Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

UHDpulse

Performance of a probe-type graphite calorimeter (Aerrow) in ultra-high dose per pulse electron beams

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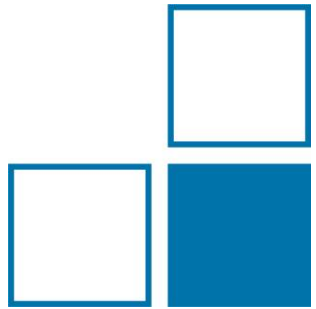


Faculty Disclosure

No, nothing to disclose

Dosimetry of FLASH beams

- Standard dosimeter for external beam reference dosimetry is the ionization chamber
  - The ultra-high dose rate means that ion recombination is very large > 80% !
- Integrating dosimeters
  - Alanine or radiochromic film have been shown to work
  - BUT not real-time (readout after 24 hours)
- … may be calorimeter

Detectors

- A probe-type graphite calorimeter

J. Renaud, Med Phys 2018, DOI: 10.1002/mp.12669

  - Developed at McGill University
  - Provided by Sun Nuclear Corporation
  - Designed for clinical measurement
  - Quasi-adiabatic mode

- Reading system
  - Temperature sensor (thermistor) directly read by high-stability DMM Agilent

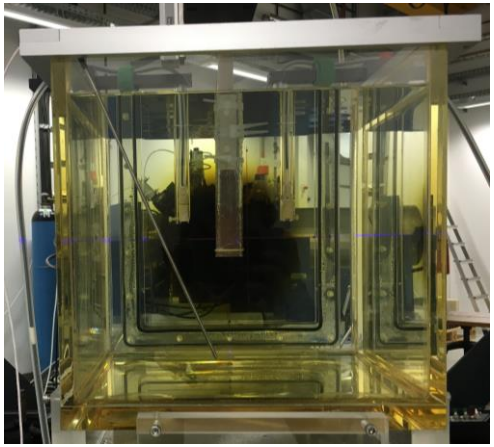
Measurement set-up

- Metrological Electron Accelerator Facility (MELAF) at PTB, Germany

- Tests carried out at 20 MeV, 5 Hz PRF, pulse width of 2.5 µs
- Dose varied between 0.6 Gy and 5.6 Gy per pulse
- Detector response compared to beam current monitor

Measurements

- Absolute dose to water measurement
  - Absolute dose measurement for a range of dose per pulse
  - Compared to a calibrated Advanced Markus (k_{sat} measured at the PTB)
  - For 4 fixed dose per pulse, tested different number of pulses delivered



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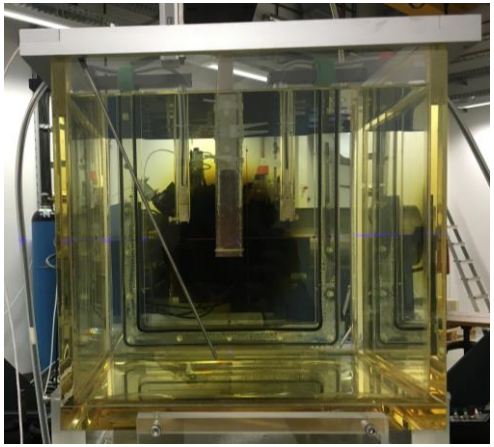
- Depth dose curve measurement
  - Maximum dose rate
  - Irradiation time of 2 s (10 pulses delivered)
  - Compared to Advanced Markus and diamond detector prototype



Dose equation

Dose to water

$$D_w = c_{gr} \cdot \Delta T \cdot K_{\mathrm{ht}} \cdot \left(\frac{D_{\mathrm{w}}}{D_{\mathrm{gr}}} \right)_{MC}$$

Dose equation

Dose to water

Specific heat capacity of graphite

Consensus value

$$D_w = c_{gr} \cdot \Delta T \cdot K_{\mathrm{ht}} \cdot \left(\frac{D_{\mathrm{w}}}{D_{\mathrm{gr}}} \right)_{MC}$$

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Temperature change
Measurement

Dose equation

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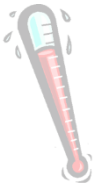
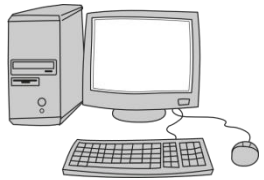


Temperature change
Measurement

Heat loss correction
Thermal Simulation

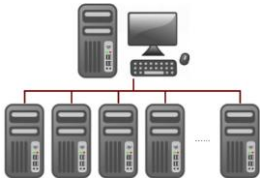


Dose equation

Dose to water

Specific heat capacity of graphite
Consensus value

Dose conversion factor
Monte Carlo



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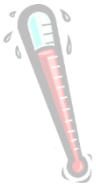

Temperature change
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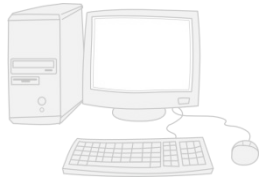
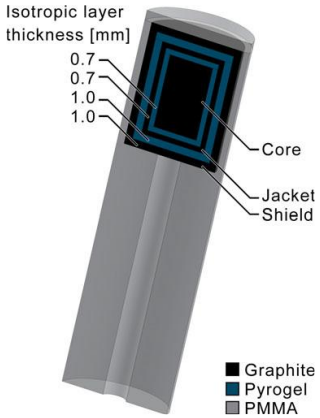
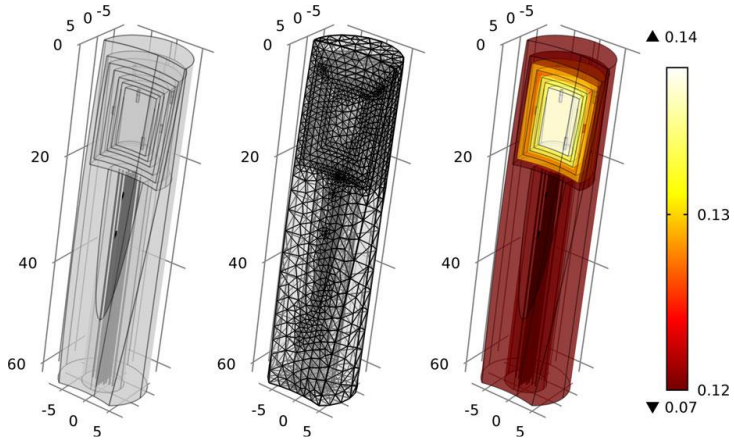


Detectors



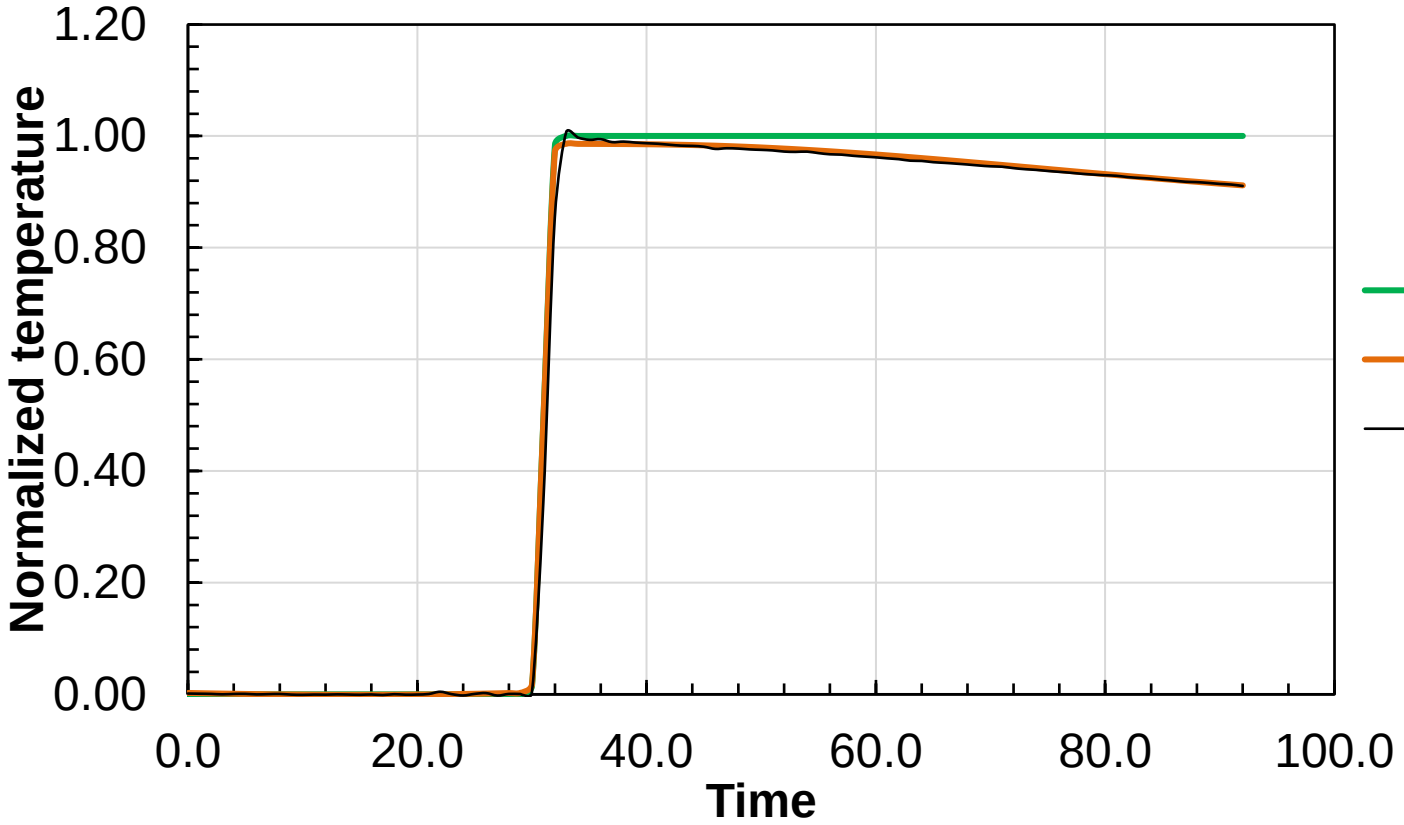
- Monte Carlo simulation
  - EGSnrc
  - Dose ratio conversion factor
  - Energy mapping for thermal simulation

- Thermal simulation
  - FEM simulation (COMSOL)
  - To calculate k_{ht}



Figures from: J. Renaud, Med Phys 2018, DOI: 10.1002/mp.12669

Thermal simulation



At z_{ref}

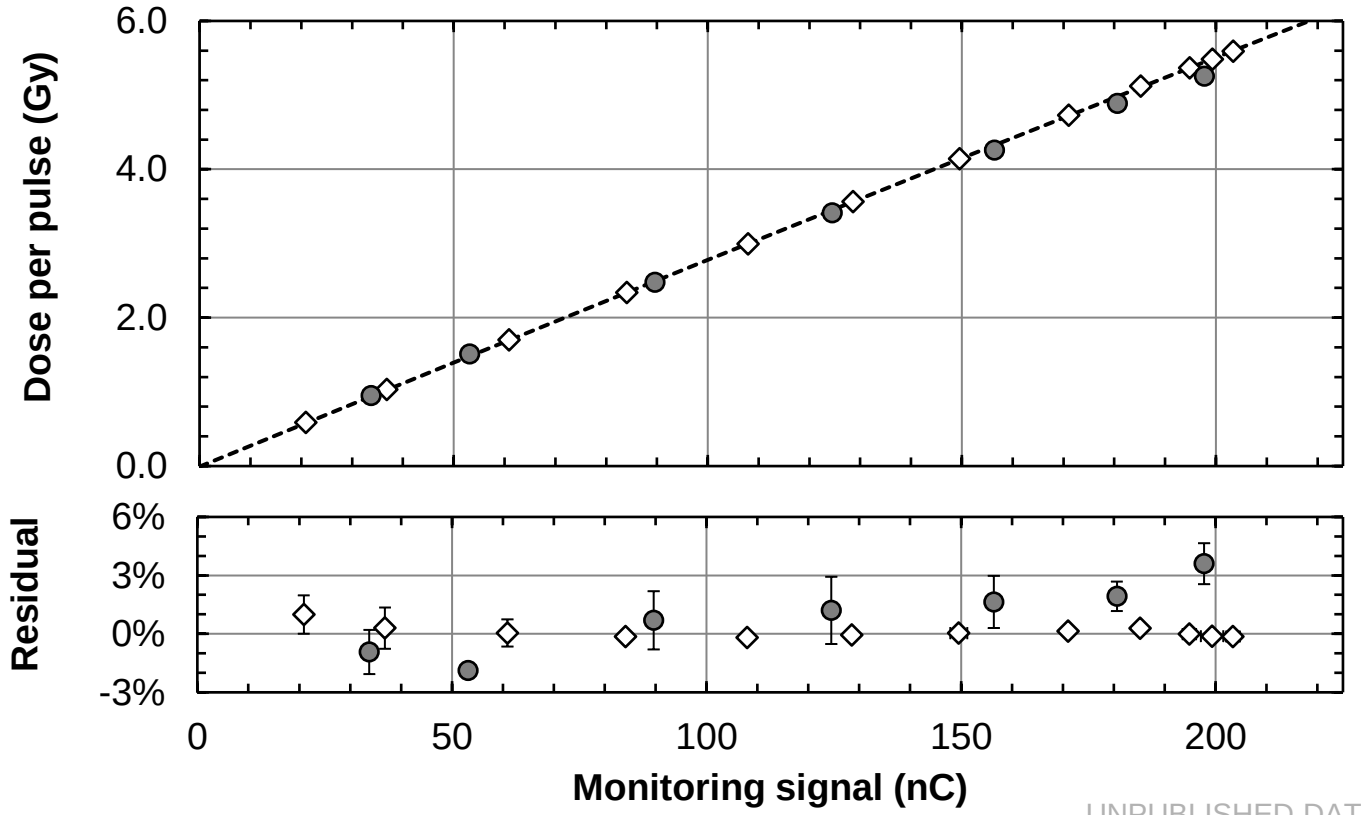
K_{ht}= 0.9920(8)

Simulation (no heat loss)

Simulation (with heat loss)

Measurement

Results: variation dose per pulse



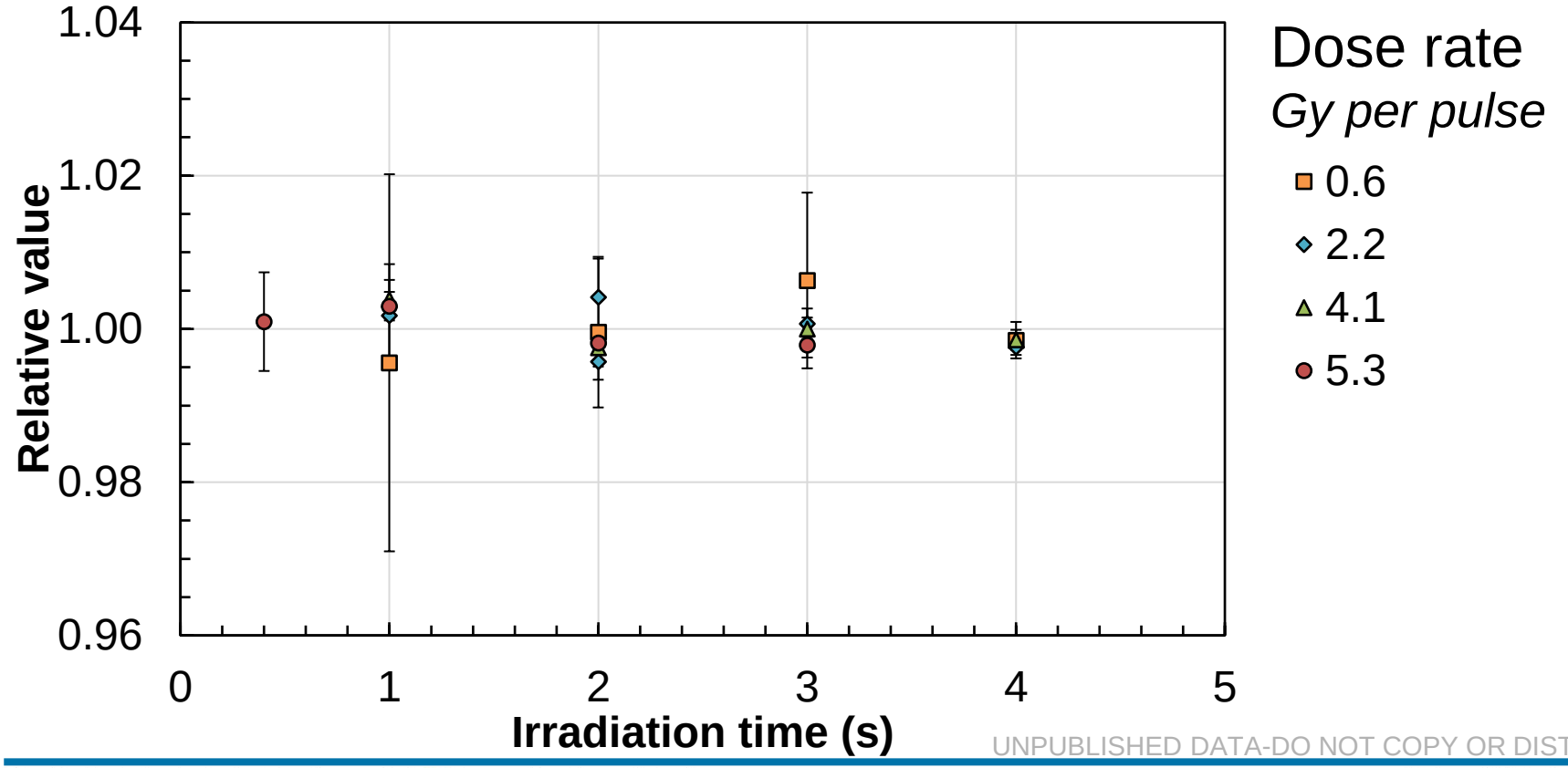
$(D_{w/gr})_{MC}$ = 1.149(1)

Fit

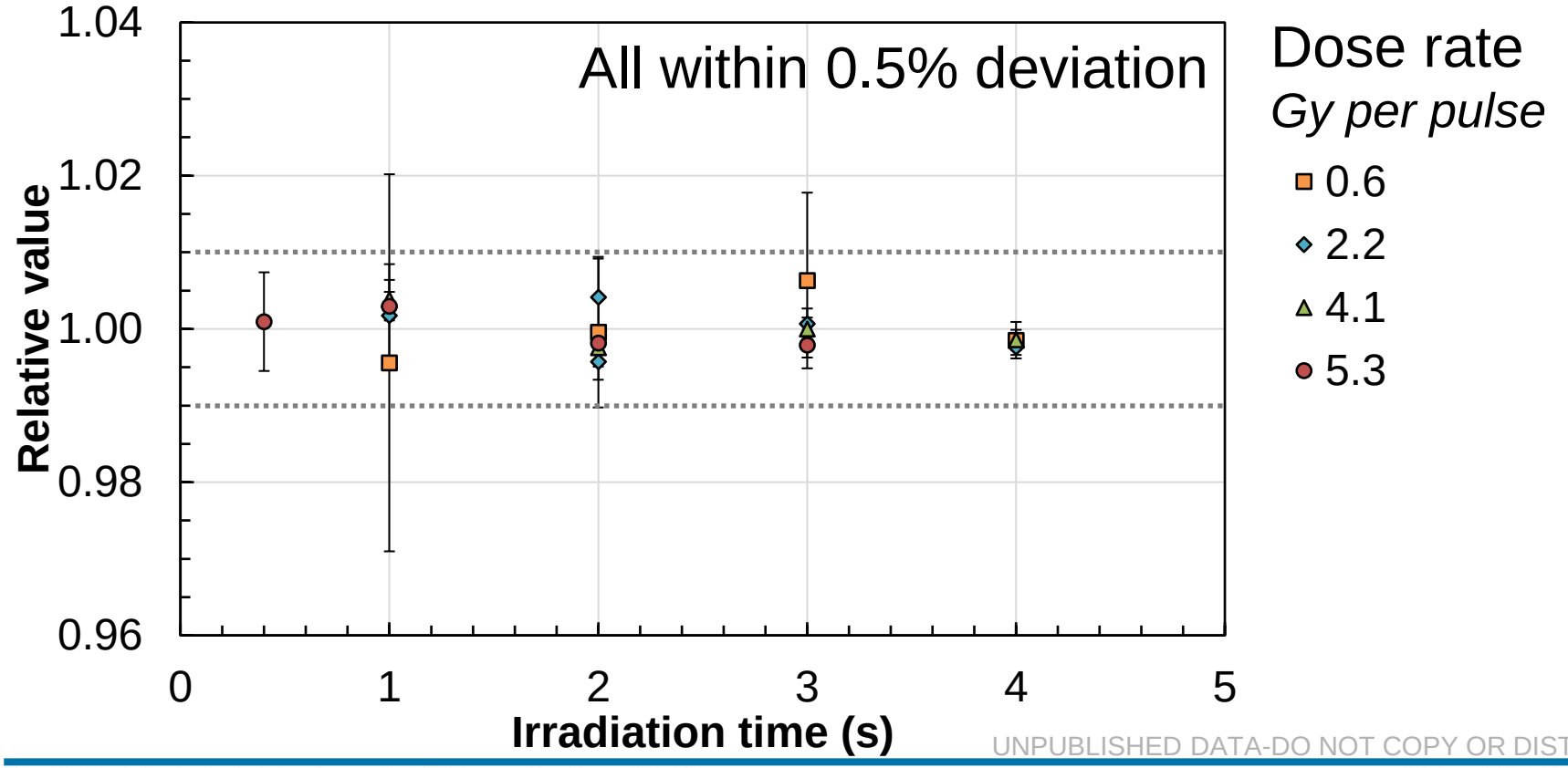
Aerrow

Advanced Markus

Results: variation number of pulses



Results: variation number of pulses



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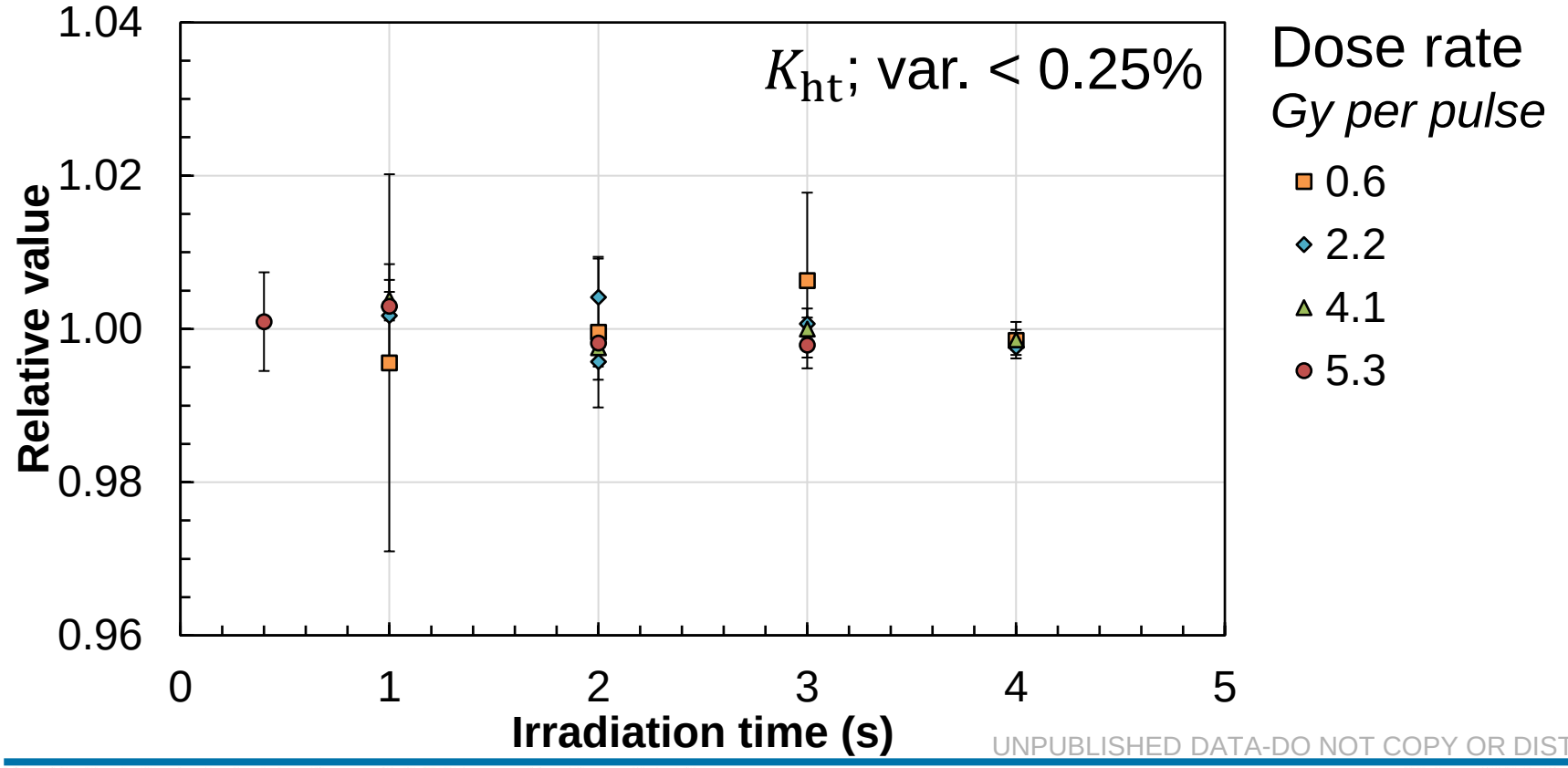
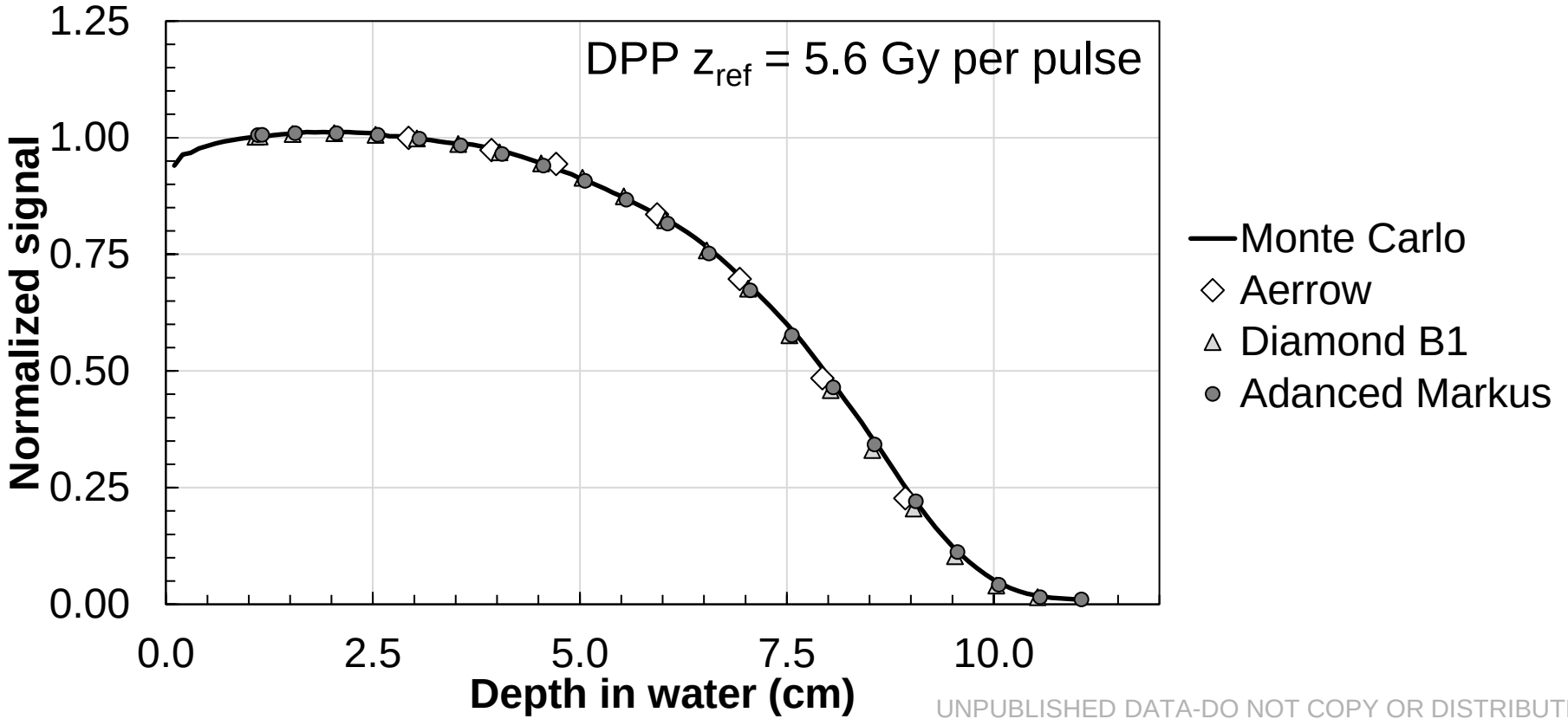


Results: depth dose curve



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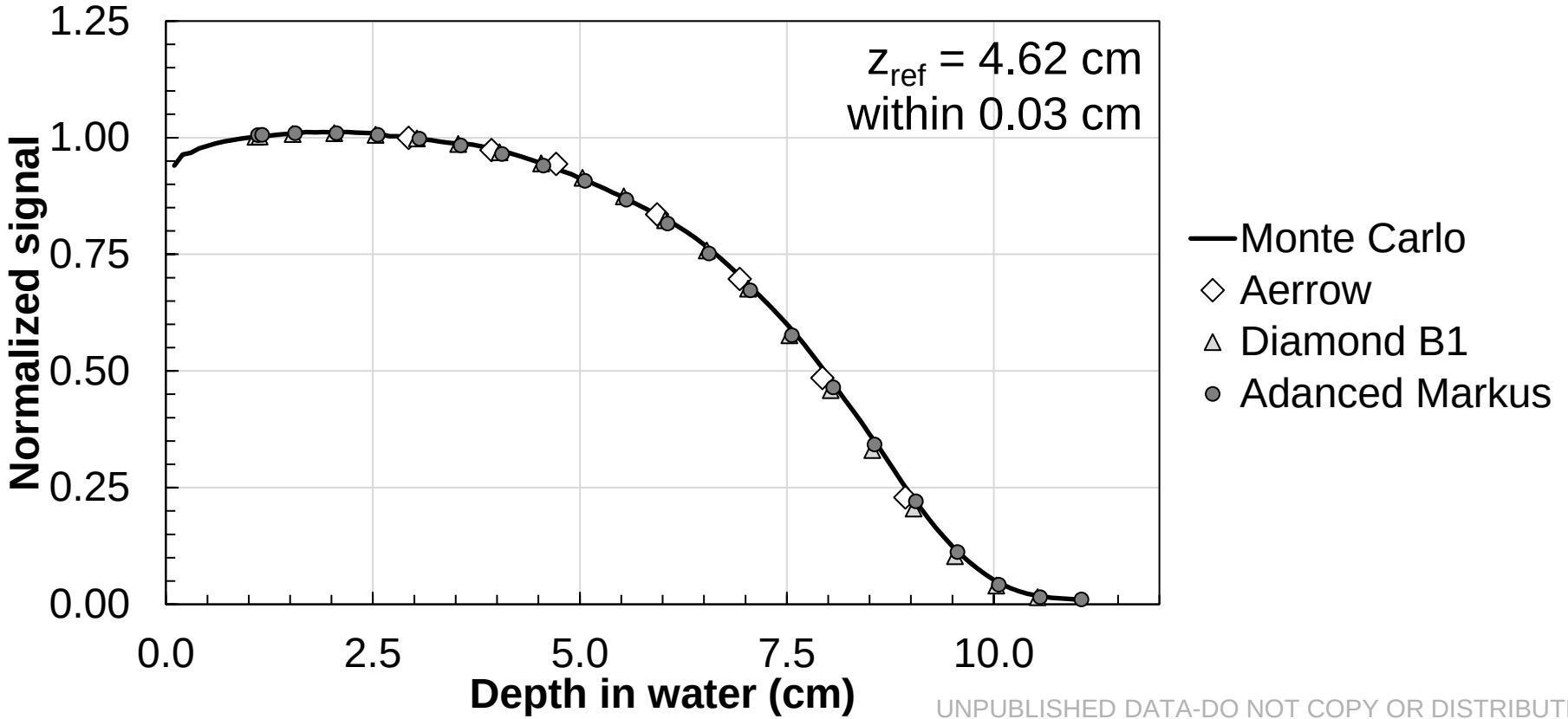

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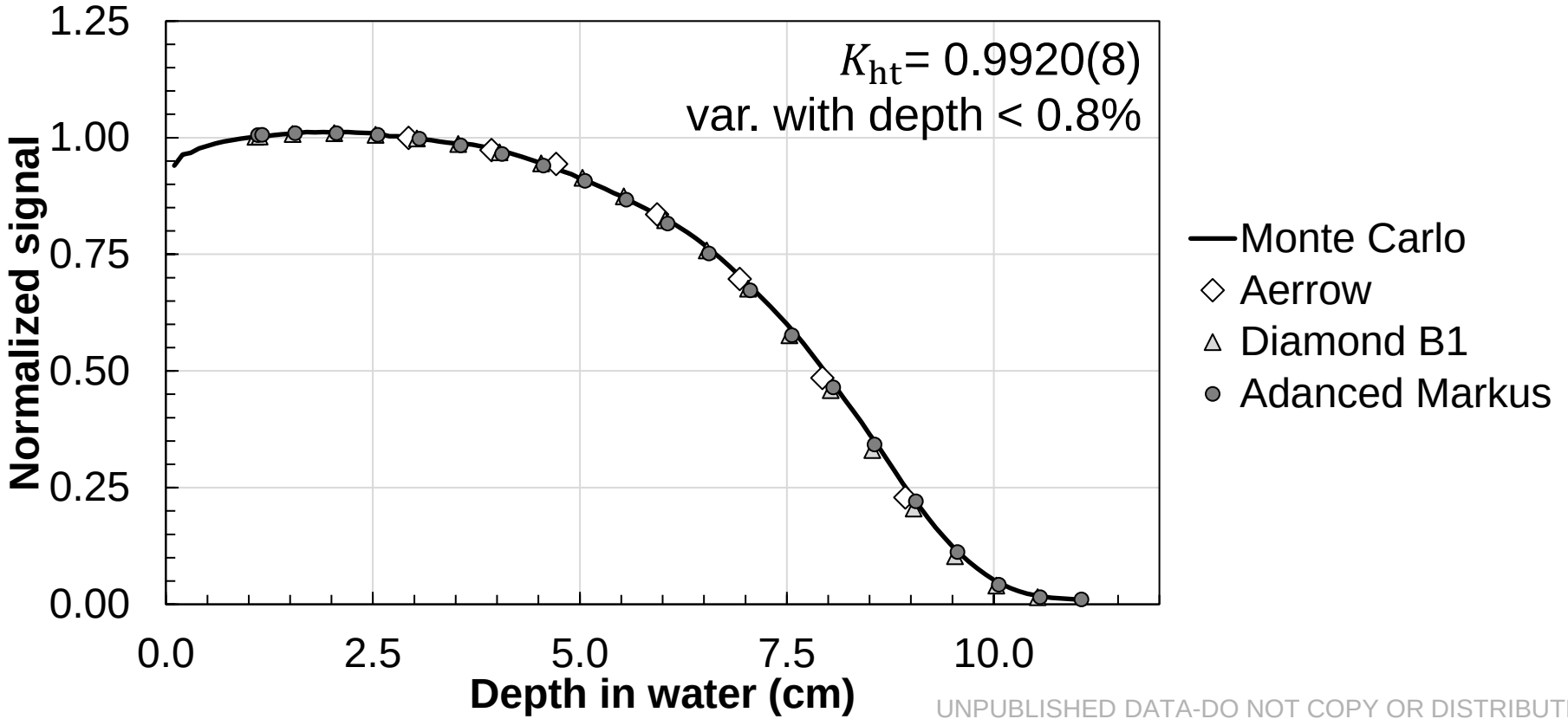

Conclusion

- Absolute dosimetry
  - Calorimeter is showing promising results for NMI and clinical dosimetric use
  - Heat lost correction factor about 0.8% (correction factor k_{sat} for ICs about 20-80%)

- For relative measurement
  - Correction factor not required (in contrast to ICs where a correction function is needed)
  - Real time measurement would be possible with specific software

Acknowledgments

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EMPIR EURAMET

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http://uhdpulse-empir.eu/

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Merci
Thank you
Dankeschön