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Modeling Ion Effects in Radiation Therapy and Protection: Connecting Physics with Biology

Abstract

Ionizing radiation provides a seeming paradox: It can harm living cells and ultimately may cause cancer, while such harm can be exploited in cancer therapy. While in radiation therapy typically X-rays are used in various approaches, in particular ion radiation delivers extremely high energy concentrations locally on microscopic scales, where accordingly more complex damage patterns are induced to cells or tissues. This talk aims to underscore the pivotal role of physics-based modeling in unraveling and quantifying the complex mechanistic processes underlying observable radiation damage.

Navigating through the realm of physics-based modeling, we explore how modeling the spatio-temporal dynamics of radiation delivery and processing offers profound insights into the reaction of tissue to radiation exposure. In particular, emphasis will be set on understanding the beneficial effects of modern approaches in radiation oncology like spatial fractionation and the combination of radiation with immunotherapy. In the context of cancer therapy with carbon ions, which is now exploited in numerous dedicated facilities in Asia and Europe, the enhanced effectiveness can be understood with biophysical models. However, the uncertainty between different model approaches is of concern and matter of current investigation, provoking the development of strategies for model comparison and validation.

By bridging between physics and biology, biophysical radiation effect models and associated validation strategies serve as invaluable tools in exploiting radiation for treatment purposes, eventually paving the way for more personalized treatments that maximize therapeutic benefit while minimizing the side effects of treatment.

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