

Probing nuclear structure with β -decay energy spectra, present and near future state II

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I. SCIENTIFIC ISSUE

β -decay has been and continues to be cutting edge nuclear physics research. The measurement of all the particles emitted in weak interaction transitions (β , ν , γ , nucleus recoil) is now possible with increased accuracy and lower uncertainties due to advances in detector technologies. There have been major challenges integrating different β -decay measurements, such as the Reactor Antineutrino Anomaly (integrates ν and β) and the Pandemonium Effect (integrates γ intensities and β -feeding patterns). The focus of this meeting is to discuss recent experimental and theoretical progress of nuclear structure impacts on β -energy spectra. In addition to affecting nuclear structure, β -energy spectra impact a broad set of fields from microdosimetry estimates in nuclear medicine to reactor antineutrino predictions and decay heat calculations, while providing a possible window to exotic physics.

Extracting quality physical information requires theoretical predictions at the same, or better, level as the experimental precision. A global, consistent description of both the weak (β -decay) and the strong (nuclear structure) interactions, while including atomic structure and QED corrections, is a unique challenge. Comparison of individual β -decay measurements is often difficult due to conflicting experimental results as well as to varied theoretical predictions. If one selects a few specific well studied and calculated β -decay transitions, different decay measurement components can be probed independently. On the calculational side, consistent theoretical description of all components of β decay, both in relative (β -energy spectrum shape) and absolute (branching ratios, half-life, $\log ft$), is extremely rare. A broad range of partial theoretical predictions exist, their disagreement essentially being in the nuclear structure model employed. In particular, there are many different nuclear structure effects to consider such as:

- Weak interaction: effective coupling constants; weak magnetism; exotic currents beyond the Standard Model.
- Nuclear structure: transition rates and energies; nuclear deformation and K-hindered transitions; test of relativistic nuclear models compared to Conserved Vector Current (CVC) predictions; Forbidden β -decay corrections.

On the experimental side, precise measurement of β -energy spectra is challenging, with consistent measurements of any single transition being very scarce, and overall <200 of the ~26 000 β -decay transitions have even been experimentally probed so far. Great improvements have been made, both experimentally and theoretically, over the last decade, opening the possibility of accurate and precise tests of weak interaction and nuclear structure models. One seeks an ideal approach that allows each community to bring its expertise and use the various results to identify:

- A β -energy spectrum measurement and its analysis, from which a reference spectrum can be established free of experimental distortions;

- β -decay calculations to extract quantities that depend on nuclear structure (matrix elements, branching ratios, etc.);
- Refinement of nuclear theoretical models to reproduce consistently these quantities.

This will reinforce exchanges between leading experimental and theoretical practitioners who need to share common practices and vocabulary, compare analysis approaches, and establish accepted standard reference data.

II. GOALS OF THE WORKSHOP

The first workshop (held from July 6-10, 2025) was successful in starting conversations between theoretical and experimental physicists, as well as between experimentalists studying β -decays from different energy regimes (low energy up to ~ 700 keV versus higher energy up to several MeV).

In summary, the goals of the second workshop are:

1. Continue encouragement for experimental and theoretical β -decay experts to discuss and exchange approaches on different models, limits, and possible improvements thereof.
2. Decide on common actions such as comparing analysis approaches of the same experimental dataset, and comparing theoretical predictions on parts of the nuclear structure models.
3. List priority nuclei and transitions for common studies, focusing on those with possible high impact on related fields. There were some conclusions on this from the first meeting.
4. Ultimately, to agree within the community on a robust procedure to improve nuclear structure models with experimental information from β -decay energy spectra.
5. Continue discussions of β -decay standards.

This workshop is anticipated as the second of several workshops as it is likely that reaching these lofty goals will require several years and several workshops.

References

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 Hayen, *et al.*, Rev. Mod. Phys. **90** 015008 (2018) - Allowed β Decay Review Article
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 Kossert *et al.*, Appl. Radiat. Isot. **185**, 110237 (2022) - Comparison theo/exp on ^{151}Sm
 Kostensalo, *et al.*, PRC C **107**, 055502 (2023)
 Quarati *et al.*, PRC **107**, 024313 (2023) - Comparison theo/exp on ^{176}Lu
 Mougeot, Applied Radiation and Isotopes **201**, 111018 (2023) - BetaShape Code
 Périssé *et al.*, PRC **108**, 055501 (2023) – Revision of the summation method for reactor antineutrinos
 Ramlo, *et al.*, PRC C **109**, 034321 (2024)
 Paulsen *et al.*, PRC **110**, 055503 (2024) - Comparison theo/exp on ^{99}Tc
 Walker and Kondev, Eur. Phys. J. Spec. Top. **233**, 983-1005 (2024) – K isomers in atomic nuclei
 Seng, *et al.*, Phys. Rev. Lett. **134**, 081805 (2025) (Forbidden Decays)

III. LIST OF TALKS

Theory & Experiment

O. Naviliat-Cuncic (MSU) - *V_{ud} once more*

E. Nseir (IJCLab) - *The essential Doorway Decay of ^{83}Ga investigated with PARIS*

B.C. Rasco (ORNL) - *Bremsstrahlung impact on beta decay*

Experiment

B. Sabot (CEA DRT) - *Influence of beta spectrum on new primary activity standards*

X. Flécharde (LPC Caen) - *Benchmarking of Geant4 for calorimetry measurements*

M. Brodeur (University of Notre Dame) - *Beta decay recoil time-of-flight measurements with St. Benedict*

M. Rodrigues (CEA DRT) - *Beta spectrum of I-129 using metallic microcalorimeters*

M. Stukel (SNOLAB) - *RAMPS: Measurement of the highly forbidden decay of Lu-176*

M. Atzori Corona (INFN) - *GAIAS: Precision Measurements of Forbidden Non-Unique Beta Spectra for the Investigation of the Axial-Vector Coupling Constant*

C. Doutre (CEA DRF DPhN) - *First experimental study of the startpoint of ^{28}Al Beta-decay with the CRAB facility*

K. Han (Shanghai Jiao Tong University) - *Nuclear physics with liquid xenon detectors & Neutrinoless double beta decay experiments*

P. Di Stefano (Queen's University) - *The KDK Experiment: Investigating 40K*

N. Cullen (Queen's University) - *The XDK (X-ray decay) experiment: Upgrading KDK for General EC Measurements*

C. Knapen (KU Leuven) - *Experimental set-up for high precision beta spectrum shape measurements at WISArD*

A. Lépine (CENBG) - *SPELS – Beta shape of ^{32}P at WISArD*

S. Leblond (CEA DRT) - *Beta spectrometry at LNHB*

G. Craveiro (KU Leuven) - *Study of $^{90}\text{Sr}/\text{Y}$ beta spectrum*

Theory

X. Mougeot (CEA DRT) - *Beta decay from the nuclear data perspective*

L. Hayen (LPC Caen) - *What can recoil spectroscopy teach us in looking for BSM?*

J. Suhonen (University of Jyväskylä) - *The many facets of beta spectral shapes*

M. Hellgren (CEA DES) - *$pnQFAM$ implementation for allowed beta-decay transitions using a Gogny interaction*

P. Navratil (TRIUMF) - *Ab initio calculations of beta decays in light nuclei*

A. Andoche (CEA DRT) - *Electronic structure and its effect on beta decay*

C. Jeudy (University of Strasbourg) - *Influence of the environment on nuclear decays*