

Abstract

For the production of the Inner Tracker (ITk) as part of the phase-II upgrade programme to prepare the ATLAS experiment for the High-Luminosity (HL) LHC, batches of Long Strip (LS) and Short Strip (SS) n-in-p type micro-strip sensors have been produced by Hamamatsu Photonics.

The full size sensors measure approximately 98 x 98 mm² and are designed and engineered for tolerance against the 9.7 x 10¹⁴, including a safety factor of 1.5, 1MeVn_{eq}/cm² fluence expected at the HL-LHC. Each sensor has 2 or 4 columns of 1280 individual channels arranged at 75.5 μm horizontal pitch.

To ensure the sensors comply with their specifications, a Quality Control (QC) procedure has been designed, comprising measurements on every individual sensor as well as on a sample basis.

Every sensor is subjected to an initial visual inspection, after which the full surface of the sensor is captured with very high resolution by an automated camera setup. Non-contact metrology is performed to obtain the sensor surface profile.

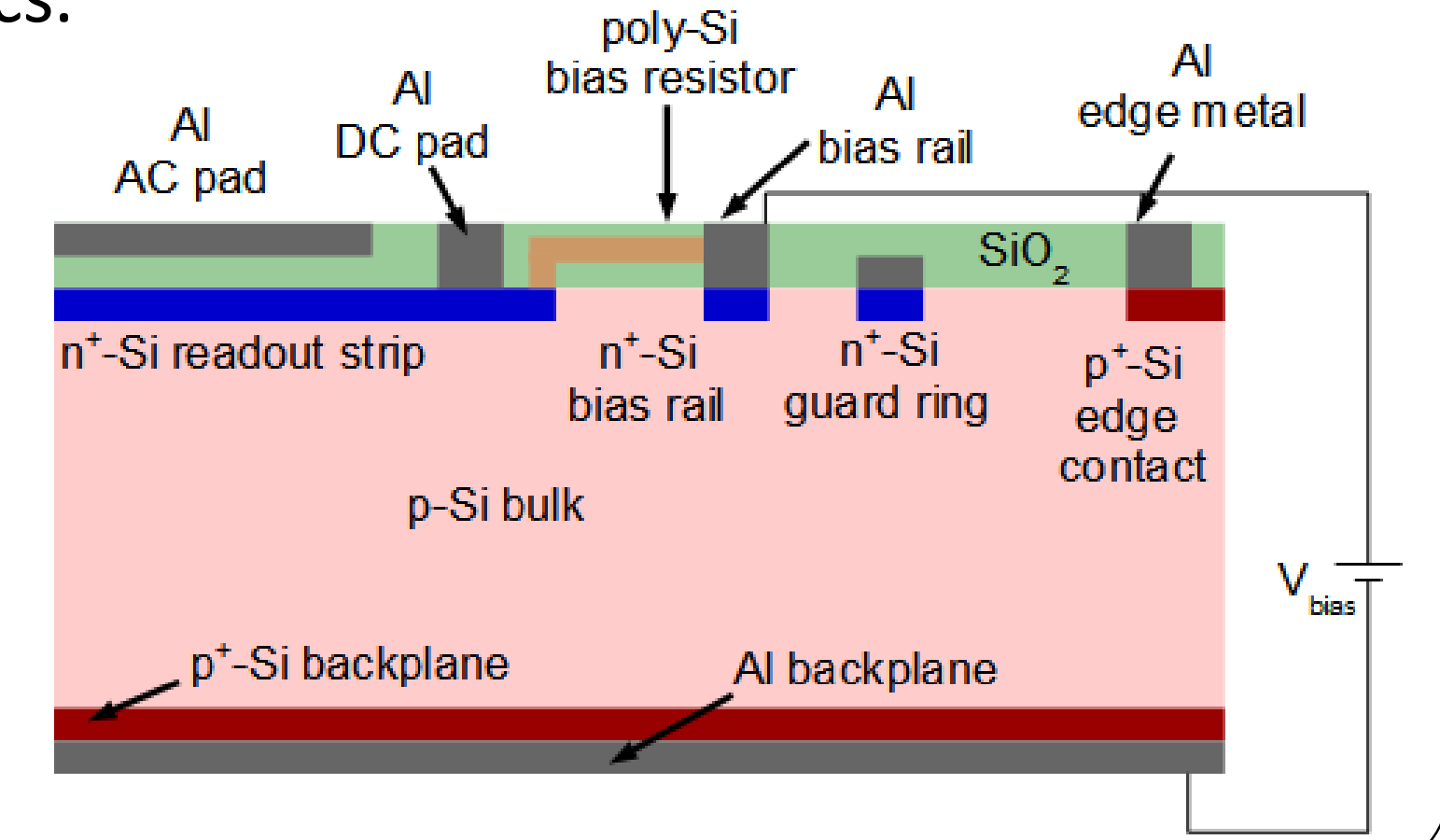
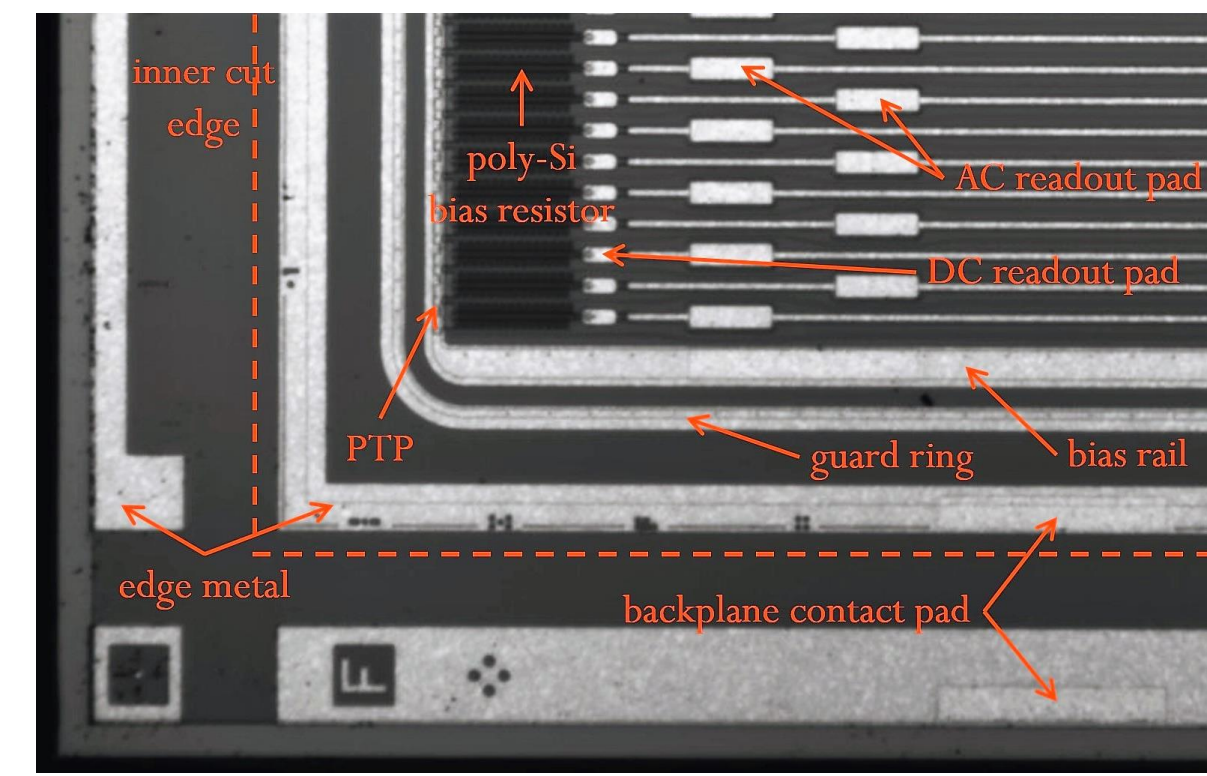
Electrical measurements establishing the reverse bias leakage current and depletion voltage are conducted automatically, with the recorded results uploaded to a production database following data quality checks. Sample sensors from every batch are subjected to 40 hour leakage stability checks in controlled atmosphere, and tests on every channel measuring leakage current, coupling capacitance and bias resistance are conducted.

ITk Strip Sensors

ITk Strip Sensors are single-sided n⁺-in-p sensors with square shape in the barrel region and wedge shape with curved edges at constant radius in the end-cap. The strip length of sensors in the inner barrel layer is half the length of outer layer sensors. For end-cap sensors there are six different layouts with radial strips.

Top metal layer strips are AC-coupled to the strip implants, which have p-stop traces running in between along the full length for strip isolation. The top metal layer is passivated with openings for probing and wirebonding.

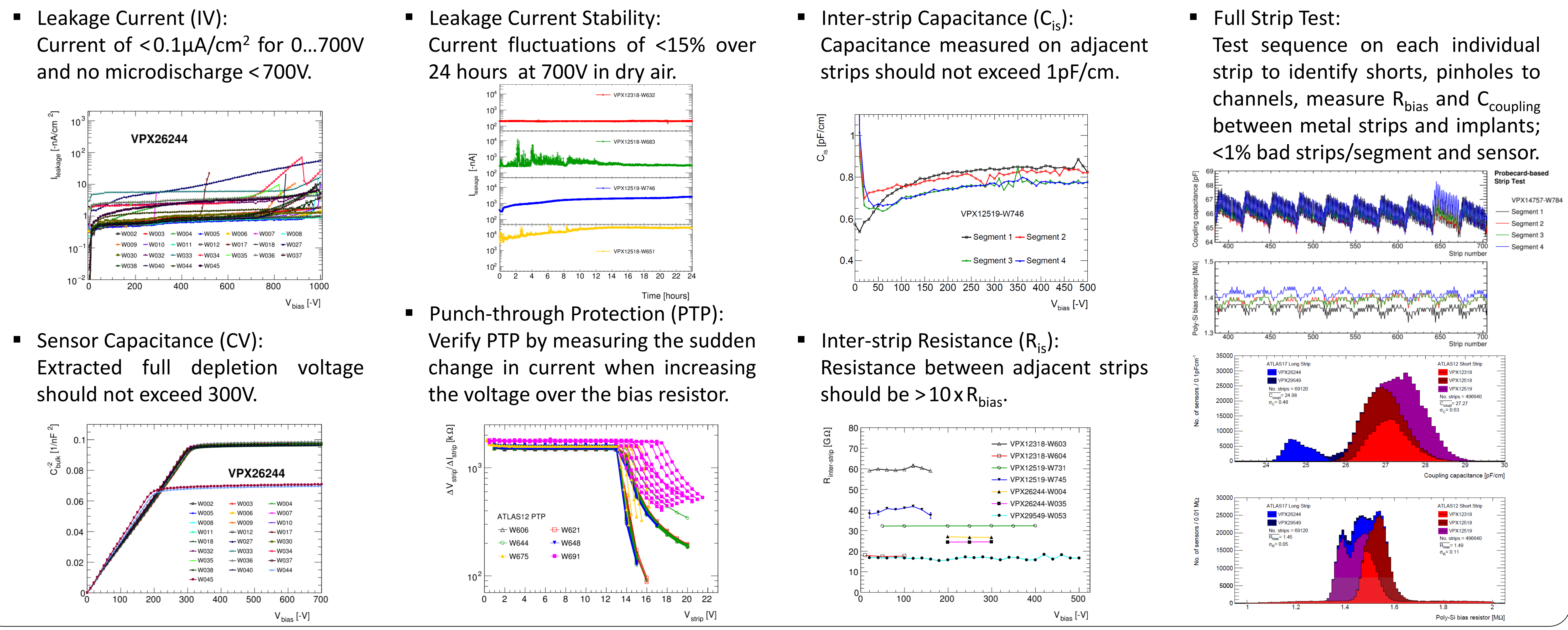
Multiple iterations of prototype sensors for extensive testing have been manufactured by Hamamatsu Photonics.



Electrical measurements – verification of Sensor Quality Control procedures

Sensor pre-production deliveries are scheduled to start in early 2020. They will undergo Quality Control (QC), which can identify emerging problems with manufacturing for single sensors or whole batches, so as to make sure only sensors which adhere to specifications are used in the assembly of detector modules.

Basic mechanical and electrical tests will be carried out for every sensor, while more detailed measurements will be done on a few samples per batch [1-4], shown here for the last prototype generations before pre-production as an example.

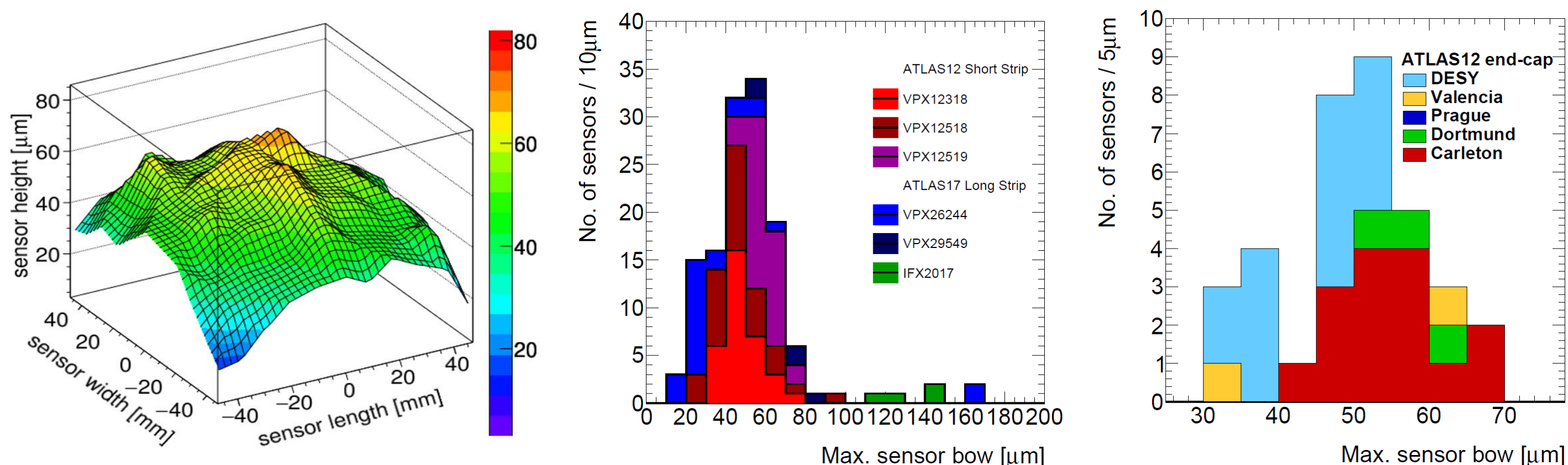
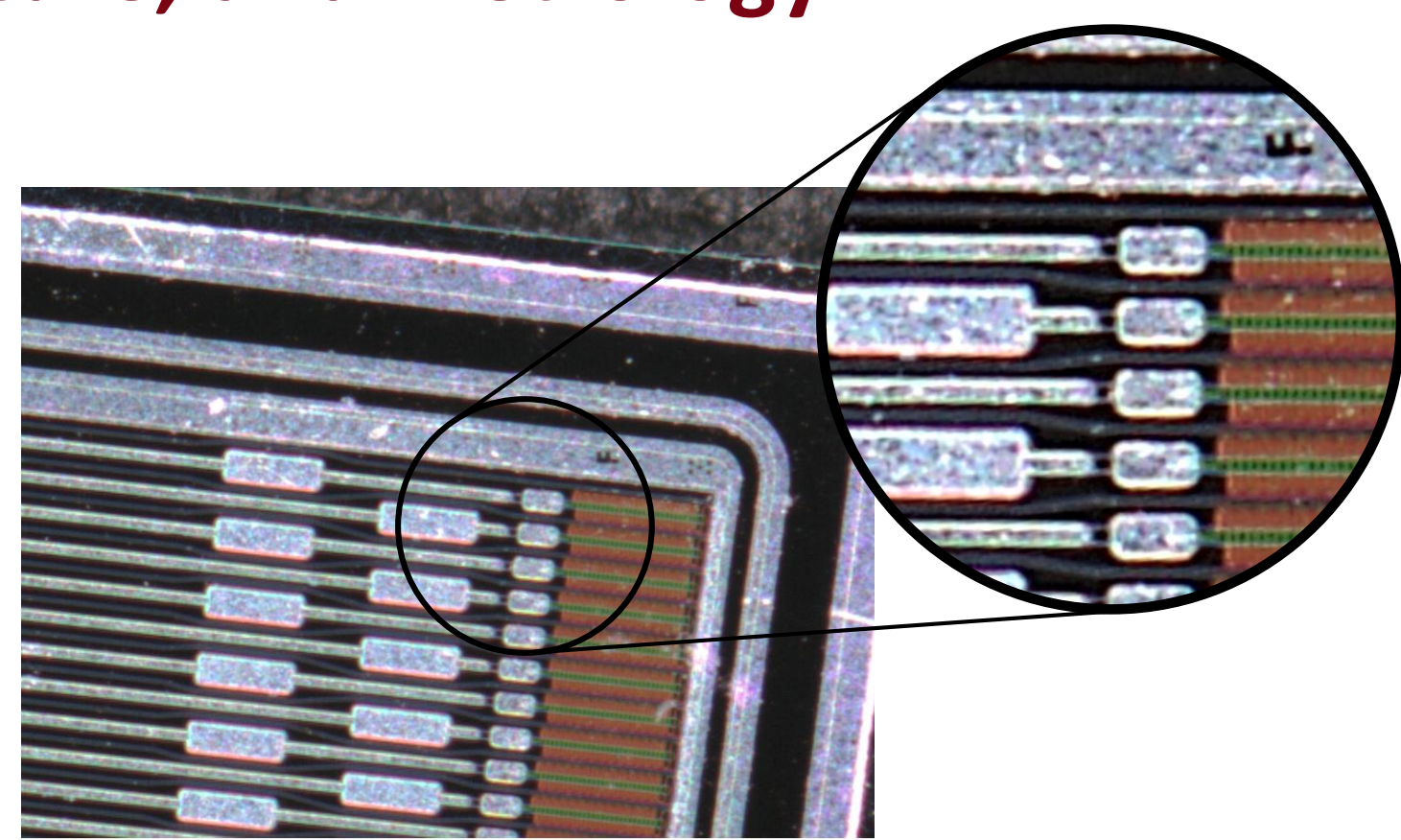


Visual inspection, surface capture, and metrology

Using high-detail imaging the sensor surface is inspected with regards to chips, cracks, or other irregularities.

The full surface of the sensor is captured with <math><2\mu\text{m}/\text{px}</math> resolution by an automated camera setup and stored for future reference.

On the sensor surface the maximum difference in z is not to exceed 200μm when measured during a non-contact metrology measurement.

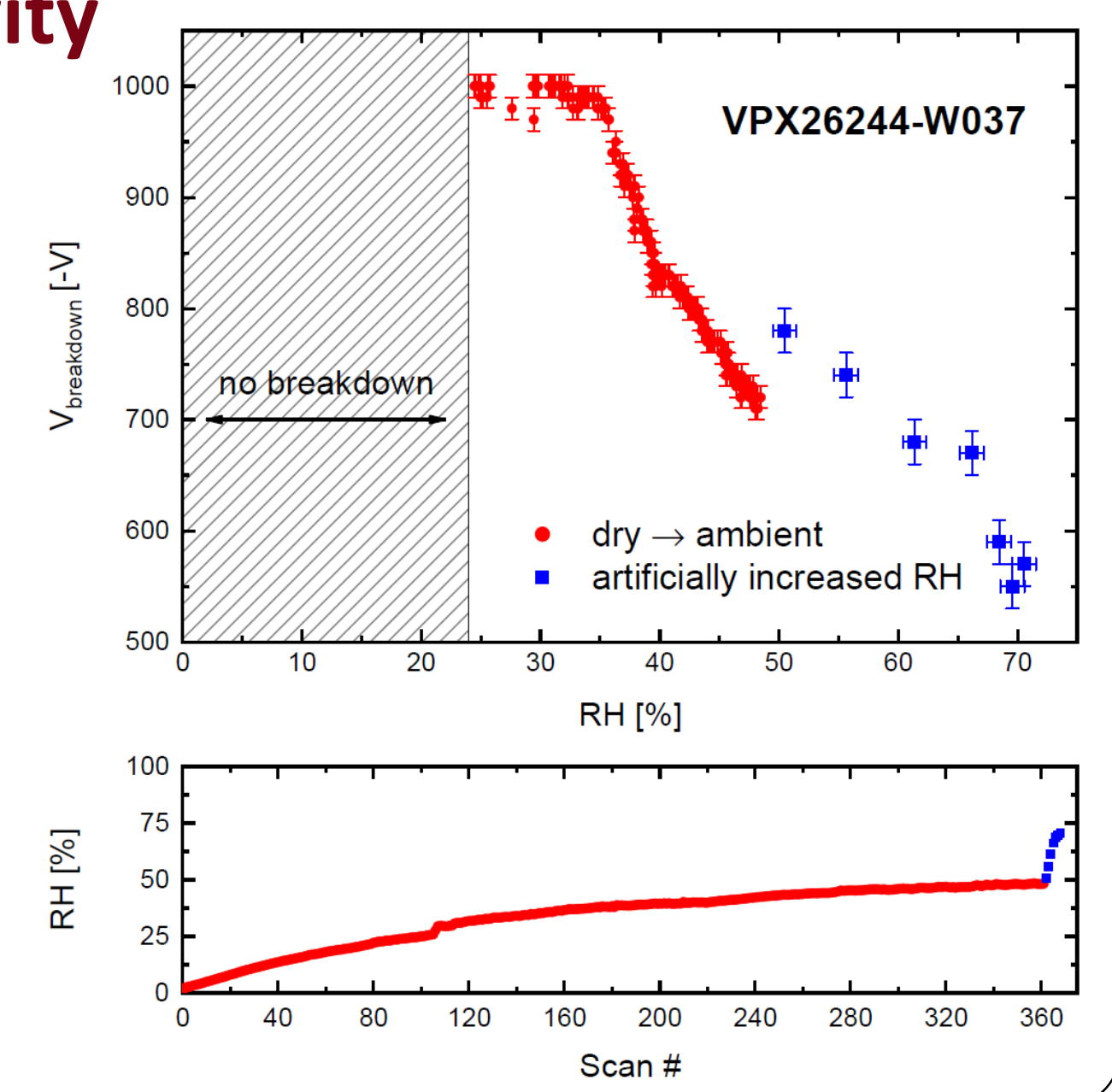


Ongoing research: humidity sensitivity

Long-term reliability is one of the key points in ITk sensor development, but a large fraction of prototype sensors do not fulfil current stability criteria in ambient atmosphere.

Sensor behaviour ranges from erratic fluctuations to continuously increasing current and abrupt breakdowns.

Repeated IV scans of sensors show systematic decrease of breakdown voltage with increasing humidity.



References

- [1] The ATLAS Collaboration, "Technical Design Report for the ATLAS Inner Tracker Strip Detector", CERN-LHCC-2017-005, ATLAS-TDR-025 (2017)
- [2] L.B.A. Hommels, et al., "Detailed studies of full-size ATLAS12 sensors", NIM A 831 (2016)
- [3] R.F.H. Hunter, et al., "First bulk and surface results for the ATLAS ITk Strip stereo annulus sensors", NIM A 924 (2019)
- [4] C.T. Klein, "Investigation of performance and the influence of environmental conditions on strip detectors for the ATLAS Inner Tracker Upgrade", <https://doi.org/10.17863/CAM.45814>