Radiation tolerance studies of silicon microstrip sensors for the CBM Silicon Tracking System

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Abstract. Double-sided silicon microstrip sensors will be used in the Silicon Tracking System of the CBM experiment. During experimental run they will be exposed to a radiation field of up to $1{\times}10^{14}$ 1 MeV n_{eq} cm^{-2}. Radiation tolerance studies were made on prototypes from two different vendors. Results from these prototype detectors before and after irradiation to twice that neutron fluence are discussed.

1. Introduction

The Silicon Tracking System (STS) [1] is the core detector of the Compressed Barionic Matter (CBM) experiment at the future Facility for Antiproton and Ion Research (FAIR) in Darmstadt, Germany. The STS is located in the dipole magnet to provide track reconstruction and momentum determination of charged particles from beam-target interactions. According to the CBM operation parts of the tracking stations will be exposed to a total particle fluence up to $1{\times}10^{14}$ 1 MeV n_{eq} cm^{-2} afterwards they will be replaced. Thus radiation tolerance is an important requirement for the STS detectors.

2. Detectors under test

The STS will employ double-sided silicon microstrip sensors mounted onto a low-mass carbon fibre support structure. The strips on the p side of the sensors are tilted with respect to the n side by 7.5° as displayed in Fig.1(a). To read out the sensor only from one edge, as required by the detector ladder structure, the end strips from one edge were connected to the end strips on the other edge as shown in Fig.1(b). This interconnection can be provided via double metallization (DM) or using external interstrip cables (SMwC). The central strips were the full-length strips without any interconnections.

The sensors were tested for electrical parameters (leakage current and bulk capacitance) and also for the charge collection both before and after irradiation (performed at KIT, Germany) using a β-source (^{90}Sr) to mimic minimum ionizing particles (MIP). All the measurements were made in a light-tight set-up with temperature control. The signals were readout with two laboratory read-out systems (nXYTER [2] and Alibava [3]) for the cross check collected results. In case of nXYTER, in order to collect charge, produced by MIPs only, a 2 mm Aluminum absorber was placed below the sensor to absorb low-energy electrons, particles were selected by requiring a coincidence with a signal in the Si-pad detector. In case of Alibava read-out,

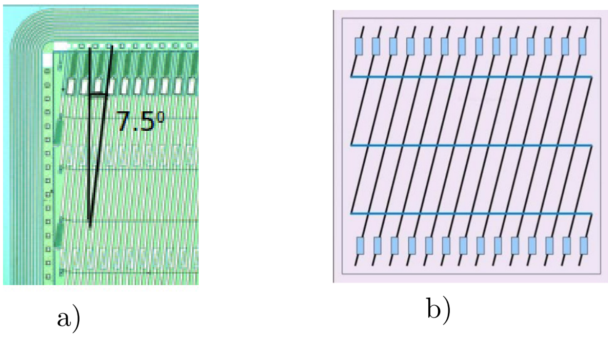

Figure 1. (a) Microscopic view on the p-side of a prototype detector with strips tilted by 7.5 °, (b) Detector topology to read out inclined strips. The interconnections of the corner strips are visible as horizontal lines.

scintillator and amplifier behind the sensor were used. The spectrum from the β-source was fitted with a Landau-Gauss convolution and the most probable value is interpreted as collected charge. The results for charge collection efficiency, based on an ADC-to-charge calibration and the expected charge in the detector according to the wafer thickness, are shown in Fig. 2 (nXYTER set-up) and on the Fig.3 (Alibava set-up). The sensor naming encodes the prototype generation (5 or 6), the manufacturer (H = Hamamatsu, C = CiS), the detector height/strip length in cm (4 or 6), and the wafer number.

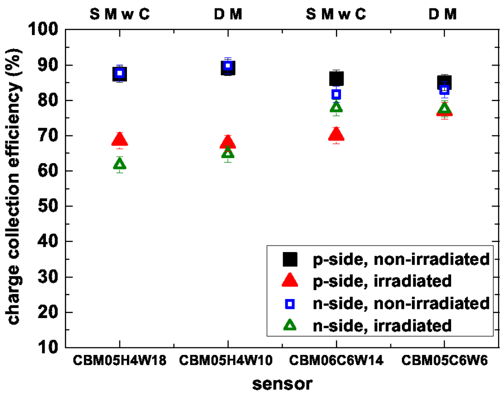

Figure 2. Charge collection efficiency results with ^{90}Sr, before and after irradiation. Measurements were performed at 470 V sensor bias and −8 °C environment.

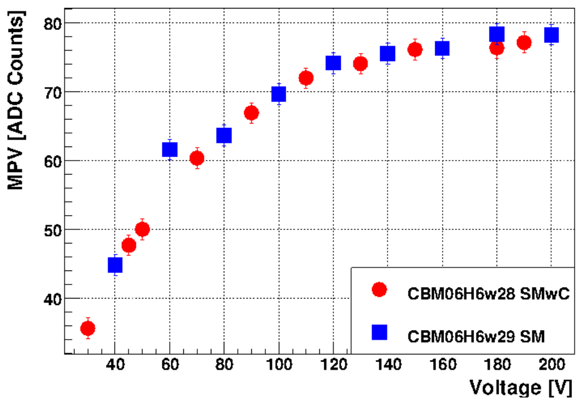

Figure 3. Dependence charge collection of applied voltage in terms of Most Probable Value.

3. Results

The prototype sensors from two vendors, in two technological configurations, show a reduction of charge collection by 15% to 25% after irradiation to twice the maximum neutron fluence expected in the CBM experiment. Measurements with the latest prototype sensors are forthcoming.

References

[1] J. Heuser et al., Technical Design Report for the CBM Silicon Tracking System, GSI Report 2013-4, http://repository.gsi.de/record/54798

[2] A.S. Brogna et al., N-XYTER, a CMOS read-out ASIC for high resolution time and amplitude measurements on high rate multi-channel counting mode neutron detectors, Nucl. Instrum. Methods A 568 (2006) 301-308

[3] http://www.alibavasystems.com/