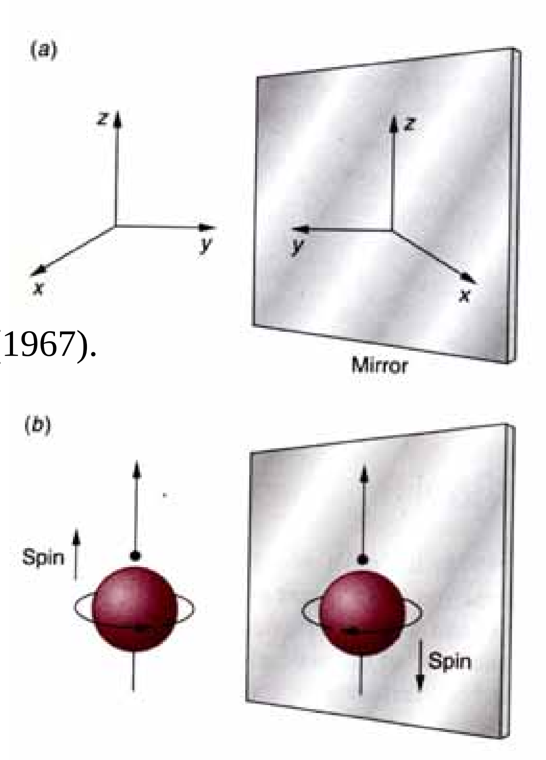
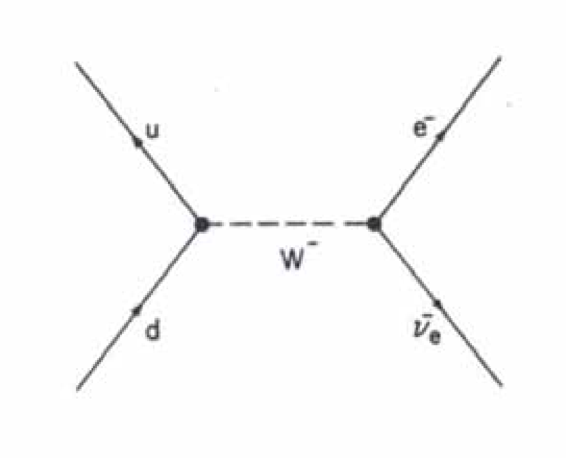
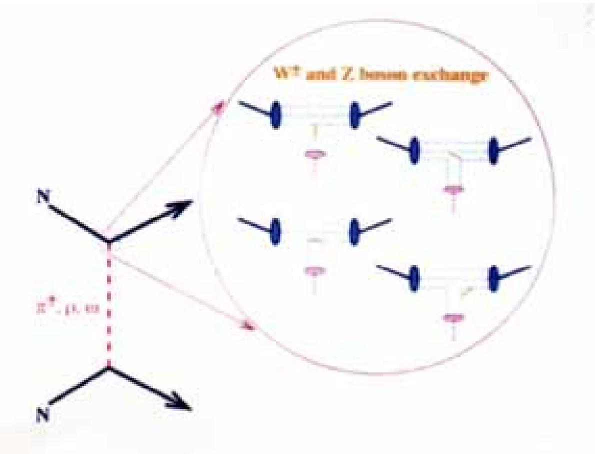
逆コンプトンガンマ線によるパリティ非保存実験



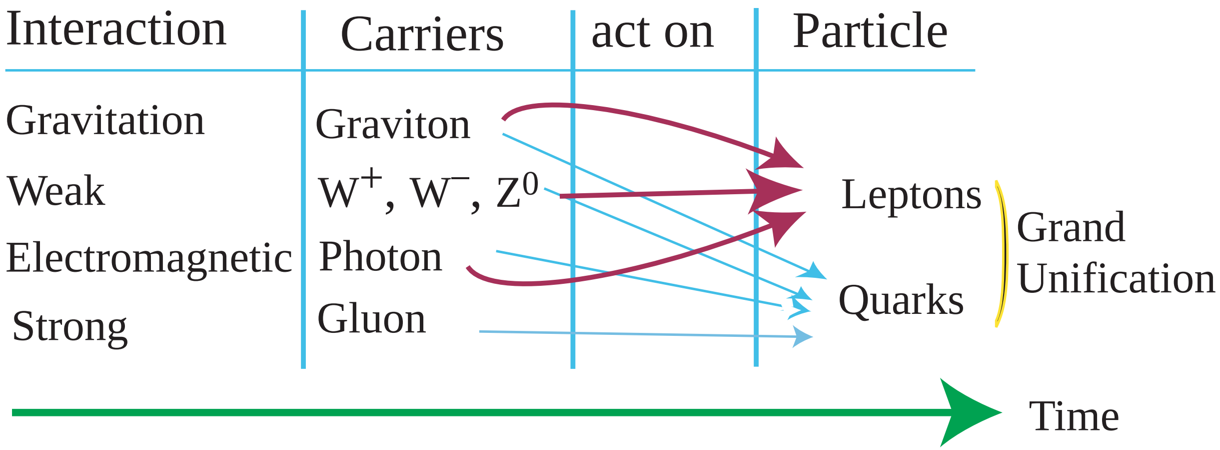
1. Beta decay: T.D.Lee and C.N. Yang, Phys. Rev. 104 (1956).
2. Exp.: C.S. Wu et al., Phys. Rev. 105 (1957) 1413.
3. γ-decay: ^{181}Ta N. Tanner, Phys. Rev. 107, 1203 (1957).
4. -6 x10^{-6}: V.M. Lobashov et al., JETP Lett. 5, 59 (1967); Phys. Lett. 25B 104 (1967).
5. Anapole moment: Ya. B. Zeldovich, Sov. Phys. JETP 6, 1184 (1958).
6. C.S. Wood et al., Science 275, 1759 (1997).

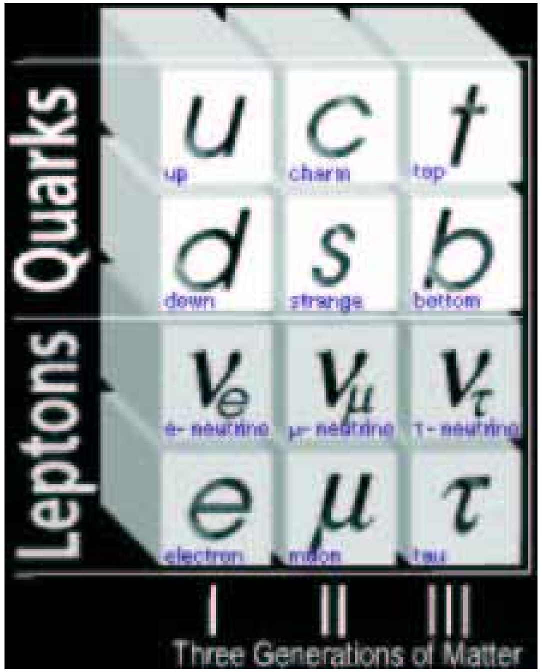




Neutrino oscillation: $\nu_e \longleftrightarrow \nu_\mu \longleftrightarrow \nu_\tau$

CMK mixing





Unified Theories for future

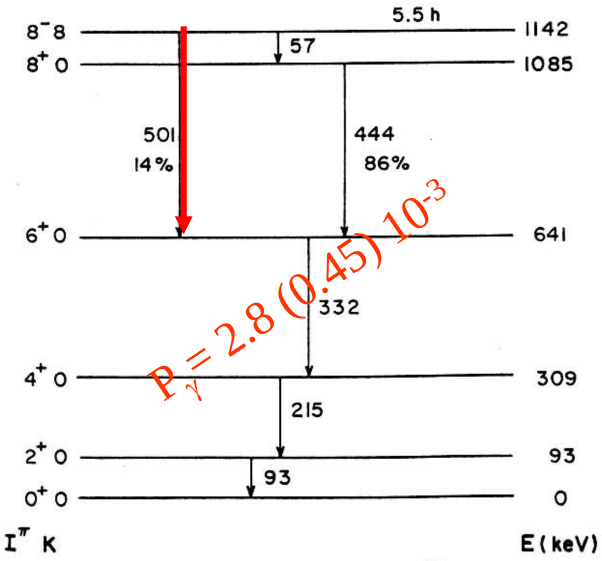


FIG. 1. Decay scheme of ^{180}Hf.

^{180}Hf: K.S. Krane et al., Phys. Rev. Lett. 26 (1971) 1579.

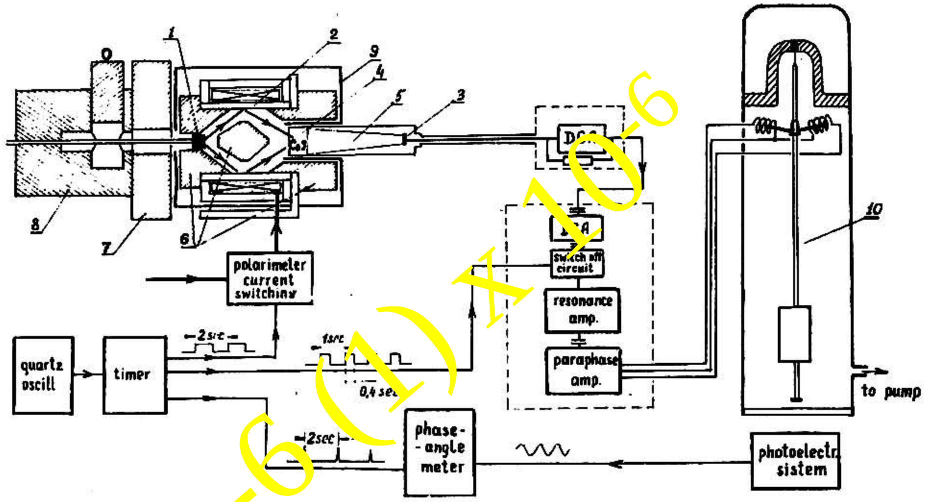
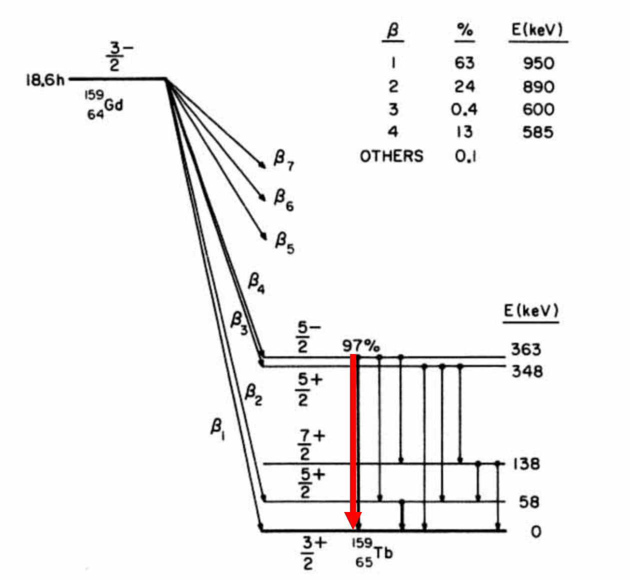
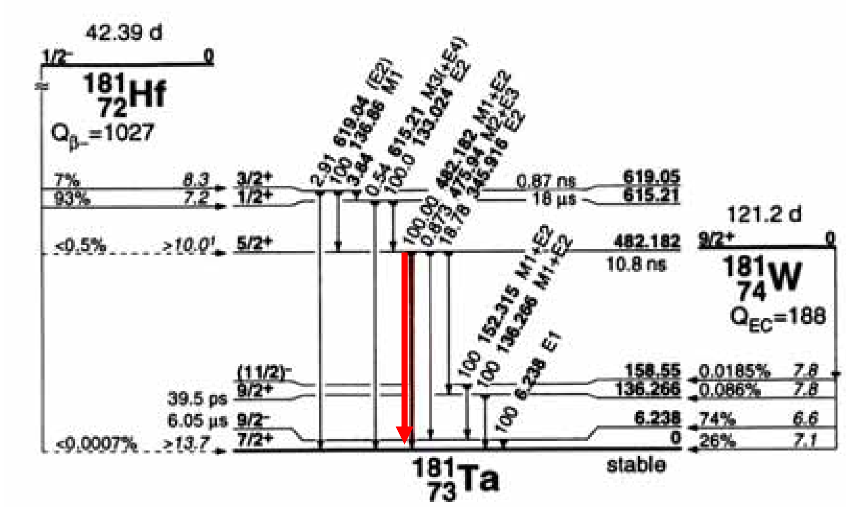


Fig. 1. Experimental arrangement.

1 – Source.
2 – Polarimeter scattering core.
3 – Photodiode
4 – CsI (Tl) crystal.
5 – Light pipe.
6 – Lead-baffled collimators.
7 – Lead shield.
8 – Shipping container.
9 – Permalloy shield.
10 – Pendulum.

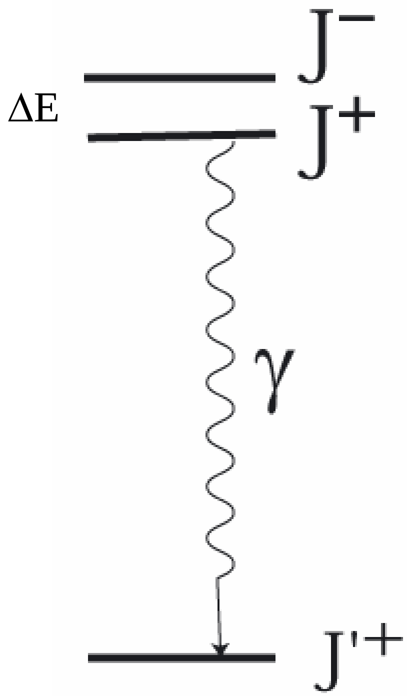
^{181}Ta: N. Tanner, Phys. Rev. 107 (1957) 1203.
V.M. Lobashov et al., PL 25B (1967) 105,





^{159}Tb: W.P Pratt et al., Phys. Rev. C2 (1970) 1499.

二準位 摂動計算

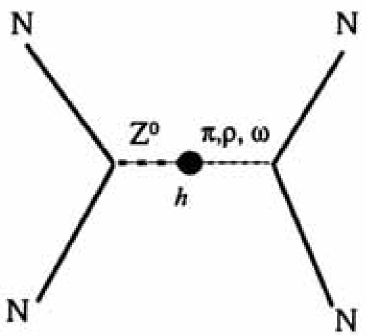


$$|\psi_{J^+}\rangle = \cos(\varepsilon)|\phi_{J^+}\rangle + \sin(\varepsilon)|\phi_{J^-}\rangle$$

$$|\psi_{J^-}\rangle = \cos(\varepsilon)|\phi_{J^-}\rangle - \sin(\varepsilon)|\phi_{J^+}\rangle$$

$$\sin(\varepsilon) \fallingdotseq \varepsilon = \frac{\langle\phi_{J^-}|H_{pnc}|\phi_{J^+}\rangle}{E_+ - E_-} = 10^{-6} - 10^{-2}$$

$$\cos(\varepsilon) \fallingdotseq 1$$



$$H_{PNC} = \sum_{i=1}^{A} \frac{g_S + g_V\tau_3(i)}{2M} \vec{\sigma}(i)\cdot\vec{p}(i)$$

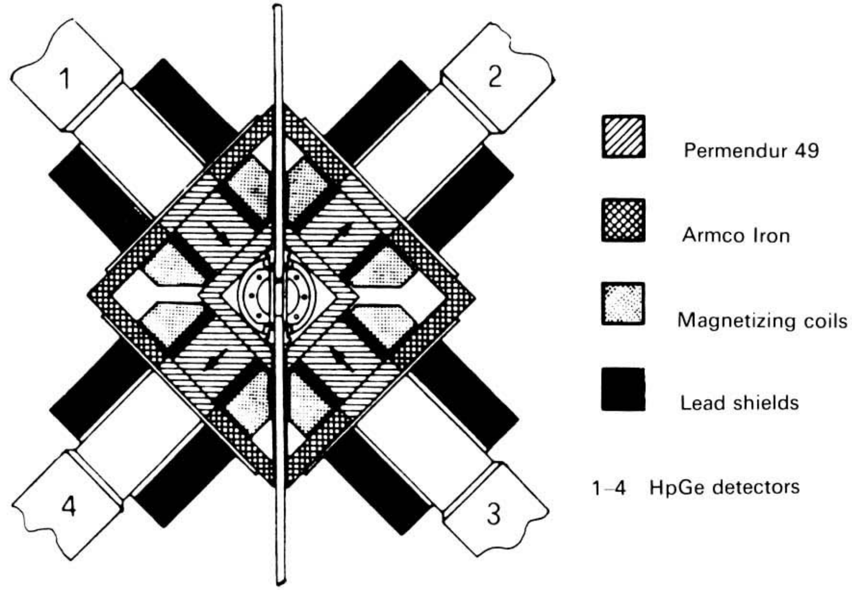


Fig. 7.11. The Four-prong polarimeter. In the centre of the polarimeter the water-jet target assembly is schematically shown. (Bini *et al.*, 1985.)

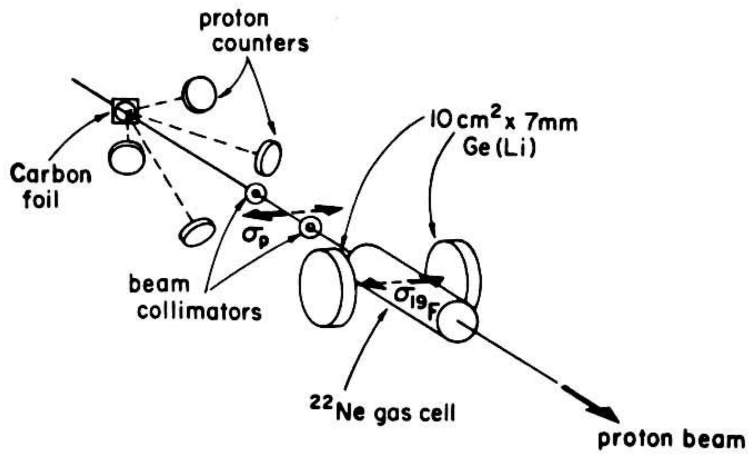


Fig. 7.13. Schematic view of the Seattle ^{19}F PNC experiment. The four proton counters view a thin carbon foil onto which a layer of Au has been evaporated. An on-line computer monitors continuously the transverse polarization by comparing the scattering yields from C and Au. (Adelberger and Haxton, 1985; Earle *et al.*, 1983.)

K.S. Krane et al., PRL 26, 1579 (1971).

PRC 4, 1906 (1971).

B. Jenschke and P. Bock, PL 31B, 65 (1970).

E.D. Lipson, F. Boehm and J.C. van den Leeden, PL 35B, 307 (1971)

W.V. Yuan et al., Phy. Rev. C44, 2187 (1991).

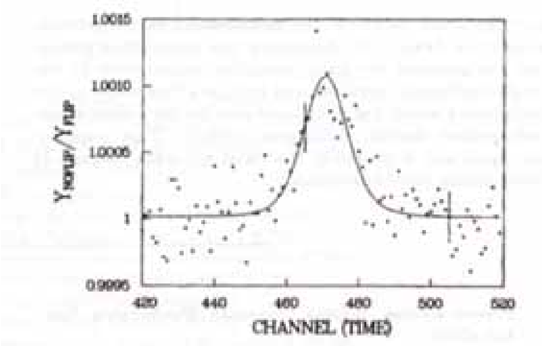
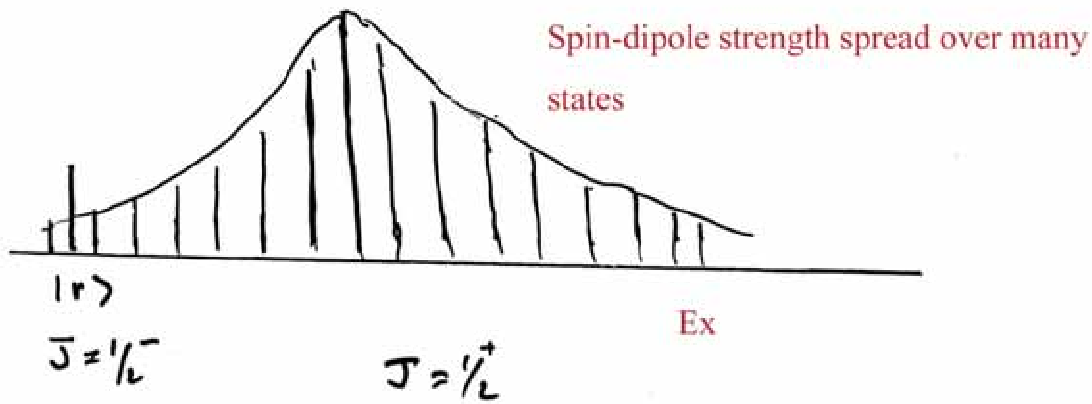


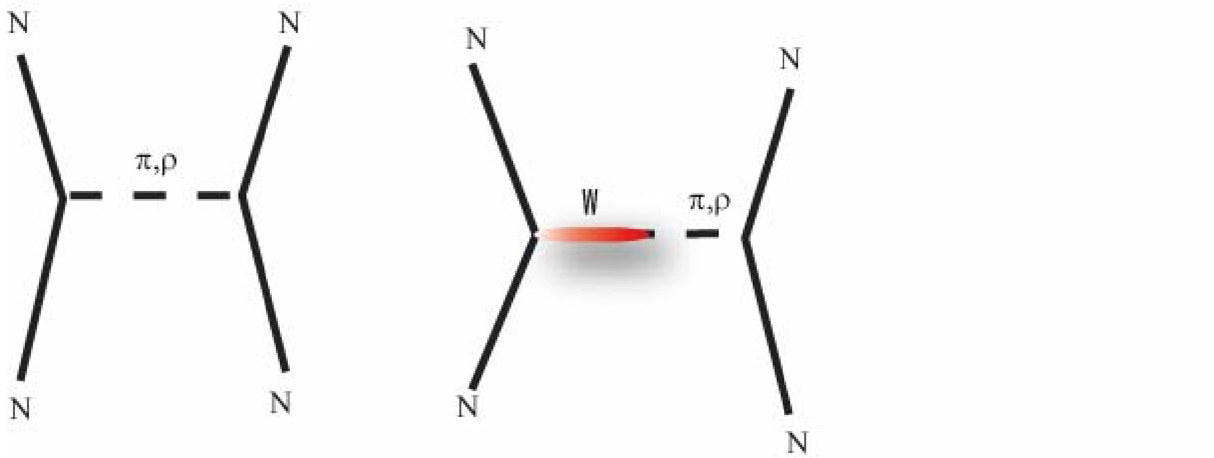
FIG. 7. Parity-violation asymmetry in the 0.734-eV resonance of ^{139}La for the sum of all 79 double-lanthanum data runs. The ratio $Y_{no\ flip}/Y_{flip}$ is plotted as a function of energy, and the parity violation is seen in the deviation of the ratio from 1.0 near the center of the resonance. Representative errors for the uncertainties in each data point are drawn in on data points in the peak region and outside the peak region.

Parity violation in neutron absorption

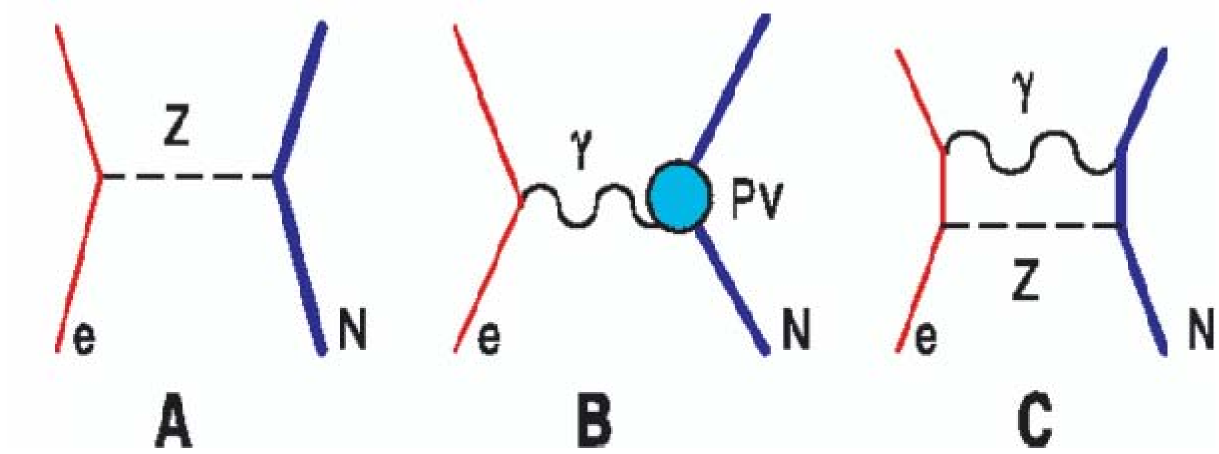
The doorway state for parity violation interaction is spin-dipole resonances (isovector and isoscalar).

Therefore, statistical treatment is essential to analyze the PNC effect.





Nuclear force by meson exchange **Parity violation interaction for NN**



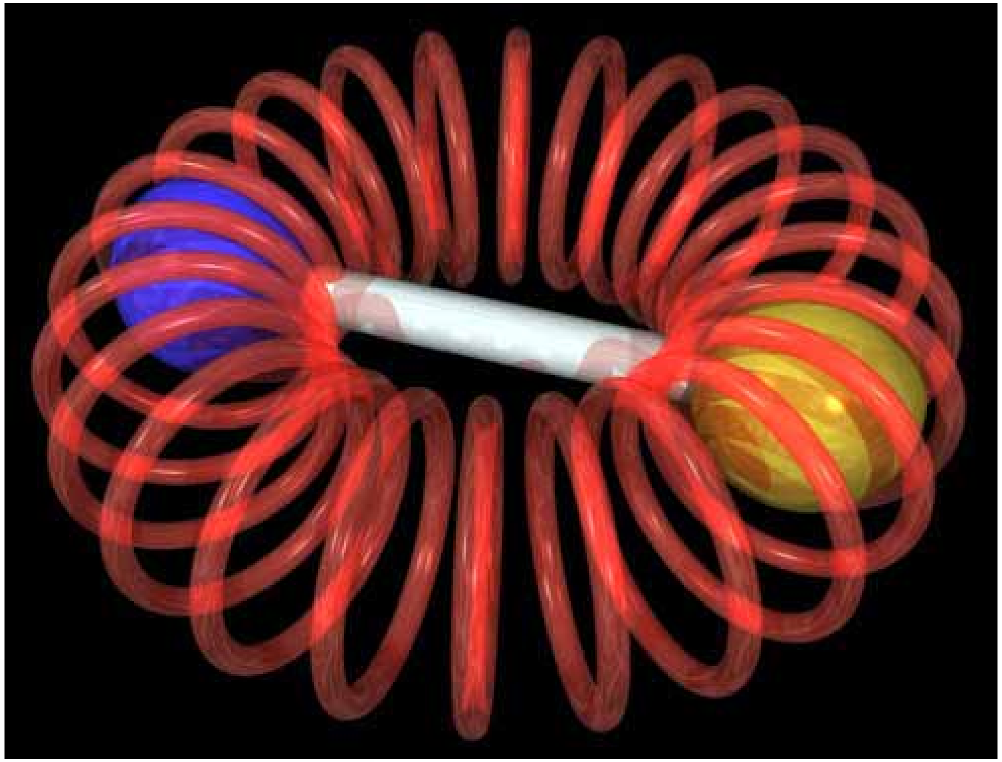
Parity violation force via electromagnetic interactions

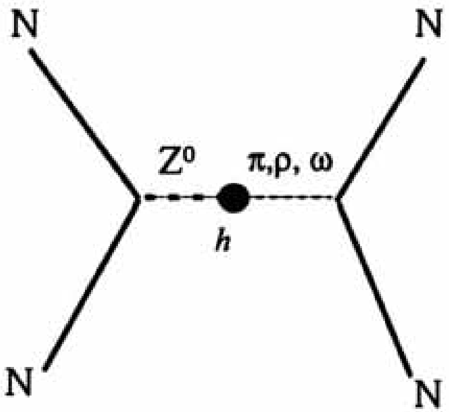
Electric moment : $\boldsymbol{D} = \alpha\ \boldsymbol{r}$

Magnetic moment: $\mu = g\ \sigma$

Anapole moment: $\boldsymbol{t} = \kappa\ \mu \times \boldsymbol{D} = \kappa\ \sigma \times \boldsymbol{r}$

$= \kappa\ \sigma \boldsymbol{p}$



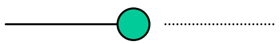


$$H_{PNC} = \sum_{i=1}^{A} \frac{g_S + g_V \tau_3(i)}{2M} \vec{\sigma}(i)\cdot\vec{p}(i)$$

Desplanques, Donoghue and Holstein (DDH) [1] as

$$
\begin{aligned}
V^{PNC}(i,j) &= i\frac{f_\pi g_{\pi NN}}{\sqrt{2}}\left(\frac{\tau_i \times \tau_j}{2}\right)_z (\sigma_i + \sigma_j)\cdot \mathbf{u}_\pi(\mathbf{r}) \\
&- g_\rho\left(h_\rho^0 \tau_i\cdot\tau_j + h_\rho^1\left(\frac{\tau_i + \tau_j}{2}\right)_z + h_\rho^2 \frac{(3\tau_i^z\tau_j^z - \tau_i\cdot\tau_j)}{2\sqrt{6}}\right) \\
&\times((\sigma_i - \sigma_j)\cdot \mathbf{v}_\rho(\mathbf{r}) + i(1+\chi_V)(\tau_i \times \tau_j)\mathbf{u}_\rho(\mathbf{r})) - g_\omega\left(h_\omega^0 + h_\omega^1 + \left(\frac{\tau_i + \tau_j}{2}\right)_z\right) \\
&\times((\sigma_i - \sigma_j)\cdot \mathbf{v}_\omega(\mathbf{r}) + i(1+\chi_S)(\tau_i \times \tau_j)\mathbf{u}_\omega(\mathbf{r})) - (g_\omega h_\omega^1 - g_\rho h_\rho^1) + \left(\frac{\tau_i - \tau_j}{2}\right)_z \\
&\times(\sigma_i + \sigma_j)\cdot \mathbf{v}_\omega(\mathbf{r}) - g_\rho h_\rho'^1 i\left(\frac{\tau_i \times \tau_j}{2}\right)_z (\sigma_i + \sigma_j)\cdot \mathbf{u}_\omega(\mathbf{r}).
\end{aligned}
$$

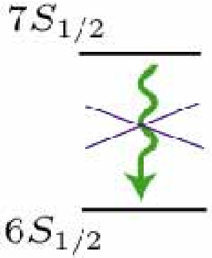
Weak coupling



Z π, ρ, ω

f_π, h_ρ^0, h_ρ^1, h_ρ^2, h_ω^0, h_ω^1

Parity -violating 7S -6S Amplitude in Cs



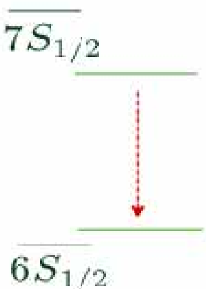
$$\langle 7S_{1/2} | D | 6S_{1/2} \rangle \quad = \quad 0$$

Electric-dipole transition is forbidden by the parity selection rules

Weak interaction leads to an admixture of states of opposite parity
(H_W is a pseudoscalar)

$$\overline{|6S_{1/2}\rangle} = |6S_{1/2}\rangle - \sum_m |mP_{1/2}\rangle \frac{\langle mP_{1/2} | H_W | 6S_{1/2} \rangle}{E_{6S} / E_{mP_{1/2}}}$$

Similarly for $\overline{|7S_{1/2}\rangle}$

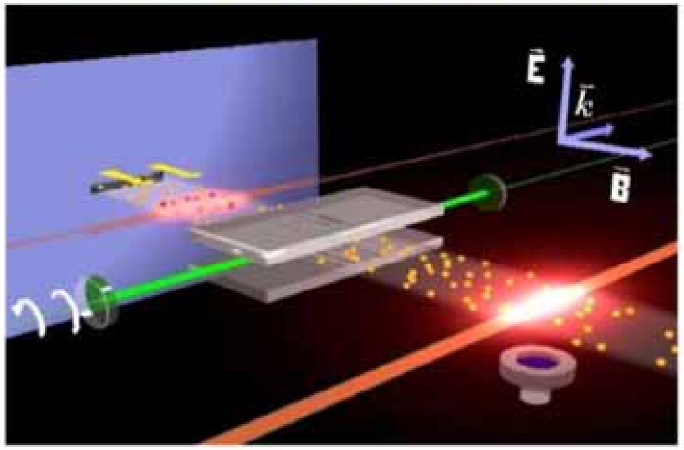


$$E_{PNC} = \overline{\langle 7S_{1/2}} | D | \overline{6S_{1/2} \rangle} =$$

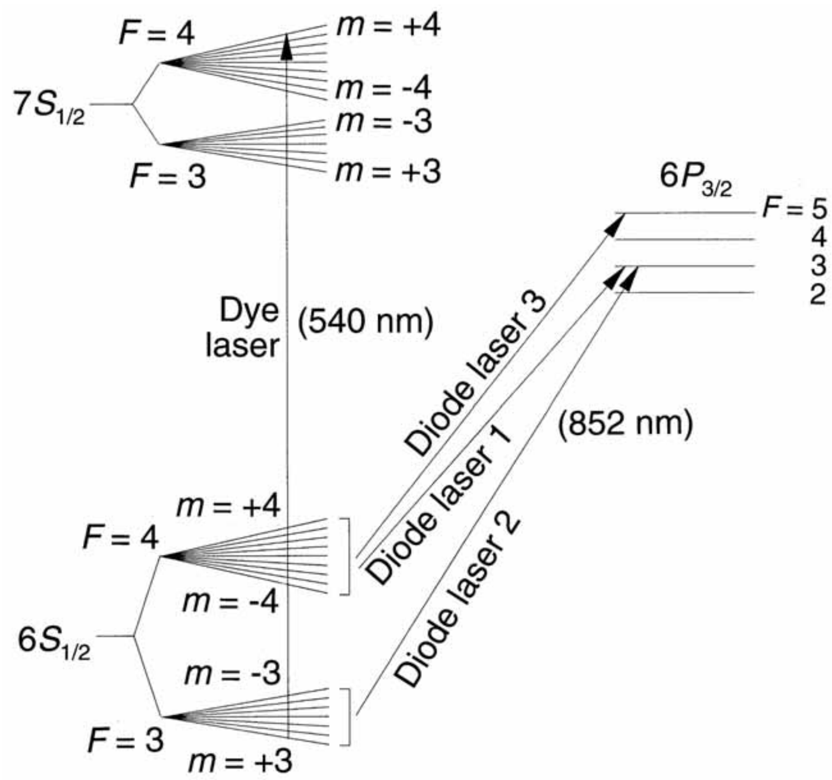
$$\sum_m \frac{\langle 7S_{1/2} | D | mP_{1/2} \rangle \langle mP_{1/2} | H_W | 6S_{1/2} \rangle}{E_{6S} / E_{mP_{1/2}}} \quad \text{c.c. } (6S_{1/2} \leftrightarrow 7S_{1/2})$$

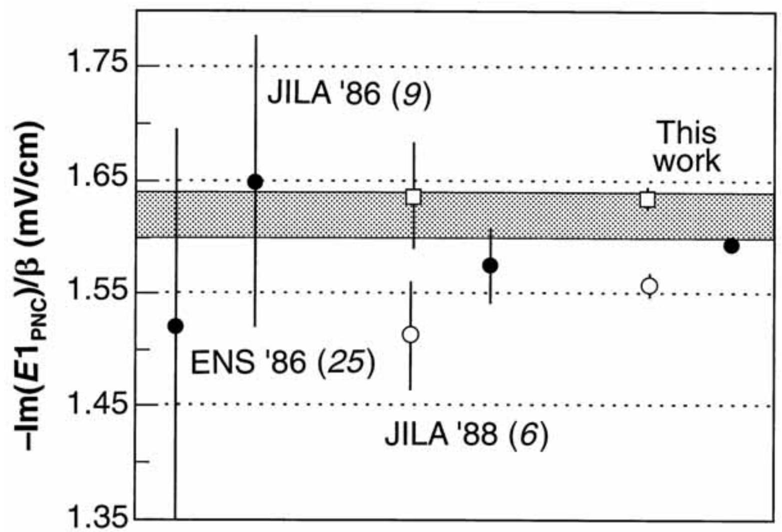
C.S. Wood et al., Science 275, 1759 (1997)
C.S. Wood, Can. J. Phys. 77, 7-75 (1999)

A Stark-Interference Experiment



Schematic of the Boulder PNC apparatus. A beam of cesium atoms is optically pumped by diode laser beams, then passes through a region of perpendicular electric and magnetic fields where a green laser excites the transition from the 6S to the 7S state. Finally the excitations are detected by observing the florescence (induced by another laser beam) with a photo-diode.





Weak Charge of ^{133}Cs (as of 1999)

Weak Hamiltonian:
Overwhelming contribution comes from axial-vector e^- and vector nucleon currents

$$H_W = Q_w \times \frac{G_F}{\sqrt{8}} \gamma_5 \rho_{nuc}(r)$$

Atomic Experiment	E_{PNC}	Q_W =-72.06(28)$_{exp.}$(34)$_{theo.}$
Atomic Structure Theory	E_{PNC} / Q_W	
Standard Model		Q_W = - 73.09(3)

$$Q_w \neq Q_w^{SM}$$

2.5σ deviation (??? new physics, other corrections ???)

New physics :
extra Z bosons, scalar leptoquarks, four-fermion contact interactions, etc

Experiment: Wood et al., Science (1997); Bennett and Wieman PRL (1999).
Theory: Dzuba et al., PLB (1989); Blundell, Johnson, and Sapirstein PRL (1990);PRD (1992).
SM calculations : Marciano and Rosner PRL (1990); Groom et al Eur. Phys. J (2000)

Deviation from the Standard Model in PNC with ^{133}Cs

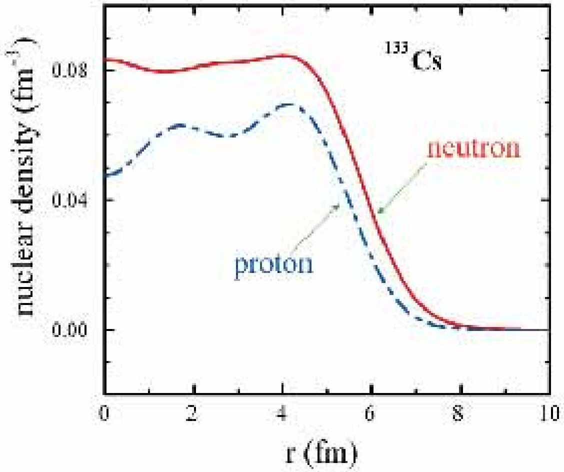
$\sigma = 0.53\%$ ($\sigma_{expt} = 0.35\%$, $\sigma_{theor} = 0.4\%$)

1999 Based on 10 year-old theory by Dzubaet al. and Blundell et al	$2.5\,\sigma$	Bennett & Wieman 1999
Breit interaction	$-1.2\,\sigma$	Derevianko (2000) , Dzuba et al (2001), Kozlov et al (2001)
Vacuum polarization	$+0.8\,\sigma$	Johnsonet al (2002), Milstein & Sushkov (2002)
Neutron skin	$-0.4\,\sigma$	Derevianko (2002)
Vertex correction	$-1.5\,\sigma$	Kuchiev&Flambaum (2002); Milstein et al (2002)
Total deviation (October 2002)	$0.4\,\sigma$	

Part of today's talk

Neutron skin/halo correction

$$H_w = \frac{G_F}{\sqrt{8}}\gamma_5 \quad N\rho_{neutron}(r) + Z\underbrace{(1-4\sin^2\theta_W)}_{\text{small}}\rho_{proton}(r)$$



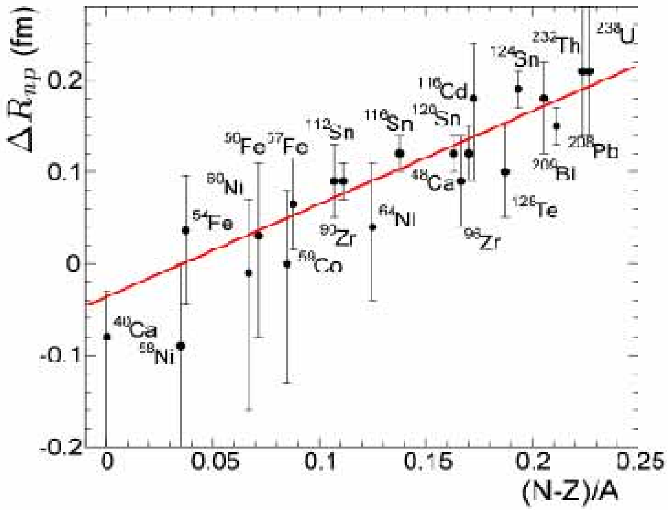
From Vretenar, Lalazissis and Ring PRC, 62 045502 (2000)

Nuclear-structure calculations differ by a factor of four for $\Delta R_{np} = R_n - R_p$

Corrections to Q_W : 0.2 σ – 0.8 σ

Nucl. Str. calcs : Pollock & Welliver, PLB, 464 177 (1999); Vretenar, Lalazissis and Ring PRC, 62 045502 (2000); Panda & Das PRC 62, 065501 (2000).

Neutron skin/halo correction



Experiments with anti-protonic atoms

$$\Delta R_{np} = (-0.04 \pm 0.03) + (1.01 \pm 0.15)\ \frac{N-Z}{A}\ \text{fm}$$

From Trzcinska et al., PRL 87 082501 (2001)

For ^{133}Cs $\Delta R_{np} = 0.13(4)$ fm

Fortson, Pang, and Willets, PRL 65 2875 (1990)

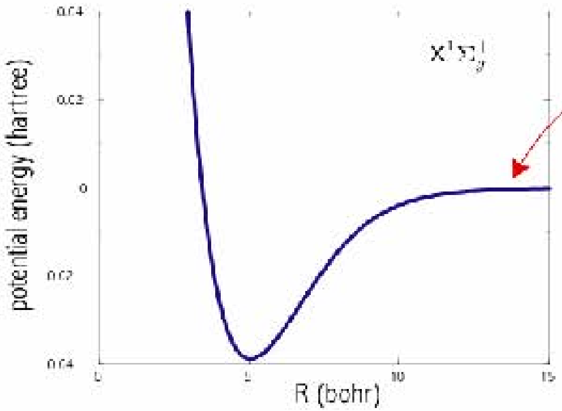
$$\frac{\Delta E^{n.s.}_{PNC}}{E_{PNC}} = -\ \frac{3}{7}\,(\alpha Z)^2\ \frac{\Delta R_{np}}{R_{np}} = -0.0019(6), \quad \text{i.e. } -0.2\%\ (-0.4\sigma)$$

Error bar of 30%

AD Phys. Rev. A65, 012106 (2002)

Also, A. Krasznahorkay, M. Fujiwara, P. van Aarle, H. Akimune, I. Daito, H. Fujimura, Y. Fujita, M.N. Harakeh, T. Inomata, J. Janecke, S. Nakayama, A. Tamii, M. Tanaka, H. Toyokawa, W. Uijen, and M. Yosoi, Phys. Rev. Lett. 82 (1999) 3216--3219.

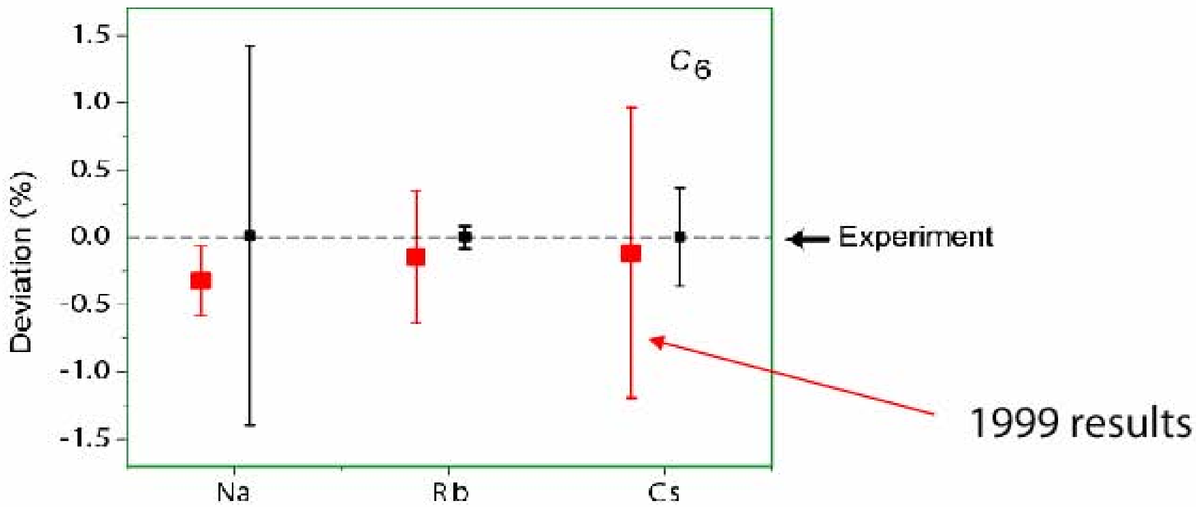
Accurate atomic calculations (modern example)



van der Waals interaction

$$U(R) = -\frac{C_6}{R^6} - \frac{C_8}{R^8} + O(\frac{1}{R^{10}})$$

C_6 may be determined from experiments with (ultra) cold atoms



Calculations: Derevianko, Johnson, Safronova, Babb, Phys. Rev. Lett., 82, 3589 (1999)

Reduce theoretical σ to 0.1%?

We need accurate atomic-structure data :

- -- Energies (known exactly)
- -- Hyperfine-structure constants (almost exactly)
- -- E1 matrix elements (pre-2002 0.2%)

Smaller corrections to E_{PNC},

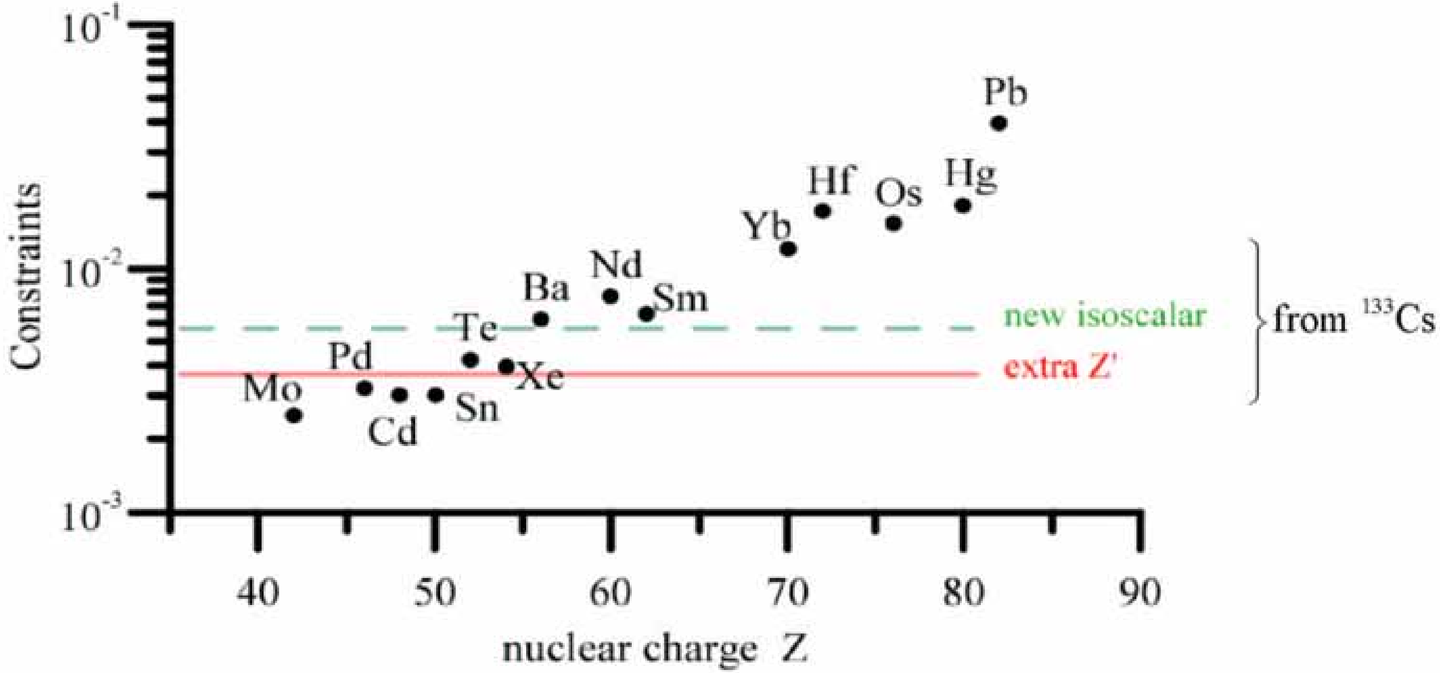
HFS constants, Energies, E1 amplitudes

Better many-body method σ

-- CCSD + IV MBPT (immediate work)

-- GVCC, CCSD+STEOM (future work)

APV in chains of isotopes



- Atoms with $Z < 50$ may be of immediate interest at present
- Since $E_{PNC} \propto Z^3$, "accidental" degeneracy scenario is required

Derevianko and Porsev *Phys. Rev. A* ***65*** *052115 (2002)*

APV in chains of isotopes

Ratio of PNC amplitudes for two isotopes N and $N'=N+\Delta N$ of the same element

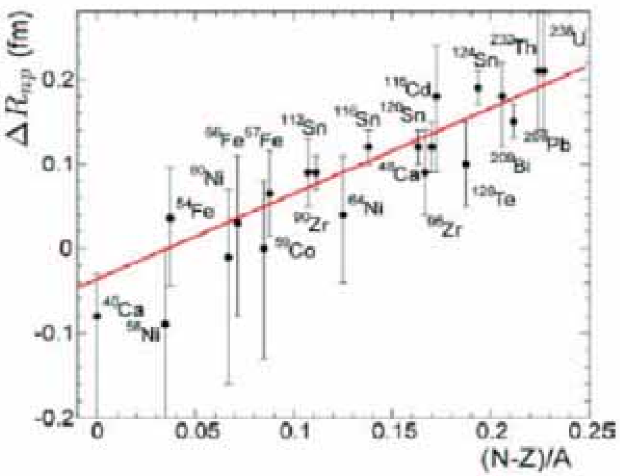
$$\mathrm{R} = \frac{E_{\mathrm{PNC}}}{E'_{\mathrm{PNC}}} = \frac{Q_W}{Q'_W} f_{\mathrm{nuclear}}\left(R_p, R'_p; R_n, R'_n\right)$$

No atomic structure uncertainties !

Constrains on "new direct physics" (the tighter the better)

$$\delta F = \frac{\delta h_p^{\mathrm{new}}}{h_n^{\mathrm{SM}}} \approx \frac{N}{\Delta N}\left(\frac{N}{Z}\right)\left[\frac{\delta \mathrm{R}}{\mathrm{R}} + \frac{3}{7}(\alpha Z)^2 \frac{\delta\left(R_n - R'_n\right)}{R_p}\right]$$

Fortson *et al* 1990 – enhanced sensitivity to uncertainties in neutron radii R_n



Experiments with anti-protonic atoms

$$\Delta R_{np} = (-0.04 \pm 0.03) + (1.01 \pm 0.15)\frac{N-Z}{A}\ \mathrm{fm}$$

From Trzcinska *et al.*, PRL **87** 082501 (2001)

W.C. Haxton et al., Phys. Rev. Lett. 86, 5247 (2001).
W.C. Haxton et al., Phys. Rev. C 65, 045502 (2003).

κ_{AM}(133Cs)=0.090(16)

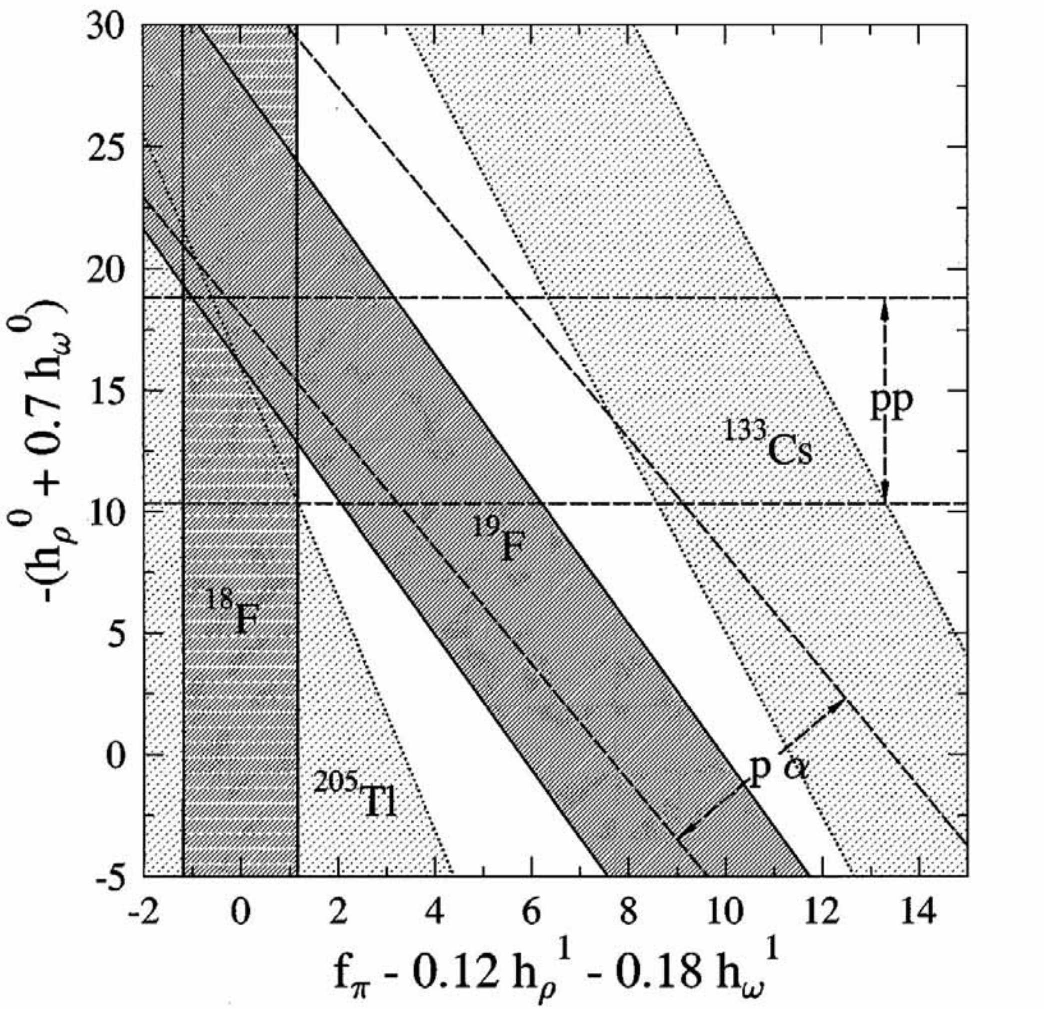
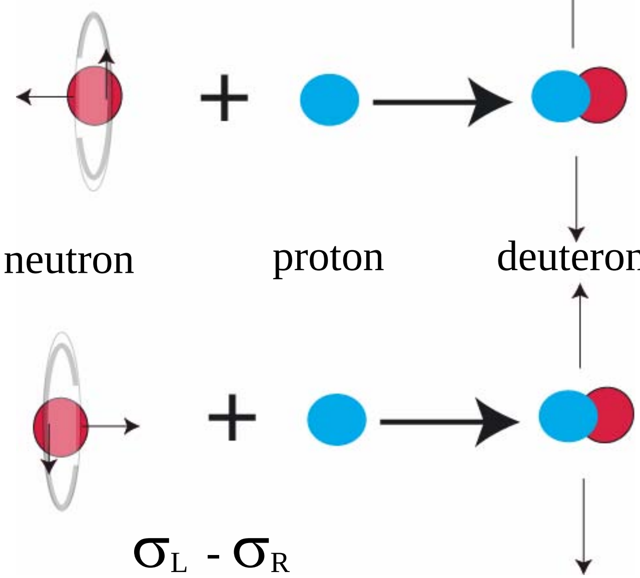


Figure 8 Constraints on the PNC meson couplings ($\times\ 10^7$) that follow from the results in Table 4. The error bands are one standard deviation. The illustrated region contains all of the DDH reasonable ranges for the indicated parameters.

Expected asymmetry -5 x 10^{-8}

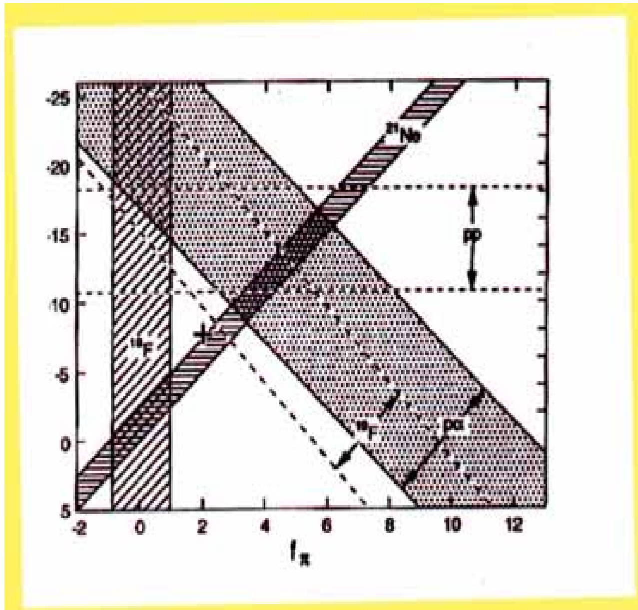
2.2 MeV

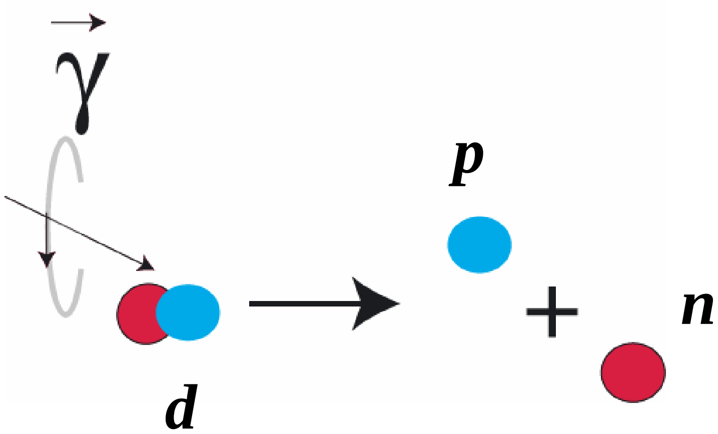
γ ray emission

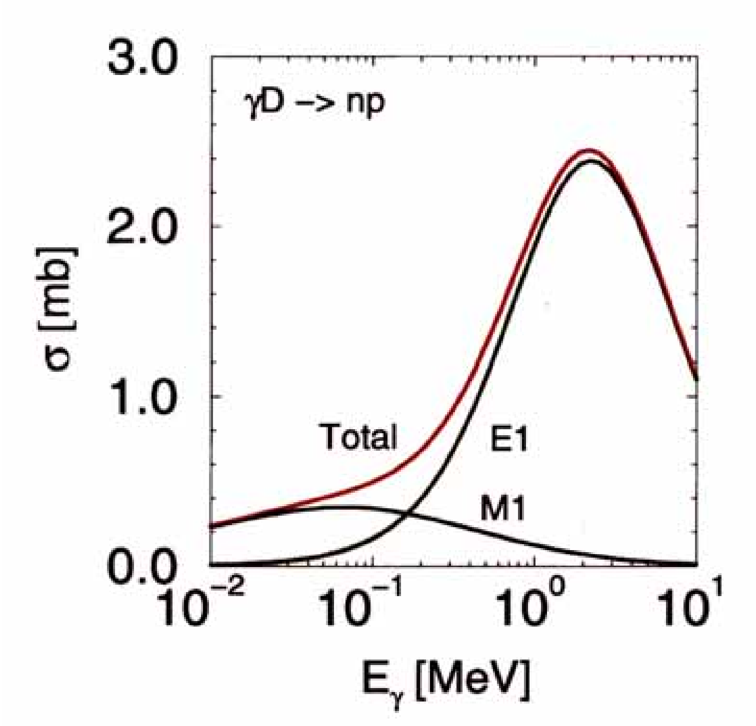


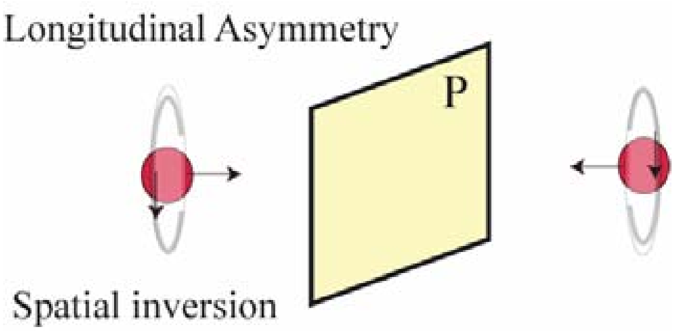
$$A\gamma = \frac{\sigma_L - \sigma_R}{\sigma_L + \sigma_R}$$

LANL project





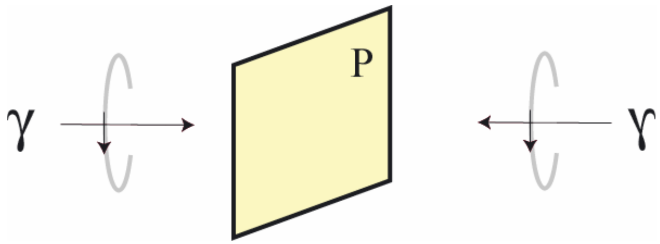




$$A_L = \frac{\sigma(\vec{p}+\overleftarrow{p}) - \sigma(\vec{p}+\vec{p})}{\sigma(\vec{p}+\overleftarrow{p}) + \sigma(\vec{p}+\vec{p})}$$

10^{-6} -- 10^{-7}

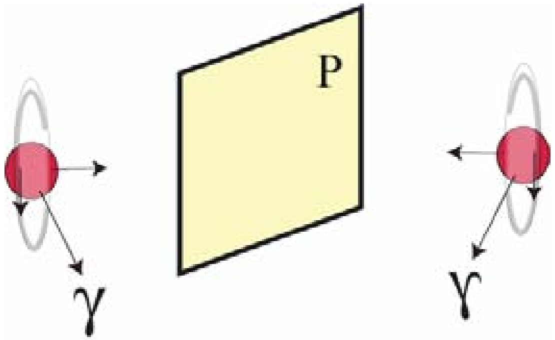
LANL, SIN, LBL, LAMPF, ANL



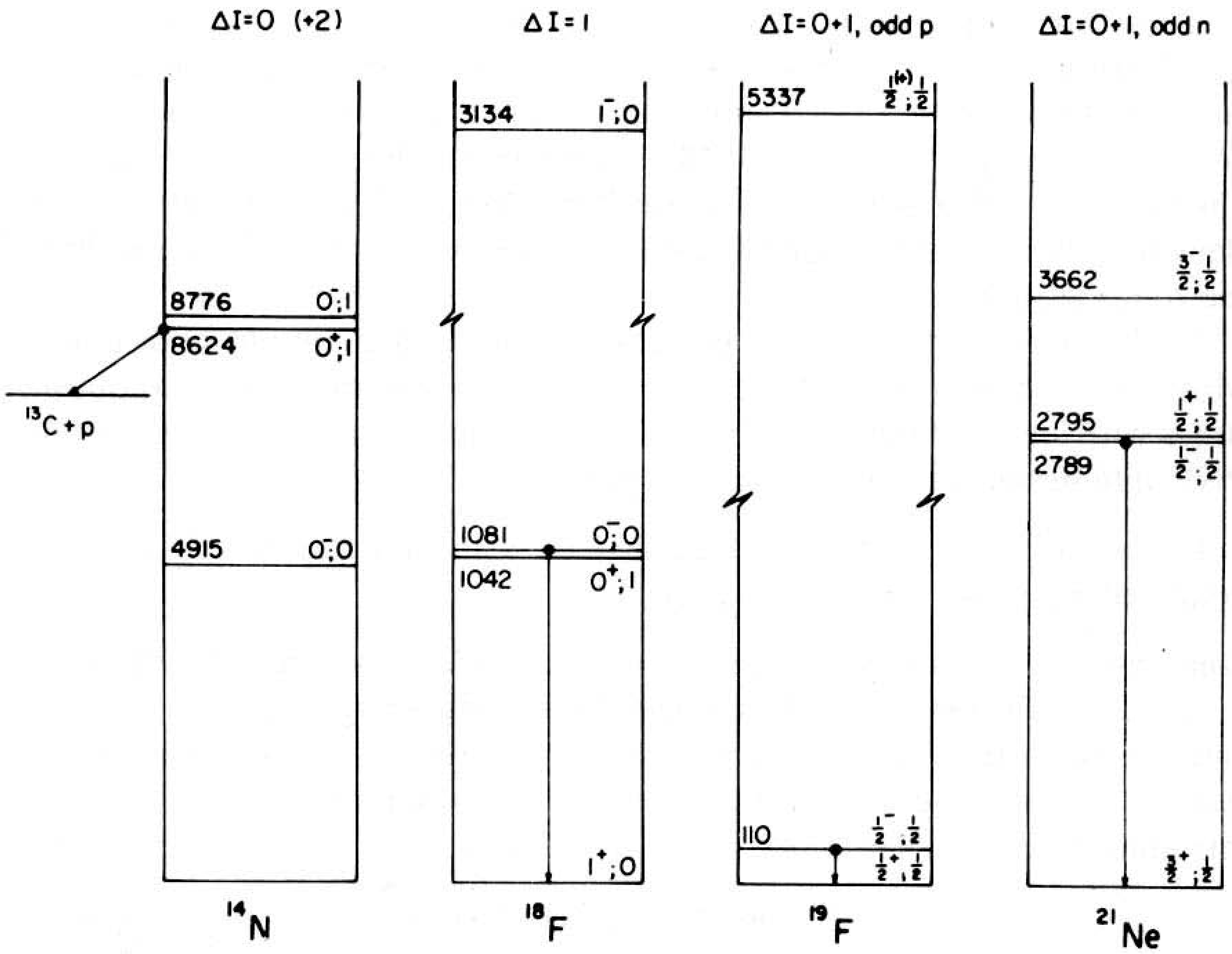
Circular polarization

Photo emission from polarized nuclei

Pγ, Aγ : ^{19}F(1.081 MeV), ^{18}F(110 keV), ^{21}Ne(2.789 MeV), ^{180}Hf, ^{181}Ta,



Gatchna, Cal Tech/Seattle, Florence, Mainz, Queens, Seattle/Chark River, Grenoble



ΔE	152−206i keV	39 keV	110 keV	5.7 keV
ΔE′	3703 keV	3134 keV	5337 keV	3662 keV
	$\sqrt{\Gamma_{0^-}/\Gamma_{0^+}} = 10.5$	$\lvert M1/E1 \rvert = 112$	$M1/E1 = 11$	$\lvert M1/E1 \rvert = 296$

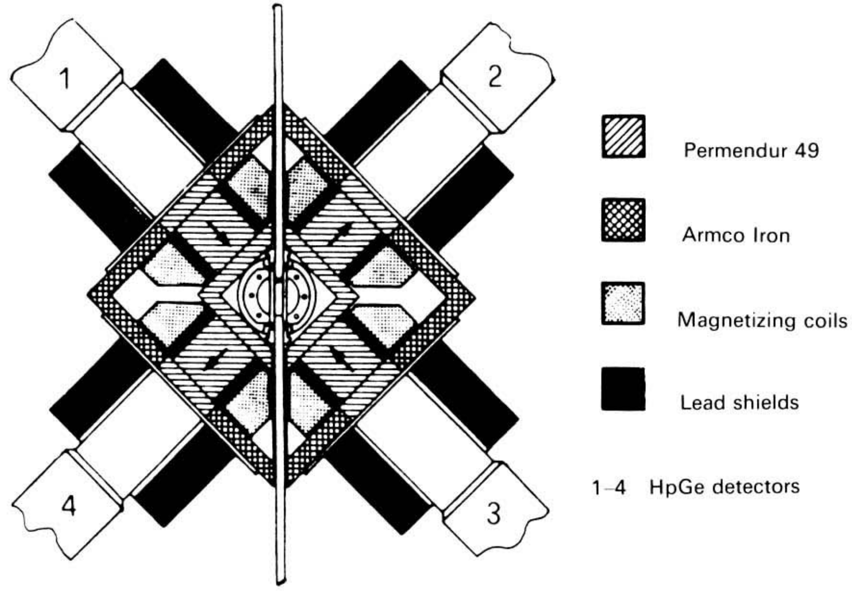


Fig. 7.11. The Four-prong polarimeter. In the centre of the polarimeter the water-jet target assembly is schematically shown. (Bini *et al.*, 1985.)

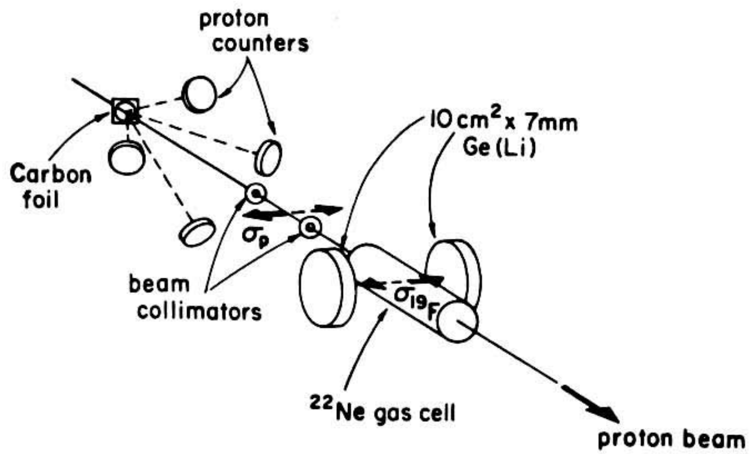
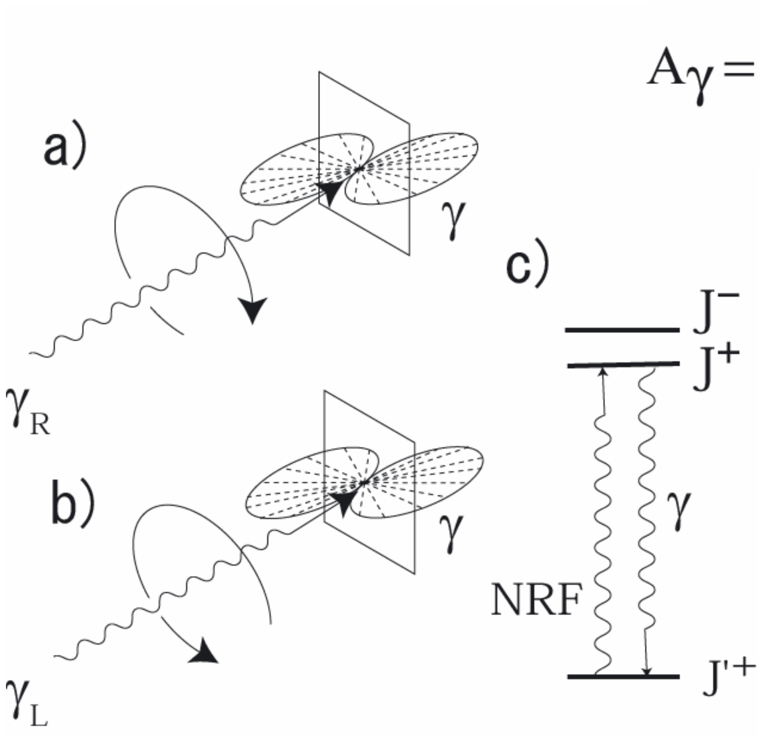


Fig. 7.13. Schematic view of the Seattle ^{19}F PNC experiment. The four proton counters view a thin carbon foil onto which a layer of Au has been evaporated. An on-line computer monitors continuously the transverse polarization by comparing the scattering yields from C and Au. (Adelberger and Haxton, 1985; Earle *et al.*, 1983.)



$$A\gamma = \frac{\sigma_L - \sigma_R}{\sigma_L + \sigma_R} = 2\varepsilon T(M1)/T(E1) \text{ or } 2\varepsilon T((E1)T(M1)$$

E1 excitation M1 excitation

1. **Direct counting of NRF yields**
2. **Both E1 and M1 excitations are used.**
3. **Self-corrections for experimental error**
4. **Circular polarized beam with high stability and High emittance is needed.**

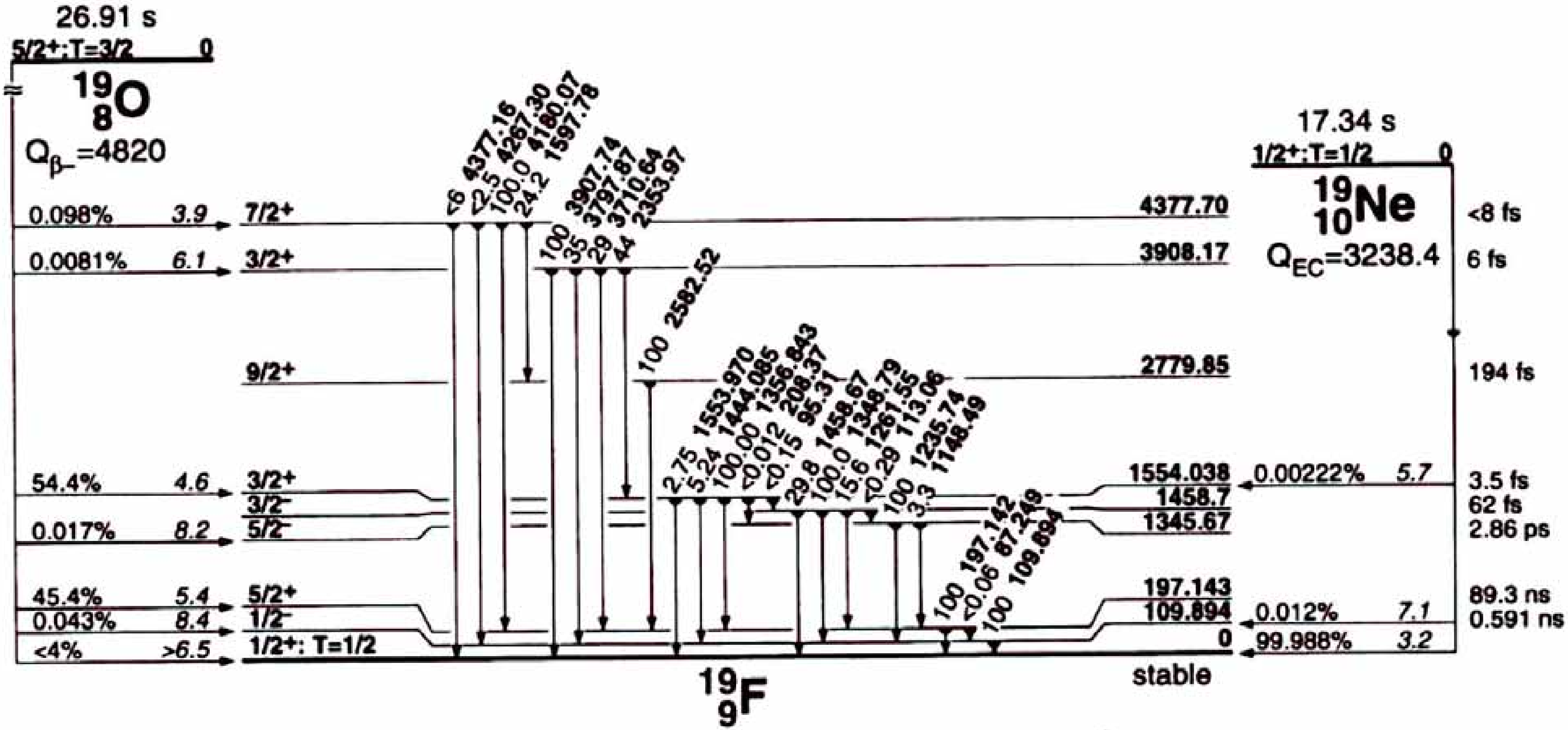
1 eV

$$A\gamma = 2 \frac{\langle \phi_{J^-} | H_{pnc} | \phi_{J^+} \rangle}{E_+ - E_-} \frac{T(E1)}{T(M1)}$$

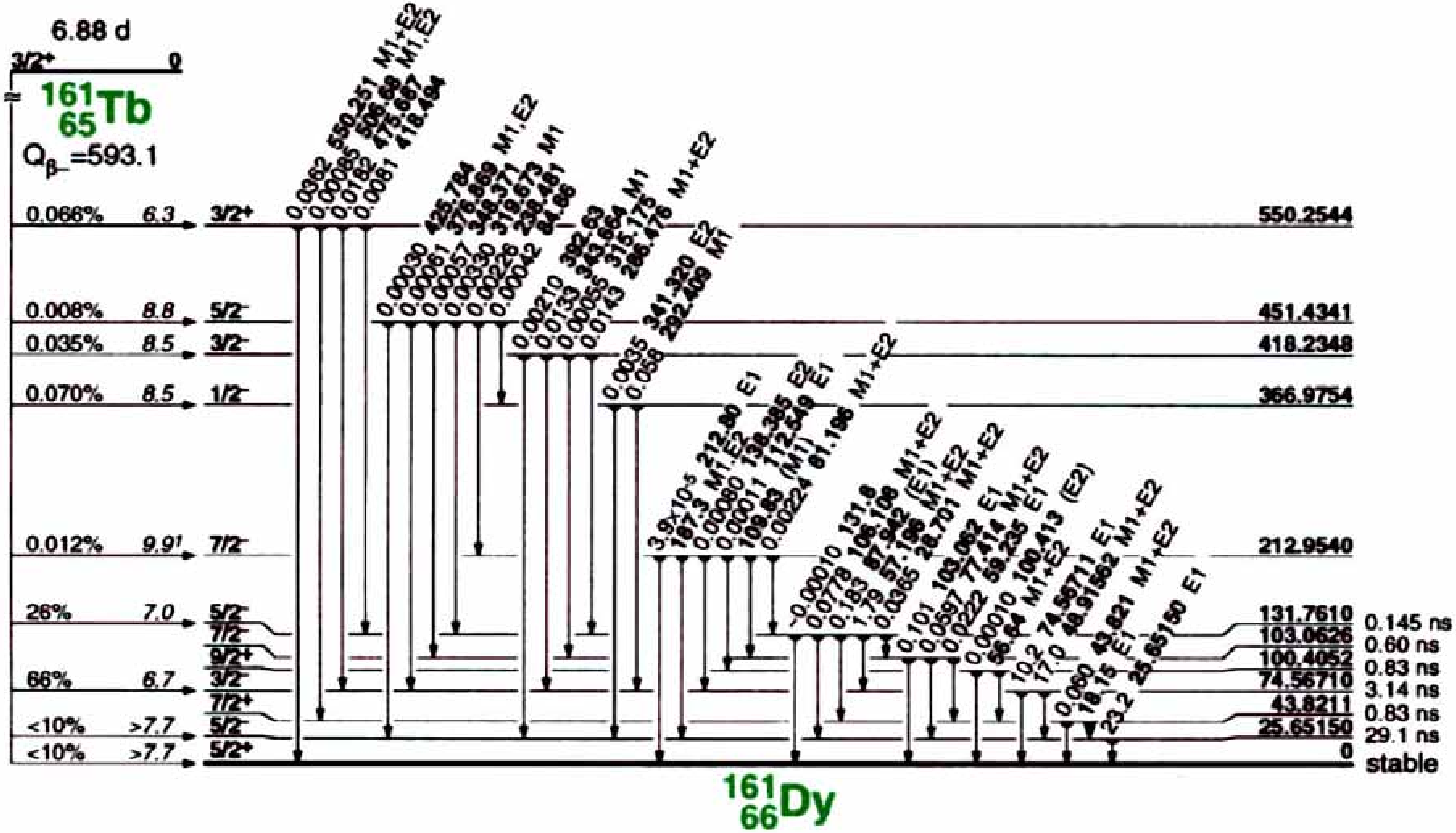
10 – 100 keV **10 - 300**

$$|\gamma_r\rangle = (\varepsilon_x + i\varepsilon_y) \exp(i\boldsymbol{kz})$$

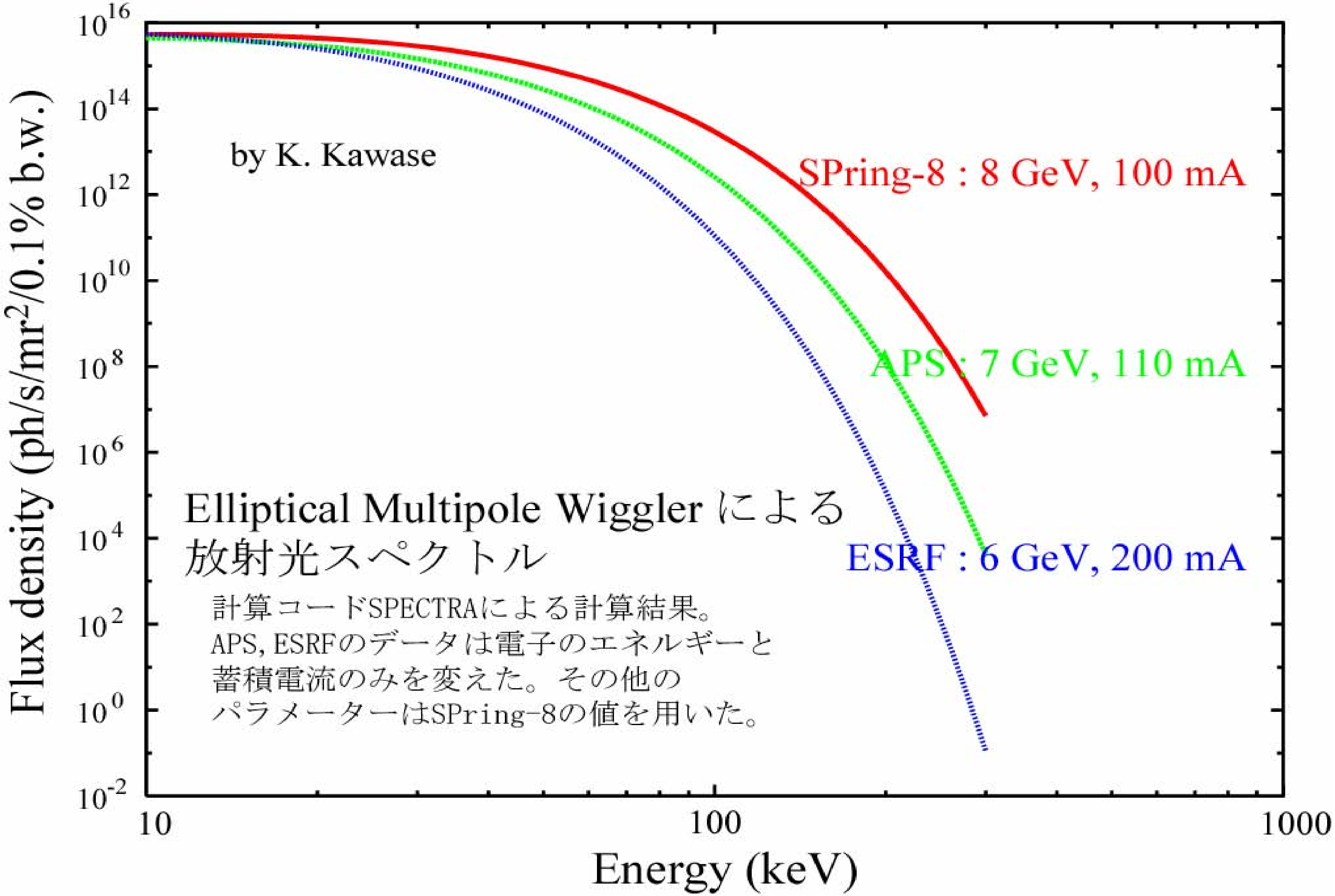
$$|\gamma_l\rangle = (\varepsilon_x - i\varepsilon_y) \exp(i\boldsymbol{kz})$$



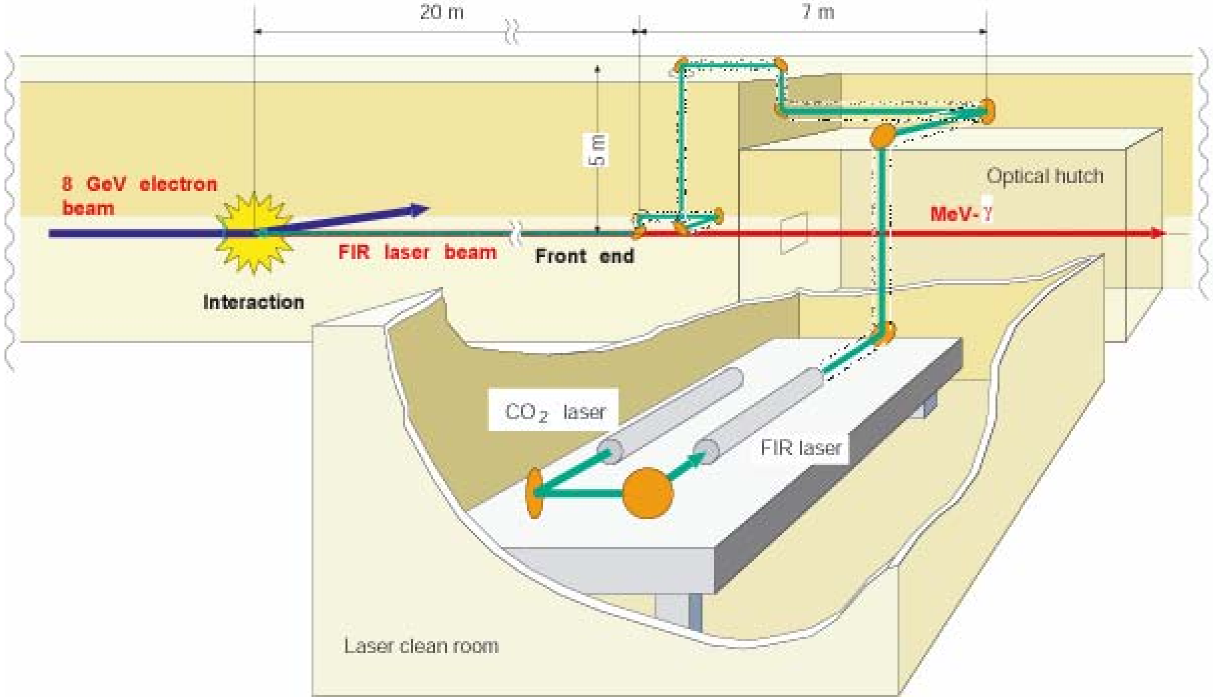
26.91 s
5/2+;T=3/2 0
19 8 O
Qβ- =4820
0.098% 3.9 7/2+
0.0081% 6.1 3/2+
9/2+
54.4% 4.6 3/2+
3/2-
0.017% 8.2 5/2-
45.4% 5.4 5/2+
0.043% 8.4 1/2-
<4% >6.5 1/2+: T=1/2
<6 4377.16
2.5 4267.30
100.0 4180.07
24.2 1597.78
100 3907.74
35 3797.87
29 3710.64
44 2353.97
100 2582.52
2.75 1553.970
5.24 1444.085
100.00 1356.843
<0.012 208.37
<0.15 95.31
29.8 1458.67
100.0 1348.79
15.6 1261.55
<0.29 113.06
100 1235.74
3.3 1148.49
100 197.142
<0.06 87.249
100 109.894
4377.70
3908.17
2779.85
1554.038
1458.7
1345.67
197.143
109.894
0
stable
19 9 F
17.34 s
1/2+;T=1/2 0
19 10 Ne
QEC=3238.4
0.00222% 5.7
0.012% 7.1
99.988% 3.2
<8 fs
6 fs
194 fs
3.5 fs
62 fs
2.86 ps
89.3 ns
0.591 ns

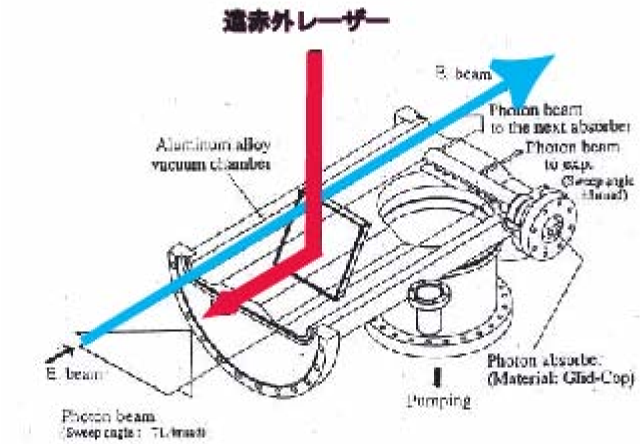


6.88 d
3/2+ 0
161 65 Tb
$Q_{\beta-}$=593.1
0.066% 6.3 3/2+ 550.2544
0.008% 8.8 5/2− 451.4341
0.035% 8.5 3/2− 418.2348
0.070% 8.5 1/2− 366.9754
0.012% 9.91 7/2− 212.9540
26% 7.0 5/2− 131.7610 0.145 ns
7/2− 103.0626 0.60 ns
9/2+ 100.4052 0.83 ns
66% 6.7 3/2− 74.56710 3.14 ns
7/2+ 43.8211 0.83 ns
<10% >7.7 5/2− 25.65150 29.1 ns
<10% >7.7 5/2+ 0 stable
161 66 Dy

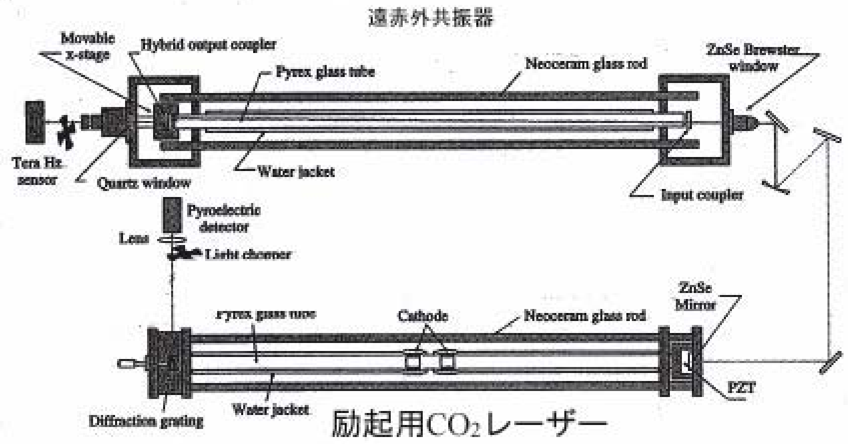


Flux density (ph/s/mr²/0.1% b.w.)
Energy (keV)
10
100
1000
by K. Kawase
SPring-8 : 8 GeV, 100 mA
APS : 7 GeV, 110 mA
ESRF : 6 GeV, 200 mA
Elliptical Multipole Wigglerによる
放射光スペクトル
計算コードSPECTRAによる計算結果。
APS, ESRFのデータは電子のエネルギーと
蓄積電流のみを変えた。その他の
パラメーターはSPring-8の値を用いた。

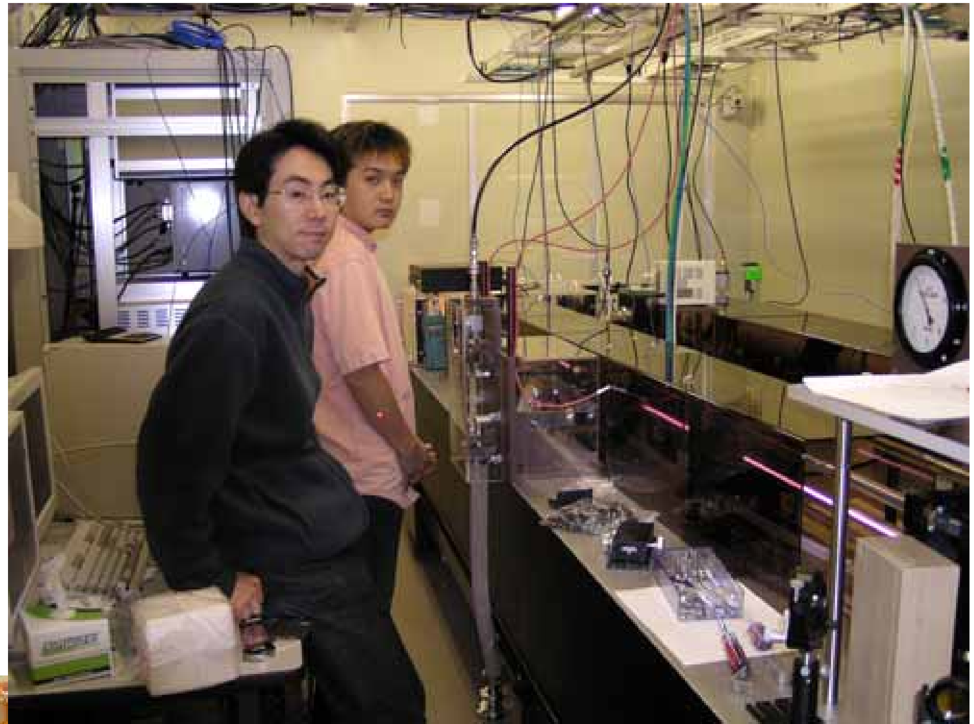


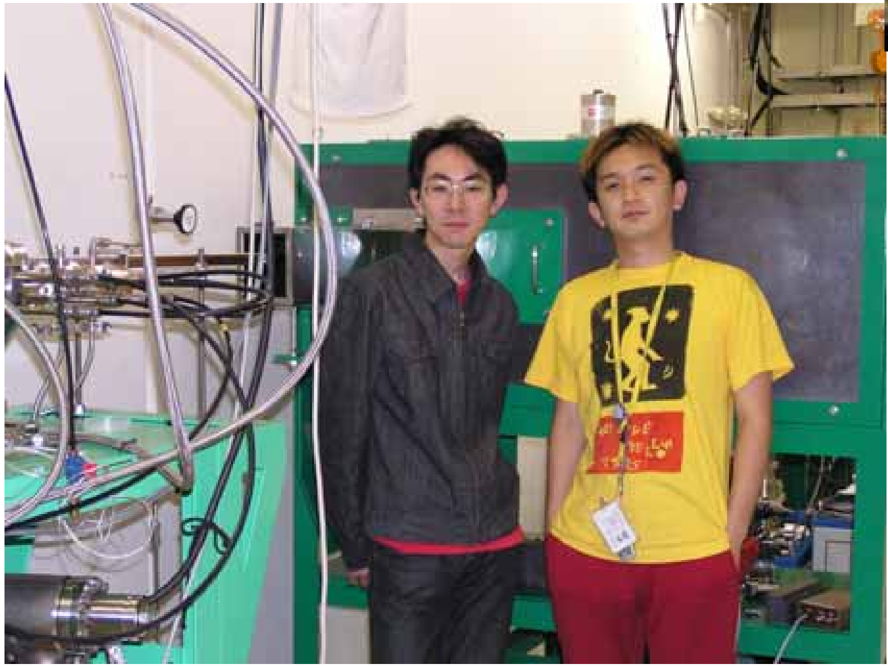


レーザー光導入チェンバー



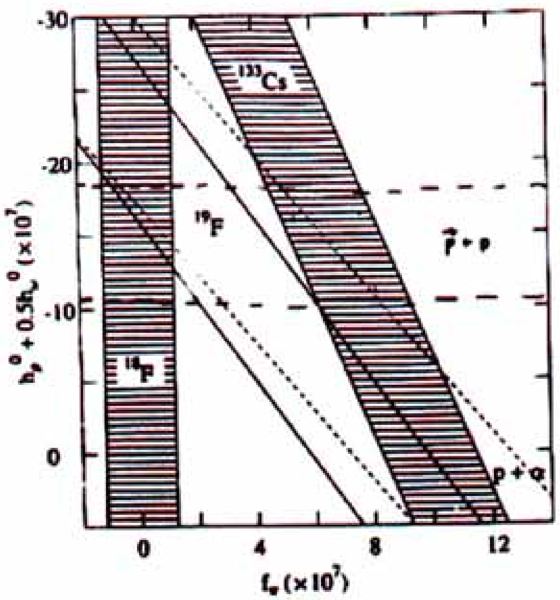
励起用CO_2レーザーおよび遠赤外レーザーシステム



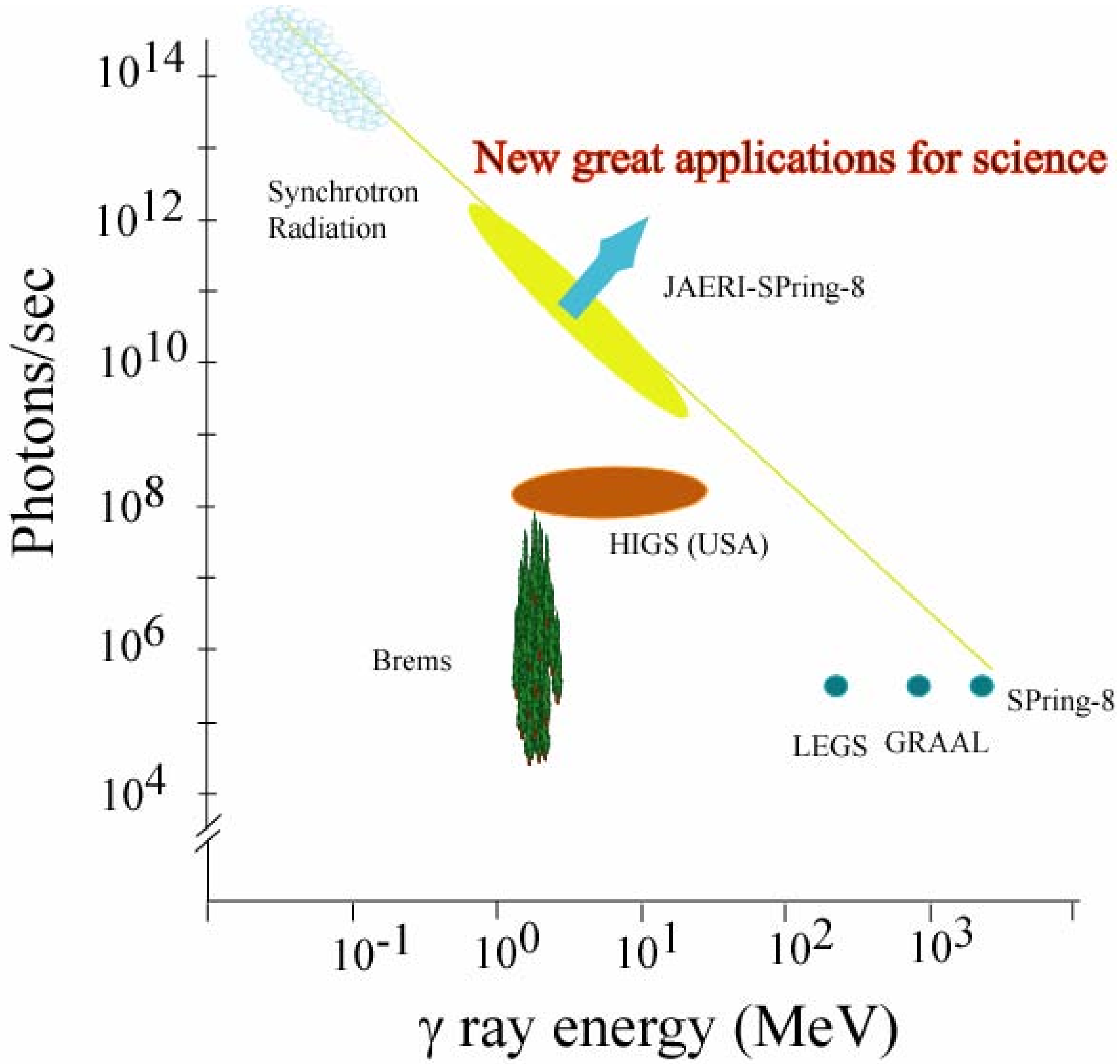


Summary

1. Brief History of Parity violation Studies:
   New physics beyond standard model
2. New possibility at SPring-8
3. NRF experiments with a circular polarized
   γ-ray beam
4. New formula for Aγ
5. Works are now in progress:
   FIRL: H. Ohkuma, Y. Arimoto, Tamura,
   S. Suzuki, et. al.,
   NRF: K. Kawase, M.F. H. Ohkuma, et al.,
   Theoretical considerations (A. Titov,
   M. Fujiwara).



^{133}Cs
^{19}F
^{18}F
$\vec{p}+p$
$p+\alpha$
-30
-20
-10
0
0
4
8
12
$h_{\rho}^{0}+0.5h_{\omega}^{0}\ (\times 10^{7})$
$f_{\pi}\ (\times 10^{7})$

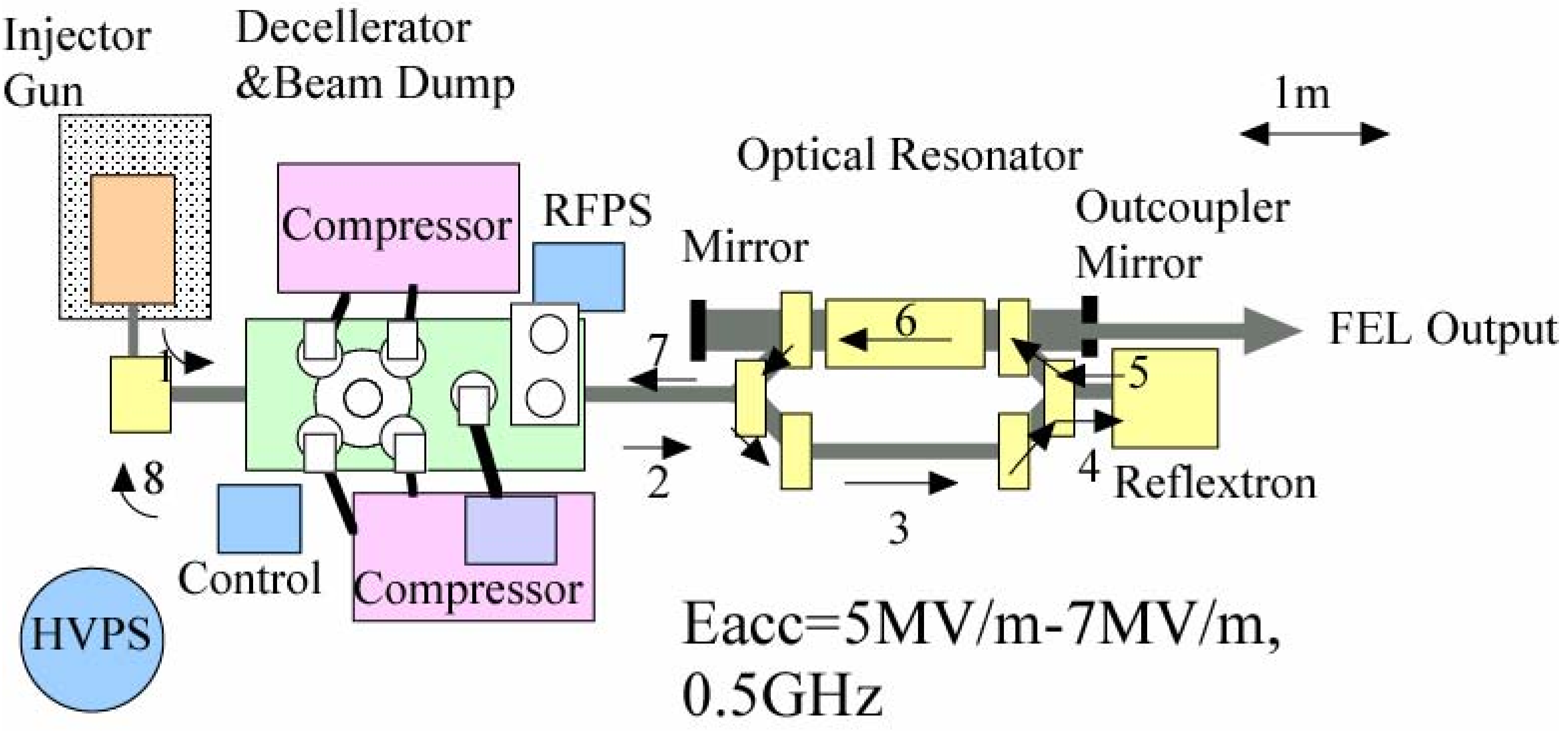


New great applications for science
Photons/sec
10^{14}
10^{12}
10^{10}
10^{8}
10^{6}
10^{4}
Synchrotron
Radiation
JAERI-SPring-8
HIGS (USA)
Brems
LEGS
GRAAL
SPring-8
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
γ ray energy (MeV)

Concept of Far Infra Red Free Electron Laser (FIRFEL) for BCS

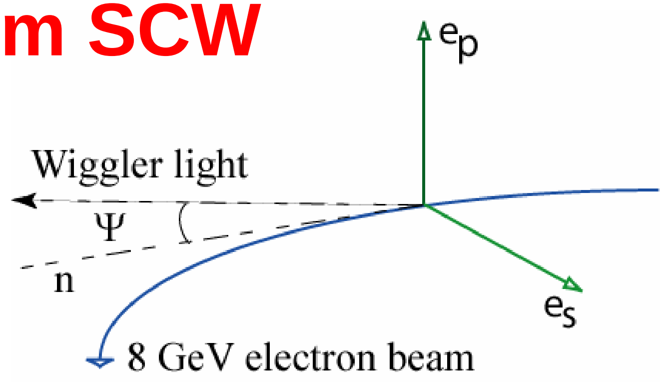
原研 (峰原) 案の遠赤外超伝導自由電子レーザー

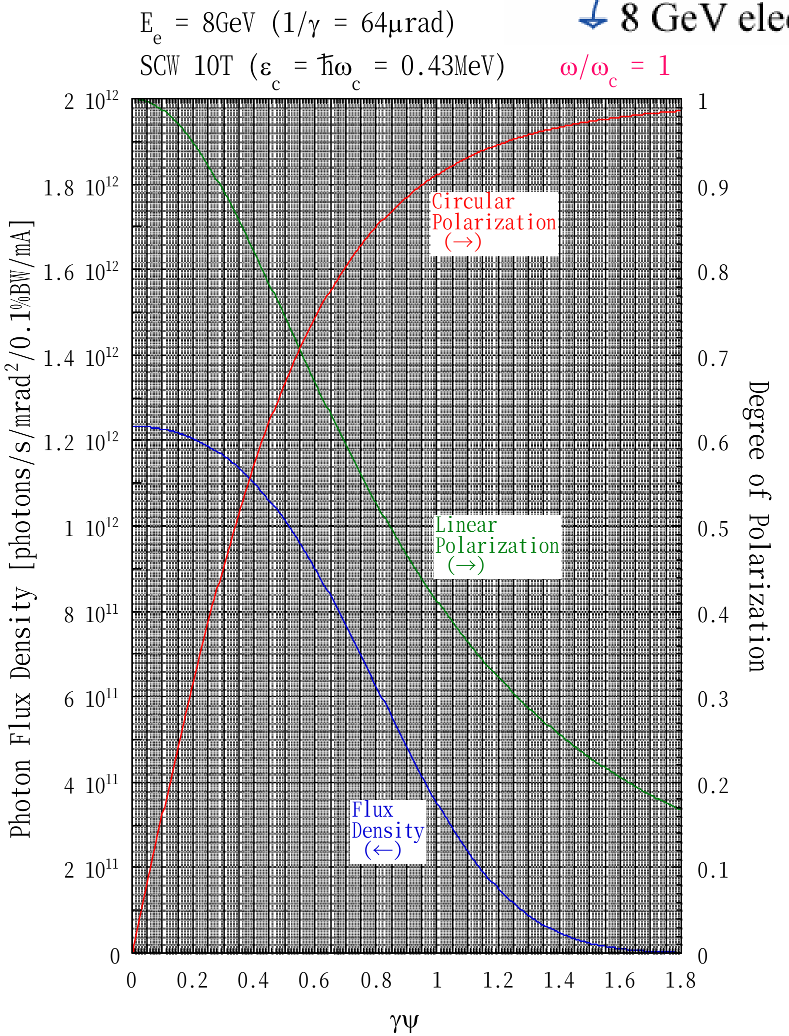
キロワット級遠赤外レーザー光 → 10^{12} photons/sec

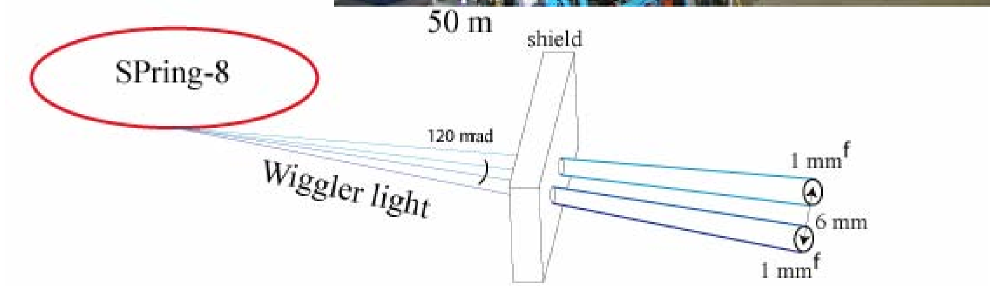


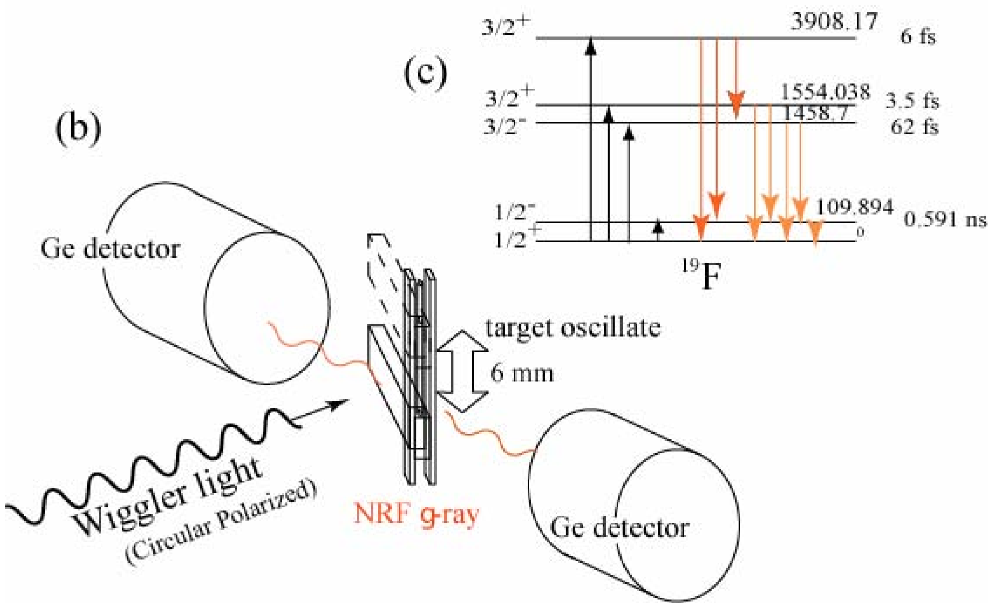
7.5-10.5 MeV, 1.5 m (acceleration Length)/5 cells,
0.5 kW FIR, wave length 50-100 μm

Photons from SCW

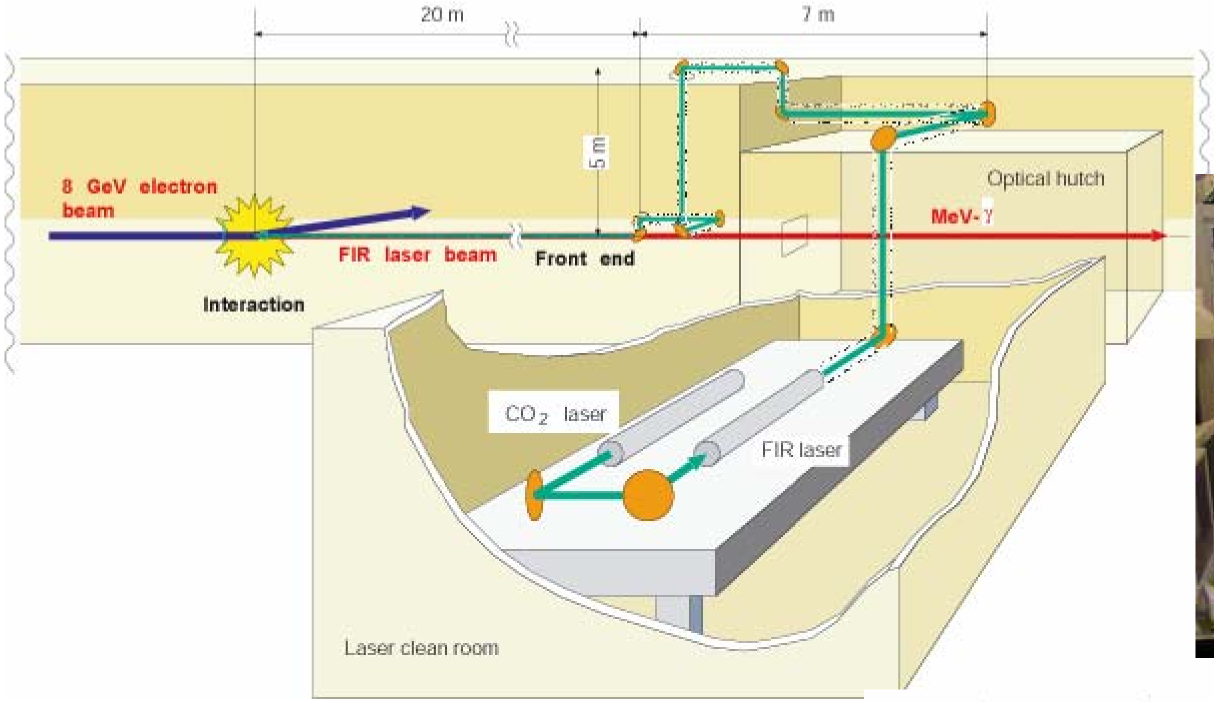


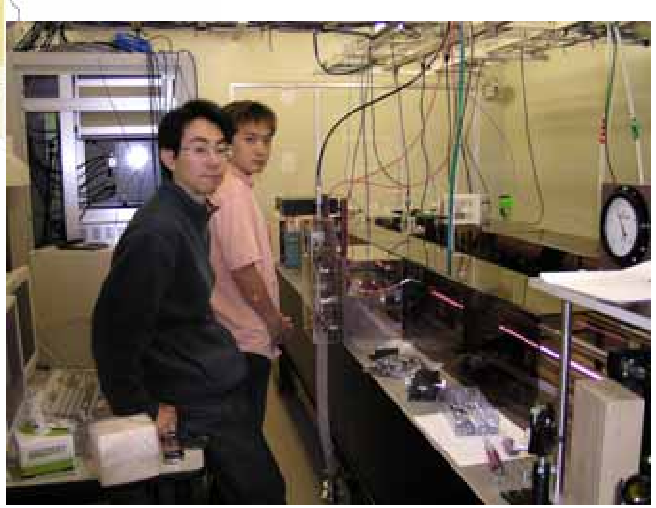


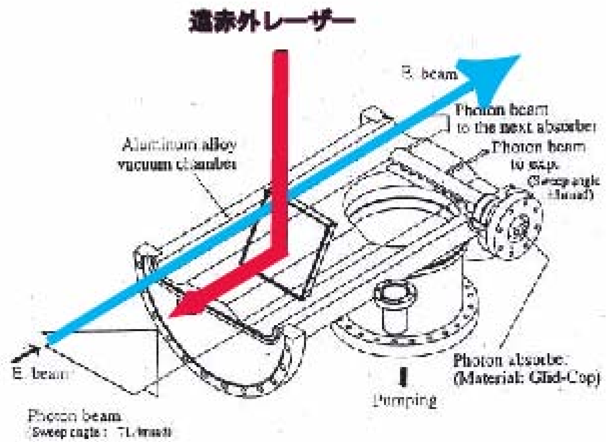




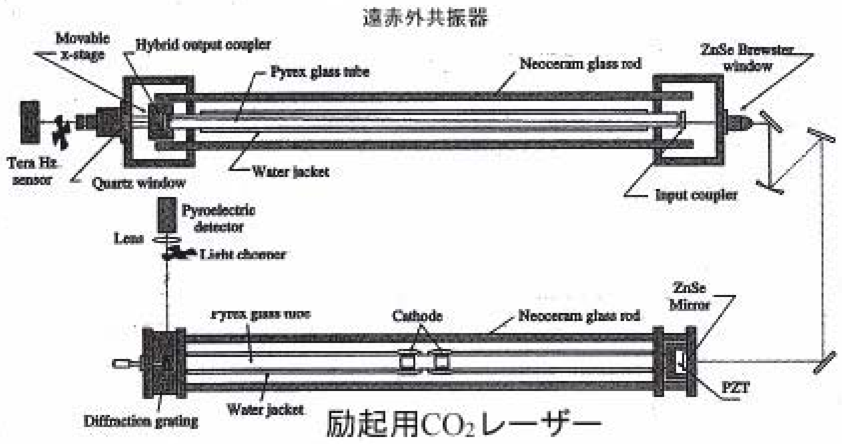
遠赤外レーザーと8 GeV蓄積電子の衝突による逆コンプトンガンマ線







レーザー光導入チェンバー

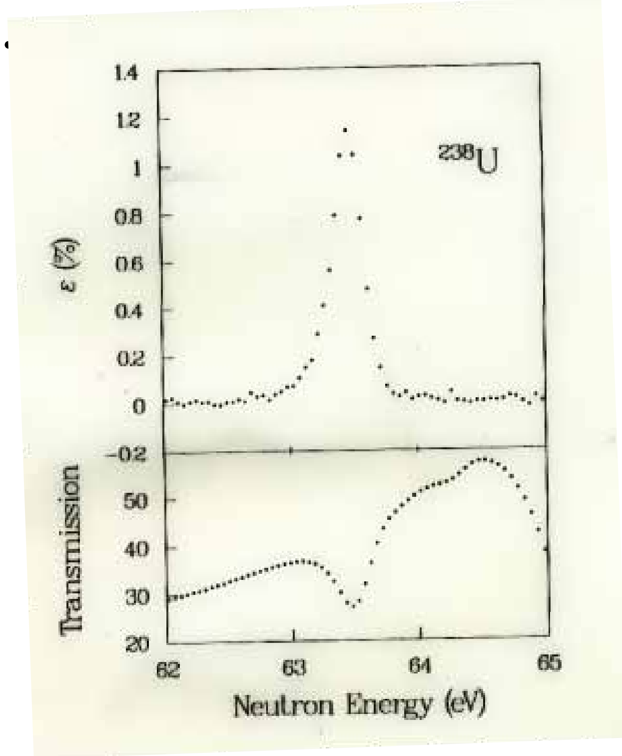


励起用CO_2レーザーおよび遠赤外レーザーシステム

原子核のM1励起とE1励起・及びPNC実験

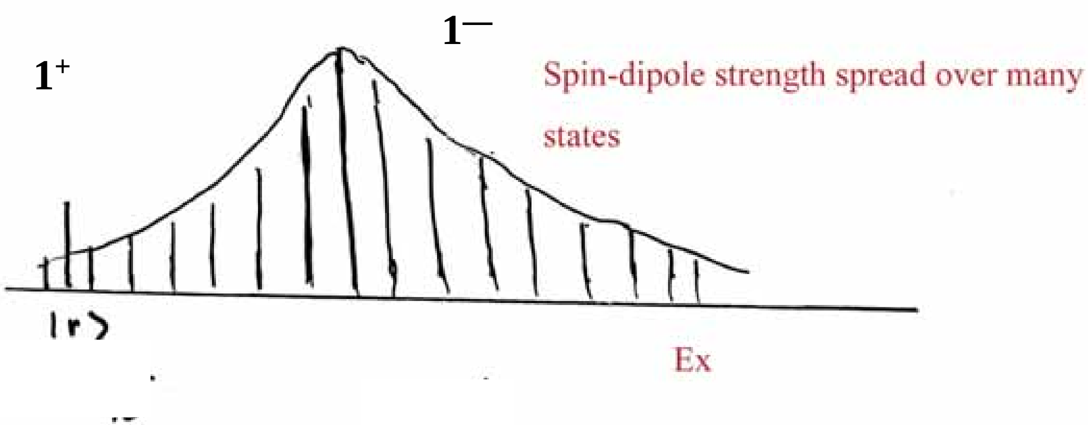
K.S. Krane et al., PRL 26, 1579 (1971).
PRC 4, 1906 (1971).
B. Jenschke and P. Bock, PL 31B, 65 (1970).
E.D. Lipson, F. Boehm and J.C. van den Leeden, PL 35B, 307 (1971)
W.V. Yuan et al., Phy. Rev. C44, 2187 (1991).

Parity violation in neutron absorption

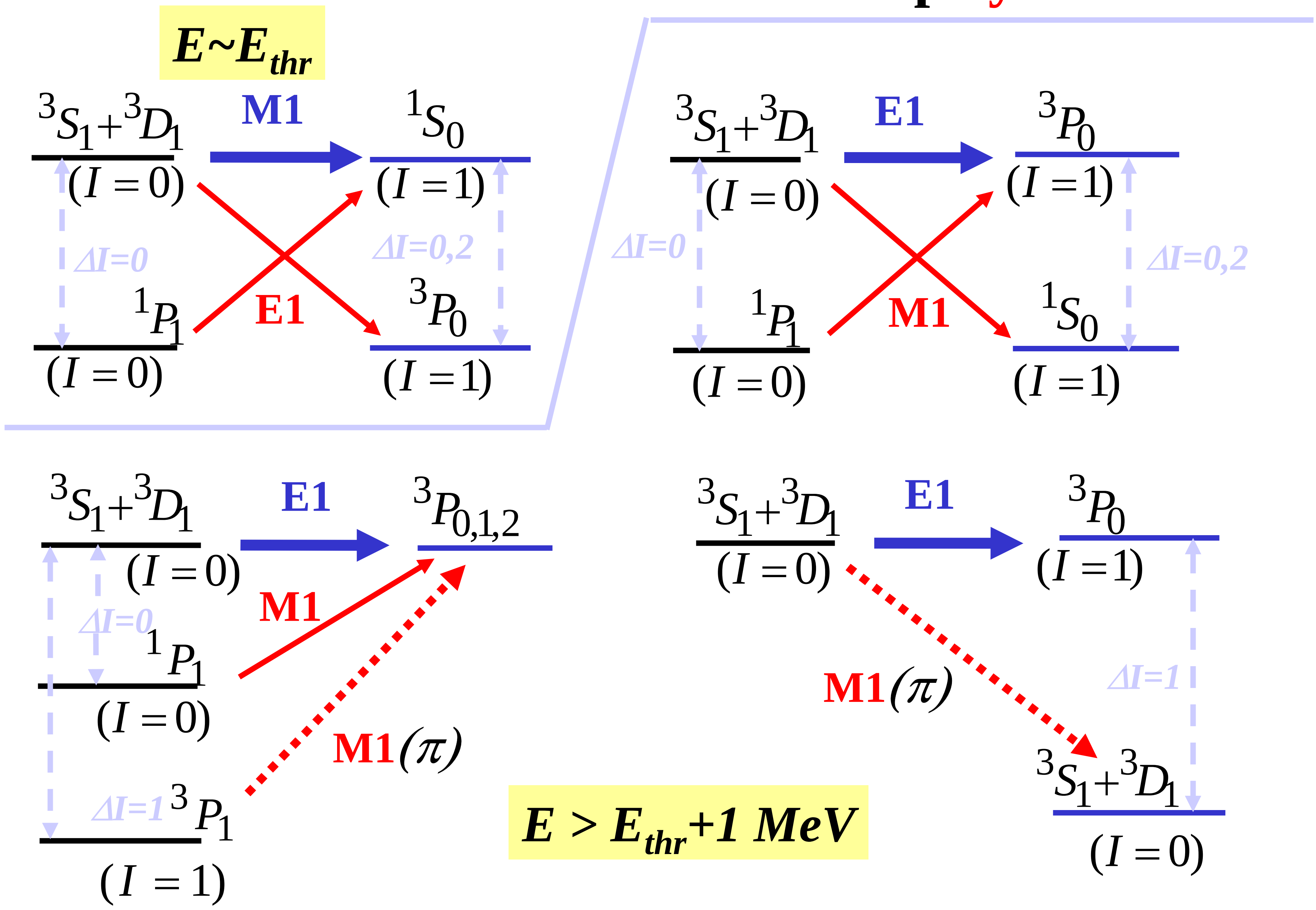


In NRF …

The doorway state for parity violation interaction is dipole resonances (isovector and isoscalar).
Therefore, statistical treatment is essential to analyze the PNC effect.

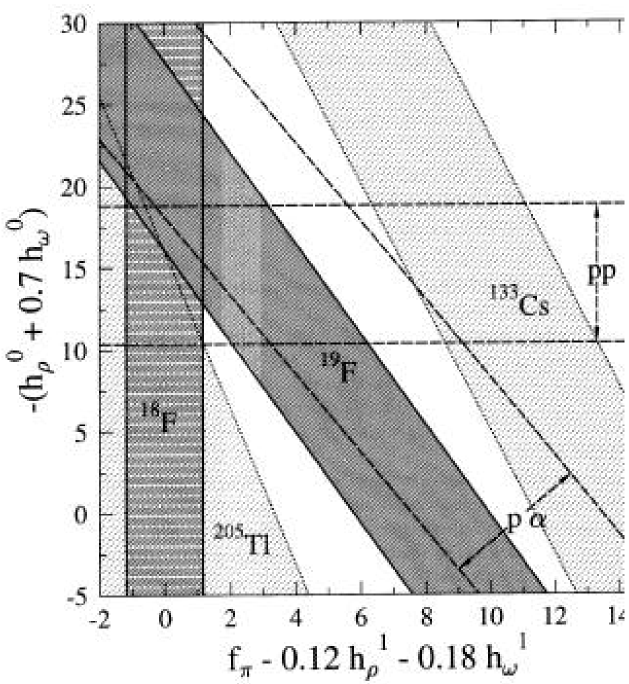


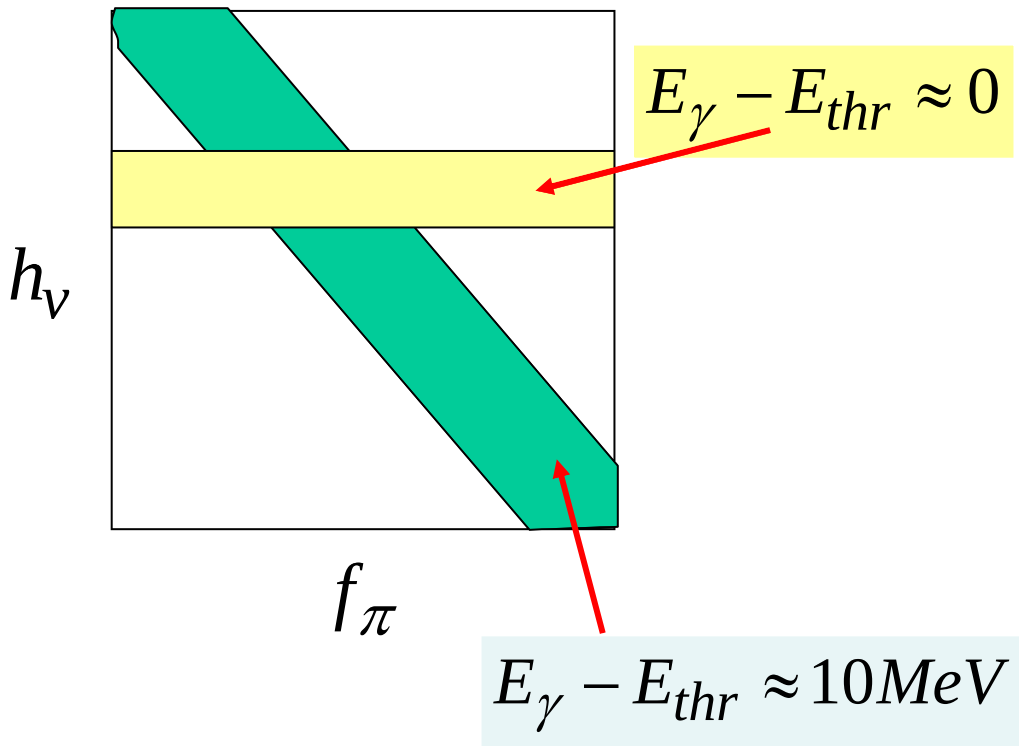
PNC transitions in np-system



一つの実験で全ての強弱結合定数の決定➔混迷からの脱出

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



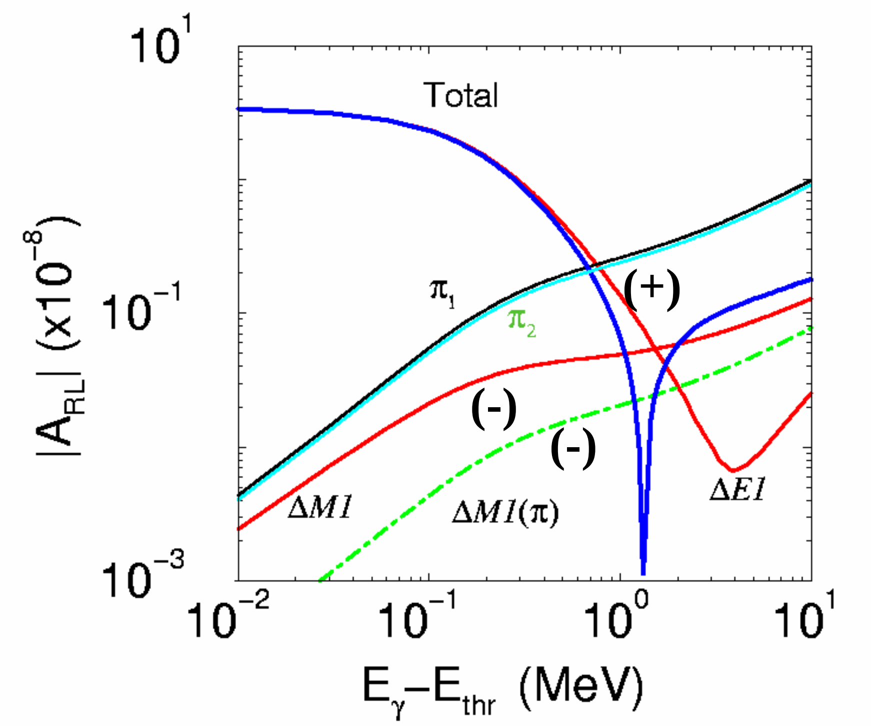


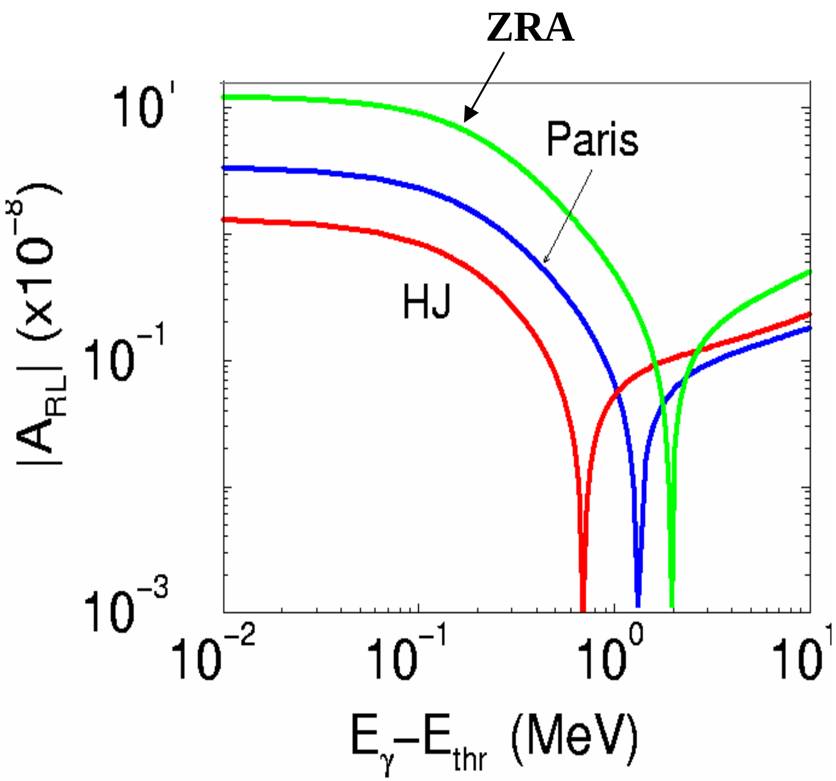
核子ー核子間、短距離力に極めて重要な情報

PNC asymmetry:polarized beam and unpolarized target

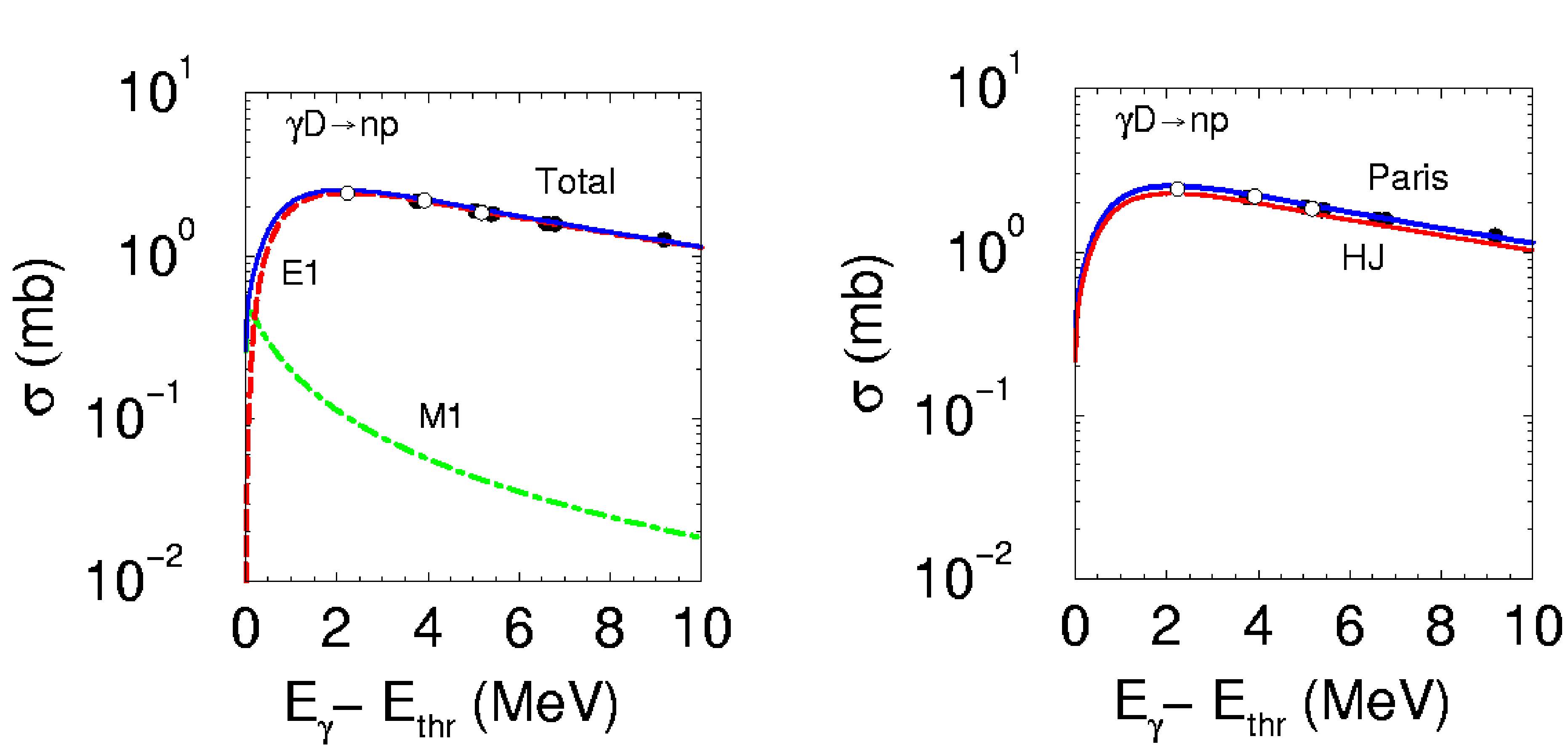
$$A_{RL}^{PNC}(E_\gamma) = 2\frac{M1 \otimes \Delta E1_V + E1 \otimes \Delta M1_V + E1 \otimes \Delta M1_\pi}{M1^2 + E1^2}$$

$$|\Delta M1(\pi)| = |\pi_1 + \pi_2| << |\pi_{1.2}|$$





Total cross section of deuteron photo-disintegration



M. Fujiwara and A.I. Titov, PRC submitted October 2003.