Title: Radionuclide beta spectra metrology

Abstract

Radionuclide metrology is gaining relevance in many areas such as environmental investigations, nuclear waste management and nuclear medicine. Proposals against this SRT should address the precise beta spectra that are required for primary activity standardisation of pure beta-emitting isotopes. They should focus on the development and application of modern spectroscopic techniques to measure beta spectra with unprecedented precision and on the improvement of beta spectra computations. The proposed combination of experimental and theoretical aspects should generate relevant nuclear data of high quality, enable significantly lower uncertainties for activity measurements of beta emitters and improve the capabilities of radionuclide metrology in Europe.

Keywords

Radionuclide metrology, traceability, beta-decay, beta spectroscopy, metallic magnetic calorimeters (MMCs), Superconducting Quantum Interference Devices (SQUIDs)

Background to the Metrological Challenges

Precise knowledge of beta spectra is crucial, e.g. when applying state-of-the-art methods in radionuclide metrology such as liquid scintillation counting (LSC) or calorimetry. In addition, well-known spectra are required for several other techniques, e.g. for analytical methods or Monte-Carlo simulations to evaluate a detector response, for Cherenkov counting techniques, ionisation chamber measurements, and for the estimation of the dose caused by radioactive decay. The most frequently used techniques for activity measurements of pure-beta emitting isotopes are based on LSC. Several NMIs have developed new instruments with two or three photodetectors. The activity can be derived using the triple-to-double coincidence ratio (TDCR) method or the CIEMAT/NIST efficiency tracing technique. Both approaches require knowledge of the beta spectra.

Current methods to calculate beta spectra provide only limited precision. Existing codes for the computation of beta spectra only calculate allowed transitions and sometimes allow for adding experimental shape factors. The most elaborate codes can handle allowed and forbidden unique transitions, but with too restrictive approximations to provide calculations of high precision. These analytical codes do not calculate any leptonic or nuclear wave functions. This widespread approach has recently been proved to be incorrect by comparing MMC measurements of the decays of ^{63}Ni and ^{241}Pu with improved calculations accounting accurately for the atomic screening and exchange effects. However, these calculations are valid only in the case of allowed transitions. Forbidden unique transitions can be calculated without involving the structure of the nuclei but a binding approximation is necessary which does not allow accounting properly for the influence of the atomic structure on the beta spectra. Improved calculations should be set out, implemented and tested with new highly precise measurements at low energy.

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 radionuclide metrology research necessary to support primary activity standardisation of pure beta-emitting isotopes.

The specific objectives are

1. To improve modern measurement techniques (e.g. metallic magnetic calorimeter - MMC detectors, Si(Li) detectors, $LaBr_3$/$CeBr_3$ scintillators) for high-resolution beta spectrum measurements, including data analysis (Monte Carlo simulations, deconvolution process of the detector response function, etc.).
2. To apply the methods for measurements of selected beta spectra, in particular with low (< 100 keV) and intermediate (< 1 MeV) end-point energy.
3. To improve theoretical computation methods on the basis of the measured spectra.
4. To validate spectra with other methods (e.g. using various methods of liquid scintillation counting including efficiency variation).
5. To facilitate the take up of the technology and measurement infrastructure developed by the project by the measurement supply chain (accredited laboratories, instrumentation manufacturers) and end users (the nuclear medicine community and the nuclear power industry).

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.

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 21 % of the total EU Contribution to the project. Any deviation from this must be justified.

Any industrial partners that will receive significant benefit from the results of the proposed project are expected to be unfunded partners.

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 nuclear sector.

You should detail other impacts of your proposed JRP as specified in the document “Guide 4: Writing a Joint Research Project”

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.