New Results of GridPix TPCs

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Abstract. The Gossip detector, being a GridPix TPC equipped with a thin layer of gas, is a promising alternative for Si tracking detectors. In addition, GridPix would be an interesting way to read out the gaseous phase volume of bi-phase Liquid Xe cryostats of ν-less double beta decay and rare event (i.e. WIMP) search experiments.

1. The GridPix detector

100 years ago, in Manchester, Hans Geiger operated the first gaseous detector, which was the basis for 'wire chambers', widely applied as track detectors in particle physics experiments. In wire chambers gas amplification occurs, close to the wire surface, due to the strong (1/R) electric field. This enables the detection of the few single electrons created in the gas by ionization radiation. In Micro Pattern Gas Detectors, areas with a strong electric avalanche field are created by one or more conductive perforated (grid) planes. The granularity of such a detector is determined by the pitch of the holes and can be much better in comparison to wire chambers. With each grid hole equipped with its own readout channel (preamp, shaper and discriminator) in the form of an active pixel array in a CMOS chip, this micro-granularity is pursued: each hole is a stand-alone detector [1]. This GridPix detector matches future demands on occupancy, position resolution and time resolution for high radiation trackers at future ILC, CLIC or sLHC colliders. Chip manufacturing processes made two innovations possible: the integration of Micro Pattern Gas Detectors with pixels chips (Integrated Grid, InGrid), and the deposit of a high-resistivity protection layer on top of pixel chips. This 'wafer post processing' technology may enable next innovations such as micro channel plates and secondary emission foils. Essentially, the application of gas as detection material, compared to, for instance, Si, offers several advantages, relevant for future tracking and imaging detector developments. For this, the development of TimePix-2, a new general-purpose pixel chip, is essential.

1. 1 The Integrated Grid (InGrid)

We constructed a Micromegas, by means of ‘Wafer Post Processing’ technology, on top of de MediPix-2 and TimePix pixel chips [2]. The inherent precision of this technology allows a perfect alignment of the grid holes with the pixel input pads, sub-micron precision in the grid hole diameters and a constant thickness of the avalanche gap; see fig.1. We have recorded an unprecedented energy resolution (5.2 % r.m.s) of the photopeak of $^{55}$Fe pulses in proportional gaseous detectors [3]. The technology, applied on single chips, is being prepared to be applied on wafers.

The present material used for InGrid is aluminum. In a new development we would like to use high-resistivity material for this, like amorphous silicon. This would add to the discharge quenching power.
1.2 Gossip: gas versus Silicon

GridPix can be considered as an active readout system for a gaseous volume in which an electric (drift) field is applied. The maximum drift length, equal to the ‘thickness’ of the gas volume, may vary between 2 m in the case of large TPCs, and 1 mm in case of the Gossip detector [4]. This detector is an alternative for Si pixel- and strip detectors where the Si is replaced by a thin gas layer. We have operated a Gossip detector which was based on the CMS pixel FE chip PSI-46.

Gas, as detection material for tracking detectors, has several advantages with respect to Si:
- gas can be exchanged: radiation damage does not occur;
- by applying a strong electric field, noiseless gas amplification is possible, resulting in arbitrary large charge signals. This reduces the required power for the input circuits, and thus the required materials for cooling;
- the source capacitance, seen at the input of preamplifiers, is minimal;
- gas is light;
- gas is generally cheap;
- gas detectors are little sensitive for (background) X-rays, gammas and neutrons;
- there is no bias current in gaseous detectors;
- gaseous detectors do not require to be operated in a cooled environment;
- $\delta$-rays can be recognized and do not cause an error in the track position measurement.

Gaseous detectors have two disadvantages: discharges occur, potentially destroying (parts of) the detector, and chamber ageing. The discharge issue has been solved [5]; the knowledge on chamber ageing has recently increased dramatically [6].

2. The application of GridPix in bi-phase LXe rare event detectors

With the gaseous planar GridPix detector, the (2D) position and the time of arrival can be registered of electrons, after their drift from their point of creation. The efficiency of detecting single electrons can be as high as 99 percent, while the noise, appearing solely as falsely detected single electrons, can be extremely low. This GridPix detector would lower the threshold of detecting rare (WIMP) events, or would improve the energy resolution in 0\nu e experiments. The measured ionisation pattern would provide information on the direction of a WIMP interaction, or, in 0\nu e experiments, the electron energy or the distribution over both electrons.

2.1 WIMP signals in liquids or gases

A recoil of a nucleus creates a track of electron-ion pairs, with a threshold of one electron. After their drift, these electrons can be detected by the GridPix readout system. If the time of creation is measured by means of PMs, the position, in three dimensions, of all participating electrons can be obtained, and therefore the ionisation
The pattern and total number of electrons define the possible interaction. A large number of participating electrons could be due to neutron capture or gamma absorption. A small number of participating electrons can be due to X-ray absorption, but this can be excluded if there is no nearby ionisation: the smaller number of participating electrons, the smaller the X-ray energy and range. The fiducial volume of the experiment is related to the amplitude of the events (self-shielding). The extreme threshold can be reached if the readout is sensitive for single electrons.

Assuming a cylindrical volume with vertical axis, PMs could be placed at the bottom plane and cylinder surface. The top (circular) surface could be covered with a continuous Gridpix surface, consisting of TimePix chips equipped with InGrid. GridPix would be sensitive for arriving electrons continuously, untriggered. Triggers from PM tubes would result in drift time-correlated electron measurement.

The measurement of the noise in GridPix is essential and well possible by switching off the drift field. This experiment does neither require to be placed in a mine to avoid cosmic muons, nor needs to be made of low-background material. These background events are well recognised, and, in fact, contribute to the knowledge of the (pixel) detector.

References
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