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A prototype for the data acquisition of the CBM Micro Vertex Detector

The Compressed Baryonic Matter Experiment (CBM) will be installed at the SIS-100/SIS-300 accelerators of the FAIR facility, which is currently under construction at Darmstadt, Germany. Its purpose is the study of hadronic matter in the region of highest net baryon density with rare probes, e.g. open charm particles.

To reconstruct those particles, a Micro Vertex Detector (MVD) with a spatial resolution of few micrometers and high frame rate capability (> 33 kHz) is required. This MVD will rely on CMOS Monolithic Active Pixel Sensors (MAPS) developed by the PICSEL group of IPHC Strasbourg. Integrating the MAPS into the global strategy of CBM requires a free streaming, dead-time free DAQ which is able to synchronize up to 300 sensors and to handle a continuous data stream of ~ 30 GB/s. We introduce our concept for a readout system fulfilling those requirements and discuss results from a test run at the CERN-SPS. This work is supported by BMBF (05P12RFFC7), HIC for FAIR, EU-FP7 HadronPhysics3 and GSI.

Summary

CMOS Monolithic Active Pixel Sensors (MAPS) provide an excellent spatial resolution in the order of few micrometer in combination with a low material budget (50 micrometer thickness have been demonstrated) and high radiation hardness. The active volume of the devices is formed by the epitaxial layer of standard CMOS wafers. This allows the integration of pixels together with analogue and digital data processing circuits on-chip.

The MIMOSA-26 MAPS integrates functionalities like pedestal correction, correlated double sampling, discrimination and a data sparsification based on zero suppression combined with a pixel matrix of $2\ \mathrm{cm}^2$. The pixel array composed of 576 lines of 1152 pixels is read out in a column-parallel rolling-shutter mode. One discriminator per column and the digital data processing circuits are located on the same chip in a 3 mm wide area beneath the pixel matrix allowing for binary hit encoding. This area also contains the circuits for pedestal correction and the configuration memory, which is programmed via JTAG. The preprocessed digital data is read out via two digital 80 Mbit/s data links per sensor, which push their data based on a low-level protocol.

The first CBM Micro Vertex Detector (MVD) prototype based on MIMOSA-26 sensors was recently assembled. To study its tracking performance, it is built as a dual-layer micro-tracking device with four additional sensors arranged in a line as a beam telescope device. The micro-tracker is sandwiched by two reference stations, again based on the same sensor type, on both sides, respectively. The results demonstrate a detection efficiency above 98.5% and a spatial resolution below 3.8 micrometer for a high-energy pion beam at the SPS.

In the context of the CBM-MVD prototype project, we developed a scalable and free-running DAQ system which allows to steer and to operate multiple MIMOSA-26 sensors. Both, the sensor control and the data management was carried out by TRBv2 boards developed by the HADES collaboration, which were complemented with general-purpose add-on cards.
Among the functionalities realized in the FPGAs of those boards were data reduction,
quality monitoring, data transportation and slow control of the freely running sensors.
The data was time stamped and transferred via 2 Gbit/s optical links to a local computer. In this setup the total bandwidth of the prototype system was 100 MB/s, however the highly scalable implementation allows extending this limit with additional hardware as needed. Furthermore, the modular design of the FPGA firmware supports also newer MIMOSA generations, e.g. MIMOSA-28 as used in the STAR detector and MISTRAL which is currently under development for ALICE.

The beam test at the CERN-SPS validated our design choices and the system could be operated synchronously and dead-time free for several days. A procedure to keep the sensors synchronous even under stress conditions was successfully tested. We introduce the concept of the DAQ system of the CBM-MVD and show beam test results demonstrating the capability of the concept to operate sizable detector systems based on CMOS MAPS. We additionally discuss recent improvements to further increase the system performance.

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