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Development of a Gas-Jet based Ionization Profile Monitor for Proton FLASH Therapy

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The global acceptance of proton therapy for cancer treatment due to the conformal dose delivery to the tumour and effective sparing of normal tissue, by the benefit of Bragg peak, has been significantly increased recently. This further lead into the development of advanced treatment delivery techniques such as proton FLASH therapy utilising instantaneous Ultra High Dose Rates. With the FLASH effect, a better Tumour Control Probability (TCP) to Normal Tissue Complication Probability (NTCP) ratio can be achieved, which indicates the improved Organ at Risk (OAR) sparing than the conventional proton therapy. One of the technical challenges to establish FLASH protons are the limited dosimetry of the high intense proton beams with short pulse width, especially for laser-driven protons. Most of the dosimetry methods are either saturates or erroneous for these proton beams. In this study, a gas-jet based minimally invasive beam profile monitor is introduced with the end goal of real-time monitoring.

The working principle of gas-jet based IPM monitor is detecting the ionization of gascurtain caused by the incident ion beam, while preserving the profile information of the ions. The produced ions are further drifted towards the detector mounted at the top of
the drift region with the help of an external electric field. The Micro-Channel Plate (MCP)- phosphor screen assembly amplifies the signal and produce the beam profile, which can be then captured by CMOS camera mounted on the detector system. The beam-profile measurement done at the University of Birmingham ensures the suitability of the system for proton beams at energies 10.8, 16, 20 and 28 MeVs. The existing
Detection part of the system modified to generate a compact extraction system, vacuum chamber and a high gain MCP-phosphor screen assembly. The modified design will be assessed to check the feasibility of easy integration with the medical accelerators and will address the space limitation.

The CST simulations were performed for the previous and upgraded designs with a target to reduce the size by 25% and to have the similar uniform electric field distribution along the drift region. The energy gained by the ions at the MCP is kept as 2 keV, which will ensure the detection efficiency of 85%. A significant inhomogeneity in energy distribution at the MCP around ±7% or more was found for the beam sizes from
10 mm. This will be addressed in the future design by adjusting the geometry and bias potential for the plates in order to focus the beam to obtain less uncertainty in the energy distribution. The shift in trajectory due to the directional velocity of the gas-jet was reflected in the profile. It is not affecting the measurement of beam profile. But
need to quantify the shift to get the precise beam position. The effect of beam fluctuations, ion states, space charge effect of the beam and the realistic density distribution of gas curtain will be accounted for future studies.

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