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Fast and compact proton radiography imaging system for proton radiotherapy

The novel proton radiography imaging technique has a big potential for the direct determination of proton stopping powers (PSPs) in various tissues in the patient. The uncertainty of PSPs needs to be minimized from 3-5% or higher, currently used in clinics, to less than 1%, crucial to make an optimum proton radiotherapy treatment plan.

To achieve that PSPs accuracy, both crucial elements in the proton radiography detection system, a position sensitive detectors and an energy detector, need to be equally fast to collect a minimum amount of protons of 10ˆ6 per cmˆ2 for a good radiography image. This amount of protons needs to be processed in a very short time down to half a minute to be applicable in clinics. Additionally, the position sensitive detectors should be able to detect the track of a proton passing through with an excellent angular resolution of a few mrad. It means that such detectors should be built with a minimum amount of material, smaller than 0.5 mm Water Equivalent Thickness (WET), to minimize the multiple Coulomb scattering of the proton before entering the patient. This is possible by using gaseous detectors, which should be (1) compact to minimize the required space on a proton gantry and (2) modular for easy size adaptation according to the needs in a clinic. The detector measuring the proton residual energy should have a high energy resolution of better than 1% for proton energies of 100 MeV and above.

The currently available Timepix3 chip and its follow-up, Timepix4, seem to be a very promising solution for fast proton radiography imaging. However, their integration with a gaseous detector needs definitely more attention to increase the rate of data collection. The energy detector for proton radiography imaging is not yet optimally matched to a position sensitive detector limiting the count rate of the system or the energy resolution.

Fast Timepix3(4)-based gaseous detectors well matched with the energy detector create an innovative compact system that would allow an accurate determination of PSPs in the patient, and thus improve the clinical outcome of proton radiotherapy.

Summary

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