Silicon and titanium as beam-activated tumour tracers for online proton therapy monitoring

Currently, proton therapy is a well established treatment method. It relies on the following principle: when protons enter the patient's body, they gradually loose energy and speed as a result of interaction with ingredients of tissue. At certain depth they are completely stopped in the tissue. There, the energy deposited in the patient's body reaches its maximum value, called the Bragg peak. The higher the deposited energy, the better the therapeutic effect. To achieve optimal treatment effects, the Bragg peak needs to be precisely directed to the tumour volume. Otherwise, healthy tissues surrounding the tumor are affected, leading to side effects, including secondary tumours. During the treatment, the Bragg peak position has some uncertainty, originating i.a. from patient positioning or internal organs movement, limiting the therapy efficiency. Thus, there are efforts to develop a method for online proton therapy monitoring. So far, there is no such method used routinely in the clinics. Having a reliable monitoring method would allow for better and safer treatment.

The purpose of this project is to investigate the possibility of using titanium and silicon as tumour tracers for online proton therapy monitoring. A tumour tracer is an element, chemical compound or a nanoparticle that is delivered to the tumour volume only. Such a tracer emits characteristic radiation (tracer signal) when irradiated with proton beam. This radiation is emitted almost instantaneously after the irradiation act (hence the name: prompt gamma radiation), so it can be registered by a detector during treatment session (online) and based on the tracer signal presence and intensity, conclusions about the place of maximum energy deposition can be drawn.

This project involves tests with a phantom that imitates a human head containing a tumour. It will be made of PMMA, which chemically resembles human tissue, and the tumour part will be doped with either titanium or silicon tracer. The phantom will be irradiated with the proton beam. The radiation produced as a result of protons interacting with the "tissue" will be registered with appropriate detector. The beam energy will be adjusted so that the Bragg peak is in different positions in the phantom, either outside or outside the "tumour" volume. The higher the beam energy, the deeper the Bragg peak position in the "tissue". For all the examined beam energies, we will register prompt gamma energy spectra. Such a spectrum gives information about the energy distribution of the observed prompt gamma radiation. In these spectra we expect to observe stronger tracer signal in the case when the maximum energy deposition was in the "tumour" volume. Such an effect was demonstrated by means of simulations in previous research and the goal of this project is to experimentally confirm it. The tracer signal is in the form of an additional peak in the energy spectrum, of the energy characteristic to the tracer. We want to determine if the tracer signal is observable and significant enough to constitute grounds for a new method of online proton therapy monitoring.