Readout Tests and Analysis of a Gaseous Pixelized Detector

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Abstract

Tests were made to review the performance of a gaseous pixelised detector, for potential use in the International Linear Collider (ILC). Subsequent data analysis was done to determine the quality of the data obtained and also the optimal method of operation for the detector.

1 Introduction

The ILC is a proposed electron positron collider which will continue in detail the study of high energy physics in the TeV energy range. Choice of technology to be included in the ILC depend on many criteria such as precision, material budget, resistance to electromagnetic interference and so on, but one of the currently proposed options is a Time Projection Chamber (TPC). The detector used for these tests is an Integrated Grid, known commonly as an InGrid, with a TimePix pixel readout chip.

2 Detector Details

A Time Projection Chamber is based on the drift chamber principle of determining the track position along the field direction, by measuring the time of drift of the primary electrons produced. It is a large cylindrical chamber typically separated into two drift regions of equal volume by means of a central high voltage plane. The endcaps of the chamber are segmented into concentric sectors filled with pads. Circular conductive strips are set at linearly decreasing voltages around the chamber in a field cage to create a uniform axial electric field with opposite field directions in the two drift regions. Arrays of anode and cathode wires are placed parallel to the pad planes for gas amplification purposes.

Primary electrons produced by a particle traversing the chamber will drift along the field and when approaching the anode wire plane, will enter a high field region where they are multiplied. Some of the ions produced in this process drift towards a pad plane and hence a pattern of hits is recorded and a two-dimensional projection of the track is obtained. The uniform field in the drift region means that the constant electron drift velocity can be used to infer the arrival time of the signals at the pads.

The group would like to use an InGrid within the TPC that they are constructing. Our InGrid consists of a Micromegas-like structure built directly above a TimePix chip, supported by pillars of SU-8. Micromegas, or Micro Mesh Gaseous Detector, uses a thin metal grid to separate the drift region where the primary electrons are produced from the amplification region where they are multiplied, supported by insulating pillars above the anode plane. SU-8 is a negative tone photoresist consisting of the SU-8 polymer (Bisphenol A Novolak epoxy oligomer), a photoacid generator (triarylsulfonium hexafluroantimonate salt) and a solvent (gamma-Butyrolactone). Detector efficiency is optimised in this construction as you can see from Fig. 1, as each pillar stands in the middle of a group of four pixels and each pixel is directly aligned with one of the holes in the grid. The high granularity of such a detector allows even single electrons to be detected, making it ideal for tracking particles.

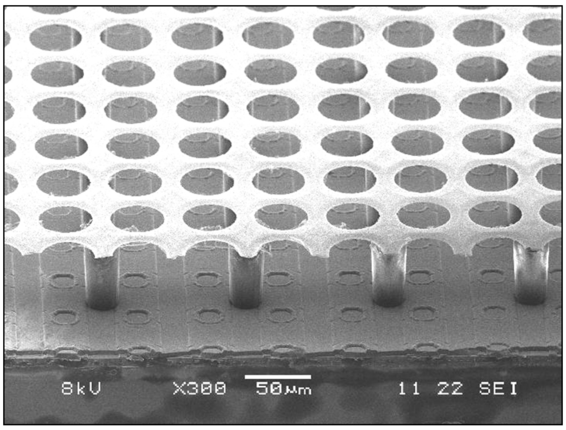

Figure 1: Showing the grid suspended over the TimePix chip by SU-8 pillars, with a protective silicon nitrate layer between the pillars and chip

The protective silicon nitrate layer in our detector is roughly 8μm and helps to protect the pixels against electrical discharges which could otherwise destroy them, by distributing the charge across a larger area. Our detector contained 256x256 pixels and had an active area of 14x14mm^2.

3 Experimental Setup

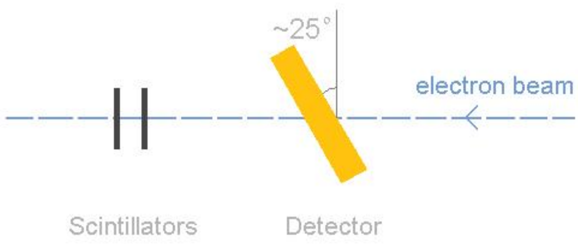

Figure 2: Birds-eye view of the setup (not to scale). Tests were done with both 4 and 5GeV electrons. The scintillators were used to provide a coincidence signal used in the logic system of the setup.

The detector was set up at a slight angle to the electron beam, and initially a 70:30 mixture of Ar:CO_2 was used as the amplifying gas, to ensure that the setup was working as desired. Later we switched to using a 80:20 mixture of He:iC_4H_{10} as better defined tracks could be produced using this gas. This is because Ar:CO_2 has a lower single electron efficiency compared to the He:iC_4H_{10} mixture - for the same voltage, the Ar:CO_2 gain is much less so higher voltages are required - this leads to a greater risk of discharge and would damage the chip.
The logic that we used for the setup is shown in Fig. 3. Data acquisition was performed with the Pixelman software, developed by the Institute of Experimental and Applied Physics, of the Czech Technical University in Prague. The detector was first operated in stand-alone mode, controlled entirely using the parameters set by the software and then later in a handshake-mode with the computer. This so called handshake-mode is used to try and capture the maximum information about a single track without introducing background hits.

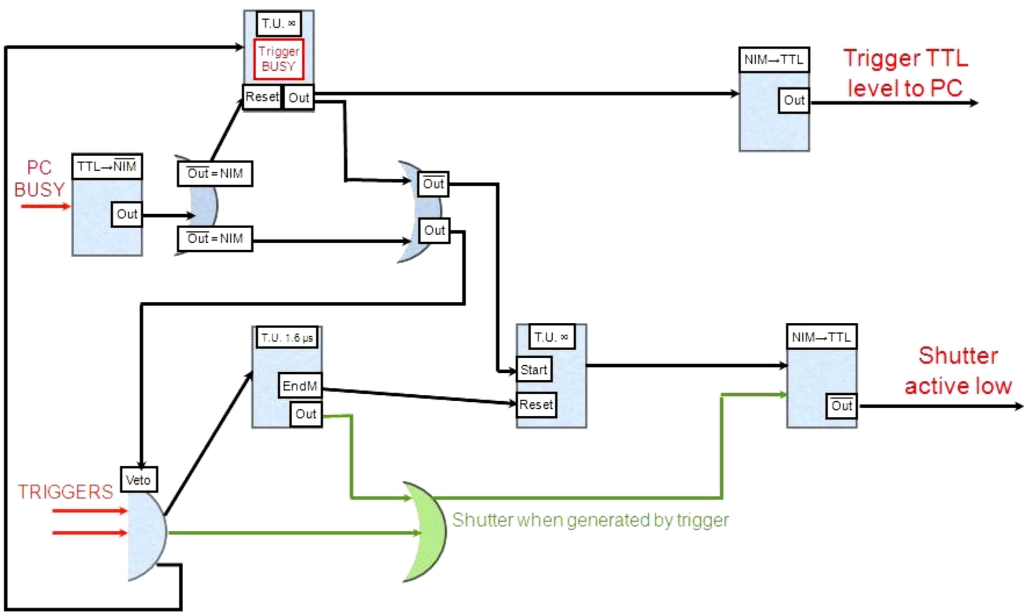

Figure 3: Schematic of the logic system used. The green lines refer to the setup operating in stand-alone mode, without the handshake with the computer.

The shutter of the detector is open at the beginning before the arrival of particles. The coincidence provided by the two scintillators causes the shutter to be closed 1.6μ after the arrival of such a trigger. This 1.6μ time interval is calculated to be the maximum time required for a particle to drift towards the anode, based on the drift velocity of the gas used. A signal is also sent to the computer such that no new triggers can be accepted while the PC is busy processing and acquiring the data. Once the computer is free again, the system is reset and the shutter is reopened to accept more triggers.

4 Measurements

Data was taken with 4GeV electrons with Ar:CO_2 at a grid voltage of 400V and then later with 5GeV electrons with He:iC_4H_{10} at grid voltages of 360, 380, 400 and 420V. Some preliminary measurements were also taken with 4GeV electrons using Ar:CO_2 during the implementation of the handshake-mode.
As expected, the tracks produced with He:iC_4H_{10} were much more defined than those of Ar:CO_2, even at lower voltages and taking into account any differences in energy. However we had also had several problems with the data taken. Firstly, especially with the Ar:CO_2 gas there were a few large discharges where most of the pixels in the chip went into overflow, as shown in Fig. 5. Also, there are some frames taken where there are no tracks at all or several tracks. Multiple tracks can be produced for example when particles arrive extremely close in time such that the logic system doesn't recognise them as separate tracks or when a particle hits the anode and is backscattered into the detector, such as in Fig. 6. Some frames containing several extra background tracks in overflow can be seen, and may be due to our configuration of the system, suggesting that our trigger efficiency is low. In addition there are some frames taken which are in fact empty and contain nothing at all.

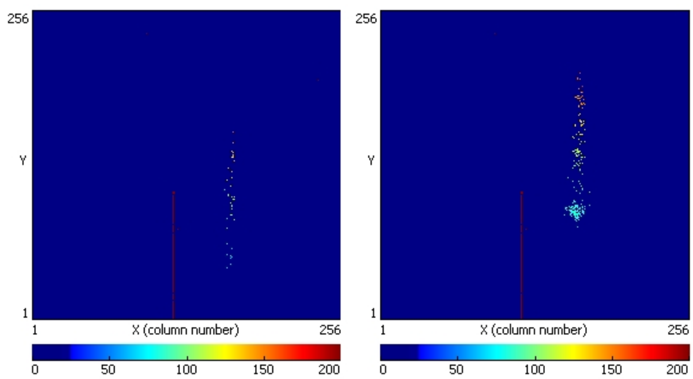

Figure 4: Both are tracks made using 80:20 He:iC_4H_{10} - the one on the left was made at a grid voltage of 360V whereas the one on the right was made at 420V. Clustering can be seen clearly in the track at 420V, showing lower diffusion close to the anode as expected.

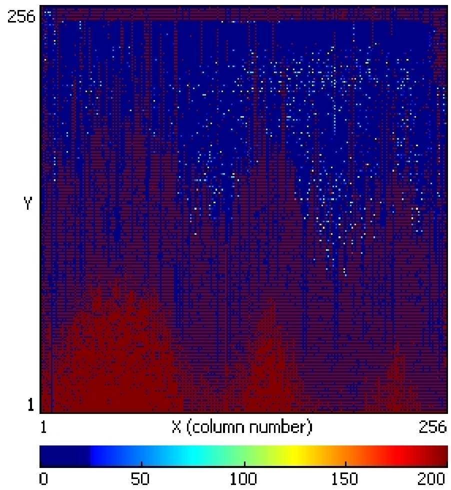

Figure 5: A large discharge over the entire chip. Many of the pixels are in overflow (shown in red in this colour scheme). The dyke used to support the grid in the detector can be seen as a thin red border around the edge of the screenshot.

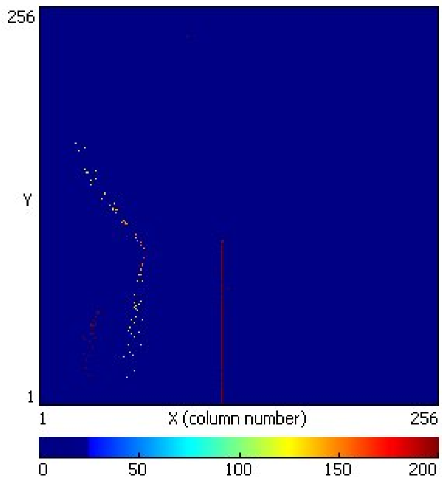

Figure 6: An example of a frame in which a particle is backscattered from the anode, producing tracks which emanate from the same point. The central red half-column corresponds to some damaged pixels and show up as an overflow in every single frame.

5 Analysis

Time spectrums of the data taken at various conditions were produced and surprisingly, have a peak width about twice that expected. For example, in Ar:CO_2 at the voltages used we expect a drift velocity of around 1cm/ms and therefore since there is a distance of the order of 1mm between the grid and anode, with the configurations used the peak in the time spectrum should fall to zero after about 100 clock counts. This is not observed at all as the Ar:CO_2 spectrums run over the time we have allowed for the shutter to close after the arrival of the trigger. With the He:iC_4H_{10} data, the peak does fall to zero within the time allowed in about 100 counts, but since the drift velocity at the voltages used are double that at similar voltages for Ar:CO_2, the peak width is still roughly double the width expected. For data taken using the He:iC_4H_{10} mixture, with increasing voltages the sides of the peak get sharper and peak width can be seen to decrease as well, which is as expected since the drift velocity increases with voltage.

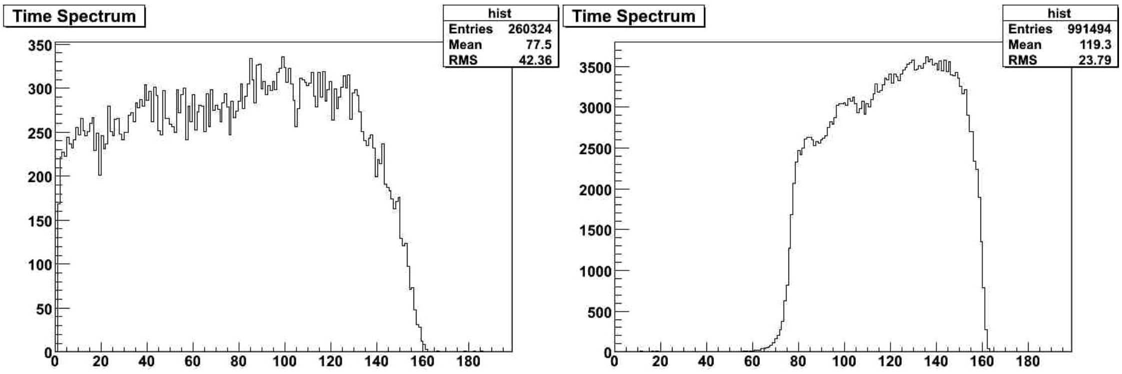

Figure 7: Time spectrums where the one on the left is for Ar:CO_2 at a grid voltage of 400V and the other is for He:iC_4H_{10} data taken at a grid voltage of 420V. Expect a sharp falloff on either side of the peak and a relatively flat top.

By making a spectrum of the number of hits in each frame, it can be seen that in the data taken with He:iC_4H_{10}, there are a significant number of empty tracks. This can be seen easily as a narrow spike corresponding to about 105 hits, which appears due to the half-column of bad pixels present. Removing such 'empty tracks' it can also be seen that the average number of hits increases with voltage as expected since the gain of the gas increases with voltage also.

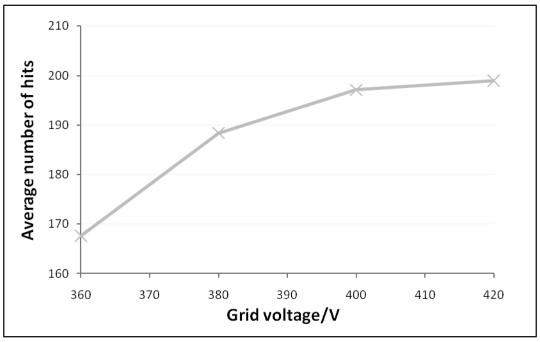

Figure 8: Graph showing the mean number of hits against the grid voltage for He:iC_4H_{10} data. As expected, the average number of hits increases with voltage.

Due to the nature of the data taken, there are a number of factors which need to be considered when analysing the data taken in addition to those mentioned previously, especially if further processing is to be done with the data obtained. For instance, in the case where there are multiple tracks present or a discharge, these can be excluded by removing any data with a very high number of hits. Any pixels which are in overflow tend not to affect the time spectrum as they are far out of the timescale we are looking at. Most frames contain a few random hits due to background noise which are not hugely significant, but could possibly be removed by implementing an algorithm which includes only hits in the vicinity of the track. There are also a few tracks which are not straight as expected, but for some reason have a small kink in them.

6 Outlook

Of most importance is to determine why the peak in the time spectrum is wider than expected and also to begin taking data in conjuction with the EUDET telescope, and not just in handshake-mode with the computer only. This will require some more work to be done in including the telescope into the logic system we are using currently. Also useful would be perhaps to analyse track quality so background or multiple tracks can be removed from the data taken.

7 Acknowledgements

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