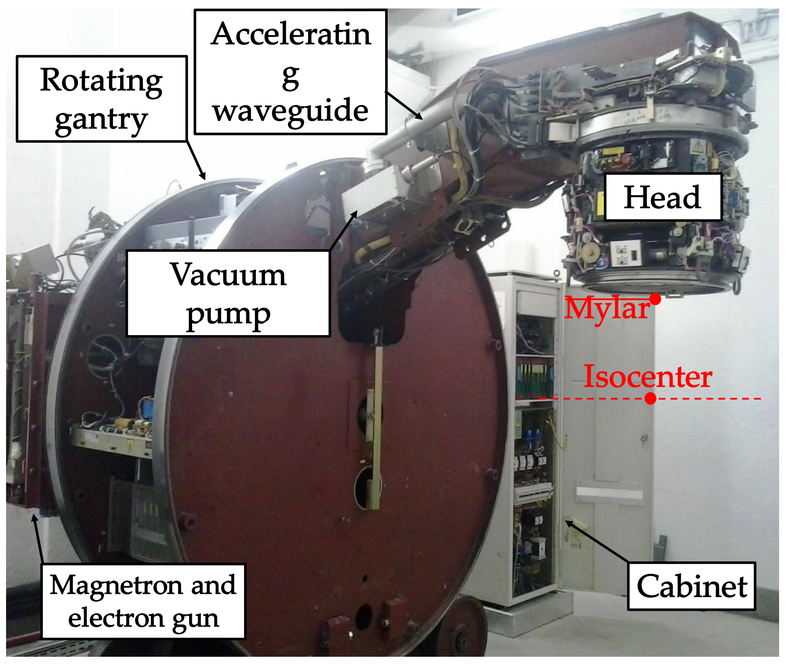
Solid state detectors for monitoring FLASH beams

INTRODUCTION

- Conventional radiotherapy (convRT) has been challenged by the emergence of the innovative FLASH radiotherapy.
- FLASH-RT: Delivery of Ultra-High Dose Rates (UHDR ≥ 40 Gy s^{-1}) in a single fraction lasting less than 200 ms [1].
- Challenges:
  - The number of facilities capable of producing UHDR is really limited.
  - Gas-filled ionization chambers (standard beam monitors used in convRT) have some limitations at high dose rates [2].


FRIDA

LINAC'S UPGRADE



LINAC ELEKTA SL 25 MV
Pulsed electron beam: 4 – 18 MeV

- Clinical LINAC modified to deliver "FLASH" electron beam.
- Upgrade stages:
  - Modification of the magnetron power configuration.
  - Secondary filters removal.
  - Development of a pulse counter circuit.
  - Installing an attenuator circuit to delay LINAC's interlock.

RESULTS & DISCUSSION

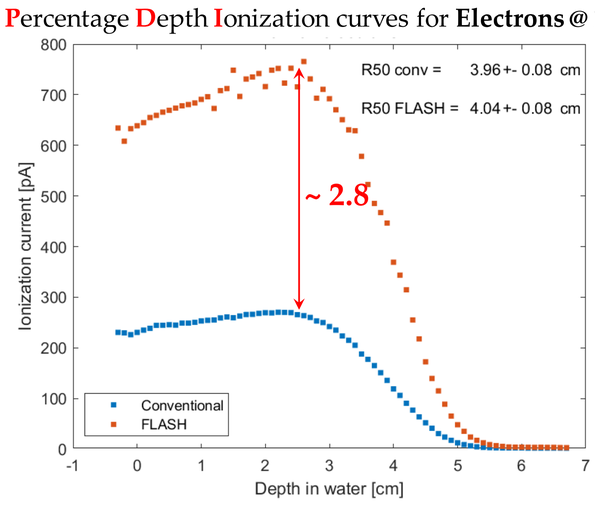
1. Dosimetry Study

A **dosimetric characterization** was performed to **verify** the **electron beam energy** after the LINAC upgrade.

ADVANCED MARKUS
Plane parallel ionization chamber
Sensitive volume: 0.02 cm^3

GAFChromic Film EBT3

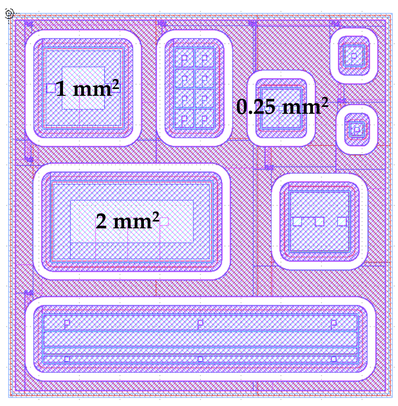
Percentage Depth Ionization curves for **Electrons @ 10 MeV**



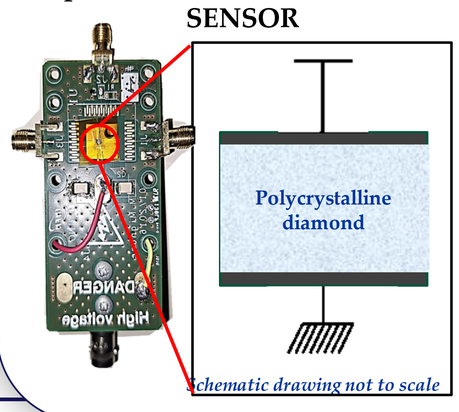
2. Innovative Solid State Detectors

SILICON PiN SENSOR

- Dimension: 4.7 × 4.7 mm^2
- Thickness: 30/45 µm
- Pad areas: 0.03 – 2.33 mm^2
- Bias Voltage: 200 V



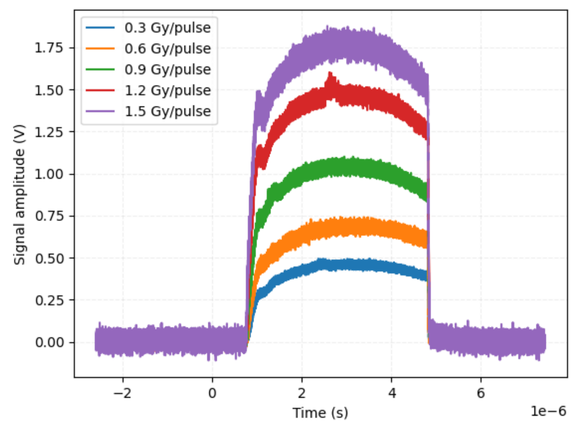
pCVD – DIAMOND BASED SENSOR

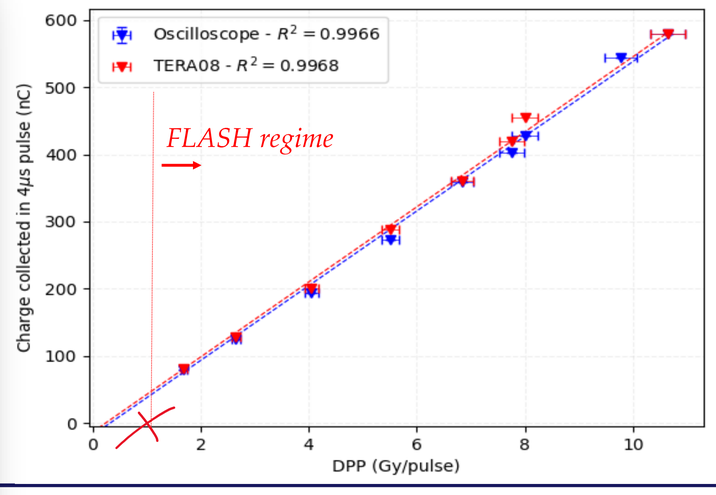


- Dimension: 1.3 × 1.3 mm^2
- Thickness: 100 µm
- Surface metalized with silver (~ 125 nm)
- Bias Voltage: 50 - 600 V

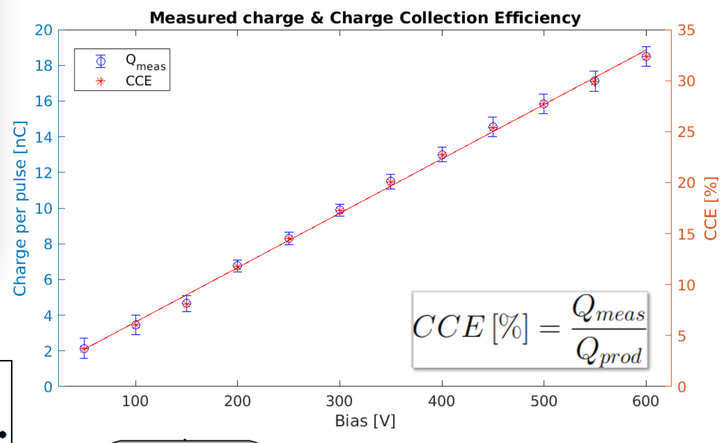
2.1 Silicon Sensor

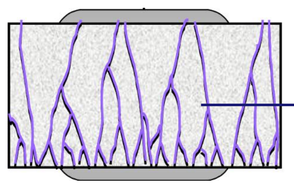
The **linear response** of the **Si sensors** was **successfully demonstrated** in an electron beam with a **DPP of up to 10 Gy** (Electron FLASH-CPFR).



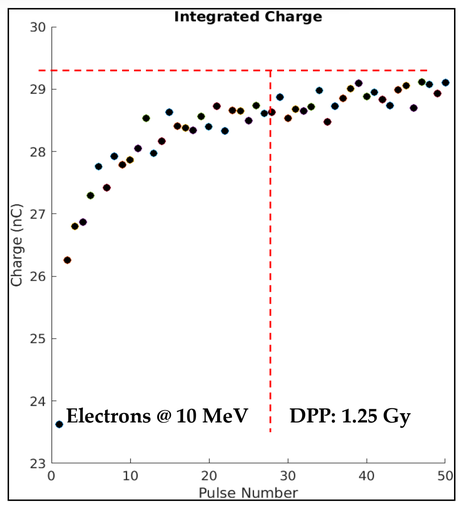


2.2 Diamond Sensor





Grain boundaries are electrons traps that act as recombination centers



The charge carriers produced by the **initial pulses "fill" the traps** allowing the **collected charge to reach a plateau** after a certain number of pulses.

Properties [3]	Silicon	Diamond
Atomic number	14	6
Band gap [eV]	1.12	5.50
Energy to form e-h [eV]	3.6	13
Displacement energy [eV $atom^{-1}$]	13	43
Charge carriers mobility [cm^2 V^{-1} s^{-1}]	~ 1350	~ 1808

CONCLUSIONS

- LINAC upgrade made it possible to deliver a 10 MeV electron beam with a higher dose per pulse than clinical beam.
- Solid-state detectors based on Silicon and pCVD-diamonds are good candidates for monitoring beams with Ultra-High Dose Rates.
- New prototypes for both sensors are being developed and tested.

REFERENCES

[1] Favaudon et al., 2014 https://doi.org/10.1126/scitranslmed.aba4525
[2] Marinelli et al., 2021 https://doi.org/10.1002/mp.15473
[3] Angelone & Verona, 2021 https://doi.org/10.3390/jne2040032

ACKNOWLEDGMENTS