

The leak microstructure

M LOMBARDI, C BAIOCCHI, A BATTISTELLA, G BALBINOT, H HUO-JA
GUOXIANG* and F S LOMBARDI†

INFN Laboratori Nazionali di Legnaro, Padova, Italy

*China Institute of Atomic Energy, Nuclear Physics Division, P.O. Box 275(80), Beijing 102413,
People's Republic of China

†Osservatorio Astronomico S. Lucia-05039-Stroncone, Terni, Italy

Abstract. The capabilities of a new microstructure, anode point based, for the detection of gas ionizing radiations are presented. For every single detected ionizing radiation it gives a pair of 'induced' charges (anodic and cathodic) of the same amount (pulses of the same amplitudes), of opposite sign, with the same collection time and essentially in time coincidence, that are proportional to the primary ionization collected. Each pulse of a pair gives the same energy and timing information, thus one can be used for these information and the other for the position. The complete lack of insulating materials in the active volume of this microstructure avoids problems of charging-up and makes stable and repeatable its behavior. It is possible to observe primary avalanches with a size of more than 2.5×10^7 electrons (4 pC), which give current pulses with a peak of more than 0.26 mA on 100 Ohm and about 30 ns duration, with 5.9 KeV X-rays of ^{55}Fe working in proportional region in 760 Torr of isobutane gas. Single electrons emitted by a heated filament ($E_c < 1$ eV) can also be detected in 760 Torr of isobutane; with an estimated gas gain of 1.2×10^6 and a counting rate up to 800 Kpulses/sec per single microstructure. Some new features and three different types of sensitive-position two-dimensional read-out detectors based on these microstructures, which are in developmental stage, are presented.

Keywords. Imaging gaseous detector.

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1. The leak microstructure

The leak microstructures (LM in the following) are described elsewhere [1–4]. Here we remind briefly that a LM (the conceptual layout is shown in figure 1) consists of a thin conductive wire-point ($\Phi = 10$ up to $50 \mu\text{m}$) or a needle (with tens of microns radius point), acting as anode, which is placed well centered and perpendicular to the plane formed by two conductive and parallel microstrips, some ten microns thick, set at a distance of $400 \mu\text{m}$ or less (cathode). As an alternative, the needle (or the wire part) is well centered in a hole $\Phi = 400 \mu\text{m}$ (or less) made on a common G-10 board of the printed circuit. An electron, produced anywhere in the gas volume, that reaches the strong electric field between the anode and the cathode, 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 anodic

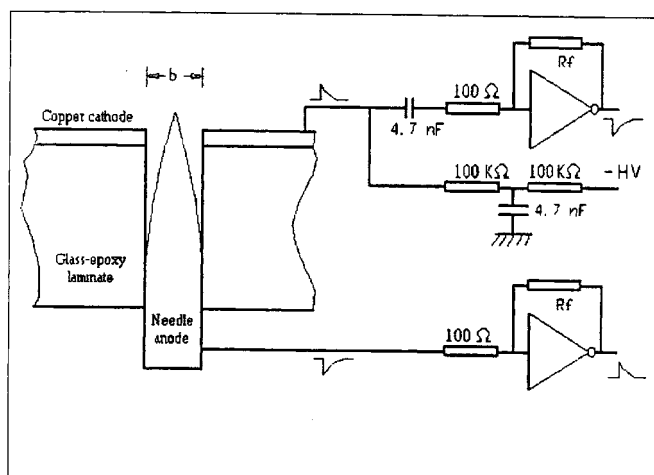


Figure 1. Cross-section of a LM (not to scale) and electronic set-up.

point. The ‘induced charges’ (anodic and cathodic) are collected by two fast wide-band current pick-ups (input impedance $Z = 100 \text{ Ohm}$, $V_{\text{out}}/V_{\text{in}} = 3$ or $0.3 \text{ mV}/\mu\text{A}$).

2. Performances and properties of the LM

We like to summarize briefly the main performances and properties of the LMs elsewhere reported [1–4]:

- The LMs are able to work in the proportional region giving spectroscopic information.
- The pair of ‘induced’ charges (anodic and cathodic) generated, giving both the same information, can be used one for energy and timing purposes and the other, in a multi-LM matrix, for the position.
- Very high gas gain (up to 6.6×10^5) in isobutane and about one order of magnitude less with Ar-methane (90–10), using a ^{55}Fe source. With alpha particles and 500 Torr of isobutane, the sizes of the primary avalanches in proportional region are more than 1.6×10^8 electrons (25 pC) giving current pulses with a peak of more than 1.3 mA on 100 Ohm and about 40 ns duration while with 5.9 X-rays of ^{55}Fe in 760 Torr of isobutane more than 2.5×10^7 (4 pC) with a peak current of $260 \mu\text{A}$ on 100 Ohm and about 30 ns duration.
- The good energy resolution (8% FWHM), obtained in a continuous run of 24 hours, with the alpha particles of a ^{241}Am source, testify the good stability of the LMs due to the absolute lack of insulating materials in their active volume which avoids problems of charging-up. The energy resolution with 5.9 KeV X-rays of ^{55}Fe is also good.
- The short duration (20–30 ns) of the current pulses permits a high counting rate. Single electrons emitted by a heated filament ($E_c < 1 \text{ eV}$), in 760 Torr of isobutane

with an estimated gas gain of 1.2×10^6 , are detected with a counting rate of up to 800 Kpulses/s per single LM.

- The fast rise time of the current pulses, in the order of one ns or less, permits a good time coincidence between the *X* and *Y* microstrips, as we shall see later.
- All the experimental data reported elsewhere [1–4] and summarized here were obtained using wide-band current pick-ups with an input impedance of 100 Ohm. The possibility to work with the LMs on low impedance permits to match the characteristic impedance of the microstrips (50–150 Ohm [5]) to prevent the ringing of the fast signals.
- The materials used for cathodes and anodes, especially if the anodes are made with tungsten points, give great ability to withstand sparking.
- High versatility with which they can be mechanically assembled to form different structures of position-sensitive two-dimensional proportional counter.

3. Further performances and properties of the LM

Figure 2 reports, using alpha particles in open air, an evaluation of what happens when the height of the point of a LM, with respect to the plane of the cathode, is changed. We can see that the detecting efficiency depends on the height of the point – higher the point more is the efficiency (but as less is the gas gain). This behavior is confirmed by the spectrum, figure 3, obtained with an ^{241}Am alpha source, lying about 15 mm above the detector without any drifting electric fields, in 500 Torr of isobutane. The detector was made with three LMs needle-hole type, working at the same high voltage (900 V), but having different height of the point to respect the plane of the cathode: (1) about 30 μm , (2) about 80 μm and (3) about 120 μm . From this experience we can infer that the energy resolution depends on the uniform size of the points and their equal height with respect to the plane of the cathode.

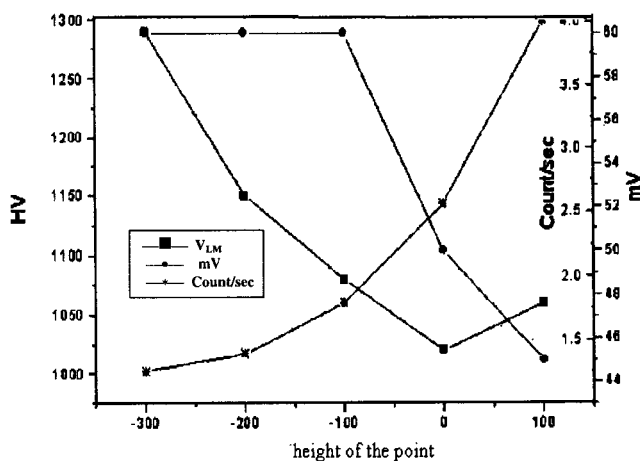


Figure 2. Gas multiplication and efficiency vs height of the point with respect to the cathode of a LM with alpha particles in open air.

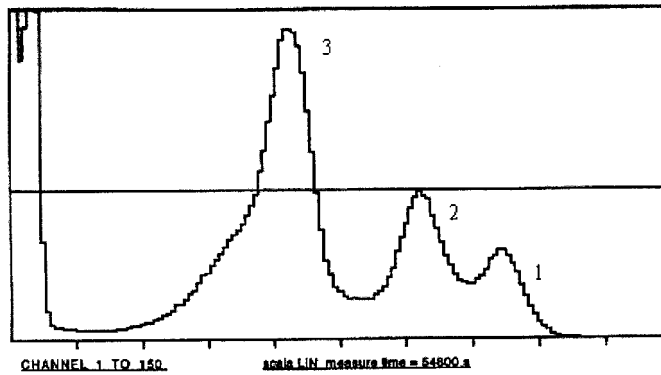


Figure 3. Spectrum with different heights of the points with respect to the cathode: 1–30 μm , 2–80 μm , 3–120 μm .

The other aspect that has to be considered before designing a position sensitive multi-LM detector is the possible photon-cross-talk between the LMs. That is if all the primary electrons produced by a single ionizing particle are collected by one LM, this LM during its avalanching does not induce detectable signals in the neighboring LMs through secondary photoelectron production mechanism. To explore this effect, measurements were made using a ^{55}Fe source, with a small detector of 3×3 LMs, which has a common cathode. The pitch of the three anodic microstrips was 1.41 mm. The height of the needle points was about 50 μm above the cathode. The schematic of the experimental setup along with the associated electronics is shown in figure 4 and the result is shown in figure 5.

In the former we set a drifting electrode, about 10 mm above the detecting surface, made with a sheet of lead in which a slit of one mm was cut to create a drifting electric field of 270 V/cm. The geometry was studied in such a manner that the primary electrons are collected only by the LMs in the middle of the detector and any possible coincidences mean photo-electron cross-talk in the other lateral LMs. In 760 Torr of argon–methane (90–10) ($V_{\text{LM}} = 620$ V, $E_d = 270$ V/cm) as well in 760 Torr of argon–isobutane (50–50) ($V_{\text{LM}} = 700$ V, $E_d = 270$ V/cm) no coincidences at all were recorded. Of course the sharing of the primary ionization between two LMs is always possible and it must be considered in designing the front-end electronics to avoid the multi-hit ambiguity. With the same experimental setup the drifting electrode (sheet of lead) was replaced by a wire mesh in such a manner that all the nine LMs working in 760 Torr of argon–methane (90–10) at 600 V, are illuminated by the ^{55}Fe source. The recorded spectrum is shown in figure 5. The flatness of the response, even if the statistics is not so high, indicates that there is no or nearly no coincidence. By recording the signals of Ch. 1 and Ch. 2 it is possible to verify that in reality, using different gas and working conditions, there is a little percentage of cross-talk within 10 ns resolving time.

Up to now all the measurements were done with the fast wide-band pick-ups made with two transistors, which have an input impedance of about 100 ohm. To verify if this value of the impedance is critical for a normal behavior of the LMs we have changed it from 50 up to 1200 ohm. It is apparent from figure 6 that the gain of the LM remains same between 50–150 ohm. In the plot, each point is the average value of 1000 pulses. On the contrary, if strips collect the anodic and cathodic signal, the input impedance of the pick-ups must match to that of the strips to prevent ringing or mismatching.

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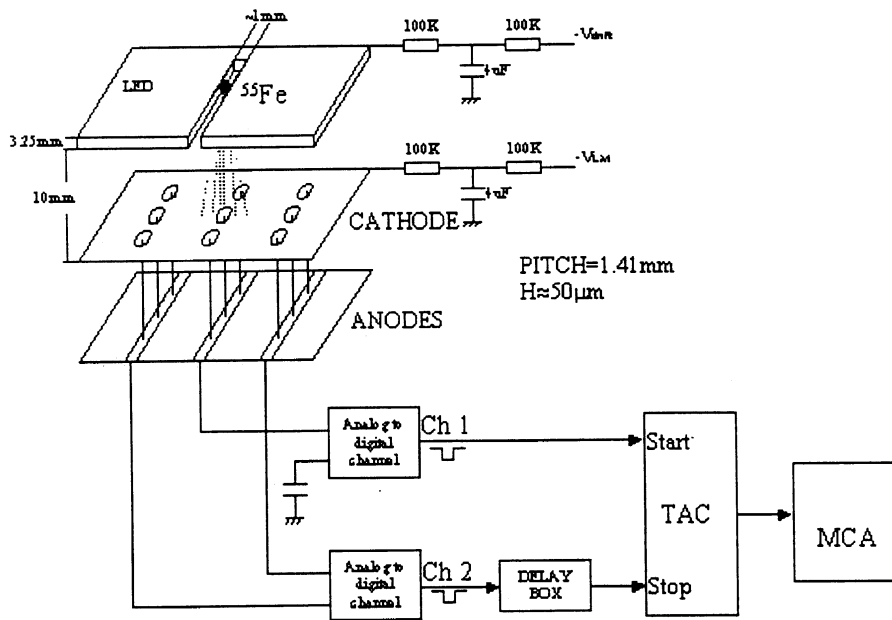


Figure 4. Experimental and electronic set-up.

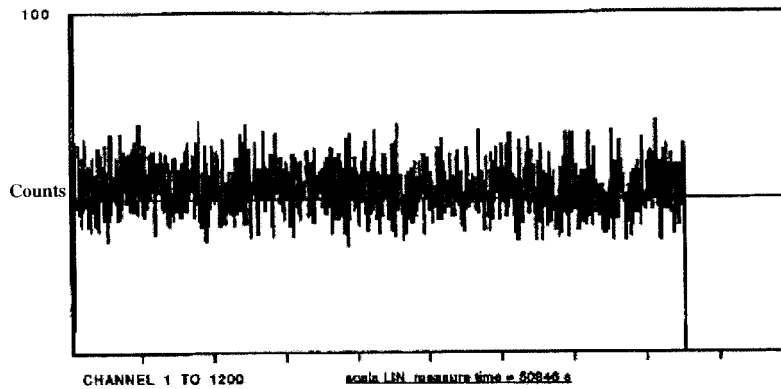


Figure 5. Spectrum of coincidences.

4. Multi-LM position-sensitive two-dimensional proportional counters

Until now we have studied three possible structures of multi-LM position-sensitive two-dimensional proportional counters.

The first structure, figure 7, consists of two sets of orthogonal microstrips separated by a ground plane. The ground plane is inserted to prevent the capacitive cross-talk between

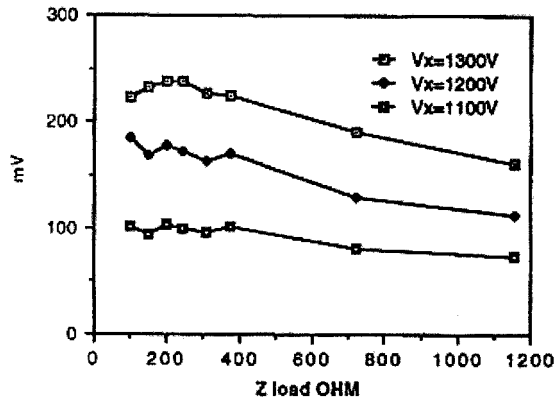


Figure 6. Gas multiplication (mV) vs input impedance of the fast wide-band pick-up.

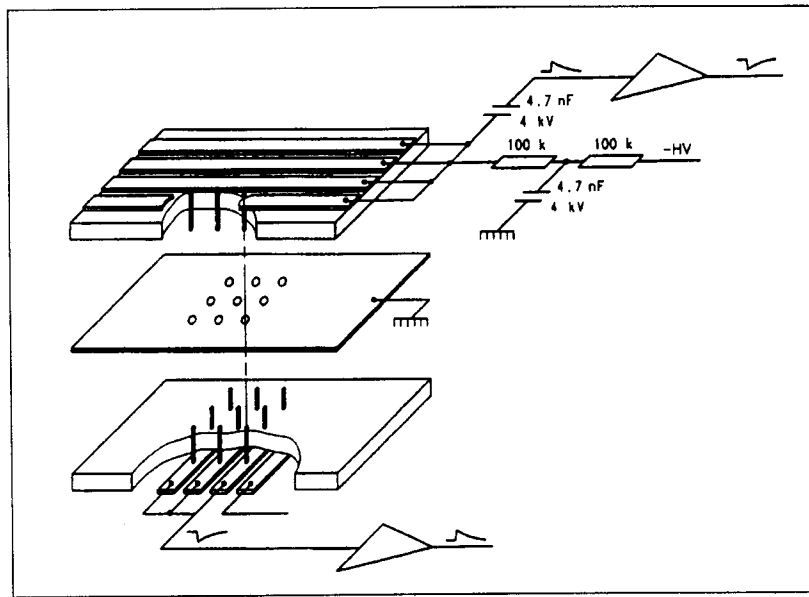


Figure 7. The LNL structure detector.

the orthogonal microstrips and to keep their characteristic impedance (about 100 ohm) well matched in order to prevent or limit the ringing of the fast signals. The wire-points (or needles) connected and starting from the anodic microstrips finish in the middle of the cathodic microstrips to form the LMs. This type of structure was developed by the 'surface treatment service' of CERN in samples of matrices of few more of 100 LMs with metalized holes and ball – bonding techniques. We verified in practice that the current pulses obtained with these samples of CERN, using ^{55}Fe as source, are able to drive directly, without any

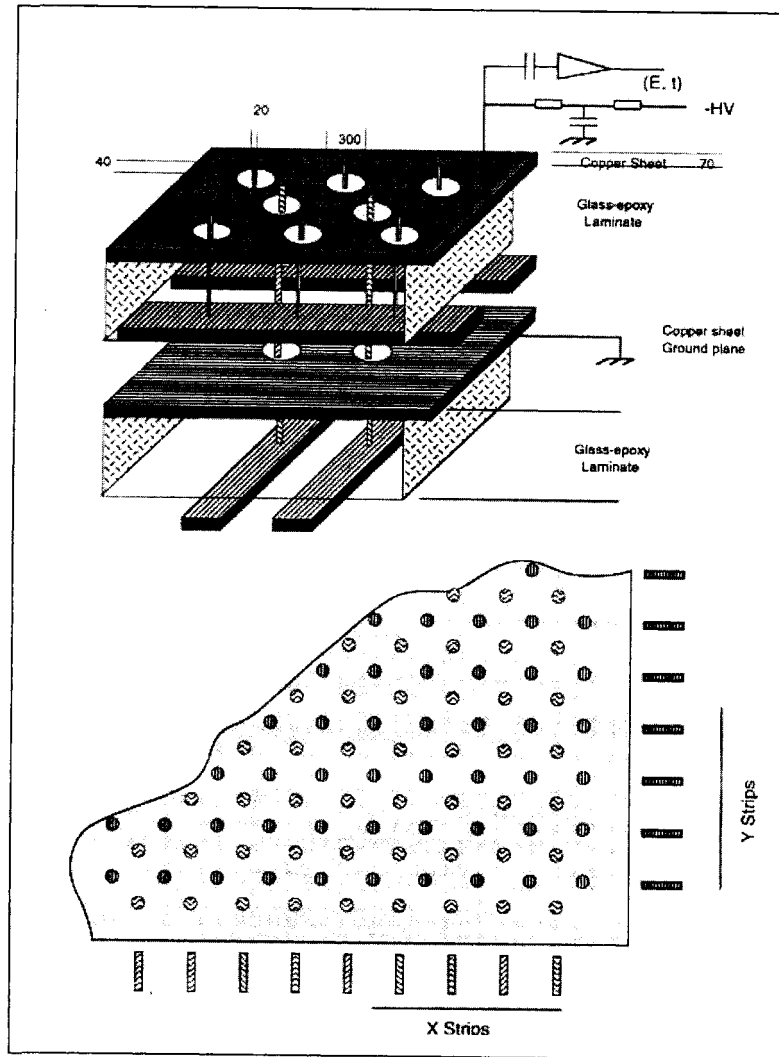


Figure 8. Modified version of the LNL structure detector.

preamplification, the front-end electronics made with fast chips by Motorola of ECL in PS family.

The second structure, figure 8, consists of a continuous cathode with a matrix of holes. Half of the needles (wire-points) are connected to the X strips while the other half is connected to the Y strips. Still there is a ground plane inserted between the orthogonal microstrips. The advantage of this structure with respect to the previous is that it has high voltage on only one cathode from which we can get the whole (the OR of all the LMs of

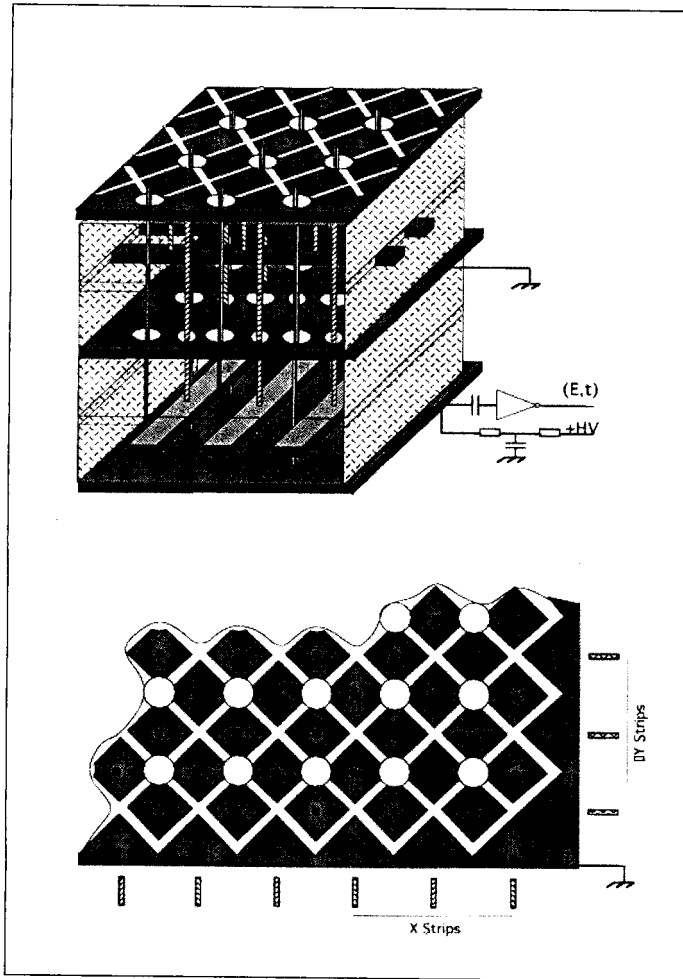


Figure 9. Multi-pad LNL structure detector.

the matrix) energy and timing information while the strips are at ground potential, thus avoiding the use of decoupling capacitors.

The third, figure 9, is a structure with multi-pad cathodes. Four pads, two for the X microstrips and the other two for the Y microstrips surround each LM. Each pad is connected to the pertinent microstrip through metalized holes and a ground plane is inserted between the X and Y microstrips. The needles are all connected together in a common anode. In this case also we have only the anode at high voltage and from which the whole energy and timing information is obtained. The latter structure described is particularly suitable for imaging purposes. The cathodic charge, distributed on the four pads according to the position of the avalanches, is 'induced' essentially in time coincidence with the anodic charge.

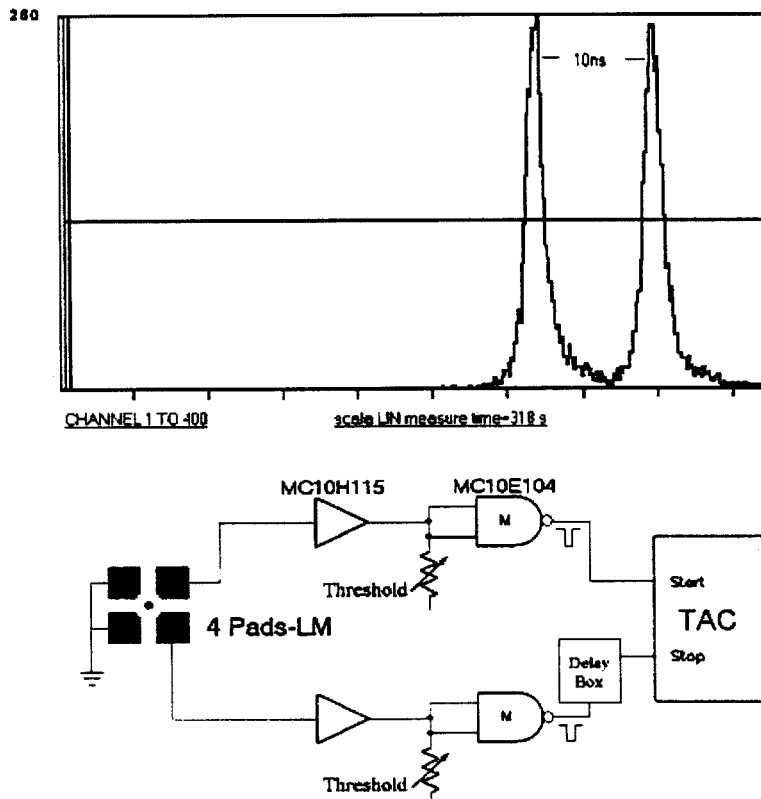


Figure 10. Timing with a pad-LM.

The coincidence between X and Y (pads) microstrips for encoding and possible electronic subdivision to enhance the spatial resolution, even if made with few electronic components (only four gates to drive directly a time to amplitude converter) gives the result of figure 10. The timing made with leading edge for simplicity allows us to observe the fast rise time of the signals in these working conditions (^{55}Fe source, 760 Torr of argon-isobutane (50–50), $V_{\text{LM}} = 1000 \text{ V}$ and $E_{\text{drift}} = 270 \text{ V/cm}$).

5. Conclusions

All the performances and possibilities offered by leak microstructures which have been reported here, makes it an extremely versatile detector for ionizing radiations. In addition, the fact that with 5.9 keV X rays of ^{55}Fe it was possible to drive on low impedance (100Ω) directly (without any preamplification) the ECLinPS fast integrated circuits by Motorola permits to simplify considerably the read-out electronics thus resulting in good performances in terms of time coincidence, counting rate, compactness and so on.

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