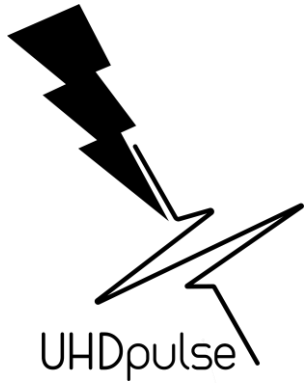
FRPT
FLASH RADIOTHERAPY & PARTICLE THERAPY 2022

Achievements of 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
Physikalisch-Technische Bundesanstalt
National Metrology Institute
Working Group 6.21 "Dosimetry for radiotherapy"

Disclosure

x	No, nothing to disclose
	Yes, please specify:

Joint Research Project UHDpulse

Titel:	Metrology for advanced radiotherapy using particle beams with ultra-high pulse dose rates
Duration:	Sep/2019-Feb/2023
Coordinator:	Andreas Schüller (PTB)
Topic:	dosimetry for FLASH radiotherapy & proton therapy
Website:	http://uhdpulse-empir.eu

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

enables European metrology institutes to collaborate with industrial and medical organisations, and academia

Joint Research Project UHDpulse

Titel:	Metrology for advanced radiotherapy using particle beams with ultra-high pulse dose rates
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Coordinator:	Andreas Schüller (PTB)
Topic:	**dosimetry for** **FLASH radiotherapy & proton therapy**
Website:	http://uhdpulse-empir.eu

Schüller et al., *The European Joint Research Project UHDpulse …*
Physica Medica 80 (2020), 134-150
https://doi.org/10.1016/j.ejmp.2020.09.020

UHDpulse Partners and Collaborators

FRPT FLASH RADIOTHERAPY & PARTICLE THERAPY 2022

Metrology Institutes

PTB – Physikalisch-Technische Bundesanstalt Braunschweig und Berlin
Central Office of Measures
NPL National Physical Laboratory
CMI Czech Metrology Institute
METAS
NRC·CNRC Canada
sck cen

Irradiation facilities / providers

CHUV Centre hospitalier universitaire vaudois
Queen's University Belfast
institutCurie
HZDR Helmholtz Zentrum Dresden Rossendorf
eli beamlines
Nuclear Physics Institute of the CAS public research institution
InspireProject
fondazione CNAO
MedAustron
DESY.
SIT
iridium
PAUL SCHERRER INSTITUT PSI
IntraOp
CPFR

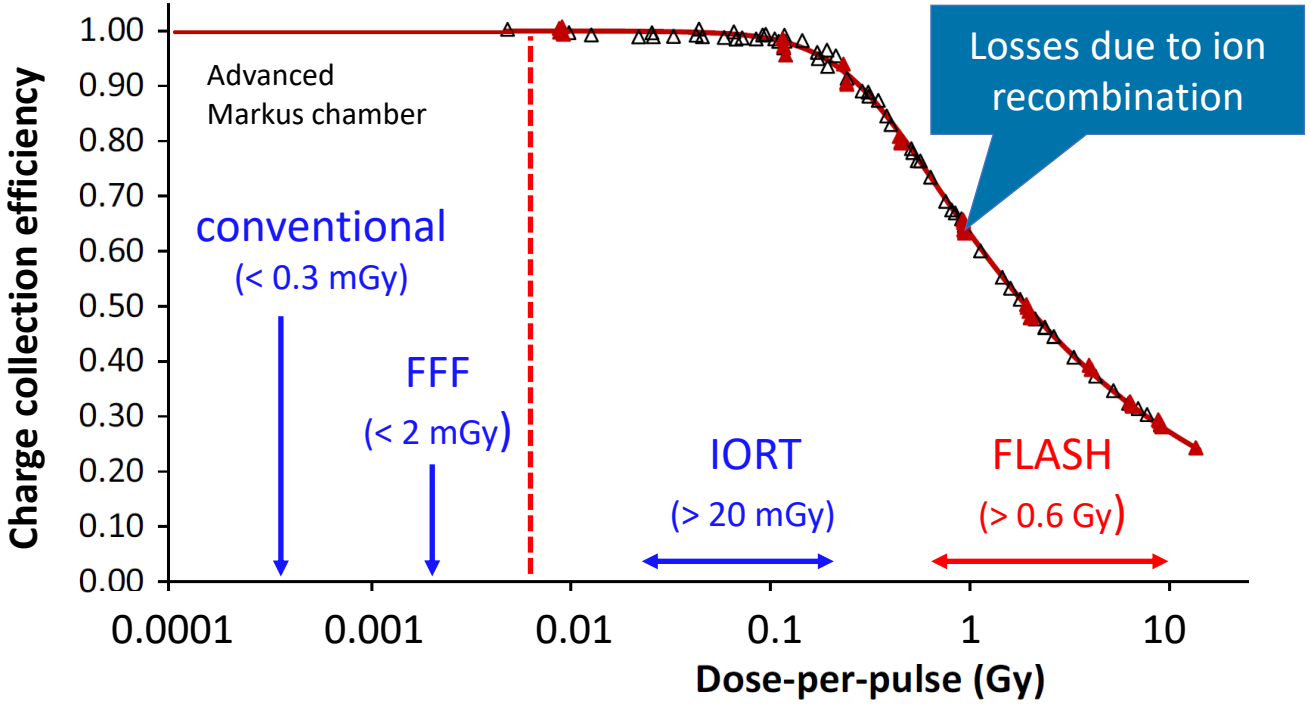
Detector developers

ADVACAM Imaging the Unseen
USC Universidade de Santiago de Compostela
PTW The Dosimetry Company
CSIC CNM
POLITECNICO MILANO 1863
Technische Universität Dresden
Carl von Ossietzky Universität Oldenburg
medscint
ScandiDos
Tor Vergata University of Rome Dept. Industrial Engineering
ECAP Erlangen Centre for Astroparticle Physics
bergoz Instrumentation
varian A Siemens Healthineers Company
lpc caen
RI.SE
SUN NUCLEAR corporation
iba Dosimetry Protect, Enhance and Save Lives
Dartmouth Engineering 1867
Instrumentation Technologies
DETECTOR Devices and Technologies Torino
Université Laval

7 Metrology institutes
6 Hospitals
9 Universities
7 Research institutes
12 Companies
+ Inspire proton therapy network

Motivation: challenge dosimetry at FLASH

- Typical performance of ionization chambers



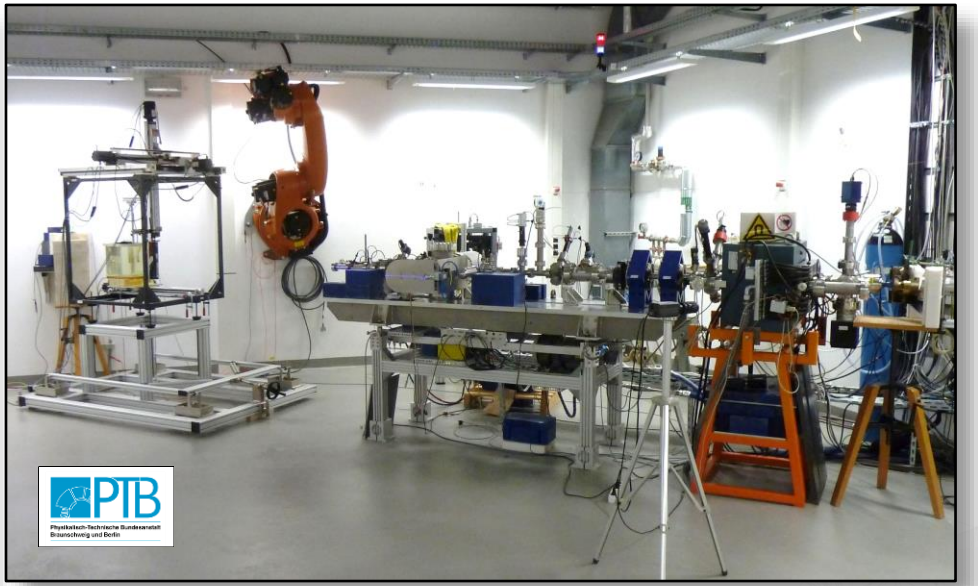
Initial situation:

- **no** active dosimeters for real-time measurements
- **no** formalism for reference dosimetry

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

UHPDR reference electron beam

PTB's Research electron accelerator

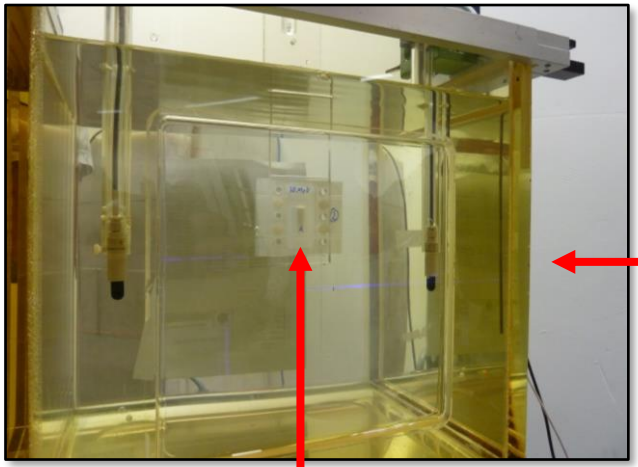


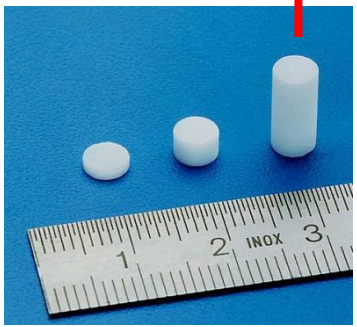
Beam line with water phantom

E = 0.5 – 50 MeV, t_{pulse} = 0.1 – 3 us
up to **12 Gy per pulse** (SSD 0.7 m, 20 MeV)

A. Bourgouin *et al*. "Characterization of the PTB ultra-high …"
Phys. Med. Biol. **67** (2022) 085013.
https://doi.org/10.1088/1361-6560/ac5de8

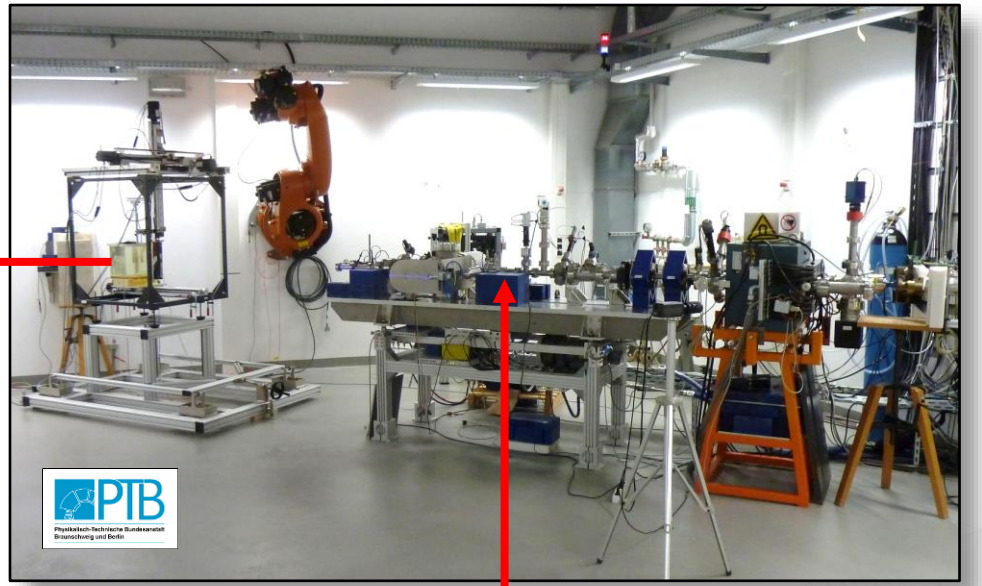
UHPDR reference electron beam





Alanine pellets at reference depth in water phantom

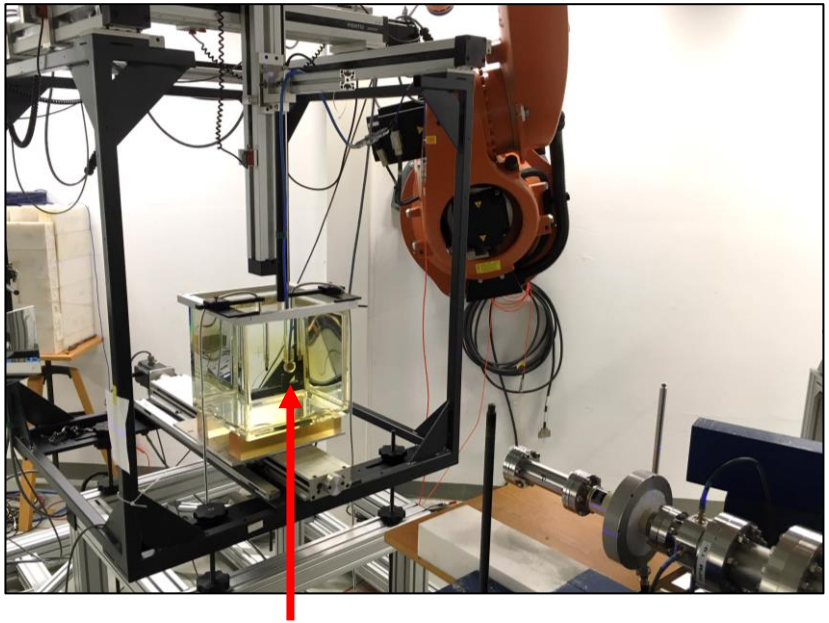
Dose traceable to PTB's primary standards



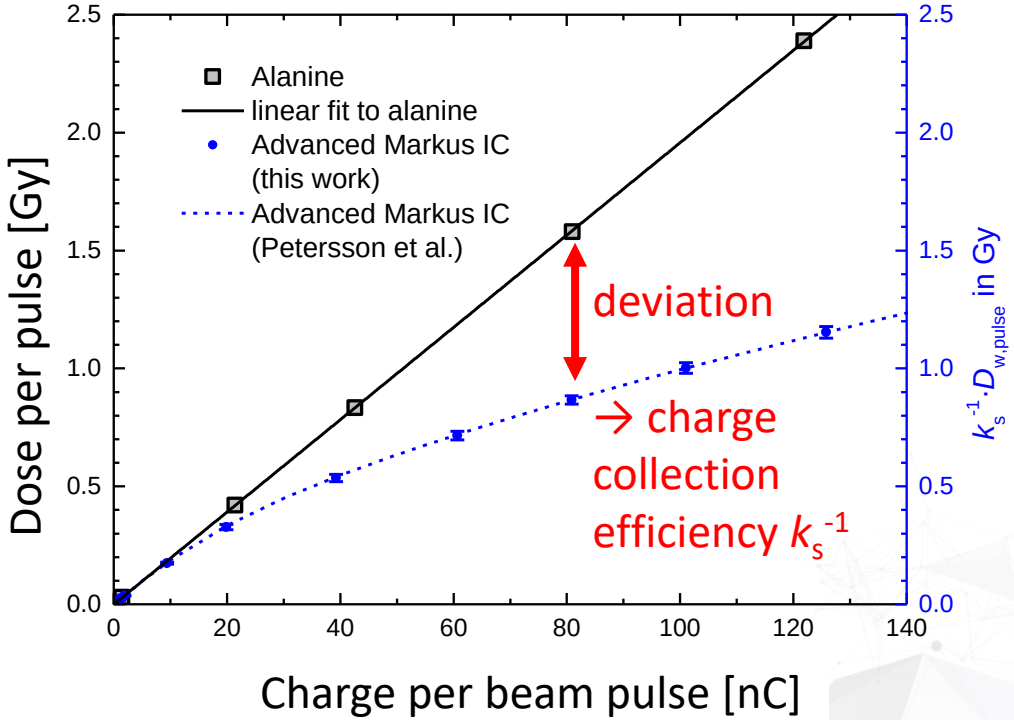
Current transformer (Bergoz ICT): Non-destructive absolute beam pulse charge measurement

A. Bourgouin *et al.*, "Absorbed-dose-to-water…" Phys. Med. Biol. **67** (2022) 205011.
https://doi.org/10.1088/1361-6560/ac950b

UHPDR reference electron beam

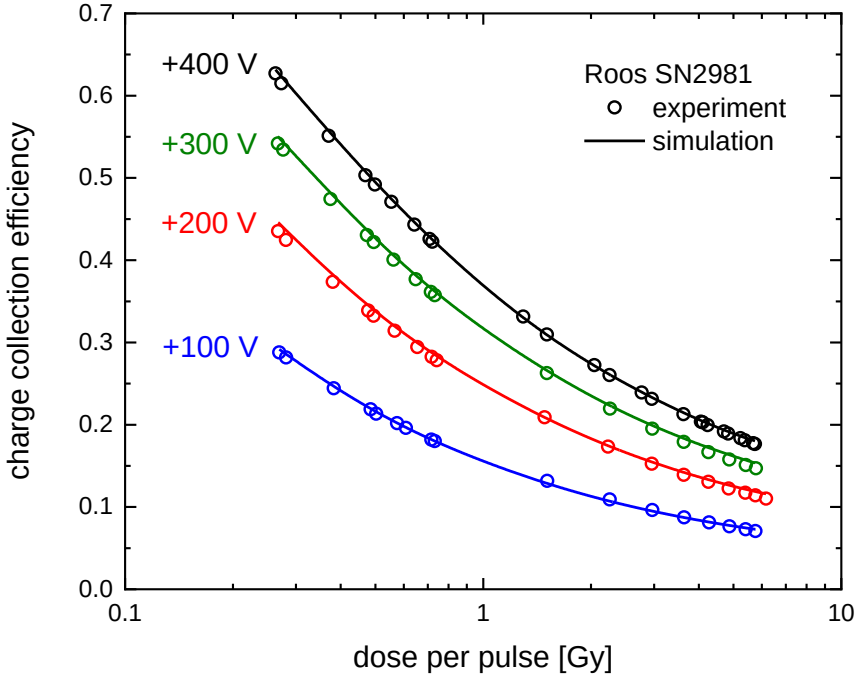


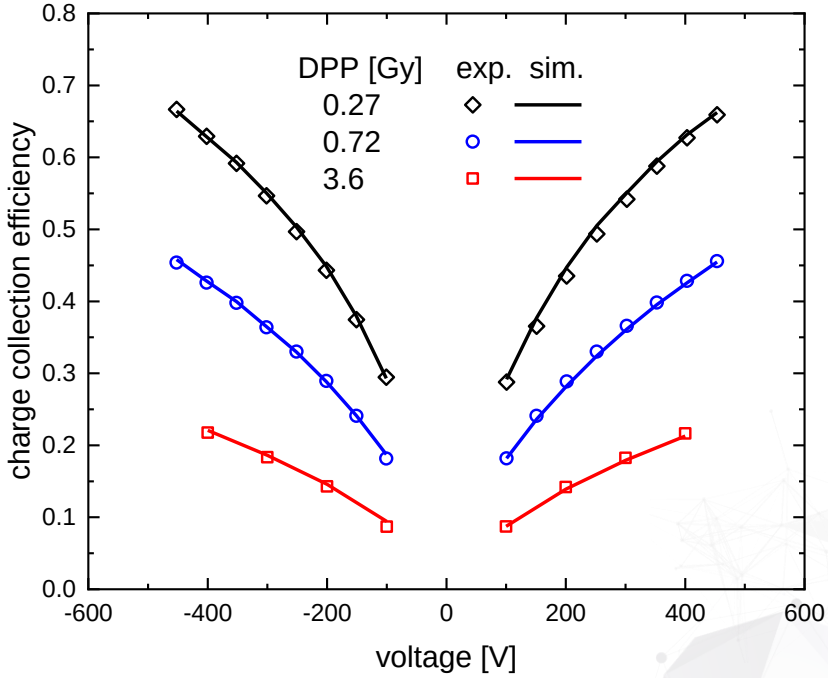
Detector under test at reference depth in water phantom



A. Bourgouin *et al.*, "Calorimeter for Real-Time Dosimetry …" Front. Phys. **8** (2020) 567340.
https://doi.org/10.3389/fphy.2020.567340

Calculation of charge collection efficiency

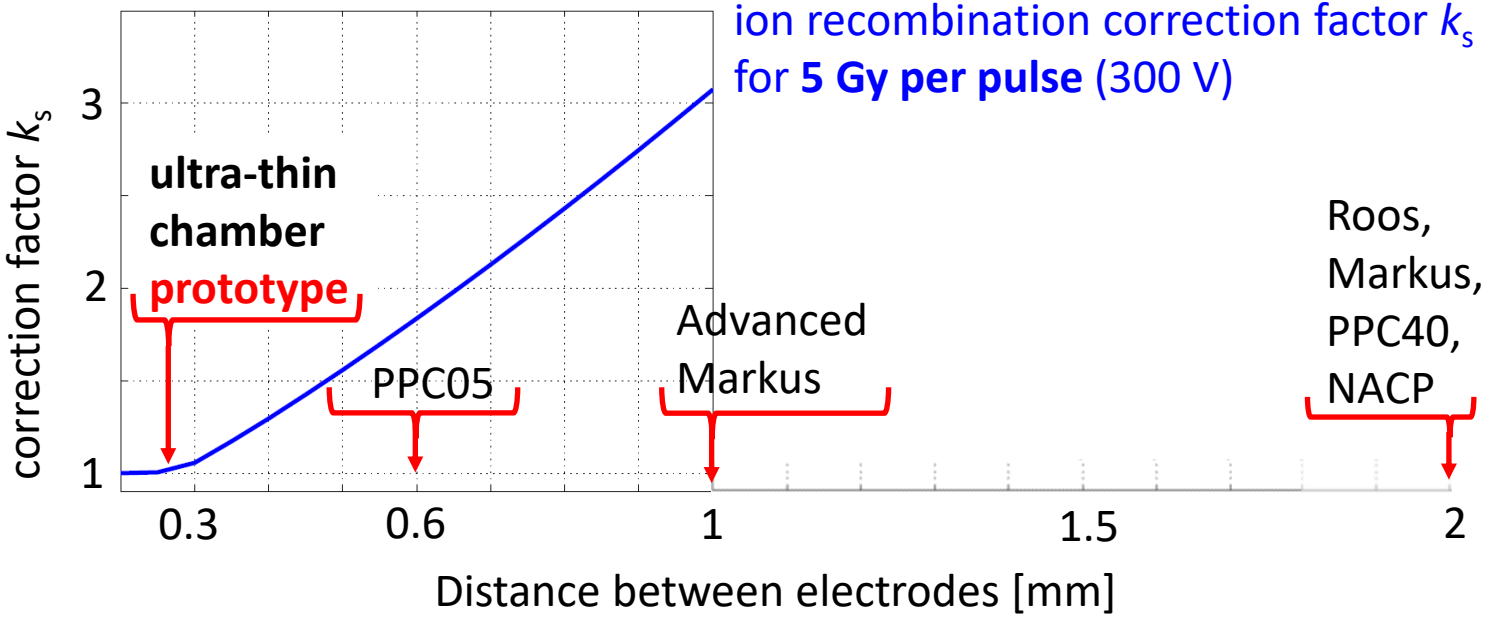




meet Jose Paz-Martín (USC) at poster EPP023, today

J. Paz-Martín *et al.*, "Numerical modelling …" Phys. Med. **103** (2022) 147.
https://doi.org/10.1016/j.ejmp.2022.10.006

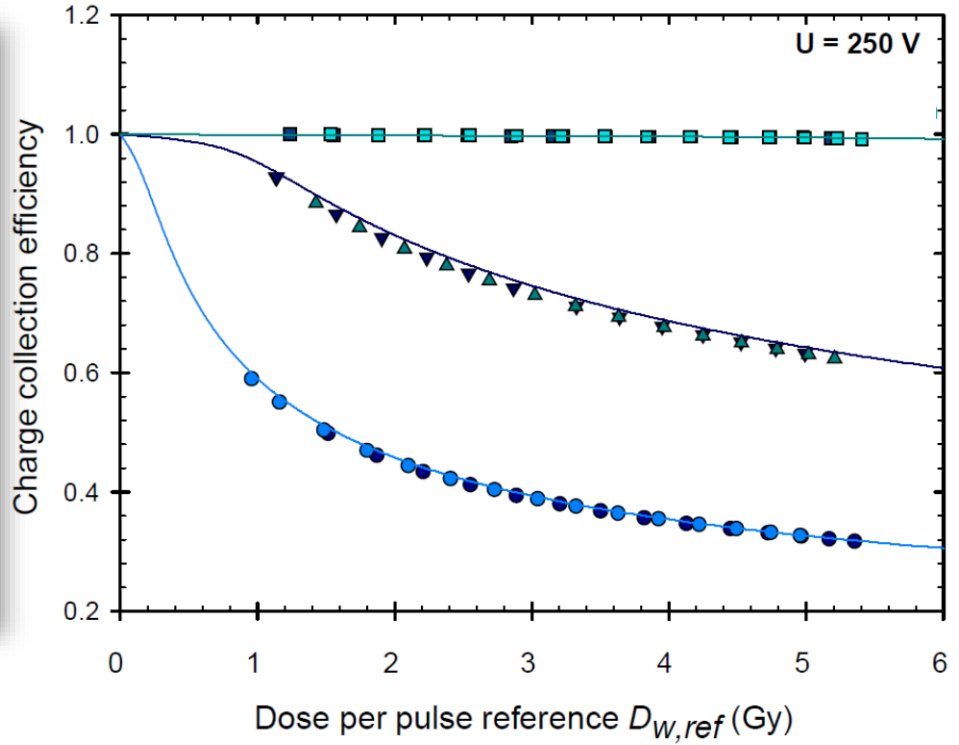
Calculation of charge collection efficiency



meet Faustino Gomez (USC) at poster EPP024, today

F. Gomez *et al.,* "Development of an ultra-thin …" Med Phys. **49** (2022) 4705.
https://doi.org/10.1002/mp.15668

Ultra-thin ionization chamber for FLASH RT



electrode distance

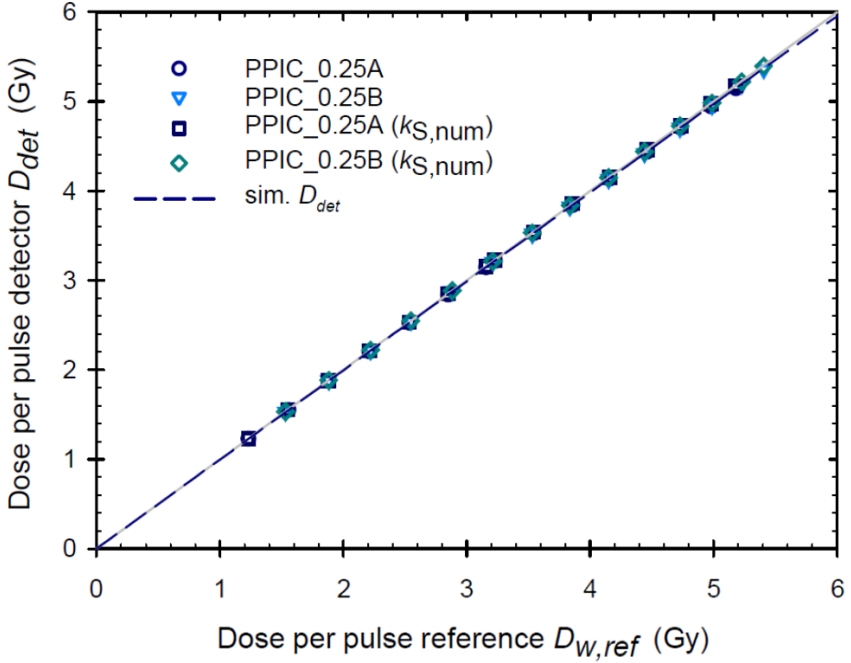
0.25 mm

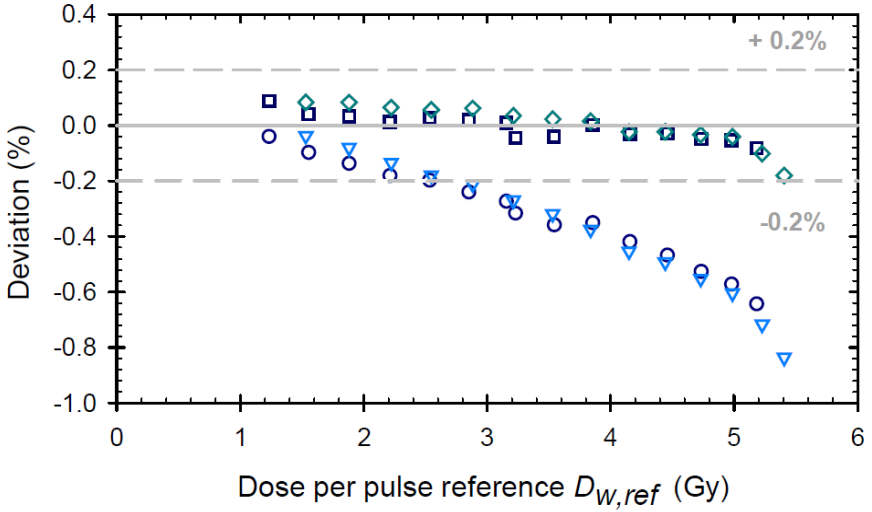
0.5 mm

1 mm

R. Kranzer *et al.* "Charge collection efficiency …" Phys Med **104** (2022) 10.
https://doi.org/10.1016/j.ejmp.2022.10.021

Ultra-thin ionization chamber for FLASH RT

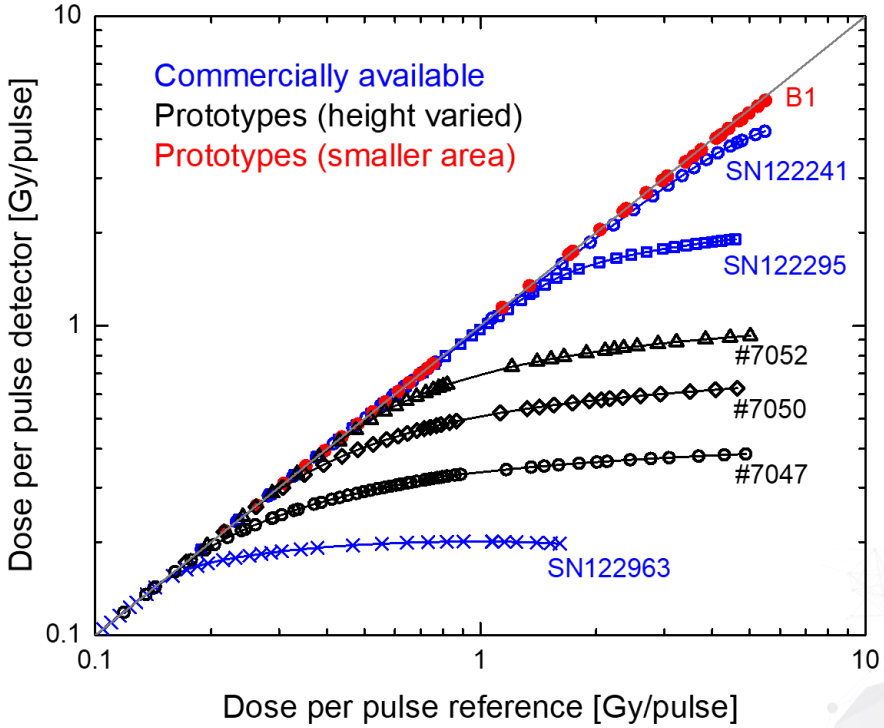




meet Rafael Kranzer at PTW booth

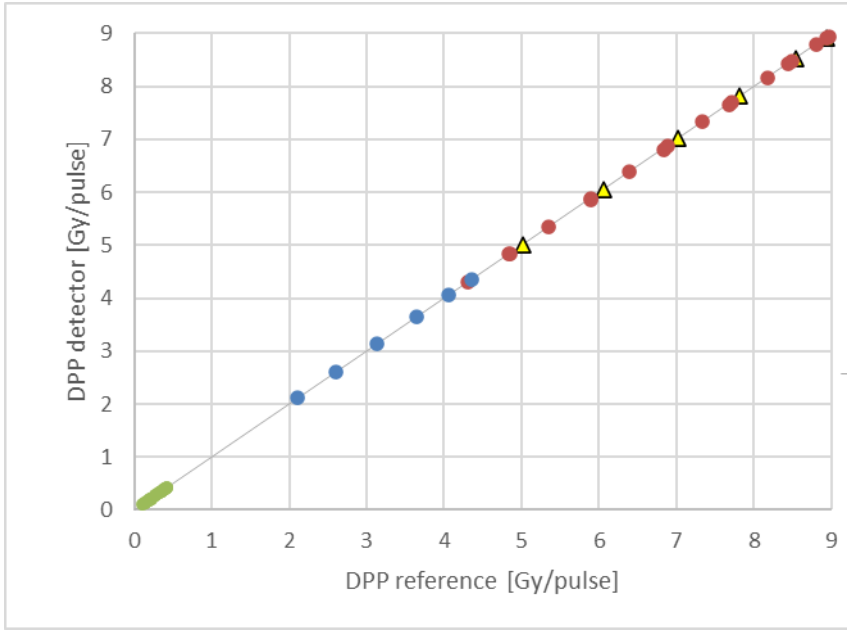
R. Kranzer *et al.* "Charge collection efficiency …" Phys Med **104** (2022) 10.
https://doi.org/10.1016/j.ejmp.2022.10.021

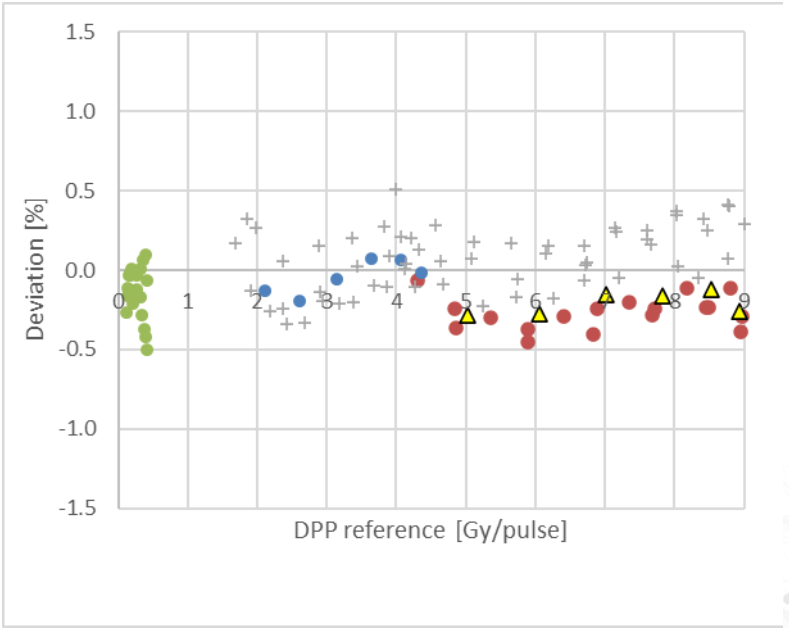
flashDiamond



R. Kranzer *et al.* "Response of diamond …"
Phys. Med. Biol. **67** (2022) 075002.
https://doi.org/10.1088/1361-6560/ac594e

flashDiamond

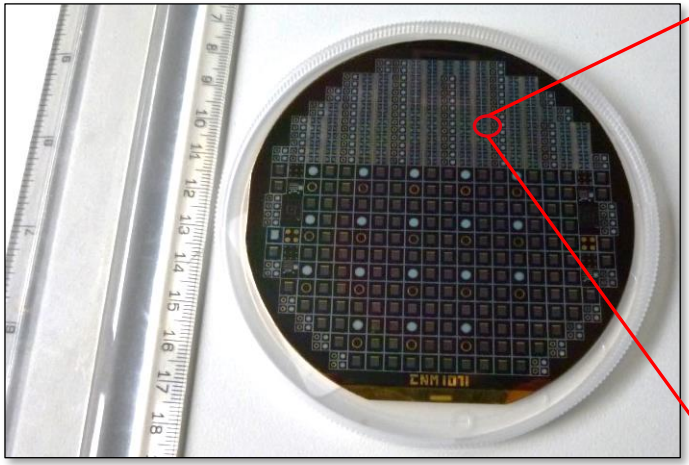




M. Marinelli et al.
"Design, realization, and …"
Med. Phys. **49** (2022) 1902.
https://doi.org/10.1002/mp.15473

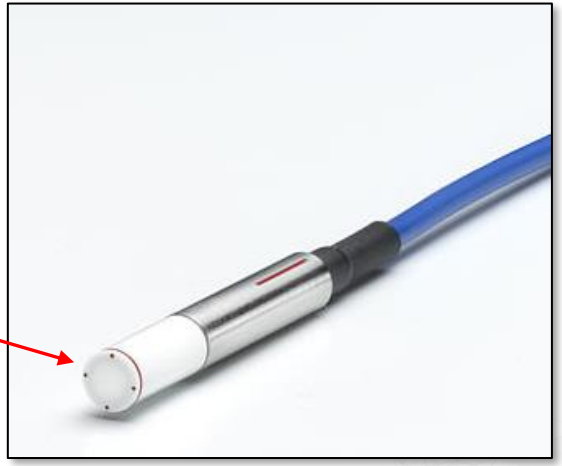
G. Verona Rinati et al.
"Application of a novel diamond …"
Med. Phys. **49** (2022) 5513.
https://doi.org/10.1002/mp.15782

SiC diodes for FLASH dosimetry



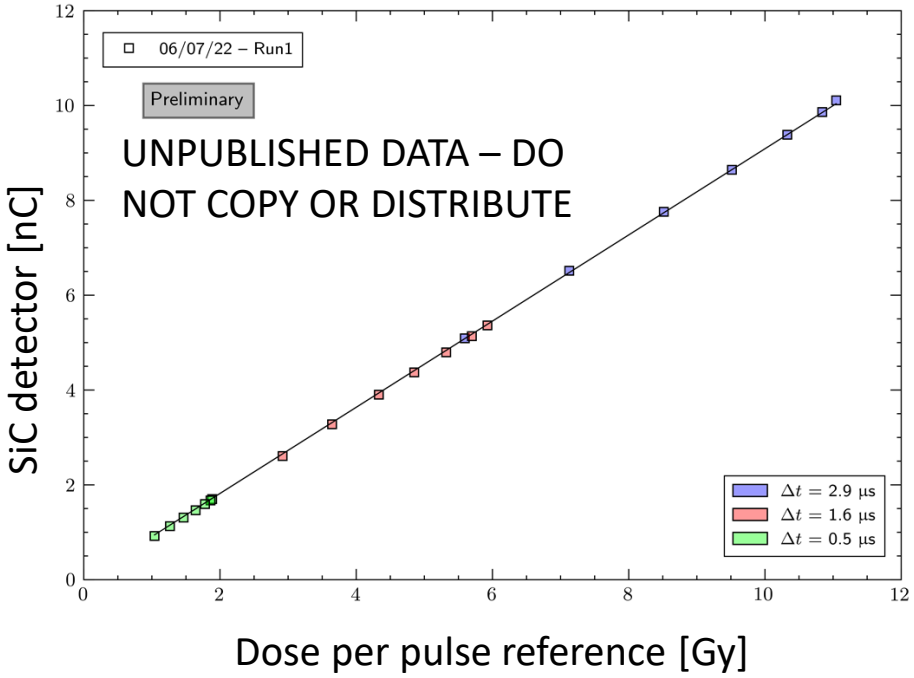
4” SiC wafer

1 mm diode



Encapsulation by PTW (microSilicon housing)

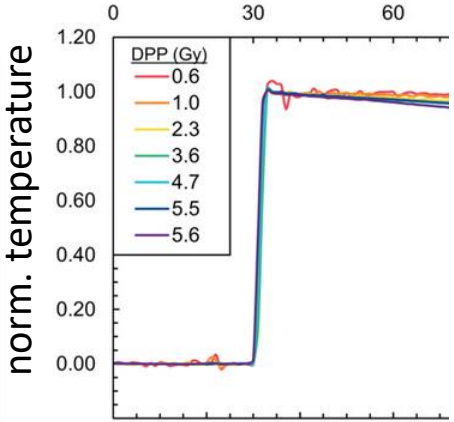
SiC diodes for FLASH dosimetry

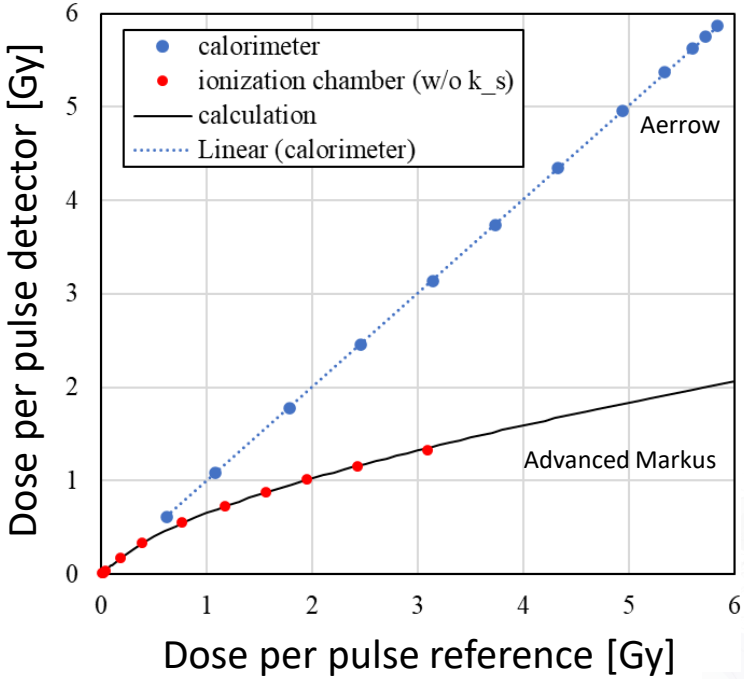


talk by Celeste Fleta (CSIC), Friday

Graphite probe calorimeter “Aerrow”

Calorimeter Aerrow
(and ionization chamber)

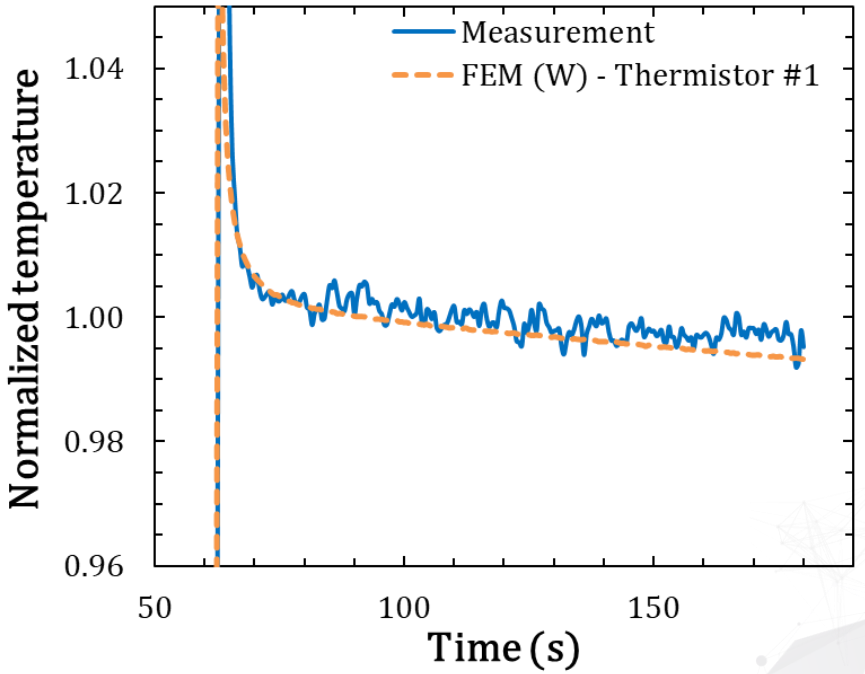




A. Bourgouin *et al.*, “The probe-format graphite …” Med Phys. **49** (2022) 6635.
https://doi.org/10.1002/mp.15899

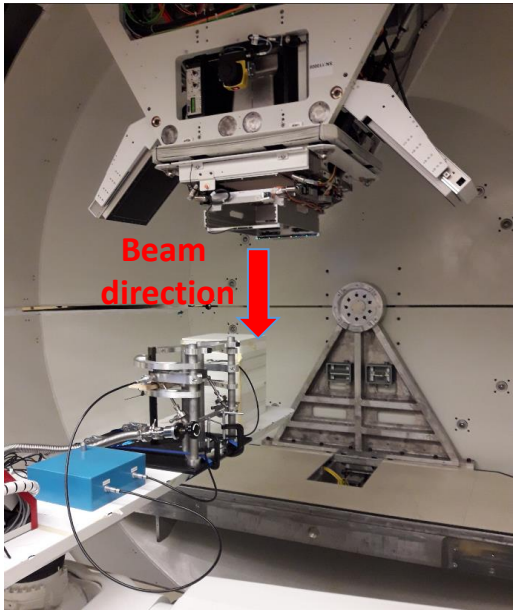
Water calorimeter

PTB's primary standard of the unit Gy

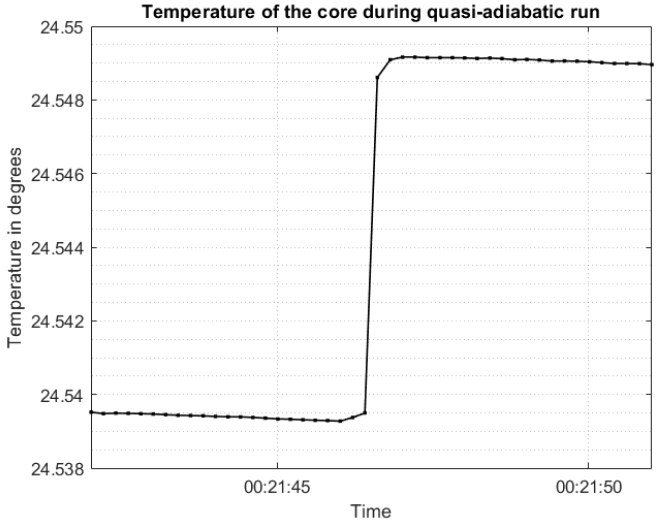


talk by Alexandra Bourgouin (PTB), Tomorrow

Calorimetry in UHDR proton beams



NPL's graphite calorimeter in Cincinnati Proton Centre



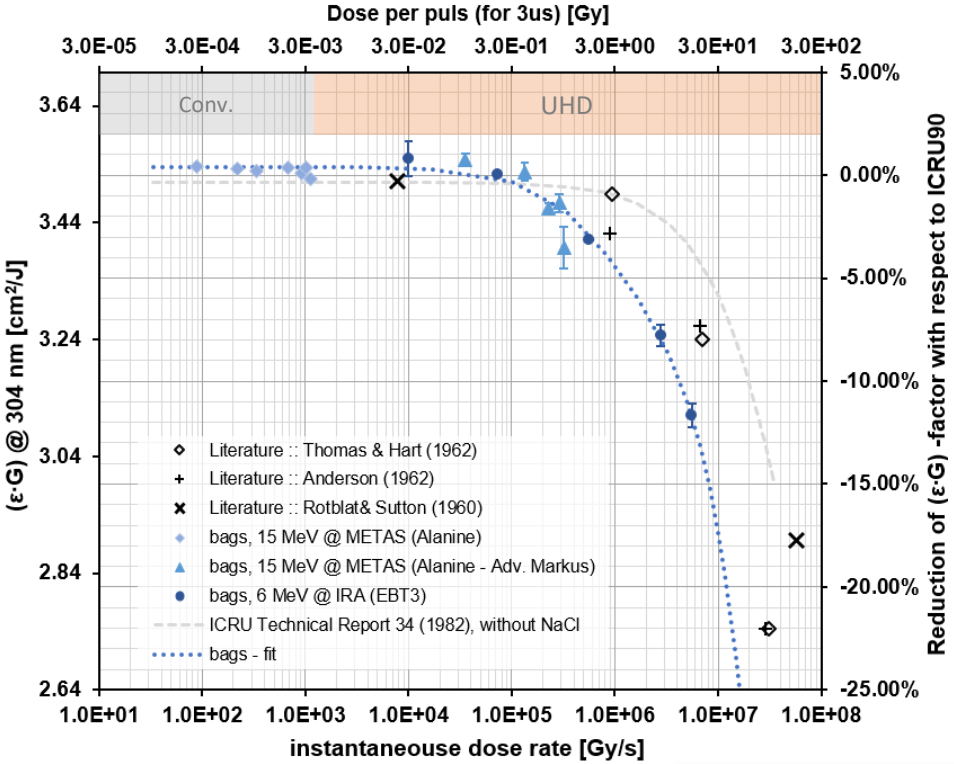
see talk "FLASH Metrology" by Anna Subiel (NPL), Friday

→ **First ever calorimetry measurements in UHDR proton beam**

- Established the correction factors required for absolute dosimetry of FLASH proton beam radiotherapy (Lourenço et al., 2022 (under review))
- Measurement uncertainty of 0.9% (k=1) – in line with clinical requirement
- **Underpinned the FDA approval and provided the hospital with confidence to commence clinical implementation of this novel technology**

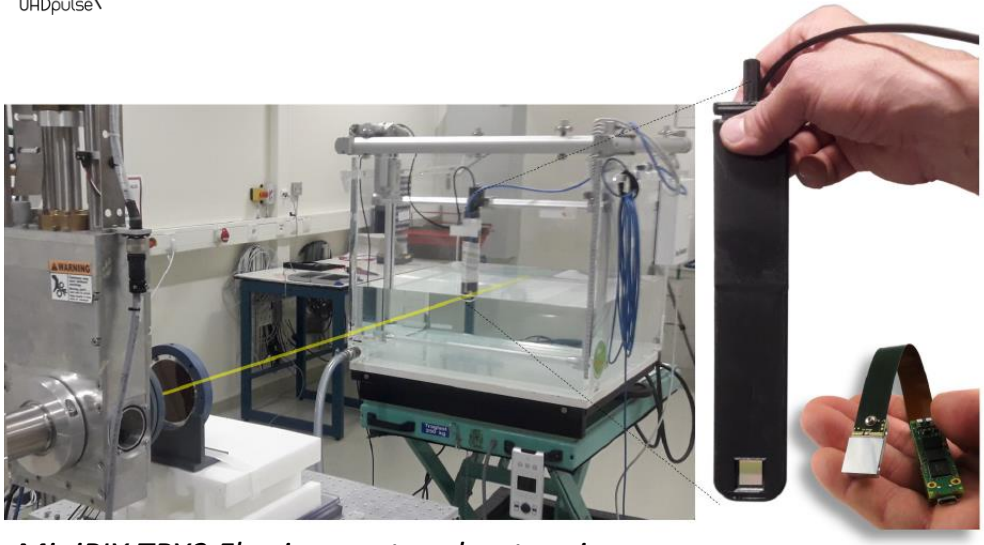
E. Lee et al. "Ultrahigh dose rate pencil beam …" Med. Phys. **49** (2022) 6171.
https://doi.org/10.1002/mp.15844

Fricke Dosimeter

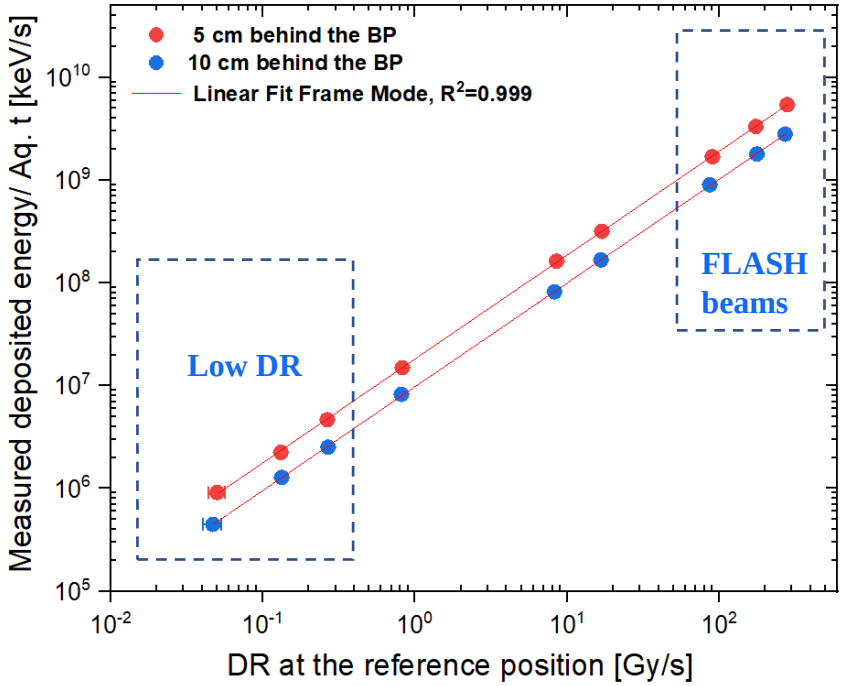


see e-poster of Franziska Frei (METAS)

TimePIX3 detector



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



see e-poster of Cristina Oancea (ADVACAM)

C. Oancea et al., Physica Medica, 2022 (under review)

Achievements of UHDpulse

http://uhdpulse-empir.eu/

up to now
27 Peer-reviewed publications (open access)
63 Oral presentations
16 Poster
40 Other publications

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.

Acknowledgement (in alphabetical order):
I. Ambrozova, U. Ankerhold, L. Archambault, R. Ashraf, C. Bailat, M. Borghesi, A. Boso, A. Bourgouin, P. Bruza, S. Busold, M. Caresana, A. Cimmino, L. De Marzi, V. Djonov, A.Douralis, M. Durante, M. Dutreix, F. Fausti, F. Keszti, G. Felici, C. Fleta, J.-M. Fontbonne, C. Fouillade, F. Frei, A. Gasparini, U. Giesen, L. Giuliano, F. Gomez, L. Grasso, T. Hackel, S. Heinrich, J. Jakubek, R.-P. Kapsch, K. Kirkby, A. Knyziak, R. Kranzer, C. Lahaye, M. Lavagno, A. Leite, V. Linhart, B. Lessard, H. K. Looe, C. Makowski, M. Marinelli, S. McCallum, M. McEwen, M. McManus, T. Michel, G. Milluzzo, S. Motta, C. Oancea, V. Olsovcova, H. Palmans, K. Parodi, J. Pawelke, J. Paz-Martin, P. Peier, K. Petersson, J. Pivec, B. Poppe, D. Poppinga, M. Pullia, J. Renaud, N. Roberts, F. Romano, S. Rossomme, K. Roškar, S. Safai, S. Salvador, C. S. Schmitzer, A. Schönfeld, B. Simon, J. Solc, F. Stephan, A. Subiel, F. Therriault-Proulx, R. A. Thomas, M. Togno, E. Touzain, M. Trachsel, F. Vanhavere, V. Vanreusel, D. Verellen, G. Verona Rinati, J. Seuntjens, R. Versaci, P. von Voigts-Rhetz, M. Zboril