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UHDpulse

Development of Improved Dosimetry Standards for FLASH Radiotherapy: The UHDpulse Project

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September 25–29, 2022
14th International Conference on Radiation Shielding and 21st Topical Meeting of the Radiation Protection and Shielding Division
Seattle, WA

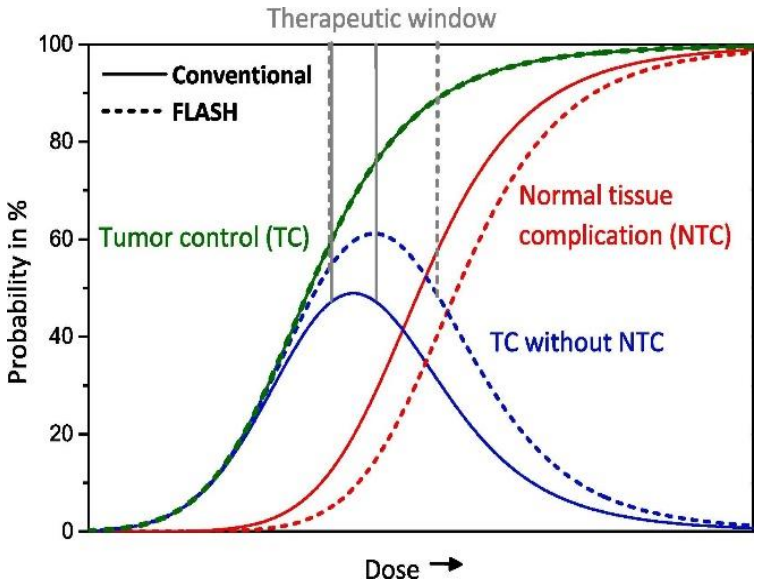
Outline

- Flash Radiotherapy
- Metrological Challenges in Flash-RT
- The UHDpulse Project
  - Objectives
  - Work Packages
  - Recent Highlights
  - Impact
- Conclusions

Flash Radiotherapy

FLASH radiotherapy (FLASH-RT) is a modern and promising cancer treatment modality still in its early stages of development and application.

- dose is delivered in few radiation pulses of ultra-high dose rate
- has been proven to significantly reduce adverse side effects to healthy tissues while being as effective for tumor control as conventional radiotherapy
- sparing effectiveness of FLASH-RT is observed using photons, protons, and electron beams
- very high energy electron (VHEE) are require for deep seeded tumor treatment (> 50 MeV)].

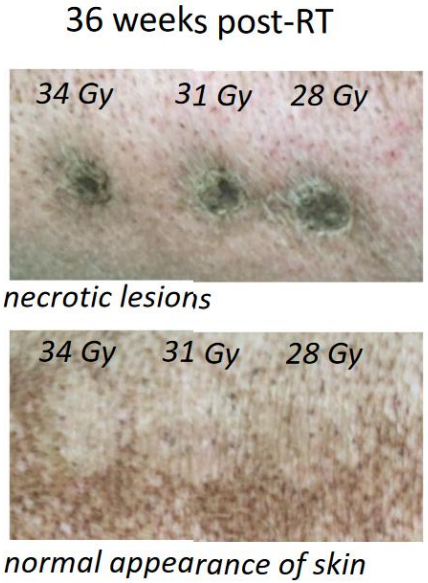


Laser-driven accelerators are seen as a compact and cost-effective accelerators for radiotherapy

- ultra-short radiation pulses of extremely high dose rate (up to 10^9 – 10^{12} Gy/s).

Flash-RT

FLASH irradiation of the skin of a pig



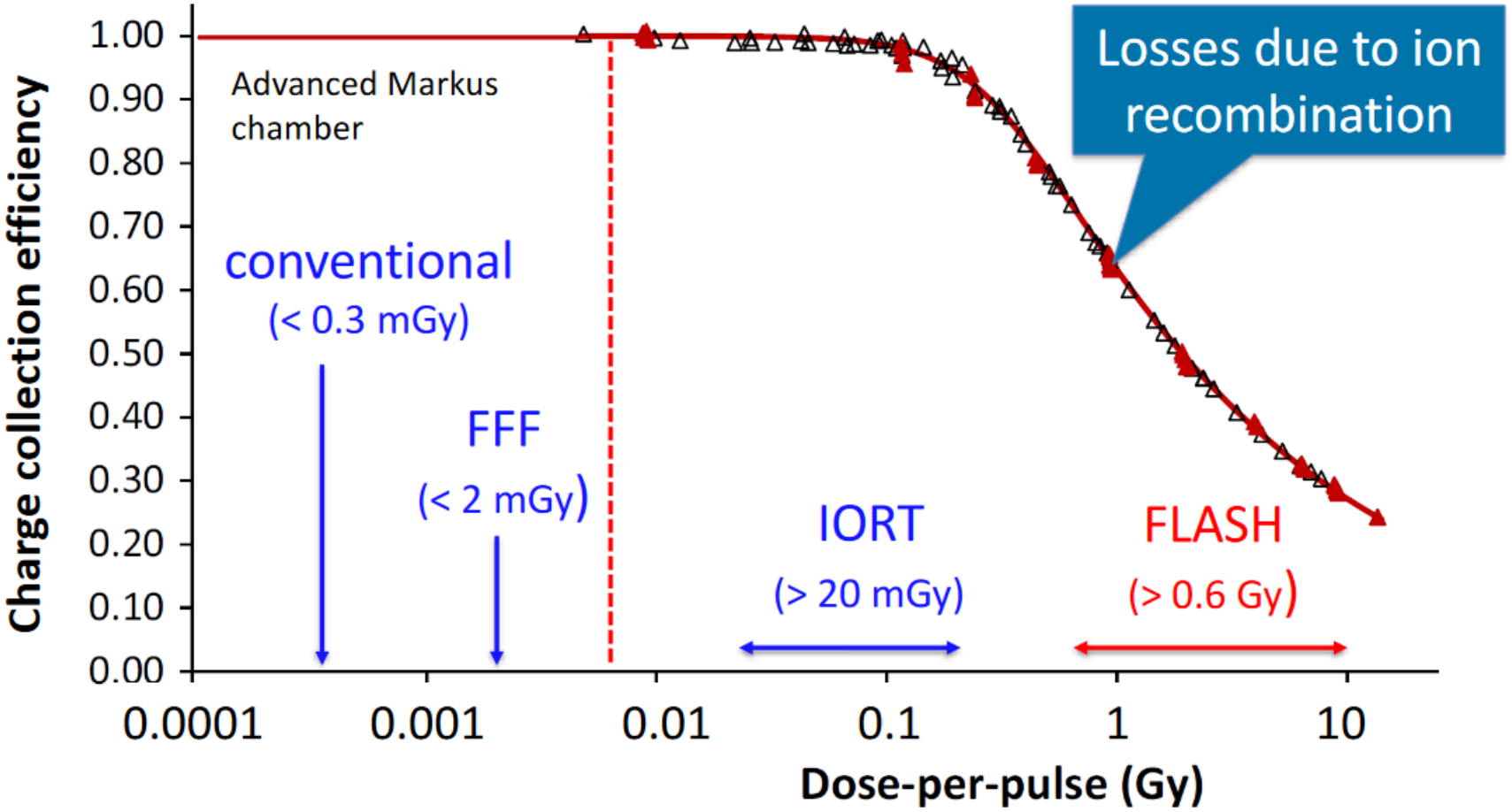
Vozenin et al., *Clin Cancer Res* **25** (2019) 35
http://dx.doi.org/10.1158/1078-0432.CCR-17-3375

FLASH treatment of a human patient (lymphoma on skin)

- Total dose 15 Gy
- 10 pulses (1us)
- Treatment time: 90 ms
- Dose /pulse: 1.5 Gy

Bourhis et al., *Radiother. Oncol.* (2019)
http://dx.doi.org/10.1016/j.radonc.2019.06.019

Metrological Challenges in Flash-RT



Petersson *et al.*, Med Phys 44 (2017) 1157
https://doi.org/10.1002/mp.12111

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"Metrology for advanced radiotherapy using particle beams with ultra-high pulse dose rates" (UHDpulse)

- Joint Research Project in the framework of the European Metrology Program for Innovation and Research (EMPIR), supported by the European Association of National Metrology Institutes (EURAMET).
- Duration: Sep/2019-Feb/2023
- Coordinator: Andreas Schüller (PTB, Germany)
- Topic: dosimetry for
  - FLASH radiotherapy
  - VHEE radiotherapy
  - laser driven beams
- Website: http://uhdpulse-empir.eu

UHDpulse

Physica Medica 80 (2020) 134–150

Contents lists available at ScienceDirect

Physica Medica

journal homepage: www.elsevier.com/locate/ejmp

Original paper

The European Joint Research Project UHDpulse – Metrology for advanced radiotherapy using particle beams with ultra-high pulse dose rates

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ARTICLE INFO

Keywords:
Dosimetry
FLASH beams
Absorbed dose
Traceability
High dose rates
European metrology project

ABSTRACT

UHDpulse – Metrology for advanced radiotherapy using particle beams with ultra-high pulse dose rates is a recently started European Joint Research Project with the aim to develop and improve dosimetry standards for FLASH radiotherapy, very high energy electron (VHEE) radiotherapy and laser-driven medical accelerators. This paper gives a short overview about the current state of developments of radiotherapy with FLASH electrons and protons, very high energy electrons as well as laser-driven particles and the related challenges in dosimetry due to the ultra-high dose rate during the short radiation pulses. We summarize the objectives and plans of the UHDpulse project and present the 16 participating partners.

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https://doi.org/10.1016/j.ejmp.2020.09.020
Received 29 January 2020; Received in revised form 17 August 2020; Accepted 23 September 2020
Available online 9 November 2020
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Schüller et al., *The European Joint Research Project UHDpulse – Metrology for advanced radiotherapy using particle beams with ultra-high pulse dose rates*, Physica Medica **80** (2020), 134-150.
https://doi.org/10.1016/j.ejmp.2020.09.020

Objectives

1. **Develop a metrological framework** which comprises SI traceable primary standards, secondary reference standards, and validated reference methods for dosimetry measurements for particle beams with ultra-high pulse dose rates.

2. **Characterize the response of available detector systems** when used in ultra-high dose per pulse or with ultra-short pulse duration particle beams.

3. **Develop traceable and validated methods for relative dosimetry**, as well as for the characterization of stray radiation outside the primary pulsed beams.

4. **Provide input data for future Codes of Practice** for absolute dose measurements in particle beams with ultra-high pulse dose rates.

Work Packages

NPL National Physical Laboratory

METAS

WP1: Primary standards

- Definition of reference conditions
- Reference radiation fields
- Adapting primary standards (water calorimeter, Fricke dosimeter)
- Prototype graphite calorimeters

WP2: Secondary standards, relative dosimetry

- Transfer from primary standards
- Characterizing established detector systems
- Formalism for reference dosimetry for future Code of Practice

CZECH METROLOGY INSTITUTE

WP5: Impact, WP6: Coordination

PTB Physikalisch-Technische Bundesanstalt Braunschweig und Berlin

WP4: Detectors and methods outside primary beam

- Active detection techniques for pulsed mixed radiation fields of stray radiation and pulsed neutrons
- Methods with passive detectors

WP3: Detectors for primary beam

- Novel and custom-built active dosimetric systems
- Beam monitoring systems

ADVACAM Imaging the Unseen

CHUV

Consortium

Metrology Institutes

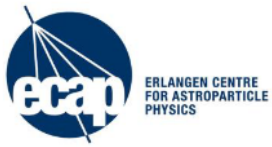
7 Metrology institutes
6 Hospitals
9 Universities
7 Research institutes
12 Companies
1 Proton therapy network

Irradiation facilities / providers

Detector developers

Collaborators

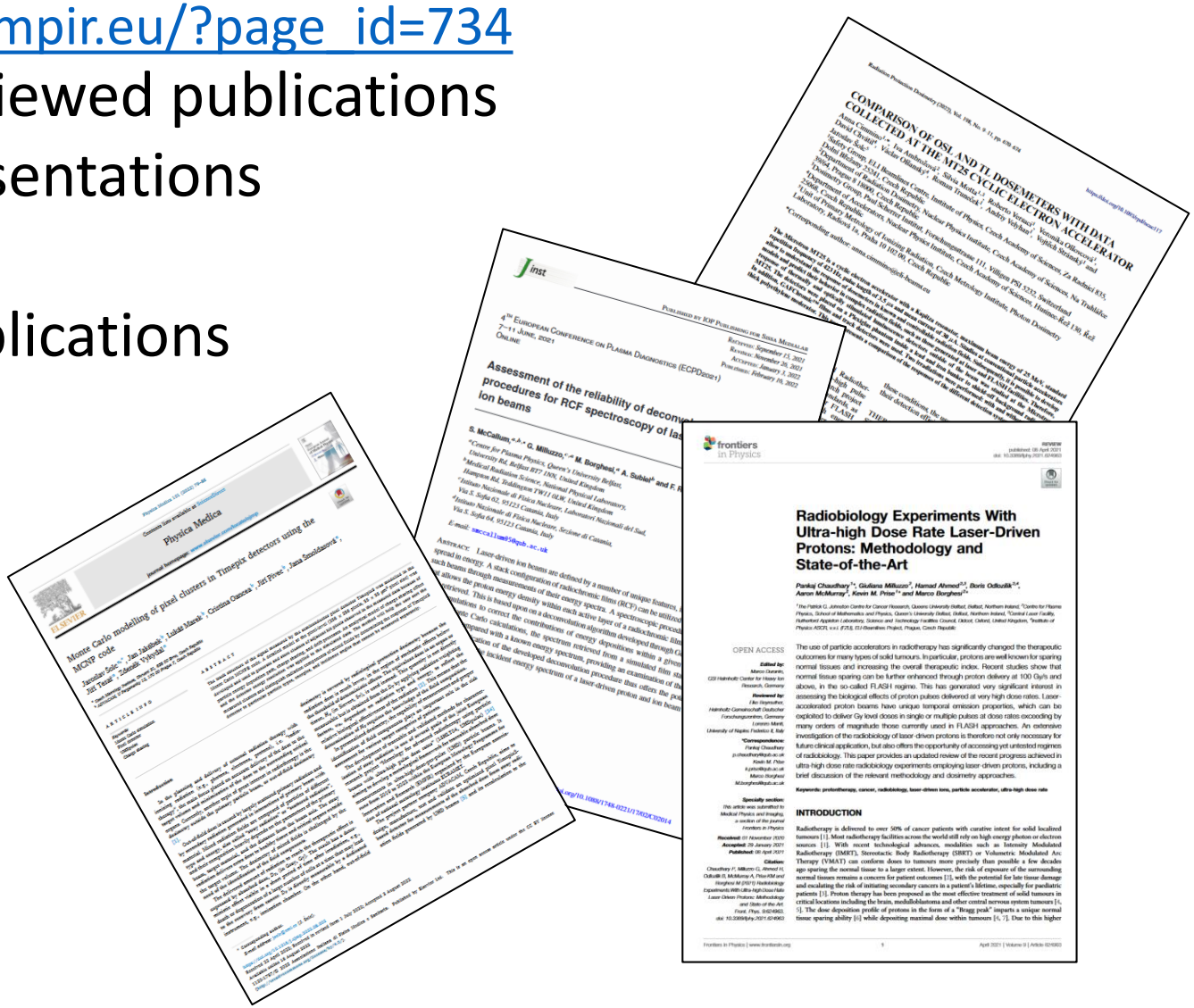
28 Collaborators joined UHDpulse up to now



Impact

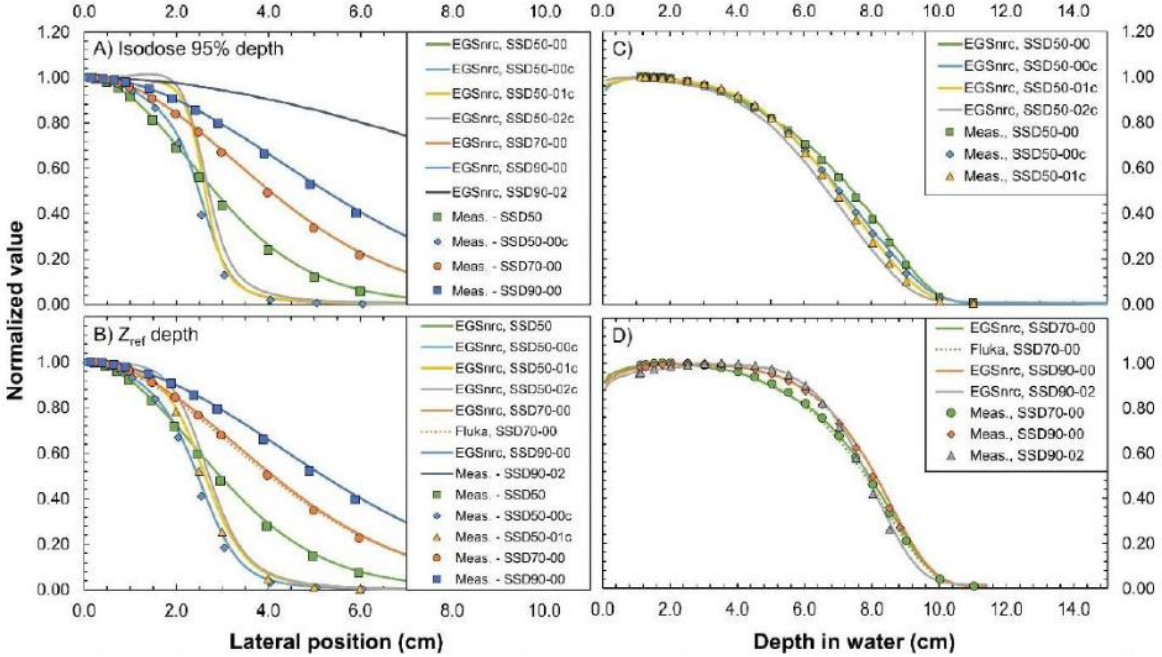
http://uhdpulse-empir.eu/?page_id=734

- 25 Peer-reviewed publications
- 62 Oral presentations
- 15 Poster
- 6 Other publications



Recent Highlights

Ultra-high Pulse Dose rate reference field at PTB



E = 0.5 – 50 MeV

t_{pulse} = 0.1 – 3 us

up to **7 Gy per pulse** (SSD 0.7 m, 20 MeV)

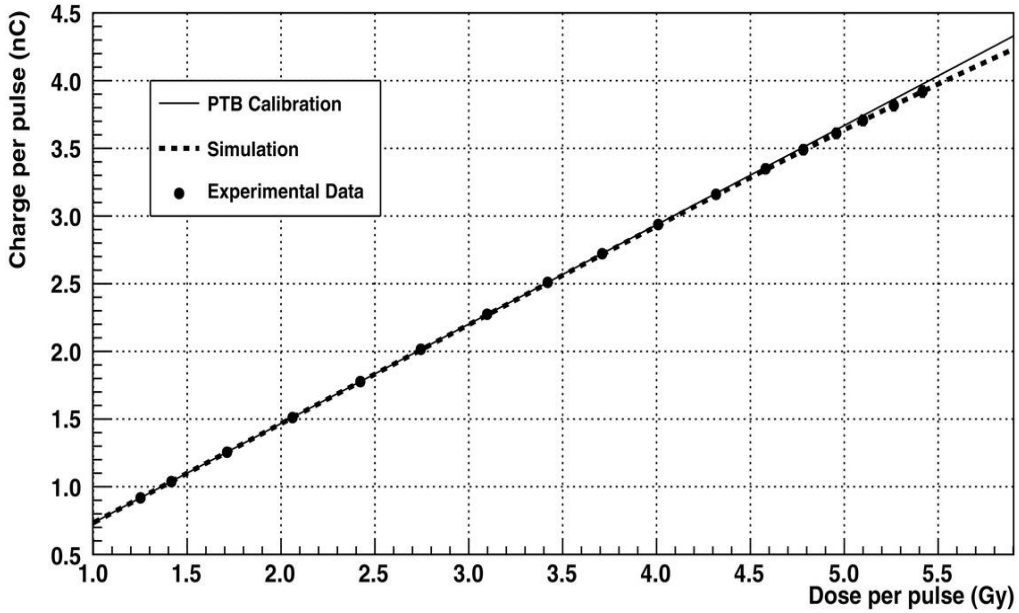
up to 15 Gy per pulse (SSD 0.5 m, 20 MeV)
in preparation

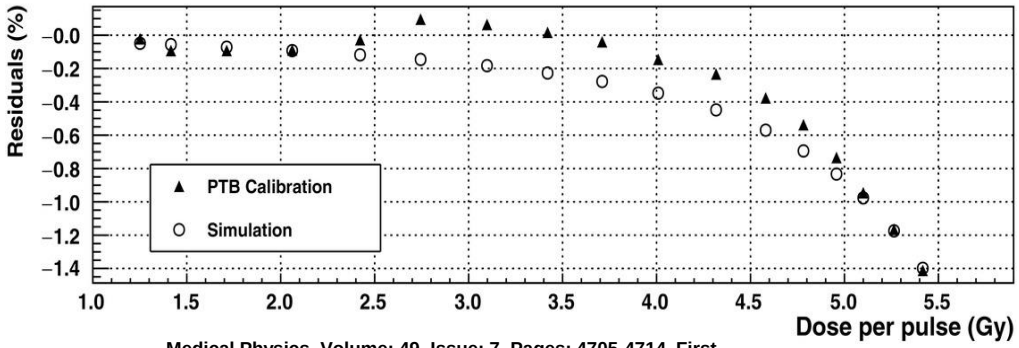
A. Bourgouin et al. *Characterization of the PTB ultra-high pulse dose rate reference electron beam*, Physics in Medicine & Biology, accepted 8 April 2022. https://doi.org/10.1088/1361-6560/ac5de8

Recent Highlights

Development of an ultra-thin parallel plate ionization chamber

F. Gómez et al. *Development of an ultra-thin parallel plate ionization chamber for dosimetry in FLASH radiotherapy*, Medical Physics, 13 April 2022. https://doi.org/10.1002/mp.15668



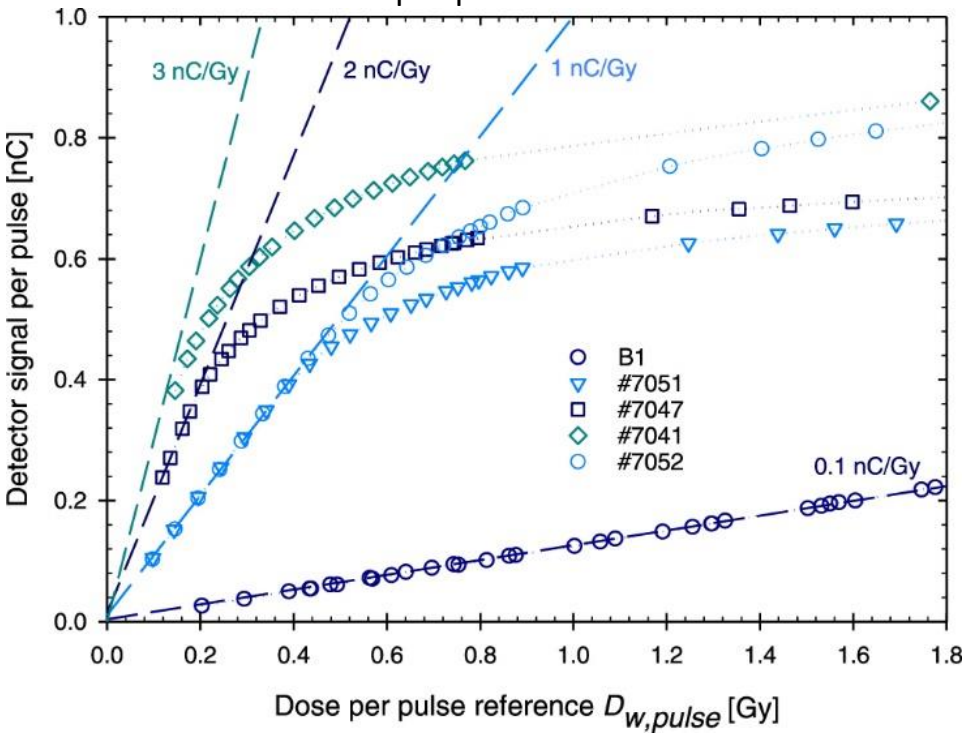


Medical Physics, Volume: 49, Issue: 7, Pages: 4705-4714, First published: 13 April 2022, DOI: (10.1002/mp.15668)

Recent Highlights

Diamond detector for ultra-high dose per pulse (DPP)

Linearity of the prototype detector signal as function of the reference dose per pulse



- Commercially available microDiamond detectors show saturation effects at different DPP levels.
- Linearity can be extended to the ultra-high DPP range by reduction of sensitivity and resistance.

Verona Rinati *et al. Application of a novel diamond detector for commissioning of FLASH radiotherapy electron beams.* Med Phys. 2022; **49**: 5513- 5522. https://doi.org/10.1002/mp.15782

Kranzer *et al., Response of diamond detectors in ultra-high dose-per-pulse electron beams for dosimetry at FLASH radiotherapy,* 2022 *Phys. Med. Biol.* **67** 075002. https://doi.org/10.1088/1361-6560/ac594e

Conclusions

- UHDpulse is a European Joint Research Project aimed at developing and improving dosimetry standards for FLASH-RT, VHEE radiotherapy and laser-driven medical accelerators.

- The project was briefly presented in order to raise awareness of its objectives, structure, and results.

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

This project (18HLT04) has received funding from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme.

UHDpulse

http://uhdpulse-empir.eu/

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Thank you for your attention!