

Title: Traceable metrology for emerging radiotherapy modalities using charged particle beams

Abstract

Radiotherapy is the most cost-effective cancer treatment, with 50 % of all patients receiving it at some point during their care. Emerging charged particle therapies offer greater spatial precision in delivering the radiation dose to the tumour while reducing damage to healthy tissue. However, they are in a very early phase of development, lacking framework, consensus, and standards for dosimetry, a requirement to ensure their safe clinical adoption. Proposals addressing this topic should aim to develop high precision absorbed dose measurement techniques to ensure consistency across treatment centres and to support more efficient implementation of new radiotherapy treatments with charged particles to a clinical routine. Its outcomes will support the safe clinical implementation, inform new codes of practice, and keep metrology aligned with advances in radiotherapy.

Keywords

Code of Practice (CoP), Very High Energy Electron (VHEE) Radiotherapy, Small-field electron beams, ion beams.

Background to the Metrological Challenges

Every year, approximately four million people in Europe are diagnosed with cancer, a figure projected to rise as the population ages. More than half of these patients receive radiotherapy as part of their treatment, underscoring the essential role of radiotherapy in modern oncology. Ensuring accurate and traceable dosimetry is crucial for patient safety and treatment efficacy. Recent innovations in radiotherapy, such as Very High Energy Electron (VHEE) radiotherapy, small-field electron beams and ion beam radiotherapy, promise to improve cancer outcomes. However, while conventional photon and electron therapies benefit from well-established frameworks (e.g. IAEA TRS-398) and international dosimetric comparisons (e.g. BIPM K6 for high energy photon beams), these new modalities lack similar established standards and traceable calibration methods. They require new reference standards, dedicated measurement protocols and/or robust international dosimetric comparisons to ensure global consistency in dose delivery and patient safety. For example, ion beam dosimetry has not yet achieved the same level of uncertainty in absorbed dose measurements as in photon beam dosimetry, partly due to the limited availability of well-established primary standards. In addition, new ion beams (e.g. helium, oxygen and mixed particle fields) are entering clinical practice and require thorough metrological characterisation. Reducing uncertainty budgets is critical to ensuring accurate and consistent dose delivery. An essential step toward this goal is the organisation of international comparisons, which serve to harmonise ion beam dosimetry across national metrology institutes by comparing and validating primary standards. These efforts play a vital role in improving traceability, promoting international consistency, and ensuring that ion beam radiotherapy is delivered at the highest possible accuracy. However, defining the appropriate scope for these comparisons poses a challenge. Conducting separate comparisons for every ion species and energy level would be exhaustive and impractical. Therefore, it is essential to develop an efficient framework for international ion beam comparisons.

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 proposal shall focus on developing traceable dosimetry in emerging radiotherapy techniques based on charged particle beams.

The specific objectives are:

1. To develop traceable metrology for Very High Energy Electron (VHEE) accelerators using the FLASH effect. This includes establishing accurate primary dosimetry standards of absorbed dose, investigation of suitable secondary standard dosimeters and measurement techniques, as well as appropriate calibration protocols to ensure precise dose delivery for VHEE treatments at ultra-high dose rates (UHDR).
2. To establish a new formalism for the dosimetry of small-field electron beams for both conventional and UHDR deliveries. To investigate application of alternative dosimetry techniques and comprehensive characterisation of various principles of detectors for small field measurements. This includes focusing on developing appropriate correction coefficients for dosimeters calibrated in a reference field when used for small-field dose measurements.
3. To reduce uncertainties in absorbed dose measurement for ion beam radiotherapy, including currently used ions and extending the developed capabilities to novel ion beams (e.g. helium, oxygen and mixed fields). To establish national primary standards for ion beam dosimetry and optimise methods to reduce uncertainties in the calibration coefficients of secondary standard dosimeters used in clinical settings. To develop a framework for international dosimetric comparisons to improve global consistency and ensure the accuracy of ion beam radiotherapy.
4. To characterise detectors for ion beam dosimetry in magnetic fields for the end-to-end testing to evaluate the overall accuracy and reliability of the dosimetry process. This includes the determination of correction factors and the development of traceable dosimetry protocols.
5. To facilitate the take up of the technology and recommendations developed in the project by standards developing organisations, (e.g. those associated with International Atomic Energy Agency (IAEA) and ICRP Committee 3 Radiological Protection in Medicine), international metrological and scientific organisations, (BIPM, CCRI, EURAMET TC-IR, EFOMP, EURADOS, ESTRO), manufacturers of measurement equipment and irradiation facilities, and end-users, (clinical and academic laboratories, hospitals)

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes, and it is expected that multidisciplinary teams will be required. To enhance the impact of the research, the involvement of the appropriate user community such as medical practitioners, medical (academic) hospitals and industry is strongly recommended, both prior to and during methodology development. Where relevant, proposals are encouraged to build on, or seek collaboration with, existing projects and develop synergies with other relevant European, national or regional initiatives and funding programmes. In particular, links are encouraged with (i) the projects funded under earlier relevant topics of the Horizon Europe programme; or (ii) other relevant European Partnerships.

Proposers should establish the current state of the art and explain how their proposed project goes beyond this. A personalised approach in developing applications is welcomed.

Proposers should note that the programme funds the activity of researchers to develop the capability, not the required infrastructure and capital equipment, which must be provided from other sources.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 2.1 M€ and has defined an upper limit of 2.6 M€ for this proposal.

EURAMET also expects the EU Contribution to the external funded beneficiaries to not exceed 35 % of the total EU Contribution across all selected projects in this TP.

Any industrial beneficiaries that will receive significant benefit from the results of the proposed project are expected to be beneficiaries without receiving funding or associated 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 proposal's 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,
- Facilitate improved industrial capability, or improved quality of life for European citizens in terms of personal health, protection of the environment and the climate, or energy security,
- Transfer knowledge to the medical 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 the Metrology Partnership 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.

Timescale

The project should be of up to 3 years duration.

Additional information

The links provided in this section are only correct at the time of publication up until the end of the Call year.

These references have been provided by EURAMET.

- [1] Council Directive 2013/59/Euratom of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation.
<https://eur-lex.europa.eu/eli/dir/2013/59/oj>
- [2] Council Directive 97/43/Euratom of 30 June 1997 on health protection of individuals against the dangers of ionizing radiation in relation to medical exposure.
<https://eur-lex.europa.eu/eli/dir/1997/43/oj/eng>
- [3] EMN Radiation Protection Strategic Research Agenda
<https://www.euramet.org/european-metrology-networks/radiation-protection>