Computational and experimental nanodosimetry for proton radiotherapy

Proton radiotherapy is a cutting-edge method of cancer treatment that allows for a highly precise delivery of radiation dose to the tumor volume while sparing healthy tissue. The state-of-the-art proton radiotherapy treatment planning methods consider the biological effects of radiation by exploring only average macroscopic physics quantities such as absorbed dose and linear energy transfer (LET) and do not directly account for radiation interactions with cellular DNA molecules at the nanoscale. This research addresses this limitation by developing and applying a new approach to incorporate nanoscale calculations into the treatment planning process and validate them experimentally, leading to more effective and personalized proton radiotherapy.

The project seeks to develop new computational and experimental approaches to treatment planning and dosimetry that consider nanoscopic physical quantities, which is called nanodosimetry. Nanodosimetry covers the so called track structure simulations that include interactions of particles at very low energy down on an event-by-event basis and experimental methods relying on measurements of ionization clusters in low-pressure gas sensitive volumes equivalent to the short DNA segments. Such a nanoscale approach to treatment planning will potentially allow for more precise predictions of how radiation affects cancer and normal tissue cells during radiotherapy. The nanoscale treatment planning approach will be validated using the actual clinical outcomes of patients treated in Switzerland, thus providing treatment planning constraints for treatment plan optimization.

In addition to refining the theoretical models, the project includes experimental work to validate the new approach. Specialized detectors will be constructed or developed to measure clusters of ionization events produced by therapeutic proton beams. Two research teams, one in Switzerland and one in Poland, will develop two independent prototypes and jointly investigate various technological solutions and cross-validate them, while a state-of-the-art nanodosimetric detector installed in Krakow will be used as a reference. The experimental works will be conducted with the final goal of miniaturizing the device to characterize and routinely measure radiation quality in a nanoscale.

The expected outcome of this research is a significant advancement in the precision of proton therapy, moving beyond current limitations and providing a more reliable way to predict patient outcomes. By focusing on the nanoscale effects of radiation, this project has the potential to transform how cancer treatments are planned and delivered, making them more personalized and effective.