Integration of the CMS Phase-2 Tracker endcaps

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SiDet R&D meeting

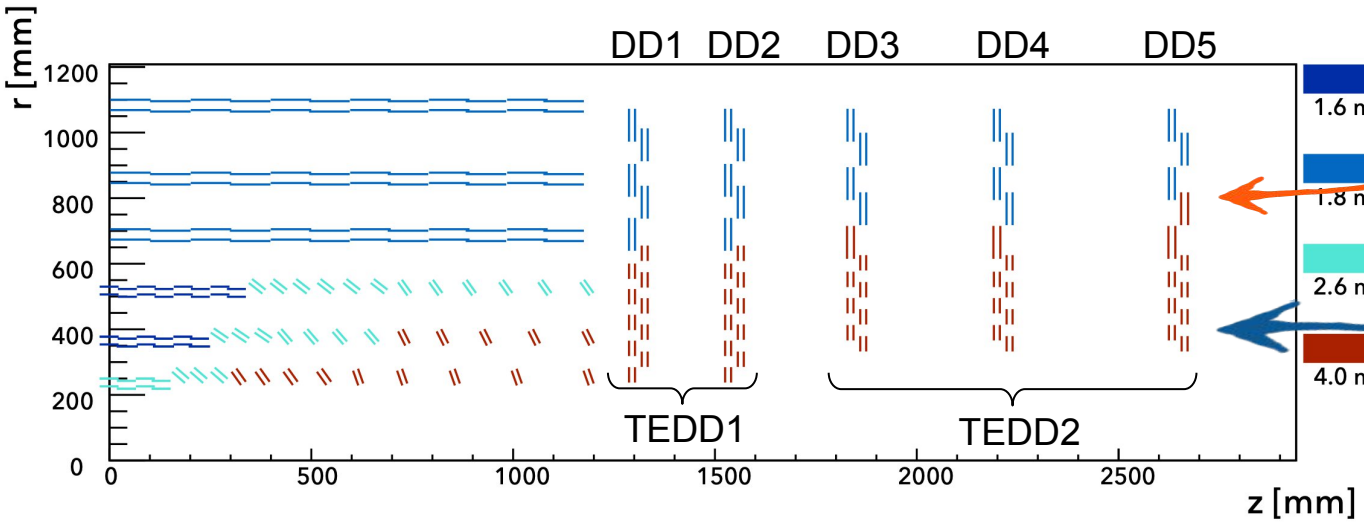
HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

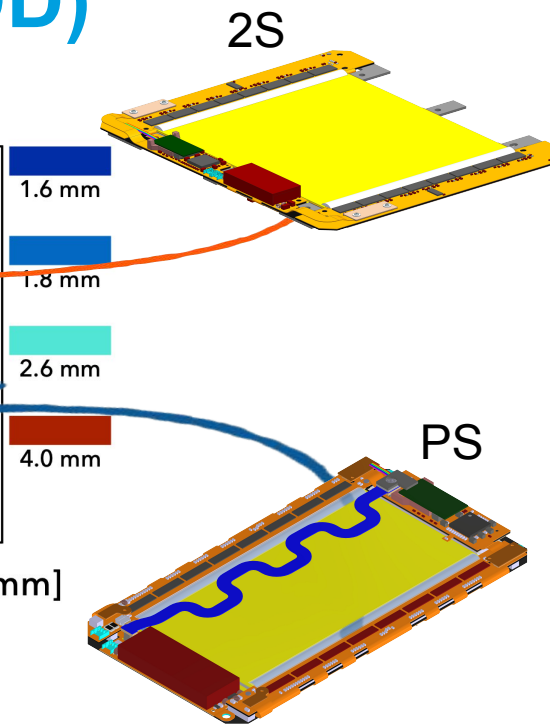
DESY.

Overview

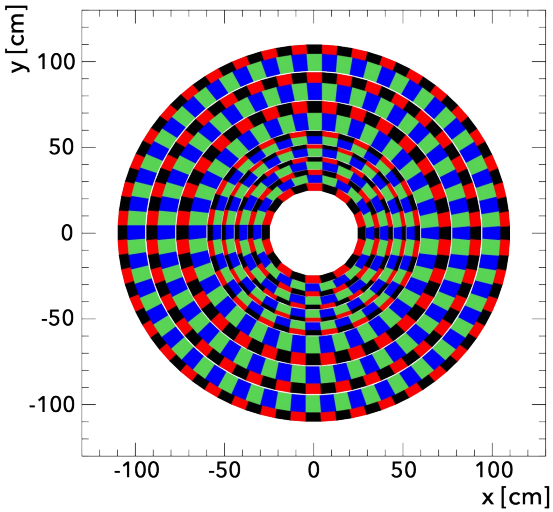
- Introduction to the CMS Phase-2 Tracker endcap (ignoring modules).
- Mechanical structure.
- Module mounting and cooling.
- Qualification of the prototype mechanical structures.
- Integration tooling and integration procedures.

Tracker Endcap Double Disk (TEDD)





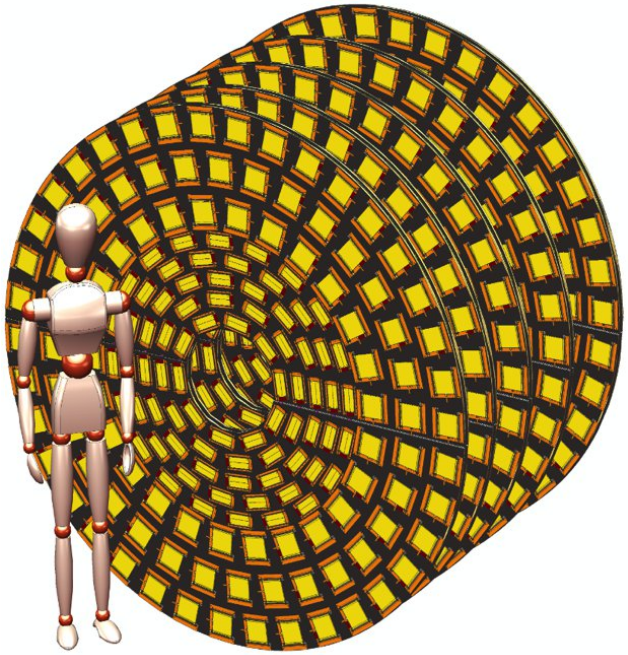
- Each TEDD is made of five Double-Disks (DD) in two flavours (TEDD1, TEDD2)
  - TEDD2 has larger radius inner bore
- Modules are arranged in rings, numbered from inner to outer per DD.
  - Inner rings have PS modules
  - Outer rings have 2S modules
- A DD comprises an even and an odd Disk, given by which rings have modules.

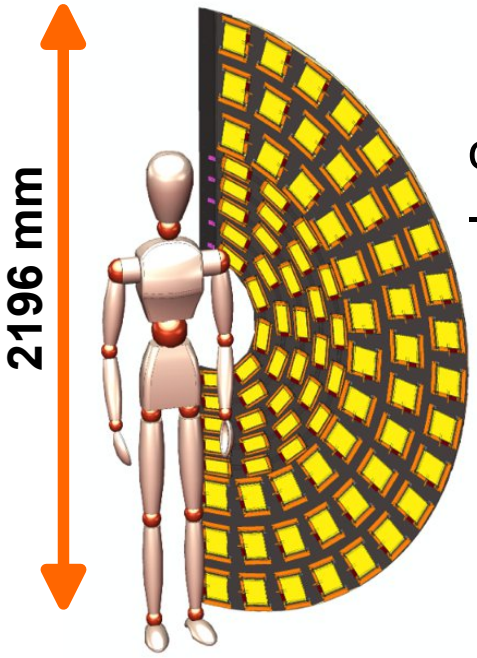


Modules on
- odd disk front/back
- even disk front/back

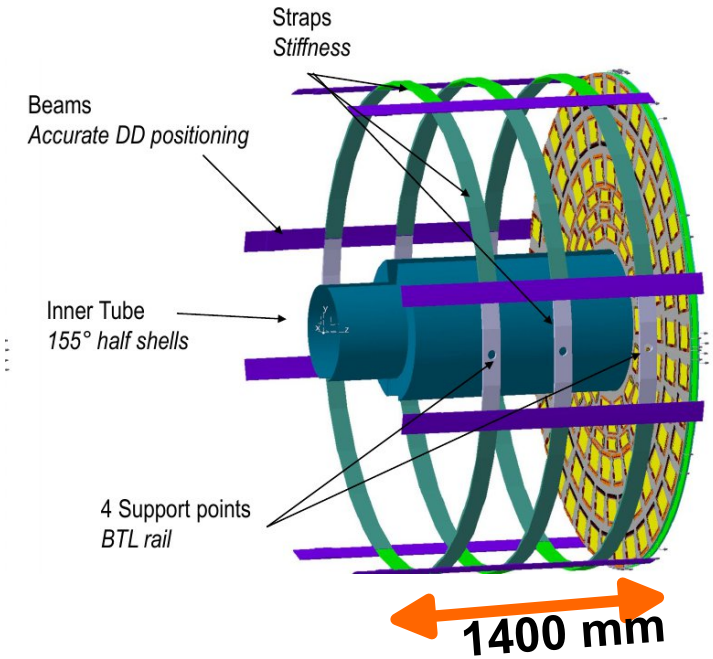
TEDD global mechanics

- A DD is an integral part of the mechanical stability.
- Outer skeleton and inner tube connect DDs.
- Each disk is made of two half-disks (Dees).
  - Dee is largest feasible structure.
- Large and fragile structures need special tooling to make the integration possible.

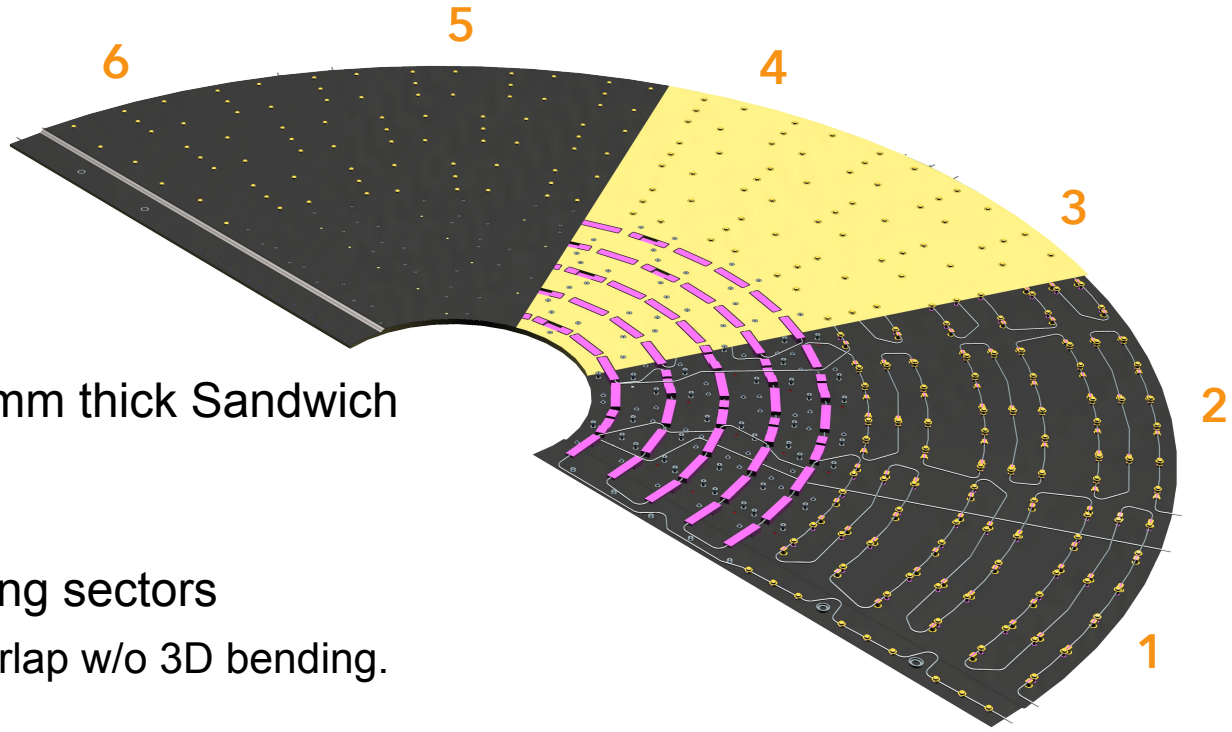




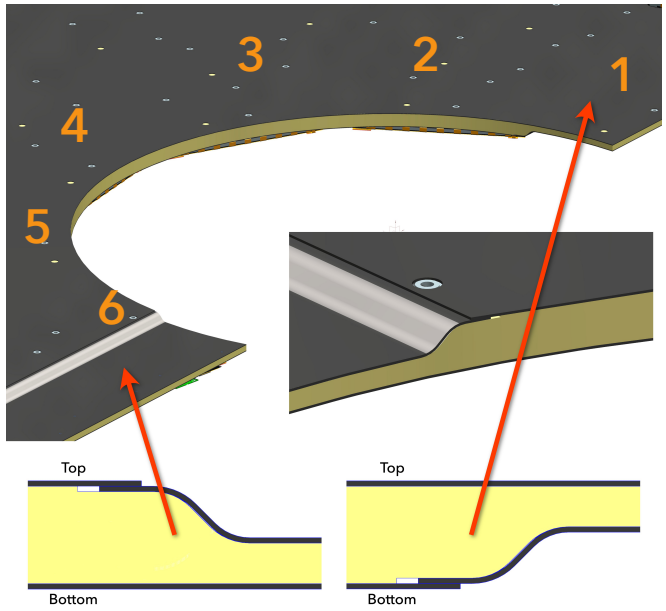
one TEDD comprises:
-> 20 Dee with up to:
-> 84 PS modules
-> 96 2S modules



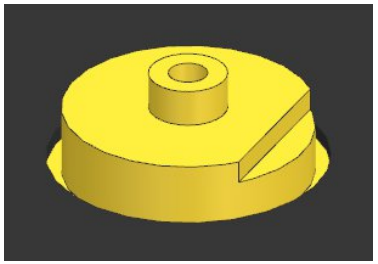
Dee Design

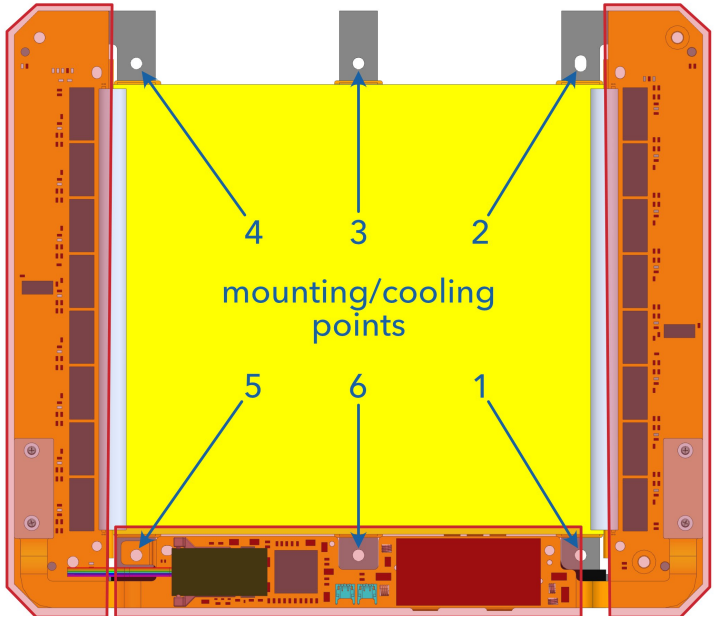


- Highly embedded 10 mm thick Sandwich
  - Airex foam core
  - CFRP facings
- 6 wedge shaped cooling sectors
  - Two tiers to allow overlap w/o 3D bending.
  - Symmetric design.
- Step at straight edge of Dee
  - Pipe routing requires step to be on opposite sides.
- Modules are positioned with Al inserts.
- Additional inserts for
  - Position reference inserts for metrology.
  - Dee-to-Dee and Disk-to-Disk assembly.
  - Patch panel support ring and global TEDD mechanics mounting.

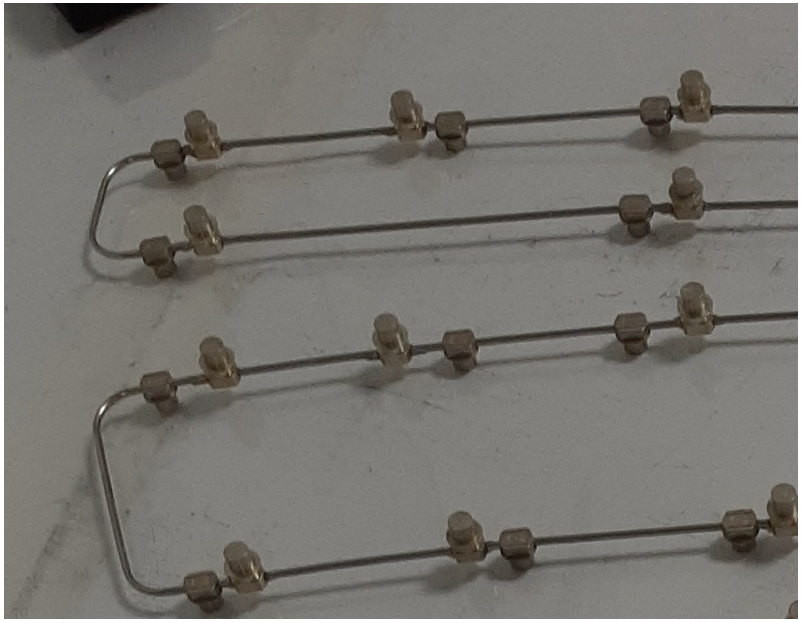


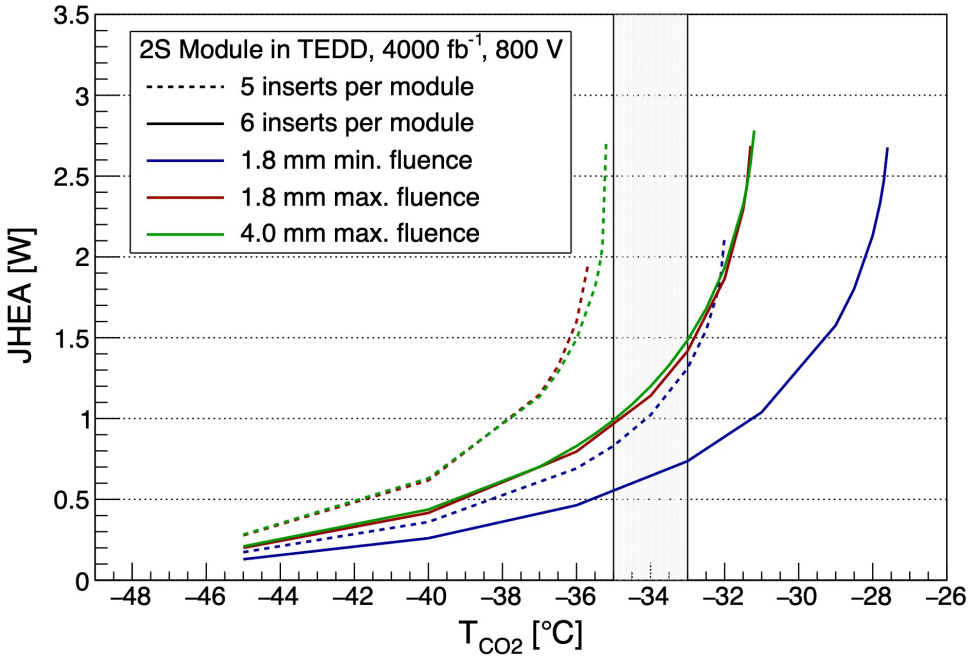
2S modules





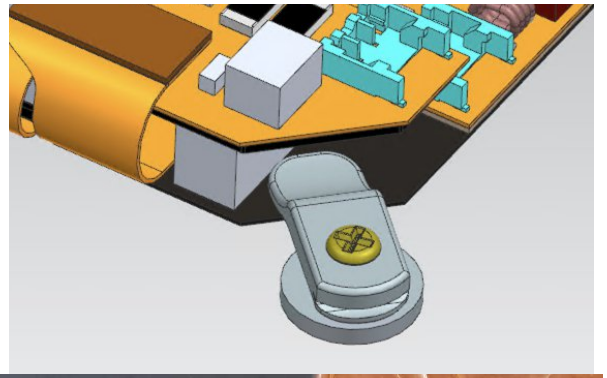
- 2S modules are installed on six Al inserts for positioning and cooling.
- Inserts for both sides are are connected to the cooling pipe.
- FEA confirms sufficient cooling at ultimate luminosity scenarios.

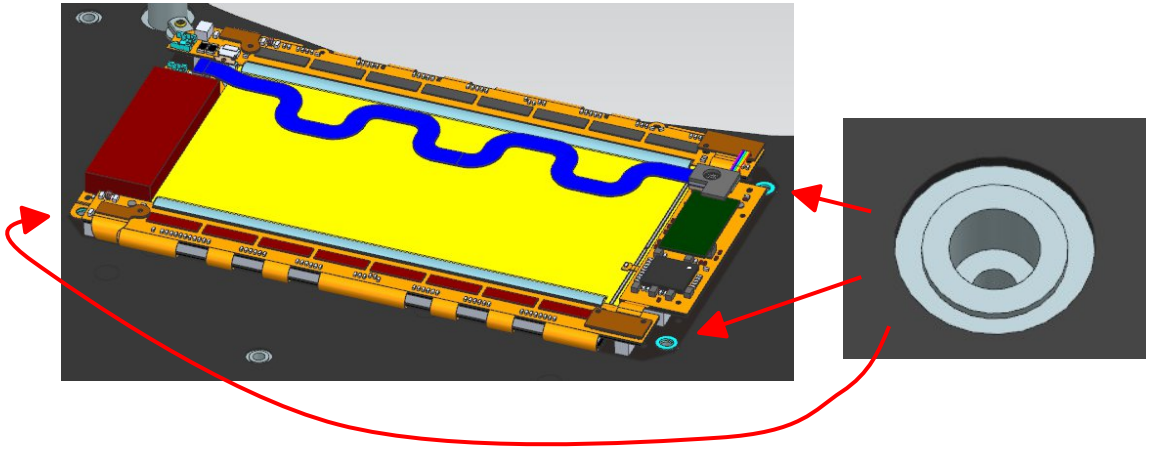




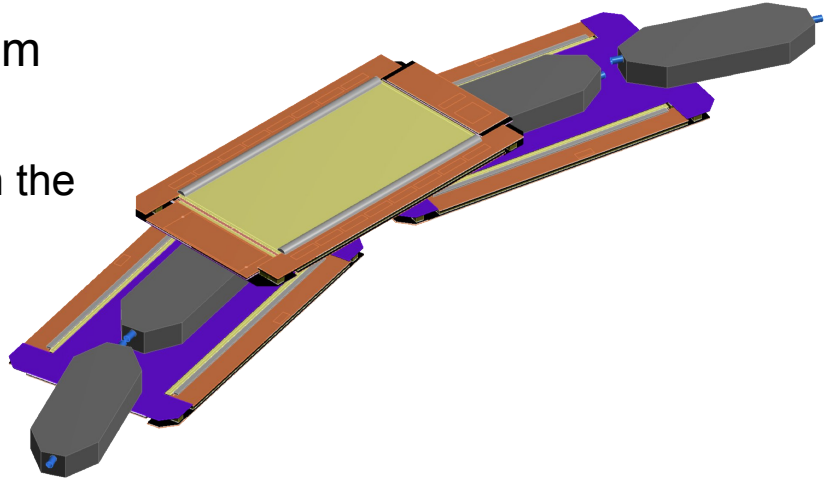
PS modules

- Three inserts to position and fix the PS module through modules base plate.
- Additional fixation point to clamp down 4th corner.



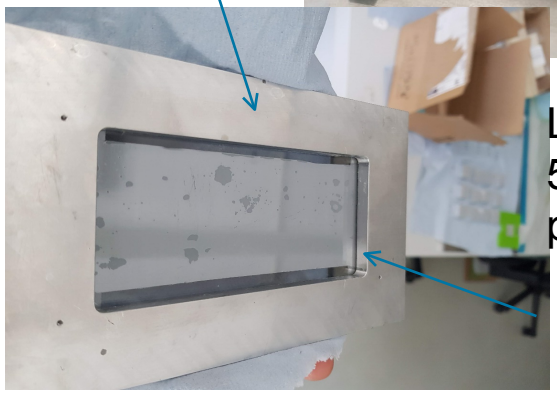


- PS modules are cooled through Carbon foam blocks glued to the pipes inside the Dee.
  - Blocks are as long and wide as possible given the limited real estate.
  - Verified and optimized with simulations.



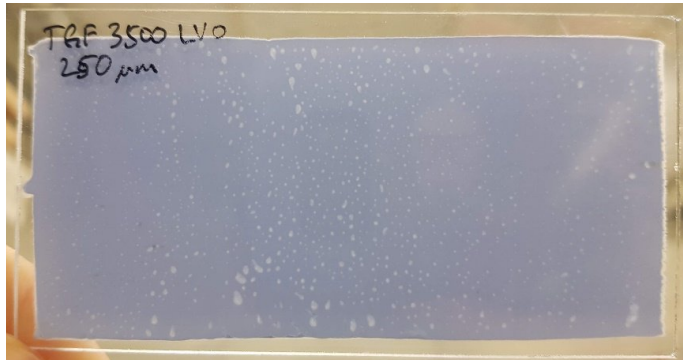
PS thermal interface material

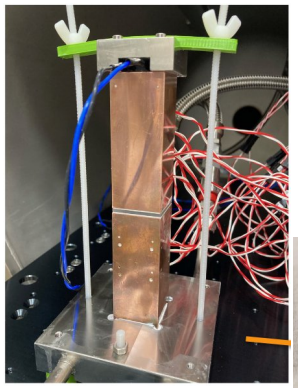
- Large area cooling interface of PS baseplate to Dee surface needed.
- Original baseline to use phase change material.
  - Needs clamping force to make contact.
  - Vacuum while heat treatment not feasible (large size)
  - Heating possible, but better to be avoided.
    - Re-working for module replacement difficult.
  - Almost no contact in tests with mechanical dummies.
- Alternative suggested material Thermal Gap Filler (Bergquist TGF 3500 LVO) under study.
  - Low volatility silicone filled with AlO
  - Two component, self curing, good re-workability
  - Thermal measurements of thermal conductivity ongoing.
  - Mechanical stability tests ongoing (soft, but weak material).
  - Thermal and mechanical samples to be irradiated.



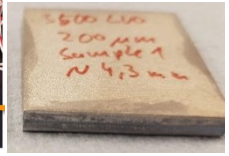
Laird TPCM 58x phase change

no contact



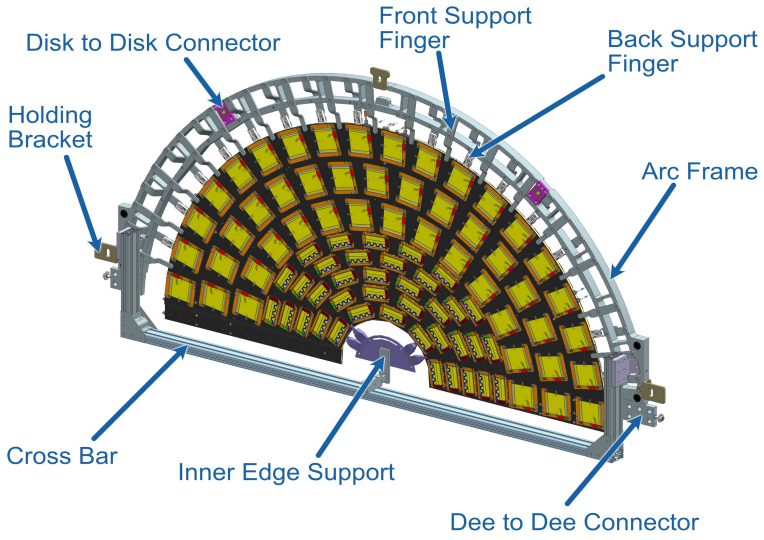


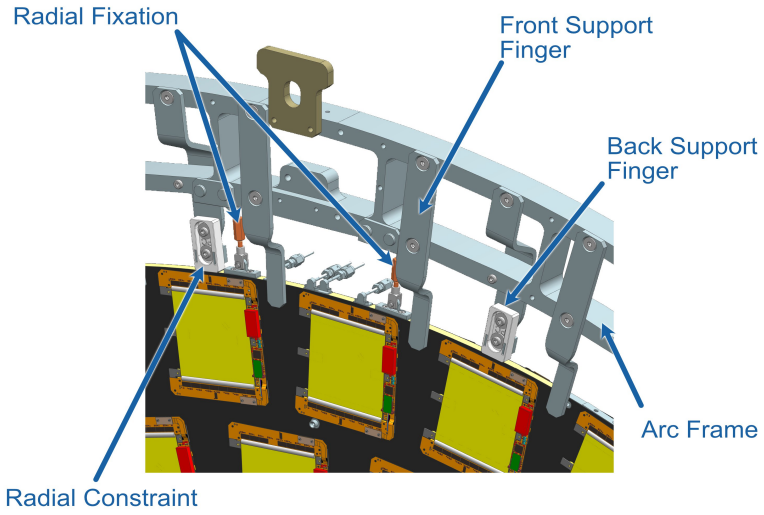
Thermal conductivity measurement



Arc frame

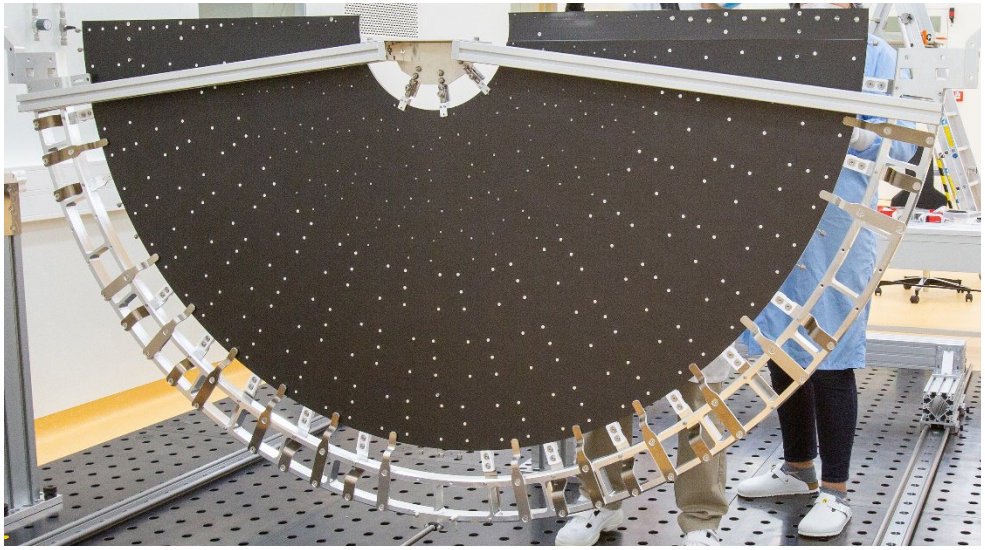
- Dee with modules can't be handled manually.
- Dedicated holding structure - Arc frame - was designed for handling of Dees.
  - Each Dee will rest in its own Arc frame up to almost the last integration step.
- Arc frame is equipped with support fingers that clamp and hold the Dee.
  - Fingers are equipped with radial constraint sliders.
- A cross bar with inner edge support provides additional support for some integration steps.
- Interfaces to all toolings (fixations, transport box, stages etc.)
- Arc frames can form a ring in disk assembly and two rings can be connected in DD assembly.





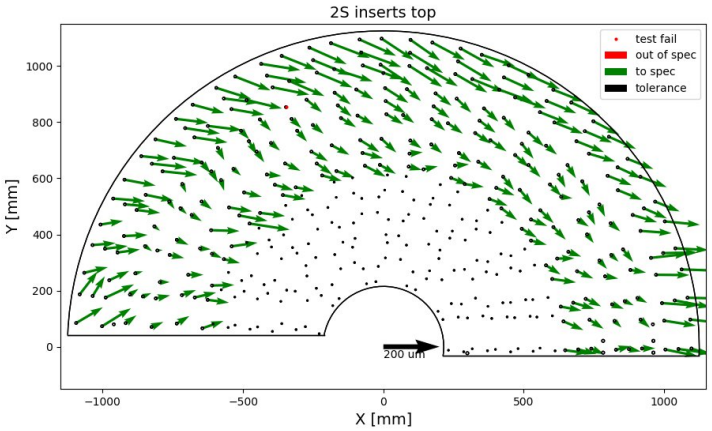
Dee prototypes

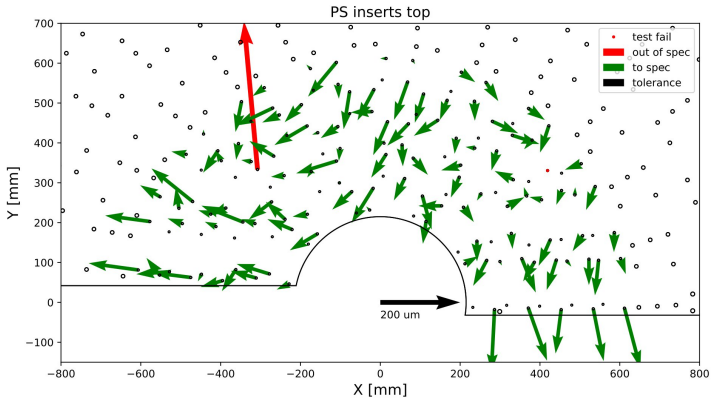
- After several small scale prototypes: three full size prototypes built so far.
  - Two TEDD1 odd, one in Lyon and one in DESY
  - One final design TEDD2 (Lyon).
- Prototype testing.
  - Metrology measurements of mechanical accuracy.
  - Cooling performance tests
  - Disk assembly exercise.
  - Module grounding measurements.

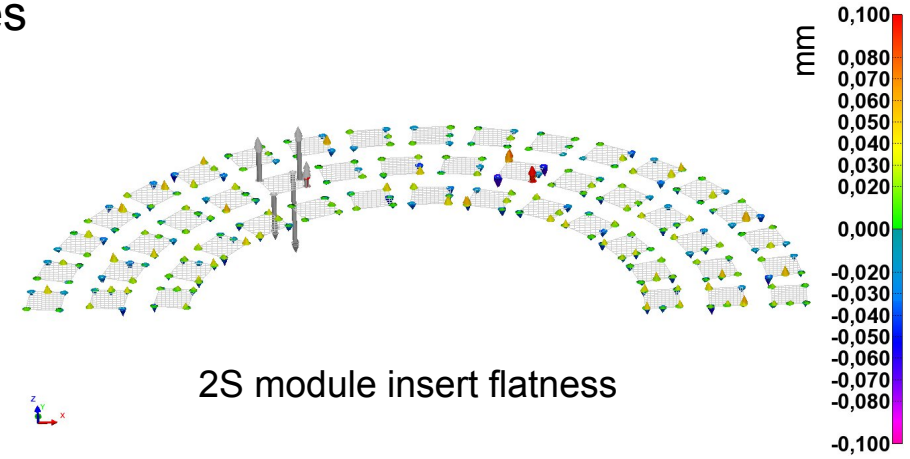


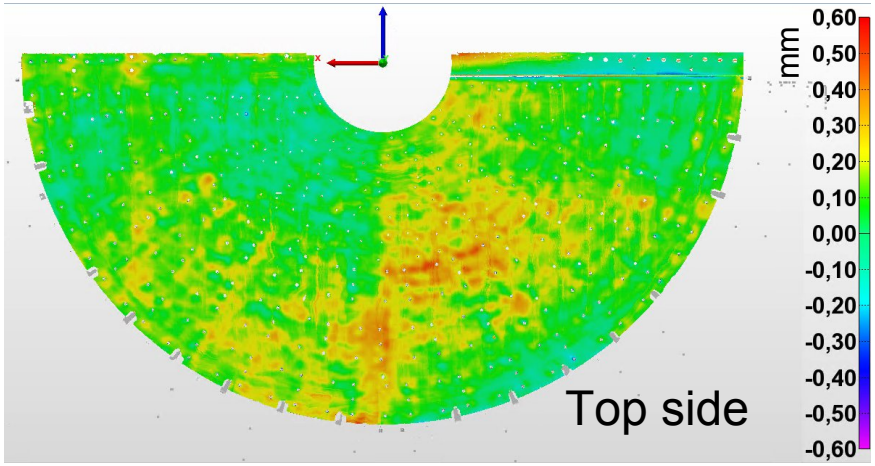
Metrology measurements

- Insert positions with 0.2 mm deviation (very few outliers)
- 2S module insert flatness < 0.2 mm
- 1 mm flatness achieved in prototypes



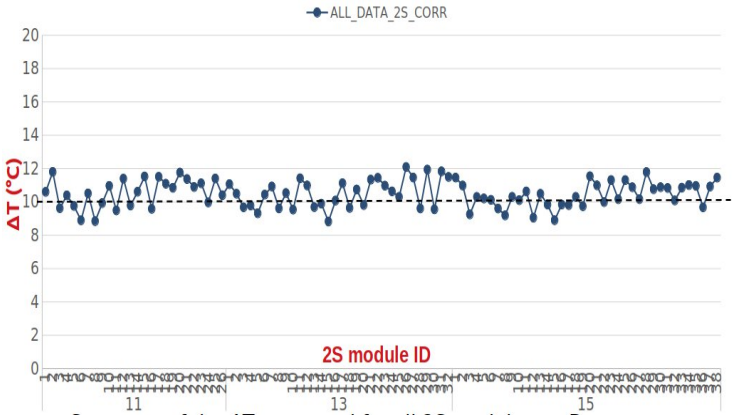


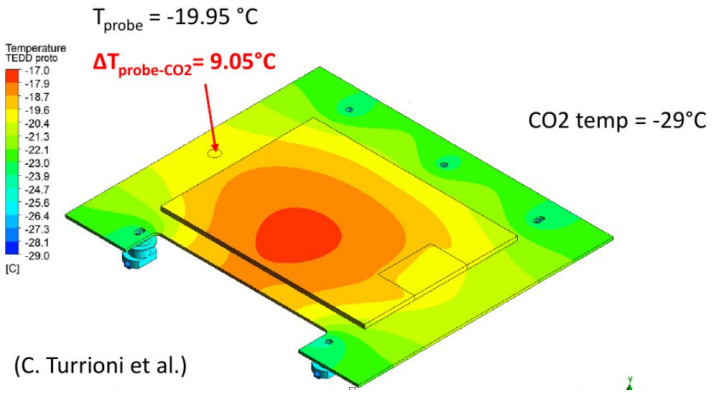


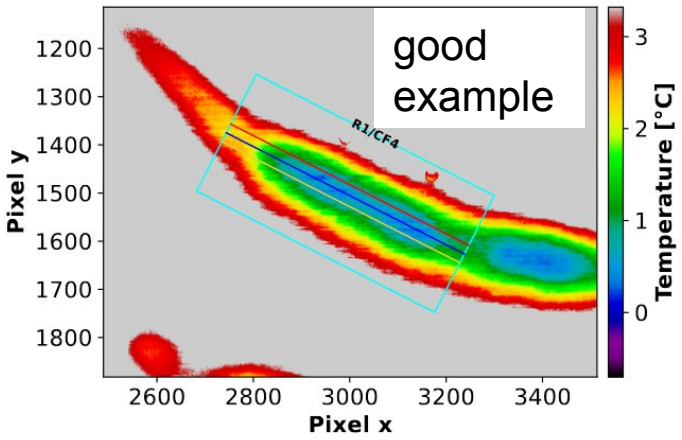


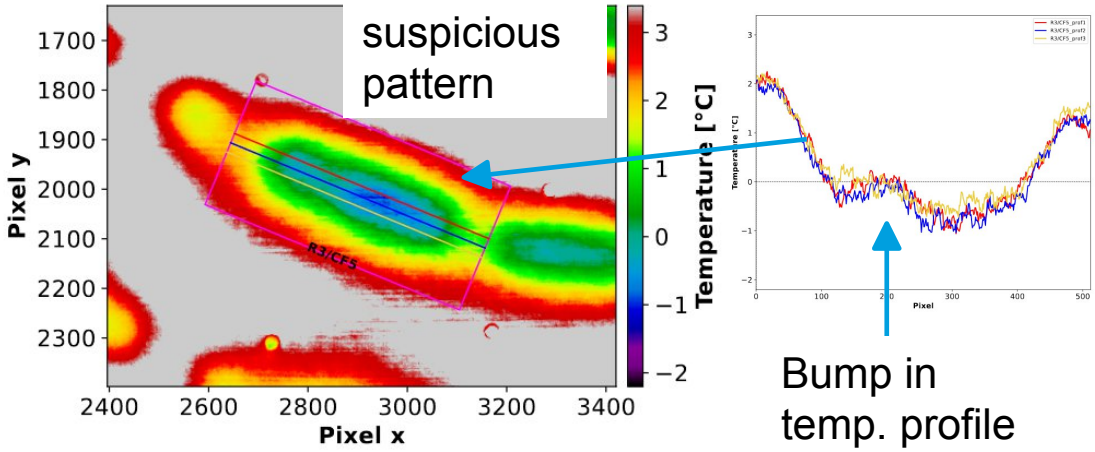
Thermal measurements

- Lyon: Thermal tests with dummy modules.
  - Direct measurement of ΔT: CO_2 - Module
  - Dummy modules with realistic footprint and heater foil.
  - For comparison setup is simulated.
- DESY: IR imaging to discover non-conformities.
  - Prototype shows one position with non-conformity.
    - Lack of glue connection confirmed with ultrasonic inspection.
  - Automated analysis under development.









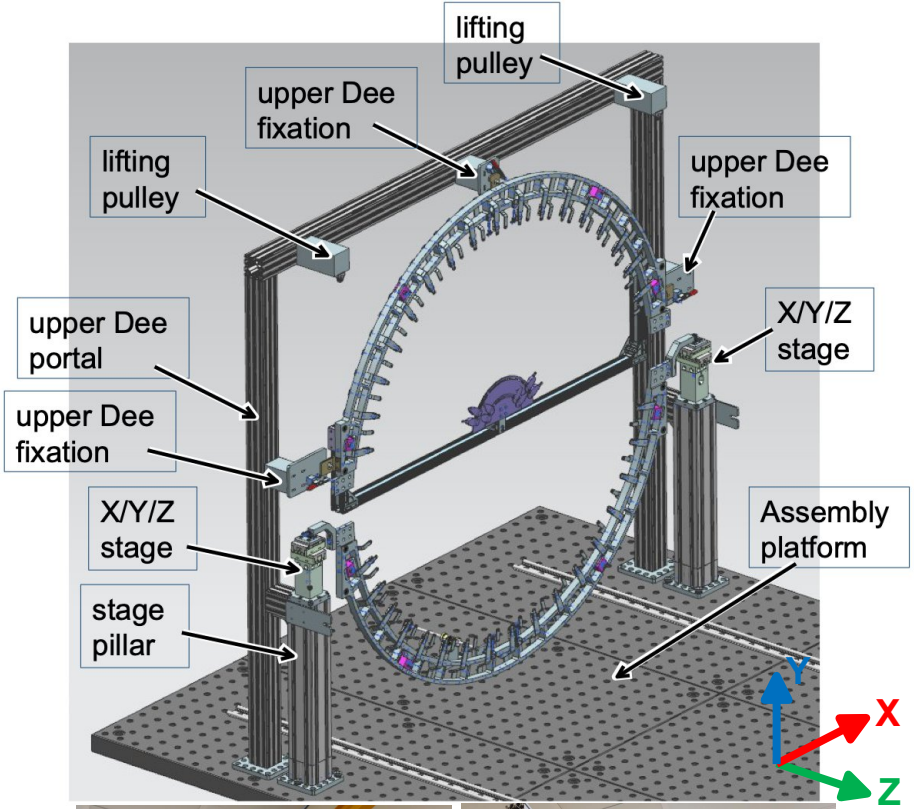
Dee integration

- For Module integration Arc frame is placed on assembly trolley.
  - Dee can around the horizontal axis.
  - Allow to adjust angle and height for optimal position of Dee.
- Irregular module arrangement complicates service routing.
- Services are routed to temporary patch panels on the Arc frame.
- Operator is guided through the integration sequence by a dedicated software tool.
  - Status of integration stored in construction database.
- Cable & fiber routing has been planned and is to be tested with mockups.
- Integration exercises needed.

Service routing and integration software developed in Louvain

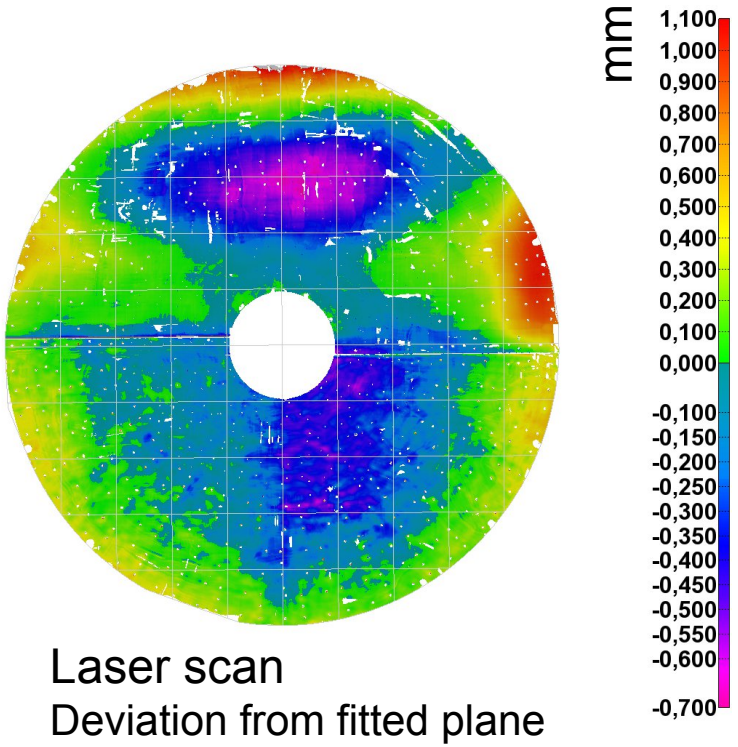
Disk assembly

- Upper Dee is mounted on upper Dee portal.
- Lower Dee is placed and x/y/z stages.
- Position of lower Dee wrt. upper Dee is measured with a metrology arm.
  - Measurements determine movements of the stages.
- Lower Dee is
  - rotated out of plane (around Y)
  - moved upwards
  - rotated back into the Disk plane
- When both Dees are align they are connect by bolts through the Dee-to-Dee inserts.
- Upper and lower Arc frames are mechanically connected.

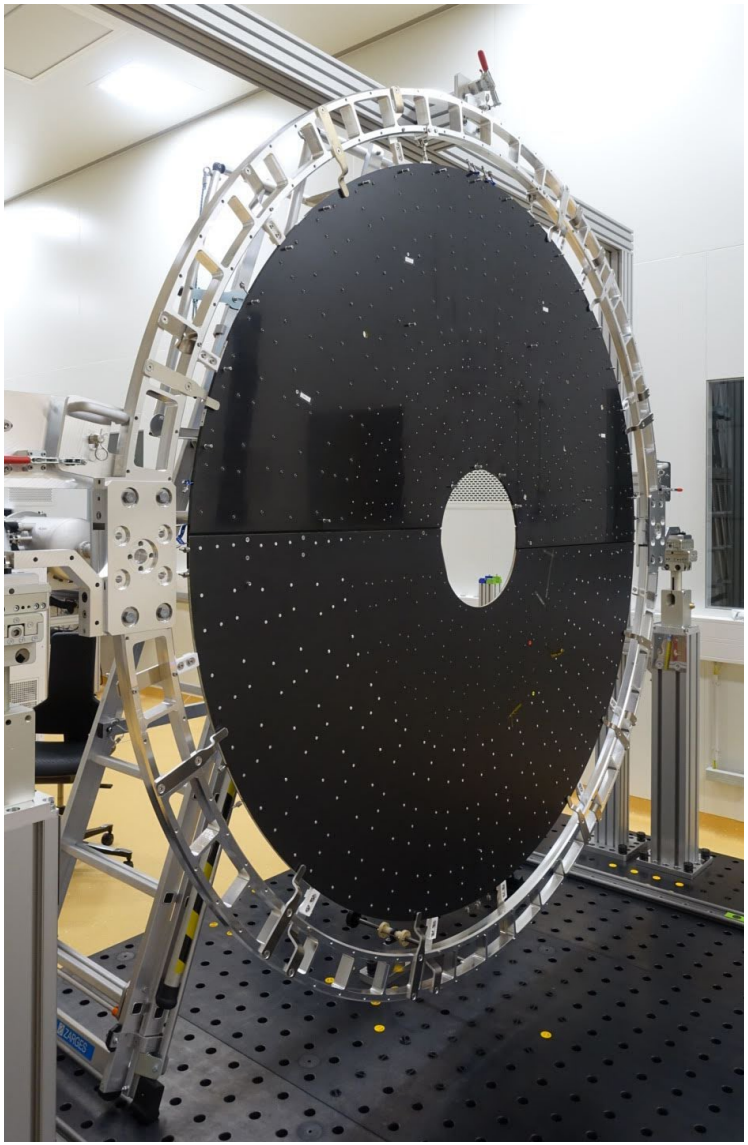


Prototype Disk

- Disk assembly procedure was validated using Dee prototypes.
- Flatness of final disk < 1.5 mm
  - Flatness driven by the shape of the upper Dee.
- In plane alignment better than 0.1 mm

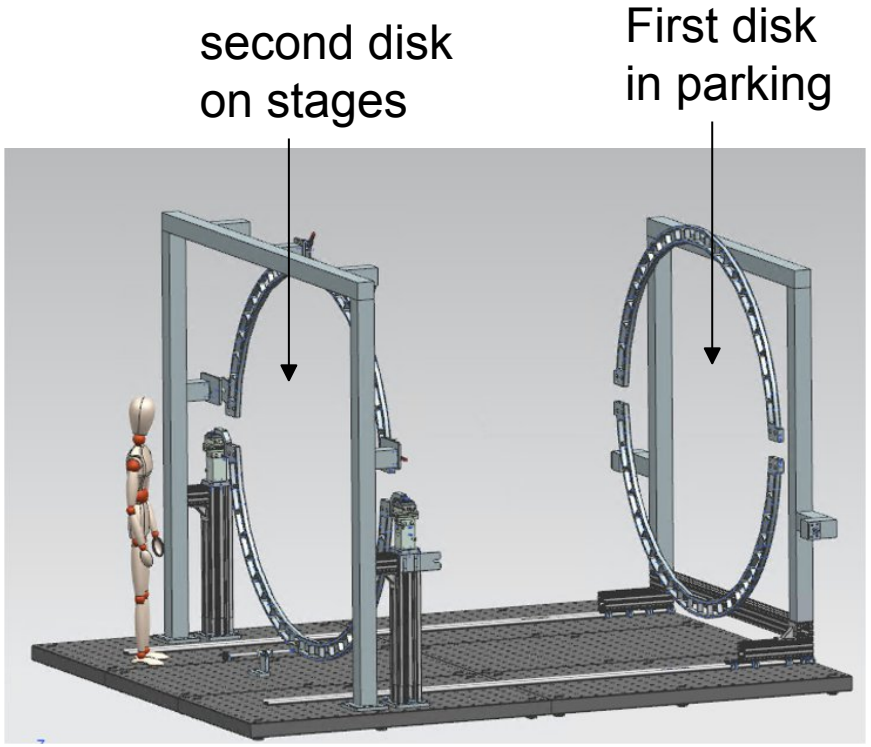


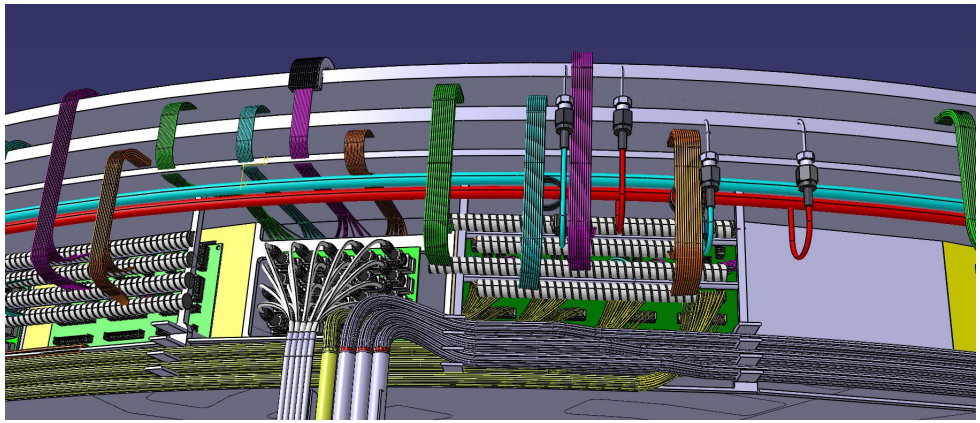
Laser scan
Deviation from fitted plane



Double disk assembly

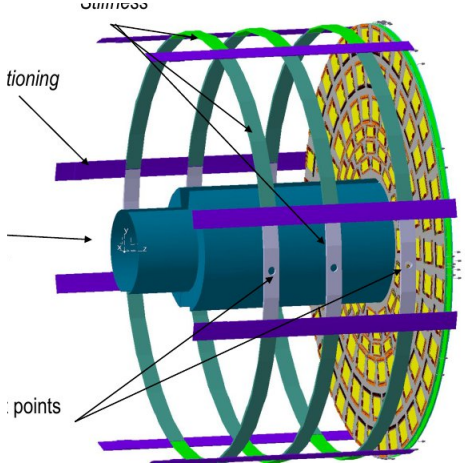
- Second Disk remains on stages.
- Previously assembled Disk is moved towards second one & "rail frame" is fixed against the stages.
- Second Disk is positioned wrt. to the first.
- Once both Disks are aligned
  - Disks are connected via the Disk-to-Disk inserts.
  - Arc frames on both Disks are connected to each other.
- Completion of DD:
  - Install patch panels and cooling manifold.
  - Route services.
  - Testing.

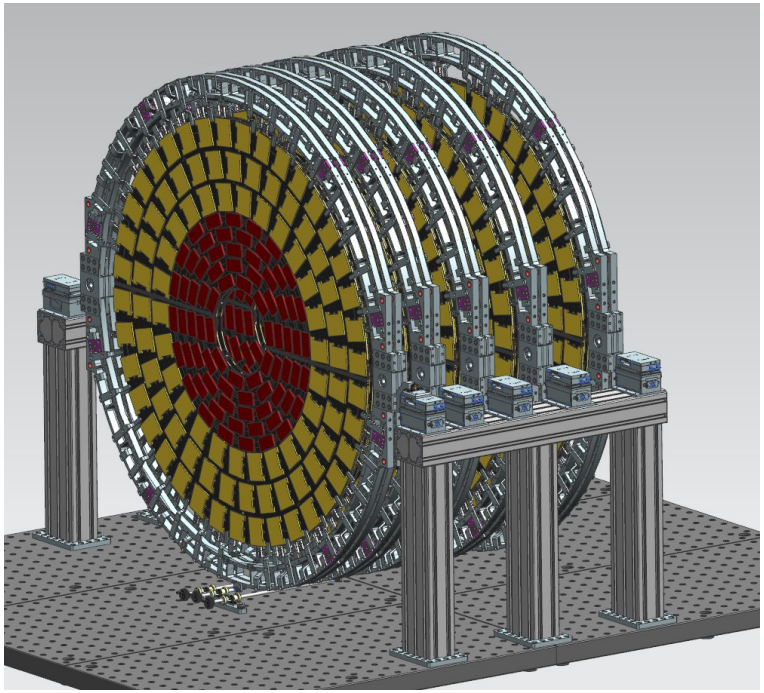




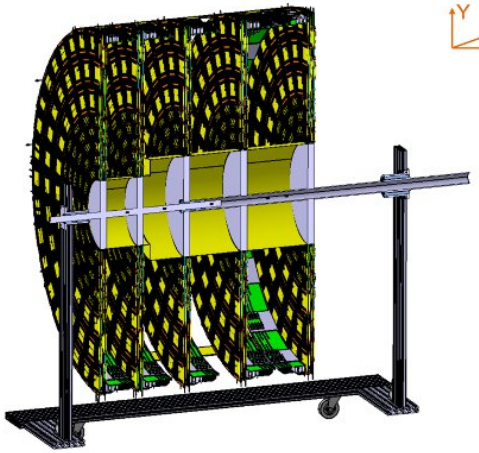
TEDD integration

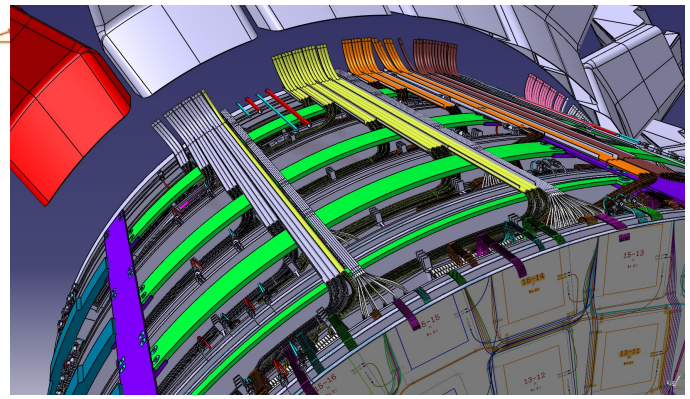
- Alignment of all 5 DD wrt each other.
  - Each DD on its set of stages.
- Installation of mechanical super structure.





- TEDD is transferred to rotation tool.
- Removal of Arc frames.
- Installation of longitudinal services.





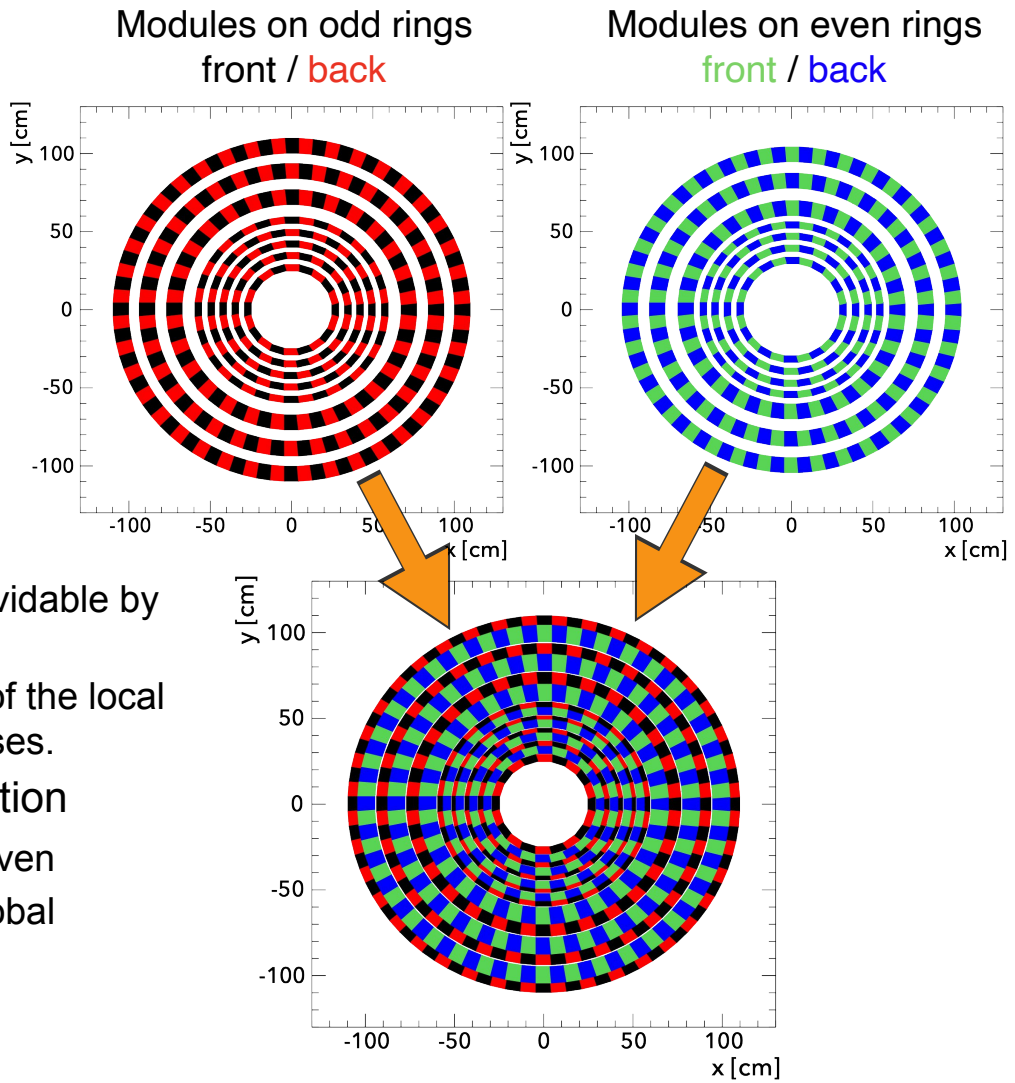
Summary / Outlook

- Dee design final and pre-production is about to start
  - 4 Dees at DESY, 3 in Lyon
- Dee qualification procedures are established (mechanical and thermal)
- Dee integration exercises planned.
  - Services routings established and to be exercised.
  - Module on Dee for grounding/noise measurements.
- Work on cooling pipes ongoing (DD manifold and longitudinal pipes).
- Tooling design advances:
  - First batch of final Arc frames were ordered.
  - Integration trolley available.
  - Disk assembly available and verified.
    - Soon to be extended for DD assembly, to be tested with pre-production Dees
  - TEDD tooling concepts maturing.
- Transport to CERN has to be studied.

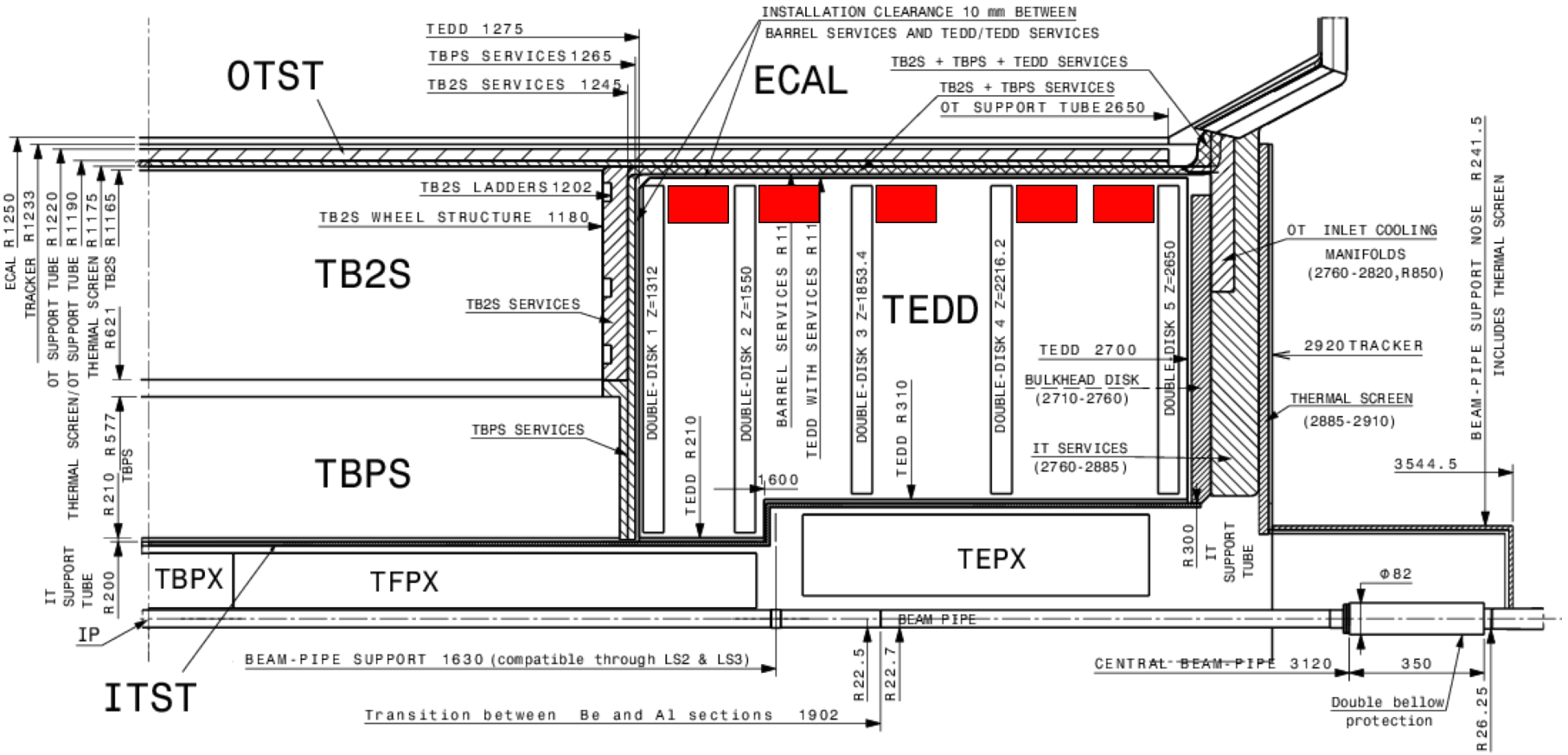
Backup

TEDD overview

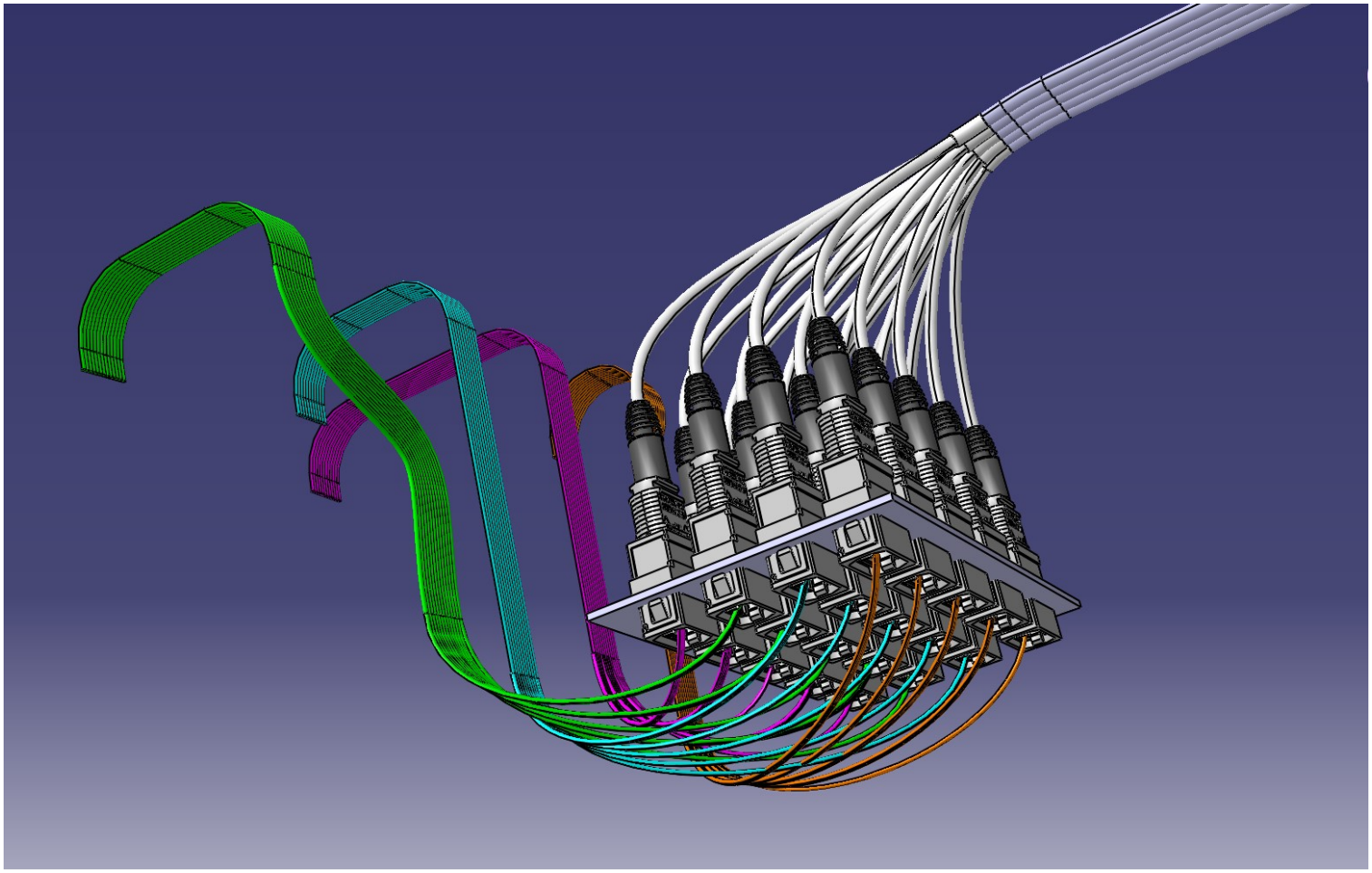
- Modules are mounted on front and back sides of Disks
  - overlap in phi established within Disk (green/blue and red/black)
  - overlap in radius established odd and even Disk are combined
- Ideal local support structure would be a full Disk.
- A subdivision has consequences:
  - Number of modules per ring has to be dividable by number of divisions.
  - With more subdivisions the contribution of the local support to the overall mechanics decreases.
- Half-Disk - Dee - is the second best option
  - number of modules only required to be even
  - Dee can significantly contribute to the global mechanics.



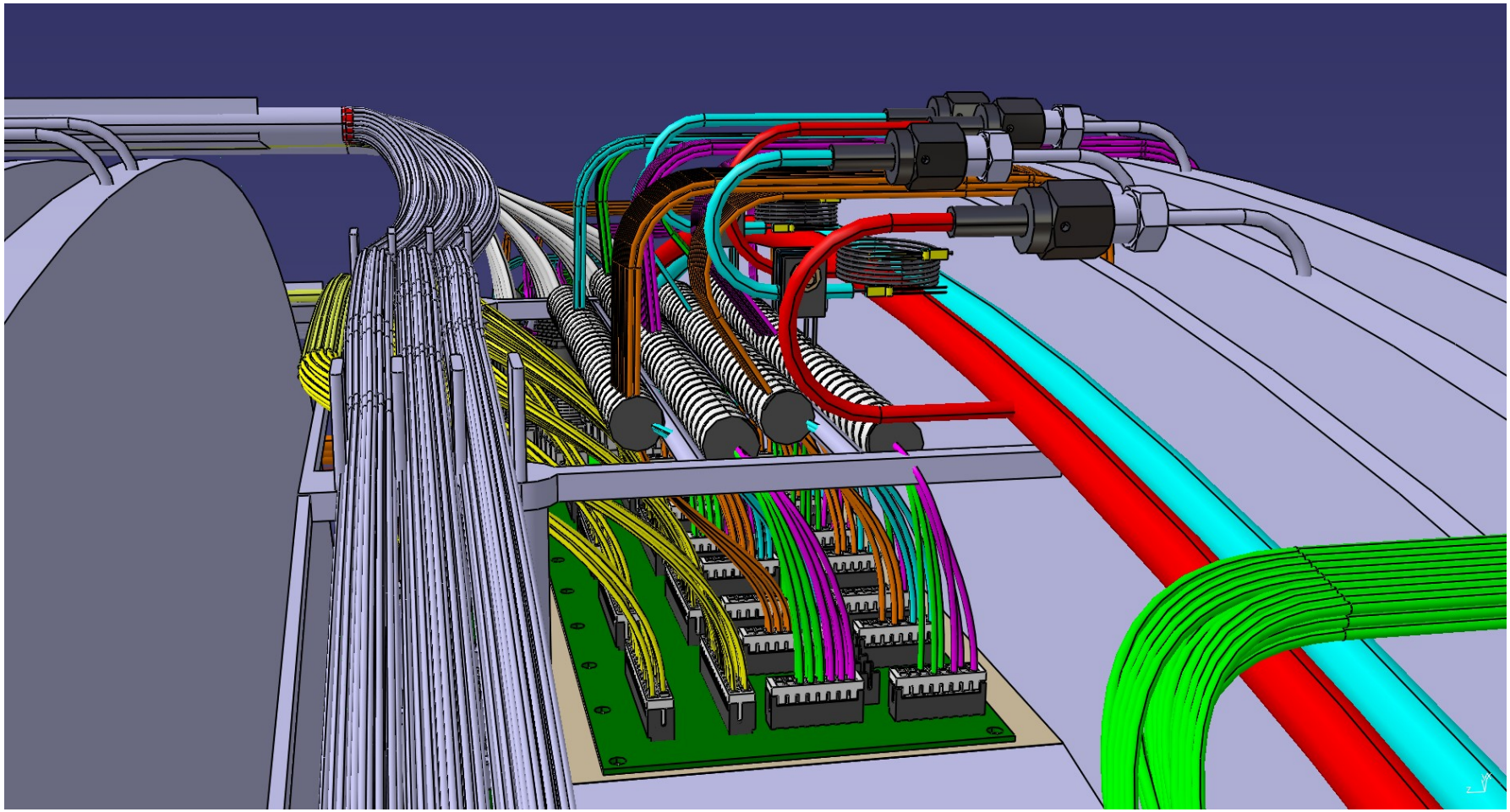
TEDD Services - Locations of PP0s



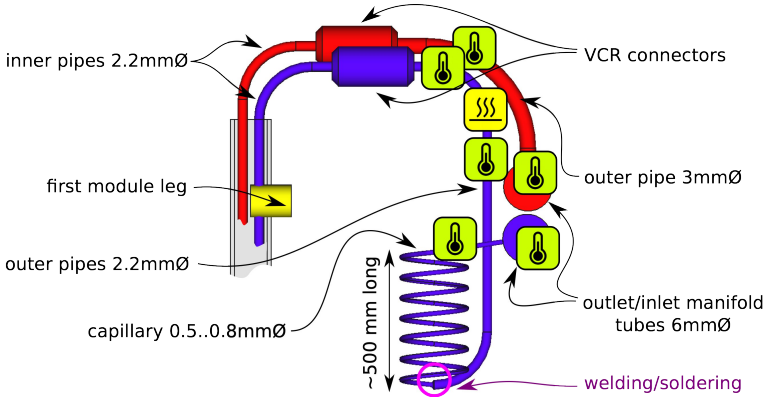
Optical PP0

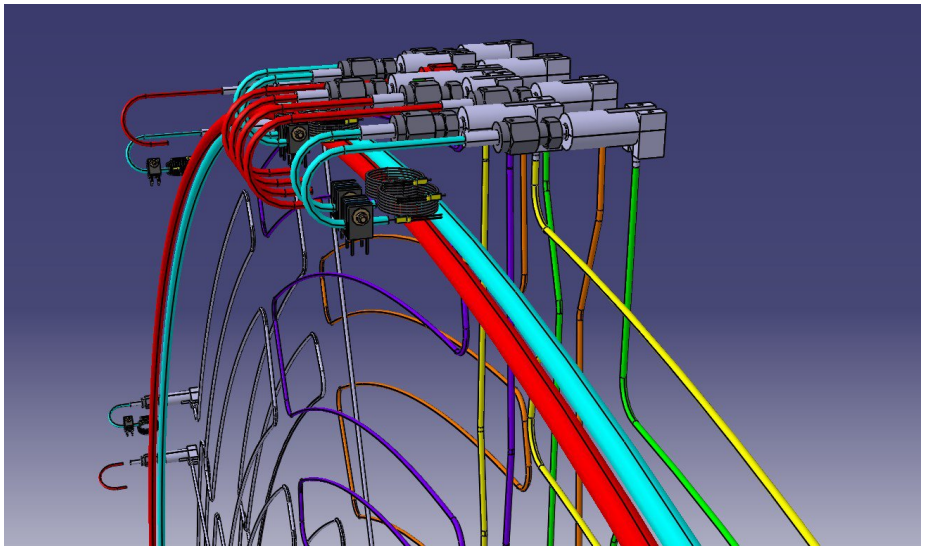


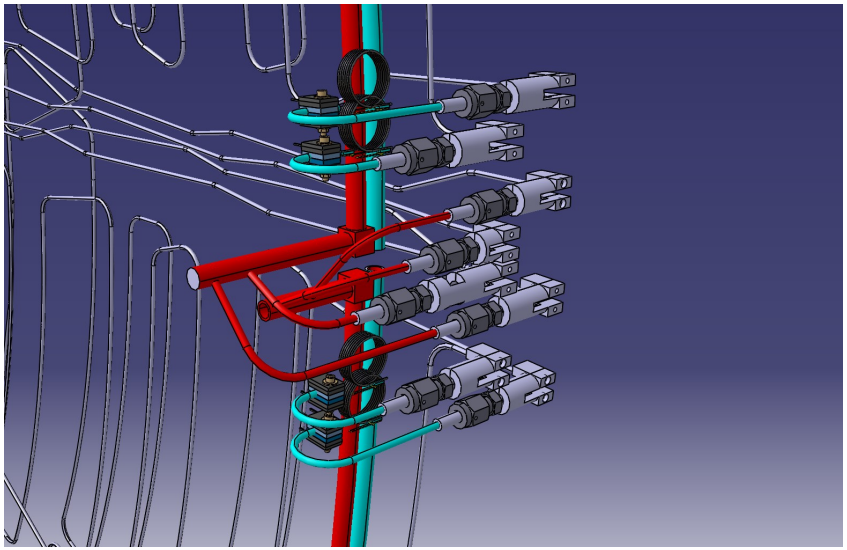
Electrical PP0



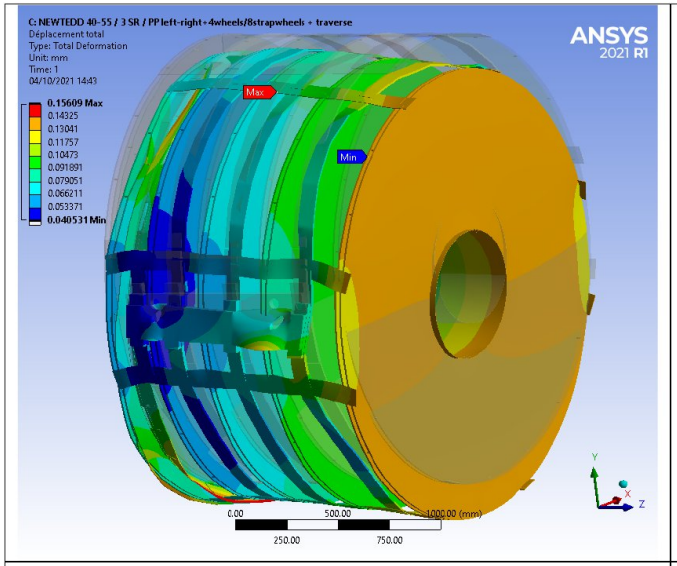
Cooling Manifold



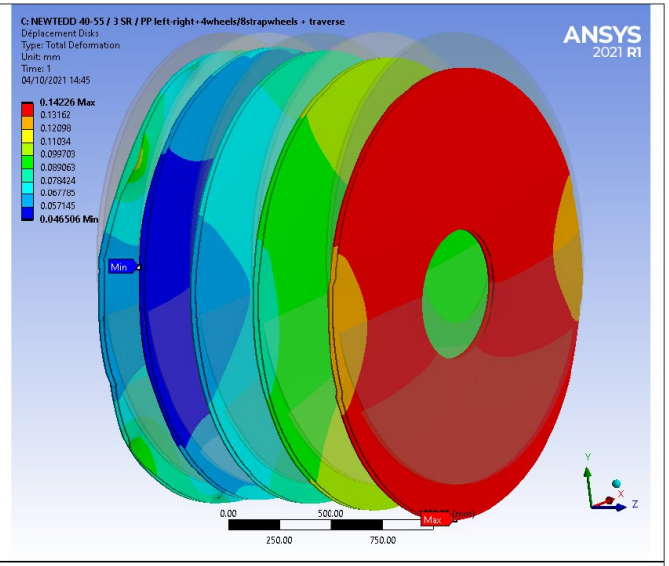




TEDD FEAs



Global TEDD deformation

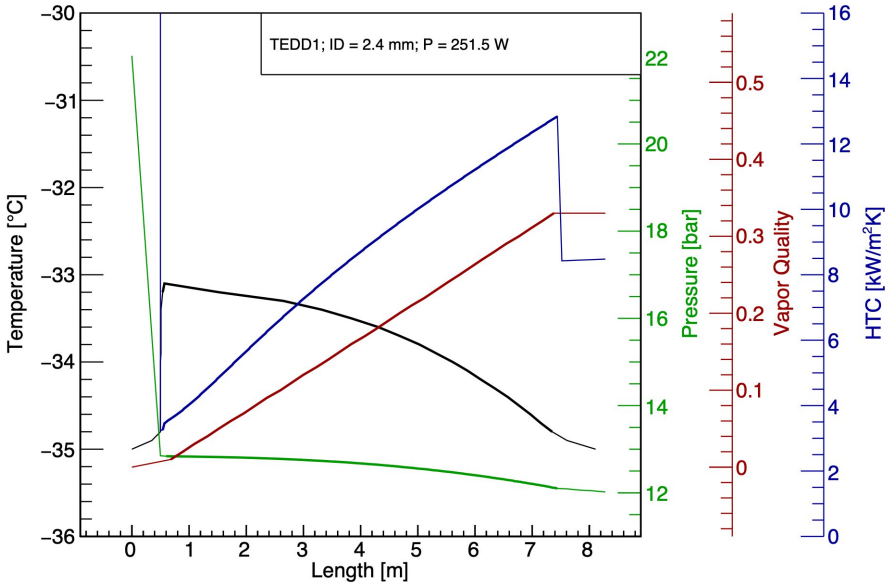


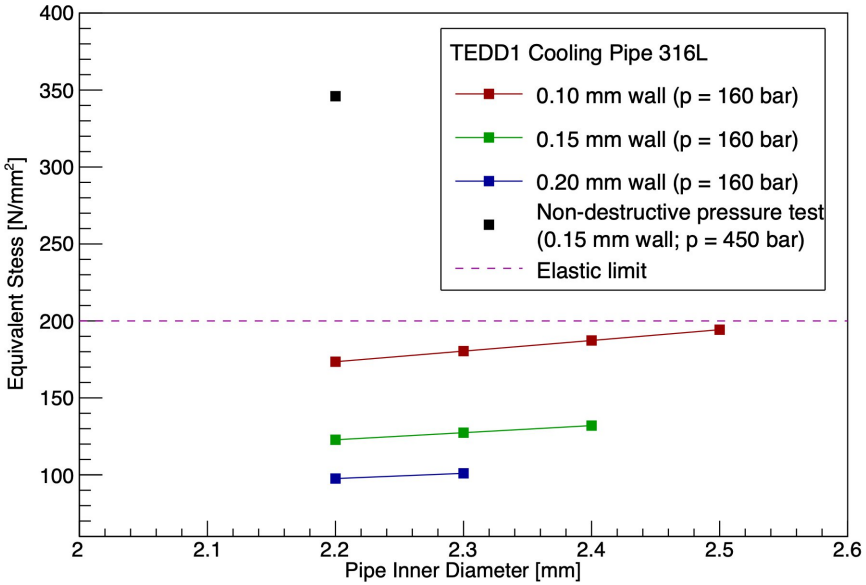
Global DoubleDisks deformation

		x	y	z
Δmax	156 µm	+65/-120	-32/-136	+/- 121
Δdisks max	142 µm	-12/-30	-43/-132	+/- 83
σVM max	27.1 Mpa			

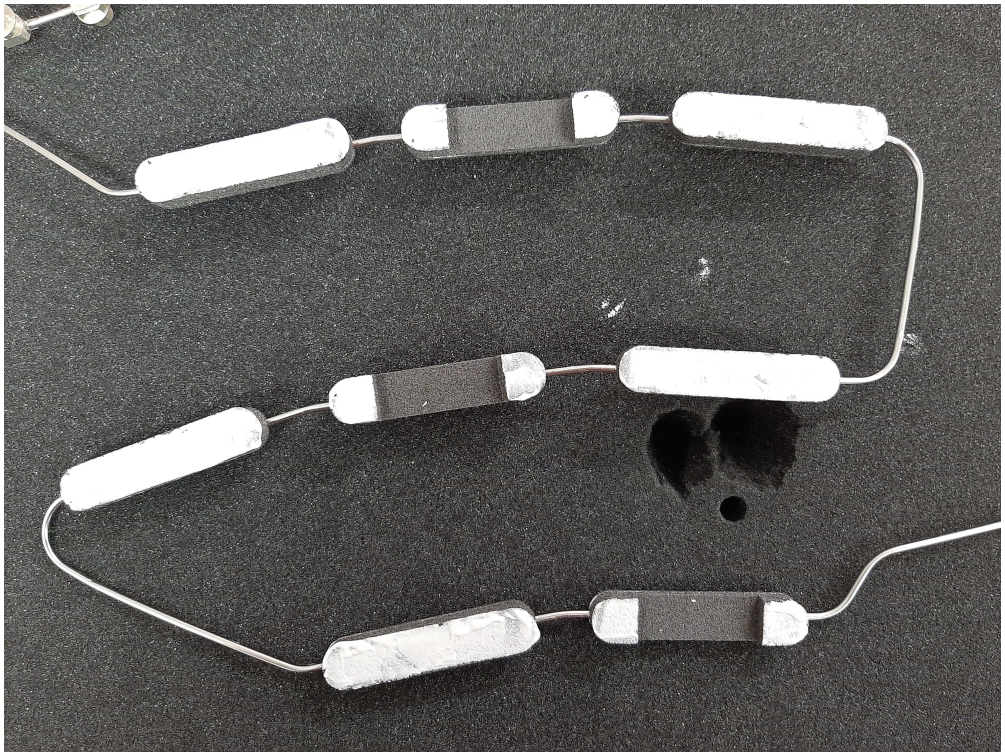
- Overall maximum deformation of the SuperStructure around 150 µm
- Overall maximum deformation of Double-Disk below 150 µm
- Maximum stress appears on beams interfaces and remains under 30 MPa

TEDD1 Cooling Pipe





TEDD2 - Cooling Sector



Integration trolley