Design and Performance of a LXe Detector for a Micro-PET Detector

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I. Introduction

THIS work is aimed at studying the interactions of 511 keV photons in liquid xenon (LXe) detectors for applications to positron emission tomography (PET). The advantages of LXe for PET compared to currently used methods include improved energy resolution, 3-D sub-mm spatial resolution, inherent Compton event reconstruction, and high sensitivity.

We have developed a concept for a micro-PET detector shown in figure 1 that takes advantage of the improved performances achieved by measuring light and charge in LXe.

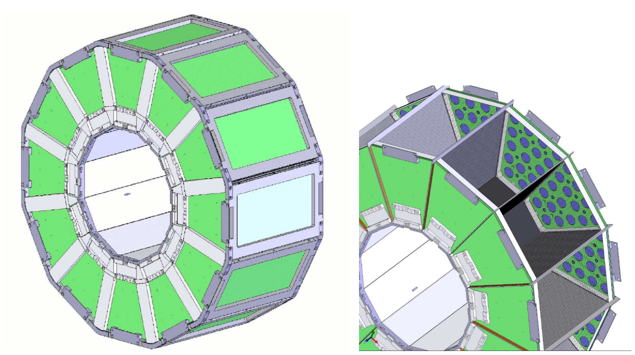

Fig. 1. The LXe PET ring concept. Scintillation light and charge are measured in each of the 12 modules consisting of a LXe time projection chamber viewed by avalanche photodiodes.

The scintillation light is measured by large area avalanche photodiodes (LAAPD), which have been found to work well in LXe [1]. The charge measurement is achieved by using a time projection chamber (TPC). Electrons produced in the liquid drift to the anode plane under an applied electric field; induction wires perpendicular to anode strips provide two dimensional position information. The third dimension is obtained measuring the electron drift time.

In order to investigate this concept we have built a prototype of one sector for the proposed micro-PET detector.

II. Design of the Sector Prototype

We foresee dividing the PET detector ring in 12 identical liquid Xenon filled trapezoidal sectors. One sector prototype has been built and tested. Figure 2 shows a partly assembled sector mounted onto the cryostat flange and a view inside the sector with field-strips, anode and APD module visible.

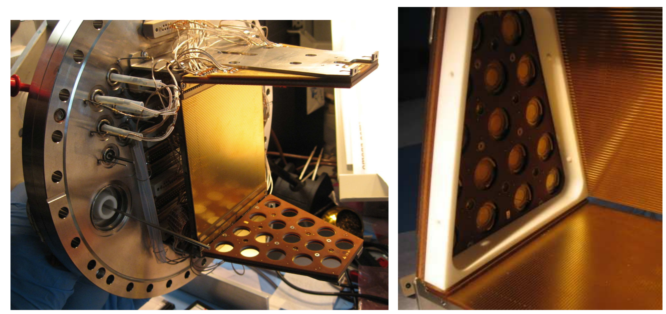

Fig. 2. Prototype of a sector for a LXe PET detector. In the left picture parts of the sector are shown mounted onto the flange that holds the detector within the cryostat. The right picture shows a view inside the sector looking onto the APD module (no APDs mounted yet) and the strips of the field cage as well as the anode module.

The anode plane is segmented into 96 strips separated by 1.1 mm for position reconstruction. Above the anode plane, 96 induction wires are strung perpendicular to the anode strips providing the second position coordinate. The maximum drift length is 10 cm. Position along the drift direction is reconstructed by measuring the time between the light flash and the charge arrival on the anode plane, knowing the drift velocity. The scintillation light is measured by 16 LAAPD mounted on each side of the trapezoid.

III. Performance of the Sector Prototype

A shematic drawing of the test setup as it was implemented in Geant4 [2] is shown in figure 3. A scintillating crystal from Saint Gobain (BrilLanCe380 made of $LaBr_3$:Ce [3]) with an effective area of $49\times49\times10$ mm^3 coupled to a 64-anode PMT array from Hamamatsu (H8500 [4]) is used as a coincidence trigger for the 511 keV photons emitted by a ^{22}Na source. The source is enclosed in a lead collimator pointing at the vacuum vessel containing the LXe volume in which the prototype is located. The γs enter the detector through the cathode.

We will present results from first measurements with the sector prototype.

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References

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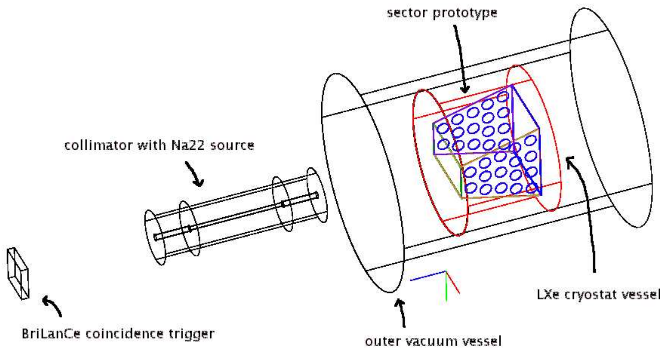

Fig. 3. Test setup implemented in Geant4, showing the coincidence trigger, the collimator containing the ^{22}Na source and the vacuum vessel with the LXe volume inside holding the sector prototype.

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