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Production yields of positron emitters for range verification in proton therapy

In proton therapy, the range of the proton beam is assumed to be between 1% to 3% and hence sizeable safety margins are applied in current treatment plannings, which limits the benefits of having a sharp Bragg peak. Reducing this uncertainty would allow a better utilization of the advantages of proton therapy over conventional radiotherapy, and hence there is an intensive research program aiming at in vivo range verification of the proton beam [1].

Among the techniques available nowdays, in-vivo PET range verification relies on the comparison of the measured and estimated activity distributions of positron emitters induced on mainly C, N, O, Ca and P present in the human body by the proton beam, right after treatment (long-lived positron emitters ^{11}C and ^{13}N) or during the irradiation (short-lived positron emitters ^{15}O, ^{29}P and ^{12}N). The accuracy of the estimated distributions is basically that of the cross-section data available, which are the main input of the Monte Carlo simulations [2]. A revision of the experimental data available in the EXFOR database [3] indicates that these cross sections have not been measured in the full energy range of interest and that there are sizeable discrepancies between the different data. Indeed, several studies confirm the need of more accurate measurement of cross sections of the reaction channels that contribute to the production of the mentioned positron emitters [4].

The aim of the work presented herein is to develop a method for measuring the production yields of the long-lived positron emitters in the most abundant isotopes in the human body (carbon, nitrogen and oxygen) in the full energy range for proton therapy (up to ~250 MeV). As a first step, the developed method has been tested and used to measure these cross sections at the CNA cyclotron. This method consists in the degradation of the 18 MeV proton beam by means of a multi-stack target configuration in order to obtain the cross sections in different energy points. The thin films used are rich in C, N and O to produce the long-lived positron emitters 11C and 13N. The activity induced in each film is then measured using the clinical PET scanner at CNA, so that the acquisition in dynamic mode provides the activity curves to identify the decay of each isotope.

The production cross sections of the different reaction channels have been obtained below 17 MeV and compared with the data available. The results obtained for the ^{14}N(p,$*$)^{11}C and ^{16}O(p,$*$)^{13}N will be presented together with the plan for measuring at high proton energies.

[1] A.C. Knopf and A. Lomax, Phys. Med. Biol. 58 (2013)
[2] H. Paganetti, Phys. Med. Biol. 57 (2012)
[3] Experimental Nuclear Reaction Data (EXFOR) https://www-nds.iaea.org/exfor/exfor.htm
[4] España et al., Phys. Med. Biol. 56(9) (2011)

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