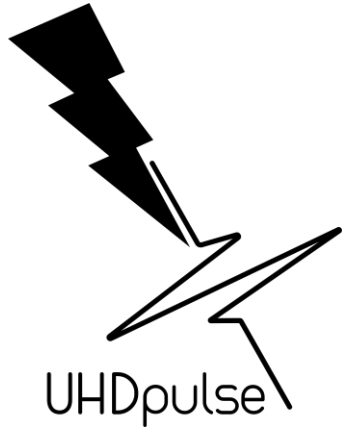
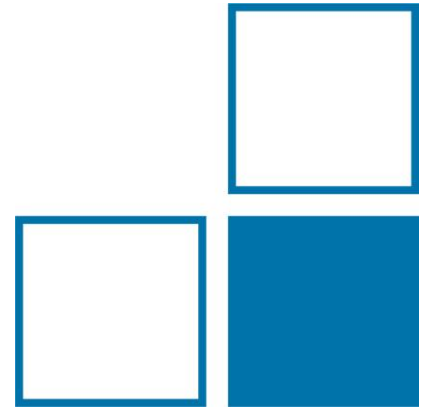
Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

The Joint Research Project UHDpulse –

“Metrology for advanced radiotherapy using particle beams with ultra-high pulse dose rates”



Andreas Schüller on behalf of the UHDpulse consortium
PTB, Department 6.2 “Dosimetry for Radiation Therapy and Diagnostic Radiology”



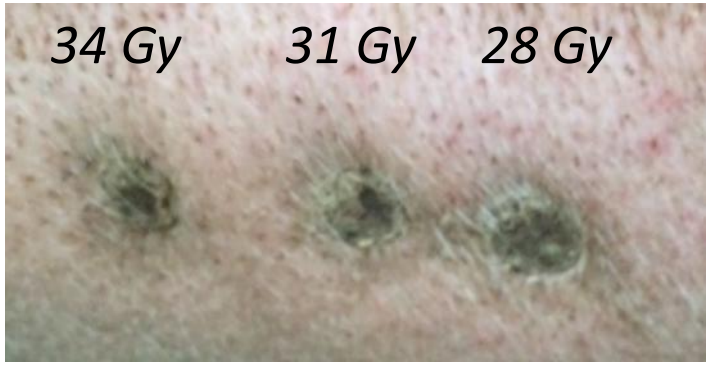
TC-IR Contact Person Meeting, 9. – 11. February 2021, Online

Introduction – FLASH radiotherapy

- FLASH radiotherapy is a radiation modality under development. If the prescribed dose is delivered at ultra-high dose rate in very short time, then the healthy tissue is spared, while the curative effect on the tumor is maintained

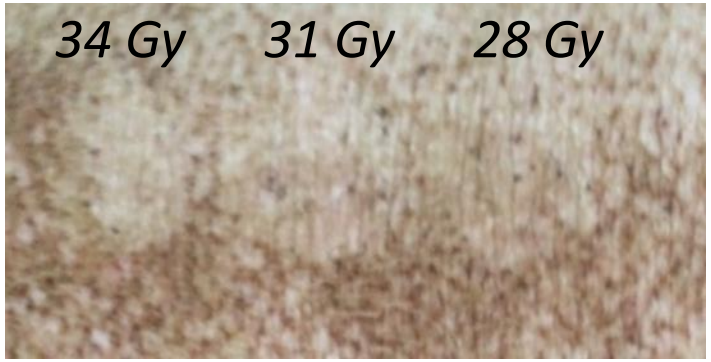
Reduced pig skin toxicity at FLASH-RT

Conventional
(5 Gy/min)
0.3 mGy/pulse



necrotic lesions

FLASH
(300 Gy/s)
3 Gy/pulse



normal appearance of skin

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

Introduction – FLASH radiotherapy

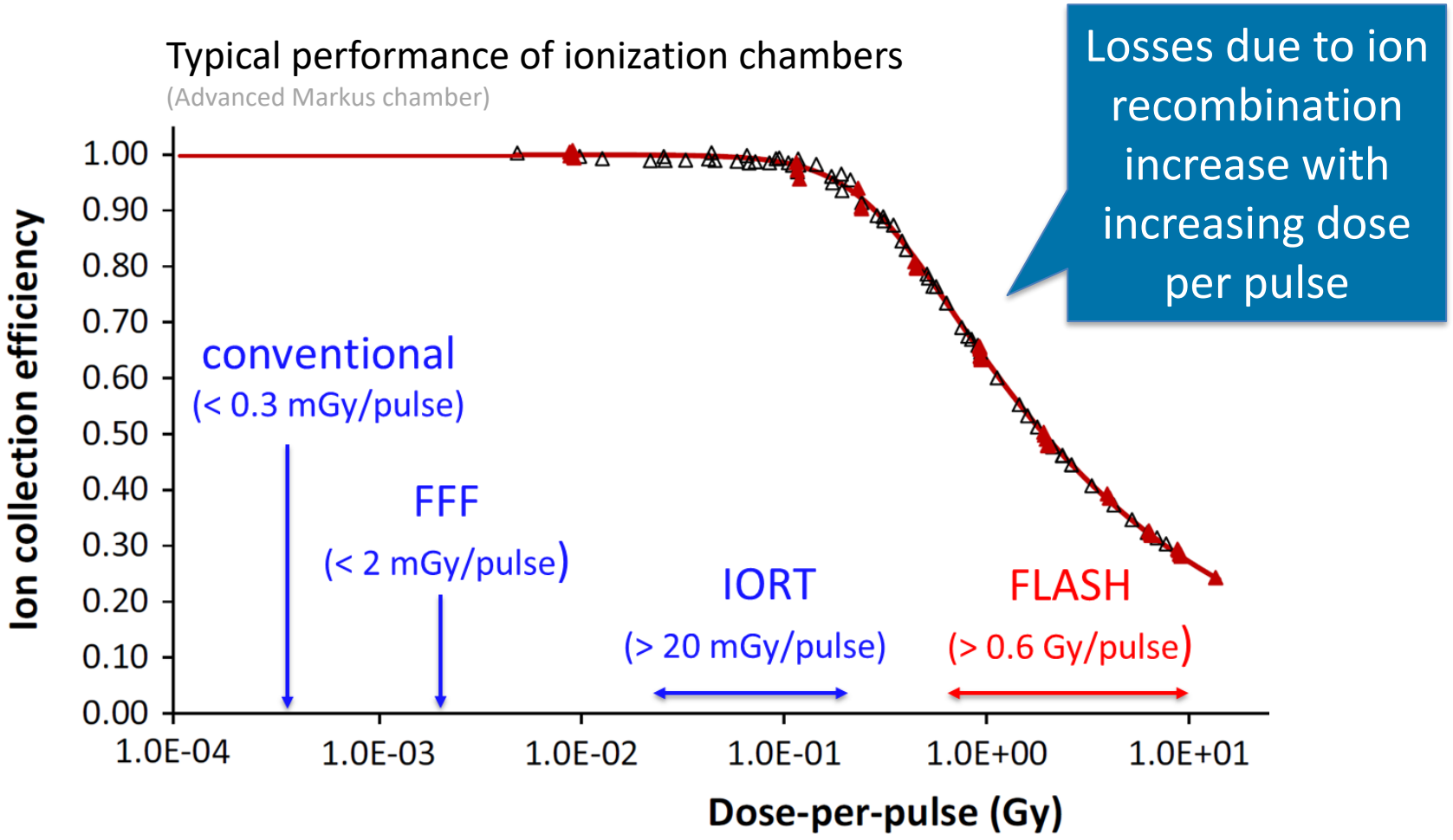
- The number of institutes interested in FLASH radiotherapy and the number of FLASH papers published per year increasing exponentially.
- Regardless of whether FLASH will play a significant role in radiotherapy in the future or not, there is just now an urgent need for traceable dosimetric measurements.

Introduction - Metrological challenge

Due to ultra-high dose rates and pulsed structure of the beams, tools and methods established in dosimetry for conventional radiotherapy are not suitable.

There are

- **no** active dosimeters for real-time measurements
- **no** formalism (Codes of Practice) for reference dosimetry
- **no** corresponding primary standards



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

Introduction - Partners and Collaborators

Metrology Institutes

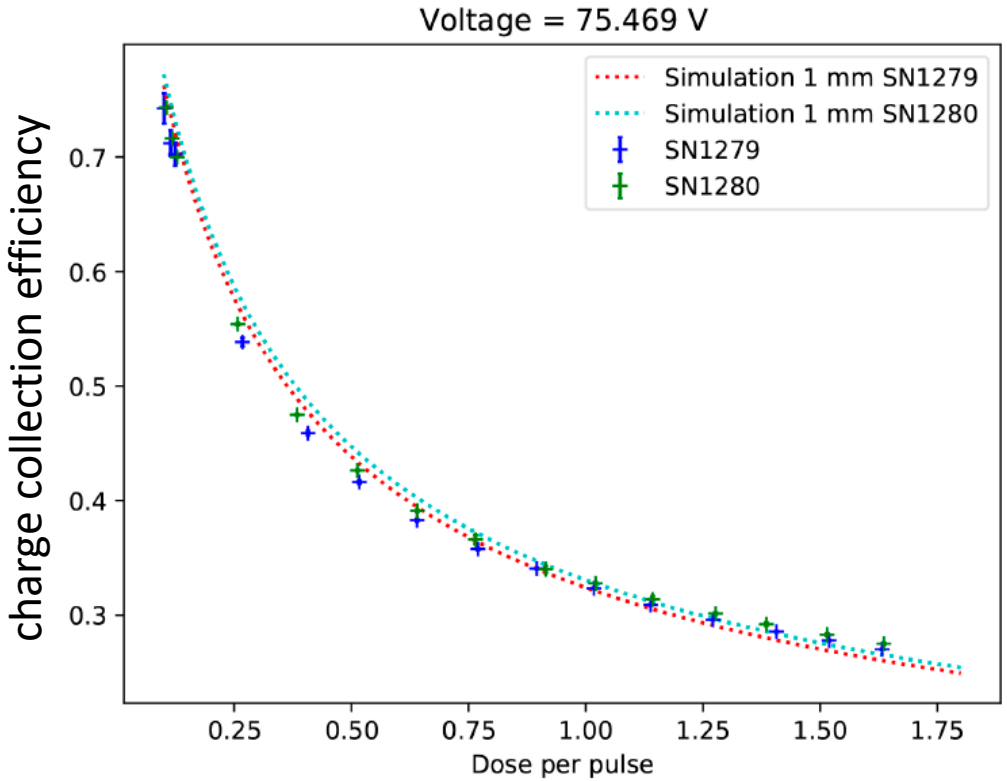
Irradiation facility provider

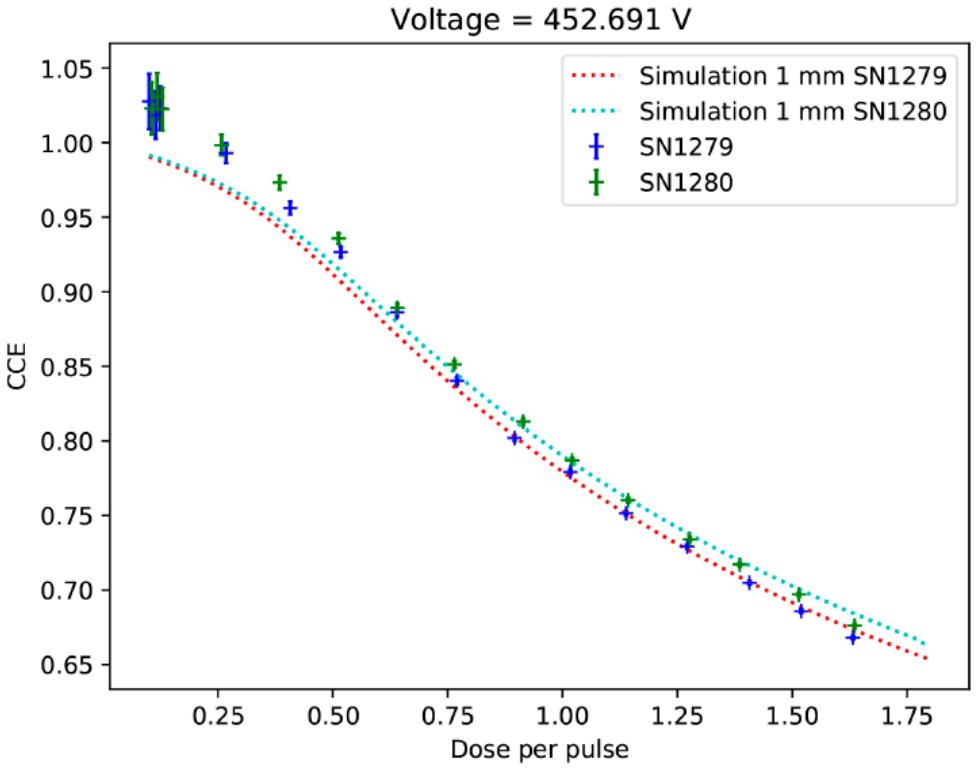
Radiation detector developer

In UHDpulse are involved:
6 Metrology institutes
4 Hospitals
6 Universities
6 Research institutes
7 Companies
+ Proton therapy network

- 12 new Collaborators joined UHDpulse in the past year

Achievements – FLASH dosimetry with ion chambers



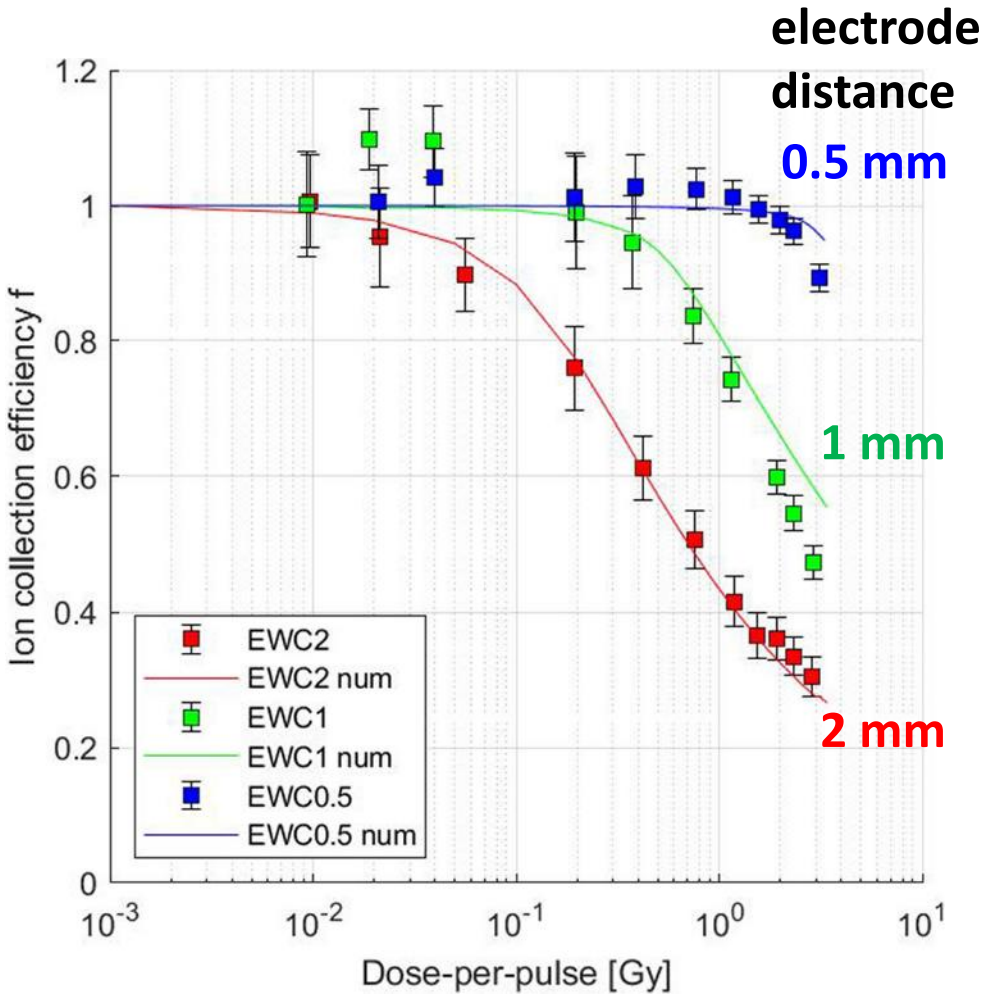


- USC as well as PTW developed theoretical models for the calculation of the charge collection efficiency of plane parallel ionization chambers at ultra-high dose per pulse. Results from both simulations agree with each other and with experimental data measured at PTB.

https://indico.ific.uv.es/event/5983/contributions/13896/

Achievements – FLASH dosimetry with ion chambers

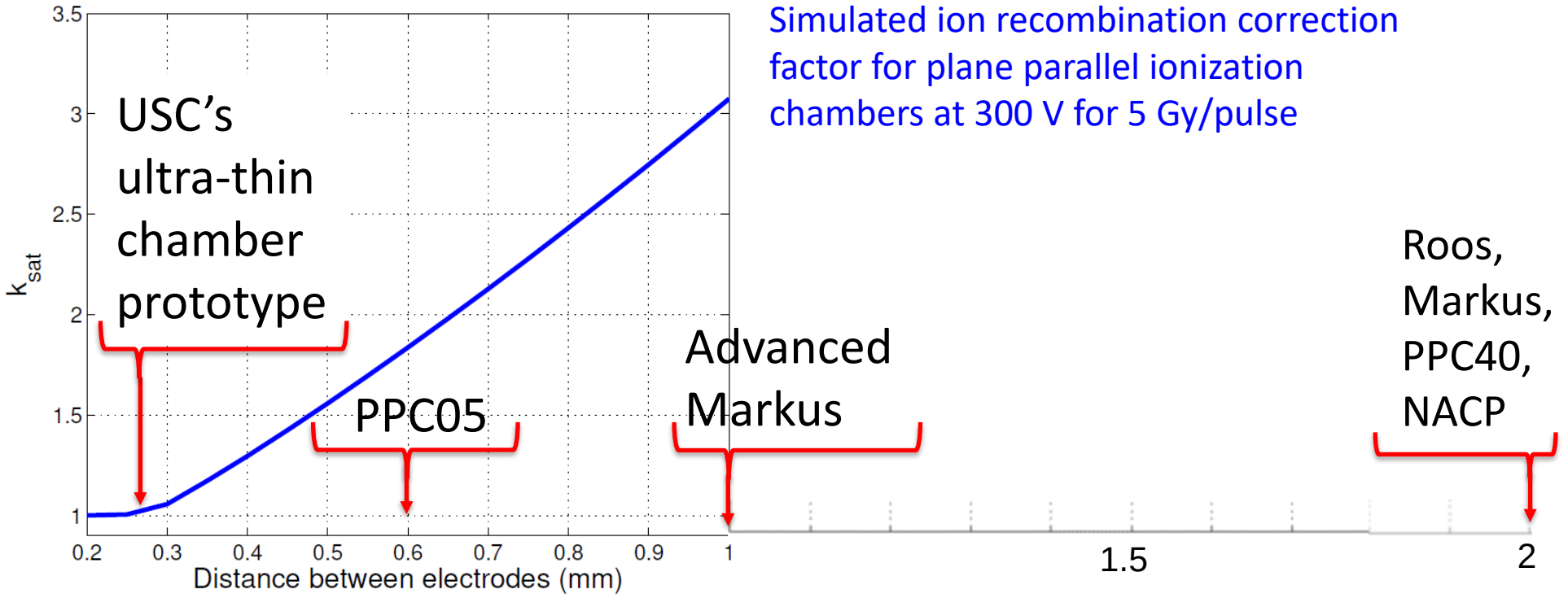
- PTW together with PTB investigated the performance of plane parallel ionization chamber prototypes with different electrode distance at ultra-high dose per pulse. The reduction of the electrode distance helps to increase the ion collection efficiency.



Kranzer et al. Med. Phys. 2021
https://doi.org/10.1002/mp.14620

Achievements – FLASH dosimetry with ion chambers

- USC build an ultra-thin plane parallel ionization chamber prototype in order to enable reliable ionization chamber measurements up to 5Gy/pulse. The prototype chamber will be tested soon at PTB and Institut Curie.



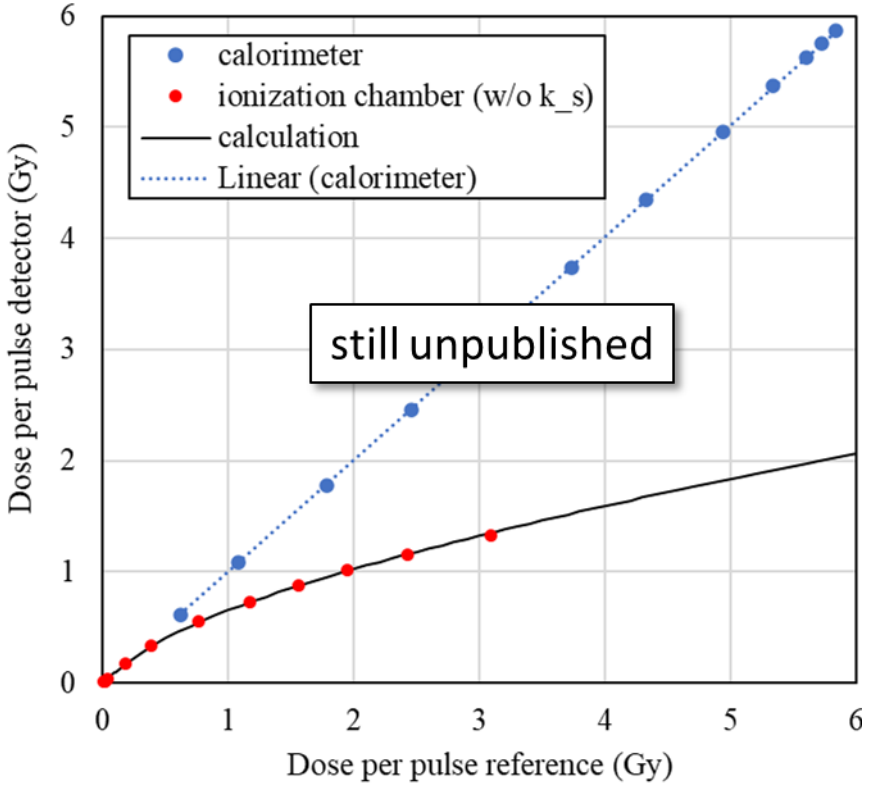
Simulated ion recombination correction factor for plane parallel ionization chambers at 300 V for 5 Gy/pulse

https://doi.org/10.1016/j.ejmp.2020.09.020

Achievements – FLASH dosimetry with calorimeters

- PTB together with Sun Nuclear and NRC investigated the performance of a Graphite Probe Calorimeter prototype intended for application in the clinic. The detector shows linear response in the FLASH range.

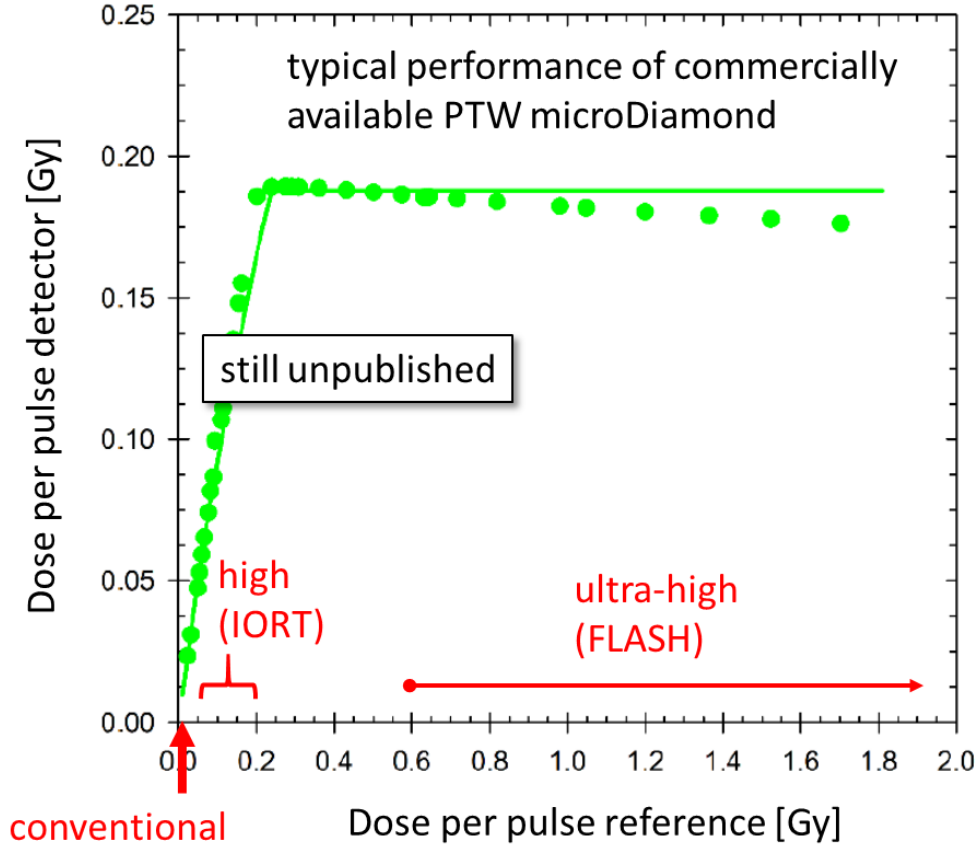
Prototype of a Graphite Probe Calorimeter from Sun Nuclear without its waterproof housing next to a Farmer chamber as a size comparative.

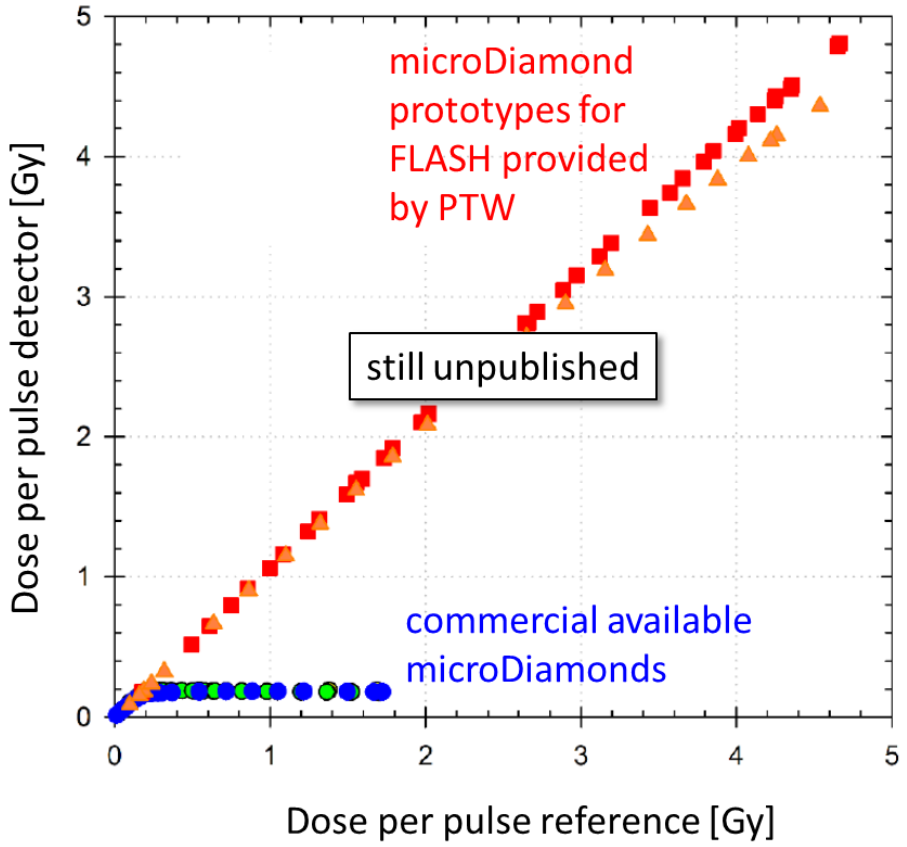


Detector response vs. dose reference from alanine/monitor. Calorimeter as well as Advanced Markus chamber (without ion recombination correction)

Achievements – FLASH dosimetry with diamonds

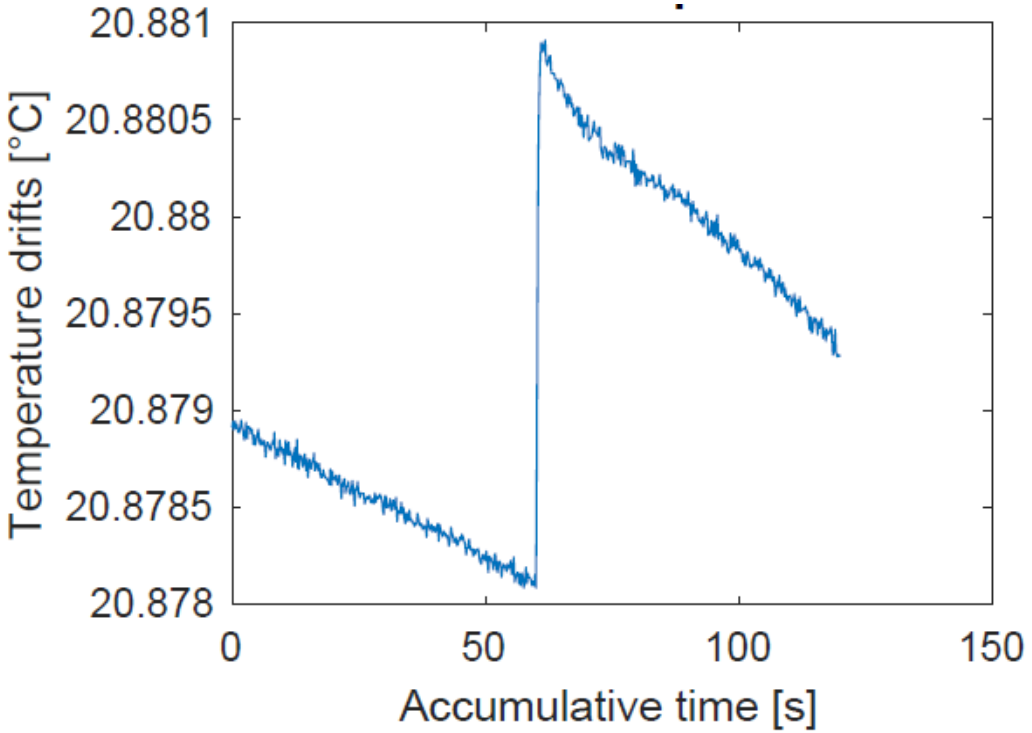
- PTW and PTB investigated the performance of commercially available microDiamond detectors at ultra-high dose per pulse. FLASH adapted microDiamond prototypes show linear response also in the FLASH range.





Achievements – dosimetry for laser driven beams

- NPL together with QUB demonstrated the feasibility of calorimetry for ultra-short ultra-high dose laser-driven ion beam pulses. Pulses between 0.4 and 2.2 Gy/pulse were measured.



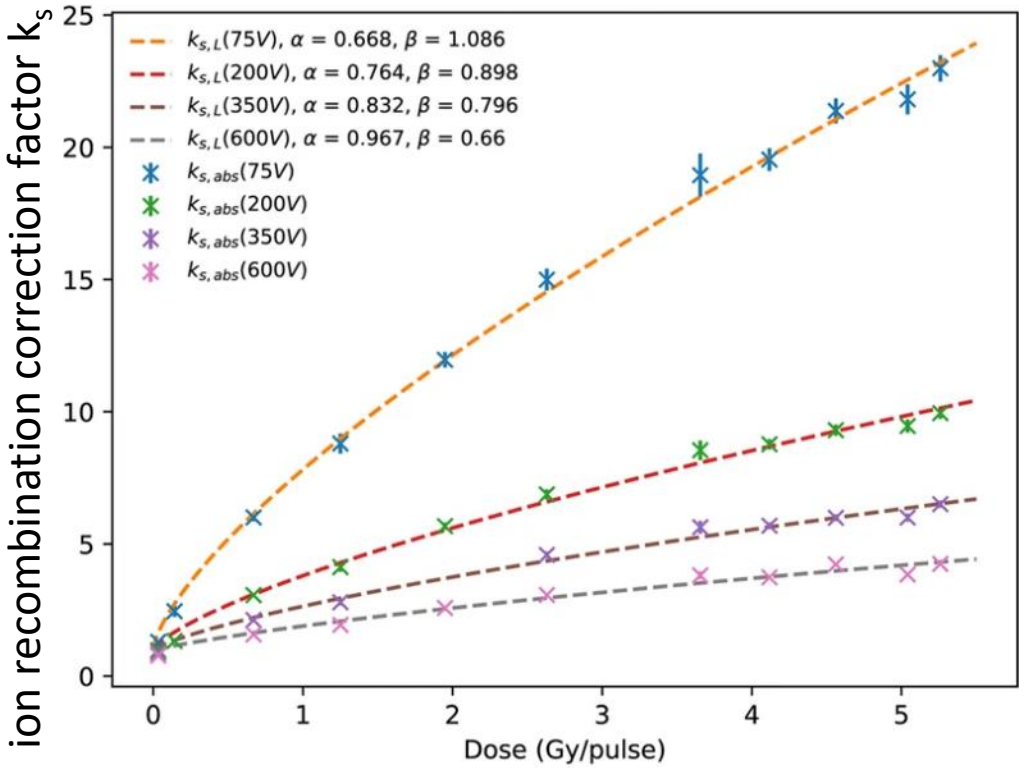
Radiation induced temperature rises of one of the core thermistors for first laser shot

Romano *et al* 2020 *J. Phys.: Conf. Ser.* **1662** 012028
https://doi.org/10.1088/1742-6596/1662/1/012028

Achievements – VHEE dosimetry

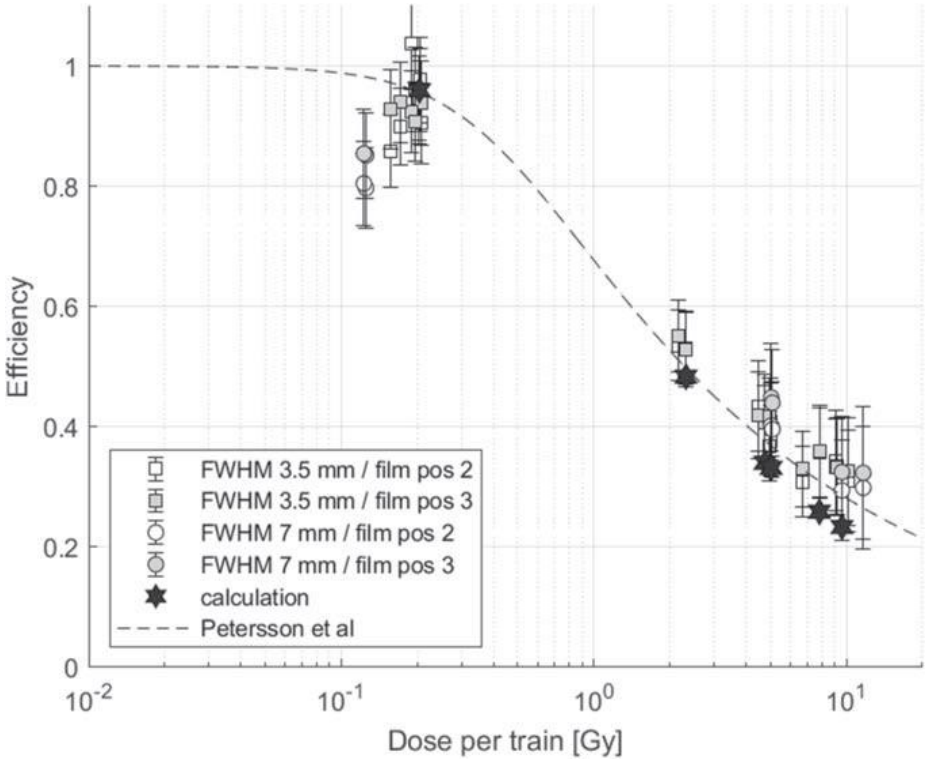
- NPL as well as PTW together with Universität Oldenburg investigated VHEE beam dosimetry under ultra-high dose rate conditions at CERN.

Roos chamber



McManus *et al. Sci Rep* **10,** 9089 (2020)
https://www.nature.com/articles/s41598-020-65819-y

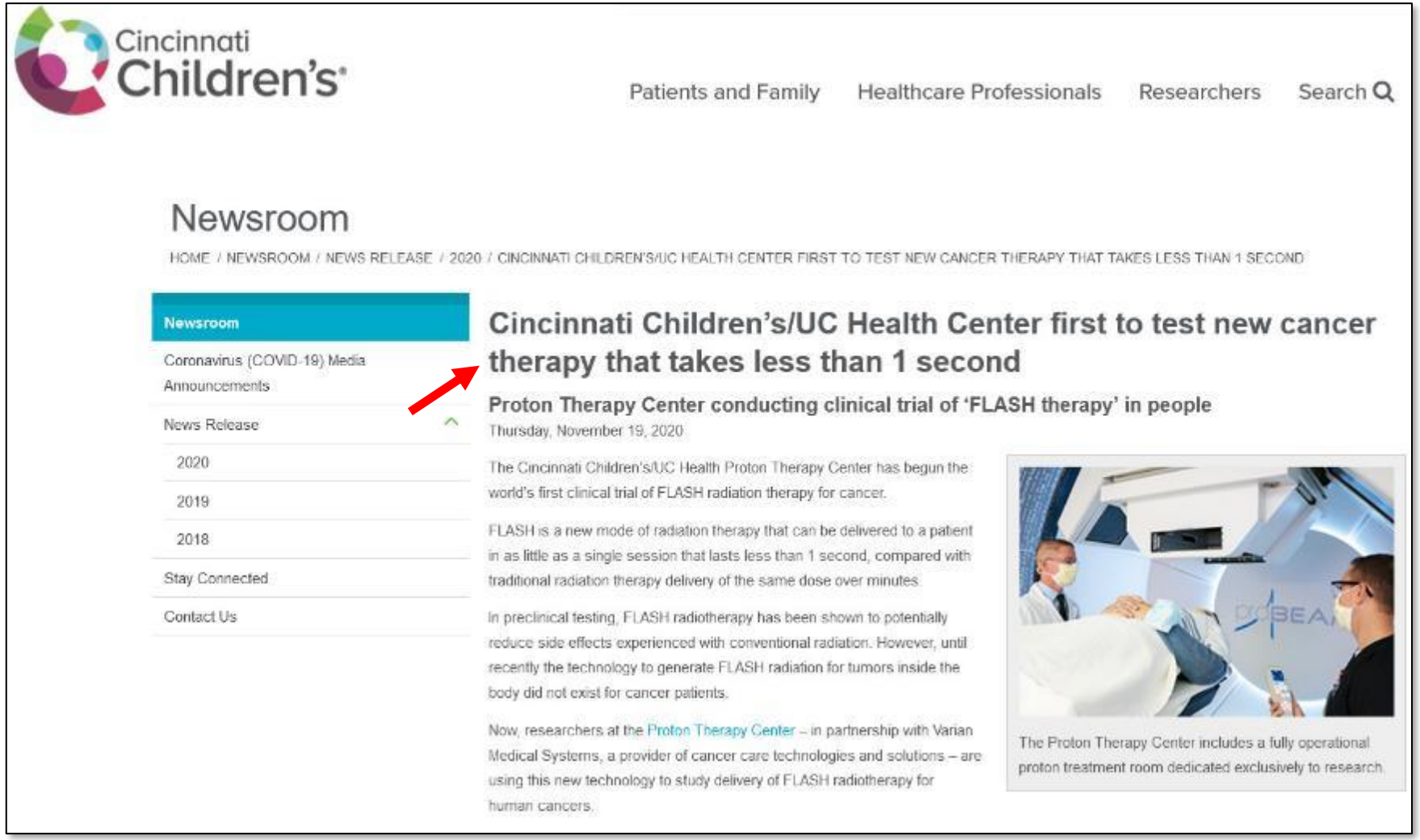
Advanced Markus chamber



Poppinga *et al.* 2021 *Biomed. Phys. Eng. Express* **7** 015012
https://doi.org/10.1088/2057-1976/abcae5

Achievements – Proton FLASH traceability

- NPL has conducted an experimental campaign at Cincinnati's Children Proton Therapy Centre, where traceability to the NPL portable graphite primary standard has been provided for their FLASH proton beam. The centre was then allowed to start the first clinical trial of FLASH proton therapy in human patients.



Cincinnati Children's

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Cincinnati Children's/UC Health Center first to test new cancer therapy that takes less than 1 second

Proton Therapy Center conducting clinical trial of 'FLASH therapy' in people

Thursday, November 19, 2020

The Cincinnati Children's/UC Health Proton Therapy Center has begun the world's first clinical trial of FLASH radiation therapy for cancer.

FLASH is a new mode of radiation therapy that can be delivered to a patient in as little as a single session that lasts less than 1 second, compared with traditional radiation therapy delivery of the same dose over minutes.

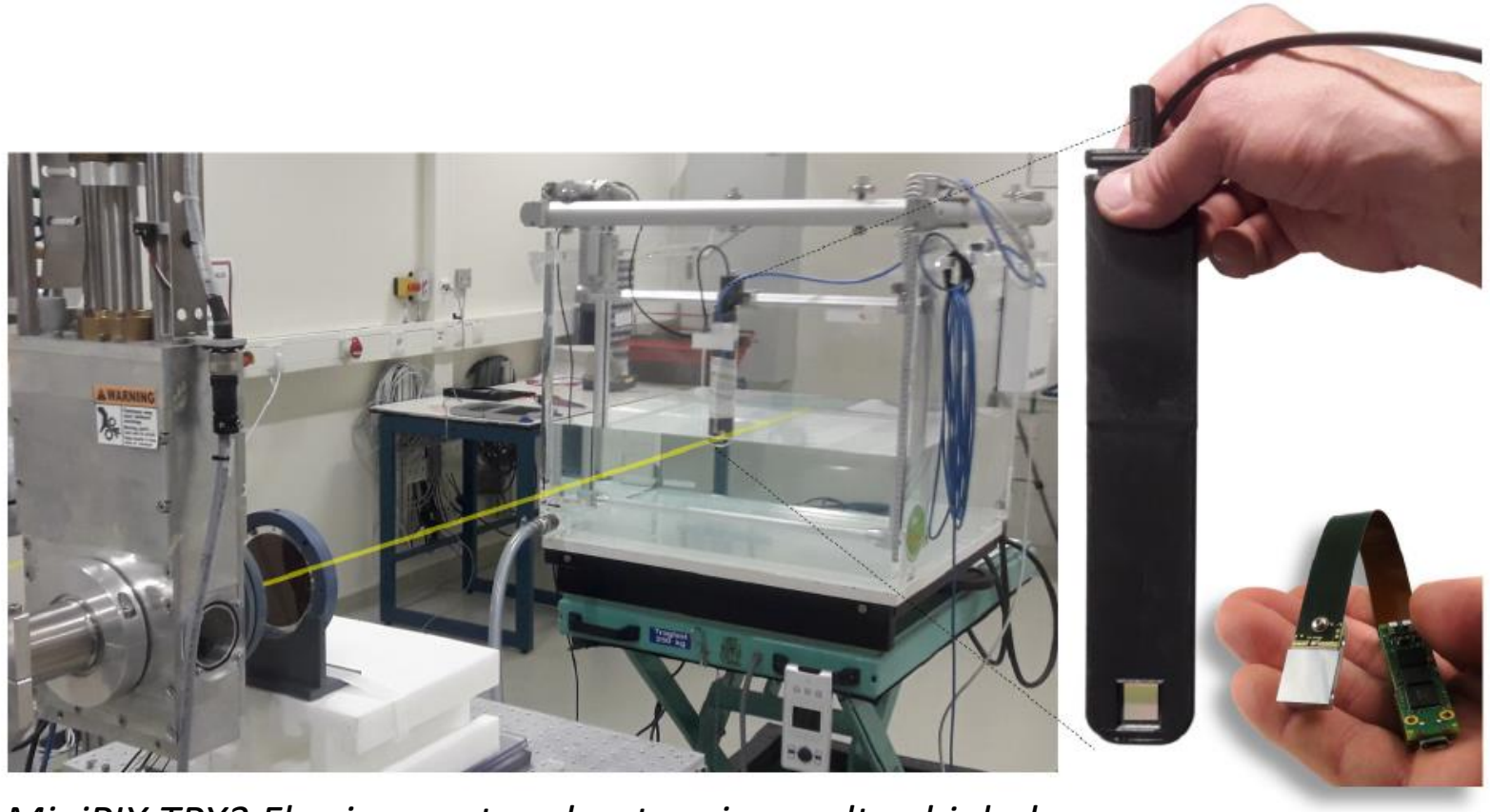
In preclinical testing, FLASH radiotherapy has been shown to potentially reduce side effects experienced with conventional radiation. However, until recently the technology to generate FLASH radiation for tumors inside the body did not exist for cancer patients.

Now, researchers at the Proton Therapy Center – in partnership with Varian Medical Systems, a provider of cancer care technologies and solutions – are using this new technology to study delivery of FLASH radiotherapy for human cancers.

The Proton Therapy Center includes a fully operational proton treatment room dedicated exclusively to research.

Achievements – measurement of pulsed stray radiation

- ADVACAM developed a new prototype detector for the real-time measurement of pulsed stray radiation. The device was tested together with CMI in a FLASH proton beam at HZDR.



MiniPIX TPX3 Flex in a water phantom in an ultra-high dose rate proton beam

Impact

- All Partners and some Collaborators (altogether 26 institutions) have written a joint overview paper describing the motivation and goals of the UHDpulse project and providing details on the state-of-the-art of the radiotherapy using particle beams with ultra-high pulse dose rates.

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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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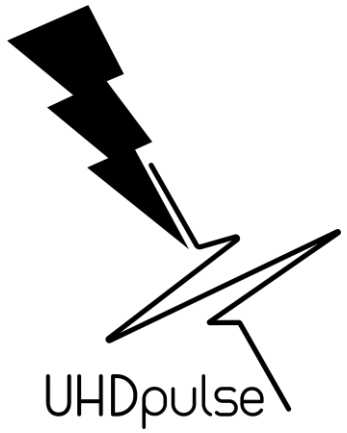
https://doi.org/10.1016/j.ejmp.2020.09.020

Impact

- CHUV, PTB, Institut Curie, and NPL organize on behalf of UHDpulse consortium the conference “FLASH Radiotherapy & Particle Therapy” (FRPT2021) together with the INSPIRE project, an integrating activity for European research in proton beam therapy. There will be FRPT2021 special issues in “Radiotherapy & Oncology” and in “Physica Medica”.

https://frpt-conference.org/

- Further and up-to-date information about the UHDpulse project can be found on the project website:



http://uhdpulse-empir.eu/

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EMPIR

EURAMET

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