Preliminary Report on a Planar Surface Chamber Working in Limited Streamer Mode

LAA Large Area Devices Group
CERN, Geneva
Switzerland
Presented by
D. Mattern and M.C.S. Williams

Abstract

This report outlines the very preliminary work that we are doing to investigate whether we can build a chamber with lines or other types of patterns on a insulating surface. The usual problem with this approach is that the insulator gets rapidly charged and makes it impossible to obtain a high enough field to work with gas gains in the proportional or limited streamer mode. However, with our surface patterns we reach a steady state with very high gas amplification. We are using anode structure widths of typically 300 μm, which can be easily obtained in a printed circuit board production line. We will discuss the measurements being done with three different chambers and give an outline of the continuing studies.

Introduction

The purpose of the LAA large area devices group is to find a suitable detector for μ-detection at future hadron colliders.

Many people have had the desire to build a chamber by 'printing' the lines on an insulator, using the techniques of printed circuit boards or some similar technology. In fact there have been successes. Neumann[1] et al. built a chamber where they attached wires onto a resistive foil and obtained efficiencies of 85%. Recently Oed[2] followed by others [3,4] have built a device with 10 μm wide lines, with 200 μm pitch evaporated onto a glass plate. They have obtained a gas gain of 10³ and 10⁴.

This was the starting point of our investigation. We decided to scale up their device and have lines of 100 μm width etched onto standard Kapton and epoxy sheets with a pitch of 1 cm.

Set-up and results

Our first surface is shown in figure 1. Basically it is a series of parallel copper lines etched onto a Kapton foil. They are alternately cathode and anode. The anode lines are 100 μm wide, with a wider section at the tip of 300 μm to reduce corona discharge problems at the ends. This surface we installed into a gas tight box through which we flowed pure isobutane. We connected the anode lines (via a transformer and diode box, as a protection against sparks) to a x5 LeCroy amplifier (LRS 335L) and then to a Tektronix 2440 digital oscilloscope. We irradiated the box with a ⁵⁷Co source (130 keV γs) and applied a positive high voltage to the anodes. At 6 kV we started to observe signals. Immediately after applying the high voltage to the surface many signals were observed, but the rate quickly dropped within a few minutes to a steady rate still correlated with the source.

Further work showed that only the tips of the 300 μm section of the anode lines remain active, i.e. giving a signal in this steady state mode.

Our initial understanding of this effect came from our work with blade chambers [5]. In figure 4 of the contribution to this conference concerning blade chambers, we show the field and equifield lines of a blade chamber. The field is highest at the tip. All field lines are in the surface of the paper. An insulator has the property that no field line ends on it (if they do, then a free electron or positive ion would be attracted to the surface changing the potential so that field lines no longer end on the surface). Thus if we could, by some magic means, insert a sheet of insulator parallel to the plane of the paper, the field should be undisturbed. This is not a true representation of the field of our printed device as the field has to be considered in three dimensions, however it is a useful way of visualising the potentials on the surface. This means that in the steady state the tip of the anode is still surrounded by a nonlinear field on the surface.

figure 2: Second surface chamber, dotted lines are on second layer

With this analogy in mind we constructed our second surface shown in figure 2. If the basic cell of this surface was a cross-section of a blade chamber, then the field on the surface should be as shown in the figure from [5].

figure 3: Counting rate vs. HV for various anode line widths with ⁵⁷Co source

We made various similar patterns with different anode line widths. Using a discriminator/scaler set-up to quantify the results, we found a similar behaviour for different
width lines, except for needing a higher voltage for wider lines. We found that lines even as wide as 1.5 mm also give signals. However with the anode-cathode spacing used on this surface, sparking occurred at several hundred volts above this point. The results for the various line widths are shown in figure 3. We show the time dependence of the counting rate in figure 4.

**Figure 4:** Rate vs. time with $^{57}$Co source

This rate drops for the first 5 minutes and is then stable giving the same rate after three hours. The rate is effectively zero without the source. We have tested the 300 $\mu$m wide lines of this chamber in a 5 GeV/c pion beam. We could measure the position of the through-going particle with a set of external drift chambers. In figure 5 we can see points in a plane perpendicular to the beam for particles that give a valid 'stop' signal to the TDC. It is easy to see that the sensitive region is located only at the tips of the anodes. The TDC spectrum is shown in figure 6. It is compatible with the assumption that we do have drift of electrons in the gas.

**Figure 5:** Minimum ionizing particles crossing foil chamber

Another strong indication of this can be seen, when we apply a cut on the drift time excluding drift times greater than 100 ns: we cut the tracks that are furthest from the tips. The $y$-projection of figure 5, also with this time cut, is shown in figure 7.

**Figure 6:** Drift time spectrum. Measured with beam particles.

Encouraged by these results we decided to make a plane of 'tips', i.e. the anode is just a small circle. This is favorable because we avoid the inefficient part (the lines) of the anodes. Since we need to connect a voltage to it, and to read out the pulses, these spots are through-plated to lines that run on the back side. The diameter of this hole is 0.5 mm with a pitch of 10 mm. These holes

**Figure 7:** $y$-projection with time cut (dashed line)

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**Figure 8:** The hole chamber: a) top view, b) cross section

we surround with a square cathode grid made of 300 $\mu$m lines. In order to control the charging of the surface we inserted a ground plane in between. This plane comes within 1 mm of the plated through hole. We show this design in figure 8.

**Figure 9:** Charge vs. High Voltage with $^{57}$Co source

We mounted a ground plane 4 mm above this surface and installed it inside a gas box filled with 3:1 Ar/Isobutane.

**Figure 10:** Envelope of hole chamber signals ($^{57}$Co source)

In figure 9 we show the average charge of the signals observed from this surface versus high voltage. One can see that the signals are large and increase with high voltage. Our digital oscilloscope displays the maximum and minimum signal that satisfy the
trigger (i.e. the envelope). This is shown in figure 10. One can see that even though the trigger is set at 25 mV the smallest signal has a peak at 200 mV. It seems that either we grow a streamer or not. Another interesting point is to test whether we are able to observe the positive ions coming from the gas amplification process. We coupled our digital oscilloscope directly to the ground plane above this surface with a 1 MΩ input impedance. The averaged pulse is shown in figure 11. Initially there is a large charge induced by the growth of the streamer, and the slow increase of the signal for 80 μs is compatible with mobility data for positive ions and the assumption of positive charge moving towards the cathode. Further work is in progress on the investigation of this surface.

![Figure 11: Drift of positive ions. measured with 57Co source](image)

Advantages of the design

There are many advantages of such a chamber. One goal is to produce a large area detector with this method. If we can find some simple pattern that works with a reasonable efficiency for minimum ionizing particles, then one can imagine printing sheets or rolls of it, and then using it somewhat like wall paper. Another big gain could be that it would be very easy to make a geometry that suits the experiment. No longer is one bound by straight stretched wires or flat surfaces. Furthermore we have been using somewhat standard printed circuit techniques to generate our surfaces. 250 μm lines are a standard line width in this business. This would lead to highly automated and simple chamber construction.

Aim and future work

These studies have only just begun. We have shown that we can have a surface that produces large pulses and that this surface works in a repeatable and stable way. Obviously the goal is to produce a chamber that is 100% efficient for minimum ionizing particles, with a good position resolution.

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References

[3] F. Angelini et al., INFN-P1/AE 89/2
[5] LAA Blade Chamber, this conference