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Cross section measurements of proton-induced nuclear reactions for the production of interesting radionuclides for nuclear medicine: A collaboration between INFN-LNL and ARRONAX facility

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Summary

This work developed in the context of LARAMED project (Laboratory of Radionuclides for Medicine) at INFN-LNL and in collaboration with ARRONAX facility (Accelerator for Research in Radiochemistry and Oncology at Nantes Atlantique, France). These research centers are the only facilities in Europe equipped with a high performance proton cyclotron (dual beam extraction, 70 MeV): at INFN-LNL the Best 70p accelerator was installed in May 2015 and it is now under commissioning, at Arronax the multi-source IBA cyclotron is working since 2007. A scientific collaboration between such peculiar facilities started in 2010 and, among the most interesting topics included, the measurement of the cross section for the production of radionuclides with medical applications plays a key role. In fact, the knowledge of the excitation function is a fundamental ingredient in the optimization of irradiation parameters (e.g. proton beam energy, target thickness, duration and cooling time): the goal is maximize the production of the desired radionuclide and simultaneously minimizing the co-production of contaminant isotopes that cannot be separated by applying a posteriori radiochemical process. Moreover, from a nuclear physics point of view, the measurement of unexamined or contradictory excitation functions can provide additional hints or missing information that are necessary to understand specific nuclear interactions and, consequently, optimize nuclear codes for each case of interest.
Recently the measurement of an unexamined nuclear cross section for the production of 67Cu developed at INFN-LNL in collaboration with Arronax facility. 67Cu is the longest lived radionuclide of copper, with a half-life of 61.83 h, and it entirely decays to different excited states of 67Zn (stable isotope), emitting β and γ radiation. 67Cu is thus one of the few theranostic radionuclides, i.e. useful for both therapy and diagnostic applications, since the energy of β-particles is appropriate for the treatment of small-sized tumors (140 keV as mean energy), while the 185 keV photons are suitable for SPECT or SPECT/CT imaging studies. The main advantage of theranostic isotopes, such as 67Cu, is the selection of patients prior therapy, by using the same radiopharmaceutical labelled with the same radionuclide to perform lower-dose imaging studies prior therapy. Moreover, 67Cu can be used in pair with 64Cu (β+ emitter) to perform low dose PET or PET/CT scans and obtain all the necessary pre-therapeutic information on effective tumor uptake, bio-distribution and dosimetry (limiting or critical organs or tissues, maximum tolerated dose, etc.). This innovative approach in nuclear medicine is a step towards the development of personalized treatments.
In order to investigate the nuclear reaction induced by the 70 MeV proton beam, a stacked-foils target was used to obtain, during an unique irradiation run, the measurement of the desired cross section at several different proton energies, by inserting some aluminium foils as energy degraders. After the irradiation it was necessary to apply a dedicated chemical process to separate Cu from Ga isotopes. In fact, during the bombardment, it is also produced 67Ga (3.2617 d half-life), a radionuclide that decays to 67Zn, emitting the same γ-lines of 67Cu. For this reason and considering the similar half-lives, it is not possible to distinguish among 67Cu and 67Ga activities with γ-spectroscopy.
In this work the accurate experimental set-up and the chemical procedure aimed at the measurement of the nuclear cross section for 67Cu production is described. Some considerations about the feasible future production of 67Cu at INFN-LNL are also given.

In the collaboration between INFN-LNL and Arronax facility the measurement of the cross section for the production of radionuclides for medical applications is a fundamental topic. In this work, the measurement of the nuclear cross section for the production of 67Cu, an emerging theranostic radionuclide, is described. Experimental set-up, radiochemical procedure and future feasible production at INFN-LNL by using the new high performance cyclotron are discussed.

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