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Some Properties of Air Spark Chambers

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Summary. The ionization discrimination ability of air spark chambers having particular geometries was investigated. It was found that good discrimination can be obtained with a single gap device between strong and minimum ionizing particles, while the discrimination between intermediate and minimum ionizing particles is poor. The rod and plate type chamber is capable of producing reliably simultaneous multiple sparks for simultaneous multiple events, provided that the pulse voltage is fed to each rod through a separation resistor and that the events do not occur along the same rod.

Introduction

Late in 1959 work was started at this laboratory to study certain features of the Cranshaw type pulsed air spark counter[1]). The author was fully aware at that time of the superiority in various respects of the Fukui and Mijamoto type noble gas discharge chambers[2]). However, for our specific needs air was a more desirable gas.

We were particularly interested to find out whether any operating condition could be established that would permit to use an air spark chamber as a reliable ionization discriminator. This interest grew out of the necessity to have such a detector for a cosmic ray experiment which we have planned[3]). The detector had to be capable of localizing the passage of intermediate and strongly ionizing events within a sea of minimum ionizing particles, without responding to the latter. It also had to be of large size, covering an area of one to several square meters.

The events under consideration were energetic photon-electron cascades. After emerging from a producer such cascades are highly collimated and have, depending on their size, a high specific ionization. In order to carry out a precise analysis of spark chamber response with respect to electron cascades it is essential to have a source producing cascades of well defined size. This, however, is a problem in itself and we have therefore chosen suitable substitutes.

Alpha particles from a Po 210 source and portions of the beta spectrum of a Sr 90–Y 90 source were used for the investigation in place of large and medium size cascades. In addition, muons were used to determine the response with respect to minimum ionizing particles. Three series of measurements were carried out with each chamber set-up, determining the counting efficiency as a function of pulse voltage for alpha particles, portions of the beta spectrum of Sr 90 and for muons, respectively. All the other parameters that govern the operation of a spark chamber were fixed. The measurements with alpha particles and muons were made with great care, while those with beta particles were coarse and served as an indication rather than a calibration.

Construction of Chamber Models

To study the spark chamber characteristics two types of models were constructed having different kinds of electrodes. Both types were aimed to overcome one of the major disadvantages of air spark chambers, namely the inability to produce reliably simultaneous multiple sparks for separate simultaneous multiple events penetrating the chamber.

The first type (Figure 1) consisted of a copper plate measuring 10 by 10 cm and of an equal array of uniformly spaced monel rods (70% Ni, 30% Cu) that was mounted parallel to the plate. Two such units were built having rod diameters of 2 and 2.5 mm, with rod spacings of 1.5 mm. The gap between the rods and the plate was 2.2 mm, measured at their closest approach and was the same for both units. Each rod was connected through a separate resistor to a bus bar to which the high voltage pulse was applied, while the plate was kept at ground potential. As must be expected from such a geometry, the electric field in the active chamber volume is not very homogeneous. However, calculations carried out to obtain the distribution of the electric field showed that the non-uniformity was not serious, provided that the rod diameter and chamber gap were not too small and the rod spacing not too large. This construction insured a certain isolation between rods which is of advantage if separate simultaneous multiple events penetrate the chamber. In this case an equal number of electron avalanches develop that will rapidly grow into sparks, provided that the conditions are favorable.

If there were no series resistors feeding the rods, jitter in the build-up process would cause the fastest growing avalanche to develop into a spark and dissipate most of the charge available to the chamber before the other discharges are able to develop fully.

The artificially introduced time constant between pulse generator and rods, which is made up of the series resistors and the rod capacities, prevents the charge stored on each rod to be consumed by any other rod instantaneously if this one is loosing rapidly charge because of spark break-down. Moreover, the potential of all other rods remains for some definite time above a certain critical value that allows development of a spark even then, when a discharge on another rod has developed more rapidly. As a result multiple events can be recorded with greater reliability.

The series resistors and rod capacities cause a slight integration and augment the pulse rise time somewhat. However, it can be kept within reasonable limits. It proved to be a problem to find small non-inductive resistors that could handle large peak powers without deteriorating. The best results were obtained with nominal $^1/_2$ Watt IRC (green body) resistors of 3900 ohms. These resistors could handle a peak power of 0.5 to 1 megawatt for pulses of approximately 0.5–1 microsecond duration without showing any deterioration, even after being pulsed many thousand times. Other values of the same type resistor were almost instantaneously destroyed.

Copper was chosen for the plates because it showed less corrosion effects for discharges in air than aluminium or brass and it was easier to machine and polish than stainless steel. The choice of monel for the rods was mainly for the same reasons. In addition, monel can be soft soldered like copper, yet it has considerably better mechanical properties than copper. The lucite holder for the rods is shown in Figure 1. The portion of insulator between rods and plate was removed because surface charges caused excessive sparking along the lucite.

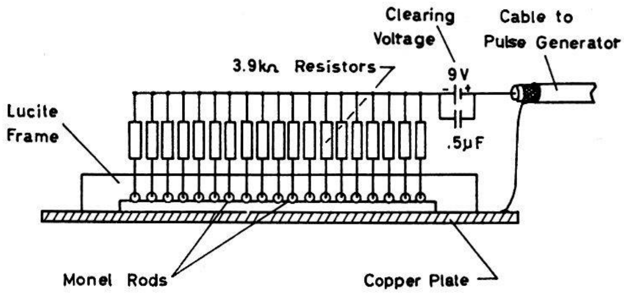

Figure 1

Side view of the rod and plate type spark chamber assembly. The copper plate serves as one of the electrodes, the array of monel rods as the other. Each rod is individually fed through a resistor and the clearing voltage is derived from a battery.

The second type of spark chamber models consisted of parallel glass plates that were coated with a transparent conducting layer (stanic oxyde, made by Corning Glass Works, Corning, N. Y.) and a similar version using coated lucite (made by Balzers Glass Works, Liechtenstein). Numerous plates with surface resistances varying from less than 10 ohms to over 1000 ohms per square were available. The purpose of using resistive coatings was again to prevent the sudden drop of the potential over the entire chamber area and with it the loss of simultaneous multiple discharges. Early experiments showed that our particular plates were not suitable for this work. The more resistive coatings produced a very large number of thin streamer discharges for each pulse, which made it impossible to identify the discharge directly related to a particle. It was observed that the number of streamer discharges decreased with decreasing plate surface resistance. Unfortunately, as the discharges became more intense and also more reliable it was noticed that the coating could not withstand the discharge current and high local temperature. Inspection of the plates later on revealed that each spark burned off a small portion of the coating, leaving a star shaped spot on the glass. It was for these reasons that further work with resistive coatings was abandoned. However, they may prove useful for work with small noble gas discharge chambers that can generally be operated with less energy than air spark chambers. This is because of the lower sparking potential of noble gases as compared to air or nitrogen for a given geometry.

Operation and Measurements

To determine the characteristics of the rod and plate type spark chamber with respect to alpha particles a small source of Po 210 was deposited onto the copper plate. The source diameter was approximately 1 mm and its activity between 200 and 300 dpm. A low activity was desired to reduce the chance for the emission of two particles within the time of resolution of the apparatus and to operate the pulser with a low duty factor. The location of the Po 210 deposit on the plate was chosen to fall in the center of the projection of a gap between two rods. An alpha particle scintillation counter was mounted 5 mm above the rods, opposite to the source. The thin zinc sulfide scintillator was covered with a 1 mg/cm^2 aluminized mylar foil to prevent the light flash of the spark from destroying the photocathode. The scintillation counter pulse was fed through an amplifier discriminator circuit to the trigger circuit which fired a 5C22 thyratron. A lumped parameter delay line with a characteristic impedence of 100 ohms, producing a 1.2 microsecond rectangular pulse was discharged through the 5C22 over a 100 ohm bifilar resistor. The pulse had negative polarity with respect to ground and a rise time of 50 nanoseconds. Its amplitude was variable from 4–16 kilovolts.

Because it was found to be convenient to keep the plate grounded it was necessary to apply the clearing voltage to the rods. This was achieved by means of a by-passed battery that was in series with the lead feeding the high voltage pulse to the rods. The overall delay was 0.5 microsecond. The spark chamber and scintillation counter set-up were placed in a black box to prevent the creation of photo electrons in the chamber. A small photomultiplier (type 931 A) was also placed in the box to record the sparks. The photocathode was directed towards the source region of the spark chamber and a light colimator prevented the recording of sparks that occurred at other locations within the chamber. Because of the excessive brightness of the sparks a very low operation voltage (350 V) was applied to this photomultiplier. The scintillation and spark pulses were recorded on separate scales. The counting efficiency was then determined simply by dividing the number of sparks by the number of trigger pulses.

The same method with a similar set-up was used to carry out measurements with beta particles. In this case the copper plate with the Po 210 source was replaced by an identical plate with a small Sr 90–Y 90 deposit and a thin window geiger counter was mounted in place of the alpha scintillation counter. An electron scintillator could not be used because the very essential low energy portion of the electron spectrum would have been lost in the noise of the photomultiplier. The long build-up time of the geiger pulse would result in a larger overall delay as compared to the previous set-up. To avoid this undesired effect a special high gain amplifier with strong differentiation was placed immediately after the geiger tube, such that the initial rise of its pulse would fire the pulser. Thus, approximately the same overall delay could be obtained as previously.

For the given set-up an electron emitted from the Sr 90 source had to have an initial energy of at least 40 keV to be recorded. This takes into account the path traversed in air and the thickness of the geiger tube window. Thus, the electrons recorded represented that portion of the Sr 90–Y 90 spectrum whose initial energy layed between 40 keV and 2.18 MeV. This energy range corresponds to an ionization range from about seven to one times minimum ionization. By inserting thin aluminum foils in front of the geiger window the low energy end of the particle beam could be cut-off. Background, mainly due to cosmic radiation, was accounted for in this case, while it was practically negligible for the alpha particle measurements. Consecutive measurements with different low energy cut-off energies would permit to calculate the chamber response for different domains of specific ionization. Since the investigation was meant to be of a rather exploratory nature, the accumulated data material concerning the beta particles was not adequate to carry out these calculations.

To establish the spark chamber characteristics with respect to minimum ionizing particles, penetrating cosmic ray components, chiefly muons, were used. A scintillation counter telescope operated in coincidence derived the trigger pulse. Each counter consisted of a one-inch thick plastic scintillator having a diameter of two inches, coupled to a 53AVP photomultiplier. Again the overall delay was adjusted to 0.5 microsecond. One of the counters was placed in the middle above the spark chamber with its scintillator pointing down, the other below the chamber in line with the first, pointing up. Otherwise the procedure and set-up were the same as before. Furthermore one run was made for each chamber to determine the percentage of spurious sparks when triggered at random.

The results of the measurements are plotted in Figures 2 and 3. All operating parameters were identical for both models and are given on the graphs. The clearing field was 9 volts for all measurements, the rods being negative with respect to the plate. Preliminary work indicated that this value was fully adequate to keep the number of spurious discharges within reasonable limits. Reversing the clearing field polarity caused no observable effect. Since our interest was mainly focused on the intermediate and particularly the strongly ionizing events we did not extend the measurements for the minimum ionizing particles into the one hundred percent plateau region. The alpha response shown in Figure 3 rises considerably steeper than that of Figure 2. This effect which must be due to the electrode geometry is not so strongly pronounced for the minimum ionizing particles.

To check the capability of the spark chamber for resolving simultaneous multiple events, two scintillation counter telescopes were used. They were identical in design to the one described before. Respective counters were mounted, side by side, above and below the spark chamber. Because of the low counting rate an automatic camera was used to record the sparks. Measurements were carried out with a pulse voltage ranging from threshold to 7.2 kilovolts. Simultaneous double and even multiple sparks were observed. The counting efficiency for double sparks was approximately equal to the square of the counting efficiency for single events at the same pulse voltage. This observation is in agreement with theoretical expectation.

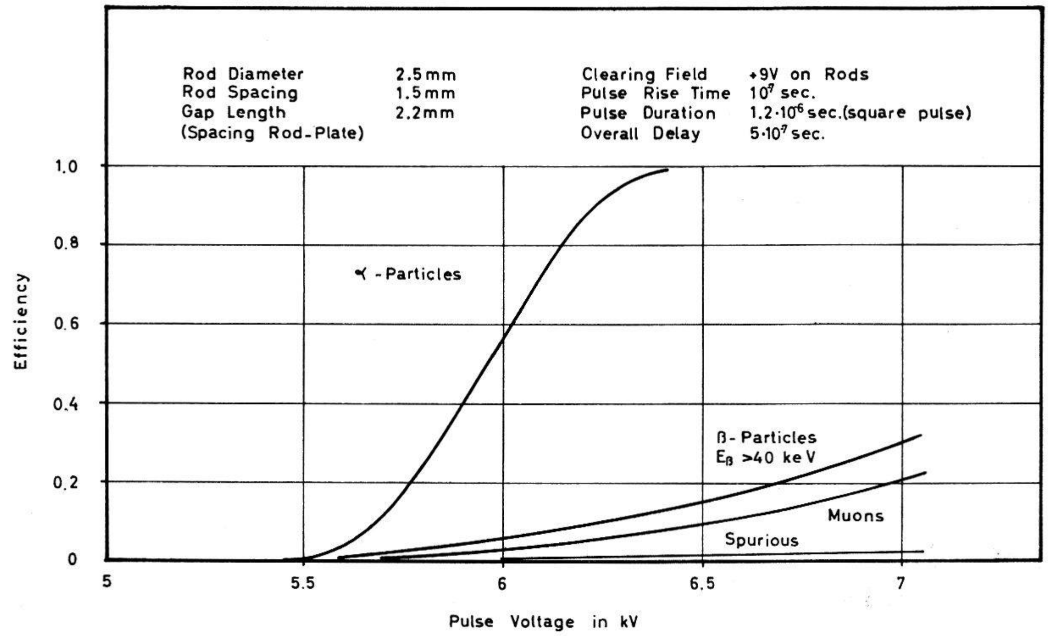

Figure 2

Efficiency as a function of pulse voltage for an air spark chamber consisting of an array of rods and a plate. Each rod has a diameter of 2.5 mm and is connected through a 3.9 kΩ resistor to the pulse generator, as shown in figure 1. The rod capacity is 12 $\mu\mu$F.

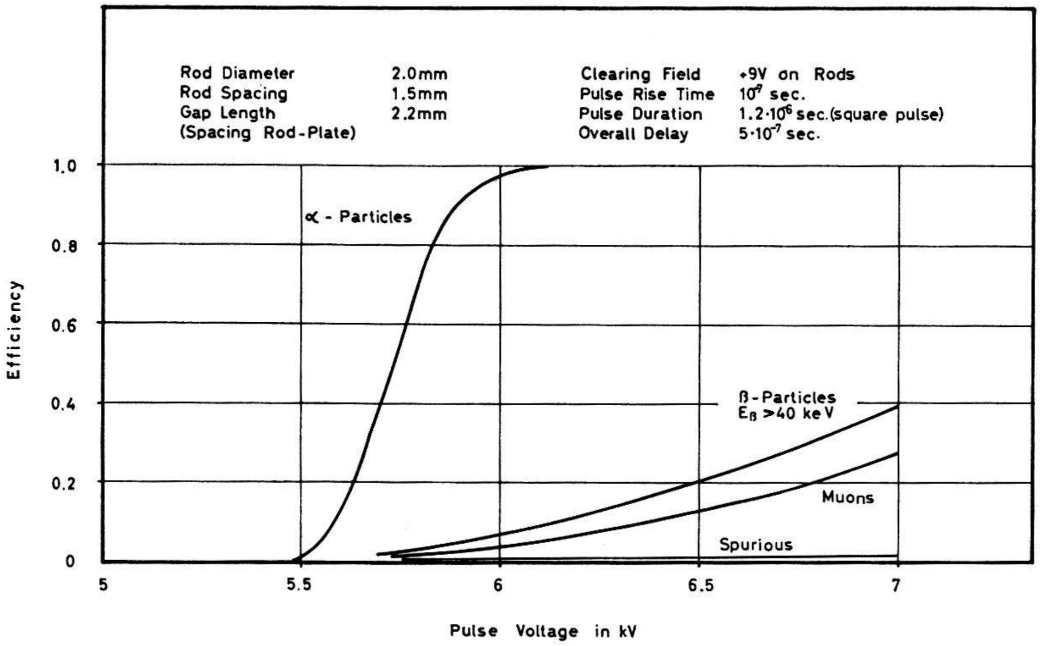

Figure 3

Efficiency as a function of pulse voltage for an air spark chamber of similar design to the one used to obtain the curves shown in figure 2. The only difference lies in the rod diameter which is now 2.0 mm.

Due to the low activity required for sources deposited on the plate of the spark chamber it was not possible to carry out similar measurements with alpha or beta particles. However, in connection with a cosmic ray experiment[3]) it was possible to show that numerous simultaneous multiple events of intermediate and high specific ionization can be recorded with such a chamber, while its efficiency for minimum ionizing particles is very low.

Conclusions

From the work presented here it is evident that ionization discrimination in a coarse way can be achieved with an air spark chamber. Furthermore, simultaneous multiple events can be recorded with such a device, provided that one of the electrodes consists of a rod or wire array and that the events do not occur along the same electrode element. Each of the elements of the array must be pulsed through a separation resistor, preventing the sudden discharge of all elements by the fastest growing spark. The rod array causes a somewhat non-uniform electric field in the gap between rods and plate. As a result slight variations of the chamber response are observable in the direction normal to the rods, parallel to the plate.

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