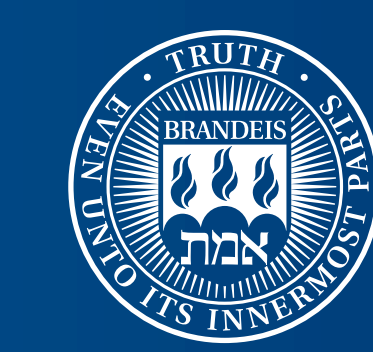


Gamma irradiation of ITk silicon strip modules with early breakdown



Brandeis

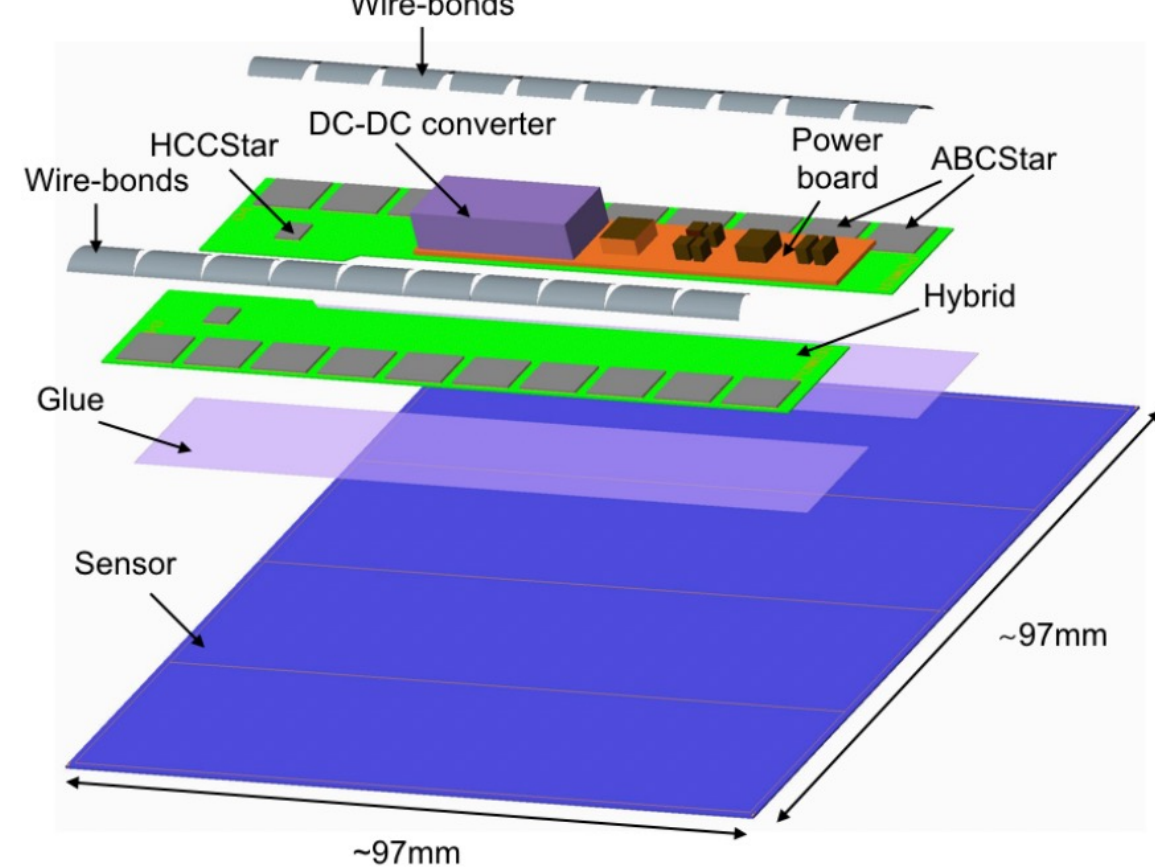


Brookhaven
National Laboratory

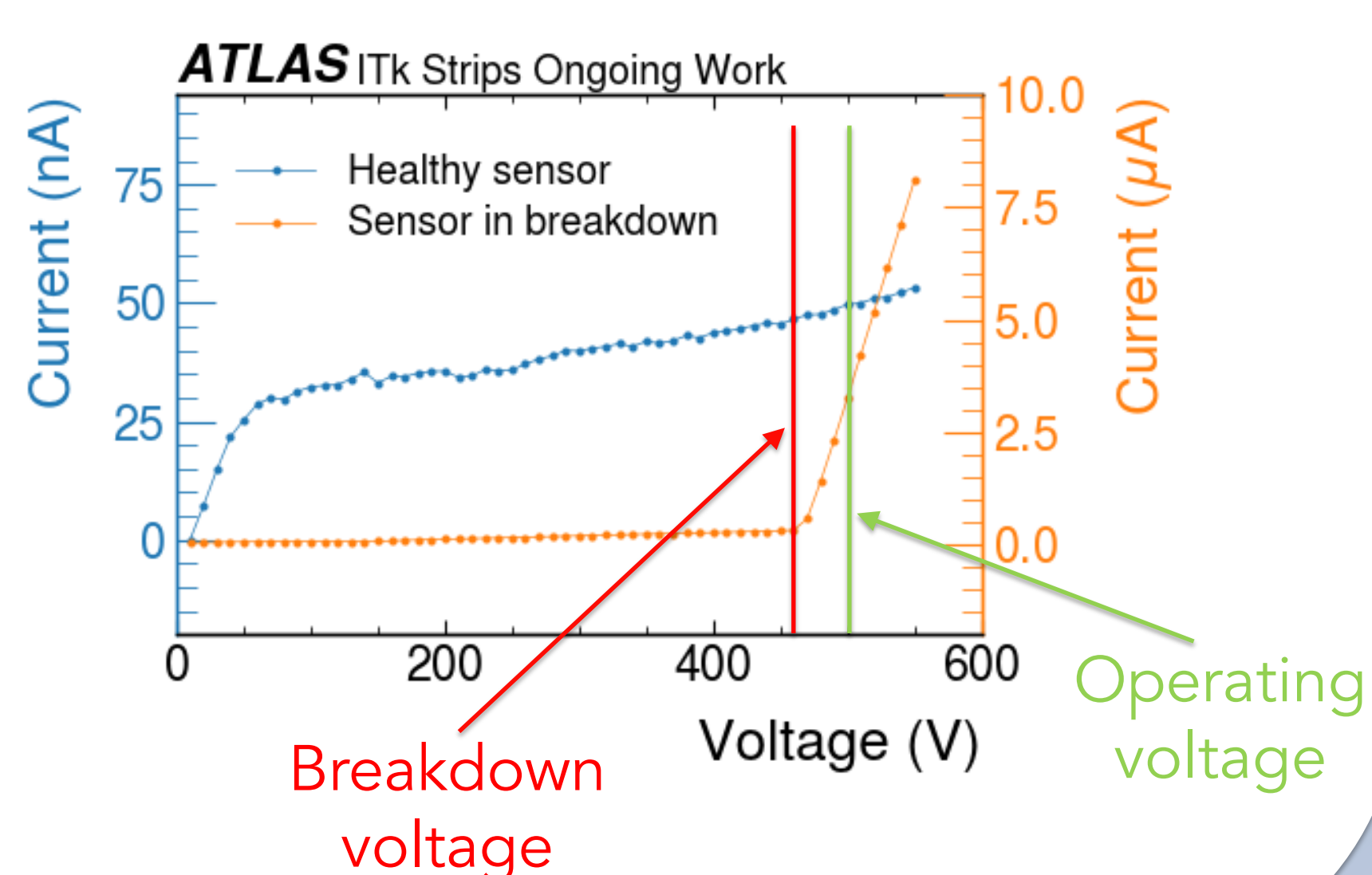
LHCP 2024: 12th Edition of the Large Hadron Collider Physics Conference
Boston, Massachusetts — 3-7 June 2024

1. Early breakdown in silicon strip modules

- ITk silicon strip sensors consist of a **silicon sensor**, **hybrids** (host readout electronics), and a **power board** (power, monitor, and control electronics)
 - Sensors require **-500V bias voltage** for operation
 - Early breakdown** observed during module assembly due to
 - Mechanical damage (chips, cracks, scratches)
 - Static charge
 - Long-term application of bias voltage
 - Glue on the guard ring [2]
 - Can we reliably recover these modules?



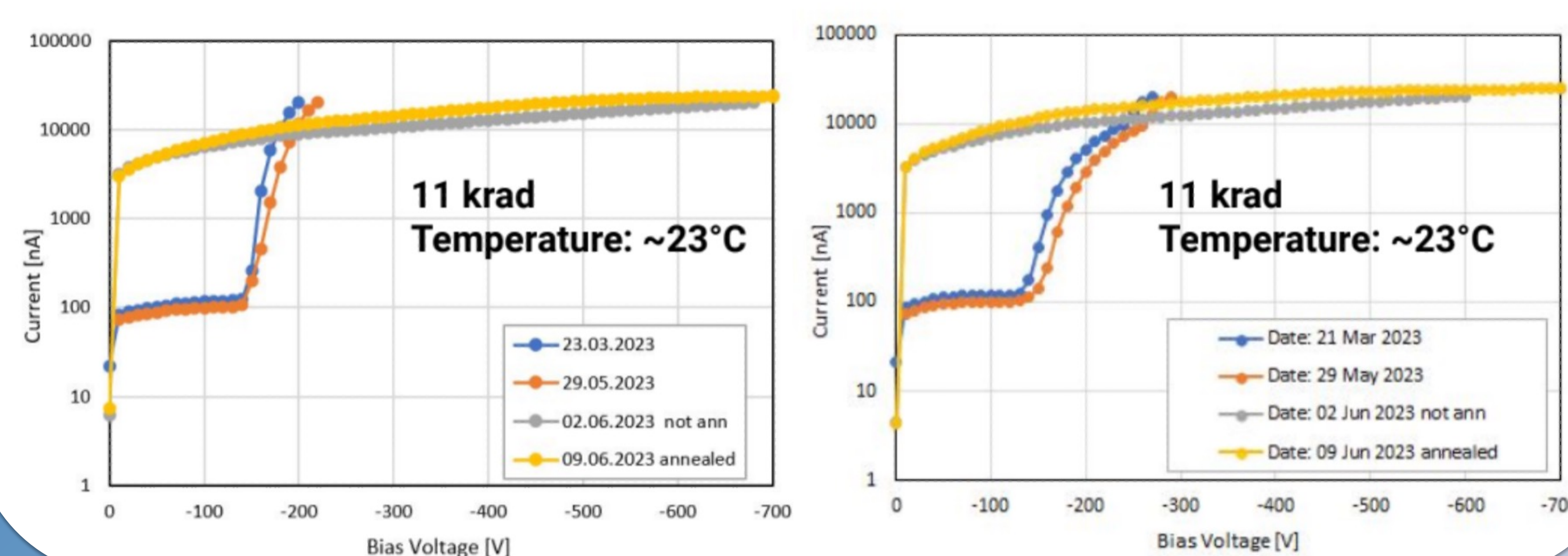
Expanded view of ITk short-strip barrel module [1]



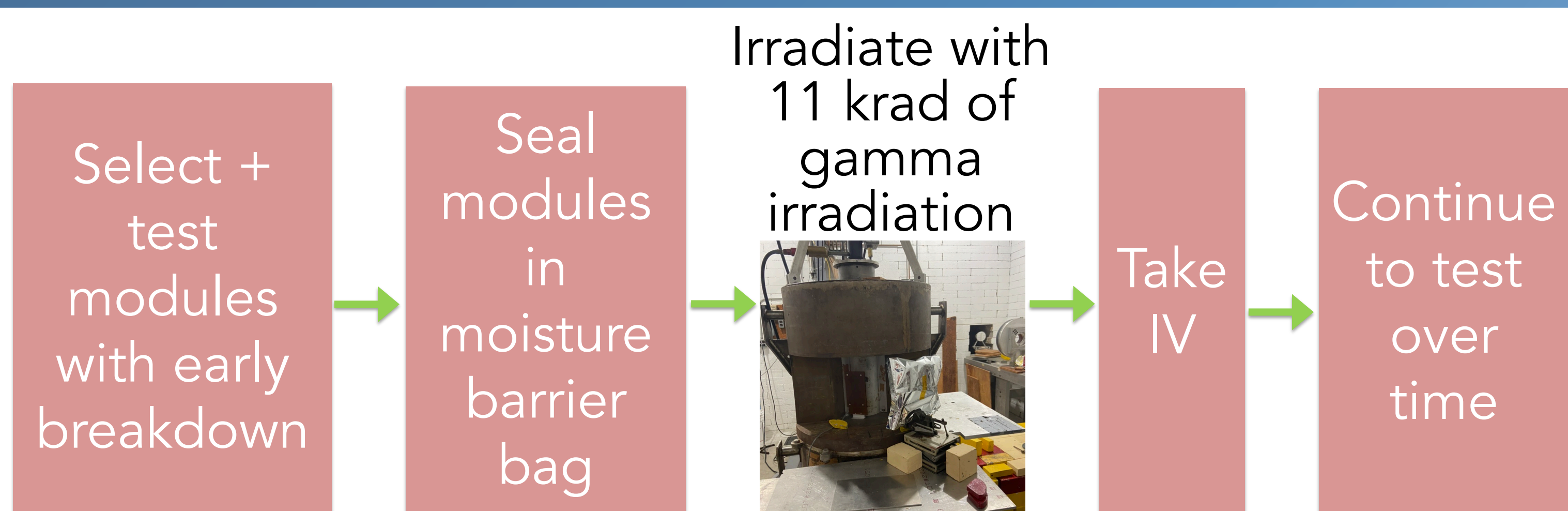
2. Gamma irradiation to cure early breakdown

- Sensors irradiated by Prague group showed early breakdown cured by 11 krad of gamma radiation [3]
 - Will we get the same effect after gluing?
- Similar ionizing irradiation can be performed at BNL gamma facility with ^{60}Co source
- We irradiated modules with 11 krad of ionizing radiation at BNL, equivalent to 1 week in HL-LHC

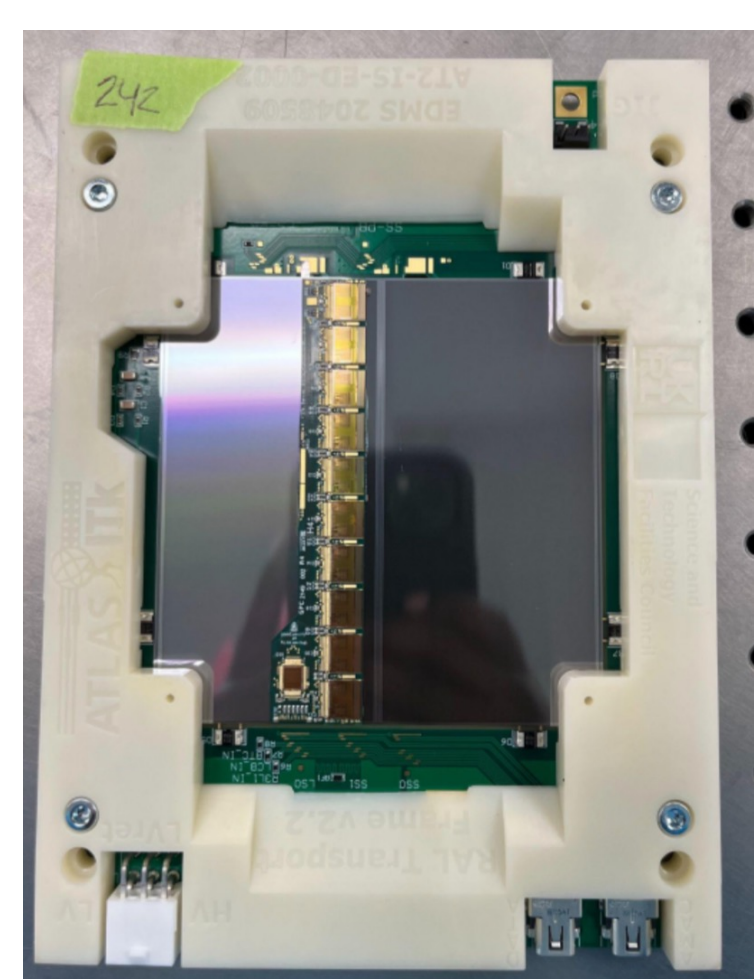
Results on bare sensors from Prague
W617 W607



3. Irradiation procedure



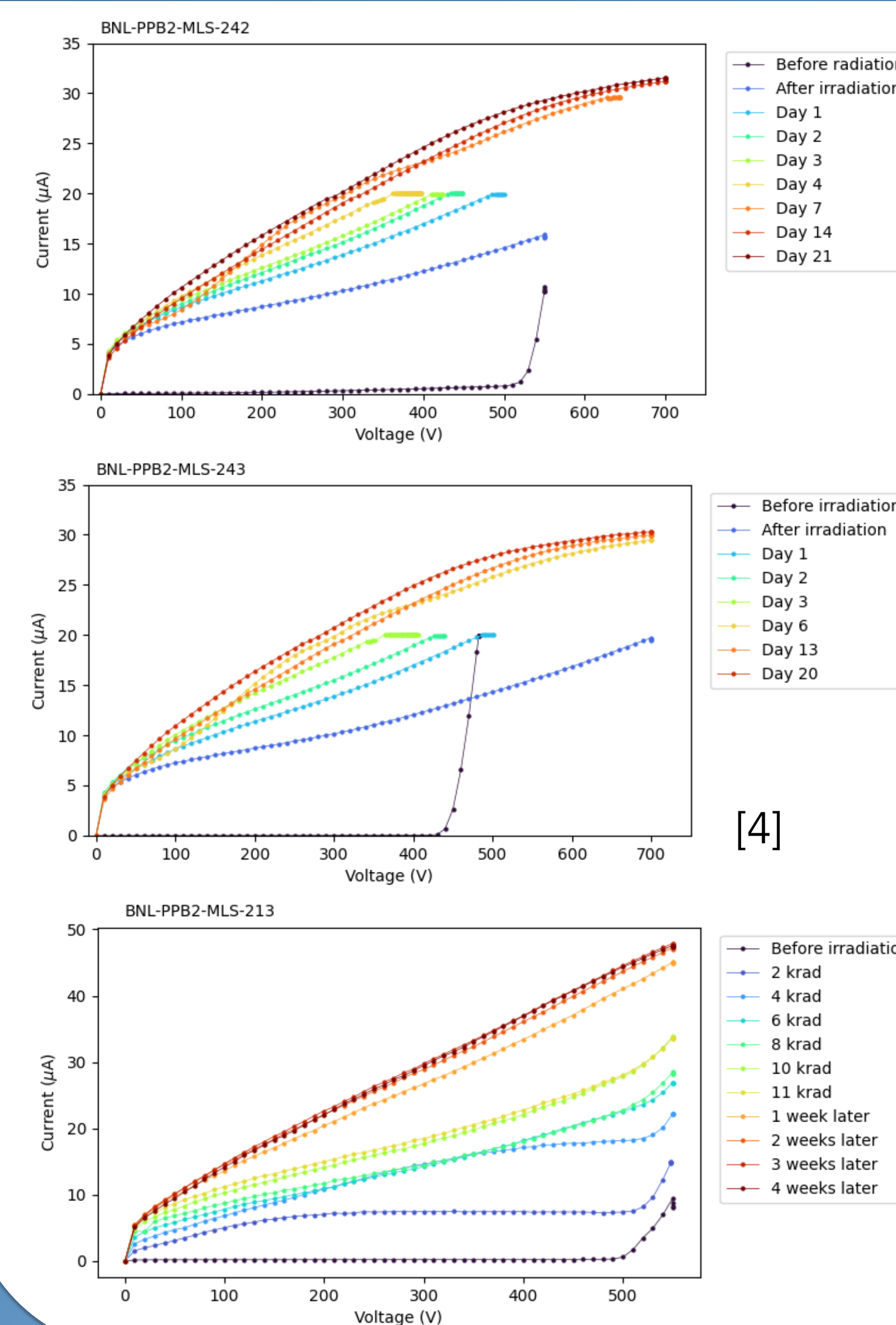
Irradiated module	Special characteristics
BNL-PPB2-MLS-242	Breakdown ~520V, unbonded
BNL-PPB2-MLS-243	Breakdown ~450V, unbonded
BNL-PPB2-MLS-213	Breakdown ~500V, glue on the guard ring



BNL-PPB2-MLS-242

- Two **unbonded** modules developed early breakdown after gluing the hybrid onto the sensor
 - Irradiated before continuing assembly
- One module with **glue on the guard ring** irradiated (known cause of early breakdown [2])

4. Results



- Because of module electronics, BNL-PPB2-MLS-213 could only be biased up to 550V
- After irradiation, we see higher leakage current due to surface currents
- Sensors appear to self-anneal over time before current stabilizes
- In all cases, **breakdown voltage improves**

5. Future work

- 11 krad of ionizing radiation cured early breakdown in 3 modules, 1 with glue on the guard ring
 - Modules will experience this dose in just 1 week of HL-LHC
- BNL plans to irradiate more modules with early breakdown as they are discovered, particularly modules with glue on the guard ring
- These results mark a significant step towards establishing a reliable pattern of component recovery during detector operation

6. References

- [1] Technical Design Report for the ATLAS Inner Tracker Strip Detector. Technical Report CERN-LHCC-2017-005. ATLAS-TDR-025, CERN, Geneva, Apr 2017.
 [2] C. Helling, L. Poley et al. Study of n-on-p sensors breakdown in presence of dielectrics placed on top surface, NIMA, Volume 924, 21 April 2019, Pages 147-152

- [3] M. Mikesikova, et al. Gamma irradiation of ATLAS18 ITk strip sensors affected by static charge, Proceedings of Science, VERTEX2023 (2024) 026

- [4] Luise Poley et al. Curing early breakdown in silicon strip sensors with radiation, NIMA, Volume 1064 (2024), 169405