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New developments of 11C post-accelerated beams for hadron therapy and imaging

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Hadron therapy was first proposed in 1946 and is by now widespread throughout the world, as witnessed with the design and construction of the CNAO, HIT, PROSCAN, MedAustron and Etoile treatment centers, among others. The clinical interest in hadron therapy lies in the fact that it delivers precision treatment of tumors, exploiting the characteristic shape (the Bragg peak) of the energy deposition in the tissues for charged hadrons.
In particular, carbon ion therapy is found to be biologically more effective, with respect to protons, on certain types of tumors. Following an approach tested at NIRS in Japan [1], carbon ion therapy treatments based on 12C could be combined or fully replaced with 11C PET radioactive ions post-accelerated to the same energy. This approach allows providing a beam for treatment and, at the same time, to collect information on the 3D distributions of the implanted ions by PET imaging.
The production of 11C ion beams can be performed using two methods. A first one is based on the production using compact PET cyclotrons with 10-20 MeV protons via 14N(p,α)11C reactions following an approach developed at the Lawrence Berkeley National Laboratory [2].
A second route exploits spallation reactions 19F(p,X)11C and 23Na(p,X)11C on a molten fluoride salt target using the ISOL (isotope separation on-line) technique [3]. This approach can be seriously envisaged at CERN-ISOLDE following recent progresses made on 11C+ production [4] and proven post-acceleration of pure 10C3/6+ beams in the REX-ISOLDE linac [5]. Part of the required components is operational in radioactive ion beam facilities or commercial medical PET cyclotrons. The driver could be a 70 MeV, 1.2 mA proton commercial cyclotron, which would lead to 2x1010 11CO+/s and 2.3x108 11C6+/spills at 1 Hz [4]. This intensity is appropriate using 11C ions alone for both imaging and treatment. Here we report on the ongoing feasibility studies of such approach and future tests envisaged within the forthcoming CERN-MEDICIS facility and MEDICIS-PROMED Horizon2020 EU program.

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