Report from Dee integration test

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On behalf of the testing team

SiDet Meeting
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HELMHOLTZ

DESY.

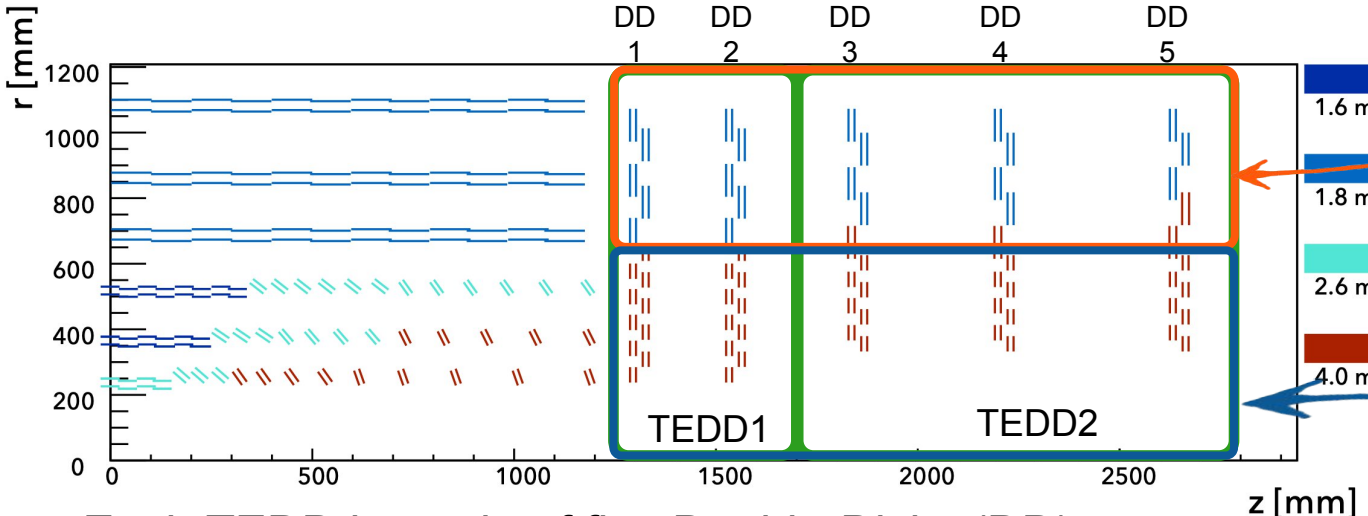
Overview

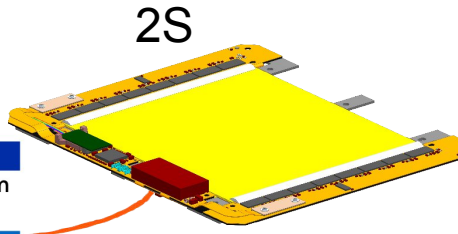
- 10 guests from 5 institutes (plus DESY people) joint to test several prototype modules on the prototype mechanics.
  - First time to have 2S modules on a Dee.
  - First time to mix 2S and PS modules.
  - 13 Modules in total

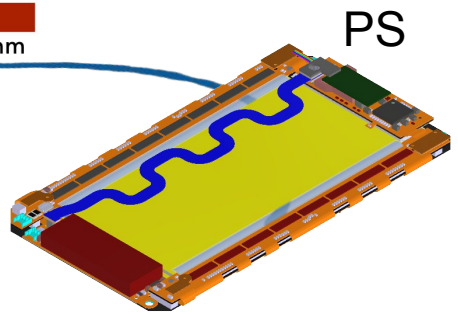
Today I try to cover:

- Introduction to the CMS Phase-2 Outer Tracker endcap.
- Test plan (before and after the test ;-))
- Test setups
- Integration of modules on the Dee.
- What are we testing
- Module test results

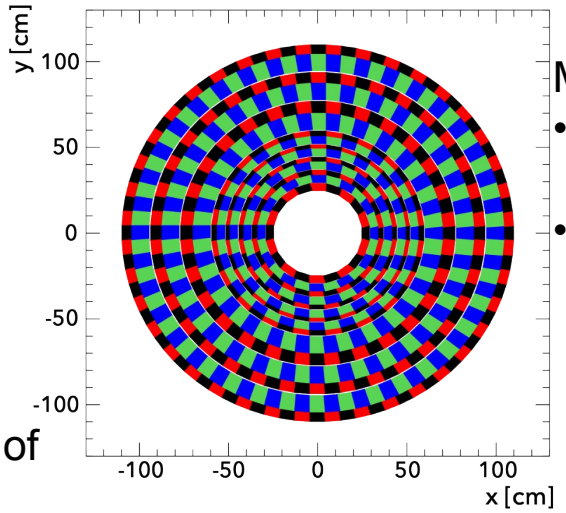
TEDD overview





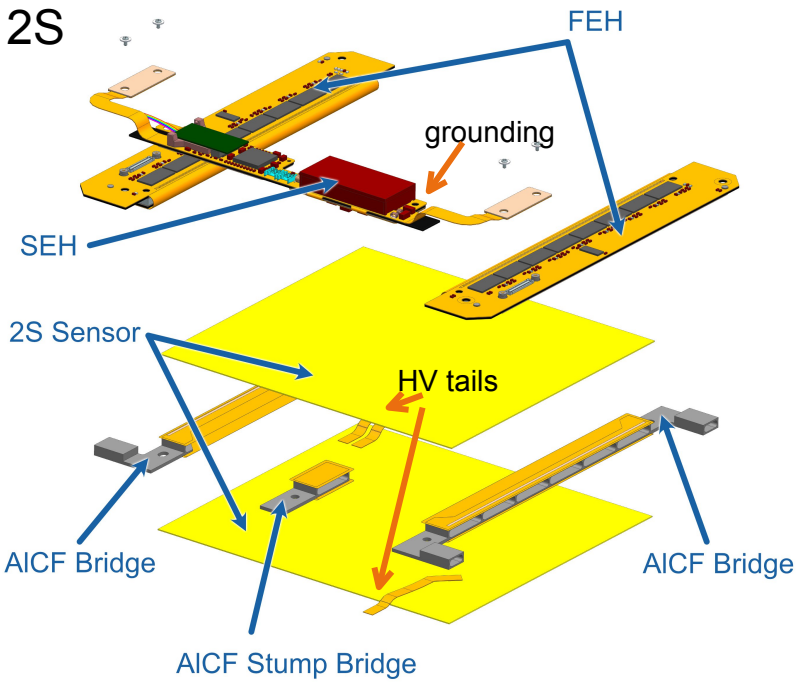


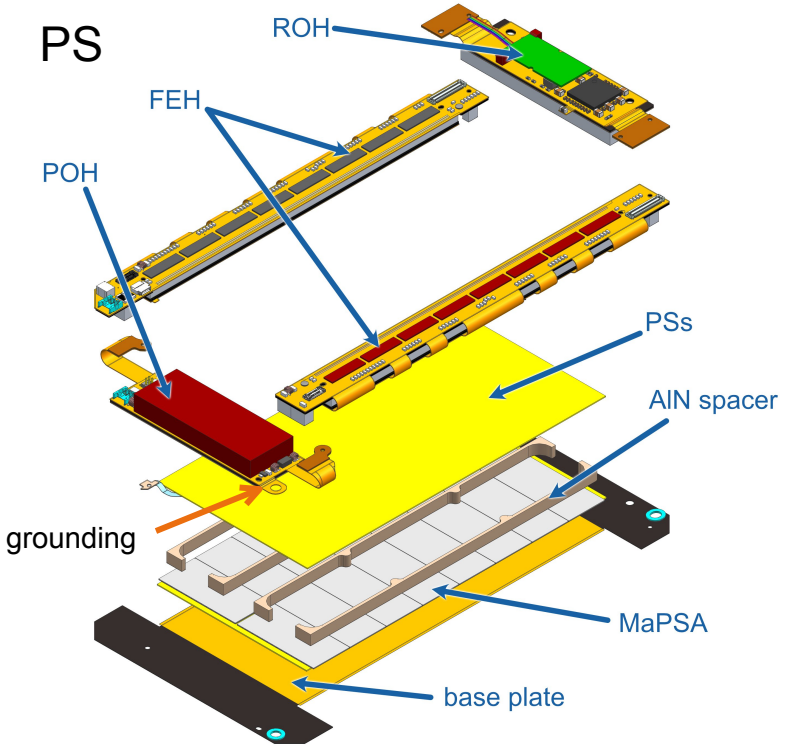
- Each TEDD is made of five Double-Disks (DD)
  - TEDD1: DD1 & DD2
  - TEDD2: DD3, DD4 & DD5
    - TEDD2 has larger radius inner bore
- Modules are arranged in rings, numbered from inner to outer per DD.
- A DD comprises an even and an odd Disk, given by which rings have modules.
- Each disk is made of two half-disks (Dees).
  - Dee is the largest feasible structure, backbone of the mechanical structure.



Modules on
- odd disk front/back
- even disk front/back

Module overview



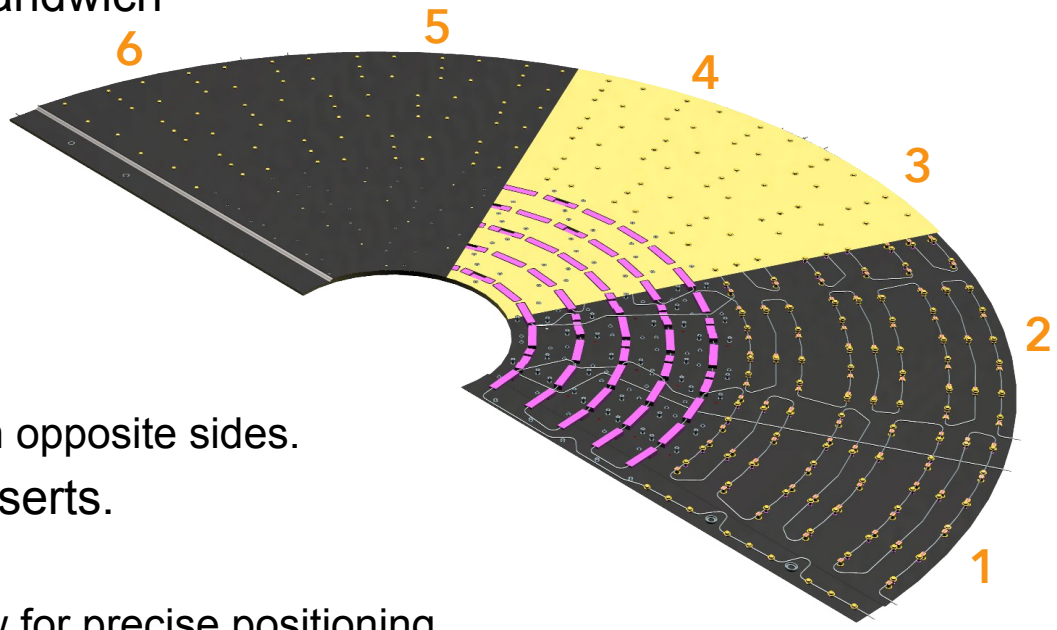


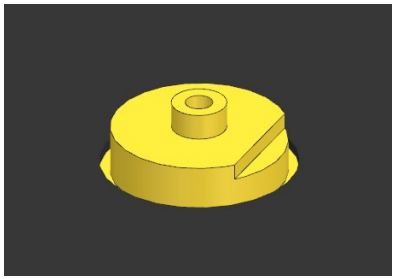
- 2S modules for TEDD have an additional stump bride on the opposite side.
- Module is positioned through holes in the Bridges. (Bride has a normal hole and one elongated hole.)

- Module is positioned through three inserts in base plate.
- Grounding of FEH additionally through spring fingers on the bottom.

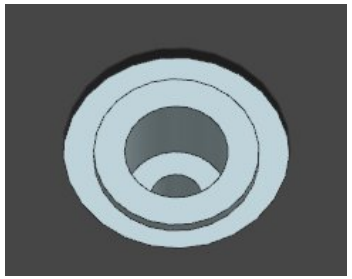
Dee Design

- Highly embedded 10 mm thick Sandwich
  - Airex foam core
  - CFRP facings
- 6 wedge shaped cooling sectors
  - Symmetry: Identical design for sectors 1 & 6, 2 & 5, and 3 & 4
- Step at straight edge of Dee
  - Pipe routing requires step to be on opposite sides.
- Modules are positioned with Al inserts.
  - 2S inserts is also cooling contact.
  - PS insert receive a shoulder screw for precise positioning.
- PS cooling through carbon foam blocks.
- Additional inserts for coordinate system and mechanical connections.





2S insert



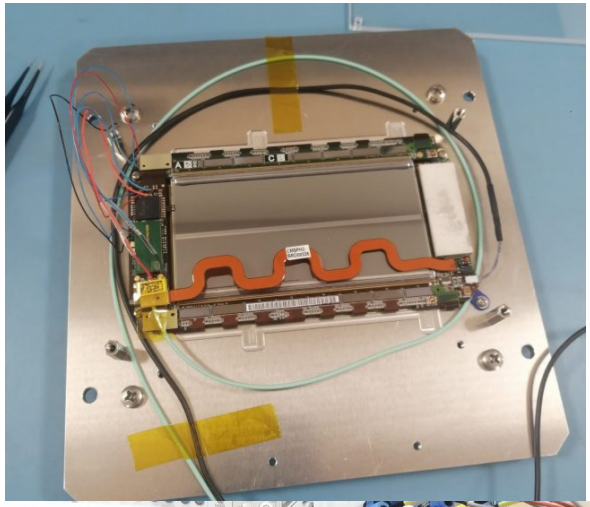
PS insert

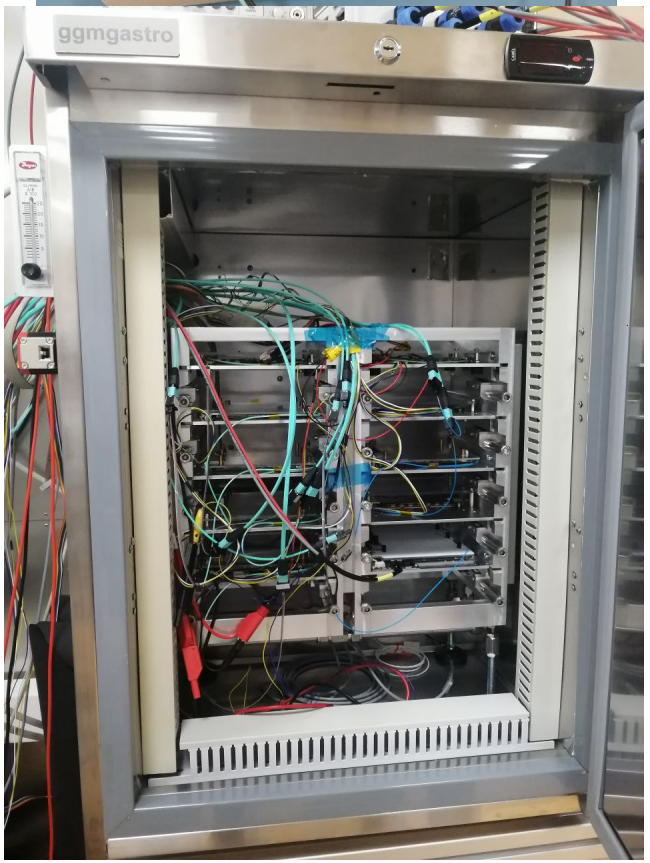
Measurement plan

- Reception test of all modules inside burn-in system.
  - Test modules in cold for this who have not been temperature cycled.
- In parallel: Exercise module integration with module dummies.
  - Many guests came to get experience on how to integrate modules.
- Place all module on the full-size prototype Dee.
- Test of modules in warm, but maintaining temperature with CO_2 cooling.
- Move modules to a single sector Dee and test at -35 °C (insulated enclosure available).
  - This was not done during the test week due to time constrains. Tests have taken place recently with DESY modules only.
- Re-testing of modules in the burn-in setup.

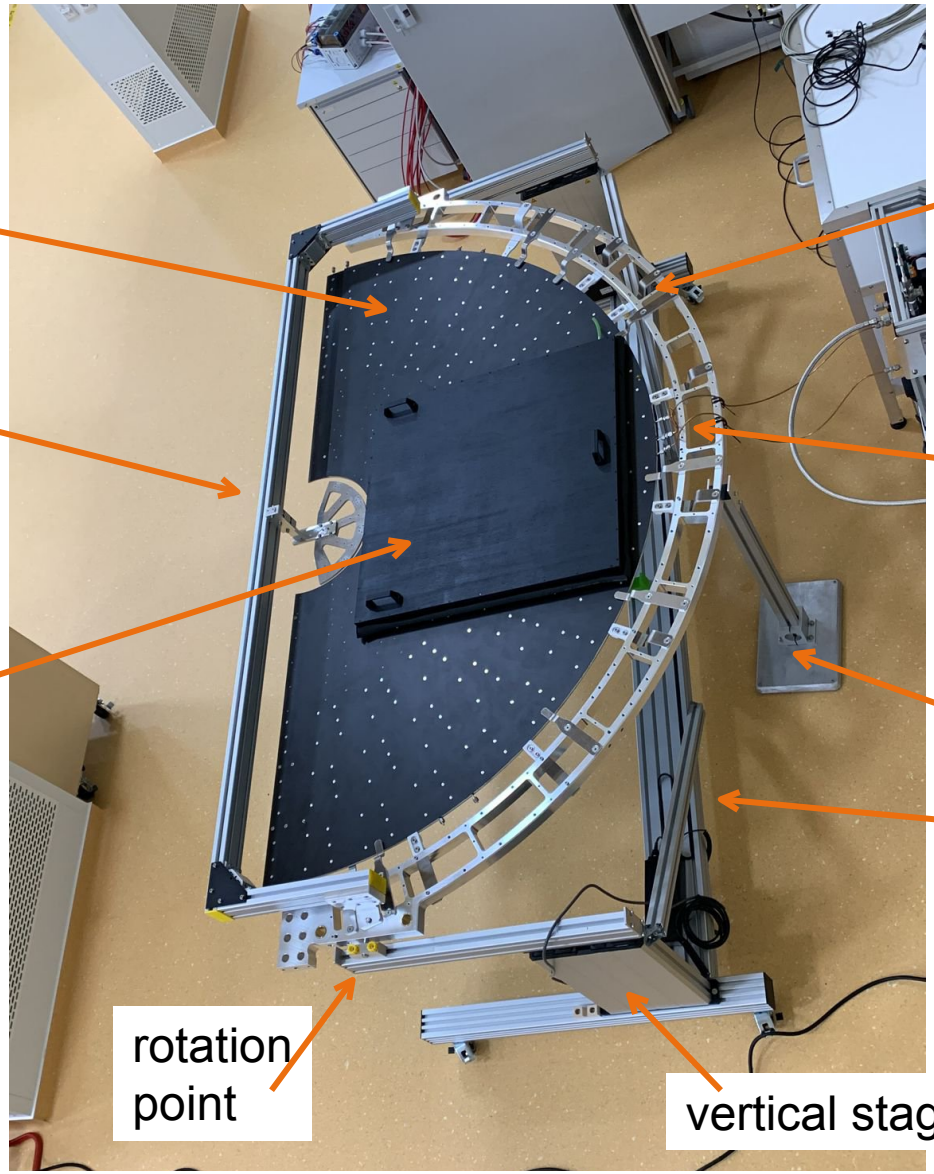
Burn-in system

- Burn-in system stress tests modules after production before integration.
  - Catch early life-cycle failures.
- Process: Temperature cycle and tests module for 24 hours as often as possible.
- At DESY later in production:
  - Burn-in all PS modules and 2S modules from Aachen
  - 2S modules from KIT are already burned-in and only are reception tested in the burn-in setup.
- Modules are transported and tested on carrier plates.
- During integration test, the burn-in system was fully loaded with 10 modules for the first time.





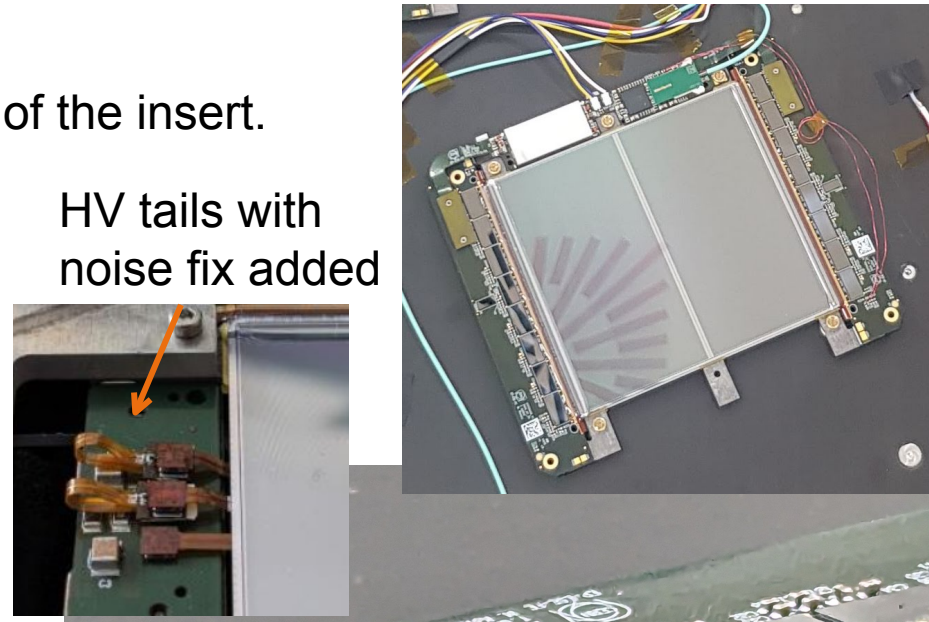
Dee integration mechanics

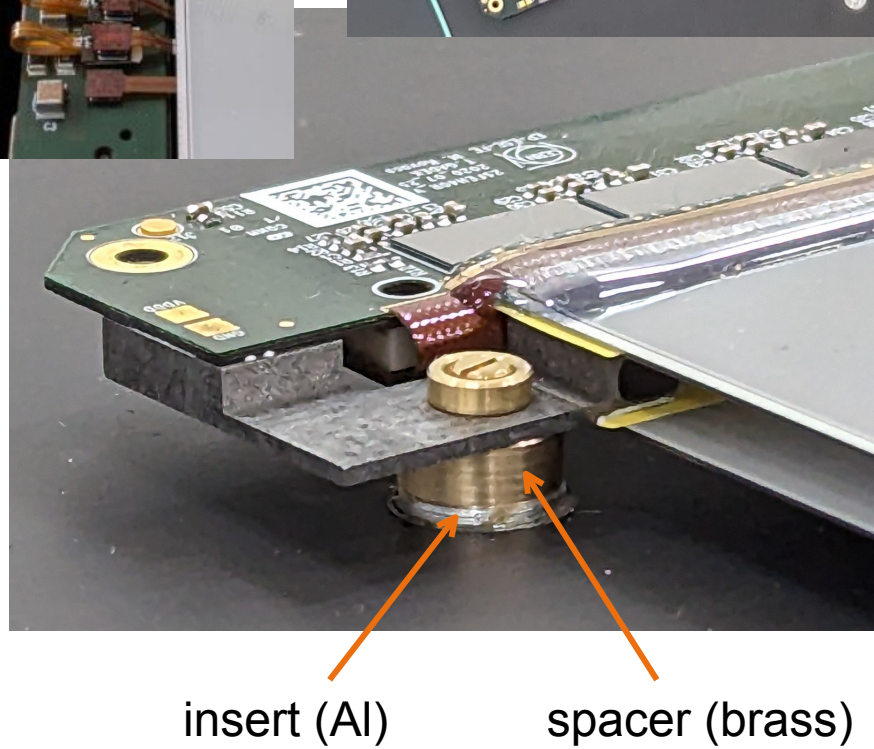


2S integration

- 2S modules are positioned through pin of the insert.
  - 2 pins are 2.5g6 mm for positioning.
  - Others are 2.2 mm
- Several 2S modules had a noise fix added, preventing installing on Dee.
  - 3 mm thick spacer disks were made.
- Two 2S modules with updated noise design were available
  - Still didn't fit: Dee prototype has the insert surface 1 mm above CF facing, final design will be ~1.7 mm. Standard M3 washers (0.5 mm thick) as spacers.
    - Cooling contact deteriorated, but cooling performance was not the goal of the test.
- 10 cNm torque used.
  - Needed for proper cooling contact

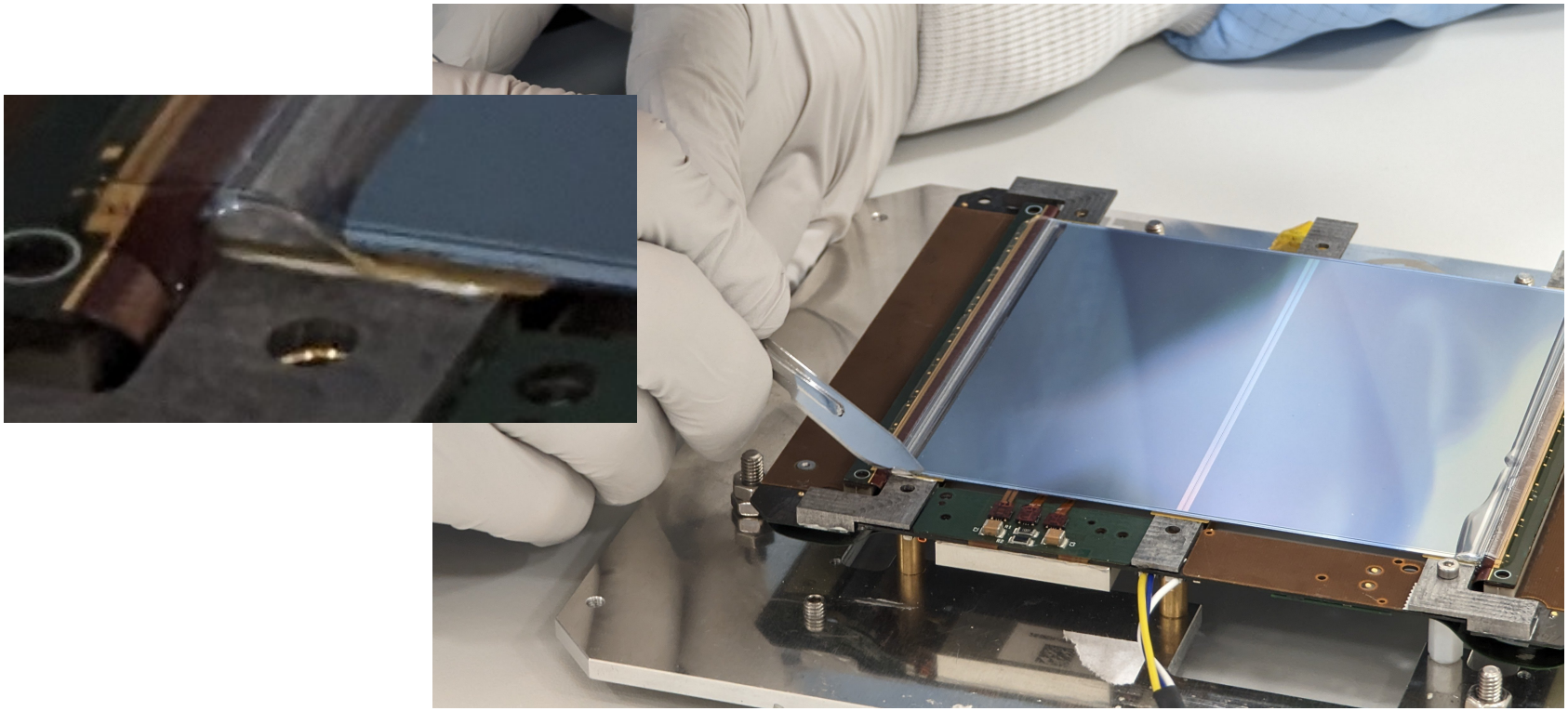
HV tails with noise fix added





2S integration

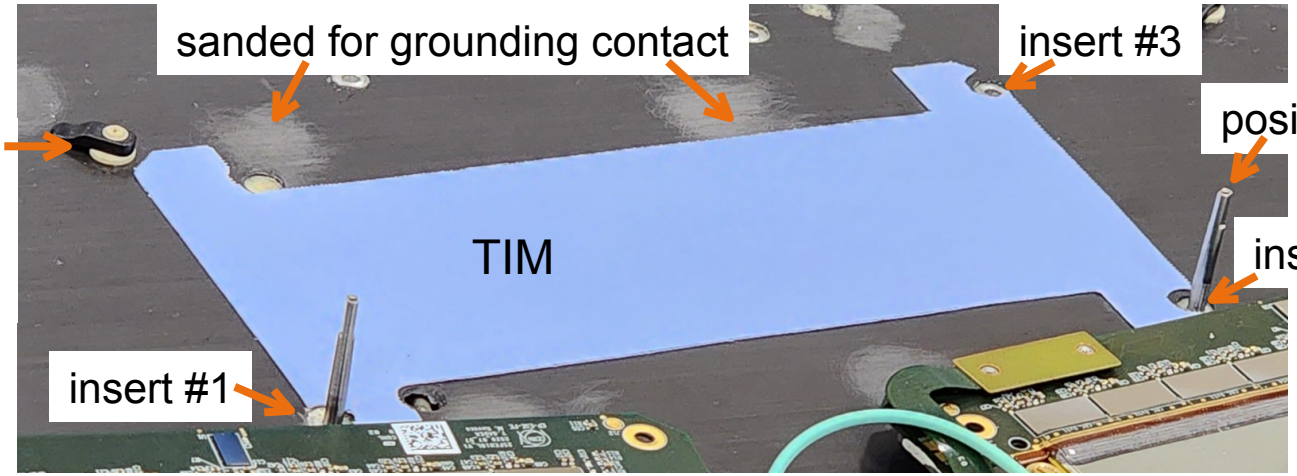
- Excessive encapsulation prevents placing the module.
  - Important to stay withing the specification for wire bond and encapsulation height.
- One module had encapsulant interfering with the Dee insert.
  - During encapsulation of this module, a wrong setting was used.
  - Excess was successfully cut with a scalpel.



PS integration.

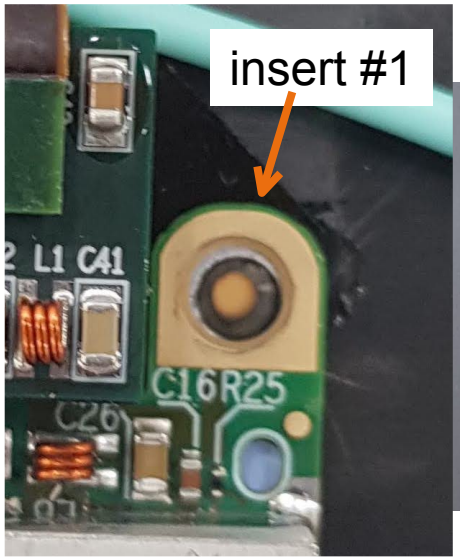
Insert #1 with silver epoxy for grounding

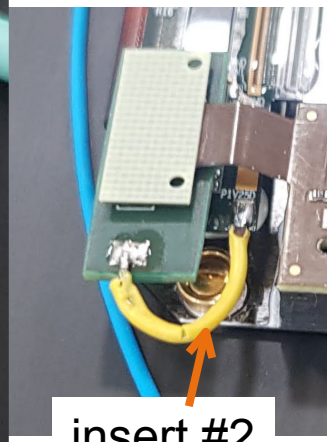
- PS is attached to Dee through 3 inserts.
  - In #1 a shoulder screw is used.
  - #2 is an elongated hole (pointing to #1) to be used with a shoulder screw.
  - In #3 a normal screw is used (large play, no positionig)
  - A 4th fixation clip holds down corner without insert.
- Baseline is to use two pins screwed into the Dee insert for positioning.
- 0.5 mm thick thermal pads cut to the shape of the base plate used as TIM.
  - Mechanically the thermal pads worked well for placing and removing. (cooling performance tests not yet done)

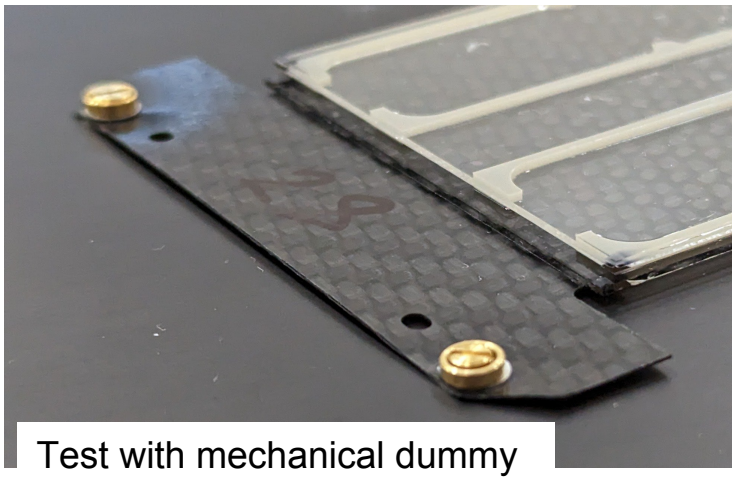


PS integration challenges

- In several cases module fixation holes were not usable due to prototype nature of the modules.
  - The grounding tail was not aligned with insert #1 preventing a shoulder screw from fitting. A normal screw was used instead.
  - Adapter board prevented placing screw #2.
  - Positioning pins could not be used in those cases.
    - Does not seem to be necessary, placing by eye is enough to insert the shoulder screw.
- Screws can't really be tightened, otherwise the base plate bends or base plate inserts break
  - Base plate insert and Dee insert nominally do not touch.
  - In final integration we tighten very lightly and use screw fixation glue.





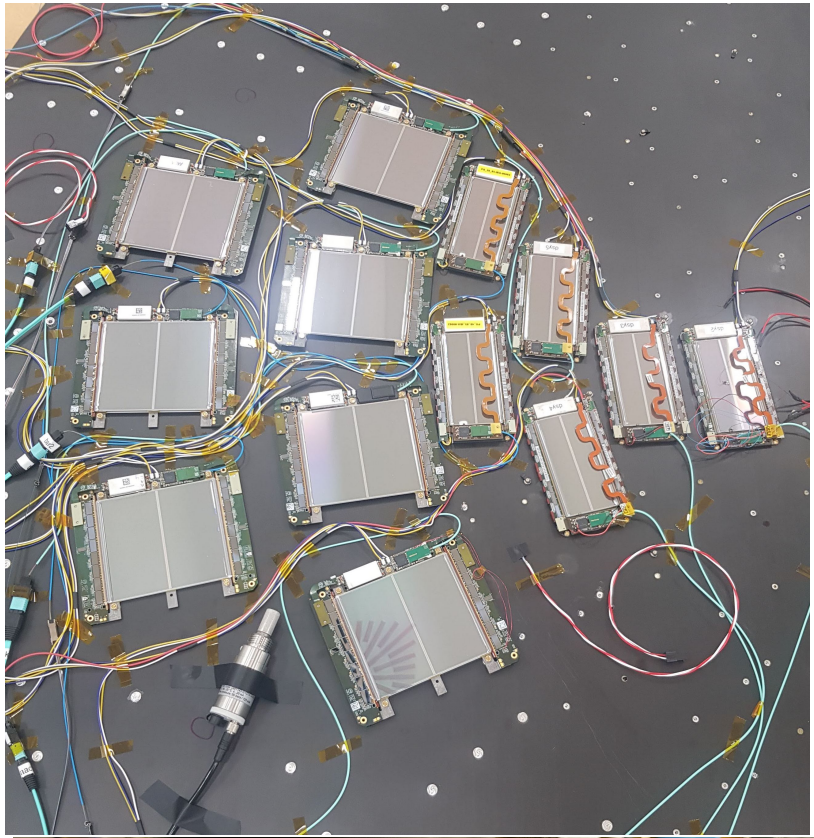


Test with mechanical dummy (base plate much sturdier)

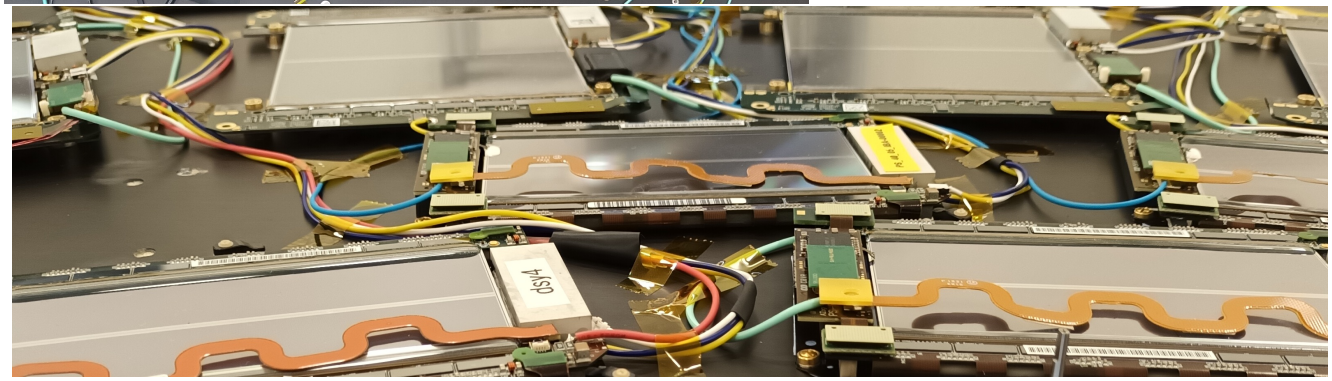
LV to mechanics resistivity

- Measurement of module LV ground to the mechanics to ensure proper grounding.
- Almost all modules showed 6-7 Ω.
  - Coincidentally 2S and PS are similar, even though they have different grounding paths.
  - One PS module we measured about 27 Ω.
- The one with higher resistivity turned out to be due to a worse insert #1 to facing connection compared to the other ones.
- PS hybrid spring fingers were not properly making contact with the facing due to the increased distance with the used thermap pads.
  - Retrospectively tested with one module. Others to be checked.
- Ensuring good grounding during final integration:
  - Verifying during integration that all grounding points are OK is difficult.
  - A test of LV ground to mechanics with an appropriate limit would be doable.
  - Dee insert #1 grounding is reliable if the silver epoxy connection is done well.
  - Influence of spring fingers to be re-checked with final design modules.

Module placement & Services

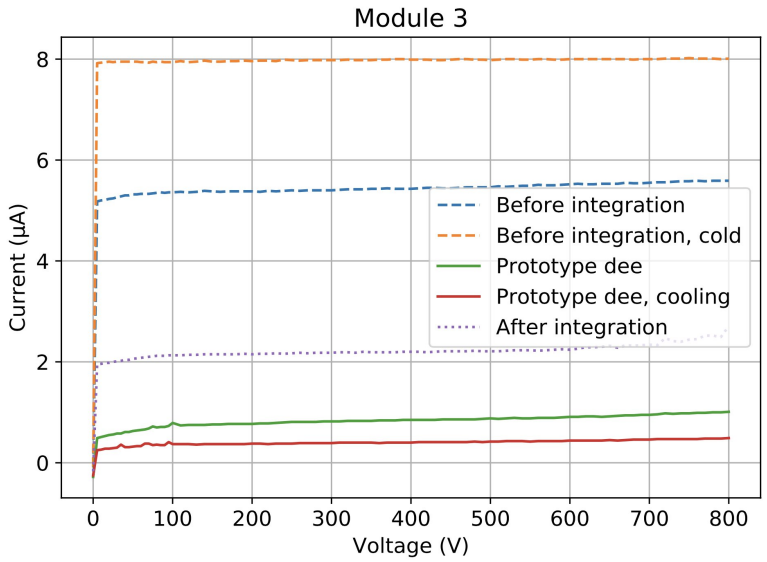


- Grouped all modules in the Dee center (PS to 2S transition area most critical)
- The used services were not final.
  - Some things were more difficult (thicker cables), some things were easier (more space underneath the 2S modules)
  - Final fibers will be more tricky due to spiral protection.
- Routing for the installed modules as in the final cabling plan (mostly).
- Laying services was already difficult with ~1/10 of the final number of modules.
  - This will be the main challenge when integrating the final Dees.

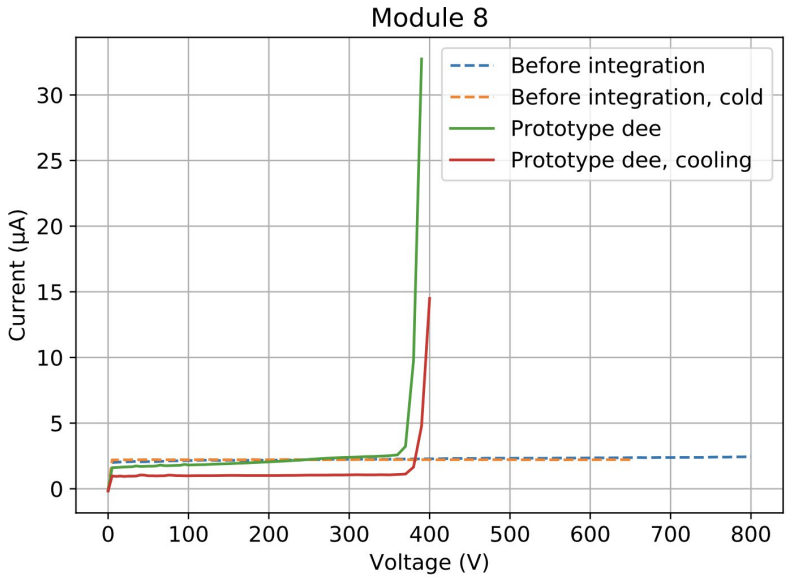


IV performance

- Due to radiation induced increase of full depletion voltage, modules have to run at up to 800 V. (In outer rings probably 600V is sufficient.)
- No systematic IV characteristics discovered.
  - Several modules with sensitivity to humidity.
  - Readout lasers induce leakage current. (known issue)



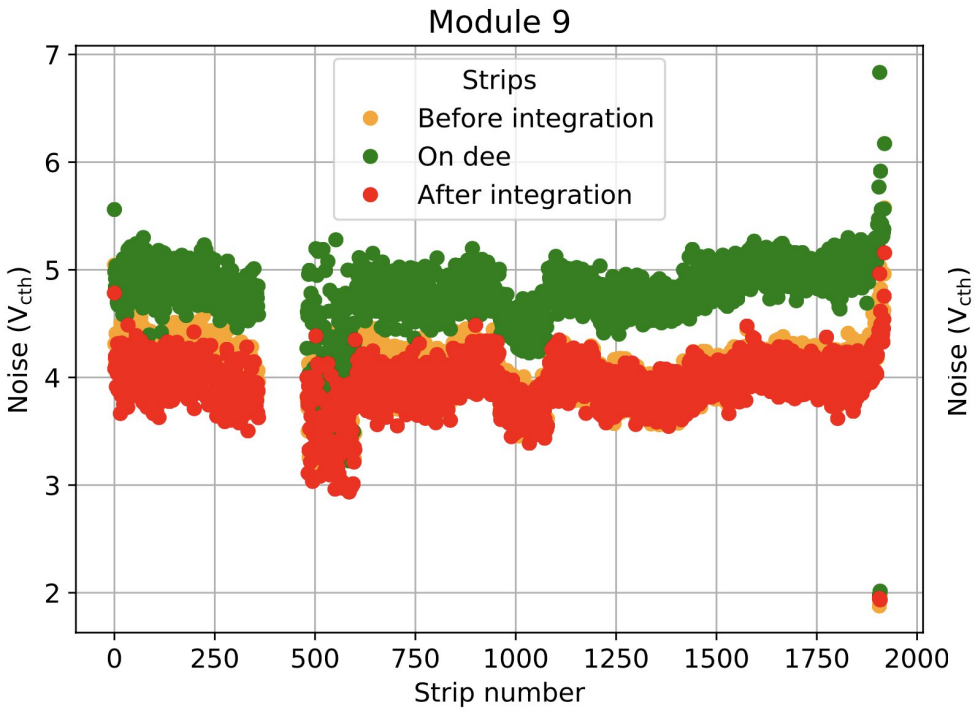
- Different on/off settings of neighboring modules change leakage current

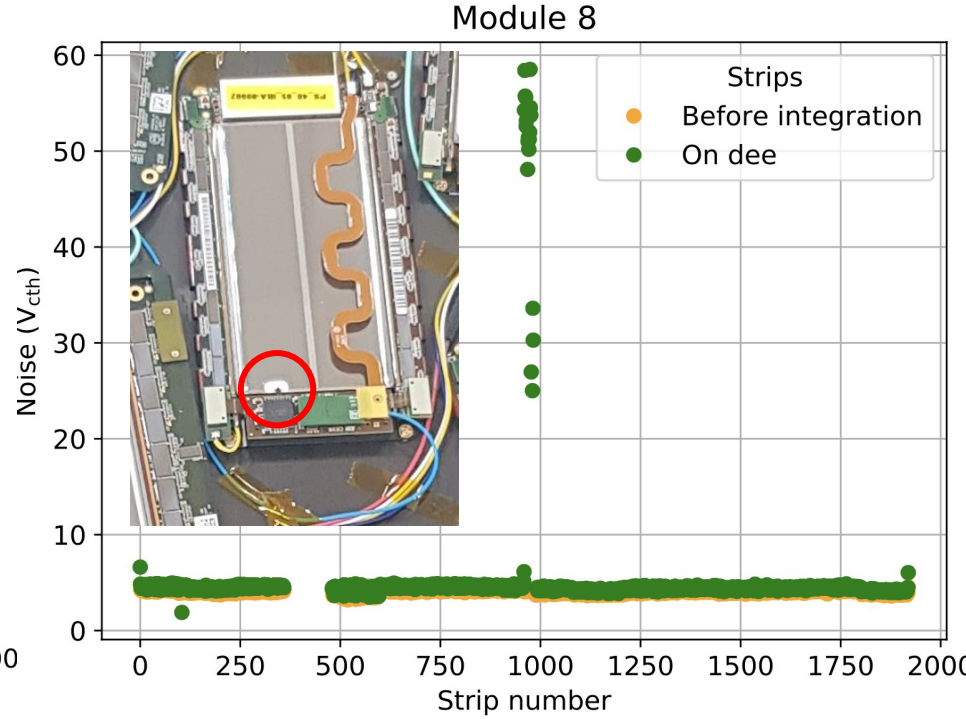


- Module (PS v2) shows early breakdown on Dee.
- Good behaviour after flushing with dry air for a long time.
- Breakdown occurs immediately when exposed to humidity.

Selected noise results

- Threshold scan with active test pulse and measurement of occupancy.
- Noise parameter extracted from gaussian fit to differential of S-curve.



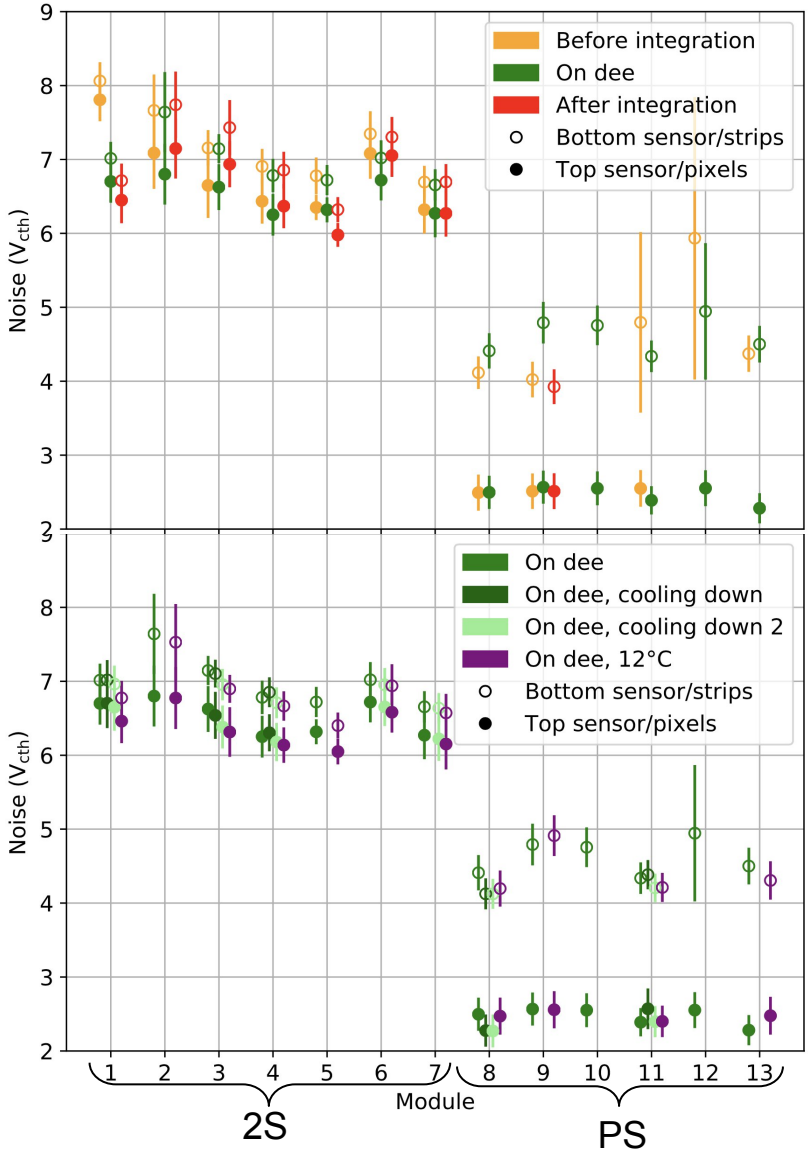


- This PS module has a slightly higher noise on the Dee.
- Could be due to grounding issues.

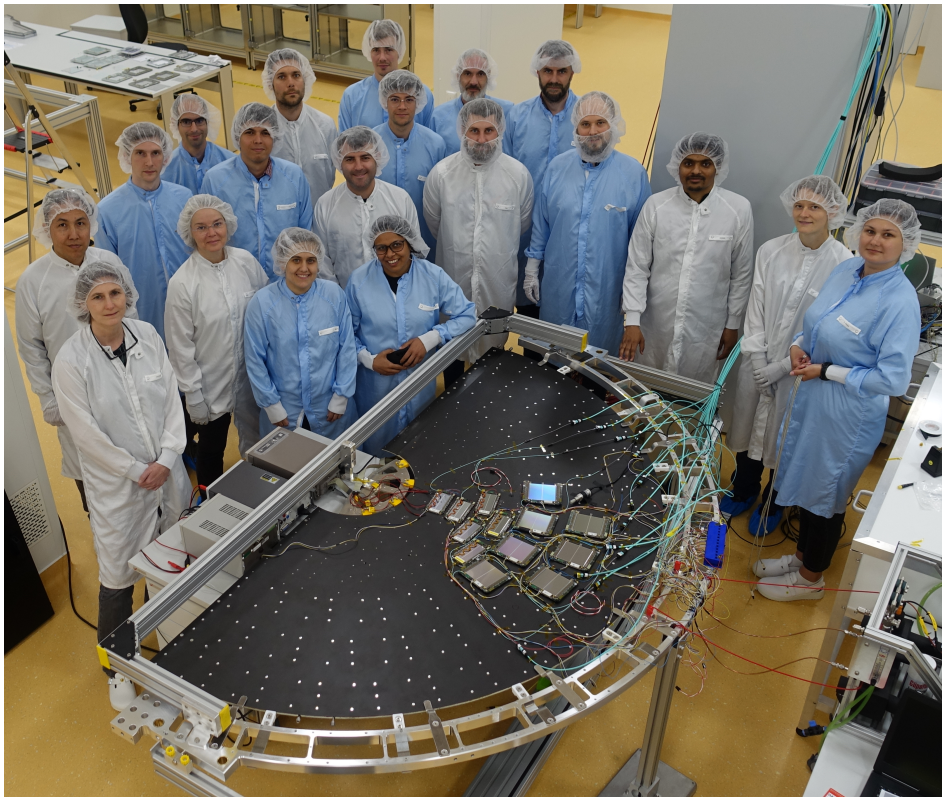
- High noise for some channels.
- This was the module with the early breakdown due to humidity.
- Could be due to temperature sensor or its gluing.

Module noise performance

- Comparison of average noise before, after and while on Dee.
- Both sensor layers considered separately.
- Note: V_{cth} threshold units are not the same for strips and pixels.
- No effect in the 2S modules.
- No effect in the PS pixels.
- PS strips are sensitive to “environment”
  - Different versions of PS modules used.
  - Old versions anyways have significant noise on 2S strips. (e.g. Modules 11 & 12)
  - Newer PS modules (e.g. 8&9) have a better noise. Small increase on Dee is visible.
- No detrimental effect due to Marta.
- 12 °C gives maybe slightly reduced noise.



Summary



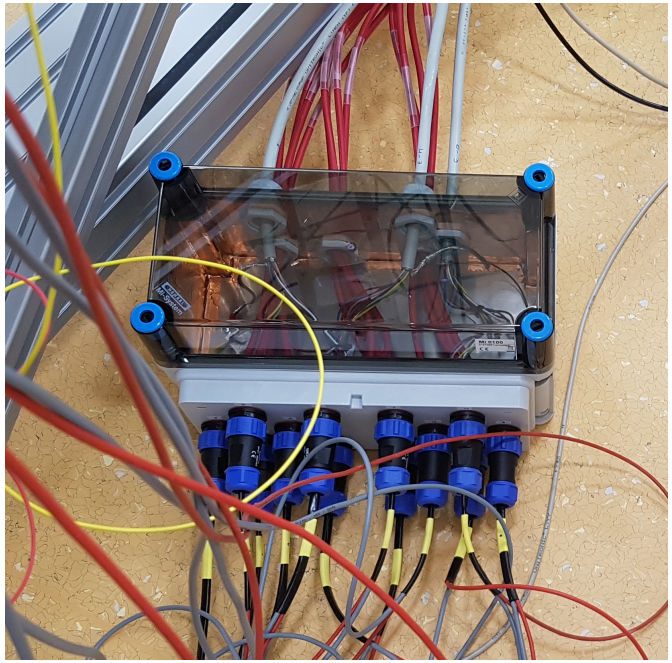
- Integration test with prototype modules on prototype Dee successful. Many lessons learned and experience gained.
- 2S modules are expected to work fine with final mechanics.
- PS module procedure is more complicated and several issues to be addressed.
- No systematic issues regarding noise or IV performance.

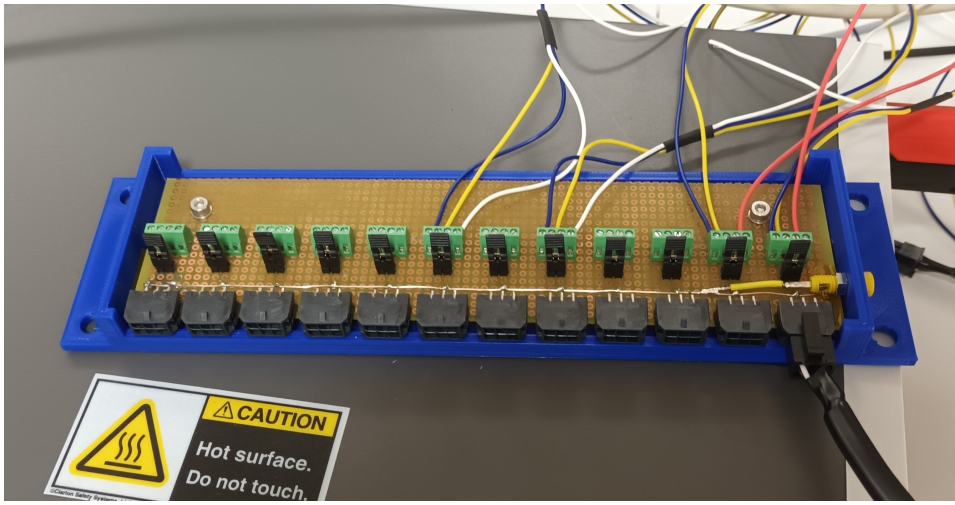
- Next:
  - Test of PS modules on single sector Dee in cold.
    - Test completed, analysis pending
  - Re-test PS v2 modules with better grounding.
  - Test of a few kick-off batch modules on pre-production Dee as final design verification.
    - Expected some time in fall

Backup

Powering and grounding

- The CAEN power system intended for the sector test was used together with the cable adapter box of the burn-in system.
  - 12 individual cables that would connect to the module carrier board.
- A box with 12 power inputs and screw terminals to connect module pig-tail cables was build.
- Each channel can be connected to a common ground rail via a jumper.
- The common ground was connected to the Dee facing





PS HV connector

- This problem did not occur in the integration test, but in this context remains to be a worry.
- On several modules the HV cable connector fell of the hybrid when removing the cable.
  - Soldering quality seems to be insufficient?
- Only occurred on HV, no problems with LV

- Prototypes were repaired with a cable soldered to the SMD components of the input filter.
- Later, the cable needs to be removed at least once, when taking modules from the carrier.
  -> Currently we can expect this problem to occur during integration.
- Is this seen elsewhere? Can we expect it to be better with final components?