EMPIR Call 2018 – Health, SI Broader Scope, Normative and Research Potential

Selected Research Topic number: **SRT-s06**
Version: 1.0

Title: Determination of relevant decay data to realise the unit of activity Bq for radionuclides with complex beta decay

Abstract

Precise data on nuclides undergoing beta decay as well as knowledge of the decay parameters are increasingly important in radionuclide metrology, with applications in nuclear medicine, environmental investigations, nuclear waste management and also fundamental research. Some potential applications would require decay data on beta emitters with complex decay schemes to be determined with unprecedented precision. The spectrum shapes and branching ratios that are required for primary activity standardisation of beta-emitting isotopes need to be measured using modern spectroscopic techniques, with the improvement of those techniques also being a key objective. The spectrum shapes should be evaluated theoretically by a calculation code validated by the experimental data. These activities should support a sustainable framework for more precise future radionuclide standardisations, i.e. realisation of the SI unit Becquerel.

Keywords

High-resolution beta spectrometry, metallic magnetic calorimeters (MMCs), solid scintillator crystal techniques, magnetic spectrometer, theoretical modelling of beta spectra, realistic nuclear mean field modelling, decay scheme, radionuclide metrology, realisation of the SI unit becquerel, traceability.

Background to the Metrological Challenges

There is a steadily increasing need for precisely determined beta spectra for the radionuclides with complex decay schemes which are crucial in many fields related to health, nuclear power, environment, and in particular in radionuclide metrology. Several state-of-the-art methods for activity standardisation such as liquid scintillation counting (LSC), calorimetry or 4π ionization chambers require the shape of beta spectra and the branching ratios in order to accurately determine the activity of beta emitters. The realisation of the SI unit becquerel for these nuclides depends on the precision of these data.

There is a need for research aimed at obtaining decay data for beta emitters with complex decay schemes: the beta spectrum shapes that are more difficult to measure than for pure beta emitters, and additional important data such as branching ratios, fractional EC probabilities or photon emission probabilities. To achieve this there needs to be an improvement in several beta spectrometry techniques beyond-the-state-of-the-art, in particular metallic magnetic calorimeter (MMC) detectors, but also Si(Li) detectors, a magnetic spectrometer, and solid scintillator crystal (SSC) detectors intrinsically including or doped with the beta decay nuclides.

The determination of high precision data of several beta decay nuclides with complex decay schemes is also required. Examples are ^{210}Pb, important in the field of environmental radioactivity, ^{177}Lu and ^{90}Y, which are among the isotopes most frequently used for targeted tumour therapy, ^{129}I, an important fission product with a long half-life, ^{40}K, and ^{204}Tl. Measurements using MMCs (^{210}Pb, ^{129}I and ^{204}Tl), SSCs (^{40}K, ^{204}Tl) and a magnetic spectrometer (^{40}K, ^{90}Y and ^{177}Lu) would provide data sets of unrivalled precision comprising the shapes of beta spectra, branching ratios, fractional EC probabilities and the most precise measurement of the small positon emission branch of ^{90}Y.

There is additionally a need to improve calculations of energy spectra from beta emissions. The high precision of MMC measurements challenges the accuracy of the theoretical models for the atomic and nuclear structures as well as for the description of the beta decay process. High precision models have already been developed for allowed transitions but elaborating one for the forbidden transitions is still a major challenge. The validation of these theoretical predictions could be done through a systematic comparison with new measurements of high precision. Precisely measured beta spectra would help to develop improved theoretical calculation methods. The measured spectra and advanced calculation methods, as well as new experimental data on

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branching ratios and the resulting improved decay schemes, would be an invaluable contribution to reducing uncertainties in activity measurement methods in radionuclide metrology.

Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the protocol.

The JRP shall focus on the traceable measurement, evaluation and validation of experimental data of beta emitters with complex decay schemes: the beta spectrum shapes, branching ratios, fractional electron capture probabilities or photon emission probabilities.

The specific objectives are

1. To measure and validate beta spectrum shapes and decay scheme parameters of radionuclides undergoing beta decay with complex decay schemes (e.g. ^{210}Pb, ^{177}Lu and ^{90}Y, ^{129}I, ^{40}K, or ^{204}Tl). In particular this should include beta minus transitions populating both ground state and excited states, and nuclides having additional electron capture or beta plus decay branches. This work should employ modern spectrometric techniques including metallic magnetic calorimeters (MMC)-based spectrometers offering ultra-high energy resolution and very high detection efficiency.
2. To compute beta spectrum shapes using an advanced calculation code including all relevant effects from atomic and nuclear structures, and to validate the calculated beta spectrum shapes against the measured spectrum shapes.
3. To develop, improve and validate beta spectrometry techniques beyond the current state-of-the-art, in particular: MMC detectors, solid scintillator crystals intrinsically including or doped with the beta emitting nuclides, application of liquid solid scintillator mixed techniques, magnetic spectrometers, and Si(Li) detectors.
4. To evaluate the impact of the improved and validated decay data on primary activity determination of radionuclides undergoing beta decay with complex decay schemes, in particular by liquid scintillation counting.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain, standards developing organisations (such as CEN, ISO, ICRU) and end users (radionuclide metrology, nuclear medicine, fusion and nuclear power industry, other European associations like NUGENIA etc.).

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. To enhance the impact of the research work, the involvement of the larger community of metrology R&D resources outside Europe is recommended. A strong industry involvement is expected in order to align the project with their needs and guarantee an efficient knowledge transfer into industry.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this.

In particular, proposers should outline the achievements of the EMPIR project 15SIB10 MetroBeta and EMPIR project 17FUN02 MetroMMC and how their proposal will build on those.

Proposers should clearly demonstrate a plan of activity aimed at stakeholder engagement.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.8 M€, and has defined an upper limit of 2.1 M€ for this project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 20 % of the total EU Contribution across all selected projects in this TP.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the “end user” community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the “end user” community (e.g. letters of support) is also encouraged.

You should detail how your JRP results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Transfer knowledge to the health, nuclear power, environment, and in particular in radionuclide metrology sector.

You should detail other impacts of your proposed JRP as specified in the document “Guide 4: Writing Joint Research Projects (JRPs)”

You should also detail how your approach to realising the objectives will further the aim of EMPIR to develop a coherent approach at the European level in the field of metrology and include the best available contributions from across the metrology community. Specifically, the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards,
- the metrology capacity of EURAMET Member States whose metrology programmes are at an early stage of development to be increased,
- organisations other than NMIs and DIs to be involved in the work,

Time-scale

The project should be of up to 3 years duration.