Instrumentation of the FLASHGuard Prototype

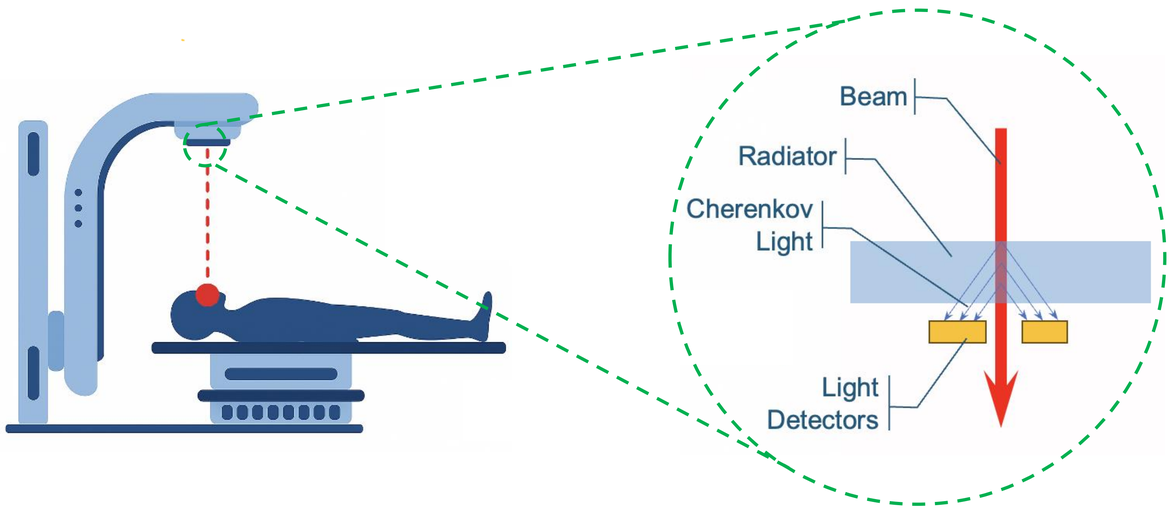
Gonçalo Roriz [a)]

a) goncalororiz@tecnico.ulisboa.pt; ist1106219

Supervisors:
Prof. Pedro Assis, Gonçalo Ribeiro

Introduction and the FLASHGuard Concept

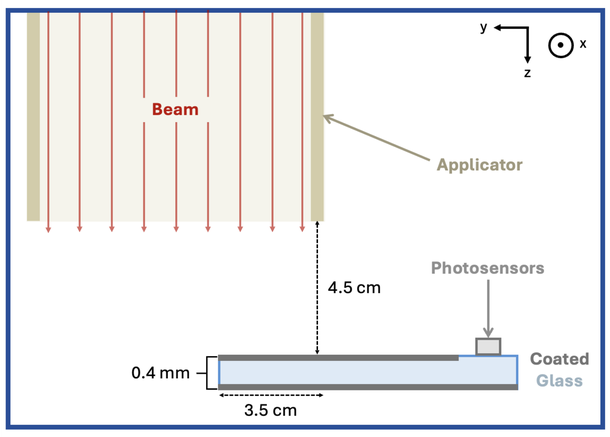
- **FLASH radiotherapy (FLASH-RT): new, game-changing therapy** that shows promise for **sparing healthy tissue while maintaining tumour control**.
- Its ultra-high dose rates (UHDR) demand **robust, fast, reliable beam monitoring**, a challenge current detectors struggle to meet.
- **Cherenkov-based detectors are a promising solution to this gap**, using light produced by the Cherenkov effect as their detection mechanism.
- **FLASHGuard**: beam monitoring device concept **(patent WO2026029686A1, 2026)** pairing a **Cherenkov radiator** with **fast photodetectors and electronics**, expected to achieve **sub-μs feedback to the machine** with **minimal beam impact**.

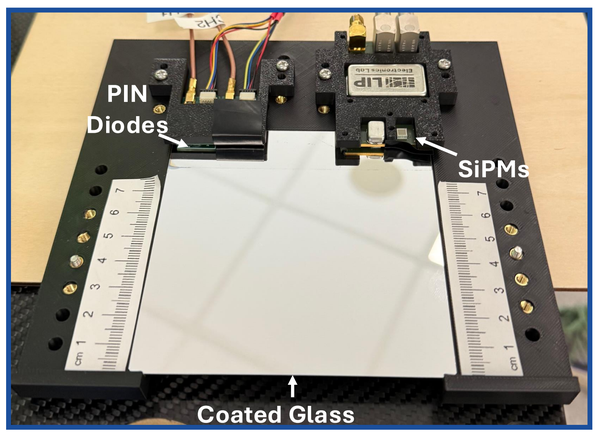


- The objective of this prototype was to **capture the internal structures of the pulses, previously unseen**, and **validate the concept in both UHDR and conventional (CONV) modes.**

Prototype Design and Testing Conditions

- **Radiator:** Thin soda-lime glass coated with a reflective thin film;
- **Optical coupling:** Photodetectors coupled to an uncoated portion of the glass using a silicon-based optical grease;
- **Shielding:** PMMA and lead based. A lead block was placed directly above the electronics.





Testing conditions:

- THERYQ FLASHKNiFE (LINAC)
- 6/9 MeV, 0.5-3 μs UHDR e^-
- 9 MeV, 1 μs CONV e^-

Readout channels:

- **SiPM1** (light detection);
- **SiPM2** (with black tape)
- **PIN1** (light detection);
- **PIN2** (with black tape)

Photodetectors and Electronics

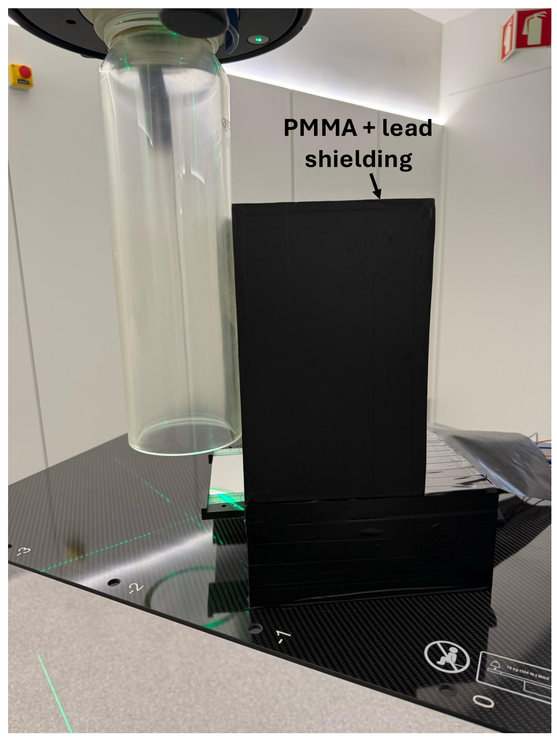
Sub-microsecond temporal resolution was necessary to resolve internal pulse structures → required fast photodetectors and electronics

- **Photodetectors:** Silicon Photomultipliers (SiPMs) and Si PIN Photodiodes (PIN Diodes)
  - **SiPM:** Hamamatsu S14160-3010PS
    - Capable of detecting single photons
    - Linear until ~10^{12} incident photons → large dynamic range, suitable for UHDR mode
    - Nanosecond rise times
  - **PIN Diode:** Hamamatsu S1223-01
    - Large dynamic range → capable of detecting high-light levels without saturation
    - Glass window + 1.3 mm air before the photosensitive surface // $A(\mathrm{Si}) \approx 12\% A(\mathrm{Total})$ → possibility for photons to exit the PIN Diode without being detected
- 2 SiPMs and 2 PIN Diodes were used in the prototype

SiPMs UHDR: Photodetector + Readout Circuit → Oscilloscope

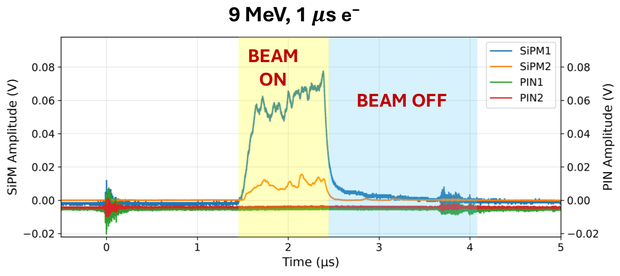
SiPMs CONV: / PIN Diodes UHDR/CONV: Photodetector + Readout Circuit → Amplifier → Oscilloscope

Results and Discussion



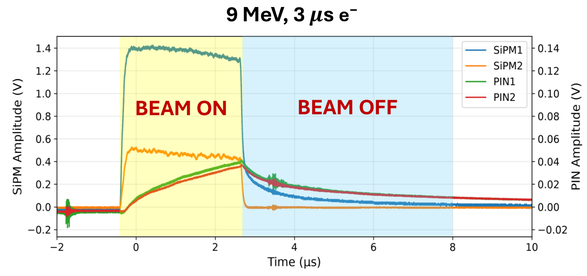
Conventional

9 MeV, 1 μs e^-



FLASH

9 MeV, 3 μs e^-



Both plots normalized by gain

- **SiPMs:** Detect light when beam is on!
  Signal-to-noise ratio: ~2 (UHDR), ~6 (CONV).
- **PIN Diodes:** Signal in UHDR only due to secondaries, no signal detected in conventional mode → **photons are not reaching the Si wafer due to the air gap after the casing**

Conclusions and Future Work

Successful operation was achieved.

The prototype was capable of resolving the internal pulse structure, which had never been seen in UHDR mode. Results also show successful operation in both conventional and UHDR mode, validating the concept for both radiotherapy modalities.

A collaboration with a major radiotherapy accelerator manufacturer to adapt the prototype for inclusion in their accelerator was established and is ongoing.

Next steps:

- Improve prototype for manufacturer needs and sell the product
- Publish results
- Continue development during PhD, partly carried out in Dartmouth College (USA) with Prof. Brian Pogue as co-supervisor

Preliminary results. Please do not disclose.

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