Double Beta Decays and Neutrinos

Present Status and Remarks

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1. Double Beta Decays (ββ) and Neutrinos (ν).
2. Present Status of ββ Experiments.
3. Nuclear Responses for ββ–ν.
4. ν and Weak Interactions by ββ.
5. Remarks.

V2000-1

Reviews

W.Haxton, G.S.Stephenson Jr, P.P.N.Phys.12 '84

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J.D.Vergados, Phys.Rep.133 '86

F.T.AvignoneIII, H.Klapdor, D.O.Caldwell, ...

M.Moe, P.Vogel, Ann.Rev.Nucl.Part.Sci.44 '94

'M

A.Faessler, F.Simcovici, J.Phys.G 24 '98

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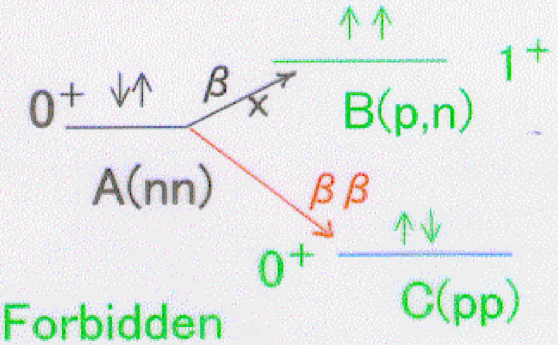
1.Double Beta Decays (ββ) &Neutrinos (ν).

1.1. ν studies by ββ in Nuclear Micro-lab.

a. β β -Decays



Asymmetric Levels

by $m_p \neq m_n$, $H_{pp} \neq H_{nn}$,

V (pair) < 0

Single β A(nn)→B(p,n) Forbidden

$T(\nu\beta)=10^{-1}/\mathrm{sec} \rightarrow 0$

b. β β -Processes

$2\nu\beta\beta$ $A(nn) \rightarrow C(pp) + \beta + \beta + \bar{\nu} + \bar{\nu}$

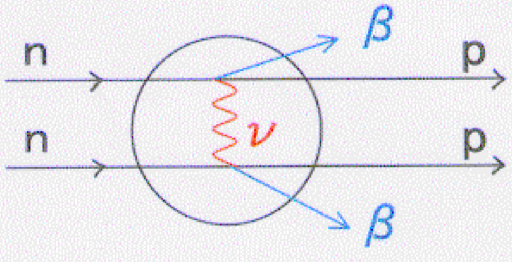
$\Delta L=0$, within SM

$T(2\nu\beta\beta) \sim 10^{-26}/\mathrm{sec}$

$0\nu\beta\beta$ $A(nn) \rightarrow C(pp) + \beta + \beta$

$\Delta L=2 \neq 0$, Beyond SM, m_ν, R, etc

ν -Exchange Between n n in a Nucleus



$T(0\nu\beta\beta) \approx 10^{-19} (m_\nu/m_e)^2/\mathrm{sec}$

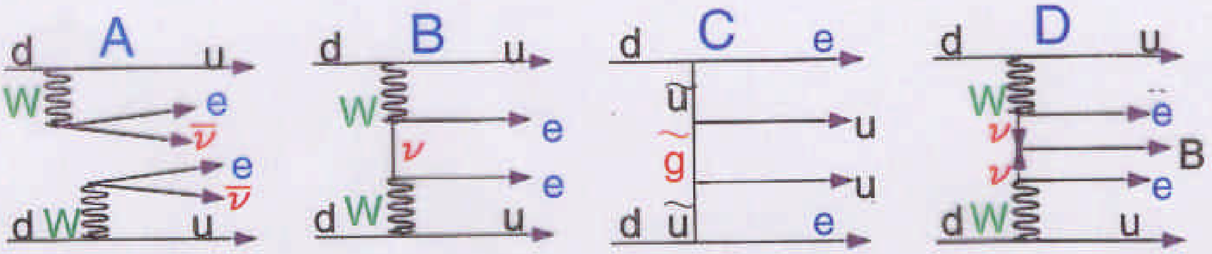
$\sim T(2\nu\beta\beta)\ 10^{8}\ (m_\nu/m_e)^2$

c. Nuclear β β Detector/Microscope with

Filtering Power of $T(\beta)/T(\beta\beta)=10^{25}$ to cut β

Enlargement Factor of 10^{8} to Find Small m_ν

1.2. ββ as Sensitive Probes for Fundamental Properties of ν and Weak Interactions



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

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

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

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

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

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

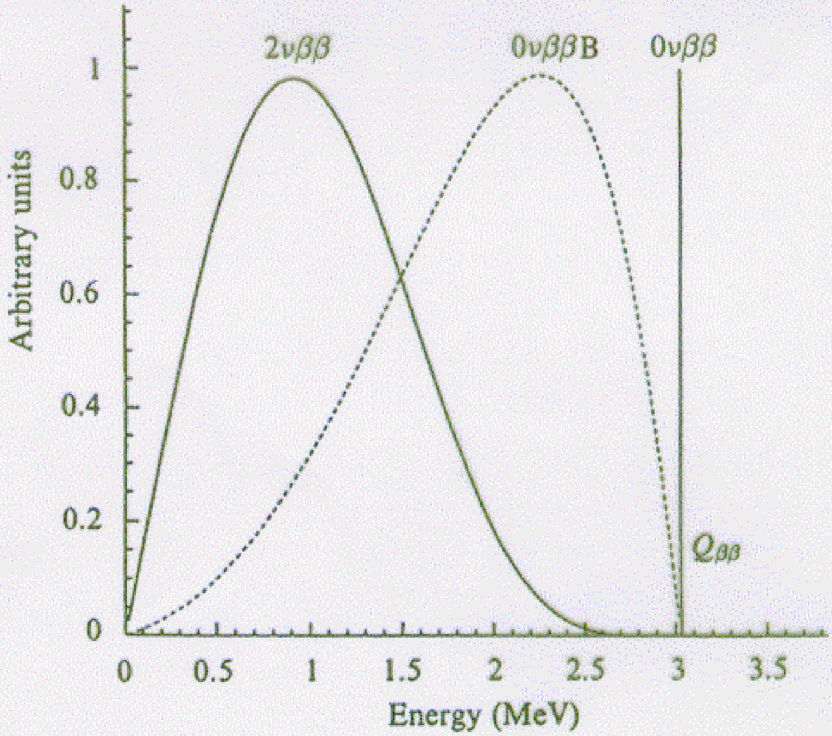
D. $0\nu\,\beta\,\beta$ M with Majoron (G–Boson for L–B Break

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

$\langle g_M\rangle = \Sigma\, g_{jk}\, V_{ej}\cdot V_{ej}$ g_M: M– ν Coupling

1.4. Energy Spectra & β_1–β_2 Correlations

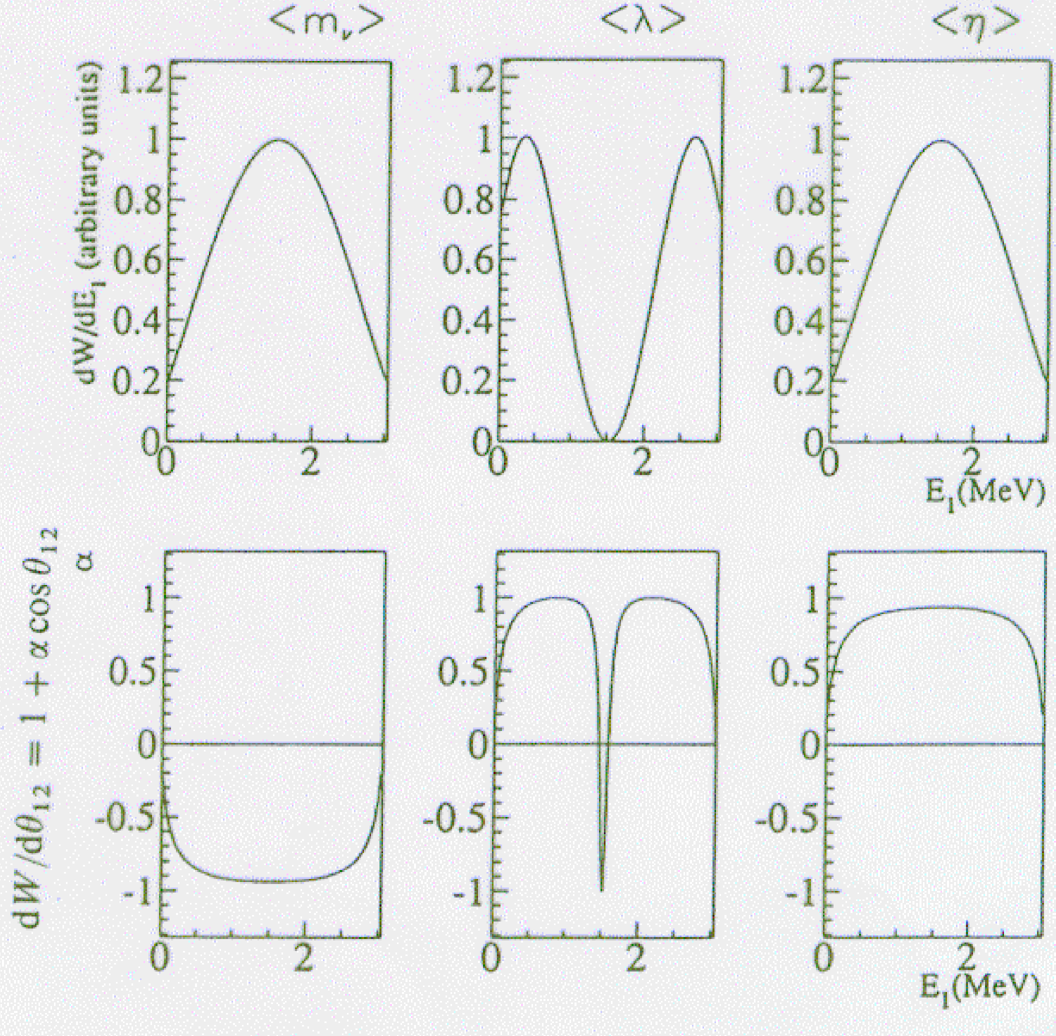
E_1+E_2



E_1

Calculated single-β energy spectra (top) and β_1–β_2 angular correlation

θ_{12}



1.5.Nuclear Sensitivities for ν

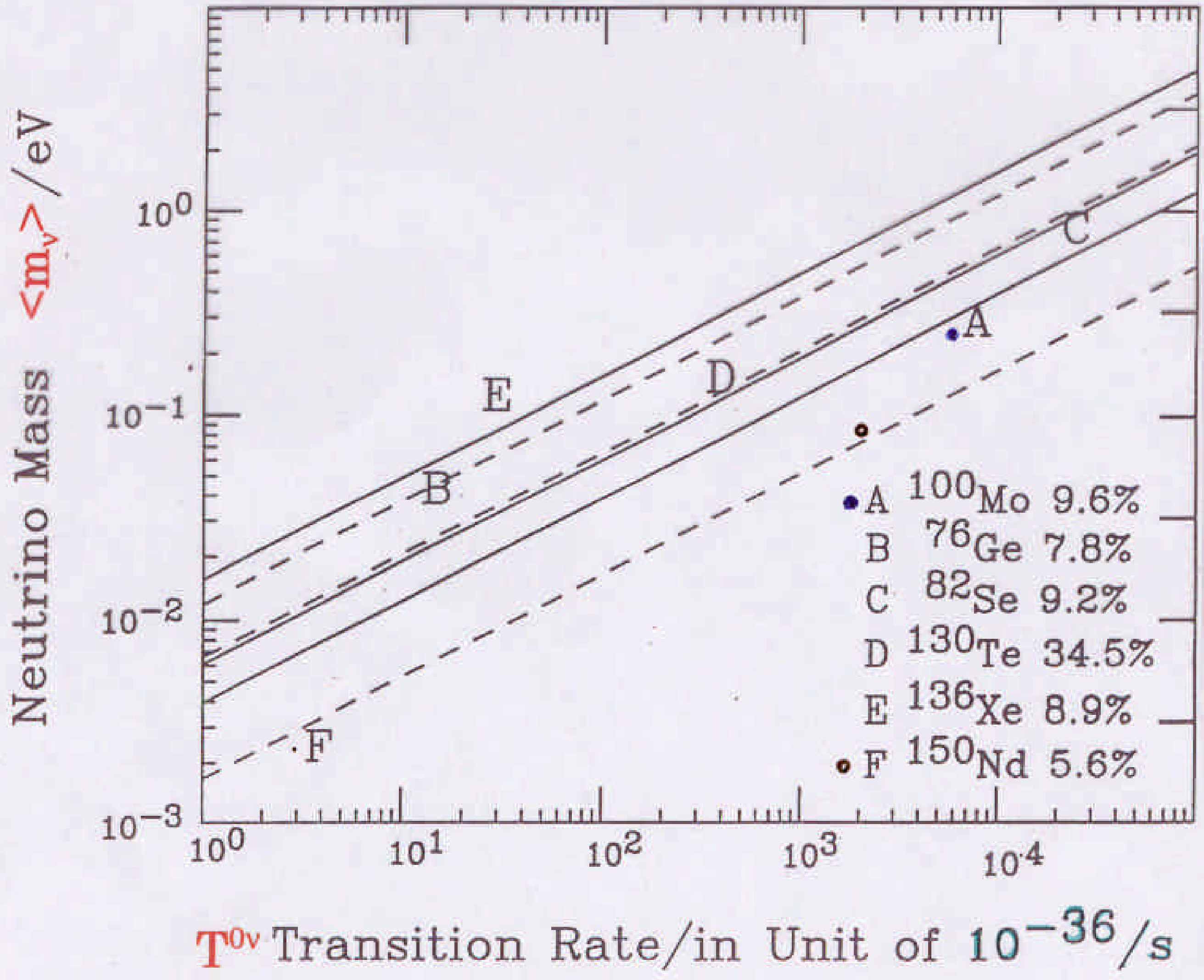
Nuclei as sensitive detectors for ν mass etc..

$$T^{0\nu} = S^{0\nu}\,[\,\langle m_\nu\rangle^2,\quad \langle RHC\rangle^2,\quad \langle g_B\rangle^2,\quad \text{etc.}\,]$$

$S^{0\nu}$:Nuclear sensitivity = $G^{0\nu}\,|\,M^{0\nu}\,|^2$

$G^{0\nu}$; Phase space volume ~$Q_{\beta\beta}{}^5$, Large Z

$M^{0\nu}$; Nuclear matrix element



2.Present Status of ββ Experiments.

2.1.Detector Sensitivities S_D

$Y_S = N_{\beta\beta}\,\varepsilon_D\, t\, T^{0\nu}$ $\quad Y_{BG} = \Delta E\,(I_{BG}/\mathrm{keV/year})$

$Y_S/(Y_{BG})^{1/2} = S_D\, T^{0\nu} > 1$

S_D detector sensitivity = $N_{\beta\beta}\,\varepsilon_D\, t\, /\, (\Delta E\, I_{BG})^{1/2}$

1.Geochemical /radiochemical method.

Inclusive count of ββ decay products for long t .

^{82}Se, ^{96}Zr, ^{128}Te, ^{130}Te, ^{238}U, ^{244}Pu, ...

$T_{\beta\beta}(\mathrm{exp}) \sim T_{\beta\beta}^{2\nu}(0^+ - 0^+)$, or limits on $T_{\beta\beta}^{0\nu}$, $T_{\beta\beta}^{2\nu}$.

2.Calorimetric method for $E_\beta + E_\beta$

Detectors with ββ-sources. Good ΔE, ε_D

$\beta^-\beta^-$ ^{48}Ca, $^{76}\underline{\mathrm{Ge}}$, ^{116}Cd, ^{128,130}Te, ^{136}Xe, ^{160}Gd

β^+/EC ^{40,46}Ca, ^{106}Cd, ^{136,140}Ce,

3.Spectroscopic method for E_1, E_2, θ_{12}.

$<m_\nu>$, $<RHC>$ by E & θ correlations.

BG analysis. Low BG.

TPC, ELEGANT/NEMO, ...

$^{82}\underline{\mathrm{Se}}$,^{96}Zr ^{100}Mo, ^{116}Cd, ^{150}Nd,

TABLE IV. Experimental results of $2\nu\beta\beta$, $0\nu\beta\beta$, and $0\nu\beta\beta B$. Halflives are given for the ground state $0^+ \rightarrow 0^+$ $\beta^-\beta^-$ transitions in even even nuclei.

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Transition	$Q_{\beta\beta}$ (MeV)	$t_{1/2}^{2\nu}$(y)	$t_{1/2}^{0\nu\beta\beta}$(y)	$t_{1/2}^{0\nu\beta\beta B}$(y)	Remark
^{48}Ca$\rightarrow^{48}$Ti	4.276		$> 9.5\ 10^{21}$		*a*
		$4.3(+2.4-1.1\pm1.4)\ 10^{19}$			*b*
^{76}Ge$\rightarrow^{76}$Se	2.039	$9.2(+0.7-0.4)\ 10^{20}$			*c*
		$1.77(\pm0.01+0.13-0.11)\ 10^{21}$		$> 7.91\ 10^{21}$	*d*
			$> 5.7(1.6^*)\ 10^{25}$		*e*
^{82}Se$\rightarrow^{82}$Kr	2.992	$1.08(+0.26-0.06)\ 10^{20}$	$>2.74\ 10^{22}$		*e*
		$0.83(\pm0.1\pm0.07)10^{20}$	$> 9.5\ 10^{21}$	$> 2.4\ 10^{21}$	*g*
^{96}Zr$\rightarrow^{96}$Mo	3.351	$3.9(\pm0.9)\ 10^{19}$			*h*
		$2.1(+0.8\text{-}0.4\ \pm0.2)\ 10^{19}$	$> 1.0\ 10^{21}$	$> 3.5\ 10^{20}$	*g*
^{100}Mo$\rightarrow^{100}$Ru	3.134	$1.15(+0.3-0.2)\ 10^{19}$	$> 6.5\ 10^{22}$	$> 6.24\ 10^{21}$	*i*
		$6.8(+0.38-0.53\pm0.68)\ 10^{18}$	$> 1.234\ 10^{21}$	$> 3.314\ 10^{20}$	*j*
		$7.6(+2.2-1.4)\ 10^{18}$	$> 2.2\ 10^{22}$		*k*
^{116}Cd$\rightarrow^{116}$Sn	2.804	$2.6(+0.9-0.5\pm0.35)\ 10^{19}$	$> 5.44\ 10^{21}$		*l*
		$2.7(+0.5-0.4+0.9\text{-}0.6)\ 10^{19}$	$> 2.94\ 10^{22}$		*m*
		$3.6(\pm0.35\ \pm0.21)\ 10^{-19}$	$> 5.0\ 10^{21}$	$> 1.2\ 10^{21}$	*n*
^{128}Te$\rightarrow^{128}$Xe	0.867	$7.7(\pm0.4)\ 10^{24}$	$> 6.9\ 10^{24}$	$6.9\ 10^{24}$	*o*
^{130}Te$\rightarrow^{130}$Xe	2.529	$2.7(\pm0.1)\ 10^{21}$	$> 2.54\ 10^{21}$	$> 2.5\ 10^{21}$	*o*
			$> 5.6\ 10^{22}$		*p*
^{136}Xe$\rightarrow^{136}$Ba	2.467	$> 3.6\ 10^{20}$	$> 4.4\ 10^{23}$	$7.2\ 10^{21}$	*q*
^{150}Nd$\rightarrow^{150}$Sm	3.368	$6.75(+0.38\text{-}0.42\pm0.68)\ 10^{18}$	$> 1.22\ 10^{21}$	$> 2.82\ 10^{20}$	*r*
^{238}U$\rightarrow^{238}$Pu	1.437	$2.0(\pm0.6)\ 10^{21}$	$> 0.84\ 10^{21}$	$> 0.8\ 10^{21}$	*s*
^{244}Pu$\rightarrow^{244}$Cm	1.352	$>1.1\ 10^{18}$	$> 1.1\ 10^{18}$	$> 1.1\ 10^{18}$	*t*

Enriched ^{76}Ge detectors $Q_{\beta\beta}$=2.039MeV ΔE 3~4keV.

Heidelberg-Moscow PRL 83 "99

Five HPGe 86% 125.5mole of ^{76}Ge. Gran Sasso

BG 0.06 /keV/y/kg.

$T^{0\nu} > 5.7\ (1.6^*) 10^{25}$y. 90 %.

* Sensitivity.

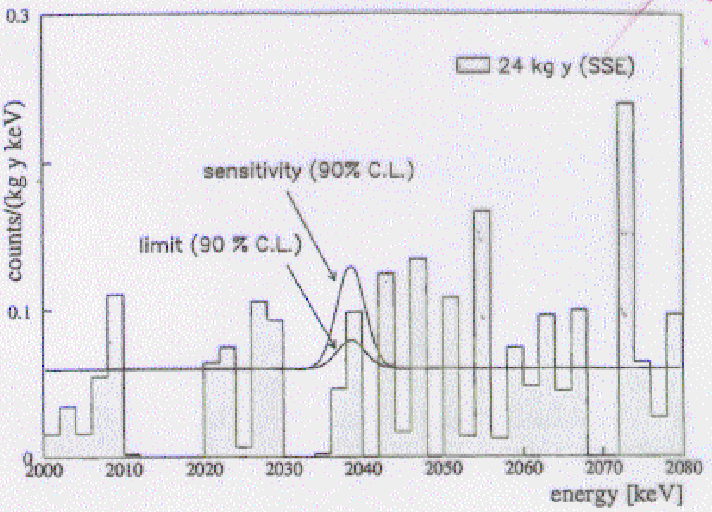
$<m_\nu> < 0.2\ (\ ^*0.38\ )$ eV.

Dependence on $M^{0\nu}$, factor 3,

on the peak interval ,

factor 2. Avignone III .

Single site event.



IGEX(International Ge Exp.) PRC 59 '99. TAUP 99.

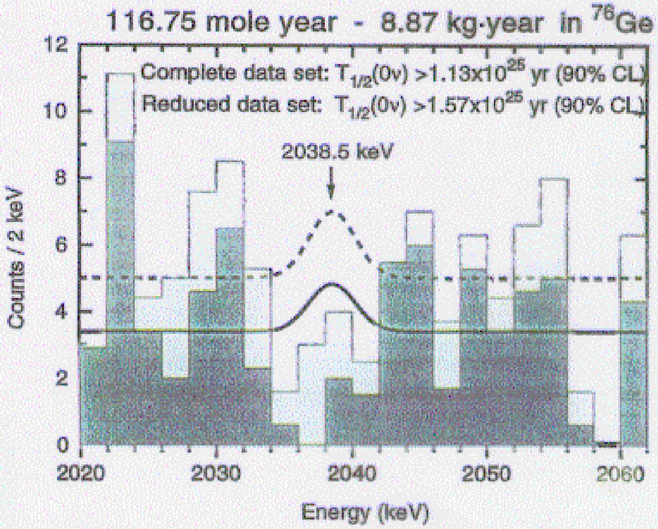
Six HPGe 90 moles. 86 %^{76}Ge Canfrane/Baksan.

Presently with 3-2kg. PSA.

BG ~ 0.06 /keV/y/kg

$T^{0\nu} > 1.57\ 10^{25}$y(90%)

$<m_\nu>$ < 0.33 ~ 1.31 eV



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Canfranc Underground Laboratory

Spanish Pyrenees

Railway tunnel (not in use)

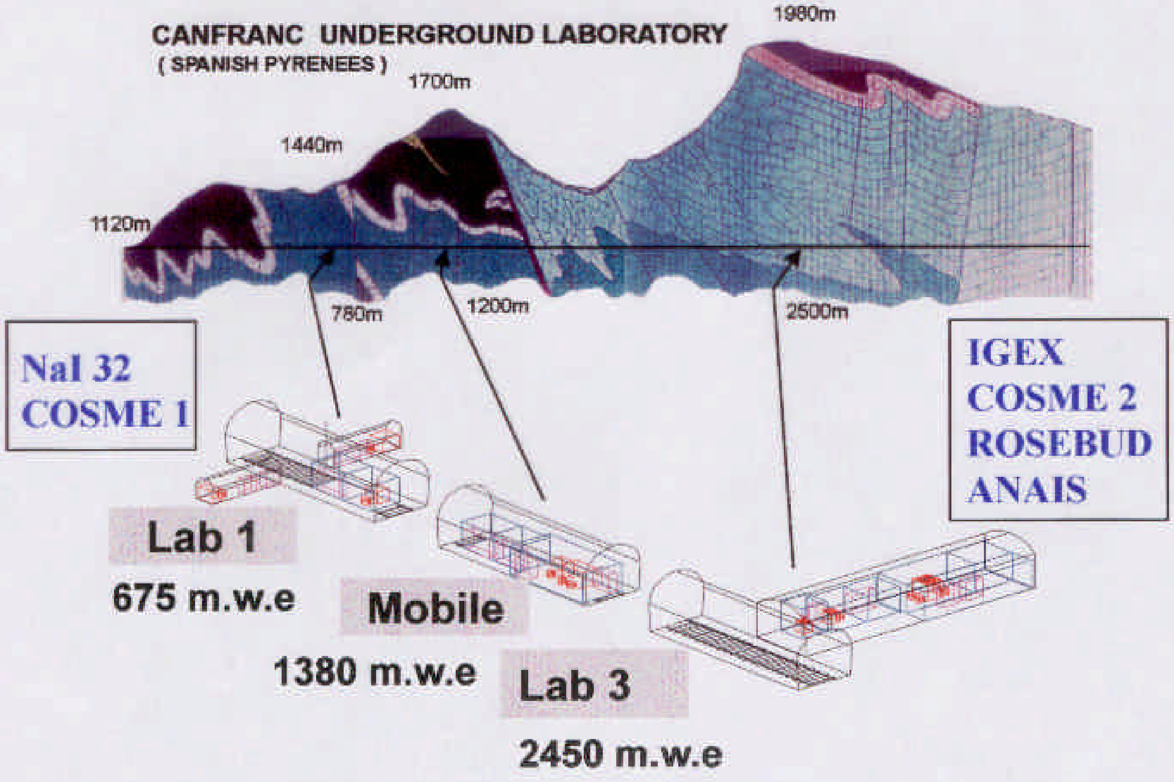


Figure 1

Bolometric method for ^{130,128}T Milano/Gran Sasso

20 crystals TeO_2 3-3-6 cm^3 : 2 of ^{130}Te, 2 of ^{128}Te

Total 6.8 kg. 0.85 kg y run for ^{130}Te.

BG 0.5 /keV/kg/y FWHM 9.5 keV

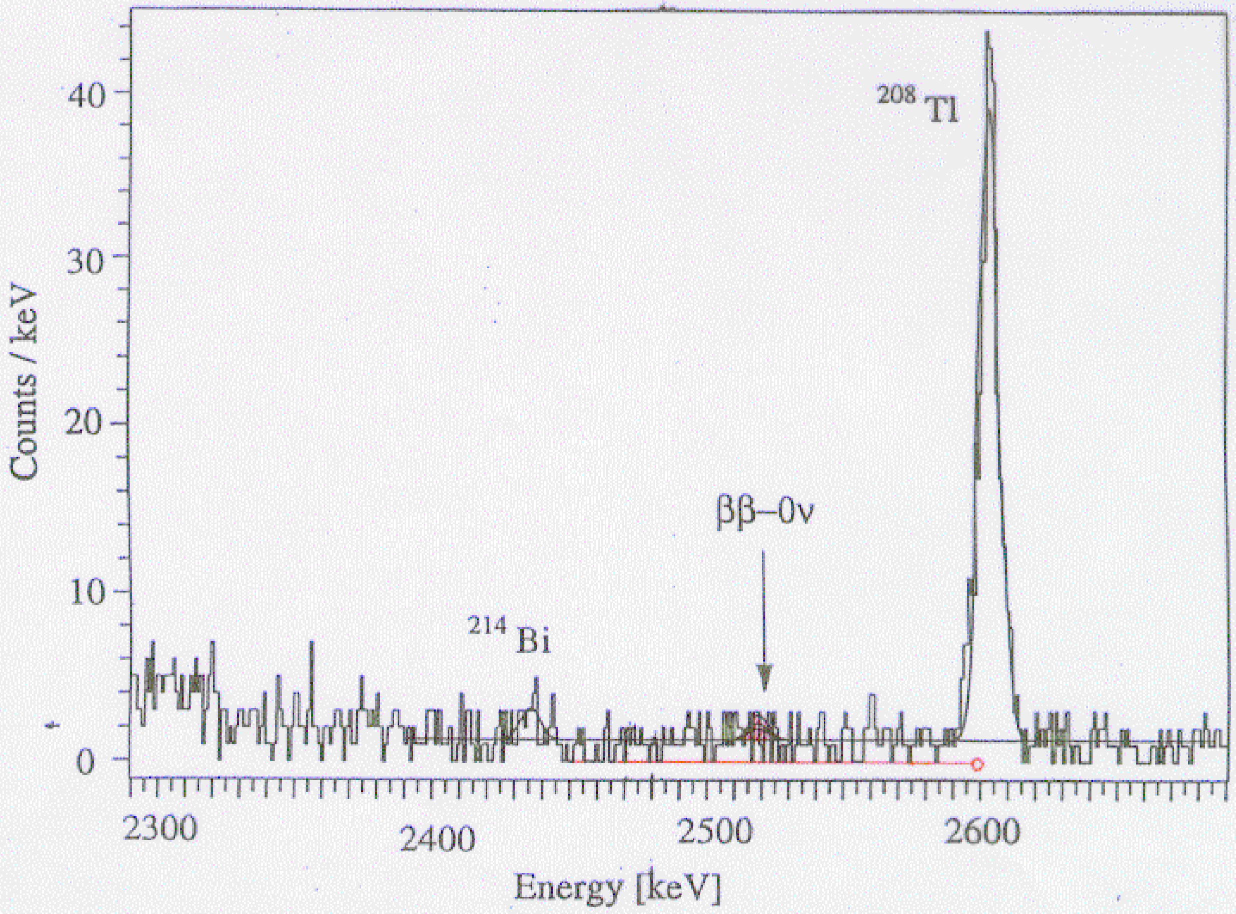
$T^{0\nu} > 8.6 \quad 10^{22}$y 90% for ^{128}Te

$1.44 \; 10^{23}$y ^{130}Te

T^{2}[illegible] $3 \quad 10^{20}$y ^{130}T

$<m_\nu>$ 1.1 ~ 2.6 eV

$<g_B> < 2.6 \sim 6.7 \; 10^{-4}$



^{100}Mo with ββ-tracking and E/T/,. $Q_{\beta\beta} = 3.034$ MeV.

ELEGANT (ELEctron Gamma Neutrino Telescope)

RCNP/Osaka Oto Lab.

Drift-chamber Plastic scintillator NaI ensemble

^{100}Mo (94%) 1.7 moles

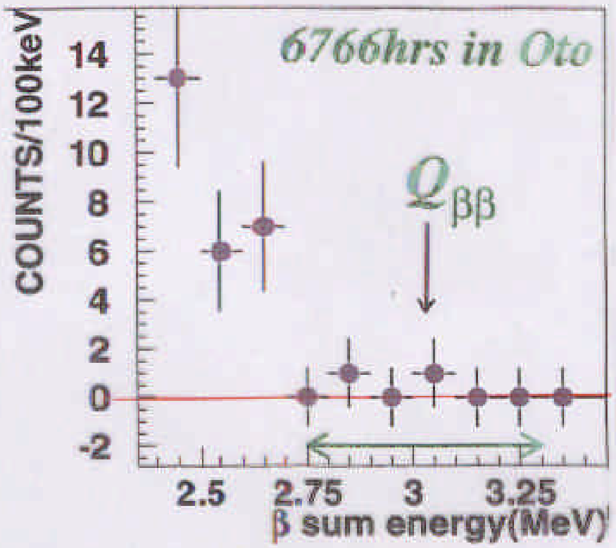
BG ~ 0.0028 /keV/y/kg

$T^{0\nu} > 4.5\ 10^{22}$ y (90%)

$<m_\nu> < 2.3$ eV

$T^{0\nu B} > 4.\ 10^{21}$ y (90%)

$<g_B> < 8.5\ 10^{-5}$



NEMO collaboration, NEMOII, III,

III . Geiger cells and plastic scintillators

20 sectors, 3 are equipped. Start 2001.

^{100}Mo 7kg. ^{82}Se 1kg,

^{116}Cd 0.5kg, ^{150}Nd 70g,

^{96}Zr 20gr.

Sensitivity~ 0.5 eV

depending on BG

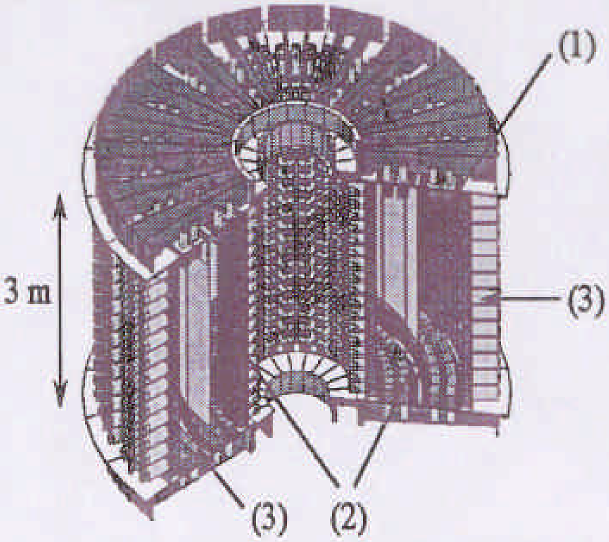
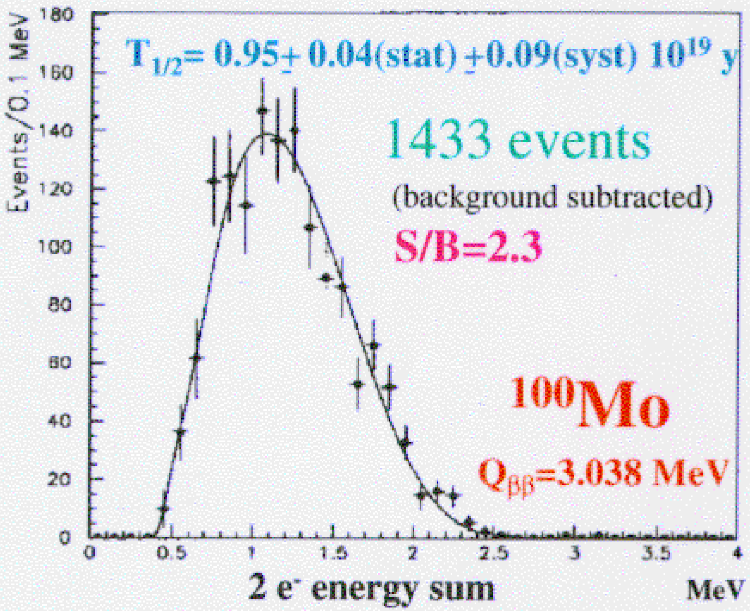
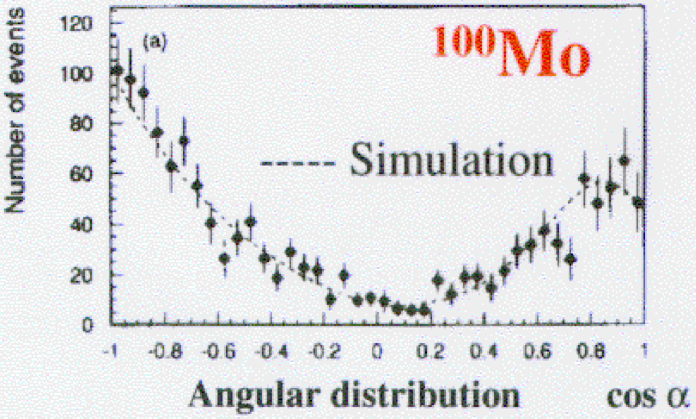
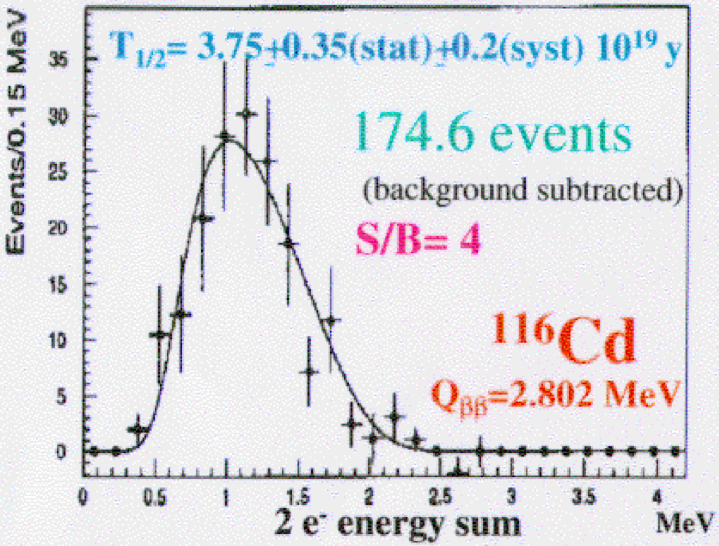


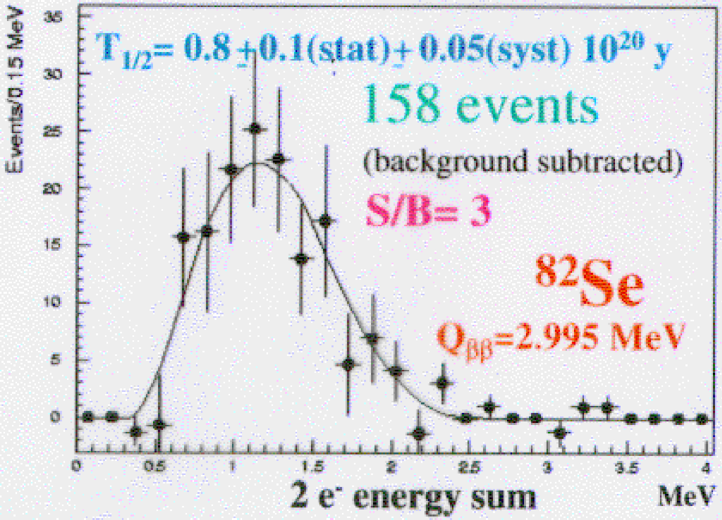
Figure 4. NEMO 3 detector. (1) Source foil, (2) tracking volumes consisting of 3 m vertical Geiger cells, (3) calorimeter made of plastic scintillators

NEMO 2 ββ(2ν) RESULTS









^{96}Zr $T_{1/2}= 2.1^{+0.8}_{-0.4} \pm 0.2$(syst) 10^{19} y

$Q_{\beta\beta}$=3.350 MeV

ββ decays from 0^+ to excited 0^+ states

$0^+ \to \beta\beta \to 0^+ \to \gamma \to 2^+ \to \gamma \to 0^+$

^{100}Mo $T \sim T^{2\nu} = 7.6\ 10^{20}$

HPGe γγ **Balabash et al '99**

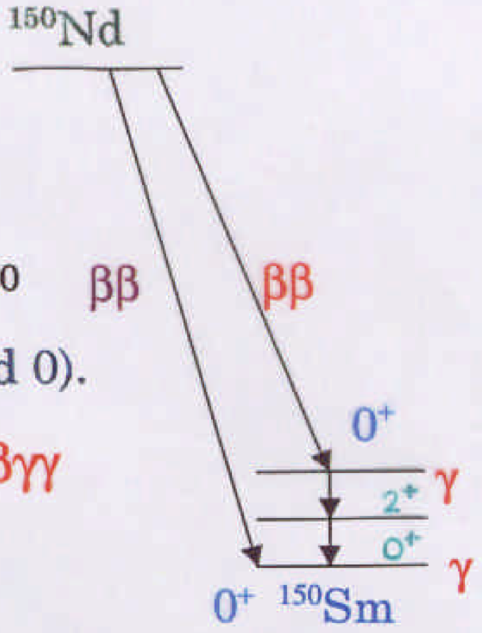
$5 \sim 8\ 10^{20}$ **Braeckeleer et al. '00**

$M^{2\nu}$ (excited 0) ~ $M^{2\nu}$(ground 0).

Then ββ to excited 0^+ with ββγγ

coincidence may be used

if the phase space is large.



^{150}Nd to ^{150}Sm $Q_{\beta\beta} = 2.65$ MeV ,Large sensitivity

Liq.Ar with Mo foil cathodes ^{100}M

$T^{2\nu}=0.85\ 10^{19}$ **Ashitkov et al.,'99**

ELEGANT NaI γγ EC/β^+ Limits on

^{50}Co, ^{58}Ni, ^{64}Zn, ^{92}Mo, ^{96}Ru, ^{100}Cd, ^{112}Sn ···

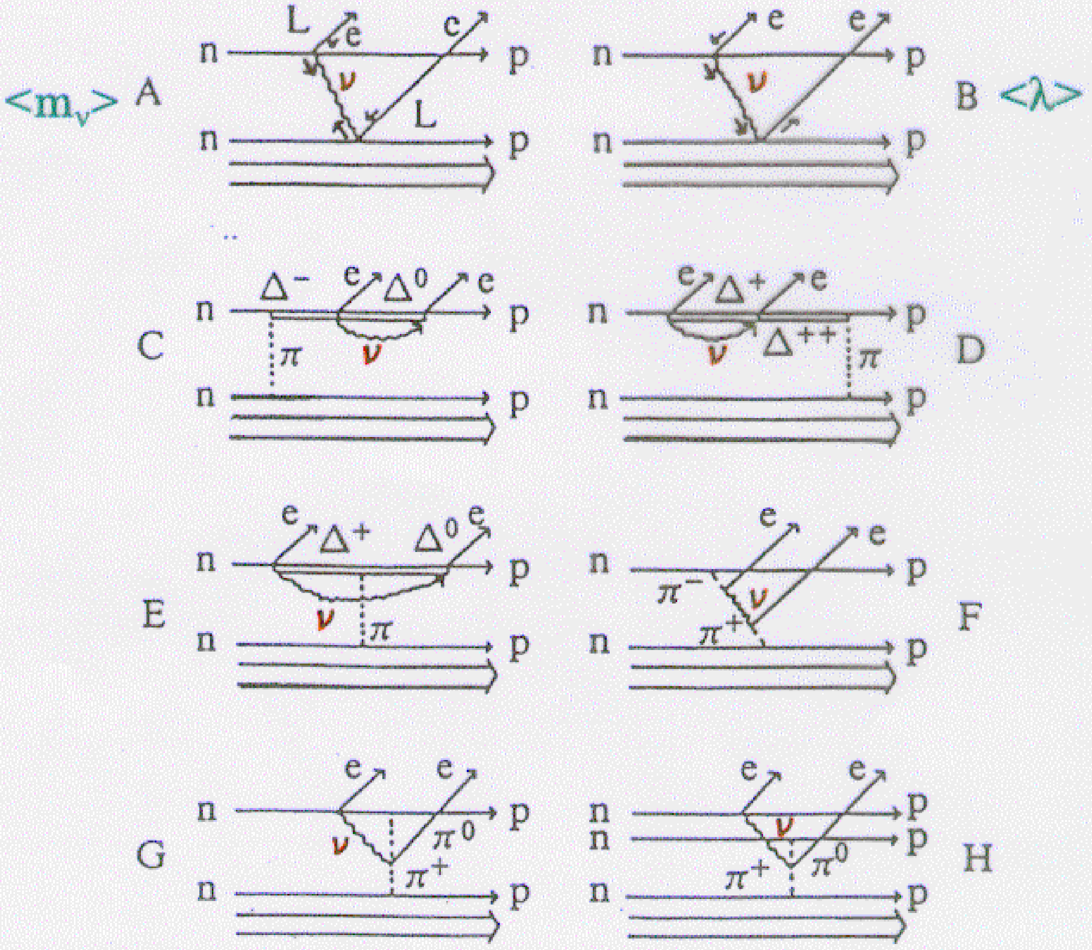
CaF_2 CeF_3, Cd+NaI Limits on $T^{0\nu}$

for ^{40}Ca' ^{46}Ca, ^{106}Cd, ^{136}Ce, ^{142}Ce Belli et al.

3.Nuclear Responses for ββ–ν

3.1. 2νββ $T^{2\nu} = G^{2\nu}\ |M^{2\nu}(\tau\sigma)|^{2}$

0νββ $T^{0\nu} = G^{0\nu}\ |M^{0\nu}(\tau\sigma q r)|^{2}\ [<m_\nu>^{2}, <\lambda>^{2}, \ldots]$



2n-mode (ν exchange between 2 N) is major.

Isobar mode (ν exchange between 2 quarks in Δ)

Pion (ν exchange between π and N) ~ 10 % , to be considered to be quantitative in $<m_\nu>$, $<\lambda>$, etc.

Nuclear matrix elements for 2νββ and 0νββ.

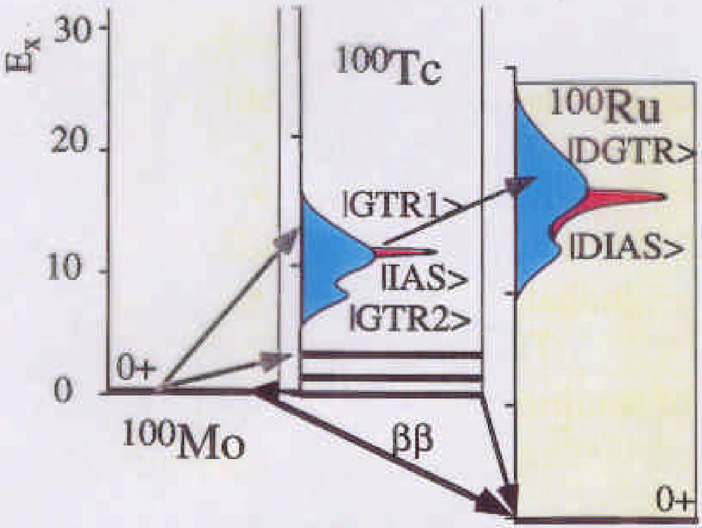
$$M^{2\nu} = \left[M^{2\nu}(GT) + \left(\frac{g_V}{g_A}\right)^2 M^{2\nu}(F) \right]$$

$$M^{2\nu}(GT) = \sum_c \frac{\langle 0_f|\tau\sigma|1_c^+\rangle\langle 1_c^+|\tau\sigma|0_i\rangle}{\Delta_c} \quad M^{2\nu}(F) = \sum_c \frac{\langle 0_f|\tau|0_c^+\rangle\langle 0_c^+|\tau|0_i\rangle}{\Delta_c}$$

$$M^{0\nu}(\tau\sigma) = \sum_c \langle 0_f|h_+(r,E_c)\tau\tau\sigma\sigma|0_i^+\rangle ,$$

$$M^{0\nu}(\tau) = \sum_c \langle 0_f|h_+(r,E_c)\tau\tau|0_i^+\rangle , \quad h_+(r,E_c) = \frac{R}{2}(H_1 + H_2)$$

$$H_k(r,E_c) = \frac{1}{2\pi^2}\int \frac{\exp(iq\cdot r)}{\omega(\omega + A_k)}\mathrm{d}q = \frac{2}{\pi r}\int \frac{q\sin(qr)}{\omega(\omega + A_k)}\mathrm{d}q , \quad \begin{array}{l} q \sim 100\ \mathrm{MeV/c} \\ L\hbar = 1\hbar \sim 5\hbar \end{array}$$



$|M^{2\nu}(\tau\sigma\tau\sigma)|^2 \sim 0.01|M^{2\nu}_{SP}|^2$ from $T^{2\nu}$(exp) .

Mostly double GTR(τσ). Used to check H(τσ) for $M^{0\nu}$

$|M^{0\nu}(\tau\sigma\tau\sigma\ r_{12})|^2$. Mostly double GR(τσ Y_L)

. No direct exp. for $M^{0\nu}$. Rely on theories.

3.2.Theoretical evaluations of $M^{2\nu}$ and $M^{0\nu}$

SM.Light nuclei. Courier et al., Koonin et al.

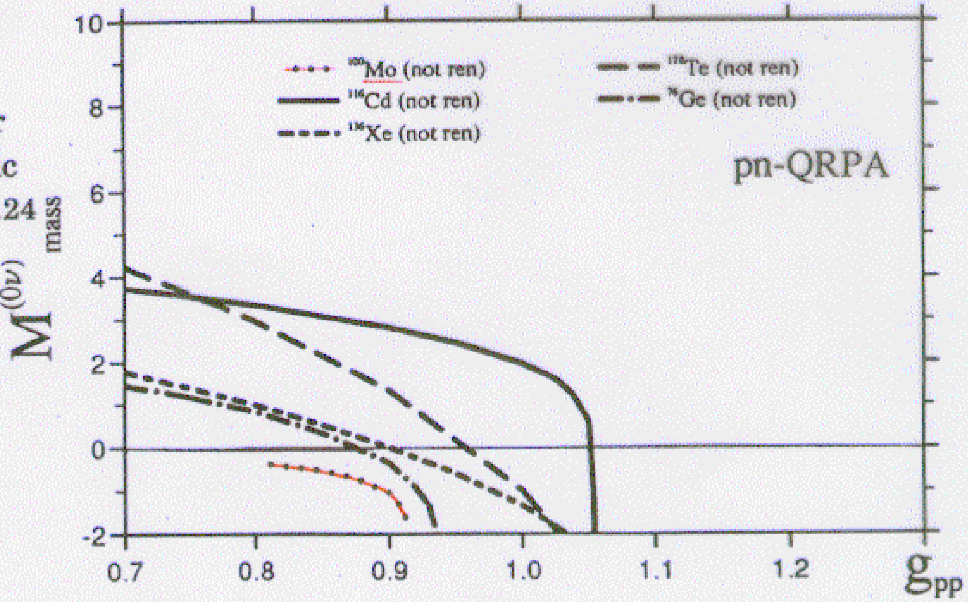
SU(4) $\tau\sigma$ sym. break. Ericson et al.,Krompotic et al.

OEM. Operator expansion method . Chin et al.

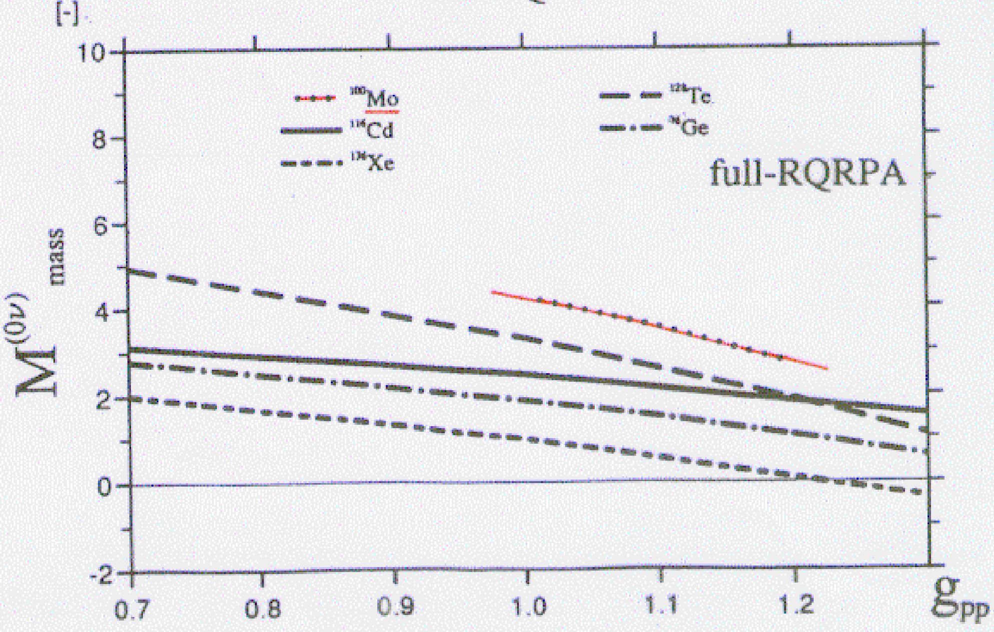
QRPA. Vogel et al., Tomoda et al., Muto et al.

RQRPA. Toivanenet al., Schweger et al. ...

Faessler
Simkovic
J.Phys.G.24
'98.



full-RQRPA



3.3. Nuclear Matrix Elements $M^{2\nu}$, $M^{0\nu}$

Revi^{e}ws, Faessler-Simkovic, Shuhonen-Civitarese, Ejiri

$M^{2\nu}$ within a factors 1.5~2 agree with $2\nu\beta\beta$ exp.

$M^{0\nu}$ within factors 2 agree with each other.

Precise theoretical values, including Δ, π ,& experimental evaluations for $M^{0\nu}$ to get $<m_\nu>$.

Experimental and calculated $2\nu\beta\beta$ matrix elements in units of $(m_e)^{-1} \times 10^{-2}$ for the ground state $0^+ \rightarrow 0^+ \beta^- \beta^-$

Transition	$M^{2\nu}_{\text{exp}}$	$M^{2\nu}_{\text{cal1}}$	$M^{2\nu}_{\text{cal2}}$	$M^{2\nu}_{\text{cal3}}$
$^{48}\text{Ca} \rightarrow {}^{48}\text{Ti}$	$2.6^{+0.6}_{-1.0}$	4.0 a	7.0 b	5.5 c
$^{76}\text{Ge} \rightarrow {}^{76}\text{Se}$	$6.5^{+0.3}_{-0.2}$	10 d	7.4 e	8.3 f
$^{82}\text{Se} \rightarrow {}^{82}\text{Kr}$	$4.6^{+0.1}_{-0.5}$	7.2 d	4.6 e	5.2 g
$^{96}\text{Zr} \rightarrow {}^{96}\text{Mo}$	$3.7^{+0.5}_{-0.4}$	2.2 h	3.6 e	2.2 g
$^{100}\text{Mo} \rightarrow {}^{100}\text{Ru}$	9.6 ± 1	25.6 i	19.7 j	5.9 g
$^{116}\text{Cd} \rightarrow {}^{116}\text{Sn}$	$6.9^{+0.8}_{-0.9}$	4.5 h	5.1 d	3.6 f
$^{128}\text{Te} \rightarrow {}^{128}\text{Xe}$	1.24 ± 0.03	—	4.6 d	0.56 g
$^{130}\text{Te} \rightarrow {}^{130}\text{Xe}$	8.8 ± 0.2	—	2.8 d	1.6 g
$^{136}\text{Xe} \rightarrow {}^{136}\text{Ba}$	< 2.4	—	4 d	3.8 g
$^{150}\text{Nd} \rightarrow {}^{150}\text{Sm}$	$5.5^{+0.4}_{-0.3}$	5.2 h	5.5 k	—

Double electron captures by SU(3) Ceron, Hirsh, PL.B471 '99.
$T^{2\nu}$ ^{156}Gd (Q=2.01 MeV) 2.7 10^{22}y, ^{162}Er, ^{168}Yb.

Momentum-dependent-induced nucleon currents reduce $M^{0\nu}$ by 30 % for light ν and up to a factor 6 for heavy ν, increase exp. $<m_\nu>$ limits by 30%. In RQRPA. Simkovic et al.,PR C 60 '99

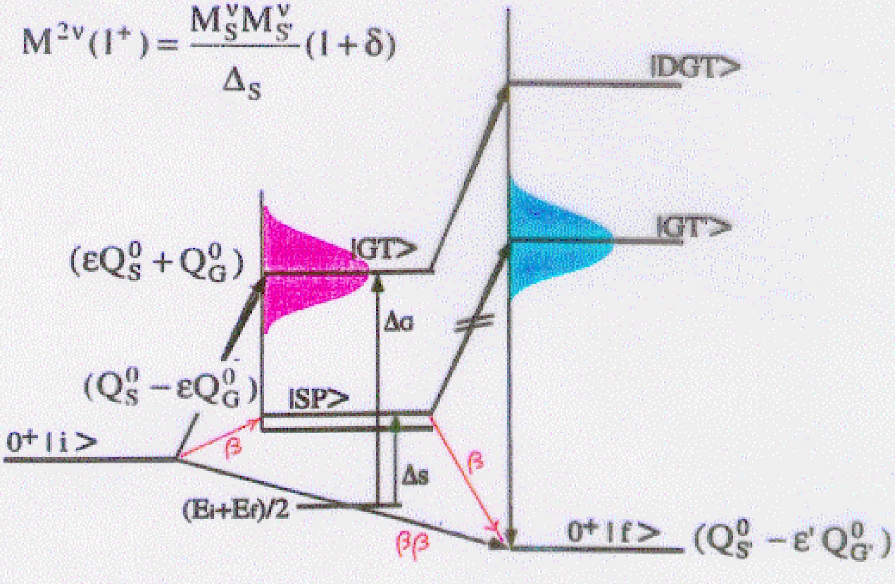
3.4.Experimental Evaluations for $M^{0\nu}$ and $M^{0\nu}$

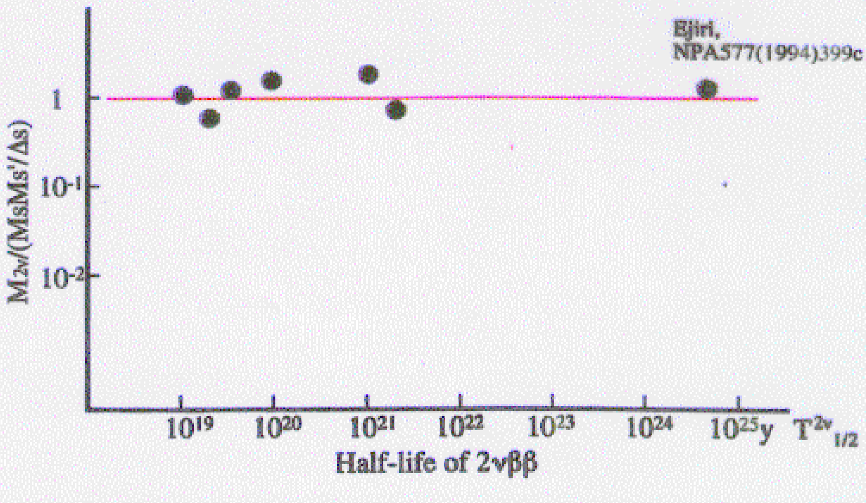
$M^{2\nu}$ Single intermediate state dominance hyposis (SSDH). Abad et al. '84.

SPHM Single particle-hole model.Ejiri '94. '96

$$M^{2\nu}(1^+)=\sum_{\kappa}\frac{M_{\kappa}^{\nu}M_{\kappa'}^{\nu}}{\Delta_{\kappa}}=\frac{\overset{\text{exp}}{M_S^{\nu}M_{S'}^{\nu}}}{\Delta_S}+\frac{M_G^{\nu}M_{G'}^{\nu}}{\Delta_G}$$

$$M^{2\nu}(1^+)=\frac{M_S^{\nu}M_{S'}^{\nu}}{\Delta_S}(1+\delta)$$





$M_S^{\nu}=|0_i\rangle\rightarrow|S\rangle=g^{eff}M_S^0$ $g^{eff}\approx 0.3$ by $-\varepsilon Q_G^0$

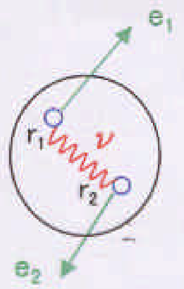
$M_{S'}^{\nu}=|S\rangle\rightarrow|0_f\rangle=g^{eff}M_{S'}^0$ $g^{eff}\approx 0.3$ by $-\varepsilon' Q_{G'}^0$

$M_S^{n}M_{S'}^{n}\approx(g^{eff})(g^{eff})M_S^0M_{S'}^0\approx 0.1\ M_S^0M_{S'}^0$

Exp. EC ,Garcia, Bhattacharya, (^{3}He,t) Osaka.

Theories. Civitarese , Suhonen, Ejiri '98, '99, '00.

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

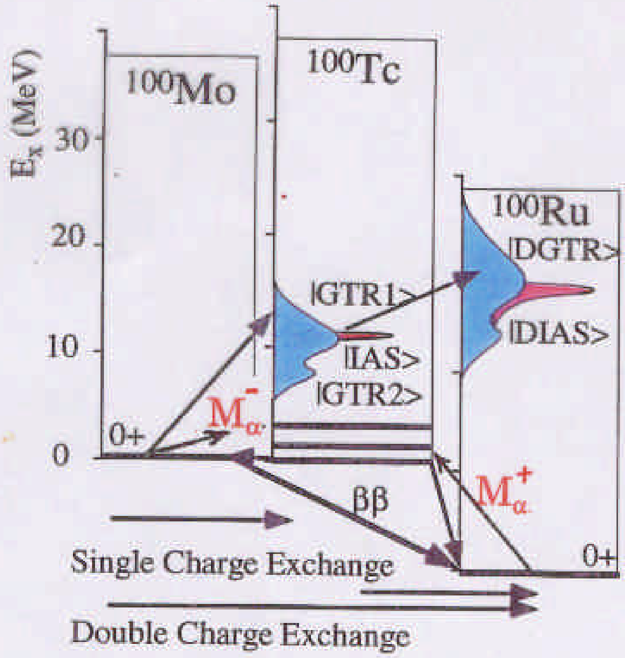
$$f(r_1, r_2) \sim \sum_\ell f_\ell\, h_\ell(r_1)\, h_\ell(r_2)$$ Ejiri, Belyaev

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

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

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

(^{3}He,t) and (t.^{3}He) reactions



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

$$M_\alpha^\pm = g_\alpha\, \tau^\pm [\sigma^S Y_L]_J$$

$M^{0\nu}$($\tau\sigma\ \tau\sigma\ r_{ij}$) by double charge exchange

$\tau^-\tau^-$ reactions with $\Delta T = 2$, (^{11}B, ^{11}Li)

4. ν and Weak Interactions by ββ

Recent results of ν and weak interactions by ββ 90% C.

	$Q_{\beta\beta}$ (MeV)	$T^{0\nu}10^{22}$	$<m_\nu>$eV	$T^{0\nu B}\,10^{21}$	$<g>\,10^{-5}$	
^{76}Ge	2.04	5700(1600)	.24(.44)			Heid-Mos.
		1900	.40			H.M.'00
		1570	.45			IGEX
^{96}Zr	3.35	.1	33	.35	30	NEMO
^{100}Mo	3.03	4.5	2.7	4	.85	ELEGANT Osaka
^{116}Cd	2.8	7	3.3	3.7	2.2	Kiev poster
^{128}Te	.87	690	[1.5]	6900	[.55]	Bernatowisz
^{130}Te	2.53	14.4	2.6			Milano
^{136}Xe	2.47	44	3.5	7.2	4.4	Luescher
^{150}Nd	3.37	0.12	7.1	.28	1.9	Silva et al

$M^{0\nu}$ by RQRPA Faessler -Simkovic

( ) sensitivity . [ ] Geo-chemical Method

Limits on $\langle m_\nu \rangle$ and weak interactions

$\langle m_\nu \rangle$	0.2~ 1.3 eV 0.3	^{76}Ge
	1.5 ~ 4	^{100}Mo, ^{116}Cd, ^{130}Te, ^{136}Xe .
	0.7 ~ 2	^{128}Te Geochenical.
$\langle \lambda \rangle$	0.4~ 1.5 10^{-6}	^{76}Ge,
$\langle \eta \rangle$	0.2 ~ 1.5 10^{-8}	^{76}Ge,
$\langle g \rangle$	0.8 ~ 2 10^{-4}	^{100}Mo
	0.3 ~ 0.6 10^{-4}	^{128}Te Geochemical.

Experimental studies on several nuclei with different methods are important in view of sensitivities on $M^{0\nu}$ and BG

$$\lambda_{111}' \; < \; \sim 5\ 10^{-5} (m_q)^2 (m_g)^{1/2}$$

$$< \; \sim 4\ 10^{-4} (m_e)^2 (m_\chi)^{1/2} \quad {}^{76}\mathrm{Ge}$$

m_a : SUSY mass in unit of 100GeV

v2000-15a

5. Remarks

1. Detector sensitivities.

$m_\nu^{-1} \sim [S^{0\nu} / T^{0\nu}]^{1/2}$ $S^{0\nu} = G^{0\nu} \, |M^{0\nu}|^2$

$S = N_{\beta\beta} \, t \, T^{0\nu} > (BG)^{1/2} = (N_{BG} \, \Delta E \, t)^{1/2}$

$m_\nu^{-1} \sim N_{\beta\beta}^{1/2} \, t^{1/4} \, M^{0\nu} \, Q_{\beta\beta}^{2.5} / [\Delta E \, N_{BG}]^{1/4}$

Present detector limits   weakly on $t^{1/4}$ with BG.

0.4~1 eV ^{76}Ge . ^{130}Te with   good $\Delta E \, N_{BG}$

1 ~ 2 eV ^{100}Mo, ^{150}Nd .. with good $Q_{\beta\beta}$

Spectroscopic studies of β_1, β_2

Need large detectors with $N_{\beta\beta}$ kg--tons to

get sensitivities of 0.02~0.05 eV regions

2. Responses $R^{0\nu}=G^{0\nu}\ |M^{0\nu}|^2$ in $T^{0\nu}=R^{0\nu}|<m_\nu>|^2$

Precise evaluations for $M^{0\nu}$ are crucial for $<m_\nu>$...

Nuclear structure theories.

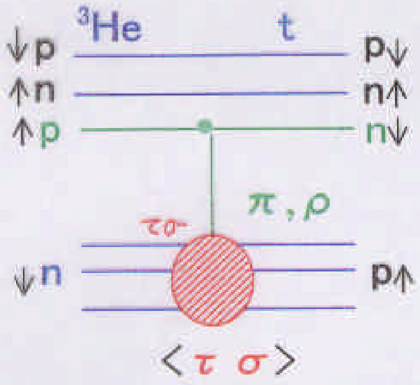
Experimental evaluations.

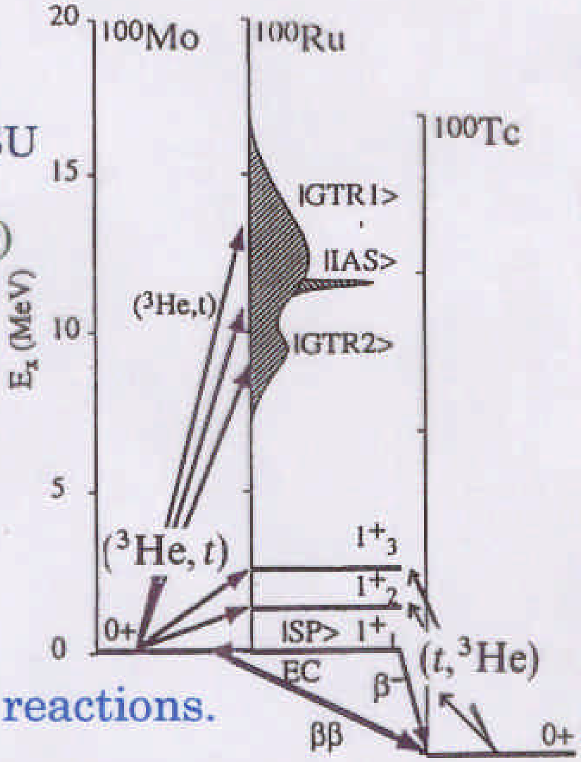
(1) Charge exchange spin-flip hadronic reactions

$M^{0\nu}\sim\Sigma\ [\tau\sigma Y_L][\tau\sigma Y_L]$.

(^{3}He,t) RCNP, (t,^{3}He) MSU

Double $\tau\ \sigma$ flip for $M^{0\nu}(\tau\sigma\ \tau\sigma\ r)$





(3) Charge exchange lepton reactions.

Weak probes,Intense leptons & large detectors.

$(\nu_e, e\,\gamma)$ $(\mu^-, \nu_\mu\,\gamma)$. ν_e, μ^- from π/μ decays

SNS/ORLaND (Avignone III et al.) 1 GeV /1 MW p & ν

Tokai/JAERI 3GeV/1MW p JHF·KEK/JAERI

3. ββ–ν detector application for URANUS.

Ultra **R**are **A**stro **N**uclear **U**nderground **S**pectroscopy.

ββ Ultra rare ($T^{0\nu}$ =10~100 DBU(10^{-36}/nucleus/sec)

for m_ν~0.03 eV) low energy (1 MeV) β γ.process.

e-decay.

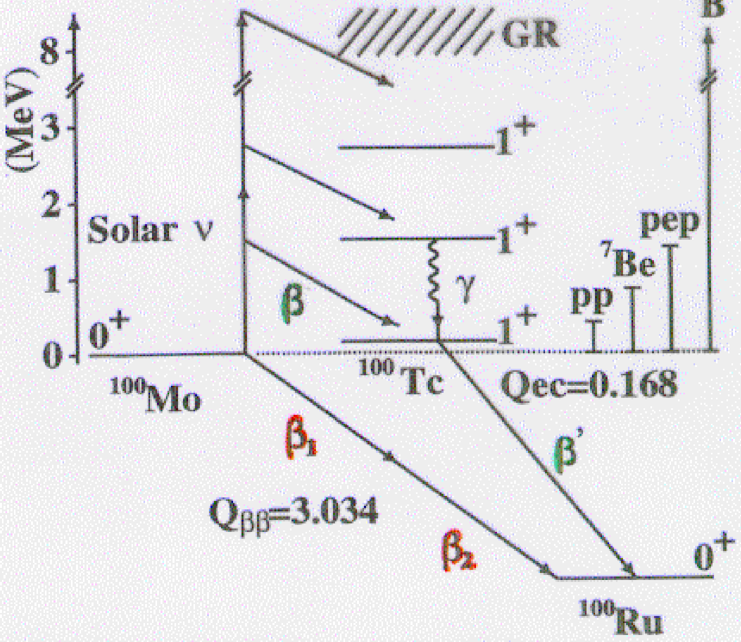
Solar-ν*, Supernova-ν,DM-WIMPs ,Pauli, Gravity,…

MOON (Mo Observatory Of Neutrinos)

* ββ nuclei - solar : Raghavan

Ejiri, Engel,
Hazama,Krastev,
Kudomi, Robertson.
NPL/UW
RCNP/Osaka,
UNC,
UW/WI,

nucl-exp.9911008 v2



Ensemble of Mo/Scintillator/ WLS fibers modules.

Two correlated ββ with $<m_\nu>$~0.03 eV

Two successive β,β' for real-time solar pp-ν, ^{7}Be-ν.

GENIUS Baudis,Klapdor-Kleingrothaus,99

ν+e=ν+e real time low energy solar ν