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Adapting a computed tomogram to Geant4 for monitoring proton therapy via prompt-gamma rays and time-of-flight PET

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Proton therapy (PT) is growing worldwide due to its ability to provide a very conformational dose to the tumor being irradiated. However, diverse variables may compromise such conformationality and lead to undesirable situations that are suspected of being correlated with tumor recurrence. Several approaches have been suggested for in vivo monitoring of the PT dose delivery and proton beam range verification. One of them, already applied in clinical practice, is based on positron emission tomography (PET) which involves detection of 511 keV gamma rays resulting from positron-emission decay of proton induced radioactive nuclides. Another group of techniques is based on detection of prompt gamma rays (PG) originating from proton-nuclear interactions within the body.

The Laboratory of Instrumentation and Experimental Particle Physics (LIP, Portugal) has been conducting studies on these two topics. In the field of PET, LIP is part of the TPPT (in-beam time-of-flight positron emission tomography for proton therapy) consortium which is thriving efforts in order to construct an in-beam TOF-PET system onto one of the therapeutic proton beam lines in the MD Anderson Cancer Center (MDACC) in Houston, Texas, USA (University of Texas). The team at LIP is responsible for the simulations that will allow a comparison between measured beta+ activity distributions versus the expected ones. Regarding the PG imaging technique, LIP has addressed efforts to develop and test a system with a multi-slat collimator oriented orthogonality to the beam direction in order to detect the PG rays that escape the patient in the perpendicular direction.

A more detailed study of both aforementioned approaches requires simulation of real treatment plans. This task includes, on one hand, the adaptation of patient computed tomograms (which are proportional to electron density) into Geant4 (which includes tissue density and stoichiometry). On the other hand, some irradiation beam parameters (e.g. position, energy, direction, among others) should also be considered in the simulations. In this work, the latest developments on this topic will be presented.

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