Gaseous Pixels

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Abstract

Several years ago a revolutionary miniature TPC was developed using a pixel chip with a Micromegas foil spanned over it. With a drift range of roughly a centimeter the energy resolution (measured on the absorption the X-rays from a 55-Fe source) was remarkably good. To overcome the mechanical stability problems and improve the positioning accuracy while spanning a foil on top of a small readout chip a process has been developed in which a Micromegas like grid is applied on a CMOS wafer in a post processing step. The aluminum grid is supported on insulating pillars that are created by etching, after the grid has been made. Several geometries have since been tested and we now believe that 'gas on a slimmed silicon chip' (Gossip) may be realized. The drift region of such a gaseous pixel detector would be reduced to a millimeter. Such a detector is potentially very radiation hard (SLHC vertexing) but ageing and sparking must be eliminated.

Key words: Pixels, Ingrid, Gossip.

1 Principle of operation

Gossip is pixel detector without a solid state detection layer. Instead the signal is formed in a thin gas layer (1 mm) and amplified in a gap (50 μm) between the surface of a CMOS chip and Micromegas [3]like grid. A minimum ionizing particle will on average produce about ten ion-electron pairs over the 1 millimeter drift space. The electrons drift towards the grid through the low field drift volume (100 V over the 1 millimeter layer). The maximum drift time is only 16 ns due to the small size of the volume. Between the grid and the readout chip a high electric field is created in which each electron will initiate an avalanche. With a potential difference of 400 V over a distance of 50 um, a gas multiplication or gas gain of 1000 is reached.

It has been shown that the Medipix chip [1] can be used to detect signals created by an electron induced avalanche when a Micromegas is mounted on

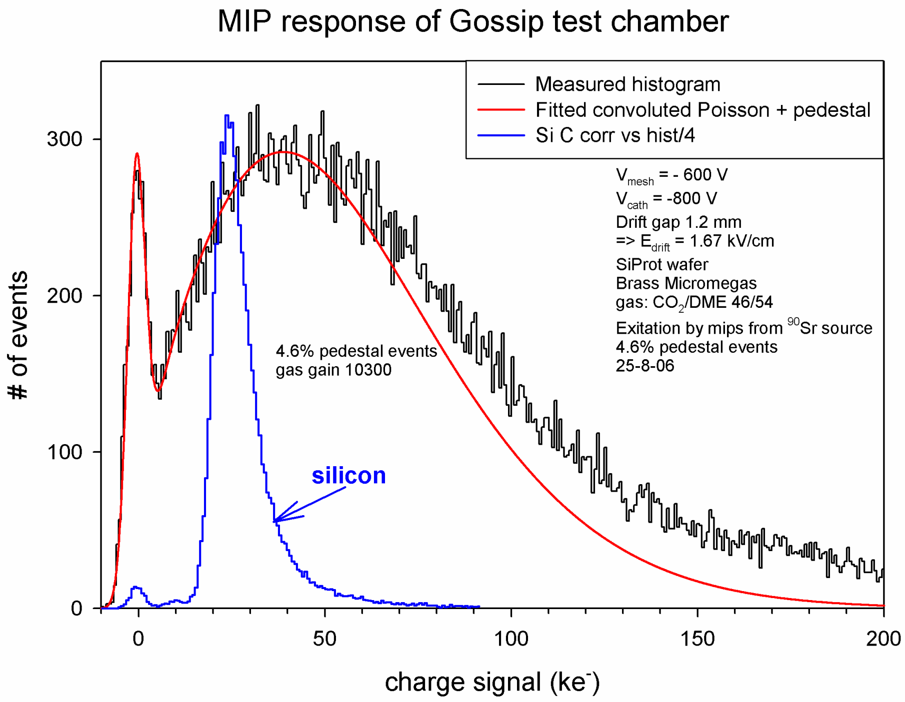

Fig. 1. Measured pulse height distribution in a one millimeter gas layer (single electrode)

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the chip [2]. For these measurements a drift volume of 14 mm was used thus constructing a small time projection chamber. At present we are developing a detector with a 1 mm drift region over a readout chip that carries an integrated grid. An existing chip (like ATLAS or CMS pixel chip) will be used to build the first Gossip detector. Until now several grid geometries have been tried and were proved to be successful. The integrated grid (InGrid [4]) can be adapted to match any pixel pitch.

Recently the first measurements were performed with a 1 mm gas gap. See figure1

2 Radiation hardness

Through constant flushing of the gas volume, direct radiation damage is usually no issue in gaseous detectors. The gas may cause however the formation of deposits on the anodes, a process referred to as ageing. First ageing tests do not show a significant degradation in performance of the chamber. In the proposed layout the gas gain and the electrical field near the anode are very moderate compared to most wire chambers.

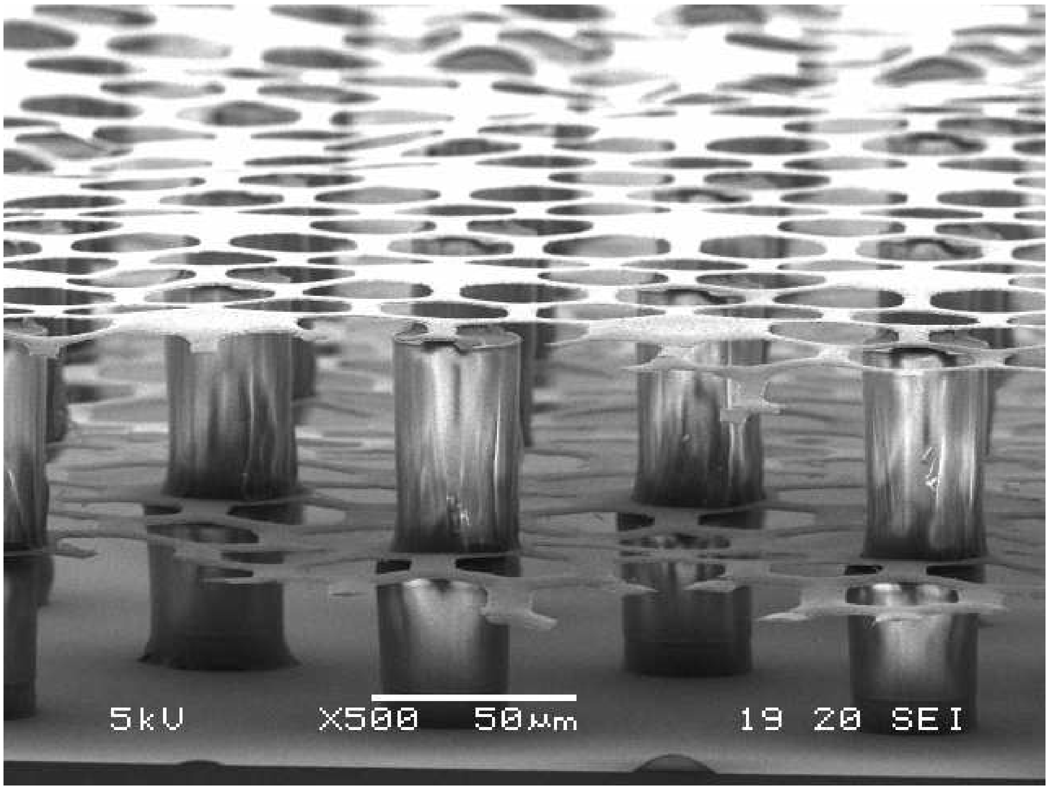

Fig. 2. TwinGrid test structure. Two grids on top of each other used for spark protection.

3 Spark protection

In principle each single electron created in the drift region (on expects roughly 10 electrons from a minimum ionizing particle) will initiate the development of an avalanche in the region between the grid an the anode. When a given particle deposits much more energy and thereby releasing many primary electrons, this may cause such a huge avalanche that the readout chip is actually destroyed. This could be melting or evaporation of surface layers or and overvoltage on the input of the CMOS preamplifier. Without protection these effects are indeed observed in the lab. Two protection mechanisms are under construction. Firstly an amorphous silicon layer is applied on top the CMOS wafer (underneath the grid). Secondly, wafers are being equipped with double grids on top of each other (TwinGrid). Both techniques are promising. The TwinGrid actually has some other interesting consequences since the second grid gets rid of the ion signal. As a result the single electron signal development is much faster (electron drift over 50 μm).

In figure 2 a picture of the TwinGrid is shown. The insulating pillars are easily recognized as well as the double layer of grids. The pitch between two holes in the grid is 50 μm.

4 Wafer thinning

To fill the detector with gas we propose to fully surround it with gas at ambient pressure. Since no bump bonding is required it is possible to thin the readout chip. A second advantage is the operating temperature. The detector can be operated at room temperature, equal to the temperature at which a full scale would be assembled.

5 Readout chip

In 2005 a preamplifier circuit was design that exploits the fact that the input capacitance of a Gossip detector is very low compared to present detectors. The first prototype of the fast (40 ns peaking time), low-noise (ENC = 60 e- (RMS) and low-power (2 μW per channel) input circuit for the Gossip chip has been successfully implemented in 0.13 CMOS technology. In 2006 the first small scale pixel chip is submitted with the same preamplifier but know quipped with a tdc for each pixel.

6 Outlook

A prototype Gossip detector is being developed. This detector combines for the first time all elements of the Gossip principle. The CMS pixel chip will be used with InGrid and readout. Several detectors will be made and put together in a beam telescope.

At the same time developments will continue in the design of a front-end chip that will fully profit from the negligible input capacitance and reduced power consumption. By the end of 2006 a 16 x 16 pixels chips will be submitted. Since there is no ageing of the gas there is no need (no harm either) in cold operation of the detector. Cooling the front-end will however be necessary and it will prove to develop tiny structures to make sure the overall material budget stays well below the present day vertex detectors. The absence of bump bonding may give substantial saving in productions cost budget.

References

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