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Gate Simulations of a Novel Positron Emission Tomography based on Liquid Opaque Detection

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The main experimental challenging developments in positron emission tomography (PET) are currently focusing on improving the sensitivity either by pushing the time of flight (ToF) performances or extending the axial field of view. As an alternative the use of 3γ detection capability enables several extra advantages, including the possible enhancement of the ToF information to better locate the annihilation vertex or enabling tissue probing through positonium study. We propose the LiquidO-PET (LPET) projet which aim to develop of a demonstrator to explore our ability to meet the aforementioned capabilities through a novel PET system paradigm. It is based on opaque scintillation of a liquid medium. The enormous light scattering forces the emission photons to stay around their source into a stochastically confined trajectory or "light ball"with a radius in the order of the centimeter and collected and mapped through a lattice of wavelength-shifting fibers embedded in the scintillator and read out by silicon-photomultipliers coupled to sub-100 ps readout electronics on both ends. The liquid scintillator medium with low-z and low density, causes the γ detection to be largely dominated by Compton scattering. Thus, a 511 keV γ manifests a sequence of several Compton scatters up to 50 cm from the injection point, each scatter leading to a point-like light ball, thus enabling the Compton interactions to be characterized by two specific signatures: i) the clear identification of the first Compton vertex (FCV), which is most precious for PET imaging and ii) the full Compton tracking (FCT) providing complementary tracking information for the full event as well as allowing 3γ detection capabilities. We present here the GATE simulations of the preliminary design and the projected performances of the demonstrator based notably on optical simulations in a diffusive medium. Expected performances range from a radial spatial resolution of a few mm to a few cm in the axial direction, a ToF resolution of 100-300 ps and a sensitivity of 200-700 kcps/MBq for an axial FoV in the 50-200 cm range.

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