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Measurement of $3\gamma/2\gamma$ 89Zr positron annihilation ratios in selection of scintillation and semiconductor detectors for future application in oncology

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Determining the oxygenation status in tumour hypoxia is a challenge in cancer imaging. There are many on-going clinical trials using conventional positron emission tomography (PET) scans and PET agents as cellular markers for detection of tumour hypoxia depending on the concept of the basic physics of 2γ annihilation. However, Kacperski and Spyrou (2004) proposed, for the first time, to use 3γ annihilation as a new PET molecular imaging modality, where the positronium and its annihilation, could serve as an oxygen-sensitive marker. The effective yield of 3γ annihilation depends on the rates of formation and quenching. Oxygen is known to be a strong positronium quencher where 2γ annihilation replaces the 3γ process. It is thus possible for hypoxic cells to be characterised by higher 3γ rates than those cells which are well oxygenated.
The peak-to-peak and peak-to-valley methods are applied to estimate the relative yields of 3γ positron annihilation. The only limitation of using the peak-to-peak method is when the positron emitting source has only one peak as in the case of 18F. The Zirconium-89 (89Zr) has recently drawn significant interest to be a promising metallo-radionuclide for use in immuno-PET. the 89Zr radionuclide has a positron yield of 22.7% as well as gamma-ray energy at 909 keV of relative intensity almost 100% which is emitted almost simultaneously. Therefore, 89Zr seems to be promising for detecting and measuring oxygenation status in hypoxic tumor by using three gamma positron annihilation based on the peak-to-peak method.
The main objective of this work is to explore the possibility of exploiting 3γ annihilation from 89Zr isotope in PET imaging for measuring the relative oxygenation of tissues in oncology applications. In this experimental study four detectors, semiconductor detecors (HPGe and CZT) and scintillation detectors (NaI(Tl)), LaBr3: Ce3+) will be used. The peak-to-peak method will used with a 89Zr source to determine these yields. Aluminium will be employed as a reference material as its high electron density reduces positronium formation and lifetimes. Teflon will also used in order to enhance the formation of ortho positronium, since quenching is low, leading to increased three photon positron annihilation.

References:

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