Laboratori Nazionali di Legnaro

L.N.L. - I.N.F.N. (REP) 114 / 96

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Submitted to Nuclear Instruments and Methods section A

A cura del servizio
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PRELIMINARY RESULTS FROM A NEW MICROSTRUCTURE FOR GASEOUS DETECTORS

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Abstract. A new microstructure for the detection of gas ionizing radiations has been characterized. For every-single detected ionizing radiation it gives a pair of "induced" charges of the same amount (pulses of the same amplitude), of opposite sign, with the same collection time and essentially in time coincidence, that are proportional to the primary ionization collected. Gas multiplication more than 10^5 with more than 10^8 electrons in the primary avalanches, working in the proportional region, are possible.The complete lack of insulating materials in the active volume of this microstructure avoids problems of charging-up and makes stable and repeatable its behaviour. This microstructure, through the use of the charge pair generated, allows the development of a position sensitive detector with a two-dimensional read-out. Using isobutane as the gas, an energy resolution of about 8% FWHM was recorded with α particles from an ^{241}Am source in ΔE fashion. Always in isobutane gas, X rays from a ^{55}Fe source were also detected.

1- Introduction

To develop a position sensitive detecting board with a two-dimensional read-out we wondered whether dimensions and working conditions for a microstructure, anode-point based, could be found that would allow the generation of charges proportional to the primary ionization collected, that is working in the proportional region. As will be seen later an anode-point configuration is well suitable for the purpose.

It was pointed out by previous investigations into this type of anode [1,2] that this strongly influences the mode of avalanching : a small (tens of microns) radius tip leads to early streamer operation. On the other hand it is also reported [2] that for a pin detector working in the proportional region the gas multiplication doubles every~ 100 V while the gas multiplication doubles in about 600 V when working in self-quenching streamer(SQS) mode. To find the proper sizes of this microstructure, and for practicality, we proceeded at first to detect α particles in room air looking for to avoid the corona noise. We tested then these microstructures in isobutane gas.

2- The leak microstructure

The leak microstructure (LM in the following), fig.1, consists of a wire-point (ϕ=10 up to 50μm) or a needle, acting as anode, well centred and perpendicular to the plane formed by two conductive and parallel strips, some tens microns thick, set at a distance b 100-400μm or less (cathode). As an alternative it can consist of a needle (or a wire-point)

as anode well centred in a hole ϕ=400 μm (or less) made on a conducting layer (a common G-10 board covered with a copper layer) as cathode [3,4,5]. An electron, produced anywhere in the gas volume, that reaches the strong electric field between the wire-point and the strips of the LM, will drift along the field lines towards the anode where it will experience an avalanche multiplication in the gas close to the surface of the wire-point. The signals from the LM are collected by the two fast wide-band pick-ups (Z_{in}=100 Ω, V_{out}/V_{in}~3 or 0.3 mV/μA) of fig.2. They give, for every-single detected ionizig radiation, a pair of charges of the same amount (pulses of the same amplitude), of opposite sign, with the same collection time and essentially in time coincidence, as can be seen in fig.3 . When the distance b (fig.1) of the two borders of the strips nearest to the wire-point is in the range 100-400 μm (or few more) , it is possible to detect α particles in room air without corona noise or instabilities due to secondary processes with a High Voltage (HV) ranging from 650 to 1200 V depending on the LM size : in fig.3 an example.

3- Experimental data

In fig.4 is reported the gas multiplication, in 760 Torr of isobutane , as function of the HV, of three different LM's [1: wire-point ϕ=20 μm, b=200 μm. 2: wire-point ϕ=20 μm, b=300 μm. 3: a needle (with tens of microns radius tip) of ϕ=400 μm centred in a hole ϕ=400 μm] . In fig. 5 pulses from a LM of the type 3 (needle) working at 1200 V with a ^{55}Fe source in 760 Torr of isobutane. In these experimental conditions the absorbed X ray of 5.9 KeV from the ^{55}Fe source gives rise up to ~200 electrons of primary ionization. With the formula $G=VT/2AZn_oe$ where G=gas multiplication, V=maximum recorded amplitude (~80 mV) of these pulses, T=the duration of the ion collection process (~30 ns.), A=electronic amplification (~3), Z=input impedance of the pick-ups (100 Ω) , n_o=200 and e is the electron charge we evaluate the gas multiplication to be about 1.25×10^5. In fig. 6 is shown an energy distribution, obtained in 86400 seconds (one day) of continuous running, with a LM of the type 3 (needle) working at 1000 V in 500 Torr of isobutane. An ^{241}Am uncollimated source was set ~16 millimetres above the LM. No electrode was inserted between the source and the LM to create a drift field. The LM collected therefore only that part of the primary ionization produced in its active volume. In particular for the α's it is a ΔE fashion measurement. In this energy distribution it is possible to distinguish two fluorescence peaks, a broad peak due to the X rays (mainly 60 KeV) and a narrow one due to α particles. Over-imposed to this distribution, for sake of comparison, is the energy distribution obtained with a ^{55}Fe uncollimated source in the same working conditions with the same LM. From these distributions, together with the pulses of fig.7 recorded during the acquisition of the distribution of fig.6, we learned, once more [3,4,5], the following things:

a) the LM has spectroscopic capabilities

b) the narrow α peak (~8% FWHM) testifies the very good stability of the gas multiplication over 24 hours of continuous running. This is due to the absolute absence of insulating materials in the active volume of the LM (see fig. 1)

c) looking at the pulses recorded in fig. 7 (5ns/div, 100mV/div) , in particular at those due to α particles (~400 mV and ~40 ns of collection time) , it is possible to calculate the number N of electrons in the primary avalanche to be $N=VT/2AZ_0e$ equal to more than $1.6x10^8$ still working in proportional region (the plot 4 in the fig.4 reports the gas multiplication, at 500 Torr of isobutane, of the LM type 3 used for the distributions of fig.6). This is an unexpected performance of the LM , considering that the maximum size of the primary avalanche before streamering is $5x10^6$ for the pin detectors [2] and $20x10^6$ for the wires [6].

An aluminium foil, 50 μm thick, was set ~3mm above the same LM type 3 (needle) in 760 Torr of isobutane. A collimated ^{55}Fe source was leaned on the aluminium foil set at -1560V. The LM worked at -1300V with an estimated (from the amplitude of the pulses ~180mV) gas multiplication about $2.8x10^5$. In fig.8 it is possible to identify the main peak of the 5.9 KeV x-rays (on the right shoulder the 6.5 KeV low intensity peak), the peak due to the aluminium fluorescence and the peak (cut) due to the few secondary electrons emitted by the surface of the aluminium foil. The left shoulder of the main peak is due to the sum of the fluorescence peaks of the materials present in the experimental set-up (the source was collimated through a hole , 1mm in diameter, on a piece of iron 2.2mm thick; the copper of the cathode; the tip of the anode-needle is nikel plated; the iso-C_4H_{10} gas). The size of the avalanches in the main 5.9 KeV peak result to be of $\sim 5.6x10^7$ electrons.

It is possible to obtain results similar to those just seen also with LM's of the types 1 and 2.

In order to have an evaluation about the active area of a single LM α particles were detected with a silicon detector and with a LM of the type 1 (b=200 μm and ϕ=20 μm , HV=-830 V , 500 Torr of isobutane) with the source set at the same distance above the two detectors . On the basis of the counting rate obtained with each detector, and the known area of the silicon detector, it was estimated that the LM was efficient in a surface of about 1-2 mm^2. This is an important information to design a multi -LM structure detector. It suggest that a pitch of 1mm is adequate to have a good detection efficiency.

4- REMARKS

At this point it has to be pointed out that for a gas detector the transition from the proportional region to SCS behaviour has , as a function of the applied high voltage, a leap character [2,6,7] , and that from the photographs of the SCS [6,7] these are objects of some hundreds microns in diameter and several hundreds microns in length .

We didn't note leaps in the pulse amplitude , as results of the increasing high voltage, working with the LM's; on the contrary we got a behaviour reported in fig.4 which is characteristic of the proportional region.

Furthermore, considering that in the LM's we have tested the distance tip-cathode was 200 microns or less, we can say that there is no enough space for the SQS development. This leads to say that a LM can work only in the proportional region or go in spark break-down through the conductive quasi-metal thread [6] SQS which short-cicuits the gap preventing any useful operation.

Defining as "neck" the volume of a LM surrounding its anode and delimited by the upper and the lower planes of the strips, the (primary) avalanche, generally starting above the tip and outside the neck, mostly will propagate thickening itself through the photo-electrons generated in the neck were the electric field has its maximum intensity. It behaves as if the neck would be an "avalanche proportionally amplifying cavity". This way of thinking, even if in a tentative way, fits the results up to now obtained and what we have observed but it requires more investigations, especially with photographic instrumentation which we don't have, to be confirmed.

5- The two-dimensional position sensitive detecting board

In a sandwich, fig 9, made with two pieces of printed circuits board (glass-epoxy laminate, both ~10x10 mm^2 and 1 mm thick, with copper foils 37μm thick coating both sides) a matrix of nine holes of ϕ=400 μm was drilled (pitch 1 mm). One of the two external conducting-layers was divided into strips, separated by the nine holes. The other external conducting-layer was also divided into strips, orthogonal to the previous ones, but centred on the holes. Nine needles, ϕ=400 μm, were inserted with their points well centred in the holes between the strips to form nine LM's. On the other external layer the needles passing in the middle of the strips were soldered to them and cut. On the two internal copper-layers, adhering to each other, and forming an intermediate conducting layer, the holes were reamed to prevent contact with the pass-through needles. The structure, therefore, consists of a cathodic surface (**detecting surface**) with nine LM's, of an **intermediate conducting layer** and of an anodic surface (**backplane**: strips in contact with the needles). Let us name this structure as the **L.N.L. structure** (Laboratori Nazionali di Legnaro). After cleaning up with trichlorethylen in an ultrasonic bath we verified that each of the nine LM's were running with α particles. In fig. 10 an energy distribution obtained with α particles with the L.N.L. structure in 600 Torr of isobutane working at 1100V with a drift field of 330V/cm is shown. The latter is the sum of the spectra of the nine LM's working together at the same HV but with different gas multiplication (due to little differences in the mechanical sizes of the LM's).

It is possible to obtain fast "kicks" pulses by connecting the intermediate layer of the L.N.L. structure to a fast pick-up. These kick pulses are the CR of the anodic and the cathodic pulses of the external surfaces (no matter how they were subdivided) offering a good trigger to coordinate them in a two-dimensional read-out system. Moreover the intermediate layer limits the capacitive cross-talk (or can shield electrostatically quite completely if grounded) between the two external surfaces allowing, at the same time, to have strips with a well

defined characteristic impedance Z_0 which, if properly matched, prevents possible reflections and/or ringing due to the very fast pulses.

CONCLUSIONS

It was put in evidence the possibility to use points, arranged in particular microstructures, to detect gas ionizing radiations working in proportional region with high gas multiplication and consequently with output pulses of high amplitude on low impedance with a rapid risetime. The ratio Q_X/Q_Y of each charge-pair supplied by these microstructures for each detected ionizing radiation is 1 and both Q_X and Q_Y charges of each pair give the same energy and time information. The energy resolution FWHM with α particles is good. The absence of insulating materials in the active volume of this microstructure gives stable and repeatable its behaviour. The possibility of communication between two conducting surfaces, via "conductivity" through the wire-points of the LM's was verified in practice with the L.N.L. structure of fig.9 The two external surfaces, which do not need to be parallel and flat, can be subdivided, not necessarily, in straight orthogonal strips, to form a sensitive position two-dimensional readout. Between the two "active surfaces" it is possible to insert a third intermediate conducting layer to limit (or practically suppress) the capacitive cross-talk between them. Moreover this intermediate layer can give a very fast OR-trigger to coordinate the charges (pulses) of the two external surfaces and to govern the data acquisition system. We are now developing four samples of the LNL structure of fig.9 using metallized holes and ball bolding techniques.

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FIGURE CAPTIONS

Fig.1- Cross-section of a LM (not in scale) and electronic set-up. Fig.2-Anodic and cathodic wide-band pick-ups. Fig.3-Anodic and cathodic pair-pulses of α particles detected in open air. Fig.4-Gas multiplication in 760 Torr of isobutane. Fig.5-Anodic pulses with a ^{55}Fe source. Fig.6-Energy distribution with an ^{241}Am source. Fig.7-Anodic pulses recorded during the acquisition of the spectrum of fig.6. Fig.8-Energy distribution with ^{55}Fe in 760 Torr of isobutane. Fig.9-The L.N.L. structure. Fig.10-Energy distribution obtained with the L.N.L.stucture.

REFERENCES

[1] G. Comby, Ph. Mangeot, J. Tichit, H. de Lignieres, J.F. Chalot et P. Monfray, Nucl. Instr. and Meth. 174 (1980) 77.

[2] J E Bateman, Nucl, Instr and Meth. A 238 (1955) 524.

[3] M. Lombardi, F. Lombardi, L.N.L.-I.N.F.N. (REP) 104/96.

[4] M. Lombardi, F. Lombardi, L.N.L.-I.N.F.N. (REP)- 105/96.-226

[5] M. Lombardi, F. Lombardi, accepted contribution to the 4th International-Conference on Position-Sensitive Detectors- The University of Manchester 9-13 September 1996.

[6] G.D. Alekseev, N.A. Kalinina, V.V. Karpukhin, D.M. Khazins and V.V. Kruglov. Nucl. Instr. and Meth. 177 (1980) 385-397.

[7] M. Atac and A.V. Tollestrup. Nucl. Instr. and Meth. 200 (1982) 345-354

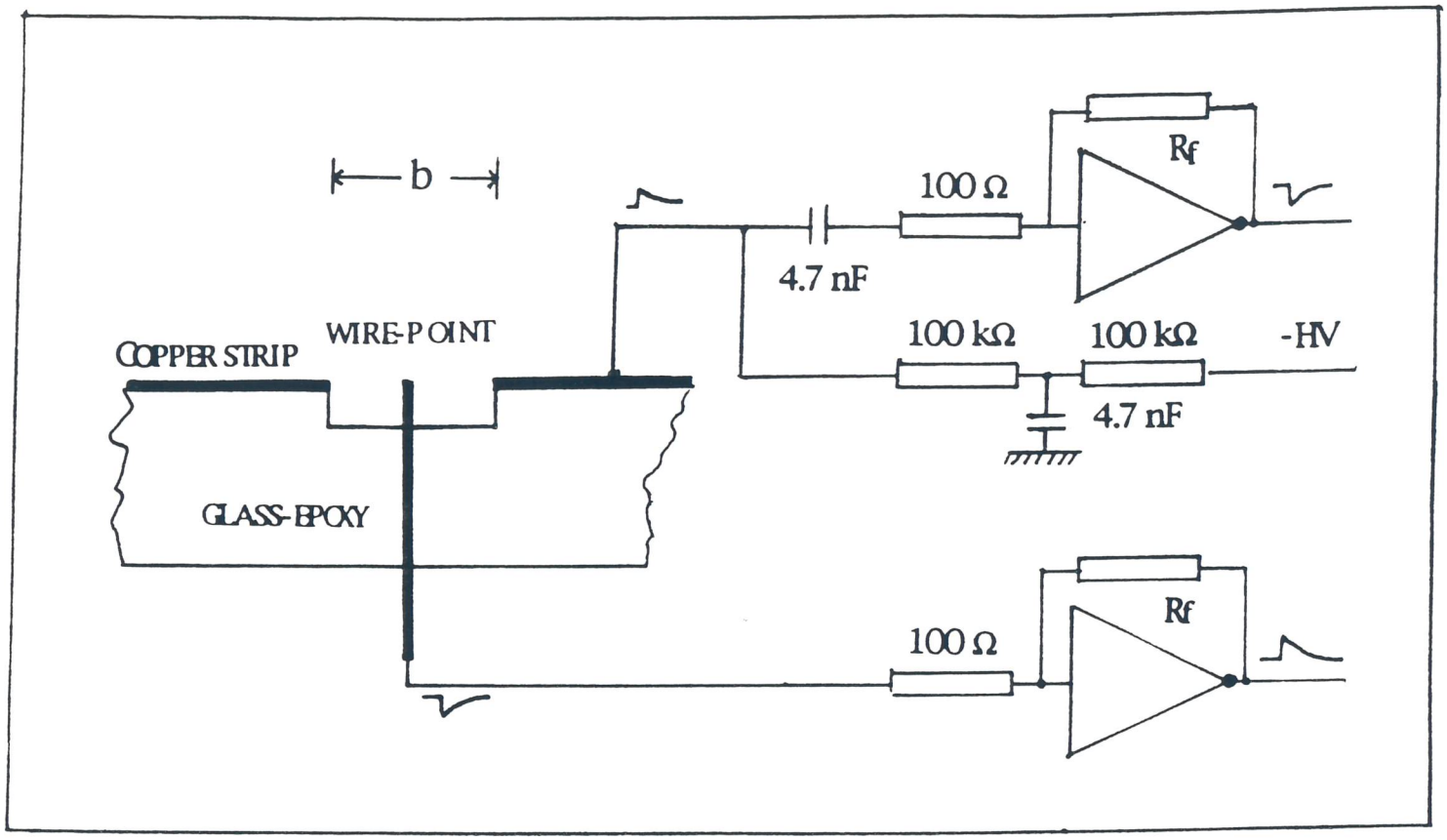
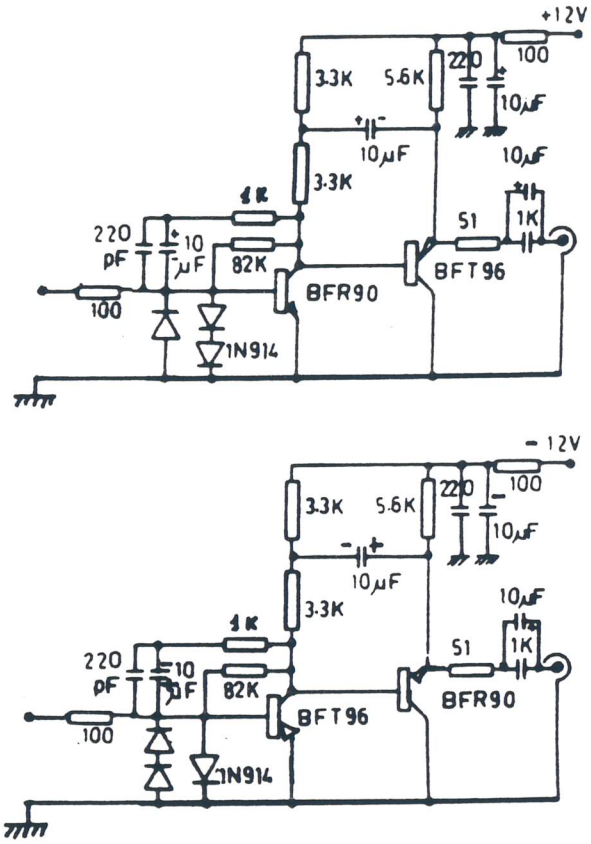

b
Rf
100 Ω
4.7 nF
COPPER STRIP
WIRE-POINT
100 kΩ
100 kΩ
-HV
4.7 nF
GLASS-EPOXY
Rf
100 Ω

Fig.1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5.6K
220
100
10µF
10µF
10µF
3.3K
4K
220
pF
10
µF
82K
51
1K
BFR90
BFT96
100
1N914
-12V
3.3K
5.6K
220
100
10µF
10µF
10µF
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51
1K
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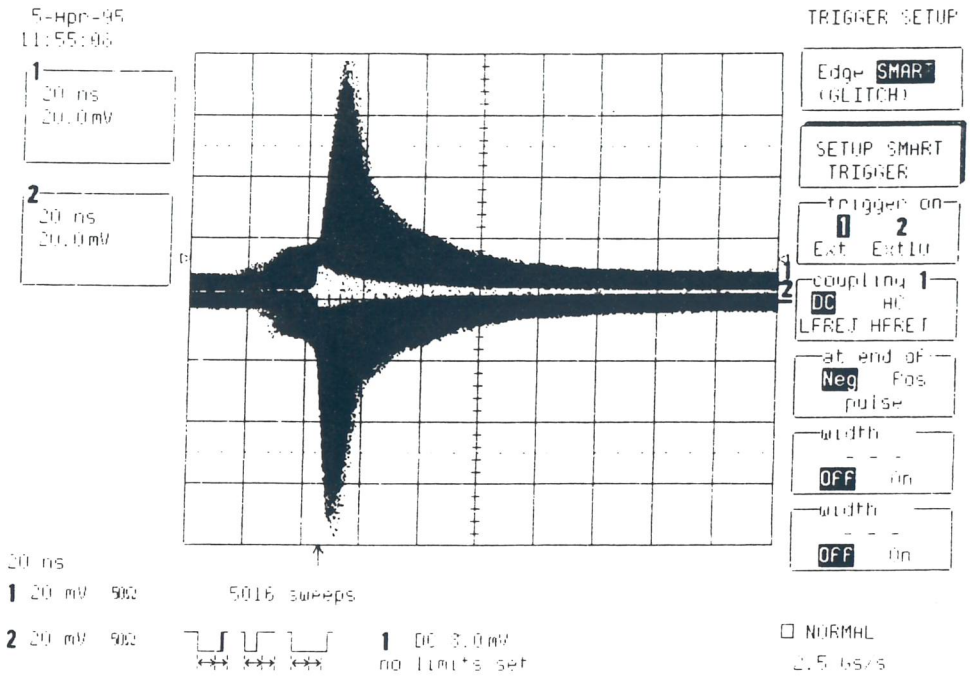
BFR90
100
1N914

Fig. 2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1
20 ns
20.0mV
2
20 ns
20.0mV
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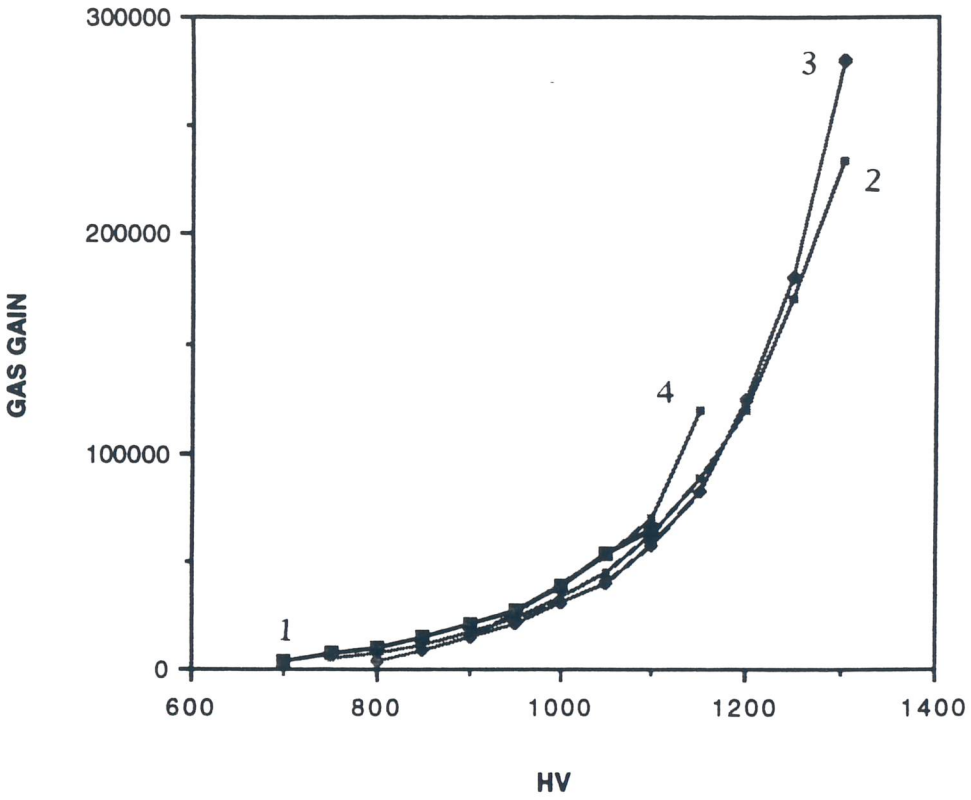
Edge SMART
(GLITCH)
SETUP SMART
TRIGGER
trigger on
1 2
Ext Ext10
coupling 1
DC HF
LFREJ HFREJ
at end of
Neg Pos
pulse
width
OFF On
width
OFF On
20 ns
1 20 mV 90Ω
2 20 mV 90Ω
5016 sweeps
1 DC 3.0mV
no limits set
NORMAL
2.5 GS/s

Fig. 3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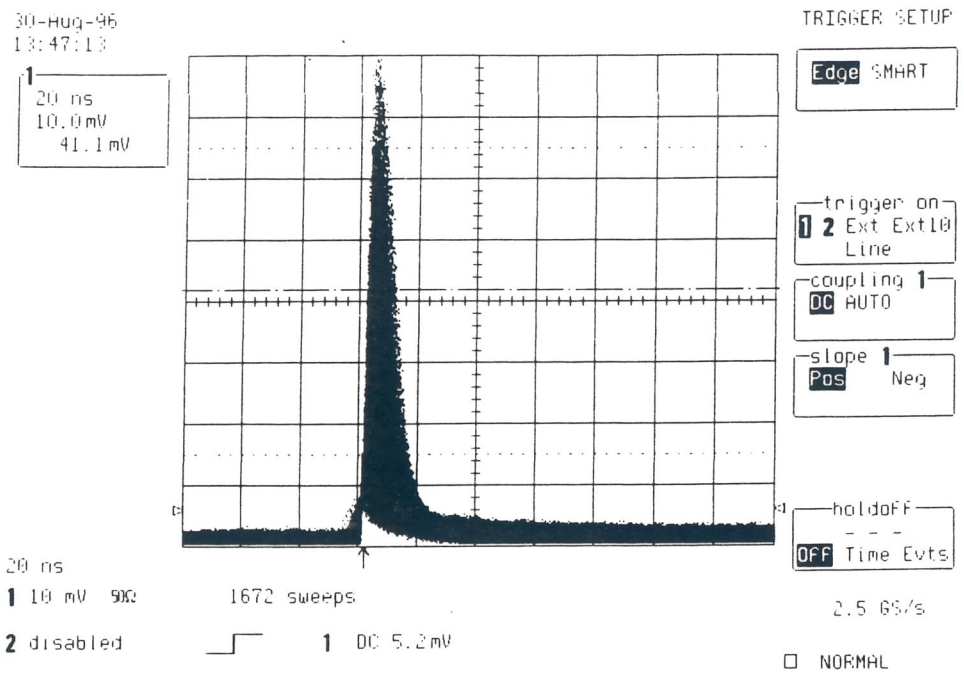
200000
100000
0
GAS GAIN
600
800
1000
1200
1400
HV
1
2
3
4

Fig. 4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1
20 ns
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41.1 mV
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Edge SMART
trigger on
1 2 Ext Ext10
Line
coupling 1
DC AUTO
slope 1
Pos Neg
holdoff
Off Time Evts
20 ns
1 10 mV 9MΩ
1672 sweeps
2.5 GS/s
2 disabled
1 DC 5.2mV
NORMAL

Fig. 5

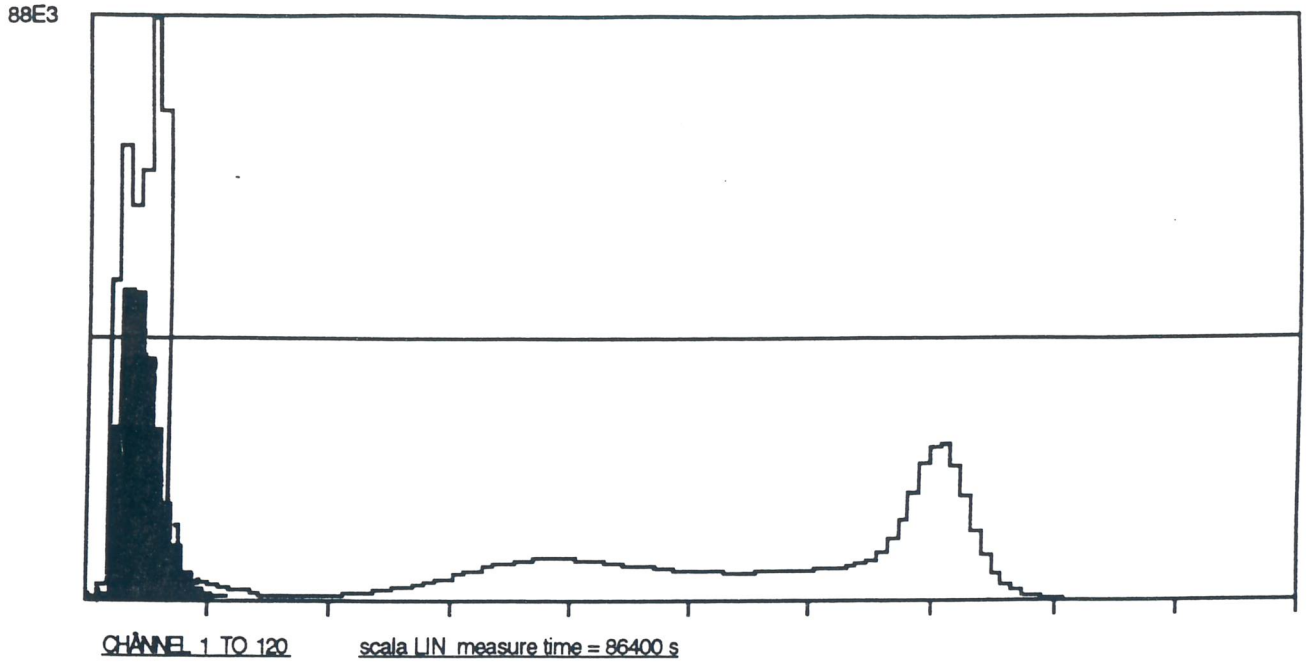
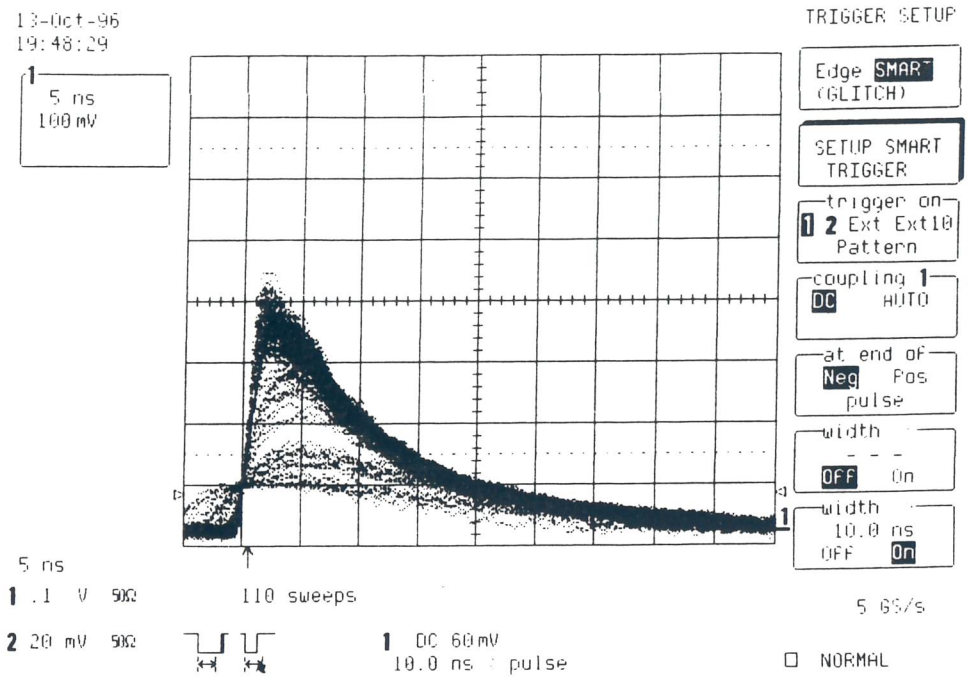


Fig. 6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1
5 ns
100 mV
TRIGGER SETUP
Edge SMART
(GLITCH)
SETUP SMART
TRIGGER
trigger on
1 2 Ext Ext10
Pattern
coupling 1
DC AUTO
at end of
Neg Pos
pulse
width
- - -
OFF On
width
10.0 ns
OFF On
5 ns
1 .1 V 9Ω
110 sweeps
5 GS/s
2 20 mV 9Ω
1 DC 60mV
10.0 ns pulse
NORMAL

Fig. 7

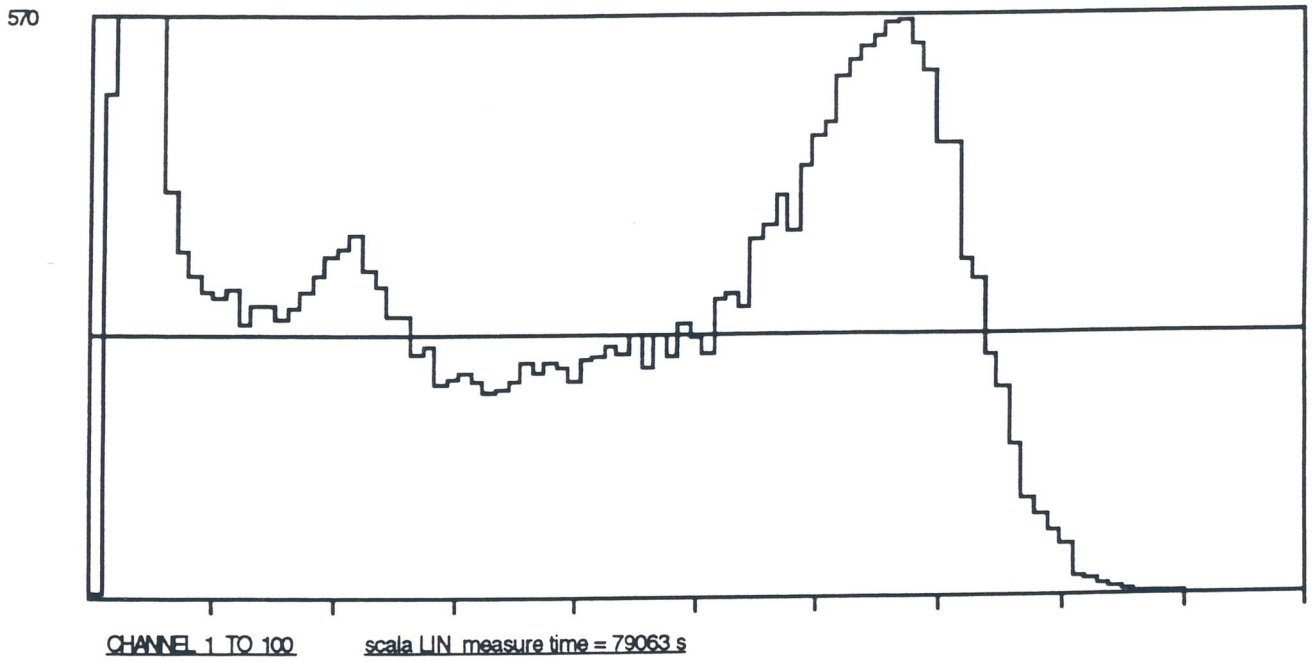

Fig. 8

Fig. 9

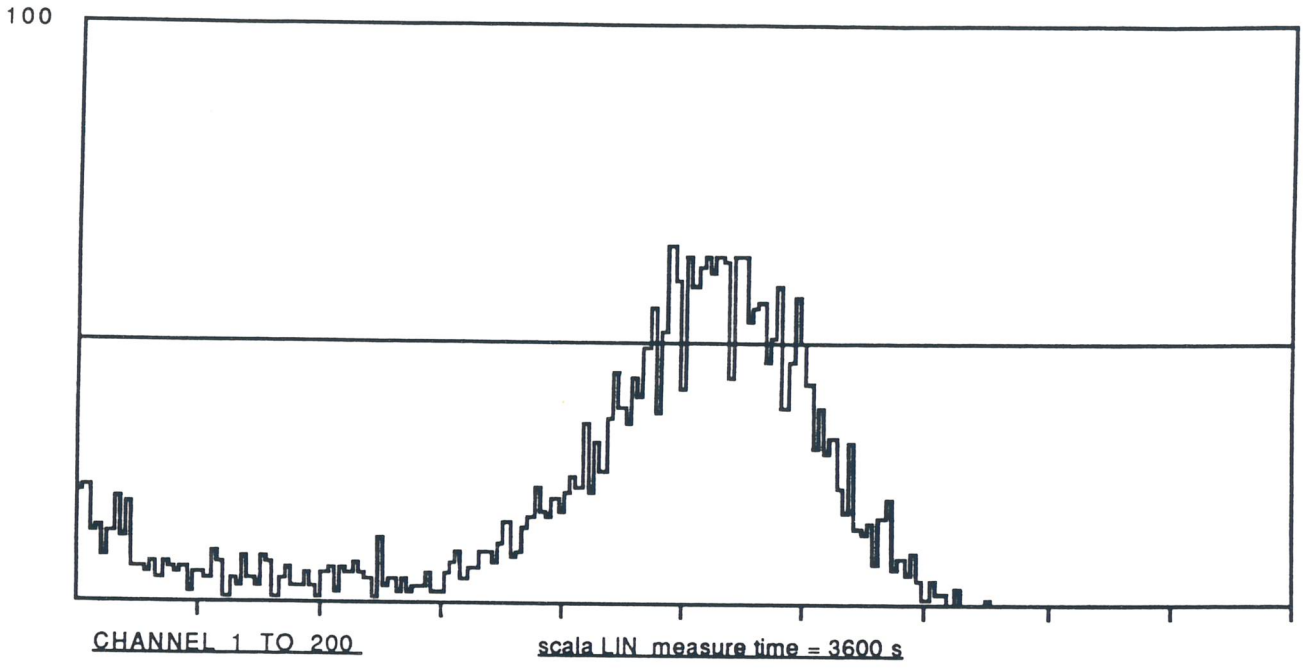

Fig. 10