Klinik und Poliklinik für Strahlentherapie und Radioonkologie

Dosimetry and FLASH Radiotherapy experiments at ARES

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The FLASH Effect and High-Energy Electrons for Future Tumor Treatment

Several preclinical studies indicate that radiotherapy treatment delivered with an ultra-high mean dose rate (>40 Gy/s) results in higher normal tissue tolerance compared to treatment delivered with a conventional dose rate of about 0.1 Gy/s (known as the FLASH effect). Furthermore, very high-energy electrons (VHEE, E > 100 MeV) have the capability to penetrate deep into the body and hold potential for effective treatment of deep-seated tumors in the future.

Exploring ARES Beam Properties for VHEE FLASH Radiotherapy

Our study aims to investigate the beam properties of ARES and establish reproducible conditions for pre-clinical experiments in very-high-energy electron (VHEE) FLASH radiotherapy. We will modify the time structure of electron bunches to achieve different mean dose rates per pulse, allowing for precise control over radiation delivery. By determining the longitudinal and lateral beam profiles, we aim to characterize the spatial distribution of radiation and optimize treatment planning. Additionally, we will analyze the shape of the depth-dose curve to gain insights into the energy deposition pattern, facilitating a deeper understanding of the treatment's effectiveness.

Accurate Dosimetry Methods for ARES Beam Investigations

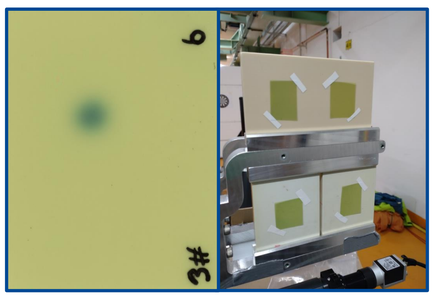


Figure 1: Initial Configuration for Film Dosimetry at ARES.
Films are mounted on Water-Equivalent Plates

In our experimental setup, we employ Gafcromic™-films, which are characterized by a dose response independent of the mean dose rate, enabling precise measurements. To investigate the three-dimensional dose delivery, water-equivalent plates are utilized in conjunction with the films (Figure 1). Additionally, we implement a rapid procedure in ARES to effectively block and integrate the dark charge during main irradiation. Accurate measurement of the absolute charge delivery is crucial for our analysis. By adjusting the charge per pulse, we can explore various dose rates per pulse. Furthermore, calibration curves are recorded using UKE medical linear accelerators to ensure accurate dose estimation (Figure 2). To achieve a flat top beam profile, we incorporate a lead collimator, although this improvement comes at the expense of dose (Figure 3).

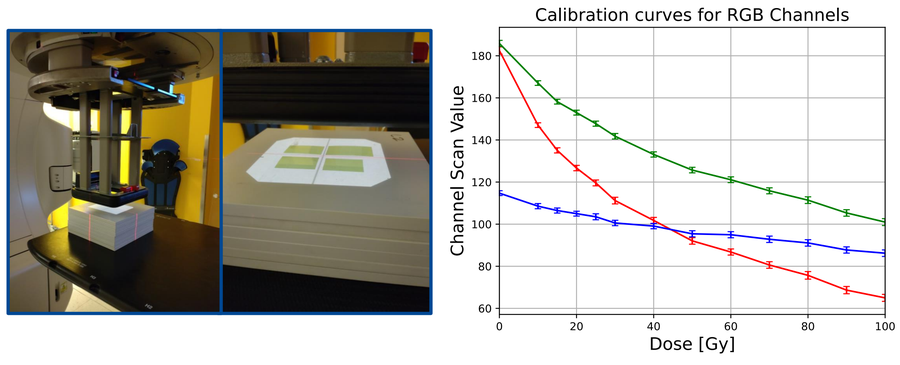
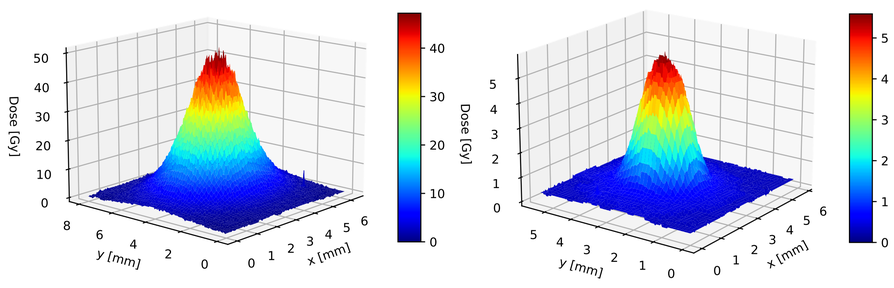


Figure 2: Film Calibration Setup at the UKE and Calibration Curves for RGB Color Channels plotted against Dose.



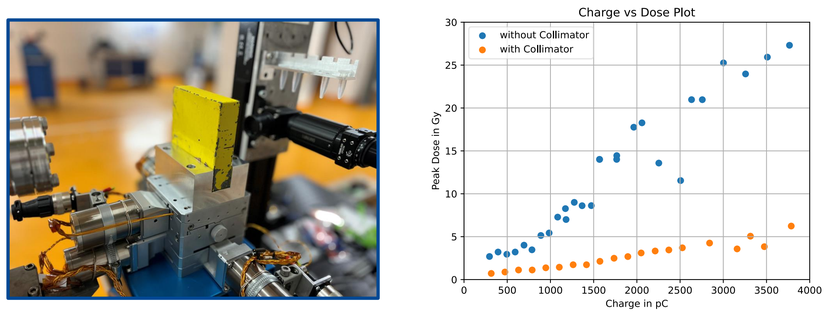


Figure 3: Dose Surface measured with Gafcromic™ Film for an Accumulated Charge of 3700 pC:
(top-left) Film without Collimator
(top-right) Film with Collimator
(bottom-left) Image of the Lead Collimator
(bottom-right) Dose vs Charge Plot with and without lead Collimator

Future Directions in ARES Beam Investigations for Radiotherapy Advancements

To advance the field of radiotherapy, our ongoing research focuses on further optimizing the irradiation procedure to ensure result reproducibility. Additionally, we aim to record a comprehensive depth dose curve spanning several centimeters, providing valuable insights into the dosimetric properties of the electron beam. Numerical simulations will be employed to compare and validate experimental data, aiding in the refinement of our findings. Furthermore, the determination of the most suitable beam size for in vitro FLASH experiments is crucial. Once these immediate objectives are achieved, our investigation will extend to exploring the FLASH effect in cell experiments. Moreover, we plan to assess the applicability of VHEE FLASH radiotherapy in pre-clinical studies by utilizing diverse phantoms, including mouse phantoms.

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