Test and extraction methods for the QC parameters of silicon strip sensors for ATLAS upgrade tracker

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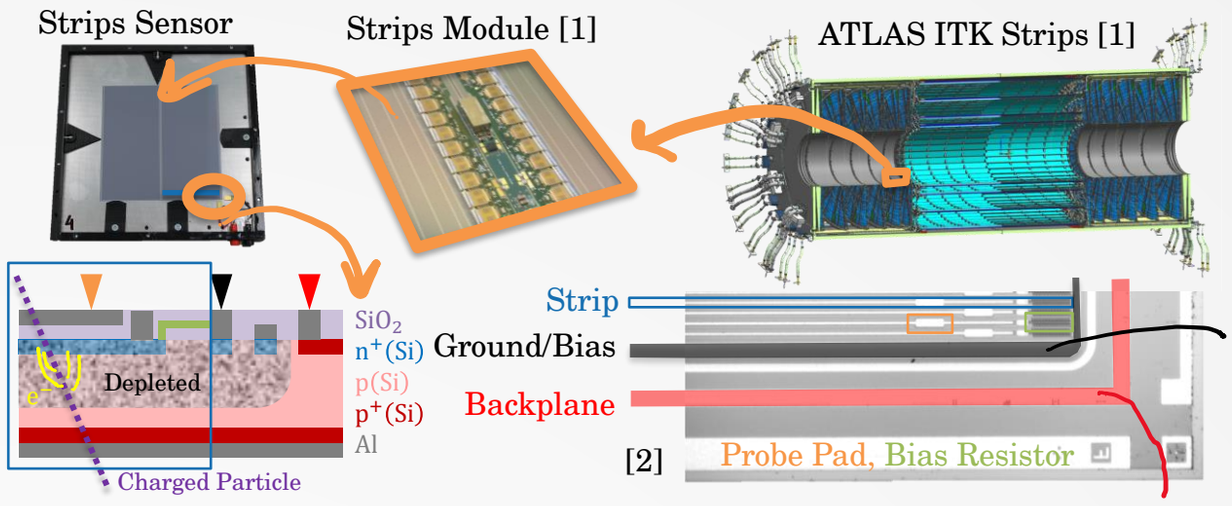
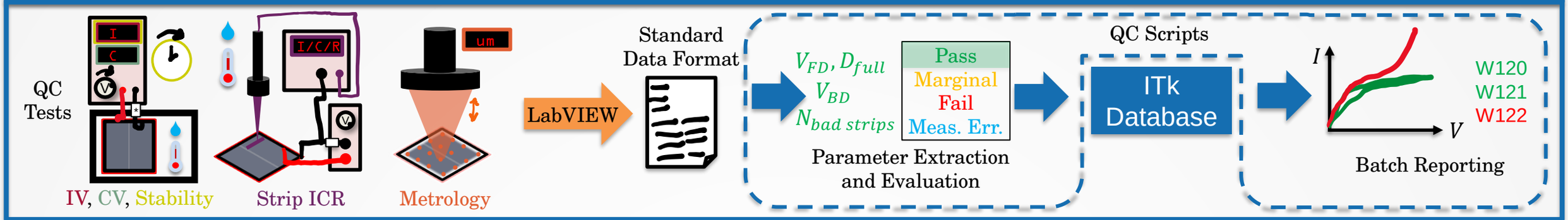
1. Motivation and the ATLAS ITk Strips Sensors

- **ATLAS Inner Tracker (ITk)** fully silicon **upgrade** comprises **pixel** and **strip** sensors
- **Strips** comprises **22000 sensors** of 8 types (2 barrel and 6 endcap)
- Each sensor to be evaluated for **quality control (QC)** at various institutes with various test setups
- For this, **developed common framework** with common algorithms to objectively **assign pass/fail**, interface with **common database**, and do **reporting**



2. Workflow



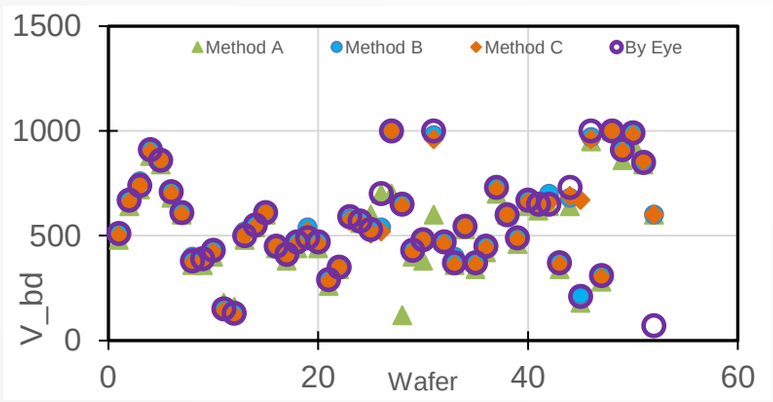
3. Treatment of Current-Voltage (IV) Tests

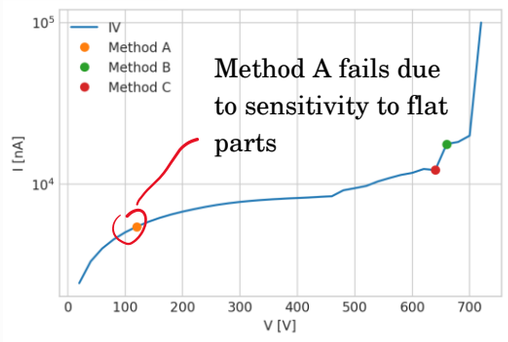
Method A: (modified from tech spec.)
V_{bd} is earliest $V_j < -100$ V that satisfies
$$\left(\frac{1}{3}\sum_{k=j-1}^{j+1}\frac{I_{k+1}-I_k}{V_{k+1}-V_k}\right) \div \left(\frac{I_{k+1}-I_k}{V_{k+1}-V_k}\right)_{min} > 5$$
i.e. avg of 3 local slopes around point divided by min local slope

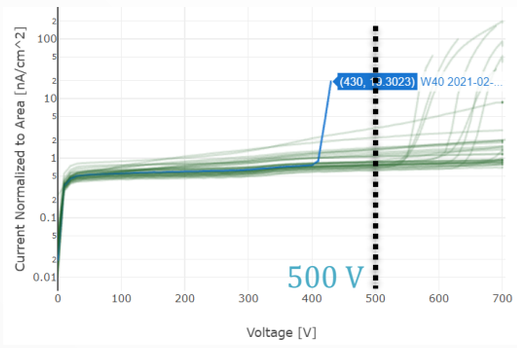
Method B: (modified from [3])
V_{bd} is earliest V_{j+1} that satisfies
$$\frac{I_{j+1}-I_j}{V_{j+1}-V_j} \div \frac{I_{j+1}}{V_{j+1}} > 5$$
i.e. local slope at point divided by slope of line from origin to point ("total derivative") > 5.

Method C: (modified from B)
V_{bd} is earliest V_{j+1} that satisfies
$$\frac{I_{j+1}-I_j}{V_{j+1}-V_j} \div \frac{I_{j+1}+I_j}{V_{j+1}+V_j} > 5.5 + \frac{\min(|V| - 500\ \text{V}, 0\ \text{V})}{100\ \text{V}}$$
i.e. B but with averaging, and running threshold to compensate for gradually decreasing total derivative

- Various algorithms for **calculating V_{bd}** explored
- Method B and C equally reliable, but **C is chosen** due to better expected robustness



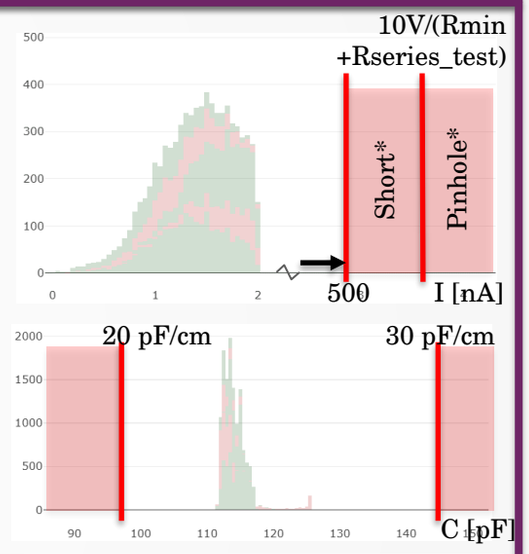




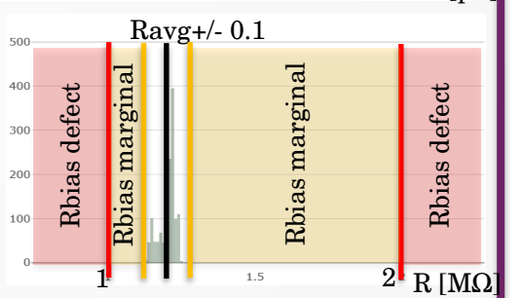
$[I_{max}(V < 500\ V)]$ Max Current < 100 nA/cm^2
$[V_{bd}]$ Breakdown Voltage > 500 V

4. Treatment of Individual Strip ICR Tests

- AC-coupled metal strips **probed automatically** to characterize strip **RC** network and AC **current**
- Combinations of this info lets scripts **distinguish different failure modes** (metal short, implant break, short, pinhole, Rbias defect), and **measurement issues**



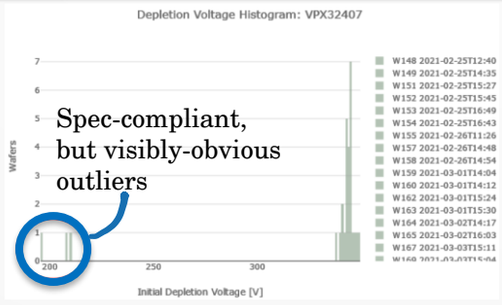
Being able to see geometric correlation helps gives leads in investigating

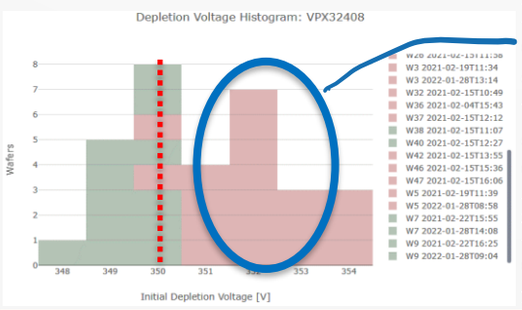


Total # bad strips < 1%
Bad strips in a row < 8

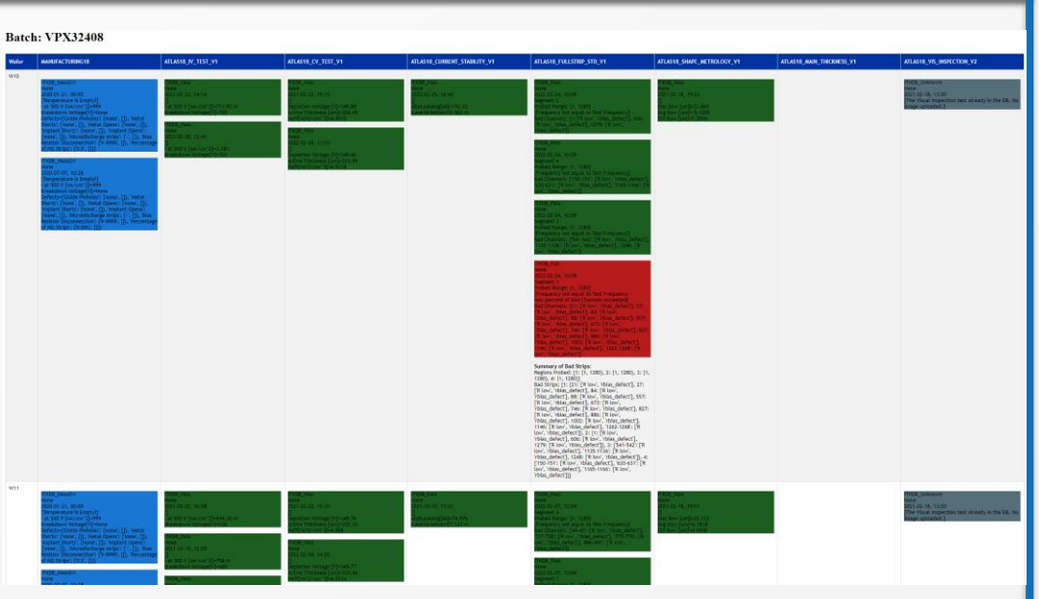
5. Batch Reporting

- QC approval done on **batch-by-batch basis**
- Reports show **interactive diagnostic histograms and plots** by batch
- Allows humans to **visually detect batch issues and outliers** not immediately obvious to an algorithm
- Reporting tool designed to provide a concise table summary and plots of all tests in a batch in a single place for monitoring
- Scripts allow for **direct interactive access to database data** in python **for studies**





Bimodal distribution of depletion voltage (not obvious in CV curves) possibly hints at different ingots



6. Current Status

- Scripts have proven a robust, reliable, and intuitive interface for reporting and monitoring, and have already been instrumental in helping catch subtle issues with sensors and testing
- Have already processed **2500 sensors through preproduction and production in 7 institutes in 5 countries**
- Undergoing continuous development to add new features useful to QC sites **as we enter production**

References & Acknowledgements

[1] CERN-LHCC-2017-005 ; ATLAS-TDR-025
[2] 10.1016/j.nima.2016.03.042
[3] 10.1016/S0168-9002(00)01207-9

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- ATLAS Inner Tracker (ITk) fully silicon upgrade includes 22000 strips sensors that all need to be evaluated for quality control (QC) at various institutes with different setups
- For this, a QC framework has been developed to take data files produced with QC tests and use algorithms to extract parameters, evaluate specification compliance, upload to a common database, and do batch reporting
- In particular, algorithms were developed to aid with the most common tests: IV, CV, individual strips, current stability, and metrology.
- For IV tests, several algorithms for determining breakdown voltage were explored and evaluated for robustness and accuracy
- For individual strip tests, particular work has gone into identifying the type of fault from various combinations of measurements of the AC metal current and the RC network
- Reporting summarizes all QC tests for a batch concisely for QC approval, which is done batch-by-batch
- Reporting gives interactive diagnostic histograms and plots by batch to allow technicians to qualitatively detect outliers or batch issues not immediately obvious to algorithms.
- Scripts have successfully processed 2500 preproduction and production sensors in 7 institutes and we are about to begin production.