Neutrino Studies By Double Beta Decays and Nuclear Neutrino Responses*

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1. Neutrino Studies By Double Beta Decays

2. Double Beta Decay Experiments
    2.1 ELEGANT's Exp. at Kamioka-Oto
    2.2 Present Status of Exp.

3. Neutrino Nuclear Responses
    3.1 Nuclear Responses for Double Beta Decays
    3.2 Nuclear Responses for Solar Neutrinos

4. Perspective of Mo Exp, MOON

5. Summary

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Nuclear Physics A 611 (1996) 85–95

NUCLEAR
PHYSICS A

Collaborators

Limits on neutrino-less double beta decay of ^{100}Mo

ββ

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PHYSICS LETTERS B

Physics Letters B 433 (1998) 257–262

ν-Responses.

Spin-isospin responses of ^{71}Ga for solar neutrinos studied by ^{71}Ga(^{3}He,tγ)^{71}Ge reaction

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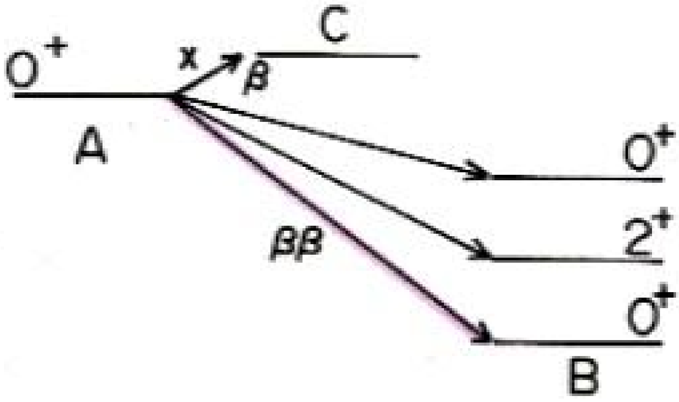
2 Neutrino(ν) Studies by Double Beta Decays($\beta\beta$) and Nuclear Spin Responses

$\beta\beta$: Sensitive To ν & Weak Interactions

$2\nu\beta\beta$: $A(nn) \rightarrow B(pp) + \beta^- + \beta^- + \bar{\nu} + \bar{\nu}$
Lepton Number $L = +2 - 2 = 0$ Conserve
Within Standard $SU(2)_L \times U(1)$ Model

$0\nu\beta\beta$: $A(nn) \rightarrow B(pp) + \beta^- + \beta^-$ (no ν)
Lepton Number $\Delta L = 2$ Violation
ν & Weak Interactions Beyond Standad Model

- ν-Majorana Particle with Mass $<m_\nu>$
- Right-Handed Weak Interactions
- ν-Majoron Coupling,
- SUSY Particle Exchange
- Heavy Neurtino
- Composite ν
- etc



1 Neutrino (ν) Studies in Nuclei and Nuclear Spin Responses

1.1 ν -Studies in Nuclei & Nuclear Spin Responses
-Nuclear Medium Effects-

Nucleus as Micro-Lab. for

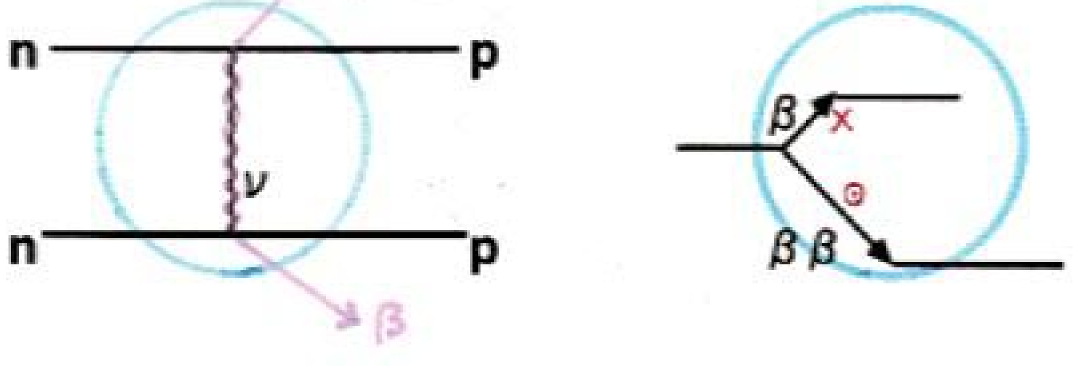
Astroparticles (Leptons) &
Fundmental Interactions (Weak)

Nucleus is Isolated & Cold Quantum System
Nucleons in Good E, J^{π}, T ···states

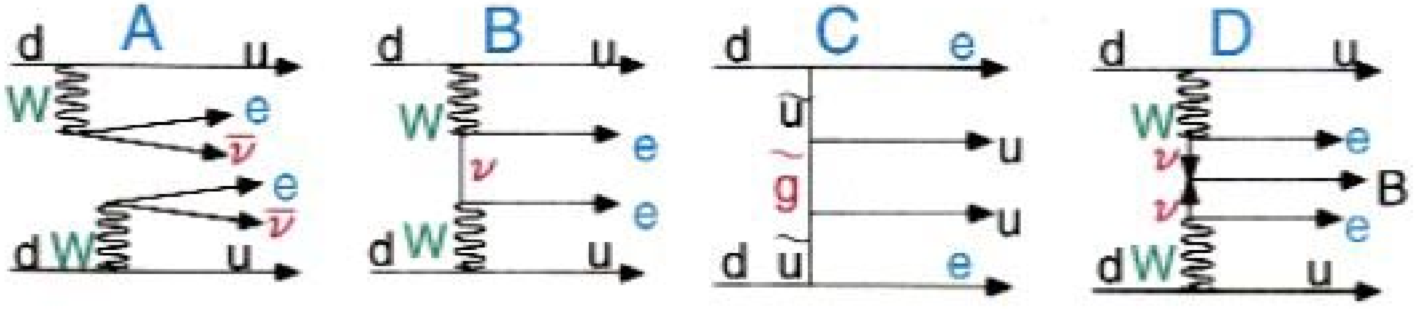
Unique Features of Nuclear Micro-Lab.

Selectivity of Particular Process
$<E_f\ J_f\ T_f\ |\ H_{JT}\ |\ E_i\ J_i\ T_i>$

Enhancement / Filter →Telescope
ν-exchange $\sim 10^{7} \cdot (m_{\nu}/m_{e})^{2}$
$T_{\beta}/T_{\beta\beta}=10^{25} \rightarrow 0$



2.3 $2\nu\beta\beta$ & $0\nu\beta\beta$ Processes



A. $2\nu\beta\beta$ within SM

$T^{2\nu}=G^{2\nu}|M^{2\nu}|$ $G^{2\nu}\propto Q_{\beta\beta}^{11}$

$M^{2\nu}\propto M_{GT}(\sigma\tau\sigma\tau)+M_F(\tau\tau)$ S-wave β

B. $0\nu\beta\beta$ with m_ν, $M(W^R)$, R/L Mixing

$T^{0\nu}=G^{0\nu}|M^{0\nu}|^2(\langle m_\nu\rangle+\langle\lambda\rangle+\langle\eta\rangle)^2$ $G^{0\nu}\propto Q_{\beta\beta}^{5}$

$M^{0\nu}\propto M(h(r_{12}), p_1\ p_2, \sigma_1\sigma_2\tau_1\tau_2)$

Neutrino Potential, Recoil, etc for ν-exchange

$\langle m_\nu\rangle = \Sigma m_j U_{ej}^2$

$\langle\lambda\rangle = \lambda\,\Sigma U_{ej}\cdot V_{ej}$ $\lambda=(M_W^L/W_W^R)^2$

$\langle\eta\rangle = \eta\,\Sigma U_{ej}\cdot V_{ej}$ $\eta=W_L/W_R$ Mixing

C. $0\nu\beta\beta$ with SUSY Exchange ($\tilde{g}$)

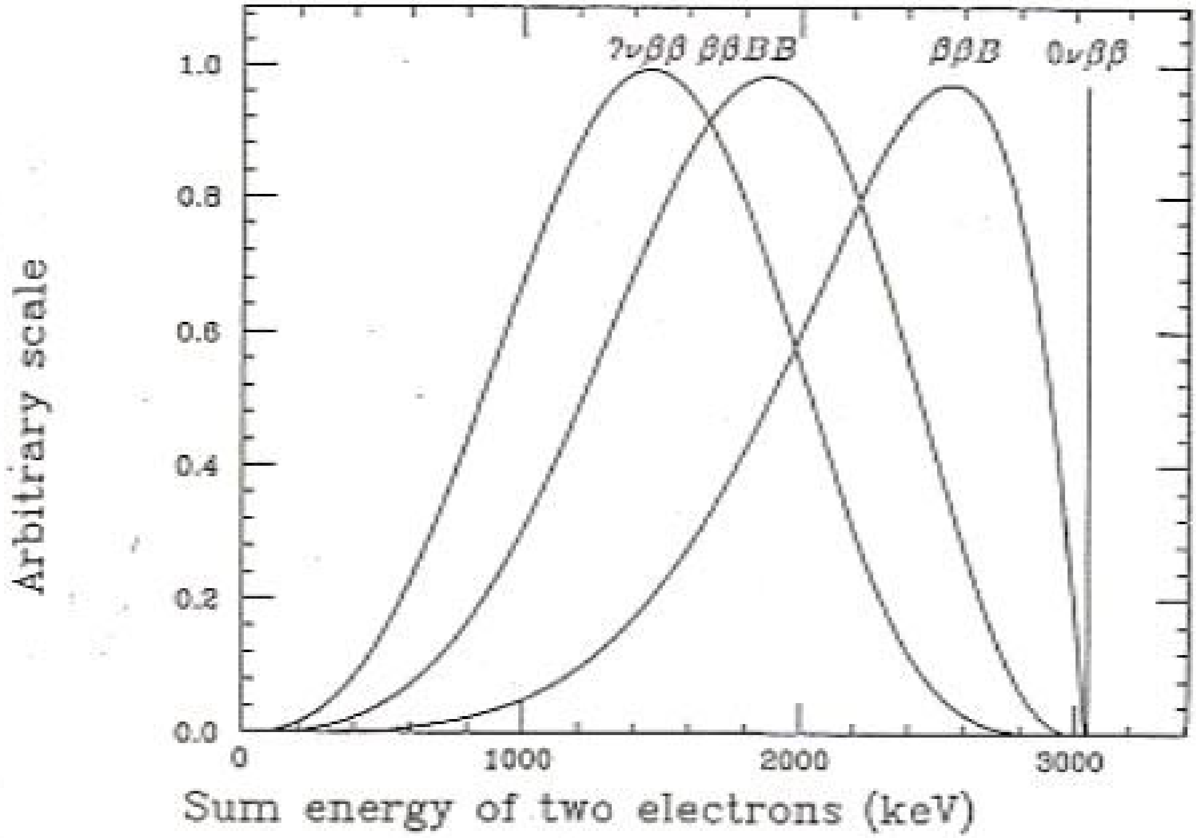
$T^{0\nu}(\tilde{g})=G f^2 M(\tilde{g})\,A\,(M(\tilde{g}))/(M(\tilde{u}))^4$ f=L−B≠0 Int.

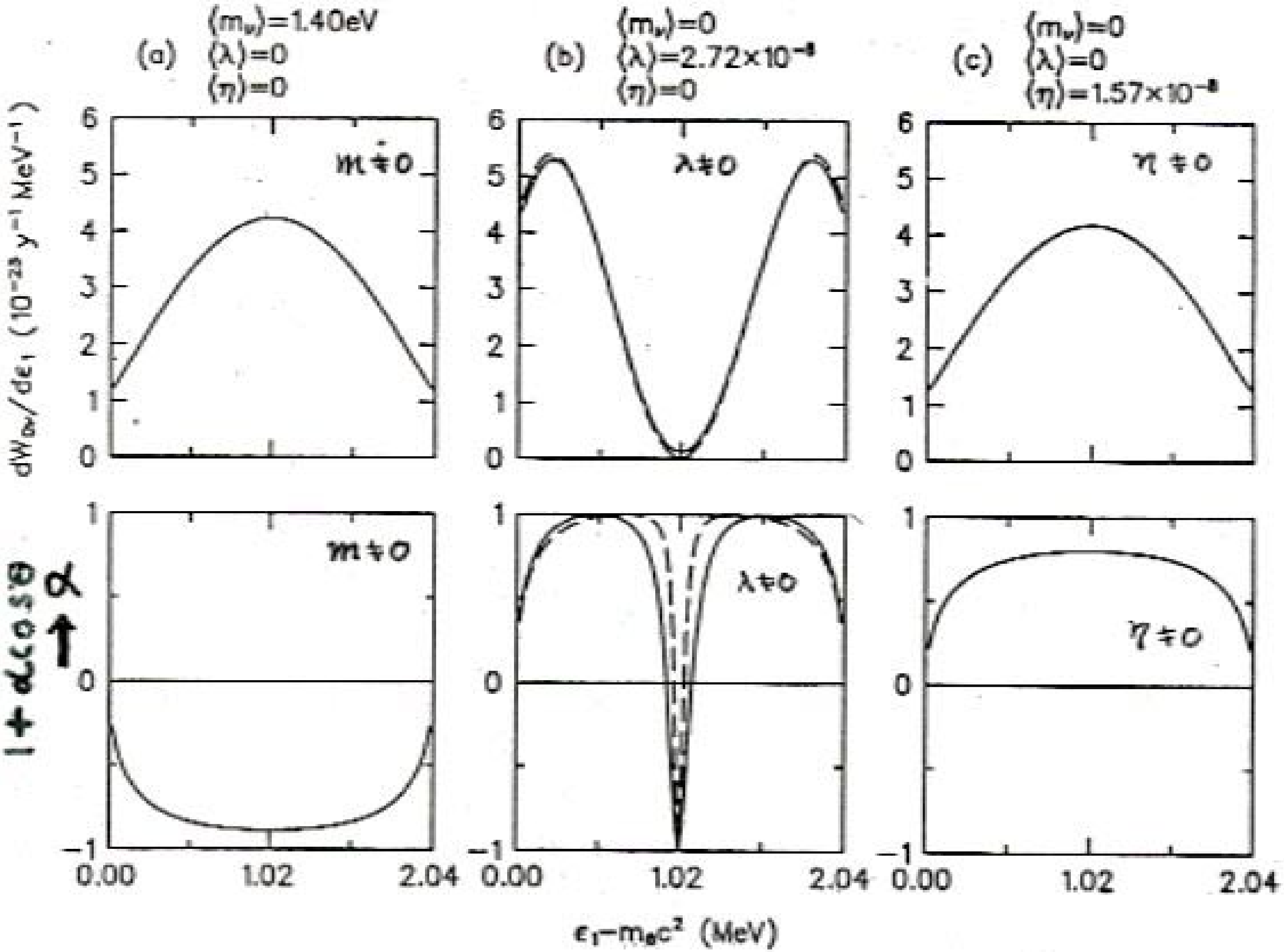
D. $0\nu\beta\beta$ M with Majoron (G-Boson for L−B Break)

$T^{0\nu M}=G^M(M^B)^2\ \langle g_M\rangle^2$

$\langle g_M\rangle=\Sigma g_{jk}U_{ej}\cdot U_{ek}$ g_M: M−ν Coupling

Haxton, Kotani, Mohapatra. Gilman. Hirsh. Takasugi. et al .....
Moe-Vogel. ... Review


2νββ
ββBB
ββB
0νββ
Arbitrary scale
1.0
0.8
0.6
0.4
0.2
0.0
0
1000
2000
3000
Sum energy of two electrons (keV)


(a) $\langle m_\nu \rangle = 1.40$eV
$\langle \lambda \rangle = 0$
$\langle \eta \rangle = 0$
(b) $\langle m_\nu \rangle = 0$
$\langle \lambda \rangle = 2.72 \times 10^{-6}$
$\langle \eta \rangle = 0$
(c) $\langle m_\nu \rangle = 0$
$\langle \lambda \rangle = 0$
$\langle \eta \rangle = 1.57 \times 10^{-8}$
$dW_{0\nu}/d\epsilon_1$ (10^{-23} y^{-1} MeV^{-1})
$m \neq 0$
$\lambda \neq 0$
$\eta \neq 0$
6
5
4
3
2
1
0
$1 + \alpha \cos\theta$
↑
α
1
0
−1
0.00
1.02
2.04
$\epsilon_1 - m_e c^2$ (MeV)

$T^{0\nu} \propto Q^{5}_{\beta\beta}$

$T^{2\nu} \propto Q^{11}_{\beta\beta}$

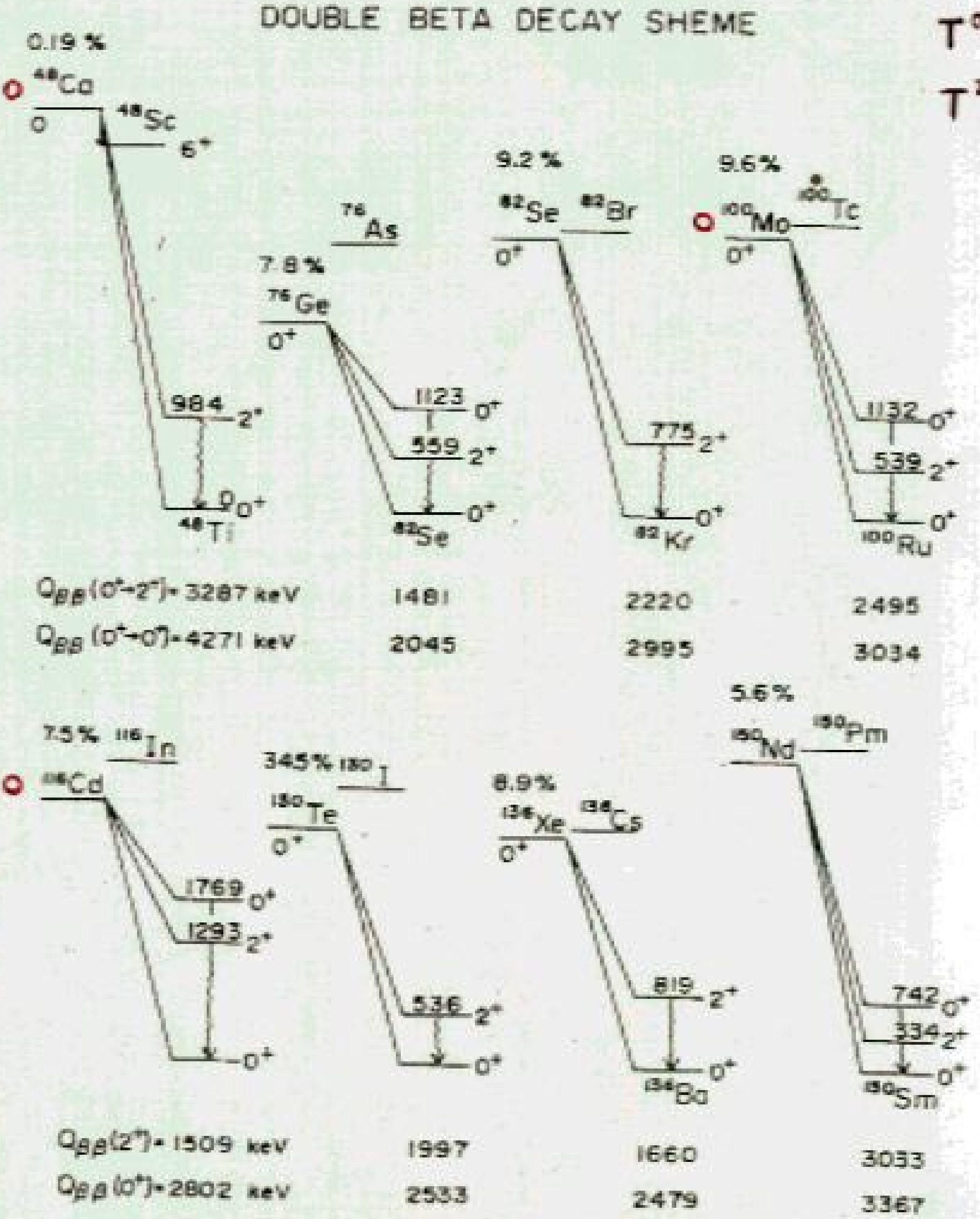


Figure 5: Level schemes of typical double beta decay.

$\beta\beta$ Exp. $A \rightarrow B + \beta + \beta + (\nu + \nu)$

$N_t = N_o k \times G \;\; M^2 \times (m_\nu{}^2) \times t$

G : Phase Space $G^{0\nu} \propto Q^5_{\beta\beta}$, $G^{2\nu} \propto Q^{11}_{\beta\beta}$

M : Nucl. Matrix Element $M^{0\nu}$, $M^{2\nu}$

N_0: No of Source Nucle

k : Efficiency

$(N_{BG})^{1/2} = (N_{BG} \cdot \Delta E \cdot t)^{1/2}$

I Indirect Geochemical & Radiochemical Analysis

Isotope B & Activity of B

Inclusive 0ν & 2ν, $0^+, 2^+, \cdots$ Final states

Long t Accumurate B

^{82}Se, ^{96}Zr, ^{128}Te, ^{128}Te, ^{238}U, etc

II Direct Counter Exp. Exclusive

1 Sum-Energy $\beta + \beta$, Source-Detector : k~1

Ge (^{76}Ge) Detector $\Delta E = 2 \sim 3$

Milano, USC/PNL, UCSB/LBL, Heid・Moscov

Osaka EL III, Zaragoza-Bordeaux

Scintillators ^{48}Ca Beijin, Osaka EL VI, ^{116}Cd Kiev

Thermal Detectors $^{130}TeO_2$ etc Milano, etc, ΔE

2 β-β Tracking β-β Energy & Angular Correlations

separate m_ν, λ, y, etc.

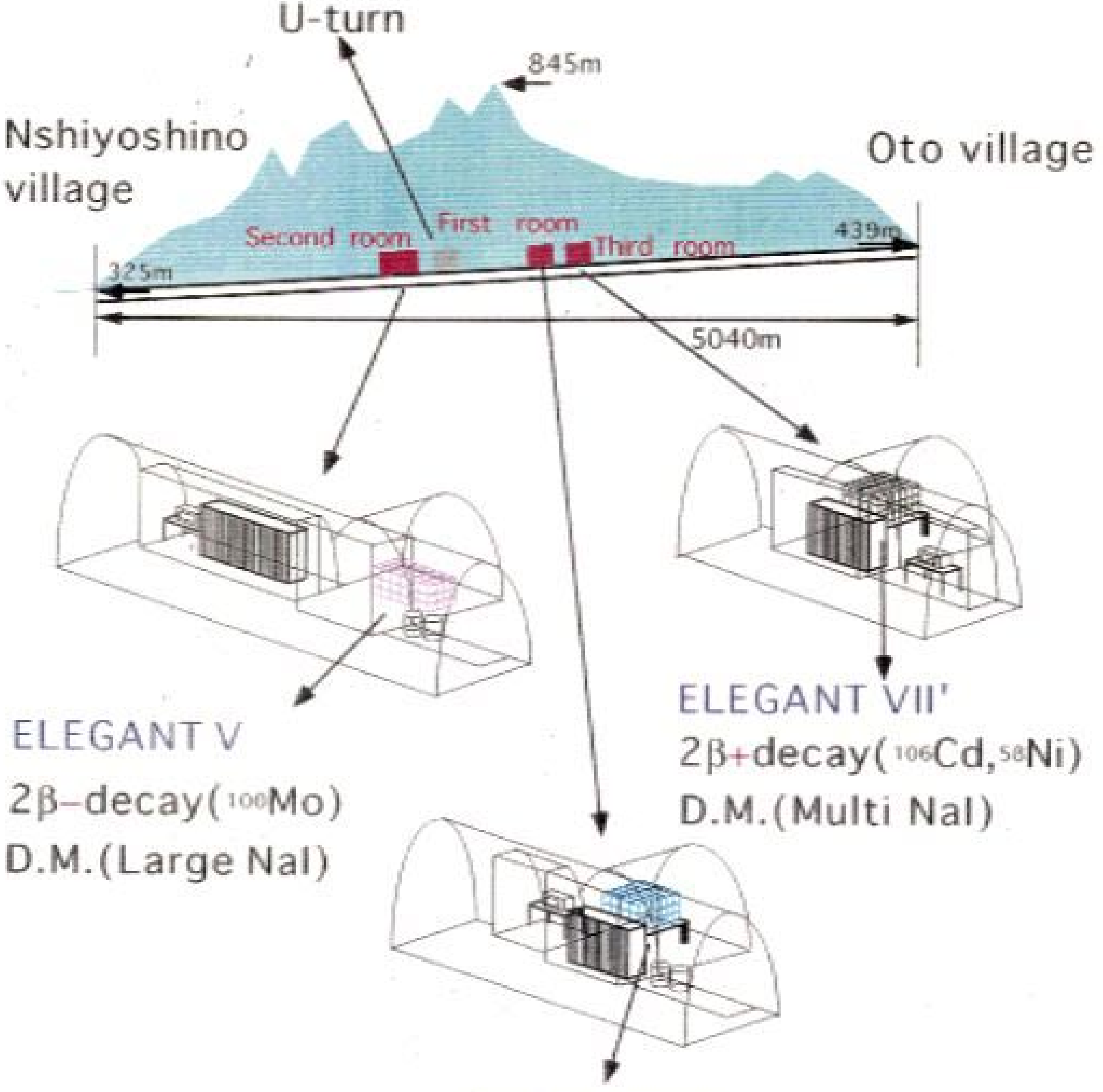
TPC : ^{82}Se Irvine, ^{136}Xe Caltech・Neuchatel PSI

DC・PL : ^{100}Mo, ^{116}Cd Osaka EL.V, MEMO

3 Multi-S_i ^{100}Mo Osaka, EL VI LBL

Oto Cosmo Observatory

Oto Village, Nara prefecture
100km from RCNP
Cosmic ray $4\mathrm{x}10^{-7}$ $\mathrm{cm}^{-2}\mathrm{sec}^{-1}$ (1500m w.e.)
Radon concentration 10Bq/m^3 →0,1 in ELV



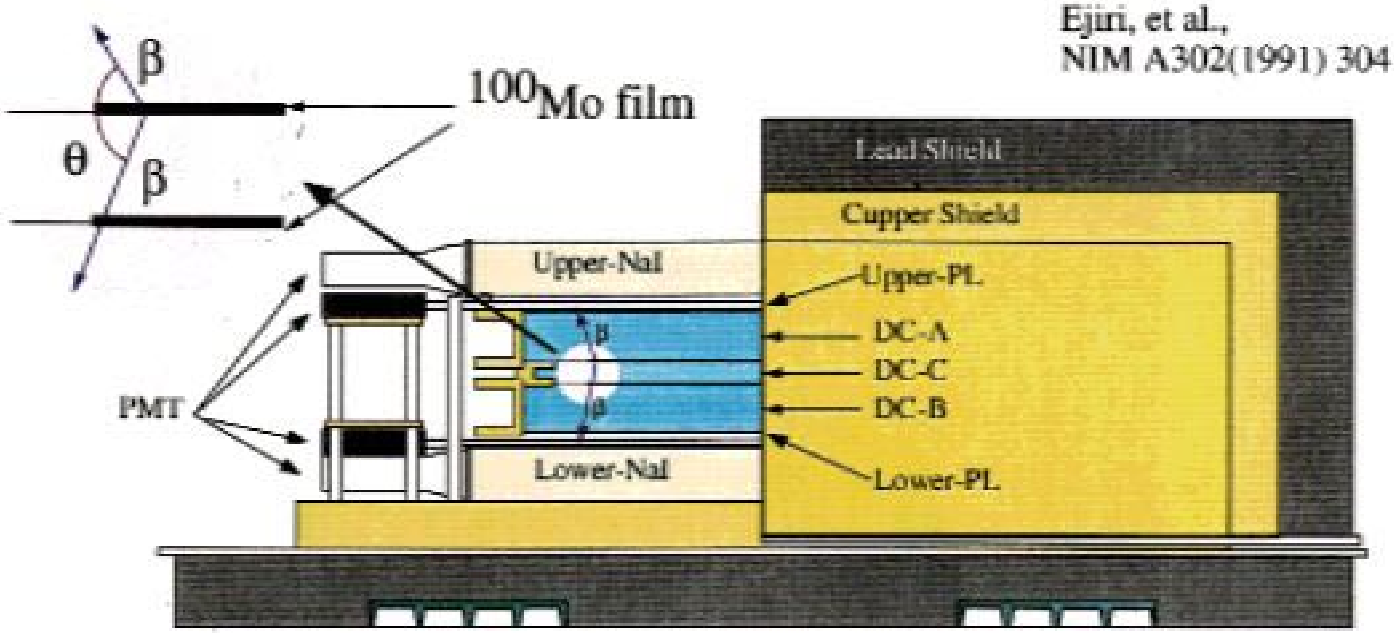
ELEGANT V
2β−decay(^{100}Mo)
D.M.(Large NaI)

ELEGANT VII'
2β+decay(^{106}Cd,^{58}Ni)
D.M.(Multi NaI)

ELEGANT VI
2β-decay(^{48}Ca)
D.M.(CaF)

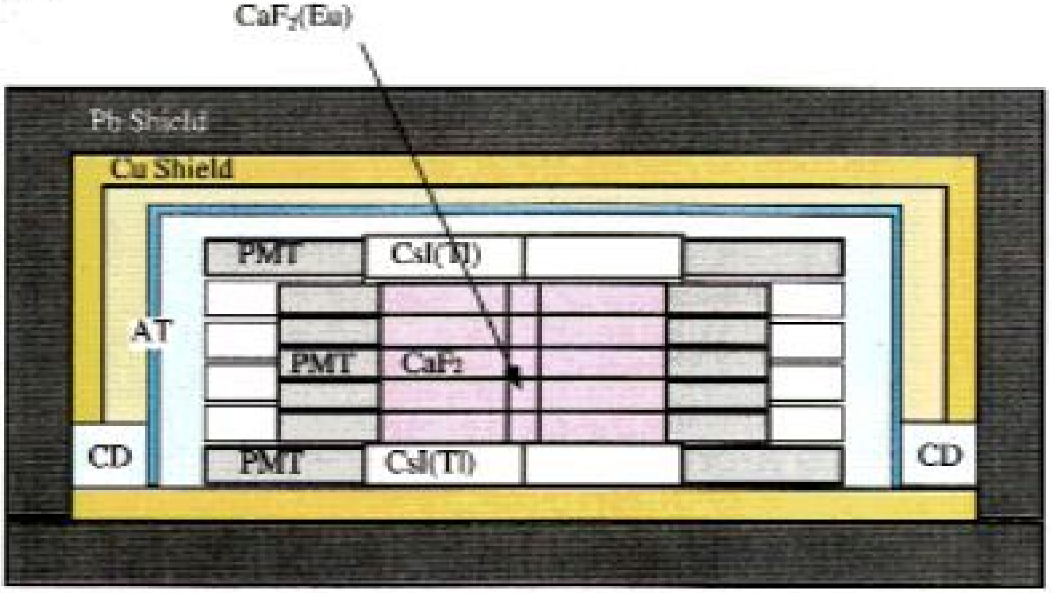
ELEctron GAmma-ray Neutrino Telescope
ELEGANT V & VI

ELEGANT V



Ejiri, et al.,
NIM A302(1991) 304

ELEGANT VI



2.6 $2\nu\beta\beta$ & $0\nu\beta\beta$ on ^{100}Mo by EL V

^{100}Mo

$2\nu\beta\beta$ $1.15 \cdot 10^{19}$ y

$M^{2\nu} = 0.09$ (m_e)

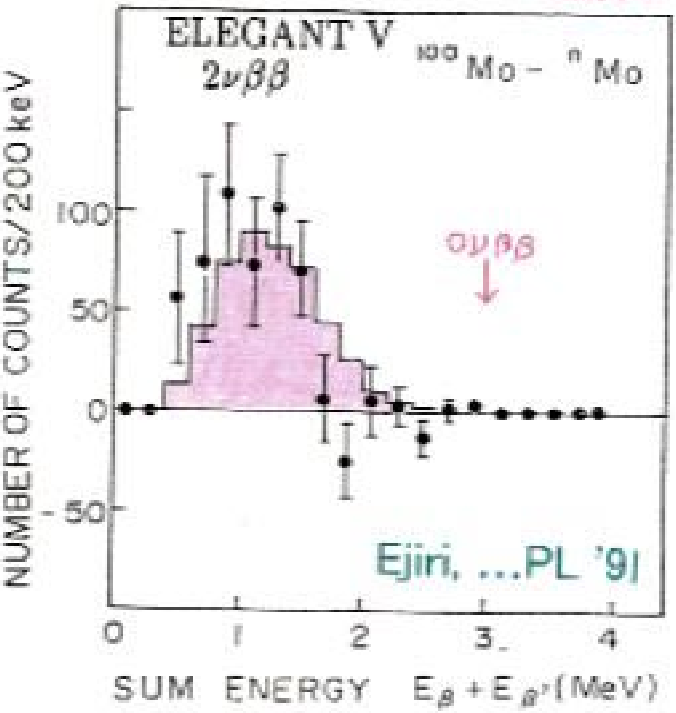
$0\nu\beta\beta$ $> 0.52 \cdot 10^{23}$ y

^{116}Cd

$2\nu\beta\beta$ $2.6 \cdot 10^{19}$ y

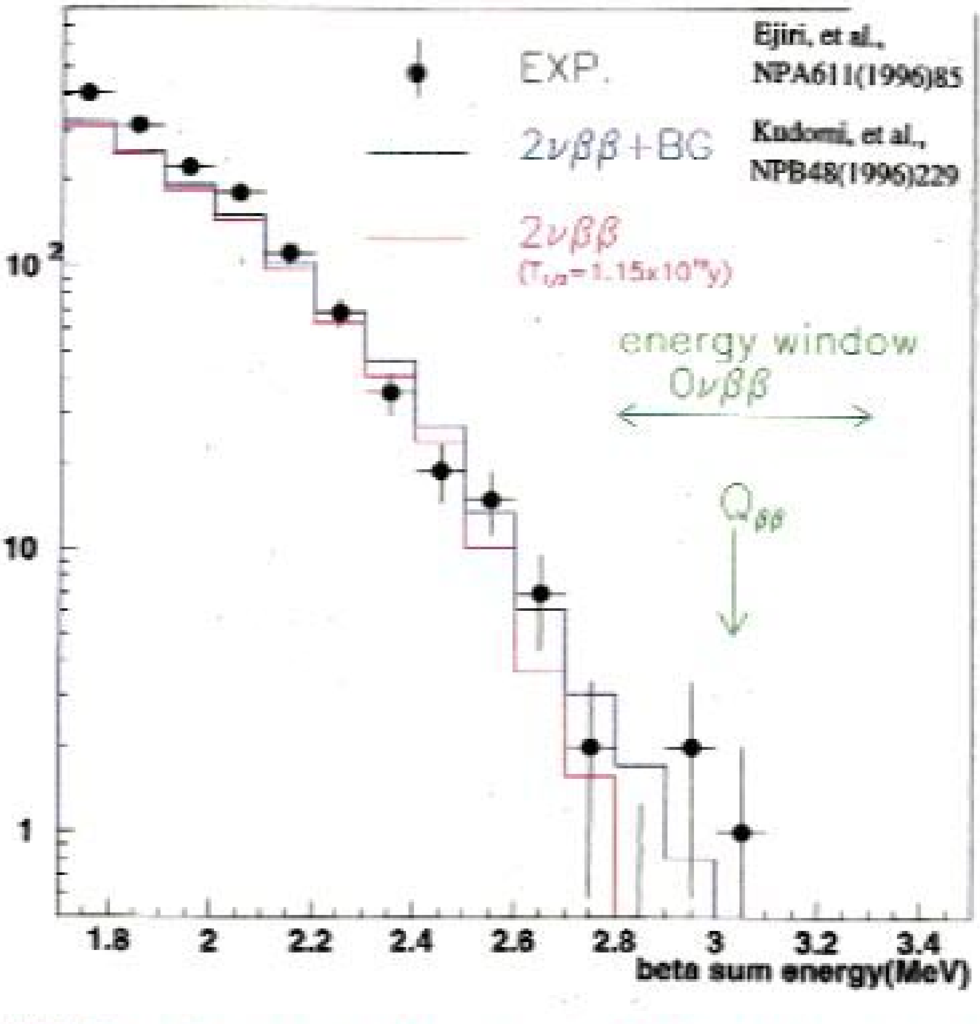
$M^{2\nu} = 0.069$ (m_e)

H.E. et al. '91 '9



Ejiri, ...PL '91

$E_{\beta1}+E_{\beta2}$ Eneryg Spectrum



Ejiri, et al., NPA611(1996)85

Kudomi, et al., NPB48(1996)229

CL.68%

m_ν	$>0.65 \cdot 10^{23}$y
	<1.9eV
λ	$>0.49 \cdot 10^{23}$y
	$<3.2 \cdot 10^{-6}$
η	$>0.64 \cdot 10^{23}$y
	$<2.2 \cdot 10^{-8}$
g_B	$>5.4 \cdot 10^{21}$y
	$<7.3 \cdot 10^{-5}$
m(ν^*)	$>1.8 \cdot 10^{4}$TeV

^{100}Mo, $0\nu\beta\beta$, EL V at Oto (New) Lab. ^{214}Bi α Vet

EL V inside Air-Tight with ~20mBq/m^3 N_2 gass

Goal $0\nu\beta\beta$~$1.4 \cdot 10^{23}$y, m_ν~1.3eV, g_B~$3 \cdot 10^{-5}$

Isotope	$T^{0\nu}_{1/2}$ (y)	$<m_\nu>$ eV	
^{48}Ca	>9.5 10^{21} +	<8.3	Beijin
^{76}Ge	>6.4 10^{24}	<0.6 → 0,2 - 0,39	Heid · Moscov
^{82}Se	>2.7 10^{22} *	<5	Irvine
^{100}Mo	>3.7 10^{22}	<2.5	Osaka
^{116}Cd	>3.2 10^{22}	<4.1	Kiev
^{130}Te	>5.6 10^{22}	<3	Milano
^{136}Xe	>4.4 10^{23}	$<2\text{-}3$	Caltech Neuchatel PSI
^{150}Nd	>1.2 10^{24}	<4	Irvine

	$T^{0\nu B}_{1/2}$		$<g_B>10^{-4}$	
^{76}Ge	>7.9	10^{21}	<2.4	Heid · Moscow
^{100}Mo	>5.4	10^{21} *	<0.73	Osaka
^{136}Xe	>1.1	10^{22}	$<0.8\text{-}1.3$	Caltech Neuchatel PSI
^{150}Nd	>5.3	10^{20}	<0.7	Irvine

Table 1 Top: Lower limits on halflives for neutrino-less double beta decay and upper limits on the Majorana neutrino masses. Bottom: ower Limits on halflives for neutrino-less double beta decays followed by the Majoron(B) and upper limits on the Majoron-neutrino couplings.Some recent data with 90%, 68 %(*) and 76%(+) confidencial levels.

Nuclear Matrix Elements

$M^{0\nu}$ for $0\nu\beta\beta$ & $M^{2\nu}$ for $2\nu\beta\beta$

$M^{2\nu} \fallingdotseq M^{2\nu}(1^+)$ Since M_F is only to $| IAS * IAS >$

Derived From $T^{2\nu}(EXP) = G^{2\nu}(M^{2\nu})^2$

$M^{0\nu} = \Sigma M^{0\nu}(J^\pi) = M^{0\nu}(1^+) + \Sigma_J M^{0\nu}(J)$

$M^{2\nu}$ leads to $H_{\tau\sigma}$, g_{pp}, for $M^{0\nu}$ & $M^{0\nu}(1^+)$

Calculations of $M^{0\nu}$, $M^{2\nu}$

1 Shell Model
  Vergados, Haxton, Zamic, Brown, Song, etc

2 Quasi-Particle RPA
  Vegel et al., Faessler Civitarese Tomoda et al., Muto Klapdor Hirsh, et al., Kuo et al., Suhonen,
  Sensitive to P-P Interaction
  - $M^{2\nu} \sim 0$ at $g_{pp} = 1$, $M^{0\nu} \neq 0$ For $J \neq 1^+$

3 Operator Expansion Method
  Chin & Ho, Muto et al.,

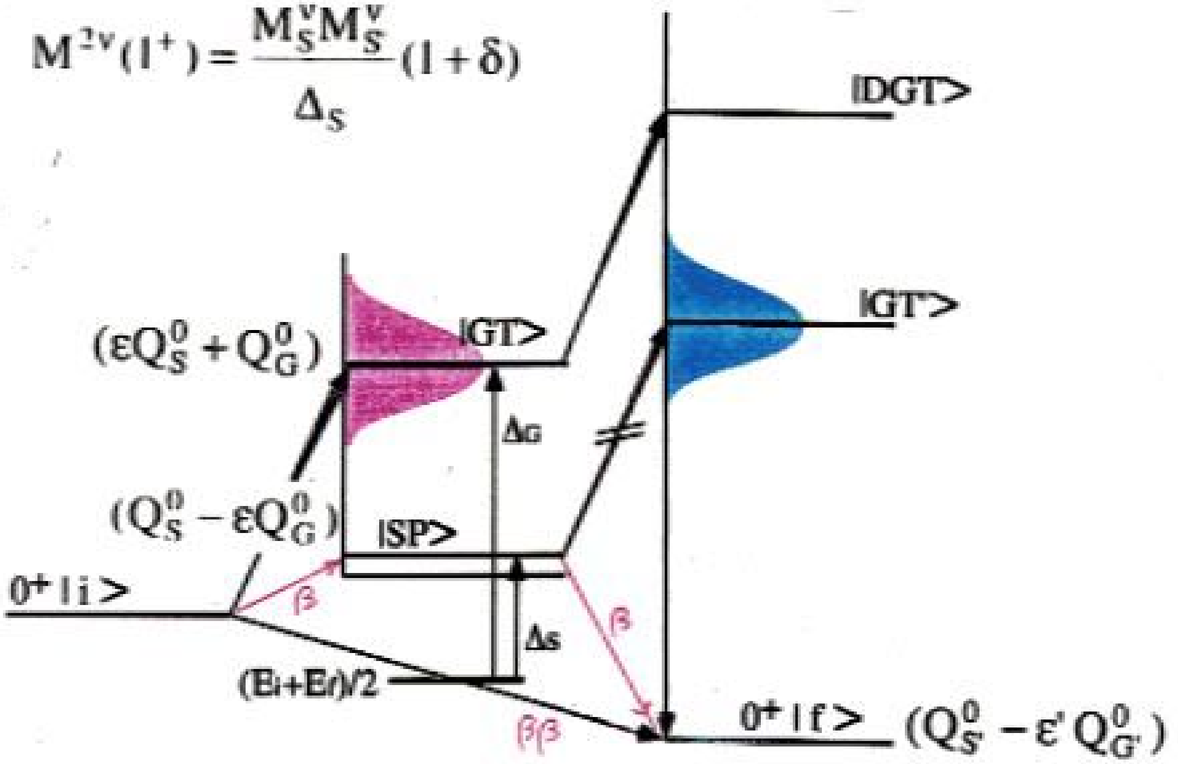
4 Exchange Current & Isobar
  Ericson…, Vergados…, Wu Huang…,

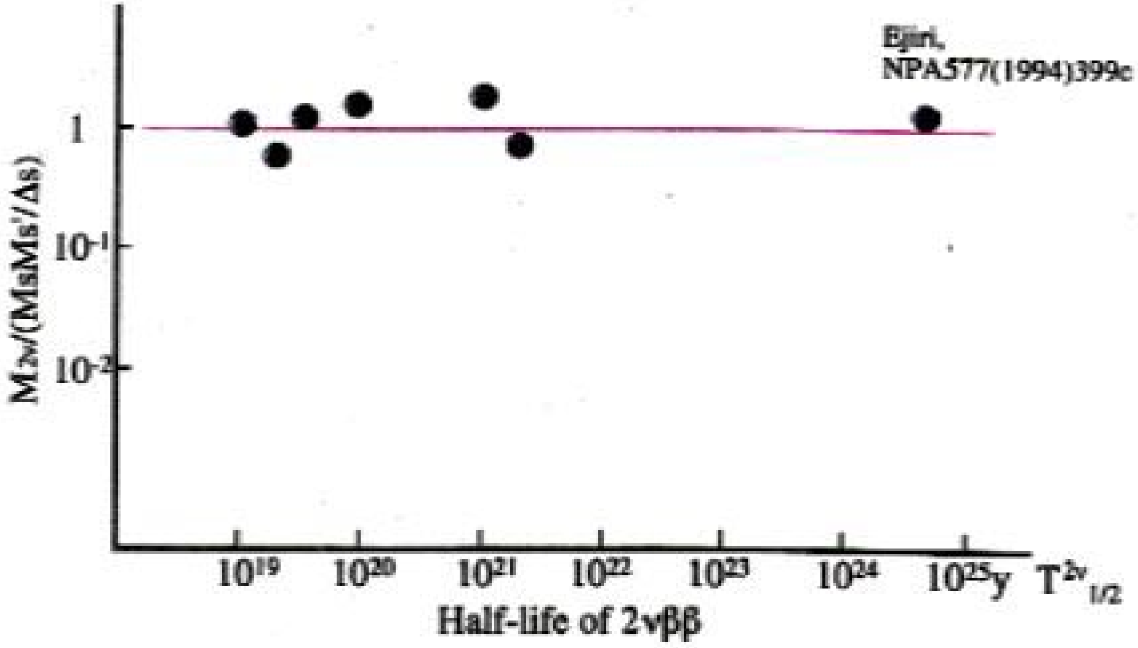
2.7 Nuclear Responses for $2\nu\beta\beta$

$H=(\tau\sigma)(\tau\sigma)$ **H. Ejiri & H. Toki, JPSJ-Lett. Jan. 96**

$$M^{2\nu}(1^+) = \sum_{\kappa} \frac{M^{\nu}_{\kappa} M^{\nu}_{\kappa'}}{\Delta_{\kappa}} = \frac{M^{\nu}_{S} M^{\nu}_{S'}}{\Delta_{S}} + \frac{M^{\nu}_{G} M^{\nu}_{G'}}{\Delta_{G}}$$

$$M^{2\nu}(1^+) = \frac{M^{\nu}_{S} M^{\nu}_{S'}}{\Delta_{S}}(1+\delta)$$





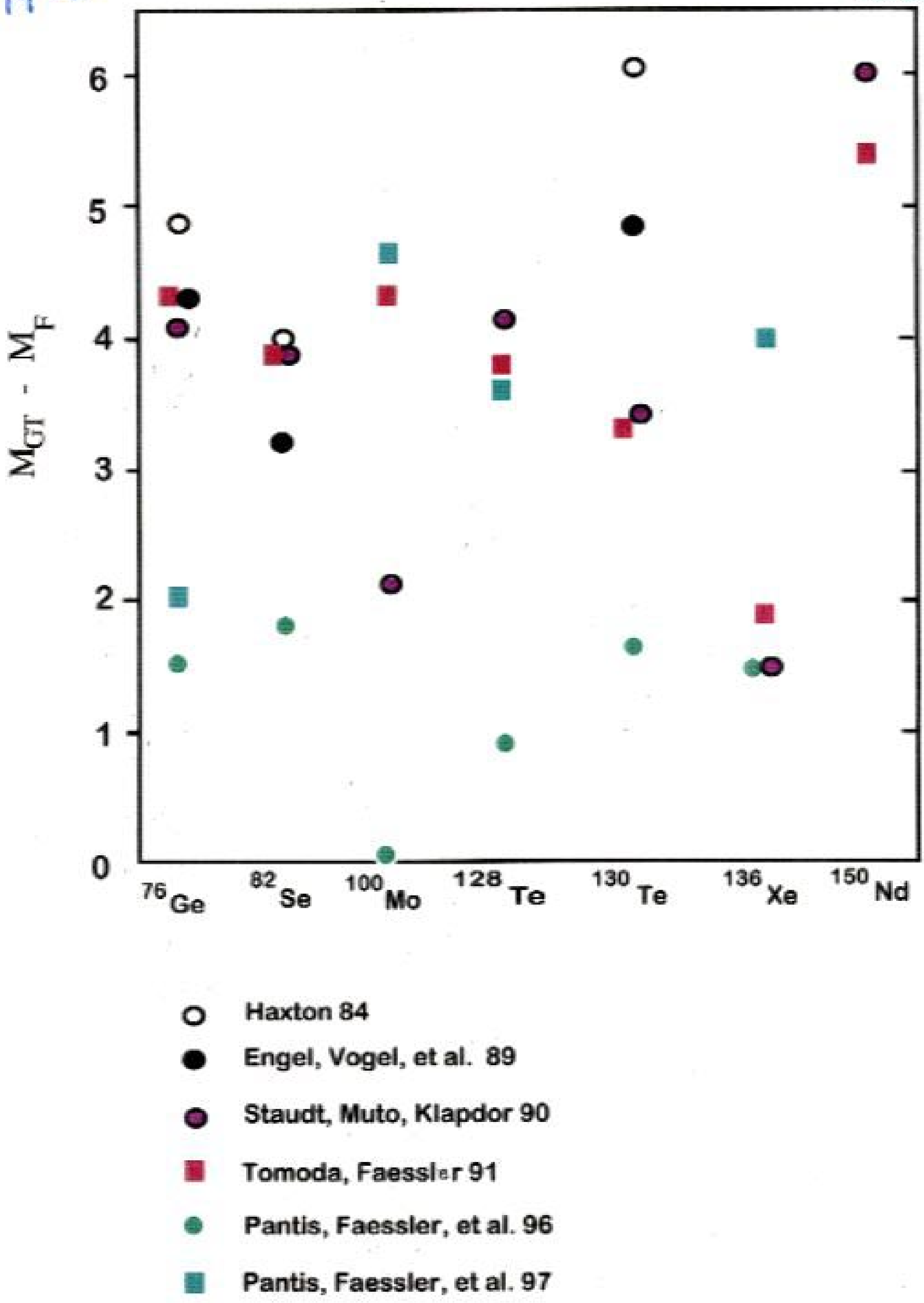
$M^{\nu}_{S} = |0_i\rangle \rightarrow |S\rangle = g^{\mathrm{eff}} M^0_S \qquad g^{\mathrm{eff}} \approx 0.3$ by $-\varepsilon Q^0_G$

$M^{\nu}_{S'} = |S\rangle \rightarrow |0_f\rangle = g^{\mathrm{eff}} M^0_{S'} \qquad g^{\mathrm{eff}} \approx 0.3$ by $-\varepsilon' Q^0_{G'}$

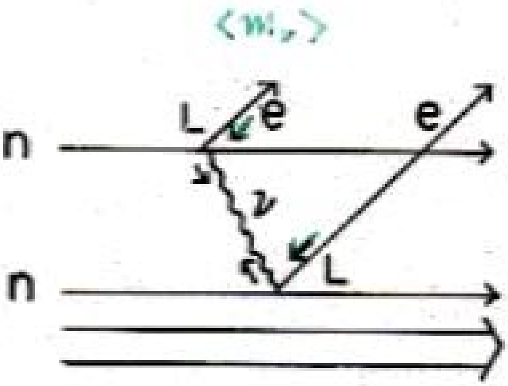
$M^{n}_{S} M^{n}_{S'} \approx (g^{\mathrm{eff}})(g^{\mathrm{eff}}) M^0_S M^0_{S'} \approx 0.1\ M^0_S M^0_{S'}$

$M^{0\nu}$

Kudomi



Need Exp. for $M^{0\nu}$


A
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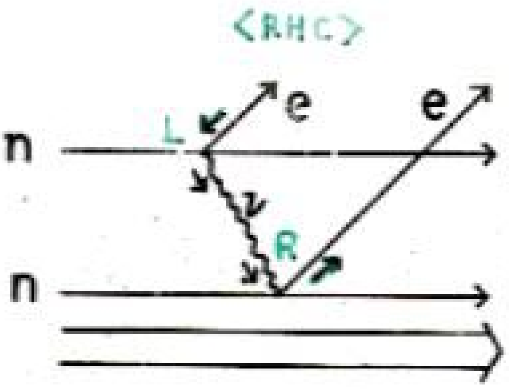
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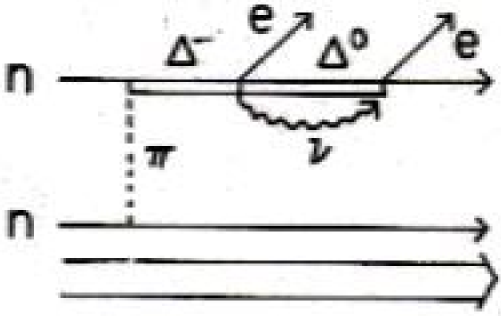
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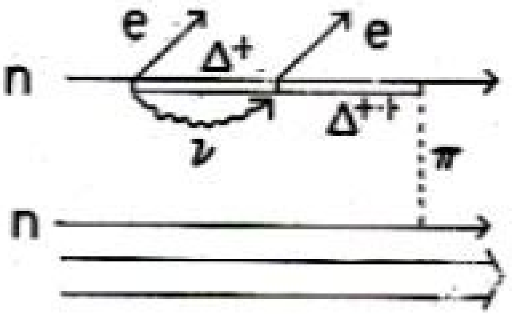
D
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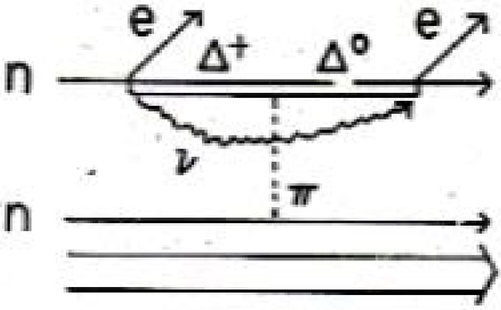
ν
Δ⁺⁺
π
n
p


E
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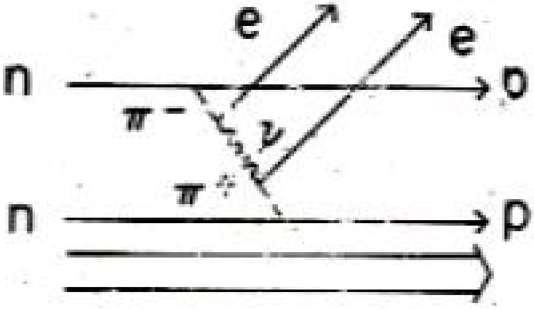
F
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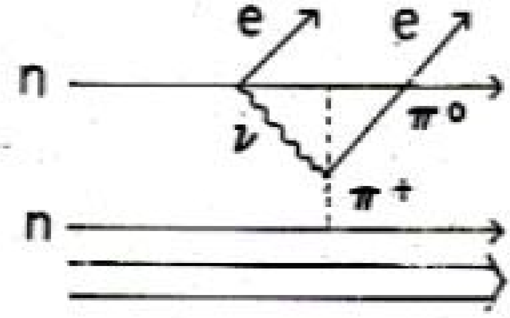
G
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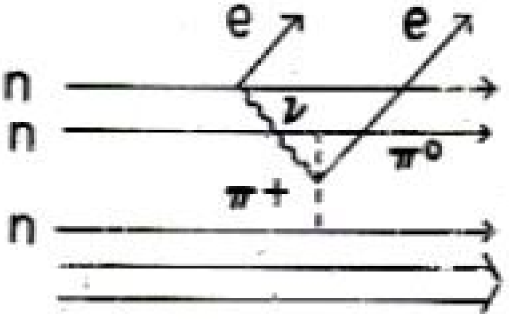
H
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π⁰
π⁺
n
p

3.3 Charge Exchange Spin-Flip Reactions for $\nu-\tau\sigma$ Responses

-RCNP, MSU, IUCF, KVI, MU, Kyoto, …Coll.-

a. Charge Exchange Spin Flip Reactions at Medium Energies

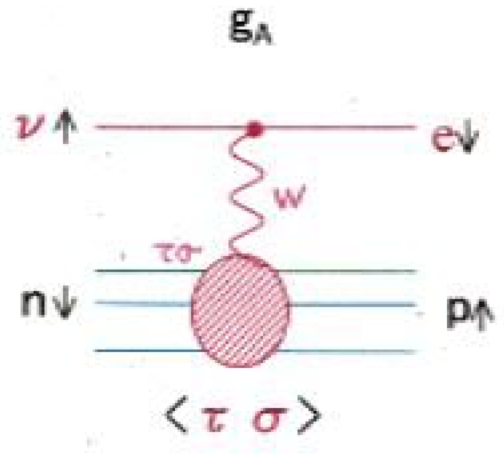
(p, n), (n, p), (d, ^{2}He), (^{3}He, t), (t, ^{3}He), (^{7}Li, ^{7}Be*)

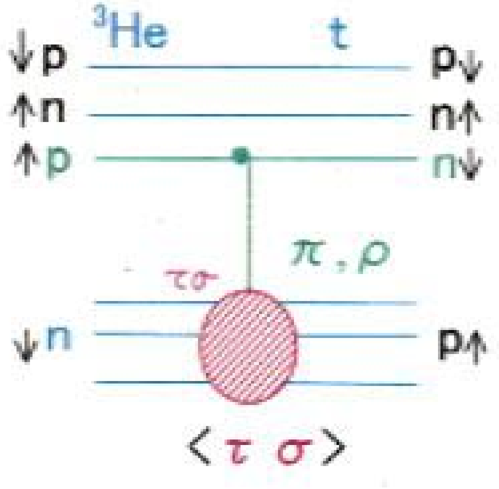
b. RCNP Cyclotron E($\vec{p}$)=0.4 GeV, E(^{3}He)=0.45 GeV

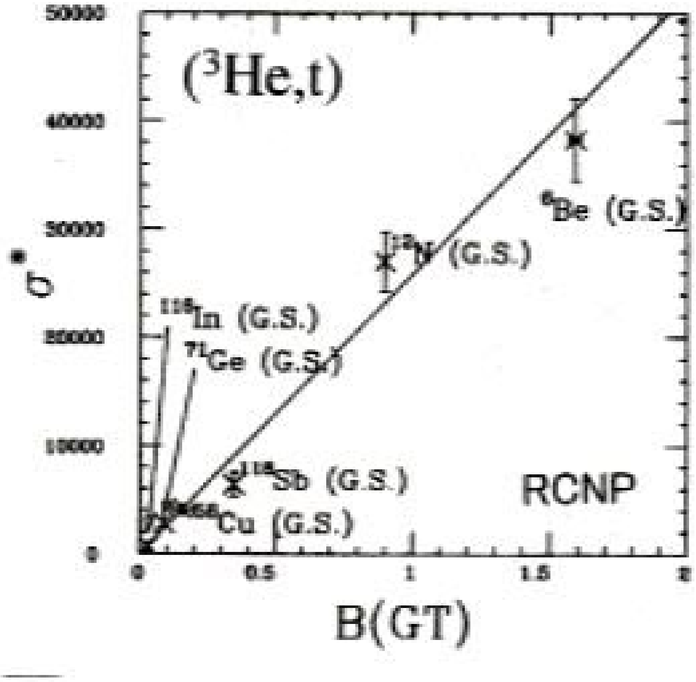
Small V_0 Distortion, Relatively Large $V_{\tau\sigma}$

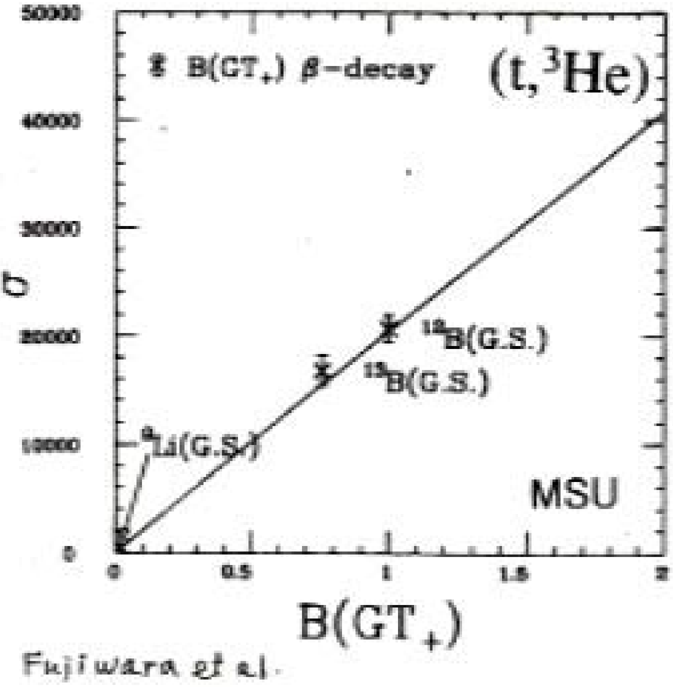
c. MSU Cyclotron α-Fragm. t with 0.38 GeV

A1200 Beam-Line Analyzer, and K800 Spectrograph



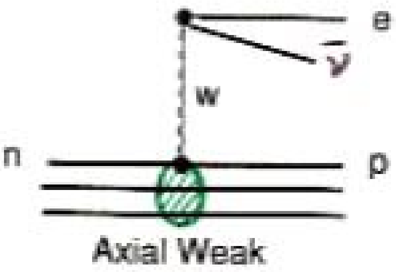


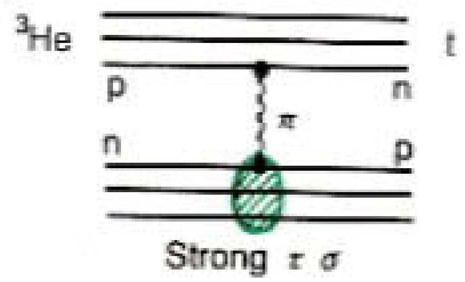


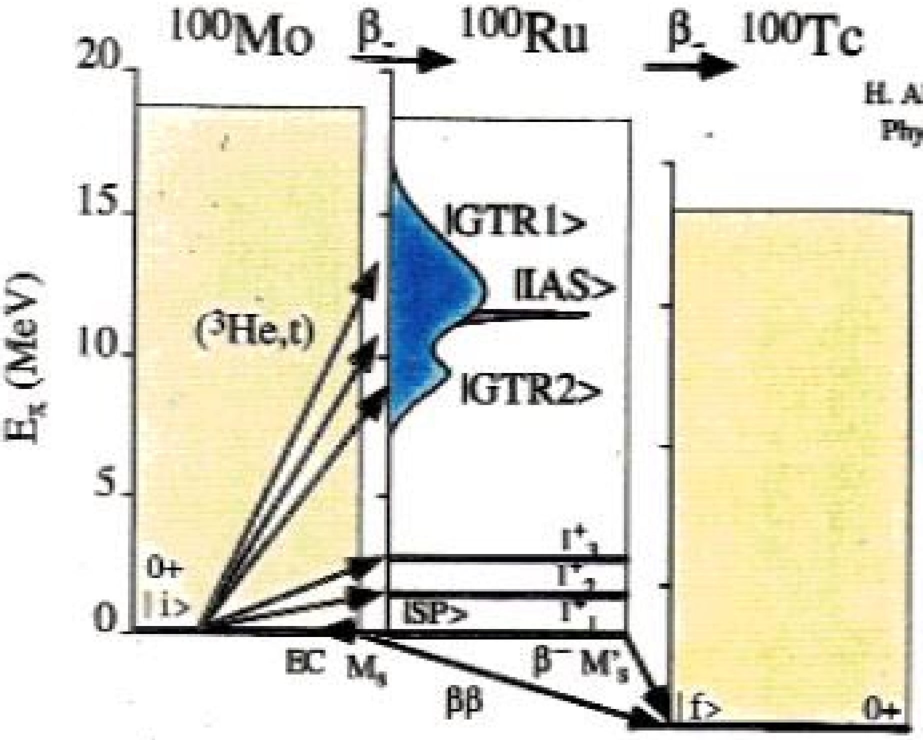


Fujiwara et al.

Spin Isospin Responces for ββ–νν







H. Akimune, H. Ejiri et al.
Phys. Lett. 394B (1997) 23

Garcia.ec.

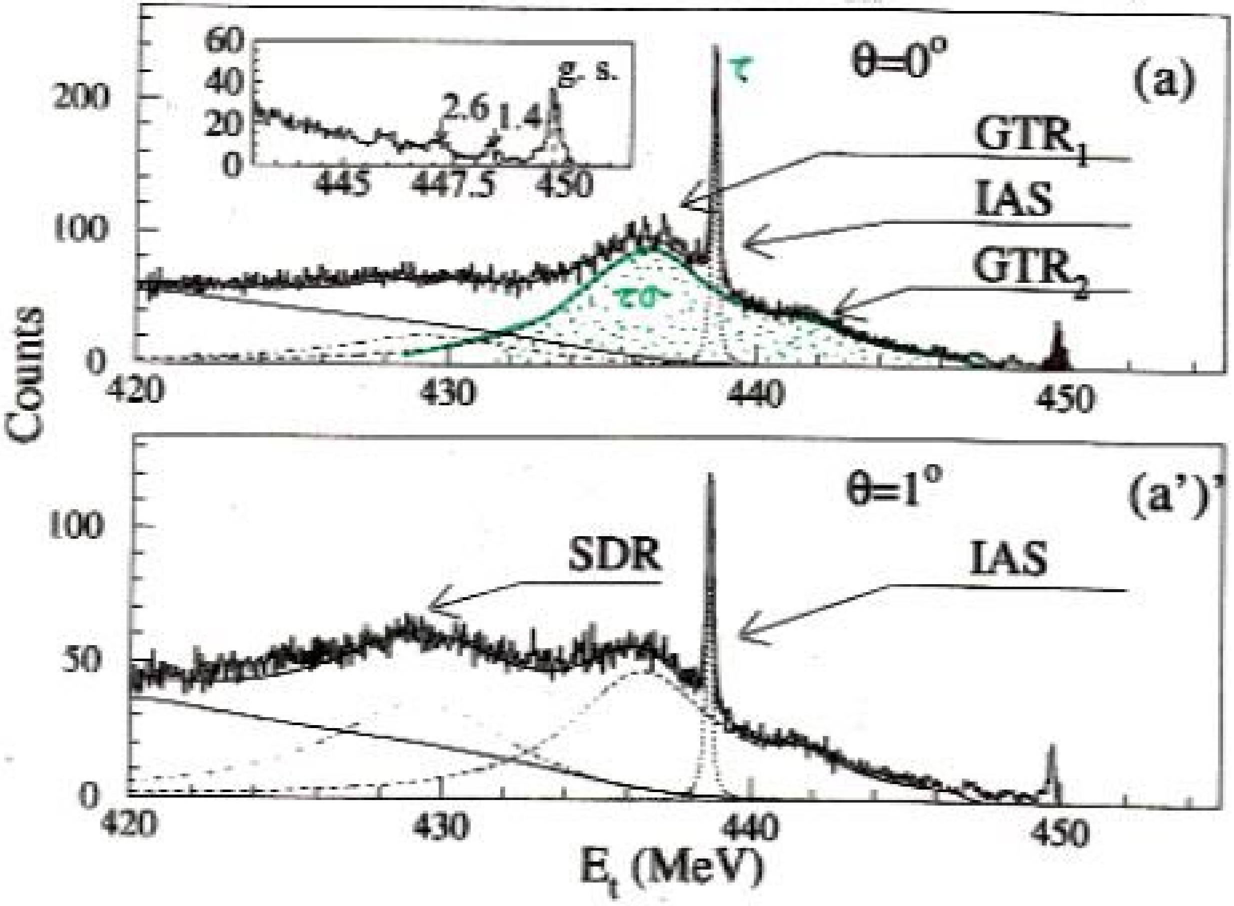
2νββ

$M_{\beta\beta}=0.096$

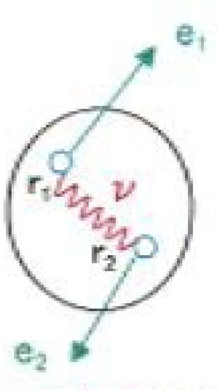
H. Ejiri et al.
Phys. Lett. 258B (1991) 17

$\frac{M_s M'_s}{\Delta}=0.10$

^{100}Mo(^{3}He,t) (E_{He} = 450 MeV)



b. Nuclear Responses for $0\nu\beta\beta$



q=04.GeV/C
ℓ=0-6

$$H(r_1, r_2, \tau_1, \tau_2, \sigma_1, \sigma_2) \sim f(r_1, r_2)\,\tau_1\,\tau_2\,\sigma_1\,\sigma_2\ldots$$

$$f(r_1, r_2)=1/|r_1-r_2|$$

Separable Form for Nucleon $r_n < r_i, r_j <$ Nuclear R_N

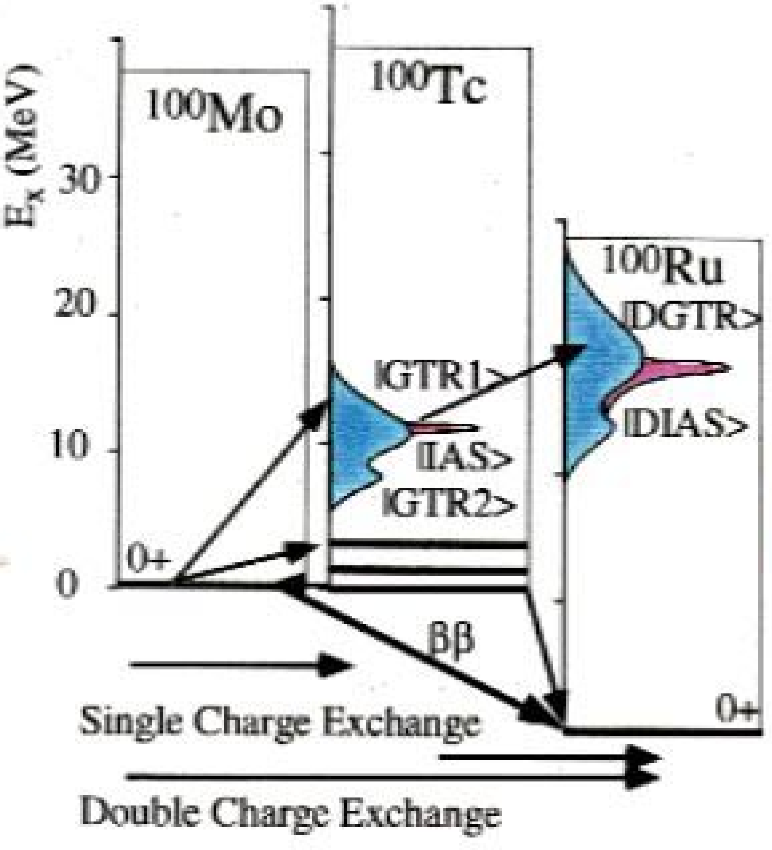
$f(r_1, r_2) \sim \sum_\ell f_\ell\, h_\ell(r_1)\, h_\ell(r_2)$ Ejiri, Belyaev, Toki PTP '99

$M^{0\nu} \sim \sum f_\ell \langle 0_f|T_\ell^+|i\rangle\langle i|T_\ell^+|0_i\rangle$ $T_\ell=h_\ell(\gamma)\,\tau\,\sigma$

$M^{0\nu} \sim \sum M_\ell^+(SP)M_\ell^-(SP) + (M_\ell^+(GR)\,M_\ell^-(GR) \rightarrow \varepsilon)$

Studied by τ^- and τ^+ Charge Exchange Reactions

Proposal **Double Gamow-Teller Excitation**



IAS: $J^\pi=0^+$, $T=T_0$

GTR: $Jp=1^+$, $T=T_0-1$

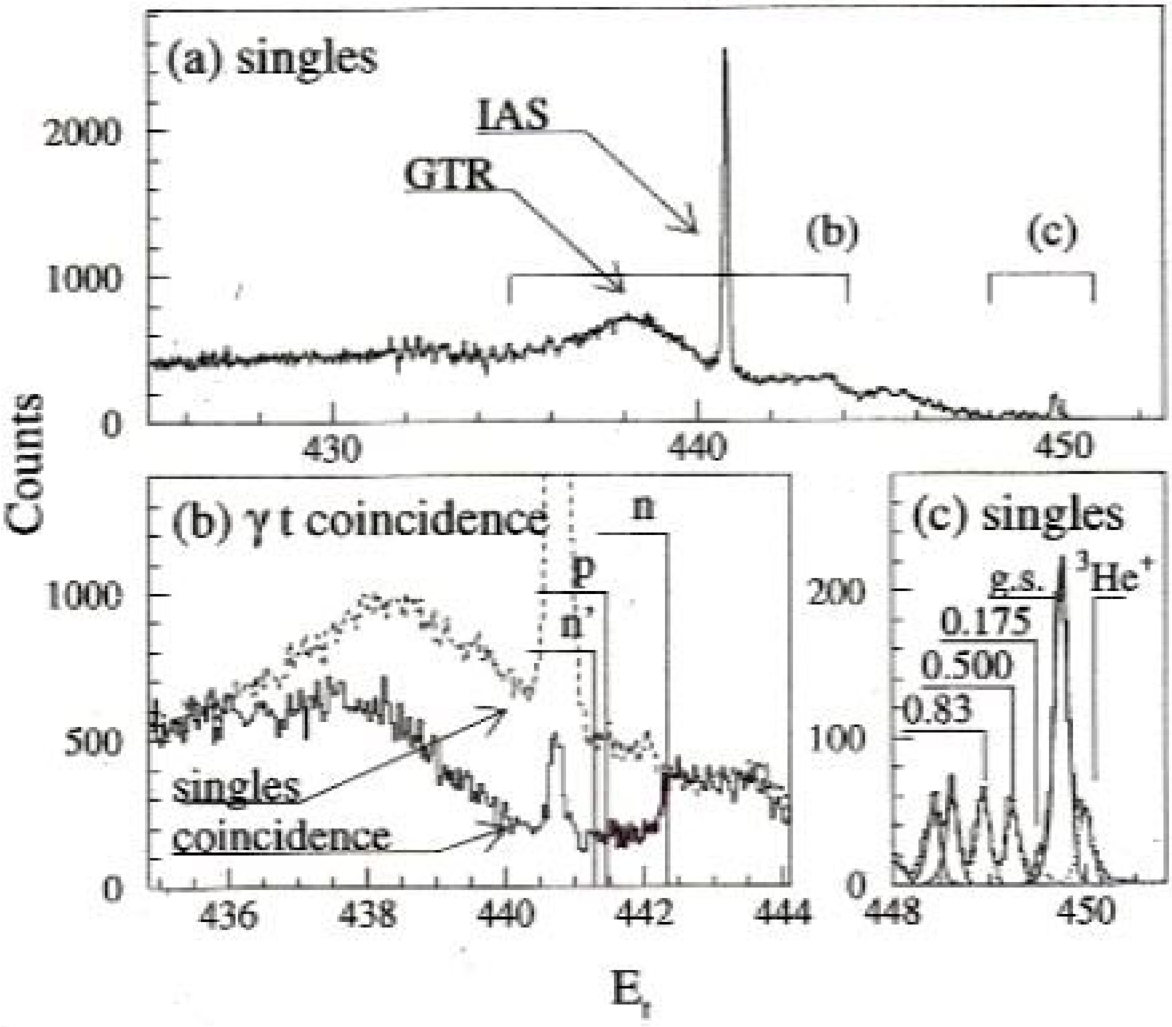
DIAS: $J^\pi=0^+$ $T=T_0$

DGT: $J^\pi=0^+, 2^+$ (1:5)
$T=T_0-2$

^{71}Ga(^{3}He, t γ)^{71}Ge

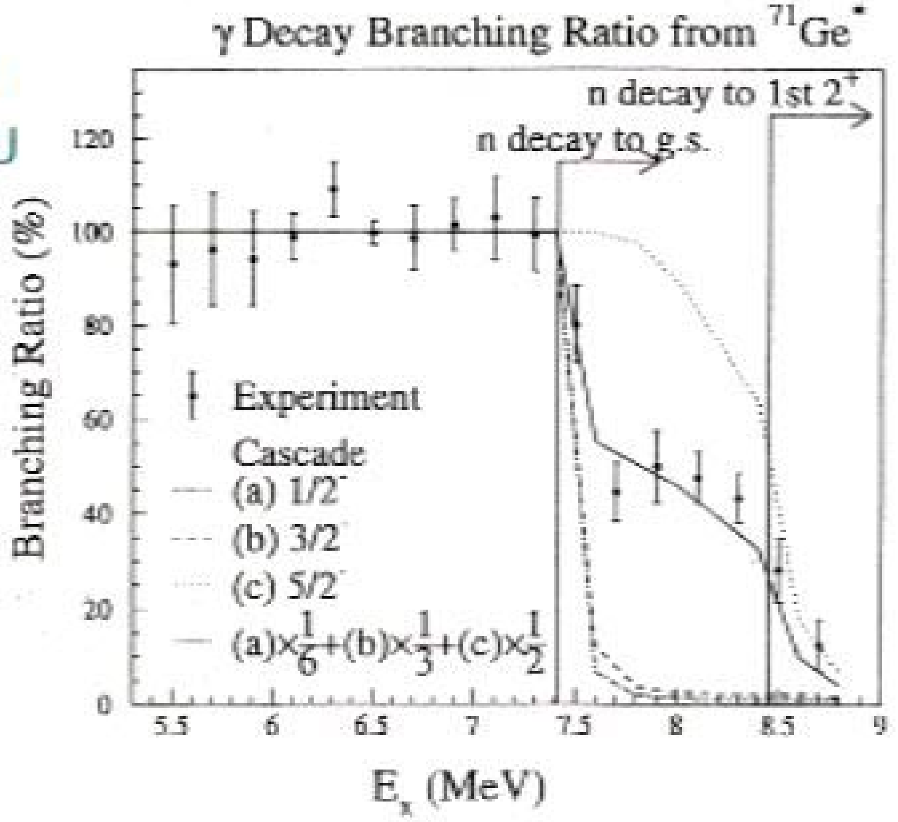
-RCNP, MSU, IUCF, KVI, MU, Kyoto, …Coll.-
Fujiwara, Akimune, Daito, et al., NP '96

Ejiri, Akimune, Ishibashi, et al., PL '98



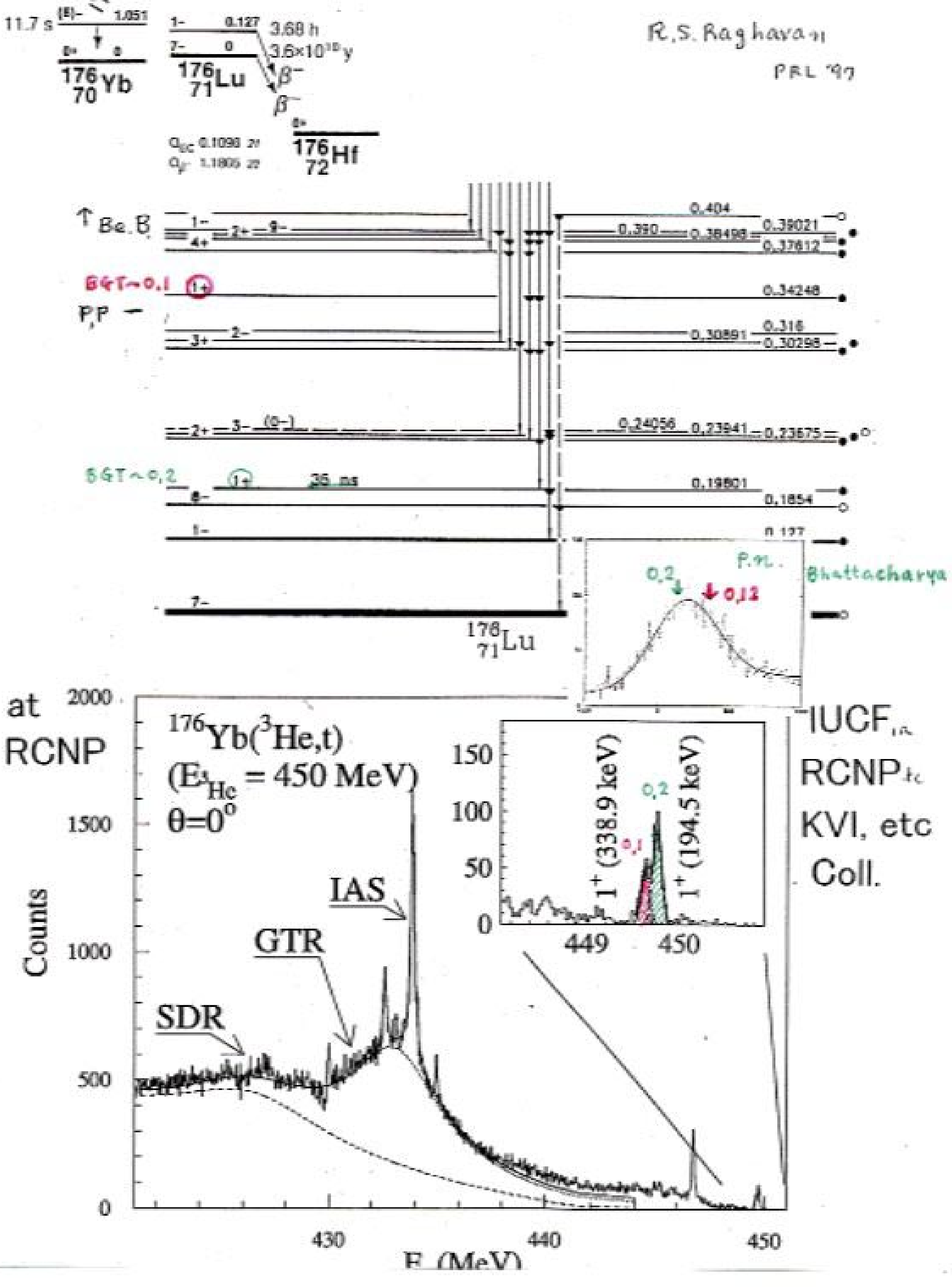
(^{3}He, t γ)→B(GT)→SNU

Gs(1/2$^-$)	114.9 SNU
1st (5/2$^-$)	17.5
Tot	131.72
Barcall	132
^{8}B all	12.9
unbound	0.35
	3%



$^{176}Y_b$ Spin Responses

R.S. Raghavan
PRL '97



at RCNP

IUCF, RCNP, KVI, etc Coll.

FUTURE PLANS FOR 0.01eV region

GENIUS

Ge(76) 1t in Liq. N Goal 0.01eV
(if BG is as present $\lesssim$ 0.05eV)
Hirh E resolution, but large BG<3MeV
Low Q(bb)=2 MeV
Calorimetric Method No m/V+A/etc

NEMO

Mo100 7-10kg Gorl 0.1eV
2 Neu bb + BG $\lesssim$ 0.5eV
Low E resolution
High Q(bb)=3MeV Low BG
Spectroscopic Method (like ELEGANT)

LENS (Solar ν)

Yb176 etc 1t ~, >0.1eV

MOON

Mo100 10t Goal 0.02eV

UWThPh-1999-41
DFTT 36/99
July 1999

Constraints from Neutrino Oscillation Experiments on the Effective Majorana Mass in Neutrinoless Double β-Decay

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$$\text{(A)} \quad \underbrace{\overbrace{m_1 < m_2}^{\text{atm}} \ll \overbrace{m_3 < m_4}^{\text{solar}}}_{\text{LSND}} \quad \text{and} \quad \text{(B)} \quad \underbrace{\overbrace{m_1 < m_2}^{\text{solar}} \ll \overbrace{m_3 < m_4}^{\text{atm}}}_{\text{LSND}} .$$

FIGURES

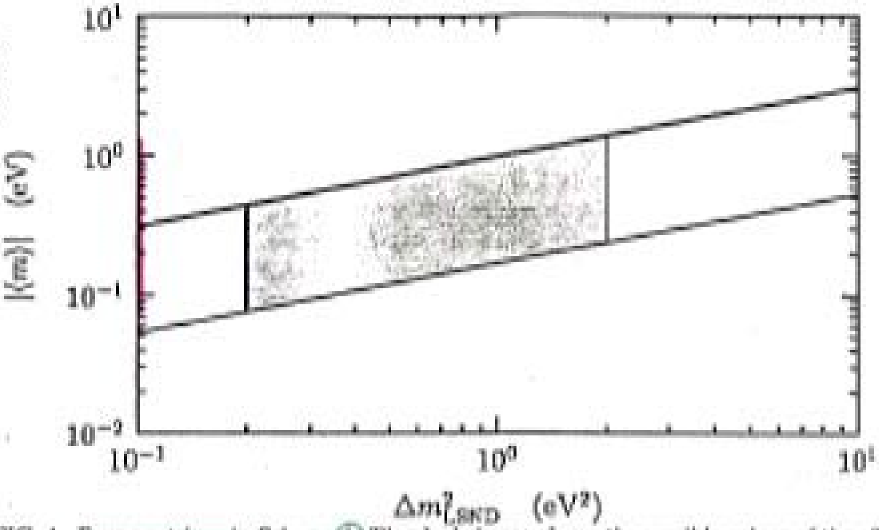

FIG. 1. Four neutrinos in Scheme (A). The shaded area shows the possible values of the effec
Majorana mass $|\langle m\rangle|$ in the range of $\Delta m^2_{\rm LSND}$.

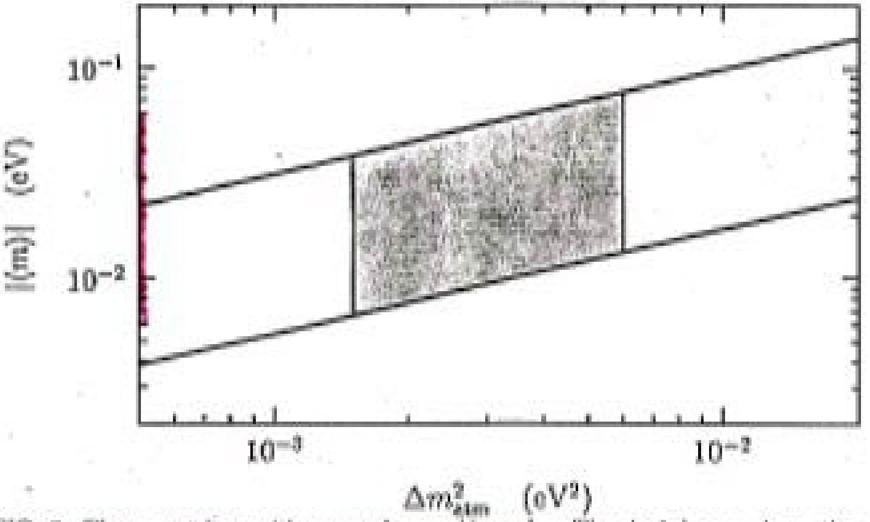

FIG. 2. Three neutrinos with reversed mass hierarchy: The shaded area shows the pos
values of the effective Majorana mass $|\langle m\rangle|$ in the range of $\Delta m^2_{\rm atm}$.

ELSEVIER Physics Letters B 456 (1999) 194–200

Majorana neutrino masses from neutrinoless double beta decay and cosmology

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Received 9 April 1999; received in revised form 21 April 1999
Editor: M. Cvetič

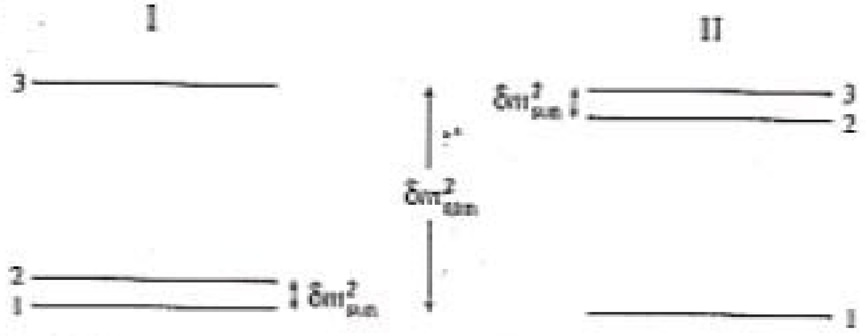
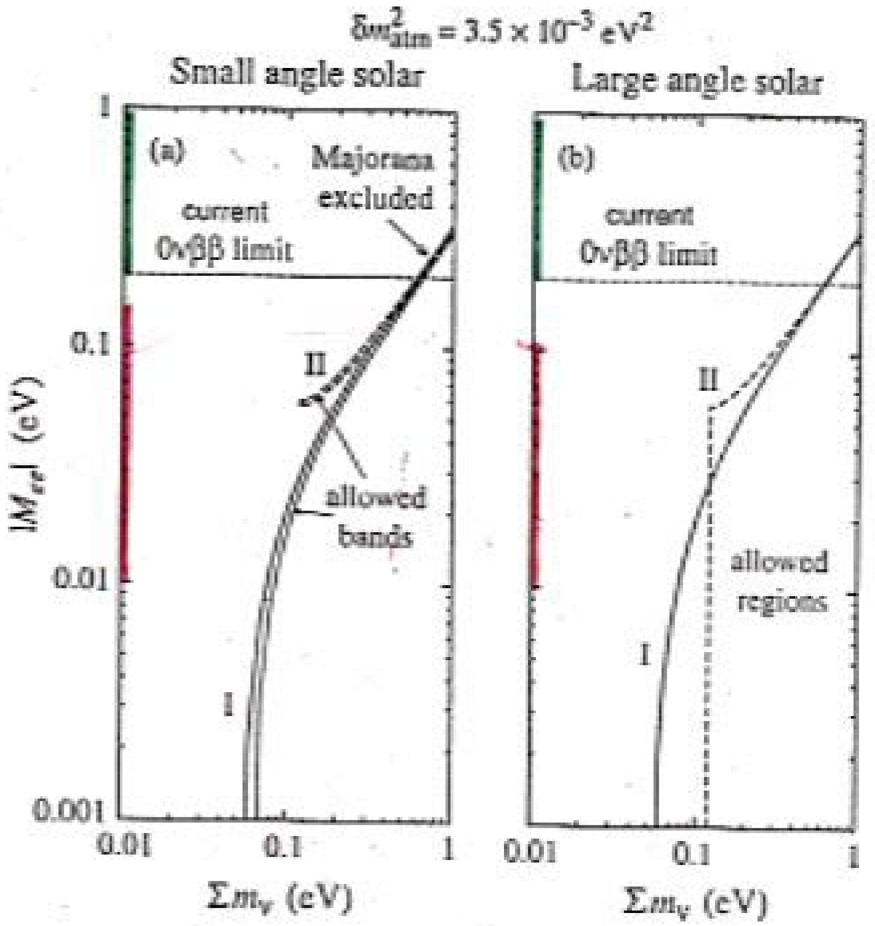


Fig. 1. The two possibilities for the three-neutrino mass spectrum.



Minakata-Yasuda PRD56 '97. NPB523, '98

DM & Degenerate Three ν. $\langle m_{\nu e} \rangle = 0.1 \sim 0.5$ sets m, mixing angl

Electron-neutrino Majorana mass and solar neutrino oscillations

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P.L. B456 '99

Received 5 March 1999
Editor: M. Cvetič

Abstract

Assuming the Majorana masses of ν_e and the linear combination $c\nu_\tau - s\nu_\mu$ to be equal from their couplings to a heavy scalar triplet ξ, I show that their radiative splitting is given by $\Delta m^2/m_\nu^2 = (3c^2/4\pi^2)(G_F/\sqrt{2})m_\tau^2 \ln(m_\xi^2/m_W^2)$. This is applicable to the small-angle matter-enhanced oscillation solution of the solar neutrino deficit and restricts m_ν to be between 0.20 and 0.36 eV if $c^2 = 0.7$ and $m_\xi = 10^{14}$ GeV.

LUME 80, NUMBER 24 PHYSICAL REVIEW LETTERS 15 JUNE 19

Weighing Neutrinos with Galaxy Surveys

Wayne Hu, Daniel J. Eisenstein, and Max Tegmark

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(Received 3 December 1997; revised manuscript received 13 March 1998)

We show that galaxy redshift surveys sensitively probe the neutrino mass, with eV mass neutrinos suppressing power by a factor of 2. The Sloan Digital Sky Survey can potentially detect N nearly degenerate massive neutrino species with mass $m_\nu \gtrsim 0.65(\Omega_m h^2/0.1N)^{0.8}$ eV at better than 2σ once microwave background experiments measure two other cosmological parameters. Significant overlap exists between this region and that implied by the Liquid Scintillator Neutrino Detector experiment, and even $m_\nu \sim 0.01$–0.1 eV, as implied by the atmospheric anomaly, can affect cosmological measurements. [S0031-9007(98)06410-2]

PACS numbers: 95.35.+d, 14.60.Pq, 98.62.Py

LUME 82, NUMBER 4 PHYSICAL REVIEW LETTERS 25 JANUARY 19

Degenerate and Quasidegenerate Majorana Neutrinos

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(Received 13 October 1998)

We study mixing and CP violation of three left-handed Majorana neutrinos in the limit of exactly degenerate masses, identify the weak-basis invariant relevant for CP violation, and show that the

Double beta decay*

Amand Faessler[1] and Fedor Šimkovic[2]

	$T_{1/2}^{0\nu-theor.}(<m_\nu>,<\lambda>,<\eta>,<g>)$ $[years^{-1}]$									
	^{48}Ca	^{76}Ge	^{82}Se	^{96}Zr	^{100}Mo	^{116}Cd	^{128}Te	^{130}Te	^{136}Xe	^{150}N
Ref.	10^{24}	10^{24}	10^{24}	10^{24}	10^{24}	10^{24}	10^{25}	10^{24}	10^{24}	10^{2}
					$<m_\nu>= 1eV$ $<\lambda>=0$ $<\eta>=0$ $<g>=0$					
[156]	6.42	17.4	2.40						12.1	
[1]	3.17	1.68	0.58				0.40	0.16		
[191]		2.30	0.92				0.45	0.24		
[167]		14.0	5.60				1.50	0.66	3.30	
[132]		4.06	1.43				1.80	0.83		
[168]		2.33	0.60		1.27		0.77	0.49	2.21	3.37
[79]		2.16	0.61		0.26		0.98	0.54	1.40	4.45
p.w.		3.15	0.80	1.09	0.34	0.77	1.63	0.94	5.29	6.11
[109]		8.95			0.25	0.70	1.09		8.76	
					$<m_\nu>=0$ $<\lambda>=0$ $<\eta>=0$ $<g>=10^{-5}$					
[156]	7.96	70.9	5.24						32.5	
[1]	3.93	6.85	1.27				5.70	4.20		
[132]		16.5	3.13				25.7	2.19		
[191]		9.36	2.01				6.41	0.63		
[167]		57.0	12.2				21.4	1.73	8.86	
[168]		9.49	1.32		2.60		11.1	1.28	5.94	5.3
[79]		8.77	1.32		0.53		13.9	1.42	3.76	6.9
p.w.		12.8	1.75	1.92	0.68	1.76	23.2	2.47	14.2	9.6
[109]		36.4			0.52	1.61	15.0		23.5	

Mo Observatory Of Neutrino *

MOON

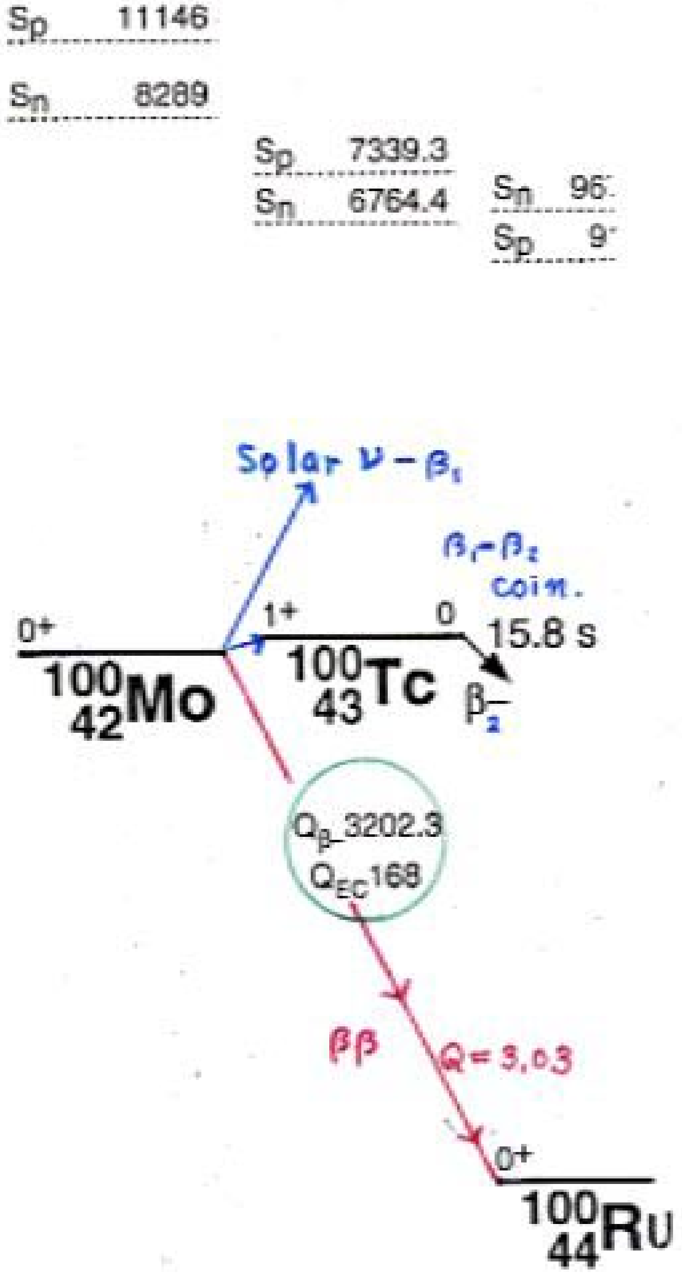
Hiro Ejiri NPL UW

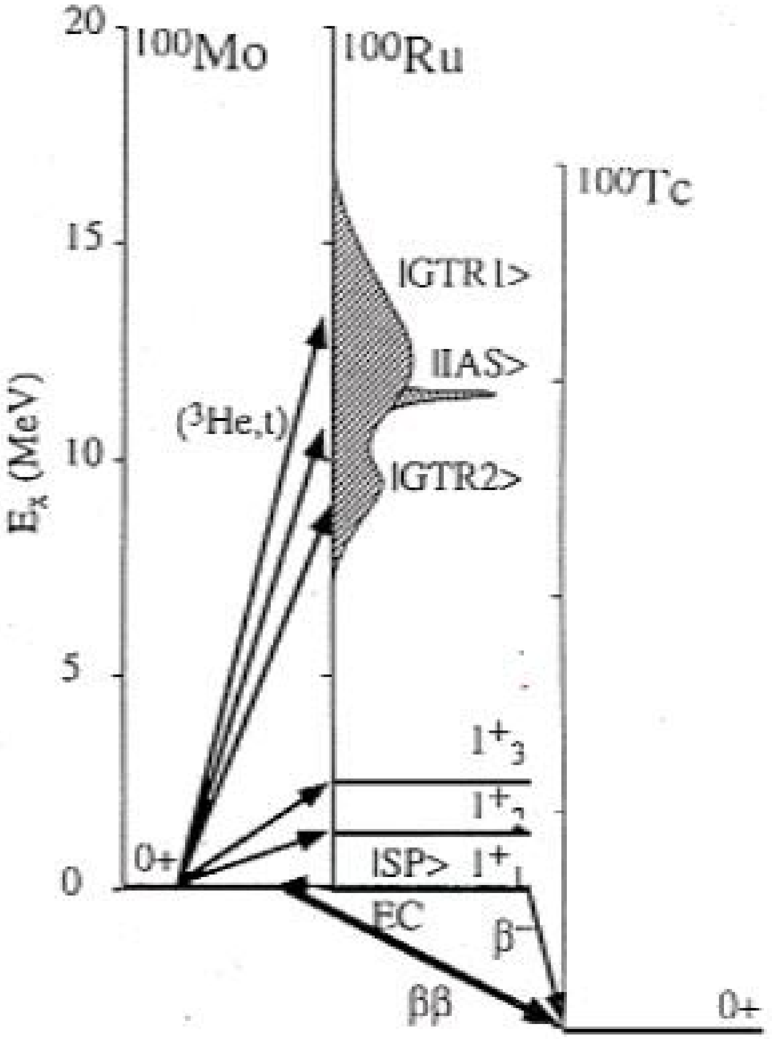
1.Majorana Neutrino With Mass ~0.02~0.03 eV
By Mo100 Double Beta Decays With Large Q=3MeV
Spectroscopic Measurement.

2.Semi Real Time Solar Neutrinos of Be7 , pp, B8.
Large Known B(GT) . Factor 5~7 of Ga.SNU.
Low Threshold .Mo100 168 keV,Mo97 562 keV
. Low BG by T-Window 3(-8)—1(-6)y (1-30sec).

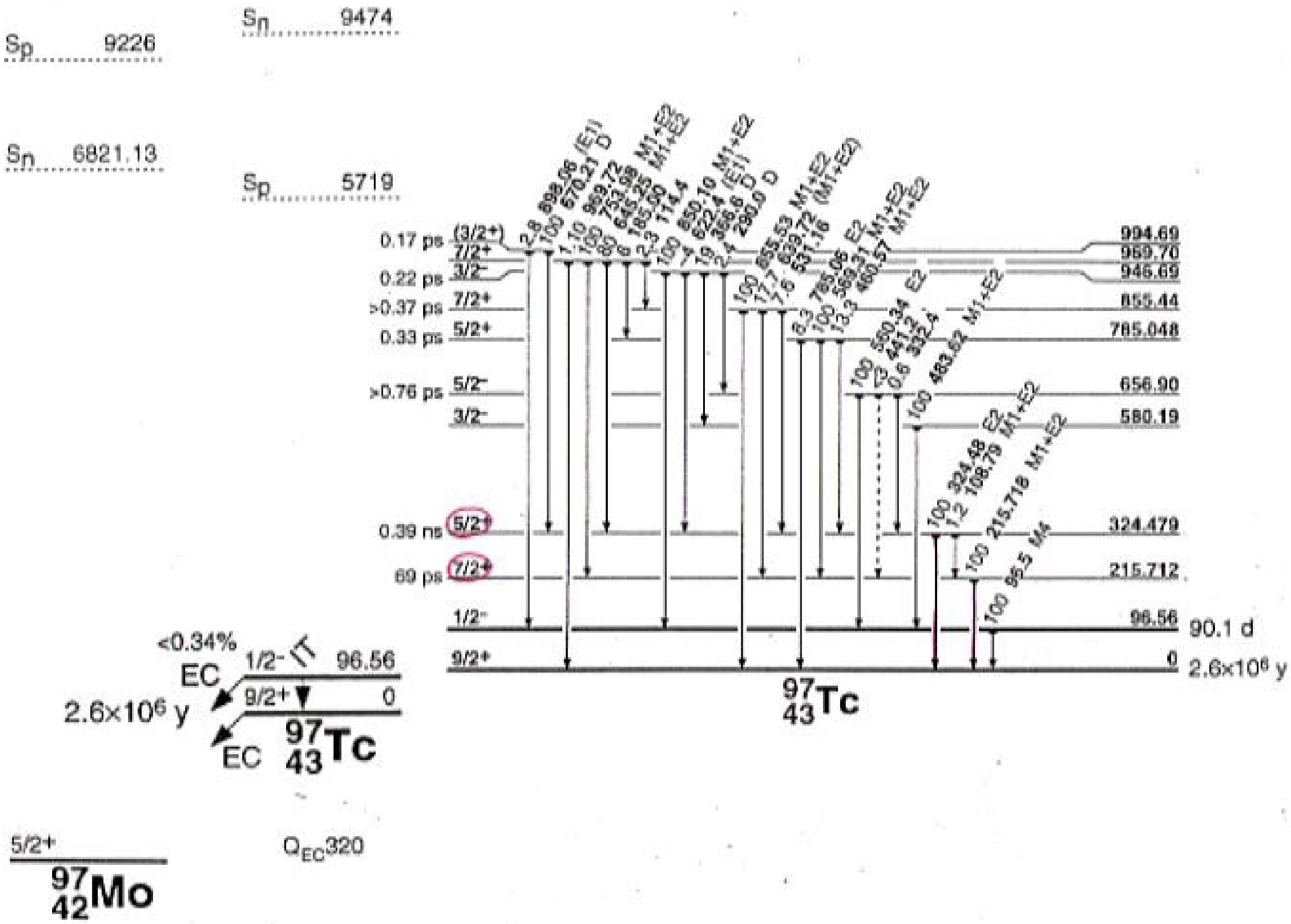
4.Realistic DetectorWith Purity of 1ppt ,1.3 Bq/gr(8)
10% Mo100 10% Mo97.Isotopic Abundance.
*100t Mo, 600t Total, 10m*10m*5m.*

* Preliminal





Excited states	^{100}Tc	
	E_x (MeV)	$B(GT)$[a]
g.s.	0.0	0.33 ± 0.04
1st 1^+	1.4[d]	0.13 ± 0.02
2nd 1^+	2.6[d]	0.23 ± 0.03
GTR1	13.3[e]	23.1 ± 3.8
GTR2	8.0[c]	2.9 ± 0.5


Sp 9226
Sn 9474
Sn 6821.13
Sp 5719
0.17 ps (3/2+) 994.69
7/2+ 969.70
0.22 ps 3/2- 946.69
>0.37 ps 7/2+ 855.44
0.33 ps 5/2+ 785.048
>0.76 ps 5/2- 656.90
3/2- 580.19
0.39 ns 5/2+ 324.479
69 ps 7/2+ 215.712
1/2- 96.56 90.1 d
9/2+ 0 2.6×10⁶ y
2.8 898.06 (E1)
100 670.21 D
1.10 969.72
100 753.98 M1+E2
80 645.25 M1+E2
6 185.00
2.3 114.4
100 850.10 M1+E2
74 622.4 (E1)
19 366.6 D
2.4 290.0 D
100 855.53 M1+E2
17.7 639.72 (M1+E2)
7.6 531.16
8.3 785.06 E2
100 569.31 M1+E2
13.3 460.57 M1+E2
100 560.34 E2
<3 441.2
0.6 332.4
100 483.62 M1+E2
100 324.48 E2
1.2 108.79 M1+E2
100 215.716 M1+E2
100 96.5 M4
97 43 Tc
<0.34%
EC
1/2- IT 96.56
9/2+ 0
2.6×10⁶ y
EC
97 43 Tc
5/2+
97 42 Mo
QEC320

GT States in Ga71 & Mo100

	Ga71-Ge71		Mo100-Tc100	
		3/2-1/2	0-1	
Spin factor		0.25		1
Q(ec) MeV		0.236		0.168
B(GT)	g.s.	0.089	g.s.	0.33
	0.175	0.005	1.4	0.13
	0.5 1.36	0.088	2.6	0.23
	GR	3.6	GR	4.4
	Sum	3.8	Sum	5.1
SNU	pp	71		~640 *
	Be7	34		~210 *
	B8	14		~ 20 *
	Sum	132		~900 *

* Preliminal

DETECTOR AND COUNTING RATE

1.Detector 100t Mo (10t Mo100 ,10t Mo97)
Mo 0.1gr/cm**2 PL 0.5gr/cm**2,
10mx10mx1000 (~5m)

2.Position 1cm**2 0.1gr/100t=10(-9)
Time Window 1-30sec. 10(-6)y

3.N(0ν) 5.3(2)/5y 5.5 10(26)y 2.5 10(-2) eV

4.N(Be)/y ~ 200(Mo100) + Mo97
N(pp)/y ~ 260(Mo100)

5.N(BG) 1 ppt U Th 1.3 10(-8) Bq/gr
N(ac),N(c) T window 0.06/y ~0/y
N(dc) Pb214-Bi214 ~170/y
N(bb) ac ~250/y
N(BG) can be measured to be corrected for

SUMMARY

1. Double Beta Decays Sensitve To
Majorana Nentrino Masses 0.01-1 eV
Majoron ,Right Handed Weak Current
SUSY etc, Beyond Standerd Thery

2. Present Exp`s Set Limits

Calorimetric Method Ge 76 by H-M
0.2(0.4)<1eV depending on M(bb)

Spectroscopic Method Energy&Angle Corr.
Mass/Right Handed Weak,...
Mo100,Xe136,..1.5-3 eV, will be 0.5~1

3. Nuclear Responses

2-nbb By He3-t and p-n Reactions
M(2nbb)~M(SP.b)*M(SP.b) Through SP.1+.
M(0nbb) with J=0,1,2,3,..6 . Also By
Nuclear Reactions, If Separable.

Solar Neutrino Responses
By He3-t Reactions For Excited Sates

4. Perspectives

GENIUS Ge76 1t Goal 0.01 eV (< 0.04)
Also For SUSY DM ....
MOON Mo100 10t Goal 0.03 eV
Also For Solar Neutrinos Be7,pp,B8.