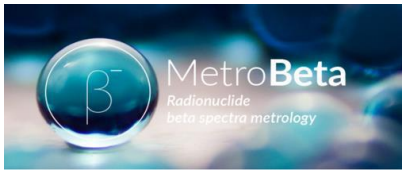

EMPIR
EURAMET
The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

Deliverable 9

Grant Agreement number	15SIB10	
Project short name	MetroBeta	
Deliverable title	Evidence of contributions to new or improved international standards with a specific focus on recommendations for improved beta spectra shapes usage in activity of radionuclides measurement, to be submitted to EURAMET TC-IR, ICRM Beta Spectrometry WG, ICRM Liquid Scintillation Counting WG, and DDEP and accreditation authorities in Europe. Examples of early uptake of project output by the measurement supply chain (accredited laboratories, instrumentation manufacturers) and end users (the nuclear medicine community and the nuclear power industry).	
Lead partner	CMI	
Due and actual dates	May 2019	September 2019

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1 Contribution to ICRM Working Groups

Consortium activities and research results have been presented at International Committee for Radionuclide Metrology Working Groups:

ICRM WG "Beta Particle Spectrometry" is devoted to the development of the metrological aspects of beta-particle spectrometry and its applications. This includes:

- Theory (beta (β±) and electron capture (ε) transitions, theoretical shape factors and influence of the nuclear current, atomic effects)
- Experiments (instrumentations used for beta spectrometry, techniques that need beta information, confidence on experimental shape factors, data analysis and unfolding methods
- Simulations (confidence on the physical processes: low energies, radioactive decays, atomic rearrangements; comparison of the results of different codes: Geant4, Penelope, etc.
- Evaluations and dissemination (confidence and uncertainties on experimental shape factors, evaluation procedure for establishing recommended experimental shape factors, mean energies, log *ft* values, database)

Project partners informed the worldwide group of metrologists and other scientists within this group about the project research results at annual meetings, especially about improvements to the theory and calculation methods, advances in the experimental techniques and Monte Carlo calculations.

Corresponding presentations were given at the ICRM Beta Spectrometry Working Group meetings in Buenos Aires, Argentina, in May 2017; Gaithersburg, USA, in September 2018; and Salamanca, Spain, in May 2019. Participants were interested in the dissemination of both the theoretical predictions and the measurements, and in understanding how accurate they are.

ICRM WG "Life Sciences" is devoted to provide a forum for ICRM members to address radionuclide metrology issues as they relate to the life sciences. This includes:

- Development of methodologies to calibrate short-lived radionuclides of interest in nuclear medicine, measurement of decay properties (half-lives, decay energies and probabilities, etc.) of radionuclides used in nuclear medicine and biological research.
- Development of measurement methodologies for transferring National Measurement Standards to the clinic and research laboratory.
- Facilitation of solutions finding to these problems through workshops, publications, electronic communications) and collaborative work.

Members of this working group have been introduced to the Bremsstrahlung measurements within MetroBeta project and new technique for beta impurities in radiopharmaceuticals measurement. Corresponding presentations were given at the ICRM Life Sciences Working Group meetings in Rome, Italy, in November 2016, and in St Petersburg, Russia, in June 2018. Participants were much interested, and the role of accurate beta spectra and accurate bremsstrahlung cross sections

was discussed when aiming at reliable Monte Carlo simulations which are widely used in ionizing radiation research including nuclear medicine etc.

ICRM WG "Liquid Scintillation Counting (LSC)" is devoted to the development of LSC techniques, especially in the field of radionuclide standardization. This concerns especially LS-source preparation, the CIEMAT/NIST efficiency tracing technique, the TDCR method as well as Čerenkov counting techniques, the corresponding theory and practice of LSC techniques, new measurement methods, the modification and construction of new LS arrangements, the commercial LS spectrometers and the counting techniques.

Project partners informed the worldwide group of metrologists and other scientists about the importance of newly calculated and measured beta spectra on absolute activity measurements. At various occasions, examples were presented (e.g. ^{63}Ni, ^{60}Co, ^{36}Cl and ^{99}Tc, see also detailed report on deliverable D7) which make clear that accurately calculated and/or measured beta spectra are essential for accurate activity standardization.

Presentations were given at the ICRM Liquid Scintillation Counting Working Group meeting in Rome, Italy, in November 2016, at the International Conference on "Advances in Liquid Scintillation Spectrometry (LSC2017)" in Copenhagen, Denmark, in May 2017, at the 21st International Conference on Radionuclide Metrology and its Applications (ICRM) in Buenos Aires, Argentina in May 2017, at the meeting of the Consultative Committee for Ionizing Radiation - Section II: Measurement of radionuclides (CCRI(II)) at BIPM in Sèvres, France, in June 2017, at the ICRM Liquid Scintillation Counting Working Group meeting in St Petersburg, Russia, in June 2018, at the 22nd International Conference on Radionuclide Metrology and its Applications (ICRM) in Salamanca, Spain, in May 2019 (planned), in all project workshops and in one project training course organized at PTB. In addition, presentations were given in other ICRM WG meetings.

The article by the project partners Kossert, K., Marganiec-Gałązka, J., Mougeot, X., Nähle, O.J. entitled "Activity determination of ^{60}Co and the importance of its beta spectrum" (Applied Radiation and Isotopes 134 (2018) 212-218) is among the Top-20 of the most downloaded articles in the journal Applied Radiation and Isotopes within last 90 days (assessed 24 April 2019). This also indicates that scientists are much interested in the outcome from the MetroBeta project.

2 Contribution to Decay Data Evaluation Project

The international **Decay Data Evaluation Project** aims to evaluate nuclear decay data for radionuclides of interest in applied research. These radionuclides are important in the nuclear power industry, nuclear medicine, remediation of nuclear waste and radionuclides used for calibration of measurement devices. The evaluated data are stored in the French NUCLEIDE database and are available from the *Laboratoire National Henri Becquerel* website (www.lnhb.fr/nuclear-data/nuclear-data-table).

These data are also published in the BIPM Monographie-5 series available from the BIPM website (https://www.bipm.org/en/publications/scientific-output/monographies-ri.html) and their use is encouraged by the CCRI for use in international activity comparisons.

The relevant data for beta transitions, e.g. *logft* values and average energies, are now calculated using the BetaShape code developed in the MetroBeta project.

3 Contribution to CCRI(II)

The fact that beta spectra and other radionuclide data are of highest importance for LSC and radionuclide metrology in general was also discussed at various meetings of the Key Comparison Working Group (KCWG) of the CCR(II) as well as in its subgroup to develop the extension of the International Reference System (ESIR) for comparisons by means of a liquid-scintillation-based technique. The CCRI(II) as well as the ICRM community are much interested in the outcome of the MetroBeta project and is was made clear that further efforts are needed in this field. Hence, follow-up projects are highly desirable in particular concerning the MMC technique, since this costly technique is only available at a few NMIs (LNHB, KRISS, PTB) but its outcome is needed by the whole radionuclide metrology community. Also the need for reliable and accessible calculated beta spectra was emphasized which also comprises non-unique forbidden beta transitions. The importance of nuclear decay data is also mentioned in a draft document (unpublished) summarizing the strategy (2018-2028) of the Consultative Committee for Ionizing Radiation (CCRI) and will be discussed and further developed at the CCRI(II) meeting at BIPM in June 2019.

4 General impact

Several **NMIs/DIs not participating in the project** showed specific interest in the project results and intend to use new nuclear data and developed beta spectrometric methods, especially for absolute activity measurement and beta impurities determination. Between them:

- ENEA (Italian Designated Institute)
- CIEMAT (Spanish Designated Institute)
- KRISS (Korean National Metrology Institute)
- NPL (UK National metrology Institute)
- NIST (US National Metrology Institute)

Other European NMIs/DIs contact persons were informed about the project and its developments at **EURAMET Technical Committee for Ionising Radiation** (TC-IR) annual meetings.

Several **universities and research organisations** are interested in the project results, especially theoretical calculations of beta spectra and influence on measurement using liquid scintillation counting. Between them:

- Czech Technical University – Faculty for Nuclear Science and Physical Engineering
- University of Valencia – Institut de Fisica Corpuscular (Spain)
- Brookhaven National Laboratory (USA)

Project results were presented at the project workshops, where also people from **industrial enterprises** participated. They were interested mainly in new measurement methods for liquid scintillation counting and Si(Li) spectrometry. Between them:

- NUVIA a.s. (instrumentation manufacturer from the Czech Republic)
- National Nuclear Laboratory (significant enterprise in nuclear industry from UK)
- Nuclear power industry via OECD-NEA JEFF Nuclear Data Library

5 Early uptake of the BetaShape code by end users

The original version of the BetaShape code was released at the end of 2016 to facilitate the knowledge transfer of the beta spectra. This code reads and writes the standard *Evaluated Nuclear Structure Data Files* (ENSDF), calculates the beta decays with an improved theoretical modelling and also includes a database of experimental shape factors.

It is available for download from the CEA/LNHB website (http://www.lnhb.fr/rd-activities/spectrum-processing-software/), and an updated version is to be made available in 2019. The corresponding webpage has been accessed more than 1000 times in 2017, 2018 and 2019.

5.1 The International Atomic Energy Agency

The **International Atomic Energy Agency** (IAEA) through the Live Chart of Nuclides webpage on the Nuclear Data Services website (https://www-nds.iaea.org/relnsd/vcharthtml/VChartHTML.html) now shows beta spectra calculated by the BetaShape code developed during this project.

The **International Network of Nuclear Structure and Decay Data Evaluators** (NSDD) (https://www-nds.iaea.org/nsdd/) organised under the auspices of the IAEA are also about to adopt the BetaShape code for use in their evaluations, published as the *Evaluated Nuclear Structure Data File* (ENSDF) (https://www-nds.iaea.org/ensdf/) in the peer-reviewed journal *Nuclear Data Sheets* (https://www.sciencedirect.com/journal/nuclear-data-sheets).

5.2 The Decay Data Evaluation Project

The BetaShape code has been officially adopted by the Decay Data Evaluation Project for data evaluations of interest for the radionuclide metrology community.

5.3 The Joint Evaluated Fission and Fusion File

The Nuclear Energy Agency (NEA) of the Organisation for Economic Cooperation and Development (OECD) oversees the Joint Evaluated Fission and Fusion File project, whose objective is to produce evaluated data libraries for use in all applications, e.g. fission energy, fusion power, medical applications, basic research. The Radioactive Decay Data sub-library is produced from evaluated decay data files coming from the DDEP and ENSDF, amongst other sources, and the BetaShape code will be used to calculate all of the relevant parameters relating to beta decay in the forthcoming version of this sub-library for these two sources.

5.4 Anti-neutrino spectra calculations

The BetaShape code was already used in an independent study from a group in the USA to calculate the reactor antineutrino flux , who published their findings in the peer-reviewed journal Physical Review Letters in 2017 (see: https://doi.org/10.1103/PhysRevLett.119.112501).

5.5 Medical applications

The BetaShape code was used by participants in the **EMPIR project 15HLT06** “Metrology for the clinical implementation of dosimetry in molecular radiotherapy” for the calculation of beta spectra for the subsequent calculation of the absorbed dose in molecular radiotherapy.