Infrared Scintillation in Liquid Argon

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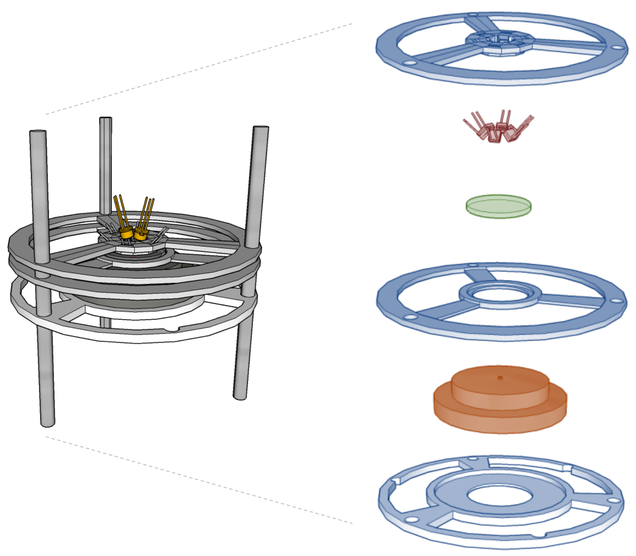
Scintillation of liquid argon in the vacuum ultraviolet (VUV) is well documented. However, there is controversial evidence that emission exists in the near infrared region (NIR). The experimental aim is to detect this scintillation light and estimate the photon yield.

Background

Ionizing particles can cause materials to scintillate by promoting molecules to an excited state, which emits photons as it decays back to the ground state. In liquid argon, the proposed mechanism for this excitation is the formation of excited dimers (excimers). An excited argon atom can interact with another argon atom to form a Rydberg state, where the two atoms are bound together. The decay of this state to the first excited level is the proposed origin of the NIR emission. However, the spectrum and mechanism of emission is not very well understood in condensed noble gases [1]. Research is important as it has several benefits over VUV, including reduced Rayleigh scattering and manipulation of light using standard optical components.

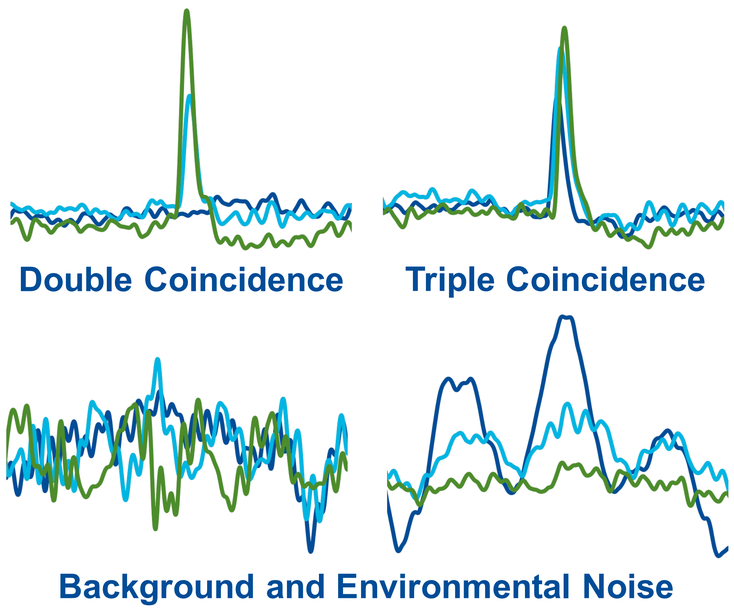
Experimental Setup



This setup was immersed in liquid argon in the SCENE cryostat. An electronics board provided a bias voltage of 45 V to the detectors and amplified the detector output. The three most efficient detectors were connected to an oscilloscope to detect single photon signals. These appear as peaks with a width of around 10 ns. The oscilloscope triggered when two detectors crossed a threshold voltage of 0.02 V, with the aim of detecting two coincident peaks.

Analysis

Electronic and environmental noise appeared as oscillations. Using LabVIEW, various criteria on the frequency, mean and number of peaks in the data eliminated these signals. Another background source are *dark counts*, which are peaks not caused by a photon. The probability of double or triple coincidences being noise are negligible.



Accepted Signals

Peaks had to fall within a *coincidence window* of 10 ns to be considered coincident. These peaks are caused by different photons caused by the same alpha particle.

Rejected Signals

Noise due to the electronic board and to noise within the lab could trigger the scope, but are false positives and were filtered out using various criteria.

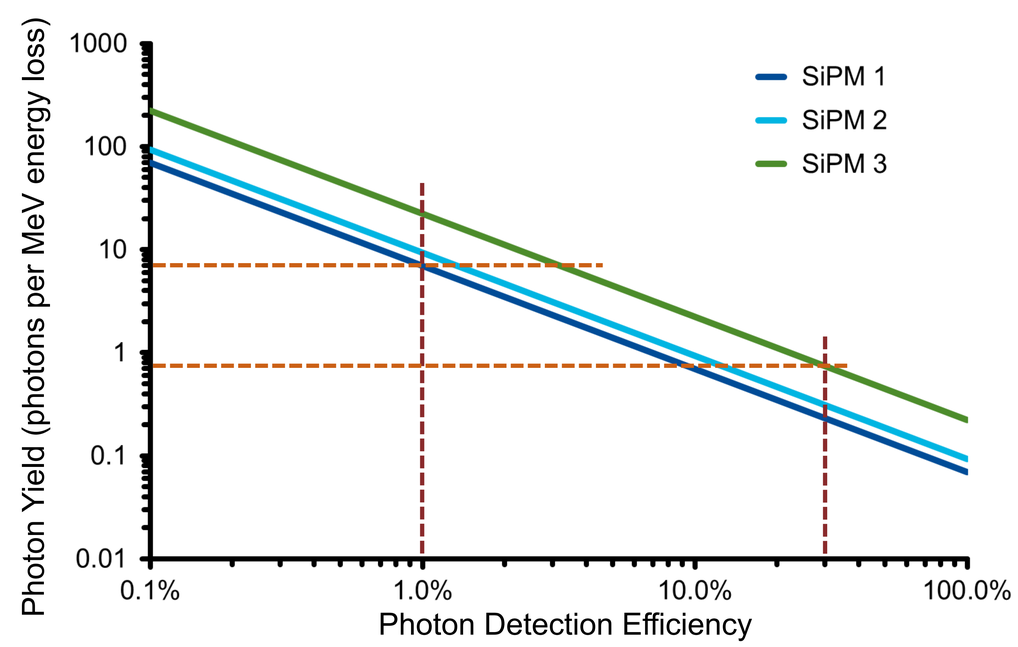
Results

Trigger	Double (hour^{-1})	Triple (hour^{-1})	Cumulative Time	Probability (%)
1 2 3	224 ± 3	1.9 ± 0.3	23h 1m	3 0.85 ± 0.13
1 2 3	586 ± 4	2.1 ± 0.2	36h 46m	2 0.35 ± 0.04
1 2 3	790 ± 5	2.1 ± 0.2	36h 0m	1 0.27 ± 0.03

The ratio of double coincidences and triple coincidences is the probability of the third detector detecting an event. The probability of detecting an event P is related to the energy lost by the ionizing particle E, the photon yield Y (photons emitted per MeV energy loss), the geometric acceptance g (fraction of emitted photons that hit detector), and the photon detection efficiency p (chance of incident photon causing a signal) by:

$$P = 1 - (1 - g\times p)^{E\times Y}$$

Both E and g are known, resulting in a relationship for p and Y. The photon detection efficiency could lie between 20% (all emission at 715 nm) and 1% (all emission at 1000 nm), giving a photon yield between 0.8 and 7 photons per MeV.



Conclusion

The calculated yield of 0.8 to 7 photons per MeV is much lower than the other reported value of 510 ± 90 photons per MeV [1]. However, that experiment utilized 30-40 keV X-rays instead of alpha particles, and could therefore undergo a different excitation mechanism. There has also been promising results using Xe-doped liquid argon, which significantly increases the photon yield [2].

References

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[2] A. Neumeier, T. Dandl, T. Heindl, A. Himpsl, H. Hagn, M. Hofmann, L. Oberauer, W. Potzel, S. Roth, S. Schönert, J. Wieser, and A. Ulrich, *EPL* **106**, 32001 (2014).

Acknowledgments

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