Coordinator's Report
Beta-Particle Spectrometry Working Group

Background

The Beta Particle Spectrometry Working Group is devoted to the development of the metrological aspects of beta spectrometry and its applications. This includes:

- Theory. Beta ($\beta^{\pm}$) 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.
- Evaluations. Confidence and uncertainties on experimental shape factors; Procedure for establishing recommended shape factors; Mean energies, log *ft* values, database.

Interested communities in radionuclide metrology are: nuclear decay data, liquid scintillation counting, ionising chambers, 4π β-γ counting.

Recent and on-going activities

- A dedicated website was created in 2016 and can be found at the following address: http://www.lnhb.fr/icrm_bs_wg/.

- Theory

  i) Further developments of calculations of electron capture decays. Precise atomic energies and radiative corrections have been demonstrated to be of high importance for accurate theoretical predictions.

  ii) Inclusion of the nuclear structure in beta decay calculation has been conducted through the determination of single particle nuclear matrix elements. Formalism has been explicitly extended to electron captures. A preliminary study has been conducted in order to include realistic nuclear structure in the calculation of some forbidden non-unique transition, with promising results.

  iii) A new version of the BetaShape code has been released in June 2019. This version includes improvements in the calculation of radiative corrections for beta decays and an update of the database of experimental shape factors. In addition, calculation of electron capture decays is included, with provision of capture probabilities and capture-to-positron probabilities for all subshells, log(ft) values and splitting of the branch between capture and beta plus transitions. This new version is made available for the community at the same address:
  http://www.lnhb.fr/activites-recherche-developpement/logiciels-traitement-spectres/

- Simulation

  i) A decay module for Geant4 has been developed at LNHB, in the same spirit as the PenNuc module developed by CIEMAT with support from LNHB, but with improvements such as a coupling with the BetaShape code. This module was

presented at the ICRM 2019 conference (May 27-31, 2019) and will be made available for the community.

ii) An unfolding algorithm has been developed at PTB based on Monte Carlo simulations (EGSnrc). The purpose is to correct a ^{36}Cl spectrum measured with a metallic magnetic calorimeter for the distortion due to the escape of bremsstrahlung photons. A similar algorithm has been developed at LNHB using Geant4 and Penelope simulations and successfully applied to beta spectra measured with silicon detectors.

- Measurements

  i) Beta spectra of ^{14}C, ^{36}Cl, ^{99}Tc and ^{151}Sm decays have been measured with metallic magnetic calorimeters at LNHB and PTB.

  ii) Beta spectra of ^{87}Rb and ^{176}Lu decays have been measured with solid scintillator crystals at TU Delft (Gonitec).

  iii) A magnetic spectrometer has been developed at IRA (CHUV) dedicated to beta spectrometry and beta spectra of ^{36}Cl, ^{60}Co, ^{99}Tc and ^{134}Cs decays have been measured.

  iv) A detection system based on silicon detectors in a quasi-4π configuration has been developed at LNHB and beta spectra of ^{14}C, ^{36}Cl, ^{99}Tc and ^{204}Tl decays have been measured. Excellent agreement has been obtained with the beta spectra measured with metallic magnetic calorimeters for ^{14}C and ^{99}Tc. Source preparation difficulties have been encountered for ^{36}Cl; work is in progress to minimize the size of the crystals. This work has been done in the context of the PhD thesis of Abhilasha Singh.

- Evaluations

  The BetaShape program is the reference code for DDEP evaluations. The first version of the code is used in the IAEA LiveChart to display beta spectra related to the decay of radionuclides: https://www-nds.iaea.org/relnsd/vcharthtml/VChartHTML.html
  Discussions are ongoing for an adoption by the NSDD network for ENSDF evaluations.

Related projects

- European metrology project (EURAMET, EMPIR programme) MetroBeta 15SIB10, 2016-2019. Website: http://metrobeta-empir.eu/. Partners are from Czech Republic, France, Germany, Netherlands, Poland and Switzerland.

  Summary. The MetroBeta project is taking both theoretical and experimental approaches to improving the knowledge of beta spectra. On the theoretical side, existing knowledge of the calculation of nuclear wave functions is being used to take into account the nuclear structure effect on these spectra. On the experimental side, beta spectrometry with MMCs is being developed, as well as solid scintillators containing the beta emitters in the structure of the scintillator crystal. Comparison of the newly calculated and measured spectra will validate the quality of the spectra.

- European metrology project (EURAMET, EMPIR programme) MetroMMC 17FUN02, 2018-2021. Website: http://empir.npl.co.uk/metrommc/. Partners are from France, Germany, Portugal, South Korea and United Kingdom.

Summary. The main objective of the MetroMMC project is to improve the knowledge of electron capture decay and subsequent atomic relaxation processes. New theoretical calculation techniques and extensive experiments using MMCs will be developed to determine important decay data which are relevant for primary activity standardisations in radionuclide metrology, in cancer therapy on the DNA level, and when studying the early history of the solar system. The experimental parts will be complemented with a new approach based on microwave coupled resonators.

Recent and future meetings

- A Working Group meeting took place in Salamanca during the ICRM 2019 conference (May 27-31, 2019). Three presentations were given:

  i) M. A. Kellett (LNHB), Overview of the MetroBeta Project.

  ii) K. Kossert (PTB), Comparison and validation of beta spectra measurements.

  iii) D. Arnold (PTB), Overview of the MetroMMC project.

- The MetroMMC Workshop took place at LNHB (October 24, 2019).
- Abhilasha Singh successfully defended her PhD thesis at LNHB (September 25, 2020) with the following topic: Metrological study of the shape of beta spectra and experimental validation of theoretical models.
- Joint radionuclide metrology meetings took virtually place at LNHB (October 26-30, 2020):

  i) Decay Data Evaluation Project (October 26, 2020).

  ii) Nuclear Decay Data Working Group (October 27, 2020).

  iii) Beta-Particle Spectrometry Working Group (October 27, 2020).

  iv) Radionuclide Metrology Technique Working Group (October 28, 2020).

  v) Gamma Spectrometry Working Group (October 29-30, 2020).

- The virtual character of the Working Group meeting (October 27, 2020) noticeably increased the audience, with 26 attendees. This possibility should be kept for future meetings, even without any travel restriction. Four presentations were given:

  i) M. Loidl (LNHB), Measurement of nuclear decay data by means of metallic magnetic calorimeters within European metrology research (EMPIR) projects.

  ii) P. Ranitzsch (PTB), MMC measurements at PTB-BS.

  iii) A. Singh (LNHB), Measurements of beta spectra with silicon detectors.

  iv) X. Mougeot (LNHB), New version of the BetaShape code.

  B. E. Zimmerman (NIST) announced that the Radioactivity Group successfully defended a project dedicated to the development of a cryogenic facility for radiation measurements. This project will last 5 years and will start in 2021.

- The next Working Group meeting has still to be planned in 2021. It was expected to take place in Bucharest during the ICRM 2021 conference (May 31 - June 4, 2021) but the conference has been postponed to 2023 due to the Covid-19 pandemic.

On behalf of the Beta-Particle Spectrometry Working Group,

Xavier Mougeot (coordinator)

CEA Saclay
Laboratoire National Henri Becquerel
Bât. 602 – PC111
91191 Gif-sur-Yvette
France

Phone: +33 1 69 08 23 32
E-mail: xavier.mougeot@cea.fr