

Title: Metrology of ionisation track structure for characterisation of clinical hadron beams

Abstract

According to the World Health Organisation, cancer is the second leading cause of death globally. Proton and ion radiotherapy are expanding rapidly and the number of proton and carbon ion therapy patients in the EU is expected to grow each year. However, a harmonised methodology for hadron therapy has not yet been developed. Proposals addressing this SRT should focus on the traceable measurement and characterisation of clinical proton and hadron beams.

Keywords

Ionising radiation metrology; radiobiology; radiotherapy; microdosimetry; nanodosimetry; particle track structure; Monte Carlo simulations

Background to the Metrological Challenges

In Europe, there are currently 21 hadron therapy centres in operation, 15 under construction and a further 7 planned. This will lead to an expected number of proton and carbon ion therapy patients in the EU of approximately 50,000 patients per year.

Biological effectiveness of radiotherapy is related to the spatial distribution of the ionisations at the scale of the particle tracks and sub-cellular structures. Nano- and micro-dosimetry aim at establishing measurable characteristics of the particle track structure at the nano- and micro-meter scale that can be translated into radiation quality factors. A correlation between measured nano- and micro-dosimetric quantities and radiobiological data has been suggested, but further work is needed.

Energetic proton and ion beams are able to create a range of secondary particles some of which are characterised by short range and very high ionisation clustering. Semi-empirical weighting factors are currently used to take into account the changes in biological effectiveness due to increase in ionisation clustering for protons whilst different radiobiological models are used to calculate the change in biological effectiveness along ion tracks. Monte Carlo simulation codes enable the detailed study of the radiation's spatial pattern of energy deposition and are commonly used in the design and validation of novel detectors, as well as in the development of radiobiological models. As these codes become more sophisticated, a common platform for benchmarking must be developed.

Operational parameters for DNA damage and repair must be defined so they can then be verified experimentally and used to draft clinically suitable measurements protocols which facilitate their integration into treatment planning systems (TPS) without the needs to use relative scaling factors.

For the successful treatment of cancer patients using hadron therapy, a standardised and traceable characterisation of clinical proton and hadron beams is necessary at the micro- and nano-dosimetric scale, and operative radiation dosimetry quantities must be defined, together with associated measurement procedures that will form the basis for designing radiobiologically optimised clinical trials.

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 traceable measurement and characterisation of clinical proton and hadron beams.

The specific objectives are

1. To assess and validate current micro- and nano-dosimetry methods, techniques and instrumentation for clinical proton and ion beams, including their validation through benchmarked Monte Carlo simulations.
2. To define new track structure operational quantities for clinical use. Data from the nano- and micro-dosimetric beam characterisation will be critically analysed in relation to established radiobiological models with the aim of extracting measurable physical quantities suitable for describing both the proton and ion track structures and their relative biological effectiveness.
3. To characterise the nature and spectra of secondary particles generated along the hadron tracks and quantify their radiobiological relevance. This requires the development of dedicated experimental setups coupled with benchmarked Monte Carlo simulations to quantitatively separate the contribution of secondary particles along and around the clinical beams.
4. To investigate integration methods of radiobiological and physical response models into treatment planning systems (TPS). This should cover Monte-Carlo approaches, analytical description of track structures, new nano- and/or micro-dosimetric quantities and alternative techniques.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by standards developing organisations (IAEA, CRU) and end users (e.g. clinical stakeholders and healthcare manufacturers).

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, hospitals and industry is strongly recommended, both prior to and during methodology development.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this. In particular, proposers should outline the achievements of the EMRP SIB06 BioQuaRT project and how their proposal will build on those.

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 35 % of the total EU Contribution across all selected projects in this TP.

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 clinical 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 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.