Neutrino Nuclear Responses for Astro neutrinos & DBD (Double Beta Decays)

Hiro Ejiri   RCNP Osaka
Yamada Science Foundation

Thanks: The organizers for the invitation

1. Neutrino nuclear responses and g_A (quenching)

2. Experimental studies for ν nuclear responses

3. Solar ν responses for ^{71}Ga and DBD nuclei.

4. Neutrino responses for DBD isotopes

Ejiri's log cabin in Tateshina 1450m

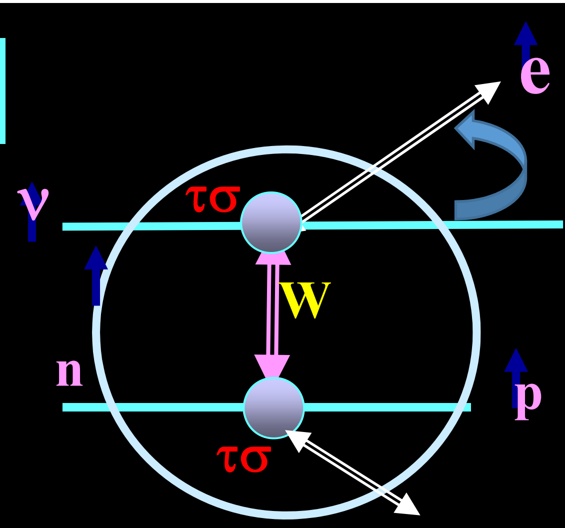
Review

H.Ejiri J.I. Fujita Phys. Rep 38 1978 85 H. Ejiri Phys. Rep. 338 2000

H. Ejiri J. Suhonen K. Zuber Phys. Rep. Submitted 2018

H2

Nuclear Response = M^2 : M=NMEs



$$T = G\,[\,M\,(m_\nu/A_\nu)\,]^2$$

Nuclear phys   Particle/astro phys.

A. DBD Neutrino-less ββ M

$M = g^2{}_A M_{DA} - g^2{}_F M_{DF} + g^2{}_A M_T$ g_i in unit of bare g_A for free N.

$M_{DA} = \langle \sigma\tau h \sigma\tau \rangle$ $M_{DF} = -\langle \tau h \tau \rangle$ $h \sim k/(r_1 - r_2)$

q~ 1/(1-5)fm ~ 40-150 MeV/c, $l\hbar \sim 0\text{-}5\hbar$ $J^\pm = 0\text{-}5^\pm$

$g^2{}_A M_{DA} \sim \Sigma\ g_A M_B \cdot g_A M_B$ 2νββ   q=3 MeV/c, GT 1^+

B. Astro ν and anti-ν response

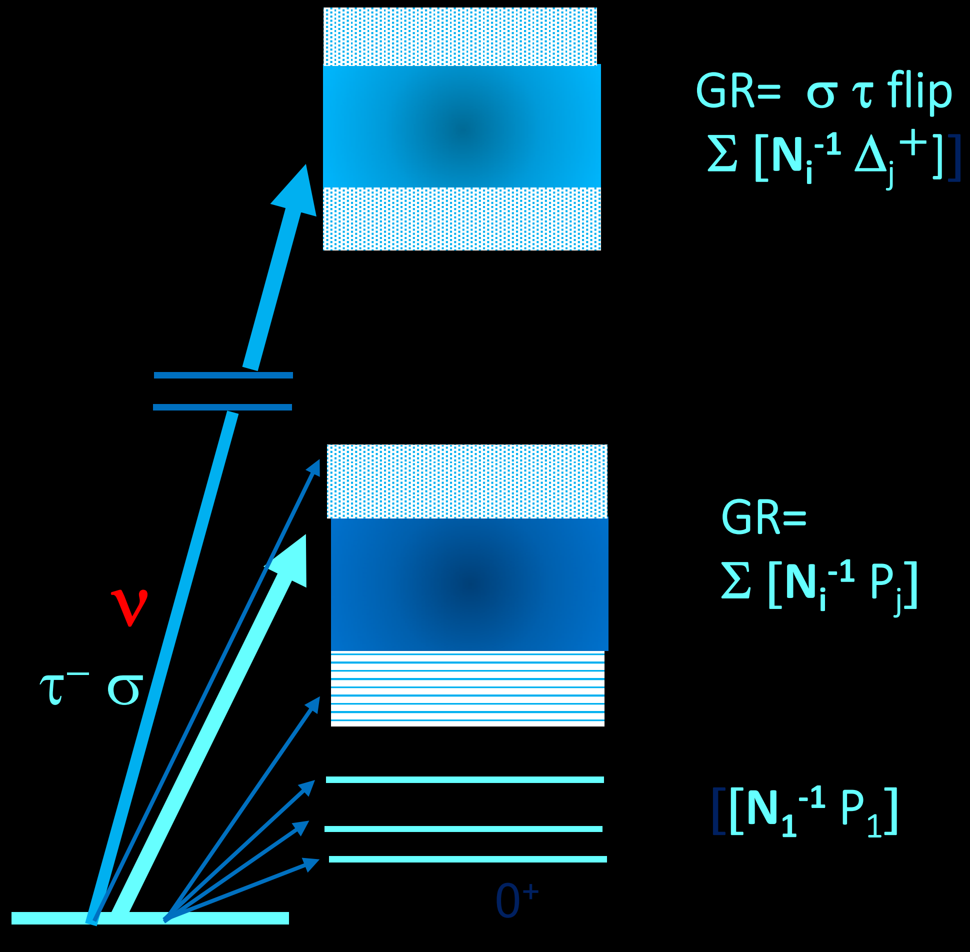
Super nova ν: E~5-50 MeV, q~ 5~ 50 MeV/c, $J^\pm = 0\text{-}3^\pm$

DBD ν and Astro ν responses are q=5-150 MeV/c, $J^\pm$ with J=0-5

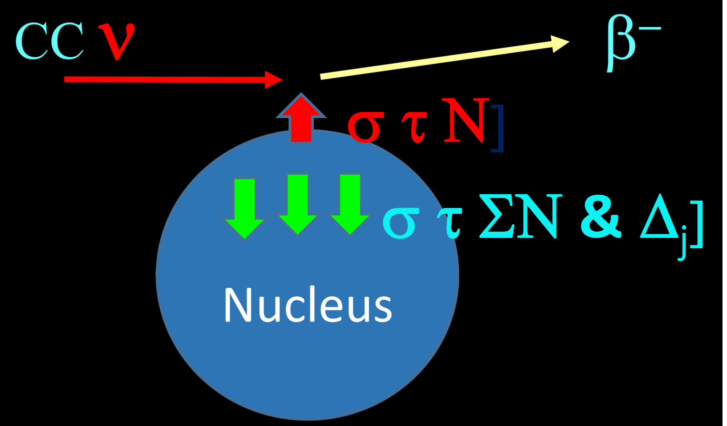
スライド 3

H2 Ejiri, 2009/07/25

Weak int.: spin isospin $\tau\sigma$ $N^{-1}N$ GR and $N^{-1}\Delta$ GR



Nuclear medium
$\tau\sigma$ polarization



1. H.Ejiri PRC 26 '82 2628
2. H. Ejiri, N. S, J. Suhonen, PL 2014, J.Phys. 2015

1+ 2-

$$|I\rangle = |NP\rangle - \varepsilon\,|GRn\rangle - \delta\,|GR\,\Delta\rangle$$

$$M^{\beta} \sim k^{eff} M_0 \quad k^{eff}(\tau\sigma) \sim 0.4 \quad k^{eff}(\Delta) \sim 0.6$$

1+ Bohr Mottelson
PL B 10 '81 10

GT 1^+ 2^-, 4^- $\tau\sigma$ axial vecor NMEs reductions

$$M^m_{exp} = k\, M_{QP}$$

$$k = 0.2 - 0.3 = k_{\tau\sigma}\, k_{NM}$$

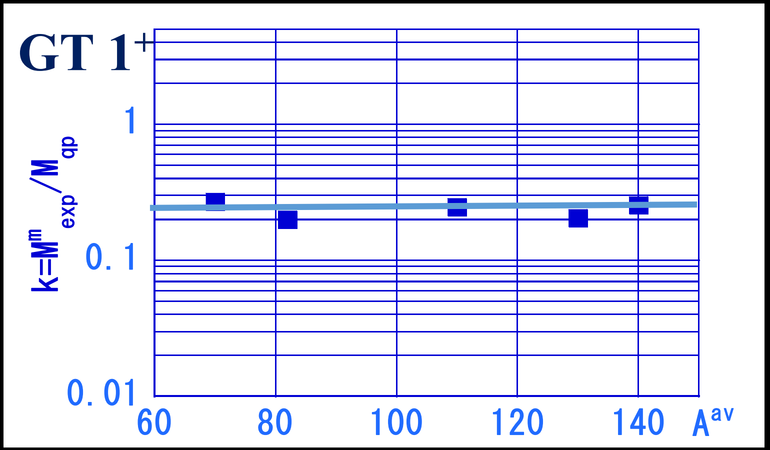
$$M_{QRPA} = k_{\tau\sigma}\, M_{QP}$$

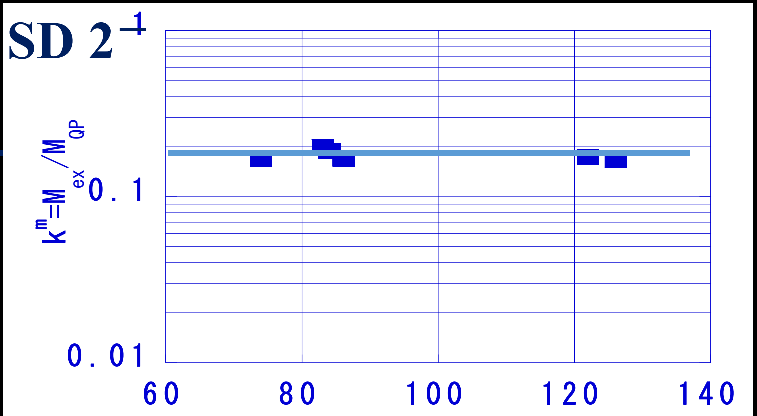
$k_{\tau\sigma} \sim 0.4$ due to NN $\tau\sigma$

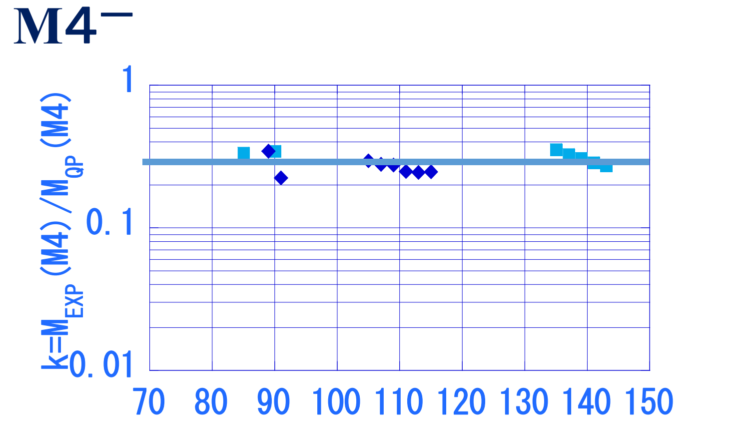
$$M_{exp} = k_{NM}\, M_{QRPA}$$

$k_{NM} \sim 0.6$ (g_A^{eff}/g_A)

$N\Delta$ π short range





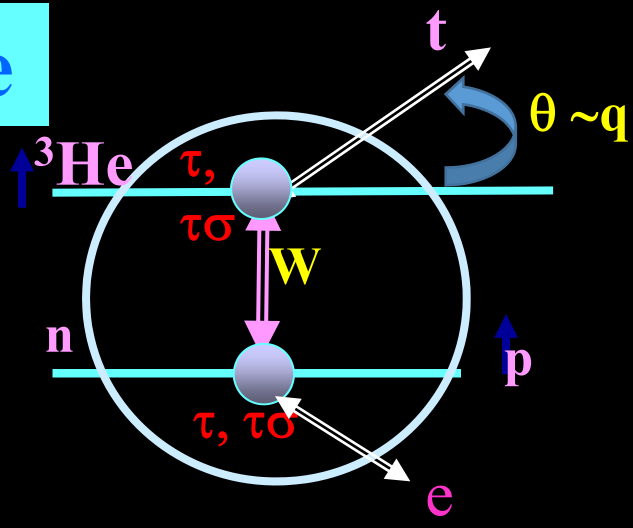


H, Ejiri J. Suhonen J. Phys. G. 42 2015 055201

H. Ejiri N. Soucouti, J. Suhonen PL B 729 27

L. Jokiniemi J. Suhonen H. Ejiri AHEP2016 ID8417598

CER. F, GT &SD q-dependence

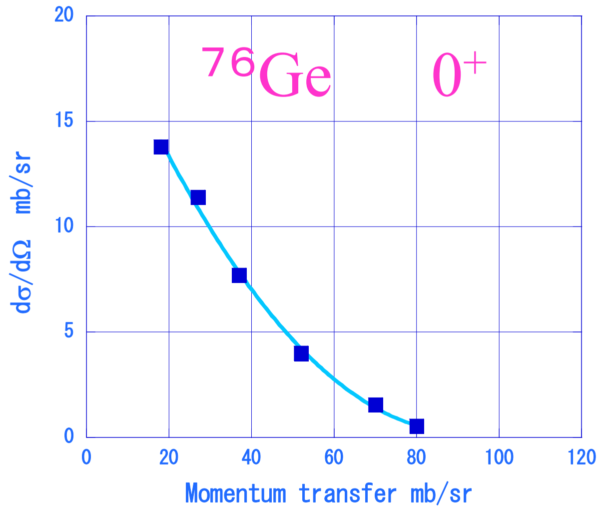


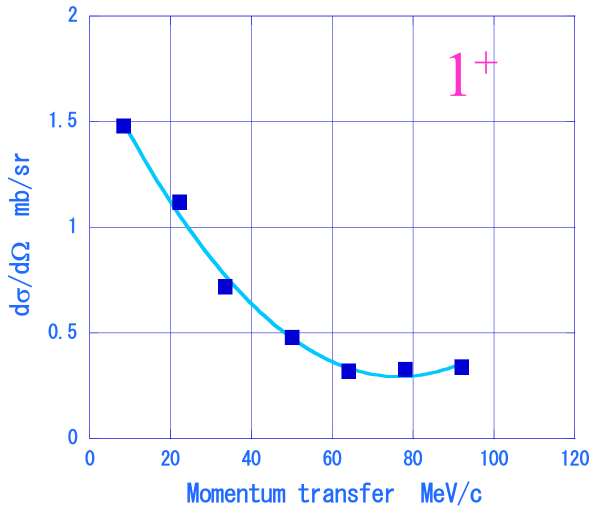
$$d\sigma(q) = C\,|j_a(qr)|^2\, M_\alpha(q)^{\,2}$$

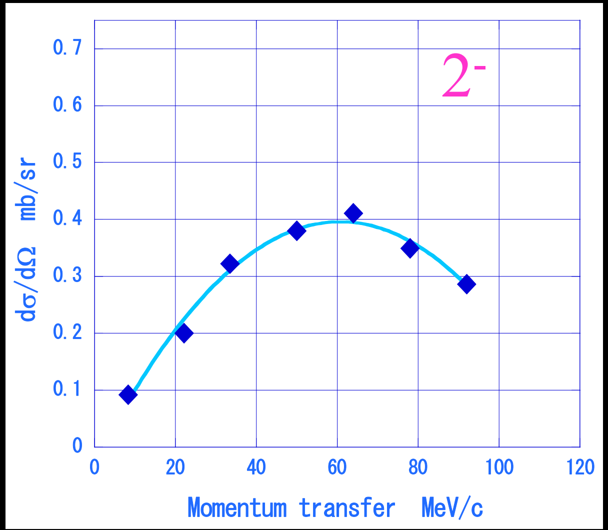
$$M_\alpha(q)=k^{eff}(q)\, M_\alpha(QP)$$

j_0 for IAS, GT, j_1 for SD

$k^{eff}(q)= g_A{}^{eff}(q) \sim$ constant q=20 – 100 MeV/c

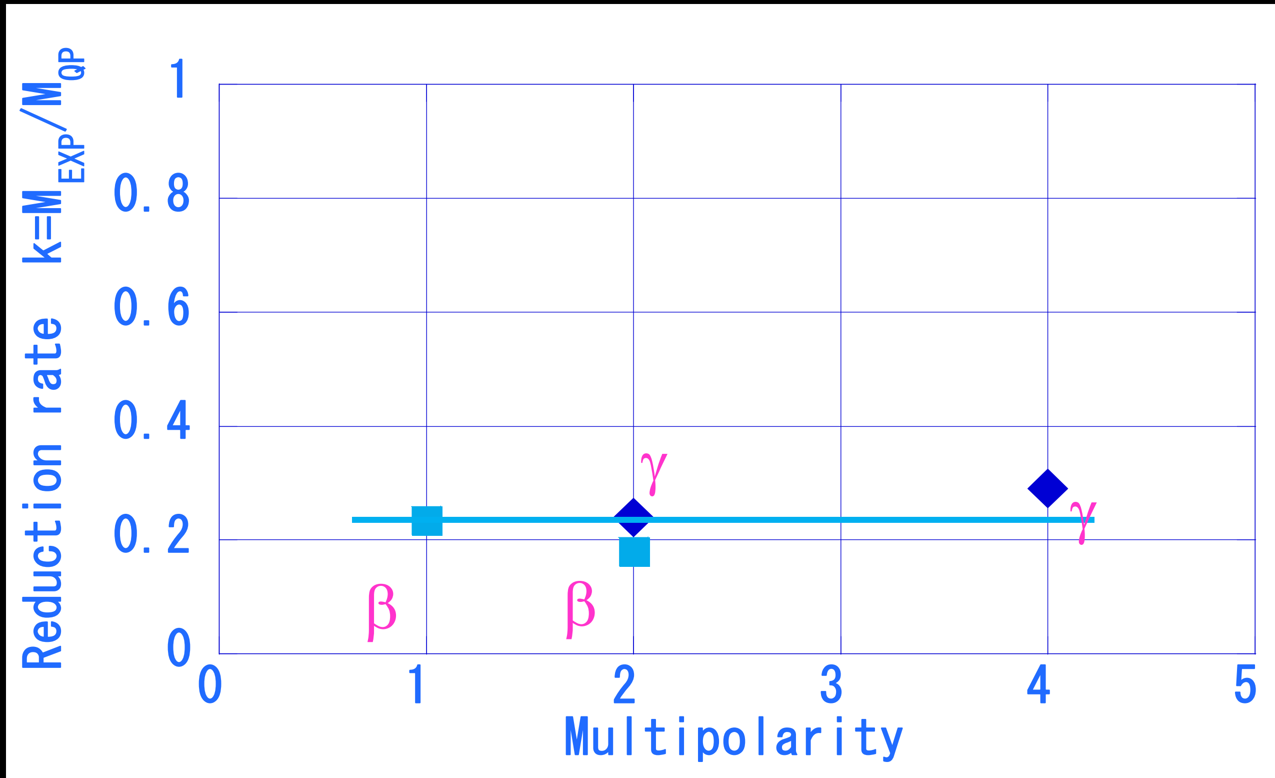






$g_A \sim$const over q=0-100 MeV/c

Universal reductions of axial vector β & γ



Ejiri Fujita PR 34 85 1978

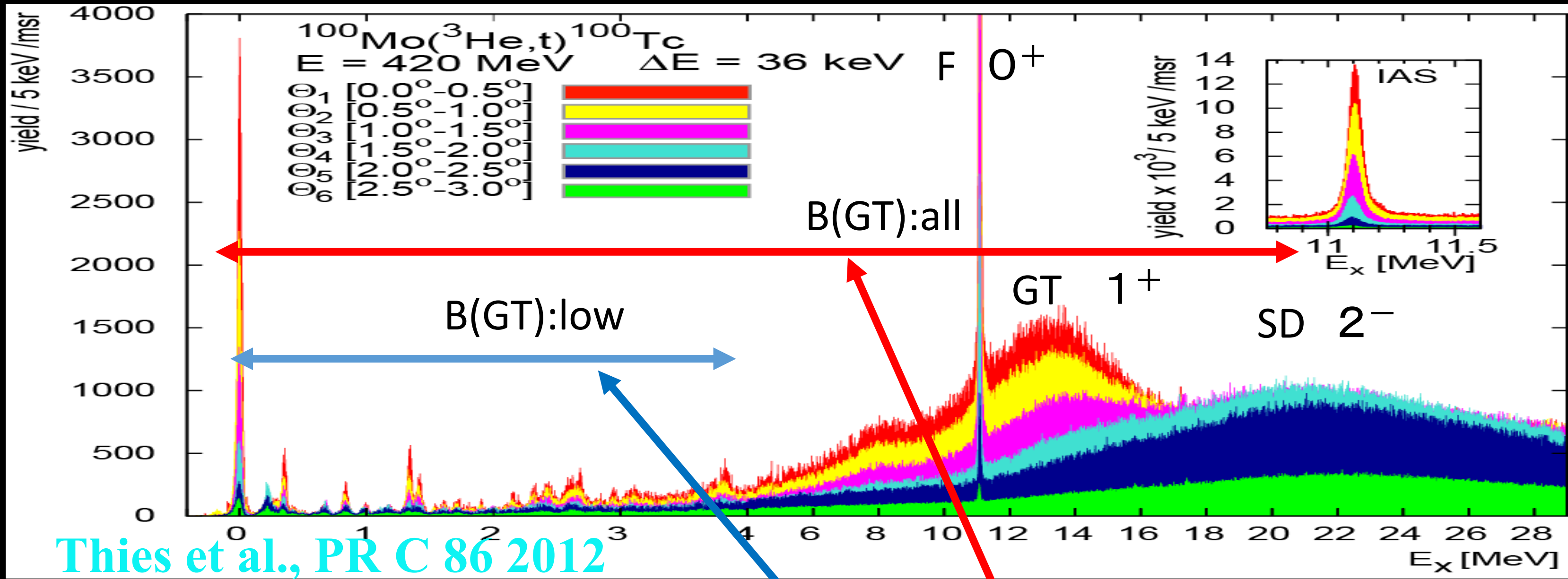
k=k(τσ) k(NM)~0.25 with respect to QRPA

k=k(τσ)~0.5 : Nucleonic long range τσ GR

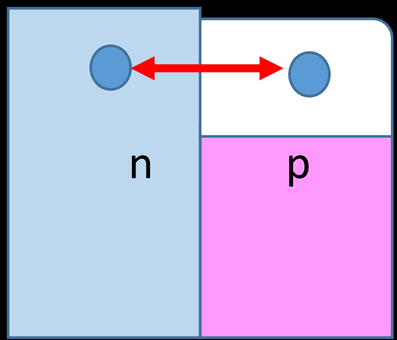
k(NM)~ g^{eff}_A/g_A~0.6 : Short range nucl. medium Δ π

Quenching Impact on DBD J. Suhonen NDM18, PR C 96 05501 2017

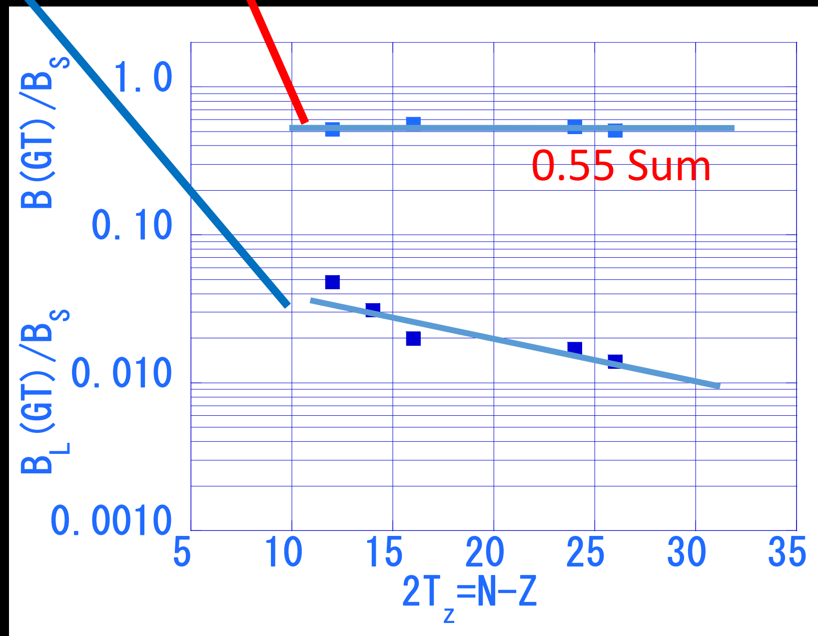
B(GT) sum strength



Thies et al., PR C 86 2012



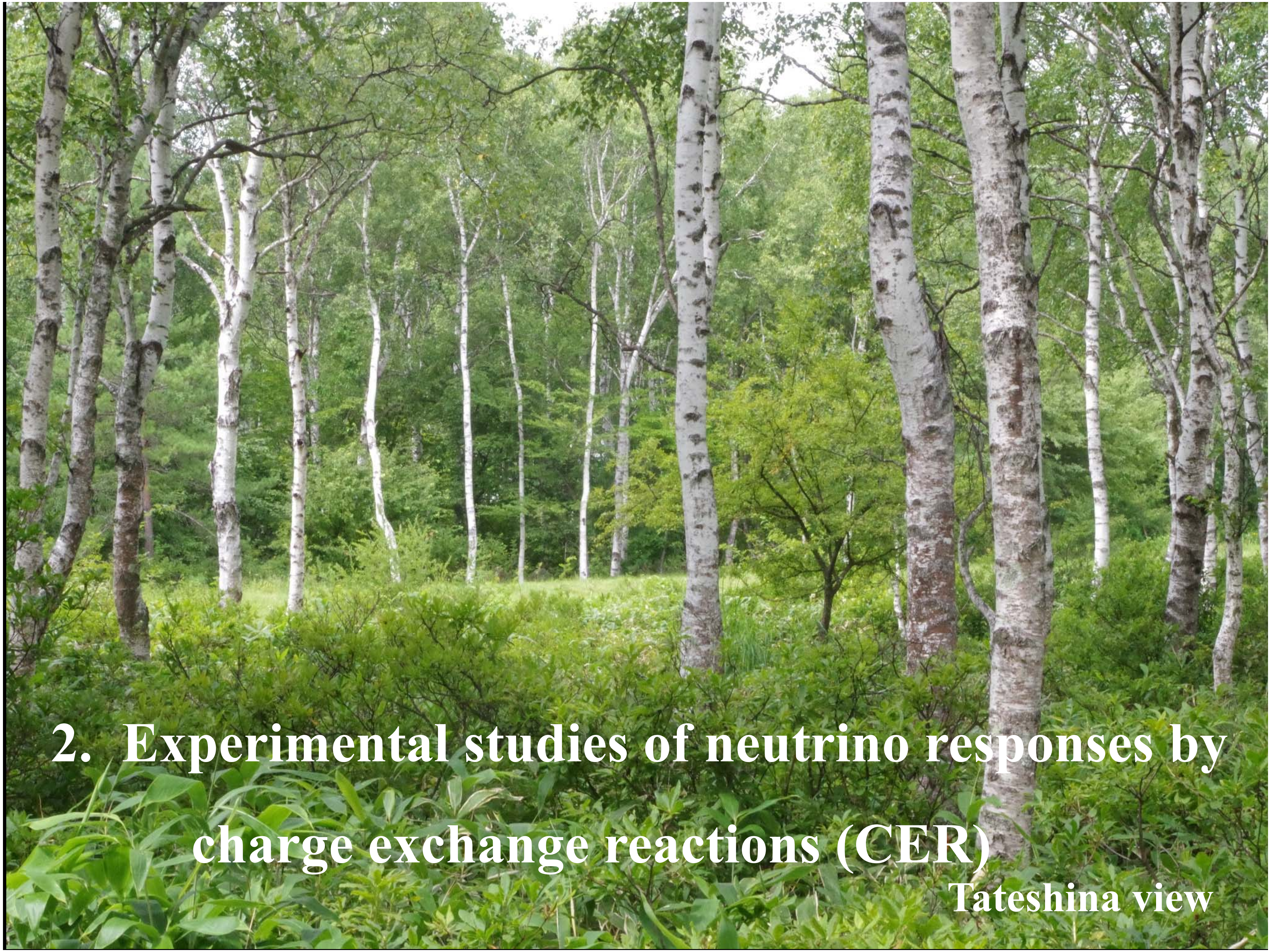
(N-Z) [B(σ)=3]



Σ B(GT)/B(σ) = 0.55 (N-Z)

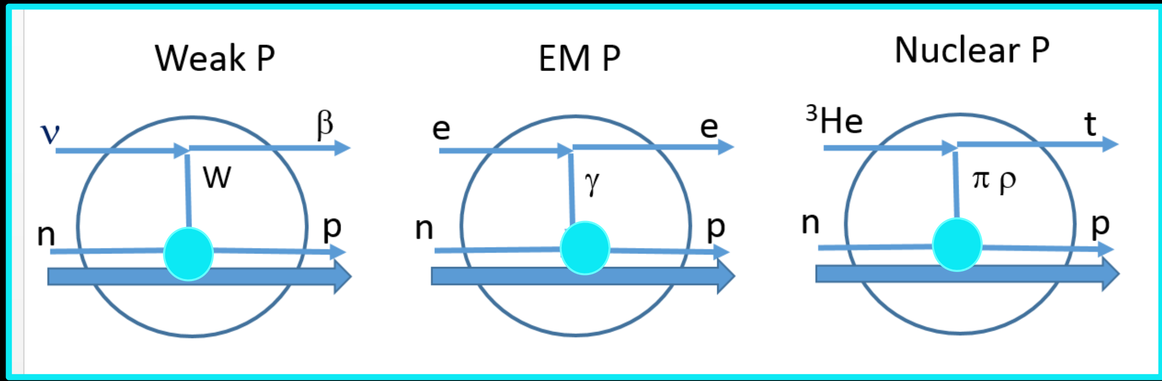
Note : Nucleon in nucleus is 0.55 free nucleon

2. Experimental studies of neutrino responses by charge exchange reactions (CER)



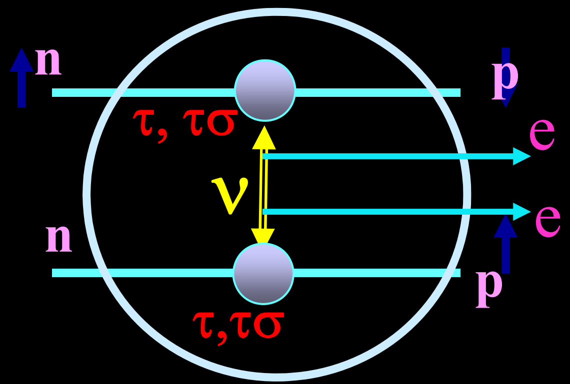
Tateshina view

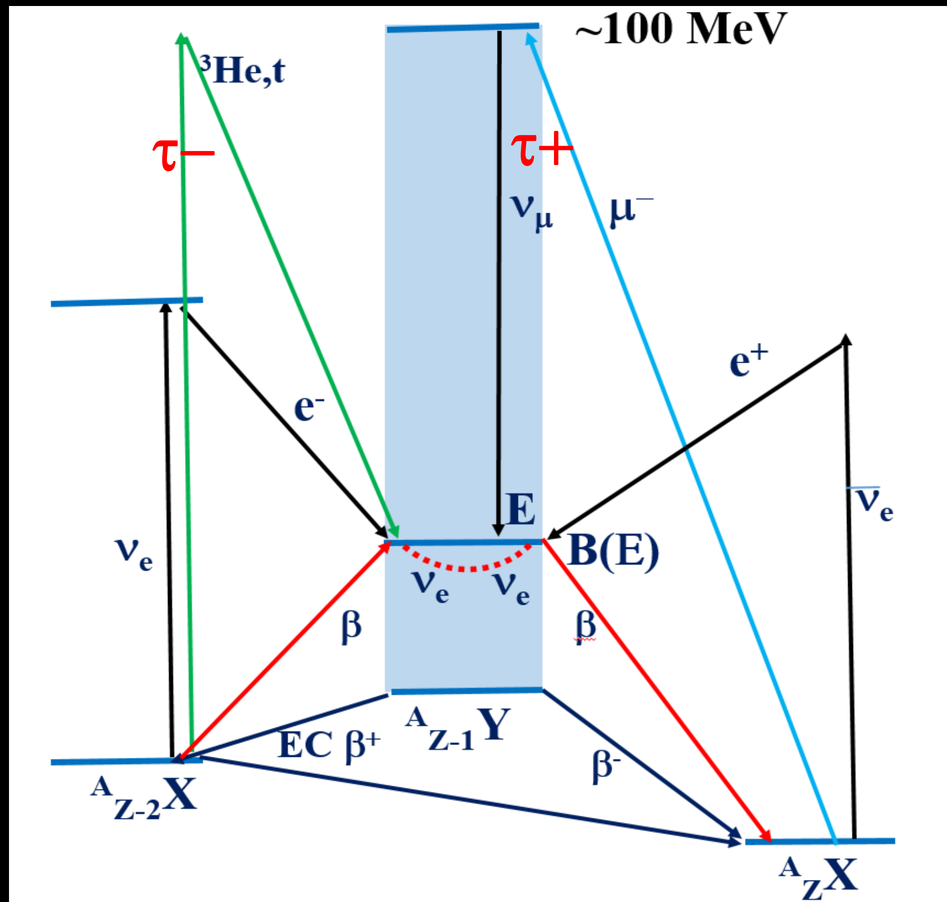
CERs for CC



$$M = g^2_A M_{DA} - g^2_F M_D$$

Sensitive to NN, NΔ/π nuclear medium effects





$M(EXP) = g_A M, \quad g_F M$

by

lepton and nuclear CERs to help calculations which are sensitive to nn & medium.

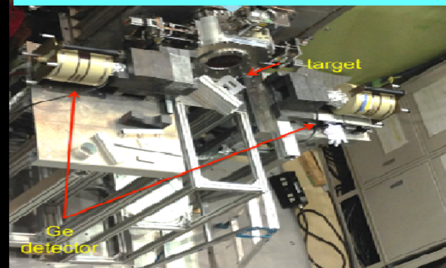
Response experiments by RCNP/Osaka

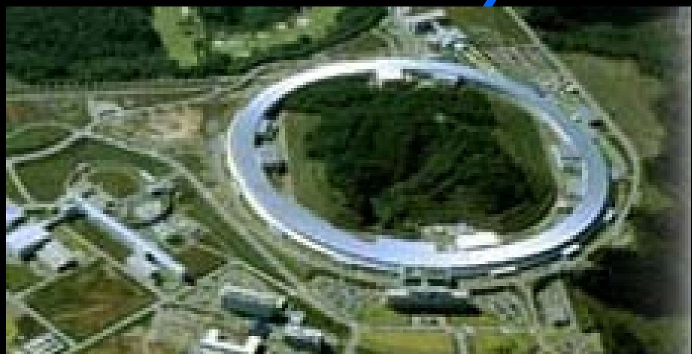
RCNP Osaka p,He,

MuSIC μ

J-PARC 3-50 GeV p, ν, μ

MLF MUSE μ

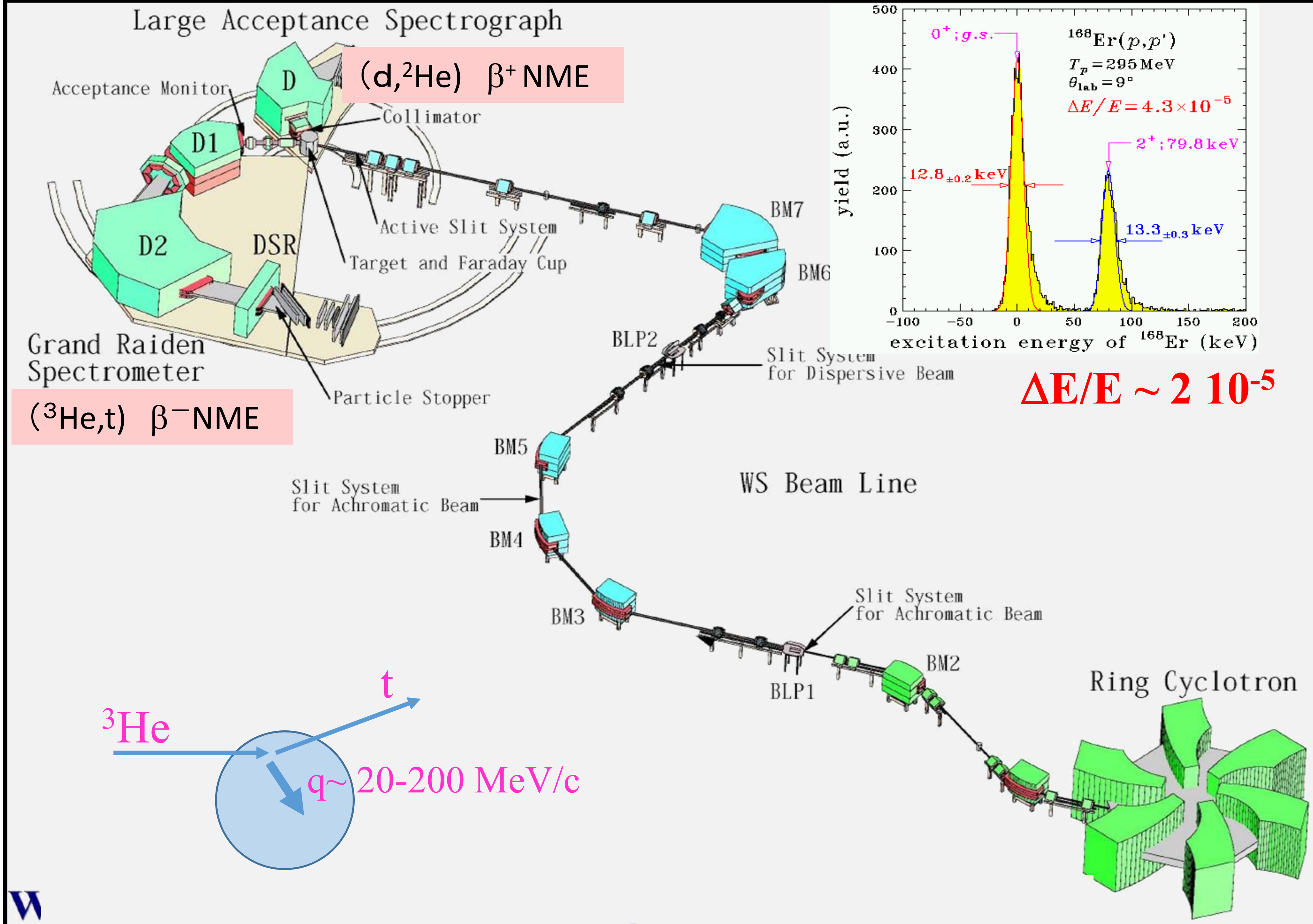




Spring-8 GeV- MeV pol. γ

Oto under gr. $\beta\beta$–ν,

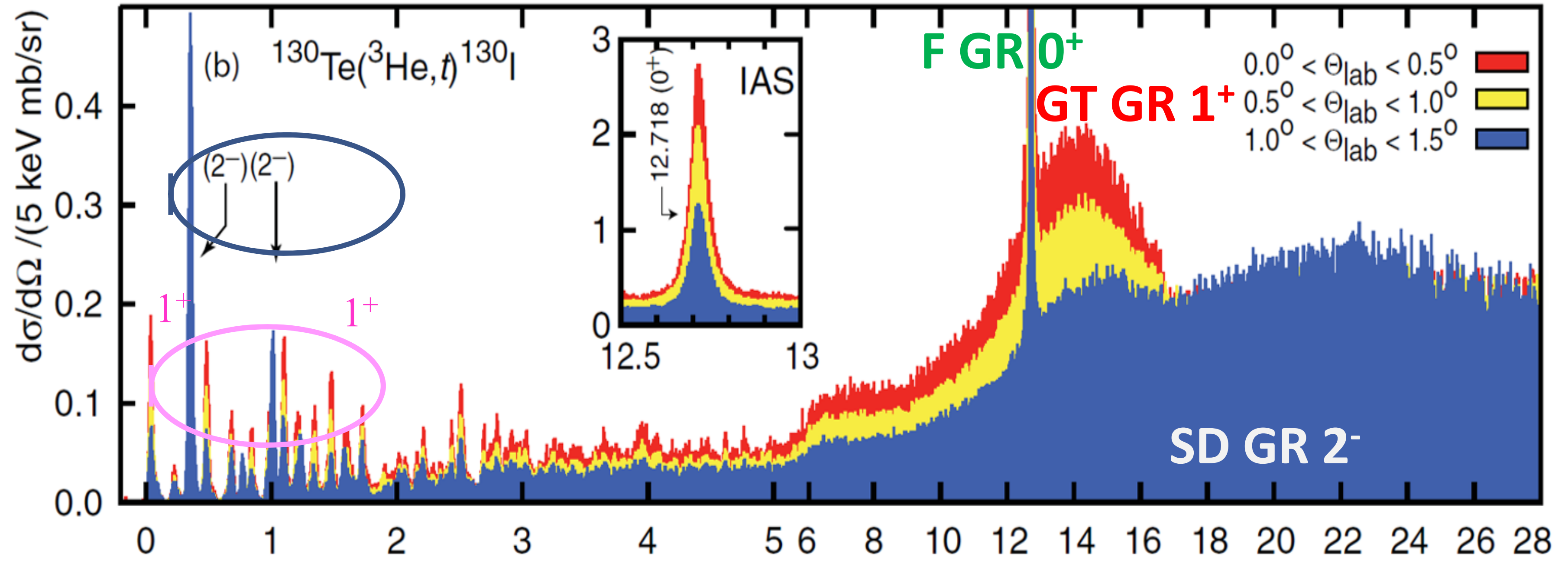
High E resolution (^{3}He,t) CERs at RCNP Osaka



RCNP CERs for DBD ^{76}Ge, ^{82}Se, ^{100}Mo, ^{128}Te, ^{130}Te ^{150}Nd

At E/A~0.2 GeV, V(τσ) dominates, thus

$M(J) = [\sigma\tau \times rY_l]_J$ θ=0~4 deg., q~ 20-150MeV/c

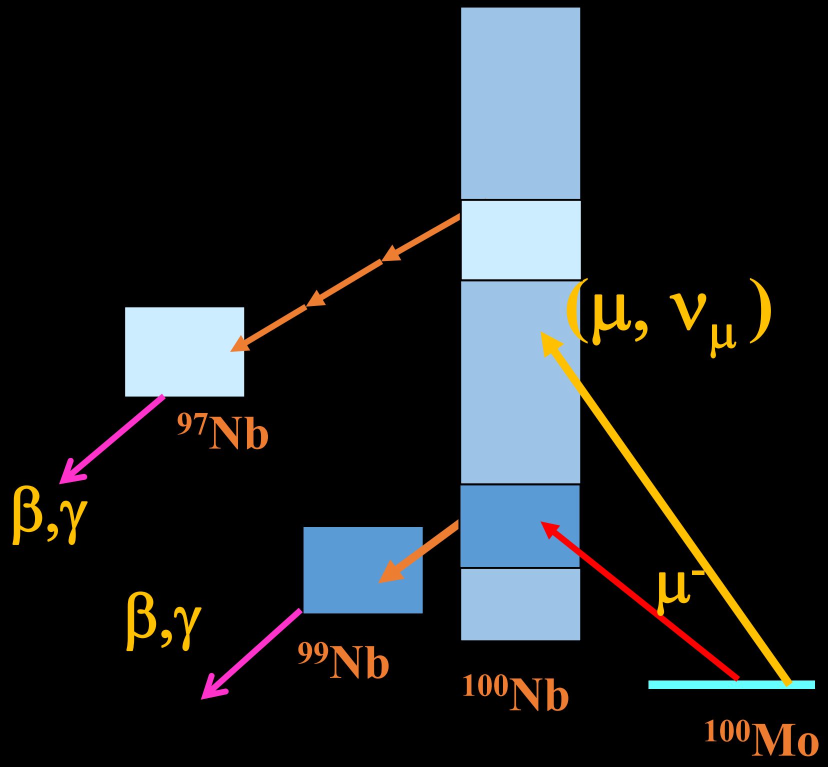


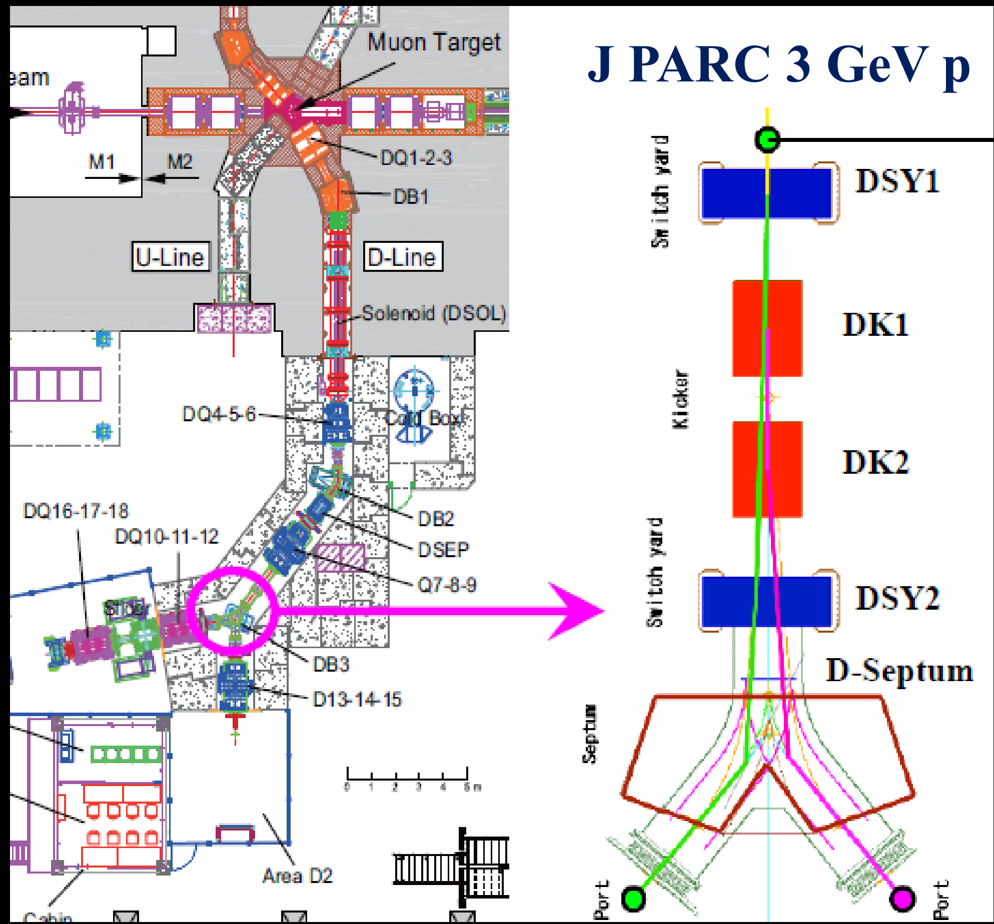
: Puppe, et al. PRC 86 044603 2012

CER at RCNP H. Akimune, H.Ejiri, D.Frekers M.Harakeh et al 1994- 2016.

No/weak F 0^+, GT 1^+ SD at low region and strong F GT SD GR

CER (μ, ν_μ, xn γ) $\bar{\nu}$–β^+ Responses q~50 MeV/c

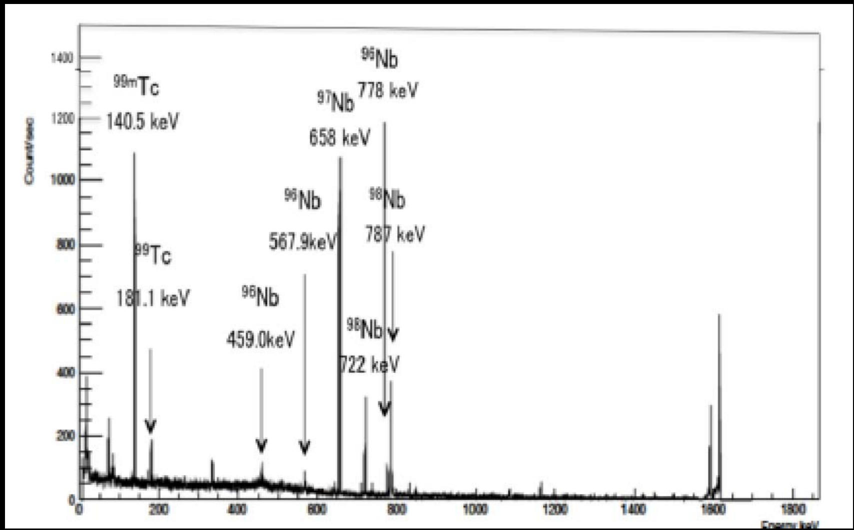


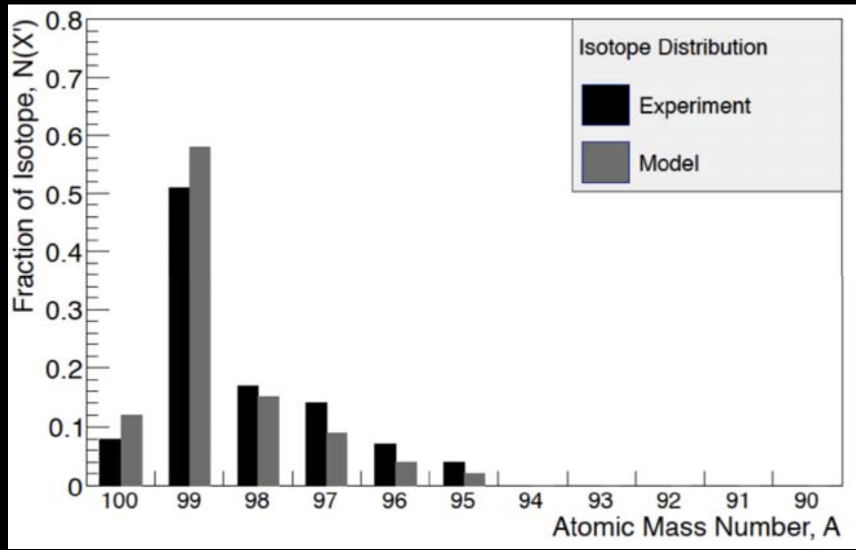


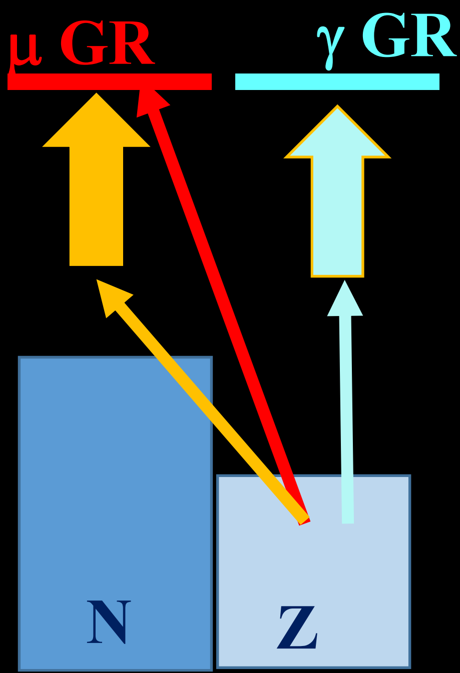
γ_i from $^{100\text{-}i}$Nb: relative strength   Life time : the absolute strength

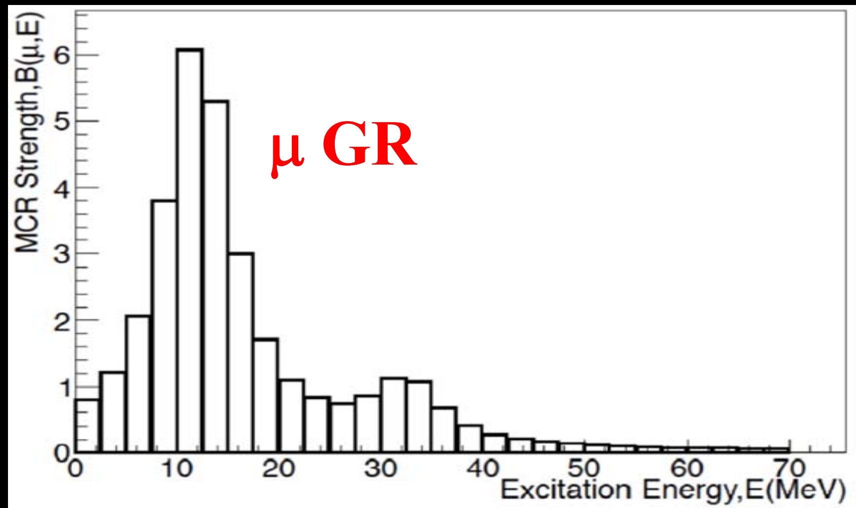
H. Ejiri Proc. e-γ conference Sendai 1972, H. Ejiri et al., JPSJ 2014

I. Hashim H. Ejiri et al., PRC 97 (2018) 014617









I. Hashim PhD Thesis Osaka 2015I.

I. Hashim H. Ejiri , 2015. MXG16, PR C 97 2018

Neutrinos reaction

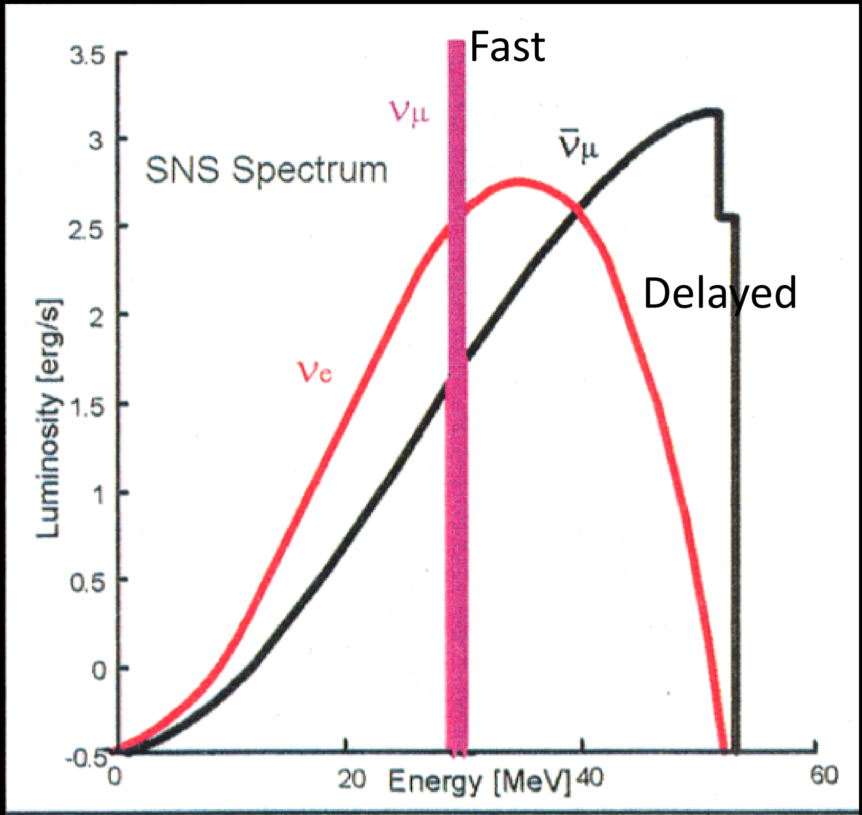
SNS ORNL , J-PARC

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

$\pi^+ \rightarrow \mu^+ + \nu_\mu$

$\mu^+ \rightarrow e^+ + \nu_e + \text{anti-}\nu_\mu$

SNS	1 GeV p	10^{15}	ν/s,
J-PARC	3 Gev p	$5\ 10^{14}$*	ν/s

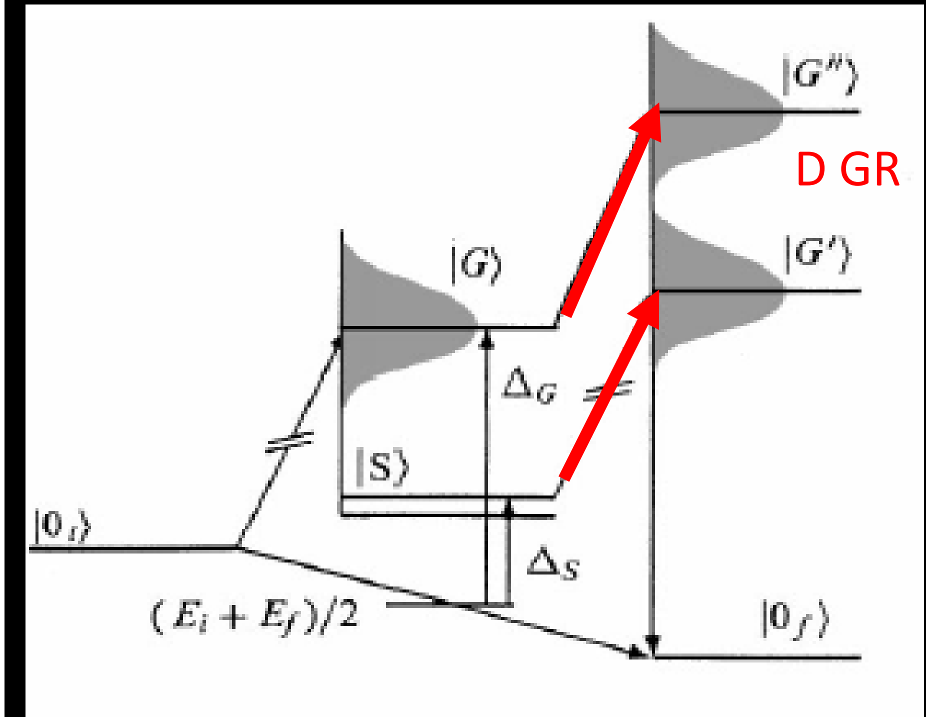


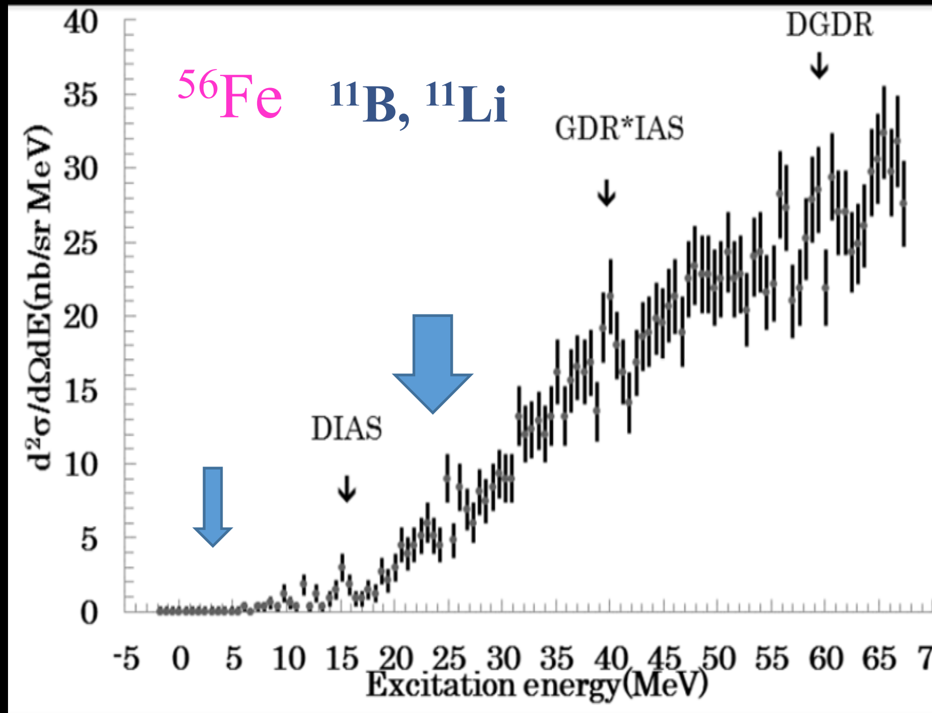
Astro nuclear responses of

$\sigma \sim 10^{-41-42}$ cm^2 with large detectors(10 tons)

* H. Ejiri NIM. 503 (2003) 276 – 278.

Double charge exchange reaction





H.Ejiri et al JPSJ 65 (1996),
No GT GR in case of $2\nu\beta\beta$

Takahisa Ejiri E/A=0.8 GeV
arXiv 170308265

Y(0-10MeV) /Y(20-30 MeV)=0.03

Uesaka NDM18
Menedez DGT NDM18

Cappuzzello et al Eur. Phys. J. A 51 145
Cappuzzello et al Eur. Phys. J. A 51 14
E/A=15 MeV Various kinds of V($\tau\sigma$ q)

2. Solar neutrino responses on ^{71}Ga & DBD isotopes

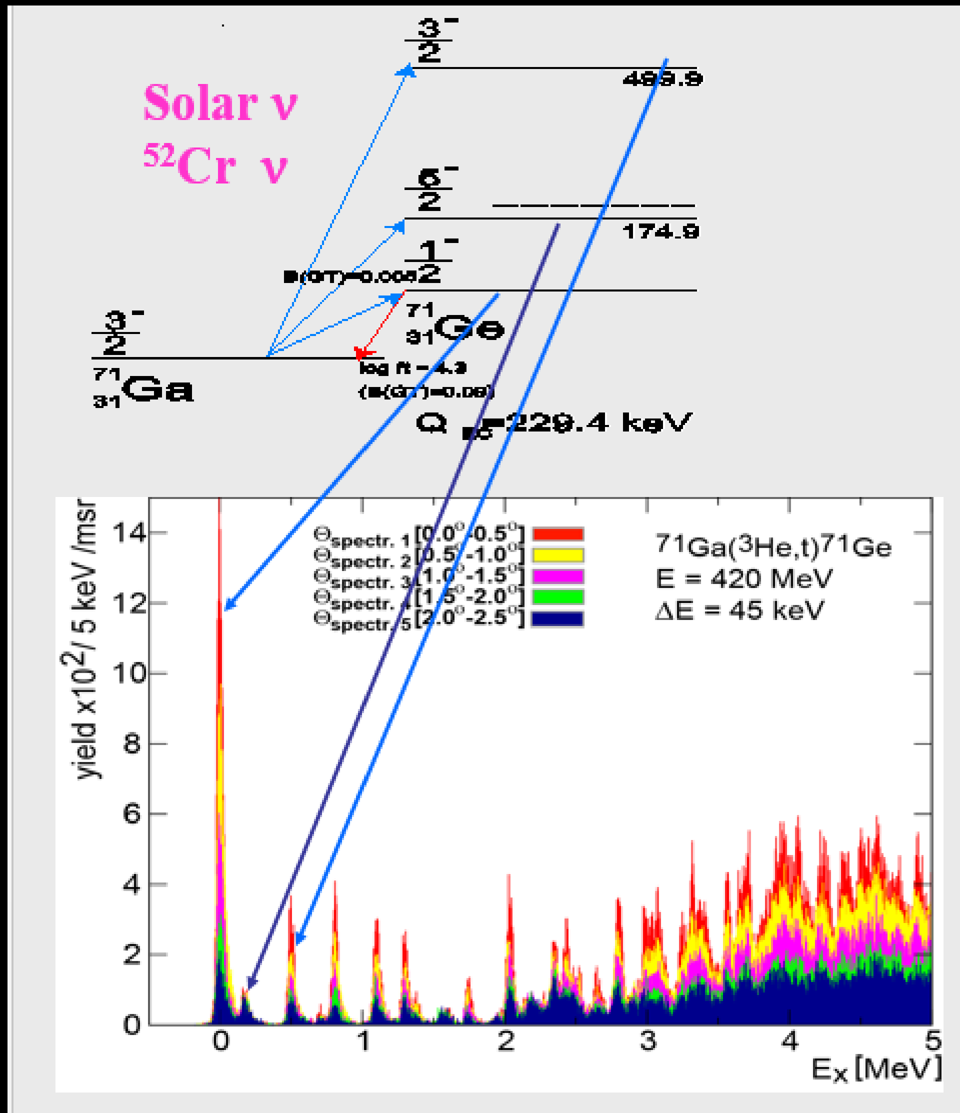
^{71}Ga neutrino response for ^{51}Cr and sterile ν ?

Ga detectors EXPs by
SAGE ^{51}Cr ^{37}Ar ,GALEX ^{51}Cr

Exp. average /Ga response
=0.87 ±0.05

1. GT response ?
2. Detector calibration ?
3. Sterile n oscillation

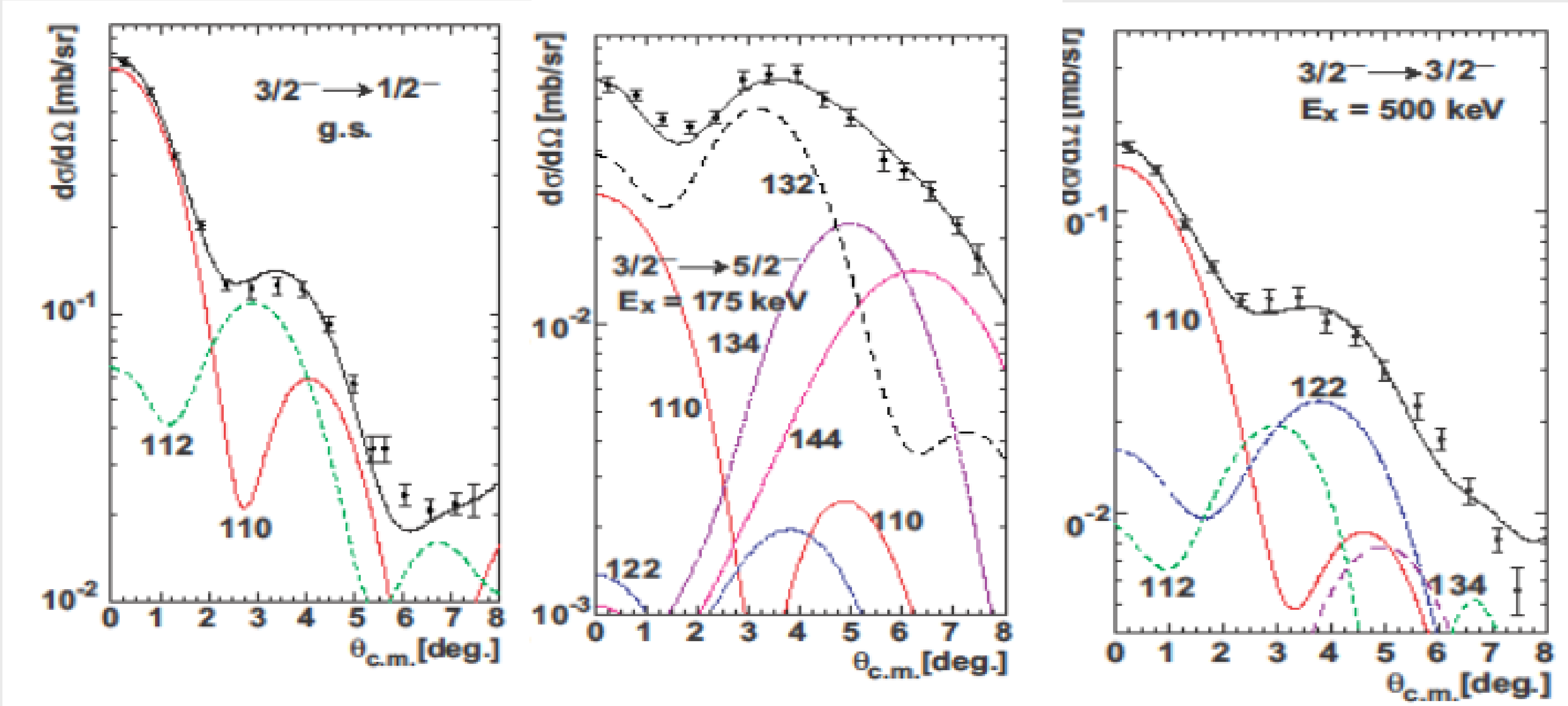
Ga response is based on Bahcall
Ga response exp. (^{3}He,t) RCNP
V. Gavrin Prop.



H. Ejiri et al PL B 433 (1998) 257; 706 (2011) 134,
D. Frekers H. Akimune H. Ejiri , V. Gavrin et al , PR C 91 (2015) 034608

Non-GT in CER $\sigma(q\sim0) = \Sigma\sigma(J_p, J_T, J_R) = \sigma(110) + \sigma(112) + \ldots$

$^{71}Ga \rightarrow {}^{71}Ge$ Ground state 1/2 known B(GT)



Gr	0	GT ratio 92%	B(GT) =8.52	Ratio=1.00
1 st	175	40%	0.34	0.027
2^{nd}	500	87%	1.76	0.045

Excited state contribution=7.2 ±2% (Bahcall 5%, Ejiri 8%)

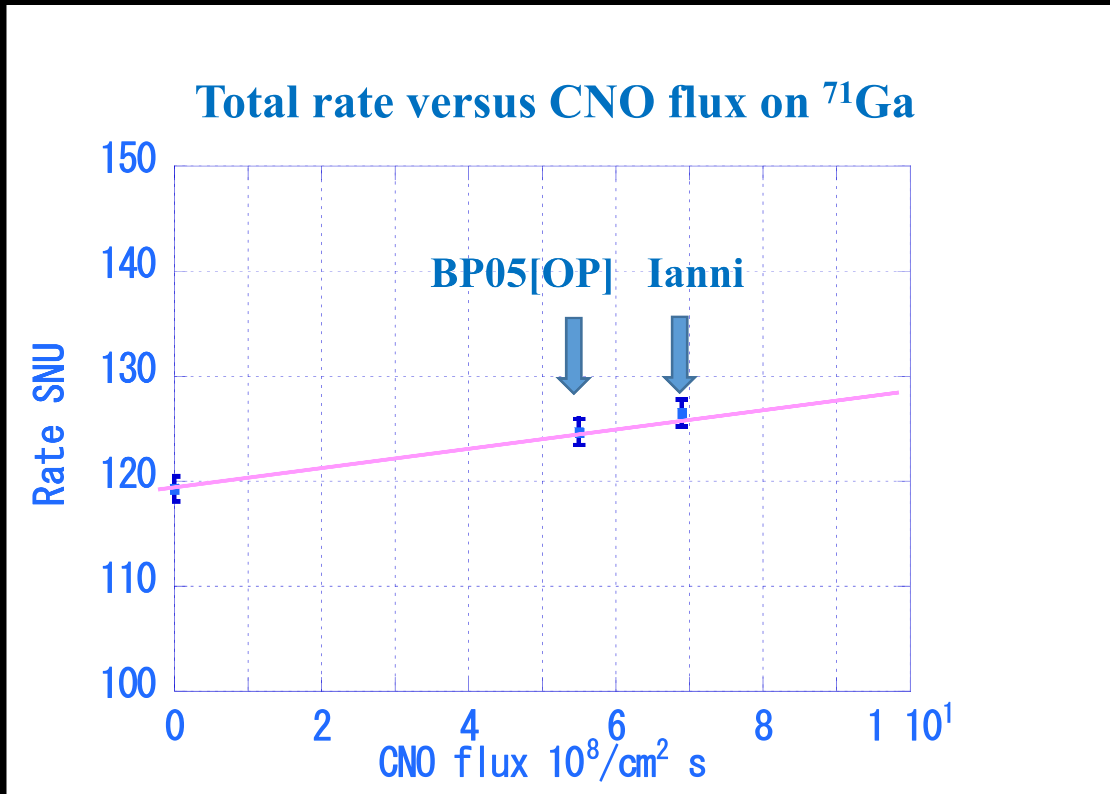
Using the measured response, missing = 0.85 (uncertainty 2%)

CNO neutrinos on ^{71}Ga Multi-ton scale Exps/

Borexino < 7.9 10^8/cm^2 s 3 σ arXiv 1701. 09279
Exp analyses < 6.8 10^8/cm^2 s 3 σ A. Ianni Phys Dark Univ. 4 2014
BP05[OP] 5.5 10^8/cm^2 s Bahcall Ast. J. Lett. 621 2005 L18 BP0
Low/high metallicity 3.8/5.3 10^8/cm^2 s J. Bergstrom

Total rate
90% from ground state
with B(GT) by β < 1 %

10 % from excited states
B(GT) by CER 10%
give 1% uncertainty



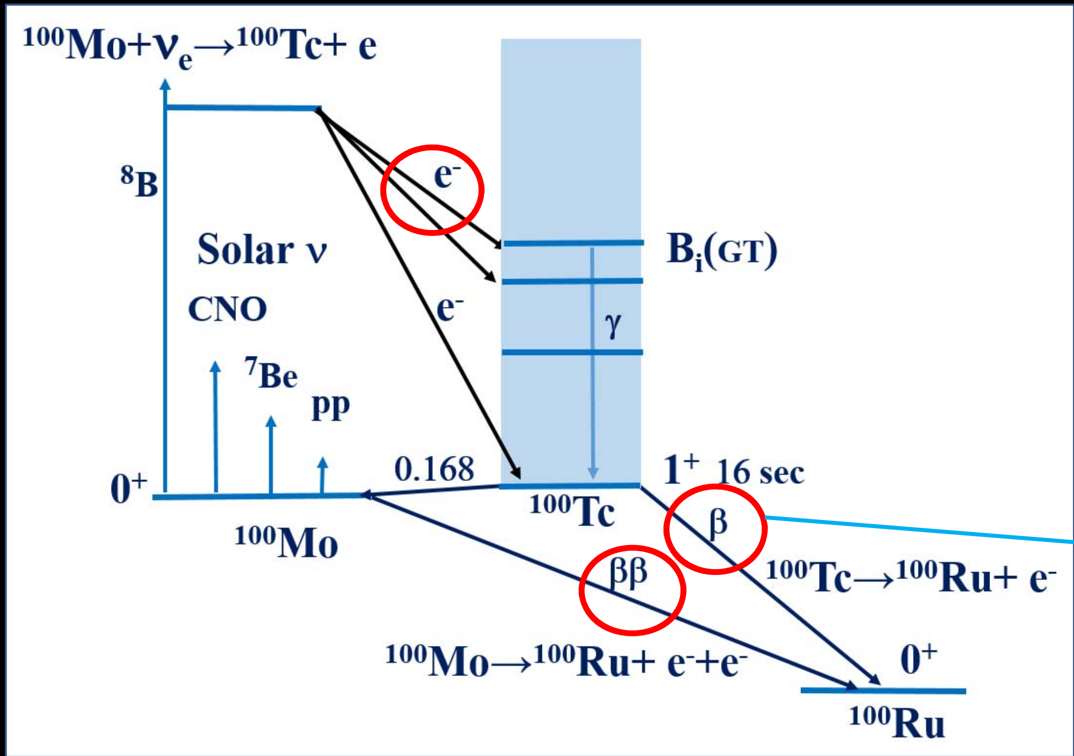
Responses: H. Ejiri 98, D. Frekers H. Ejiri et al PR C 2011 Agree within 0.5 %.

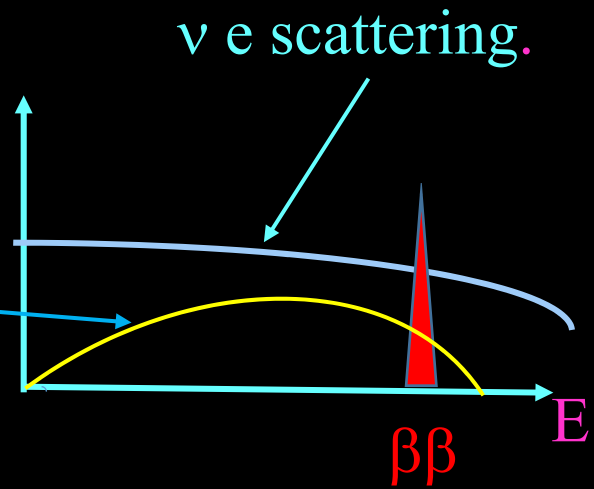
Solar-ν interactions with nuclei and atomic electrons in DBD/DM* detectors are serious BGs

Solar e with γ–β in coincidence / DBD 2νββ BG

DBD 0νββ signal / solar ν e,β BG

Similar rates and similar energy



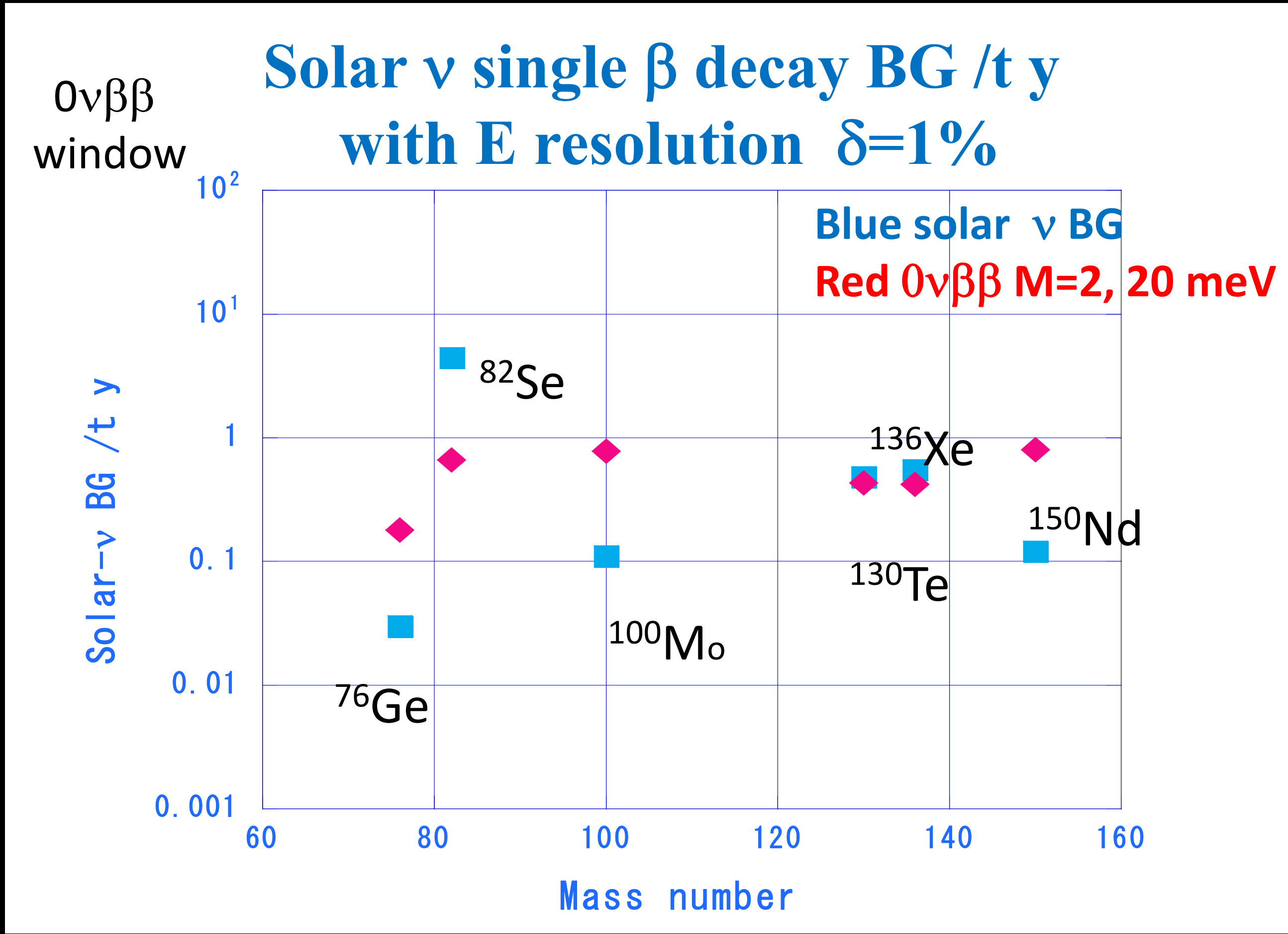


H. Ejiri S. Elliott, PR C 89 055501 2014, *J. Vergados H. Ejiri NP B 804 144 2008

H. Ejiri K. Zuber J. Phys. G. 43 045201 2016

DBD rates for IH mass: 0.5-0.9 / t y except 0.2 for ^{76}Ge

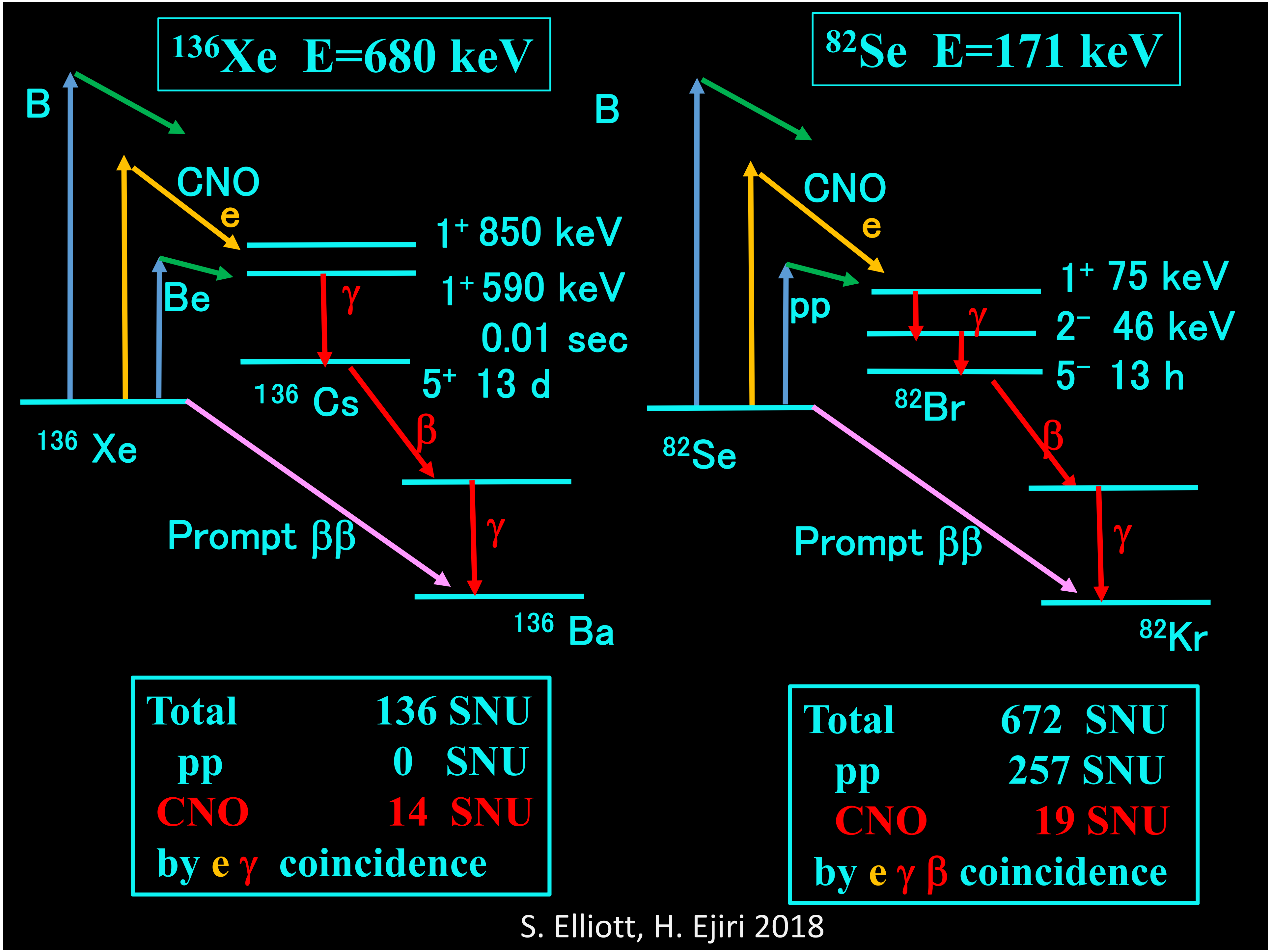
Solar ν BG should be <0.2-0.3 /ty except <0.1 for ^{76}Ge



^{82}Se detector δ << 0.1 % , and ^{130}Te ^{136}Xe δ <1% bolometers.

If δ >1%, needs tracks, γ rejection, time correlation to reject BGs

H. Ejiri and S. Elliott PR C 89 055501 2014, 95 055501 2017

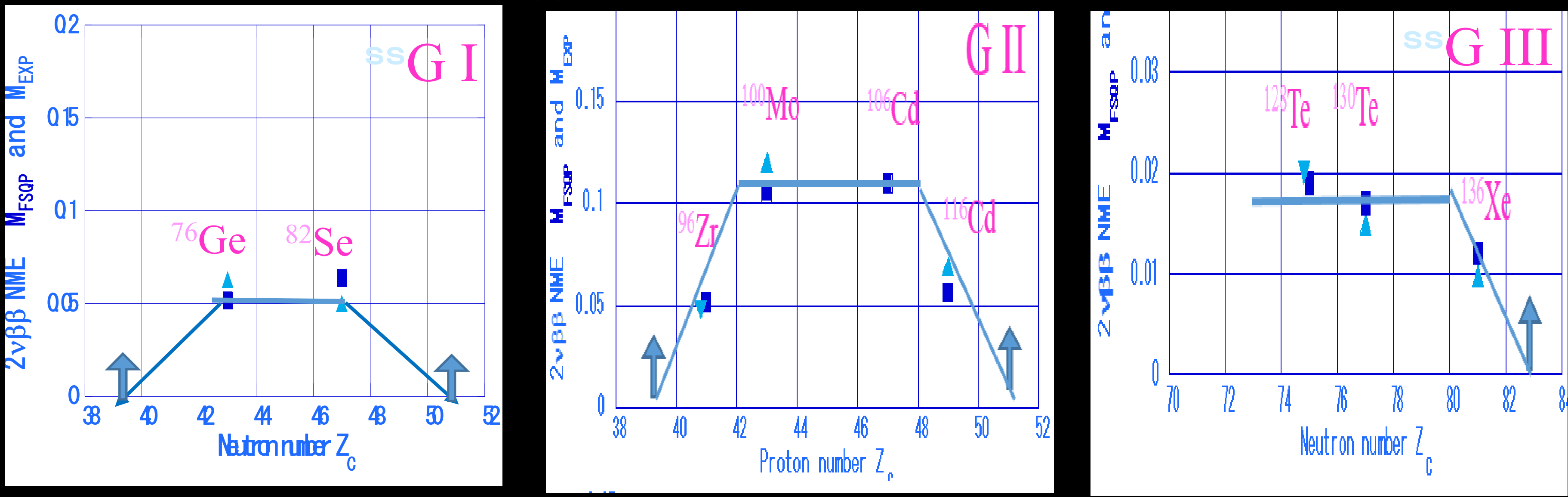


136Xe E=680 keV
B
CNO
e
1+ 850 keV
1+ 590 keV
Be
γ
0.01 sec
136 Cs
5+ 13 d
136 Xe
β
Prompt ββ
γ
136 Ba
Total 136 SNU
pp 0 SNU
CNO 14 SNU
by e γ coincidence
82Se E=171 keV
B
CNO
e
1+ 75 keV
pp
γ
2− 46 keV
5− 13 h
82Br
82Se
β
Prompt ββ
γ
82Kr
Total 672 SNU
pp 257 SNU
CNO 19 SNU
by e γ β coincidence
S. Elliott, H. Ejiri 2018

III. Neutrino nuclear responses (NMES) for DBD.

DBD $2\nu\beta\beta$ and $0\nu\beta\beta$ NMEs

QRPA $0\nu\beta\beta$ NMEs (Engel et al. PRC 89 (2014) 064308



$2\nu\beta\beta$ NMEs square exp, triangle FSQP(Ejiri) J. Phys. 2017

$$M^{2\nu\beta\beta} = \Sigma_k \, M^-_k M^+_k / \Delta_k$$

$$M^-_k = (k^{eff}_i) \; m_{ij} V_n U_p , \quad M^+_k = (k^{eff}_f) \; m_{ij} U_n V_p ,$$

$$(k^{eff}_A)^2 \sim (0.23)^2 = 0.05$$

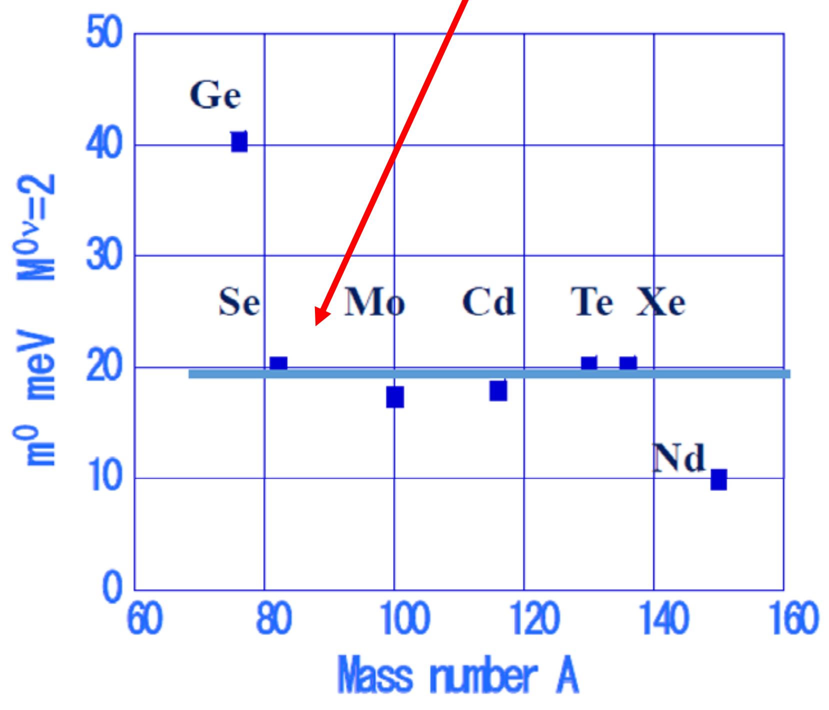
Shell closure makes U or V small, and thus UV small .

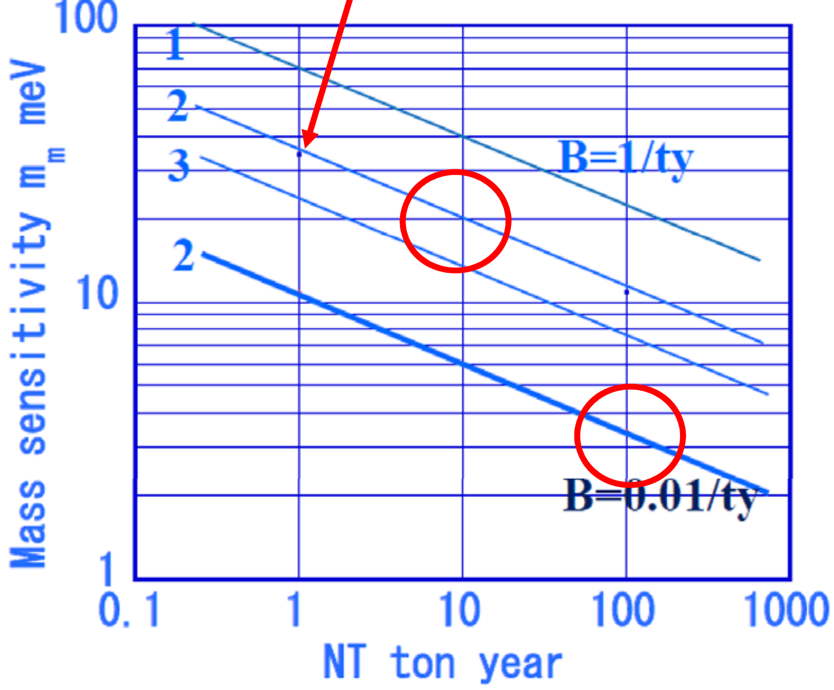
DBD $0\nu\beta\beta$ NMEs and DBD mass semsitivity

Mass sensitivity mass to be detected $m_m = m^0 D$

Nuclear sensitivity $m^0 = k\,[G^{0\nu}/A]^{-1/2}[M^{0\nu}]^{-1}$ mass for 1/t y

Detector sensitivity $D = h\,[BG/NT]^{1/4}$ N/ton T/year BG/t y





$M^{0\nu} = k^2$ M(QRPA) ~ 2 , $k = (g^{eff}/g) \sim 0.7$

Neutron decay to DM χ in ^{11}Be

H. Ejiri & J. Vergados arXiv 1805.04477

Free n weak decay life by beam exps is longer than the life in bottle

A possible n decay to DM χ 10^5 sec B.Fornal B. Grinstein arXiv 1802.0

Bound n decay to χ without γ

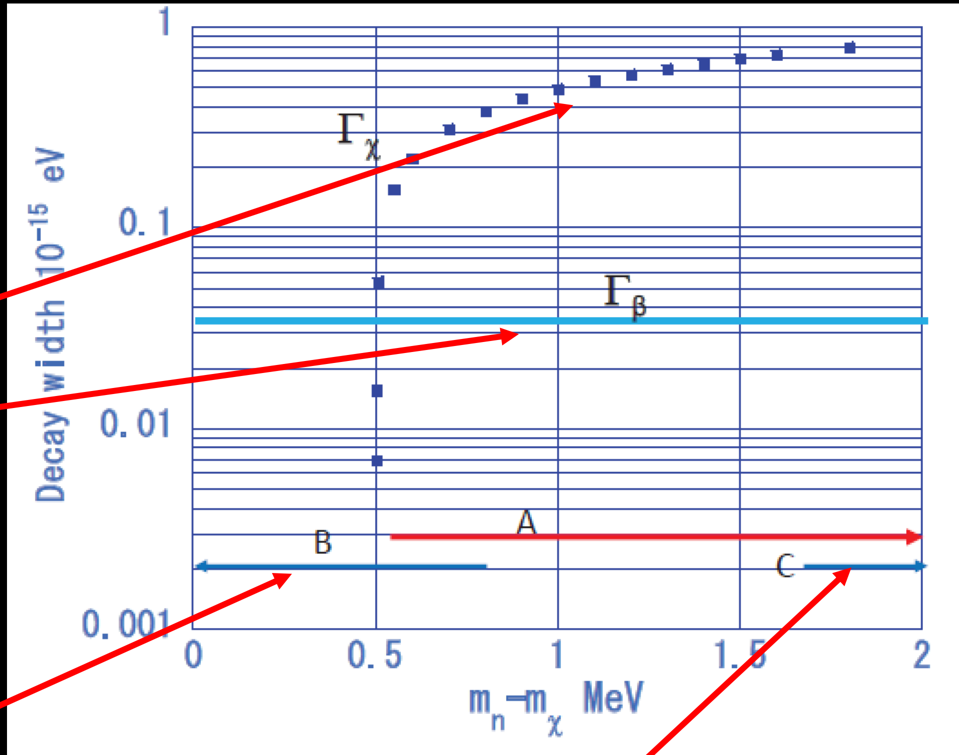
^{11}Be 15 sec. B_n=0.5 MeV

χ mass < Mn-0.5 Me

^{11}Be $(n\rightarrow \chi)$ Evaluated width

>> ^{11}Be $(n\rightarrow p+\beta)$ Exp. width

exclude A



Excluded by no χ decay to $p+e^+$

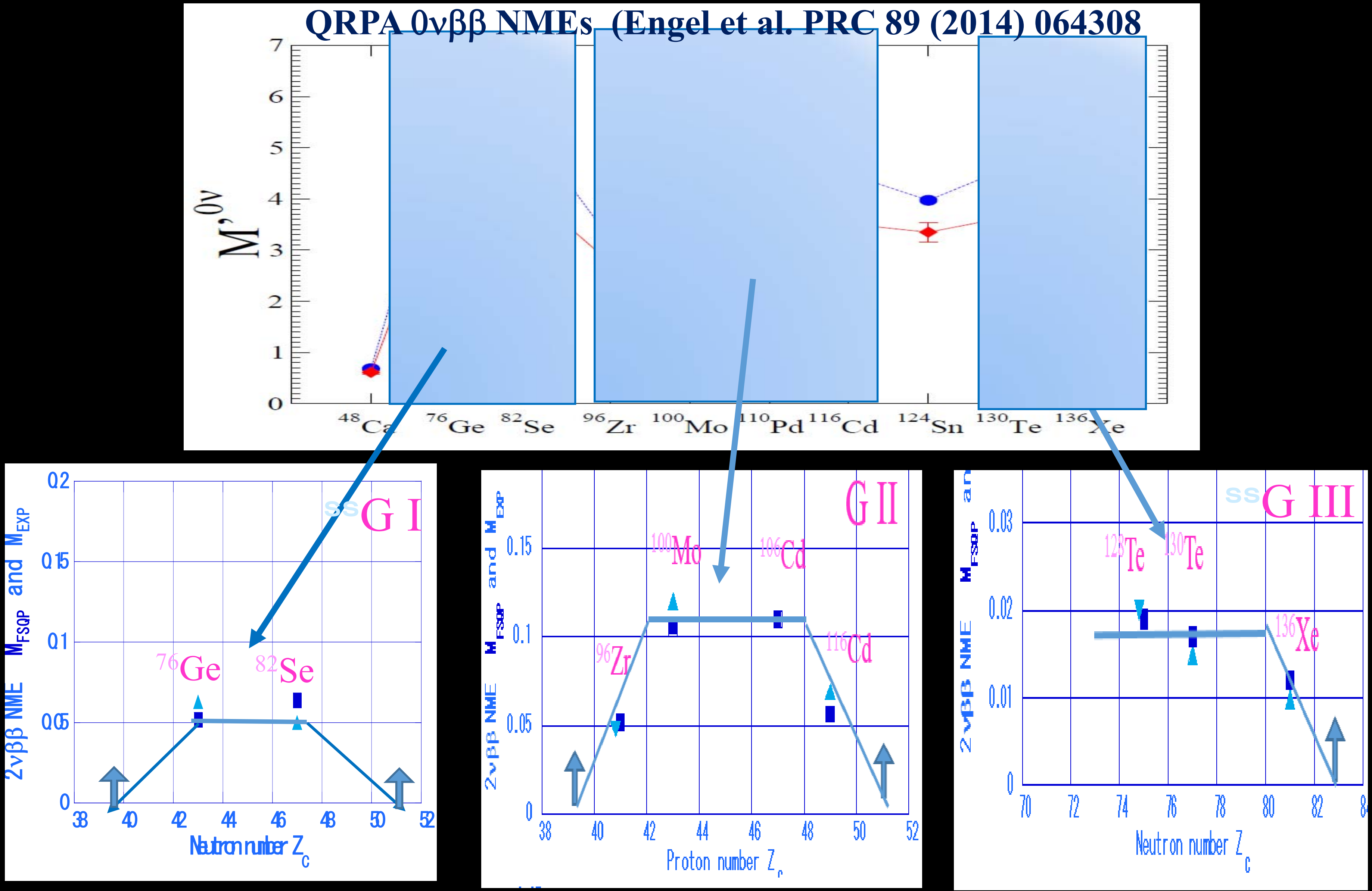
Excluded by no decay in stable ^{9}Be with Bn=1.665 MeV

Remarks

1. CER: (^{3}He,t), (μ,xn) provide M(GT,SD) used for evaluating astro ν and DBD responses.
2. M_{EXP}(GT,SD) are reduced from M_{QP} by $k^{eff}\sim 0.2$-0.25, $k_{ts}\sim 0.4$-0.5 by nucl. $\tau\sigma$, $k_m \sim 0.5$-0.6 by others (g_A^{eff}/g_A).
3. ^{71}Ga responses show ^{51}Cr-^{37}Ar ν missing of 87% is not due to ν-responses but to detector or sterile ν.
4. Solar ν BGs for DBD (IH mass) is serious if $\Delta E/E > 1\%$.
5. Possible CNO measurements are DBD (ν,e γ β) studies.
6. Neutron life anomaly is NOT due to the n decay to DM.


Thanks for your attention　Greenary Nimph 翠の精

Nuclear structures on 2νββ NMEs

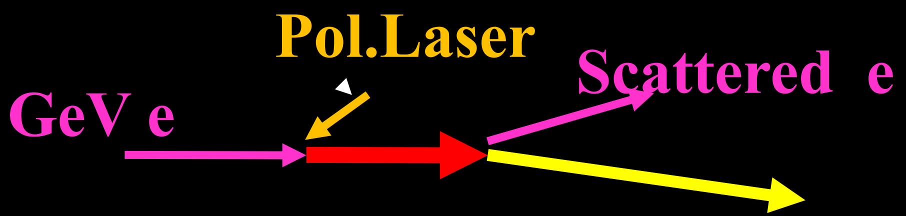


2νββ NMEs square exp, triangle FSQP(Ejiri) J. Phys. 2017

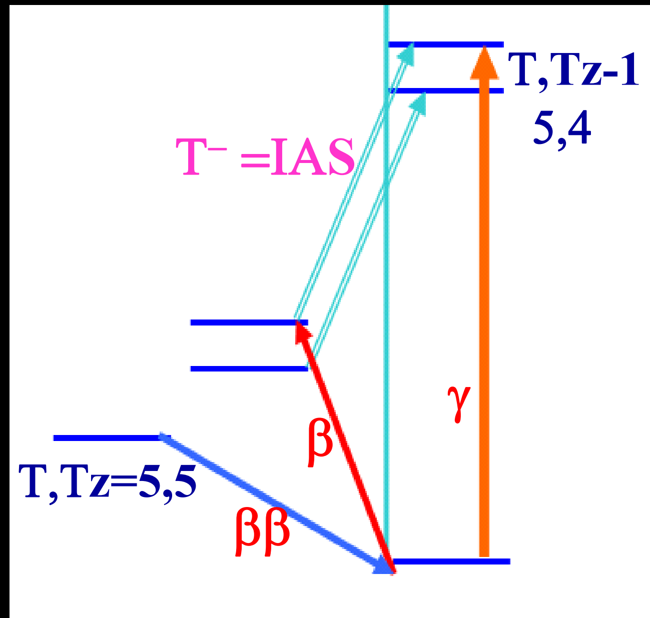
LEPS Photon probe

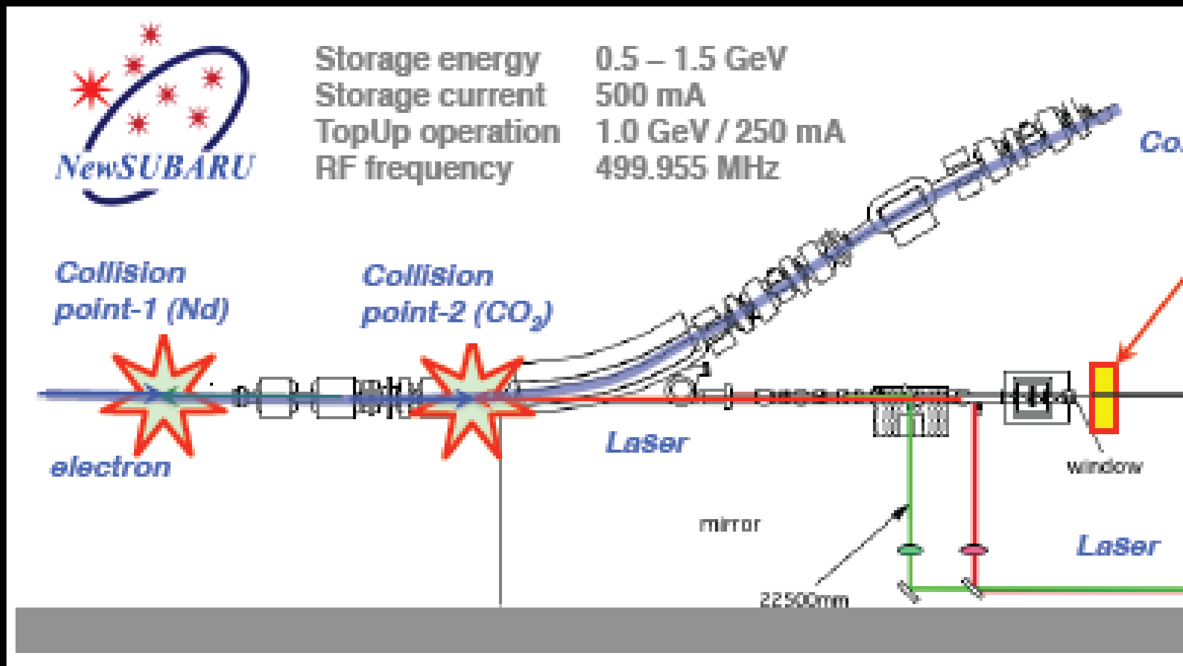
H. Ejiri PRL 21 ’68, PR 38 ’78
H. Ejiri, A. Titov PR C 88 054610 2013

Laser electron photon sources



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





β^+ NME via IAS γ

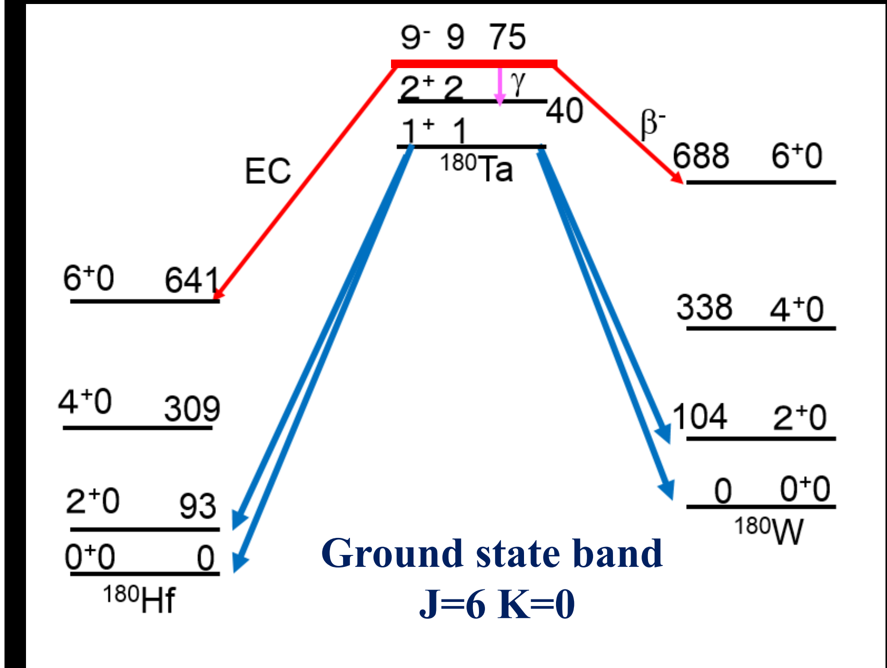
$<f\,|g\,M_\beta|\,i> =$

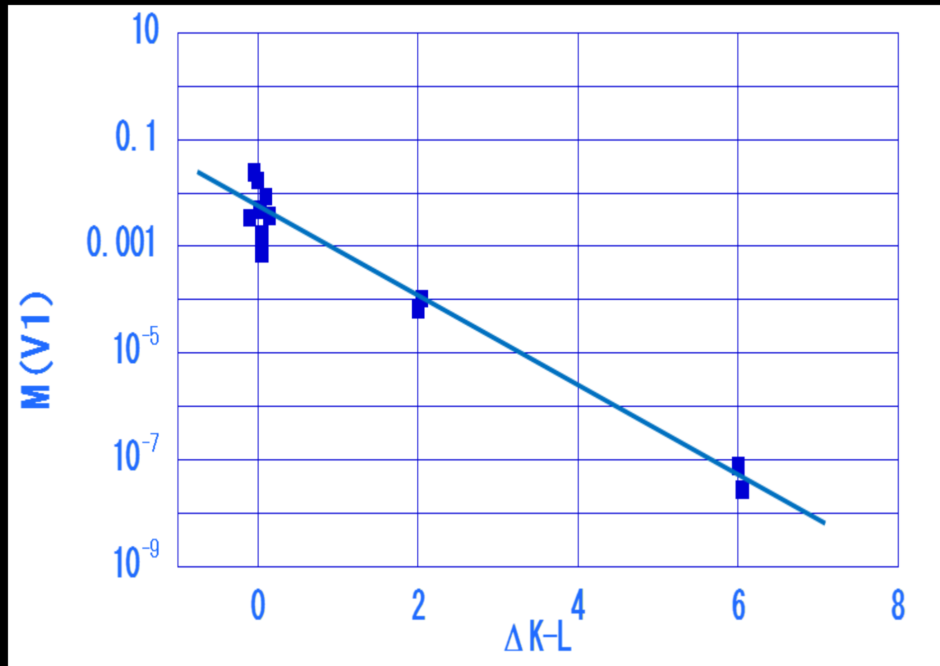
$g/e\ (2T)^{1/2} <f\,|\,em_\gamma\,|\,I>$

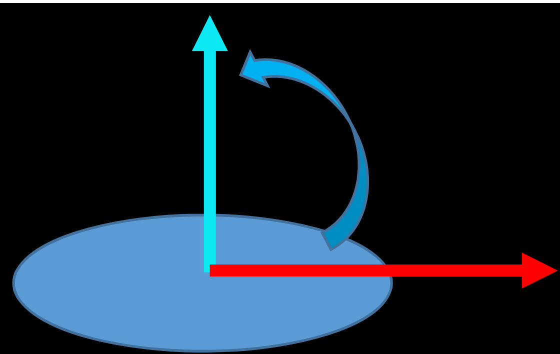
Particle γ for good resolution CNNP17 Brandao de Oliveira

Neutrino nucleosynthesis ^{180}Ta, 2.4 10^{-12} per 1 Si

Synthesis $\sim M^2$ for 5-40 MeV   H. Ejiri T. Shima J. Phys. G. 44 2017 065101







^{181}Ta isomer J=9 K=9

$M=kF^{\Delta K-L}$, F=0.15 by every ΔK-L

EC $T_{1/2}=1.4\ 10^{20}$ y   Exp 2 10^{17} y

β⁻ $T_{1/2}=5.4\ 10^{23}$ y   Exp 1 10^{16} y

Exp Lehnert et al Dresden 2016

Schematic view of ν/β response

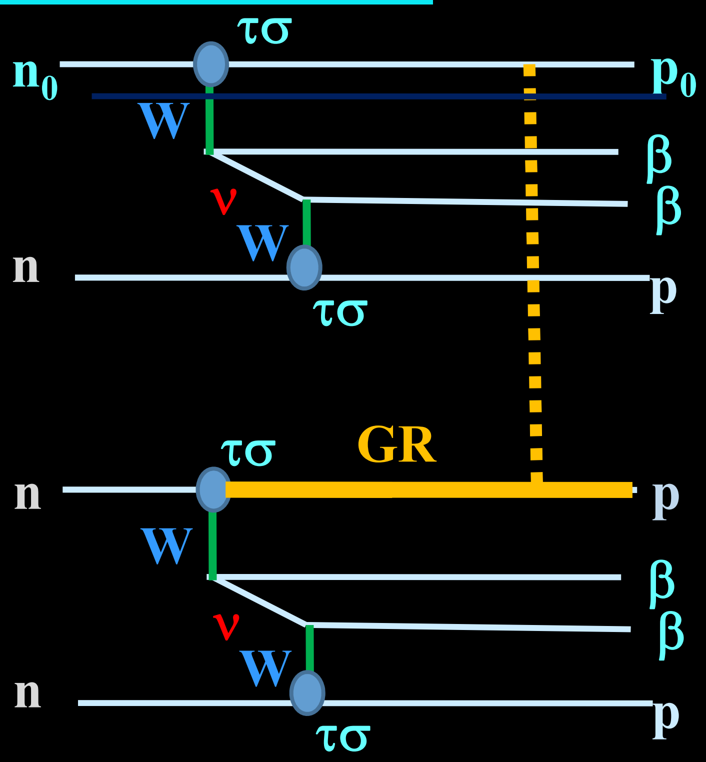
1. n_0 and p_0 at the gr. 0^+ state on the diffused Fermi surface

2. Coupling with GR= Σ |n^{-1}p>

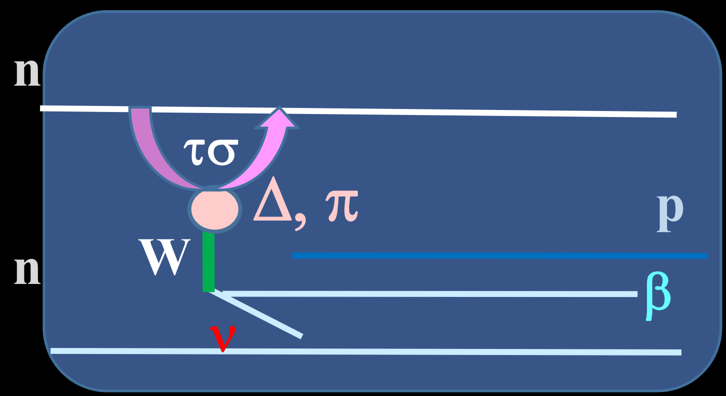
$$M = \kappa_{\tau\sigma} M \qquad \kappa_{\tau\sigma} = 1/(1+\chi_{\tau\sigma})$$

$\kappa_{\tau\sigma}$: renormalization

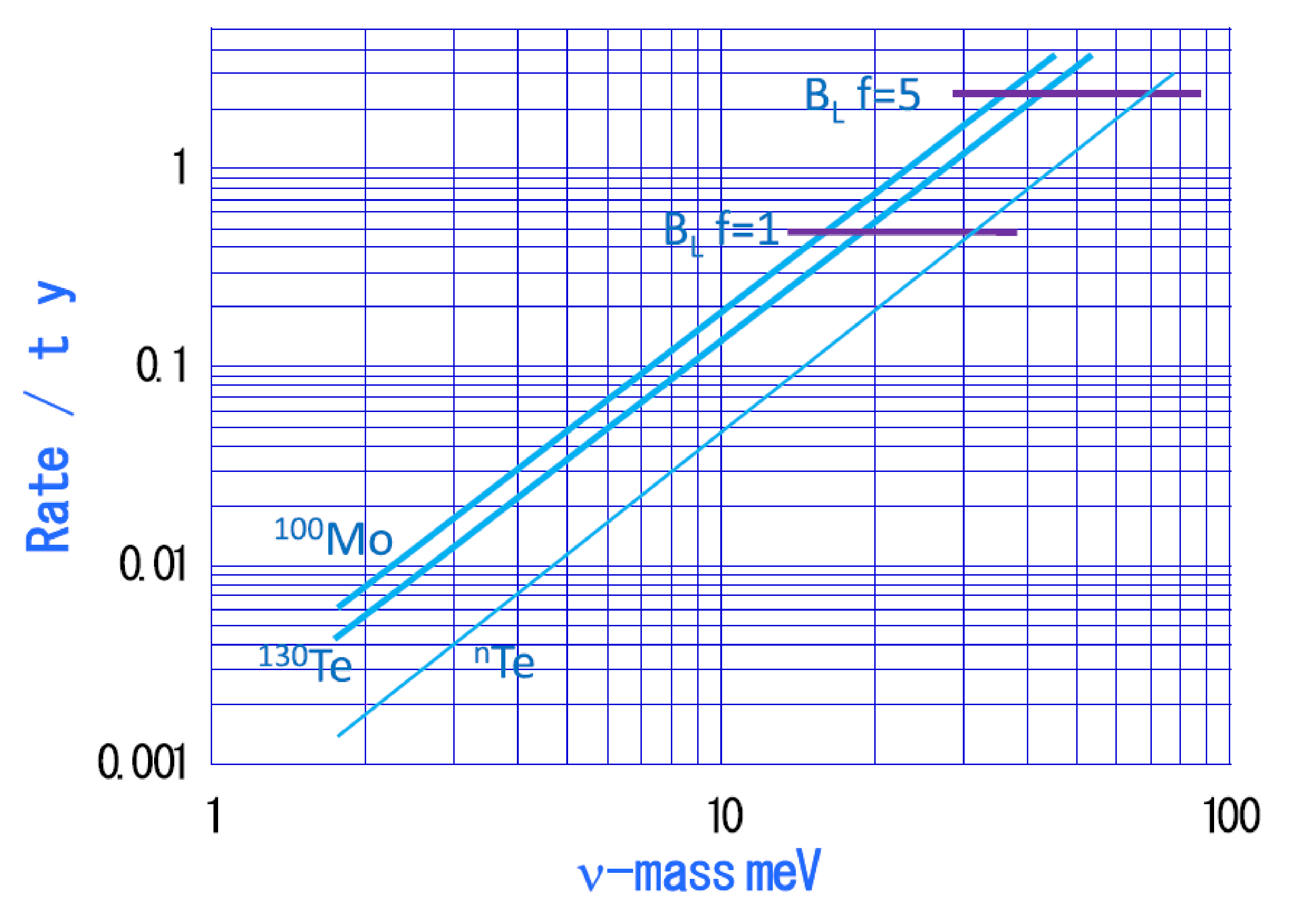
$\chi_{\tau\sigma}$: susceptibility=E(GR)/E



3. Non nucleonic medium and short range effects
   π, Δ fields modified, no more free nucleon. k_M~0.6 amplitude
   Effecive g_A and g_V give Δ origin.



Solar-ν on atomic electrons in liquid scintillators



f=δ/R with δ energy resolution and R DBD isotope concentration,
In case of f=5, R=1%, δ =5%, BG ~2.5. Need f=1 , R=1% δ=1%

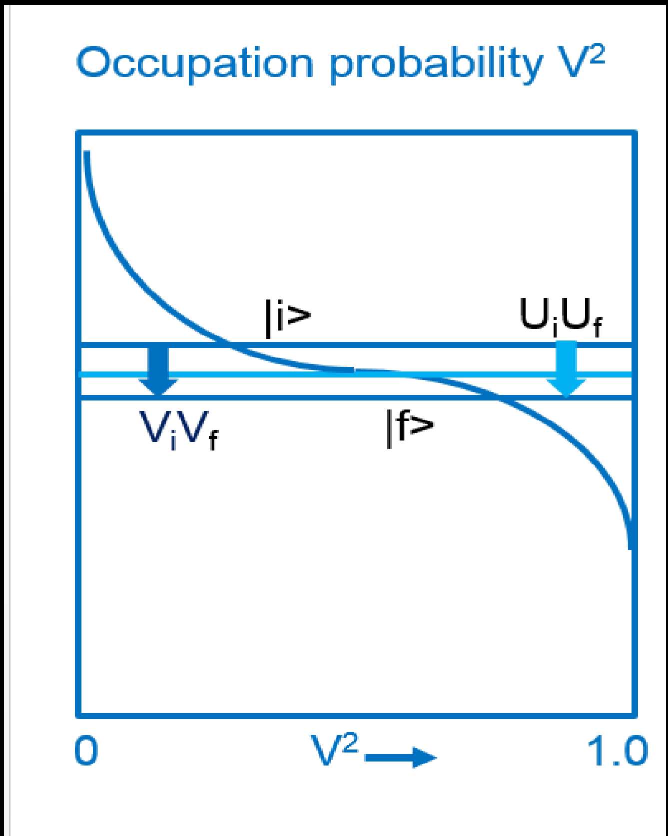
H. Ejiri K. Zuber J. Phys. 43 045201 2016

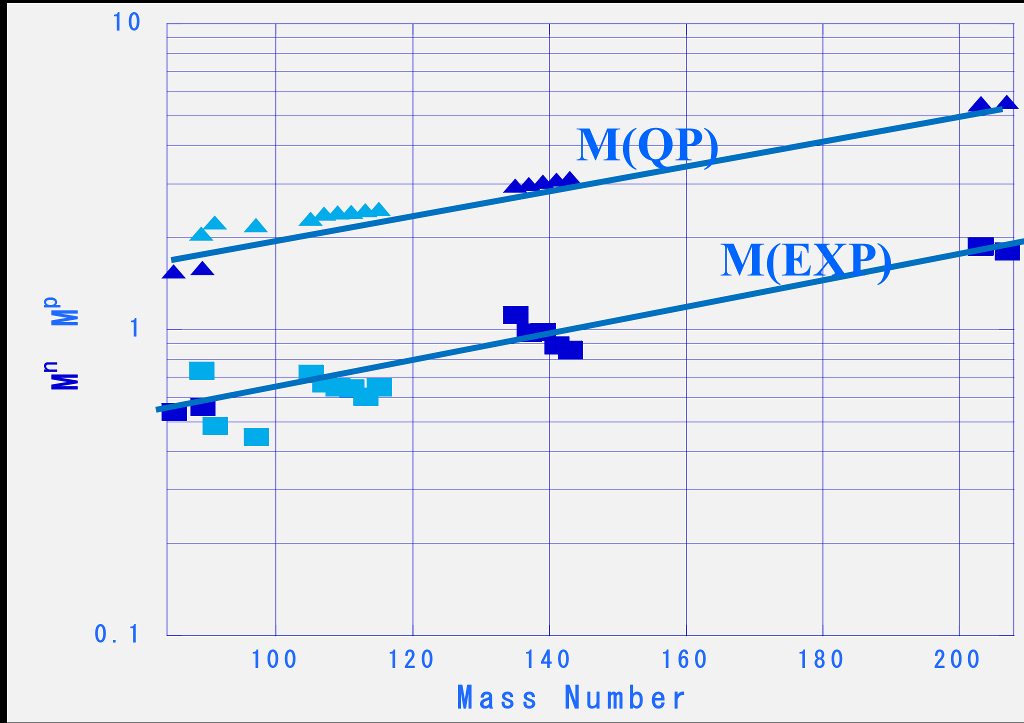
SH (Spin Hexadecapole 4^-) ν-responses

$$M(SH) = <\tau^{\pm} (\sigma \times r^3 Y_3> \gamma$$

$$M(M4) = M_{sp} P$$

$$P = V_i V_f + U_i U_f \sim 1$$





M4 γ M(EXP) =kM(QP)

k~0.3 for proton and neutron

Jokiniemi, Suhonen, Ejiri AHEP2016

CER B(SD) for ^{76}Ge & ^{130}Te from SD NMEs for ^{74}Ge & ^{122}Sn

$d\sigma/d\Omega$=K N B   B=M^2

K kinematical , N distortion factors. $M = V\, j_l(qR)\, M^*$,
$M^* = \int \phi_i\, \phi_f\, r^2\, dr \sim \Delta R$, $M(\gamma) = \int r\, \phi_i\, \phi_f\, r^2\, dr \sim R^{eff}$.
σ(^{76}Ge SD)=k B(^{76}Ge SD) , σ(^{128,130}Te SD)=k B(^{128,130}Te SD) ,
with k from σ(^{74}Ge and ^{122}Sn) and their B(SD) from β-drcay

M(^{76}Ge SD) =1.75 (EXP) 2.1 (FSQP) k=0.23
M(^{128}Te SD) = 3.55 (EXP) 3.4 (FSQP) k=0.22
M(^{130}Te SD) = 4.05 (EXP) 3.7 (FSQP) k=0.22

with k=M/M(QP) =QRPA effect ~0.5 and medium(g_A) effect 0.5

q dependence of M* from σ (q=60MeV/c) , while Mγ(q~5 MeV/c)

$M(SD\ 2^{-})EXP = k\ M(SD\ QP)$

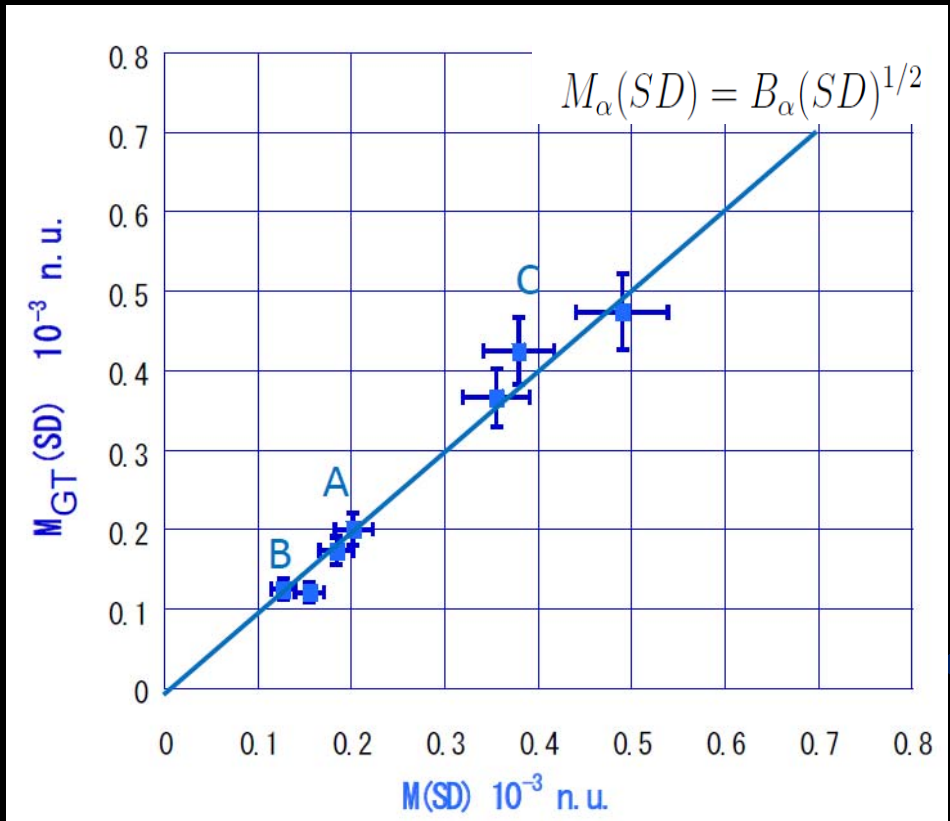
Ejiri D. Frekers
J. Physics G. 43 11L01

$$\frac{\sigma_\alpha(q,\omega)}{d\Omega} = K(E_i,\omega) f_\alpha(q) N_\alpha^D(q,\omega) J_\alpha^2 B(\alpha),$$

α denotes the Fermi, GT and SD mode excita

$$B_\alpha(SD) = R_\alpha B_{R\alpha}(SD),$$

$$B_{R\alpha}(SD) = [\frac{d\sigma_{SD}(\theta_1)}{d\Omega}][\frac{d\sigma_\alpha(\theta_0)}{d\Omega}]^{-1} B(\alpha),$$



	M(CER)	M (FSQP)
^{76}Ge (SD)	2.0	2.1
^{128}Te (SD)	3.55	3.4
^{130}Te (SD)	4.05	3.7

SD NMEs with k~0.25 from ft data in neighboring nuclei.

k=M/M(QP) = QRPA ~0.5 and medium(g_A) effect 0.5

cs G. Letters Sept.

SD RCNP Akimune, Ejiri, RCNP Catania, Munster KVI with