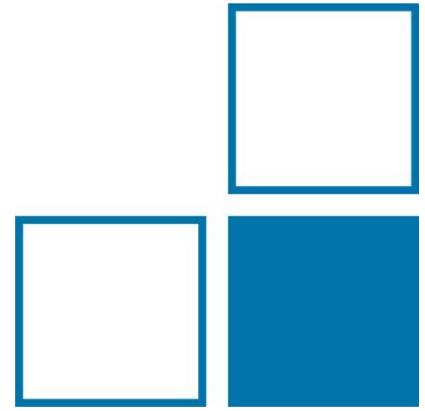
Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

Highlights from EMPIR JRP UHDpulse – “Metrology for advanced radiotherapy using particle beams with ultra-high pulse dose rates”

UHDpulse

Andreas Schüller
Working Group 6.21 “Dosimetry for radiotherapy”
on behalf of the UHDpulse consortium



TC-IR Contact Person Meeting, 24. – 28.1.2022, Online

EMPIR JRP “UHDpulse”

Duration: Sep/2019-Feb/2023

Coordinator: Andreas Schüller (PTB)

Topic: dosimetry for

- FLASH radiotherapy

- VHEE radiotherapy

- laser driven beams

Website: http://uhdpulse-empir.eu

Outline

Highlights
Abstract
Keywords
1. Introduction
2. Overview of novel radiotherapy techniques using ultra-...
3. Metrological challenges and possible solutions for dosi...
4. The UHDpulse project
5. Conclusion
Acknowledgements
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Figures (15)

Physica Medica
Volume 80, December 2020, Pages 134-150

Original paper

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

Andreas Schüller [a], Sophie Heinrich [b], Charles Fouillade [b], Anna Subiel [c], Ludovic De Marzi [b, d], Francesco Romano [e, c], Peter Peier [f], Maria Trachsel [f], Celeste Fleta [g], Rafael Kranzer [h, i], Marco Caresana [j], Samuel Salvador [k], Simon Busold [l], Andreas Schönfeld [m], Malcolm McEwen [n], Faustino Gomez [o], Jaroslav Solc [p], Claude Bailat [q] ... Marie-Catherine Vozenin [q]

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

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Highlights

- Ultra-high dose rate reduces adverse side effects in radiotherapy (FLASH effect).
- Studies and implementation in practice requires accurate dose measurements.
- An European joint research project was started to develop a measurement framework.
- Tools for dosimetry of ultra-high pulse dose rate beams will be provided.

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

FLASH radiotherapy

<u>FLASH-RT:</u>
Electron beam
10 pulses (of 1 μs duration) in 90 ms
with **1.5 Gy per pulse**

(conventional RT: 0.3 mGy per pulse)

Ultra-high dose rate / dose per pulse
-> sparing healthy tissue

human patient, lymphoma on skin

Day 0

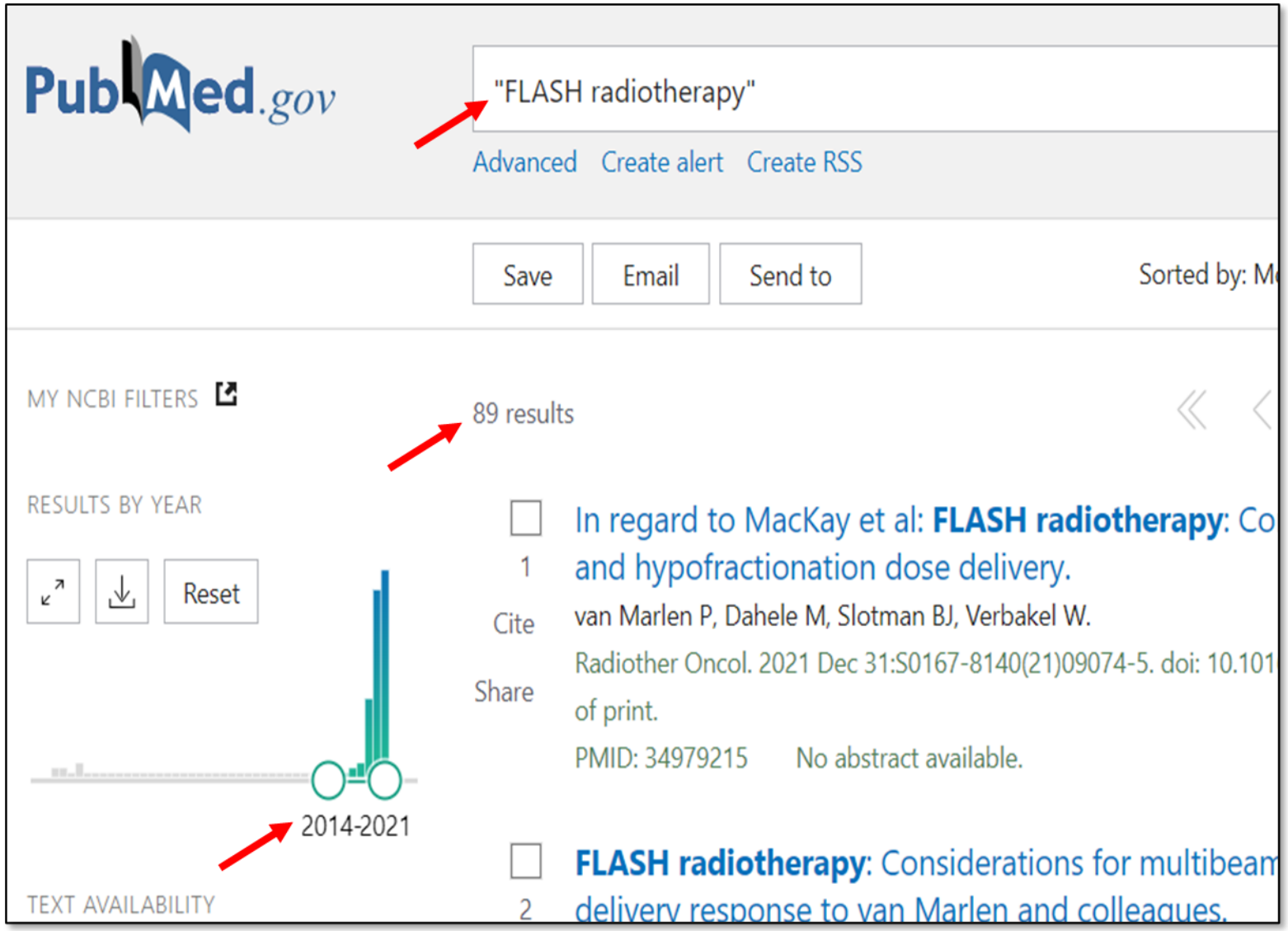
3 weeks

5 months

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

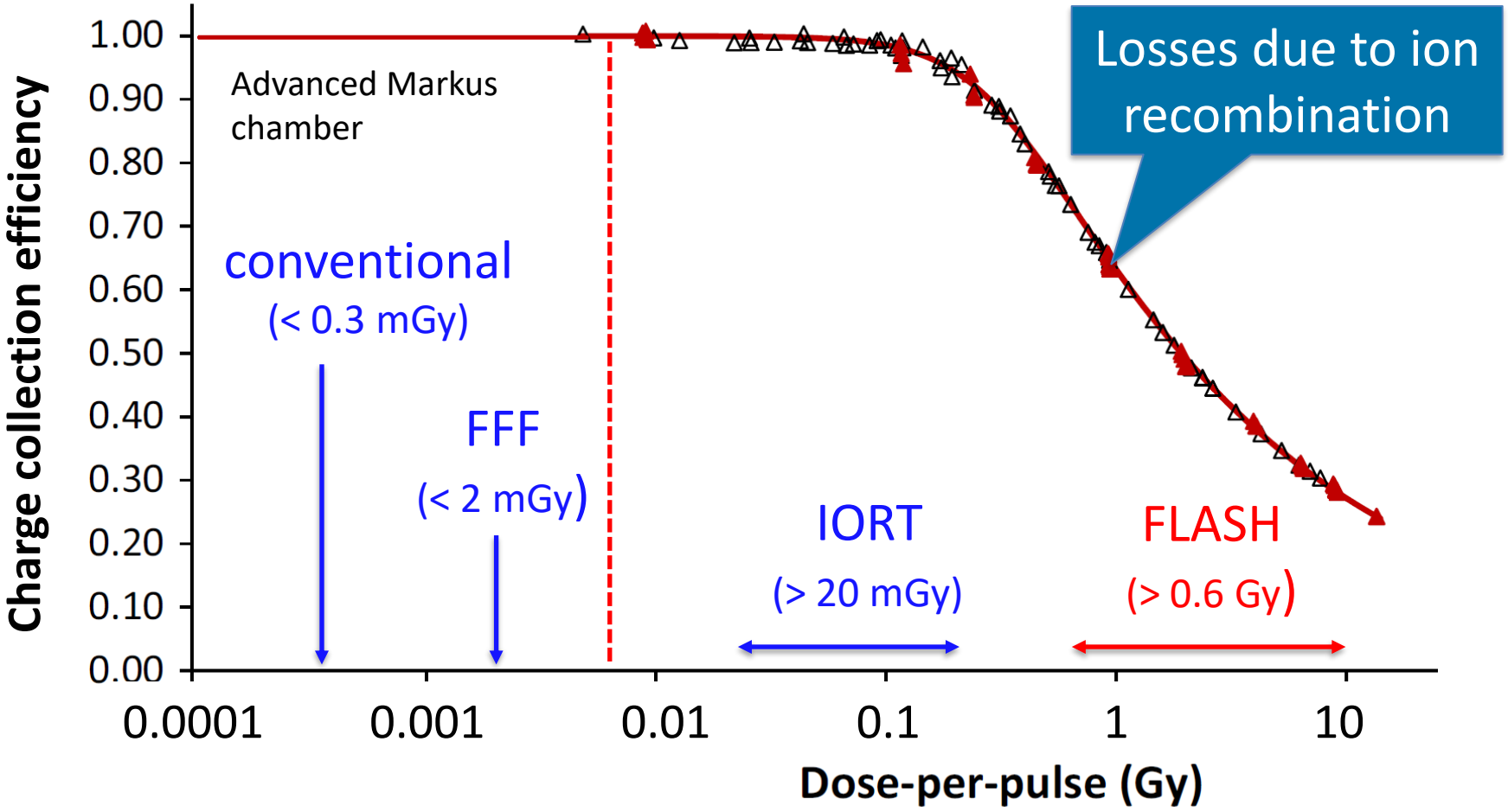
FLASH radiotherapy

- interest in FLASH RT increasing rapidly.
- **2021: 1.4 paper/week about** “FLASH RT” or “ultra-high dose rate”
- just now an urgent need for Dosimetry for FLASH RT



Metrological challenge at FLASH radiotherapy

Typical performance of ionization chambers



There are

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

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

Partners and Collaborators

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 network – Topzorg in radiotherapie
- PAUL SCHERRER INSTITUT PSI
- IntraOp

Detector developers / providers

- TOR VERGATA University of Rome – Dept. Industrial Engineering
- ECAP – Erlangen Centre for Astroparticle Physics
- ADVACAM – Imaging the Unseen
- USC – Universidade de Santiago de Compostela
- CSIC – Consejo Superior de Investigaciones Científicas; CNM – Centro Nacional de Microelectrónica IMB
- Politecnico Milano 1863
- PTW – The Dosimetry Company
- Carl von Ossietzky Universität Oldenburg
- LPC Caen – Laboratoire de physique corpusculaire
- SUN NUCLEAR corporation
- iba Dosimetry – Protect, Enhance and Save Lives
- varian – A Siemens Healthineers Company
- DETECTOR – Devices and Technologies Torino
- Dartmouth Engineering 1867
- Université Laval

7 Metrology institutes
6 Hospitals
7 Universities
6 Research institutes
8 Companies

Collaborators

21 Collaborators joined UHDpulse up to now

8 new Collaborators in 2021

SUN NUCLEAR corporation

UNIVERSITÉ LAVAL

DESY.

DETECTOR DEVICES AND TECHNOLOGIES TORINO

iba Dosimetry Protect, Enhance and Save Lives

MedAustron

SIT

CARL VON OSSIETZKY universität OLDENBURG

NRC·CNRC Canada

fondazione CNAO

DARTMOUTH ENGINEERING 1867

lpc caen laboratoire de physique corpusculaire

varian A Siemens Healthineers Company

sckcen

ecap ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

bergoz INSTRUMENTATION

netwerk iridium Topzorg in radiotherapie

PAUL SCHERRER INSTITUT PSI

TOR VERGATA UNIVERSITY OF ROME Dept. Industrial Engineering

IntraOp

KU LEUVEN RESEARCH & DEVELOPMENT

WPs

UHDpulse

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

Highlights of 2021 - D1: reference fields

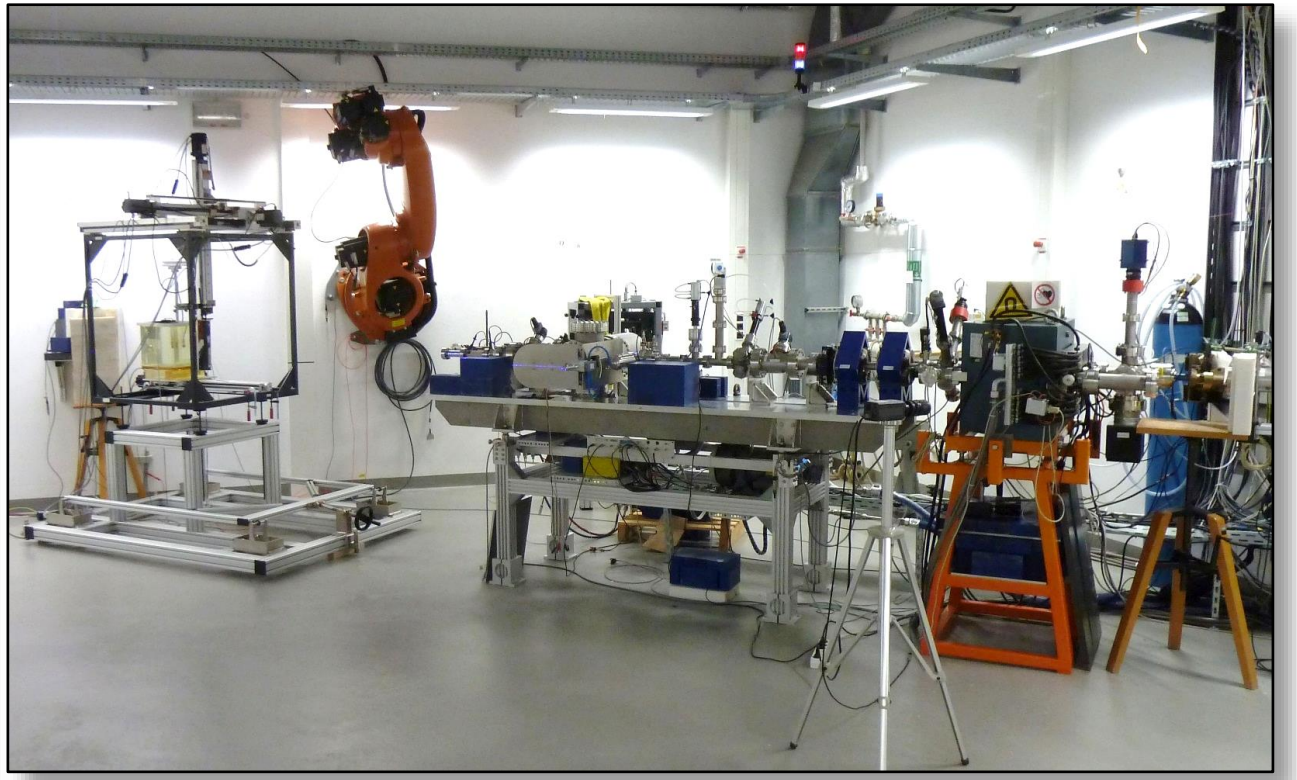
B1.c List of deliverables

Relevant objective (Activity delivering the deliverable)	Deliverable number	Deliverable description	Deliverable type	Partners (Lead in bold)	Delivery date
1 (A1.1.6)	D1	Report describing the new reference fields for dosimetry in electron beams with ultra-high pulse dose rates	Report	**PTB**, METAS, GUM	Feb 2021 (M18)
1 (A1.2.9)	D2	Report describing the traceability to a primary standard that will be provided for FLASH proton beams at the Proton Therapy Centre of Curie	Report	**NPL**, Curie	Apr 2021 (M20)
1 (A1.2.5)	D3	Report on the comparison of the primary standards of PTB and METAS for absorbed dose to water in ultra-high dose per pulse electron beams	Comparison report	**METAS**, PTB	Dec 2021 (M28)
1, 2, 3	D4	Recommendation report about the	Recommendation	**CHUV**	Apr 2022

Highlights of 2021 - D1: reference fields

Ultra-high pulse dose rate reference fields at PTB

PTB's Research electron accelerator



Beam line with water phantom

E = 0.5 – 50 MeV

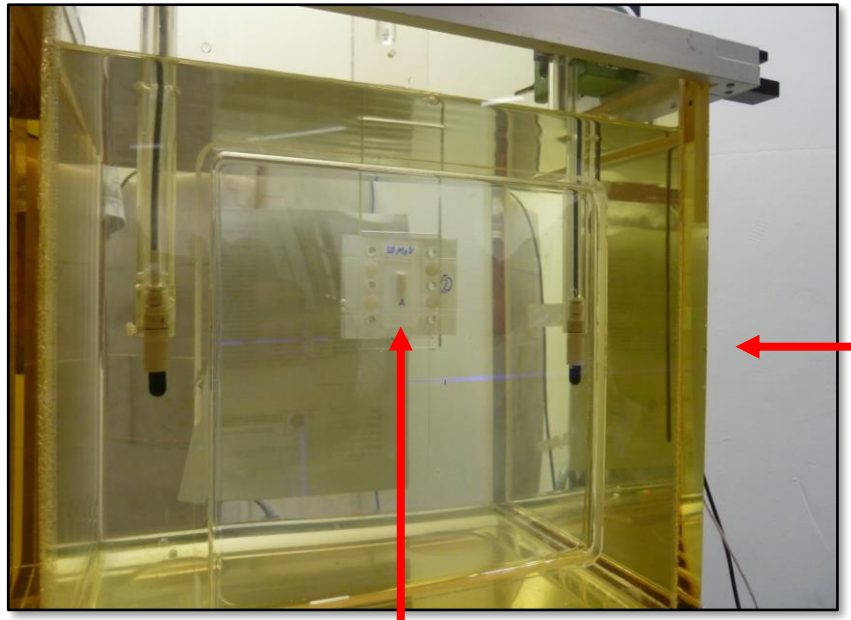
t_{pulse} = 0.1 – 3 us

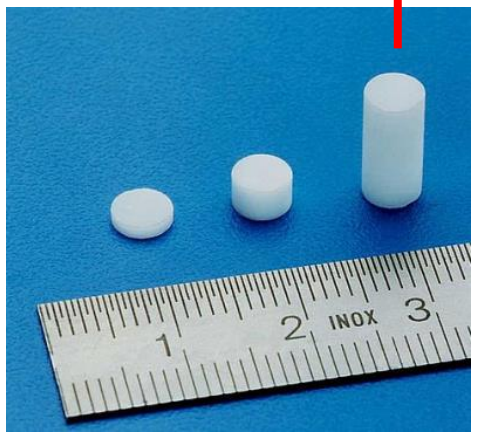
up to **7 Gy per pulse** (SSD 0.7 m, 20 MeV)

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

Highlights of 2021 - D1: reference fields

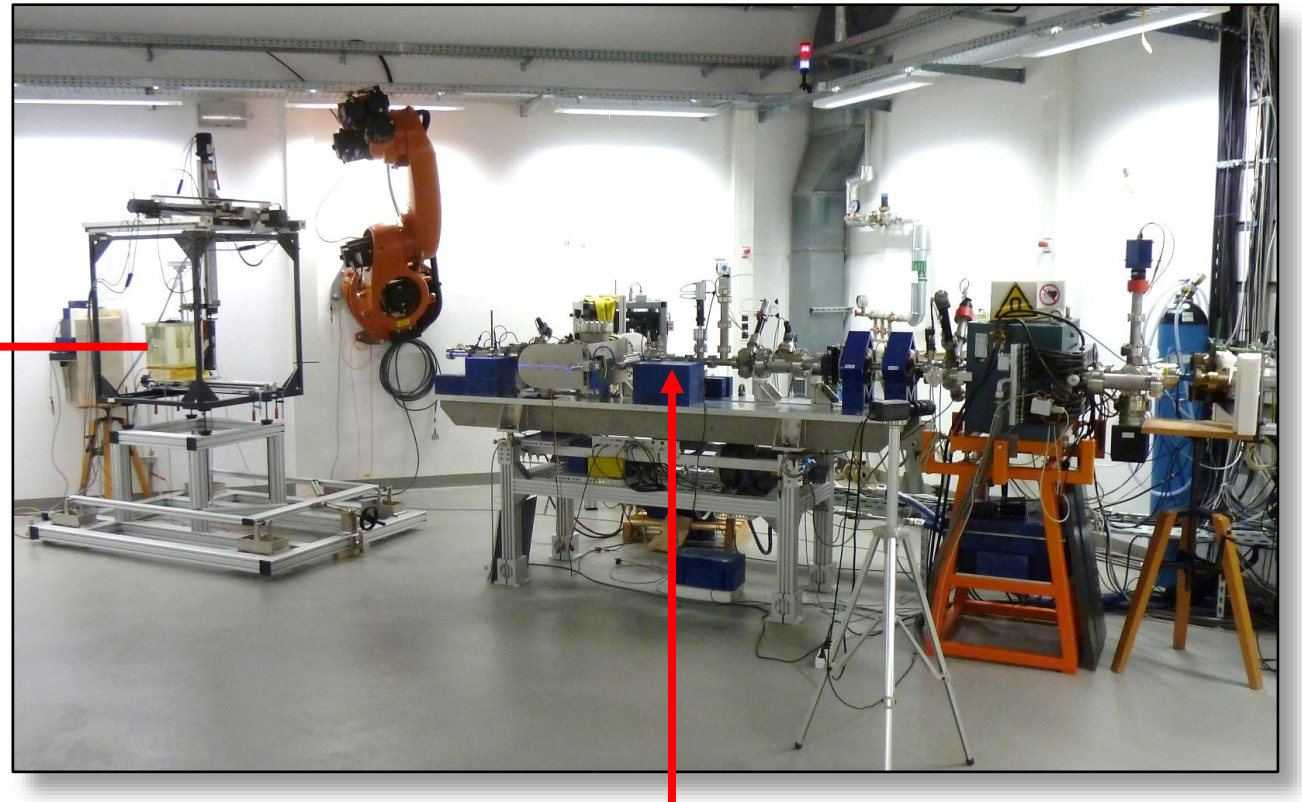
Ultra-high pulse dose rate reference fields at PTB





Alanine pellets at reference depth in water phantom

Dose traceable to primary standard

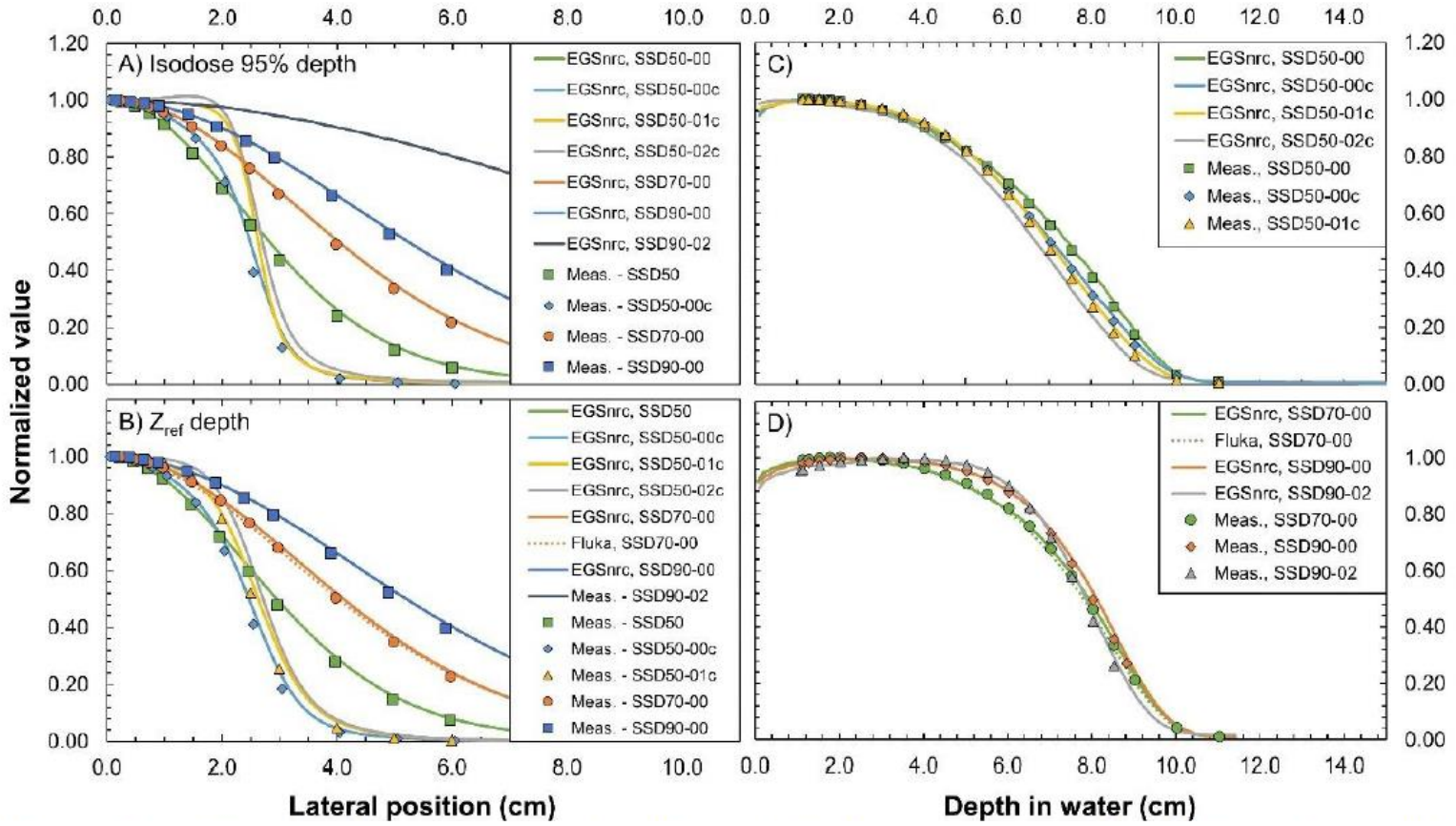


Current transformer (Bergoz ICT): Non-destructive absolute beam pulse charge measurement (uncertainty < 0.1 % @70 nC/pulse)

Highlights of 2021 - D1: reference fields

Ultra-high pulse dose rate reference fields at PTB

MC-Simulation vs. Experiment



Highlights of 2021 - D1: reference fields

Ultra-high pulse dose rate reference fields at METAS

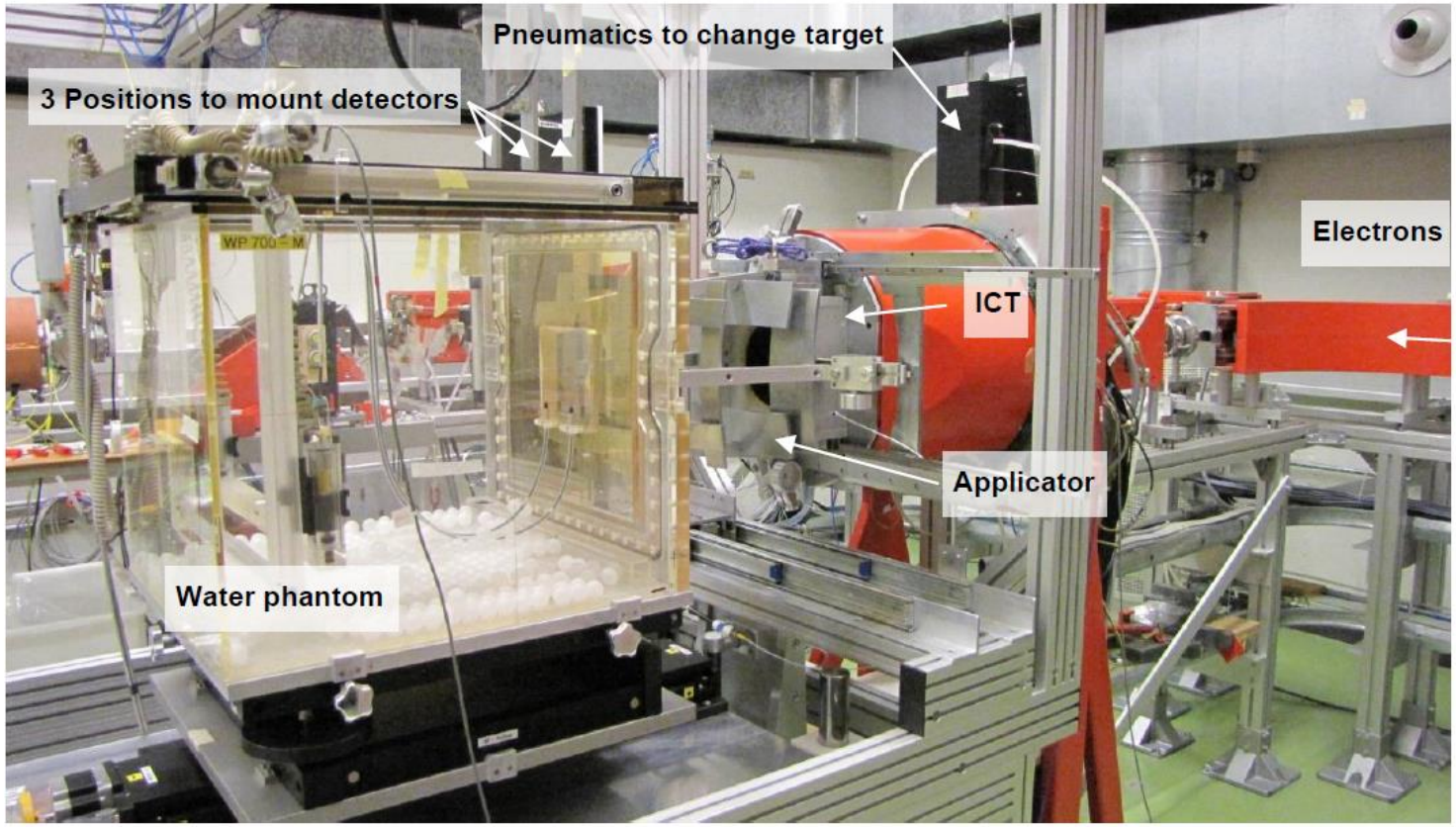
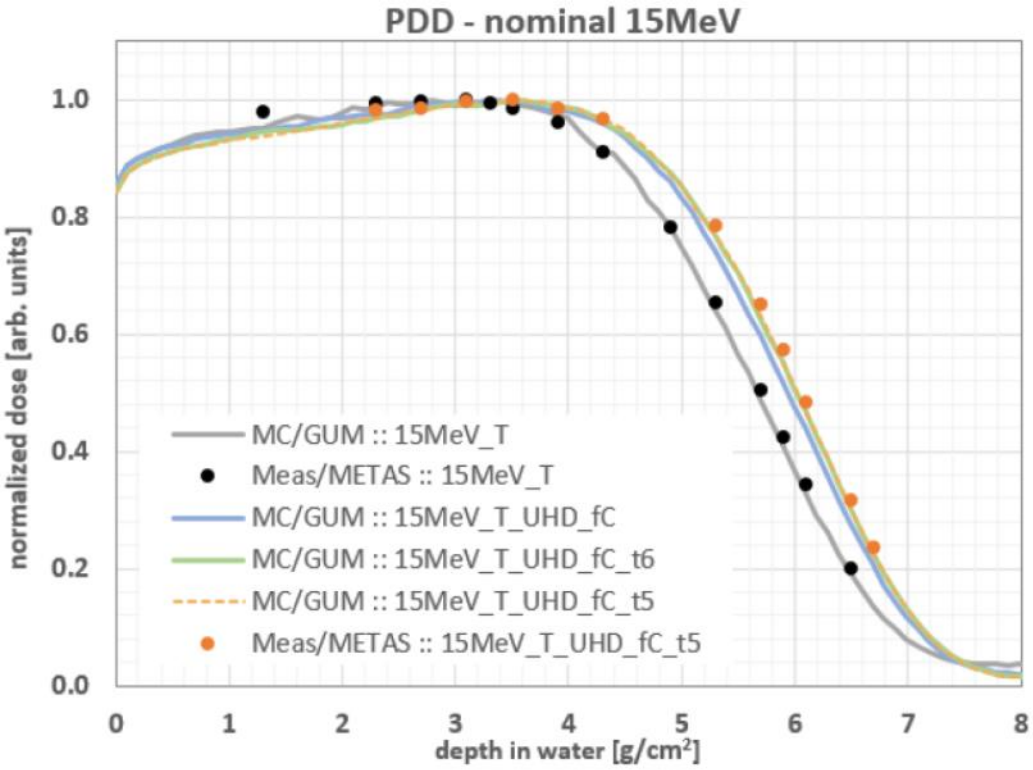


Figure 18: Wellhöfer WP700 phantom, applicator, ICT and treatment head. The water phantom is only filled with water during measurements. The plastic balls are used to prevent water evaporation and thereby minimizing evaporative cooling.

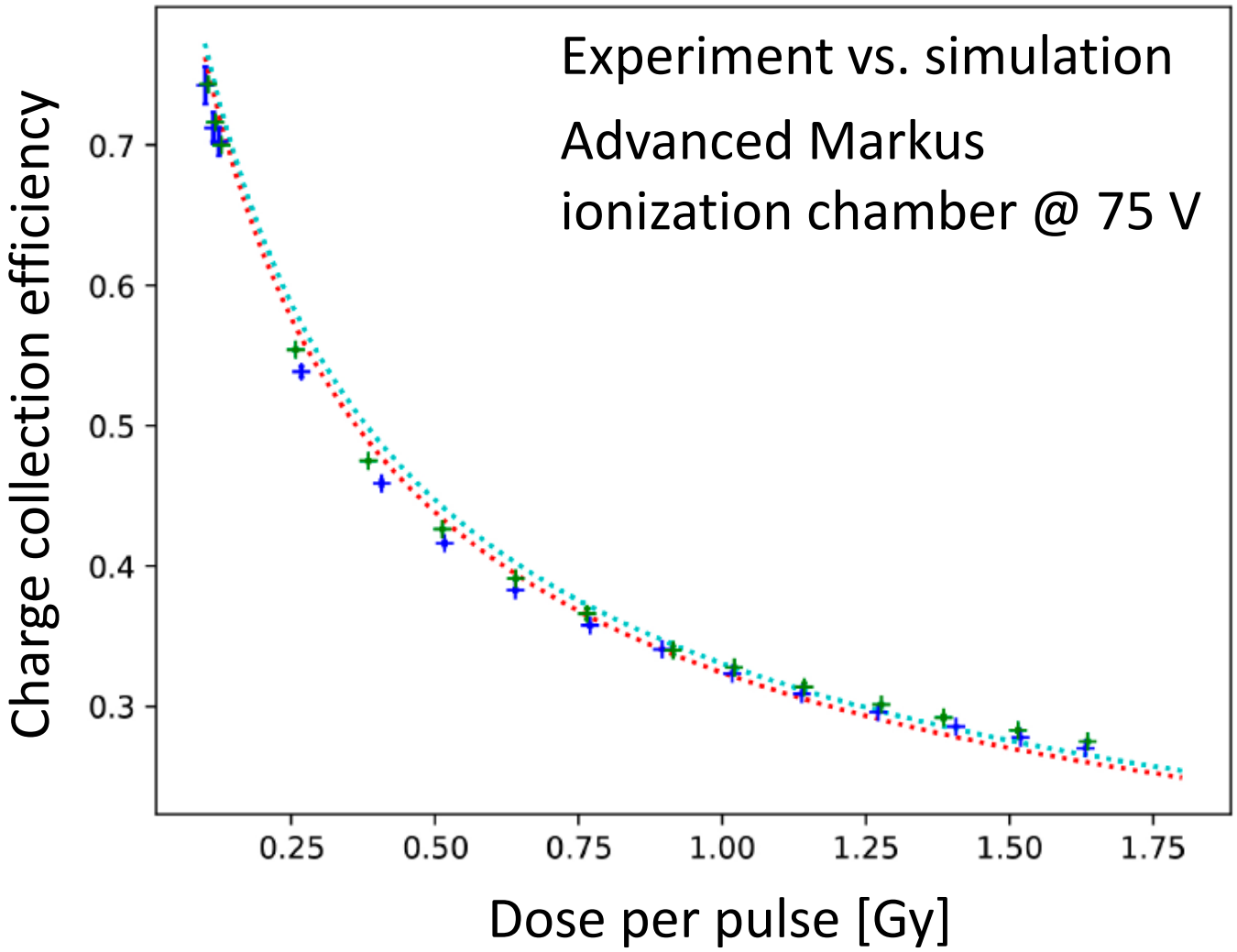
Highlights of 2021 - D1: reference fields

Ultra-high pulse dose rate reference fields at METAS

MC-Simulation vs. Experiment



Highlights of 2021 – theoretical models for ICs

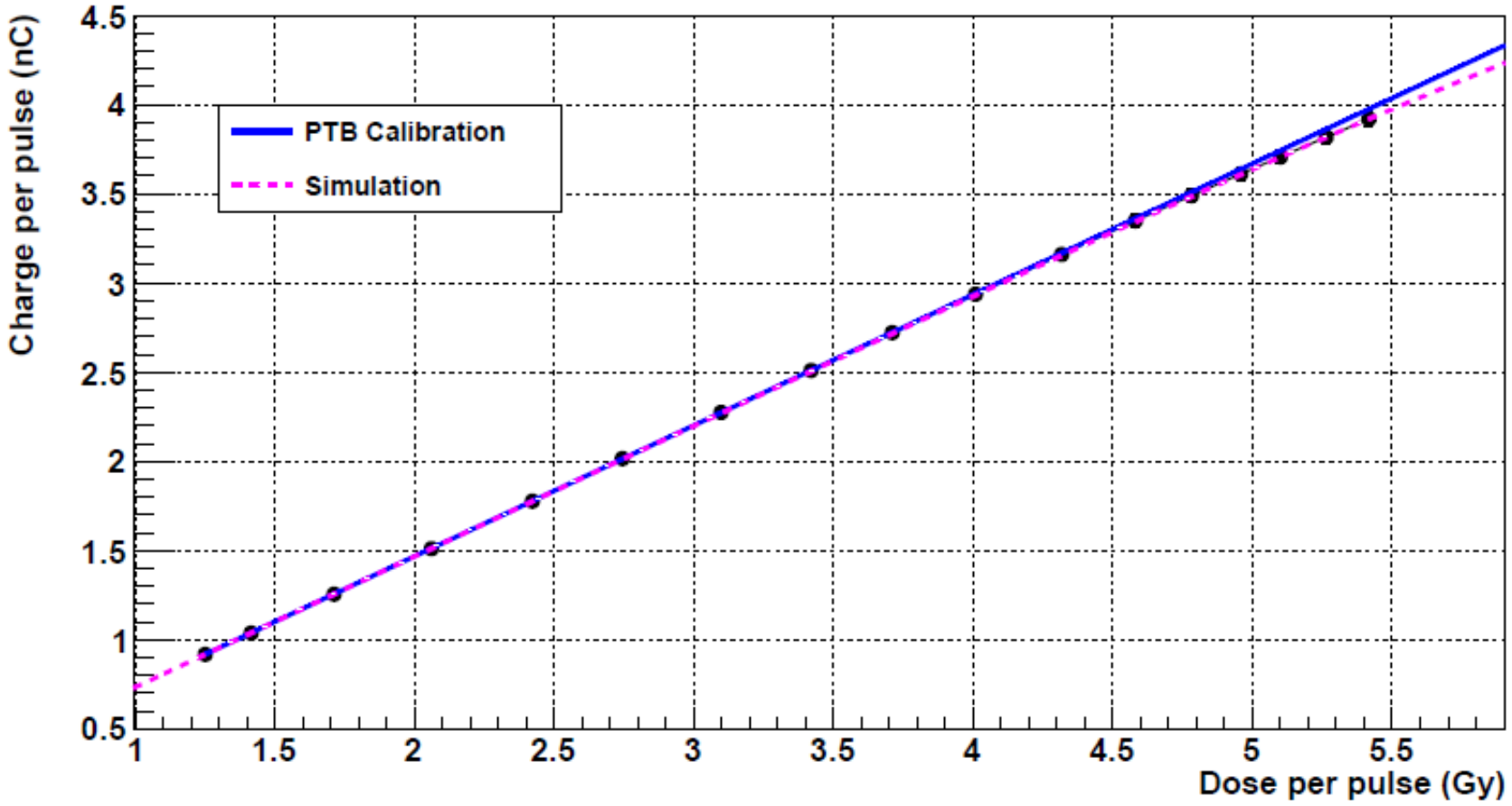


Faustino Gomez et al., in preparation

Highlights of 2021 - ultra-thin IC prototypes

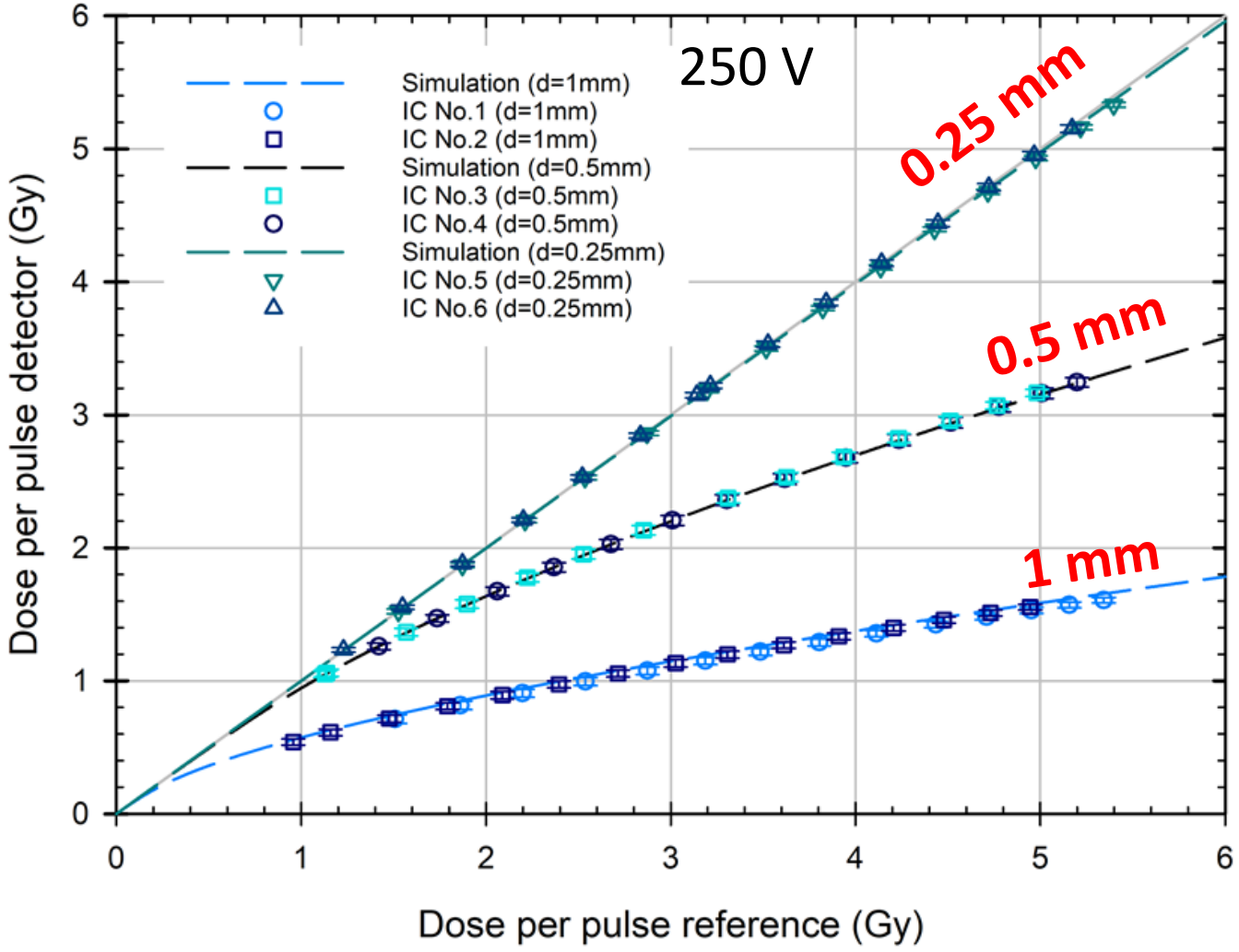
Ionization chamber prototype

electrode distance: 0.27 mm



Faustino Gomez et al., submitted

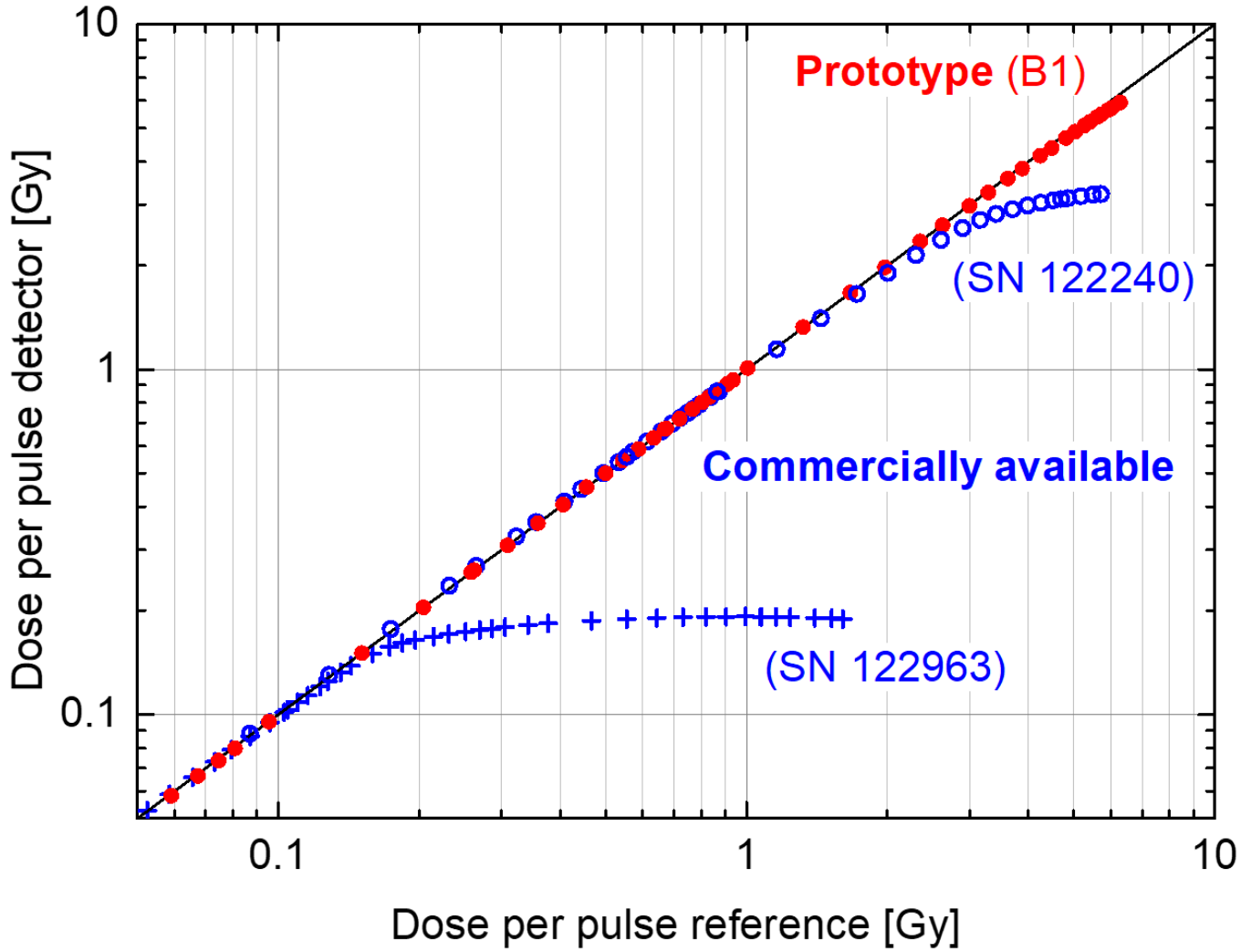
Highlights of 2021 - ultra-thin IC prototypes



Rafael Kranzer et al., in preparation

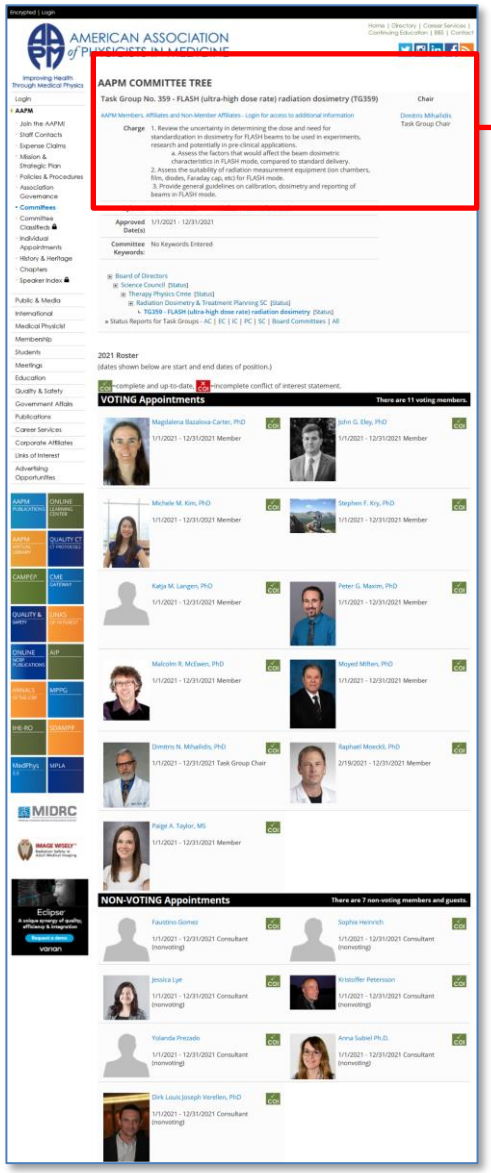
Highlights of 2021 - flashDiamond

*



Rafael Kranzer et al., submitted

Highlights of 2021 – AAPM TG No. 359



TG359

"FLASH (ultra-high dose rate) radiation dosimetry"

- Assess the suitability of radiation **measurement equipment** (ion chambers, film, diodes, Faraday cap, etc) for FLASH mode.
- Provide general **guidelines** on calibration, dosimetry and reporting of beams in FLASH mode.

UHDpulse

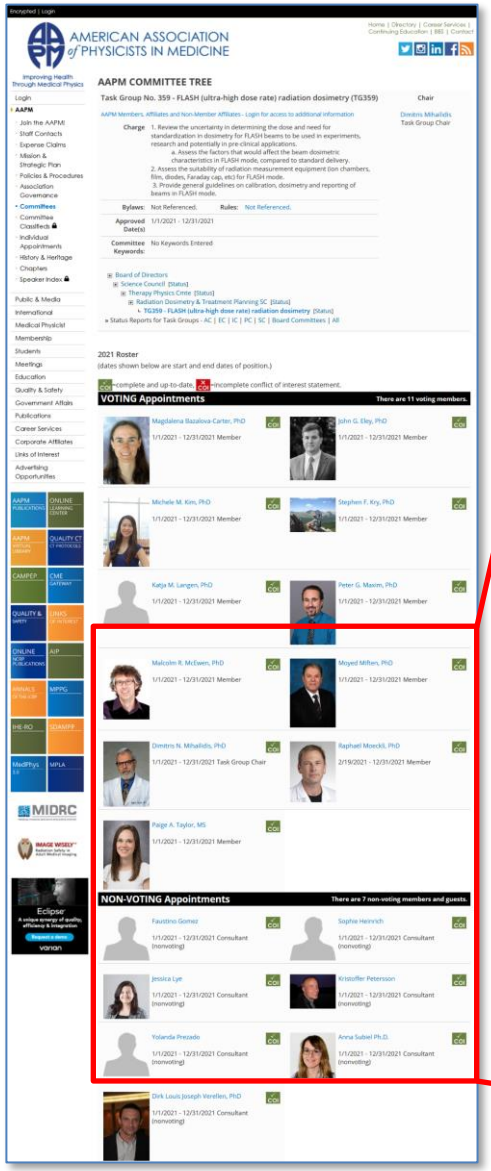
Objective 5:
to facilitate the uptake of the project's achievements by **standards developing organizations** and end users

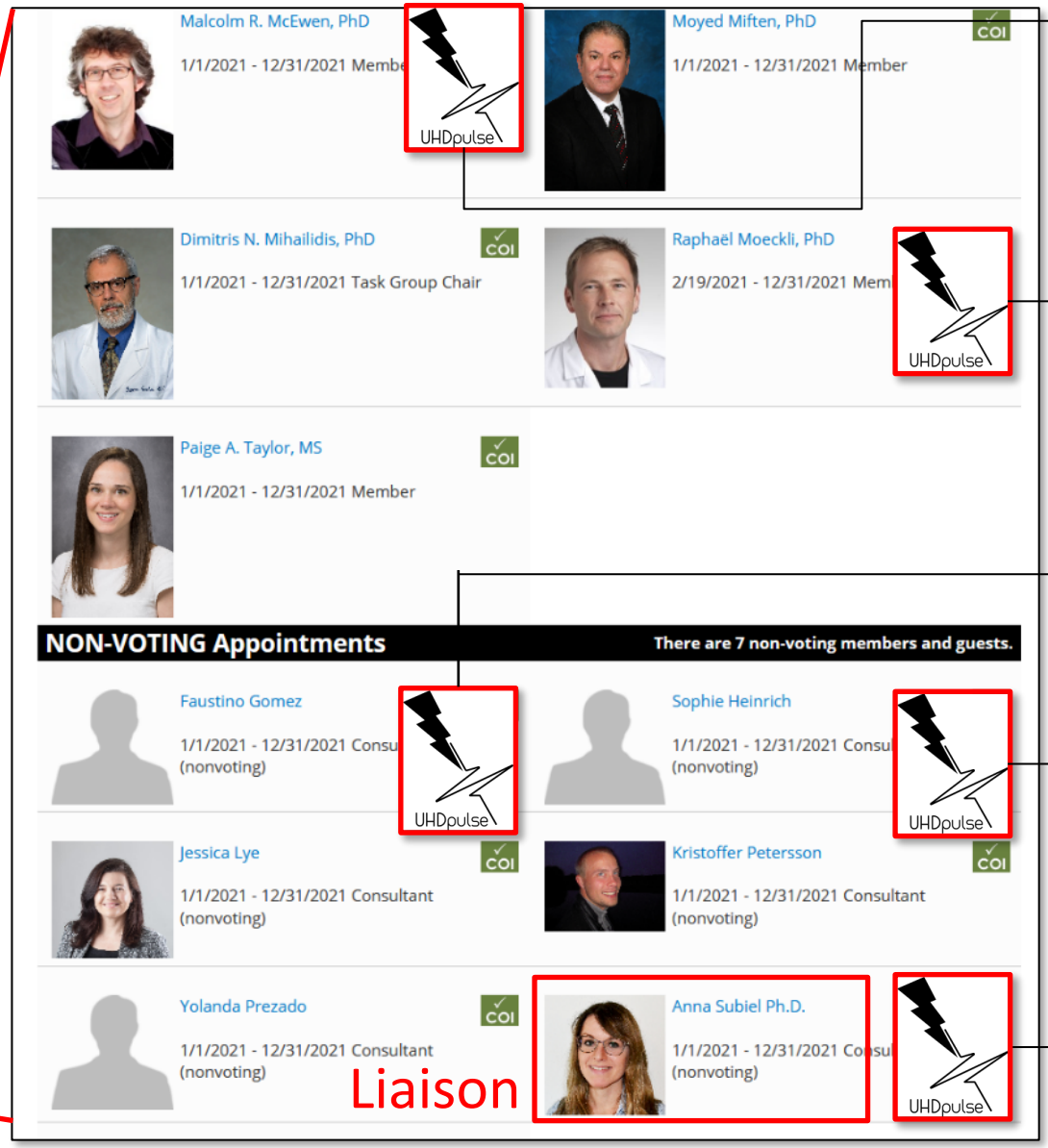
Objective 2:
to characterise the response of available **detector systems**

Objective 4:
provide the input data for **Codes of Practice**

https://www.aapm.org/org/structure/default.asp?committee_code=TG359

Highlights of 2021 – AAPM TG No. 359





https://www.aapm.org/org/structure/default.asp?committee_code=TG359

UHDpulse members:

- NRC-CNRC Canada
- CHUV Centre hospitalier universitaire vaudois
- USC Universidade de Santiago de Compostela
- institutCurie
- NPL National Physical Laboratory
- SIT
- iridium network Topzorg in radiotherapie
- PTW The Dosimetry Company
- iba Dosimetry Protect, Enhance and Save Lives

Highlights of 2021 - UHDpulse stakeholder workshop

https://frpt-conference.org/

Highlights of 2021 - UHDpulse stakeholder workshop

FRPT 2021
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VIRTUAL CONFERENCE
1-3 DECEMBER 2021
Earn up to 20 CME Credits

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Institut Curie, France
Organizer of the 1st FLASH Workshop

Karen Kirkby
University of Manchester and The Christie, UK
Coordinator of INSPIRE

Andreas Schüller
PTB, Germany
Coordinator of UHDpulse

Marie-Catherine Vozenin
CHUV, Switzerland
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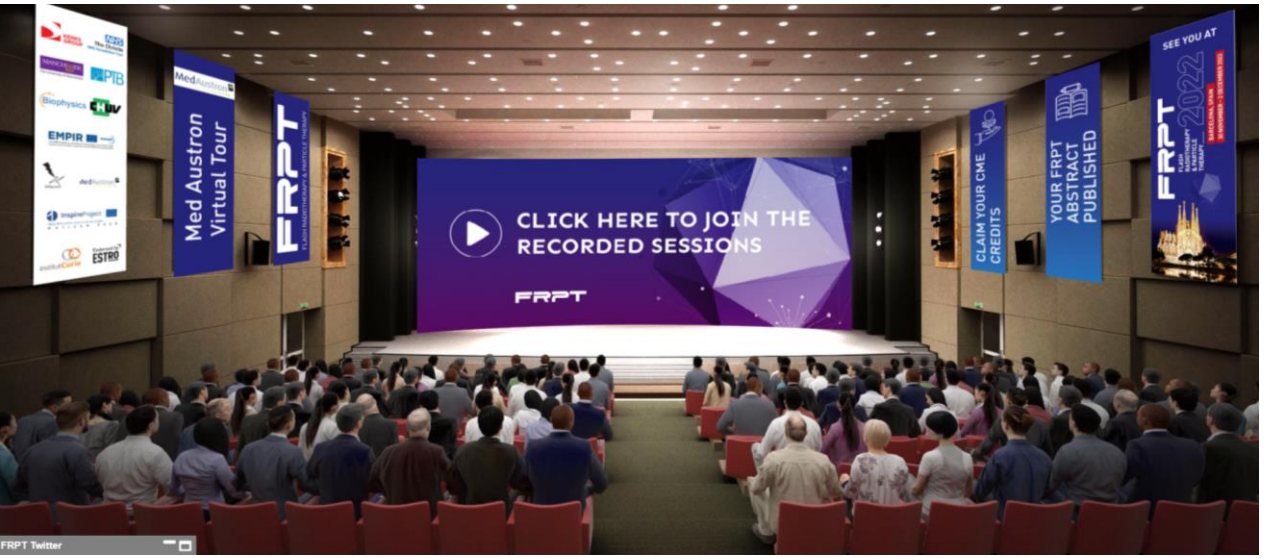
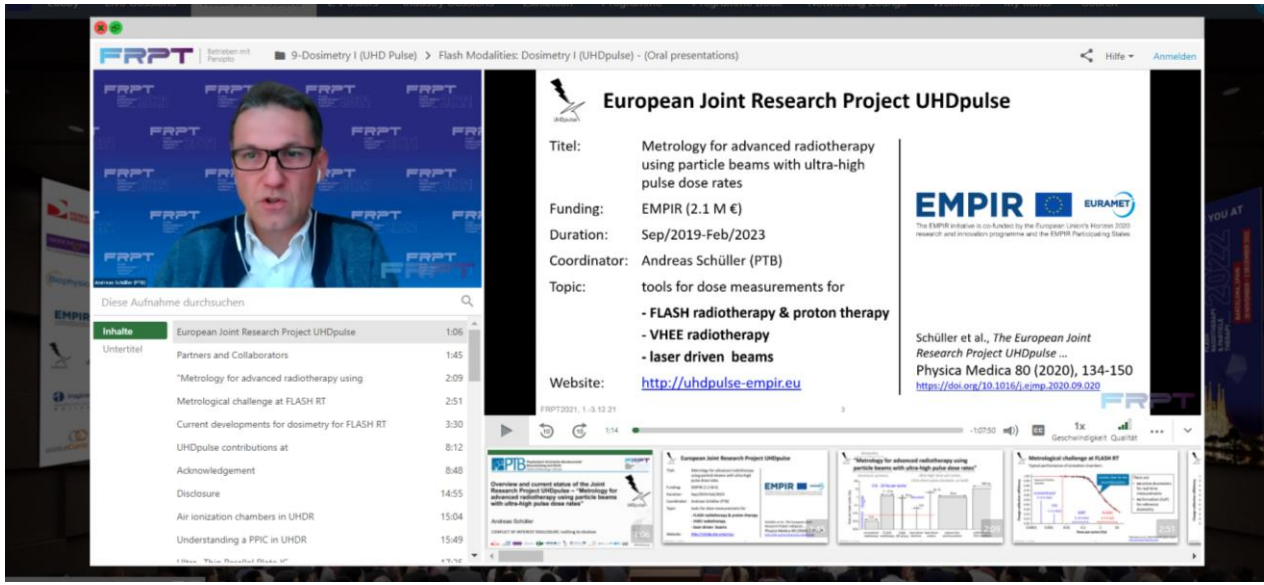
Highlights of 2021 - UHDpulse stakeholder workshop





Highlights of 2021 - UHDpulse stakeholder workshop

34 Contributions with abstract with UHDpulse Acknowledgement
(25 oral presentations, 9 poster, all UHDpulse Partners involved)
abstracts and invited full papers will be published in in "Physica Medica"

Highlights of 2021 - Impact

8 Peer-reviewed publications

53 Oral presentations

16 Poster

4 Other publications