# A Real-time Fibre Optic Beam Monitor for VHEE FLASH Radiotherapy

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## Abstract

- Beam monitoring for Ultra High Dose Rate (UHDR) radiation therapy using Very High Energy Electrons (VHEE) is major challenge.
- Beam monitor consisting of a 2D array of silica optical fibres connected to a photodetector measures Cherenkov from VHEE beam is proposed in this work.
- First measurements with 200 $\mu$m silica optical fibre monitor at CLEAR using 200 MeV electrons at UHDR.
- Linear response observed at dose rates over 30 Gy/pulse.
- Excellent candidate for real-time beam monitoring for VHEE FLASH RT.

## Introduction

- Ionisation chambers saturate in the ultrahigh dose per pulse conditions required for VHEE FLASH [1].
- Radioluminescence-based detection capable of performing fast real-time measurements with high temporal and spatial resolution [2].
- Cherenkov radiation could be utilised for UHDR dosimetry due to instantaneous production and low energy dependence at VHEE energies [3].
- A novel detector for VHEE UHDR real-time beam monitoring consisting of array of silica optical fibre-based Cherenkov sensors connected to a photodetector could be an alternative technology.

## Materials and Methods

- **200 $\mu$m silica fibre** with 20 cm sensitive region.
- Tested at CLEAR with **200 MeV electrons**.
- One setup with either SiPM or PMT (with ND = 6.0 optical filter) attached directly to sensitive region.
- Second setup with fibre sensitive region rotated 45°, and 28 m transport fibre, readout with CCD camera.
- Charge per pulse to dose-in-water per pulse conversion obtained using radiochromic films.

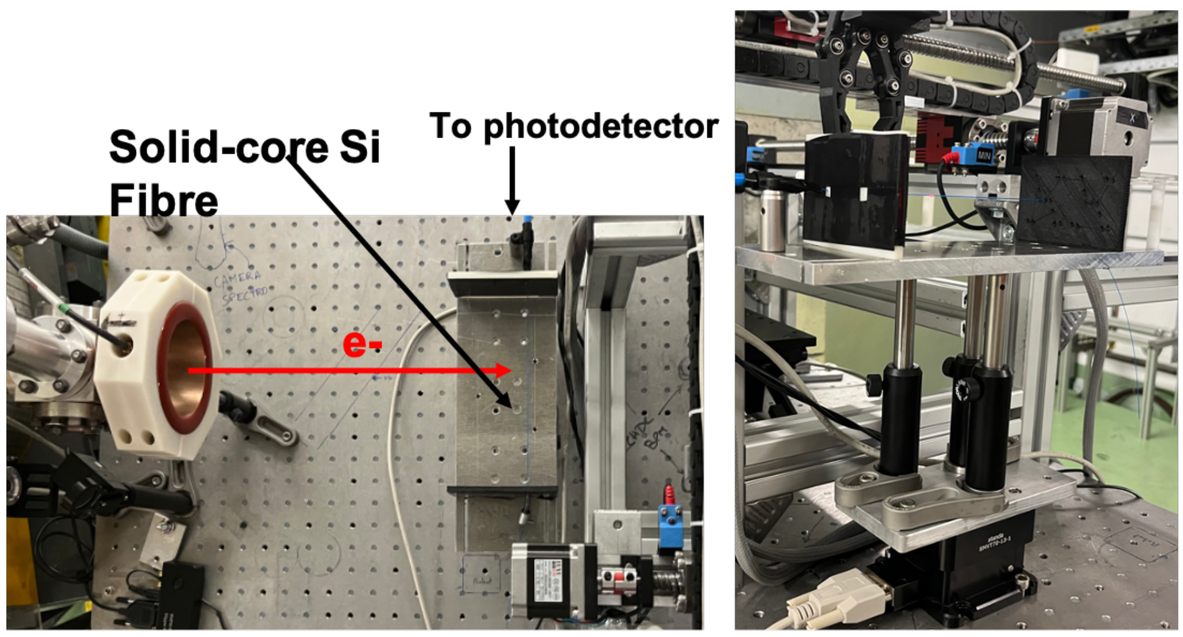


Figure 1. Setup of the fibre optic detector at CLEAR for the SiPM and PMT photodetectors (for the CCD camera the sensitive region of the Si fibre was oriented at 45° to the direction of the beam).

## Results

### SiPM Setup

- Linear response seen up to **38 Gy/pulse**.
- SiPM response begins to saturate around 50 bunches.

### PMT Setup

- Near linear response seen up to **20 Gy/pulse**.
- Non-linearities in PMT response occurs after this due to saturation and changes in instantaneous dose rate.

### CCD Setup

- Linear response seen up to **39 Gy/pulse**.
- Projection of vertical profile measured for 10 nC pulse as **1.70 ± 0.064 mm**, compared to **1.83 ± 0.059 mm** measured on YAG screen.
- Signal-to-noise ratio is low below pulse charges of 1 nC - reducing accuracy of beam profile and intensity measurement.

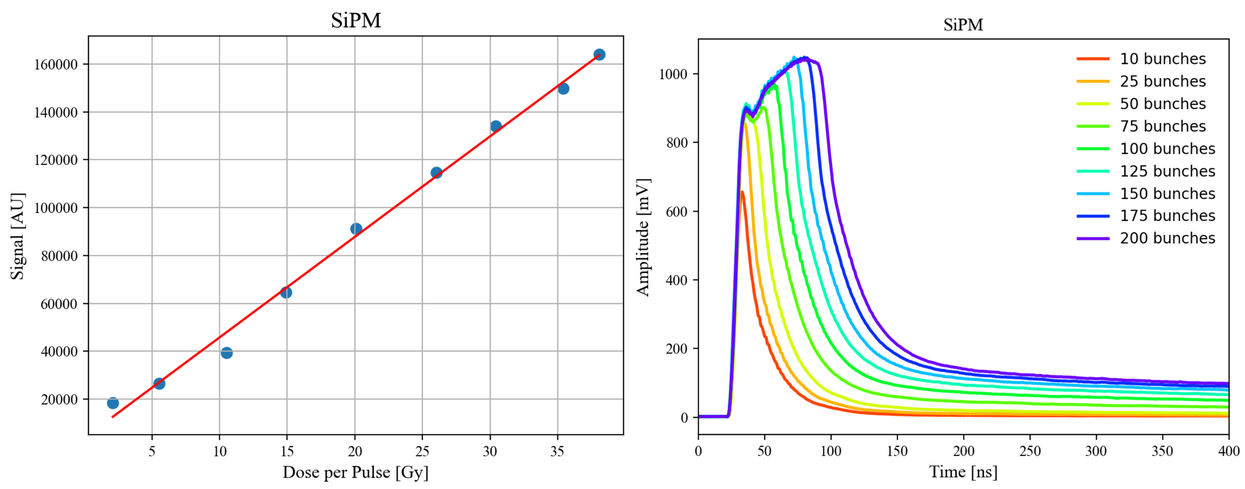


Figure 2. Dose per Pulse response (left) and individual responses to 1.1 - 19.9 nC (right) for the SiPM setup.

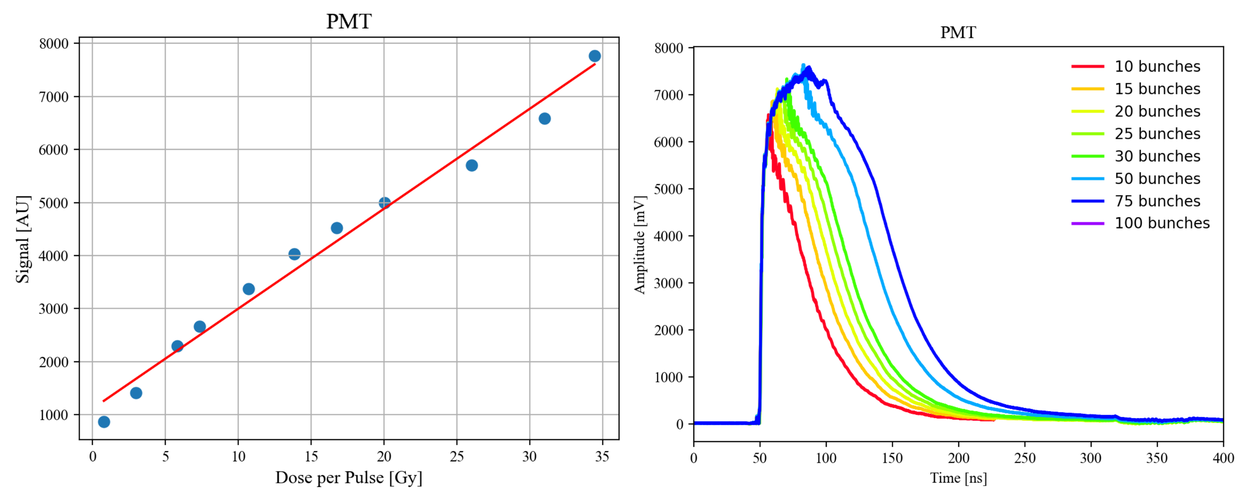


Figure 3. Dose per Pulse response (left) and individual responses to 0.4 - 18.2 nC (right) for the PMT setup.

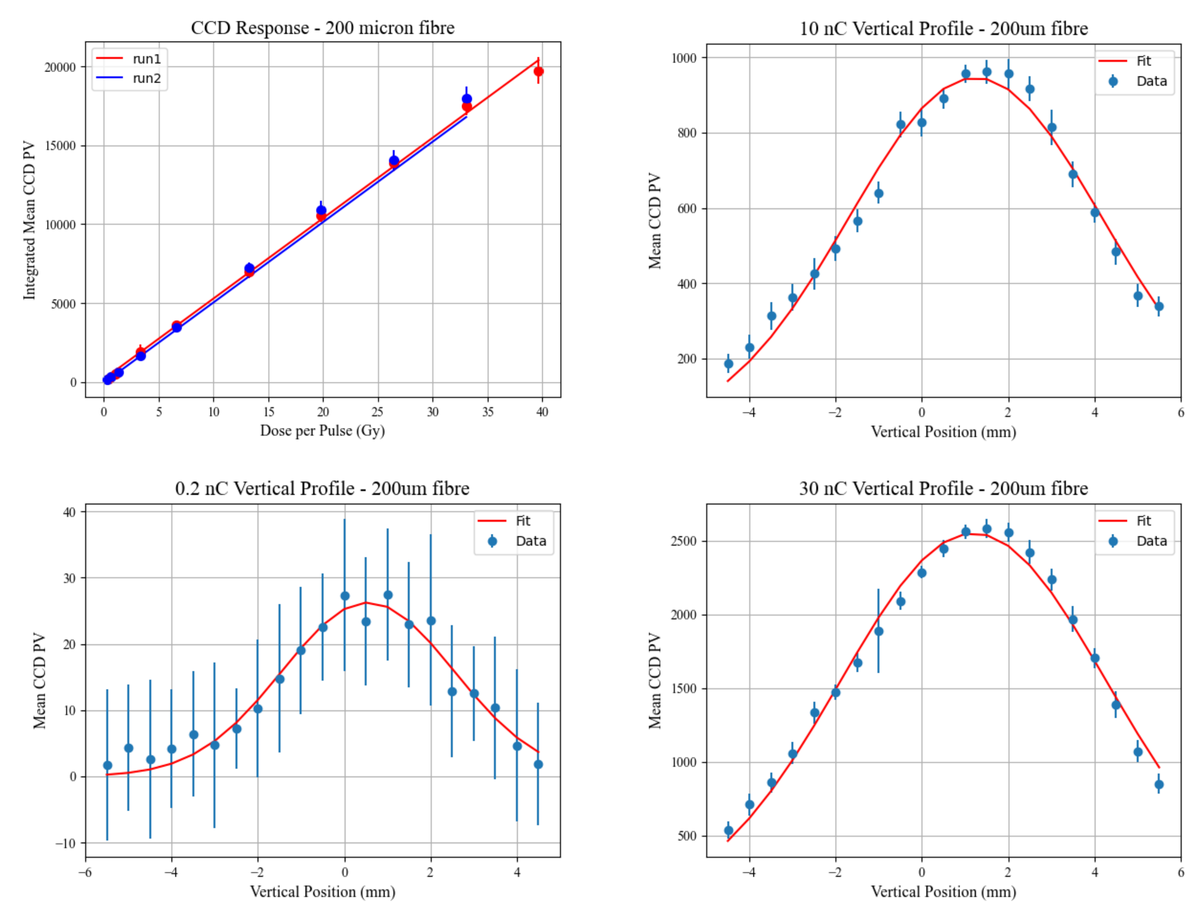


Figure 4. Dose per Pulse response (left) and projection of the vertical profiles of the VHEE beam with a pulse charge of 10 nC (top right), 0.2 nC (bottom left) and 30 nC (bottom right) for the CCD camera setup.

## Conclusions and Future Work

- CCD camera setup provided most linear response over largest range into UHDR regime, but had poor signal-to-noise ratio at lower pulse charges.
- SiPM and PMT have best temporal resolution but response saturated.
- Next step to build array and use a single CCD camera for readout, with a PMT/SiPM for temporal information.

## References

[1] M. M. *et al.*, "The challenge of ionisation chamber dosimetry in ultra-short pulsed high dose-rate Very High Energy Electron beams," *Sci Rep*, vol. 10, p. 9089, 2020.

[2] F. R. *et al.*, "Ultra-high dose rate dosimetry: Challenges and opportunities for FLASH radiation therapy," *Med Phys*, vol. 9, pp. 4912–4932, 2022.

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