Dosimetry for advanced radiotherapy approaches using particle beams with ultra-high pulse dose-rates in the EMPH UHPulse project

A. Subiel, M. McManus 1, F. Romano 2, N. Lee 3, A. Lorencou 4, H. Palmiers 1, 5, R. Thomas 1, W. Farabolini 6, A. Girard 7, A. Mascia 8, S. Joseph 9, L. Lee 10, A. Schubert 2

1. Metrology Science, National Physical Laboratory, Harrow Road, Teddington, Middlesex, TW11 8LW, UK
2. National Research Institute for Physics and Mathematics, Institute of Experimental Physics, Janiszewskiego 43, 00-681 Warsaw, Poland
3. Department of Physics, University of Cincinnati, Cincinnati, OH, USA
4. CEA, Centre de Saclay, Saclay, France
5. Acute Treatment Hospital Bron, France
6. Medical Physics Institute, CAS, Prague, Czech Republic
7. School of Physics and Astronomy, University of Nottingham, UK
8. CERN, Geneva 1217, Switzerland
9. MedAustron, Marie Curie Strasse 5, 2700 Wiener Neustadt, Austria
10. University of Cincinnati Medical Center, Cincinnati, OH, USA

INTRODUCTION
The European Metrology Programme for Innovation and Research (EMPIR) UHPulse project aims to develop the metrological tools needed to establish traceability in absorbed dose measurements of pulsed particle beams with ultra-high dose-rates. Delivery of doses at ultra-high-dose-rate has been of particular interest due to remarkable reduction of normal tissue toxicity (known as the FLASH effect) with respect to conventional treatments. Pulses of particle beams with dose-rates orders of magnitude higher than in conventional radiotherapy present significant metrological challenges in dosimetry, which need to be addressed to enable the translation of these novel radiotherapy techniques to clinical practice.

AIM
The main goal is the development of the metrological tools needed to establish traceability in absorbed dose measurements of UHPDR particle beams, generated by both conventional, (radiofrequency), as well as laser-driven radiation sources. Different types of UHPDR particle beams, investigated in this project are shown below.

CONSORTIUM
The multidisciplinary consortium consists of:
- 5 National Metrology Institutes - leading in the field of dosimetry
- 3 academic hospitals - pioneers in FLASH/RTOG dosimetry expertise
- 3 universities - experts in detector development (pioneers in laser-driven beams
- 3 national research institutes - pioneers in detector development/therapy radiation expertise/access to radiation facilities
- 1 European research institute - laser-driven beam research infrastructure
- 5 companies - expert in detector development

METHOD
NPL's graphite calorimeter has been employed to measure the dose delivered from a 200 MeV pulsed very high energy electron (VHEE) beam. This was compared to the charge measurements of dosimeters in particle beams, generated by both conventional, (radiofrequency), as well as laser-driven radiation sources. Different types of UHPDR particle beams, investigated in this project are shown below.

OBJECTIVES
The objectives of the project are to be addressed in the four work packages summarized in Figure 2. These include:
2. Characterization of available detector systems in particle beams and with ultra-short pulse duration.
3. Development of traceable and validated methods for relative dosimetry.

RESULTS
The experimental setup allowed to carry out side-by-side measurements (Figure 3). A PTW 7802 Monitor chamber was placed between the vacuum chamber and the phantom setup allowing for the normalisation of any beam fluctuations in the measurements.

CONCLUSIONS
Graphite calorimeter and PTW Ross ionisation chamber were used to determine the absolute reconstruction factor $k_{pol}$ of the ion chamber as a function of dose-per-pulse when exposed to high-dose-per-pulse VHEEs. The reconstruction factor was found to be approximately $k_{pol} = 1.1$ at a collecting voltage of 75 V and dose per pulse of 5.26 Gy/pulse, corresponding to a chamber collection efficiency of $k_{pol}^c = 0.9$. The system collection efficiency was measured at 0.03 Gy/pulse, which is similar to what would be expected in a standard clinical radiotherapy beam. This significant decrease in collection efficiency indicates that understanding the process of ion collection in the chamber is fundamental in the translation of FLASH therapy and laser-driven sources into clinical practice. Behaviour of ion chambers and other dosimeters needs to be well understood before implementing them as secondary standard detectors in new radiotherapy applications such as FLASH and high-dose-per-pulse VHEE RT. This work is a foundation towards the development of metrology and tools traceable to national standards for these novel radiotherapy approaches.

This work has been carried out within the framework of the EMPH UHPulse project, which aims to develop the metrological tools needed to establish traceability in absorbed dose measurements of pulsed particle beams with ultra-high dose-rates.

ACKNOWLEDGEMENTS
This project has received funding from the EMPIR programme co-financed by the Participating States and from the EU Horizon 2020 research and innovation programme.

REFERENCES

CONTACT INFORMATION
anna.subiel@npl.co.uk