DEVICES FOR STUDYING
NUCLEAR REACTION AT
INTERMEDIATE ENERGY

SINGLE GRID SPARK COUNTER
INVESTIGATION OF THE RANGE OF Po^{210} ALPHA-PARTICLES
IN AIR

22064

A THESIS
Submitted in Partial Fulfilment of the Requirements
for the Degree of
MASTER OF SCIENCE

B y

HOSNIA MOHAMED ABU-ZEID

T o
THE FACULTY OF WOMEN
AIN SHAMS UNIVERSITY

1 9 6 6

A B S T R A C T

A new type of gridded spark counter is described. The normal Chang-Rosenblum type counter is provided with a grid between the source and the anode.

Investigations were made on the counting characteristics in relation to their **dependence** on grid voltage, as well as, grid-to-cathode and anode-to-cathode spacing. Also the counting rate was examined when the alpha-source was moved perpendicular to the cathode.

The satisfactory profile of the counting plateaux and the strong **dependence** of their levels on the adabted grid voltage is evident.

The grid voltage has been shown to be a decisive element of the steady corona current conformation and hence the sensitivity of the counter.

By this system a homogeneous detection efficiency at all points of the detecting volume has been achieved.

A mathematical treatement of the working characteristics is given, and the different related mechanism of the detector is explained.

Also, this system was used to determine the extrapolated number - distance range for Po^{210} alpha-particles in air, and the result is comparable to a good shallow ionization chamber.

CONTENTS

PART FOUR

SINGLE-GRID SPARK COUNTER WITH
DOUBLE WIRE ANODE

PART FIVE

RANGE OF ALPHA PARTICLES

APPENDIX 1

APPENDIX 2

STATISTICAL TREATMENT OF OBSERVATION

I N T R O D U C T I O N[1,2]

The detectors for nuclear radiations which were available to early investigators in the field of radioactivity were affected by the level of technology of the period. As new techniques and instrumentations have become available, a series of radiation detectors has been developed using different fundamental methods, of which the theory and technology supply the foundation to allow of a unified presentation.

The principle on which is based the detection of particles in nuclear experiments is the fact that a charged particle passing through matter leaves along its path a string of ionized or excited atoms or molecules which can be detected and counted. Neutral particles produce directly neither ionization nor excitation, but neutrons and gamma-rays in passing through matter occasionally give rise to a charged secondary particle with considerable energy. In the case of neutrons these energetic secondaries are recoil nuclei produced by collisions or disintegration products emitted when a neutron is captured. Gamma-rays produce secondary electrons by photoelectric and compton effects or by pair production and heavy charged particles as, for instance, protons by nuclear photoelectric effect. By recording ionization or excitation of these

...........tes the presence of non-ionizing primary ....
ascertained. A direct detection of the neutrino has so far
..en unsuccessful, since its interaction with matter is ex-
tremely small.

The ionization caused by the passage of a charged particle
through a suitable material is measured by the detectors. If
an electric field is maintained across the material, the ions
will be set in motion and the ionization current can be detected.
Ionization chambers and crystal counters work on this principle.
The ionization current which can be obtained by the passage of
a single particle through matter is usually quite small, and it
has to be amplified considerably by suitable electronic arrange-
ments before the current can be measured. Another method of
obtaining this amplification is used in proportional counters,
Geiger-Muller counters and spark counters. In the Geiger Muller
counter the ionizing particle causes an increase of the already
existing (dark) current and thereby initiates a corona discharge.
The particle in the spark counter initiates a spark. In these
instruments the primary ionization products are so highly
accelerated by an external electric field that they produce
secondary ionization by collision with other atoms of the
gaseous volume of the counter. In the Geiger Muller counter

a considerable contribution to the ionization arises from photoelectrons ejected by photons which accompany the process of collision or recombination. Since the total number of ion pairs produced in an ionization chamber is proportional to the energy loss of the particle within the chamber, the time integral of the current pulse or total charge collected on one of the electrode is a measure of this energy loss. This is also true of a proportional counter. In a Geiger-Müller counter, the time integral of the current pulse is almost entirely independent of the amount of primary ionization and no information on the energy loss of the primary particle can be obtained from the pulse size.

The most recently developed detector, the scintillation counter makes use of the fluorescence radiation emitted when a charged particle passes through certain materials. The observation of the fluorescence was done visually or recorded by photocells.

In the cloud chamber the presence of ions is recorded by direct observation. Condensation of a suitable vapour takes place preferentially on an electric charge, and this results in the formation of a visible drop of liquid around each ion present during the period of condensation.

Part three describes the gridded single wire spark counter.
The working characteristics is represented and its mechanism is
studied. The control function of the grid on both the corona
current and counting characteristics is clearly demonstrated.
The different prameters of the counter are studied in detail.

Part four deals with the gridded double-wire anode counter
characteristics. It has been proved that gridded system improves
.the efficiency, as well as, produces a homogeneous sensitive
volume throughout the whole volume of the multi-wire counters.

Part Five gives a short review about the range of alpha-
particles in air and the experimental results determined by the
author for the extrapolated number - distance range of Po^{210}
alpha - particles in air.

At the end, there is an appendix including an account of
the statistical observational data, dead time determination and
correction of the data.

It has to be noticed that all data represented in this
thesis was corrected for dead time of the detector.

PART ONE

1.1. GENERAL SURVEY OF PREVIOUS WORK ON SPARK COUNTERS :-

Since the early experiments of Greinacher[3], made nearly
30 years ago, it has been known that a useful device capable
of counting ionizing particles or quanta could be made by pass-
ing such radiation through the sensitive region of an electrode
gap. The name "Spark Counter" was proposed and subsequent
papers by the same author[3,4] described in general terms the
properties of various types of electrodes and various geometry
arrangements. Later more detailed investigations were published
by other workers[5-8]. In all these counters a discharge is
initiated in air at atmospheric pressure from a point (or spheric
of small radius of curvature) electrode on to a metal plate
(mostly), at a distance of about 1 mm. The point is maintained
at a positive potential of about 3000 V with respect to the
plate and the discharge is limited by a high resistance. This
type of counter, although sensitive to gamma-rays, ultra-violet
photons as well as to alpha and beta particles, suffers from
the following disadvantage.

(1)   The absence of any form of plateau, unless very particu-
      lar electrode systems were used[7].

(2)   Operation was extremely sensitive to the surface conditions of the metal electrodes.

(3)   A very high background of accidental sparks.

(4)   Instability , i.e. one ionizing particle may give more than one spark.

Recently Laborie and Blanc[9] succeeded to improve the characteristics of this detector such that it becomes very similar to other types of spark counters. However, their system has even certain superiority over other counters inherent in its geometry.

(1)   Its self-capacity being very small, the detector gives a faster response.

(2)   Unlike in the case of wire counters, efficiency is independent of particle incident direction.

(3)   Its sensitive volume, that of a solid of revolution around the axis of symmetry of the detector amounts to a few cubic mm, being very clearly defined, permits realization of accurate telescopic devices.

(4)   Oxides during the spark is not of great significance.

In 1945 Chang and Rosenblum[10] introduced spark counter which is sensitive only to heavily ionizing particles such as

alpha particles and fission fragments. In its basic form, this counter is operated in air and consists of an anode which is a thin wire of about 0.1 mm diameter stretched parallel to and at a distance of a few millimeters from a flat metal plate. If a d.c. voltage of the order of few kilovolts is applied to the system so that a faint corona glow is visible around the anode, then the passage of the ionizing particle through the sensitive volume of the counter produces a visible spark which can be quenched by a resistance-capacity network. The sensitive volume of the counter is confined to the corona region around the anode which has a diameter of about 0.5 mm.

However, Payne[11] showed that this system becomes sensitive to protons and beta-rays when operated in air at twice atmospheric pressure or in carbon dioxide at atmosphic pressure. The counter then suffers from the disadvantage of not having a long plateau.

Pidd and Madansky[12,13] in 1949 constructed a parallel plate spark counter to provide a uniform sensitive avalanche volume for the detection of ionizing radiation. The counter avoids the random delay errors inherent in counters with cylindrical geometry. The main advantages of this counter over other detectors lies in its speed of response. It was possible to

improve the time characteristic[14] of the parallel plate
spark counter and a resolving time could be achieved[15] as
low as 10^{-10} sec.

Conner[16] in 1951 and others[17,18] replaced the flat
metallic cathode by a rod of a few millimeter diameter. The
properties of the two types of counter appear to be very
similar. The wire rod counter does not appear to present any
advantages above the wire-plate counter.

To improve the sensitivity of the spark counter Connor[16]
and then Andreeschchev and Isaev[19] in 1955 replaced the flat
cathode by a cathode containing a semi-cylindircal cavity with
the anode wire stretched along the axis of the cavity.

Pulsing the counter voltage seems to be a possible method
of improving the efficiency and counting characteristics. The
principle of pulsing is based upon the fact that if the voltage
across a spark gap is raised somewhat above spark potential,
no discharge occurs unless electrons are present between the
electrodes. The technique of pulsing has been used successfully
by Henning[20] in 1957 and others[21-28] to improve the working
properties of both parallel - plate[20-25,28] and multi wire[25-27]

spark counters. In parallel-plate geometries, the spark occurs in the neighbourhood of the particle track[20,21,29], and with noble gas fillings, triggered parallel - plate detectors record the passage of more than one simultaneous particle[29-31].

The main weakness of the chang and Rosenblum spark counter lies in its small sensitve volume. Attempts have been made to increase the sensitive volume by increasing the number of wires and placing them as close together as possible and applying d.c. voltage between the wires and the metal plate. These attempts have met with partial success only. Chang and Rosenblum[10] found considerable interaction between the wires which leads to multiple sparks. El-Nadi and Aly[32] found that multi-wire counters have satisfactory properties only if the number of the wires is less than about 6 and the distance bet- ween the wires is about 5 mm. Connor[33] showed that the eff- iciency of a multi-wire counter consisting of 22 wires is about 22% . Another weakness of multi-wire counters is the non-uniform counting response of the different wires of the counter.

It was recently shown by Kawata and Aragaki[34] 1961 that the response becomes uniform if resistors are connected in series with each wire[34-36]. Singh and Saha[37] 1961 found a similar improvement when the flat cathode was replaced by a cathode