A novel method for assessment of nuclear interactions of therapeutic helium-ion beams using the Timepix detector

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Purpose: Ion beam radiotherapy exploits the advantageous shape of the Bragg curve, resulting in conformal dose distributions. Helium ions, being heavier than protons, exhibit lower scattering than protons. Moreover, their lower charge leads to lower biological effectiveness when compared to carbon ions. These characteristics make helium ions attractive for future radiotherapy, especially for pediatric patients. However, before helium ions can be implemented in the clinical practice, it is necessary to obtain further information on the nuclear interactions between beam particles and patient tissues. Particularly important factors are the attenuation of primary ions fluence and the amount of arising secondary fragments. This information is an important input for biological models employed in treatment planning. In this contribution we present a novel method for measurement and identification of ions in mixed helium beams.

Materials and methods: Measurements were performed at the Heidelberg Ion-Beam Therapy Center (HIT) in Germany. Abundance of helium ions and lighter fragments arising in PMMA, water, and different tissue-equivalent materials were investigated. Single particles were detected using the highly pixelized (55 μm) semiconductor detector Timepix [1], developed by the Medipix Collaboration at CERN. Its sensitive volume consists of a 300 μm thick silicon layer with an area of 1.4x1.4 cm². Timepix detectors were placed perpendicular to the helium beam. The first of them in front of the target served for monitoring of single incoming particles. The second one behind the target was used to register helium ions and fragments. The information on the time coincidence between the two detectors enabled us to relate the beam particles and patient tissues. Particularly important factors are the attenuation of primary ions fluence and the amount of arising secondary fragments. This information is an important input for biological models employed in treatment planning. In this contribution we present a novel method for measurement and identification of ions in mixed helium beams.

Results: Pattern recognition [2] of the single particle signals was found to be capable of distinguishing between helium ions and lighter fragments, as shown in Fig.1. The numbers of helium ions and fragments behind the used targets were quantified. As expected, we found an increasing amount of fragments and a decreasing amount of helium ions for increasing the thickness of PMMA targets. Furthermore, a comparison of measurements behind PMMA and water targets, with the same water-equivalent thicknesses, shows that the numbers of helium ions and fragments agree rather well for thin targets while greater differences were found for thicker targets.

Conclusion: The small and versatile Timex detectors allow to investigate the abundance of different ion types in helium ion beams. The whole setup is about two orders of magnitude smaller than previously used apparatus based on time-of-flight measurements. This method is promising to acquire large data sets on helium nuclear interactions and thus improve the treatment planning in helium radiotherapy.

References: