Abstract einer Präsentation auf der Joint Conference of the ÖGMP, DGMP and SGSMP, 19.-22. September 2021, *Dreiländertagung 2021, Abstractband.*
Deutsche Gesellschaft für Medizinische Physik, Stuttgart, Deutschland
ISBN 978-3-948023-16-4

On the localization of the proton Bragg peak position in 3D using multilateration of ionoacoustic signals

Ronaldo Kalunga, Hans-Peter Wieser, Julie Lascaud, Pratik Dash, Anna-Katharina Schmidt, Sonja Gerlach, Roghieh Haghani, Marco Riboldi, Jörg Schreiber, Walter Assmann, Katia Parodi

Department of Medical Physics, Ludwig-Maximilians-Universität, München, Germany

Introduction

When energy is deposited in a medium by a pulsed proton beam, it generates thermoacoustic waves, also called ionoacoustics (IA). Multilateration uses the arrival time estimated from IA signals at different sensor locations to determine the proton beam stopping position. This work investigates different time-of-flight (ToF), e.g., maximum amplitude (MA), zero-crossing, and multilateration methods using experimental and in-silico data.

Materials & Methods

Acoustic range verification was experimentally assessed in a homogenous water phantom at a research accelerator facility using a 20 MeV pulsed proton beam. The IA pressure was measured by 4 single element piezoelectric transducers (1 and 3.5 MHz centre frequency, 0.5 inch diameter). The transducers were chosen according to the expected frequency spectrum at the given position. Range verification was performed employing two different multilateration methods: time difference of arrival (TDOA) and time of arrival (TOA). The accuracy and robustness of the TDOA and TOA were assessed in-silico by modelling systematic uncertainties (e.g., trigger offset), and random uncertainties (ToF error depending on the estimation method and sensor position w.r.t. the Bragg-peak).

Results

According to simulations, the expected proton range in water was 4.17 mm. The relative error of the reconstructed ranges were 0.14% (TDOA) and 10.21% (TOA) using ToF-MA. These results refer to single proton shot measurements, each corresponding to a maximum dose of 0.52 Gy at the Bragg-peak. The robustness study revealed that TDOA is more robust against systematic uncertainties, whereas TOA is more robust against random uncertainties. The localization error also depends on the ToF method e.g., it reduces to 3.21% using TOA combined with zero-crossing.

Conclusion

The accuracy of Bragg-peak localization depends on the multilateration method, ToF estimation and sensor location. Next, we will study the influence of heterogeneities, and design a multilateration system for beam monitoring in a small-animal irradiator.

Supported by ERC.