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Letter to the Editor

A MICROSTRIP AVALANCHE CHAMBER WITH TWO STAGES OF GAS AMPLIFICATION

F. ANGELINI, R. BELLAZZINI, A. BREZ, M.M. MASSAI, G. SPANDRE and M.R. TORQUATI
Università degli Studi di Pisa and INFN Sezione di Pisa, Via Livornese 582/A, 56010 San Piero a Grado, Pisa, Italy

F. SAULI
CERN, Geneva, Switzerland

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The operation of a microstrip gas chamber with two stages of gas amplification is discussed. An average gas gain for ionizing tracks of ≈ 10 is obtained while drifting the ionization electrons in a uniform electric field of 6 kV/cm, while a further factor $\approx 5\times10^3$ is obtained from the avalanche process starting close to thin anodic microstrips. The operation of the microstrip gas chamber in this regime should improve both time and spatial resolution, especially for inclined tracks.

The microstrip gas avalanche chamber has been recently proposed as an alternative detector to solve the severe problem of tracking at the next generation of high-luminosity hadron colliders [1]. This new detector aims to reproduce the structure and intensity of the electric field of the standard MWPC, but on a geometrical scale reduced by at least a factor 10 [2]. This has been made possible by using a microelectronics technology (electron beam lithography) to define the field shaping electrodes with a precision of 0.1 μm. Thin anodic and cathodic parallel strips were laid down on a 500 μm thick glass substrate, with a 200 μm pitch. An upper cathode seals the chamber and allows to define the drift region for ionization charges. Fig. 1 shows a cross section of the detector, while fig. 2 shows a microphotograph of the anode–cathode structure.

With a proper gas filling and applying a few hundred volts between anodes and cathodes, the detector can reach proportional gains of $\approx 10^4$ [3]. During laboratory tests with low-energy X-ray sources we have shown how this detector can provide very promising performances (energy resolution $\approx 15\%$ at 6 keV, rate capability $> 10^5$ counts/s mm^2) [4]. The gas gain was limited to $\approx 10^4$ by occasional sparking at the edges of the detector where the electric field has its highest intensity. The gas mixture was argon–dymethyl ether (90–10). While a gas gain of 10^4 is probably high enough when the primary ionization is > 100 e$^-$, it could become a limiting factor when the primary ionization is quite lower as when using very thin detectors (2–3 mm) at atmospheric pressure. Thin detectors are needed, for example, at the next high-luminosity hadron colliders (LHC, SSC) to reduce the detector memory (i.e. the

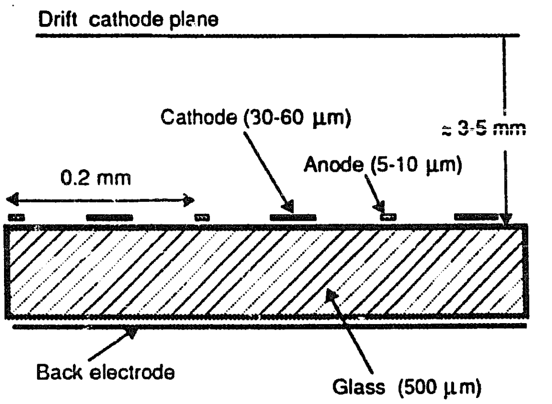

Fig. 1. A cross section of the detector (not to scale).

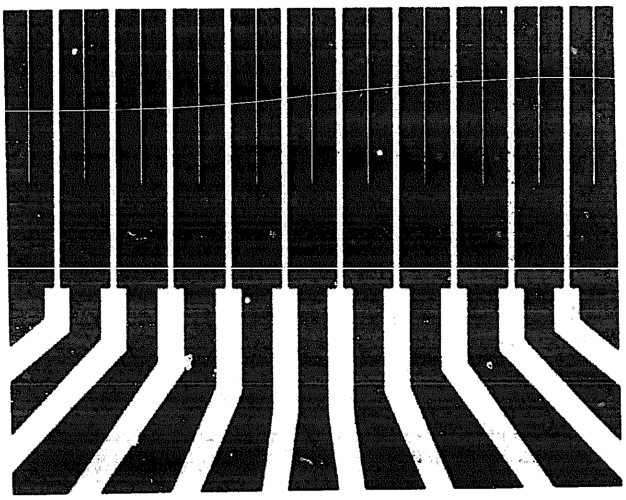

Fig. 2. A microphotograph of the anode–cathode structure and of the cathode fan-out.

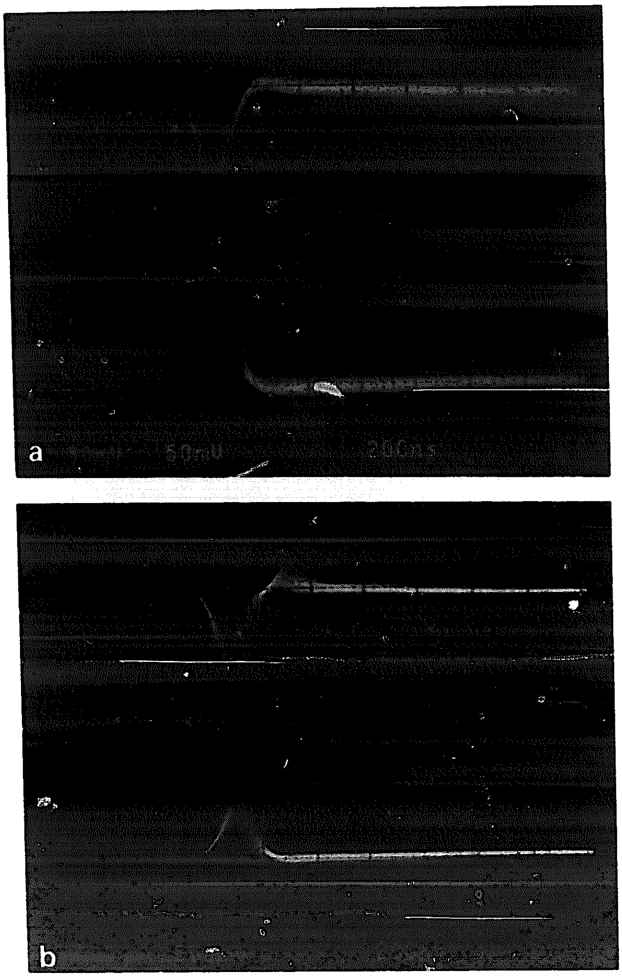

Fig. 3. (a) Cathode (upper trace) and anode (lower trace) ^{55}Fe signals observed when the detector works without gas gain from the drift region; (b) the same as (a) but with a contribution to the gain coming also from the drift region.

electron drift time). For tracking at LHC or SSC a higher gas gain could therefore be desirable.

Because no more gain could be obtained from the amplification process around the thin anode strips, we have tried to get a further stage of gain from the drift region which is in front of the amplification region [5]. The electric field in the 5 mm thick region was originally set to 2 kV/cm which is below the threshold for gas multiplication. By reducing the quencher fraction to 5%, and by increasing the field to 6 kV/cm, we succeeded in starting the multiplication process already in the uniform field region. A 6 kV/cm field is rather modest and quite comfortable. Figs. 3a and 3b show the ^{55}Fe signals obtained from the anodic and cathodic strips when operating the chamber in the two different regimes, i.e. with or without amplification in the drift region. When all the gain comes from the anodic strips (fig. 3a) the signals show the classical ^{55}Fe line (gain independent of the conversion point), while when working with two stages of gain the signals show an almost continuous spectrum typical of a parallel-plate operation (gain dependent on the conversion point, $G(x) = \exp \alpha x$, where x is the drift path of the photoelectrons). Note the change of vertical scale of a factor 10. The maximum gas gain in the drift region is obtained when the ^{55}Fe X-ray is converted in the first layer of gas so that the photoelectrons are multiplied by a factor $G_{\text{drift}}^{\max} = \exp \alpha d$, where d is the total gas thickness. The ratio of the maximum amplitude of the signals of fig. 3b to the amplitude of the line of fig. 3a is a measure of $G_{\text{drift}}^{\max}$. A typical value, for $d = 5$ mm, was $G_{\text{drift}}^{\max} = \exp \alpha d \approx 30$. An important parameter when detecting the almost uniform ionization generated by a charged particle crossing the detector is the mean gas gain along the track, which is given by

$$G_{\text{drift}}^{\text{mean}} = \frac{1}{d}\int_0^d e^{\alpha x} dx = \frac{1}{\alpha d}[e^{\alpha d} - 1] = \frac{1}{\ln G_{\text{drift}}^{\max}}[G_{\text{drift}}^{\max} - 1] \approx 10. \quad (1)$$

The overall gain was limited to 6×10^4. This is probably due to the growth of the avalanche size which at this gain is no more negligible in comparison with the anode-cathode distance (80 μm). The operation in this new regime was very stable. No sparking was observed during 48 h of continuous operation at a rate higher than 10^4 counts/s mm^2. There should be also two positive side effects of the operation in this mode: (i) a reduction of the time jitter because the dominant ionization is the one coming from the farther region of gas which has the highest amplification (this has the meaning of an electronic reduction of the effective thickness of the detector), (ii) reduction, for the same reason, of the expected worsening of the spatial resolution for inclined tracks. Despite a more complicated mechanical assembly, the insertion of an intermediate mesh separating the conversion from the preamplification region (as in the original multistep chamber design) would have the additional advantage of a constant (instead of an exponential) amplification of the charge released in the conversion region, and of introducing an intrinsic delay useful for triggering purposes. We have tried also this approach and we measured a similar gain boost [4].

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