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Dark photon dark matter search in the 6-8 eV energy range with URIDA Experiment

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The dark photon emerges as an additional gauge boson in a U (1) Standard Model extension and is coupled to the ordinary photon via kinetic mixing. To investigate the energy band from 6-8 eV, where photons are highly absorbent due to molecular oxygen with an absorption length on the order of cm at atmospheric pressure, we developed the Ultraviolet Range Initiated photons from Dark-photons of Ambient (URIDA) Experiment, motivated by other work. In order to minimize attenuation, the detection system was housed in a vacuum chamber. We constructed our detector system using a low dark rate photomultiplier that is sensitive at these energies and included an aluminum reflector to enhance collection. We report on URIDA's performance.

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1. Introduction

The formalism for the interaction between dark photons and photons through kinetic mixing, along with the potential for detection using a dish antenna are described for instance in these Refs. [1, 2, 6]. Dark photon searches in the energy band from 6-8 eV, are motivated by previous work [3–5]. This specific energy band poses challenges due to molecular oxygen absorption. To investigate dark photons in this band, we built the URIDA Experiment.

2. Experimental Setup

The PMT inside the vacuum chamber has a diameter of 25 mm and was custom made from Hamamatsu for low pressure environments with suitable quantum efficiency at these wavelengths. For the dish we used a parabolic aluminum reflector from Edmund Optics with a total effective area of ~0.13 m^2, chosen because aluminum has high reflectively in vacuum UV region. The vacuum chamber was operated at a pressure of $\sim 10^{-4}$ torr. Figure 1 shows the experimental setup and the four different run combinations. Data was collected in four distinct setups, as illustrated in Fig.1 (Right): a mechanical shutter was utilized to close ("on") or open ("off") the PMT, and the PMT's position was adjusted from the focal point location to an offset location to address background effects.

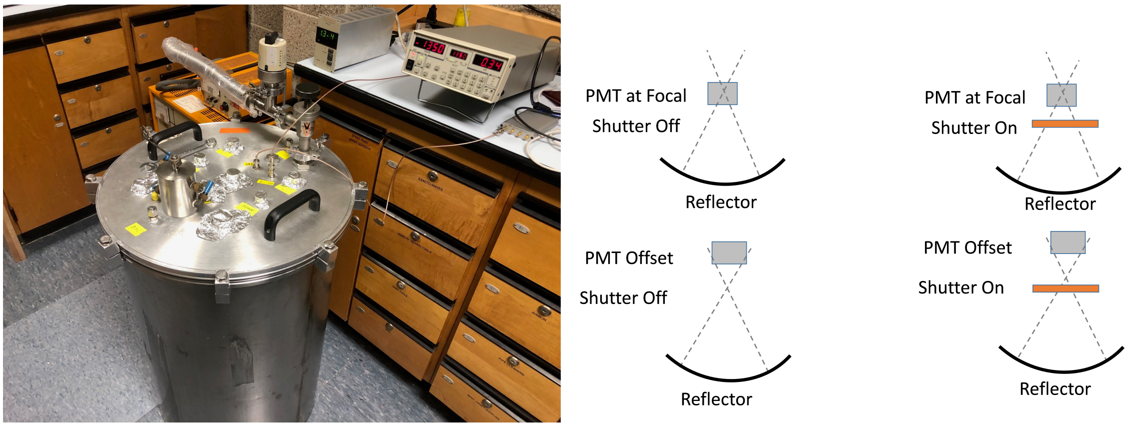

Figure 1: (Left) Vacuum Chamber with the PMT mounted inside. (Right) The four different experimental configurations.

3. Results & Discussion

Figure 2 shows a typical single photon pulse recorded at the PMT, along with the accompanying ADC spectrum, demonstrating excellent single photon resolution. Figure 3 on the other hand, depicts the counts per minute over time for the two distinct shutter settings (on and off). The upper plot displays the results for the PMT positioned at the focal point, while the lower plot depicts the results with the PMT offset by 10 cm. The results of Fig. 3 indicate that the count rate is higher when the shutter is in the open position compared to when it is in the closed position, and when the PMT is positioned at the focal point as opposed to being offset.

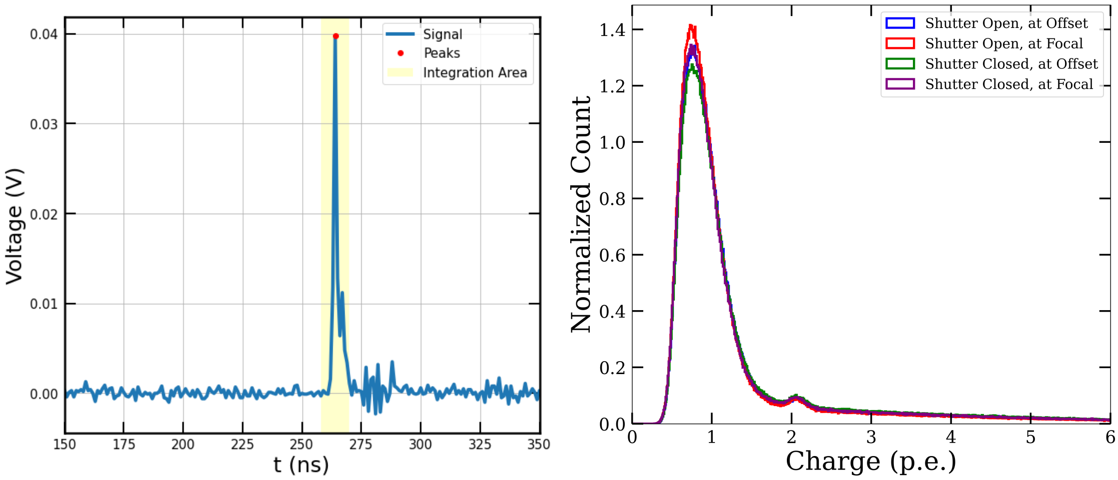

Figure 2: (Left) Single photon pulse. (Right) Charge spectrum for all four settings.

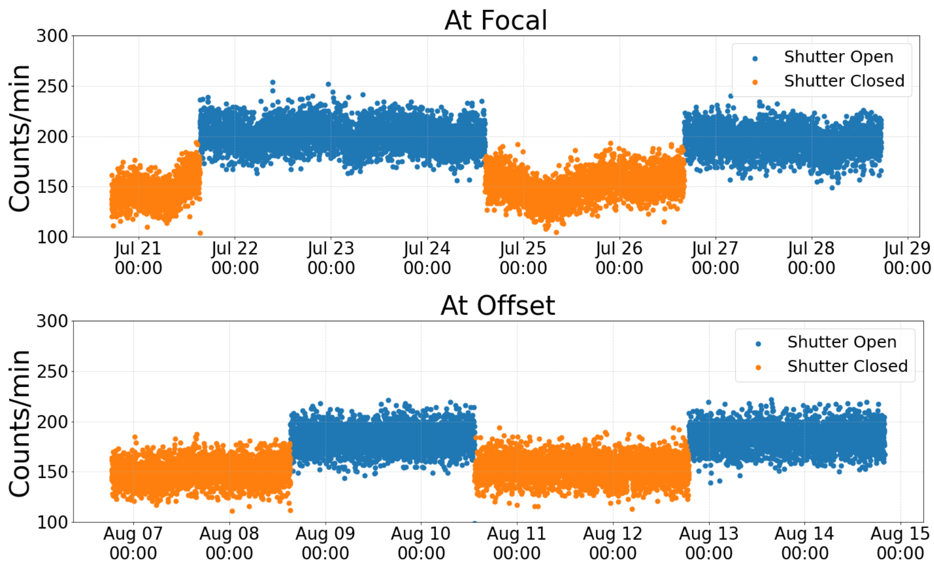

Figure 3: (Top) Counts per minute versus time when the PMT is at the focal point while (Bottom) is the same when the PMT is offset.

Figure 4 depicts the time intervals between consecutive events for two different shutter configurations: one with the shutter is closed and the other with the shutter is open. On the left, the PMT is placed at the focal point, while on the right, it is offset. The figure hints at the presence of non-Poissonian processes across all settings, with a pronounced effect in time intervals of less than 0.5 seconds.

4. Conclusion

We assembled a vacuum-based dish antenna detector designed to investigate the conversion of dark photons into regular photons occurring at the surface of a parabolic aluminum reflector.

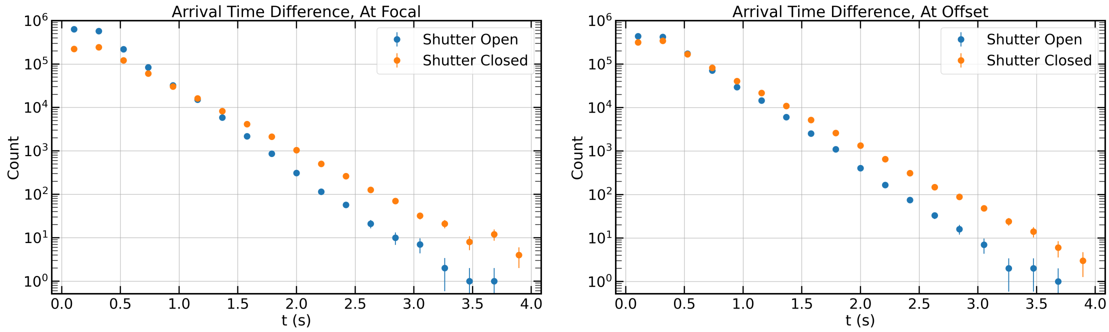

Figure 4: Arrival time between successive events for the PMT at the focal point (Left) and offset (Right).

Following this, these converted photons would then be detected by the PMT. Our exploration of the vacuum UV range in the 6-8 eV window was prompted by previous investigations. In our initial analysis, we have observed a difference in the count rate between the PMT being at the focal point and at the offset position. This difference becomes more evident when the shutter is open as opposed to when it is closed. These events are most likely characterized by arrival time differences of less than 0.5 seconds and may potentially originate from Cherenkov events produced by muons passing through the PMT's glass window. The reflector may redirect these photons, which are subsequently detected by the PMT. Further analysis is underway to understand their source.

References

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