**EMPIR Call 2017 – Industry, Fundamental, Normative and Research Potential**

Selected Research Topic number: **SRT-f08**
Version: 1.0

# Title: Measurement of fundamental nuclear decay data using metallic magnetic calorimeters


## Abstract

Determining the age of the solar system or how cancer treatments damage DNA are two research areas that both rely on very precise nuclear decay probabilities produced by electron capture during radioactive decay. Current nuclear data sets are over 20 years old and need replacement in order to achieve the required accuracy for today's radionuclide metrology. Nuclear decay emission spectra of a few eV to a few 100 keV can be identified with high detection efficiencies using innovative energy dispersive metallic magnetic calorimeter (MMC) detectors. However MMC require validation and optimisation before improved electron capture nuclear data can replace existing data sets.



## Keywords

Electron capture probabilities, X-ray, high-resolution spectrometry, metallic magnetic calorimeters (MMCs), nuclear decay, radionuclide metrology


## Background to the Metrological Challenges

Accurately determining the radioactivity of materials by techniques such as liquid scintillation counting relies on using theoretical models to link electron and photon emissions produced during radioactive decay and their probability to the counting response measured. Other examples of measurements that require very precise electron capture (EC) probabilities include accurate dating of solar system age based on the long-lived isotope $^{41}$Ca and also in nuclear medicine where internal dosimetry of EC isotopes (e.g. $^{125}$I) are used in cancer treatment.

Precise knowledge of electron and photon emission spectra and electron capture probabilities is a prerequisite for state-of-the-art liquid scintillation counting (LSC) techniques such as TDCR which are frequently used for radioactivity standardisations in radionuclide metrology. Electron capture probabilities define the atomic shell in which a primary vacancy is created during nuclear decay and, consequently, the contribution from each shell to the subsequent atomic relaxation process. Fractional electron capture probabilities define the LSC measurement uncertainty and these are based on experimentally determined electron capture probabilities.

Atomic data for EC decays have been derived from measurements and calculations performed more than 20 years ago and these are now causing significant measurement problems. Accurate experimental X-ray emission intensities are needed to establish consistent EC decay schemes and theoretical models of subsequent relaxation processes. In addition, X-ray emission intensities are key data used to quantify the activity of a radioactive material by X-ray spectrometry. Thus, their uncertainties play a major role in the corresponding uncertainty budgets.

Innovative and groundbreaking metallic magnetic calorimeter (MMC)-based detectors have been successfully used in high-resolution spectrometry of X-rays and gamma-rays emitted from radionuclides with high atomic numbers. Spectrometry using energy dispersive MMC detectors has been shown to be particularly suitable for measuring radioactive decay emission spectra in the energy range of few eV to a few 100 keV. High detection efficiency can be obtained by embedding the radioactive source into the MMC absorber but absorber-detector configurations need to be optimized for radio-nuclides with low and high atomic numbers, such as $^{41}$Ca, $^{65}$Zn, $^{109}$Cd, $^{125}$I using simulations. New techniques to prepare absorbers are also needed to accommodate chemical coupling. In particular techniques aiming at very fine dispersion of the radioactive material within the absorber, are required for the rapid maximum absorption of a particles energy to achieve the best high-energy resolution.

Data acquisition and analysis procedures currently used for the existing MMC-based spectrometers also need further improvement and validation.

Some of these developments are currently being carried out within the EMPIR project 15SIB10 MetroBeta for pure beta-emitting isotopes with endpoint energies in the range from 70 keV to 700 keV. The development of MMC-based techniques to study EC decays and X-ray emissions for the selected emitters would both benefit from the MetroBeta research activities and, at the same time, extend the applications and impact of high-resolution radionuclide spectrometry.

## 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 metrology research necessary to support spectrometry techniques and theoretical calculation methods for improving electron capture (EC) nuclear data used in radionuclide metrology.

The specific objectives are

1. To improve experimental techniques for spectrometry based on novel cryogenic detectors for radionuclide metrology in the energy range of 20 eV - 100 keV.
2. To determine fractional electron capture probabilities of selected radionuclides by means of spectrometry based on novel cryogenic detectors with distinguished high energy resolution using sources embedded in the detector absorber.
3. To measure absolute X-ray emission intensities of selected radionuclides by using a combination of high-resolution spectrometry based on novel cryogenic detectors using sources outside the detector absorber and accurate primary activity determination.
4. To improve theoretical models of the electron capture process and subsequent atomic relaxation and to validate them using high-precision experimental data from this project.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by radionuclide metrologists, nuclear physicists and other researchers.

Proposers shall give priority to work that aims at excellent science exploring new techniques or methods for metrology and novel primary measurement standards, and brings together the best scientists in Europe and beyond, whilst exploiting the unique capabilities of the National Metrology Institutes and Designated Institutes.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this and also those from EMPIR project 15SIB10 MetroBeta.

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

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.5 M€, and has defined an upper limit of 1.8 M€ for this project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 40 % of the total EU Contribution to the project.

## 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,

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.