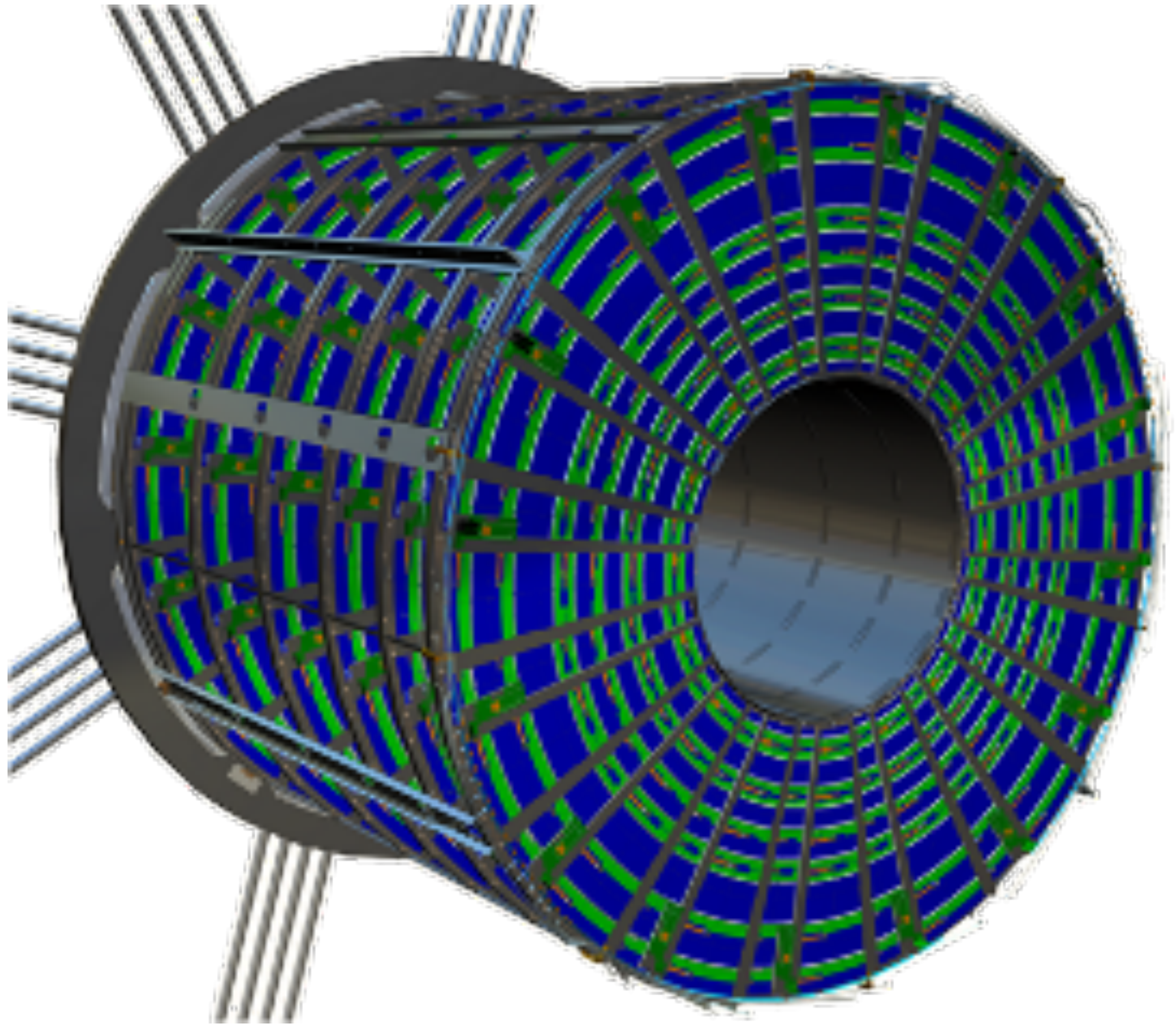
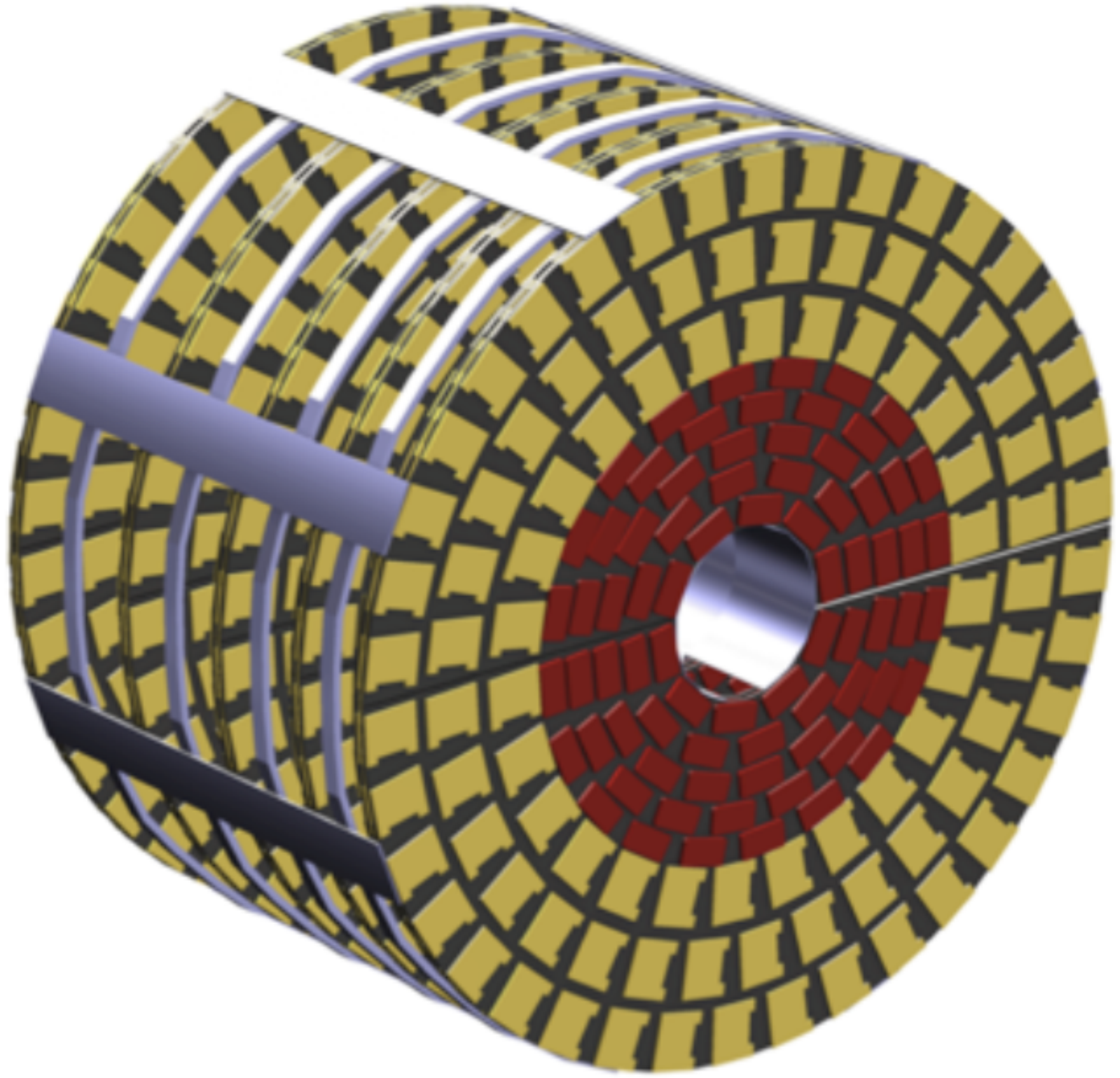
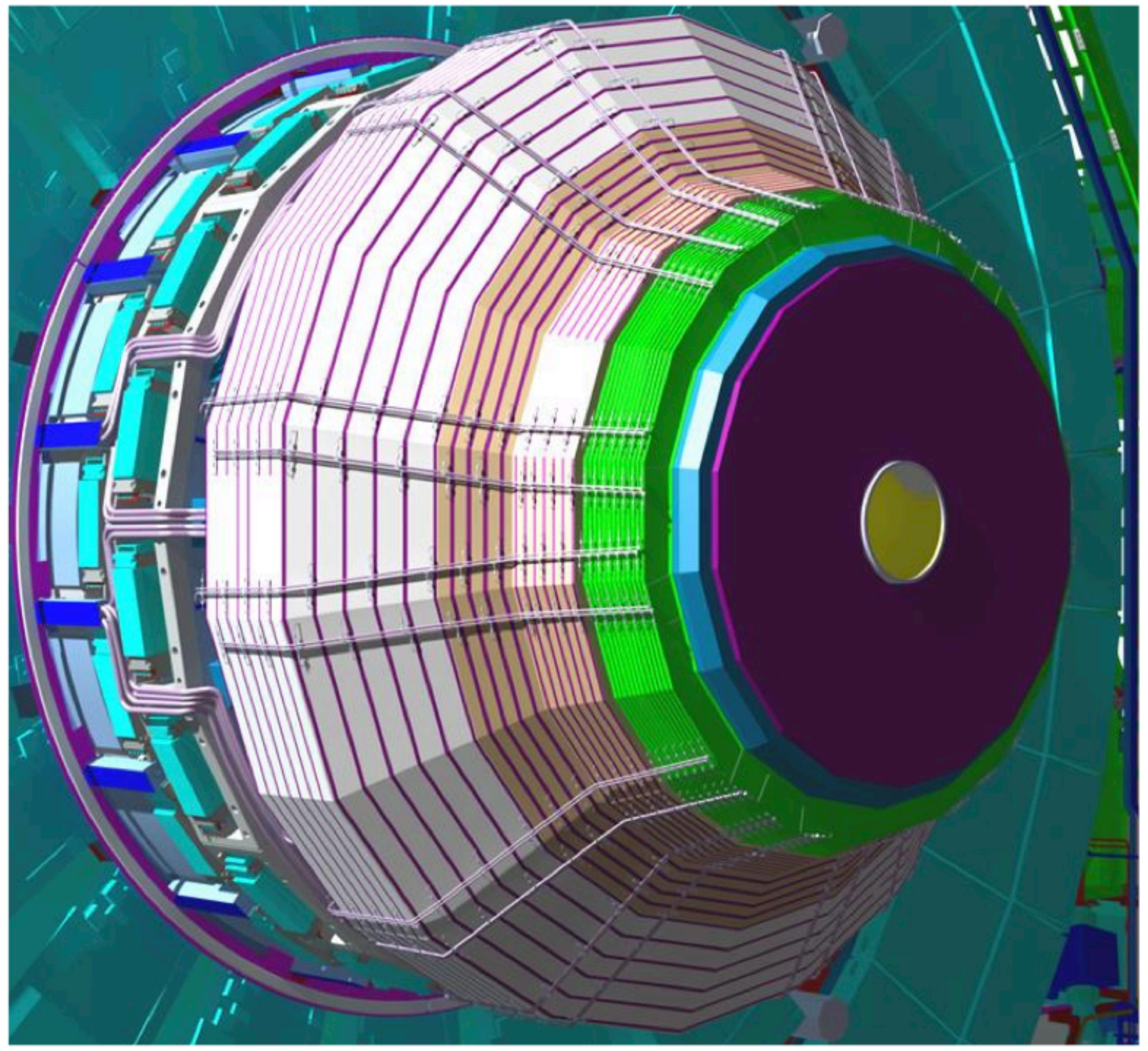
LHC Upgrade Activities in Hamburg and Zeuthen



ATLAS ITK Endcap



CMS Tracker Endcap

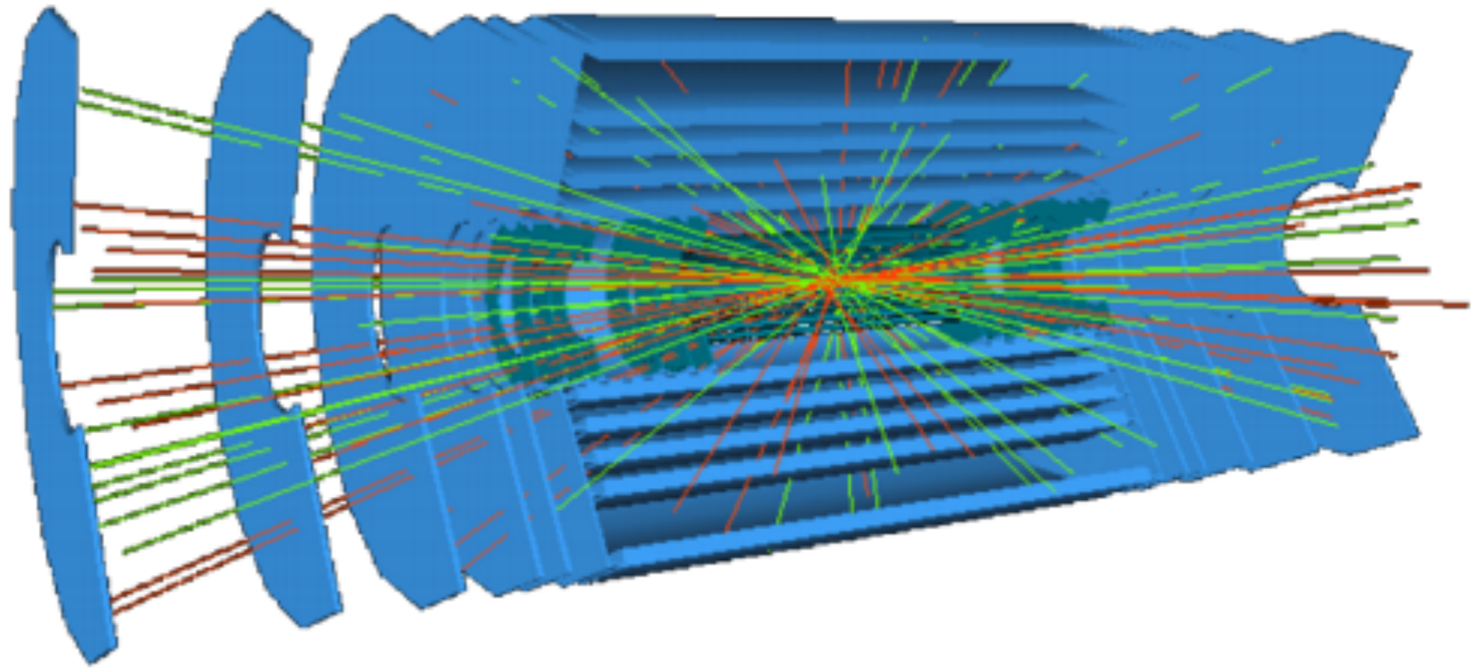


CMS High-granularity Calorimeter

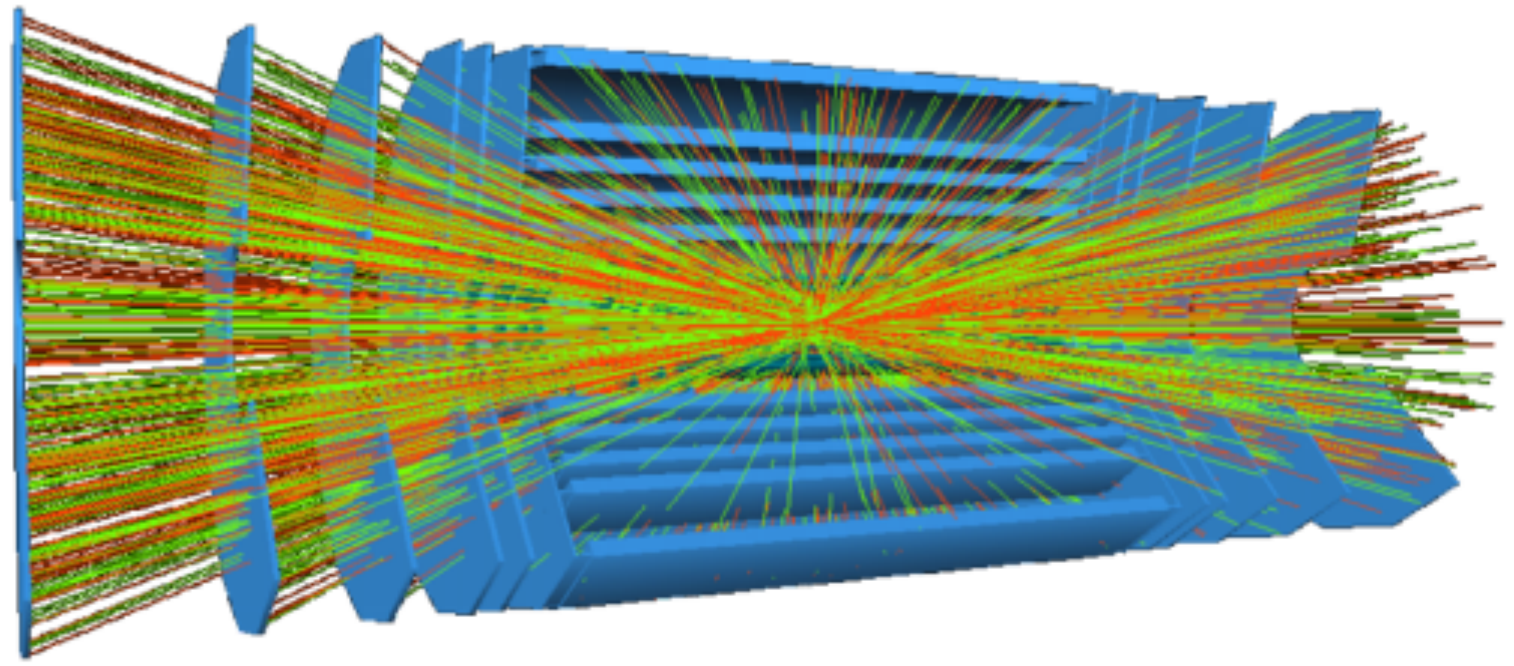
Why do we need the Detector Upgrades?

- Upgrade of accelerator in order to exploit full physics potential
- At HL-LHC:
  - peak luminosity will increase by a factor of 5-7
  - integrated luminosity will increase by a factor of 10
  - radiation fluences will increase by a factor of 10
  - pile-up will increase to about 200

—> upgrade of detectors needed
  - with enhanced trigger capabilities
  - with enhanced radiation hardness

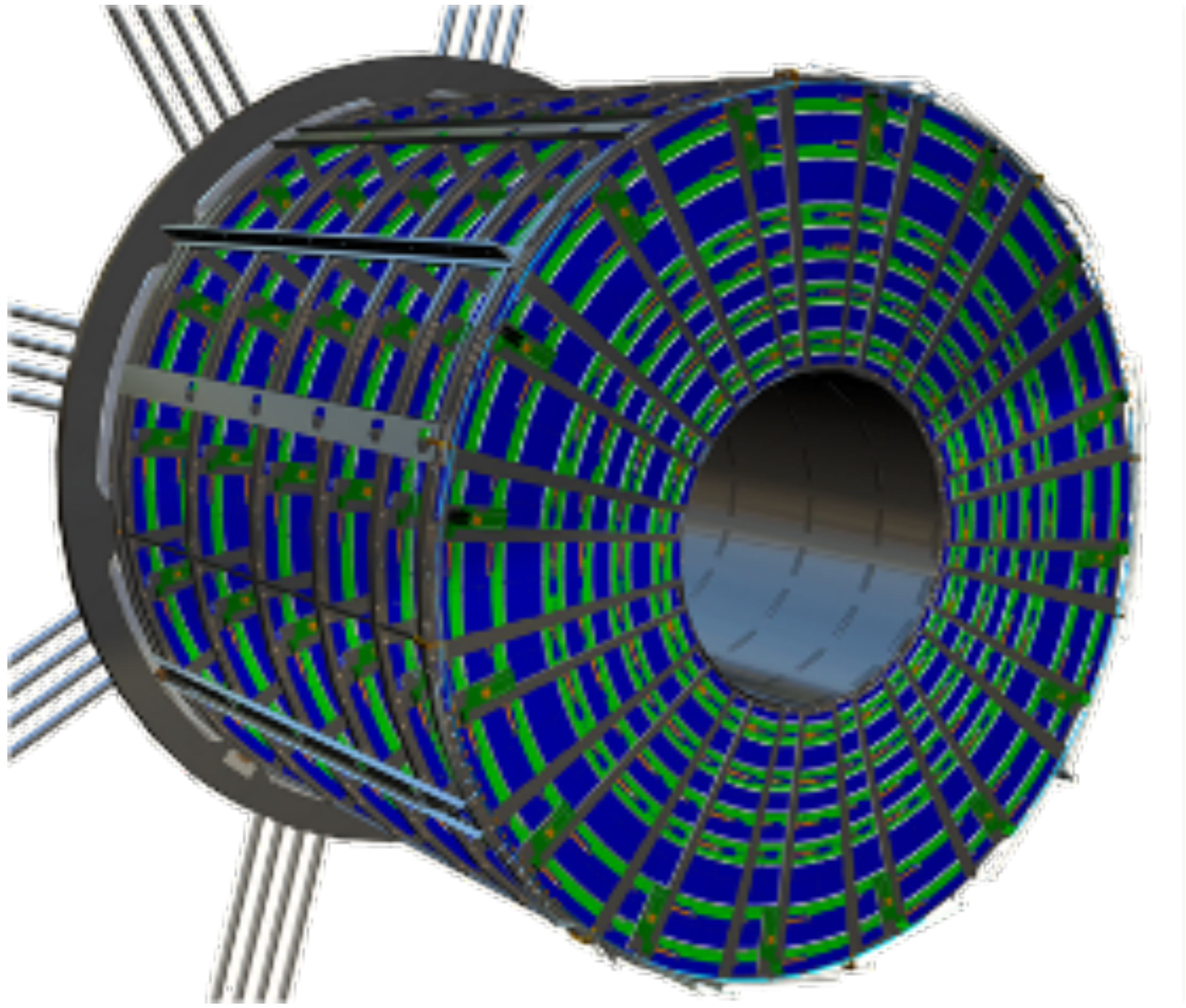


LHC, 20 - 55 pile-up events



HL-LHC, 140 - 200 pile-up events

ATLAS Inner Tracker Detector Upgrade



ATLAS at DESY - Overview of Activities

- DESY ATLAS is working on the realisation of one full end-cap of the ITk
- In Germany: Strong collaboration with HU Berlin, TU Dortmund and Uni Freiburg

other from collaborating institutes
QA/QC

Pipe bending
QA/QC

co-curing of facesheets + bus tapes
QA/QC

carbon foam machining
QA/QC

other from industry
QA/QC

Module assembly
QA/QC

Petal cores
QA/QC

EoS cards
QA/QC

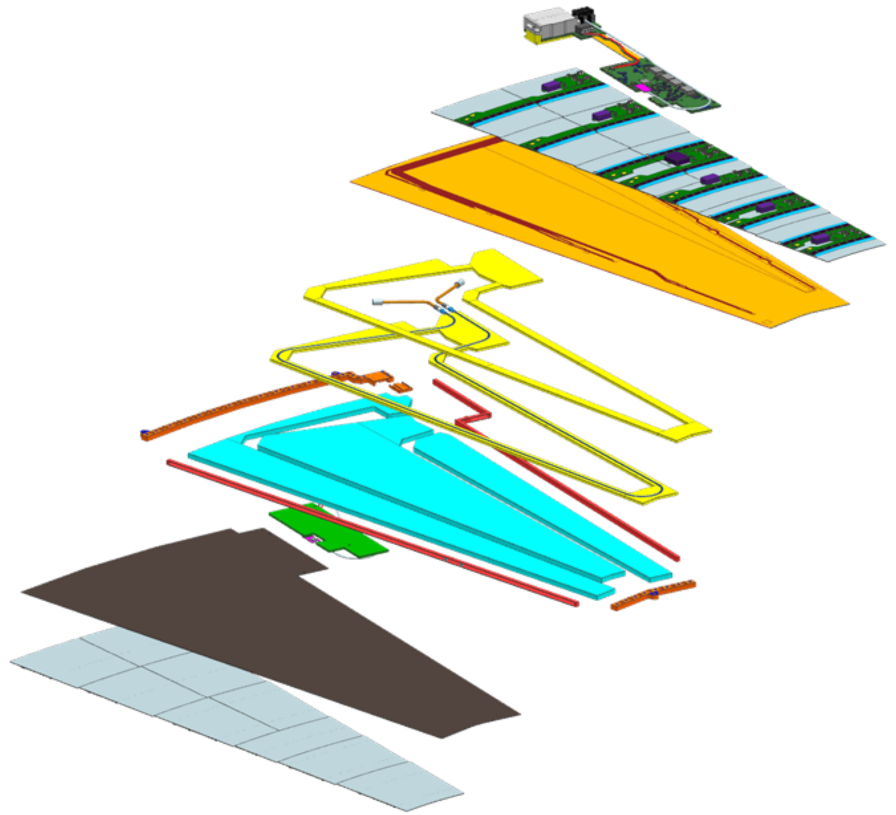
Petal assembly
QA/QC

End-cap structure
QA/QC

services
QA/QC

Service module integration
Petal Insertion
QA/QC

One End-Cap to CERN



ITk Modules

Module Activity Coordinator

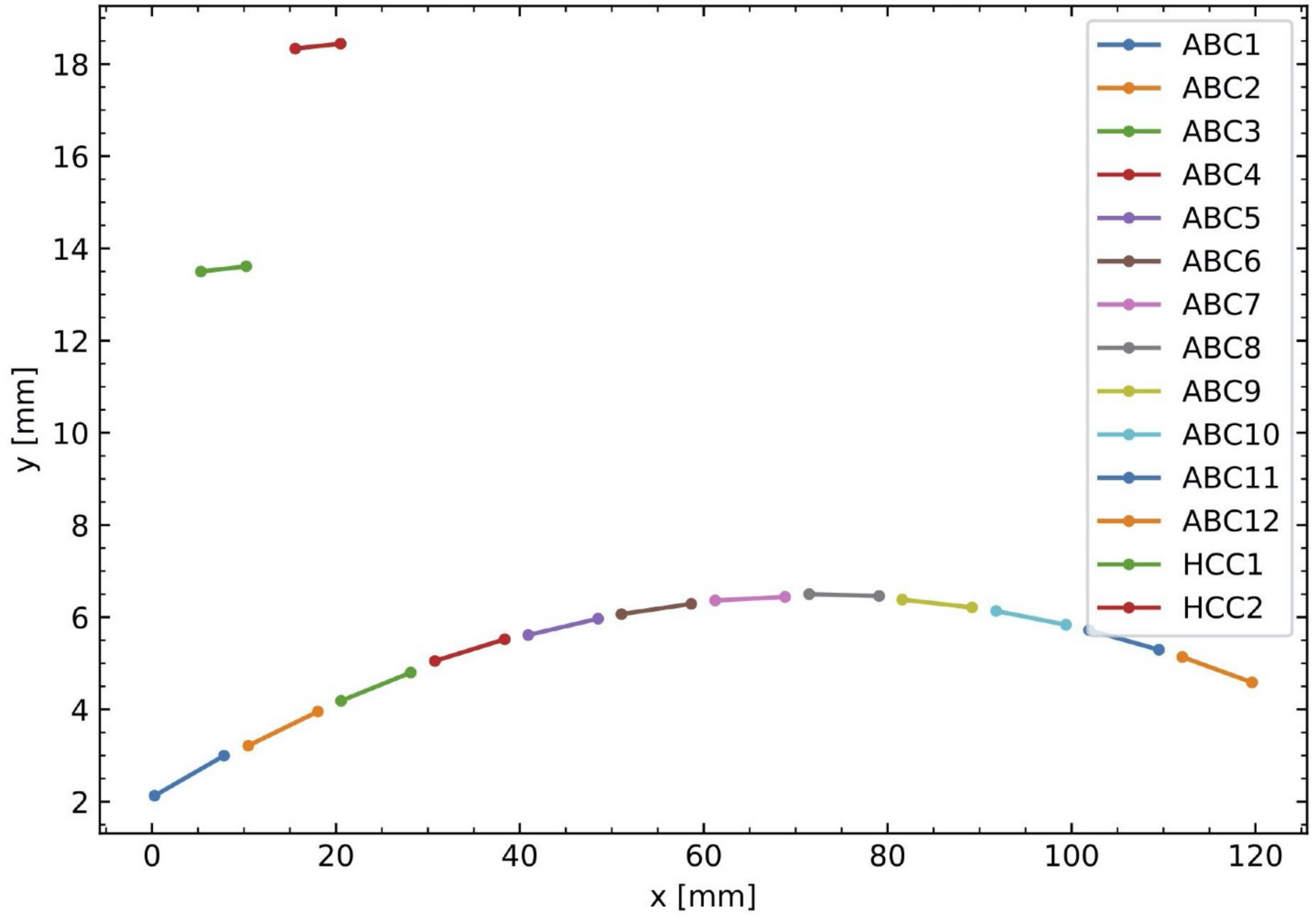
All Modules flavours built a DESY

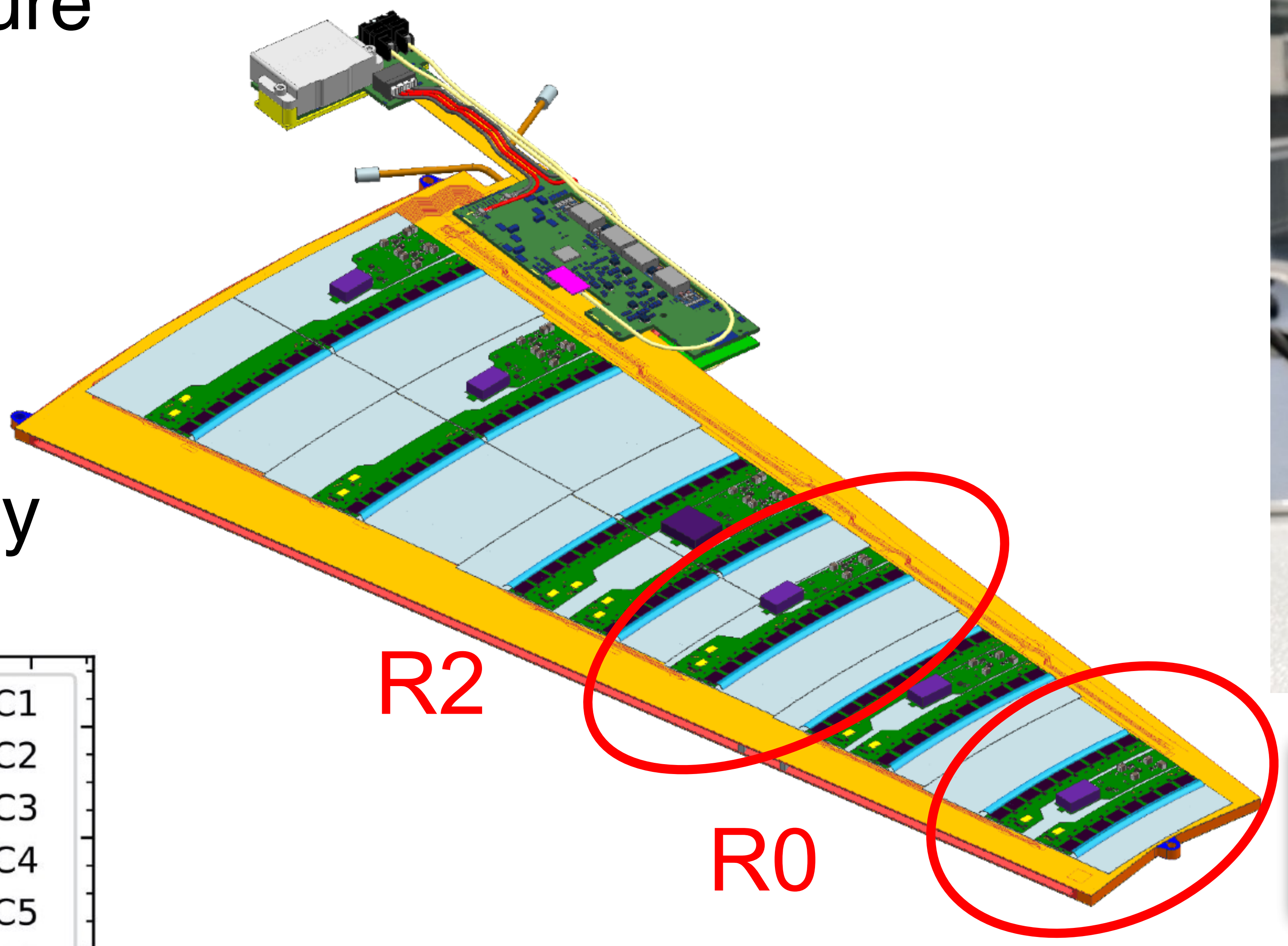
- Commissioning of **glue dispensing robot** to ensure good control over glue amount in hybrid-sensor gluing
- Refine R2 hybrid-sensor gluing procedure
- Power-board gluing tests

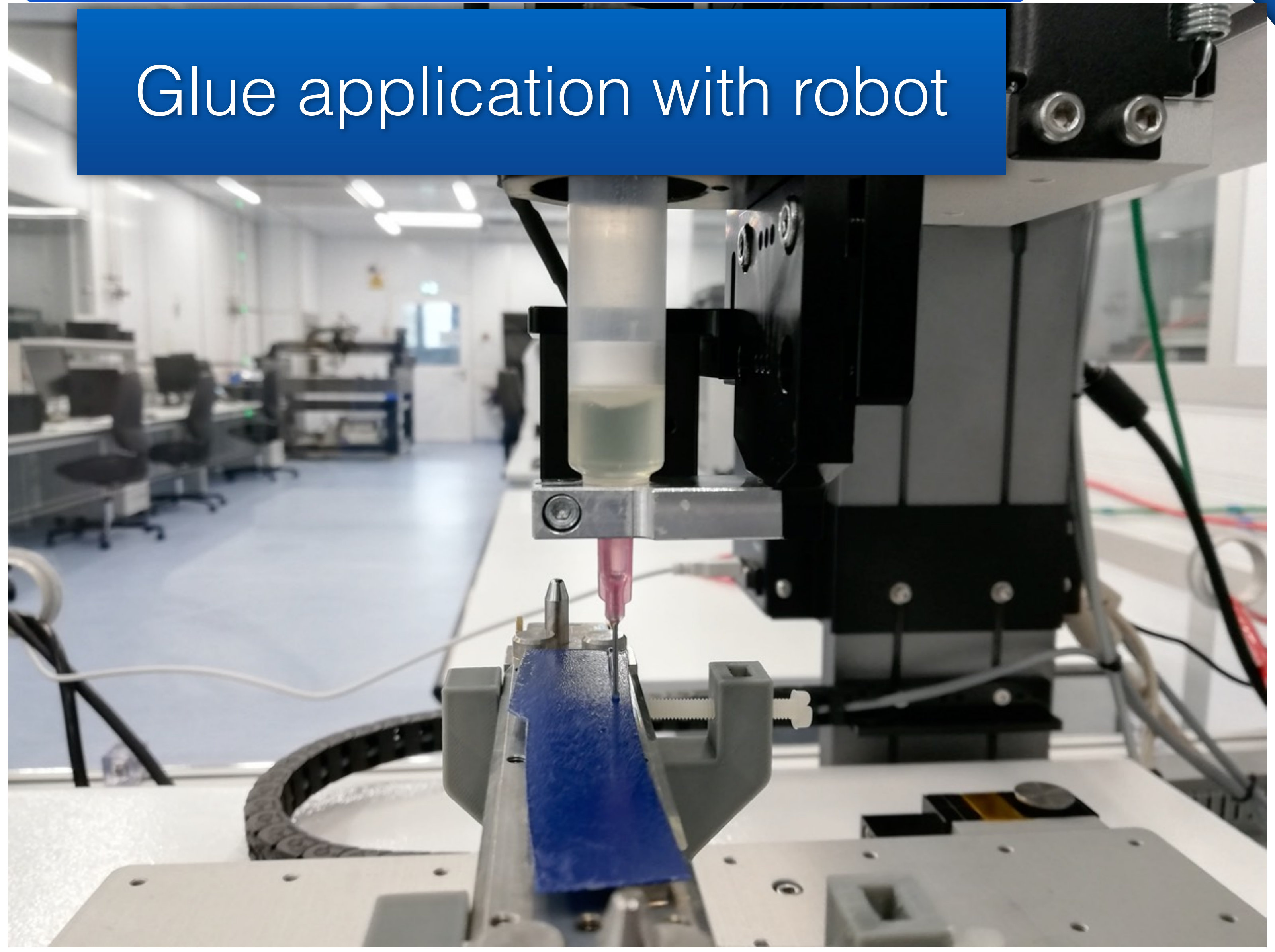
Site qualification preparation

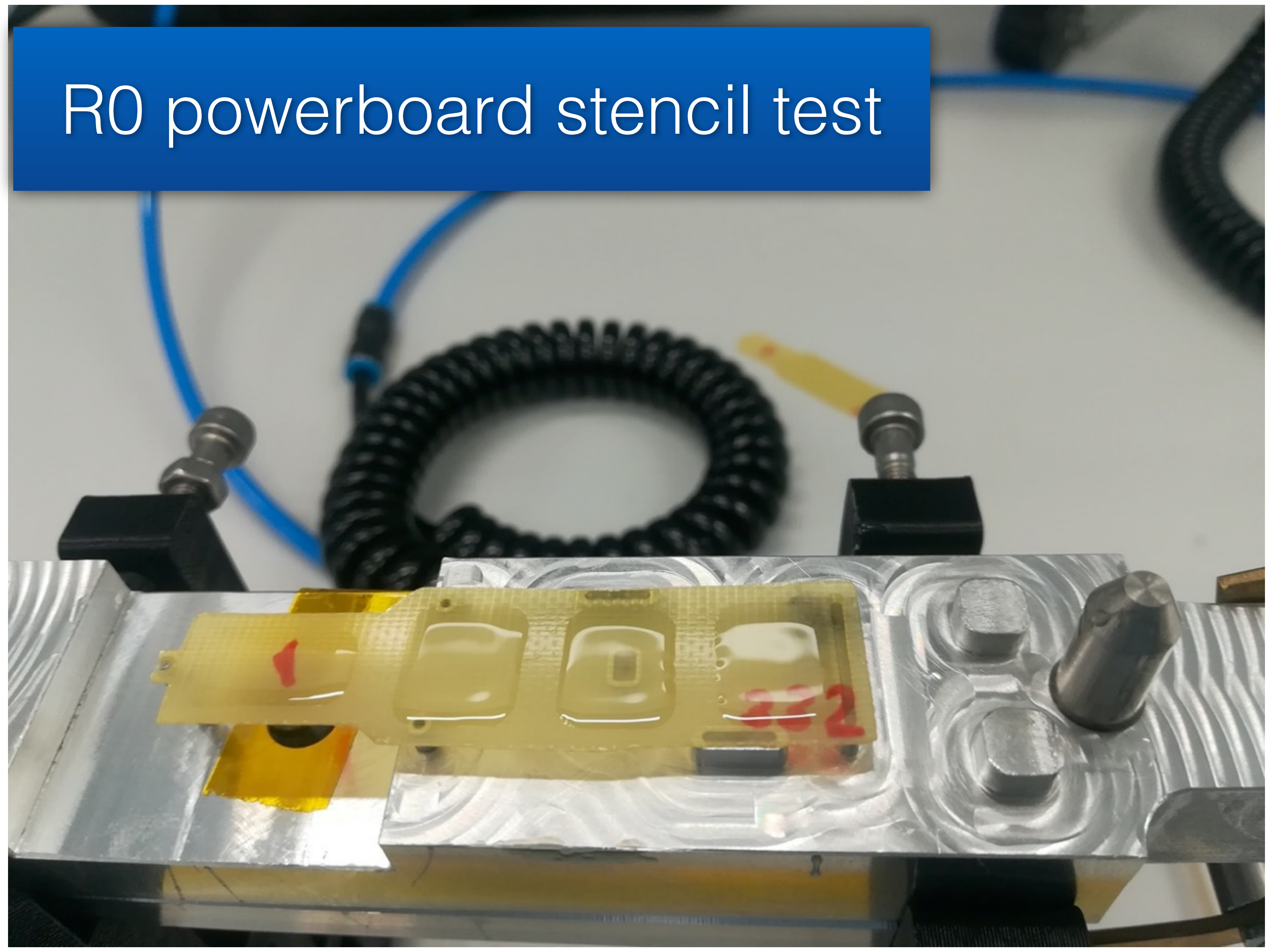
- Harmonize procedures between sites
- Finalize QA/QC methods e.g. metrology

Chip position (R2 star mechanic hybrid)



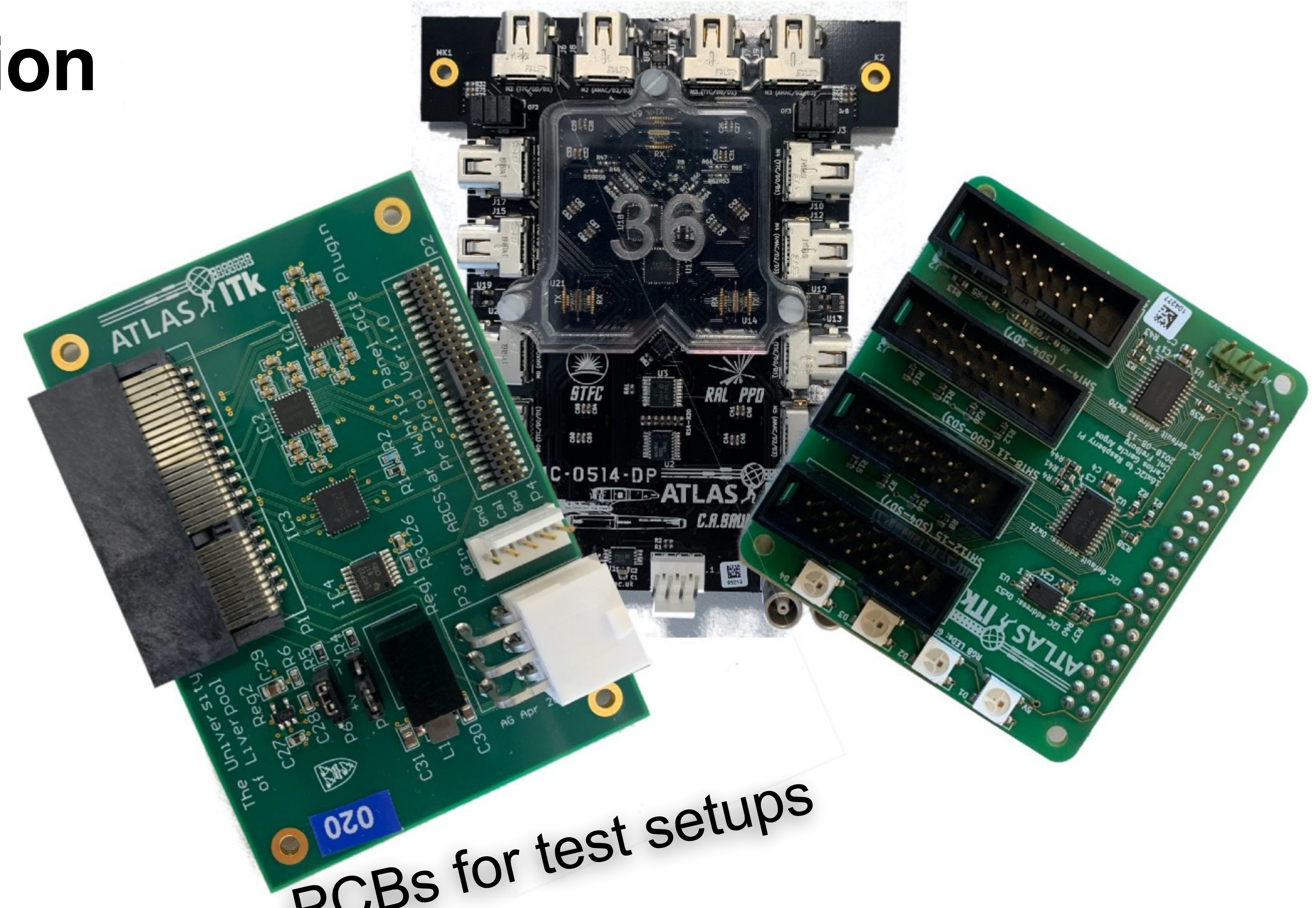






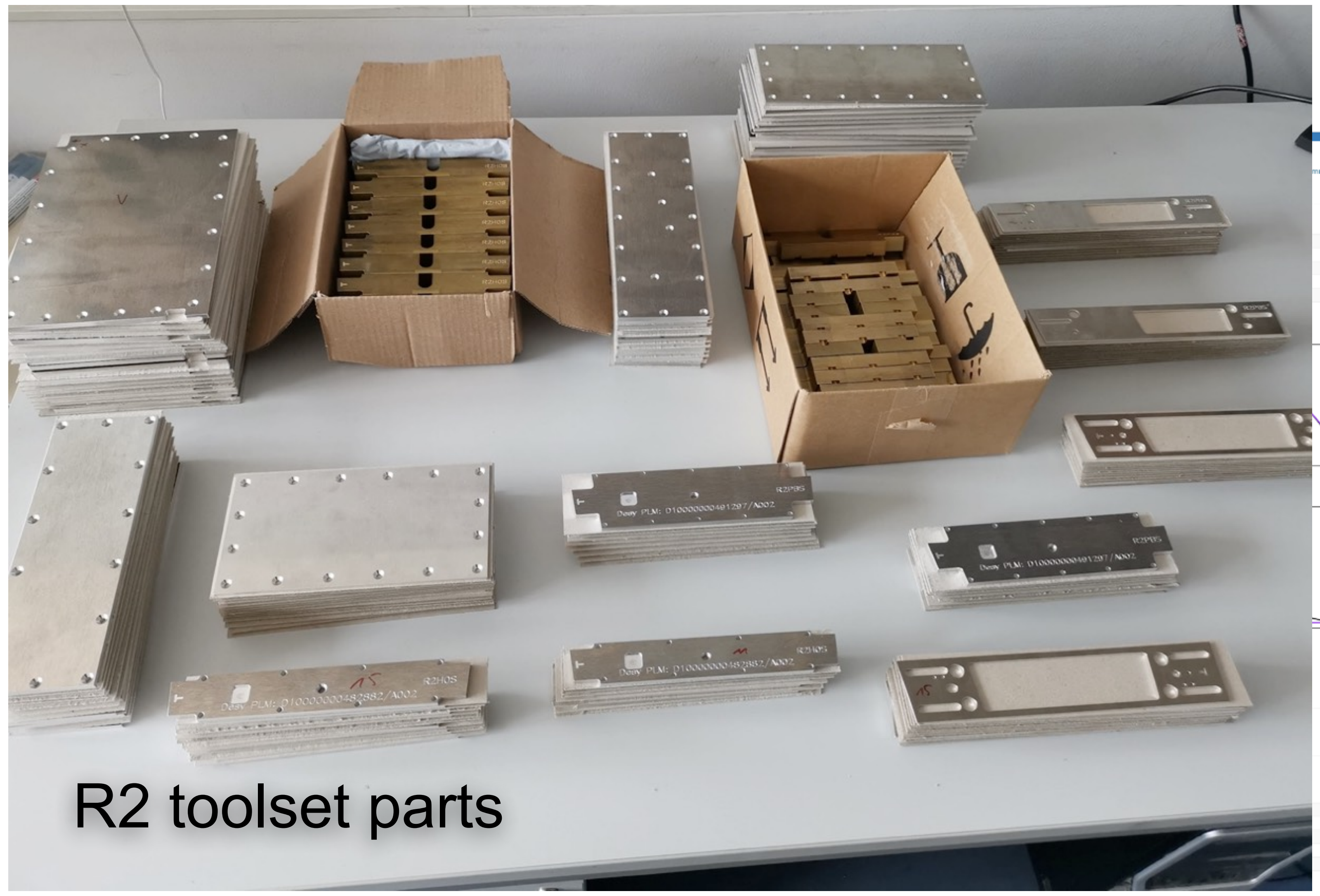
Preparation for module production - with and for the collaboration

- **Towards Global ITk quality control during production**
  - Produced hybrid and module test PCBs for collaboration
  - Working on finalising the “Hybrid burn in” QC setup (SW / HW)
  - Working on integrating production database with DAQ software
    - bad channel tracing
    - DB upload format agreements

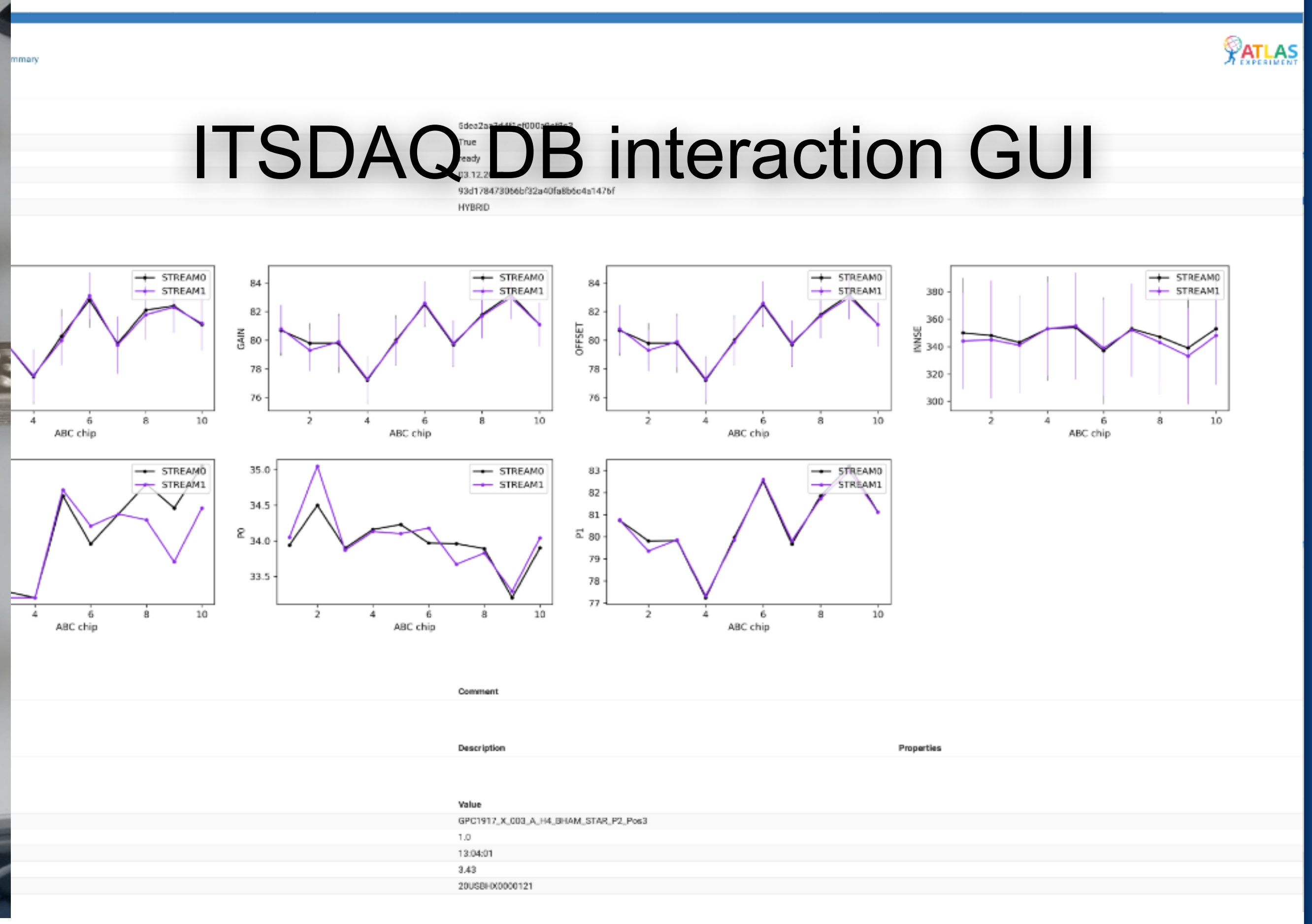


PCBs for test setups

- **Towards Globally coherent tooling**
  - Took part in 3D tool drawing reviews
  - High precision module assembly tools for the R2 module type
    - Produced 2D tool production drawings
    - Now producing the assembly tools



R2 toolset parts



ITSDAQ DB interaction GUI

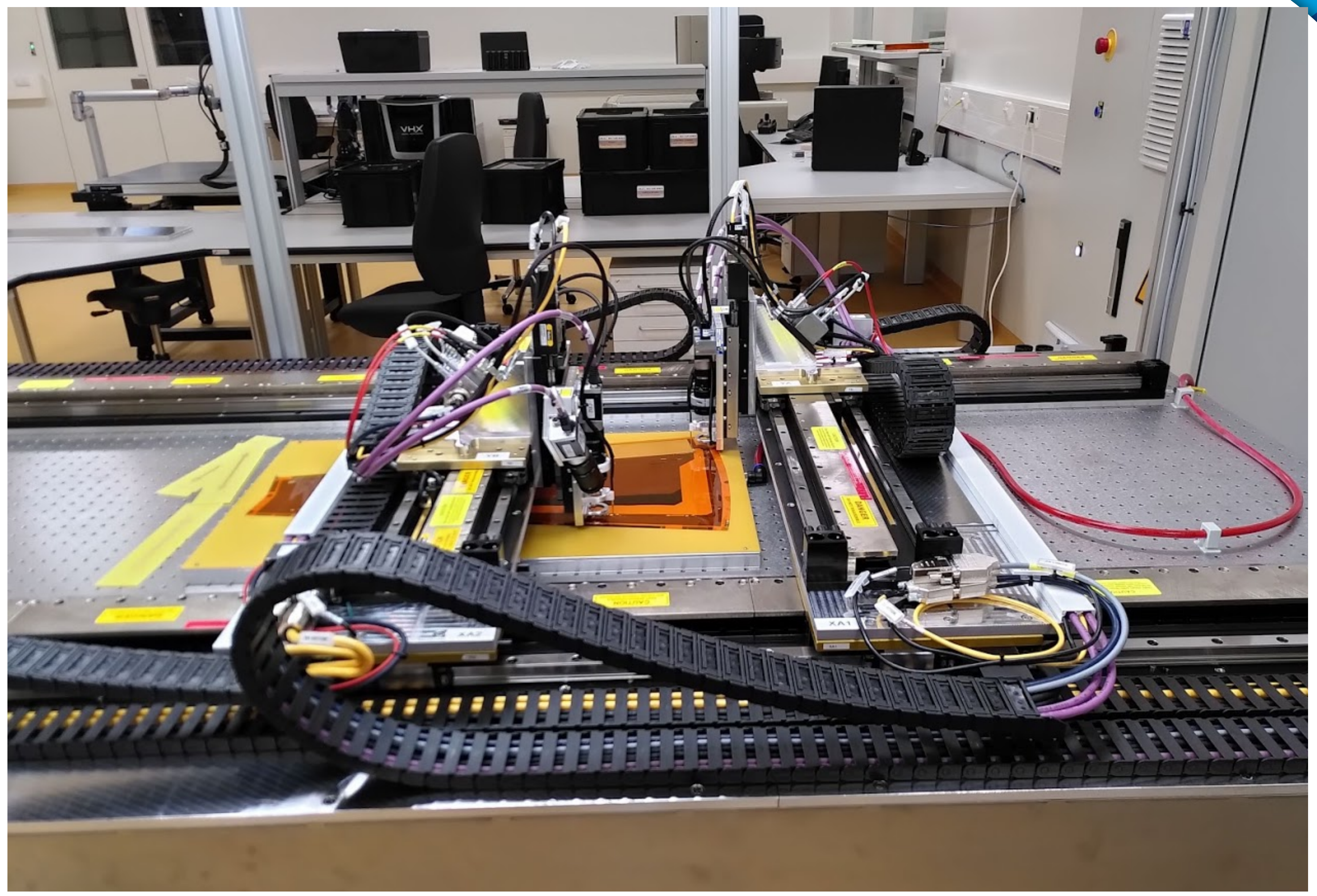
Quality Control During Production

Coldbox for module quality control during production

- Investigated different coolants
- Built a frame holding the coldbox
- Ongoing work on automation

Crate for hybrid quality control during production

- Dismiss hybrids that do not survive test or suffer any damage
- Optimisation of self-regulated, fan-based cooling system finalised
- Development of user software on-going



Robot to test electrical connectivity in bustapes

- Measure any deformations, resistance along lines, short circuits, leakage currents
- Should be able to run full tests within a few weeks
- Next: automation, database interaction

Petal Cores - Prototyping and Testing

Local Support Cores Activity
Coordinator

Two pre-production A petals manufactured at DESY

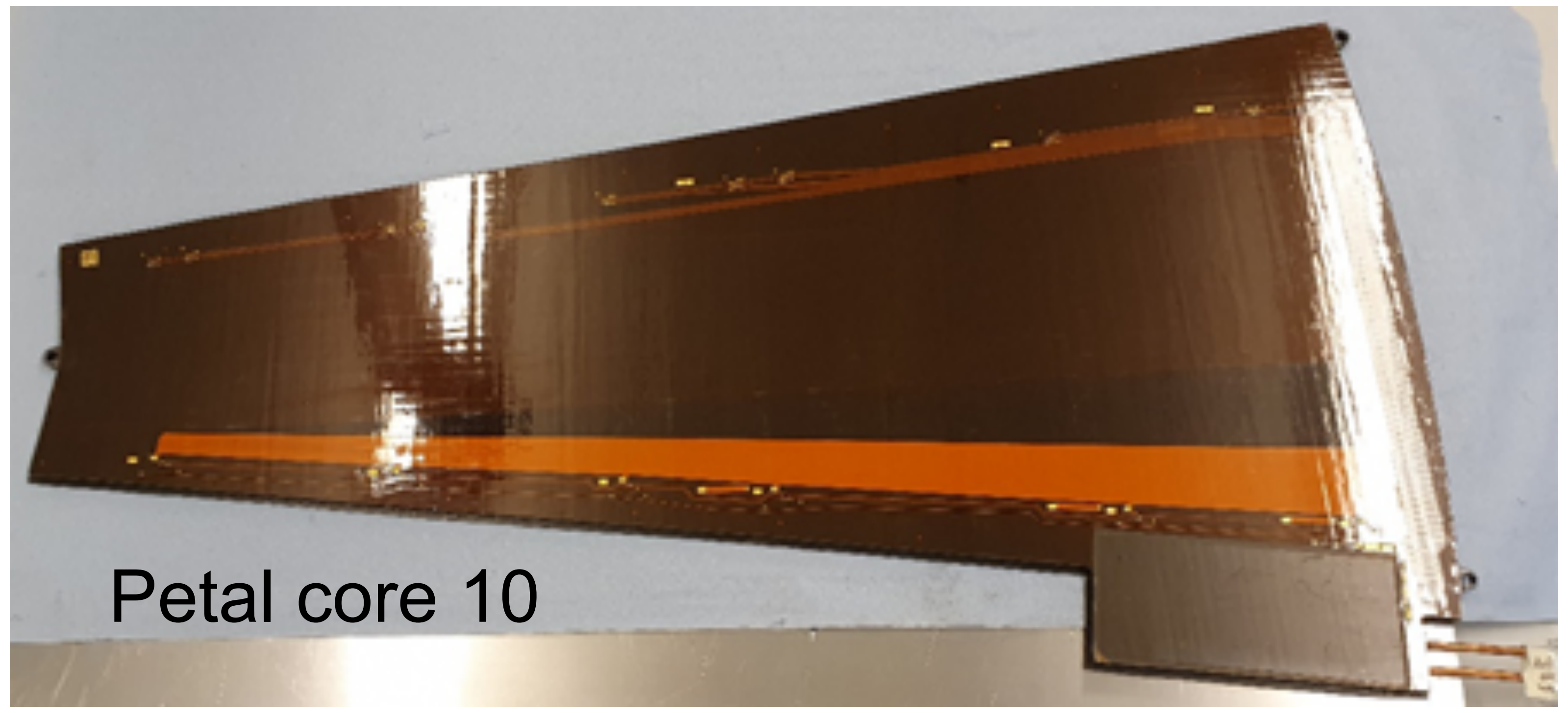
- Petal 09 (electrical petal) and petal 10 (soon to be sent for module population)

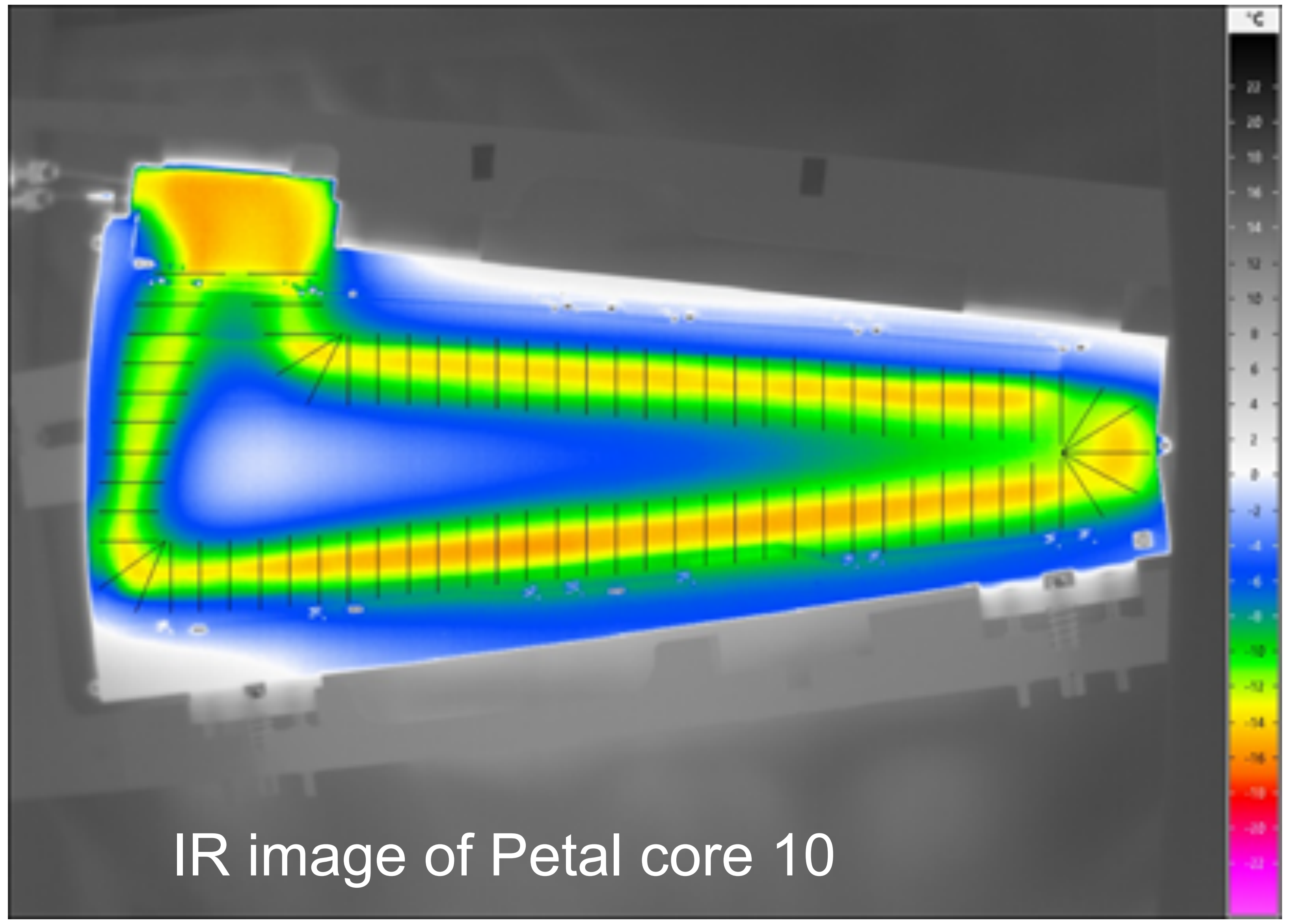
QC setups evolving rapidly and being used for the evaluation of petal 10

- Core metrology
- MARTA CO_2 test setup for cold testing + design of petal cold box
- Bus tape testing robot
- Pressure test setup

Tendering process for production core assembly completed at CERN: pre-selected vendor

- Next steps: vendor design files → review → prototype construction → QC and evaluation→ **green light for production**
- DESY will provide machined foam, cooling loops and co-cured facesheets
  - Already in hand for first prototype construction


Petal core 10

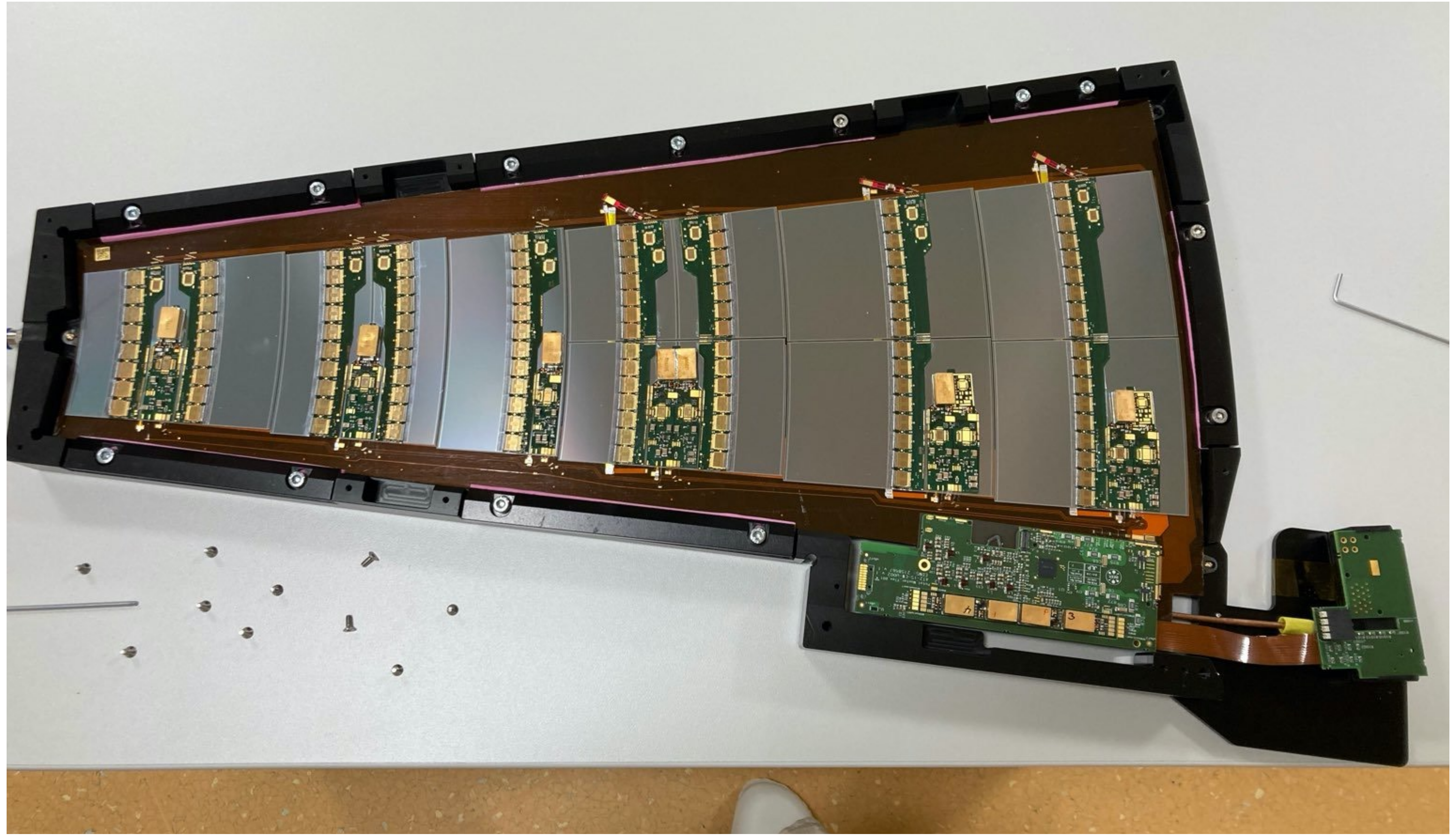

IR image of Petal core 10

Petal Testing

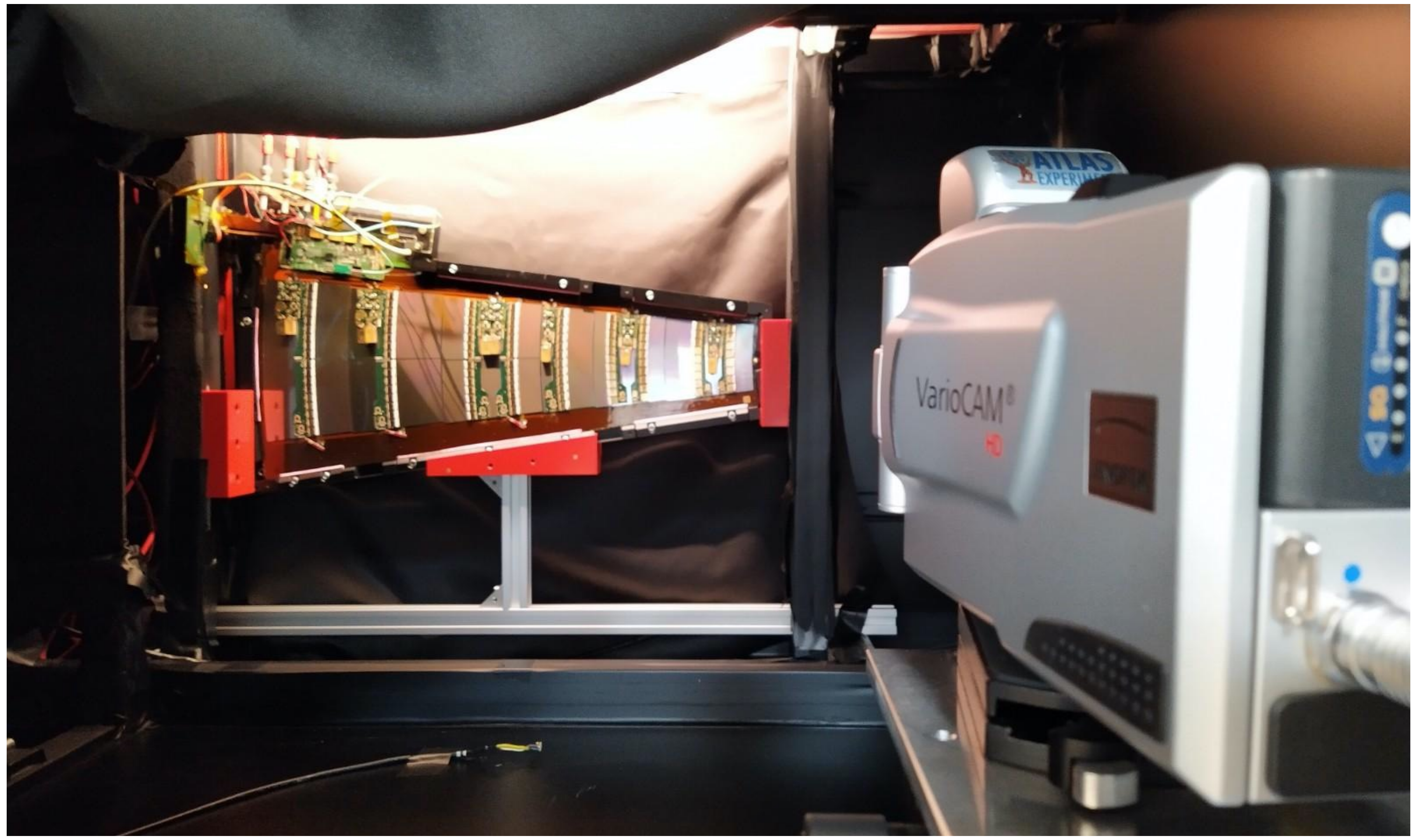
First fully electrical star petal at DESY for testing

- First batch of star modules received with final chipset
- Petal 9 loaded on one side with these modules
- Currently being tested with TRACI and MARTA CO_2 cooling systems in the thermal test chamber
  - allows to take IR images of the petal while testing
- Noise investigation at low temperature and HV scan ongoing to confirm the bustape and EoS design

Electrical Petal in assembly frame

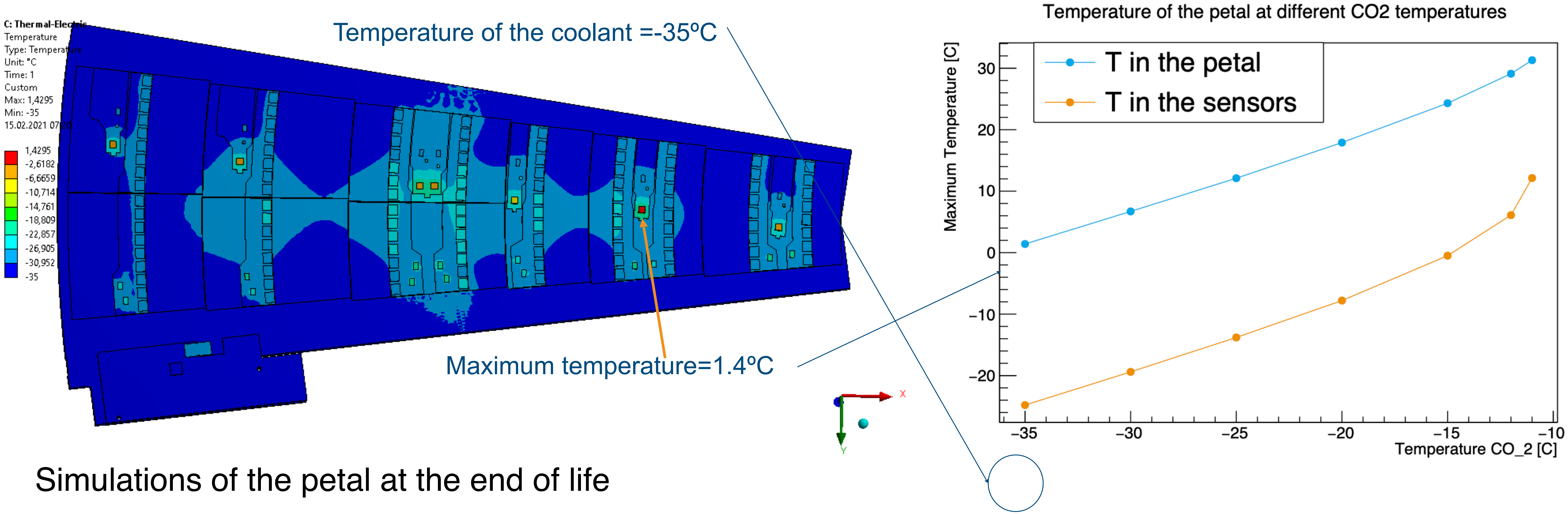


Petal placed into the PTM chamber



Petal Simulation

Thermoelectrical FEA simulations of the petal: runaway temperature



Simulations of the petal at the end of life

- Silicon considered with the resistivity received with a fluence of 6.34 x 10^{14} n_{eq}/cm^2

The runaway temperature will be reached at -11° C of the coolant temperature

Future simulations considering the exact glue pattern of the sensors to the bus tape might decrease slightly the runaway temperature (this simulation consider a full coverage of the glue with the sensor)

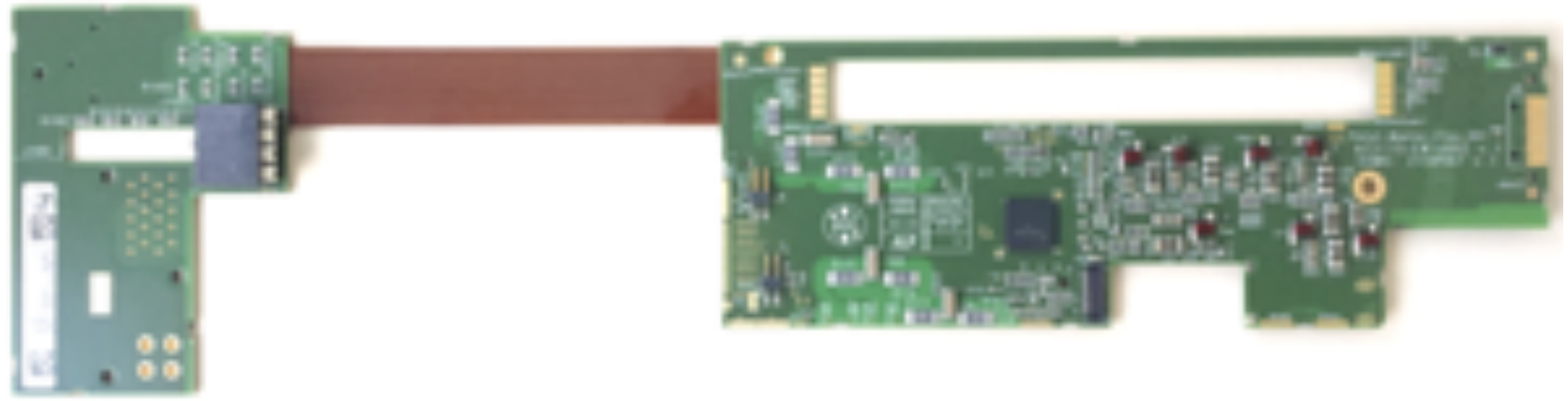
End of Substructure (EoS) card

Gateway between on- and off-detector components providing 10 Gbit/s links

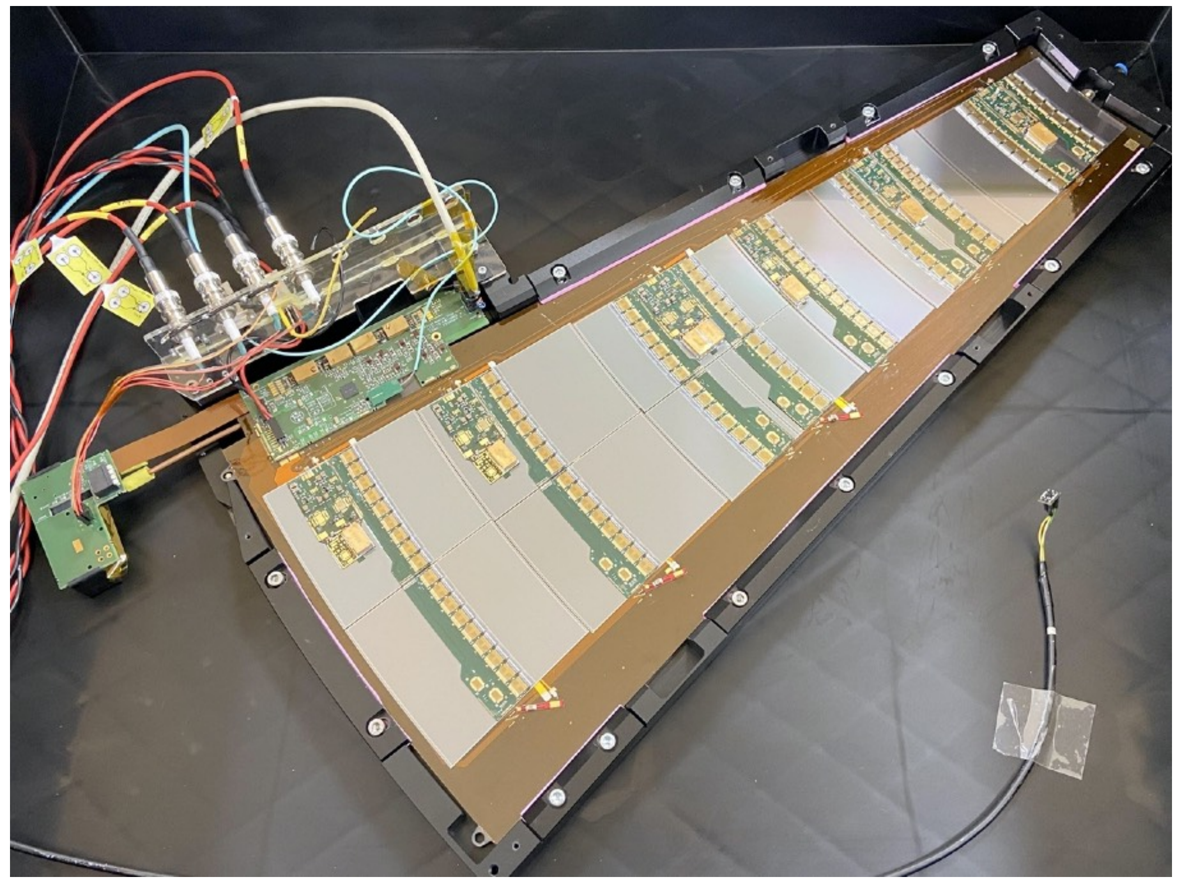
Local Support Electronics Activity Coordinator

- Production of EoS cards for ITk strip tracker at DESY (~2000 cards for both barrel and end-cap)
- At DESY: full infrastructure for designing and developing EoS cards, approval process, and production with short turnaround → important for system integration tests also outside DESY
- Petal master EoS card successfully used to readout data from populated petal core from Freiburg
- QC test-stands using the DAF infrastructure
  - Simultaneously probing hundreds of points on the EoS card using “needle-probe” test-stand
  - Environmental chamber stress tests
  - All test-stands approaching completion
  - Development of multi-tool control software (LabVIEW)

Ramping up for full production in 2021



EoS card
Prototype petal master

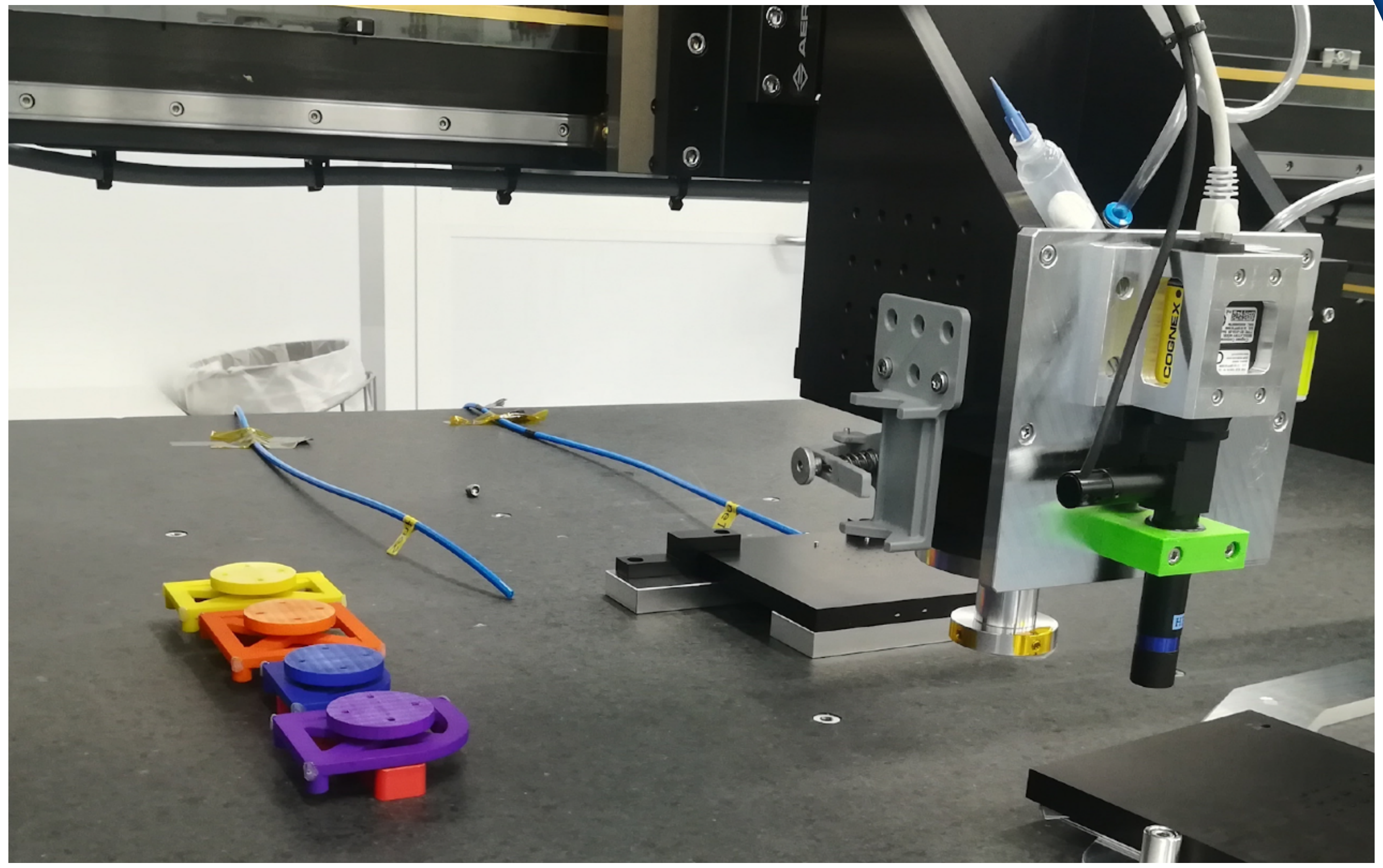


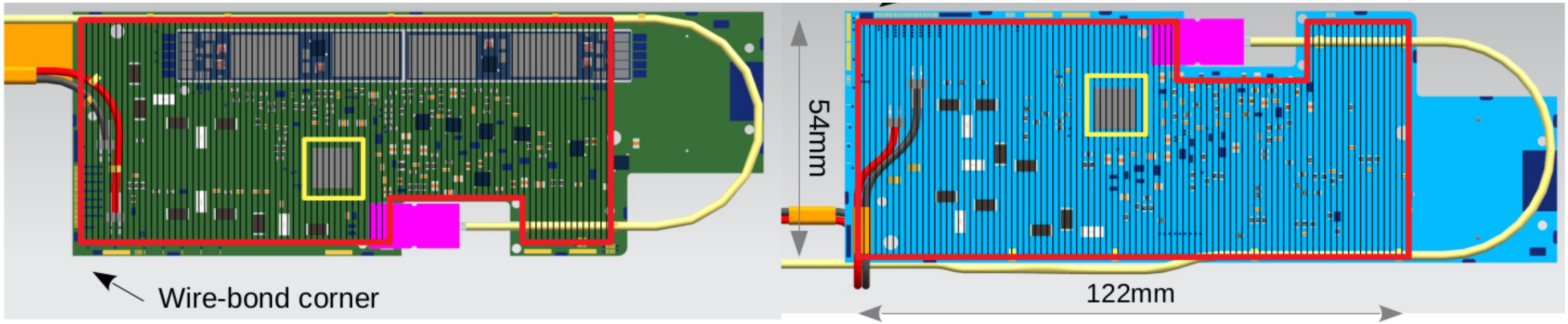
EoS integration
Petal core 09 loaded with modules and EoS master at DESY

Needle-probe test-stand at DESY

Fully automated technique to pick and place modules and EoS on the petal core

- Routine for module placement optimized to fulfil the requirements
- 3D printed pickup tool changed to be suitable for Star modules
- Gluing pattern development for Master and Slave Petal EoS ongoing
  a. 120 um glue thickness provided by kapton spacer (same concept as for modules)
  b. lpGBT (on both cards) and DC/DC (on master card only) to be cooled down
  c. holes in the PCB to be avoided

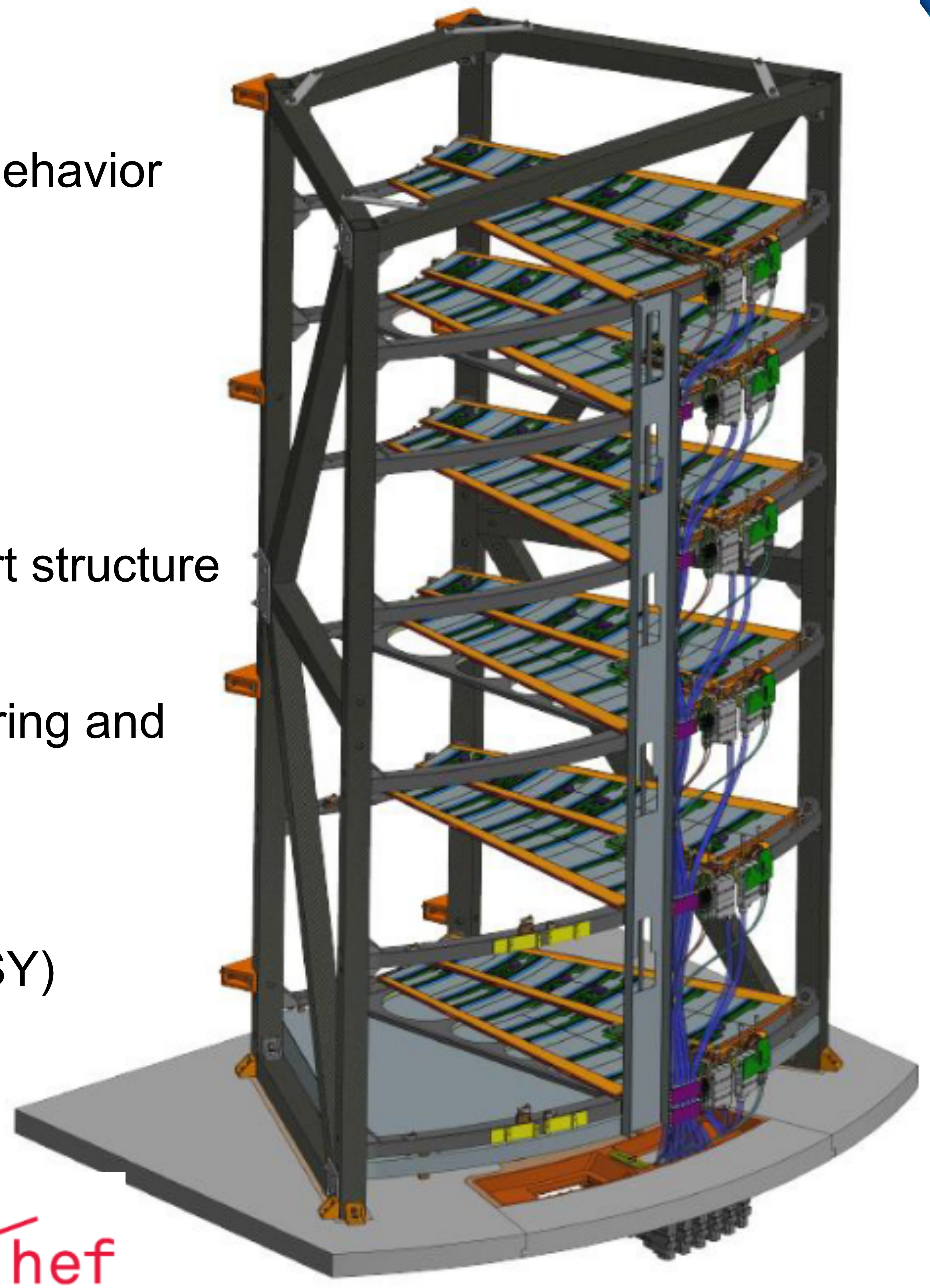




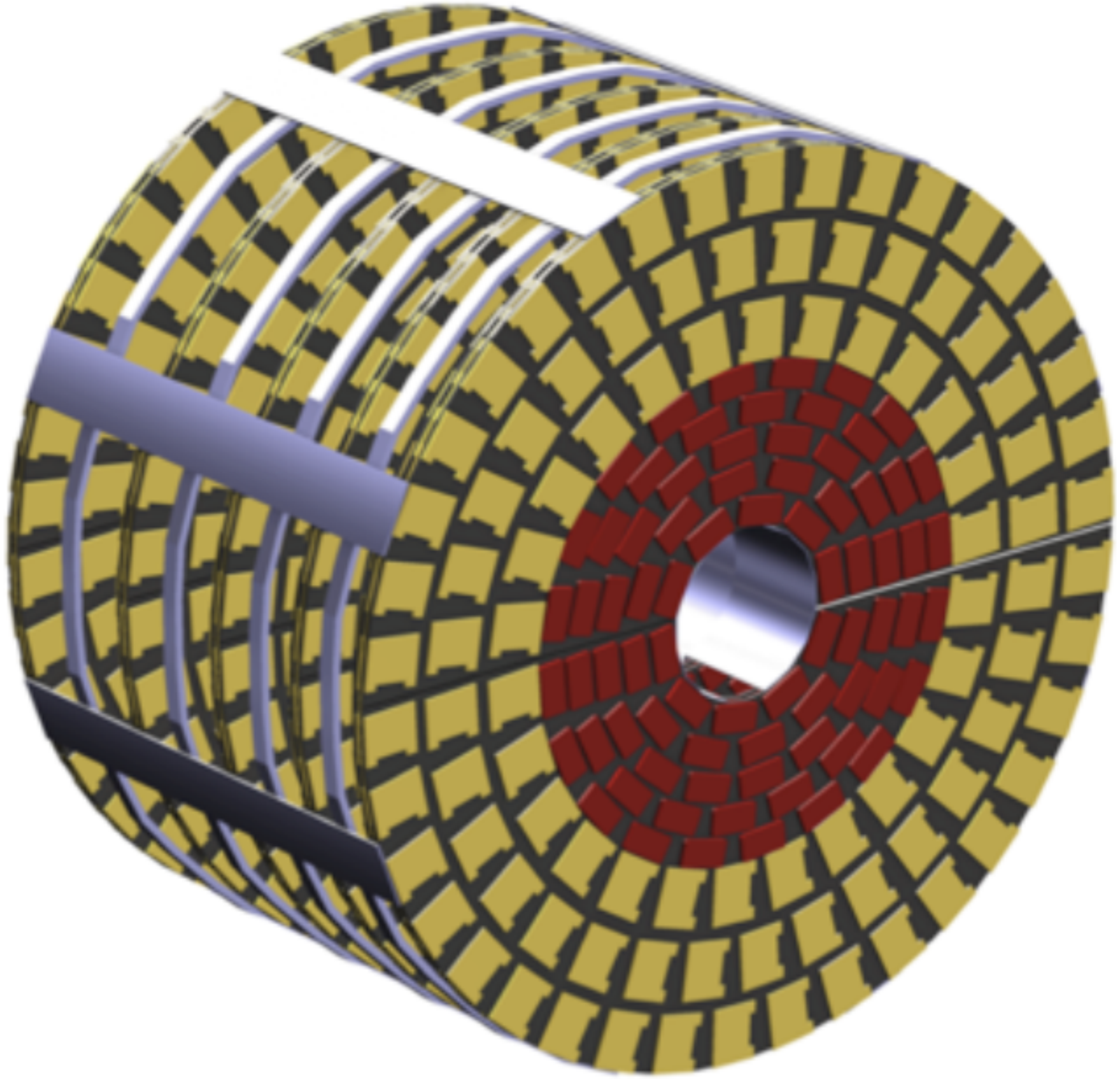
Master EoS (petal front side) **Slave EoS (petal back side)**

Designing the setup

- Plan: built a 1/8th slice of the EC populated with in total 12 petals
  - test different permutations of petals in the structure to study electrical noise behavior between petals
  - will be located at DESY, afterwards move to CERN for full strips system test
- Need realistic mechanical structure with electrical services and cooling infrastructure
  - real mechanical CF disk structure with bulkhead and additional lateral support structure (designed by IFIC, built by NIKHEF)
  - real CF service tray (built by DESY) with prototype electrical cables for powering and readout (provided by IFIC)
  - CO_2 cooling lines with temporary connections (provided by NIKHEF)
  - thermal / humidity / Faraday enclosure for full setup (designed & built by DESY)

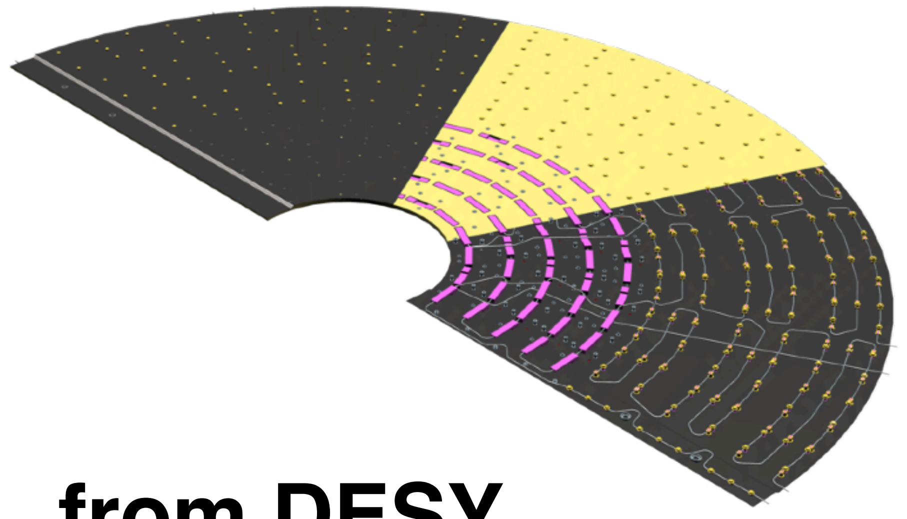


CMS Tracker

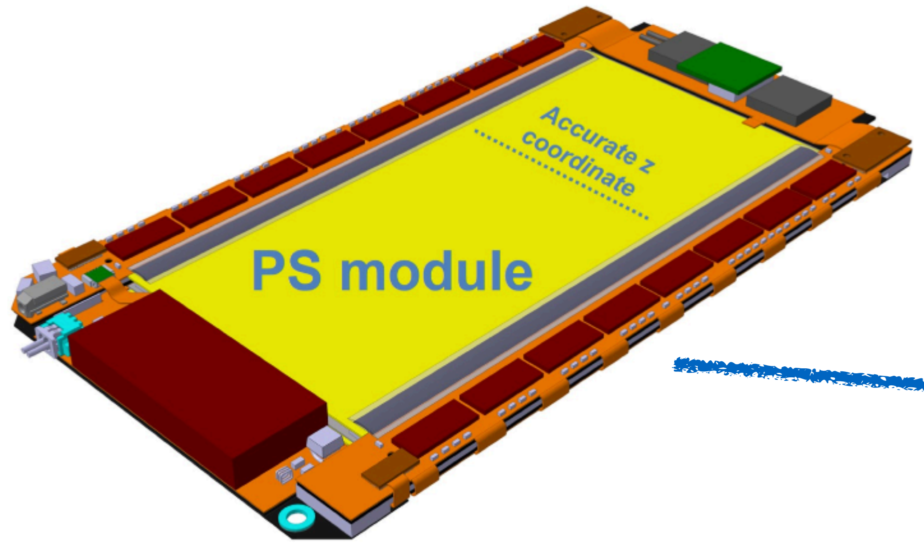


From Modules to TEDD

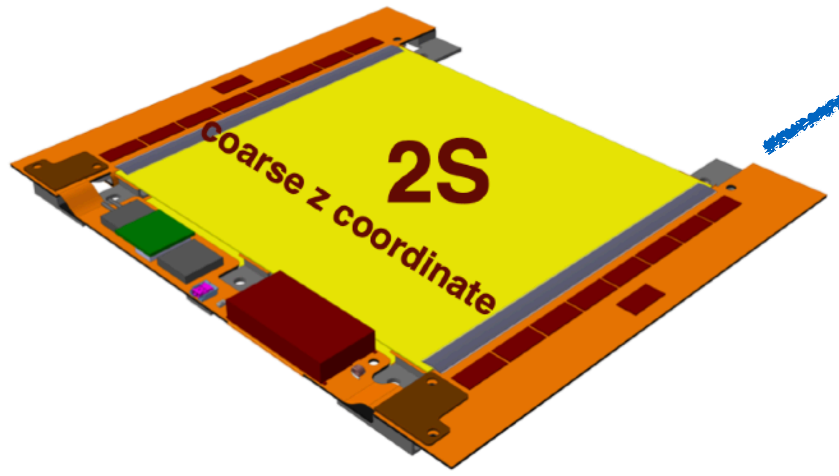
Modules Dees | **even/odd Dees** | **Discs** | **Double-Discs** | **TEDD**



from DESY

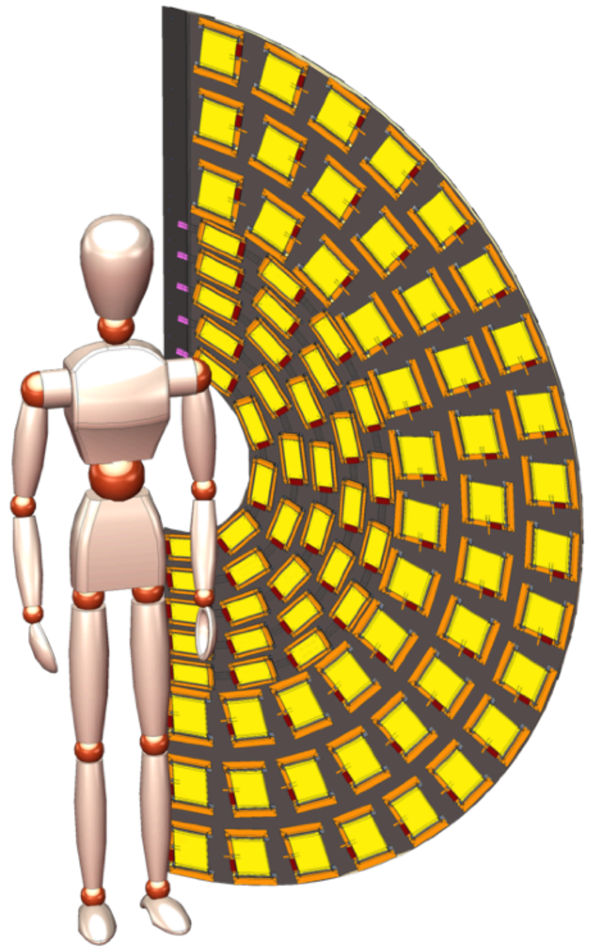


from Aachen, other institutes

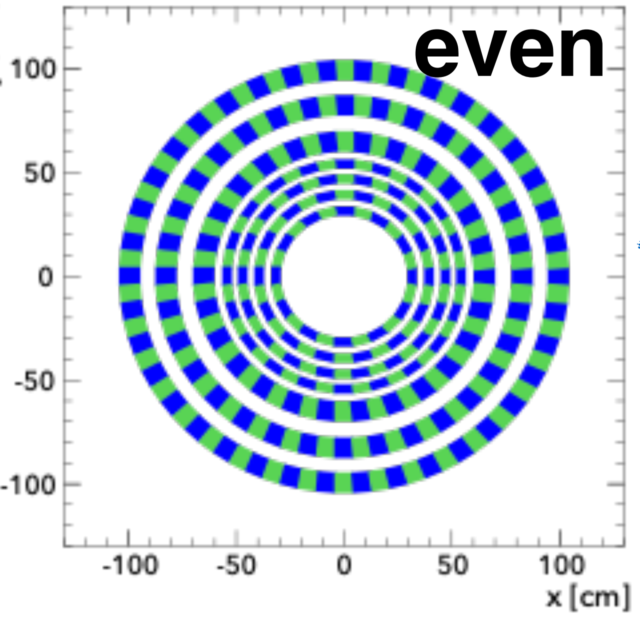


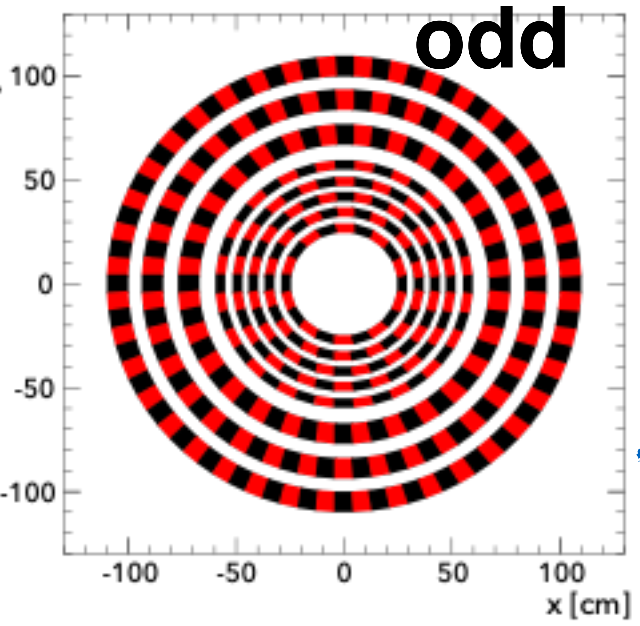
Thermal Test Metrology

Burn-In

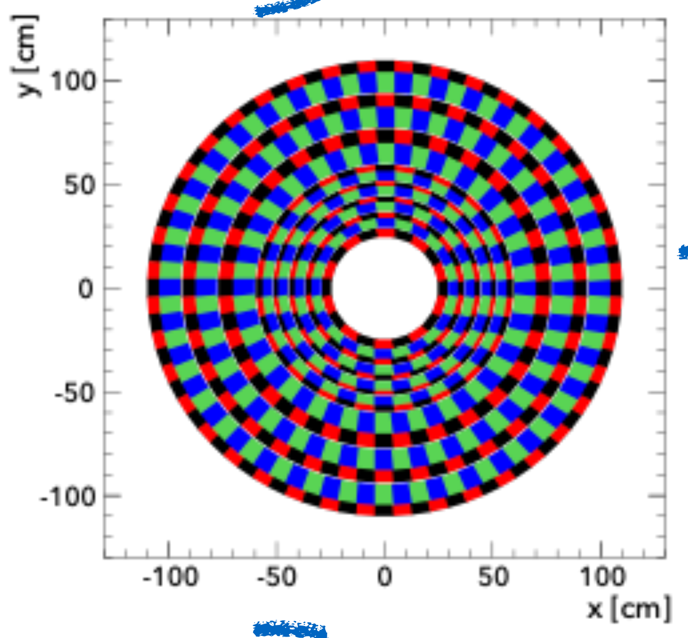


upper + lower Dee



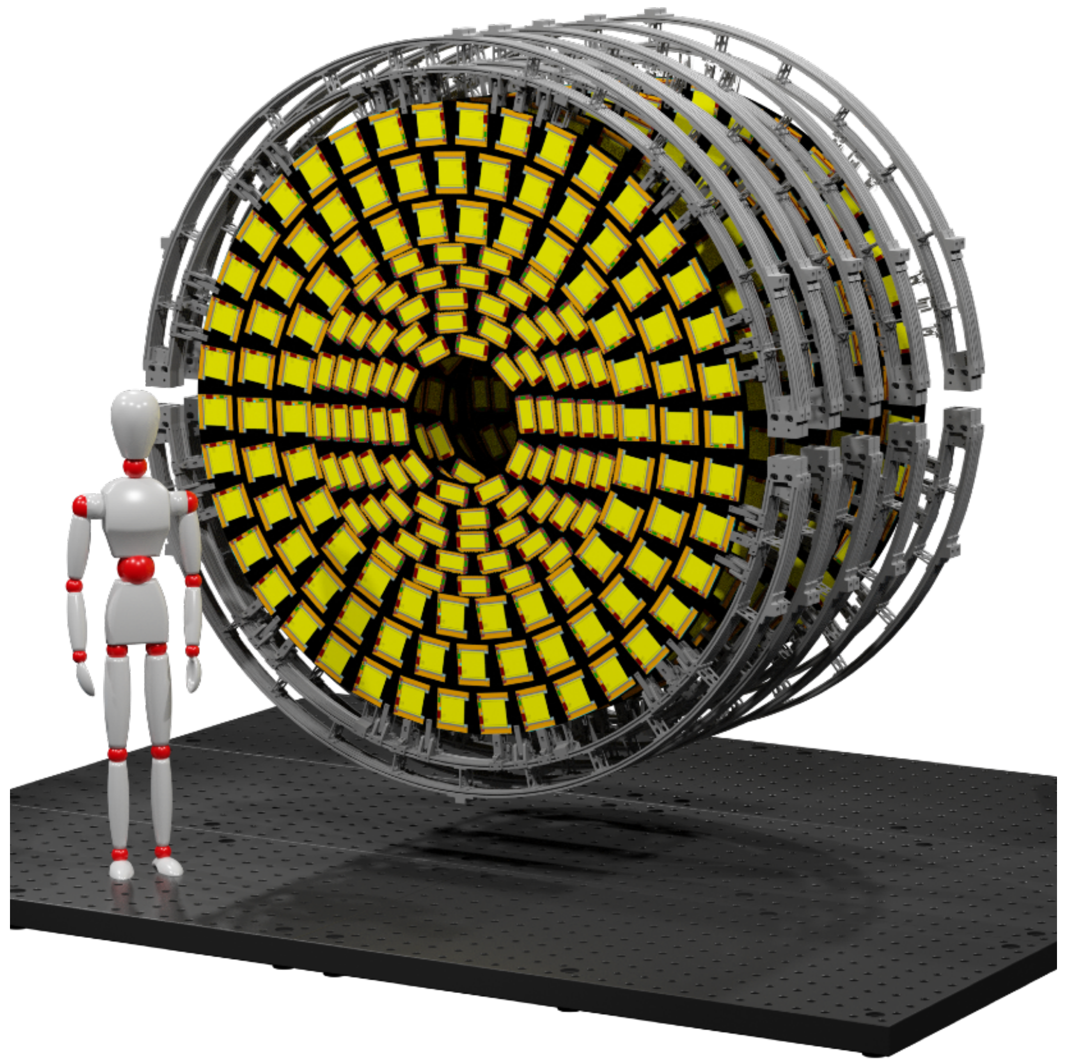


even + odd Disk

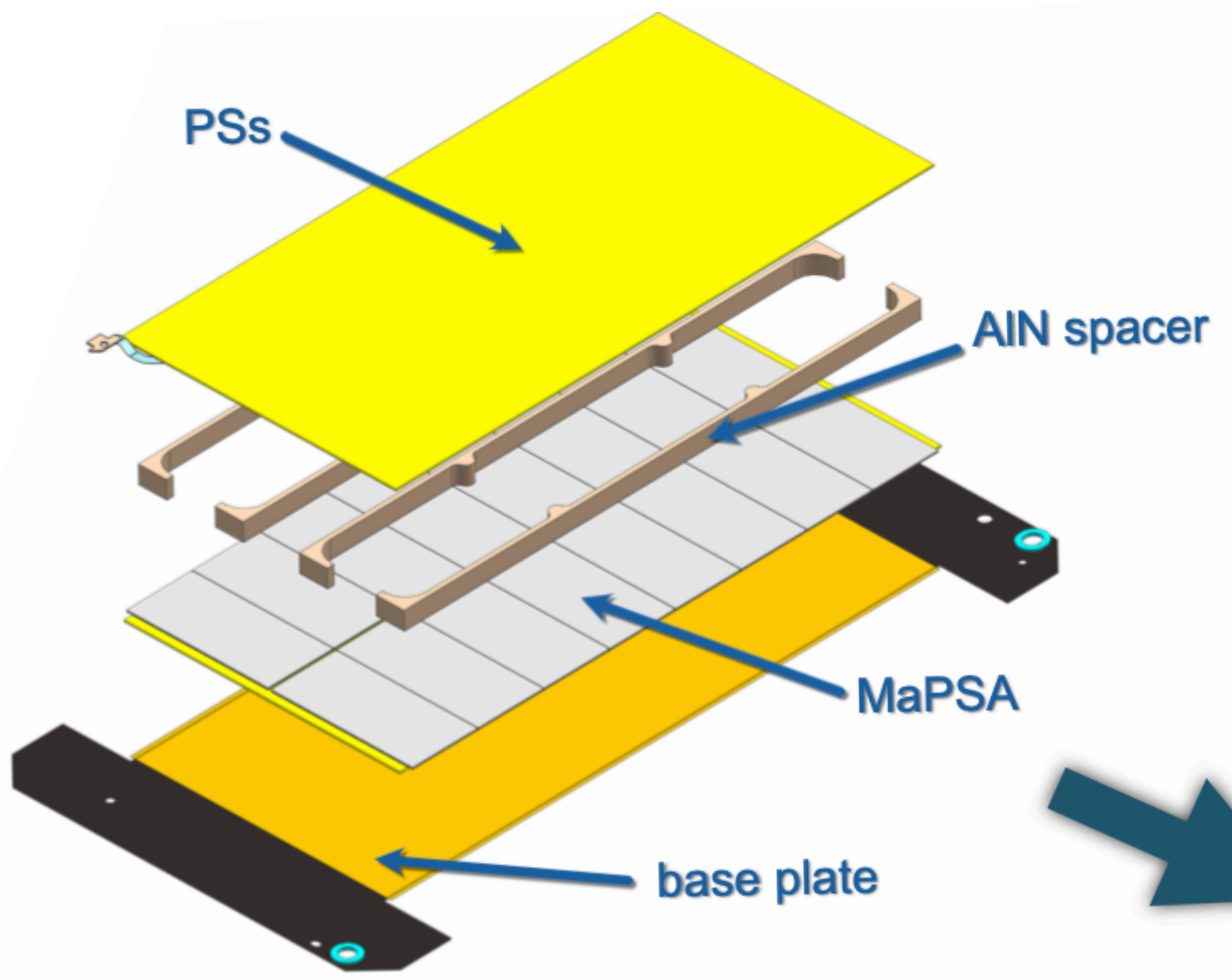


Dee Sector Test Metrology

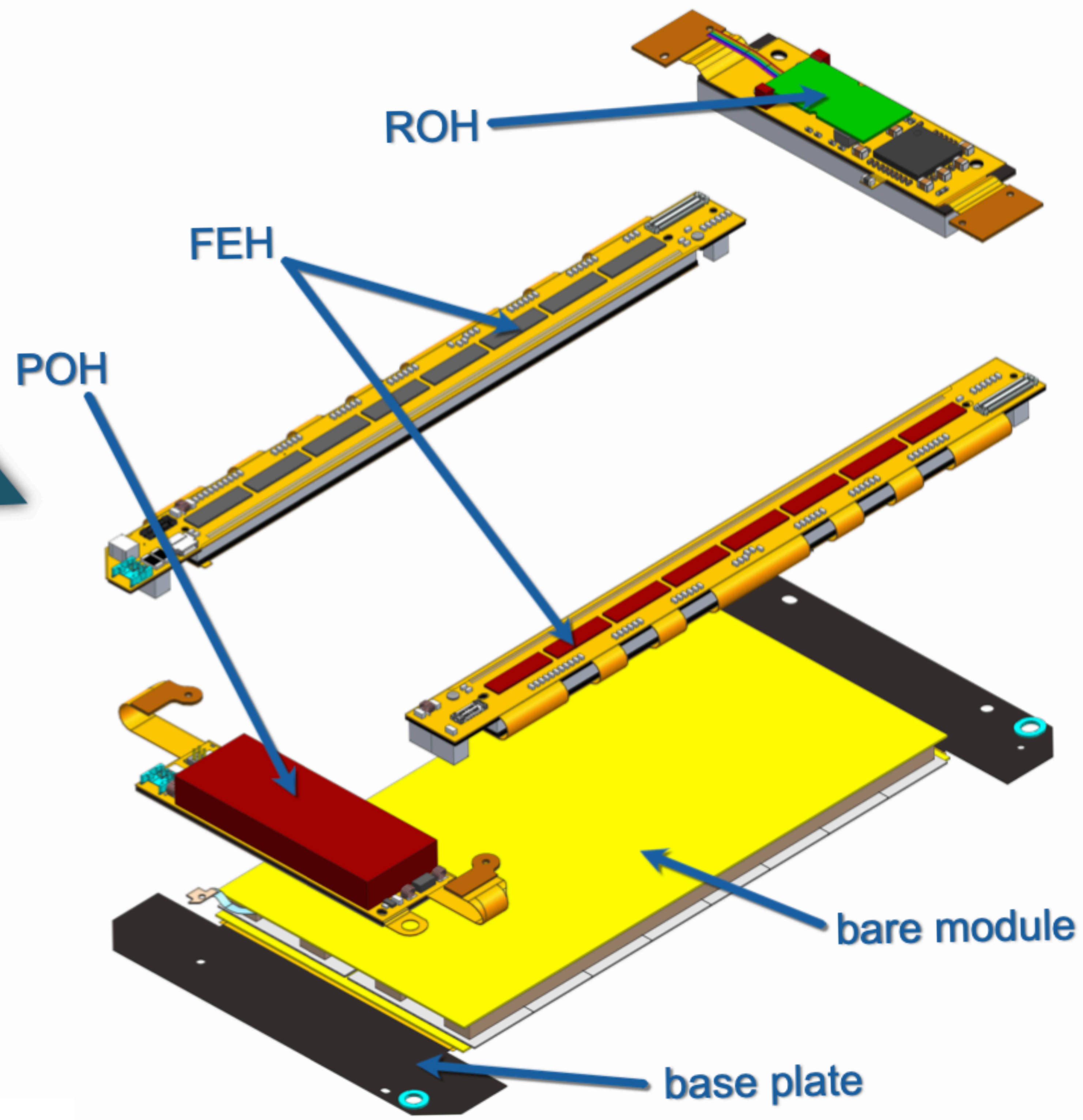
5 Double-Disks



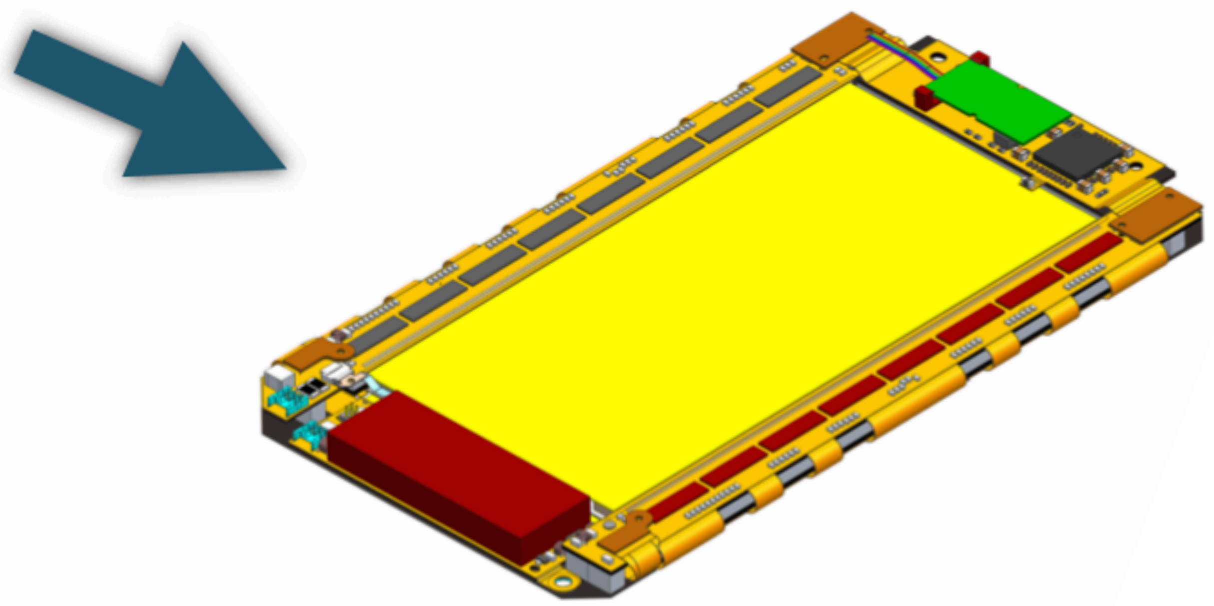
Module Assembly - PS Modules



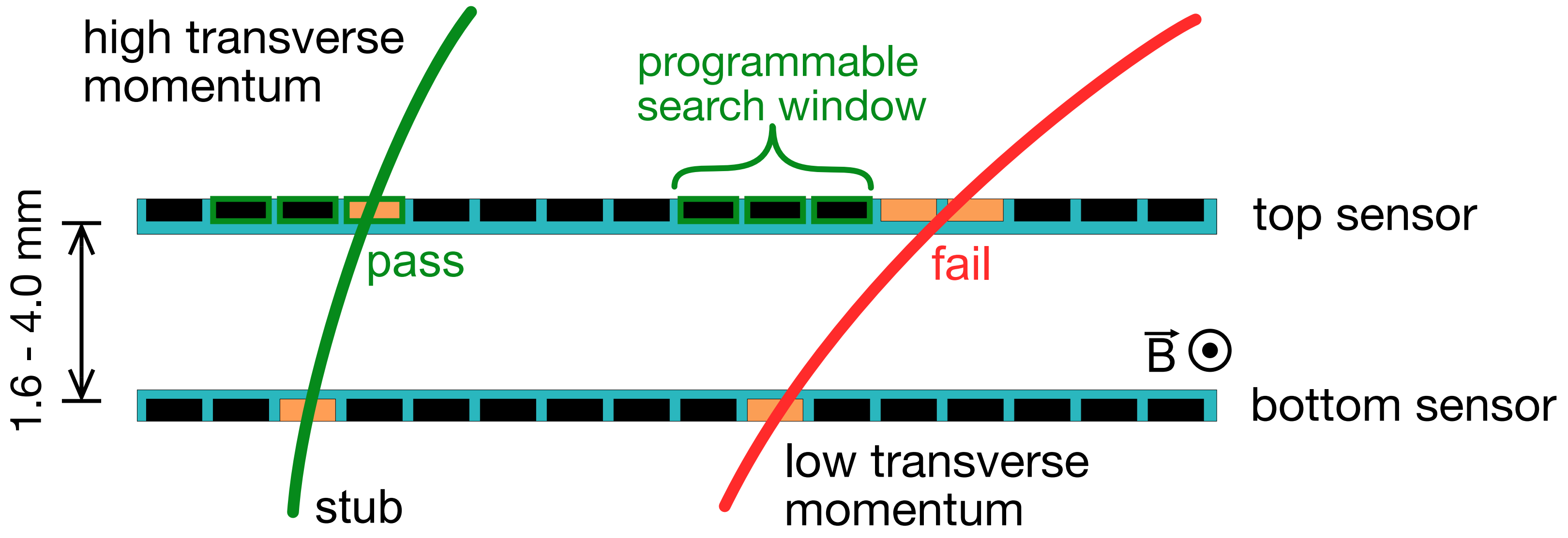
- Relative sensor to sensor alignment $\leq 800\ \mu rad$
- Assembly is done on a robotic system



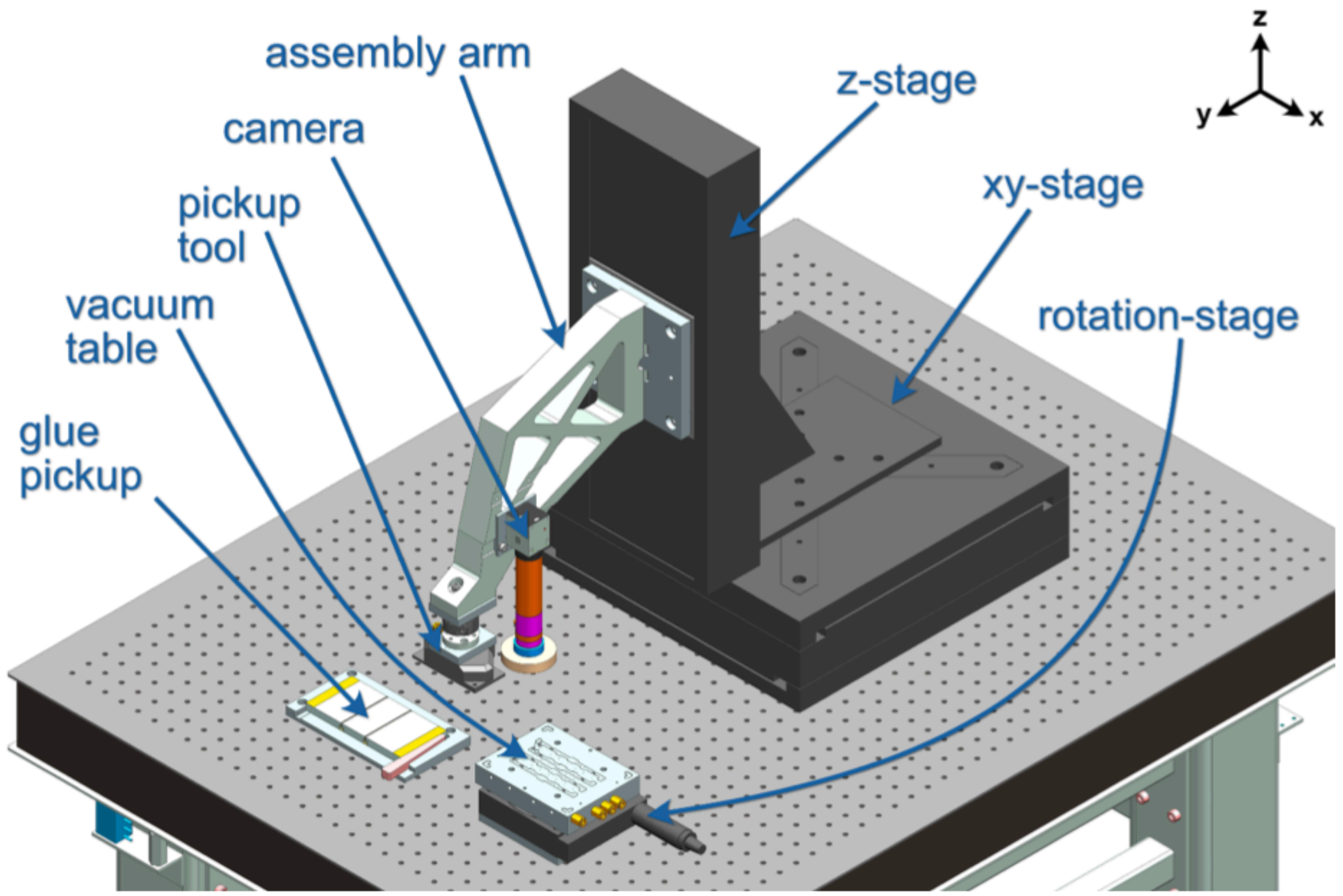
Hybrids are attached to bare module using jigs

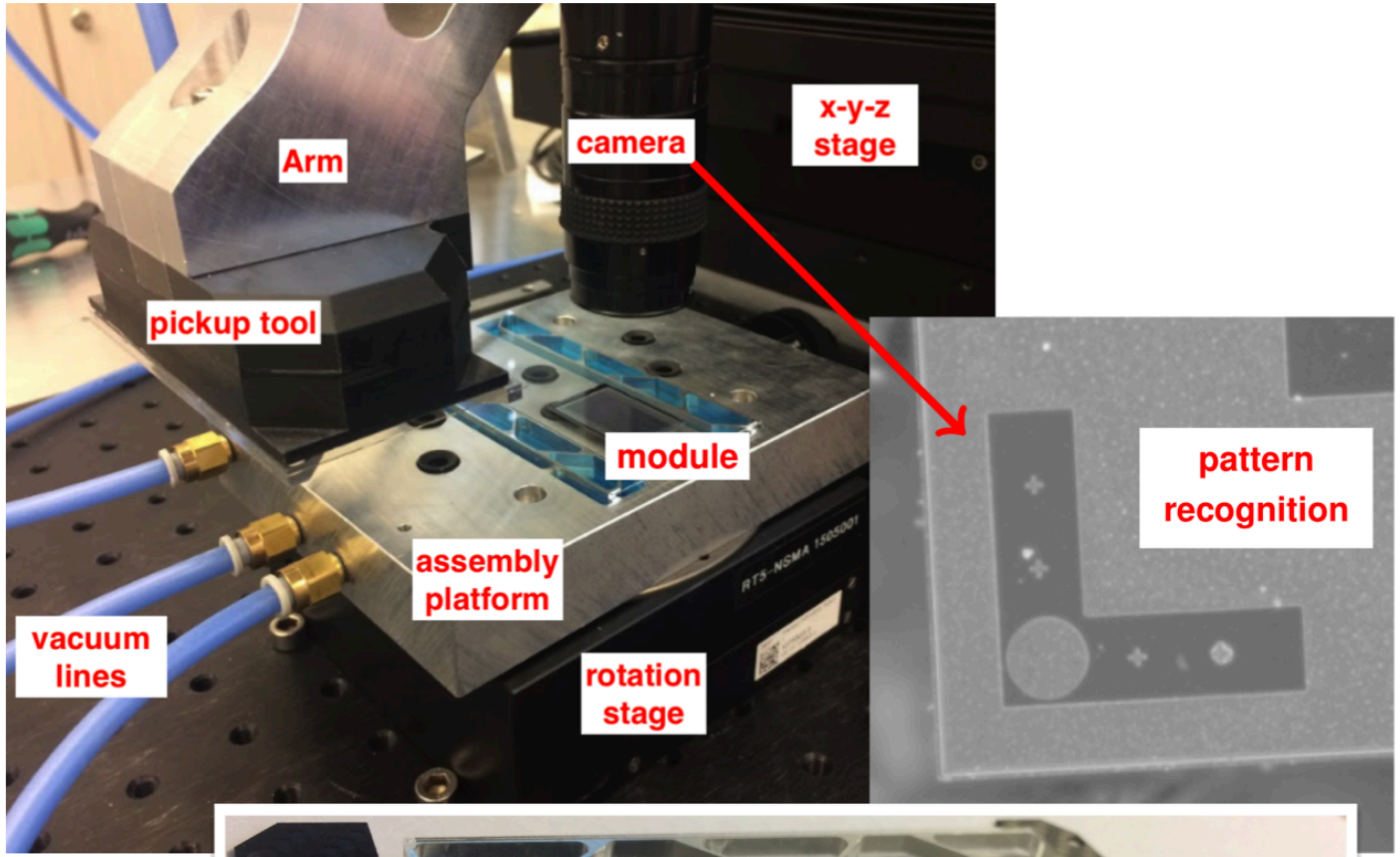


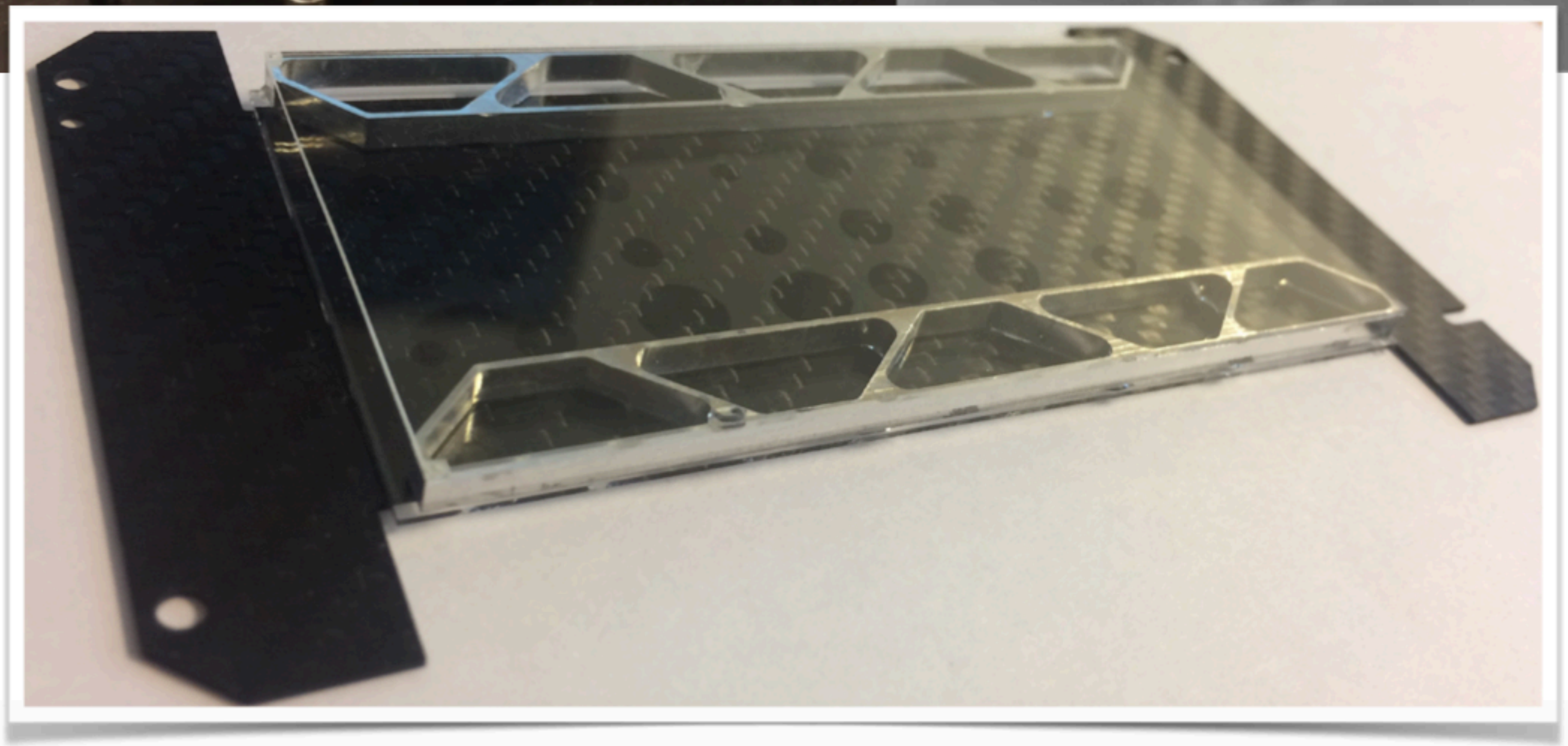
1250 PS modules to be built at DESY



Automated Assembly of Bare Module







- Relative alignment of object is measured with microscope camera and pattern recognition
- Assembly precision does not rely on cut edges of sensors
- Development of the system driven by DESY
- Setup in the meantime also copied at Brown and FNAL

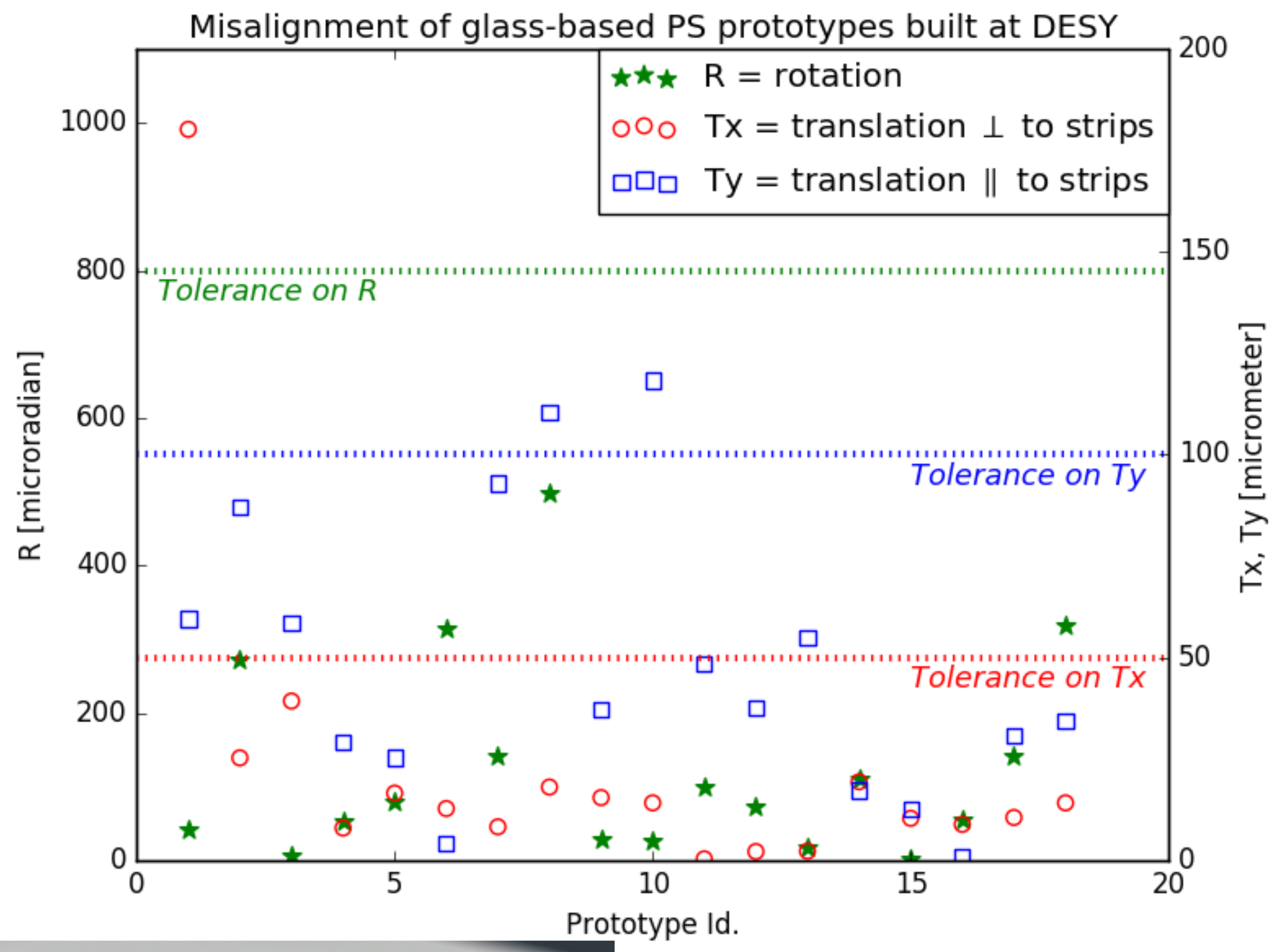
Module Plans 2021

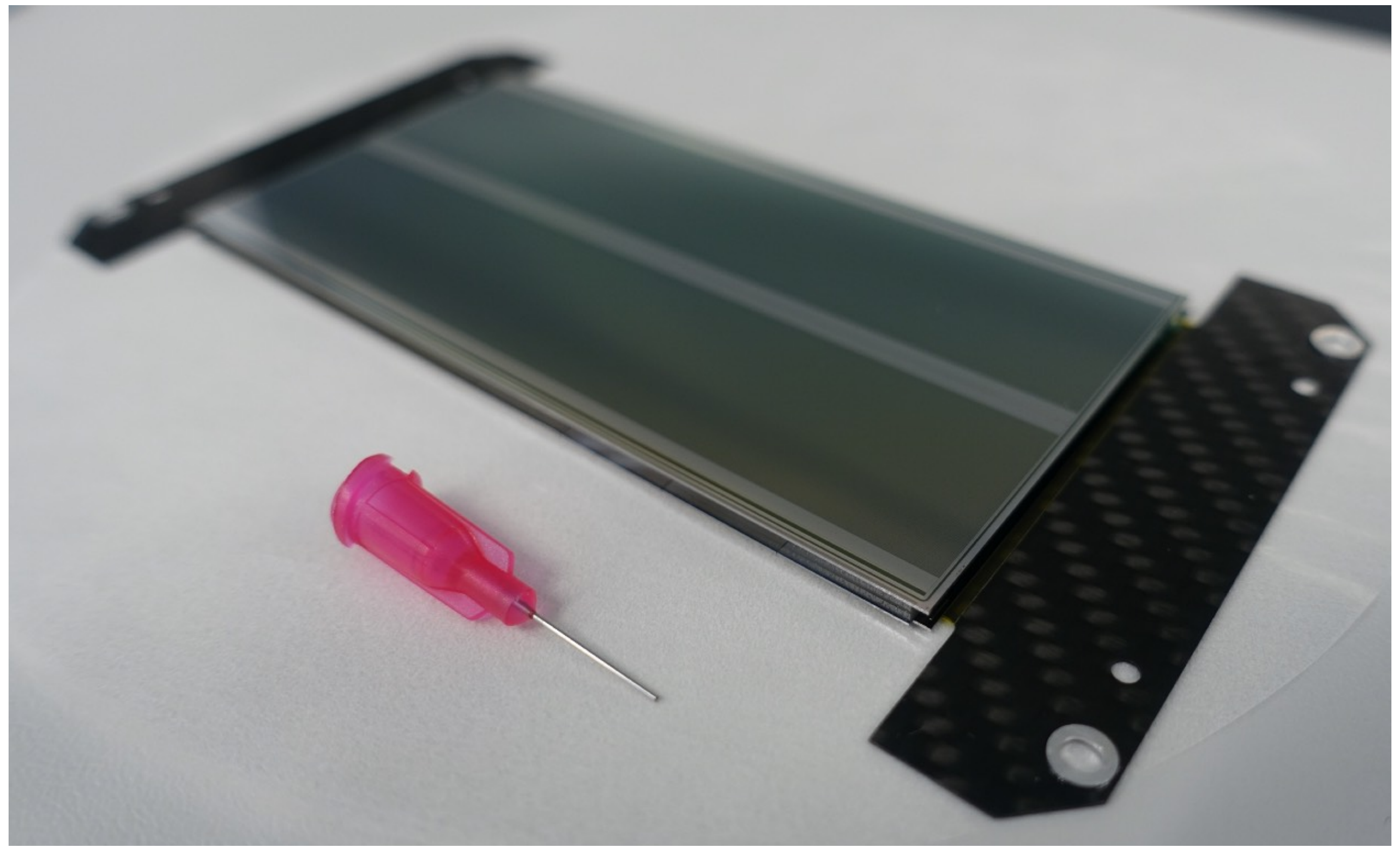
- Have produced several prototype modules with glass samples of different thickness
- Extensive tests and optimisations of automatic assembly procedures
- Adaptations to changes in design (spacers)
- A mechanical prototype with silicon dummy sensors built within specifications
- Preparing for qualification as module production site

- Plans for 2021 for final prototypes:
  - Production of 1/2 PS module
  - Test-beam in end of June
  - Currently preparing remaining tooling for module assembly
  - Production of one full 2.6mm PS module
  - Production of three full 4mm PS modules

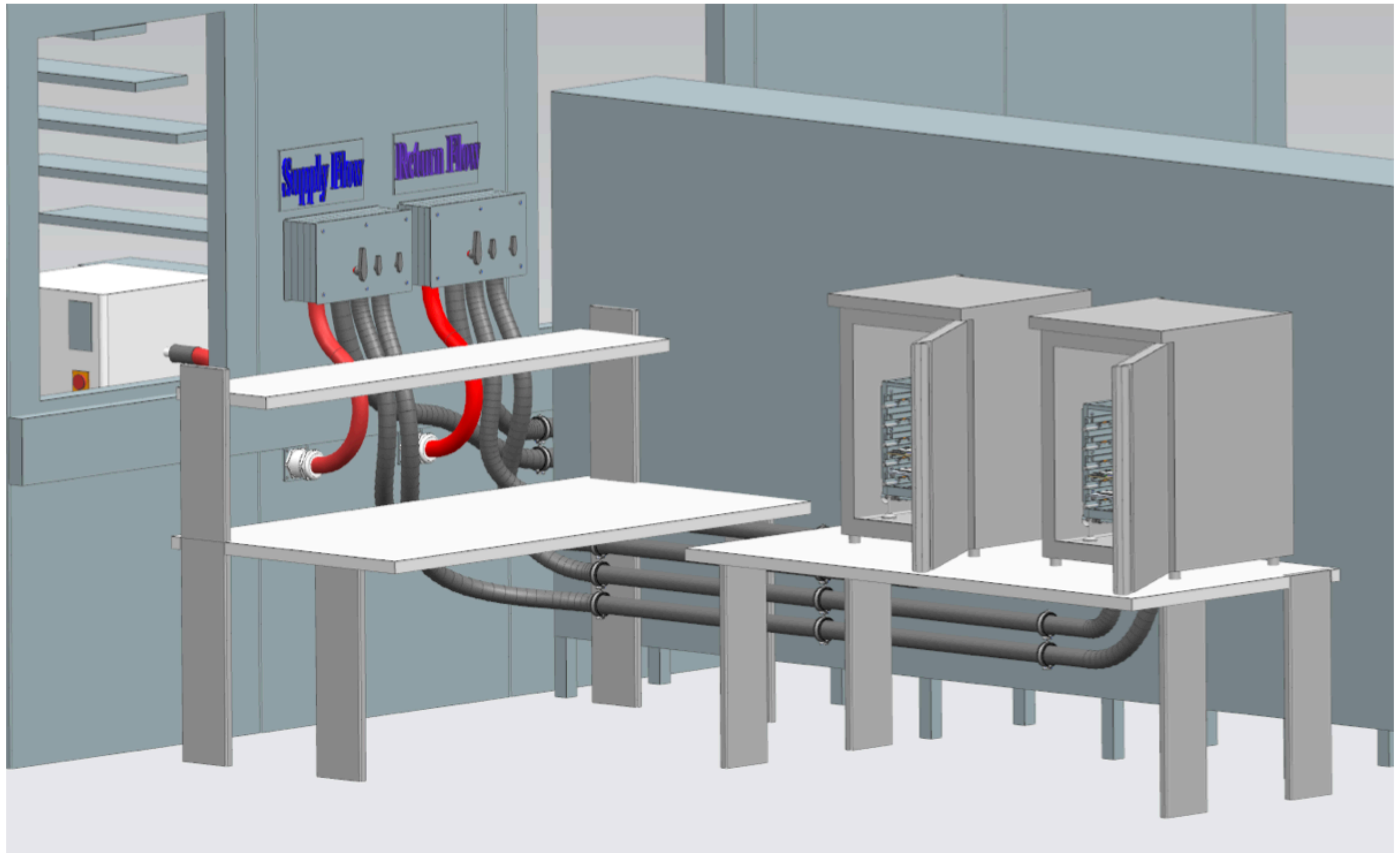
- Test beam in June essential for the project
  - first PS module with CIC2
  - first testbeam with PS and 2S modules in parallel
  - essential for testing system aspects

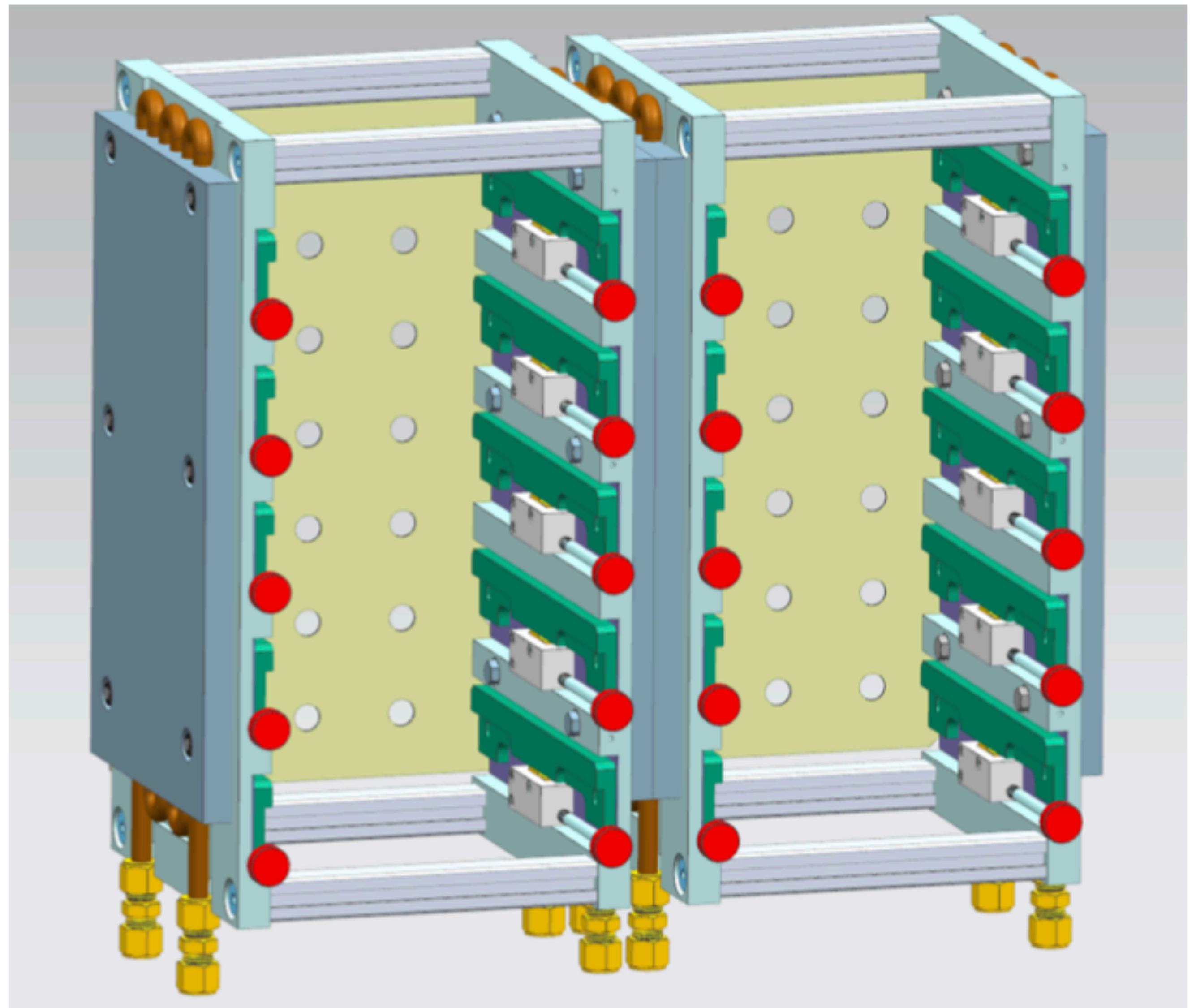
  - Module pre-production to start in August 2022

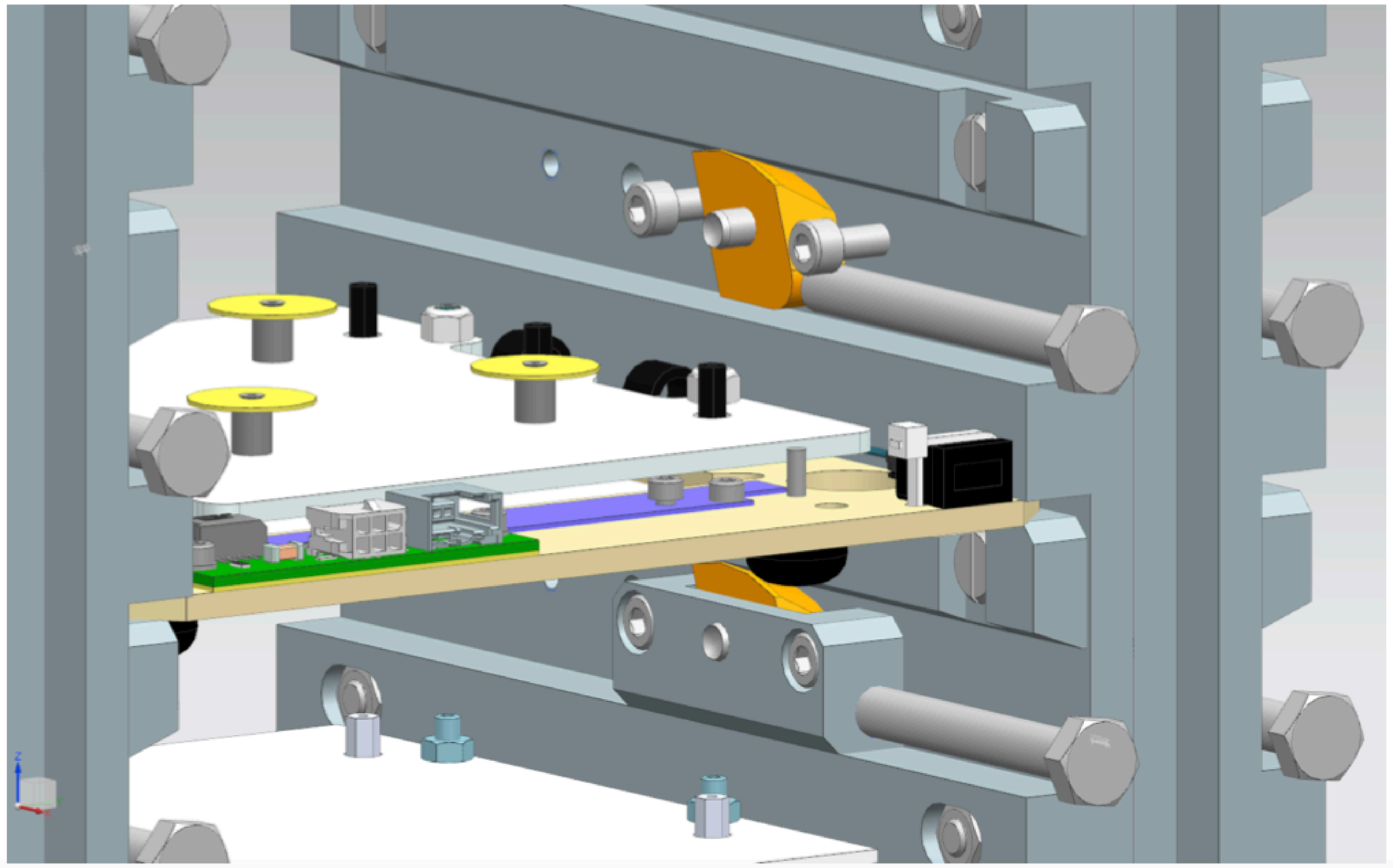




Module Burn-In Setup





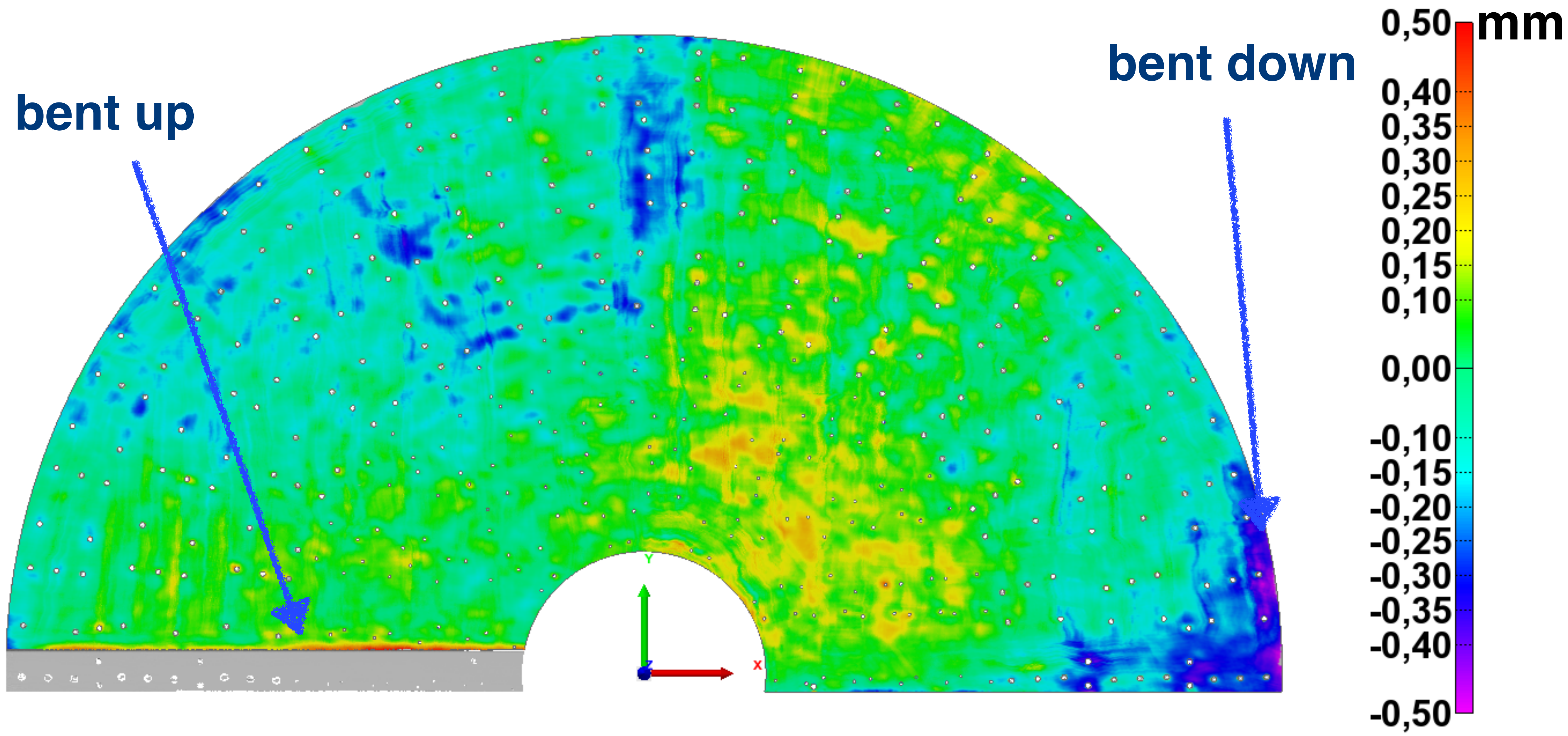


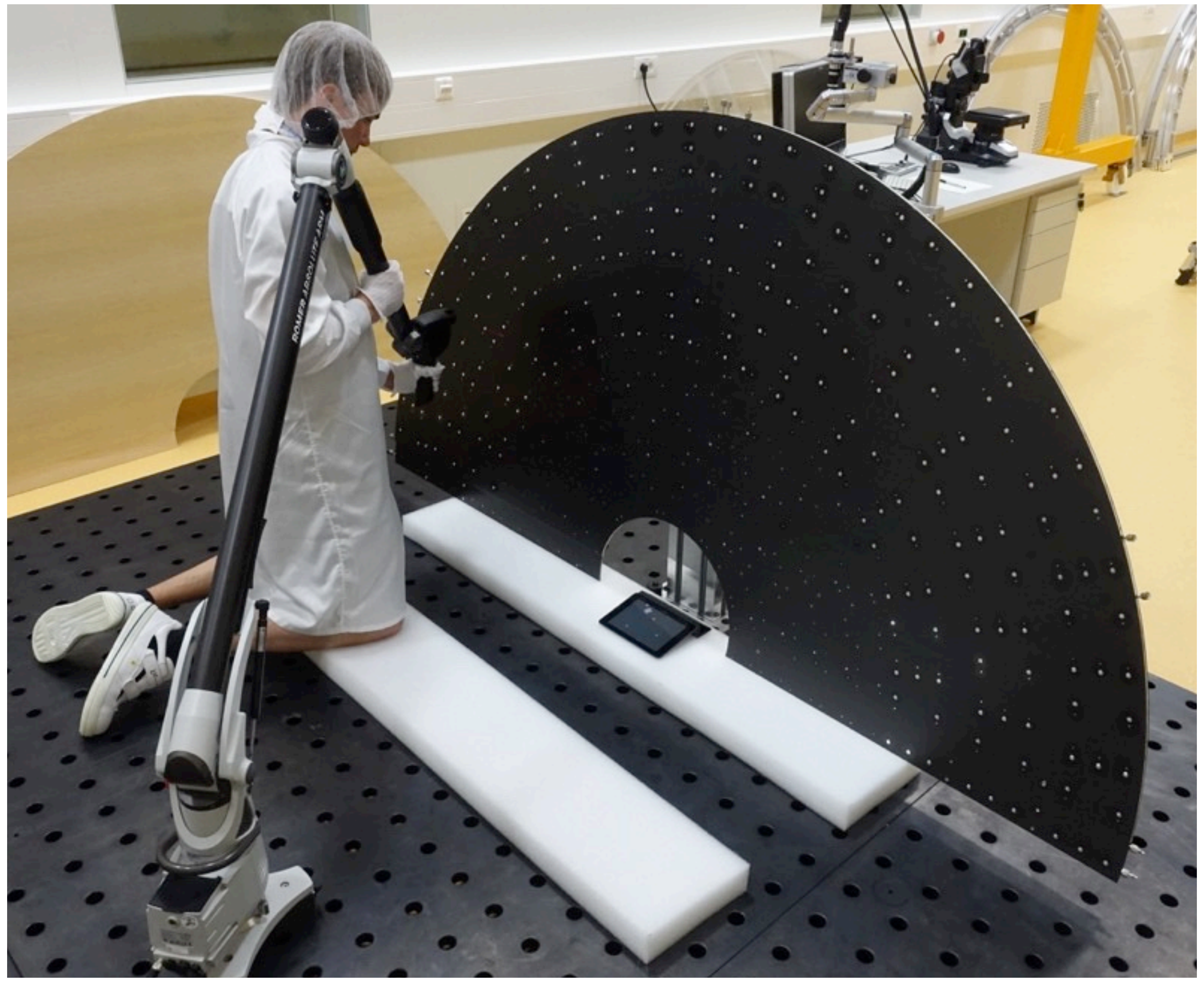
- System designed at FNAL and adapted
  - only metric parts used in the DESY system
- Modules on their carrier plates are clamped to cooling plates
- Two independent setups with 10 slots each
- DESY will perform burn-in test for the DESY PS modules and all 2S modules built in Aachen
- Delivery of all parts is expected by the end of June

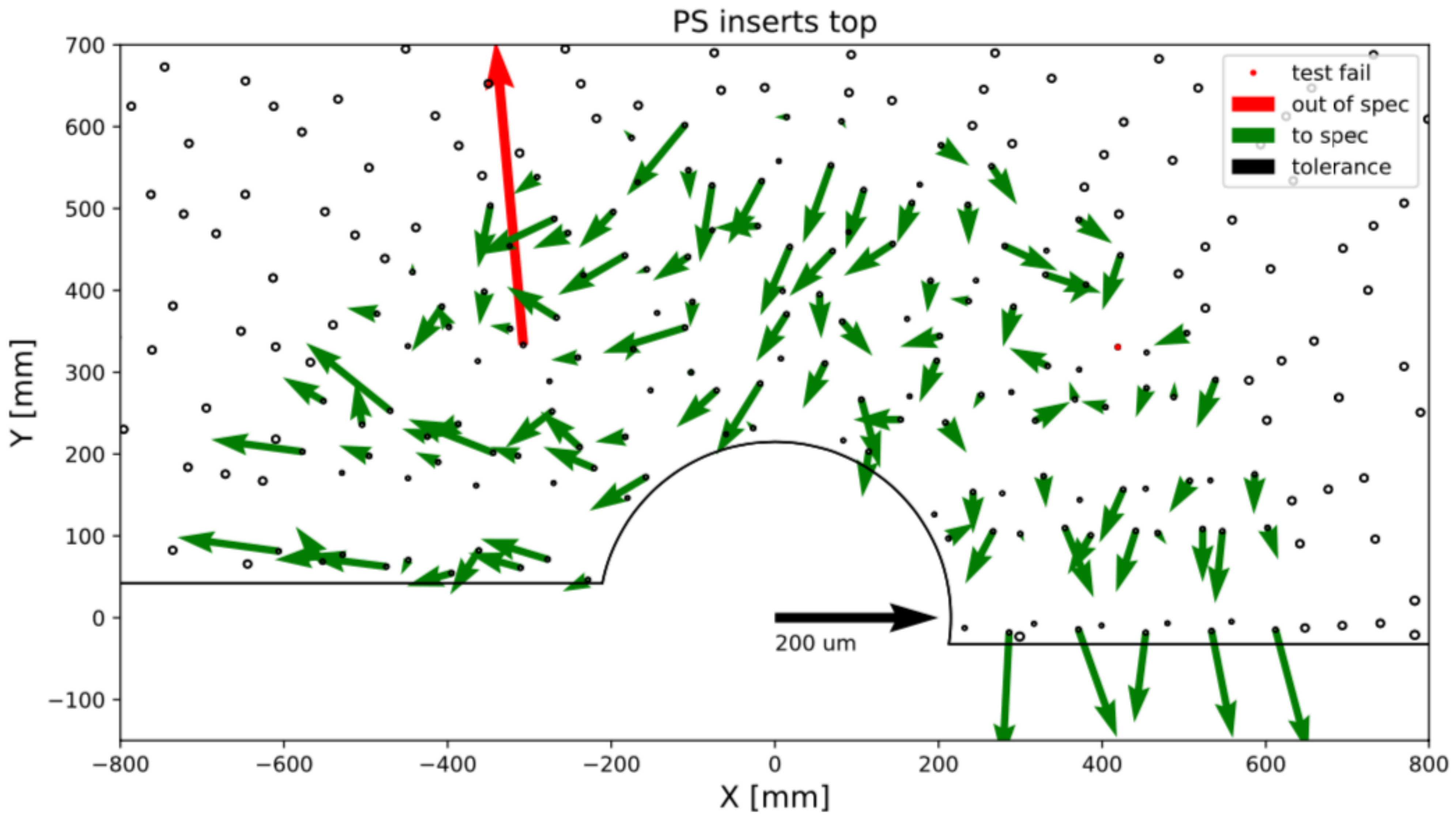
Dee Reception Test - Metrology

- Full size Dee Prototype received
- Metrology of inserts and laser scan performed
  - Results mostly satisfying
  - Sufficient flatness
  - inserts mostly positioned within 200um tolerance (green arrows), one outlier (red)
  - some inserts filled with glue

—> production process will be improved for future production



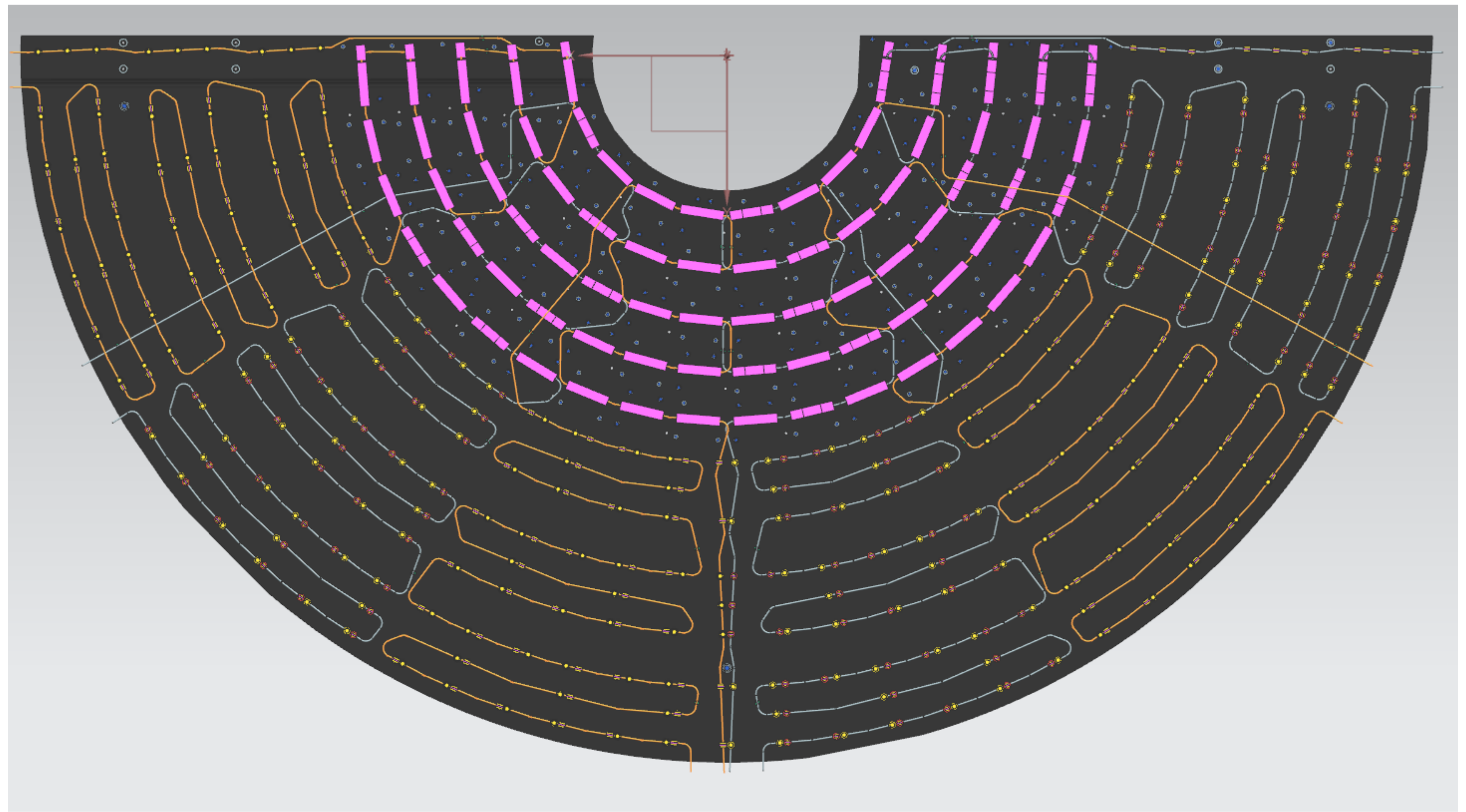




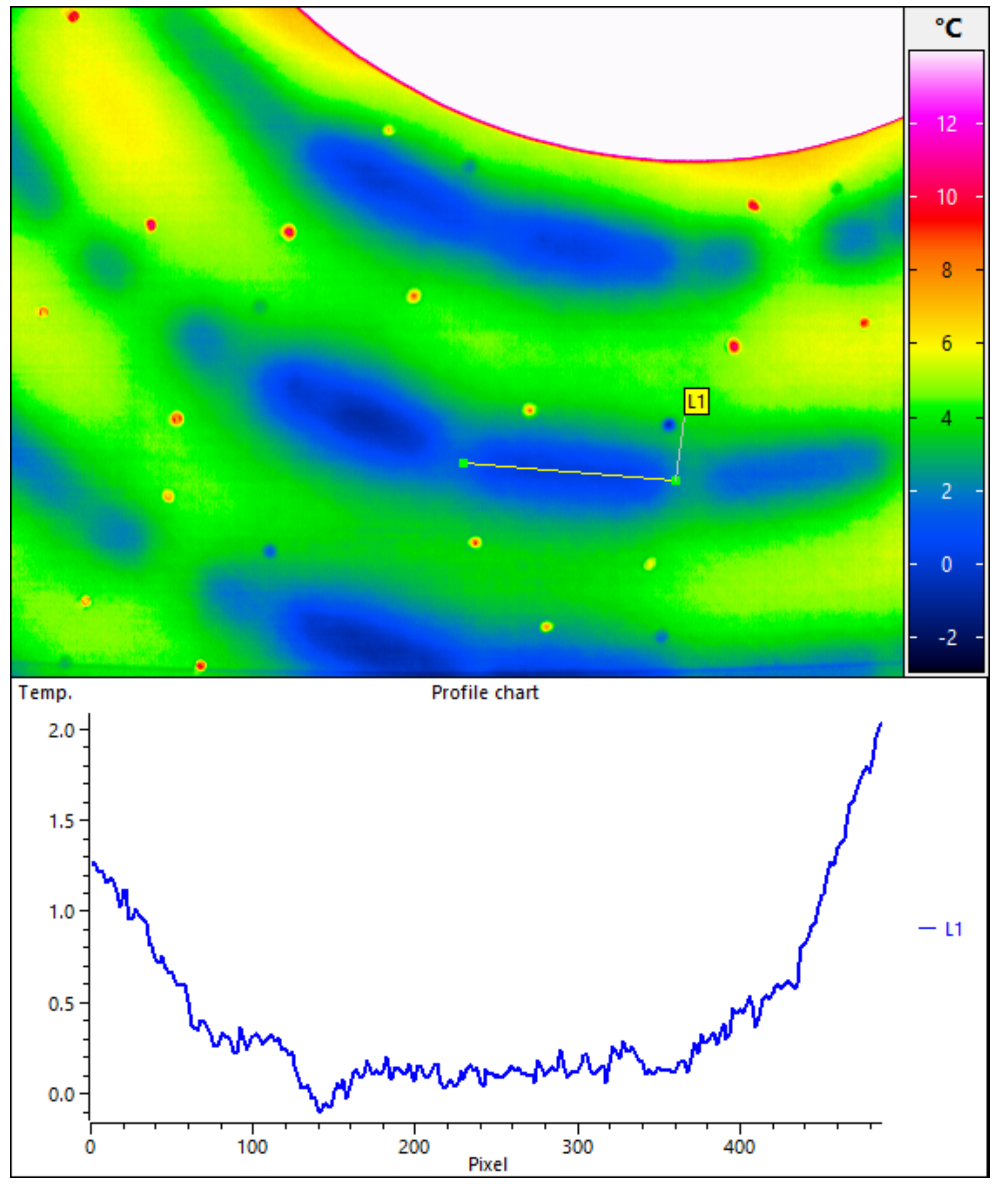
Dee Reception Test - Thermal Testing

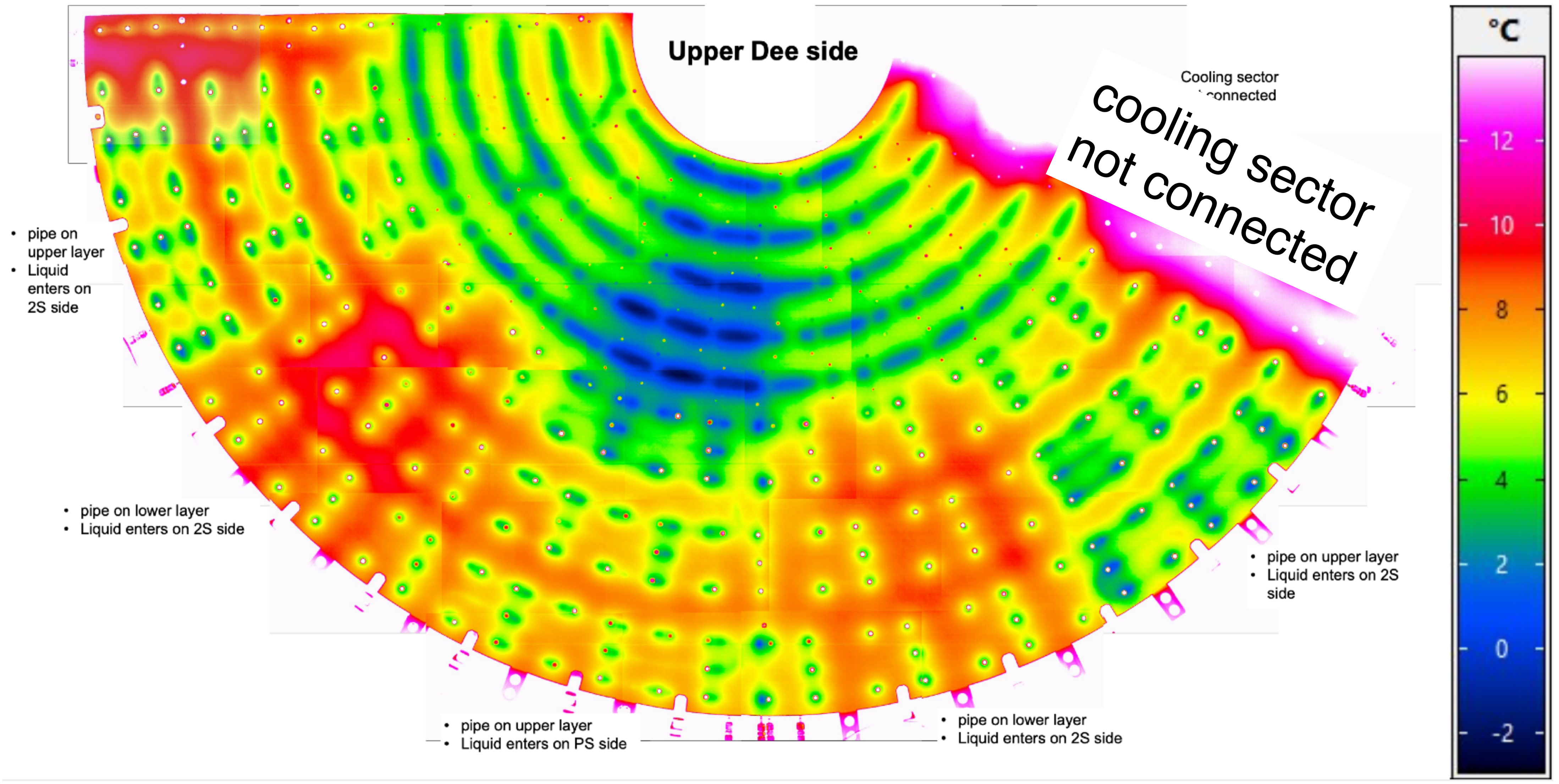
- Dee is sitting inside an arc frame with a cooling manifold
  - All sectors are simultaneously cooled with conventional cooling
- Camera on vertical and horizontal stage

- Most PS cooling blocks show uniform temperature distribution
- Some improvements to the setup done
- IR Test setup now operational



uniformity along cooling block

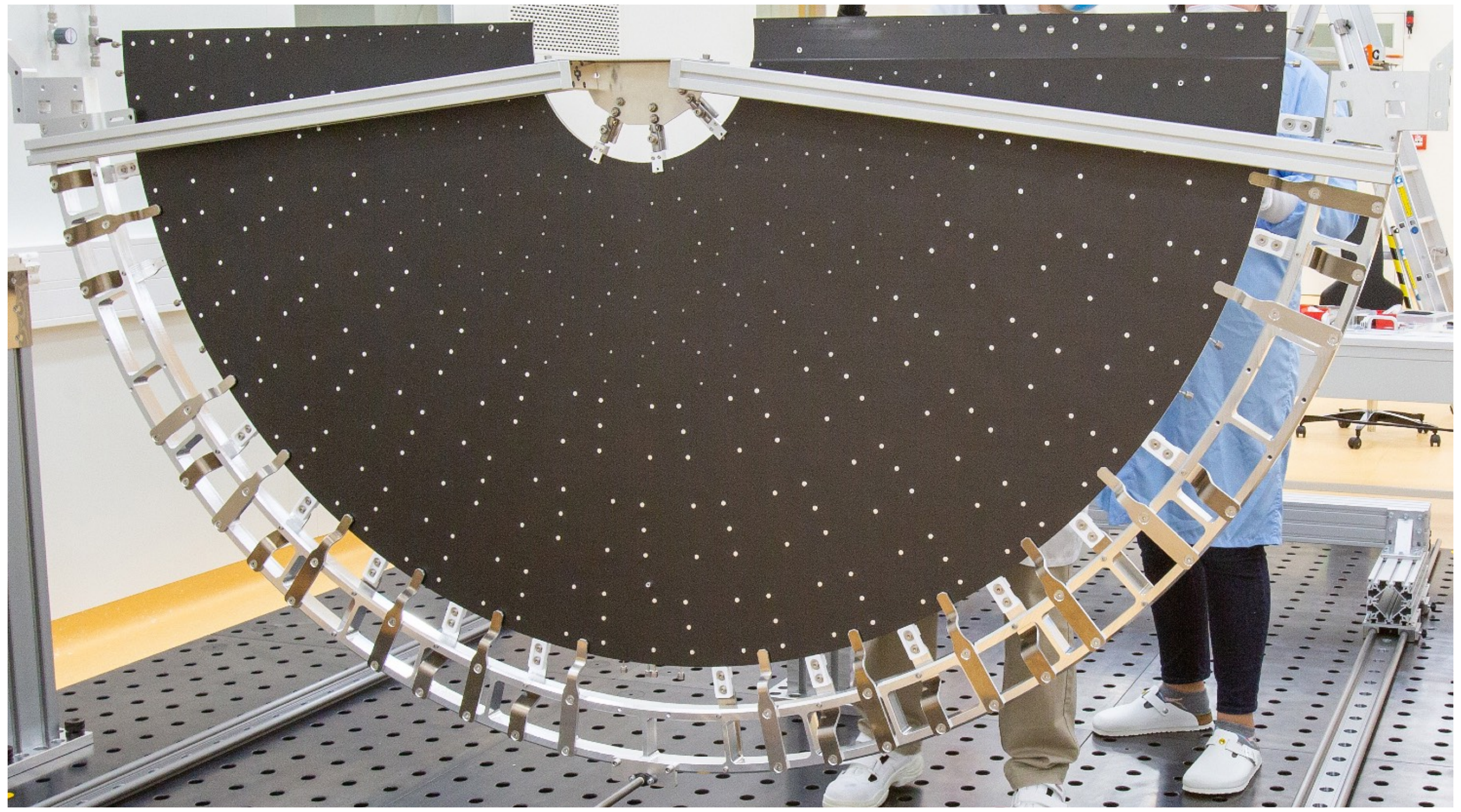


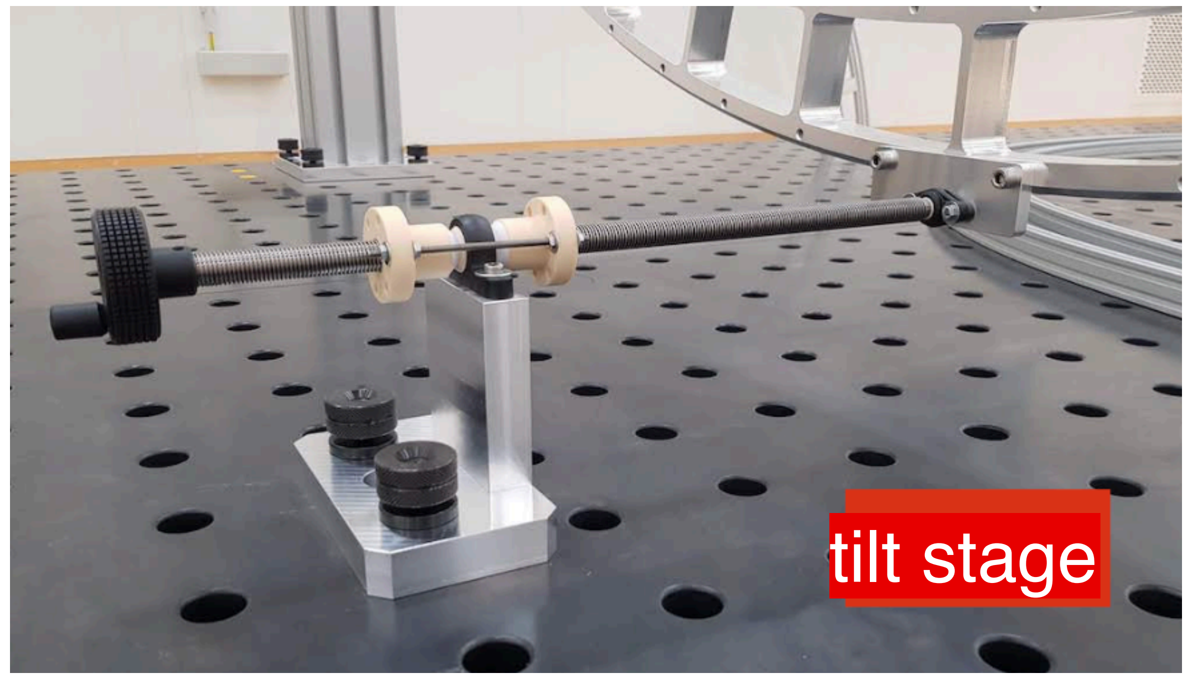


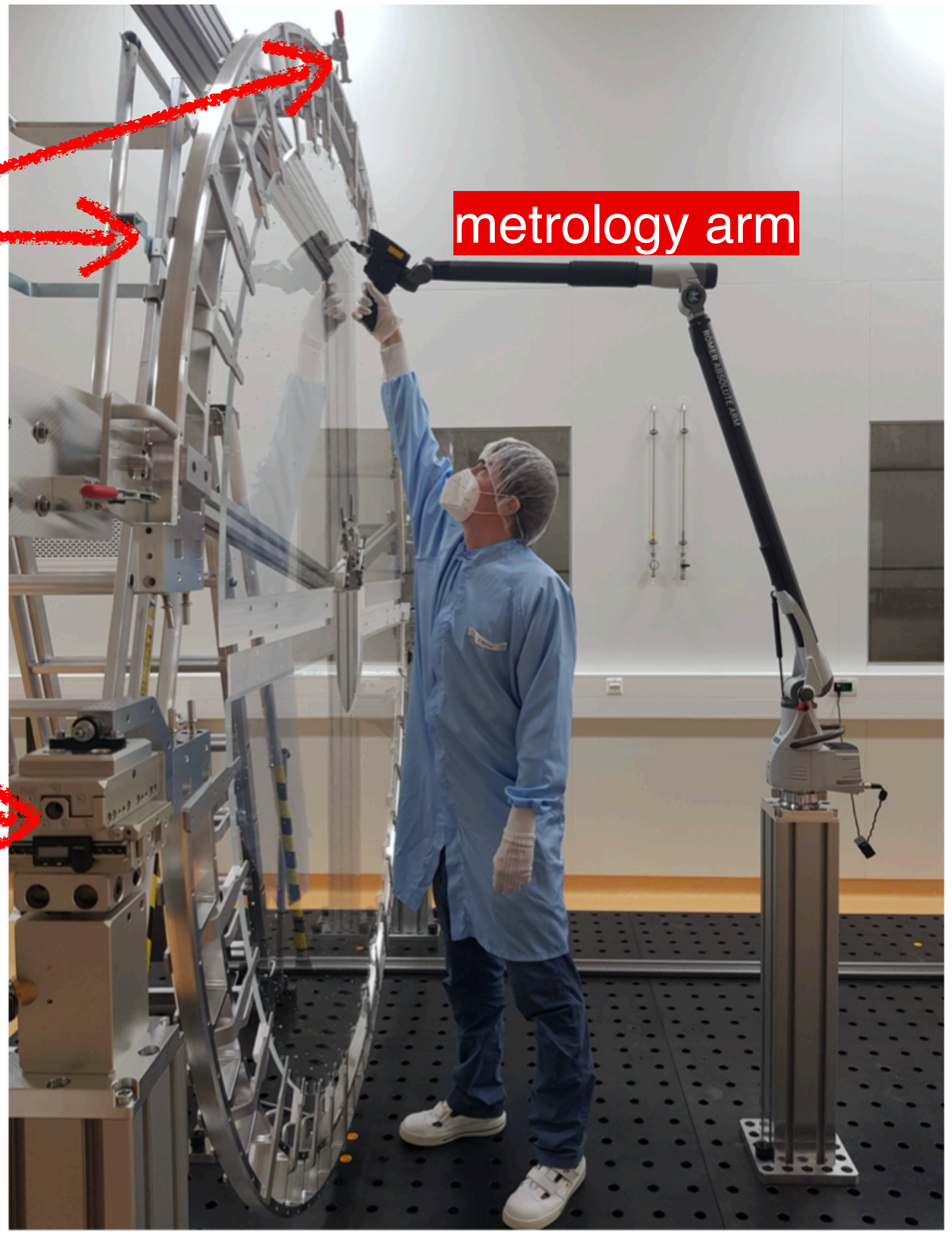
Arc Frames and Disc Assembly

- Backbone of handling Dees are the Arc frames
- All Dees will rest inside one from bare Dee reception testing to TEDD assembly
- Arc machined out of one piece Aluminum with attached fingers holding the Dee
- Interfaces to all TEDD toolings including integrated Dee shipment
- Combines to a ring when making disks, and to double rings when making double disks

- Upper Dee fixed at 3 points
- Lowe Dee rests on the x/y/z stage on the sides and has a tilt stage on the bottom
- Metrology arm used to measure position and perform relative alignment
  - relative positioning iteratively
- connect Dee to Dee inserts and merge arc frames to ring
- successfully tested with acrylic glass Dees
- position as in CAD file



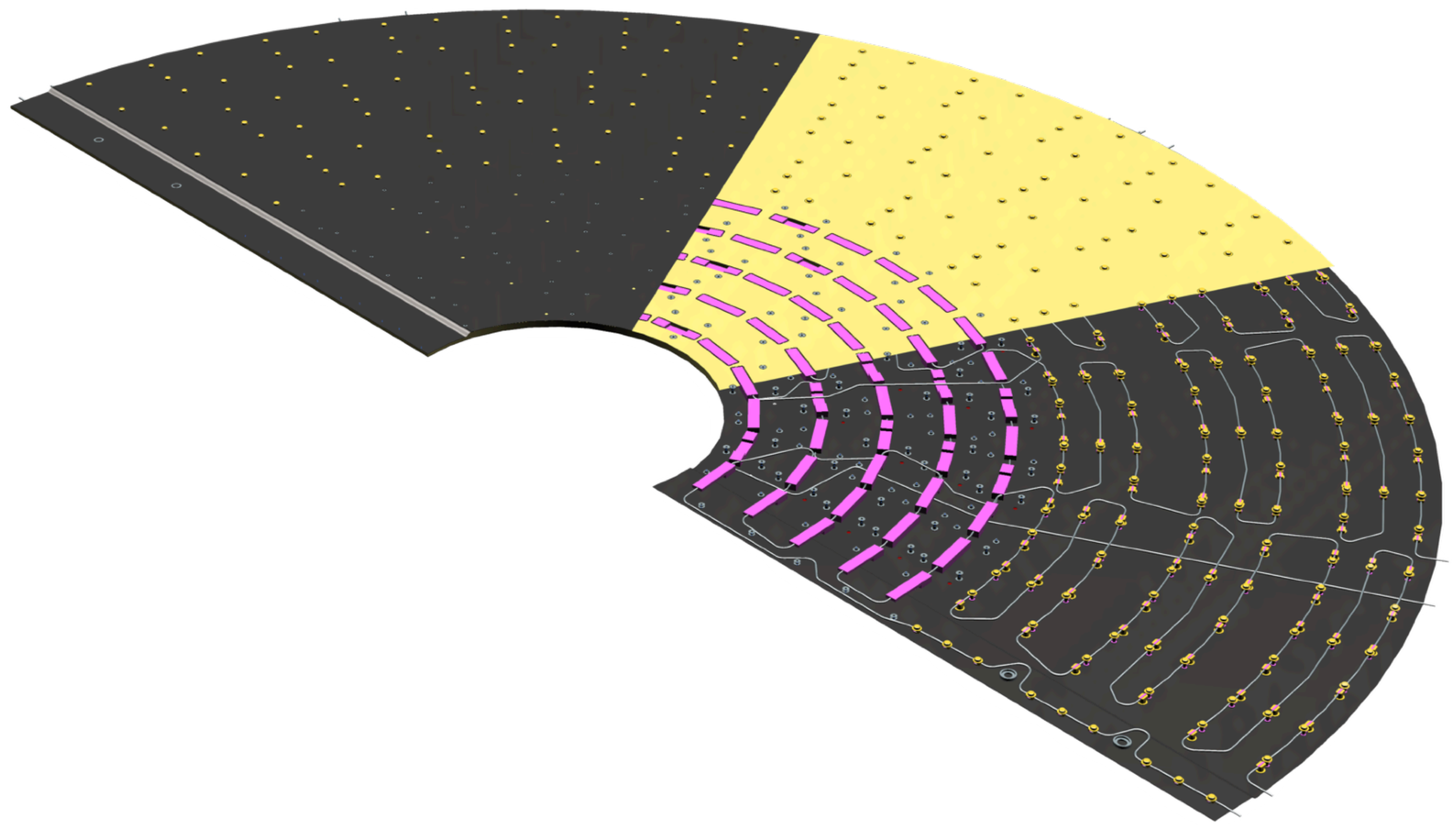


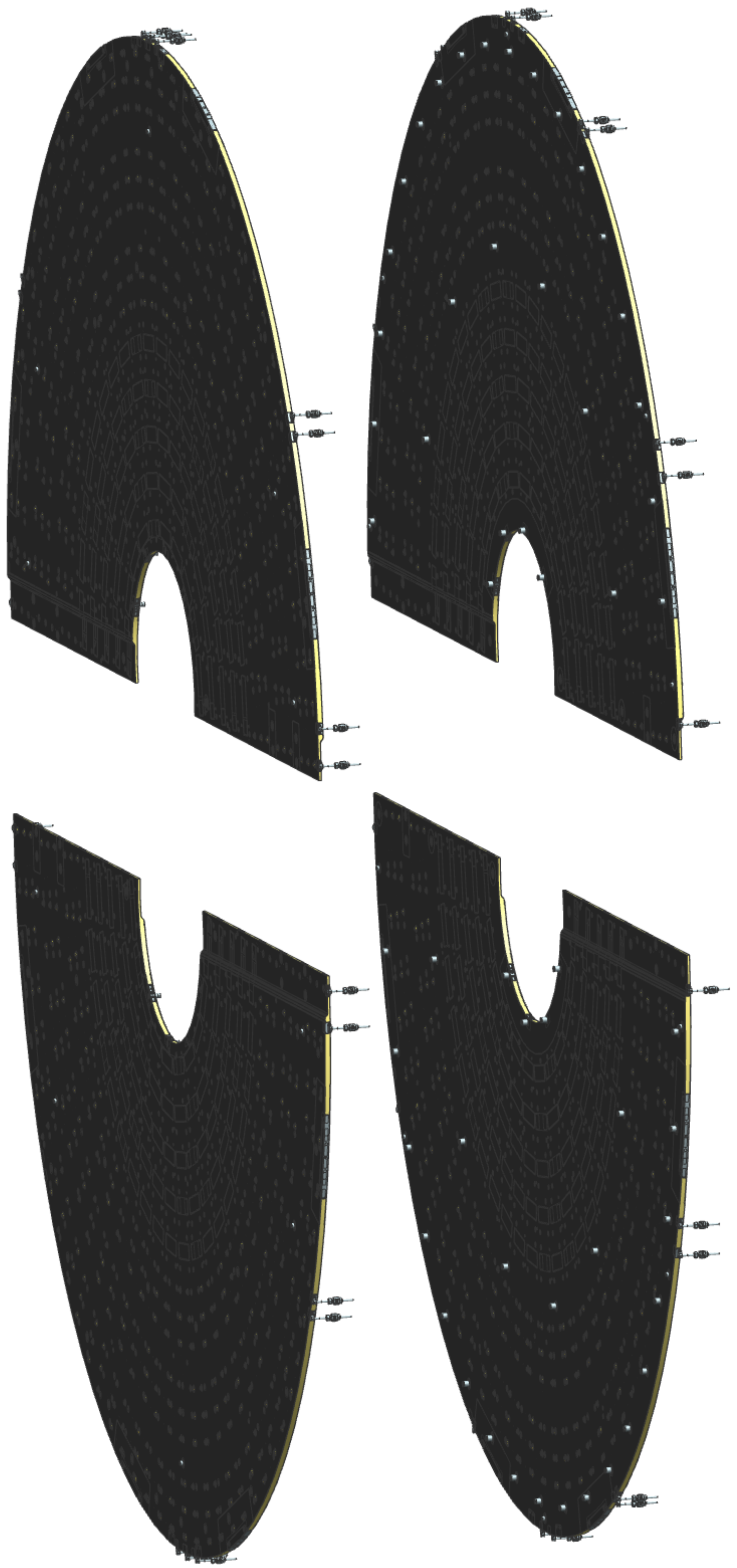


Preparation for Dee Pre-Production

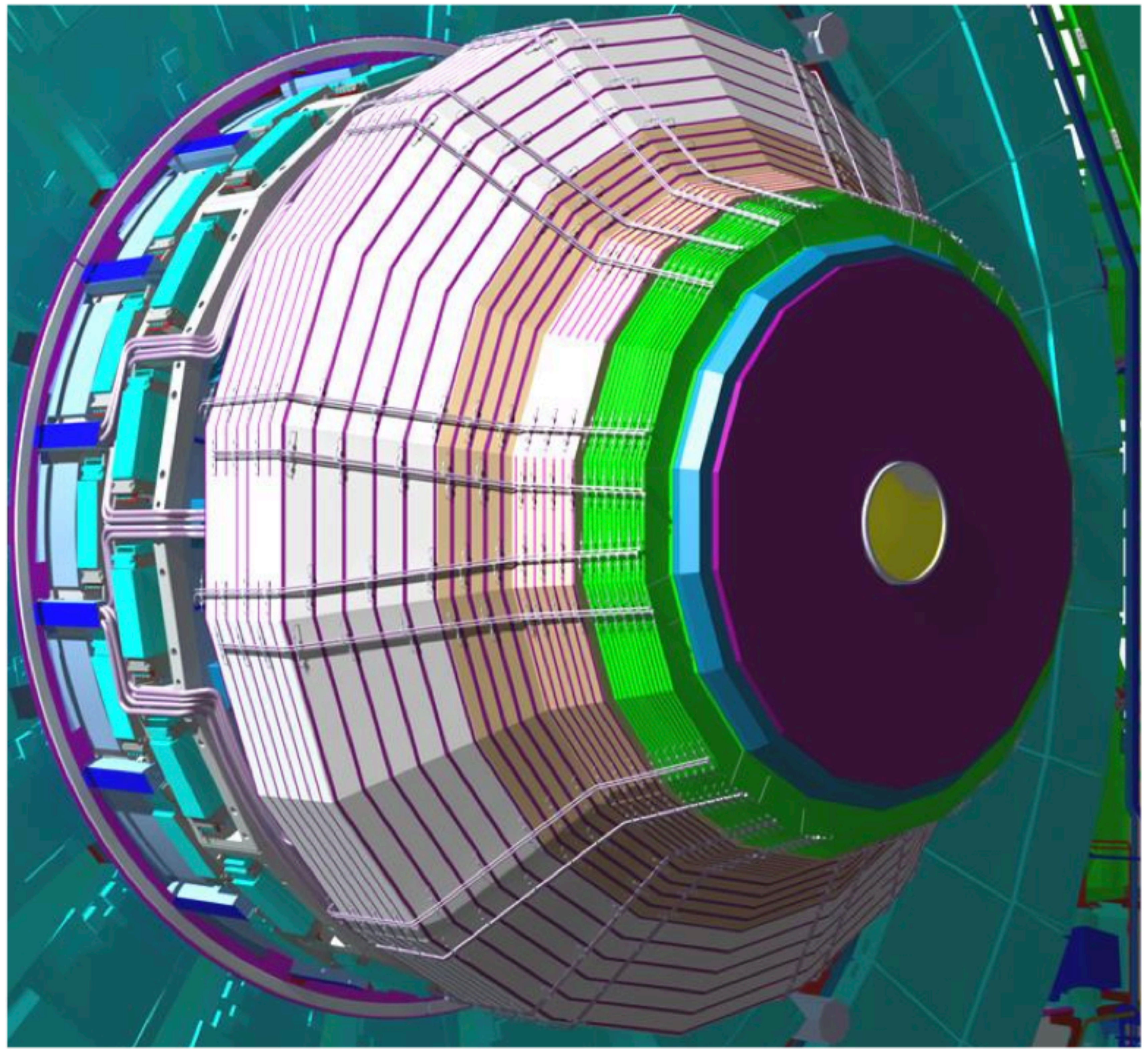
- Pre-production of Dees will start after EDR (September)
- Plan to build 2 odd and 2 even Dees
  - goal is final quality
  - could go into detector or as spares

- production procedure refined with company
- design files submitted
- order of parts placed





CMS HGCAL

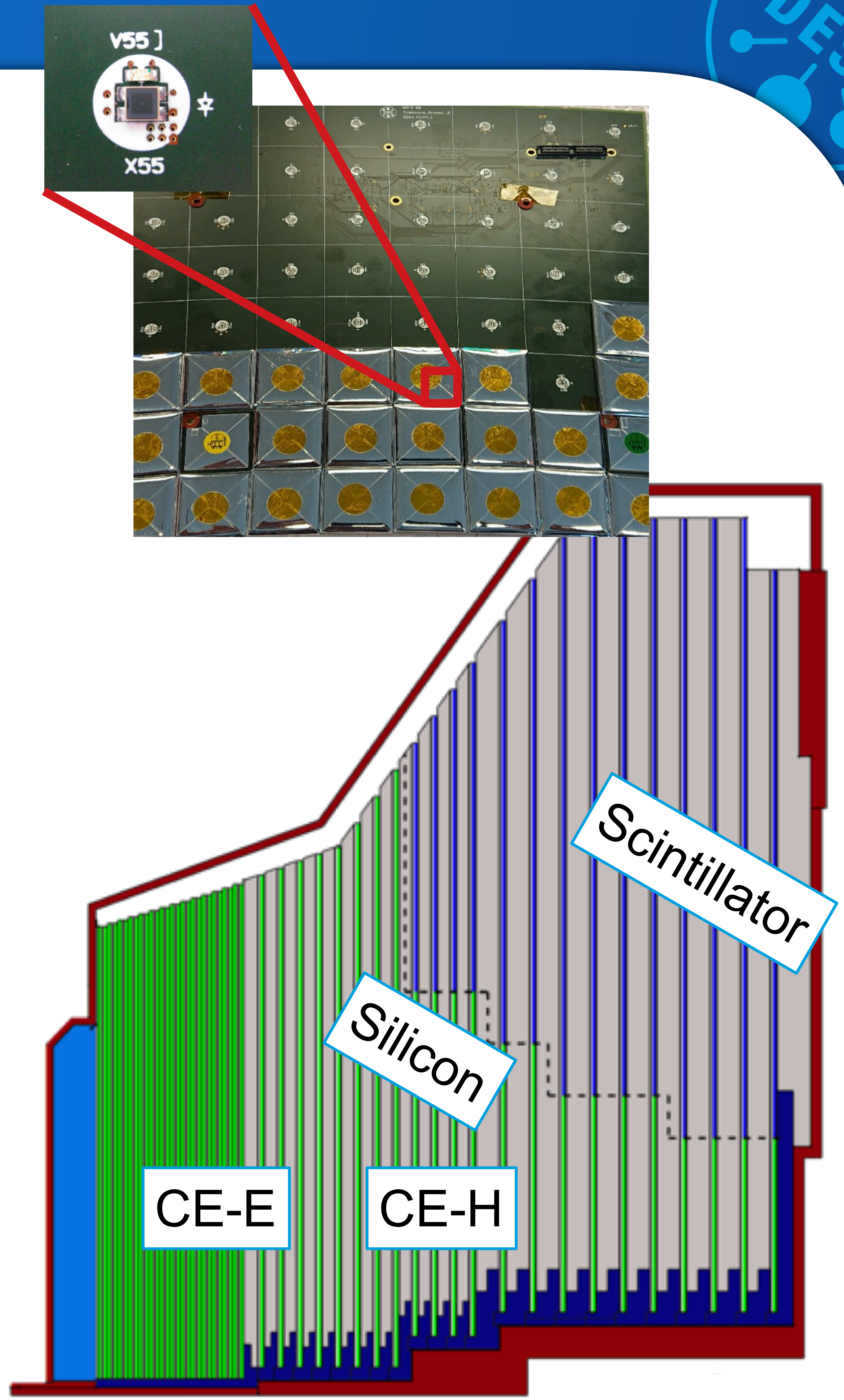


SiPM-on-Tile technology the HL-LHC upgrade of the calorimeter endcap

- CMS calorimeter endcap will be replaced for HL-LHC by **H**igh-**G**ranularity **cal**orimeter
- **Synergy** with high granularity calorimeter concepts developed for electron-positron colliders
  - new challenges: radiation hardness, high data rates, cold operation (-30 deg C)
- use SiPM-on-tile technology wherever radiation levels allow, silicon in high-radiation area

- **Transition to construction phase now**
- engineering design, final choice & qualification of components
- setting up of construction procedures

- **DESY responsibilities:**
- Tileboard development
- Lead Tile Module Assembly Centre
- Beam test and analysis

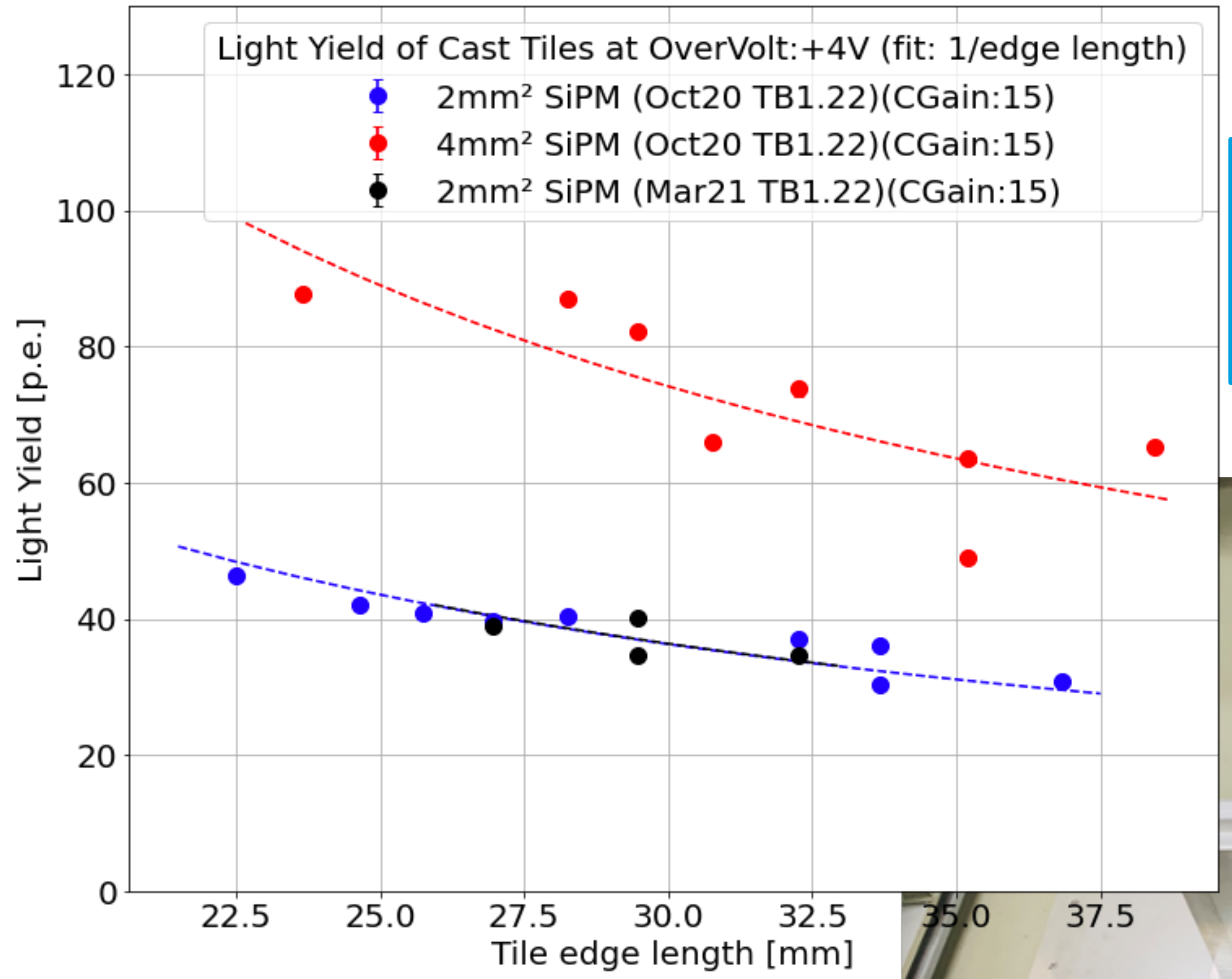


Status and progress of DESY responsibilities

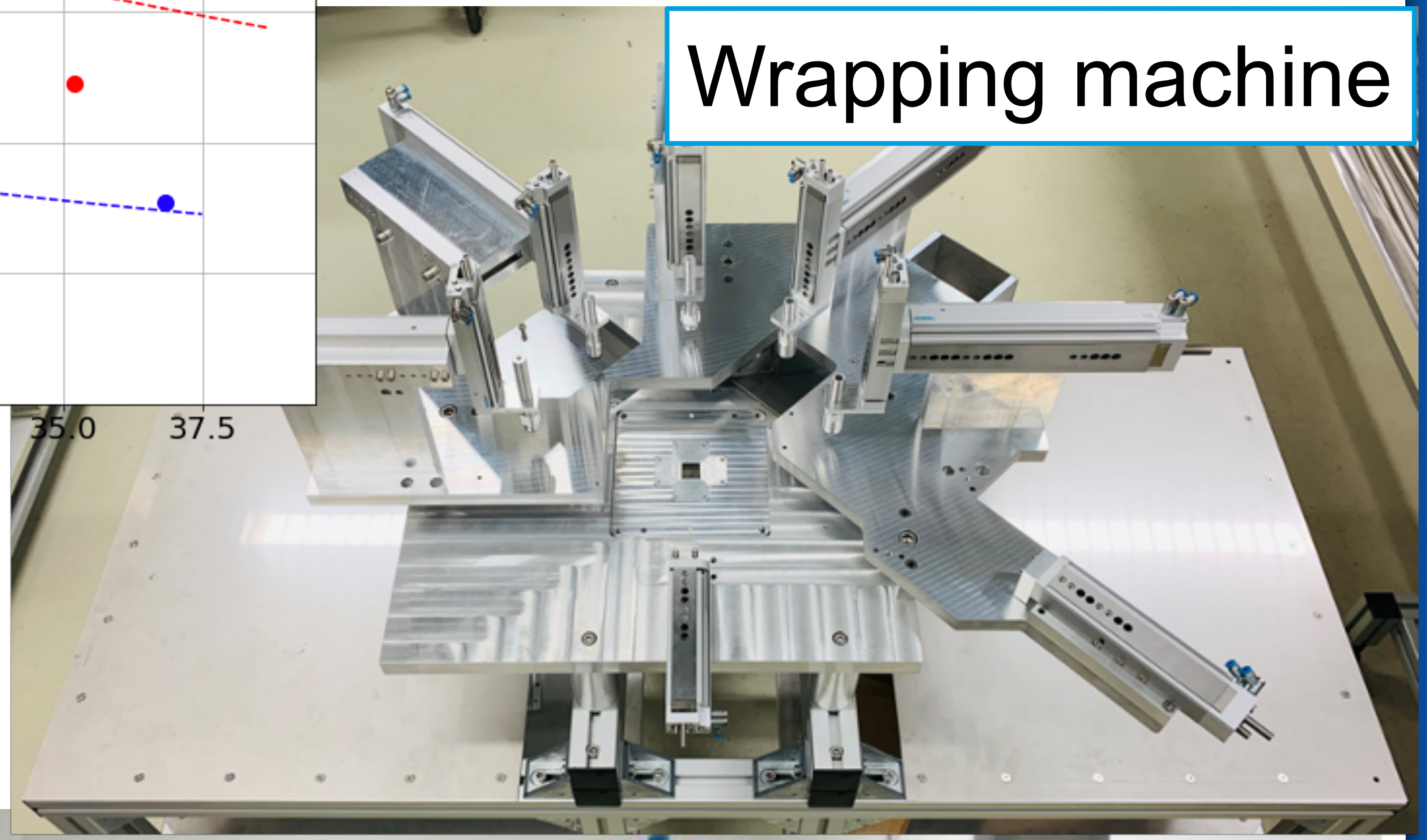
- **Design and test of tileboards**
  - Testbeams of tileboards:
    - first particle signals observed with HGCROCv2 (Oct 2020)
    - signal studies of irradiated SiPMs (ongoing)
  - Climate chamber for cold tests arrived at DESY
  - Design of tileboards for HGCROCv3 started

- **Tile wrapping and placement**
  - wrapping machine progressing
  - new Pick&Place machine in DAF, first test assembly (of dummies) done

- **Setup of assembly and QA chain of tile modules**
  - full chain of electronics assembly of tileboards, wrapping and placing of tiles, and all necessary QA tests during assembly
  - in close collaboration with Russian partners
  - delayed because of Covid travel restrictions



Testbeam measurement of Light Yield vs. Tile size

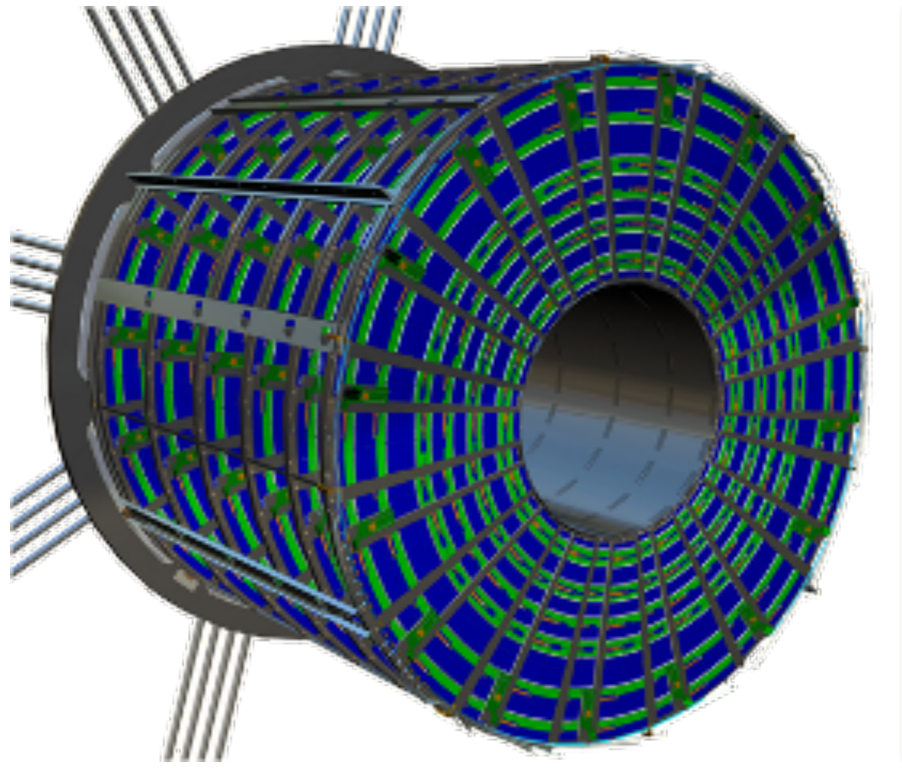


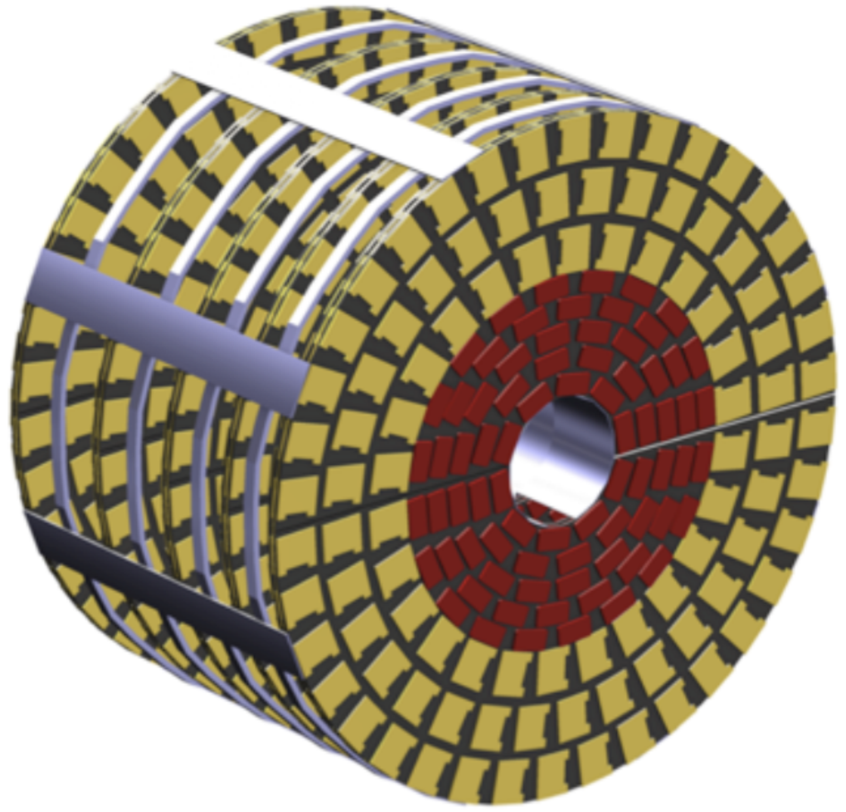
Wrapping machine

Pick&Place machine in DAF

Summary

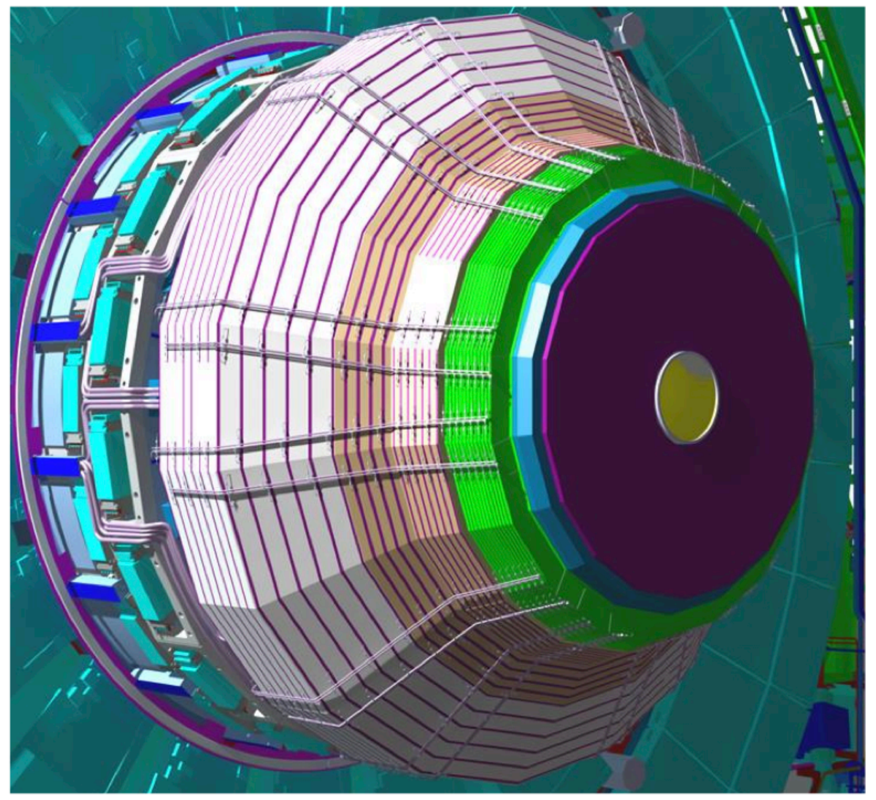
- first fully electrically functioning star petal built
- working towards construction site qualification
- good progress made to put QA/QC procedures in place





- working towards module construction site qualification and EDR
- preparing to build first functioning PS modules
- IR setup commissioned and other QA procedures progressing

- transition to construction phase
- QA procedures progressing



All feel impact due to Covid

Backup

Lab Space for ITk Project

All laboratories and clean rooms operational, gearing up for site qualification

Hamburg DAF assembly and QC Clean Room (ISO-7)

Zeuthen ATLAS upgrade production lab (ISO-6)

Hamburg DAF module/petal building Clean Room (ISO-6)

Hamburg DAF Integration Clean Room (ISO-7)

CMS Phase 2 Tracker

Andreas Mussgiller

WP1: R&D and Prototyping

Andreas Mussgiller, Doris Eckstein

WP2: Modules and MaPSA

Doris Eckstein, N.N.

WP3: Burn-In Test

Günter Eckerlin, Andreas Mussgiller

WP4: Dee

Roberval Walsh, Oskar Reichelt

WP5: TEDD

Moritz Guthoff, Oskar Reichelt

Production work flow