School on Dark Matter and Neutrino Detection

EL TPCito – Illustration of Time Projection Chamber

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Abstract

When a particle enters a time projection chamber (TPC) volume it may interact with the fluid it holds exciting and ionizing the matter. Electrons can therefore be collected by applying high electromagnetic fields in this volume. This technique is commonly used for rare events detection due to its good charged particles trajectory reconstruction and calorimetry performance. Scintillation light can also be detected. In this laboratory students will operate a small TPC with a coupled photomultiplier tube (PMT) to detect light from the interaction of alpha particles in a gaseous argon/nitrogen mixture. Groups of 2-3 students will analyze the initial ionization signal as well as the electroluminescence (EL) one in order to characterize the electron drift as a function of the variables of the system (cathode/anode voltages, argon/nitrogen mixture).

Disclaimer: This material is an adaptation of the previous work realised for the EDIT symposium in 2012.

Goals

- Understand the main interaction processes happening inside an EL TPC volume
- Learn about the components of such device and their purpose ()
- Get acquainted with the main operation parameters and their optimal values of the setup
- Obtain the typical observed light signal and its behavior as function of the parameters

The EL TPCito

Created by J. T. White, the experimental setup for this lab session will allow us to observe the main features of an EL TPC. Figure 1a shows a 3D model of the device and its components. The sensitive volume is surrounded by a high density polyethylene cylinder as its main structure giving mechanical support, from bottom to top, to the cathode plane, the five field rings along the 4.6 cm length interaction region (IV), the gate grid as the lower limit for the 1.5 cm length electroluminescence volume (EV), the anode grid as the upper limit and a closing acrylic window. The high voltages are supplied via feedthroughs served at the bottom of the cathode plane. Light signals are read out with a photomultiplier coupled on the top window.

Once a radiation source is positioned just outside below the cathode center one can measure the light signals produced by the scintillation due to the incoming particles (S1) and from the electroluminescence (S2). Considering the drift time for the electrons to arrive from the IV to the EL region it is expected the two signals to be observed separately. Figure 1b is a cartoon that illustrates the PMT output time dependence features.

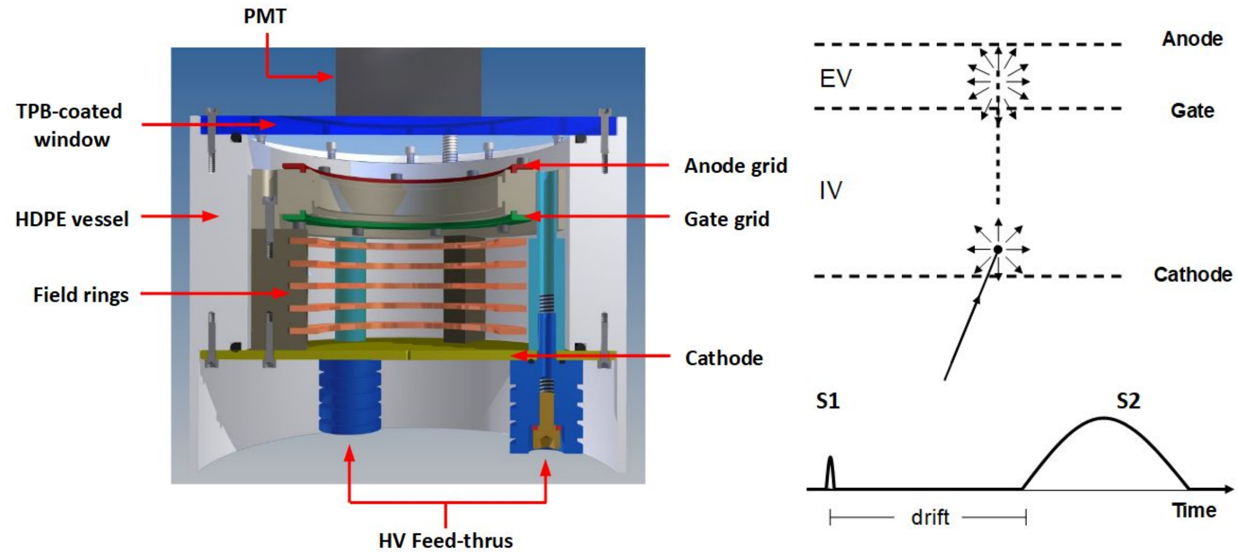

Fig. 1: Schematics of the EL TPCito (left). Light production mechanisms - scintillation and electroluminescence (right).

Experimental Procedure

Setup

- View internals of toy detector
- Assemble HV & signal cables, gas lines, and PMT → This is done!
- Add alpha source → This is done!

Caution

This experiment involves the use of an alpha/ɣ-rays source. Improper use could result in long term health consequences. The source should NOT be handled. The TPCito detection system is fragile and very expensive. Please handle with care.

- Enclose setup with dark box
- Make sure the experiment is covered with the black cloth

Measurements

Caution

Do not apply voltage to the PMT unless it is covered by the black box and cloth!!!

- Apply HV to PMT and observe single electron dark current on oscilloscope
    - Estimate the area of a single electron pulse.

- Turn on gas flow (pure argon only)
    - Analise the scintillation signal (S1). What is the time it takes the signal to return to the baseline value and peak amplitude? Try to estimate the decay time as the time it takes for the voltage value to fall to 1/e * peak value.

- Apply bias to: $V_{cathode}$ = -1500 V; V_{grid} = 0 V

$V_{cathode}$	-1500 to 1000 V
V_{grid}	0 V
V_{anodet}	2500 to 3000 V
V_{PMT}	-1300 V

Table 1. Conditions during data taking. $V_{EL} = V_{anode} - V_{grid}$ is the applied voltage applied between the two meshes, $V_{drift} = V_{cathode} - V_{grid}$ the applied voltage in the drift region, and V_{PMT} is the average PMT bias voltage. Values should not be varied out of the indicated ranges.

- Raise V_{anode} to ~ 3000 V and observe S1 & S2 signals
    - Do you see any difference in S1 signal (amplitude and time)? Would you expect to see any change?
    - Can you determine the drift time from S1 to start of S2? This is tricky!
    - What is the time duration and peak amplitude of S2? Get an estimate on the number of photons that are being recorded by the PMT. Is it close to the value we expected?
- Vary drift field and EL field – observe changes
- Vary the gas mixture (add ~ 0.2% N_2) and observe change in light yield, drift time and pulse width
    - Can you explain the observed behavior?
- Measure area of S2 pulse measure light yield.
- Turn off voltages applied to the TPCito and observe S1 only. Are there changes with the argon/nitrogen mixture?