Yield studies on a fully integrated sensor for the CBM-MVD*

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The CBM-experiment will study the phase diagram of hadronic matter in the region of highest baryon densities by means of rare probes like open charm particles. Reconstructing those particles calls for a vertex detector providing a unique combination of excellent spatial resolution, light material budget and high rate capability. To match those requirements, we intend to use CMOS Monolithic Active Pixel Sensors, which are developed by the PICSEL group of IPHC Strasbourg and evaluated at the IKF Frankfurt within an common R&D project.

A first fully integrated sensor, MIMOSA-28, was developed in the AMS $0.35\ \mu m$ CMOS process and it is used in the STAR-HFT since 2014. However, this sensor does not match the requirements of CBM regarding radiation tolerance and readout speed. Therefore, the sensor architecture was migrated to a novel $0.18\ \mu m$ process. This process was found to provide a higher tolerance to ionizing radiation [1]. Moreover, its higher packing density allows for reading two lines in parallel, which accelerates the readout by a factor of two with respect to the elder design.

In 2014, a first fully integrated prototype sensor (FSBB-M0) was realized in the new process [2]. The sensor was realized in two flavors (FSBB-M0a and FSBB-M0b), which differ slightly in the dimensions of some transistors. It features 416×416 pixels of $22 \times 33\ \mu m^2$ pitch and it is read out within $40\ \mu s$ via a pair of discriminators at the end of each column. Hereafter, the digital data is zero-suppressed and sent out via two 320 Mbps digital links. The sensitive surface of the FSBB is $13.7 \times 9.2\ mm^2$. The final sensor of the CBM-MVD will presumably consist of three FSBBs. The FSBB-M0 was tested at the CERN-SPS and provided a detection efficiency for minimum ionizing particles of $\gtrsim 99,5\%$, a noise occupancy of $\lesssim 10^{-5}$ and a spatial resolution of $< 5\ \mu m$ in both dimensions [3], which matches the requirements of CBM.

To test the robustness of the design and to assess the production costs for the CBM-MVD, we measured the production yield of the FSBB. In accordance with our experience, we assumed that flaws due to production mistakes would turn into a measurable deterioration of the noise of the sensors. A total of 25 (17 FSBB-M0a and 8 FSBB-M0b) sensors was bonded on PCB and operated with a suited readout system. By measuring the transfer functions we revealed the temporal noise (TN) of the individual pixels and the fixed pattern noise (FPN), which is caused by the offset of the dark signal of the pixels.

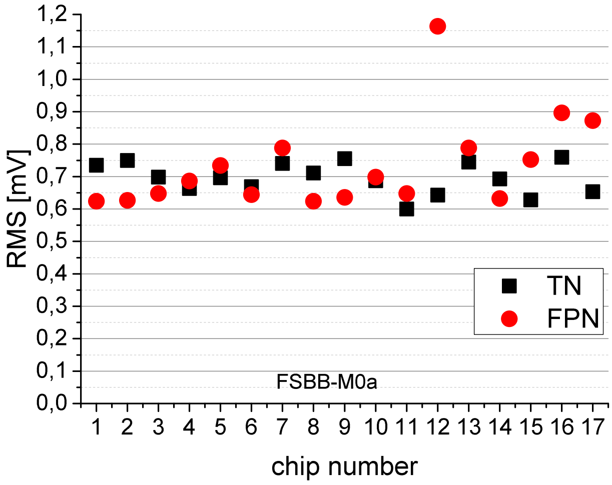

Figure 1: Temporal noise and fixed pattern noise measurement of all 17 FSBB-M0a chips.

The results of the study on the FSBB-M0a are shown in Fig. 1. We found all sensors tested to be operational and they provided a $TN = (0.70 \pm 0.05)\ mV$ and $FPN = (0.73 \pm 0.14)\ mV$. Only one of the tested sensors showed a higher FPN of $\sim 1.2\ mV$, which might still be acceptable. Similarly good results were observed with the eight FSBB-M0b tested, which all found being operational (not shown).

We conclude that a first full size sensor meets the requirements of CBM with respect to surface size, data rate and spatial resolution. Moreover, the design mostly meets the specification in terms of readout speed. Measurements demonstrated that the sensor provides a good detection of minimum ionizing particles and the production yield was found to exceed 95%.

References

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