Double beta decays and neutrinos

High-sensitivity experiment MOON & Nuclear matrix elements

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Praha SPIN08   Thanks Prof. Finger and the organizers.

SPIN2007 General review of ββ and neutrinos. Review of MOON ββ experiments. So in 2008.

- **Introduction :**
  Double beta decays (DBD) and Neutrinos

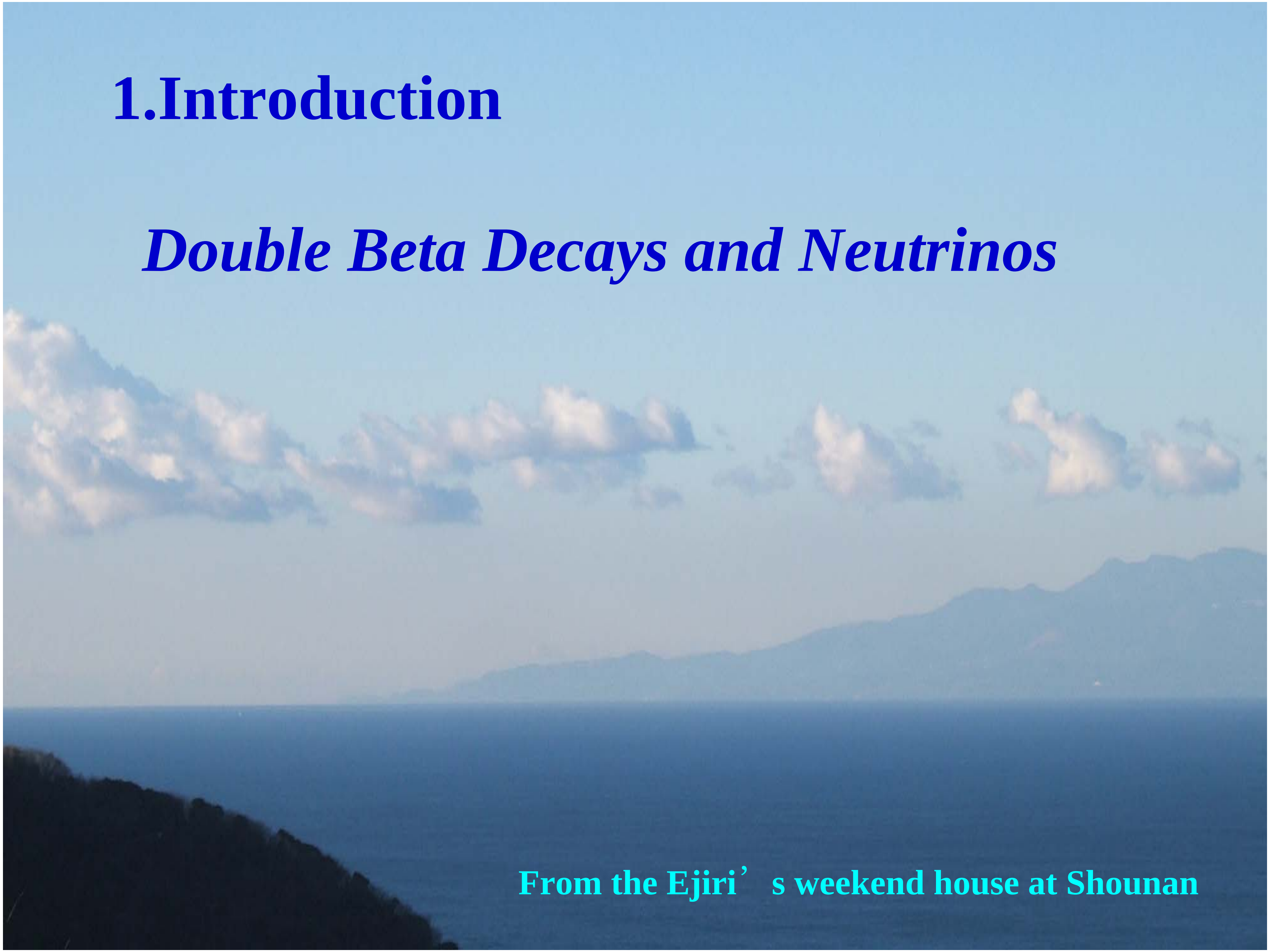
2. MOON the present and future
Majorana/Mo Observatory Of Neutrinos

3. Neutrino spin responses in ββ decays
FSQP and Charge exchange reactions

4. Concluding remarks.

1.Introduction

Double Beta Decays and Neutrinos



From the Ejiri's weekend house at Shounan

1.Neutrino-less ββ decays

$A = B + \beta + \beta$

Lepton number ΔL=2 beyond SM.

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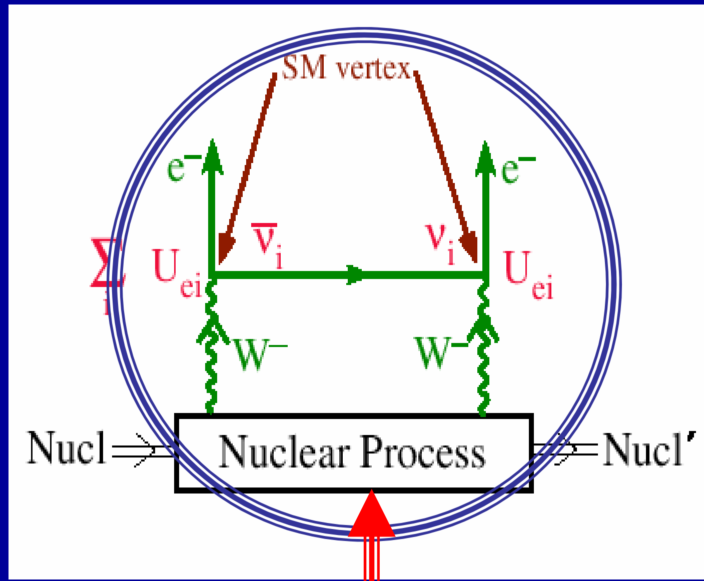
Part. ν physics
Majorana ν, m_ν CP

$T^{0\nu} = G^{0\nu} [M^{0\nu} m_\nu]^2$

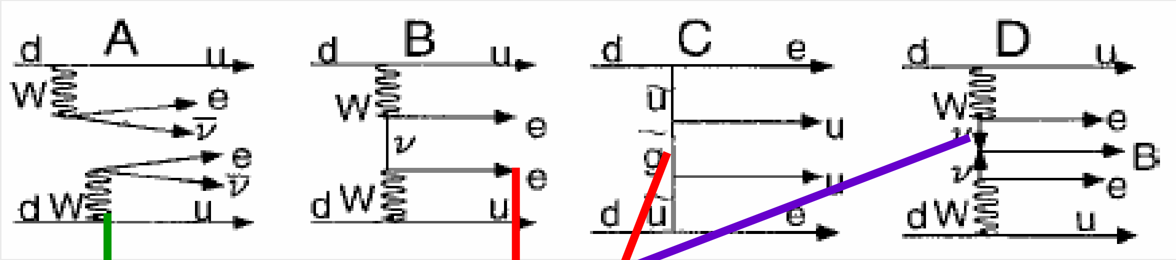
Nucl. physics. pp,ph,
tensor interactions
τ σ correlation

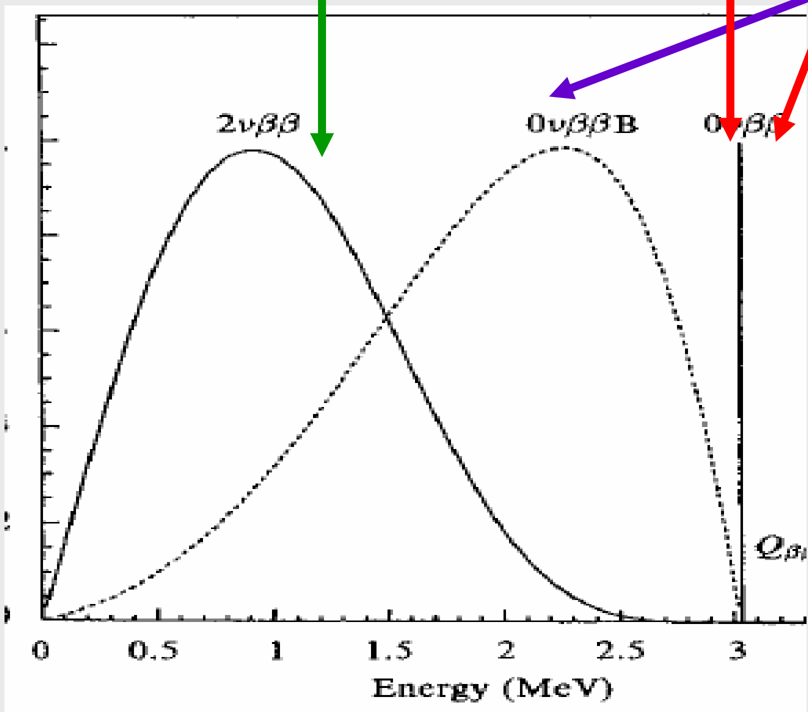
Cosmology
DM
Leptogenesis



Nucl. micro-lab.
to selectively enhance
. ν-exchange

ββ processes by ν-mass, RHC, SUSY, & others





$A^{2\nu}$=$GM^{2\nu}$ A^{M}=<g_M> M

Energy spectra 4,3,2 body

$A^{0\nu}$ = LHC + RHC

<m> +SUSY <λ> ~$k(M_L/M_R)^2$

LHC / RHC

Θ_{21} and E_{12} correlations

LHC m_ν / SUSY

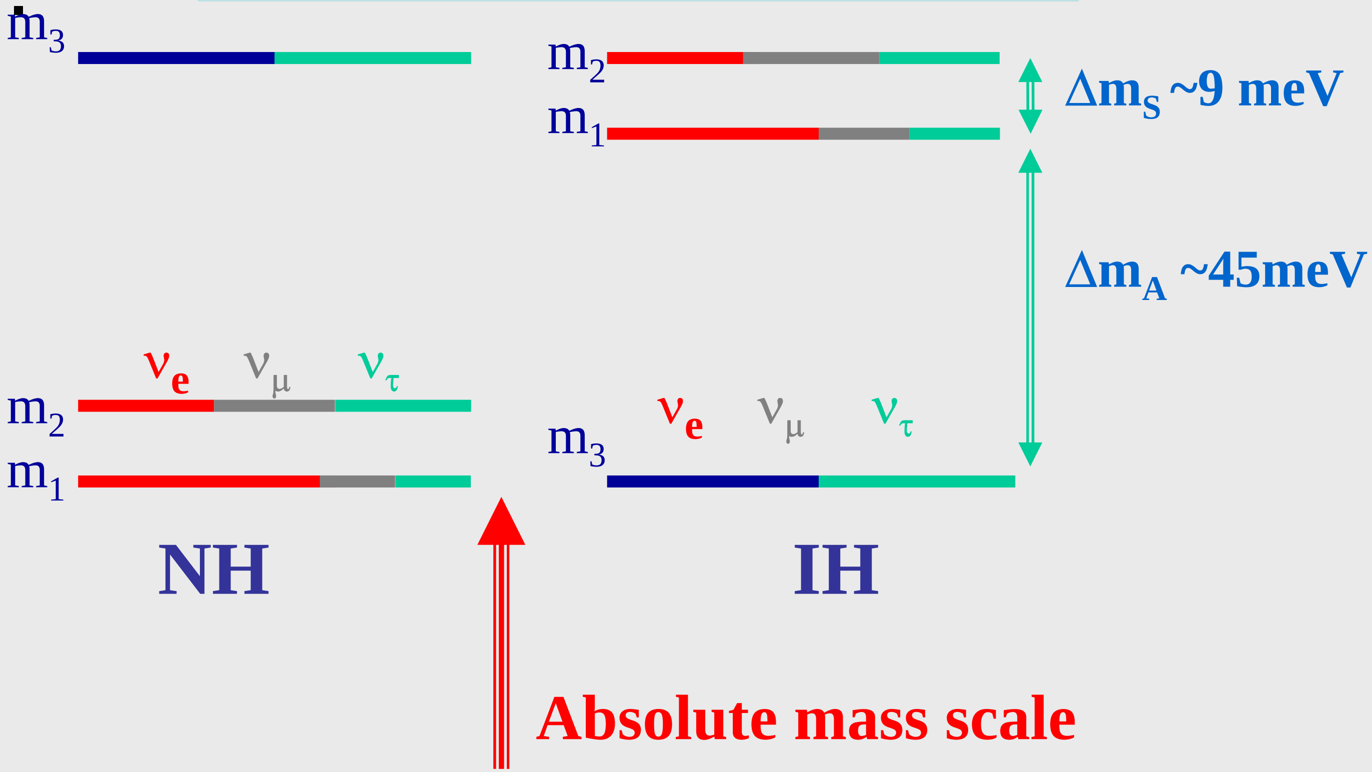
$m_\nu M^{0\nu} + kM^S$

Different isotopes and states with different M

$0\nu\beta\beta$ by light Majorana ν exchange

ν -mass spectra

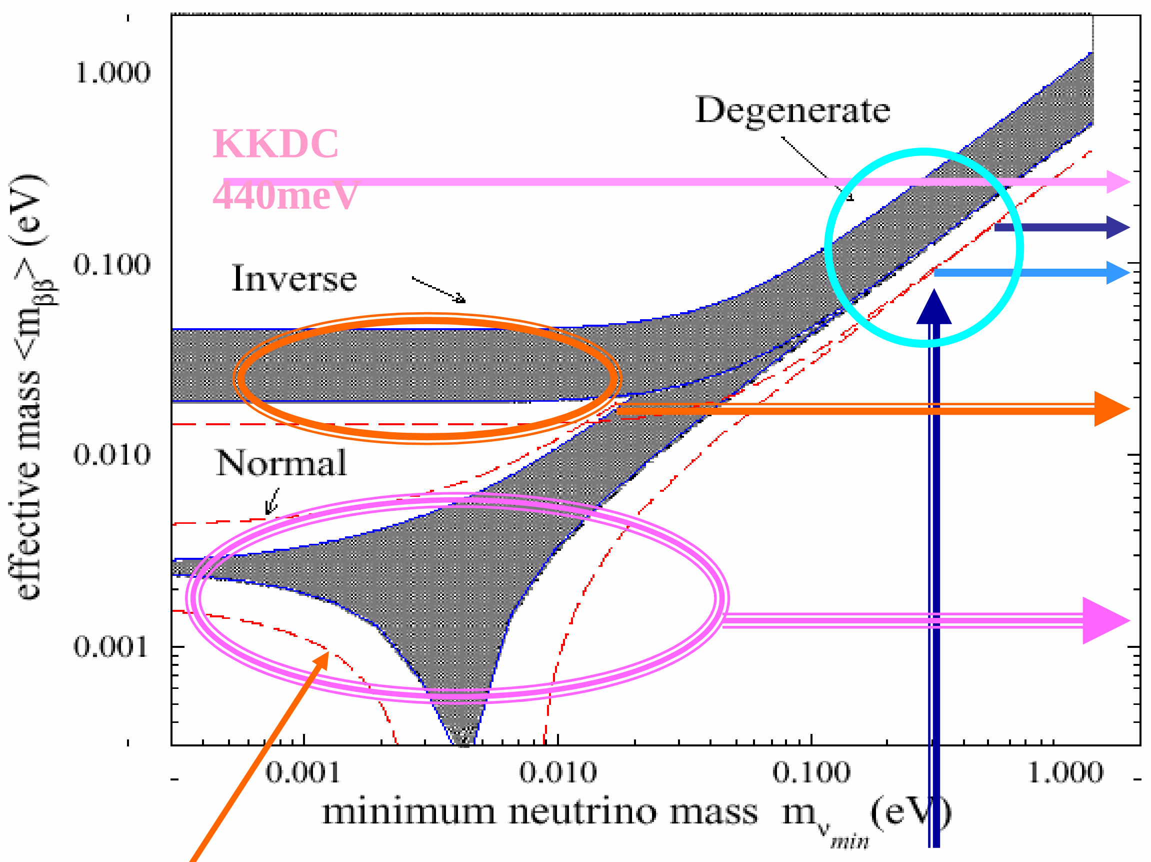
$$T^{0\nu} = G^{0n} |M^{0\nu}|^2 \; |<m>|^{\,2}$$



$$< m_\nu > = \Sigma\, k_i \;\; \exp(i\, \phi_i)\; m_i$$

is given by using k_i Δm_S, Δm_A given by ν oscillations

- **Effective ν masses and ββ experiments**



QD 100~300 meV

NEMO3 CUORITINO

Future I 100 meV

IH: Future II 25 meV

NH: Future III 2 meV

θ_{13} $e^{i\phi_3}(\delta m_A^2 + m_1)^{1/2},$

Phase +/- ~ 2 IH/NH ~ 10

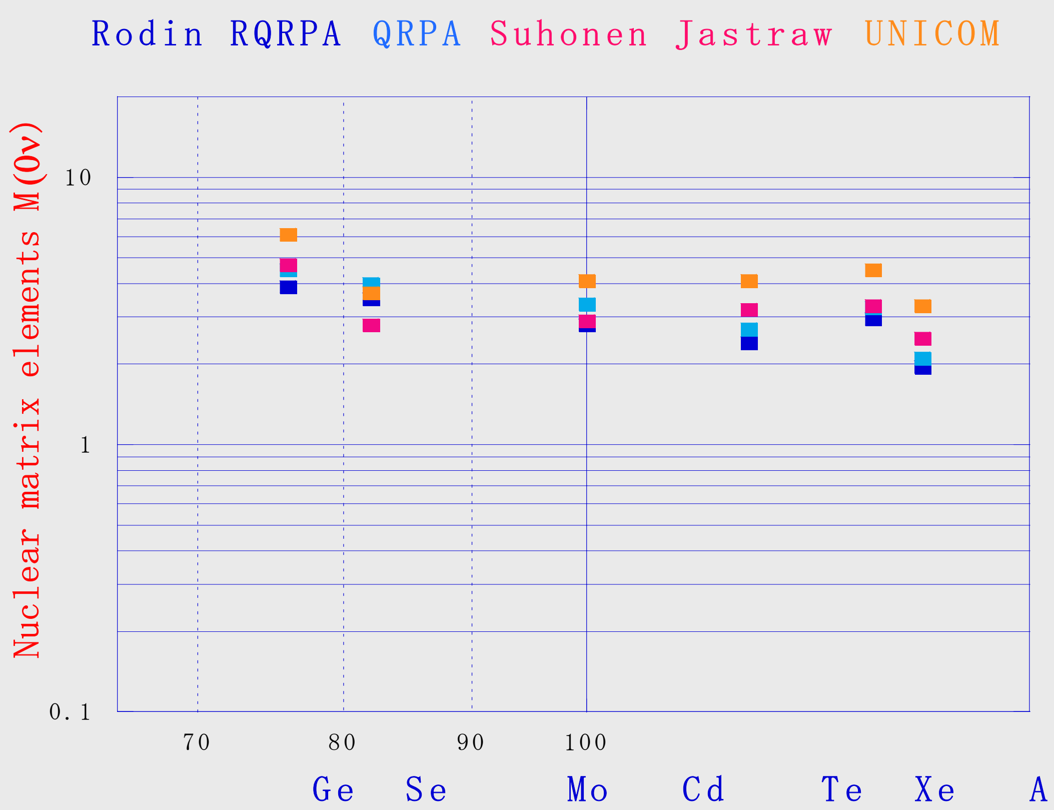
QD: Cosmological 200 ~ 300 meV

Single β ~ 200 meV

Mass sensitivities and nuclear sensitivity

$$<m_\nu> = S_N^{-1/2} \, (N^{eff})^{-1/2} \, \delta^{1/2}$$

$S_N^{-1/2} = 13\,(GM^2/0.01\,A)^{-1/2}$ $N^{eff} = \varepsilon^{0\nu}$ N ton y, $\delta \sim (BN)^{1/2}$



V. Kukuline
Sort-range correlation

$M^{0\nu} \sim 24/r = 18/A^{1/3}$

M ; excited state and Nd M = M/3

^{100}Mo and ^{82}Se , enriched by centrifuges, are good candidates.

Mass sensitivities and nuclear sensitivity

$<m_\nu> = S_N^{-1/2} \ (N^{eff})^{-1/2} \ \delta^{1/2}$

$S_N^{-1/2} = 13 \ (GM^2/0.01 \ A)^{-1/2}$

Nuclear sensitivity : m_ν

N=1 t y and $Y^{0\nu} = \delta = 1$

$S_N^{-1/2}$ =20~10 meV for M=18/A

$N^{eff} = \varepsilon^{0\nu}$ NT ton year

δ = No signals for 90 % CL

~2.3 if B~0

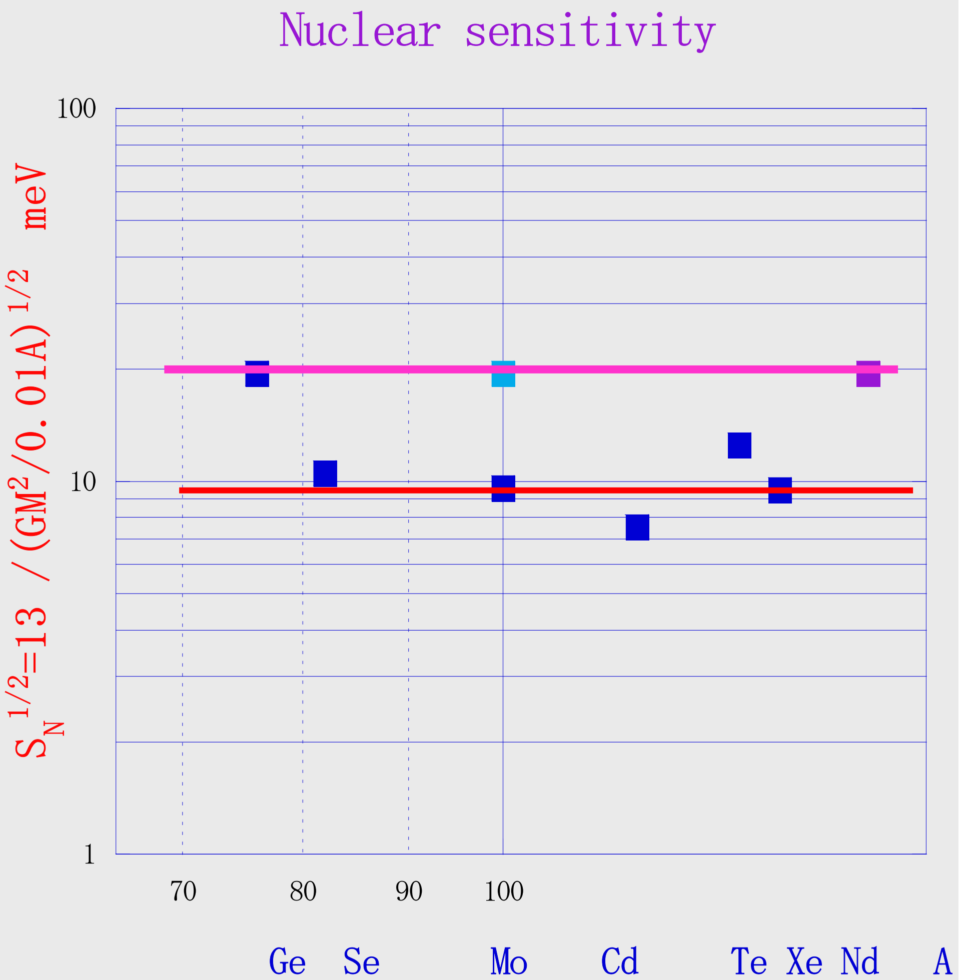
~1.6 + 1.7 $(BN)^{1/2}$

BG =B/t y N ton year

B=[B(RI) + B(2ν)]

$B(2\nu)=4.2(\varepsilon^{2\nu}/t^{2\nu}_{1/2})(100/A)$,

$\varepsilon^{2\nu}$ 10^{-7} and $t^{2\nu}_{1/2}$ 10^{20}

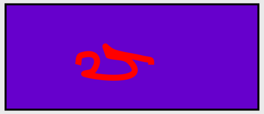


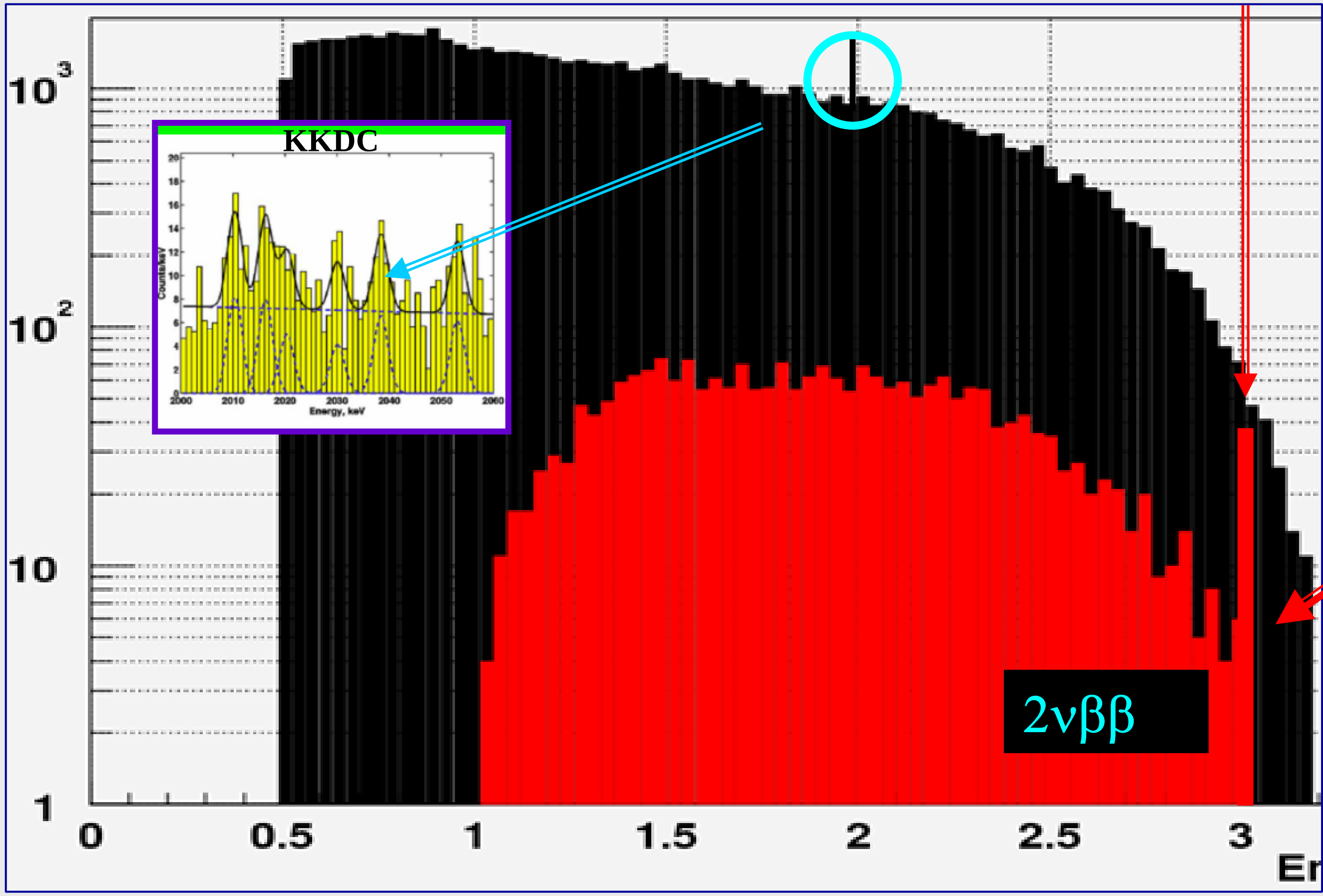
M ; excited state and Nd M = M/3

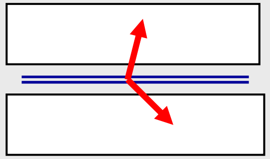
Signal of 0νββ and RI BG schematic spectra

Calorimetric. Detector=Source
Low Q, RI-BG, sharp-peak

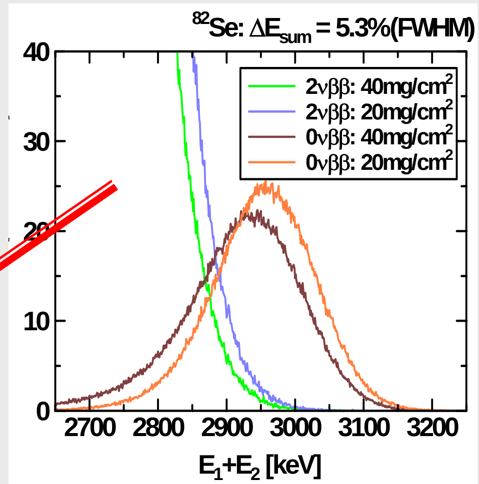
Spectroscopic Detector ≠ Source
high Q, low RI, Broad-peak







Resolution



Crucial points of $\beta\beta$ experiments

1. Extremely rare event $T = k m_{\nu}^{2}$ ~1/t/y. Large ton-scale $\beta\beta$ source and 10 t scale detector.

   International collaboration.

2. Low E (MeV) rare signal S/N ~ 10^{-8}

   High sensitivity low BG detectors at underground labs.

3. $T \sim |M^{0\nu}|^{2}$ and $E^{0\nu}$ are $\beta\beta$ nuclear dependent.

   Several $0\nu\beta\beta$ processes such as light-ν mass, RHC, SUSY.

   Different $\beta\beta$ isotopes with different (calorimetric/spectroscopic) methods

Future projects

$$\langle m_\nu \rangle \sim S_N^{-1/2}\,[N_{\beta\beta}/BG]^{-1/4}$$

A. Select isotopes with large $S_N = G(M^{0\nu})^2$ and

B. Detectors with $N_{\beta\beta}$, ~0.1 ~1 t , B ~ 1 / t y

Isotope	A %	$Q_{\beta\beta}$ MeV	$S_N\,10^{-24} y^{-1}\,(\mathrm{eV})^{-2}$	Experiment/collaboration
^{48}Ca	0.187	4.276	0.11	CANDLES[a]
^{76}Ge	7.8	2.039	0.22	MAJORANA[b] GENIUS[c] GERDA[d]
^{82}Se	9.2	2.992	0.86	MOON[f] Super-NEMO[e]
^{100}Mo	9.6	3.034	2.02	MOON[f]
^{116}Cd	7.5	2.804	0.90	COBRA[g] CAMEO[h]
^{130}Te	34.5	2.529	0.73	CUORE[i], COBRA[g]
^{136}Xe	8.9	2.467	0.13	EXO[j], XMASS[k]
^{150}Nd	5.6	3.368	11.3	Super-NEMO[e]

SNO+

Spectroscopic experiments

2. MOON detector

From the Ejiri's weekday flat at Yokohama

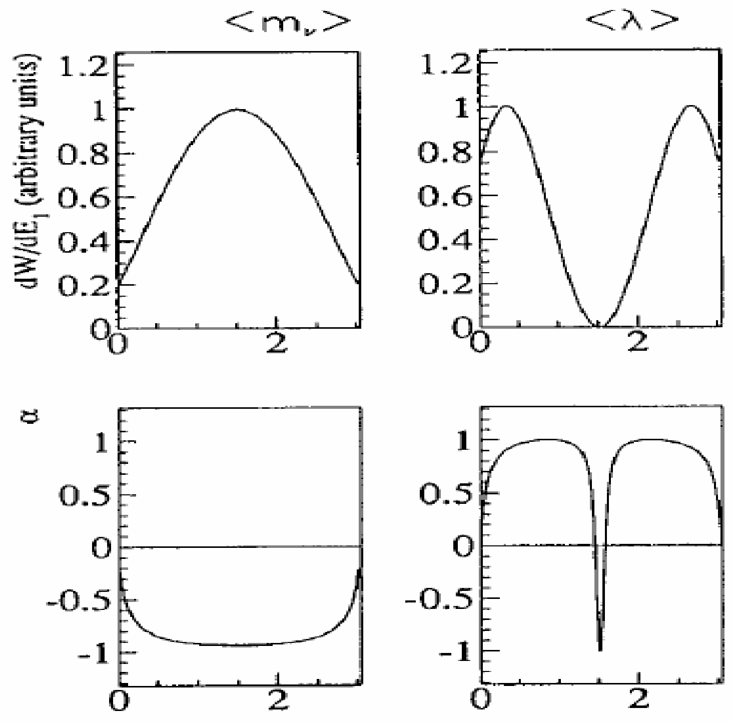
MOON : Spectroscopic studies of DBD in QD-IH

Multilayer modules, expansion of 2-layer ELEGANT V(1990-)

1. Individual ββ and their E_{12}-Θ_{12} correlations to identify m_ν term

2. Detector ≠ source. Select ββ nuclide of $Q_{\beta\beta}$ > RI and easy enrichment
   Two ββ nuclides and/or ground & excited states identify $\langle m_\nu \rangle$ or SUSY

3. Two β tracking reduces all RI BG by SSSC and SSTC.



4. Modest E-resolution reduces 2νββ tail in 0νββ window.

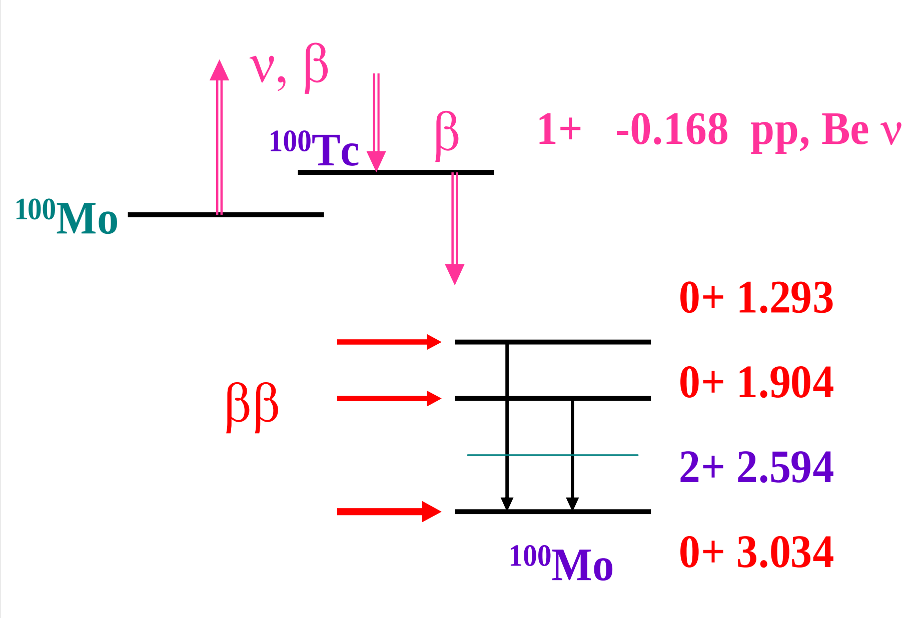
H. Ejiri et al., Phys. Rev. Lett. 85 (2000) 2917-2920 .
H. Ejiri, J. Phys. Soc. Japan, Invited Review, 74 (2005) 2101.
H. Ejiri, Mod. Phys. Lett. A, Vol. 22, No. 18 (2007) pp. 1277-1291.

Excited 0^+ states

ββ–γ–γ reduce BG's, 2νββ, RI.

- Cancellation, but not at both.
- GRS and EXS

$$T^{0\nu} = G\,|M^{\nu}\, m_{\nu} + M^{s}\,\lambda\,|^2$$

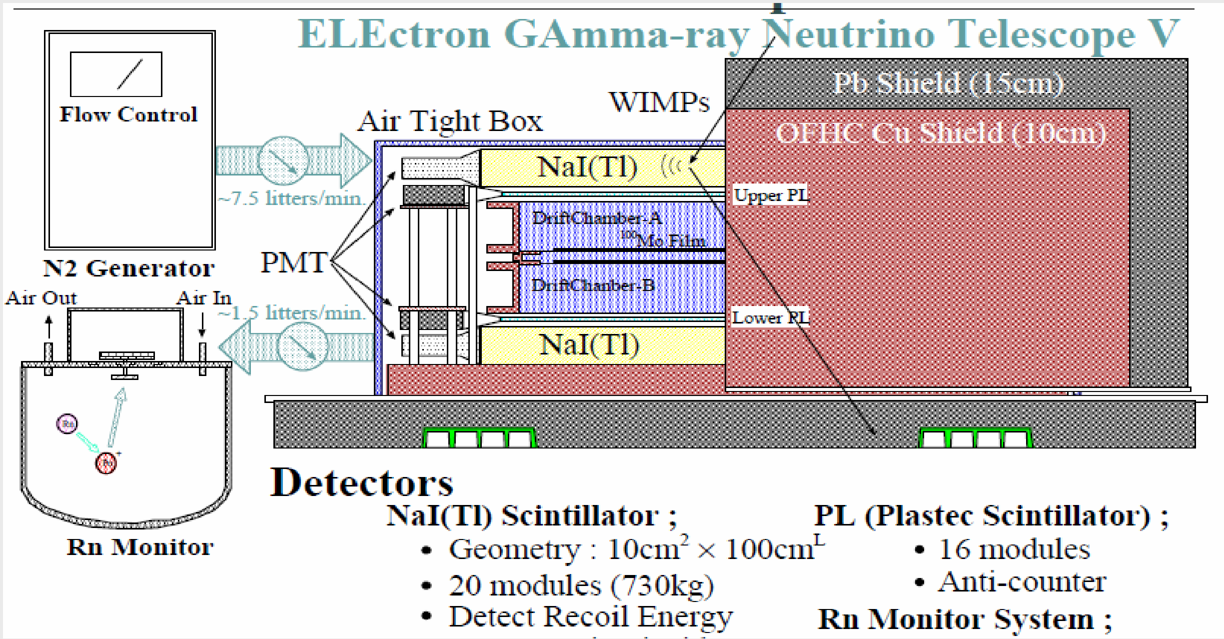


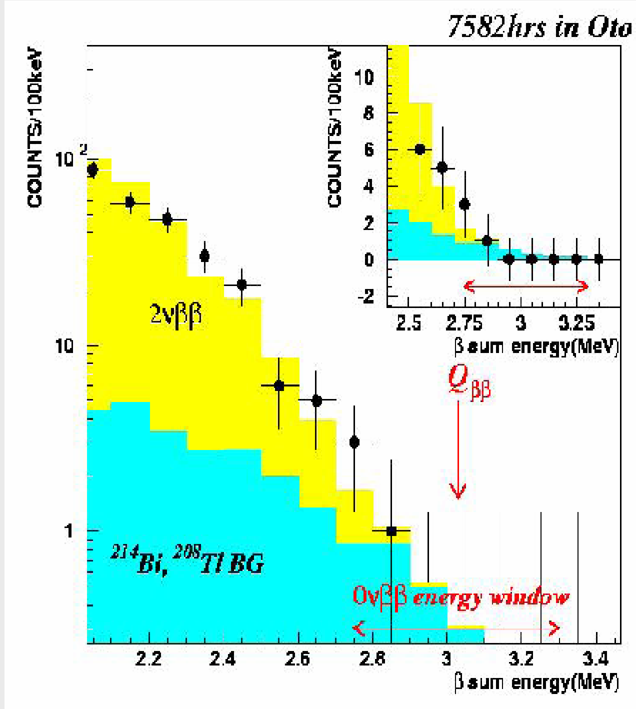
Isotope State	^{100}Mo GRS	^{100}Mo EXS	^{150}Nd GRS	^{150}Nd EXS
$Q_{\beta\beta}$ (MeV)	3.034	1.903	3.368	2.113
$S_N^{1/2}$ meV	9.6	19.5	19.5	42
<m> meV /5 y t	44	39	78	96

σ ~ 2.2 % Nd M/3 is assumed for deformation change.

ELEGANT VI   11 layers Si-disks   with ^{100}Mo T^{2n} 1989

ELEGANT V   2-layers PL-NaT-DC with^{100}Mo /^{116}Cd





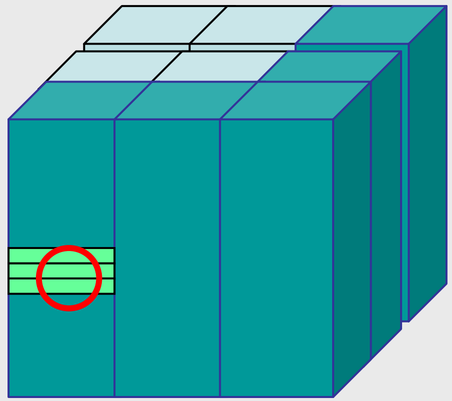
$T^{2\nu}$ First data 1990/91 & 1995 for ^{100}Mo &^{116}Cd,   UC, NEMO II & III

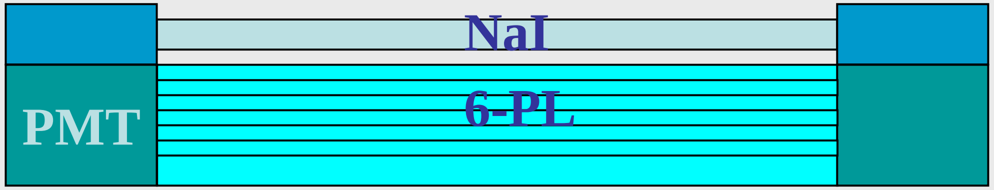
$T^{0\nu}$ > 1.0 10^{23}y , 1.5 eV 68%CL   1995-2001, Renewed by NEMO III

H.Ejiri, et al., Phys. Rev. C 63 '01, 65501

DM Annular modulation with 0.75 ton NaI: Season effect of Rn

MOON concept & an option of PL/NaI/PL-Si module





One unit : 11.5 m^3 =1.75*1.75*4.25 m 30 kg 17 modules .

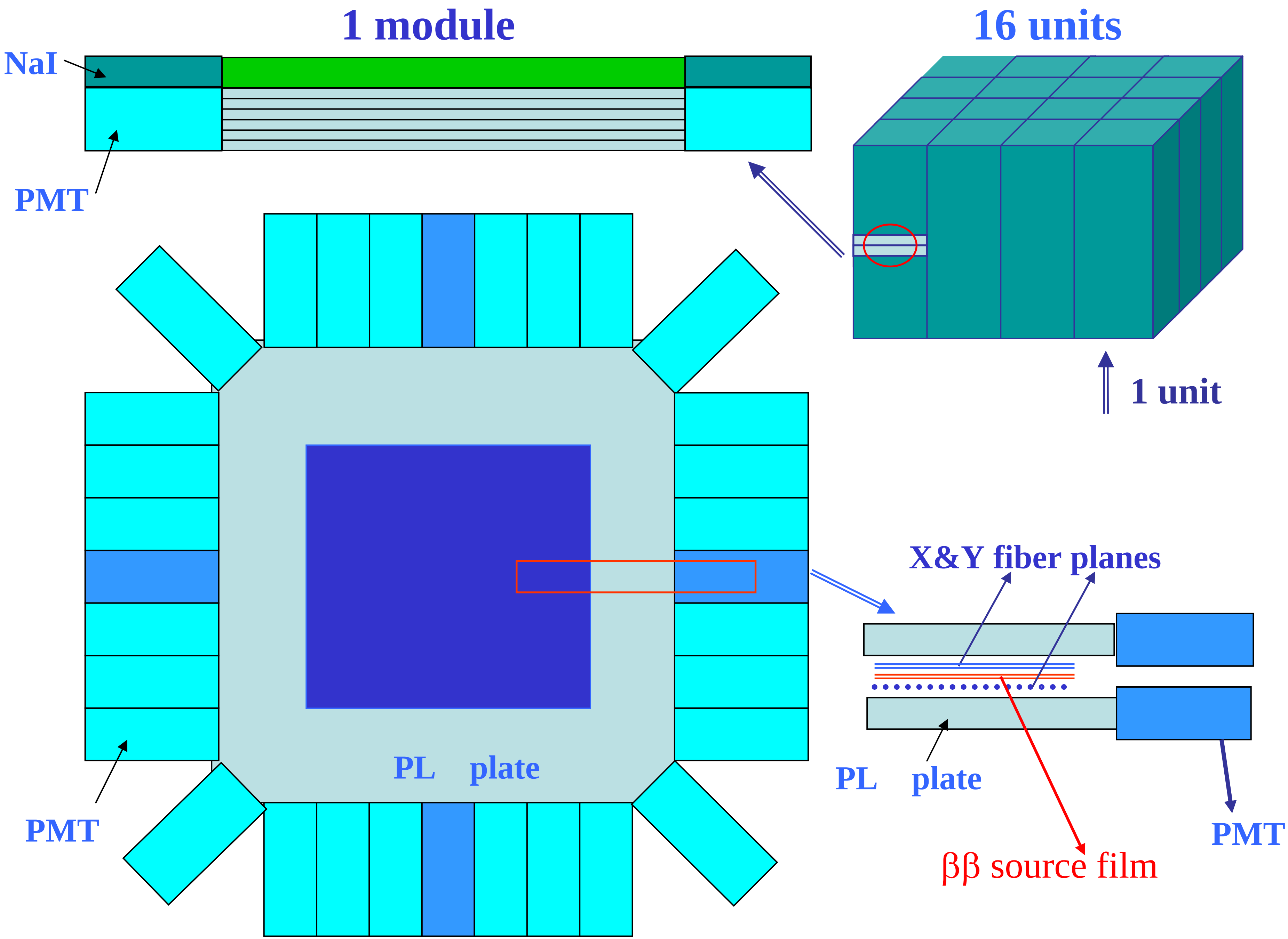
Including PMT

One module : 0.77 m^3 =1.75*1.75*0.25 m 1.8 kg 5 layers

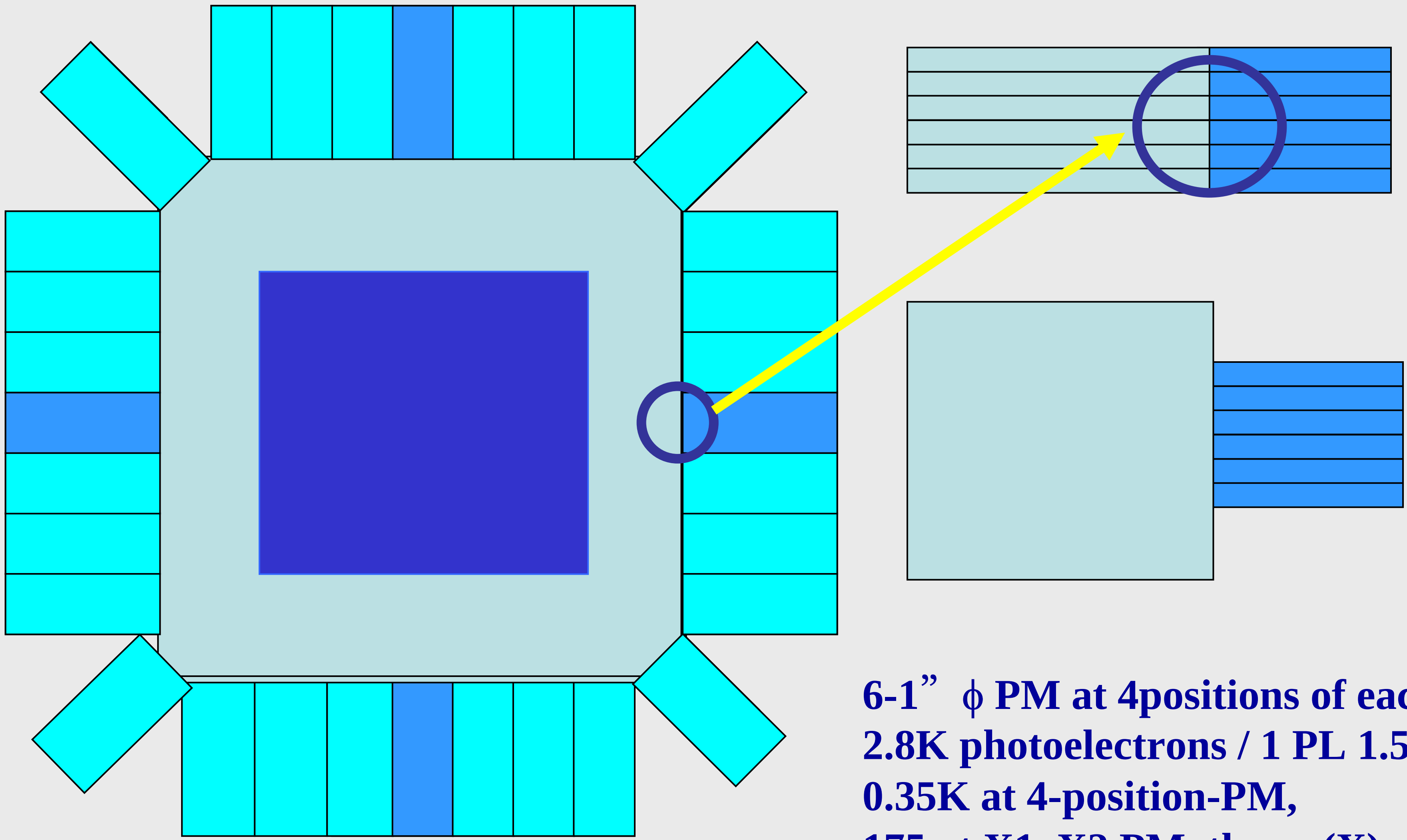
One layer : PL 1.25 *1.25*0.015m^3
ββ 0.85*0.85*50mg =0.36 kg, Si-PL fibers

16 units 208 m^3 = 7m*7m*4.3m ββ =0.5 tonne

Compact module, easy construction, maintenance and expansion

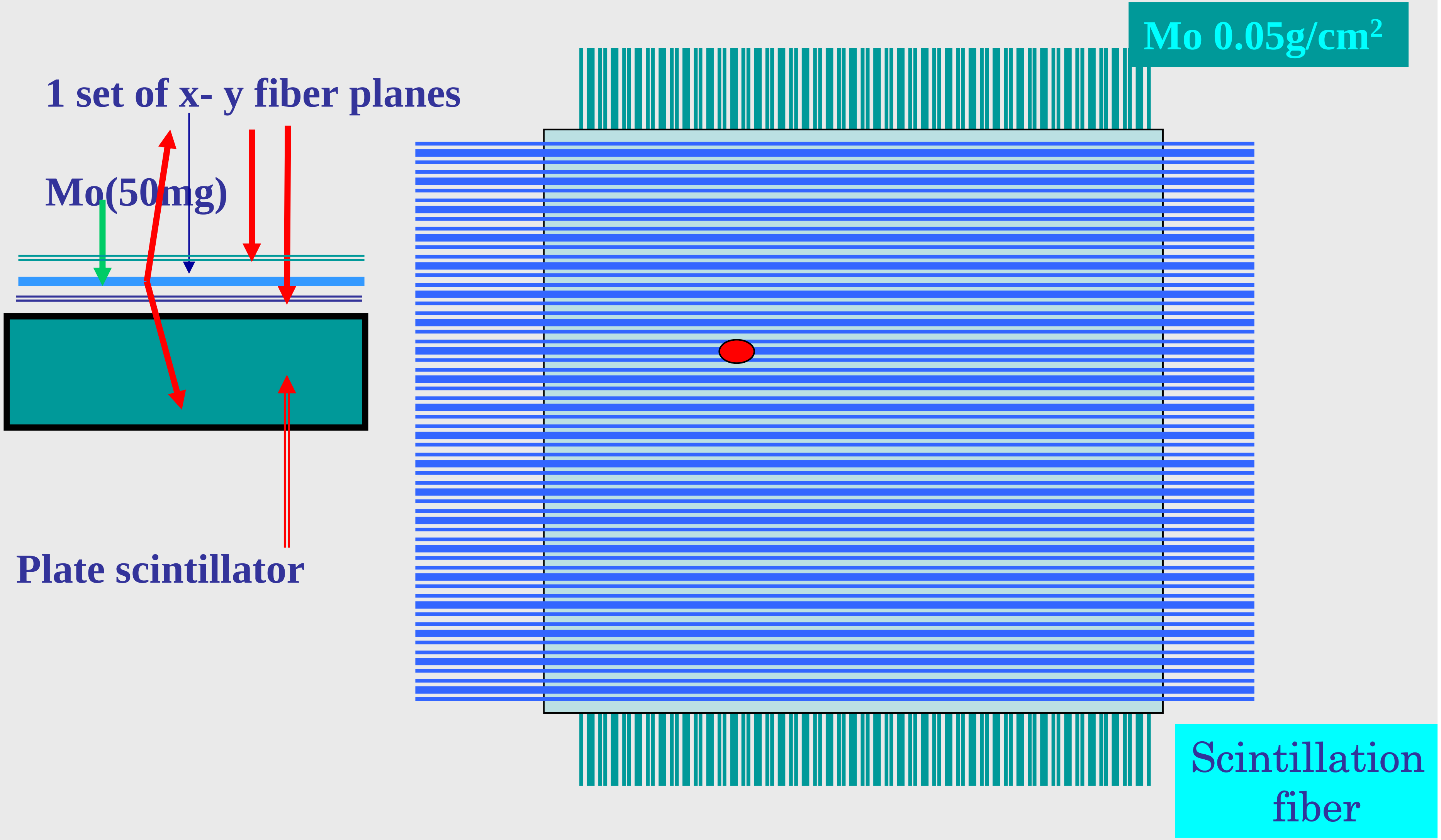

1 module
16 units
NaI
PMT
1 unit
X&Y fiber planes
PL plate
PL plate
PMT
PMT
ββ source film

Position identification by PL photon distribution



6-1” ϕ PM at 4positions of each PL
2.8K photoelectrons / 1 PL 1.5 MeV
0.35K at 4-position-PM,
175 at X1, X2 PM, thus $\sigma(X)$=5cm

MOON Plastic fiber-Mo Ensemble

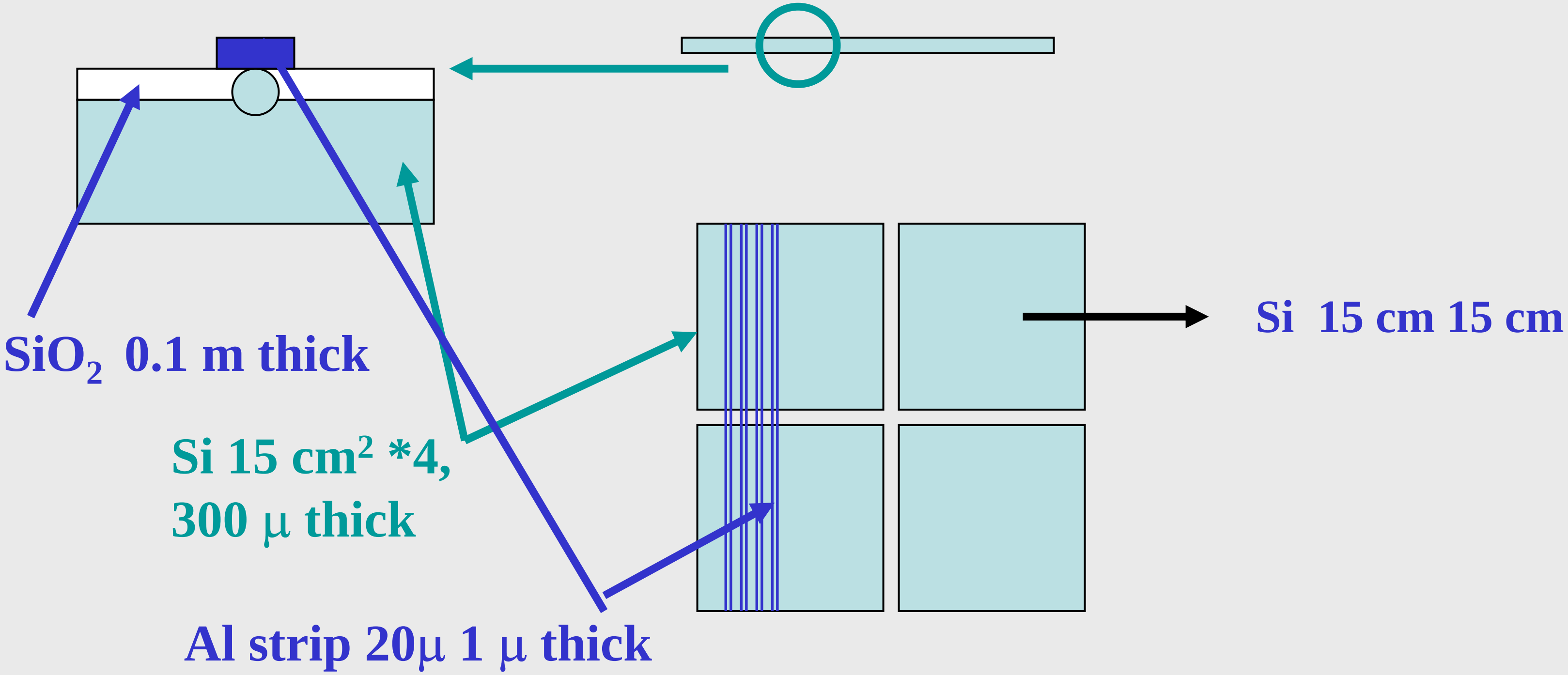


Si pad and Al read out

Phase III option better P &E-resolutions (V.Veba)

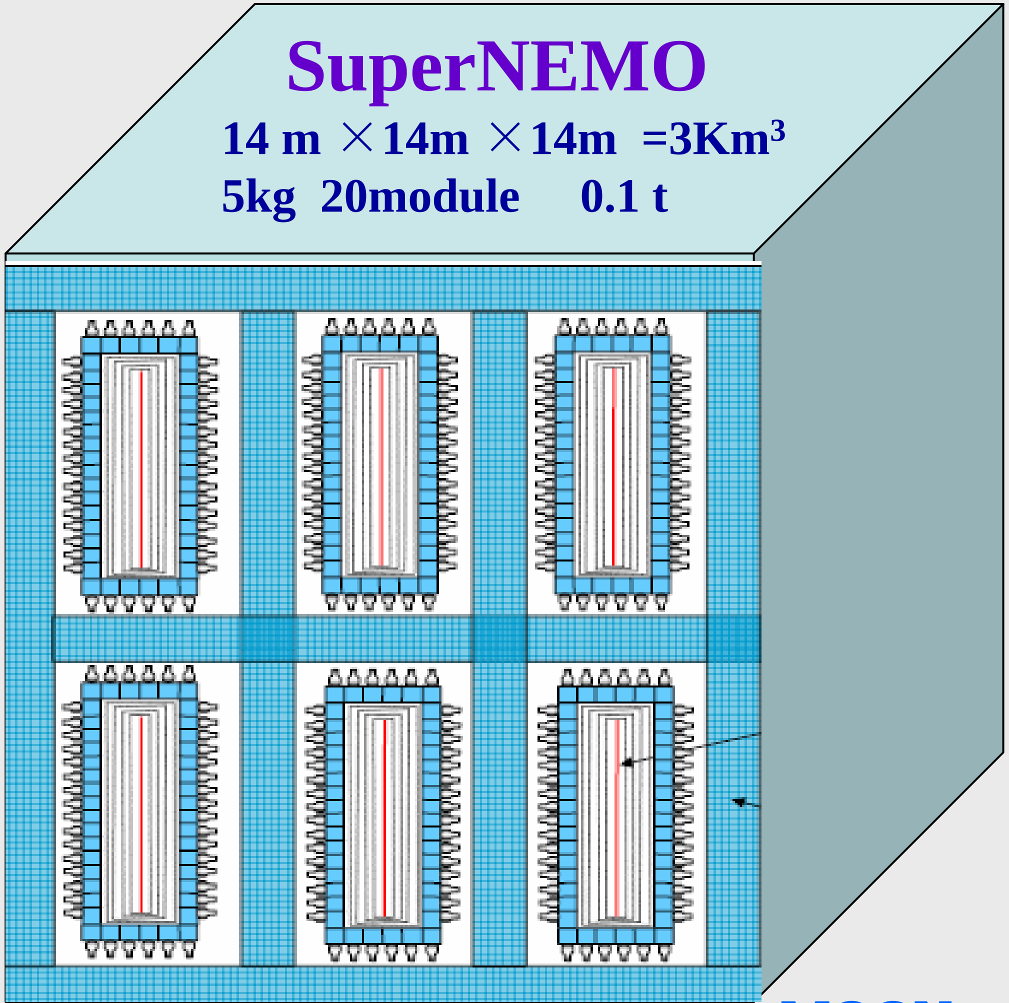
One Si plane 60 cm 60 cm = 4 Si cells, each 30 cm 30 cm.

Each cell = 4 Si pads, each 15 cm 15 cm 300 μ thick.



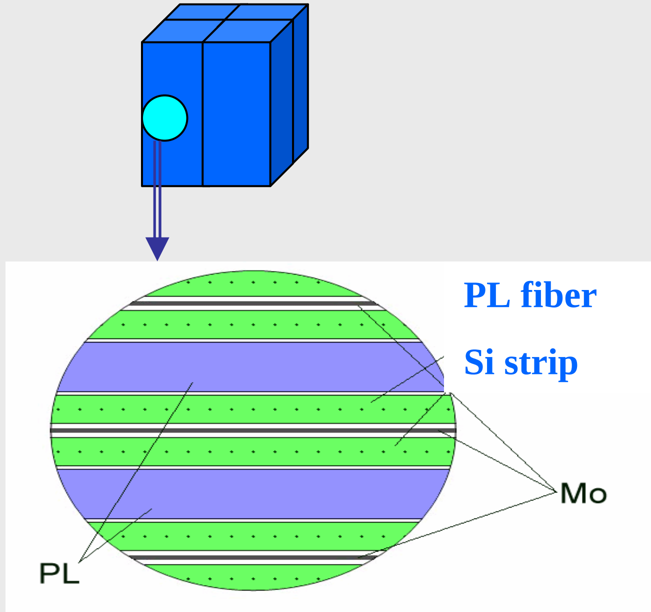
Spectroscopy DBD

E_{12}-Θ_{12} Detector ≠ source



MOON 4-units, 0.12 t

3.5 m × 3.5m × 4m =43 m³



^{214}Bi < 10 μBq/kg
^{208}Tl < 2 μBq/kg
Radon < 2 μBq/m³

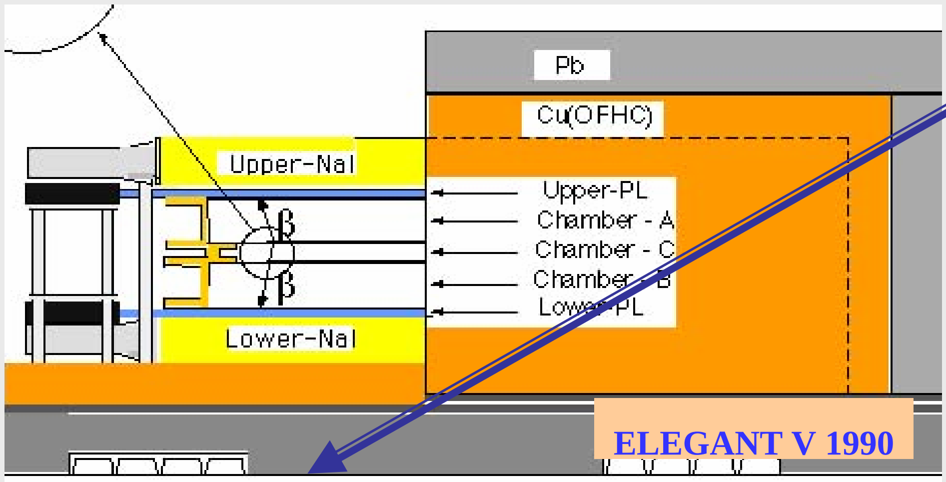
^{82}Se, ^{150}Nd

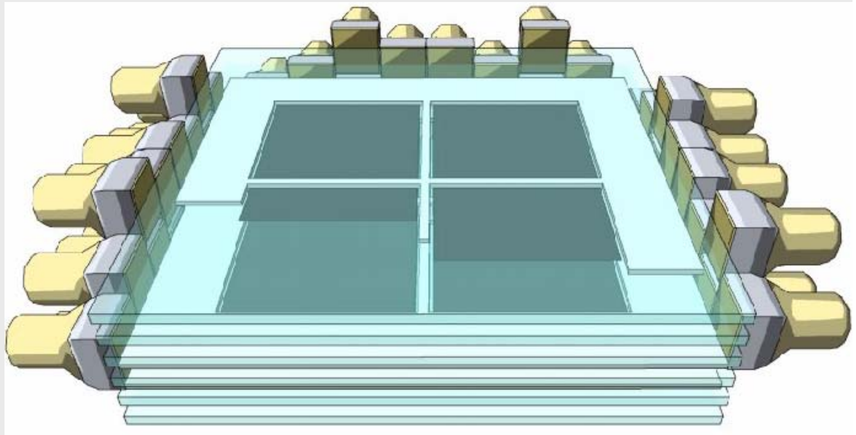
	Detector	modules	V m³/t
MOON	Multi-layer	100	0.4 K
S-NEMO	Single	20	30 K
			factor 100

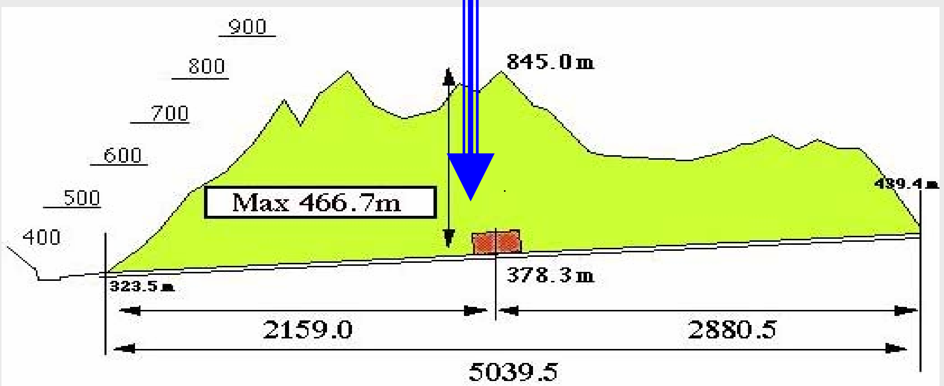
MOON 1 prototype detector

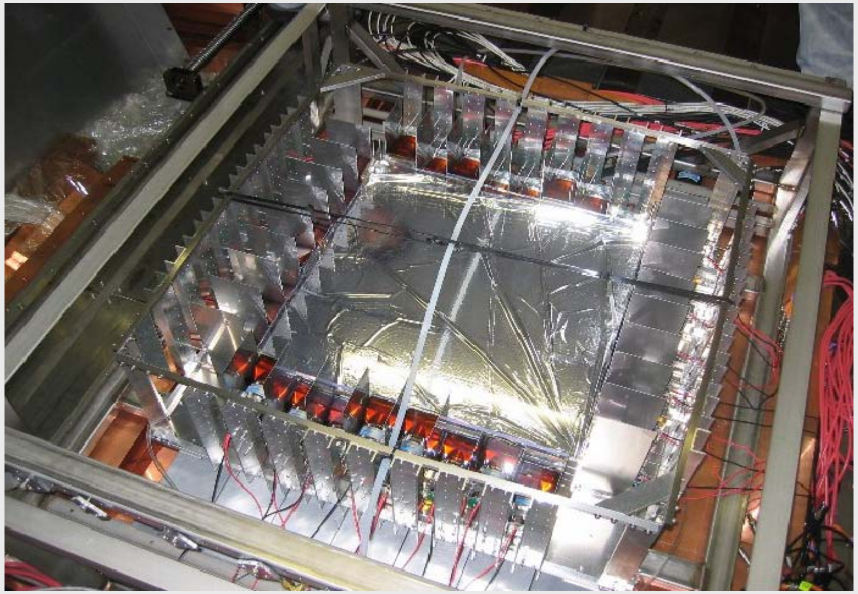
H. Nakamura JPSJ 76 (2007) 114201

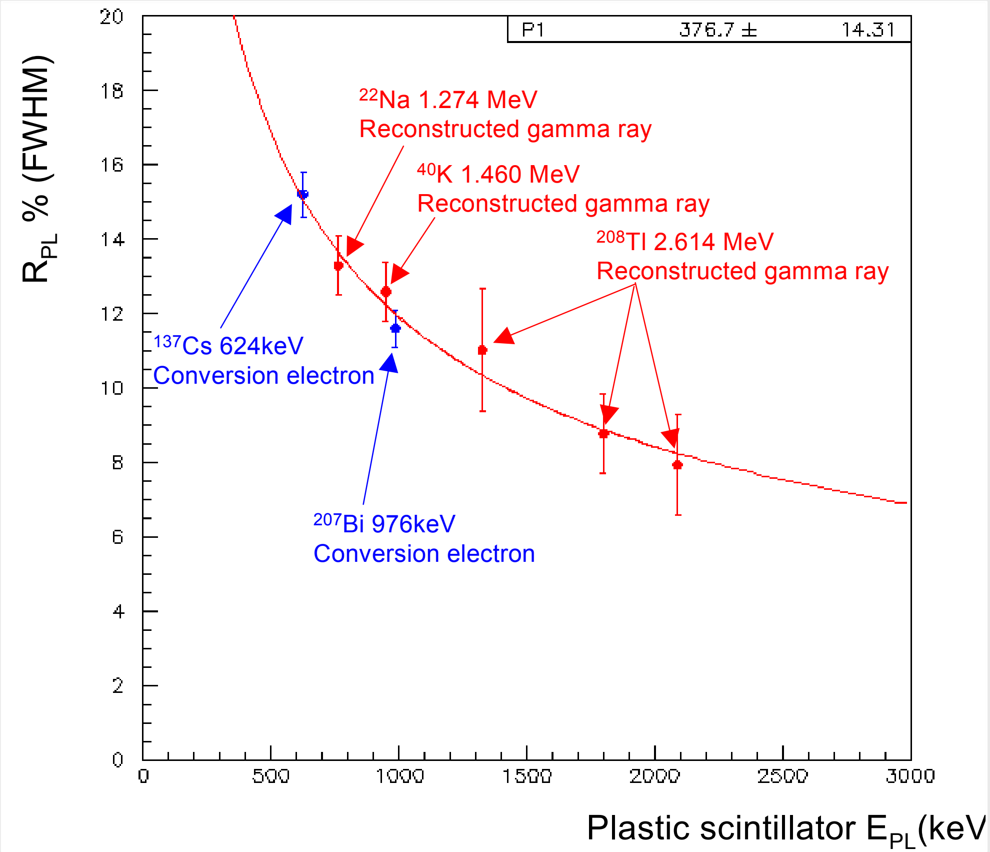
PL 6 layers, 53x53x1 cc BC408. equ.^{100}Mo, 142g 40mg, 3 layers

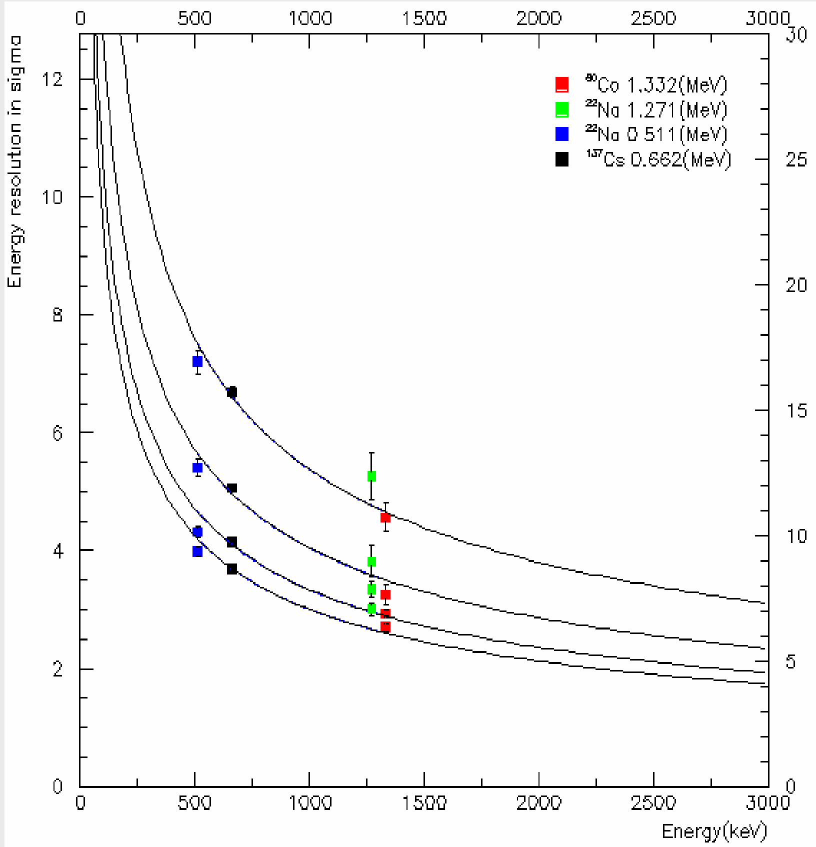












E-resolution PL σ = 2.8% at @ $Q_{\beta\beta}$ =3 MeV for all area,

2.2 % @ $Q_{\beta\beta}$ for small PL, position-define

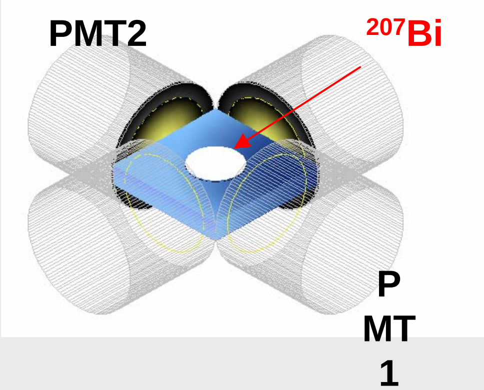
H. Ejiri, Czeck. J. Physics, 56 (2006) No 5, 459.

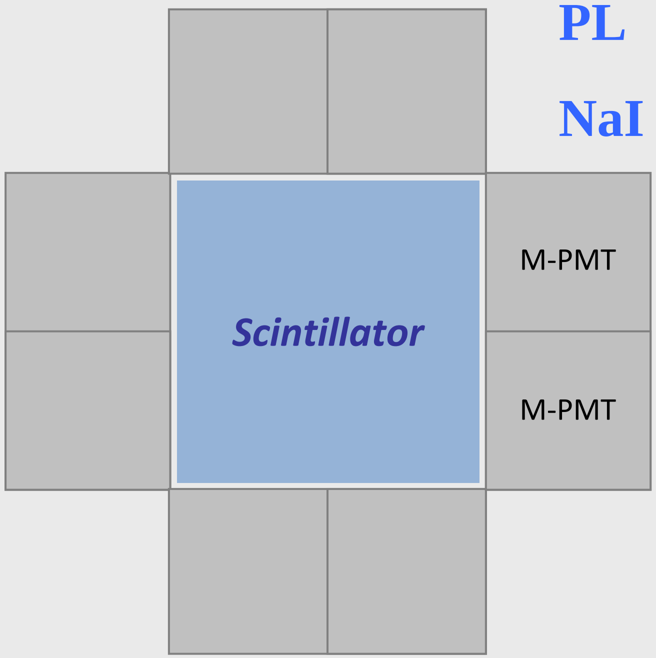
H. Nakamura, et al., JPSJ 76 (2007) 114201 1-9.

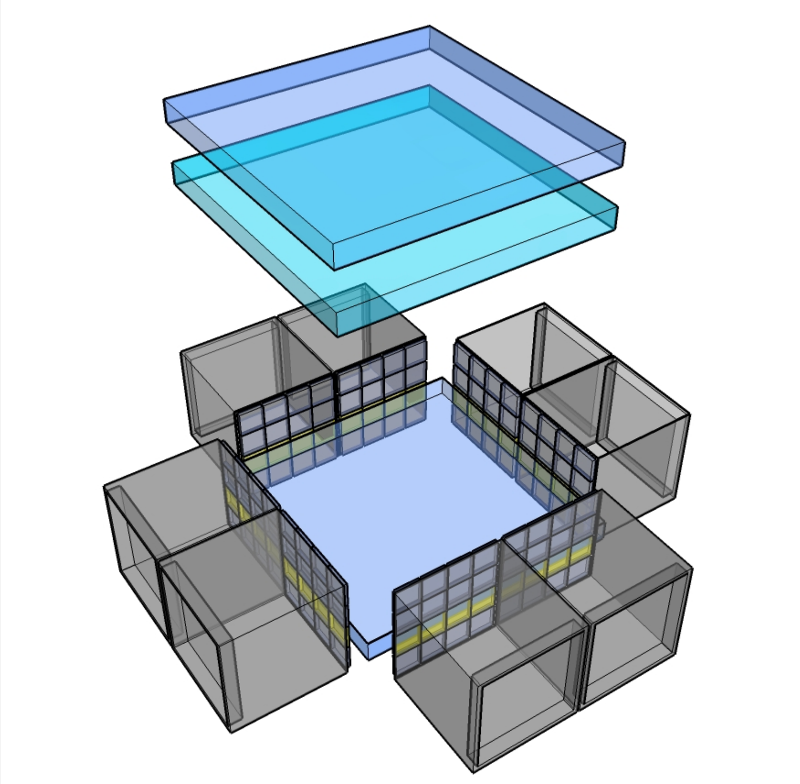
CROSS

H.Nakamur et al.

Correlation Responses of Scintillation Signals





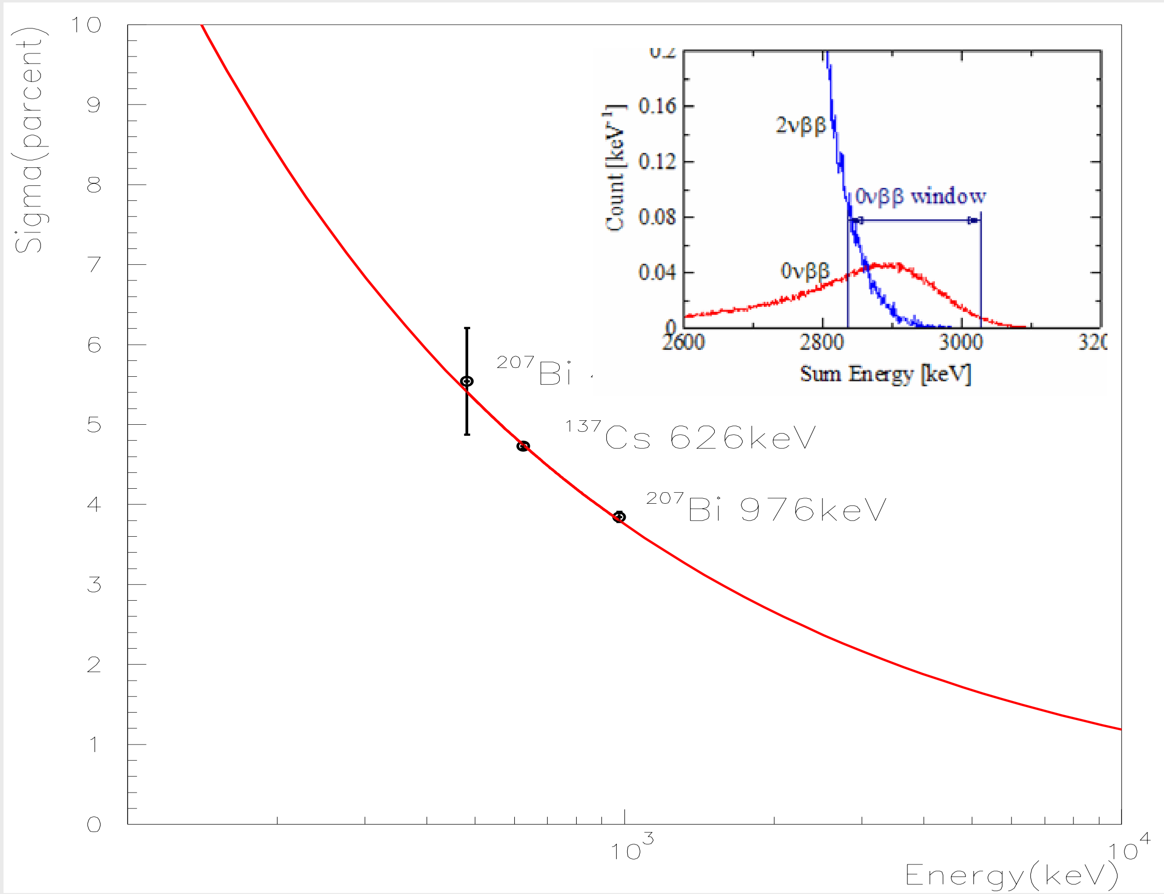


Energy resolution

Cs 625 σ= 4.73 ±0.04 %
Bi 976 σ= 3.84 ±0.06 %

ββ 3.000 σ= 2.1±0.1 %

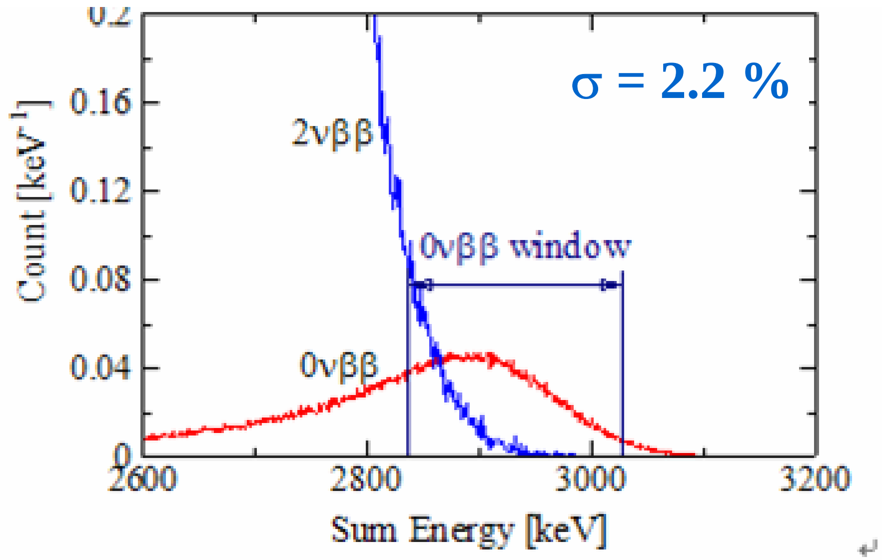
Ensure search for
IH (25-50 meV) mass
with large scale PL plates.

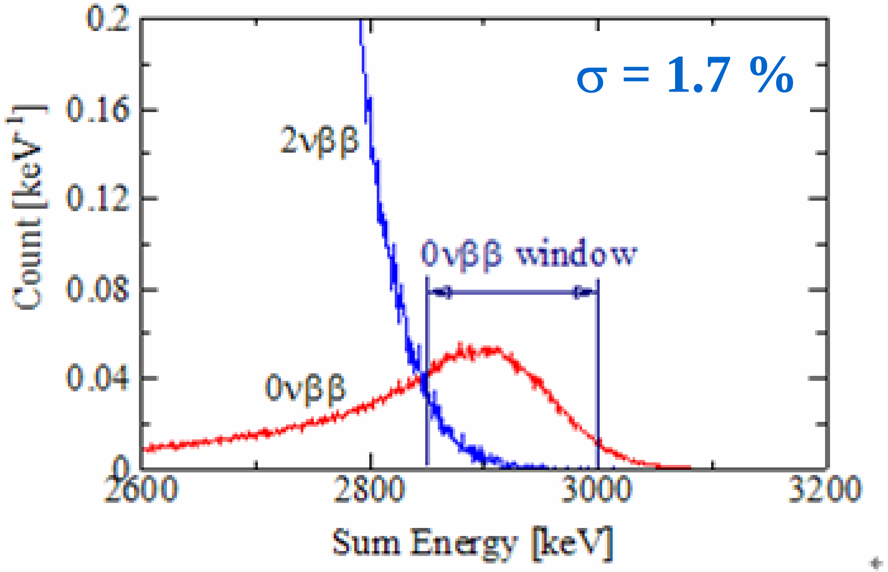


	MOON	ELEGANT V	NEMO III
σ 3 MeV ^{100}Mo, ^{82}Se	2.1 %	3 %	~5.5%
BG(2ν) ratio ~σ^5	1	5	100
m_n meV for 0.5 t y	40 meV	(~1eV)	300 meV

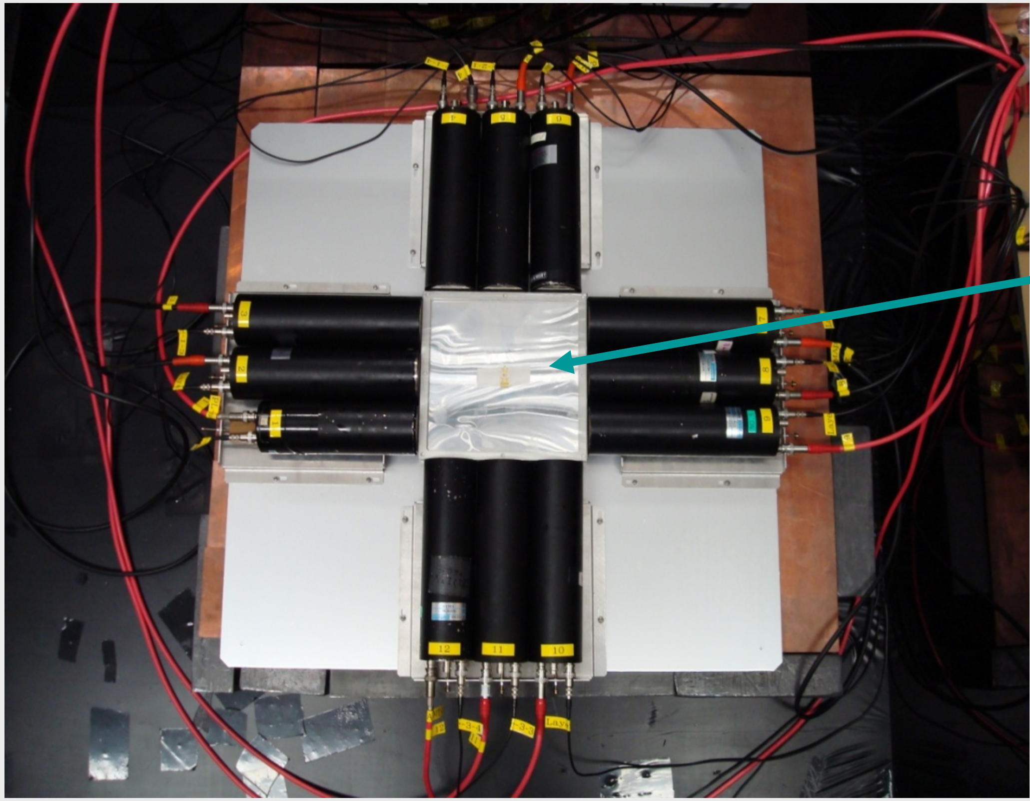
0.6 t y 72 meV

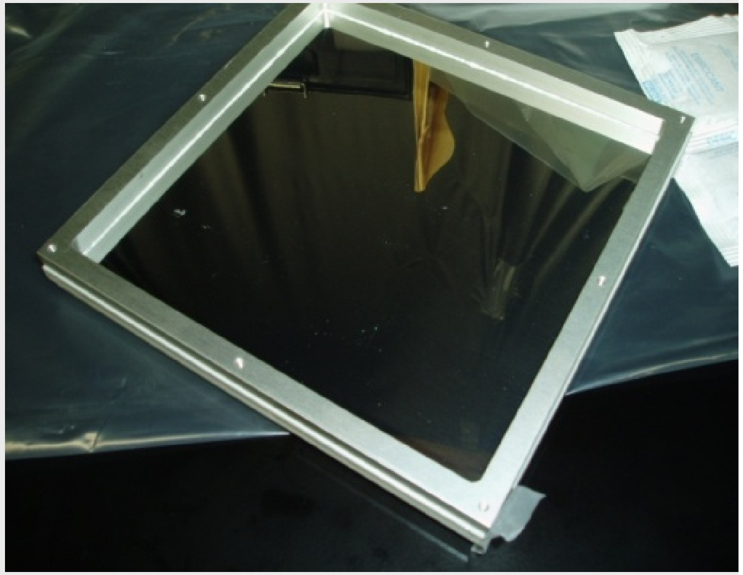
$Y^{0\nu}$ ~ 20/2 ty



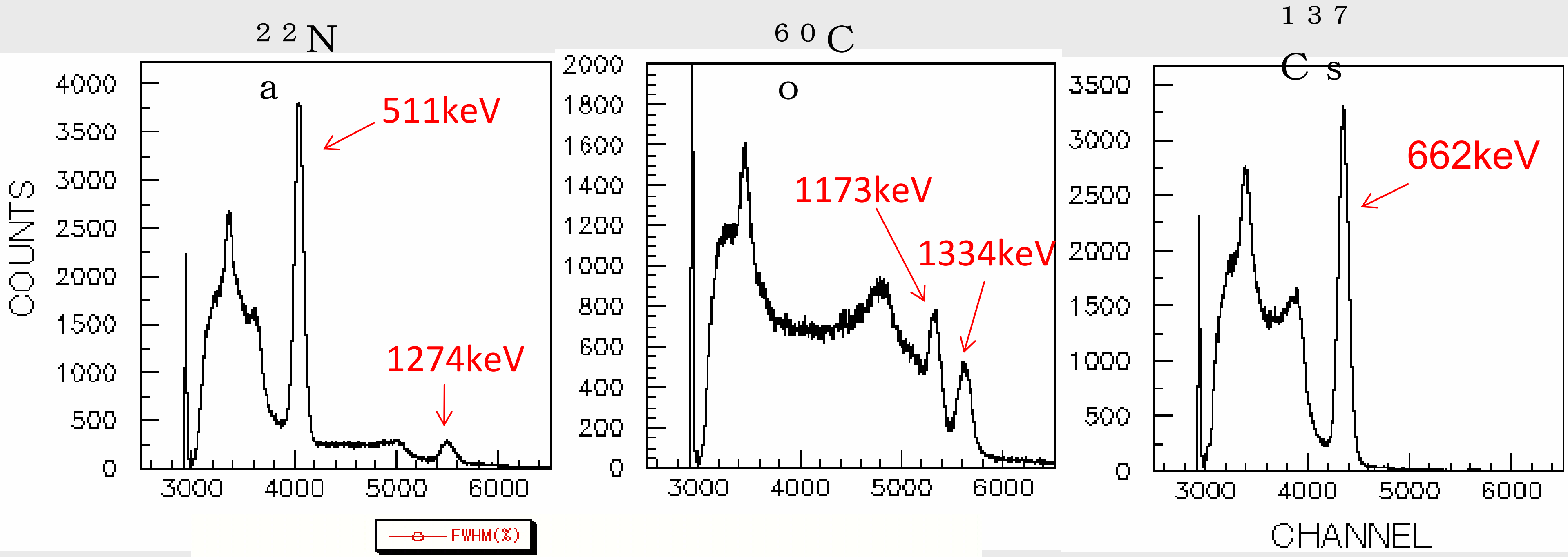


Experiment

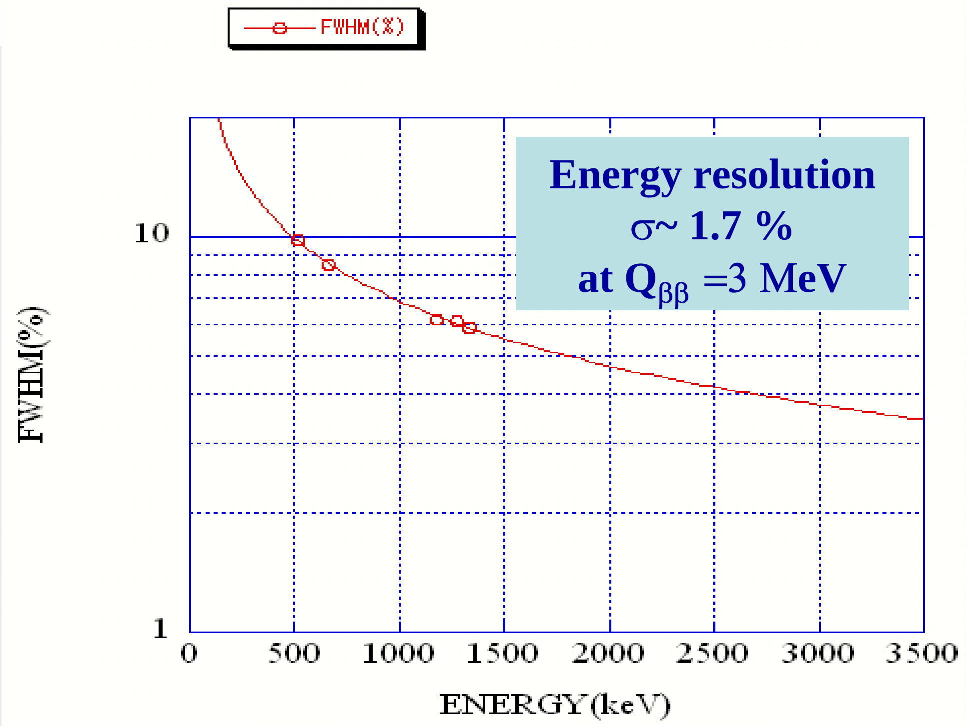




NaI(Tl)　　18cmX18cmX0.5cm

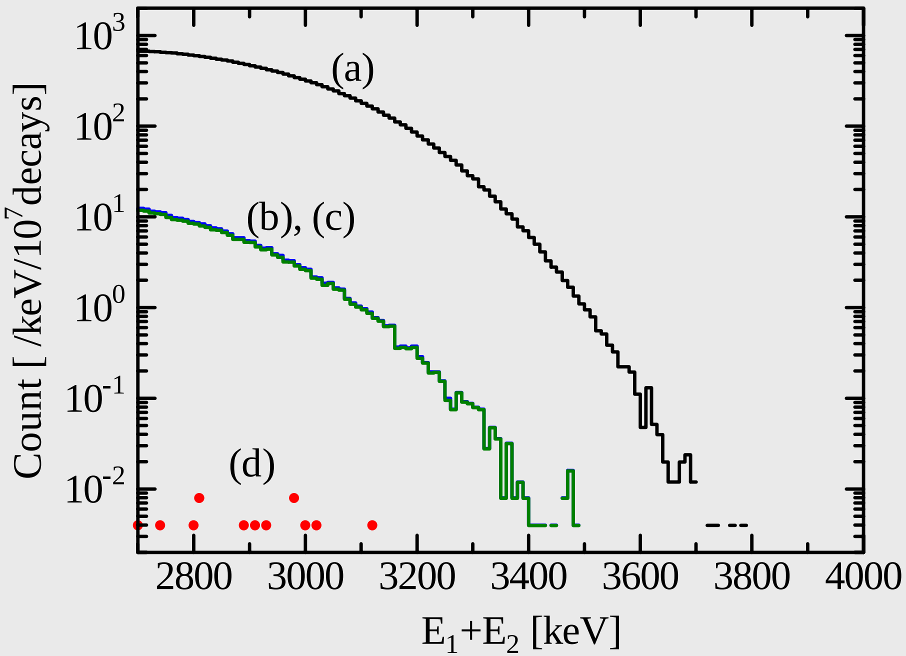


22Na
60Co
137Cs
COUNTS
CHANNEL
511keV
1274keV
1173keV
1334keV
662keV



FWHM(%)
Energy resolution
σ~ 1.7 %
at Qββ =3 MeV
FWHM(%)
ENERGY(keV)

^{214}Bi : β 3.27MeV (BR=18.2%)



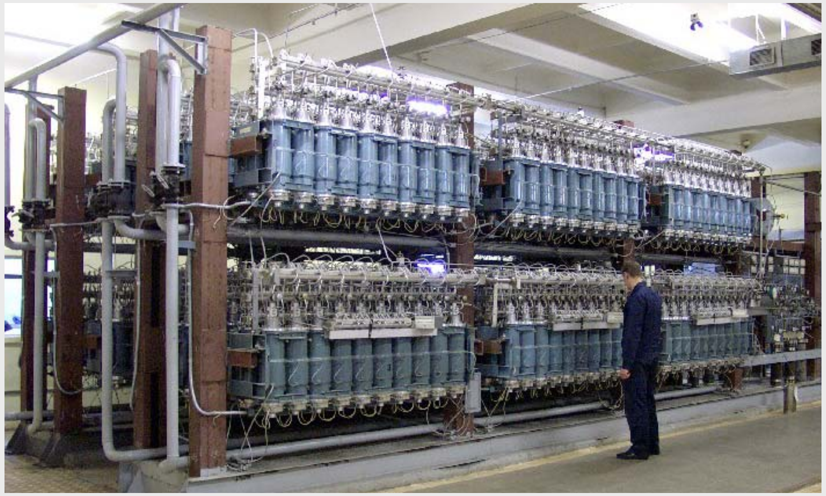
^{214}Bi 300μBq/kg	Count in 0.48 t•y
(a) Total	6300
(b) E1, E2>500keV	62
(c) Veto by other PL	60
(d) 2 tracks & 1 vtx	0.023

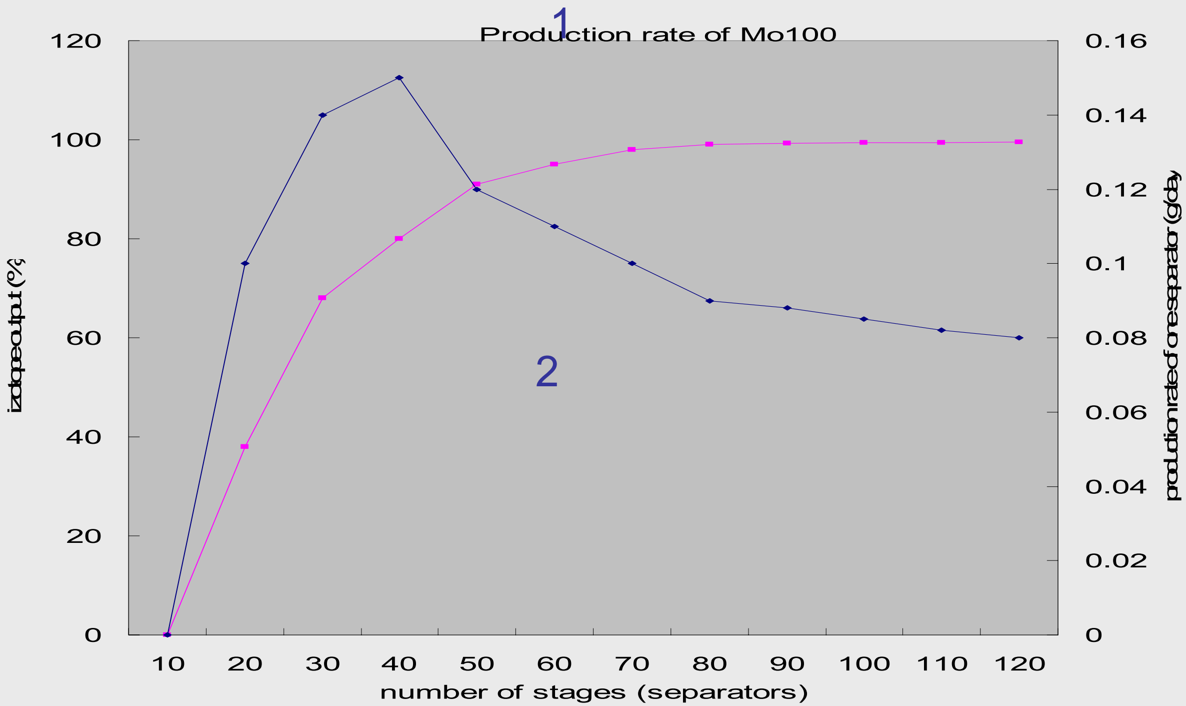
* Energy resolution for β-ray was assumed as σ=2.2% at 3MeV.
* Resolution for vertex position was assumed to be 10mm×10mm (discrete).

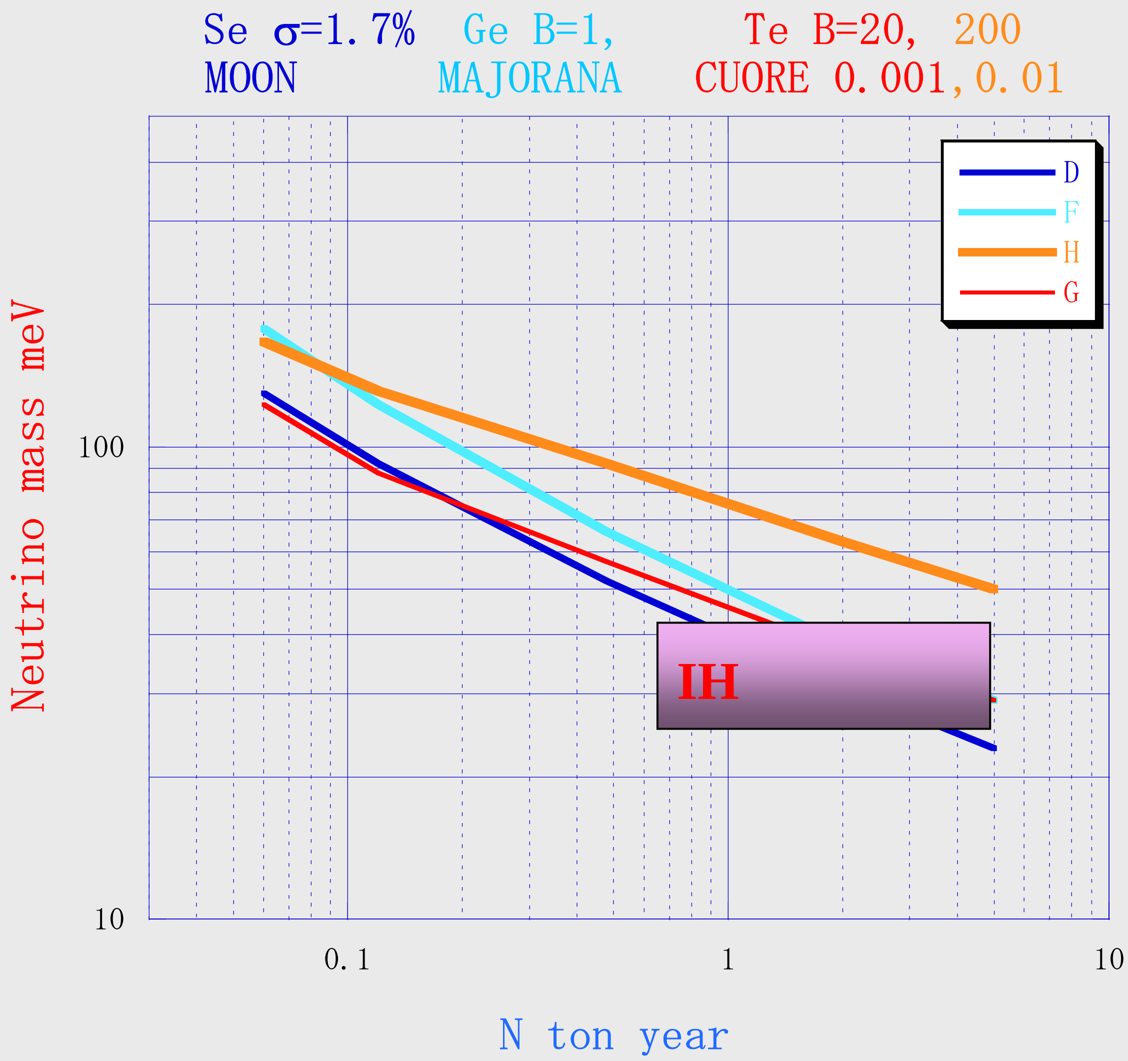
T.Shima

Isotope separation

Centrifugal technology at VNIIEF:MoF_6 gas. Using 6000 centrifuges and 40 steps, ^{100}Mo isotopes with 85 %, 350 gr per day, and a half ton in 5 year.







^{130}Te B =6000 for CUORITINO **B=200 for 0.01 /y kev kg of TeO_2**

Run plan (possible option) in case of ^{82}Se

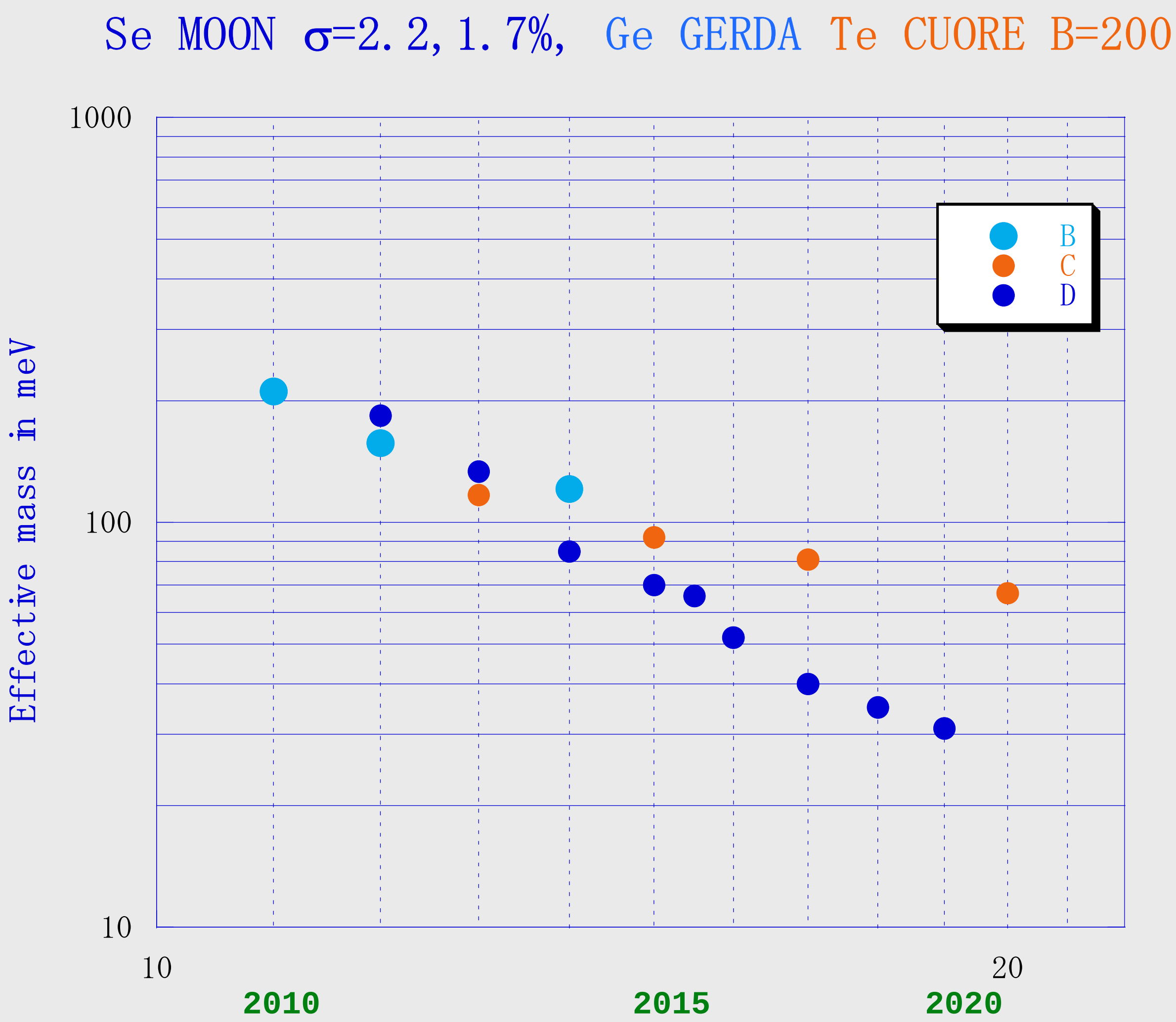
M=3.9, Phase I. II, σ=2.2 , Phase III σ=1.7 %

Phase Start Run .	$N_i = n_{\beta\beta}$ n	Σ Ni	n-mass meV
I 2008 2012-2013	0.03 - 1	0.06 ty	HM/QD 134
II 2012 2014 -2015	0.12 - 4	0.3	QD/IH 70
III 2014 2016-2019	0.48 16	1.92	IH 31

Phase II - III / NEMO III

$n_{\beta\beta}$:		17 - 70
BG 2νββ	$\sigma^4 = (1.7\ \%/3.3\%)^{-4}$	14
Efficiency $\varepsilon^{0\nu}$	0.3 / 0.08	4
S/N ~	$\varepsilon^{0\nu}\ [n_{\beta\beta}\ /\sigma^4\ ]^{1/2}$	55 – 110
ν-mass		0.14 – 0.1

MOON, GERDA, CUORE sensitivity



σ~ 1.3 %50 t y

for IH 4 meV

Phase I Phase II Phase III

3. Neutrino spin responses

in ββ decays

Nuclear spin isospin responses

Nuclear matrix element

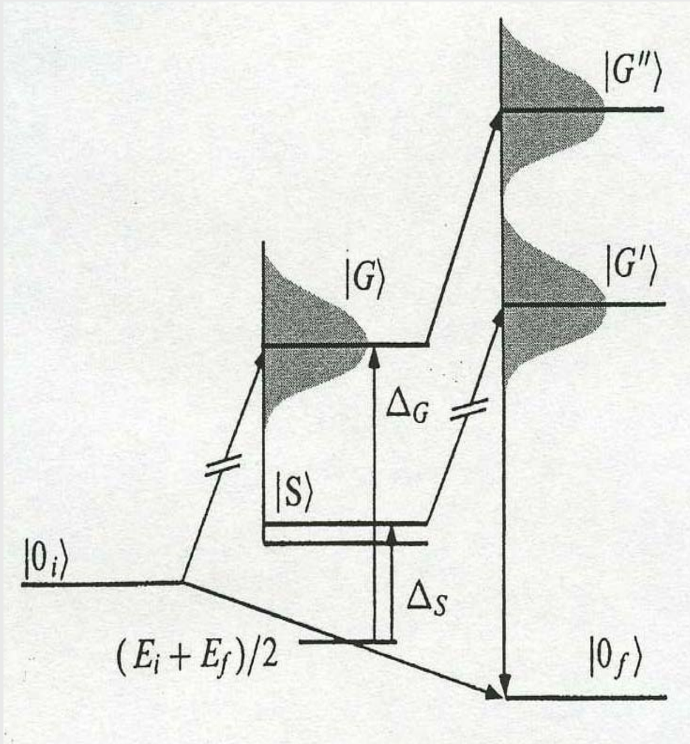
$T^{0\nu} = k m^2_\nu \, [M^{0\nu}]^2 \, [n_{\beta\beta}/B]^{1/2}$ in case of B>>1

1. $M^{0\nu}$ is crucial for extracting m_ν designing exps.
2. Sensitive to nuclear structures,

   τ σ corr., effective g_A , short-range,

   Extremely small, 10^{-2} M^{SP}, 10^{-4} M^{GR}

3. Theory: Shell model, QRPA,



Single-β and ββ

1963-65 Fujita Ikeda GT GR- g_A

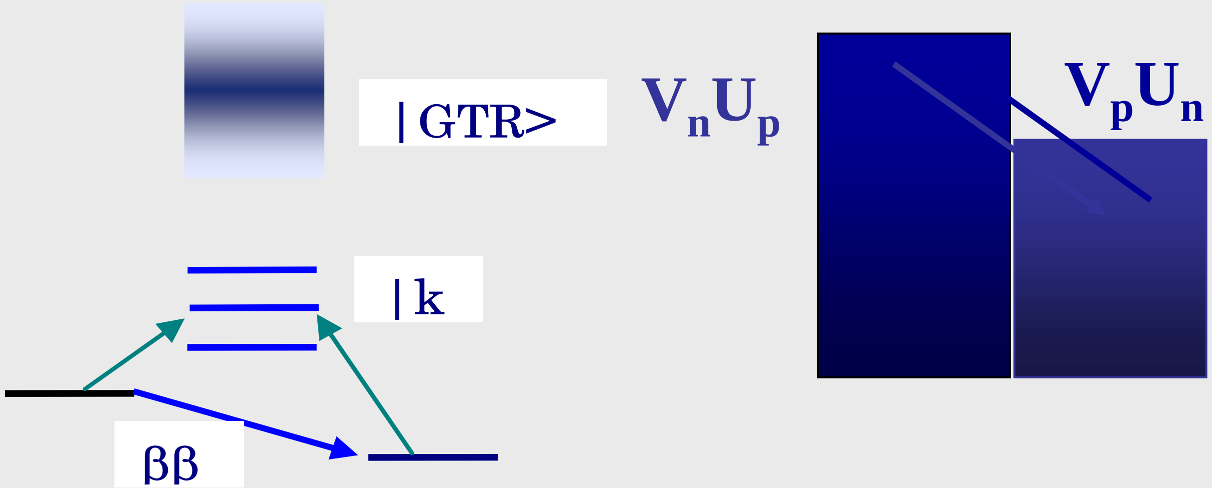
1968 Ejiri Fujita Forbidden β GR- g_A

1978 Ejiri Fujita PR 38c 75

1994 95 Ejiri Toki GT ββ GR and g_A(ββ)

$M^{2\nu} \sim M^\beta . M^\beta$ trough low-states >> GR

FSQP: Fermi Surface Quasi Particle Model



$$\Sigma\, g_A^{\,2}\, V_nU_pV_pU_n\ m^2_{jJ}$$

QP in the dif ｆ used Fermi-surface by the pairing interaction

H. Ejiri, Phys. Report 338 (2000) 265.

H. Ejiri and H. Toki, (1996) J. Phys. Soc. Japan Lett. 65 (1996) 7.

$$\mathbf{M = \Sigma\, M_k} \;\Longrightarrow\; \mathbf{\Sigma_L\, M_k}$$

$$\mathbf{M_k = M(k) \,/\, \Delta(k),}$$
$$\mathbf{\Delta(k) = M(I_k) - (M(i) + M(f))/2}$$
$$\mathbf{M(k) = M_i(k)\, M_f(K)}$$

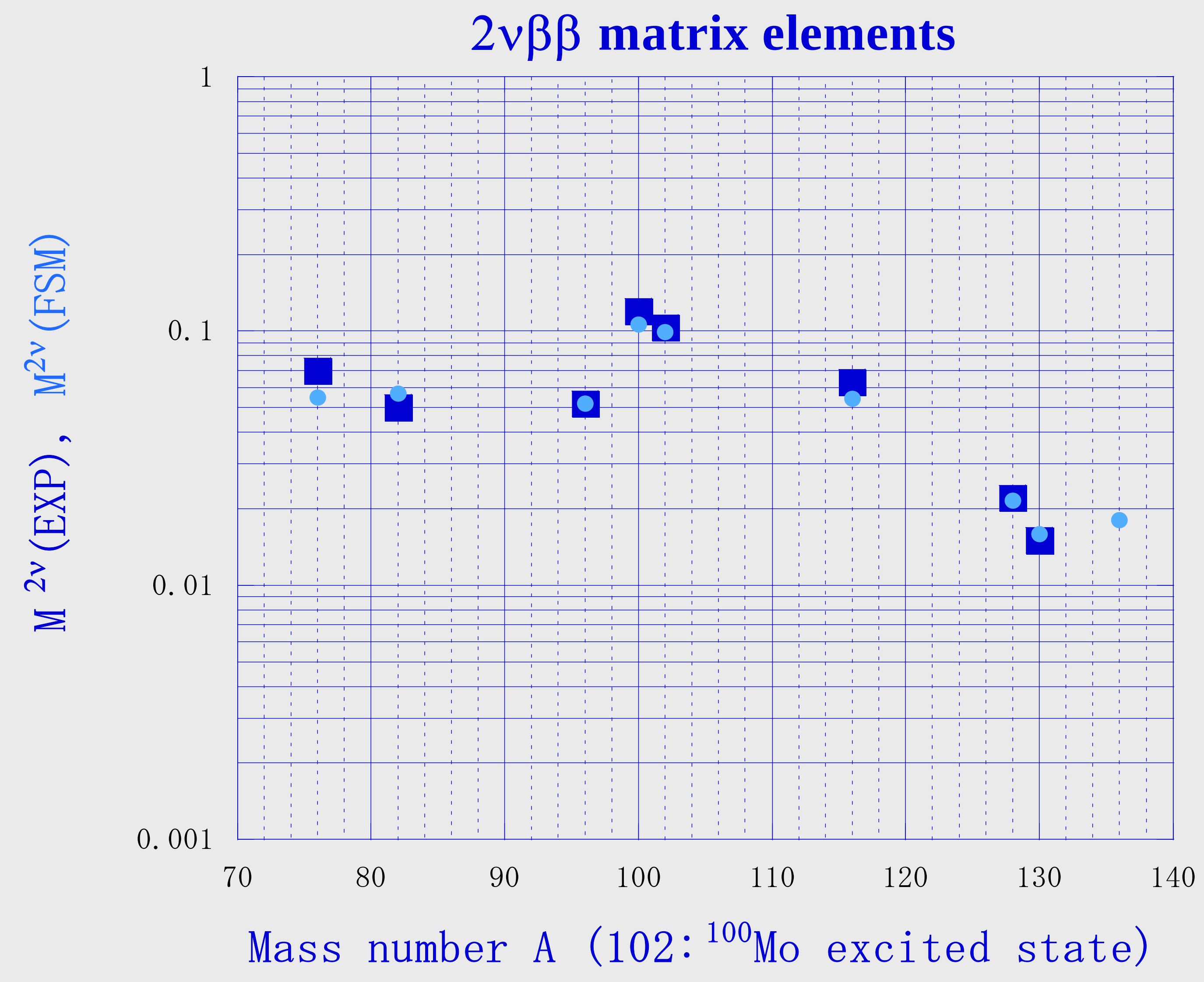
P-space Fermi-surface QP   Experiments and QP calculations

Q-space High-lying GR $\tau\ \sigma$ medium polarization g^{eff} by exp.

$$\mathbf{M_i(k) = (g_A{}^{eff}/g_A)_i\, m(j_k\ J_k)\, P_i(k),}$$
$$\mathbf{M_f(K) = (g_A{}^{eff}/g_A)_f\, m(j_k\ J_k)\, P_f(k),}$$
$$\mathbf{M(k) = (g_A{}^{eff}/g_A)^2\, m(j_k\ J_k)^2\, P_i(k)\, P_f(k),\ \ Exp.}$$
$$\mathbf{P_f(k) = U_p(J_k)\, V_n(j_k), \qquad P_f(k) = V_p(J_k)\, U_n(j_k)}$$

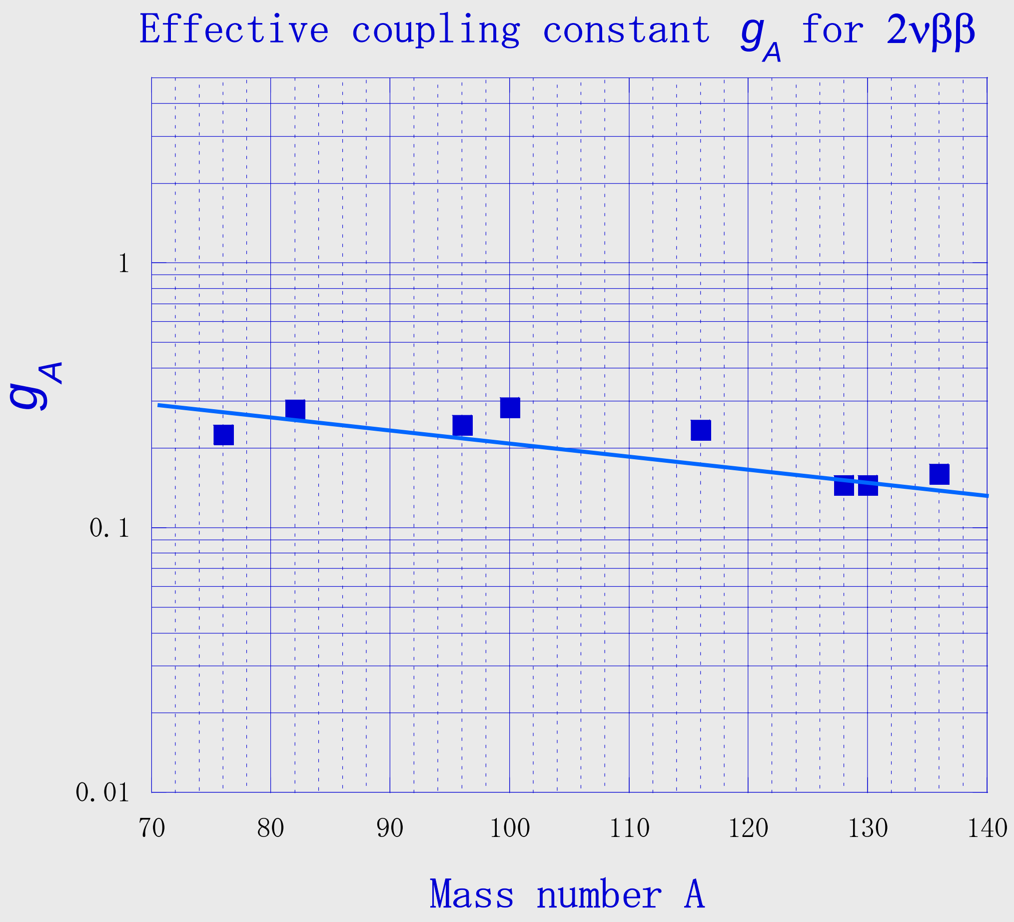
In case of no exp.use nighboring $M'_\iota(1)\ M'_\phi(1)$ **by**

$M_\iota(1)\ M_\iota(1) = M'_\iota(1)\ M'_\phi(1)$ $\mathbf{[(P_i(1)\ P_f(1))/(P'_i(1)\ P'_f(1))],}$



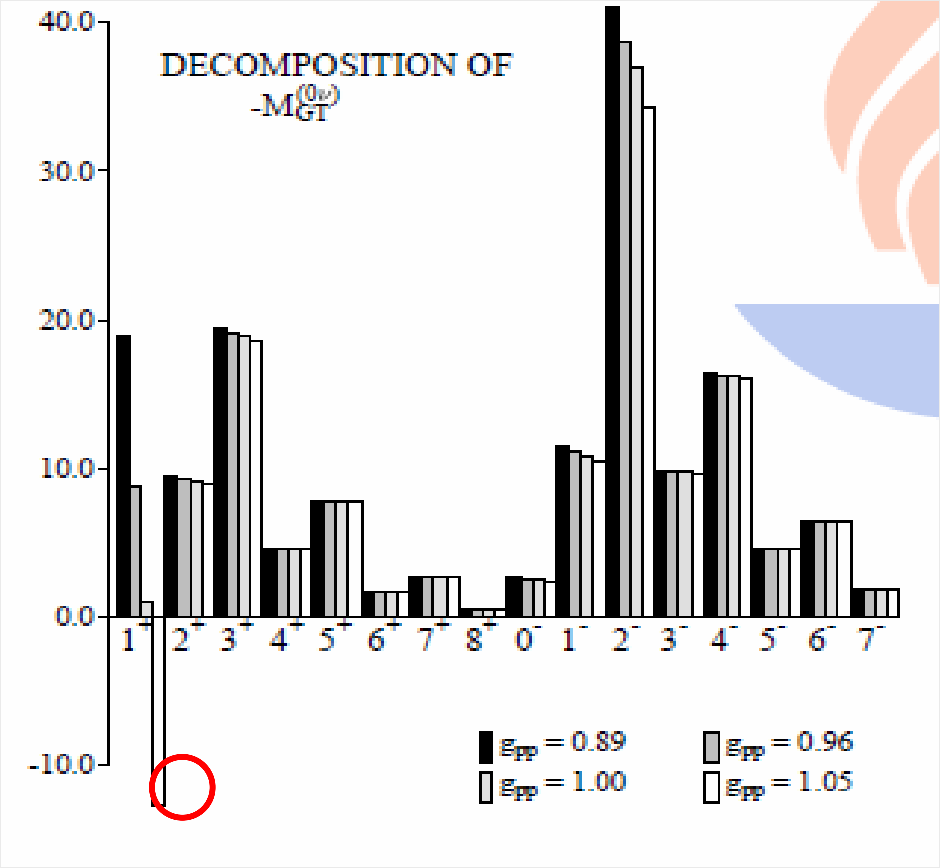
2νββ matrix elements
1
0.1
0.01
0.001
M 2ν (EXP), M2ν (FSM)
70
80
90
100
110
120
130
140
Mass number A (102: 100Mo excited state)

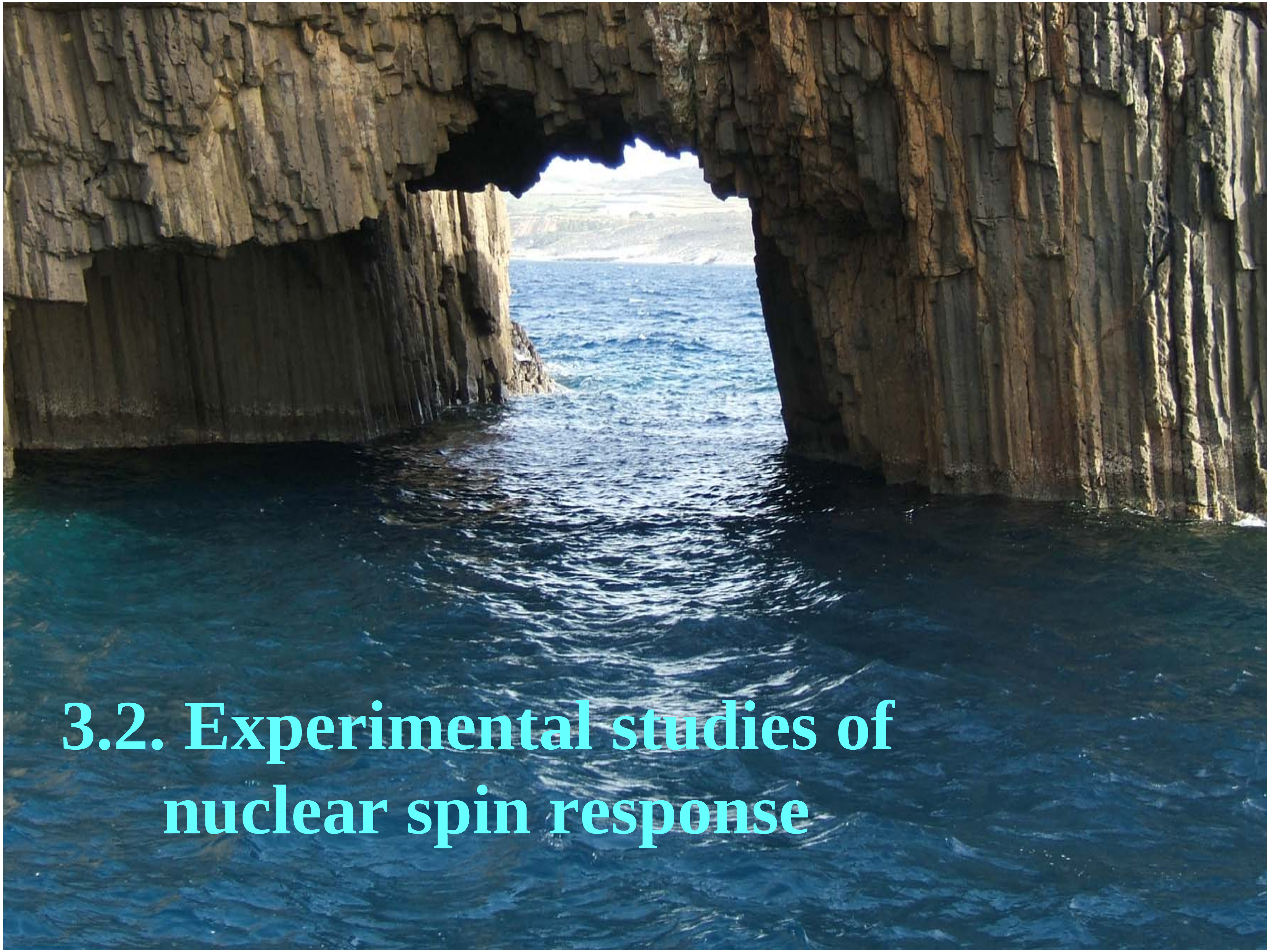
Effective coupling constant: $g_A \sim (g_A^{eff} / g_A) \sim 0.24/0.01$ **A,**
$g_A^{eff} / g_A = 1/[1+k_+ + k_-]$; k_+ ,$-k_-$ **backward, forward correlations.**



Extension to 0νββ matrix elements

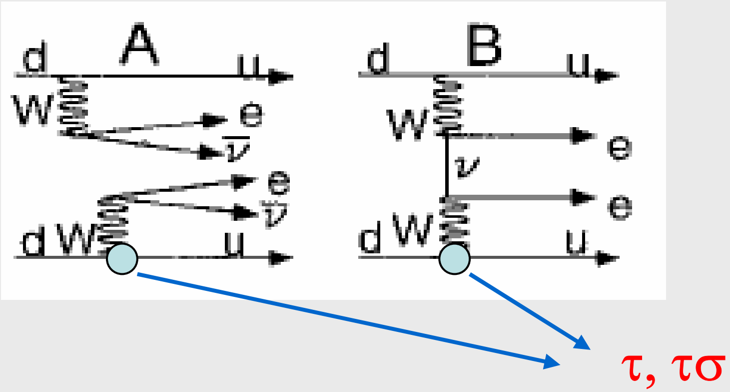
Suhonen





3.2. Experimental studies of nuclear spin response

Nuclear spin isospin responses for ν in ββ

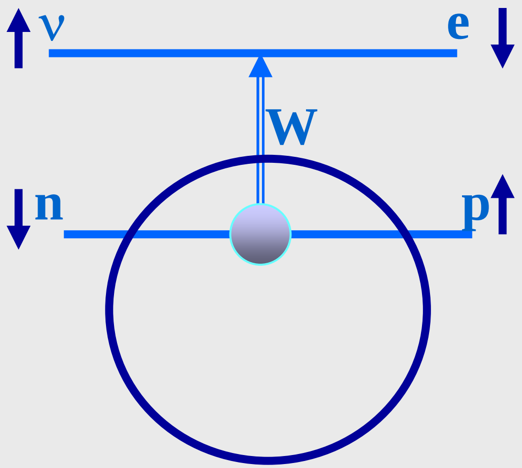


Nuclear weak responses

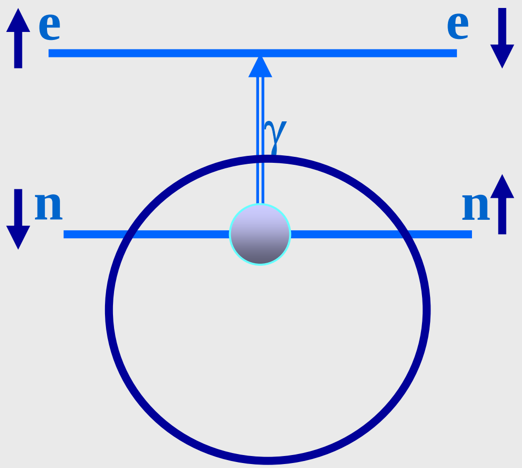
ββ–ν, solar-ν

Fermi- Isospin τ

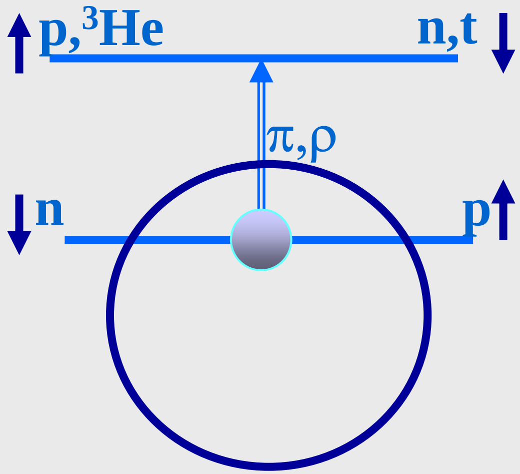
GT Spin Ispspin τσ



β-decay, e capture
ν-probe from J-PARC

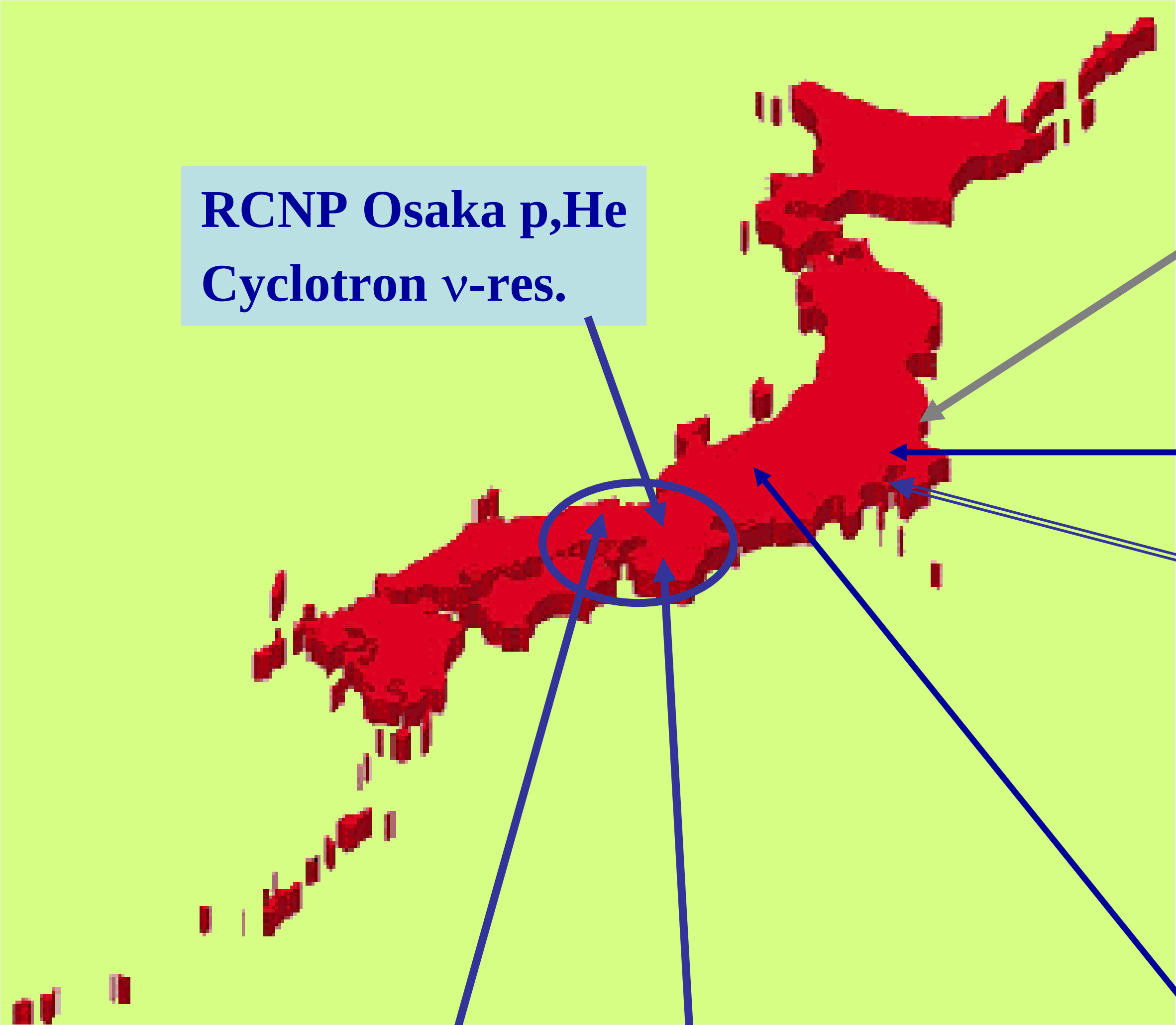


γ-capture, e scattering
γ from Spring-8



^{3}He,t t,^{3}He d,^{2}He
RCNP, MSU, KVI

Nuclear Particle physics lab. in Japan



RCNP Osaka p,He Cyclotron ν-res.

J-PARC Japan Proton Accelerator Research Complex 3-50 GeV p, K, n. ν

KEK e-collider B-fatoy CP, ν

RIKEN HI cyclotron

Spring-8 8 GeV e, GeV-MeV pol. γ, quark-nuclei

Oto under ground lab. ββ–ν, DM in nuclei

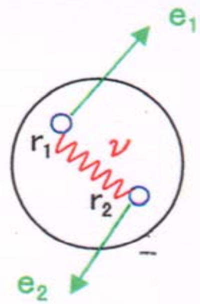
SK/KamLAND Underground lab. ν-osc. K2K, T2K. ν / SN, the sun and earth,

Nuclear Responses ($M^{0\nu}$) for $\beta\beta$

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

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

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



q=04.GeV/C

ℓ=0−6

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

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

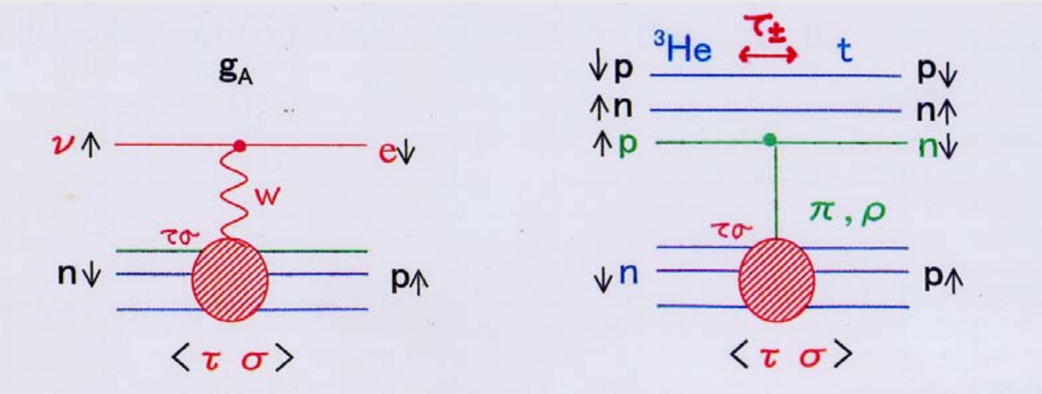
$$M^{0\nu} \sim \Sigma M_\ell^+(SP) M_\ell^-(SP) + (M_\ell^+(GR)\ M_\ell^-(GR) \rightarrow \varepsilon$$

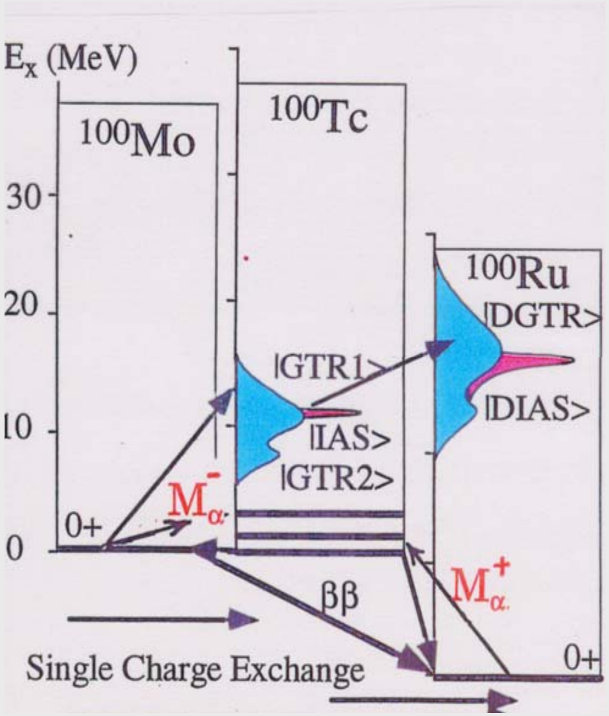
Studied by τ^- and τ^+ Charge Exchange Reaction:

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

Charge exchange reactions give information relevant to $\beta\beta - M^{0\nu}$

RCNP Osaka (^{3}He,t) (^{7}Li, ^{7}Be), MSU (t,^{3}He), KVI (d,^{2}He)





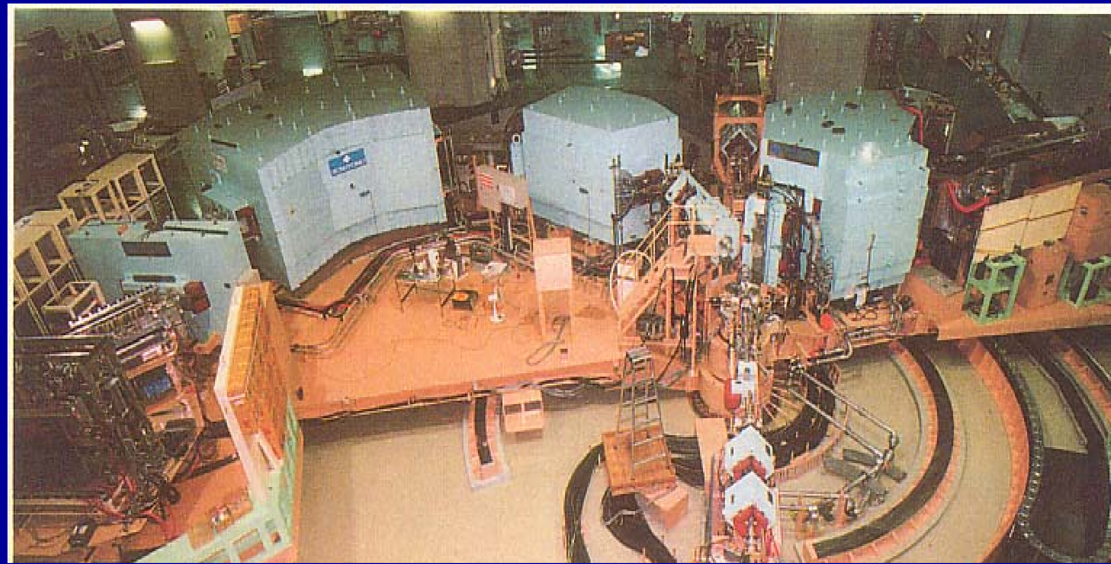
RCNP CER (^{3}He, t)

E=0.45 GeV V(τσ) is very large.
High resolution

Start ~ 1995 Akimune Ejiri et al, '97 PL
Ejiri et al solar-ν '98 PL
2007 - Improved resolution, Freckers et al, Zegers et al.
H.Ejiri, Phys. Rep. 338 '00 265

Charge exchange reaction

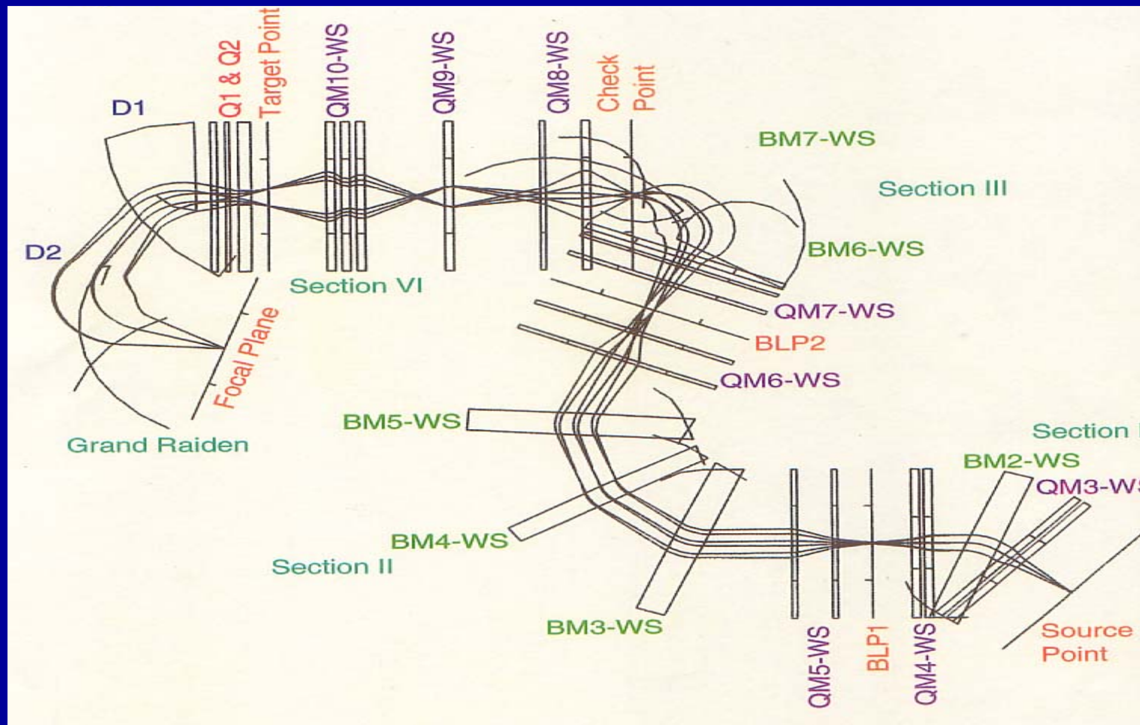
at RCNP



High E resolution of ΔE ~ 0.01 %

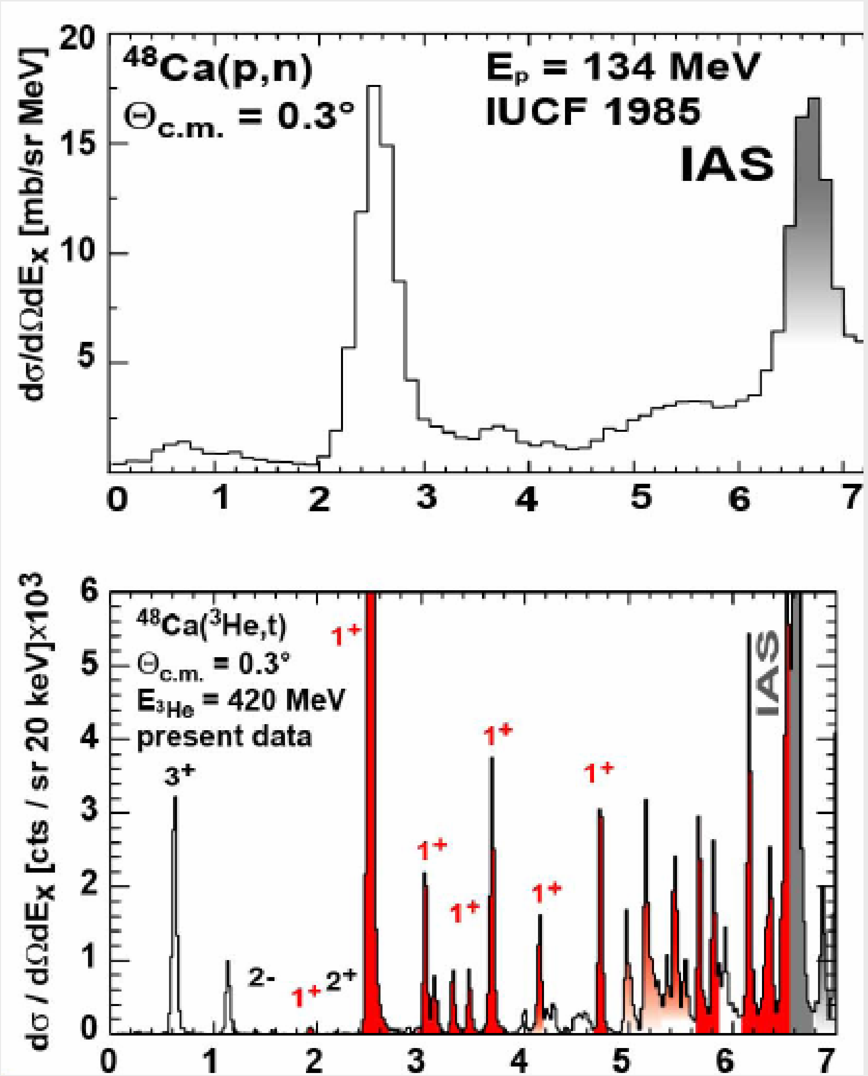
to resolve

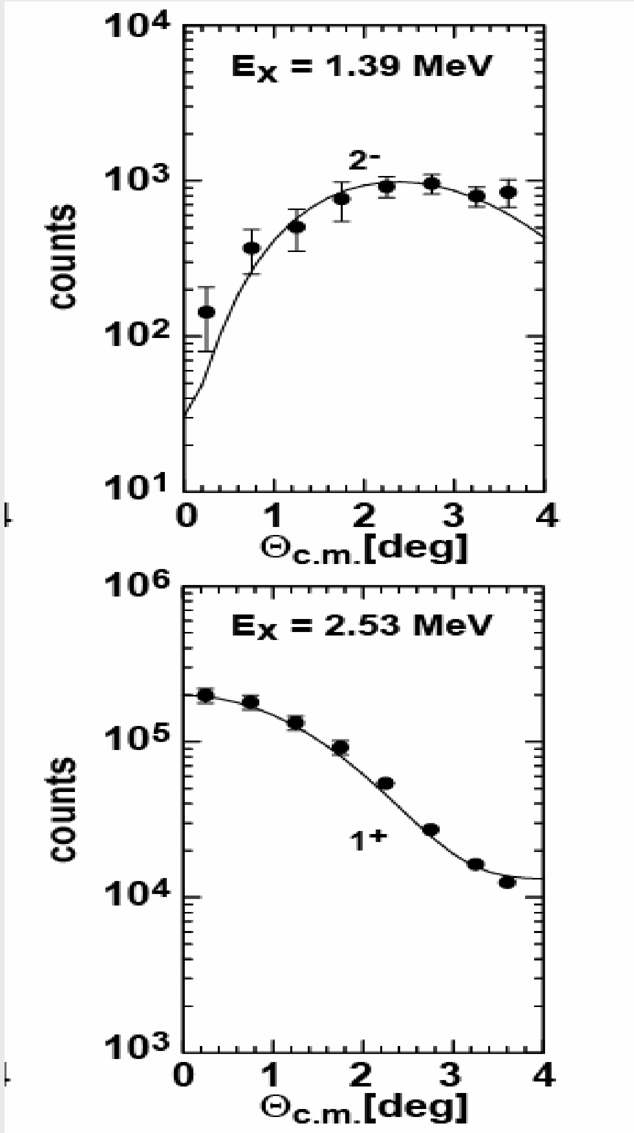
individual states



RCNP CER (^{3}He, t) Start ~ 1995 Akimune, Ejiri et al, '97

Improved resolution, Freckers et al, Zegers et al.



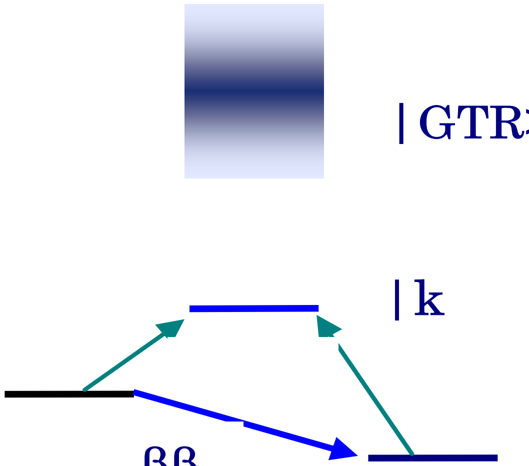


Resolution is crucial

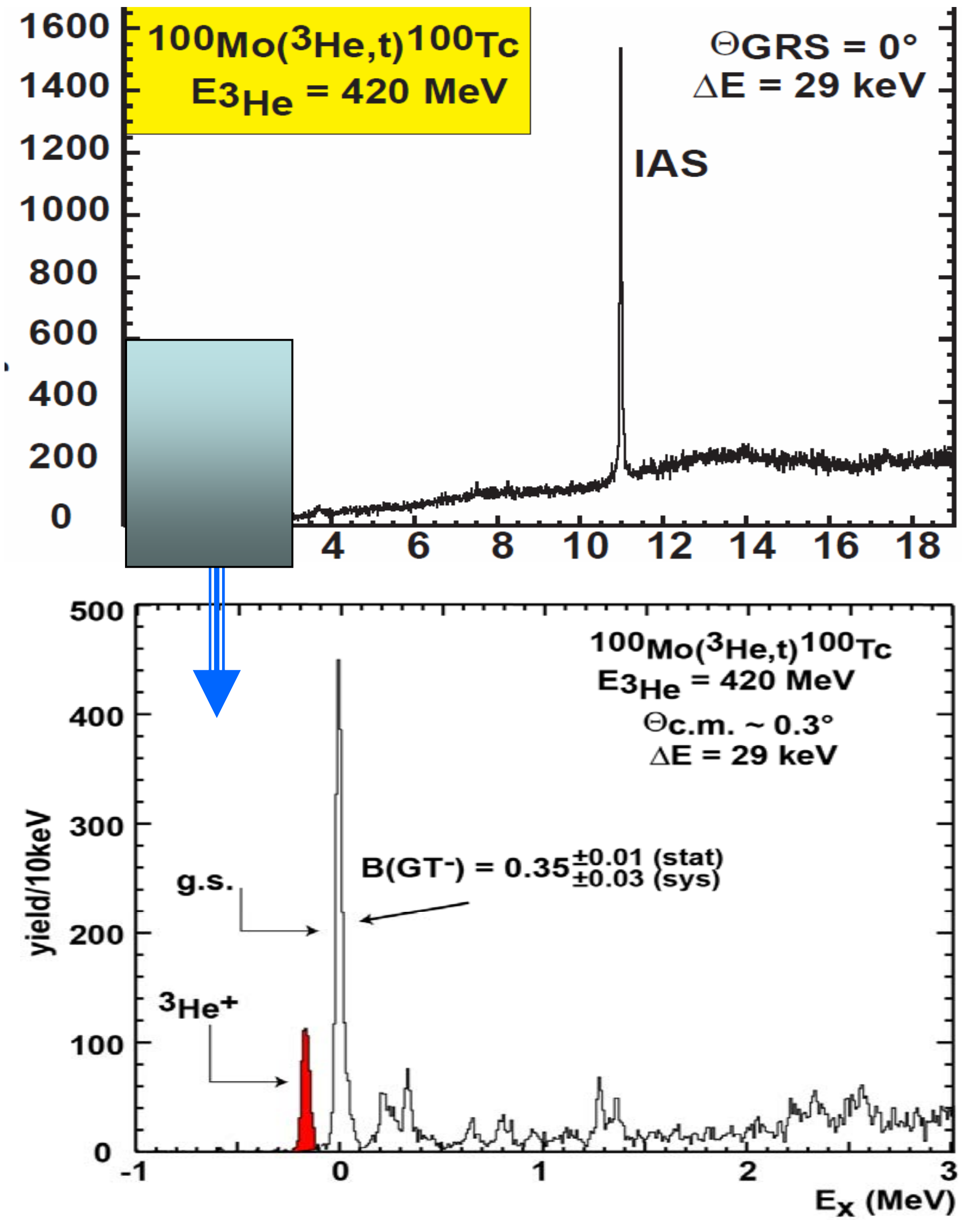
One state in FSQP,

M_i = 0.57 (^{3}He, t) at RCNP '97 OK
Mi = 0.59 with good ΔE '08, by

Frekers et al ,



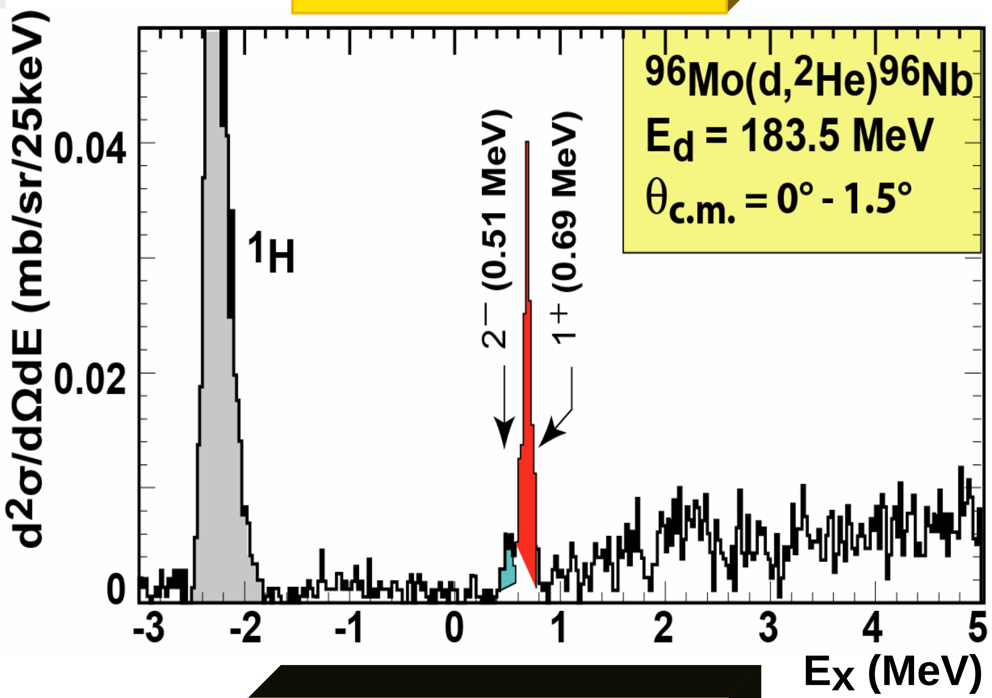
$M_f = 0.55\ \beta$

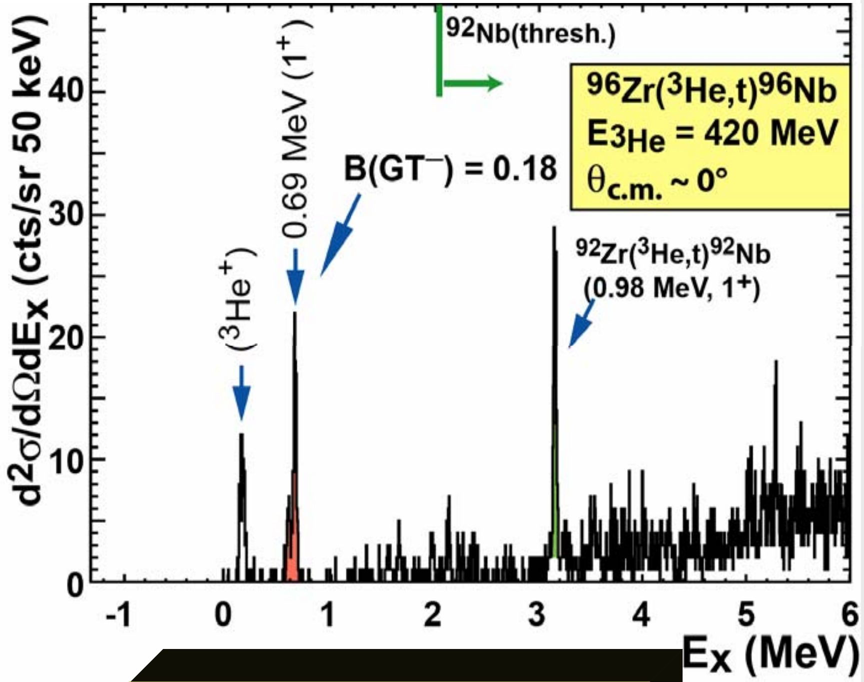


M_1 = 0.11 , agree with

$M^{2\nu}$ = 0.12(EL V, NEMO)

(d,^{2}He) Freckers (^{3}He,t)





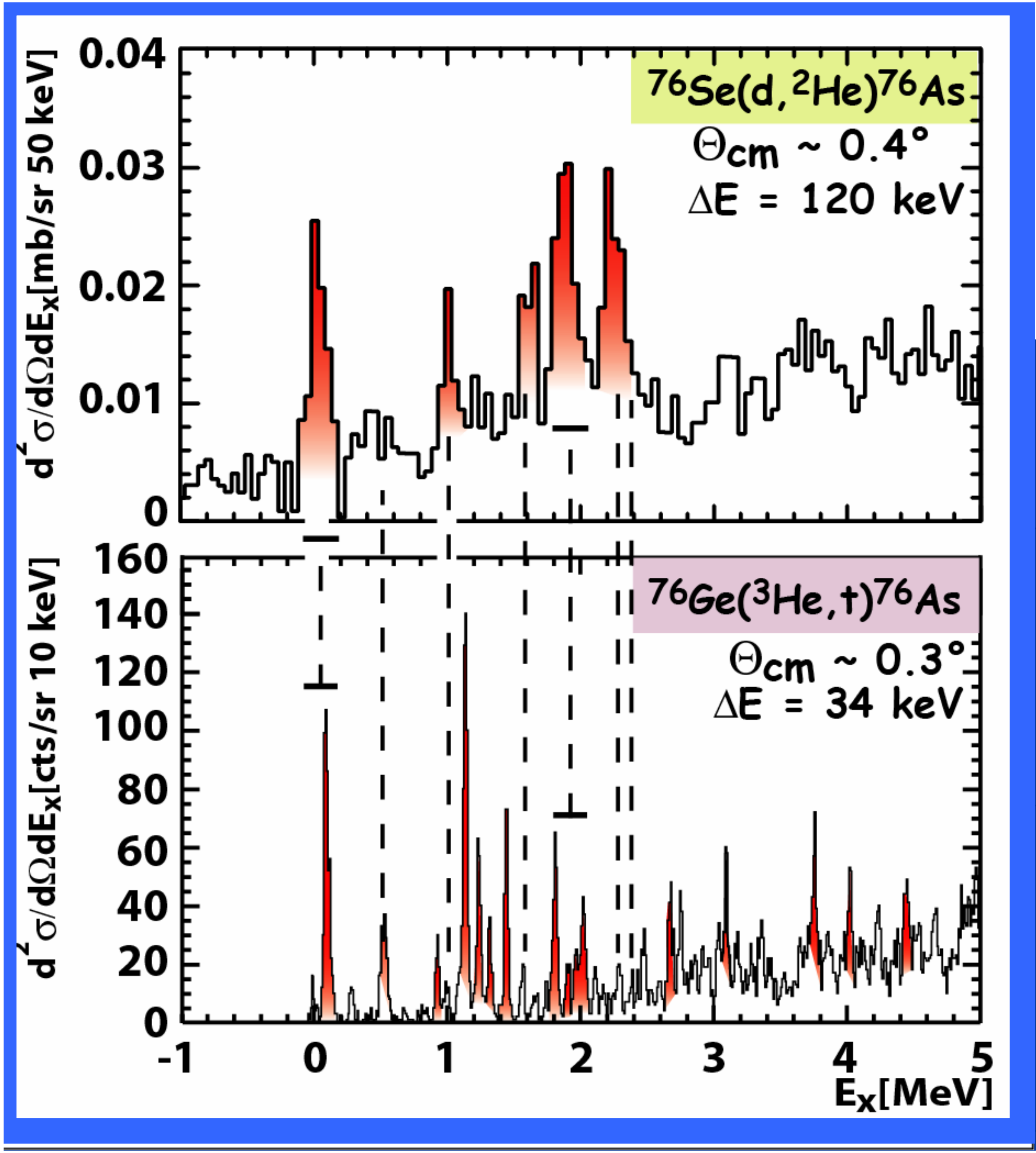
B(GT$^+$) = 0.3

B(GT$^-$) = 0.18

Fascination: With this 1 level only:

$$T_{1/2}^{calc.}(2\nu\beta\beta) = (2.2 \pm 0.3)\cdot 10^{19}\ \text{years}$$

$$T_{1/2}^{exp.}(2\nu\beta\beta = (2.2 \pm 0.4)\cdot 10^{19}\ \text{years}\ \ \text{(NEMO3-result)}$$



Again!!

an anticorrelation of strength

! ! ! ! ! ! !

An effect of the difference of deformation ??

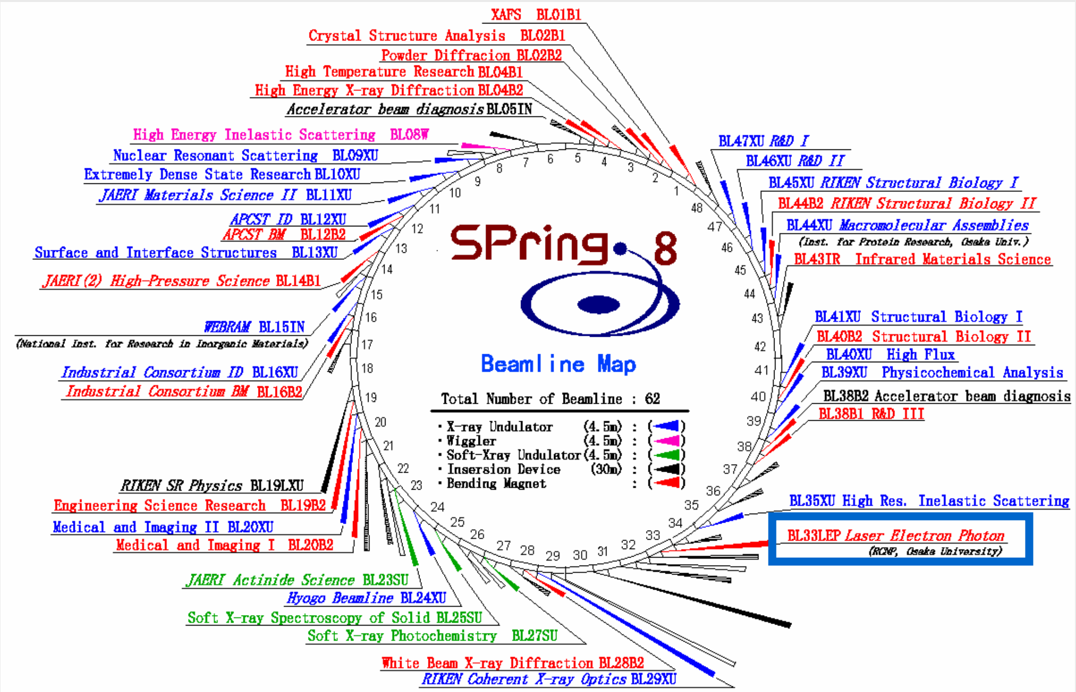
^{76}Se:
oblate
(β_2 ~ −0.2)

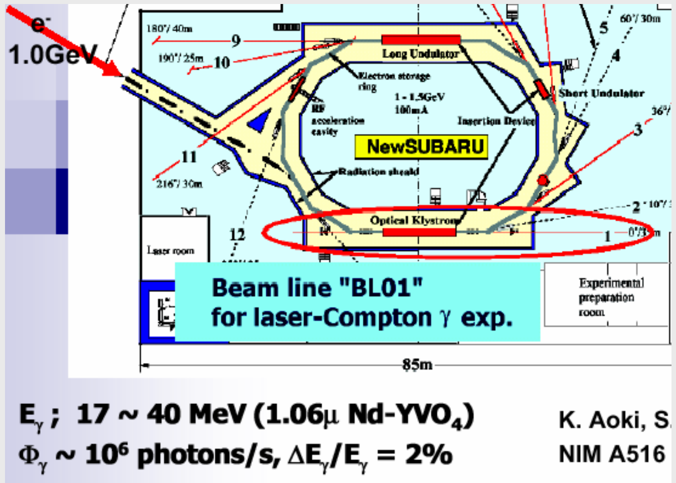
^{76}Ge:
moderately oblate/ prolate
(β_2 ~ 0.1)

Photon probes via electromagnetic interaction

Polarized GeV-MeV photons from laser scattered off GeV electrons for electric and magneic trasitions.

Spring8 8 GeV 100 mA Eγ:0.5–3.5 GeV





1 GeV electron ring

γ **Neutral Z current responses**

Isospin rotation for charged current responses

γ + A = IAS B for β + A = ν + B,

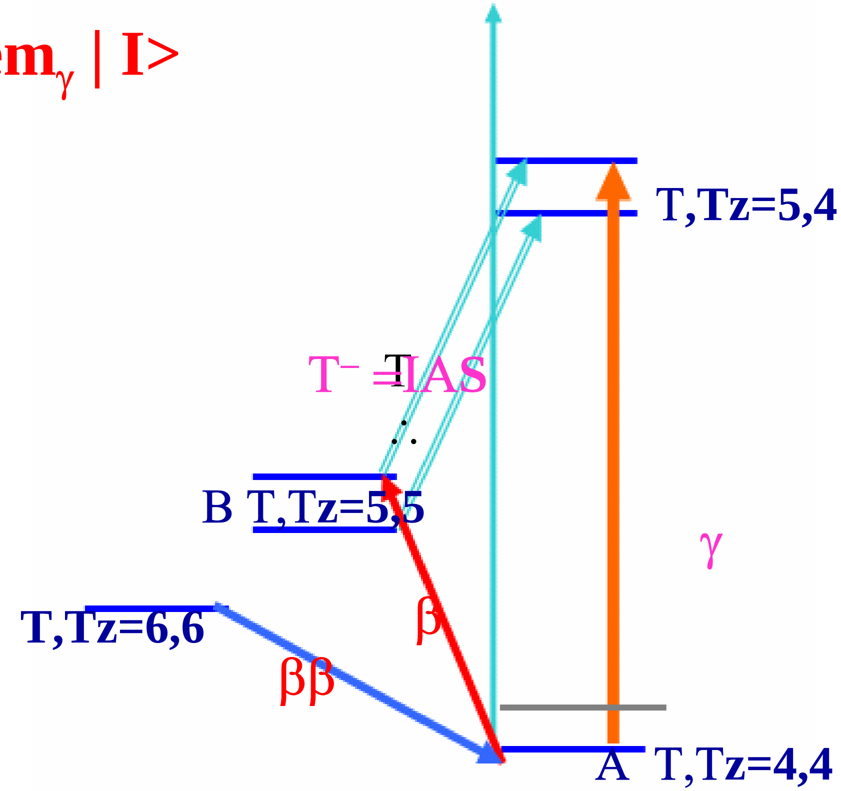
$\langle f | g M_{\beta} | i \rangle = g/e\,(2T)^{1/2} \langle f | em_{\gamma} | I \rangle$

r, σ, r x σ by E1 and M1 γ

$P_{\gamma}(L)$ azymuthal distribution

Excited states |i’> in B by

IAS of |i’> = T-|i’>.

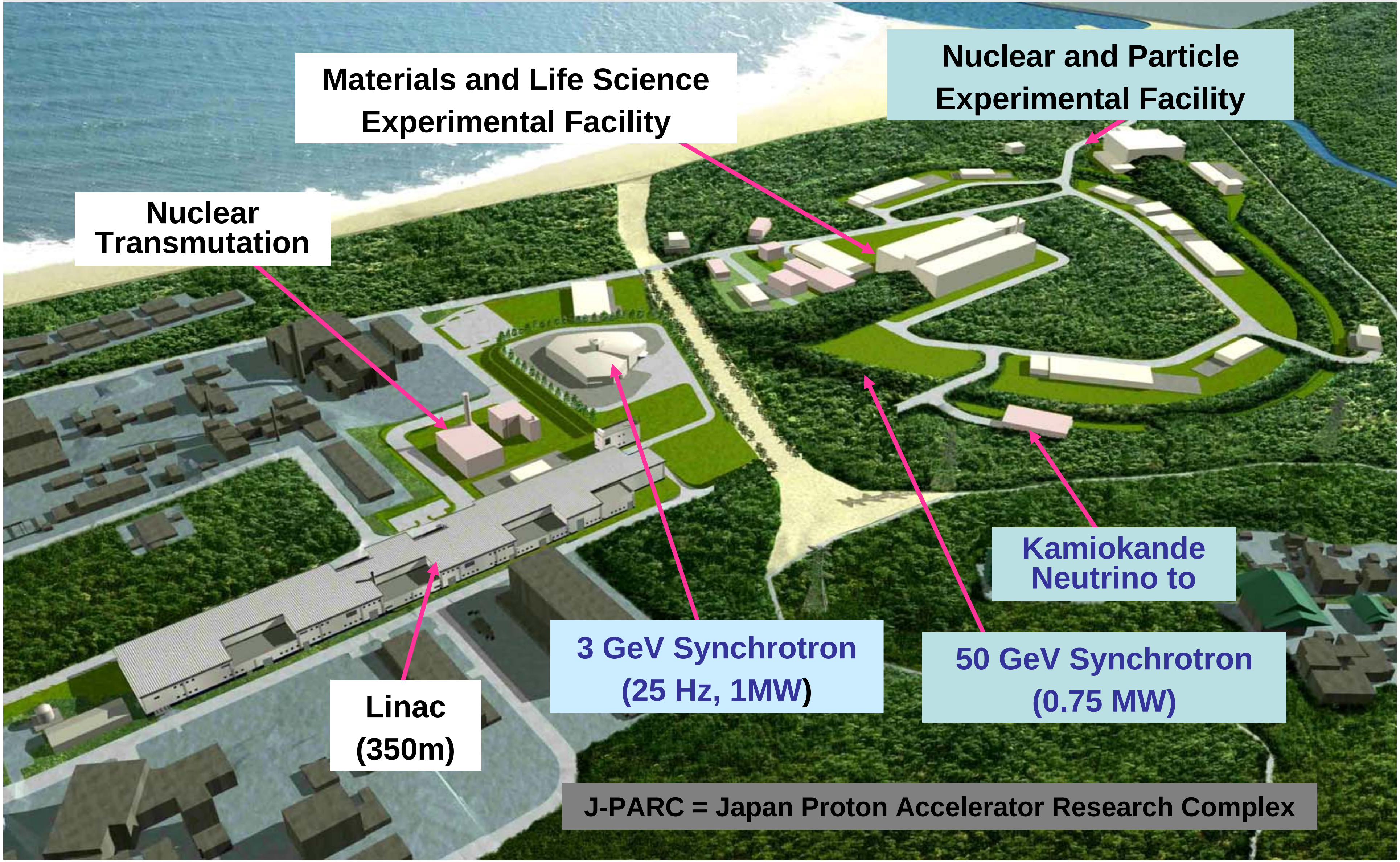


H. Ejiri PRL 21 ’68, H. Ejiri PR 38 ‘78

Low energy Neutrinos at J-PARC

Noumi

p 1.2 10^{15} ν 5 10^{14}



Low energy Neutrinos

Stopped p^+ SNS ORNL and
J-PARC of potential interest

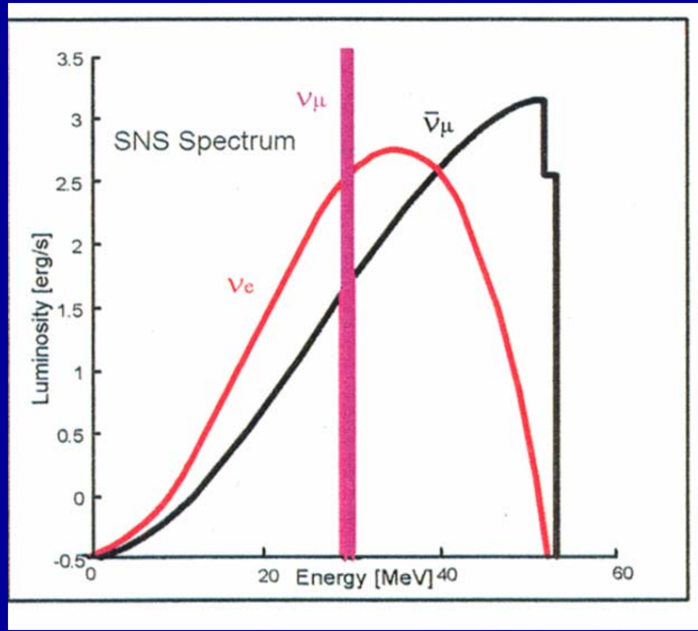
$$p + Hg \rightarrow n\, \pi^+$$

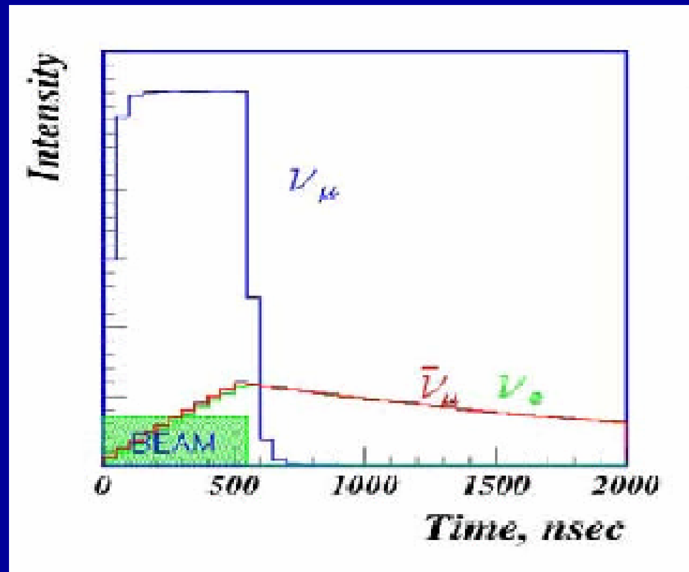
$$\pi^+ \rightarrow \mu^+ + \nu_\mu \qquad \mu^+ \rightarrow e^+ + \nu_e + \text{anti-}\underline{\nu}_\mu$$

Intense ($\sim 10^{15}$/sec) ν's from 1 MW p, time structures and ν spectra are used to study astro nuclear responses of $\sigma \sim 10^{-41\text{-}42}$ cm^2 with large detectors(10 tons)

Source	E GeV	Np	Nν /s
SNS	1	$6\ 10^{15}$	$1\ 10^{15}$
J－PARC	3	$1.2\ 10^{15}$	$5\ 10^{14}$

H. Ejiri NIM. 503 (2003) 276 – 278.





6. Concluding remarks

From the Ejiri's weekday flat at Yokohama

1. **Neutrino-less DBD is the realistic and sensitive probe to study the Majorana ν and the Majorana ν-mass in QD, IH, and NH.**

2. **Spectroscopic DBD studies of E-Θ correlations for 2-3 isotopes and/or states are indispensable for identifying the 0νββ ν-mass.**

3. **The spectroscopic MOON experiment with detector ≠ ββ souces is the high-sensitivity compact exp. for the IH ν-masses with realistic σ ~ 2.2 % and ~20 mBq/t . QD ~100 meV and IH~30 meV masses are studied by N~0.1 and 1 t y with ^{82}Se , ^{100}Mo.**

4. **The proto-type MOON1 and MOON module demonstrate the feasibility of the MOON experiment.**

5. **The ββ–ν nuclear responses are given by σ τ nuclear matrix elements, which are sensitive to σ τ nuclear correlations.**

   The 2νββ matrix elements are reproduced by FSQM. Extension of FSQM to the 0νββ matrix elements is of great interest.

6. **Charge exchange reactions with the high-resolution RCNP ^{3}He probes, the NewSUBARU/HIGS photon probes and the J-PARC ν probes in future are used to get the $M^{2\nu}$ and $M^{0\nu}$.**

INTERNATIONAL STATEMENT ON DBD 2003

http://www.rcnp.osaka-u.ac.jp /ejiri/DBD-Lett

Form an international DBD network in order to endorse a coordinated approach to executing next-generation DBD and to encourage internationl collaborations for them..

MAJORANA/GERDA, MOON/SuperNEMO , etc are encouraged

Neutrino Nuclear Responses in ββ : Durham Osaka 2005

RCNP, KVI, MSU and others provide unique opportunities for the experimental studies of the ββ matrix elements.

H.Ejiri, D. Frekers, M. Harakeh, K. Zuber, R. Zegers, others.

International Review 2007

It is very important to pursue the MOON project, as it is very complementary to the calorimetric experiments, and is unique in its ability to be expanded . Progress made thus far on MOON R&D is impressive. It will very probably be one of the real world class experiment

MOON collaboration

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- P.J.Doe, R.G.H.Robertson*, D.E.Vilches, J.F.Wilkerson、D. I. Will. CENPA, Univ. Washington.
- S.R.Elliott, V. Gehman, LANL
- J.Engel. Phys.Astronomy, Univ. North Carolina.
- M.Finger, M. Finger, K. Kuroda, M. Slunecka , V. Vrba.
- Phys. Charles Univ. and CTU Prague
- K.Fushimi, H. Kawauso, K. Yasuda, GAS, Tokushima Univ. Tokushima
- M. Greenfield, ICU, Tokyo.
- R. Hazama, Hiroshima Univ.
- H. Nakamura, NIRS.
- A. Para FNAL
- A. Sissakian, V. Kekelidze, V. Voronon, G. Shirkov A. Titov, JINR
- V. Vatulin, P. Kavitov, VNIIEF
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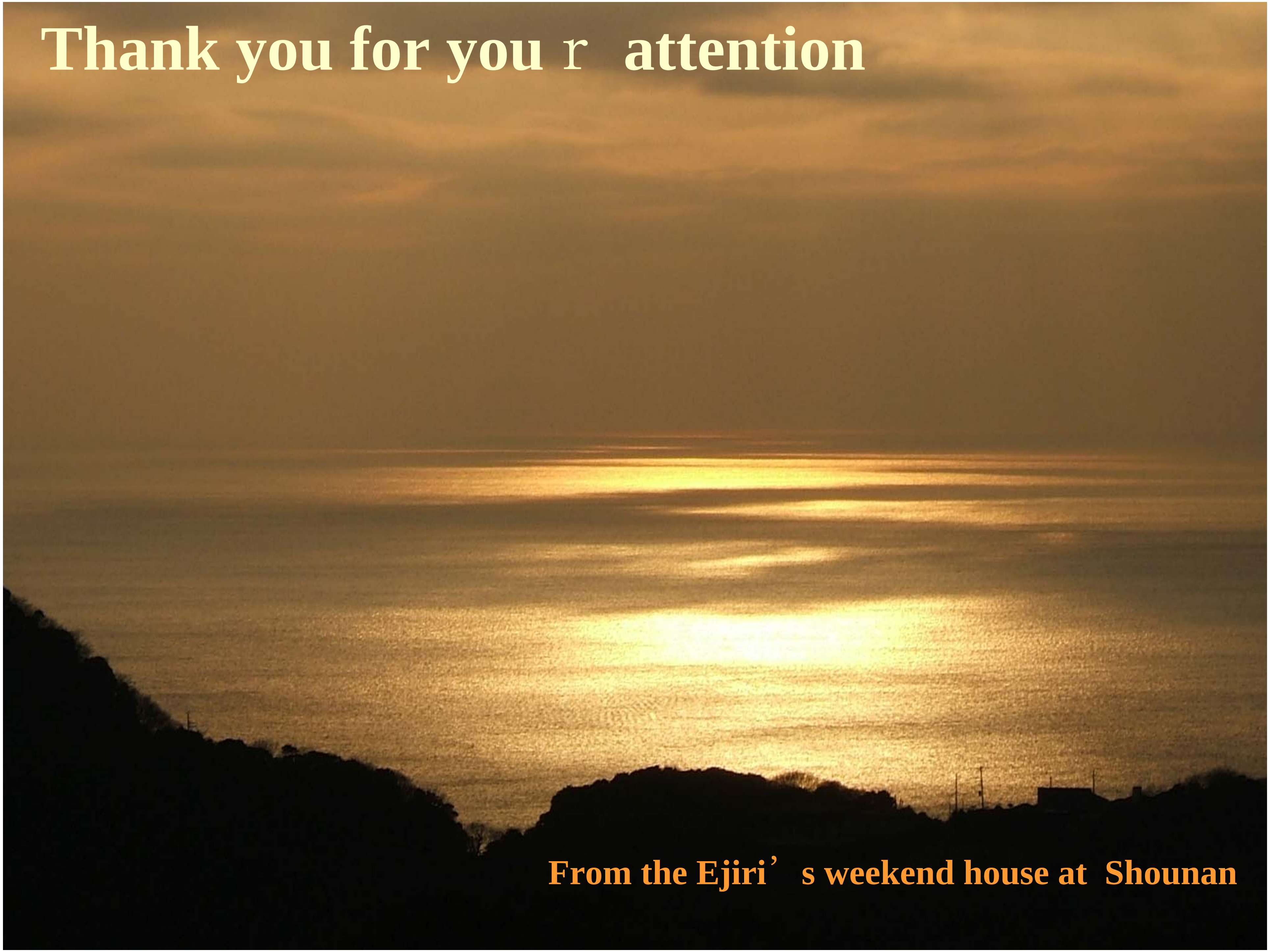
Thank you for you r attention
From the Ejiri's weekend house at Shounan