# A Swift High Resolution Pixel Sensor for the CBM MVD *

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## Introduction

Swift, high resolution CMOS pixel sensors are being developed for the CBM Micro Vertex Detector (MVD), allowing for high density particle tracking. Designed at IPHC, the sensors are manufactured by the CMOS industry and can be thinned down to $\leq 50\ \mu m$.

To accommodate the data rate, the signals delivered by the sensors are discriminated before being filtered by an integrated zero-suppression logic. A fast read-out is achieved by grouping the pixels composing the sensitive area in columns read out in parallel. The development of this architecture relies on two parallel tasks. One of them addresses the upstream part of the signal conditionning chain, including the pixel array and the discriminators ending the columns. The other concerns the downstream part, combining a zero-suppression logic with output memories.

## Pixel array with binary outputs

Small prototypes were fabricated and tested in previous years to develop the upstream part of the sensor architecture [1]. *MIMOSA-22* is the final prototype of this R&D line. It was designed and fabricated in two versions. Both of them were characterised in 2008, first at IPHC with an $^{55}$Fe source and next at the CERN-SPS, mounted on a silicon-strip beam telescope.

The sensor features 136 columns read out in parallel, each containing 576, 18.4 $\mu m$ pitch, pixels. 128 columns are ended with a discriminator, while 8 columns have analog outputs for test purposes. The chip incorporates a JTAG controller. The frame read-out time is 92.5 $\mu s$. Various pixel designs were integrated in the chip, allowing to explore different sensing diode sizes, amplification schemes, ionising radiation tolerant designs, etc.

A modest noise value was found for most pixel designs, ranging from about 10 to 14 $e^-$ENC, with a mild operating temperature dependence. The 128 discriminators exhibited a modest threshold dispersion ($\pm$ 4 % standard deviation) and contributed marginally to the total noise. No significant non-uniformity was found over the sensitive area of any of the 6 sensors tested.

When exposed to a 120 GeV $\pi^-$ beam at the CERN-SPS, a signal-to-noise ratio in the range 17–21 (most probable value) was observed, depending on the pixel design. Table 1 illustrates the measured detection performances.

| Threshold | Detection eff. | Fake rate | Resolution |
|---|---|---|---|
| 3 mV | 99.8 $\pm$ 0.05 (stat) % | $\sim 4{\cdot}10^{-4}$ | $\sim 3.7\ \mu m$ |
| 4 mV | 99.7 $\pm$ 0.05 (stat) % | $\sim 7{\cdot}10^{-5}$ | $\sim 3.5\ \mu m$ |

Table 1: Detection efficiency, average fake hit rate and single point resolution measured at the CERN-SPS with MIMOSA-22 for two discriminator threshold values.

The observed detection efficiency remains $> 99.5$ % for threshold values high enough to keep the fake hit rate $< 10^{-4}$, a value ensuring that the signal processing micro-circuits will not be saturated by pixel noise fluctuations. The single point resolution is $< 4\ \mu m$, well below the MVD requirement of $\lesssim 5\ \mu m$. These results validate the architecture for its integration in the final sensor.

## Zero-suppression micro-circuit

*SUZE-01* incorporates the zero-suppression micro-circuit and output memories composing the downstream part of the sensor architecture. Fabricated in Autumn 2007, it was tested extensively in the laboratory until Spring 2008 with millions of patterns at its nominal clock frequency (i.e. 100 MHz) and above. No failures were spotted for frequencies up to 115 MHz. This guarantees that the architecture is suited to the final sensor specifications.

## Towards the complete sensor

The final sensor (called *MIMOSA-26*) was designed in 2008 within the EUDET project [2] and sent for fabrication. It combines the architecture of *MIMOSA-22* and *SUZE-01* in a complete charge sensing and signal read-out chain, providing discriminated signals in a binary mode including the pixel address. It features 1152 columns of 576 pixels, read out in $\sim 100\ \mu s$. It will be extensively tested in 2009 and equip the final version of the EUDET telescope. If satisfactory, this architecture will next be evolved to substantialy shorter read-out time, aiming to reach the 10 $\mu s$ regime ambitionned for the MVD.

## References

[1] M.Winter et al., "Achievements of CMOS Pixel Sensors for the CBM Micro-Vertex Detector", GSI Scientific Report 2007.

[2] EUDET collaboration, "Detector R&D towards the International Linear Collider", supported by the E.U. within FP6, http://www.eudet.org/.

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