FRPT
FLASH RADIOTHERAPY & PARTICLE THERAPY 2021

ULTRA THIN PLANE-PARALLEL IONIZATION CHAMBERS: EXPANDING THE RANGE OF AIR IONIZATION CHAMBERS INTO ULTRA-HIGH DOSE RATE

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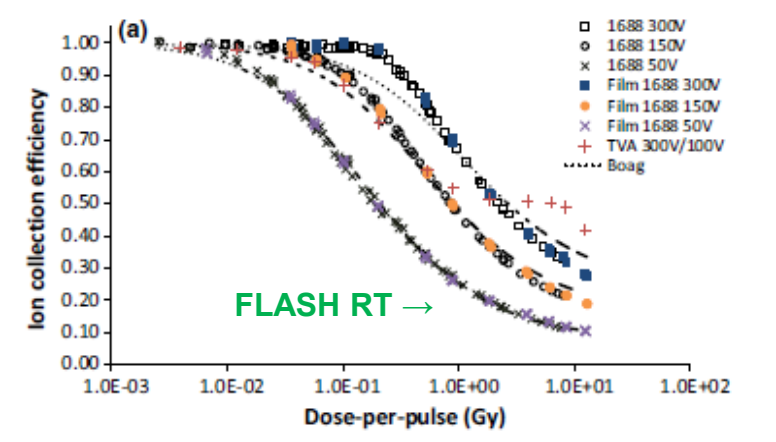
Disclosure

- Rafael Kranzer is a PTW employee.
- Giuseppe Felici is a SIT employee and shareholder.
- This project (18HLT04) has received funding from the EMPIR program cofinanced by the Participating States and from the European Union's Horizon 2020 research and innovation program.

Air ionization chambers in UHDR

← Conventional RT



FLASH RT →

- Commercial chambers exhibit very large recombination effects.
- Boag-like analytical expressions for recombination do not agree with data.
- Option to use phenomenological models (i.e. logistic).

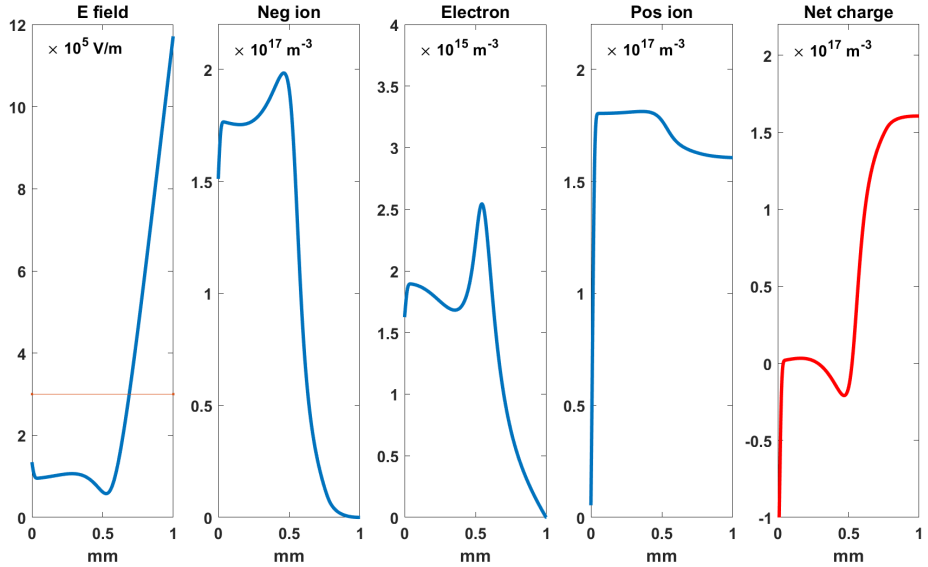
$$k_s \approx \left(1 + \left(\frac{DPP[\mathrm{mGy}]}{U[\mathrm{V}]}\right)^{\alpha}\right)^{\beta}$$

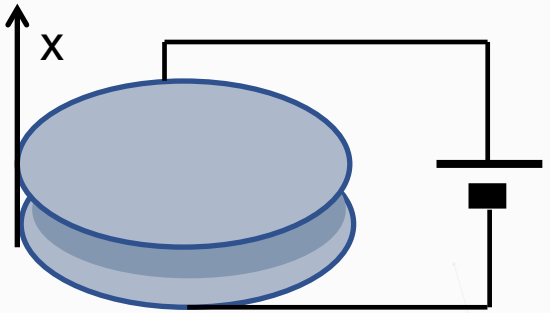
K. Pertersson et al. Med Phys; 44(3):1157-1167 (2017)
McManus, M., Romano, F., Lee, N.D. *et al. Sci Rep* **10,** 9089 (2020)
Rafael Kranzer et al. Med Phys; 48(2): 819-830 (2020)

More details: **"ION COLLECTION EFFICIENCY IN ULTRA-HIGH DOSE PER PULSE ELECTRON BEAMS"** Alexandra Bourgouin Session "Dosimetry I UHDpulse", Wednesday 15:40.

Understanding a PPIC in UHDR

2.5 µs





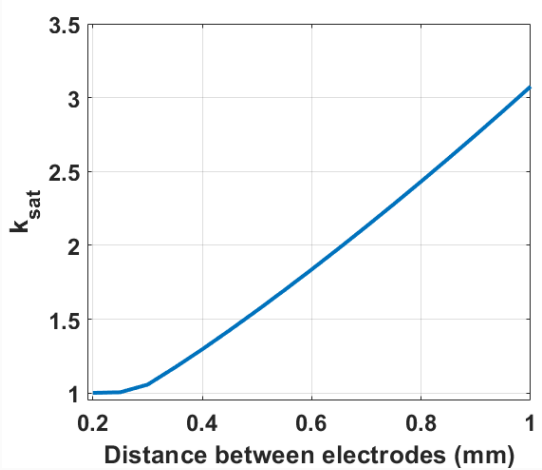
Advanced Markus (1 mm electrode distance) 300 V, 1 Gy pulse duration 2.5 µs

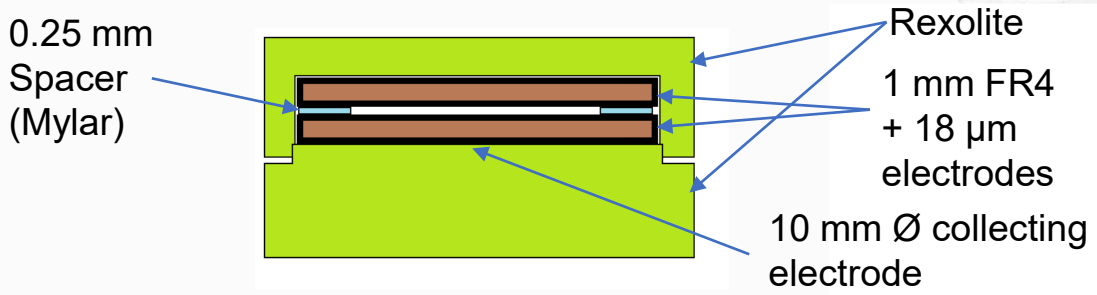
Numerical model similar to the approach of M. Gotz *et al* 2017 *Phys. Med. Biol.* **62** 8634

More details: "**SECONDARY STANDARD DOSIMETRY: UNDERSTANDING THE IONIZATION CHAMBERS FOR THE FUTURE ULTRA-HIGH DOSE RATE APPLICATIONS"** Jose Paz Martín
Session "QA and Dosimetry II", Thursday 11:30.

Ultra-Thin Parallel Plate IC

Prediction from simulation for a plane parallel air ionization chamber operated at 300 V for 5 Gy dose per pulse (DPP) with 1 µs duration (*).



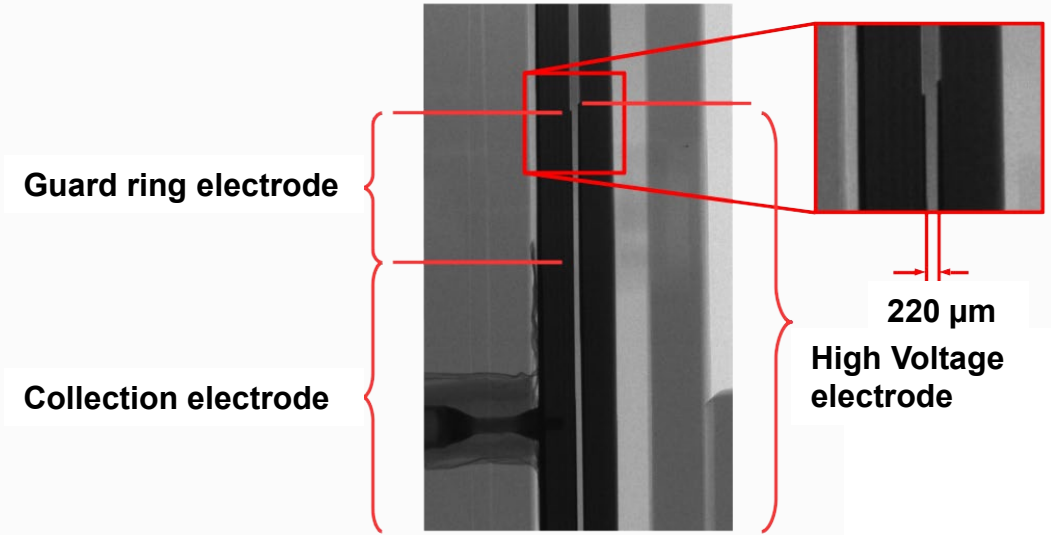


(*) Andreas Schüller et al. “The European Joint Research Project UHDpulse – Metrology for advanced radiotherapy using particle beams with ultra-high pulse dose rates Physica Medica” Vol 80, P134-150, December 01, 2020

Ultra-Thin Parallel Plate IC

Actual distance was verified after assembly with MicroCT (Bruker Skyscan 1272).

Prototypes	Electrode distance (mm)
UTIC01	0.27
UTIC02	0.22

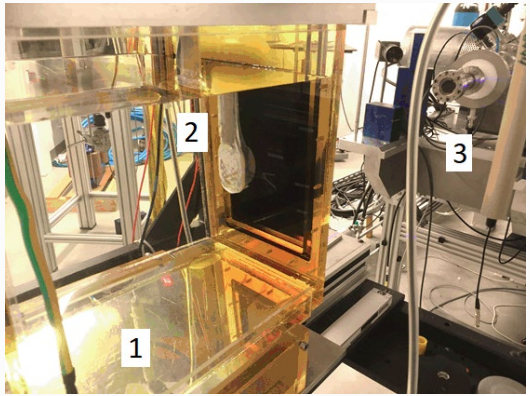


New chambers : "**VENTED IONIZATION CHAMBERS FOR ULTRA-HIGH DOSE PER PULSE CONDITIONS"** Rafael D. Kranzer, Session "Dosimetry II (UHDpulse)", Friday 14:50.

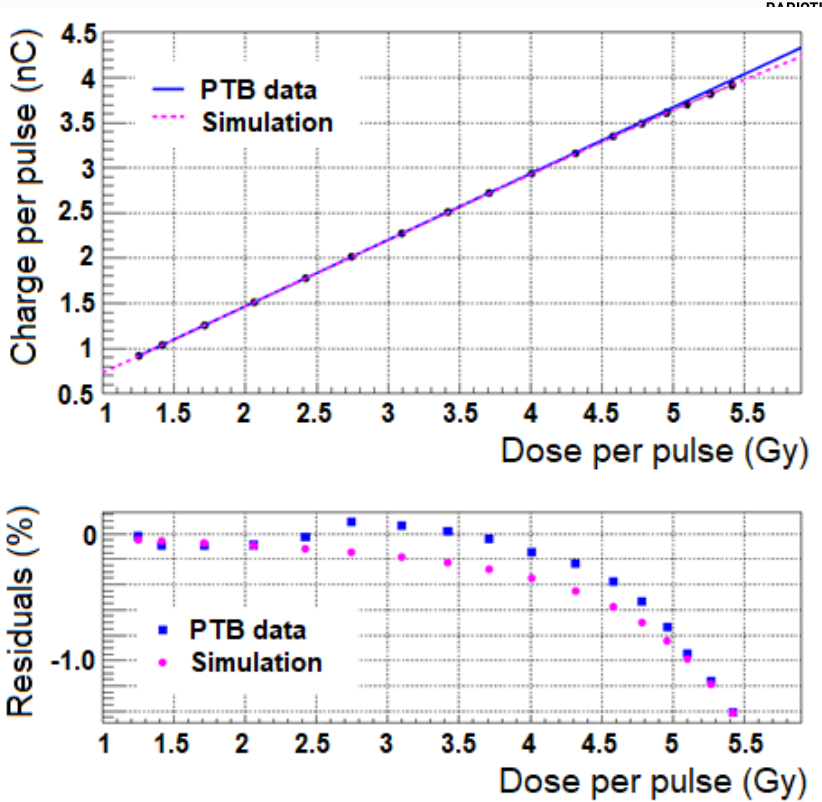
F. Gomez et al. "Development Of An Ultra-Thin Parallel Plate Ionization Chamber for Dosimetry in FLASH Radiotherapy" Submitted to Medical Physics

Results

UTIC01 measurements at PTB MELAF facility
Electron energy 20 MeV
Pulse duration 2.5 µs
Repetition rate 5 Hz
Chamber polarization +250 V



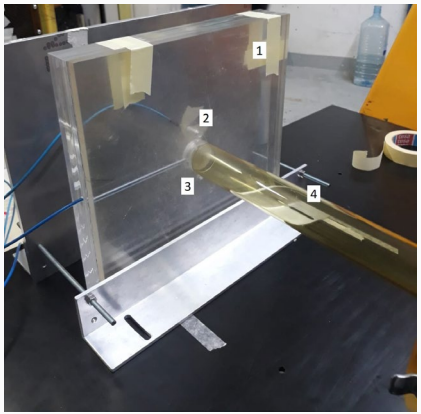
1 Water phantom
2 UTIC01 Plane parallel ionization chamber
3 Electron beam output window



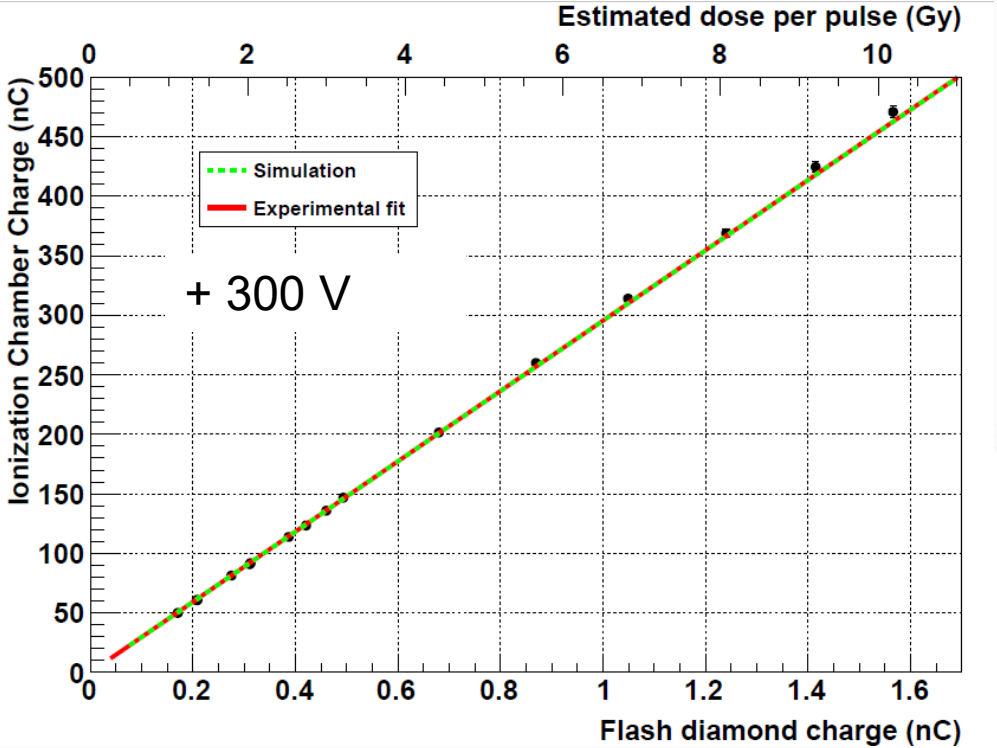
F. Gomez et al. “Development Of An Ultra-Thin Parallel Plate Ionization Chamber for Dosimetry in FLASH Radiotherapy” Submitted to Medical Physics

Results

UTIC02 measurements at SIT.
Electron energy 9 MeV
Pulse duration 0.1 - 4.0 μs
Repetition rate 10 Hz



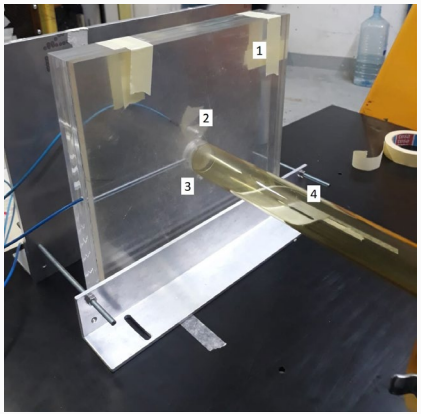
1 PMMA Phantom
2 Flash diamond detector (*)
3 UTIC02 Plane parallel ionization chamber



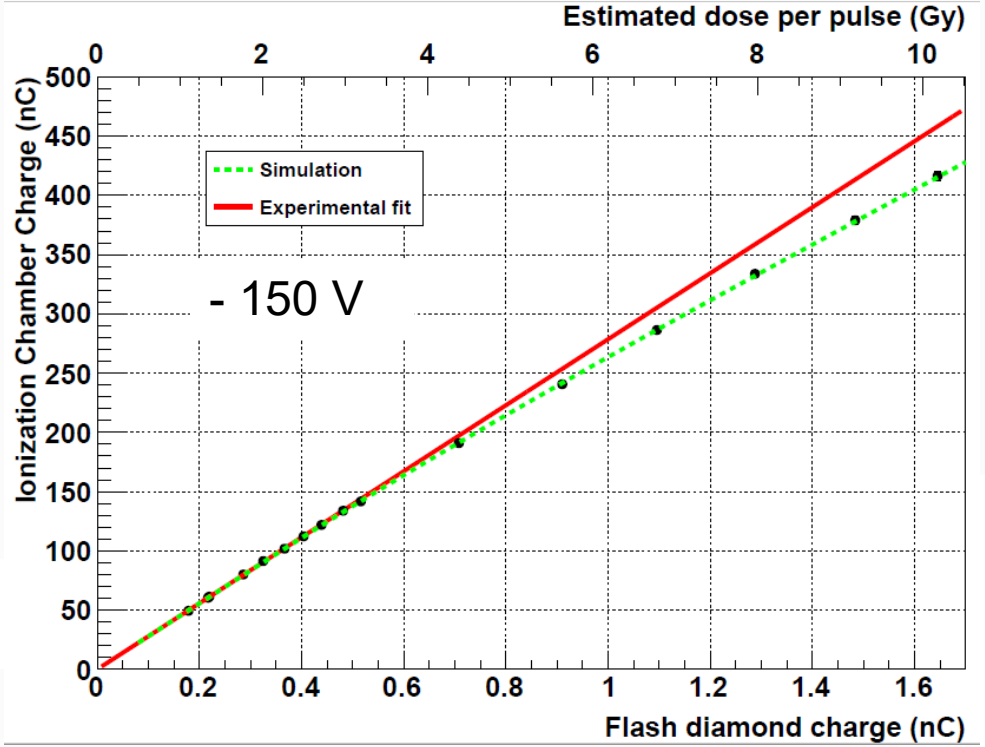
(*) M. Marinelli et al. “Design, realization and characterization of a novel diamond detector prototype for flash radiotherapy dosimetry” Submitted to Medical Physics

Results

UTIC02 measurements at SIT.
Electron energy 9 MeV
Pulse duration 0.1 - 4.0 μs
Repetition rate 10 Hz



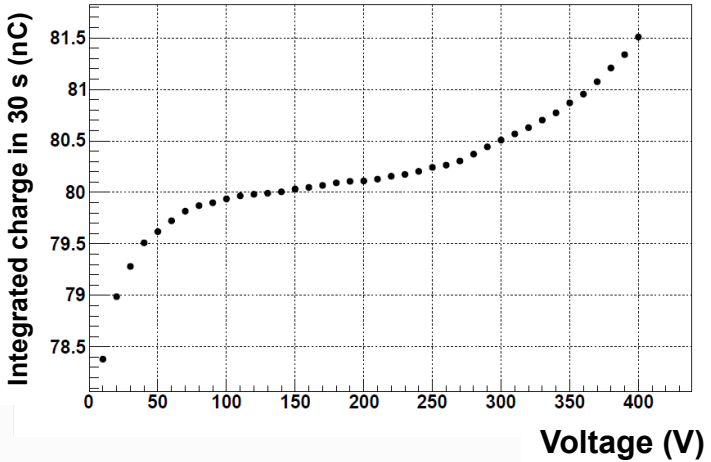
1 PMMA Phantom
2 Flash diamond detector (*)
3 UTIC02 Plane parallel ionization chamber

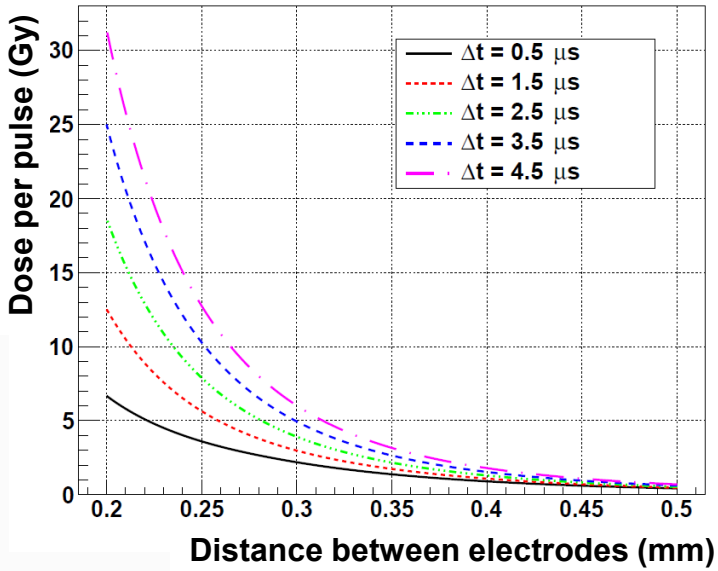


(*) More details: "**REALIZATION AND CHARACTERIZATION OF NOVEL DIAMOND DETECTOR PROTOTYPES FOR FLASH THERAPY APPLICATIONS"** Gianluca Verona
Session "QA and Dosimetry II", Thursday 11:00.

Physical limitations

UTIC02 measurements with 50 kV x-ray
Dose rate 4 Gy/s.
Charge multiplication is enhanced by the small gap/high electric field.





Lines for 99% charge collection efficiency (CCE) from simulation.
Performance depends not only on dose per pulse but also on dose rate during pulse.
Ion collection time < 3 μs at 300 V.

F. Gomez et al. “Development Of An Ultra-Thin Parallel Plate Ionization Chamber for Dosimetry in FLASH Radiotherapy” Submitted to Medical Physics

Conclusions

- **Ultra-thin parallel plate air ionization chambers** (UTPPIC) with electrode distance around 0.25 mm **respond to Ultra-High DPP with small recombination effects**. (i.e. CCE >99% for dose per pulse of 10 Gy with a duration of 4 μs at 300 V).

- UTPPIC works thanks to **large free electron fraction** (~97% @ 300V) and **fast ion collection** (< 3 μs @ 300 V)**.**

- The availability of this type of chambers could provide a **natural extension of current Code of Practice** to the UHDR beams.

- **Recombination** effects on UTPPIC **depend** not only on dose per pulse but **also on dose rate during pulse**.

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Thanks for your attention!
Questions?

EMPIR EURAMET
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UHDpulse
USC UNIVERSIDADE DE SANTIAGO DE COMPOSTELA