ISTITUTO NAZIONALE DI FISICA NUCLEARE

Sezione di Pavia

INFN/TC-92/26
16 Novembre 1992

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Servizio Documentazione
dei Laboratori Nazionali di Frascati

INFN - Istituto Nazionale di Fisica Nucleare
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November 3, 1992

Abstract

The Resistive Plate Counter (*RPC*) detectors are described together with some of their applications to High Energy Physics. A possible use of *RPC*'s in the Muon System of the Solenoidal Detector Collaboration (*SDC*) is outlined. They could be employed as part of the system devoted to the identification of muons and for trigger purposes.

1 Introduction

Plastic scintillators coupled to photomultipliers have been used since the beginnings of High Energy Physics to build detectors with a time resolution of few nanoseconds. On the other hand, wire and drift chambers are employed to obtain high spatial resolution. The time fluctuations of the discharge process are an hindrance to a time resolution comparable to that one of scintillators.

A fast gas detector requires a strong and uniform electric field so that the sequence of transitions:

$$\text{free electron} \rightarrow \text{avalanche} \rightarrow \text{streamer}$$

takes place in a very short time and with minimal fluctuations. Small high pressure gas counters using plate electrodes with a high volume resistivity achieved a time resolution better than 0.1 ns [1] [2].

The Resistive Plate Counters (*RPC*'s) are particle detectors with high resistivity electrodes filled with a gas mixture at normal pressure. They have been developed by R. Santonico and collaborators [3] [4] in the late seventies. Their main characteristics, reported in Table 1, are:

- Excellent time resolution;
- Short pulse risetime and large pulse signals that do not require preamplification;
- Low cost and the possibility to instrument very easily large areas.

They have been initially used as veto counters for cosmic rays in passive physics experiments [5] [6]. The first beam test of *RPC*'s, to investigate their behavior under an intense beam flux, was done at CERN in 1988 [7]. The positive results of the test made possible the use of *RPC*'s as muon detector for a fix target beauty hadroproduction experiment, FNAL *E*771 [8] [9] [10].

2 RPC's features and performances

Resistive plate counters are operated in a limited streamer mode, under a 4 kV/mm uniform electric field. The active region is filled with an argon/butane mixture at normal pressure, plus a small amount of freon. The gas flows at 0.1 vol/h.

The schematic of an *RPC* module is shown in Fig. 1. Two plates of bakelite, a phenolic polymer with high volume resistivity ($\sim 10^{11}\ \Omega cm$), are separated by a 2 mm gap. In order to keep constant the distance between the two plates, *PVC* spacers are located in between every 10 cm. The module is sealed using a *PVC* frame. The outer surfaces of the bakelite plates are coated with a graphite paint. The metallic HV electrodes and ground (GR) are applied to the graphite surface. The gas mixture is fluxed inside the chamber through connectors located on opposite sides of the external frame [9] [10] [11].

Table 1: RPC's parameters and characteristics

Bakelite plates resistivity	$\sim 10^{11}\ \Omega cm$
Electric field	$\sim 4\ kV/mm$
Time resolution of an RPC module	$\sim 1\ ns$
Dark current	$8\div10\ \mu A$
Average stochastic noise	$600\ Hz/m^2$
Pulse amplitude	$\sim 500\ mV$
Pulse rise time	$\sim 4\ ns$
Time of discharge	$10\ ns$
Generated charge	$100 \div 200\ pC$
Dead area	$\sim 5\ mm^2$
Recovery time of the dead area	$10\ ms$

When a charged particle crosses the volume of the chamber ionizing the gas, the applied electric field starts a discharge process. Such a process is localized and does not propagate to the entire volume of the chamber because of three different mechanisms [4] :

- The high resistivity of the bakelite plates causes the electric field to drop almost to zero only in a limited region around the discharge area;
- The gas mixture offers a high absorption coefficient for ultraviolet light. UV photons generated during the discharge are quickly absorbed, reducing the probability of secondary discharge in other regions of the chamber;
- The freon high electron affinity prevents the electrons from propagating outside the streamer region, limiting the size of the discharge and reducing the possibility of lateral propagation.

The characteristic time of the discharge process is $\tau_{dis} \simeq 10\ ns$ [4].
The recovery time of the resistive plates can be evaluated as:

$$\tau_{rpc} = RC = \rho \frac{l}{S} \cdot \epsilon \frac{S}{d} \simeq \rho\epsilon$$

where l is the thickness of the bakelite plate and d is the spacing between the outer surfaces of the two plates. Since $\rho \simeq 10^{11}\ \Omega cm$ and $\epsilon \simeq 26.2\ pF/m$ then $\tau_{rpc} \simeq 10\ ms$ [4].

Since $\tau_{rpc} \gg \tau_{dis}$ the plane electrodes can be considered as insulators during the discharge process. Consequently, only a limited area S around the discharge point is deadened for a time of the order of τ_{rpc} while the surrounding area remains ready to detect charged particles crossing the volume of the chamber. The dimensions of the dead area can be evaluated assuming that the RPC be a perfect parallel plate capacitor: $S = Q/\epsilon_0 E$ where Q is the average charge generated during the ionization process and E is the electric field inside the gas [4]. For typical values of $Q \simeq 200\ pC$ the area deadened by the discharge comes out to be $S \simeq 5\ mm^2$ [7].

The charge produced during the streamer process is collected by electrical induction on copper pads or aluminum strips[1] located on a polycarbonate structure and facing the HV plate electrode (Fig. 1). The dimensions of the pads are limited to a maximum of 12 cm × 12 cm to prevent the capacitance of the pads from degrading the quality of the signal. The strips are typically 3 cm wide and 200 cm long.

A pair of twisted cables picks-up the generated signals from each strip or pad and sends it to the readout electronics. Each RPC module as well as the pad or strip readout plane are contained into a metallic frame operating as support structure as well as electrostatic shield. HV cables, gas tubes and readout connectors are plugged into the external structure [9] [10] [11].

As shown in Table 1, the time resolution of an RPC supermodule[2] exposed to cosmic rays is about 1 ns, at least as good as the one of a small plastic scintillator. Furthermore, a high granularity of the detector can be easily achieved at a cost much lower than for a scintillator. The fast time response and the low cost candidate the RPC's as an ideal detector for experiments of large dimensions in High Energy Physics.

3 Test beam results

The performances of two $(2 \times 1)\ m^2$ RPC modules have been tested at CERN in 1988 using a 5 GeV/c pion beam [7]. The beam was concentrated on a limited fraction (~ 10%) of the entire RPC's area. To study the time evolution of the RPC behavior during the spill, the total beam gate (240 ms) has been divided into four intervals, 60 ms each, and the data acquisition system collected data for each interval. Pads of three different sizes, namely $(5 \times 5)\ cm^2$, $(10 \times 10)\ cm^2$ and $(20 \times 20)\ cm^2$, have been used as constituents of different readout planes. The data show that the capacitance of the larger pads degrades the quality of the signal. Features and performances of the two smaller pads, on the contrary, are similarly good.

After each RPC discharge, a local reduction of intensity of the internal electrical field, due to the recovery time τ_{rpc} of the area around the point of the discharge, should be expected. Consequently, efficiency, time resolution and pulse delay should depend upon the rate of the ionizing particles crossing the RPC module.

The percentages of the gas mixture have been decided using a fixed argon/butane ratio (2.5) and studying the dependence of the RPC efficiency versus the freon percentage under a 46 Hz/cm^2 pion beam. The best results have been obtained for a 69% argon, 27% butane and 4% freon mixture, that was used during the following tests.

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[1] Usually one end of the strip is directly connected to the readout cards, while the center of each pad is connected to the readout board using twisted pair cables.

[2] Three modules have been assembled in a supermodule of $(580 \times 48)\ cm^2$ useful area. Gas was flowing serially from a module to the next. The pickup strips where covering the full length of the supermodule [4].

The dependence of the RPC efficiency versus the applied HV has been studied for different beam fluxes in the range $10 \div 140\ Hz/cm^2$ (Fig. 2). The efficiencies are plotted in Fig. 3 versus the beam flux intensity. A linear fit shows that the efficiency decreases for increasing flux at a rate of $(6\%)/(100\ Hz/cm^2)$. The efficiency of the OR of two RPC modules has a smoother dependence versus the incoming flux: $(2\%)/(100\ Hz/cm^2)$. Moreover, the performances of RPC detectors composed by two modules ORed together are much more stable and uniform than the ones of single module detectors.

If two pads belonging to two different RPC's are facing one other, it is possible to measure the OR of the two signals. The expected value is

$$Eff_{(1+2)} = Eff_1 + Eff_2 - Eff_{(1*2)}$$

where Eff_1 and Eff_2 are the efficiencies for the two pads and (1*2) is the AND of the two signals. The measured value differs by less than 2% from the expected one, indicating a small correlation effect between the recovery times of the dead areas in the two RPC's crossed by the same particle.

The dependence of the RPC timing characteristics on the beam rate is shown in Fig. 4. Mean values[3] (∘) and standard deviations[4] (•) of the time of flight between an RPC and a scintillation counter (used as start signal) versus beam flux are reported up to $140\ Hz/cm^2$.

4 Cosmic rays tests

A set of systematic tests with cosmic rays has been performed on RPC's instrumented with pad readout planes during 1990 [10] [11]. The best measured efficiency (97%) for $(12 \times 12)\ cm^2$ pads with a $30\ mV$ discriminator threshold has been obtained for a 0.67 butane/argon ratio. The presence of spacers inside the active volume of the RPC chamber limits the efficiency of the detector to the measured value. A higher efficiency is usually obtained by assembling two RPC chambers ORed together with staggered spacers.

The efficiency and the start point of the plateau region are insensitive to the percentage of freon content in the mixture, in the range $3 \div 9\%$. On the contrary, the average generated charge and the time resolution of the $RPC's$ are dependent upon the freon content, as shown in Fig. 5. These two quantities are also dependent on the butane/argon ratio, that effects the dimensions of the streamer. Clearly the choice of the optimal gas mixture is the result of a balance among different effects that have to be taken into account, and is also dependent on the particle rate the RPC's will experience.

Dark currents of RPC's equipped with $(6 \times 6)\ cm^2$ and $(12 \times 12)\ cm^2$ pads are shown in Fig. 6. The stochastic noise is $0.4\ Hz/cm^2$ at $8200\ V$ with a threshold of $60\ mV$. It must be stressed that these results have been obtained using a pad readout plane and with a now

[3] Mean values of the time distributions contain a common arbitrary additive constant.

[4] The standard deviation has been calculated by evaluating the interval around the most probable value of the time distribution containing 68.3% of the total area. The contribution to the time resolution due to the scintillator counter used for the timing has been subtracted.

obsolete kind of *RPC*. The cross-talk between adjacent pads has been measured. Even for very large HV values (up to 9500 *V*), in average it does not exceed 2%. The time resolution of the two different sizes of pads is shown in Fig. 7. The possible values vary in the range 0.50 ÷ 1.75 *ns* according to the pad size and the HV value.

The high efficiency, the existence of an extended plateau region and the time resolution of the *RPC*'s candidate this device as an ideal detector for muons, particularly in the case of low particle rates.

5 The RPC muon system of E771

The *RPC*'s have been used at Fermilab in *E*771 as muon detector as well as for triggering purposes (first level single and dimuon triggers) [12]. In *E*771 a muon is recognized as a spatial and temporal coincidence among three planes of *RPC*'s, each with a total surface of $(6 \times 3)\ m^2$. During the 1991 run *RPC*'s have worked in a stable and continuative way under incident fluxes varying from 10 up to 50 Hz/cm^2, without any radiation damage effect. The used gas mixture was 55% argon, 41% butane and 4% freon [9].

The HV working point has been set at 8000 *V* for all *RPC*'s in order to have signal pulse delays as uniform as possible (see Fig. 9) for all the modules of the muon detector. The average efficiency of each of the three *RPC* planes is still under investigation but a preliminary analysis indicates[13] that:

$$Eff_{plane1} = (92 \pm 1)\% \qquad Eff_{plane2} = (93 \pm 1)\% \qquad Eff_{plane3} = (96 \pm 1)\%$$

The time resolution of an entire module of *RPC* is shown in Fig. 8 and it is about 5 *ns* for HV = 8000 *V*. This value is five times larger than the one measured with cosmic rays [4] and reported in Table 1. When an *RPC* is crossed by the particles generated in a target interaction, the flux of the crossing particles is not uniform over the entire area of the *RPC* module. Consequently, the time resolution of the module is larger [14] than in the case of cosmic rays, where the flux per unit area is uniform.

The signal pulse delay is particularly relevant for trigger systems based on *RPC*'s, where one aims at having a time delay as constant as possible over the whole *RPC* detector, during the entire run. Fig. 9 shows the signal pulse delay for an *RPC* module. The numerical values of the delay are arbitrary (since measured using a QVT), while the analytical dependence ($\Delta t/\Delta V \simeq 1\, ns/100\, V$) of the pulse delay versus the applied voltage is meaningful. To have a pulse delay as uniform as possible over the entire *RPC* system, all *RPC*'s have been set at the same working point during the *E*771 period of run.

6 R&D for RPC's

R&D to improve the *RPC*'s characteristics and to produce *RPC* modules based on different materials such as glass is in progress. The front-end electronics for *RPC*'s is also under development and new boards able to read and elaborate the signals coming from the *RPC*'s will soon be available. They will represent a further improvement both of the readout cards made by R. Cardarelli [3] [4] almost ten years ago and of the newer electronics built for $E771$ [15] [16].

6.1 New RPC modules

During the last year a new kind of RPC's, still based on bakelite but with new building techniques and improved features, has been constructed. The new modules have bakelite planes with the areas corresponding to the spacers with no graphite coat. This shrewdness reduces the dark current from values of about 200 μA (old modules) to $8 \div 10$ μA (new modules).

The new RPC's are also lighter and cheaper then the old ones. The modules used for $E771$ were embedded into a metallic frame operating as support structure as well as electrical insulator. The total cost, volume and weight of the module were considerably increased by the external frame. The new modules are lodged between two layers of a special plastic foam at low density. Each foam layer is 10 mm thick and its surface is slightly larger than the bakelite plate surface (the foam layers are 200.3 cm $\times$ 100.3 cm, compared to 200.0 cm $\times$ 100.0 cm of each bakelite plane). The total thickness of an RPC module is reduced to 28 mm and the total weight is about 30 kg for a module (2×1) m^2 in size.

The mechanical tension between the two bakelite plates is guaranteed by a crossbow, while the electrical insulation is obtained adding to the outer faces of the two foam layers a 0.5 mm aluminum foil, and laterally by a 1.5 mm steel band that frames the entire module.

It is also possible to build RPC's with double inner chambers. In this case the two chambers are facing one other and a single readout plane of strips is placed in between. The thickness of a double RPC module is 35 mm. The performances of a double chamber RPC are more stable and uniform than the ones of a standard RPC module. By staggering the spacers in the two chambers it is possible to increase the maximum efficiency of the RPC from 97% to at least 99%. Finally, it is also feasible to join together several (2×1) m^2 modules to build supermodules up to (10×1) m^2.

6.2 Readout electronics

The design of a new RPC readout system that allows to handle signals coming from pads or strips is in progress. The project foresees the construction of a stand alone system, to be used for triggering purposes as well as to process the RPC signals in a fast data acquisition chain to investigate the RPC detector performances.

There are two kinds of electronic modules: readout card and control card, the last one based on a DSP (Digital Signal Processor). The front-end electronics is located on little boards on the RPC frame while the VME size control boards are located in a remote $D - VME$ crate.

Each readout module is equipped with a VME interface allowing two operating modes. If the trigger rate is not exceedingly high, it is possible to read the data from the readout

modules, and to send them to the computer by means of a standard *VME* crate controller. At very high trigger rates, it is preferable to use the control module. A dedicated program running on the *DSP* handles the data and reorganizes them before sending the informations to the data acquisition computer.
The main features of the system are:

- New front-end electronics;
- Remote preset of the threshold value;
- Remote preset of the signal width;
- Remote test of the electronics;
- Fast processing of the signals for triggering purposes;
- Standard *VME* interface on each module.

The *RPC* signals are received, discriminated and amplified by the front-end electronics. The threshold of the discriminators and the width of the output signals can be preset by the computer.

The readout module receives, via twisted pair flat cables, 32 *RPC* signals which are buffered into a *FIFO* memory (at a maximum frequency of 16 *ns*), waiting for the first level trigger signal. The *RPC* signals are also sent to a logic circuit located on the same board and based upon *PAL* (Programmable Array Logic). Its function is to process the data for triggering purposes by means of boolean operations. A fast logic *OR* of the 32 input channels is also available on the front panel.

When a trigger signal reaches the board, the memory addresses related to the event responsible for the trigger are sent, via the *VME* interface, to the crate controller. Even while the transfer of informations from the memory to the controller is in progress, it is possible to read new data from the *RPC* detector.

This *RPC* electronics is meant to be a stand alone system to be used for test purposes. A more sophisticated system able to match the *SDC* requirements for first level trigger related electronics could be developed at a later stage on the basis of the present project.

7 RPC's for SDC

In the present configuration of the detector, the *SDC* muon system employs scintillation counters to identify the beam crossing time associated to each detected muon. The wire chambers are not suitable for this function since their maximum drift time of $\sim$1.0 μs corresponds to 60 beam crossings. Identification of the correct beam crossing is essential at all trigger levels as well as in the offline analysis since event's reconstruction combines data from many different devices that must be properly correlated in time. The required time resolution must allow an unambiguous tagging of the beam crossing, and is set to $8 \div 10$ ns by the beam crossing period of 16 ns [17].

The option of replacing all scintillation counters of the SDC muon detector with RPC's is interesting because of both technical and financial considerations. RPC's have a higher radiation hardness and are expected to be almost transparent to intense neutron fluxes[5]. Moreover, it is possible to achieve a better granularity than using scintillators. Finally, total cost of scintillators and related electronics for the SDC muon system is estimated to be 7.5 M$ while the cost of the RPC alternative could be as low as[6] 2.5 M$.

Using the RPC's for timing purposes in the SDC detector requires a total time resolution of $8 \div 10$ ns. It is therefore very important to minimize all possible sources of jitter associated with the detector and the related electronics. To contain the jitter of the signal from each pad or strip within 2.5 ns, given a signal propagation delay of 5 ns/m, the maximum length of strips must be set to 50 cm. An upper limit to the jitter from the readout electronics can be estimated to be ~8 ns on the basis of the existing RPC electronics [15] [16]. A careful programming of the RPC readout electronics could drastically reduce such jitter. Even taking into account additional sources of time spread, like for instance the RPC time resolution and the cable length uncertainty, the total jitter should be contained within 13 ns. The overall jitter might be considered too close to the beam crossing period. In such case the accelerator RF signal can be used as a clock to synchronize all the RPC signals [16]. This would ensure the proper tagging of the beam crossing with unitary probability.

The total area to be covered with a single RPC layer in the barrel region of the detector is 2240 m^2 [17]. The single RPC supermodule, whose length is ~8 m and whose width (along the Z direction) is 1 m, covers a slice of the total BW2 (or, alternatively, BW3) surface. The RPC supermodules are staggered and slightly overlapped along the ~8 m borders (Fig. 10), to allow seamless coverage of the barrel area. Approximately 280 RPC supermodules are needed to cover the barrel, 35 for each of the 8 rectangular surfaces. The use of double chamber RPC's with a common readout plane made of two rows of strips, each 50 cm long in the Z direction, is proposed. The expected particle rate in the barrel region of the detector is 10^{-2} Hz/cm^2 [17] and consequently the efficiency should be comparable to the one measured with cosmic rays. For double chamber RPC's an efficiency close to 99% is reachable.

The maximum possible width of the single strip (in order to contain the total number of channels) has to be determined by specific tests. Certainly a (50×4) cm^2 strip is suitable

[5] Measurements with thermal neutrons, made by M. Terrani, show that the RPC's detection probability per neutron is of the order of $10^{-4} \div 10^{-5}$ [14]. Data collected by I. Pless and collaborators using ~1 MeV neutrons give a result of 5×10^{-3} [18].

[6] At present, it is hard to evaluate the total cost since the available prices for RPC modules are based on orders of a few counters. The unitary cost for orders of hundreds modules will decrease considerably, but the exact amount of the cost reduction is unknown. Moreover, the readout electronics for the RPC system has to be designed and built according to the specification requirements for devices used in the first level trigger. A realistic cost estimate for the electronics can only be done after completion of the technical design. Certainly a board built using VLSI technology will be much cheaper than the one presently used, based on discrete components.

and should work as well as a standard (200 $\times$ 3) cm^2 strip. There would be ~400 strips for each RPC supermodule, arranged into two rows of 192 strips each (Fig. 11). A total of 107,520 channels is needed, corresponding to 1680 readout boards, if 64 channels/board is assumed as standard. A total of six boards, located on both sides of the longer edge of the RPC supermodule, are needed to read and to process the signals coming from each RPC supermodule (Fig. 11).

In the forward regions, that will experience a higher rate, a coincidence between the two detector's elements indicated as FS4 and FS5 in Fig. 12 (were it is assumed the use of plastic scintillator counters) is required. The area of an FW4 octant is ~15 m^2 while the surface of the FW5 octants is ~26 m^2. The total number of octants in the two forward regions is 16 FW4 plus 16 FW5, and the total area is approximately 16$\times$(15 + 26) = 656 m^2. In order to completely cover an horizontal slice of an octant with a single RPC supermodule, the forward supermodules have a trapezoidal shape, a common vertical height of 1 m and different lengths (Fig. 13). The length of the forward RPC supermodules varies (in FW4) from a minimum of ~2.1 m to a maximum of ~ 5.3 m. A total of 4 forward supermodules is needed to cover each FW4 octant. The FW5 regions present an active area whose radial dimension is ~5.5 m and consequently could be covered using 5 (under covering) or 6 (over covering) forward supermodules for each octant. Assuming the average value of 5.5 RPC supermodules to cover each FW5 octant, a total of 152 supermodules is required for the forward regions. The forward supermodules are staggered and partially overlapped, as the barrel supermodules, to have a full coverage of the octant area and to make room where to accommodate the readout boards. As in the case of barrel supermodules, the use of double chamber RPC's with a common readout plane is proposed. The expected particle flux in the forward regions is not known in detail [17], but the rate of charged particles should not be greater than 1 Hz/cm^2. Consequently the RPC's efficiency should not be effected by the particle's rate.

The structure of the readout planes has to be different from the one of the barrel region. While in the central region of the detector the readout strips are orthogonal to the RPC supermodules (Fig. 11), in the forward regions the readout elements have to be horizontal and perpendicular to the Z direction, as the forward supermodules themselves (Fig. 14), to allow a precise measurement of the θ angle, the coordinate in which the magnetic bending of muon trajectories takes place. The definition of appropriate trigger roads in θ, having a transverse momentum response that is angle independent, is achieved by scaling the widths of the bands of the detector, along the radial coordinate, as $sin^{1.35}\theta$ [17]. For the FS4 region, this is obtained with 31 different radial bands, ranging from 7.0 cm to 22.6 cm.

To mimic such a structure for FW4 and FW5 implies the use of 2 cm wide horizontal aluminum bands, running from one edge of the RPC supermodule to the opposite one (Fig. 14). The signal coming from each readout band is read at both ends. A mean timer is used to obtain an output that is essentially independent of muon position with a resolution that could be as low as 1 ns. The radial dimension of the readout bands (2 cm) is chosen is such a way that it is possible to approximate the widths of the radial bands ORing together the RPC signals coming from vertically adjacent readout bands. A total of about 7,600 readout bands is required to collect all the signals from the forward supermodules. Since the total area of each forward supermodule is subdivided into 50 redout bands, and two signals are read from each band for mean timing purposes, 2 readout boards are needed to handle the signals coming from a forward *RPC* supermodule. This corresponds to a minimum of 288 readout boards (under covering of FW5) and to a maximum of 320 readout cards (over covering of FW5).

Beside the maximum possible dimensions for pads/strips, two major problems have to be investigated in detail before granting the possibility to use *RPC*'s for *SDC*:

- The stochastic noise of the *RPC* modules used for *E*771 is 1000 Hz/m^2 at working voltage (8000 V). Very recent measurements, done at CERN using 10 *RPC* double chamber modules of the new kind, show that the single rate is 12 kHz out of spill [14]. Since the total area of the detector is 20 m^2, the stochastic noise of the new *RPC* modules is 600 Hz/m^2. Therefore, *RPC* noise results to be 12 times larger than the one of plastic scintillators (50 Hz/m^2). This figure should not be considered conclusive. Specific tests with cosmic rays could further investigate the problem and study possible ways to reduce the stochastic noise of *RPC*'s.

- The gas mixture used so far for *RPC*'s contains ~1/3 butane and is flammable. The use of such a gas mixture in a large area *RPC* detector exceeds the safety standards required by the SSC Lab, and could impose an exceedingly complex gas-leak monitoring system. It is also possible to operate the *RPC*'s with isobutane at a concentration appreciably lower than ~1/3. All the characteristics and performances of the *RPC*'s are basically unaffected by this change of the gas. A set of careful laboratory tests using a non flammable (low isobutane percentage) gas mixture has to be carried out to guarantee high performances of the *RPC*'s using such a non flammable gas mixture.

With a total of ~430 *RPC* supermodules it is possible to replace the scintillators of the *SDC* Muon System with a detector that offers a better granularity (up to ~115,000 channels to be compared with ~4500 scintillator counters) at a lower cost. A considerable amount of work has to be done to ascertain all the details of such a project, but the prospects are certainly promising.

8 Acknowledgements

We gratefully acknowledge R. Santonico for useful discussions and for providing some unpublished data, H. Lubatti and J. Elias for elucidating some technical details and S. R. Amendolia for support and help during the drafting of the present work.

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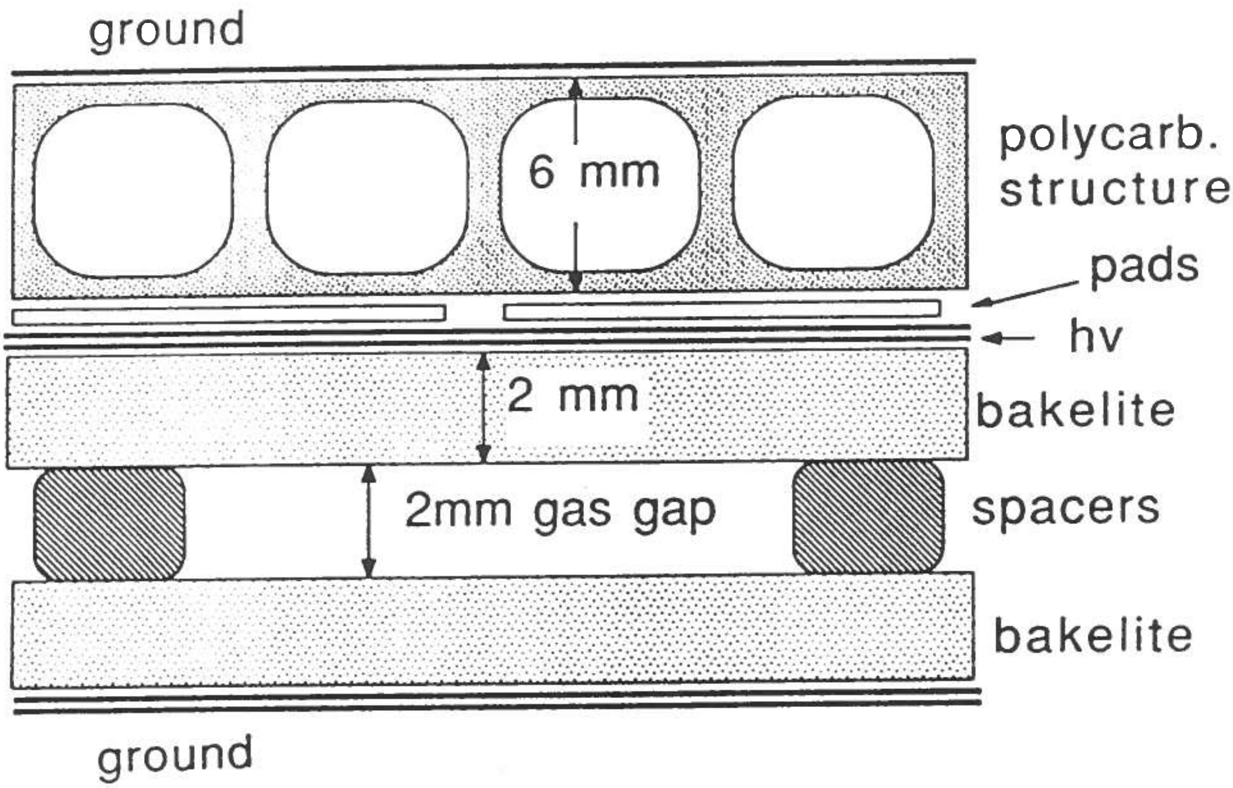

Fig. 1 - Stratigraphy of an *RPC* module.

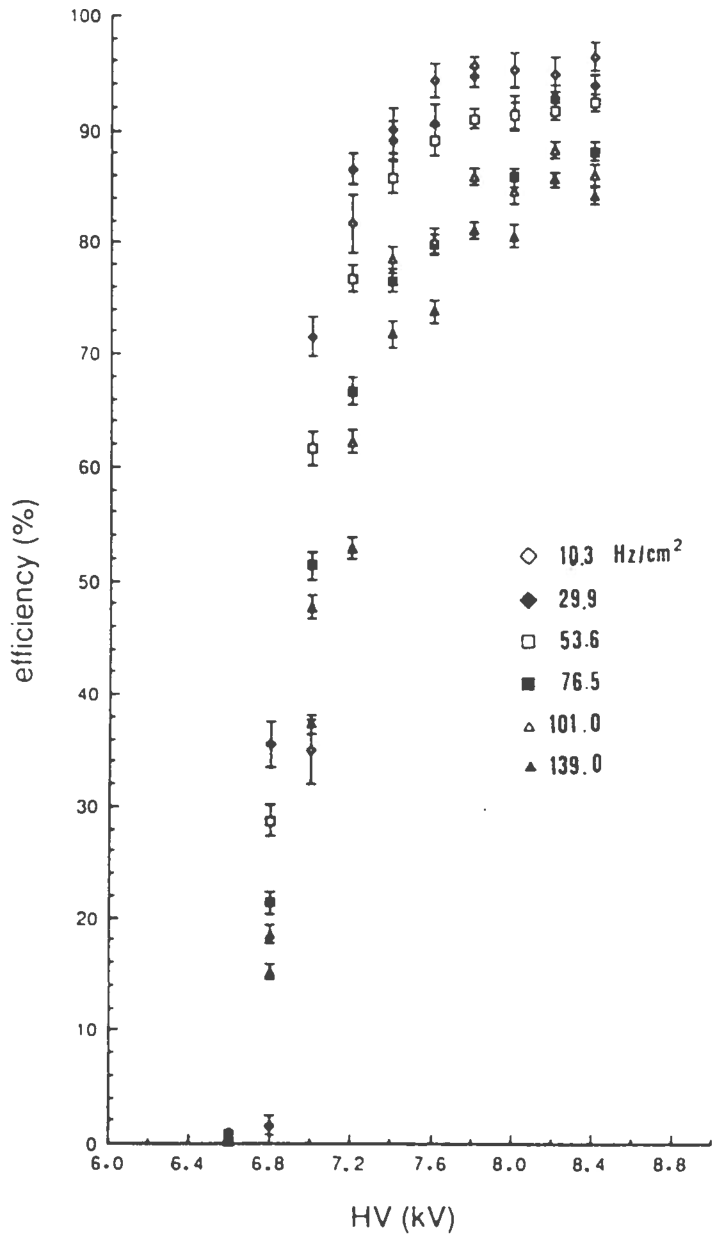

Fig. 2 - *RPC* efficiency vs HV for different beam rates.

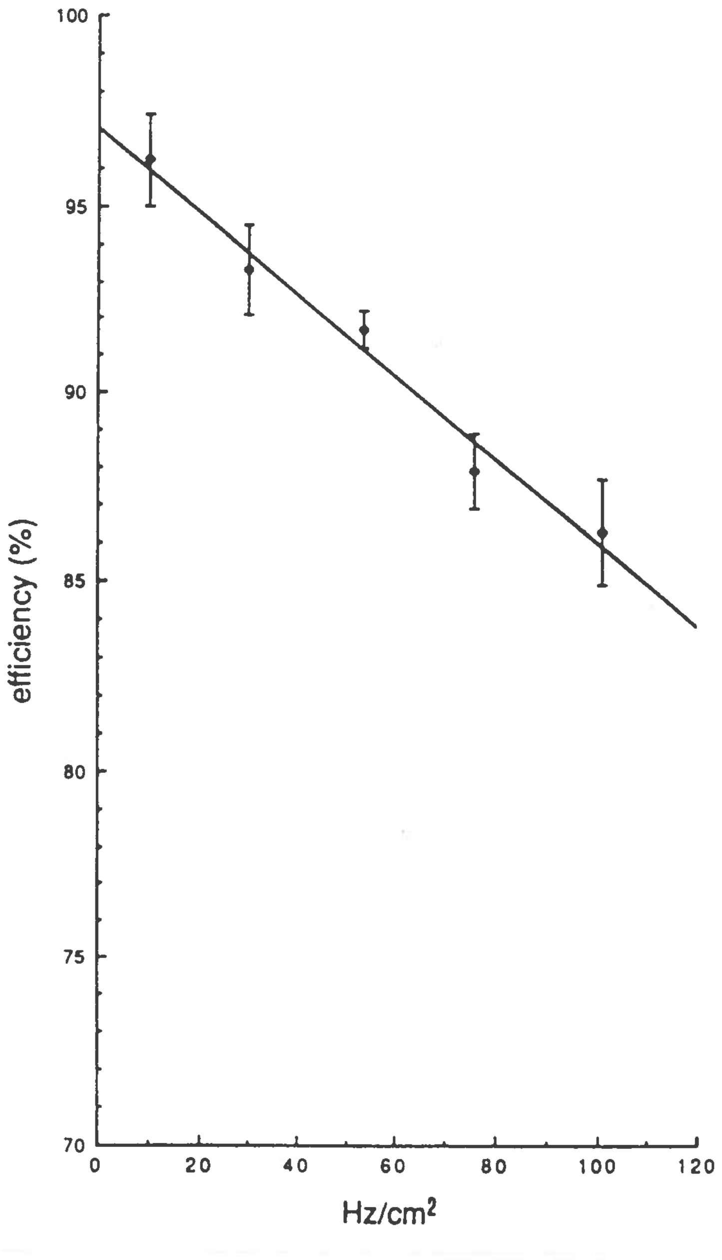

Fig. 3 - Plateau values of the efficiencies vs beam rate.

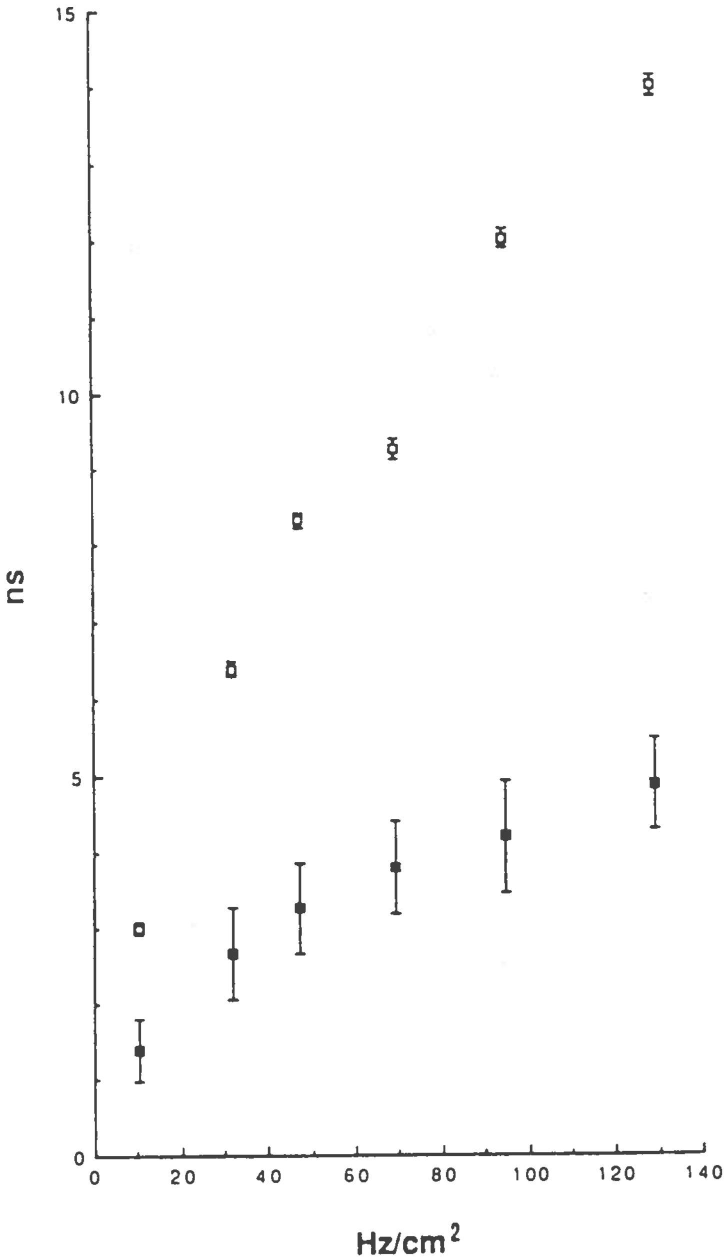

Fig. 4 - Mean value (○) and standard deviation (●) of the time between an *RPC* and a beam counter vs beam flux.

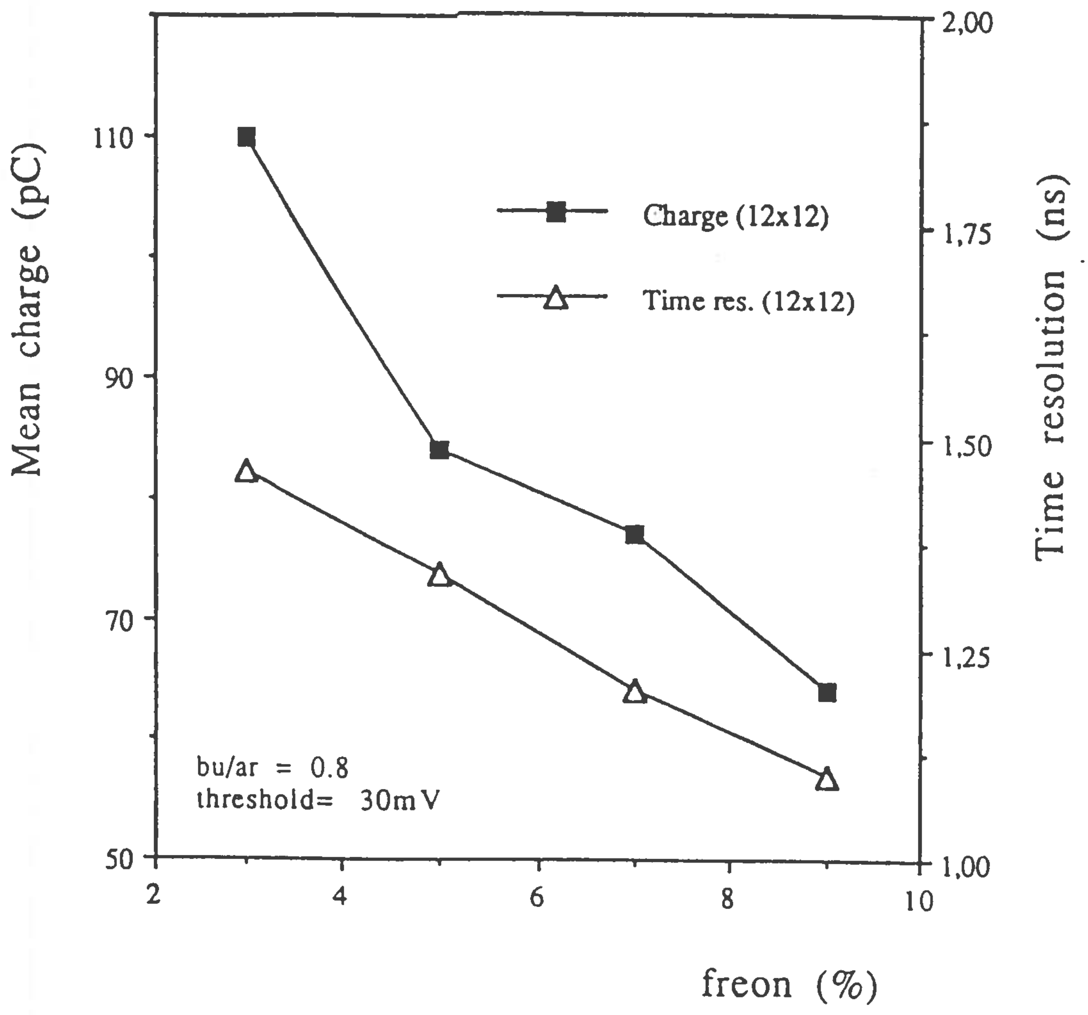

Fig. 5 - Single pad time resolution and mean charge vs freon percentage.

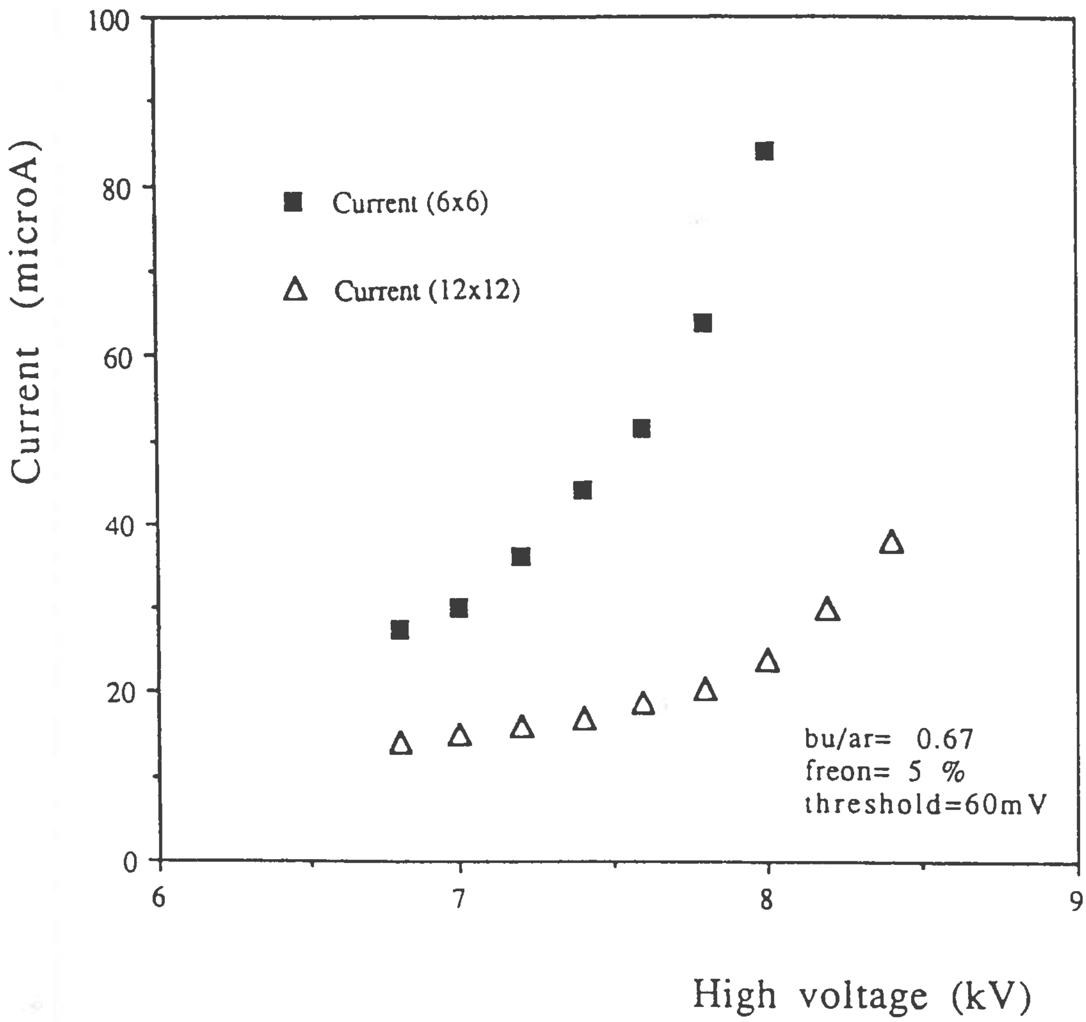

Fig. 6 - Dark currents for (6 × 6) cm^2 and (12 × 12) cm^2 pads.

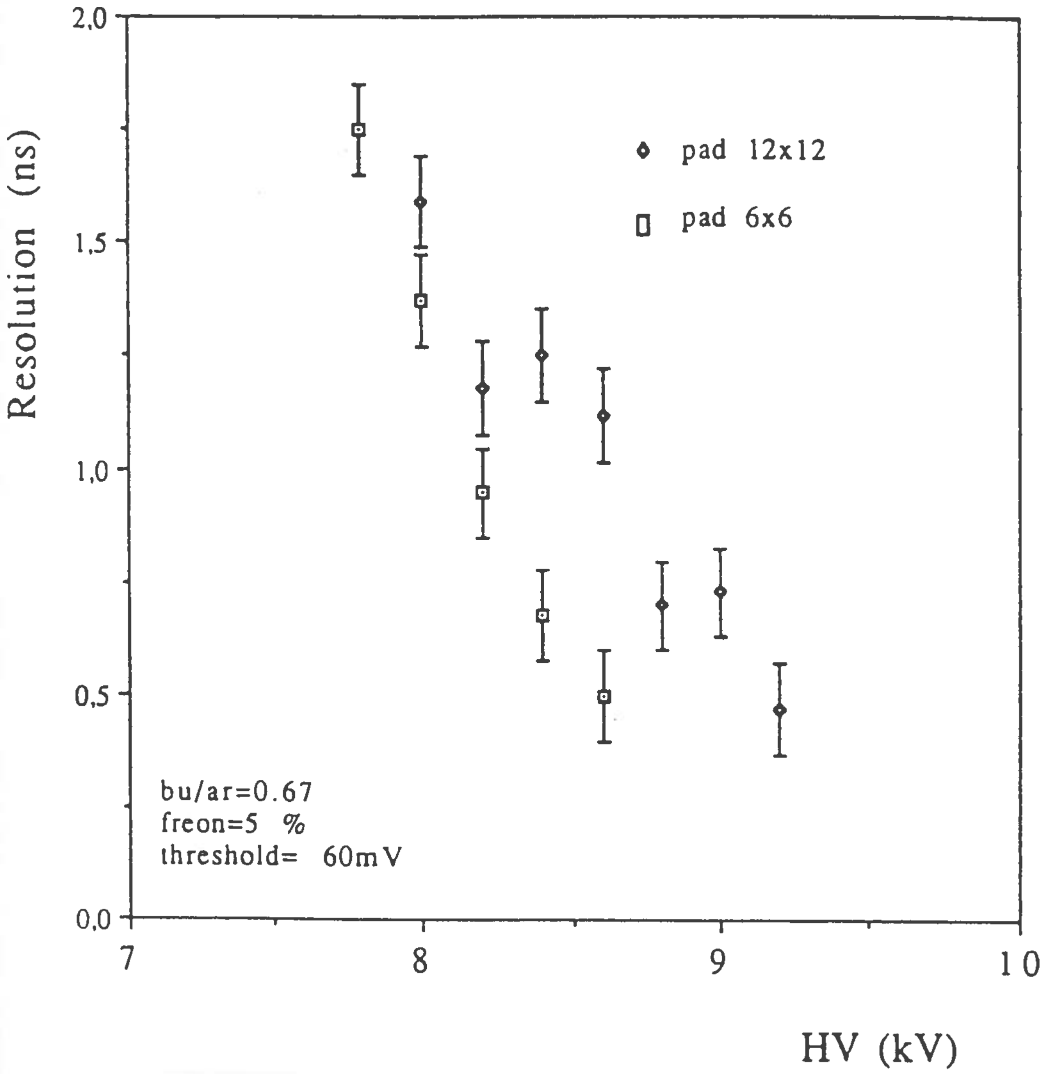

Fig. 7 - Time resolution vs HV for a single pad.

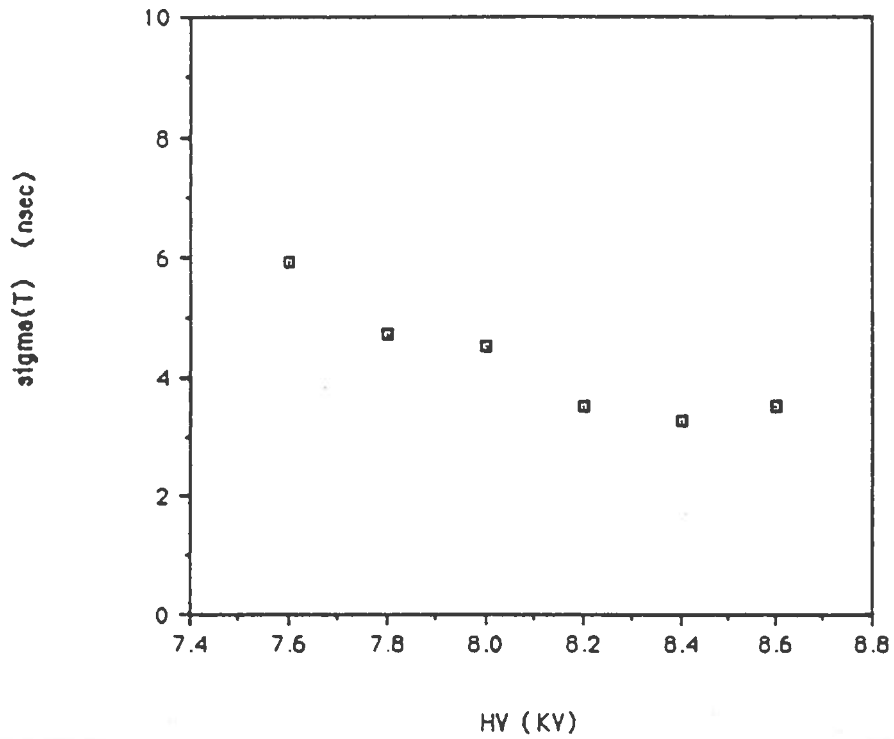

Fig. 8 - Time resolution vs HV for a (2 × 1) m^2 RPC module.

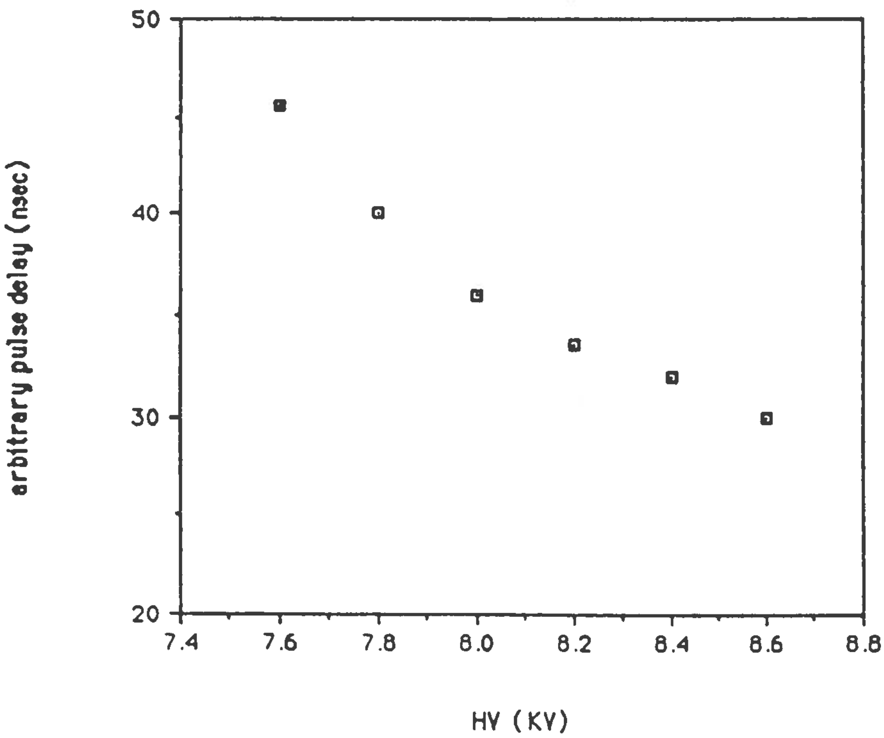

Fig. 9 - Signal pulse delay for a (2 × 1) m^2 RPC module vs HV.

Fig. 10 - Supermodules overlapping in the barrel region.

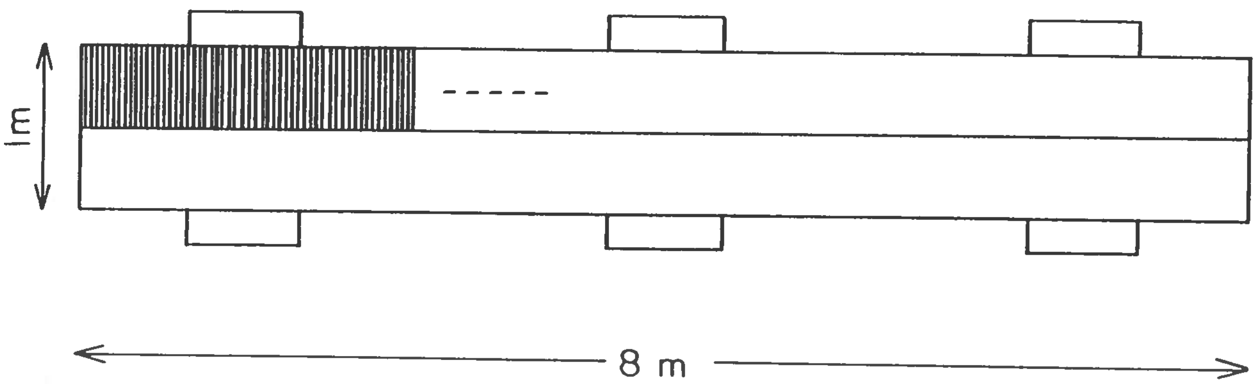

Fig. 11 - *RPC* supermodule, strips and readout boards for the barrel region.

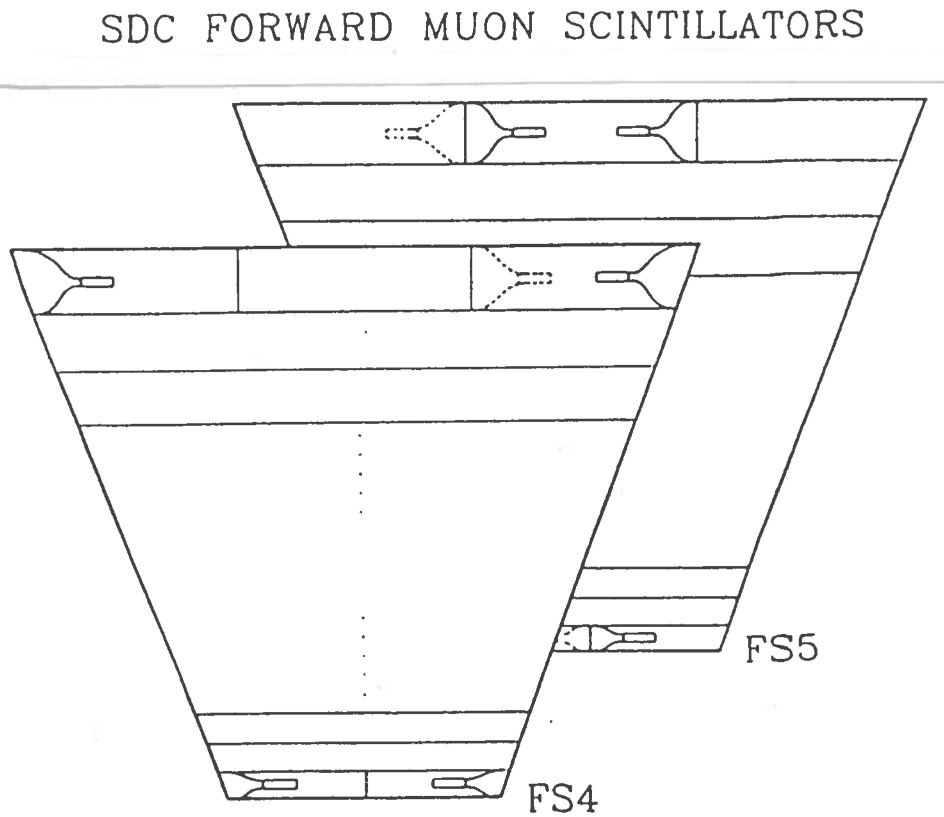

Fig. 12 - Corresponding octants in the forward regions.

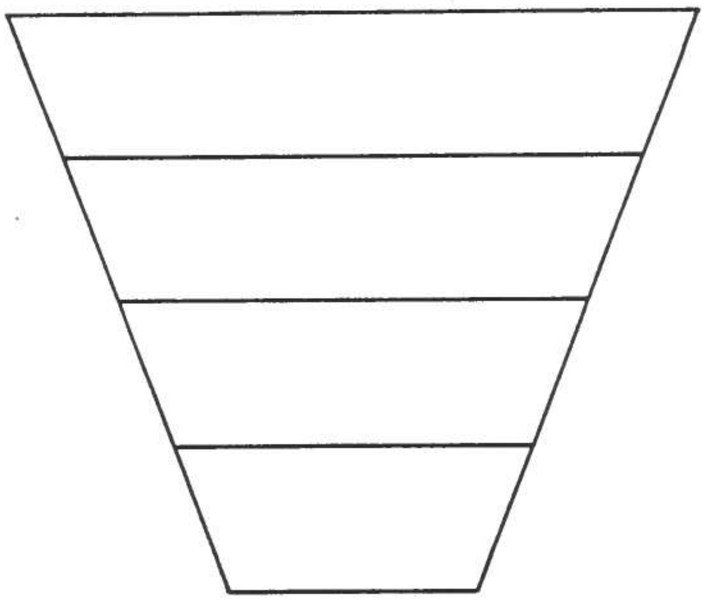

Fig. 13 - *RPC* supermodules in a forward octant.

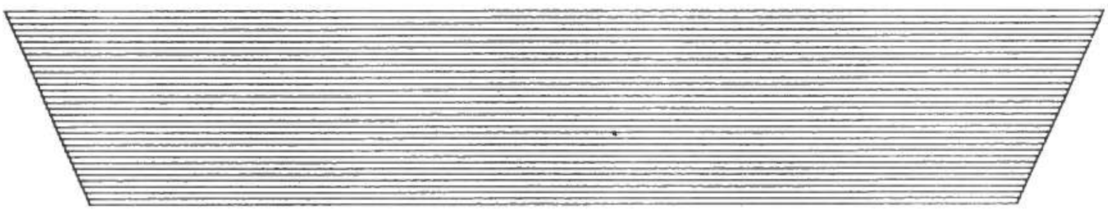

Fig. 14 - *RPC* supermodule and readout bands for the forward regions.