Electric Field and Ionization Signal Simulation in Liquid Xenon Detectors for PET

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1. Purpose

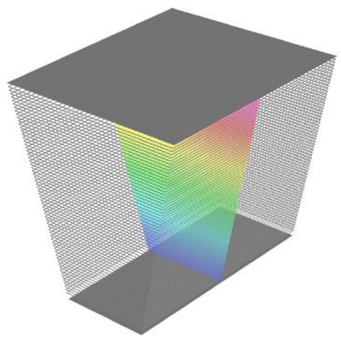
A liquid xenon (LXe) detector prototype was developed to assess the performance of LXe for use in positron emission tomography (PET).

In this prototype, the measurement of ionization signals was achieved by using a time projection chamber (TPC), and scintillation light was measured by large area avalanche photodiodes.

This work is aimed to simulate the electric field in the drift area and readout signals in the LXe detector prototype.

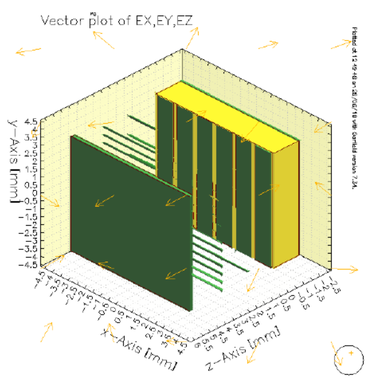
3. Methods

The electric field was calculated through the finite element method using the software of Opera-3d. The simulation model consists of a cathode, an anode, and field cage strips, which were immersed in a liquid xenon volume.



Sector model in Opera-3d

The signal simulations were implemented with the computer program Garfield.

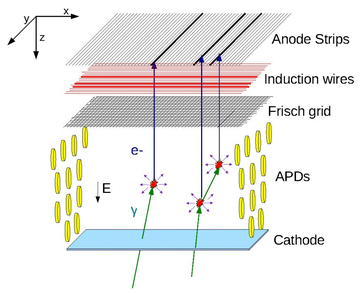


Anode model in Garfield

2. LXe PET Detector - Principle of Operation

Photons interact in the LXe producing:

- prompt scintillation light
  - ➔ measured by light sensors (avalanche photodiodes)
- ionization electrons
  - ➔ drifts under the applied electric field to the anode (sub-mm resolution in 3D)

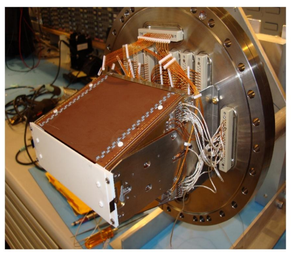


•The electron signal induced on the wires and collected by the anode strips provides the 2D (x,y) position of the interaction

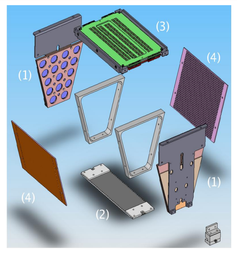
• The z-coordinate is calculated from the drift time and the known drift velocity

3. LXe PET Detector - Prototype

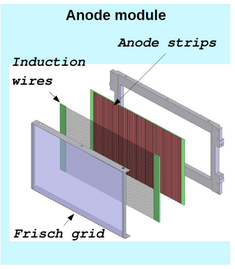
•TPC: 1.1 L active volume filled with LXe
•32 Avalanche Photodiodes
•Anode module: 96 induction wires and
•96 orthogonal anode strips



Prototype mounted on a flange



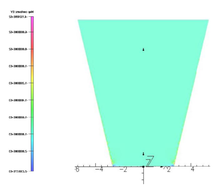
(1) APD module
(2) Cathode
(3) Anode module
(4) Field cage



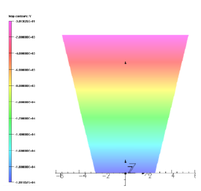
• grid of wires pre-ceding the anodes
• anode segmented to strips perpendicular to the wires
• shielding grid

4. Results - Electric Field

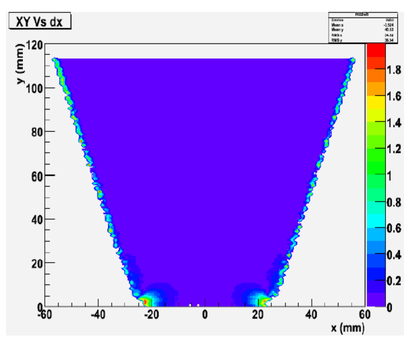
Three-dimensional simulation results within the prototype detector showed that the field was nearly uniform in the center, with electron trajectories deviating by less than 1 mm between the cathode and anode. The region of dead space constitutes 2.9% of the total volume in this sector.



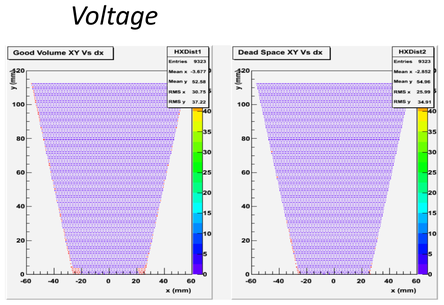
Electric field



Voltage



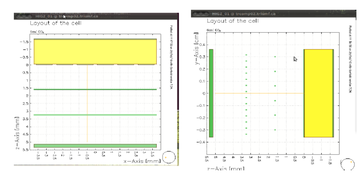
Electron deviation contour



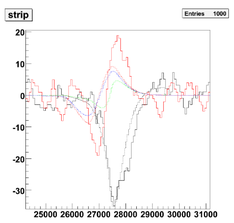
Good volume and dead space in the center of the sector

5. Results – Ionization Signal

The simulation signals on induction wires and collection strips were in a good agreement with measurements.



Electron track of top view and side view



Comparison of simulation and measurement signals

6. Conclusions

Based on the 3D electric field map, we can assign correction factors to correct the non-uniformity through out the sector. We also correctly simulated the signals of the TPC.

7. References

Amaudruz *et al: "Simultaneous reconstruction of scintillation light and ionization charge produced by 511 keV photons in liquid xenon: potential application to PET";* Nuc. Instr. and Meth. in Phys. Res. A, **2009**

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