Development of high-precision pixel sensors for the CBM vertex detector

M. Winter for the IPHC team
IPHC, Strasbourg, France

The physics program of the CBM experiment translates into stringent constraints on its Micro-Vertex Detector (MVD). CMOS sensors, which are granular and thin enough, are developed since several years to adapt them to the high hit rate expected. An important step was achieved in 2010 with a high-resistivity CMOS process, which was investigated with two sensors.

The first full-scale sensor featuring fast readout with integrated zero suppression, called MIMOSA-26 [1], was manufactured in 2008/2009 in a 0.35 μm CMOS technology based on a standard, low-resistivity epitaxial layer. More recently, high-resistivity epitaxial layers became available, reducing the thermal diffusion of the signal charges, for the benefit of the SNR and thus the radiation tolerance. MIMOSA-26 was re-fabricated with a 400 $\Omega{\cdot}cm$ resistivity, 10, 15 or 20 μm thick, epitaxial layer. Laboratory measurements were performed by illuminating these sensors with ^{55}Fe and ^{106}Ru sources [2]. The SNR obtained with the high-resistivity epitaxial layer ($\sim$ 35-40) was about twice higher than with the standard one ($\sim$ 20).

Sensors were tested with a $\sim$ 100 GeV particle beam at the CERN-SPS. The results are summarised in Fig. 1. The detection efficiency remains close to 100 % for high discriminator threshold values, indicating that even after a potential increase of the noise, consecutive e.g. to irradiation, a threshold value should still be found with a detection efficiency well above 99% and an affordable fake hit rate.

The sensitivity to non-ionising radiation was investigated for a fluence of 10^{13} n_{eq}/cm^2. The sensor performances were measured at the CERN-SPS for a temperature of 0°C (see Fig. 1). A threshold of 5-6 mV allows keeping the fake hit rate below 10^{-4} with a detection efficiency of nearly 100 %.

In order to optimise the detection performances of the sensor in this new, high-resistivity process, a dedicated prototype was manufactured in spring 2010. By sub-dividing the sensitive area in sub-arrays, each equipped with different pixels, alternative amplification schemes were investigated as well as a larger pitch (20.7 μm instead of 18.4) and enclosed transistor designs. The sensor detection performances were assessed in the laboratory and with a test beam as already mentioned for MIMOSA-26.

Beam tests were in particular performed at a temperature of +30°C with pixels featuring a 20.7 μm pitch read out in 125 μs, irradiated with 1 MeV neutrons (fluence of $3{\cdot}10^{12}$ n_{eq}/cm^2) and 10 keV X-Rays (150 kRad). A detection efficiency of 99.8 % was still observed for a 5 mV threshold, with a fake hit rate well below 10^{-4}. One may derive from these results that for typical CBM-MVD running conditions (20-40 μs integration time and negative operating temperature), a substantially larger irradiation level would still be affordable. This study is under way.

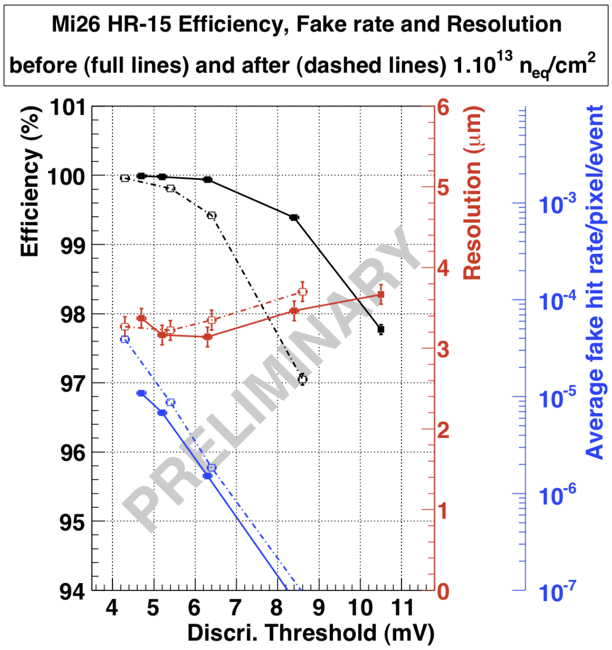

Figure 1: MIMOSA-26 beam test results for a 15 μm thick high-resistivity epitaxy. The detection efficiency (black), fake hit rate (blue) and spatial resolution (red) are shown as function of the discriminator threshold. They are displayed at 20°C before irradiation (full lines) and after an equivalent dose of 10^{13} n_{eq}/cm^2 at 0°C (dashed lines).

The next step of the development will consist in moving from the coarse 0.35 μm technology used up to now to a substantially smaller feature size, i.e. 0.18 μm. This translation is expected to benefit several aspects of the sensor, in particular the ionising radiation tolerance. A first prototype (MIMOSA-27) was fabricated in such a technology in 2010. Its tests at the CERN-SPS are foreseen in spring 2011.

References

[1] M. Winter and M. Deveaux, *CBM Progress Report 2009*, Darmstadt 2010, p. 5

[2] M. Deveaux *et al.*, *Radiation tolerance of a column parallel CMOS sensor with high resistivity epitaxial layer*, accepted for publication by JINST