ATLAS silicon microstrip tracker operation and performance

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A B S T R A C T
The Semi-Conductor Tracker is a silicon microstrip detector at the heart of the ATLAS experiment at the CERN Large Hadron Collider. Together with the rest of the ATLAS Inner Detector it provides vital precision tracking information of charged particles. In this paper the performance and operational status of the Semi-Conductor Tracker in the last two years of ATLAS data taking are reviewed.

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1. Introduction

The ATLAS Inner Detector (ID) [1] is responsible for the tracking of charged particles and consists of three sub-detectors using different technologies: closest to the beams the silicon pixel detector, next the Semi-Conductor Tracker (SCT) and furthest away from the beam axis the Transition Radiation Tracker (TRT). The ID is located in a solenoidal 2 T magnetic field. The outer dimensions of the ID are 5.6 m (length) and 2.1 m (diameter).

The 6.3 million silicon strip channels of the SCT are grouped into 4088 modules with 1536 channels per module [2]. The modules are placed in four barrel cylinders and 18 end-cap disks, designed so particles will pass four SCT layers on their way from the interaction point through the detector. Modules are constructed with back-to-back layers of strips, rotated with a stereo angle of 40 mrad with respect to each other to provide tracking information in the longitudinal (beam) direction. The strip pitch for barrel modules is 80 μm.

In 2010 and 2011, LHC delivered 47 pb⁻¹ and 5.6 fb⁻¹ integrated luminosity of 7 TeV proton–proton collision data. During these periods the SCT recorded good quality data in 99.9% and 99.6% of the time.

In the typical operation configuration of the SCT during data taking 99.3% of the SCT modules have been in operation. Only very few (~ 30) modules have been disabled from operation due to either problems in a cooling loop, HV connectivity failures or failures of the optical transmitters.

2. Lorentz angle

Due to the strong magnetic field the drift direction of the charge carriers in the strips is affected by the Lorentz force. The number of strips which is collecting charges from a track, also referred to as the cluster width, varies with the incident angle of the track. The angle with the smallest cluster width is called the Lorentz angle. This angle depends on both the strength of the magnetic field, the module temperatures and the bias voltage, which makes this quantity important to monitor. By plotting the cluster width as a function of the incident angle for different layers of the SCT barrel, Lorentz angle can be extracted as the minimum of each curves. The obtained values of Lorentz angles, listed in Fig. 1, show good agreement with model predictions.

3. Calibration

The online calibration of the SCT monitors the noise level in two different ways [3]: through a response curve test and through a noise occupancy test. The response curve test measures the noise level via charge injection in the front end chip and fitting the number of hits from the binary readout as a function of the discriminator threshold. The alternative method of noise occupancy test monitors the hit occupancy in events where no particle activity in the detector is expected. Noise occupancies obtained by this method for 2010 data is shown in Fig. 2. Both methods give a noise occupancy below the design criteria of 5 × 10⁻⁴ at a threshold of 1 fC.

4. Intrinsic hit efficiency

As shown in Fig. 3 the strip hit efficiencies of the SCT are well above the design criteria of 99%. The hit efficiency is derived as the measured fraction of hits on a track per possible hits along the track trajectory, and is derived both using SCT standalone tracks and tracks from the full ID. For the SCT standalone tracks, efficiencies for the innermost and outermost layer will be biased since holes on tracks are only counted from the first to the last measured point.
5. Alignment

The alignment of the SCT modules is done by minimising a $\chi^2$ based on the track-hit residuals of tracks reconstructed in the ID [4]. A track-hit residual is defined as the distance from the trajectory of the reconstructed track to the measured space point. The alignment is constantly improving over time. During 2010, the residuals measured in the direction across the strips in the local module frame for barrel and endcap modules changed from 42 $\mu$m and 44 $\mu$m in the spring to 36 $\mu$m and 38 $\mu$m in the autumn. In comparison, simulations of a perfectly aligned detector have shown to give residuals for barrel and endcap of 34 $\mu$m and 38 $\mu$m.

6. Radiation damage

The effects of radiation damage in the SCT are monitored through the leakage current in the HV supplies. As expected significant increases in leakage currents have been observed. In Fig. 4 the measured leakage currents for barrel modules are shown together with the LHC luminosity and sensor temperatures since these are directly correlated [5]. Simulations of the expected effects from radiation damage have been carried out using the Hamburg model [6] and the foreseen dose of radiation predicted by FLUKA [7]. The mode predictions, also shown in Fig. 4, are found to be in excellent agreement with the measured leakage currents.

7. Conclusion

During the last two years of ATLAS data taking, the SCT has been delivering vital tracking data with an extremely high data acquisition efficiency. Both the alignment, hit efficiency and the noise level of the SCT have been found to be well within design limits. The effects of radiation damage are monitored and shown to be in agreement with the model predictions based on the luminosity and temperature profiles.

References


