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Short-lived positron emitters in beam-on PET imaging during proton therapy

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Due to the large dose deposit in the Bragg peak, proton beam radiotherapy is sensitive to a variety of possible differences between the actual and planned treatment situation. Therefore, a technique for in-vivo dose delivery verification is needed. The only such technique in clinical use today is positron emission tomography (PET) of the positron emitters produced in the patient during irradiation. PET during irradiation maximizes the number of counts and minimizes biological washout. In such a scenario, also short-lived positron emitters will be observed. As very little is known on the production of such nuclides, we measured the production of short-lived positron emitters in the stopping of 55 MeV protons in water, carbon, phosphorus and calcium targets. The most copiously produced short-lived nuclides are: 12-N on carbon, 29-P on phosphorus and 38m-K on calcium. No short-lived nuclides are produced on water. The experimental results were used to calculate the number of decays, integrated over an irradiation, in 4 tissue materials as function of the duration of the irradiation. 12-N needs to be considered as the image blurring caused by its large positron range may noticeably degrade image quality. In (carbon-rich) adipose tissue, 12-N dominates up to an irradiation duration of 70 s. In bone tissue, 12-N dominates over 15-O during the first 8-15 s. The short-lived nuclides created on phosphorus and calcium substantially improve the visibility of bone tissue in in-beam PET compared to PET imaging after an irradiation.

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