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Production of intense mass separated 11C beams for PET-aided hadron therapy

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We will present a novel production system based on the ISOL method (Isotope Separation On-Line) for intense mass separated ^{11}C beams for PET-aided hadron therapy. Hadron therapy, and particularly carbon therapy, is a very precise treatment for localized tumors where the tumor is irradiated with a pure, monoenergetic and high intensity particle beam. Carbon therapy significantly reduces the dose exposure to healthy tissue compared to conventional photon therapy. However, the verification of the actual dose deposition in the human body remains difficult. Complex treatment planning systems are required that simulate the beam trajectory, and thus, calculate the dose distribution of the particle beam to the human body. Such treatment planning systems suffer from uncertainties that originate for instance from range deviations and from moving organs due to the patient's breathing. Therefore, within the Marie Skłodowska-Curie innovative training network MEDICIS-Promed, a ^{11}C based carbon therapy protocol is being developed. ^{11}C is a β^+-emitter ($T_{1/2}$ = 20.4 min) widely used in PET-imaging. Consequently, by replacing the stable ^{12}C beam with its radioactive isotope ^{11}C, therapy can be combined with on-line PET-imaging. The PET-images that are recorded simultaneous with the treatment, represent a 3D dose distribution map of the irradiation field, and thus, provide an on-line dose verification. While the advantages of a ^{11}C based hadron therapy are obvious, the challenge remains to produce a radioactive particle beam of sufficient intensity. Effective treatments require $4 \cdot 10^8$ ions/spill delivered to the patient. As a result, this implies a radioactive ion beam production system that is capable to produce a ^{11}C beam of high intensity. Therefore, we propose a production system based on the ISOL method, which is capable to produce pure and intense radioactive ion beams. This technique includes the irradiation of a solid target with a particle beam. The isotope of interest is produced, among many others isotopes, via a nuclear reaction inside the target. The isotopes then have to be released from the target and effuse to an ion source, where the atoms are ionized. Subsequently, the ions can be accelerated and mass separated by a deflecting magnet that bends the ions on trajectories according to their mass-over-charge ratio, producing (radioactive) ion beams. To ensure highest intensity as possible, optimization of the different steps from target irradiation until mass separation and beam formation is essential. We present our proposed production system, consisting of a solid boron nitride target, a cyclotron for low-energy proton irradiation and an ECR ion source. Optimization of important aspects, such as isotope release, transport and ionization efficiency will be discussed.

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