Measurement of scanned ion beam parameters using 2D MatriXX detector

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Background

The quality assurance (QA) procedure has to check the most relevant beam parameters to ensure the delivery of the correct dose to patients. Practical implementation of a QA program depends on the detail of the beam delivery. The specificity of scanned heavy ion beams for cancer treatment requires the development of accurate QA checks that is most commonly performed with film dosimetry. Films do not provide immediate results and the time required for developing, scanning, calibration, and off-line analysis is time consuming.
The purpose of this work is to answer the question whether for ion (proton and Carbon) beam therapy, film dosimetry can be replaced with a 2D detector, specifically with MatriXX as a real time tool.

Methods

I'mRT MatriXX, a commercial 2D matrix of ionization chambers, is intended for pre-treatment verification of 2D dose distribution mainly for routine QA of high energy photon and electron beams. The device is equipped with 32×32 parallel plate vented ion chambers pitch of 7.619 mm.
MatriXX, placed at the isocenter, and GAFCHROMIC® film, positioned on MatriXX entrance, were exposed to proton and carbon ion beams at CNAO facility. The beam energy was kept constant and equal to 131.44 MeV for proton and 221.45 MeV for Carbon ion beam.
MatriXX data taking, in conjunction with the OmniPro-I'm*RT*® software, gives the possibility of acquiring consecutive snapshots. Time interval covered by a snapshot was chosen equal to 500 ms, so that each spill (≈1 s) was split over three snapshots and the beam cycle (≈4 s) into 9 snapshots. The out-of-spill snapshots were used to measure the electronics background level. Data from each snapshot were logged as text files for further analysis, which was implemented with NI LabVIEW. Radiochromic films, exposed concurrently with most of the data taking session, were scanned with EPSON scanner and analyzed using software programs developed in-house.
Being the width of carbon ion beam rather small (≈6 mm) w.r.t. the MatriXX chamber pitch (≈7.62 mm), a correction according to the beam position was carried out following a simulation and then applied to the actual MatriXX measurements.

Results

For both proton and carbon ion beams, we focused on field dose uniformity, flatness, beam position measurement and beam width determination.
For a region of interest covering 6×6 cm^2 square field the resulting field flatness was found to be better than 2%. The relative standard deviation from being constant of 2×2, 4×4 and 6×6 pixels from MatriXX measurement gives the uniformity equal to 1.5% in good agreement with those obtained from film.
MatriXX determined the beam center position with a resolution better than 200 µm for Carbon and less than 100 µm for proton beam.
The FWHM determination is affected by the actual beam transverse spread; for a beam wider than 10 mm (FWHM) the results are satisfactory, whilst smaller beams the determination is uncertain.

Conclusion

Precise beam position and fast 2D dose distribution can be determined in real time. The level of accuracy reached shows that MatriXX is quick and accurate enough to be used in charged particle therapy QA.