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DEVELOPMENT OF RESISTIVE PLATE COUNTERS

R. SANTONICO and R. CARDARELLI
Istituto di Fisica dell'Università di Roma, Roma, Italy; Istituto Nazionale di Fisica Nucleare, Sezione di Roma, Italy

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A dc operated particle detector has been developed and tested, whose constituent elements are two parallel electrode bakelite plates between which, in a 1.5 mm gap, a gas mixture of argon and butane at ordinary pressure is circulated. The counter has 97% efficiency and ~1 ns time resolution at an operating voltage of about 10 kV. The output pulse needs no amplification, being typically 300 mV over 25 Ω.

The detector presented in this paper, which will be called "Resistive Plate Counter" (RPC) is based on essentially the same principle as that recently developed by Pestov and Fedotovich [1]. Nevertheless the drastic simplifications introduced in its realization, such as the absence of high pressure gas, the low requirements of mechanical precision, and the use of plastic materials instead of glass, makes it of potential interest in a different and possibly wider range of applications. In particular it could replace with great economic advantages plastic scintillators, whenever large detecting areas are needed under not exceedingly high fluxes of particles.

An RPC is a particle detector utilizing a constant and uniform electric field produced by two parallel electrode plates, one of which at least is made of a material with high bulk resistivity.

The gap between the electrodes is filled with a gas of a high absorption coefficient for ultraviolet light. When the gas is ionized by a charged particle crossing the counter a discharge is originated by the electric field. The discharge, however, is prevented from propagating through the whole gas because, due to the high resistivity of the electrodes, the electric field is suddenly switched off in a limited area around the point where the discharge occurred. Out of this area the sensitivity of the counter remains unaffected. On the other hand, due to the ultra-violet absorbing component of the gas, the photons produced by the discharge are not allowed to propagate in the gas, thus avoiding the possibility to originate secondary discharges in other points of the detector.

RPCs exhibit much better time resolution than wire chambers or limited streamer tubes [2]. This is an obvious advantage arising from the uniform field with respect to the $1/r$ field which introduces large time fluctuations due to the electron drift motion.

Time resolutions considerably better even than those attainable by scintillators and fast photomultipliers have recently been obtained [1] utilizing RPCs in a very sophisticated version in which extremely flat electrodes of semiconducting glass and high pressure gas were utilized.

What we present here is a new type of RPC utilizing resistive electrodes of paper treated with a phenolic resin which is commonly well known under the name of bakelite, having a bulk resistivity of the order of 10^{10}–10^{11} Ω cm.

This kind of detector works at ordinary pressure, it has a small mass thickness (0.7 g/cm^2 before the gap) it is inexpensive and easy to build even in large dimensions.

The prototype of counter we built has a sensitive area of 85 × 13 cm^2 and consists (see fig. 1) of two parallel plate electrodes, connected to the high voltage supply between which a gas mixture of argon (50% in volume) and butane at ordinary pressure is circulated. The ground connected electrode is a bakelite plate of dimensions 103 × 22 × 0.2 cm^3 on which a copper foil 50 μm thick is glued on the side not facing the gas *. The high voltage electrode is a

* The cement used here and in the following is epoxy resin which has been proven to guarantee a sufficient electrical contact between copper and bakelite. Its conductivity can be increased, if needed, by adding a small amount of graphite.

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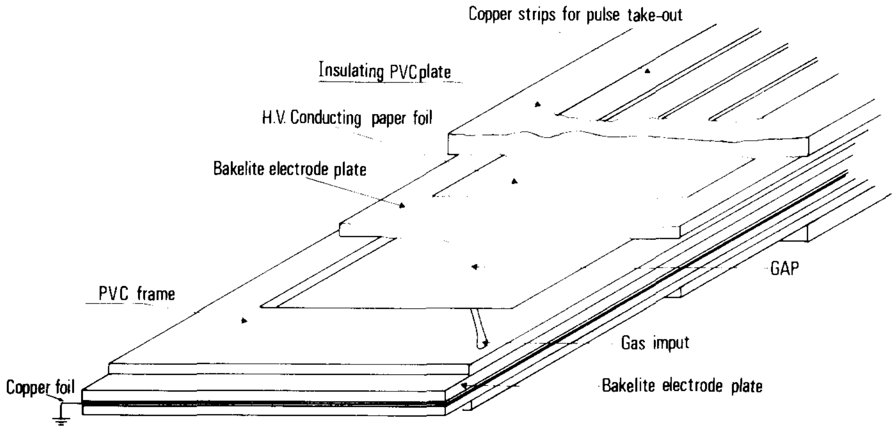

Fig. 1. Sketch of the RPC. The prototype shown consists of two identical counters which are rigidly superposed on one another and have the same copper foil as common ground plate. The experimentation reported refers to only one of them.

similar bakelite plate onto which a thin foil of conducting paper is glued. Due to the high surface resistivity, about 1 MΩ/□, this conducting foil is transparent to electric pulses originated inside the counter, which can so be read through copper strips not connected to high voltage, electrically isolated from the conducting foil. For this reason a PVC (polyvinyl chloride) plate 3 mm thick is glued on the paper. The two plates, of PVC and bakelite respectively, with the conducting paper in the middle, constitute a single mechanically rigid panel.

The two electrodes are kept separated and parallel to one another by inserting between them a rectangular frame of PVC 1.5 mm thick which is used also for gas containment.

This frame is glued on the ground electrode so as to make with it a second rigid panel. The two panels are taken together utilizing a biadhesive tape fitting on the PVC frame which allows to open the counter if needed. The surfaces of the bakelite plates facing the gas have both been polished and painted with a linseed oil based semiconducting paint. The use of this paint turned out to be essential to get high efficiency and low noise level.

The electric field is applied to the counter by connecting the conducting paper foil to the high voltage and the copper foil to ground. The output pulses are read out by copper strips applied outside the counter on the PVC plate. These strips which are 3 cm wide and separated by about 2 mm one from the other, constitute, together with the grounded copper foil, strip lines of 50 Ω characteristic impedance, so that the connection to the discriminator can be made using standard coaxial cables. The end of the line not connected to the cable is terminated over a 50 Ω resistor. When a potential difference of about 9 kV is maintained between the electrodes, the counter exhibits output pulses of amplitude 200–400 mV and a few ns rise time in coincidence with charged particles crossing it. These pulses which are fed into a standard Lecroy model 621 CL discriminator have been observed to come with a few ns delay after the physical event.

A systematic test of the counter concerning efficiency and time resolution has been made utilizing cosmic radiation as a source of particles.

The experimental set-up, shown in fig. 2, consists of three identical scintillation counters, T1, T2, T3, of $60 \times 10 \times 3\ cm^3$ dimensions and a lead screen 10

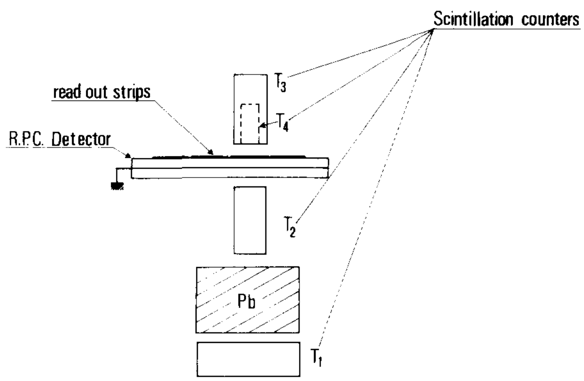

Fig. 2. Transversal section of the experimental set-up used for the tests with cosmic rays. T3 and T4 are used alternatively, for the time resolution and for the efficiency test respectively.

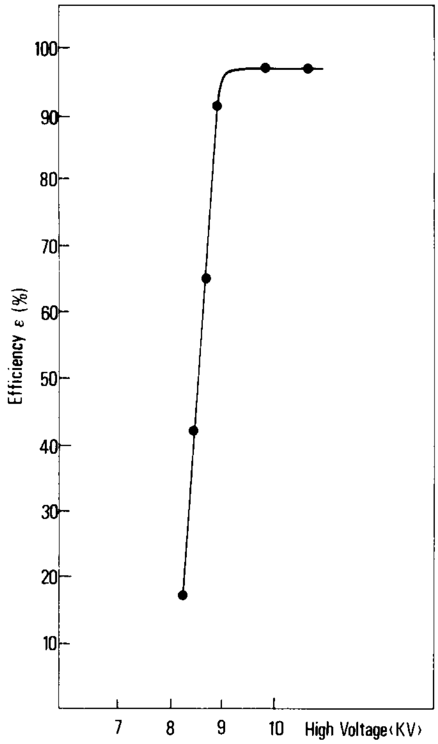

Fig. 3. Efficiency of the RPC as a function of the high voltage applied. The efficiency is defined from the ratio CT/T where C is the logic signal from the counter and T = T1 · T2 · T3 is the triple coincidence of the scintillators. The discrimination threshold is 30 mV.

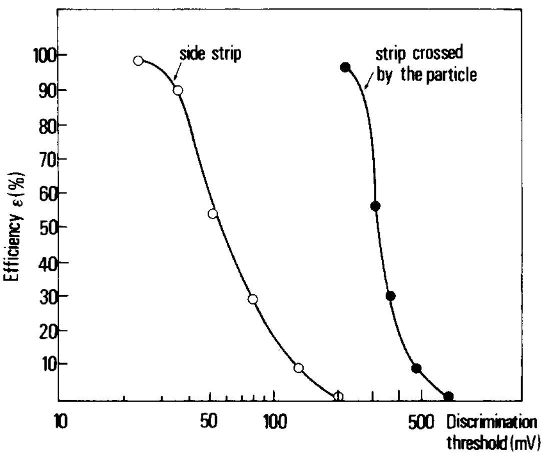

Fig. 4. Efficiency of the RPC as a function of the discrimination threshold for the strip crossed by the particle and for a side strip. The diagram shows that the pulse amplitude was, on average, 300 mV in the first case and 50 mV in the second. The high voltage was 9.25 kV.

cm thick to absorb electromagnetic showers.

The triple coincidence T = T1 · T2 · T3 defines a cosmic ray "beam" of section 3 X 60 cm^2 not exceeding the dimensions of a single strip so that individual strips can be tested. The efficiency of the RPC has been derived from the measured ratio ϵ = CT/T between the simultaneous rates of the coincidences CT and T, where C indicates the pulse from the RPC counter. The value of ϵ as a function of the voltage V applied to the counter for a 30 mV discrimination threshold is shown in fig. 3. The plateau value of 97% is reached at about V = 9 kV.

The pulse amplitude distribution has been obtained by measuring the efficiency for various values of the discrimination threshold. The results, at V = 9.25 kV, are given in fig. 4 where the distribution is given both for the strip directly crossed by the cosmic ray "beam" defined by the coincidence T and for a contiguous strip. The average value of the distribution corresponds to an amplitude of about 300 mV in the first case and to 50 mV in the second. The considerable difference (15 dB) between these two values

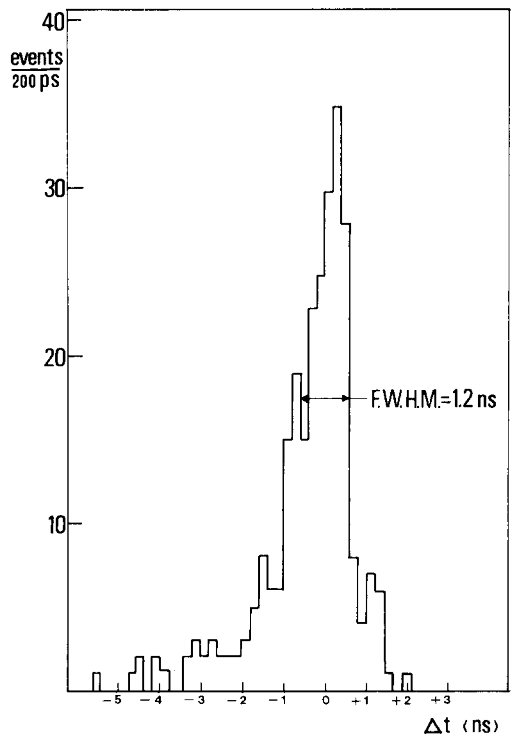

Fig. 5. Distribution of the relative delay Δt between the RPC and a small scintillation counter (T4) viewed by an XP 2020 photomultiplier. The fwhm of the distribution is 1.2 ns. The short tail on the left originates from delayed pulses of the RPC.

shows that the discharge inside the counter is indeed limited to a region of dimensions much smaller than the width of the strip. The rate of pulses from a single strip (255 cm^2 sensitive area) was 35 Hz at 9.5 kV and 240 mV discrimination threshold.

The time resolution of the counter has been measured utilizing a small counter, T4, of NE 110 plastic scintillator, of $10 \times 6 \times 2$ cm^3 dimensions (see fig. 1), viewed by an XP 2020 photomultiplier whose output pulses were shaped by a Lecroy model 621 CL discriminator. The logic pulses C and T4 are sent to the START and STOP respectively of a Laben model 6290 time-to-amplitude converter whose gate is opened by the coincidence T1 · T2 · T4.

The distribution of the relative delay between C and T4 for an applied voltage of 11 kV and a discrimination threshold of 30 mV is shown in fig. 5.

The fwhm of the distribution is 1.2 ns.

Conclusions. The detection technique presented in this paper could replace with great advantage as to simplicity and low cost the use of plastic scintillators in large area detectors such as those required, for example, in neutrino physics and proton lifetime experiments. For its good time resolution it appears also promisingly applicable to large time-of-flight systems.

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