Forbidden spectral shapes – implications to reactor neutrino anomaly

NDM18

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Outline

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Motivation

Why study β spectra forbidden decays?

- Effective value of $g_{\rm A}$ $\Rightarrow$ implications to $0\nu\beta\beta$ half-lives
- Background in rare-event searches
- Reactor neutrino anomaly $\Rightarrow$ sterile neutrinos?

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Spectrum shape

The β spectrum shape is given by

$$\frac{dN}{dW} = pW(W - W_0)^2 F(Z,W) C(Z,W) K(Z,W), \qquad (1)$$

where

- $pW(W - W_0)^2$ Kinematics
- $F(Z,W)$ Fermi-function (interaction of beta particle with the nucleus)
- $C(Z,W)$ Shape factor $\Leftarrow$ Nuclear physics!
- $K(Z,W)$ Higher-order corrections

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Shape factor

In the first-order the shape factor is simple for allowed and unique decays, complicated for non-unique decays.

For non-unique decays the shape factor depends on

- The nuclear matrix elements
- The effective value of g_A
- Kinematic factors

$\Rightarrow$ The theoretical β spectrum can be used to extract the effective value of g_A by comparing to the experimental spectrum (SSM).

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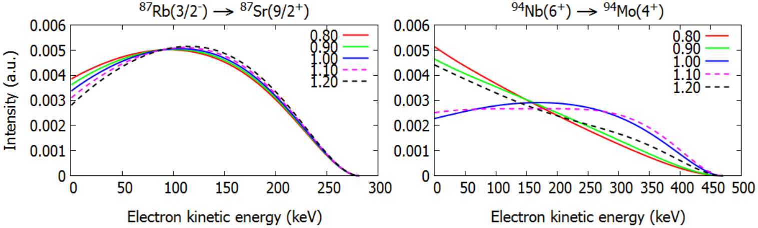
Theoretical results

Some spectra depend on g_A...



J. Kostensalo and J. Suhonen, Phys Rev. C **96**, 024317 (2017).

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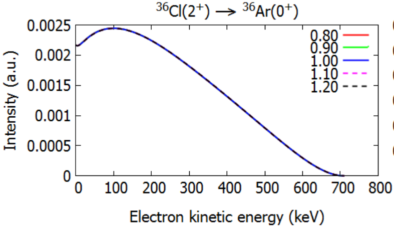
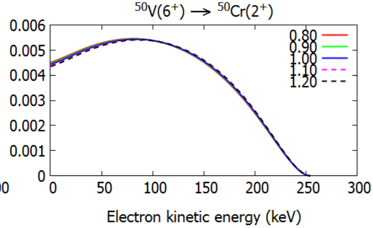
Theoretical results

... but many don't.





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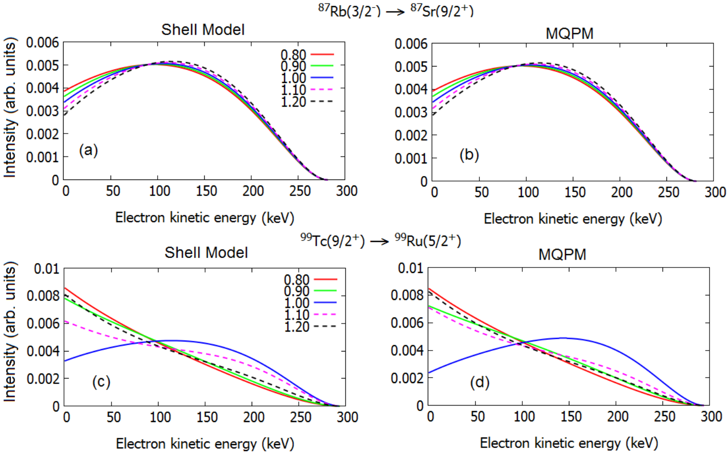
Theoretical results

SSM is a robust method of extracting g_A.



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J. Kostensalo and J. Suhonen, Phys Rev. C **96**, 024317 (2017).

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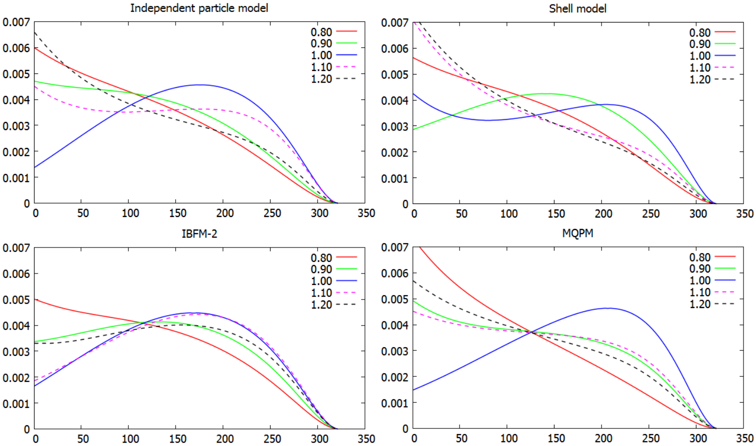
Theoretical results: ^{113}Cd

Theoretical spectra for ^{113}Cd.



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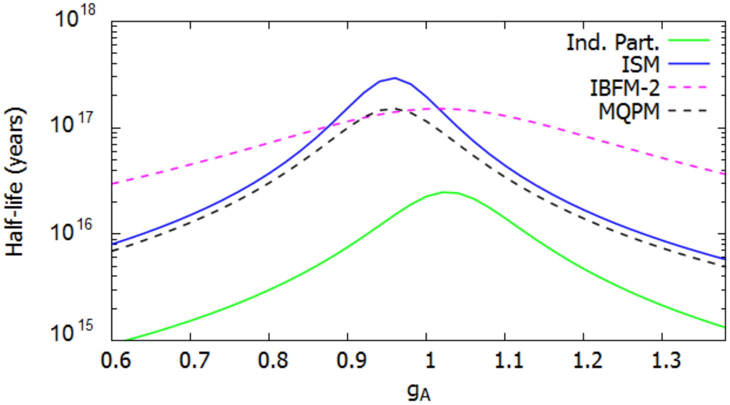
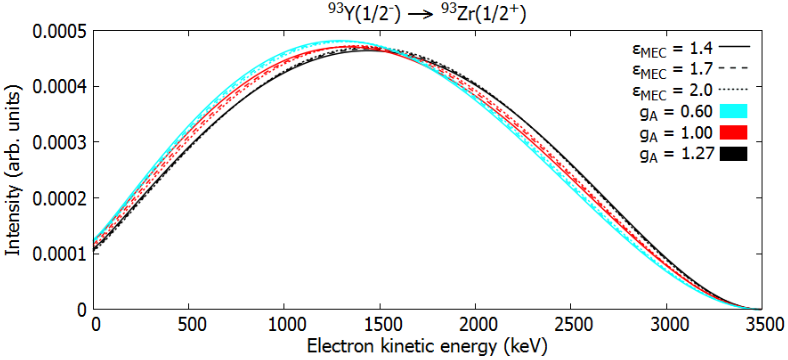
Theoretical results: ^{113}Cd

Half-life for ^{113}Cd (Experimental: 8×10^{17} yr).



Theoretical results

For first-forbidden $J^+ \leftrightarrow J^-$ decays the mesonic enhancement of the axial-charge NME plays a role.



J. Kostensalo and J. Suhonen, Phys Lett. B **781**, 480-484 (2018).

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Recent and on-going experiments

- ^{87}Rb – Proposal approved, Gran Sasso
- ^{99}Tc – Proposal approved, Gran Sasso
- ^{113}Cd – (COBRA experiment) TU Dortmund, TU Dresden, CTU Prague, JYU
- ^{115}In – CSNSM, MIT, CEA/IRFU, JYU
- ^{210}Bi – TU Dresden, JYU

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Preliminary results

^{113}Cd		^{115}In	
ISM:	$g_A = 0.92 \pm 0.02$	**ISM:**	$g_A = 0.83 \pm 0.03$
MQPM:	$g_A = 0.91 \pm 0.01$	**MQPM:**	$g_A = 0.94 \pm 0.04$
IBFM:	$g_A = 0.94 \pm 0.09$	**IBFM:**	$g_A = 0.88 \pm 0.06$

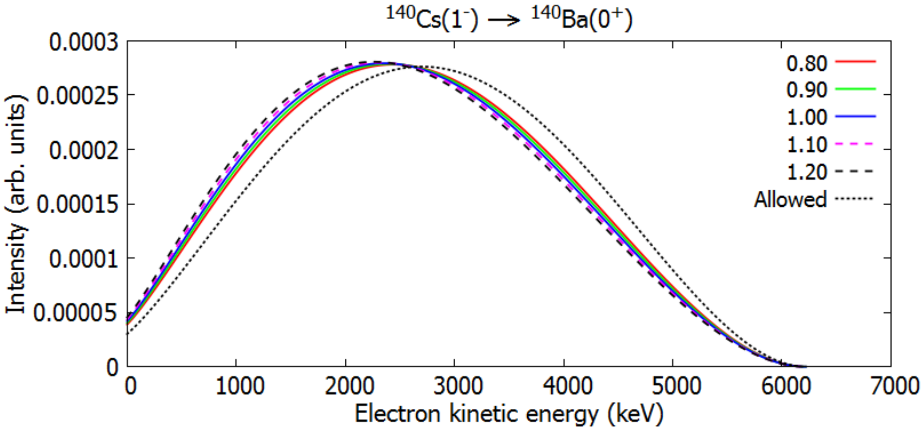
Reactor neutrino anomaly

Short-baseline reactor neutrino experiments have two problems when compared to theory:

1) Total number of detected antineutrinos is 6 % lower
2) Detected energy spectrum has a bump

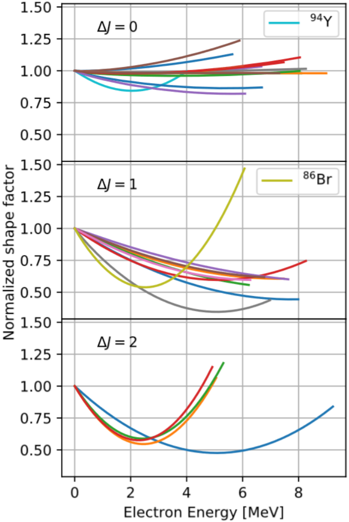
Many of the contributing decays are forbidden but often treated as allowed or unique to simplify the calculations.

The allowed approximation is not always good:



J. Kostensalo and J. Suhonen, Int. J. Mod. Phys. A **33**, 1843008 (2018).

The shape factors of 29 most important decays:



L. Hayen, J. Kostensalo, N. Severijns, J. Suhonen, **arXiv:1805.12259** [nucl-th] (2018).

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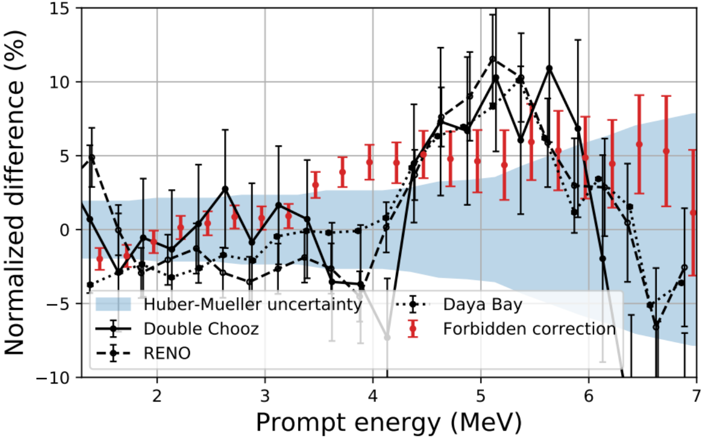
The inclusion of the forbidden spectra mitigates the spectral shoulder.



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The shell model results drop the theory predictions by ≈5 % and mitigate the bump.

⇒ Decreases the statistical significance of the reactor neutrino anomaly significantly.

Summary

- The spectral shapes of β decays can be used to study the effective value of g_{A} in a robust way.
- The spectra can be used to eliminate background in rare-event searches.
- Important for reactor neutrino anomaly:
  1) Decreases the difference between experiment and theory
  2) Mitigates the bump

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