Update on the simulation geometry for the Silicon Tracking System

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Introduction

The Silicon Tracking system (STS) [1] is a key detector of the CBM experiment placed inside the 1 Tm dipole magnet. It uses double-sided microstrip silicon sensors of four different sizes, 6.2 $\times$ 2.2 cm^2, 6.2 $\times$ 4.2 cm^2, 6.2 $\times$ 6.2 cm^2, and 6.2 $\times$ 12.4 cm^2 which at 8 tracking stations along the beam axis, cover the area from close to the beam axis outwards. The sensors are produced with a thickness of 320 $\pm$ 15 μm. Each sensor has 1024 microstrips on both p and n-sides, positioned with a pitch width 58 μm. A detector module consists of a silicon sensor connected via Aluminium (Al) polyimide micro-cables to the Front-End Boards (FEBs), placed outside the detector active area, in order to minimize the material budget. It is mounted on ladder space frames made from carbon fibre to minimize multiple scattering of particles. These ladders are assembled on C-frame structures made from Al, as shown in Fig. 1.

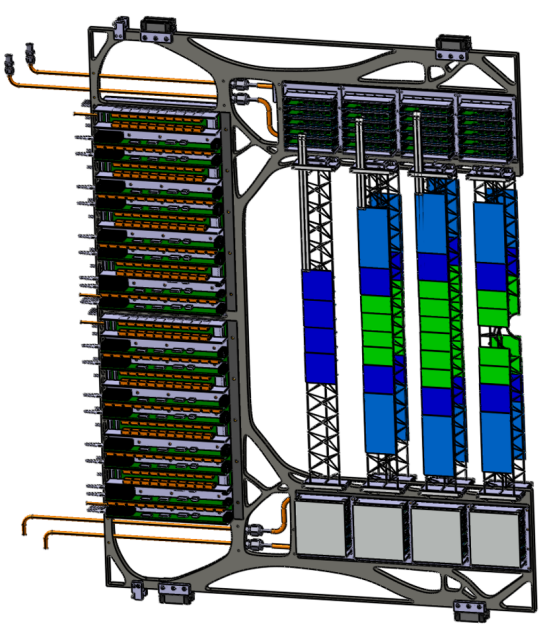

Figure 1: Design of a C-frame along with dector ladders, FEB boxes, POBs, ROBs and cooling interfaces [2].

Updates in STS geometry

Significant developments have been made in the past on the design of different detector componets which play crucial role in the physics performance of the detector. Therefore it is important to implement all the design hardware updates in the ROOT-based description of the STS geometry. The most significant changes in the STS geometry are:

- Passive wall material
- Pitch between the stations
- Carbon fibre ladder length
- Sensor thickness
- Micro-cable material
- Beam pipe

Passive walls

The passive thermally and electromagnetically shielding wall around the STS is made from carbon fibers and Airex foam of density 1.5 g cm^{-3} and 0.065 g cm^{-3} respectively. The foam is sandwiched between two carbon fibers sheets of 2 mm thickness.

Pitch between STS stations

The spacing between the STS stations (Pitch) in CAD and ROOT-based geometry was 100 mm. However, new development in the detector design have put stringent limit on the spacing between different electronic components and therefore it was decided to increase the pitch by nearly 5 mm, keeping the last station at the same position [3, 4]. The recent CAD and ROOT-based design of STS detector now have a 105 mm pitch between stations. At the time when this design was made, it was decided that the target should be moved upstream by 40 mm to make space for the elongated STS and its box.

Silicon sensors

To achieve adequate signal to noise ratio, radiation hardness etc, 320 $\pm$ 15 μm thick silicon sensors from Hamamatsu were chosen. In the prototyping phase, 285 $\pm$ 15 μm thick sensors from CiS were explored as well [5, 6].

Micro-cables

The micro-cables connected to the sensors for signal read-out are made from aluminium coated with polyimide and have a thickness of 15 μm (metal) and 10 μm (polyimide), respectively.

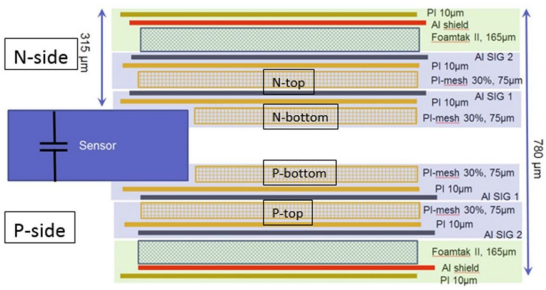

Figure 2: Schematic diagram of the micro-cable stackup of a module [7].

Figure 2 shows a schematic cross-section of the micro-cable. The total thickness of the micro-cables is 774 μm (including both p and n-side) and total radiation length was found to be 0.124%. The material budget per cable was re-calculated using the information of the different layer thickness and fill factor. In the ROOT geometry the micro-cable is implemented as a single volume with the same thickness as the silicon sensors (320 μm.) By solving the implicit function, as given in Equation 1, it is concluded that the material in the mico-cable of thickness 320 μm could be approximated by Manganese with density of 0.5656 g cm^{-3} [8].

$$X_0 Z(Z+1)\log\left(\frac{287}{sqrt(Z)}\right) = 716.4\ \frac{g}{cm^{-2}}A \qquad (1)$$

The material budget for 8 STS stations, recalculated after the modification of the silicon sensors thickness, micro-cable material, and carbon fibre ladder lengths, is shown to exhibit X/X$_0$ smaller than 1.4% in the active area of the STS detector (Fig. 3).

Beampipe

The ROOT-based STS geometry includes a conical shaped beampipe (Fig. 4) made from carbon fiber reinforced plastic. Two possible configurations are considered for further studies, with the same conical shape, thickness (1 mm) and diameter (104 mm) on the downstream side, but two different diameters on the upstream side: 40 and 55 mm, respectively, for further studying effects at beam energies as low as 2 GeV/nucleon.

In addition, the back side wall has also been adapted to the beampipe flange. Moreover, the vacuum chamber which host the MVD dectector has also been modified as shown in Fig. 5.

Discussion

Different versions of the STS geometries, which include recent technical design modifications, allow the study of impact on the acceptance, tracking efficiency, and momentum resolution. Table 1 shows a summary of the STS geometries, the main developments included, the beampipe and the target position. As can be seen from Fig. 3, the material budget amounts to 0.34% for the silicon sensors of thickness 320 μm, 0.12% for the Aluminium-polyimide micro-cables, while fully assembled ladders with modules amounts to material budget from 0.3% to 1%.

References

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