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Quantification of CaLIPSO PET scanner potential for personalized medicine in oncology and neurology

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Positron emission tomography (PET) is a powerful molecular imaging method that plays an increasing role in personalized medicine. Brain PET is especially useful for investigating the molecular dysfunctions associated with neurodegenerative diseases (ND). It contributes to the diagnosis of ND and to the monitoring of the functional changes over the course of ND. For such studies it is important to have a PET scanner with high detection efficiency, high spatial resolution and high time resolution simultaneously. The aim of the CaLIPSO project (French acronym for Liquid Ionization Calorimeter, Scintillation Position Organometallic) is to fulfill these requirements. We aim to develop the proof of concept for a new PET detector dedicated to human brain imaging. The objective is to achieve a spatial resolution of about 1 mm3 with an efficiency of about 7% similar to that of conventional PET scanner or HRRT scanner. Moreover, an excellent time resolution (˜150 ps FWHM) is also needed for time of flight measurements (TOF). The CaLIPSO scanner is thus intended to be the first scanner for brain studies including TOF. A high image resolution, about 1 mm, and contrast are targeted, which might be a definite assess for neurological studies. Such performances will also be helpful in personalized neuro-oncology. It makes possible to extensively assess the tumor heterogeneity and tune the therapeutic approach accordingly.

The high CaLIPSO PET scanner performance is possible thanks to the double detection of the incident 511 keV-gamma though photoelectron conversion in trimethyl bismuth, an innovative liquid filling a PET cell. Created photoelectron emits Cherenkov photons and ionizes the medium. Both light and free charges are collected and used for the reconstruction of the time, 3D position of the interaction and for the estimation of the deposited energy.

We have developed a GATE simulation model to design a full PET scanner and to compare our simulation results with the performance of other high resolution PET systems such as the HRRT by Siemens that is currently the brain PET scanner with the performance of reference. The geometry of the CaLIPSO scanner is cubical with ˜30 cm inner diameter. Such geometry is non-standard and possible in case of the CaLIPSO prototype thanks to the reconstruction of the depth of interaction point in the detection module with high precision. The comparison of the main parameters (Noise Equivalent Count Rate and image resolution) for CaLIPSO and HRRT shows the higher performance of foreseen CaLIPSO scanner. For example, the image resolution is about 1.2 mm for CaLIPSO, but 2.2-2.5 mm for HRRT. We also started development of the reconstruction algorithms on simulated brain images. The first reconstructed images of a brain with different tracers distributions demonstrated the ability of the CaLIPSO PET scanner to be a key tool to study neurodegenerative and brain diseases.

The CaLIPSO is promising ongoing project for a PET scanner with a high potential for brain imaging.

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