



UNIVERSITÀ
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FLASH Radiotherapy with high
Dose-rate particle beams

FRIDA Final General Meeting

WP2: UHDR Turin Facility
Overview of the Turin facility status

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4 March 2026

The LINAC

CONVENTIONAL CLINICAL BEAMS

Energy and Monitor Units calibrated

- Electrons 6 MeV
- Electrons 10 MeV
- Electrons 18 MeV
- X-Ray 15 MV
- X-Ray 18 MV

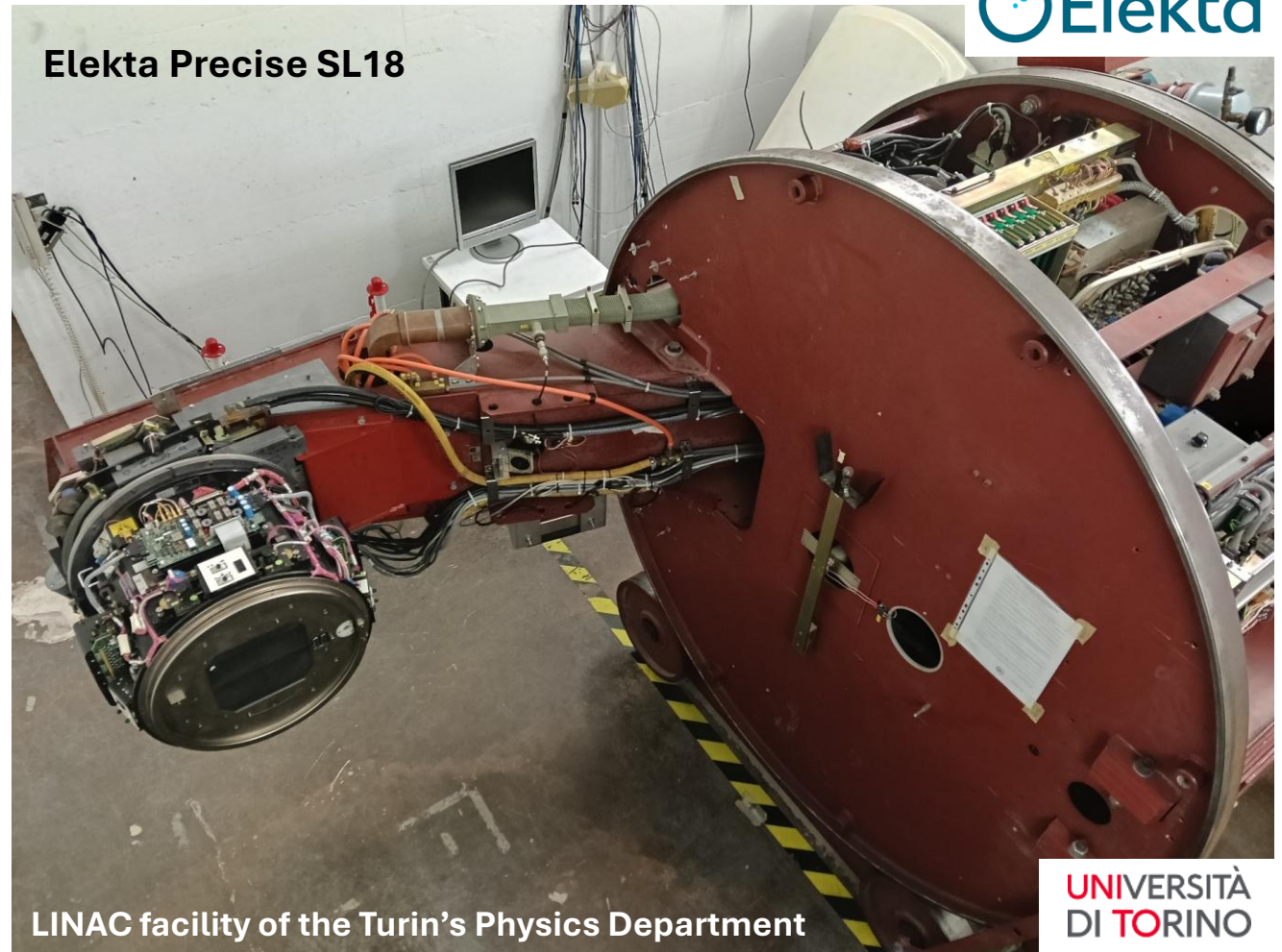
UNCONVENTIONAL BEAMS for Specific Projects

- Electrons 18 MeV without filters
- X-Ray 18 MV without flattening filter

These configurations are preset, to switch from one to another 1 min is needed (via software).

Beam structure

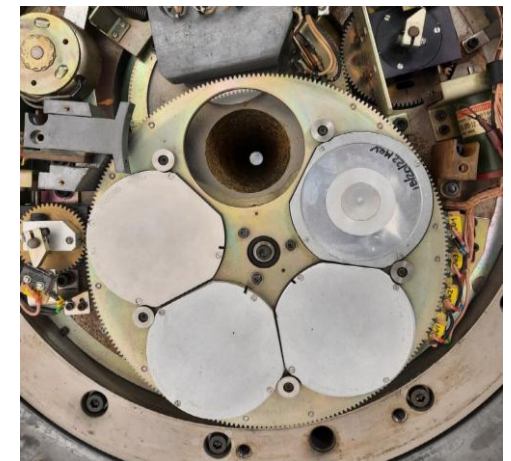
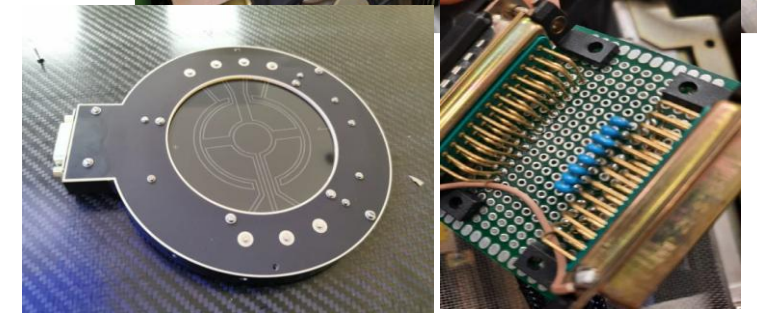
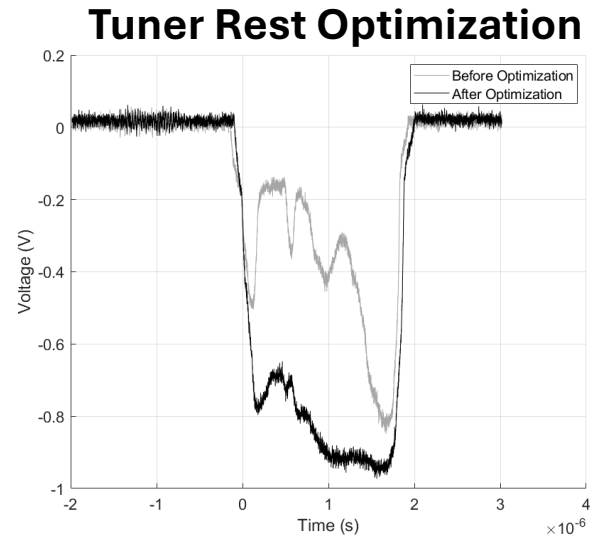
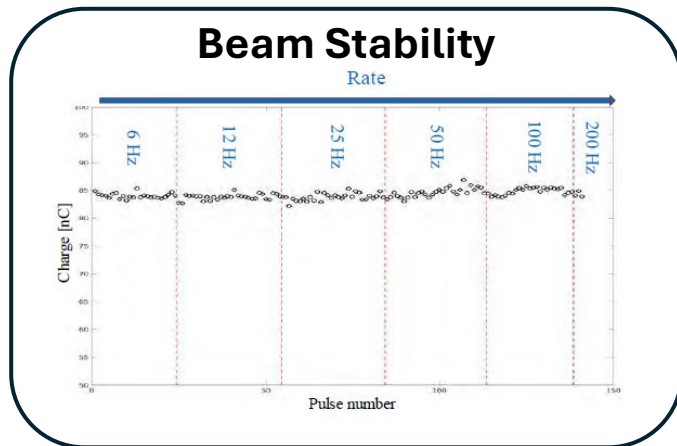
- Pulsed beam with frequency between 6 and 400 Hz
- Irradiation field between 0.5cm and 40cm
- Fixed pulse duration: 2 μ s



The LINAC Upgrade

Steps of the Upgrade:

- Upgrade of the pulse forming network. Two charging cycles were implemented, increasing the RF power and consequently the number of transported electrons
- Addition of two UHDR modes to the linac:
 - Electrons 10 MeV Ultra High Dose Rate HIGH POWER (dose per pulse 10^3 higher than conventional mode)
 - Electrons 10 MeV Ultra High Dose Rate LOW POWER (35% lower than HIGH POWER)
- Removal of the secondary scatter filters
- Exclusion of the dose interlock
- Study of beam stability using silicon diode



The LINAC - Working Points

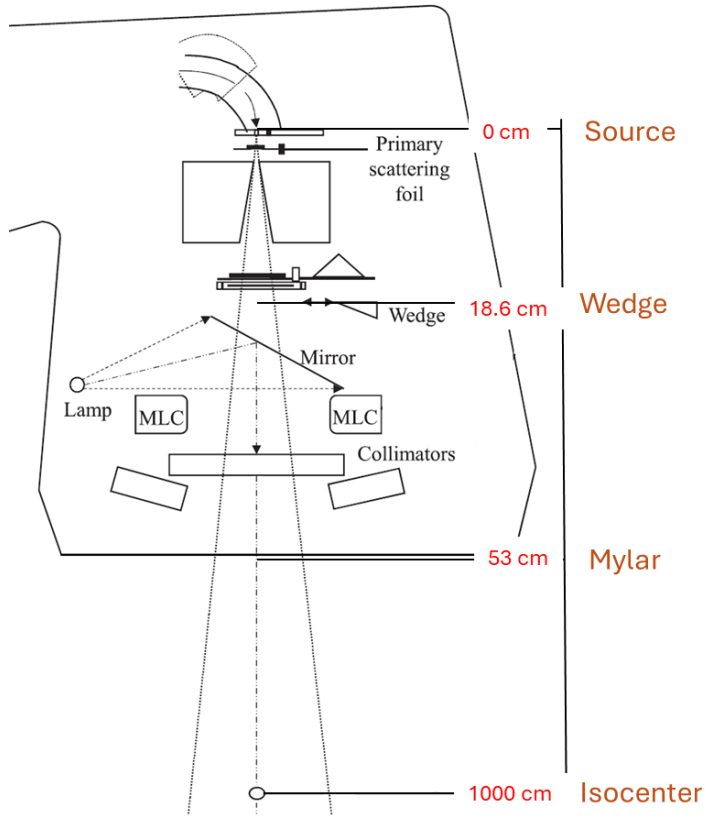
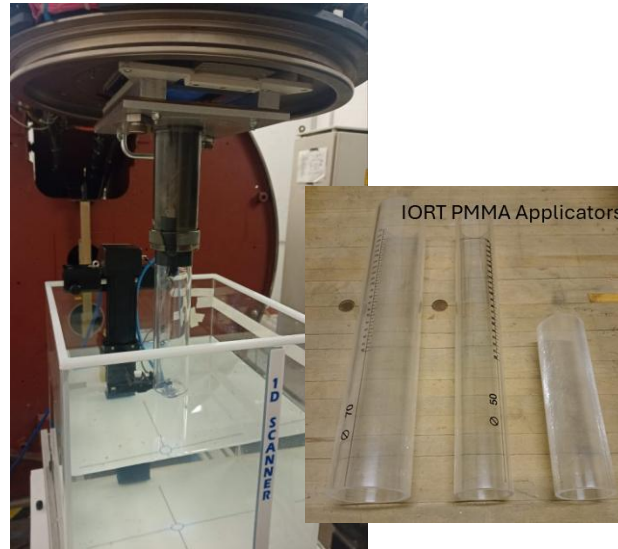


Table 2. Dosimetry results.

Setting	Mode	Dose Per Pulse (Gy)		Average Dose Rate (Gy/s)	
		Conv	UHDR	Conv	UHDR
Setting	Isocenter	$(1.60 \pm 0.08) \times 10^{-4}$	0.63 ± 0.04	$(1.60 \pm 0.08) \times 10^{-2}$	83.6 ± 4.2
	Applicator	$(2.52 \pm 0.13) \times 10^{-4}$	0.81 ± 0.04	$(2.52 \pm 0.13) \times 10^{-2}$	89.5 ± 4.5
	Crosshair foil	$(6.76 \pm 0.34) \times 10^{-4}$	2.22 ± 0.11	$(6.76 \pm 0.34) \times 10^{-2}$	309 ± 16
	Wedge *	$(0.92 \pm 0.05) \times 10^{-2}$	27.2 ± 1.4	$(92.3 \pm 4.6) \times 10^{-2}$	n.d. **

* Dose in air without build up. ** n.d.: not determined.

Deut, Umberto, et al. <https://doi.org/10.3390/app14177582>



Position	Conventional (mGy/pulse)	UHDR HP (Gy/pulse)
Isocenter	0.16	0.67
∅7cm Applicator	0.22	0.91
∅5cm Applicator (short)	0.25	1.5
Mylar (crosshair foil)	0.67	2.5
Wedge	9.1	27

Conventional vs Conventional with long applicator (5cm): +70% dose at isocenter

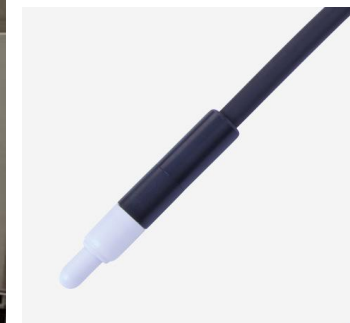
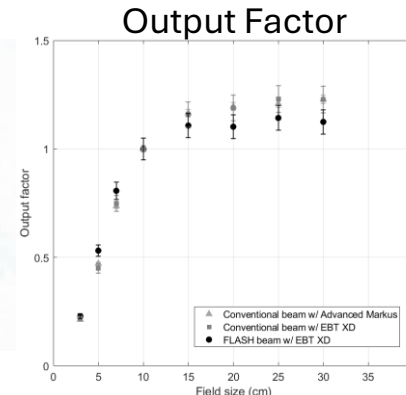
↓
Pulse Counting technique exploiting native IC of the linac



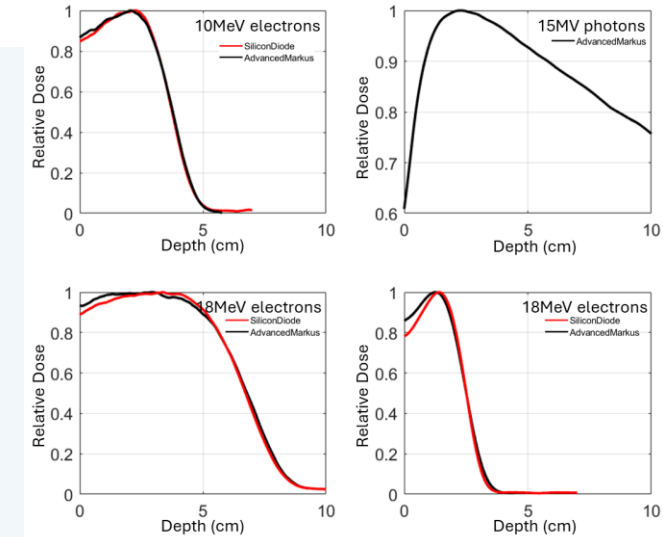
Beam characterization techniques and dosimetry

First dosimetry campaign (2023-2024)

conducted at the isocenter in clinical conditions following TRS-398, ICRU, IPEM, and AAPM TG-51 protocols.



Electrometer for Relative Dosimetry



Beam characterization techniques and dosimetry

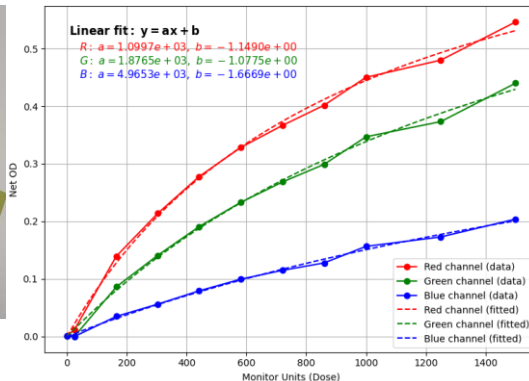
Second dosimetry campaign (2024-2025)

Accelerator characterization under ultra-high dose-rate (UHDR) beam conditions due to ionization chamber saturation.

Beam Profile and Absolute Dosimetry with Radiochromic Films

Ashland Gafchromic film type:

- **EBT3:** ~0.2–10 Gy
- **EBT4:** ~0.2–10 Gy
- **EBT-XD:** ~0.4–40 Gy



- High spatial resolution: down to 25 μ m
- Net optical density energy dependence (100keV to 18 MeV): 5%
- Dose measurement uncertainty after scanning procedure: ~5%

Calibration performed at the INFN linac, at San Luigi Hospital and Centro Pisano per la FLASH Radiotherapy (AOU Pisana)

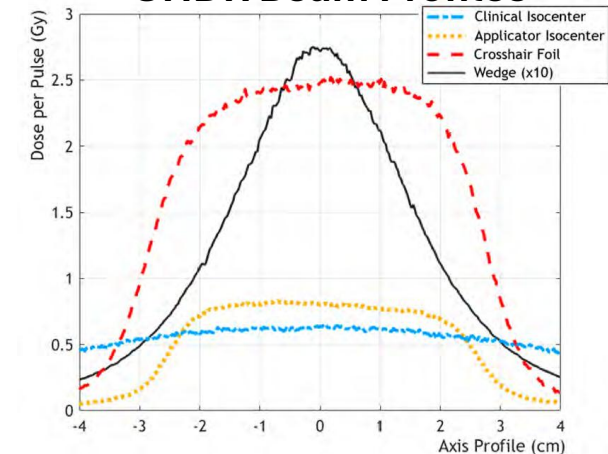
Solid Water Phantom (total thickness of 4.7cm)



RW3 PTW (30x30cm)

- 4 slab of 5mm
 - 4 slab of 2mm
 - 2 slab of 10mm
 - 2 slab of 10mm with adv markus holder
- GAMMEX 457 Standard Grade SolidWater**
- 1 slab of 20mm

UHDR Beam Profiles

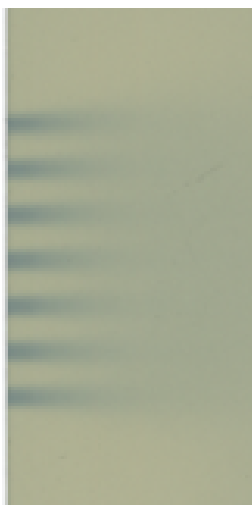


Beam characterization techniques and dosimetry

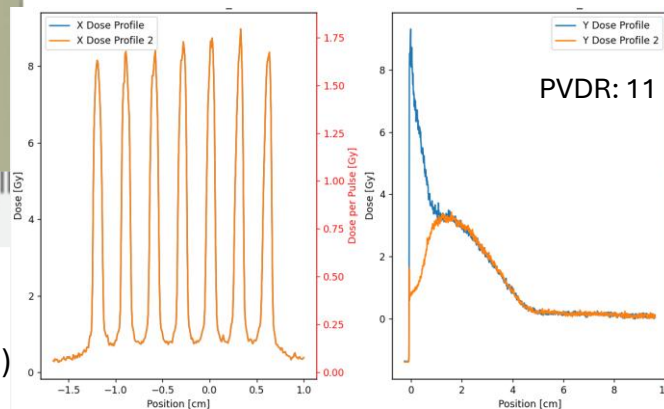
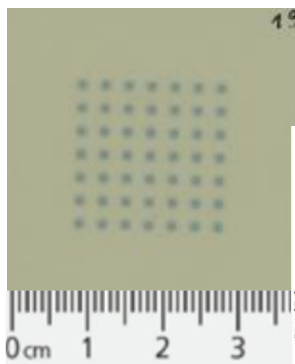
Third measurement campaign (ongoing)
Accelerator characterization for UHDR Spatial Fractionation

Radiochromic film inside RW3 Solid Water slabs

Dose decrease with depth
(vertical orientation)

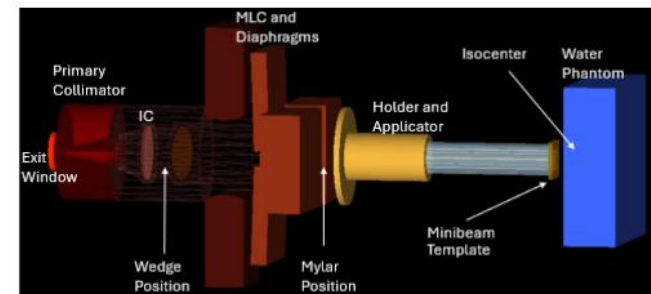


Beam profiles
(transverse orientation)



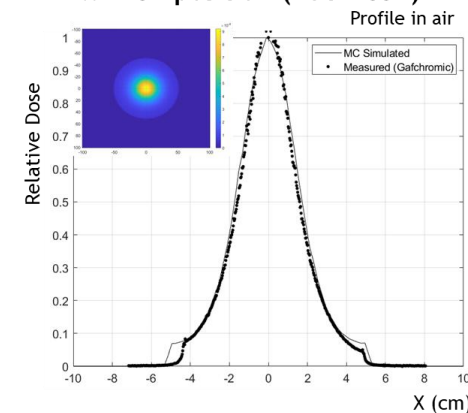
Up to **1.7 Gy/pulse** at the peaks
(@200Hz corresponding to 370 Gy/s)

Monte Carlo Simulations for beamshaping design

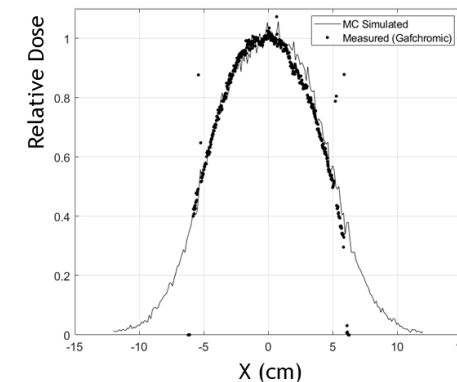


Specifically validated for electron beams

WEDGE position (18cm SSD)

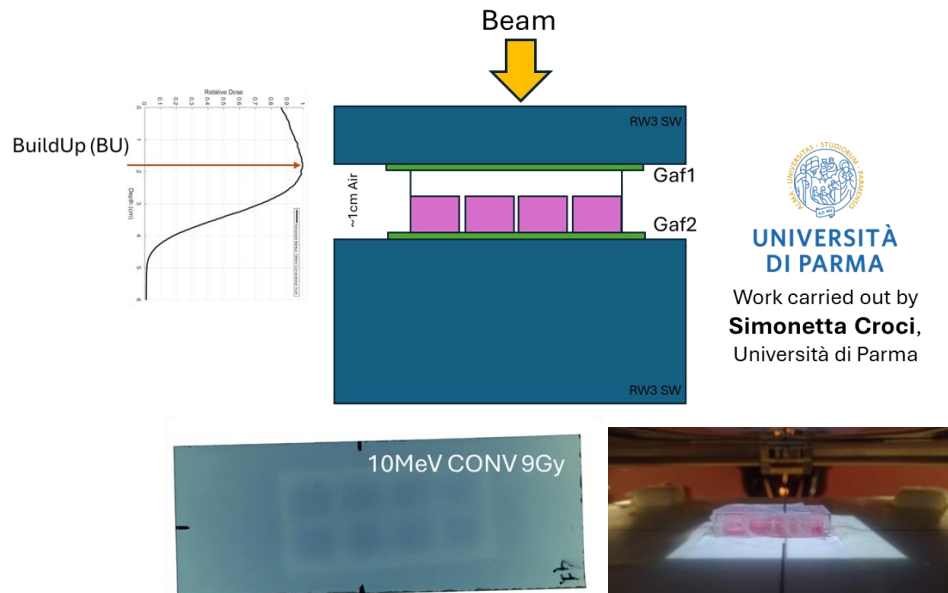
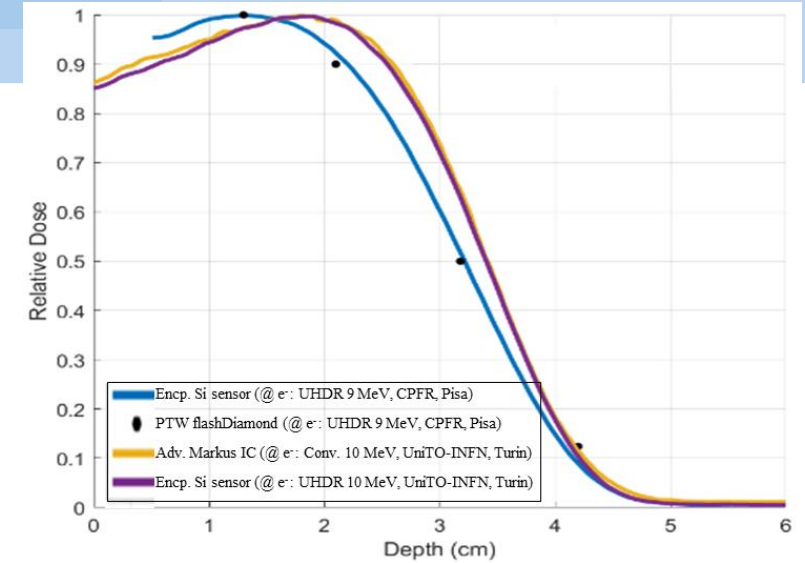


ISOCENTRE position (100cm SSD)

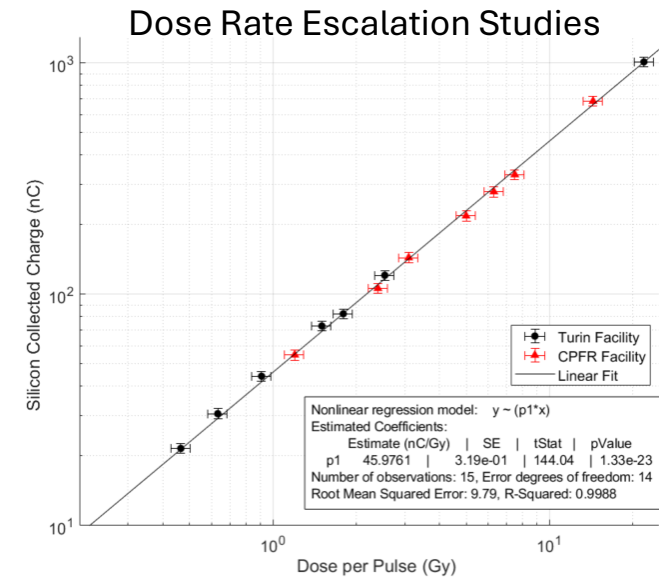


Activities

- UHDR Upgrade of a Conventional Linac
- Large irradiation field allowed technologies intercomparison
- Studies of new detectors for UHDR dosimetry
- Develop new readout electronics
- In-vitro radiobiology



UNIVERSITÀ DI PARMA
Work carried out by **Simonetta Croci**, Università di Parma





FLASH Radiotherapy with high
Dose-rate particle beams



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Thank you