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Direct readout of gaseous detectors with tiled CMOS circuits

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Abstract

A coordinated design effort is underway, exploring the three-dimensional direct readout of gaseous detectors by an anode plate equipped with a tiled array of many CMOS pixel readout ASICs, having amplification grids integrated on their topsides and being contacted on their backside.

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Recently several successful attempts were made to operate a Micro-Pattern Gas Detector (MPGD), directly read out by a CMOS pixel ASIC as active anode (see e.g. Refs. [1–3]). Both Micromegas [4] and GEM [5] devices have been used. An example of a minimum ionising cosmic track detected in an Ar/iC_4H_{10} gas mixture is shown in Fig. 1. A clear signature of single primary ionisation clusters can be observed.

In order to exploit these techniques in larger detectors, like a Time Projection Chamber, anode plates equipped with tiled arrays of many CMOS pixel readout ASICs are needed. In this short contribution we describe a coordinated design effort to arrive at such larger prototypes.

An important step in the development of this detector technology is the manufacturing of the Micromegas-like amplification grid onto the silicon wafer, using wafer post-processing techniques. Initial results from a first prototype detector showed excellent energy resolution and uniformity for the photopeak from an ^{55}Fe source, reflecting the extremely good geometrical precision of the device [6]. At present, several grid structures with different geometries (gap thickness, hole shape and hole pitch) have been routinely produced and their operational characteristics are being measured. An example of such results is given in Fig. 2.

Because of the high electric field ($\approx 80\,kV/cm$) in the gap just above the CMOS readout ASIC, the chip can easily be damaged by possible discharges. Currently, the deposition of an amorphous silicon layer with a thickness of a few μm and volume resistance of order $G\Omega \cdot cm$ is being investigated.

So far, the "proof-of-principle" experiments of Refs. [1,3] were performed using the Medipix2 pixel readout chip [7] as anode. Two-dimensional projected track images like the one shown in Fig. 1 could be obtained from this 256 × 256 array of pixels of size $55 \times 55\,(\mu m)^2$. In the framework of the EUDET project for Linear Collider detector R&D [8] a modified version of the Medipix chip (called TimePix) is being developed, where a 100 MHz clock will be distributed to every pixel, thus providing a drift time measurement and allowing for three-dimensional tracking.

Another variant of this detection principle consists of the Gossip ("Gas On Slimmed Silicon Pixel") detector, where the "thinned" CMOS pixel readout chip + grid is operated with only 1 mm thick gas layer [9]. Such a detector can possibly be used as a vertex detector in high-radiation environments as e.g. a luminosity upgraded Large Hadron

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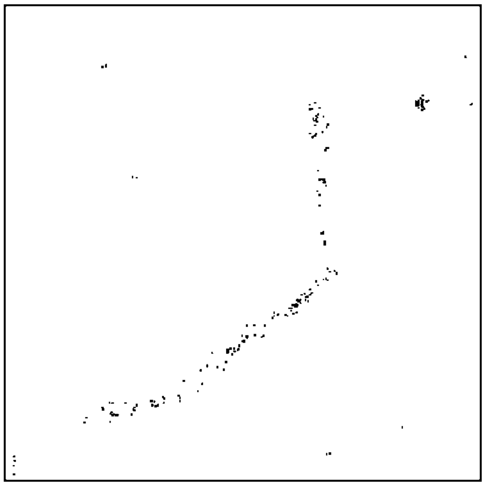

Fig. 1. Image recorded from the MediPix2/Micromegas prototype TPC showing charged particle tracks. The image measures $14 \times 14\,mm^2$ and consists of 256×256 pixels. The gas mixture used was Ar/iC_4H_{10} 80/20.

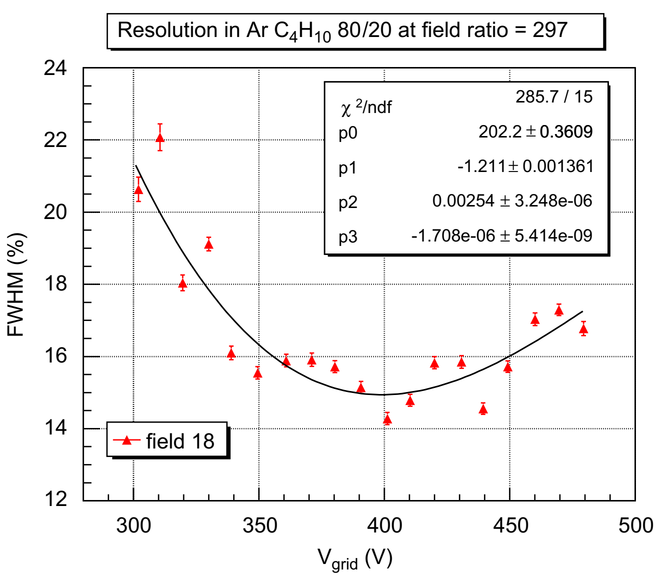

Fig. 2. Resolution (FWHM) for the photopeak from an ^{55}Fe source in a Ar/iC_4H_{10} 80/20 mixture as a function of the grid voltage, keeping the electric field ratio in the multiplication gap and drift space constant at a value of 297.

Collider (SLHC). Work is in progress to design a new (very low noise) input stage for the corresponding pixel readout chip in 130 nm CMOS technology.

For large scale integration of many detector modules, we plan to make use of semiconductor processing technologies that are being developed within the Eureka project "high-

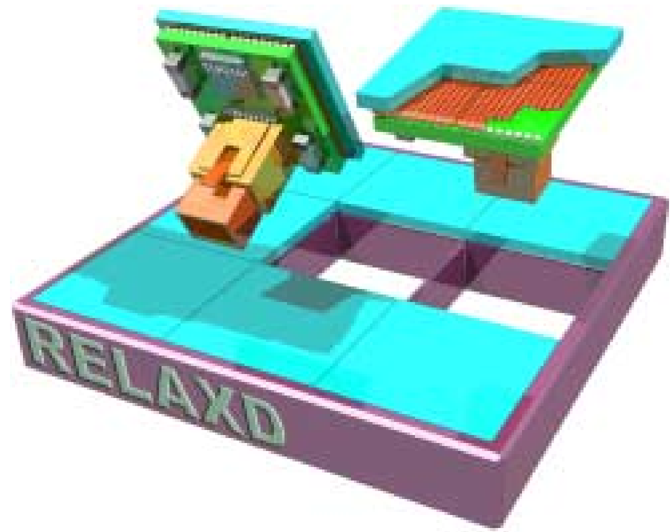

Fig. 3. Artist impression of the modular RELAXD X-ray imager, consisting of nine tiled microsystems of $3 \times 3\,cm^2$ each. Every microsystem contains a 0.25 megapixel sensor diode, 4 Medipix2 chips, and a 3.125 Gbit/s serial readout circuit.

Resolution Large-Area X-ray Detector" (RELAXD) [10], which aims for mass-manufacturable modular X-ray detector microsystems (Fig. 3). These new technologies, like through-the-wafer via etching to allow backside contacting of chips with ball-grid-array techniques, edge-less ASICs (and sensors), are directly applicable in our application. They will allow a very high fill factor. Within this project also multi-gigabit per second (serial) readout with standard protocols is being addressed [11].

References

[1] P. Colas, et al., Nucl. Instr. and Meth. A 535 (2004) 506; M. Campbell, et al., Nucl. Instr. and Meth. A 540 (2005) 295.

[2] R. Bellazzini, et al., Nucl. Instr. and Meth. A 535 (2004) 477 and contribution to this conference.

[3] A. Bamberger, et al., contribution to this conference.

[4] Y. Giomataris, et al., Nucl. Instr. and Meth. A 376 (1996) 29.

[5] F. Sauli, et al., Nucl. Instr. and Meth. A 386 (1997) 531.

[6] M. Chefdeville, et al., Nucl. Instr. and Meth. A 556 (2006) 490.

[7] X. Llopart, et al., IEEE Trans. Nucl. Sci. NS-49 (2002) 2279; X. Llopart, M. Campbell, Nucl. Instr. and Meth. A 509 (2003) 157.

[8] EUDET, Detector R&D towards the International Linear Collider ⟨http://www.eudet.org⟩.

[9] M. Campbell, et al., Nucl. Instr. and Meth. A 560 (2006) 131.

[10] E!3624 RELAXD, see ⟨http://www.eureka.be/inaction/AcShowProject.do?id=3624⟩.

[11] J.H.R. Schrader, et al., IEEE J. Solid State Circuits 41 (2006) 990.