Commissioning of the SCT

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Abstract

In September 2008, the Large Hadron Collider (LHC) at CERN was switched on with successful tests of circulating beam in both directions of the ring. The ATLAS SemiConductor Tracker (SCT) has been installed in the ATLAS cavern since summer 2007 and then integrated with the rest of the ATLAS subdetectors, in preparation for this event. After the SCT was assembled on the surface, the process of being commissioned using cosmic ray events began, and continued after the SCT was installed in the cavern with the rest of the ATLAS detector. Performance results will be given for the recent cosmic runs.

1. Introduction

The commissioning of the SCT detector is a vital activity to ensure that both the detector itself and the software infrastructure are ready for proton-proton collisions at the LHC. The commissioning tests are real data trials of the SCT as the different subcomponents are integrated. Tests occurred in the SR1 assembly hall and then in the ATLAS cavern itself, as the SCT detector was integrated into the rest of the ATLAS detector.

The SCT is part of the ATLAS Inner Detector[1] which is comprised of three different subdetectors, each using different detector technologies, to accurately measure the path and momentum of charged ionizing particles traversing the detectors. Located closest to the interaction point is a 50-400 μm Pixel detector. Outside of the Pixel detector is a microstrip silicon detector (SCT) (with 80 μm pitch in the barrel and 57-90 μm pitch in the endcaps). The SCT has 4 barrel layers and 9 disks in each endcap. Exterior to the SCT lies the transition radiation tracker (TRT) which consists of 4 mm diameter straw tubes with additional transition radiation detection for particle identication.

In February 2006 the barrel section of the SCT was inserted into the barrel section of the TRT at the SR1 assembly area at CERN. Later in June 2006, this barrel section was used for the first commissioning test, before being lowered into position in the cavern in August 2006. In a similar fashion, each SCT endcap

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Preprint submitted to Elsevier *November 16, 2008*

was inserted into the corresponding TRT endcap in SR1. Detailed results for these surface commissioning tests can be found in [2]. The first of the SCT-TRT endcap sections was installed in the ATLAS cavern in May 2007. In June the second SCT-TRT section and the pixel detector were installed.

The entire Inner detector is now installed in the pit and integrated it into the combined ATLAS DAQ. In the ATLAS cavern, the Inner Detector is partially enclosed by a superconducting solenoid of radius 1.247 m, length 5.283 m and 1154 turns. When operated at the nominal current of 7730 A, the ATLAS solenoid produces an axial (z) magnetic field of 2 T near the centre (z=0m), dropping to 0.8 T at the end of the Inner Detector region (z = 3m)[3].

From September 2008, the commissioning has proceeded with cosmic tests, with the solenoid on and off, and events with the LHC beam.

2. The SCT detector

The SCT is designed to provide accurate position measurements between 25 and 50 cm from the beam pipe. It has an active silicon area of 61 m^2, designed to provide 4 space point measurements for a particle originating from the interaction point, up to a pseudo-rapidity coverage of $\eta \geq 2.5$.

The basic element of the SCT detector is the module as shown in figure . Each SCT module comprises of single-sided back-to-back p-on-n sensors. Each sensor consists of 768 channels readout by 6 chips. There is a 40 mrad stereo-angle between the direction of the silicon strips on the two sides of the module. The sensors have binary read-out with optical communication. The resultant spacepoint resolution they can provide is $17\mu m (580\mu m)$ in the $r\phi(z)$ direction. The individual strip resolution is 23\$$mum$. Each sensor is currently cooled at -10C using C3F8 coolant (-25 degC foreseen for normal operation) and can operate up to a bias voltage of 50 V. The power consumption of a module is 5.6 W, expected to increase to 10 W after 10 years of running. Due to the LHC conditions, the SCT must be radiation hard. The modules have been tested to 2×10^{14} 1-MeV neutron equivalent/cm^2. Scattering and interactions of the charged particles with the non-active elements of the innerdetctor will reduce the resolution of the detector. In order to reduce this the SCT has been designed to have only $3\% X_0$ per layer (measured for $\eta = 0$).

3. The SCT Module Front End

The SCT module front end consists of 128 channel Application Specic Integrated Circuits (ASICs) [4] with binary architecture, incorporated on the module. A charged particle traversing the detector induces a current in a strip. This generated current signal is passed to a pre-amplifier and shaper. This provides the pulse shaping according to the timing requirements and it filters the noise in order to maximise the signal to noise ratio. The signal then compared to pre-defined threshold. If the pulse height is above(below) the threshold a 1(0) is registered for a 25ns window. This binary result is stored in a binary pipeline.

For a given triggered event in the SCT detector, three pipeline bins are readout, corresponding to the triggered bunch-crossing cycle plus the hit information of the proceeding and subsequent bunch crossing cycles.

Optical links are used to transfer the data from the modules, as well as the bunch crossing clock, level 1 triggers and commands to the modules [5].

4. Overview of Commissioning tests

Every one of the 4088 SCT modules has been thoroughly tested. For each one, the electrical connections were checked to test that the LV signal arrives at the modules and HV current scans were performed. All the optical connections were tested to check for good fibre connections and that the correct mapping was in place.

Calibration tests, including the digital and analogue functionality of the front-end, gain curve, noisy/dead channel maps, noise occupancy tests were under taken. Finally cosmic tests have been performed in global commissioing runs with the rest of the ATLAS detector, to ensure each SCT detector is correctly timed in with respect to rest of ATLAS and the other modules, the alignment is measured and the performance is checked.

5. SCT cooling

The SCT is cooled using a C_3F_8 evaporative cooling system. Fluid is evaporated through cooling loops, and remaining liquid is boiled away by heaters in the exhaust of the cooling lines. The temperature of the gas must be raised above the cavern dewpoint temperature in order to avoid any condensation. The gas is then condensed and the liquid is recovered. In 2007, the SCT heaters failed. The heaters were completely redesigned inorder to prevent the problem reoccuring. As a precaution, they were also moved to a more servicable area. To date, there has been no more problems with the heaters.

Since the middle of August 2008, the cooling is on for the SCT and running stably, with the exception of two cooling loops, effecting 36 SCT modules in total. One of these loops is off due to short on the heater cable, which is due to be fixed this winter. The other cable is off to a small leak. It is believed that once the cooling is run at the design temperature of $\sim$ -25degC, the back-pressure will be near atmospheric reducing the pressure on the leak.

6. Overview of SCT Commissioning from August 2008

It has been found that the SCT had a high rate of failures in the TTC link of the off-detector optical plugin boards. The failure results in some SCT channels generate no pin current (TX). The suspected reason for this is ESD damage during manufacture. Currently this issue is affecting 2.5% of the SCT modules. To compensate, redundancy is used wherever possible. If there is a broken tx fibre or dead PIN, an SCT module can use the clock and control of a neighbouring module. In order to solve this issue, the plugin boards are due to be replaced. The replacements are due to start this winter and a production of a complete set of replacement boards is planned.

On the 10th September 2008, the LHC had its first circulating beam at the injection energy of 450 GeV. Whilst testing the section of the LHC upstream of the ATLAS detector, the beam was steered into the collimator which protects ATLAS from beam accidents. The collision of the beam with the tungsten collimator produced a shower of muons travelling through the ATLAS detector. During this test, the SCT endcaps were operated at 20V, as opposed to the nominal operating voltage of 150V. The barrel was off as a precaution against high charge deposited along barrel strips. Figure 1 shows one of these events. These events were used to help time in the SCT endcap modules.

Unfortunately, on the 19th September, a suspected faulty electrical connection caused a magnet in the LHC to quench, and a premature end to the beam tests. In the period from 10th Sep. to 27th Oct. 2008, approximately 800,000 (200,000) cosmic tracks in the SCT detector, have been collected with the solenoid on (off). These have been used to debug the data acquistion and Detector Control System, to test the detector monitoring systems, to calibrate the timing of the modules, to debug offline reconstruction and test the alignment methods with real data. We can study the detector performance in terms of efficiency, mechanical tolerances and resolution. The alignment of the barrel section shows similar residuals to the cosmic test in spring 2008, with only a $< 50\mu m$ shift between the solenoid field being on and off. Figure 2 shows the hit efficiency measured in the recent cosmic runs, is in agreement with the design specification of 99%.

7. Conclusion

The SCT is being commissioned with cosmic rays, in the ATLAS cavern, whilst integrated it into the combined ATLAS DAQ. Over one million SCT tracks have been reconstructed. Earlier problems with the SCT heaters have been resolved. Replacements of the off-detector optical plugin boards is planned to address the high rate of failures in their TTC links.

The reconstruction, alignment, calibration and monitoring chains have been successfully tested with real data and cosmic rays events and are providing prompt feedback to the detector performance.

References

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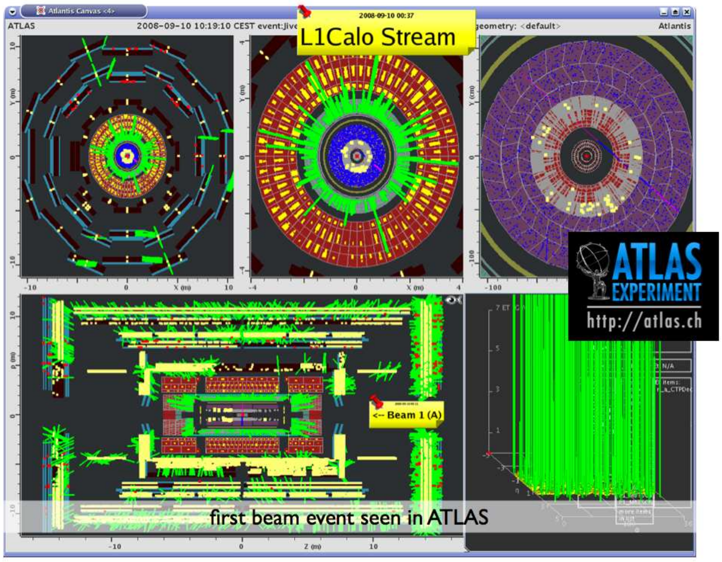

Figure 1: Event display of the first beam event observed in the ATLAS detector.

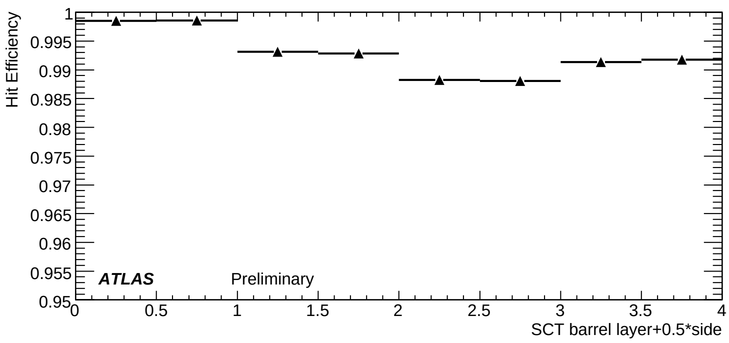

Figure 2: Measured hit efficiency of the barrel SCT modules.