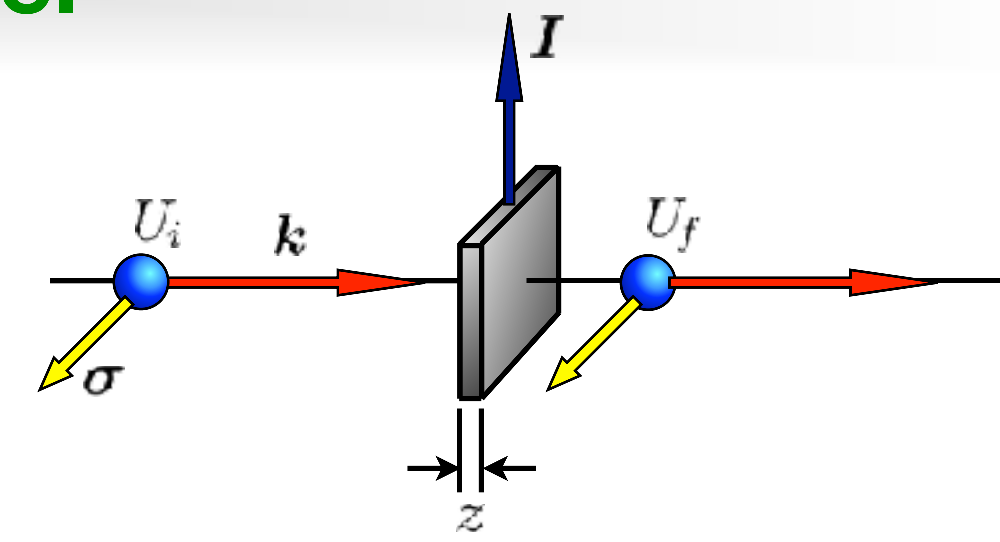
$$\simeq 10^5[\mathrm{b}]\times\boxed{\kappa(J)}\times\boxed{\bar{g}_\pi^{(0)}}$$

$$\boxed{|\Delta\sigma_{\mathrm{T}}^{nA}| < 2.5\times10^{-4}[\mathrm{b}]\times\kappa(J)}$$

More sensitive measurement with $0.25[\mathrm{mb}]\times\kappa(J)$

T-odd Correlation in Compound Nuclei

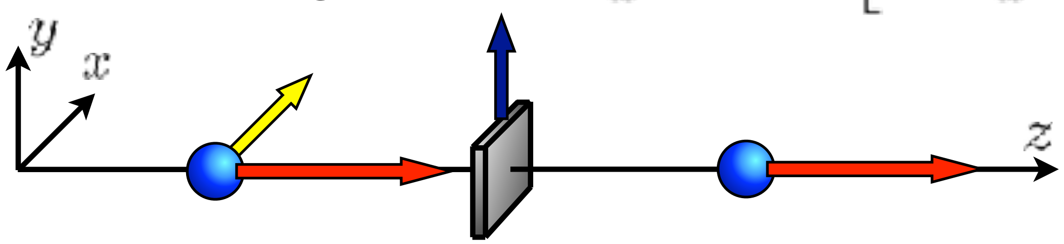
$$U_f = \delta U_i \qquad \delta = e^{i(n-1)kz} \qquad n = 1 + \frac{2\pi\rho}{k^2} f$$



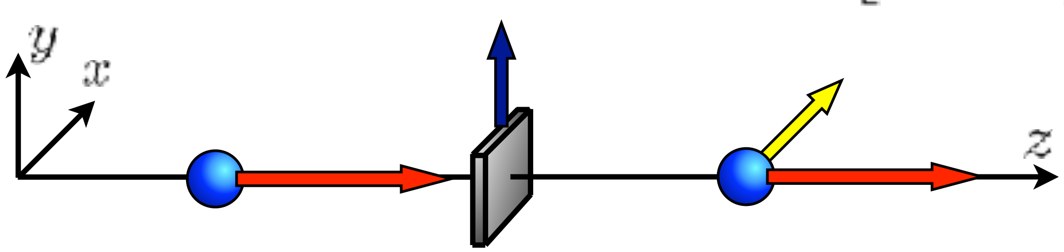
$$\delta = A + B\boldsymbol{\sigma}\cdot\hat{\boldsymbol{I}} + C\boldsymbol{\sigma}\cdot\hat{\boldsymbol{k}} + D\boldsymbol{\sigma}\cdot\left(\hat{\boldsymbol{I}}\times\hat{\boldsymbol{k}}\right)$$

- A: Spin Independent, P-even T-even
- B: Spin Dependent, P-even T-even
- C: P-violation, P-odd T-even
- D: T-violation, P-odd T-odd

Analyzing Power $A_x \equiv \mathrm{Tr}\left[\delta^\dagger \sigma_x \delta\right]$

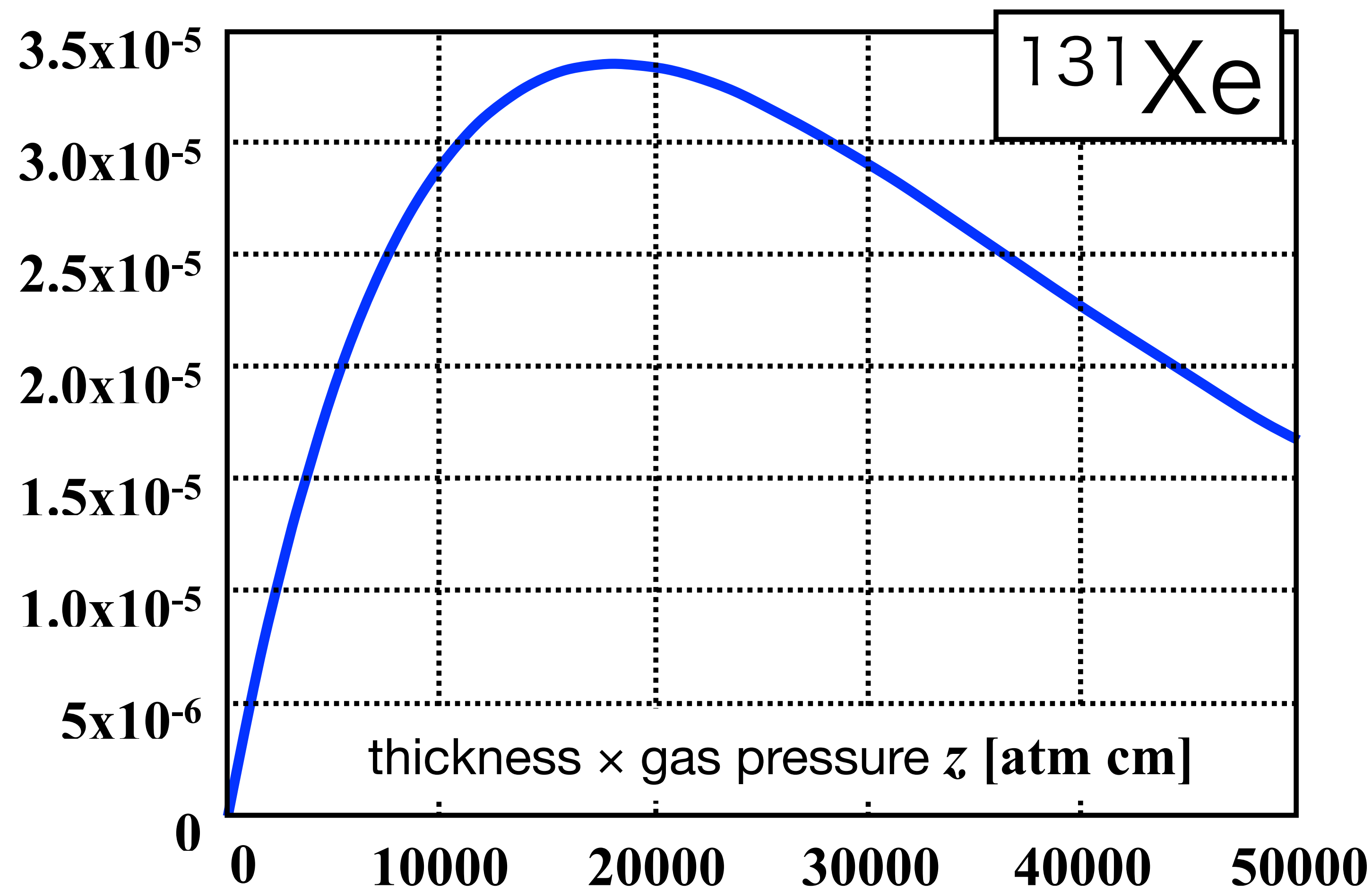


Polarization $P_x \equiv \mathrm{Tr}\left[\sigma_x \delta^\dagger \delta\right]$



$$A_x + P_x = 8\mathrm{Re}\, A^* D$$

$8\mathrm{Re}\, A^* D$



T-odd Correlation in Compound Nuclei

NOP-T

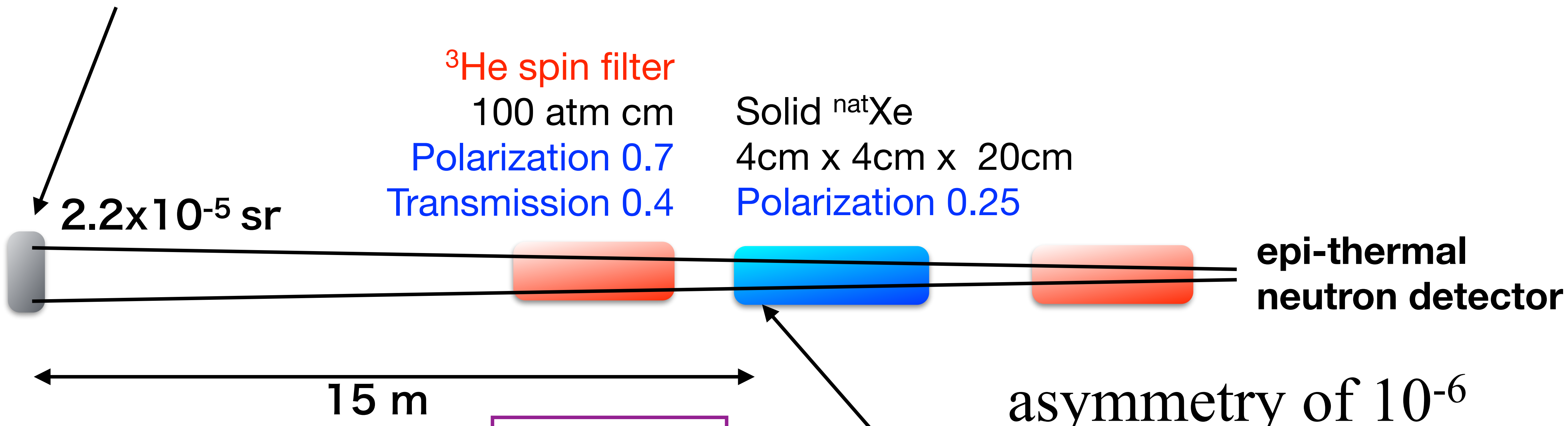
Experimental plan

p-wave resonance $E_n = 3.2$ eV

$\Gamma_n = 0.1$ eV

J-PARC BL07（Poisoned Moderator)

10^{11} n cm^{-2} s^{-1} sr^{-1} eV^{-1} MW^{-1}



asymmetry of 10^{-6}

$$\kappa(J) = 1$$

$$\frac{w}{v} = \frac{g_{CP}}{g_P} = 10^{-3}$$

7 x 10^6 n s^{-1} at sample position

~ 5 days

T-odd Correlation in Compound Nuclei

	^{139}La	^{81}Br	^{117}Sn	^{131}Xe	^{115}In
large $\Delta\sigma_P$	◎	○	◎	◎	◎
low E_p [eV]	◎	◎	○	○	△
small nonzero I	7/2 △	3/2 ○	1/2 ◎	3/2 ○	9/2 △
isotopic abn	◎	○	×	△	◎
large $\lvert\kappa(J)\rvert$	○?	?	?	◎?	?
method of pol.	DNP	—	—	OP	—

Feasibility studies and R&D

Target of NOP-T

Target nuclei

- Large T-violating effect
- Easy to polarize

Epithermal neutrons

- High-intensity beamline
- Polarized neutrons

Target of NOP-T

Nuclei with large $\kappa(J)$ is suitable.

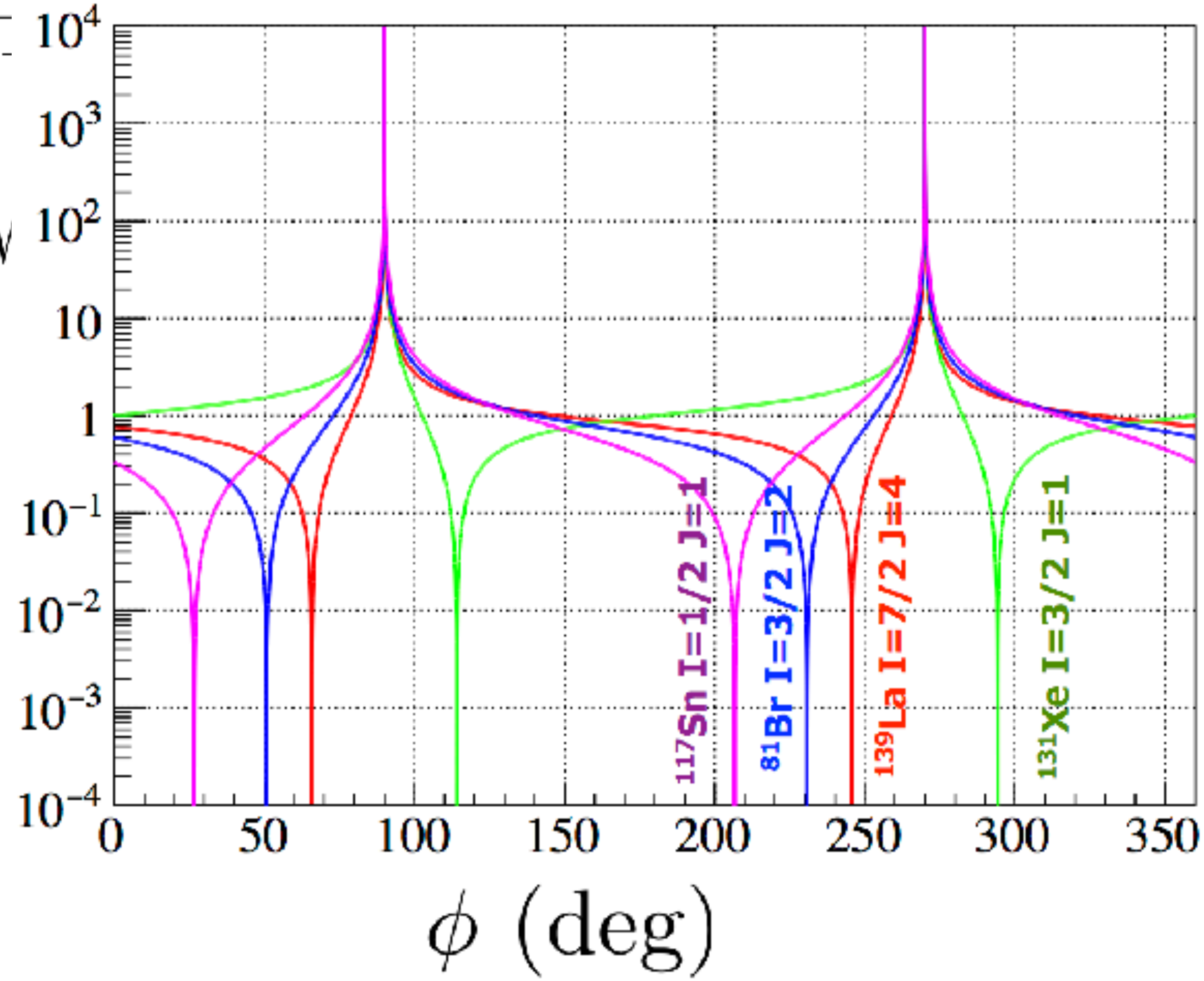
$$\kappa(I-\frac{1}{2}) = (-1)^{2I}\left(1+\frac{1}{2}\sqrt{\frac{2I-1}{I\ldots}}\,y\ldots\right)$$

$$\kappa(I-\frac{1}{2}) = (-1)^{2I+1}\frac{I}{I+1}\left(1-\frac{1}{2}\sqrt{\ldots}\right.$$

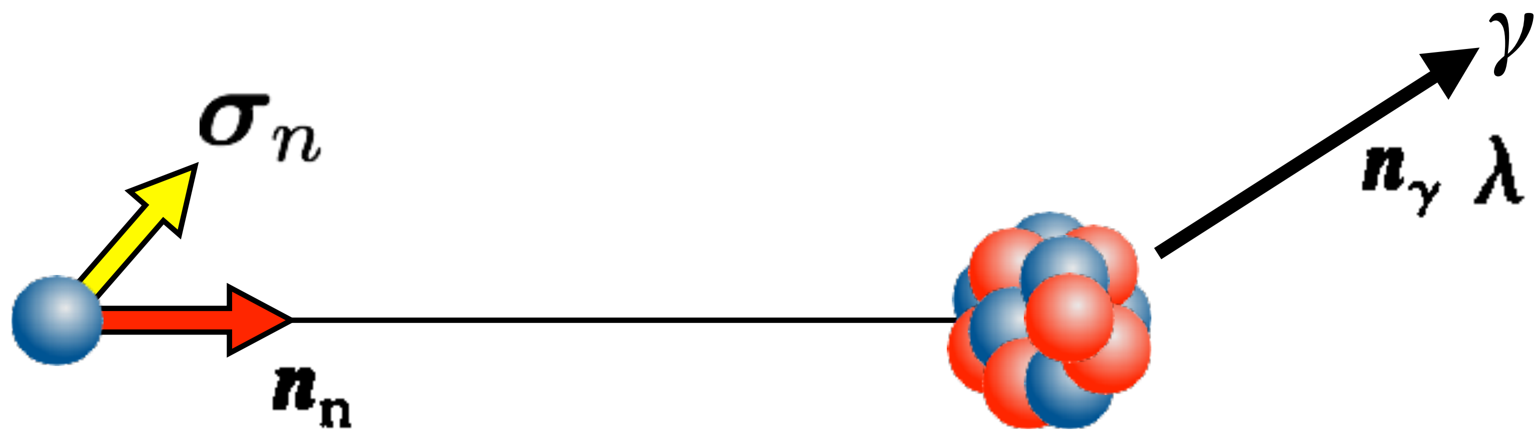
$$x^2 = \frac{\Gamma^n_{p,1/2}}{\Gamma^n_p} \qquad y^2 = \frac{\Gamma^n_{p,3/2}}{\Gamma^n_p}$$

$$x^2 + y^2 = 1$$

$$x = \cos\phi \qquad y = \sin\phi$$



Cross section of the (n,gamma) reaction



$$\frac{d\sigma(\boldsymbol{n}_\gamma, \lambda)}{d\Omega} = \frac{1}{2}\{a_0 + a_1(\boldsymbol{n}_\mathrm{n}\cdot\boldsymbol{n}_\gamma) + \tilde{a}_2\boldsymbol{\sigma}\cdot[\boldsymbol{n}_\mathrm{n}\times\boldsymbol{n}_\gamma] + a_3[(\boldsymbol{n}_\mathrm{n}\cdot\boldsymbol{n}_\gamma)^2 - \tfrac{1}{3}]$$

$$+\tilde{a}_4(\boldsymbol{n}_\mathrm{n}\cdot\boldsymbol{n}_\gamma)\boldsymbol{\sigma}\cdot[\boldsymbol{n}_\mathrm{n}\times\boldsymbol{n}_\gamma] + a_5\lambda(\boldsymbol{\sigma}\cdot\boldsymbol{n}_\gamma) + a_6\lambda(\boldsymbol{\sigma}\cdot\boldsymbol{n}_\mathrm{n}) + a_7\lambda$$

$$\times[(\boldsymbol{\sigma}\cdot\boldsymbol{n}_\gamma)(\boldsymbol{n}_\gamma\cdot\boldsymbol{n}_\mathrm{n}) - \tfrac{1}{3}(\boldsymbol{\sigma}\cdot\boldsymbol{n}_\mathrm{n})] + a_8\lambda[(\boldsymbol{\sigma}\cdot\boldsymbol{n}_\mathrm{n})(\boldsymbol{n}_\mathrm{n}\cdot\boldsymbol{n}_\gamma) - \tfrac{1}{3}(\boldsymbol{\sigma}\cdot\boldsymbol{n}_\gamma)]$$

$$+a_9(\boldsymbol{\sigma}\cdot\boldsymbol{n}_\gamma) + a_{10}(\boldsymbol{\sigma}\cdot\boldsymbol{n}_\mathrm{n}) + a_{11}[(\boldsymbol{\sigma}\cdot\boldsymbol{n}_\gamma)(\boldsymbol{n}_\gamma\cdot\boldsymbol{n}_\mathrm{n}) - \tfrac{1}{3}(\boldsymbol{\sigma}\cdot\boldsymbol{n}_\mathrm{n})]$$

$$+a_{12}[(\boldsymbol{\sigma}\cdot\boldsymbol{n}_\mathrm{n})(\boldsymbol{n}_\mathrm{n}\cdot\boldsymbol{n}_\gamma) - \tfrac{1}{3}(\boldsymbol{\sigma}\cdot\boldsymbol{n}_\gamma)] + a_{13}\lambda + a_{14}\lambda(\boldsymbol{n}_\mathrm{n}\cdot\boldsymbol{n}_\gamma)$$

$$+\tilde{a}_{15}\lambda\boldsymbol{\sigma}\cdot[\boldsymbol{n}_\mathrm{n}\times\boldsymbol{n}_\gamma] + a_{16}\lambda[(\boldsymbol{n}_\mathrm{n}\cdot\boldsymbol{n}_\gamma)^2 - \tfrac{1}{3}]$$

$$+\tilde{a}_{17}\lambda(\boldsymbol{n}_\mathrm{n}\cdot\boldsymbol{n}_\gamma)\boldsymbol{\sigma}\cdot[\boldsymbol{n}_\mathrm{n}\times\boldsymbol{n}_\gamma]\}\,.$$

Flambaum, Nucl. Phys. A435 (1985) 352

Selection of target nuclei

(n, γ) reaction (for unpolarized case)

$$\frac{d\sigma}{d\Omega} = \frac{1}{2}\left(a_0 + a_1 \boldsymbol{k}_n \cdot \boldsymbol{k}_\gamma + a_3\left((\boldsymbol{k}_n \cdot \boldsymbol{k}_\gamma)^2 - \frac{1}{3}\right)\right)$$

$$a_0 = \sum_{J_s} |V_1(J_s)|^2 + \sum_{J_s,j} |V_2(J_p j)|^2$$

$$a_1 = 2\mathrm{Re} \sum_{J_s,J_p,j} V_1(J_s) V_2^*(J_p j) P(J_s J_p \frac{1}{2} j 1 I F)$$

$$a_3 = \mathrm{Re} \sum_{J_s,j,J'_p,j'} V_2(J_p j) V_2^*(J'_p j') P(J_p J'_p j j' 2 I F) 3\sqrt{10} \left\{ \begin{array}{ccc} 2 & 1 & 1 \\ 0 & \frac{1}{2} & \frac{1}{2} \\ 2 & j & j' \end{array} \right\}$$

$$V_1 = \frac{1}{2k_s}\sqrt{\frac{E_s}{E}} \frac{\sqrt{g\Gamma_s^n \Gamma_\gamma}}{E - E_s + i\Gamma_s/2}$$

$$V_2(j) = \frac{1}{2k_p}\sqrt{\frac{E_p}{E}} \sqrt{\frac{\Gamma_{pj}^n}{\Gamma_p^n}} \frac{\sqrt{g\Gamma_p^n \Gamma_\gamma}}{E - E_p + i\Gamma_p/2}$$

$V_2(j=1/2) = xV_2 = V_2 \cos\phi$

$V_2(j=3/2) = yV_2 = V_2 \sin\phi$

$$P(JJ'jj'kIF) = (-1)^{J+J'+j'+I+F} \frac{3}{2}\sqrt{(2J+1)(2J'+1)(2j+1)(2j'+1)} \left\{ \begin{array}{ccc} j & j & j' \\ I & J' & J \end{array} \right\} \left\{ \begin{array}{ccc} k & 1 & 1 \\ F & J & J' \end{array} \right\}$$

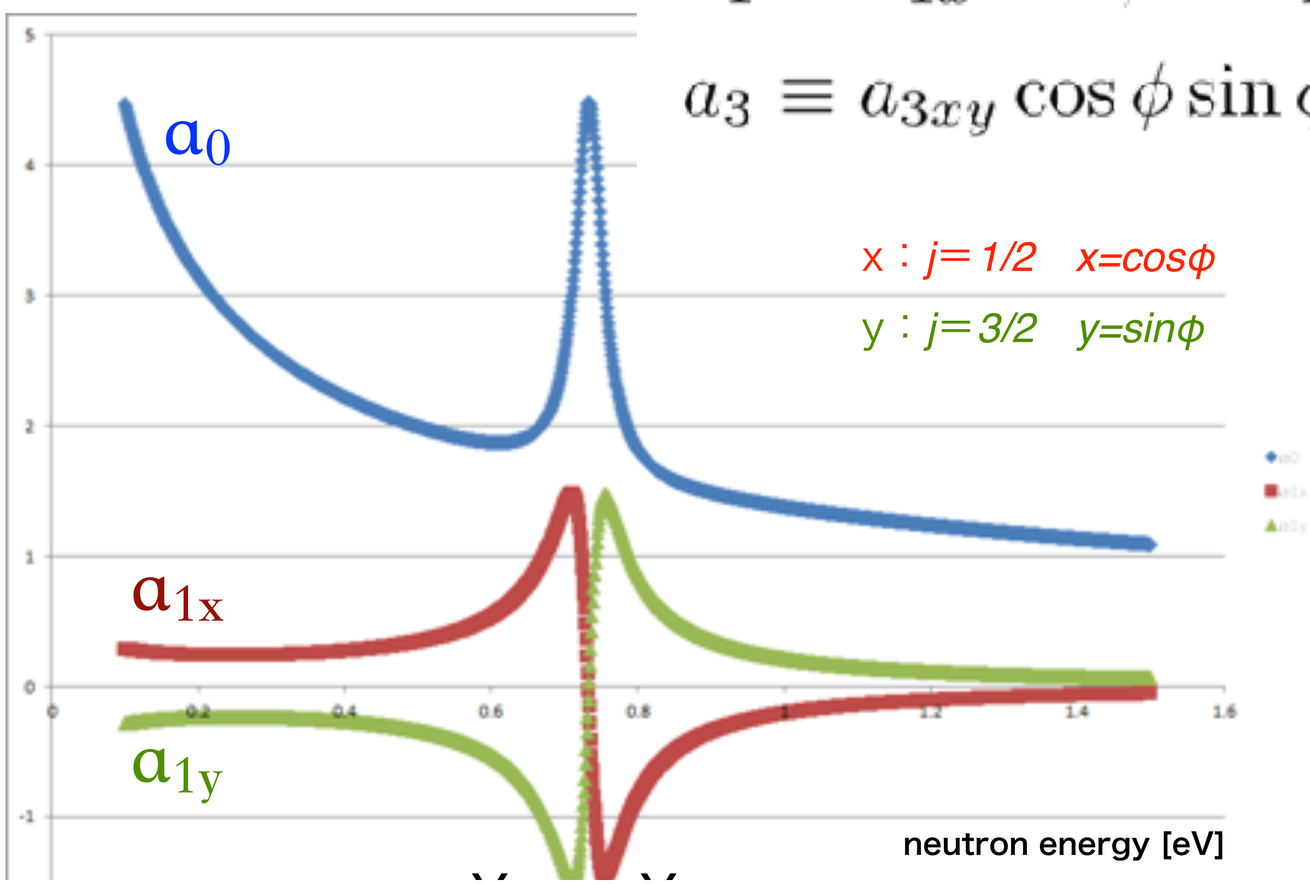
Selection of target nuclei

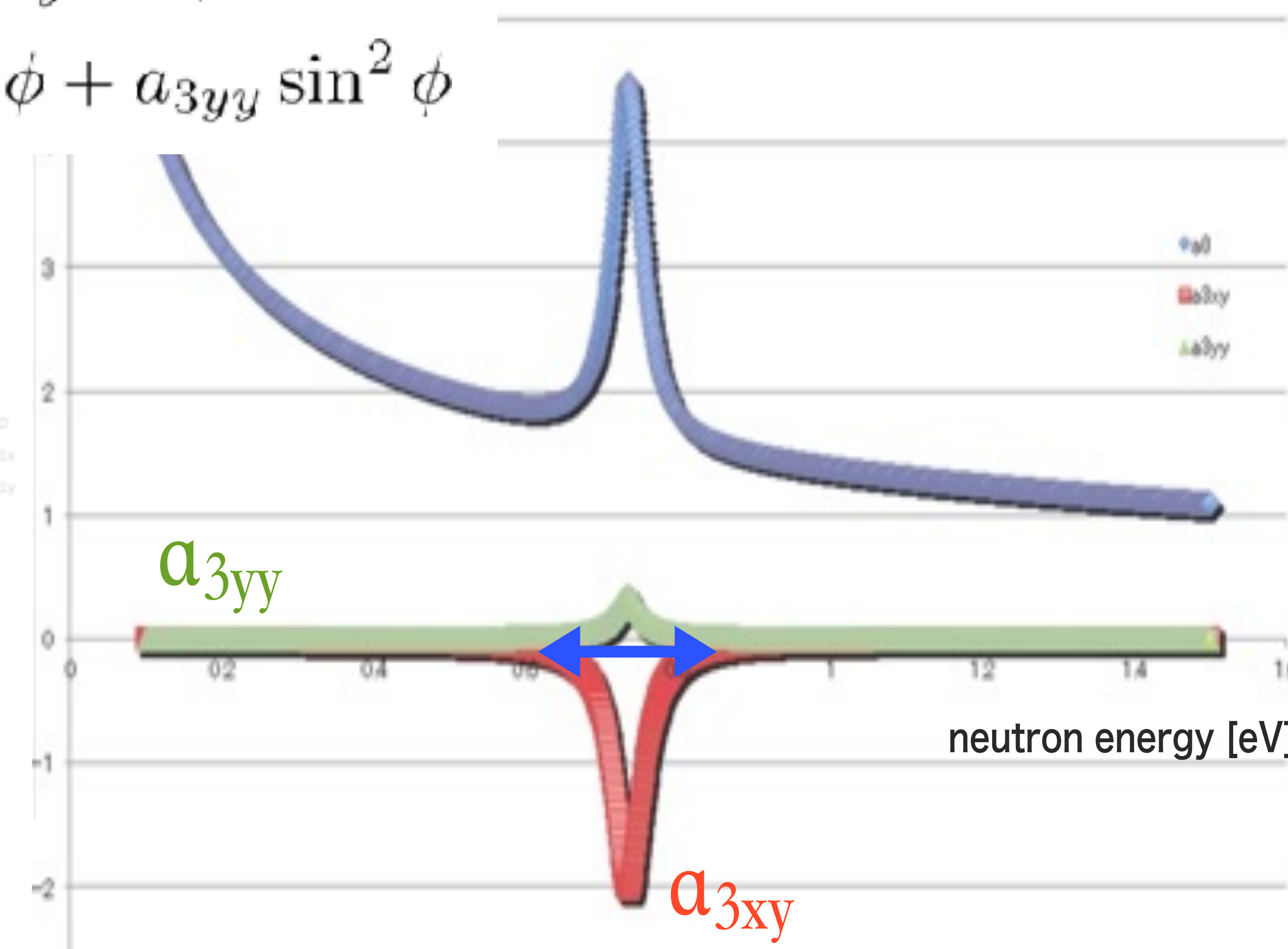
(n, γ) reaction (for unpolarized case)

$$\frac{d\sigma}{d\Omega} = \frac{1}{2}\left(a_0 + a_1 \boldsymbol{k}_n \cdot \boldsymbol{k}_\gamma + a_3\left((\boldsymbol{k}_n \cdot \boldsymbol{k}_\gamma)^2 - \frac{1}{3}\right)\right)$$

$$a_1 \equiv a_{1x}\cos\phi + a_{1y}\sin\phi$$

$$a_3 \equiv a_{3xy}\cos\phi\sin\phi + a_{3yy}\sin^2\phi$$





Selection of target nuclei

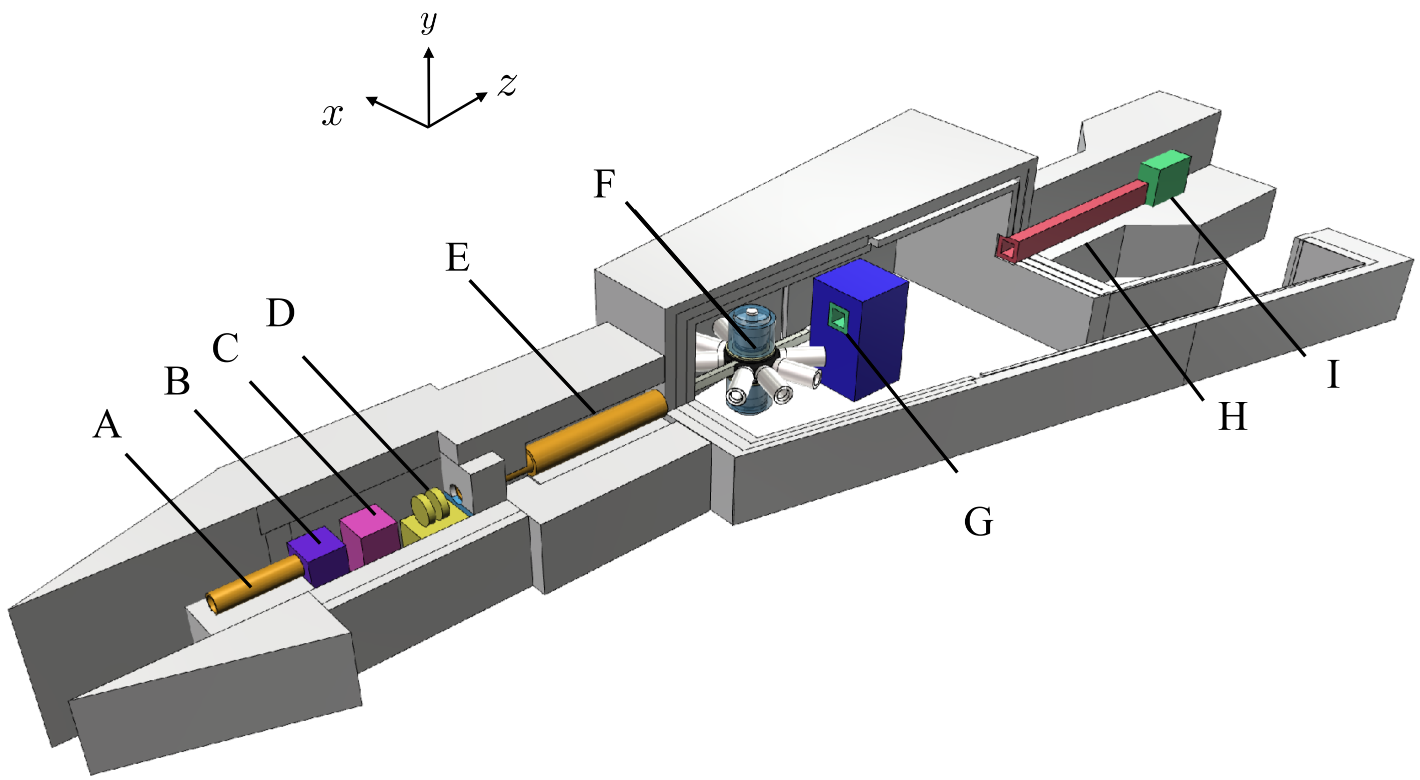
(n, γ) reaction measurement at J-PARC BL04 ANNRI

$$\frac{d\sigma}{d\Omega} = \frac{1}{2}\left(a_0 + a_1 \boldsymbol{k}_n \cdot \boldsymbol{k}_\gamma + a_3\left((\boldsymbol{k}_n \cdot \boldsymbol{k})^2 - \frac{1}{3}\right)\right)$$

$$a_1 \equiv a_{1x}\cos\phi + a_{1y}\sin\phi$$

$$a_3 \equiv a_{3xy}\cos\phi\sin\phi + a_{3yy}\sin^2\phi$$

Single unknown parameter $\kappa(J)$ can be estimated by observing the shape of p-wave resonance peak.



Sample Materials : ^{nat}La, $La^{nat}Br_3$, ^{nat}In

Intensity : ~ 3×10^5 n/cm²/s : 0.9 eV < En < 1.1eV @300kW

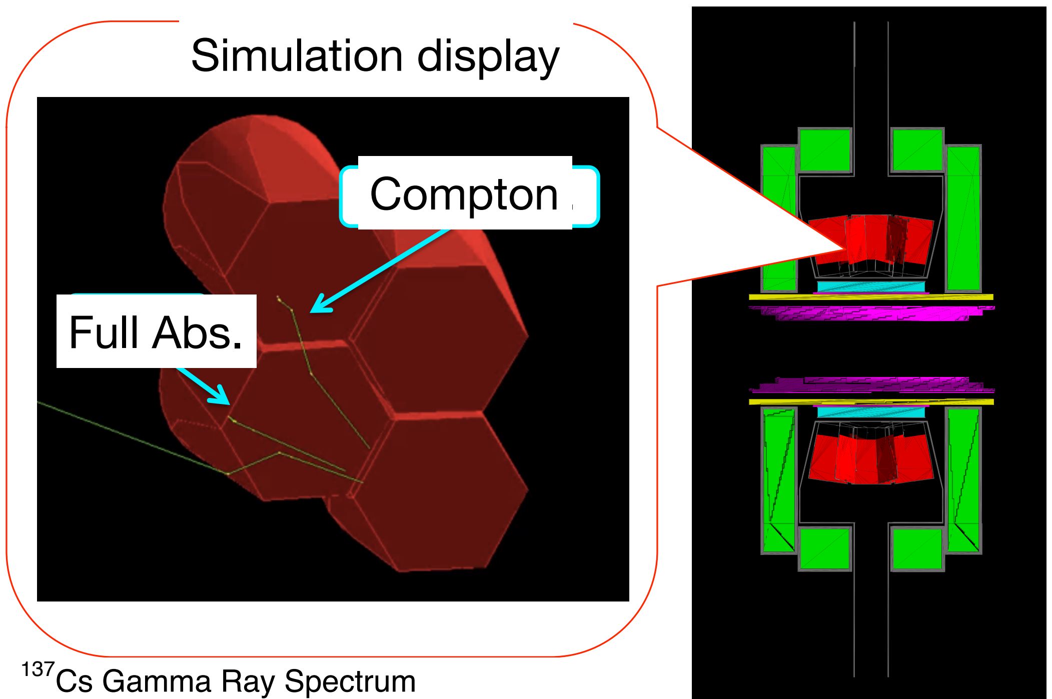
Selection of target nuclei

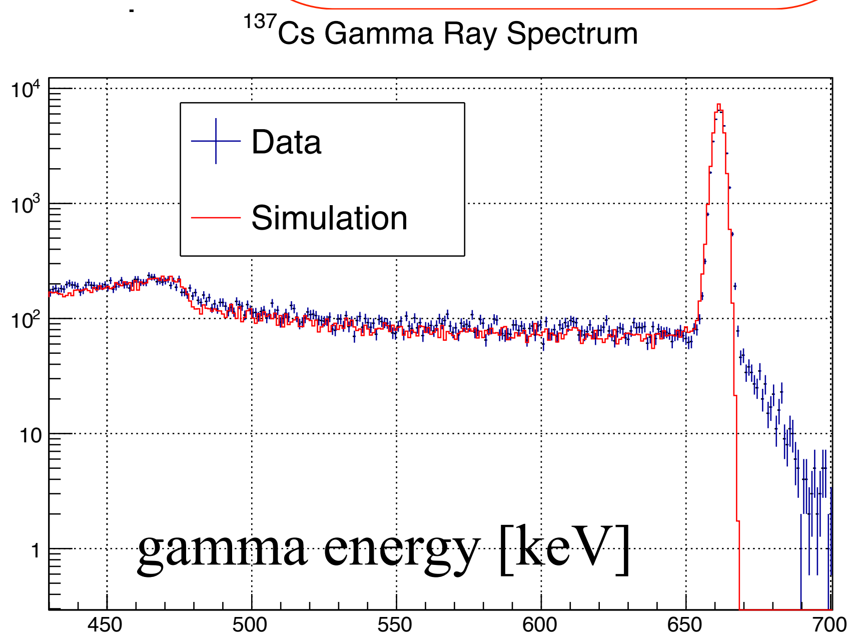
(n, γ) reaction measurement at J-PARC BL04 ANNRI

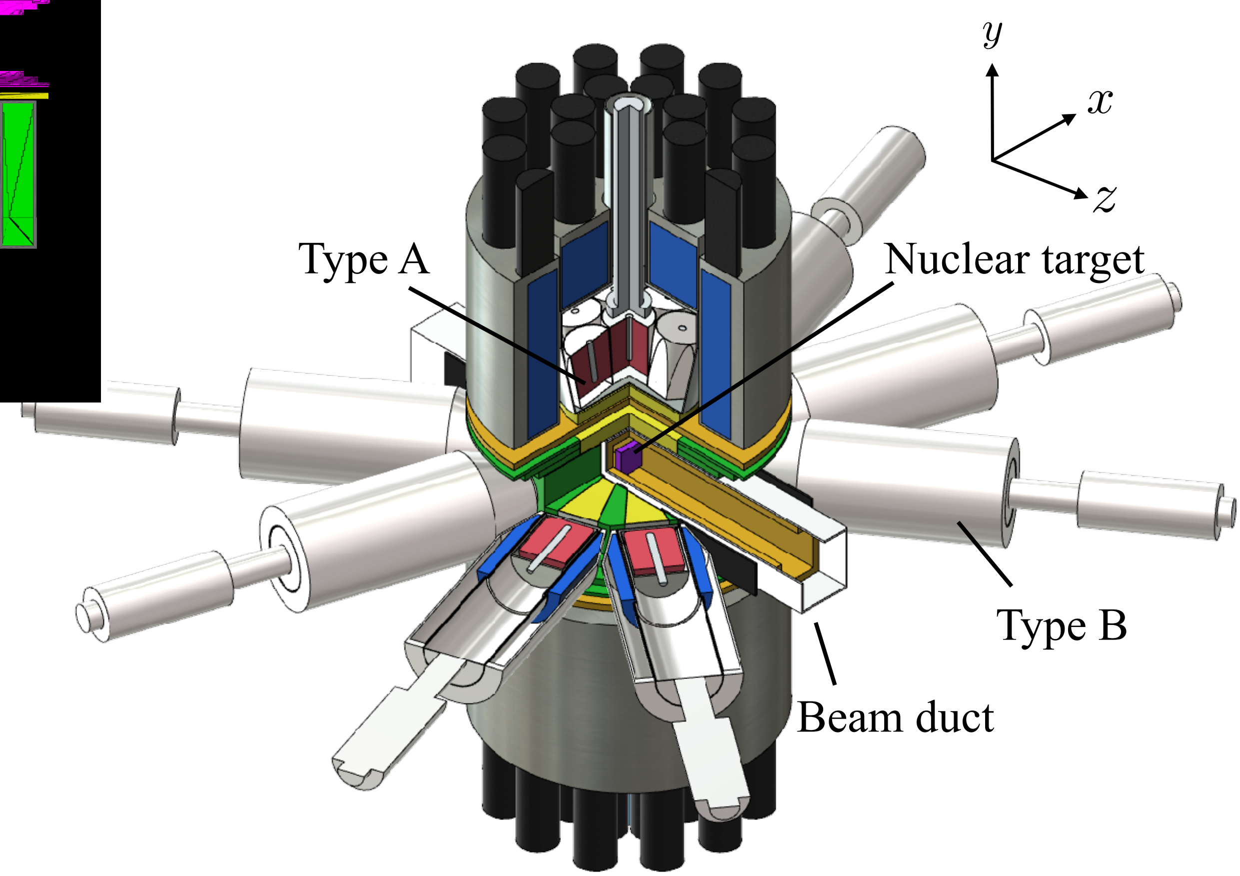
$$\frac{d\sigma}{d\Omega} = \frac{1}{2}\left(a_0 + a_1 \boldsymbol{k}_n \cdot \boldsymbol{k}_\gamma + a_3\left((\boldsymbol{k}_n \cdot \boldsymbol{k})^2 - \frac{1}{3}\right)\right)$$

$$a_1 \equiv a_{1x}\cos\phi + a_{1y}\sin\phi$$

$$a_3 \equiv a_{3xy}\cos\phi\sin\phi + a_{3yy}\sin^2\phi$$

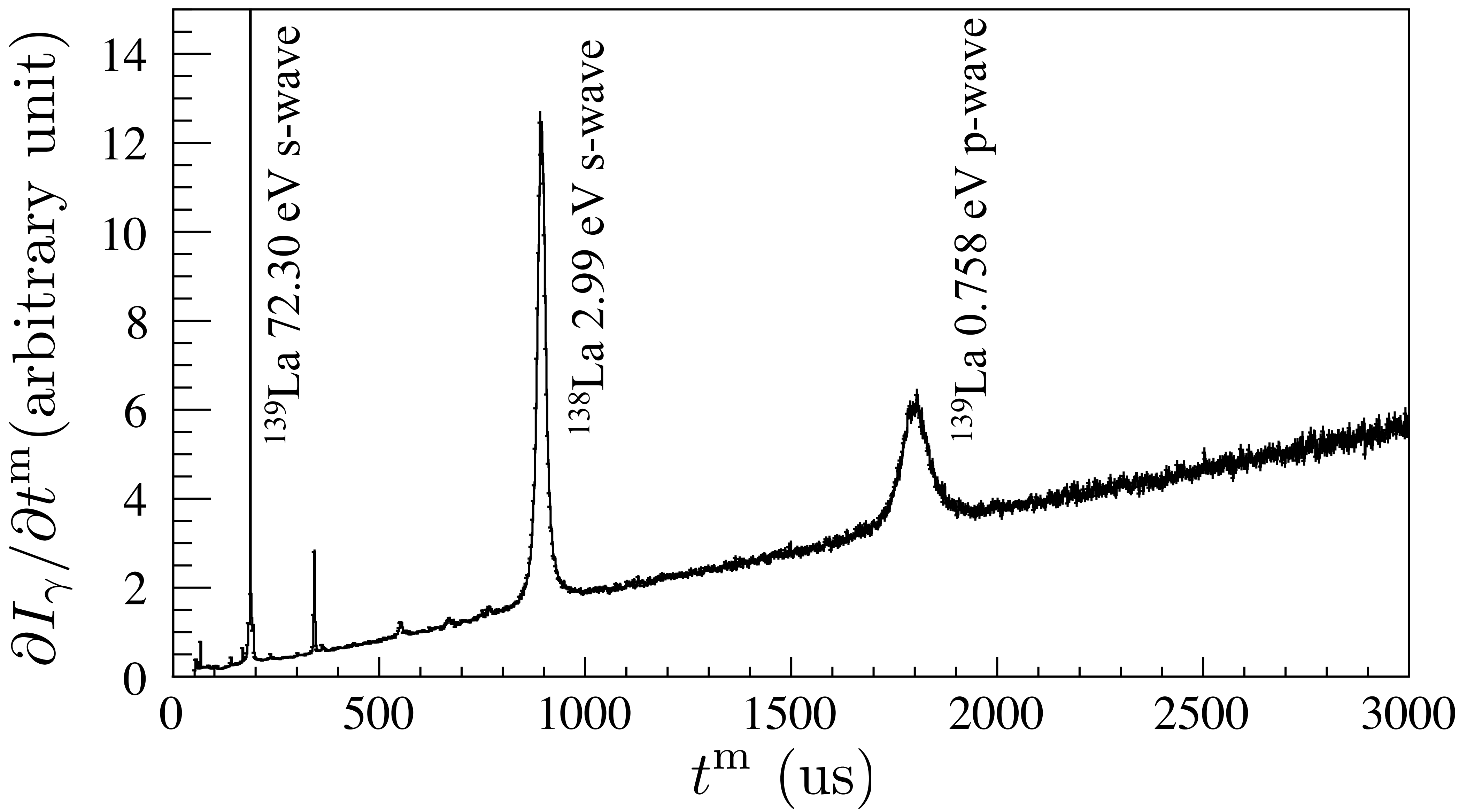






Selection of target nuclei

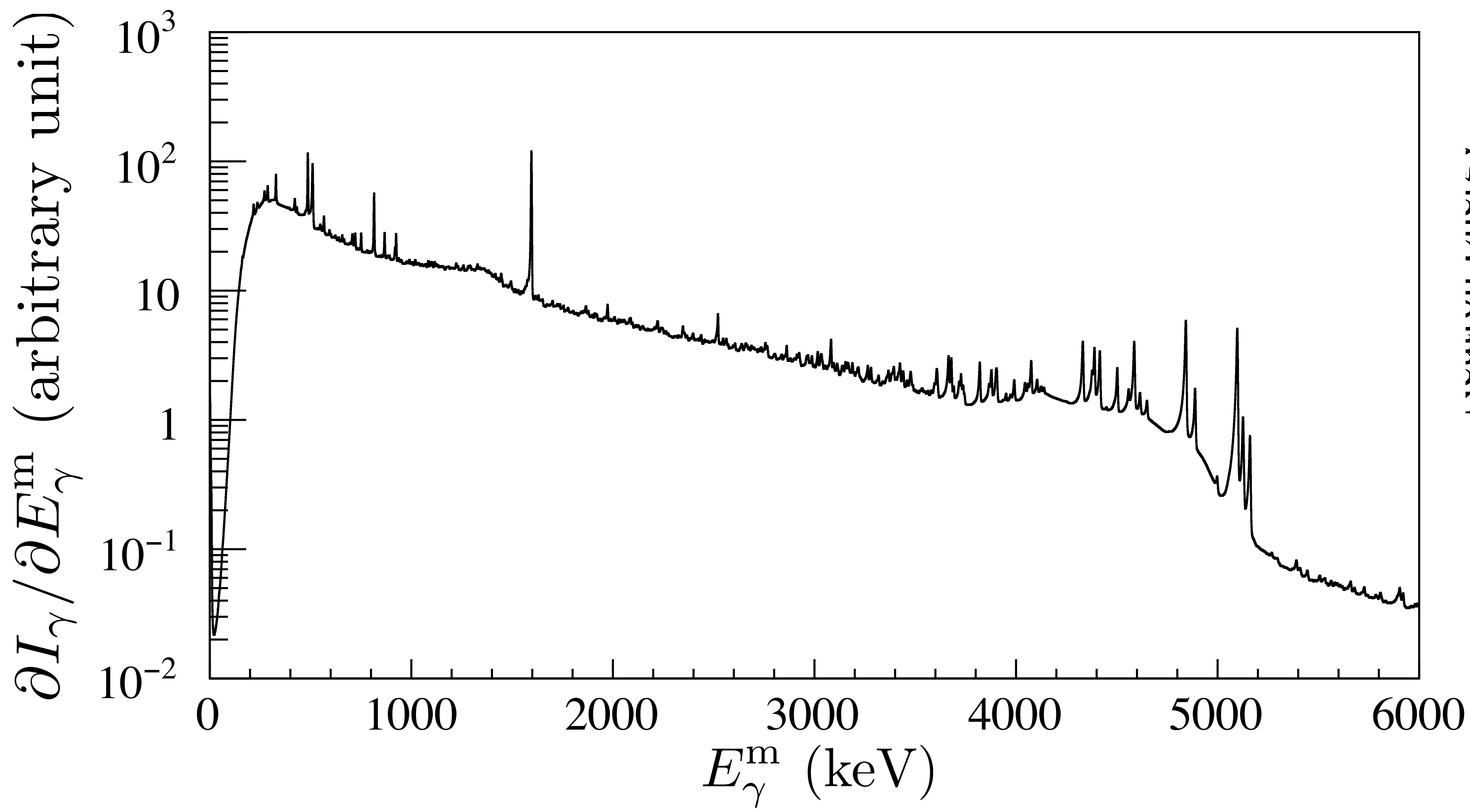
p-wave resonance was observed clearly

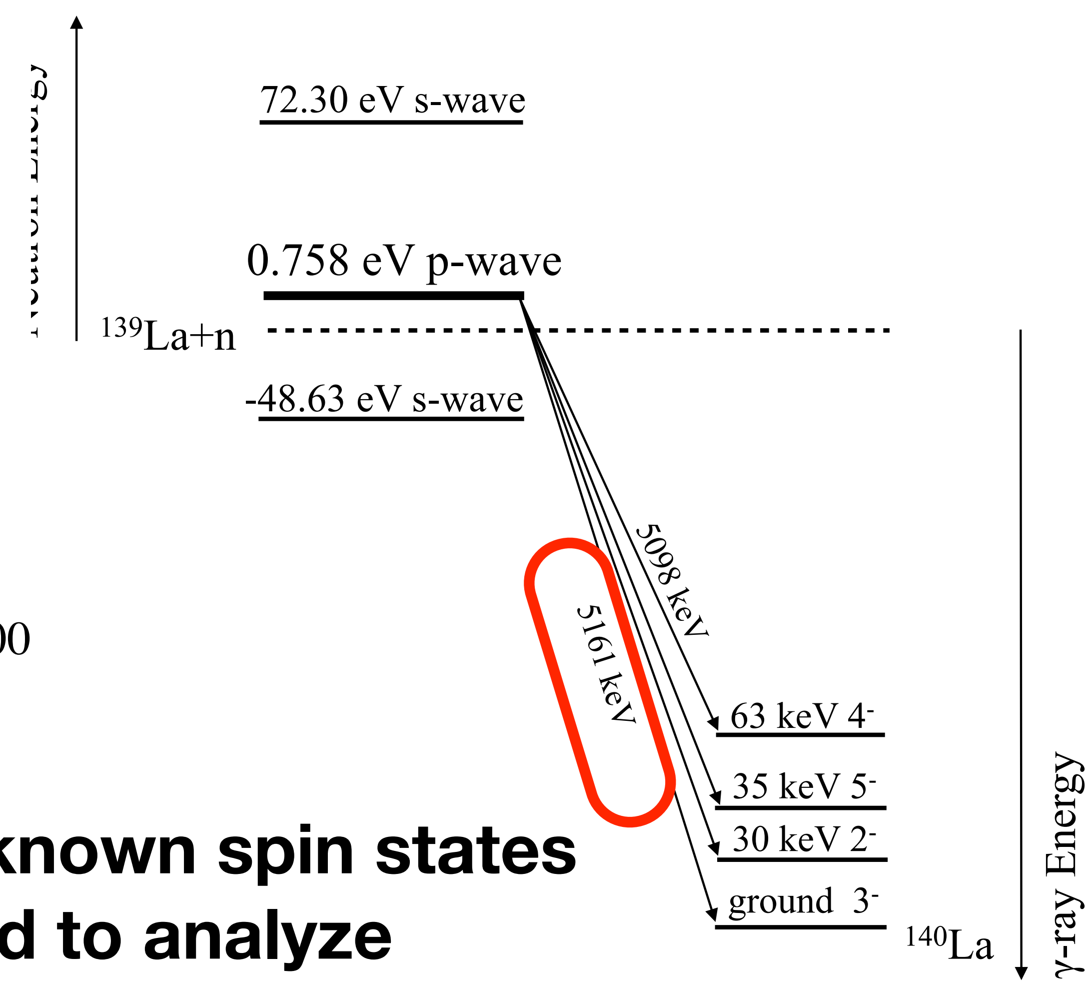


T. Okudaira, et.al., https://arxiv.org/abs/1710.03065

Selection of target nuclei

γ rays were observed individually





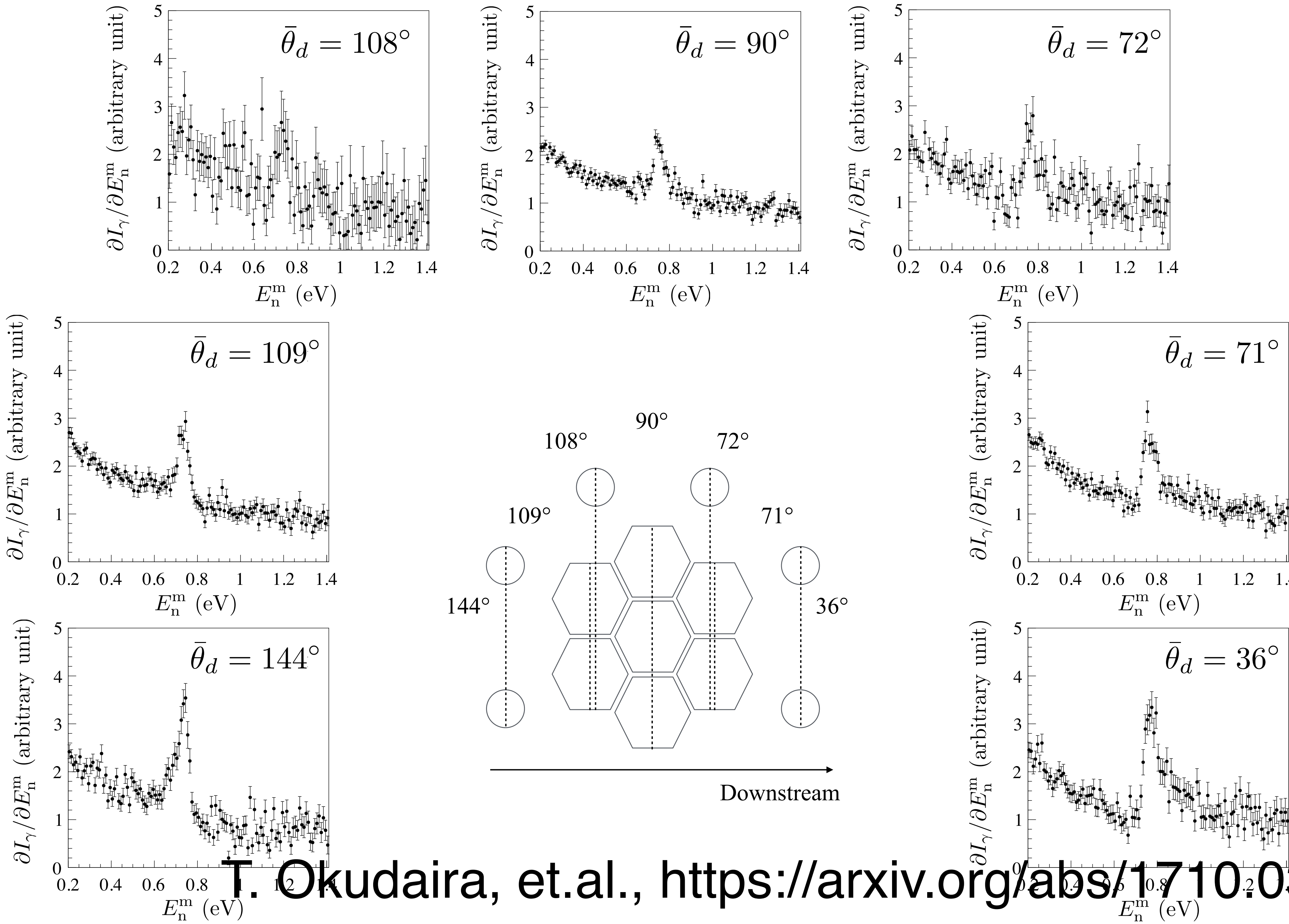
Only well-known spin states were gated to analyze

FIG. 10. Transitions from ^{139}La+n to ^{140}La. Dashed line shows separation energy of ^{139}La+n.

T. Okudaira, et.al., https://arxiv.org/abs/1710.03065

Selection of target nuclei

Shape of resonance peak changes according to the angle

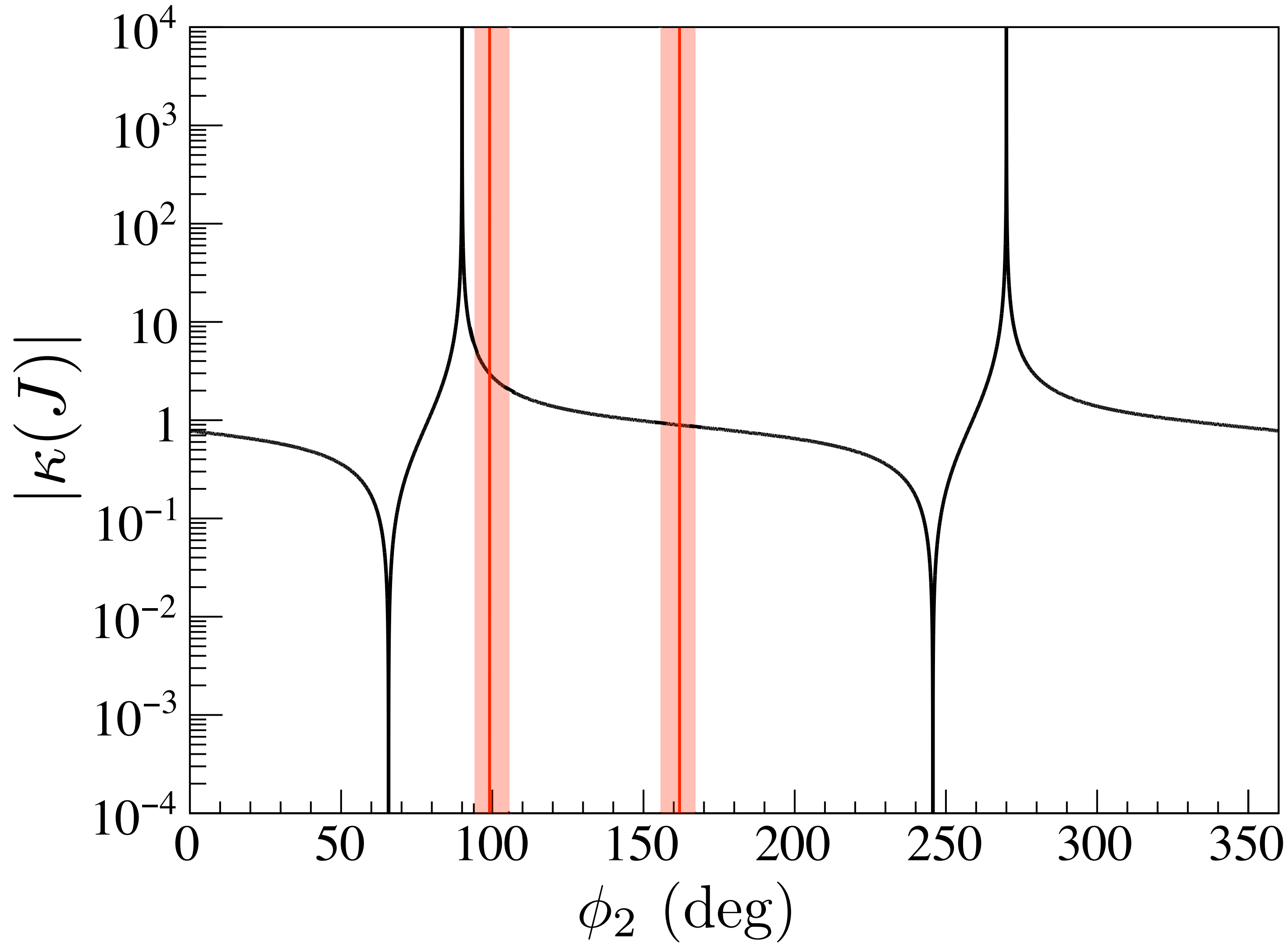


T. Okudaira, et.al., https://arxiv.org/abs/1710.03065

Selection of target nuclei

$\kappa(J)$ is NOT zero !

La can be used for T-violation search!



$$\kappa(J) = 2.95^{+2.98}_{-0.90}, \quad 0.89^{+0.04}_{-0.04}$$

T. Okudaira, et.al., https://arxiv.org/abs/1710.03065

T-odd Correlation in Compound Nuclei

Experimental plan

p-wave resonance $E_n = 3.2$ eV

$\Gamma_n = 0.1$ eV

J-P

Epi-thermal neutron Optics

epi-thermal neutron transport optics,
spin control, . . .

Epi-thermal neutron Detector

^{10}B doped liquid scintillator

SEOP ^{3}He spin filter for neutron polarization

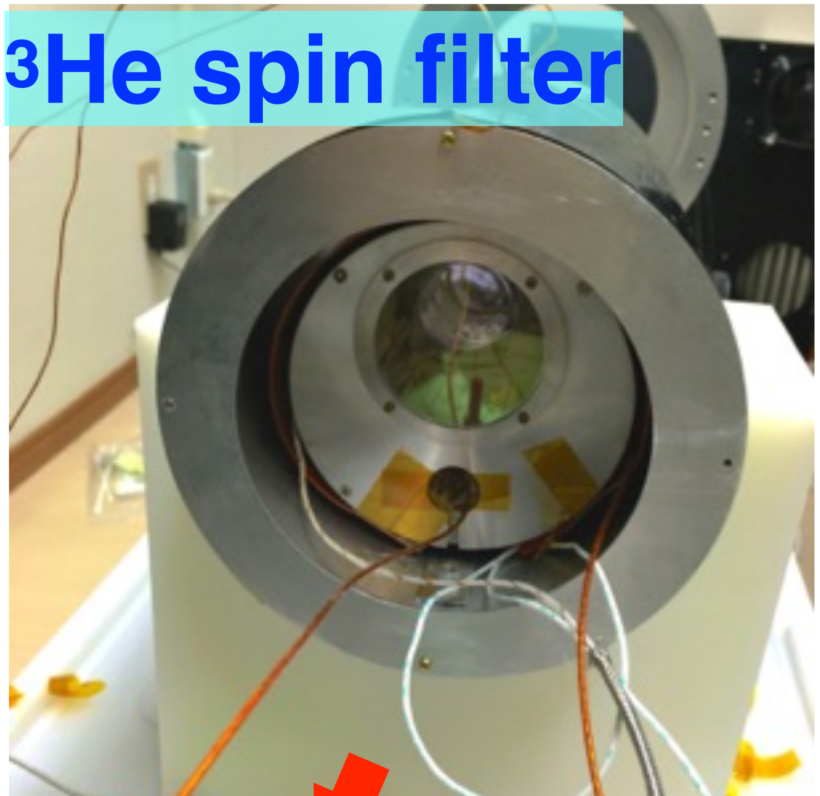
Polarized Target

Solid Polarized Xe with laser

developed for nEDM co-magnetometer

Neutron Polarization

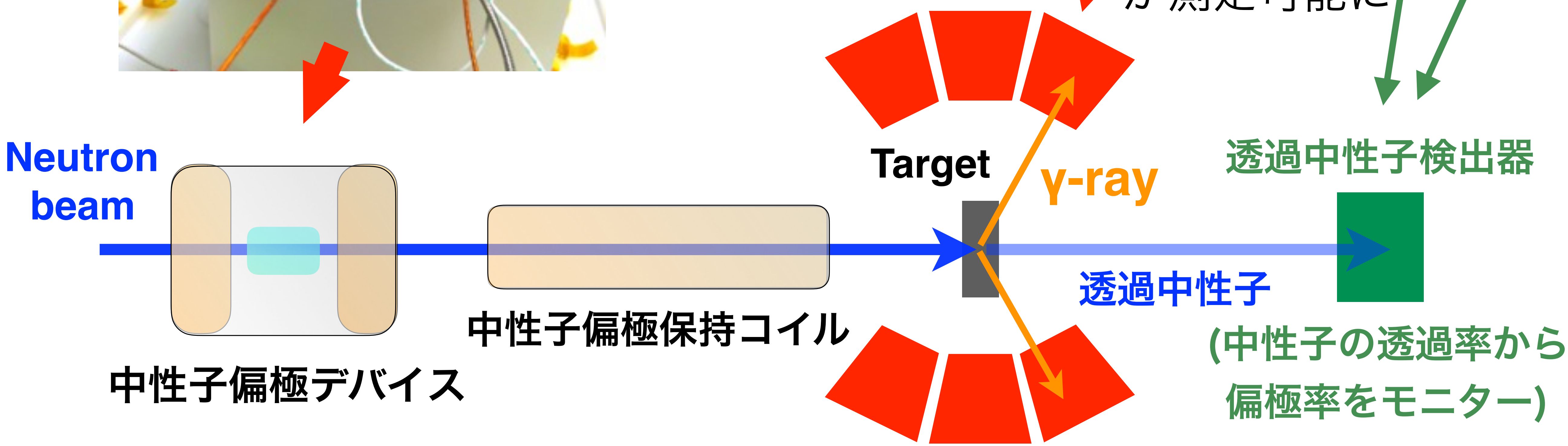
^{3}He neutron spin filter was installed to BL04



Flambaum, Nucl.Phys. A435(1985)352

$$\frac{d\sigma}{d\Omega} = \frac{1}{2}\left[a_0 - \frac{1}{3}a_3 + a_9\left(\sigma_n \cdot k_\gamma\right) + a_{10}\left(\sigma_n \cdot k_n\right) + a_{11}\left\{\left(\sigma_n \cdot k_\gamma\right)\left(k_\gamma \cdot k_n\right) - \frac{1}{3}\left(\sigma_n \cdot k_n\right)\right\}\right]$$

a_9, a_{10}, a_{11} が測定可能に

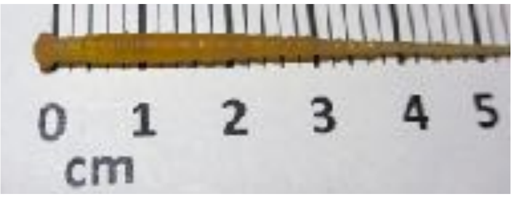


Target Polarization

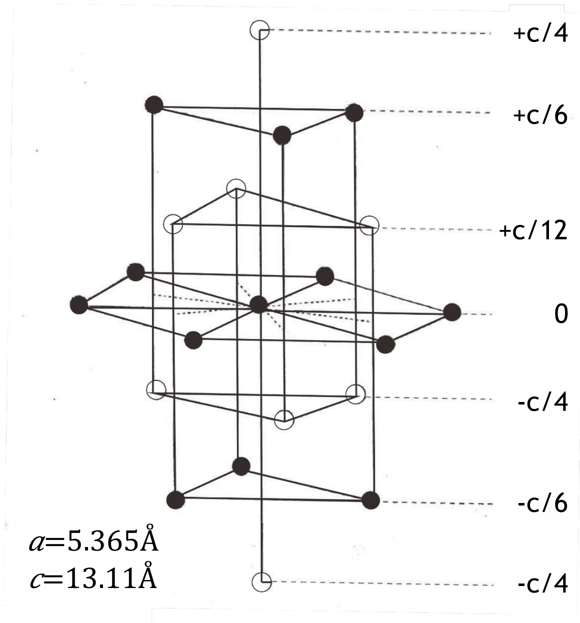
La DNP

Yamagata Univ.
Tohoku Univ.
Hiroshima Univ.
Nagoya Univ.

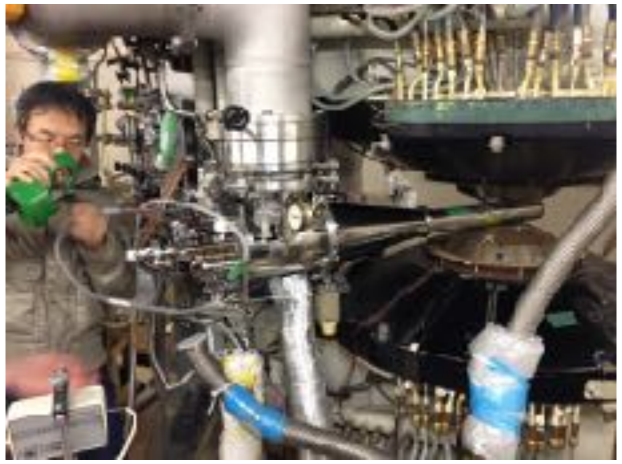
New crystal
by Tohoku univ.



$Nd^{3+}LaAlO_3$



DNP in Yamagata

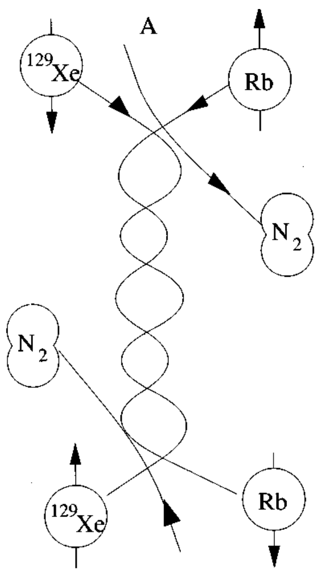


2.3T, 0.3K P~50% was reported（Kyoto Univ. PSI)

Retry with better crystals

Xe SEOP UBC

Spin Exchange Optical Pumping

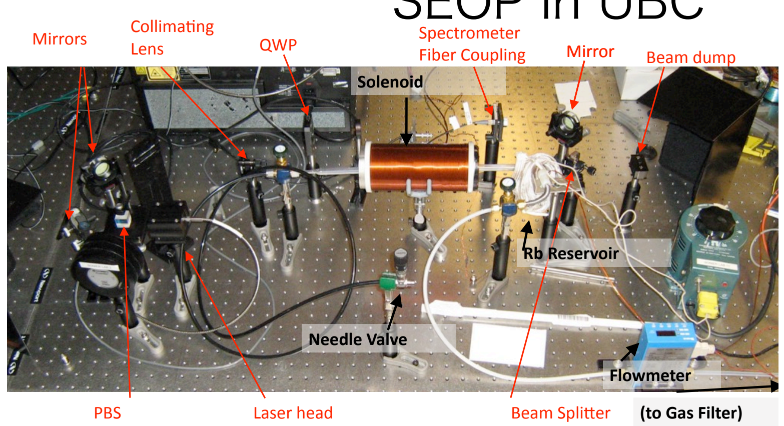


Rb polarized with laser

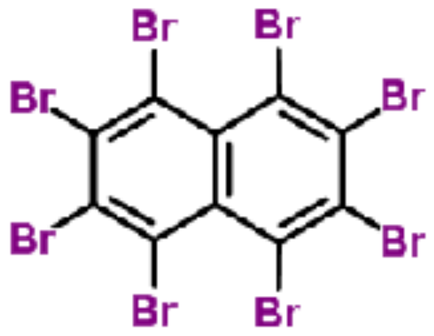
^{129}Xe was reported.

Try solid ^{131}Xe.

SEOP in UBC



Br Triplet-DNP RIKEN



Collaboration

NOPTREX

NOP-T

Nagoya University
H.M.Shimizu, M.Kitaguchi, K.Hirota, T.Okudaira, A.Okada, K.Nagamoto, M.Yokohashi, T.Yamamoto, I.Itoh, T.Morishima, G.Ichikawa, Y.Kiyanagi

Kyushu University
T.Yoshioka, S.Takada, J.Koga

JAEA
K.Sakai, A.Kimura, H.Harada

Univ. British Columbia
T.Momose

Hiroshima Univ.
M.Iinuma

Yamagata Univ.
T.Iwata, Y.Miyachi

RIKEN
N.Yamanaka, Y.Yamagata

KEK
T.Ino, S.Ishimoto, K.Taketani, K.Mishima

Kyoto Univ.
M.Hino

TREX

Indiana University
W.M.Snow, J.Curole

Univ. South Carolina
V.Gudkov

Oak Ridge National Lab.
J.D.Bowman, S.Penttila, X.Tong

Kentucky Univ.
B.Plaster, D.Schaper

Paul Scherrer Institut
P.Hautle

Southern Illinois University
B.M.Goodson

Univ. California Berkeley
A.S.Tremsin

Summary of T-violation search

T violation is enhanced in compound nuclei reaction.
(Sensitivity can be better than EDM experiment.)

T violation search in compound nuclei experiment requires complex system.

- Intense neutron source
- Epithermal neutron polarizer
- Target polarization
- Fast and efficient detector for epithermal neutrons
- Neutron spin control

We start US-Japan collaboration NOPTREX.