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The Effect of Vacuum Chamber Size on Maximum Electron Energy for Pyroelectric Crystal Electron Accelerators

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ABSTRACT

Optimizing the ambient gas pressure can more than double the maximum electron energy observed when a pyroelectric crystal is thermally cycled in ambient gas. We call this phenomenon gas amplification. In general as the pressure is raised from a pressure below about 0.1 mTorr towards about 10 mTorr the electron energy will increase to a maximum and then begin to decrease. The optimum pressure varies from system to system and is unique to each vacuum system. In this paper we will explore the relationship between optimum pressures and the shape and size of the vacuum chamber that houses the crystal.

Method

A cylindrical $LiNbO_3$ crystal 4 mm in diameter and 10 mm long was epoxied to a 62-ohm resistor (heater) and placed in cylindrical vacuum chamber as depicted in Fig. 1. The vacuum chamber is made of clear Plexiglas. The chamber was designed so the effective volume that surrounds the detector and crystal could be changed without changing the primary vacuum system or the relative position of the crystal to the detector. This was accomplished by opening the chamber and inserting volume restrictor tubes as shown at (b) and (c) in Fig 1.

This accomplished three things (1) the effective volume of the crystal/detector system could be changed without changing the primary vacuum system or any other element of it (2) the material that effectively enclosed crystal/detector system could be changed from plastic to glass to metal and (3) the volume restrictor could be grounded or not grounded at will. The residual gas was N_2.

For each experiment the system was pumped to the desired pressure with a control N_2 leak into the chamber. The +Z end of the crystal was heated to ~150 ^oC and let cool to room temperature. Data was collected in the form of electron energy vs. pressure for three effective vacuum volumes and as the number of electron detected per unit time following the crystal cooling to room temperature in three volumes and various materials.

Results and Conclusions

1. The maximum electron energy is pressure, material and volume dependent.

2. The optimum pressure is volume dependent.

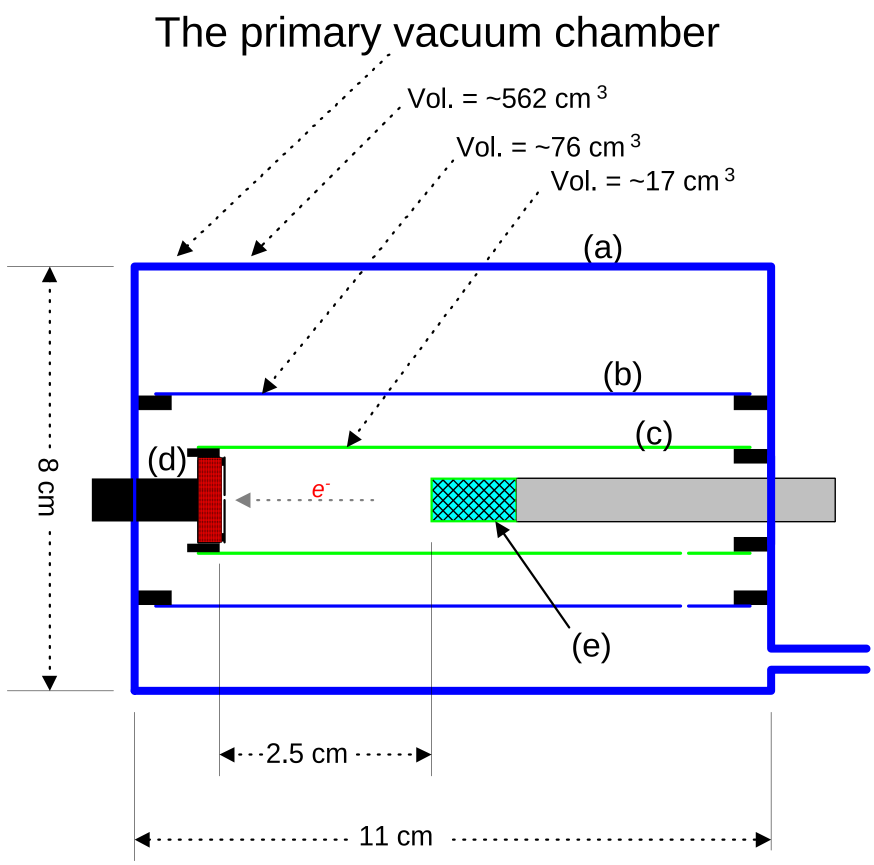
3. To maximize the time that electrons are produced material selection is important.

4. Grounding may not be very important.

5. Figure 2 shows that 75 cm^3 gives rise to the highest energy electron and the least sensitivity to pressure change.

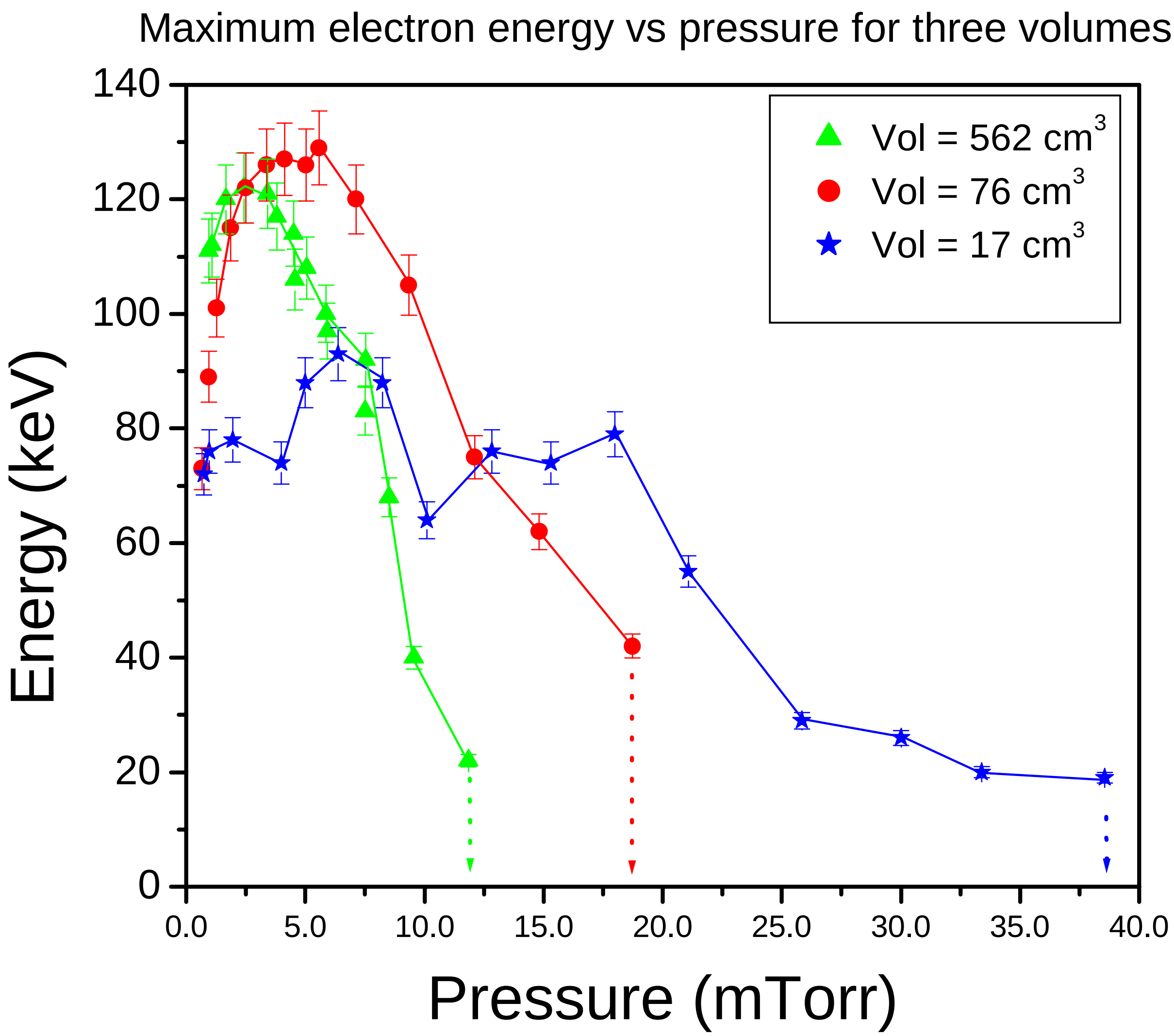
6. Figures 5 and 7 (data taken with two different volumes) also show the dramatic reduction in long term counting rate when a plastic tube is lined with aluminum. This must be related to the different spatial dependence of charge build-up and therefore electric field for the different materials.

Experimental setup



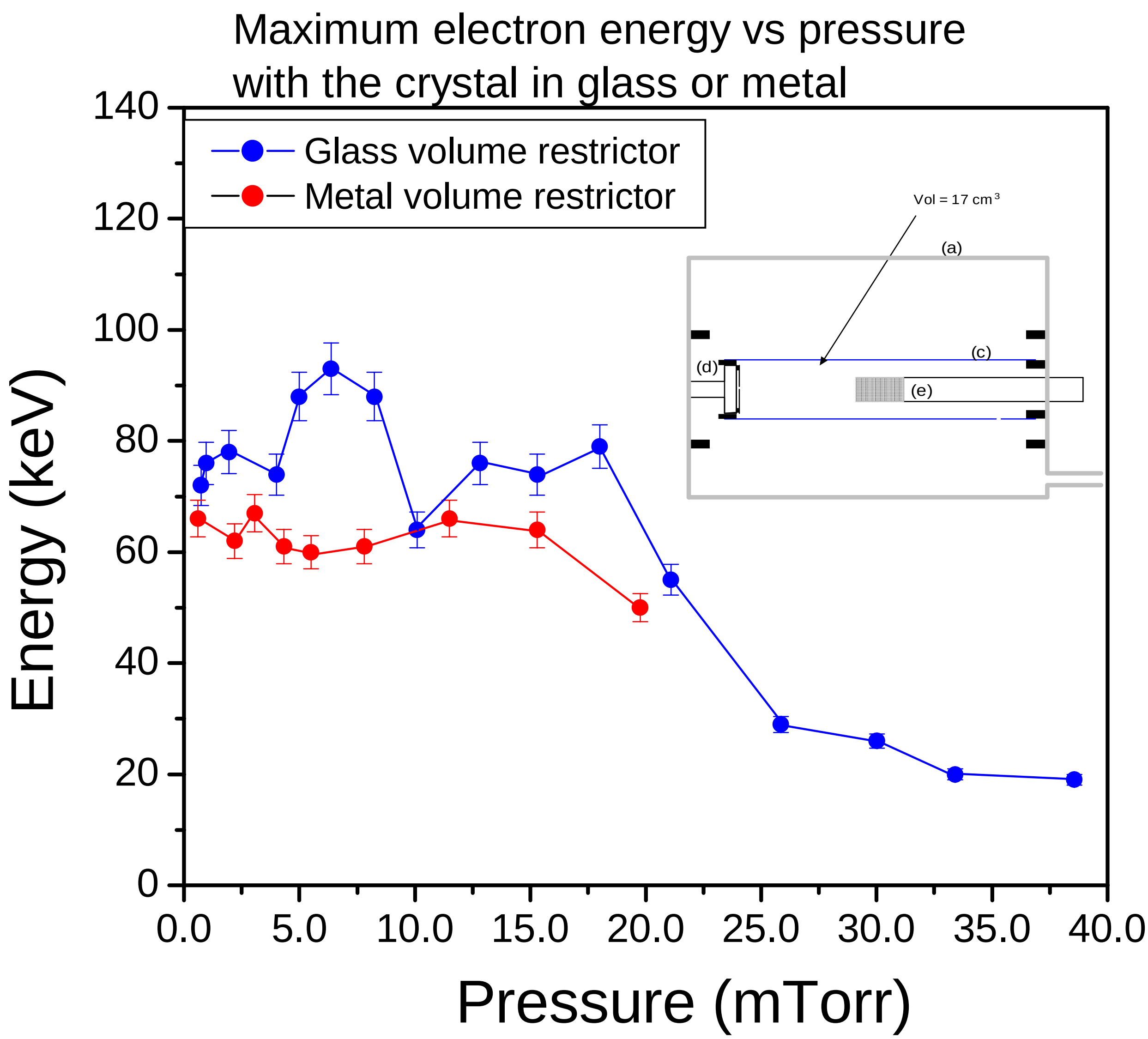
(a) the primary vacuum chamber is plastic.
(b) the 1st. volume restrictor is plastic.
(c) the 2nd. volume restrictor is either glass or aluminum.
(d) Si surface barrier detector.
(e) $LiNbO_3$ crystal 4 mm in diameter and 10 mm long.

Fig. 1



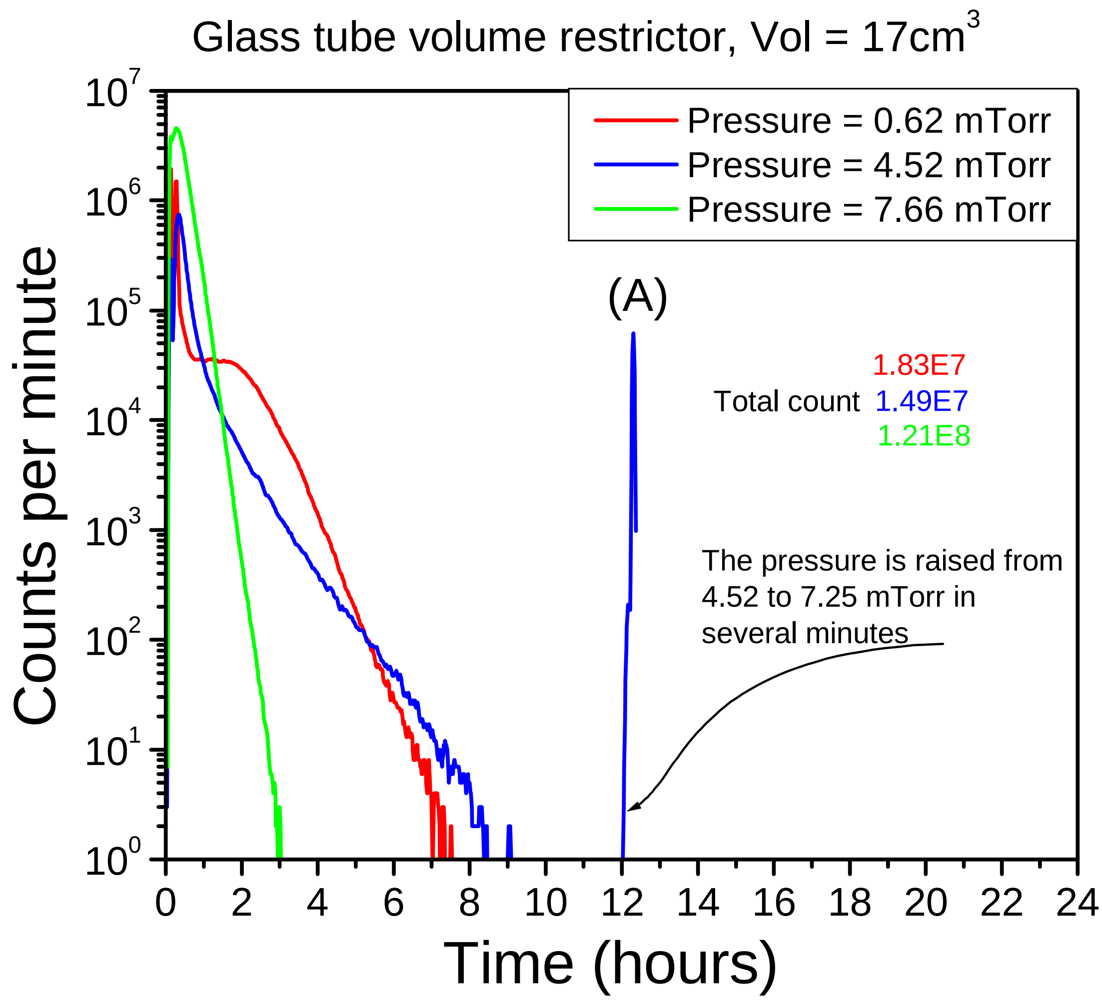
Here we show the effect of reducing the effective volume around the crystal without changing the size of the vacuum chamber. We attempted to assure pressure equilibrium by waiting for not less than 30 minutes between pressures changes and 24 hours between changes in volume restrictors.

Fig. 2



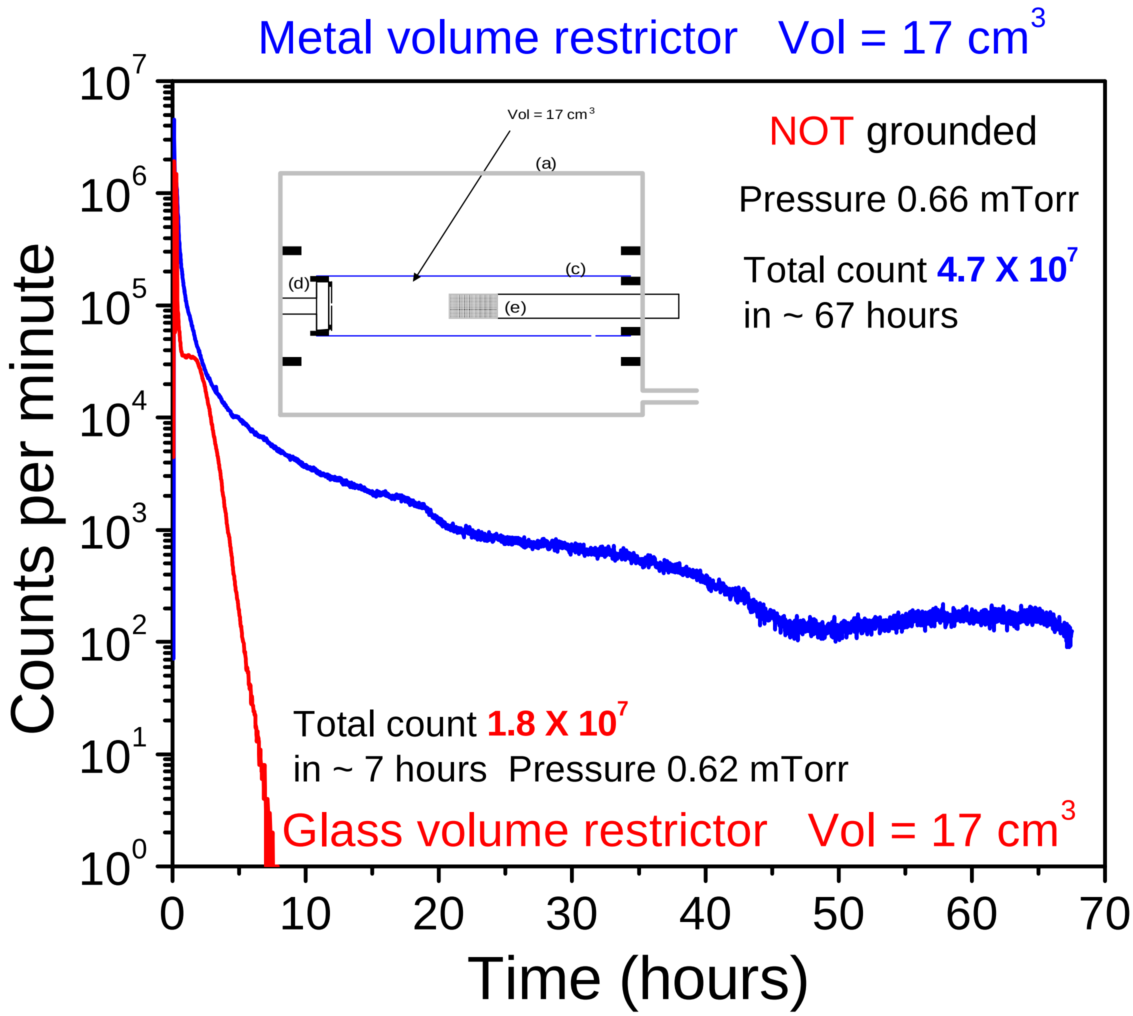
Here we show the effect of using glass vs. metal as a volume restrictor around the crystal. The maximum energy is less when metal is used and the maximum pressure at which the crystal will produce electrons is also less. There were several discharges during runs with the glass tube. A discharge reduces the maximum electron energy.

Fig. 3



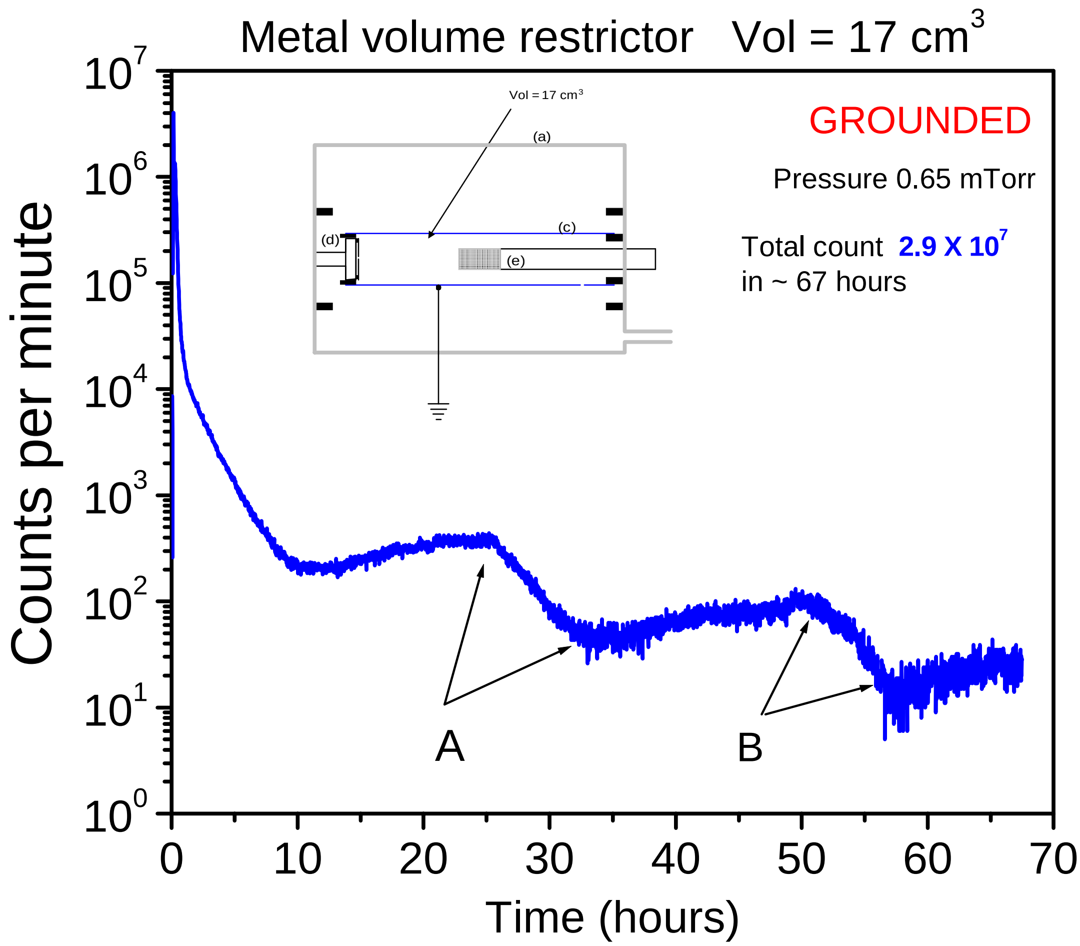
Here we show the effect of pressure on how long the crystal will produce electron after it was heated to 150 ^{o}C and left to cool. The peak at the point marked (A) is the result of increased electron production when the pressure was raised from 4.52 mTorr to 7.25 mTorr.

Fig. 4



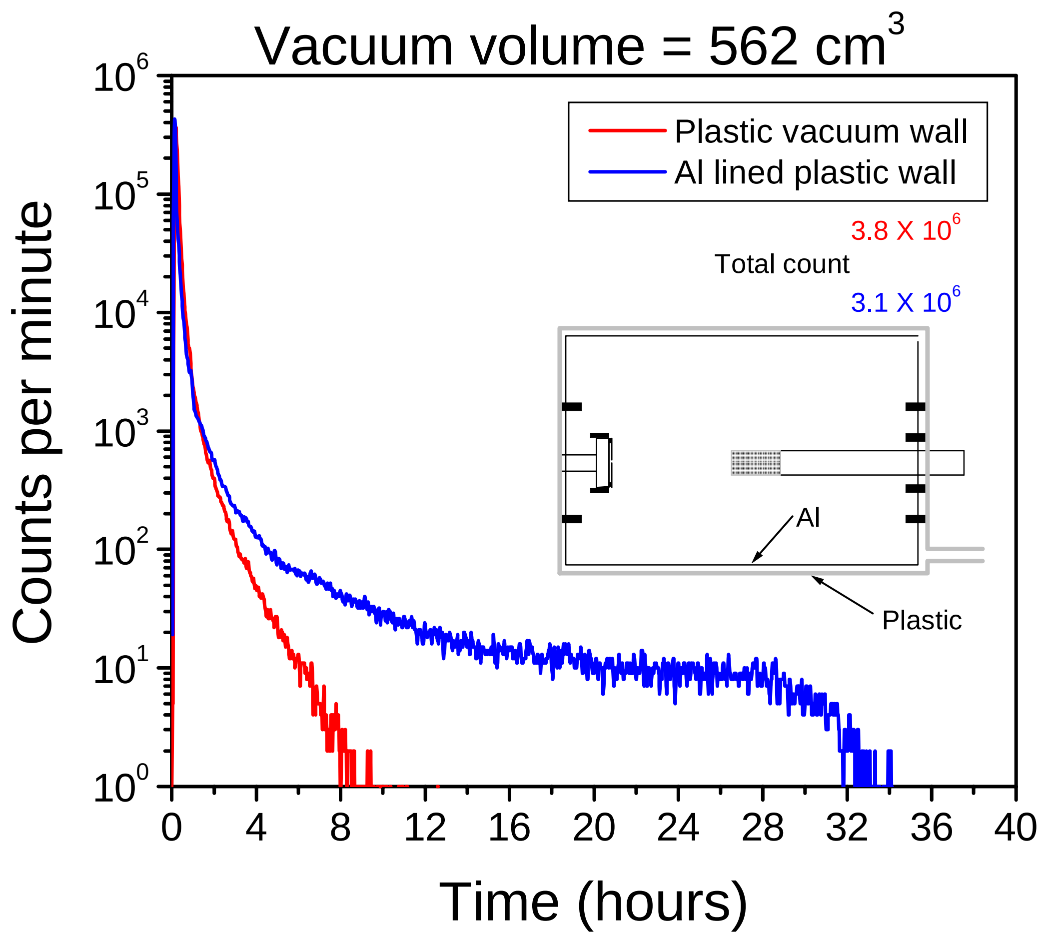
Here we show the effect of an **ungrounded** metal volume restrictor. The +Z base of the crystal was heated to ~150 ^{o}C and left to cool to room temperature. Data was collected for more than 67 hours. The **red** trace shows what happened when the metal tube is replaced with a glass tube.

Fig. 5



Here we show the effect of a **grounded** metal volume restrictor. The +Z base of the crystal was heated to ~150 °C and left to cool to room temperature. Data was collected for more than 67 hours. The change in count rate at **A** and **B** is believed to be caused by a large change in room temperature between night and day.

Fig. 6



Here we show the effect of lining the **plastic** vacuum chamber wall with **Al** foil. The Al foil is grounded. The +Z base of the crystal was heated to ~150 ^{o}C and left to cool to room temperature. Data was collected until the count rate fell to about 1 count per minute.

Fig. 7

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