

MHSP with position detection capability

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Abstract

The first implementation of a position sensitive readout for a Micro Hole and Strip Plate (MHSP) is described and tested. The readout consists on a resistive layer crossing the anodes and connected to a preamplifier on each side. By weighing the charge pulses on both preamplifiers it is possible to determine the interaction point. A 100–200 Ω resistance layer between consecutive strips was found to be the best compromise between position linearity and energy resolution. Preliminary results using 22.1 keV X-rays present a good linearity between the measured and the actual position with a mean deviation of about 0.15 mm and a position resolution of 1.6 mm full-width at half-maximum (FWHM), being limited by the analogue division electronic circuit. The performance of the MHSP position detector will be presented and discussed for 1D readout.

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1. Introduction

X-ray imaging has become a very useful tool in many branches of science. It is of major importance for analysis and diagnosis in biology and medicine, but its use is also increasing in neutron applications. The need of gas detectors with high gains and good stability at high pressure has put the novel Micro Hole and Strip Plate (MHSP) [1] in a privileged position for its development for neutron detection [2]. The MHSP has an intrinsic capability for position detection [1]. This gaseous electron multiplier is conceived as a combination of a Gas Electron Multiplier (GEM) and a Micro Strip Gas Chamber (MSGC) in a single, double sided element, integrating two successive independent stages of charge amplification: a GEM-like hole-avalanche and an MSGC-like anode-strip avalanche. Like the GEM, the MHSP is fabricated with

printed circuit board (PCB) technology from a 50- μm KaptonTM film, metallized with 5- μm -thick copper-layers on both sides. On the top-side, a GEM-like pattern of holes is etched through, where on the bottom side a standard microstrip pattern is etched, with the holes centered on the cathode strips. The MHSP achieves gains in excess of 10^4 in a Xenon atmosphere [3], and a ratio between top and anode signals of about 0.35, allowing measuring the charge signal produced on both sides with good efficiency.

In this work, a special MHSP was designed with independent anodes to measure 1D X-ray interaction position. A resistive layer was placed, by serigraphy deposition, connecting all the anodes, Fig. 1. The signals produced by the incoming radiation were collected from both ends of this resistance. The method of resistive charge division is the most simple and inexpensive to implement in this type of microstructures. Delay lines [4] or independent readout of the anodes by high-density electronics [5] are not compatible with the objective of building a simple, low-cost position sensitive gas detector, such as that proposed here. Furthermore, resistive charge division for position

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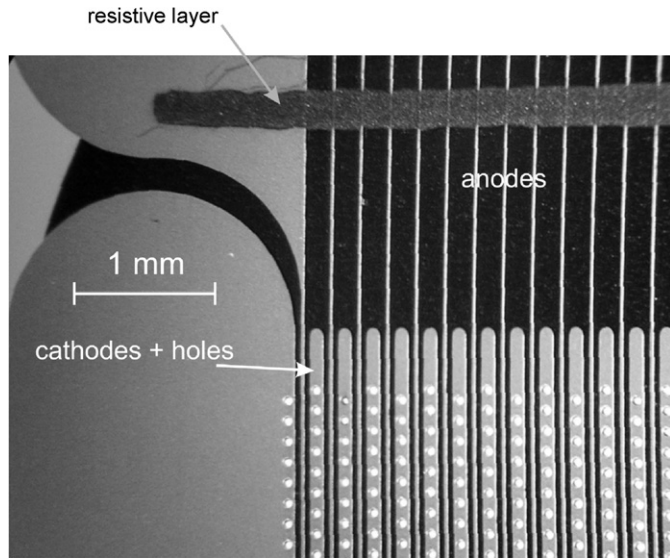


Fig. 1. The bottom side of the MHSP adapted for position readout, with the resistive layer crossing all the independent anodes.

detection has already been successfully used in MSGC [6,7], with spatial resolutions of 1.2 mm for neutron detection.

2. Experimental setup

The working principle of the MHSP can be found in Ref. [1–3, and references therein]. Fig. 1 shows a detail of the bottom face of the structure developed for this work, where the perforated cathodes, the independent anodes and the new resistive layer can be seen. The cathodes are 100 μm wide and the pitch is 200 μm . The distance between the holes in the cathode direction is 140 μm . The detection area is 28 \times 28 mm^2 .

The best value for the resistance between each anode provides a compromise between position linearity with minimization of side effects and acceptable S/N ratio. This value was determined by dividing the charge collected from a standard proportional counter—simulating one single anode—through different resistor chains, and plotting the simulated position. The best value was found to be between 100 and 200 Ω per anode strip, which means around 20 $\text{k}\Omega$ in total.

The MHSP was placed 5 mm from the 25 μm thick MylarTM window of the detector and 3 mm from the induction plane at the bottom. The detector filling gas was Xenon, purified through SAES Getters.

The charge produced by the detector is collected by the two preamplifiers connected to the left and right ends of the resistive layer. The position X of the interaction is derived by

$$X = k \frac{X_L}{X_L + X_R}, \quad (1)$$

where X_L and X_R are the amplitudes of the pulses collected from the left and the right sides of the resistive layer, respectively and k is a calibration constant.

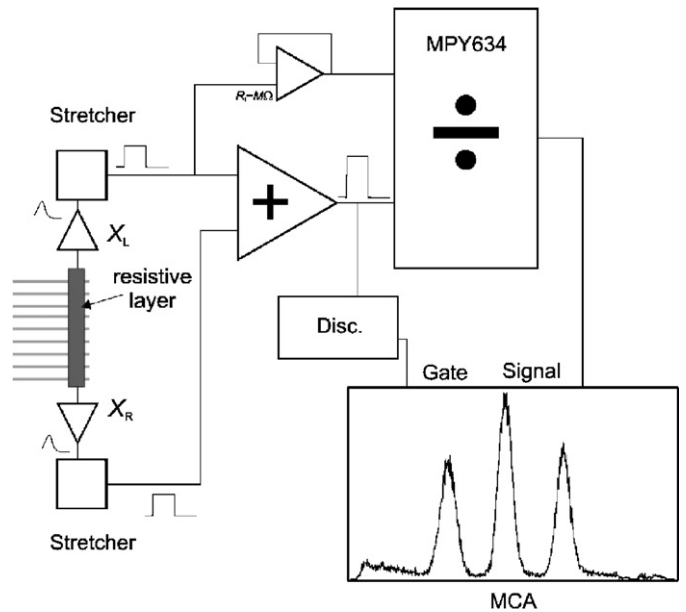


Fig. 2. The low-cost analogue circuit used in this work for the position readout.

The readout was made using Canberra 2006 charge pre-amplifiers and Tenelec 243 amplifiers with shaping time of 0.5 μs . Fig. 2 shows the processing electronics based on standard components, including a low cost analogue divider MPY634. This layout is similar to that used in Ref. [7]. Since there is a maximum time difference of about 100 ns between the arrival of both pulses to the amplifiers, they were stretched in order to achieve a better accuracy when summing and dividing.

For the measurements, the Ag K_α and K_β X-rays of a ^{109}Cd source were used to irradiate the detector window through five different holes, 2 mm in diameter, of a 3 mm thick stainless steel collimator. The holes are separated 6 mm from each other, over a width of 24 mm, and aligned perpendicularly to the MHSP strips. A discriminator was used to reject the pulses due to X-ray fluorescence from the copper present in the MHSP, Xe escape peaks and electronic noise. The TTL pulses arising from the discriminator provide the gate signal for the ADC of the multi-channel analyzer.

3. Experimental results and discussion

To evaluate the position linearity, separated measurements were made in the five holes of the detector window collimator. Fig. 3 shows the relationship between the position of the X-ray source and the correspondent measured position using Eq. (1). The peaks were measured separately and were normalized. On the left- and right-most positions the peaks are distorted because they are located at the borders, which correspond to the limits of the 28 mm detection width of the MHSP.

The right side of the graphic shows the difference between the X-ray source position and the measured

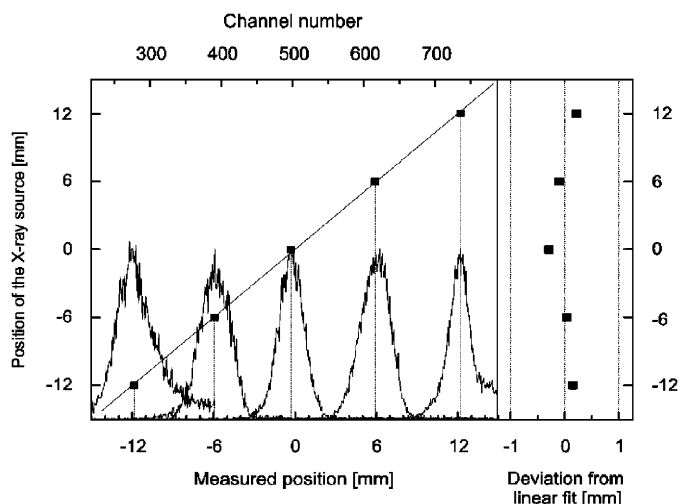


Fig. 3. Position linearity of the system and deviation from linearity trend line.

position. The mean of the absolute value of this difference is 0.15 mm. This demonstrates good position linearity, and the image distortion caused by this deviation is small compared with the achievable position resolution.

The peaks shown in Fig. 4 were obtained with the X-ray source placed 5 cm above the detector window. At the best measuring conditions, the peaks are totally separated from each other due to its spatial resolution and low background. The higher intensity of the central peak reveals that the source was placed at the center position. Due to the above-mentioned distortions the peaks at the borders are not shown in this graphic. The full-width at half-maximum (FWHM) of the central peak is lower than the 2 mm of the hole because we have used circular holes instead of slits, meaning that only at the center the hole width is 2 mm. The other peaks show slightly higher FWHM due to the fact that for these positions the X-rays do not enter the window perpendicularly.

When a smaller collimator was used (0.5 mm diameter hole) no improvements in spatial resolution were noticed. To test if the limitations in resolution are due to the detector or else, to the analogue division circuit, a BNC pulse generator was connected directly to the inputs of both shaping amplifiers, substituting the detector and charge pre-amplifiers. It was noticed that, for each constant pulse height, the degradation in the position resolution introduced by the processing electronics is negligible. However, for an increase of about 10% in height of the signal output in both shaping amplifiers (which is the typical detector energy resolution for 22.1 keV in this experimental conditions) a position variation of 30 channels was observed, corresponding to about 1.3 mm. This suggests that the spatial resolution of the detector is being limited by the accuracy of the analogue division circuit, which has a pulse height-dependent behavior. This confirms the need for upgrades made in recent models of analogue devices, which are no longer sensitive to variable denominator voltages [8]. These upgraded devices will be

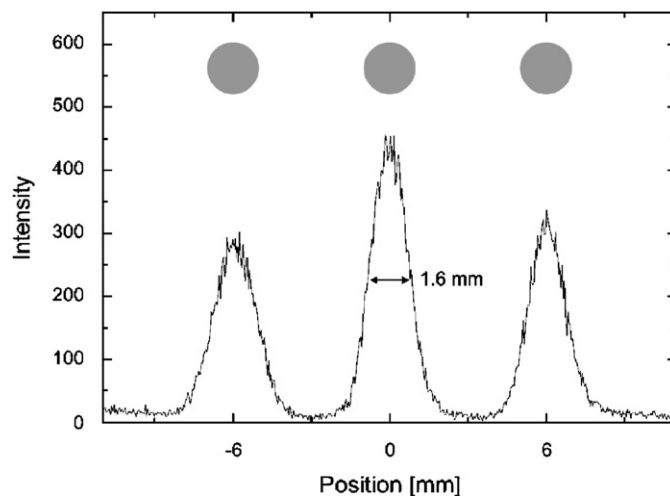


Fig. 4. X-ray position when the ^{109}Cd source is irradiating the three central holes of the window from a distance of 5 cm.

part of the next analogue division circuit to minimize this effect, and fully exploit the position detection capabilities of this detector.

4. Conclusion

The 1D position detection capability of the MHSP operated with a resistive layer charge division was investigated. A good position linearity was achieved, while the position resolution was limited to 1.6 mm. The present studies have shown that this limitation is due to the poor accuracy achieved by the analogue division electronics and not to the detector.

Future work will aim an improved low-cost electronic readout that introduces a negligible contribution to the intrinsic position resolution of the detector. In addition, a new MHSP with 2D position capability, having a structured top surface with strips perpendicular to those on the bottom surface [1], using resistive charge division is already in preparation.

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