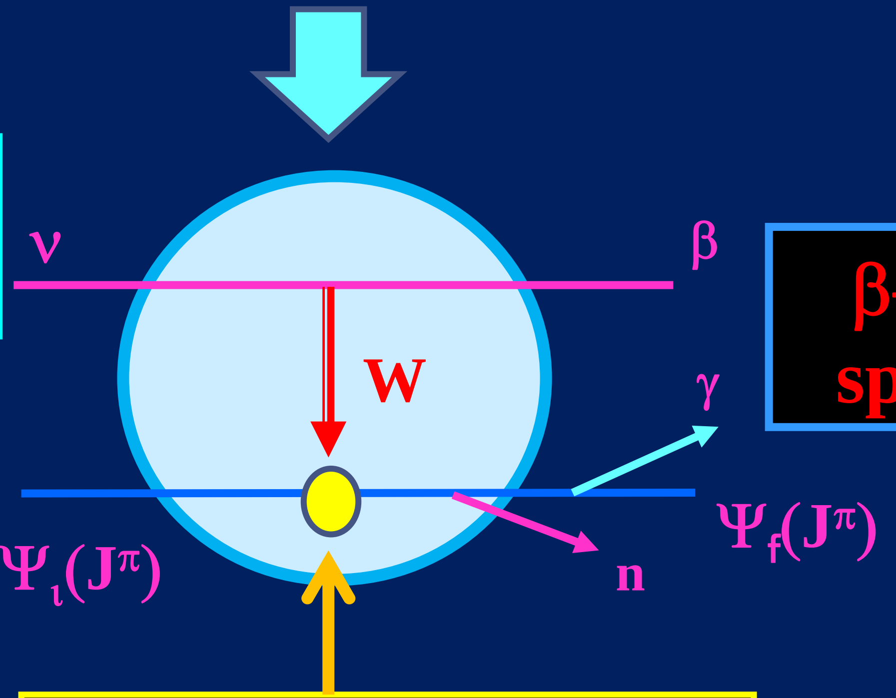
Nuclear Spectroscopy for ν and DM studies in nuclei

Hiro Ejiri
RCNP Osaka &CTU Praha

Nuclear Femto (10^{-15} :fm) Lab. for ν, χ

Astro-ν ββ– ν
DM χ

^{3}He, γ, μ, ν
probes



β–γ, p,d,t、X
spectroscopy

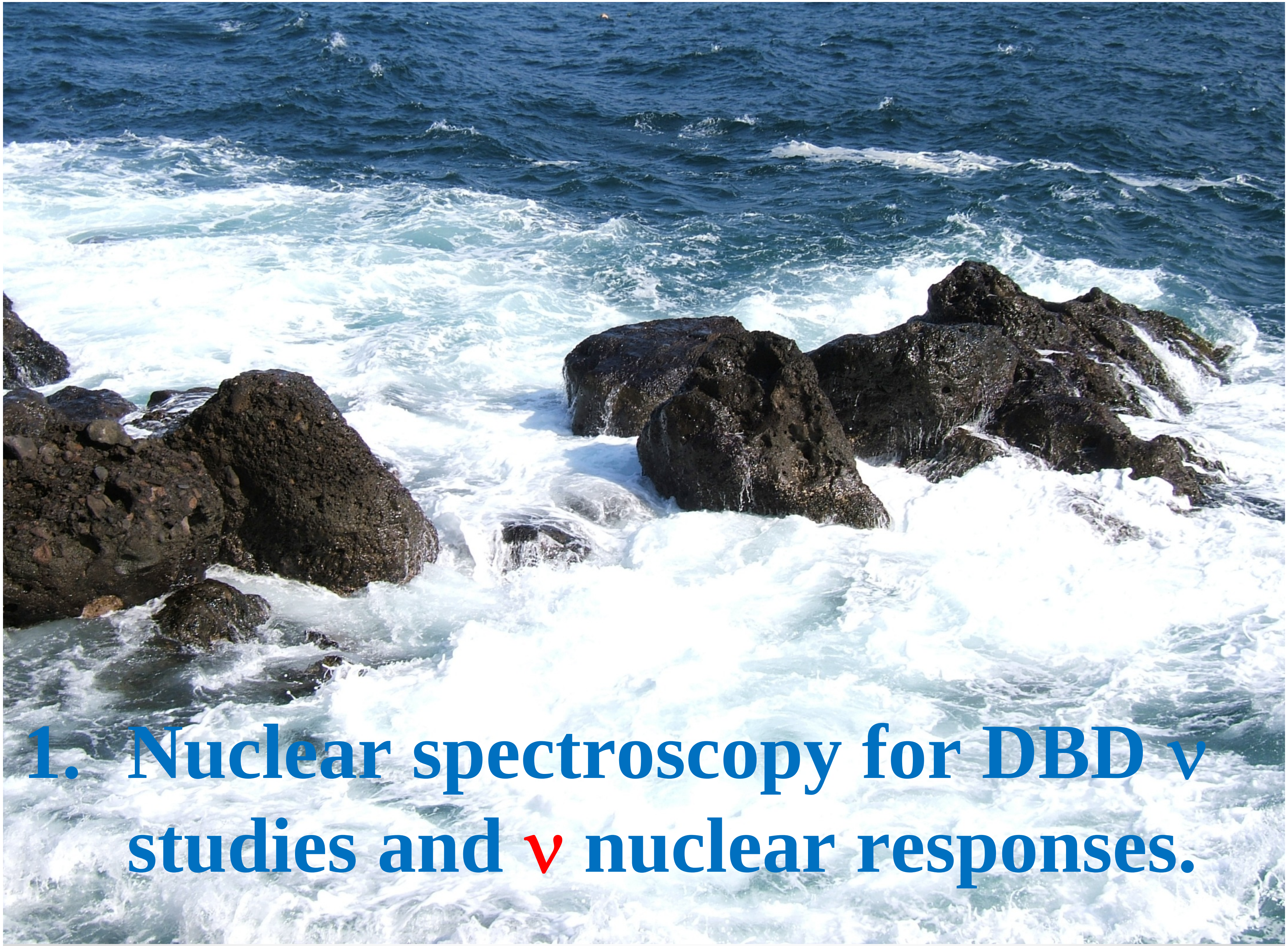
Nuclear ν & DM
responses τ s B(GT)

Nucleus , a quantum system of nucleons with E, J^π, T is used a femto lab. to study ν & χ via β–γ spectroscopy

1. Nuclear spectroscopy and nuclear responses for DBD ν studies.

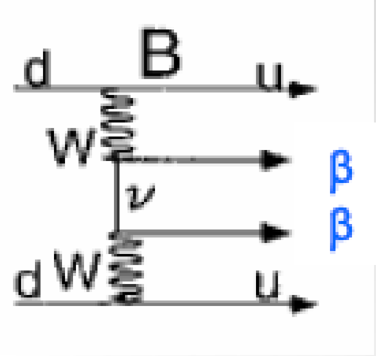
2. Nuclear responses for solar- ν and supernova ν's.

3. X and γ ray spectroscopy for DM studies in nuclei.



1. Nuclear spectroscopy for DBD ν studies and ν nuclear responses.

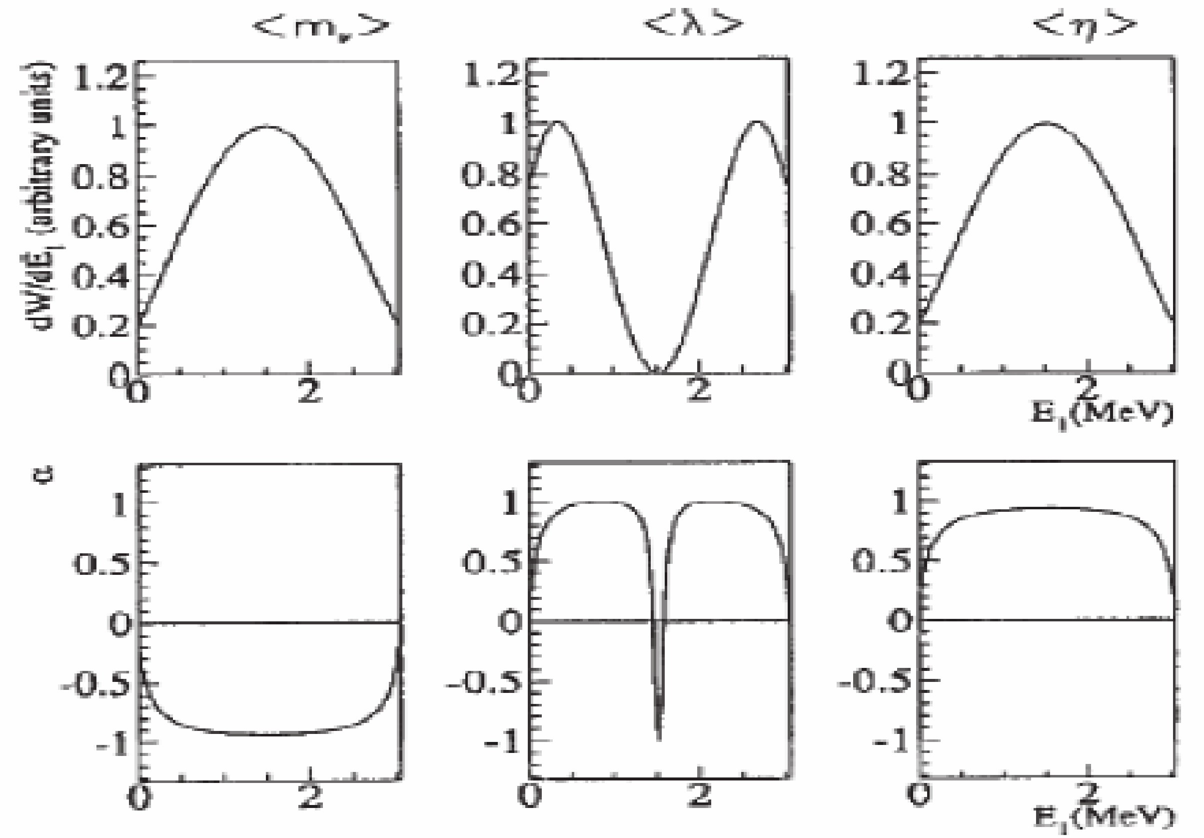
ββ Θ_{21} and E_{12} correlations to identify LHC/RHC



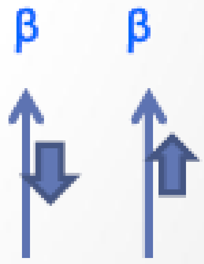
LHC L/R weak boson mass ratio λ and mixing θ

$<m>=|\Sigma m_j U_{ej}|$ $<\lambda>=(M_L/M_R)^2|\Sigma U_{ej} V_{ej}|$ $<\eta>=\tan\theta_{LR}|\Sigma U_{ej} Vej|$

$0^+ - 0^+$



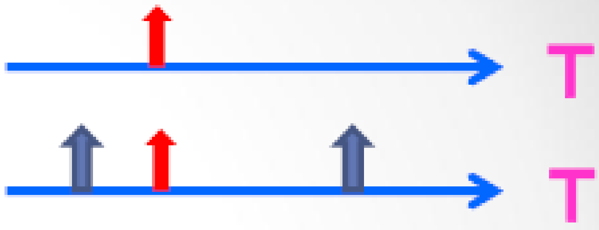
$0^+ - 0^+$



$W(\theta_{12}) = 1+\alpha\cos\theta_{12}$ Ejiri PR Doi 1985

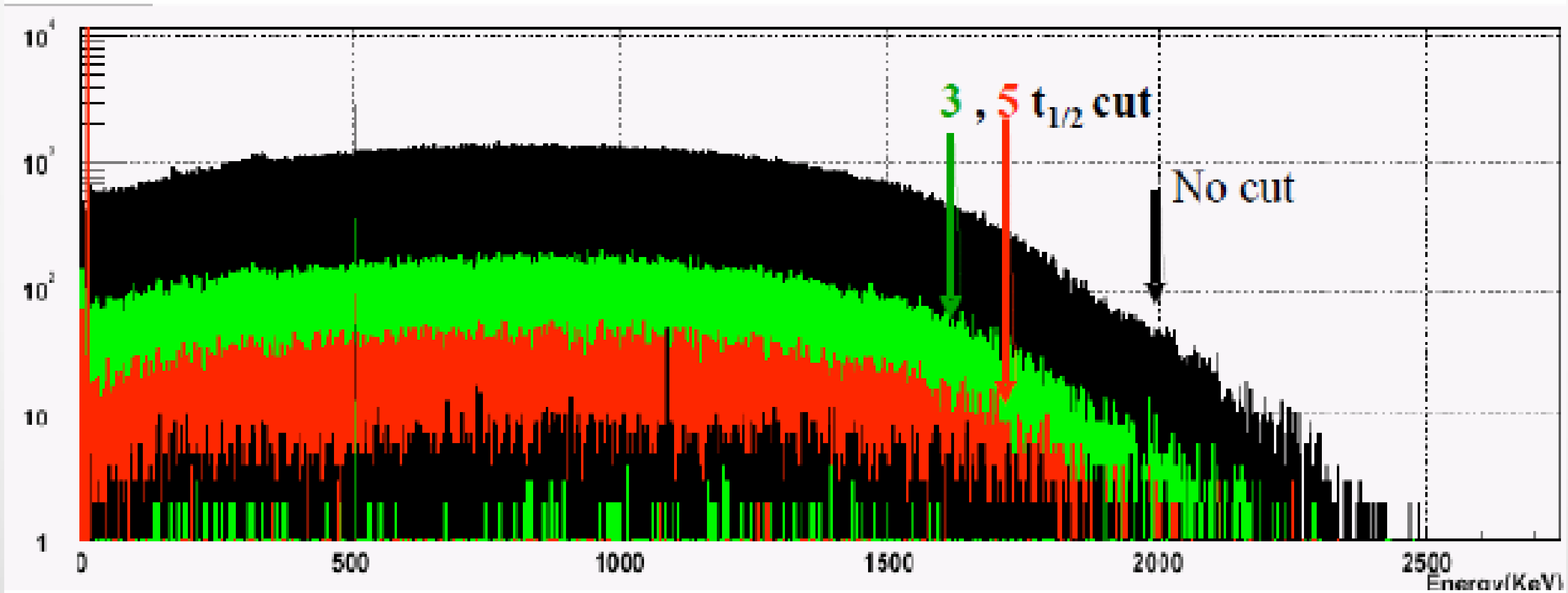
SSTC Signal Selection by Time Correlation

Ultra Rare ββ ground state, DM elastic :
Signals are isolated in time and space.



BG RI β γ sequential decays ; time correlated

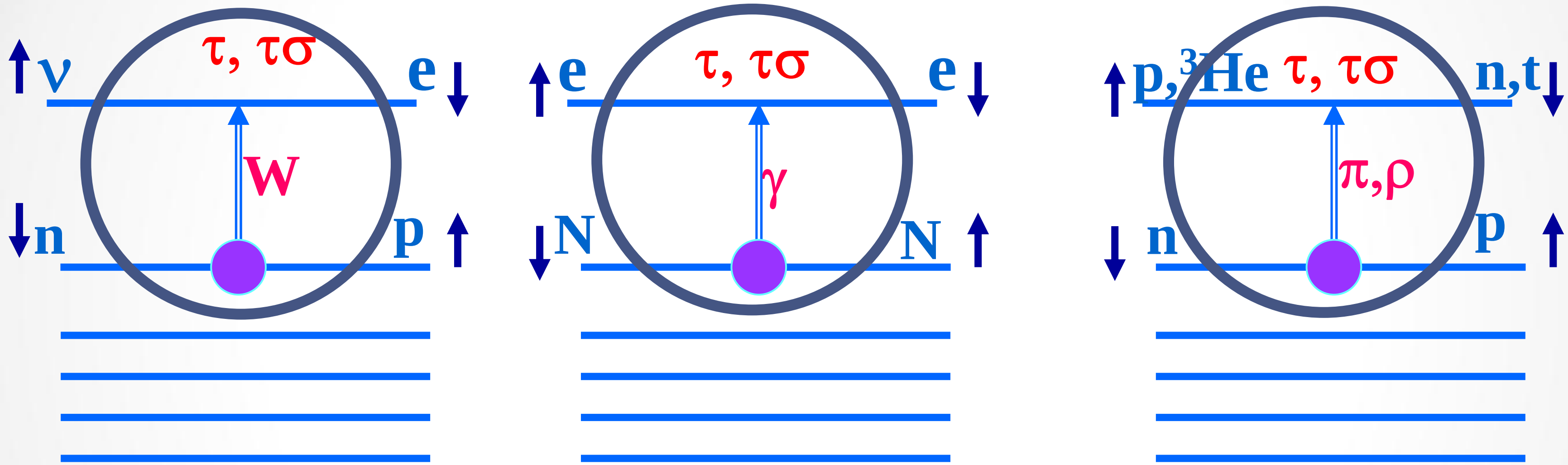
^{68}Ge EC 11 keV X rays prior to the ^{68}Ga 2 MeV β /DBD $T_{1/2}$ ~ 1.1 hrs.
^{210}Bi 1 MeV β $T_{1/2}$ ~ 5 d after ^{210}Pb 20 keV β /DM ,



^{68}Ga rejected by 11 k X rays in 3-5 t ½ (hours)time windows MAJORANA Prop.

Nuclear $\tau\sigma$ responses for ν in β &$\beta\beta$

Weak probe	EM probe	Nuclear probe



β-decay, e capture ν, μ probe J-PARC	γ-capture, e scattering γ from Spring-8 HIGS	CER ^{3}He,t t,^{3}He d,^{2}He N RCNP, MSU, KVI

H. Ejiri, Prog. particle Nuclear Physics, 64 ’10 249

RCNP Cyclotron Facility

Energy Resolution

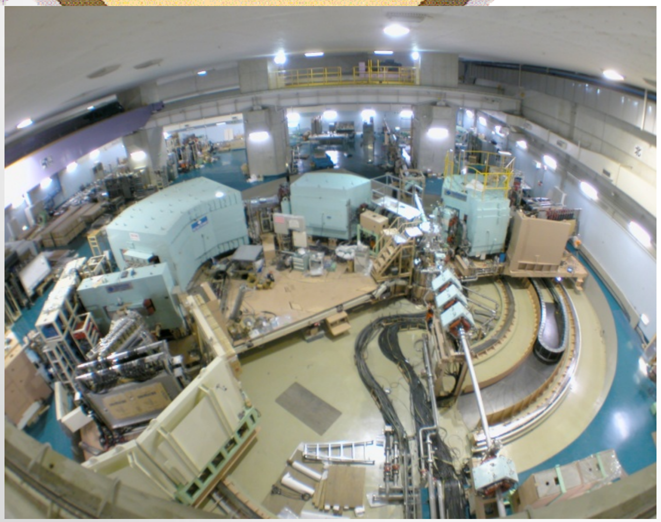
$\Delta E/E \sim 0.004\%$

$\sim$10 keV/0.4 GeV

Ring Cyclotron

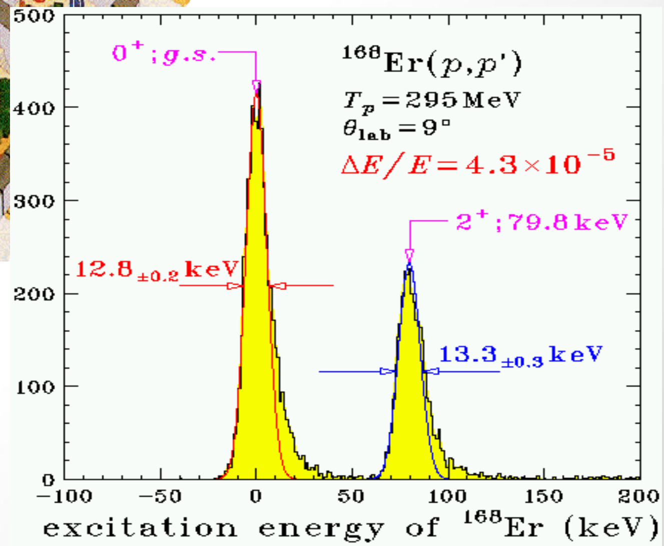
E = 0.4 GeV

$\Delta E/E \sim 0.01\%$

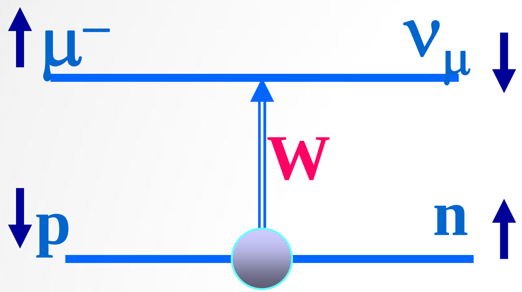


ΔE=10-30 keV as required to identify individual states

M.Fukuda

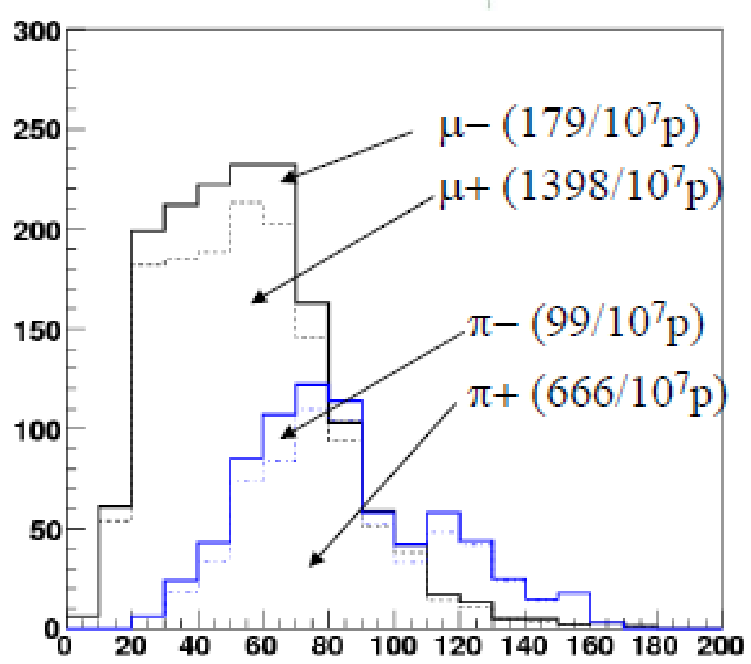


μ lepton probe



μ⁻ *MUSIC RCNP Osaka 10⁸/s 1μA*

Shima Sato



E ~ 50 MeV

β+ responses

for ββ–ν and SN ν

μ Capture rate ~ 1 (2012)

H. Ejiri Proc. EM interactions 1972.

AIP Conf. MEDEX11

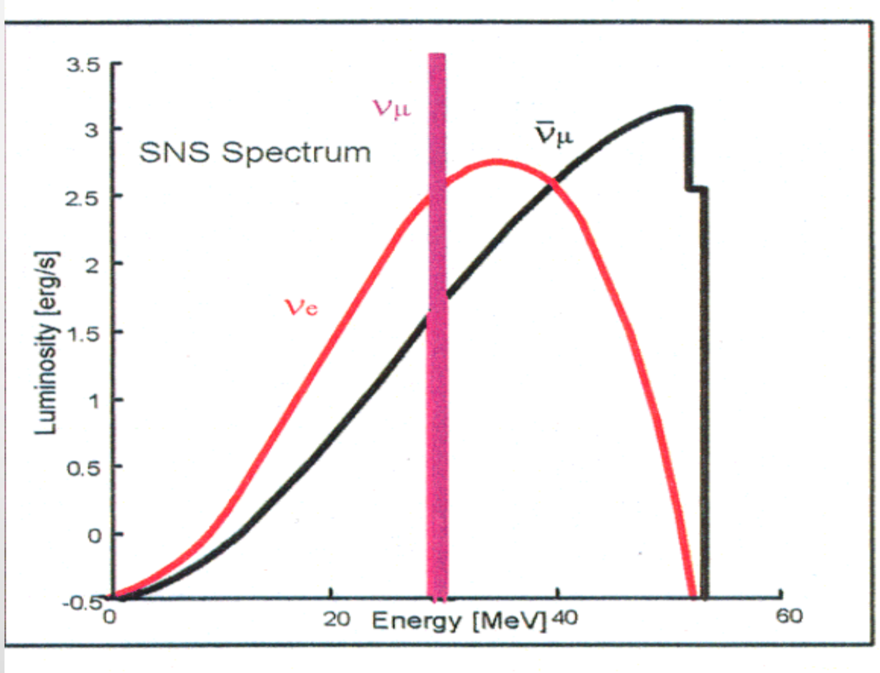
J. Suhonen, M. Kortelainen Czech. J. Phy. 56 2006 519, EXP 453.

V. Egorov (μ, γ , n γ, p γ) on ^{48}Ti, ^{76}Se 2004 γ -exp.

Low energy

Neutrinos Probes

$p + Hg \rightarrow n\ \pi^+$
$\pi^+ \rightarrow \mu^+ + \nu_\mu$
$\mu^+ \rightarrow e^+ + \nu_e + \text{anti-}\underline{\nu_\mu}$



H. Ejiri NIM. 503 (2003) 276 – 278.

$E(\nu_e)\ E(\nu_\mu) \sim 20\text{-}50$ MeV

$\sim E(\nu\ SN),\ E(\nu\ \beta\beta)$

$I(\nu) \sim 10^{14}$ / MW

$\sigma \sim 10^{-40}\ cm^2$

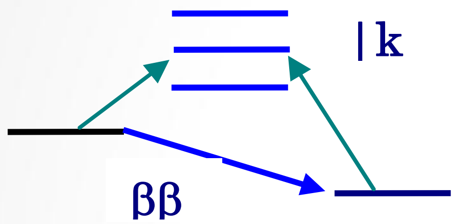
Detectors ~ 1 ton

J-PARC 0.4 – 3 GeV,

SNS 1GeV

FSQP: Fermi Surface Quasi Particle Model for DBD

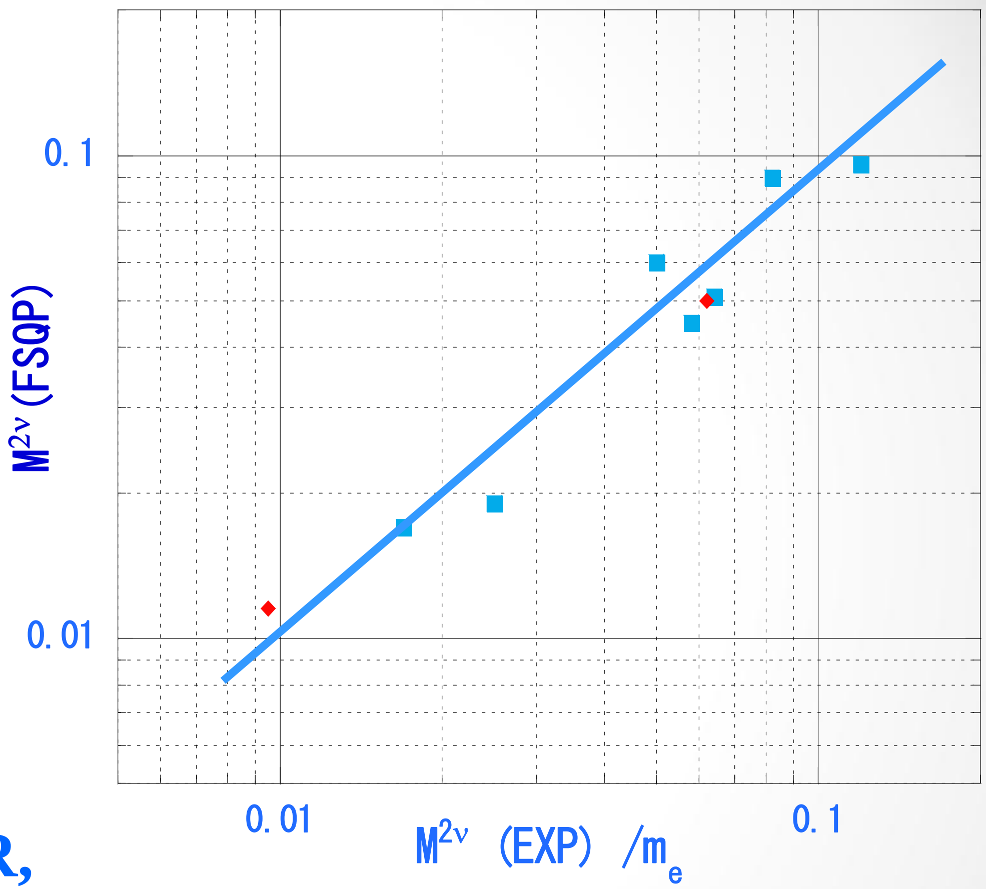
Ground state ββ
Fermi surface
0^+ (nn) → 0^+ (pp)



$M^{2\nu\beta\beta} = \Sigma_k M^{\beta}_k M^{b}_k / \Delta_k$

$M^{\beta}_k = (k^{eff}_i)\ m_{ij} V_n U_p$

$M^{\beta}_k = (k^{eff}_i)\ m_{ij} U_n V_p$

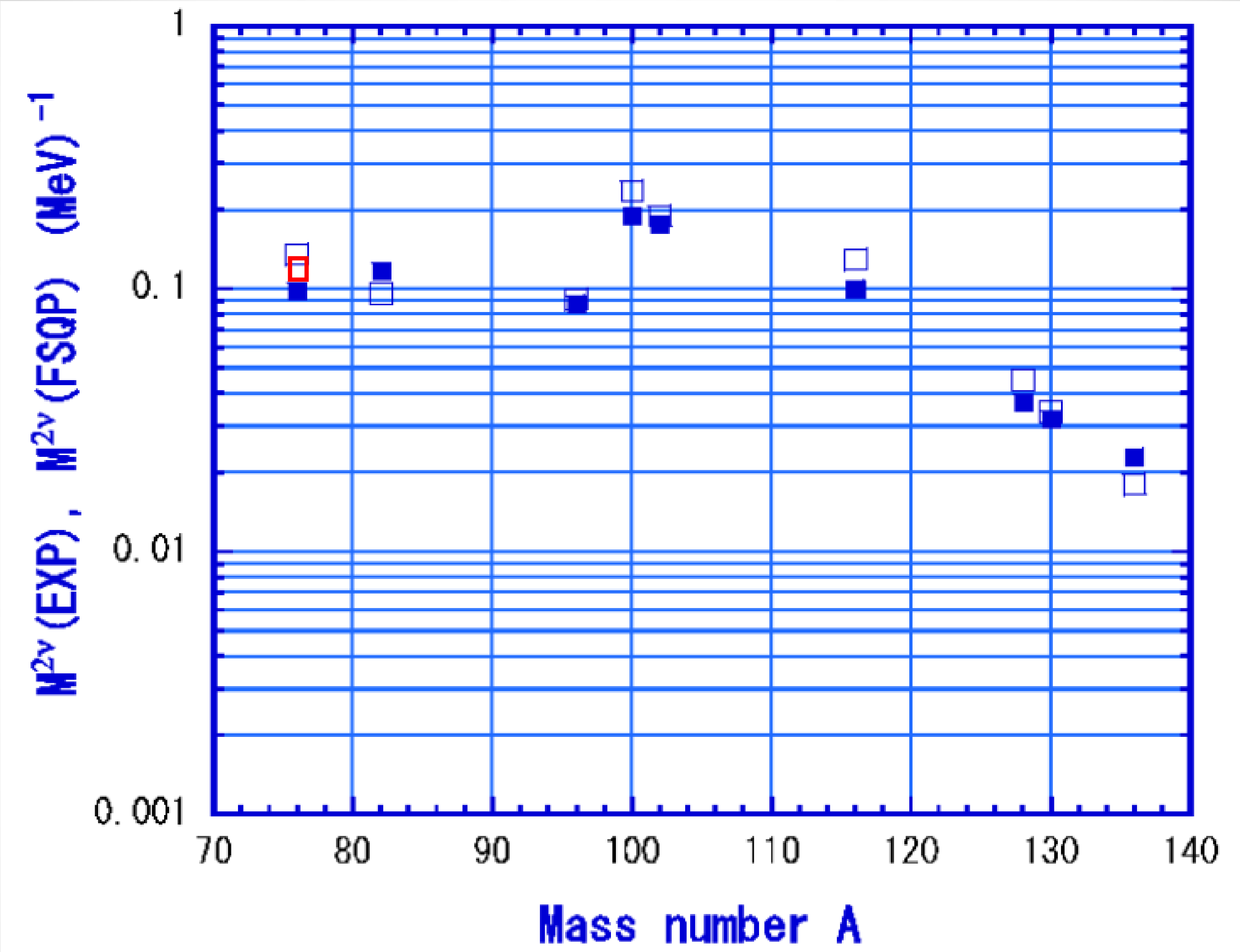


k^{eff}_A **from exp. β, EC, CER,**
Nucl. medium, σ τ polarization

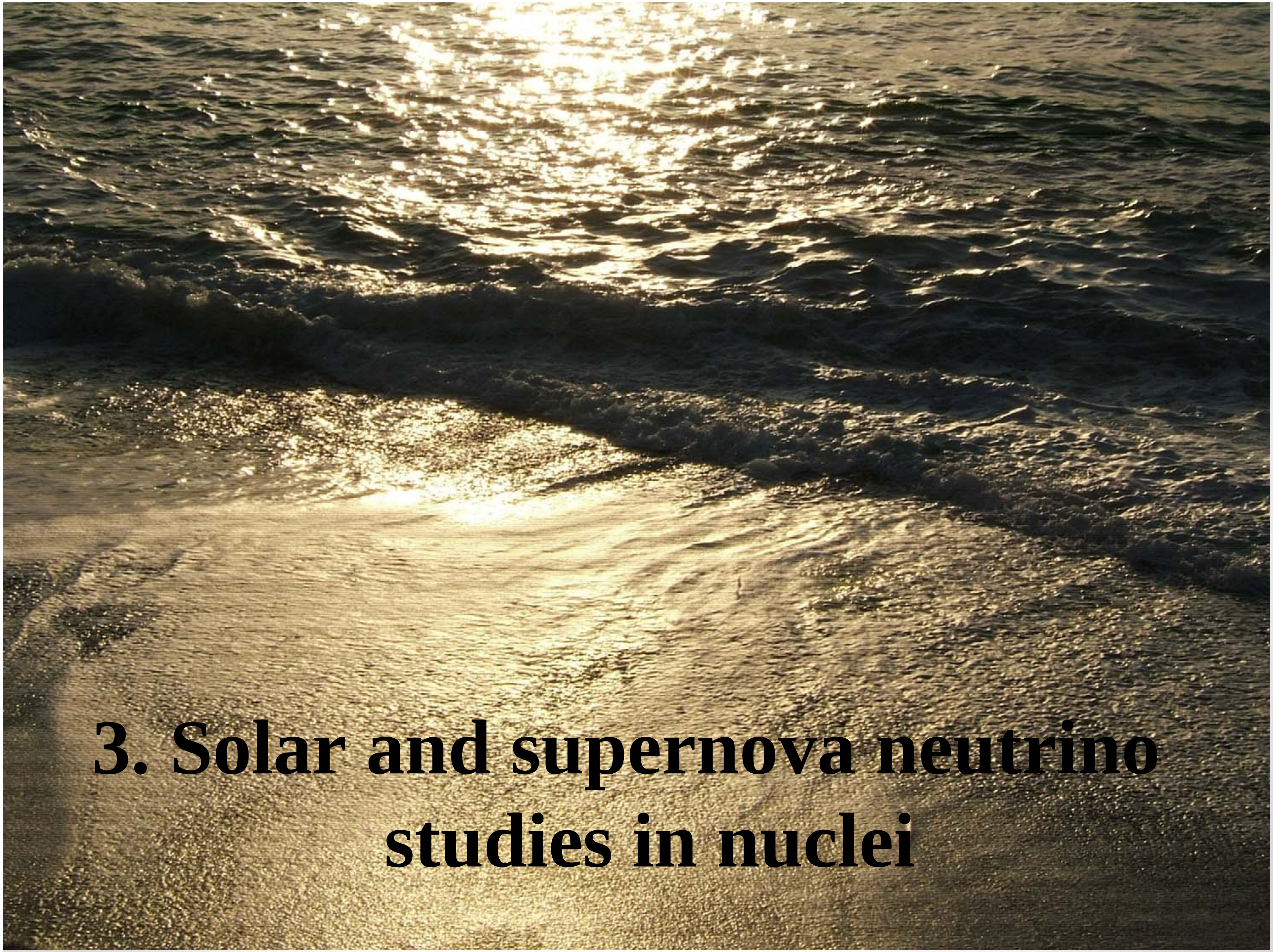
^{136}Xe Te Se Ge Cd Mo H.E.2012

H. Ejiri et al. J. Phys. Soc. Japan Lett. 65 (1996) 7.
H. Ejiri J. Phys. Soc. Japan, 78 (2009) No 7.
H. Ejiri J Phys. Soc. Japan Lett. 81 (2012) 3320

$(k^{eff}_A)^2 \sim (0.25)^2 = 0.05$
$T^{0\nu} \sim (k^{eff}_A)^4 = 0.002$
Frekers 12th

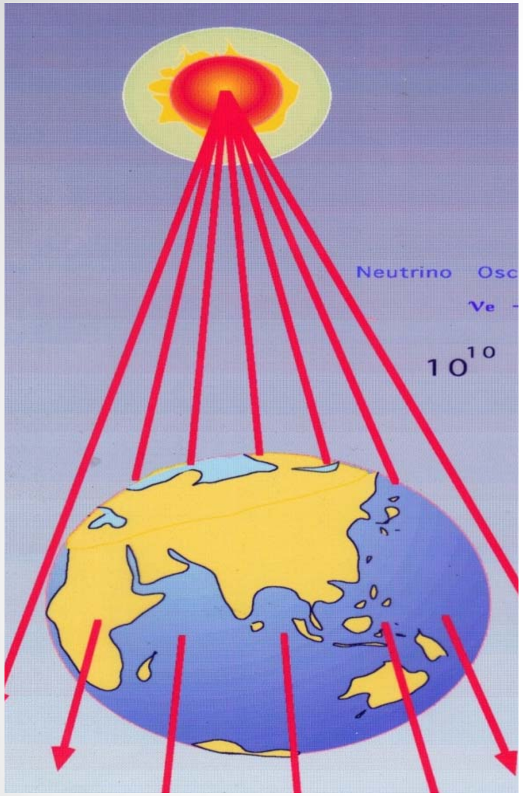


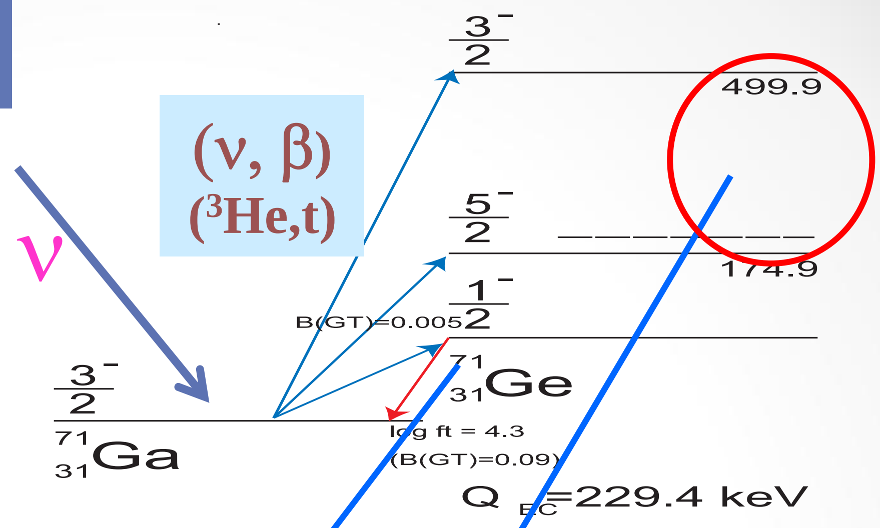
1
0.1
0.01
0.001
70
80
90
100
110
120
130
140
Mass number A
$M^{2\nu}$(EXP), $M^{2\nu}$(FSQP) (MeV)$^{-1}$

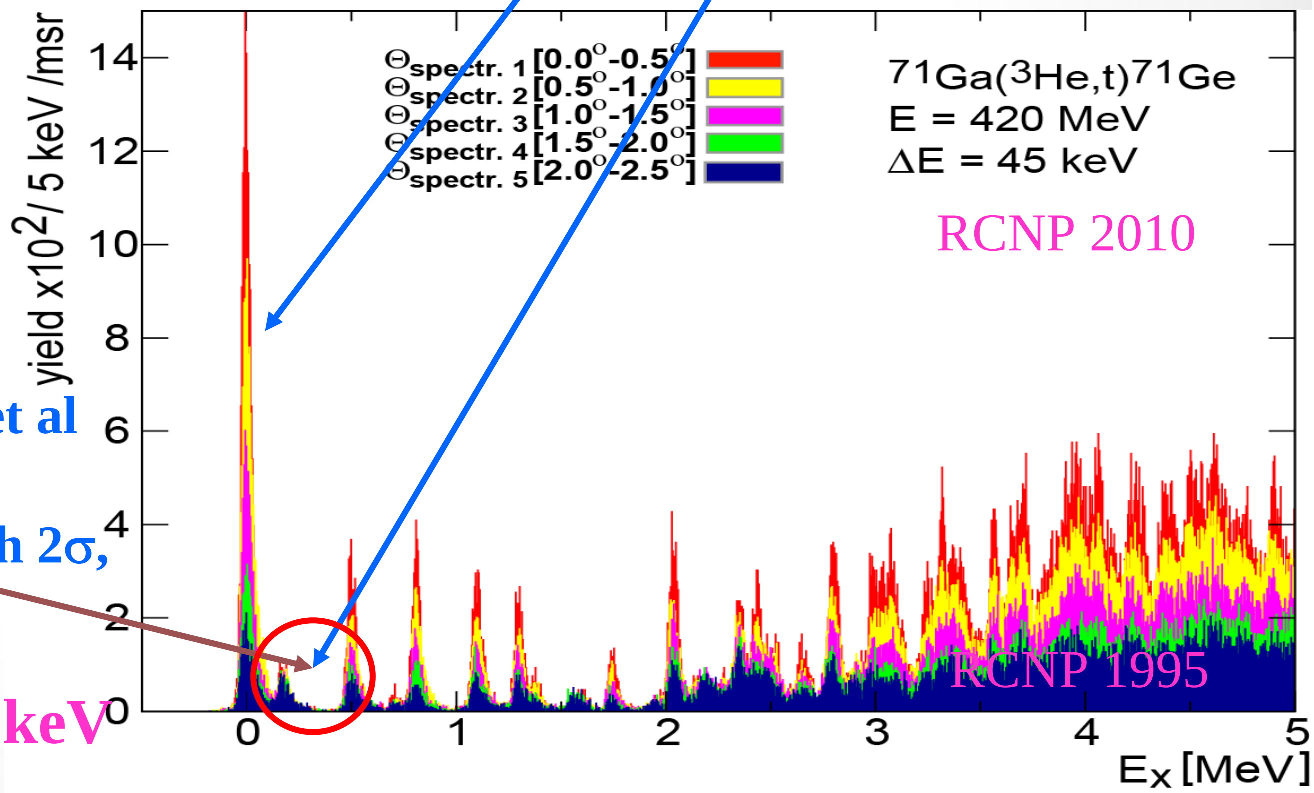


3. Solar and supernova neutrino studies in nuclei

Solar pp neutrino







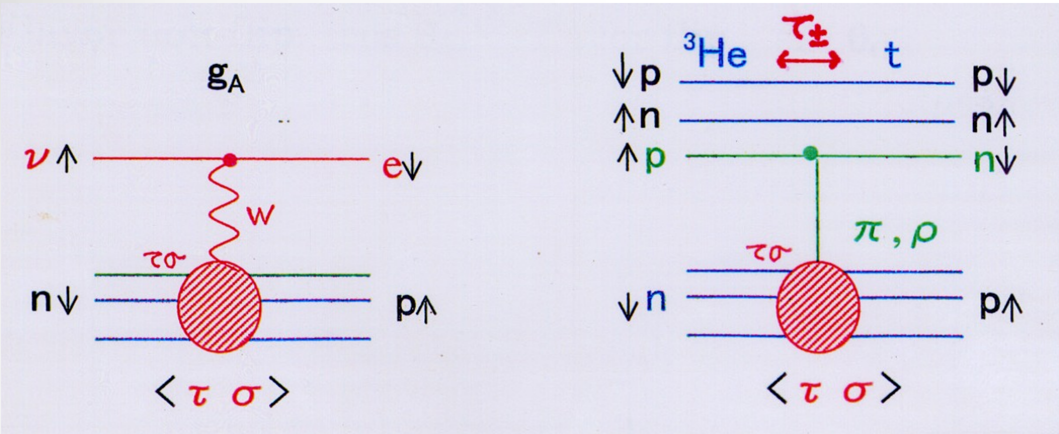
Frekers Ejiri. Akimune et al
PL B 706 (2011)

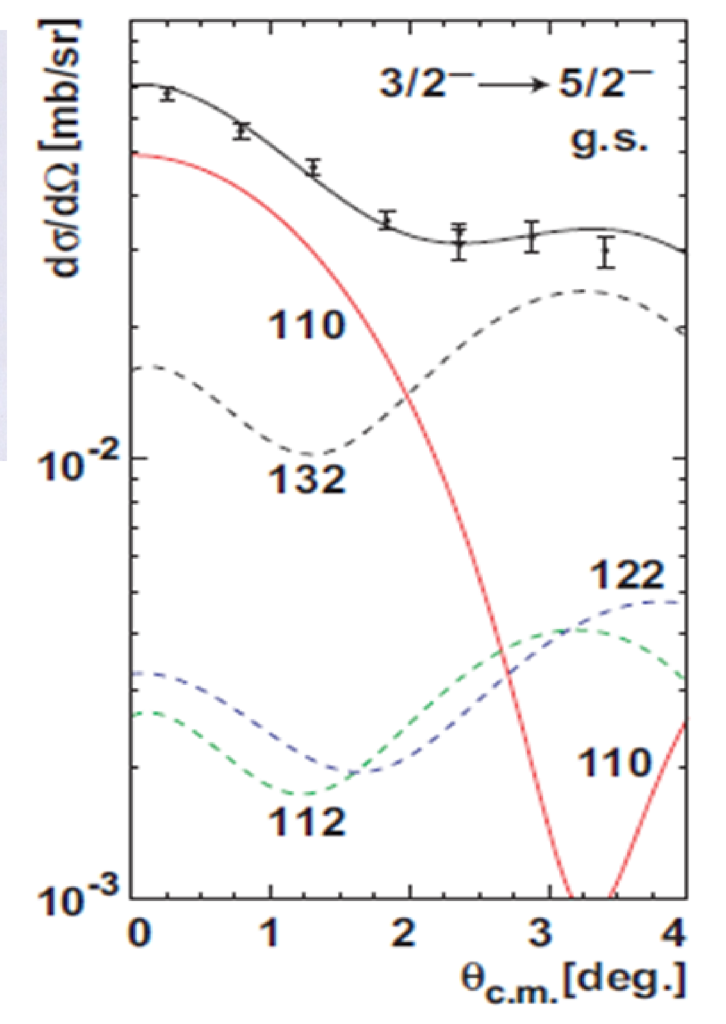
Excited states > 3% with 2σ,

Sterile ν (Gavrin)

E-Resolution 30 keV

Weak τ σ responses by nucl.reaction   CER Harakeh





$$T = \tau\sigma + \delta\tau(\sigma\times Y_2)_1 + \varepsilon\tau(\sigma\times Y_2)_2$$

Augular distribution

$$M(110) = M(\tau\sigma) + \delta M(\sigma\times Y_2)_1$$

^{69}Ga 0.15 = 0.085 + 0.065

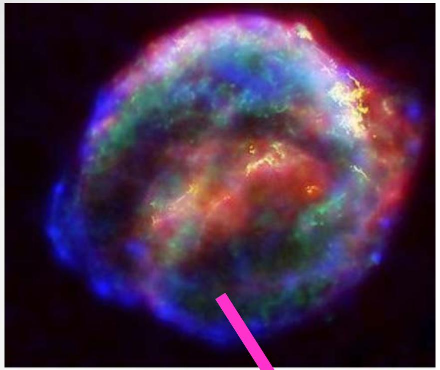
CER β-decay deduced

^{71}Ga

- M(110) = 0.1, M(τσ) < 0.1

^{69}Gr(^{3}He,t): Frekers H.E
Akimune Ejiri et al PL 2011

SN –ν nuclear resp.

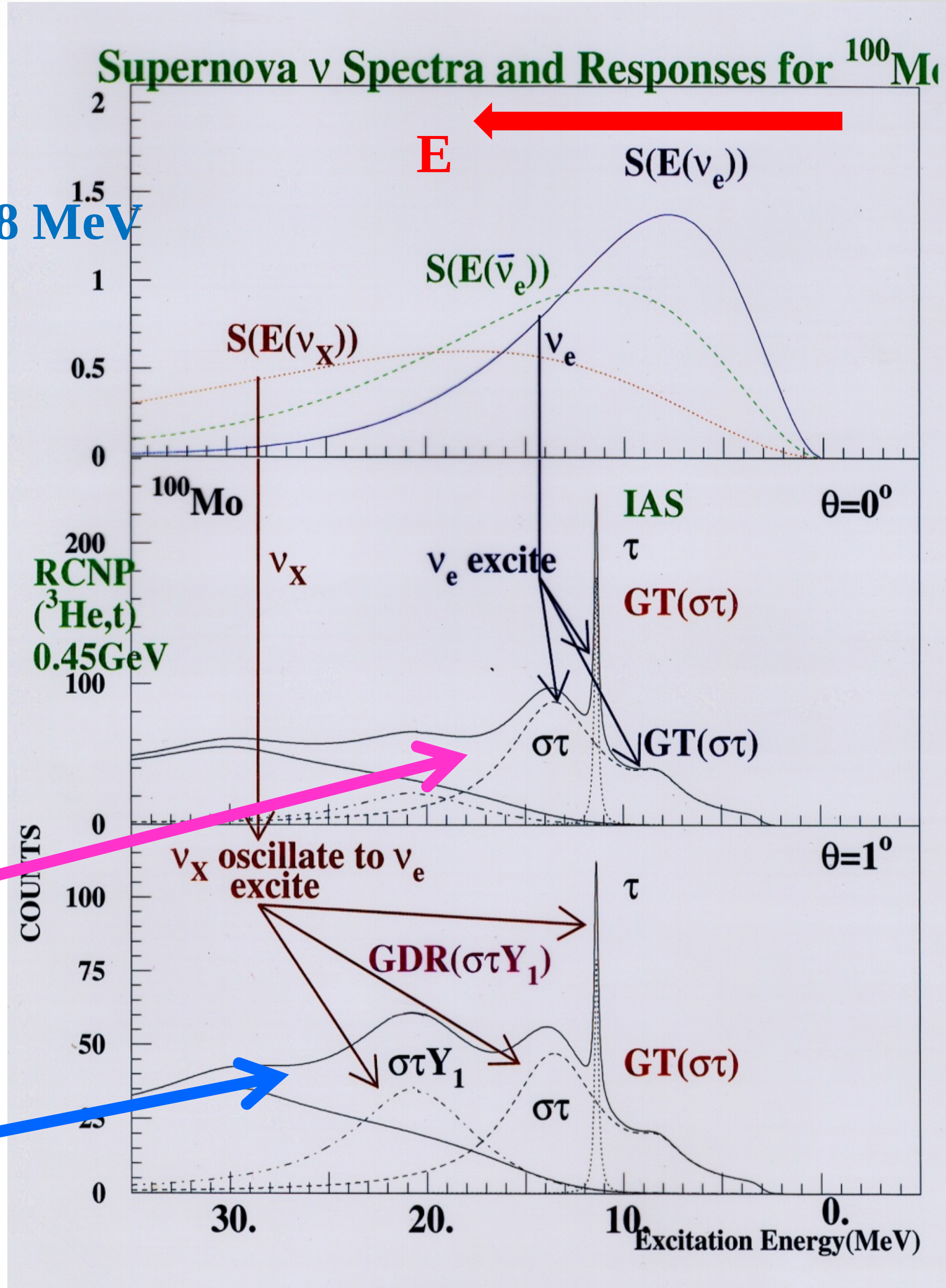


ケプラーの超新星 (SN 1604) の超新星残骸。スピッ

T : 3.5, 5, 8 MeV

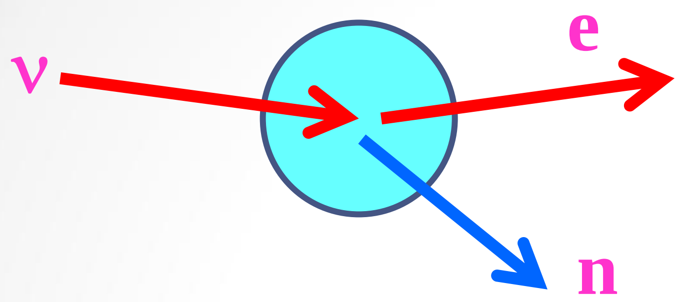
Spin resonance 1+

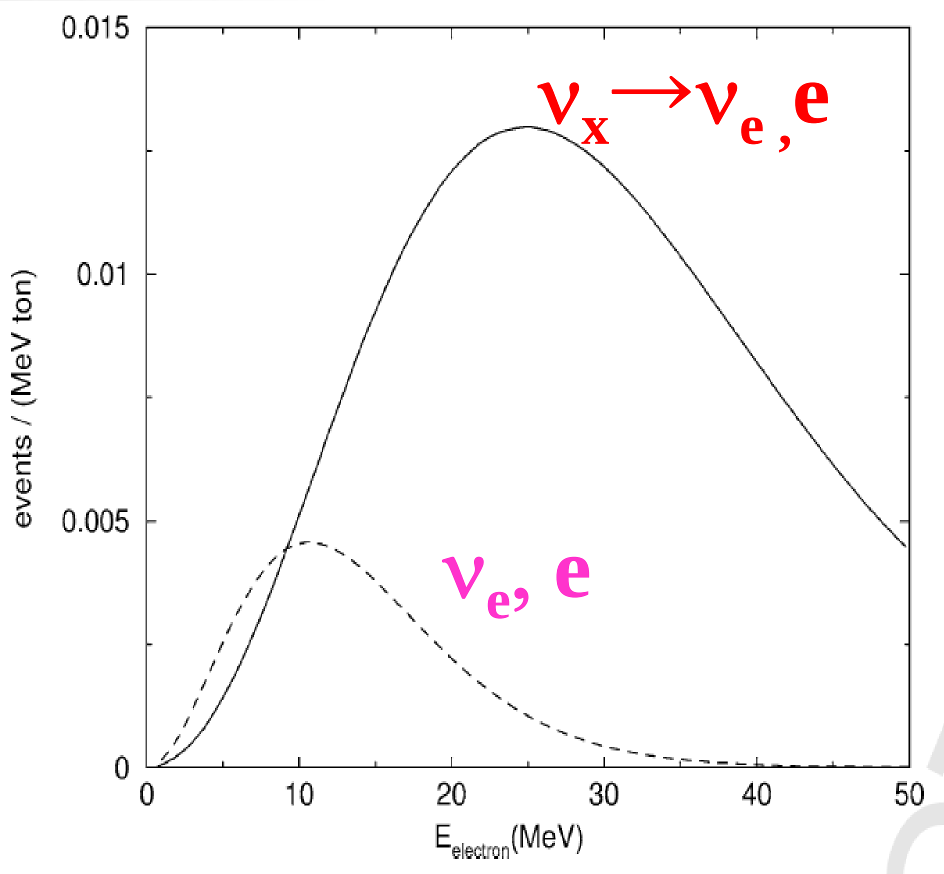
Spin dipole resonance 2-

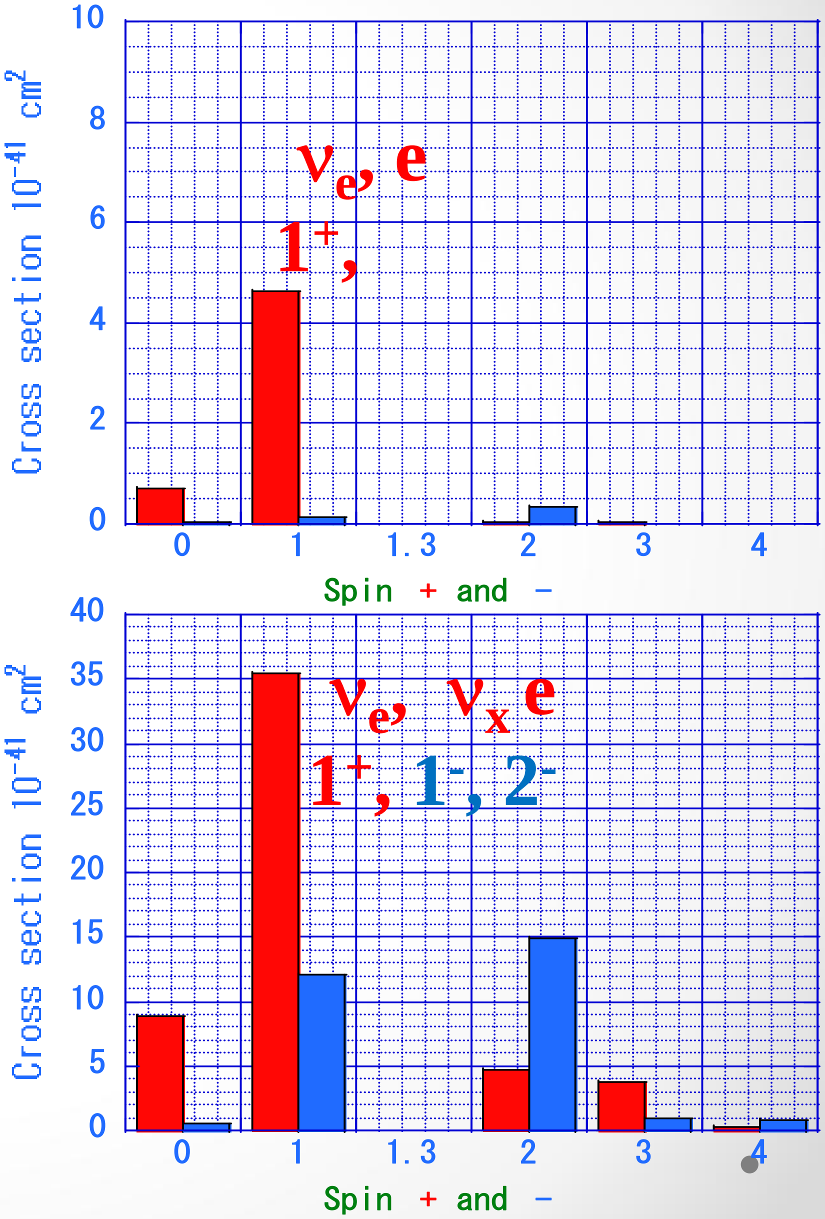


H. Ejiri J. Engel N. Kudomi PL B 530 2002

SN ν_e, ν_x oscillation

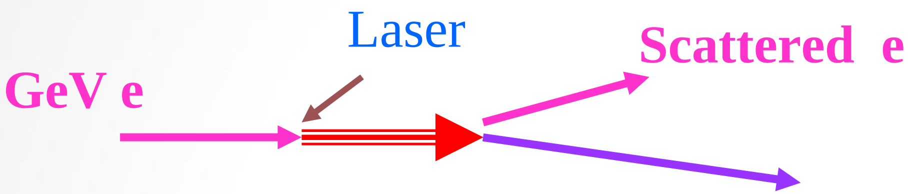






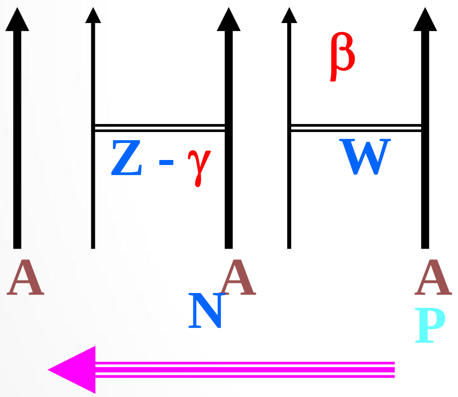
Photon Probes Shima

HIGS Tornow γ+D Bosewell
LEPS Laser electron photon Sources

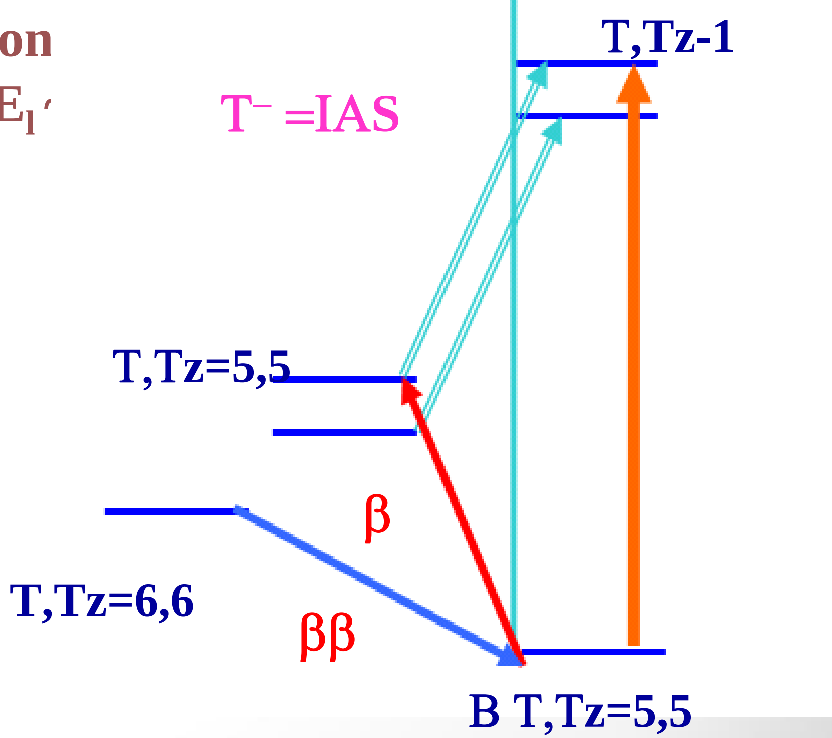


Laser electron photon

$E_\gamma \sim 4\,\gamma^2\,E_l = 2\;10^8\,E_l$



T^- isospin rotation



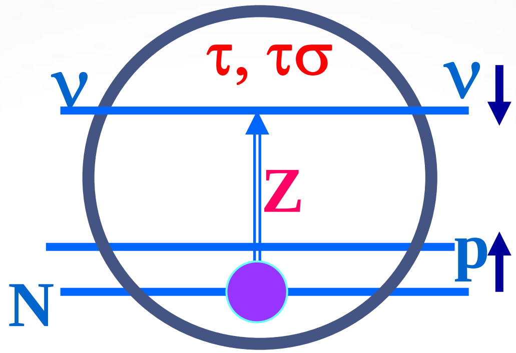
Responses via IAS

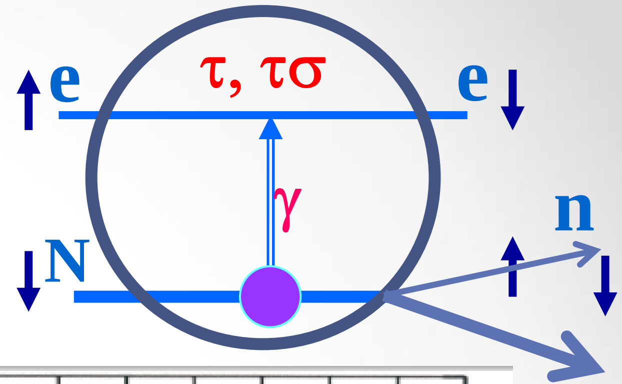
$<f\,|g\,M_\beta|\,i> = g/e\,(2T)^{1/2} <f\,|\,em_\gamma\,|\,I>$

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

Bosewell 11th

Neutral Current NC responses by photon probes





Polarized photon

Vector C τ

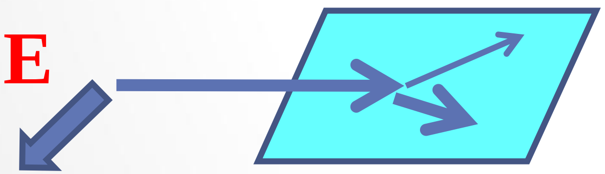
Axial vector C $\tau\sigma$

$\gamma + {}^{100}Mo = n + {}^{99}Mo$

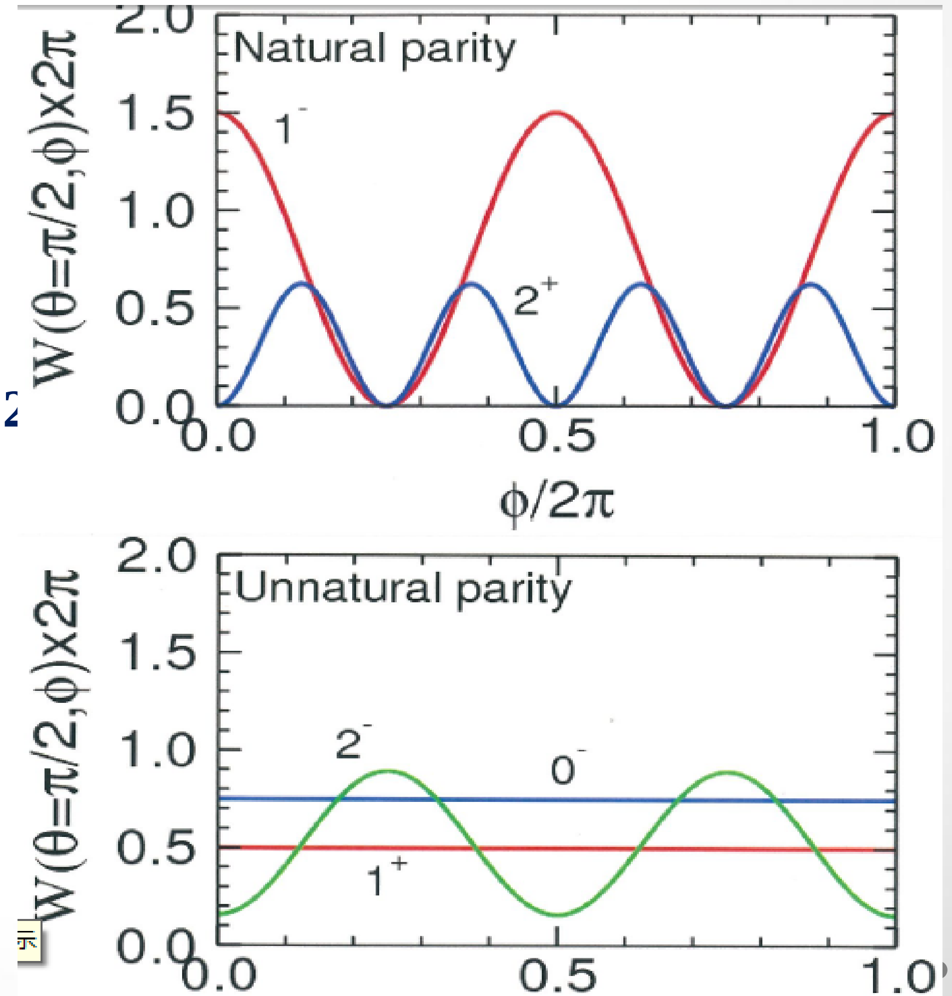
Ejiri Shima PR ST 15 2012

Polarization

E

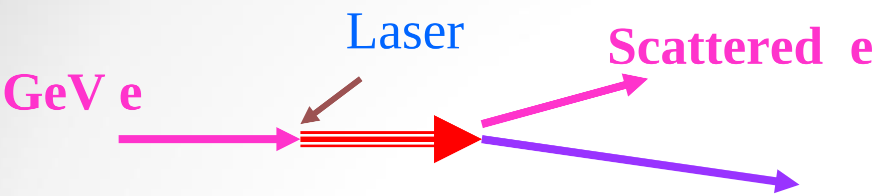


$\sigma = k \sin^2\theta \cos^2 \Phi$



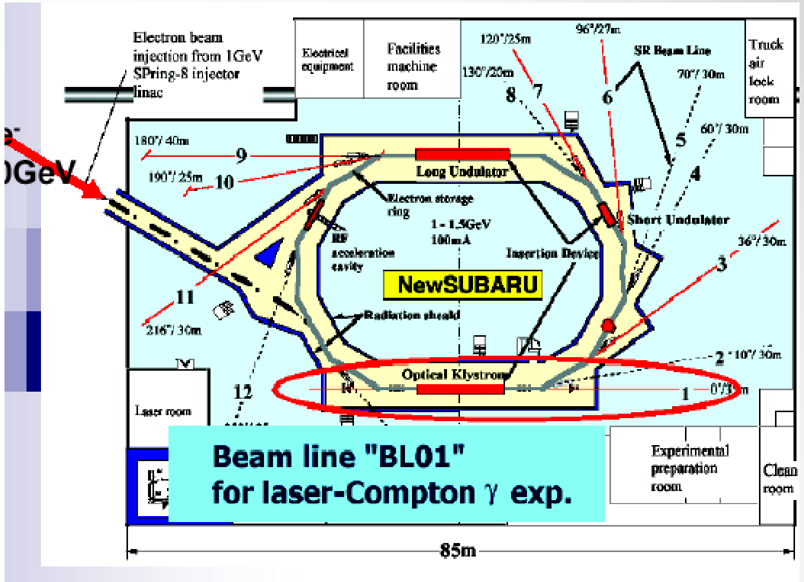
Ydrefprs 14^{th} Ejiri Titov 2012

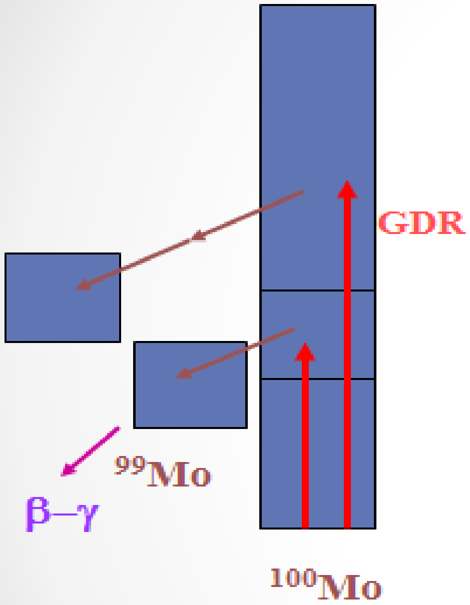
LEPS Laser electron photons

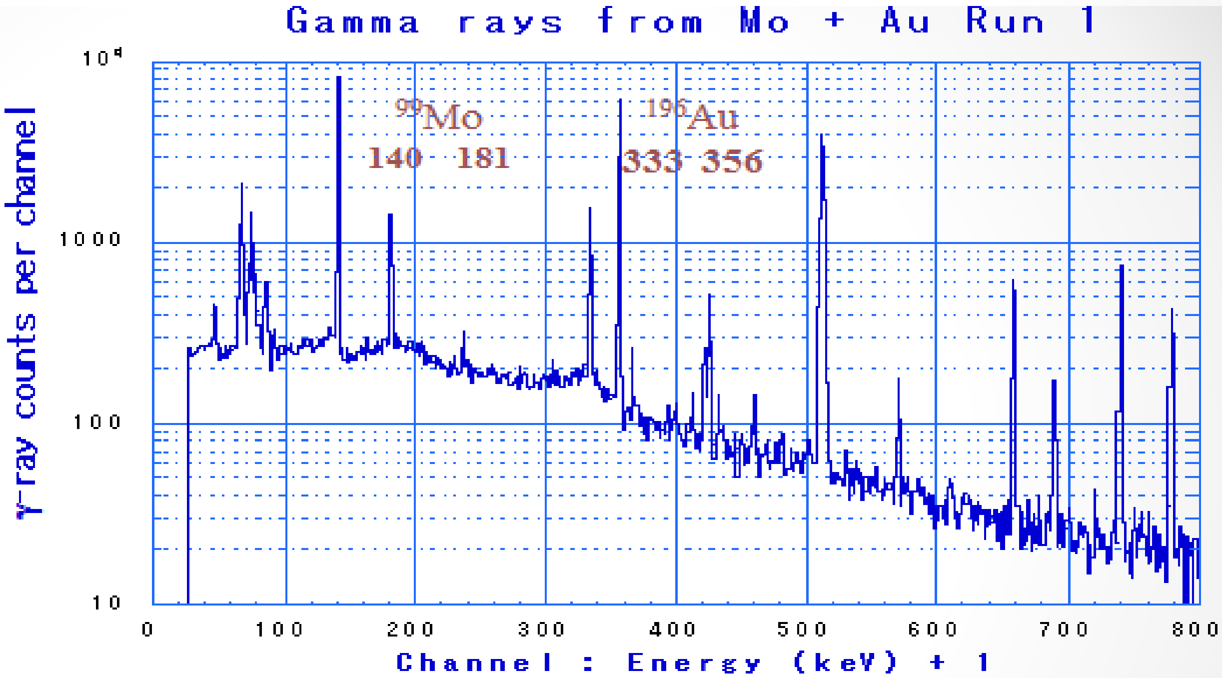


$E_\gamma \sim 4\,\gamma^2\, E_l = \; 2\;10^8\; E_l \sim 20$ MeV,

New SUBARU



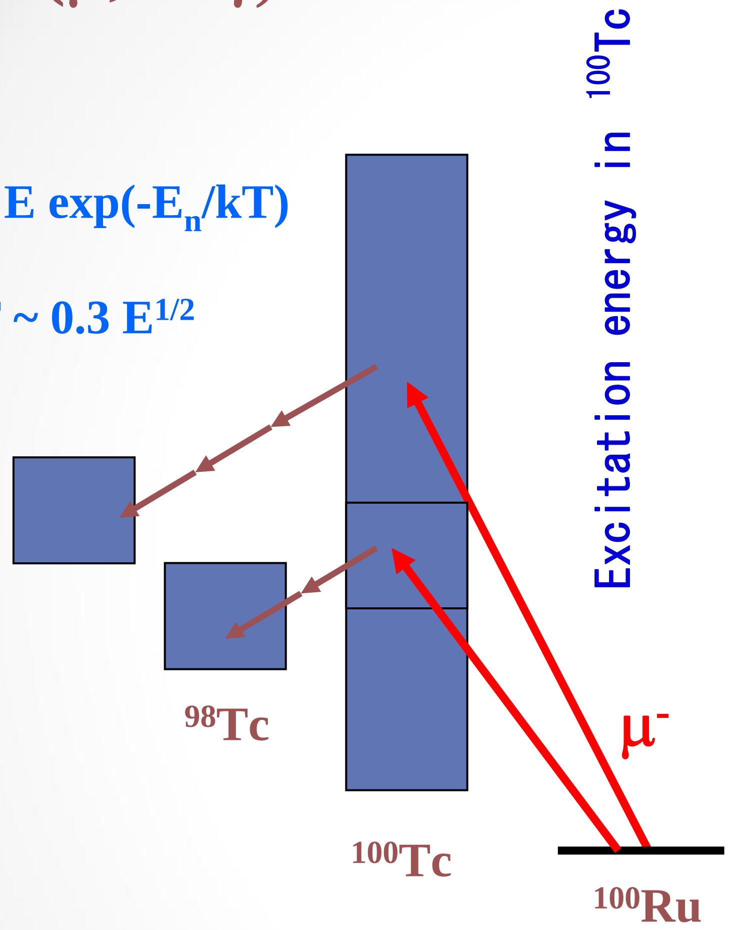


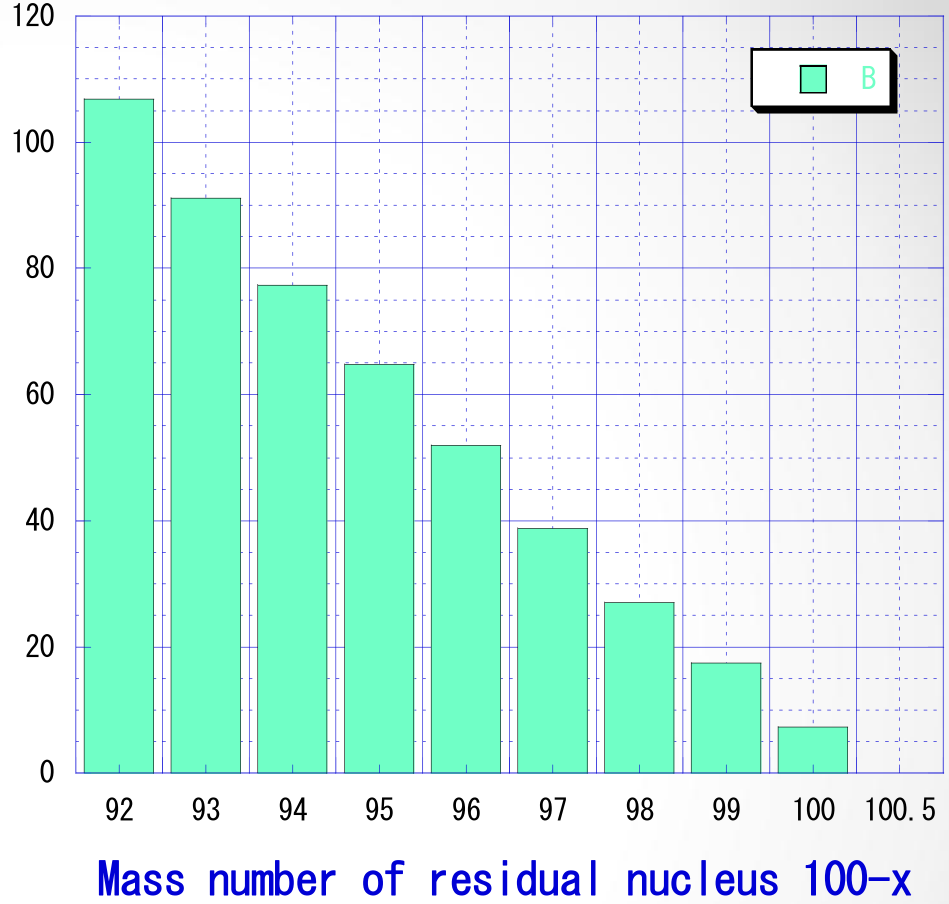


$^{100}Ru(\mu,xn\,\gamma)^{100-x}Tc$

$F(E_n) = E \exp(-E_n/kT)$

$E_n = 2kT \sim 0.3\, E^{1/2}$





$E(x+1) = (x+1)B_n + xE_n$

$E(x) = (x)B_n + xE_n$

$N = [M]E, \quad E = [M^{-1}]N$

$N(x) = \Sigma\, M(x,i)E(i)$

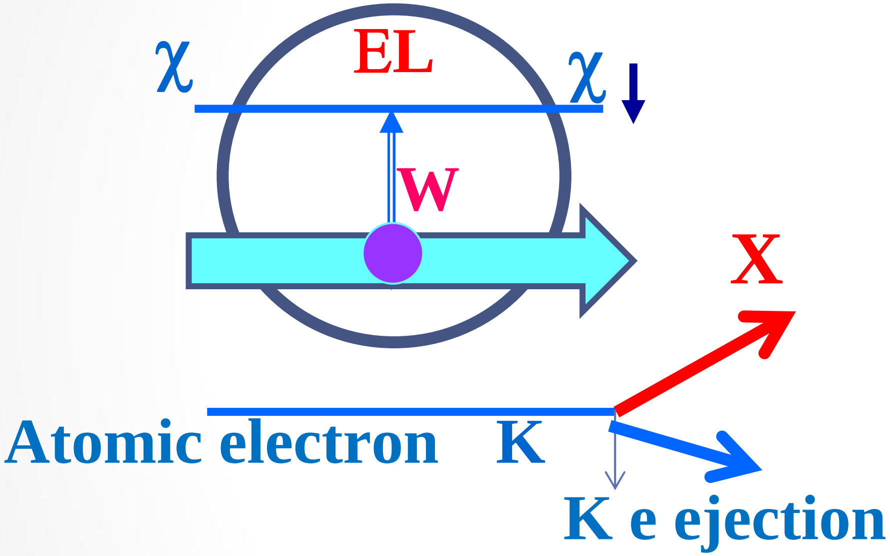
$E(i) = \Sigma\, M(x,i)N(x)$

H. Ejiri Proc. e-γ conference Sendai 1972

3. X-ray & γ spectroscopy for DM studies in nuclei

X γ spectroscopy for DM WIMPs search

SD, SID Elastic S

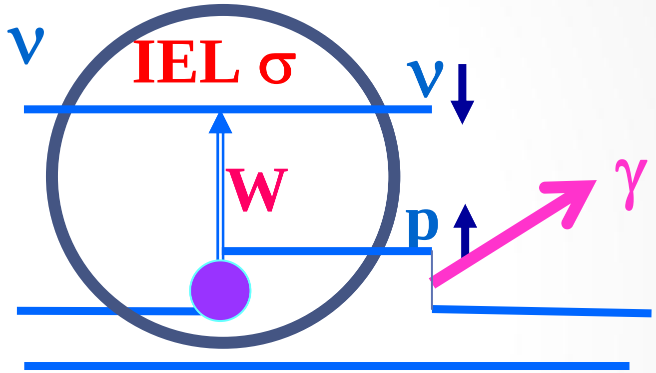


E(x) discrete higher

no quenching

σ(X) ∼0.25 σ(R)

SD



E(γ) discrete higher

no quenching

M(SF) ~ M(elastic)

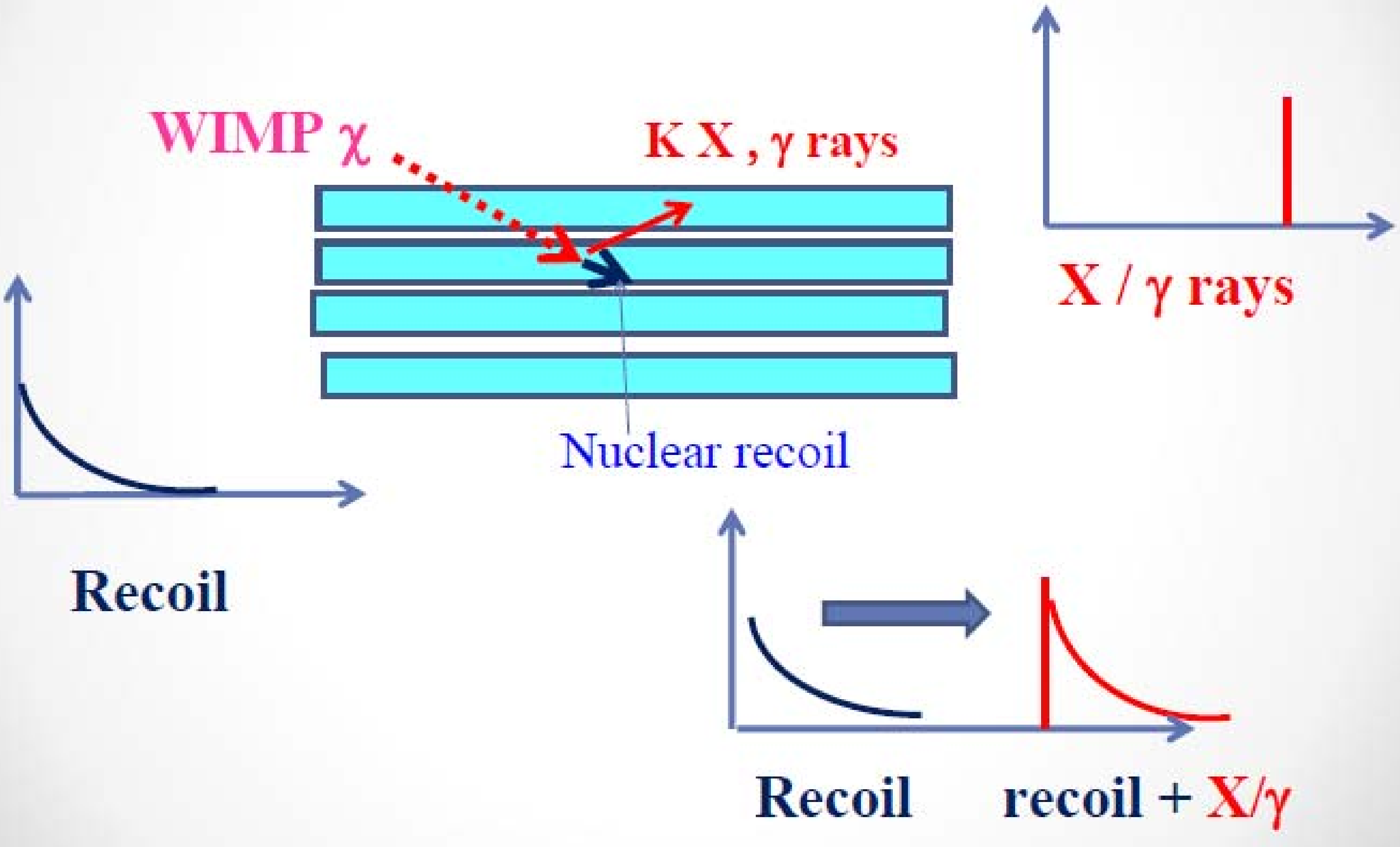
from M1 γ life

H. Ejiri, Ch. C. Moustakidis, J.D. Vergados, P L. B. 639 (2006) 218

H.Ejiri, K. Fushimi, H. Ohsumi, Phys. Lette. B317 (1993) 14

X & γ ray recoil WIMPs spectroscopy

Fushimi



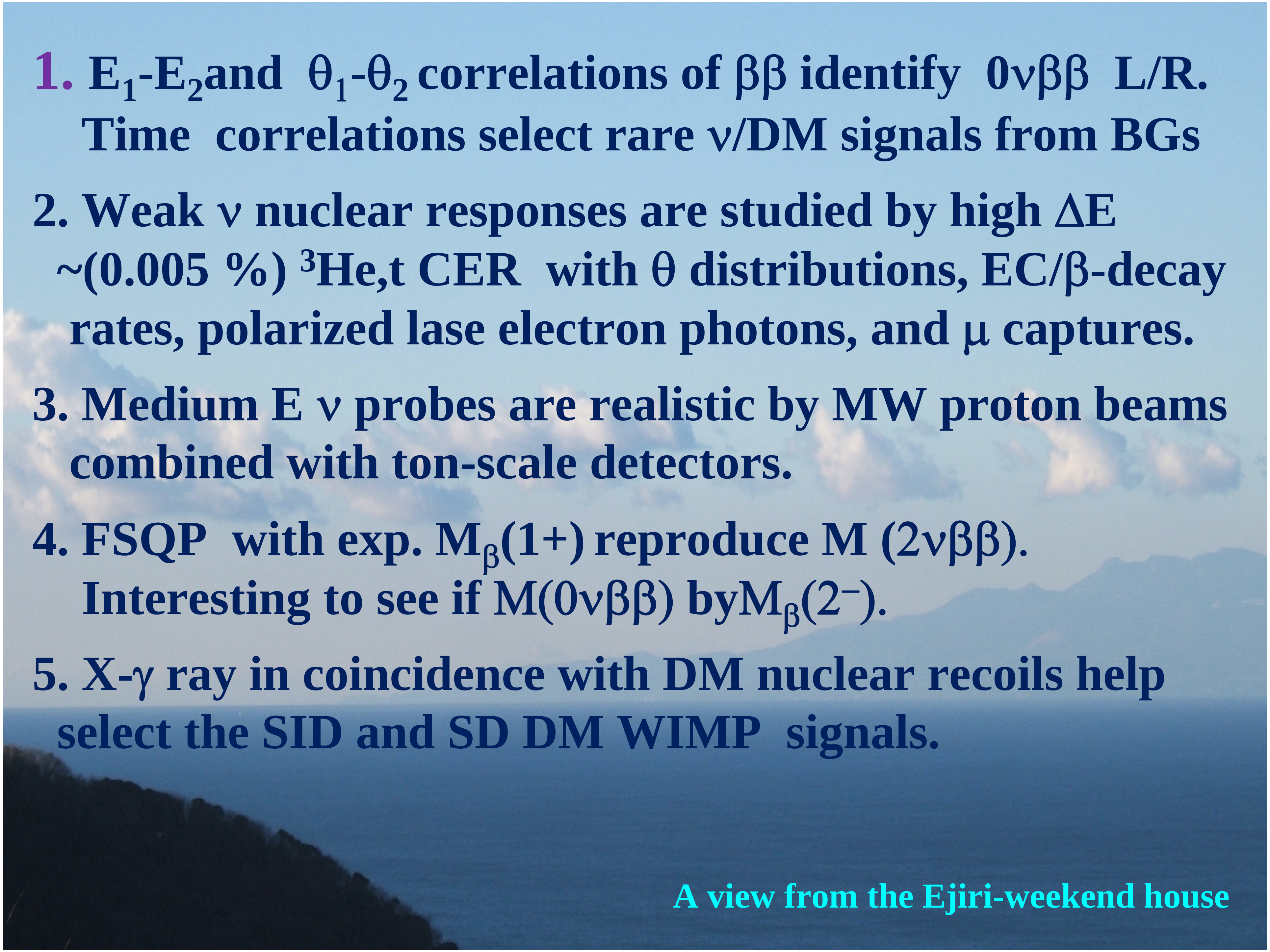
1. E_1-E_2 and θ_1-θ_2 correlations of $\beta\beta$ identify $0\nu\beta\beta$ L/R. Time correlations select rare ν/DM signals from BGs

2. Weak ν nuclear responses are studied by high ΔE ~(0.005 %) ^{3}He,t CER with θ distributions, EC/β-decay rates, polarized lase electron photons, and μ captures.

3. Medium E ν probes are realistic by MW proton beams combined with ton-scale detectors.

4. FSQP with exp. $M_\beta(1+)$ reproduce M $(2\nu\beta\beta)$. Interesting to see if $M(0\nu\beta\beta)$ by $M_\beta(2^-)$.

5. X-γ ray in coincidence with DM nuclear recoils help select the SID and SD DM WIMP signals.



A view from the Ejiri-weekend house


Thank you for your attention
Ejiri-weekend house at Shounan