



ATLAS ITk Strip Sensor quality control and review of ATLAS18 pre-production sensor results

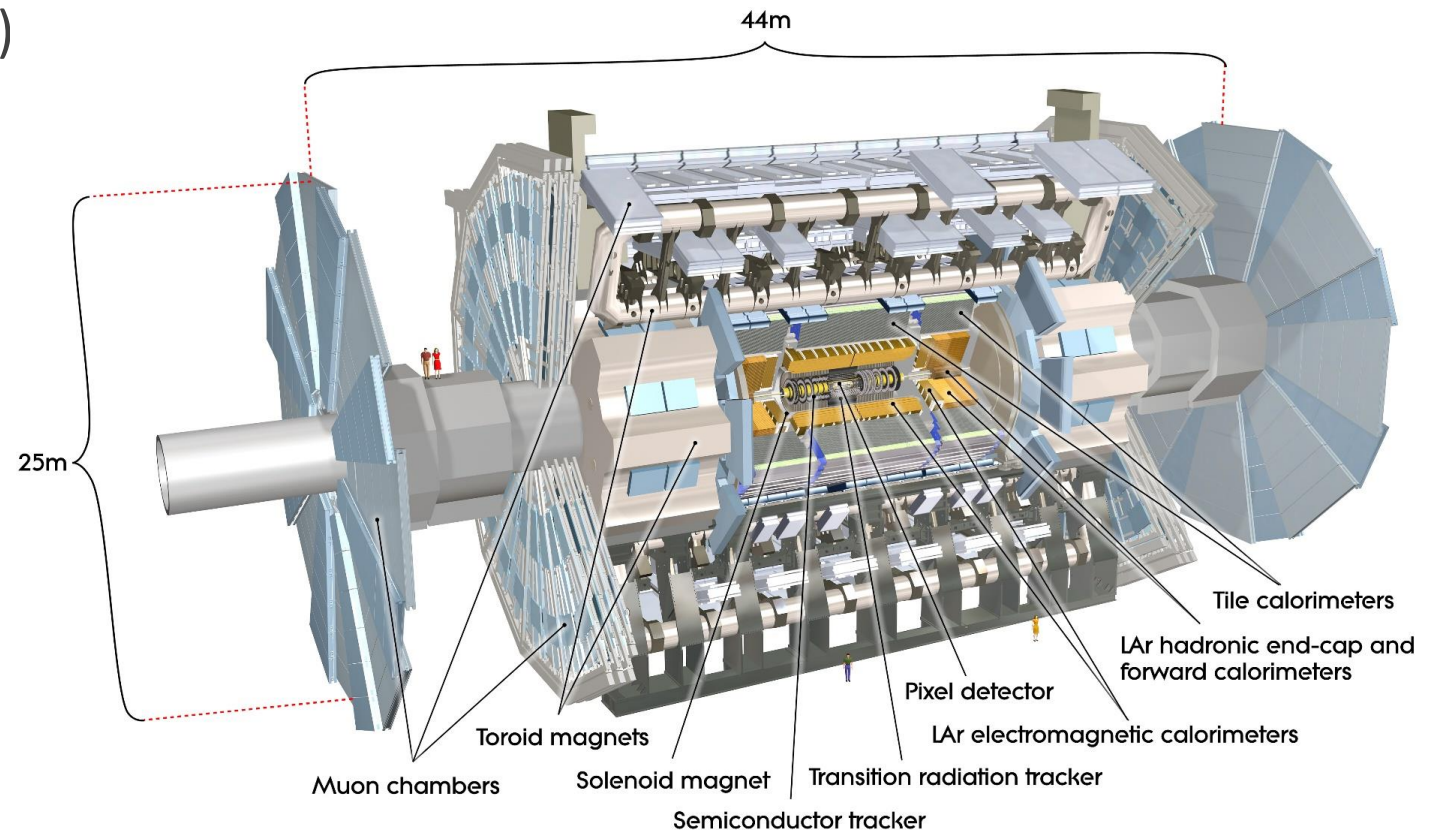
CHRISTOPH KLEIN (ON BEHALF OF THE ITK STRIP SENSOR COLLABORATION)

CARLETON UNIVERSITY, OTTAWA

VERTEX 2022 WORKSHOP

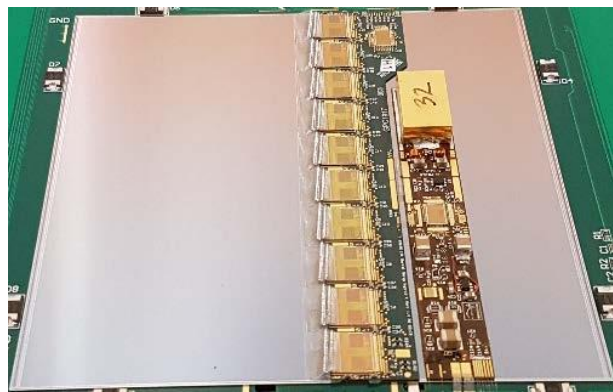
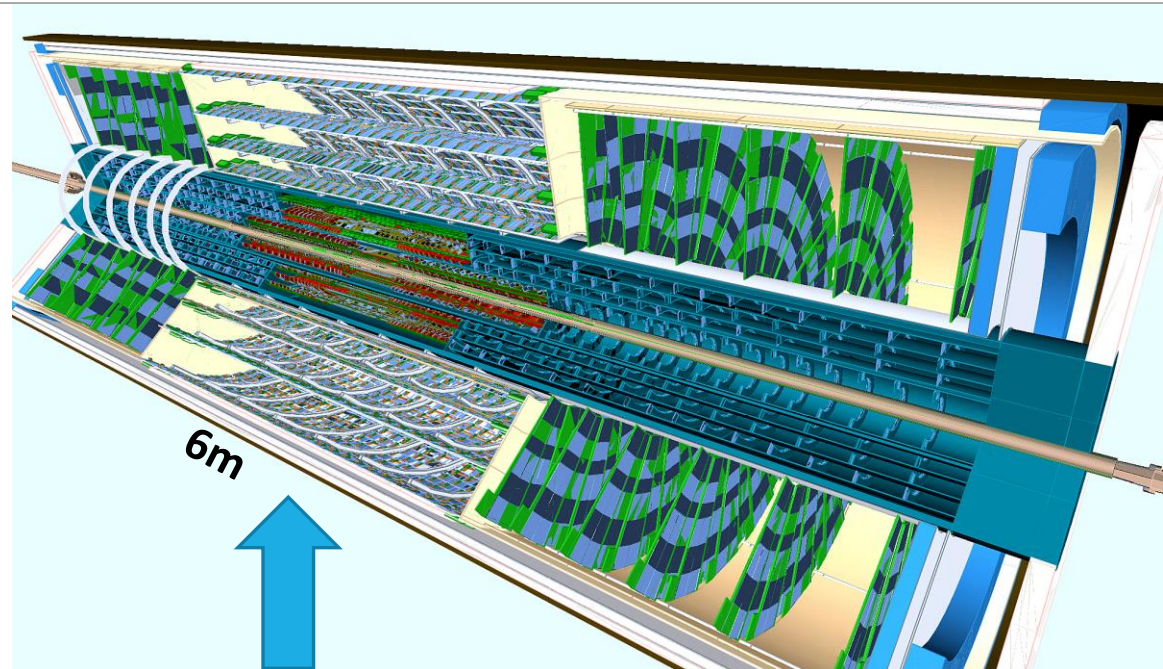
Introduction: the ATLAS Inner Tracker (ITk)

- ITk replaces current Inner Detector from Run 4 (2029) onwards (HL-LHC)
- all silicon pixel + strip detector
- large area sensor surface



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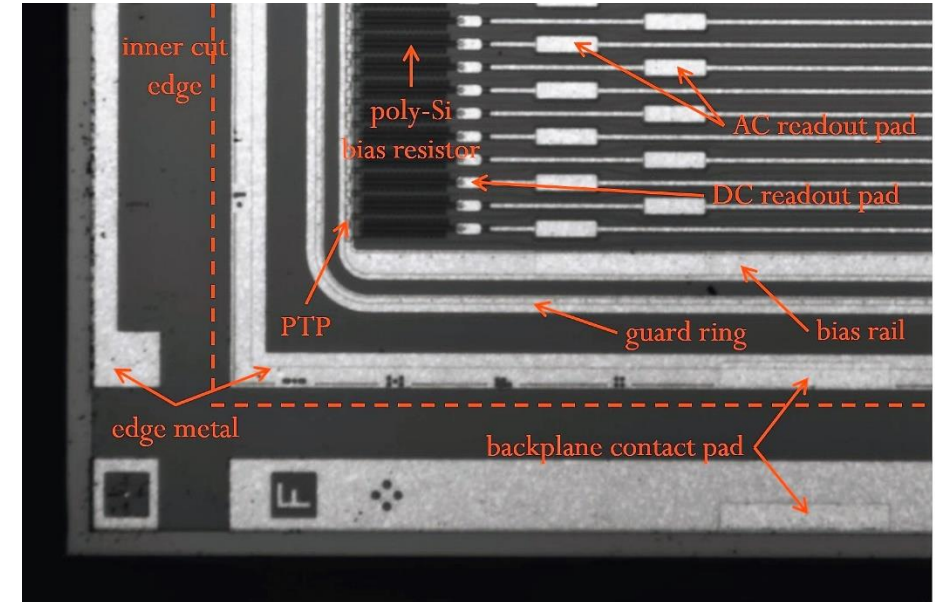
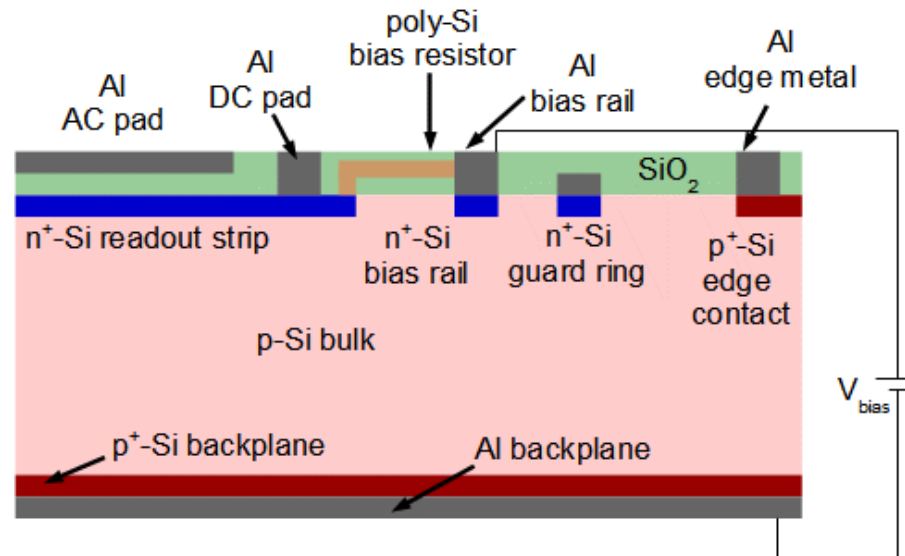
10cm



1.4m

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History of Strip Sensor submissions

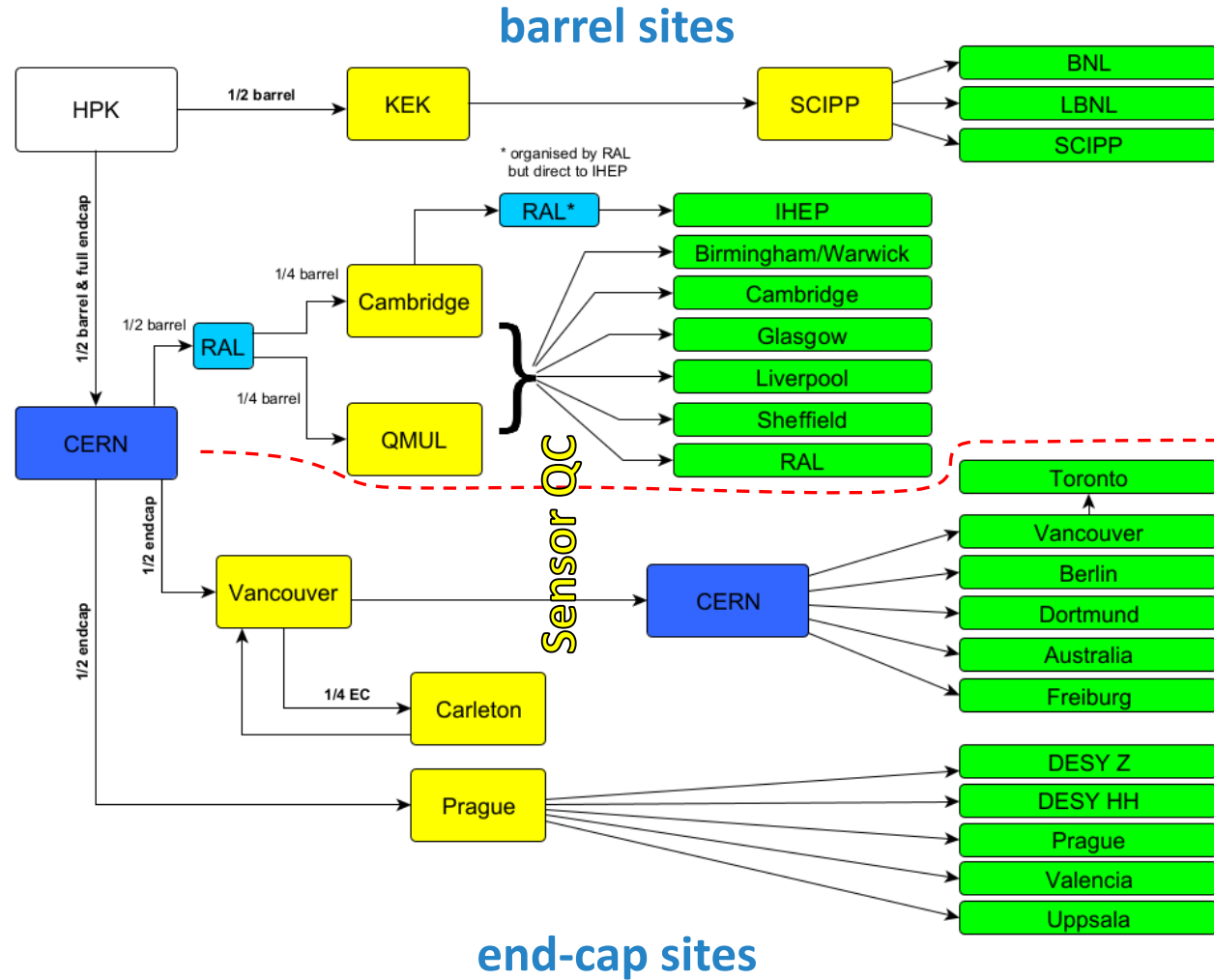
	Order type	Sensor type	Contractor	No. sensors	Sensor area	Status	
prototype	ATLAS07	barrel SS	HPK	143	1.4 m ²	completed	} same deliveries
	ATLAS12	barrel SS	HPK	120	1.1 m ²	completed	
	ATLAS12EC	end-cap R0	HPK	135	1.2 m ²	completed	
	ATLAS17LS	barrel LS, final size	HPK	70	0.7 m ²	completed	
	ATLAS17LS	barrel LS, final size	HPK	60	0.6 m ²	completed	
	ATLAS17LS	barrel LS, final size	IFX	40	0.4 m ²	cancelled	
	ATLAS18SS	barrel SS, final layout	HPK	60	0.6 m ²	completed	
	Pre-production	all 8 types	HPK	1,041	9.2 m ²	completed	
	Production	all 8 types	HPK	20,800	190.3 m ²	ongoing	

[link to recent publication](#)

- **pre-production:** establish QC/QA procedures and verify sensor quality
- **2020:** 1,041 pre-production sensors (5% of production) + 60 ‘extra’ (prototype)
 - delays due to Covid-19 closure at CERN

Strip Sensor Part Flow

- all sensors undergo QC
- all end-cap sensors distributed through CERN
 - $\frac{1}{2}$ EC sensors to Prague
 - $\frac{1}{4}$ each to Vancouver and Carleton
- barrel sensors divided between KEK and CERN
 - QC test subset for $\frac{1}{2}$ barrel by KEK (HPK) and SCIPP
 - $\frac{1}{4}$ each to Cambridge and QMUL
- subsequent distribution to module assembly sites



Strip Sensor QC

EVERY SENSOR

- visual inspection
 - look for scratches, chips, etc.
- image capture
- sensor metrology
 - sensor bow < 200μm
- sensor IV
 - $V_{\text{breakdown}} > 500\text{V}$
 - $I_{\text{leakage}} @500\text{V} < 0.1\mu\text{A}/\text{cm}^2$
- sensor CV
 - $V_{\text{depletion}} < 350\text{V}$

BATCH SUBSET

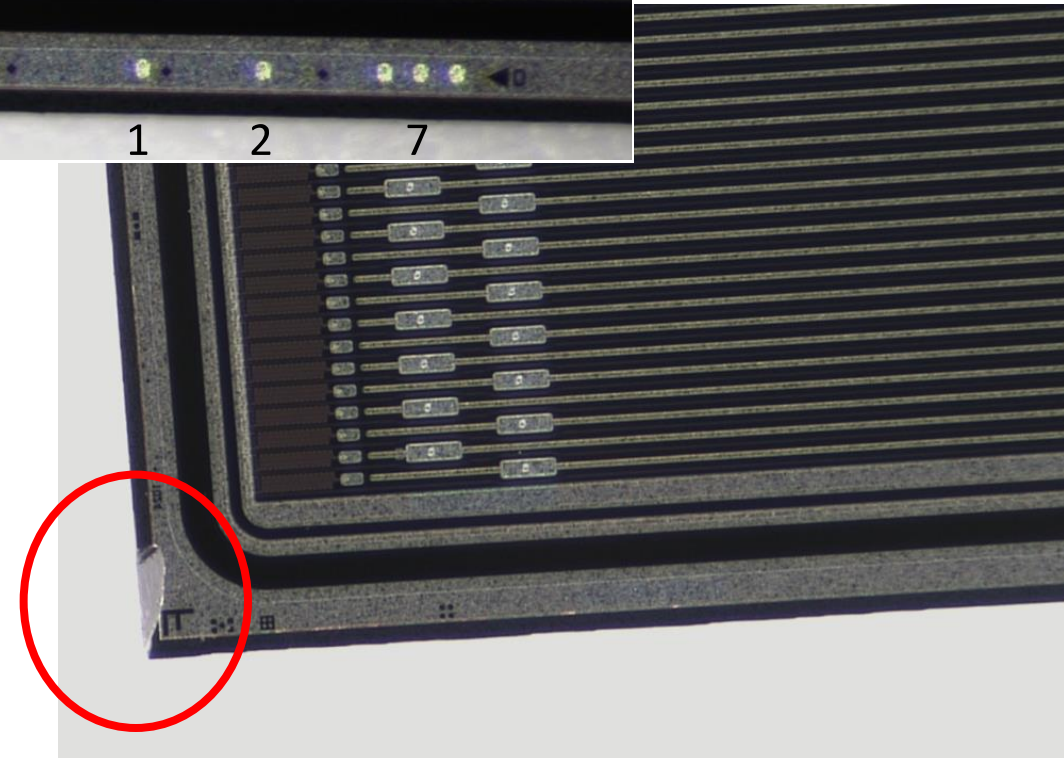
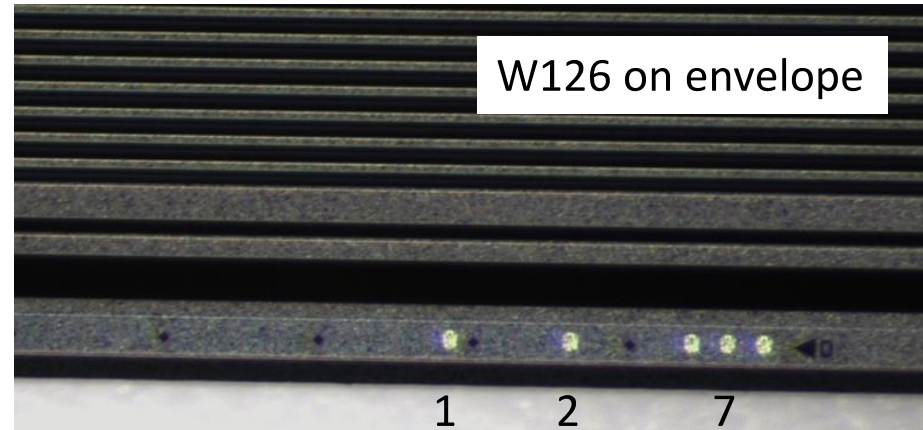
- mechanical thickness
- long-term current stability (10% - 20%)
 - current fluctuations < 15% for 24h+
- Full Strip Test (2% - 5%)
 - $I_{\text{strip}} < 200\text{nA}$, $1\text{M}\Omega < R_{\text{bias}} < 2\text{M}\Omega$,
 $C_{\text{coupling}} > 20\text{pF}/\text{cm}$
 - < 1% failed strips/segment
< 8 consecutive failed strips

if needed (test structures available):

- inter-strip capacitance & resistance
- punch-through protection (PTP)

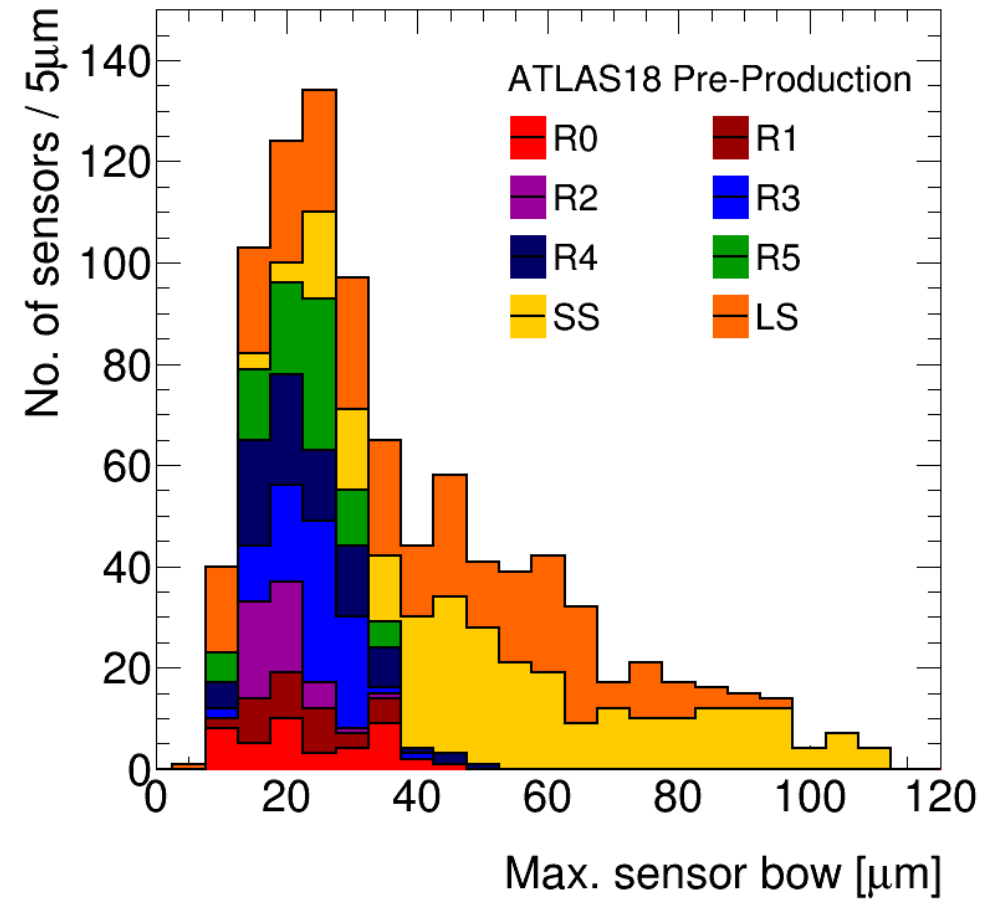
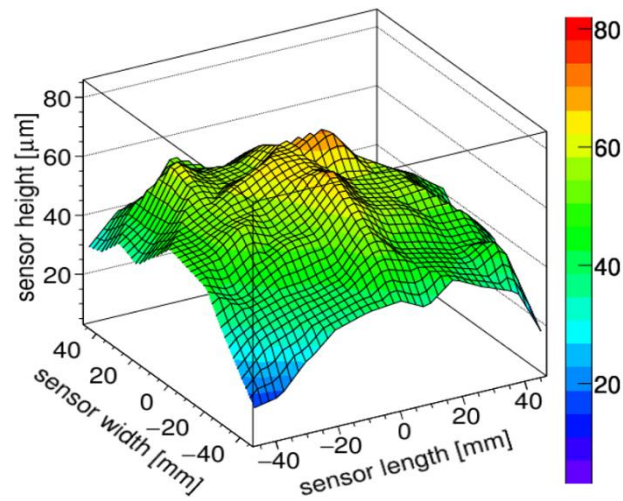
Visual inspection findings

- scratch marks (serial number) on 4 sensors did not match serial number on HPK envelope
- one sensor had chipped corner
- no other major issues observed
- typical minor issues:
 - (light) scratches
 - debris on surface



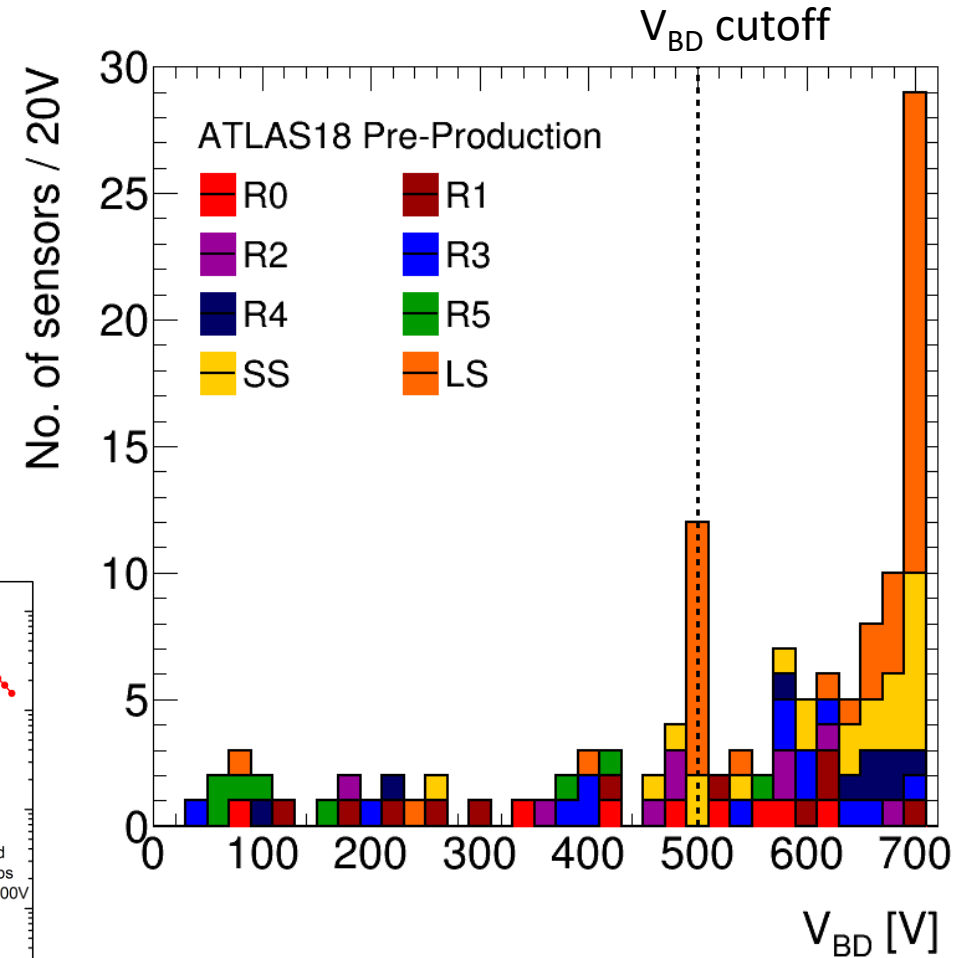
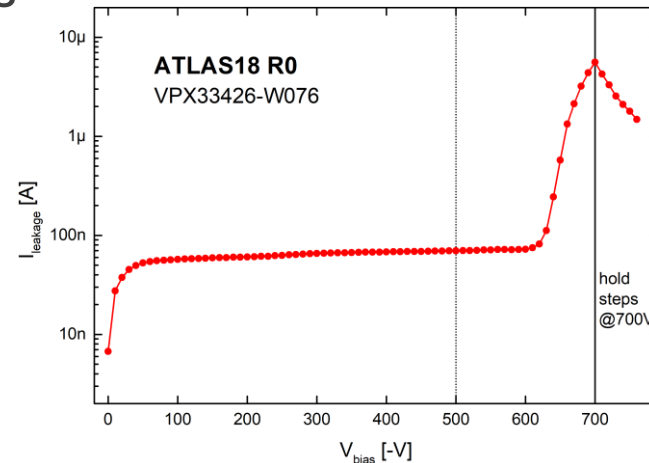
Metrology results

- ‘bow’ is defined as maximum height difference from a reference plane (to correct sensor tilt)
- majority of sensors even have bow below $50\mu\text{m}$
- no failures



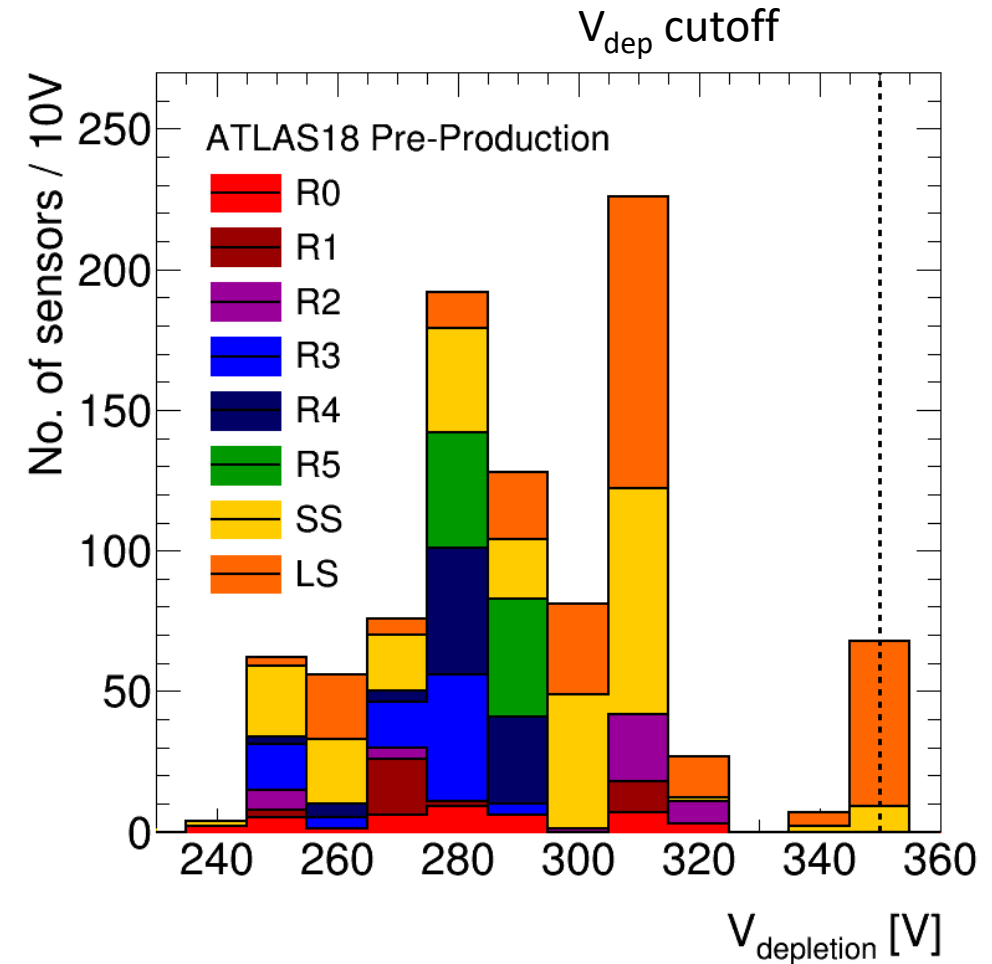
IV results

- IV is the most-failed QC test
- sensors fail to meet breakdown criteria $V_{BD} > 500V$
 - rather than current limit spec
- some sensors with $500V < V_{BD} < 700V$ show recovery during hold steps
 - candidates for stability test



CV results

- one barrel shipment with larger number of 'marginal' sensor
 - V_{dep} less than 5V above specification for ~20 sensors
 - ⇒ partially related to measurement steps
 - sensors otherwise good
 - discussion with HPK, stricter internal process, acceptance criteria loosened slightly (<360V)
- vast majority of sensors fully deplete well below 350V



Strip test results

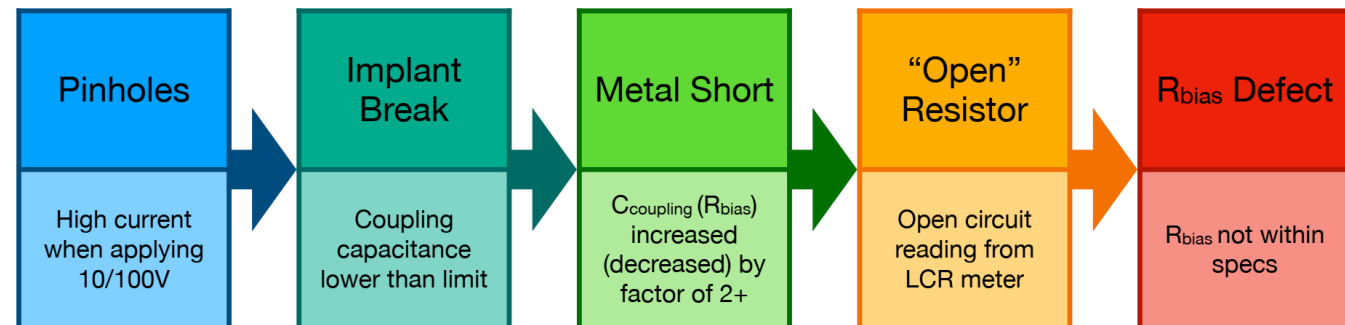
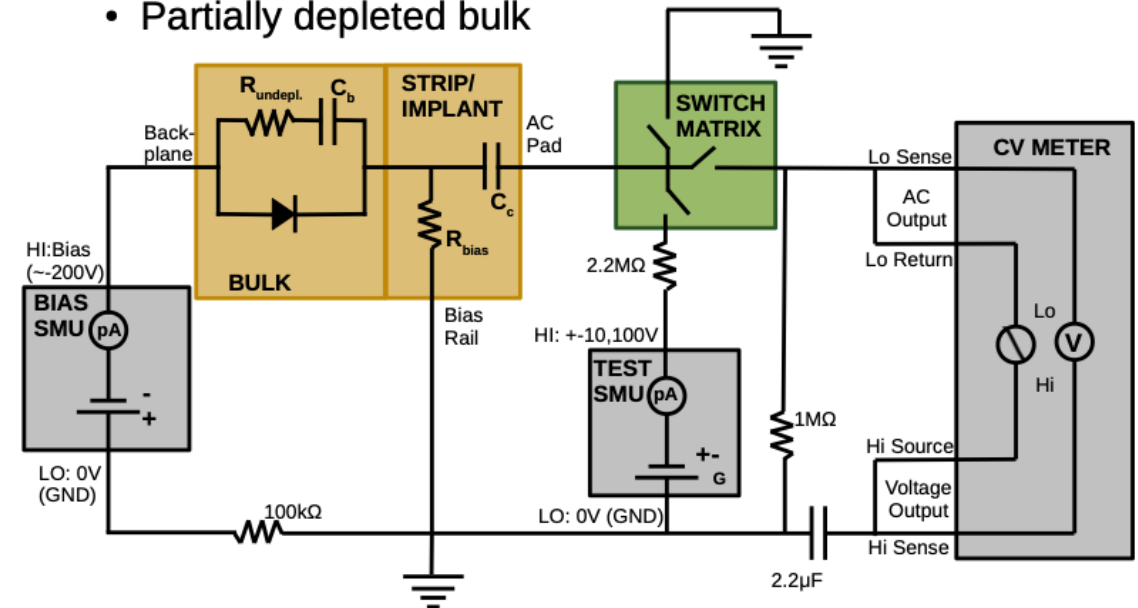
measurement procedure:

- sensor partially depleted (-150V), strips isolated, contact each strip
- readout strip isolation, current through dielectric (10V/100V applied to AC pad)
- coupling capacitance to strip implant
- bias resistance to bias rail

⇒ measured values determine failure mode

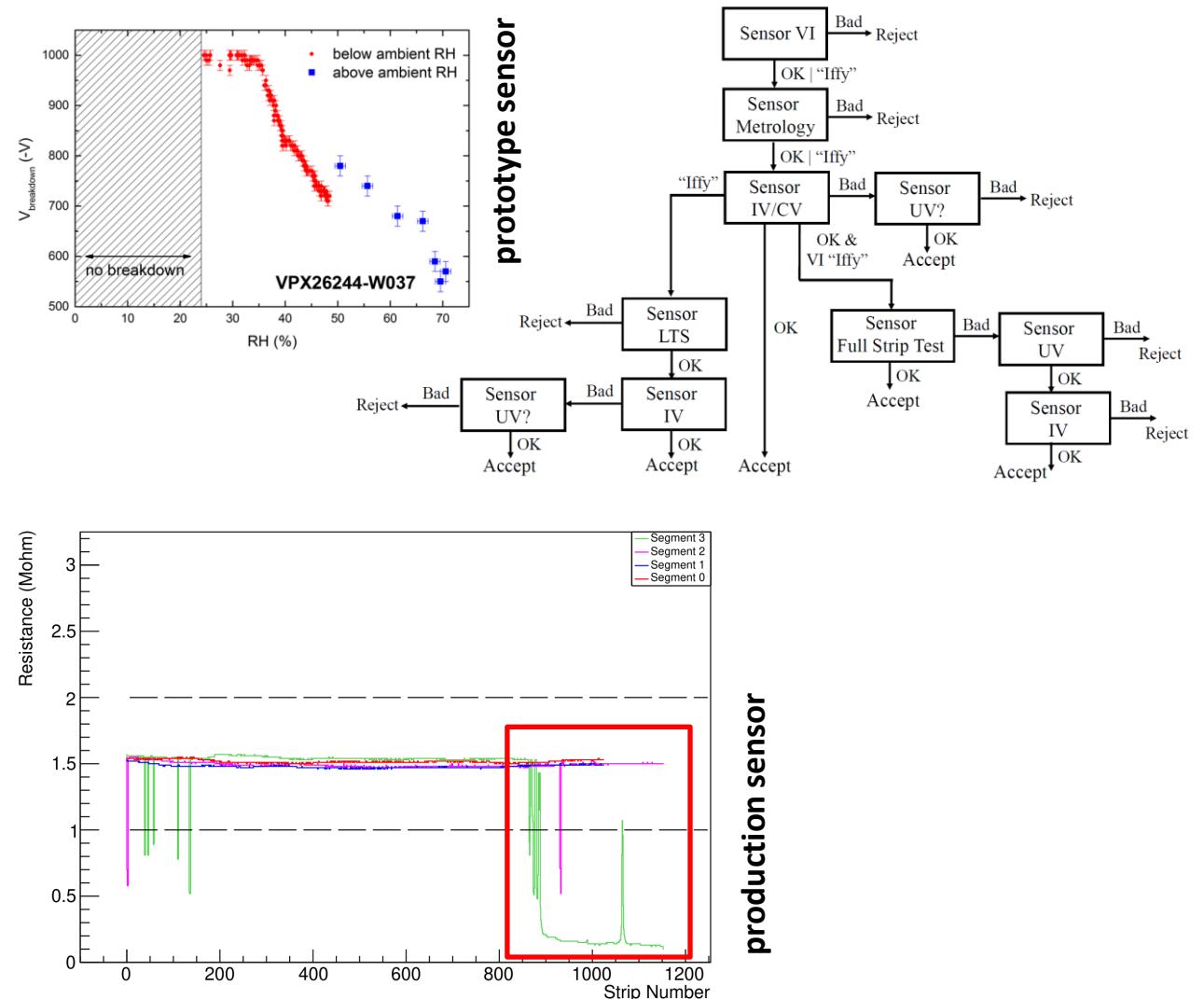
- 1 out-of-spec sensor identified
- usually <10 failed strips, if any

- Partially depleted bulk



Beyond pre-production: some lessons learned

1. visual inspection is important
 - failed sensors often have some kind of visible irregularity
 - influences IV + striptest mainly
 - cross-check serial number / scratch marks
2. plan for sufficient dry storage before testing
3. repeated IVs can be necessary during QC, e.g. after LTS
 - difficulty finding time for large scale investigation of failures during constrained production schedule
4. implementation of 'Fast Striptest'
 - production sensors with regions of low strip isolation
 - higher testing rate with similar precision for batches with more failures

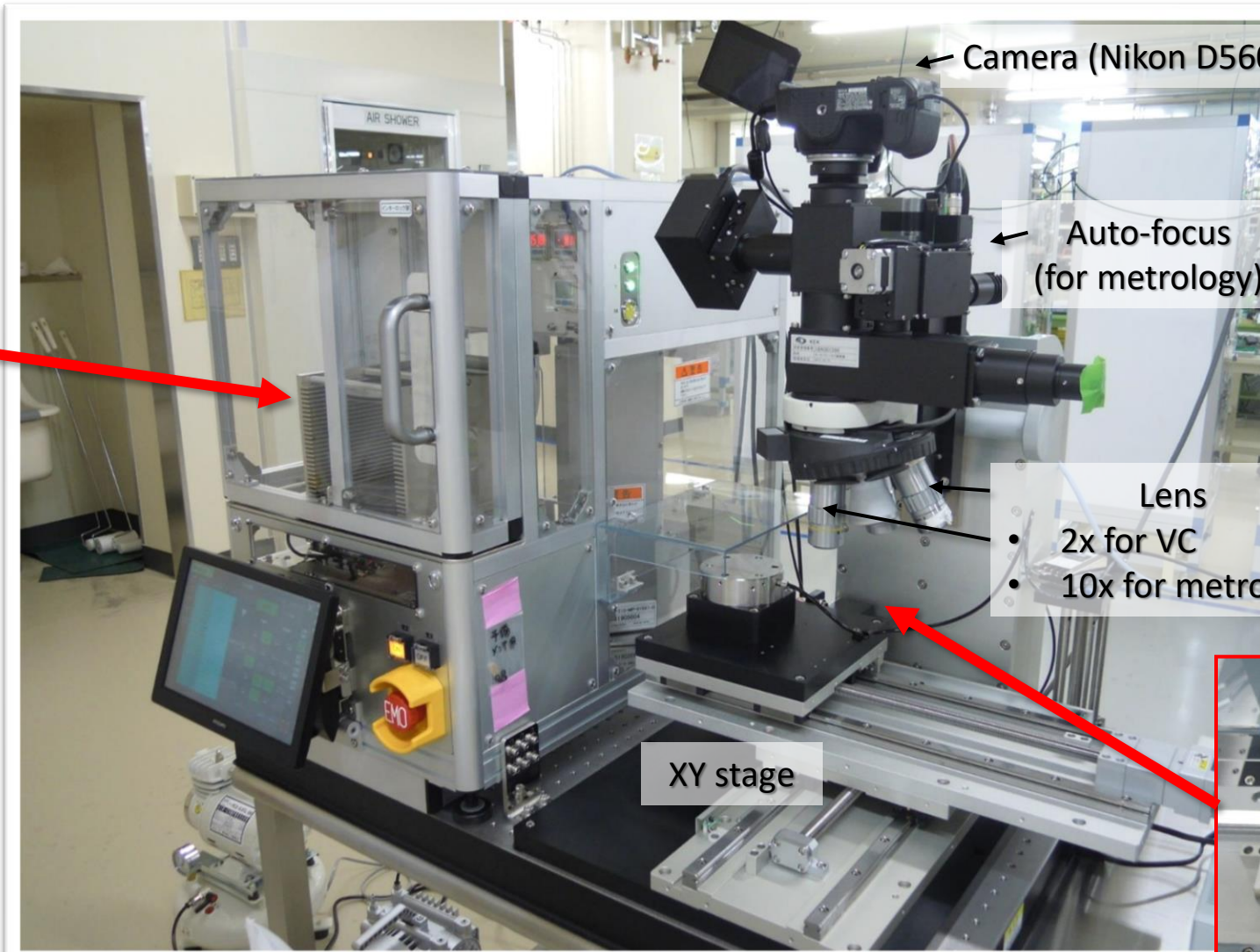
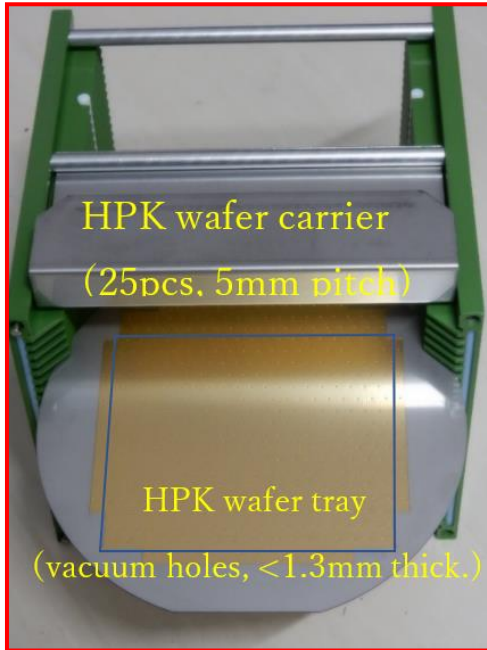


Summary

- QC of pre-production sensors was performed in 2020
 - 1041 'pre-production sensors' + 60 additional prototype sensors were tested
- verified quality of final layouts for all 8 types of sensors manufactured by HPK (ATLAS18 types; SS/LS/R0-5)
- refined part flow of sensor shipments
- fully established QC site testing procedures with finalised setups and hardware
- use of ITk Production Database
 - records of all tests by HPK + ATLAS sites
 - shipments through database (object ownership + upload rights)
 - information sharing between sites (QC/QA and module sites)

backup

Sensor QC tests: labs & equipment

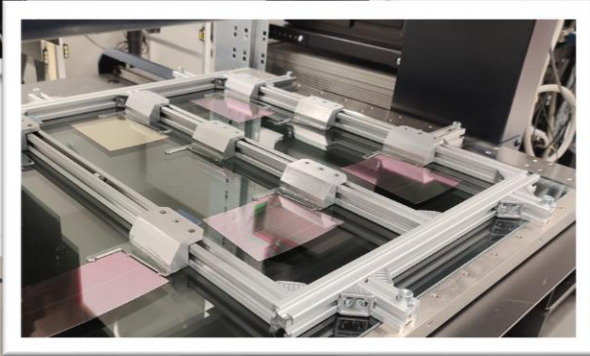
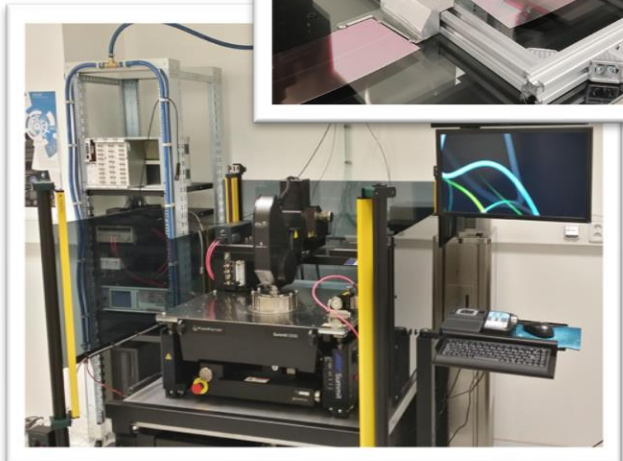


KEK/Tsukuba

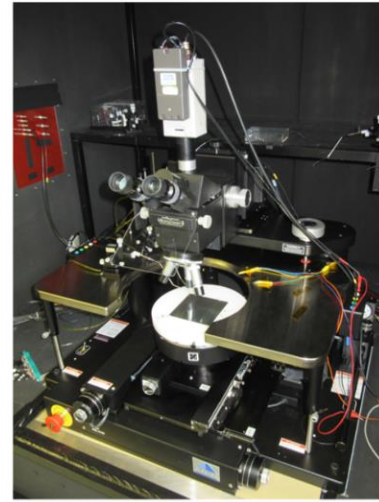
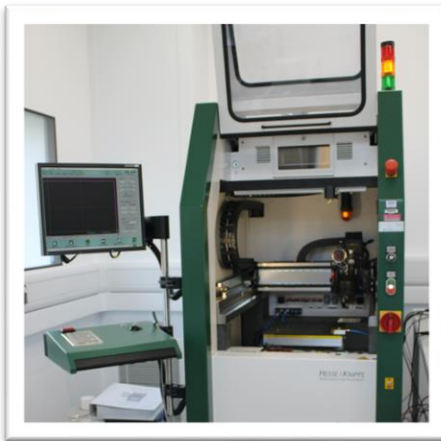
Sensor QC tests: labs & equipment



Prague



Cambridge



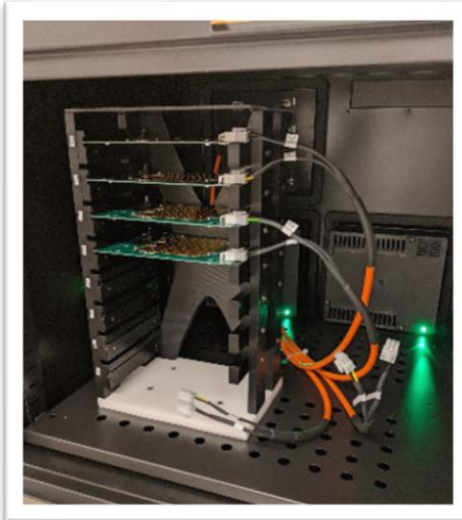
Carleton



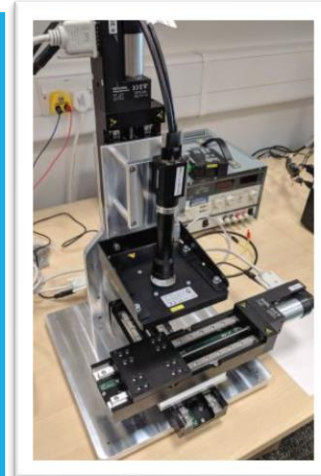
Sensor QC tests: labs & equipment



SFU/
TRIUMF



SCIPP



QMUL

