DESY CONTRIBUTION ZUM LHC UPGRADE.

ITK Atlas phase 2 upgrade

Dario Ariza on behalf of the ATLAS Group

Oskar Reichelt on behalf of the CMS Group

19.06.2025

HELMHOLTZ

DESY.

DESY CONTRIBUTION TO THE LHC UPGRADE

ITK Atlas phase 2 upgra

SPOILER!!! DISCLAIMER!! ALERT!!

Main Topic of this talk is to highlight some of the many contributions of the DESY ATLAS & CMS Team to the LCH Experiment. A lot of pictures ☺☺☺

Dario Ariza on behalf of the ATLAS Group

Oskar Reichelt on behalf of the CMS Group

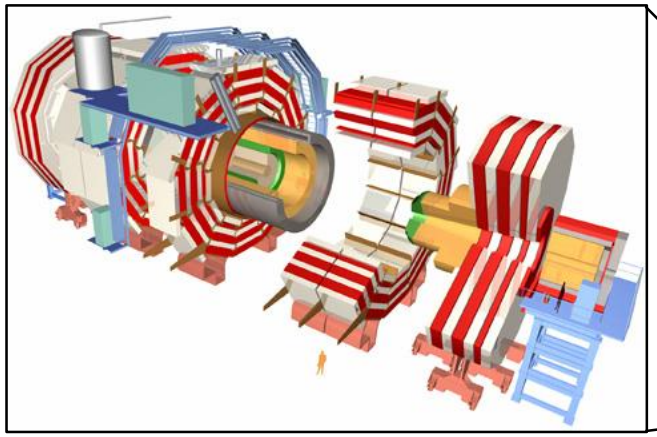
19.06.2025

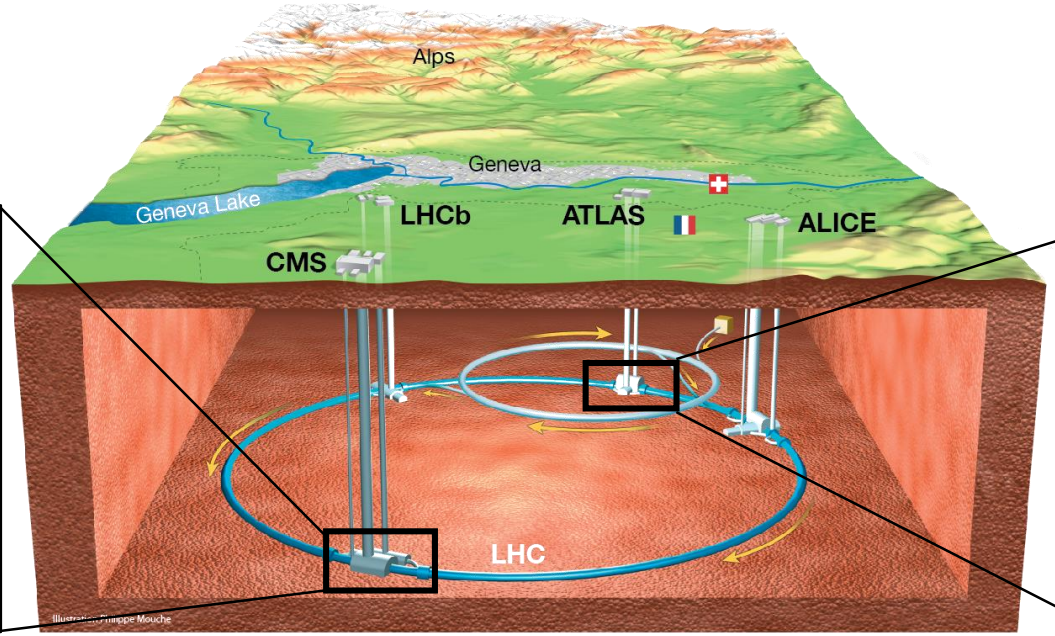
HELMHOLTZ

DESY.

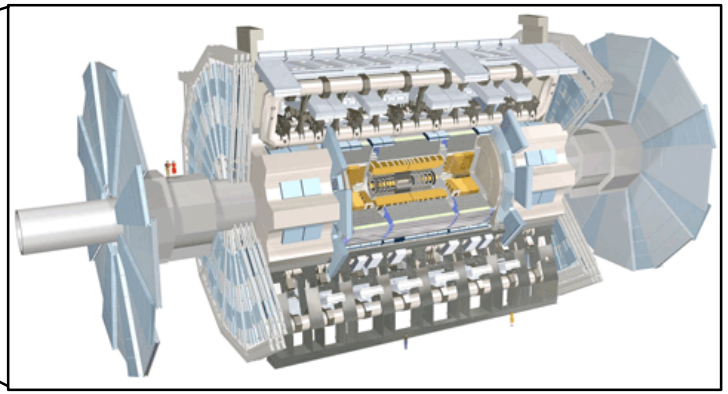
High Luminosity LHC

CMS





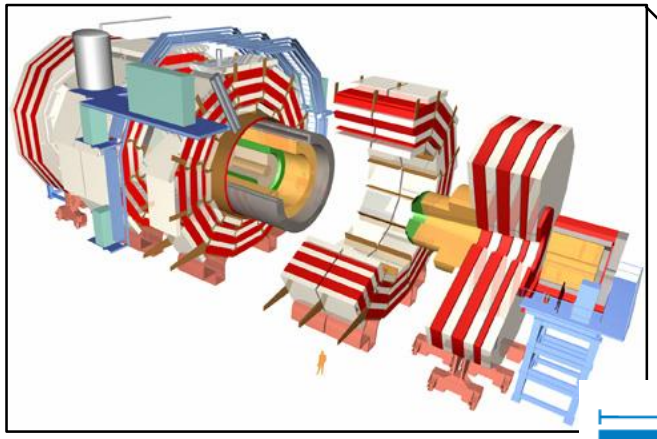
ATLAS

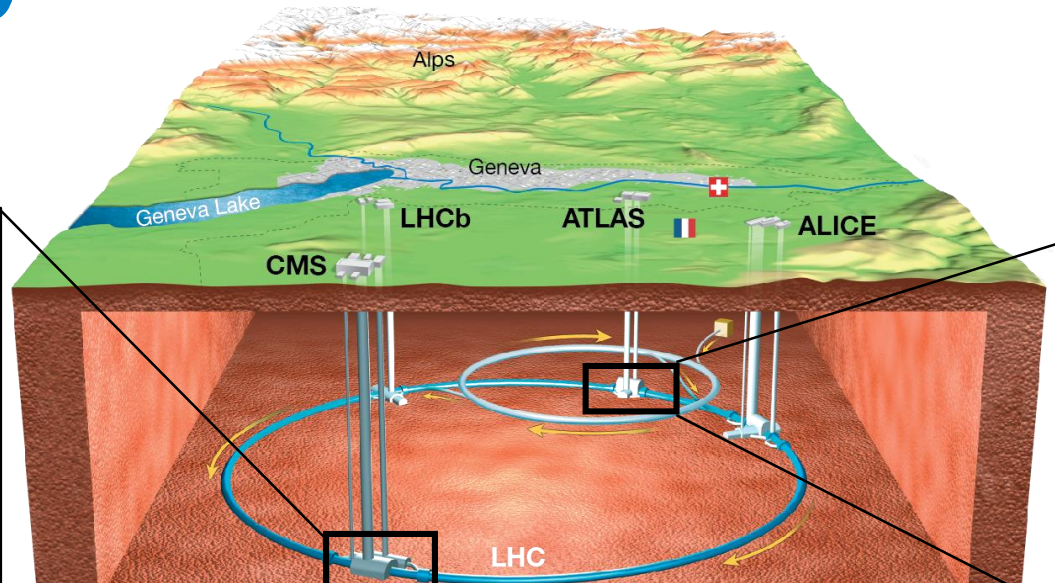


In Genf betreibt die internationale Forschungseinrichtung CERN (***C**onseil **e**uropéen pour la **r**echerche **n**ucléaire*) den Large Hadron Collider (LHC), den leistungsfähigsten Teilchenbeschleuniger der Welt. Im unterirdischen 27 Kilometer langen Ring werden Protonen nahezu auf Lichtgeschwindigkeit beschleunigt und zur Kollision gebracht. Für die Phase-2-Upgrades des LHC müssen die Detektoren an die deutlich erhöhten Herausforderungen angepasst werden: Sie müssen höheren Strahlungswerten, größeren Datenmengen und einer Vielzahl gleichzeitiger Teilchenwechselwirkungen standhalten. Daher werden wesentliche Komponenten der Detektoren – wie der Inner Tracker – neu entwickelt und gebaut, um auch unter diesen extremen Bedingungen zuverlässig zu funktionieren.

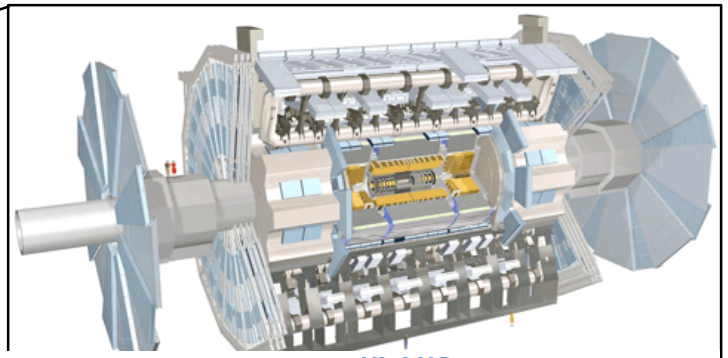
High Luminosity LHC

CMS

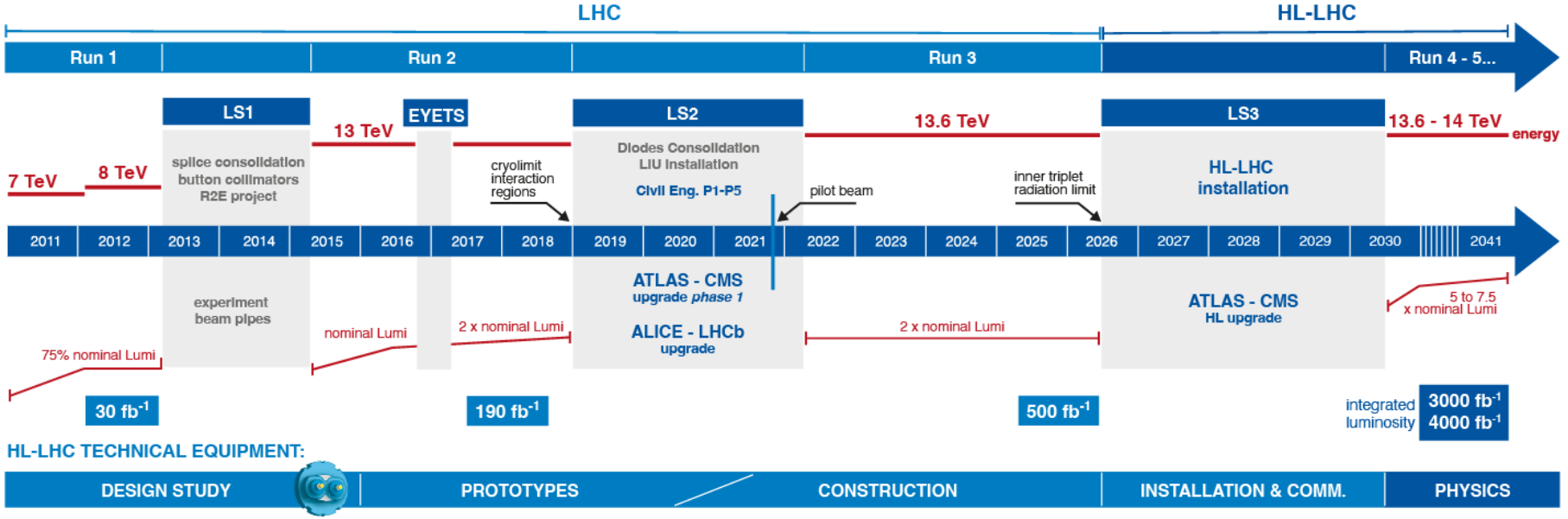




ATLAS



- Strahlungshärte
- Geringe Masse
- Thermische und Positionsstabilität
- Präzision
- Kühlung Integration
- …

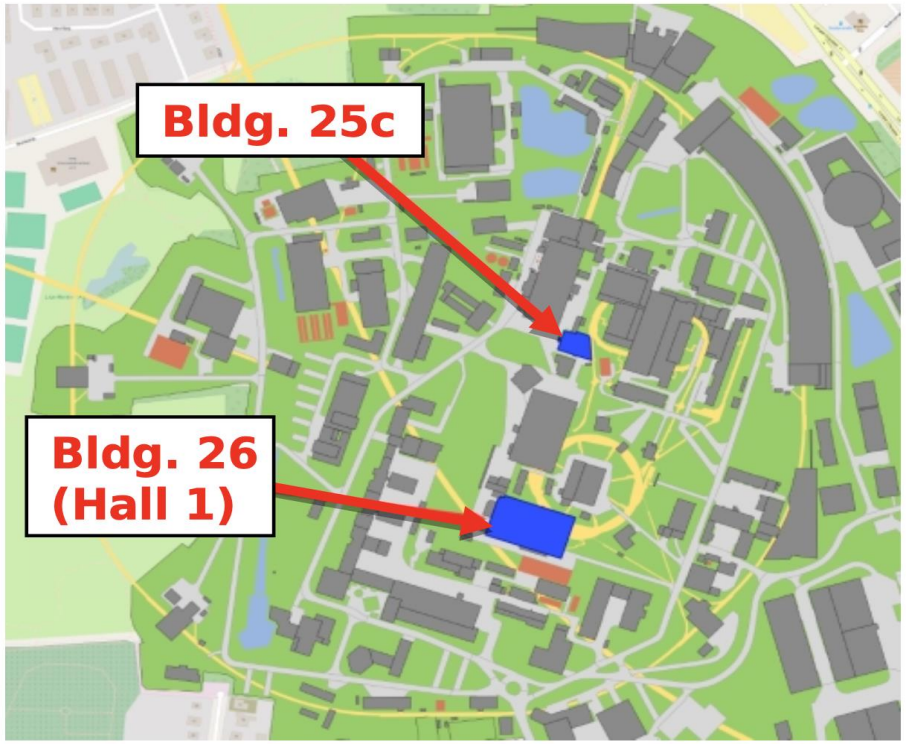


DAF – Detector Assembly Facility

2 Reinräume für LHC Upgrade

Gebäude 25c: 250 m² ISO-6 für Sensormodul Produktion

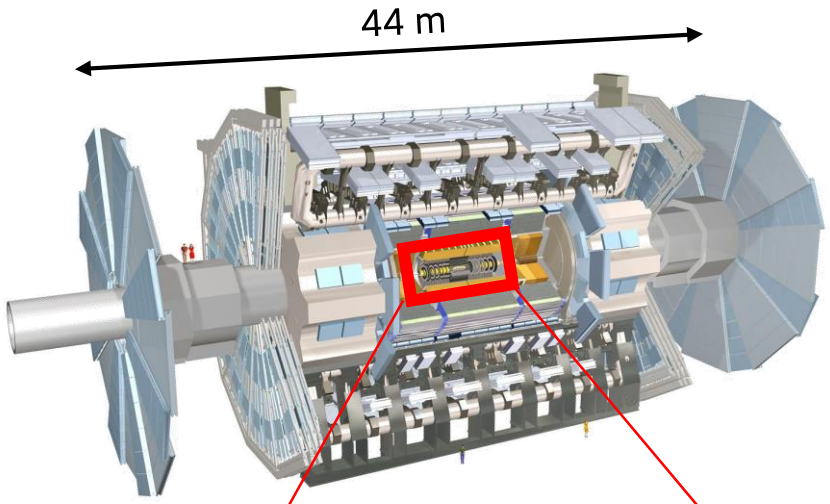
Gebäude 26: 700 m² ISO-7 für Montage und Integration, Integration Bereich (grün) 5 m Deckenhöhe, Trockenluft, Kühlwasser



DAF Geb. 26 Raumplan und Innenraum

ATLAS Upgrade

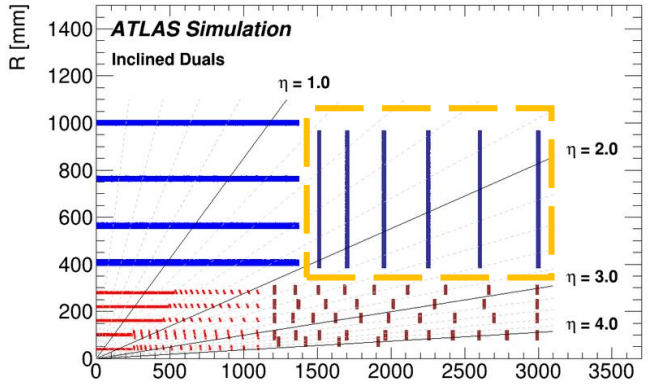
Atlas Detector

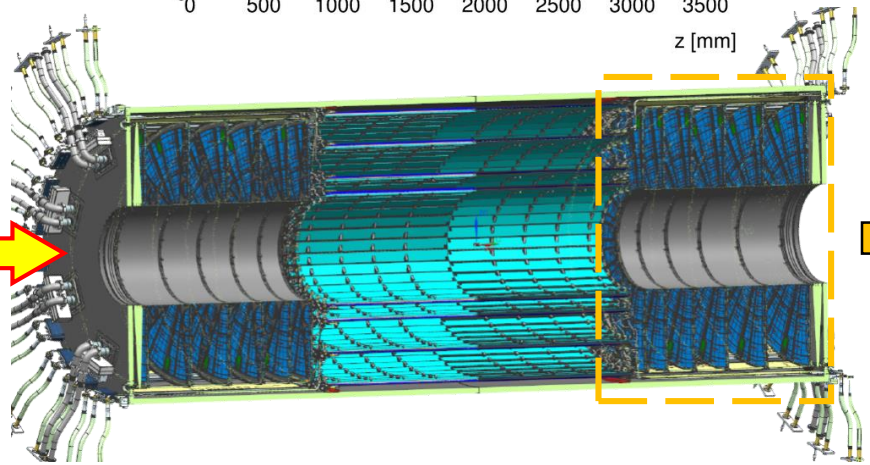


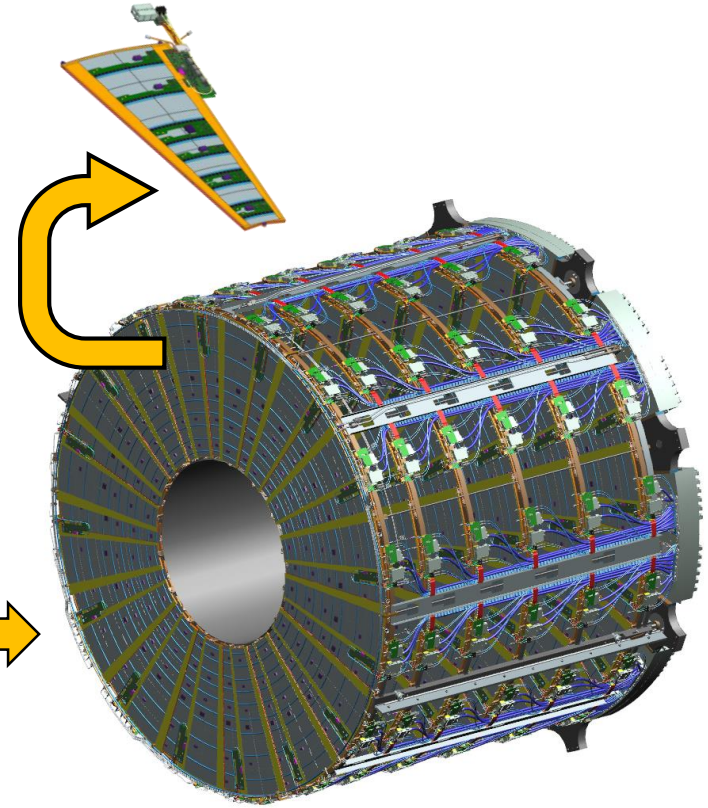
ITK (Inner Tracker)

ATLAS phase II upgrade with a completely new Inner Tracker:

- Highly summarized: The main goal from Desy is to deliver one Endcap to CERN



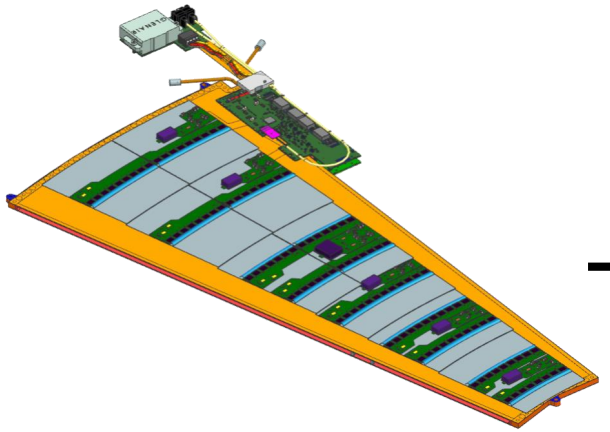




Desy Contributions zum LHC

The Endcap, Teil de ITK – a carbon-fiber-based detector

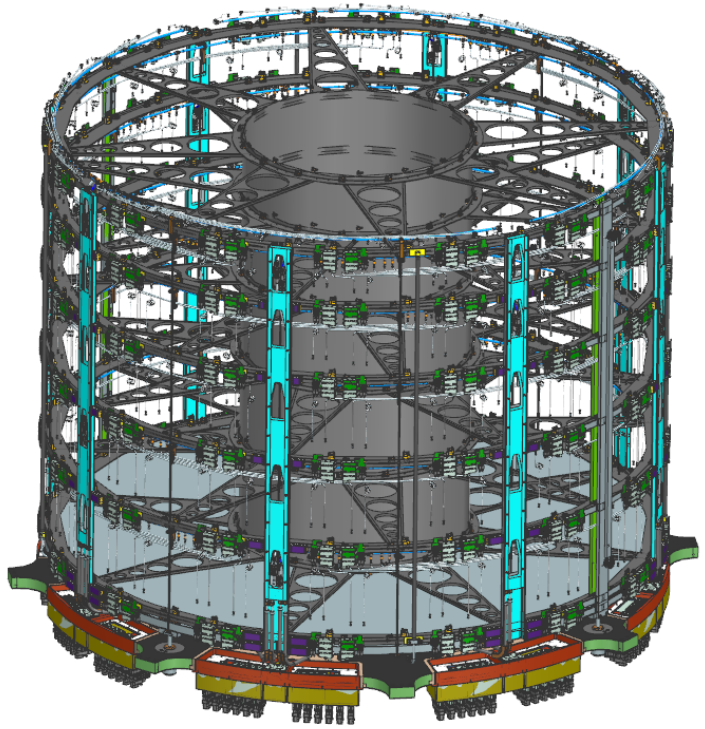
Local Support
(Petal)



3456 Si-Sensors
in 192 Petal cores.

+

Global Support



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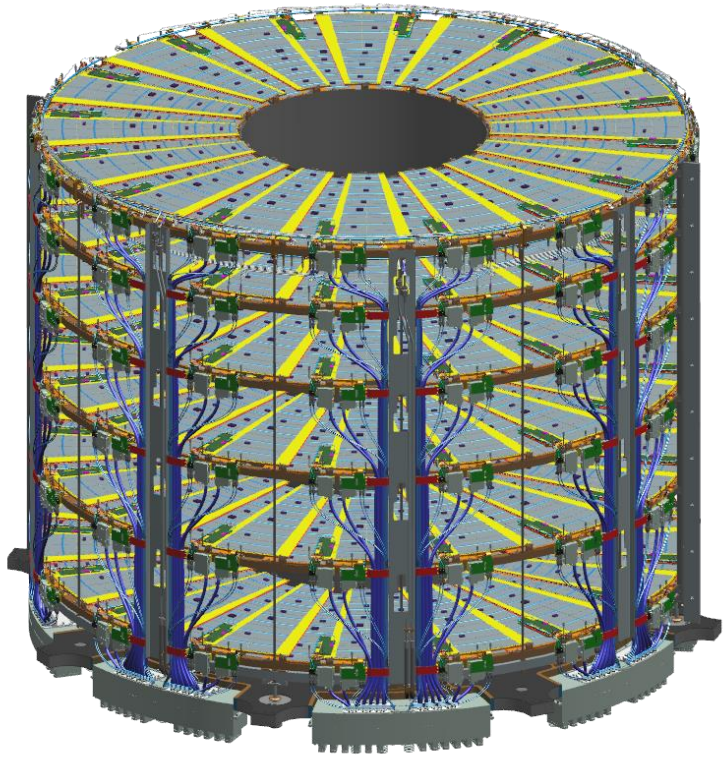
Endcap



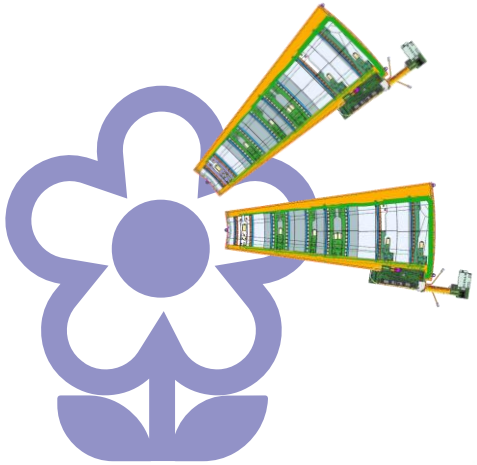
Desy Contributions zum LHC

Der Petal – the local support structure

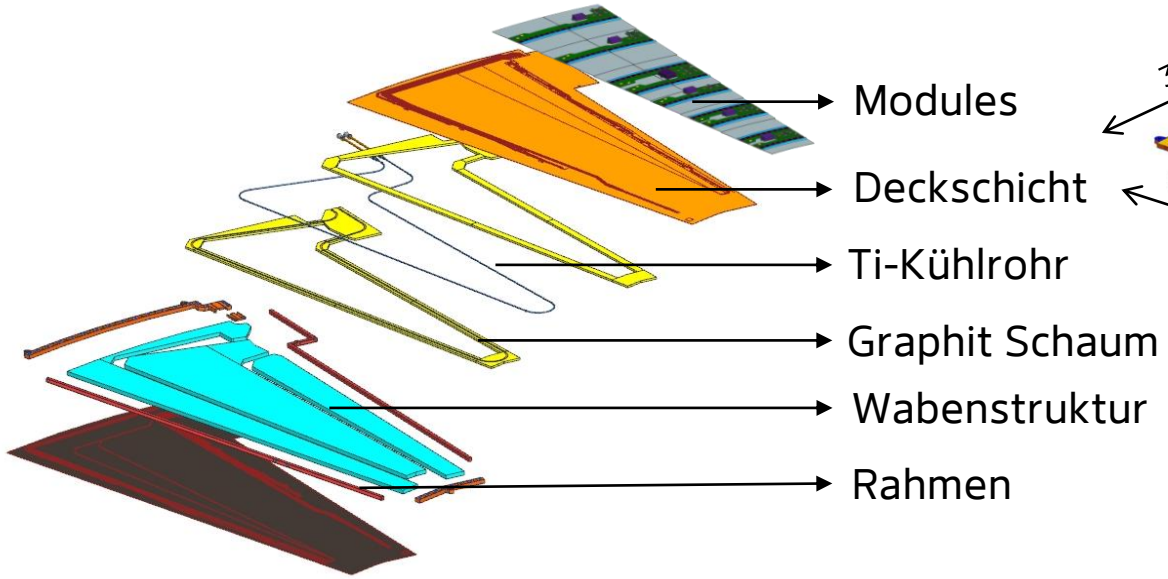
Leichte, kompakte Trägerstruktur mit eingebauter Kühlung für Sensoren und Elektronik.

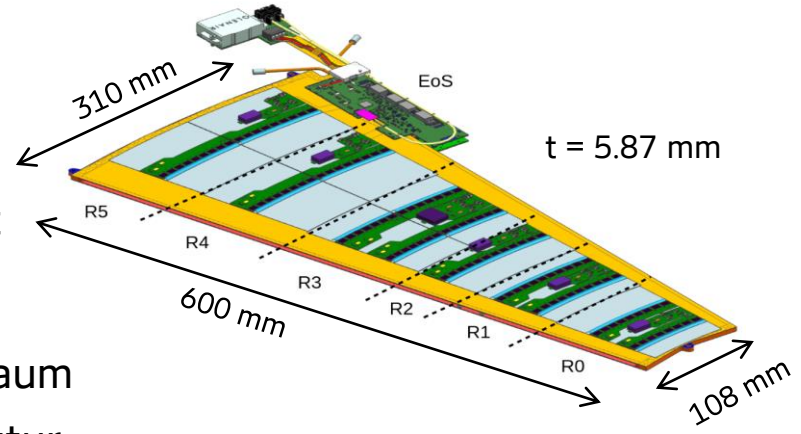
Wichtige Eigenschaften:

- Kohlenstoff Schaum zur effizienten Wärmeableitung
- Wabenstruktur für mechanische Steifigkeit
- Eingebettete Flexible Leiterplatte (Bustape/Deckschicht)
- Präzise Positionierung
- Leichte Bauweise: 250 g



Petal (eng) = Blütenblatt

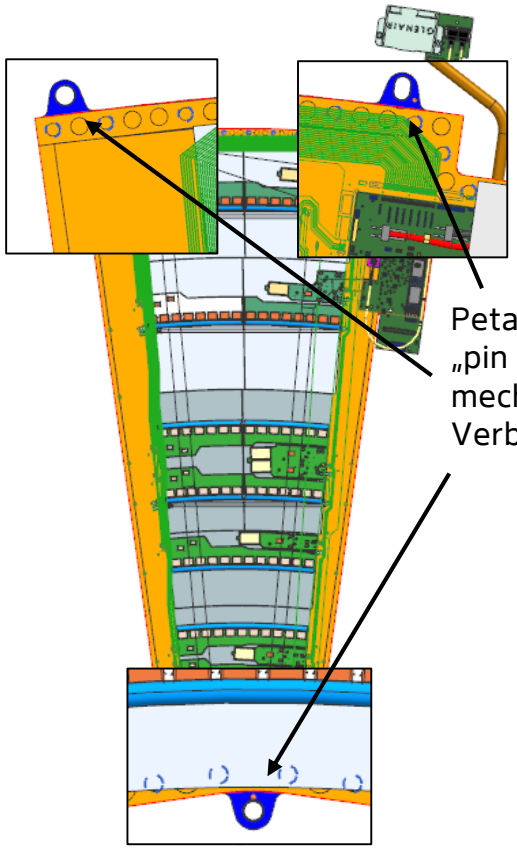




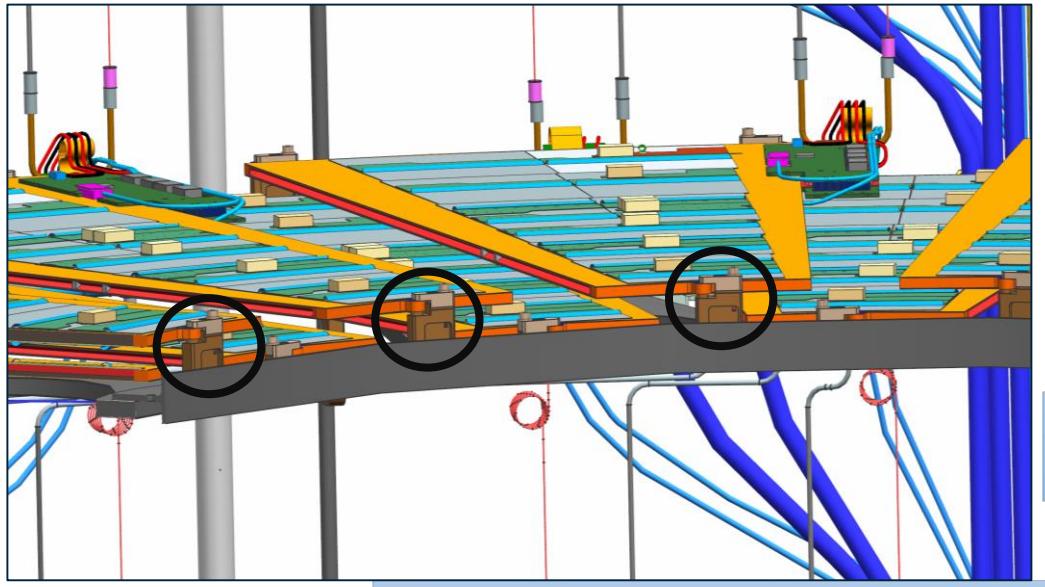
Desy Contributions zum LHC

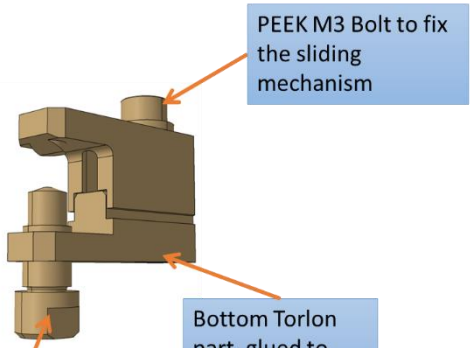
Der Petal – the local support structure

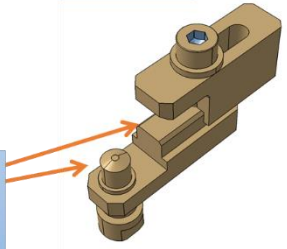
Leichte, kompakte Trägerstruktur mit eingebauter Kühlung für Sensoren und Elektronik.



Petal locators aus Torlon: „pin and hole" locking mechanism („Stif-Loch Verbindung")

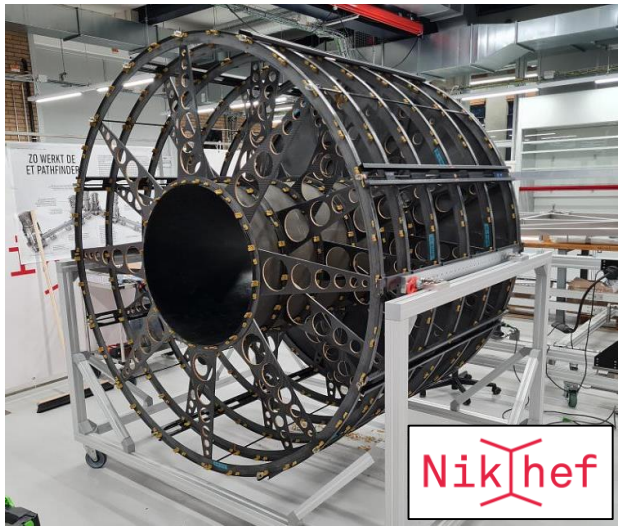






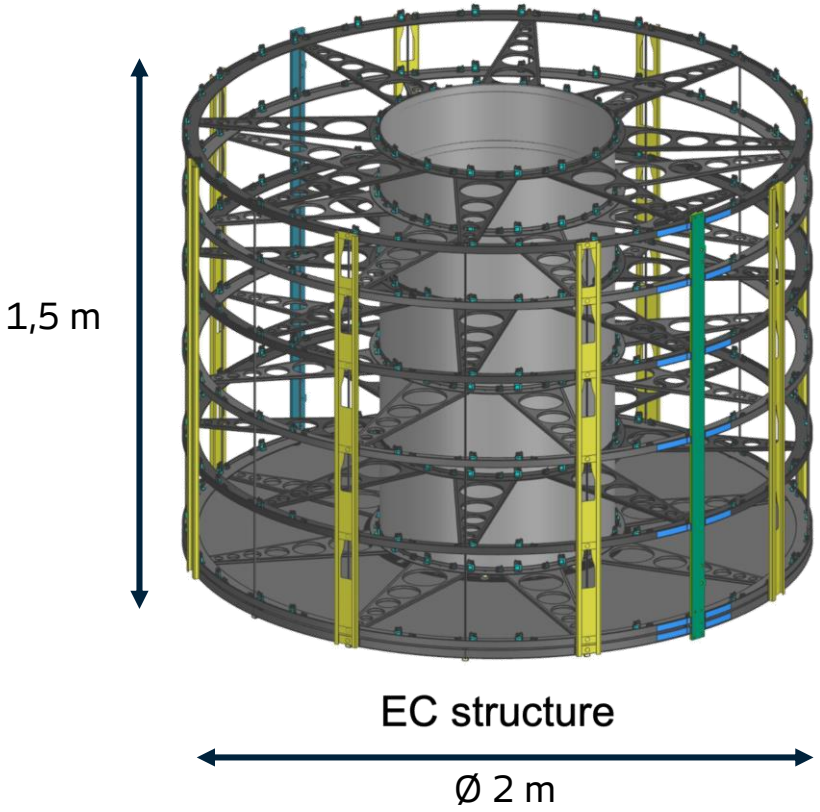
The important locations (Pin [XYZ], Slide [Z]) for positioning petals are machined in a single step AFTER placing the locking points on the CFRP structure

Desy Contributions zum LHC



Die Endcape

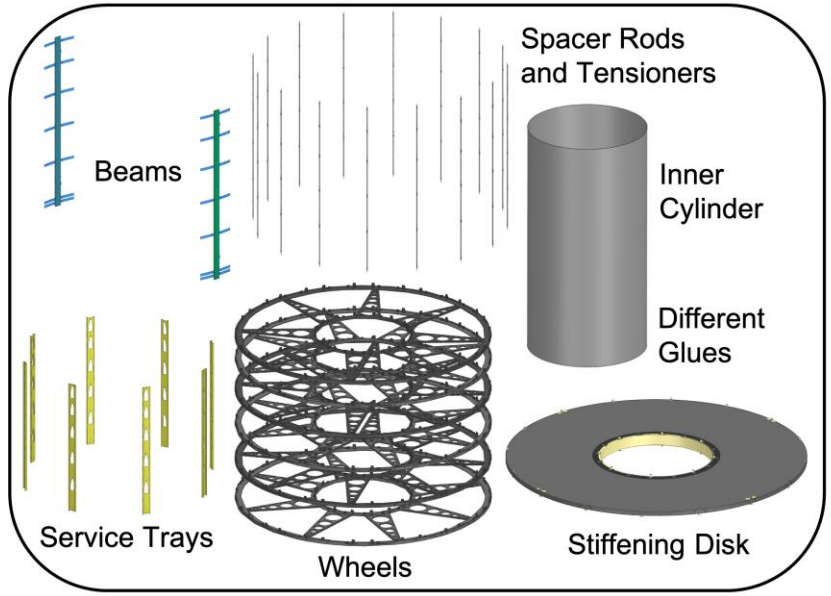
Die Endcape ist eine, verhältnismäßig, leichte Struktur, die thermische und mechanische Stabilität für die unterstützten Unterkomponenten gewährleistet und gleichzeitig eine hohe Präzision beibehält. Außerdem dient es als Träger für Servicekabel und Kühlleitungen.



192 Petals
32 Petals pro Disc
6 Discs pro Endcape

Gewicht: ca. 100 kg

Besteht aus:



Desy Contributions zum LHC

Die Endcape

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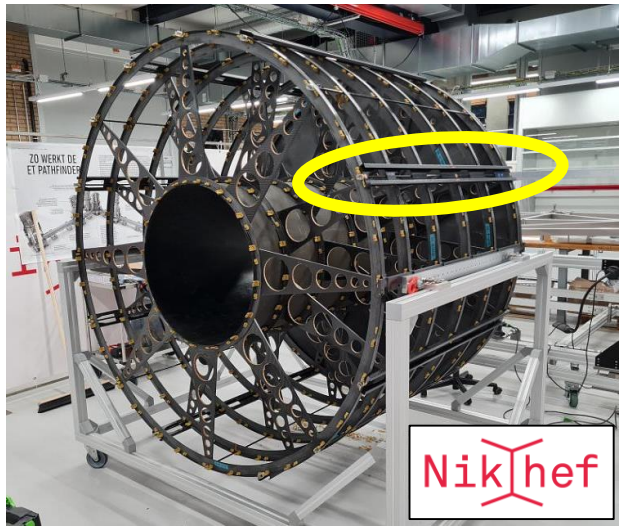
Stabilität für die unterstützt eine
hohe Präzision beibehält. A
Kühlleitungen.



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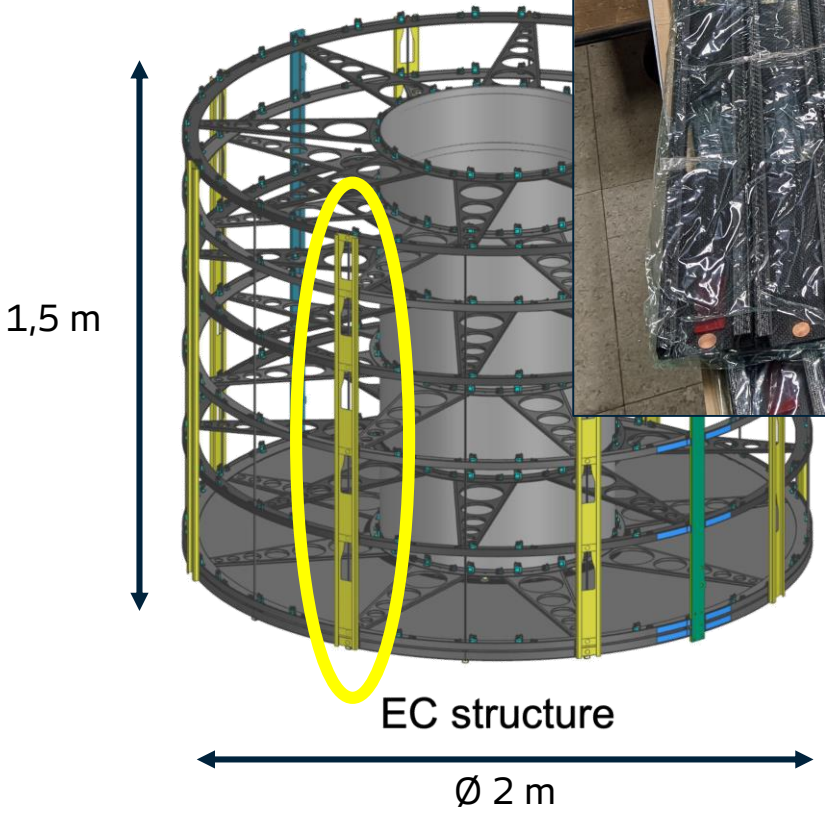
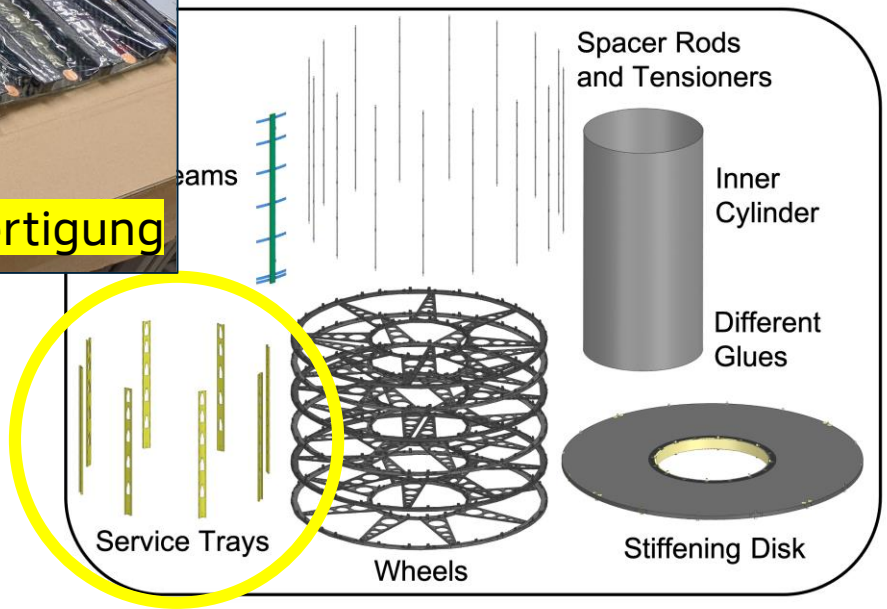


Service Trays
(8 x 2 EC)



Desy Contributions zum LHC

Die Endcape

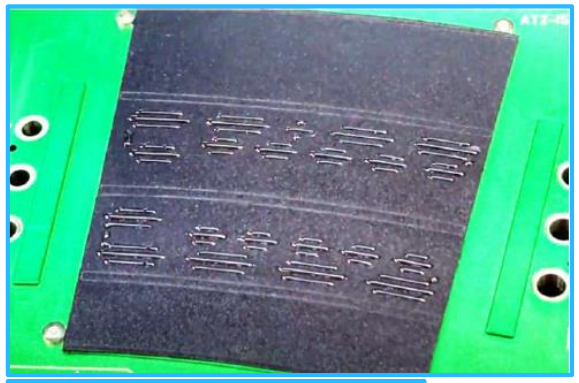
Nikhef, Amsterdam

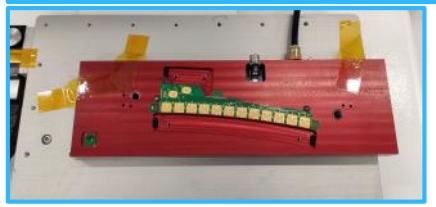
DESY HH

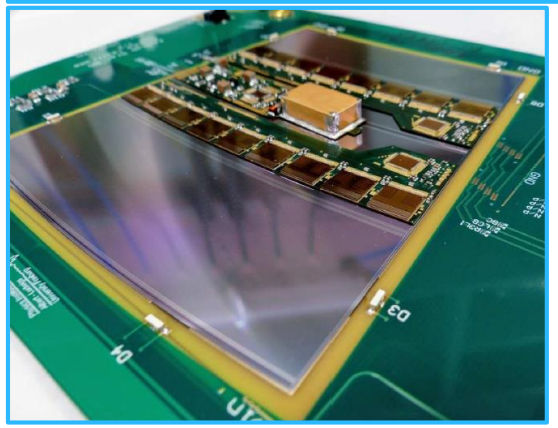
Other activities & Contributions

Module building & Module loading (incl. QC)

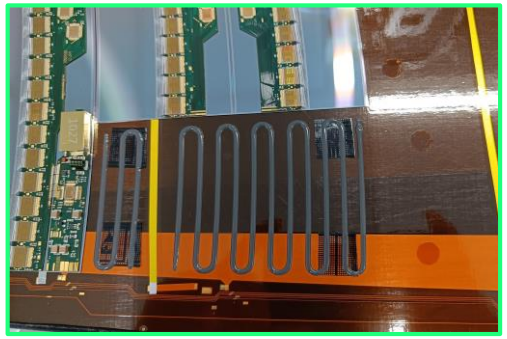
Glue pattern for hybrids dispensed by the robot

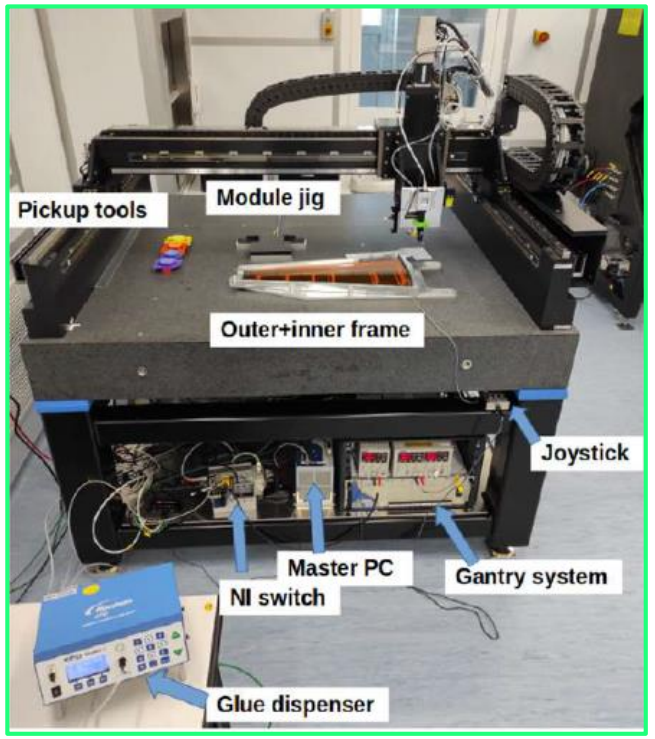


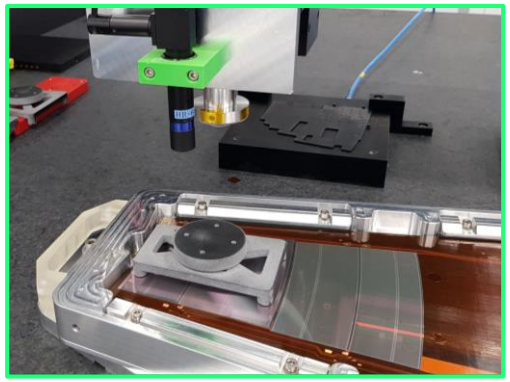


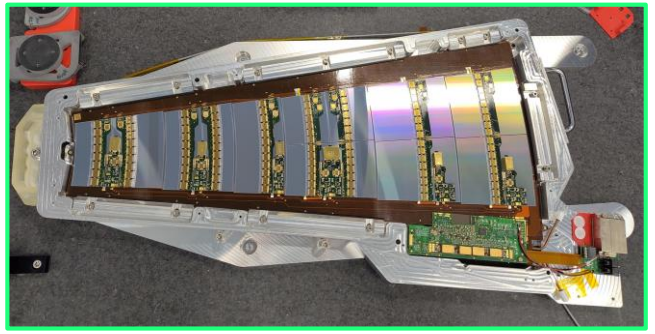


- Dedicated effort on tooling and procedures to avoid learning curves for different module types.
- Automation of glue dispensing to maximize reproducibility





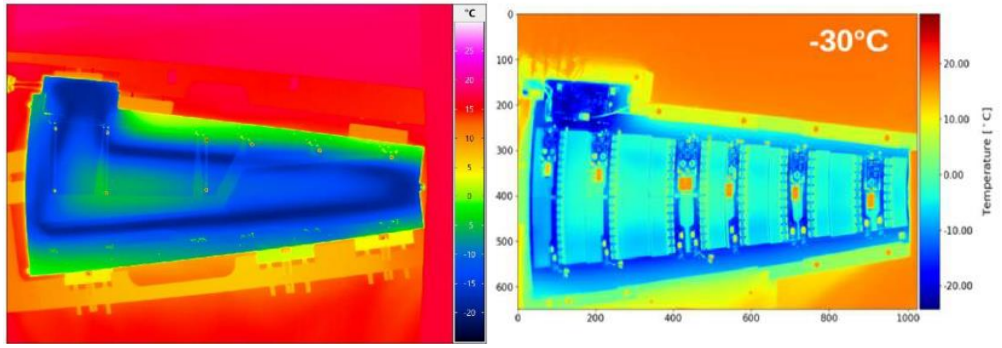




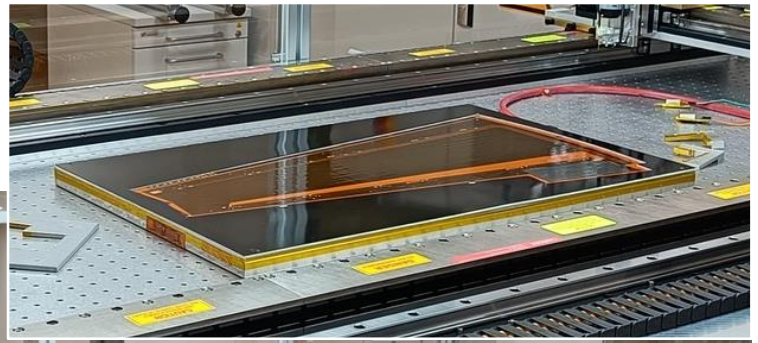
Other activities & Contributions

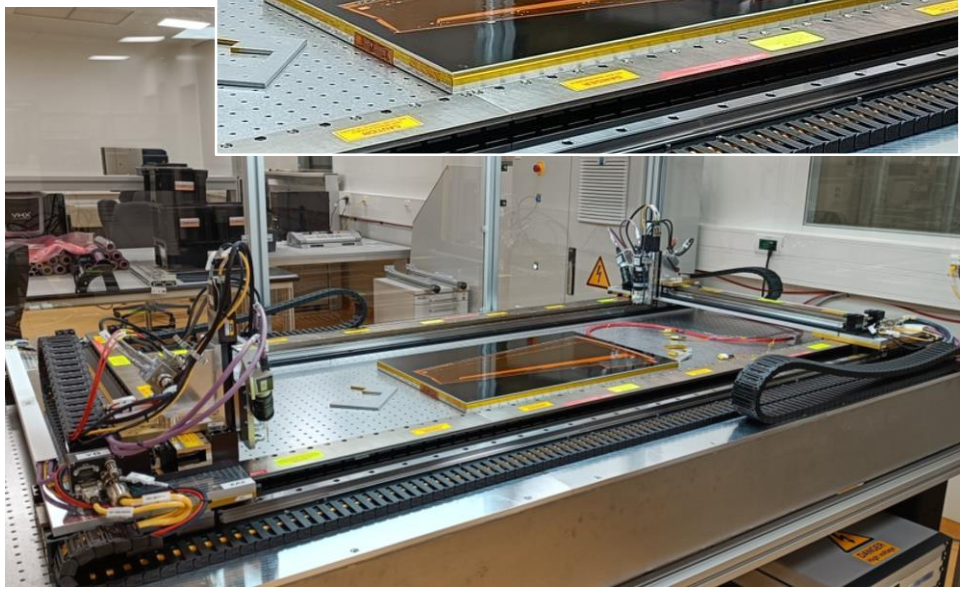
Petal core Thermal QC & Elec. Test

Petal Thermal Chamber



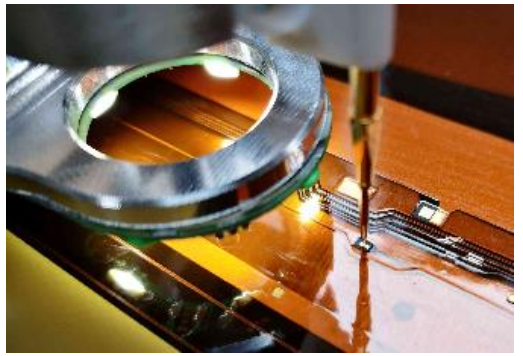
Bus tape testing robot (BTTR)

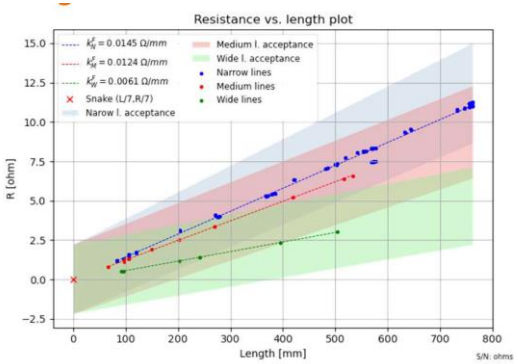




Das BTTR führt eine elektrische Charakterisierung der differentiellen und Stromversorgungsleitungen der Bustapes durch, einschließlich Durchgangstests jeder Leitung, Hochspannungs-Isolationswiderstandstests (HVIR) der HV-Leitungen sowie Kurzschlusstests. Zusätzlich werden die geometrischen Abmessungen der Referenzmarken (Fiducials) und die Positionen der Pads auf dem Bustape überprüft.

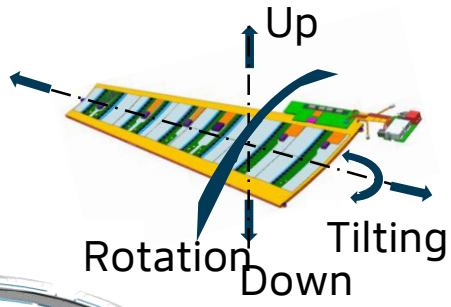
- Die elektrische Isolierung (E-Break) im Petal Core zwischen die Rohre und das Erdungspad auf dem Bustape. Widerstand > 20 MΩ.
- Die elektrische Leitfähigkeit zwischen den beiden Petal-Seiten. Widerstand < 10 Ω.

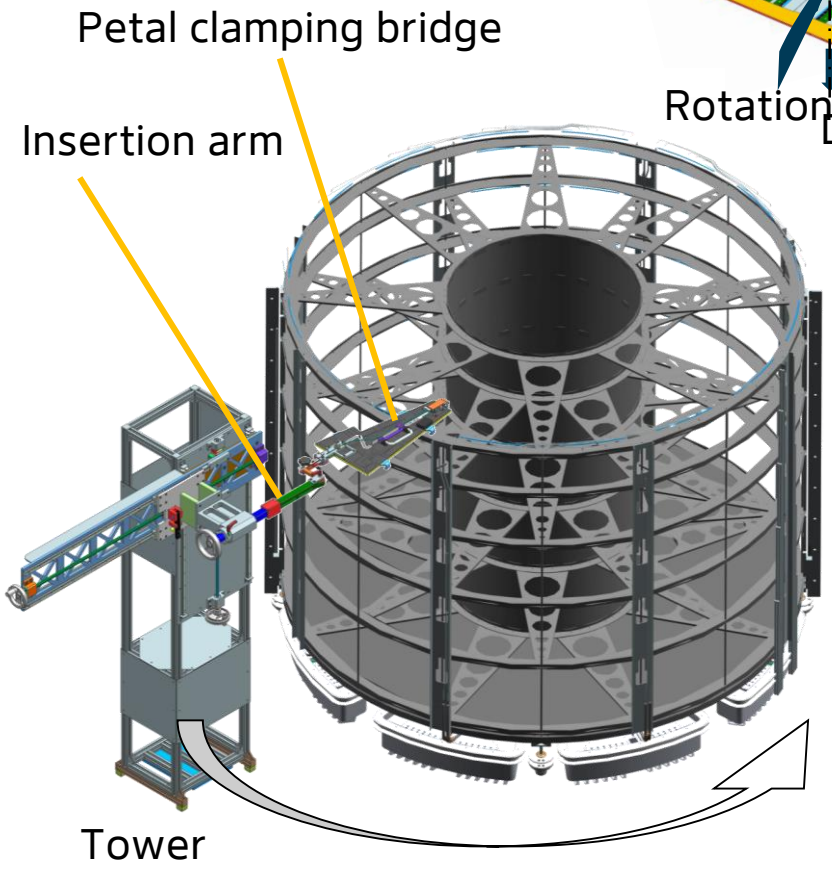




Other activities & Contributions

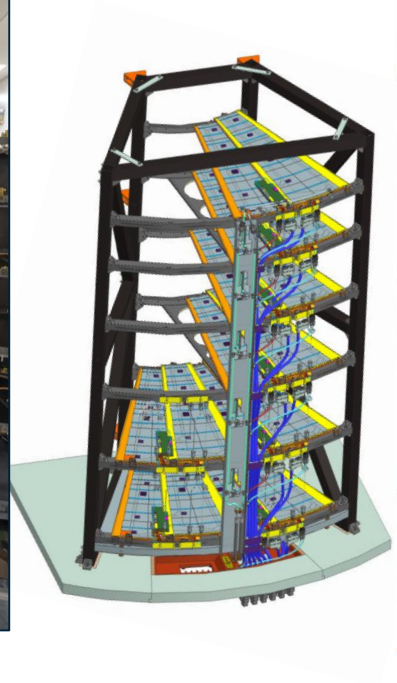
Petal Insertion & System Test





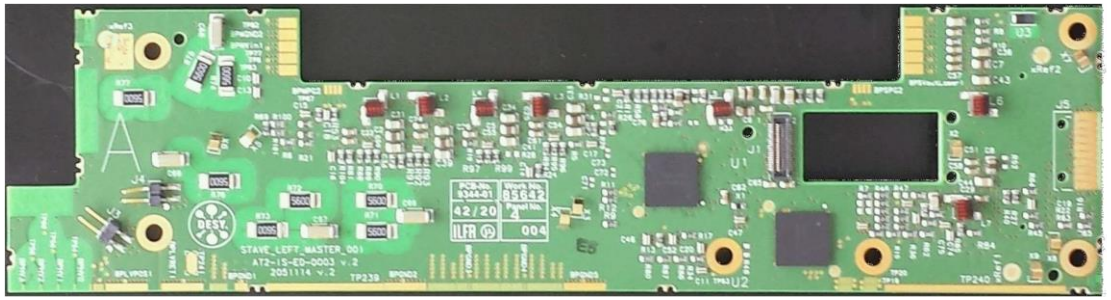
System Test goals:

- Demonstration des vollständigen ITk-Strip-Detektorsystems in Bezug auf Stromversorgung, Kühlung, Auslese usw.
- Test und Erprobung von Werkzeugen (z. B. Einbauwerkzeuge) und Verfahren (z. B. Schweißprozesse) für die finale Detektorintegration.
- Entwicklung und Erprobung von DAQ-Systemen (z. B. Hochfrequenz-Auslese) und DCS-Systemen (z. B. Interlock-Mechanismen).
- Nutzung als Teststand über die gesamte Lebensdauer des Experiments hinweg, z. B. für Betriebsschulungen



Other activities & Contributions

PCB Design (FE), Fertigung & QC

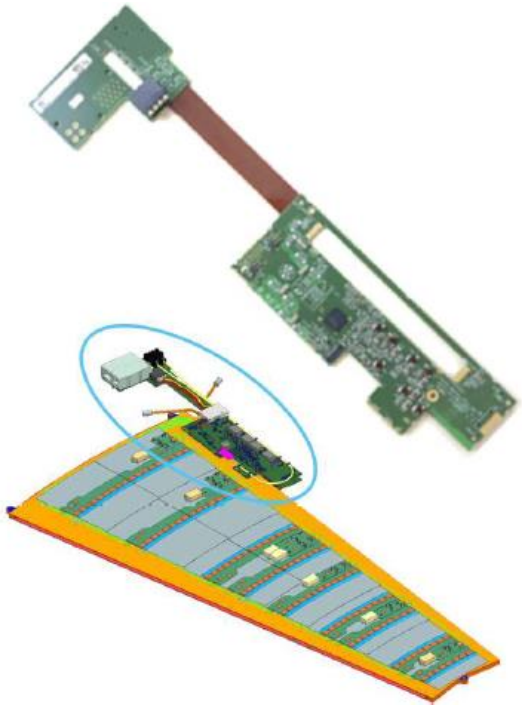


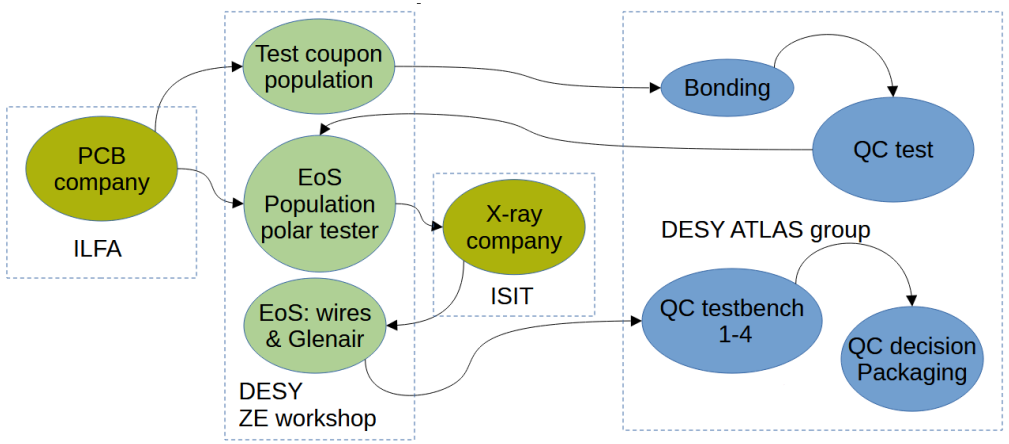
„End of Substructure" (EoS): Die Schnittstelle eines Petal oder Stave zur Außenwelt
DESY ist für jedes einzelne EoS (Staves und Petals) verantwortlich

Unbestückte Platine

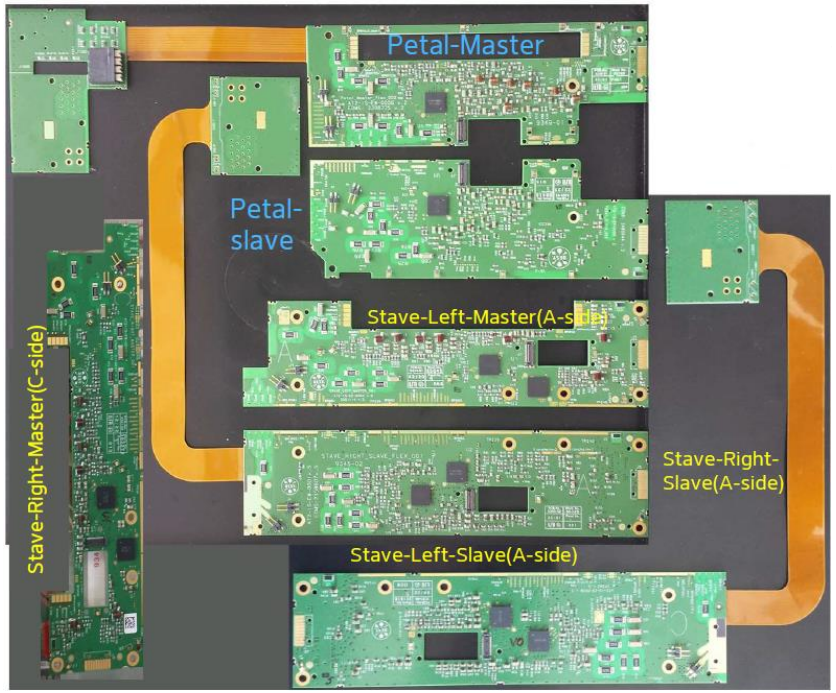
→ Bestückt, gelötet und getestet (@ZE)

→ Getestet, verpackt und verteilt





Ca. 1600 PCBs in total



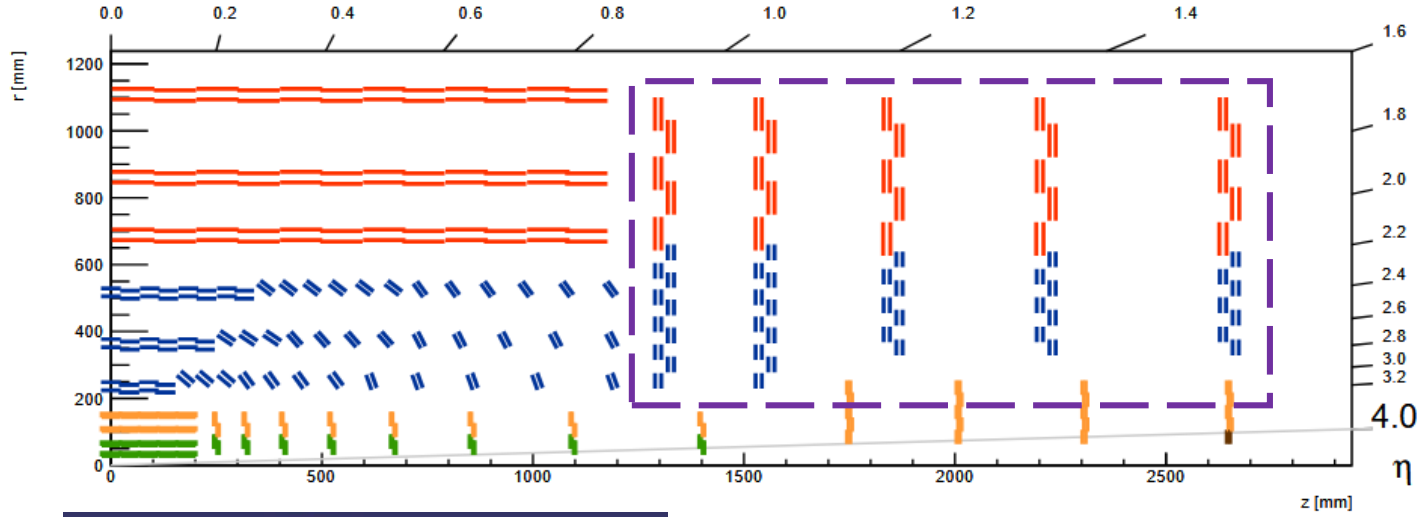
CMS Upgrade

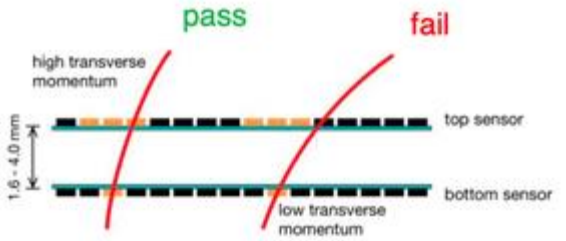
Aufbau

CMS Upgrade

Aufbau

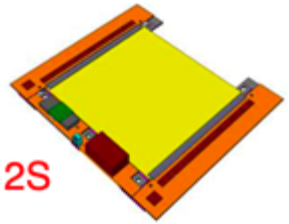
TEDD – Tracker Endcap Double Disk

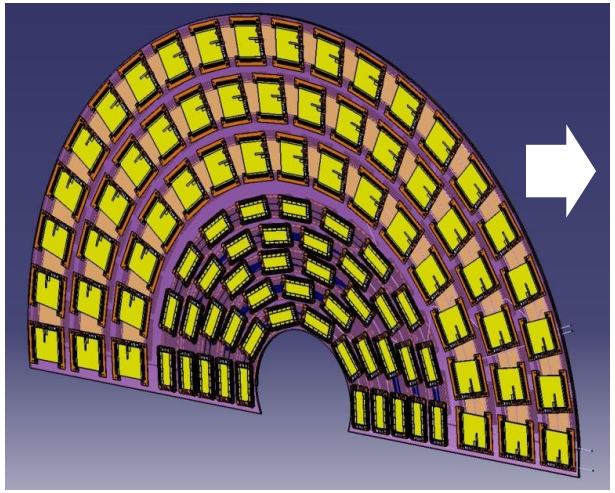




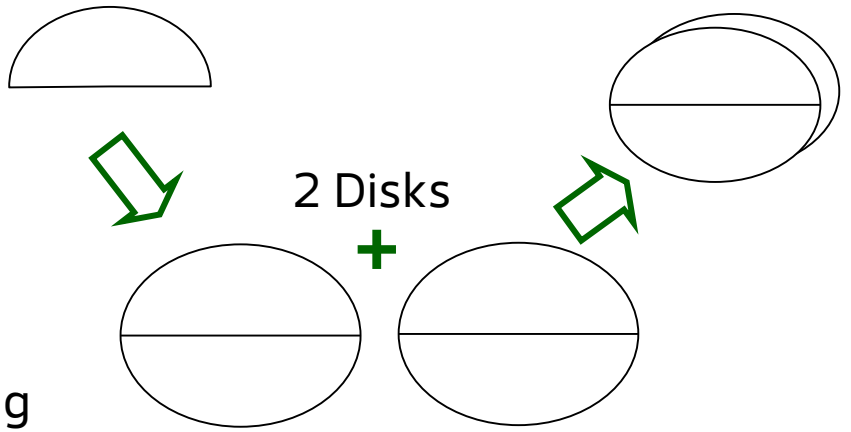
TEDD Endkappe:

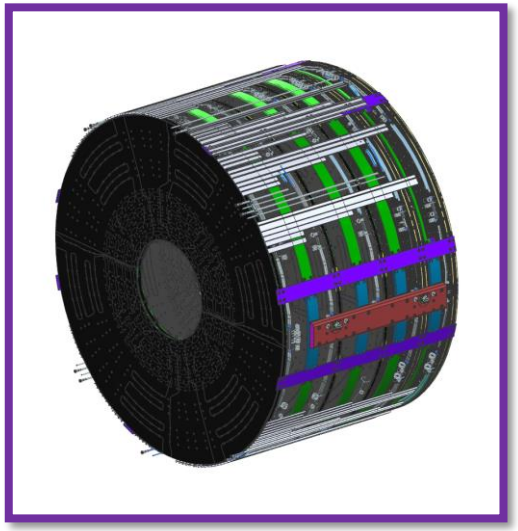
- 2x 5 Double Disks
- 2 Sensormodultypen
  - zweilagiger Silizium Sensor
  - r > 60 cm: 2 Streifen (2S)
  - r < 60 cm: Pixel-Streifen (PS)





CFK Sandwich mit int. Kühlung

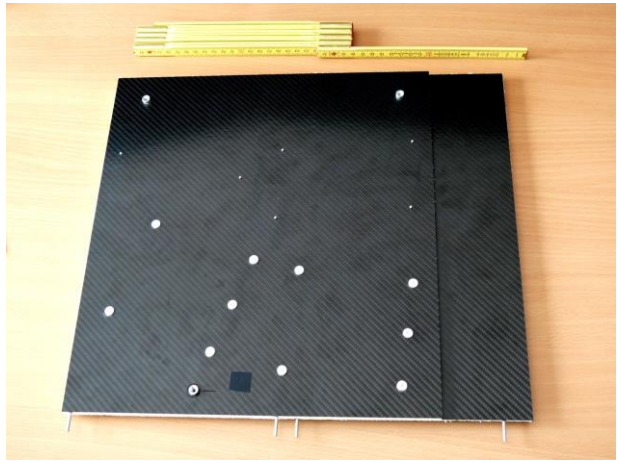




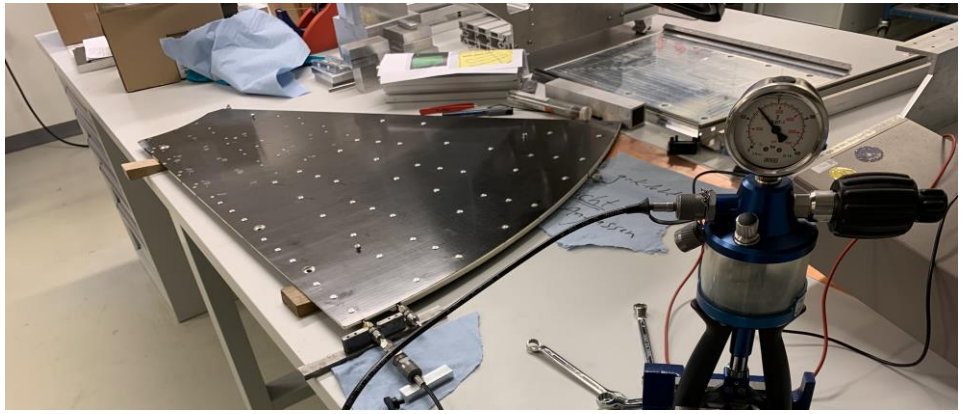
TEDD Endkappe

Entwicklung Trägerstruktur

Prototyp bis Serienproduktion



Dee Prototyp #1 (2015)



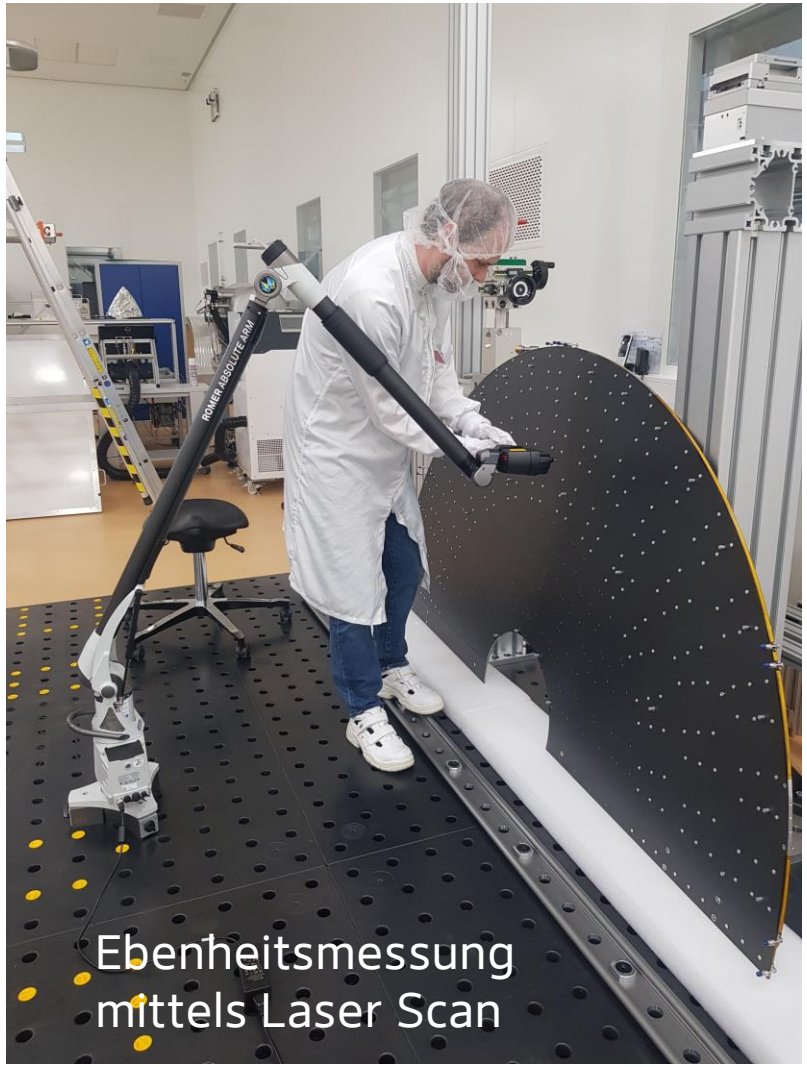
Dee Prototyp #3 (Sektorprotyp)

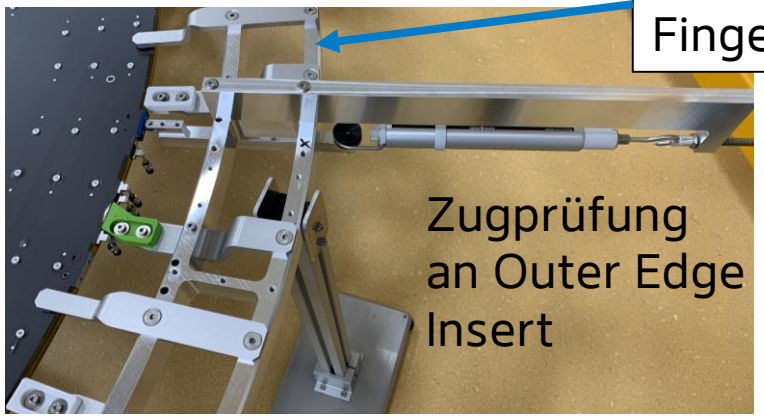
- 6 Kühlrohre à 7 m
- DM 2,4 x 0,15 mm
- ca. 80 Biegungen
- $^1/_8$ VCR (male) Anschluss vakuum-gelötet mit Kupfer

Dee @ Invent GmbH (externer Partner, Serienfertigung seit 2025)

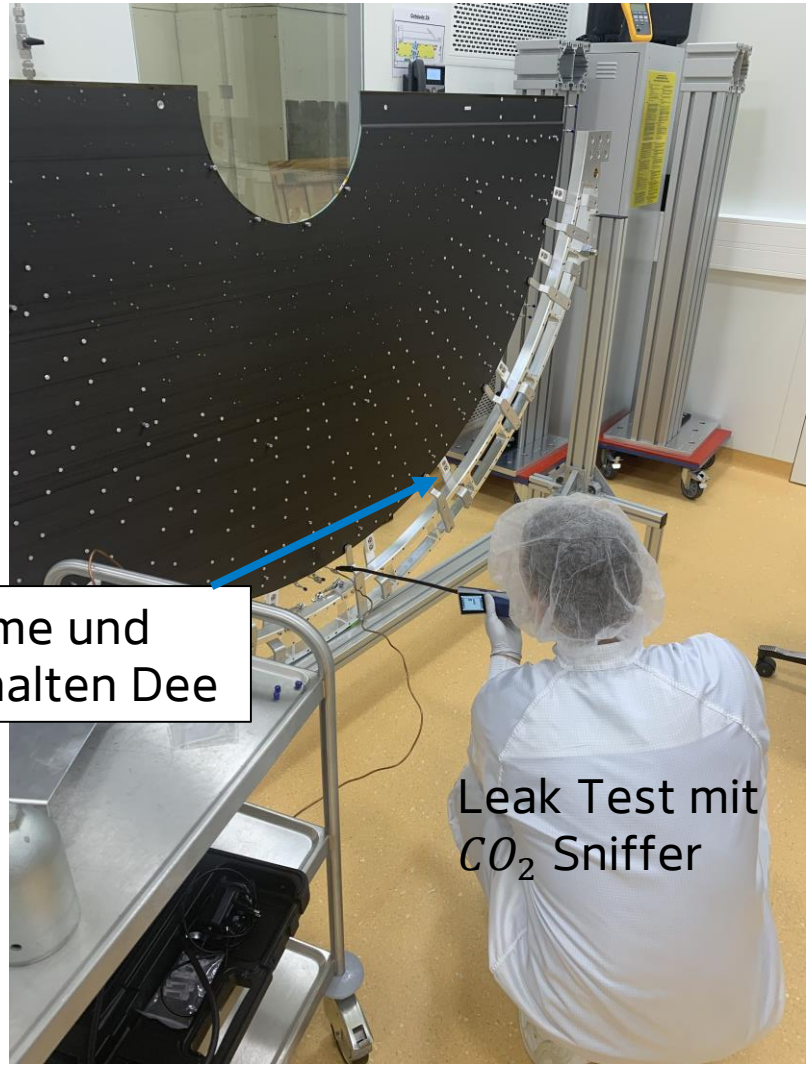
Dee Eingangskontrolle

Insert Metrologie, Ebenheit (global / lokal), Druck- und Leaktest, Thermische Verm., Zugprüfung, Erdungsmessung





Arc Frame und
Finger halten Dee

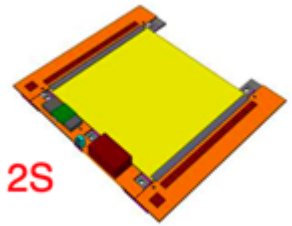


Dee Integration Test

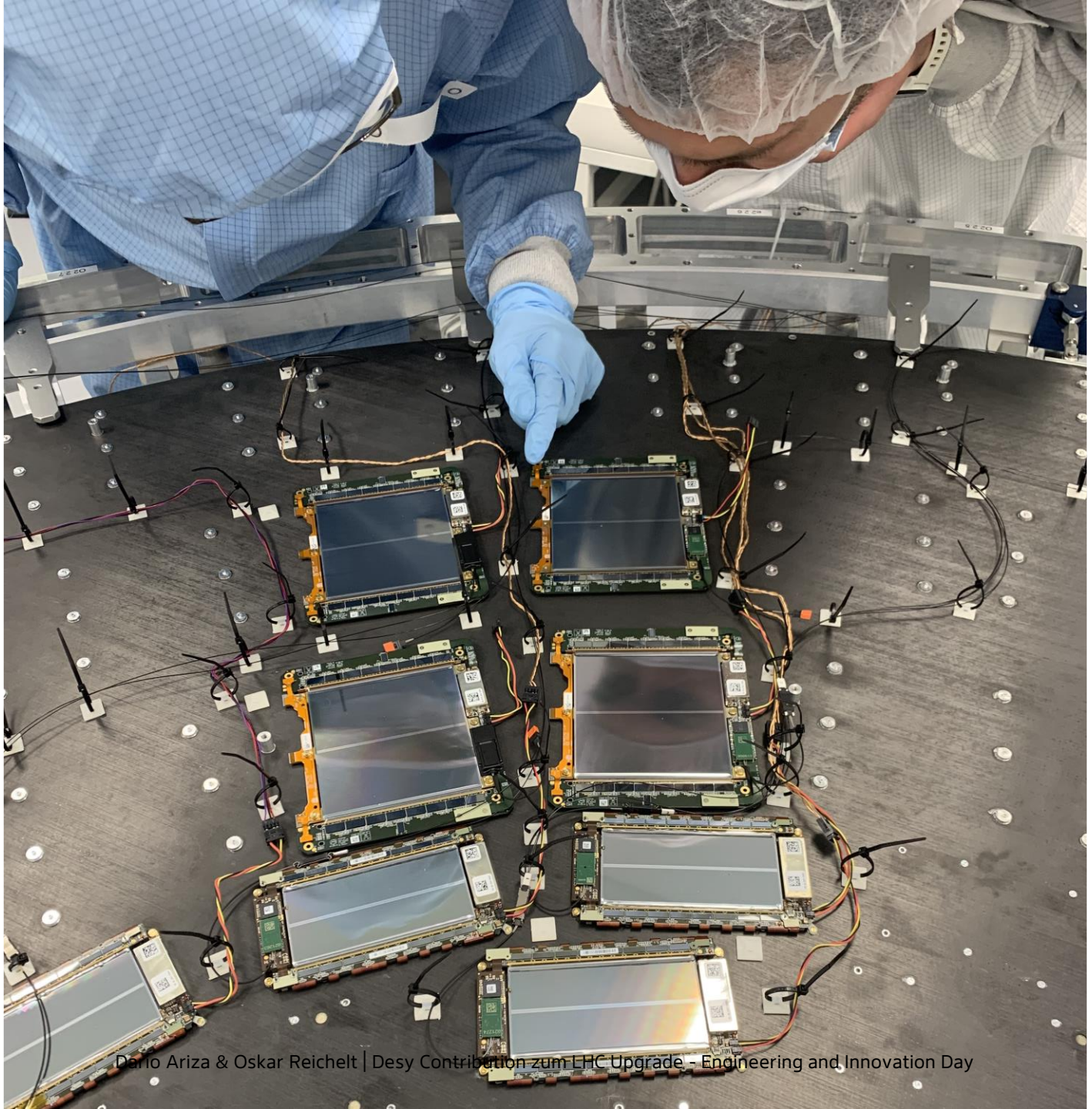
In Louvern la Neuve im April ‘25

Probeweise Integration von Sensormodulen auf Trägerstruktur und Verkabelung

- 2S Sensormodul fixiert mit 6 M1,6 Schrauben

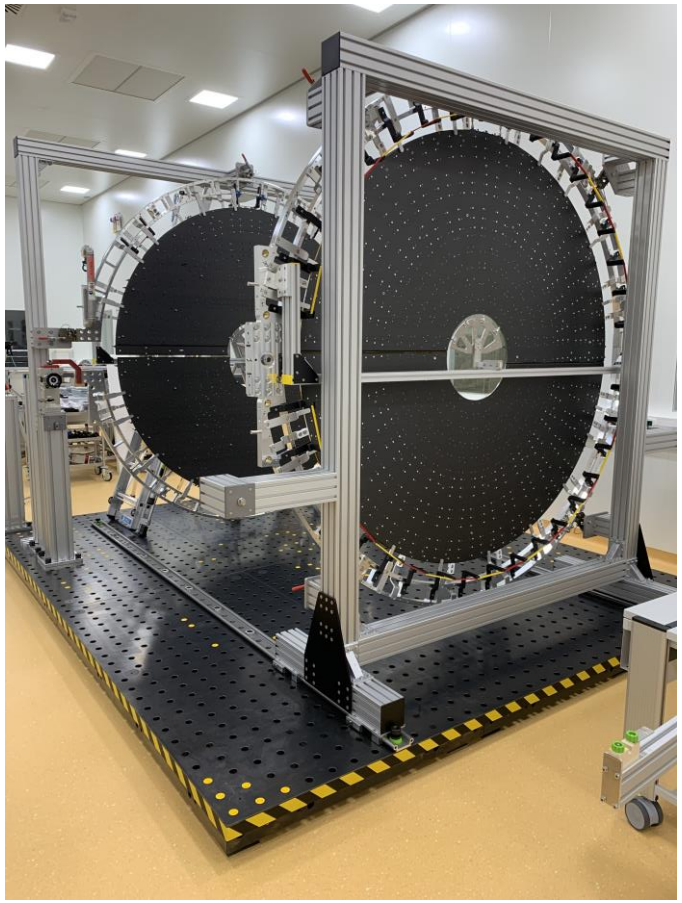


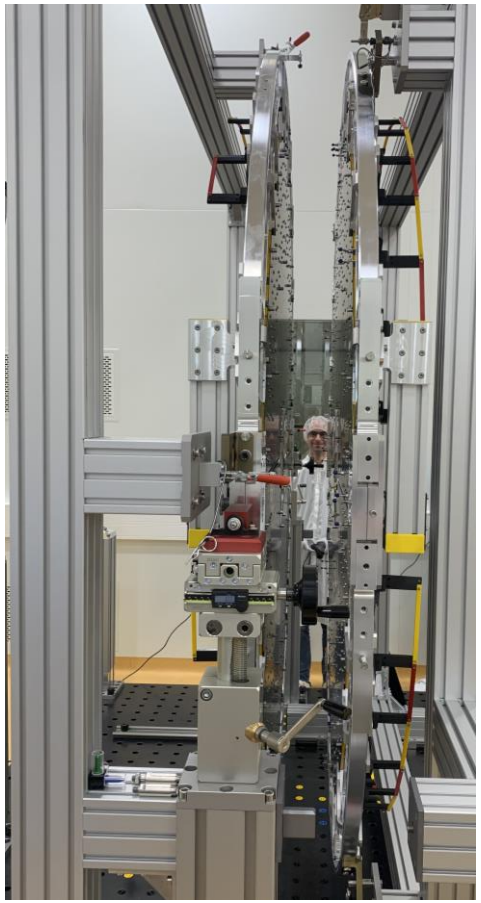
- PS Sensormodul fixiert mit therm. Paste (TIM) und 3 M1,6 Schrauben (2x Passschraube, 1x Standard)

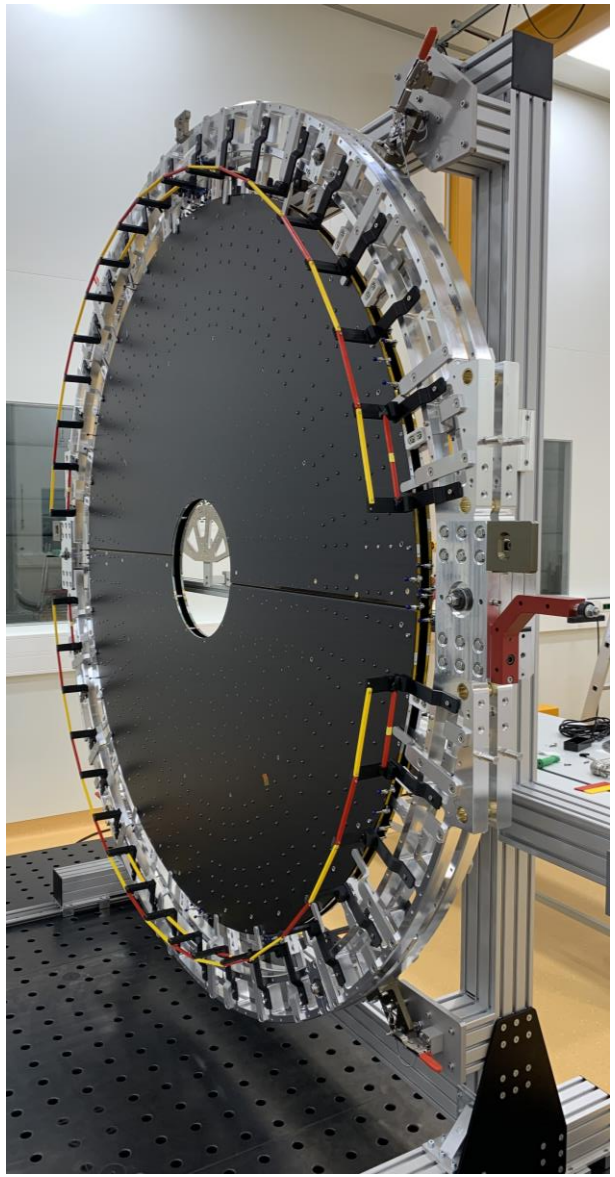


Double Disk Test Assembly

Von einer Dee zur Double Disk März ‚25



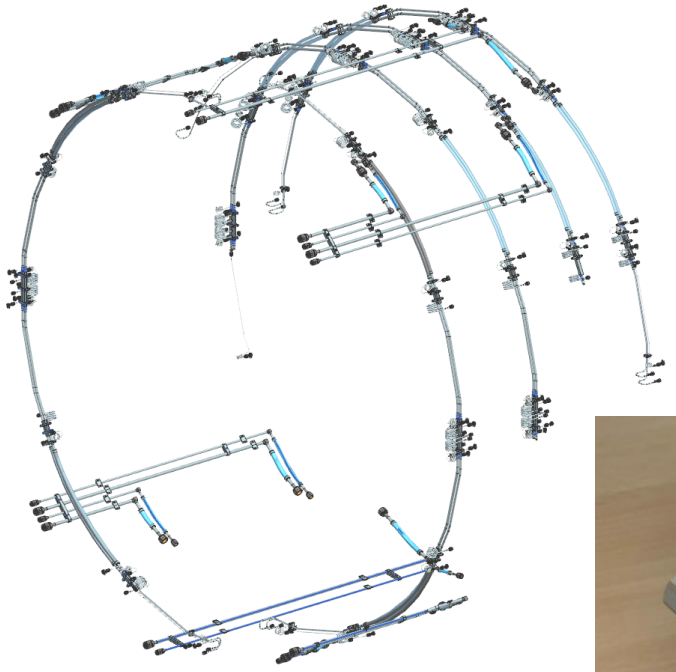




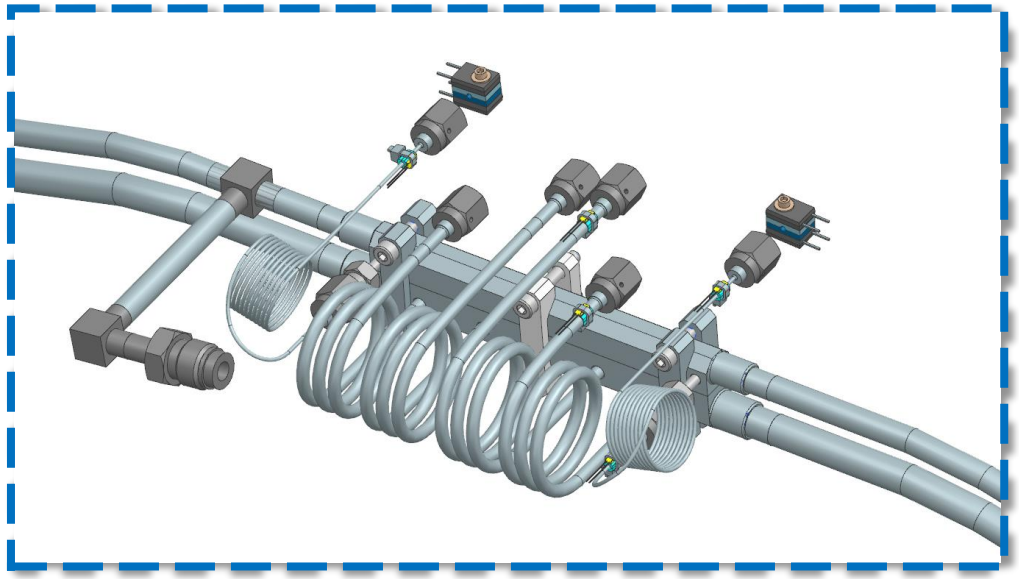
Aus 4 Dees mach 2 Disks & aus 2 Disks mach eine Double Disk. Ebenheit 1,2 mm auf ca. 2 m Durchmesser.

Cooling Manifold

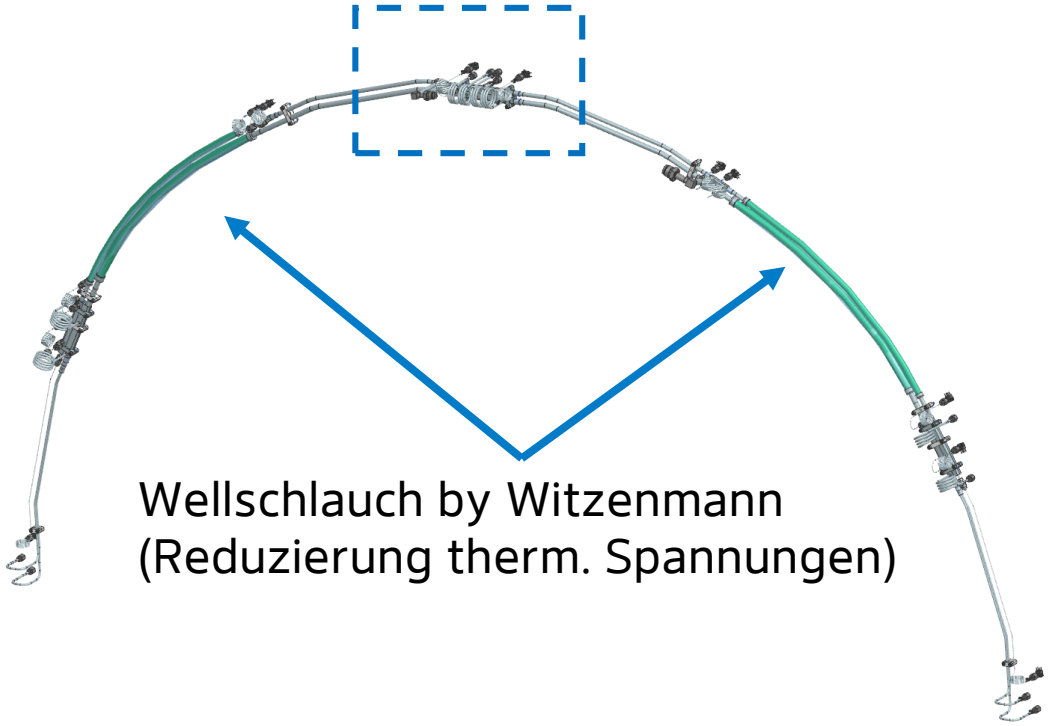
Anschluss der Kühlrohre in Dees an CO_2 Kühlsystem



Edelstahl Doppelringleitung
mit thermischer Kopplung
von Hin- und Rücklauf



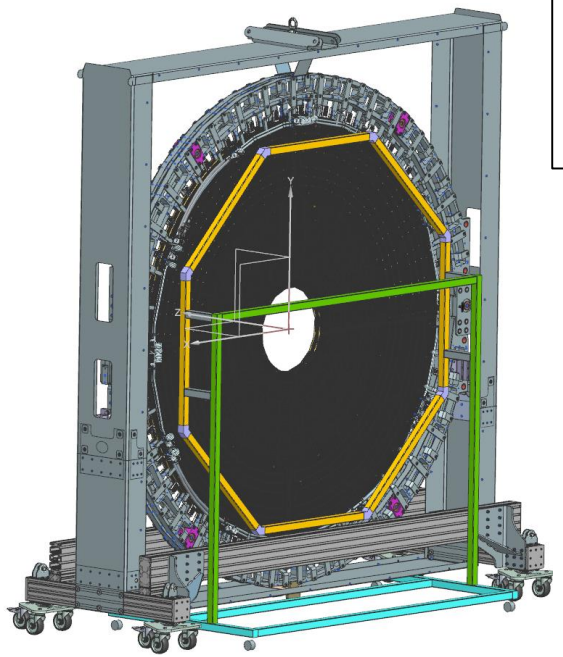
Manifold Prototyp (Rücklauf,
vakuumgelötet)



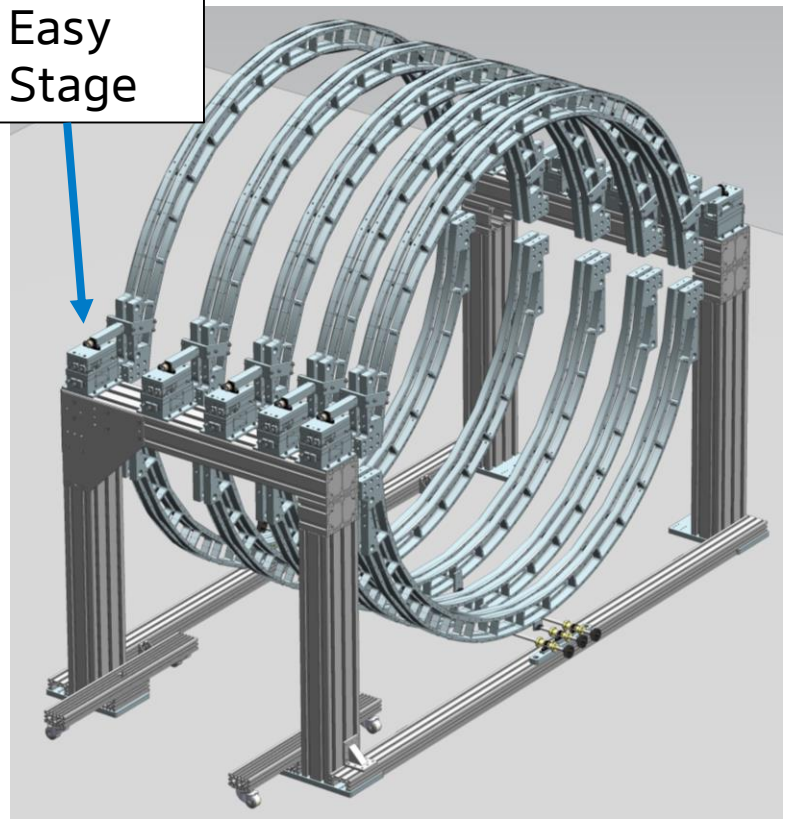
Wellschlauch by Witzenmann
(Reduzierung therm. Spannungen)

Endmontage am CERN

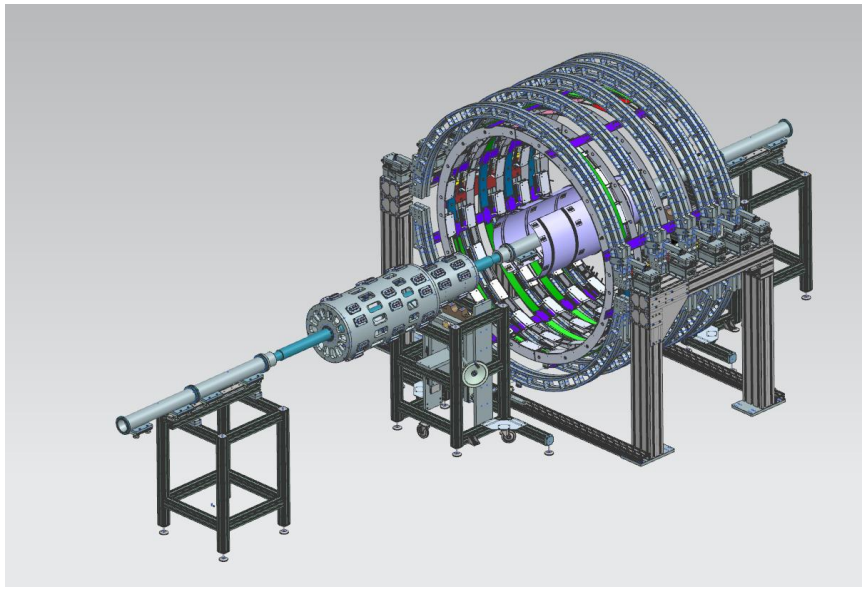
Transport von 10 Double Disks ans CERN zum Bau von 2 Endkappen



Transport zum CERN
und Manifold Test

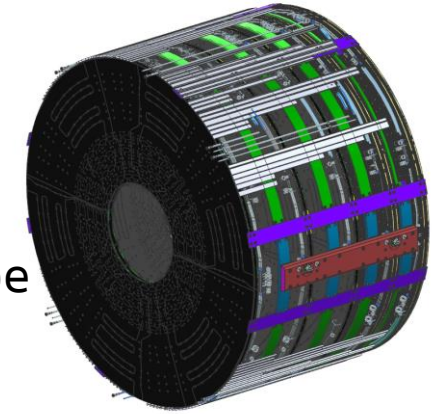


TEDD Assembly Tooling - 5 Double Disks &
Tragestuktur werden eine Endkappe (TEDD)



Rotation Tooling – Aufnahme der TEDD über zentrale Achse, Rückbau der Arc Frames und Integration der Services (CO_2 Leitungen, Verkabelung, Trockenluft)

TEDD
Endkappe



Vielen Dank

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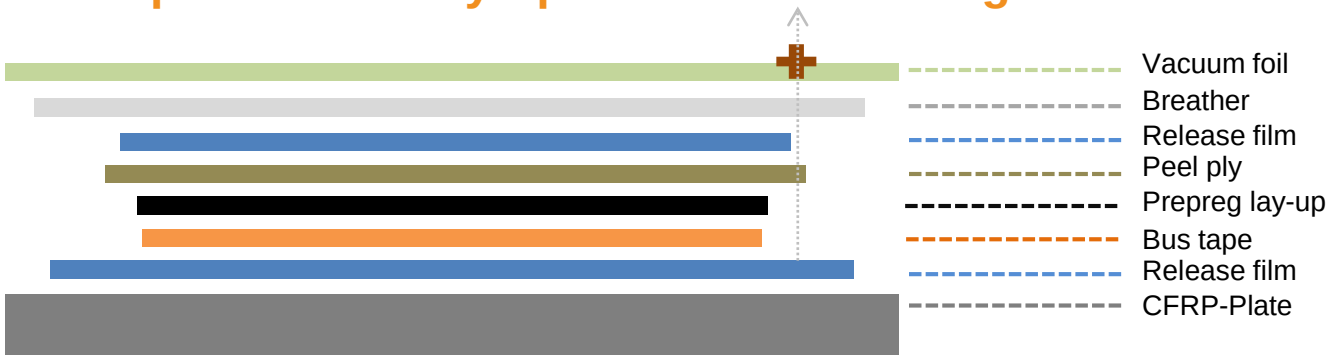
Deutsches Elektronen-Synchrotron DESY

Atlas Gruppe
Notkestraße 85
22607 Hamburg
www.desy.de

Backup slides

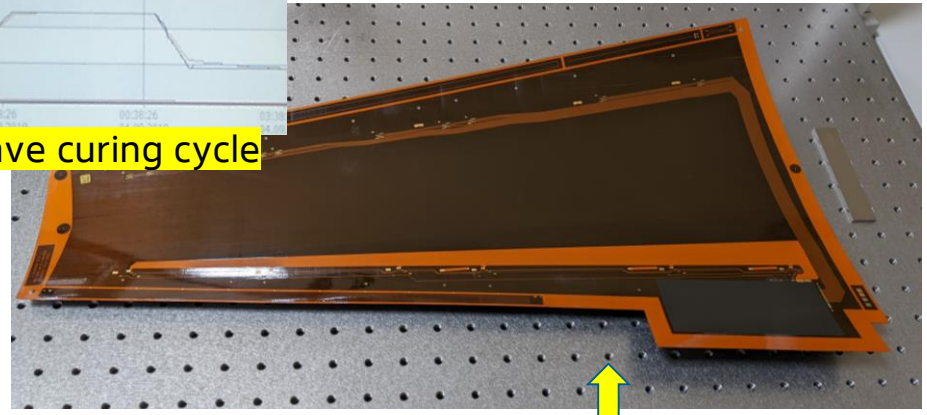
Atlas – Backup slides

Description of the lay-up for the Petal facing

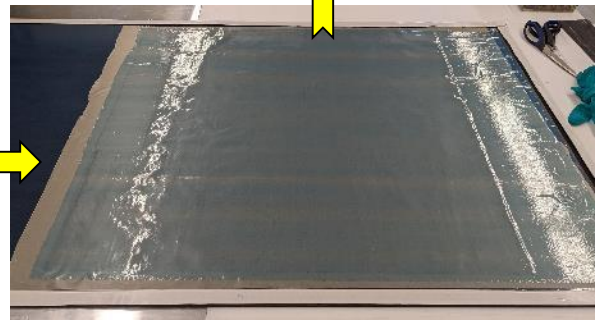


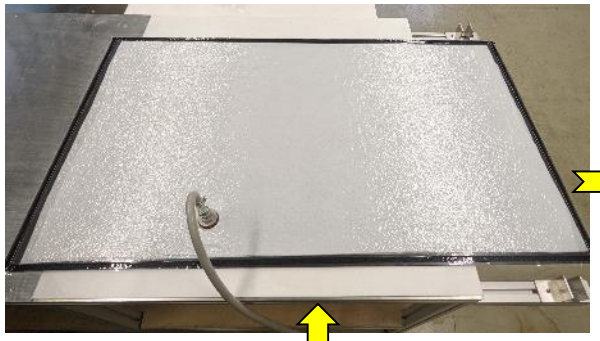
Autoclave curing cycle

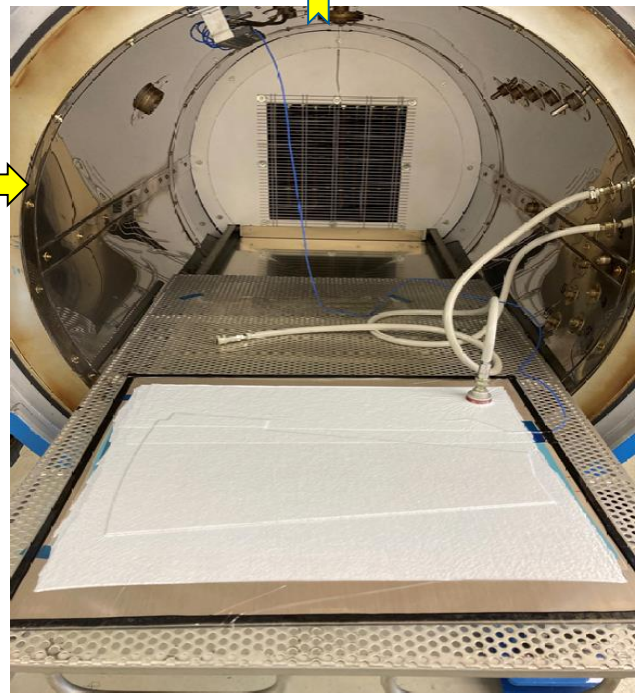
Ramp up to 121°C with ca. 1,2°C/min with 3 bar.



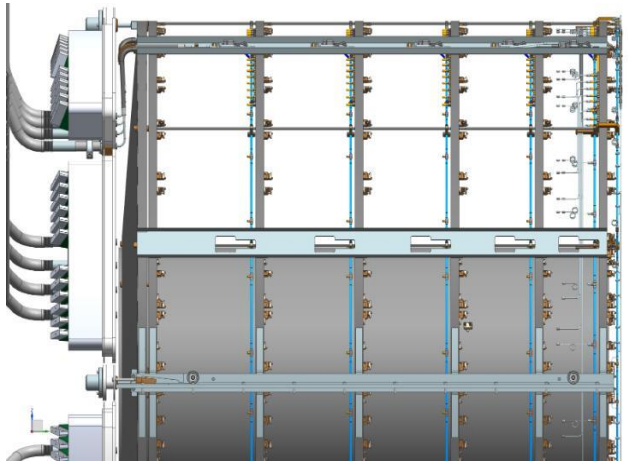
- CFRP-Plate (4 mm)
- Release film (Wrightlon 5200B)
- Bus tape
- Prepreg lay-up [0°/90°/0°]
- Peel ply (Ease 234 TFP-1)
- Breather (Airweave N10)
- Vacuum foil (Wrightlon-7400)





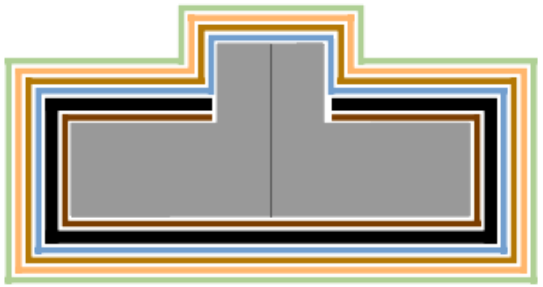


Atlas – Backup slides



Service trays serve as

- Holders of cooling and electrical services and environmental sensors
- Structural component of the ECs providing stiffness
- Electrical connections of all the CF components of the global structure (<10 Ohms paths to the Faraday cage)



Manufacturing process:

- Vacuum press moulding
  - 6 layers of 200 µm thick 0/90 T300/EX1515 woven pre-preg
  - 18 produced in total, 1400 mm long x 80 mm wide
  - Final machining step required to achieve final precision

electrical connection (Cu)

Atlas – Backup slides

Atlas Detector

The endcap local supports (the petals) are manufactured in industry, but numerous endcap components are produced (and QC'ed) in-house at DESY

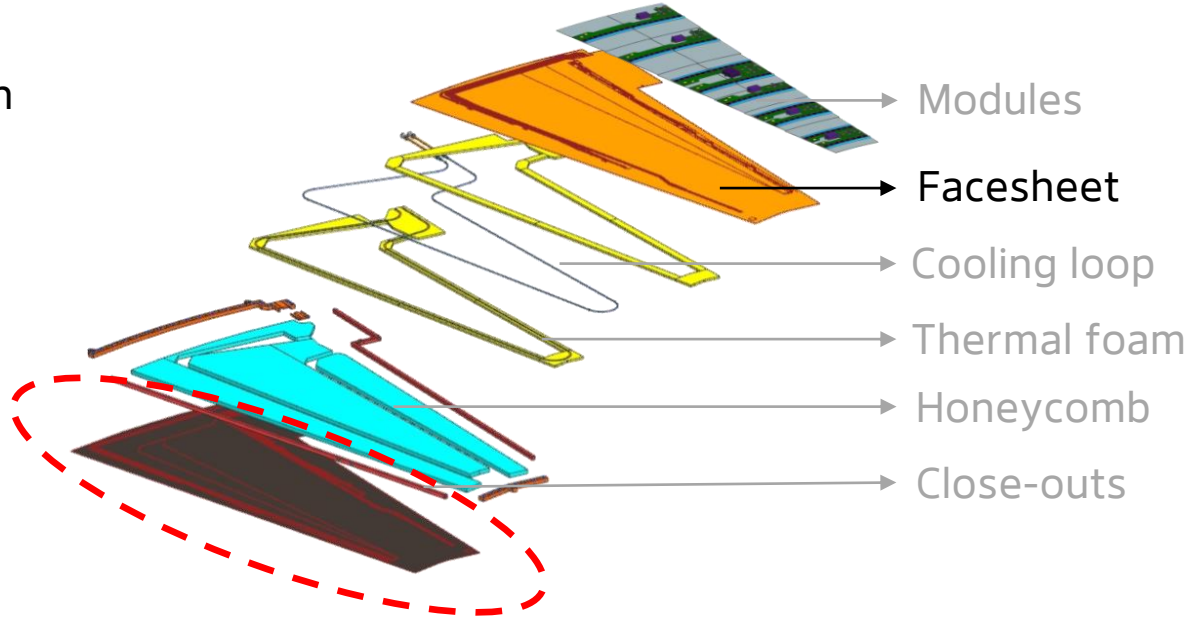
- Cooling loops
- Thermal foam sets
- **Co-cured facesheets (the "skins" of the petals)**

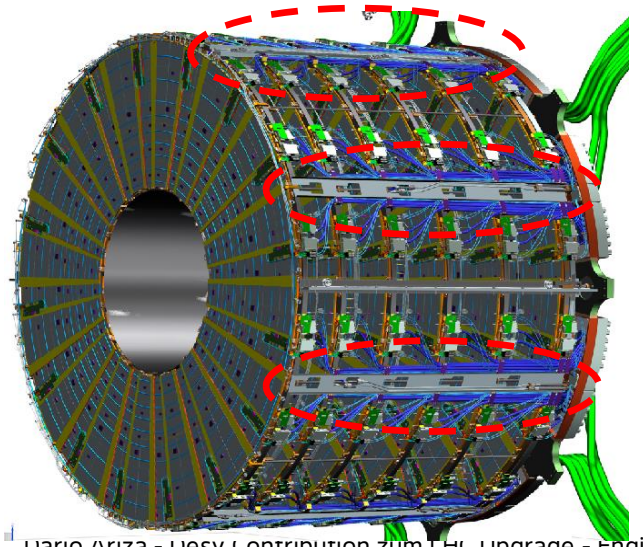
DESY is the Endcap site which produces the full amount of co-cured facesheets of the petals

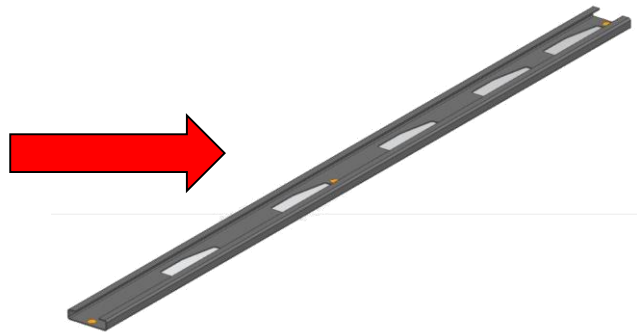
- ~400 pairs ("front" and "back"), 800 tapes in total

DESY is also responsible for the production of the CF beams on the global structure holding the cooling and electrical services **(the "service trays")**

- 16 service trays in total, 8 per EC







Atlas – Backup slides

Metrology QC - The Smartscope - Optical CMM (coordinate measurement machine)

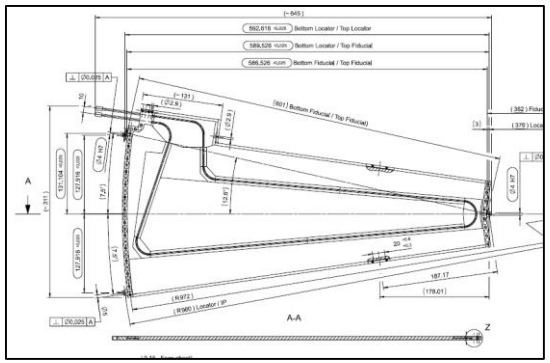
During Petal development and quality assurance (QA) many prototypes were studied/surveyed to review the Petal core assembly process.
One key measurement is the flatness, specified <0,050 mm on 100x100mm, required by module loading.

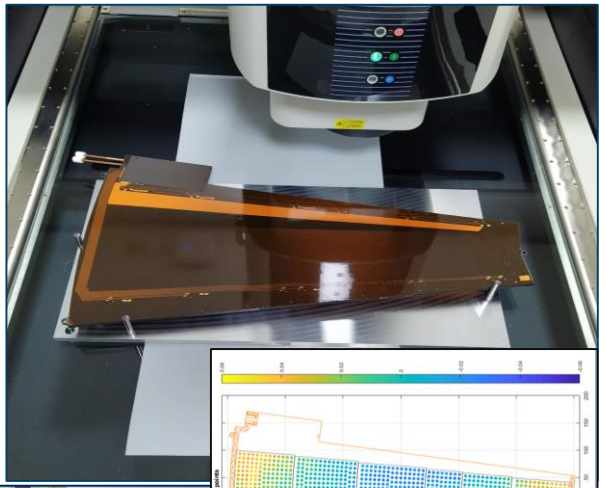
Currently every deliverd Petal core is measured thoroughly as stated in the QC document (eg. diameter, location, planarity, local flatness).

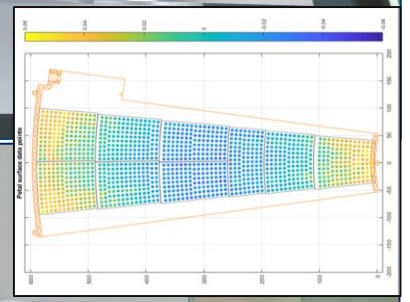
A versatile equipment used already by several other groups from time to time.

Main technical information:

- 650 x 660 x 200 mm (XYZ travel)
- 3D CAD modell integration in the measuring software
- Gridprojector to measure on transparent and reflective surfaces
- Field of view max = 8 x 6 mm, min = 0,9 x 0,8 mm
- Exy = (2.0 + 5L/1000) µm & Ez = (3.0 + 8L/1000) µm

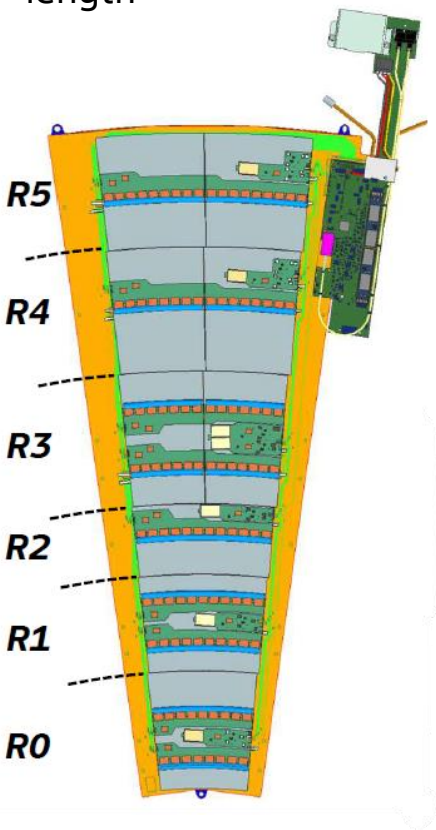


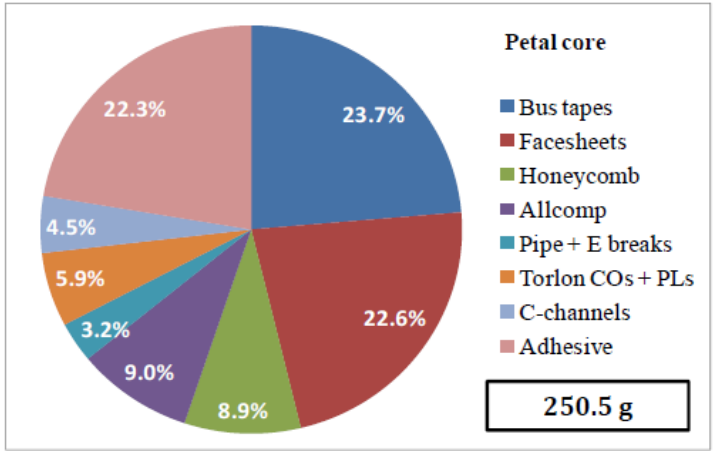


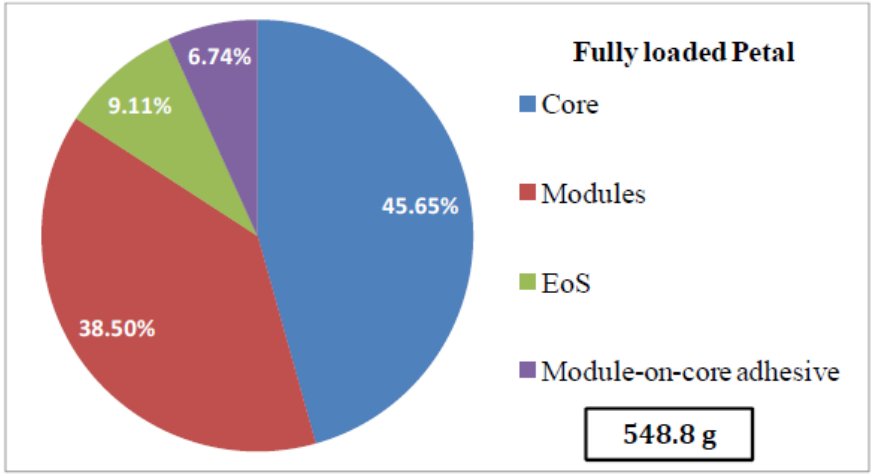


Atlas – Backup slides

- Strip lengths chosen to cope with occupancy
- 75 μm average pitch
- 20 mrad stereo angle built into the petal
- IP pointing strips for optimal φ resolution
- Trapezoidal-like shapes to maintain uniform strip length



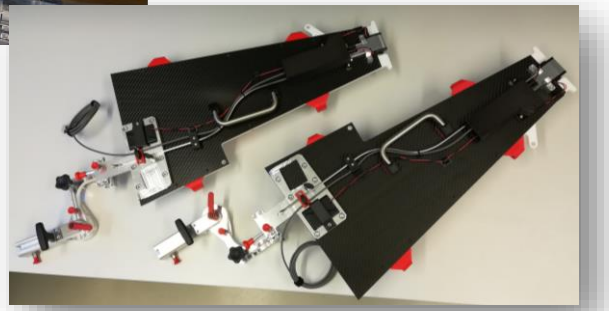




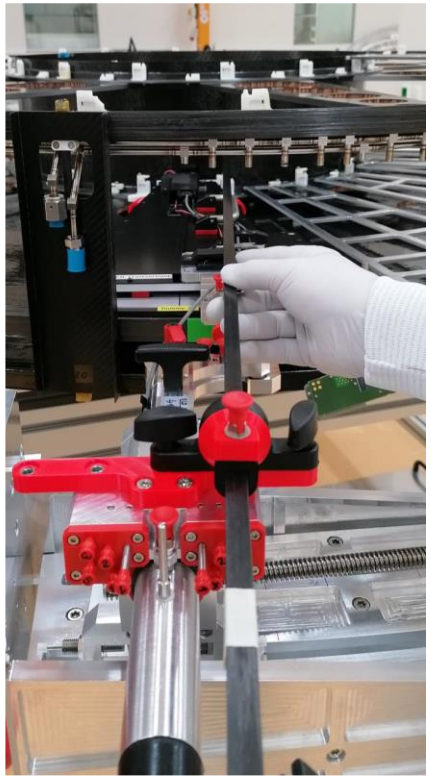
Atlas – Backup slides

Insertion tower on tower platform with **rail system**

Insertion tower with **insertion arm**

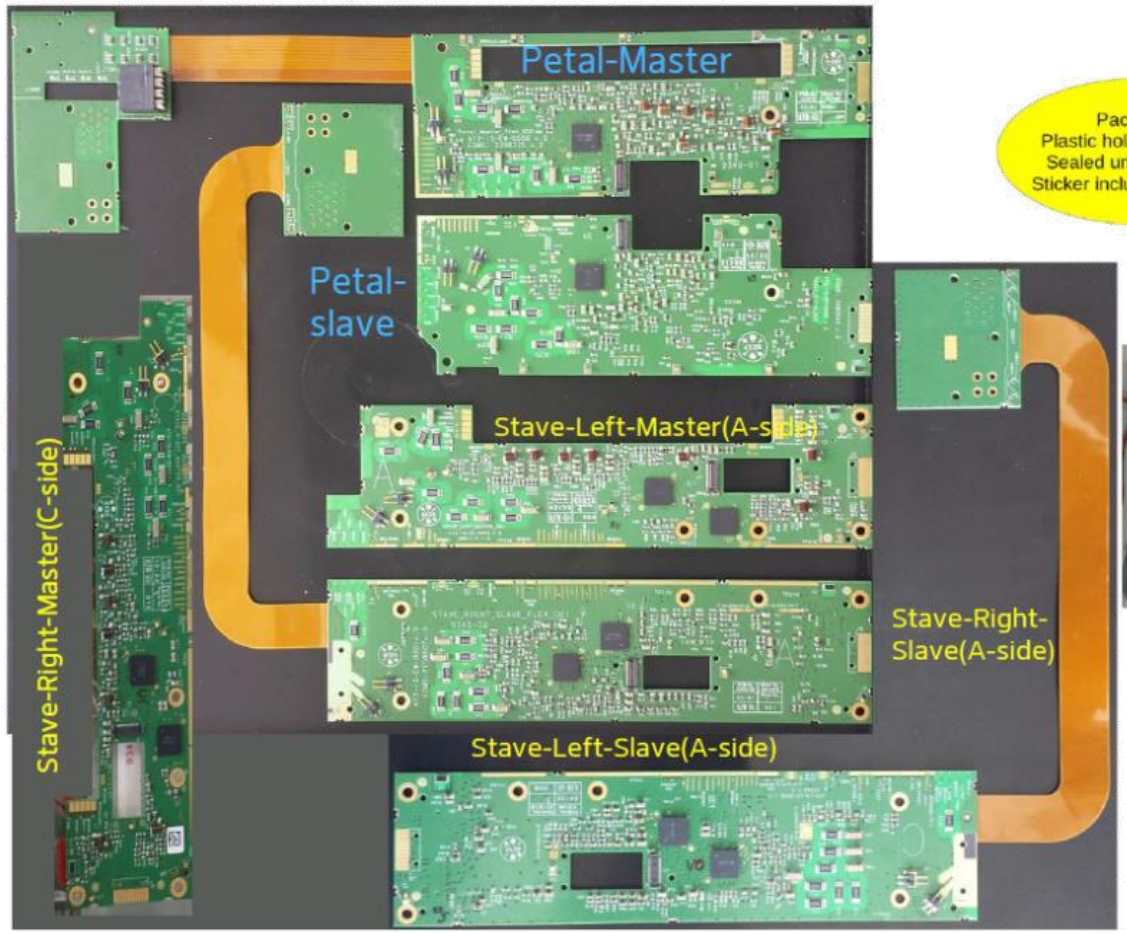


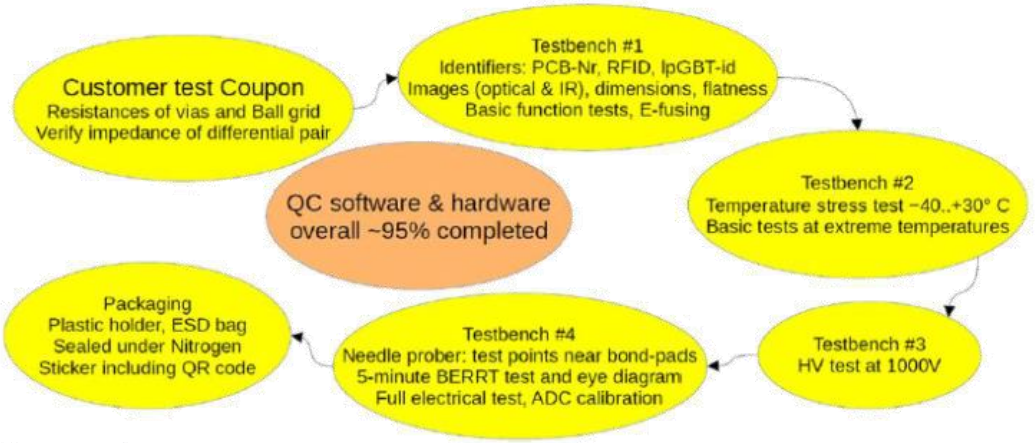
Petal hands for lifting of petal (FL and BL variant) – designed against bending frame



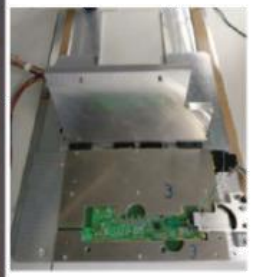
Long arm tool for manual closing of locking points

Atlas – Backup slides

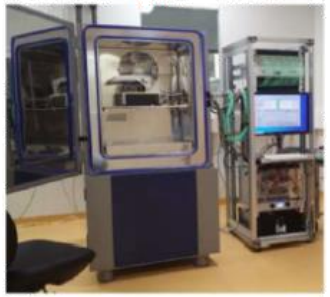




TB#1

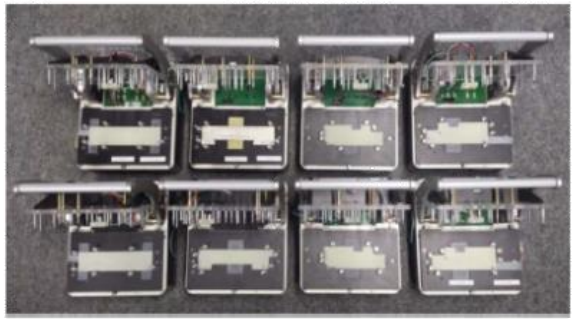


TB#2



TB#3

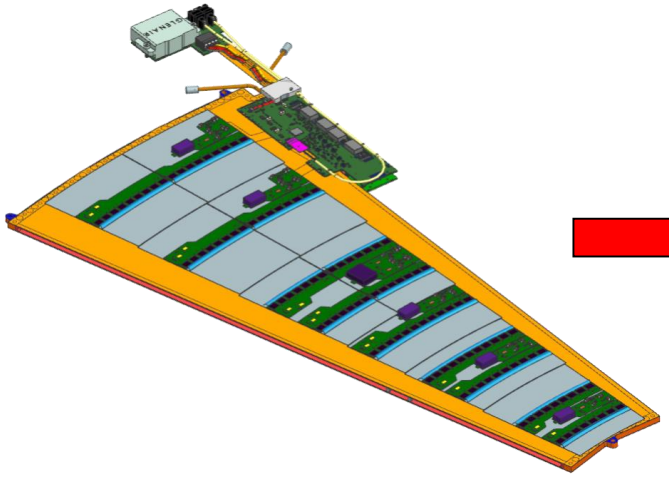
TB#4

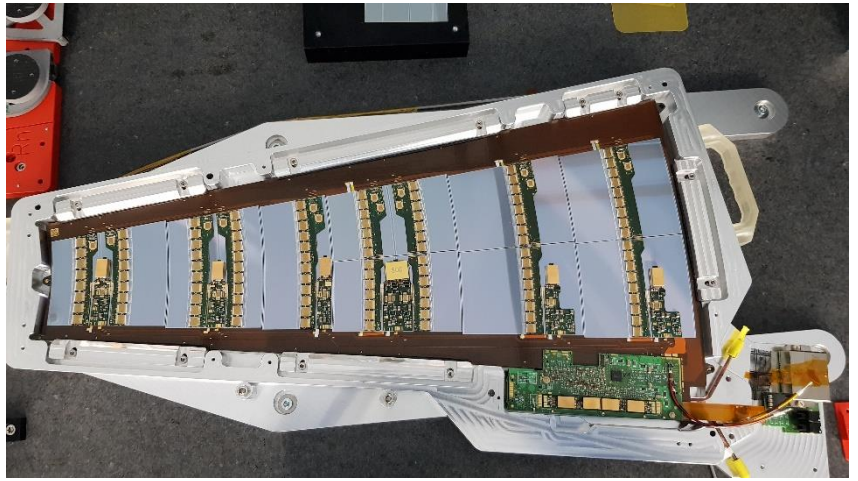


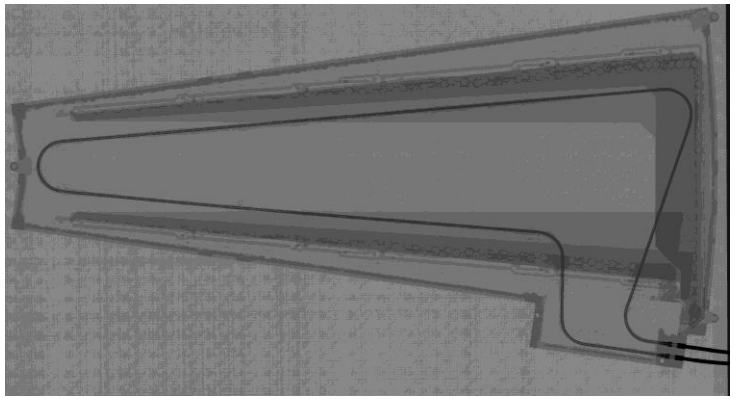
Desy Contributions zum LHC

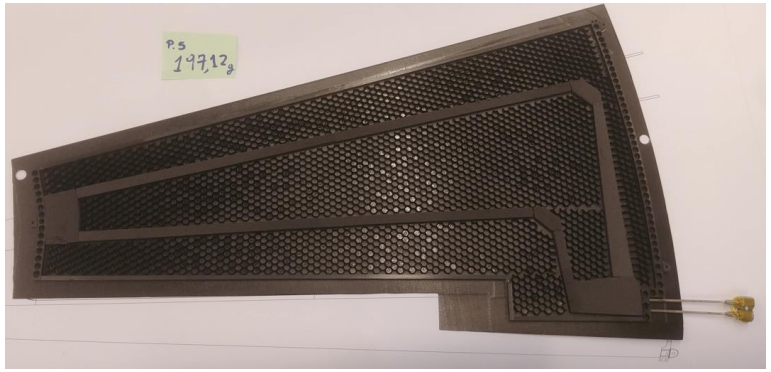
Der Petal – the local support structure

Wichtige Anforderungen für das Montieren der Sensoren:
Ebenheit < 0,050mm für 100x100 mm
Position der Bohrungen < 0,075 mm





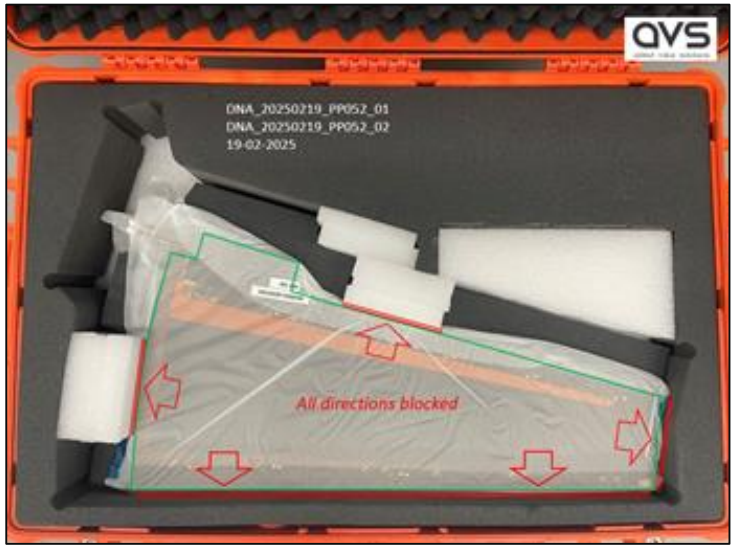




Desy Contributions zum LHC

Der Petal – the local support structure

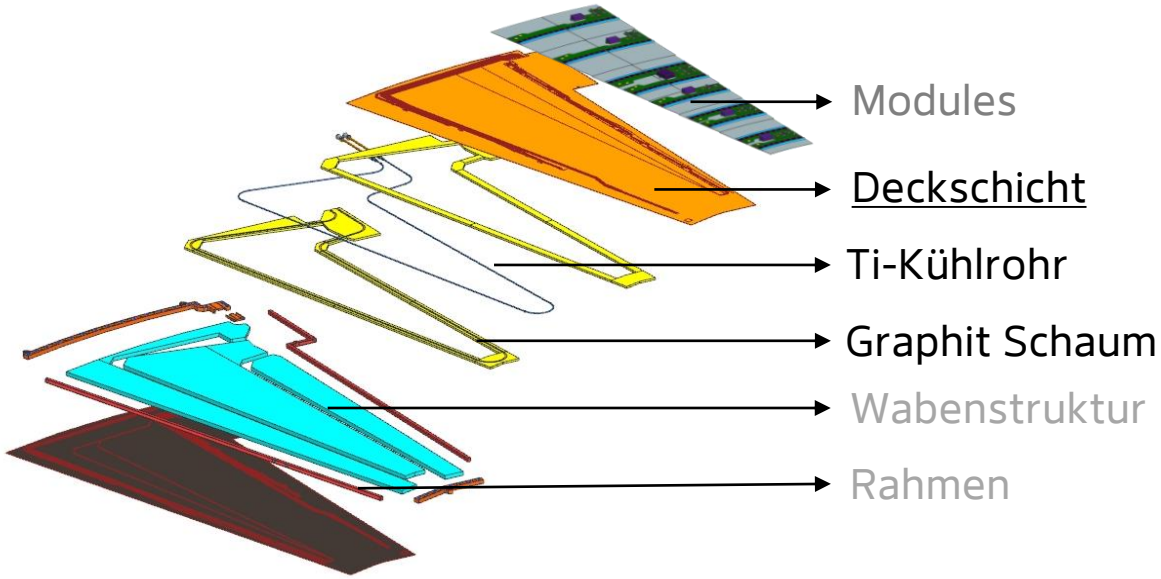
Die Produktion der Petals erfolgt in Kooperation mit der Industrie. Die Komponenten werden zugeliefert, um eine Batch-Fertigung von jeweils 20 Petals zu ermöglichen.

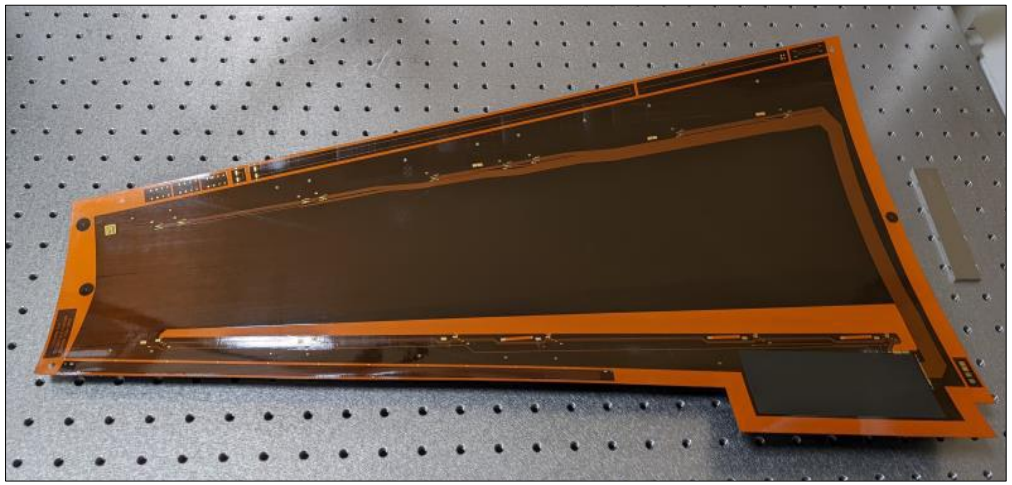


Desy Contributions zum LHC

Der Petal – the local support structure

In-house Fertigung inkl. QC:

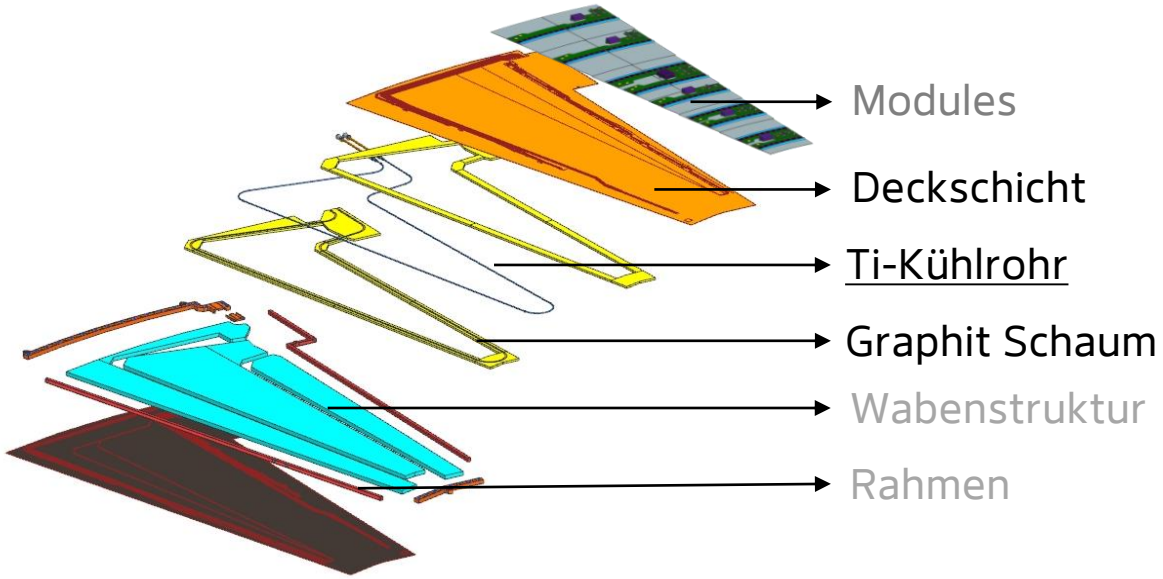


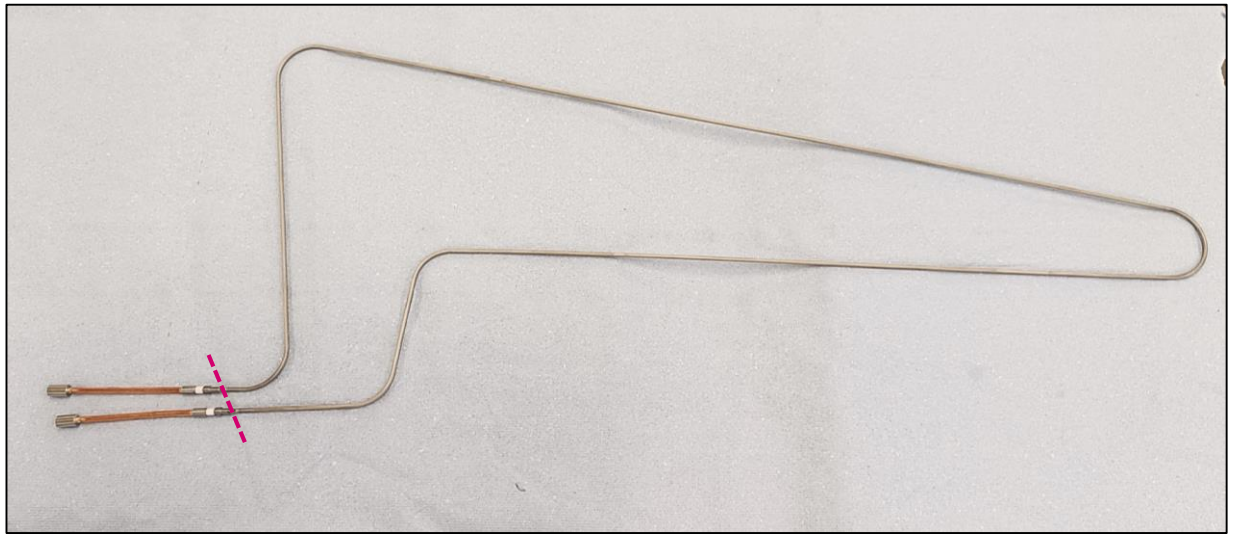


Desy Contributions zum LHC

Der Petal – the local support structure

In-house Fertigung inkl. QC:

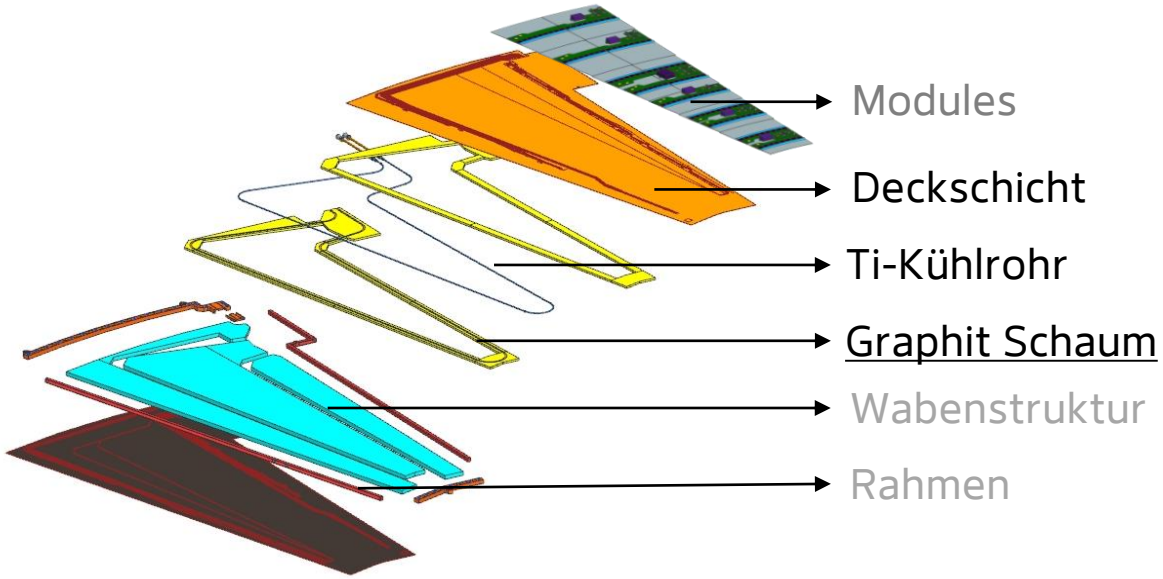




Desy Contributions zum LHC

Der Petal – the local support structure

In-house Fertigung inkl. QC:



Atlas – Backup slides