ST 5: Focus Session: Range Verification in Particle Therapy

Time: Thursday 11:00–13:00 Location: KH 01.013

Invited Talk ST 5.1 Thu 11:00 KH 01.013

Prompt-Gamma-Based Range Verification — •Beatrice Foglia — Ludwig-Maximilians-Universität München, Department of Medical Physics, Garching b. Muenchen, Germany

Prompt gammas (PG) are high-energy (~MeV) photons emitted immediately after nuclear interactions of ions with matter along nearly the entire beam path. As such, PG emission can provide valuable information on the ion beam range, making it a promising tool for in vivo range verification. Their nanosecond-scale emission and detection enable real-time monitoring, which is particularly attractive for adaptive therapy and is driving strong interest in the radio- and hadrontherapy community. Since the first proposal by Stichelbaut and Jongen at the PTCOG meeting in 2003, PG-based range verification has become a topic of worldwide research interest. Several workflows have been developed, generally relying on comparisons between measured PG profiles and expected signals obtained from Monte Carlo simulations or analytical models. Various PG detection modalities have been proposed and optimized to address challenges such as low PG yields and the broad, high-energy PG spectrum. Moreover, although PG emission and dose deposition arise from different physical processes, recent studies have demonstrated the feasibility of reconstructing dose distributions from PG signals. This talk will provide an overview of widely used PG-based range verification workflow, PG detection modalities and analytical PG modeling, and recent advances extending PG applications beyond range verification toward dose reconstruction and adaptive treatment strategies will be discussed.

Invited Talk ST 5.2 Thu 11:30 KH 01.013

Carbon-ion radiotherapy monitoring with charged nuclear fragments — •Maria Martisikova[1,2,3], Laurent Kelleter[1,2,3], Rebekka Kirschgässner[1,2,4], Pamela Ochoa[1,2,4], Semi Harrabi[5,6], Jan Jakubek[7], Oliver Jäkel[1,2,3,5], and Jürgen Debus[2,3,5,6] — [1]Heidelberg Institute for Radiation Oncology HIRO, National Centre for Research in Radiation Oncology NCRO — [2]German Cancer Research Centre DKFZ, Department of Medical Physics in Radiation Oncology — [3]National Center for Tumor Diseases (NCT) Heidelberg — [4]Department of Physics and Astronomy, Heidelberg University — [5]Department of Radiation Oncology, Heidelberg University Hospital — [6]Heidelberg Ion-Beam Therapy Center (HIT) — [7]ADVACAM s.r.o., U pergamenky 12, Prague, Czech Republic

Our group has been investigating the potential of measured secondary ion emission profiles to assess delivered dose distributions. A secondary-ion tracking system has been developed and successfully implemented in the clinical environment of the Heidelberg Ion Beam Therapy Facility. Within the InViMo clinical trial, secondary ion emission profiles have been measured during at least two treatment fractions for 35 patients to date. While the measured profiles were consistent between fractions for the majority of patients, pronounced inter-fractional changes were observed in several cases. These differences correlate with plausible anatomical locations.

Invited Talk ST 5.3 Thu 12:00 KH 01.013

Radioactive ion beams for real-time PET-guided adaptive particle therapy — •Daria Boscolo for the BARB Collaboration — GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany

Heavy ion particle therapy offers superior dose conformity compared to conventional radiotherapy, but its clinical potential is limited by high sensitivity to range uncertainties at the distal edge of the Bragg peak. To ensure tumor coverage, large safety margins are often applied, partially negating the benefits of particle therapy. Online range verification methods are therefore essential, particularly for adaptive treatment strategies. Positron emission tomography (PET) is among the most established techniques for in-beam range verification; however, in conventional 12C-ion therapy its accuracy is constrained by low signal-to-noise ratios, spatial mismatches between activity and dose peaks, and long acquisition times. The direct use of β^*-emitting radioactive ion beams for both treatment and imaging offers a promising solution to these limitations. Within the BARB project, the feasibility of 11C-ion beams combined with real-time in-beam PET imaging has been extensively investigated. We report the first demonstration of real-time adaptive particle therapy using radioactive ion beams in a living mouse model, showing that dynamic beam repositioning produces spatially resolved PET signals correlated with distinct treatment outcomes. These results provide compelling evidence that 11C-beams-based imaging can enable precise range verification, adaptive treatment delivery, and improved tumor control with reduced toxicity.

Invited Talk ST 5.4 Thu 12:30 KH 01.013

Helium as a Range Probe in Carbon-Ion Therapy: From Concept to Mixed-Beam Experiments — •Lennart Volz for the PROMISE collaboration — GSI Helmholtz Zentrum für Schwerionenforschnung GmbH, Darmstadt, Germany

Carbon ion therapy offers superior dose conformity compared to conventional radiotherapy, but its full potential is limited by the lack of real-time, in-beam range verification. The PROMISE project (ERC Grant No. 101124273) investigates a novel approach based on mixed ion beams to enable simultaneous treatment delivery and particle-based imaging. Carbon and helium ions have nearly identical charge-to-mass ratios and can therefore be accelerated simultaneously to the same velocity in a synchrotron. At equal velocity, helium ions have a threefold larger range than carbon ions. While the carbon component delivers the therapeutic dose, the helium ions act as a low-dose imaging probe. This contribution reports on the first experimental realization of mixed beam range verification and imaging at GSI's SIS18 synchrotron. Experiments on a lung-cancer-mimicking setup reveal that a mixed beam enables tracking a spherical tumor at sub-millimeter accuracy, with high sensitivity to range changes down to $<0.1\%$ of the beam range using a particle imaging scintillator detector. Simulations on patient CT data are used to explore the clinical potential of this technique. This work represents an important step toward fully image-guided heavy-ion therapy.