DDEP and BetaShape Status

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USNDP meeting 2024

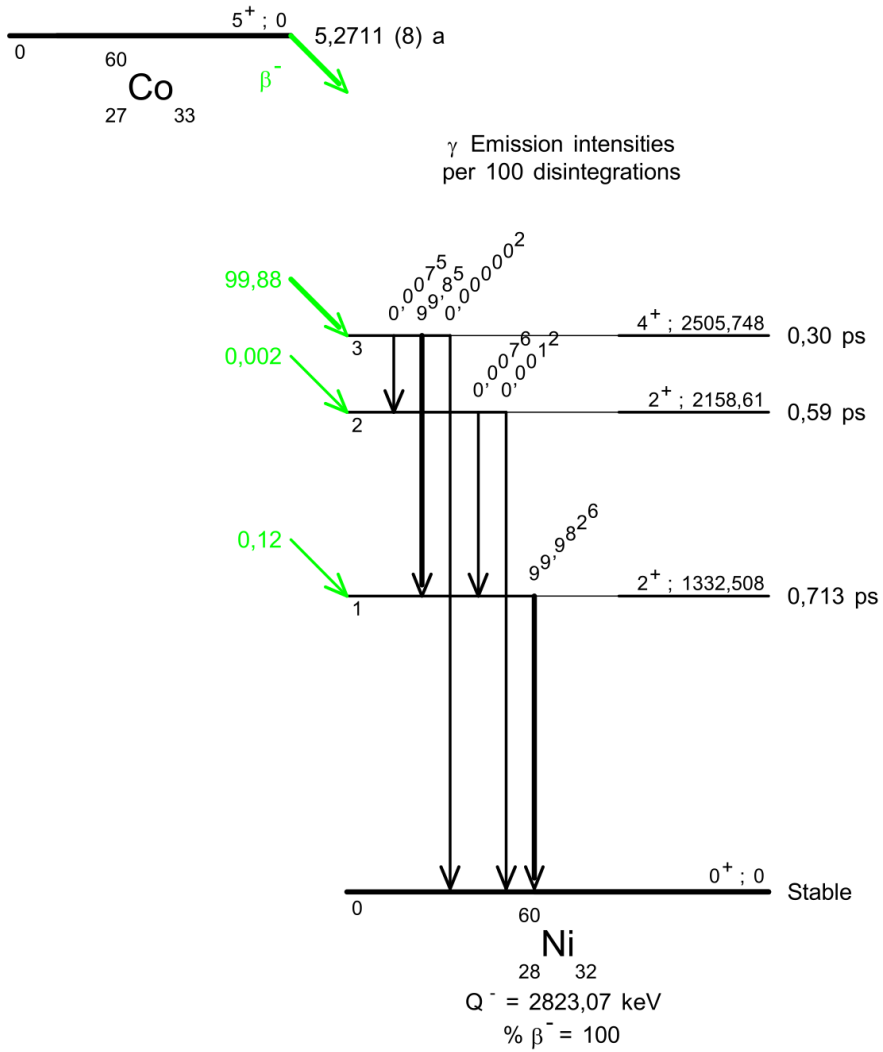
DDEP Status

DDEP – Missions

- **Provide recommended decay data to non-specialists**
  - ✓ Metrology
  - ✓ Fundamental physics (detector calibration)
  - ✓ Nuclear medicine
  - ✓ Nuclear industry

- **Main information of interest**
  - ✓ Half-life, Q-value
  - ✓ Decay scheme
  - ✓ Intensity and energies (transitions, emissions)
    - Alpha / beta / electron capture
    - Gamma and internal conversion
    - X-rays & Auger electrons

Symmetric uncertainties only



DDEP – Members

→ **None of the members are full-time-equivalent, far from it.**

- **DDEP Coordination**: Xavier Mougeot

- **LNHB Local team** (evaluation, review, edition, publication)
  - Sylvain Leblond
  - Xavier Mougeot
  - Mark A. Kellett (Special advisor)
  - Christophe Dulieu (IT support)

- **Decay data evaluators**
  - Alan L. Nichols* (Surrey University, UK)
  - Aurelian Luca (IFIN, Romania)
  - Brian E. Zimmerman (NIST, USA)
  - Rob Shearman (NPL, UK)
  - Xialong Huang (CIAE, China)
  - Nikolai Kuzmenko (KRI, Russia)

- **Additional support**
  - Tibor Kibédi* (BrIcc and BrIccMixing codes)
  - Balraj Singh*† (ENSDF collaboration)

* Retired.

† Deceased.

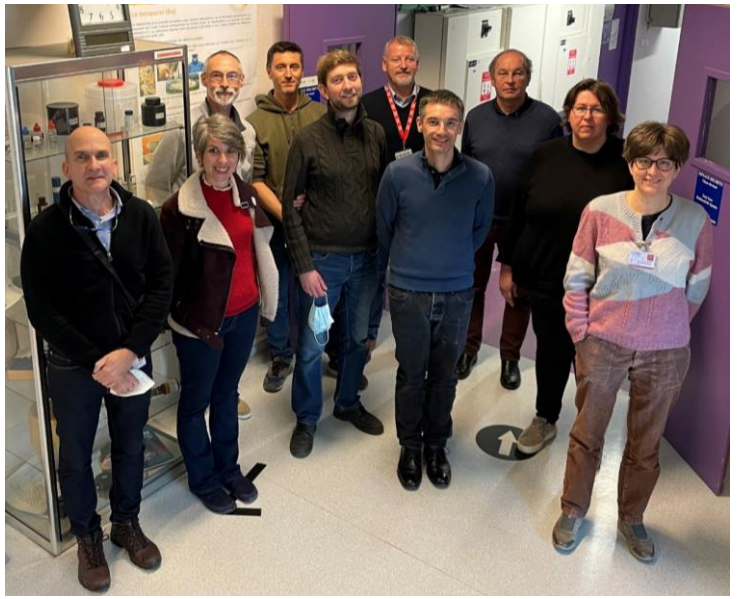
DDEP – Attempts to increase the workforce

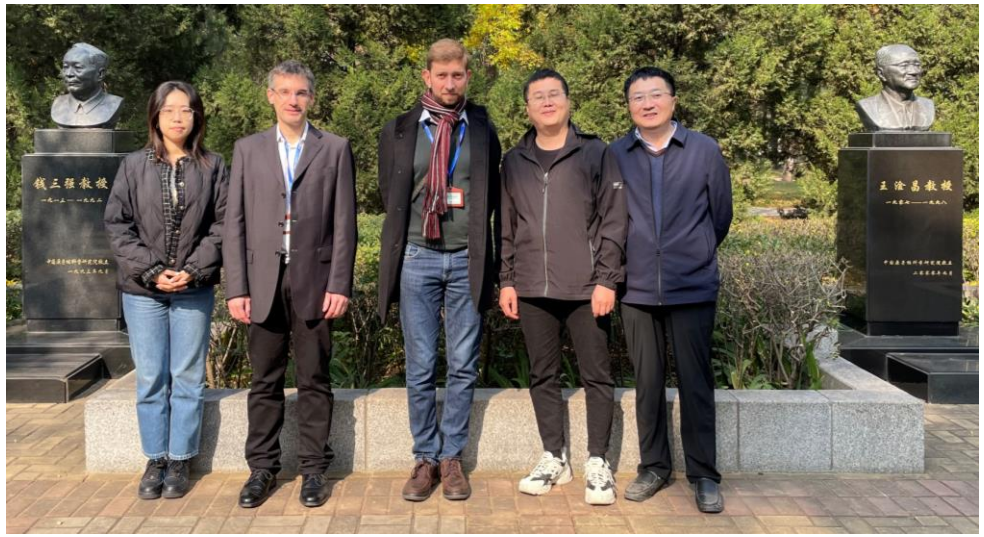
DDEP workforce remains limited. Actions engaged:

- ✓ 7th to 9th of March 2022: Organisation of a DDEP workshop dedicated to evaluator training.
- ✓ 21st to 28th of October 2023: Visit of China Nuclear Data Centre (Beijing, China).
- 7th to 11th of October 2024: Visit of China Nuclear Data Centre (Beijing, China).
- 21st to 25th of October 2024: Organisation of a DDEP workshop dedicated to evaluator training.

  8 participants from the US, China and Europe + local (LNHB) participants.

→ Efforts which require additional work and time, taken on availability dedicated to DDEP.





DDEP – Evaluations

- ✓ Since 2021 (change of coordination), 17 evaluations published.
- ✓ Since latest BIPM vol. 8 monography (2016), 21 evaluations published.
- ➢ By end of 2024, ^{45}Ti and ^{56}Co are also expected.

Nuclide		Z	Vol. (?)	UpDate
Co-55	^{55}Co	27	9	04/09/2024
Rh-103m	^{103m}Rh	45	9	29/08/2024
Pd-103	^{103}Pd	46	9	29/08/2024
Ho-166	^{166}Ho	67	9	24/06/2024
Fe-55	^{55}Fe	26	9	19/03/2024
Sn-129m	^{129m}Sn	50	9	13/03/2024
Ac-225	^{225}Ac	89	9	20/12/2023
Cs-137	^{137}Cs	55	9	07/09/2023

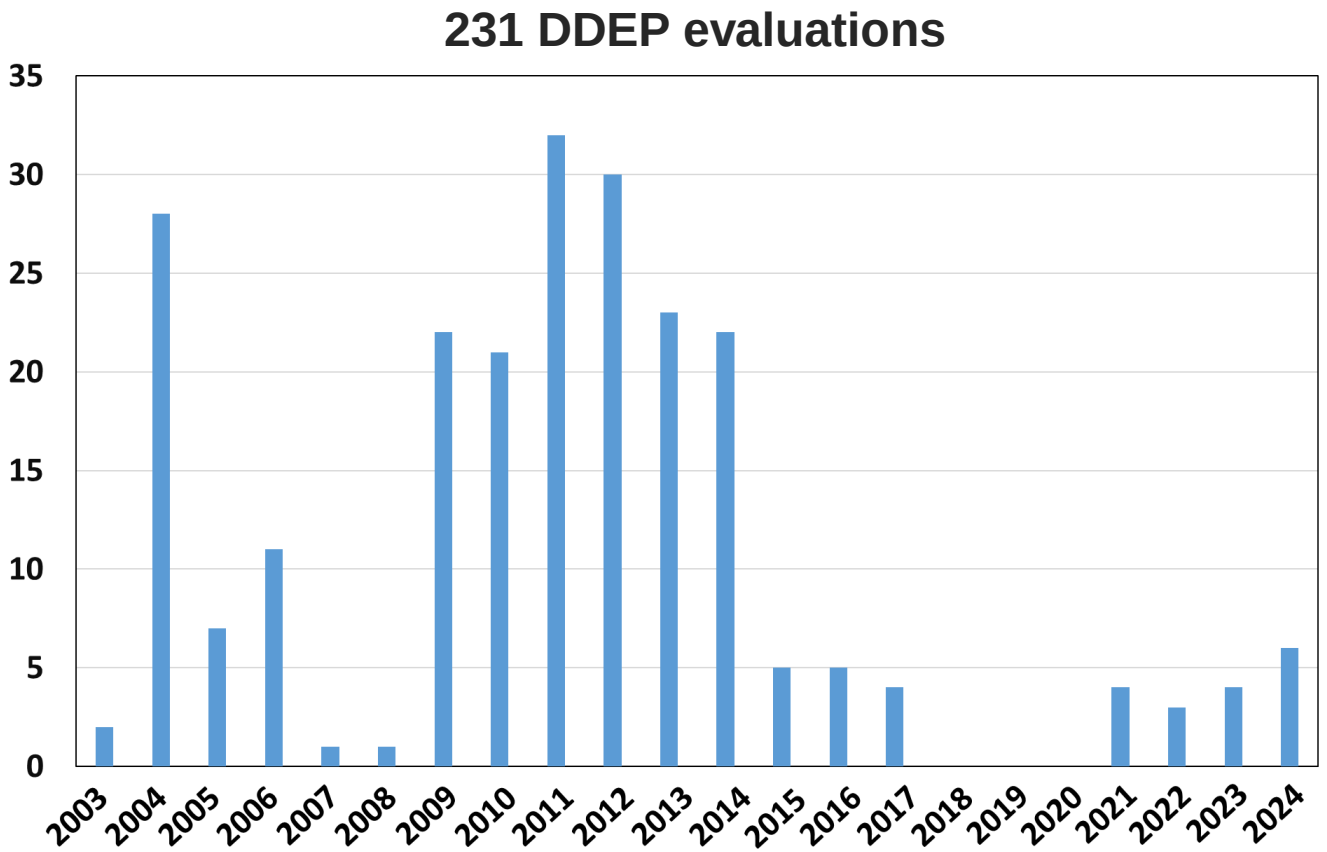
Nuclide		Z	Vol. (?)	UpDate
Ba-137m	^{137m}Ba	56	9	07/09/2023
Sm-151	^{151}Sm	62	9	07/09/2023
He-6	^{6}He	2	9	10/11/2022
Al-26	^{26}Al	13	9	10/11/2022
Rb-87	^{87}Rb	37	9	24/05/2022
Cs-131	^{131}Cs	55	9	21/09/2021
I-124	^{124}I	53	9	20/07/2021
Mn-52	^{52}Mn	25	9	09/02/2021
Mn-52m	^{52m}Mn	25	9	09/02/2021

Conclusion

DDEP evaluations are back on track…
But manpower still remains limited

Lot of work to somehow maintain the situation

- Pending evaluations need to be finalized.
- New DDEP evaluators (and evaluations) needed.
- Updates of existing DDEP evaluations needed.

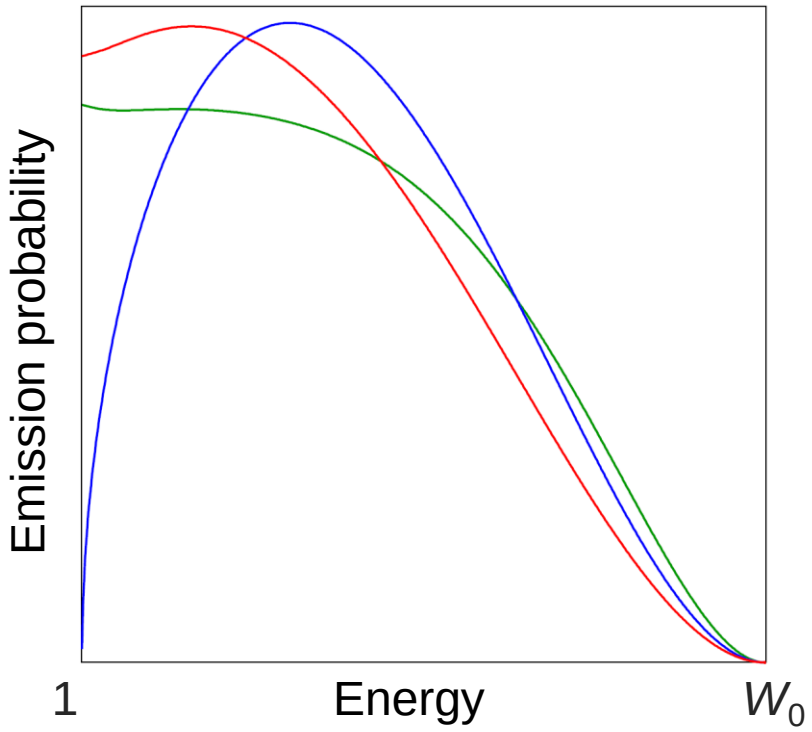


BetaShape Status

Beta spectrum shape

Phase space Fermi function Shape factor

$$\frac{\mathrm{d}P}{\mathrm{d}W} \propto \boxed{pWq^2} \cdot \boxed{F(Z,W)} \cdot \boxed{C(W)}$$



W electron energy, W_0 transition energy

p electron momentum, q neutrino momentum

Allowed	$C(W) = 1$
First forbidden unique	$C(W) = q^2 + \lambda_2 p^2$
Second forbidden unique	$C(W) = q^4 + \lambda_2 q^2 p^2 + \lambda_3 p^4$
Third forbidden unique	$C(W) = q^6 + \lambda_2 q^4 p^2 + \lambda_3 q^2 p^4 + \lambda_4 p^6$
	Etc.

- ✓ The BetaShape program (version 2.4) now replaces the LogFT code for the new ENSDF evaluations. Electron captures also treated.

  → Available on IAEA-NSDD GitHub: https://github.com/IAEA-NSDDNetwork

- ✓ $F(Z,W)$ and λ_k parameters determined from the relativistic electron wave functions, obtained by numerical solving of the Dirac equation.

- ✓ Included: extended nucleus; atomic exchange, overlap and screening; radiative corrections; database of experimental shape factors.

For forbidden non-unique transitions, coupling with nuclear structure is necessary.

→ ξ-approximation possible but accuracy is questionable.

Developments for version 2.3

Technical

- ✓ Rounding limit can be changed via a simple option.
- ✓ Provision of *f*-values and average energy of emitted neutrinos (B and EC).
- ✓ Handling of branching ratios (BR and NB from N and PN records) and propagation of their uncertainties.
- ✓ Modification of forbiddenness assignment when J^{π} are ambiguous.

Physical model

- ✓ Tabulation of atomic screening and exchange effects from full numerical calculations.
- ✓ Inclusion of the atomic overlap correction in beta decays. Negligible influence except close to the end-point energy, which can appear lower by hundreds of eV.

Uncertainties

- ✓ Treatment of non-numeric uncertainties (AP, SY, GT, etc.). Up to version 2.2, treated as null.
- ✓ Treatment of asymmetric uncertainties. Important for large uncertainties on intensities and transition energies.

Summary on the recent versions

✓ Version 2.3 (September 2023), was released with all requests implemented.

→ Feedbacks at 2023 USNDP meeting

✓ Version 2.3.1 in December 2023.

- A few bugs fixed in generated CSV files.
- Insertion of a comment line with the code version in updated ENSDF files.
- Description of CSV format in a separate Microsoft Office Excel file.

→ Feedbacks at 2024 NSSD meeting

✓ Version 2.4 in June 2024.

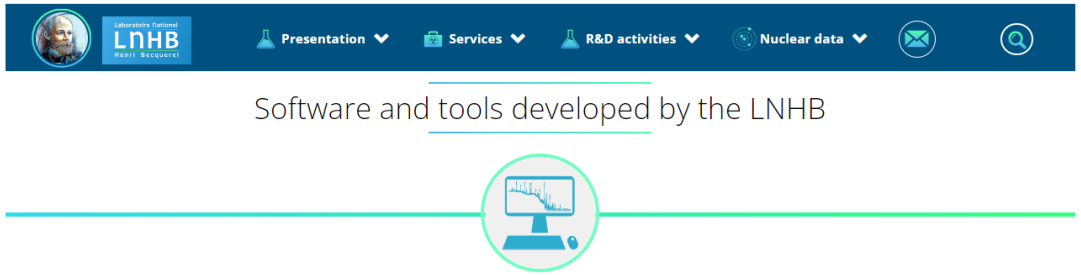
- Acceleration of electron capture calculations by a factor of 50. Could take several minutes per transition before. Extensive tabulation of wave function overlaps.
- An environment variable (**`BSINSTALL`**) can be defined to run the code from any directory.
- Validation of the code on the entire ENSDF database, archived version of January 2024.

→ **Feel free to send me any bug report or suggestion of improvements. I already have some from Jun Chen.**

Where to get BetaShape

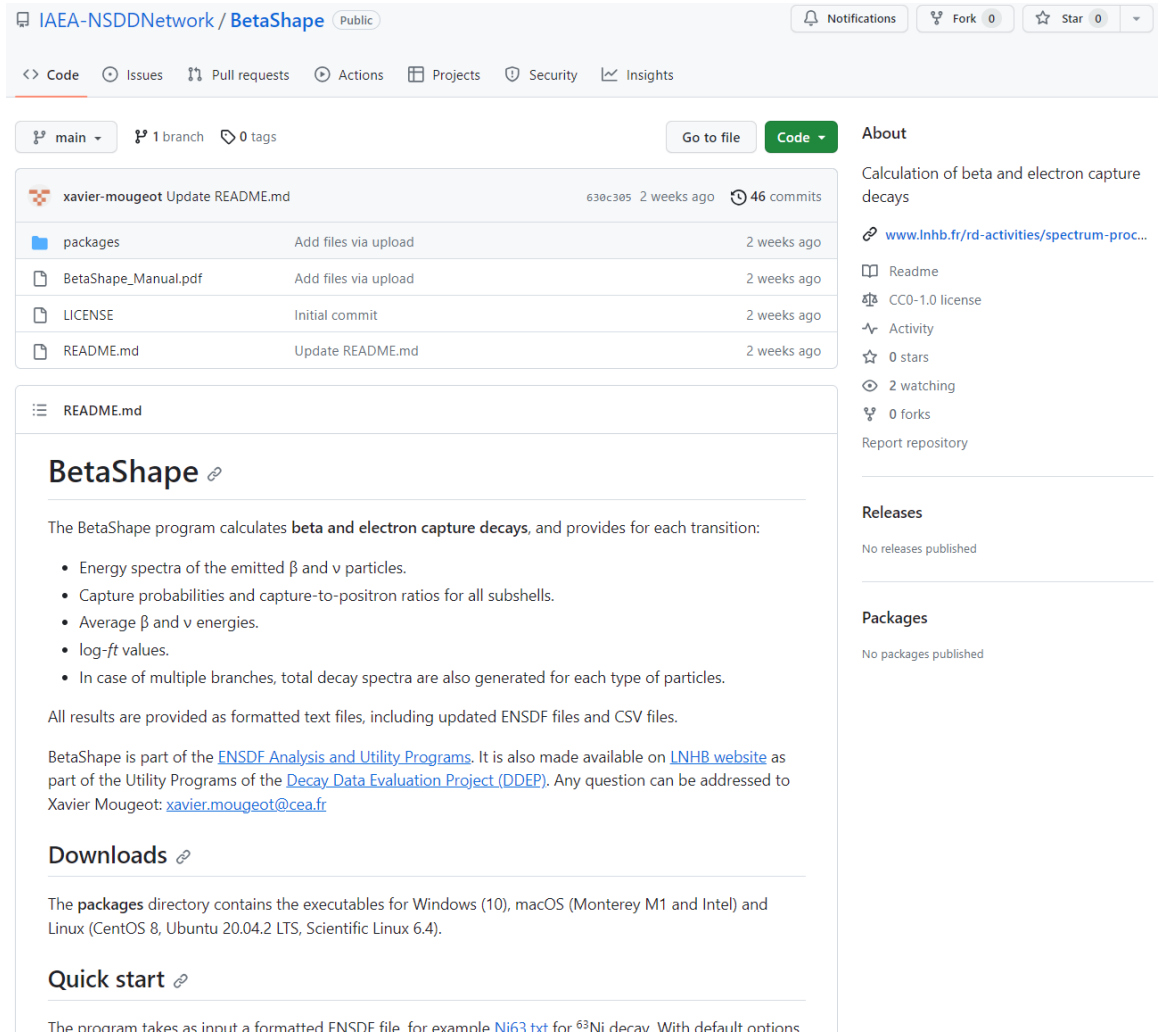
LNHB website

http://www.lnhb.fr/rd-activities/spectrum-processing-software/



IAEA GitHub Repository

https://github.com/IAEA-NSDDNetwork



Effective coupling constants

- Free-nucleon value g_V = 1 according to CVC
- Free-nucleon value g_A = 1.2754 (13) [PDG 2020]

Review of J. Suhonen in Front. Phys. 5, 55 (2017)

→ Coupling constants g_V and g_A of the weak interaction can be affected by:

- Nuclear medium effects

  The nucleon decays within a finite nucleus. Beyond the impulse approximation.

- Nuclear many-body effects

  Simplification of the many-body problem: core excitation, nucleon correlations, etc.

Unfortunately, it is almost impossible to disentangle between these two categories of effects by analyzing beta decays.

Spectral shapes can help for a better quantification of the effective values → **the Spectrum Shape Method**.

→ **1st forbidden non-unique**

g_V^{eff} ~ 0.3 – 0.7 and g_A^{eff} ~ 0.46 – 0.56

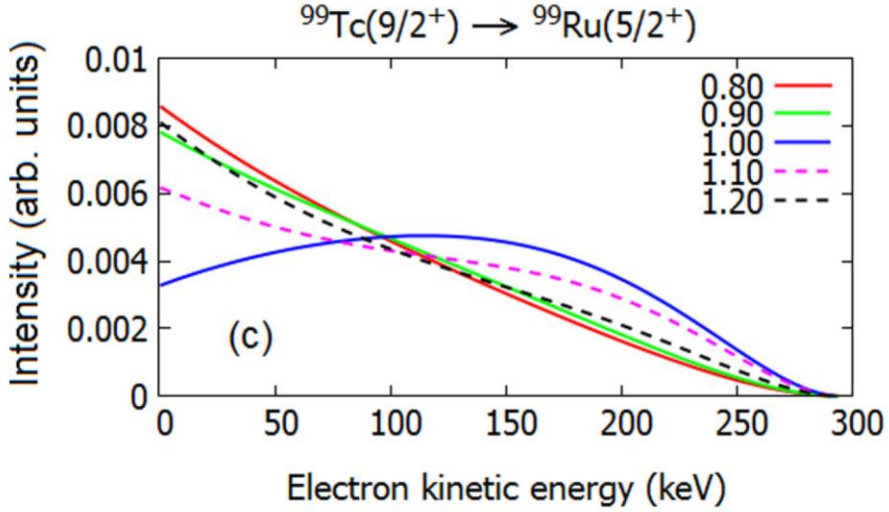
→ **Higher non-unique**

Lack of high-quality measurements

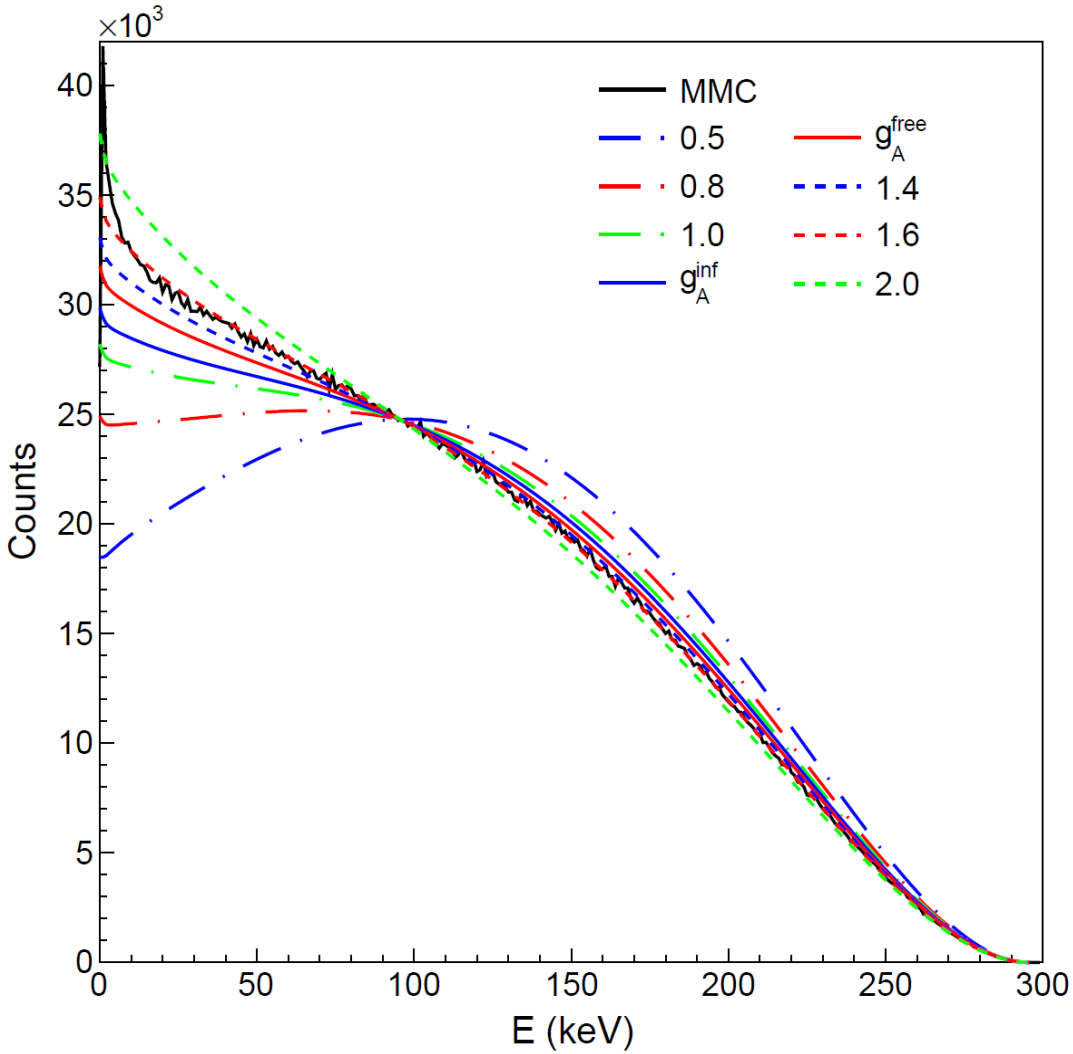
Suggests g_V = 1 and g_A^{eff} ~ 0.4

^{99}Tc beta spectrum, second forbidden non-unique, predicted to be very sensitive to g_A.

J. Kostensalo, J. Suhonen, PRC 96, 024317 (2017)



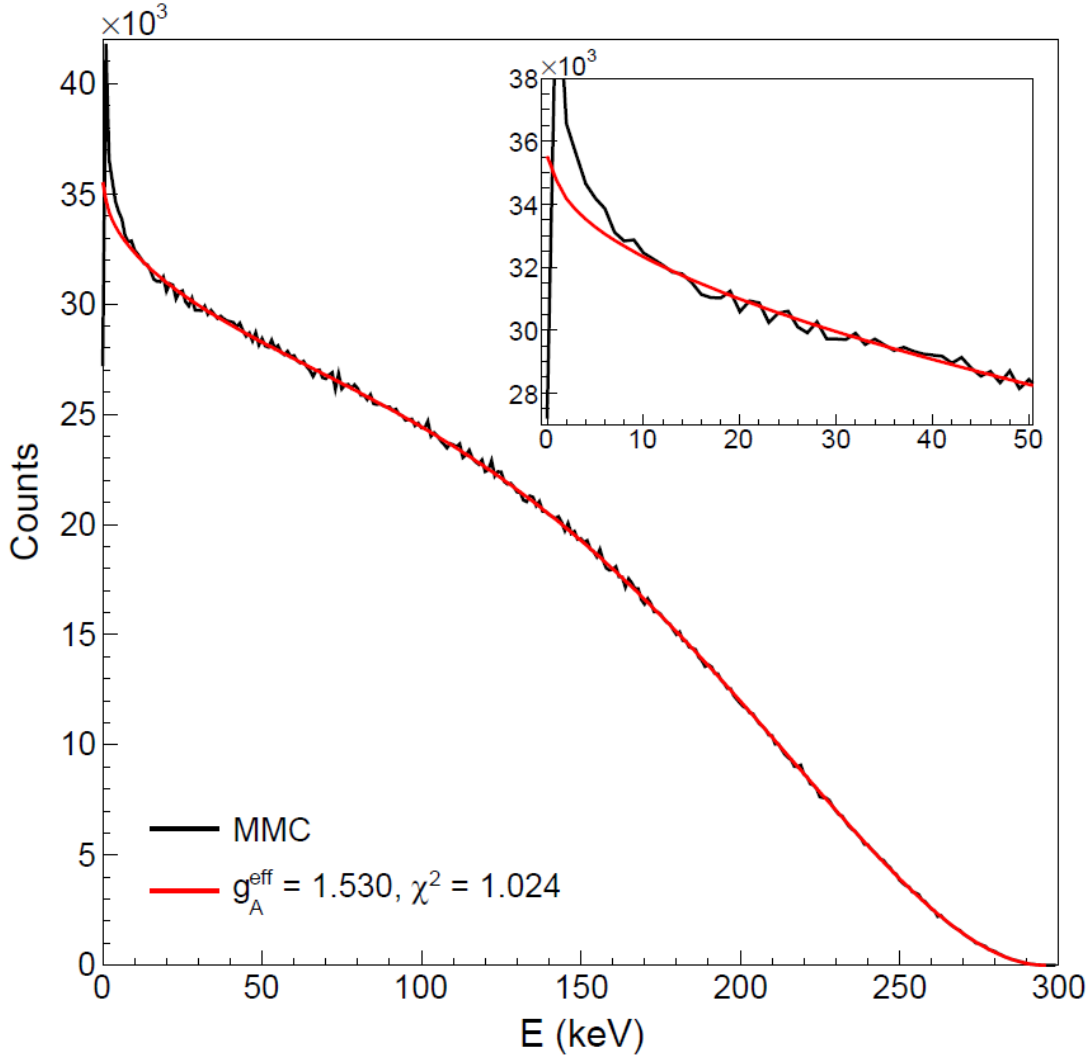
^{99}Tc 2nd forbidden non-unique decay



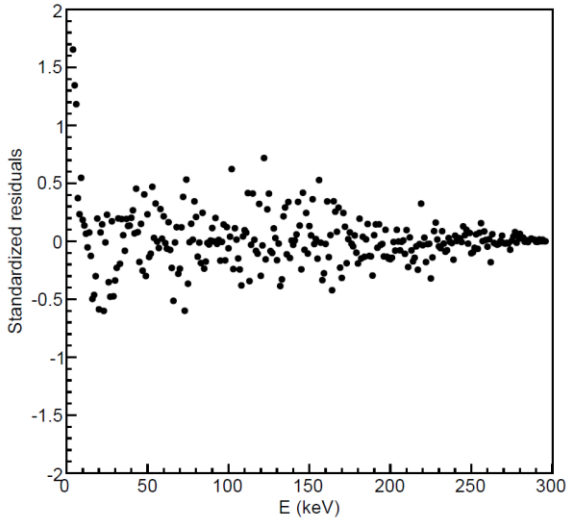
Within the European project PrimA-LTD

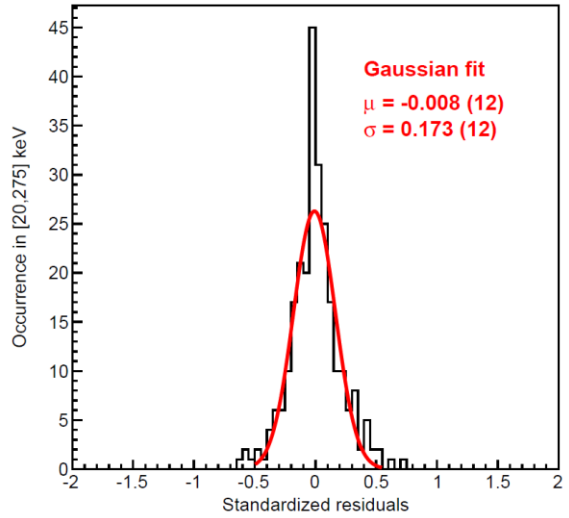
- ✓ High-precision measurements of ^{99}Tc spectrum with MMC at CEA-LNHB and PTB, and with Silicon detectors at CEA-LNHB.
- ✓ Excellent agreement of all the three spectra.
- ✓ **New Q-value = 295.82 (16) keV** not consistent with AME2020 value of 297.5 (9) keV.
- ✓ **High sensitivity to the effective value of g_A confirmed.**

^{99}Tc 2nd forbidden non-unique decay



- ✓ Three different model spaces used with NushellX (GL, GLEKPN, jj45pn) to quantify the influence of nuclear structure.
- ✓ Theoretical calculations with nuclear structure, CVC and complete lepton current.
- ✓ Best adjustment gives an effective axial-vector coupling constant g_A^{eff} = 1.526 (92), far from g_A^{eff} ~ 0.4.
- ✓ Excellent residuals, without any trend down to 6 keV.





^{99}Tc 2nd forbidden non-unique decay

‼ Effective g_A value is **enhanced** while should be **quenched**. What happens?

➢ Calculated half-life is about one order of magnitude too low.

➢ From DDEP: $T_{1/2}$ = 211.5 (11) · 10^3 y

Evaluated value is mainly based on one publication, authors providing a *suggested* value.

➢ We can use it to renormalize the calculation and obtain a consistent picture: accurate shape, accurate half-life.

First possibility: **renormalization of the OBTD**

Example: GLEKPN

Multipole	Transition	Original	Corrected
K = 2	n $1g_{7/2}$ → p $1g_{9/2}$	0.00994	0.00362
	n $2d_{5/2}$ → p $1g_{9/2}$	0.47752	0.17383
K = 3	n $1g_{7/2}$ → p $1g_{9/2}$	-0.01709	-0.00622
	n $2d_{5/2}$ → p $1g_{9/2}$	-0.43403	-0.15800
	n $2d_{3/2}$ → p $1g_{9/2}$	0.03143	0.01144

Second possibility: **renormalization of g_V and g_A**

→ g_V^{eff} = 0.376 (5) and g_A^{eff} = 0.574 (36)

Consistent with 1st forbidden non-unique results

g_V^{eff} ~ 0.3 – 0.7 and g_A^{eff} ~ 0.46 – 0.56

→ **What about CVC hypothesis?**

➢ Eventually, one also deduces: log *f* = -0.47660 (22), log *ft* = 12.3478 (23), $\overline{E_\beta}$ = 98.51 (23) keV.

Thank you for attention