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MICROSTRIP GAS CHAMBERS ON THIN PLASTIC SUPPORTS

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ABSTRACT

We describe the development of microstrip gas chambers manufactured on thin-foil plastic supports. Gains up to 10^4 and energy resolutions around 20% fwhm have been obtained for low rate 5.9 keV x-rays. A space-charge dominated gain drop appears only at very high rates, close to 10^6 $s^{-1} \cdot mm^{-2}$. The measurements show however long-term time-dependent modifications (charging up), particularly for high resistivity supports; nevertheless, the results are very encouraging and further developments may lead to the development of a new family of light, flexible detectors with high resolution.

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Abstract

We describe the development of microstrip gas chambers manufactured on thin-foil plastic supports. Gains up to 10^4 and energy resolutions around 20% fwhm have been obtained for low rate 5.9 keV x-rays. A space-charge dominated gain drop appears only at very high rates, close to 10^6 $s^{-1} \cdot mm^{-2}$. The measurements show however long-term time-dependent modifications (charging up), particularly for high resistivity supports; nevertheless, the results are very encouraging and further developments may lead to the development of a new family of light, flexible detectors with high resolution.

1-Introduction

Microstrip gas chambers (MSC) [1], in which anodes and cathodes are realized as thin metal strips alternating on a glass support can be made with very small spacings between electrodes, providing good granularity and resolution at high fluxes. Proportional gains above 10^4 with good energy resolutions, position accuracies around 30 µm rms for minimum ionizing particles, high rate capabilities have been demonstrated [2-5]. This may offer a way to cope with the experimental requirements at high luminosity machines, seriously challenging the rate capability of existing position-sensitive gaseous detectors and substantially cheaper than solid state devices. There are however some shortcomings connected with the use of a glass support: to avoid charging up the plates have been ion-implanted on the surface, a rather expensive proposition, and the detectors are rather thick (one mm or so) with as consequence a disturbing contribution to multiple scattering and photon conversion probability.

We have investigated the feasibility of detectors manufactured on thin (100 µm) plastic foils. There are three distinctive advantages of plastic over glass supports: they are flexible and allow to realize detectors of non-planar design, for example cylindrical geometries with very small radii; they can be much thinner and made of low Z materials; the availability of plastics in a wide range of bulk resistivities may allow to solve the charging up problems in a simple way and over large surfaces. This paper relates the preliminary results obtained with MSC realized on plastic supports. A research along similar lines has been reported by another group [6].

2-Experimental set-up

We have found so far two supports, Kapton and Tedlar+ suitable for the realization of microstrip chambers, both mechanically stable and with a good surface quality and having a sufficiently strong adherence of the vacuum-evaporated metal layer. The two materials have quite different bulk resistivities, about 10^{17} and 10^{14} ohms.cm respectively. A schematic cross section of a chamber is shown in Fig 1, and the computed electric field lines in the region close to the strips in Fig. 2:

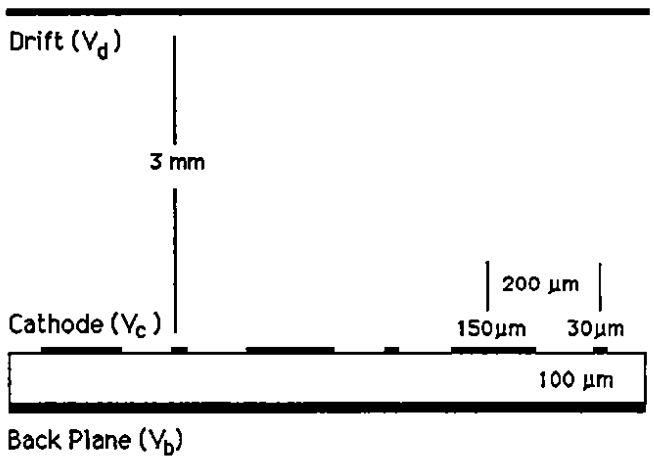

Fig. 1

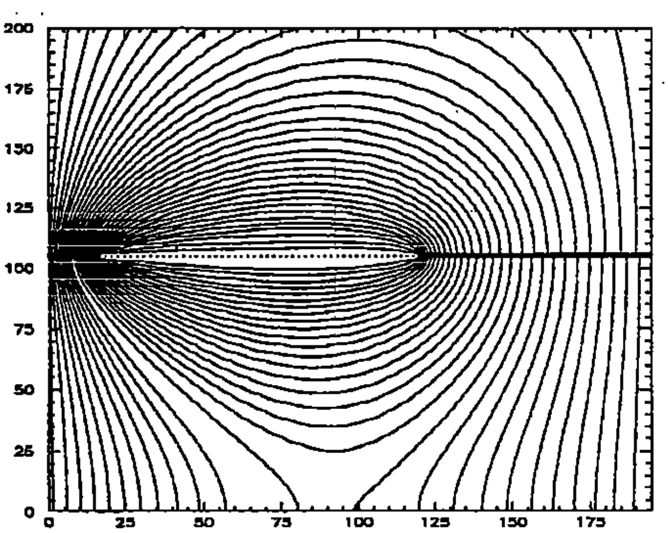

Fig. 2

The pattern was realized by photo-litography followed by etching of a layer of aluminum, about 0.3 µm thick, vacuum-evaporated on the support; anode and cathode strips alternate at a distance between centers of 200 µm, with a width of about 30 and 150 µm respectively. Due to the resolution limits in the production facility, we have adopted a pitch coarser (by a factor of two) than the one used in previous works on MSC on glass supports. This has as consequence an enhancement of the charging up processes, due to the wider insulating regions between anodes and cathodes. Moreover, all measurements were realized using as radiation sources either 5.9 keV x-rays from ^{55}Fe or a collimated 8 keV x-ray tube, both producing a larger and more localized cluster of charges as compared to minimum ionizing particles.

The quality of the etching tended to be better for Kapton, probably because of the smoother surface and the higher

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tolerance to thermal treatments. We have tested two models of chambers, with a sensitive area of 40x10 and 100x30 mm^2 respectively; in all tests, groups of anodes (20 to 30 strips) were connected together to a low-noise charge amplifier. All measurements were realized using an argon-methane 90-10 gas mixture, at atmospheric pressure; while not the best for obtaining high stable gain, this mixture is convenient for reproducibility and because the gas parameters are well known and can be easily introduced in a simulation.

3-Results

The dependence of proportional gain on the anode voltage (with the cathode strips grounded, all other potentials fixed) is shown in Fig. 3. One can see that for both the Kapton and the Tedlar chambers we could safely reach gains close to 10^4; the small difference in the operating voltage is due to a slightly different width of the anode strips.

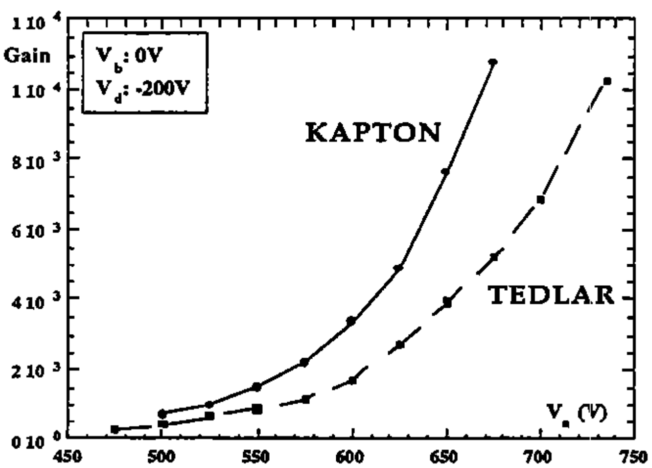

Fig. 3

A typical pulse height spectrum measured at low flux for Tedlar is shown in Fig. 4; the resolution is better than 20% fwhm:

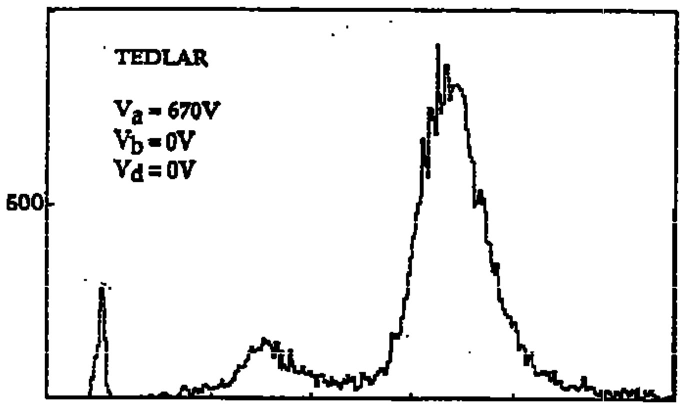

Fig. 4

Both measurements shown above were realized at low rates (below 100 counts/mm^2.s). At higher fluxes, one expects two processes to set in, resulting in a modification of gain: a space-charge dominated gain drop, due to the high density of positive ions migrating in the drift space, and a modification of the field induced by charges (ions or electrons) accumulating on the insulating support between the strips. The first process is very similar to that observed in conventional multiwire chambers.

Fig. 5 shows the effect of space-charge on the gain. The measurement was realized exposing the MSC to increasing fluxes of collimated x-rays, for a time just sufficient to accumulate a good statistics (from a few minutes to a few seconds at the higher rates). The exposure time is long compared to drift times of ions, but presumably short enough to avoid the appearance of surface charging-up effects. As one can see, a gain drop is observed only at rates approaching 10^6 c/s.mm^2, a rather remarkable performance when compared to MWPCs. The reduction of space-charge related effects is a well understood consequence of the observation that a large fraction of the ions produced in the avalanches are collected very quickly by the neighboring cathode strips.

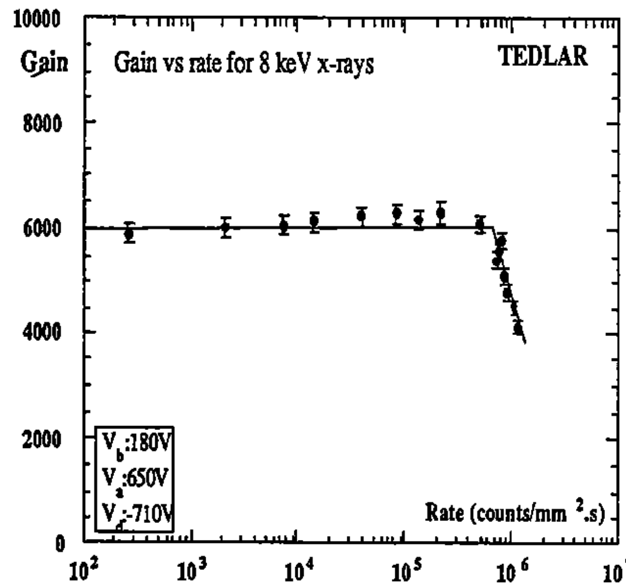

Fig. 5

As mentioned, the main problem found operating the chambers is connected with charging up of the support, that depends on the resistivity of the foil and the irradiation rate. Moreover, as will be shown, the distribution of potentials applied to the various electrodes affects the charging up rate. Kapton and Tedlar have resistivities different by 3 orders of magnitude; as a consequence, we expected and indeed found rather different behaviors. As expected the voltage applied to the back plane plays a role on the charging up rate, namely the accumulation of charges is slower for a positive back plane, a situation expected to reduce the number of field lines leading from the anode close to or into the insulating surface. This is apparent in Fig. 6, a time-dependent gain measurement at moderate fluxes realized at several values of the back plane potential.

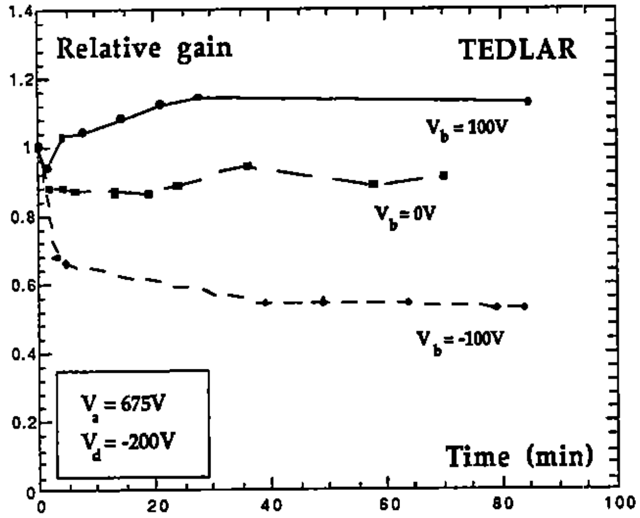

Fig. 6

We have studied the charging up effects measuring the long-term variations of gain of chambers exposed to constant radiation fluxes. Figure 7 shows the variation of gain with time at various fluxes for the Kapton chamber. One can see that even at very low irradiation levels (the zero flux points), the gain of the chamber shows a very strong decrease during the first minutes after turning on the voltages, followed by a slow but steady decrease afterwards. A second measurement at zero flux on Kapton (the dashed curve) does not reproduce the first, showing evidence of long-term charging up of the surface.

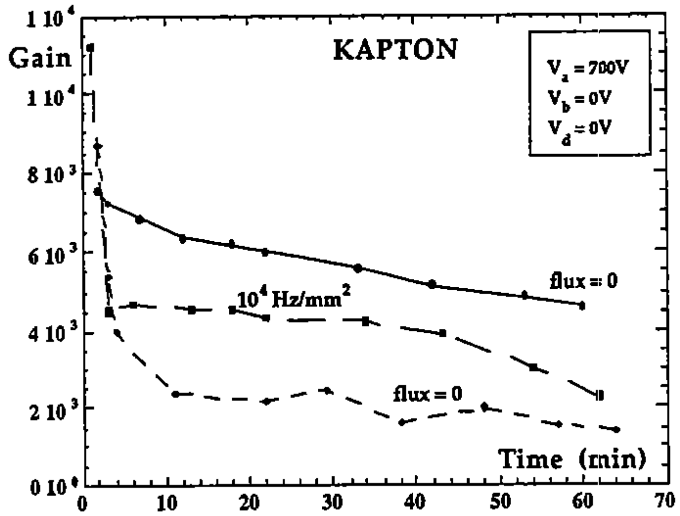

Fig. 7

Fig. 8 shows the gain as a function of flux for the Tedlar chamber. The initial small increase, observed also in other conditions (see Fig. 6), is not understood but is presumably connected to a modification (polarization?) of the material. The gain remains constant afterwards at moderate fluxes (300 c/mm^2·s). At higher rates, one can see a drop towards a rate-dependent value, due to the slow accumulation of charges on the insulating surface. It is not clear if responsible for the gain drop are electrons, ions or both accumulating in the space between anode and cathode strips. The small resistivity of Tedlar, as compared to Kapton, obviously slows down the rate of accumulation of charges, but is obviously not sufficient at high fluxes. One can deduce from the results that a bulk resistivity at least an order of magnitude lower (10^{12} to 10^{13} ohms.cm) would considerably reduce the charging up processes, the lower limit being set by the leakage current produced on a low resistivity support.

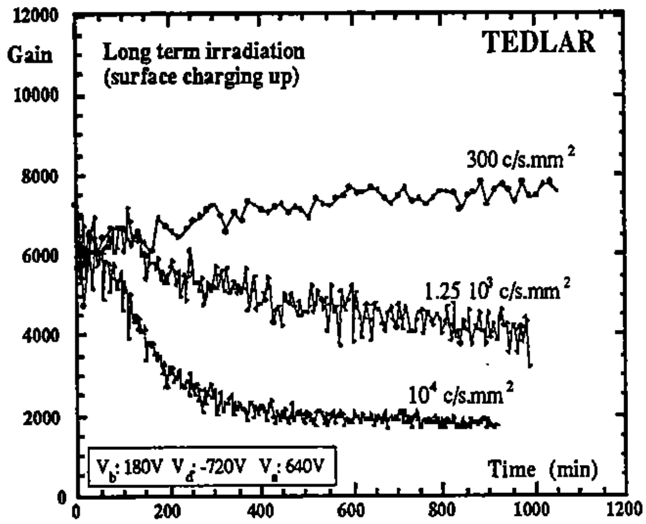

Fig. 8

4 - Conclusions and future developments

We have demonstrated that gaseous microstrip chambers realized on thin plastic supports can be operated at large proportional gains with good energy resolutions. Choosing a material with moderate resistivity such as Tedlar, charging up processes due to deposition of ions or electrons on the support are not impairing the operating characteristics at moderate fluxes, while an overall rate-dependent gain decrease is observed at high fluxes. The potential applied to the back plane electrode influences the charging up rate by reducing the number of field lines entering the insulator. One should note that for thin supports like those tested the optimum potential for the back plane electrode is equal or close to ground, the same, the cathode strips being also grounded; this allows in a simple way to design a two-dimensional readout scheme with pickup strips on the back plane at an angle with the anodes and cathodes, conveniently read-out without the need of decoupling capacitors.

Non-planar chambers can be easily manufactured with the thin plastic foils, in order to allow tracking very close to a collider vacuum tube. Fig. 9 shows the first model of a microstrip chamber with 10 mm radius; its total thickness in the radial direction is less than 10^{-3} of a radiation length. This kind of accurate, light tracking detector may find applications in specialized high-rate colliders (B- and ϕ-factories).

Further work is certainly required to find other supports, possibly with bulk resistivities at least an order of magnitude lower than Tedlar, in order to extend the rate capability of the detector.

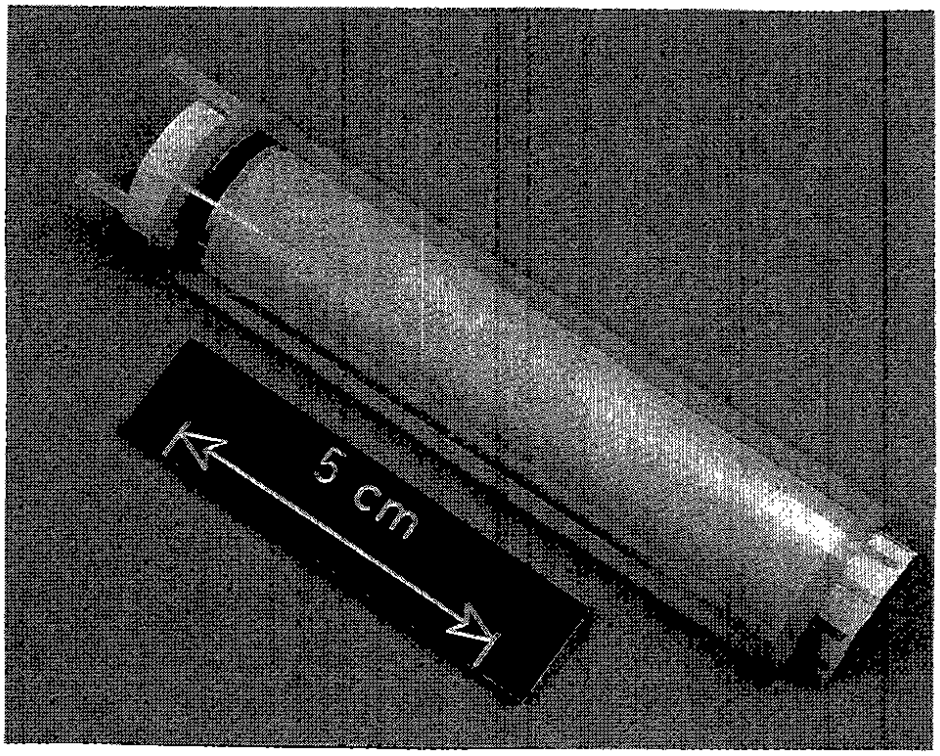

Fig. 9

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