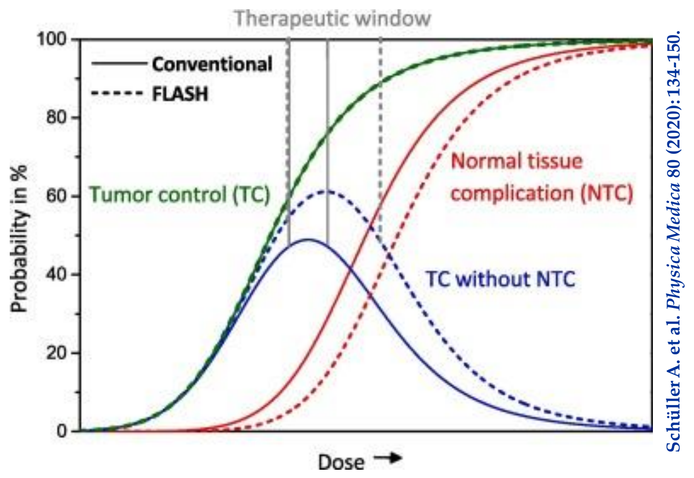
Innovative Radiotherapy Techniques

FLASH RT delivers radiation (electrons, photons, particles) at ultra-high dose rate (UHDR) with average dose rate > 40 Gy/s in < 200 ms.

Beam Characteristics	CONV	FLASH
Dose Per Pulse D_p	~0.4 mGy	~1 Gy
Dose Rate: Single Pulse $\dot{D}_p$	~100 Gy/s	~10^5 Gy/s
Mean Dose Rate: Single Fraction $\dot{D}_m$	~0.1 Gy/s	~ 100 Gy/s
Total Treatment Time T	~days/minutes	< 500 ms

Ashraf M R. et al. Frontiers in Physics 8 (2020): 328.



FLASH EFFECT: reduction of normal tissue complication probability (NTCP) while maintaining the same tumour control probability (TCP) as for conventional RT

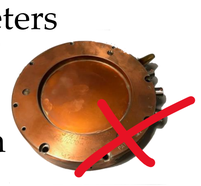
Challenges:

- Understanding and modeling the FLASH effect;
- Research and development in beam acceleration and delivery;
- Novel beam monitoring and dosimetry techniques;
- Software tools for FLASH treatments planning.

FRIDA project

Development of a new beam monitor system

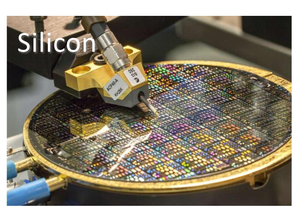
- New devices are needed to continuously check the beam parameters during UHDR irradiations
- **Ionization chambers (ICs)** (used in conventional RT) suffer from recombination effect and slow collection time in UHDR irradiations



- High temporal and spatial resolution
- Beam transparency
- Large response dynamic range
- Large sensitive area
- Radiation hardness

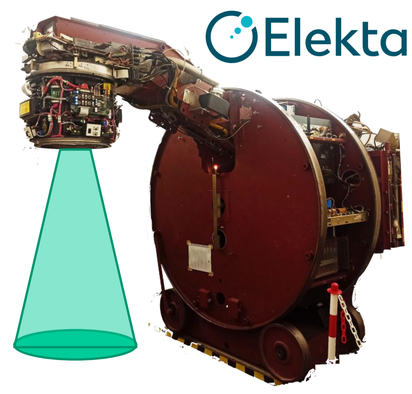
→ **Solid state detectors** fast signal (~ns) and temporal resolution < 100 ps

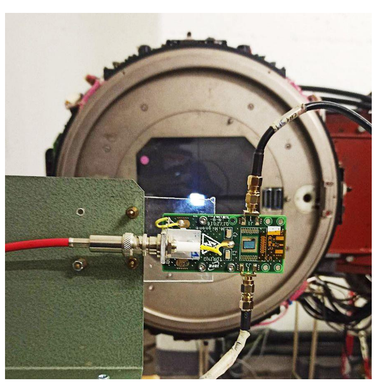
Three technologies are investigated within FRIDA :

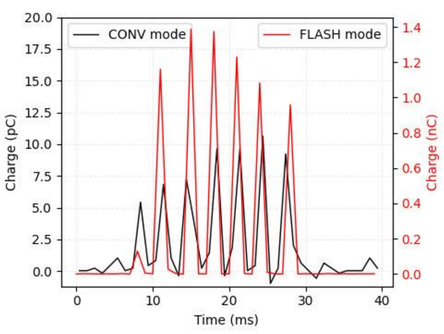


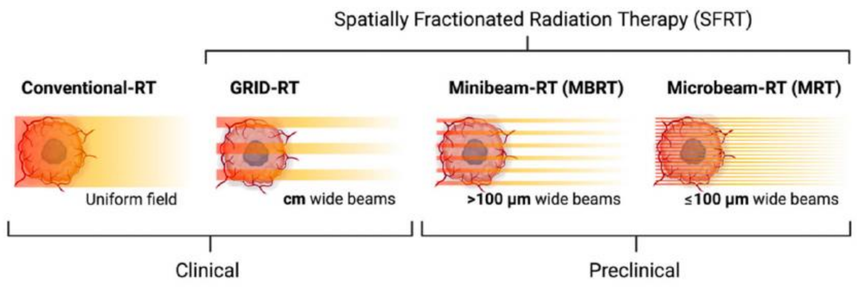
Upgrade of LINAC Elekta in our department

- LINAC **Elekta SL 25 MV** in the Torino Physics Dept.
- Electrons energy between 4 MeV and 18 MeV
- Modifications to the LINAC to enable the delivery of **10 MeV electron beams** at high dose-rates
- Gafchromics film, ionization chambers, silicon and diamond sensor → Beam characterization

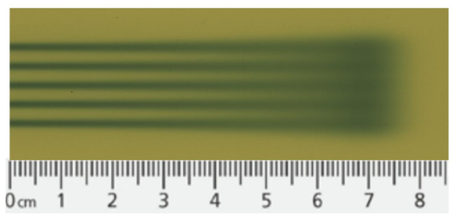




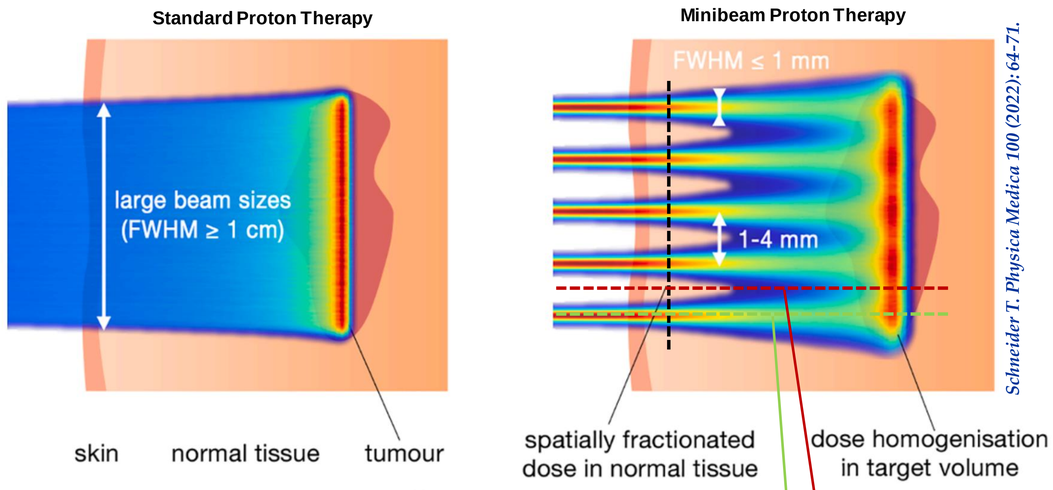




Fernandez-Palomo C. et. al. Cancers 14.15 (2022): 3625.



MINIBEAM EFFECT: Reduction of damages to normal tissues due to the spatial fractionation of the dose while maintaining a homogeneous coverage of the tumour volume.

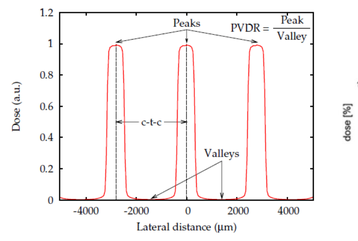


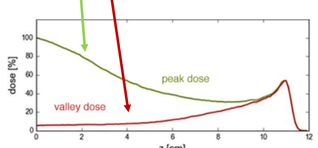
- Study minibeam electron beams up to 18 MeV with the Torino LINAC;
- Study the combination of minibeam and FLASH effect

The project is based on a strict collaboration with CPFR (Pisa) currently pioneering in-vivo radiobiology studies with FLASH and minibeam techniques.

Particles under study for minibeam RT:

- Protons
- Megavoltage Photons
- Electrons

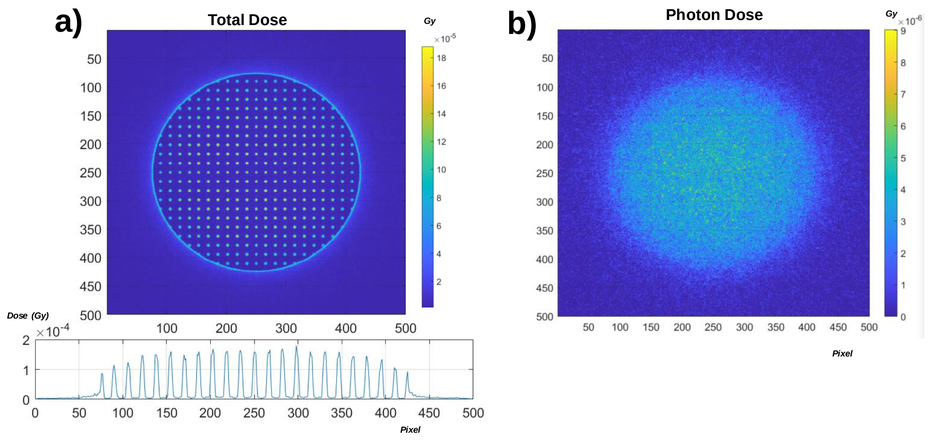




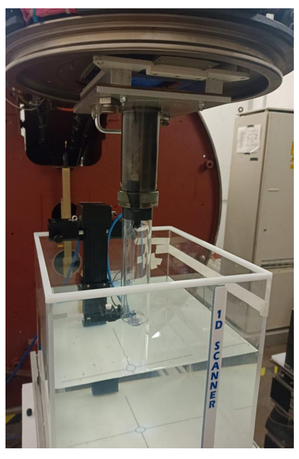
MIRO project

Collimation System Study – Simulations and Dosimetry

Monte Carlo simulation of 18MeV electrons on tungsten collimator (5mm thickness, 1mm holes, 3.2mm spacing). Dose distribution (a) and secondary particles contamination (b).



Beam Monitoring with Silicon Detectors



Our goals:

- Design the collimation and the applicator system
- Characterize the electron beam in terms of dosimetric quantities and secondary particle contamination
- Measure the beam profiles under FLASH conditions at the LINAC
- Monitoring with silicon detectors and 2D submillimetric mechanical positioning