Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

UHDpulse

Work Package 1

PTB Highlights

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Overview

SI-traceable primary standards for absorbed dose measurements, towards the development of a primary standard

- Development, optimisation and commissioning of reference radiation fields for electron beams with ultra-high dose per pulse

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- Development and testing of primary standards for absorbed dose in electron beams with ultra-high dose per pulse

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  - No Monte Carlo beam model

Optimisation of the exiting beam:

1- Characterize the electron beam in the vacuum beamline of the research linac.

Baseline to construct the Monte Carlo beam model

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2- Create an initial reference beam to validate the Monte Carlo beam model

By removing the scintillating window, able to reach a ~80 mm beam size (still Gaussian) with a dose rate between 1 Gy to 6 Gy per pulse.

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4- Using the Monte Carlo beam model, 6 different beam set-ups were created and measured.

Enabling dose rate range between 0.1 Gy to 15 Gy per pulse

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-> Publication in PMB journal in 2022

Reference UHPDR electron beams:

- Two beams were establish as reference;

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- A third beam setup, DPP up to 15 Gy (5 Hz, 2.5 µs)
  - Large number of relative measurements with diamond detector and TimePix3 (out-of-field)
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-> Pulse length can be modulated between about 1 µs to 3 µs

Development of primary standards for absorbed dose in electron beams

- Develop and test primary standards for absorbed dose in electron beams with ultra-high dose per pulse:

PTB's primary standard is the **water calorimeter**

Development of primary standards for absorbed dose in electron beams

$$D_{\mathrm{w}} = \Delta T \cdot c_w \cdot K_{HD} \cdot K_{HC} \cdot K_p \cdot K_{rp} \cdot K_{T,dept\,h} \cdot K_e,$$

Parameter		
ΔT	Radiation-induced temperature rise	Validated the measurement procedure
c_w	Specific heat capacity of water at 4 °C	4206.8(1.3) J kg−1 K−1
K_{HD}	Heat defect correction factor	Independent of the dose rate; 1.0000(14)
K_{HC}	Heat transfer correction factor	To be determined by FEM simulations
K_p	Field perturbation correction factor	MC simulations
K_{rp}	Radial beam profile correction factor	MC simulations
$K_{T,depth}$	Water temperature and depth correction factor	Calculation and MC simulations
K_e	Self-heating correction factor	Independent of the dose rate; measured

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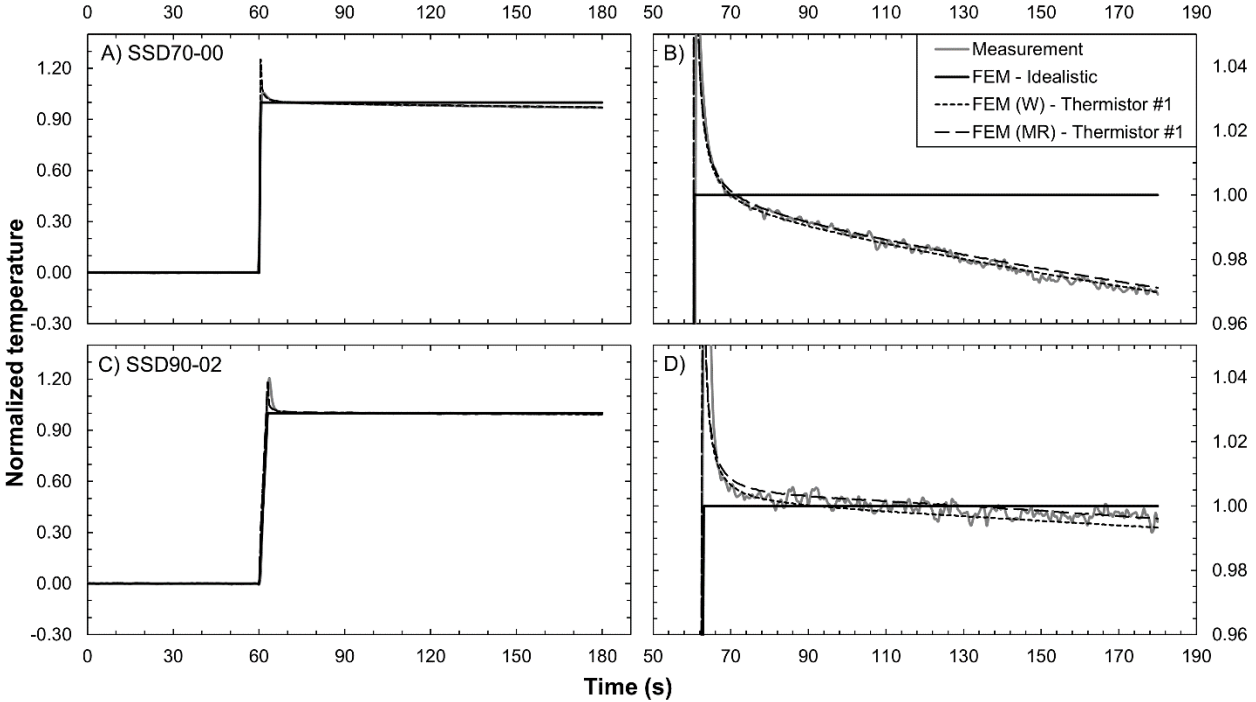
Development of primary standards for absorbed dose in electron beams

1- Perform thermal simulations and measurements to validate them along with the protocol



2- Calculate the correction factors required to perform absolute dosimetry in UHDR

Parameter	Conventional electron beam (20 MeV)		UHPDR electron beam (20 MeV)	
	Value	Uncertainty, k=1 [%]	Value	Uncertainty, k=1 [%]
ΔT [mK]	0.95	0.12	1.32 - 2.26	0.22
c_w [J·kg^{-1}·K^{-1}]	4206.8	0.03	4206.8	0.03
K_{HD}	1.0000	0.14	1.0000	0.14
K_{HC}	0.9965 – 1.0027	0.23	0.9965 - 1.0040	0.20
K_p	1.0005	0.15	0.9982	0.25
K_{rp}	1.0007	0.05	0.9982 – 1.0000	0.25
$K_{T,depth}$	0.9996 - 1.0004	0.02	1.0006 – 1.0011	0.05
K_e	1.0004	0.05	1.0000	0.05
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-> **Manuscript submitted to PMB journal in Dec. 2022**

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Validation of primary standards for absorbed dose in electron beams

3- Validate the absolute dose to water using the calorimeter by comparing with another primary standard

Water calorimeter

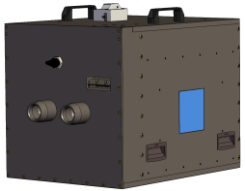
Validation of primary standards for absorbed dose in electron beams

3- Validate the absolute dose to water using the calorimeter by comparing with another primary standard (Fricke from METAS, Deliverable 3)

Water calorimeter

Fricke dosimeter

Validation of primary standards for absorbed dose in electron beams



PTB

Water calorimeter

Fricke dosimeter

METAS

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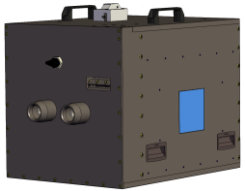


Fricke dosimeter

PTB

Big and heavy equipment
Requires new set of correction factors

METAS

Water calorimeter

Validation of primary standards for absorbed dose in electron beams

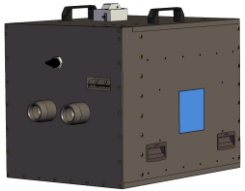
PTB

Water calorimeter

Fricke dosimeter

METAS

Validation of primary standards for absorbed dose in electron beams



Water calorimeter

Travel with unstable chemical
or
Travel with a portable lab

Fricke dosimeter

Validation of primary standards for absorbed dose in electron beams

Water calorimeter

Transfer dosimeter…

Easy to transport
Requires no additional expertise

Fricke dosimeter

Validation of primary standards for absorbed dose in electron beams

PTB

Water calorimeter

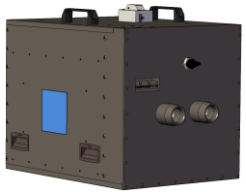
Alanine dosimeter!

Fricke dosimeter

METAS

Validation of primary standards for absorbed dose in electron beams

PTB



METAS

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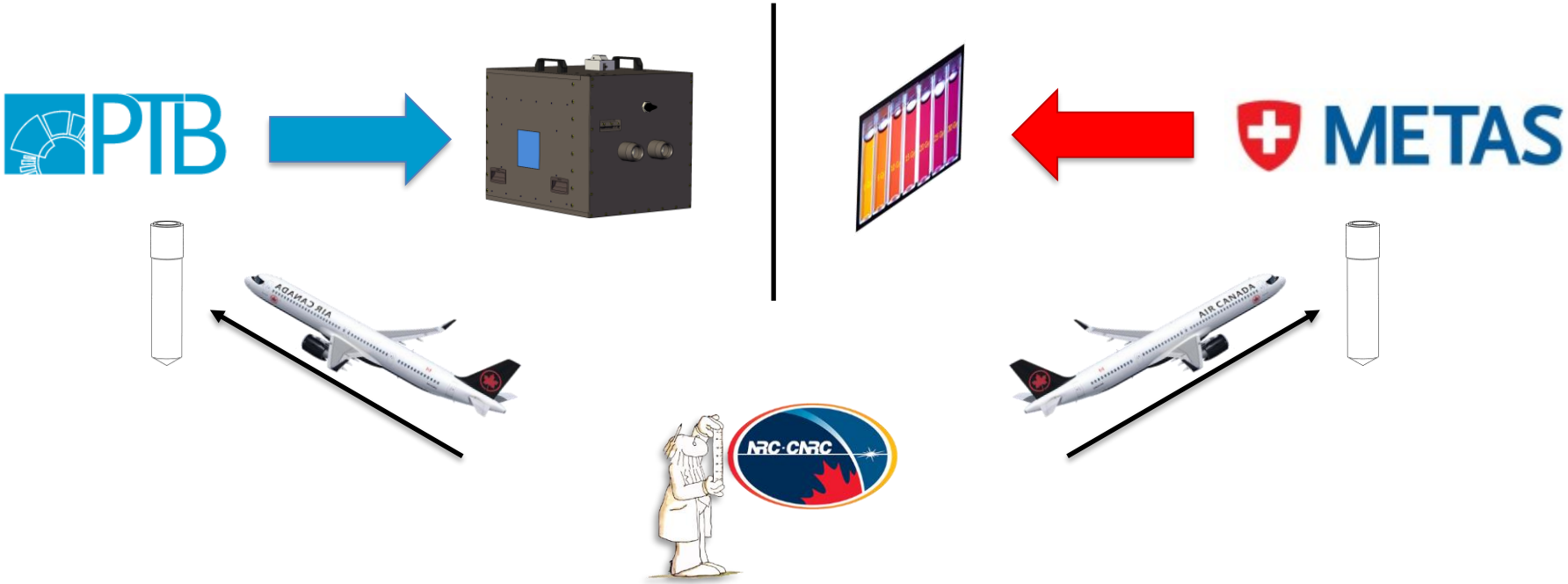

Sealed alanine dosimeters (mailed)

Results

$$D_{\mathrm{METAS/PTB}} = 1.002 \pm 0.012$$

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$D_{METAS/PTB} = 1.002 \pm 0.012$

$D_{PTB/NRC} = 0.9997 \pm 0.0080$

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- The PTB's water calorimeter has been establish successfully with an uncertainty budget under initial expectation.
- PTB's and METAS's primary standard are consistent within stated uncertainty (1.002 ± 0.012).

Overview

All this with an average delay of just 6 months!

…much better than the Berlin airport construction delays

http://uhdpulse-empir.eu/

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EMPIR EURAMET

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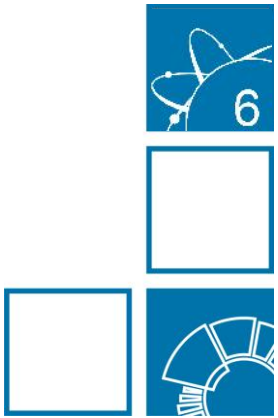

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Merci
Thank you
Dankeschön