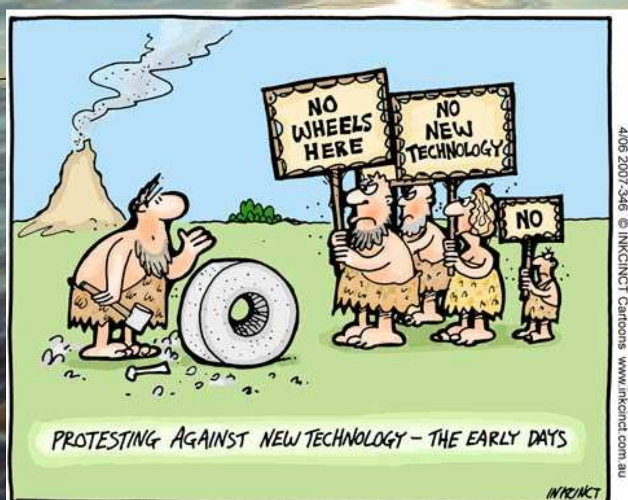
Vertex 2011
Rust, Austria | 19–24 June 2011

New Technologies in Tracking detectors

By Franck CADOUX, University of GENEVA



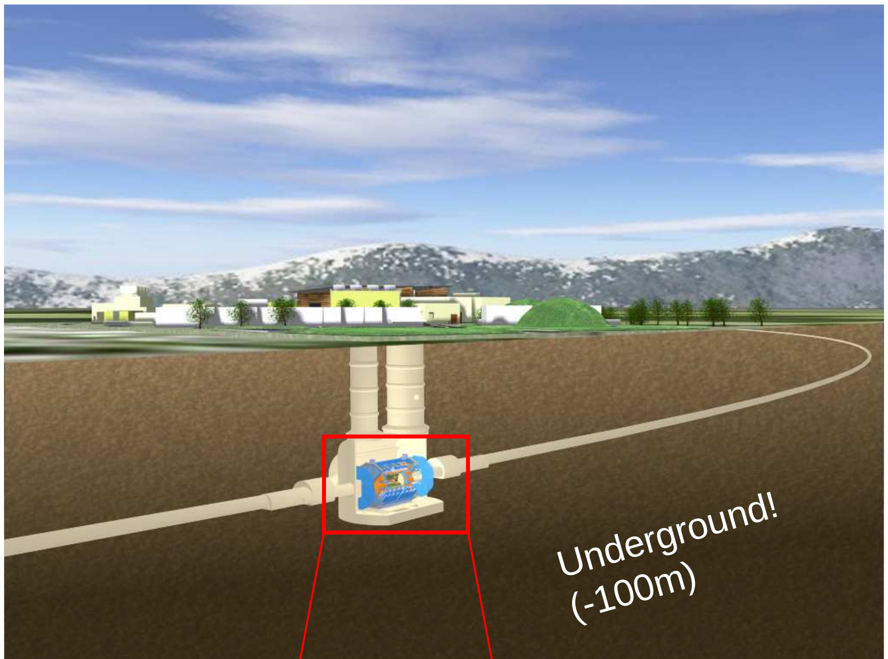
A quick view on some current Detectors & an Overview towards the Upgrades…

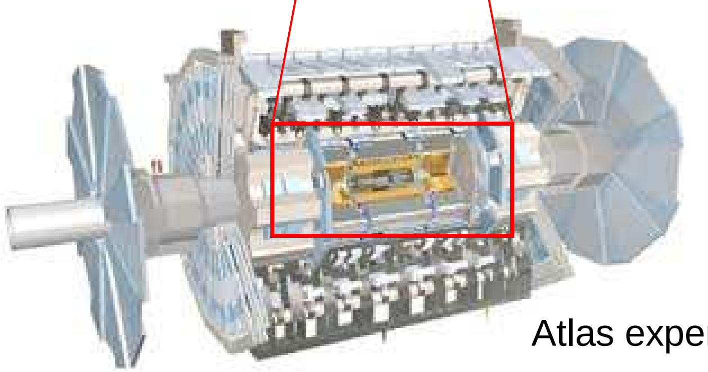
Supported by: HAMAMATSU PHOTON IS OUR BUSINESS
MICRON SEMICONDUCTOR LIMITED

Current situation on Trackers (ATLAS, AMS-02)

➢ Let's start with a feedback on **2 different cases** on current Trackers: ATLAS, AMS-02… non exhaustive!

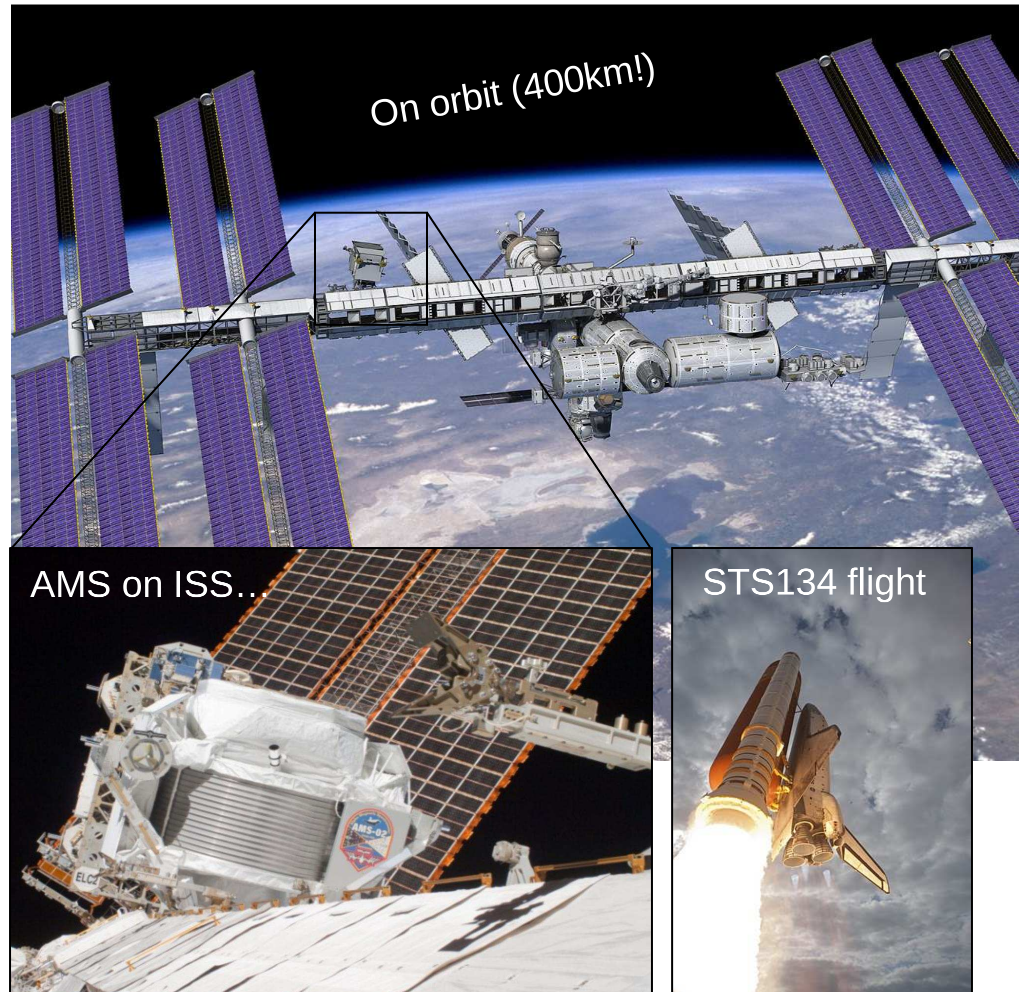
Highlight on **Atlas SCT**
(collaboration with UNIGE)





Atlas experiment

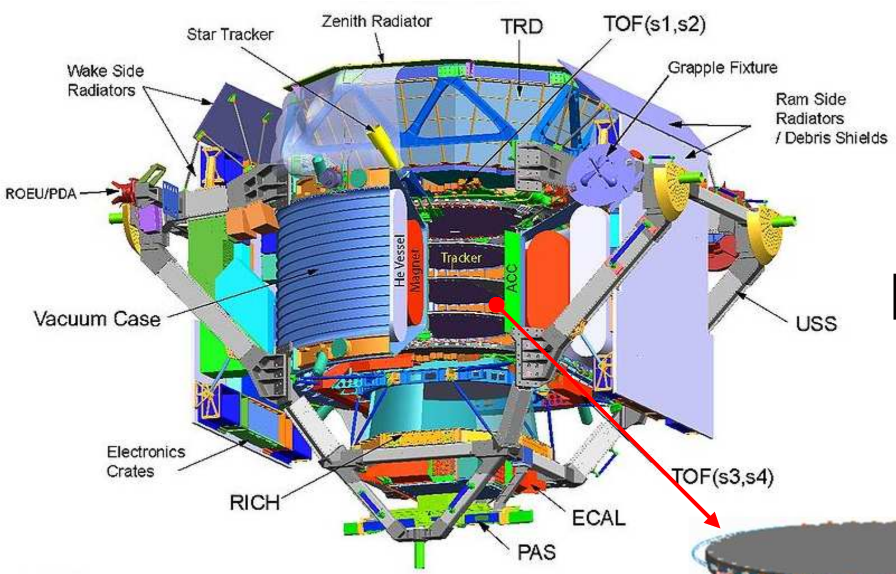
UNIGE on the **AMS Tracker**
Design & Assembly



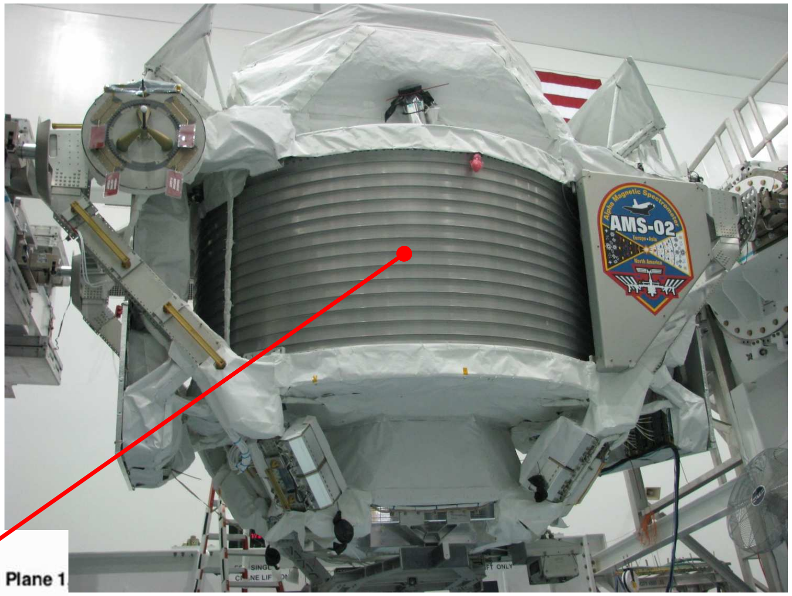
Current situation on Trackers (AMS-02)

- **AMS-02 Tracker** started in early 1999, following experience on AMS-01
- Re use of most of the technique from AMS-01 (silicon ladder), except the cooling system (TTCS)
- Different steps to get to the final AMS-02 configuration (very late change of the Magnet)
- Environmental constraints due to Space shuttle (logistics) and ISS location (site of experiment)

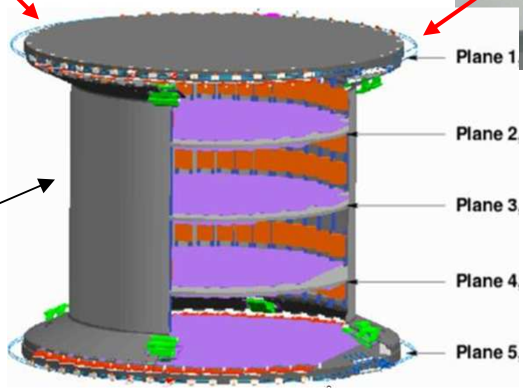
Simplified model of AMS-02 (stacking of TRD, Tracker, Tof, RICH, and ECAL)



As it was in the clean room @ CERN… since 2007

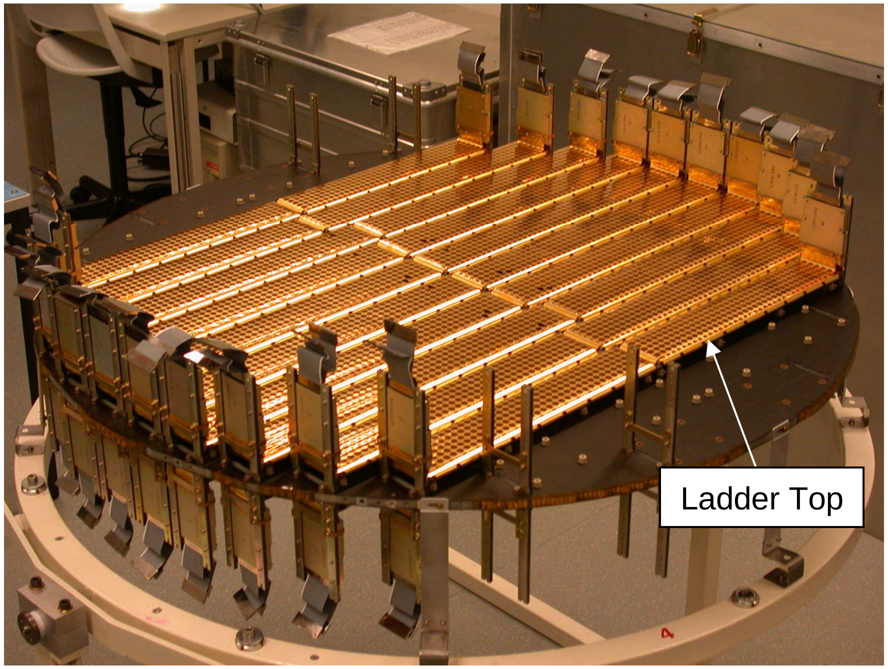


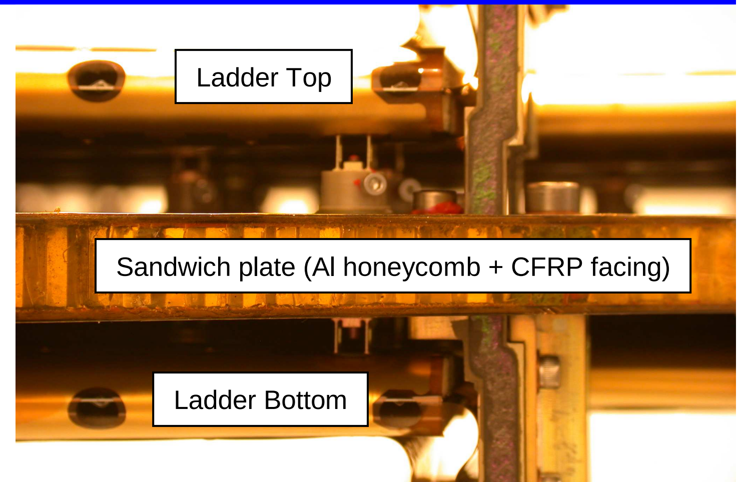
AMS Tracker as foreseen until 2009



Current situation on Trackers (AMS-02)

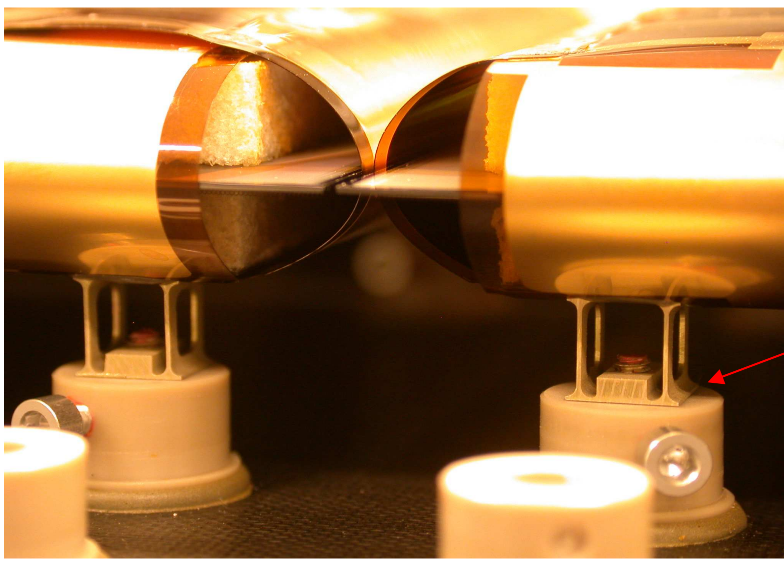
- Overview on 1 **Plane** fully equipped with Silicon ladders



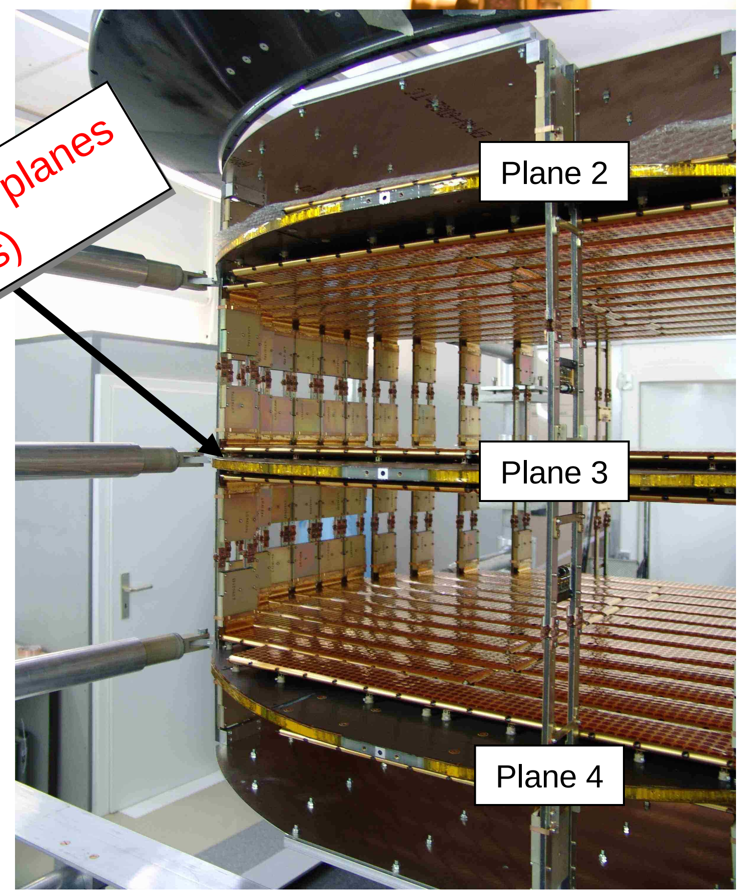


Reuse of AMS-01 planes (with adaptations)

Connection between silicon ladder and honeycomb plate

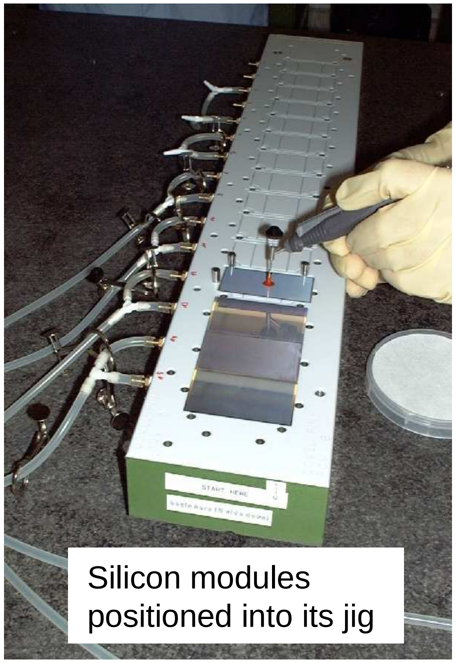


Ladder feet
(CTE mismatch,
Plate deformation)

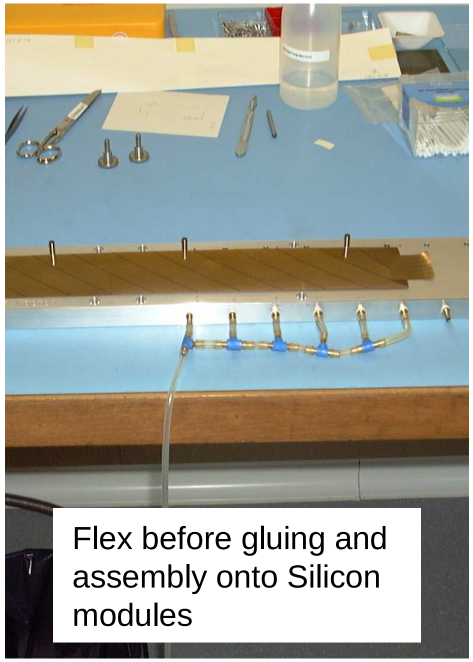


Current situation on Trackers (AMS-02)

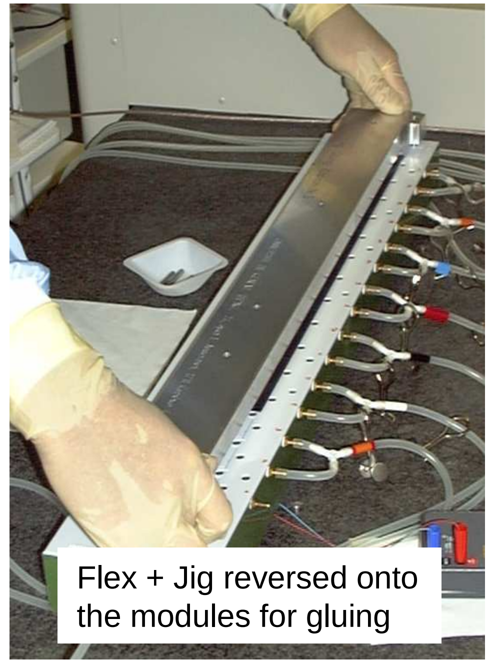
- Overview on the different **assembly steps** to get to the "Ladder" (precision achieved by jigs, controlled by CMM)



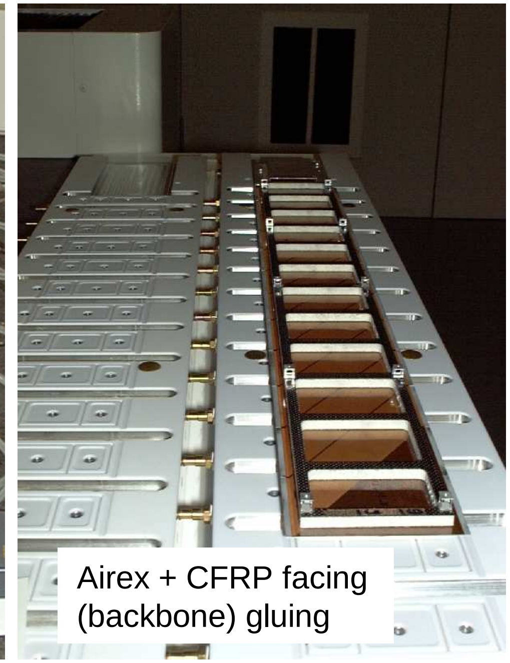
Silicon modules positioned into its jig



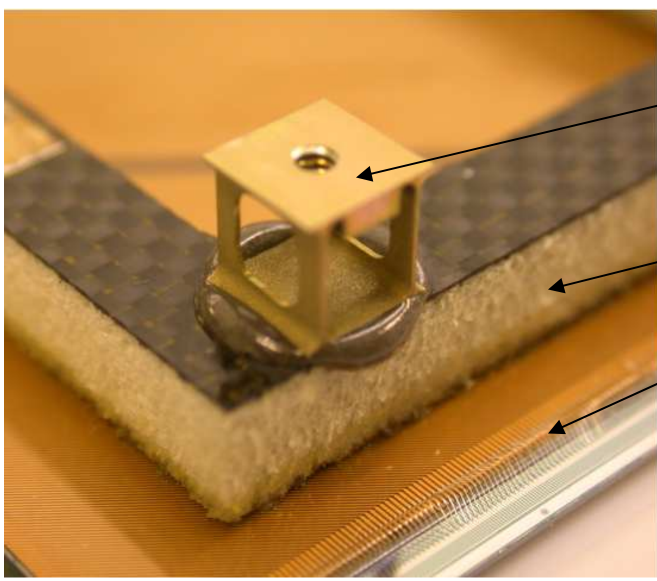
Flex before gluing and assembly onto Silicon modules



Flex + Jig reversed onto the modules for gluing



Airex + CFRP facing (backbone) gluing

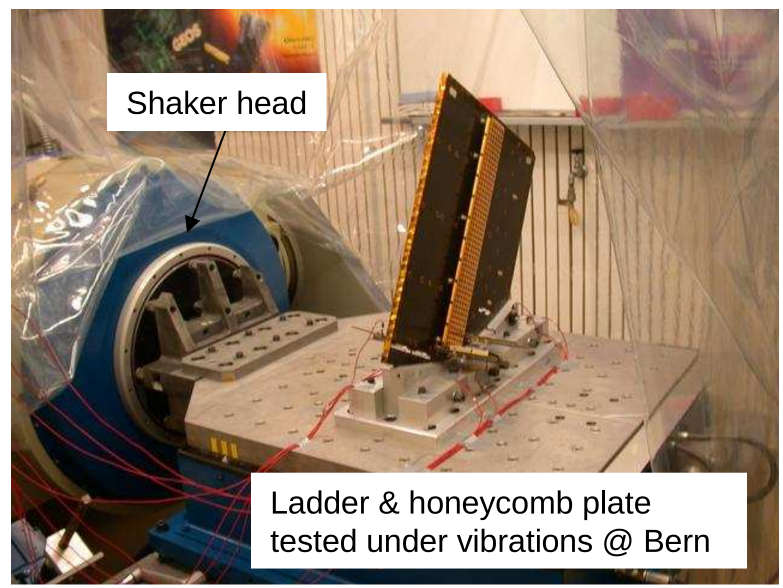


Ladder Foot (aluminum 7075, by Electro erosion)

Airex foam + CFRP (space qualified)

Wire bonds

To be qualified by tests…

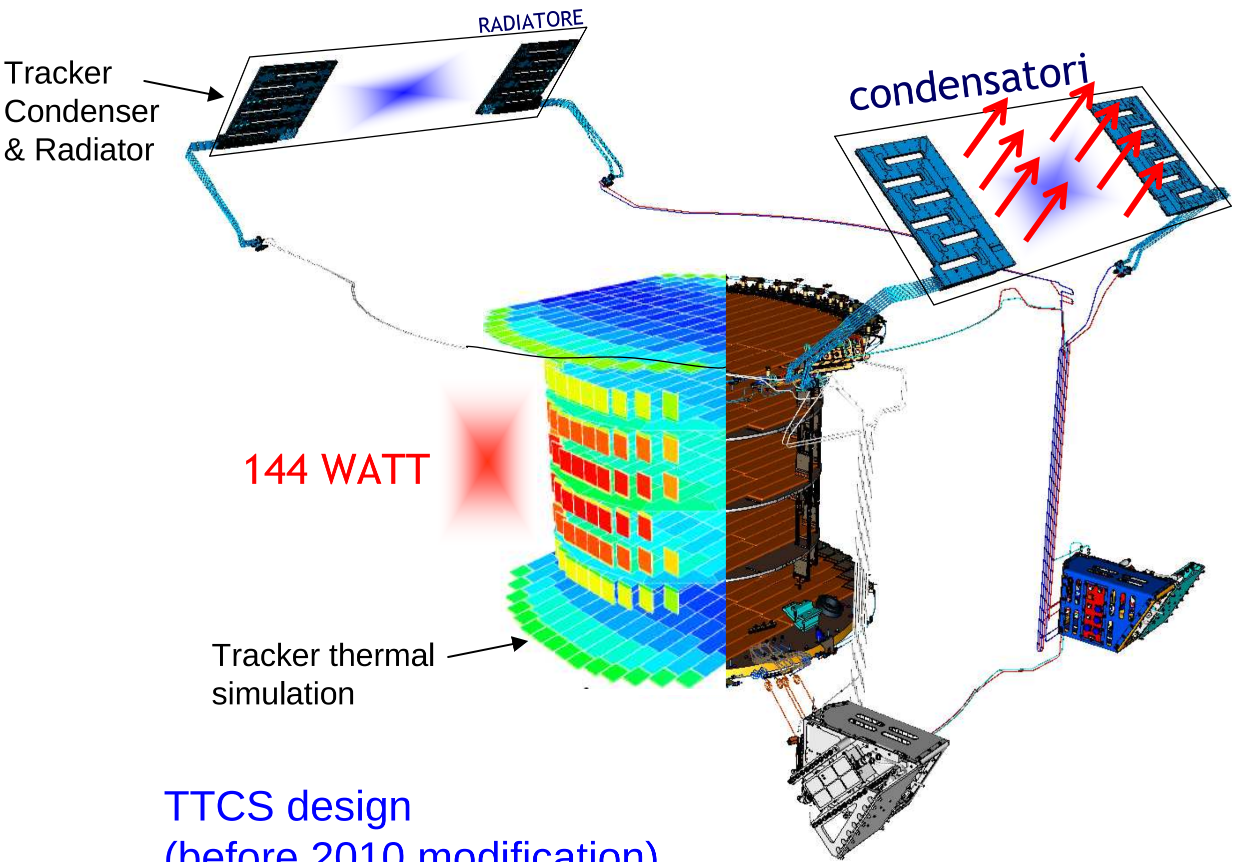


Ladder & honeycomb plate tested under vibrations @ Bern

Current situation on Trackers (AMS-02)

One of the key part: The TTCS (Cooling system)

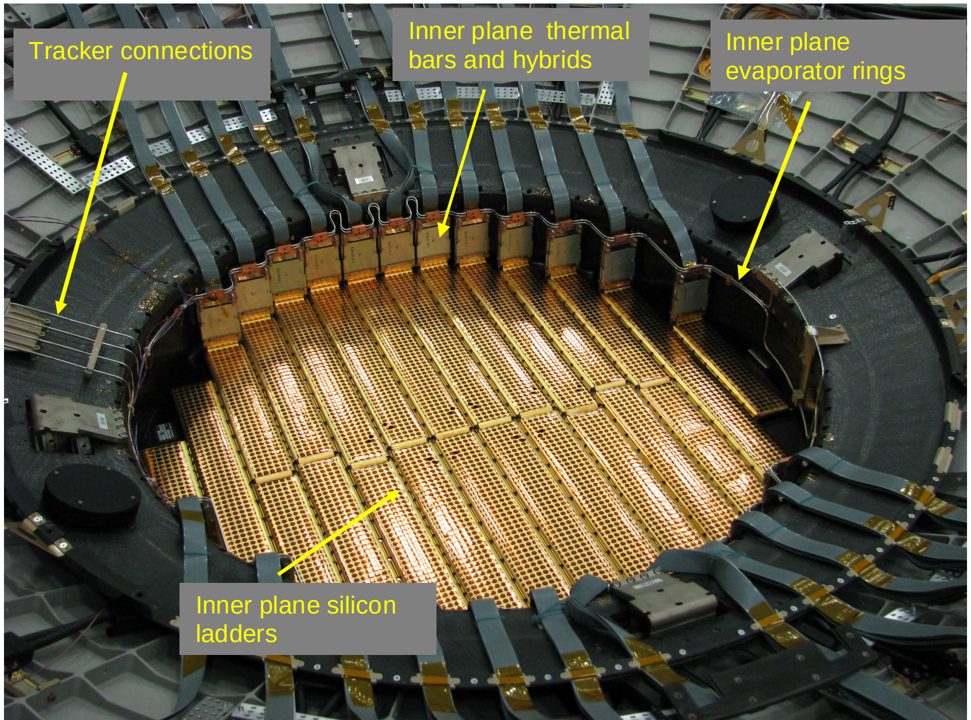
- AMS-01 was a passive cooling system (use of Permanent Magnet thermal inertia)
- AMS-02 Tracker designed with active cooling system (CO_2 coolant)
- System designed for Space (QA documentations “as thick as the detector itself”, welding checks,…)
- Redundant approach as required by NASA (2 lines A and B)
- 150 Watts to be dissipated, Temperature stable within 3°C over orbits
- 2 Phases Accumulator Controlled Loop (2PACL) as developed by NICKHEF



TTCS design
(before 2010 modification)

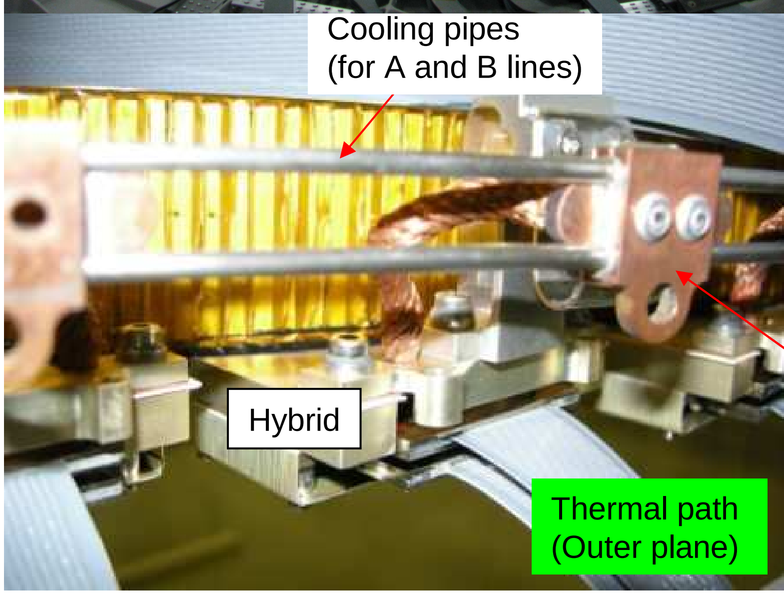
NASA Paper work…

Current situation on Trackers (AMS-02)

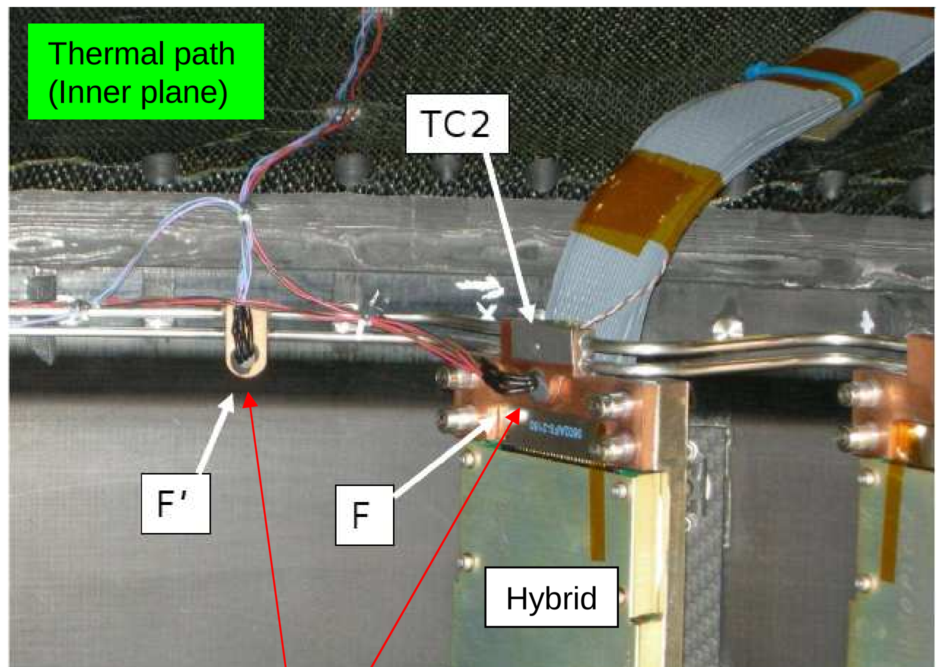


- Orbital welding used in TTCS for every connector
- Cooling loops tested up to 250 bars (MoS)
- TTCS fully tested @ ESTEC late in the Integration (can only work under vacuum!)

- so far…IT WORKS PERFECTLY on the ISS !!



Thermal block



Thermal sensor all the way long…

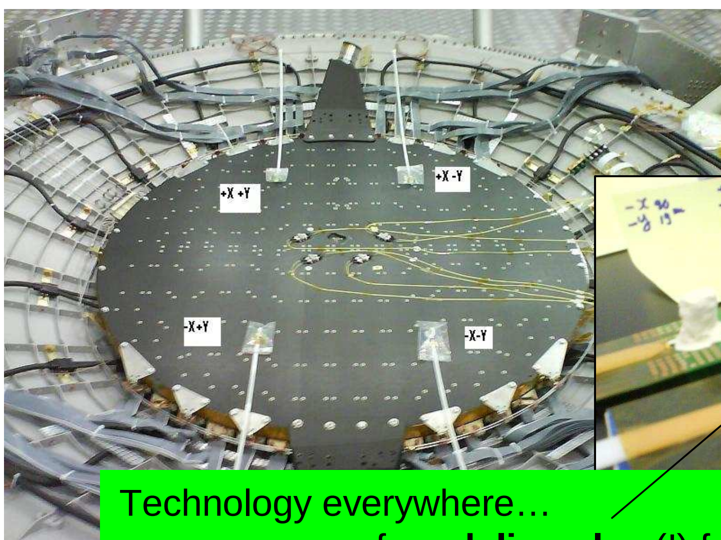
The tricky equation…

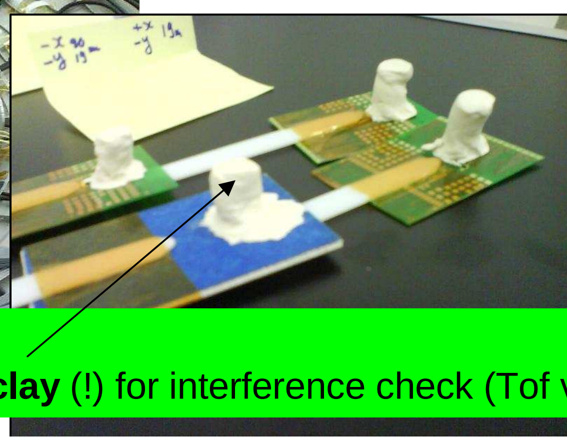
- Tracker Assembled at **1G**, not different from experiment on ground…
- But, Launched into space at **6G**…
- To finally end up at **0G** !!!...when Thermo cycling starts!

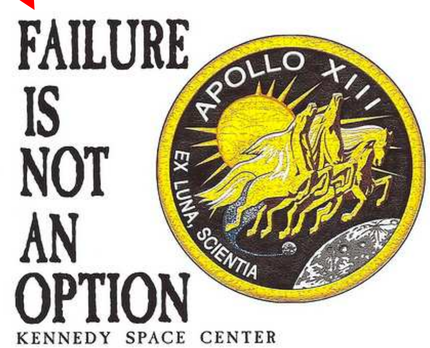
… But it's not an issue since the 6G load will drive the design anyway!
And tends to oversize things (margin of safety) even if 1 plane is estimated at **0,65%** X/X_0

- As a consequence, **FEA method** and **Testing** are mandatory in this field
- New technologies are welcome…but "new materials" are "suspicious"
(NASA qualification process among aging, out gassing, …)

No way back in case of failure…
Full system to be secured at every steps!
Some similarities on Atlas



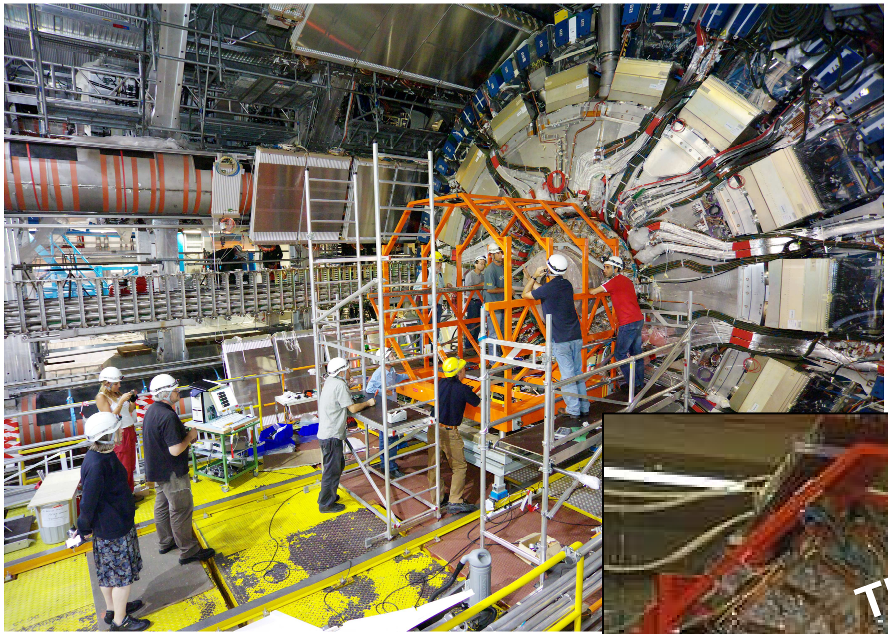




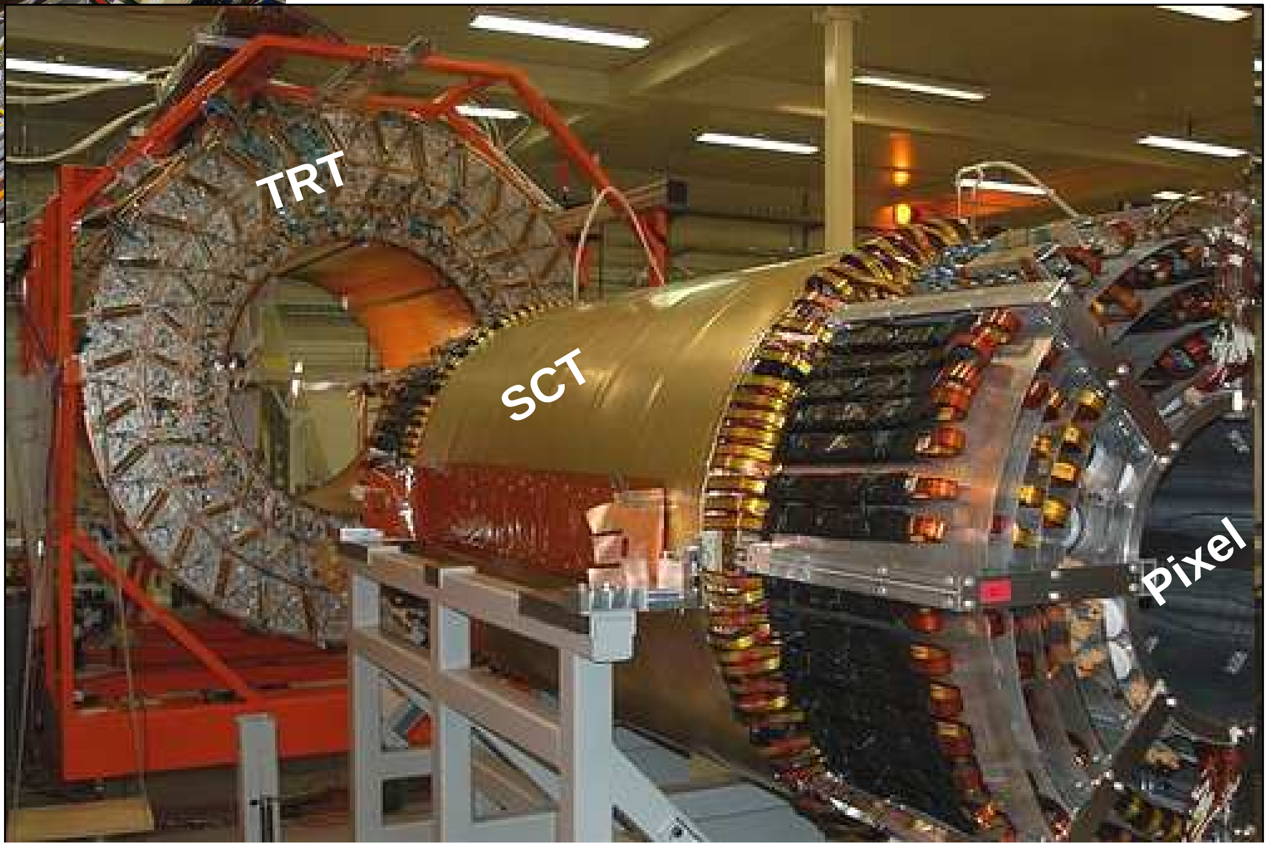
Technology everywhere…
use of **modeling clay** (!) for interference check (Tof vs Tracker)

Current situation on Trackers (ATLAS)

➢ Now let's move on to the ATLAS pit (about 100m underground…complete different environment, but with some similarities)



… with more focus on the **Barrel SCT**

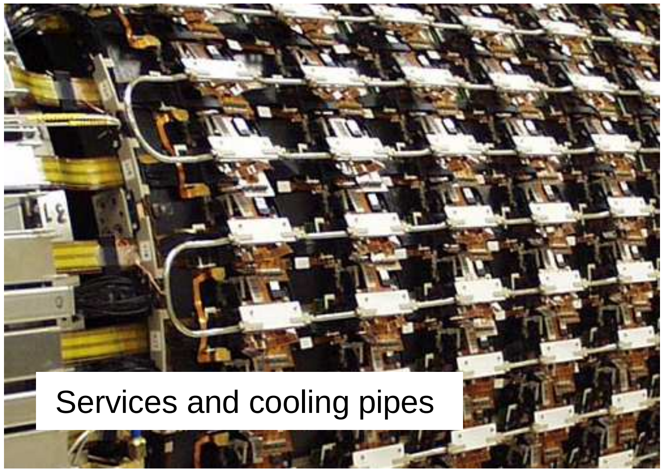


*On behalf of the **Barrel SCT** Engineering Team (UNIGE within a large collaboration)*

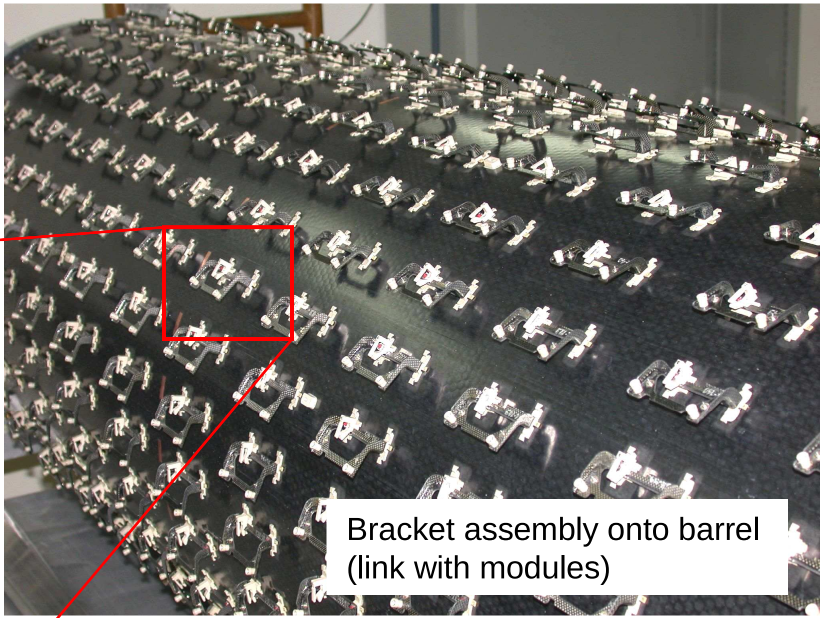
Current situation on Trackers (ATLAS)

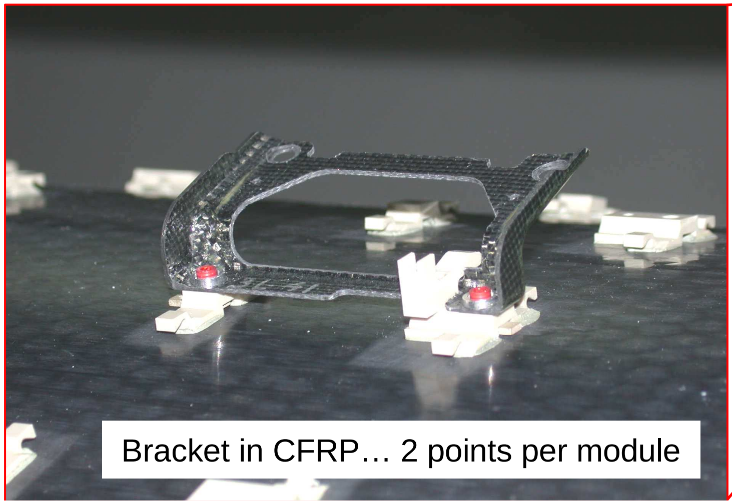
- **4 Concentric barrels** connected with 8 Interlinks (Sandwich structure, XN50/RS3 facing, core in honeycomb with the same fiber type)
- **Individual bracket** to hold modules (many links to barrels)
- **Services and Cooling** assembled onto the barrel prior module mounting


Dry assembly on barrels 3 and 6


Services and cooling pipes

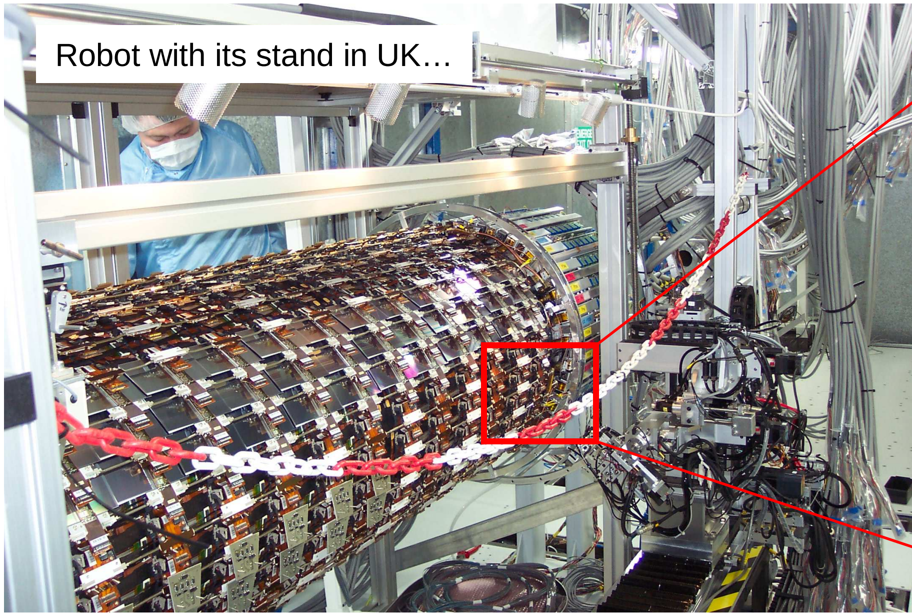
Sandwich panel

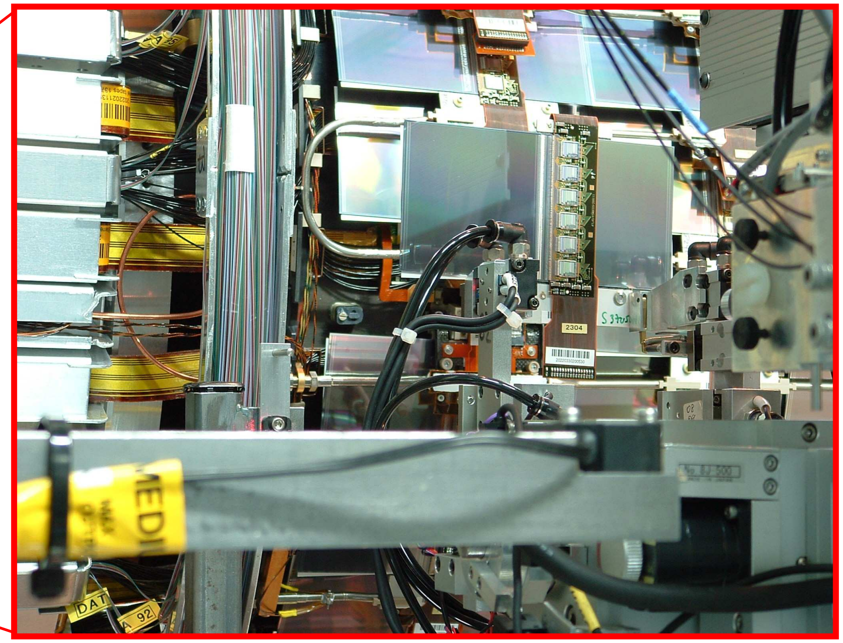


Bracket assembly onto barrel (link with modules)

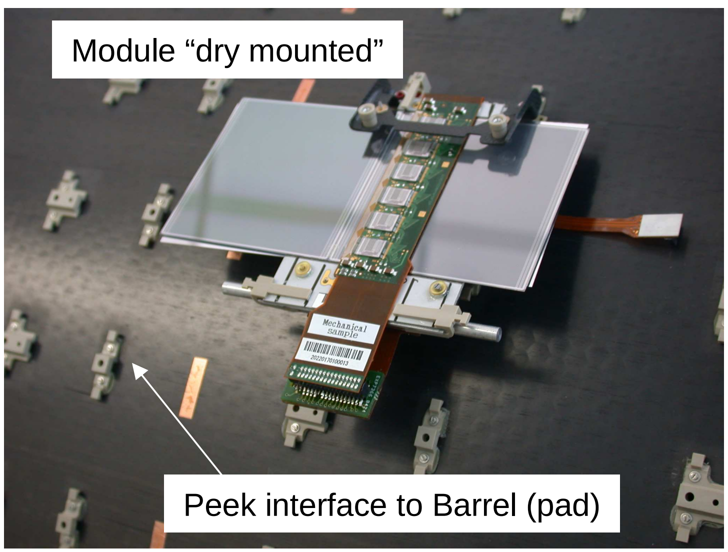

Bracket in CFRP… 2 points per module

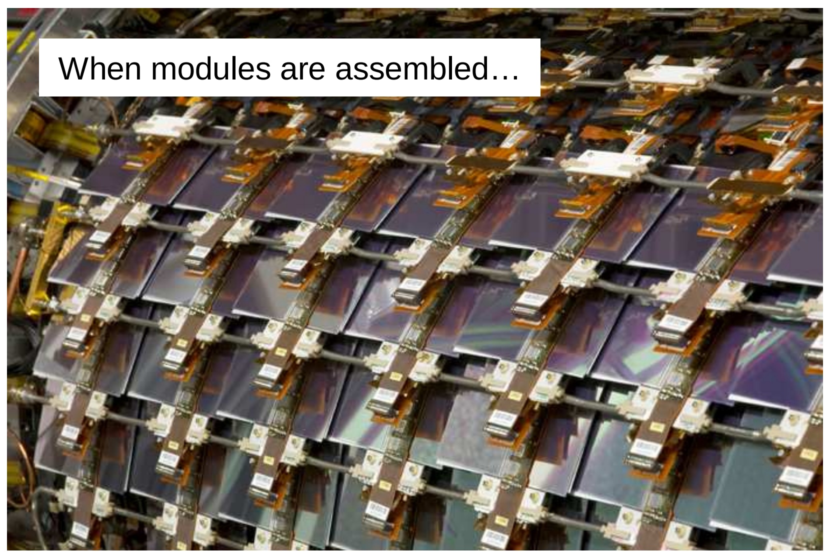
Current situation on Trackers (ATLAS)

- **Module loading** done 1 by 1 on barrel (Robot developed by KEK and UK)
- **Barrel assembly** only AFTER MODULES ARE LOADED AND TESTED





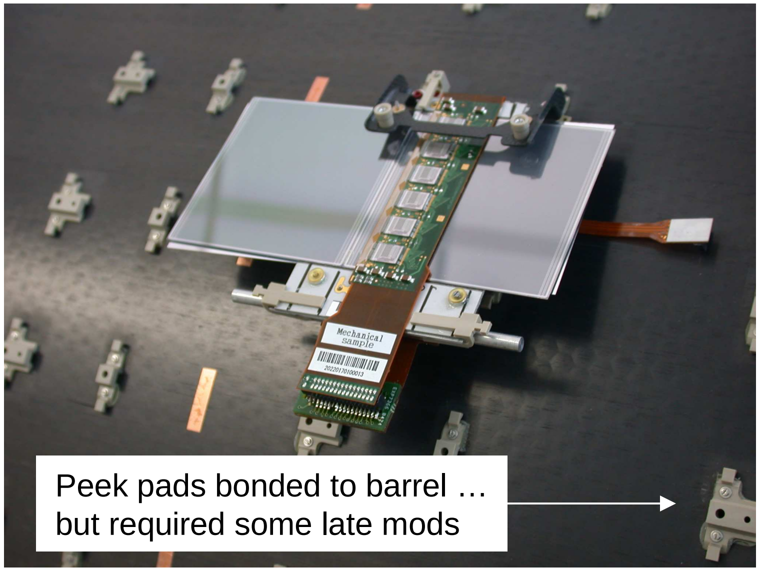




Technical assessment… and Feedback

Barrel machining

- Use of such honeycomb panel exhibited very **good stability!**
- …and **very light structure!** Could be pushed still more…. but risky!
- **Mounting precision** achieved by Barrel machining (within 50 microns)
- The estimate of services early in the design was too optimistic (late changes made the optimization difficult!)
- Better use an **integrated CAD model** (Cabling, cooling, electronics, …)
- Such long barrel are **difficult to re machine** after lamination
- Some Peek pads de bonded at some step, and required a lot of rework



Peek pads bonded to barrel … but required some late mods

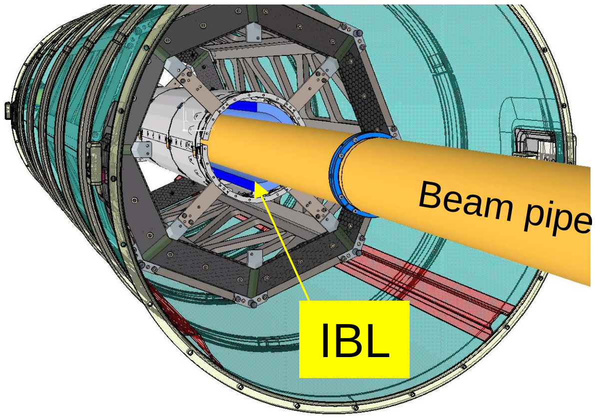
Towards the Upgrades! Some new philosophies inherited from the past experiences…

Peek pads preparation

Outlooks towards the Upgrade (ATLAS)

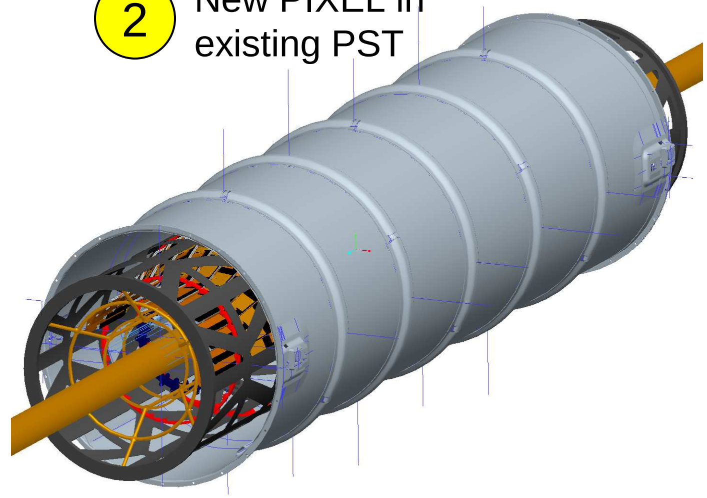
- Different steps in the Upgrades: IBL, PIXEL in 2017, and the rest in 202x…
- Try to summarize the new Ideas / Techniques developed among those projects

1 IBL in 2013 shutdown

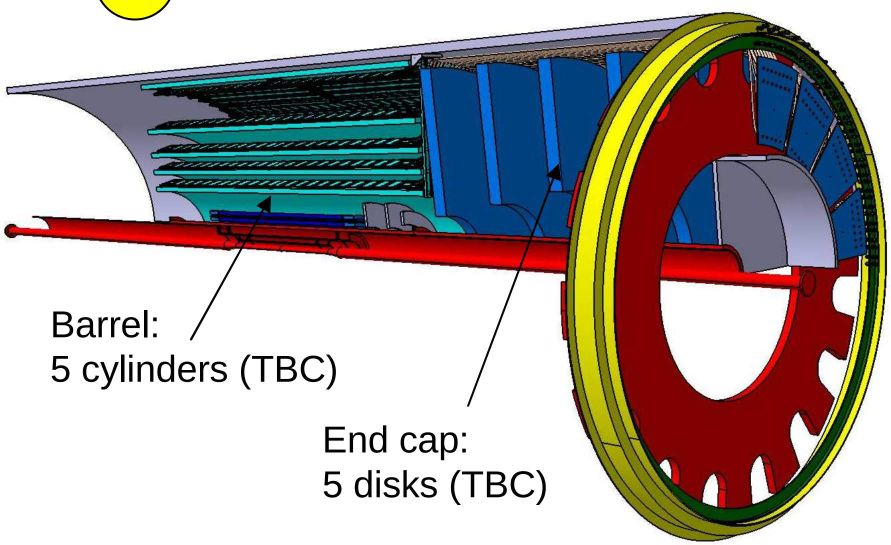


Pushing both mechanical and thermal performances to the limits…

2 New PIXEL in existing PST



3 Strips (Barrel+ End cap) in 202x



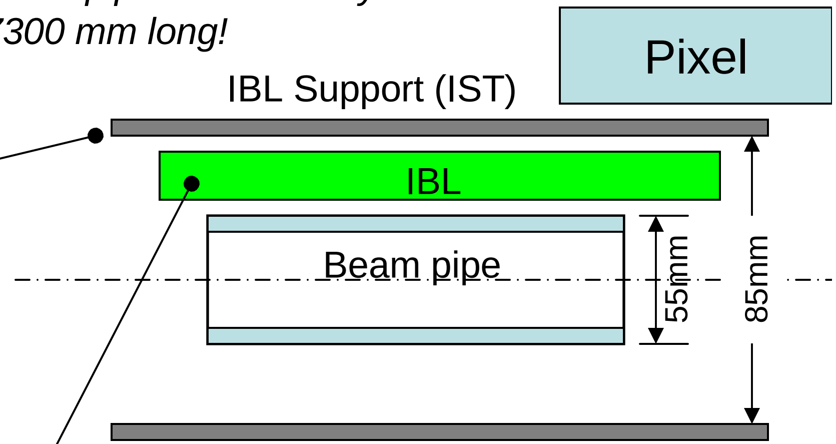
Common approach:
Service managements early in the project (use of CAD integrated tool)
…as part of the whole project!

Outlooks towards the Upgrade (ATLAS)

- Overview on **IBL developments** (what are the challenges…?)

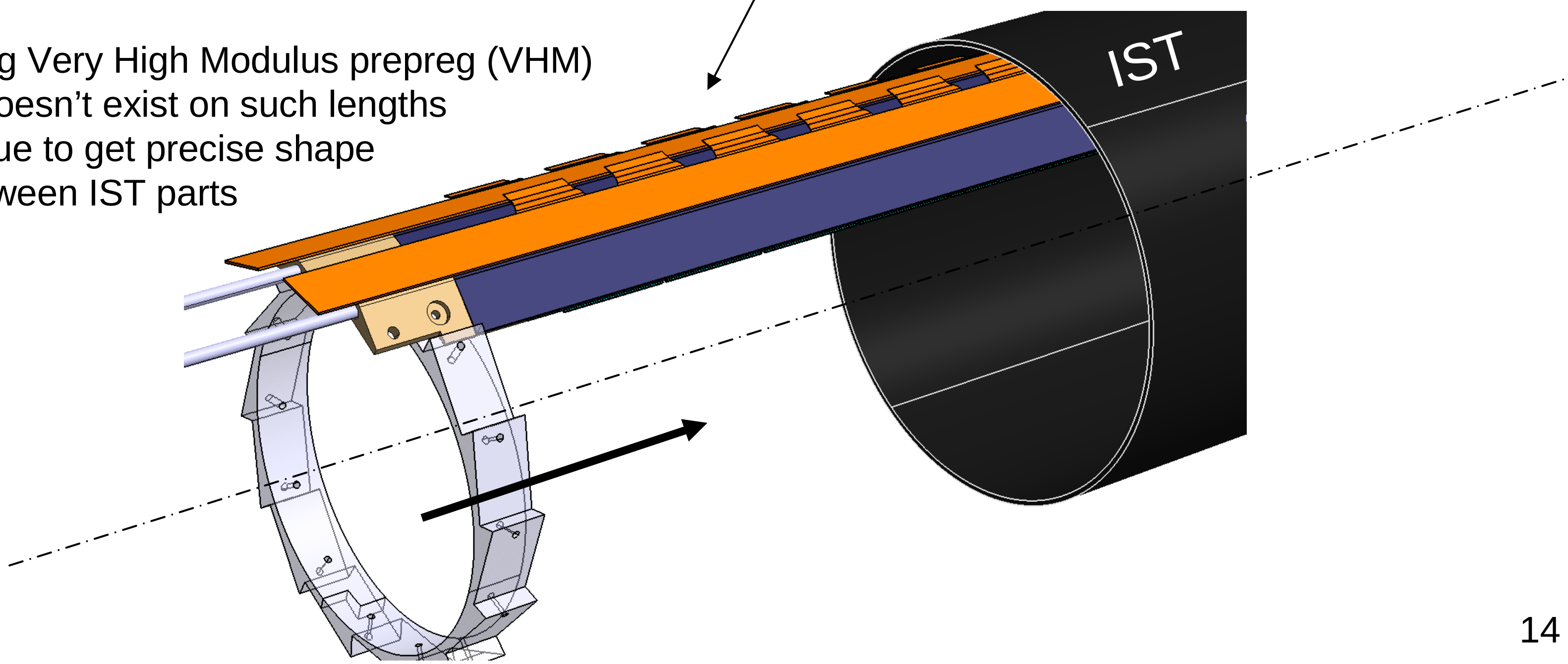
  Try to insert "something" (or some sensors…) in between Beam pipe and Pixel layer 1

  *… in term of figures: ID 55mm < **IBL** < OD 85mm… over 7300 mm long!*

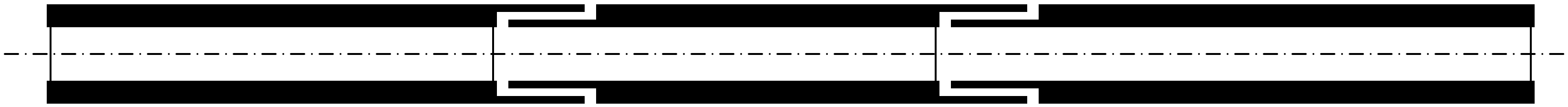


For **IST**, huge constraints!
- Only 4 supports over its length
- Limited gap / Pixel (2mm)
- Thickness between 0,5 and 1mm (optimization)
- Main support structure for IBL+ BP
- Get a 6600mm long object!!

R&D using Very High Modulus prepreg (VHM)
- Tubes doesn't exist on such lengths
- Technique to get precise shape
- Link between IST parts

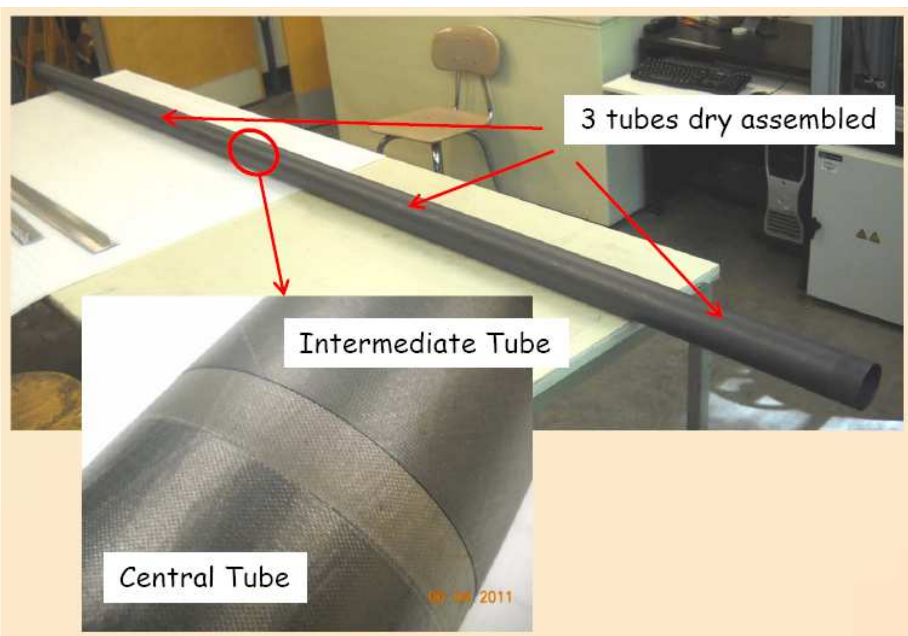


Outlooks towards the Upgrade (ATLAS)

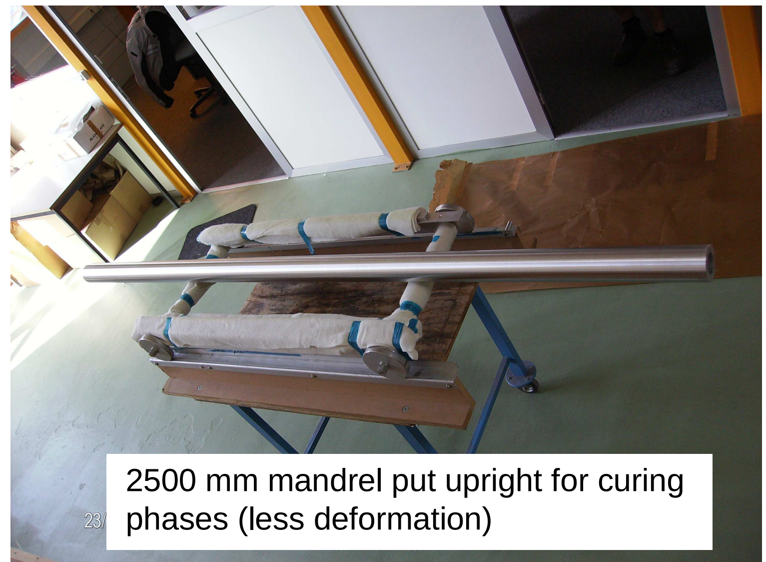


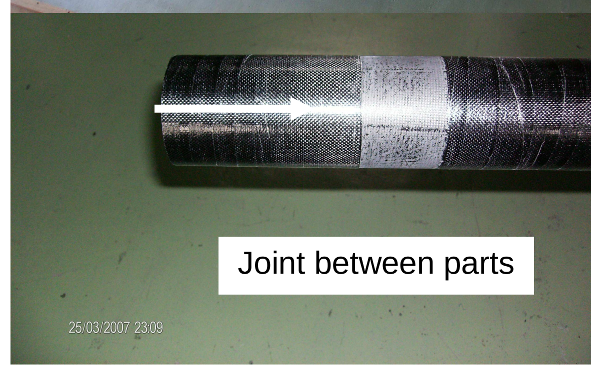
➢ **IST** development in parallel in **Seattle** and **Lausanne**

- Using K13C/RS3 prepreg (VHM)
- Optimization of the lay up (number of layers, and their orientation)
- Include an outer mesh for shielding
- Could potentially see high temperatures (BP bake out) …resin chosen accordingly



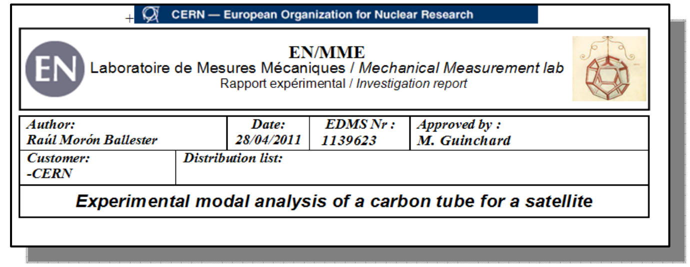
- Using T300 woven prepreg
- Aluminum mandrel
- Cured in vertical position





Outlooks towards the Upgrade (ATLAS)

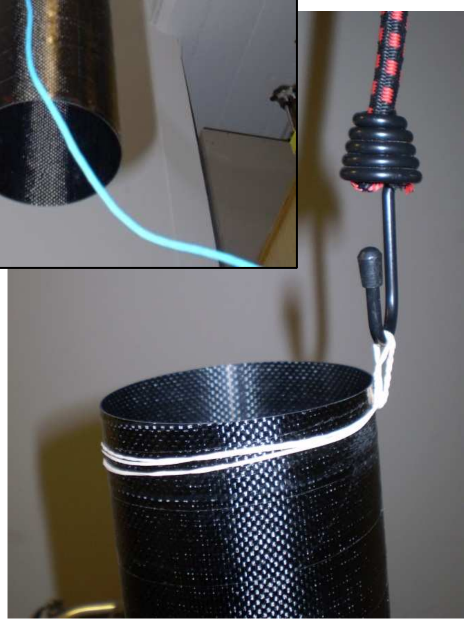
- A work is being done with CERN EN/MME, to check the structural behavior on a prototype…and correlation with FEA
  - Eigen value search
  - And Modal shape analysis


CERN — European Organization for Nuclear Research

EN/MME
Laboratoire de Mesures Mécaniques / *Mechanical Measurement lab*
Rapport expérimental / *Investigation report*

Author: Raúl Morón Ballester	Date: 28/04/2011	EDMS Nr: 1139623	Approved by: M. Guinchard
Customer: -CERN	Distribution list:		

Experimental modal analysis of a carbon tube for a satellite



CFRP pipe hanging from the roof with elastic ropes (free-free conditions)
- 2 accelerometers
- Smart hammer shock (mapping)

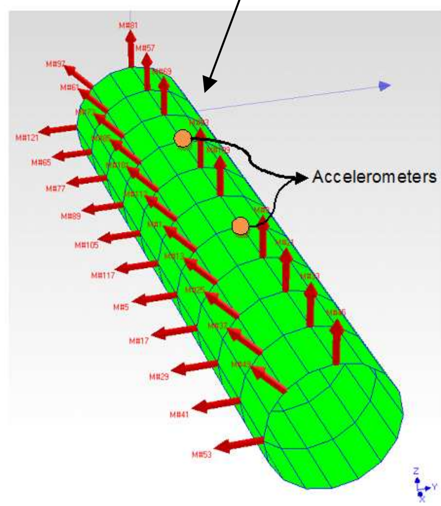
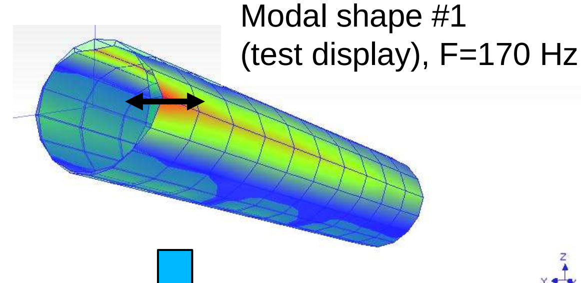


Figure 1: Model of the tube with the grid, the impact points (arrows) and the accelerometers position

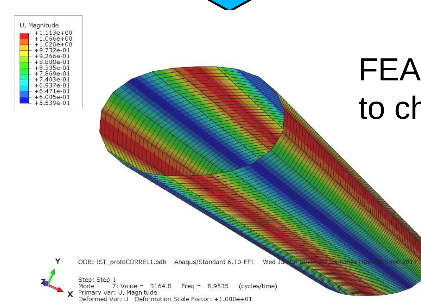
Results from Tests…

Mode	Frequency (Hz)	Damping (Hz)	Damping (%)
1	170	2.95	1.73
2	176	2.52	1.43
3	274	3.44	1.26
4	579	2.85	0.493
5	731	2	0.273

Table 1: Modal parameters of the carbon tube



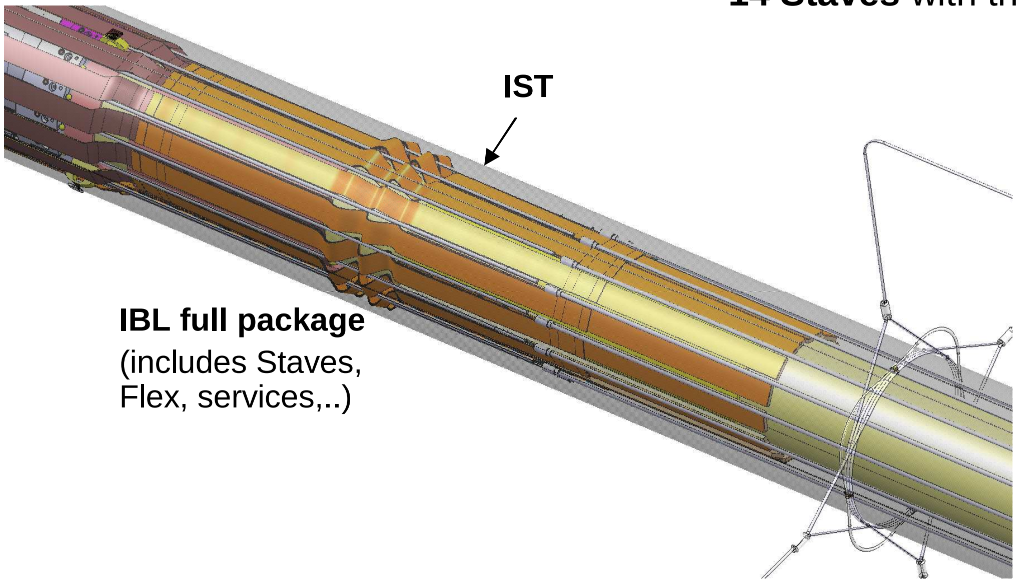
Modal shape #1 (test display), F=170 Hz

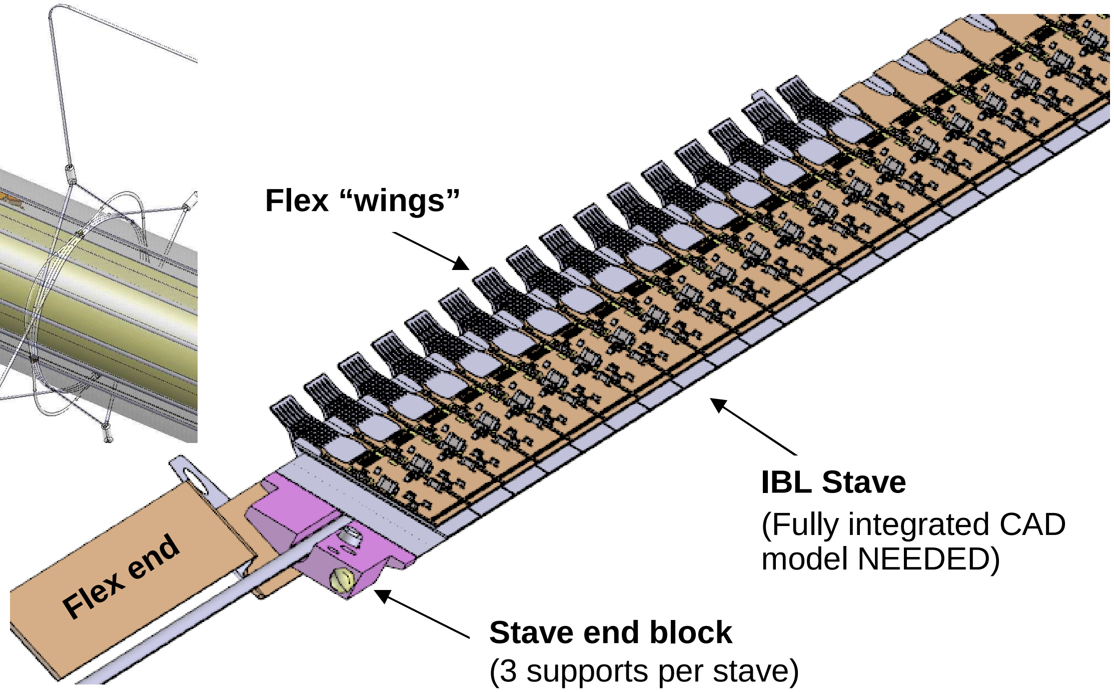


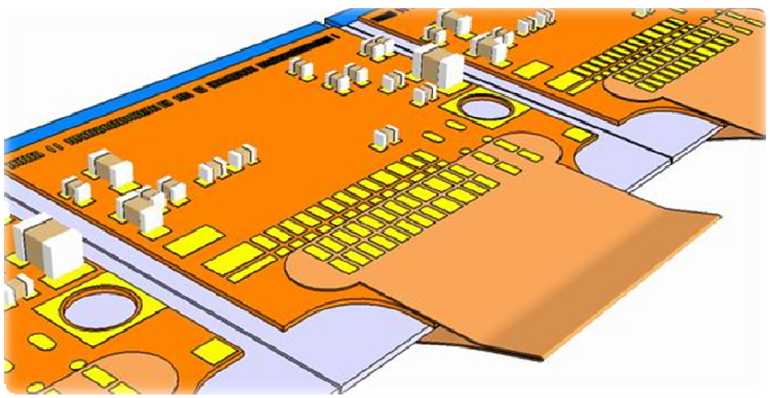
FEA results to check…

Outlooks towards the Upgrade (ATLAS)

- **… don't forget** the "stuff" to be inserted thru the IST:
  14 Staves with their services! Not the least…







CAD Model approach

Early in the design, necessity to work on an Integrated model (Services, mechanics, and even some details on electronic components…).

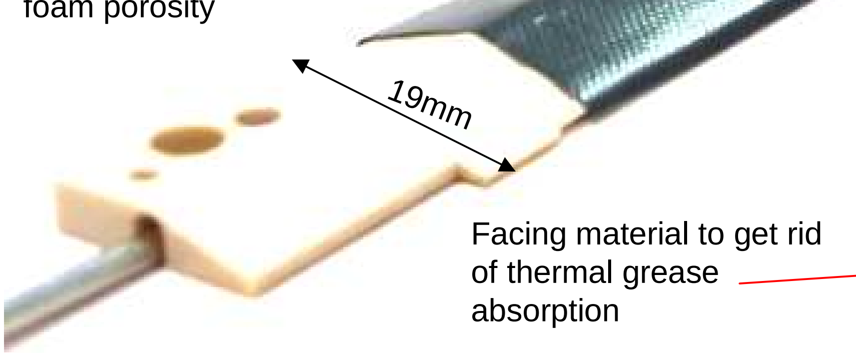
- Due to short clearances on IBL!

Outlooks towards the Upgrade (ATLAS)

- **Stave** development… in search for a light, stable, and thermally good object! Sort of **sandwich structure**
  Several stave prototypes by Wuppertal, CERN, SLAC to test:
  - Manufacturing processes (challenging)
  - Assembly techniques (co curing, re machining,…)
  - Options in term of facing material, foam type…Validated by FEA and Thermal Tests @ CPPM (Marseille)

Stavelet from **SLAC** (loaded with Si-Heater @ UNIGE), **first proto with CFRP facing**

It clearly shows a glue issue!
Too much penetration… due to foam porosity



First Stave full length proto (by CERN)

CNC machining on a delicate material:
Pocofoam, K9 from Allcomp

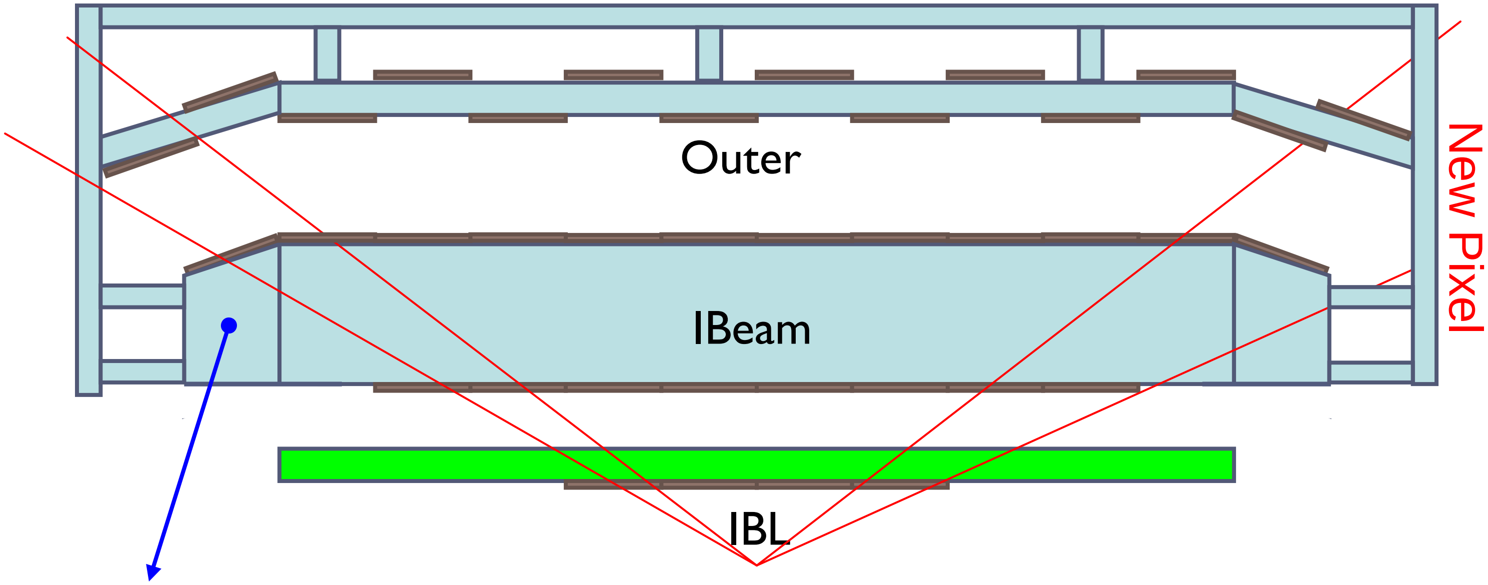
Facing material to get rid of thermal grease absorption

Stavelet from **Wuppertal** (loaded @ UNIGE)

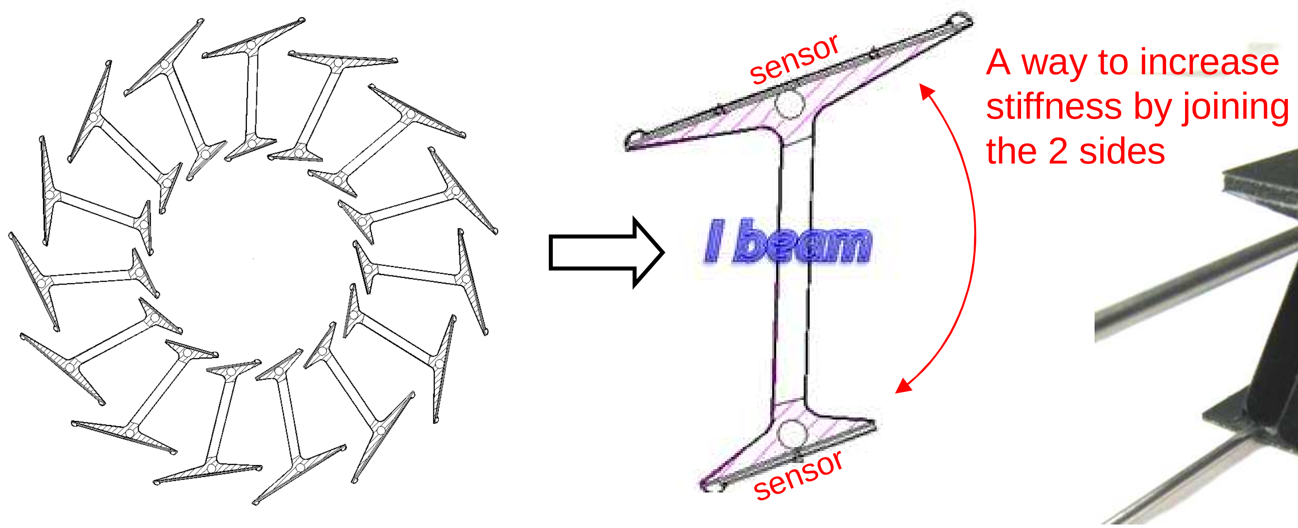
Outlooks towards the Upgrade (ATLAS)

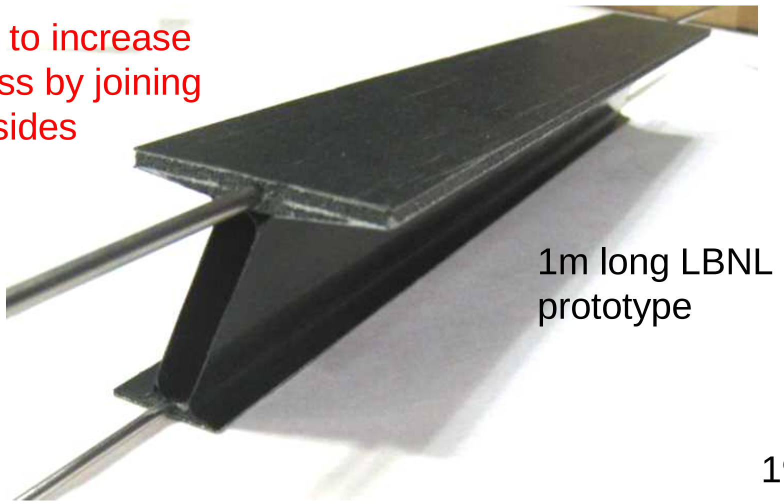
- An overview on **PIXEL** latest studies (for 2017 replacement). On behalf of **LBNL group**

*1 of the 3 layouts as proposed by N. Hartman in March 2011 (**No disks**)*



- Focus on a self supporting structure: the "**I Beam**" conceptual approach (challenging)

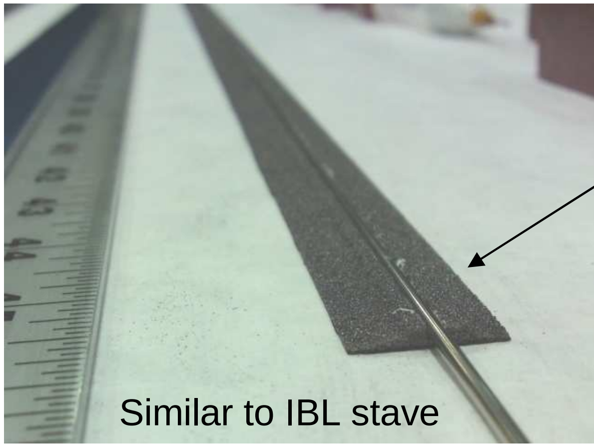




1m long LBNL prototype

Outlooks towards the Upgrade (ATLAS)

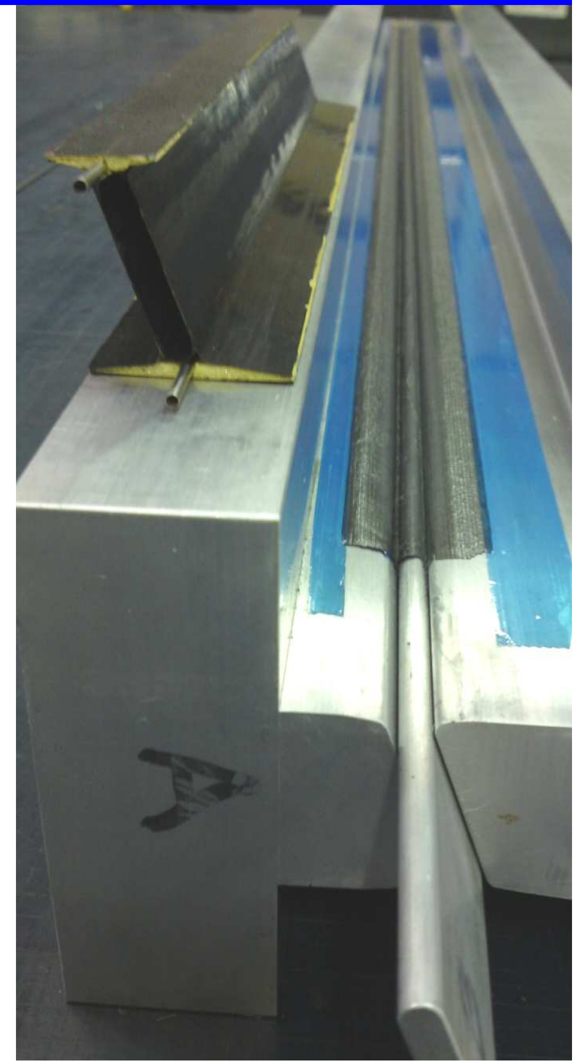
➢ Full length prototype manufacturing and FEA's

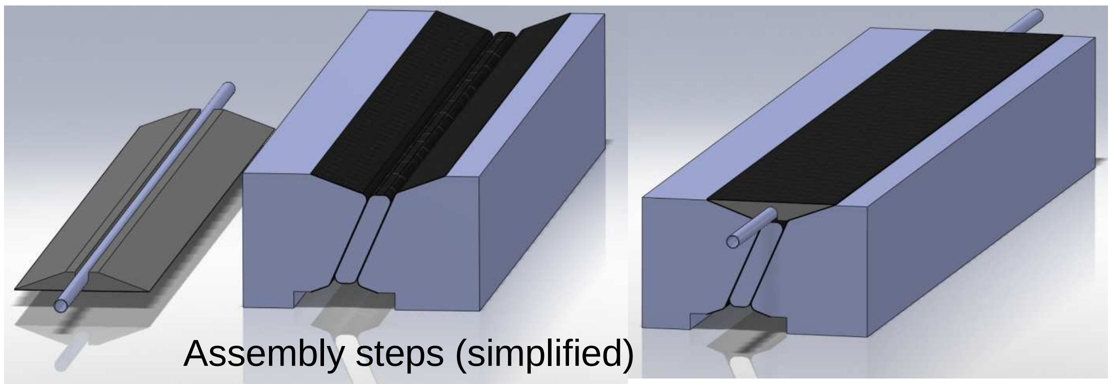


Similar to IBL stave

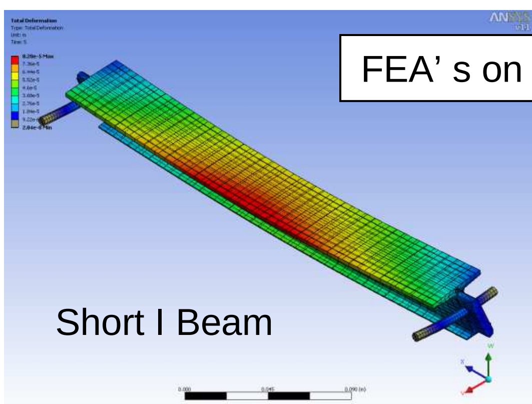
K9 low density foam (as for IBL, **40W/mK**)
Laminates in M46J for proto
…changed into K13C (?)

We see a lot a complementary studies with IBL (mutual benefits)





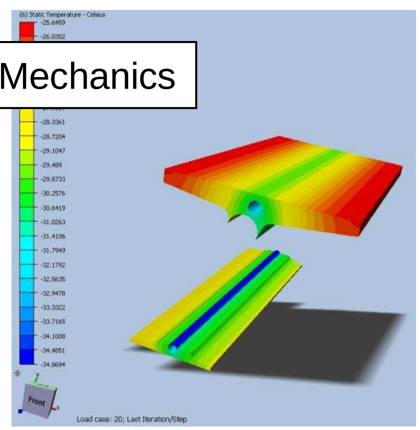
Assembly steps (simplified)



Short I Beam

FEA' s on both Thermal and Mechanics

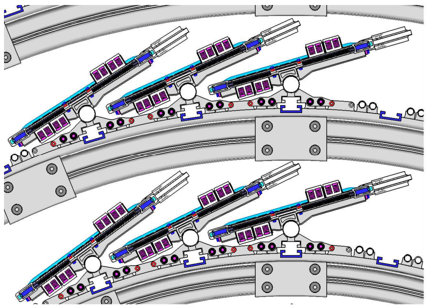
Very good agreement / Tests

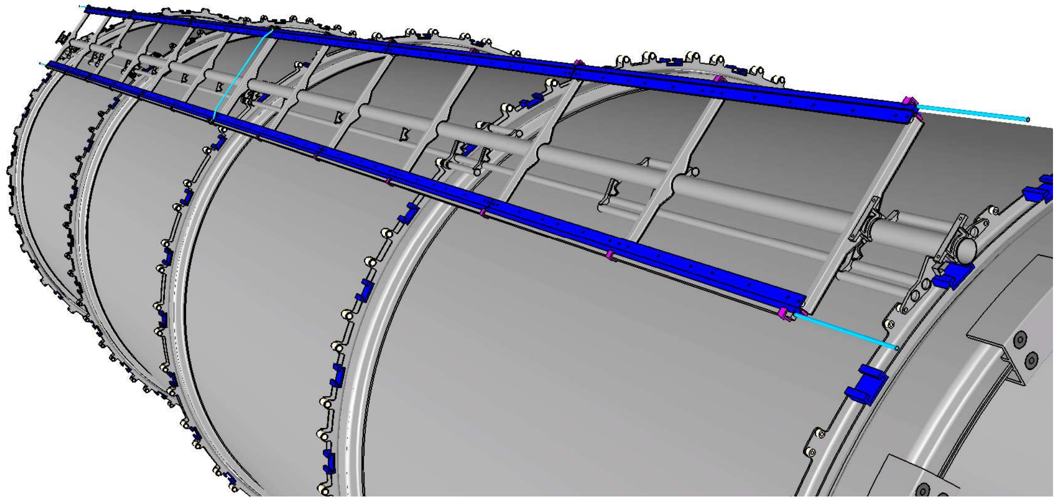


Next step is to work on I Beams integration and services

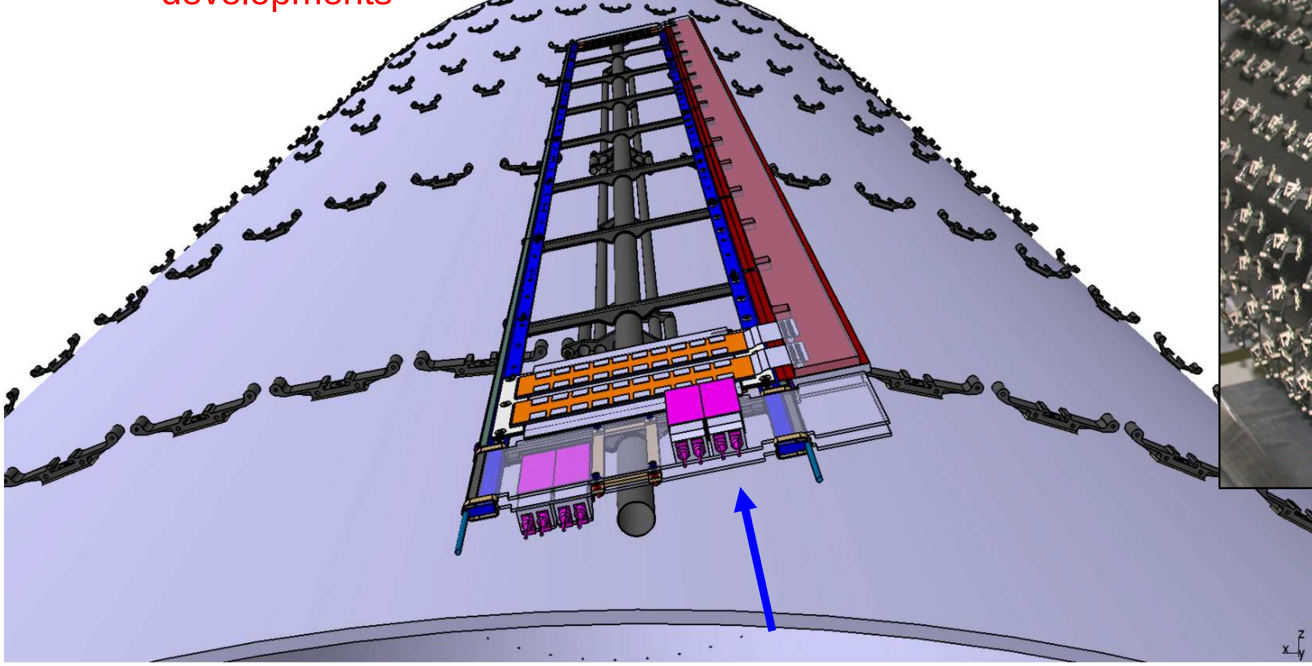
Outlooks towards the Upgrade (ATLAS)

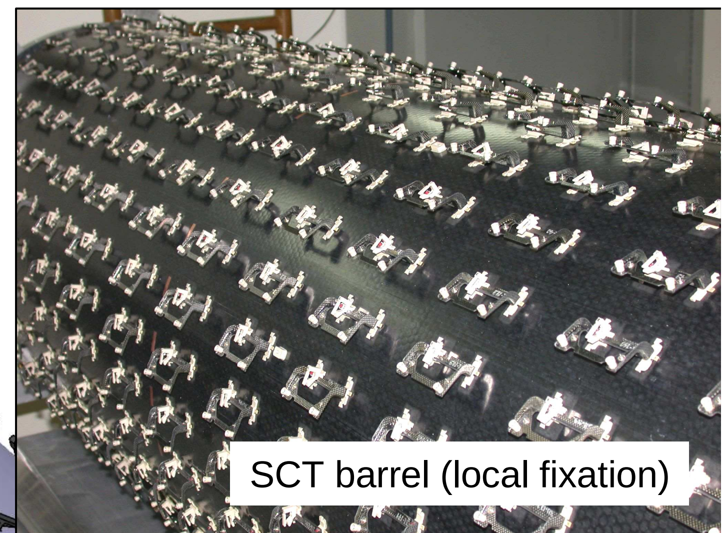
- and finally, for the outermost part…the developments on **STRIP** detector
  There are a lot of approaches being designed, tested in parallel (Staves, SuperModules, Petals)





Looking back to current SCT…
- No individual module fixation onto barrel
- A structure to hold a row of modules
- the **End Insertion** is the key point of the developments



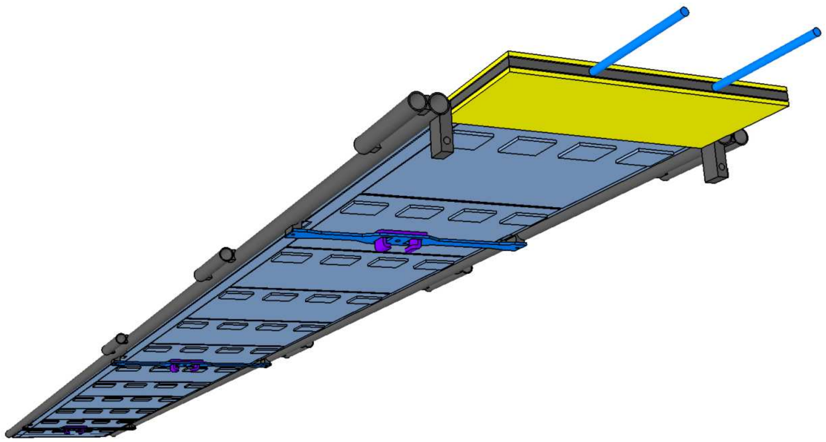


SCT barrel (local fixation)

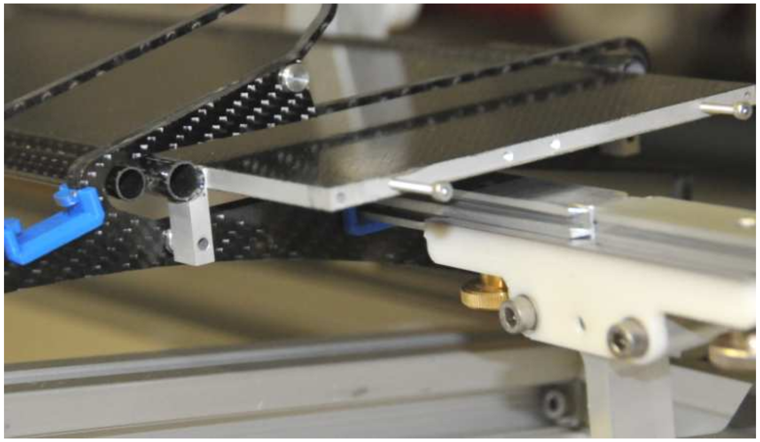
Outlooks towards the Upgrade (ATLAS)

- 2 approaches in parallel to hold 12 modules (or more…): **Staves** & **SuperModules**
  - Self supporting structure to be assembled / inserted into barrels (5 barrels)
  - Independent part including Modules, Services, and its own Cooling
  - to be assembled after barrel assembly
  - Replacement at any moment (thanks to End Insertion)

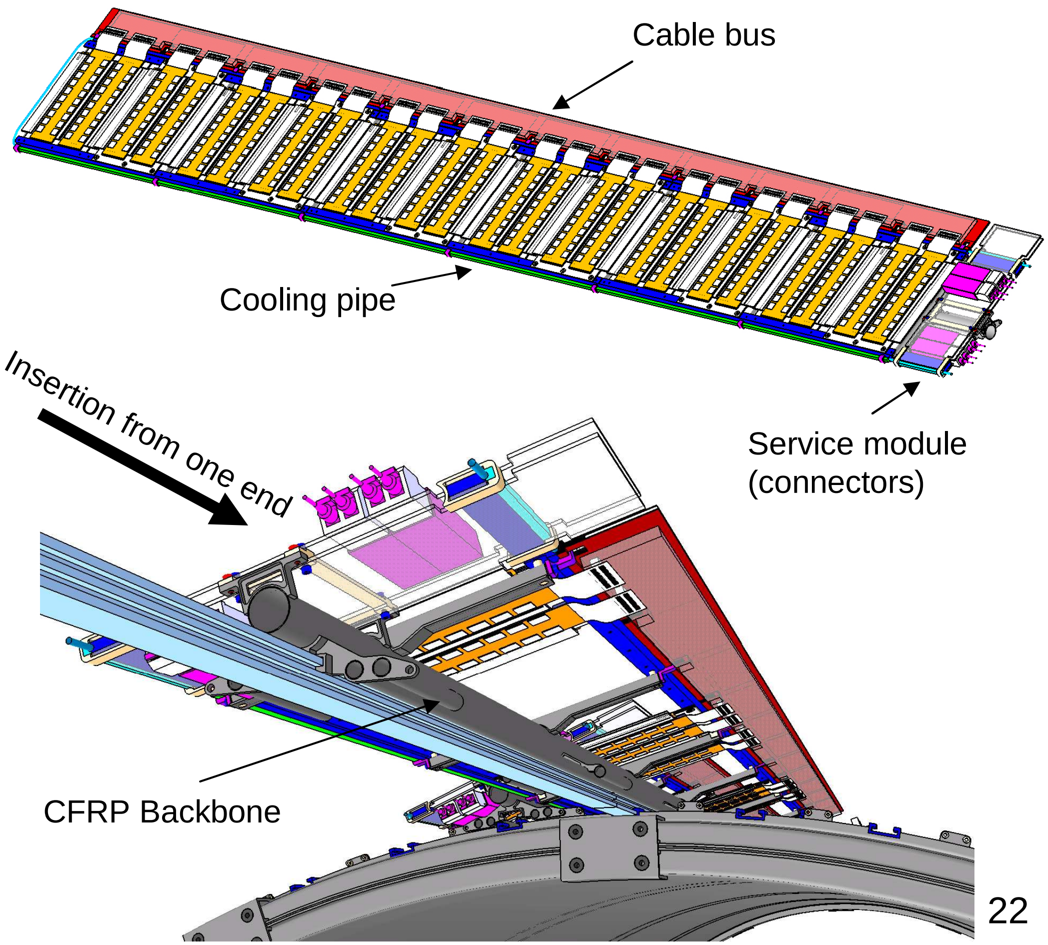
Stave approach



A kind of sandwich plate,
double sided with modules…see next

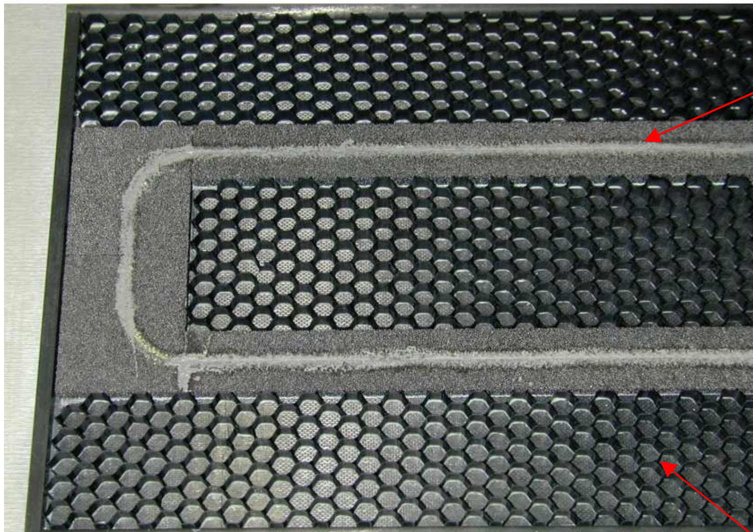


SuperModule approach



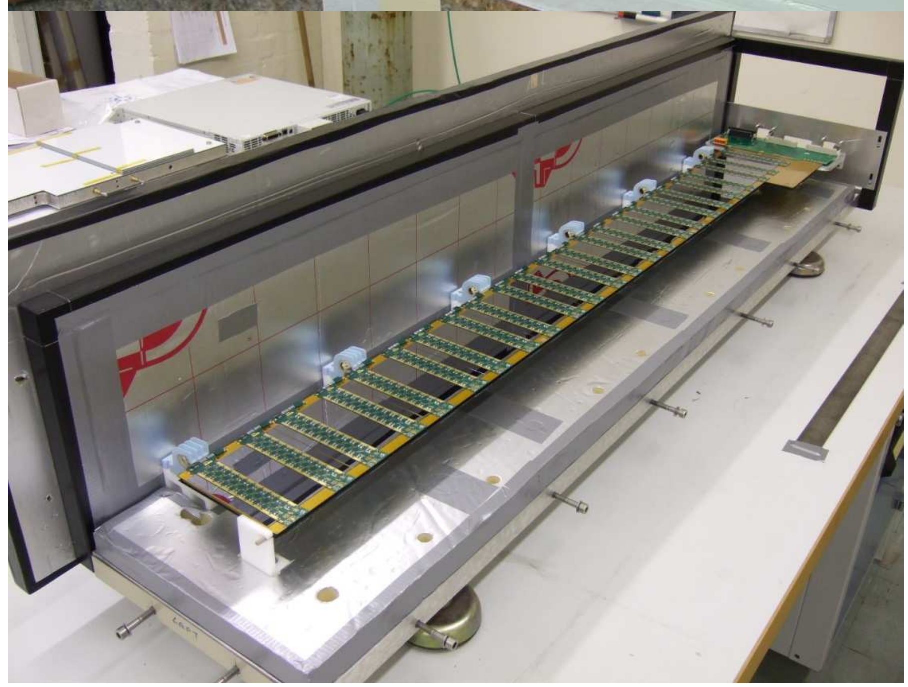
Outlooks towards the Upgrade (ATLAS)

- **Stave** program is being developed in several places (UK, US, …) to solve:
  - Assembly procedure of the main core (thermal foam, honeycomb, facing, the way to cure)
  - Cable bus bonding to stave
  - Module loading to guarantee the targeted precision
  - Locking mechanism coupled with end insertion



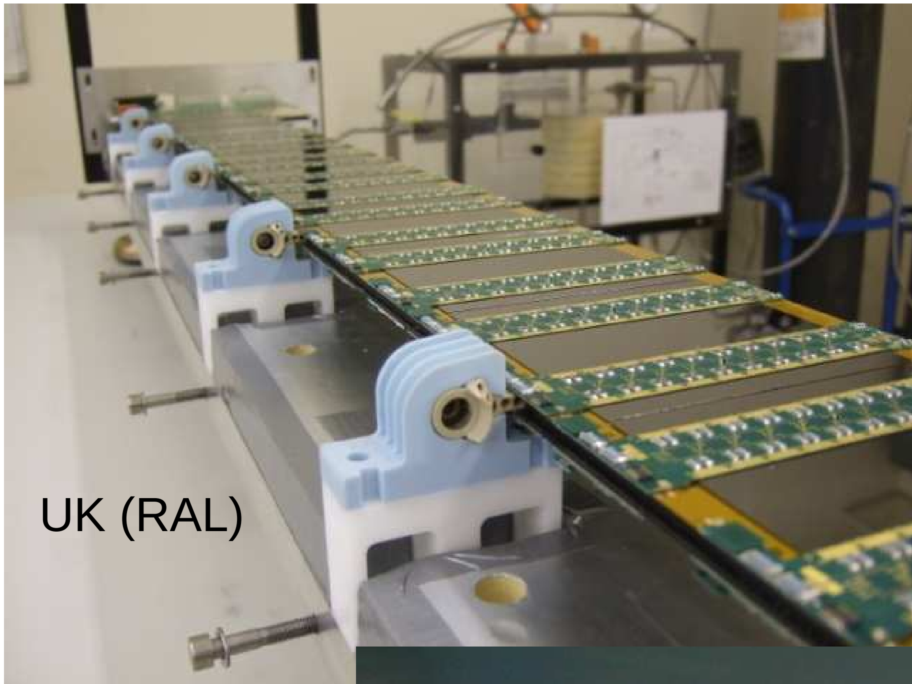
Allcomp foam (for cooling spreading) + Cooling pipe (drives the stave thickness)

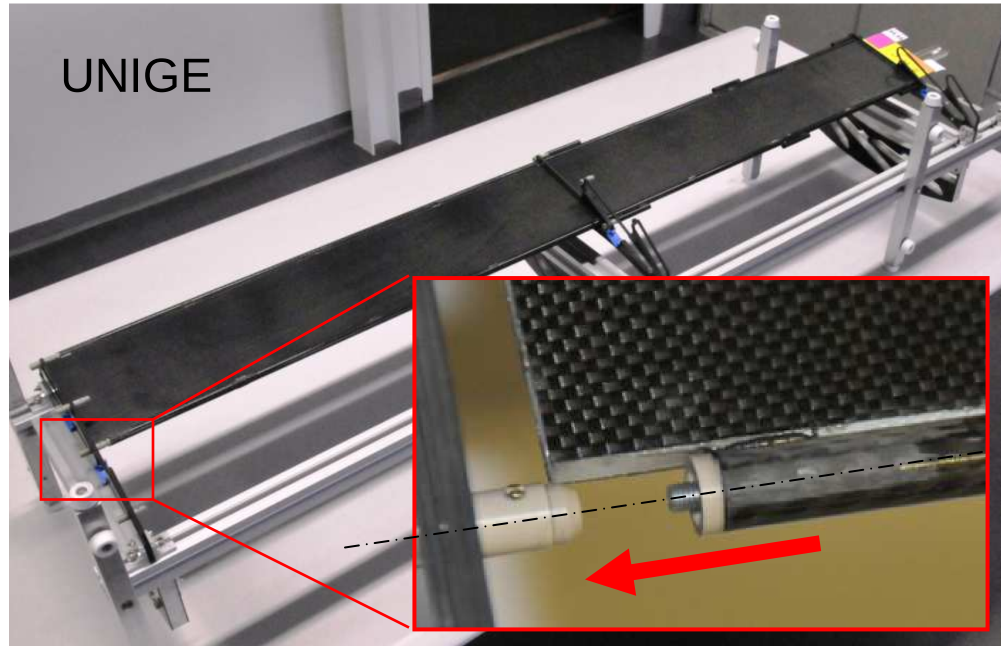
CFRP Honeycomb



Outlooks towards the Upgrade (ATLAS)

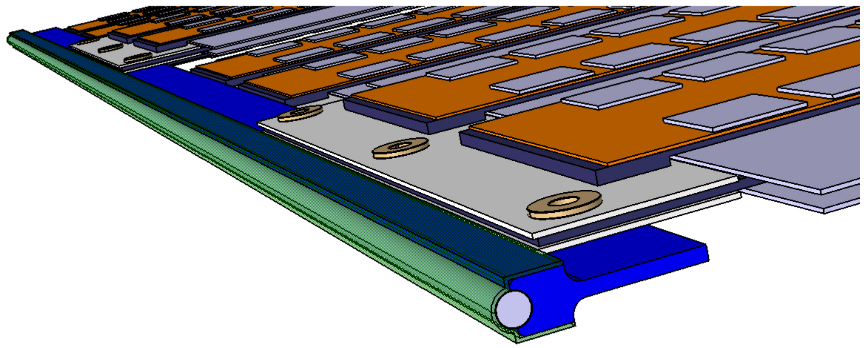
- **Stave** locking mechanism to barrels: several approaches under prototyping

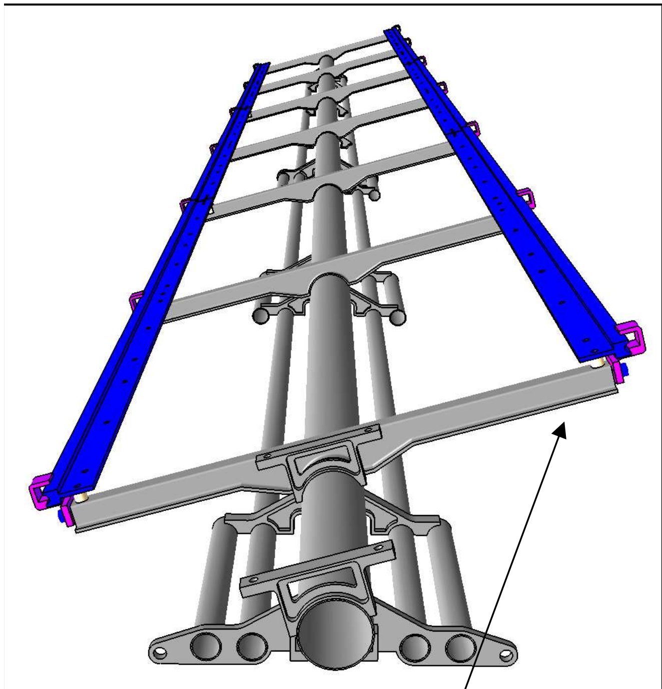


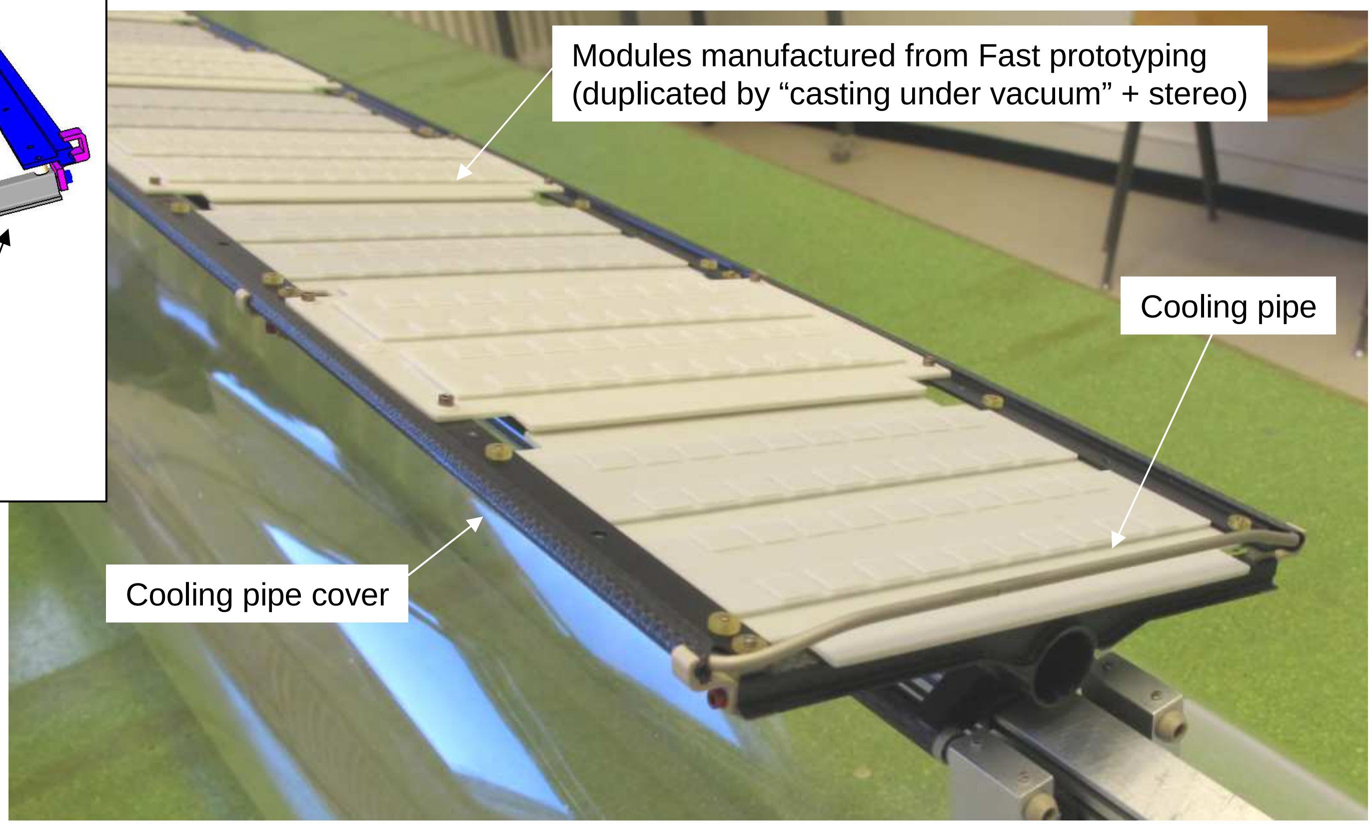


Outlooks towards the Upgrade (ATLAS)

- **Super Module (SM)** program developed in UNIGE and KEK
  - a sort of backbone in CFRP which holds the modules thru cooling plates
  - overall thickness independent on cooling pipe size (choice of coolant can be done late)
  - Cable bus on one side of the SM
  - amount of glue is limited (no foam used)
  - Modularity at the level of modules (sensor and Front End)

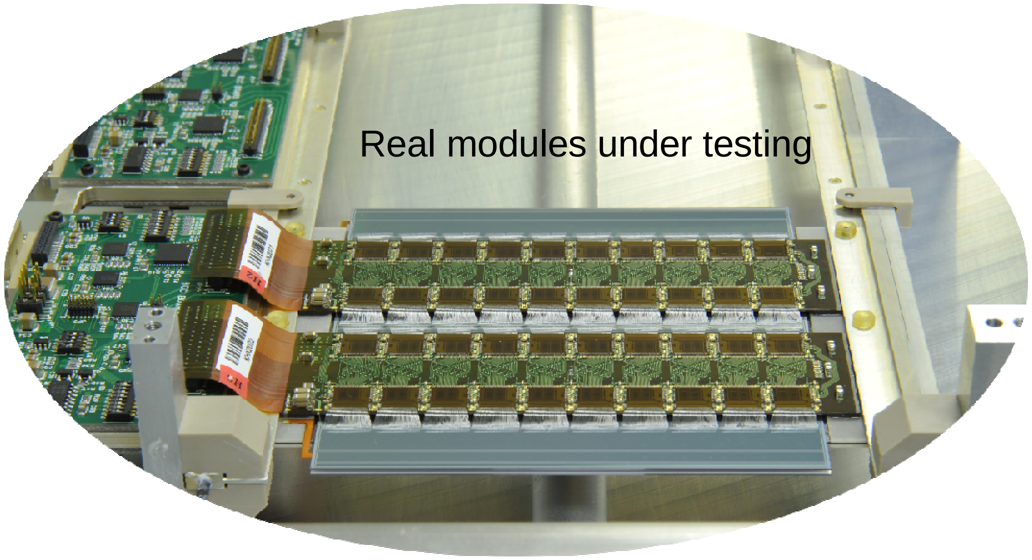


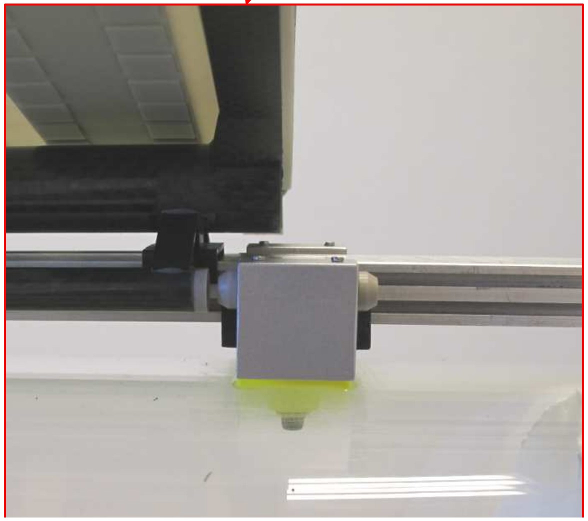




Outlooks towards the Upgrade (ATLAS)

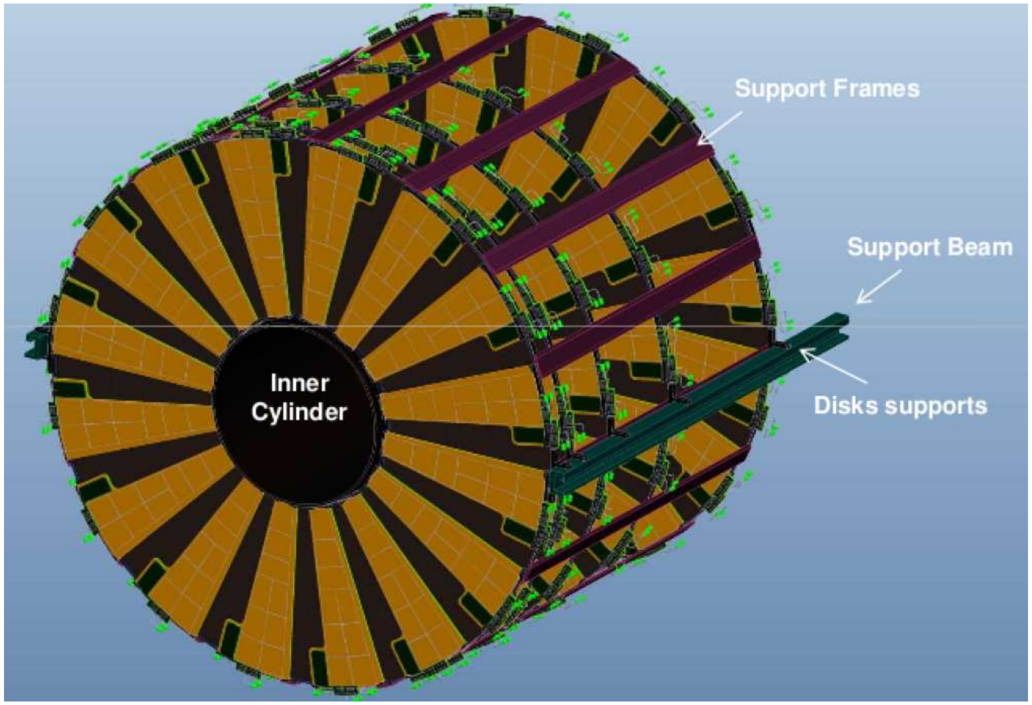
- **SuperModule** locking mechanism to barrels on 3 points



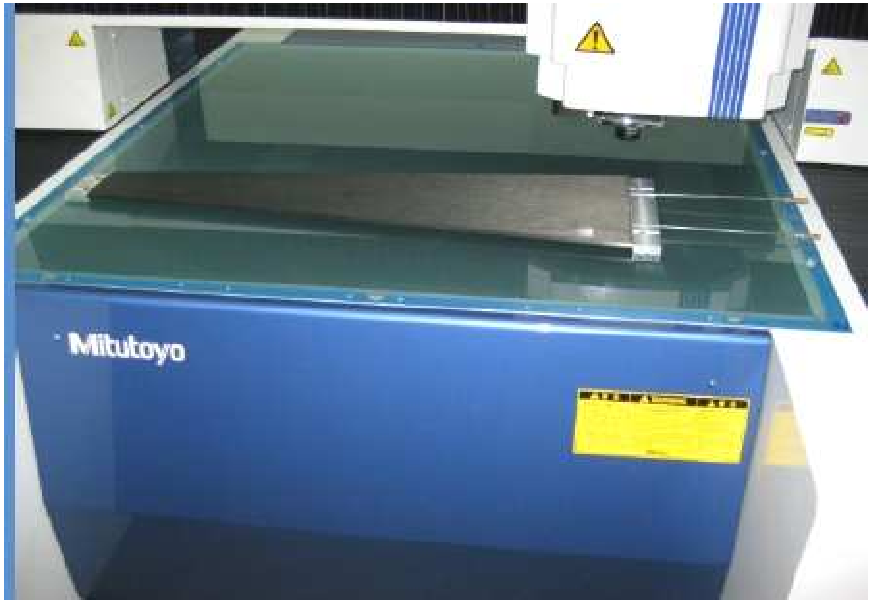


Outlooks towards the Upgrade (ATLAS)

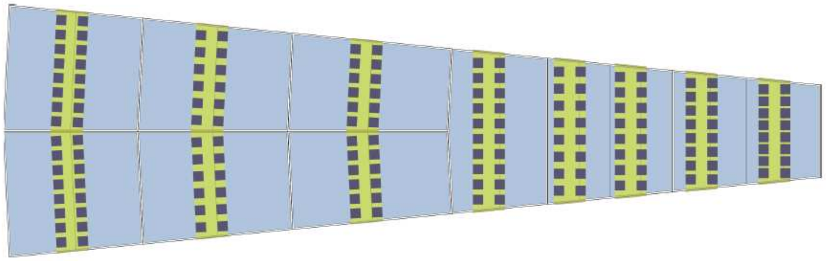
- **End Cap Stave** (petal)
  - very close design to STRIP Stave (common developments)



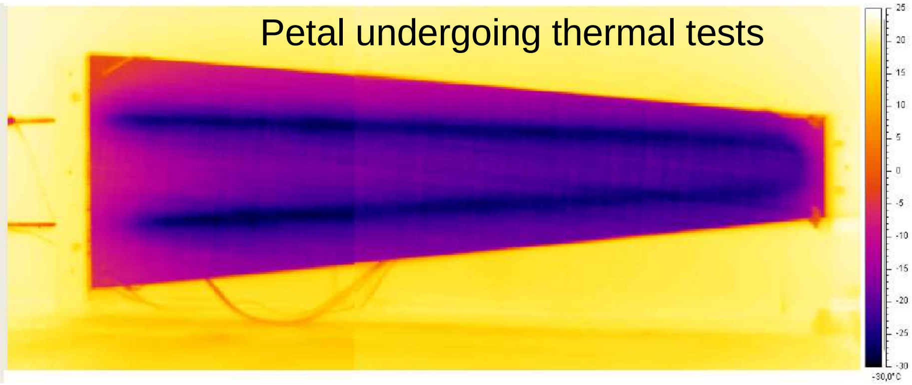
Petal undergoing metrology in Valencia



Petal shape and sensor layout



Petal undergoing thermal tests



Some conclusions

The question is more about “**how to better use the existing technology**”…
than discovering new ones (we have tools available)
Both on Atlas or AMS, the need to use a fully integrated system (electronics, CAD) is (or was) real…
For instance, we paid a lot on AMS-02 of thinking about services a bit too late...!

It seems that the approach used on the Upgrades is going to the right direction, the issues about integration, services, cooling is tackled soon in the design!
It should help defining the interfaces