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Cathodoluminescence Events Coincident with Muon Detection

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Motivation

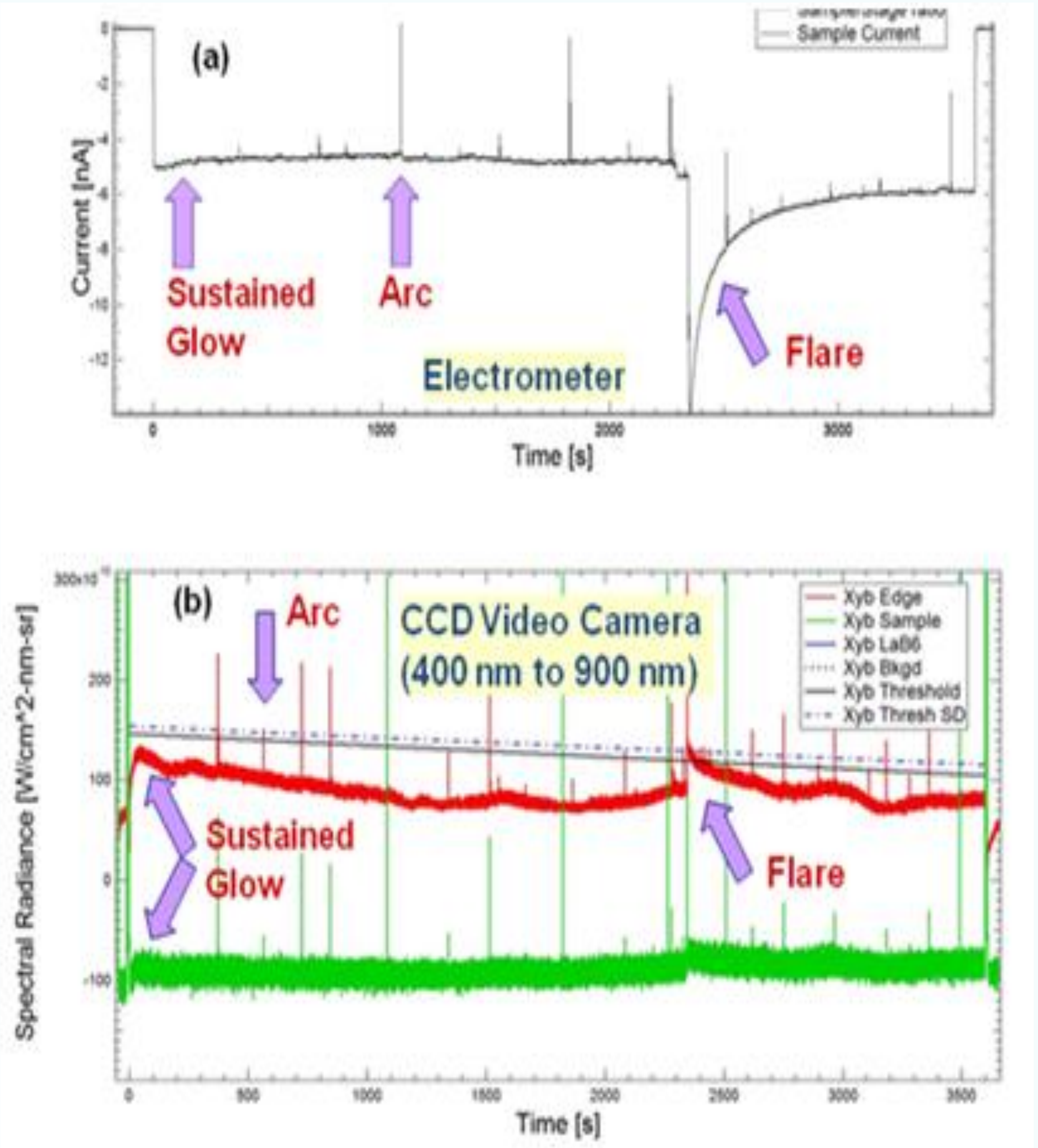

Fig. 1 (a) Current through sample vs. time showing the three types of emission. (b) Optical intensity vs. time showing the three types of emissions[Dennison, 2013].

Observed Optical Emissions

1. Cathodoluminescence
   A glow produced from optical emissions of charged insulator sample during continuous exposure to electron beam (Fig. 1: shown as sustained current in (a) and sustained radiance in (b)).
2. Arc
   Fast discharge of built up charge from sample (Fig. 1: seen as a drop in current (a), and as intense light (b)).
3. Flare
   Infrequent occurrence of prolonged discharge and sharp increase of current through sample with sustained electron beam. (Fig. 1: (a) is case with jump in current and slow return towards cathodoluminescence, and (b) optical emission over time).

Muon Origins

High energy cosmic rays interacting with the upper atmosphere decay into Muons that are present at the surface. Due to interactions with the atmosphere, they have a decay rate that is proportional to the altitude. With this correlation we were able to determine counts per minute on the order of ~1/hour in Logan Utah (altitude 1370 m). Fig. 2 also shows and angle dependence though the muon's decay.

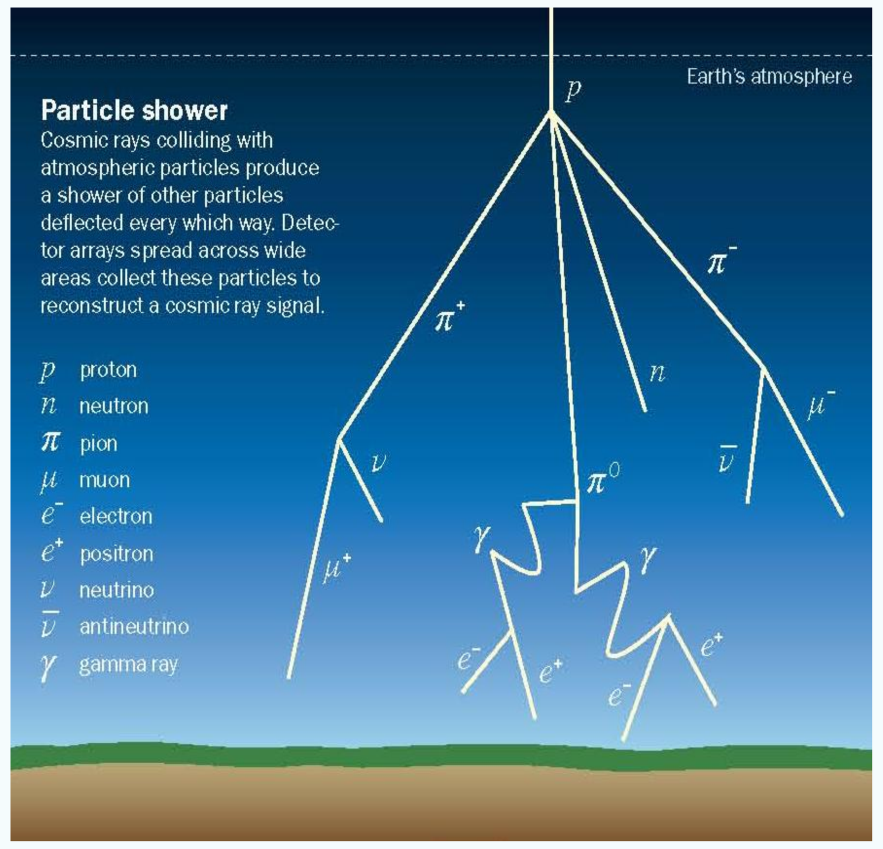

Fig. 2 Shows decay of cosmic rays into muons [Drake 2012]

Abstract

Samples of highly disordered insulating material were irradiated with 1 keV electron beams, resulting in three forms of light emission with differing duration: arcs (<1 s duration), flares (~100 s), and cathodoluminescence (as long as beam is on). The arc and cathodoluminescence phenomena are well understood, while the flares are not. Flares were observed at intervals of ~2 per hr. This is within a factor of 2 for the expected muon cross-section at an altitude of Logan, UT (1370 m) caused by high altitude cosmic rays. Based on this suggestive evidence, we have proposed incorporation of standard muon coincidence detection apparatus into our vacuum cathodoluminescence test facility. Measurements of the muon cross-section zenith angle and angle-dependence will provide calibration of the muon detector. If muon evidence coincides with the flare events, this will provide definitive evidence of the flare origin. We will discover whether a correlation between flares of charged sample are caused by transitory muons which trigger discharge and subsequent recharging during our testing of space materials.

Muon Detection and Coincidence

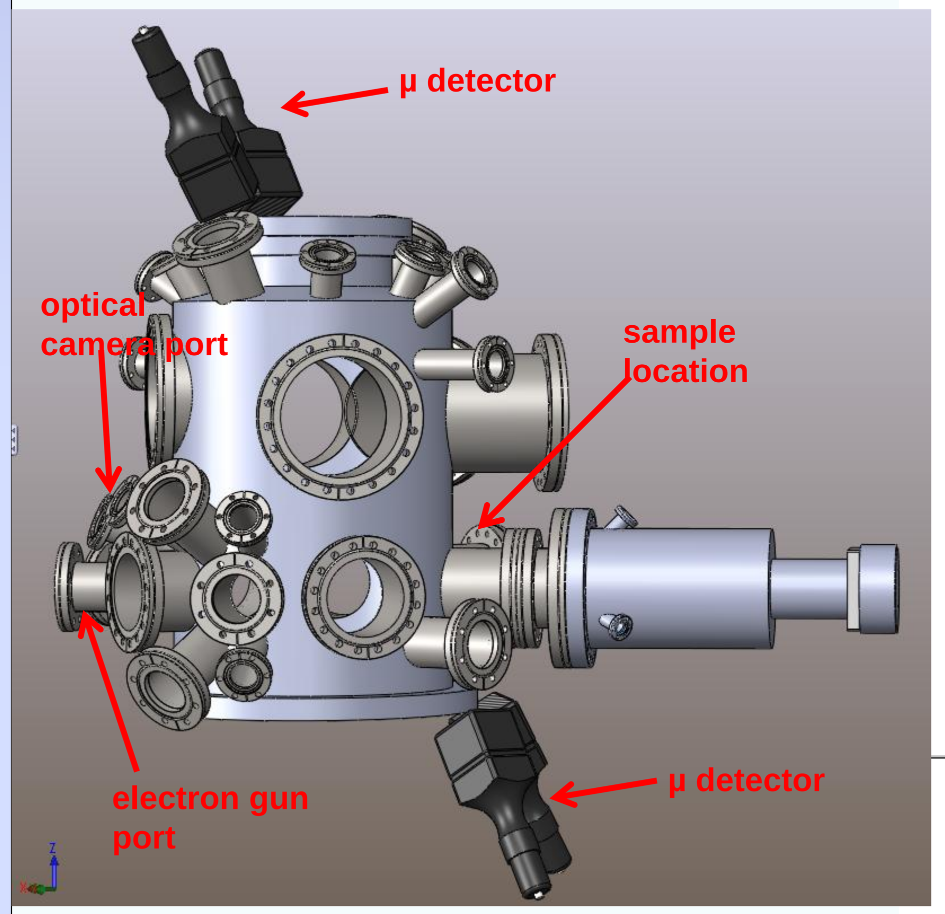

Fig. 3 – Vacuum chamber with scintillating detectors arranged around the sample.

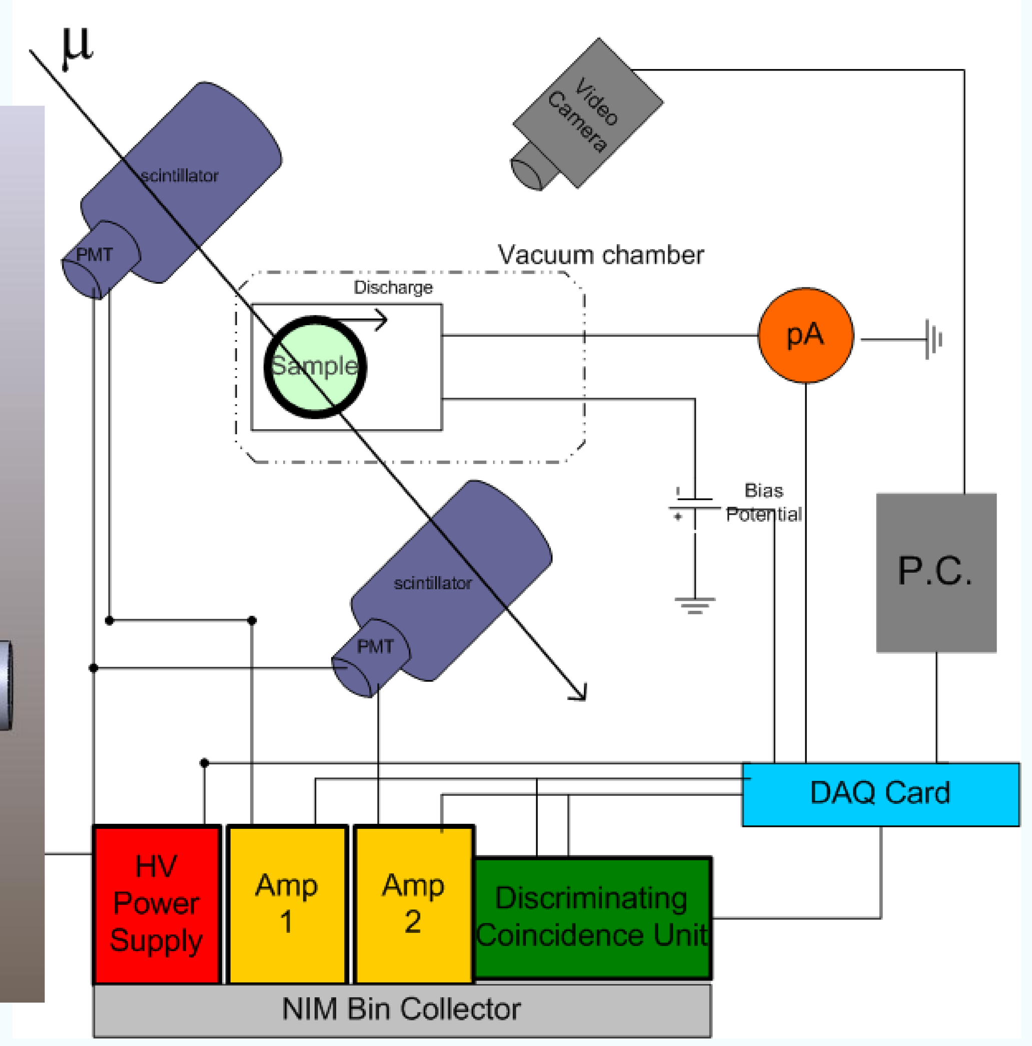

Fig. 4– Coincidence experiment schematic.

Detector Arrangement

•Limitations

❑<u>Electron Emission Test chamber (EET chamber)</u> has challenging geometry for placement of the detectors (Seen in Fig. 3)

❑<u>Efficiency</u> of finding coincidence with the detectors relies on the incident angle of the muons and is restricted by the chamber. (optimally the detectors would be closely positioned on top and bottom of the sample with very little room for the muons to interact with the sample without being detected).

•Solution

❑By determining the angle with the greatest flux of muons, we can cut down efficiency of the detectors' coincidence ability.

Muon Detection

•Muon decays in the atmosphere and travels into the laboratory.

•Muon interacts with first detector and creates a current pulse.

•Muon deposits charge onto the sample and creates a flare.

•Muon interacts with the second detector and joins the first pulse of current in the coincidence unit.

Coincidence

❑All three sets of data (Detector 1, detector 2, and EET chamber data) are collected into the discriminating coincidence unit to determine coincidence between the flare and muon.

Scintillators' Setup and Calibration

Scintillator Construction

•Parts

❑Photomultiplier Tube (PMT)
Ordered unit, designed with sensitivity for light in the blue spectrum.

❑Inorganic Scintillator
A crystalline structured material that excites through interaction with cosmic rays and emits blue light.

•Assembly

Assembled into one unit with the scintillator attached to the PMT's face and allows for optical transmission directly to the PMT.

Fig. 5 Hamamatsu R6233 PMT

Fig. 6 BNC Mounting apparatus for PMT

PMT's are checked for optimal operation voltage and current (minimize dark current). Scintillating detector is set at specific angles to determine the angle of incidence for maximum muon flux due to the decay at the specific altitude. Then with both scintillators, efficiency of the two being able to count the same particle at a set separation and angle are needed to account for the percentage of flares observed without proper coincidence with one scintillator detecting and the other not for wider or narrower angles of incidence.

Bell-curve represents the atmospheric muons that are being detected.

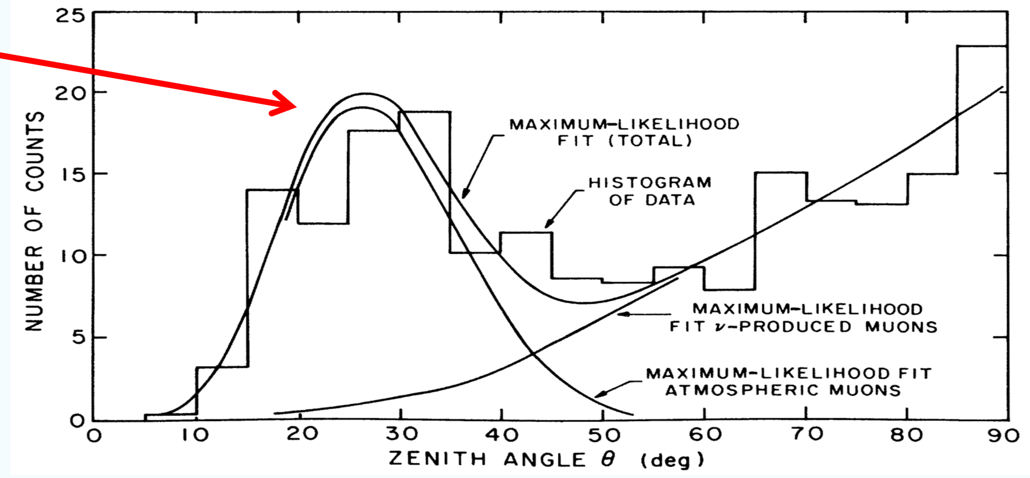

Fig. 7 – Angular dependence of muon counts [Landecker, 1978].

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