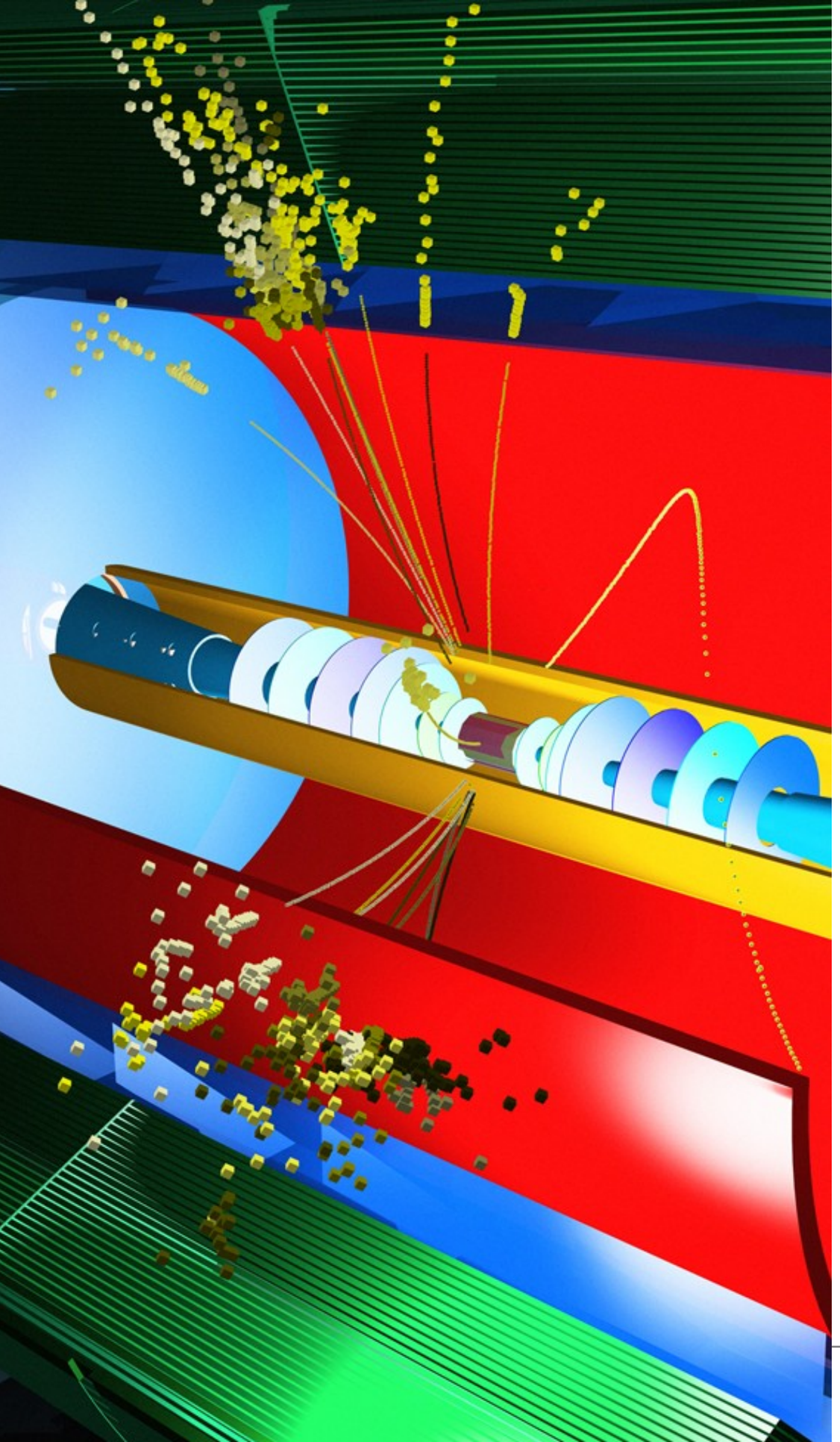
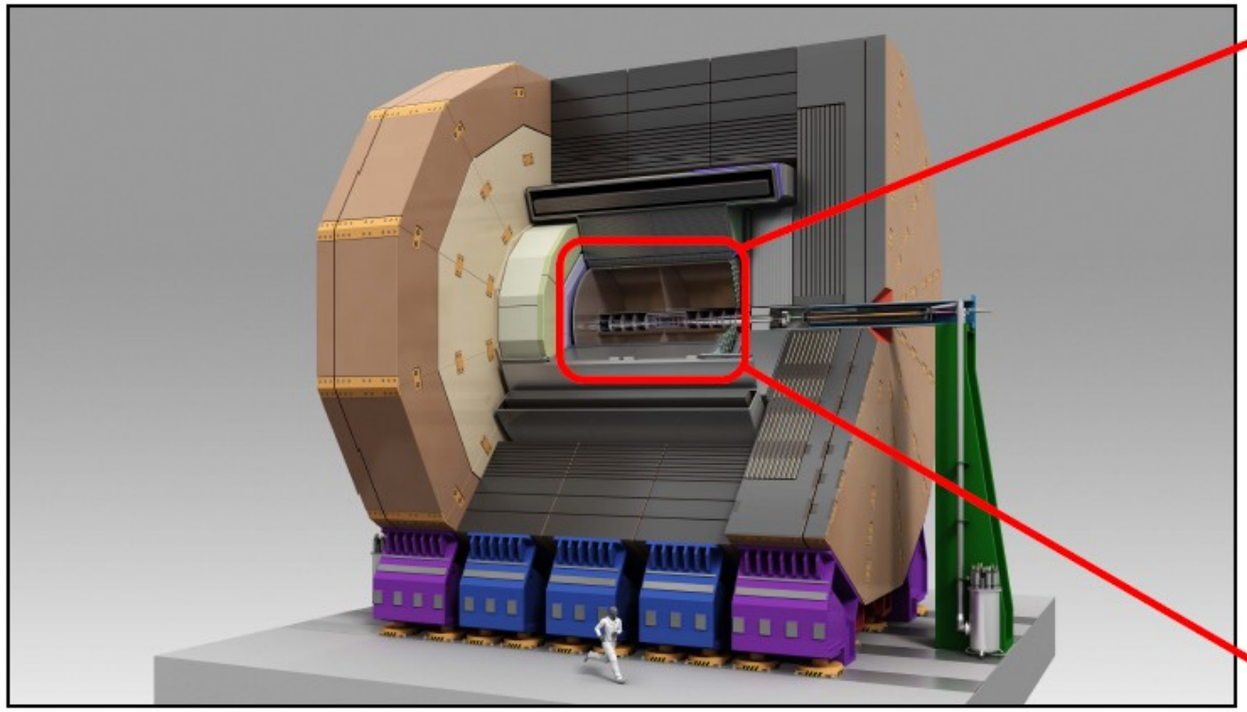


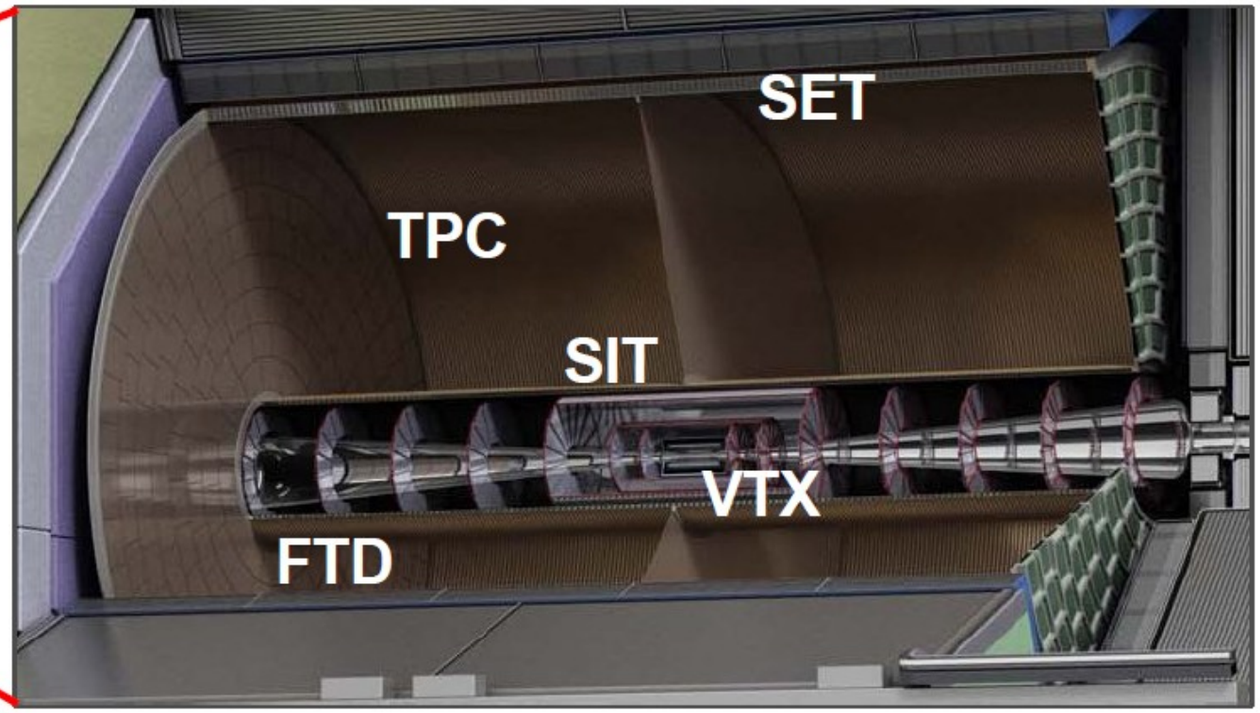
The mechanics of ultra-transparent silicon. Developing the forward tracking disks for the ILD detector

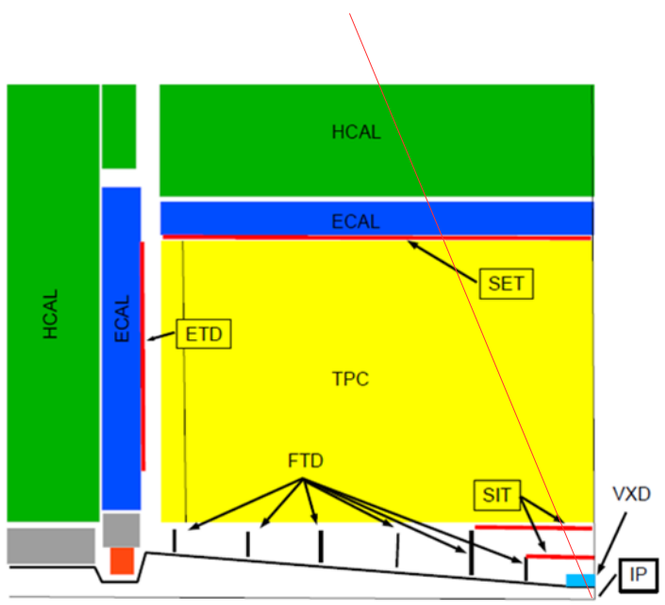
Linear Collider Workshop '18
Arlington, November 2018

Miguel Angel Villarejo, Martín Perelló, Marcel Vos
IFIC (U. Valencia/CSIC), Spain
Laci Andricek (MPG/HLL), Malte Frövel, Maria de la Torre (INTA)
Carlos Marinas (U. Bonn), David Moyá, Ivan Vila (IFCA)

ILD tracking







Increasing radius

Tracker sub-systems

Beam pipe

Vertex Detector (VXD)

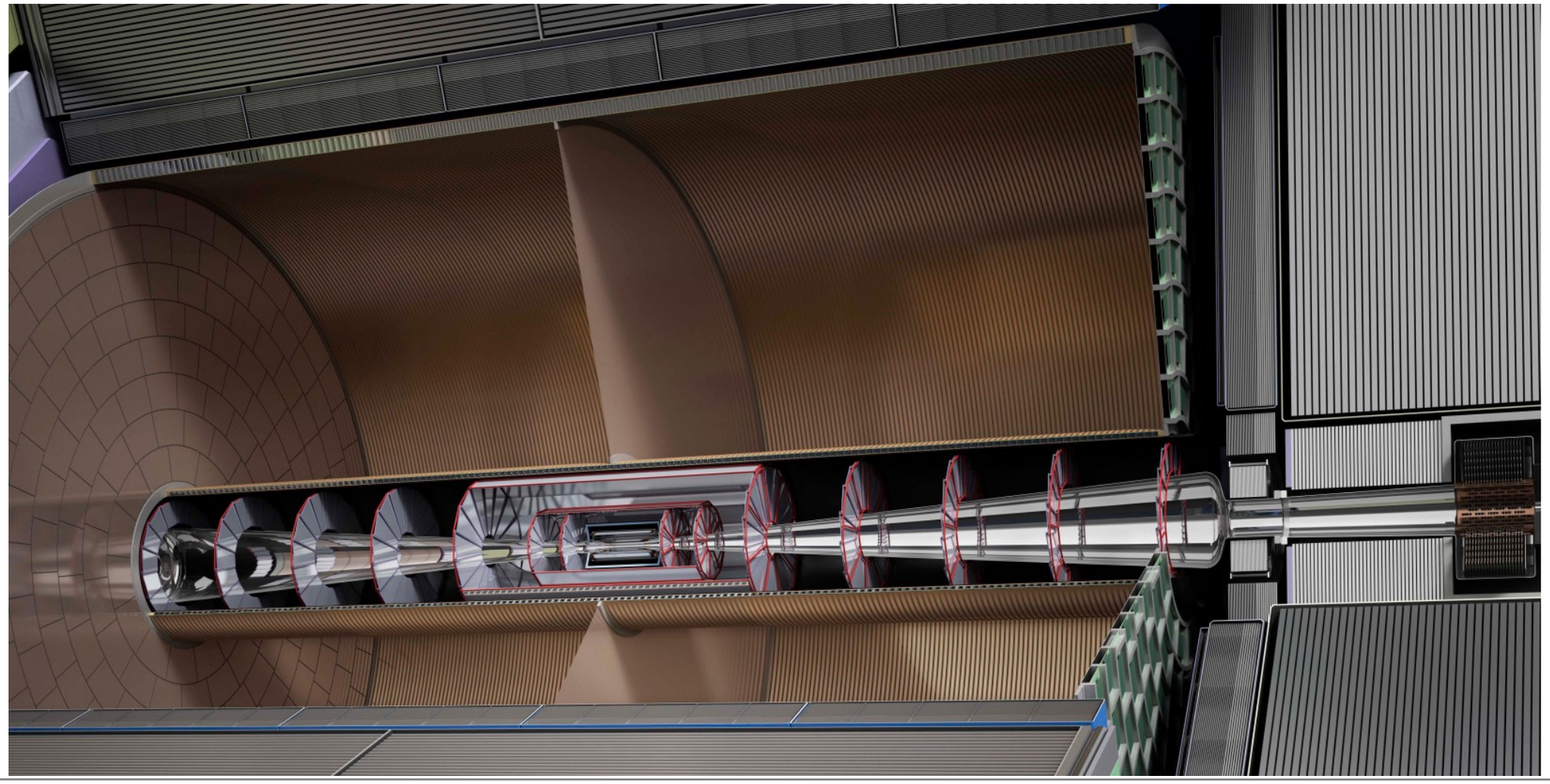
Silicon Intermediate Tracker (SIT)

Time Projection Chamber (TPC)

Silicon Envelope Tracker (SET)

The ILD tracker and FTD

- Mixed silicon (vertex, FTD, SIT, SET) and gaseous system (TPC)
- Seven disks cover the forward region between the TPC and the beam pipe.
- Innermost two disks pixelated single layer of silicon sensors
- Five outer disks equipped with a double layer of strip-based silicon sensors (→ CMOS?)



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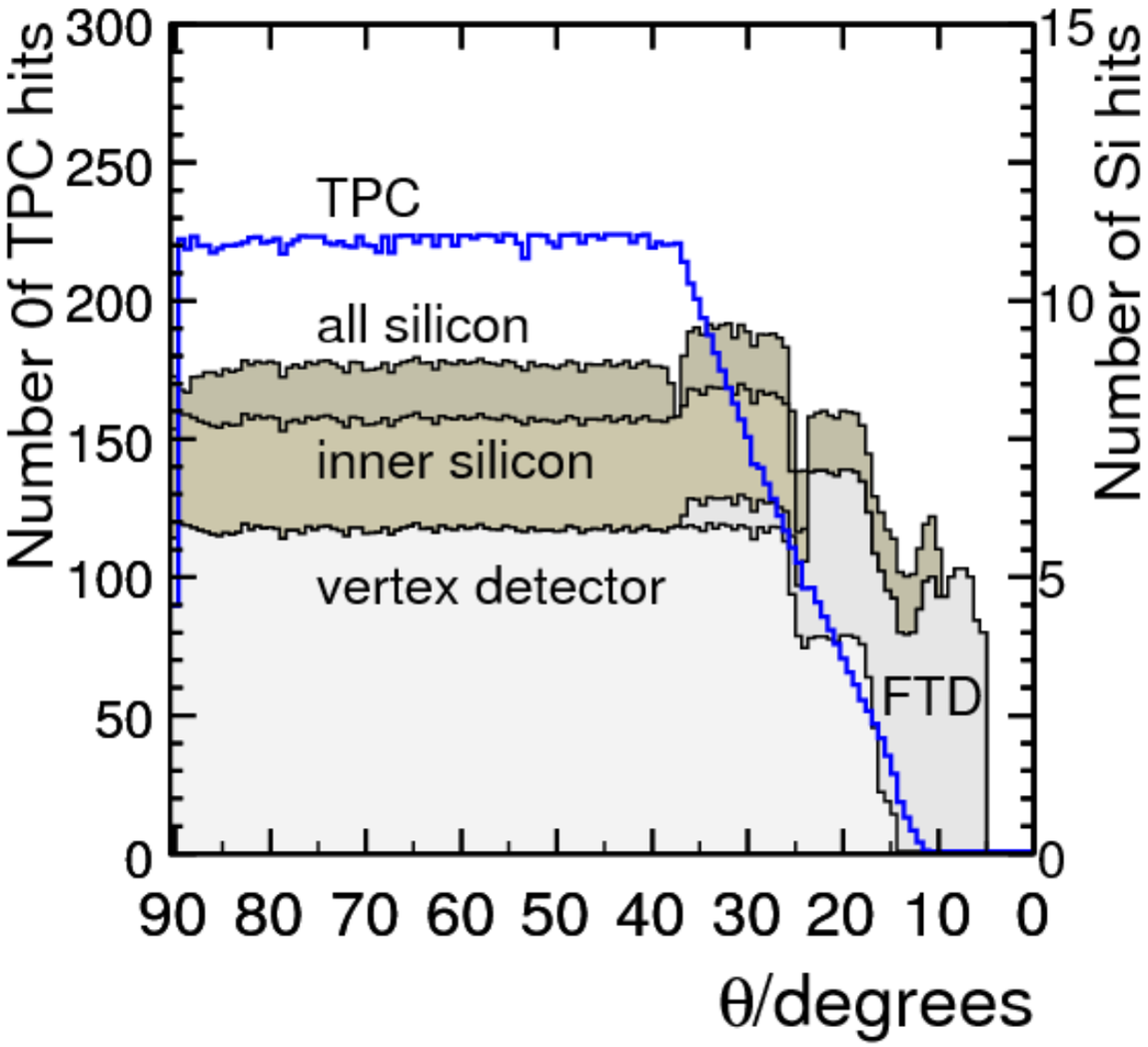
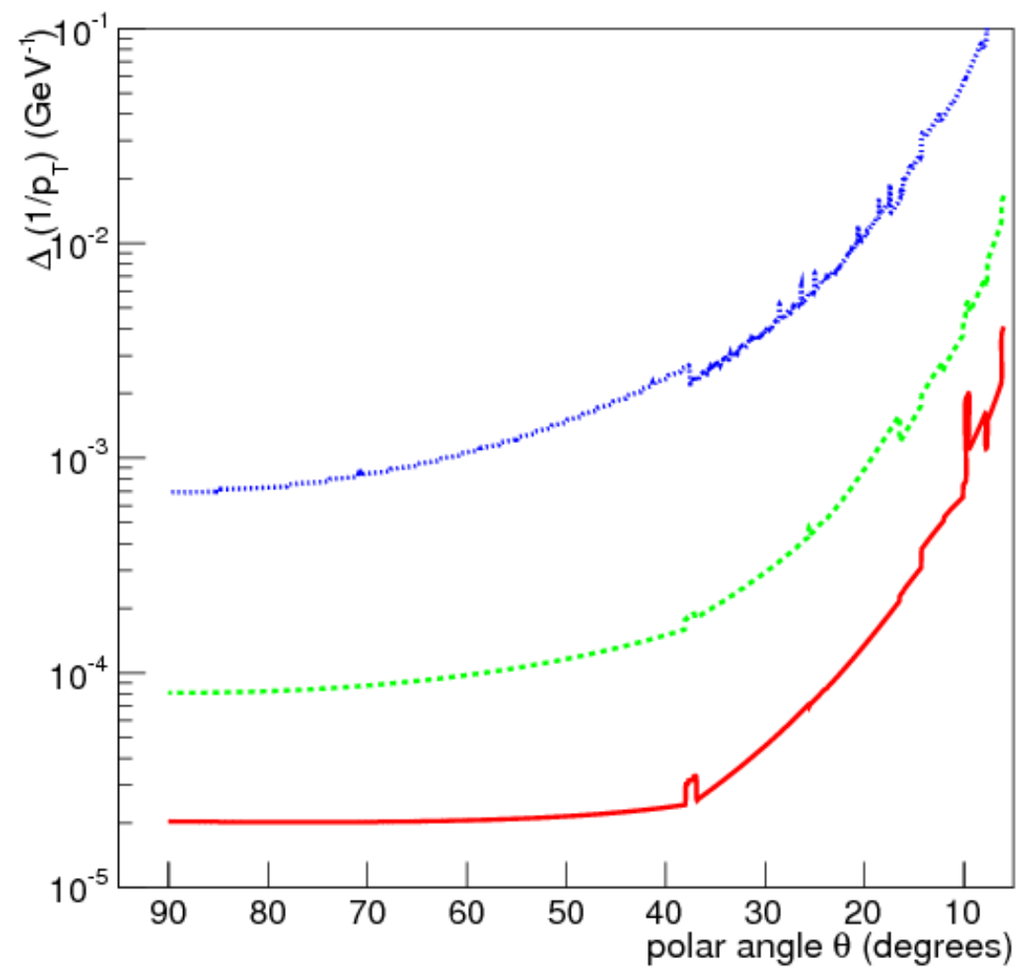
The role of FTD in tracking

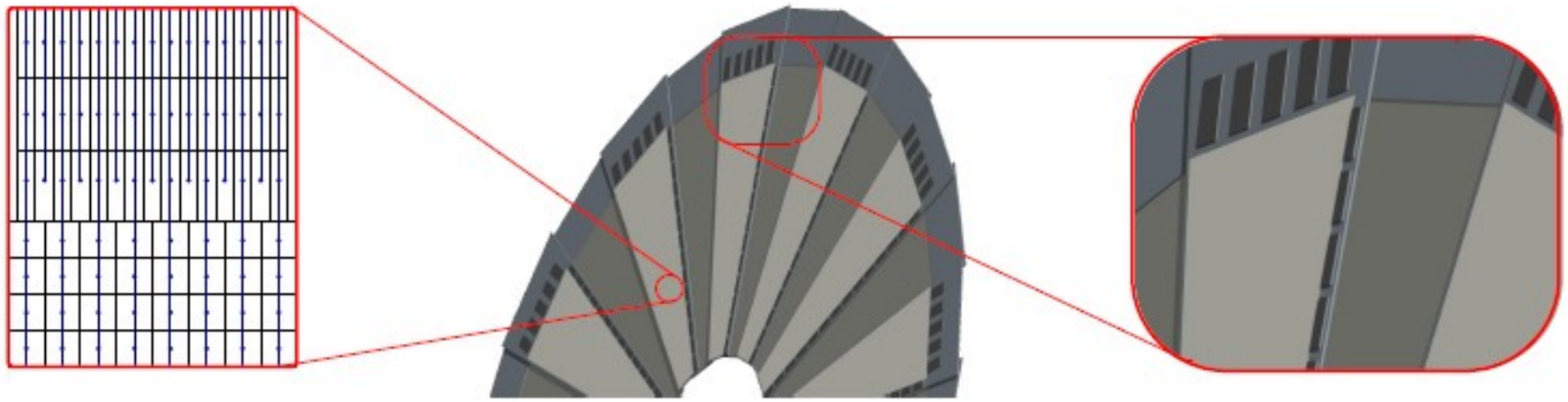


Number of hits in different sub-systems vs. polar angle



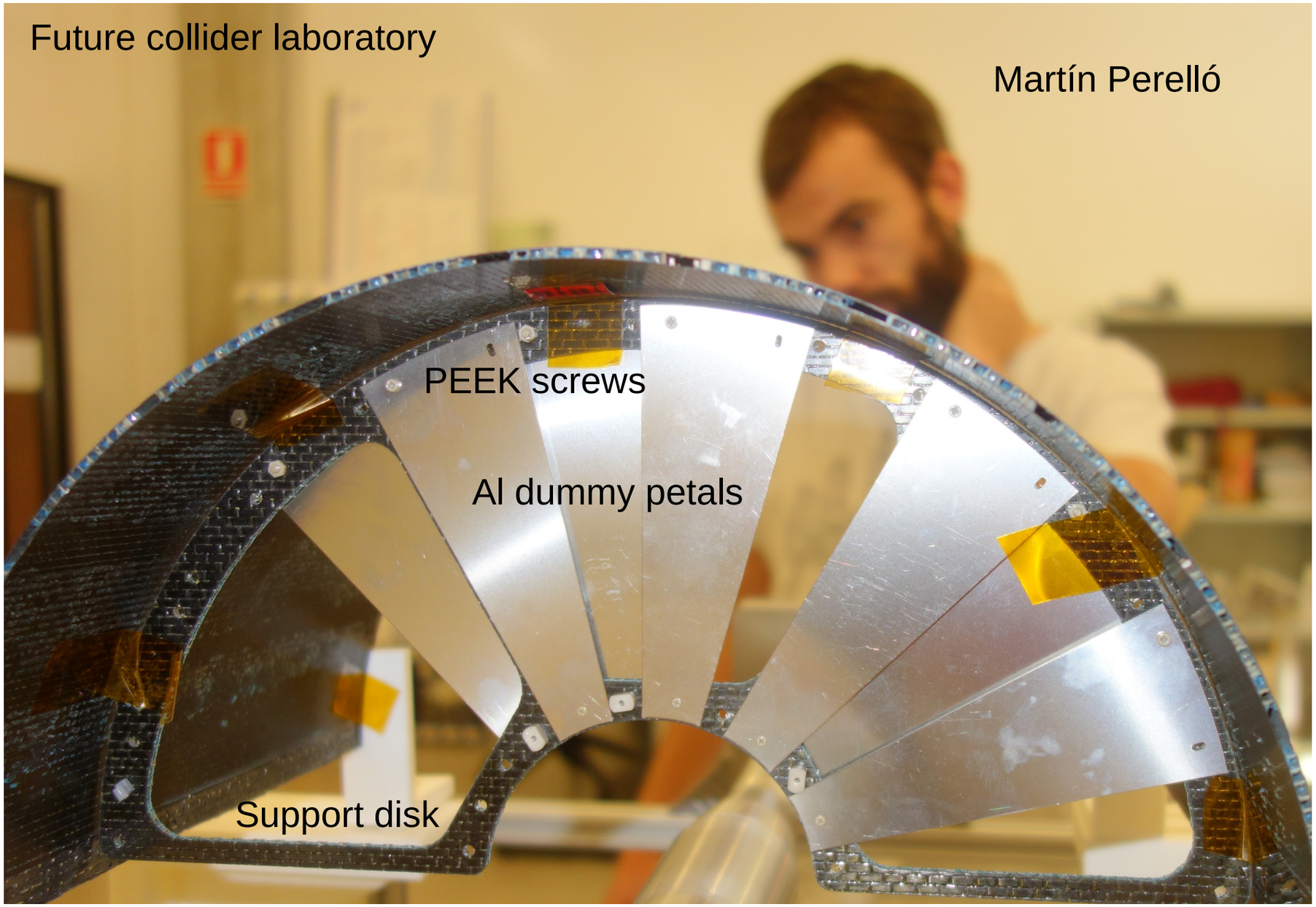
LiCToy transverse momentum resolution vs. polar angle for 1, 10, 100 GeV muons

Technologies for FTD 1 & 2



- All technology options remain open
  - CMOS
  - FPCCD
  - DEPFET
  - 3D-integrated
  - SOI
  - ...
- Conceptual adaption of barrel design to disk geometry for some technologies, but no fully engineered design
- This talk: develop a realistic prototype (mock-up) and simulation
- Assess thermo-mechanical performance

The old mock-up



In the long term, the mock-up should develop into a complete system, including beam pipe, support and services, and micro-strip disks under development at IFCA in Santander

A mock-up for FTD 1 and 2

Dimensions reflect ILD design

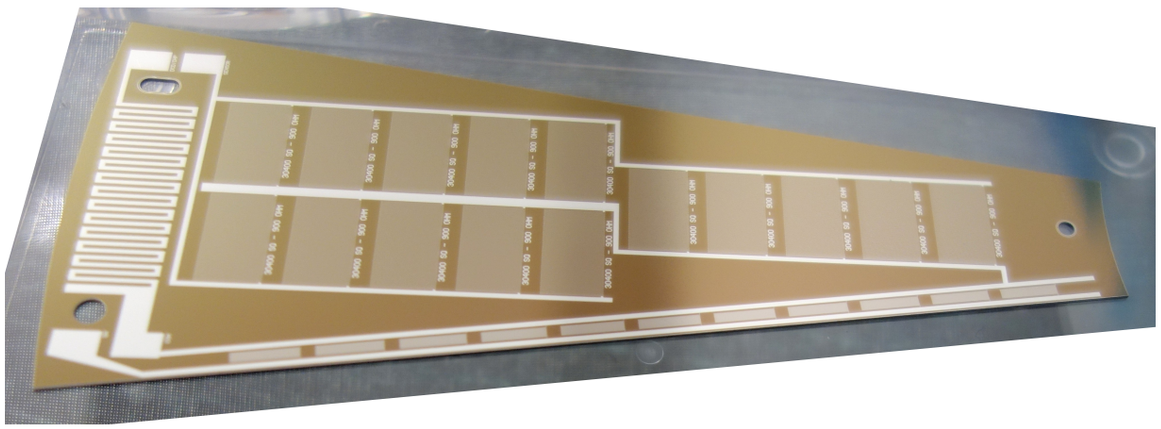
Goal: gain hands-on experience with thermal and mechanical performance of ultra-thin CF+silicon structure

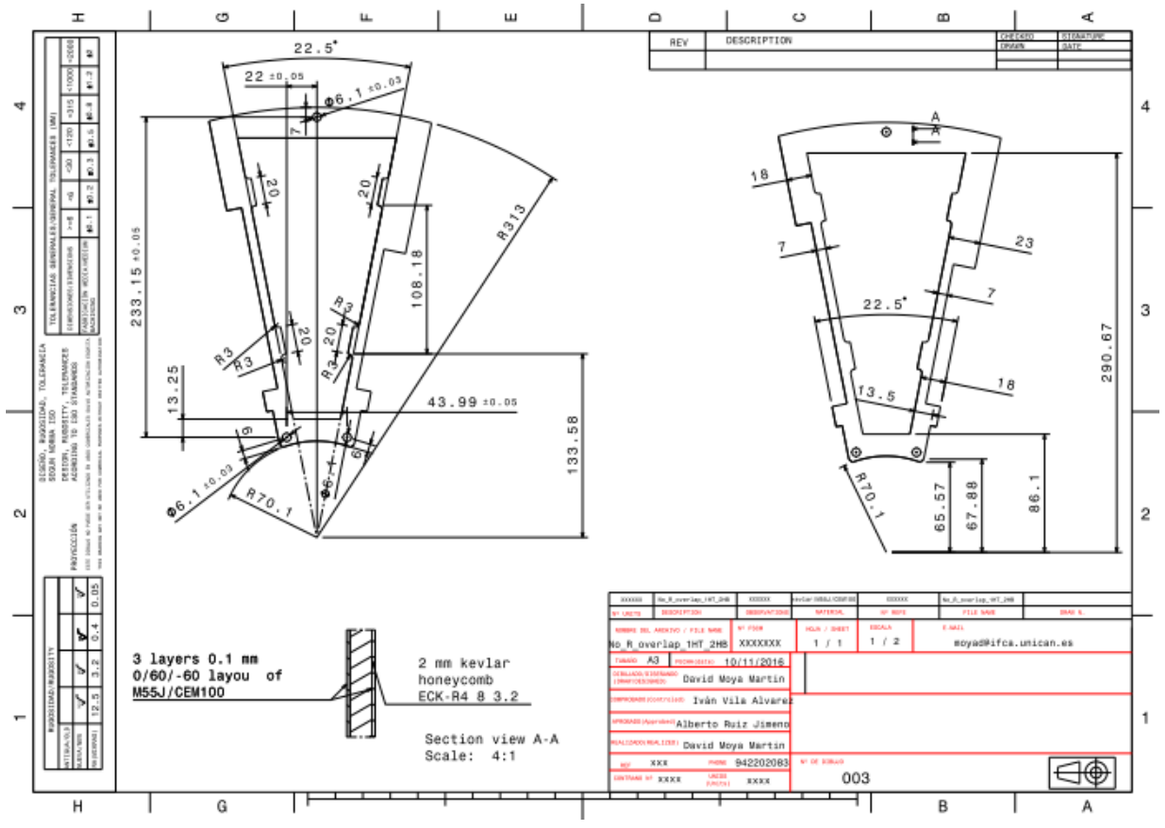
Silicon petal design by Miguel Angel Villarejo (IFIC) in collaboration with Ladislav Andricek (MPG-HLL)

Material budget:

sensor = 50 μm Si = 0.05 % X_0

frame = 500 μm Si = 0.5 % X_0





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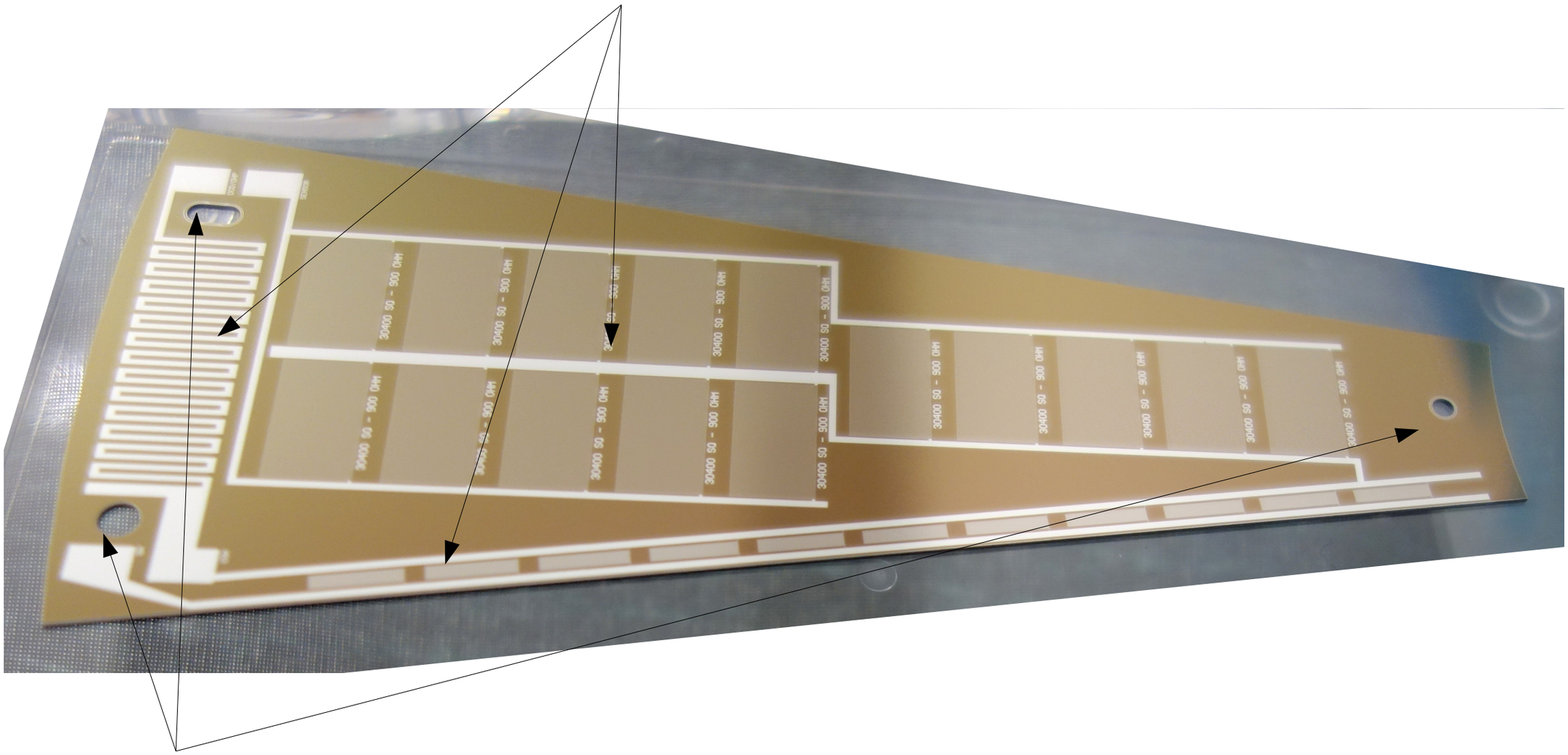
A mock-up for FTD 1 and 2

Heater circuits on the sensor (single Al metal layer)

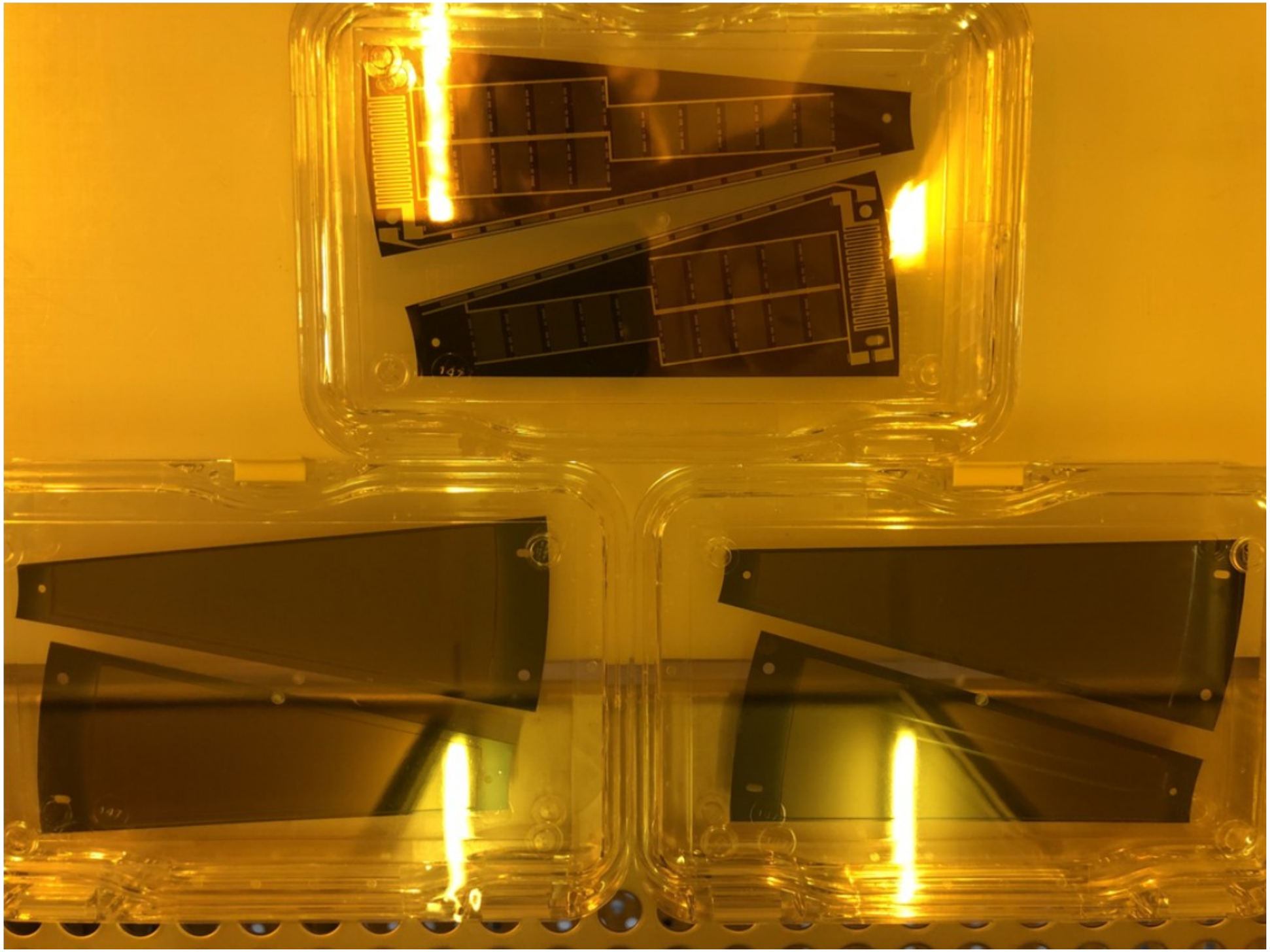


Kinematic mounting slots: when the sensors are mounted with a PEEK screw with a precisely controlled torque, these mountings provide a solid 3D constraint, while leaving the sensor enough freedom for thermal expansion.

All-silicon petals

New production at silicon lab of the Max Planck society in Munich

Petals arrived at IFIC in September 2018 and are currently being mounted on mock-up structure

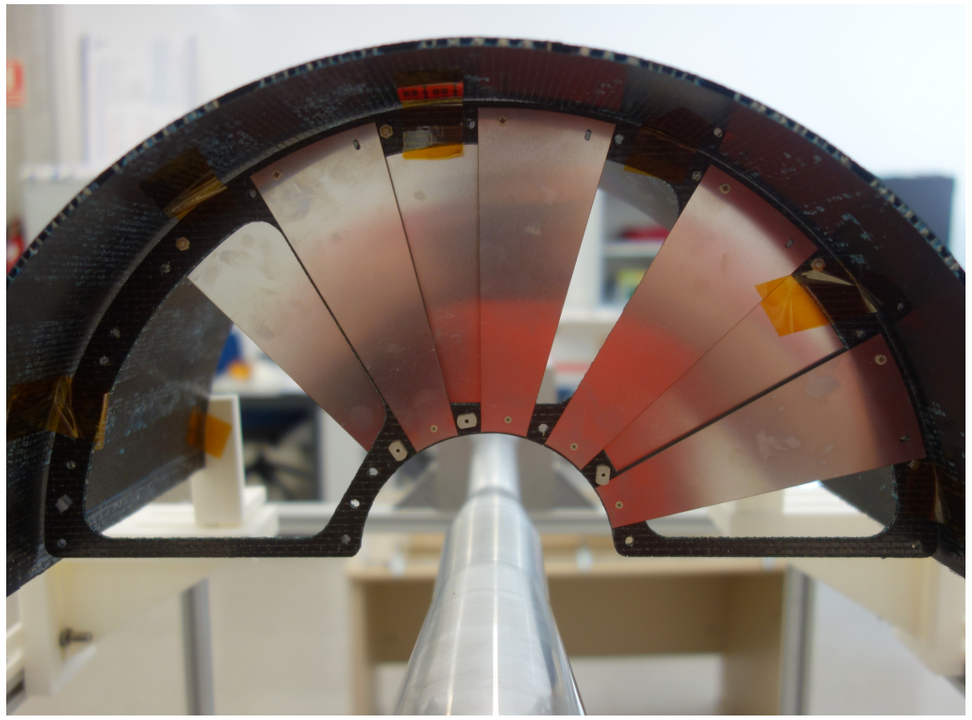


A mock-up for FTD 1 and 2

Dimensions reflect ILD design

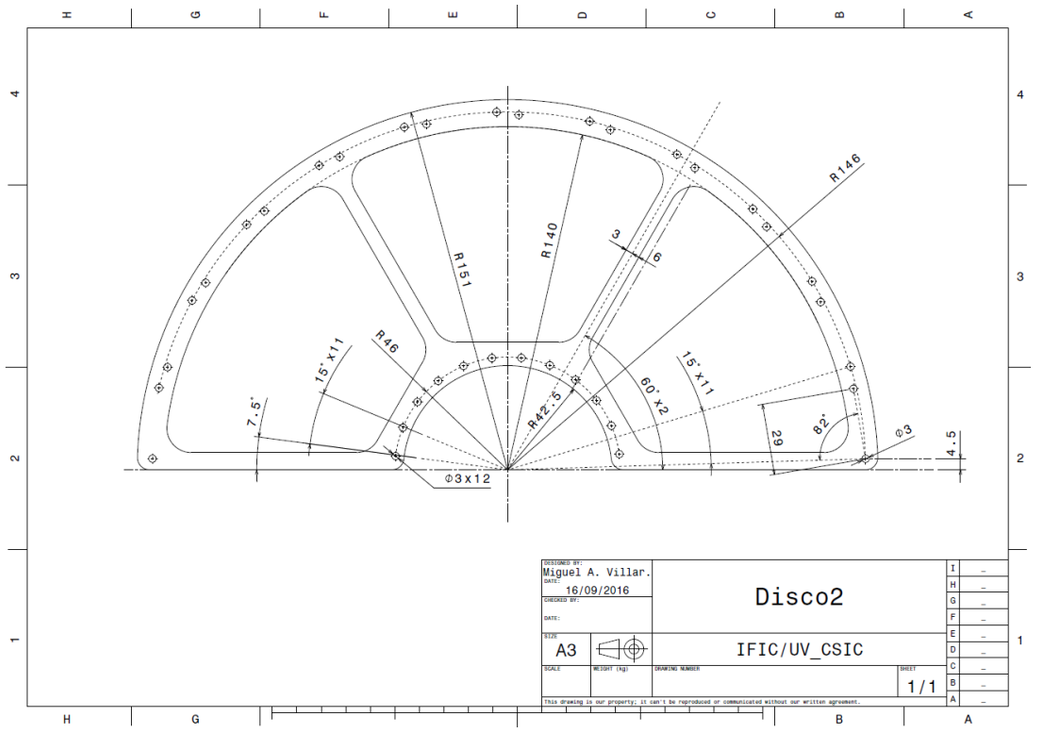
Goal: gain hands-on experience with thermal and mechanical performance of ultra-thin CF+silicon structure

Support structure by M.A. Villarejo with Malte Frovel and Maria de la Torre of the composite materials group at INTA in Madrid



Average material budget:

C-fiber: 0.038% X_0 (skin + honeycomb)
Epoxy : 0.0006% X_0
PEEK : 0.0033% X_0 (inserts + screws)
Glue : 0.0006% X_0
Total : 0.042% X_0



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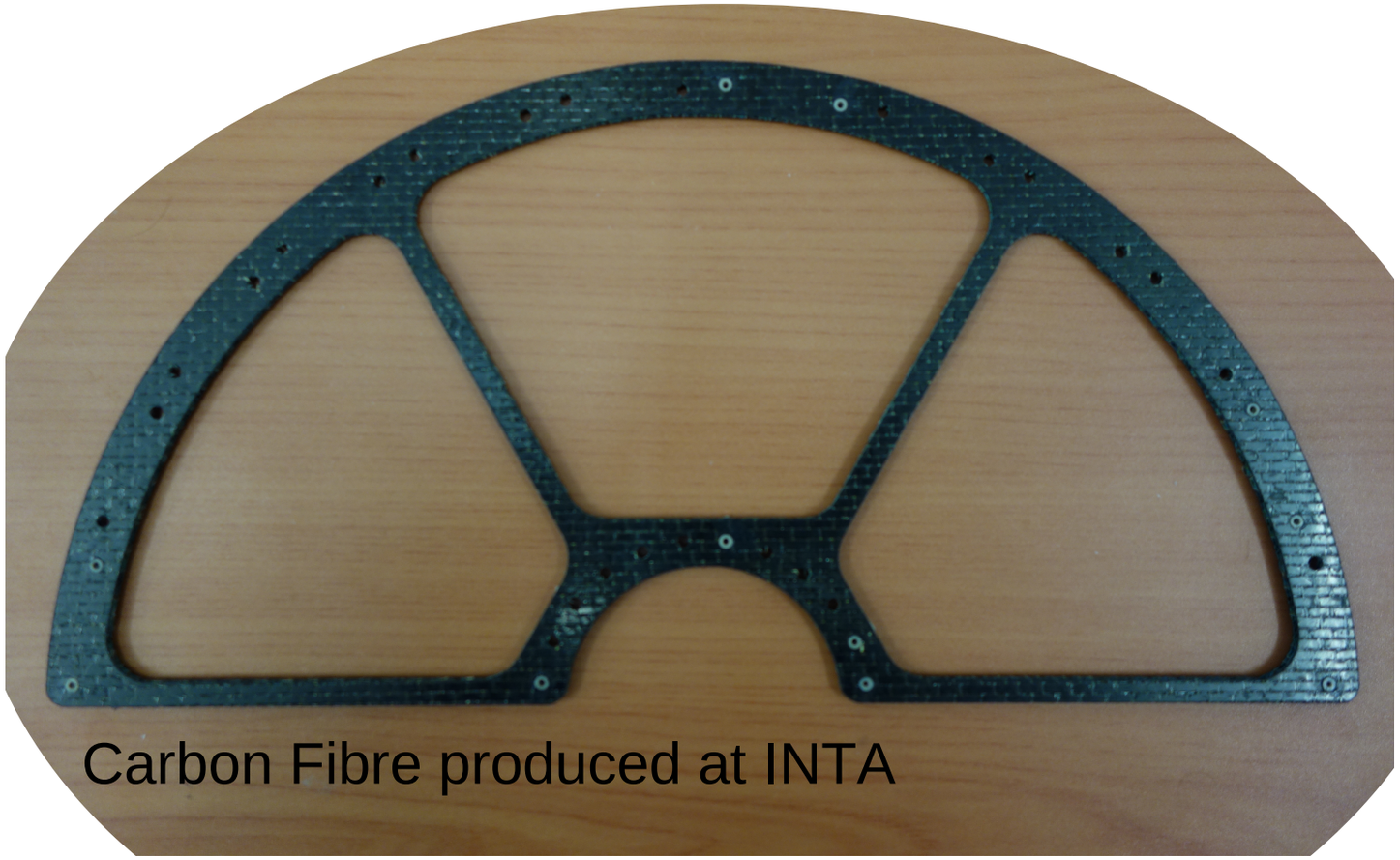
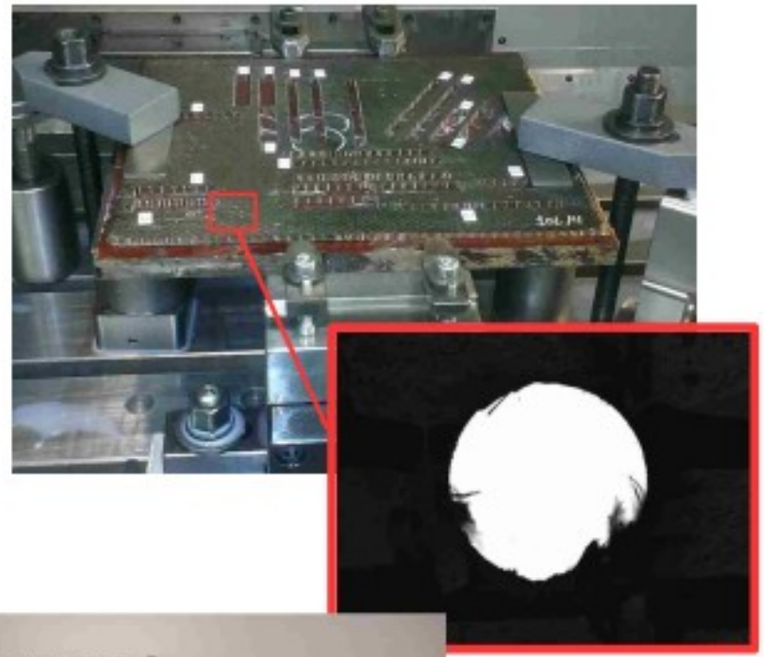
Carbon Fibre disk production



Cutting at Ramem (Madrid)

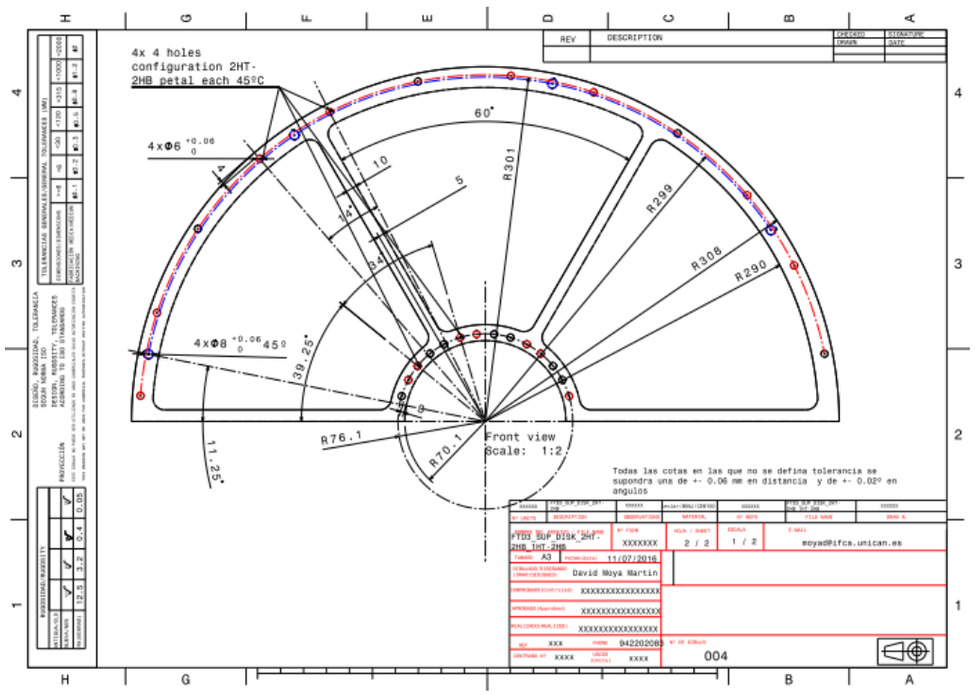


test samples

Young's modulus: measurements compatible

Planarity:

Mechanical characterization



MINISTERIO DE DEFENSA | SECRETARIA DE ESTADO DE DEFENSA | INSTITUTO NACIONAL DE TECNICA AEROESPACIAL

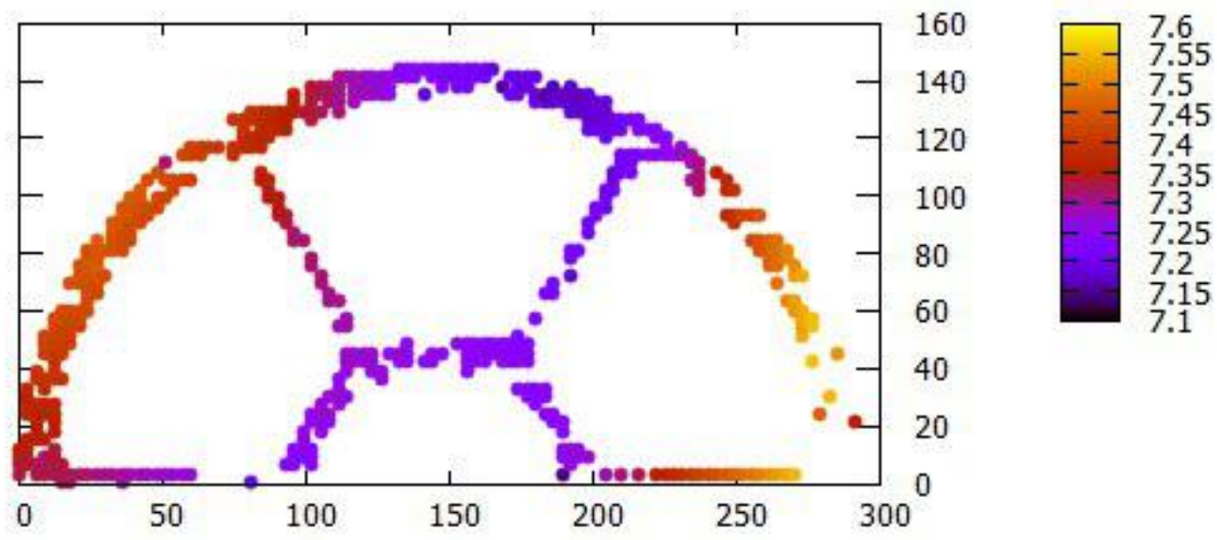
AREA DE MATERIALES COMPUESTOS

LABORATORIO DE CARACTERIZACIÓN MECÁNICA

	Sample ID	thickness (mm)	width (mm)	Module E (GPa)
1	IFCA-01	1.568	12.656	272.0
2	IFCA-02	1.547	12.660	253.3
3	IFCA-03	1.578	12.589	246.8
4	IFCA-04	1.539	12.618	278.5
5	IFCA-05	1.537	12.677	253.5
6	IFCA-06	1.576	12.711	252.3
Maximum		1.578	12.711	278.5
Minimum		1.537	12.589	246.8
Average		1.557	12.652	259.4
Standard dev.		0.02	0.04	12.68
C.V.		1.20	0.34	4.89

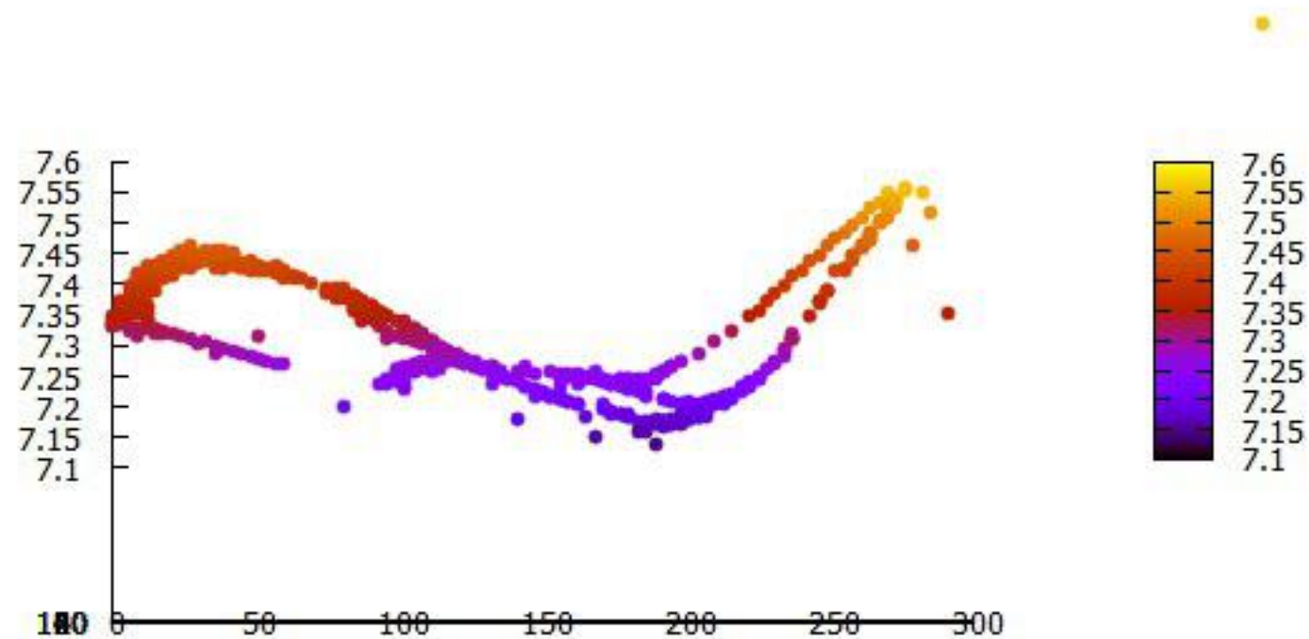
Standard measurements of deformation under compression ASTM D695 M

Planarity

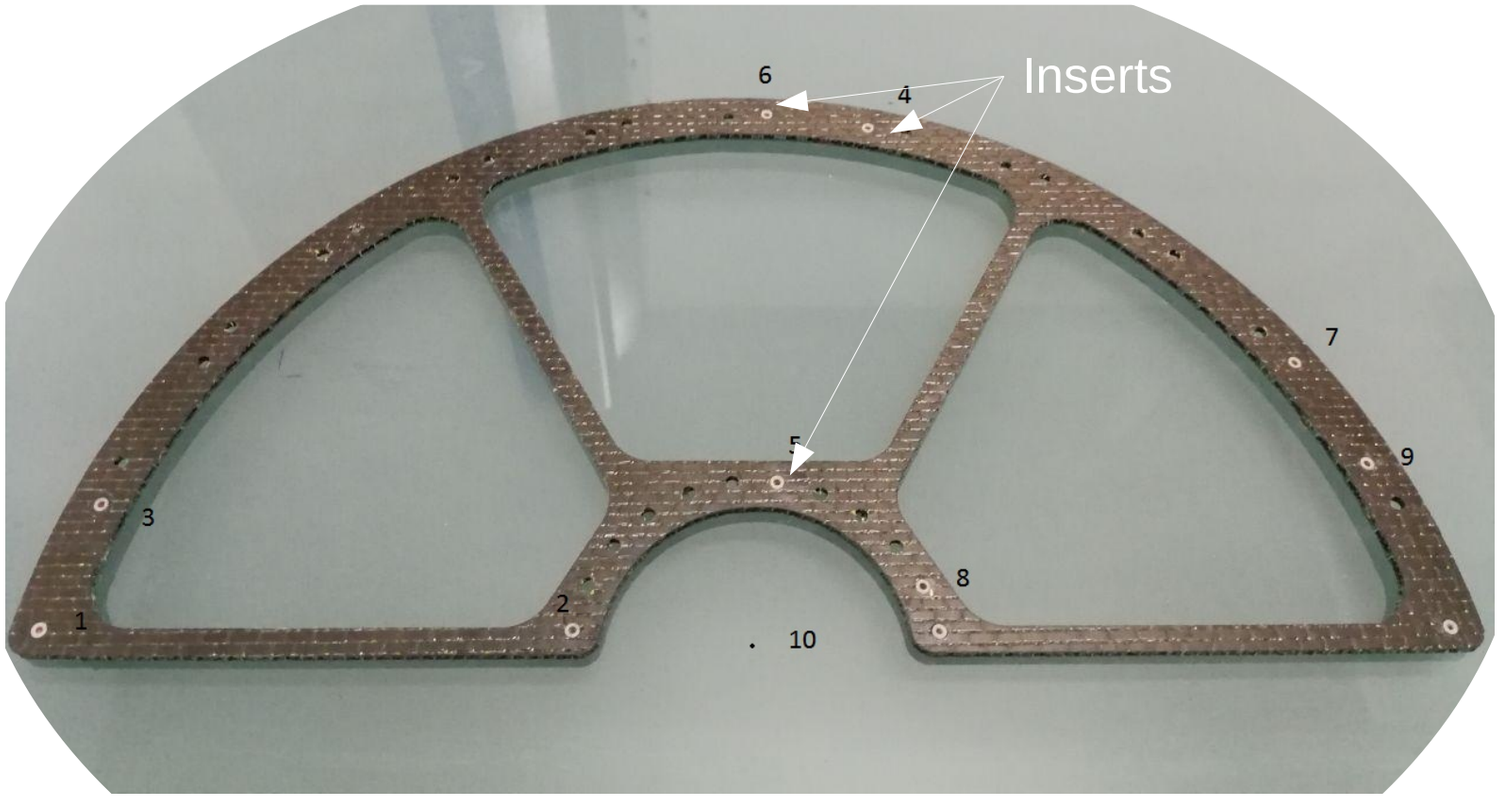


The CF disks have been extensively surveyed in a precise metrology system.

Planarity over 30 cm:
- peak-to-peak ~500 μm
- RMS ~ 200 μm

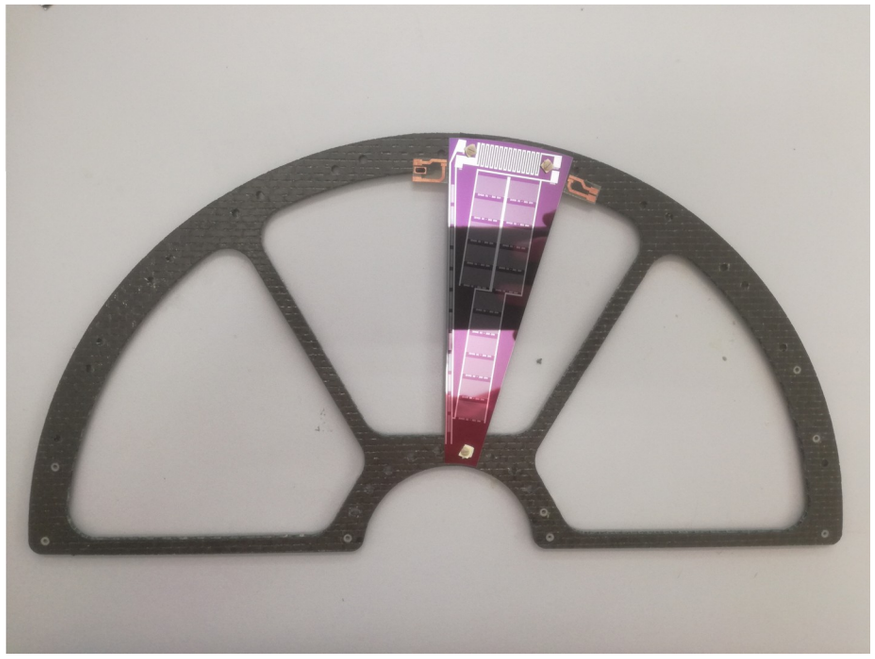


Mounting & inserts



The mounting points for the silicon sensors are formed by PEEK precision inserts

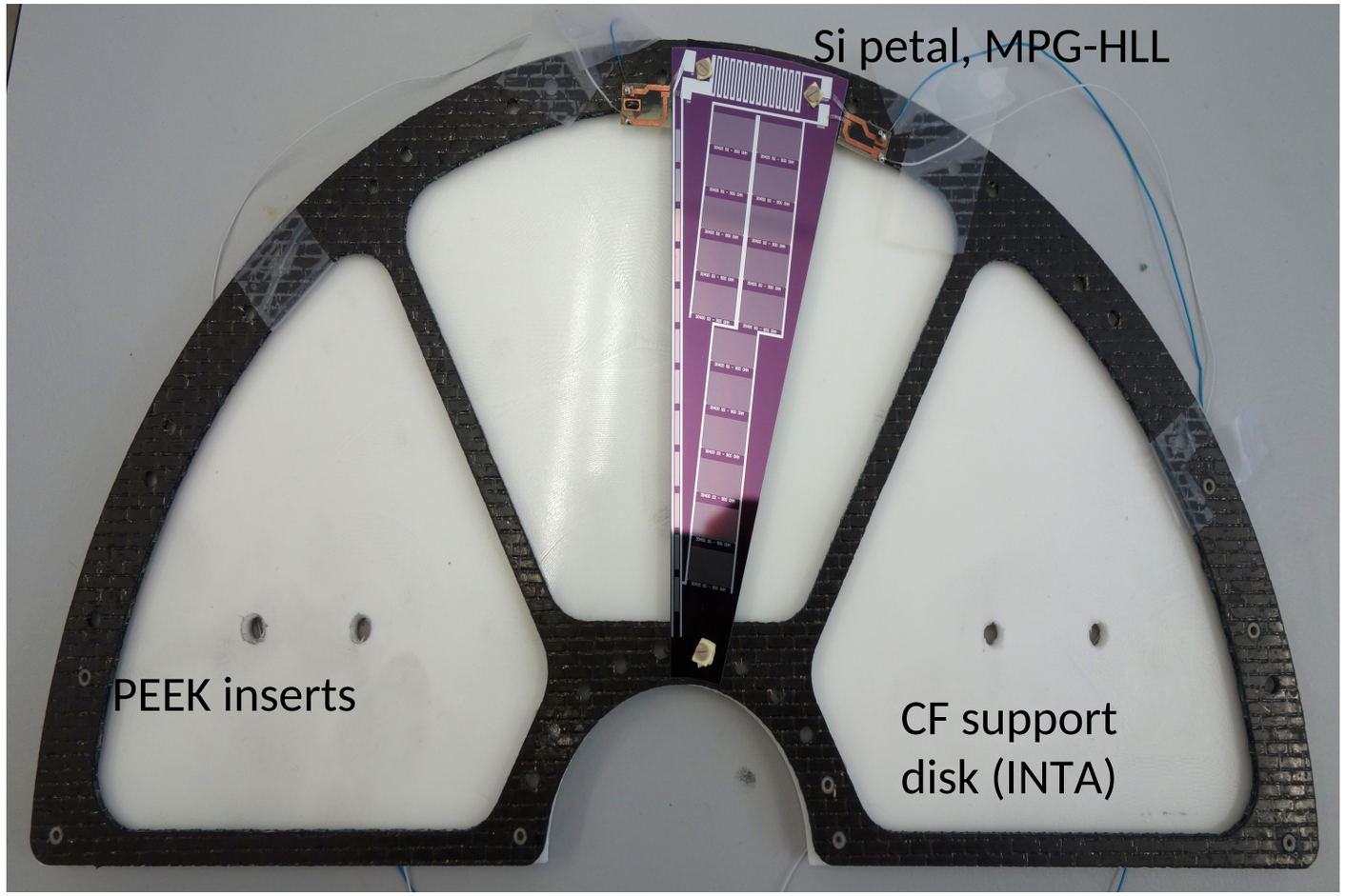
Inserts are glued into the Carbon Fibre with a jig that guarantees good relative precision of the three mounting points for each sensor

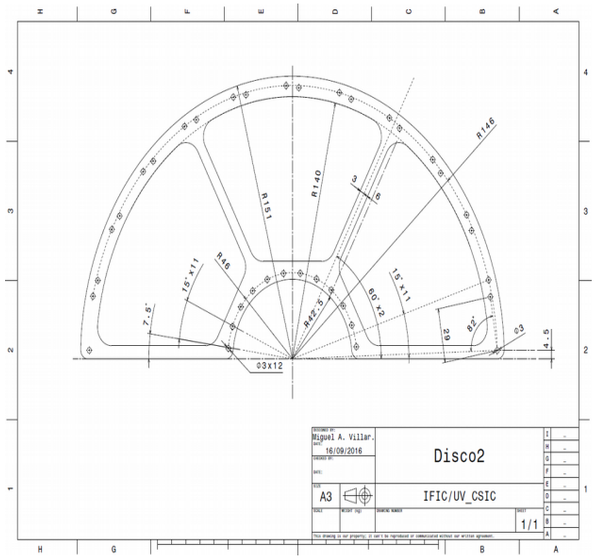


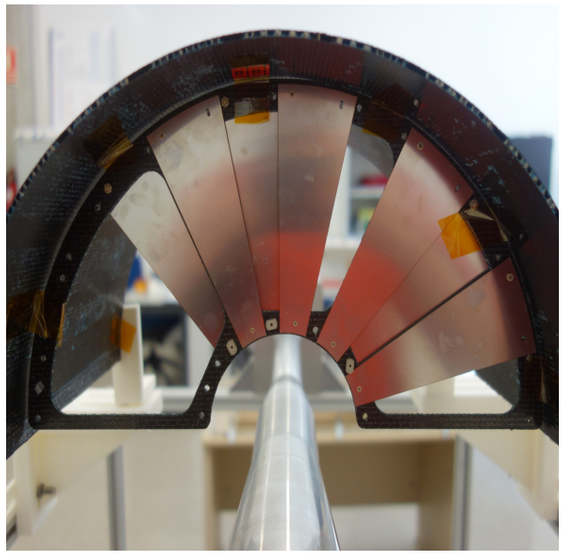
Planarity: 170 μm (RMS over 9 points, unloaded)
Placement precision of inserts: 100 μm (within triplet)

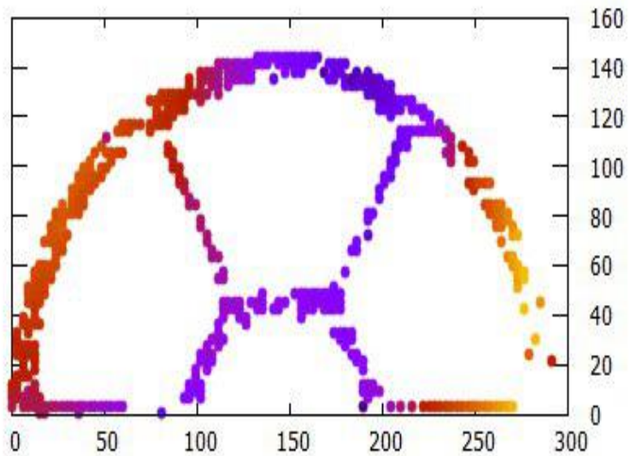
Mock-up for Forward Tracking Disks

Mock-up for FTD1 and 2 is being assembled at IFIC







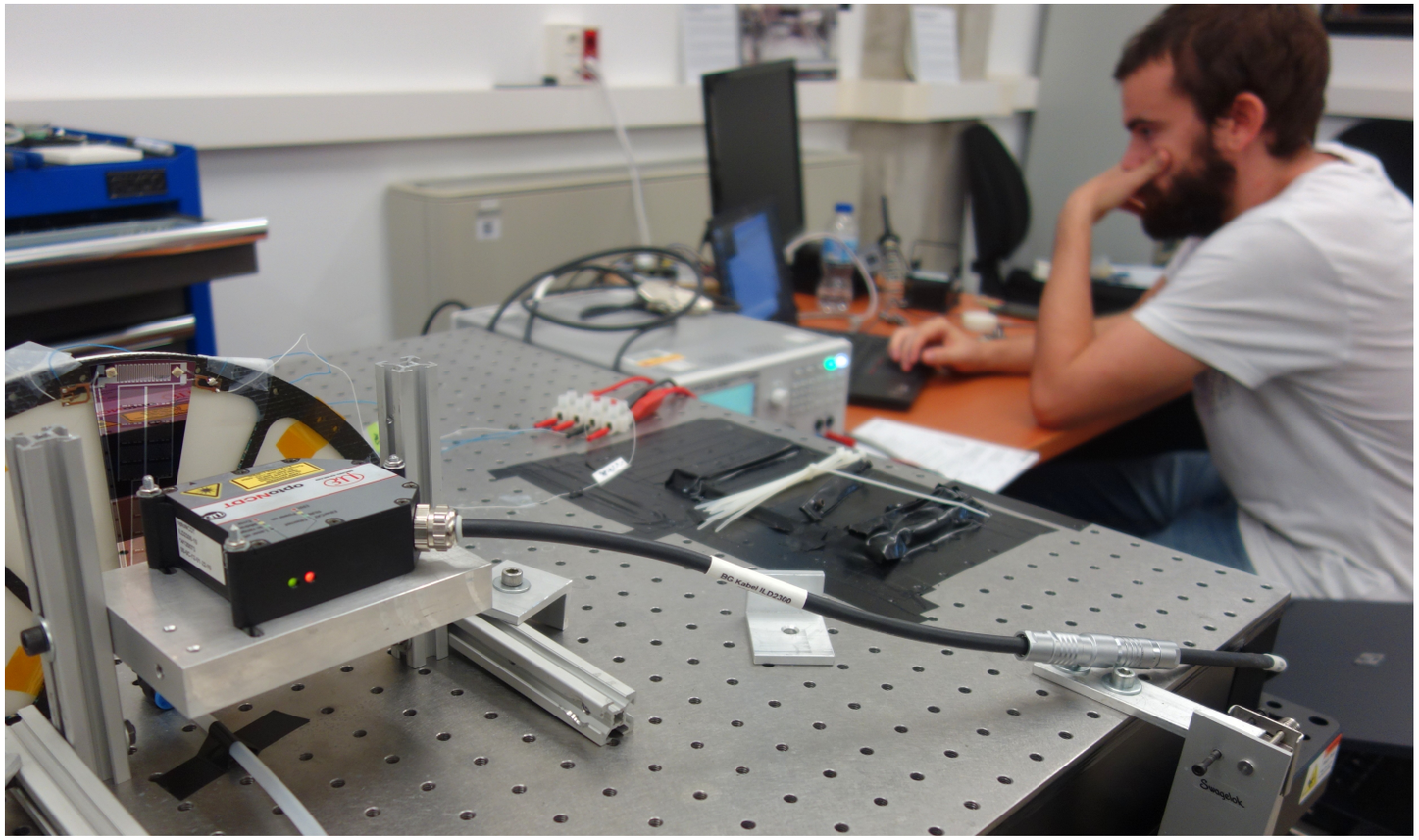


sensors : 50 μm Si + 500 μm frame

support : 0.042% X/X_0 (CF + PEEK inserts/screws + glue)

First measurements of mechanical stability are very promising

Thermo-mechanical properties



The null measurement without external distortion yields good results:
sub-μm long-term stability and sub-μm vibrations

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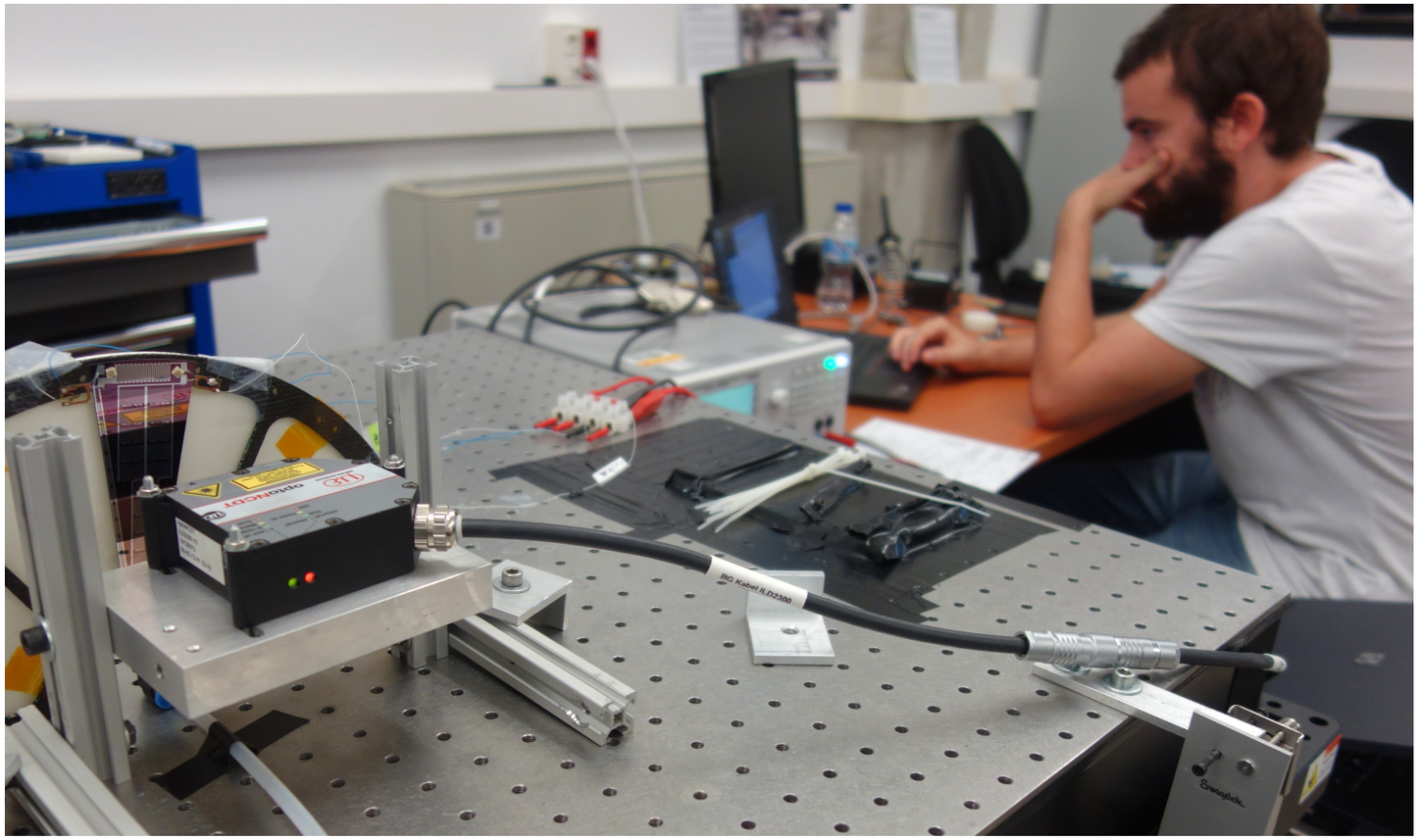
Thermo-mechanical properties

power dissipation:
nominal DEPFET power
with 20% power-pulsing



Thermal expansion of silicon is handled by kinematic mounting of sensor:
- distortion in plane as expected from CTE
- distortion out-of-plane limited to ~5 μm

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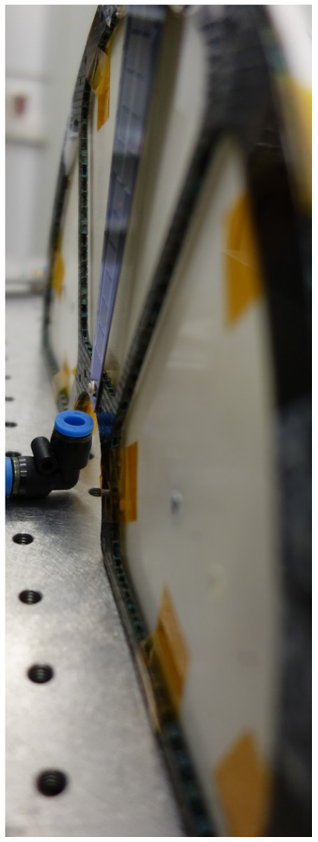
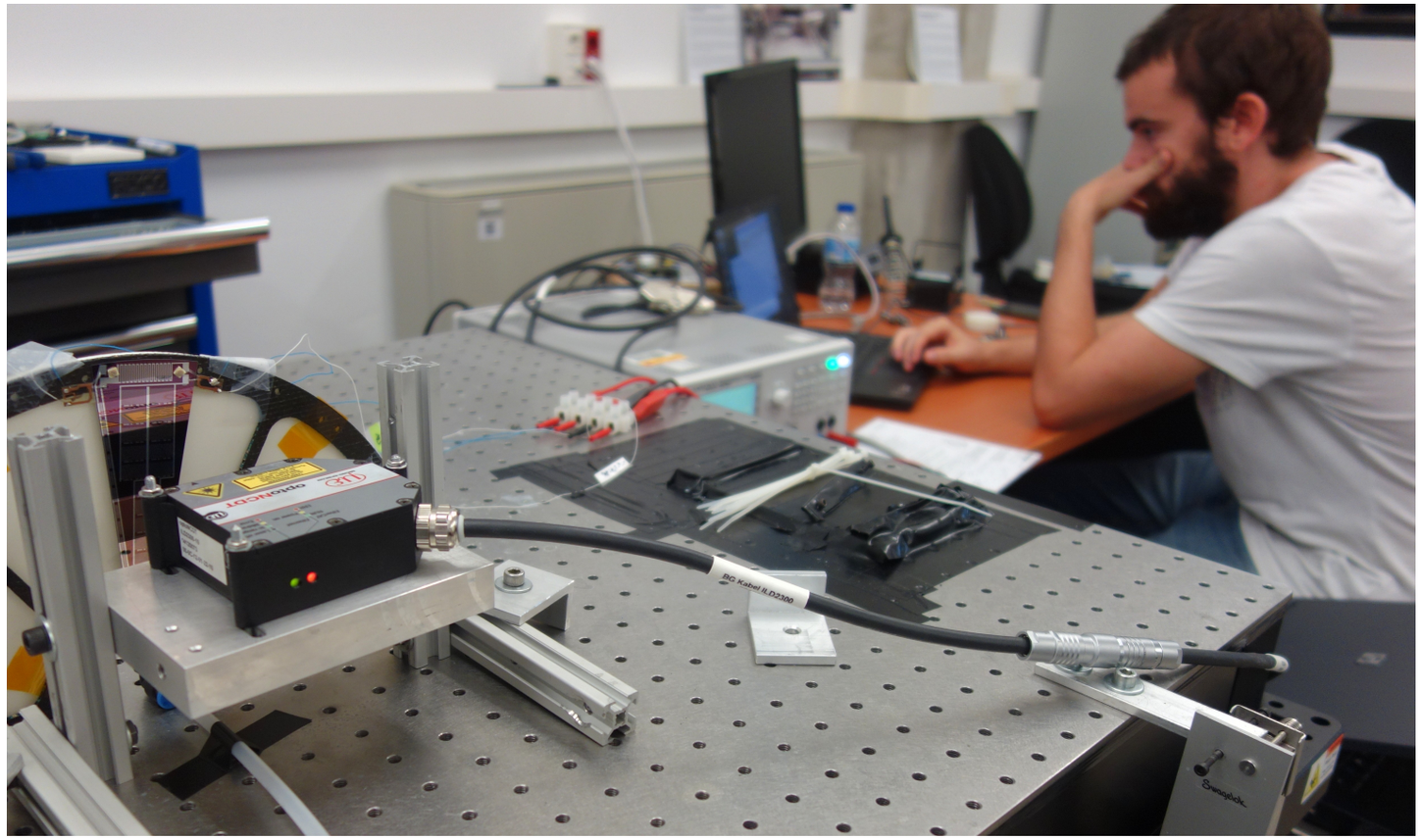
Thermo-mechanical properties

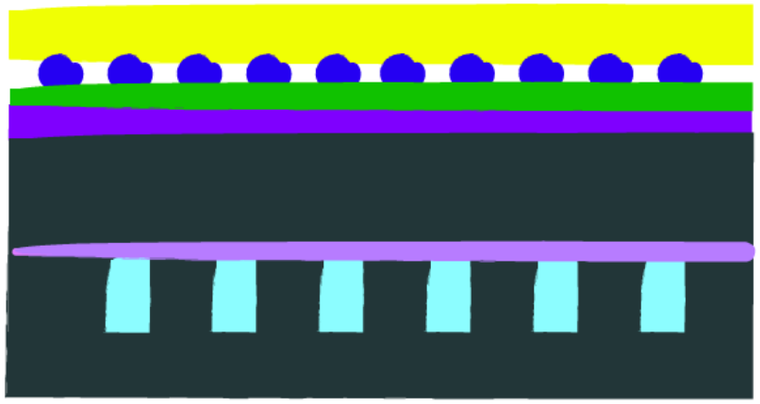


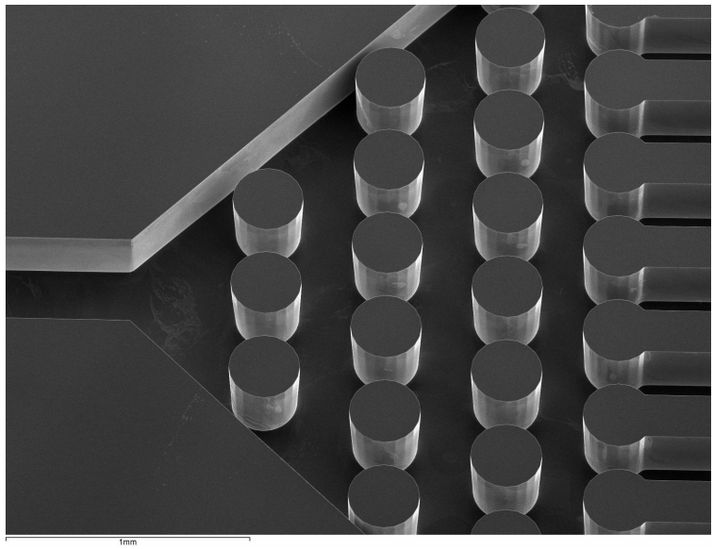
Forced air flow:
Air is blown radially
from inner radius

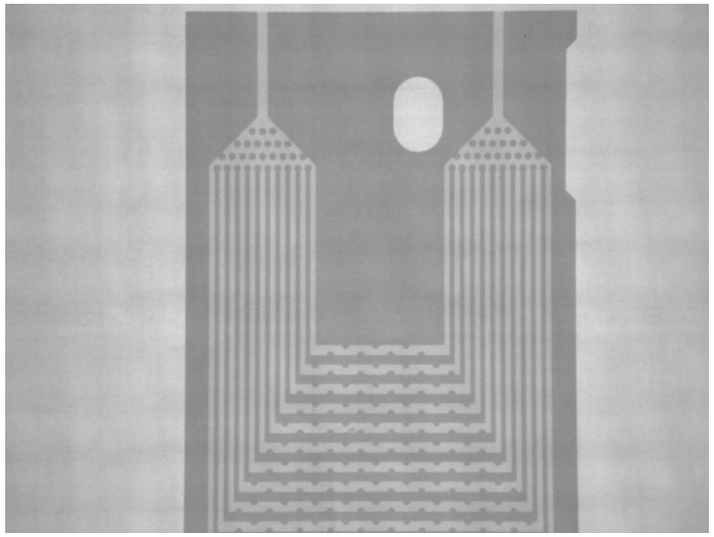


Forced air flow over the silicon leads to the expected effect:
- vibrations increase with air pressure
- static distortion limited to ~5 μm

Cooling + supports

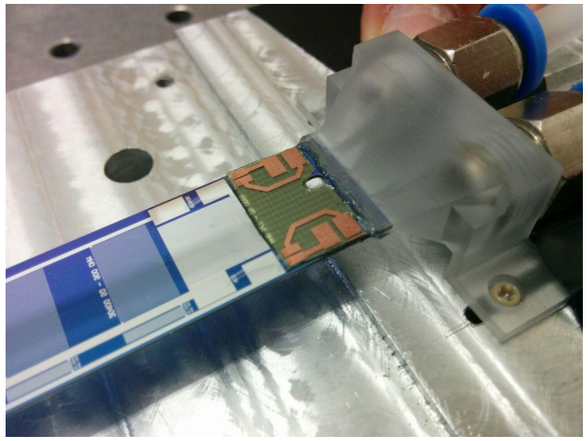


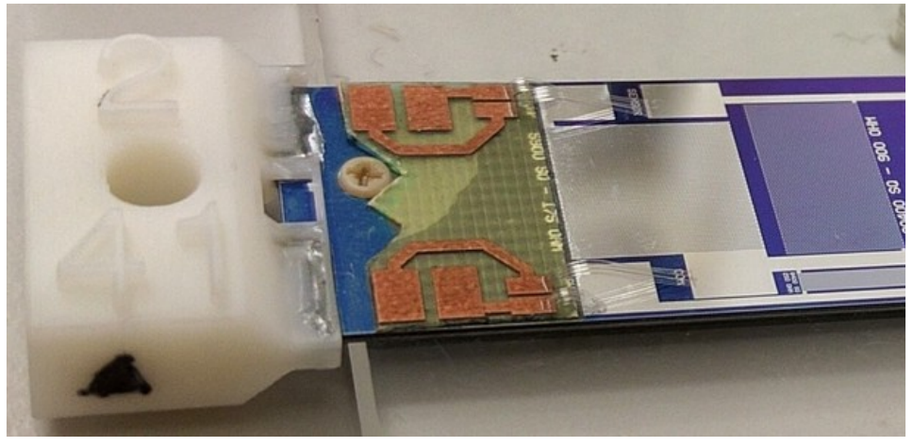


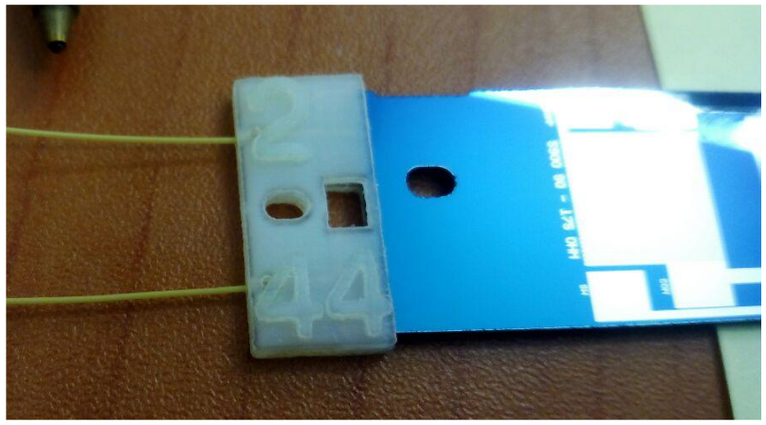


Micro-manifold before (photograph) and After wafer bonding (X-ray image) Samples produced at HLL.

(arXiv:1604.0877)







High-tech plumbing: custom, 3D-printed interfaces to commercial piping

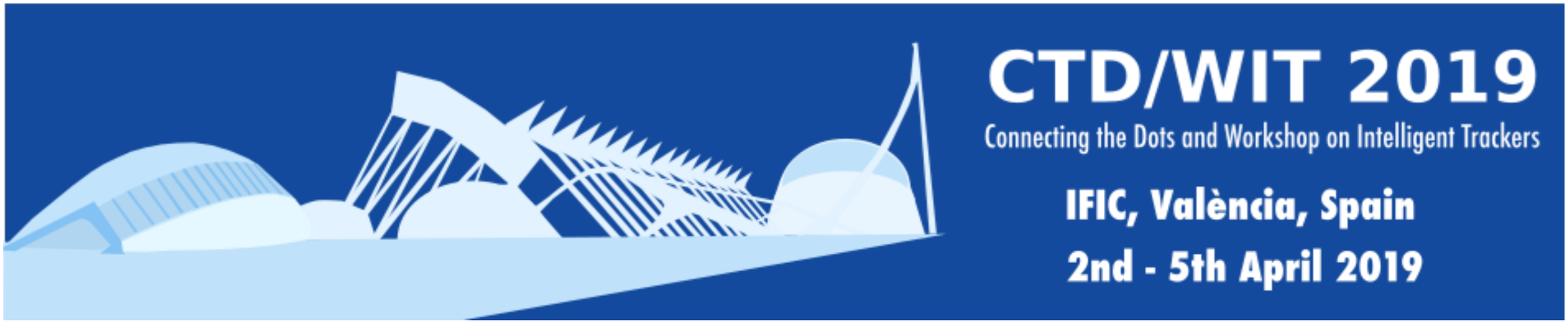
New MCC samples have arrived at IFIC from MPG-HLL
→ news in the next meeting

Invitation

You missed the Forum on tracking detector mechanics, Valencia, 25-27 june 2018

Another chance:

Connecting the dots/workshop on intelligent trackers, Valencia 2-5 April 2019



Summary

After a long preparatory phase the mock-up assembly has started

Aim: demonstrate thermo-mechanical stability of design for FTD 1&2
based on all-silicon petals (MPG-HLL) and ultra-thin CF support structure (INTA)

First measurements look promising:
- kinematic mount absorb thermal expansion as expected
- deformations under power load and air-flow are O(5 μm)
- mechanical stability in stable conditions is much better

Another step towards a realistic design of a forward tracker for the (I)LC