The challenge of high dose rates for ionisation chambers

Dr. Daniela Poppinga

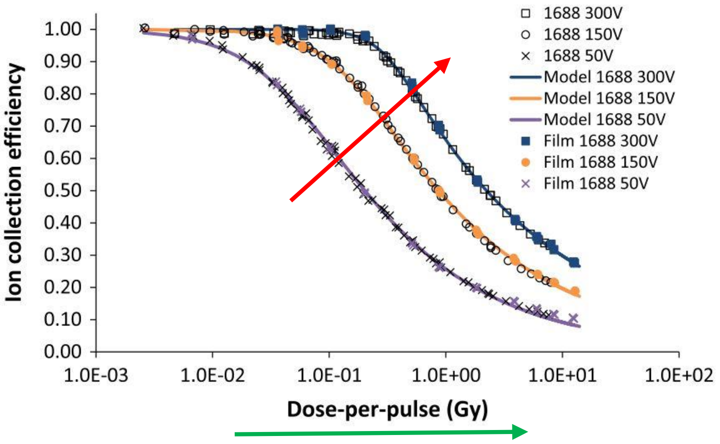
Motivation

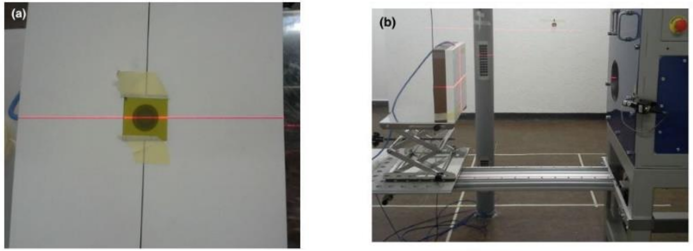
Ionization chamber dosimetry at UHDR beams

- Ionization chamber dosimetry based on air-filled ionization chambers is the gold standard in clinical conditions in radiation therapy
- In this field the dosimetry with ionization chambers is very well understood and the ionization chambers are available worldwide and easy to use
- The FLASH effect has been discovered and it is now attractive to use VHEE with UHDR beams in clinical practice.

- **Question for this talk:** Can ionization chamber dosimetry also be used under VHEE conditions? Active monitoring of dosimetry would be essential for the clinical use of VHEE beams.

- Main problem: Recombination losses in ionization chambers at very high dose rates
    - *Peterrson et al* studied ion collection efficiency with simultaneous film and chamber measurements
        - Voltage dependent
        - Dose per pulse dependent



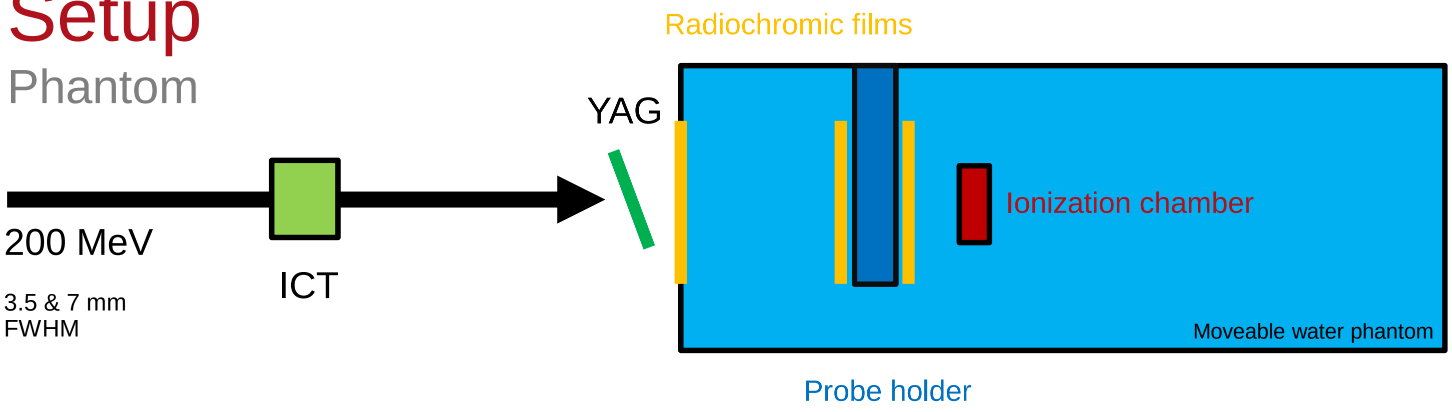


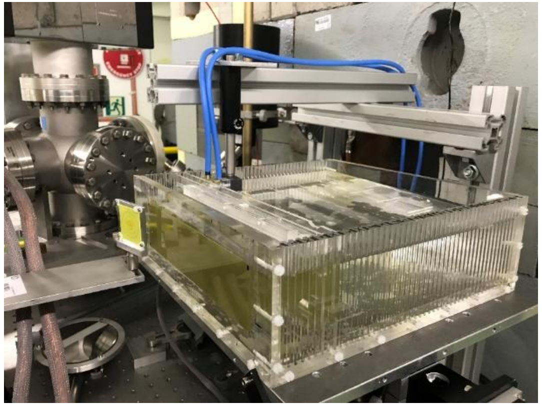
Petersson K, Jaccard M, Germond J-F, Buchillier T, Bochud F, Bourhis J, Vozenin M-C and Bailat C 2017 High dose-per-pulse electron beam dosimetry - A model to correct for the ion recombination in the Advanced Markus ionization chamber Med. Phys. 44 1157–67

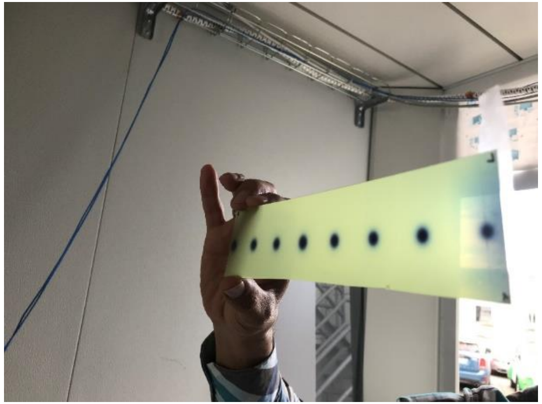
THE DOSIMETRY COMPANY

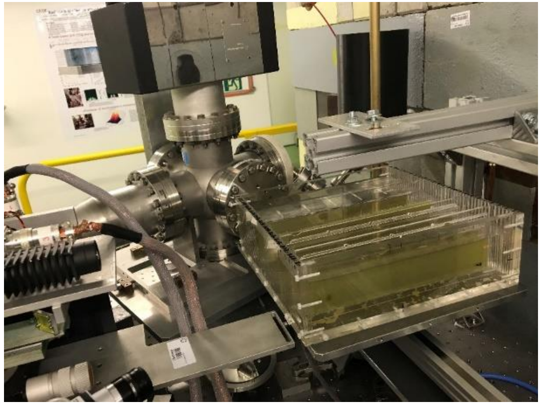
Setup

Phantom





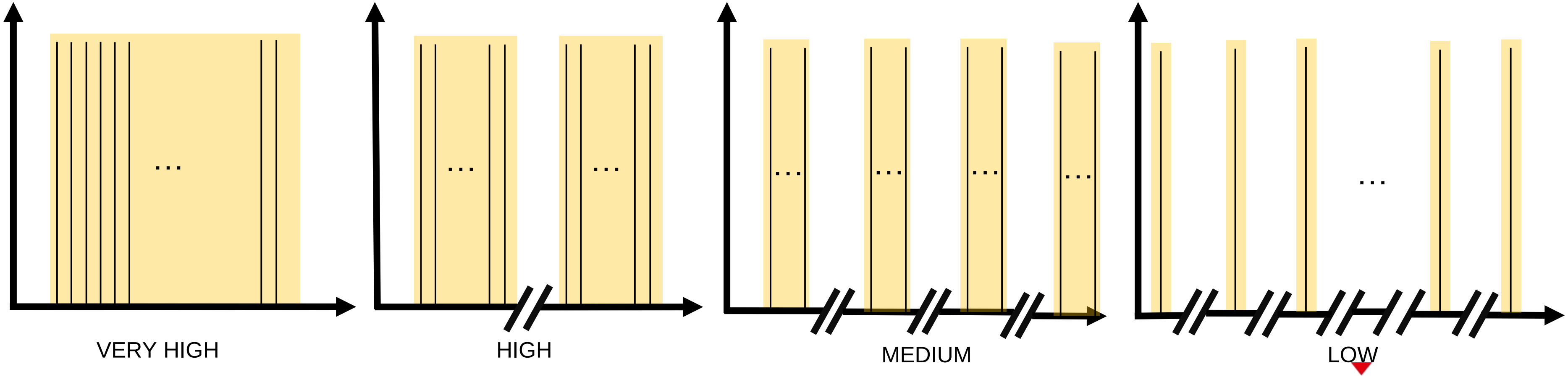




Setup

Beam structures

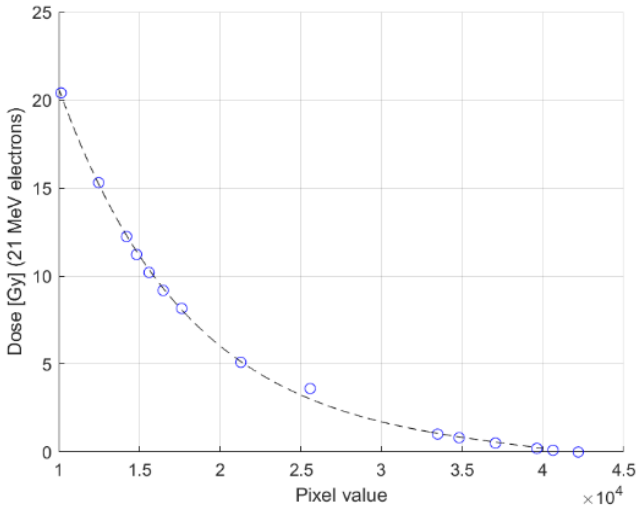
	VERY HIGH	HIGH	MEDIUM	LOW
Number of trains	1	2	4	36 - 80
Time length of one train	66 ns	33 ns	16 ns	~ 1 fs
Time between two trains	1.2 s			
Number of bunches per train	100	50	25	1-2
Time between two bunches	666 ps (1.5 GHz)			

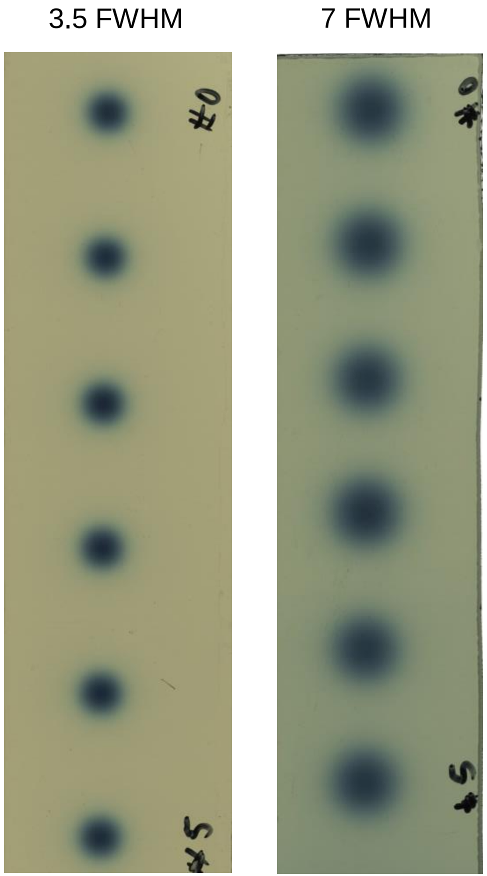


Measurement

Film calibration

- Film analysis: Epson 10000 XL scanner, 16 bit per color channel, no auto corrections, single channel analysis
- Film calibration with 21 MeV electron beam

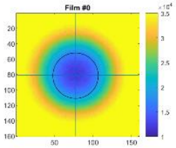


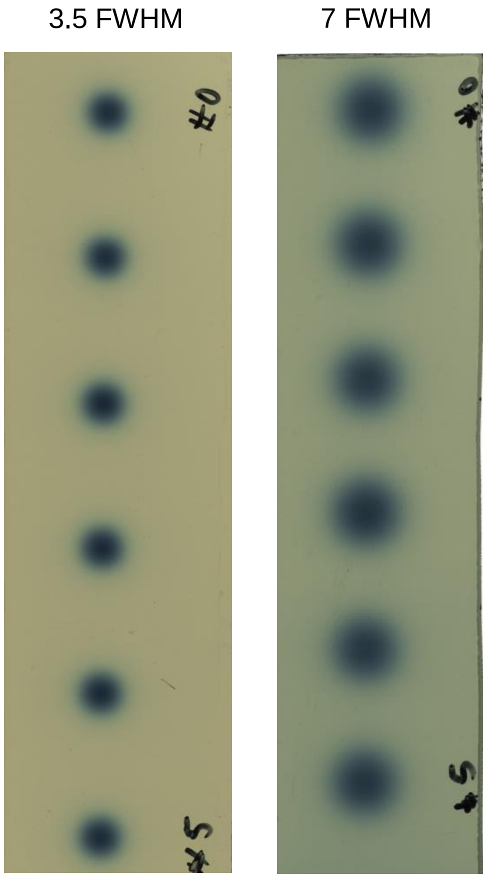


Measurement

Film measurement

- Dose value was determined by averaging according to chamber diameter





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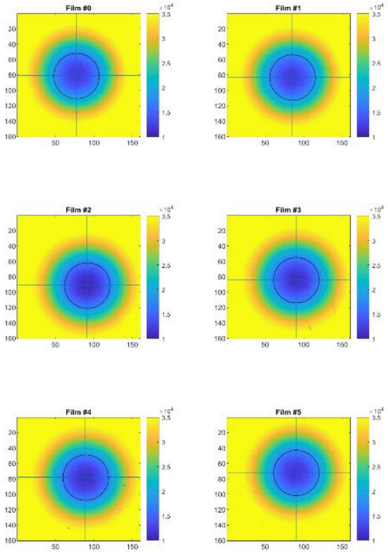
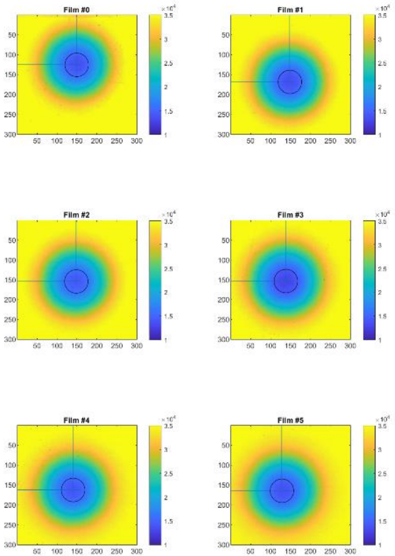
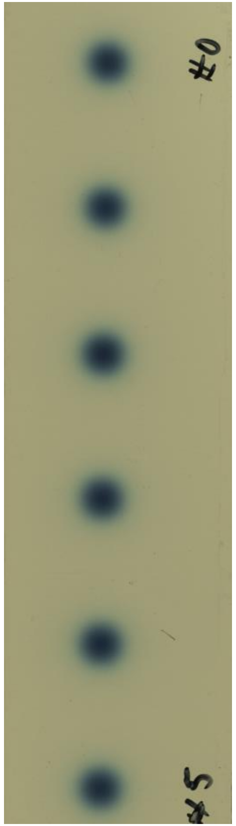


3.5 FWHM

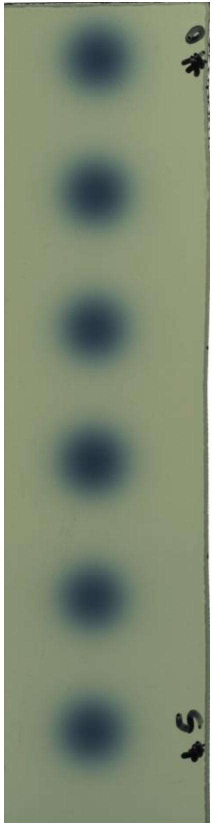


7 FWHM

3.5 FWHM



7 FWHM



Measurement

Chamber measurement

- Dose measurement with ionization chamber according to international protocols (AAPM TG 51 / TRS 398 / DIN 6800-2)

Calibration factor for Co60 [Gy / C]

Recombination losses correction

Energy correction

$$Dose\ to\ water = M \cdot N \cdot k_{TP} \cdot k_E \cdot k_P \cdot k_S$$

Chamber signal [C]

polarity correction

Temperature pressure correction

Measurement

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$$k_E = \frac{\left(s_{w,a}^{\Delta}\right)_{200\ MeV,7.2cm} \cdot p_{200\ MeV,7.2\ cm}}{\left(s_{w,a}^{\Delta}\right)_{Co60,5\ cm} \cdot p_{Co60,5\ cm}}$$

Monte Carlo simulation (University of Oldenburg)

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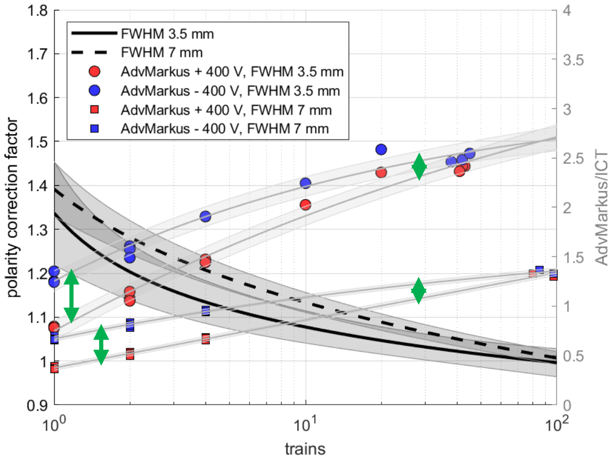

Experimentally determined at different number of trains

Measurement

Chamber measurement

- Dose measurement with ionization chamber according to international protocols (AAPM TG 51 / TRS 398 / DIN 6800-2)

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Temperature pressure correction

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Comparison to film measurement

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Results

Chamber saturation at very high dose rates

- Dose measurement with ionization chamber according to international protocols (AAPM TG 51 / TRS 398 / DIN 6800-2)

Calibration factor for Co60 [Gy / C]

Energy correction

Recombination losses correction

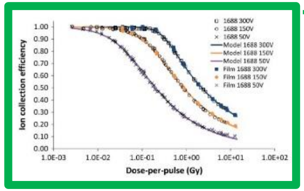
$$\mathit{Dose\ to\ water} = M \cdot N \cdot k_{TP} \cdot k_E \cdot k_P \cdot k_S$$

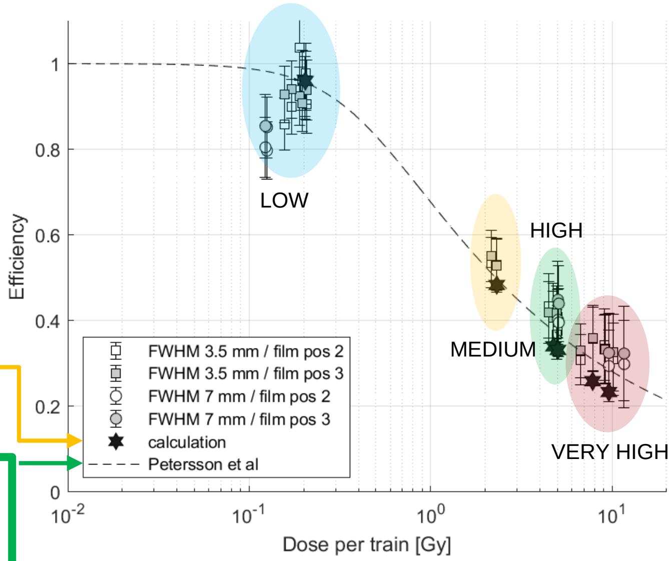
Chamber signal [C]

Temperature pressure correction

polarity correction

Based on Gotz et al



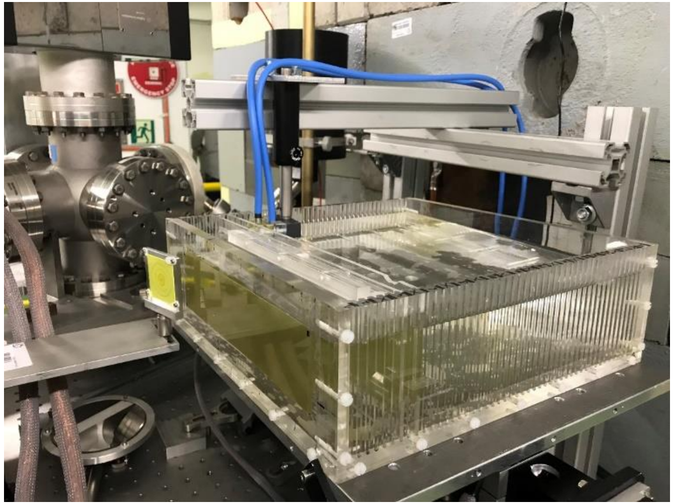


Gotz M, Karsch L and Pawelke J 2017 A new model for volume recombination in plane-parallel chambers in pulsed fields of high dose-per-pulse Phys. Med. Biol. 62 8634–54 Online: https://doi.org/10.1088/1361-6560/aa8985

Results

In summary

- Ion collection efficiency of an ionization chamber was determined by comparison to film measurement
- Ion collection efficiency was studied at CLEAR facility under different dose per train conditions and two beam sizes
- Results comparable to theoretical calculations and previous study by Petersson et al
- The work has shown that dosimetry via vented ionization chambers is possible at the CLEAR facility. *This allows an active and directly read-out monitoring of the dosimetry during experiments.*



Acknowledgement

Thank you

Rafael Kranzer

Roberto Corsini
Wilfrid Farabolini
Antonio Gilardi
Vanessa Wyrwoll

Björn Poppe
Hui Khee Looe
Björn Delfs
Lukas Garbisch

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

This project 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.

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