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XEMIS: liquid xenon Compton camera for 3γ imaging

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We report on an innovative liquid xenon Compton camera project, XEMIS (XEnon Medical Imaging System), for a new functional medical imaging technique based on the detection in coincidence of 3 γ-rays. The purpose of this 3γ imaging modality is to obtain a 3D image using 100 times less activity than in current PET systems. The combination of a liquid xenon time projection chamber (LXe-TPC) and a specific (β^+,γ) radionuclide emitter ^{44}
Sc is investigated in this concept.

In order to provide an experimental demonstration for the use of a LXe Compton camera for 3γ imaging, a succession of R&D programs, XEMIS1 and XEMIS2, have been developed using innovative technologies. Nevertheless, the ultimate goal consists in a large camera XEMIS3 for whole human body imaging building. The first prototype XEMIS1 has been successfully validated showing very promising results for energy, spatial and angular resolutions with an ultra-low noise front-end electronics (below 100 electrons fluctuation) operating at liquid xenon temperature of 101 $^{\circ}$C at 1.2 bar. A timing resolution of 44.3$\pm$3.0 ns for 511 keV photoelectric events has been estimated from the drift time distribution, equivalent to a spatial resolution along z-axis of roughly 100 μm. The second phase dedicated to a 3D images of small animals, XEMIS2, is now under qualification.

XEMIS2 is a monolithic liquid xenon cylindrical TPC that holds around 200 kg of liquid xenon, totally surrounding the small animal. The active volume of detector is covered by 64 Hamamatsu PMTs and two end segmented anodes with a total amount of 20000 pixels, to detect simultaneously the UV scintillation photons and ionization signals produced after interaction of ionizing radiation. Characterizations of ionization signal using Monte Carlo simulation and data analysis have shown good performances for energy measurement. Besides, in order to maintain the normal operation liquid xenon at the desired temperature and pressure, or to recover as fast as possible in urgent case, an innovative compact liquid xenon cryogenics subsystem (called ReStoX) has been successfully developed and validated. The XEMIS2 camera will be operational this year for preclinical research at the Center for Applied Multi-modality Imaging (CIMA) in the Nantes Hospital, while the detector performance has been evaluated through a dedicated simulation analysis.

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