Testing efficiencies of Argon Scintillation with Xenon doping

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Gaseous argon and xenon particle detecting chambers are of increasing use in high energy physics. They have been observed to be advantageous over liquid xenon/argon chambers in tracking particles and energy resolution. Time Projection Chambers (TPCs) are able to test the recombination and scintillation efficiencies of various rare gas mixtures. It is believed that a precise doping of xenon to argon gas will provide for the most efficient rate of scintillation which could enhance the performance of the gas-phase Ar detector for DUNE. We have repurposed the TeaPot for gas mixture studies at UTA with the goal to determine the time constant of recombination for the singlet and triplet states in various mixtures of argon and xenon. Initial analyses have been done in vacuum, pure argon, and a 3% volume of xenon, using a single photomultiplier tube (PMT) for observation of scintillation. This poster will present the progress to constrain the experiment to proper control conditions in pure Ar.

1

Efficiency improvement in Xe doped LAr

- **The current standard medium for the Deep Underground Neutrino Experiment (DUNE) is liquid argon (LAr). Use of Xe-doped LAr has shown to be advantageous over pure Ar in terms of scintillation yield and efficiency as well as resolution and discrimination of signals [4,5].**
- **It has been observed that Xe added to LAr produces emission at the Xe-scintillation wavelength of 175 nm ($\lambda_{Ar} \approx$ 128nm) and faster emission time constants than liquid argon. The goal of this study is to examine this effect in gas [6].**
- **Efficiency of scintillation can be analyzed by calculating the time constant of decay for the triplet and singlet sates of the excimer as shown in Fig. 2 [6].**

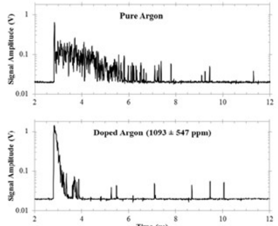

Figure 1. Above are figures that represent an observed signal in pure and doped LAr [7].

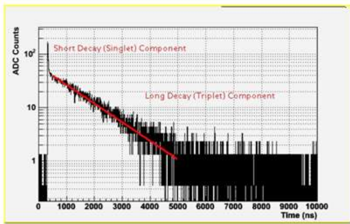

Figure 2. Above is a figure that demonstrates the singlet and triplet decays that comprise the signal from LAr [1].

2

Scintillation and Recombination

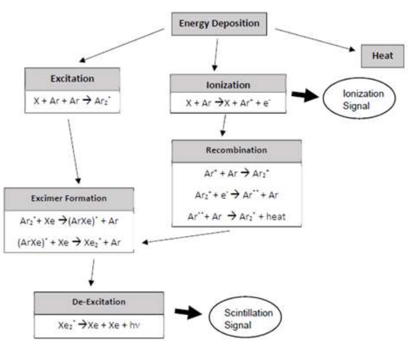

Figure 3. Above is a diagram that demonstrates the processes energy from particle interaction produces a scintillation signal. Adapted from [3].

- **Particles travelling through the chamber will interact with the gas. These interactions provide energy for either the ionization or excitation of electrons [3,4].**
- **Energy is transported through various combination processes to be released as a photon [3].**
- **These processes can be complicated and are different for various gases and mixtures.**
- **The diagram to the left illustrates the process of main interest in this study.**
- **For this experiment we examine the scintillation produced by incident α and β radiation from ^{210}Po and ^{90}Sr sources, respectively.**

3

The TeaPot

The Teapot is a small ionization chamber built at Lawrence Berkeley National Laboratory in order to test the properties of gas mixtures and repurposed for use at UTA [5].

- **Internal parallel plate electrodes**
  → Isolated signal electrode avoids induced charge outside the gap
- **Can be pressurized up to 8 bar (116psi)**
  → Current testing done between 0.7-1.4 bar (10-20 psi)
- **Chamber is evacuated then gas is flushed to help avoid contamination**
  → Recirculation assembly available but not currently in use
- **Capable of using up to 4 PMTs**
  → Currently 1 in use
  → -1250 V bias

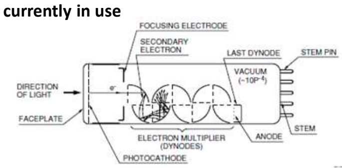

Figure 4. This image illustrates how a PMT generates a signal by a photoelectron cascade [6].

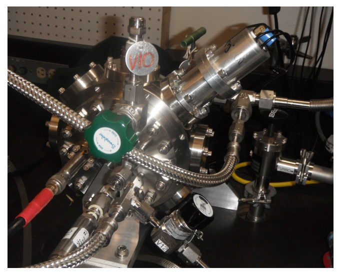

Figure 5. The Teapot, located in the Science Hall at UTA.

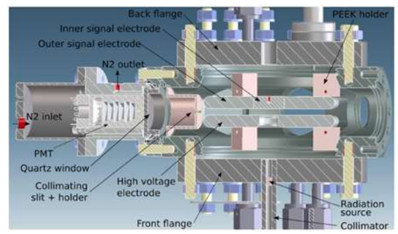

Figure 6. The above figure illustrates the internal schematic of the Teapot and a PMT [5].

5

Pure Argon and Noise Reduction

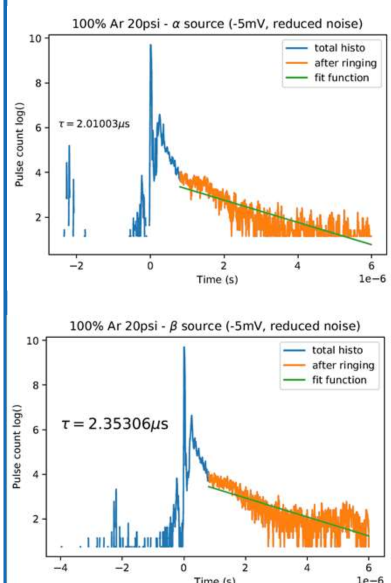

Figure 10. The above plot displays a logscale histogram of the signal produced by α (TOP) and β (BOTTOM) radiation in pure Ar @ 20 psi. A linear fit has been generated for the triplet state decay for which the time constant can be taken as the negative-inverse slope.

- **To determine the time constant of decay, pulse histograms are analyzed in logscale such that the decay becomes a nearly linear function.**
- **Linear best fit lines were generated for the time range of the pulse associated with the decay of the excimers triplet state because of the smaller error involved than the quick singlet decay.**
- **It is important to note that the excimer that provides scintillation are not the same for pure and doped argon, nor are the energy transfer processes from incident α and β radiation**
- **Pure Ar has been found to have a time constant of ~3.2 µs for pressures between ~1-30 bar [2]. Replication of these results in our experimental setup will establish a viable control before further testing of xenon doping.**
- **Current results have shown the time constant to be quicker than expected. This may be because of nitrogen contamination [1].**
- **We aim to improve these results by using a gas filter and recirculation system as well as extending our observed time domain.**

4

Average Waveforms and Initial Observations

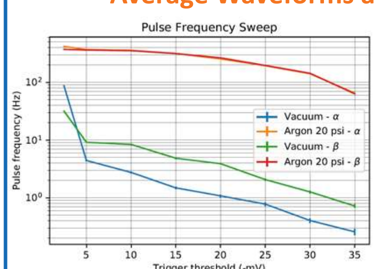

Figure 7. The above plot displays a logscale comparison of pulse frequency in vacuum and Ar @ 20 psi. This figure clearly demonstrates the necessity of using a medium for detection of scintillation.

- **Average waveforms were generated from a collected of ~10000 pulses from α-radiation (Fig. 8), but sample size has since increased to ~16000.**
- **A pulse is define as being the point in the waveforms at which the late end of the peak exceeds a specified threshold just above the noise level.**
- **For this experiment our trigger threshold has been selected as -5 mV for a pulse frequency of approximately 360 Hz (Fig. 7).**
- **Histograms were generated for those contributions to the waveform that exceed the specified threshold, indicating there was a pulse at this time for some number of observed waveforms (Fig. 9).**

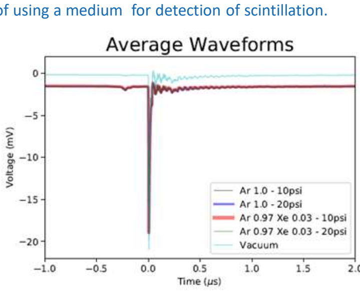

Figure 8. The above plot displays the average observed signal or pulse in 2 gas mixtures at 2 pressures and vacuum (~10^{-7} – 10^{-6} Torr).

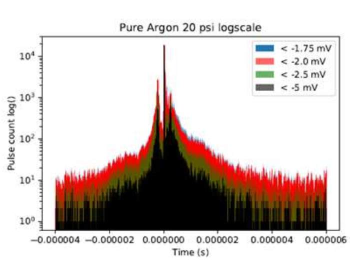

Figure 9. The above plot displays a logscale histogram of the signal produced by α-radiation in pure Ar @ 20 psi, for various trigger thresholds.

References

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[2] Amsler C., Boccone V., Buchler A., et al JINST, **3** (2008)
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[4] Nakajima Y., Goldschmidt A., Long M., et al., J. Phys. Conf. Ser., **650** (2015)
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[6] *Photomultiplier Tubes: Principles and Basics*, 3rd (a) Ed., (Hamamatsu Photonics, 2007), pg. 13
[7] Wahl C.G., Bernard E.P., Lippincott W.H., et al., JINST, **9** (2014)