Prototyping the CBM Micro-Vertex Detector (MVD).*

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This report will summarize the goals and achievements of the beam tests performed with the CBM-MVD CVD-diamond based, double-sided prototype.

The need for prototyping and characterizing the CBM-MVD motivated the construction of an ultra-low mass, high precision detector setup incorporating several prototype stations. Each station consists of a "core module", that is two 50-µm thick MIMOSA-26 CMOS pixel sensors [1] adhesive-bonded to a mechanical support ensuring heat evacuation and wire-bonded to the dedicated Flex Print Cable. Three mechanical supports were used: 1-mm thick aluminium with openings, a 200-µm thick CVD Diamond with and without (double-sided module) openings. The openings are 16.5×8.2 mm^2 in size and located in the middle of an active area of the MIMOSA-26 sensor. Modules with openings ensure stable mechanical support with minimum material budget of 0.05% X$_0$ (Si only) at the region of openings. The double-sided unit features a material budget of 0.3% X$_0$ (Si + adhesive + CVD).

Figure 1: CDV diamond support with openings to reduced the material budget.

The detector setup discussed here incorporates four single-sided reference stations and one double-sided station in the middle which is called a Device Under Test (DUT) and serves for both, a high-precision stand-alone tracking device as well as a test site for advanced integration concepts, with the focus on high-performance materials (e.g., CVD diamond). In addition, the full setup allows for validating the customized and scalable readout system design together with dedicated data analysis tools.
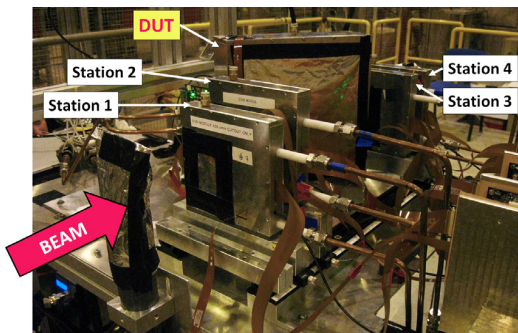

Figure 2: The IKF detector setup installed at CERN-SPS extraction (EHN1-North Area).

The beam test was ongoing for five days in November 2012 (at the CERN-SPS H6 extraction line) highlighting several aspects, as described in the following.

To validate our concepts regarding sensor integration and read-out the main focus was given at reproducing the test-beam results achieved with MIMOSA-26 sensors by the IPHC-Strasbourg: A detection efficiency of $>99.5\%$ and spatial resolution of about 3.5 µm (σ) were observed for an average fake hit rate[1] of about 10^{-5}, very well in accordance with the previously known sensor characteristics.

The precise knowledge about the sensor response to charged particles needed to address proper simulations of the CBM detector motivated the beam-test runs taken for different inclination angles ($0°$, $30°$, $45°$, $60°$), beam energies (10, 80 and 120 GeV) as well at various DUT-heat-sink temperatures ($-6°C$, $+6°C$, $+17°C$) and threshold voltages of the pixel discriminators housed by the chip. This analysis is on-going, based on a precise alignment of the single-sided stations.

Since the double-sided CVD-diamond based prototype was designed to serve as a precise micro-tracking device, some test runs with a metal target in front of the DUT were addressed.

The MIMOSA sensors have never been tested at running condition imposing the high sensor occupancy. Since such conditions are expected at the CBM experiment, tests at high beam intensities were addressed. The average flux was expected to be at about 10 hits/frame but due to the beam non-uniformity about 300 hits/frame are expected for some frames.

Simultaneously to data taking, it was possible to monitor the data quality and stability of the readout system. A typical frame rate was 8.68 kHz corresponding to the data rate of $6 - 25$ MB/s for the whole telescope (12 sensors running in parallel). The readout system was observed to be very stable for different data load generated by ten working in parallel MIMOSA-26 sensors. An absence of lost or corrupted frames was observed. Moreover, sensors were synchronized with precision of one signal clock.

The developed beam setup allowed studying different aspect related to sensor behavior needed for further simulations as well as proved the DAQ flexibility and mechanical stability. The results obtained for different detector setups and for various sensors parameters and running conditions are considered as very successful. The data analysis is in progress and announces gaining further insights in sensor operation and integration concepts.

[1] C. Hu-Guo et al.: http://dx.doi.org/10.1016/j.nima.2010.03.043

[1] The fake hit rate is defined as the average number of fake hits per pixel per frame.