CLAS-NOTE 2008-033

Studies of the Transmission of Gases for the Čerenkov Counters

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(Dated: January 13, 2009)

PACS numbers:

I. INTRODUCTION

When a charged particle travels through a medium (in our case, a gas) it disturbs the local electromagnetic field. As the particle passes and the local atoms fall back into equilibrium, they emit photons. When the charged particle is moving faster than the speed of light in the medium, these emitted photons interfere constructively creating what is known as Čerenkov radiation. Čerenkov detectors use the mass dependent threshold energy of Čerenkov radiation to differentiate between lighter and heavier particles. This is an important component of particle detection at Jefferson Lab. Currently, the Čerenkov Gas being used is C_4F_{10}; however this gas has recently become expensive and difficult to get. To solve this problem, research is being done in order to find a new Čerenkov Gas that will work as well as the C_4F_{10}. The first gas to be tested is C_4F_8O. It is important that the Čerenkov Gas is very transparent so as many particles as possible are transmitted through it to increase accuracy in the detection process. Air and CO_2 were also tested.

II. THE EXPERIMENT

To study transmission, a setup involving a deuterium lamp, monochromator, photomultiplier tube (PMT), discriminator, logic unit, and scaler was used. An Oriel 66080 deuterium source with an Oriel 63161 lamp was chosen because it has a good spectrum at low wavelengths, which can be seen in figure 1.

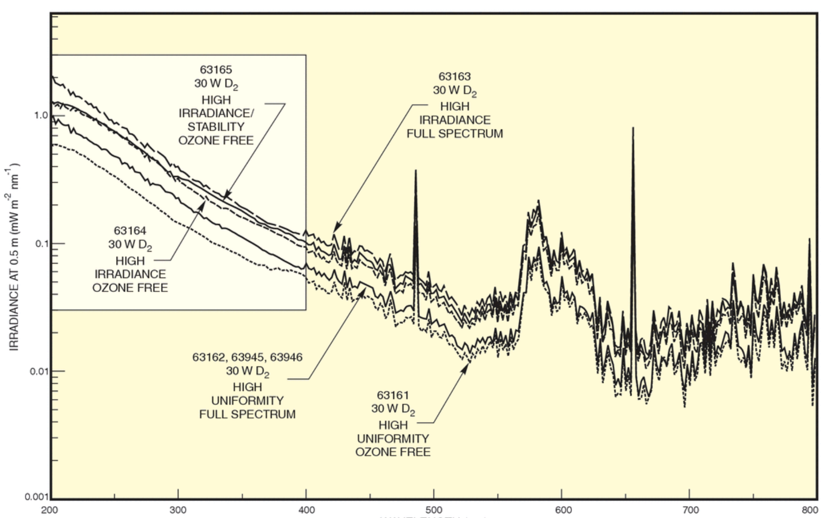

Figure 1: Spectrum for Oriel 66080 from newport.com.

The deuterium lamp creates light that is sent to an Oriel 74125 monochromator, with a spectral range of 180 nm - 24 μm, which can be set to emit a single wavelength within 0.1 nm. This light of a single wavelength is then sent through a BFH22-200 quartz fiber with a high transmittance, to the bottom of a dark tube containing gas.

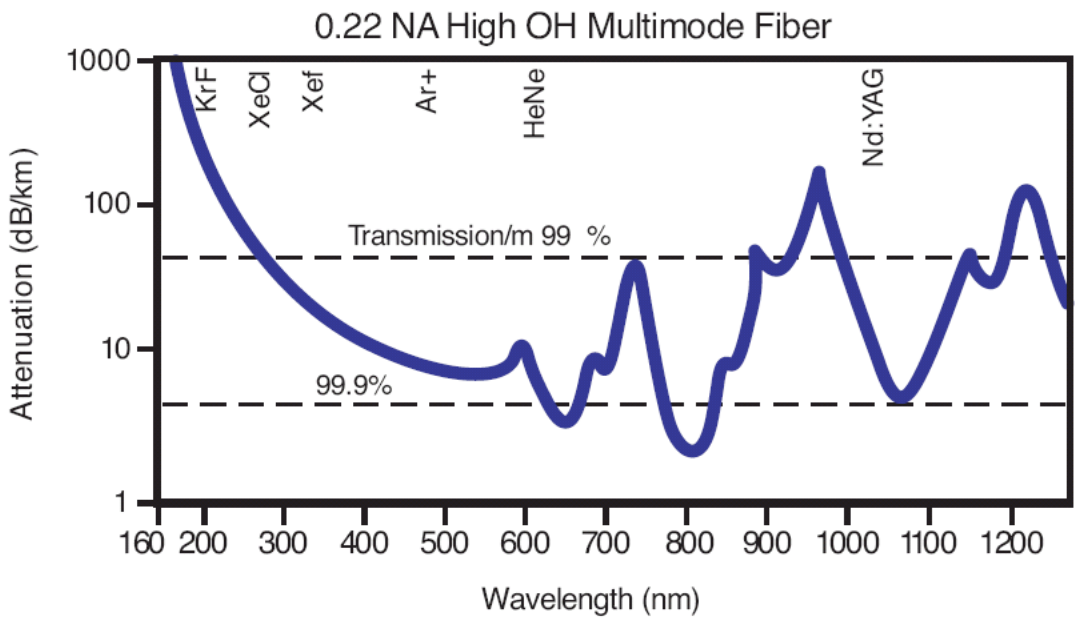

Figure 2: Attenuation of quartz fiber from thorlabs.com.

Using figure 2, it is estimated that the transmittance of this quartz fiber (2 meters long), at 200 nm, is about 99.98%, and therefore adds only a negligible amount of attenuation.

From here, the light travels through the gas to the PMT located at the top of the tube. The PMT used was a five inch Photonis XP 4500 with a UV window and a working point of 1800 Volts.

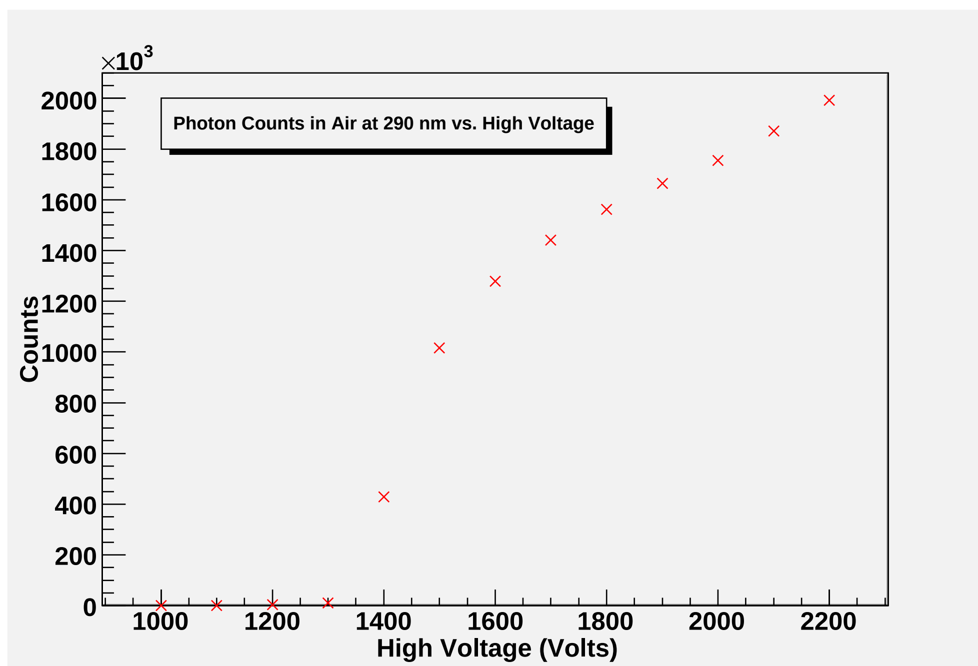

Figure 3: Plot of photon counts vs. high voltage used to determine the working point of the PMT.

Next, the discriminator and logic unit convert the analog PMT signal to a digital signal that can be counted by the scaler. Many measurements were made in order to produce plots of transmission vs. wavelength for different gasses.

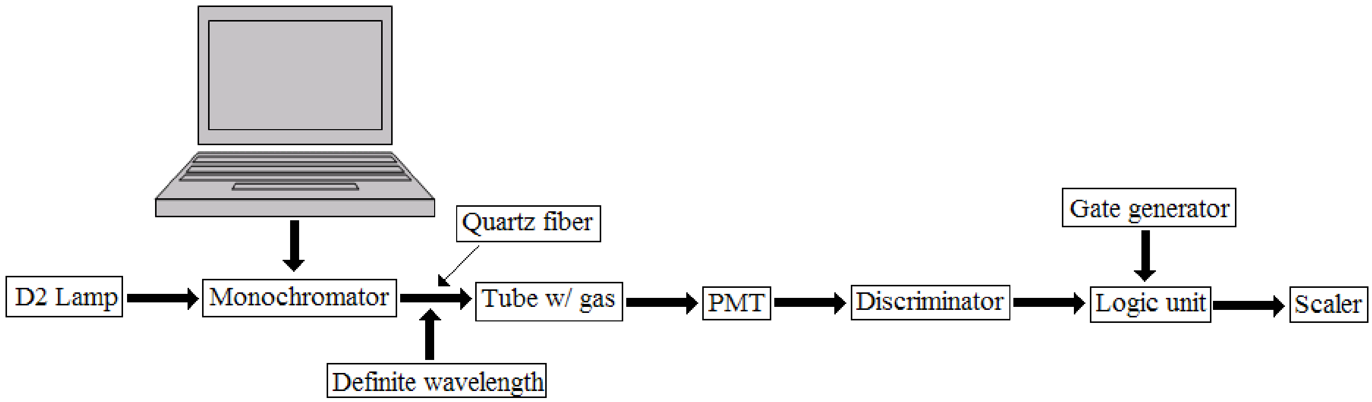

Figure 4: Schematic of the experimental setup.

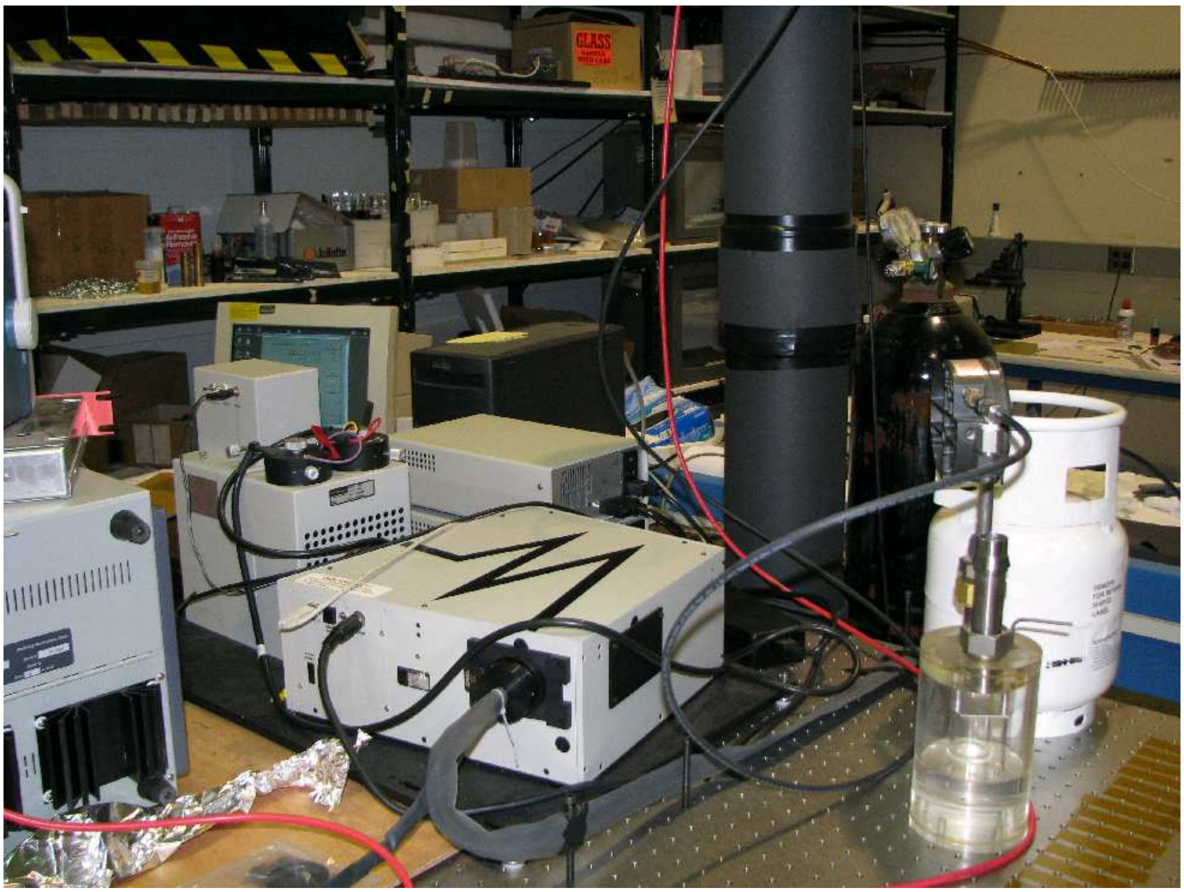

Figure 5: An image of the experimental setup. In the front center the monochromator can be seen with the quartz fiber coming from it. Also on the table, next to the monochromator, the deuterium lamp and computer can be seen. Behind the table is the dark tube that holds the gas being tested.

Figure 6: Another view of the experimental setup. In the center is the dark tube; the PMT is located at the top of the tube. The red wire is the high voltage for the PMT. The black hoses comming from the the top and bottom of the tube, the gas tanks, and the bubbler (far left, on table) are used for pumping gas into the tube.

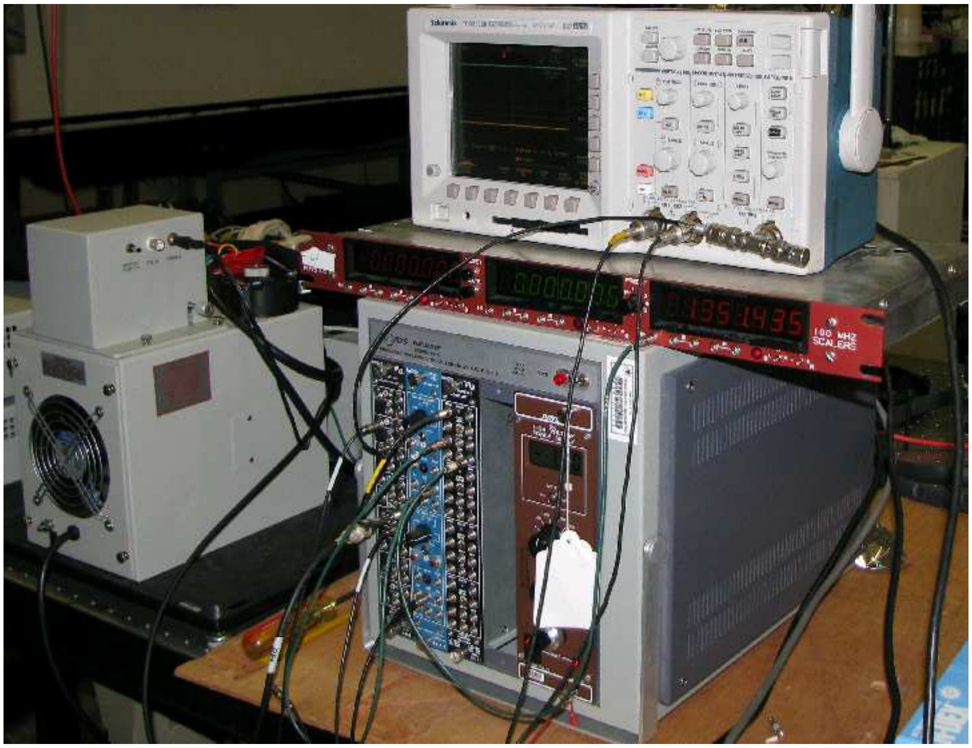

Figure 7: Another view of the experimental setup. On the left the deuterium lamp can be seen. In the center is the discriminator, gate generator, logic unit, and scaler. On the top is an oscilloscope that was used to make sure everything was working properly.

III. CALIBRATION

For measuring transmittances ($T = \frac{N_{out}}{N_{in}}$, where N_{out} is the number of photons at the exit of the gas tube, and N_{in} is the number of photons at the enterance of the gas tube) of gasses for our conditions (1.5 m x 1 atm at 21°C), we need to know N_{in} and N_{out}. N_{out} is measured; N_{in} is determined by measuring N_{out} for Nitrogen. It is known that the transmittance of Nitrogen is equal to 1 in our region of interest (190nm - 500nm)[1], therefore $N_{in} = N_{out}$ for Nitrogen. We will use these values of N_{in} for our measurements of other gasses.

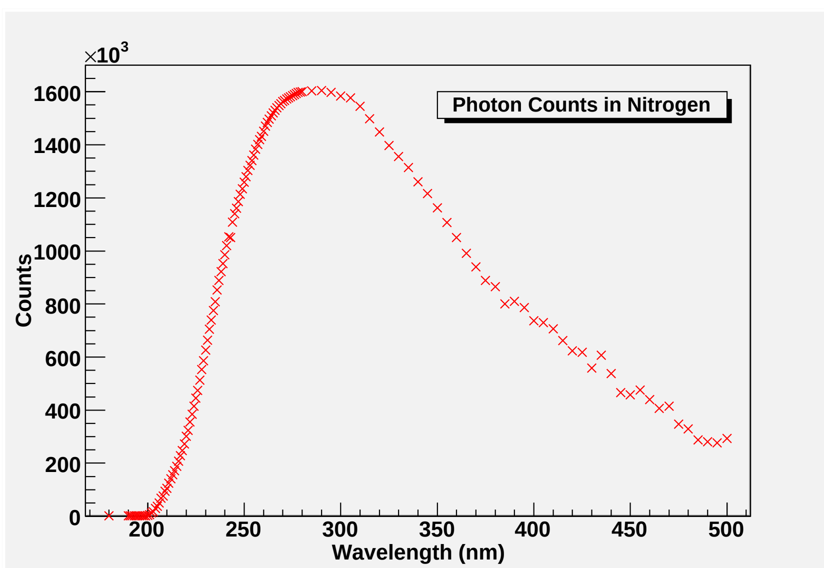

Figure 8: Photon Counts vs. Wavelength for 1.5 m x 1 atm at 21°C of Nitrogen.

IV. TRANSMISSION OF AIR

The first measurement was done with air in order to make sure all components of the experiment were working properly before testing the more expensive gasses.

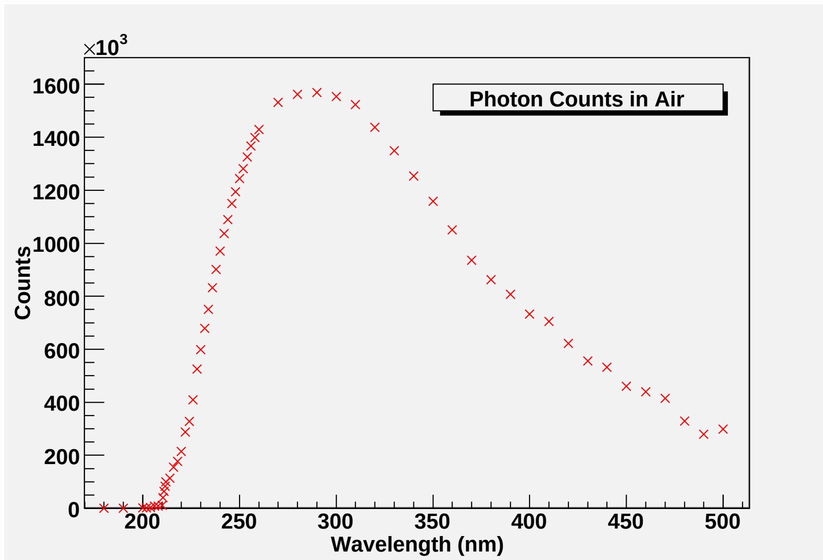

Figure 9: Photon Counts vs. Wavelength for 1.5 m x 1 atm at 21°C of Air.

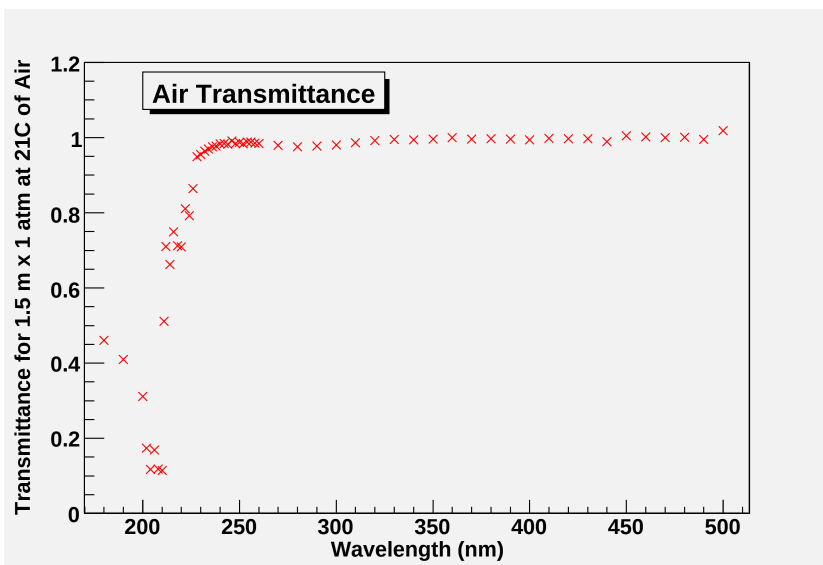

Figure 10: Transmittance for 1.5 m x 1 atm at 21°C of Air.

It can be seen in figure 10 that the points near 210 nm and below are not very reliable. This is due to a possible light leak and the fact that the number of photon counts in this region is low.

V. TRANSMISSION OF C_4F_{10}

After air and nitrogen, C_4F_{10} was measured. This was done for comparison purposes.

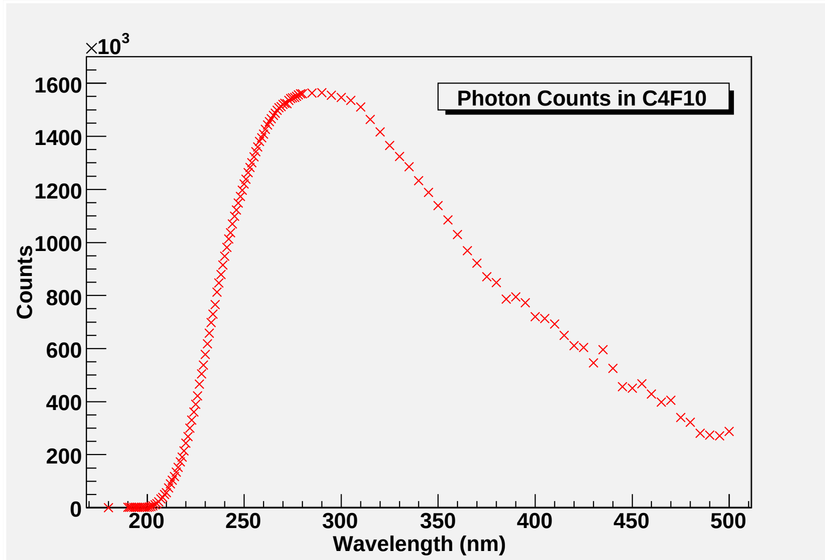

Figure 11: Photon Counts vs. Wavelength for 1.5 m x 1 atm at 21°C of C_4F_{10}.

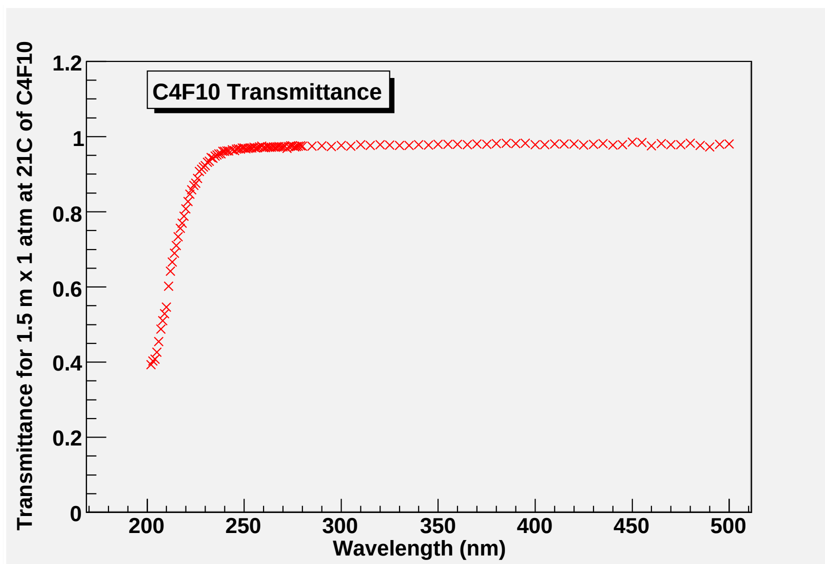

Figure 12: Transmittance for 1.5 m x 1 atm at 21°C of C_4F_{10}.

VI. TRANSMISSION OF C_4F_8O

C_4F_8O was measured next so it's transmittance could be compared to the transmittance of C_4F_{10}.

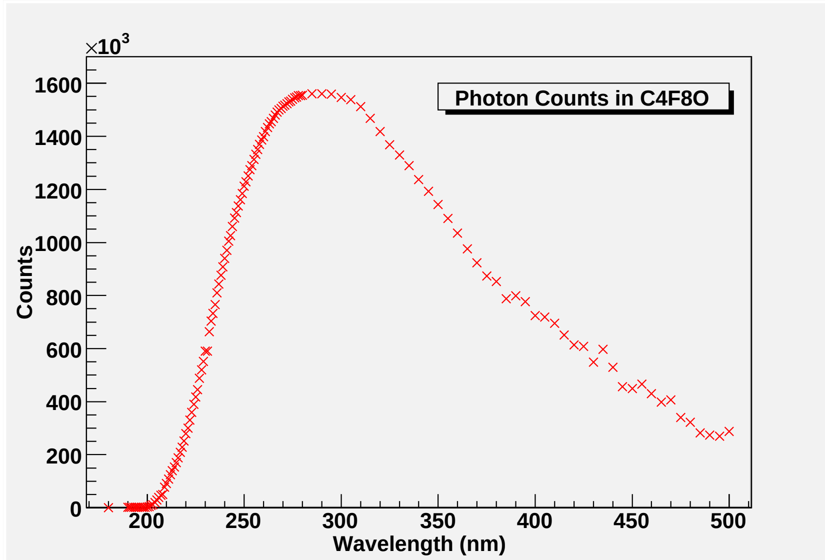

Figure 13: Photon Counts vs. Wavelength for 1.5 m x 1 atm at 21°C of C_4F_8O.

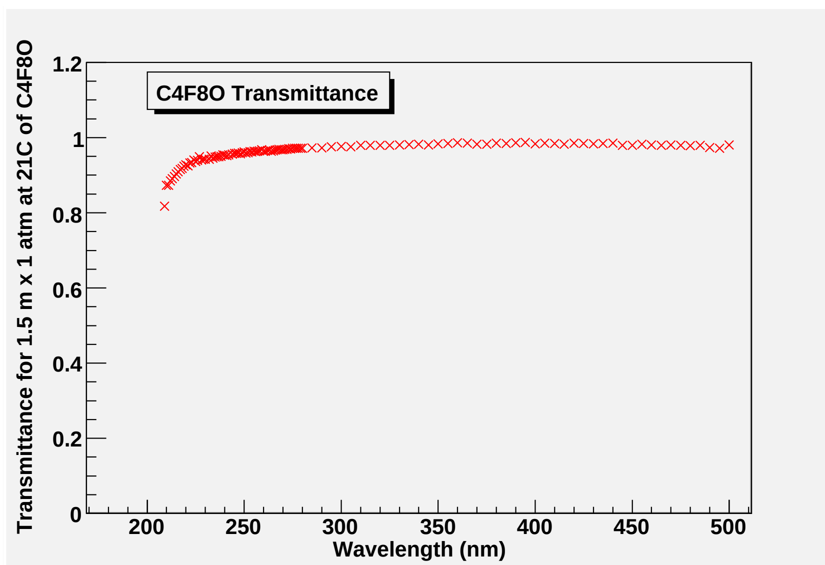

Figure 14: Transmittance for 1.5 m x 1 atm at 21°C of C_4F_8O.

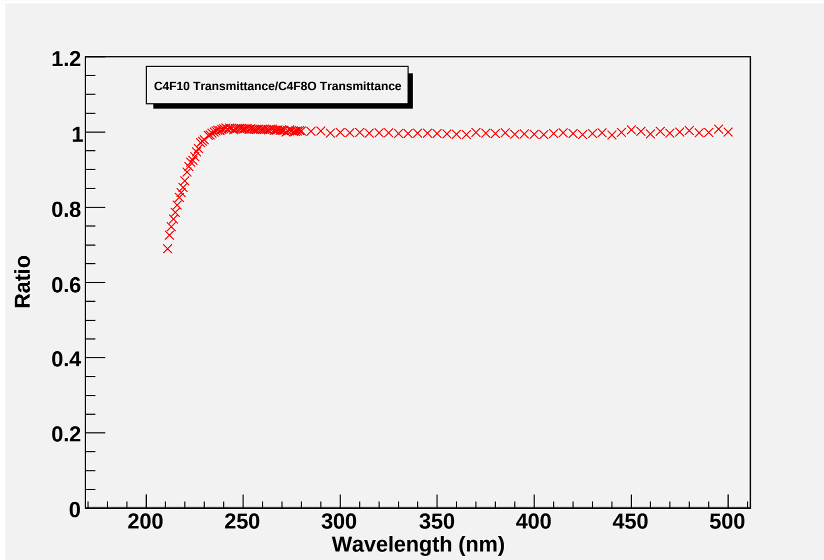

Figure 15: A plot of the ratio of C_4F_{10} transmittance to C_4F_8O transmittance.

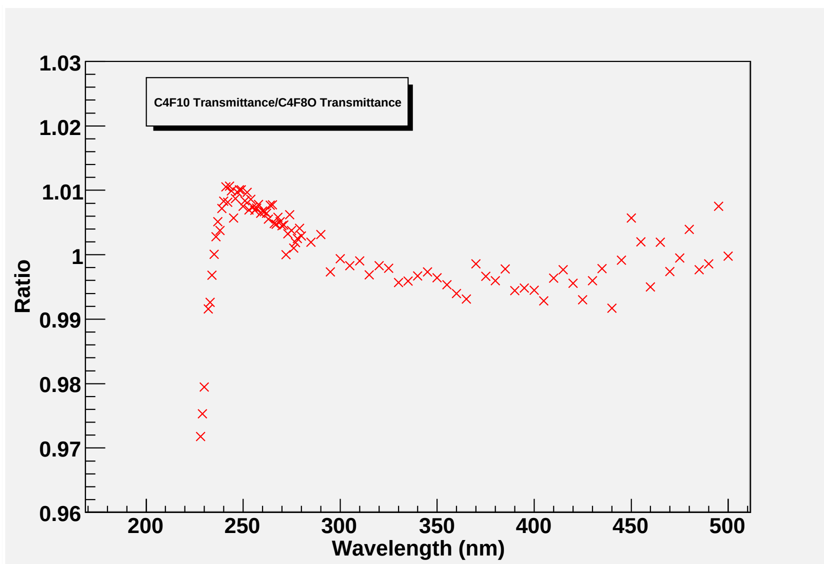

Figure 16: The same plot as figure 15, but zoomed in for more detail.

VII. MEASUREMENTS WITH A PMT WITH A QUARTZ WINDOW

In order to achieve greater confidence in the results, the measurements of the transmittance of C_4F_8O were repeated using a Photonis XP 4508 PMT, which has a quartz window. CO_2 was then also tested using this quartz PMT.

To find the working point of this new PMT, another plot of photon counts vs. high voltage was made for a constant wavelength of 260 nm.

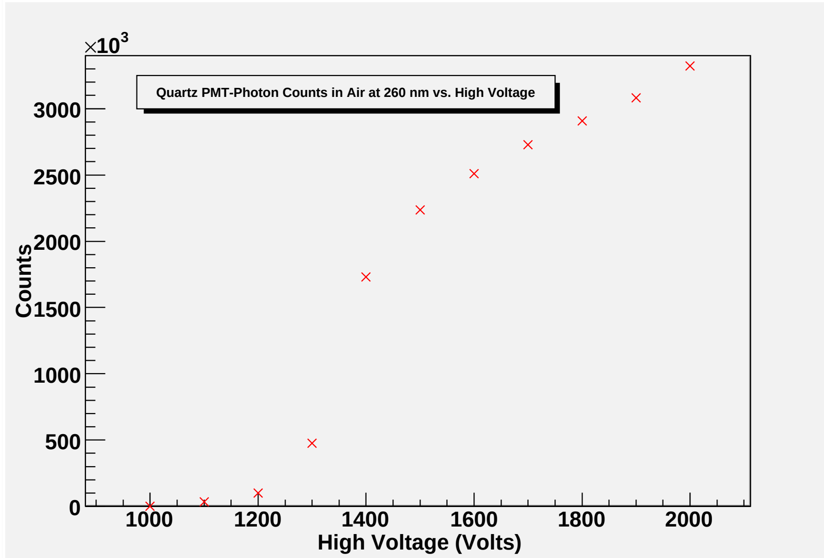

Figure 17: Plot of photon counts vs. high voltage used to determine the working point of the quartz PMT.

1500 Volts was chosen as the working point. Next, nitrogen was again measured for calibration purposes.

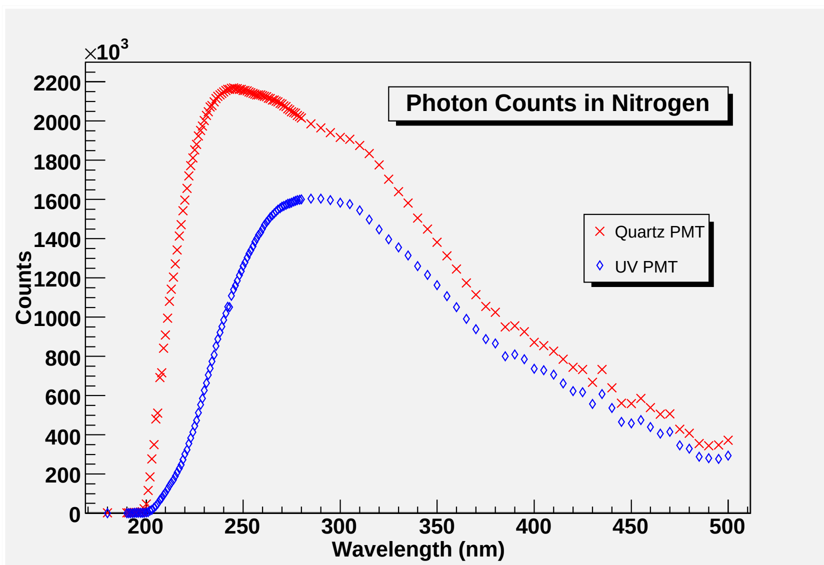

Figure 18: Photon Counts vs. Wavelength for 1.5 m x 1 atm at 21°C of Nitrogen, using a quartz PMT. Also included is the plot from the UV PMT for comparison purposes.

The absolute number of counts is somewhat arbitrary since it depends on the high voltage. To account for this, figure 19 shows the plots normalized to 320 nm. 320 nm was chosen because it is known that the quartz window and UV window have the same transparency at this wavelength.

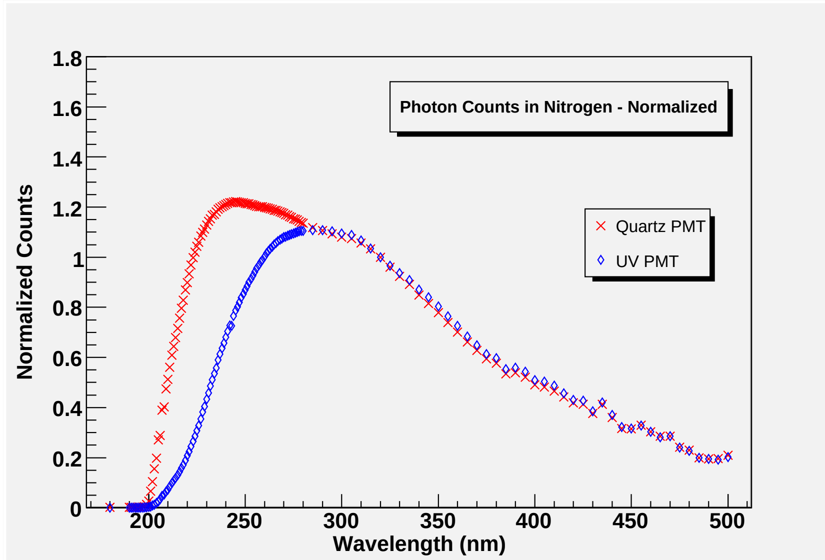

Figure 19: Photon Counts vs. Wavelength for 1.5 m x 1 atm at 21°C of Nitrogen, normalized to 320nm.

As expected, the spectrum is shifted to the lower wavelengths for the quartz PMT. This can be seen below in figure 20.

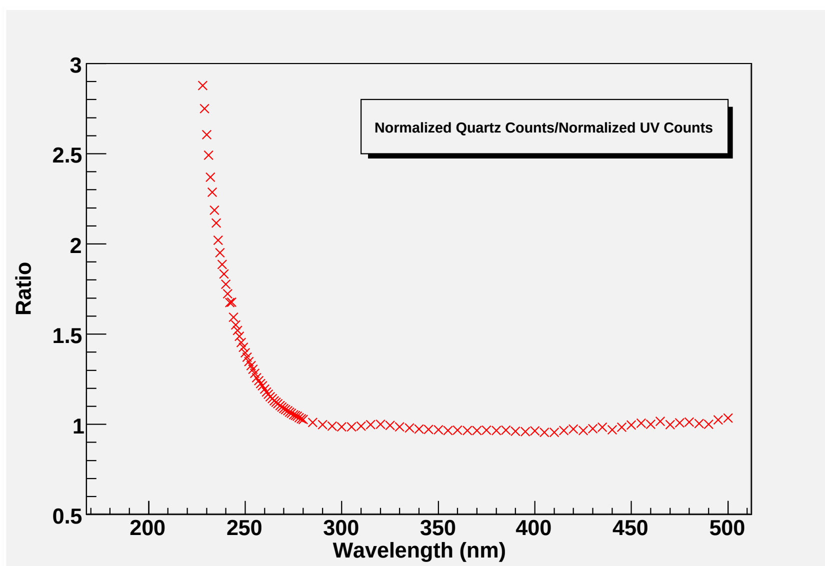

Figure 20: The ratio of normalized quartz PMT counts to normalized UV PMT counts for nitrogen.

Next, C_4F_8O was measured and compared to nitrogen in order to get it's transmittance.

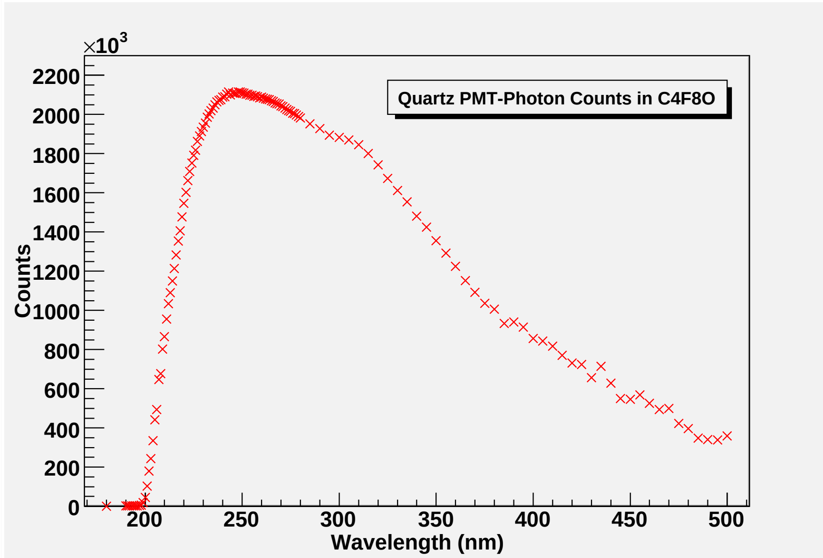

Figure 21: Photon Counts vs. Wavelength for 1.5 m x 1 atm at 21°C of C_4F_8O, using a quartz PMT.

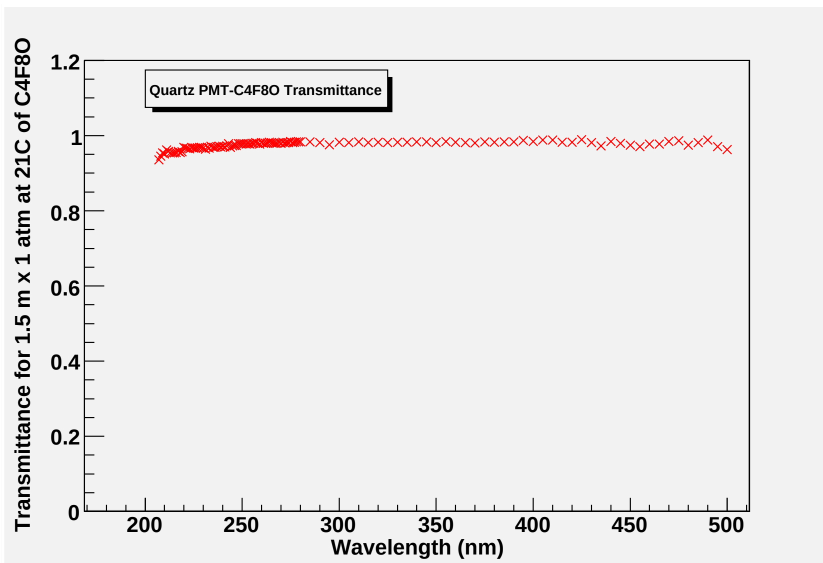

Figure 22: Transmittance for 1.5 m x 1 atm at 21°C of C_4F_8O, using a quartz PMT.

Similarly, CO_2 was measured and compared to nitrogen to get it's transmittance.

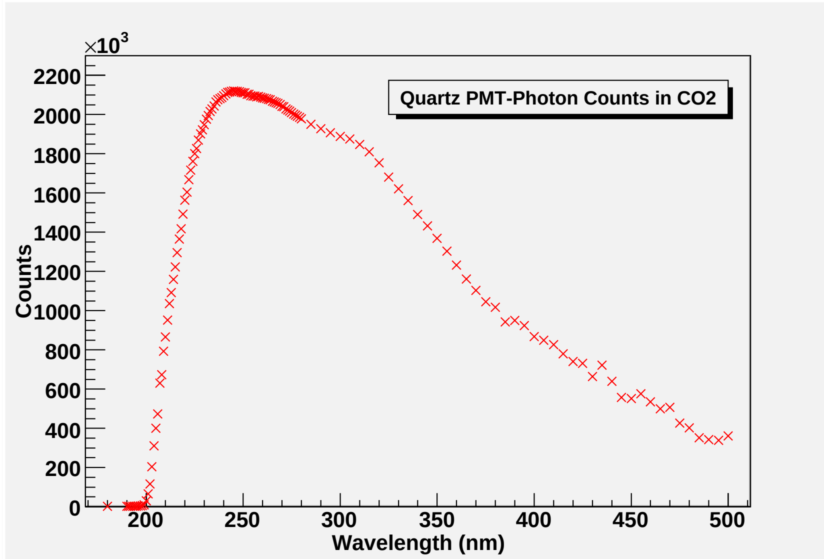

Figure 23: Photon Counts vs. Wavelength for 1.5 m x 1 atm at 21°C of CO_2, using a quartz PMT.

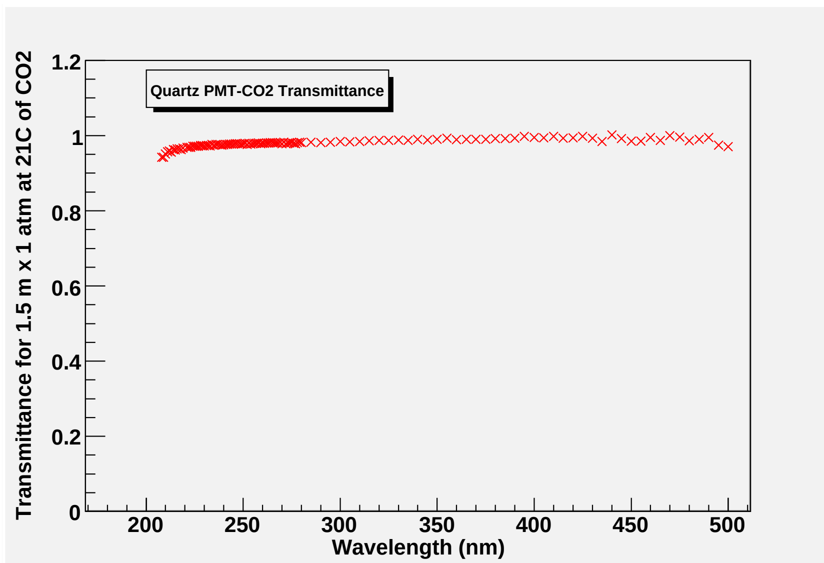

Figure 24: Transmittance for 1.5 m x 1 atm at 21°C of CO_2, using a quartz PMT.

VIII. CONCLUSIONS

Although the C_4F_{10} used is these experiments was possibly contaminated with oxygen or other gases, the fact that the C_4F_8O was still more transparent than it means that C_4F_8O is a very promising Čerenkov Gas. CO_2 also proved to be very transparent, and is therefore a suitable Čerenkov Gas as well.

IX. REFERENCES

1. E.L. Garwin and A. Roder, Optical Transmittance of Common Čerenkov Counter Gases, SLAC-PUB-857, February 1971 (EXPI)