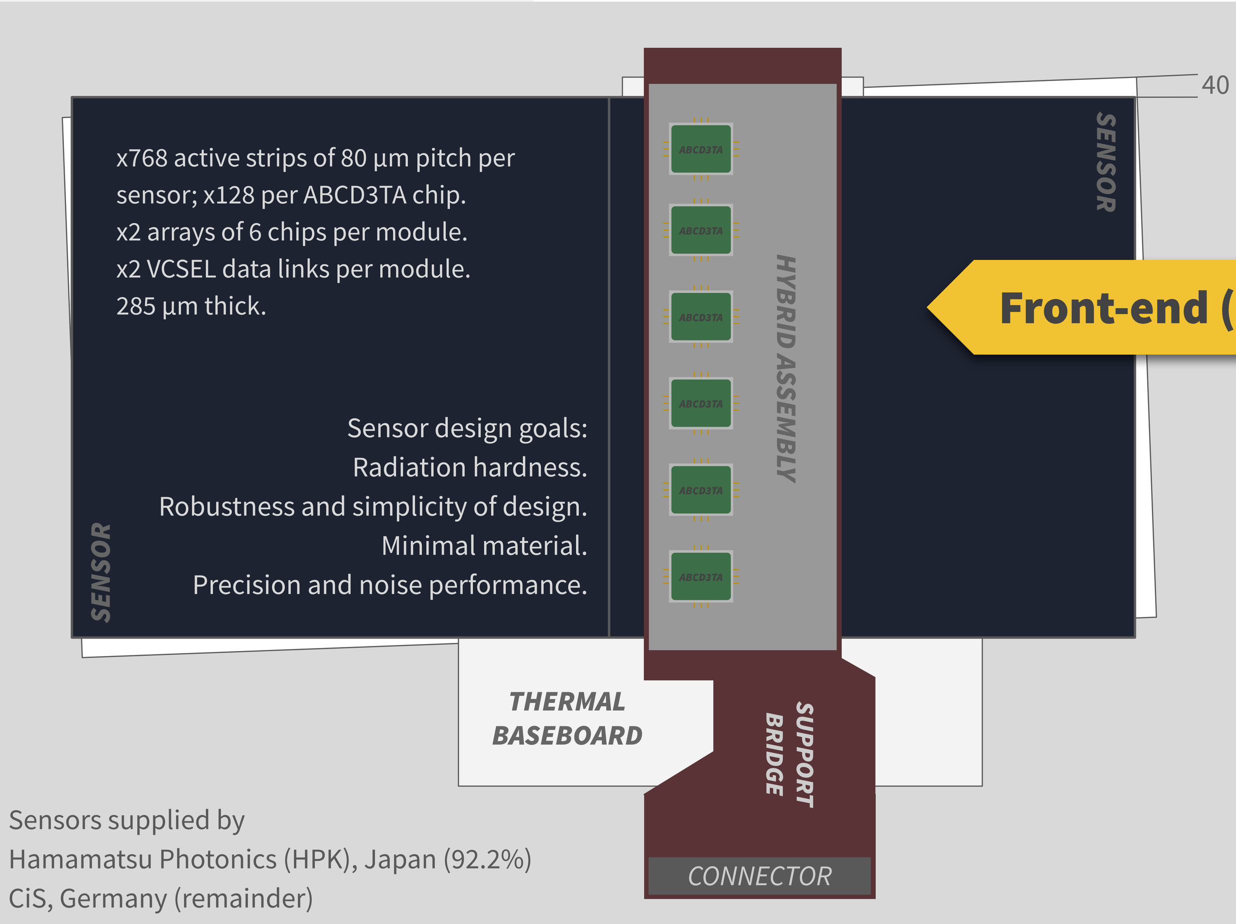
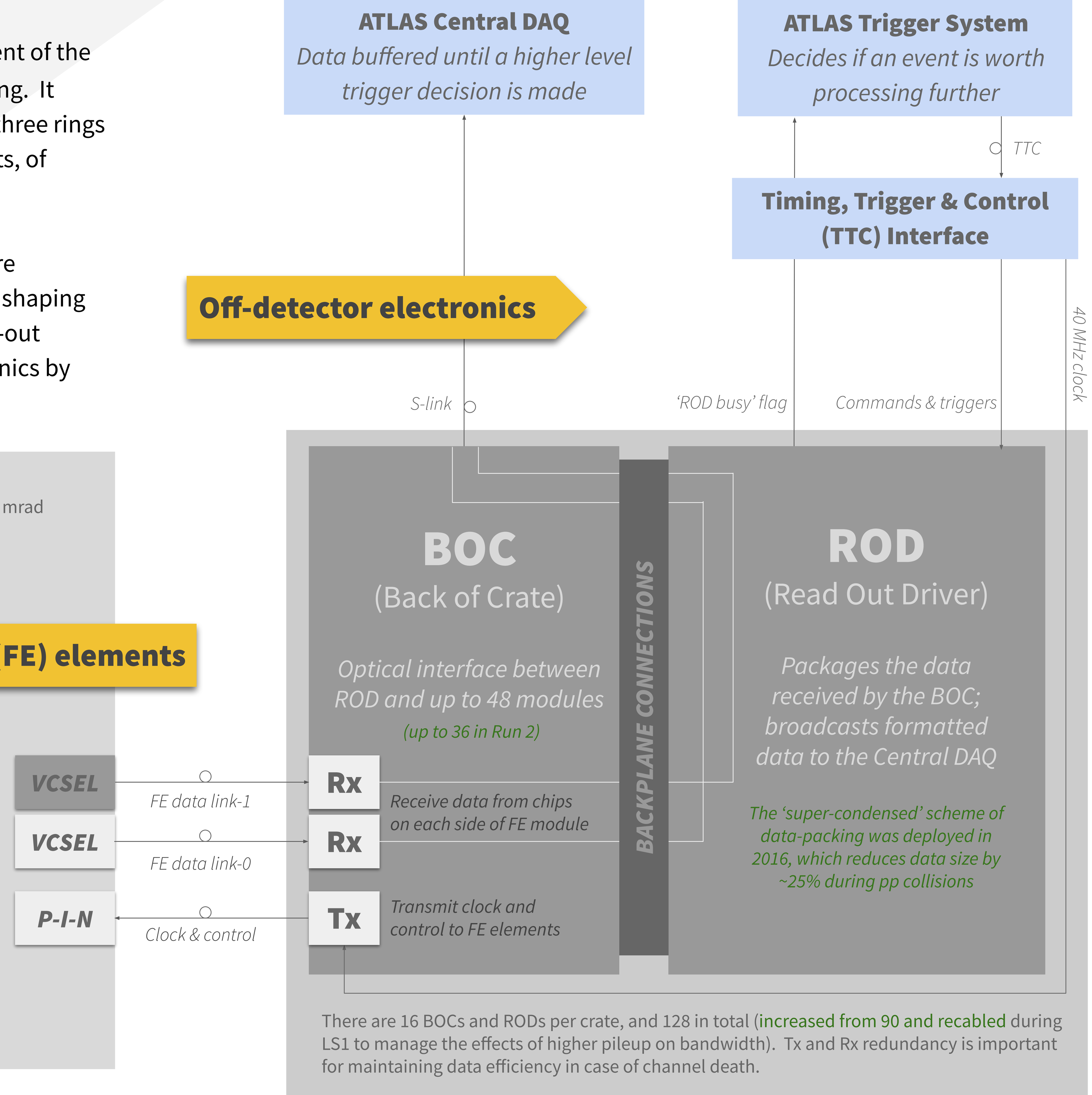
The Semiconductor Tracker (SCT) of ATLAS is the middle component of the inner detector and plays an important role in precision charged particle tracking. It comprises four barrel layers (numbered 3 to 6) and nine disks (1 to 9) of up to three rings in each end-cap. These structures are tiled with modules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

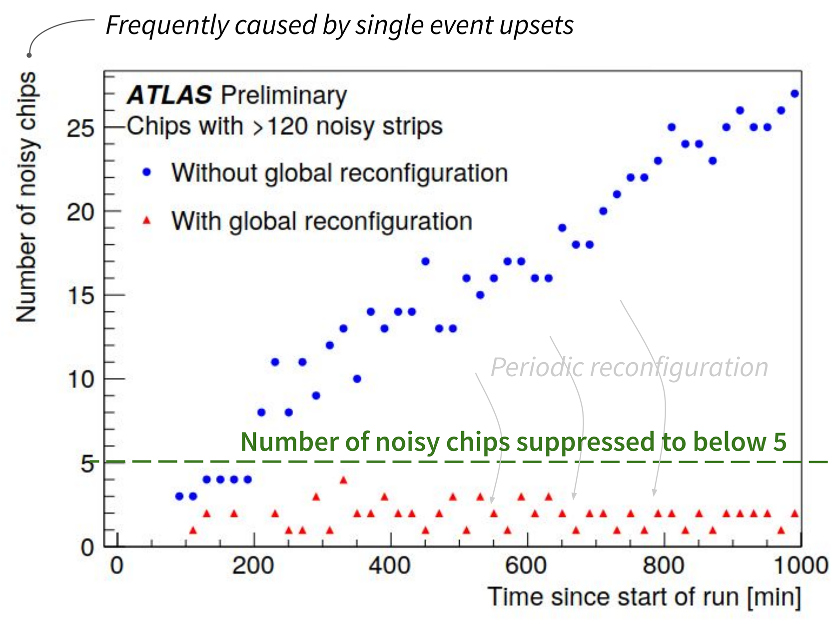
The detecting elements are p-in-n silicon microstrips of 80 µm pitch. These are AC-coupled to ABCD3TA custom ASICs, which provide front-end amplification, shaping and discrimination of signal. Upon receipt of a first-level trigger, signal is read-out serially by a master ABCD3TA, and then transmitted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





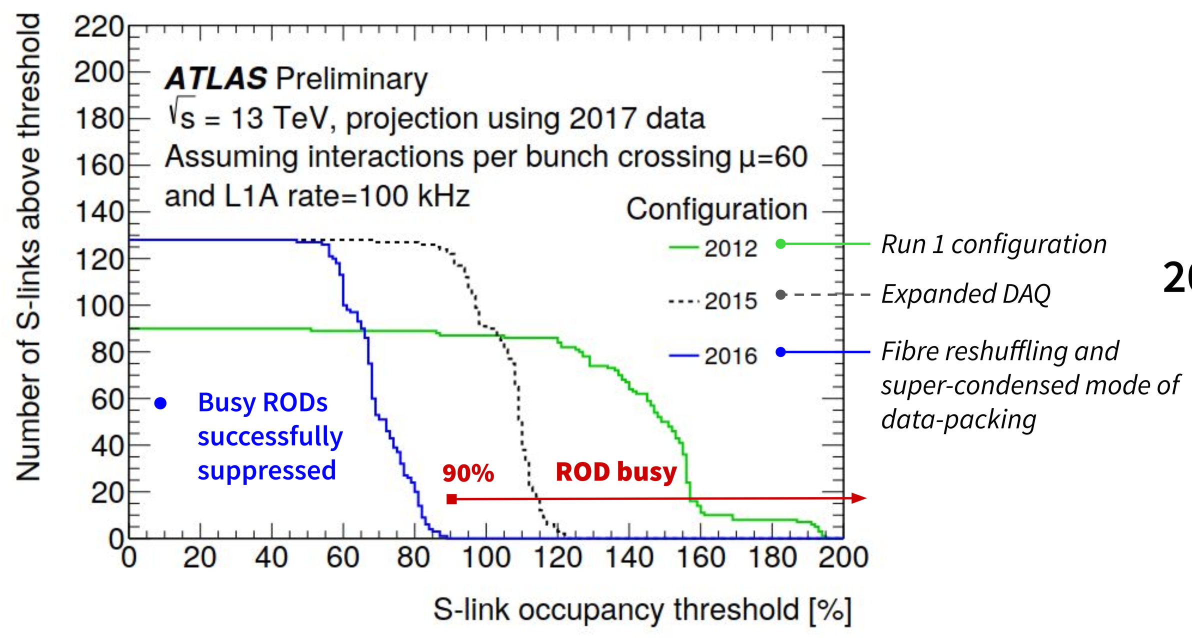
High pileup operation

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, µ (the average number of *pp* interactions per bunch crossing). The SCT — designed to operate at µ ~ 23 — was asked to operate at µ ~ 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.



Since it is difficult to identify noisy chips online, a system is implemented that applies a periodic global reconfiguration of the SCT DAQ. The number of noisy chips is kept below 5 in the run of 2018 shown on the left in red.

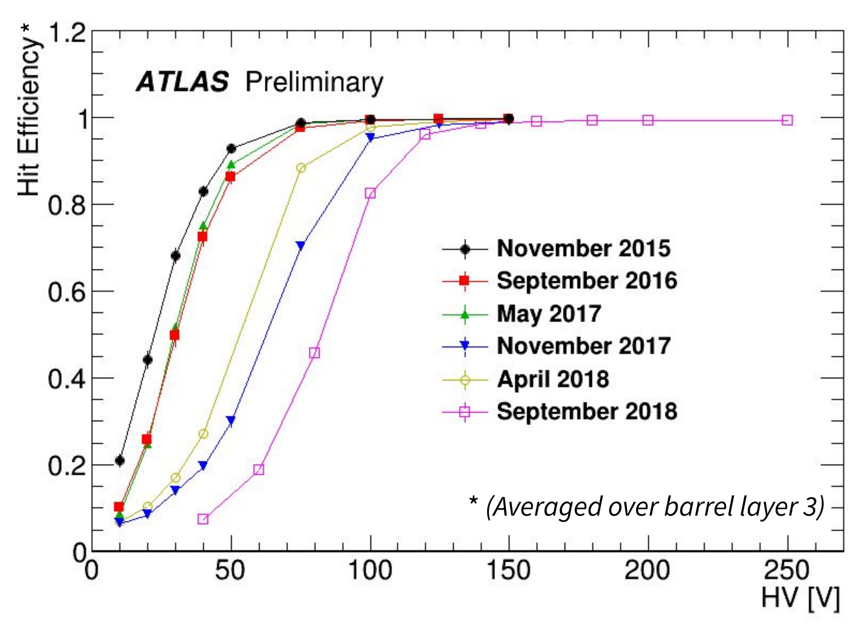
The bandwidth of the S-links is a bottleneck of data transmission: when the occupancy of an S-link exceeds 90%, the corresponding ROD asserts a busy flag and suspends the central DAQ. The plot on the right, where the number of S-links above threshold is simulated under different DAQ configurations, shows the number of busy RODs being suppressed in 2016.



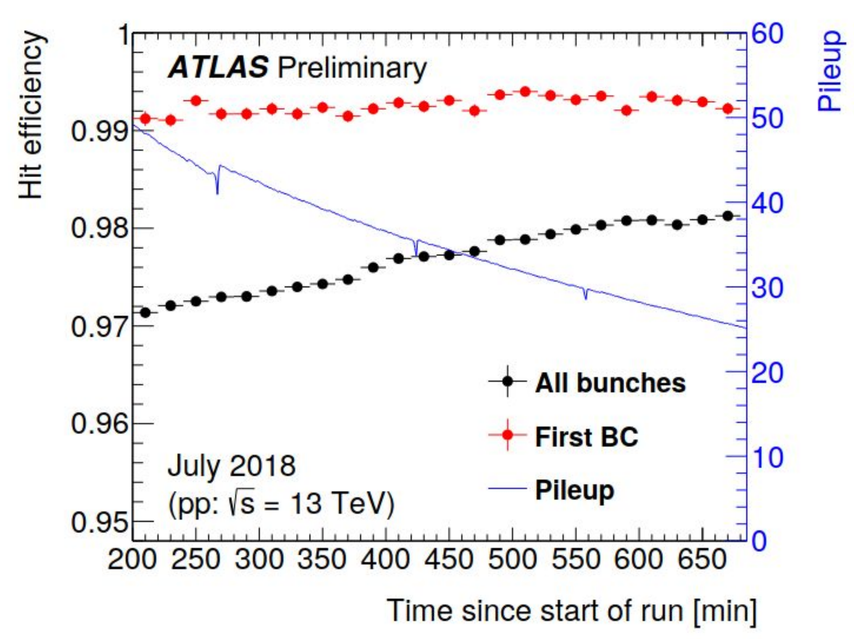
Radiation damage and performance

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.



The operational High Voltage (HV) of the SCT had to change to maintain hit efficiency at ~1 — the HV in barrel layer 3 was increased from 150 V to 250 V in September 2018. The slower increase in hit efficiency with HV from November 2017 indicates the occurrence of type inversion.

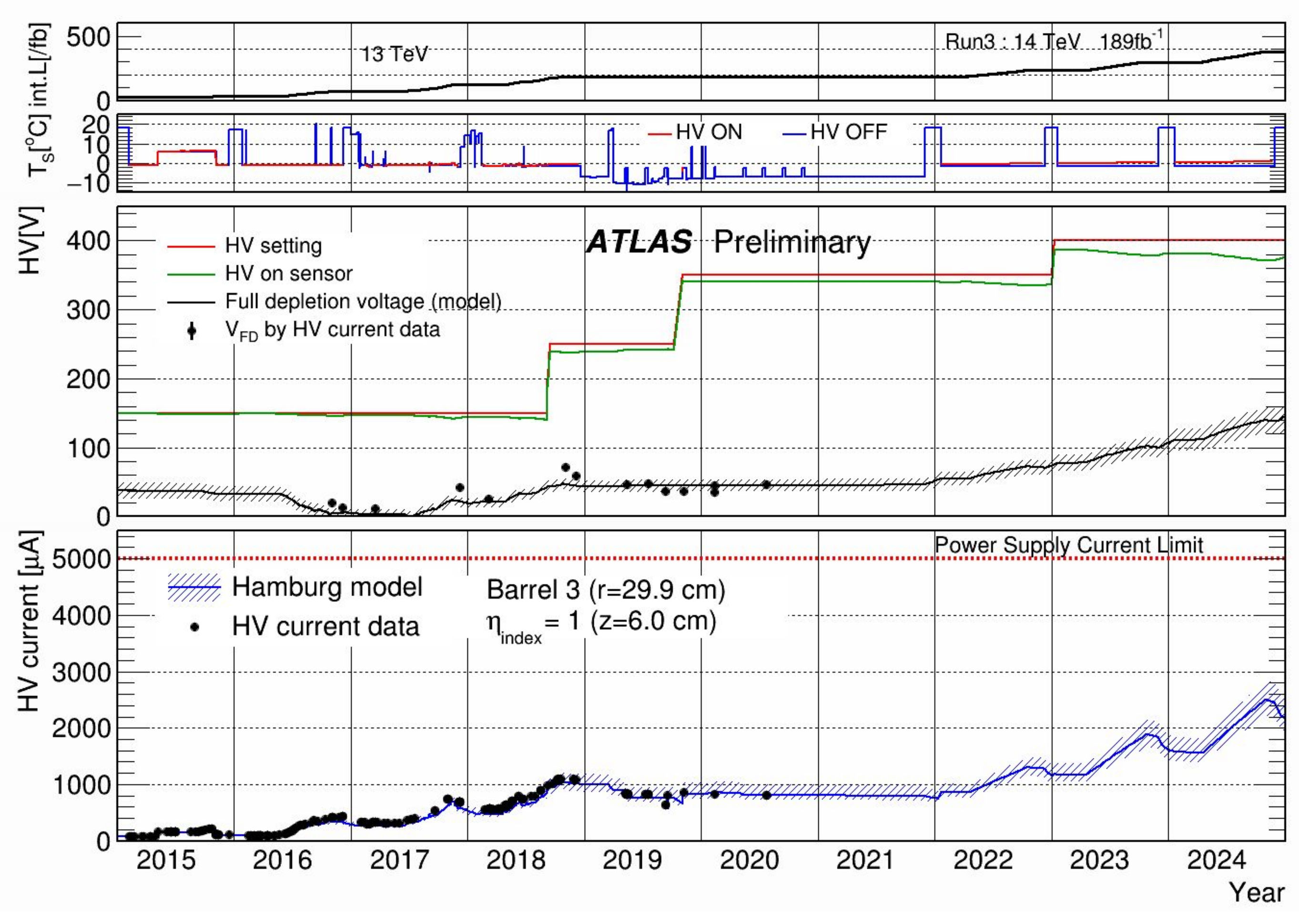


The intrinsic hit efficiency (measured in the first bunch-crossing) of the SCT was maintained above 99% up to the end of Run 2, and was stable with respect to pileup.

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 tallied an integrated luminosity of 29 fb^{-1} at 7-8 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, according to extrapolations from the Run 2 data.

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 hypothesis about the parameters of Run 3 operation (that 189 fb^{-1} of *pp* collision data will be collected at 14 TeV and at the sensor temperatures indicated in the second plot).

← SCT developments
Context →

2005 — The ABCD3TA ASIC for readout
Nucl. Inst. Meth. **A552** (2005) 292

2006 — The barrel and end-cap modules
Nucl. Inst. Meth. **A568** (2006) 642

2007 — Nucl. Inst. Meth. **A575** (2007) 353

The optical links
JINST **2** (2007) P09003

The silicon microstrip sensors
Nucl. Inst. Meth. **A578** (2007) 98

2008 — SCT DAQ and calibration systems
JINST **3** (2008) P01003

The evaporative cooling system
JINST **3** (2008) P07003

LHC Machine
JINST **3** (2008) S08001

The ATLAS Experiment
JINST **3** (2008) S08003

2009 — **LHC RUN 1**
29 fb^{-1} of *pp* data at 7-8 TeV

2012 — Higgs Boson
Phys. Lett. B 716 (2012) 1

2013 — **LONG SHUTDOWN 1 (LS1)**

Insertable B-Layer (IBL)
JINST **13** (2018) T05008

2014 — SCT Run 1 summary
JINST 9 (2014) P08009

Expanded DAQ
Production of extra RODs and BOCs

2015 — **LHC RUN 2**
156 fb^{-1} of *pp* data at 13 TeV

The thermosiphon cooling system
Int. J. Chem. React. Eng. **13** 511

Cable remapping
Data links to BOCs reorganised to distribute S-link occupancy more uniformly

2016 — *Data compression*
'Super-condensed' mode of data packing deployed in ROD firmware

2017 — *Chip masking*
...done on-the-fly in software, deployed in 2017 when pileup values were exceptionally high.

2019 - **LONG SHUTDOWN 2 (LS2)**
Phase I Upgrades of the ATLAS detector; Covid-19 pandemic

Phase I Upgrades
CERN-LHCC-2011-012

ATLAS Run 2 DQ report
JINST **15** (2019) P04003

SCT Run 2 summary
(Under preparation)

TIPP 2021
Ynyr Harris
on behalf of the ATLAS Collaboration

2022 - **LHC RUN 3**
189 fb^{-1} of *pp* data at 14 TeV?

Miscellaneous References

M. Moll, The Hamburg model, 1999
DESY-THESIS-1999-040