Partial Replication of Storms/Scanlan Glow Discharge Radiation

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Introduction

The Storms/Scanlan paper[1] presented at the 8th international workshop in Catania described two types of radiation produced in a deuterium glow discharge. One type was thought to be mono energetic electrons in the 0.8 MeV range. A second type of emission, obtained when oxygen was added to the D_2, was also described by Storms/Scanlan.

We have produced radiation with similar characteristics to this second type of emission. This radiation has been characterized with GM tubes, absorbers, silicon diode detector, and magnetic deflection. We propose that conventional low energy x-rays would produce behavior consistent with our observations.

Experimental Apparatus

A 1.8 liter chamber is evacuated with a turbomolecular pump as shown in Fig. 1. Gas pressure is measured with Baratron gauges. A 1 mm Pt rod, with all but the last 2-3 mm encased in glass, is used for the anode. The high voltage is supplied on the left hand side of the chamber. The cathode is driven with a negative voltage from a DC power supply capable of 2000 V at 100 mA. The chamber and anode are grounded. There is no provision for cooling the cathode or chamber. Radiation detectors and absorbers are mounted in the chamber through ports located on the right hand side of the chamber.

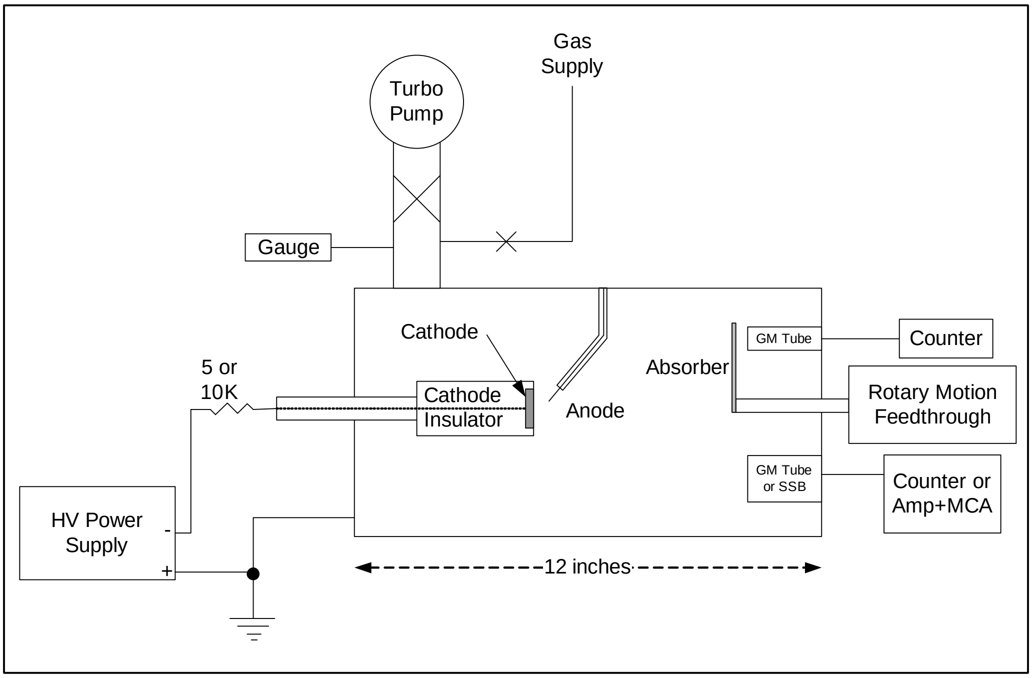

Figure 1. Diagram of experimental apparatus

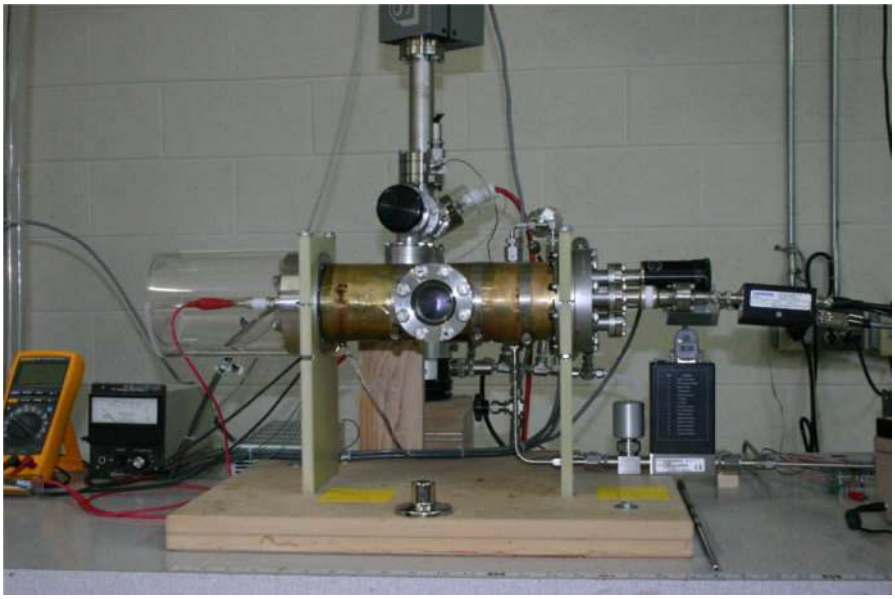

Figure 2. Vacuum chamber with high voltage supplied to cathode on the left, and ports for various detectors on the right

The cathode assembly is electrically insulated with glass and ceramic as pictured in Figure 3. Both copper and Pd cathodes have been used. The Pd cathodes are constructed by diffusion welding a 100 micron Pd foil to a copper substrate.

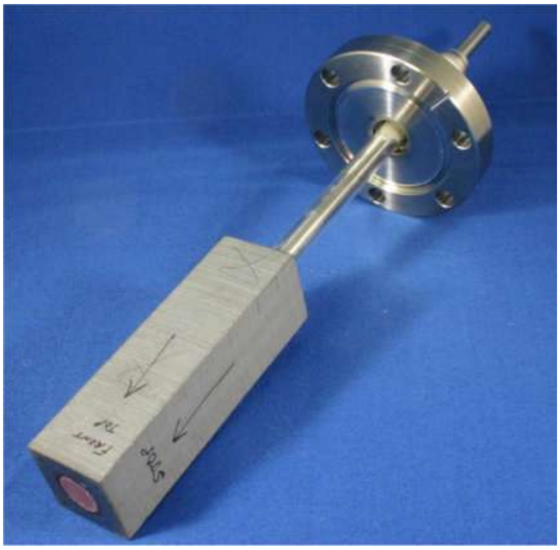

Figure 3. Cathode insulator assembly

GM detectors with 2mg/cm^2 windows (LND 712) and 10 mg/cm^2 windows (LND 71221) have been used. A rotary feed through is used to move an absorber in front of the GM tubes. Figure 4 shows the detector end plate configured with 2 GM tubes and a plastic absorber.

In a different configuration one of the GM tubes is replaced with a silicon diode detector (25 mm^2, 1.5 mm thick) (Ortec BA-016-025-1500). Figure 5 shows the Si detector shielded from visible light with a 1.2 micron Al foil. In this configuration, a 1.8 micron Al foil absorber and a CR-39 nuclear track detector are mounted on the rotary feed through. The background noise of the Si detector limited the minimum detectable energy to about 50 keV.

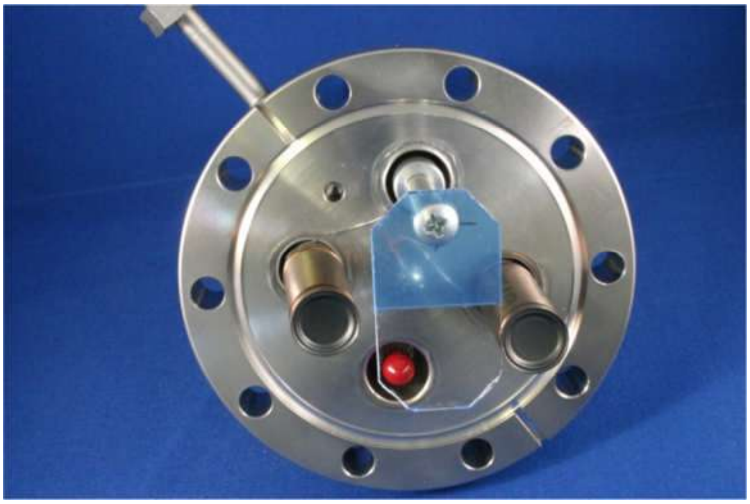

Figure 4. Detector end-plate configured with dual GM tubes and plastic absorber. (CR-39 is used here as a 100mg/cm2 absorber.)

Figure 5. Detector end-plate configured with 2mg/cm^2 GM tube, Si detector, 1.8 micron aluminum absorber and CR-39 detector.

In another test configuration the absorber was replaced with an electromagnet assembly designed to deflect charged particles away from a slit placed in front of the GM tube. A toroidal transformer core, about 1 inch outside diameter, was cut to form a 0.4" gap. The core was wrapped with 100 turns of magnet wire. Currents up to 3A are possible without overheating the magnet assembly. The magnetic field was measured at 100 gauss per Amp. A diagram of the deflector assembly is shown in Figure 6.

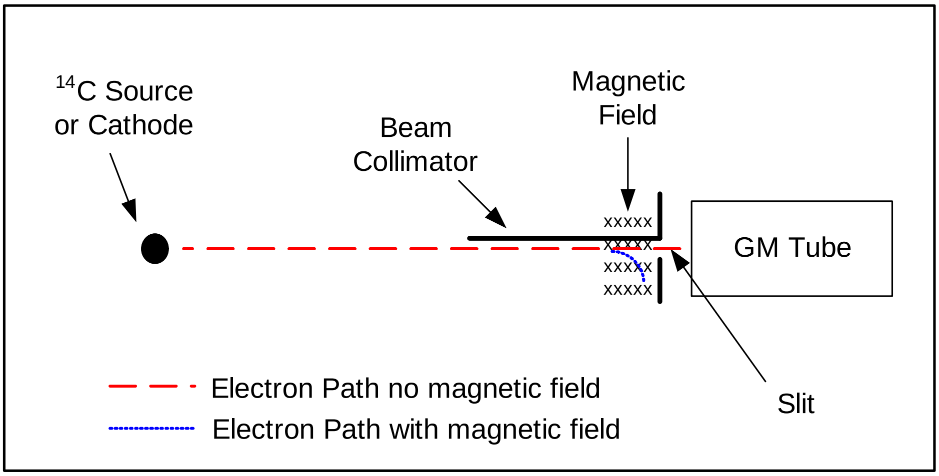

Figure 6. Magnetic deflection experiment schematic. (A simple half collimator is used to prevent off-axis particles from being deflected into the GM detector when the magnet is turned on.)

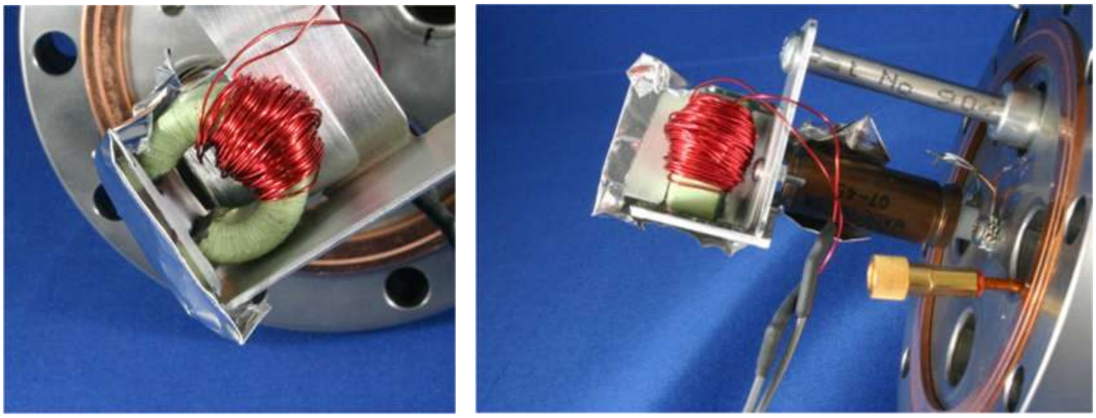

Figure 7. Photographs of deflection assembly using electromagnet with slit in front GM tube

Experimental Procedures

- **D_2+O_2 glow** - Equal parts of deuterium and oxygen are added to the chamber. These are then reacted with a glow lasting a few minutes. At this point the chamber pressure is typically between 1.5 and 3 Torr. A 25% duty cycle glow discharge is used, typically 4 seconds on and 12 seconds off, to keep the temperature of the cathode below 60 deg C. Average glow power is between 2 and 10 watts. Glow voltages are varied between 500 and 1200 volts.
- **H_2+O_2 and He+D_2 glow –** Same as above only with H_2 or He added to an equal amount of deuterium.
- **Single gas glow –** 2 Torr of O_2, D_2, H_2, He, or N_2 are added to the chamber. Glow as above.
- **Cathode –** Experiments were carried out with Pd cathodes as well as with copper cathodes.
- **Absorber –** GM tube counts are logged for 1 minute then the absorber is rotated in front of the GM tube. Counts are logged for another minute. The absorber is then rotated back to the starting position and counts are logged for an additional minute.
- **CR-39 –** The CR-39 nuclear track detector is placed in the chamber. Numerous glow runs are done with D_2+O_2 , the CR-39 is removed from the chamber and etched and inspected with a microscope for tracks.
- **Silicon detector –** 5-minute glows are done in D_2+O_2 while collecting the output of the Si detector with a multi-channel analyzer (MCA).
- **Magnetic deflector –** The deflector assembly was calibrated with a ^{14}C beta (156 keV) source in vacuum as well as in 2 Torr of O_2 with electromagnet current being varied from .1A to 3A. The deflection test was done with a 5-minute glow in D_2+O_2 as well in O_2 with magnet currents varied from .1A to 3A.
- **Count timing test –** A digital storage oscilloscope is used to record the position of the GM counts vs. the glow waveform. The glow discharge is turned on for 500ms. Count positions from numerous 500ms glow pulses are collected.

Results

- In oxygen containing plasmas, counts from the 2 mg/cm^2 GM tube are seen whenever the glow voltage is greater than about 600V. In D_2, H_2, He, and N_2 plasmas counts start when the glow voltage is greater than 900-1000V. Count rates increase non-linearly with increasing voltage. See Figure 9.
- GM Counts are stopped by a 100mg/cm^2 plastic absorber; Counts are not seen with a 10 mg/cm^2 GM tube.
- Count rates for D_2+O_2 plasmas (V<900) are reduced by 66% with a 1 micron Mylar absorber (0.14 mg/cm^2), by 75% with a 1.2 micron Al absorber (0.3 mg/cm^2) and by 95% with a 1.8 micron Al absorber (0.5 mg/cm^2). Counts are stopped by total areal density of 2.5 to 3.0 mg/cm^2.
- Similar count rate and absorber attenuation results are seen with D_2 +O_2 using either Cu or Pd cathodes. Also, similar count rate and absorber attenuation results are seen with H_2+O_2 and D_2+O_2 discharges using a Cu cathode.
- The CR-39 detected no radiation above background.
- No counts above background have been observed with the Si detector.
- Transmission through a 1.8 micron Al or 1 micron Mylar absorber increases with increasing glow voltage for voltages greater than 900V. In an oxygen containing plasma, transmission through a 1.8 micron Al absorber or a 1 micron Mylar absorber is constant for voltages less than 900V. See Figures 10 and 11.
- Counts are observed during the on periods of the glow pulse, but do not occur (above background) during the off periods.
- An electromagnet deflector had no effect on GM count rates produced with a D_2+O_2 glow discharge on a Pd cathode or with an O_2 glow on a Pd cathode. The electromagnet did affect count rates of beta particles from a ^{14}C source in vacuum as well as in 2 Torr of O_2. Count rates for ^{14}C were reduced by 50% with 1A magnet current and by 80% with 2A magnet current.

Discussion

The absorber attenuation data showing particles are stopped by 2.5 – 3 mg/cm^2 could be explained by particles in the range (say +/-20%) of:

- 3 MeV alphas
- 0.7 MeV protons
- 30keV electrons
- 600 eV photons

based on stopping power data from NIST as shown below in Figure 8.

Since x-ray photons are never actually stopped by an absorber, we have used an attenuation figure of 10^{-5} to calculate an equivalent stopping distance for x-rays.

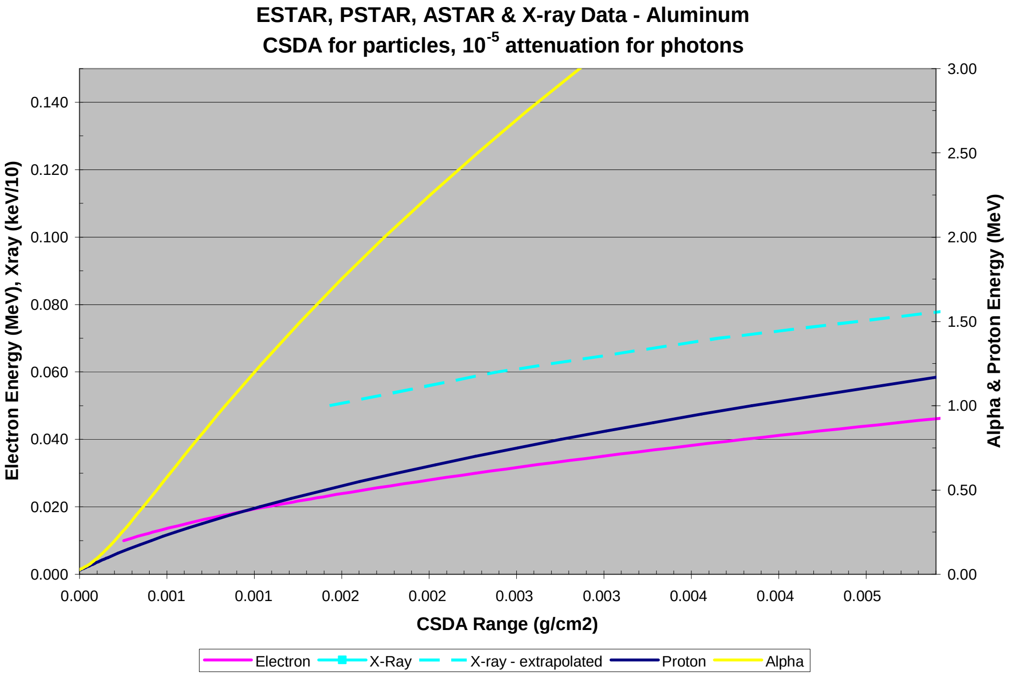

Figure 8. Energy vs. CSDA Range – taken from NIST databases. Photon "equivalent stopping power" calculated with 10-5 attenuation from extrapolated NIST photon mass attenuation data.

The lack of pits on CR-39 and the lack of counts with the Si detector rule out alphas and protons as the cause of the GM counts.

The lack of any effect on the radiation by a magnetic field rules out electrons as the cause of the GM counts.

The data observed appears consistent with conventionally produced low energy x-rays.

X-ray hypothesis

In an abnormal glow discharge most of the electrons leaving the cathode fall region have an energy corresponding to the glow voltage.[2] X-rays with energies as high as the plasma voltage will be produced in the glow discharge as a result of collisions between energetic electrons in the cathode fall region and atoms in the gas. Two types of x-ray emissions should be observed from gas mixtures containing oxygen: K-alpha x-rays at 525 eV and Bremsstrahlung emissions that increase in energy with increasing glow voltage.

Only the Bremsstrahlung radiation should be detected for the non-oxygen gases used. (The K-alpha photon for nitrogen is 392 eV and will be attenuated below the detector noise floor by the 2 mg/cm^2 GM tube window.) The energy of the Bremsstrahlung radiation should increase with increasing glow voltage.

Is it reasonable to generate enough k-shell x-rays to account for the observed counts? If we assume an x-ray generation efficiency of 0.1%, and an electron energy distribution where 0.1% of the electrons have sufficient energy, and factor in the attenuation of the 2 mg/cm^2 mica GM tube window, and the collection efficiency of our apparatus we expect around 100 counts per minute per mA of glow. This is in line with the 50 or so counts per minute per mA we observe with a 700 V glow.

Figure 9 shows Count Rate vs. Voltage data collected for different gases. For oxygen containing gas mixtures, the count rate increases slowly from 600 volts to 900V as shown in the inset graph. Above 900V the count rate increases rapidly for all gases. We propose the counts in the sub 900V region are caused by the oxygen k-alpha x-ray (525 eV) and the counts above 900V are produced by Bremmstrahlung. (N2 also produces a K-alpha (392 eV) but it is not energetic enough to pass through the 2mg/cm^2 GM window.)

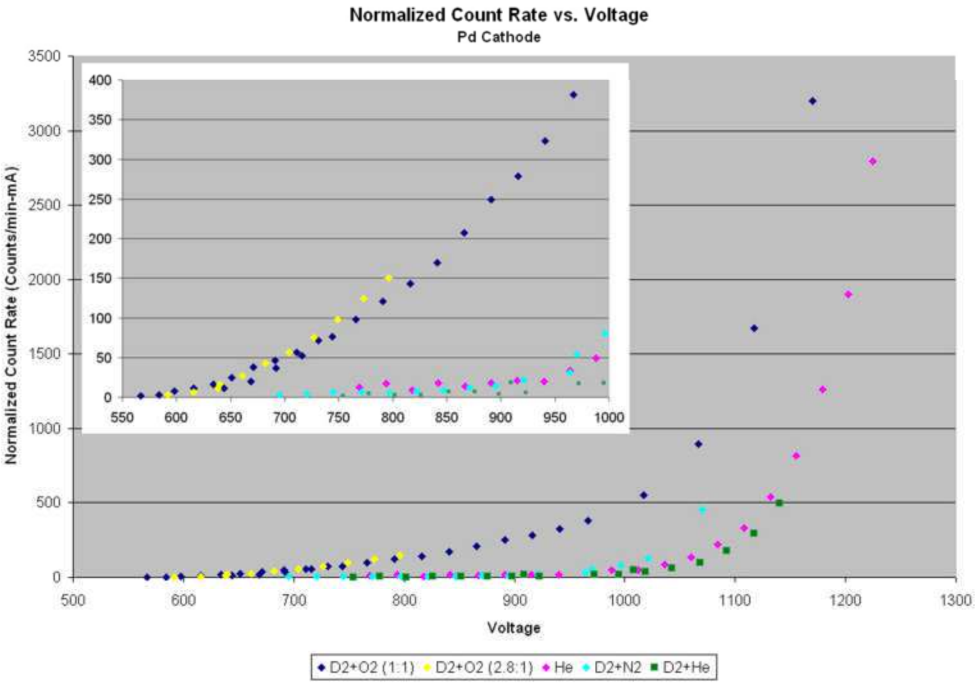

Figure 9. Normalized Count rate vs. Voltage of various gases. The insert shows the lower voltage and lower count region in more detail.

K-alpha radiation produced in gas mixtures containing oxygen will give constant absorber transmission (I/I_0) similar to observed transmission for lower voltages also seen in Figures 10 and 11.

An increase in Bremsstrahlung x-ray energy with increasing glow voltage will give rise to increased transmission through an absorber similar to observed aluminum and Mylar absorber transmission at higher voltages seen in Figures 10 and 11.

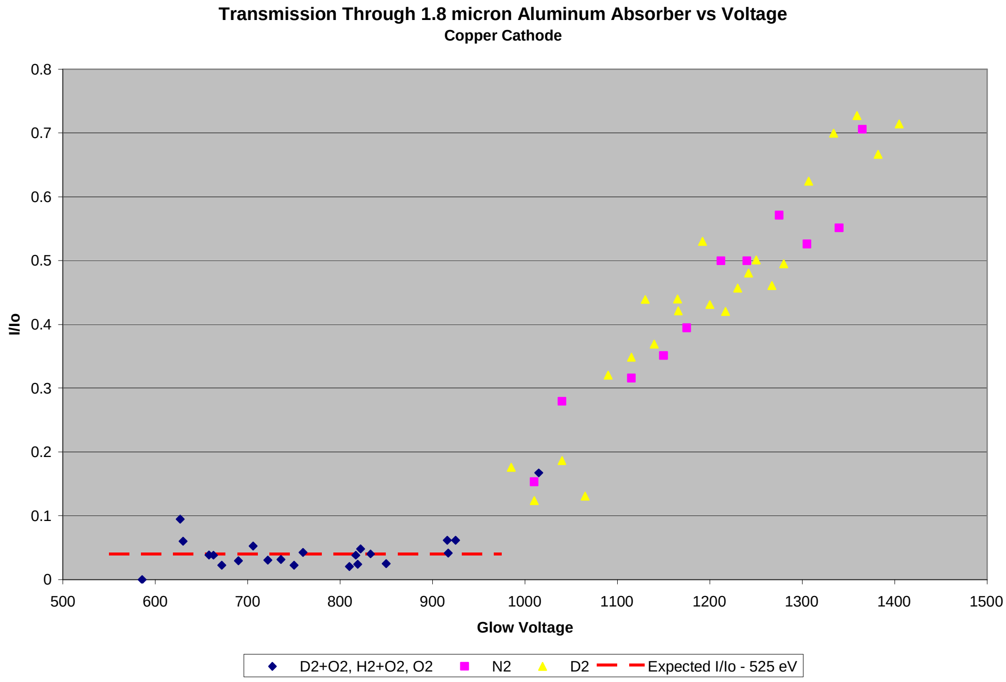

Figure 10. Transmission through a 1.8 micron Aluminum absorber vs. glow discharge voltage. Dashed line shows calculated attenuation of 525 k-alpha x-rays passing through the a 1.8 micron Al absorber.

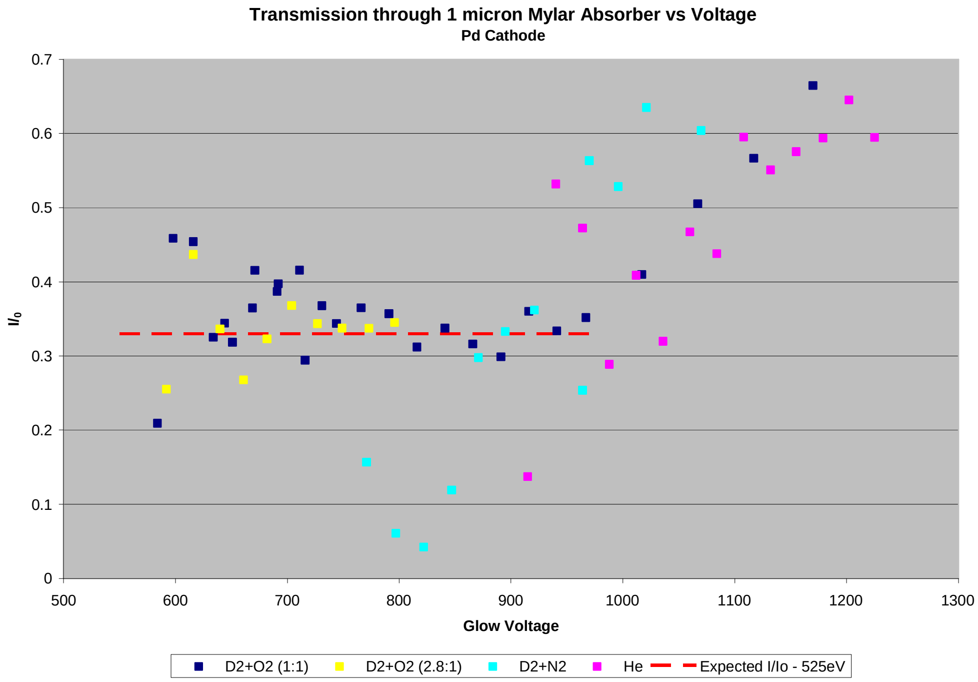

Figure 11. Transmission through a 1 micron Mylar absorber vs. glow discharge voltage. Dashed line shows calculated attenuation of 525 k-alpha x-rays passing through the a 1 micron Mylar absorber.

Finally, X-ray attenuation with different thickness Al absorber is similar to the observed attenuation curves as shown in Figure 12.

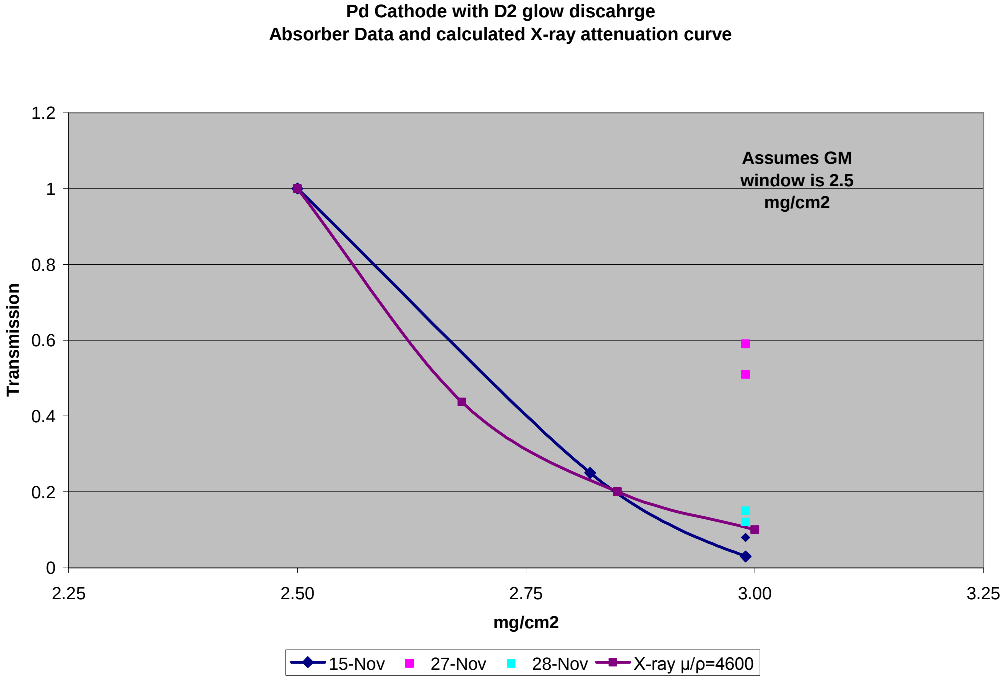

Figure 12. Attenuation vs. total absorber thickness. X-ray attenuation assumes an attenuation coefficient (mu/rho) of 4600 cm2/gm which is obtained by extrapolating the NIST aluminum curve to 600 eV.

Conclusions

The repeatable results, consistent absorber behavior and count timing test have convinced us that our results are not caused by electrical noise. Radiation is being produced and detected in these experiments. The combination of properly grounded GM tubes and insertion of CR-39 inside the chamber provide an inexpensive and reliable way to detect a broad spectrum of radiation. If radiation is detected, a variety of other means must be used to identify it.

We believe the data observed in our series of experiments is consistent with the generally accepted mechanisms for production of Bremsstrahlung and Oxygen K-line x-rays. In particular, we are satisfied that the magnetic deflector tests rule out significant production of anomalous energetic electrons in our experiments, and that both our CR-39 results and Si barrier detector results rule out any significant production of heavier energetic particles. If any anomalous radiation was produced, it was below the sensitivity threshold of our detection systems.

A challenge for further investigations is to separate out the numerous low energy photons produced in the glow from any anomalous radiation that may be produced in a glow discharge initiated LENR.

Acknowledgements

Edmund Storms provided numerous suggestions as well as engaged in many helpful discussions with us. Scott Little read an early draft of this report and suggested changes that made this much more readable.

References

1. E.K. Storms and B. Scanlan, in *Radiation produced by glow discharge in deuterium*, Catania, Sicily, 2007 (http://www.lenr-canr.org/acrobat/StormsEradiationp.pdf)
2. B. Chapman, Glow Discharge Processes, (New York, John Wiley & Sons, 1980), 105