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The sound of protons - Ionoacoustics for ion range determination

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Ions offer a more advantageous dose distribution than photons for external beam radiotherapy, due to their invers dose deposition and, in particular, a characteristic dose maximum at their end of range (Bragg peak). Therefore, a more conformal therapeutic dose can be applied to the tumor while sparing the surrounding healthy tissue, even if organs at risk are in striking distance. This makes, however, a precise positioning of the Bragg peak inside the tumor volume a challenging demand.
Range verification in ion beam therapy relies to date on nuclear imaging techniques which require complex and costly detector systems, and none has still reached clinical maturity. In this project, we make use of the pressure pulse and related acoustic wave induced by ions stopping in tissue (ionoacoustics) to measure the ion range with ultrasound methods. This technique could offer a simple and more direct possibility to correlate, in-vivo and in real-time, the conventional ultrasound echo of the tumor region with the position signal of the ion Bragg peak.
The idea of using acoustic signals in water for detection of high energy particles, in particular of neutrinos, has long been proposed and ultrasound signals have first been measured in 1979 with energetic protons. The first demonstration of an acoustic pulse generated in a patient during radiation treatment with a proton beam was performed in 1995, but the accuracy needed in radiation therapy could never been reached. However, to-day's more advanced irradiation schemes with active beam scanning and dose delivery with higher pulse intensities are in favor of a more accurate ionoacoustic approach. This presentation will address our experimental and simulation work investigating the potential of the ionoacoustic method to enable sub-mm imaging of the Bragg peak. The proof-of-principle experiments were performed at the Tandem accelerator of the LMU and TU Munich, using a 20 MeV proton beam and different focused US transducers.

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