



HAL
open science

The C.A.T. Pixel Proportional Gas Counter Detector

F. Bartol, M. Bordessoule, G. Chaplier, M. Lemonnier, S. Megtert

► **To cite this version:**

F. Bartol, M. Bordessoule, G. Chaplier, M. Lemonnier, S. Megtert. The C.A.T. Pixel Proportional Gas Counter Detector. *Journal de Physique III*, 1996, 6 (3), pp.337-347. 10.1051/jp3:1996127 . jpa-00249460

HAL Id: jpa-00249460

<https://hal.science/jpa-00249460v1>

Submitted on 4 Feb 2008

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

The C.A.T. Pixel Proportional Gas Counter Detector

F. Bartol, M. Bordessoule, G. Chaplier, M. Lemonnier (*) and S. Megtert

Laboratoire pour l'Utilisation du Rayonnement Électromagnétique, 91405 Orsay Cedex, France

(Received 9 June 1995, accepted 20 December 1995)

PACS.29.40.Cs – Gas-filled counters: ionization chambers, proportionnal and avalanche counters
PACS.29.40.Gx – Tracking and position-sensitive detectors

Abstract. — A simple geometry of real pixel gas detectors has been evaluated that circumvents the limitations of a microstrips, namely aging, gain drift and flux limitation due to the dielectric charging. A good resolution has been obtained while preserving a large active size and a high gain and counting rate capabilities.

1. Presentation

Synchrotron radiation laboratories offers a very large range of photon energies. In the UV and X-ray region emerges an important demand for a large variety of detectors. The main and most often required features are:

- high counting rate and low background to ensure a large dynamic range,
- the detector must work in a sufficiently large energy range in order to cover the demand of various experiments,
- one or two dimensions large-area detectors with accurate spatial resolution.

It appears to the L.U.R.E. detector group that the proportional counter remains in this respect the most flexible and suitable detector at least for synchrotron radiation experiments.

We have therefore developed and tested what could be the simplest proportional gas detector, achieving good performances. Its principle can be situated between parallel plate avalanche counters and micro-strip detectors.

The parallel plate avalanche counters [1] use two closely spaced parallel conductive planes (typically 4 mm) to define the necessary avalanche region. Each plane can be a grid or a sheet for the anode. But an event induces a relatively long pulse [3] of several microseconds duration, thereby limiting the counting rate as well as the amplitude of the signal.

The multistrip detectors bear thin electrodes each plated on the same dielectric with very short spacing down to 100 μm , and hence yield good spatial resolution [3]. The dielectric charging problems are difficult to avoid, leading to signal fading, although the path separation for secondary electrons and the escaping ions trajectories would allow high counting rates.

(*) Author for correspondence (e-mail: lemonnier@lure.u-psud.fr)

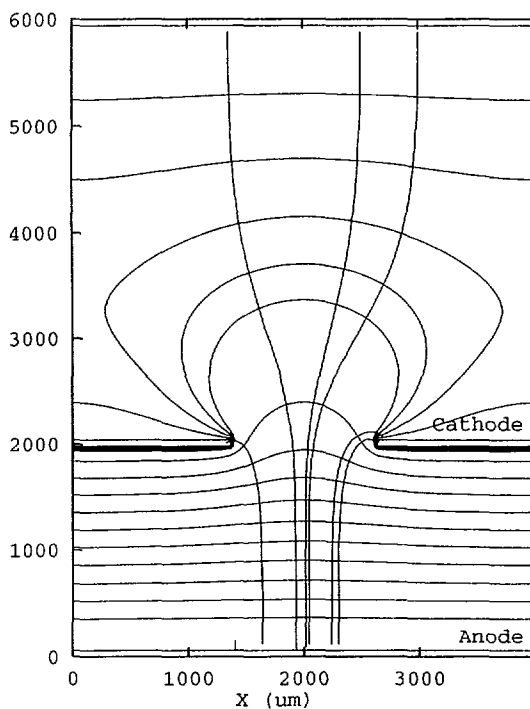


Fig. 1. — Cross-section view and equipotential contours. The field lines appear as arbitrary ion or electron paths. Potentials are: Drift = -25 V, Cathode = 0, Anode = $+3$ kV.

Various authors [2, 3] built perched anodes in attempts to get rid of dielectric problems. The collected signal [3] lasts a few hundred nanoseconds.

Our detector encompasses both features in a simple design. This geometry works like a buried anode microstrip. It consists of a cathodic metallic foil drilled in its center and a conductive anode plane parallel to the cathode plane. An insulating sheet can be placed between the electrodes; this spacer is drilled and this hole and the cathode hole are aligned. We obtain a structure which, in a suitable gas, constitutes a fair quality proportional counter, which we call the C.A.T.: the French acronym for “Compteur À Trou”.

2. Device Description

The cross section view of the structure is depicted in Figure 1.

It can be seen that the equipotential lines are parallel to the electrodes except in the vicinity of the hole. Around this region these lines bulge, forming an electrostatic lens. This lens has its focus close to the anode plan.

The funnel-shaped electric field lines collect the primary charges formed in the drift region and focus them toward the axis of the hole. The primary electrons enter the hole very close to its axis. The aim of the design is to generate an electron trajectory in the multiplication region independent of the origin of the primary charges. Where ever the X-ray photon absorption takes place over the collecting drift zone, the avalanche gain remains the same. It can be expected

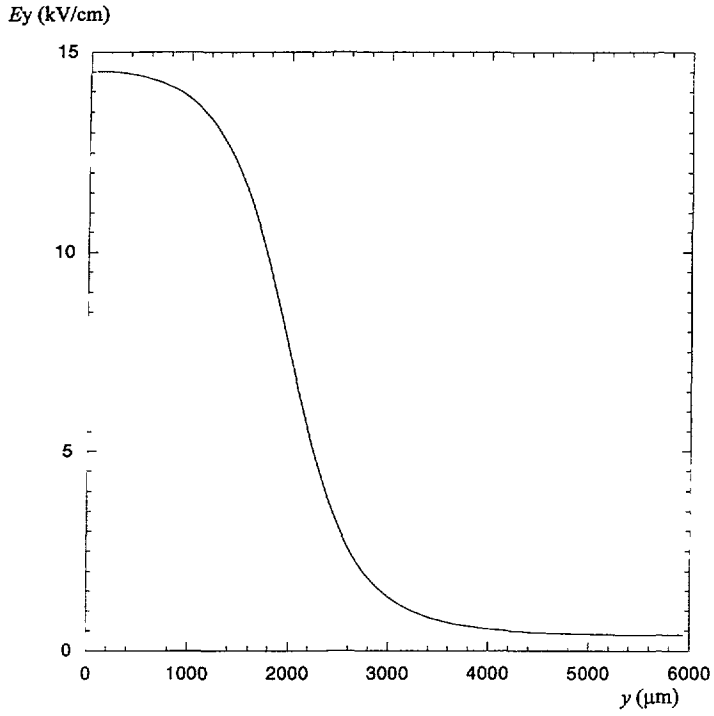


Fig. 2. — Field along the symmetry axis of the hole in Figure 1.

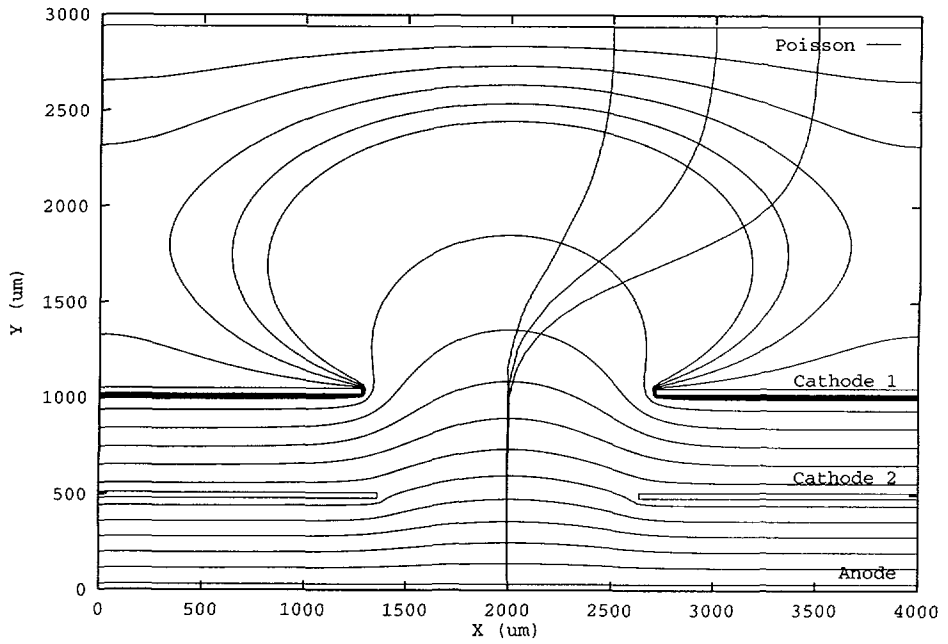


Fig. 3. — Double cathode counter. Potentials as in Figure 1 with the second cathode at +1500 V.

then that the energy resolution is good when using this electrode arrangement because the charges flow in a narrow tube on the axis of the C.A.T.

Another advantage is that the focalizing lens of the cathode aperture drags a comparatively large drift volume of the absorption region. This ensures a good collecting efficiency of the detector.

The equipotential lines and some arbitrary field lines drawn in Figure 1 were computed with the two-dimension Poisson code [4]. The axial field is plotted in Figure 2. The field in the focusing and amplification zone is weakly dependent on the permittivity or resistivity of the spacer. As in a microstrip structure, primary incoming electrons are focused on the anode structure axis while the moving ions, due to space charge effect, are defocused on the cathode.

Although the detector presents only metallic parts to the source side, it is understood that if a heavily ionizing particle crosses the cathode foil, an avalanche could appear out of the anode center (in case of a gas spacer between electrodes).

The incoming electrons of an event do not meet the ions left by the preceding avalanche. By measuring the intensity, we found that the C.A.T. can withstand high count rates (up to 500 000 events per second per square millimeter were observed without any amplitude shift). The dielectric hole is larger than the cathode hole to insure that the position of the insulating layer is not in the vicinity of migrating ions. Hence a possible charge trapping on the surface of the dielectric has no measurable effect on the focusing or amplifying field. The metallic electrodes are thick enough for even a continuous discharge not to be destructive.

Another aspect is that the cathode to anode potential defines both the amplification factor and the focusing effect. This can be improved by adding a second cathode to the C.A.T., resulting in a gain boost. This gives more latitude to separate the two functions of focusing and amplification as shown in Figure 3. The hole diameter of the upper cathode is larger than the first one. This superimposes a second electrostatic lens that collects charges in a larger volume of the absorption zone. The efficiency of the detector is then increased. The signal collected on the sandwiched cathode is bipolar.

The strongest electric field is located near the cathode edge, in a dielectric-free region of the structure. The ratio of the electric field in the avalanche region and in the dielectric can be reduced, at the price of the focusing strength, by modifying the anode geometry as in Figure 4. This configuration allows one to work at the same gain with a lower voltage applied to the anode. The structure of such a detector is comparable to the needle counter as described in references [5,7] but the multiplication takes place on the flat top of the anode, providing good energy resolution.

3. Experimental Results of the C.A.T.

Due to the simplicity of the assembly, measurements were conducted with quite a variety of materials and techniques. First, the dimensions of the structure were of a size in the range of conventional electronic printing board. The detector is made of an epoxy board 150 μm thick, with 17 μm copper layers coated on both sides. One hundred 150 μm holes are drilled with a pitch of 1.27 mm. The backplane is a plain anode.

These conventional materials for electronics can achieve a fair energy resolution counter as shown in Figure 5.

We built counters with different cathode hole diameters from 100 μm to 2 mm. The shape of the hole can be circular, square, triangular or hexagonal without altering the features of the counter. By respecting a ratio of about 1.5 between the anode to cathode distance and the cathode hole diameter, we currently obtain about 16% energy resolution and a gain of 5000, maintaining a sufficiently short pulse length.

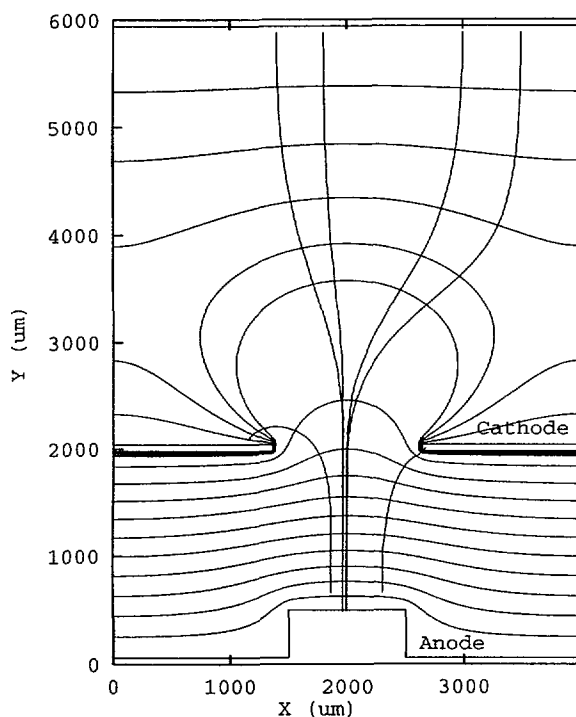


Fig. 4. — Anode pad counter, same potentials as in Figure 1.

All the detectors were tested in an Ar 90% CO₂ 10% mixture at atmospheric pressure. All of the prototypes we have made perform well, however there might exist some limitation to counter efficiency when using a cathode foil with a high thickness to diameter ratio.

Another prototype uses an electroplated cathode having a 1.25 mm diameter hole in a 60 μm thick stainless steel plate. The distance between electrodes is 1.5 mm. The entrance window is grounded, the cathode is at a voltage of +250 volts and the anode is at +1 500 volts. The gain *versus* anode voltage is shown in Figure 6 and the best FWHM energy resolution obtained is 20% with 5.4 keV photons. We can see that the exponential variation of the gain with the polarization is comparable to other proportional gas counters.

The typical electric signal shape out of the electrodes is shown in Figure 7. The fast leading edge of the electrons arrival precedes the flat part of the pulse due to the slower ions return onto the cathode. For example a 100 μm gap between electrodes gives a 200 ns pulse duration (Fig. 8). An inherent property of the C.A.T. is that the cathode signal is the opposite of the anode signal.

Comparing Figure 2 and Figure 7 shows a good agreement with the theorem of Ramo [6] which states that the proportionality between the current i through the connected electrode and the electric field E across the charged particles trajectory is,

$$i \propto qEv$$

where q and v are the particle charge and velocity. The spike at the leading edge depicted in Figure 7 can be interpreted as the fast electron contribution to the signal. The slower contribution, born from the ions, is in good agreement with the preceding statement, assuming

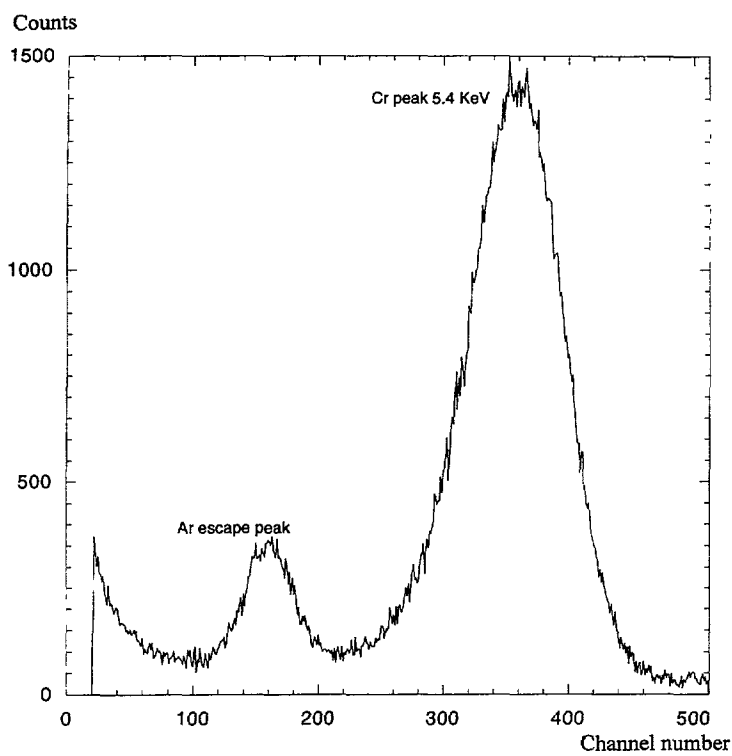


Fig. 5. — Energy resolution of a C.A.T. made of a thick epoxy plate ($V_K = 180$ volts, $V_A = 1\ 100$ volts, Gain = 2 000, Count rate = 20 000 Counts/s).

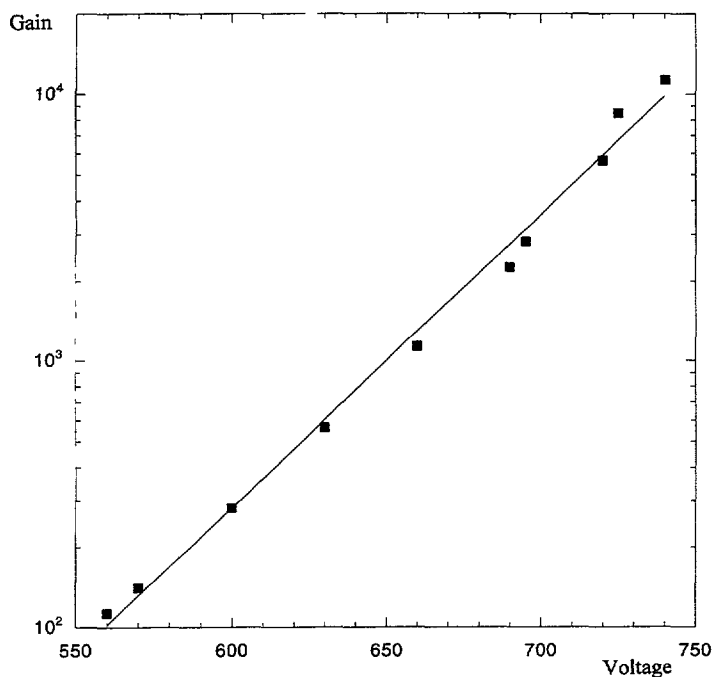


Fig. 6. — Gain *versus* voltage for electroplated cathode.

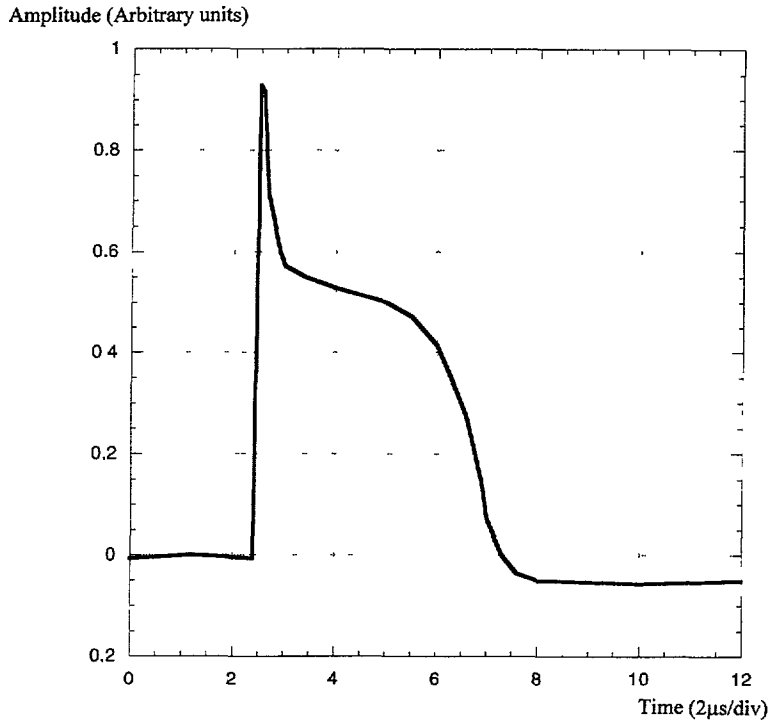


Fig. 7. — Amplitude of the averaged signal (20 mV/div) *versus* time (2 µs/div).

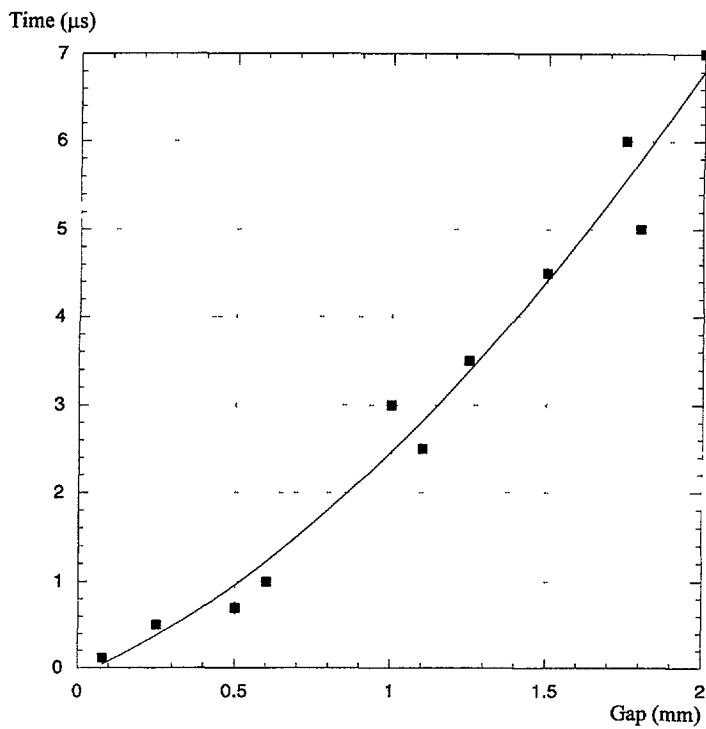


Fig. 8. — Dependence of plateau length with the cathode-anode distance.

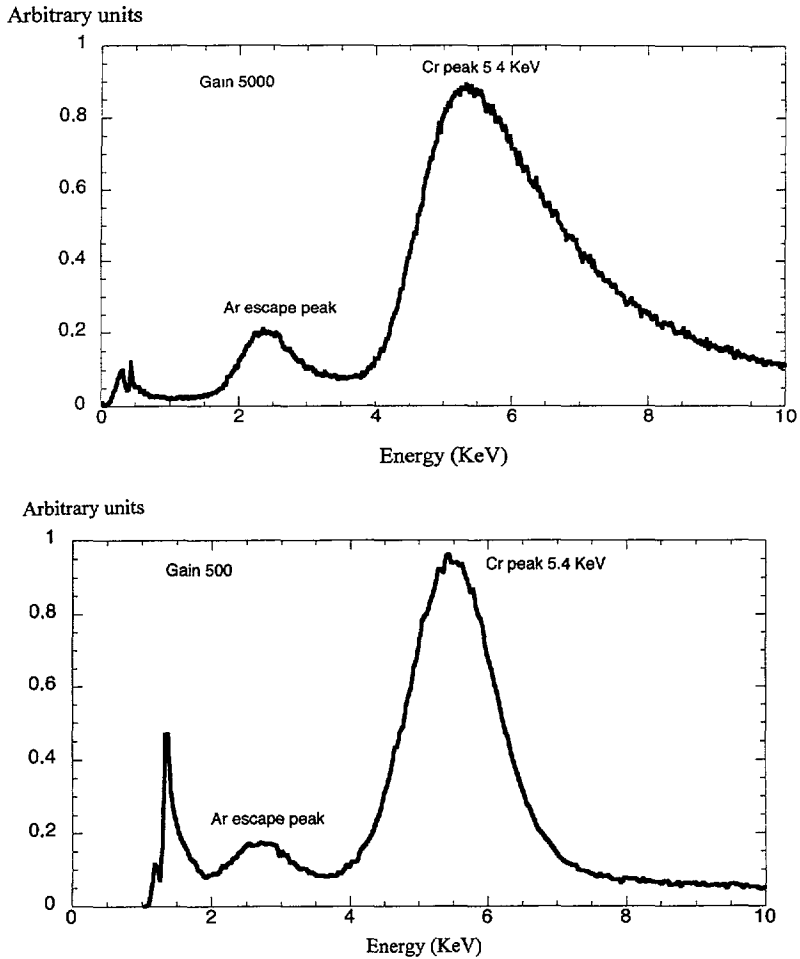


Fig. 9. — Energy resolution of a trench detector for a gain of 500 (thick line) and 5000 (thin line).

$v = 300 \mu\text{m}/\mu\text{s}$ ion velocity. So, the progressive field yields a significant electron contribution to the signal, a particularity of this kind of detector.

Our measurements have shown no variation of gain with aging. It is noteworthy that sparks can occur without damaging the detector, or diminishing its performances. This will ensure a long life for this kind of counter.

We used an Ortec 142PC charge preamplifier and an Inel 516 filter amplifier with a $2 \mu\text{s}$ time constant.

4. Extensions of the C.A.T.

This very simple detector geometry can be varied in many ways. First the drawing of Figure 1 can be considered as a trench cross section. In this case the counter has the same properties as the simple hole counter. It is worth to note that the gain is uniform along the trench as long as the electrodes remain parallel with enough precision. This is achieved by placing an

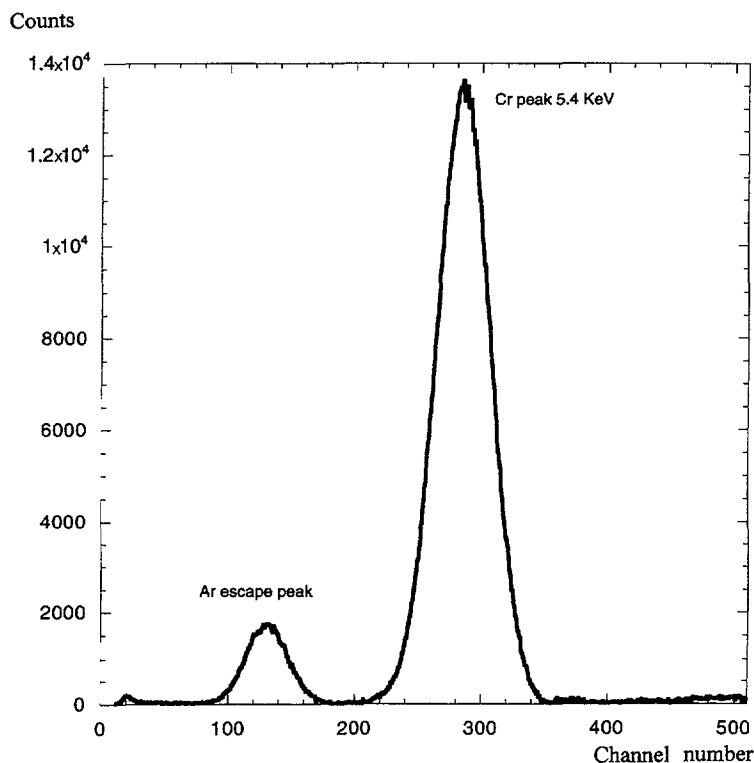


Fig. 10. — Energy resolution of a multi C.A.T.

insulating spacer between anode and cathode. The energy resolution obtained with a 0.5 mm width trench and 1 mm thick spacer is shown in Figure 9 for two values of the gain.

A second extension is to make many holes in the cathode. The anode can be simply a continuous conductive plane, a set of strips or discrete pads which can be placed in regard of each cathode hole. We then obtain as many independent C.A.T.s as holes, or in other words a pixel proportional counter or multi-C.A.T. The electrodes are thick enough not to induce a height-position coupling due to resistivity.

Such a detector has been made of an electroplated cathode with holes of 100 μm diameter and 330 μm pitch. The dielectric is 125 μm thick gas. We measured 16% FWHM energy resolution at 5.4 keV with a gain of 2 500 (Fig. 10).

The duration of the signal is related to the dimensions of the structure (Fig. 8). The pulse duration could appear long in some cases but it must be born in mind that this is only a single pixel output so that in reality the total throughput appears quite a challenge for the readout designer of a multi-CAT detector.

5. Readout Example

We used the 60 mm long one-dimensional multi-C.A.T. with a 330 k Ω resistive anode for one-dimensional encoding. The two anode ends were connected to charge preamplifiers, a 0.4 μs time constant filter and a time-to-amplitude converter. This set-up achieves a spatial resolution of 330 μm when working at a gain of 10,000. The performances are shown in Figure 11.

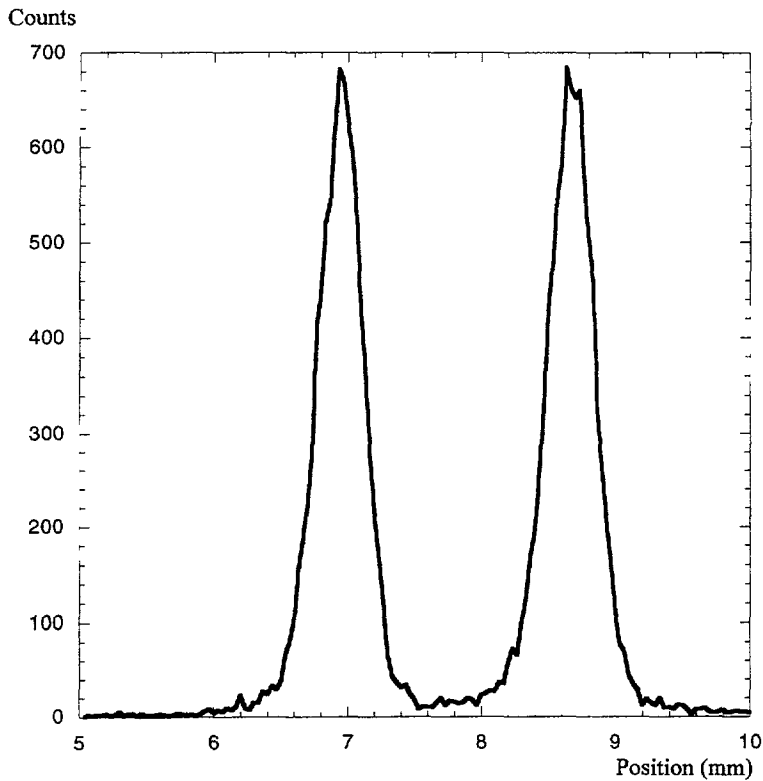


Fig. 11. — Example of spatial resolution with a 0.2 mm FWHM incoming beam for two successive positions distant of 2 mm.

6. Conclusion

Simple structures for gas detectors have been simulated, built and tested. The robustness and stability of this two dimensional pixel structure makes it a strong competitor for glass microstrips. The gain reaches a value of 10^4 and the energy resolution is 16%, with a high flux acceptance and the ability to withstand arcing.

Acknowledgments

We would specially thank MM. Alain Lena and André Szvec from the LURE laboratory for their kindness and contribution on mechanical realization.

References

- [1] Smith A.D. *et al.*, A high counting rate parallel-plate gas proportional counter for fluorescence extended X-ray absorption fine structure studies, *Rev. Sci. Instrum.* **63** (1992) 837-841.

- [2] Lemonnier M. *et al.*, First experimental results on new microstrip three dimensional geometry, *NIM A* **349** (1994) 274-276.
- [3] Angelini F. *et al.*, The micro-gap chamber, *NIM A* **335** (1993) 69-77.
- [4] Colman J., The use of the IBM-PC computer in accelerator design calculations, Linear Accelerator Conference Proc. (SLAC-303 1986) p. 333.
- [5] Comby G. *et al.*, Détecteur multi-pointes à focalisation cathodique, *NIM* **174** (1980) 77-92.
- [6] Ramo, Currents induced by electron motion, *Proc. IRE* **27** (1939) 584.
- [7] Comby G. *et al.*, Compteur multipointes à F.C. appliqué à la détection de l'émission exoélectronique thermostimulée (E.E.T.S.), *Rev. Phys. Appl.* **18** (1983) 263-270.