USE OF RESISTIVE PLATE CHAMBERS FOR THE DETECTION OF EXTENSIVE AIR SHOWERS

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Abstract

The potentialities of the Resistive Plate Chamber (RPC) in the detection of Extensive Air Showers (EAS) are analysed. Preliminary experimental results concerning a small full coverage test array are presented.

1 Introduction

The study of EAS was carried out so far by using large scintillator arrays as detector. The high time resolution of the scintillator coupled to photomultipliers allows indeed to measure the primary direction, typically with 1 deg error, from the relative delay of the signals detected by different counters of
the array. This technique, in spite of the considerable cost of the scintillator, is appropriate as far as the coverage ratio, defined as the sensitive area over the total area covered by the array is $\ll 1$. On the other hand, an efficient detection of low energy EAS demands high coverage arrays due to the small number of particles in the shower.

Gaseous detectors are more suitable than the scintillator for high or full coverage arrays: they are by far less expensive and allow a much larger segmentation which can be obtained just by a convenient choice of the read out electrodes. Their time resolution can be made comparable to that of the scintillator provided that the field acting in the gas is the uniform field generated by two parallel electrode plates rather than the more usual one produced by a charged wire.

The RPC [1], sketched in fig. 1, is a gaseous detector working with a field of about 5 KV/mm generated by two parallel plates of a plastic phenolic material with a volume resistivity ranging in the interval $10^{10} - 10^{12} \Omega \cdot cm$. The 2 mm gas gap is filled with a mixture of Argon-Butane in the ratio 60/40 in volume and a small amount (3-5%) of freon. The electrode plates are coated, on the external sides, with thin graphite layers connected to high voltage and ground respectively. Due to their high surface resistivity, about $100 K \Omega / \square$, these graphite electrodes are transparent to the transient of electrical discharges generated inside the gas thus allowing the capacitive read-out, through virtually grounded pads which are fixed or simply pressed on the detector walls. A PVC-Polythene film 0.3 mm thick, glued on the graphite is used to insulate the high voltage electrodes from the read-out pads. Construction details are visible in fig 2.

The RPCs are usually operated in the streamer mode. Recently a lower gas amplification mode has also been successfully tested for high counting rate applications [2]. The electrons freed in the gas by an ionizing particle produce the avalanche and the streamer within a very short time and with minimal fluctuations. The discharge is quenched by a twofold mechanism based both on the high electrode plates resistivity and the UV photon absorption of the gas organic component which prevents secondary discharges due to the gas photoionisation. The quenching due to the resistivity can be understood by comparing two characteristic time constants of the system: the discharge duration which has been measured and is about 10 ns and the electrode plate relaxation time given by the product of the resistivity and the dielectric constant which is of the order of 10 ms. Due to the large factor,
about $10^6$, between these time constants the electrodes behave like insulators during the discharge thus insuring the quenching. RPCs have been tested in a very wide range of different working conditions using both cosmic rays [3] and accelerator beams [4].

2 Temperature and pressure test

The EAS physics requires usually to operate the detector in mountain sites where the environment conditions, particularly those related to the temperature and the pressure, are different and more severe than in a normal laboratory.

Specific tests concerning the response of RPCs in different conditions of temperature and pressure are in course. We present here preliminary results.

The tests are carried out on two chambers of area $2 \times 2 \text{ m}^2$. Each chamber consists of two RPC modules $2 \times 1 \text{ m}^2$ coupled along the $2 \text{ m}$ side and read-out by $2 \text{ m}$ long and $3 \text{ cm}$ wide aluminium strips running parallel to the $2 \text{ m}$ side. These strips work as transmission lines where the induced signal propagates without losses of amplitude and time information, apart for a systematic delay of $5 \text{ ns/m}$, up to the ends. Here the line is terminated on $50 \Omega$ and connected to the frontend electronics which is mounted on boards situated at both sides of the module. Each board contains 16 frontend channels that can be serially read out and a single fast OR output which is optimised for time measurements, as the input to output delay is the same for all the 16 ORed channels.

The two test chambers were mounted vertically, $30 \text{ cm}$ apart, into a closed hut where the temperature could be controlled in the range $0-30 \text{ C}$ with an accuracy of $1 \text{ C}$. The hut was placed aside of the MINI [3] telescope as shown in fig 3.

The telescope, at room temperature, is equipped with fourteen chambers identical to those already described and also mounted vertically so that the horizontal cosmic muons selected and tracked by the telescope could be used to test the performance of the chambers inside the hut.

Fig 4 shows the counting rate per unit surface of the test chambers vs the operating voltage for different temperatures. An exponential rise of the rate at high voltages is observed which is more evident at high temperature. This is mostly due to the noise produced by the spacers which are used to
keep the plates parallel to one another.

The detection efficiency vs operating voltage is shown in fig 5a for different temperatures. A plateau is reached at 95% efficiency. Most of the 5% inefficiency is due to the dead areas of the spacers and seals as well as to the uncovered area between the two RPC modules.

Comparison among different curves in fig 5a shows that the same efficiency is reached at higher voltage for a lower temperature. This is well explained as an effect of the temperature on the gas density: at lower temperature the density is higher and this is equivalent to a larger gas gap which requires a higher operating voltage. If this effect is accounted for by renormalising the voltage scale with the factor $T/T_0$, where $T$ is the actual temperature and $T_0 = 293$ K is the standard room temperature, all the points fit on the same curve as is shown in fig 5b.

Muons reconstructed in MINI as going in the direction from the test chambers towards the telescope, were used to measure the time of flight between the test chambers. The mean time $(t_1 + t_2)/2$ between the arrival times of the signal at the opposite ends of the strip was used to correct for the systematic delay due to the propagation time of the signal along the strip.

The time of flight distribution at 30°C and 9100 Volt is shown in fig 6. It is characterized by a sharp peak of 2.0 ns FWHM and two non gaussian tails that have been demonstrated to be due to trajectories crossing one of the chambers near a spacer.

The experimental conditions, with respect to previously published data [3], are different in the following points: higher operating voltage (1.6 KV inside the plateau instead of 1.0 KV), higher frontend threshold (100 mV instead of 50 mV) and small differences in the construction procedure concerning the graphite layer which, in this case, was removed at the spacers position.

Fig 7 shows the delay (7a) and the time resolution (7b) of the test chambers vs the operating voltage.

Pressure tests are in progress. The detection efficiency vs operating voltage is shown in fig 8a for two different pressures: 1000 and 500 mbar. The operating voltage scales with respect to the pressure in good agreement with the rule $E/p=constant$ as is shown in fig 8b.
3 The RPC test array

A 30 m$^2$ RPC array is under test at the University of Roma 2. The array consists of 15 RPC modules of area 1x2 m$^2$ grouped in 5 lines or "corridors" of 1x6 m$^2$ as shown in fig 9 and in the photograph of fig 10.

Each station of the array, according to the lay out shown in fig. 11, is composed of a RPC module, 128 read out aluminium strips of size 3x50 cm$^2$, two grounded aluminium foils that shield both faces of the detector, two plastic foam plates 1 and 2 cm thick used as spacers and a 15 mm thick photon converter of iron subdivided in plates of 20x20 and 20x50 cm$^2$. All these elements are not fixed but just superposed to one another and held together by the weight of the iron converter which is also used as a basement for the fixation of the frontend boards.

Each station is read out by 8 boards symmetrically disposed along the 2 m sides of the RPC module and each board is connected to 16 strips 50 cm long running along the 1 m side of the module. The strips are terminated at 50 Ω only at the end connected to the board; the opposite end is left open. The fast OR of the board which has been already described in the previous section, gives a single timing signal for a portion of detector of size 50x50 cm$^2$. The details of the shower pattern inside this area are given by the 16 strips that are serially read out at any trigger occurrence.

We present here preliminary results concerning single corridors of the array. A dedicated electronics which will handle all the signals of the 120 boards at the same time will be ready in the next future.

A single corridor of 1x6 m$^2$ is subdivided in 12 regions of size 1x0.5 m$^2$ by using the OR of pairs of opposite boards (see fig 9). EAS are selected by a trigger condition requiring the coincidence of all the regions of the corridor. TDCs are used to measure the arrival time of the signals of each region.

The plot of the time delay vs position is given in fig. 12a,b,c for three events. The best linear fit of the experimental points is also shown in fig 12. The slope of the straight line fitting the data gives the direction of the shower.

The angular distribution of 200 recorded EAS is shown in fig 13.
REFERENCES

1 R. Santonico and R. Cardarelli, Nucl. Instr. and Meth. 187 (1991) 377
2 R. Cardarelli, A. Di Ciaccio and R. Santonico, Nucl. Instr. and Meth. A
   333 (1993) 399
3 M. Abbrescia et al., Nucl. Instr. and Meth. A336 (1993) 322
4 M. Bertino et al., Nucl. Instr. and Meth. A283 (1989) 654
   C. Bacci et al., Nucl. Instr. and Meth. A324 (1993) 44
   T. Moers et al., Nucl. Instr. and Meth. A345 (1994) 474

FIGURE CAPTIONS

Fig. 1- Sketch of a RPC

Fig. 2- Photograph showing construction details of a RPC

Fig. 3- Sketch of the test chambers and of the MINI telescope

Fig. 4- Counting rate per unit surface of the test chambers vs operating
   voltage for different temperatures

Fig. 5a- Detection efficiency vs operating voltage for different temperatures

Fig. 5b- Same as in fig. 5a but with the voltage scale renormalized by
   the factor $T/T_0$ where $T$ is the actual temperature and $T_0 = 293$ K is
   the standard room temperature.

Fig. 6- Time of flight distribution between the test chambers at 30 C and
   9100 V

Fig. 7a- Time delay of the test chambers vs operating voltage for different
   temperatures. The delay is measured with respect to the MINI telescope
   kept at room temperature and fixed voltage
Fig. 7b- Time resolution vs operating voltage for different temperatures

Fig. 8a- Detection efficiency vs operating voltage for two different pressures at 20°C

Fig. 8b- Operating voltage for 50% efficiency vs pressure

Fig. 9- Sketch of the test array for the detection of EAS

Fig. 10- Photograph showing details of the array

Fig. 11- Lay out of a station of the array

Fig. 12- Space-time pattern of three showers detected by the array, giving position and timing of the detected hits. The line represents the best fit of the points

Fig. 13- Angular distribution of the detected showers
Resistive electrode plates
(phenolic polymers
\( q = 10^{11+1} \ \Omega \times \text{cm} \))

P.V.C. spacers

Pick-up x-strips

High Voltage
+8 KV

Graphite painted electrodes
~100 K\( \Omega \) /\( \square \)

Insulating film

GAS Argon / n-Butane - 60/40
Freon 3-5%

P.V.C. spacers

Pick-up y-strips

Fig. 1
Fig 3
Fig 4
Fig 5a
Fig 5b
T = 30°C
HV = 9100V

T.O.F. F.W.H.M. = 2 ns
Single R.P.C $\sigma = 600$ ps
Fig 7a
\[ \frac{FWHM}{2.36 \sqrt{2}} \]

Fig 7.6

309
P = 500 mb  
T = 20°C

P = 1000 mb  
T = 20°C

Fig 8a
Fig 8.6

HV (KV)

P (m bar)

311
Fig 12