

Novel Radiation Detector Based on a Metal

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Abstract

In spite of the advancements on radiation detectors, there are not, so far reported, radiation detectors based on solid metals. Here is the design, construction, characterization, and operation of a novel radiation detector, based on an Aluminum $7\text{ cm} \times 7\text{ cm} \times 0.20\text{ cm}$ plaque. When this detector is exposed to natural radiation, cosmic rays, in horizontal position, with an applied electric field between 0 Vdc/cm and $|\pm 4000|\text{ Vdc/cm}$, there are no detected pulses (triggers); the pulses start to appear above $|\pm 4000|\text{ Vdc/cm}$, and with $|\pm 40|\text{ mV}$ of oscilloscope trigger level. This radiation detector was tested extensively over many possibilities on the origin of these randomly produced pulses. All the collected information is consistent with that the pulses are produced by cosmic ray hits; therefore, this is a novel technique based on a metal, to detect ionizing radiation, in particular cosmic rays.

1 Introduction

There are many sort of published radiation detectors based on almost all kind of materials and their physical phase states [1–4]. However, in spite of these developments, there are not, so far, reported radiation detectors based on solid metals.

Here is a proposed, and demonstrated, one; this is, a novel radiation detector based on a machined Aluminum $7\text{ cm} \times 7\text{ cm} \times 0.2\text{ cm}$ plaque, with the appropriate basic electronics, in prototype stage. See Figure 1.

2 Design and Construction

It has two 8 cm long, 0.6 cm wide, 10 mil thickness, glued Copper tape collectors at the opposite big surfaces. This first layer is electrically insulated with black electric tape, 10 mil ($2.54 \times 10^{-2}\text{ cm}$) thickness, 3M scotchrap; the minimum electronic circuit to read out electrical signals is connected to collectors -to one collector a capacitor, $C1$, in series with an electric resistance, $R1$, and then to ground, and to the second collector another electric resistance, $R2$, and ground; the values are

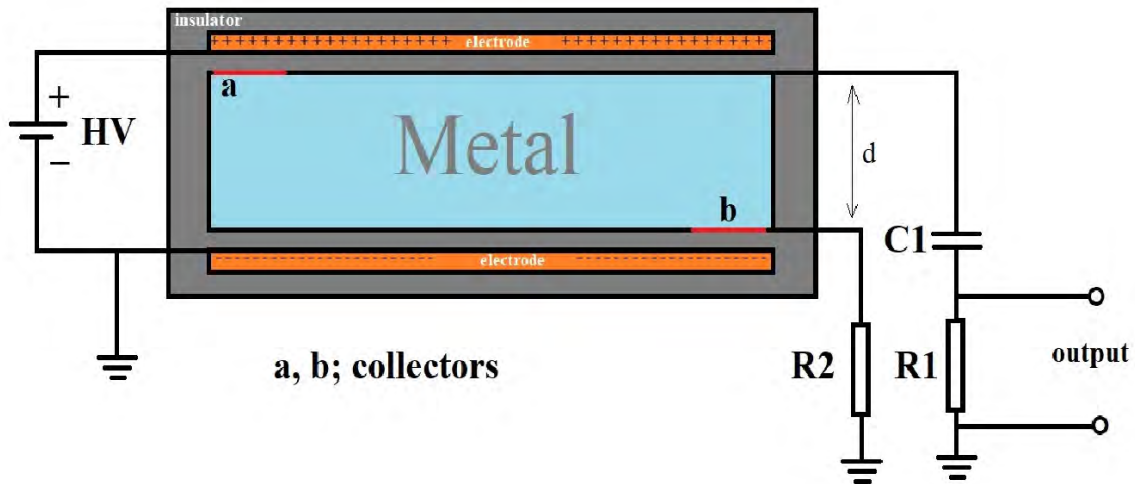


Figure 1: Layout of the radiation detector based on an Aluminum $7\text{ cm} \times 7\text{ cm} \times 0.2\text{ cm}$ plaque; this is an electron gas radiation detector. Not to scale. For illustration only.

appropriate to match detector and instruments impedances together-; the detector signal is read out at R1 using a Tektronix TDS 3034B four channel color digital phosphor oscilloscope e* Scope, 300 MHz (2.5 GS/s) DPO, or another technically similar oscilloscope. A couple of $7\text{ cm} \times 7\text{ cm}$, 10 mil thickness, Copper sheet electrodes is attached to the $7\text{ cm} \times 7\text{ cm}$ parallel surfaces of the electrically isolated metallic plaque; there is where a $0\text{ Vdc} \mid \pm 3000 \mid \text{Vdc}$, high voltage, is applied using a very stable dc power supply (Fermilab power supply Model 1570 1-3012V, 40 mA, high voltage calibrated DC power source; power designs Inc. Westbury, NY, Palo Alto California). The whole device, in prototype stage, is electrically insulated, compacted, mounted, and operated horizontally on a solderless breadboard. Figure 2.

3 Operation and Characterization

This not so simple, or obvious, device functions as a radiation detector in general, and as a cosmic ray detector in particular. Many tests were performed to study its operation and the way it detects radiation. High Voltage (HV) from 0 Vdc to $\mid \pm 1600 \mid \text{Vdc}$ was applied incrementing its values in steps of $\mid \pm 100 \mid \text{Vdc}$.

When the applied high voltages were below $\mid \pm 800 \mid \text{Vdc}$ no signals (triggers) appeared at all, with the $\mid \pm 40 \mid \text{mV}$ of trigger level in the oscilloscope, and monitoring for more than one hour; for voltages little higher than $\mid \pm 800 \mid \text{Vdc}$, some occasional signals (triggers) appeared: With negative values for negative high voltages, and with positive values for positive high voltages. The signals are randomly produced in both amplitude and occurrence, with almost the same decaying and rising time. At these voltages, distinctive signal amplitudes are about $\mid \pm 100 \mid \text{mV}$, with 10 mVpp of electronic noise, and $\mid \pm 40 \mid \text{mV}$ of oscilloscope trigger. At higher voltages the signal amplitudes are bigger, see Figure 3. The forms of these triggers are perfectly distinguishable from the electrical outlet noise.

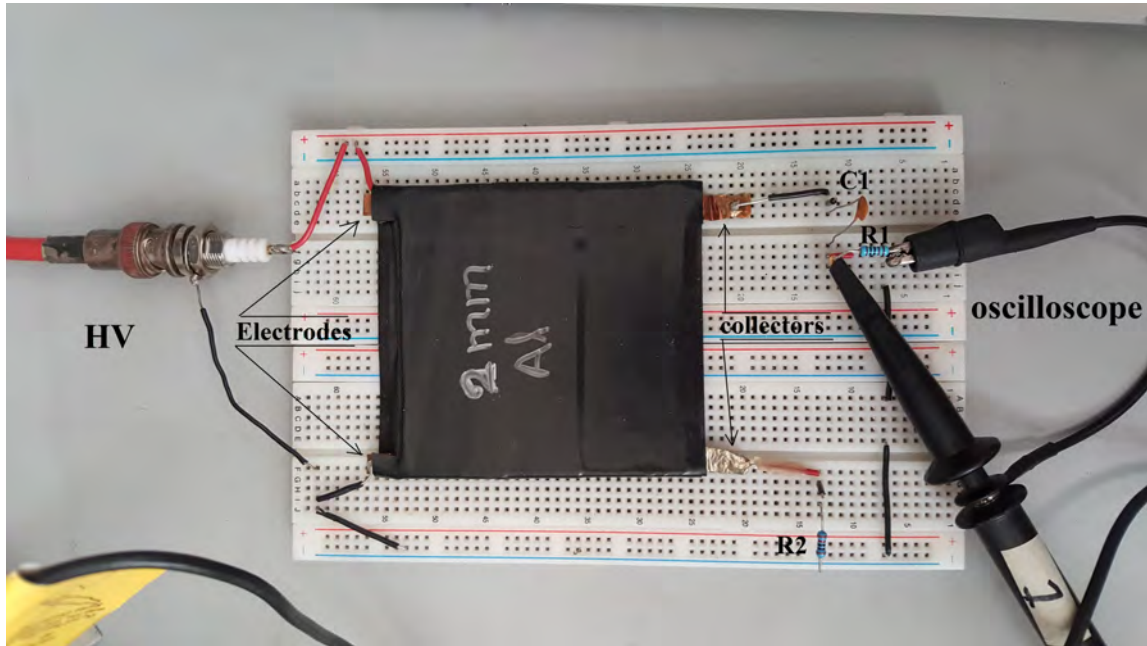


Figure 2: Final configuration and electrical connections to operate the radiation detector based on Aluminum. Working prototype stage.

The process of incrementing applied high voltage in steps of $|\pm 100|$ Vdc was stopped at $|\pm 1600|$ Vdc, for the readout signal amplitudes were very big. No signal amplification electronic circuit is needed, nor really high voltages.

To try and to demonstrate the way this detector works, several tests were performed, and the following results were obtained:

1. Without applied high voltages there are not triggers at all, but noise signal could randomly appear from time to time.
2. The stability of this detector was continuously tested for more than 15 hours, during this period the detector triggered without interruptions, at high voltages above $|\pm 800|$ Vdc and $|\pm 40|$ mV of trigger. No electrical sparks or other malfunctions were observed.
3. When the high voltage is increased, in absolute value, there appears a period of instability, the detector triggers rapidly, with random amplitude and showing up trigger signals. After about one minute the detector regains its stability and starts triggering regularly. This means that the show up triggers are related with momentaneous disturbances (increases) of the external applied electric field. This effect is not observed when the high voltage is decreased, in absolute value, merely the trigger amplitudes decrease.
4. When the detector was entirely protected with 1.0 mil Aluminum foil to shield it from external electromagnetic radiation, the triggers remained without interruption. This means that triggers are generated inside the Aluminum plaque, not as a consequence of electromagnetic induction over the electronic circuits.
5. The Aluminum plaque radiation detector was directly heated using a hot air flux gun, that very common one used for unsolder electronic components, starting from ambience temperature (around 15°C) up to around 80°C . The detected triggers haphazardly and dramatically

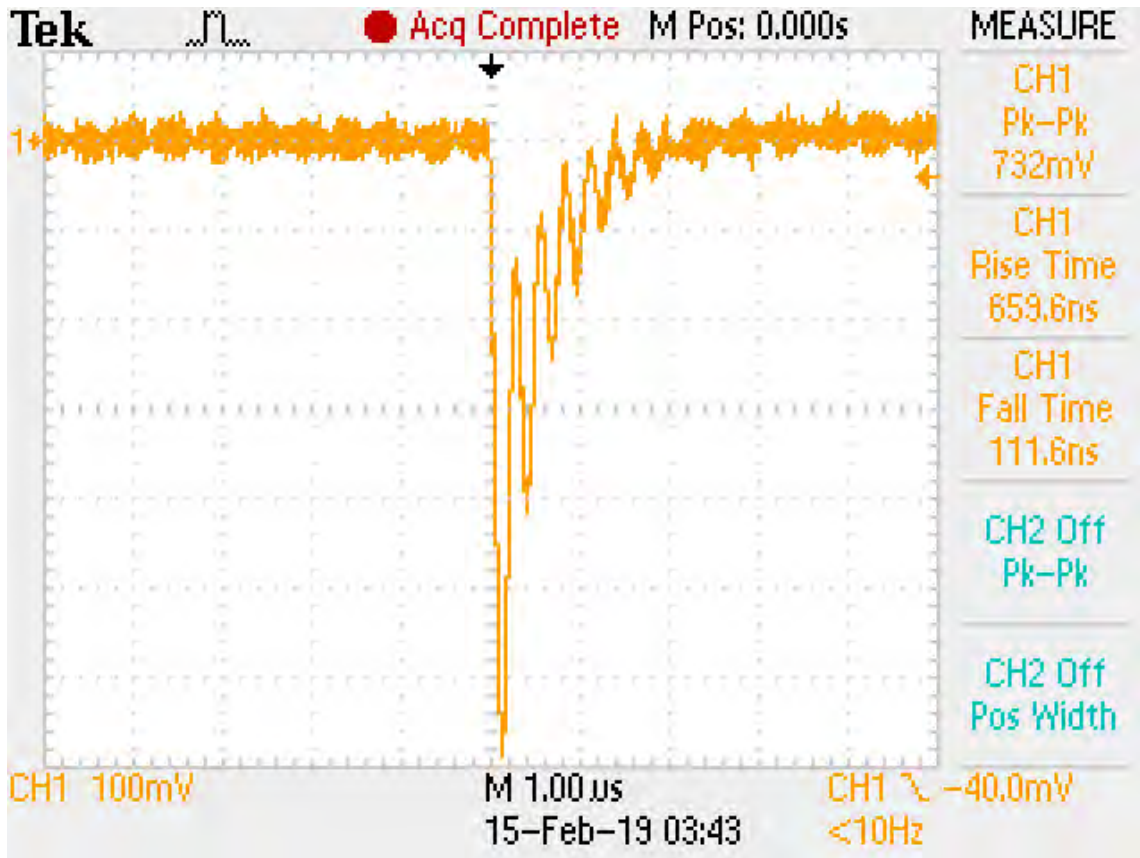


Figure 3: Typical signal (triggers) with positive high voltages. Rising time about 110 ns, falling time about 675 ns.

increased, in both amplitude and showing up. When the detector was freely cooled down, back to ambience temperature, its triggering reduced to its initial triggering activity. When the metallic plaque was cooled down, using iced gel at -2°C , triggers reduced dramatically in both amplitude and showing up. These facts are interpreted in the sense that the electrical activity (movements of ions) inside the metallic plaque -with the internal electric field- is the cause of the detected signals; and that many of the detected signals are from thermal fluctuations of the metallic plaque, but also from hitting radiation particles which by some nanoseconds disturb the internal electric field. None radiation detector is 100% free of thermal effects; this present radiation detector is not an exception. Some of the detected signals are from the incidence of cosmic ray particles.

6. Very feeble (around 1 microcurie) ^{241}Am radiation source was applied on the top surface of the radiation detector Aluminum plaque. No significant modification of the triggering activity was observed. Normally the oscilloscope is very slow to detect these fast triggers if any was produced by this feeble radiation source.
7. In the prototype Aluminum detector without connecting R1C1 and R2 components, a home-made electroscope was connected to the point **a** or **b** of the detector, Figure 1. Without the applied high voltage there were not electric charges detected, for metallic plaque is electrically neutral. When high voltage is applied, either positive or negative, some electric charges, are

detected; its numerical value depends on the applied high voltage; the higher the applied high voltage, the higher the quantity of electric charge accumulated at either point **a** or **b**. These measurements mean that there is an electrical polarization of the metallic plaque, a spatial separation of electric charges that create an internal electric field that compensates the external electric field, generated by the applied high voltage; these measurements are predicted from the Coulomb Principle in elementary electrostatic.

8. When the components R1C1 and R2 are reconnected, and the homemade electroscope is connected at point **a** or **b** of the Aluminum detector, no electric charges were detected, even if high voltage is applied up to $|\pm 2900|$ Vdc. As the detector system is grounded, inside it must be electrically neutral and without some electrical polarization. Therefore, there must be an electric field inside the metal, that exactly corresponds to the external electric field originated by the applied high voltage. This externally originated electric field inside the metallic plaque, after annulling or grounding the polarization electric field, is the operation key of this radiation detector based on a metal.
9. Similar detectors were constructed based on Fe, Cu, Pb. All of them trigger similarly. This means that metallic plaque is fundamental for the operation of this radiation detector.
10. Similar detector was constructed based on an acrylic $5\text{ cm} \times 7\text{ cm} \times 0.2\text{ cm}$ plaque. The obtained trigger amplitudes were consistent with 0 mV, at high voltages from 0 Vdc to $|\pm 2900|$ Vdc. Very small and rare triggers, about $|\pm 120|$ mV of amplitude, with the RC discharge shape, at $|\sim \pm 3000|$ Vdc, were obtained. These facts are interpreted as that the metallic (Aluminum) plaque is fundamental to generate the big amplitude detected triggers; with a high resistive plaque (acrylic) the triggers have very low amplitude. From this experience, acrylic plaques can be used directly to detect radiation in general, or cosmic rays in particular, but metallic plaques are far better to detect radiation and cosmic rays.
11. Two equal detector devices were operated, horizontally, in stack at the same applied high voltage. Many simultaneous triggers showed up, within times less than 1 ns; others triggers were not inside this period, clearly showing up one after the other sometimes with more than one second of difference in time arrival. This information is consistent with that a radiation particle crosses both detectors and interacts with the metal detectors, leaving some trace of ionized atoms inside the detectors, which originates the trigger in each detector. Two simultaneous triggers are used to define a cosmic ray. This is, cosmic rays are detected by this Aluminum based detector.

From the above experimental facts, detected triggers are not spurious signals from electrical line, power supply, or from anywhere else. Triggers are from electrical disturbances of the electric field inside the metal, either from hitting cosmic ray particles or from thermal fluctuations. Most of the thermal fluctuations can be eliminated, and hitting cosmic ray particles can be selected, using the coincidence signal technique.

This Aluminum based detector has the following plausible way of operation: Incident particles, cosmic rays, ionize the metallic atoms along its trajectory; by the externally applied electric field electrons are accelerated, gain energy and create more ions; an avalanche of electrons is originated, with the R1C1 circuit the electron signal is collected and discharged to be detected as a trigger.

4 Discussions

This Aluminum based detector has some advantages with respect to other kind of radiation detectors: Since liquid Argon ionization energy is 26.4 eV, and Aluminum ionization energy is 5.99 eV [4], a detector based on Aluminum, or another metal, could be a better radiation detector, especially for low intensity or low interacting radiation, for Aluminum is twice denser than liquid Argon and more than two thousand times denser than the gas Argon. In particular, this radiation detector has many advantages with respect to the Resistive Plate Chamber or with respect to the Multiwire Proportional Chamber, or similar detectors: It is easier to construct and maintain, cheaper, no gas problems, safer, no aging problems, simpler, not needed electronic amplifier, not required so high voltages, denser, more suitable to detect low intensity and low interacting radiation like neutrinos or cosmic rays.

This kind of radiation detector could be improved exploiting metal properties like high electric conductivity; for instance, it could be very efficient where speedy, and high dense, instruments are needed, like in neutrino detection, etc., since it could be useful as the base to develop huge neutrino detectors.

5 Conclusions

From all above stated, this is a novel detector based on a metal, with many advantages over other traditionally used radiation detectors. Technological possibilities are immense. Many studies and developments are under way.

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