The Silicon Tracking System of the CBM experiment at FAIR - Development of microstrip sensors and signal transmission lines for a low-mass, low-noise system

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The Compressed Baryonic Matter (CBM) [1] experiment is one of the major scientific pillars of the upcoming Facility for Antiproton and Ion Research (FAIR) at Darmstadt, Germany. The main goal of this experiment is to explore the QCD phase-diagram in the regions of high Baryonic densities and moderate temperatures.
The CBM experiment will be operated with high beam intensities for long running period to measure the rare probes where the collision rate in Au+Au collisions is expected up to 10 MHz with the particle flux of the order of 10^9 particles/sec. In order to handle such high rates, the detector system should be highly granular and radiation hard. Low material budget is required with in the detector acceptance to minimize multiple scattering which would limit high-precision measurements.
The Silicon Tracking Station (STS), a core detector of the CBM experiment, is designed to provide track reconstruction and momentum determination of the charged particles originated from the beam-target interactions. The double-sided silicon microstrip detectors (DSSDs) have been used in several planar tracking stations. The readout electronics is planned to be installed at the periphery of the tracking stations along with the cooling system. Low-mass multi-line readout cables shall bridge the distance between the microstrip detectors and the readout electronics. The CBM running operational scenario suggests that some parts of the tracking stations are expected to be exposed to a total integrated particle fluence of the order of 10^{14} n_{eq} cm^{-2}. Thus radiation hardness is an important requirement for the detectors. Moreover, to cope with the high reaction rates, free-streaming (triggerless) readout electronics with online event reconstruction must be used which require high signal-to-noise (SNR) ratio (*i.e.*, high signal efficiency, low noise contributions). Therefore, low-noise, low-mass radiation hard system is a major goal for the detector and cable development and is the focus of this doctoral work.
For the DSSDs both detector sides must be operating even after radiation damage, *i.e.*, the detector should be fully depleted. The full depletion voltage of a detector is compromised by it's breakdown. Several detector prototypes available were characterized by performing various tests which includes current (I_{leak}) and capacitance behavior as a function of bias voltage, interstrip capacitance (C_{int}), interstrip resistance, metal trace resistance (R_{tr}), charge collection efficiency (CCE) and signal-to-noise ratio (SNR). The I_{leak}, C_{int} and R_{tr} are the important contributor's to the noise. Operating the detectors at lower temperatures, however, can control the I_{leak}. Some of these parameters were found to be imperfect in the first batches of the detector prototypes which were identified via TCAD simulations and measurements leading to improved designs in the next generation of prototypes. Using the optimized detector design [2], the breakdown voltage has been increased by 63%, and the C_{int} has been reduced by 25% while maintaining a high CCE. On the basis of these

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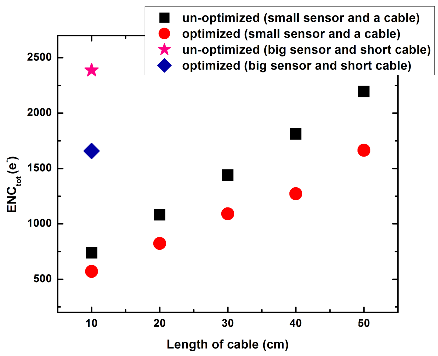

FIG. 1: Comparison of noise for the present prototype module and the optimized modules with new sensor (or detector) design and readout cables.

results, two new detector prototypes were procured in the year 2013. The new detector prototypes are under study in terms of their radiation hardness and noise performance.

It has been observed during the characterization that the readout micro-cable prototype-I have some shortcomings like even-odd effect which disqualifies these cables to be used in the experiment. FEM simulations were performed for these cables and based on the simulation results a new prototype has been prepared. However, later on it was found that the capacitive load from these cables prototype-II on the front-end electronics is very high which lead to the higher noise values.

Further simulations were performed to realize an optimized design with lower capacitive (and resistive) load from the readout cables and the low material budget. Several ways of lowering the capacitance (and resistance) values, which then lowers the noise, and charge losses with low material budget have been discussed [3]. The optimized design was found to have the capacitance decreased by the factor of 35% and the noise was decreased by about 500 e^- while maintaining the low material budget of $\simeq 0.11\%$ X_0.

The first STS prototype modules were tested for their noise performance. The module is the basic constituent of the tracking station. It consists of the single or daisy-chained detectors with the readout cables and electronics attached to it. From the tests of these modules with radioactive source, the charge transmission efficiency was observed to be more than 85%. The reason for the loss of 15% charge is due to the higher capacitance from the readout cables, which leads to charge sharing between neighboring traces. The new module prototype comprising optimized detectors and readout cable prototype-III will be procured by the end of the year 2013 and then will be tested for the noise and charge collection studies. The new prototypes are expected to have much lower capacitance and hence high charge transmission efficiency and lower noise.

Figure 1 shows the comparison of noise obtained via simulations for the present prototype module (un-optimized) and the optimized modules with new sensor design and readout cables. Two cases have been shown; one for the inner detectors in the tracking station (small detectors with 2 cm long strips attached to cables of different length) and second case for the outer long sensors with 12 cm long strips attached to a 10 cm long cable. Using the optimized detectors and readout cables the noise can be reduced up to 700 e^-. The new optimized modules will be subjected to extensive in-beam tests in December 2013 at the COSY synchrotron at the Research Center Jülich, Germany. Detailed results on the simulations and characterization of STS prototypes will be presented during the Symposium.

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