Search for unknown interaction with neutrons

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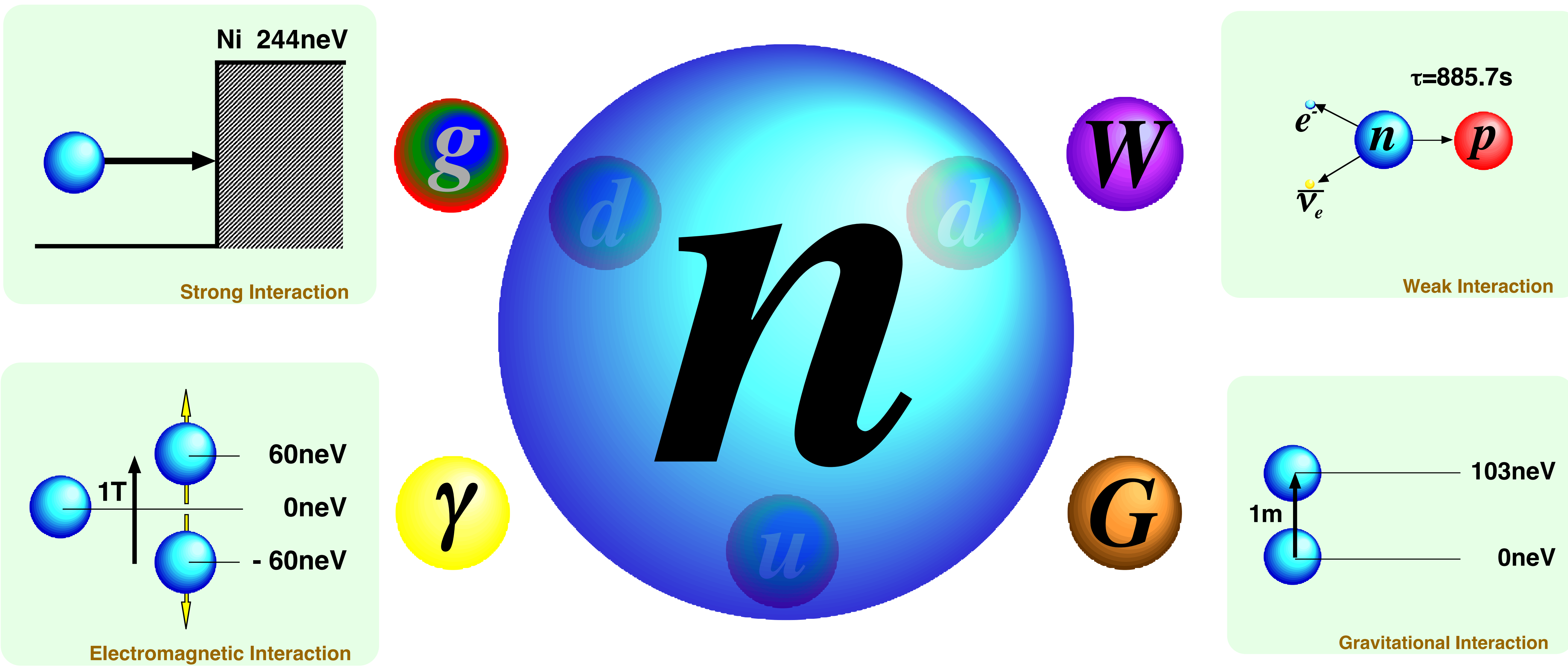
Laboratory for Particle Properties

Neutron Optics and Physics

Fundamental Physics with Neutrons



suitable for precision measurement

Fundamental Physics with Neutrons

Unknown source of CP violation can be searched.

Neutrons can be used for a good probe of CP violating interactions through . . .

T-odd correlation in compound nuclei

Neutron EDM

Unknown intermediate-range force can be detected.

Precise measurement of the potential between neutron and material enables us to search . . .

Extra-dimension

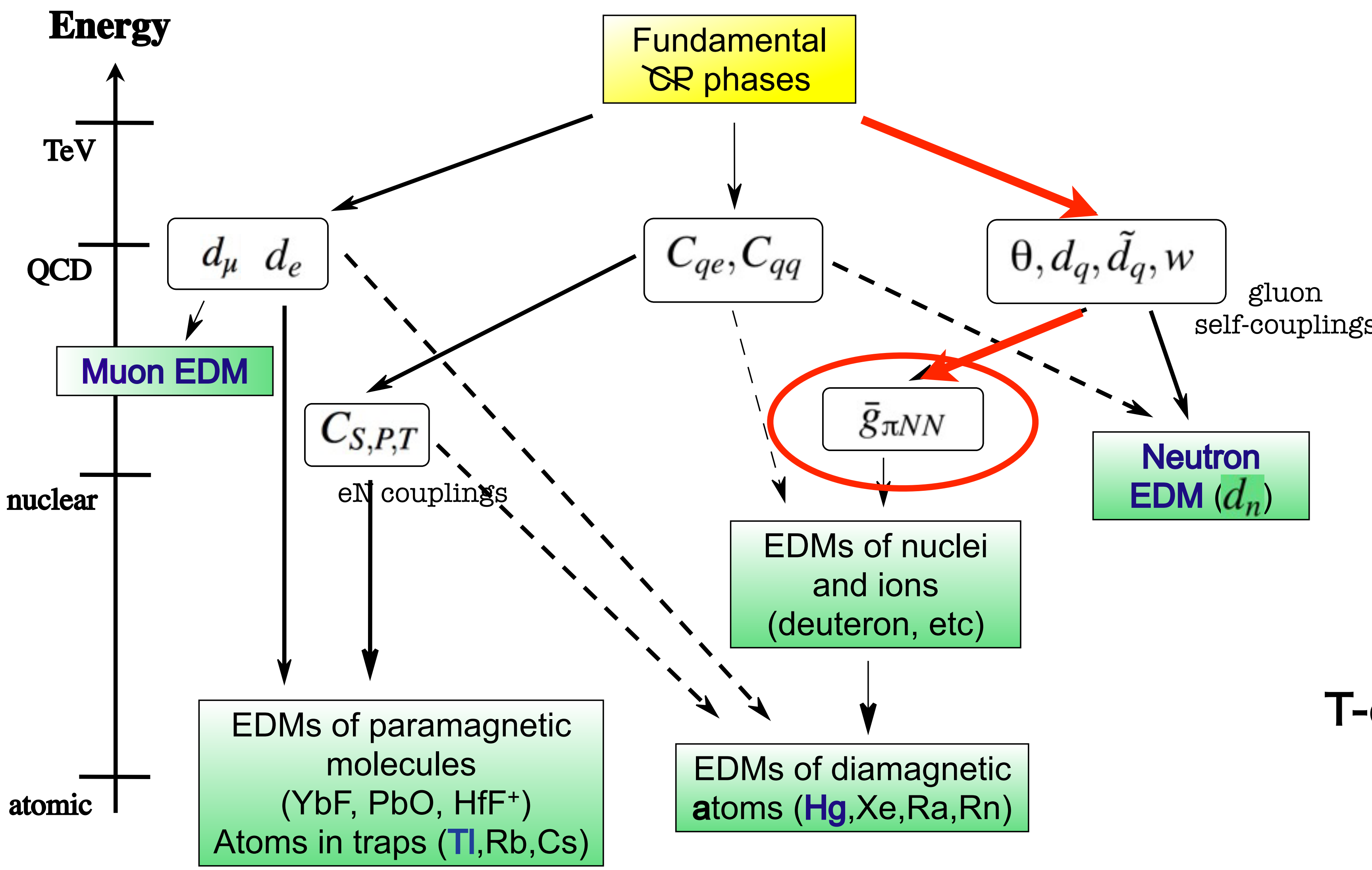
Extended gravity (Dark energy)

Intermediate-range force

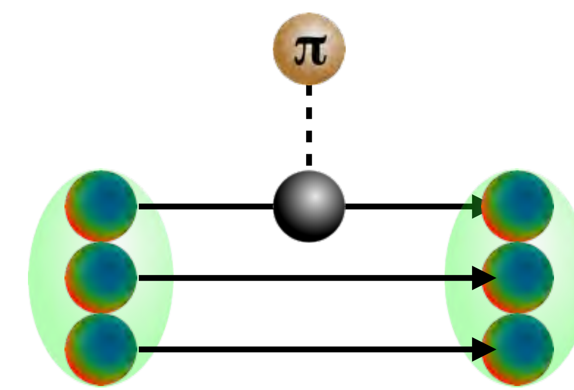
e.g. Chameleon field

T-odd correlation in compound nuclei

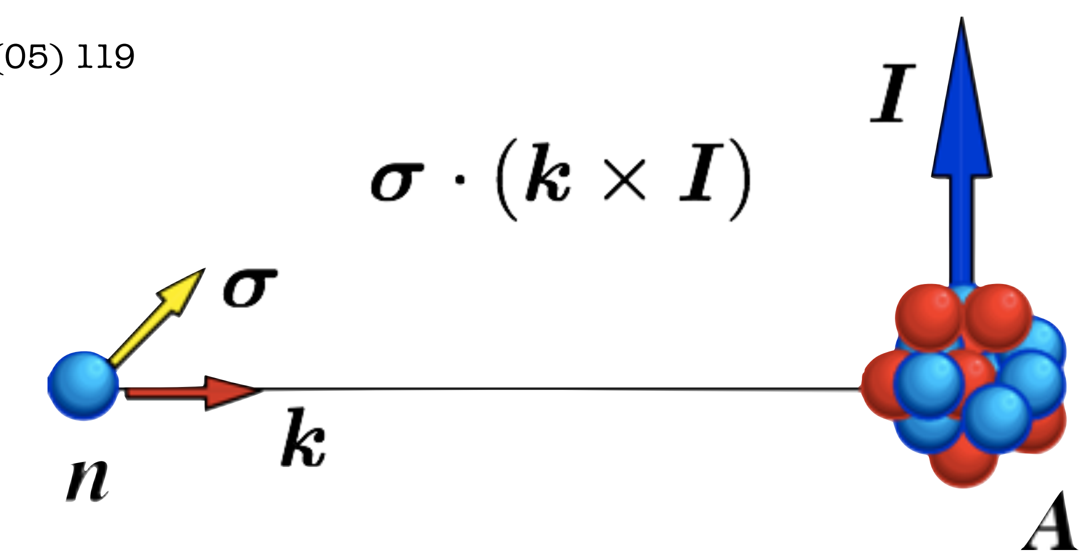
T-odd Correlation in Compound Nuclei



Pospelov Ritz, Ann Phys 318 (05) 119

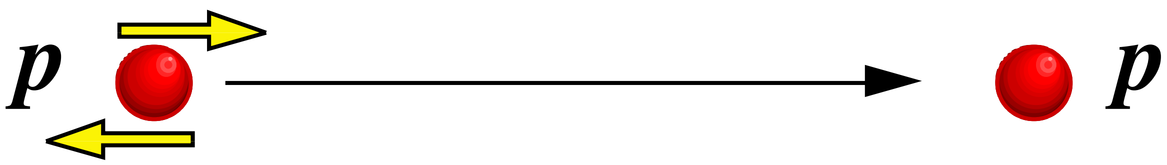


T-odd P-odd pion-nucleon coupling



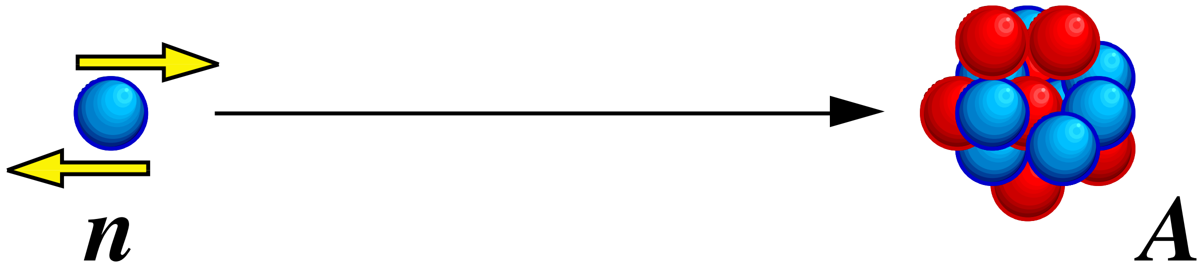
P-violation in compound nuclei

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

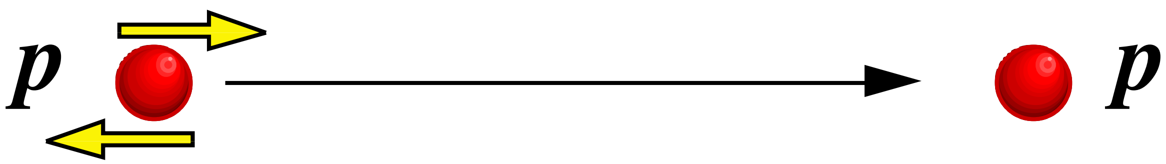


^{139}La	$E_n = 0.734$ eV	0.097 ± 0.003
^{81}Br	$E_n = 0.734$ eV	0.021 ± 0.001
^{111}Cd	$E_n = 4.53$ eV	$-(0.013^{+0.007}_{-0.004})$

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

P-violation in compound nuclei

P-violation in nucleon



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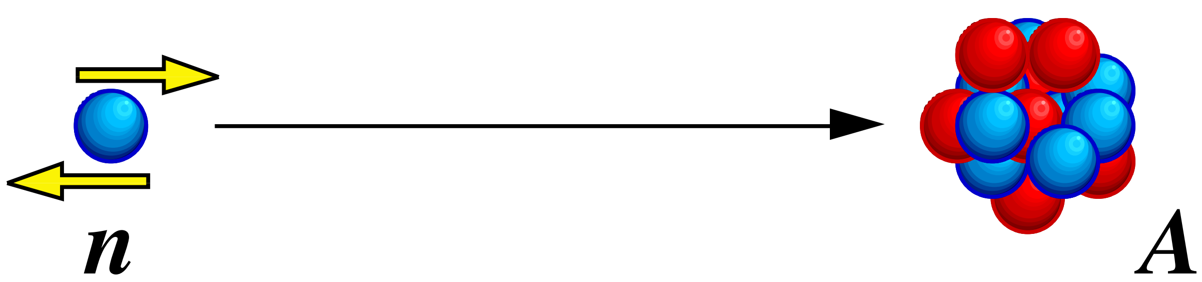

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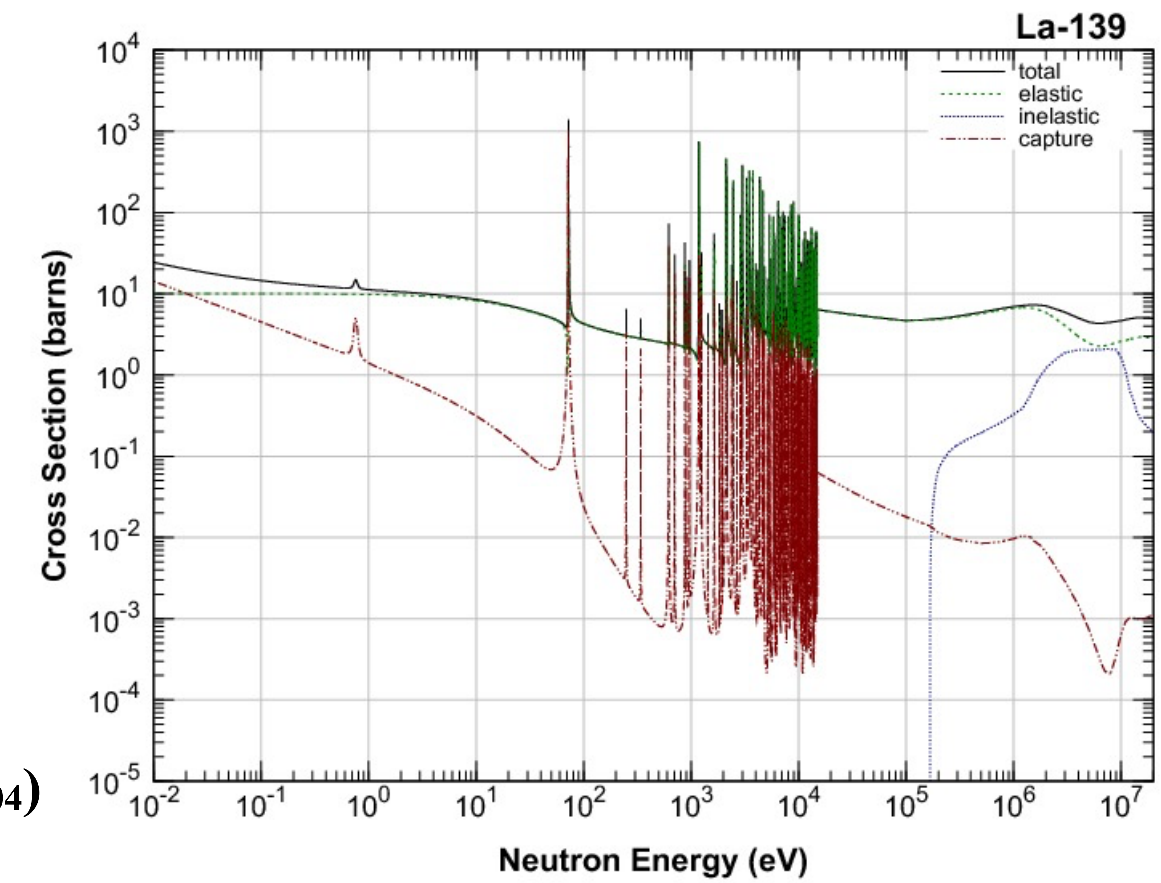
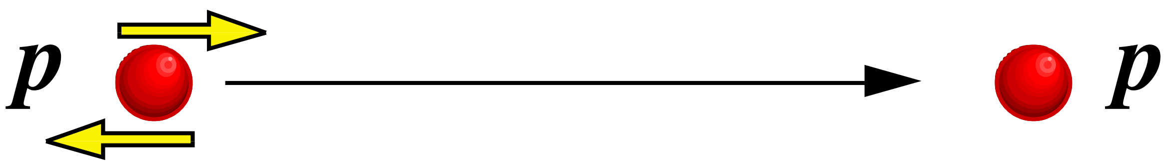


P-violation is enhanced in p-wave resonance of compound nuclei

P-violation in compound nuclei

NOP-T

P-violation in nucleon



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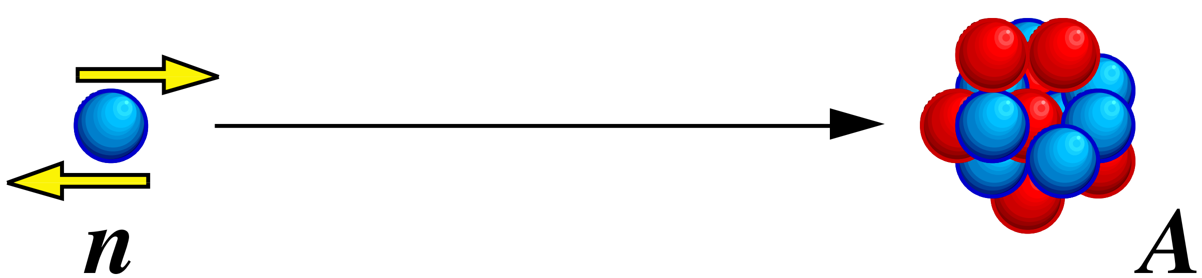

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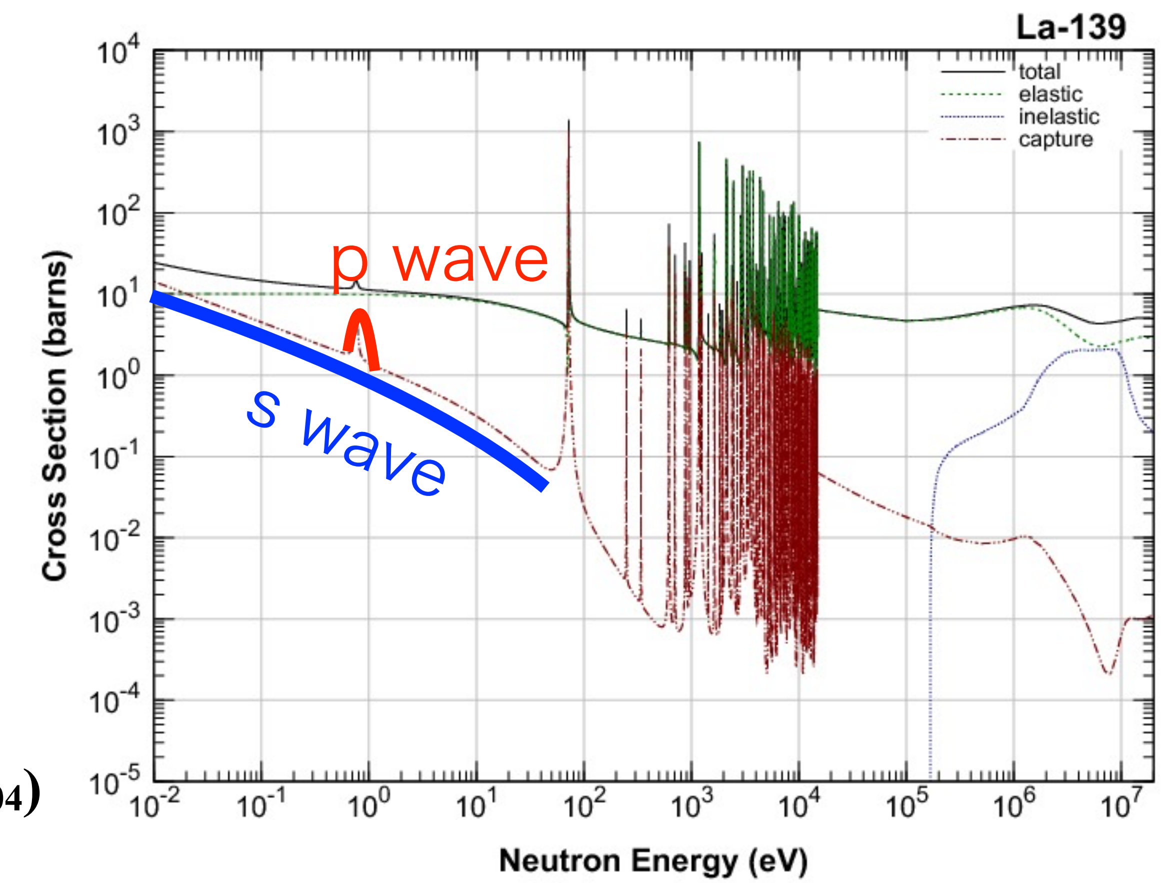

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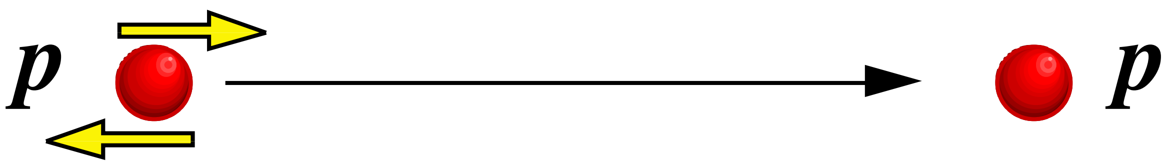
P-violation in compound nuclei

P-violation in nucleon



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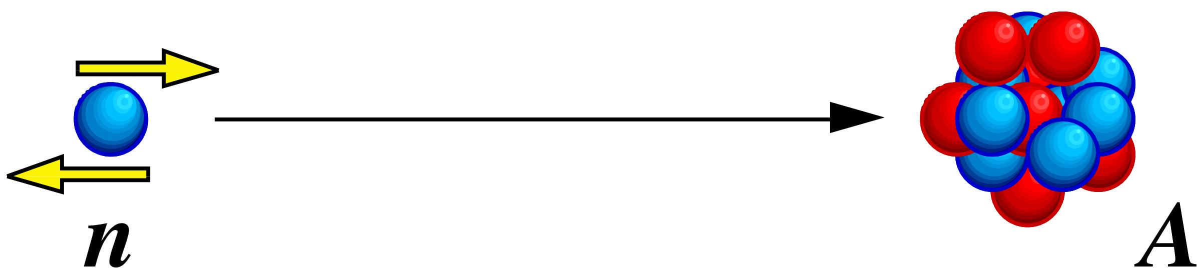

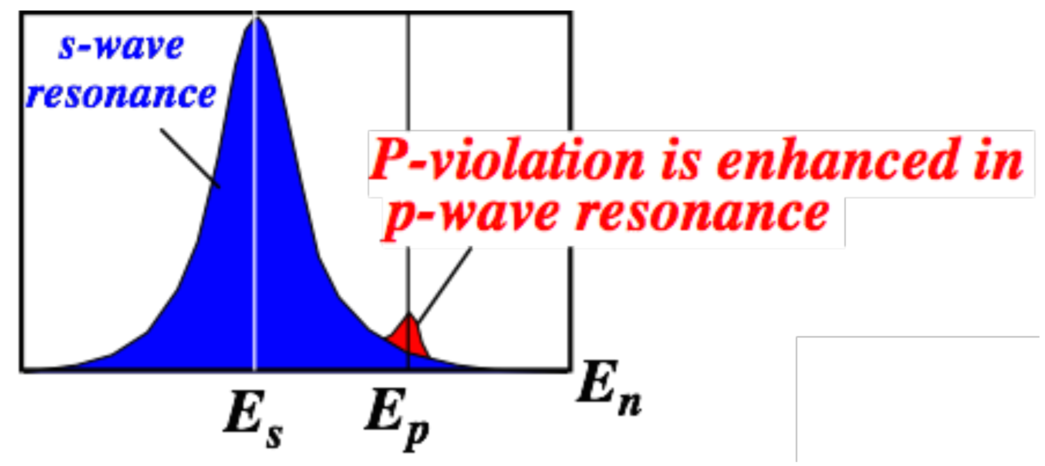

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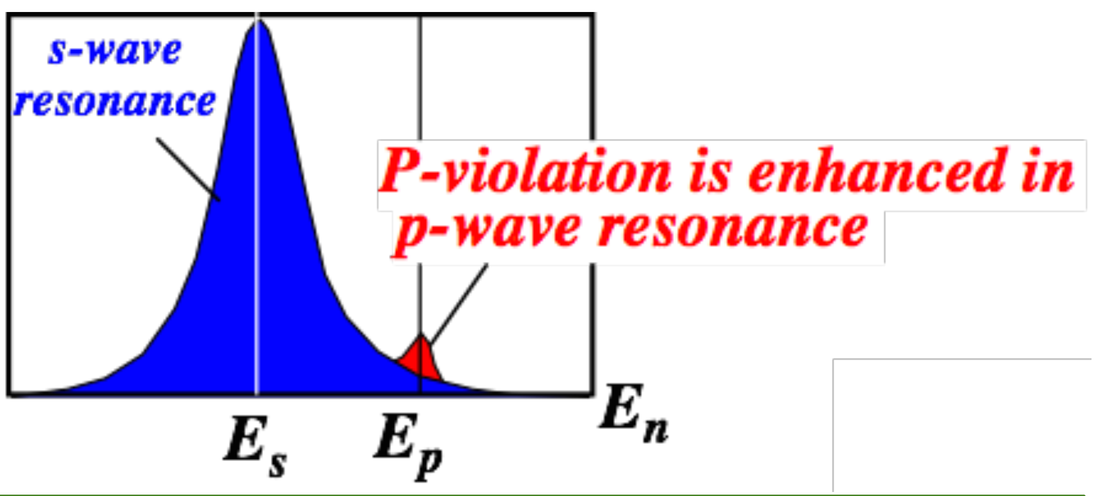
2% of p-wave total cross section

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

P-violation in compound nuclei



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

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

$l = 0$ s-wave resonance s

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

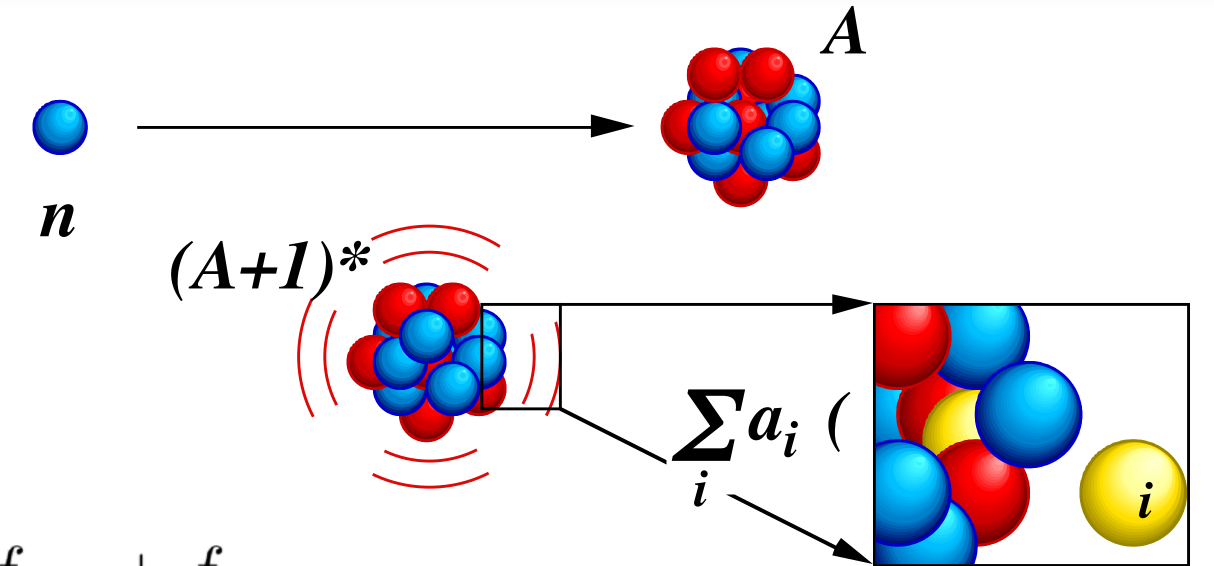
$l = 1$ p-wave resonance

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

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

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

$$\xrightarrow{E = E_p} \frac{2W}{|E_p - E_s|}\sqrt{\frac{\Gamma_s^n}{\Gamma_p^n}}$$

10^2 - 10^3 ~ 10^3

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

Estimation in effective field theory

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

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

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

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

compare with EDM

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

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

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from upper limit of EDM

$$|d_n| < 2.9 \times 10^{-26}\,\mathrm{e\,cm}$$

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

T-odd Correlation in Compound Nuclei

NOP-T

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T-violation

g_{CP}/g_P 10^{-3}

P-violation $10^{-2}\,\sigma_{\mathrm{tot}}$

compare with EDM 

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$$\boxed{|\Delta\sigma_{\mathrm{T}}^{nA}| < 2.5 \times 10^{-4}[\mathrm{b}] \times \kappa(J)}$$

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

T-violation in compound nuclei

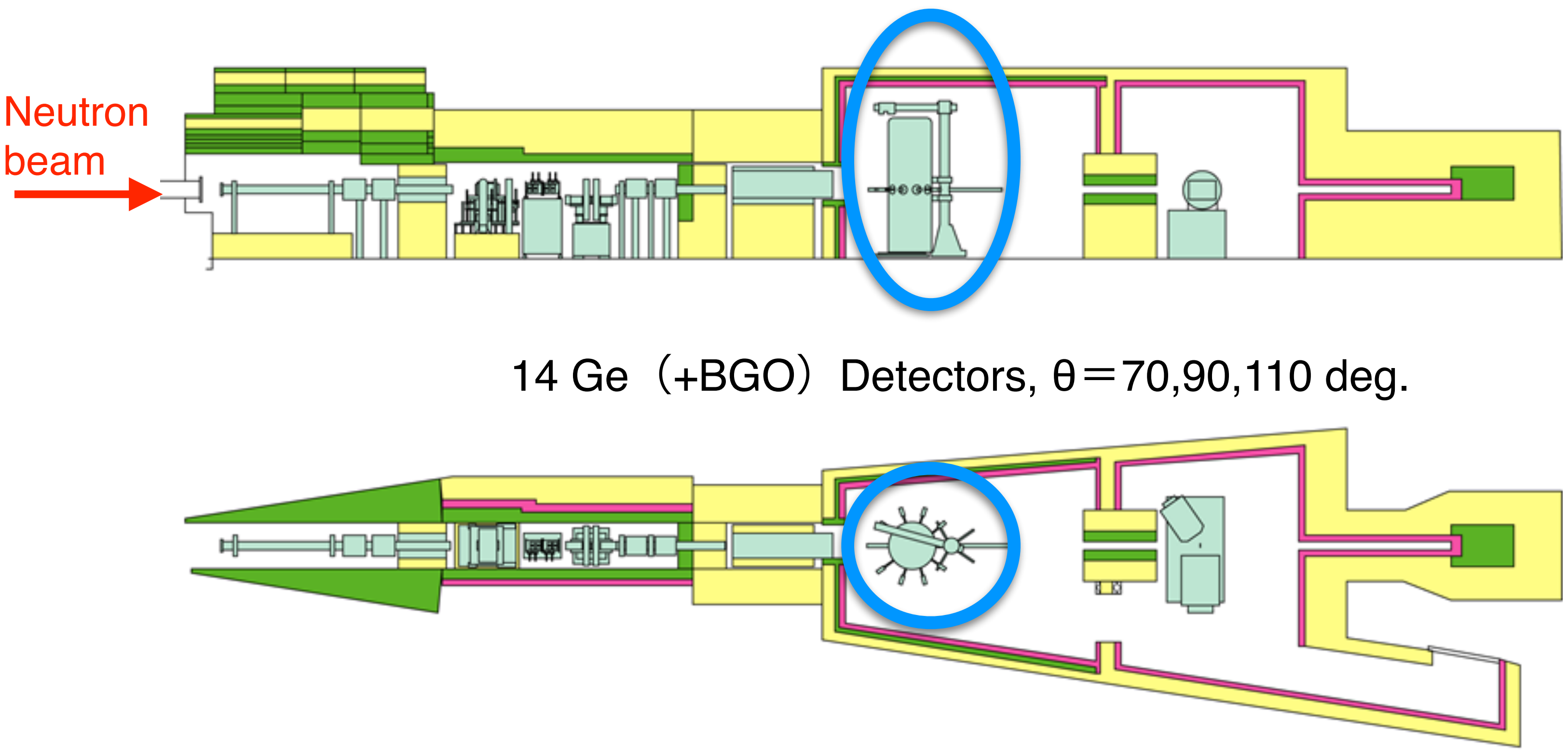
(n, γ) reaction measurement at J-PARC BL04 ANNRI

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

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

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

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



14 Ge（+BGO）Detectors, θ＝70,90,110 deg.

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

Intensity : ~ 3 x 10^5 n/cm^2/s ： 0.9 eV < En < 1.1eV @300kW

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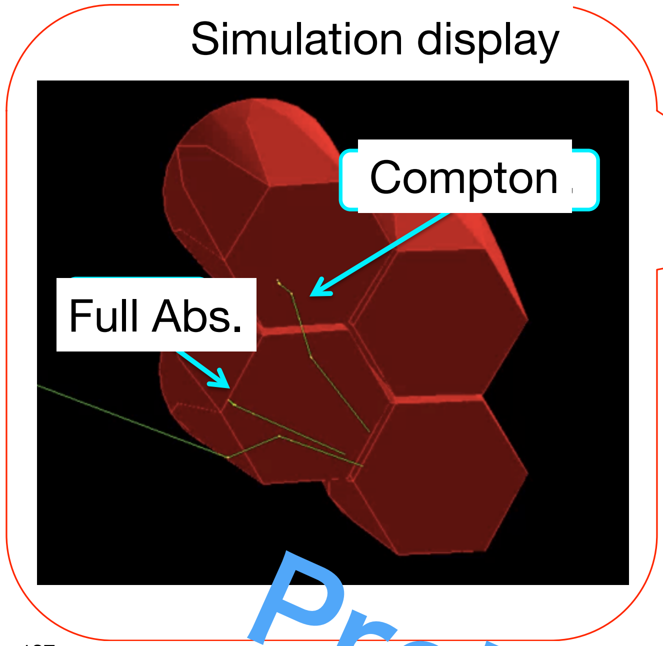

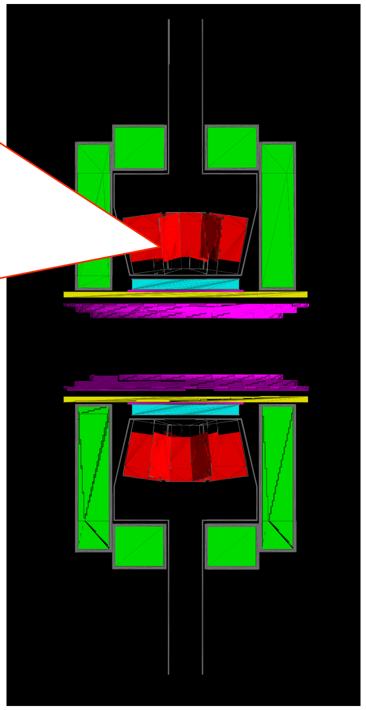

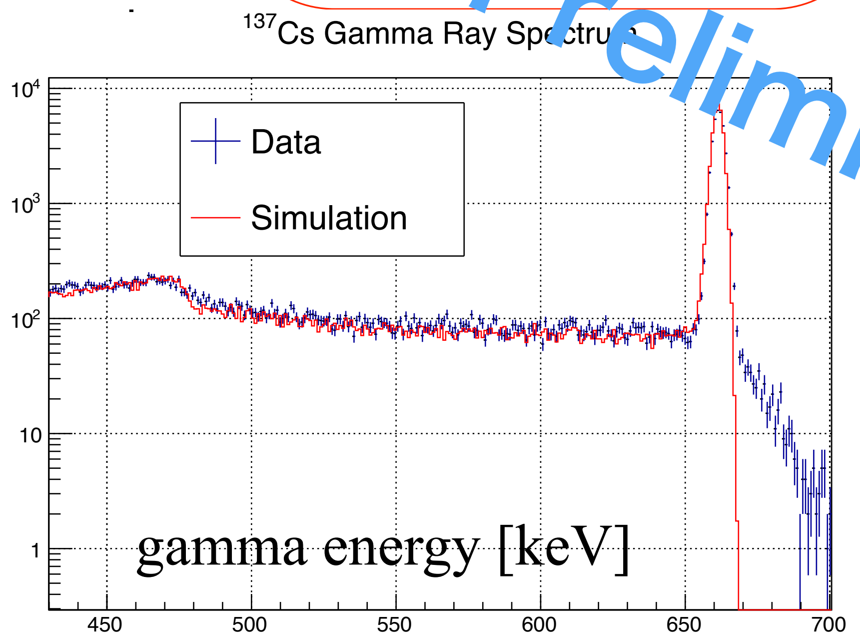

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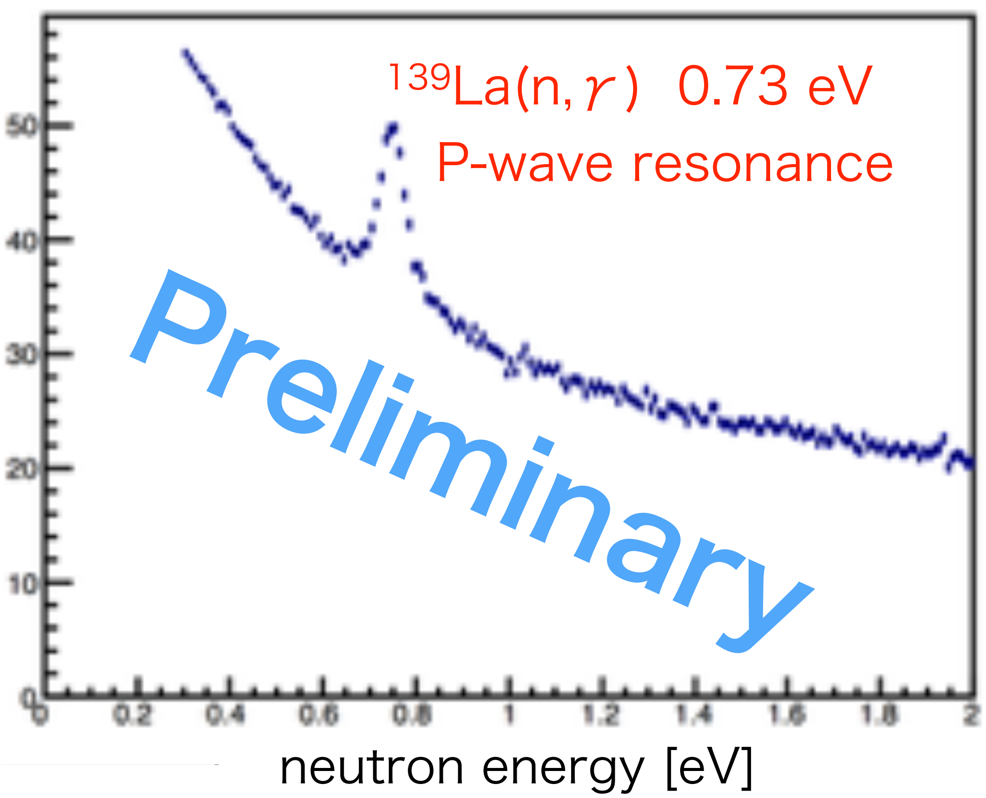
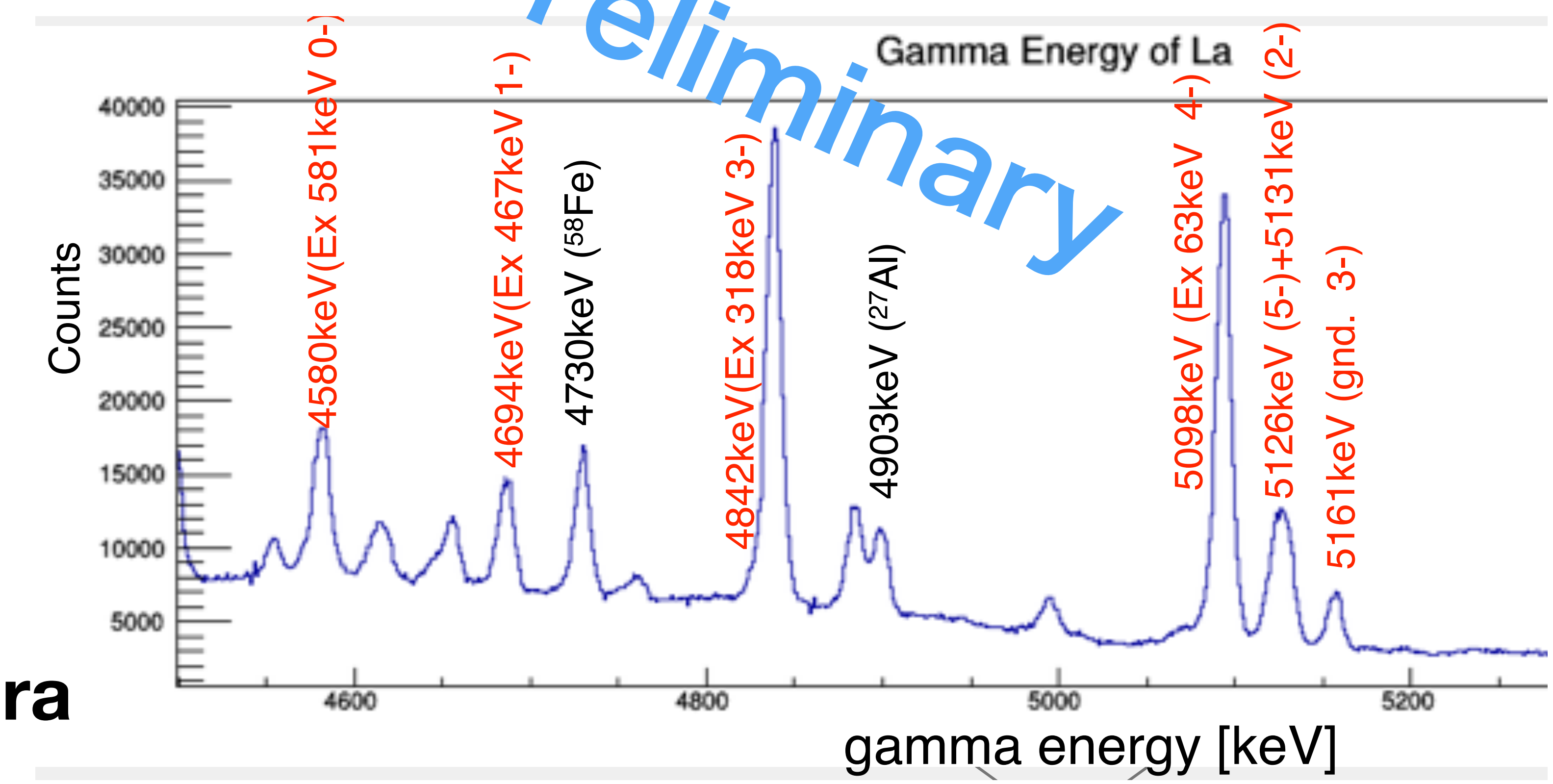


Analysis is on going …



More detail
-> Poster 14, Takuya Okudaira

T-odd Correlation in Compound Nuclei

NOP-T

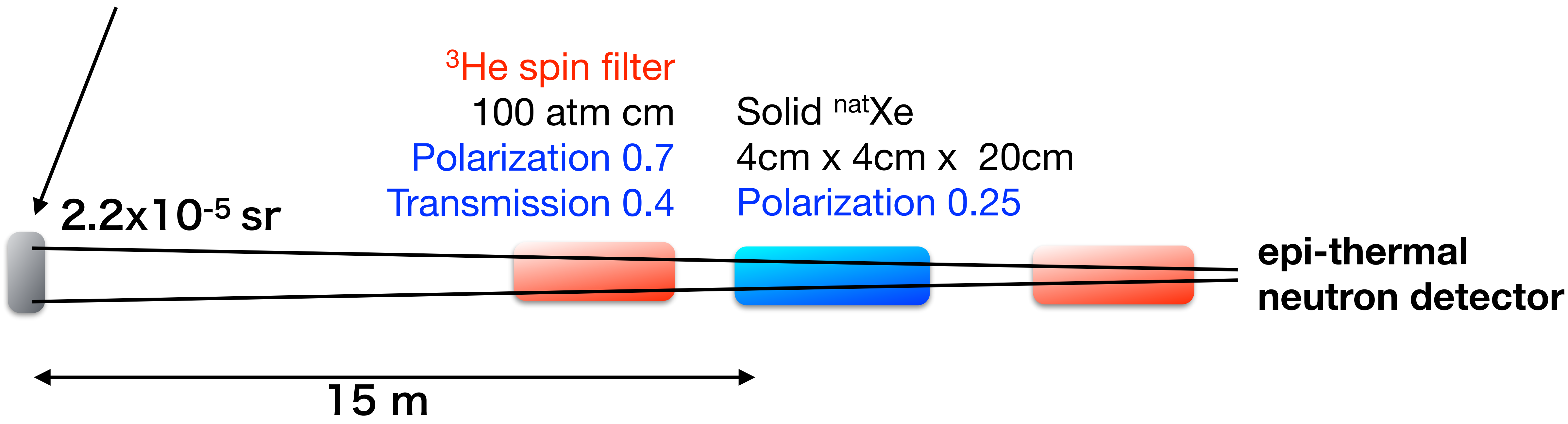
Experimental plan

p-wave resonance $E_n = 3.2$ eV

$\Gamma_n = 0.1$ eV

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

J-PARC BL07（Poisoned Moderator)



$$\kappa(J) = 1$$

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

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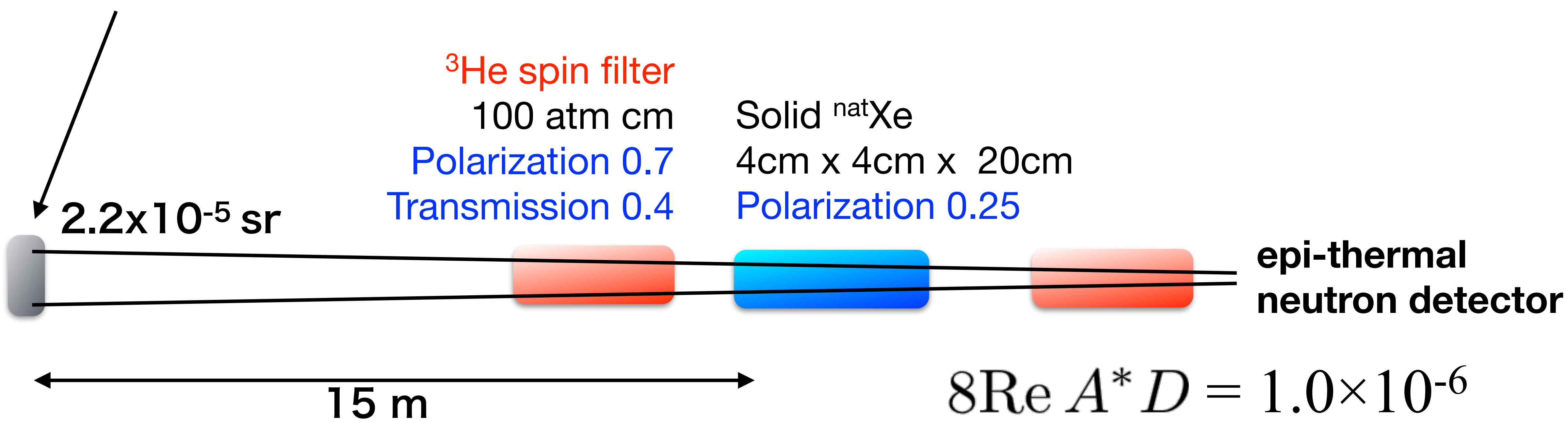

$$8 \mathrm{Re}\, A^* D = 1.0\times 10^{-6}$$

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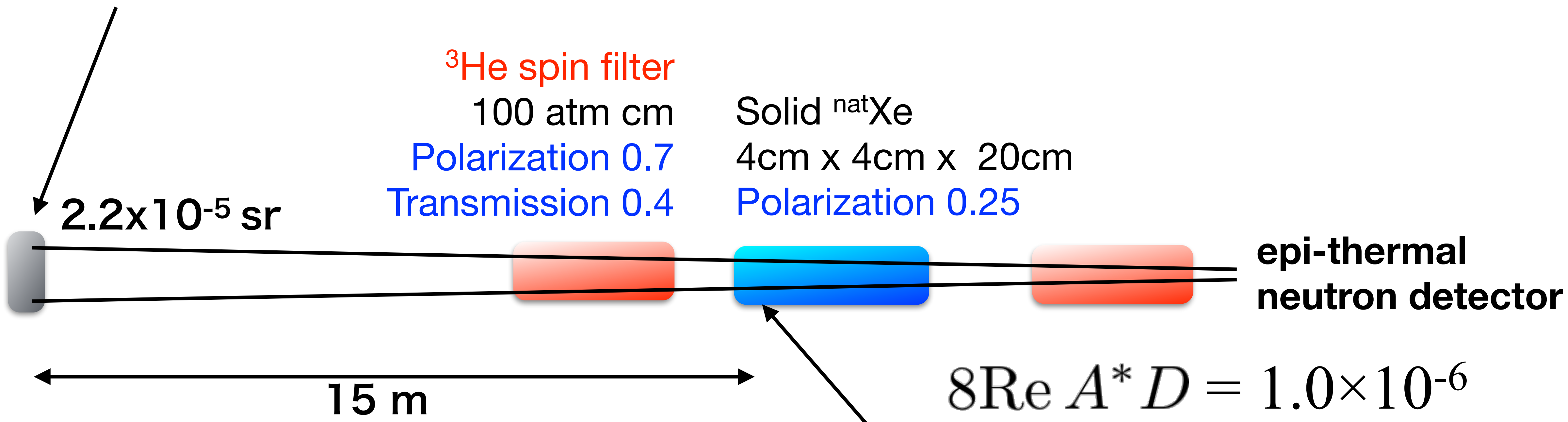

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7 x 10^{6} n s^{-1} at sample position

~ 5 days

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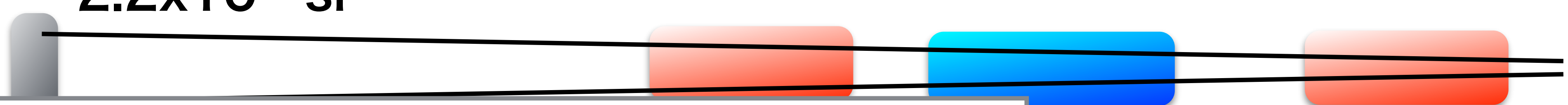
^{3}He spin filter
100 atm cm
Polarization 0.7
Transmission 0.4

Solid ^{nat}Xe
4cm x 4cm x 20cm
Polarization 0.25

2.2x10^{-5} sr



epi-thermal neutron detector

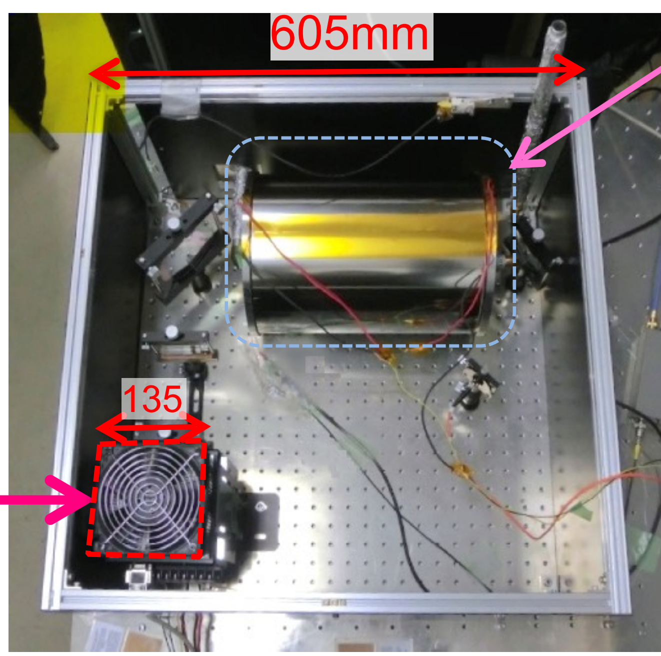
$$8\mathrm{Re}\, A^* D = 1.0\times10^{-6}$$

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

$\sim$ 5 days

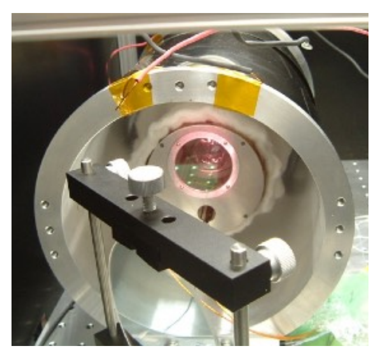
0^{-3}

SEOP ^{3}He spin filter is available



laser system

coil
in mu-metal shield



^{3}He cell

T-odd Correlation in Compound Nuclei

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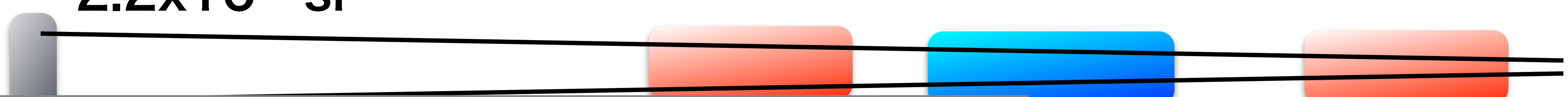

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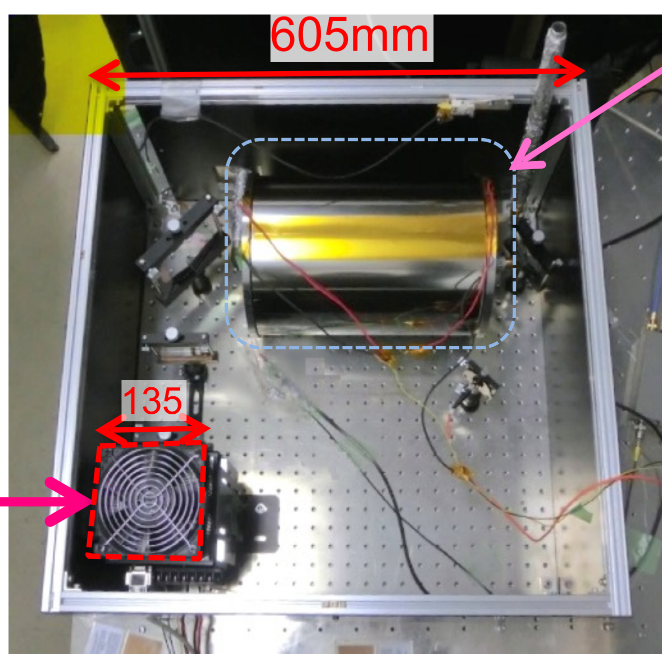

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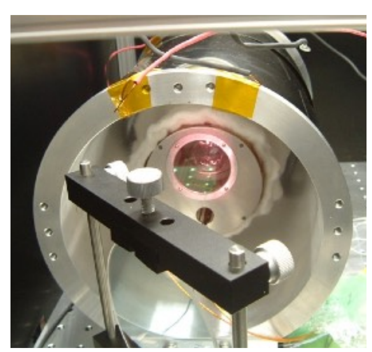

^{3}He cell

Polarized Target

Solid Polarized Xe with laser

developed for nEDM co-magnetometer

T-odd Correlation in Compound Nuclei

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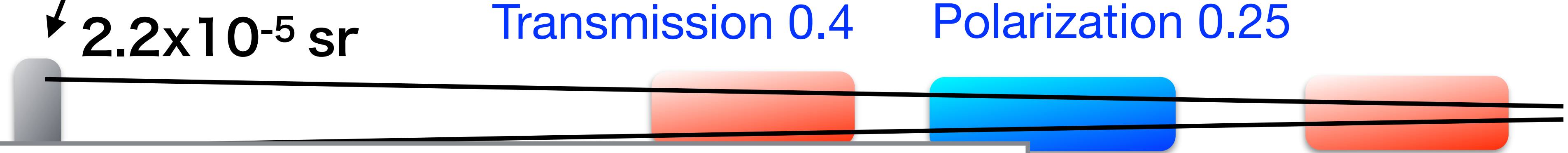
J-PARC BL07 (Poisoned Moderator)

Epi-thermal neutron Detector

^{10}B doped liquid scintillator

^{3}He spin filter
100 atm cm
Polarization 0.7
Transmission 0.4

Solic
4cm
Polarization 0.25



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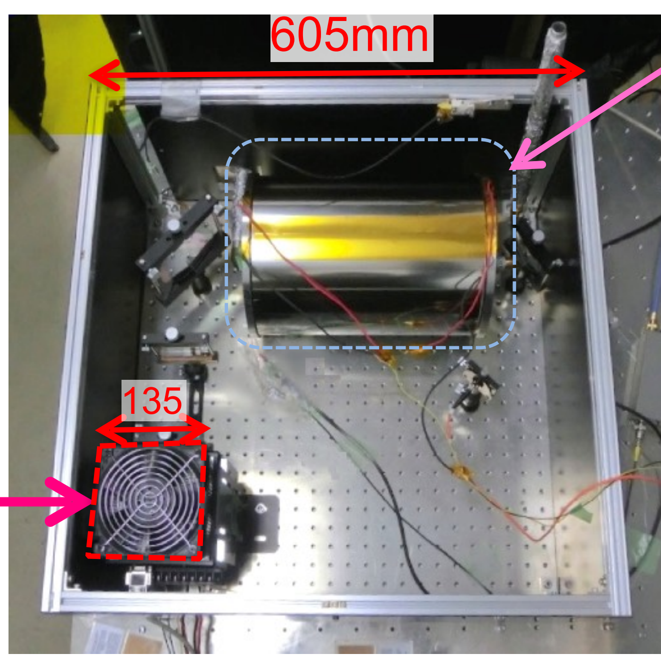

coil
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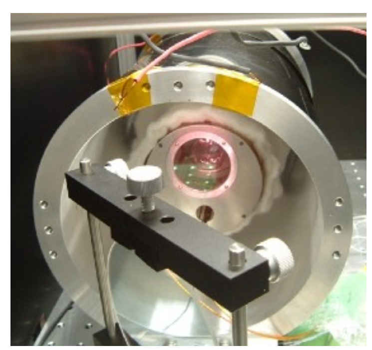

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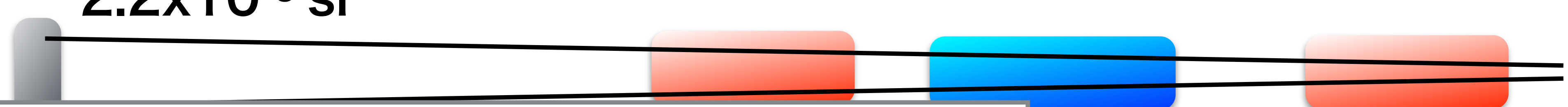
J-P

Epi-thermal neutron Optics

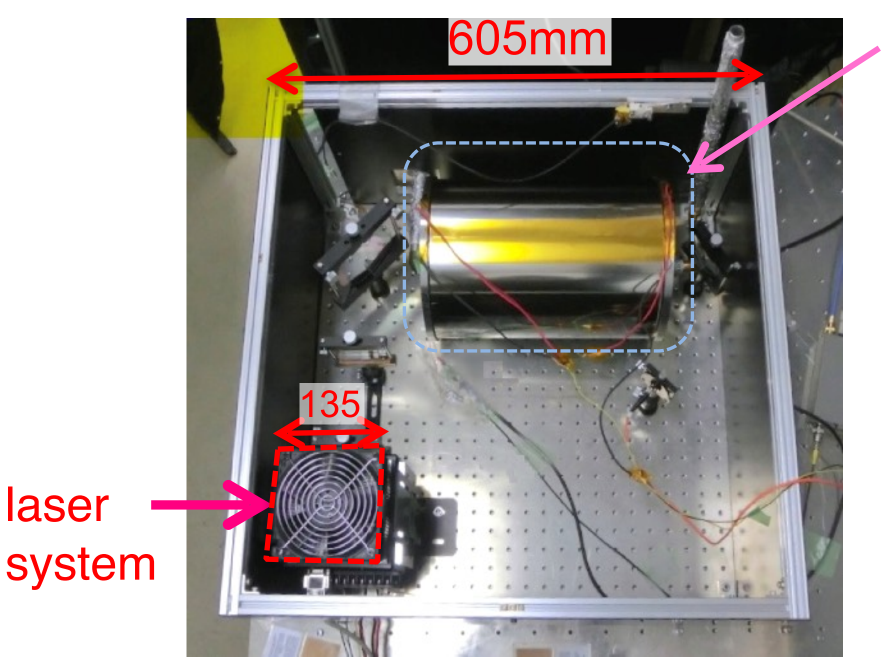
epi-thermal neutron transport optics,
spin control, . . .

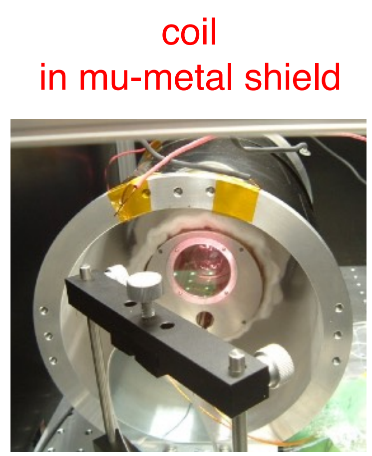
Epi-thermal neutron Detector

^{10}B doped liquid scintillator



SEOP ^{3}He spin filter is available





Polarized Target

Solid Polarized Xe with laser

developed for nEDM co-magnetometer

T-odd Correlation in Compound Nuclei

Experimental plan

p-wave resonance $E_n = 3.2$ eV

$\Gamma_n = 0.1$ eV

J-P

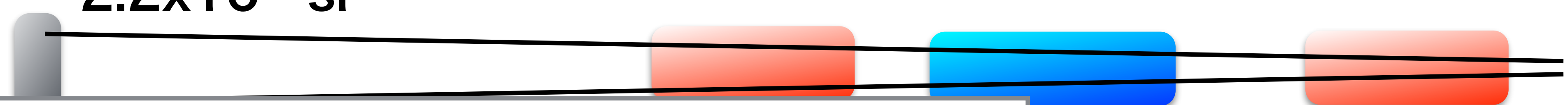
Epi-thermal neutron Optics

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

Epi-thermal neutron Detector

^{10}B doped liquid scintillator

2.2x10^{-5} sr



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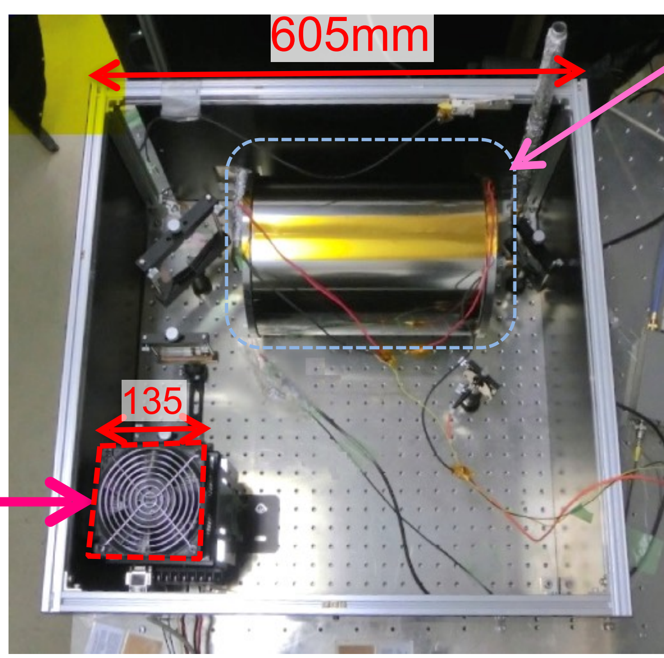
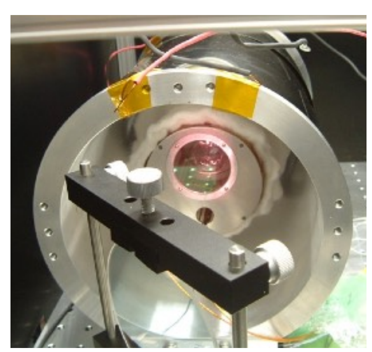


laser
system

coil
in mu-metal shield



^{3}He cell

Polarized Target

Solid Polarized Xe with laser

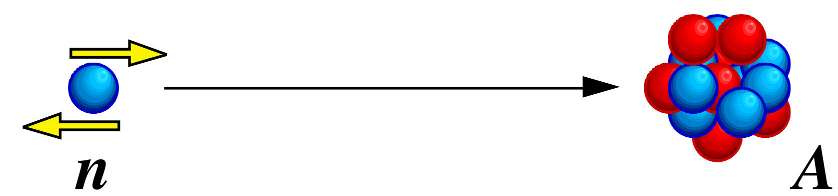
developed for nEDM co-magnetometer

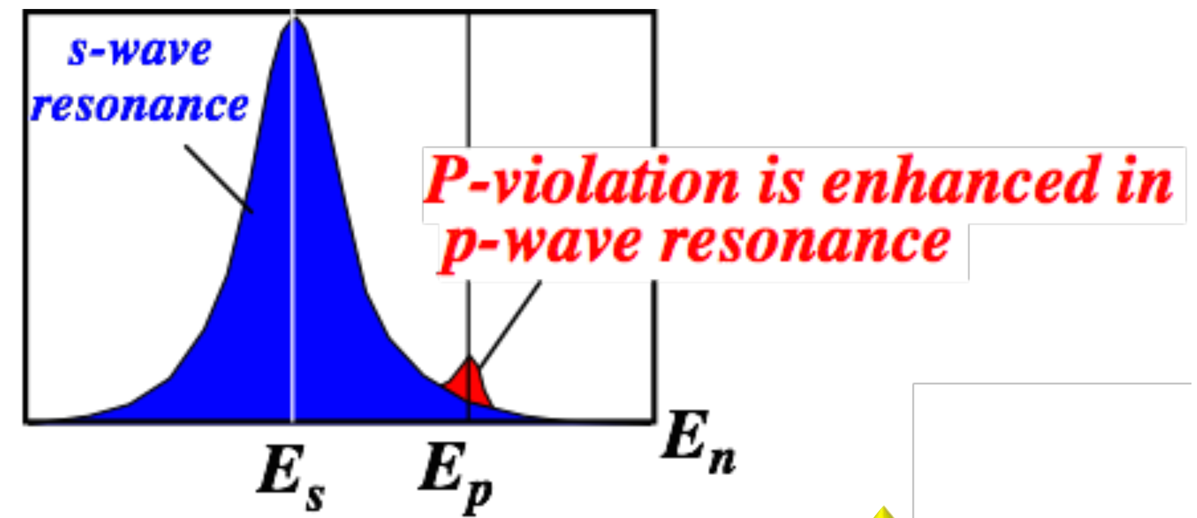
More detail
-> Poster 12, Tomoki Yamamoto

T-odd Correlation in Compound Nuclei

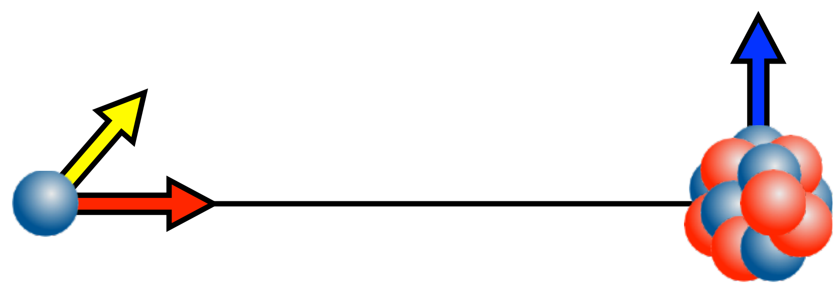
NOP-T

P-violation is enhanced to 10^6 with interference between partial wave functions of compound nuclei.





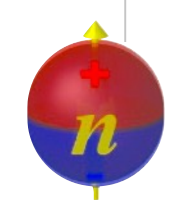
T-violation is also enhanced?



$$\left|\Delta\sigma_{\mathrm{T}}^{nA}\right| < 2.5 \times 10^{-4}[\mathrm{b}] \times \kappa(J)$$

can be measured at J-PARC.

compare with EDM



Enhancement factor $\kappa(J)$ is estimated with measurement of (n, γ) reaction.

Feasibility studies are now going on at BL04 ANNRI in J-PARC.

More detail -> Poster 14, Takuya Okudaira
Poster 12, Tomoki Yamamoto

R&D for T-violation experiments has also started.

T-odd Correlation in Compound Nuclei

NOP-T

NOPTREX collaboration

Nagoya University
H.M.Shimizu, M.Kitaguchi, K.Hirota,
T.Okudaira, A.Okada, K.Nagamoto,
M.Yokohashi, T.Yamamoto,
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

Yamagata Univ.
T.Iwata, Y.Miyachi

RIKEN
N.Yamanaka, Y.Yamagata

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

Kyoto Univ.
M.Hino

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

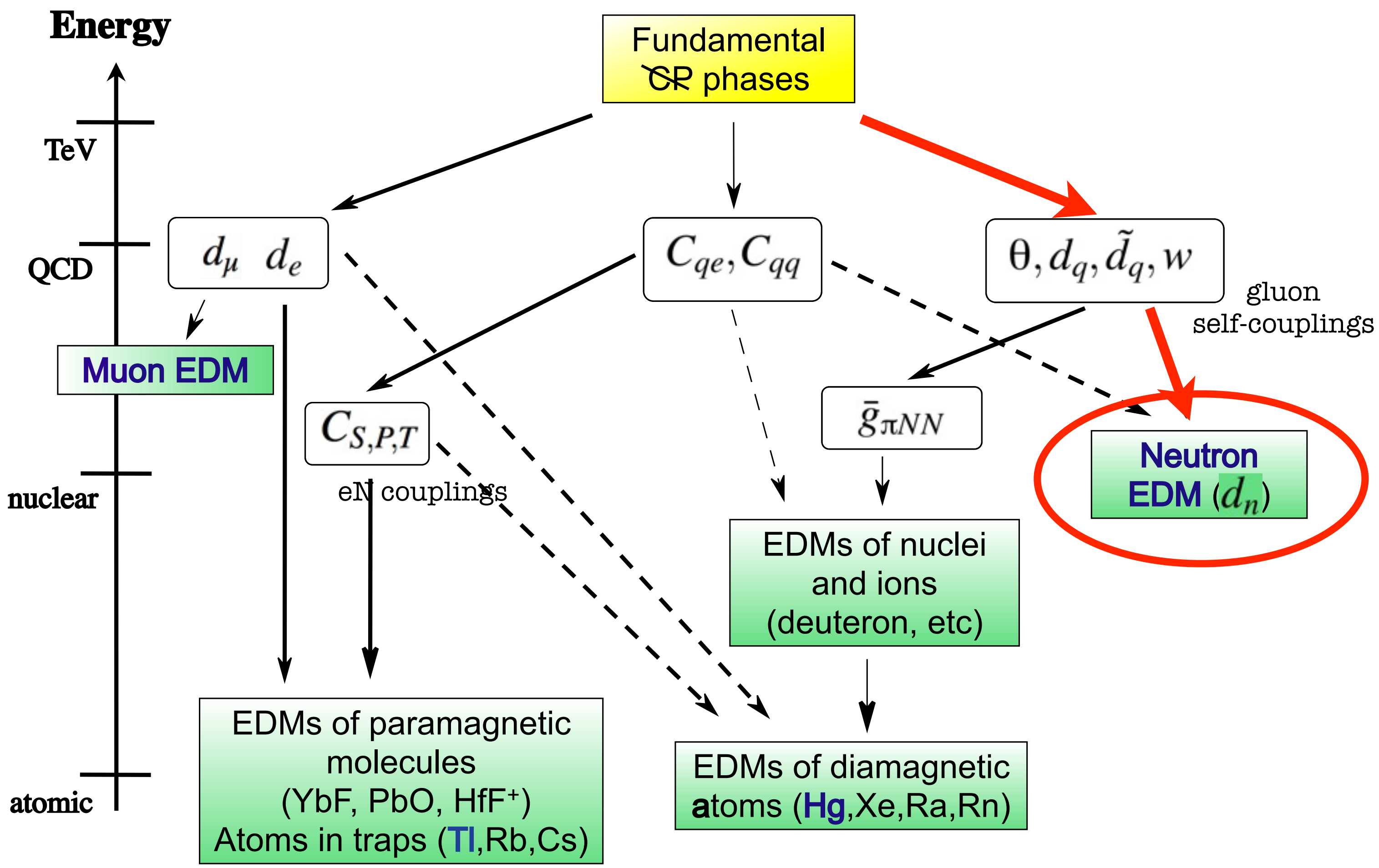
Paul Scherrer Institut
P.Hautle

Southern Illinois University
B.M.Goodson

Univ. California Berkeley
A.S.Tremsin

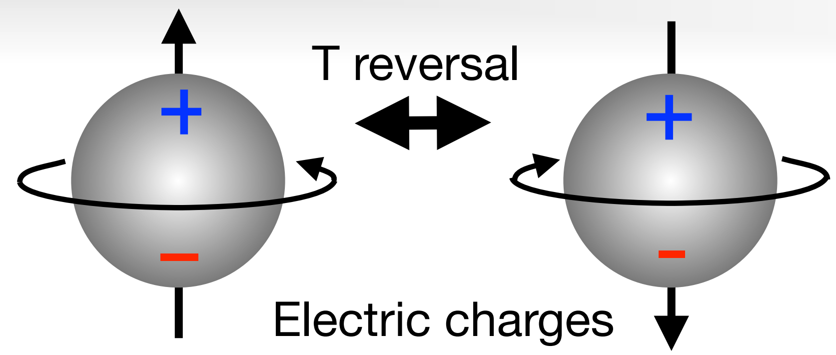
Neutron Electric Dipole Moment

Neutron EDM

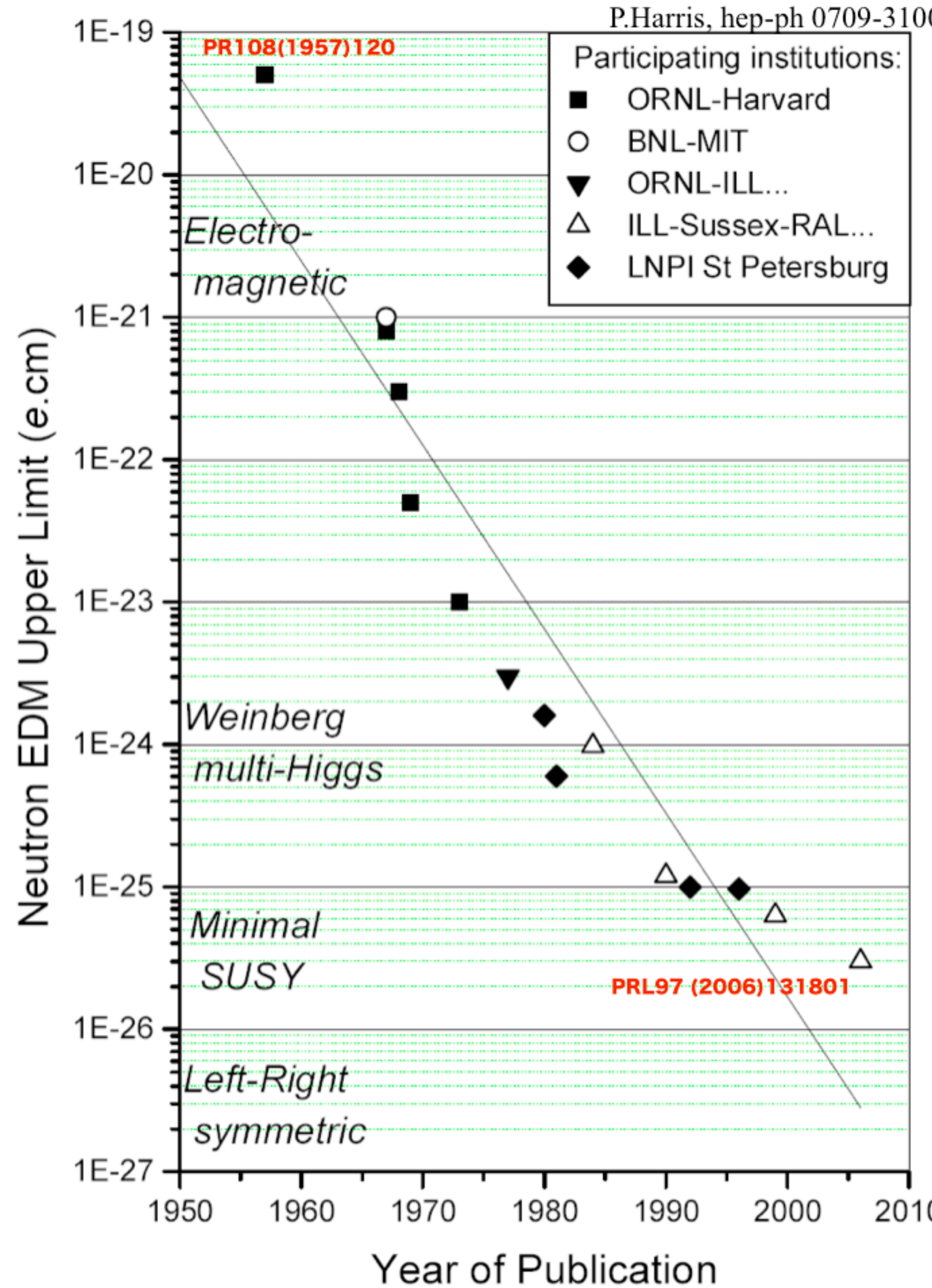


Pospelov Ritz, Ann Phys 318 (05) 119

Spin is reversed.



Electric charges don't change.



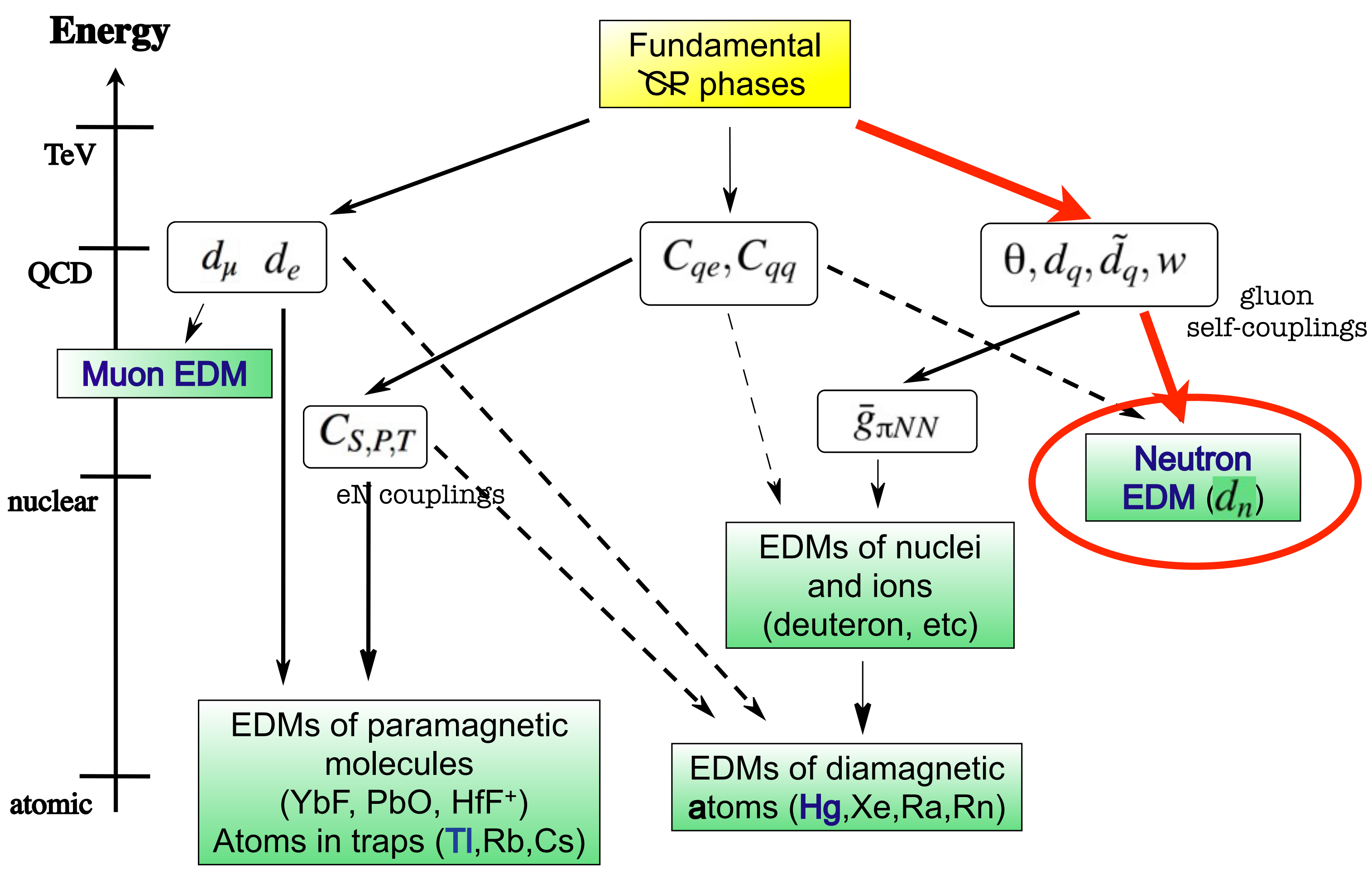
Present upper limit $|d_n| < 2.9 \times 10^{-26}\ e$ cm

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

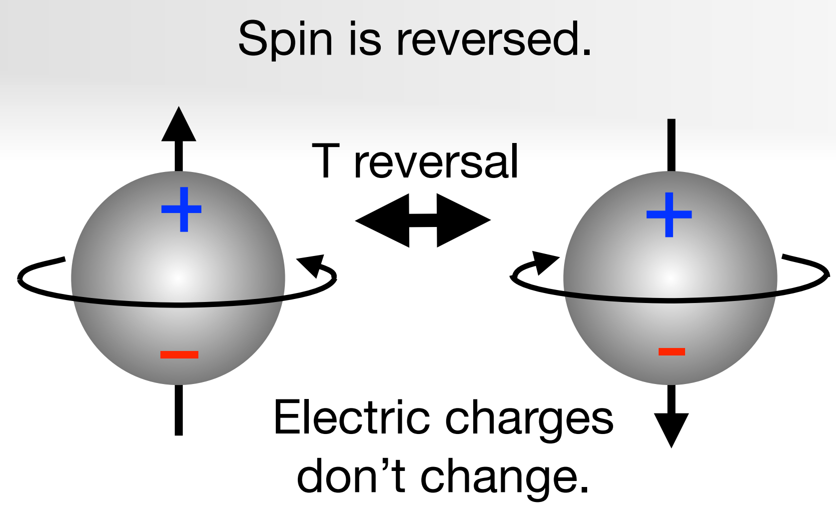
Standerd Model : $|d_n| \sim 10^{-32}\ e$ cm

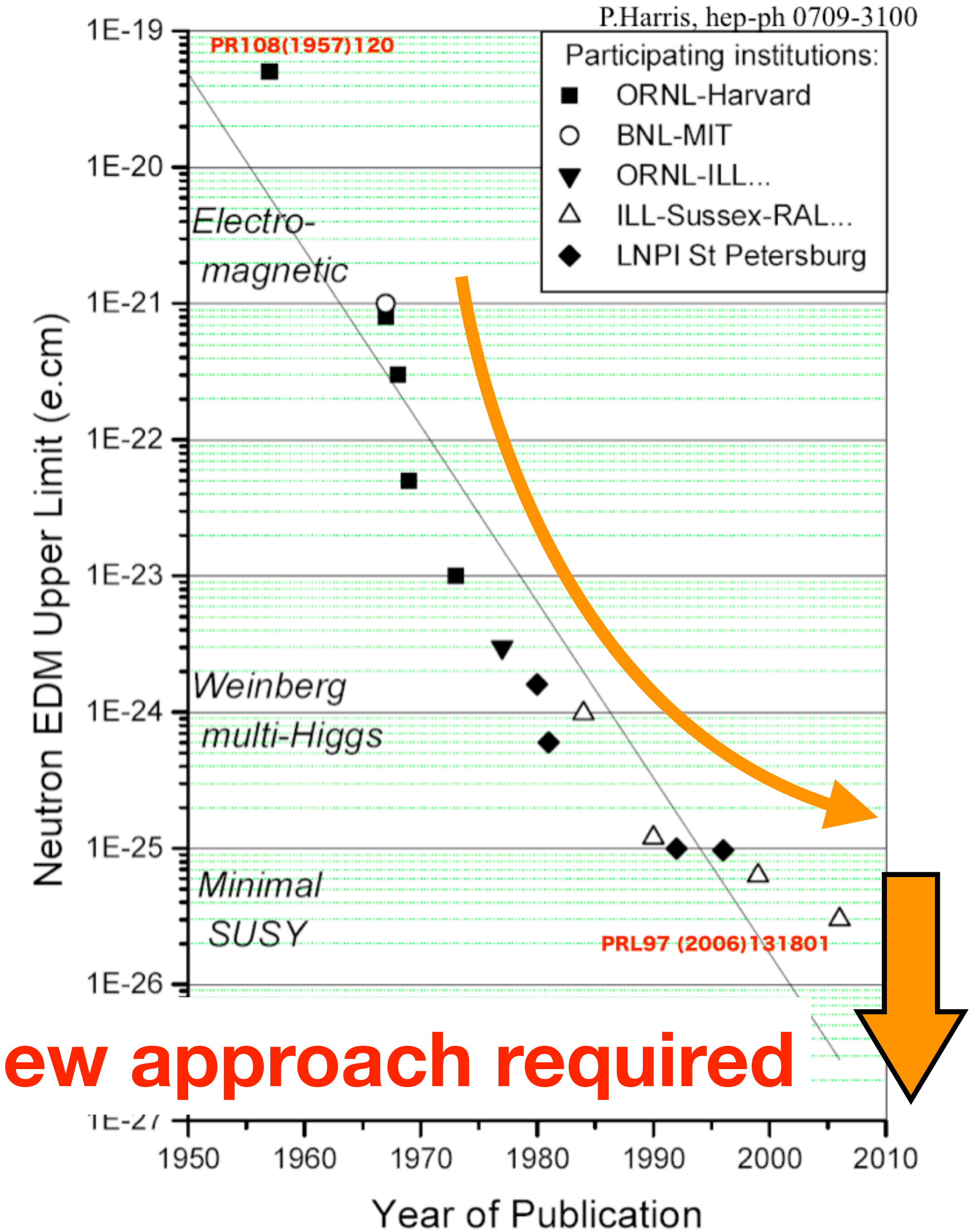
New Physics (SUSY ...) : $|d_n| \sim 10^{-27 \sim -28}\ e$ cm

Neutron EDM



Pospelov Ritz, Ann Phys 318 (05) 119





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

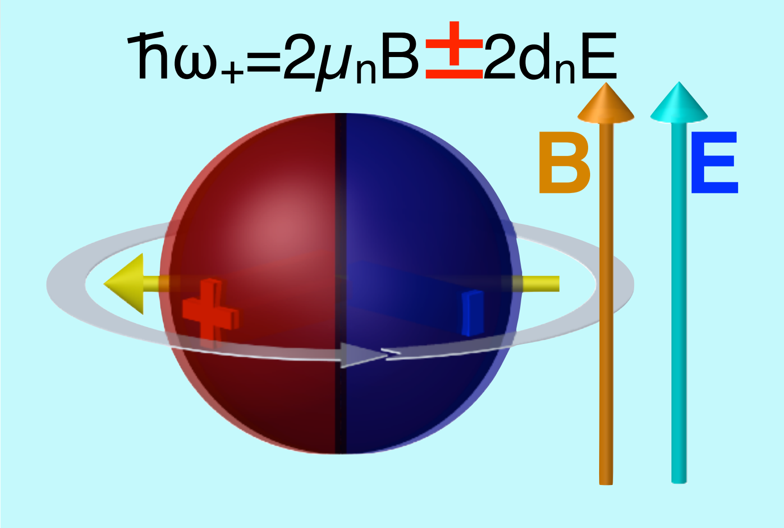
Neutron EDM

Dense UCNs

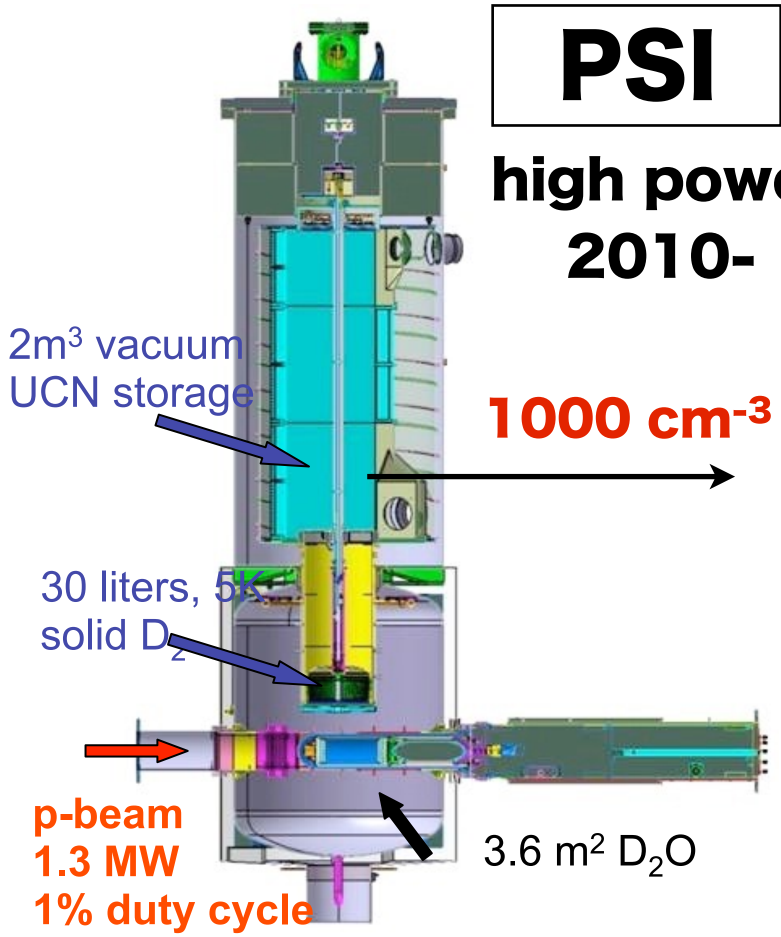
Precessions of stored UCNs are measured.

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

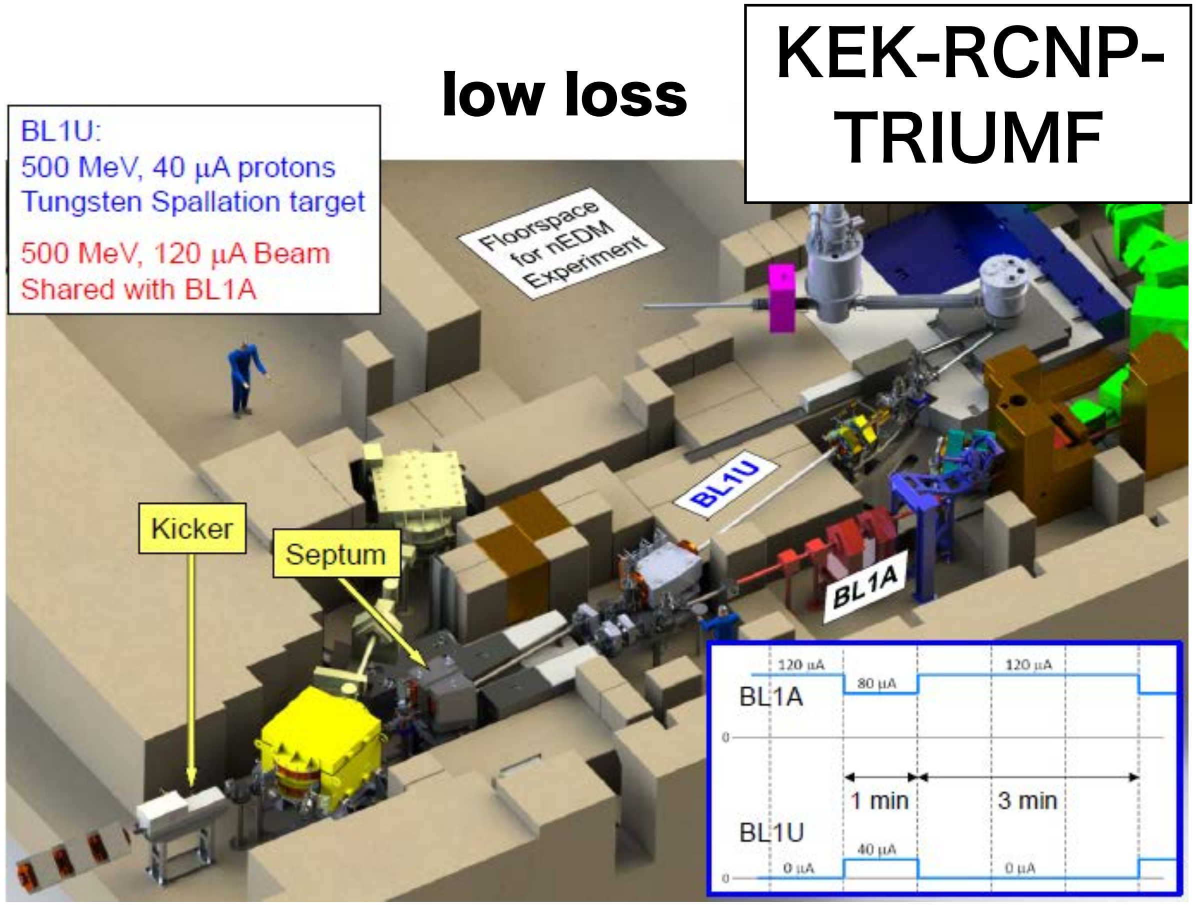
1 μT 1fT equiv.



Use intense source



average = 13kW
max. peak power = 1.3MW



average=20kW
max. peak power = 200kW

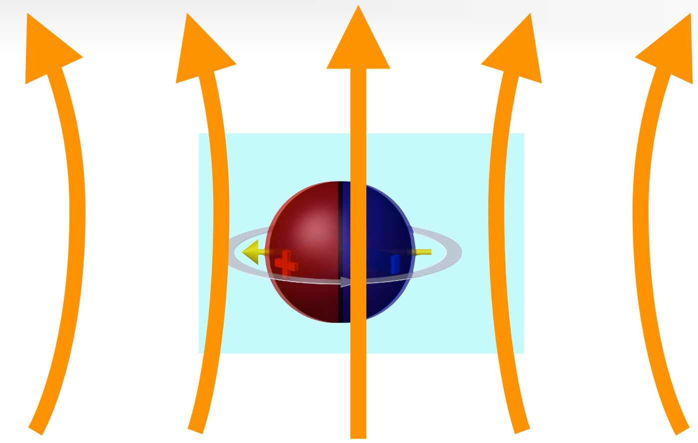
Neutron EDM

Dense UCNs

Precessions of stored UCNs are measured.

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

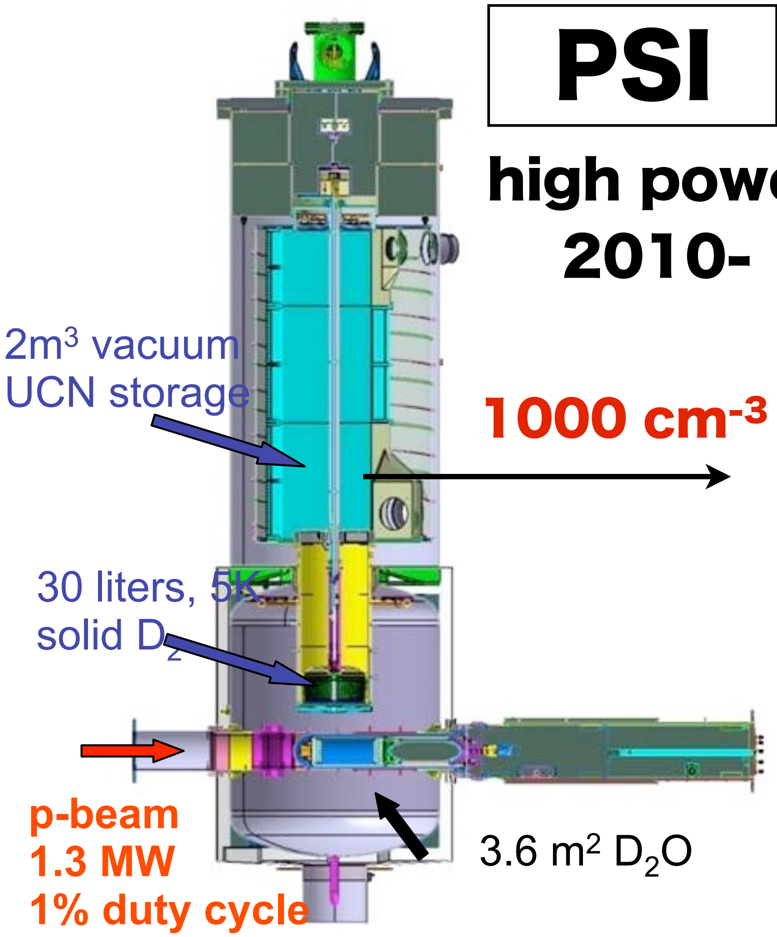
$1\,\mu$T 1fT equiv.



Use intense source

PSI

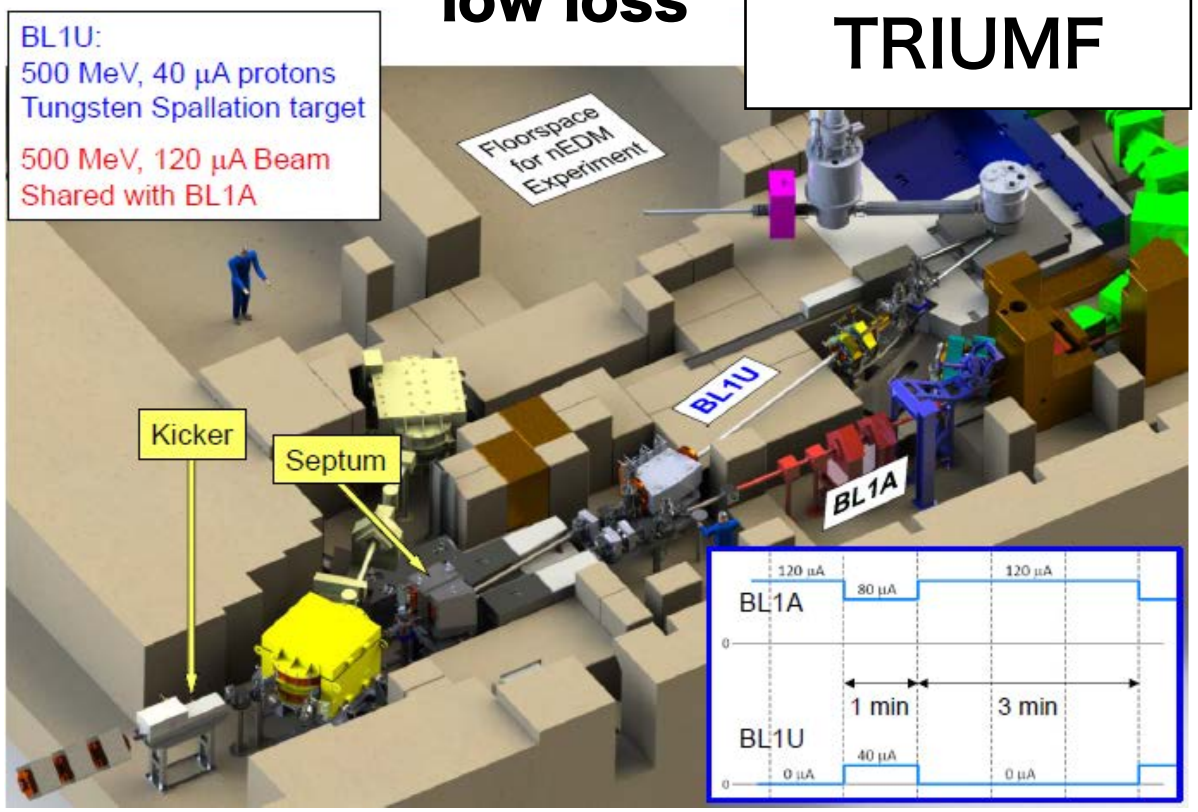
high power 2010-



average = 13kW
max. peak power = 1.3MW

low loss

KEK-RCNP-TRIUMF



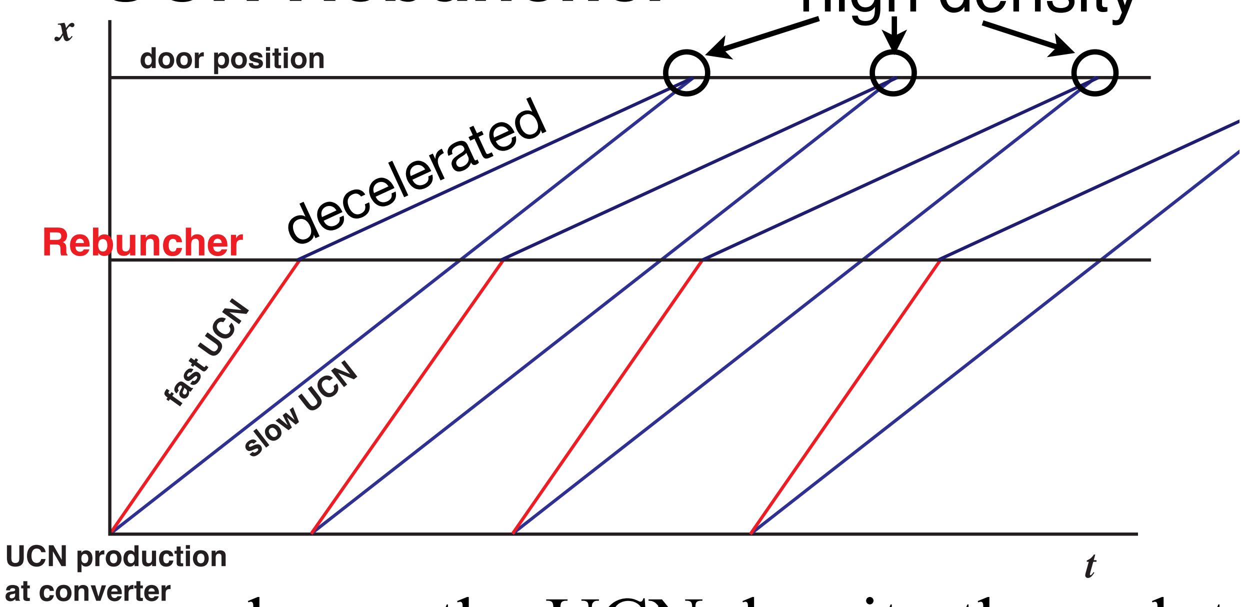
average=20kW
max. peak power = 200kW

Neutron EDM

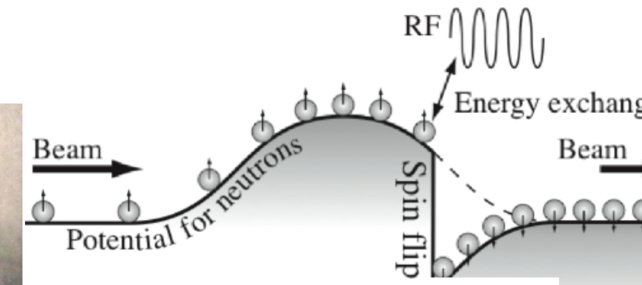
UCN optics

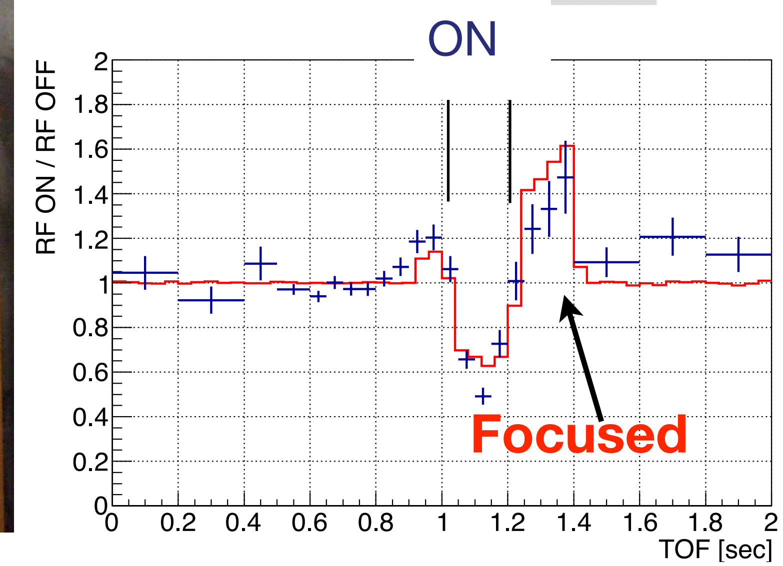
for next generation UCN experiments

UCN Rebuncher



keeps the UCN density through transport.



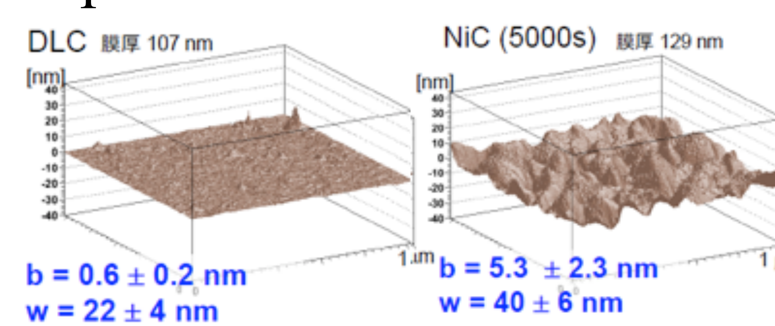


Arimoto, et. al., PRA86, 023843(2013)

DLC mirror

Neutron mirror with high reflectivity on complex shape can be fabricated using diamond-like carbon by CVD.

potential 240 neV
off-specular reflection < 1%



Simulation of UCN movement

We have developed the simulation tools based on GEANT4.

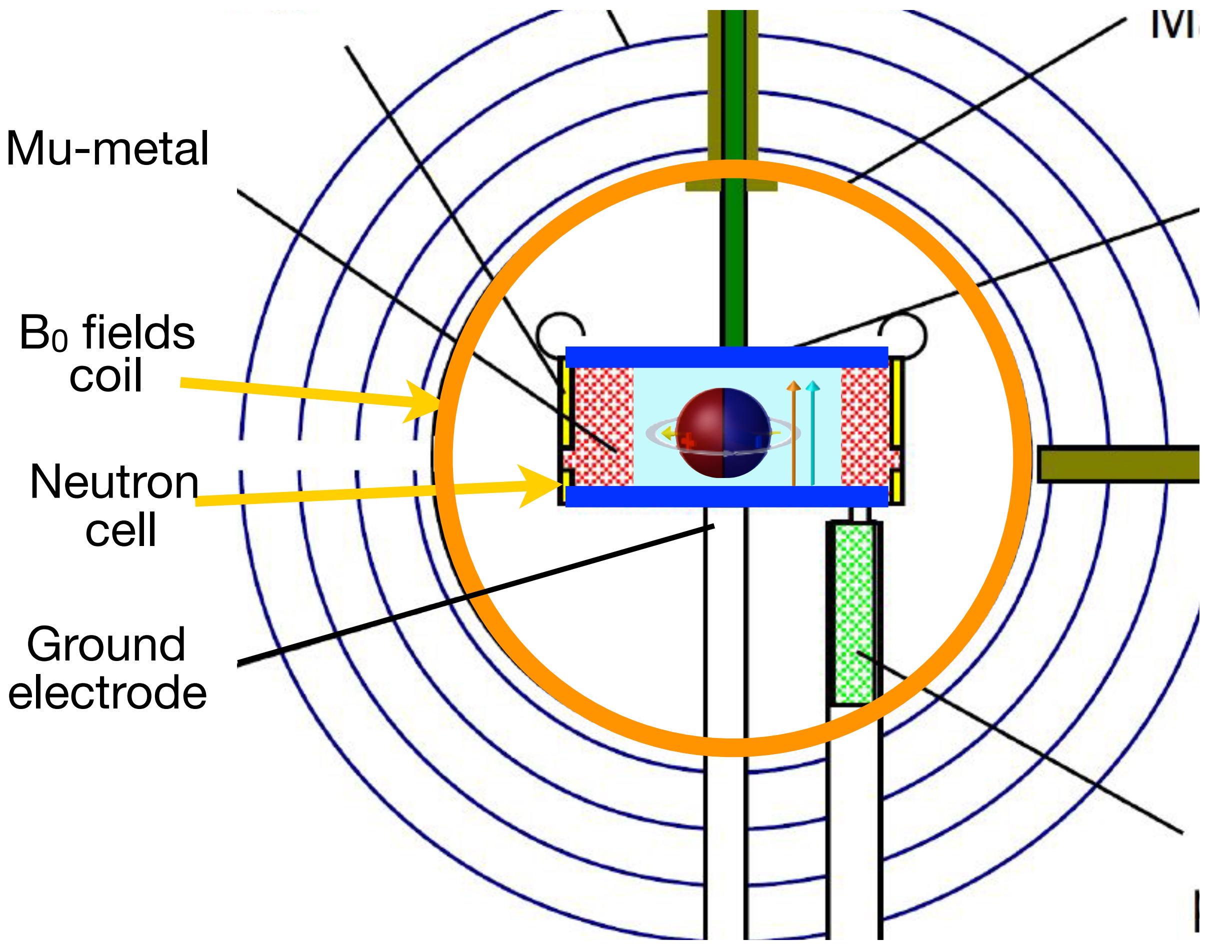
Neutron EDM

Crystal EDM

measures spin precession in strong electric field
in non-centrosymmetric crystal.

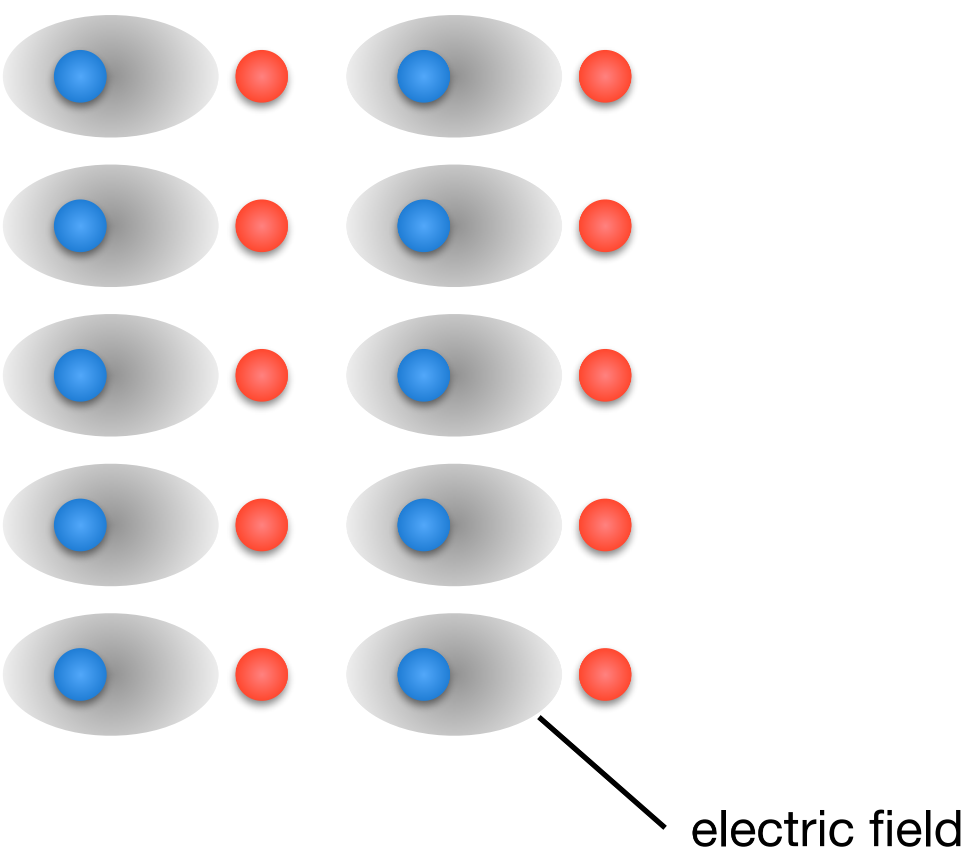
UCN storage

~ 10^4 V/cm



Crystal diffraction

~ 10^8 V/cm



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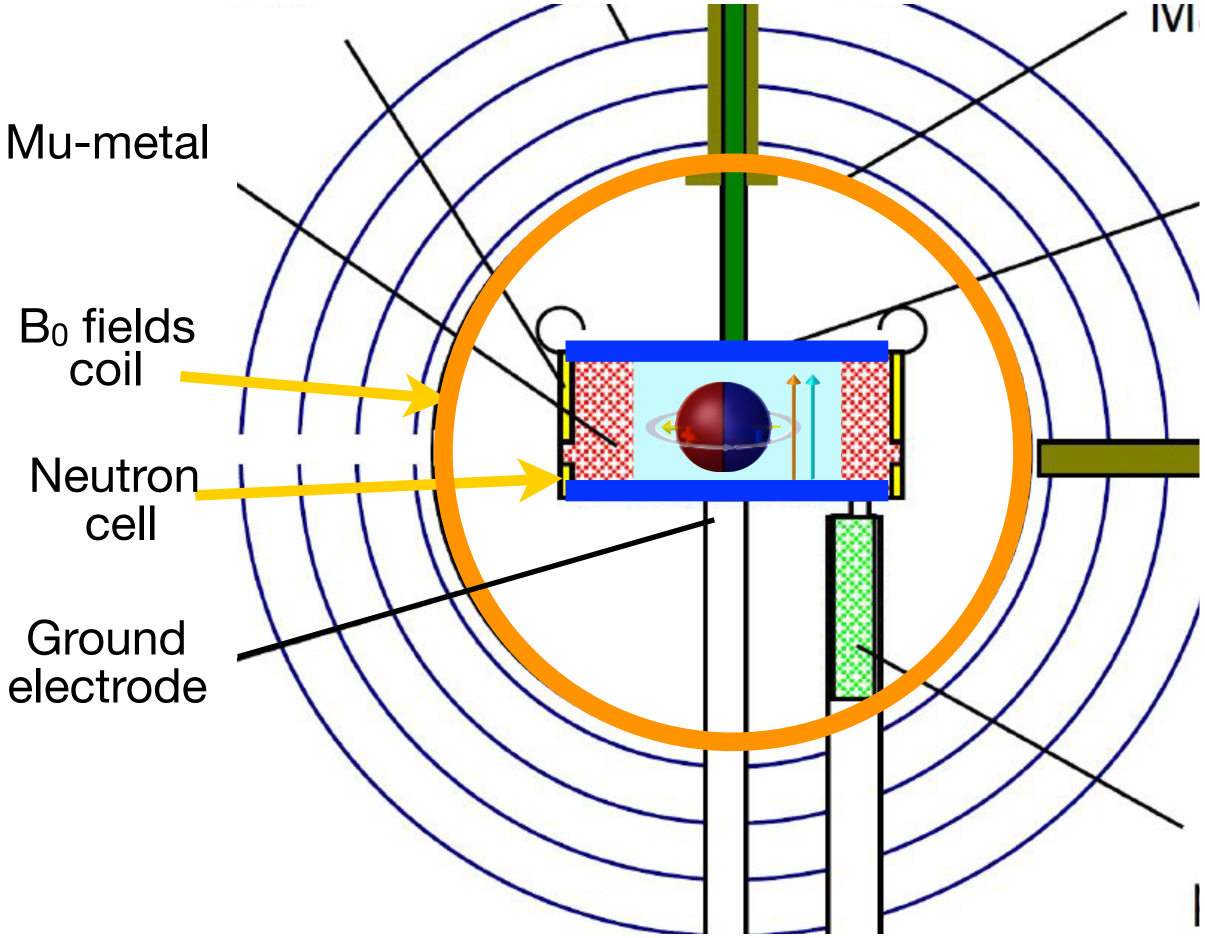
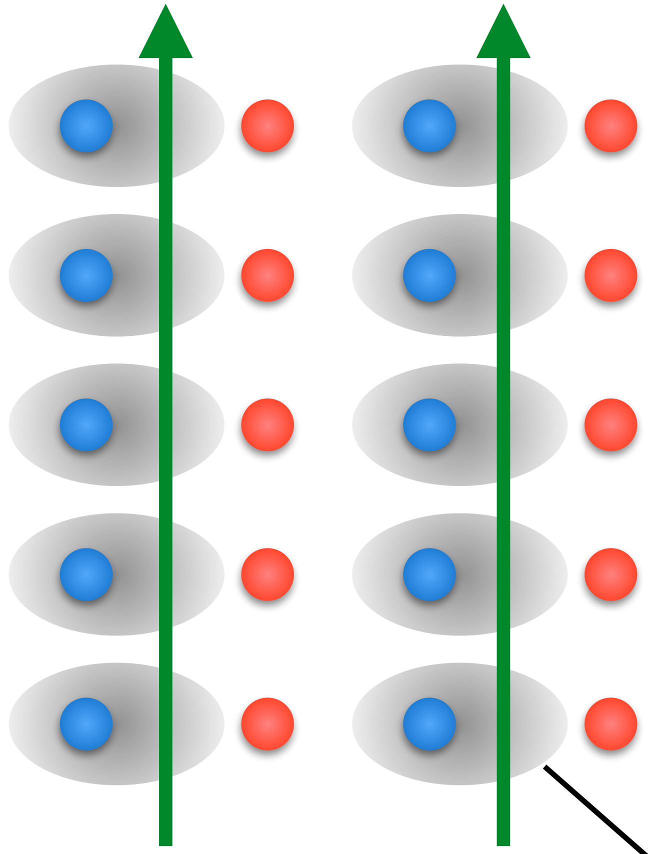
~ 10^4 V/cm



Crystal diffraction

~ 10^8 V/cm



Neutron EDM

Crystal EDM

measures spin precession in strong electric field
in non-centrosymmetric crystal.

$$\sigma(d_n) = \frac{h}{2E\tau\sqrt{nT}}$$

Same order of sensitivity can be achieved.

	UCN method	diffraction method
E	$\sim 10^4$V/cm	$\sim 10^8$V/cm
τ	~100sec	~1msec
n	~100/sec	$\sim 10^4$/sec
$\sigma(d_n)$	$\sim 10^{-25}/\sqrt{D}\quad e\cdot cm$	$\sim 10^{-25}/\sqrt{D}\quad e\cdot cm$

Neutron EDM

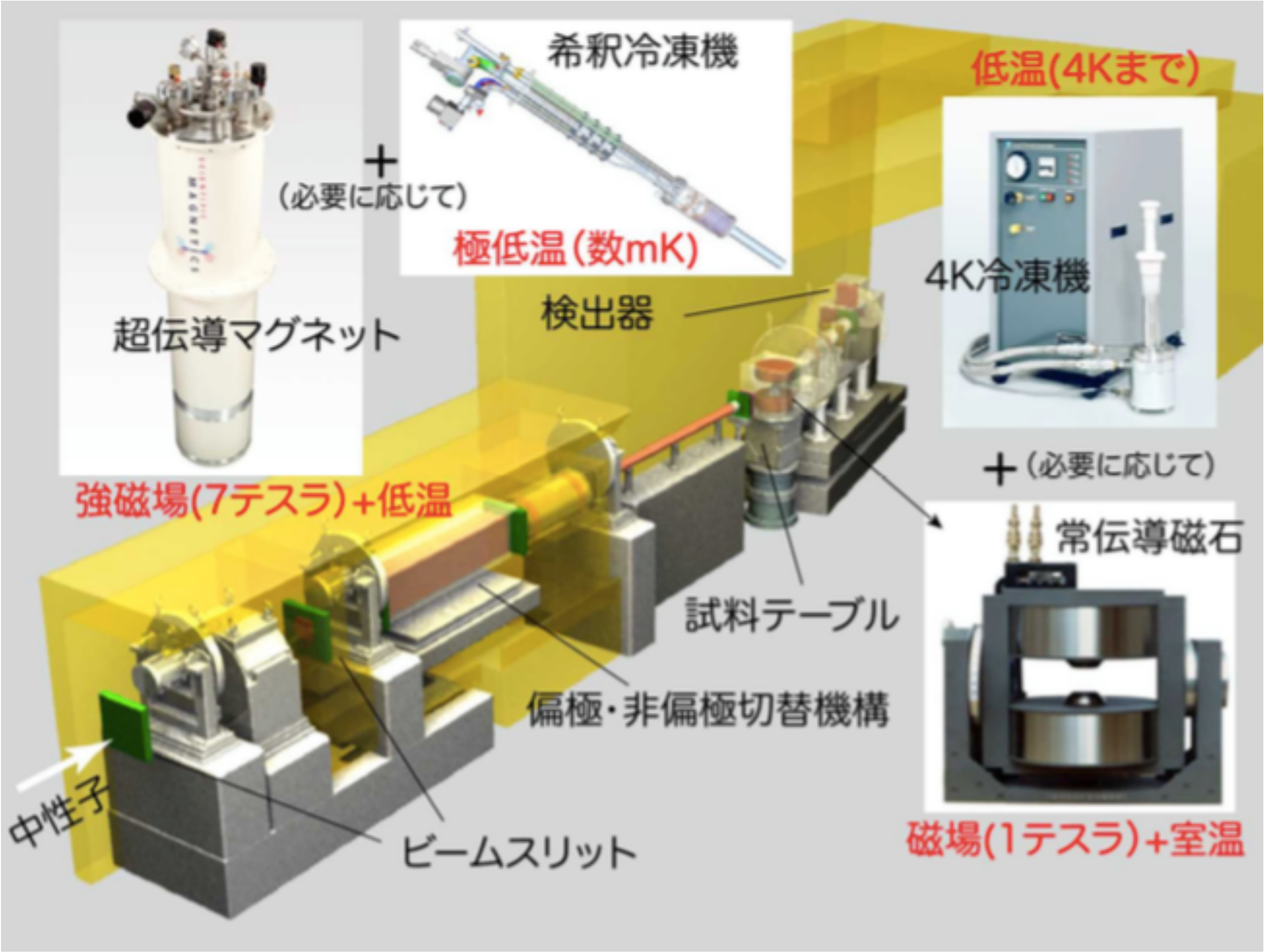
Crystal EDM

結晶	対称群	hkl	d_{hkl} Å	Eg 10^8V/cm	L cm	τ msec	Eg*τ kV s/cm
SiO_2 (α–quartz)	32 (D63)	111	2.24	2.30	3.36	1.45	333
		110	2.46	2.00	3.86	1.83	366
$Bi_{12}GeO_{20}$	I23	433	1.74	5.20	1.48	0.50	259
		312	2.71	2.40	3.22	1.68	403
$PbTiO_3$	4mm	411	0.92	17.80	0.43	0.08	137
		002	2.08	14.20	0.54	0.22	309
BeO	6mm	011	2.06	5.40	1.43	0.57	307
		201	1.13	6.50	1.19	0.26	168
$Bi_4Si_3O_{12}$	-43m	242	2.10	4.60	1.68	0.68	312
		132	2.75	3.20	2.41	1.28	409

We prepared BGO crystals.

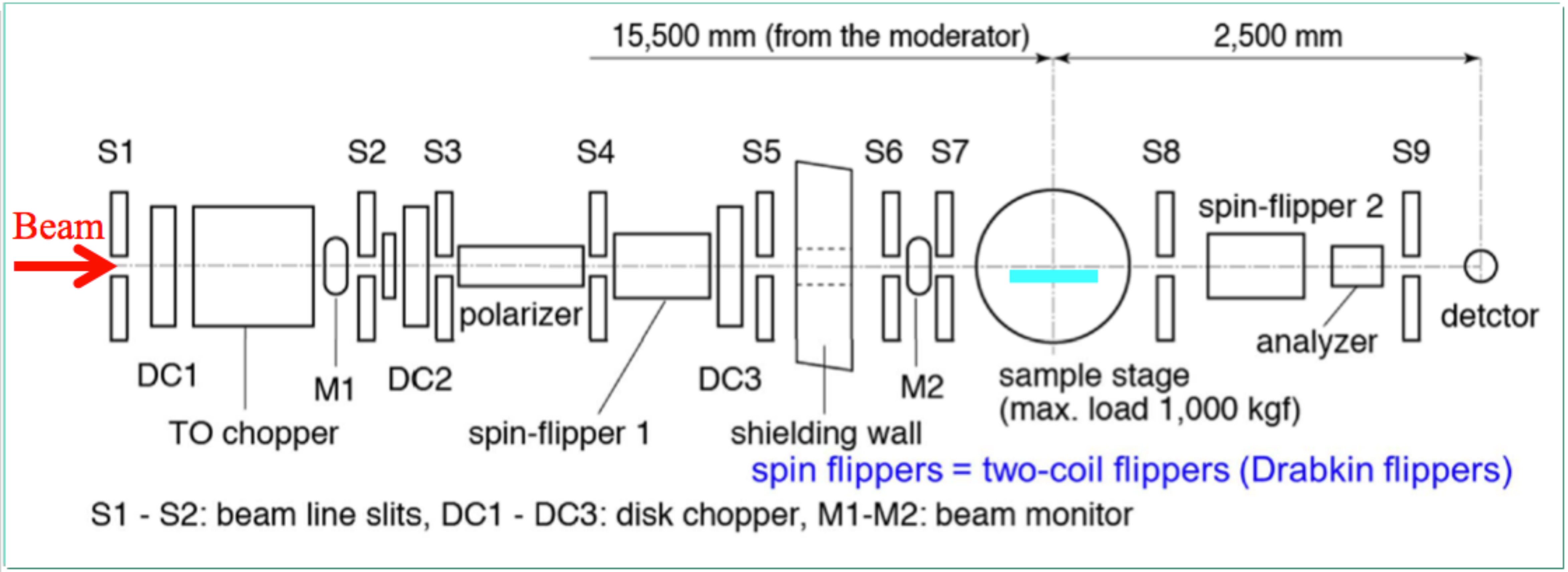
Neutron EDM

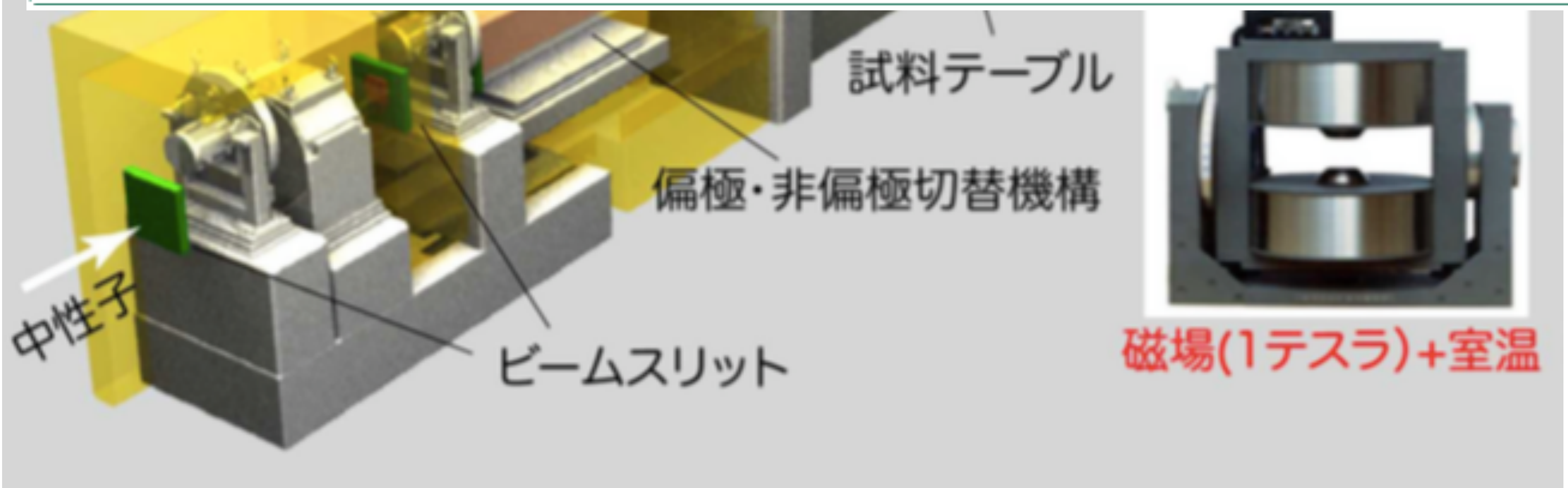
Crystal EDM at J-PARC



Neutron EDM

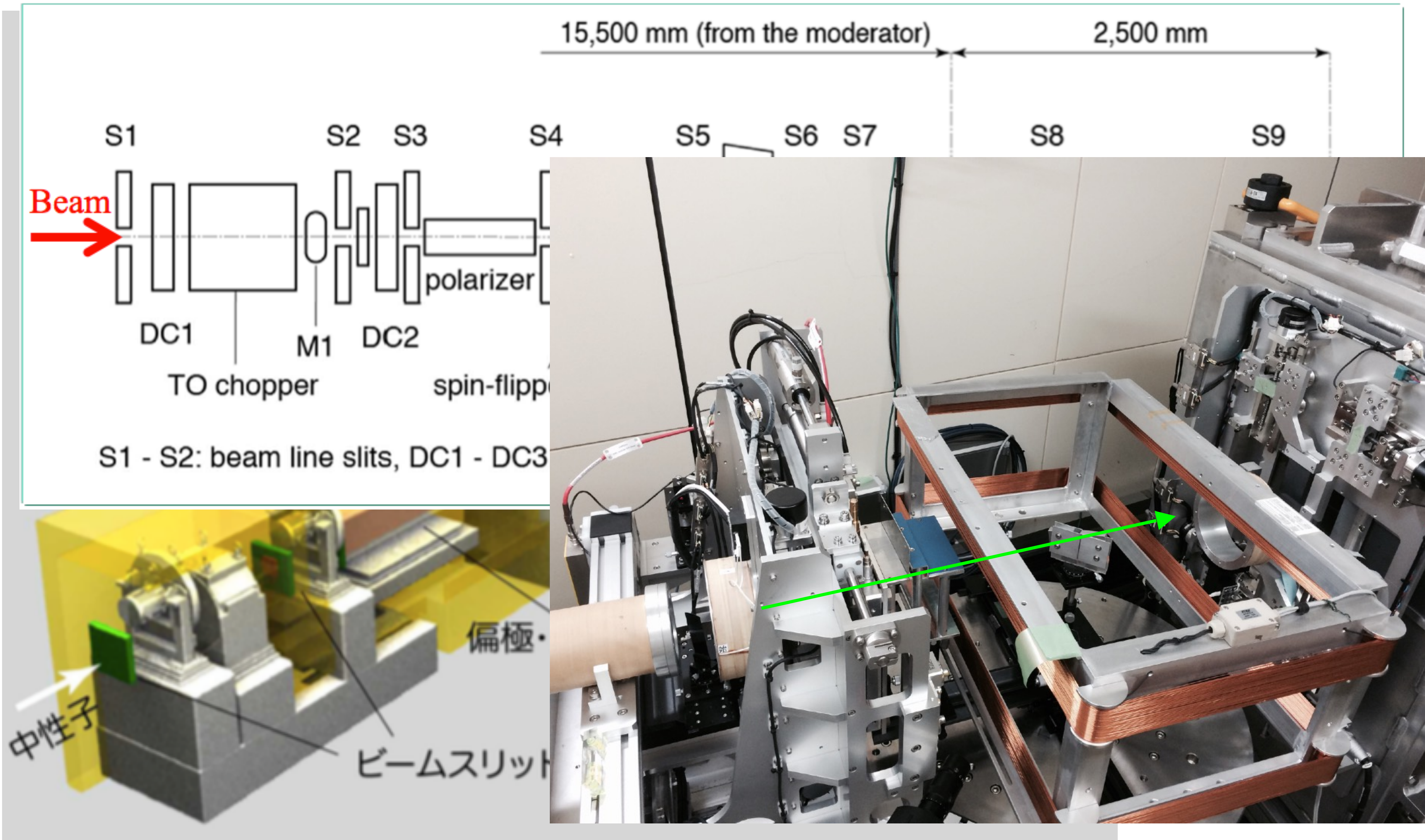
Crystal EDM at J-PARC





Neutron EDM

Crystal EDM at J-PARC

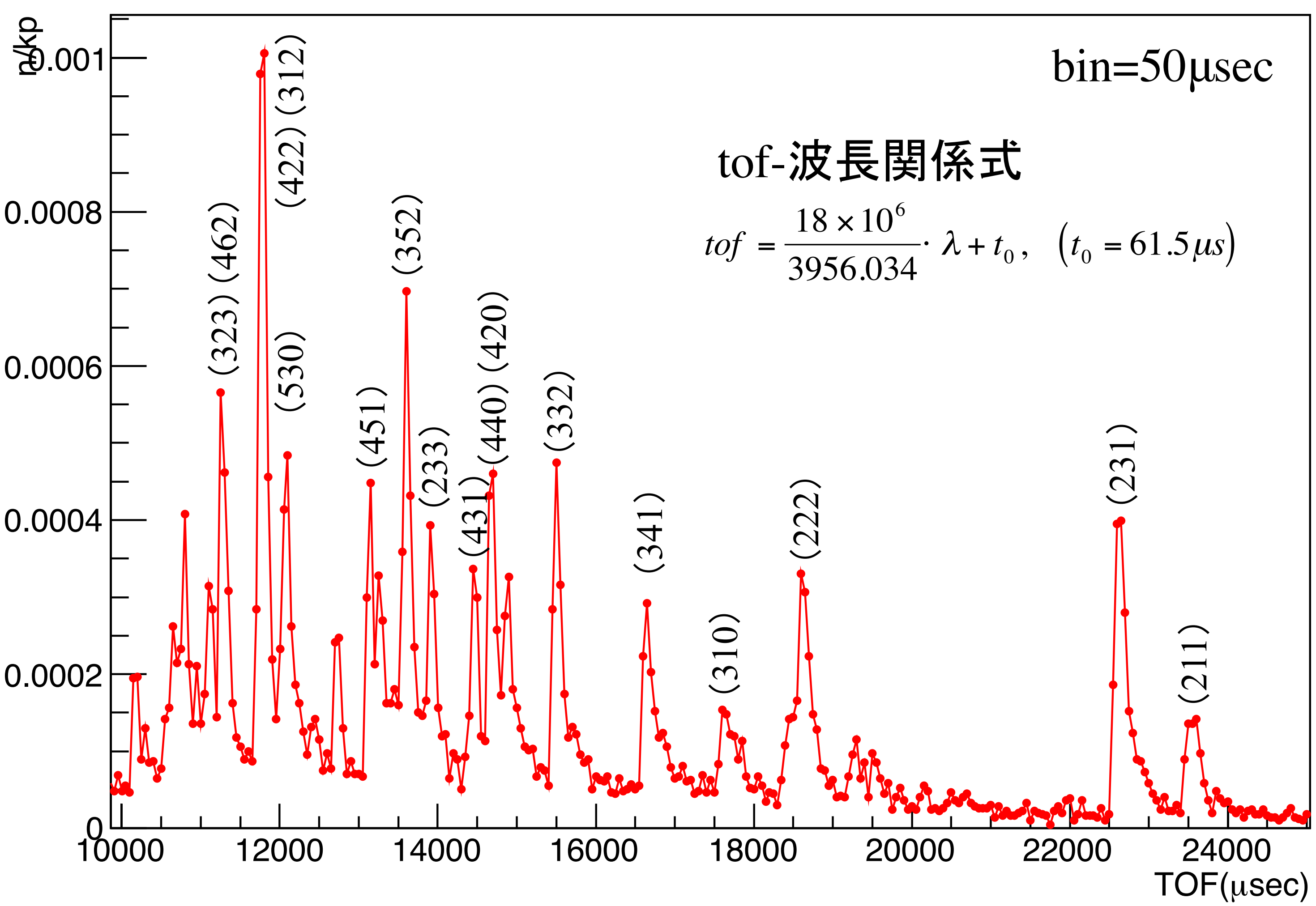


Neutron EDM

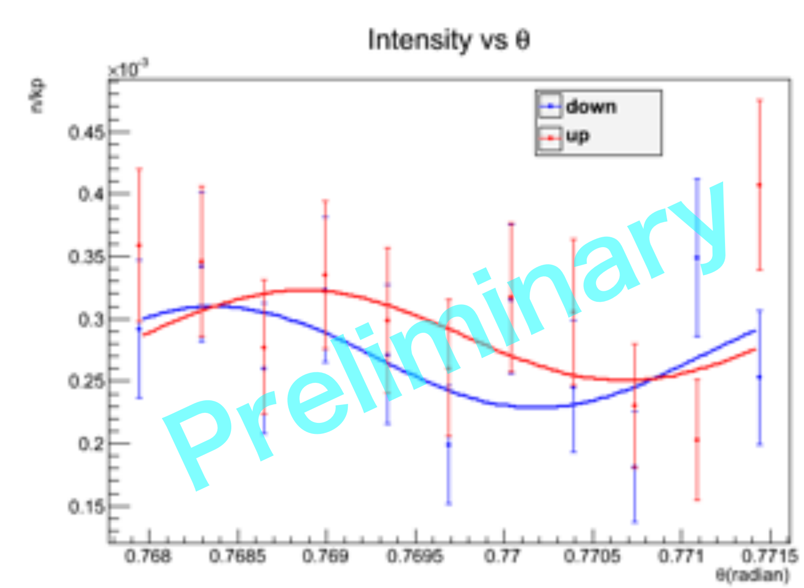
Crystal EDM at J-PARC

Diffraction peaks were observed.
The effect from the electric field in the crystal can be estimated.

$Bi_{12}GeO_{20}$ Intensity vs TOF(396)



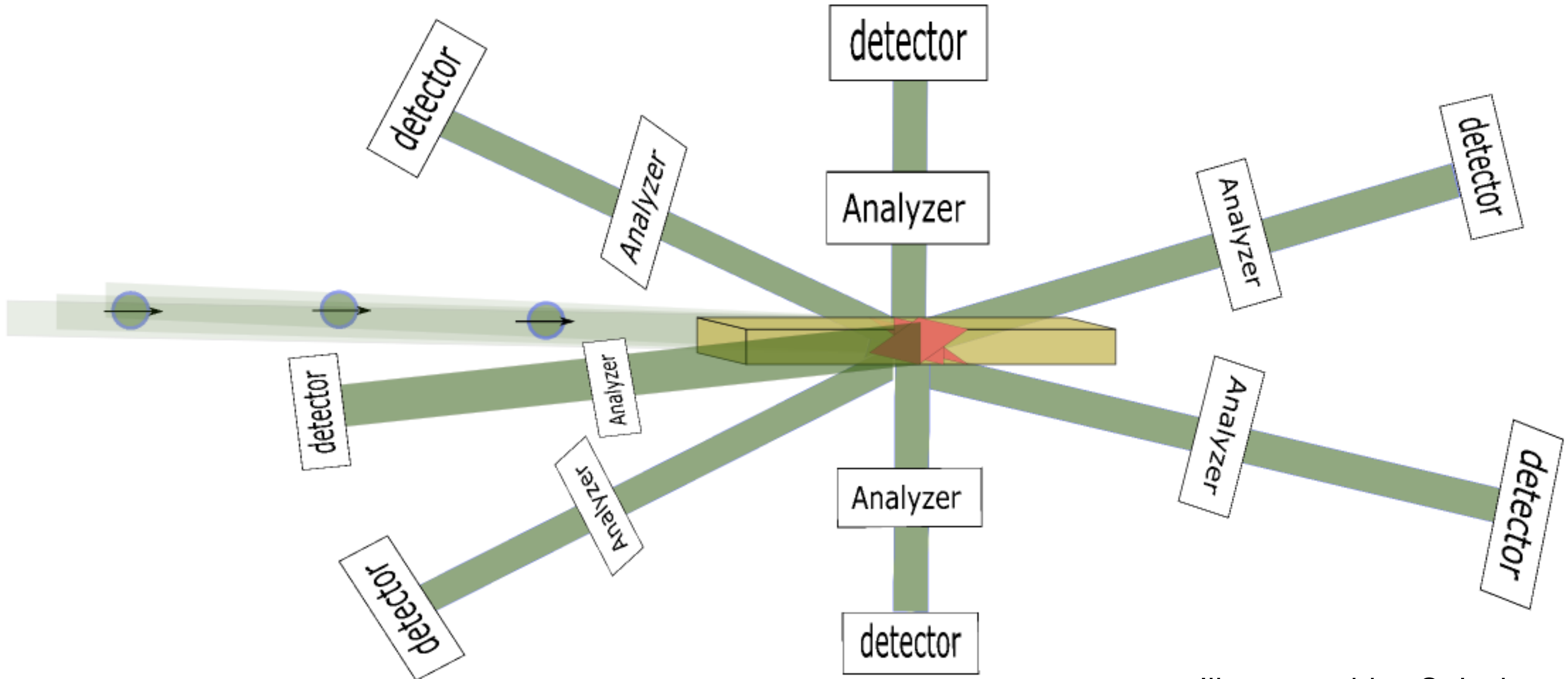
BGO（231）



Neutron EDM

Crystal EDM at J-PARC

Many diffractions from different lattice planes can be measured by using pulsed neutrons.



illustrated by S. Itoh

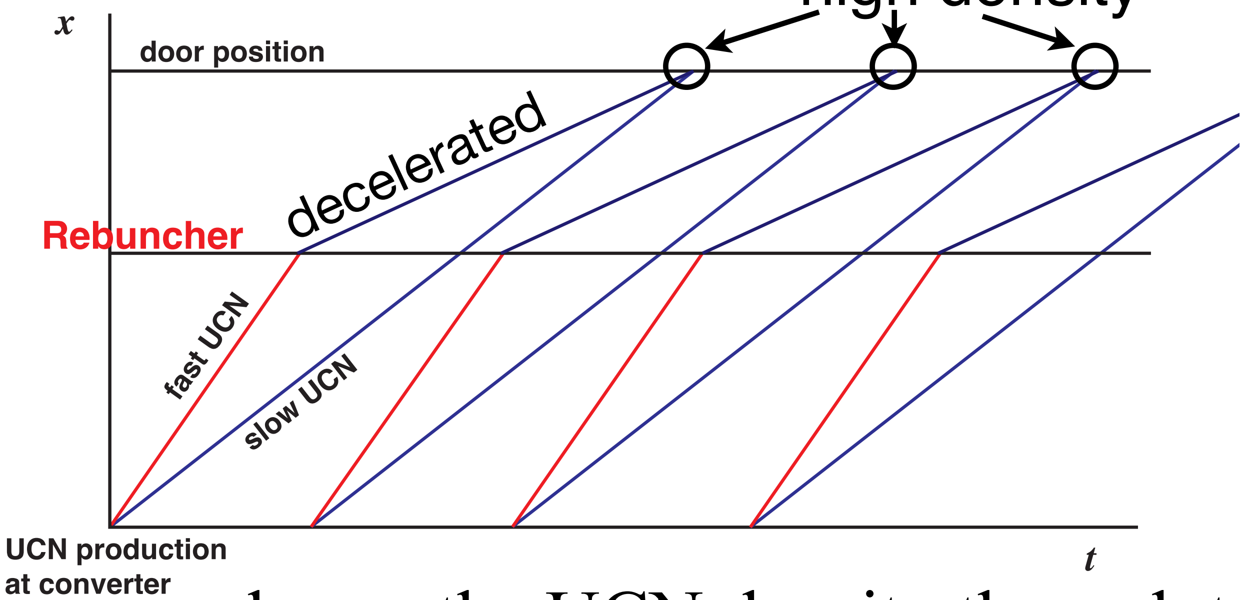
Neutron EDM

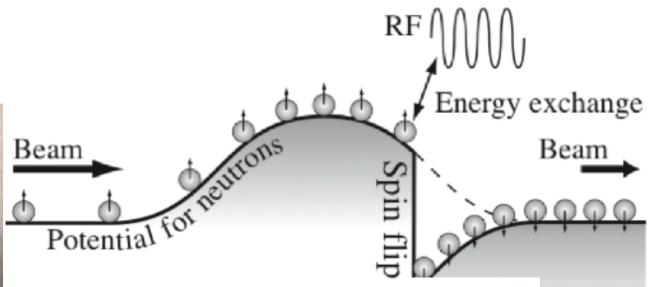
UCN optics

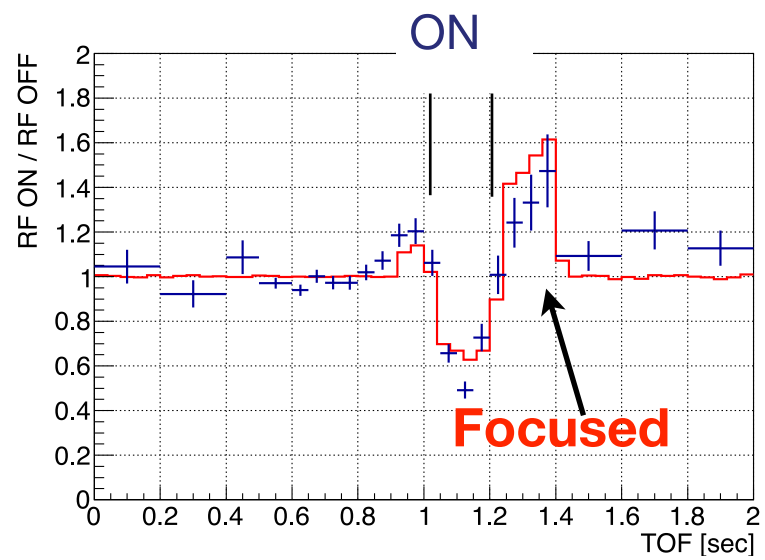
for next generation UCN experiments

UCN Rebuncher

high density







Arimoto, et. al., PRA86, 023843(2013)

keeps the UCN density through transport.

Crystal EDM

Same order of sensitivity can be achieved.

measures spin precession in strong electric field in non-centrosymmetric crystal.

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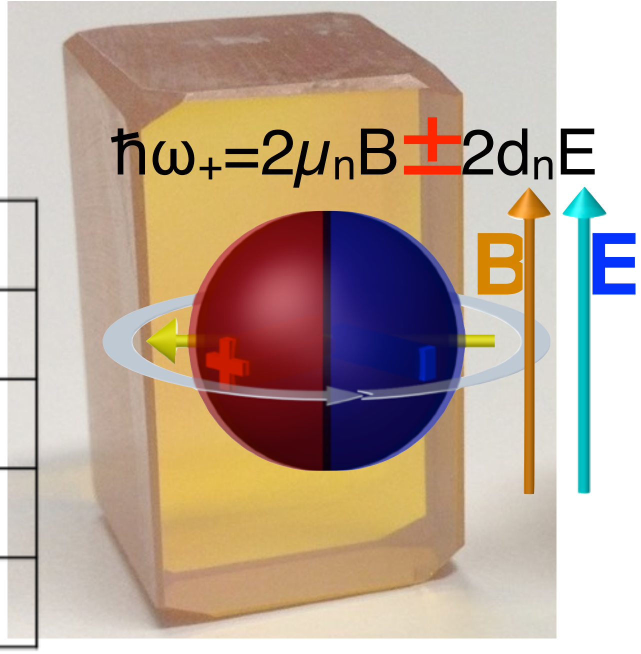
τ	~100sec	~1msec
n	~100/sec	~10^4/sec
$\sigma(d_n)$	$\sim 10^{-25}/\sqrt{D}$ $e\cdot cm$	$\sim 10^{-25}/\sqrt{D}$ $e\cdot cm$

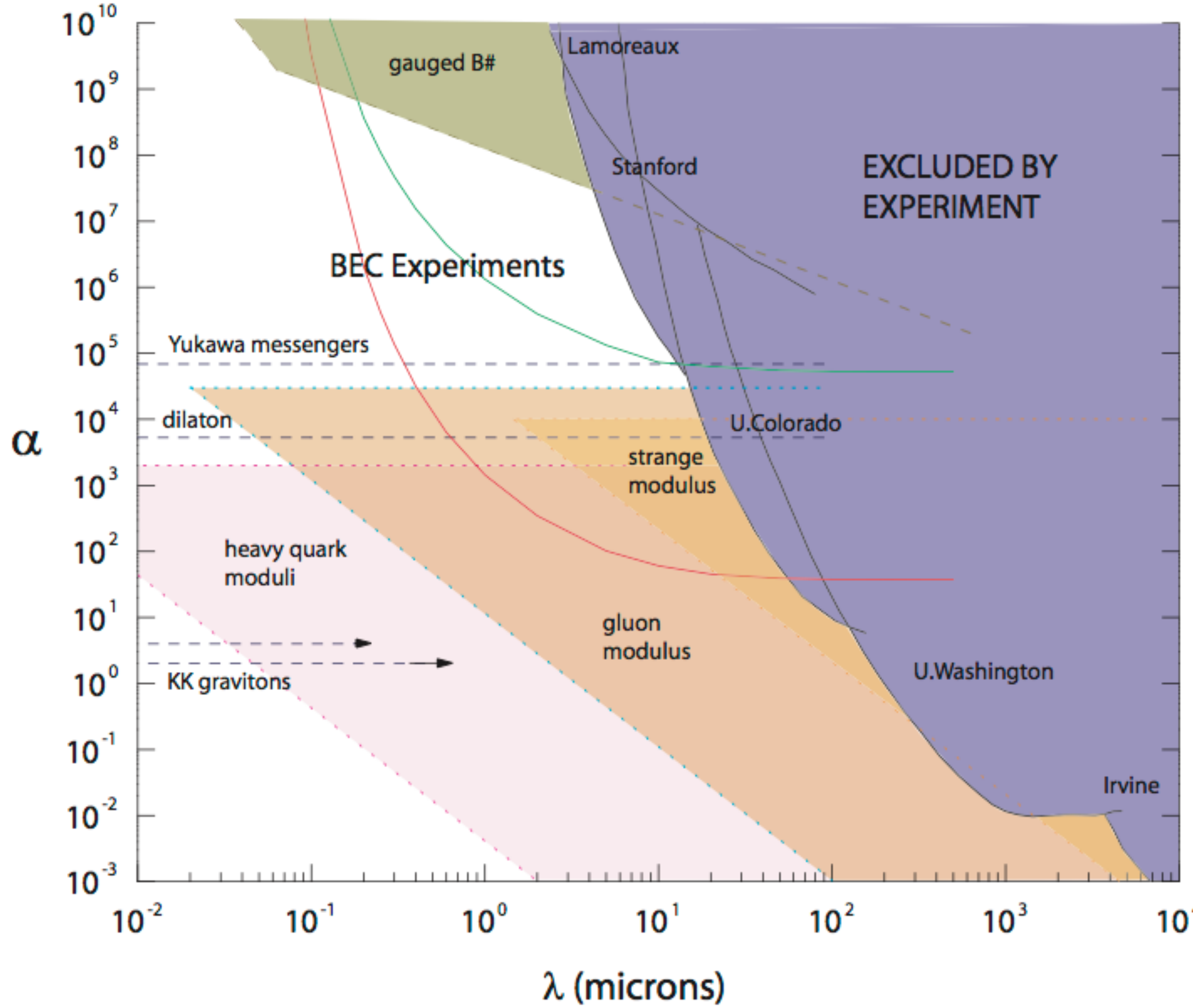


Scattering Experiment
to study Intermediate-range Force

Non-Newtonian Gravity ?

Newtonian — exotic interaction (Yukawa-type)

$$V_G(r) = V_g(r)\cdot\left(1 + \alpha\exp(-r/\lambda)\right) \qquad \left(V_g(r) = -G\frac{M\cdot m}{r}\right)$$



For example…

Gravity for 3-Dimension

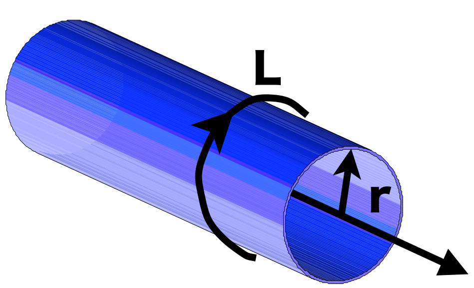
$$F_3(r) = G_3\frac{m_1 m_2}{r^2}$$

Gravity for N-Dimension

$$F_N(r) = G_N\frac{m_1 m_2}{r^{N-1}}$$

Connect at $r = R^*$

$$\frac{G_3}{R^{*2}} = \frac{G_N}{R^{*N-1}} \Rightarrow G_3 = \frac{G_N}{R^{*N-3}}$$



Extra-dimension is compactified.

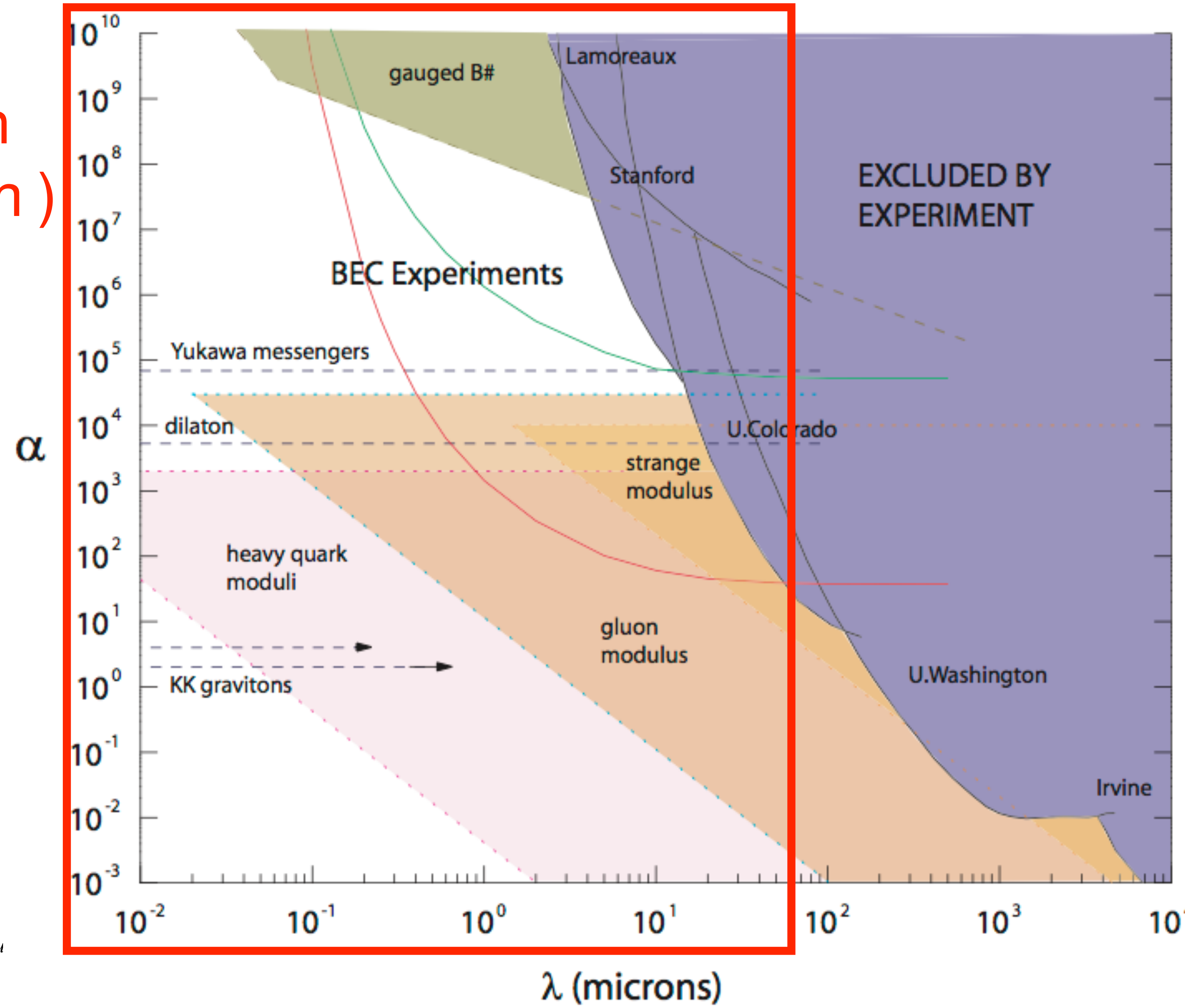
$$\frac{V(r)}{m_1 m_2} = G_3\sum_{(k_1,\ldots,k_n)}\frac{e^{-(2\pi|k|/L)r}}{r} \xrightarrow[r<<L]{} G_3\frac{1}{r}\left(\frac{L}{2\pi r}\right)^n\int d^n u\, e^{-|u|}$$

Non-Newtonian Gravity ?

Newtonian   exotic interaction (Yukawa-type)

$$V_G(r) = V_g(r)\cdot\left(1+\alpha\exp(-r/\lambda)\right) \qquad \left(V_g(r) = -G\frac{M\cdot m}{r}\right)$$

Search for additional force in intermediate-range (μm - nm)



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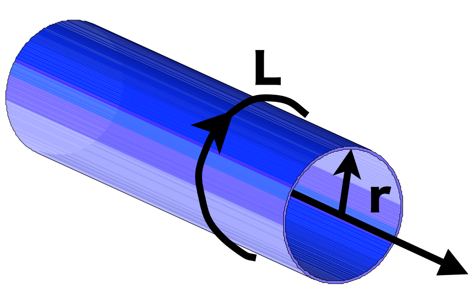
$$F_3(r) = G_3\frac{m_1m_2}{r^2}$$

Gravity for N-Dimension

$$F_N(r) = G_N\frac{m_1m_2}{r^{N-1}}$$

Connect at $r = R^*$

$$\frac{G_3}{R^{*2}} = \frac{G_N}{R^{*N-1}} \Rightarrow G_3 = \frac{G_N}{R^{*N-3}}$$



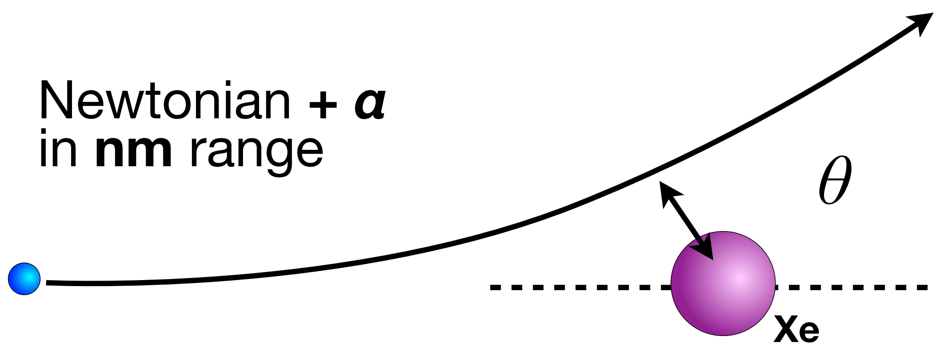
Extra-dimension is compactified.

$$\frac{V(r)}{m_1m_2} = G_3\sum_{(k_1,\ldots k_n)}\frac{e^{-(2\pi|k|/L)r}}{r} \underset{r<<L}{\longrightarrow} G_3\frac{1}{r}\left(\frac{L}{2\pi r}\right)^n\int d^n u e^{-|u|}$$

Scattering Experiment to study Intermediate-range Force

Small angle scattering with noble gas

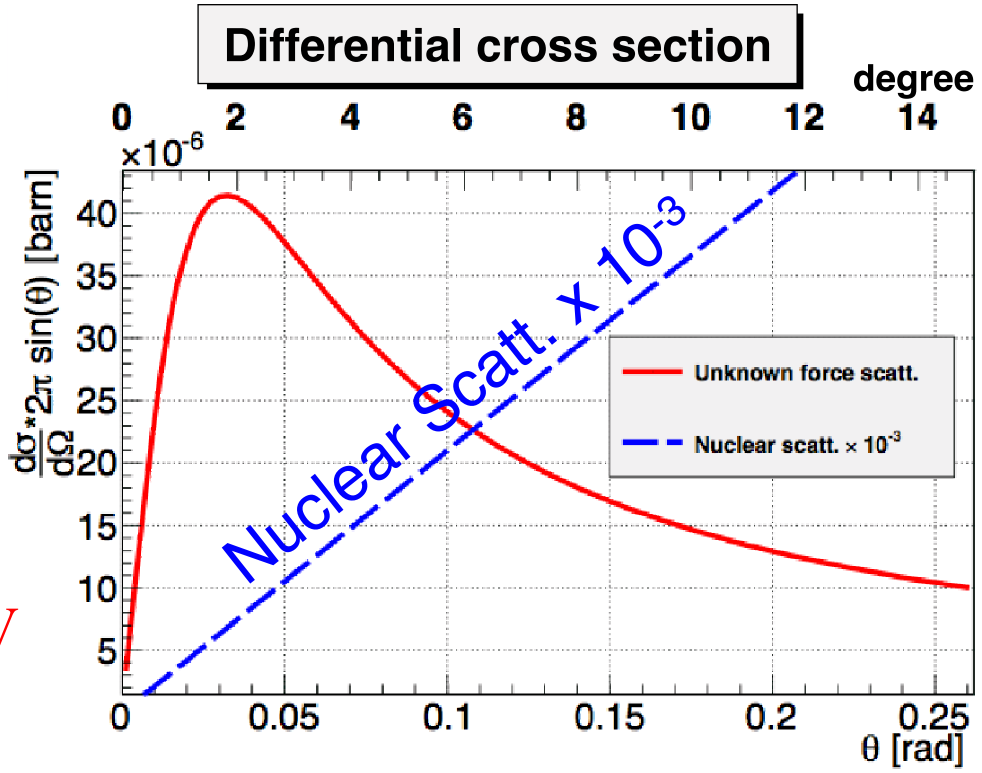
to search the deviation from nuclear scattering



$\alpha = 10^{23}$

$\lambda = 0.5$ nm

$E_n = 20$ meV



$$\frac{d\sigma(\theta)}{d\Omega} = \left[a_N + a_{ne} Z F_e(\theta) + a_G F_G(\theta)\right]^2$$

$$\cong a_N{}^2 + 2 a_N a_{ne} Z F_e(\theta) + a_{ne}{}^2 Z^2 F_e(\theta)^2 + 2 a_N a_G F_G(\theta)$$

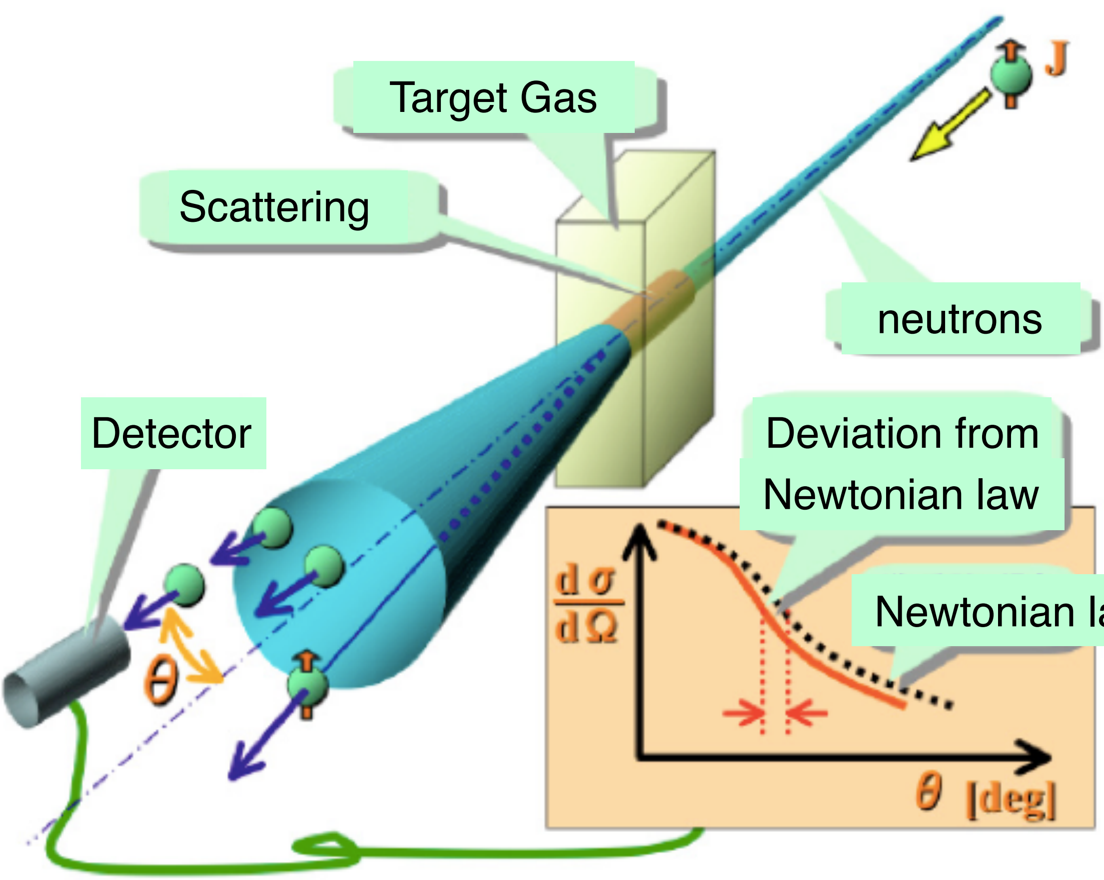
$a_G \propto \alpha$

$$\frac{d\sigma_G(\theta)}{d\Omega} = 2 \cdot \sigma_N^{1/2} \cdot \alpha \cdot \left(\frac{G \cdot m_n \cdot M}{4}\right) \cdot \left(\frac{1}{\frac{1}{m_n c^2}\left(\frac{\hbar c}{\lambda}\right)^2 + 8 E_n \sin^2 \frac{\theta}{2}}\right)$$

Scattering Experiment to study Intermediate-range Force

Small angle scattering with noble gas

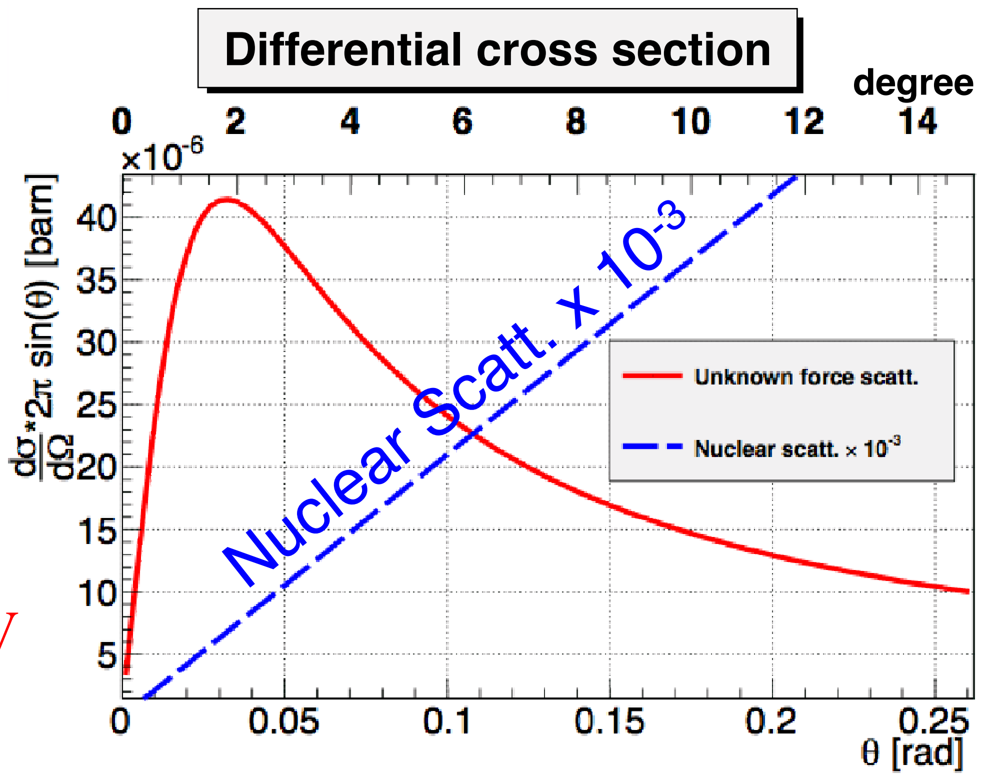
to search the deviation from nuclear scattering



$\alpha=10^{23}$

$\lambda=0.5$ nm

$E_n=20$ meV



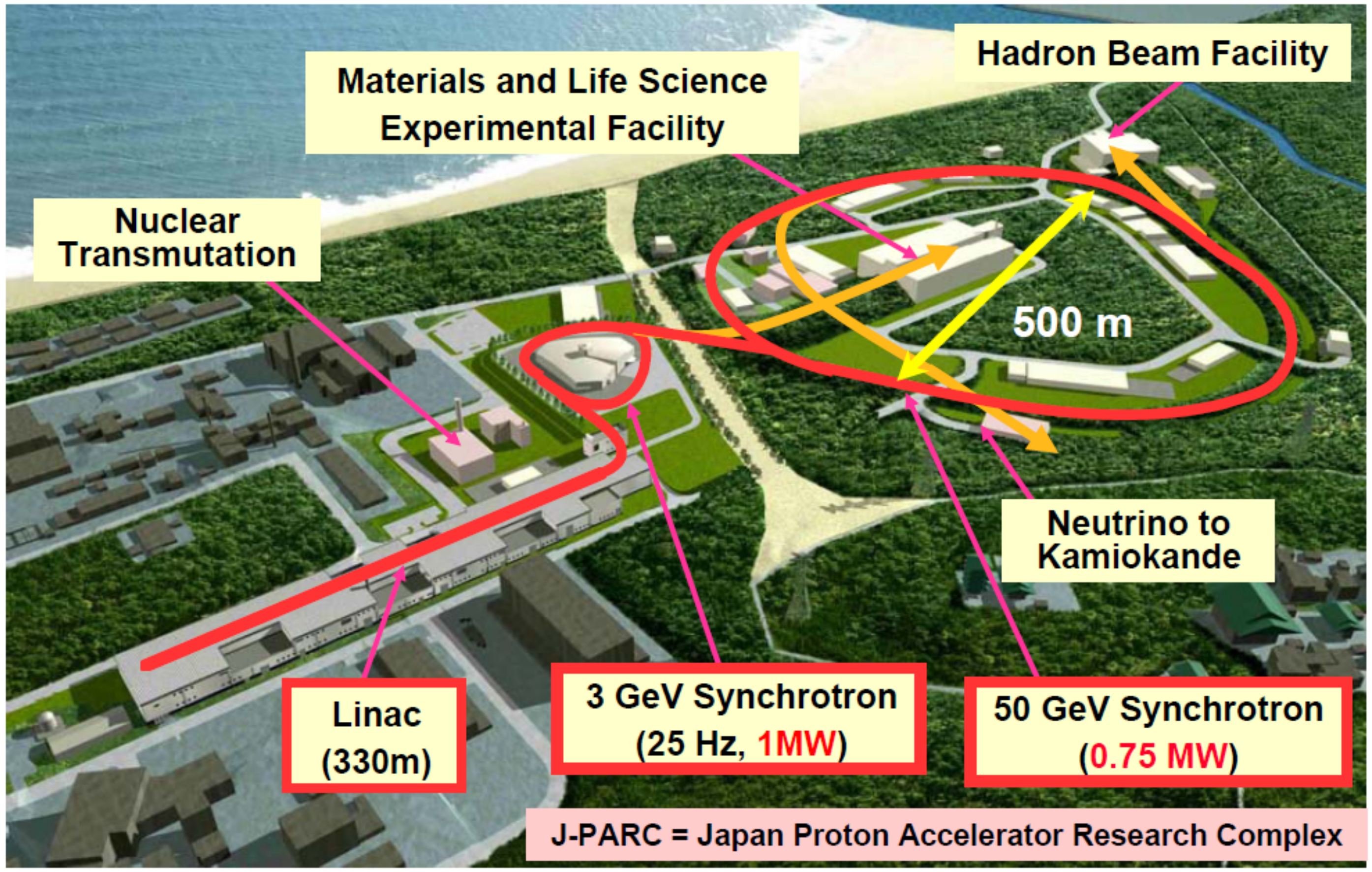
$a_G \propto \alpha$

$$\frac{d\sigma(\theta)}{d\Omega}=\left[a_N+a_{ne}ZF_e(\theta)+a_G F_G(\theta)\right]^2$$

$$\cong a_N{}^2+2a_N a_{ne}ZF_e(\theta)+a_{ne}{}^2 Z^2 F_e(\theta)^2+2a_N a_G F_G(\theta)$$

$$\frac{d\sigma_G(\theta)}{d\Omega}=2\cdot\sigma_N^{1/2}\cdot\alpha\cdot\left(\frac{G\cdot m_n\cdot M}{4}\right)\cdot\left(\frac{1}{\frac{1}{m_n c^2}\left(\frac{\hbar c}{\lambda}\right)^2+8E_n\sin^2\frac{\theta}{2}}\right)$$

Neutron Optics and Physics (NOP) beamline



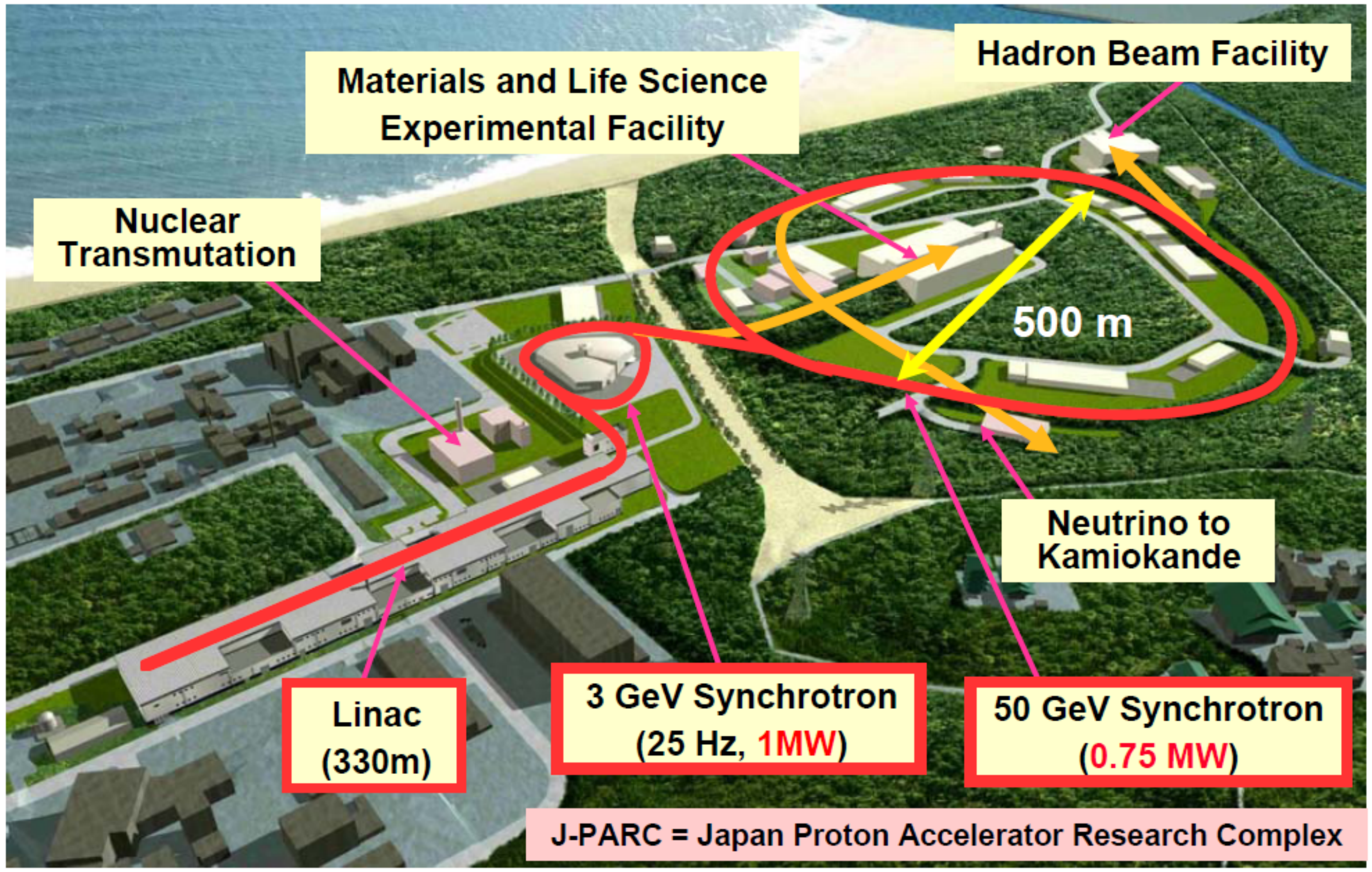
Joint Project between KEK and JAEA

We constructed the cold neutron beamline "**NOP**" for fundamental physics in Material and Life science Facility.

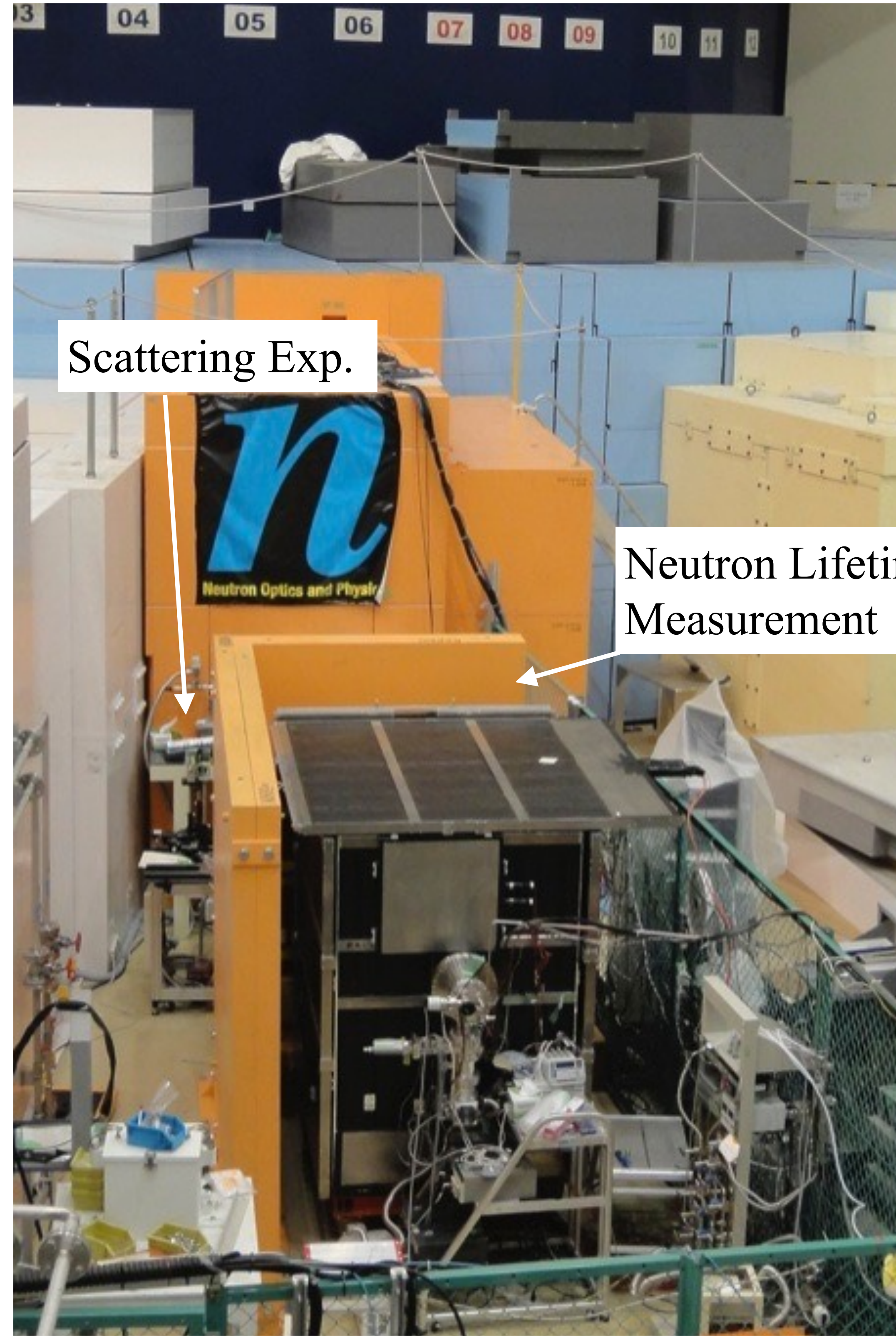
Tree branches are available.

- Polarized beam
- Unpolarized beam
- Low-divergence beam

Neutron Optics and Physics (NOP) beamline



Joint Project between KEK and JAEA



We constructed the cold neutron beamline "**NOP**" for fundamental physics in Material and Life science Facility.

Tree branches are available.

- Polarized beam
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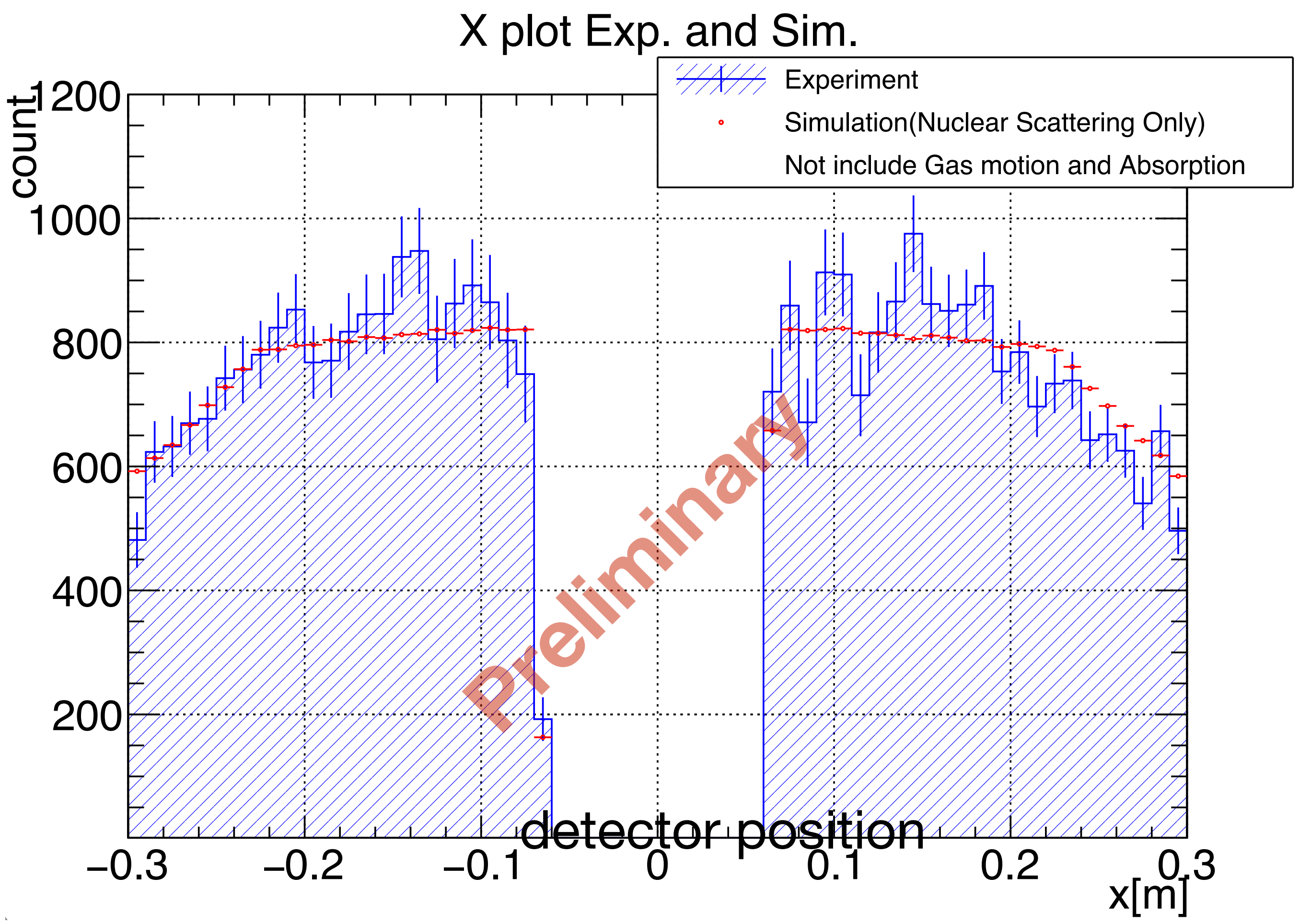
- Low-divergence beam

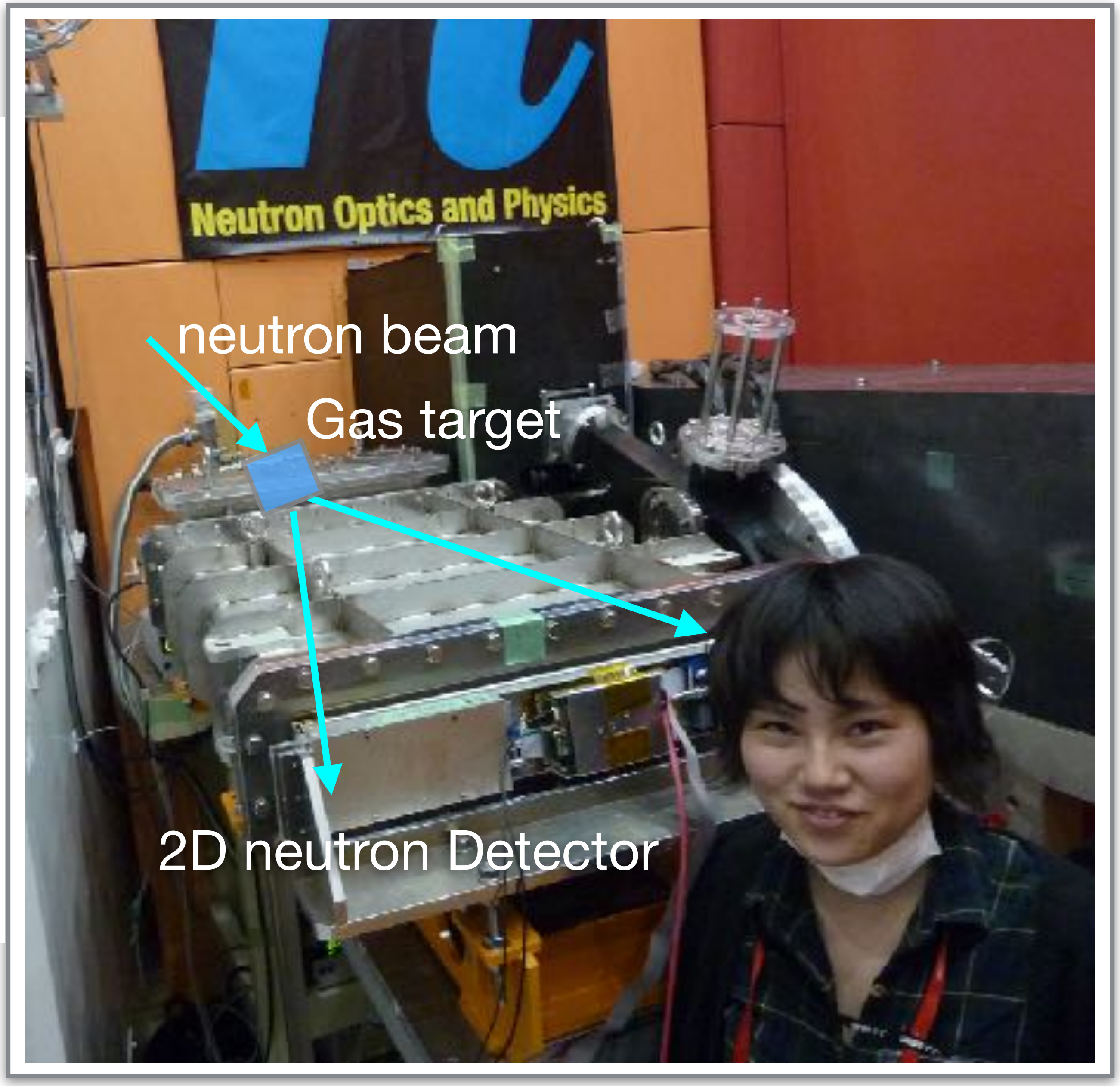
Scattering Experiment to study Intermediate-range Force

Physics data has just taken at NOP beamline at J-PARC.

Analysis is on going …



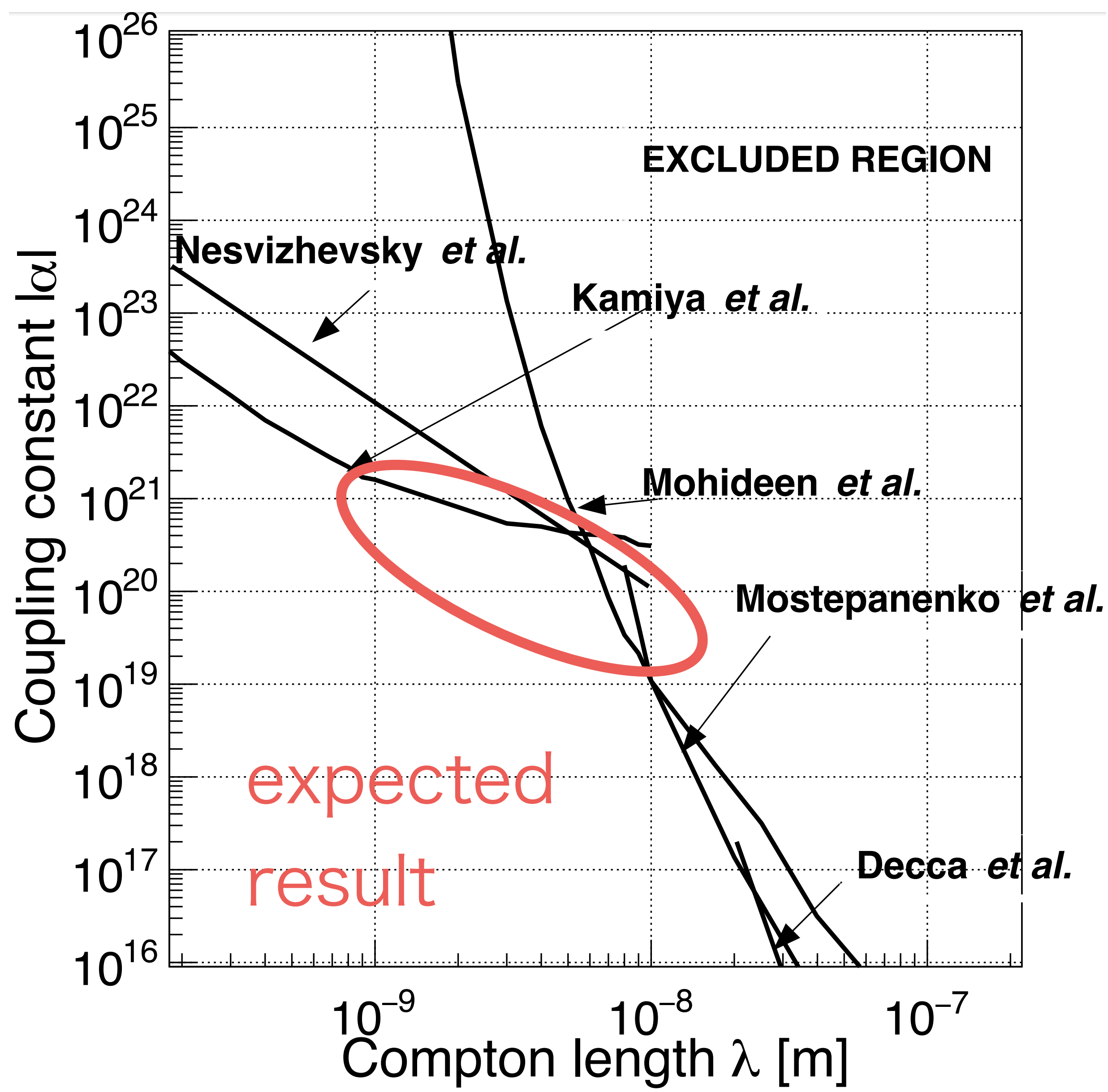
Xe scattering data compared with Monte-Carlo simulation without exotic interactions

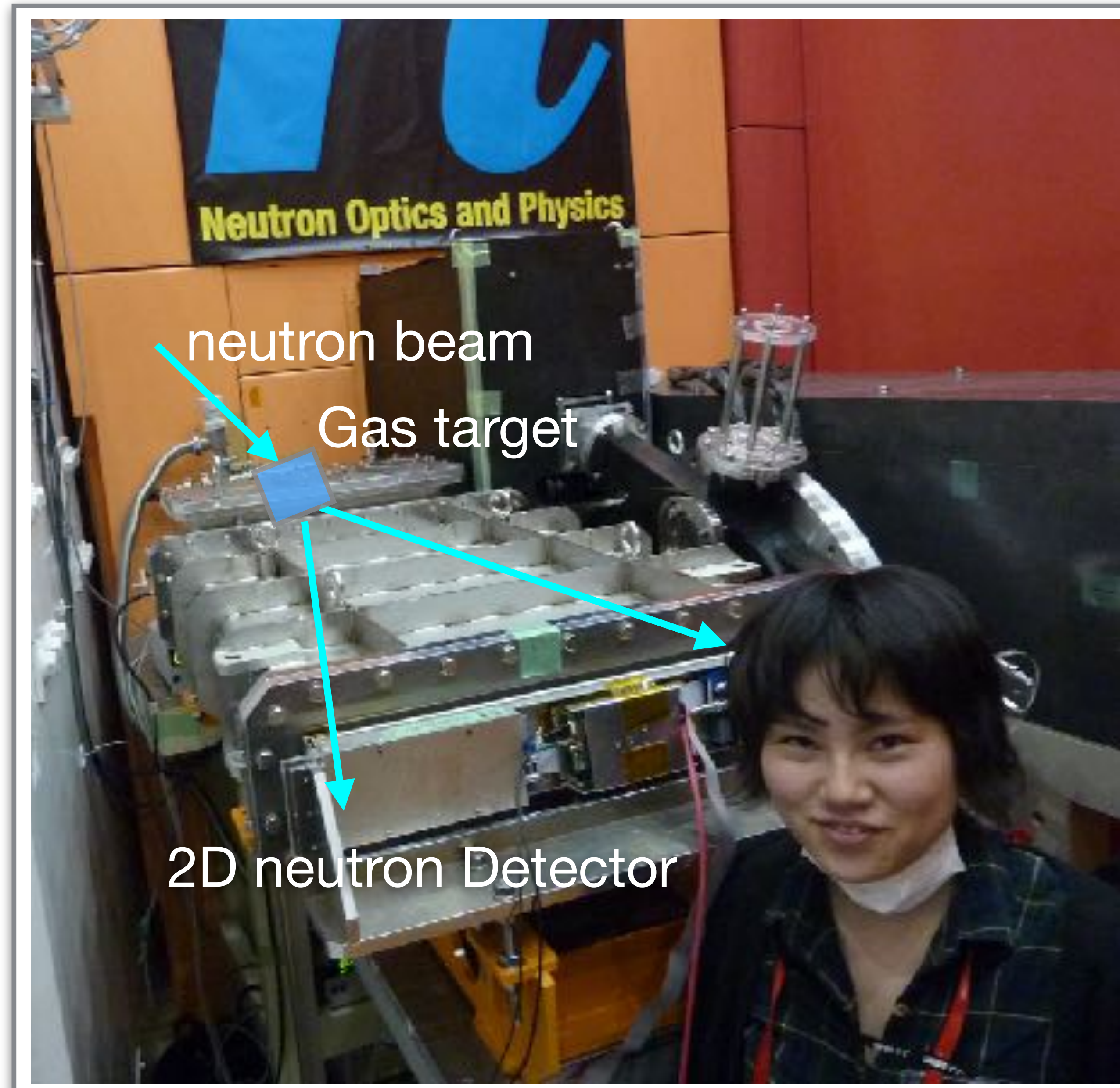


More detail -> Poster 13, Noriko Oi

Scattering Experiment to study Intermediate-range Force

Physics data has just taken at NOP beamline.





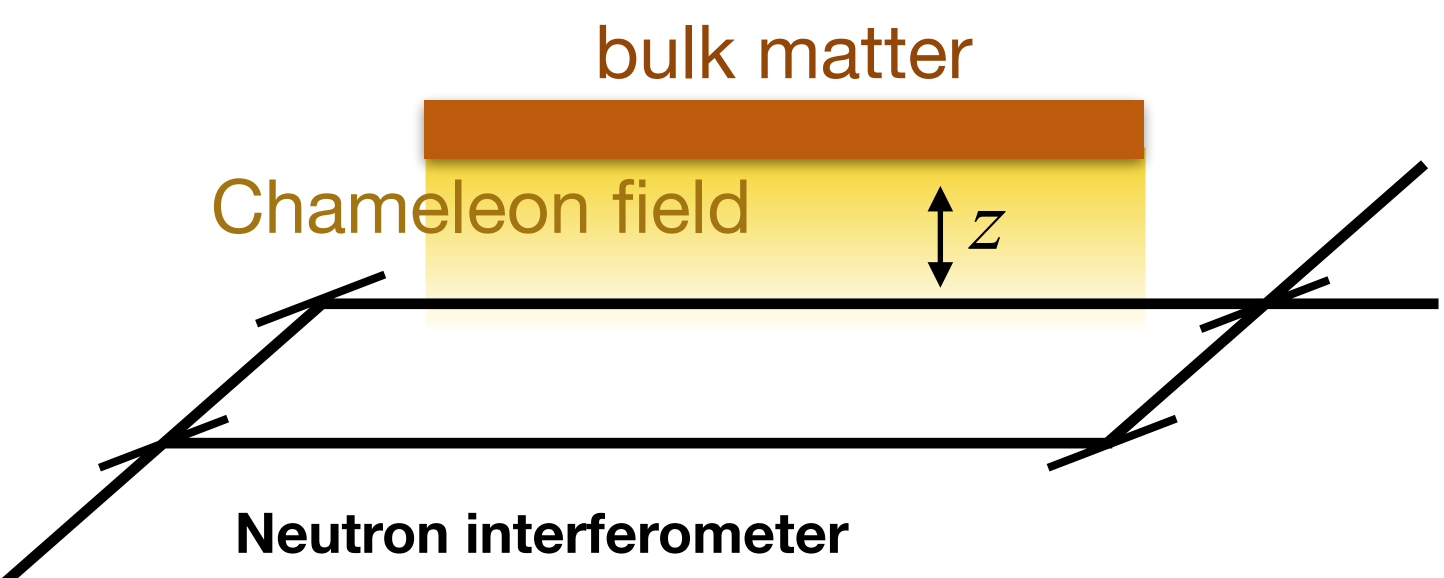
More detail -> Poster 13, Noriko Oi

Neutron interferometer
to study Extended Gravity Field

Neutron interferometer to study Extended Gravity Field

Chameleon field

results phase shift
in interferometer



Neutron interferometer

$$V(z) = V_0\left(\frac{z}{\lambda}\right)^{2/(2+n)}$$

$$V_0 = \beta \cdot 0.9 \cdot 10^{-21}\ \mathrm{eV}\left(\frac{2+n}{\sqrt{2}}\right)^{2/(2+n)}$$

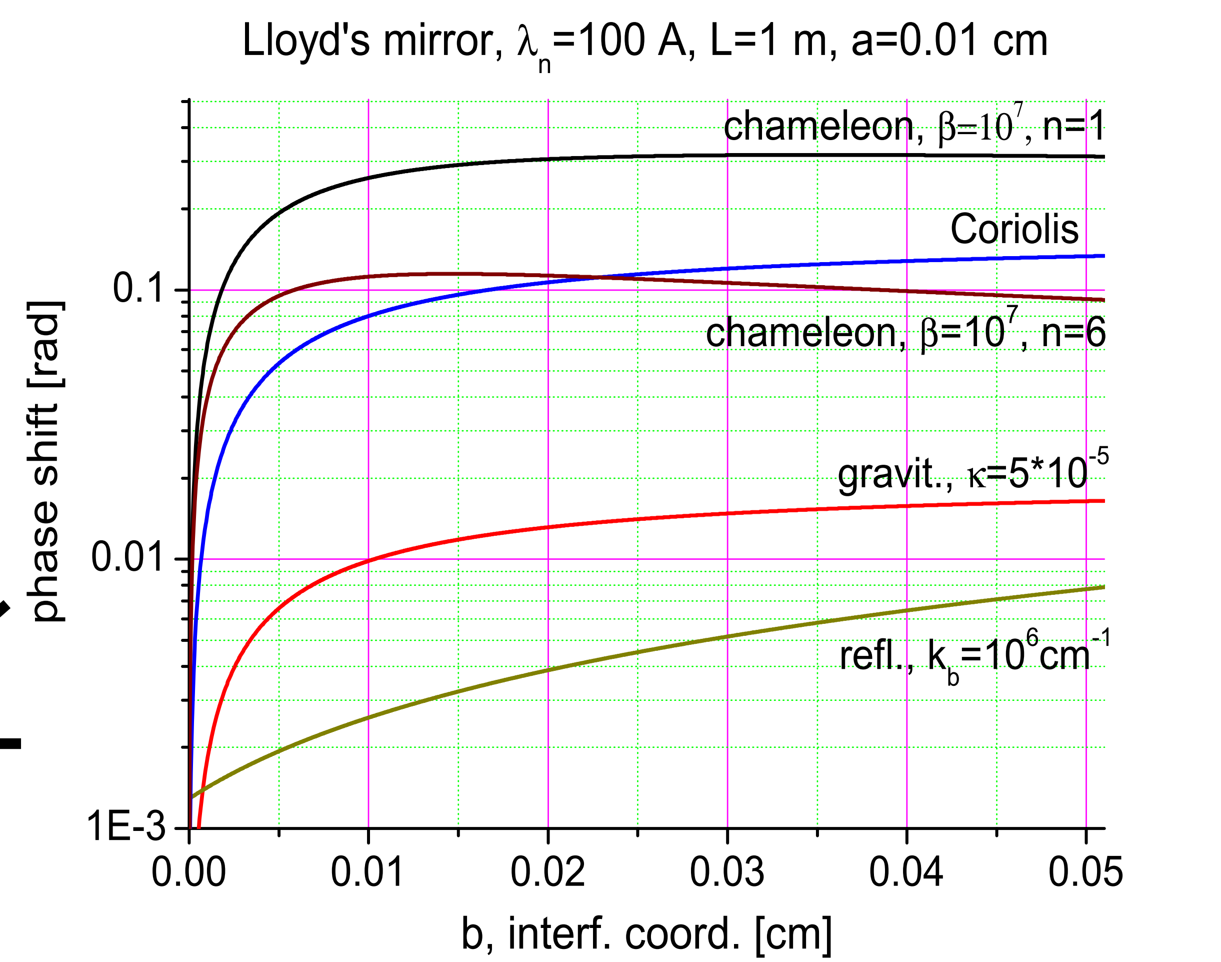


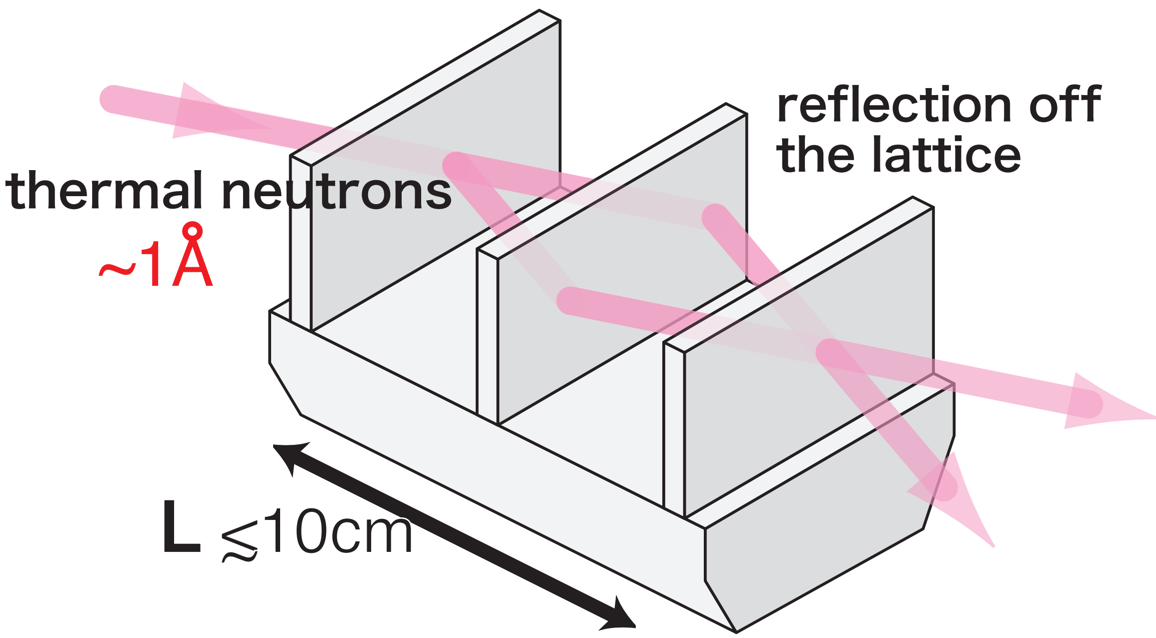
Fig. 2. The neutron wave phase shifts φ in the Lloyd's mirror interferometer with parameters: the neutron wave length 100 Å, $L = 1$ m, $a = 0.01$ cm, the interaction parameters of the chameleon field with matter $\beta = 10^7$, $n = 1$ and $n = 6$. Also shown: the gravitational phase shift φ_{gr} at $\kappa = 5 \times 10^{-5}$; the Coriolis phase shift, and the effect of reflection as $\delta\varphi_{refl} = \pi - \varphi_{refl}$ ($k_b = 10^6$ cm^{-1}).

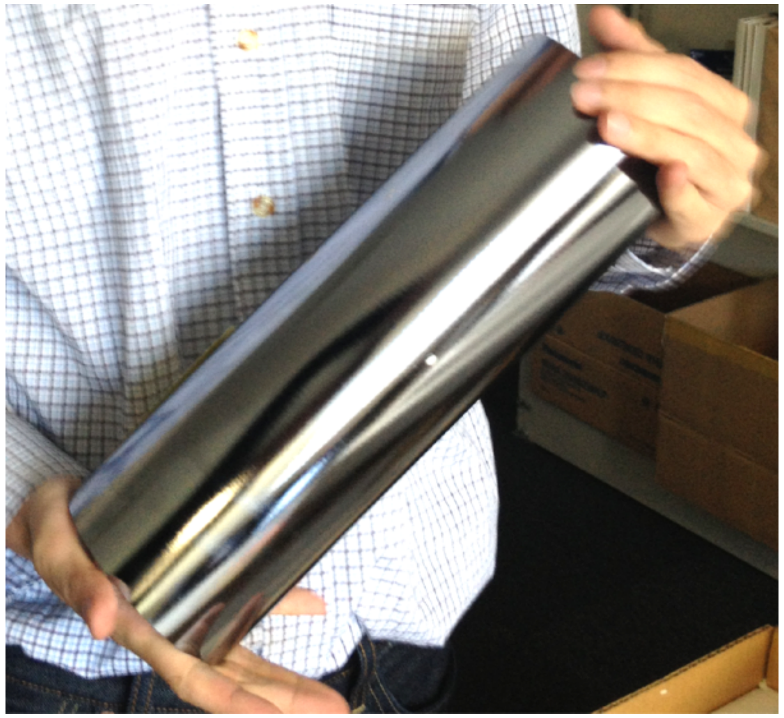
Yu.N. Pokotilovski / Physics Letters B 719 (2013) 341–345

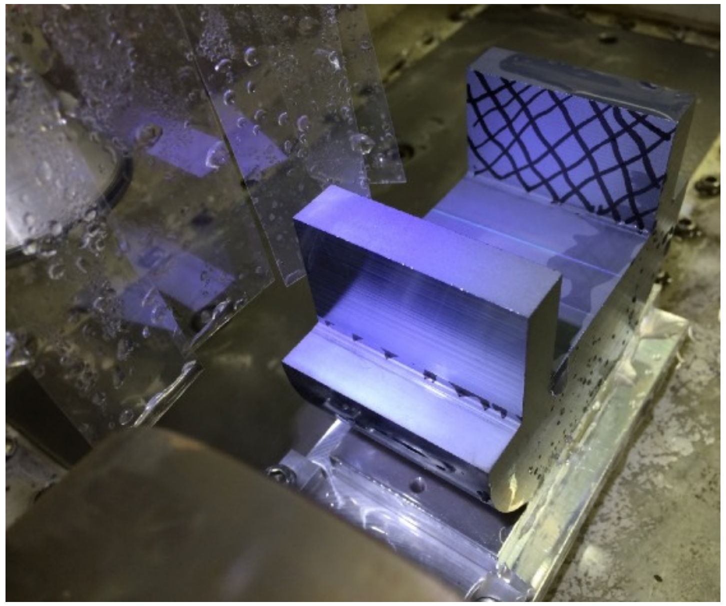
Neutron interferometer to study Extended Gravity Field

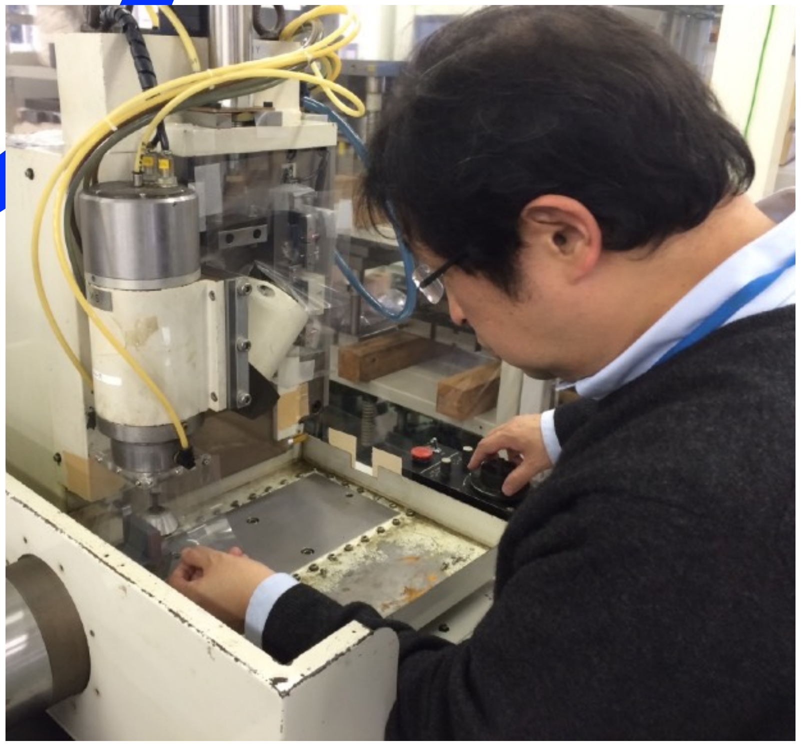
Neutron interferometer

using large silicon ingot is tested now.







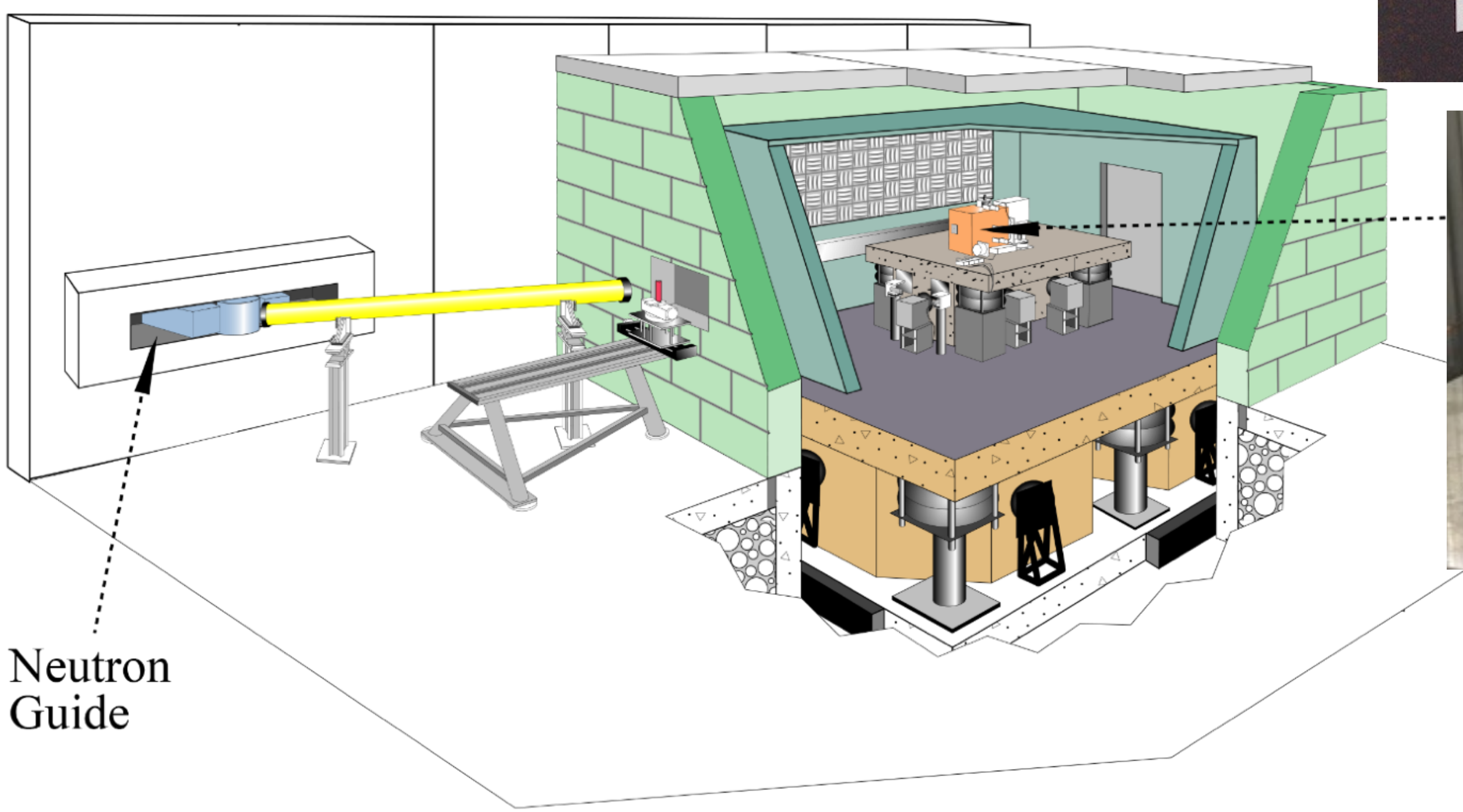


Neutron interferometer to study Extended Gravity Field

Neutron interferometer Test at NIST

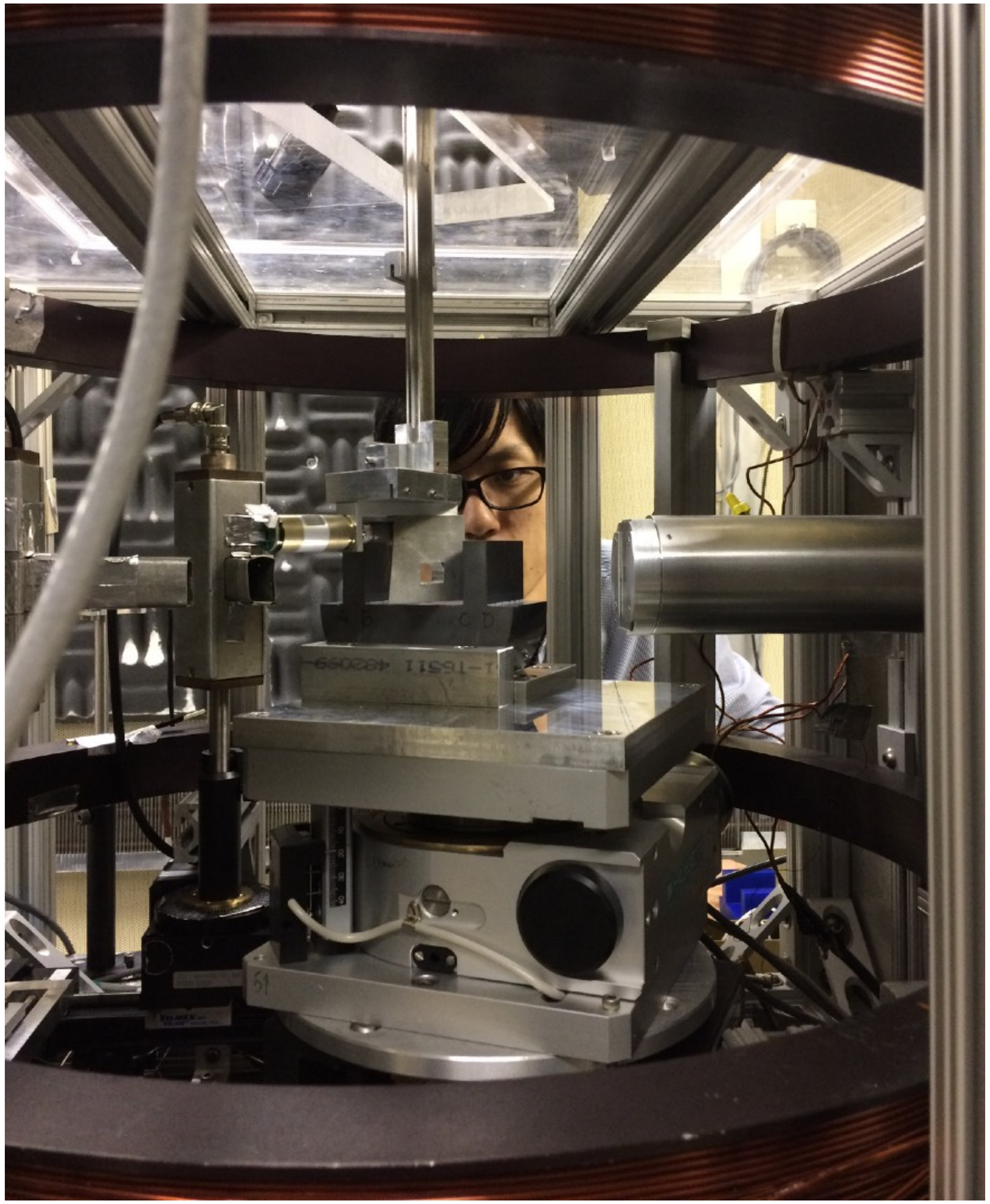
Neutron Optics and Interferometry Facility (NIOF)

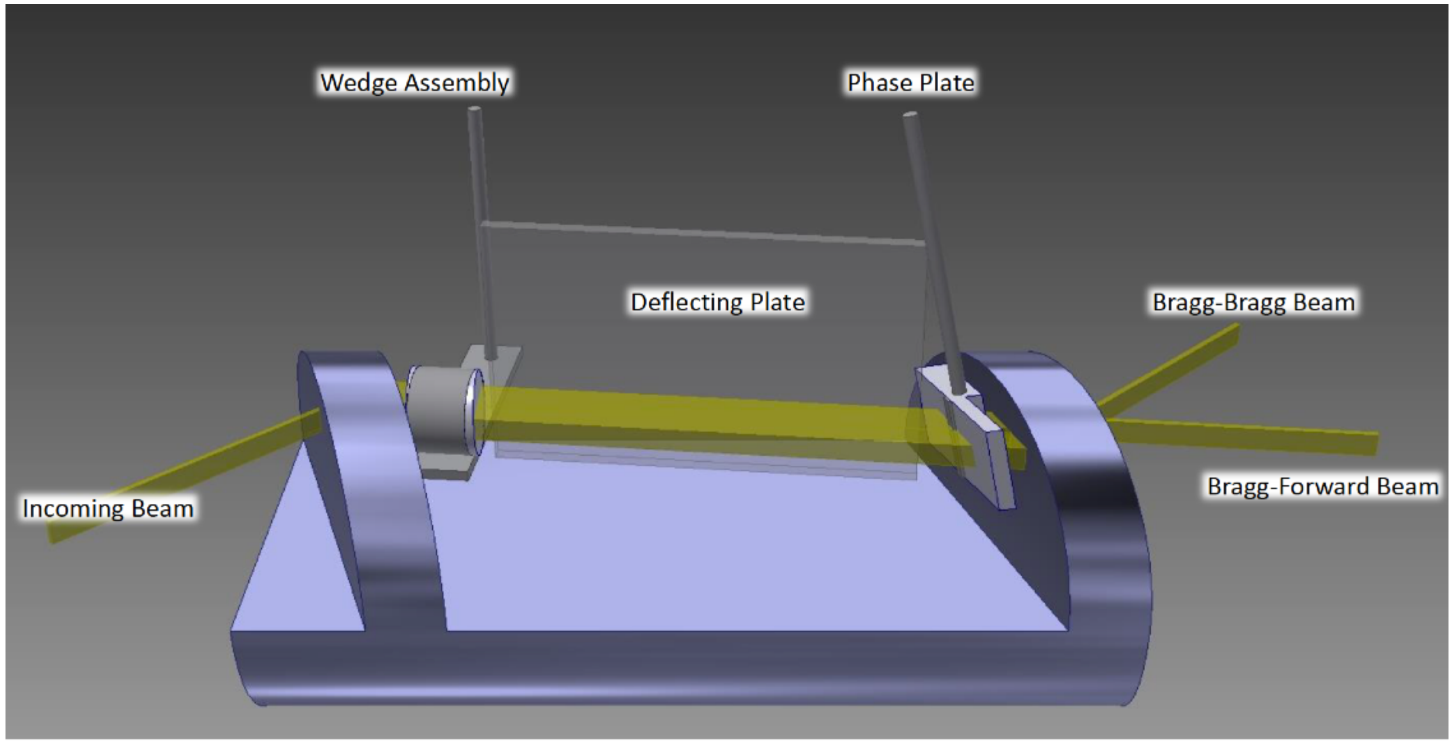
Isolated 40,000 Kg room is supported by six airsprings
Active Vibration Control eliminates vibrations less than 10Hz
Temperature Controlled to +/- 5 mK



Neutron interferometer to study Extended Gravity Field

Neutron interferometer Test at NIST has started !





Summary

Neutron is suitable for the precision measurement of the small influence of new physics beyond the standard model of elementary particles.

T-odd P-odd correlation in nuclear reaction can be enhanced in some compound nuclei. Feasibility studies are now going on at BL04 ANNRI beamline in J-PARC.

More detail -> Poster 14, Takuya Okudaira

More detail -> Poster 12, Tomoki Yamamoto

Development of next generation UCN optics for Neutron EDM.
Crystal EDM is also important, as a method with another systematics.

Small angle scattering to study intermediate-range force is now going on at BL05 NOP beamline in J-PARC.

More detail -> Poster 13, Noriko Oi

Neutron interferometer with slow neutrons has the advantage to measure small interaction, induced by gravity, dark energy.