TESTS OF RPCS FOR THE ARGO EXPERIMENT AT YBJ

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ON BEHALF OF ARGO COLLABORATION

The ARGO experiment is a full coverage air shower array consisting of a RPC carpet of size 100×100 m^2 being installed at the YBJ laboratory (4300 m a.s.l., Tibet, P.R. of China). Its main purpose is the study of gamma ray astrophysics in the energy range from 100 GeV to several TeV. In this paper the cosmic ray tests performed at sea level on a few ARGO RPC prototypes are described.

1 Introduction.

ARGO [1] [2] is an experiment for the detection of cosmic ray showers located at the YBJ laboratory (4300 m a.s.l., Tibet, P.R. China). It is composed by an array of Resistive Plate Chambers displaced over an area of 100×100 m^2, with full coverage on 74×78 m^2. The full coverage, combined with the site altitude, permits to explore gamma ray astrophysics in an energy range from several TeV down to a threshold as low as about 100 GeV [1]. Resistive Plate Chambers [3] [4] are well suited for instrumenting the ARGO carpet because of the good time resolution, about 1 ns, the robustness and the low cost. The quoted time resolution is needed for reconstructing the primary direction [2] from combined measurements of hit position and arrival time.

RPCs for ARGO are operated in streamer mode [5] with the gas mixture $C_2H_2F_4/Ar/i-C_4H_{10} = 75/15/10$. The gas gap is 2 mm thick, as well as the electrode plates, which have the bulk of phenolic polymers and the superficial layer faced to the gas of melaminic polymers. The overall resistivity is about $5 \times 10^{11}\Omega \times$ cm. The inner surfaces of the plates are coated with a few micron thick polymerised linseed oil layer. ARGO RPC units have size 1.25×2.80 m^2.

The chamber read-out is performed by means of 80 pick-up strips, 7×62 cm^2 wide. The basic unit for the digital read-out is a 56×62 cm^2 "pad" [2], consisting of 8 strips served by a single front-end board embedded in the strip panel inside the detector Faraday cage [6]. The front-end boards contain an 8 channel GaAs full custom die, which is composed of a 3 stage voltage amplifier followed by a comparator [7]. Each strip is coupled to the board through one

1/6 resistive voltage partition, in order to match the high amplification with the amplitude of the ARGO streamer signals. The die indeed can be used both in avalanche and in streamer mode. The overall voltage amplification is 50 with 100 MHz bandwidth, the threshold on the detector signal is about 10 mV and the power consumption 22 mW/channel. The low threshold improves the time resolution at operating voltages just above the efficiency plateau knee.

At the same time, an analog read-out is performed with two large pads of size 1.25×1.40 m^2, each one covering half of the chambers.

In this paper, the cosmic ray tests of detector prototypes at sea level are described.

2 Experimental lay-out

The experimental set up of the tests described in this paper is shown in figure 1. Four RPCs are used for tracking cosmic rays with a resolution of 1 cm in an area of 50×50 cm^2. The trigger signal is the threefold coincidence of the ORed short strips of layers 2, 3 and 4.

The monitor and test chamber hit patterns are registered using commercial CAMAC latches. For efficiency and cluster size measurements, isolated tracks are selected applying offline algorithms described in [8]. Arrival times have been measured for a few strips using a commercial CAMAC TDC. Operating currents are extimated from the voltage drop on a 100 $k\Omega$ resistor placed in the chamber High Voltage circuit. A NIM scaler has been employed for measuring the counting rates.

3 Test results

In order to take into account the different environment conditions during data-taking, operating voltages have been rescaled [9, 10] to $T_0 = 293\ K$ and $P_0 = 1010\ mbar$ using the relationship $V = V_a \times (T/T_0) \times P_0/P$, where V_a and V are the applied and the rescaled voltage respectively. It must be pointed out that the tests decribed here have been performed at sea level, with environment conditions quite different from those present in YBJ laboratories, where $P = 600\ mbar$ and the temperature T ranges from 8 to 25 centigrade degrees during the year.

The efficiencies measured for ten different pads are shown in figure 2. Due mainly to the different operating pressure, the full efficiency is reached at operating voltages (above 9 kV) 2 kV higher than at YBJ [6]. The 60% efficiency voltage dispersion is ± 75 V on 8.8 kV, which is comparable with the gap spacers thickness tolerance ($\pm 15 \mu m$ on 2 mm).

In figure 3 are reported the cluster size distributions for different operating voltages: the average cluster size remains below 1.2 strips even well inside the efficiency plateau, with cluster size larger than 2 observed on few percent of the cases. The cluster size is strongly related to the impact point of the track on the strip. Cluster size 2 tracks e.g. are well localised in the interstices between adiacent strips, as shown in figure 4.

The distribution of the time of flight between two overlapped RPCs is shown in figure 5. The time resolution improves for increasing voltages and becomes of the order of the ns few hundreds of Volts inside the efficiency plateau (see figure 6). The arrival times measured for different strips are also reported in figure 6.

The pad counting rate vs operating voltage depends slightly on the electronics threshold, as shown in figure 7, where the rate of the coincidences between two overlapping pads is also reported for comparison. It is worth mentioning that the pad rate measured at YBJ is ~ 1.5 kHz/m^2 [6], due to the higher intensity of cosmic rays.

The detector currents vs voltage, which are reported in figure 8, increase linearly at low voltages (below 6 kV) and exponentially around the operating voltages, where gas multiplication phenomena are relevant. The linear term is a "dark" current and depends on the temperature (see figure 8).

The analog read-out of the chamber is performed by using two "big pads" 1.25×1.40 m^2 wide. Each big pad is a floating electrode, separated from a grounded layer by a 190 μm thick insulator foil. The pick-up circuit [11] includes also the R=50Ω terminating impedance of the cables used for transporting the signals induced on the big pad. The time constant of the pick-up circuit, RC $\simeq 5\mu$s, is much larger than the streamer duration, about 20 ns. In this condition the signal waveform is integrated by the pad capacity and shows a risetime of 20 ns (approximately the streamer duration) and a peak amplitude of Q/C (where Q is the total charge induced on the electrode). Examples of signals acquired on a digital scope are shown in figure 9, where large amplitude signals should be due to cosmic showers.

The total charge induced on the read-out electrode is roughly proportional to the number of charged particles hitting the detector inside the big pad. Analog signals from the big pads will be used for measuring particle densities in showers of energy above 10 TeV.

4 Intrinsic noise investigations

A study of the detector counting rate on the cm^2 scale was performed by using a small circular pad with 4 cm diameter, as shown in figure 10. Such a small pad is particularly suitable for studying possible noise around the spacers. The small pad capacity C is of the order of pF and therefore the time constant RC is lower than the streamer duration. In this case the observed signal gives the time profile of the discharge current inside the gap. A typical signal acquired on a digital scope using a small pad is shown in figure 11, where the avalanche precursor is clearly distinguished from the following streamer signal.

Spacers are disposed on a 10 cm lattice inside RPCs and ensure the gas gap uniformity over large surfaces. A detailed sketch of a spacer can be found in [8]; it is composed by a cylindrical body 2.00 mm thick with 4 mm radius, surrounded by a guard ring having a radius of 6 mm. In figure 12 the counting rates measured over a sample of spacers and outside them are shown. The distribution of the rates measured over the spacers presents a significant tail extending at higher rate values. This is an indication of the fact that spacers are in some case a source of noise.

5 Conclusions

ARGO is an Extensive Air Shower detector which, combining together the site altitude (4300 m a.s.l.) and the full coverage over 74×78 m^2, can detect γ primaries with an energy threshold as low as 100 GeV, which are also accessible to satellite experiments. Resistive Plate Chambers, because of their time resolution (about 1 ns), robustness and low cost are well suited for implementation. The tests described on this paper, though performed at sea level, verify that RPCs fulfill the requirements of the experiment. With the help of small pads it has been shown that some spacers could be the source of spurious hits.

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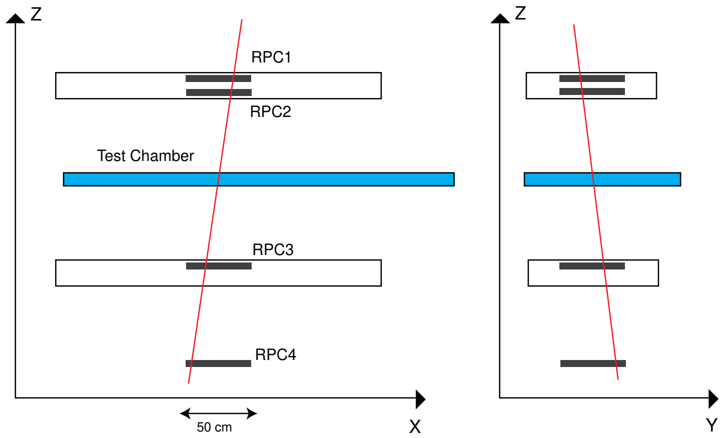

Figure 1. Experimental lay-out. The cosmic ray monitor is a set of four RPCs, RPC1, RPC2, RPC3 and RPC4, operated in avalanche mode with a gas mixture composed of $C_2H_2F_4$, i-C_4H_{10} and SF_6. X and Y coordinate measurements are performed for each monitor chamber using two orthogonal strip panels, with read-out pitch 3.1 cm. The size of tracking stations RPC1, RPC2 and RPC3 is similar to ARGO RPC units, but only 16 strips per view are read out, so that the sensitive area is 50×50 cm^2, as the size of RPC4.

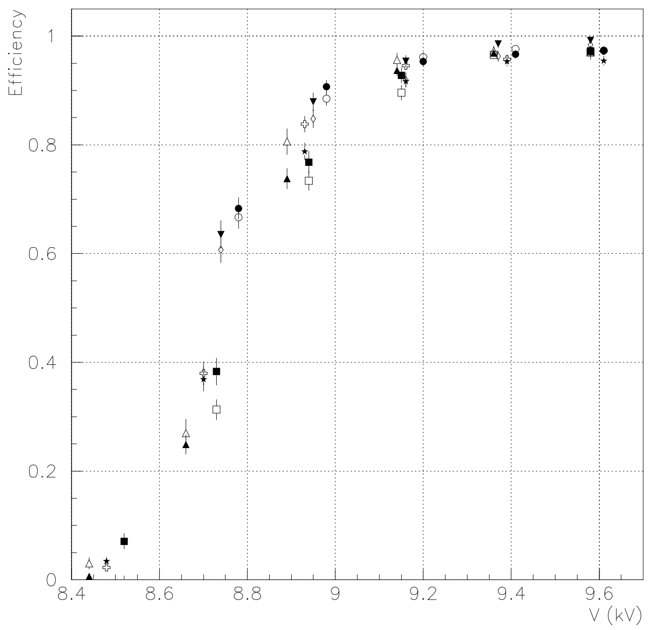

Figure 2. Efficiency vs voltage measurements for ten different pads with a threshold of 500 mV on amplified signals.

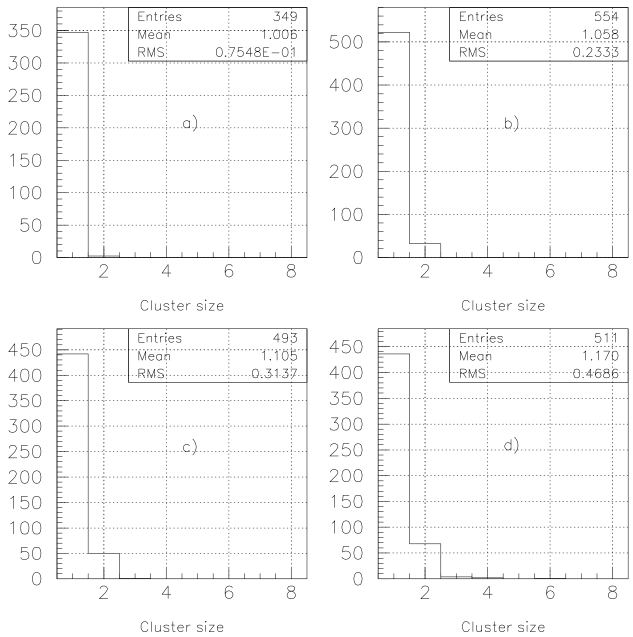

Figure 3. Cluster size distributions measured with a threshold of 500 mV on amplified signals at different operating voltages: a) 8.8 kV, b) 9.0 kV, c) 9.4 kV, d) 9.6 kV (400 V inside the efficiency plateau).

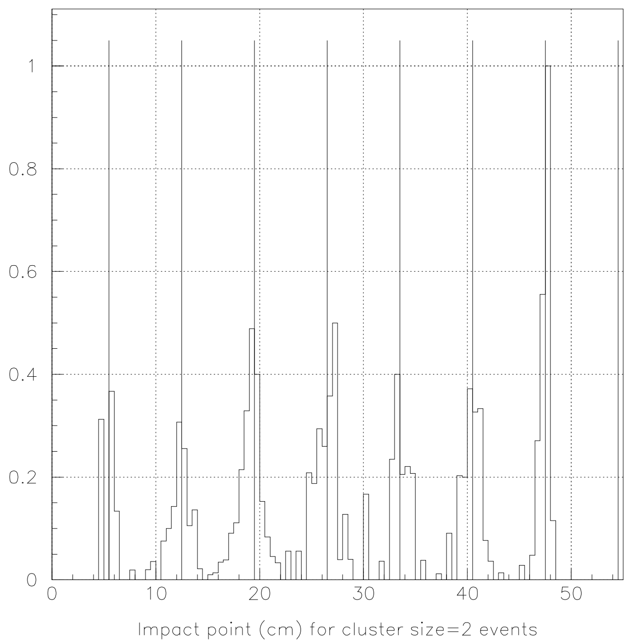

Figure 4. Reconstructed impact point on test chamber for tracks with cluster size 2. The drawn lines correspond to the interstices between adiacent strips.

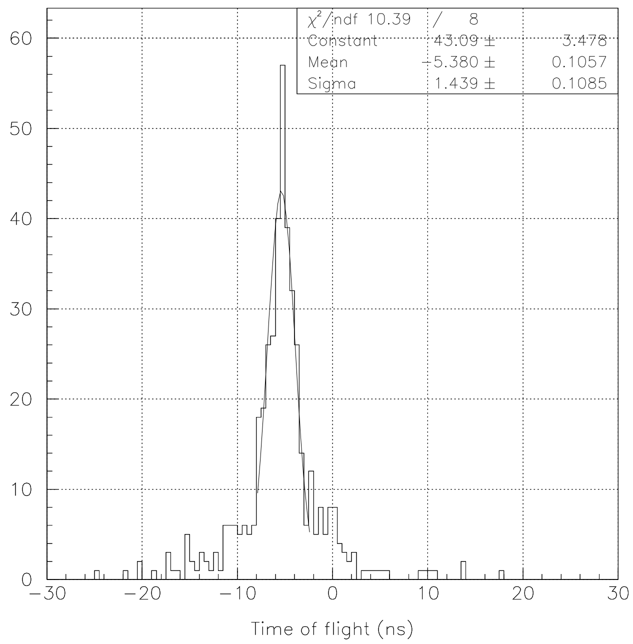

Figure 5. Distribution of the time of flight between two overlapped strips belonging to different RPCs operated at 9.7 kV. The quoted standard deviation divided by $\sqrt{2}$ can be assumed as the time resolution of a single RPC.

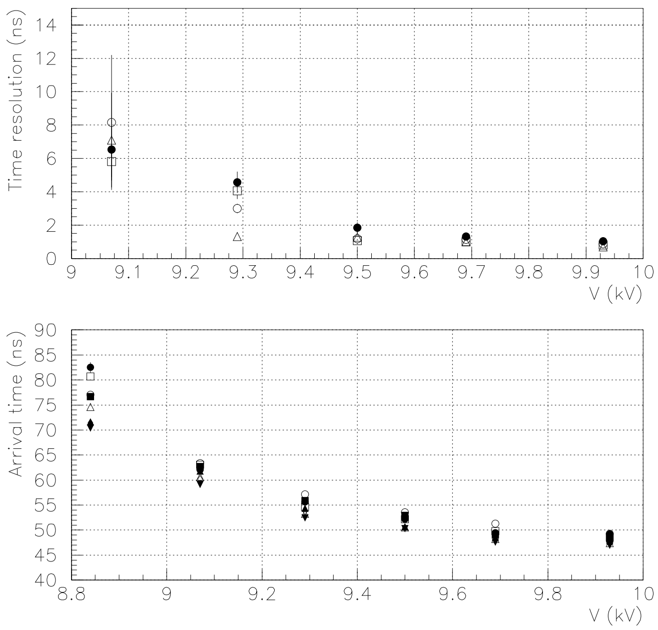

Figure 6. Time resolutions measured using four different pairs of overlapped strips (upper plot) and arrival times for the eight considered strips (lower plot).

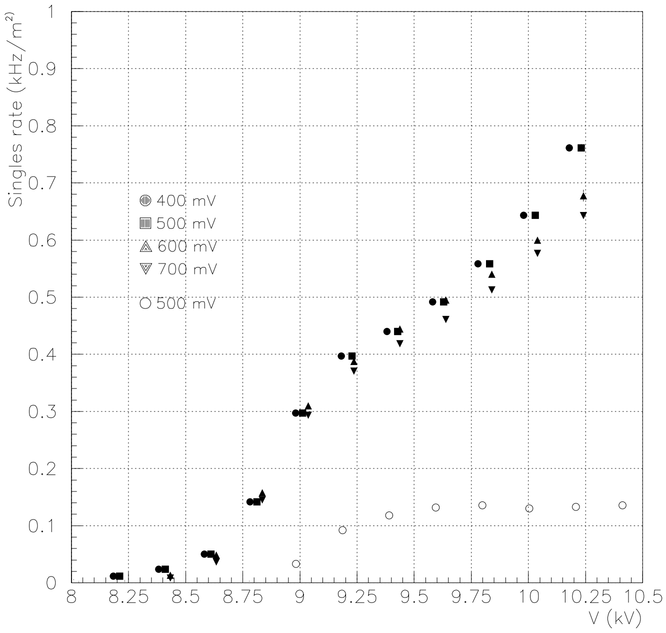

Figure 7. Pad counting rates vs operating voltages for different discrimination thresholds on the amplified signals (full markers). The double coincidence counting rate between two overlapped RPCs is also reported (blank markers).

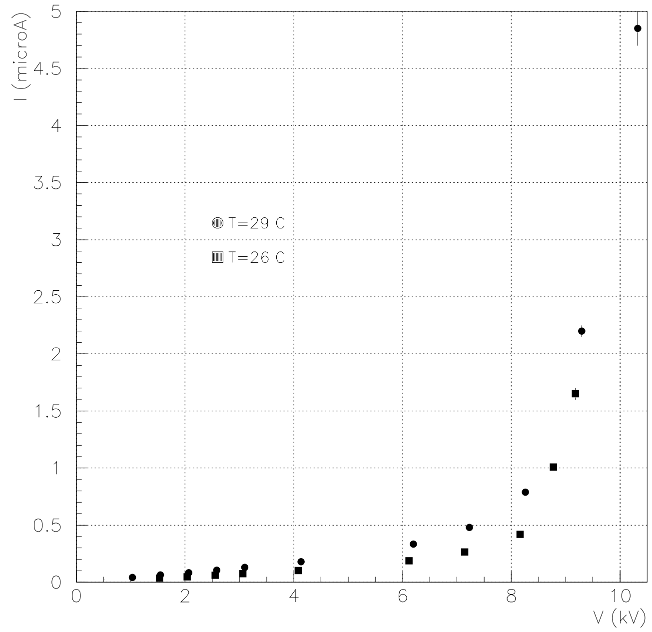

Figure 8. Operating currents measured for an ARGO RPC unit at two different temperatures.

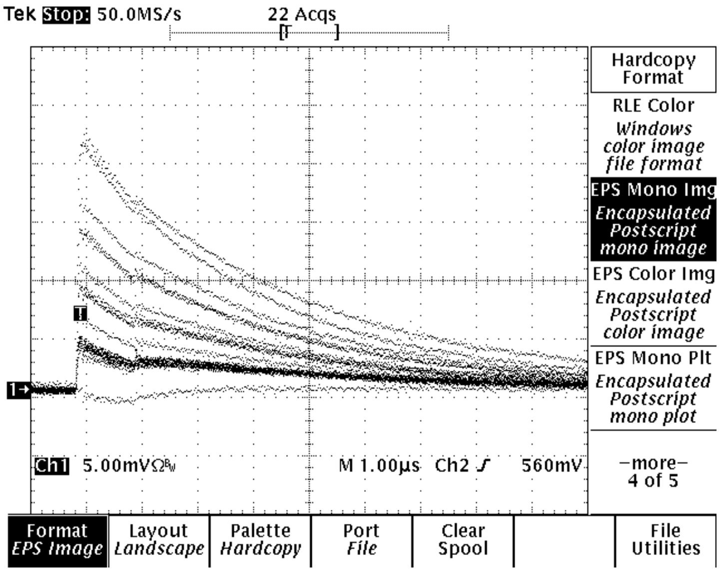

Figure 9. Examples of signals induced on a "big pad" and acquired with a digital scope. The horizontal scale is 1 μs and the vertical scale is 5 mV.

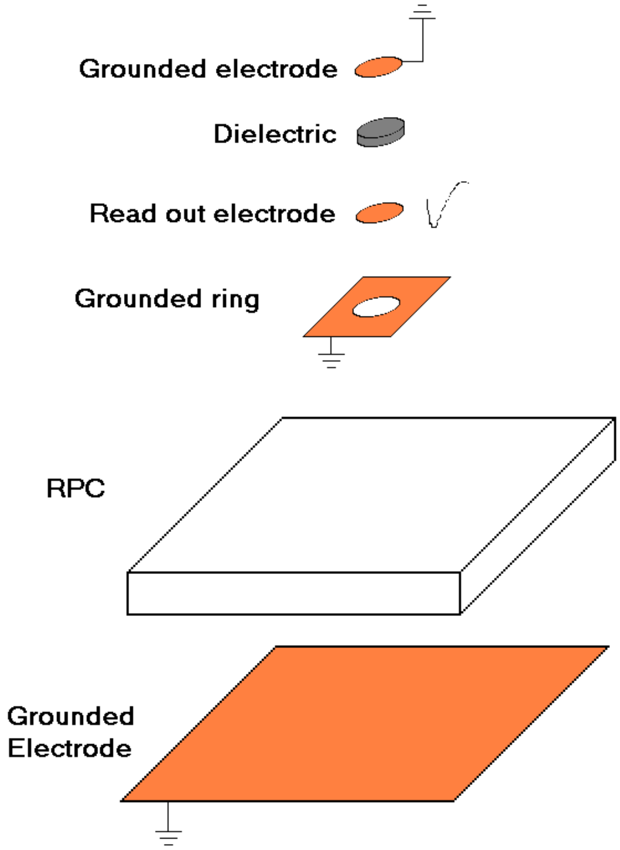

Figure 10. Set up for intrinsic noise measurements on the scale of the cm^2. The signal is picked up with small pads of area ~ 10 cm^2 and thickness of few mm. The grounded ring is used in order to not pick up discharges outside the pad area.

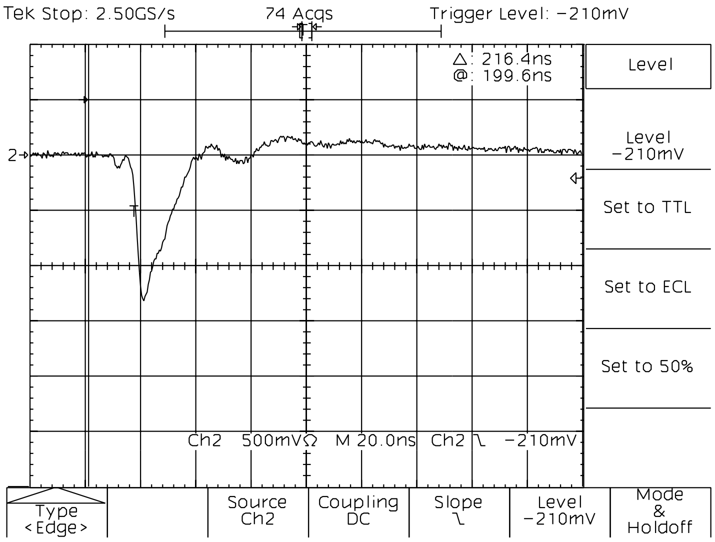

Figure 11. Example of a typical signal induced on a small pad and acquired with a digital scope. The horizontal scale is 20 ns and the vertical scale is 500 mV.

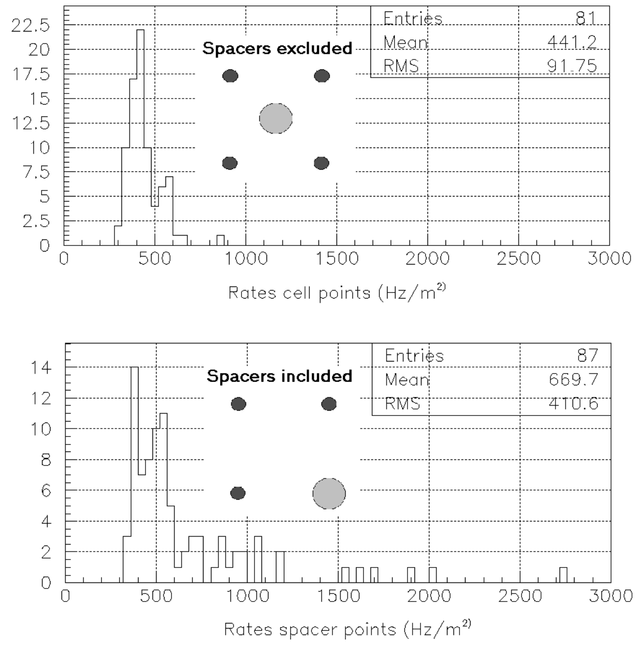

Figure 12. On-spacer (lower plot) and out-of-spacer (upper plot) counting rates measured with the small pad (HV=9.6 kV, threshold=200 mV).