NEW OR IMPROVED? CRITICAL BUILD DECISIONS IN THE ATLAS ITK STRIP END-CAP

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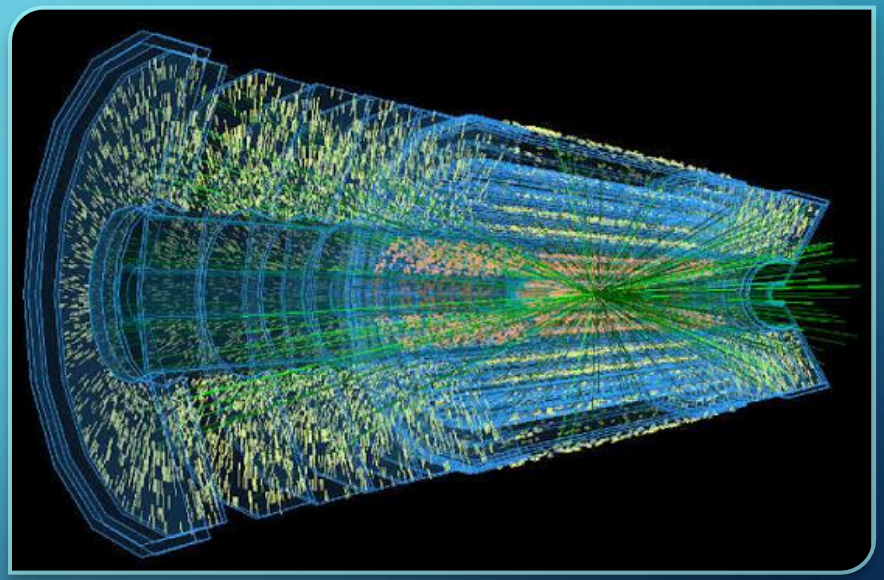
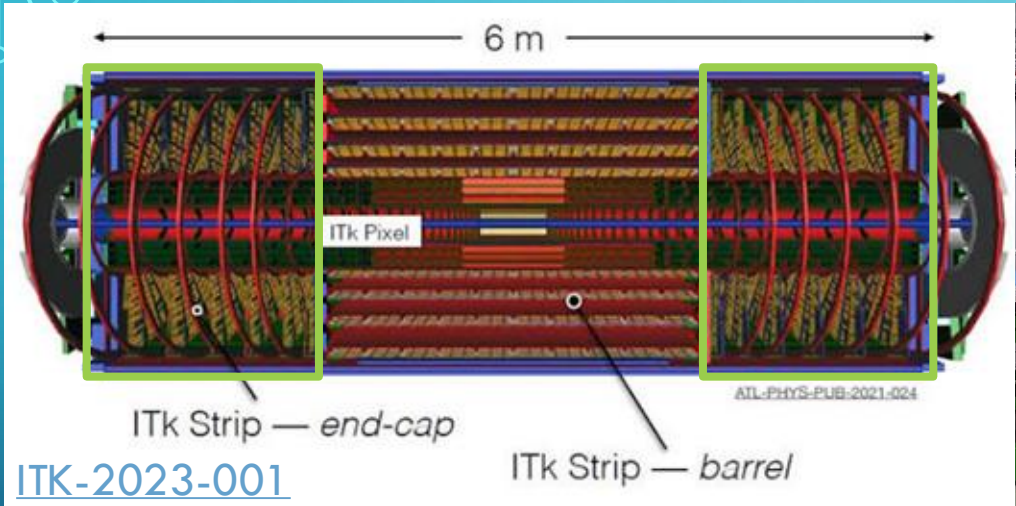
MOTIVATING THE ITK UPGRADE FOR THE HL-LHC

- The High-Luminosity LHC (HL-LHC) will produce collisions at ~3 x rate of LHC
  - ~3 x pile up at 3.8x instantaneous luminosity
- ATLAS is upgrading its Inner Detector to the Inner Tracker (ITk)
  - All-silicon with improved radiation hardness and reduced material
- Higher granularity: 50x as many channels (100M → 5000M)
- Improved $|\eta|$ coverage: 2.5 → 4.0
- Readout electronics improved to match higher data rate



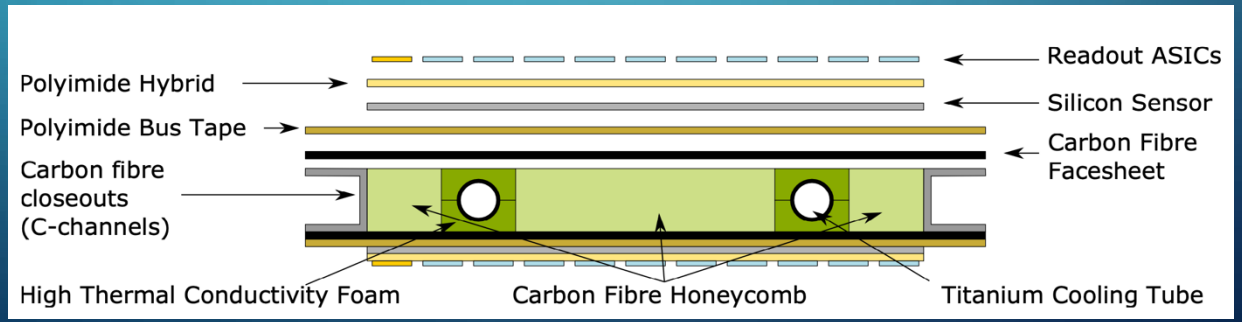
CANADA IS BUILDING STRIP END-CAP PETALS



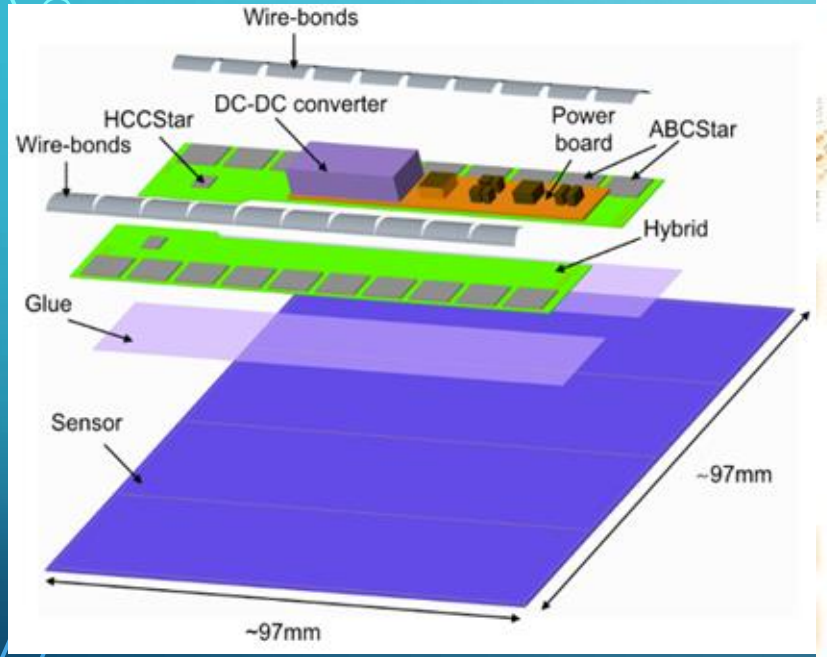
Canada will build about ¼ of the petals required for the End-Cap (88 of the 382)

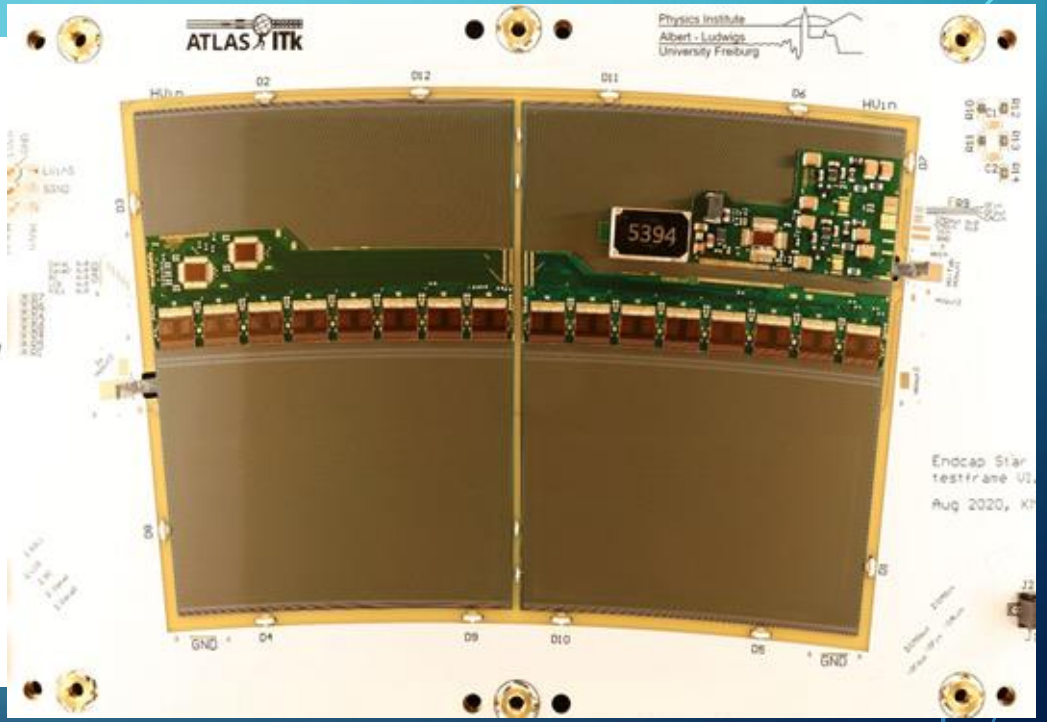
PETAL BUILDING

- 6 different shapes of modules are loaded on a core
- Double sided
- Electronics added for power and readout



MODULE BUILDING





CERN-LHCC-2017-005

Strip Module diagram (L) and built module (R)

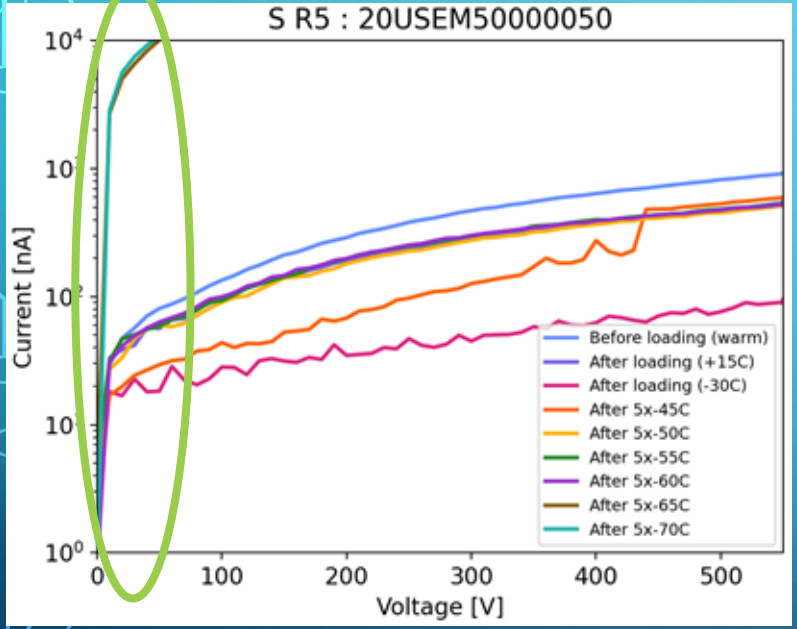
PETAL TESTING

Cycle 1 Warm	Cycle 1 Cold	Cycle 2 Warm	Cycle 2-4 Cold	Cycles 3-5 Warm	Cycle 5 Cold	End Warm
TEST	TEST	TEST			TEST	TEST

- Petals undergo electrical (IV) and noise tests at warm (15C) and cold (-35C) temperatures to mimic the conditions of the detector, as the CO2 cooling plant provides cooling to -35C
- Earlier tests went down from -45C to -70C to check for headroom in case of cooling failures. Unfortunately, this led to cracking of some silicon sensors.

IDENTIFYING CRACKS

Early Breakdown



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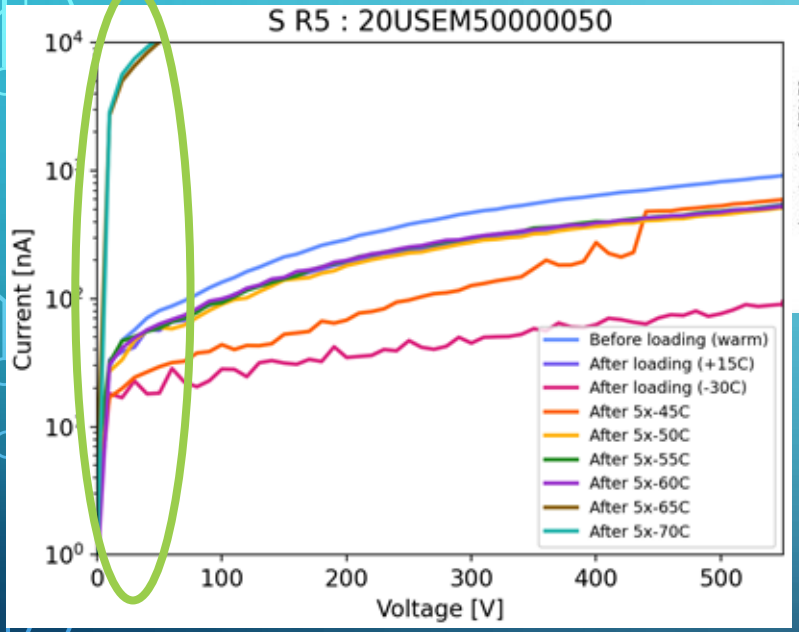
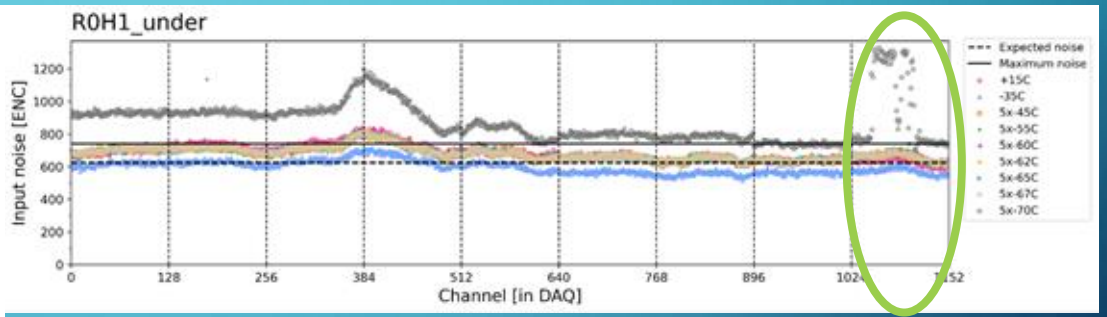


Noisy Channels



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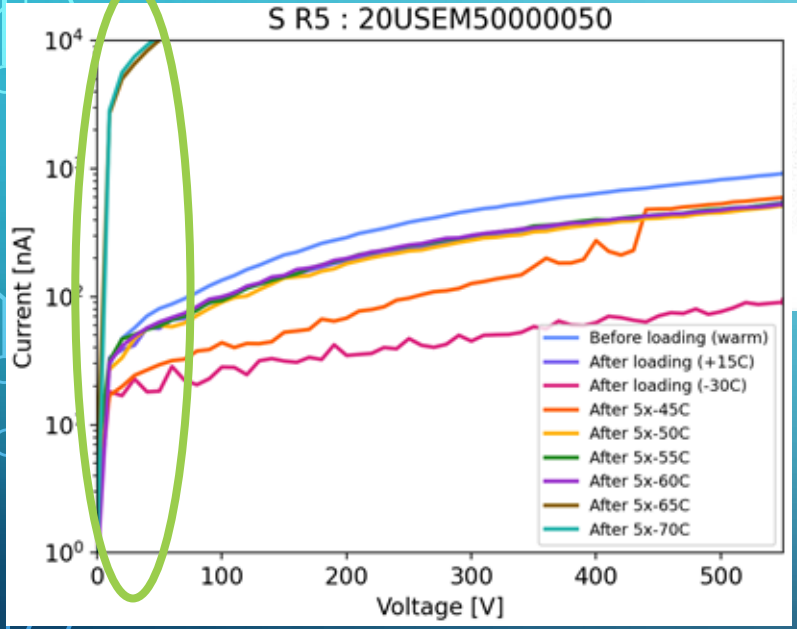
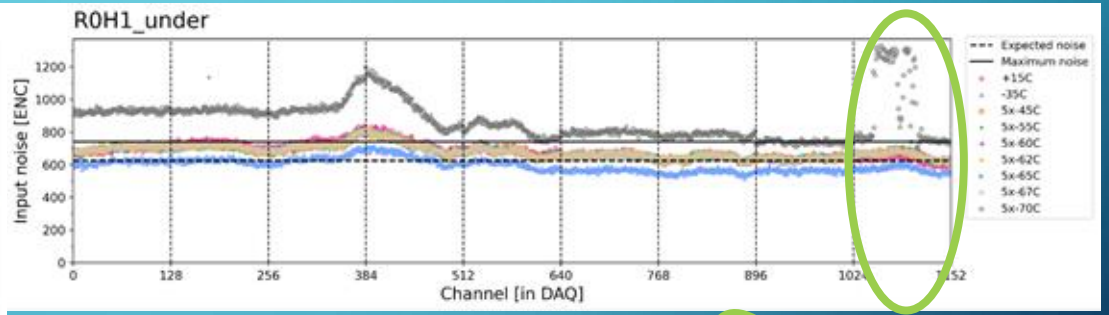
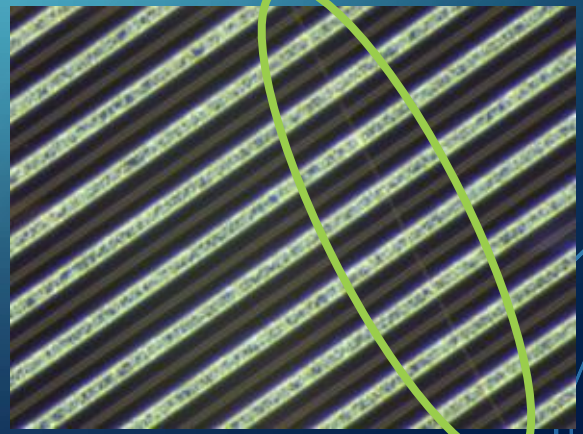


Noisy Channels

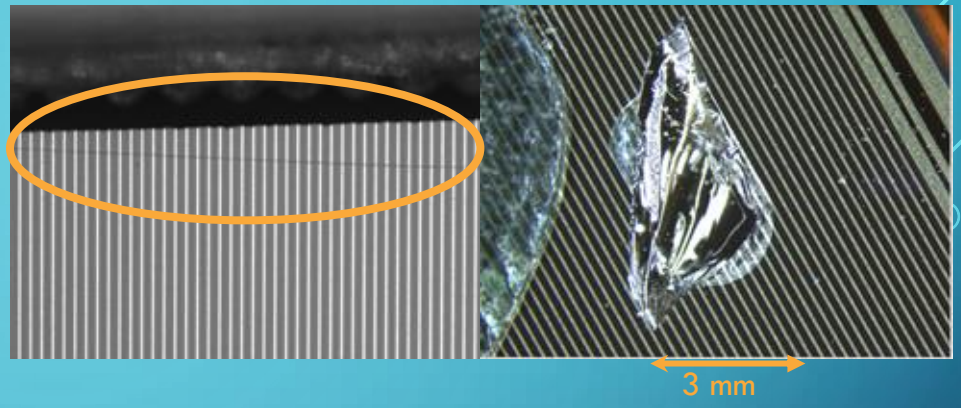


Visual Confirmation



CRACKS ON MODULES

Manifests as physical hairline fractures, or in some cases, caused a chunk of silicon to fall away



- All seemed to occur at similar locations, between powerboard and hybrid, or at edge of hybrid
- Corresponds to areas of peak stress

Renders sensor unusable

MITIGATION STRATEGIES

- Use a harder glue between the PCB and sensor
  - Less movement from harder glue reduces stress
- Change the glue pattern
  - Use smooth pattern instead of many small dots, to reduce stress caused by non-glued areas
- Use an interposing layer of kapton with a softer glue
  - Reduces stress by separating harder glue from sensor

MITIGATION STRATEGIES

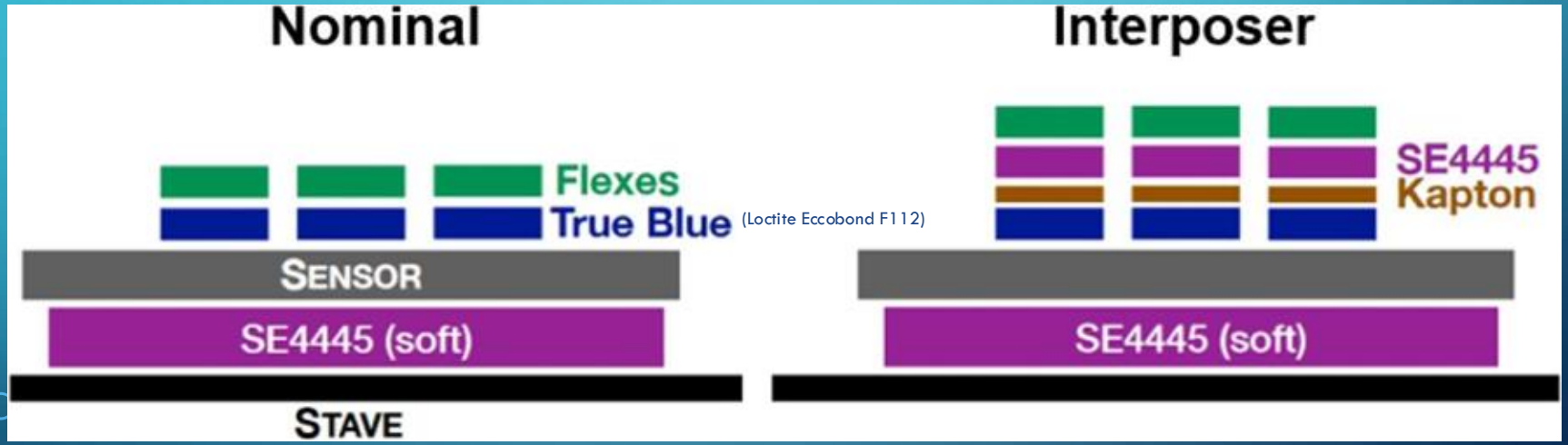
- Use a harder glue between the PCB and sensor
  - Less movement from harder glue reduces stress

Caused even more issues, with cracking at -45C!

- Use an interposing layer of kapton with a softer glue
  - Reduces stress by separating harder glue from sensor
- Change the glue pattern
  - Use smooth pattern instead of many small dots, to reduce stress caused by non-glued areas

NEW: INTERPOSERS

Adding a thin layer of kapton between hybrid and sensor, glued using a more flexible glue (SE4445), which reduces mechanical stress on sensor

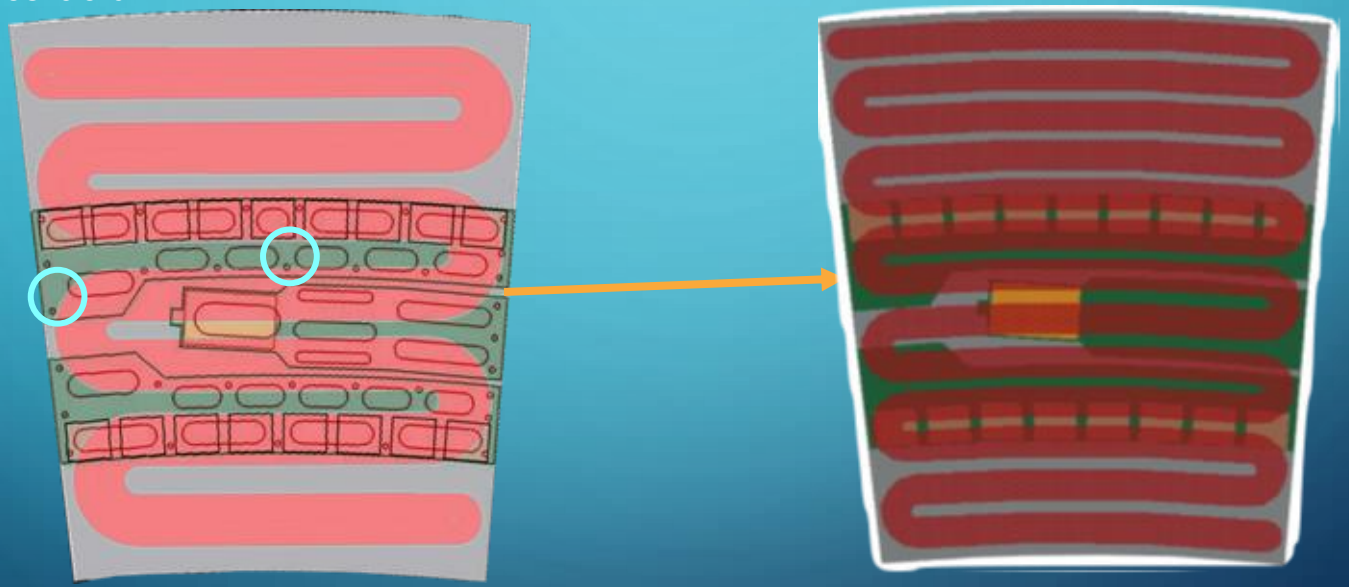


Pros: already used by Barrel community, known solution

Cons: cause unreliable breakdown behaviour, additional building step requiring new quality control procedures, unknown production ramp-up speeds

IMPROVED: NOMINAL

Improving module-to-petal glue pattern to provide support for wirebonding without stress-inducing small glue dots.



Pros: no additional building steps, known production ramp-up rates, reliable noise profile at module and petal level

Cons: cracks still occurring at lower temperatures, glue variations highly influential

THE DECISION

In early 2025, both solutions were presented to the community

At that time, only 4 Improved Nominal petals had been built, with 2 Interposed petals to compare build methods

It was agreed that Canada would build Improved Nominal petals until parts were exhausted, and Interposers were proven effective in the End-Cap, while European petal sites built Interposed components

In late 2025, Canada transitioned to building only Interposed components

TODAY

- Canada has built seven Improved Nominal petals
  - All have been tested, at least partially
  - There have been eight cracked sensors across four petals
  - Depending on part availability, cracked sensors have been replaced with a combination of Improved Nominal and Interposed modules
- Canada has built their first production (Interposer) petal
  - Testing has confirmed that noise and electrical results are well within specifications and this petal is detector-ready
  - We will fulfil our quota of petals using interposed parts