

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

B. Charles Rasco (rascobc@ornl.gov)
Physics Division, Oak Ridge National Laboratory

Xavier Mougeot (xavier.mougeot@cea.fr)
CEA-LIST, Laboratoire National Henri Becquerel

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I. Scientific Issue

β -decay has been [Pauli, Fermi, Cowan, Wu] and continues to be [Ahmad, Mention, Dolinski] at the cutting edge of 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 [Mention] (ν and β) and the Pandemonium Effect [Hardy] (γ and β feeding patterns). The focus of this proposed meeting is to discuss nuclear structure impacts of β -energy spectra. In addition to affecting nuclear structure, β -energy spectra impact a broad set of fields from micro dosimetry 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 the entire 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 [Ramlo24]. 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.

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 $\sim 26\,000$ β -decay transitions having even been experimentally probed so far [Mougeot2015]. 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 WORKSHOP

In summary, the goals of the proposed workshop are:

1. To allow experimental and theoretical β -decay experts to discuss and exchange their approaches on different models, limits, and possible improvements thereof.
2. To 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. To list priority nuclei and transitions for common studies, focusing on those with possible high impact on related fields.
4. Ultimately, to agree in the community on a robust procedure to improve nuclear structure models with experimental information from β -decay energy spectra.

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

References

- Ahmad, et al., Phys. Rev. Lett. **89**, 011301 (2002) (Solar Neutrinos)
 Cowan, et al., Science **124**, 3212 (1956)
 Dolinski, et al., Ann. Review of Nucl. and Particle Science **69**, (2019) ($0\nu\beta\beta$ decay)
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 Hardy, Phys Lett B **71**, (1977)
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 Severijns, Rev. Mod. Phys. **78** 991–1040 (2006)
 Wu, et al., Phys. Rev. **105**, 1413 (1957)

III. Speakers

Monday 7th - Precision weak interaction studies

Precision and accuracy of current measurements (or lack thereof)

Opening X. Mougeot (CEA LIST LNHB) & B.C. Rasco (ORNL)

O. Naviliat-Cuncic (FRIB-IRL-MSU) I. *Beta decay within and beyond the Standard Model*

O. Naviliat-Cuncic (FRIB-IRL-MSU) II. *Searches for tensor-type interactions in beta decay*

B. C. Rasco (ORNL) *The dominant corrections in beta decay*

L. Jokiniemi (TRIUMF) *Ab initio calculations on beta decays for beyond-standard-model studies*

P. A. Hervieux (IPCCMS, Univ. Strasbourg) *Influence of atomic modeling and chemical environment on electron capture decay*

Tuesday 8th - Nuclear Structure Influences on Beta Decay

M. Loidl (CEA LIST LNHB) *Beta-decay with microcalorimetry measurements*
(^{241}Pu , ^{63}Ni , ^{14}C , ^{99}Tc , ^{129}I , ^{36}Cl)

X. Mougeot (CEA) *Beta spectrum calculations with the nuclear shell model*

S. Péru (CEA DAM DIF) *Charge exchange QRPA using Gogny interaction for nuclear structure studies*

G.-B. Kim (LLNL) *^{241}Pu Beta Spectrum Measurement with Magnetic Microcalorimeters and a New Approach for Low Energy Rate Estimation down to 0.0 eV*

G. de Gregorio (INFN, Napoli) *Beta decay calculations within the realistic shell model*

A. Glick-Magid (INT, Univ. of Washington) *Unique forbidden transitions for precision weak interaction studies*

Wednesday 9th - Nuclear Structure Influences on Beta Decay

E. Cantacuzene (IJCLab) *Nuclear structure beyond the neutron threshold in the N=50 region from beta-decay experiments at ALTO*

B.C. Rasco (ORNL) *Isolating individual beta transitions in complex beta decay*

A. Algora (IFIC Univ. of Valencia) *TAGS measurements in Jyvaskyla*

J. Menéndez (ICC Barcelona) *Double-beta decay electron spectra: theory confronts experiment*

A. Andreyev (Univ. of York) *Selected examples of beta-decay studies of Hg-Fr isotopes at the ISOLDE Decay Station*

Thursday 10th

G. Alcalá (IFIC, University of Valencia) *Beta Decay Spectra Measurements for the Study of Reactor Antineutrino Spectra*

IV. Program

	Monday 7th July	Tuesday 8	Wednesday 9	Thursday 10
	<i>9h30 OPENING</i>			
<i>9h30</i>	O. Naviliat I	M. Loidl	E. Cantacuzene	<i>9h30-10h G. Alcalà</i>
<i>10h30</i>	<i>Break</i>	<i>Break</i>	<i>Break</i>	<i>Break</i>
<i>11h</i>	B.C. Rasco	X. Mougeot	Seminar B.C. Rasco	<i>Discussions Working group</i>
<i>11h45</i>	O. Naviliat II	S. Péru		
<i>12h30</i>	<i>Lunch</i>	<i>Lunch</i>	<i>12h15 Lunch</i>	<i>Lunch</i>
<i>14h15</i>	L. Jokiniemi	G. B. Kim	A. Algora	End
<i>15h</i>	P.A. Hervieux	G. de Gregorio	J. Menéndez	
<i>15h45</i>	<i>Break</i>	<i>Break</i>	<i>Break</i>	
<i>16h15</i>	<i>Discussions</i>	A. Glick-Magid	A. Andreyev	
<i>16h50 ~17h30</i>	<i>Discussions</i>	<i>Discussions</i>	<i>Discussions</i>	