Beta spectral shapes – A versatile tool for probing weak interactions

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Contents:

- Intro: Effective value of g_A
- Double beta decays and the g_A problem
- Enhancement of axial charge
- Electron spectral shapes and reactor $\bar{\nu}$
- Spectral shapes and the g_A problem
- About backgrounds in rare-events experiments

Effective value of the weak axial coupling g_{A}

The PCVC hypothesis $\Rightarrow g_{\mathrm{A}} = 1.27$

$\Downarrow$ Non-nucleonic degrees of freedom (delta resonances)

$\Downarrow$ Nuclear many-body effects (two-body currents)

$\Downarrow$ Nuclear-model effects (configuration-space truncations, neglect of three-nucleon forces,...)

Effective value: $g_{\mathrm{A}}^{\mathrm{eff}}$

Effective value of g_A affects everything

Motivation:

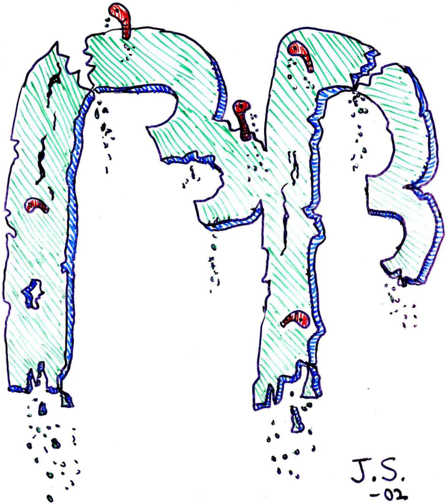
Effective value of the weak coupling g_A is involved in all weak processes, and thus have impact on

- studies of rare β decays
- processes in neutrino physics ($\beta\beta$ decay, low-energy (anti)neutrino-nucleus scattering, nuclear muon capture, . . .)
- processes in astrophysics (allowed and forbidden β decays, (anti)neutrino-nucleus scattering cross sections,. . .)

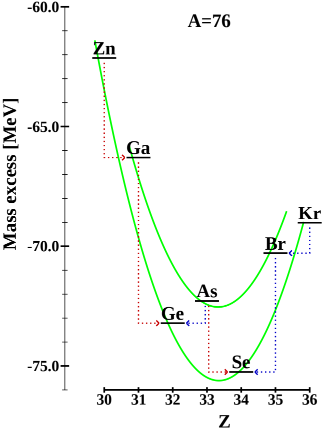
$\Downarrow$

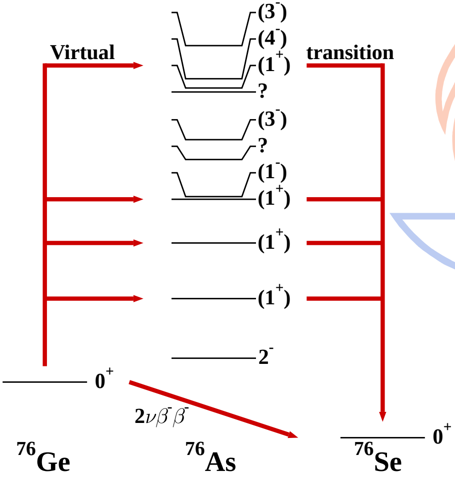
Affects (strongly) the determination of neutrino properties!

Motivation for the Work: Double Beta Decay

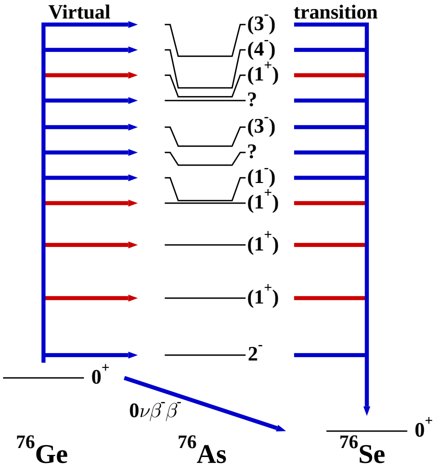


$2\nu\beta\beta$ decay from nuclear-structure point of view





$0\nu\beta\beta$ decay from nuclear-structure point of view



Decay rate:

$$\frac{\ln 2}{T_{1/2}} = (g_{\rm A})^4 g^{(0\nu)}(Q)[M^{(0\nu)}]^2\langle m_\nu\rangle^2$$

- $g^{(0\nu)}(Q) \propto Q^5$ is the phase-space factor
- $M^{(0\nu)}$ = NUCLEAR MATRIX ELEMENT
- Effective neutrino mass:

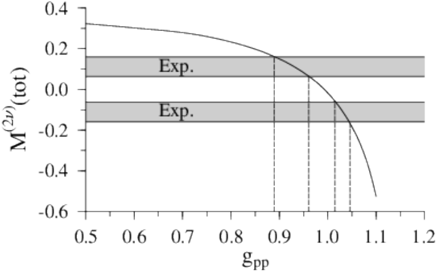
$$\langle m_\nu\rangle = \sum_{j=\text{light}} \lambda_j^{\rm CP}|U_{ej}|^2 m_j$$

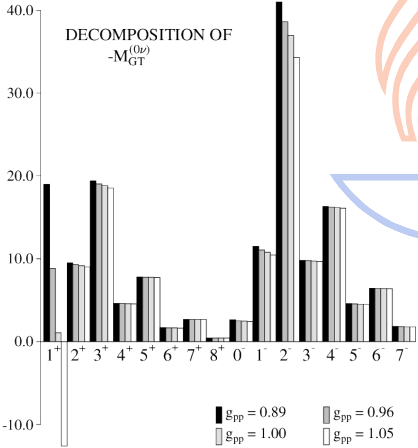
- Light and heavy Majorana-neutrino exchange: J. Hyvärinen and J.S., Phys. Rev. C 91 (2015) 024613

Decomposition of the $0\nu\beta\beta$ NME in pnQRPA

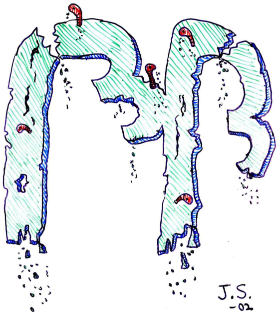
$$M_{\rm GT}^{(0\nu)} = \sum_{J^\pi} M_{\rm GT}^{(0\nu)}(J^\pi) \ ,$$

$$M_{\rm GT}^{(0\nu)}(J^\pi) = \sum_{n\lambda} (0_f^+ \| \sum_j \left[\boldsymbol{\sigma}_j F_\lambda(\mathbf{r}_j)\right]_J t_j^- \| J^\pi{}_n) \times (J^\pi{}_n \| \sum_j \left[\boldsymbol{\sigma}_j F_\lambda(\mathbf{r}_j)\right]_J t_j^- \| 0_i^+)$$





Motivation for the studies of $g_{\rm A}^{\rm eff}$



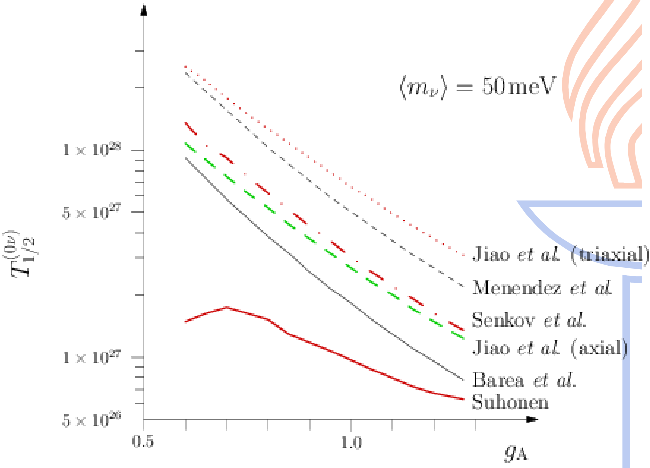
- DECAY:

$$\boxed{2\nu\beta\beta - \text{rate} \sim \left|M^{(2\nu)}_{\rm GTGT}\right|^2 = (g_{\rm A})^4 \left|\sum_{m,n} \frac{M_{\rm L}(1^+_m)M_{\rm R}(1^+_n)}{D_m}\right|^2}$$

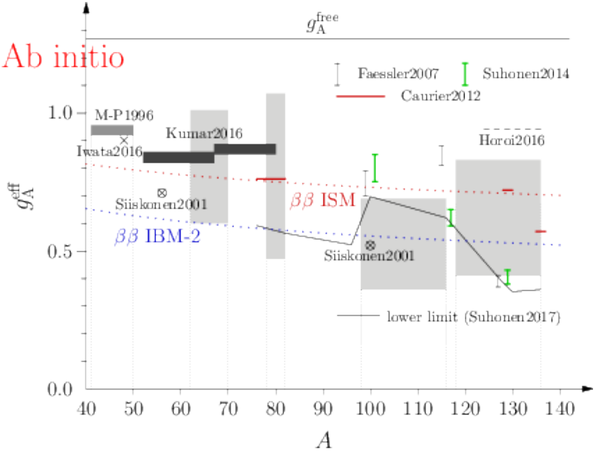
$$\boxed{0\nu\beta\beta - \text{rate} \sim \left|M^{(0\nu)}_{\rm GTGT}\right|^2 = (g_{{\rm A},0\nu})^4 \left|\sum_{J^\pi} (0^+_f||\mathcal{O}^{(0\nu)}_{\rm GTGT}(J^\pi)||0^+_i)\right|^2}$$

Example: $0\nu\beta\beta$ NMEs of ^{76}Ge, effect on the half-life

- Jiao *et al.*: Phys. Rev. C 96 (2017) 054310 (GCM+ISM)
- Menendez *et al.*: Nucl. Phys. A 818 (2009) 139 (ISM)
- Senkov *et al.*: Phys. Rev. C 93 (2016) 044334 (ISM)
- Barea *et al.*: Phys. Rev. C 91 (2015) 034304 (IBM-2)
- Suhonen: Phys. Rev. C 96 (2017) 055501 (pnQRPA + $g_{\rm pp}$ + isospin restoration + data on $2\nu\beta\beta$)



Collection of results extracted from the GT $\beta^\pm$/EC and $2\nu\beta\beta$ calculations



Ab initio: P. Gysbers *et al.*, Nature Physics 15 (2019) 428

- Faessler2007: pnQRPA A. Faessler *et al.*, arXiv 0711.3996v1 [Nucl-th]
- Suhonen2014: pnQRPA J. Suhonen *et al.*, Nucl. Phys. A 924 (2014) 1
- Suhonen2017: pnQRPA J. Suhonen, Phys. Rev. C 96 (2017) 055501
- Caurier2012: ISM E. Caurier *et al.*, Phys. Lett. B 711 (2012) 62
- Horoi2016: ISM M. Horoi *et al.*, Phys. Rev. C 93 (2016) 024308
- M-P1996: ISM G. Martínez-Pinedo *et al.*, Phys. Rev. C 53 (1996) R2602
- Iwata2016: ISM Y. Iwata *et al.*, Phys. Rev. Lett. 116 (2016) 112502
- Kumar2016: ISM V. Kumar *et al.*, J. Phys. G 43 (2016) 105104 Phys. Lett. B 711 (2012) 62
- Siiskonen2001: ISM T. Siiskonen *et al.*, Phys. Rev. C 63 (2001) 055501
- $\beta\beta$ ISM and IBM-2: J. Barea *et al.*, Phys. Rev. C 87 (2013) 014315
- Light hatched regions: pnQRPA H. Ejiri *et al.*, J. Phys. G 42 (2015) 055201 ; P. Pirinen *et al.*, Phys. Rev. C 91 (2015) 054309 ; F. Deppisch *et al.*, Phys. Rev. C 94 (2016) 055501

Enhancement of the axial charge and quenching of g_A

Results from:

Effective value of g_A

as derived from

half-lives and β spectral shapes of

first-forbidden non-unique β decays

First-forbidden non-unique $J^+ \leftrightarrow J^- \ \beta$ decays

Enhancement of the time component of the axial current:

Nuclear matrix elements

$$g_{\rm A}\mathcal{M}_{K+1,K,1} \text{ (unique transitions) } ; \ g_{\rm A}\mathcal{M}_{K,K,1} \ ; \ g_{\rm V}\mathcal{M}_{K,K,0} \ ; \ g_{\rm V}\mathcal{M}_{K,K-1,1}$$

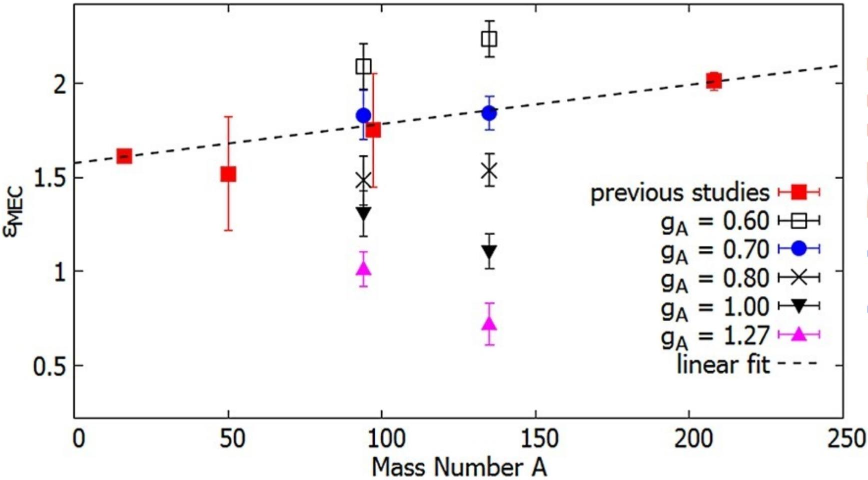
for K-fold forbidden β transitions emerge from the nucleonic current $j^\mu_{\rm N} = g_{\rm V}\gamma^\mu - g_{\rm A}\gamma^\mu\gamma^5$.
Two additional contributions ($g_{\rm A}\mathcal{M}_{0,1,1}$; $g_{\rm A}\mathcal{M}_{0,0,0}$) for $J^+ \leftrightarrow J^- \ \beta$ decays:

$$\begin{array}{lccc} \text{space components} & g_{\rm A}\gamma^k\gamma^5 & \longrightarrow & g_{\rm A}\mathbf{r}\cdot\boldsymbol{\sigma} \\ \text{time component} & g_{\rm A}\gamma^0\gamma^5 & \longrightarrow & g_{\rm A}(\gamma^5)\frac{\boldsymbol{\sigma}\cdot\mathbf{p}_e}{M_{\rm N}c^2} \quad \text{(axial charge)} \end{array}$$

Axial-charge NME $g_{\rm A}(\gamma^5)\mathcal{M}_{0,0,0}$

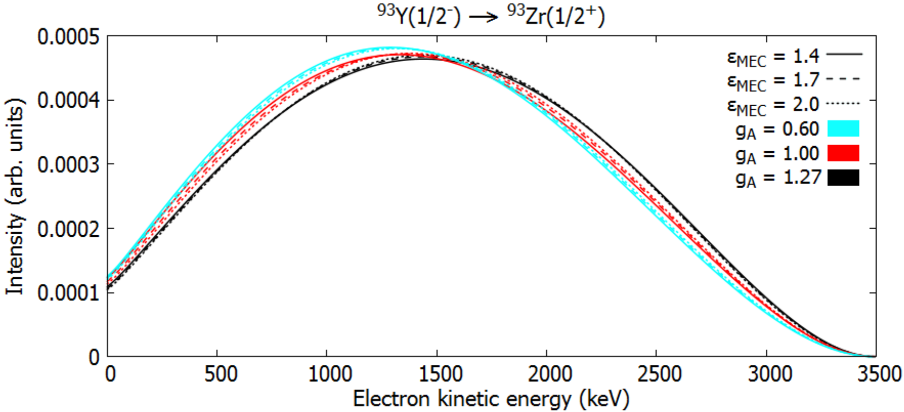
ENHANCED through $g_{\rm A}(\gamma^5) = \varepsilon_{\rm MEC} \times g_{\rm A}$: Predicted 40 years ago by arguments based on soft-pion theorems and chiral symmetry. In the 90's studied from the perspective of exchange of heavy mesons.

Axial-charge strength as function of the mass number



Previous studies: E. K. Warburton, I. S. Towner and B. A. Brown, Phys. Rev. C 49 (1994) 824 ; E. K. Warburton, J. A. Becker, B. A. Brown and D. J. Millener, Annals of Physics 187 (1988) 471 ; E. K. Warburton, Phys. Rev. C 44 (1991) 233.

Effect of axial-charge strength on β spectra



From: J. Kostensalo, J. S., Mesonic enhancement of the weak axial charge and its effect on the half-lives and spectral shapes of first-forbidden $J^+ \leftrightarrow J^-$ decays, Phys. Lett. B 781 (2018) 480 (computed by using the ISM).

Introducing the SSM: Spectrum-Shape Method

$$\boxed{g_{\mathrm{A},0\nu}(J^\pi) \xrightarrow{q\to 0} g_{\mathrm{A}}(J^\pi)}$$

Higher-multipole transitions: Spectrum-Shape Method (SSM)*:

Effective value of $g_{\mathrm{A}}(J^\pi)$

as derived from

electron spectra of

forbidden non-unique β decays

*First introduced in: M. Haaranen, P. C. Srivastava and J. S., Forbidden nonunique β decays and effective values of weak coupling constants, Phys. Rev. C 93 (2016) 034308

Spectral shape of higher-forbidden non-unique β decays

Half-life:

$$t_{1/2} = \kappa/\tilde{S} \, .$$

Dimensionless integrated shape function:

$$\tilde{S} = \int_1^{w_0} S(w_e) \mathrm{d}w_e \, , \quad S(w_e) = C(w_e) p w_\mathrm{e} (w_0 - w_e)^2 F_0(Z_f, w_e) \, .$$

Shape factor:

$$C(w_e) = \sum_{k_e, k_\nu, K} \lambda_{k_e} \left[M_K(k_e, k_\nu)^2 + m_K(k_e, k_\nu)^2 - \frac{2\gamma_{k_e}}{k_e w_e} M_K(k_e, k_\nu) m_K(k_e, k_\nu) \right] ,$$

where

$$\lambda_{k_e} = \frac{F_{k_e - 1}(Z, w_e)}{F_0(Z, w_e)} \, ; \quad \gamma_{k_e} = \sqrt{k_e^2 - (\alpha Z_f)^2} \, ,$$

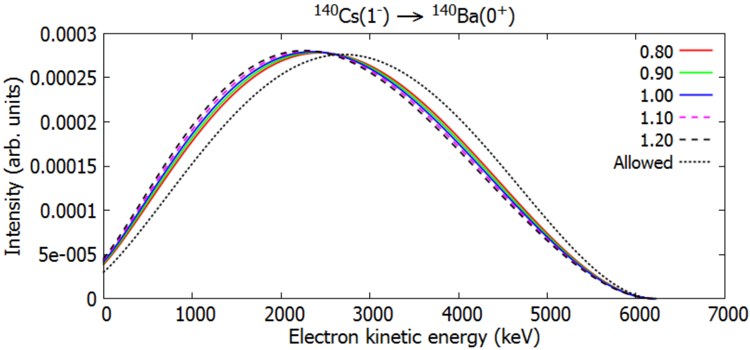
$F_{k-1}(Z, w_e)$ being the generalized Fermi function.

Decomposition of the shape factor:

$$\boxed{C(w_e) = g_\mathrm{V}{}^2 C_\mathrm{V}(w_e) + g_\mathrm{A}{}^2 C_\mathrm{A}(w_e) + g_\mathrm{V} g_\mathrm{A} C_\mathrm{VA}(w_e).}$$

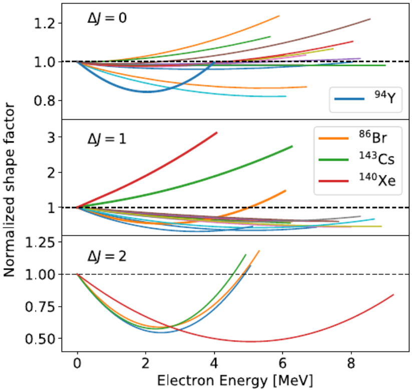
EXAMPLE: 1*st*-forbidden nonunique decay of ^{140}Cs

First-forbidden nonunique β^- transition $^{140}\mathrm{Cs}(1^-) \rightarrow {}^{140}\mathrm{Ba}(0^+)$: a high-yield fission product$\longrightarrow$ Contributes to the reactor-flux anomalies!



For the allowed approximation we have just a multiplicative factor and a universal spectral shape (independent of g_A): $C(w_e)_\mathrm{allowed} = \frac{1}{2J_i+1}\left(g_\mathrm{A}{}^2M_\mathrm{GT}^2 + g_\mathrm{V}{}^2M_\mathrm{F}^2\right) \neq$ function of w_e

Important contributions from first-forbidden β decays to the reactor antineutrino spectra (deviations from the allowed spectral shape)

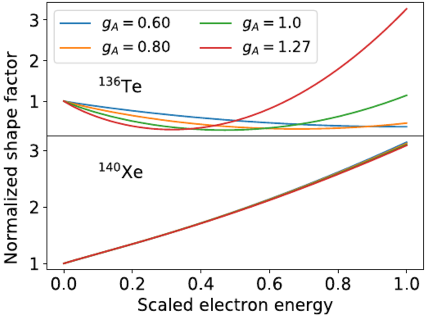


pseudoscalar ($\Delta J = 0$, non-unique),

pseudovector ($\Delta J = 1$, non-unique) and

pseudotensor ($\Delta J = 2$, unique) transitions

Pseudovector transitions with (^{136}Te) and without (^{140}Xe) g_A dependence



The transitions $^{137}\text{Xe}(7/2^-) \rightarrow {}^{137}\text{Cs}(7/2^+_{\text{gs}}, 5/2^+_1)$ are highly interesting: Measurement of the spectral shapes by EXO-200

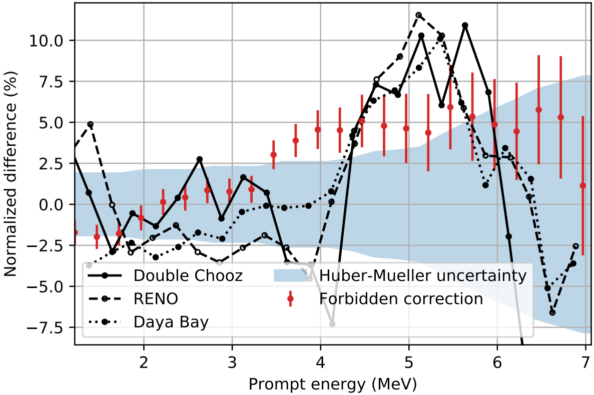
Results from the analyses including the β spectra

Taking into account the (first-forbidden) decays of

^{86}Br(0^+), ^{86}Br(2^+), ^{87}Se, ^{88}Rb, ^{89}Br($3/2^+$), ^{89}Br($5/2^+$), ^{90}Rb, ^{91}Kr($5/2^-$), ^{91}Kr($3/2^-$), ^{92}Rb, ^{92}Y, ^{93}Rb, ^{94}Y(0^+), ^{94}Y(0^+), ^{95}Rb($7/2^+$), ^{95}Rb($3/2^+$), ^{95}Sr, ^{96}Y, ^{97}Y, ^{98}Y, ^{133}Sn, ^{134m}Sb(6^+), ^{134m}Sb(6^+?), ^{135}Te, ^{136m}I, ^{137}I, ^{138}I, ^{139}Xe, ^{140}Cs, ^{142}Cs

changes the $\bar{\nu}$ flux by a few % !

HKSS flux model:



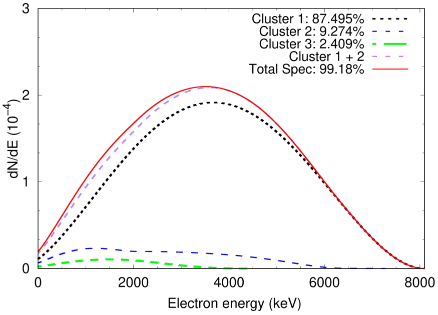
The spectral shoulder appears due to forbidden spectral corrections !

See: L. Hayen, J. Kostensalo, N. Severijns, J.S., First-forbidden transitions in reactor antineutrino spectra/in the reactor anomaly, Phys. Rev. C 99 (2019) 031301(R) ; Phys. Rev. C 100 (2019) 054323

Clear evidence of a contribution to the spectral "bump": The case of ^{92}Rb

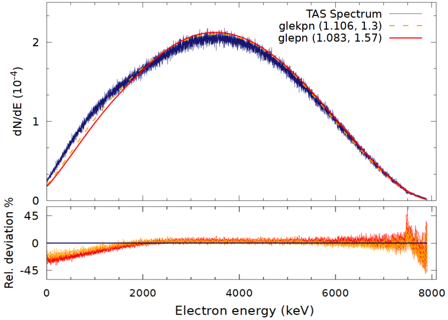
Pioneering calculation of a total β-electron spectrum of a high-Q reactor fission product: The β^- decay of ^{92}Rb with a Q value of 8.095 MeV

Computed cumulative electron spectrum



Cluster 1: gs-to-gs transition (based on TAS-measured branching), Cluster 2: known 1*st*-forbidden transitions (based on TAS-measured branchings), Cluster 3: unresolved higher-energy 1*st*-forbidden and allowed transitions

Comparison of the computed total spectrum with the TAS spectrum. Computations done by using two available shell-model interactions.

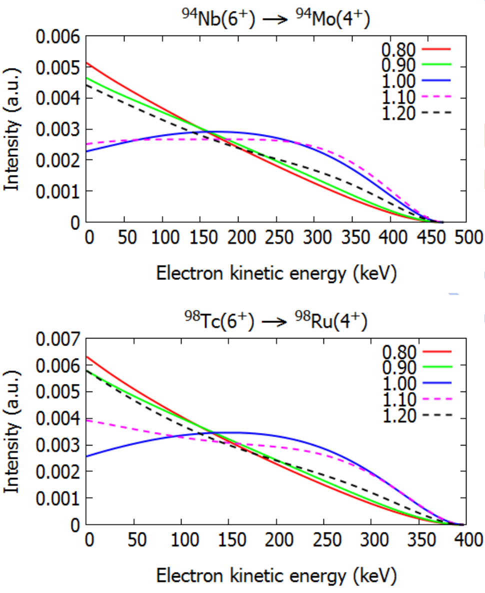


TAS spectrum obtained from the TAS-measured (A. Algora *et co.*) branchings assuming all transitions to be allowed.

ISM-computed β spectra for different values of g_A

Normalized ISM-computed electron spectra for the 2*nd*-forbidden nonunique β^- decays of ^{94}Nb and ^{98}Tc ($g_V = 1.0$).

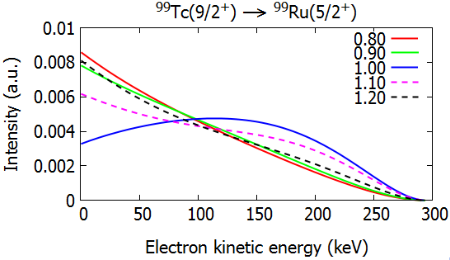
From: J. Kostensalo and J. S., g_A-driven shapes of electron spectra of forbidden β decays in the nuclear shell model, Phys. Rev. C 96 (2017) 024317



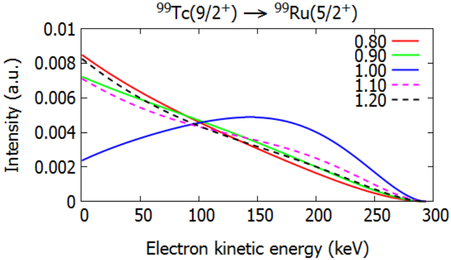
Example: ISM- and MQPM-computed electron spectra

Normalized electron spectra for the 2*nd*-forbidden nonunique β^- decay of ^{99}Tc ($g_V = 1.0$) using different values of g_A.

Going to be treated by the IBS-KNU-KRISS-LUKE-JYFL group: gA EXPERiment and Theory collaboration = gA-EXPERT and the GSSI-INFN-LNGS-LUKE-JYFL Collaboration: Array of Cryogenic Calorimeters to Evaluate Spectral Shapes = ACCESS



(ISM)

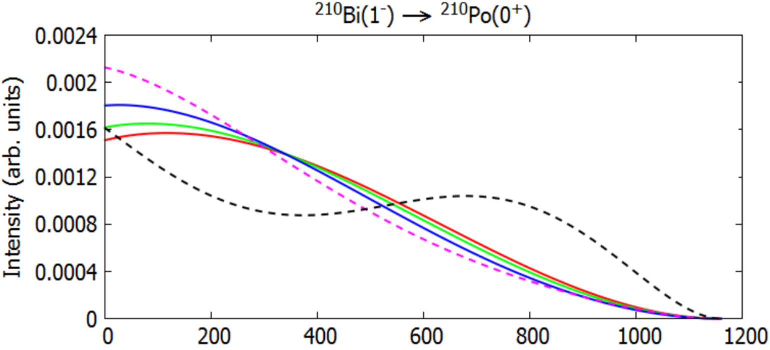


(MQPM)

EXAMPLE: 1*st*-forbidden nonunique decay of ^{210}Bi

First-forbidden nonunique β^- transition $^{210}\mathrm{Bi}(1^-) \to {}^{210}\mathrm{Po}(0^+)$

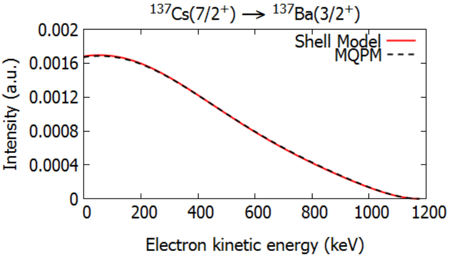
Spectral shapes for different values of $g_A = 0.80$(solid red), 0.90, 1.00, 1.10, 1.20(dashed black)



Measured and currently analyzed by the gA-EXPERT.

β spectral shapes without dependence on g_A

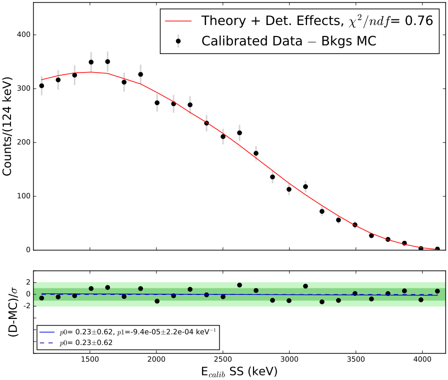
Normalized computed electron spectrum for the 2*nd*-forbidden nonunique β^- decay of ^{137}Cs



From: J. Kostensalo and J. S., Phys. Rev. C 96 (2017) 024317

First-forbidden nonunique β^- decay

^{137}Xe$(7/2^-) \rightarrow {}^{137}Cs(7/2^+)$.



From: S. Al Kharusi *et al.* (EXO-200 Collaboration), Phys. Rev. Lett. 124 (2020) 232502.

Old list of g_A-dependent β-spectrum shapes

Transition	$J_i^{\pi_i}$ (gs)	$J_f^{\pi_f}$ (n_f)	Branching	K	Sensitivity	Nuclear model
^{59}Fe → ^{59}Co	$3/2^-$	$7/2^-$ (gs)	0.18%	2	Moderate	ISM
^{60}Fe → ^{60}Co	0^+	2^+ (gs)	**100%**	2	Moderate	ISM
^{87}Rb → ^{87}Sr	$3/2^-$	$9/2^+$ (gs)	**100%**	3	Moderate	MQPM, ISM
^{94}Nb → ^{94}Mo	6^+	4^+ (2)	**100%**	2	**Strong**	ISM
^{98}Tc → ^{98}Ru	6^+	4^+ (3)	**100%**	2	**Strong**	ISM
^{99}Tc → ^{99}Ru	$9/2^+$	$5/2^+$ (gs)	**100%**	2	**Strong**	MQPM, ISM
^{113}Cd → ^{113}In	$1/2^+$	$9/2^+$ (gs)	**100%**	4	**Strong**	MQPM, ISM, IBFM-2
^{115}In → ^{115}Sn	$9/2^+$	$1/2^+$ (gs)	**100%**	4	**Strong**	MQPM, ISM, IBFM-2
^{136}Te → ^{136}I	0^+	(1^-) (gs)	**8.7%**	1	**Strong**	ISM
^{137}Xe → ^{137}Cs	$7/2^-$	$5/2^+$ (1)	**30%**	1	**Strong**	ISM
^{138}Cs → ^{138}Ba	3^-	3^+ (1)	**44%**	1	**Strong**	ISM
^{210}Bi → ^{210}Po	1^-	0^+ (gs)	**100%**	1	**Strong**	ISM

- Electron spectra of ^{113}Cd (L. Bodenstein-Dresler *et al.*, Phys. Lett. B 800 (2020) 135092) measured by the COBRA collaboration.
- Electron spectrum of ^{115}In measured by using LiInSe$_2$ bolometers (Experimentalists-Jyväskylä collaboration).

BUT: Very recent NSM calculations for medium-mass nuclei including the treatment of the small relativistic vector NME (sNME)

Motivation:

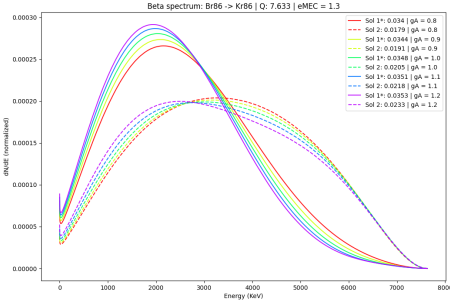
Quest for g_{A} sensitive β spectral shapes in the mass $A = 86-99$ region using the nuclear shell model (NSM) (sNME used as a fitting parameter)

CVC value of sNME $(K, K-1, 1)$ obtained from large vector NME $(K, K, 0)$, K =forbiddeness:

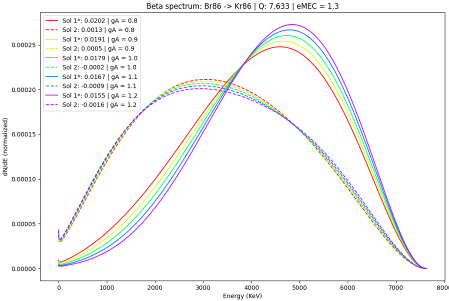
$$\begin{aligned} {}^{V}\mathcal{M}^{(0)}_{KK-11} &= \frac{1}{\sqrt{K(2K+1)}}\left[\frac{(W_0+M_pc^2-M_nc^2)R}{\hbar c}+\frac{6}{5}\alpha Z\right]\ {}^{V}\mathcal{M}^{(0)}_{KK0}/R \\ &= \frac{1}{\sqrt{K(2K+1)}}\left(\frac{\Delta_{T,T-1}R}{\hbar c}\right)\ {}^{V}\mathcal{M}^{(0)}_{KK0}/R \end{aligned} \tag{1}$$

Role of the sNME: Transition $^{86}\mathrm{Br}(1^-) \rightarrow {}^{86}\mathrm{Kr}(0^+)$

sNME 1* (solid lines) can be considered more consistent with the CVC value of sNME



With the *glekpn* NSM Hamiltonian

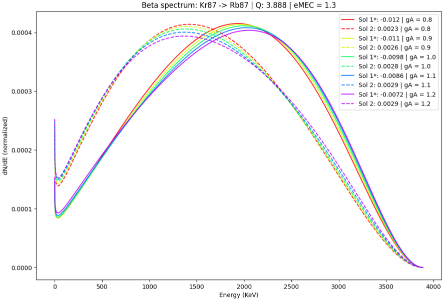


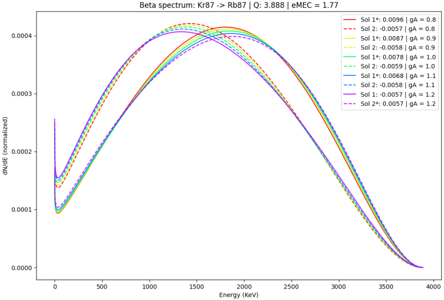
With the *jj45pnb* NSM Hamiltonian

These sepectra depend on g_A, sNME and the NSM Hamiltonian!

Role of the sNME: Transition $^{87}\mathrm{Kr}(5/2^{+}) \rightarrow {}^{87}\mathrm{Rb}(3/2^{-})$

sNME 1* (solid lines) can be considered more consistent with the CVC value of sNME





With the *glekpn* NSM Hamiltonian

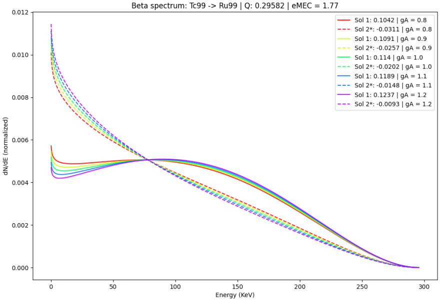
With the *jj45pnb* NSM Hamiltonian

These sepectra depend on g_{A} and sNME!

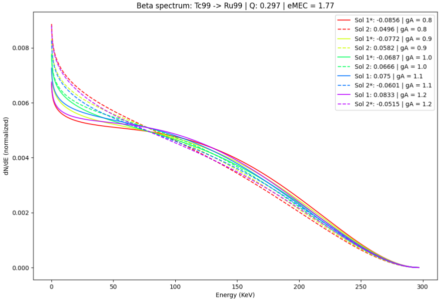
Role of the sNME: Transition $^{99}\mathrm{Tc}(9/2^+) \rightarrow {}^{99}\mathrm{Ru}(5/2^+)$

sNME 2* (dashed lines) can be considered more consistent with the CVC value of sNME

It also looks consistent with the recently measured experimental spectrum !



With the *glekpn* NSM Hamiltonian

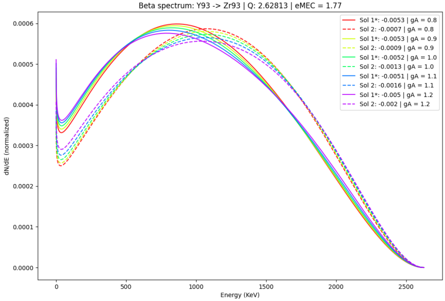


With the *jj45pnb* NSM Hamiltonian

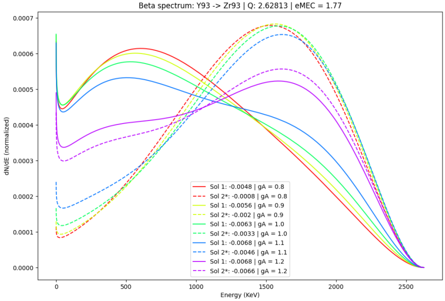
These sepectra depend on g_{A}, sNME and the NSM Hamiltonian!

Role of the sNME: Transition $^{93}\mathrm{Y}(1/2^-) \rightarrow {}^{93}\mathrm{Zr}(3/2^+)$

sNME 1* (solid lines) for the *glekpn* interaction and sNME 2* (dashed lines) for the *jj45pnb* interaction can be considered more consistent with the CVC value of sNME



With the *glekpn* NSM Hamiltonian

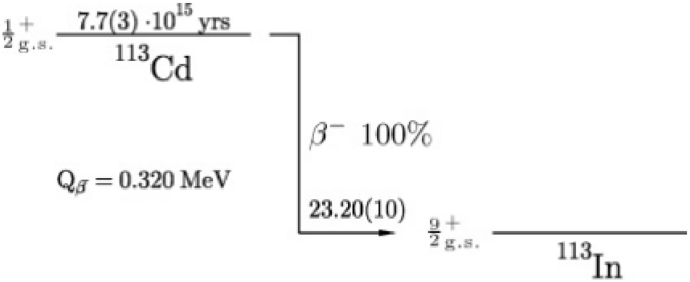


With the *jj45pnb* NSM Hamiltonian

These sepectra depend on g_A, sNME and the NSM Hamiltonian!

EXAMPLE: 4*th*-forbidden nonunique decay of ^{113}Cd

4*th*-forbidden nonunique β^- transition $^{113}\mathrm{Cd}(1/2^+) \rightarrow {}^{113}\mathrm{In}(9/2^+)$



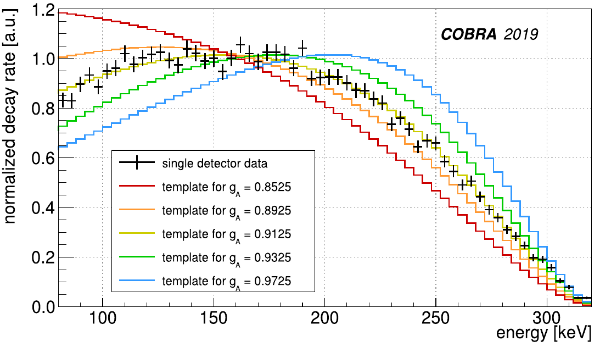
Calculated by using the Interacting Shell Model (ISM), the Microscopic Quasiparticle-Phonon Model (MQPM) and the microscopic Interacting Boson-Fermion Model (IBFM-2).

Decay of ^{113}Cd – Comparison with data

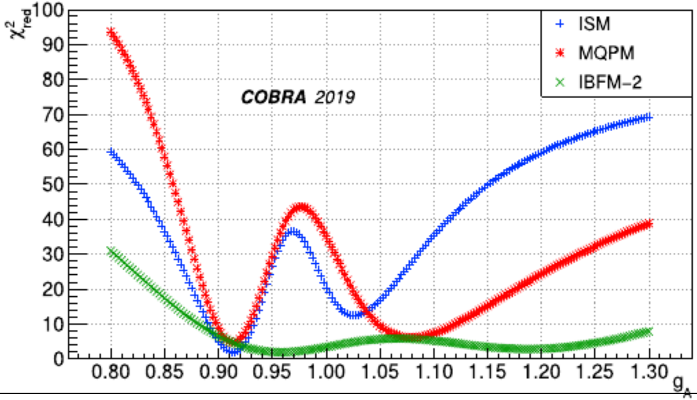
Normalized electron spectra for the *4th*-forbidden nonunique β^- transition $^{113}\mathrm{Cd}(1/2^+) \rightarrow {}^{113}\mathrm{In}(9/2^+)$ ($g_\mathrm{V} = 1.0$).

Experimental data from The COBRA collaboration: PLB2020: L. Bodenstein-Dresler *et al.*, Phys. Lett. B 800 (2020) 135092.

Measured spectrum by detector no. 54:



Decay of ^{113}Cd – Comparison with data



PLB2020 : $\bar{g}_{\rm A}$(ISM) $= 0.914 \pm 0.008$; PLB2021 $:= 0.907 \pm 0.064$(sNME included)
PLB2020 : $\bar{g}_{\rm A}$(MQPM) $= 0.910 \pm 0.013$; PLB2021 $:= 0.993 \pm 0.063$(sNME included)
PLB2020 : $\bar{g}_{\rm A}$(IBFM-2) $= 0.955 \pm 0.035$; PLB2021 $:= 0.828 \pm 0.140$(sNME included)

PLB2021: J. Kostensalo, J. S., J. Volkmer, S. Zatschler and K. Zuber, Phys. Lett. B 822 (2021) 136652

Decay of ^{113}Cd – $g_{\mathrm{A}}^{\mathrm{eff}}$ using spectral moments

SMM = Spectral Moments Method

$$\mu_n = \int_{w_{\mathrm{thr}}}^{w_0} S(w_e) w_e^n \mathrm{d}w_e \, ,$$

$n = 0$ ↔ area under the spectral curve ↔ $T_{1/2}$

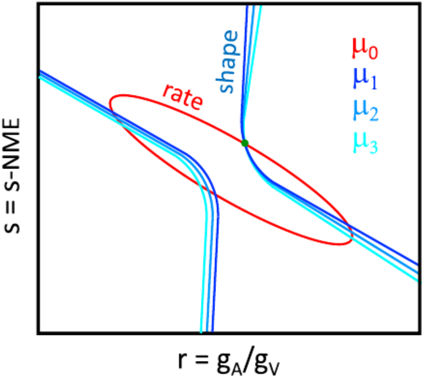
$n = 1$ ↔ mean energy

$n = 2$ ↔ variance

Usually only first few moments μ are enough!

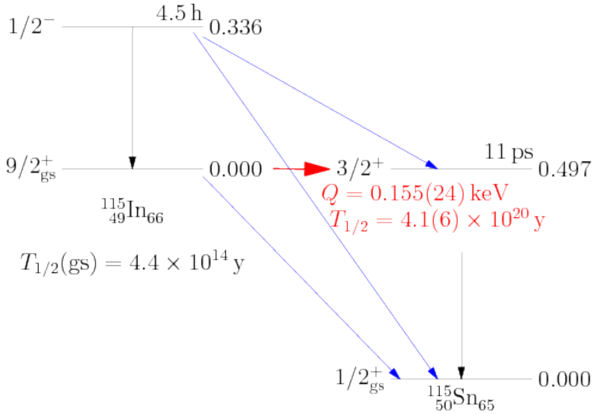
Result from

J. Kostensalo, E. Lisi, A. Marrone and J. S., ^{113}Cd β-decay spectrum and g_{A} quenching using spectral moments, Phys. Rev. C 107 (2023) 055502.



$$\bar{g}_{\mathrm{A}}(\mathrm{ISM}) = 0.96 - 0.99$$
$$\bar{g}_{\mathrm{A}}(\mathrm{IBFM\text{-}2}) = 1.03 - 1.13$$
$$\bar{g}_{\mathrm{A}}(\mathrm{MQPM}) = 1.02 - 1.07$$

EXAMPLE: 4*th*-forbidden nonunique transition $^{115}\mathrm{In}(9/2^+) \rightarrow {}^{115}\mathrm{Sn}(1/2^+)$



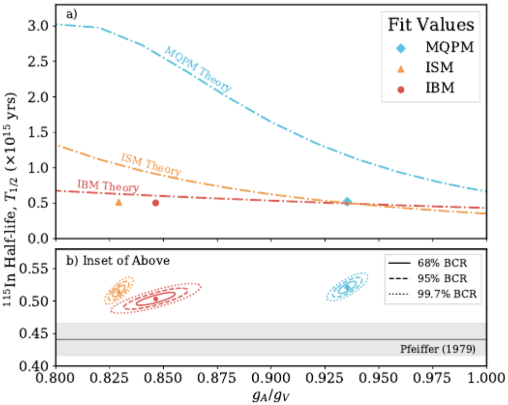
Interesting ultra-low Q-value transition: The 2*nd*-forbidden unique transition $^{115}\mathrm{In}(9/2^+) \rightarrow {}^{115}\mathrm{Sn}(3/2^+)$ has the smallest known Q value of a nuclear transition: J. S. E. Wieslander *et al.*, Phys. Rev. Lett. 103 (2009) 122501; B. J. Mount *et al.*, Phys. Rev. Lett. 103 (2009) 122502.

Decay of ^{115}In – Comparison with data

Normalized electron spectra for the *4th*-forbidden nonunique β^- decay $^{115}\text{In}(9/2^+) \rightarrow {}^{115}\text{Sn}(1/2^+)$ ($g_\text{V} = 1.0$).

Result from

The CEA-CNRS-CSNSM-INR-JYFL-MIT-LUKE-UCB collaboration: A. F. Leder *et al.*, Phys. Rev. Lett. 129 (2022) 232502 (analyses without the sNME adjustment procedure !)



$$\bar{g}_\text{A}(\text{ISM}) = 0.830 \pm 0.002$$
$$\bar{g}_\text{A}(\text{IBFM-2}) = 0.845 \pm 0.006$$
$$\bar{g}_\text{A}(\text{MQPM}) = 0.936 \pm 0.003$$

NOTE: Spectral shapes as background: Total β spectrum of ^{214}Pb

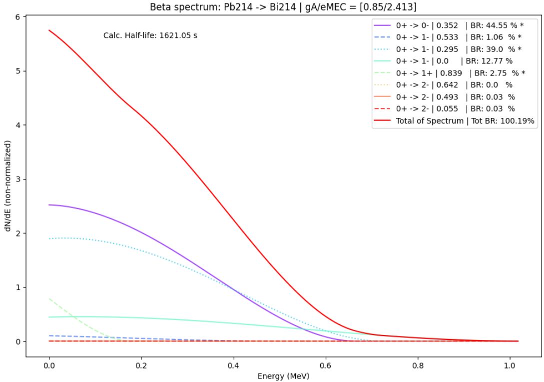
^{85}Kr, ^{212}Pb and ^{214}Pb are backgrounds in dark-matter experiments like XENON1T, XENONnT, PandaX, etc. (see S. J. Haselschwardt et al., Phys. Rev. C 102 (2020) 065501.

Beta decay of ^{214}Pb includes several first-forbidden non-unique transitions from 0^+ to 0^- and 1^- states within the decay Q window.

Total spectrum from

M. Ramalho *et al.*, in collaboration with the PandaX dark-matter experiment

The decay chains $^{212,214}\text{Pb} \rightarrow {}^{212,214}\text{Bi} \rightarrow {}^{212,214}\text{Po}$ stem from the ^{220,222}Rn backgrounds



Conclusions about g_A and the spectral shapes

Conclusion 1:

The long chain of ISM calculations and the recent pnQRPA and IBM-2 calculations of Gamow-Teller β decays and $2\nu\beta\beta$ decays are (surprisingly!) consistent with each other and clearly point to a A-dependent quenched g_A

Conclusion 2:

The spectrum-shape method (SSM) and the spectral moments method (SMM) for forbidden non-unique β decays seem robust tools (largely independent of the nuclear model, the assumed Hamiltonian and mean field) to search for the effective value of g_A and to try to solve other problems, like those related to the reactor-$\bar{\nu}_e$ spectra and backgrounds in rare-events experiments