核モーメントによる不安定核の構造研究

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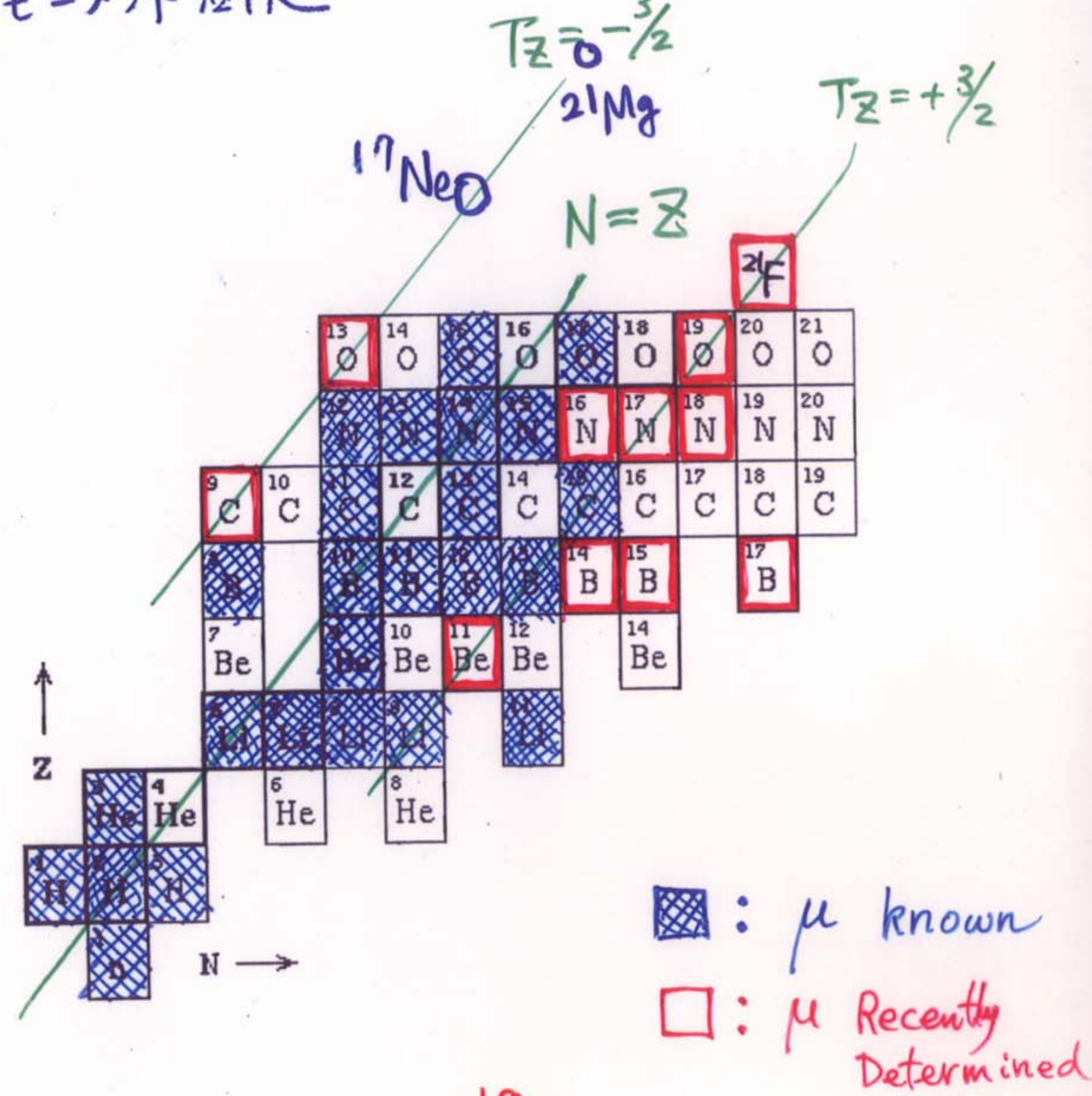
for 阪大－理研－放医研－LBL Collaboration

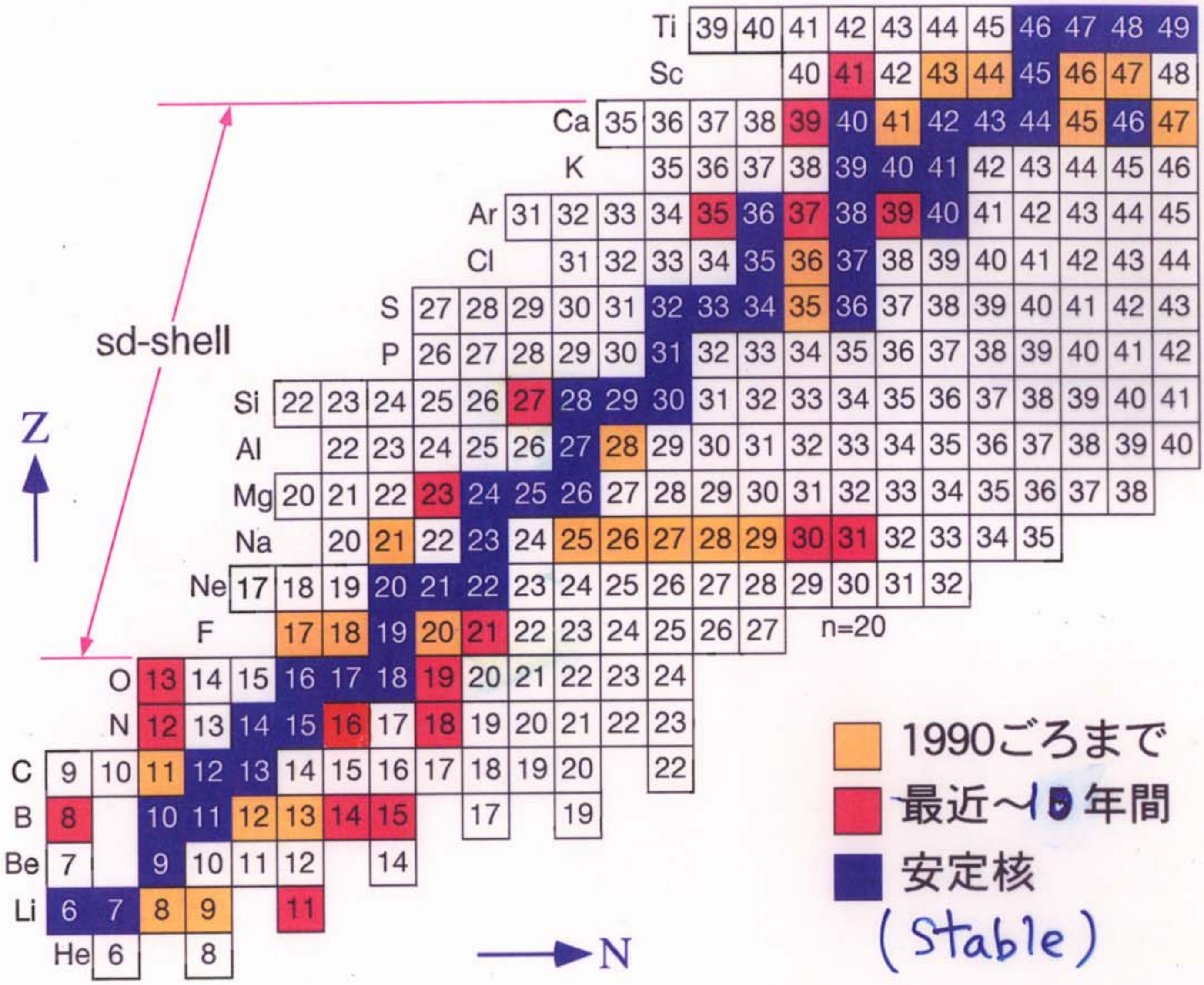
- 軽核のモーメント測定の現状
- 偏極不安定核の成生法
- 鏡映核磁気モーメント
  ^{9}C, ^{13}O の $\langle\sigma\rangle$
- sd シェル核の Q モーメント
  ^{27}Si の異常 Q
  有効電荷の減少 (^{16}N 他)
- $f_{7/2}$ シェル核の現状
- 精密β線角分布他

最近の軽核の
磁気モーメント測定



日本 = $\frac{10}{11}$

Qモーメントが測られた核



Nuclei with known Q moment

理研 3+3
HIMAC 2
バンデ ~~4~~5

日本 $\frac{\cancel{12}\,13}{\cancel{18}\,19}$

CERN ISOLDE $\frac{6}{\cancel{18}\,19}$

Low E. Direct Reaction $^{11}B(d,p)^{12}B$

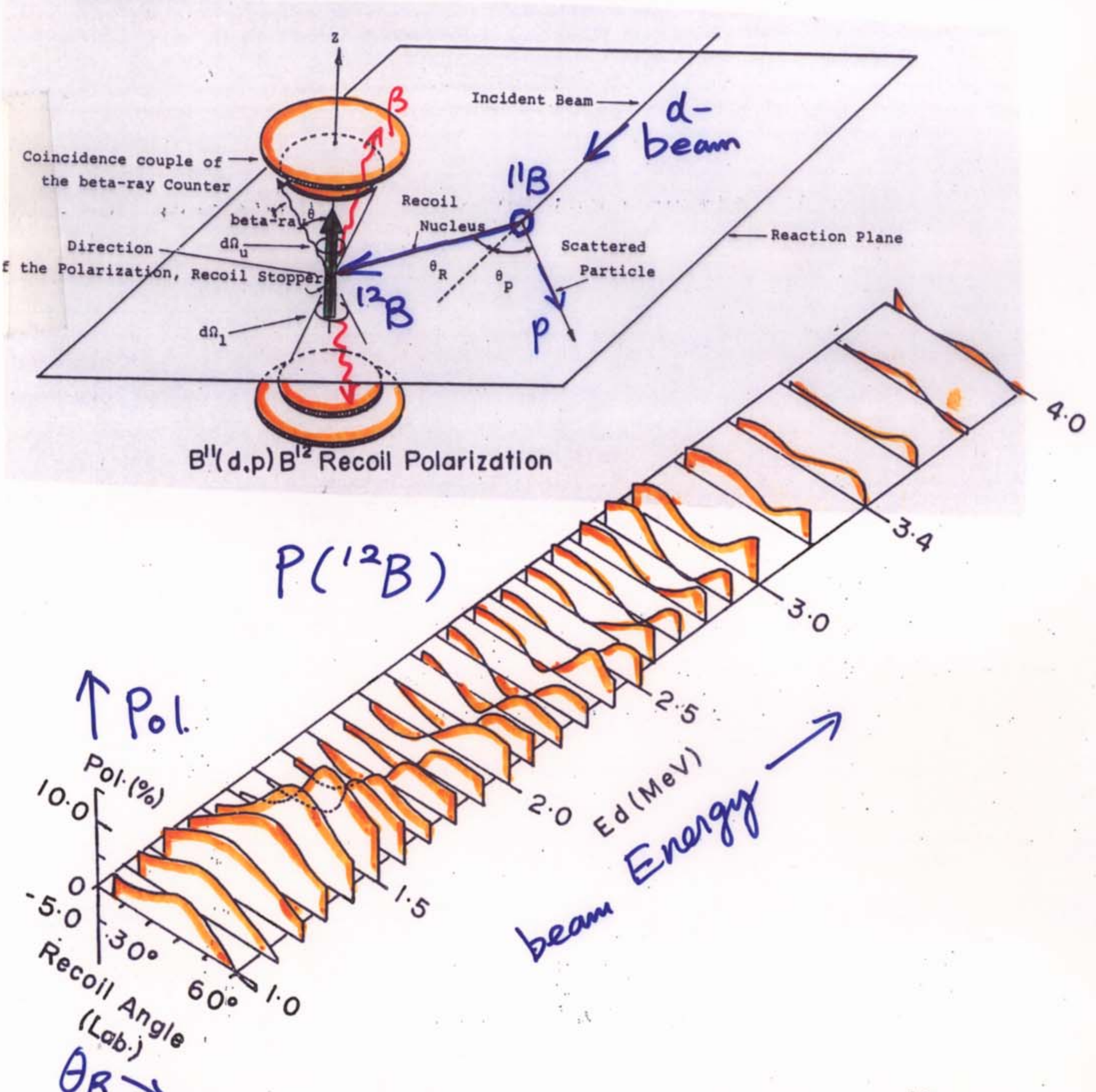
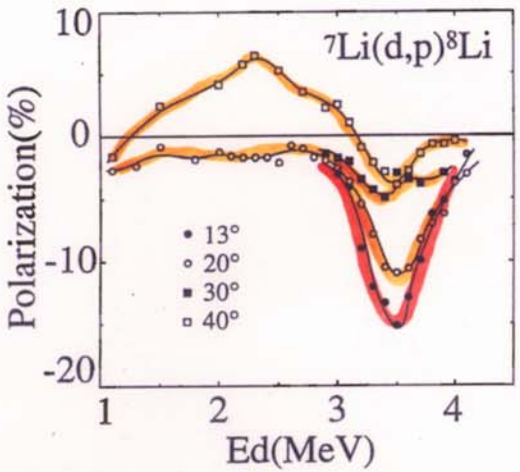


Fig. 8-4 Stereographical view of observed polarization of ^{12}B.

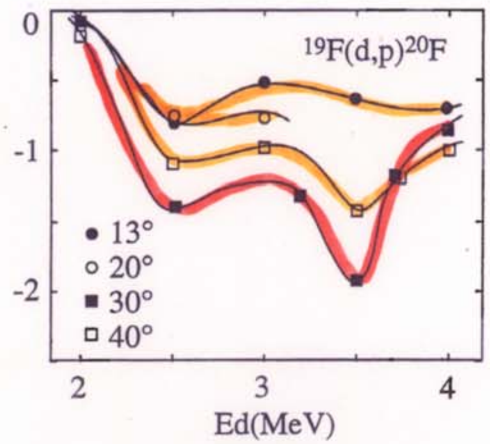
from: PhD thesis Prof. Masayoshi Tanaka

低エネルギー直接反応で生成される核偏極

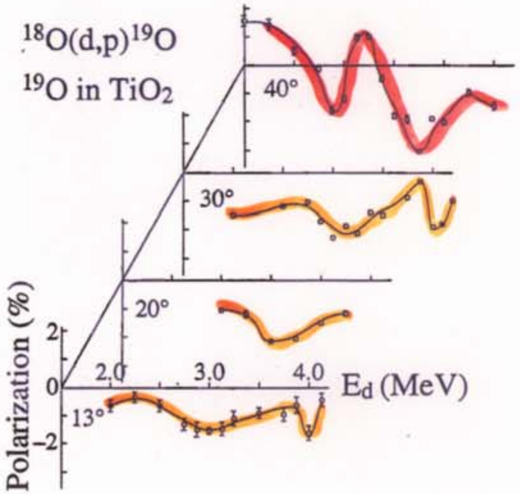
^{8}Li



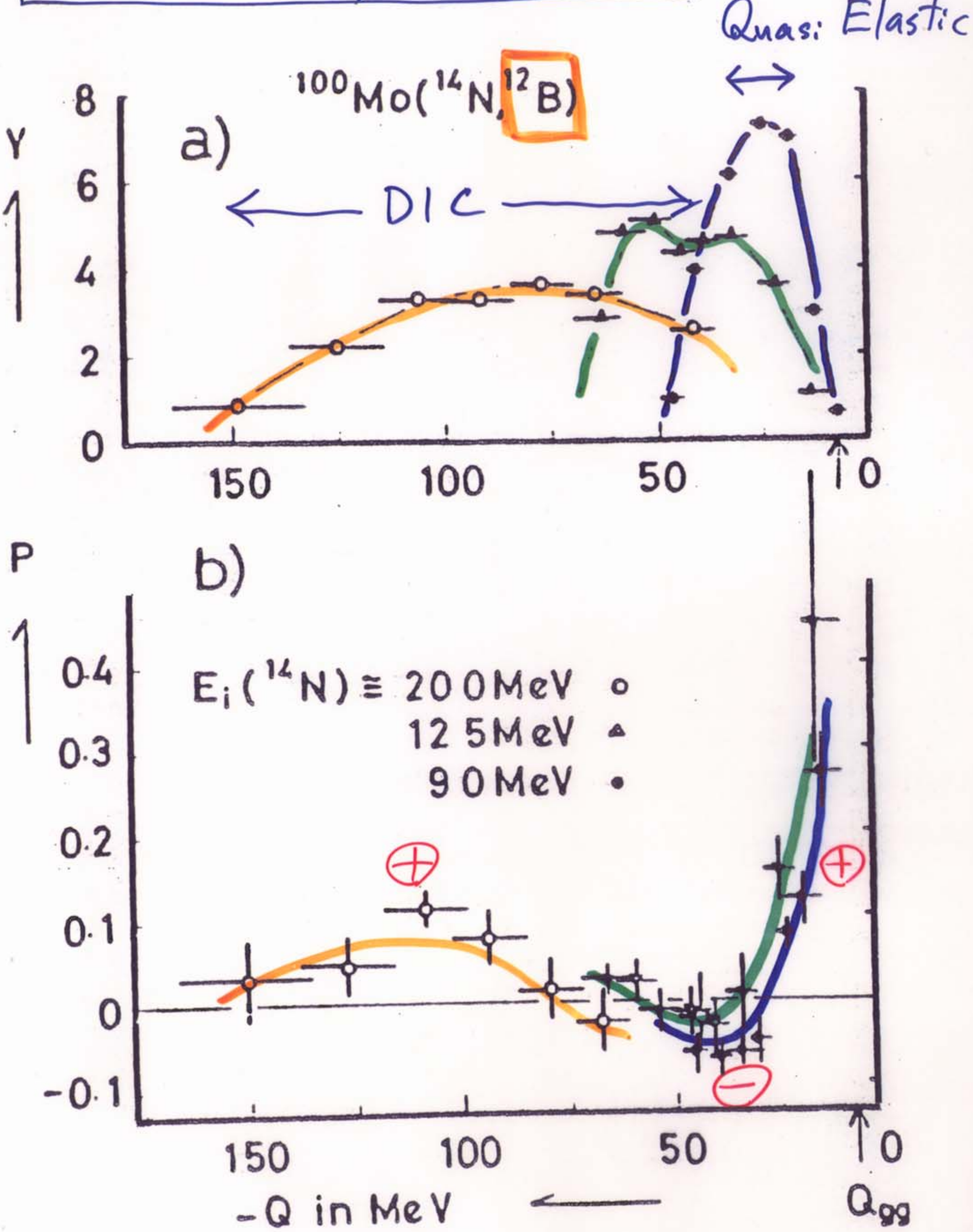
^{20}F



^{19}O



Low E. Heavy Ion Reaction



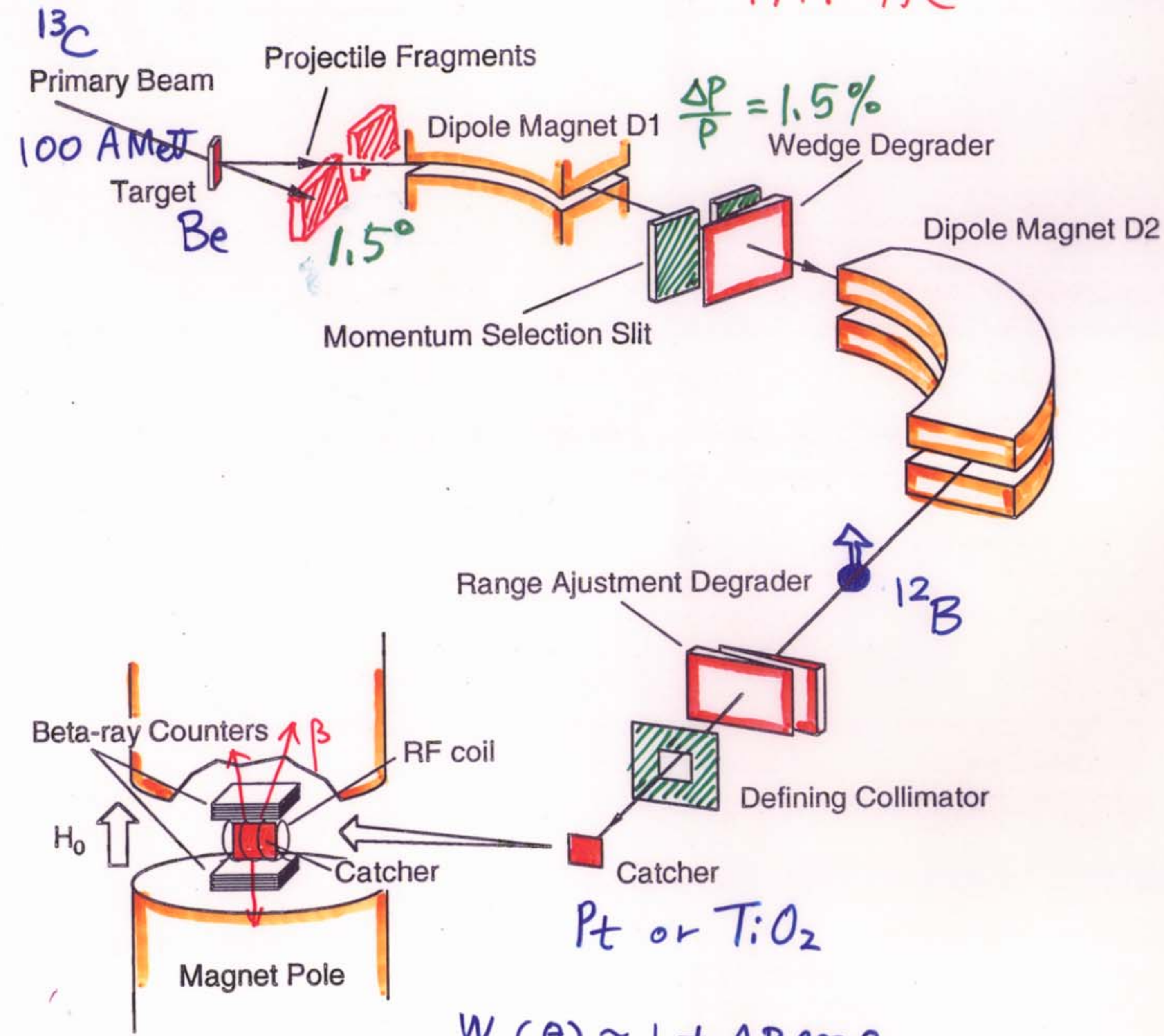
Experimental

(^{13}N) (^{13}B)

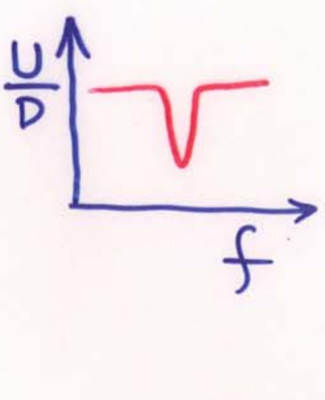
$^{13}C + Be \to {}^{12}B + X$

@ 100 MeV/A

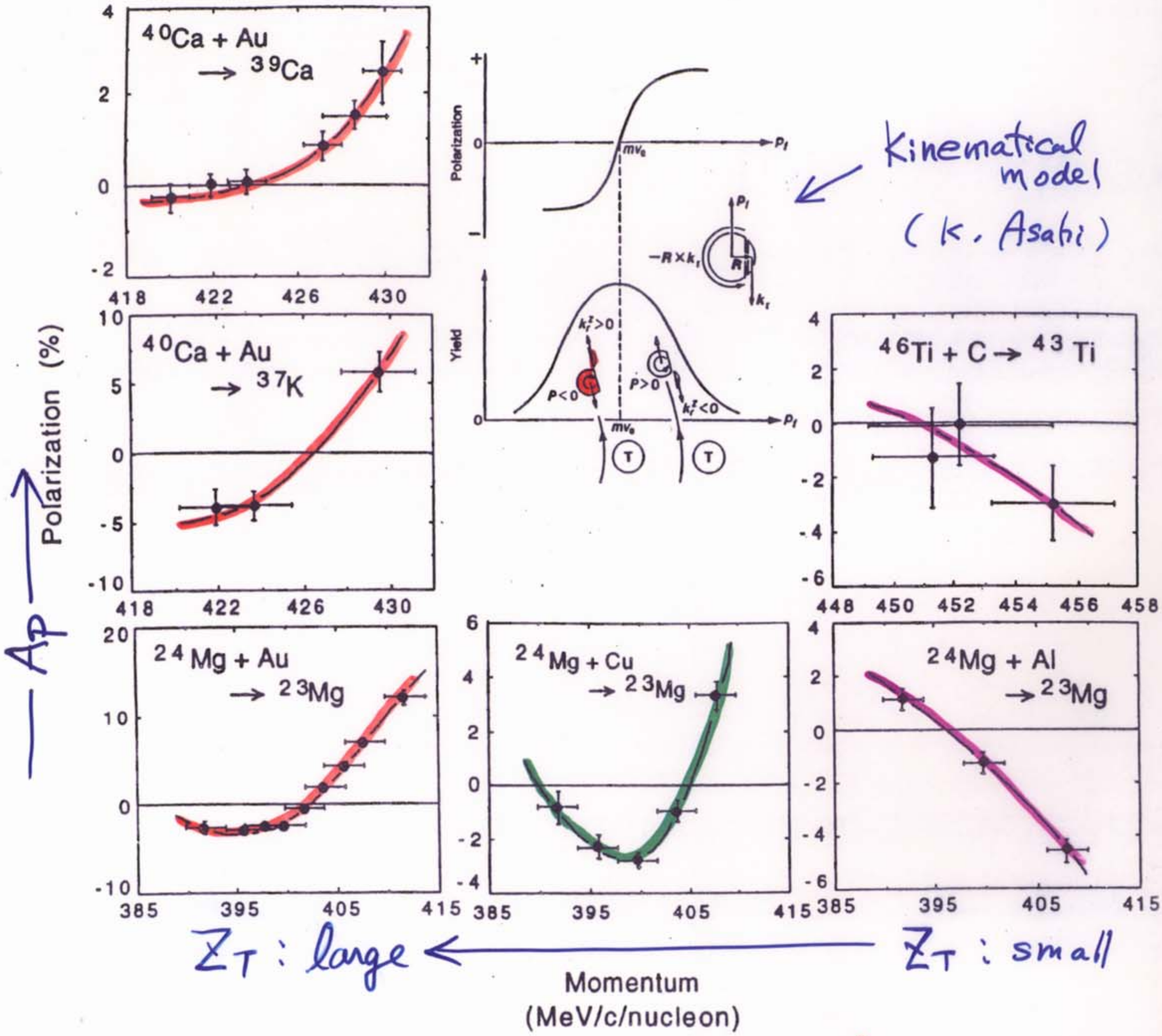
HIMAC

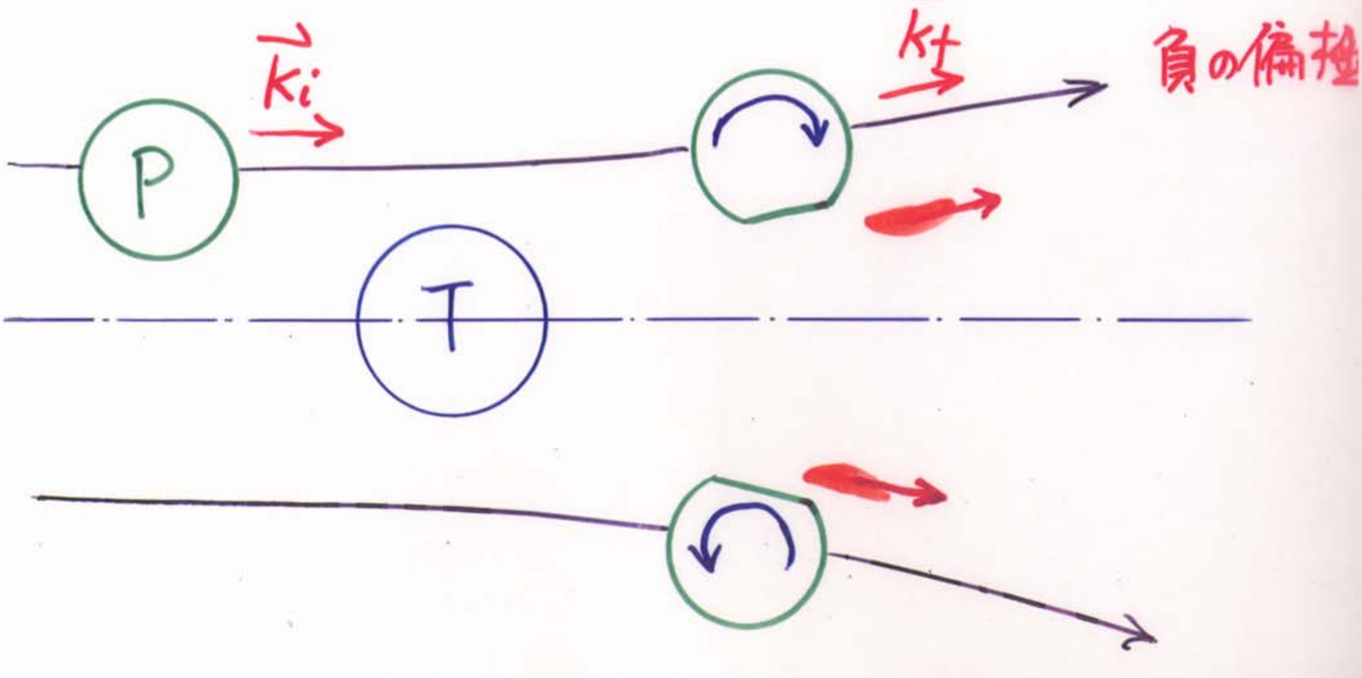


$$W(\theta) \simeq 1 + AP\cos\theta$$

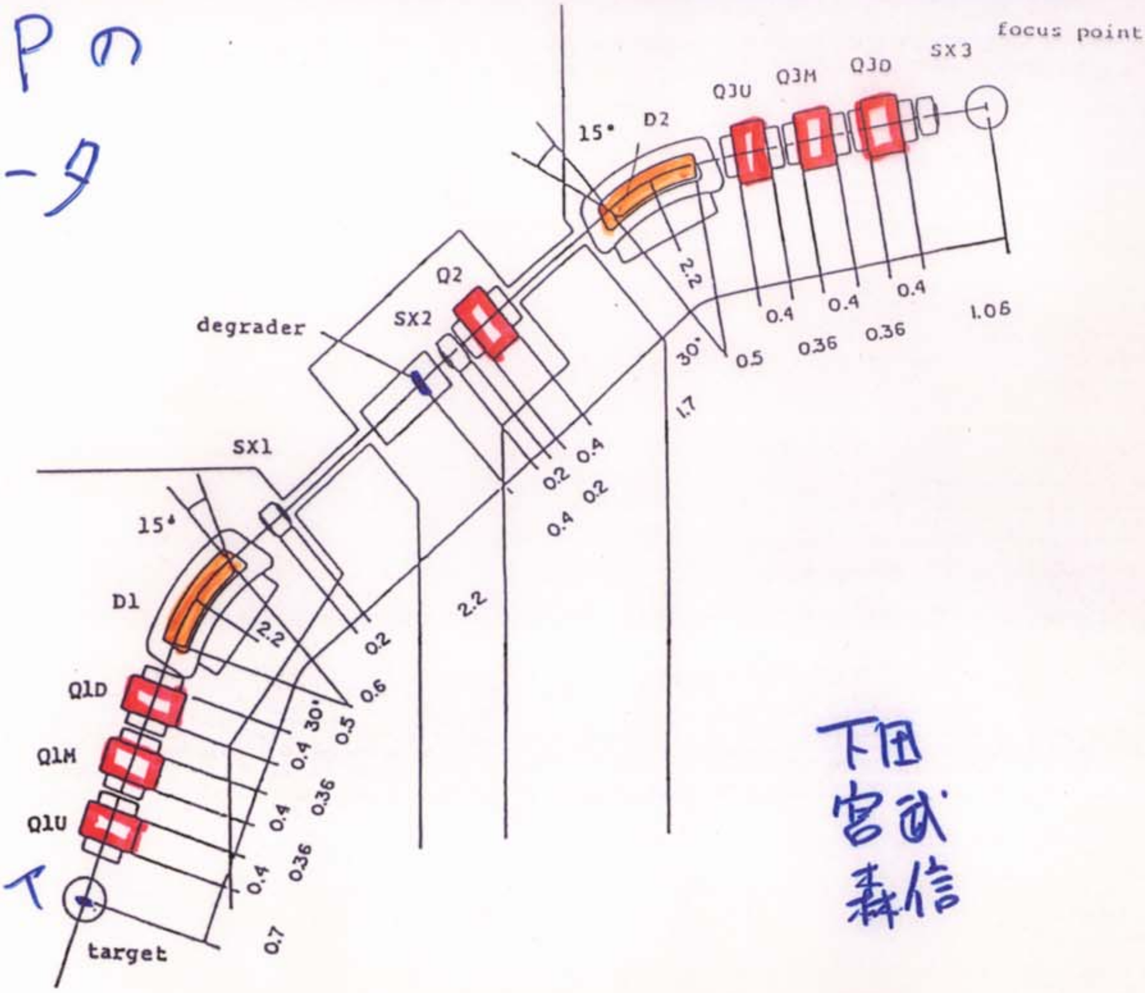


Momentum dependence of Polarization





RCNPの
セパレータ



下田
宮武
森信

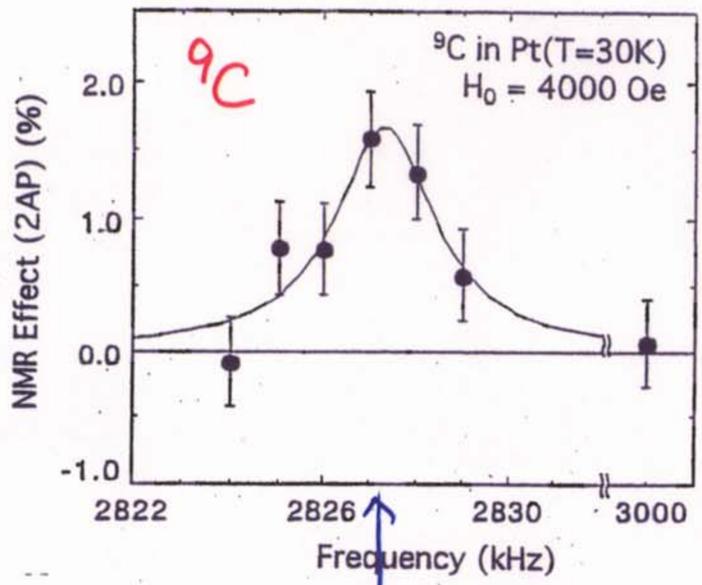
Specifications of the RCNP secondary-beam line

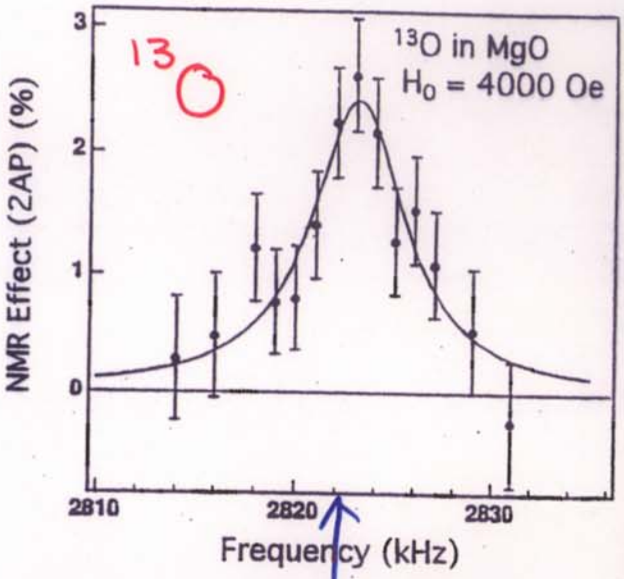
Configuration	QQQDSX(F1) SXQDQQQSX(F2)
Maximum magnetic rigidity	3.2 T m
Energy acceptance	$\Delta E/E = \pm 8\%$
Angular acceptance	$\Delta\theta = \pm 20$ mrad
	$\Delta\phi = \pm 14$ mrad
Energy dispersion at F1	0.866 m
Tilted angle of F1 focal line	90°
Energy degrader	uniformly thick
Tilted angle of F2 focal line	86.6°
x magnification	2.0 (variable)
y magnification	1.4 (variable)
A dispersion	6.51 mm/% ($d_0/R = 0.5$, variable)
Z dispersion	−3.91 mm/% ($d_0/R = 0.5$, variable)
$A/\Delta A$ ($x_0 = \pm 0.5$ mm)	326 ($d_0/R = 0.5$, without energy straggling)
$Z/\Delta Z$ ($x_0 = \pm 0.5$ mm)	195 ($d_0/R = 0.5$, without energy straggling)
Path length of the central orbit	14.774 m

c.f. ±40mrad
RIPS
$\Delta\theta \sim \pm 10$mrad

^{9}C, ^{13}O の μ

@ RIKEN





$\nu_L = 2827.3$ kHz

↓

Diamagnetic
$+2.7 \times 10^{-4}$
Knight Shift
$|K| < 2.5 \times 10^{-4}$

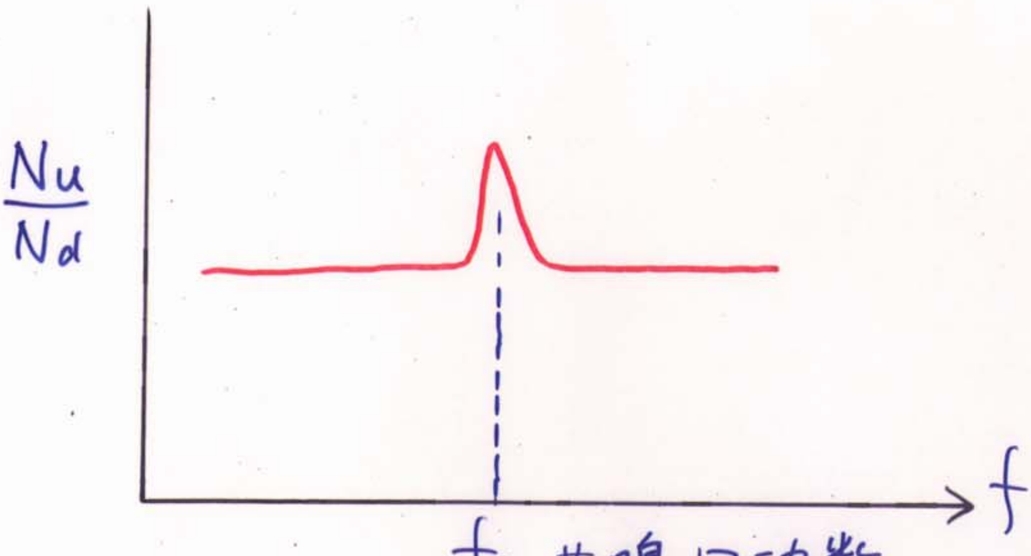
$\nu_L = 2823.2$ kHz

↓

Chemical shift
287 (15) ppm

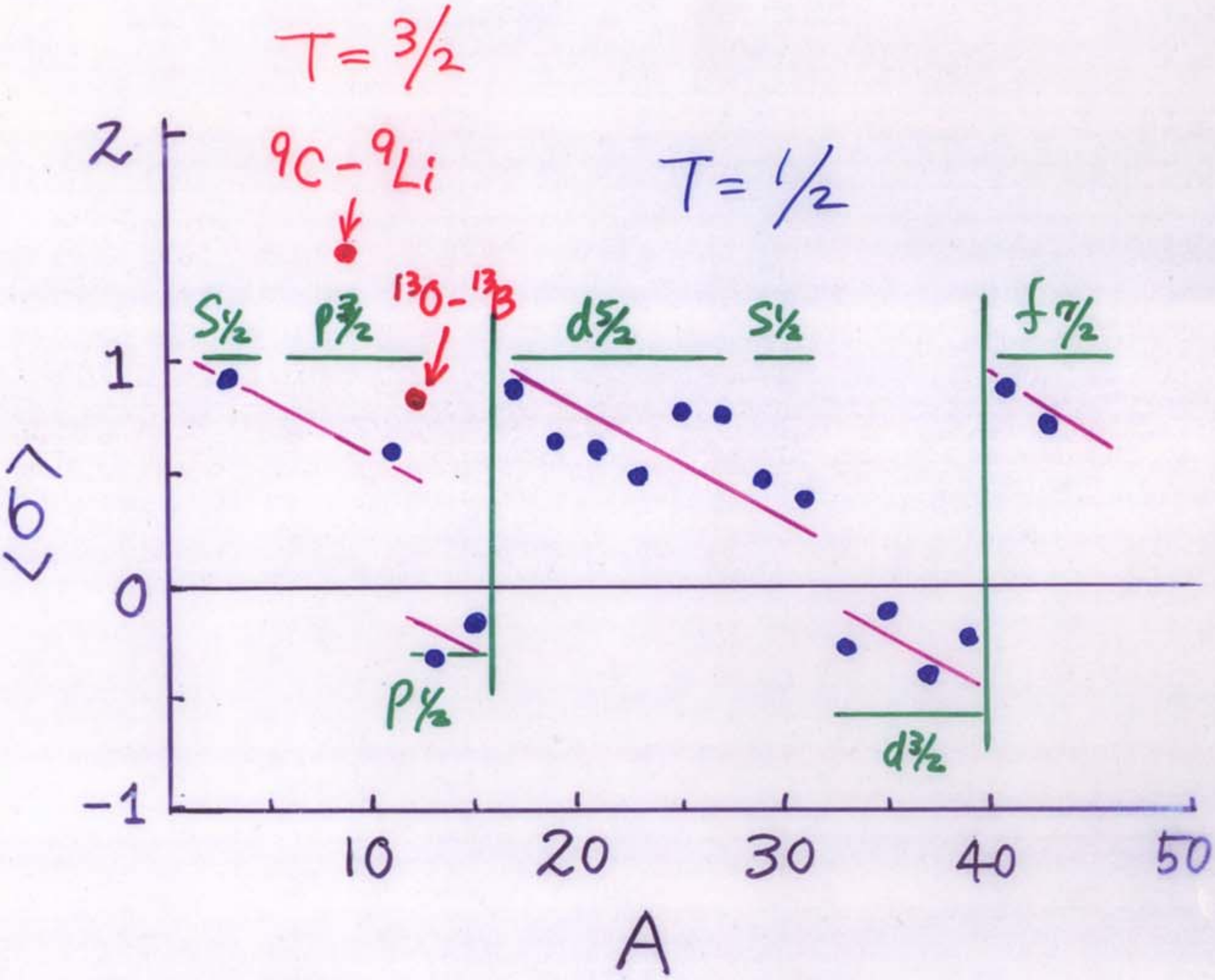
↓

$\mu(^{9}C) = (-)\,1.3914(5)\,\mu_N$, $\mu(^{13}O) = (-)\,1.3891(5)\,\mu_N$



f_0 共鳴周波数

$\langle\sigma\rangle$: Spin expectation values



$\langle\sigma\rangle = 2\mathcal{S}$

$$\langle\sigma\rangle = \frac{\mu(^9C) + \mu(^9Li) - J}{0.38}$$

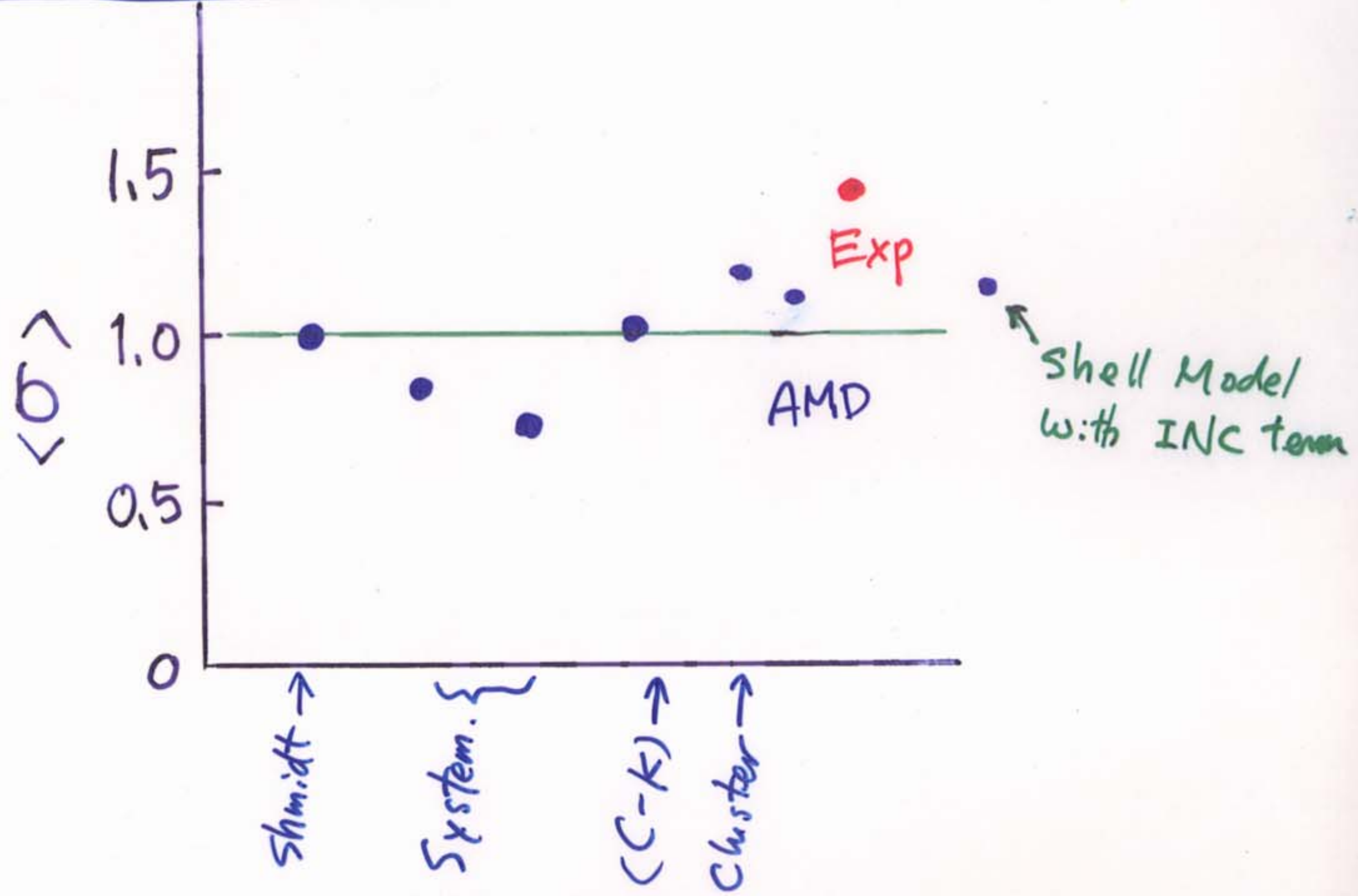
$$= 1.44 \quad > 1$$

^9C

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

$\ell = 1$

スピン期待値



Isoscalar Moment

$$\mu({}^9Li) + \mu({}^9C) = g_\ell^s \langle \ell \rangle + \mu_N^s \langle \sigma \rangle$$

$$J = \langle \ell \rangle + \frac{1}{2}\langle \sigma \rangle$$

$$g_\ell^s = 1, \quad g_N^s = \mu_p + \mu_N$$

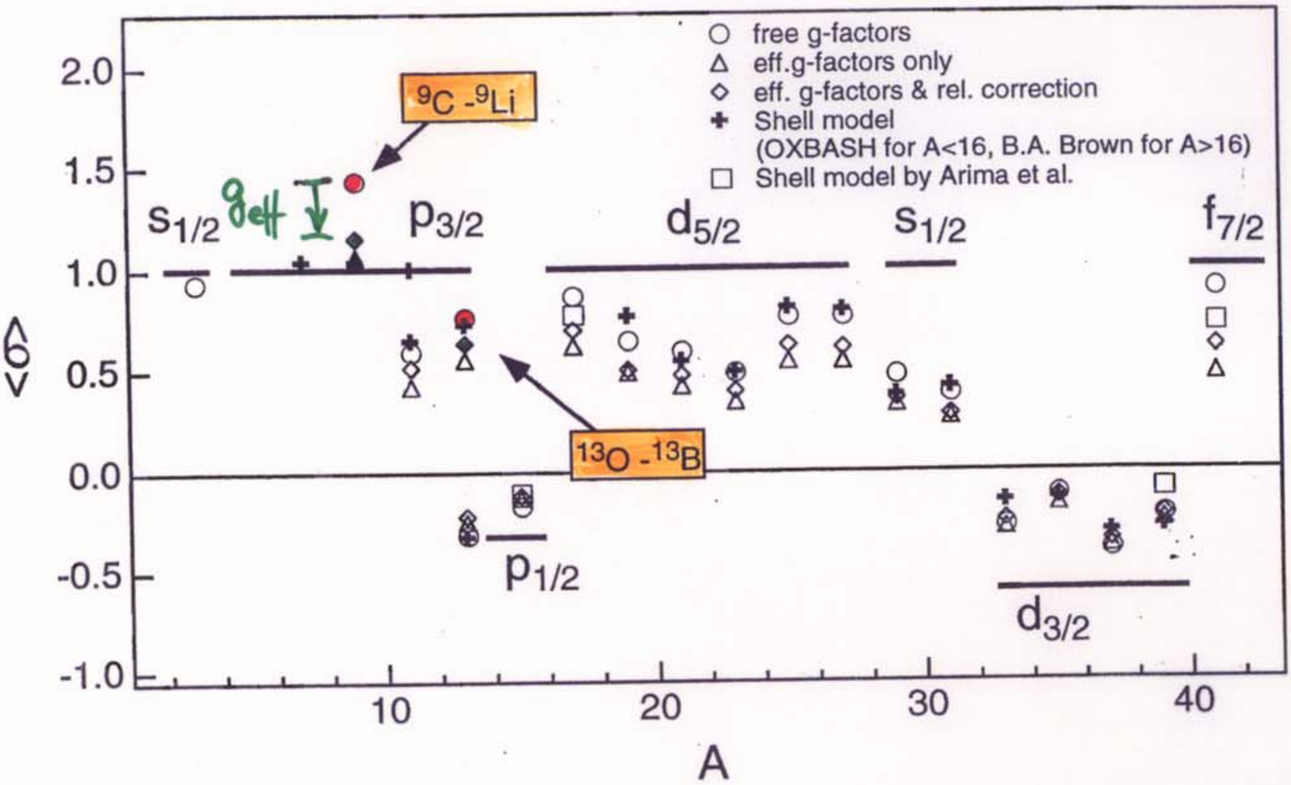
$$\therefore \quad = J + \underbrace{\left(\mu_p + \mu_n - \frac{1}{2}\right)}_{= 0.380} \langle \sigma \rangle$$

$\mu({}^9C) = (-)1.3914$

$\mu({}^9Li) = 3.4391 \longrightarrow$

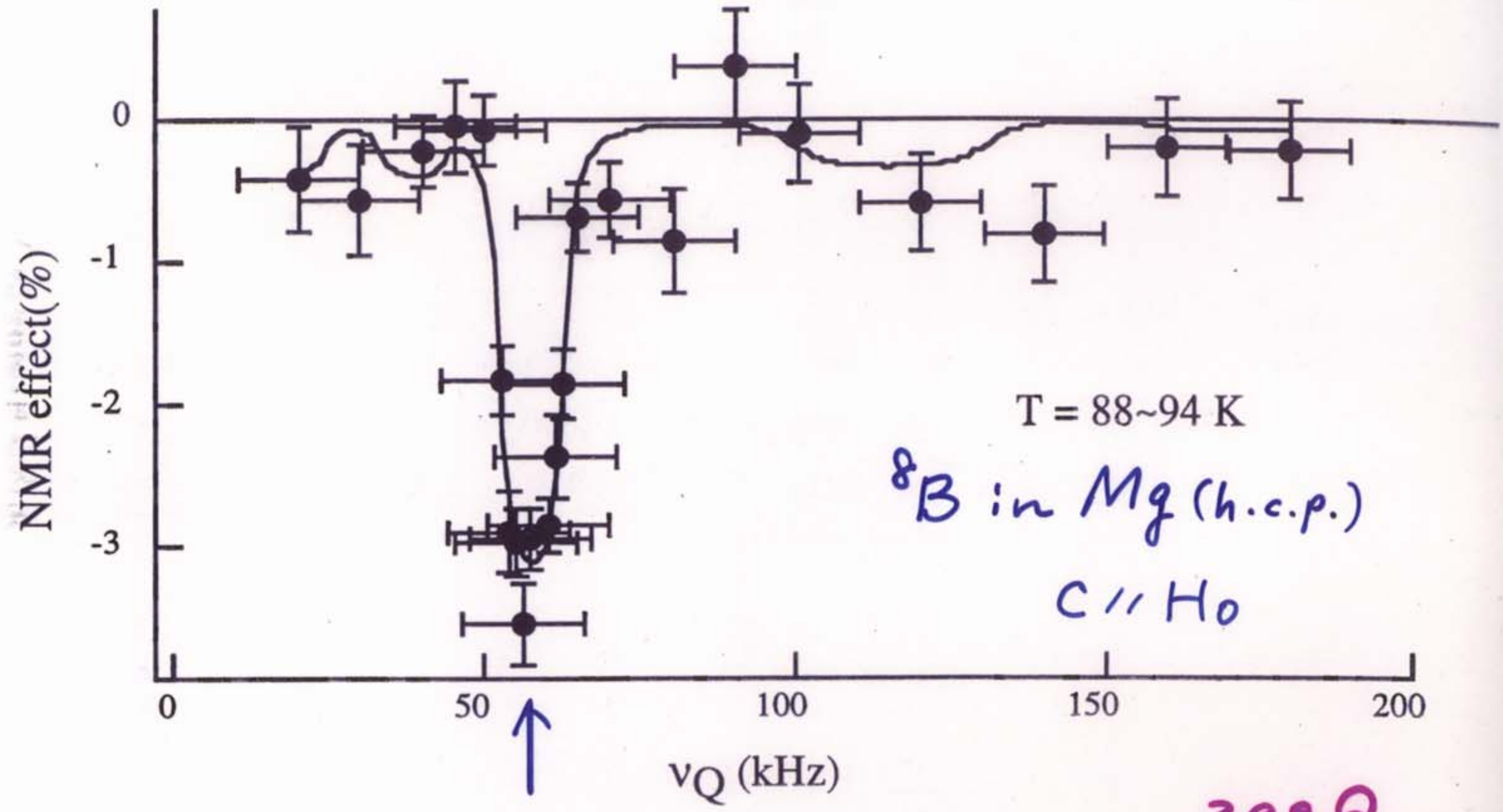
$$\langle \sigma \rangle_{exp} = 1.44$$

g_{eff} 導入


free g-factors
eff.g-factors only
eff. g-factors & rel. correction
Shell model
(OXBASH for A<16, B.A. Brown for A>16)
Shell model by Arima et al.
^{9}C - ^{9}Li
^{13}O - ^{13}B
g_{eff}
$s_{1/2}$
$p_{3/2}$
$d_{5/2}$
$s_{1/2}$
$f_{7/2}$
$p_{1/2}$
$d_{3/2}$
$\langle\sigma\rangle$
A

Q モーメント (^{8}B)

阪大バンデ



$$\nu_Q = 57.5(2)\ \mathrm{kHz} \quad \equiv \frac{3eqQ}{2I(2I-1)h}$$

$$\left|\frac{eqQ}{h}(^8\mathrm{B\ in\ Mg})\right| = 229.9\,(2.6)\ \mathrm{kHz}$$

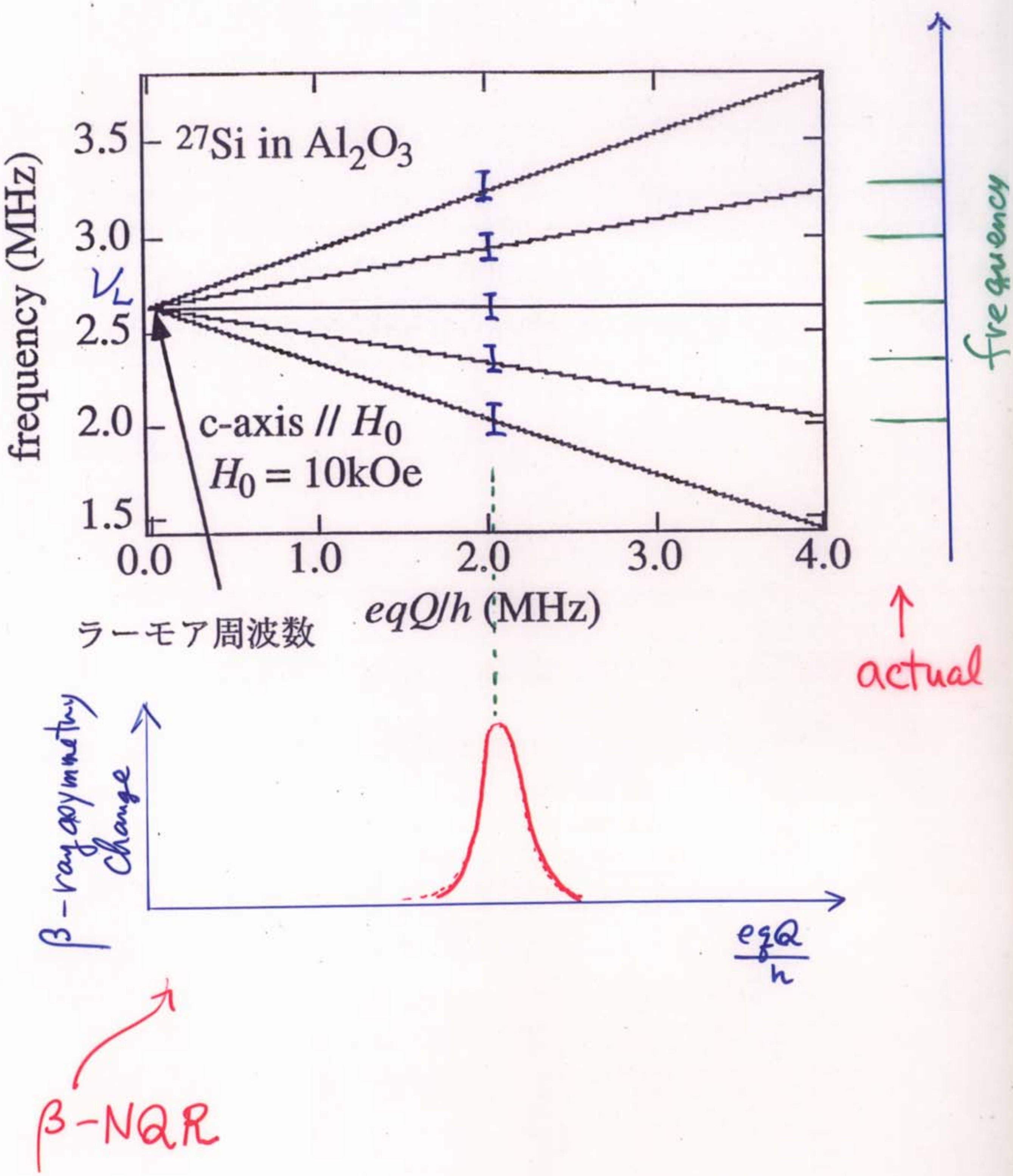
$$\downarrow \quad \frac{eqQ}{h}(^{12}\mathrm{B\ in\ Mg}) = 47.0(1)\ \mathrm{kHz}$$

$$\left|\frac{Q(^8\mathrm{B})}{Q(^{12}\mathrm{B})}\right| = 4.89\,(6)$$

$$\downarrow \quad Q(^{12}\mathrm{B}) = 13.20\,(25)\ \mathrm{mb}$$

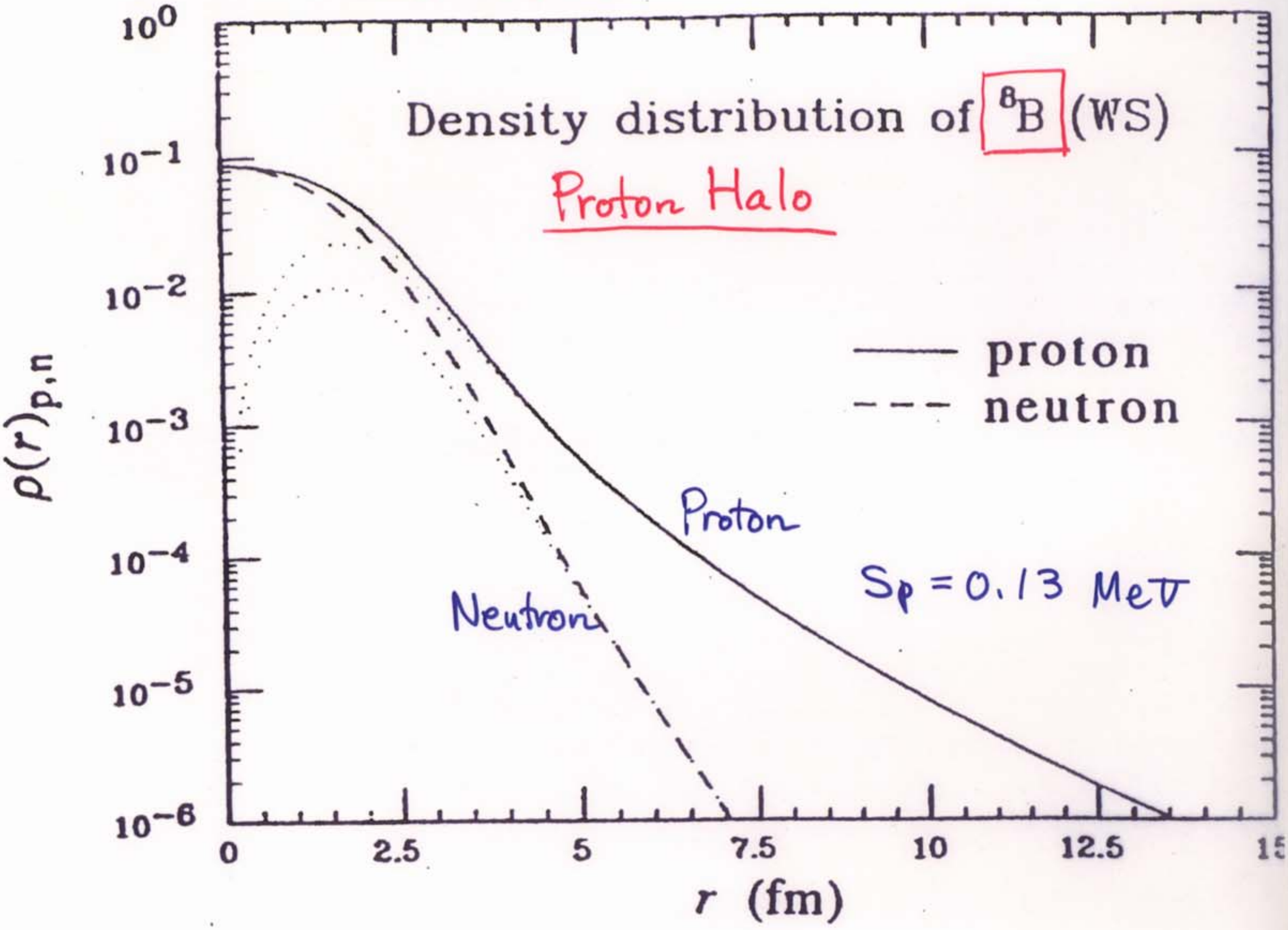
$$|Q(^8\mathrm{B})| = 64.6\,(1.5)\ \mathrm{mb}$$

eqQ splitting of the resonance frequency



$Q(^8B)$: 68 mb 1992

$\propto \langle r^2 \rangle^{1/2}$



β-NQR Spectrum ^{13}O in TiO_2

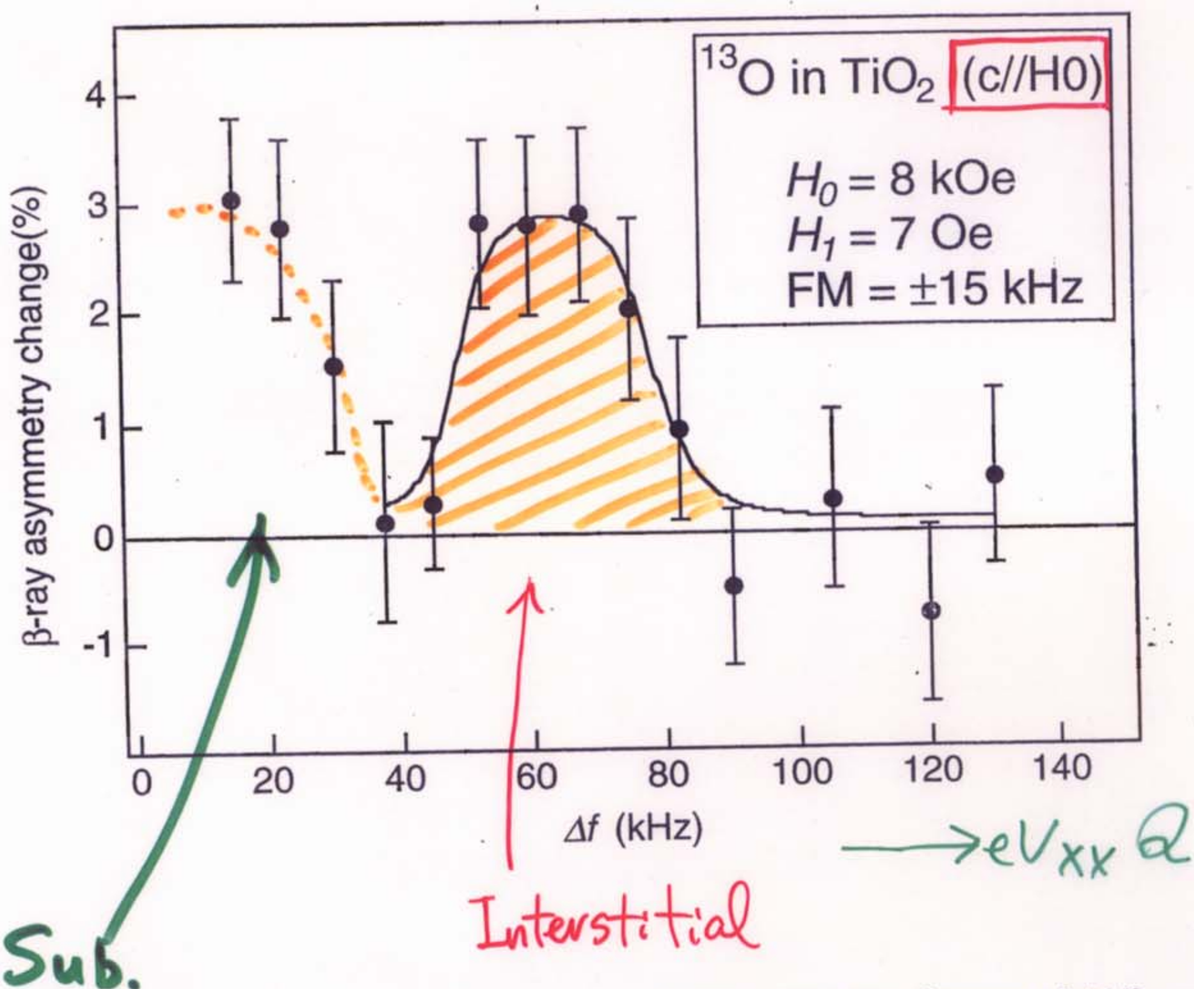


Fig. 5-15. Typical NNQR spectrum of TiO_2. Δf is the distance of $\pm 1/2 \leftrightarrow \pm 3/2$ transition frequency from $-1/2 \leftrightarrow +1/2$ transition.

$$\left(\frac{1-\eta}{2}\right)\left(\frac{eqQ}{h}\right)$$

$q^{(2)} = 390(40) \times 10^{19}\ V/m^2$

$\eta^{(2)} = 0.760(9)$

$\rightarrow |Q(^{13}O)| = 11.0 \pm 1.3$ mb

	I^{π}	Exp. present $\lvert Q \rvert$ (mb)	Theory HO (No halo)	Theory HF (with halo)
^{13}O	$3/2^-$	11.0 ± 1.3	15.7	9.0
^{19}O	$5/2^+$	3.7 ± 0.4	−3.5	−6.0

$Q(^{13}O)$ proton halo effect, $S_p = 1.5$ MeV

$Q(^{19}O)$ no neutron halo, $S_n = 4.0$ MeV

sd シェル鏡映核の Q

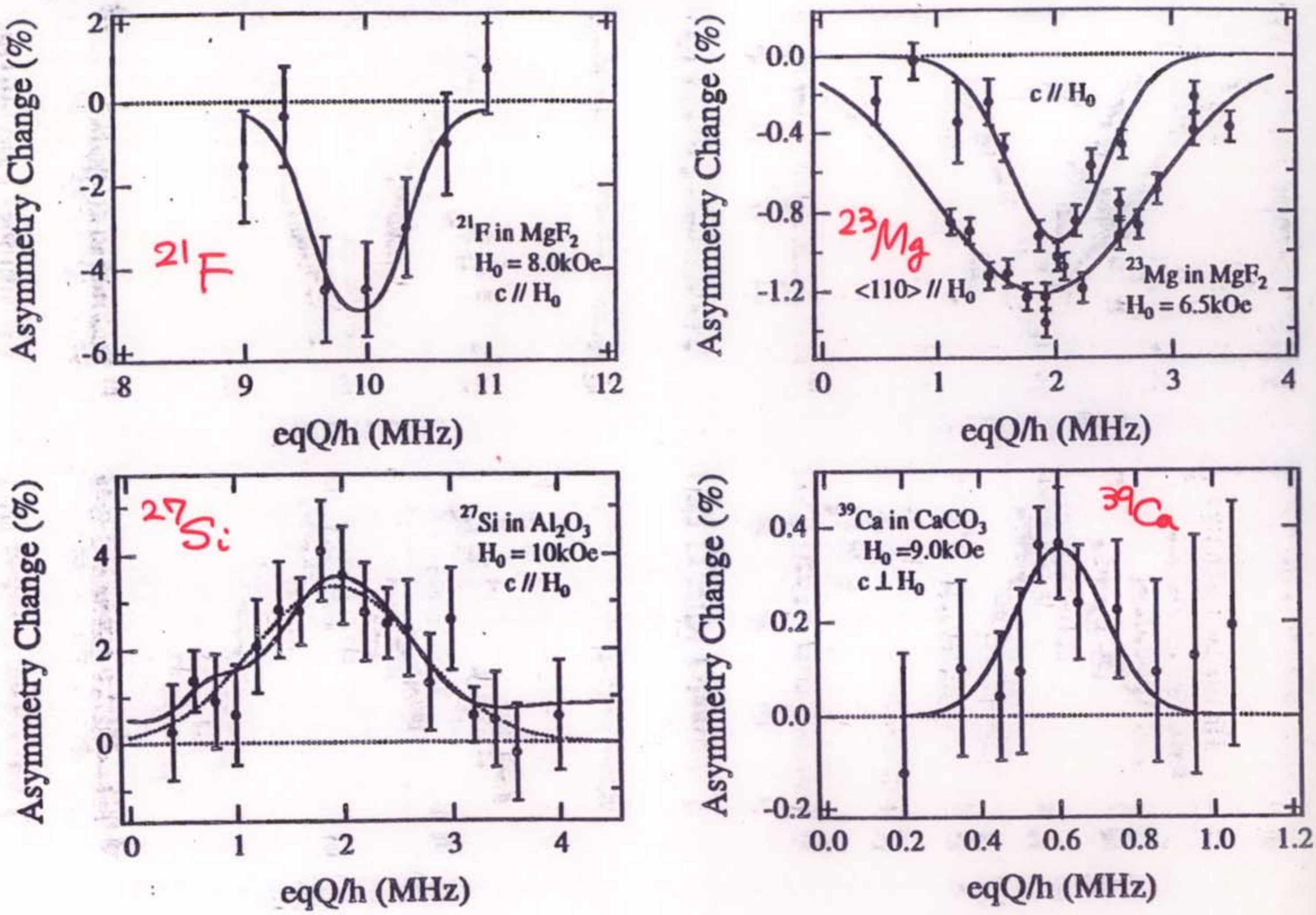


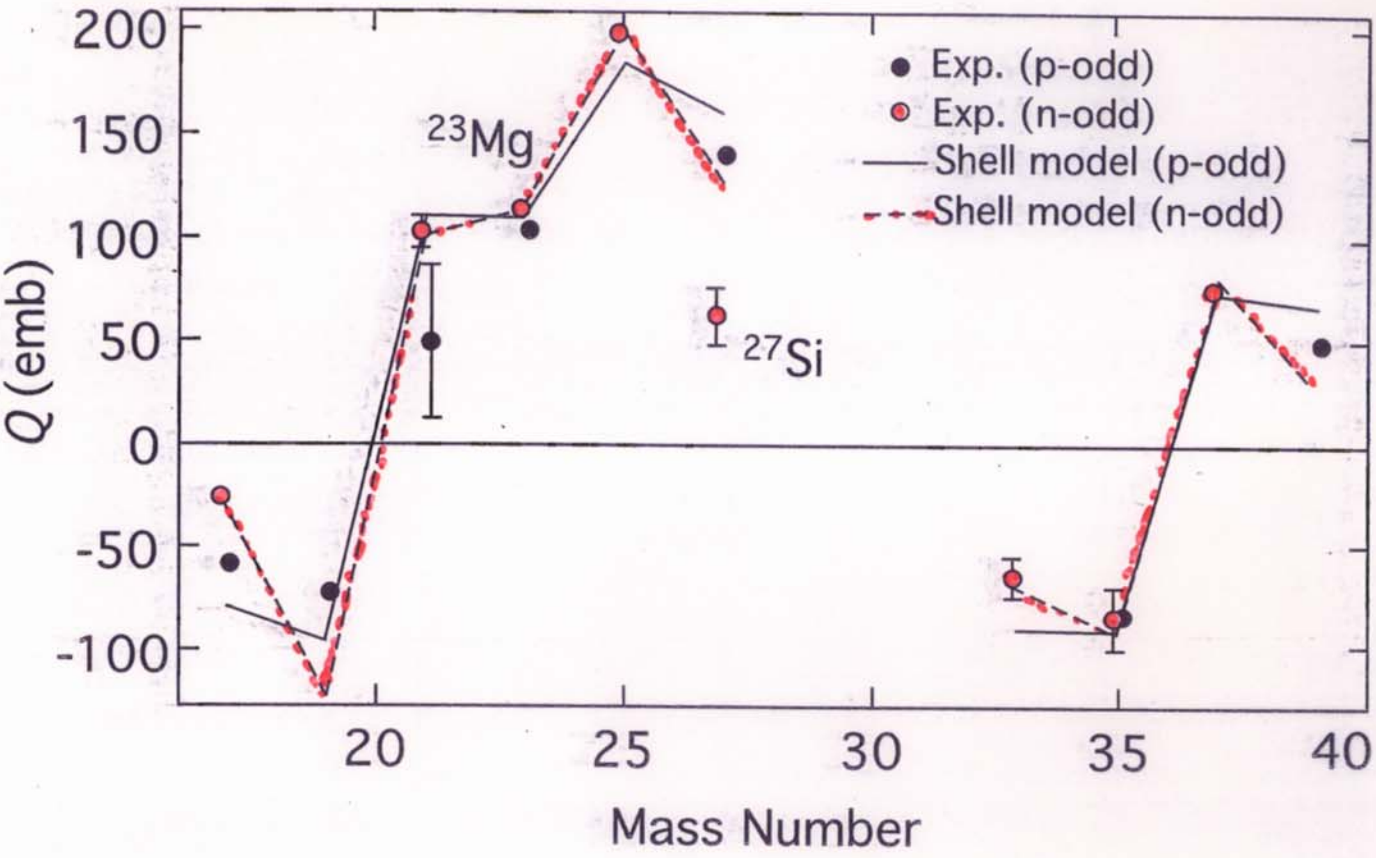
Figure 2. β-NQR spectra for ^{21}F, ^{23}Mg, ^{27}Si and ^{39}Ca.

$T=3/2$ ← | → $T=1/2$

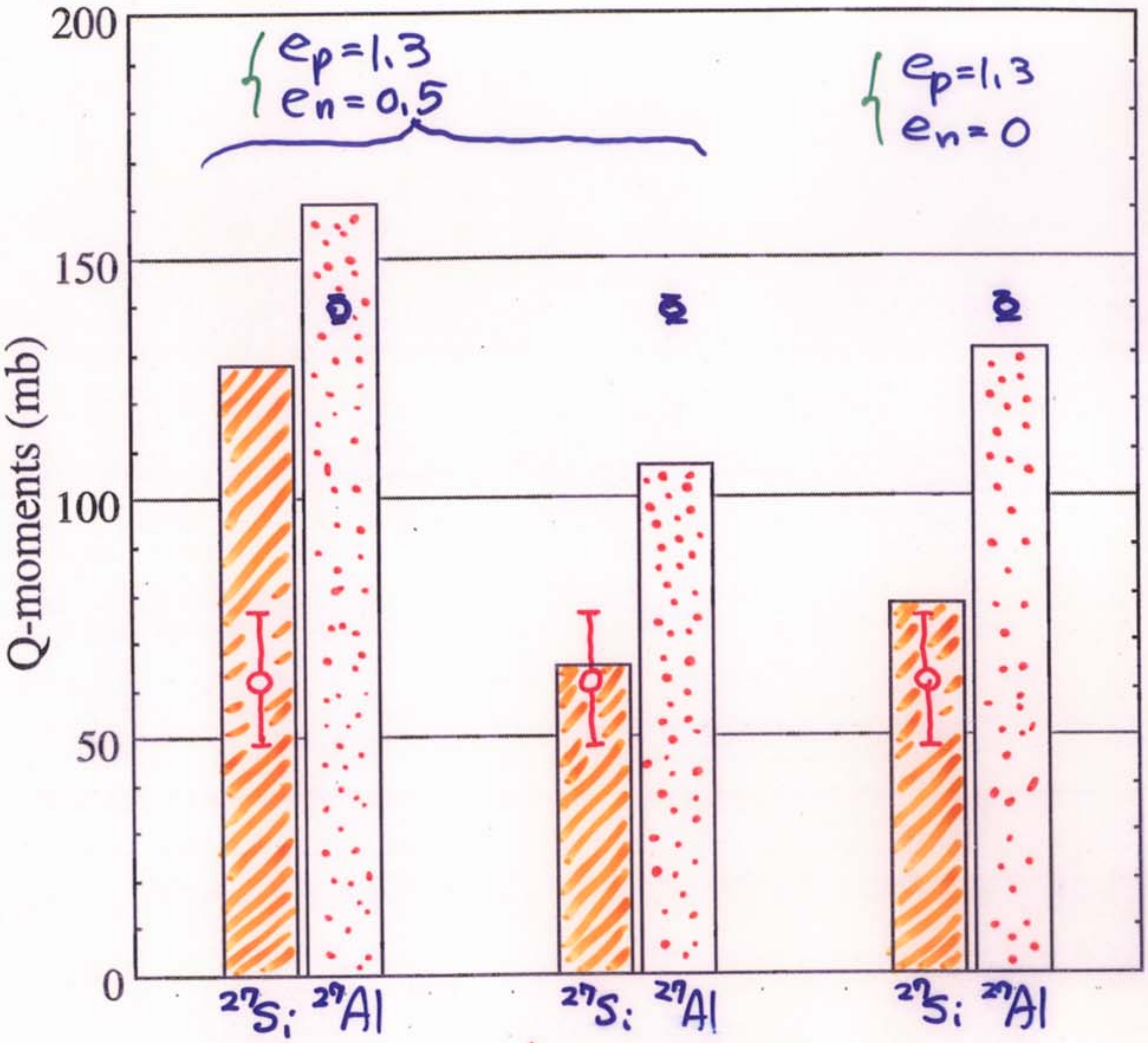
	^{21}F	^{23}Mg	^{27}Si	^{39}Ca
$\lvert eqQ/h \rvert$ (MHz)	9.94(9)	1.96(6)	1.96(4)	0.68(2)
q (10^{15} V/cm^2)	370	70	130(26)*	70(10)*
$\lvert Q \rvert$ (mb)	110(22)	114(3)	63(14)	40(6)
OXBASH	−110	114	128	26

* KKR calc.

T=1/2 鏡映核の Qモーメント



^{27}Si $-$ ^{27}Al ペアの Q



OXBASH

$\left\{ \begin{array}{l} \tilde{Q}_0 = 101 \\ \tilde{Q}_e = 60 \end{array} \right.$

$d_{3/2}$への励起なし

$\left\{ \begin{array}{l} \tilde{Q}_0 = 75 \\ \tilde{Q}_e = 22 \end{array} \right.$

$\Downarrow$

$\left\{ \begin{array}{l} \tilde{Q}_0 = 105(7) \\ \tilde{Q}_e = 8(12) \end{array} \right.$

でパーフェクト

$\tilde{Q}_0, \tilde{Q}_e$

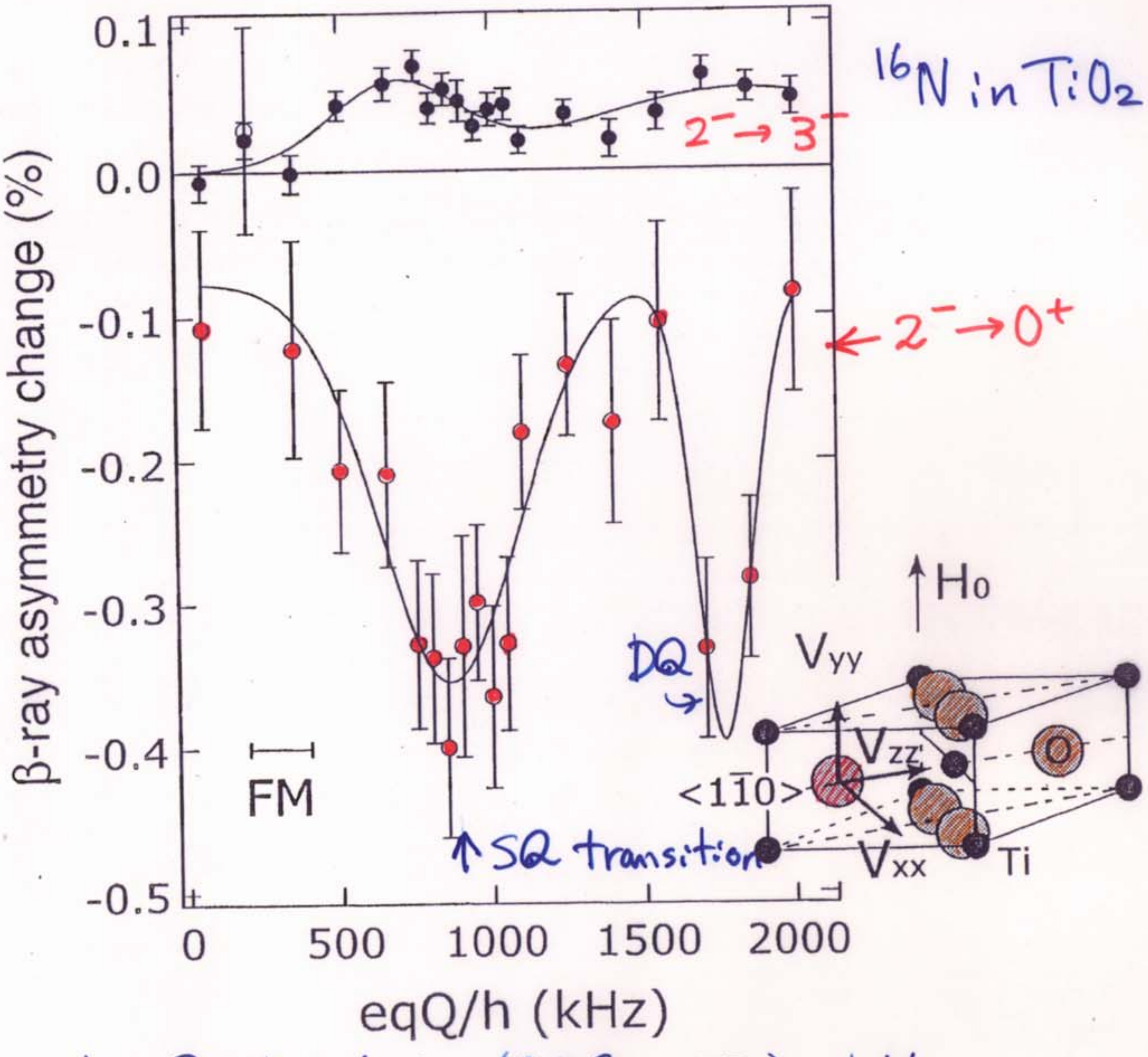
$\Downarrow$

$\left\{ \begin{array}{l} e_p = 1.6(1) \\ e_n = -0.3(2) \end{array} \right.$

でパーフェクト

- Shape Asymmetry の可能性有り

β-NQR



$|eqQ(^{16}N)/h| = (859 \pm 17)$ kHz

cf. $|eqQ(^{12}N)/h| = (469 \pm 5)$ kHz

$|Q(^{12}N)| = (9.8 \pm 0.9)$ mb

↓

$|Q(^{16}N)| = (17.9 \pm 1.7)$ mb

^{16}N	exp	Shell model H.O.	Shell model HF halo
μ (μ_N)	(±) 1.9859 (11)	−2.148	−2.084
Q (mb)	(±) 17.9 (1.7)	−31.5	−27.3

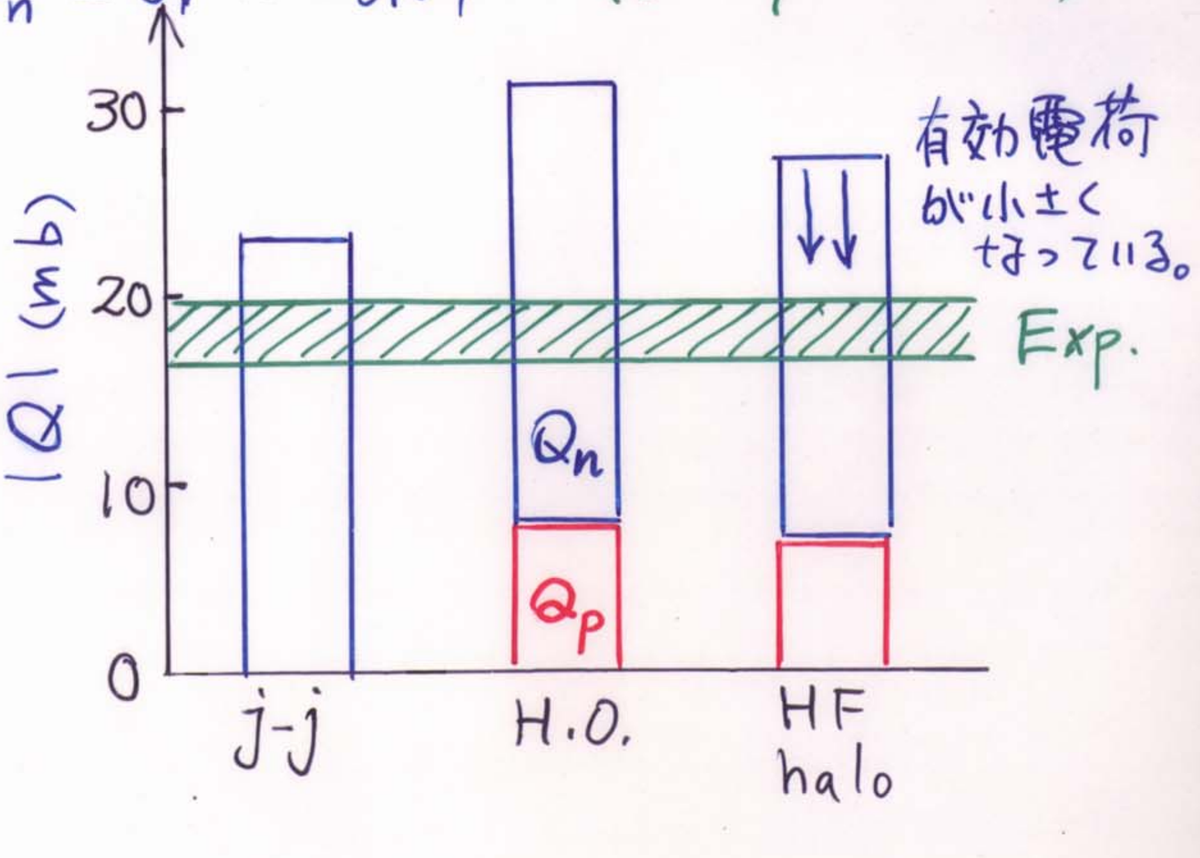
$e_p^{eff} = 1.48$ $\quad e_p^{eff} = 1.32$

$e_n^{eff} = 0.48$ $\quad e_n^{eff} = 0.34$

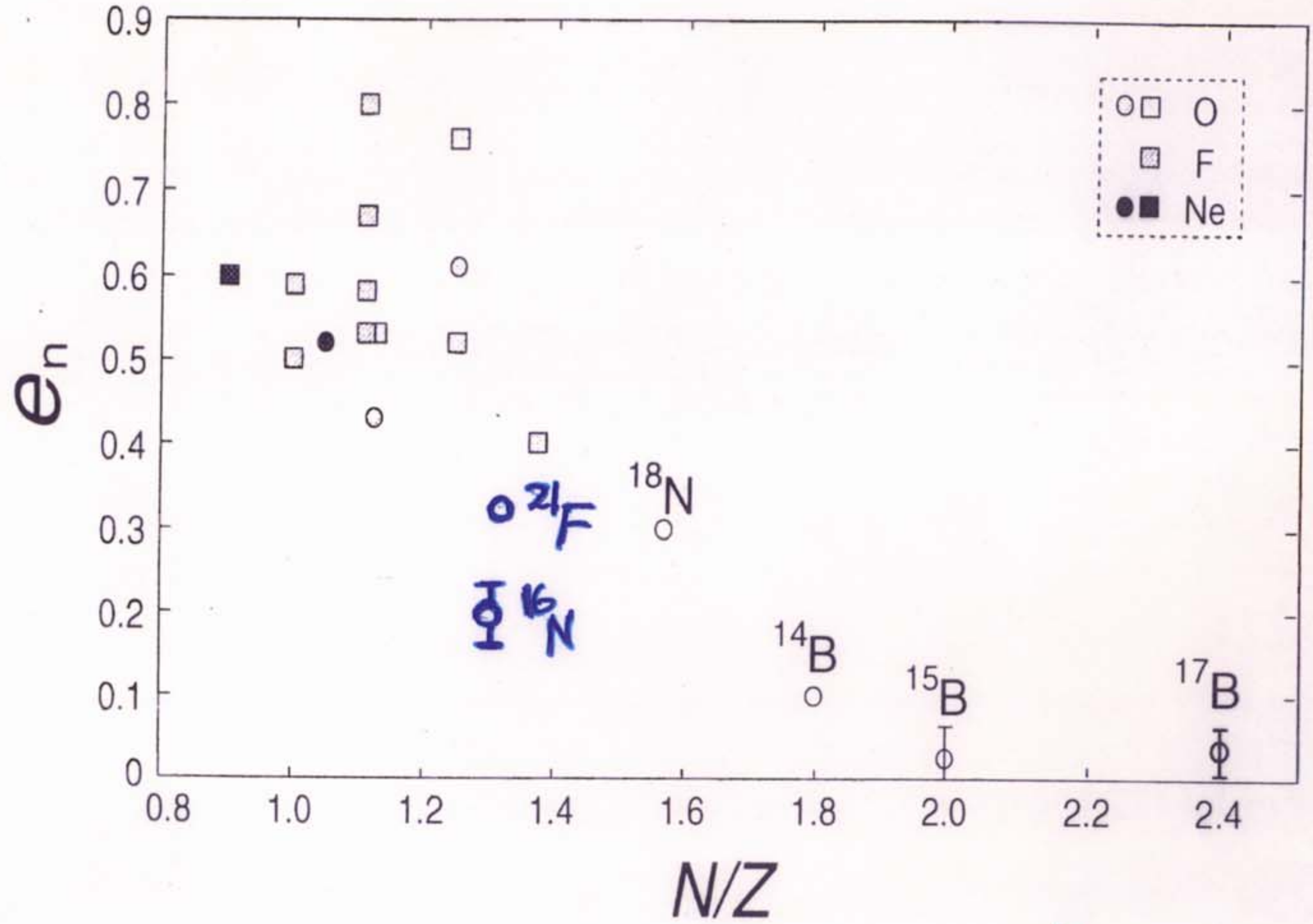
$$Q = \underbrace{-5.1\, e_p^{eff}}_{Q_p} \underbrace{- 60.4\, e_n^{eff}}_{Q_n}$$

insensitive

$e_n^{eff} = 0.20 \pm 0.04$ (for $e_p^{eff} = 1 \sim 1.3$)



中性子有効電荷の減少



旭プロット

Overlap Integral