Advanced Detector Technologies for Dosimetry in Conventional and FLASH Radiotherapy

G. Petringa[1], A. D. Pappalardo[1], R. Catalano[1], S. Arjmand[1], G. Cuttone[1], D. Oliva[1], J. Suarez-Vargas[1], F. Abubaker[1], F. Farokhi[1], S. Fattori[1], M. Guarrera[1], A. Hassan[1], A. Kurmanova[1], N. Macaluso[1], A. Sciuto[1] and G.A.P. Cirrone[1]

1) Istituto Nazionale di Fisica Nucleare - Laboratori Nazionali del Sud (INFN LNS) - Catania, Italy.

Dosimetry for conventional and ultra-high dose rate (FLASH) beams involves fundamentally different challenges and requirements, directly influencing the choice and design of detectors. Conventional beam dosimetry typically operates at dose rates of 1-10 Gy/min, allowing for the use of detectors with different properties as moderate temporal, spatial and energetic resolution combined with a well-established calibration protocol. In contrast, FLASH radiotherapy delivers doses at rates exceeding 40 Gy/s, necessitating detectors with ultra-fast temporal resolution, high saturation limits, and resistance to dose rate-induced artifacts. These differing requirements underscore the critical role of advanced detector technologies in ensuring precise and reliable dosimetry for both modalities.

A variety of detector technologies are currently employed to meet these demands. Silicon detectors, widely used for conventional beam dosimetry, offer high sensitivity and mature fabrication techniques but face limitations in radiation hardness under high-dose exposure. Silicon carbide detectors, known for their exceptional radiation tolerance and fast response, have proven effective for both conventional and FLASH applications. Ionization chambers, the gold standard in clinical dosimetry, provide high precision and stability, though their temporal resolution may fall short for FLASH therapy. Scintillators, valued for their ability to provide real-time measurements, and diamond detectors, with their superior charge carrier mobility and radiation hardness, further expand the toolkit for dosimetry.

Emerging materials, such as perovskites and organic-inorganic hybrids, offer exciting opportunities to address the limitations of existing systems. However, challenges related to stability, reproducibility, and scalability remain critical hurdles to overcome.

This work integrates an overview of the challenges in dosimetry for conventional and FLASH beams with a review of current detector technologies, highlighting their strengths, limitations, and potential for future development. By advancing these technologies, we aim to enable more precise and effective radiation therapies, particularly in the rapidly evolving field of FLASH radiotherapy.