Karolinska Institutet

Department of Oncology-Pathology

Production of High Quality ^{11}C Beams for Radiation Treatment and Accurate PET-CT Dose Delivery Verification

AKADEMISK AVHANDLING
som för avläggande av medicine doktorsexamen vid Karolinska Institutet offentligen försvaras i CCK Seminar Room, R8:00, Karolinska Universitetssjukhuset, Solna.

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av
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ABSTRACT

Radiation therapy with external beams of positron emitter light ions offers the optimal solution for simultaneously treating and *in vivo* monitoring the delivery of the dose in 3D with Positron Emission Tomography (PET) or PET-Computed Tomography (CT) imaging. Specifically, positron emitter light ion beams merge the main distinctive advantages of light ion therapy, namely a high conformal and biological effective dose delivery to the tumor, an optimal penumbra, and sparing of the surrounding normal tissues, with the advantage of a high β^+-activity signal mainly produced directly by the beam itself, and therefore not primarily dependent on the specific stoichiometry of the body tissues.

The aim of this thesis is to explore a method to maximize the generally low production yield of ^{11}C ion beams through in-flight fragmentation of a primary ^{12}C ion beam on a dedicated decelerating target. The thesis provides a practical solution applicable to cyclotron, synchrotron and linac based hospital facilities. The study investigates the main steps from the production of the beam and the transport through the beam optics system to the purification of the beam from other potentially contaminating fragments. Analytical models of transport of ions in matter, as well as the Monte Carlo code SHIELD-HIT were used to conduct the analysis.

The proposed beam line includes a composite production target made of a 20 cm thick liquid hydrogen section followed by a variable thickness section consisting of plane parallel slabs of polyethylene. The first section is selected to maximize the ^{11}C ion beam intensity, whereas, the second section is used to reduce the beam energy to the desired value, maintaining the high ^{11}C ion yield. To be able to minimize the energy spread of the beam, and the contamination from other fragments, a variable wedge-shaped degrader and a Time Of Flight (TOF) Radio-Frequency driven velocity filter are included in the beam line together with dipole and quadrupole magnets.

A ^{11}C ion beam intensity of about 4-6% of the primary ^{12}C ion beam intensity with radial spot size confined to 0.5 cm in radius, and an energy and angular spread of about 1% and 1°, respectively, are achievable. The ^{11}C ion beam purity is expected to be about 99%. The proposed system for production of high quality ^{11}C ion beams contributes to the developments of an accurate PET-CT based dose delivery verification, ultimately aiming towards a biologically optimized adaptive radiation therapy.