

超微細相互作用と β -NM(Q)Rで進めた研究：
高精度核電磁気モーメントによる核構造と
弱核子流の荷電空間パリティ保存限界

於 研究会；The Playing Field of Physics 30年史
—杉本先生と開いた新しい道—

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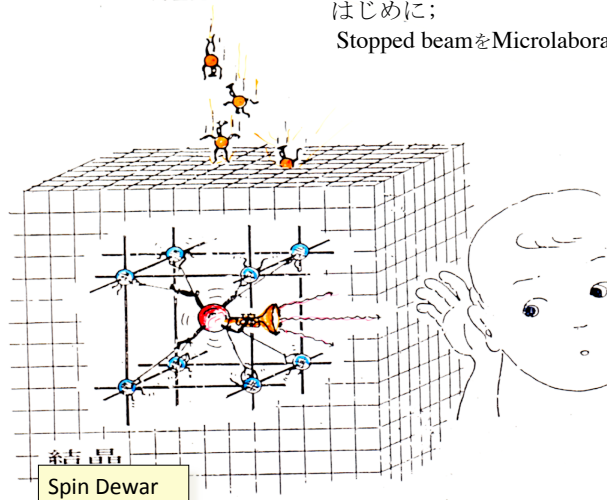
はじめに

- 核磁気モーメントと二重閉殻 ± 1 核子核の殻構造
実験に考察必要；植込み位置、 δg_I 、 m^* 、 ^{90}C の $\langle \sigma \rangle$ 異常、
- 1次元結晶内電場勾配理論と核四重極モーメント —二重閉核 ± 1 核子核の Q —
終わっていない；閉殻 ± 1 核子核 Q と e^{eff} 、 $Q(^8\text{B})$ と陽子ハロー
- 弱核子流SCCの存在限界と核内核子質量再規格化
整列核- β 線角度相関係数；SCC、Strong CVC.
- 反応断面積と核子密度分布

福田光順

同位元素ビーム

はじめに；
Stopped beamをMicrolaboratoryとして



格子中短寿命核の役割

局在量子構造：

粒界、空孔、不純物の電子構造

放射線損傷

短寿命核のトラップ

Spin Dewar

Picture by A. Kitagawa, NIRS

はじめに Microlaboratoryの手続

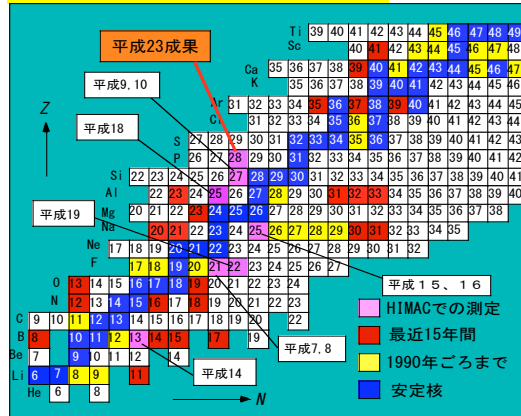
➤ 不安定核製造法格段に発展: 第一段階

High Disp. Beam-Line, BEVALAC, G. Krebs et al., *LBL-22143*, 1987. Y. Nojiri et al., *HFI* **35** (1987) 1019.

RIPS, T. Kubo et al., *Nuclear Instrument and Methods for Physics Research* **B70** (1992) 309.

HIMAC 分離器, M. Kanazawa et al., *Nucl. Phys. A* **701** (2002) 244c.

軽核領域のQモーメント測定の現状



はじめに Microlaboratoryを可能にした

➤ 偏極(核スピ)が大きくなった: 第2段階

反跳角選択+運動量選択, K. Matsuta, et al., *Phys. Lett.* **B281** (1992) 214;

阪大VdG, HIMAC, RIKEN, *Rad. Nucl. Beams*, ed. W.D. Meyers et al., World Scientific Pub. (1992) p361.

HIMAC; 最近巨大 P M. Mihara et al., *Proc. HFI C.*, September, (2012) Beijing, To be published.

核破碎片+ISOL+ Opt. p., TRIUMF, C.D.P. Levy et al., *Nucl. Phys.* **A701** (2002) 253c.

偏極ビーム核反応積分, UTIAC, T. Minamisono et al., *Nucl. Phys.* **A236** (1974) 416.

➤ スピDewarの成功: 伊勢結晶(TiO₂)中の偏極保持: 第3段階

Nucleus($T_1, T_{1/2}$)	P/P_0	Sites	T_1	ref.
$^8\text{Li}(0.84\text{s})$	30%			1)
$^8\text{B}(1^+, 0.77\text{s}), ^{12}\text{B}(1^+, 20\text{ms})$	100	2(9:1)		1)
$^{12}\text{N}(1^+, 11\text{ms}), ^{16}\text{N}(2^-, 7.1\text{s})$	100	2(1:1)	> 10s	2)
$^{13}\text{O}(3/2^-, 8.6\text{ms}), ^{19}\text{O}(5/2^+, 27\text{s})$	100	2(7:3)	~100s	3)
$^{20}\text{Na}(2^+, 446\text{ms})$	36	1	3.4s	4)
$^{41}\text{Sc}(7/2^-, 596\text{ms})$	100	1 Ti sub.	~5s	5)
ZnO				
$^{20}\text{Na}(2^+, 446\text{ms})$,	73%	2(9:1)	9s	4)
Mg				
$^{20}\text{Na}(2^+, 446\text{ms})$,	76%	1	4.5s	4)

- ☞ 任意の元素に使用可.
- ☞ 結晶内植込み位置固定.
- ☞ 電場勾配単純.
- ☞ 室温で使う; $T_1 > 20\text{s}$.
- ☞ 安価、安定、取扱容易.
- 容易に手に入る.

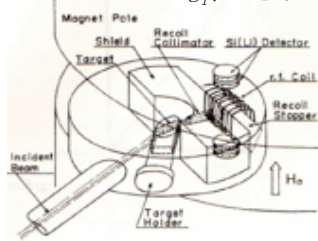
1) *Z. Naturforsch.* **57a**(2002) 599. 2) *Z. Naturforsch.* **57a** (2002) 293.

2) *Phys. Lett.* **B457** (1999) 9; *Ibid.* **B459** (1999) 81.

4) *HFI* (2005) DOI 10.1007/s10751-005-9107-2.

5) *Nucl. Phys.* A559 (1993) 239. *Z. Naturforsch.* **57a** (2002) 595.

I. $\mu(^{41}\text{Sc})$ と $\mu(^{17}\text{F})$ の精度1桁上げた
 δg_I 、 m^* を求めて.



β -NM(QR)と8-AP法

$$W(\theta) = 1 + AP \cos \theta.$$

$$\text{def. } R(P_{\uparrow}) = N_{\beta}(0)/N_{\beta}(\pi),$$

$$R(P_{\uparrow})/R(P_{\downarrow}) - 1$$

$$= G(1+AP_{\uparrow})/(1-AP_{\uparrow}) \times (1-AP_{\downarrow})/G(1+AP_{\downarrow}) - 1$$

$$\doteq +2A(P_{\uparrow} - P_{\downarrow})$$

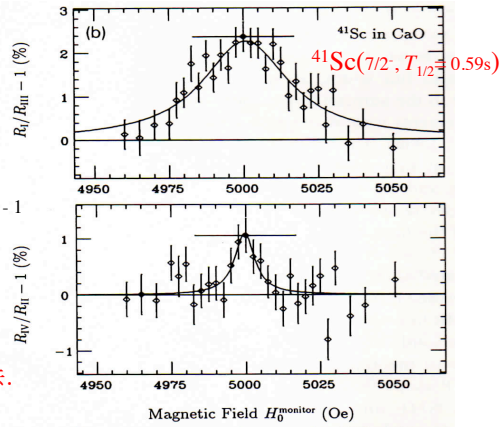
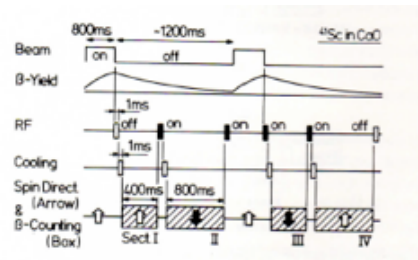
次のbeam-count 時に $P_{\downarrow}$ から $P_{\uparrow}$ に

2 beam-count サイクルを比較

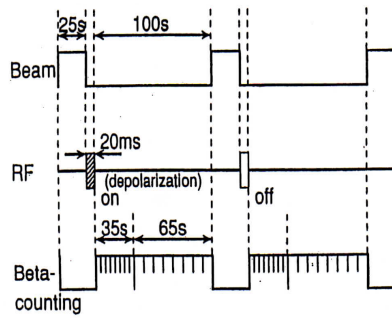
$$[R(P_{\uparrow})/R(P_{\downarrow})] - [R(P_{\downarrow})/R(P_{\uparrow})]$$

$$\doteq +4A(P_{\uparrow} - P_{\downarrow}) \sim 8AP_{\uparrow}.$$

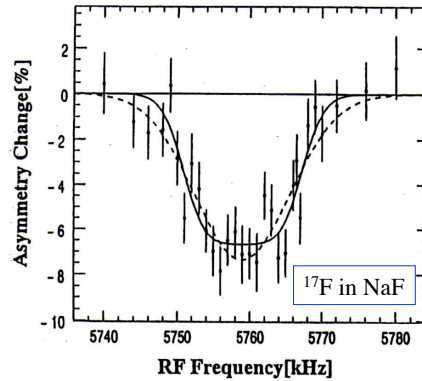
測定器非対称と β - γ 揺動効果除去.



II. μ of ^{17}F ($I^{\pi}=5/2^+$, $T_{1/2}=64.5\text{s}$)



Time sequence program



Cf.

$$\mu(^{17}\text{F}; 5/2^+) = 4.72130 \pm 0.00025 \text{ nm}$$

$$H_0 = 4.0 \text{ kOe measured by } ^{12}\text{B}.$$

$$\sigma(\text{diamag. shift in NaF}) = +378 \pm 10 \text{ ppm}.$$

$$\mu(^{41}\text{Sc}; 7/2^-) = 5.4305 \pm 0.0018 \text{ nm}$$

$$H_0 = 6.000 \text{ kOe measured by } ^{12}\text{B}.$$

$$\sigma(\text{Sc}^{3+} \text{ in CaO}) = +1600 \pm 100 \text{ ppm}.$$

$$\text{Knight Shift } K(\text{Sc in Pt}) = -(0.4 \pm 5.43)10^{-4}.$$

$$\text{cf. } K(3\% \text{ Sc in Pt}) = +(3 \pm 4)10^{-4}.$$

☞ σ と ℓ のアイソスカラー- g -因子と核子 Deconfinement

Magnetic moment of the LS doubly closed shell ± 1 nucleon Nuclei

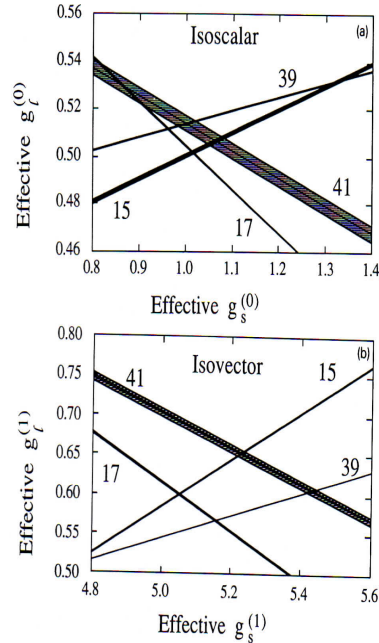
A	I^π	μ_S [nm]	μ_{exp} [nm]	a)		b)		c)
				$\delta\mu^{(0)}_{exp}$ [nm]	$\delta\mu^{(0)}_{exp}/\mu^{(0)}_S$ (%)	$\delta\mu^{(0)}_{conf}/\mu^{(0)}_S$ (%)	$\Delta\mu^{(0)}_S$ (%)	
15	^{15}N 1/2-	-0.26428	-0.2831892	d)				
	^{15}O 1/2-	+0.63773	(+)0.71951(12)	e)				
	$2\mu^{(0)}$	+0.37345	+0.43632(12)		+0.03144(6)	+16.8(2)	+22.85	-6.1
17	^{17}O 5/2+	-1.91315	-1.89379	f)				
	^{17}F 5/2+	+4.79274	(+)4.72133(17)	g)				
	$2\mu^{(0)}$	+2.87959	2.82754(17)		-0.02603(8)	-1.808(7)	-2.95	+1.14(1)
39	^{39}K 3/2+	+0.12435	+0.3915063	h)				
	^{39}Ca 3/2+	+1.14789	1.4131(2)	i)				
	$2\mu^{(0)}$	+1.27224	+1.4131(2)		0.0705(1)	+11.08(2)	+12.49	-1.41(2)
41	^{41}Ca 7/2-	-1.91315	-1.594780(9)	j)				
	^{41}Sc 7/2-	+5.79274	(+)5.4305(18)	k)				
	$2\mu^{(0)}$	+3.87959	+3.8357(18)		-0.0221(9)	-1.14(5)	-2.70	+1.56(5)

a) $\delta\mu^{(0)}_{exp} = \{\mu^{(0)}_{exp} - \mu^{(0)}_S\}$, where $\mu^{(0)} = (\frac{1}{2})\{\mu(T_z = +\frac{1}{2}) + \mu(T_z = -\frac{1}{2})\}$.

b) $\mu^{(0)}_{conf}/\mu^{(0)}_S$ is the configuration mixing correction to the isoscalar magn. divided by μ_S given by Ichii et al. [IS87]. c) $\Delta\mu^{(0)}_S = \{\mu^{(0)}_{exp} - (\mu^{(0)}_S + \mu^{(0)}_{conf})\}/\mu^{(0)}_S$. d) [BJ59]. e) [CE63], [TM93].

f) [AF51]. g) [MT92], [SK66]. h) [SW74]. i) [MT76]. j) [BE62]. k) [MT90]. l) [SK73]

☞ アイソスカラーモーメントの残渣と核子再規格化効果



$$\mu^{(0)} = (\frac{1}{2})\{\mu(T_z = +\frac{1}{2}) + \mu(T_z = -\frac{1}{2})\}$$

$$\delta\mu^{(0)}_{exp}/\mu^{(0)}_S = \{\mu^{(0)}_{exp} - \mu^{(0)}_S\}/\mu^{(0)}_S$$

$$\text{define; } \langle S_z \rangle_{exp} = (\mu^{(0)}_{exp} - 1/2)/(\mu_p + \mu_p^{-1/2})$$

2 次の配位混合: Ichii, & TK 理論; 一致はよい.
高励起配位 + Tensor correlation を取り入れ.

残渣: $\Delta\mu^{(0)}_S = \{\mu^{(0)}_{exp} - (\mu^{(0)}_S + \mu^{(0)}_{conf})\}/\mu^{(0)}_S$ 有意!

残渣と核子再規格化効果

$$\begin{aligned} \therefore \Delta &= \mu^{(0)}_{exp} - \{\delta\mu^{(0)}_{cross} + \delta\mu^{(0)}_p + \delta\mu^{(0)}_{def} + \delta\mu^{(0)}_{rel}\} \\ &= [(I - \langle S_z \rangle_{eff}) \{g_l^{(0)} + \delta g_l^{(0)}(exp)\} + \langle S_z \rangle_{eff} \{g_s^{(0)} + \delta g_s^{(0)}(exp)\}] \mu_N. \\ \text{cf, } \delta\mu^{(0)}_{def} &= 0, \delta\mu^{(0)}_{cross} \sim \delta\mu^{(0)}_{rel}/100, \delta\mu^{(0)}_p \sim 2\delta\mu^{(0)}_{rel}/30. \end{aligned}$$

Meson Exc. $\Rightarrow g_l$ に効き、

Free motion of $M \Rightarrow \mu_N^{eff} = e\hbar/2M_p$ を再規格化する.

$$\mu_N^{eff} = \mu_N (1 + \kappa) \text{ として、}$$

$$\kappa = \delta g_l^{(0)}(exp)/g_l^{(0)} = +(3.3 \pm 0.6)\%$$

$$\kappa = \delta g_s^{(0)}(exp)/g_s^{(0)} = +(8.5 \pm 5.4)\%.$$

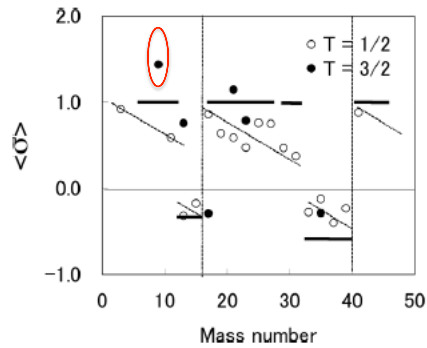
軽くなっている!

m^* について、後で既存のデータを示す.

Isoscalar g-factors and quark deconfinement.					Effective g -因子	
	Matrix from IBA		Matrix from TK		核子質量再規格化	
	mass 16	40	mass 16	40	A=16	A=40
With relativistic corr.						
$g_{\ell}^{(0)}$ (experiment)	0.502	0.514	0.510	0.520		
$g_s^{(0)}$ (experiment)	1.015	1.003	0.929	0.907		
$\delta g_{\ell}^{(0)}/g_{\ell}^{(0)}$ (exp) (%)	-0.4	2.8	2.0	4.0	κ (f. δg_{ℓ}) = 1.2(9)%	3.3(6)%
$\delta g_s^{(0)}/g_s^{(0)}$ (exp) (%)	15.4	13.9	5.5	3.1	κ (f. δg_s) = 10(5)%	8.5(5.4)%
Without relativistic corr.						
$g_{\ell}^{(0)}$ (experiment)	0.487	0.499	0.496	0.505	Free N.; $\mu_N^{eff} = e\hbar/2M_p$	
$g_s^{(0)}$ (experiment)	0.986	0.956	0.902	0.867	Renorm.; $\mu_N^{eff} = \mu_N(1 + \kappa)$.	
$\delta g_{\ell}^{(0)}/g_{\ell}^{(0)}$ (exp) (%)	-2.6	-0.1	-0.9	1.0		
$\delta g_s^{(0)}/g_s^{(0)}$ (exp) (%)	12.1	8.7	2.5	-1.4		
Effective g-factors and in $A = 16$ and 40 regions.						
	mass 16	mass 40	Free values.			
$g_{\ell}^{(1)}$ (experiment)	0.599	0.607	0.500			
$g_s^{(1)}$ (experiment)	5.050 $\pm$ 0.002	5.435 $\pm$ 0.002	4.706			
A=16 region						
proton	$\delta g_{\ell} = +0.100$	$\delta g_s = +(0.480 \pm 0.004)$				
neutron	$\delta g_{\ell} = -0.098$	$\delta g_s = -(0.209 \pm 0.004)$				
A= 40 region						
proton	$\delta g_{\ell} = +0.120$	$\delta g_s = +(0.851 \pm 0.003)$				
neutron	$\delta g_{\ell} = -0.098$	$\delta g_s = -(0.606 \pm 0.003)$				

$\delta g_{\ell} \approx 0.1\tau_3$
H. Miyazawa, *Theoret. Phys.*
6 (1951) 801.

☞ ${}^9\text{Li}$ - ${}^9\text{C}$ 対のアイソスケーラーモーメント異常



${}^9\text{C} (I^\pi = 3/2^-, T_{1/2} = 127 \text{ ms})$ in $\text{Pt} (T = 30 \text{ K})$

$H_0 = 4.0000 \text{ kOe}$, $S_p = 1.3 \text{ MeV}$.

$|\mu({}^9\text{C}; 3/2^-)| = 1.3914(5) \text{ nm}$.

K. Matsuta et al., *NP A588* (1995) 153c.
HFI 97/98 (1996) 519.

cf. $\mu({}^9\text{Li}; 3/2) = +3.4391(6) \text{ nm}$.

F.D. Correl et al., *PR C28* (1983) 862.

E. Arnold et al., *Z. Phys. A331* (1988) 295.

$\langle \sigma \rangle_{\text{exp}} = 1.44 > 1$!?

Here, $\langle \sigma \rangle_{\text{shell model}} = 1.03$.

Isoapin non cons. terms incl.

$\langle \sigma \rangle_{\text{INC}} = 1.18$. K.Huta et al., *PR C57* (1988) R2790.

Multi cluster; $\langle \sigma \rangle_{\text{MC}} = 1.13$. K.Valga et al., *PR C52* (1995) 3013.

AMD $\langle \sigma \rangle_{\text{AMD}} = 1.08$ Y.Kanada-Enyo et al., *PR C54* (1996) R468.

二準位の ℓ に非対;

A. Arima, *Nucl. Phys. A704* (2002) 1c.

Theory by Y. Utsuno,

Y. Utsuno, *PR C70* (2004) 011303.

Thoms-Ehrence Eff. In ${}^9\text{C} \rightarrow \text{Shell quench}$

$\rightarrow$ g.s. mix with Intruder Config.

II. 分子結晶内電場勾配と

$Q(\text{F}; \pi d_{5/2})$ 異常、 ^{40}Ca 芯の変形、 $Q(^8\text{B}, 2+)$ のハロー効果

➤ $Q(\text{F}; \pi d_{5/2})$ 異常

- ☞ $^{17, 20, 21}\text{F}$ の β -NQR 結果、
- ☞ Metal F_2 結晶中 F 位置での電場勾配；理論、
- ☞ $eqQ(^{17, 20, 21}\text{F})/h$ の実験値から Q_{exp} 、
- ☞ OXBASH & HF 理論との比較、
- ☞ 実効電荷に問題が残った。
- ☞ $Q(^8\text{B}, 2+)$ のハロー効果。⇒ 福田さん。

1. はじめに 2

^{19}F in C_2F_4 , K. Sugimoto

1548

Short Notes

(Vol. 13,

J. PHYS. SOC. JAPAN **13** (1958) 1548

Quadrupole Moment of the Second Excited State of ^{19}F

By Kenzo SUGIMOTO*, Akira MIZOBUCHI
and Hisasi YAMAMOTO

Department of Physics, Faculty of Science,
Osaka University, Osaka

(Received October 9, 1958)

Angular distributions of the 200-keV gamma-radiations by the reaction $^{19}\text{F}(p, p')^{19}\text{F}^*$ have been measured by bombarding a CaF_2 target and also a polytetrafluoroethylene ($(\text{C}_2\text{F}_4)_n$) target of each about 200-keV thickness for 1.4-MeV protons. Each distribution was fitted to the form $W(\theta) = 1 + A_2 G_2 P_2(\cos \theta)$, where A_2 is the coefficient of the

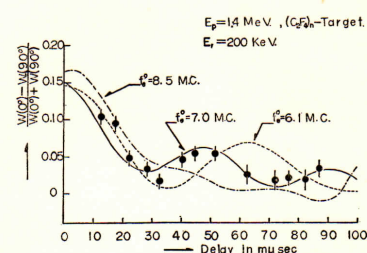


Fig. 1. Delayed angular distribution of the 200-keV radiations. The curves drawn in this figure were calculated theoretically for the respective frequency of the quadrupole coupling f_q^0 . The errors indicated are only statistical ones.

$^{19}\text{F}(I^\pi=5/2^+, T_{1/2}=89 \text{ ns}, E_x=197 \text{ keV})$ in C_2F_4 ,

EFG at F in C_2F_4 molecule was calculated by J. Kanamori.

電気+磁気
相互作用
Hamiltonian

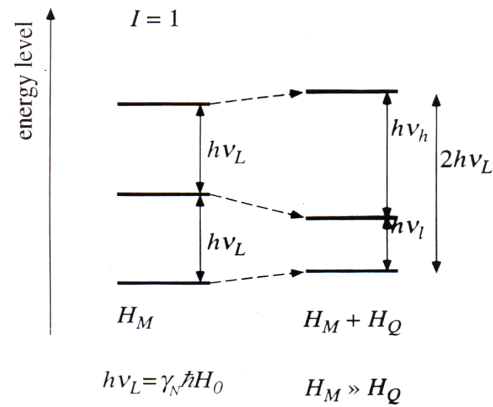
NMR (nuclear magnetic resonance)

magnetic interaction

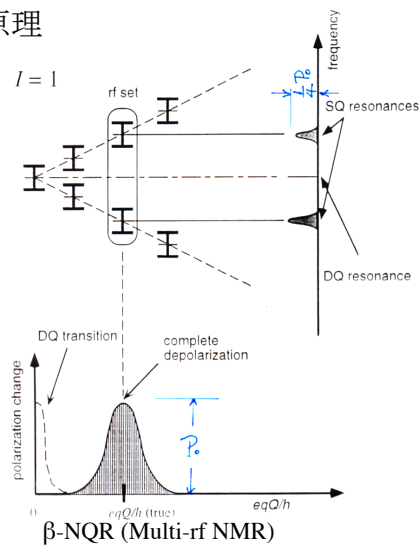
$$H_M = -\vec{\mu} \cdot \vec{H}_0$$

electric quadrupole interaction

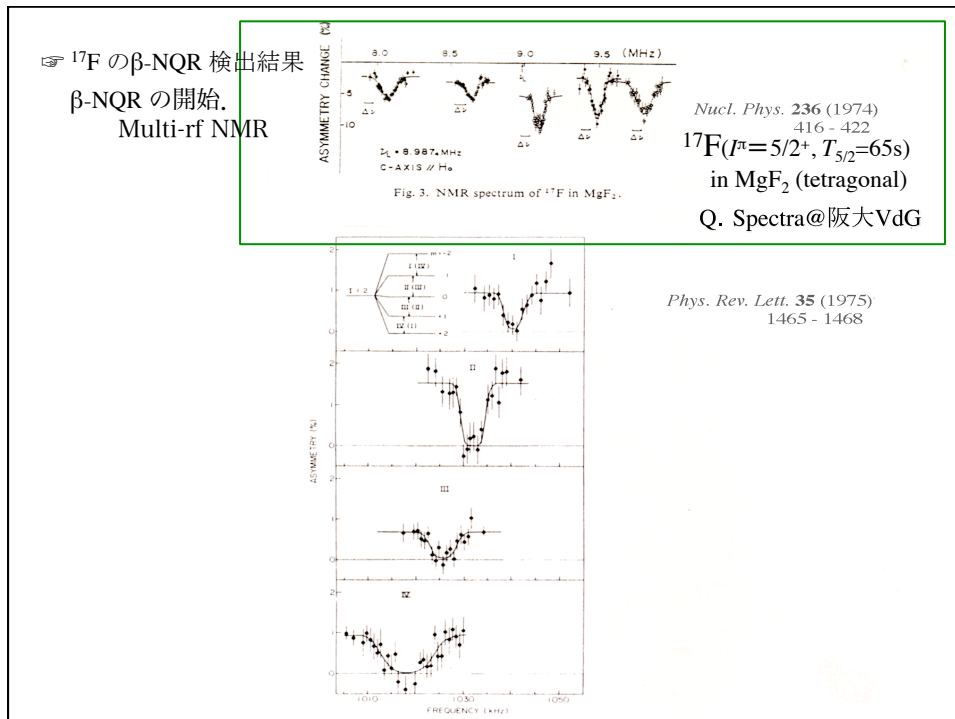
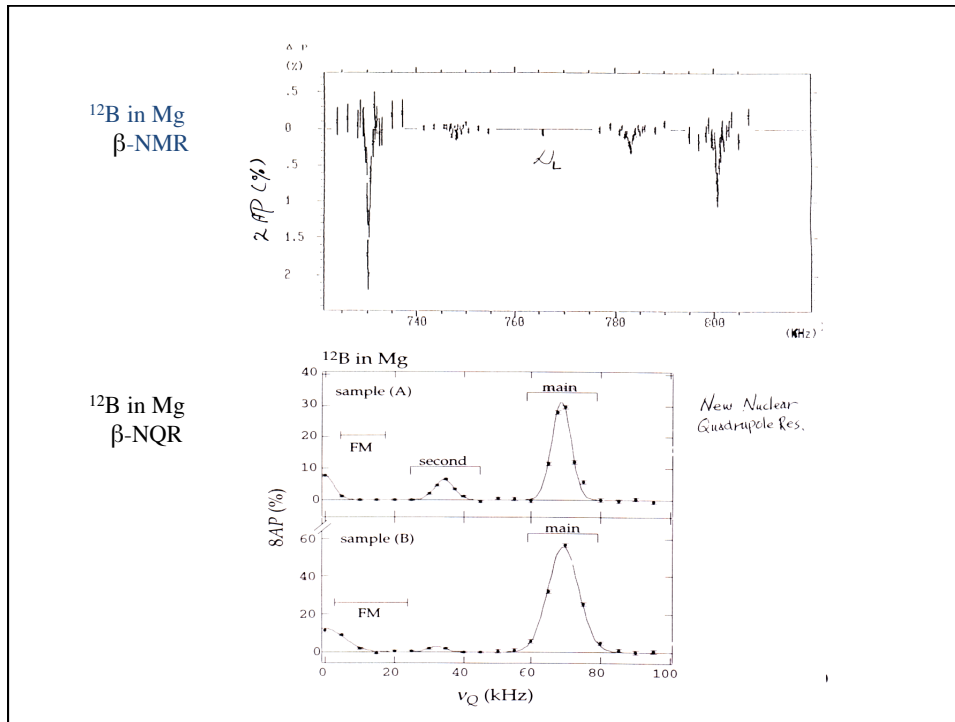
$$H_Q = \frac{eqQ}{4I(2I-1)} \left\{ 3I_z^2 - I(I+1) + \frac{\eta}{2}(I_+^2 + I_-^2) \right\}$$



β-NQR 原理



時間稼いだ！
 $2I$ 本分離線測定/ μH 一本のみ
 $\propto 2I \times \{2I(I+1)(2I+1)/3\}^2$
 但し $a_m - a_{m-1} = \Delta$ 一定仮定,
 for $I = 1$; 32倍時間、
 $I = 5/2$; 2.5万倍時間、
 $I = 7/2$; 5万倍時間.



^{21}F の β -NQR 検出結果

β -NMR Detection of $^{21}\text{F}(5/2^+, 4.2\text{s})$

高エネルギー衝突
(核破砕片生成と
反跳偏極)の
 β -NQRとの結合

MgF_2 中 $^{17,19,21}\text{F}$ の
 eqQ/h と η を得た.

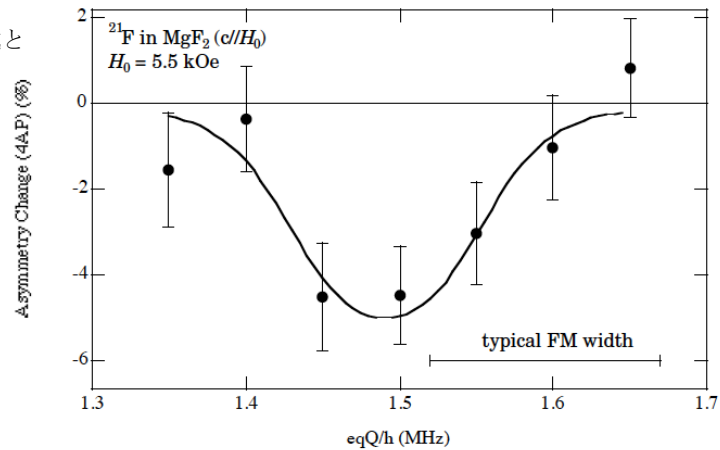


Fig. 4-10 β -NQR spectrum of ^{21}F in MgF_2 . The solid line is the best fit function to the data.

T. Ohnishi, D. Thesis '02 Osaka U.

☞ MF_2 結晶中の q ; 理論、

$eqQ/h \leftrightarrow Q$; q ?

q 実験値無→理論必要

FP-KKR; 理論構築

M. Ogura, Thesis,
'04 Osaka U.

- ✓ Full potential
- ✓ sd hybridization
- ✓ lattice relaxation
- ✓ super-cell method

右図; HCP金属格子位置
 V_{zz} 計算値-実験値

実験値を $\pm 10\%$ で再現する.

但し、 $V_{zz} = (200 \sim 800) \times 10^{19} \text{ V/m}^2$.

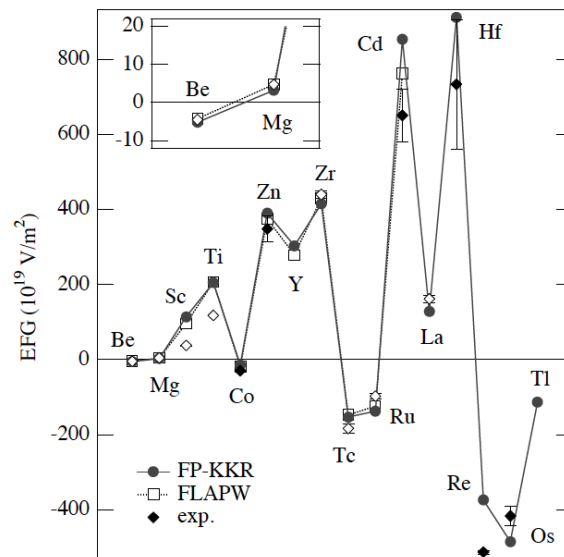


Figure 15: Theoretical and experimental EFGs in HCP metals. The filled and open diamonds indicate the data the sign of which is known and unknown, respectively.

Metal F₂結晶中F位置での電場勾配

FP-KKR;

M. Ogura; *Thesis*, '04 Osaka U.

M. Ogura, H. Akai & T. Minamisono;

Hyp. Int. **158** '04 95-98.

- ✓ Full potential
- ✓ *sd* hybridization
- ✓ lattice relaxation
- ✓ super-cell method

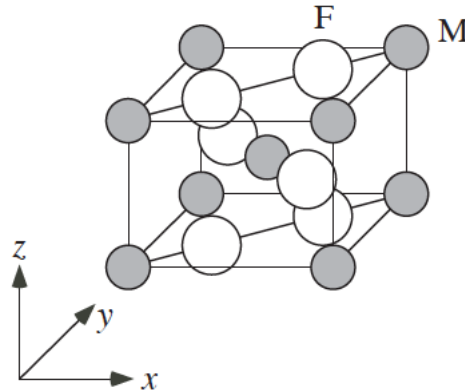
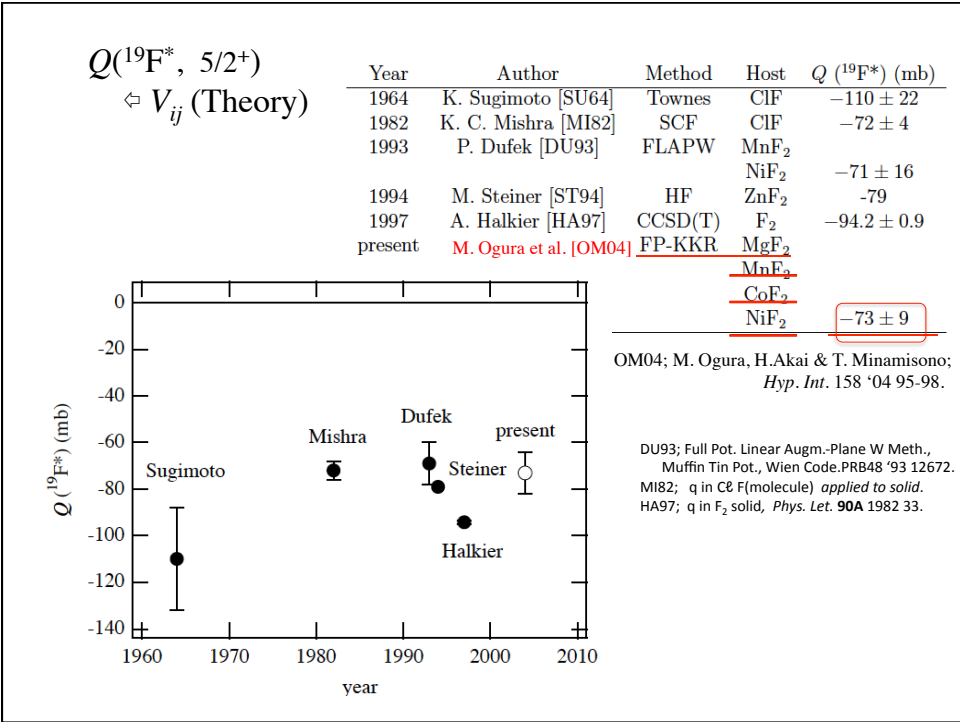
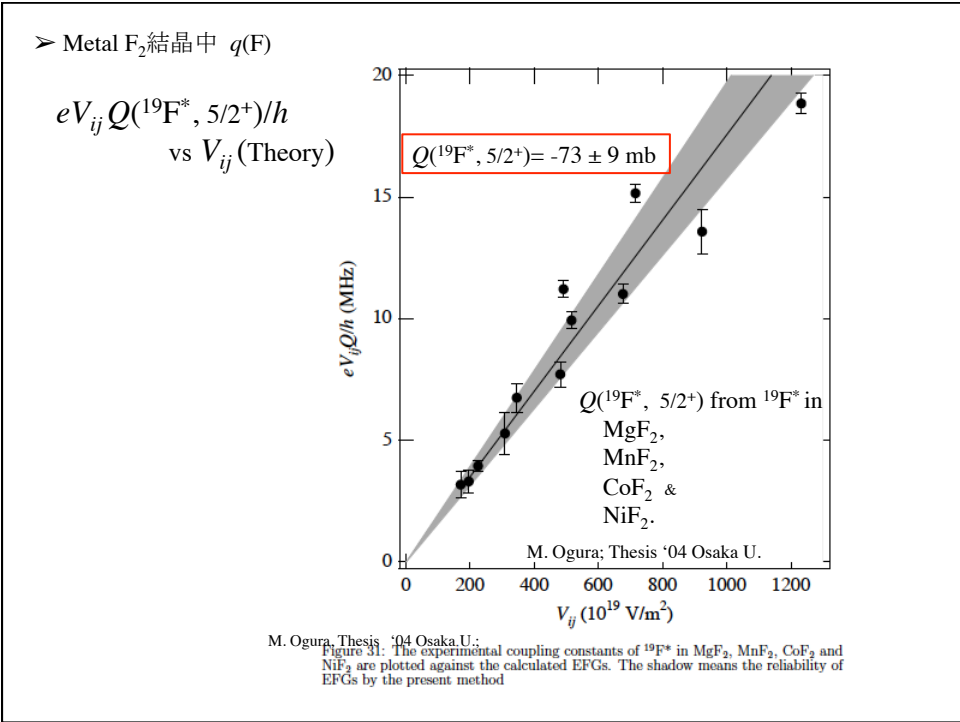


Figure 17: The rutile structure and the definition of the principal coordinate in the subsection. M indicates metal atoms and F indicates oxygen or fluorine atoms.

F in MetalF₂ ;
 $eqQ(^{17,20,21}\text{F})/h$ & η
 実験値

Table 9: Measurement of quadrupole coupling constants of F isotopes. [†]Estimation of error is mentioned in the appendix. M. Ogura; Thesis 04 Osaka U.

Year	Author	Nuclei	Host	eqQ/h (MHz)	η
1964	K. Sugimoto	¹⁹ F*	CIF	<u>82.7 ± 4.0</u>	•
	[SU64]	¹⁹ F*	(C ₂ F ₄) _n	60 ± 2.7	
1968	F. W. Richter	¹⁹ F*	BeF ₂	22.3 ± 0.4 [†]	0.00 ± 0.03
	[R168]	¹⁹ F*	MgF ₂	9.93 ± 0.3 [†]	0.36 ± 0.03
		¹⁹ F*	CrF ₂	13.1 ± 0.4 [†]	1.00 ± 0.03
		¹⁹ F*	MnF ₂	11.0 ± 0.4 [†]	0.40 ± 0.03
		¹⁹ F*	FeF ₂	12.6 ± 0.4 [†]	0.47 ± 0.03
		¹⁹ F*	CoF ₂	15.2 ± 0.4 [†]	0.48 ± 0.03
		¹⁹ F*	NiF ₂	18.8 ± 0.4 [†]	0.44 ± 0.03
		¹⁹ F*	CuF ₂	19.1 ± 0.4 [†]	1.00 ± 0.03
1972	H. Ackermann	²⁰ F	MgF ₂	5.77 ± 0.02	0.317 ± 0.002
	[AC72] [ST74]				
1973	T. Minamisono	¹⁷ F	MgF ₂	8.57 ± 0.45	0.34 ± 0.03
	[MI73]				
1974	T. Minamisono	¹⁷ F	MgF ₂	<u>8.41 ± 0.24</u>	<u>0.32 ± 0.02</u>
	[MI74]				
1980	H. Barfuss	¹⁹ F*	MgF ₂	10.6	0.25
	[BA80]	¹⁹ F*	CrF ₂	13.8	1.00
		¹⁹ F*	MnF ₂	11.1	0.48
		¹⁹ F*	FeF ₂	12.1	0.42
		¹⁹ F*	CoF ₂	16.6	0.48
		¹⁹ F*	NiF ₂	19.1	0.35
		¹⁹ F*	CuF ₂	19.9	0.90
		¹⁹ F*	ZnF ₂	17.5	0.43
1982	H. Barfuss	¹⁹ F*	F ₂	127.2 ± 1.0	
	[BA82]				
1983	K. B. Nielson	¹⁹ F*	Ge	27.3 ± 0.4	0
	[NI83]			33.4 ± 0.4	0
1984	K. B. Nielson	¹⁹ F*	Si	23.1 ± 0.2	0
	[NI84]			34.9 ± 0.2	0
1992	E. Sideras-Haddad	¹⁹ F*	C(diamond)	56 ± 2	
	[SI92]			63 ± 2	
2002	T. Onishi	²¹ F	MgF ₂	<u>9.94 ± 0.09</u>	
	[ON02]				



4. $eqQ(^{17,20,21}\text{F})/h$ の実験値と Q
 $eV_{ij}Q(^{17,20,21}\text{F}, \text{exp})/h$
 vs $eV_{ij}Q(\text{Theory})$

M. Ogura; *Thesis*, '04 Osaka U.
 M. Ogura, H. Akai & T. Minamisono;
Hyp. Int. **158** '04 95-98.

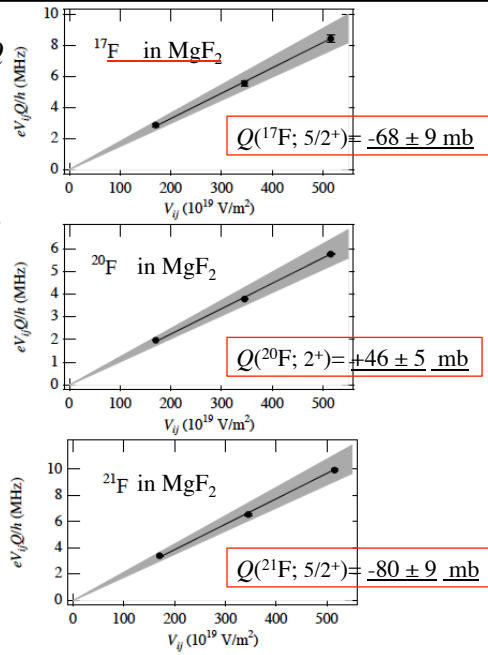


Figure 32: The experimental coupling constants of ^{17}F , ^{20}F and ^{21}F in MgF_2 are plotted against the calculated EFGs. The shadow means the reliability of EFGs by the present method.

Q_{exp} of F isotopes
 Compared with
 OXBASH & HF

M. Ogura, H. Akai & T. Minamisono;
Hyp. Int. 158 '04 95-98.
 M. Ogura; *Thesis* '04 Osaka U.
 Full Pot. KKR.

- Kitagawa; *PTP* **102** '99 1015.
- Onishi; *Thesis* Osaka U. 2002.
- ◆ D. Baye et al.; *PR C* **58** 545.
- Two effect. NN force in Generator coord.
 & R matrix method.
- $^{16}\text{O}(p,\gamma)^{17}\text{F}$ reaction,
 Hallow structure in $1/2^+$ state,
 $\langle r_2 \rangle^{1/2} = 2.58$ fm for ^{16}O O.K.
 $\langle r_2 \rangle^{1/2}(5/2^+) = 2.67$ fm,
 $\langle r_2 \rangle^{1/2}(1/2^+) = 2.79$ fm.
- $Q(^{17}\text{F}, 5/2^+) = -80$ mb by Volkof int.
 -70 mb by Minnesota.
 NN exchange param. &
 S-L amplitude adj.
 (p, γ); reprod. Well.

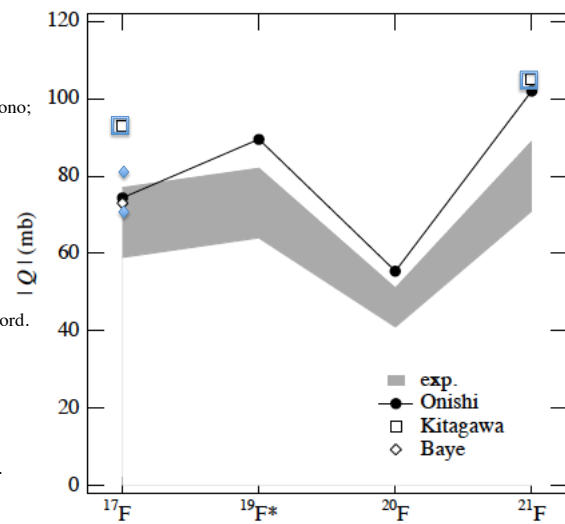


Figure 33: Experimental and theoretical quadrupole moments of F isotopes. The shadow shows the experimental values with the errors. Filled circles mean the OXBASH calculations with W effective interactions by Onishi [ON02], open squares mean the HF calculations by Kitagawa [KI99] and open diamond means the cluster model calculation by Baye et al. [BA98].

☞ $Q(^{17,20,21}\text{F})$ 実験値⇔実効電荷

$$Q_{\text{expt}} = e_{\pi}^{\text{eff}} q_{\pi} + e_{\nu}^{\text{eff}} q_{\nu}, \quad q_{\pi} = (16\pi/5)^{1/2} \cdot \sum e_i^{\text{eff}} \cdot (1/2 \pm t_z) r_i^2 \cdot Y_{20}(\Omega_i).$$

	$Q(\text{mb})^{\#}_{\text{expt}}$	OXBASH ^{##} (W Int.)			HF ^{###} (Small S_p , Energy effect)		
		q_{ν}	q_{π}	$Q(\text{mb})$	q_{ν}	q_{π}	$Q(\text{mb})$
^{17}F $5/2^+$	-68 ± 9	0	-60.5	-79	0	-75.6	-93
$^{19}\text{F}^*$ $5/2^+$	-73 ± 9	-76.4	-44.8	-90			
^{20}F 2^+	$+46 \pm 5$	54.6	25.1	+60			
^{21}F $5/2^+$	-80 ± 9	-87.4	-51.0	-110	-96.6	-50.36	-105

[#] M. Ogura; *Thesis* '04 Osaka U.

[#] M. Ogura, H. Akai & T. Minamisono;

Hyp. Int. 158 '04 95-98.

^{##} T. Ohnishi; *Thesis* '01 Osaka U.

$e_{\nu}^{\text{eff}} = 0.50e$, $e_{\pi}^{\text{eff}} = 1.3e$

^{###} H. Kitagawa; *PTP* 102 '99 1015.

Empirical effective charges;

$Q(\text{mb})^{\#}_{\text{expt}}$	OXBASH ^{##} (W Int.)				HF ^{###} (Shallow p sep. Energy effect)			
	q_{ν}	q_{π}	e_{ν}^{eff}	e_{π}^{eff}	q_{ν}	q_{π}	e_{ν}^{eff}	e_{π}^{eff}
¹⁷ F -68 ± 9	0	-60.5	{---	1.12(15)e}	0	-75.6	-----	0.90(12)e
¹⁹ F* -73 ± 9	-76.4	-44.8						
(²⁰ F $+46 \pm 5$	54.6	25.1)						
²¹ F -80 ± 9	-87.4	-51.0			-96.6	-50.36	0.362e	< 0.90(12)e
	<u>Average(A=17,19,21) 0.28e 1.12e</u>				<u>Av.(A=17, 21) 0.36e < 0.90e</u>			

緩く結合(Halo)核子による芯励起(E.Q. Giant res.)評価？

それとも、FPKKRの信頼性を疑う必要が有るか？

➤ $Q(^{16}\text{N})$; ^{16}N in TiO_2

$^{16}\text{N}(I^{\pi}=2^-, T_{1/2}=7.13\text{s})$

$= |(\pi p_{1/2})^{-1} (v d_{5/2})^{+1} \rangle$

$S_n = 2.49 \text{ MeV}$

Decay Branches:

	E_{β}^{max}	A
$2 \rightarrow 0^+$	10.4 MeV	負
$2 \rightarrow 3^-$	4.2 MeV	正

$|Q(^{16}\text{N}; 2^-)| = 17.9 \pm 1.7 \text{ mb}$

HF;

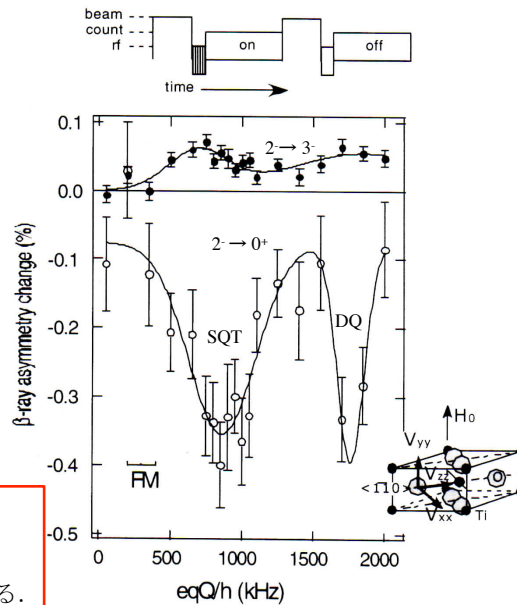
$Q_n(\text{HF; Halo}) = -60.4 e_{\pi}^{\text{eff}}$,

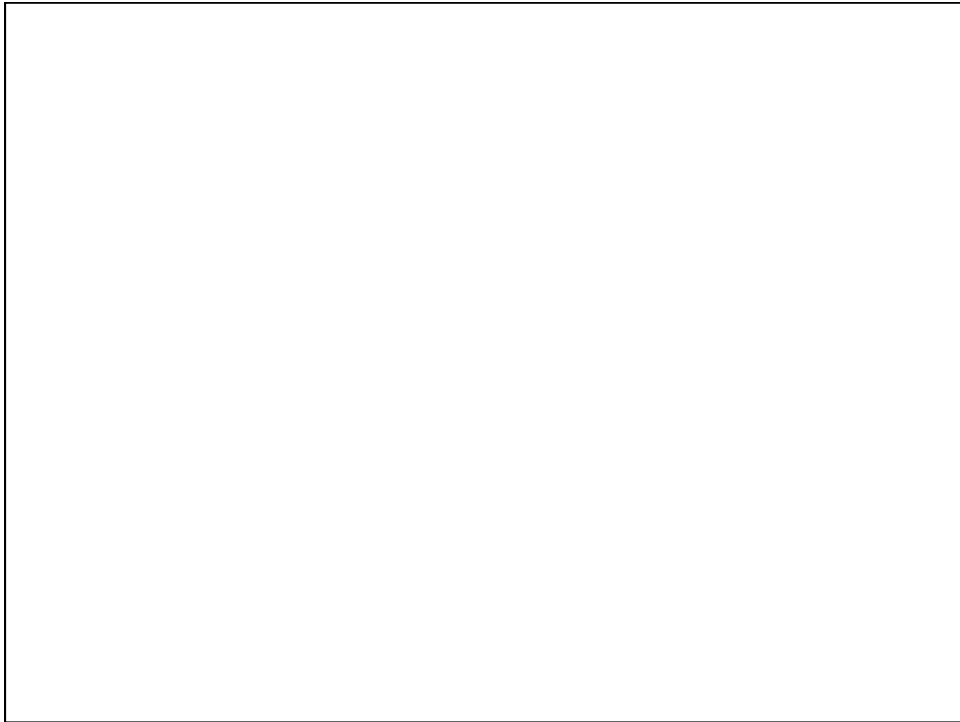
$Q_p(\text{HF}) = -5.1 e_{\pi}^{\text{eff}}$,

At least; $e_{\pi}^{\text{eff}} = 0.19e \sim 0.21e$.
~ 40% of 0.48 for $d_{5/2}$.

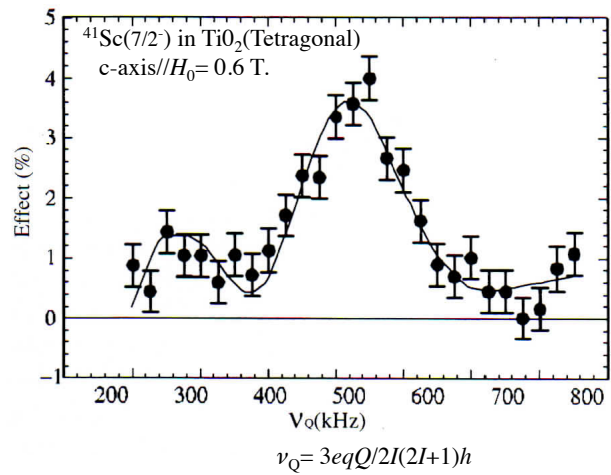
q は $Q(^{12}\text{N}; 1^+)$ 実験で決めた！

緩く結合(Halo)した核子による
芯励起(E.Q. Giant res.)は弱くなる.





➤ β -NQR Detection of ^{41}Sc ($I^\pi=7/2^-$, $T_{1/2}=0.59\text{s}$)
 ($S_p=1.1\text{ MeV}$)



Result;
 $|eqQ(^{41}\text{Sc})/h| = 7.31 \pm 0.07(\text{stat}) \pm 0.06(\text{syst}) \text{ MHz.}$

V_{ij} ; from FT-NMR of ^{45}Sc in $\text{Ti}_{1-x}\text{Sc}_x\text{O}_2$

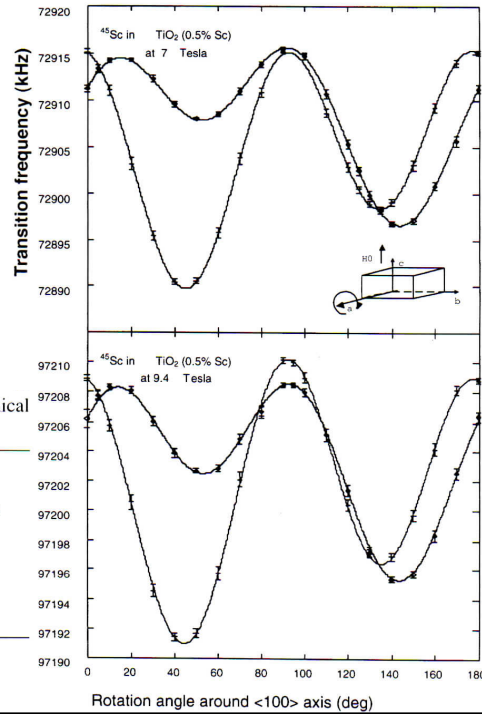
Detection of V_{ij} Tensor:

FT-NMR of ^{45}Sc in $\text{Ti}_{1-x}\text{Sc}_x\text{O}_2$

Synthesized by Earth Jewelry: 1987
 $\text{Ti}_{1-x}\text{Sc}_x\text{O}_2$; $x = 0.5\%$.

Table 1. The experimental EFG and anisotropic chemical shift at the ^{45}Sc (0.5 atom% of Ti) site in TiO_2 (rutile).

$ eqQ(^{45}\text{Sc})/h $ (MHz)	11.02 ± 0.01
η ($V_{ZZ} \parallel <110>$)	0.983 ± 0.003
V_{YY}	parallel to c -axis
$ q $ (10^{15}V/cm^2)	193 ± 2
Anisotropic chemical shift (ppm)	
σ_{XX}	61.6 ± 0.6
σ_{YY}	3.6 ± 0.4
σ_{ZZ}	-65.2 ± 0.7



Core Deformation from $Q(^{41}\text{Sc}; 7/2^-)$ & $Q(^{41}\text{Ca}; 7/2^-)$

$|Q(^{41}\text{Sc}; I^\pi = 7/2^-, T_{1/2} = 0.596\text{s})| = 156 \pm 3 \text{ mb}$; Revised.

New atomic hfi of ^{45}Sc ; $B(^{2S+1}L_J) = eqQ(^{45}\text{Sc})$. W.J. Childs, *PR* **A4** (1971) 1767.

Sternheimer Pol. Corr.

R.P. Gupta et al., *PR* **A7** (1973) 850.

$|Q(^{41}\text{Ca}; I^\pi = 7/2^-)| = 90 \pm 1.8 \text{ mb}$; Revised.

New MCHF calc. of atomic hfi of $^{43}\text{Ca}(7/2^-)$

M Fukuda, *Th. Osaka* 1995.

C.F. Fisher, *Comp. Phys.* **64** (1991) 431.

P. Jonsson, *Comp. Phys.* **74** (1993) 399.

Q Prediction:

H. Kitagawa et al., *NP A551* (1993) 16.

$$Q(N_p, N_n) = e_n^{\text{eff}} Q(N_p) + e_p^{\text{eff}} Q(N_n)$$

$$e_n^{\text{eff}} = 0.525, e_p^{\text{eff}} = +1.31. \text{ For } B(E2) \text{ worked well. A.K. Dahr et al., } PR \text{ C16 (1977) 792.}$$

$$^{41}\text{Sc}(S_p = 1.1 \text{ MeV}): Q_{\text{th}}(21) = -115 \text{ mb}, Q_{\text{th}}(20) = -0 \text{ mb}; Q_{\text{th}}(^{41}\text{Sc}; 7/2^-) = 151 \text{ mb.}$$

$$^{41}\text{Ca}(S_p = 8.9 \text{ MeV}): Q_{\text{th}}(21) = -107.5 \text{ mb}, Q_{\text{th}}(20) = -0 \text{ mb}; Q_{\text{th}}(^{41}\text{Ca}; 7/2^-) = 68.8 \text{ mb.}$$

逆に、実験から e_n^{eff} ? ;

$$e_p^{\text{eff}} = (156 \pm 3 \text{ mb}) / 115 \text{ mb} = 1.36e ; \quad \text{異常なし.}$$

$$e_n^{\text{eff}} = (90 \pm 1.8 \text{ mb}) / 107.5 \text{ mb} = 0.84e ; \quad 1.6 \text{ 倍も大きい.}$$

1. 6 倍を Core Deformation、 Q_{def} 、のせいにする?

$$Q_{\text{exp}}(^{41}\text{Ca}; 7/2^-) = (90 \pm 1.8) \text{ mb} = Q_{\text{th}}(n) e_n^{\text{eff}} + Q_{\text{def}}; \quad Q_{\text{def}}(\text{from } ^{41}\text{Ca}) = (30 \pm 2) \text{ mb.}$$

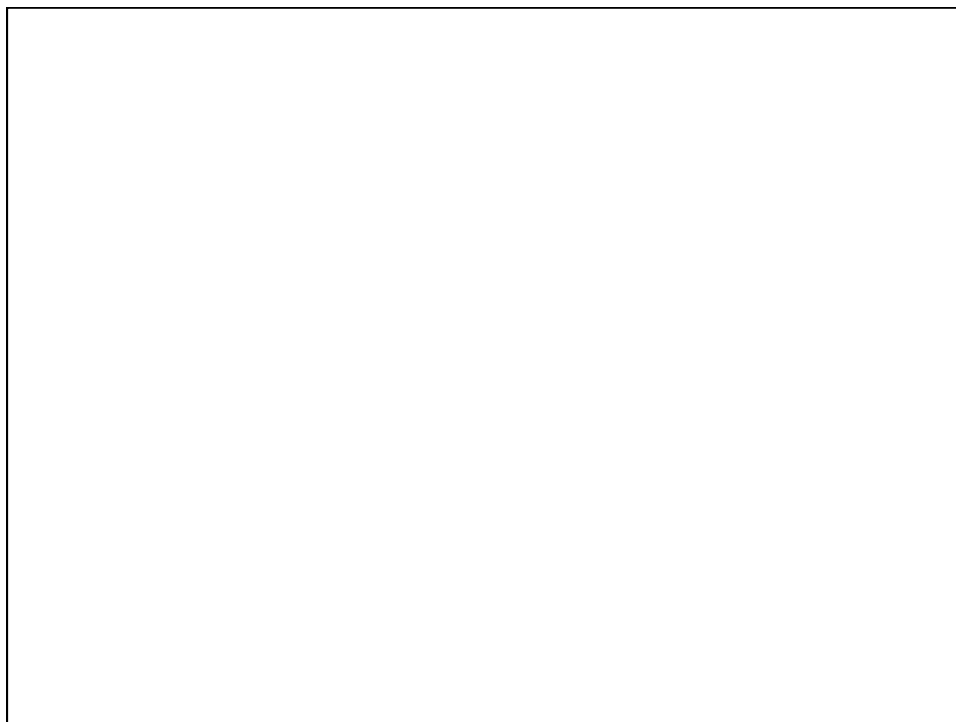
$$Q_{\text{exp}}(^{41}\text{Sc}; 7/2^-) = (156 \pm 3) \text{ mb} = Q_{\text{th}}(p) e_p^{\text{eff}} + Q_{\text{def}}; \quad Q_{\text{def}}(\text{from } ^{41}\text{Sc}) = (5 \pm 4) \text{ mb.}$$

Finite isovector component in def.?

$$\text{Or, if } e_p^{\text{eff}} = 1.1e, \therefore S_p = 1.1 \text{ MeV. } Q_{\text{def}}(\text{from } ^{41}\text{Sc}) = 156 - 115 \times 1.1 = 30 \text{ mb !!}$$

$$= Q_{\text{def}}(\text{from } ^{41}\text{Ca})$$

Cf. Soft core; T. Nomura, *JPSJ* **34** Suppl. (1973) 331.



弱核子SCCの存在限界と核内核子質量再規格; 核純粋スピン整列-β線角度相関測定

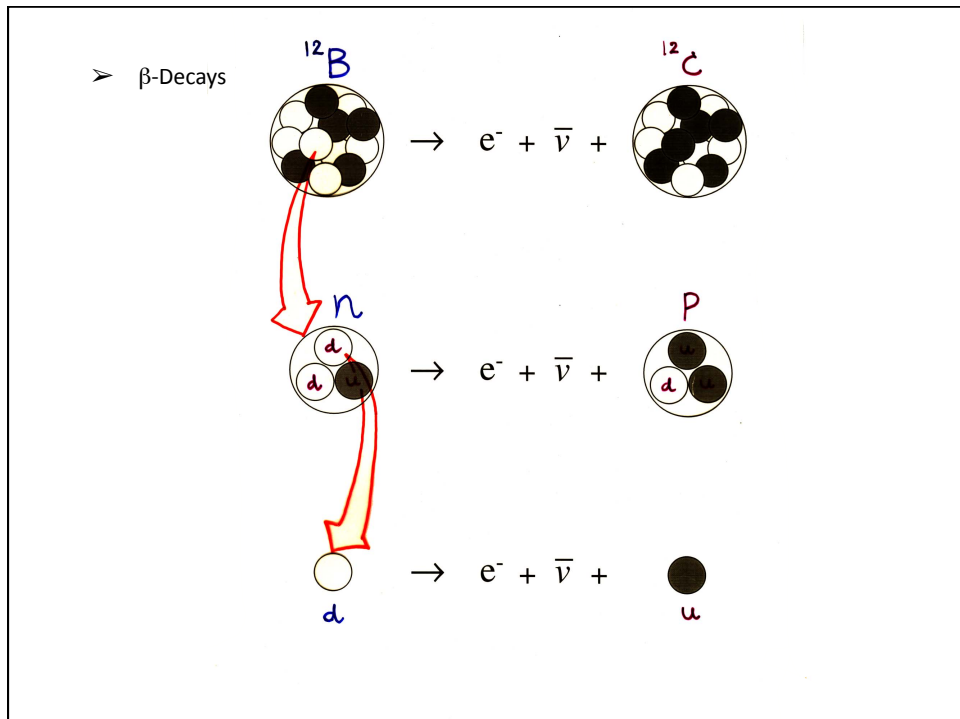
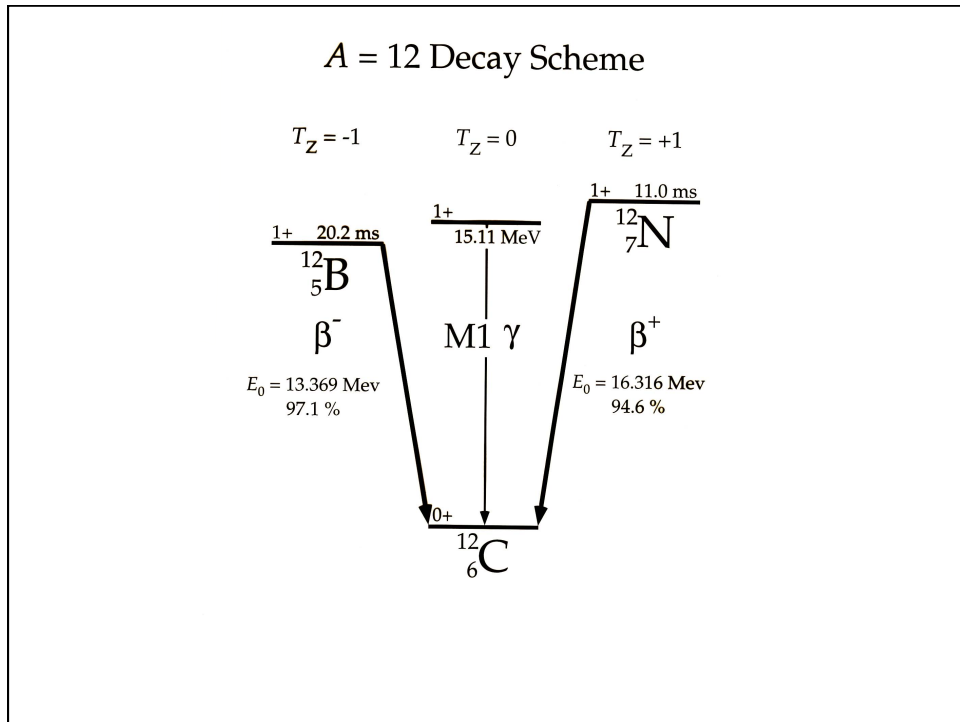
於 研究会 ; The Playing Field of Physics 30年
—杉本先生と開いた新しい道—

南園忠則、松多健策、福田光順、三原基嗣
大阪大学大学院理学研究科

- 弱核子誘導テンソル流と ^{12}B と ^{12}N β崩壊.
- 核スピン純粋整列状態の作り方.
- 整列-β 相関係数 ; $A=12$ 系、 $A=8$ と 20 系.
- 弱核子誘導テンソル項 : SCCの存在限界とクォーク質量
- Axial Chargeの巨大 β 効果と核子質量再規格化
核子密度依存性?

研究参加者 ;

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M. Morita (理論) 城西国際. K. Koshigiri (理論) 大阪教育.
Y. Nojiri 阪大. K. Sugimoto 阪大. T. Minamisono 阪大. 他多くの方々.



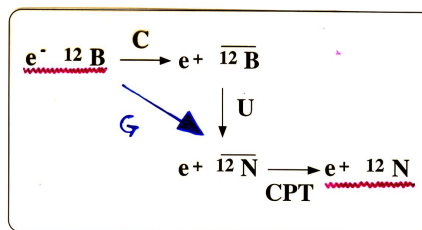
G Parity in Nuclear β Decay

$$G = C \cdot \exp(-i\pi T_2)$$

C : Charge Conjugation
 $\exp(-i\pi T_2)$: Charge Symmetry



Parity in the Charge Space



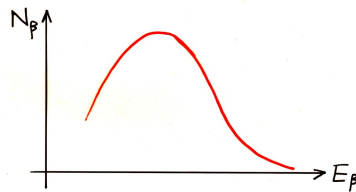
G Parities for the Nucleon Currents

$$H_I = \sqrt{\frac{1}{2}} (V_\lambda + A_\lambda) (\bar{\psi}_e \gamma_\lambda (1 + \gamma_5) \psi_\nu)$$

$$V_\lambda = \underbrace{\bar{\psi}_p}_{\text{G}} \left[\underbrace{f_V \gamma_\lambda}_{+} + \underbrace{f_W \sigma_{\lambda\rho} k_\rho}_{+} + \underbrace{if_S k_\lambda}_{-} \right] \psi_n$$

$$A_\lambda = \underbrace{\bar{\psi}_p}_{\text{G}} \gamma_5 \left[\underbrace{f_A \gamma_\lambda}_{-} + \underbrace{f_T \sigma_{\lambda\rho} k_\rho}_{+} + \underbrace{if_P k_\lambda}_{-} \right] \psi_n$$

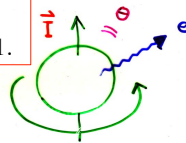
$f_T \rightarrow$ G Parity Violation

β Decay

Spin Orientation:

$$P = (1/I) \sum m a_m,$$

$$A = \{3/I(I+1)\} (\sum m^2 a_m) - 1.$$



$$W(\theta) \sim 1 + a \frac{P \cos \theta}{E_\beta} + A \frac{3 \cos^2 \theta - 1}{2}.$$

Experimental Method

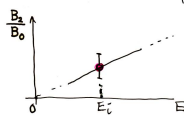
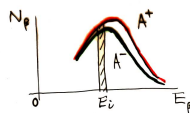
1. Production of Polarized Nuclei

2. Recoil Implantation
Mg Single Crystal

3. Spin Manipulation

$$P \leftrightarrow A^\pm, \mu H + \frac{\sigma \hbar B}{h}$$

4. Spectra Measurement

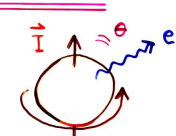


$$\frac{B_2}{B_0} = \frac{1}{A - A'} \left[\frac{m(A')}{m(A)} - 1 \right]$$

β -Ray Angular Distribution from
Spin Aligned ^{12}B and ^{12}N

$$W(E, \theta) \propto 1 + P \frac{B_1(E)}{B_0(E)} P_1(\cos \theta) + A \frac{B_2(E)}{B_0(E)} P_2(\cos \theta)$$

Set Zero

$$\frac{1}{E} \left(\frac{B_2(E)}{B_0(E)} \right)_{\mp} = \frac{2}{3} \left\{ \pm \left(a - \frac{f_T}{f_A} \right) - \frac{y_{\mp}}{2M} \right\}$$


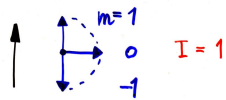
$$\frac{1}{E} \left(\frac{B_2(E)}{B_0(E)} \right)_{^{12}\text{B}} - \frac{1}{E} \left(\frac{B_2(E)}{B_0(E)} \right)_{^{12}\text{N}} = \frac{4}{3} \left(a + \frac{\Delta y}{2M} - \frac{f_T}{f_A} \right) \quad \text{or Parity}$$

$$\frac{1}{E} \left(\frac{B_2(E)}{B_0(E)} \right)_{^{12}\text{B}} + \frac{1}{E} \left(\frac{B_2(E)}{B_0(E)} \right)_{^{12}\text{N}} = -\frac{2}{3} \frac{y}{M} \quad \text{Axial Charge}$$

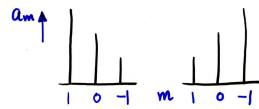
$$a = \frac{f_W}{f_A} - \frac{1}{2M} \frac{f_V}{f_A} \quad \text{Weak Magnetism}$$

$$y_{\mp} = -2M \frac{[i\gamma_5]r}{\int \sigma} \quad \Delta y = \frac{y_+(^{12}\text{N}) - y_-(^{12}\text{B})}{2} \quad \text{Asymmetry in } y$$

Polarization · Alignment

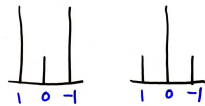


$$P \equiv \frac{\sum m a_m}{I} = a_1 - a_{-1}$$



$$R(P_{\uparrow})/R(P_{\downarrow}) - 1 = 4P,$$

$$A \equiv \frac{3}{I^2} \left\{ \sum m^2 a_m - \frac{I(I+1)}{3} \right\} = 1 - 3a_0$$



$$R(A_{\uparrow})/R(A_{\downarrow}) - 1 = 2A\alpha E, \quad \text{for Up \& Down}$$

Exp. Equip. & Meth.

実験方法

パルスビーム法 Pulsed Beam Meth.

1. 偏極核の生成 Creat. of Pol.

 $P \sim 10\%$ (^{12}B)
 20% (^{12}N)

2. 結晶への植え込み

Mg Impl. Into Crys.

 $\mu\text{H} + eqQ$ int.

3. スピン操作 Spin Manip.

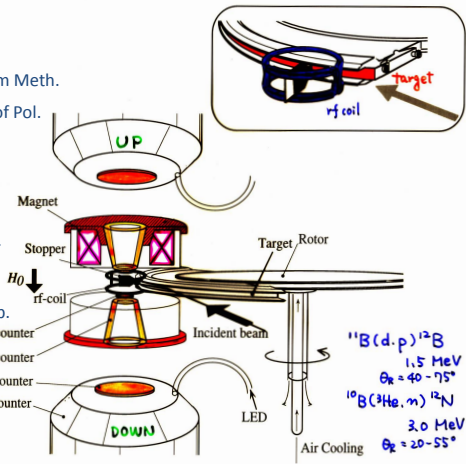
NMR 法

 $P \rightarrow A$

4. スペクトル測定

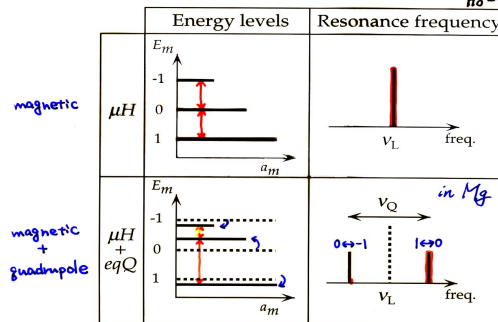
Meas. Of E. Spectra

UP/DOWN 非対称 偏極 測定

Meas. P from U/D ratio!

Quadrupole Interaction

& NMR Lines

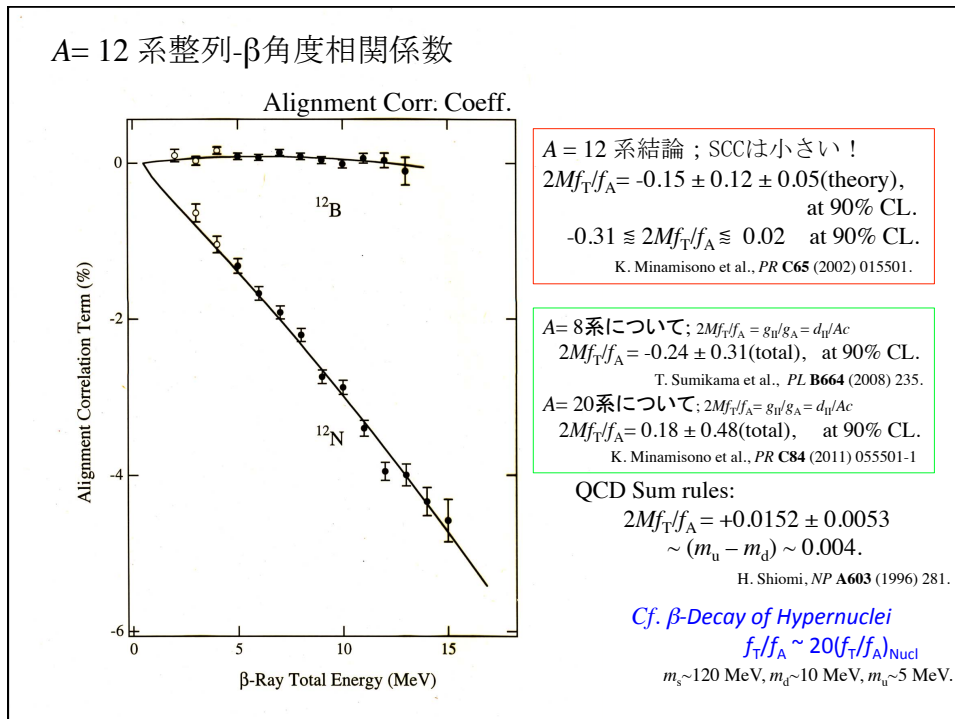
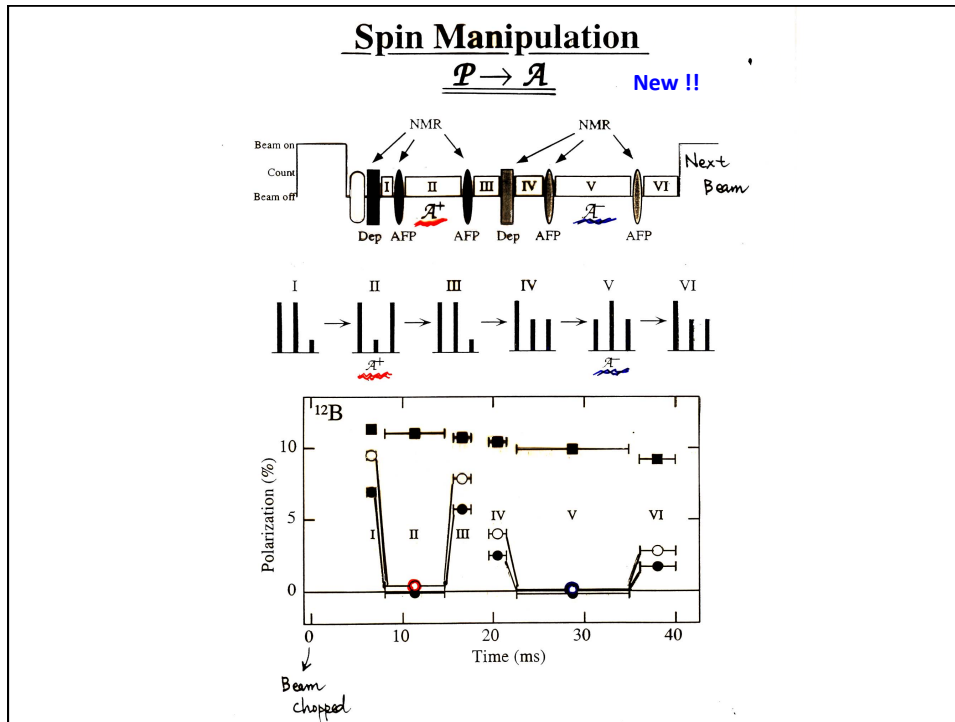
case ; $I = 1$
 $H_0 = \text{Constant}$ 

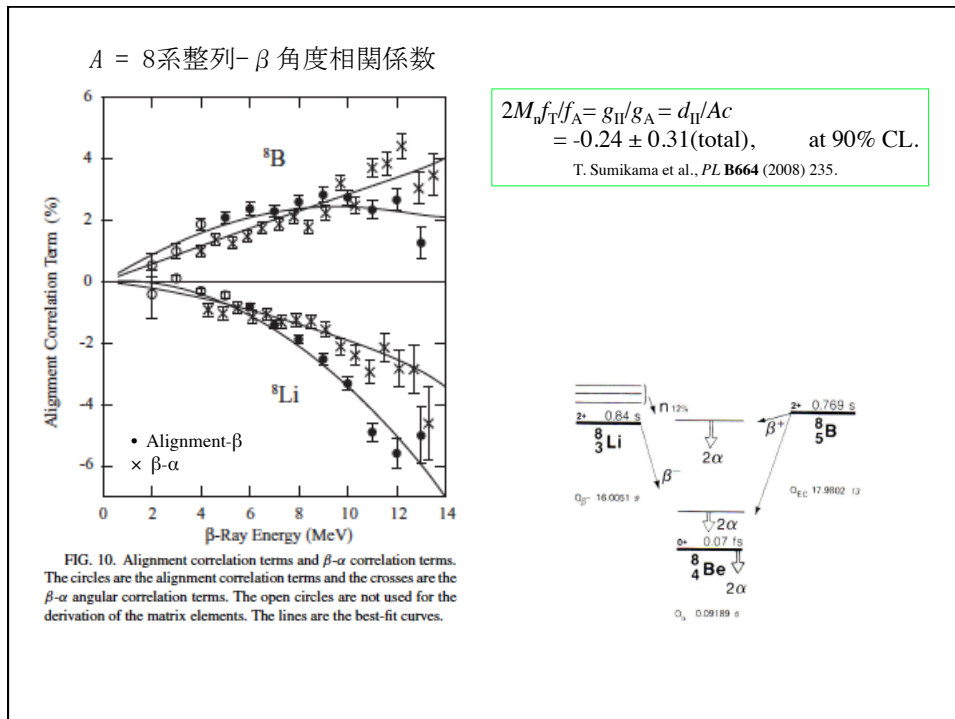
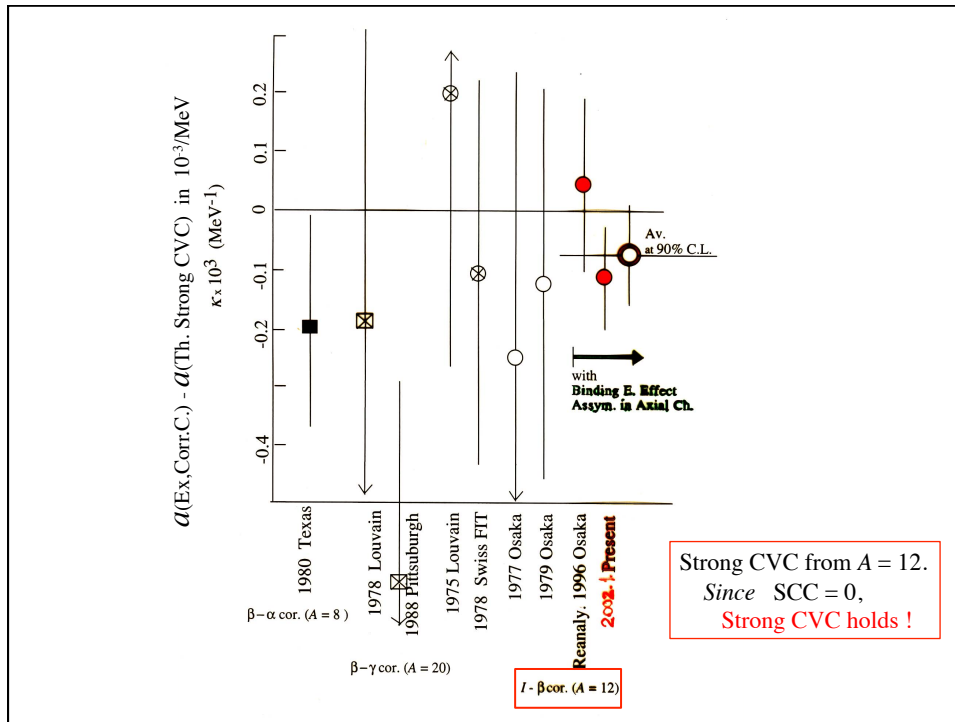
Conditions

initial polarization	$P_0 > 0$	$P_0 \sim 10\%$ (^{12}B) $\sim 20\%$ (^{12}N)
initial alignment	$A_0 > 0$	$A_0 \sim 5\%$ ($^{12}\text{B}, ^{12}\text{N}$)
magnetic moment	$\mu > 0$	
quadrupole coupling constant	$eqQ < 0$	(in Mg)
EFG orientation	$\beta = 0^\circ$	($\parallel H_0$)

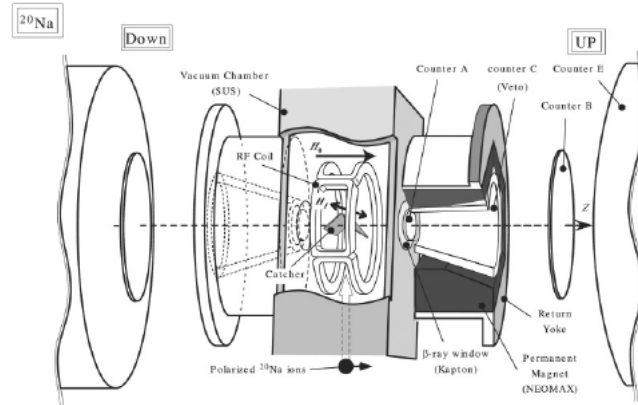
$$eqQ/h \text{ (}^{12}\text{B)} = -47.0 \pm 0.1 \text{ kHz}$$

$$\text{(}^{12}\text{N)} = -59.3 \pm 1.7 \text{ kHz}$$



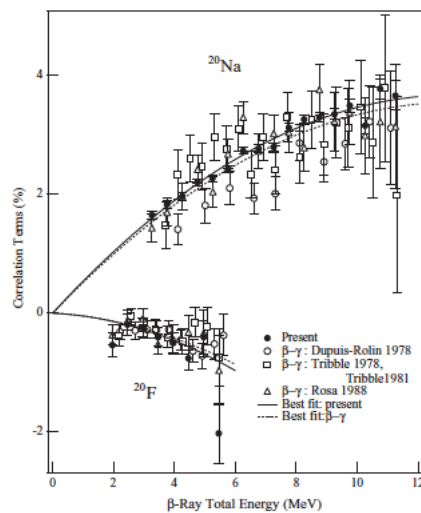


A=20 整列-β角度分布相関係数



TRIUMF 偏極RI 実験コース
阪大ーTRIUMF国際共同

A= 20 整列-β角度分布相関係数



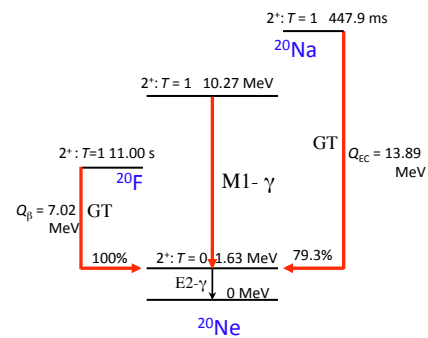
整列-β相関係数+ β-γ 相関係数
同時分析.

$$2Mf_T f_A = g_T / g_A = d_{II} / A c$$

$$= 0.18 \pm 0.42(\text{stat}) \pm 0.24(\text{syst})$$

$$= 0.18 \pm 0.48(\text{total}). \text{ At } 90\% \text{ CL.}$$

K. Minamisono et al., *PR C* **84** (2011) 055501.





KDR Model

K. Kubodera, J. Delorme and M. Rho,
Nucl. Phys. **B66**, 253 (1973).

$$if_T \sigma_{\lambda\rho} k_\rho \gamma_5 \rightarrow i(f_T \sigma_{\lambda\rho} k_\rho \gamma_5 + if_T' P_\lambda \gamma_5)$$

$$\zeta = -(f_T + f_T') : \text{OFF Shell Effect}$$

$$\omega \rightarrow \pi + e + \nu : \lambda : \text{G Violating Decay}$$

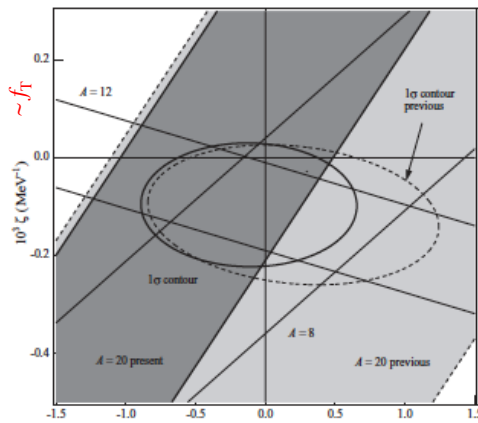
$$k = \zeta + \lambda L \approx f_T$$

K. Kubodera et al.,
Phys. Rev. Lett. **38**, 321 (1977).
M. Oka et al.,
Phys. Lett. **B 90**, 45 (1980).

k from Correlation Type Experiments

<i>A</i>	$10^3 k \text{ (MeV}^{-1}\text{)}$	<i>L</i> (MeV ⁻¹)	Reference
8	-0.19 ± 0.18 $\beta-d$	-0.25	R. E. Tribble et al., Phys. Rev. C 12 , 967 (1975). R. D. Mckeown et al., Phys. Rev. C 22 , 738 (1980). L. De Braeckeleer et al., Phys. Rev. C 51 , 2778 (1995).
12	-0.10 ± 0.09	0.09	Present Experiment K. Minamisono et al., Phys. Rev. C65 , 015501 (2002).
20	-0.27 ± 0.40 $\beta-\gamma$	-0.43	N. D. Rolin et al., Phys. Lett. 79B , 359 (1978). R. E. Tribble et al., Phys. Rev. C 22 , 738 (1980). R. D. Rosa et al., Phys. Rev. C 37 , 2722 (1988).

A = 8, 12, 20 SCC/KDR Constraint



$$ig_T \sigma_{\lambda\rho} k_\rho \gamma_5 \rightarrow i(g_T' \sigma_{\lambda\rho} k_\rho \gamma_5 + ig_T'' P_\lambda \gamma_5).$$

$$[2M\zeta = g_T' + g_T'']$$

$$\lambda = \frac{m_\pi^3 g_{\pi NN}^2}{24\pi M^2} \left(\frac{g_T''}{2M} - \frac{g_{\omega NN} F_\omega}{g_{\pi NN} m_\omega^2} \right),$$

$$\kappa = \zeta + \lambda L \approx \frac{g_T}{2M},$$

$$2M\zeta = g_T' + g_T'',$$

L = matrix e. of the 2-body transition op.

No Short range corr.

$$\kappa(A=8) = -(0.16 \pm 0.20) \times 10^{-3} \text{ MeV}^{-1},$$

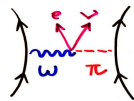
$$\kappa(A=12) = -(0.10 \pm 0.09) \times 10^{-3} \text{ MeV}^{-1},$$

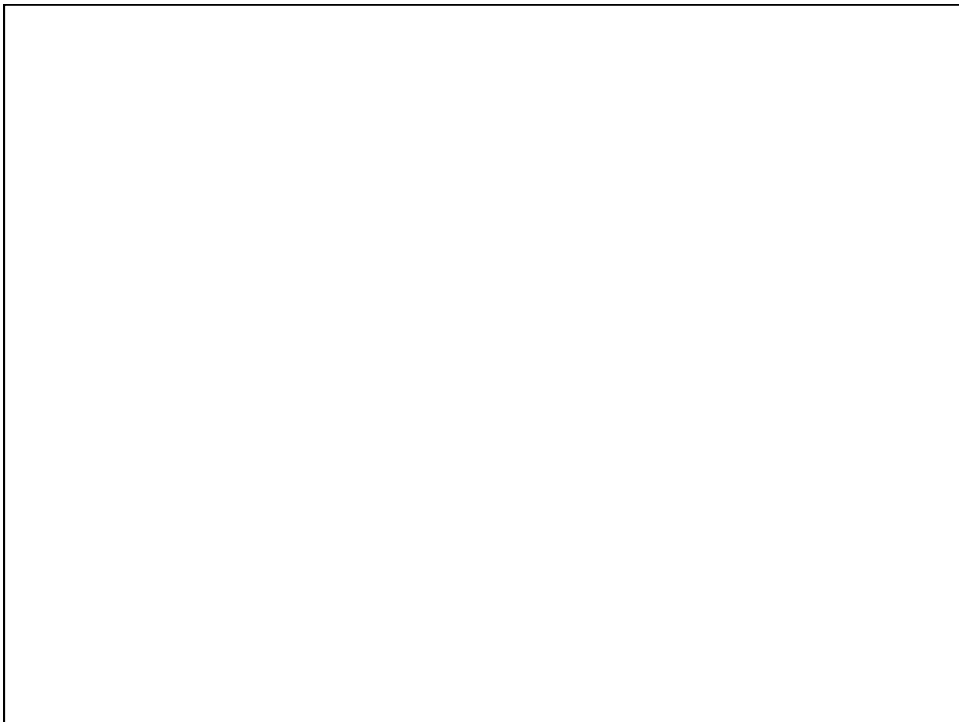
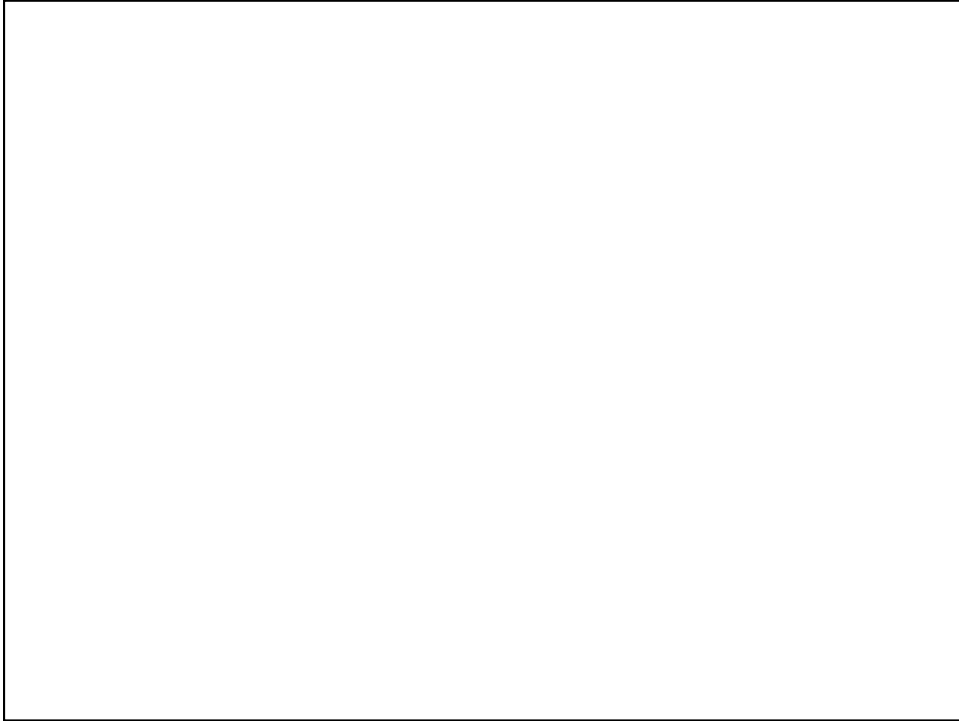
$$\kappa(A=20) = -(0.12 \pm 0.33) \times 10^{-3} \text{ MeV}^{-1}.$$

$$\zeta = -(0.10 \pm 0.13) \times 10^{-3} \text{ MeV}^{-1},$$

$$\lambda = -(0.10 \pm 0.77) \times 10^{-3} \text{ MeV}^{-1}.$$

$$\omega \rightarrow \pi + e + \nu$$





Axial Charge : g

(1) Purely Obtained

$$y_{\pm} = -2M \frac{[i\gamma_5]r}{\int \sigma}$$

$$\frac{\left(\frac{1}{E} \frac{B_2(E)}{B_0(E)}\right)_{12B} + \left(\frac{1}{E} \frac{B_2(E)}{B_0(E)}\right)_{12N}}{2} = -\frac{2}{3} \frac{y}{M}$$

(2) Large π -on Contribution

$\sim 40\%$ Enhancement relative to IA value

K. Kubodera, J. Delorme and M. Rho,
Phys. Rev. Lett. 40 (1978) 755.

Result of the Theoretical Fit

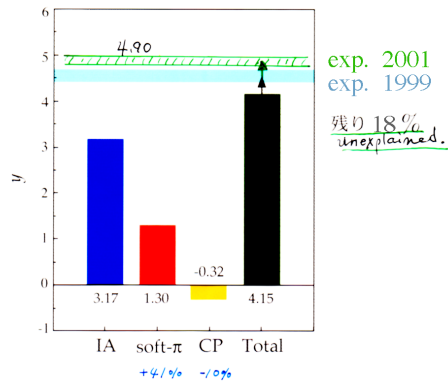
Year	$2M_{\rm T}^f/f_{\rm A}$	Error			Year	y	Error					
		stat	syst	theor.			stat	syst				
Without Δy					2001	4.97	0.09	0.05				
2001	-0.31	0.09	0.07									
1996	-0.02	0.17	0.15									
With Δy									1996	4.65	0.17	0.14
2001	-0.21	0.09	0.07	0.05								
1996	+0.08	0.17	0.15	0.05								
Mean	-0.15	0.12	0.05	Mean	4.90	0.10						

All values are in the unit of $1/2M$.

$$y = 0.10 \pm 0.05 : \text{Asymmetry in } y$$

$$a = \frac{4.04 \pm 0.03}{2M} : \text{Weak Magnetism}$$

Ex. Axial Ch. Comp. With Theory
Axial charge of $A = 12$



Hauge-Morpuru
+
Sussex

K. Koshigiri, M. Morita
Prog. Theor. Phys. 66(8) 358.

K. D. R.
Phys. Rev. Lett. 40(78) 255

How can the discrepancy
be explained?

1, Nuclear Structure : $A=12$ OK
(core polarization)

- K. Koshigiri, et al.,
Proc. Nuclear Weak Processes and Nuclear Structure ('89) 152
- E. K. Warburton
Phys. Rep. 243 ('94) 103

2, Heavy Meson Exchange

- K. Koshigiri, et al. Proc 4th Int. Conf. WEIN ('95) P361
- M. Kirchbach, et al. Nucl. Phys. A542 ('92) 616
- I. S. Towner. Nucl. Phys. A542 ('92) 631

: 18% Discrepancy is left unexplained

3, In-Medium Scaling of
Nucleon masses

- Tae-Sun Park, et al. Nucl. Phys. A579 ('94) 381
- G. E. Brown and M. Rho, Phys. Rev. Lett 66('91) 2720

In-Medium Mass Renormalization

$$\frac{m_N^*}{m_N} \equiv \frac{m_\sigma^*}{m_\sigma} \equiv \frac{m_\rho^*}{m_\rho} \equiv \frac{m_\omega^*}{m_\omega} \equiv \frac{f_\pi^*}{f_\pi} \equiv \Phi(\rho)$$

$$M_1^* = \frac{M_1}{\Phi} \quad \text{1 Body Axial Charge Matrix}$$

Tae-Sun Park, et al.,
Nucl. Phys. A579 ('94) 381
G.E. Brown and M. Rho,
Phys. Rev. Lett. 66 ('91) 2726

$$M_2^* = \frac{M_2}{\Phi} \quad \text{2 Body}$$

$$\varepsilon_{MEC} \equiv \frac{M_1^* + M_2^*}{M_1} = \frac{1}{\Phi} \left(1 + \frac{M_2}{M_1} \right)$$

$$M_1^* + M_2^* = 4.90 \pm 0.09 \quad : \text{Present Experiment}$$

$$\left. \begin{array}{l} M_1 = 2.85 \\ M_2/M_1 = 0.46 \pm 0.06 \end{array} \right\} \text{Theory}$$

$$\Phi(A=12) = (84 \pm 4) \%$$

Mass Reduction of (16 ± 4) %

(90% CL)

T. Minamisono et al., PRL 82, 39, 1994
K. Minamisono et al., PRC 66, 1, 2002

In-Medium Mass Renormalization

$$A = 12 \quad -(16 \pm 4) \% \quad \begin{array}{l} \text{Present work} \\ \text{Alignment Correlation Term} \end{array}$$

$$A = 208 \quad -(17 \pm 9) \% \quad 0^+ \rightarrow 0^+$$

$$A = 132 \quad -(7 \pm 4) \% \quad \text{First Forbidden } \beta \text{ Decay}$$

E.K. Warburton, et al.,
Phys. Rep. 243 ('94) 103

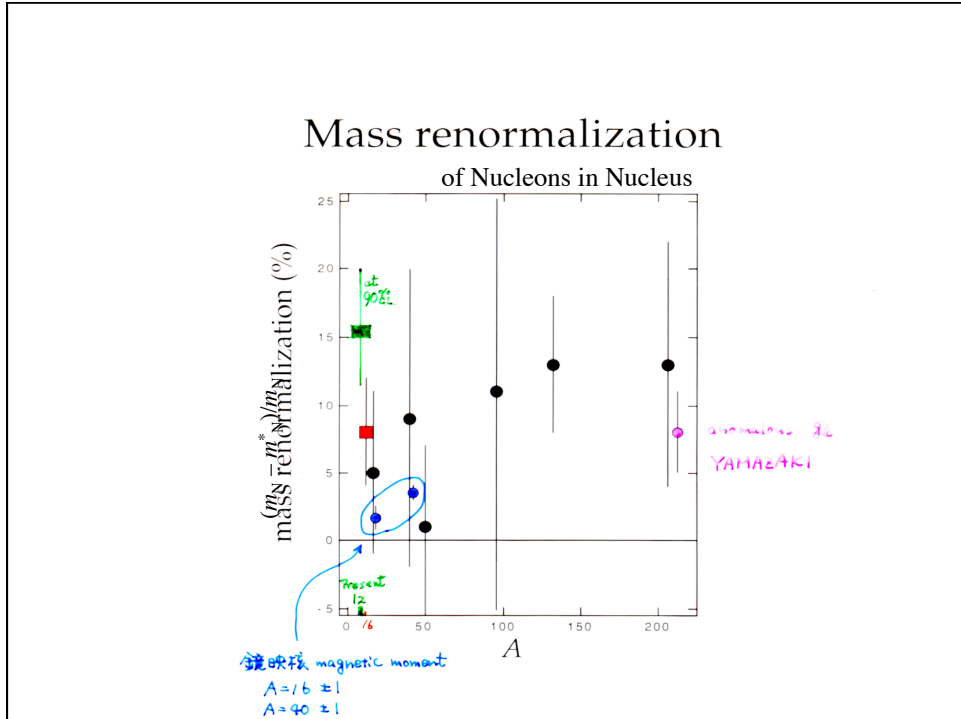
K. Kubodera, et al.,
Phys. Rev. Lett. 67 ('91) 3479

$$A = 16 \text{ and } 40 \quad \sim -3 \% \quad \begin{array}{l} \text{Magnetic moment of} \\ \text{mirror nuclei} \end{array}$$

T. Minamisono et al.,
Nucl. Phys. A516 ('90) 365 Nuclear Moment

$$A \sim 200 \quad -(8 \pm 3) \% \quad \begin{array}{l} \text{Anomalous orbital} \\ \text{g-factors} \end{array}$$

T. Yamazaki
Phys. Lett. 160 B ('85) 227 Nuclear Moment



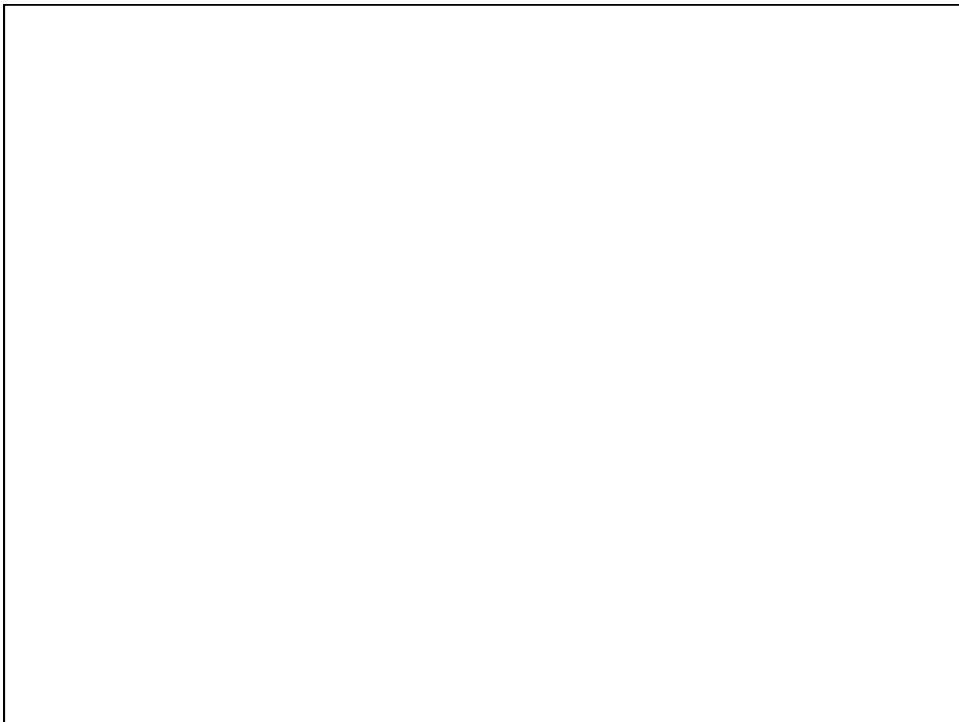
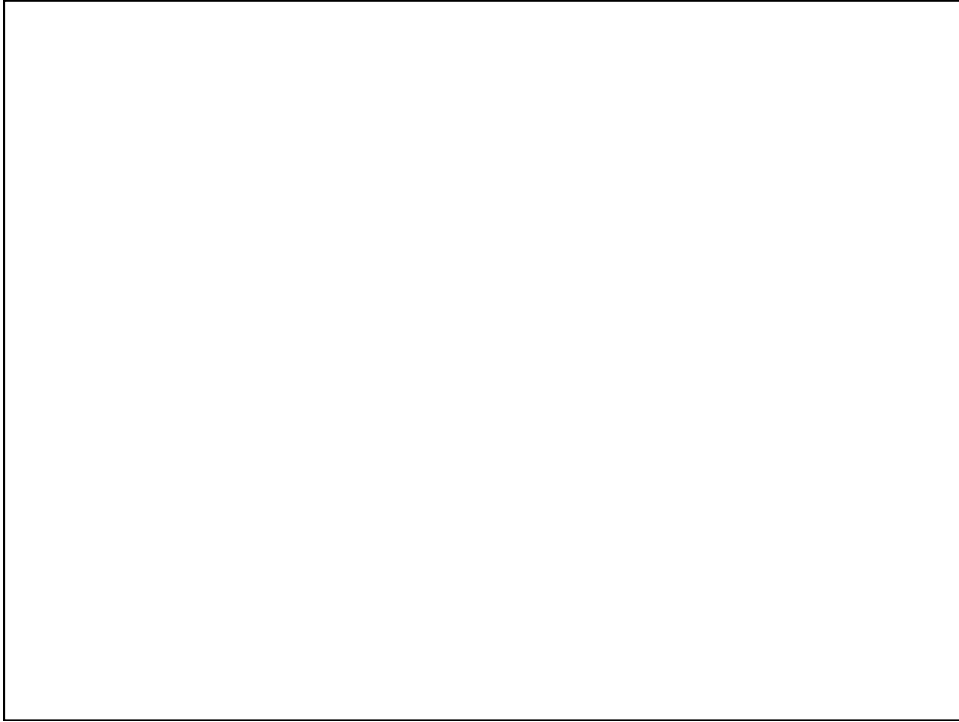
おわりに

- 核磁気モーメントと二重閉殻±1核子核の殻構造
Spin Dewar、実験法の発展、 δg_I 、 m^* 、 ^{12}C の $\langle \sigma \rangle$ 異常、
- 体心立方結晶内電場勾配理論と核四重極モーメント 一重閉殻±1核子核の Q —
閉殻近傍核の Q と実効電荷異常、 $A=40$ core, deformed?
安定核 Q 、HFI(atomic)、の見直し必要。
- 弱核子流SCCの存在限界と核内核子質量再規格化
SCCは小さい！ $A=12$ 系結論；
 $2M_T/f_A = -0.15 \pm 0.12 \pm 0.05(\text{theory})$, at 90% CL.
Strong CVC を保証した！
整列核- β 線角度相関係数 $\leftrightarrow$ Quark mass差 ($m_u - m_d$) に近い？
Hyperon- β 線角度相関係数測定なら シグナル20倍！
Axial Chargeの巨大マソン効果 $\leftrightarrow (m - m^*)/m = 16\%$ ！
- Dr. Science 21人、修士70人巣立って行きました。

このあと、

- 反応断面積と核子密度分布

福田光順



実験原理: $P_0 // H_0 \perp H_1$

^{17}F の β -NM(Q)R装置(1970);
 室温測定: 単結晶選択 ($T_1 \leq 100\text{s}$)
 HFIの理解 μ 測定から向上(偏極の保持)
 ^{17}F 収率極大化(標的構造)/KS66 10倍
 偏極(核反応)条件の選択/KS66 5倍

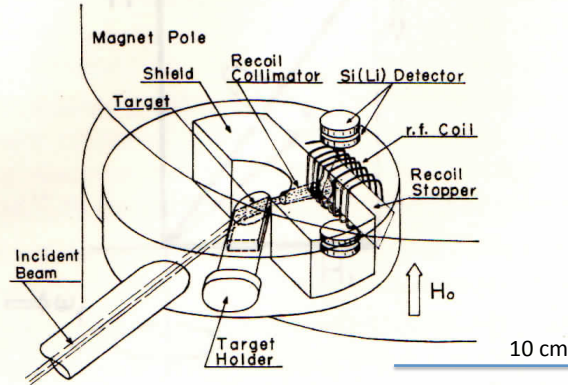


Fig. 1. Schematic view of the nuclear-magnetic-resonance experiment.

1. はじめに

$^{152}\text{Sm}^*(I^\pi=2^+, T_{1/2}=1.4\text{ns})$ $W(\theta)$ 回転

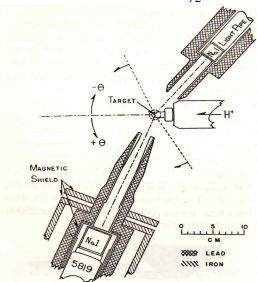


Fig. 4. Plan view of the detector arrangement.

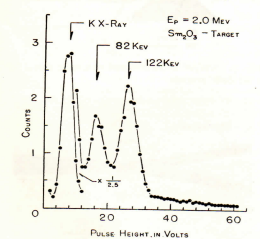


Fig. 5. Pulse height spectrum obtained by bombarding the samarium oxide target with 2 MeV protons. The 122 keV and 82 keV peaks were identified with the de-excitation radiation from the samarium isotopes of Sm^{152} and Sm^{154} respectively.

was corrected within 1%.
 The pulse height spectrum of the scintillation spectrometer obtained by bombarding the samarium oxide target with 2-MeV protons is shown in Fig. 5. Radiation from a tantalum target was used to calibrate the energy scale. When the angular yield was measured, the net yield for the 122-keV radiation was determined from the count of the peak portion of the spectrum by subtracting the background which was estimated by extrapolating the just upper part of the spectrum.

§ 3. Experimental Results and Derivation of g -factor

The observed angular distributions of the 122-keV radiation at the magnetic field of ± 22000 -gauss are shown in Fig. 6.

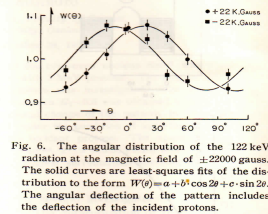


Fig. 6. The angular distribution of the 122-keV radiation at the magnetic field of ± 22000 gauss. The solid curves are least-squares fits of the distribution to the form $W(\theta) = a + b \cos 2\theta + c \sin 2\theta$. The angular deflection of the pattern includes the deflection of the incident protons.

The theory of the Coulomb excitation predicts the angular distribution of the 122-keV radiation following the excitation by 2-MeV protons as follows,

$$W(\theta) = 1 + 0.142 \cdot \cos 2\theta + 0.002 \cdot \cos 4\theta$$

When the analysis of the observed distribution was done, the term of $\cos 4\theta$ was neglected. And the experimental points were fitted by the method of least-squares. The apparent angular shift of the pattern thus obtained was

御逝去:

杉本健三先生 (12.10.06.)

金森順次郎先 (12.11.14.)

放射線検出HFI開始, 1958.

cf. 菊池, 渡瀬, γ - γ Ang. Corr.;

Z. Phys. **119** (1942) 185.

Hamilton, Ang. Corr.(Th); 1940.

Nuclear Spin Orientations produced through Nuclear Reactions were first introduced into the HFI studies.

Implantation in substitutional site in Sm_2O_3 .

世界を牽引.

J. Phys. Soc. Jap. **13** (1958) 240.

$^{152}\text{Sm}^*(122 \text{ KeV})$ in Sm_2O_3 .

$g(^{152}\text{Sm}^*, 2^+) =$

$+(0.36 \pm 0.16) \text{ nm.}$

1. はじめに 2

 ^{19}F in C ℓ F, K. Sugimoto

1548

Short Notes

(Vol. 13,

J. PHYS. SOC. JAPAN **13** (1958) 1548**Quadrupole Moment of the Second Excited State of ^{19}F**

By Kenzo SUGIMOTO*, Akira MIZOBUCHI and Hisasi YAMAMOTO

Department of Physics, Faculty of Science, Osaka University, Osaka

(Received October 9, 1958)

Angular distributions of the 200-keV gamma-radiations by the reaction $^{19}\text{F}(p, p')^{19}\text{F}^*$ have been measured by bombarding a CaF_2 target and also a polytetrafluoroethylene $((\text{C}_2\text{F}_4)_n)$ target of each about 200-keV thickness for 1.4-MeV protons. Each distribution was fitted to the form $W(\theta)=1+A_2G_2P_2(\cos\theta)$, where A_2 is the coefficient of the

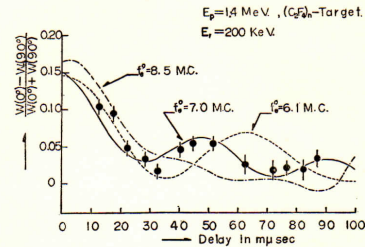


Fig. 1. Delayed angular distribution of the 200-keV radiations. The curves drawn in this figure were calculated theoretically for the respective frequency of the quadrupole coupling f_Q . The errors indicated are only statistical ones.

relation is shown in Fig. 1. The curves drawn in

$^{19}\text{F}(I^\pi=5/2^+, T_{1/2}=89 \text{ ns}, E_x=197 \text{ keV})$ in C ℓ F,
EFG at F in C ℓ F molecule was calculated by J. Kanamori.

6. 問題が残った.

- OXBASH# $e_\nu^{\text{eff}} = 0.50e$, $e_\pi^{\text{eff}} = 1.3e$ $(Q_{\text{exp}} - Q_{\text{th}})/Q_{\text{exp}} = -(15 \sim 30)\%$
- HF* $e_\nu^{\text{eff}} = 0.34e$, $e_\pi^{\text{eff}} = 1.323e$ **-30%**

H. Sagawa & B.A. Brown; *NP A430* '84 77.

* H. Kitagawa; *PTP 102* '99 1015.

浅い陽子分離エネルギーを取り入れた！

Wave F. と Q_{exp} より、effective ch. に責任転嫁すると、

- OXBASH# $e_\nu^{\text{eff}} = 0.275e$, $e_\pi^{\text{eff}} = 1.124e$ Average(A=17, 19, 21)
- HF* $e_\nu^{\text{eff}} = 0.362e$, $e_\pi^{\text{eff}} = 0.89e$ Averaged(A=17, 21)

異常に小さくなっている.

説明の必要が残った.

緩く結合している核子による core polarization の評価？

FPKKR の信頼性を疑う必要が有るか？

Q (OXBASH);

Table 12: The quadrupole matrix elements of F isotopes calculated with the OXBASH code [ON02]. The quadrupole moments are deduced from then and Sagawa's effective charges [SA84].

nucleus	I^π	$Q(N_p)$ (mb)	$Q(N_n)$ (mb)	Q (mb)	$Q(\text{mb})$ HF	$Q(\text{mb})$; Exp.
W interaction						
^{17}F	$5/2^+$	-60.5	0.0	-74.4	-93.0	-68 ± 9
$^{19}\text{F}^*$	$5/2^+$	-44.8	-76.4	-89.5		-73 ± 9
^{20}F	2^+	+25.1	+54.6	+55.4		$+46 \pm 5$
^{21}F	$5/2^+$	-51.0	-87.4	-102	-105	-80 ± 9

Q (HF);

Table 13: The quadrupole matrix elements calculated using the HF wave functions [KI99]. The quadrupole moments are deduced from then and Sagawa's effective charges [SA84].

nucleus	I^π	$Q(N_p)$ (mb)	$Q(N_n)$ (mb)	Q (mb)	
^{17}F	$5/2^+$	-75.613	0.000	-93.0	$e_\pi^{\text{eff}} = 1.323$
^{21}F	$5/2^+$	-50.363	-96.628	-105	$e_\nu^{\text{eff}} = 0.34$

H. Sagawa & B.A. Brown, N.P.A **430** '84 84.
H. Kitagawa, Progr. Theor. Phys. **102** '99 1015.

$Q(\text{F})/Q(^{19}\text{F}, 5/2^+)$

nuclei (E_x , keV)	Experimental ratio ($^{19}\text{F}^*=1$)	Theoretical (OXBASH, W interaction)			
		ratio	$Q(\text{mb})$	$Q_p(\text{mb})$	$Q_n(\text{mb})$
^{17}F	0.847 ± 0.024	0.815	-78.6	-60.5	0.0
$^{19}\text{F}^*(197)$	1.000 ± 0.031	1.000	-96.4	-44.8	-76.4
^{21}F	1.001 ± 0.009	1.141	-110.0	-51.0	-87.4
^{23}F	—	0.805	-105.4	-56.4	-64.2

1. はじめに 3

軽核領域のQモーメント測定の実況

