Radiation hardness of low-mass readout cables for the CBM experiment

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For the fixed-target heavy-ion experiment CBM at FAIR, a low-mass silicon tracking detector system is being developed that can track at high rates the hundreds of charged particles that will be created when an intense beam of heavy nuclei interacts with the target [1]. The detector is based on silicon microstrip technology. Fast self-triggering front-end electronics will be located at the periphery of the tracking system. The distance between the detectors and the electronics will be bridged with thin long aluminium cables structured into microstrip lines and insulated with polyimide. In the CBM environment, the exposure to ionizing radiation is estimated to be about 100-200 kGy in several years of operation. For reliable operation, radiation-induced changes of the bulk and/or surface conductivity of the dielectric material have to be excluded.

Several cable prototypes with lengths between 10 and 30 cm, shown on Fig. 1, were manufactured at SE SRTIIE, Kharkov, Ukraine [2]. A cable consists of two signal layers, a shielding layer, and a mesh spacer. Each signal layer is structured into 64 aluminium lines (14 μm thick, 20 μm wide, at 100μm pitch, on 10μm thick FDI-A-24 dielectric).

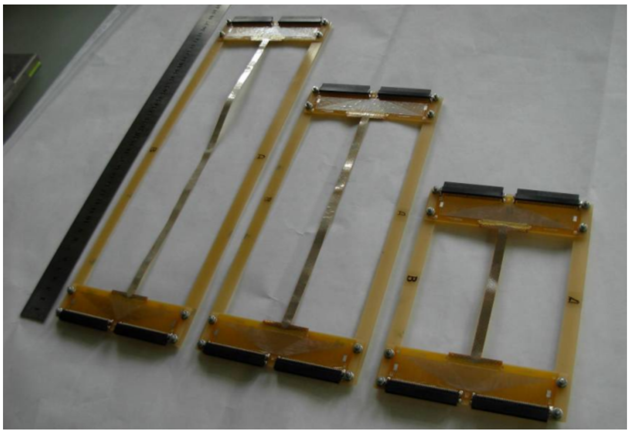

Figure 1: Different prototypes of microstrip line cables

For a first radiation hardness test, a 10 cm long multi-layer flat-wire of the CBM detector demonstrator was mounted on an aluminium plate and irradiated with 4.8 MeV/u Au ions at the M3-beamline of the UNILAC. The size of the beam spot was about 1 cm^2. Three single-circuit paths were connected to a charge-frequency converter (IFC). The IFC records charges down to 100 fC and is triggered by the beam pulse. On-line measurements thus allow us to monitor beam-induced currents passing through the device.

In stage A of the experiment, the beam spot was set besides the flat-wire lines to check any indirect radiation effect (section A in Fig. 2). Comparing the ion-beam flux and the signal during the irradiation of the test device clearly shows that no additional electric current appears in the back plate. During stage B, the middle part of the flat-wire was irradiated on a length of 1 cm with a flux of 2.5×10^7 ions/cm^{2}s. The IFC recorded a signal of 22 pC which follows synchronously the beam flux signal. Even small flux variations are visible.

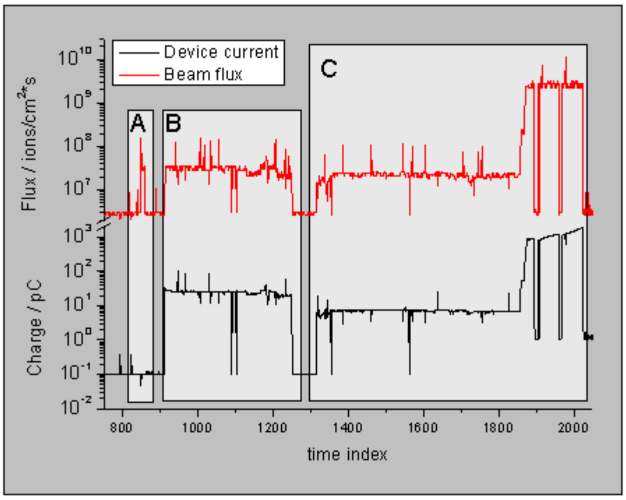

Figure 2: Device signal (black, bottom) and flux of the ion beam (red, top) during different irradiation tests A-C (see text for details)

In stage C, only one single wire (instead of three) was measured. At a fixed flux of 2.3×10^7 ions/cm^{2}s, the measured charge for three contacted wires was 21.9 pC compared to 7.2 pC for a single wire, confirming a linear scaling behaviour. In the last phase of experiment C, the flux was increased by two orders of magnitude. Under this high-flux condition, the current increased significantly with time, indicating either a serious temperature increase or a pronounced change of the electrical properties.

This demonstrator device, which has been exposed in total to 1.56×10^{12} ions/cm^2, will be tested off-line especially with respect to loss of insulation properties due to radiation damage of polyimide [3].

References

[1] J. M. Heuser, PoS(VERTEX 2008)017 (2008)

[2] V. M. Borshchov *et al.*, *CBM Progress Report 2009*, Darmstadt 2010, p. 15

[3] D. Severin et al., Nucl. Instr. Meth. Phys. Res. **B 236** (2005) 456