TRIUMF

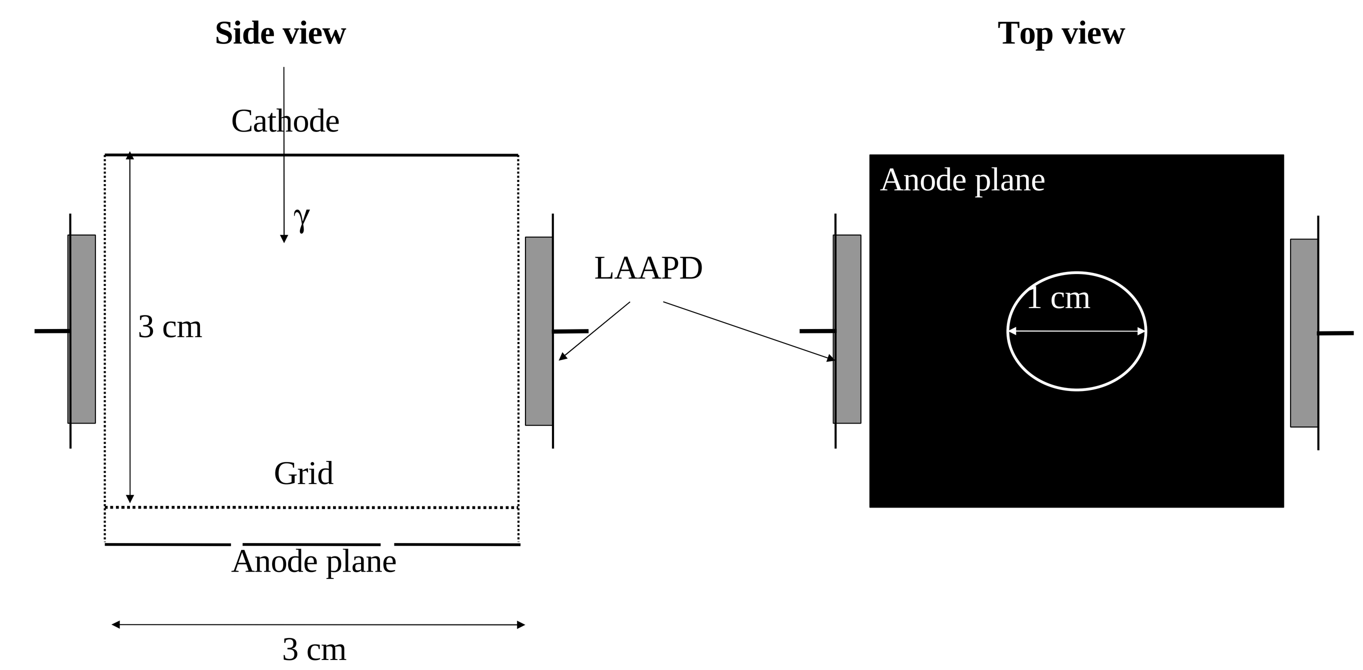
Li Xenon PET

Liquid Xenon Positron Emission Tomography

Investigation of Liquid Xenon Detectors for PET: Simultaneous Reconstruction of Light and Charge Signals from 511 keV photons

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 solid crystals include improved energy resolution, sub-mm spatial resolution, and larger detector volumes with high sensitivity. Using a small test chamber we measured scintillation light and ionization charge signals in order to study the energy resolution in LXe.



Test Chamber: side and top views of the test Chamber

The Test Chamber

A small test chamber (27 cm³) was constructed to measure light and charge signals. An electric drift field was applied between the cathode and the shielding grid located near the anode charge collection plane. Two large area avalanche photodiodes (LAAPD) were used to detect the scintillation light. Charge was collected on a central 1 cm dia. electrode (A1) or on an outer electrode (A2). The 511 keV photons emitted by a ^{22}Na source entered the test chamber (along the z axis) through the cathode plane and coincidences with an external NaI detector were studied.

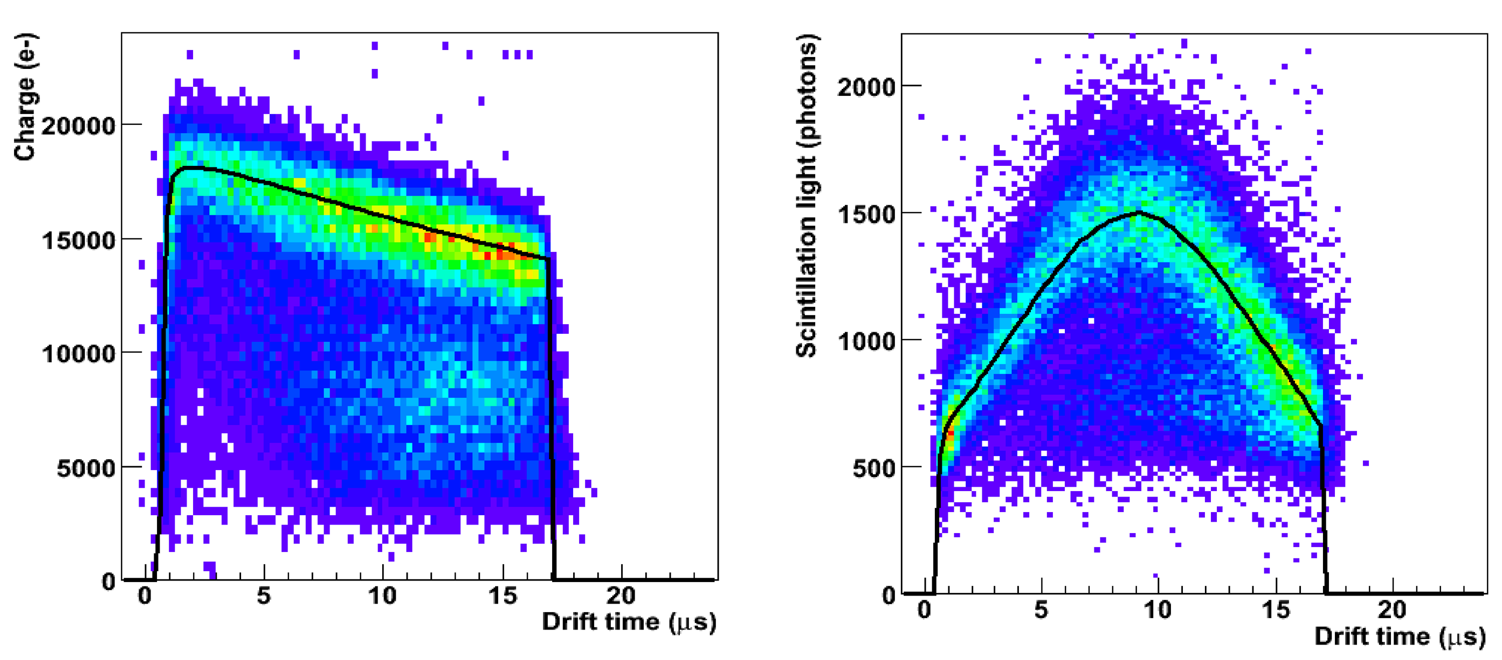
Charge and Light Collection

Table 1 gives results for charge and light collection at different drift fields for 511 keV photons. Photoelectric peak events and Compton scattering interactions were observed. From the charge distributions, the drift velocity, total charge, and the charge attenuation length (or electron drift lifetime) were measured. From the observed light distribution, the total number of photons and the charge drift velocity were obtained.

The spatial resolution in the drift direction using only the observed light amplitude of the two LAAPDs for photopeak events was 3 mm; the spatial resolution from charge measurements is expected to be approximately 0.3 mm in all three dimensions.

Table 1

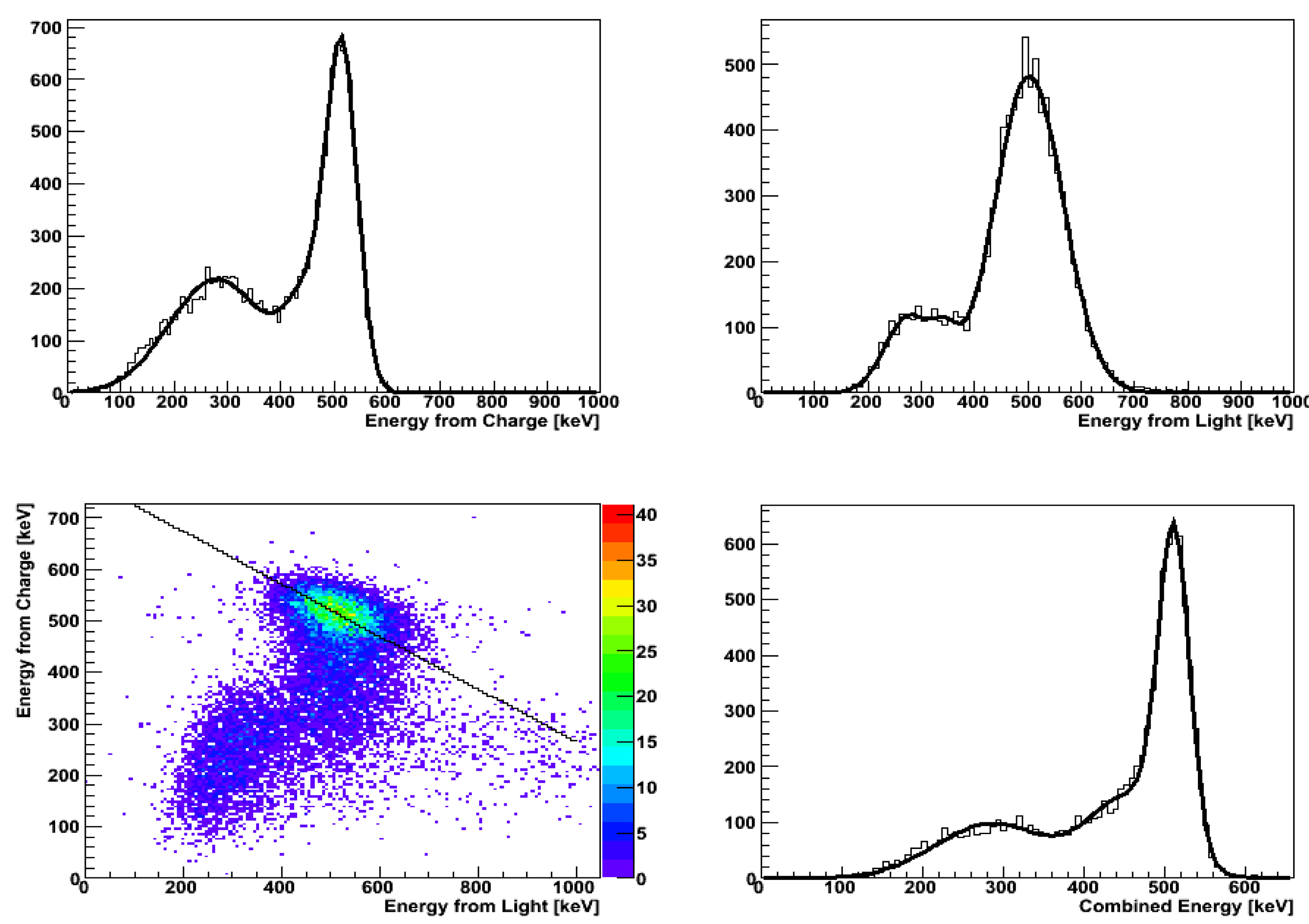
Electric field [kV/cm]	Drift velocity [cm/µs]	Electrons	Photons
0.33	0.15 ± 0.01	16,000 ± 2,000	16,500 ± 1,000
1	0.17 ± 0.01	19,000 ± 2,000	14,500 ± 1,000
2	0.20 ± 0.01	21,000 ± 2,000	13,500 ± 1,000



Charge and light signals: Charge (left) and light (right) collection as a function of drift time for a 1kV/cm drift field. The curves are fits based on parametrizations obtained from current calculations and solid angle.

Energy Resolution

To study the energy resolution we focused on the central region of the test chamber. The figure on the right shows the energy distributions observed for charge, light and the combination of both. The 511 keV region ellipse of the charge-light anti-correlation was fit and projected along the ellipse axis. Combining the information of the light and charge measurements, energy resolutions as low as 3.78% were achieved.



Energy spectra: The observed charge spectrum (upper left plot), light spectrum (upper right plot), correlation between light and charge signals (lower left plot), and combined spectrum using the correlation (lower right plot) for 511 keV photons with a drift field of 2.66 kV/cm.

Results summary

- Electron lifetime: > 200 µs
- Time resolution: 1 ns
- Energy resolution: <4%
- Spatial resolution obtainable from charge (light): 0.3 (3) mm

Future Work

A complete single sector for a PET ring is under construction. This will be followed by coincidence measurements using two or more sectors.

This work was supported in part by the Canada Foundation for Innovation, the University of British Columbia, and TRIUMF which receives federal founding via a contribution agreement through the National Research Council of Canada.

Participating Institutions: