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An in-vivo monitoring system for ion-beam radiotherapy based on tracking of charged nuclear fragments with 28 Timepix3 detectors

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Cancer is a leading cause of death worldwide, with about 10 million fatalities every year. A large fraction of cancer patients receives radiotherapy in the course of their treatment, of which the vast majority is treated with X-rays. Ion-beam radiotherapy offers steeper dose gradients and a higher biological effectiveness (ability to neutralise cancerous cells) compared with conventional X-ray radiotherapy. In order to improve the general effectiveness of radiotherapy, the treatment is split into fractions which are administered daily over several weeks. However, variations in the daily patient setup as well as potential anatomical changes over the treatment course have a greater impact on the quality of ion beams than X-rays, because of their steep dose gradients. It is therefore highly desirable to develop a feedback system that monitors the dose distribution in-vivo (i.e. in the patient) without applying additional dose and with minimal time and resource cost. Secondary radiation escaping the patient during therapy could form the basis of such a monitoring system.
At the German Cancer Research Centre in Heidelberg, we developed a monitoring system based on 28 hybrid silicon pixel detectors (Timepix3) to harvest the information carried by the nuclear fragments that are produced when the ion beam disintegrates into lighter ions. The system was characterised in extensive test beams with patient models as well as in Monte Carlo simulations. By comparing the detected fragment tracks of consecutive treatment fractions, the system was shown to be capable of detecting and locating anatomical changes and thus measure changes in the in-vivo dose distribution. Encouraged by these results, the monitoring system is now being used in the in-vivo-monitoring (InViMo) clinical trial with head-and-neck cancer patients at the Heidelberg Ion Beam Therapy Centre. In this contribution I will present preliminary results of the first patient cohort monitored with the novel system.

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