13th MT ARD ST3 Meeting 2025

DESY, Zeuthen, Germany

25th June 2025

Status of instrumentation and new dosimetric approaches for FLASH radiotherapy

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Outline

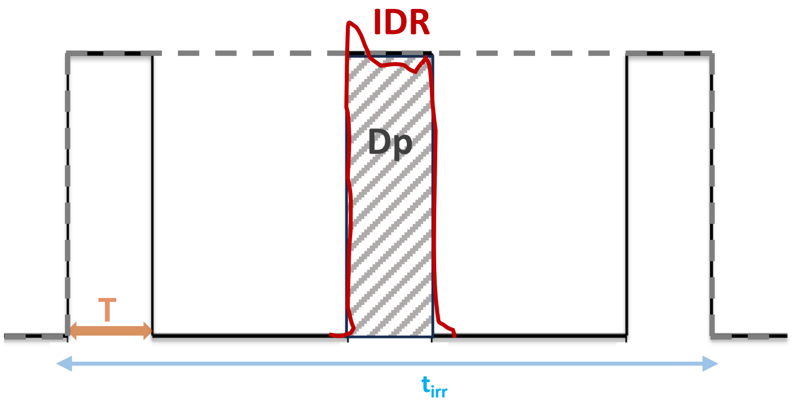
- Role of physical parameters for dosimetry of UHDR beams
- Different pulse structures and accelerators for FLASH Radiotherapy
- Limits of ionization chambers for UHDR reference dosimetry
- Adapting ion chambers and new methods to overcome limitations
- Novel approaches
- Final considerations

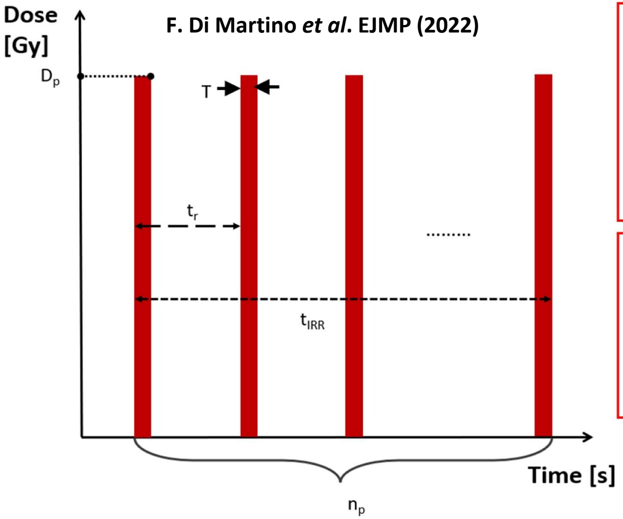
Involved physical parameters for FLASH radiotherapy

Physical beam parameters for conv radiotherapy:

- Particle type [e-, p, ions, X-ray, …]
- Energy [MeV]
- Fluence [p/cm^2]
- Dose [Gy]

- **Time [s]** **FLASH (UHDR)**





T Pulse width [s]

D_p Dose per singe pulse [Gy]

PRF Pulse Repetition Frequency [Hz]

n_p number of pulses

t_r time between two pulses = $1/PRF$ [s]

t_{IRR} total irradiation time = $\frac{n_p - 1}{PRF} + T$ [s]

DR Average dose rate [Gy/s]

DR = $\frac{\text{Tot Dose}}{t_{IRR}} = \frac{n_p \cdot D_p}{t_{IRR}} \approx D_p \cdot PRF$

IDR Instantaneous dose rate [Gy/s]

IDR = $\frac{D_p}{T}$

Requirements for ideal (active) dosimeters at UHDR:

- Linear signal-dose relationship, tissue equivalence, dose accuracy, spatial resolution, use convenience, …
- Accurately measure the **D_p**
  - independent on DR
  - corrections to be implemented
- Accurately measure the **IDR**
- Characterize the **pulse temporal structure** (high temp. res.)
  → a combination of technologies...
- **Passive** dosimeters (alanine, RCF, Fricke):
  - Lot of work done at the beginning
  - Still used to characterize novel detectors
  - reliable, but not suitable for clinical routine

Physical parameters to look at?

CONVENTIONAL RADIOTHERAPY

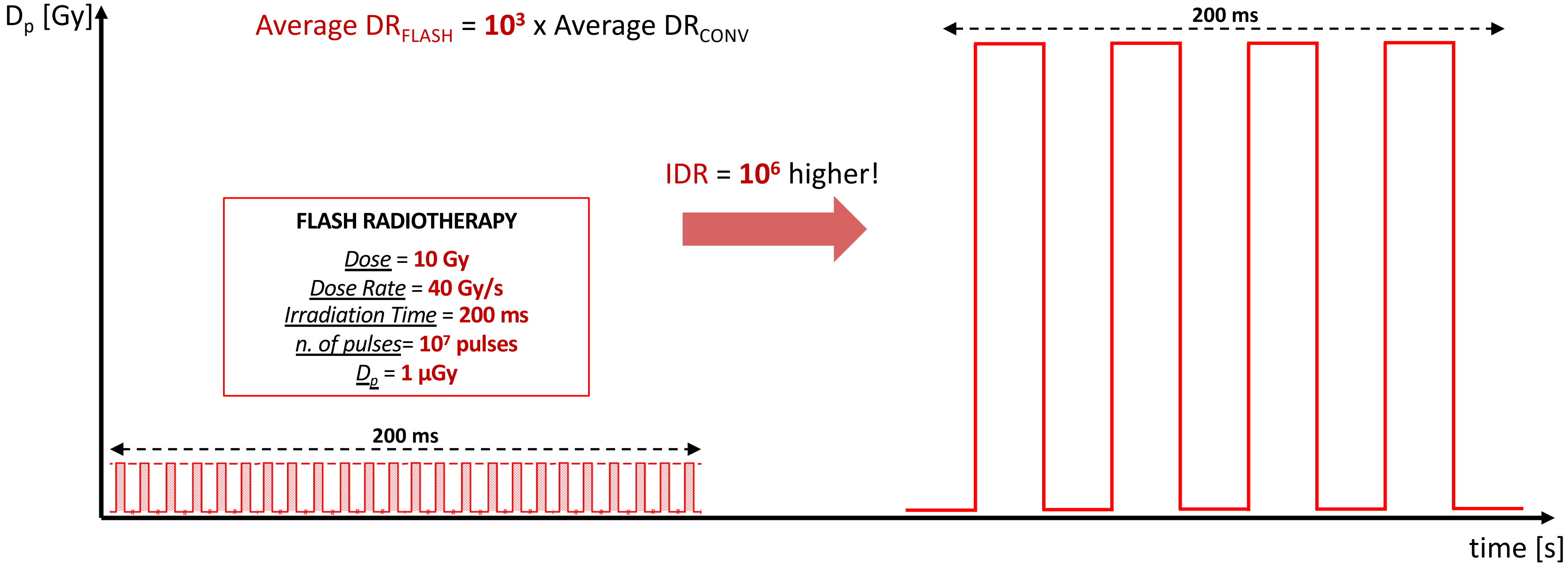
Dose: ~2 Gy/fract. (x 30 fractions)
Dose Rate: ~ Gy/min
Irradiation Time: few minutes

FLASH RADIOTHERAPY

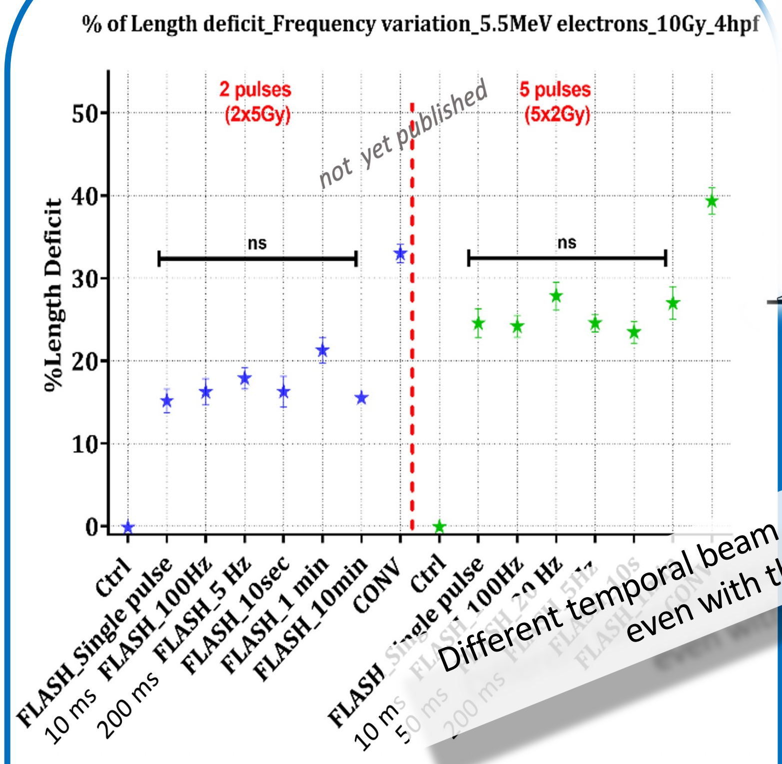
Dose: > **10 Gy** (x 1 fraction?)
Dose Rate: > **40 Gy/s**
Irradiation Time: < **200 ms**

FLASH RADIOTHERAPY

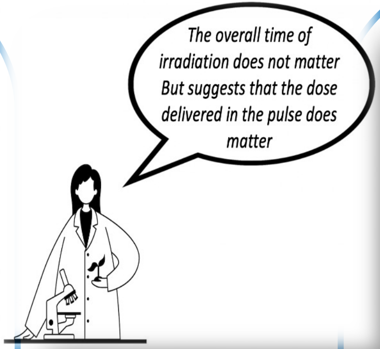
Dose = **10 Gy**
Dose Rate = **40 Gy/s**
Irradiation Time = **200 ms**
n. of pulses= **4 pulses**
D_p = **2.5 Gy**



Does only the average dose rate and total irradiation time matter?



Courtesy of M.C. Vozenin (BelFLASH Symposium, Belgium, June 2024)



Different temporal beam structures lead to different treatment outcomes
even with the same Dose and Average Dose Rate

https://www.biorxiv.org/content/10.1101/2024.04.19.590158v1.full

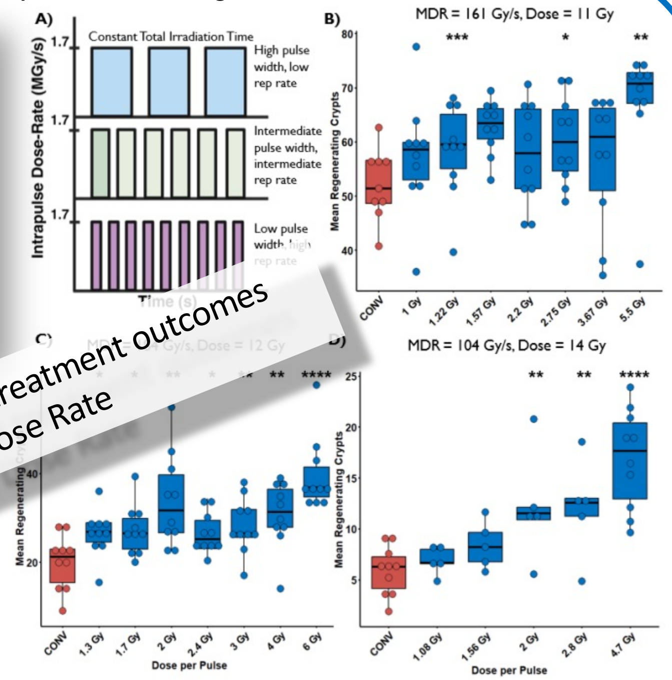


Fig. 2. (A) The beam structure schema (not to scale) illustrating how pulse width (PW) and pulse repetition frequency (PRF) are varied to achieve a delivery of different dose per pulse (DPP) while maintaining constant intrapulse dose rate, total irradiation time, mean dose rate (MDR), and total dose for each set of experiments in B-D. The mean number of regenerating crypts per circumference for mice receiving a total abdominal irradiation by either CONV - (0.3Gy/s, 10mGy/pulse, Red) or FLASH (Blue) to a dose of B) 11 Gy, MDR = 161 Gy/s, C) 12 Gy, MDR = 184 Gy/s, and D) 14 Gy, MDR = 104 Gy/s. An unpaired parametric t-test was used to compare the FLASH treated groups with the CONV treated group. * p< 0.05; ** p < 0.01; *** p < 0.001; **** p < 0.0001. For doses of 11-14 Gy and MDR of 104-184 Gy/s, sparing of crypts increases progressively with increasing DPP, especially at 14 Gy/104 Gy/s. At the lower doses/higher MDRs of 11-12Gy/161-184 Gy/s tested here; significant sparing of crypts is observed at DPPs > 1 Gy.

Realization of UHDR beams …and related accelerators

Year	Radiation type	Machine	Energy (MeV)	Average dose rate (Gy/s)	Dose per pulse (Gy/pulse)	Pulse repetition rate (Hz)	Field size	Purpose	Dosimetry method
2020	Proton[32]	IBA isochronous cyclotron (USA)	227.5	130	N/A	106 MHz (quasi-continuous)	1.6 × 1.2 cm^2 ellipse	Mouse (partial abdomen irradiation)	Plane-parallel IC, FC, MC simulation, EBT3 RCF
2020	Photon[33]	ANSTO Australian Synchrotron	0.07 and 0.09 mean	40–350 (at treat-ment depth and fil-tration)	200 (at 20 mm reference depth and filtration)	Continuous	2 × 2 cm (reference dosimetry size)	Rat study (brain cancer irradiation)	Pinpoint IC (reference), silicon semiconductor, and MC
2021	Proton[25]	Mevion synchrocyclotron (USA)	60	120–160	0.22 Gy/pulse (9.3 × 10^3 Gy/s instantaneous)	750	Ø 1.1 cm FWHM (5 mm @ 90% isodose)	Feasibility of SOBP beam using a synchrocyclotron	IC, FC, MC simulation, and EBT-XD RCF
2021	Electron[34]	Varian Clinac 2100 C/D (USA)	10	240–260	0.81 Gy/pulse	360	Ø 1–1.5 cm	Feasibility of UHDR at the machine's isocenter	EBT-XD RCF
2021	Proton[35]	Research isochronous cyclotron (Germany)	68	75	N/A	20 MHz	Ø 1.3 cm	Preclinical setup for mouse irradiation	IC and RC
2021	Proton[36]	COMET[38] isochronous cyclotron (Switzerland)	170—250	9000 (for a single spot)	N/A	72.85 MHz	~2.3–5 mm (16 × 1.2 cm^2 by scanning)	Feasibility study	FC
2021	Helium ion[26]	Synchrotron (Germany)	145.74 MeV/u	185	N/A	Quasi-continuous	1 cm^2 (by spot scanning)	In vitro study of dose, LET, and O_2 concentration	Parallel-plate IC
2021	Carbon ion[27]	Synchrotron (Germany)	280 MeV/u	70	N/A	Quasi-continuous	1 cm^2 (by spot scanning)	Dosimetry and in vitro study	IC and EBT3 RCF

F. Romano *et al.* Med. Phys. (2022)

- e- : Research / modified clinical LINACs
- p : Isochronous cyclotrons
- p : Synchro cyclotrons
- γ, ions : Synchrotrons

Challenges of dosimetry for electron UHDR beams

*First studies on **ion recombination** for commercially available chambers* → ***determining** ion **collection efficiency***

Petersson et al., Med Phys 44 (**2017**) 1157

High dose-per-pulse electron beam dosimetry — A model to correct for the ion recombination in the Advanced Markus ionization chamber

Kristoffer Petersson,[a] Maud Jaccard, Jean-François Germond, Thierry Buchillier, and François Bochud
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Claude Bailat
CHUV, Institut de Radiophysique, Rue du Grand-Pré 1, CH-1007 Lausan...

Kranzer et al., *Medical Physics, 48 (2), February* ***2021***

Ion collection efficiency of ionization chambers in ultra-high dose-per-pulse electron beams

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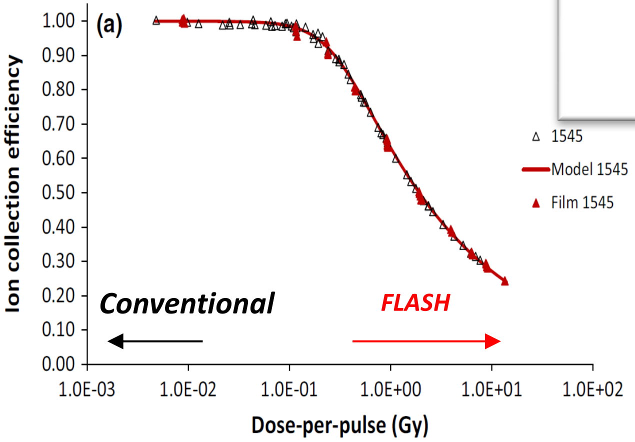
UHDpulse

k_s = 1/(ion coll. eff.)



A. Bourgouin Phys. Med. Biol. 68 (**2023**) 235002

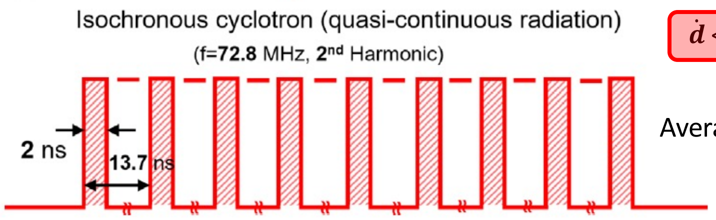
PAPER

Charge collection efficiency of commercially available parallel-plate ionisation chambers in ultra-high dose-per-pulse electron beams

Alexandra Bourgouin[1,*], Jose Paz-Martín[2], Yunus Can Gedik[3], Franziska Frei[4], Peter Peier[4], Séverine Rossomme[5], Andreas A Schönfeld[6], Andreas Schüller[1], Faustino Gomez Rodriguez[2] and Ralf-Peter Kapsch[1]

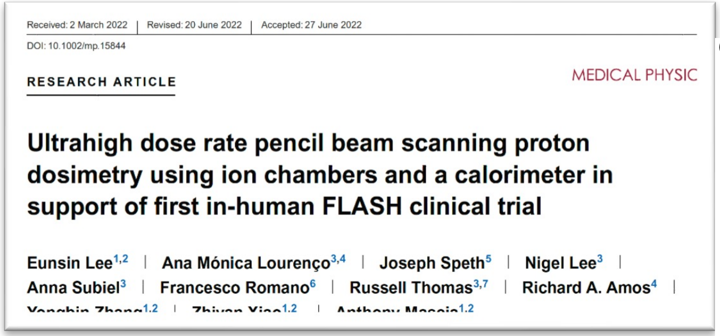
UHDR proton beams (isochronous cyclotrons)

IBA, Varian, Hitachi



$\dot{d}$ < 2 kGy/s

Average DR 100-400 Gy/s

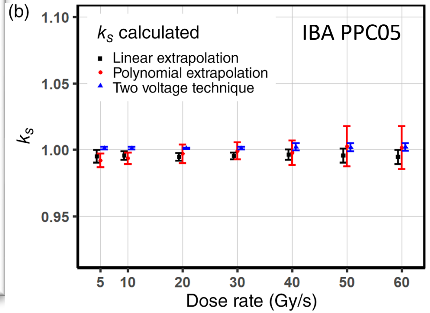

Received: 2 March 2022 | Revised: 20 June 2022 | Accepted: 27 June 2022
DOI: 10.1002/mp.15844

RESEARCH ARTICLE

MEDICAL PHYSIC

Ultrahigh dose rate pencil beam scanning proton dosimetry using ion chambers and a calorimeter in support of first in-human FLASH clinical trial

Eunsin Lee[1,2] | Ana Mónica Lourenço[3,4] | Joseph Speth[5] | Nigel Lee[3] | Anna Subiel[3] | Francesco Romano[6] | Russell Thomas[3,7] | Richard A. Amos[4] |



Average dose rate 5-60 Gy/s

Chambers:

PTW Advanced Markus

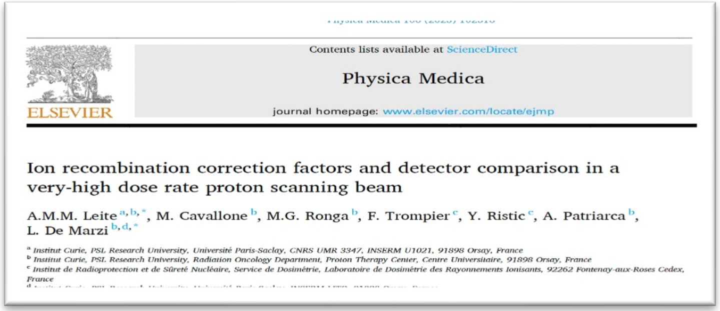
IBA PPC05

PPC05

K_{sat}:***1.002***

Adv Markus

K_{sat}: ***1.001-1.006***


Contents lists available at ScienceDirect
Physica Medica
journal homepage: www.elsevier.com/locate/ejmp

ELSEVIER

Ion recombination correction factors and detector comparison in a very-high dose rate proton scanning beam

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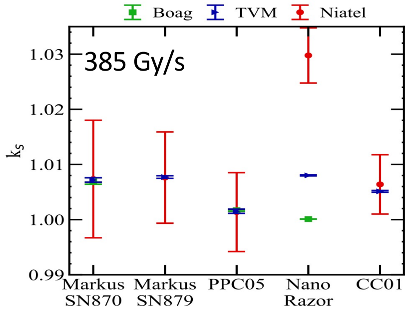


Average dose rate 4 Gy/s - 385 Gy/s

Instantaneous dose rates:

up to 1000 Gy/s

Chambers:

Razor Nano-chamber CC01,

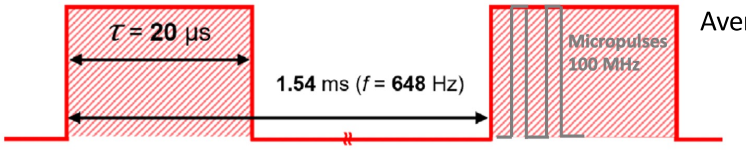
PTW Advanced Markus, PPC05

UHDR proton beams (synchrocyclotrons)

IBA, Mevion

Synchrocyclotron (FLASH dose rate)

$\dot{d}$ < 10 kGy/s



Average DR < 200 Gy/s

Feasibility of proton FLASH irradiation using a synchrocyclotron for preclinical studies

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Townsend Zwart, Miles Wagner, and Daniel Catanzano
Mevion Medical Systems, 300 Foster St., Littleton, MA 01460, USA

Jeffrey F. Williamson, Nels Knutson, Baozhou Sun, Sasa Mutic, and Tianyu Zhao
Department of Radiation Oncology, Washington University School of Medicine, St. Louis, MO 63110, USA

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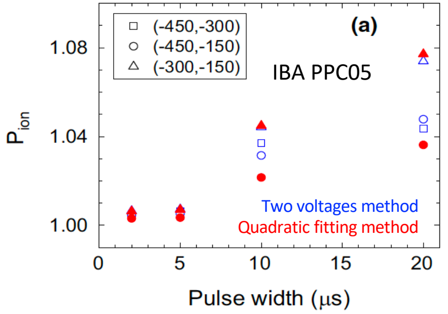


230 MeV **passive** proton beam

Average dose rate: **100-200** Gy/s,

Instantaneous: dose rate **1.66 10^4** Gy/s

Pulse duration: **2-20 us**

Received: 3 January 2021 | Revised: 25 May 2021 | Accepted: 26 May 2021

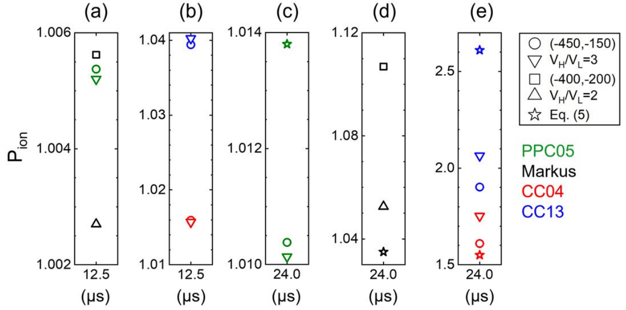
DOI: 10.1002/mp.15021

MEDICAL PHYSICS

RESEARCH ARTICLE

Spread-out Bragg peak proton FLASH irradiation using a clinical synchrocyclotron: Proof of concept and ion chamber characterization

Arash Darafsheh[1] | Yao Hao[1] | Xiandong Zhao[1] | Townsend Zwart[2] | Miles Wagner[2] | Tucker Evans[2] | Francisco Reynoso[1] | Tianyu Zhao[1]



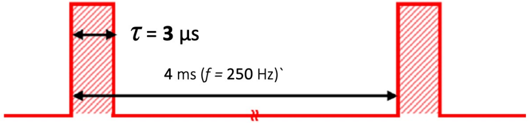
Chambers: PPC05, Markus

K_{sat}: **1.003–1.1**

UHDR electron beams (LINAC)

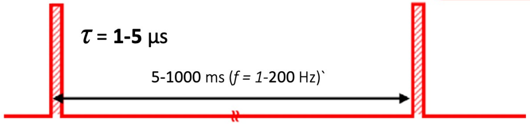
Average DR < 200-700 Gy/s

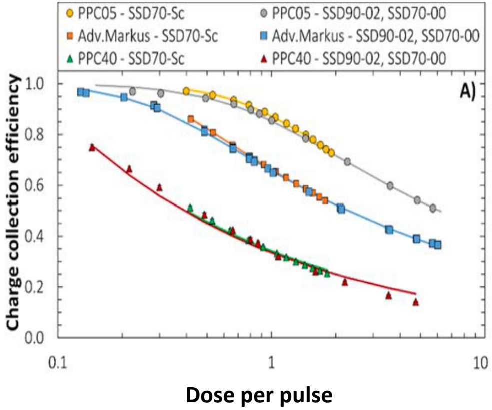
Clinical LINAC for Radiotherapy (modified) $\dot{d}$ < 100 kGy/s



Average DR < 2 kGy/s

Research LINAC for pre-clinical studies $\dot{d}$ < 5 MGy/s





A. Bourgoin Phys. Med. Biol. 68 (2023) 235002

Modified clinical LINACs

Research LINACs

TABLE I. Characteristics of currently available electron devices.

	Kinetron (CGR-MeV/PMB-Alcen)	Oriatron eRT6 (PMB-Alcen)	Oxford linac	Modified Varian (Stanford)	Modified Elekta	Mobetron (IntraOp)	FLASH-knife (PMB-Alcen)	SIT (Sordina)	FLEX (RadiaBeam)	PITZ
Available beam energy (MeV)	4.5	5	6	17	8 and 10	6 and 9	6–10	5–12	9	22
Maximum average dose rate (Gy/s)	2500	1000	1500	750	≥300	>700 at 6 MeV, >800 at 9 MeV	Up to 350 Gy/s at 30 mm depth	1500	7500	10 000
Maximum dose per pulse (Gy)	6.3	12	5	3	1.9	>8 at 6 MeV, >9 at 9 MeV	···	18.2	>25	1000
Max. beam size for at least 1.5 Gy/pulse (cm)	5	20.5 (FWHM)	5 (FWHM)	5	2 (5% flatness)	6 at 90%	···	1.3 (FWHM)	6	15
Max. beam size at max. dose rate (cm)	0.012	0.5	···	5	2 (5% flatness)	4 at 90%	···	0.5 (FWHM)	6 (FWHM)	2
Short-term stability (%)	···	<1	···	<2	1 to 4	0.8	···	···	±2%	<1%
Long-term stability	···	4.1%	···	~4%	···	1.8 at 6 MeV, 2.3 at 9 MeV	···	···	±2%	<1%
Commissioning reference(s)	Lansonneur *et al.* (2019)	Petersson *et al.* (2017), Jaccard *et al.* (2018), and Jorge *et al.* (2019)	···	Schueler, Trovati *et al.* (2017)	Lempart *et al.* (2019)	Moeckli *et al.* (2021)	···	Di Martino *et al.* (2020)	Kutsaev *et al.* (2021)	Stephan *et al.* (2022)
FLASH effect validated	Favaudon *et al.* (2014), Vozenin *et al.* (2019), and Fouillade *et al.* (2020)	Montay-Gruel *et al.* (2017, 2019, 2020, 2021), Vozenin *et al.* (2019), Alaghband *et al.* (2020), Allen *et al.* (2020), Limoli *et al.* (2020), Chabi *et al.* (2021), Kacem *et al.* (2022), and Rohrer Bley *et al.* (2022)	Ruan *et al.* (2021)	Simmons *et al.* (2019), Levy *et al.* (2020), Y.-E. Kim *et al.* (2021), and Eggold *et al.* (2022)	No	Valdes Zayas *et al.* (2023)	No	No	No	No
Dosimetrically intercompared	Dismantled in 2020	Gonçalves Jorge *et al.* (2022)	No	Gonçalves Jorge *et al.* (2022)	No	No	No	No	No	No
Biologically intercompared	Dismantled in 2020	Yes	No	Yes	No	No	No	No	No	No

M. C. Vozenin *et al*. Rev. Mod. Phys. (2024)

What's the current status of instrumentation for UHDRs?

Using commercially available **ion chambers**?

↓

Adapt them for UHDRs: corrections for k_{sat}!

↓

Which limitations for this?

New technologies

- **New prototypes** of **ionization chambers**
  - **fDiamond**
- Active **solid state detectors**
  - **scintillators**, **silicon** and **SiC** diodes
- Small portable **calorimeters**

0.5-2 Gy/p — 5-10 Gy/p — > 10 Gy/p — D_p [Gy]

What's the current status of instrumentation for UHDRs?

Using commercially available **ion chambers**?

Investigating new methods to correct for the k_{sat} for commercially available chambers (up to specific D_p)

Analytical methods

Phenomenological methods

Ionometric (self-consistent)
or
non-ionometric (external reference) methods

0.5-2 Gy/p

D_p [Gy]

Ionization chambers: determine the ion rec corr (ksat) for commercial chambers

dose per pulse

up to 0.5 Gy/p

Intermediate Range

The recombination can be determined analytically

Analytical ionometric method

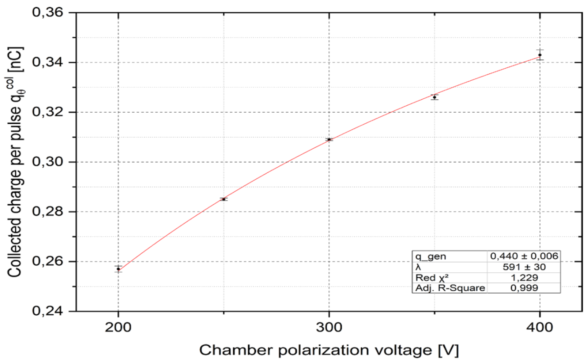
Up to 2 Gy/p

UHDR

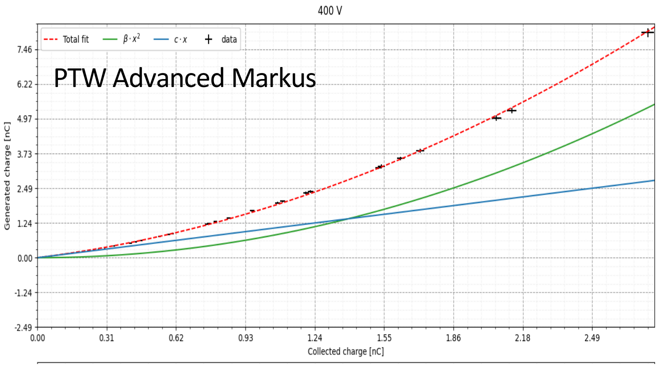
The perturbation of the electric field due to the produced charge is not negligible

Phenomenological ionometric method

F. Di Martino et al., Physica Medica 103 (2022) 175–180



L. Masturzo et al., Med. Phys., under review



What's the current status of instrumentation for UHDRs?

New technologies

Exploring <u>new approaches</u> and designing <u>new chambers</u> for mitigating the ion recombination correction

Collect as "fast" as possible produced charges

Try to reduce the produced charges

Reducing the gap or the gas pressure between the chamber electrodes

5-10 Gy/p

D_p [Gy]

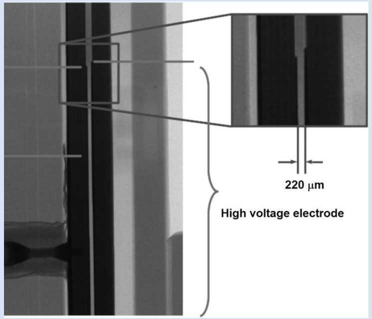
Challenges of dosimetry for electron UHDR beams

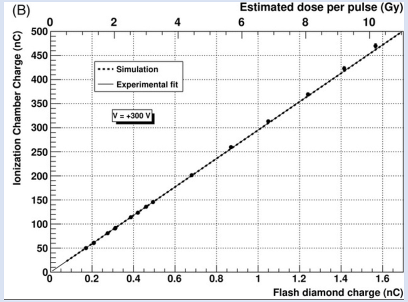
New approaches and chamber designs for decreasing ion recombination on new prototypes

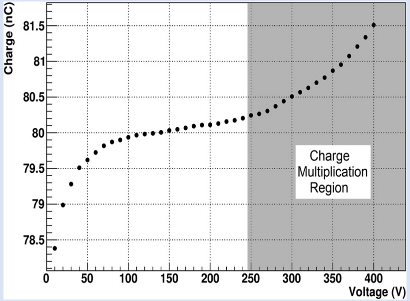
Ultra-thin ionization chambers

F. Gomez et al., Med. Phys. 2022

R Kranzer et al., Physica Medica 104 (2022) 10–17







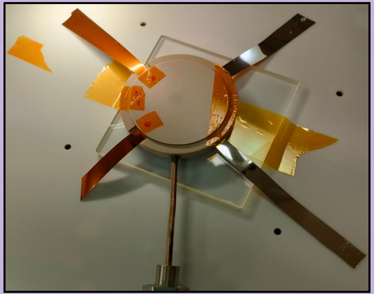
USC (University of Santiago De Compostela)

Noble gas filled ion chamber: the ALL chamber

F. Di Martino et al., EJMP 2022

Fill the cavity with **a noble gas** to prevent the **capture of electrons** and then the production of negative ions which are responsible of the ion recombination (and decreasing gas preassure)

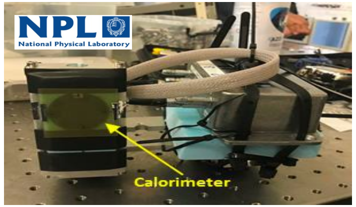
1st prototype



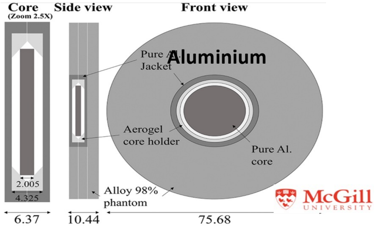
2nd prototype

- ✓ 2nd prototype filled with N_2 gas at 1 bar, 500 mbar, 100 mbar
- ✓ First tests with 9 MeV UHDR at CPFR show linearity up to **5 Gy/pulse** at 100 mbar pressure

INFN Pisa Division, CPFR and USC

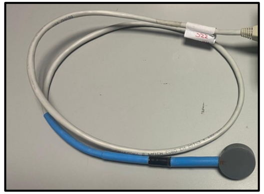


F. Romano et al., Journ. of Phys. (2020)
S. Mc Callum et al., App. Science (2023)



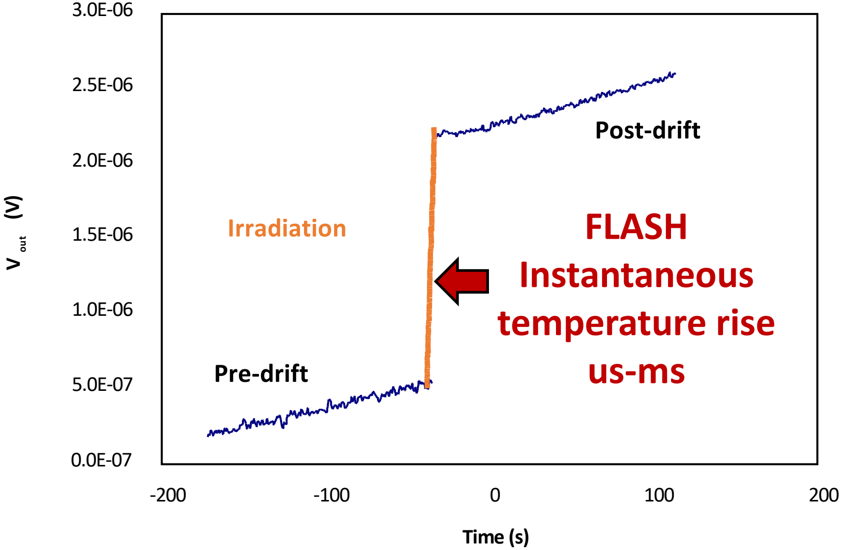
Bourgouin et al., Front. In Phys., 2020

Bourgoin et al., *Med Phys. 2022;49:6635–6645*



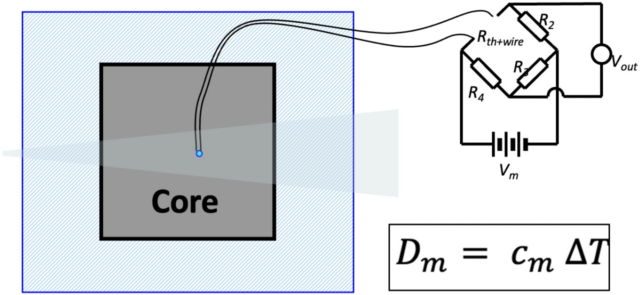
G. Bass et al., Br. J. Radiol. (2023)

What's the current status of instrumentation for UHDRs?



New technologies

Thermistor



$$D_m = c_m \Delta T$$

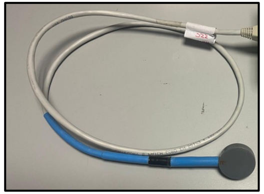
Courtesy of H. Palmans

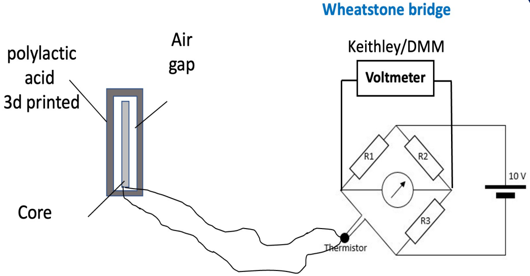
Small portable **calorimeters**

> 10 Gy/p D_p [Gy]

Test of the calorimeter with UHDR electron beams @ CPFR in Pisa

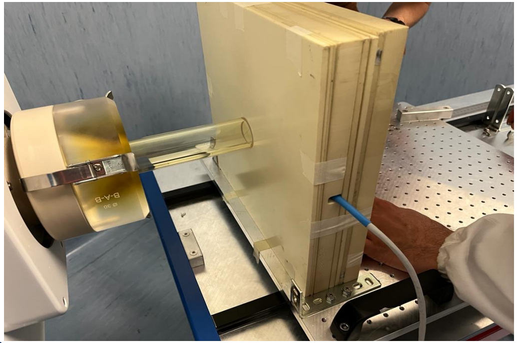
G. Bass et al., Br. J. Radiol. (2023)



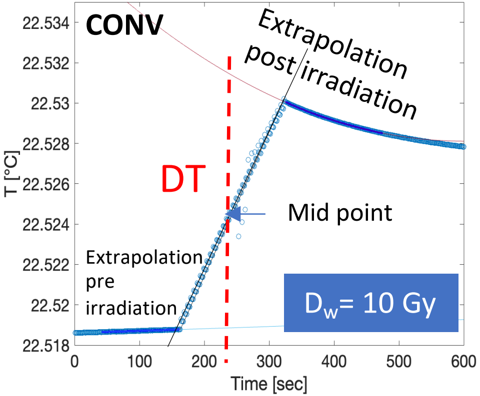


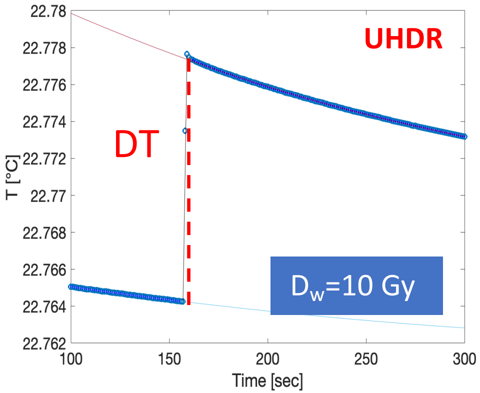
- Developed by NPL
- Simple usage and low cost
- 2 mm graphite core
- 1 single termistor connected to the Wheatstone bridge
- IBA PPC05 ion chamber geometry (same holders)

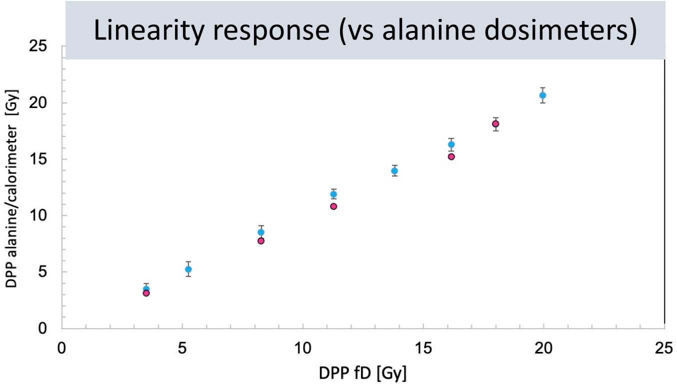
- Tested at CPFR with the SIT ElectronFLASH LINAC
- E = 9 MeV; **single pulse duration: 4 us**



- **Dose per pulse: from 0.1-6 Gy**
- **IDR** up 2 MGy/s
- Repetition frequency:1-245 Hz







Tested also with UHDR proton beams

What’s the current status of instrumentation for UHDRs?

New technologies

Novel **solid state detectors**

- *Reference and small field dosimetry*
- *Relative dosimetry*
- *Pulse structure measurements (IDR)*

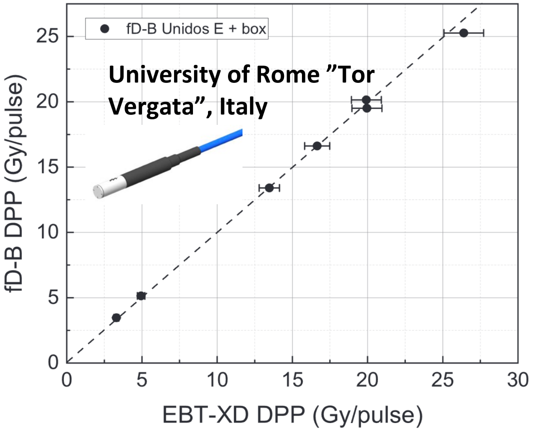
fDiamond

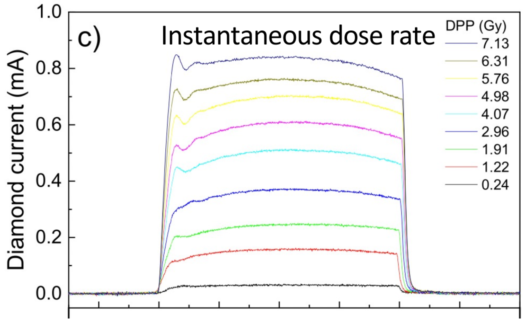
scintillators, **silicon** and **SiC** diodes

> 10 Gy/p D_p [Gy]

fDiamond for reference dosimetry and IDR measurements

PTW FLASH diamond





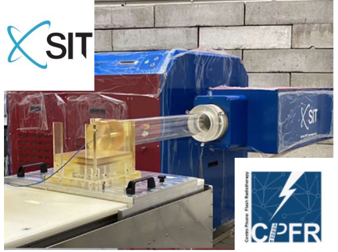
- Linear response at UHDRs
- pulse structure measurements
- High spatial resolution (<< 1 mm)

Table 1. The summary of devices and their applications in UHDR beams.

Device/instrument	UHDR beam modality	Energy (MeV)	DPP (Gy)	Instantaneous dose rate (Gy μs^{-1})	Average dose rate (Gy s^{-1})	Pulse duration (μs)	Pulse repetition rate (Hz)	Standard uncertainty	Availability	References
Potential secondary/tertiary standards										
UTIC	Electrons	9 20	1–10 1.2–5.4	0.25–2.5 0.48–2.2	10–100 6–27	4 2.5	10 5	1.40%	Under development	(Kranzer *et al* 2021) (Gómez *et al* 2022) figure 3
Alanine	Electrons	20	0.15–9	0.15–3.3	0.75–45	1.35, 2.5, 2.7	5	0.85%	Commercial (through calibration laboratories)	(Bourgouin *et al* 2023a) Figure 4
flashDiamond	Electrons	7, 9 20	0.3–26 0.2–10	0.5–6.6 0.15–3.3	Up to 960 1–50	1–4 1.35–3	5−245 5	1% @ 0.25 Gy μs^{-1} 3% @ 2.5 Gy μs^{-1}	Commercial	(Kranzer *et al* 2022a) (Marinelli *et al* 2022) (Marinelli *et al* 2023) (Tessonnier *et al* 2023) (Verona Rinati *et al* 2022) (Di Martino *et al* 2023) figure 5
SiC diode	Electrons	20 9	0.4–11 0.02–5	0.7–3.8 0.01–1.2	2–55 0.6–53	2.9, 1.6, 0.5 2, 4	5 30	3% —	Under development	(Fleta 2024) (Romano *et al* 2023) (Milluzzo *et al* 2023)
Aerrow graphite probe calorimeter	Electrons	20	0.6–5.6	0.24–2.24	3–28	2.5	5	1.06%	Commercial	(Bourgouin *et al* 2023b)
Commercially available ionization chambers	Electrons Protons (PBS)	20 227	0.14–6.2 4.3, 17.5, and 38.1	0.352–2.48 4 × 10^−6–3.85 × 10^−3	0.7–31 4–385	2.5 1 × 10^6, 99 × 10^3	5 Single pulse (PBS)	2.5% up to 10% [a] 1.5% [b]	Commercial	(Bourgouin *et al* 2023b) (Leite *et al* 2023)

A. Subiel et al., Phys. Med. Biol. 69 (2024)

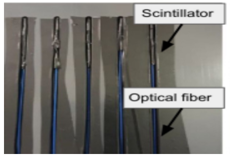
Response of other active solid-state detectors a UHDRs



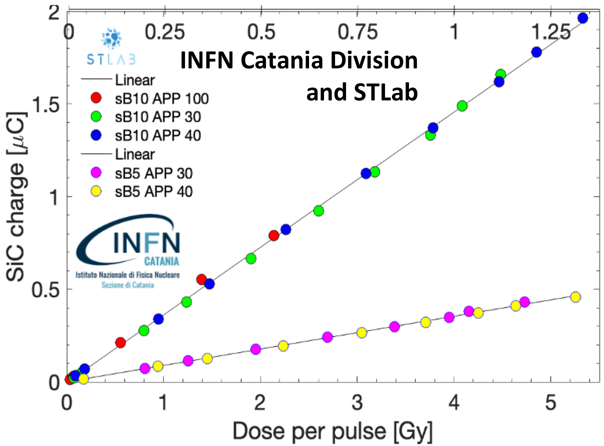
- Linear response at UHDR
- High spatial resolution (< 1 mm) → small fields
- Good stability (long-term response stability?)
- Water equivalence
- Possibility for 2D configurations
- Encapsulation to be used in reference conditions

SiC detectors

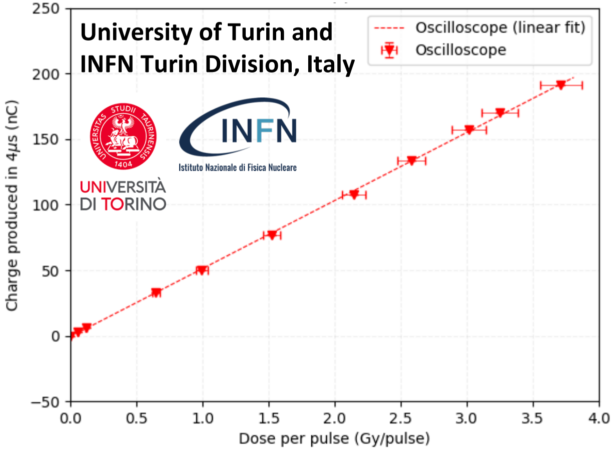
Silicon detectors



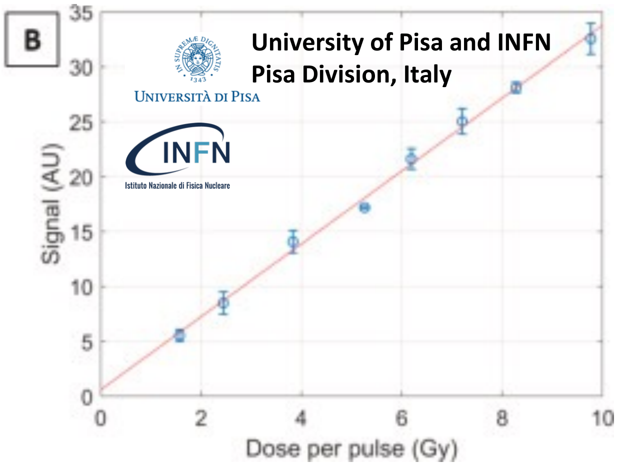
Scintillators/scintillator fibers



F. Romano et al. Appl. Phys. (2023)
G. Milluzzo et al. (2024)
C. Okpuwe et al 2025 Rad. Res. (2025)



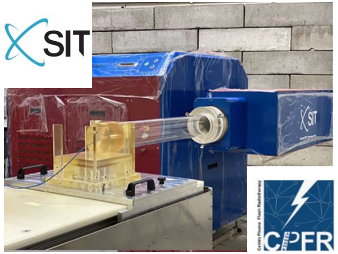
E. Medina *et al.*, Frontiers in Physics (2022)

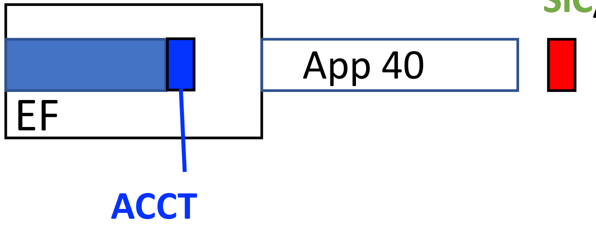


M. Morrocchi et al. JINST (2022)
E. Ciarrocchi et al., Physica Medica (2024)

Beam pulse structure / IDR measurements:

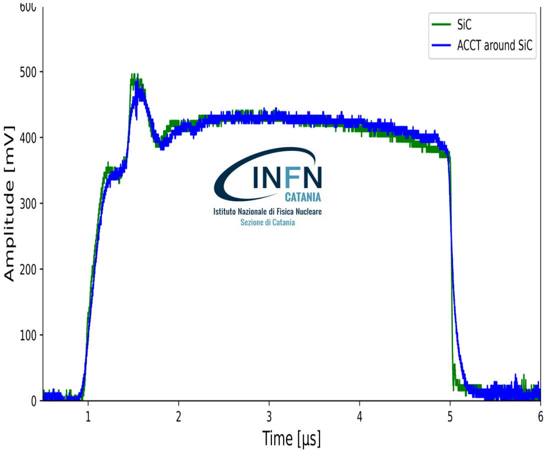
ACCT (AC current transformer)





SiC/Silicon/Scintillators

SiC detectors



F. Romano et al. Appl. Phys. (2023)
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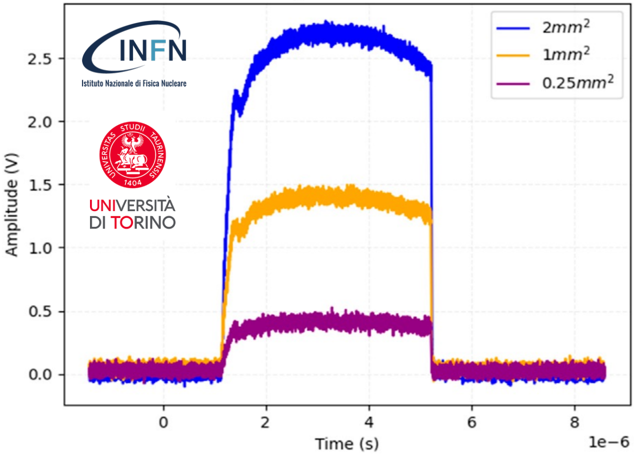
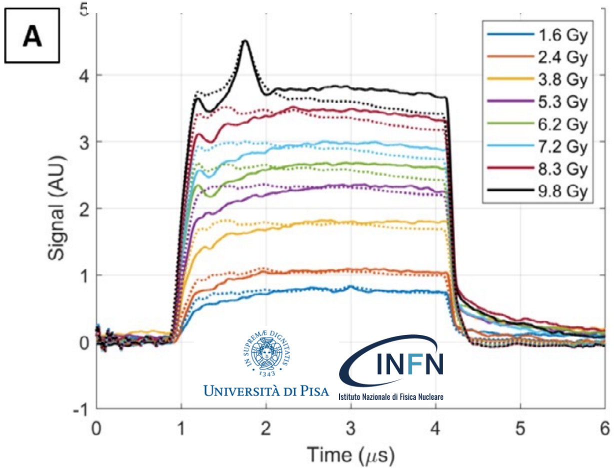
Silicon detectors



E. Medina *et al.*, Frontiers in Physics (2022)

Scintillators/scintillator fibers



M. Morrocchi et al. JINST (2022)
E. Ciarrocchi et al., Physica Medica (2024)

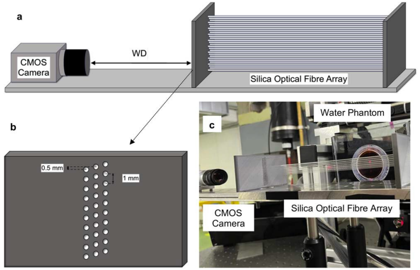
QA devices to support clinical trials (and address radiation protection issues?)

Multi scintillating fibers

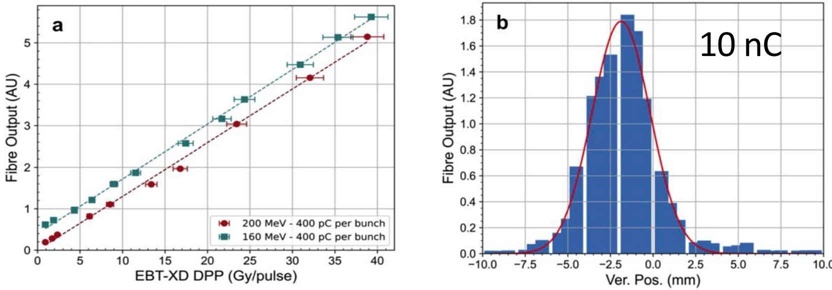
- 28 fused silica optical fibres
- 0.4mm in diameter
- 30 cm length

clear

UNIVERSITY OF OXFORD



Joseph J Bateman et al 2024 Phys. Med. Biol. 69 085006



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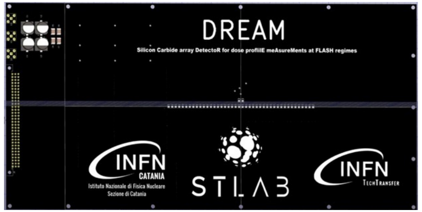
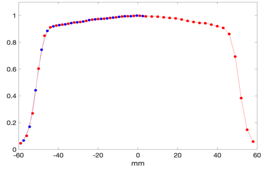
SiC 1D geometrical configurations for real time dose profile measurements **(DREAM)**



R4I Research for Innovation



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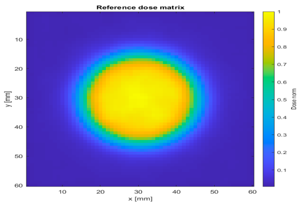
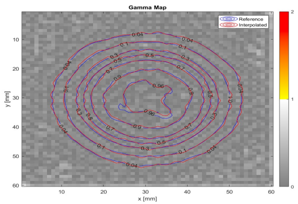
SiC 2D geometrical configurations for real time dose map measurements **(DALI')**





Final considerations

- Huge effort in the last years on **characterizing technologies for dosimetry** and develop **new approaches**
- The final goal is probably less challenging than it was thought at the beginning (20-30 Gy/p vs few Gy/p)
- Now clinical trials push physicists to address new challenges:
  - **Compare performances** of dosimeters with dedicated experiments at the same conditions
  - **Small field** dosimetry, **pulse structure** characterization, **radiation protection** …most suitable technology
  - Understanding which developed dosimeters are "useful" for **medical physicist** and for which cases
- Dosimetry:
  - Less critical for **proton beams**: small corrections for isochronous cyclotrons, larger with synchrocyclotrons
  - More effort required for **electron beams** (Linacs):
    - **commercial ion chambers** reliably used with correction methods up to 2 Gy/p: to be also used for Linac output periodic checks (**new chamber prototypes** under development for higher Dpp)
    - **calorimeters** for higher Dpp or stability check for novel detectors (semiconductors) and commissioning
    - **Solid state detectors** for relative dosimetry, small field dosimetry, temporal reconstruction (IDR)
    - **2D systems** (**scintillators**, **semiconductors**,…) for: i) QA; ii) addressing radiation protection issues; iii) (in a future perspective) dosimetric check of treatment plans
- Protocols and current initiatives : **AAPM** task group 359, **ESTRO** FLASH FOCUS Group, **AIFM** (for low E e-)

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Thank you for your attention

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BAC project of National Plan for PNRR Complementary Investments "DALI'"

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