The Semiconductor Tracker (SCT) of ATLAS is the middle component of the inner detector and plays an important role in precision charged particle tracking. It comprises four barrel layers (numbered 3 to 6) and nine disks (1 to 9) up to three rings in each end-cap. These structures are tiled with modules of detecting elements, of which there are 4088 in total - 2112 in the barrel region and 988 per end-cap.

The detecting elements are p-in-n silicon microstrips of 80 μm pitch. These are AC-coupled to ABCD3TA custom ASICs, which provide front-end amplification, shaping and discrimination of signal. Upon receipt of a first-level trigger, signal is read-out serially by a master ABCD3TA, and then transmitted to the off-detector electronics by vertical cavity surface emitting lasers (VCSELs) for further processing.

The figure on the left shows extrapolated values of HV and HV current in a central module of barrel layer 3 from 2015 to 2024, based on the Hamburg model and Run 2 data, given a change basic properties of the sensors. The SCT’s Run 2 experience studied.

During Run 2, the LHC exceeded its design instantaneous luminosity of $10^{34}$ cm$^{-2}$ s$^{-1}$ by a factor of two, which entailed correspondingly higher values of pileup, $\mu$ (the average number of pp interactions per bunch crossing). The SCT — designed to operate at $\mu < 23$ — was asked to operate at $\mu > 60$. Several steps were taken before and during operation to mitigate the adverse effects of increased pileup on data acquisition, transmission and quality. Two example metrics are shown here: number of noisy chips and number of S-links above threshold.

The operational High Voltage (HV) of the SCT had to change to maintain hit efficiency at $\approx 25\%$ during pp collisions.

The figure on the right shows the hit efficiency measured in the first bunch crossing of the SCT was maintained above $90\%$ up to the end of Run 2, and was stable with respect to pileup.

The sensors of the SCT are subject to severe irradiation by a broad spectrum of particles during LHC operations. This irradiation acts to change basic properties of the sensors. The SCT’s Run 2 experience provides a valuable dataset in which radiation damage can be studied.

Two key parameters are the leakage current (the quiescent current that flows when there are no real hits) and the full depletion voltage (the potential across a sensor’s depletion region). These properties were monitored throughout Run 2 by way of periodic High Voltage (HV) scans and are well understood based on the Hamburg model. With this understanding, hit efficiency could be maintained.

How the SCT was available for 99.9% of the integrated luminosity of Run 2 with a data quality efficiency of 99.85%...

THE PERFORMANCE AND OPERATIONAL EXPERIENCE OF THE ATLAS SEMICONDUCTOR TRACKER (SCT) DURING LHC RUN 2

...and what to expect in Run 3

The SCT was designed to endure 700 fb$^{-1}$ of pp interactions at a collision energy of 14 TeV. Run 1 caller an integrated luminosity of 29 fb$^{-1}$ at 7 TeV, while Run 2 accumulated 156 fb$^{-1}$ at 13 TeV; therefore there remains a safe margin for Run 3 operations.

The SCT is expected to operate safely throughout the Run 3 years, with the HV current remaining within the hardware limit of 5 mA, regardless of extra pileup from Run 2 data.