Dark photon DM search in 6-8 eV energy range with URIDA Experiment

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Introduction

Dark photon is a natural U(1) extra gauge boson in extension to Standard Model which couples kinetically to photons. The kinetic mixing parameter spaced has been explored extensively over wide range of energies. The optical region has been explored by dish antenna experiments for example FUNK [3]. There is motivation to search for vacuum UV dark photons from temperature excursion and absorption band a these energies in upper stratosphere [5, 4]. The photons at energies 7-8 eV (150-180 nm) have absorption length of ~cm so even if they are produced from dark photon conversion they are absorbed primarily from oxygen. We designed a dish antenna experiment similar to FUNK and placed in a vacuum chamber in order to be able to detect these photons and report on performance and preliminary kinetic mixing sensitivity.

Experimental Setup

For the photodetecor we use ET Enterprises Electron Tubes photo-multiplier 9107QB with sensitivity from 160-630 nm. This photomuliplier has lower dark rate and excellent single photon resolution. We determined the best operating high voltage for the photomultiplier was 1050 V for best single photon resolution. For the dish we used a parabolic aluminum reflector from Edmund Optics with a diameter of xx cm, chosen because aluminum has high reflectively in vacuum UV region. The dish had to be customized to fit inside the vacuum chamber with a total effective area of 0.05 m^2. The vacuum chamber was operated at a pressure of $\sim 10^{-5}$ torr, and the light exposed areas were covered with black cloth material. This particular PMT does not operate in vacuum so it was mounted on outside viewing through a MgF_2 glass window with transmission of light in vacuum UV up to 90%. Figure 1 shows the vacuum system and the reflector inside.

A DRS4 Evaluation board was used for data acquisition of the events.

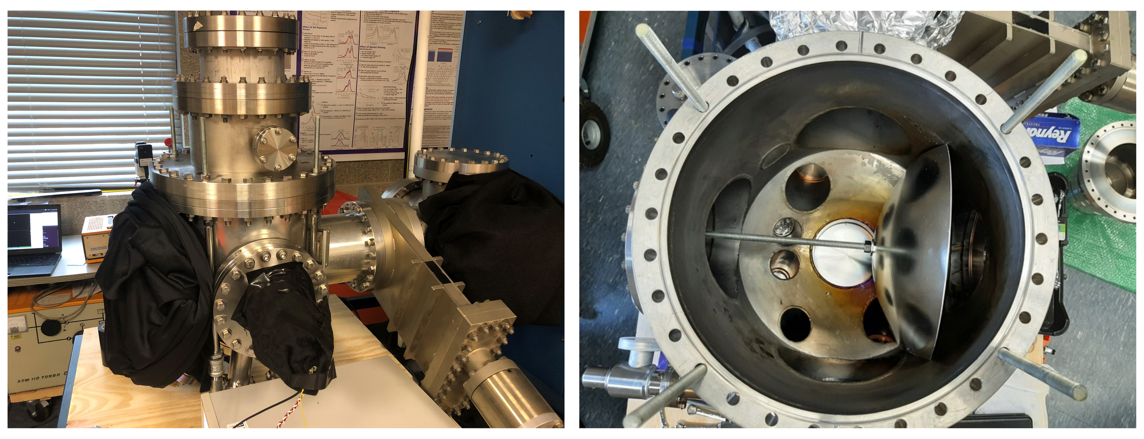

Figure 1. (Left) Vacuum Chamber with photodetector mounted on outside. (Right) A picture of parabolic mirror inside the vacuum chamber facing the PMT.

Measurements & Analysis

We acquired about 10 million events each for three different configurations; closed PMT for dark counts, aligned PMT with the mirror for Data, and offset PMT for a control sample. Additionally we applied some quality cuts on the data

Figure 3 shows the arrival time difference between subsequent events. The number of events for the dark and control run is normalized to the number of events in data run. The arrival time distribution is approximately exponential for the dark run indicating not correlated events. However for both control and data we see the appearance of a cluster at arrival times of 1-1.5 seconds. This cluster of events arriving once every 1-1.5 seconds are consistent with Cherenkov events caused by cosmic ray muons inside the glass of the vacuum chamber.

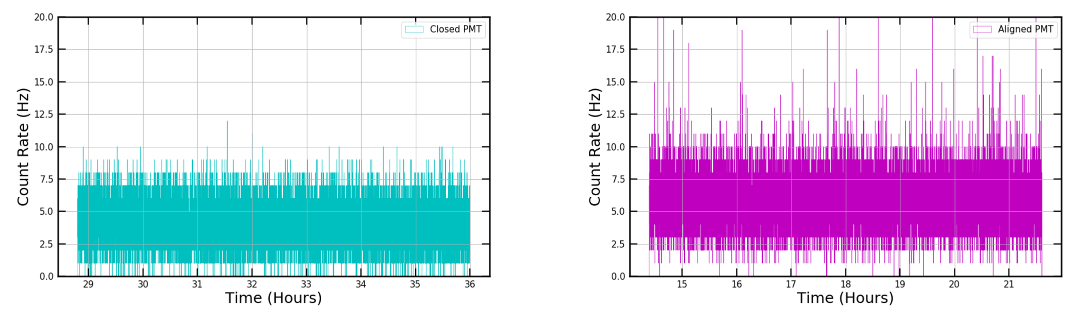

Figure 2. (Left) Trigger Rate for a subset of Dark Run. (Right) Trigger Rate for a subset of Data Run.

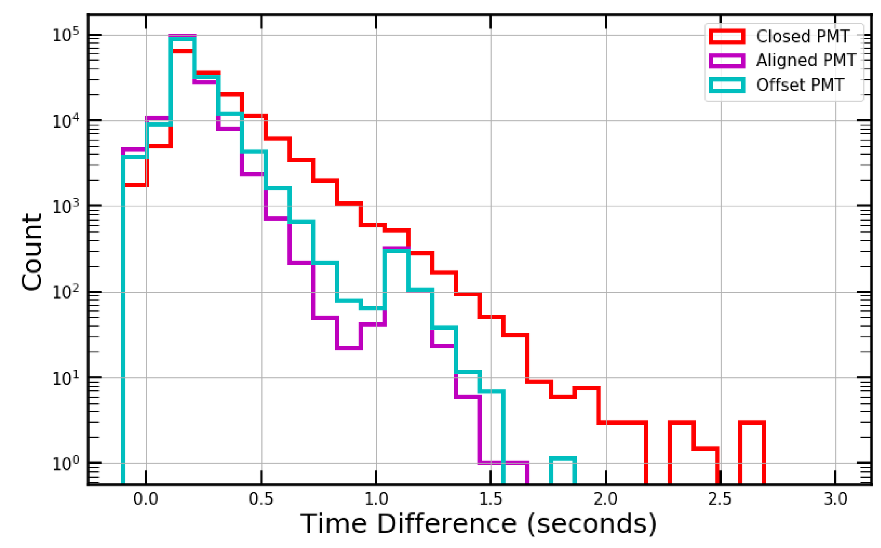

Figure 3. Arrival Time between successive events for dark , control, and data run

Figure 4 shows the charge distribution for these three different runs normalized to data event number.

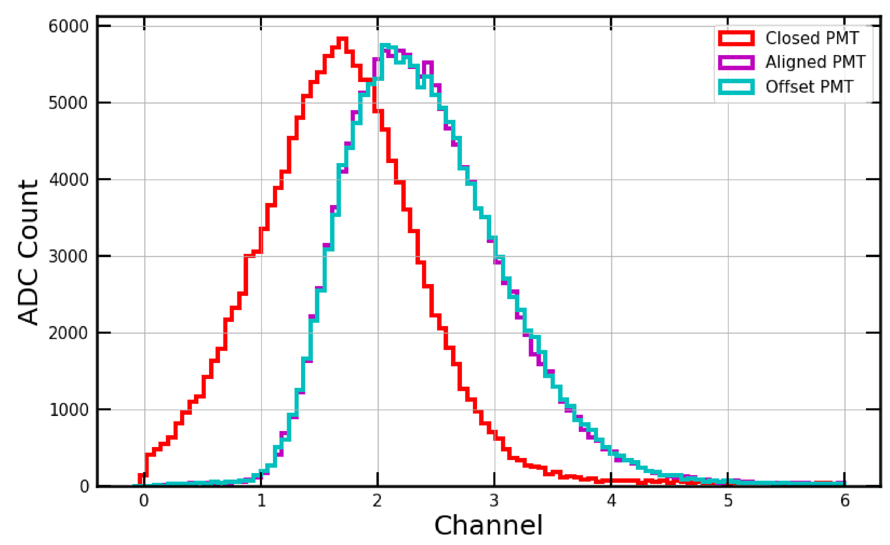

Figure 4. Charge distribution for dark , control, and data run

Figure 5 shows the count rate difference between data and control which would be a measure of the signal. There is some modulation which is explained by that fact that in offset configuration the PMT was more exposed to Cherenkov events from the larger vacuum window. For this case a count rate of $\nu \sim 0.01$ Hz determines the limit we can place on dark photon kinetic mixing.

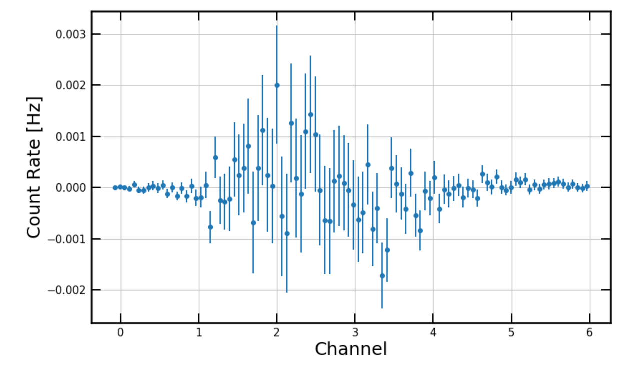

Figure 5. Difference in count between data and control

The kinetic mixing for this count rate according to [2, 3] is:

$$\chi_{sens} \simeq 5.5\times10^{-13}\left[\left(\frac{0.1}{\eta}\right)\left(\frac{\nu}{\text{Hz}}\right)^{1/2}\left(\frac{100\text{days}}{\text{T}}\right)^{1/2}\left(\frac{0.3}{\rho_{CD}}\right. \quad (1)$$

where $\eta \sim 0.08$ is the efficiency, $\nu \sim 0.01$ Hz, T is live-time of experiment in days (0.3 days) for this particular run, and $A_{eff} \sim 0.05\text{m}^2$. The sensitivity is $\chi_{sens} \simeq 10^{-11}$. This preliminary sensitivity is for energy ranges in optical region in addition to vacuum UV. We plan to design a much larger area detector in vacuum and be able to isolate the Cherenkov events and other events and eventually carry out a more stringent search in vacuum UV energy ranges.

Conclusion

We constructed a dish antenna detector in vacuum to search for dark photon to photons conversions happening at the surface of a parabolic aluminum reflector which then would be detected by the PMT. The vacuum UV search was motivated by other studies for Dark Matter allowing us to study the 7-8 eV range window. In this study we included also the optical region. We learned the source of the correlated noise caused by Cherenkov events in glass and we placed a preliminary kinetic mixing limit. In future studies, we plan to collect more data, isolate the noise better, include a larger area in vacuum, and carry out a more detailed analysis

Acknowledgement

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References

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