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BEAM TEST RESULTS ON OPERATED IN AVALANCHE MODE RPCs OBTAINED IN APRIL 1996 WITH THE IHEP ACCELERATOR.

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Introduction

The operation of RPC in avalanche mode is still a matter of *R&D* work. This note presents our first results obtained in April 1996 run of U70 accelerator for multichannel RPCs having 2 mm gas gap and $10 * 10\ cm^2$ RPCs with 4 mm gas gap. The study was done in the framework of the ATLAS project. The aims of the study were:

- to find optimal parameter of operations for 2 mm gap RPC in avalanche mode,
- to test strip panel design providing with reduced strip-strip cross-talk,
- to get first experience in operation with "wide gap" RPCs.

Experimental setup

Beam tests were carried out in the test zone of the IHEP U70 accelerator. RPCs were exposed in wide, 10 by 10 cm^2, parasitic beam containing $\sim$ 3 GeV hadrons with intensity of few hundred Hz per cm^2. Beam trigger system consisted of three scintillation counters, installed ahead and behind of tested modules. It provided with trigger time with 1 $nsec$ accuracy.

Two RPCs with size of $50 * 50\ cm^2$ and with 2 mm gas gap were tested. Each chamber was composed of 1.6 mm thick melamine-phenolic plate with volume resistivity of $2 * 10^{11} \Omega cm$. Each 2 mm gap module had two orthogonal systems of strips, $2 * 16$ strips, to measure both coordinates. Width of strip was 28 mm, spacing between strips was 2 mm. Front-end electronics for each module consisted of 32 amplifier-discriminator, ATL16. Two modifications of ATL16, for cathode and for anode read-out, were used. Threshold of ATL16 was checked with a pulse generator. For pulses having symmetric triangular shape and width 5 $nsec(FWHM)$ threshold was $0.4 - 0.5$ mV. Output of ATL16 is differential ECL signal. This output was used to estimate time resolution and efficiency. In case, when $50 * 50$ cm^2 RPC was tested, a beam counter with 20 mm width scintillator was included in the beam trigger hodoscope to select hits taking place only in region of one choosen strip. Below we call strip panel containing selected strip as "X-panel", opposite strip panel will be denoted as "Y-panel". If in X-panel width of beam "was limited" by width of one strip, in Y-plane beam was shared between three strips. For 2 mm gap we did not find big difference between anode and cathode strip read-out. That is why we do not specify here which (anode or cathode) was X (Y) strip plane.

Signal coming from selected X-strip was amplified with special amplifier, U3-33, (400MHz, gain=26db) and was used to analyse charge distribution. So, each $50 * 50$ cm^2 RPC was connected by 32 twisted pair cable and one coaxial line with ADC and TDC modules strobed by beam trigger signal.

4 mm gap RPCs had only one $\sim 10 * 10$ cm^2 cathode pad. Signal from this pad was amplified with U3-33 for charge measurement or amplified and shaped with ATL16 for time measurement.

Our DAQ system included SUMMA (CAMAC-like system) and IBM PC-386. As TDC and charge integrating ADC we used the following SUMMA modules: P267T with 0.66 $nsec$ bin and P267 with 0.3 pC bin.

Test of 2 mm gap modules

The RPCs were operated with gas mixture of argone-isobutane in the ratio 2 : 1 and containing 15% of CF_3Br. Fig.1 shows mean charge, Q, of avalanche and of streamer at different values of high voltage, HV. Behaviour of Q versus HV in the figure looks very similar to what was presented[1] at the RPC95 Workshop for gas mixture $10\% Ar + 7\% nC_4H_{10} + 83\% C_2H_2F_4$

proposed to use for RPCs in the ATLAS.

Contribution of streamer process is given in fig.2 as a function of HV. Like as it was observed for mixture with $C_2H_2F_4$[1], the figure shows that streamer appears just when saturation of avalanche charge ("at knee") is seen.

Distribution on time of RPC response is shown in fig.3 for X-plane (upper picture) and for Y-plane (lower picture). Approximation of data from fig.3 with the gauss distribution gives the following values of time resolution $\sigma = 2.7\ nsec$ for $X - plane$ and $\sigma = 3.3\ nsec$ for $Y - plane$.

Based on distribution shown in fig.3, a 25 $nsec$ time gate (from 30 to 55 $nsec$) was applied to define efficiency of RPC and a number of fired strips. A strip was considered as fired if signal from it arrived in time inside this gate.

Fig.4 shows an efficiency of RPC as a function of HV. Outputs from Y-panel were used for this figure.

Looking at figures 1 and 2 one can see three regions of operation:

- $HV < 8\ kV$: pure avalanche mode;
- $HV = 8-8.2\ kV$: a begining ("knee") of avalanche charge saturation;
- $HV > 8.2\ kV$: region of strong streamer contribution.

Which region of HV may be choosen for operation in the ATLAS detector? Region of strong streamer contribution does not ensure high rate capability. Therefore a choise should be done between first and second regions.

Below knee a gas gain varies strongly with the electric field. It is unreasonable to choose this region. Any variation in gas mixture or in atmoshperic pressure will lead to necessaty to change HV. Variation in gap dimension by 50 μm is equal for 2 mm gap RPC to changing in HV by 200 V (at $HV \sim 8\ kV$). It means, that different RPC modules (or even different part of one module) will need their own working HV (at fixed threshold of electronics). Furthermore, mean value of charge in this region is very small. Attempt to get high efficiency by reducing of threshold will bring hard probrem of noise and cross-talk. Fig.5 presents distribution on charge measured for avalance signal and for noise ("pedestal") obtained at $HV = 8\ kV$. Data on pedestal demonstrates how was $Q-$distribution smeared in our measurements. The figure shows that even at knee the avalanche signal from 2 mm gap is very close to noise.

Second region is a region of avalanche with $3-20\%$ admixture of streamer. Problem of this region is multistrip clusters produced by streamer signal because of strong strip-strip cross-talk. This problem is discussed in the next section.

Strip-strip cross-talk. How to reduce it?

Data presented in previous figures were obtained with "classical" performance of strip panels: both X and Y strip system were made of 3 mm foam sheet on one side of which 16 strips were glued, opposite side was covered with foil (see fig.6a). Such strip panel is very simple for manufactoring, however it has unpleasant feature - strong cross-talk between strips. Our study[2] has showed that cross-talk between neighbouring strips in such panel is about $8-10\%$. It means, that if amplitude of signal going along strip is greater than $10 * T$, where T is a threshold of front-end electronics, a "firing" of neighbouring strips takes place. The higher the ratio Q/T is, the greater is a number of fired strips.

Fig.7 shows correlation between number of fired strips per one hit in X and Y planes. Data given in fig.7 was obtained at $HV = 8.2\ kV$ with panel design shown in fig.6a. The figure demonstrates how big is a fracton of multistrip clusters. Furthermore, the figure demonstrates good correlation of information coming from X and Y-strips.

To reduce cross-talk between neighbouring strips we performed new strip panels and tested them. Construction of new panel may be understood from fig.6b. General idea was "to break" field lines between edges of neighbouring strips by approaching of ground electrode (6 mm width) very close to edges.

Averaged number of fired strips per one hit as a function of Q is given in fig.8 for "old" and "new" design. At $Q < 10\ pC$ the figure shows reduction of cross-talk in data obtained with new panels: average number of fired strip from new panel is close to unit. No improvement was obtained for higher amplitude: the figure shows no differences between data obtained with new and old panels at $Q > 10\ pC$. Fig.9 presents distribution on number of fired strips obtained with new and old strip panels in ranges $Q < 3\ pC$ and

$Q > 10\ pC$. Fig.8 and fig.9 show that if RPC is operated in mixed mode: avalanche+ streamer, there is a problem of noise produced by strong streamer signal. To registrate the avalanche signal with high efficiency one should use front-end electronics with very low threshold. However, low threshold leads to multistrip noise in case of streamer signal even if an effort to suppress cross-talk is done.

Test of 4 mm gap RPCs.

We tested 4 mm gas gap RPCs with hope to find HV-region with pure avalanche process where Q does not depends strongly on electric field. Starting this test we took in mind the results on wide gap RPCs[3]. Gas mixture was $75\% Ar + 15\% Isobut + 10\% Freon$.

Mean collected charge of avalanche and streamer signals is shown in fig.10 at different HV. Probability of streamer signal as a function of HV is given in fig.11. Mean value of saturated avalanche charge was $\sim 2\ pC$. The greater charge is, more effective is signal/noise separation. However, more useful feature of 4 mm gap is that streamer appears only at many hundred volts above "knee". Fig.10 and fig.11 show that there is about 1 kV interval in which saturated avalanche signal with only few percent admixture of streamer process was observed.

Fig.12 shows efficiency of 4 mm gap RPC as a function of HV.

Time resolution of RPC measured for pure avalanche above "knee" was estimated as $\sigma \sim 4\ nsec$.

General conclusions

As it comes from our tests, there is no convenient interval of HV to operate 2 mm gap RPC in avalanche mode. Pure avalanche signal was observed only in range of HV where gas gain dependes strongly on electric field. With growth of HV a saturation of avalanche charge was observed. But just when saturation takes place, streamer signal appeares. This result is in a good agreement with published data on the avalanche to streamer transition (see, for example,[1]) for 2 mm gap.

Cross-talk between strips and low threshold of front-end electronics are a reason of the multistrip firing. Our attempt to suppress cross-talk by introduction of ground electrode close to edge of strip has brought a positive result: mean number of fired strips per hit was reduced for avalanche signal.

However, no success in suppression of multistrip effect produced by streamer signal was obtained. Further efforts on design of cheap strip panels with reduced strip-strip cross-talk are needed.

Promising results were obtained with 4 *mm* gap chambers. We have got that the avalanche signal is not followed with streamer over many hundred voltages above point of saturation.

Time resolution, $\sigma \approx 4\ nsec$, was reached with 4 *mm* gap modules. Our results on 4 *mm* gap chamber are in agreement with study on wide gap RPCs done in[3]. We intend to performe more serious tests on wide gap modules.

References

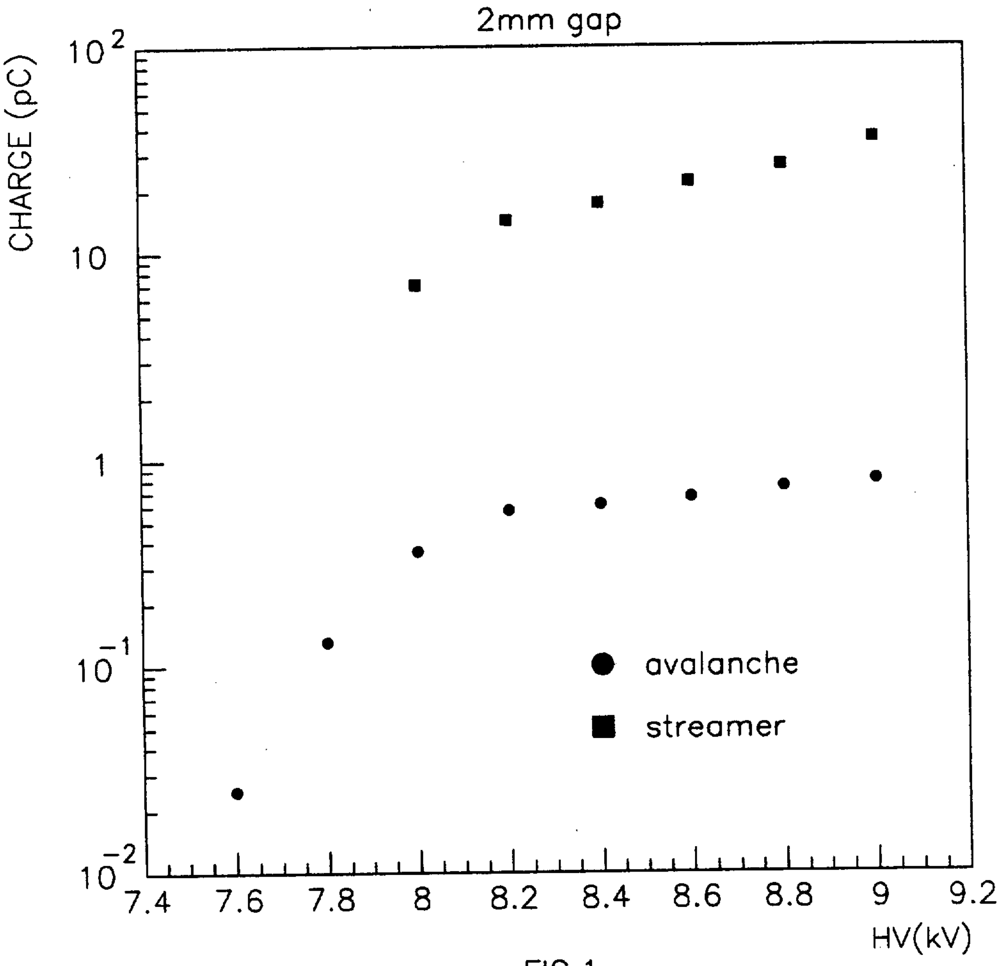
[1] R.Cardarelli,R.Santonico and V.Makeev, "The avalanche to streamer transition in RPC's", report done at III Workshop on RPC and Related Detectors, Pavia 11-12 oct. 1995.

[2] V.Ammosov et.al., "RPC: avalanche signal and cross-talk noise", research note, IHEP, February 1996.

[3] I.Crotty et.al., NIM A346(1994)107-113,
I.Crotty et.al., preprint CERN PPE/95-146

Figure caption

Fig.1 2 *mm* gap RPC: mean charges of avalanche and streamer signals measured at different high voltage.
Fig.2 2 *mm* gap RPC: probability of streamer as a function of HV.
Fig.3 2 *mm* gap RPC: Distribution on time on response. Upper picture is for X-plane, lower - for Y-plane.
Fig.4 2 *mm* gap RPC: efficiency as a function of HV.
Fig.5 2 *mm* gap RPC: charge distribution for avalanche signal and for noise, $HV = 8\ kV$.
Fig.6 Cross section of "old" and "new" strip panel design.
Fig.7 Correlation between number of fired strips in X and Y planes.
Fig.8 Average number of fired strips as a function of charge.
Fig.9 Distribution on number of fired strips at $Q < 3\,pC$ and at $Q > 10\,pC$. Two upper pictures are for "old" design, two lower - for "new" one.
Fig.10 4 *mm* gap RPC: mean charges of avalanche and streamer signals measured at different HV.
Fig.11 4 *mm* gap RPC: probability of streamer as a function of HV.
Fig.12 4 *mm* gap RPC: efficiency as a fuction of HV.



2mm gap
CHARGE (pC)
10^2
10
1
10^{-1}
10^{-2}
7.4
7.6
7.8
8
8.2
8.4
8.6
8.8
9
9.2
HV(kV)
avalanche
streamer

FIG. 1

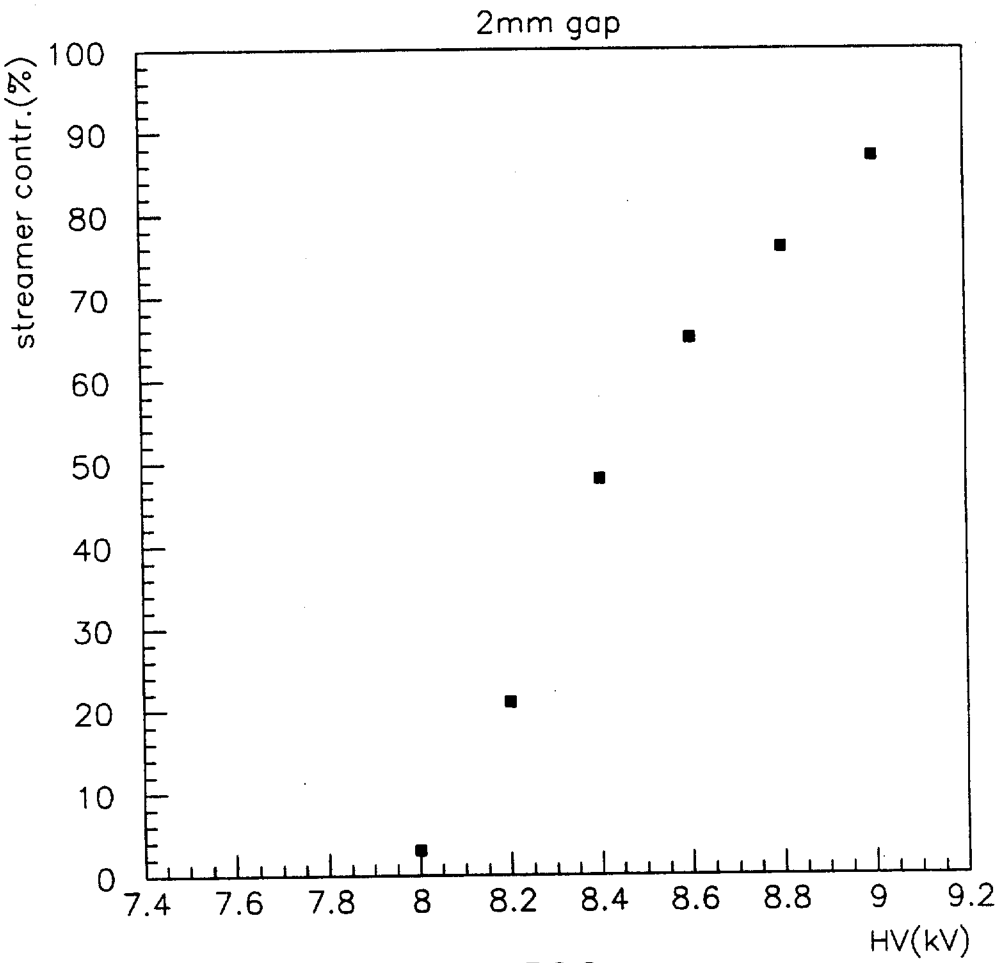

2mm gap
streamer contr.(%)
100
90
80
70
60
50
40
30
20
10
0
7.4
7.6
7.8
8
8.2
8.4
8.6
8.8
9
9.2
HV(kV)

FIG.2

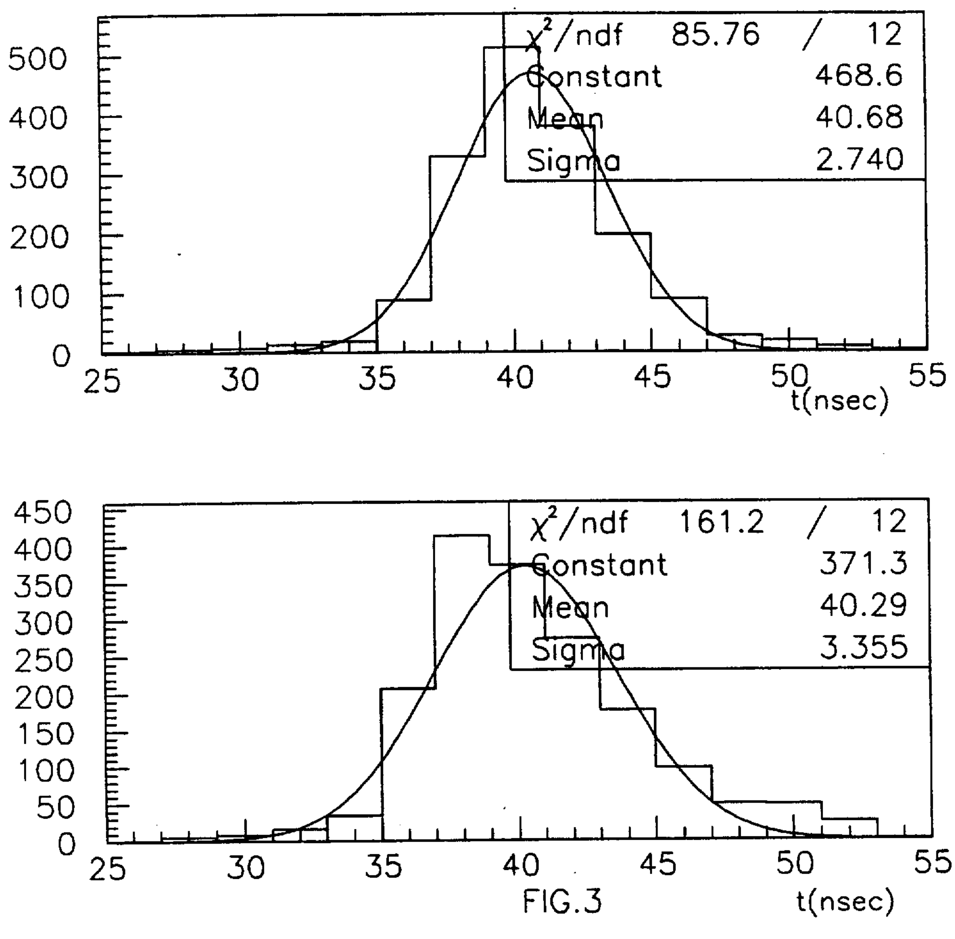

χ^2/ndf 85.76 / 12
Constant 468.6
Mean 40.68
Sigma 2.740
500
400
300
200
100
0
25 30 35 40 45 50 55
t(nsec)
χ^2/ndf 161.2 / 12
Constant 371.3
Mean 40.29
Sigma 3.355
450
400
350
300
250
200
150
100
50
0
25 30 35 40 45 50 55
t(nsec)

FIG.3

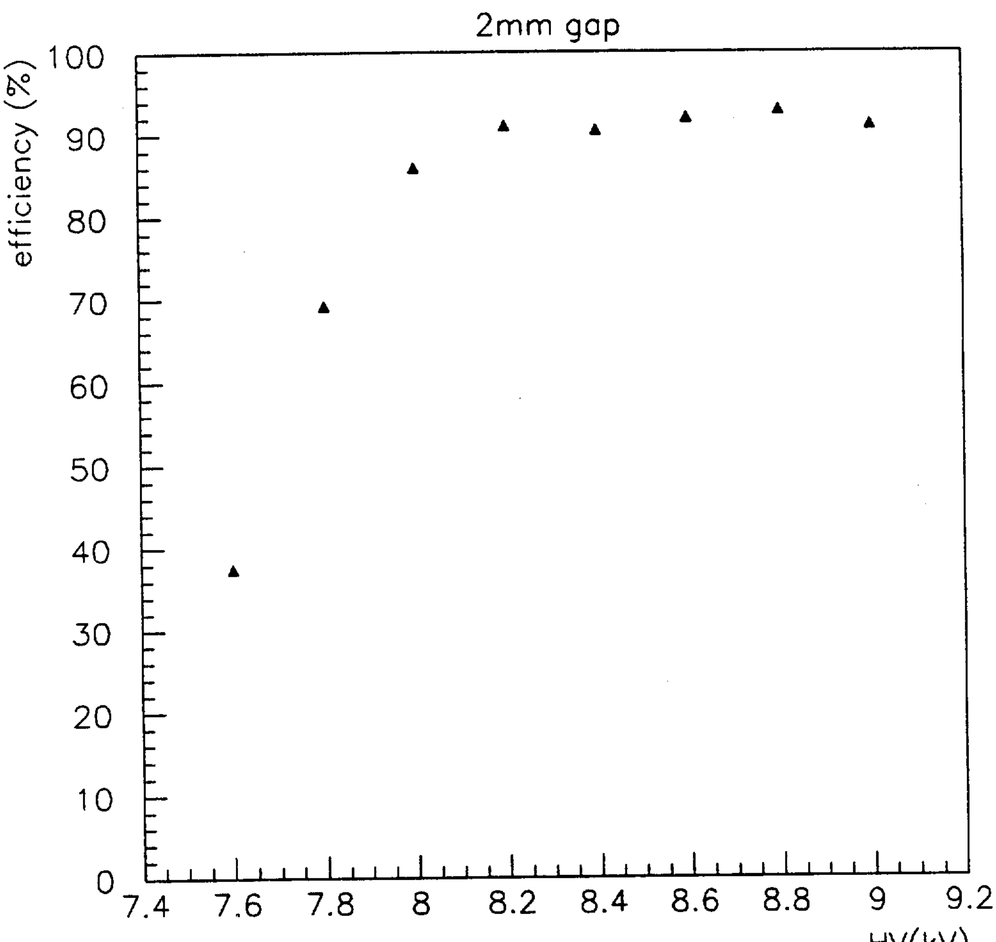

2mm gap
efficiency (%)
100
90
80
70
60
50
40
30
20
10
0
7.4
7.6
7.8
8
8.2
8.4
8.6
8.8
9
9.2
HV(kV)

FIG.4

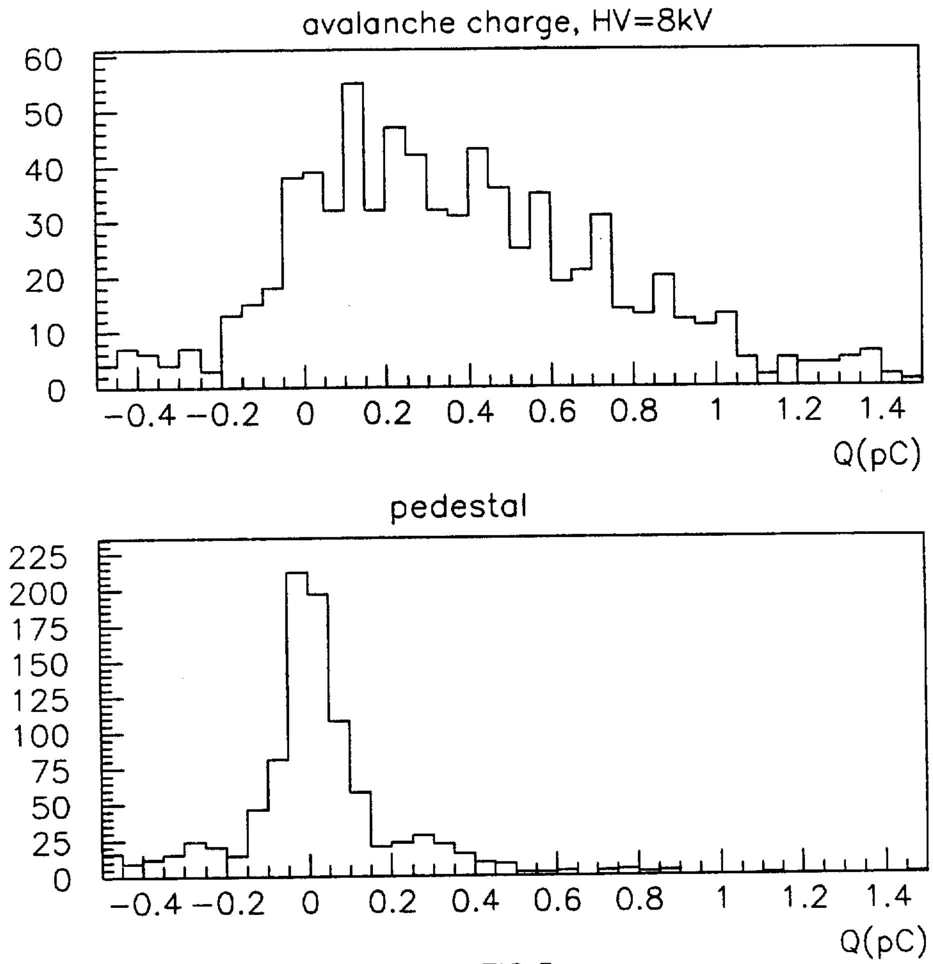

avalanche charge, HV=8kV
60
50
40
30
20
10
0
−0.4 −0.2 0 0.2 0.4 0.6 0.8 1 1.2 1.4
Q(pC)
pedestal
225
200
175
150
125
100
75
50
25
0
−0.4 −0.2 0 0.2 0.4 0.6 0.8 1 1.2 1.4
Q(pC)

FIG.5

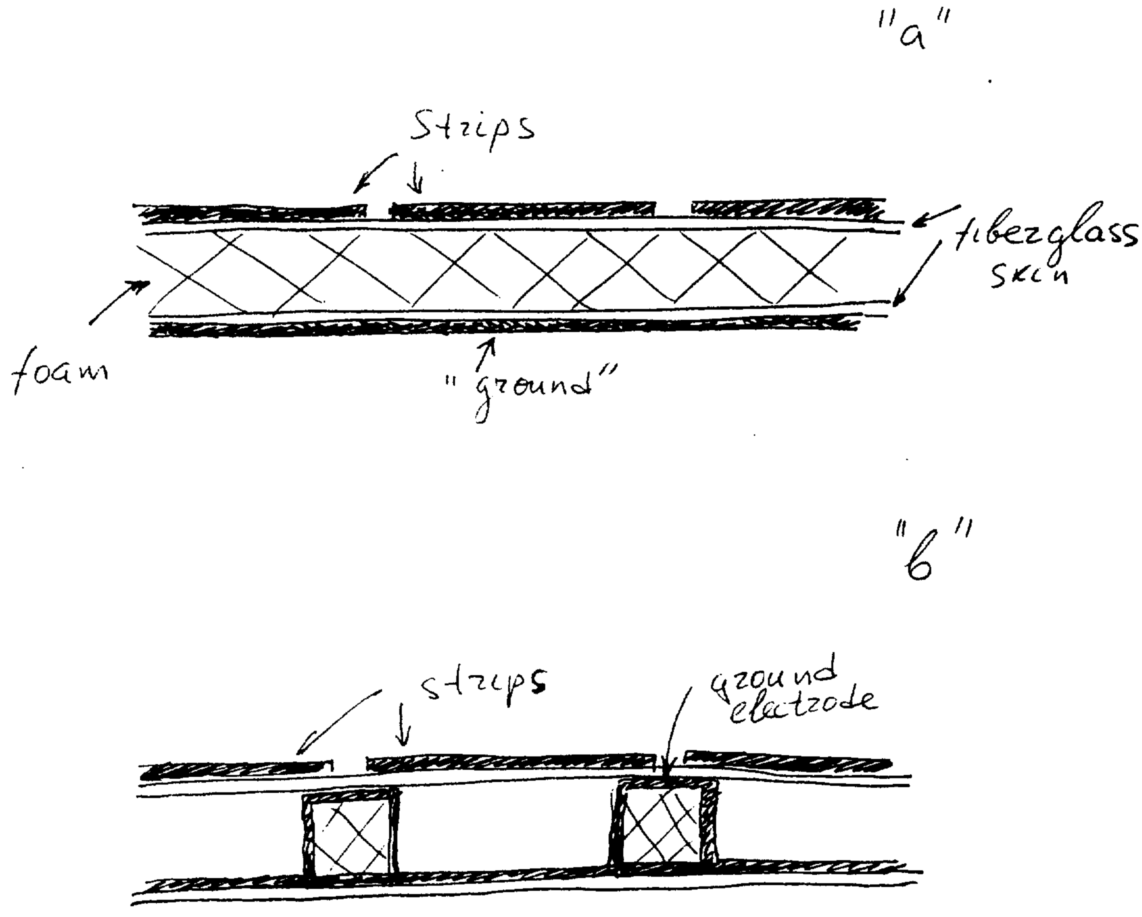

"a"
Strips
fiberglass skin
foam
"ground"
"b"
strips
ground electrode

Fig. 6

NstripX – NstripY correlation

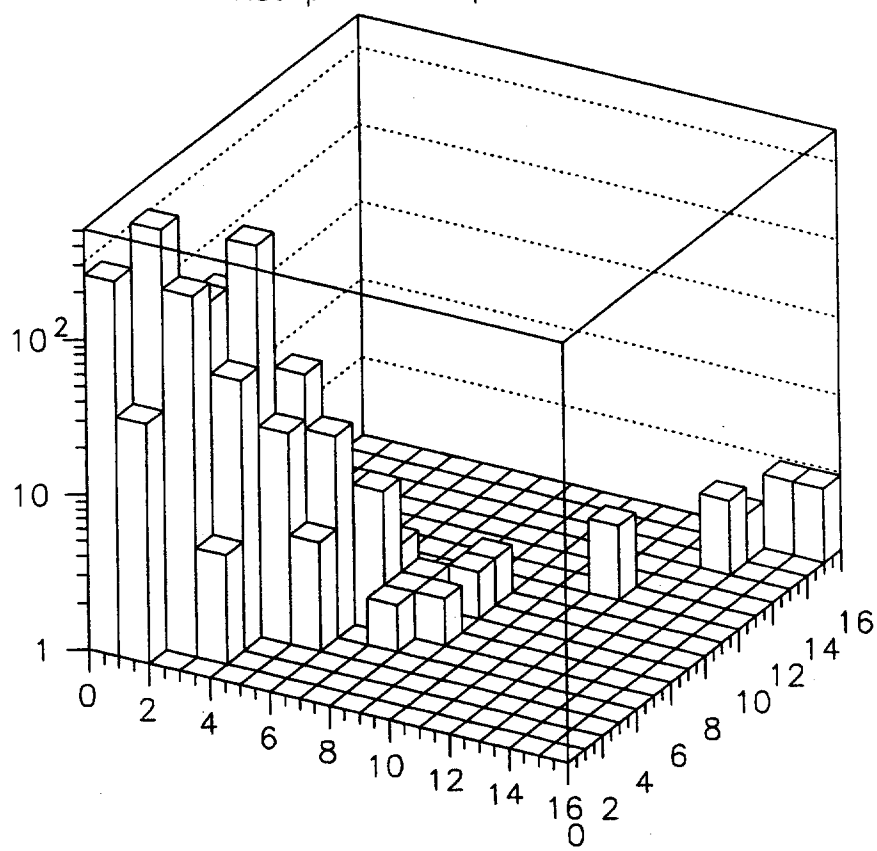
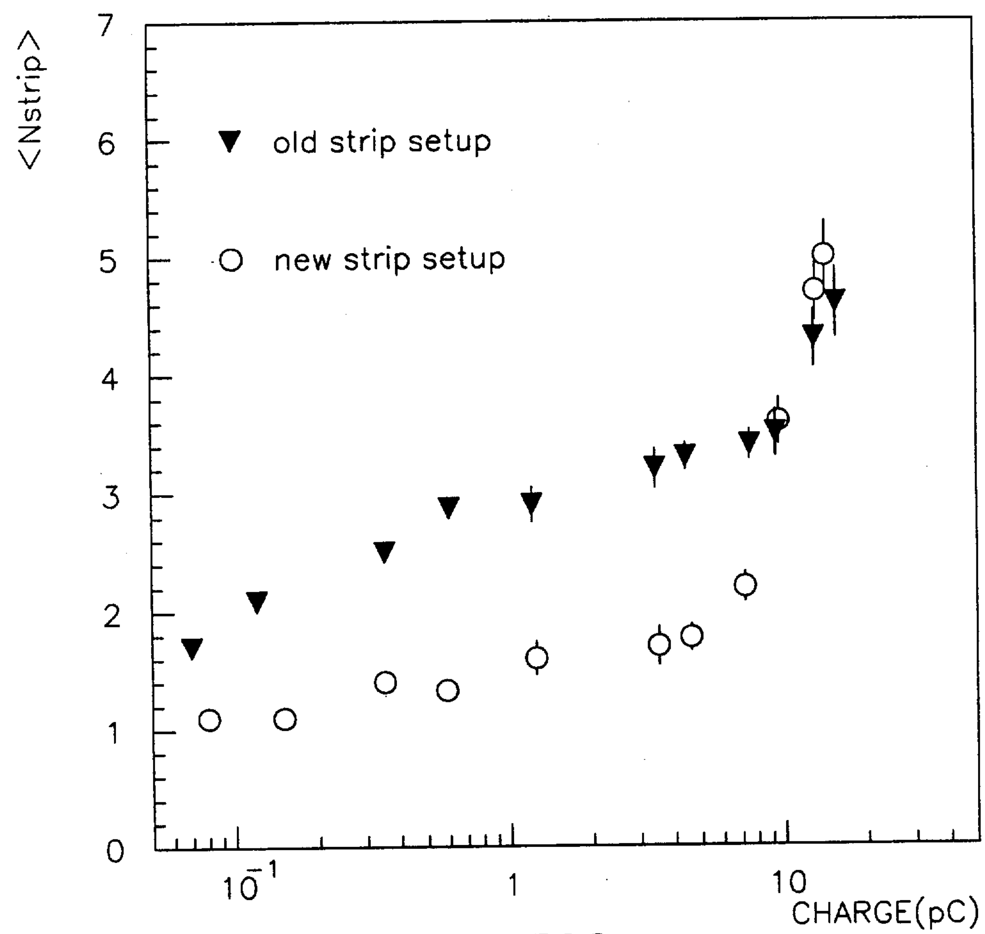


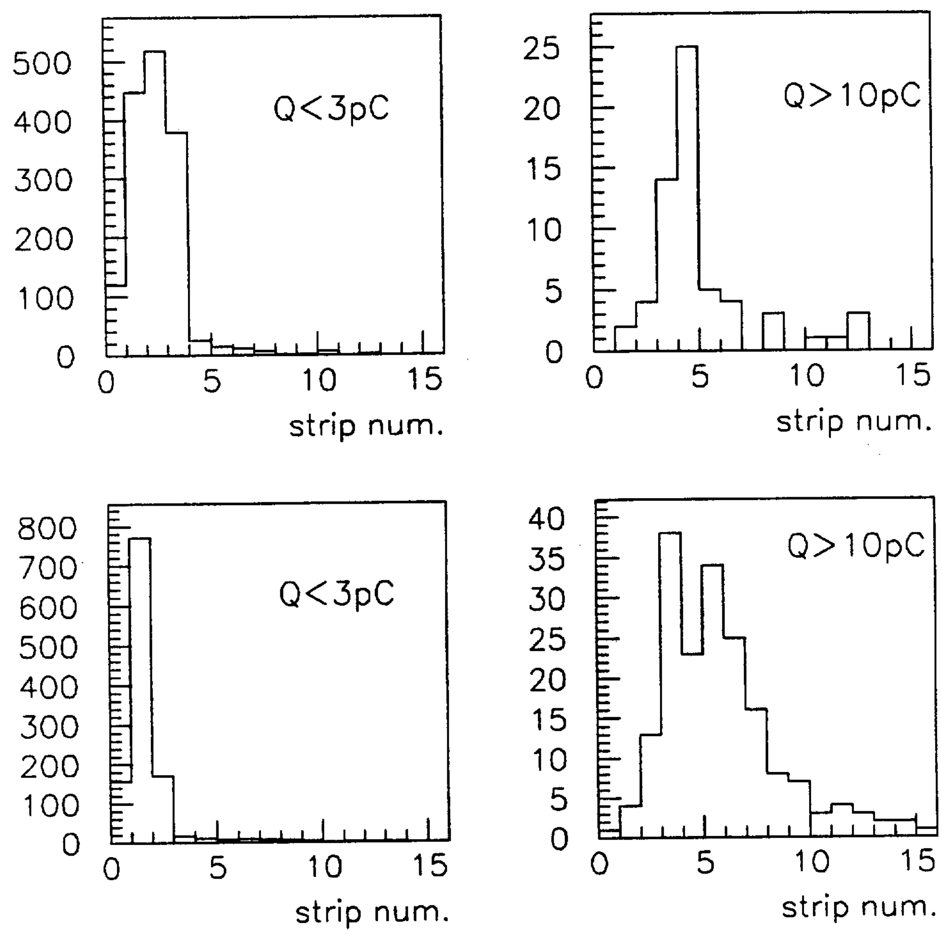
FIG.7



<Nstrip>
7
6
5
4
3
2
1
0
old strip setup
new strip setup
10^{-1}
1
10
CHARGE(pC)

FIG.8

FIG.9



500
400
300
200
100
0
0
5
10
15
Q<3pC
strip num.
25
20
15
10
5
0
0
5
10
15
Q>10pC
strip num.
800
700
600
500
400
300
200
100
0
0
5
10
15
Q<3pC
strip num.
40
35
30
25
20
15
10
5
0
0
5
10
15
Q>10pC
strip num.

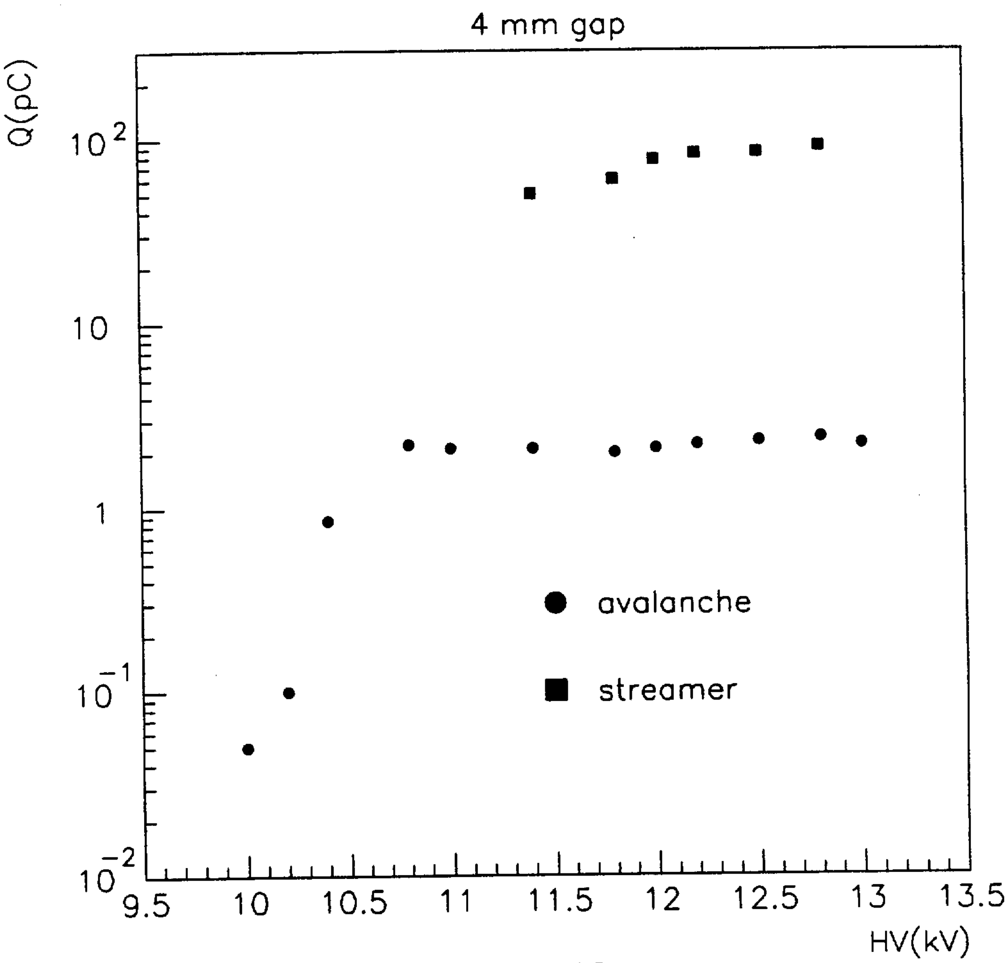
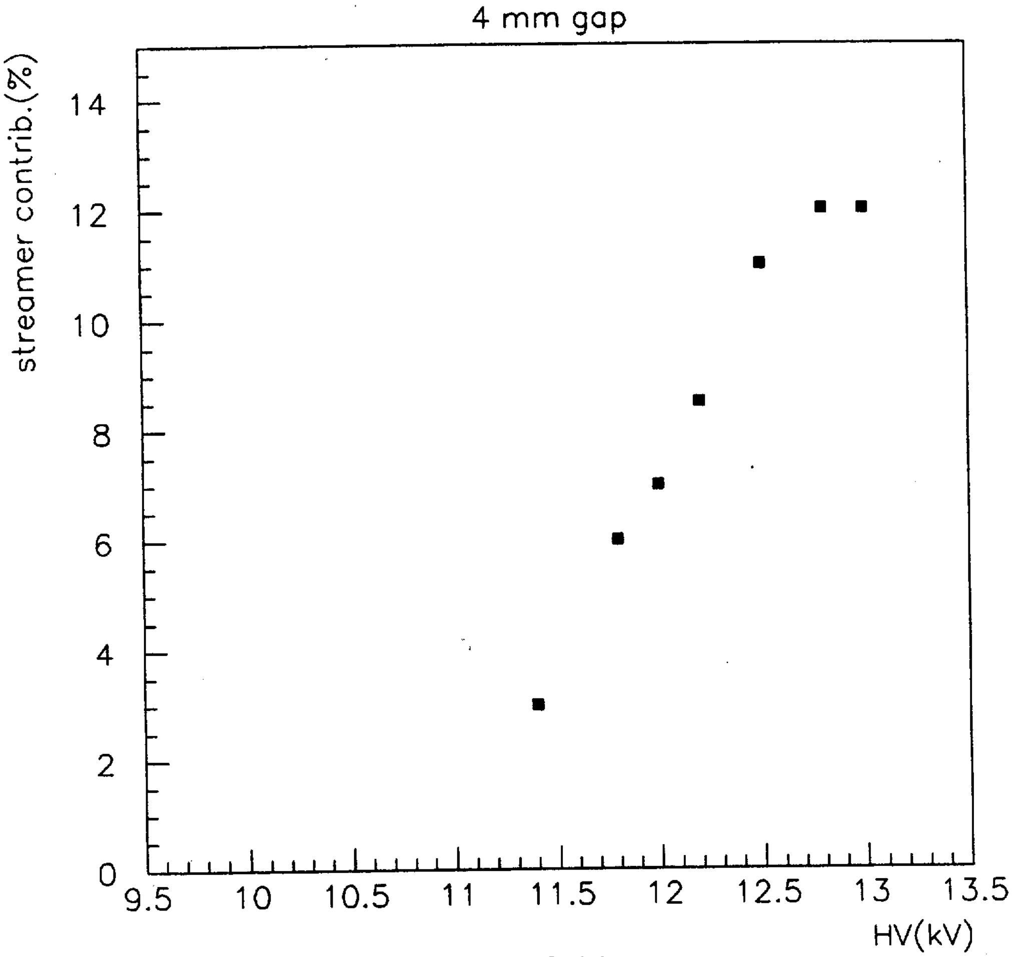

4 mm gap
Q(pC)
10^2
10
1
10^{-1}
10^{-2}
9.5
10
10.5
11
11.5
12
12.5
13
13.5
HV(kV)
avalanche
streamer

FIG.10



4 mm gap
streamer contrib.(%)
14
12
10
8
6
4
2
0
9.5
10
10.5
11
11.5
12
12.5
13
13.5
HV(kV)

FIG.11

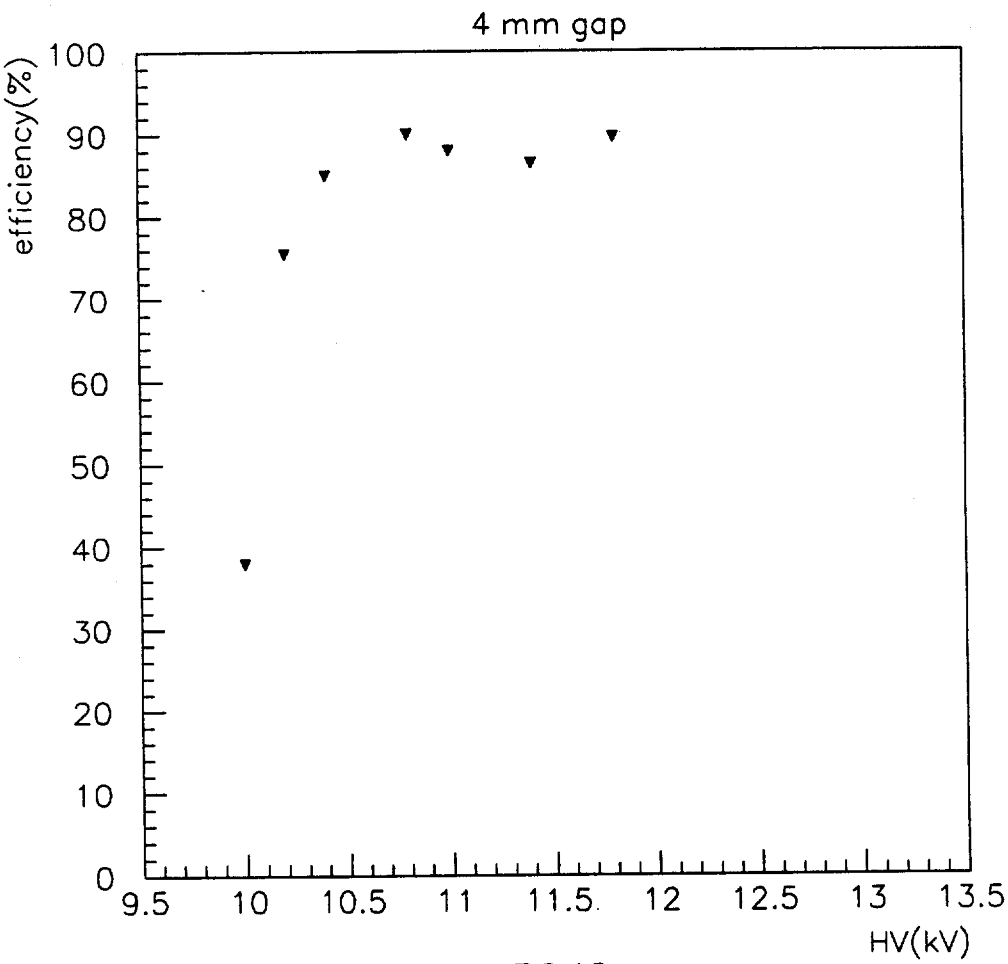

4 mm gap
efficiency(%)
100
90
80
70
60
50
40
30
20
10
0
9.5
10
10.5
11
11.5
12
12.5
13
13.5
HV(kV)

FIG.12