Non-nucleonic correlations in DBD NMEs

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Thanks the organizers

The spin isospin strengths fade away from our place of DBD

Subjects to be discussed

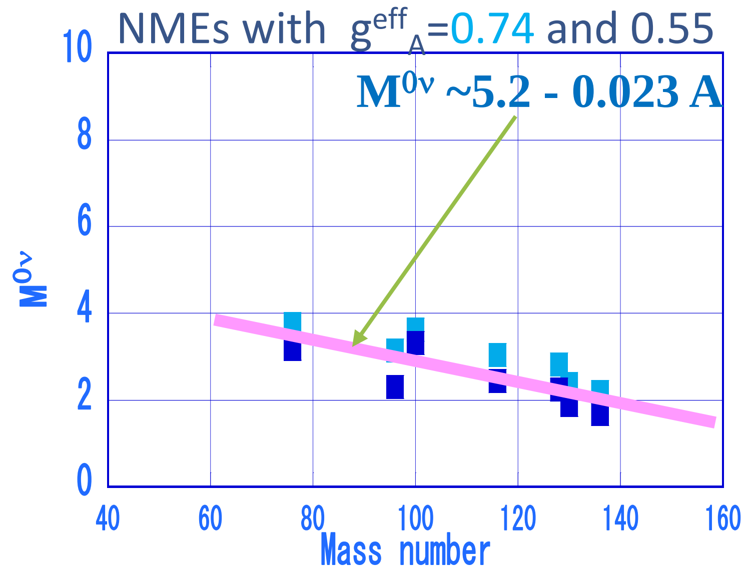
- 1. Experimental approaches to DBD -Astro- ν. NMEs.
- 2. Nuclear physics with N and B (Δ) and
- Spin isospin NMEs and NN and NΔ GRs (Giant Res.)
- 3 GT and SD summed strengths and $g_A(\Delta)$
- 4. QRPA with NN and NΔ
- 5. QP-GT, SD and DBD NMEs by QRPA with NΔ
- 6 . Concluding remarks

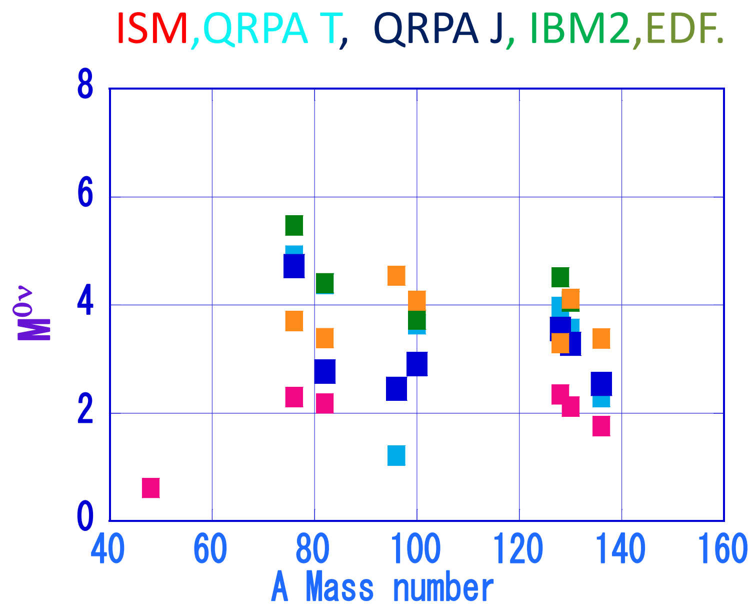
S. Umehara and H. Ejiri, Universe 10-00247 (202$)
H. Ejiri, Phys. Rev. C. Letters C108, L011302 (2023)
H. Ejiri, L. Jokiniemi and J. Suhonen, Phys. Rev. C Letters 105, L02250 (2022).
H. Ejiri, J. Suhonen and K. Zuber, Phys. Rep. 797, 1 (2019).

1. Exp. approaches to DBD and astro ν NMEs

Double –ν & astro-ν P~100 MeV τ σ *l*=0-6

NMES are sensitive to models and τσ correlations,





pnQRPA with experimental inputs

Ejiri Jokiniemi Suhonen
PRC L 104 2022

$M^{0\nu}$~ depends on models
(g_A^{eff}/g_V=1)

ROPP 2014 Vergados Ejiri Simkovic

g^{eff} from $2\nu\beta\beta$
M(EXP)/M(Model)

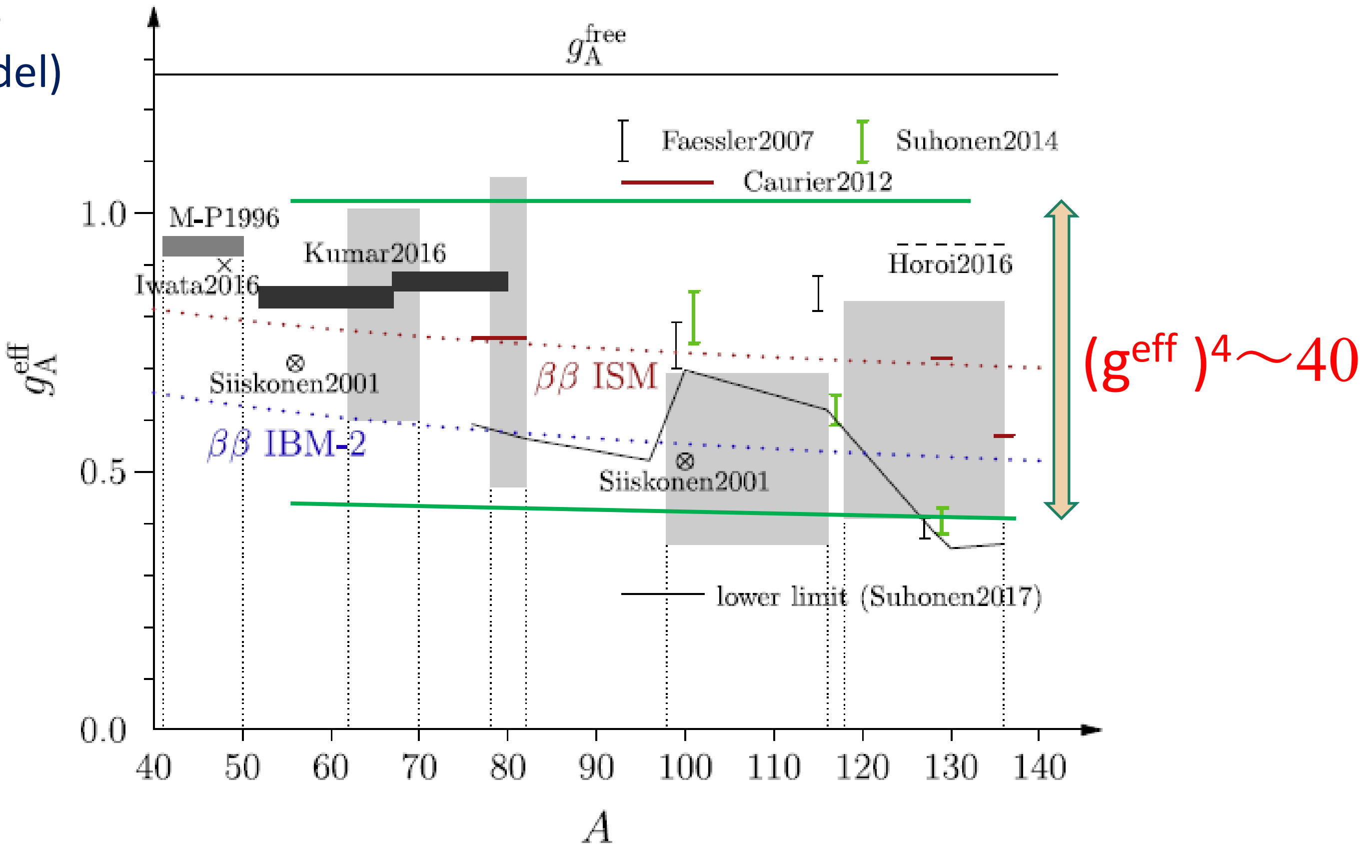
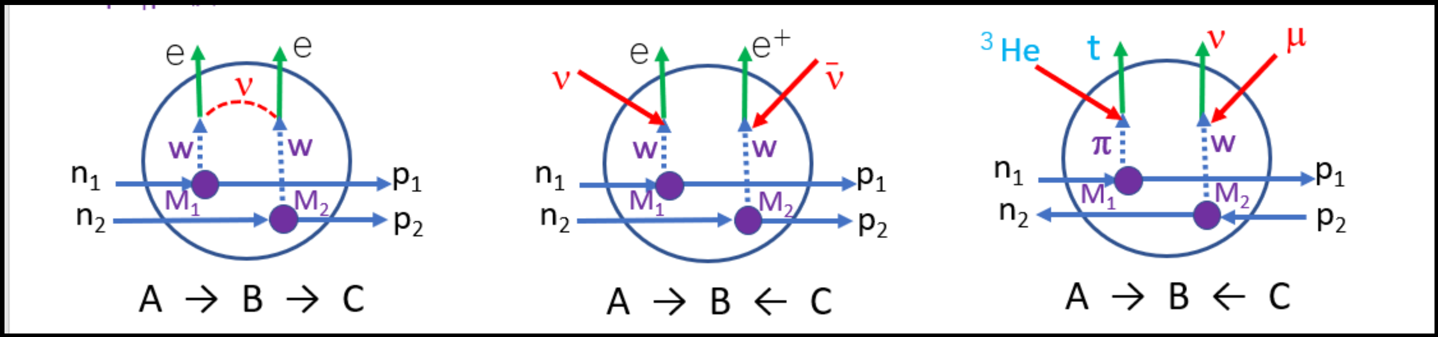
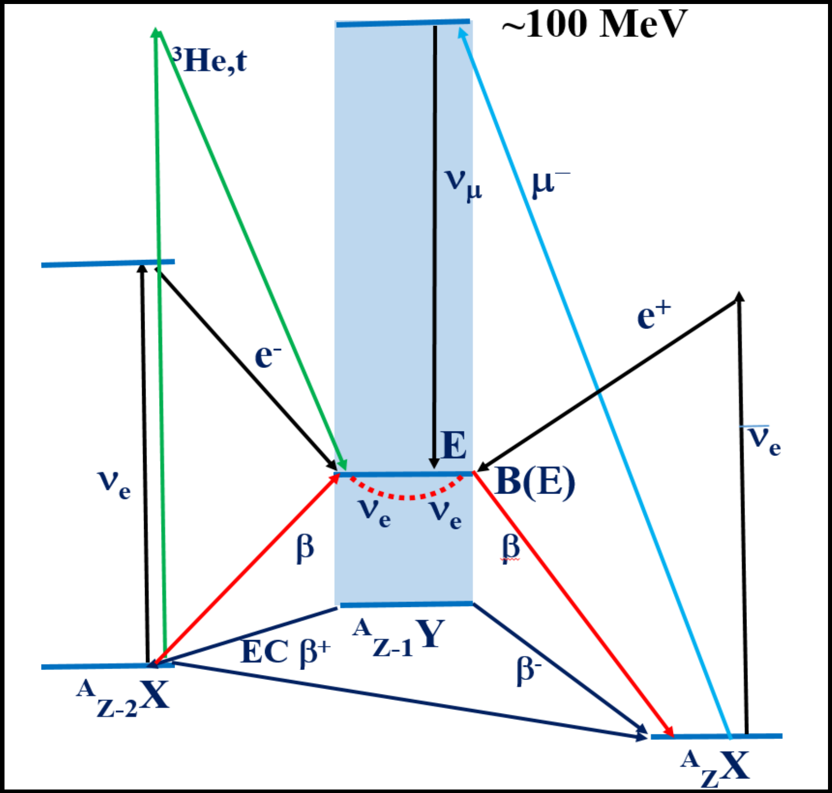


Fig. 29. Effective values of g_A in different theoretical β and $2\nu\beta\beta$ analyses for the nuclear mass range $A = 41 - 136$. The quoted references are *Suhonen2017* [216], *Caurier2012* [233], *Faessler2007* [242], *Suhonen2014* [243] and *Horoi2016* [235]. These studies are contrasted with the ISM β-decay studies of *M-P1996* [229], *Iwata2016* [230], *Kumar2016* [231] and *Siiskonen2001* [228]. For more information see the text and Table 3 in Section 3.1.2 and the text in Section 3.1.3.

. Ejiri H, Suhonen J and Zuber Z 2019 Phys. Rep. 797 1

Double β decay, astro- νs and CERs at RCNP





A: Weak ν interaction is very weak
μ,ν_μ capture

B: EM photon via IAS

C: Strong interaction
Nuclear reaction Strong interaction

Summed strength by CE Nuclear reactions

1 Central interactions
with τ, τσ, and Y_L as weak
F and GT multipole ones.
Used weak τσ response study
Dominant at the RCNP
E/A~0.1-0.2 GeV.

2. Tensor LS as well at
q=0 – 0.5 /fm

3. Distortion and multi-step
process get minimum at
E/A=0.2 - 0.4 GeV.

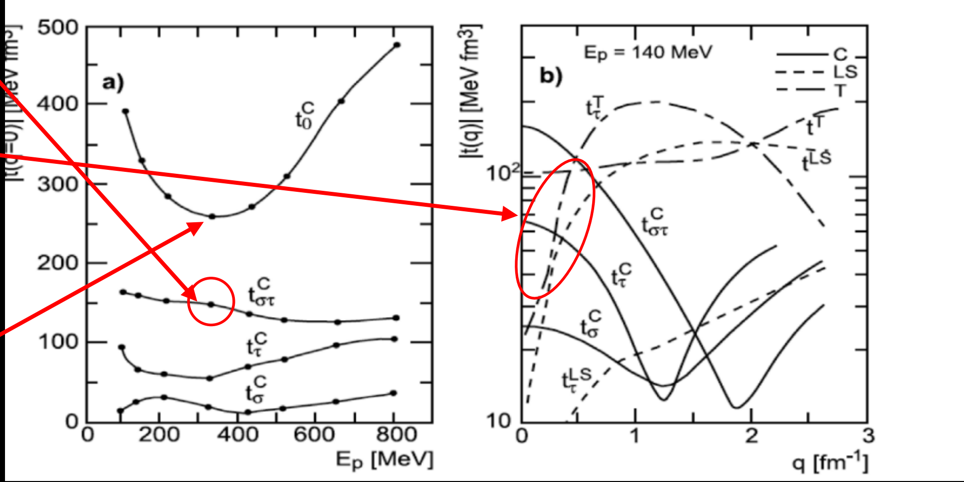
$$V^{\mathrm{eff}} = V^{\mathrm{C}} + V^{\mathrm{LS}} + V^{\mathrm{T}},$$

$$V^{\mathrm{C}} = V^{\mathrm{C}}(r_{ij}) + V^{\mathrm{C}}_{\sigma}(r_{ij})\boldsymbol{\sigma}_i \cdot \boldsymbol{\sigma}_j + V^{\mathrm{C}}_{\tau}(r_{ij})\tau_i\tau_j + V^{\mathrm{C}}_{\sigma\tau}(r_{ij})\boldsymbol{\sigma}_i \cdot \boldsymbol{\sigma}_j\tau_i\tau_j,$$

$$V^{\mathrm{LS}} = \left[V^{\mathrm{LS}}(r_{ij}) + V^{\mathrm{LS}}_{\tau}(r_{ij})\tau_i\tau_j\right]\mathbf{L}\cdot\mathbf{S},$$

$$V^{\mathrm{T}} = \left[V^{\mathrm{LS}}(r_{ij}) + V^{\mathrm{LS}}_{\tau}(r_{ij})\tau_i\tau_j\right]S^{T}_{ij}.$$

H. Ejiri, J. Suhonen and K. Zuber / Physics Reports 797 (2019) 1–102



OMC Muon capture on ^{100}Mo at RCNP

^{100}Mo $(\mu,\nu_\mu)^{100\text{-}n}$Nb

Hashim-Ejiri Shima et al

Jokiniemi Suhonen Ejiri Hashim

I. H. HASHIM *et al.* PHYSICAL REVIEW C **97**, 014617 (2018)

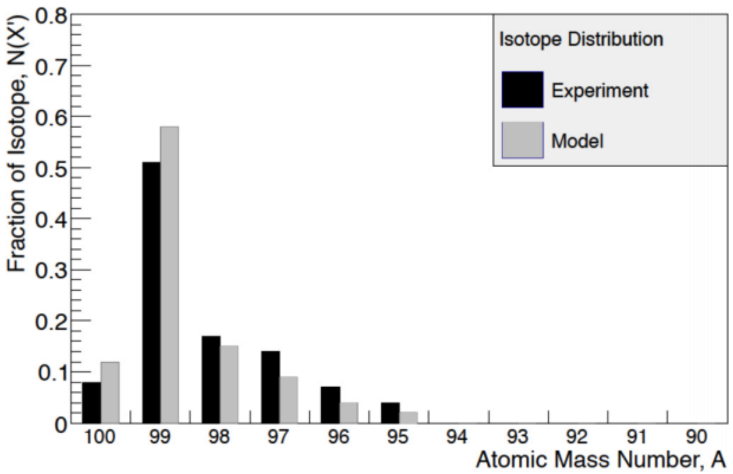


FIG. 5. Nb RI mass distribution for OMCs on ^{100}Mo. The black and light gray histograms are the experimental and calculated yields.

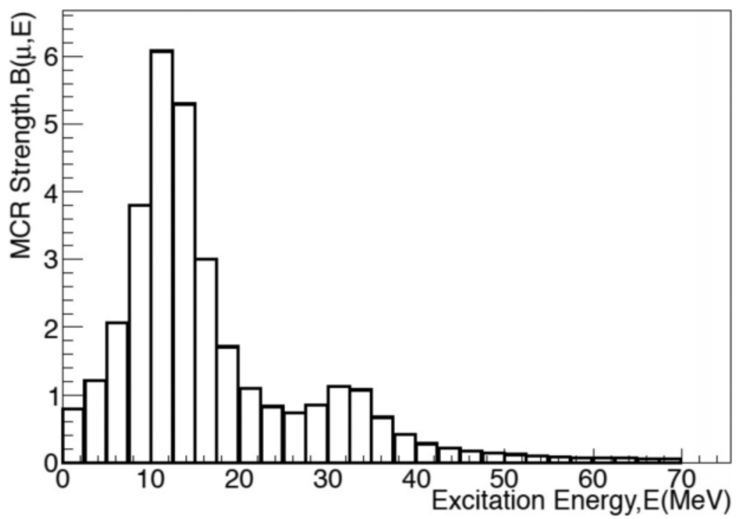


FIG. 6. The OMC strength distribution suggested from the experimental RI distribution. E_{G1} and E_{G2} are the OMC GRs at around

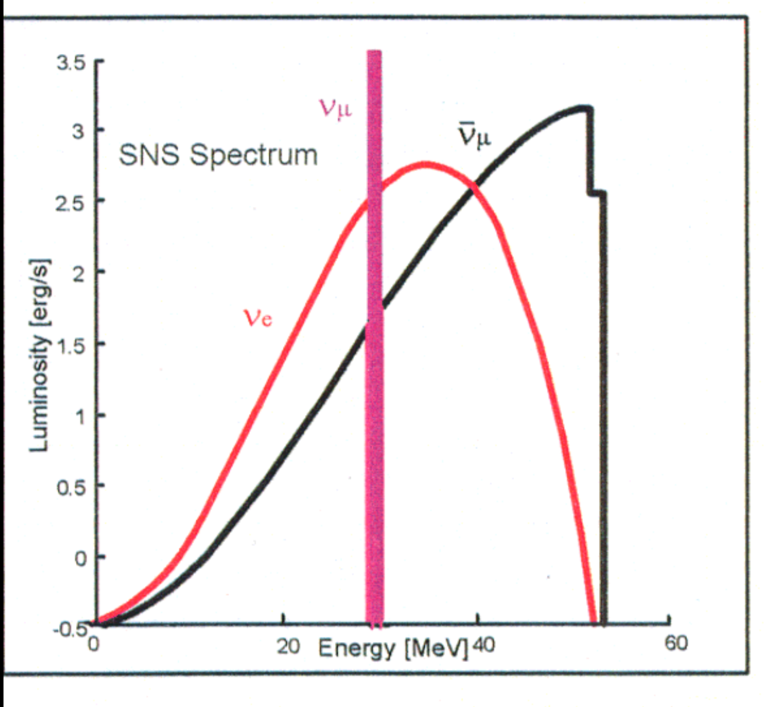
A: ν from intense p

SNS (Spallation N) ORNL JPARC

$\pi^+ = \mu^+ + \nu_\mu \quad \mu^+ = e^+ + \nu_e + \text{anti}-\nu_\mu$

N~10^{15}/sec. 10% is used to irradiate 1 ton target

Yield = 0.6 10^{-1}/sec for 10^{-41}cm^2 for a low GT state



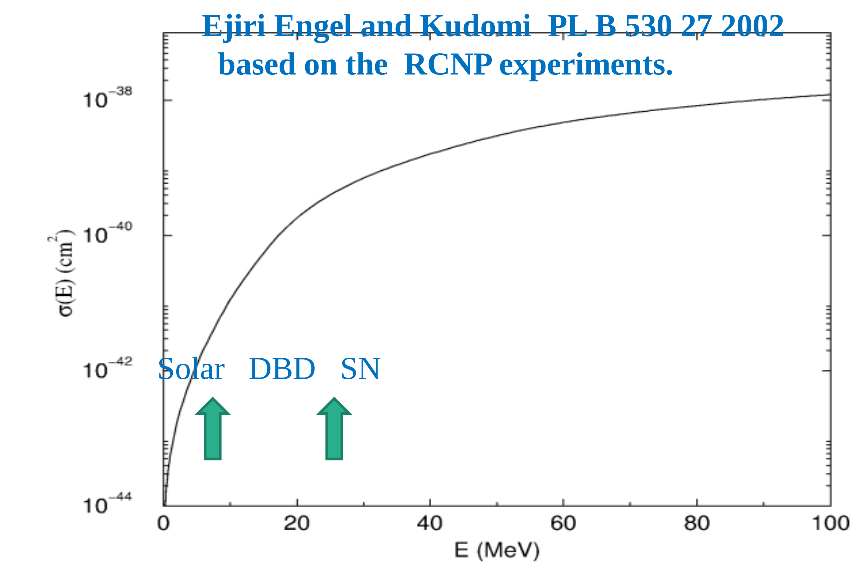


Fig. 1. The calculated cross section for ν_e charged-current scattering on ^{100}Mo, as a function of neutrino energy.

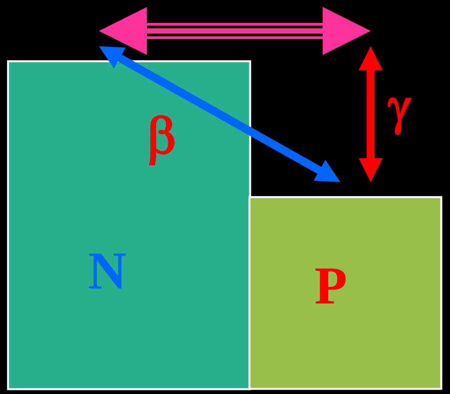
Accelerator ν: reactions H. Ejiri , NIM A503, 276 2003.

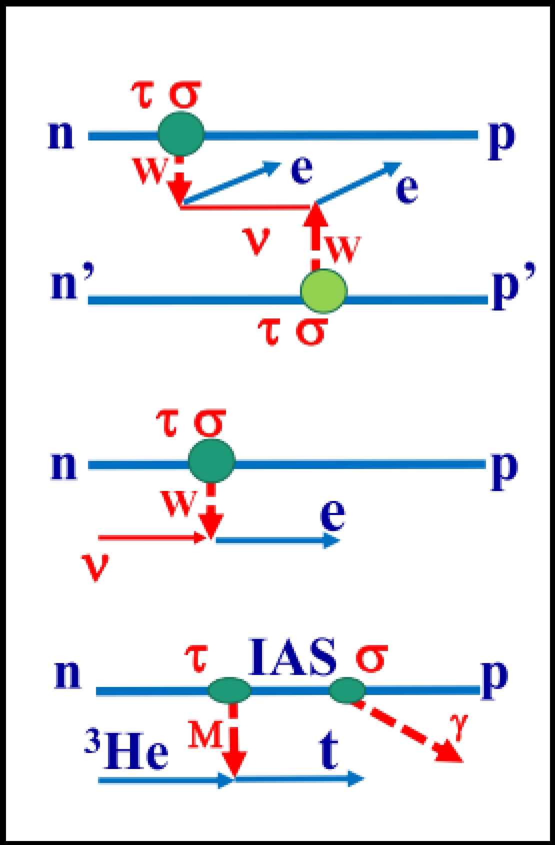
Lepton (e ν μ) CERs μ-ν_μ CER used at Hashim Ejiri RCNP

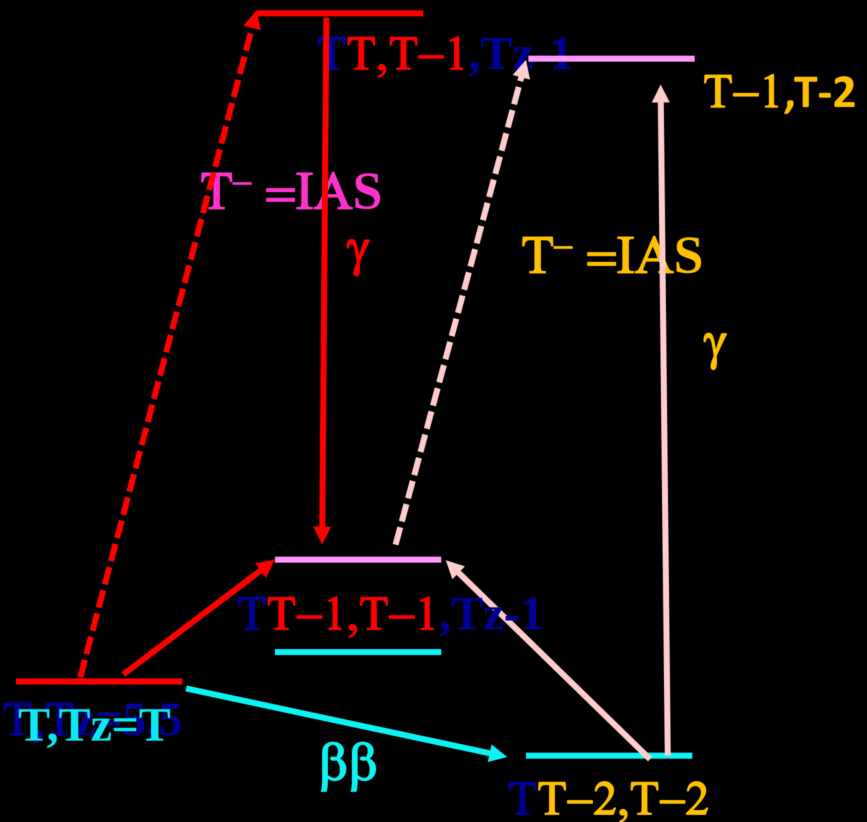
Photon γ

Isospin rotation for
charged current responses via IAS

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



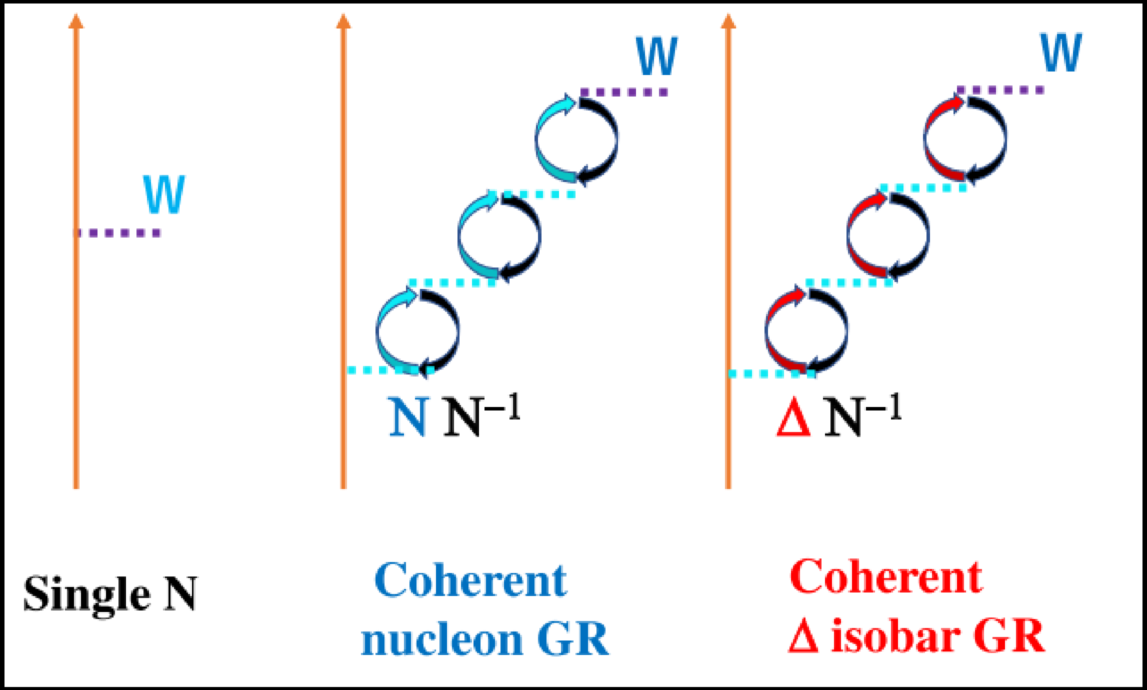




H. Ejiri PRL 21 '68, H. Ejiri PR 38 '78, PR C Letters 108, L011302, 2023

2. Low E (0.01 GeV) nuclear physics with A

A = No of Baryons to be conserved, not nucleon number
Nucleus <0.01 GeV is composed A baryons, p,n,Δ etc. with interaction fields of π, ρ, K, and other mesons.

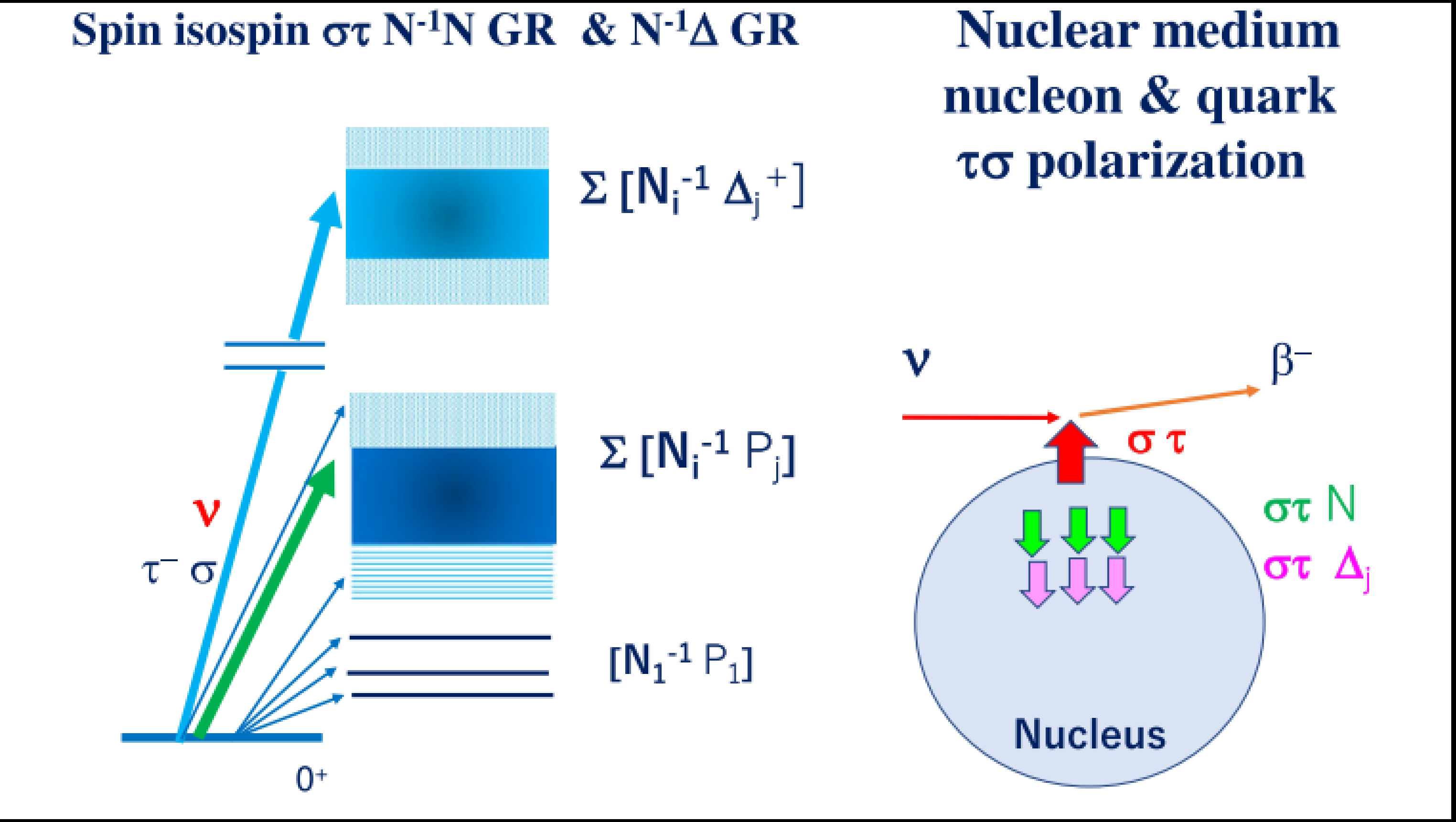


Baryons like Δ(1232) etc are effective in case of resonances, i.e
Amplitude : V=50/A MeV / mass difference =300 MeV =0.001,
Probability=(Amplitude)^2=0.0000001 per nucleon.
NME= 200 coherent Δ amplitudes =0.2 quench or enhance

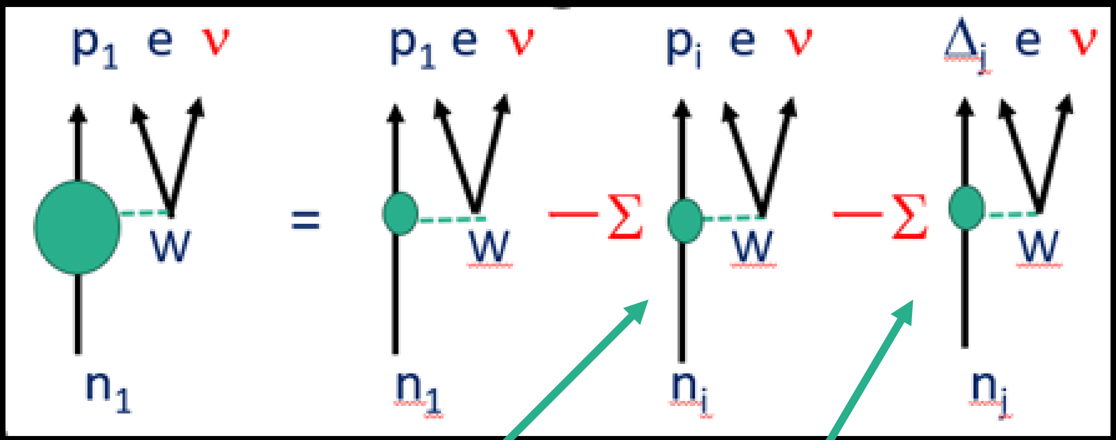
2. Nuclear physics with N and B (Δ) co exist

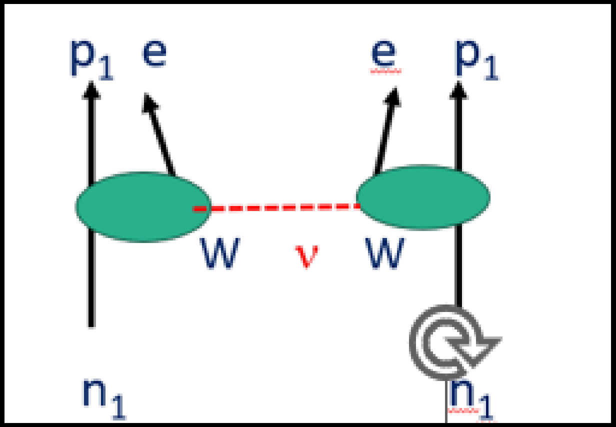
Coherent NN and ND correlations negative polarize τσ fields to get

g_A^{eff} <1 as electric field positive polarize to get pol. e^{eff} > 1



Weak $n^{-1}p$ transition with $n^{-1}p$ GR and $N^{-1}\Delta$ GR





$M=M_0 - \varepsilon M(\text{GR-N}) - \delta M(\text{GR-D})$ Tamn Dankoff

NN: $(V=30\,\text{MeV/A})/10\,\text{MeV}$ = mixing amplitude ~ $3\ 10^{-2}$

$(3\ 10^{-2}) \times$ (N-Z =20 coherent) =0.6 quench .

NΔ: $(V=50\,\text{MeV/A})/300\,\text{MeV}$ mass difference =

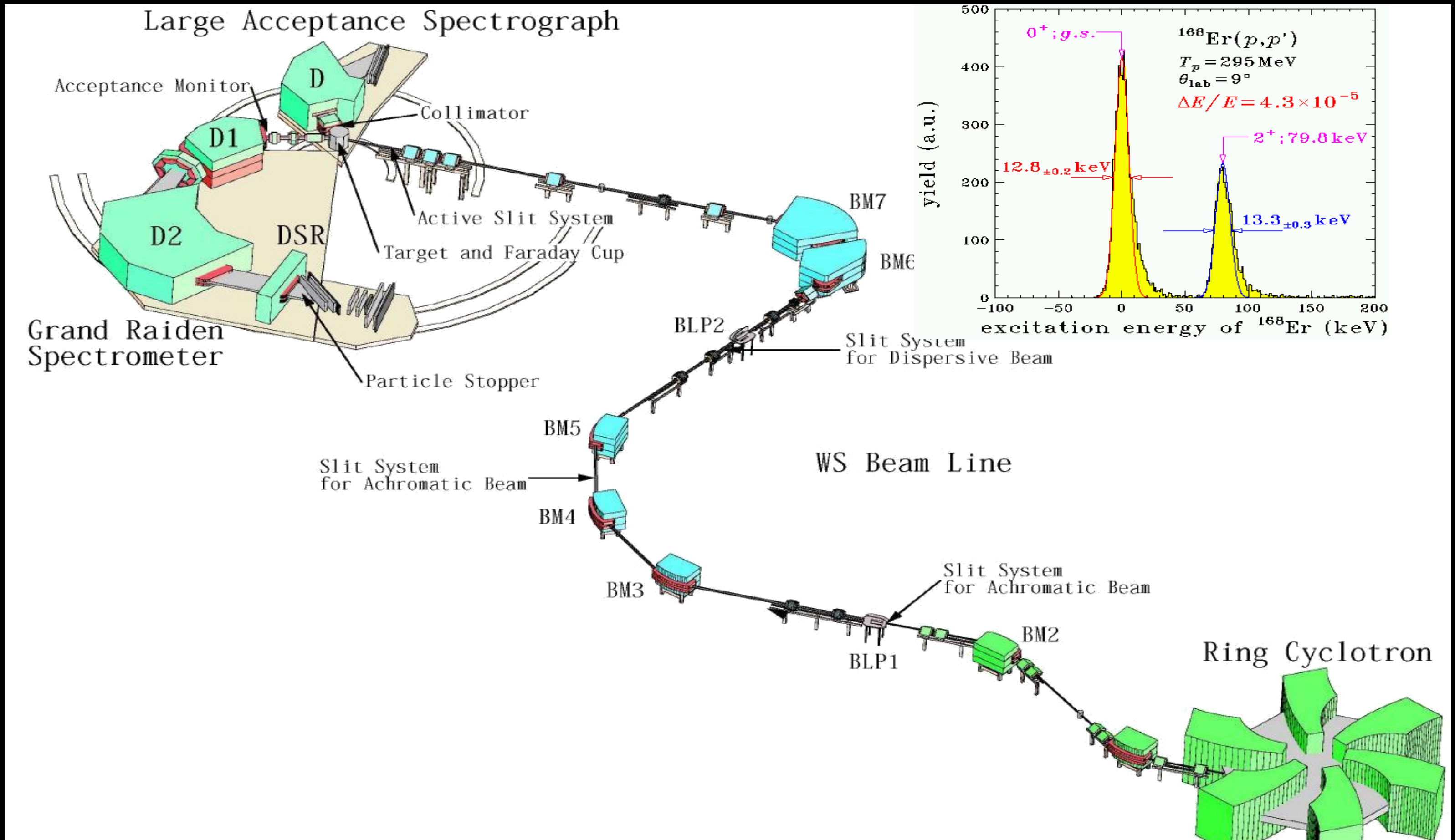
= mixing amplitude for A=100 is ~$6\ 10^{-4}$.

A -nucleons produce 2A Δ of Δ^0 Δ^- Δ^+ Δ^{++} coherent

$6\ 10^{-4} \times 2A=0.3$, reduce $K_\Delta= 0.2$ reduction

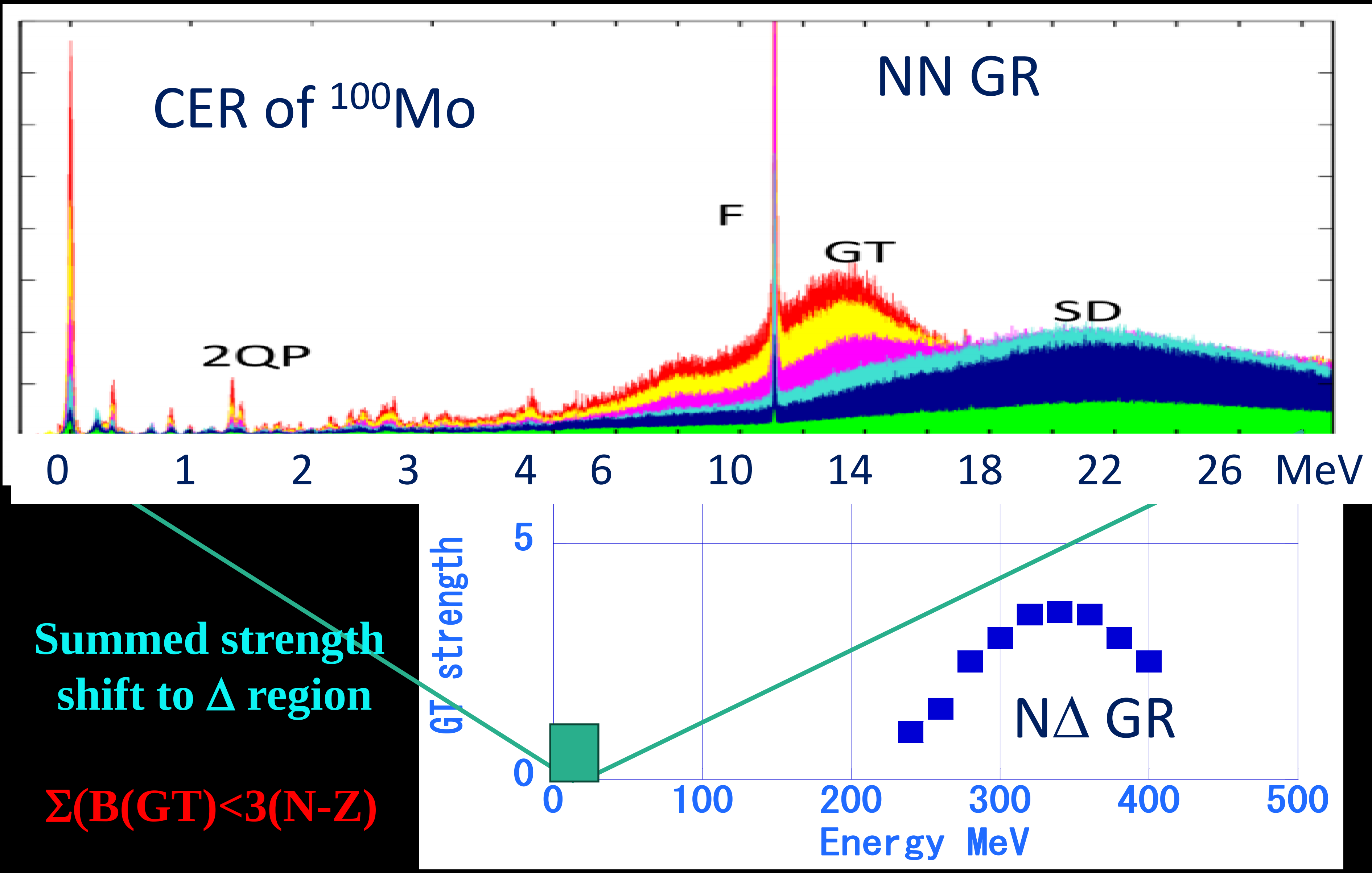
Δ probability in A nucleus $=(6\ 10^{-4}) \times 2A = 10^{-4}$

RCNP cyclotron E/A= 0.1 GeV warrants one step CER. Spectrometer with energy resolution 30 keV is used to select individual states up to 30 MeV of current interest. Momentum transfer 0-200 MeV/c at θ=0-3 deg.,for L=0.1.2. These are powerful for studies of astro-ν and DBD NMEs



WS Beam Line and Two-Arm Spectrometers at RCNP

3. GT and SD summed στ strengths shift to NN GR and NΔ GR reflecting non-nucleonic Δ correlations



Summed strength shift to Δ region

$\Sigma(B(GT)<3(N-Z)$

CER nuclear interaction

Cross section for GT at 0 deg. L=0, J=I+ cross section with $|j_0(qr)|^2$

$\sigma(\sigma^S, f(r)\, r^n, Y_l\ , J)$ L

S=1, 0

n=0, 2,4,6 Radial node n=2,4, Dominant >20 MeV

l =0, 1, 2, 3, 4

J=1+, 1,- 2±, 3± at 0 deg.

GT as well as non GT , which is partly as quasi-free scattering

RCNP (^{3}He.t)

$B(GT^-)$= 0.48 × Sum=3(N-Z) *

$g'_{\Delta N}$ = 0.43

- IFF Sum –rule $\beta^- - \beta^+$=3(N-Z)
- based on the simple nucleon model ,
- Made of A nucleons (not in case of A baryons).

RCNP CERs with (^{3}He,t) reactions

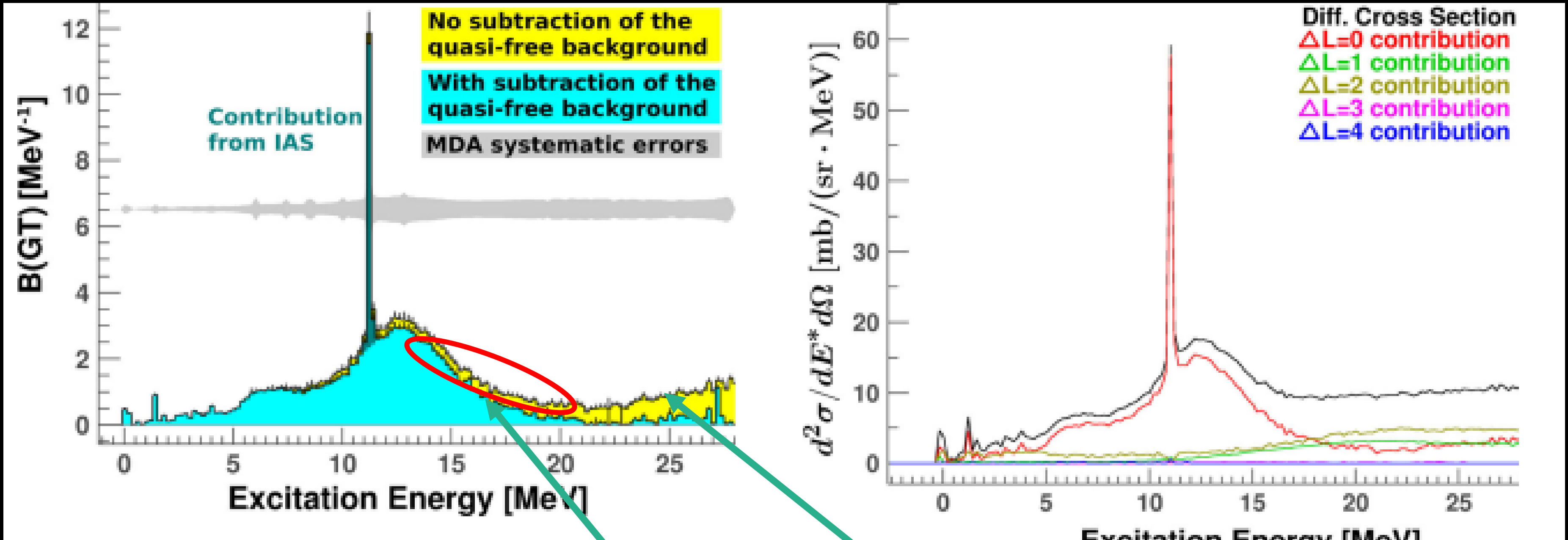


Fig. 14 Same as Fig. 13, but now for the ^{122}Sn(^{3}He, t)^{122}Sb reaction

Fig. 16 Same as Fig. 15, but now for the ^{122}Sn(^{3}He, t)^{122}Sb reaction at 140 MeV/u

QF Quasi-free scattering with Δn=0 (GT), Δn=2, 4, 6 =Non GT from the calculated ratio of n=0 and n=2

C. Douma et al, Ejiri RCNP Euro Phys 56 51 2020

6. NN GR GT Energy and NN interaction

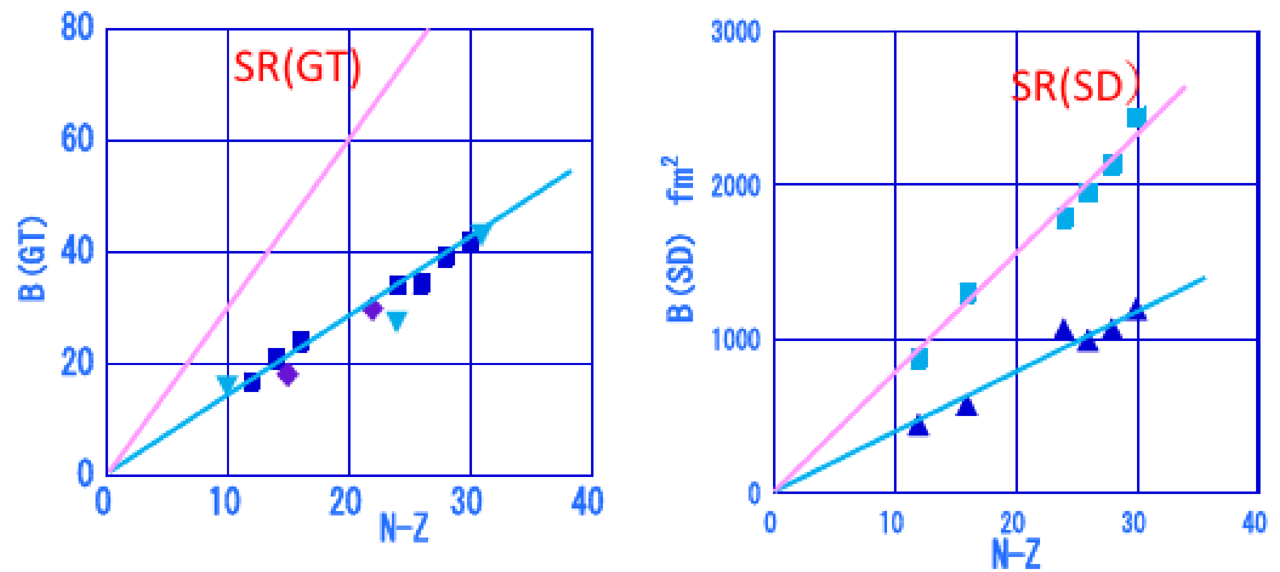


FIG. 3. Left panel: Summed GT strength of S^-(GT). Blue sqares: (^{3}He,t) on DBD nuclei. Blue diamonds: (^{3}He,t) on Sn isotopes. Light blue squares: (p,n). Solid thin line: S_{N}(GT). Thick line: 0.47 S_{N}(GT). Right panel: Summed SD strength of S^-(SD). Blue triangle: (^{3}He,t) on DBD nuclei. Light blue sqaure: sum rule limit of S_{N}(SD). Thick line: 0.50 S^-_{N}(SD).

IFF $S(GT)=3(N-Z)$ $\quad S^-(SD)=\Sigma(2l+1)(N^{eff}/2\pi)\langle r^2\rangle$

$r^2=0.6\ R^2$ with $R\sim1.35\ A^{1/3}$ for n to p effective radius

Summed GT strengths ~ 0.5 of IFF.
One claims

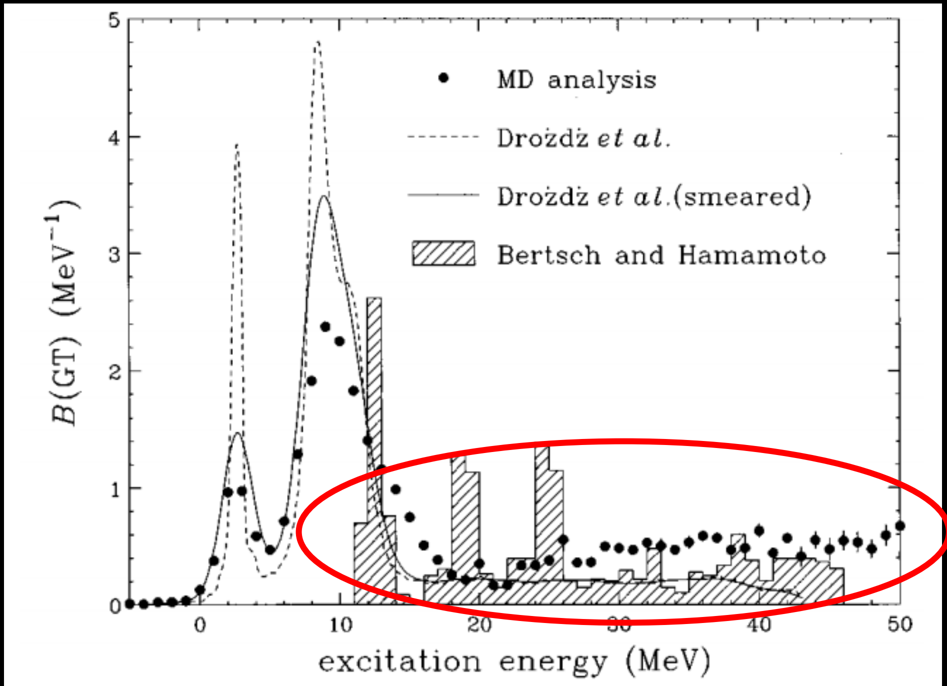
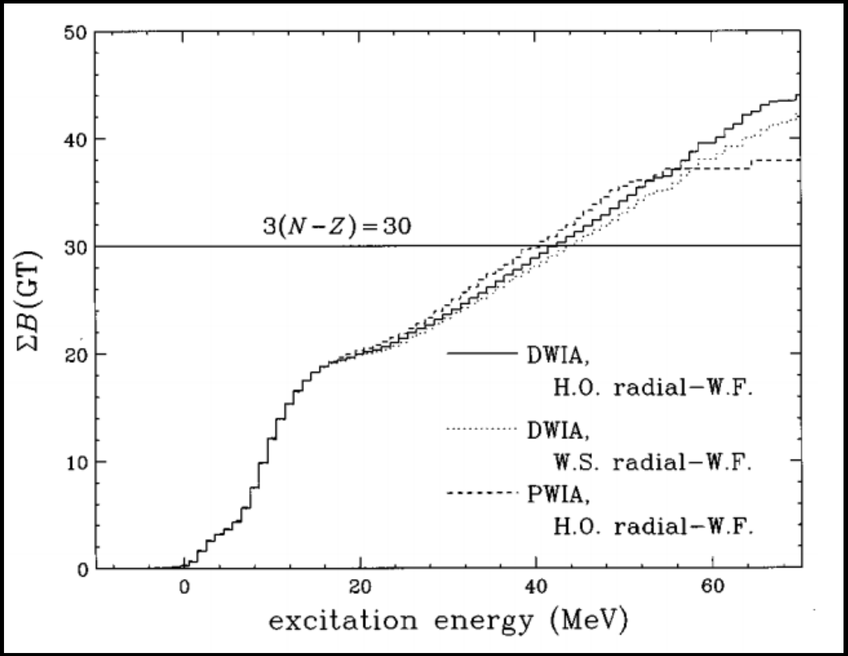


FIG. 13. Gamow-Teller strength distribution (filled circles) obtained from the 0° $L=0$ cross section which is deduced from the MD analysis. The dashed curves and hatched histogram represent the SRPA calculation by Drożdż *et al.* [22] and the perturbative calculation by Bertsch and Hamamoto [15], respectively. The



Wakasa et al PR C 55 2909 1997
Full 3(N-Z) , mainly in 2,4,6 hω

Berch Hamamoto PR C 26 1323 1082
B(GT) > 50 % of 3(N-Z)
beyond GT-GR No Δ coupling

5. Exp. Axial vector ($\tau\sigma$) QP NME

M(QP)= UV M(SP) Vacancy-occupation corrected SP NME

M(EXP) = K_{EX}M(QP) K_{EX}~ 0.21 : reduction coefficient

K_{EX}=K_{QR} K_X K_Δ k_{QR} =0.4 for NN $\tau\sigma$ correlations (NN GR)

K_Δ=0.7 NΔ $\tau\sigma$ correlations (NΔ GR)

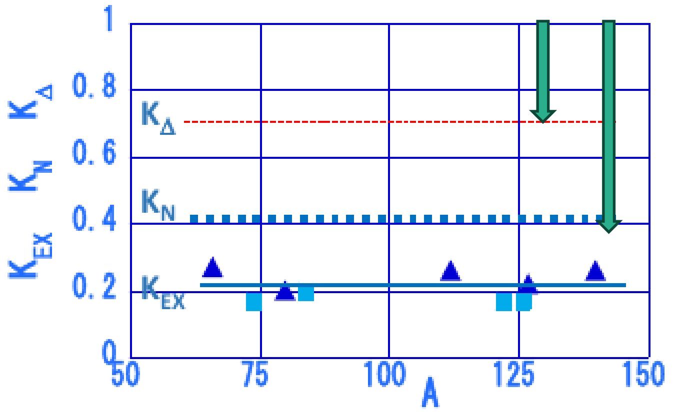
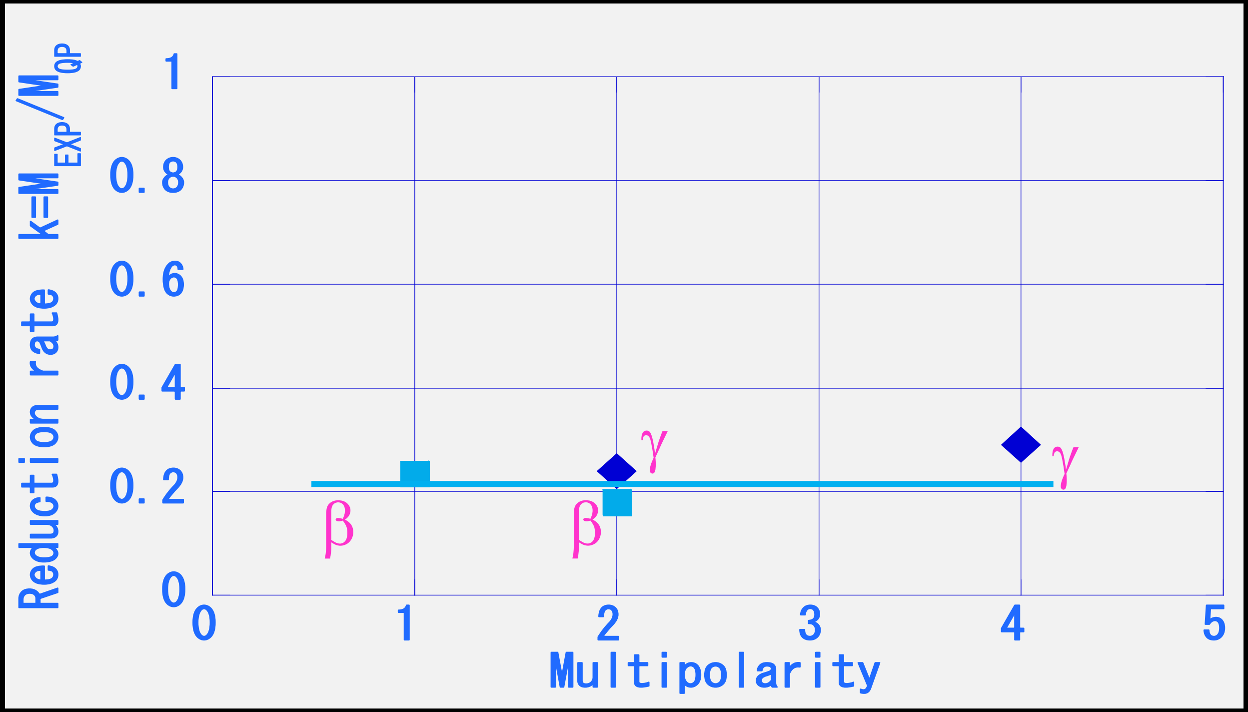


FIG. 4. Quenching coefficients. Blue triangles: K_{EX}(GT) and Blue squares: K_{EX}(SD). Thick blue line: K_{EX}=0.21. Thick dotted blue line: K_N. Thin dotted red line: K_Δ=0.7.

K_m =0.8 NN medium effect (deformation)

Universal reductions of axial vector β & γ in low p



Ejiri Fujita
PR 34 85 1978

k=k(τσ) k(NM)~0.25 with respect to QP

k=k(τσ)~0.4 : Nucleonic long range τσ GR

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

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

H. Ejiri N. Soucouti, J. Suhonen PL B 729 2014 .

L. Jokiniemi J. Suhonen H. Ejiri AHEP2016 ID8417598

g_A=1 for quark in case of hadron physics like one baryon.
g_A=1.27 for nucleon effective g_A in case of nucleon (n, p)
g_A^{eff}=0.7x1.27=0.9 for nuclear physics of effective nucleons with reduced spin –isospin amplitude

Present Δ
0.7 x 1.27 = 0.9

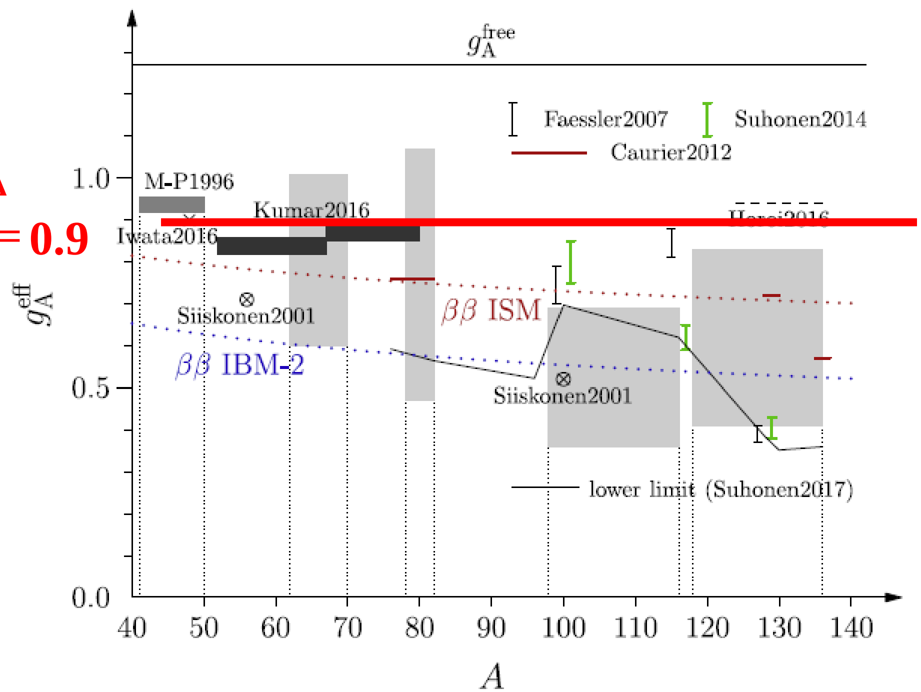
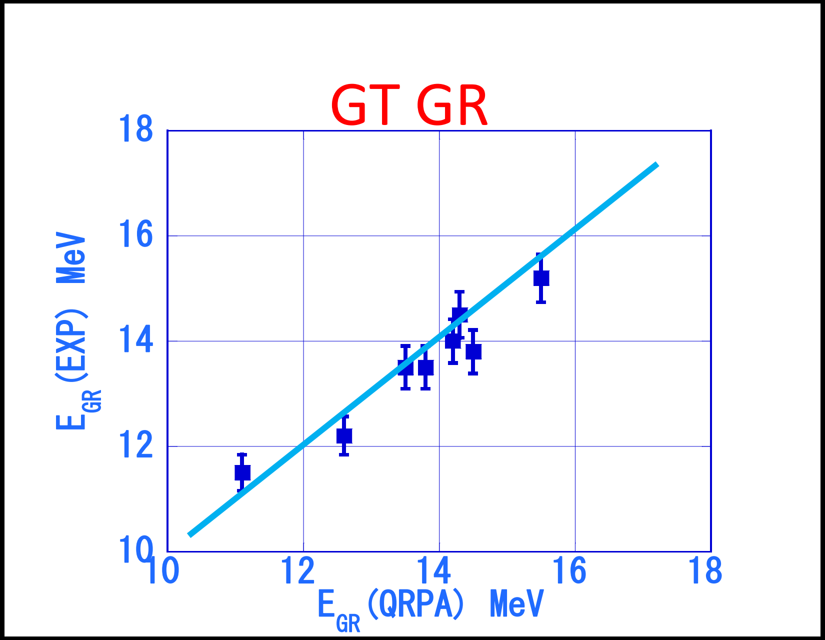


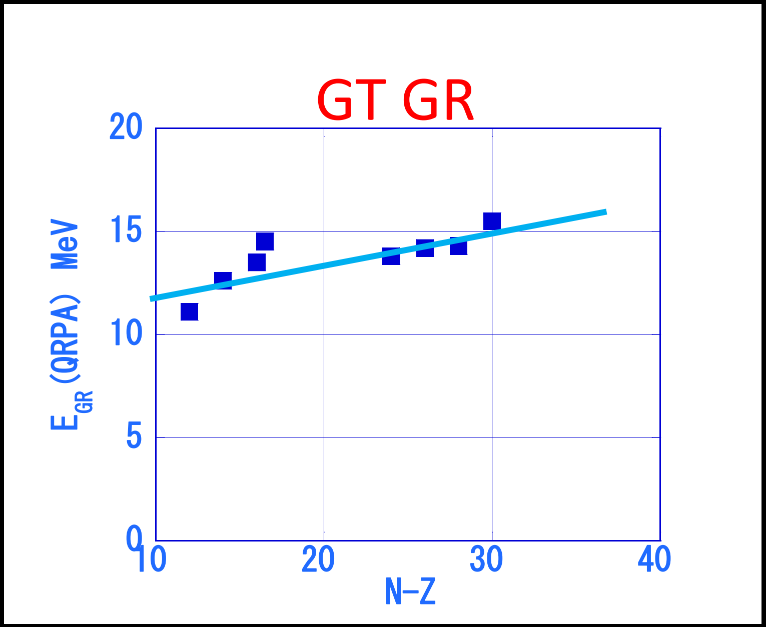
Fig. 29. Effective values of g_A in different theoretical β and $2\nu\beta\beta$ analyses for the nuclear mass range $A = 41 - 136$. The quoted references are *Suhonen2017* [216], *Caurier2012* [233], *Faessler2007* [242], *Suhonen2014* [243] and *Horoi2016* [235]. These studies are contrasted with the ISM β-decay studies of *M-P1996* [229], *Iwata2016* [230], *Kumar2016* [231] and *Siiskonen2001* [228]. For more information see the text and Table 3 in Section 3.1.2 and the text in Section 3.1.3.

. **Ejiri H, Suhonen J and Zuber Z 2019 Phys. Rep. 797 1**

NN GR GT Energy and NN interaction

ND interaction pushes down the NN GR(GT)
NN interaction pushes up the NN GR(GT).
Using ND $g'_{N\Delta}$=0.5 ((χ_Δ=48MeV) from the summed strength,
and the experimental N-GR GT energies,
one gets g'_{NN}=0.62 (χ_N=30 MeV), as Julich Tokyo potential





Delta GR energy and cross section

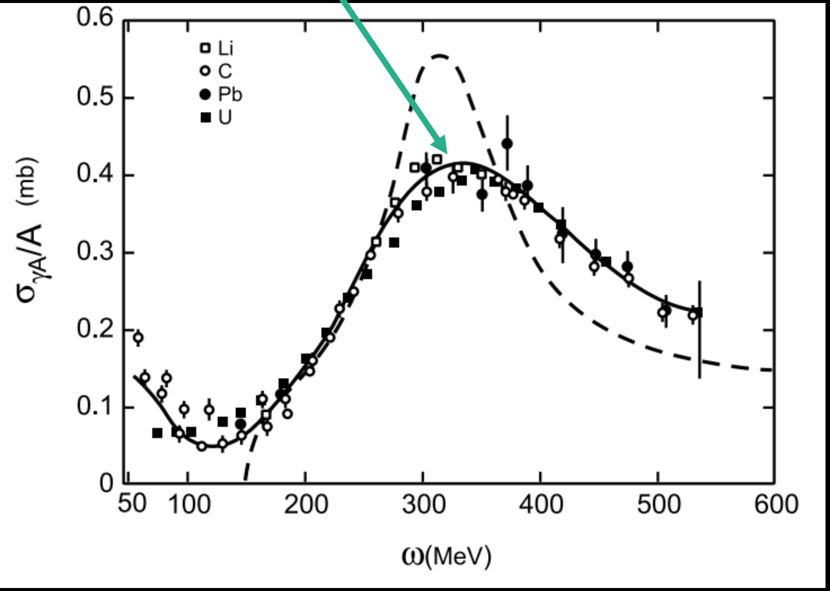
Cross sections are proportional to A as observed in (γ,A)

Recoil energy ~ 50 MeV for p and 0.5 MeV for A=100.

$$E(\mathrm{GR}_\Delta) = E_\Delta(0) + \frac{\chi_\Delta}{A}\frac{6Z+N}{3} = 335\ \mathrm{MeV}$$

48 MeV/A

Δ in a nucleus ~294-10 =284 MeV.



PR 362 303 2002

Giorgio Cattapan[b,c], Lídia S. Ferreira[a,*]

J. Ahrens, L.S. Ferreira, W. Weise, Nucl. Phys. A 485 (1988) 621.

5. QRPA (τσ) QP NME

M(QP)= UV M(SP) Vacancy-occupation corrected SP NME

Reduced(quenched) due to NN and NΔ τσ correlations

$$M = K_{\mathrm{N}\Delta} M_{\mathrm{QP}}, \quad K_{\mathrm{N}\Delta} = \frac{1}{1 + \kappa_{\mathrm{N}} + \kappa_{\Delta}},$$

$K_{N\Delta}$ = NN and NΔ τσ GR correlations
χ_Δ=48 MeV from the summed strength =0,7 κ_Δ =0.43

$$\kappa_N = \frac{\chi_N}{A} \frac{N_f G^2}{\bar{\epsilon} - \epsilon_1},$$

κ_N=2.1 from NN τσ correlations χ_N=30 MeV
derived from EXP GR GT energy

$K_{\Delta N}$ =1/(1+2.1 + 0,43)=0.28,

Further reduction of K_m=0.8 due to nuclear medium effect to get the K=0.21 as observed. This is for all particle transfer reaction.

6. Concluding remarks

1. The summed GT and SD (spin dipole) strengths measured by (^{3}He,t) on DBD nuclei are quenched by $(g^{\Delta}_A/g_A)^2=(0.7)^2$ with respect to 3(N-Z) IFF limit based on a simple N model. This indicates non-nucleonic $\tau\sigma$ Δ (lowest baryon) correlation.

2. Axial vector β QP NME and $\beta\beta$ NME are reduced by K_{EX}~0.21, due to the NN correlations of K_N~0.4 and the nuclear medium effect of K_M~0.8 and the Δ GR effect of K_Δ =0.7.

3. The experimental quenching coefficients are well reproduced by the QRPA with such NN and NΔ interactions of g'_{NN} ~0.62 and $g'_{N\Delta}$=0.5. that reproduce the experimental NN and NΔ GR (giant resonance) energies and the summed strength.

4. The Δ effect, being due to the strong nuclear $\tau\sigma$ interaction, quenches all weak, electro-magnetic and strong $\tau\sigma$ NMEs.

Sun set /rise ?   Thank you for your attention