# Performance of neutron irradiated prototype sensors for the CBM Silicon Tracking System *

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We report on the performance of prototype microstrip sensors for the CBM Silicon Tracking System (STS) after their exposure to neutron equivalent fluences as they are expected for the running scenario in the CBM experiment.

## CBM radiation environment

The neutron fluence at the STS detector is expected to reach about $2\times10^{13}$ $n_{eq}cm^{-2}$ per year, depending on the detailed physics programme performed and accumulating over several years of running. The maximum integrated fluence in some areas of the tracker will amount to $10^{14}$ $n_{eq}cm^{-2}$ beyond wich the affected detector modules will be replaced [1]. During the CBM experimental runs, periods of two or three months per year, the sensors will be operated at -5°C to limit radiation-induced leakage currents and to prevent from thermal runaway. During the periods of shutdown, the STS detector system may have to be warmed up to allow for maintenance of its components. The radiation damaged sensors will undergo annealing processes, with properties like leakage current, full depletion voltage ($V_{fd}$) and breakdown voltages changing with temperature and time.

## Irradiation of prototype sensors

We have irradiated small test sensors from the most recent production of CBM05 prototypes, produced by CiS, Erfurt, Germany. The exposure to neutrons was performed at Institute Jozef Stefan, Ljubljana, Slovenia, within the EU-FP7 project AIDA. The sensors were irradiated in sets of four to the fluences $1\times10^{13}$, $5\times10^{13}$ and $1\times10^{14}$ $n_{eq}cm^{-2}$. During transport and storage after irradiation, a log of temperature and humidity was kept.

## Full depletion voltage, charge collection

The sensors were installed in printed circuit boards allowing to apply bias voltage and to read out a number of strips with fast self-triggering front-end electronics. The sensors were operated in a nitrogen conditioned freezer at -5°C. Through the bias cable, scans of the bulk current and capacitance were made as a function of the applied reverse voltage. The determined depletion voltages as a function of the neutron equivalent fluence are summarized in Table 1. Applying significantly higher bias, the sensors' charge collection performance was determined with reading out signals induced with a $^{241}$Am source and its 59 keV and lower energy gamma lines. Spectra of collected charge are shown in Fig. 1, applying a simple clustering algorithm to combine charge simultaneously seen on neighbouring strips. The results are reported in the table, assuming gain calibration factors of 117±3 ($p$) and 113±3 ($n$) ADC units for the full signal to yield the charge collection efficiencies.

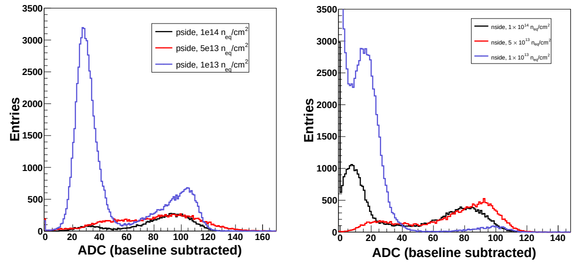


Figure 1: Charge distributions from the sensors' $p$ (left) and $n$ (right) sides as a function of neutron equivalent fluence.

Table 1: Charge collection performance of the sensors.

| fluence ($n_{eq}cm^{-2}$) | $V_{fd}$ (V) | $V_{bias}$ (V) | peak ADC $p$ ±3 | peak ADC $n$ ±3 | eff. (%) $p$ ±4 | eff. (%) $n$ ±4 |
|---|---|---|---|---|---|---|
| 0 | 80±2 | 160±1 | 117 | 102 | 100 | 90 |
| $1\times10^{13}$ | 35±5 | 130±1 | 105 | 100 | 90 | 88 |
| $5\times10^{13}$ | 45±5 | 180±1 | 95 | 95 | 81 | 84 |
| $1\times10^{14}$ | 110±2 | 300±1 | 95 | 81 | 81 | 71 |

## Annealing studies

The leakage currents increase linearly with neutron fluence. The value of the damage constant, $\alpha$, is initially at around $4.0\times10^{-17}$ $Acm^{-1}$. After annealing at different temperatures, $\alpha$ can be used to yield the evolution of dark currents and $V_{fd}$. According to [2], radiation damage in silicon has several contibutions: a constant, a "beneficial annealing" and a "reverse annealing" component. Their determination is in progress.

## 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] M. Moll et al., *Nucl. Instrum. Methods. A* 439 (2000) 282.

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