ATLAS Silicon Microstrip Tracker Operation and Performance

A. Mayne a, on behalf of the ATLAS SCT collaboration

 a Department of Physics and Astronomy, University of Sheffield, Hicks Building, Hounsfield Road, Sheffield, UK

This overview presents the current status of the ATLAS SemiConductor Tracker, including results from the latest data-taking periods in autumn 2009 and spring 2010, and from the detector alignment. We report on the operation of the detector and observed problems. The main emphasis is given to the performance of the SCT with the LHC in collision mode, in a comparison with the expected parameters and with the Monte Carlo simulations.

1. Introduction

The ATLAS detector is one of two general-purpose detectors built at the Large Hadron Collider (LHC) [1]. The Inner Detector (ID) is the charged-particle tracker in ATLAS. It occupies the space nearest to the beam pipe at the centre of the ATLAS detector. The three tracking systems within the ID are the Pixel Detector, the SemiConductor Tracker (SCT) and the Transition Radiation Tracker (TRT). The ID is designed to reconstruct isolated leptons with $p_T > 5$ GeV with 95% efficiency out to $|\eta| < 2.5$. The required transverse momentum and transverse impact parameter resolutions are $\sigma(p_T)/p_T = 0.05\% p_T$ (GeV) $\pm 1\%$ and $\sigma(d_0) = 10 \mu m \pm 140 \mu m/p_T$ (GeV) [2]. These place the following design requirements on the SCT:

- SCT strip efficiency $> 99\%$
- Noise occupancy $< 5 \times 10^{-4}$ per bunch crossing
- Maximum of 1% of strips defective

2. The SCT

The SCT consists of 4088 modules of silicon microstrip detectors arranged in four concentric barrel layers and two endcaps of nine disks each. Each of the barrel modules is made up of 4 silicon wafers. These wafers have 768 silicon strips with a strip pitch of 80 microns. Two pairs of silicon detectors are glued back-to-back at a stereo angle of 40 mrad, allowing for a 2-dimensional position measurement on the module. The construction of the endcap modules is very similar to that of the barrel modules except that the strip pitch varies from 56.9 mm to 94.2 mm.

Each module has 2 sets of 768 channels read out by 12 ABCD3T ASIC chips. Each chip reads out 128 strips. The readout for every channel is binary (0 for no hit, 1 for a hit) and a hit is stored, providing the charge exceeds a programmable threshold, until the level-1 trigger decision.

3. Calibrating the Detector

After installing the SCT within the ATLAS cavern the detector underwent commissioning and calibration tests. Response curve tests used injections of fixed charges to tune the discriminator threshold of each channel and measure the noise in each channel. Figure 1 shows the input noise values for each of the chips in the SCT. The values are shown for the different types of modules as the noise level is highly dependent on the strip length. The mean value of around 1500 e is well below the typical threshold of 1 fC (around 6240 e). The noise occupancy is measured to be around $10^{-5}$, less than the design specifications. The few strips ($< 0.2\%$) with noise occupancy greater than $5 \times 10^{-4}$ are disabled.
4. Performance

The readout of the SCT is synchronized with the bunch crossing time to ensure that the signal is sampled at the peak of the charge response curve. The SCT reads out three consecutive 25 ns time bins, with the readout centered on time bin 1. Figure 2 shows the mean time bins (0, 1 or 2) of SCT hits for each of the endcap disks and barrel layers, commissioned with a threshold of 1 fC. Ideally, for hits corresponding to collision particles, the mean time bin should lie between 1 and 2. In fact the mean time bin is very close to 1 and the timing is already very uniform without final adjustments from a fine timing scan.

A comparison of the number of strips per module side (occupancy) for data and Monte Carlo samples is shown in Figure 3. The 900 GeV collision data is shown by the blue data points with the simulated sample shown by the yellow histogram. The samples are normalized by number of events and show good agreement. The discrepancy at low N is due, in part, to there being more noise in data than in Monte Carlo simulations.

The intrinsic hit efficiency of the SCT is given by $\epsilon = \frac{N_{\text{clusters}}}{N_{\text{clusters}} + N_{\text{holes}}}$ (a hole is where a hit is expected but not found). Figure 4 shows the efficiency for the SCT barrel layers to be consistently above 99.5%. This is also true for all of the SCT endcap disks. Dead modules and chips are excluded from this distribution. Tracks require at least 20 TRT hits and at least 6 SCT hits.

Figure 5 shows the SCT barrel residuals for 7 TeV collision data, using the alignment determined from cosmic-ray and 900 GeV collision data, compared to Monte Carlo simulation with nominal alignment. Prior to collisions, ATLAS took a large amount of cosmic-ray data for testing the detector and providing the initial track-based alignment. The alignment now lies very close to the nominal alignment. Figure 6 shows the invariant mass distribution of the $K^0_s$ meson. Good alignment of the SCT and Inner Detector
Figure 4. SCT barrel module intrinsic strip efficiency

Figure 5. SCT barrel alignment using all cosmic-ray and collision data

is vital for accurate tracking and reconstruction of invariant masses like these.

As the ID operates within a magnetic field of 2 T, it is important that the effect this field has on the charge carriers in SCT modules is understood. The Lorentz angle, measured from 7 TeV and cosmic-ray data, is shown in Figure 7 for each of the SCT barrel layers (as they operate at different temperatures). The measured value is in agreement with that of the model.

5. Conclusions

The SCT has performed very well during commissioning, cosmic-ray data taking and collisions. Currently 99.3% of all SCT modules are operational and the number of operational strips exceeds the specifications. Both the noise occupancy and the efficiencies are better than the design specifications. The alignment is very close to nominal and has been shown to allow accurate invariant mass reconstruction.

REFERENCES