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Development and characterisation of an air-fluorescence-based beam monitor for ultra-high dose rates

Maximising tumour control while reducing harm to surrounding healthy tissues is a central goal of radiotherapy (RT) and particle therapy. Recent pre-clinical studies in delivering ultra-high dose rates (UHDR, >100 Gy/s) within very short treatment times (<500 ms), through narrow (~µs) and high-dose (~1 Gy) pulses, have observed an enhanced protection of normal tissues from radiation-related damages while maintaining an anti-tumour effectiveness comparable to that of conventional RT. This phenomenon is referred to as the "FLASH effect". The strong interest sparked by this experimental evidence has driven extensive research into monitoring methods for charged particle beams at UHDR. FLASH introduces unique challenges, as conventional detectors often suffer from non-linearities caused by the extremely high particle flux.
A specific research line pursued within the FRIDA collaboration of the National Institute for Nuclear Physics (INFN) has been dedicated to real-time measurements of beam fluence and spatial distribution of a therapeutical beam at UHDR; among the various proposed solutions, the proponents have investigated the possibility to exploit the detection of optical photons produced by fluorescence from the passage of charged particles across a volume of air. A detector based on this principle, applied innovatively in this context, could offer a linear response across different charged beams and a wide range of dose rates and energies, ultimately enabling the development of a simple and cost-effective device. Another significant advantage of this system is the capability to perform a non-destructive measurement with minimal impact on the beam energy and spatial distribution.
Several prototypes have already been built for proof-of-concept tests, supported by FLUKA Monte Carlo simulations for geometry optimisation. Background evaluation has proven critical for detector design, leading to the exploration of multiple approaches to isolate the relevant optical photon signal. Data analysis from test beam campaigns with electrons delivered at FLASH intensities by the ElectronFlash LINAC at the CPFR in Pisa and at the Beam Test Facility (BTF) at the National Laboratories of Frascati (LNF) demonstrated a linear relationship between the detected signal and the delivered dose-per-pulse across the entire intensity range studied, and a preliminary algorithm has been implemented in the analysis showing that it was indeed possible to observe a shift of the beam position with respect to a reference axis. These results confirm that fluorescence can be reliably used for beam monitoring in FLASH-RT investigations.
In this contribution, the project will be presented, along with its expected performances, results from test beams performed with electron beams in FLASH mode and insights in future activities.

Topic

Gas detectors

Title

Development and characterisation of an air-fluorescence-based beam monitor for ultra-high dose rates

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