R&D at IFCA for future e+e- colliders.

I. Vila IFCA (CSIC-UC)

6th Spanish Workshop on Future Accelerators
Granada May 2011

_Outline

- R&D framework.
- Silicon Sensor R&D
- Fiber Optic sensors
- Contribution to ILD inner silicon trackers.
- Outlook

_IFCA's R&D activities framework

- All IFCA's R&D activities are carried out in close collaboration with other network members.
  - New sensor development: IMB-CNM
  - Fiber Optics Sensors for EPP: IFIC
  - Power distribution system and EMC issues: ITA
  - New opportunity, very fine pitch sensors: USC
- Reinforced with other national and international collaborations:
  - INTA (Instituto Nacional de Técnica Aeroespacial)
  - HEPHY (HEP Institute of Austrian Academy of Science)
  - Charles University in Prague.
- More recently, TT to industrial partners of this R&D.

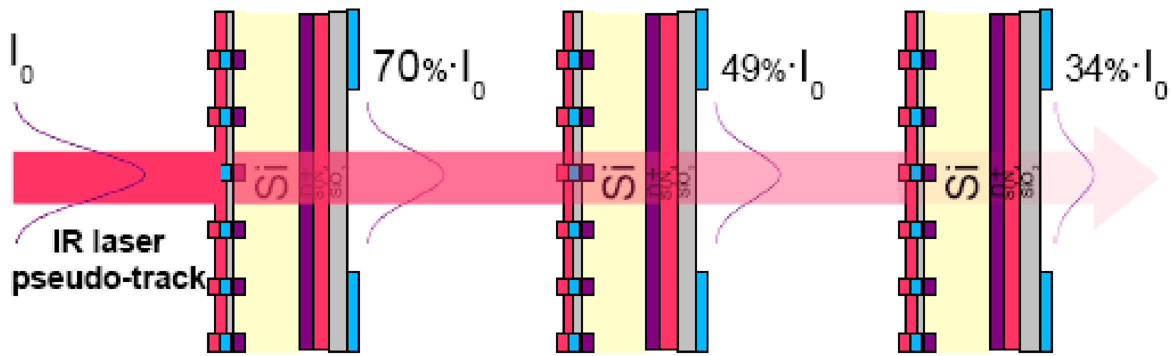
Caveat

- Here only R&D of use for the ILD, sLHC specific developments no included.
- Impossible to fit in a single talk all the R&D activities in a sensible way.

1. R&D on Silicon Sensors

_R&D on silicon sensors: Transparent microstrip sensors

- Laser tracks can be used by a hardware system to align the tracker



%T	#
90	30
80	15
70	10
60	7
50	5
40	4

- First implemented by AMS I, then AMS II and CMS. Envisaged for sLHC and ILD's FTD

- Goal: improve transmittance to infrared light of microstrip detectors without altering the standard production process

- R&D done at IFCA+CNM (Spain), then know-how transfer to larger producer

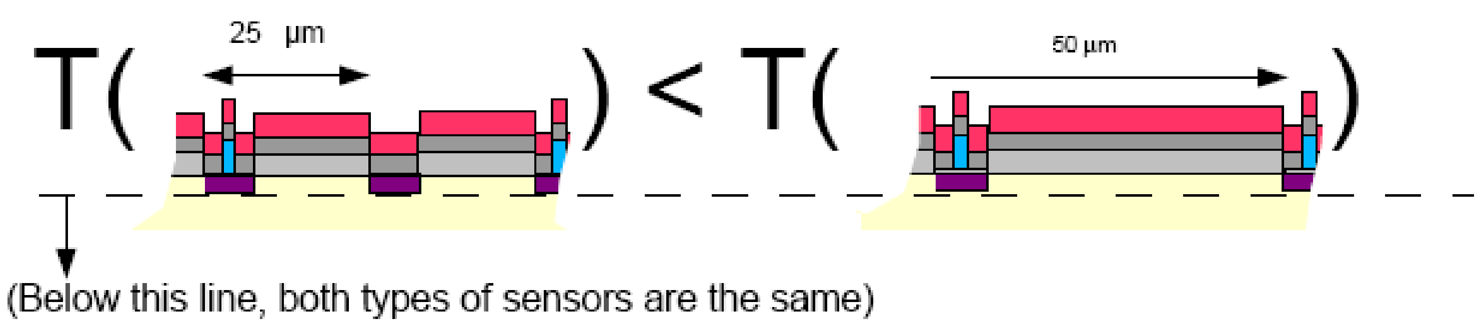
_R&D on silicon sensors: Transparent microstrip sensors (2)

IFCA

— Strip width increase (mirror effect):
→ increases reflectance (1st order), reduces transmittance (2nd order).

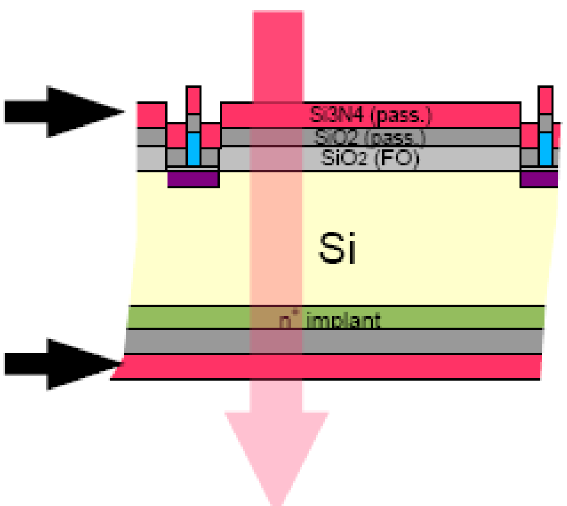
— Pitch reduction (=closer strips):
→ decreases transmittance (1st order effect), increases reflectance (2nd order).

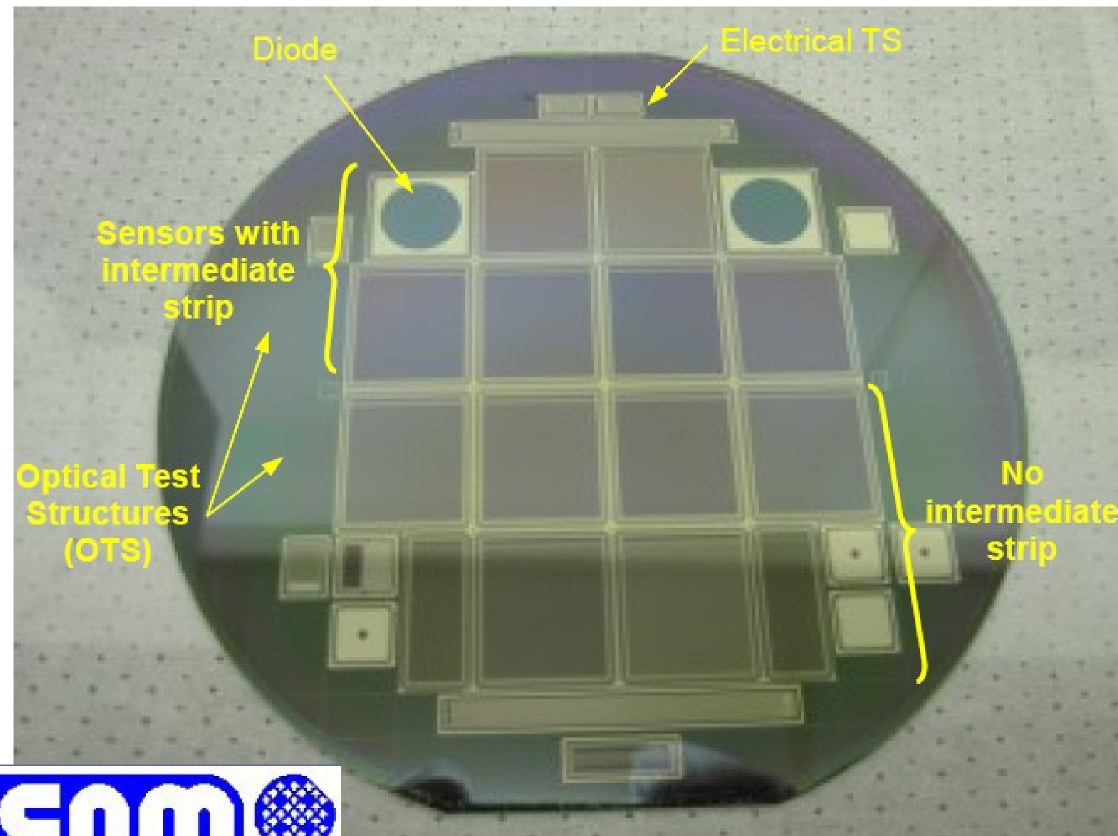
— Strips having metal or not (i.e. intermediate strips) behave as a diffraction grating.
Busier pitch ⇒ lower transmittance



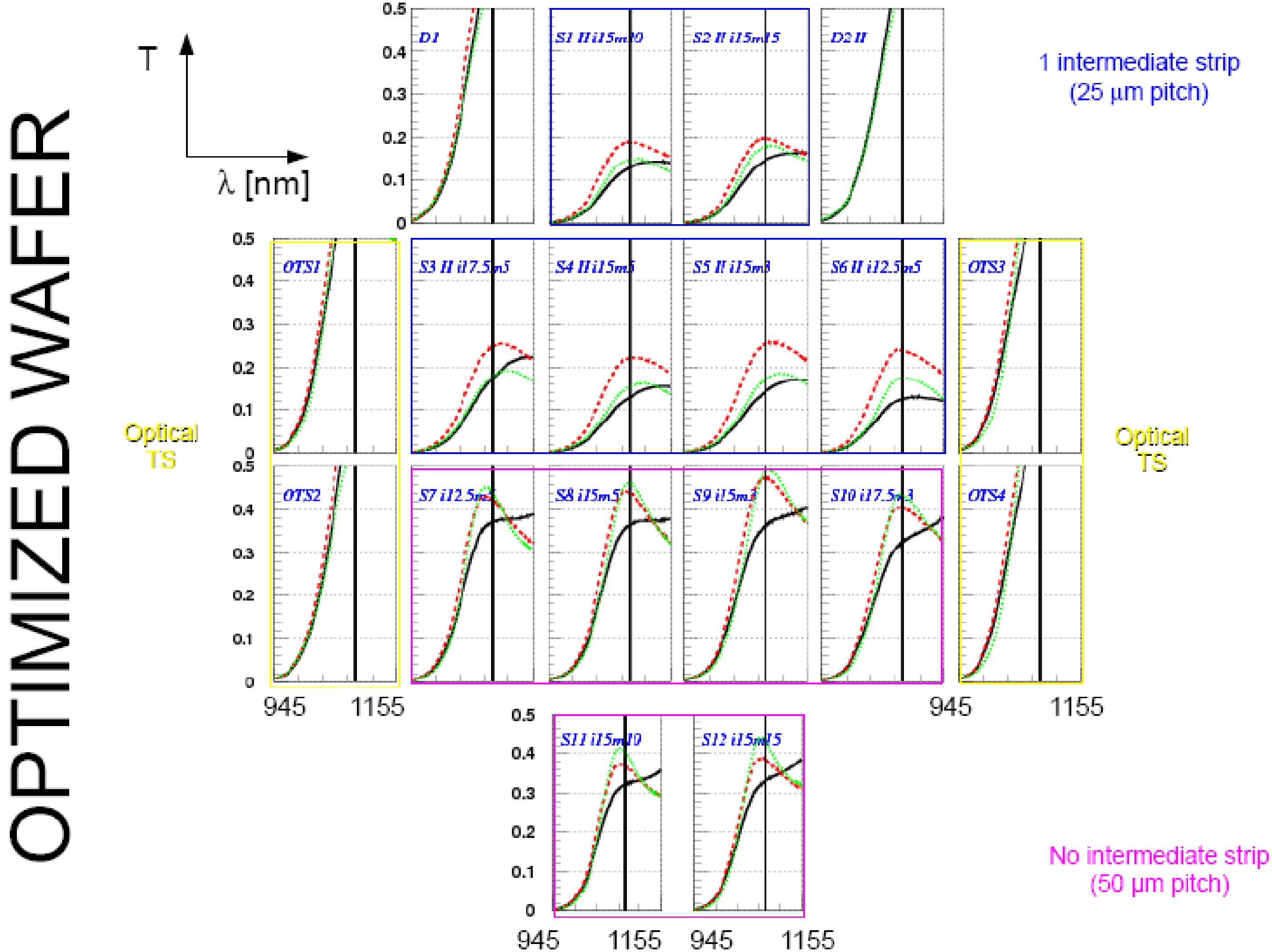
_R&D on silicon sensors: Transparent microstrip sensors (3)

— Top and bottom **nitride** layers behave as an **A**nti**R**eflection **C**oating (ARC)





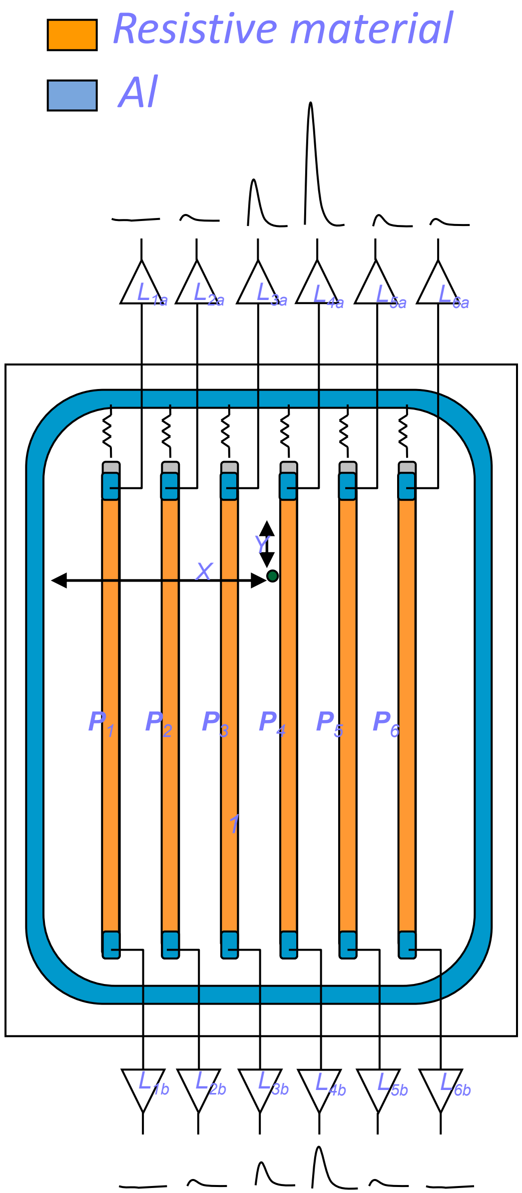
_R&D on silicon sensors: Transparent microstrip sensors (4)



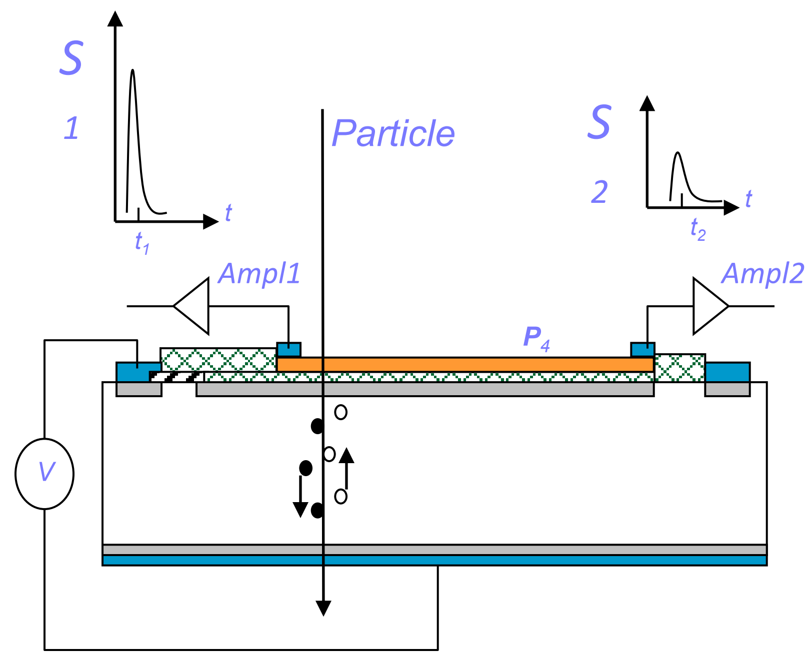
_microstrips with resistive electrodes (1)

– Charge division used in wire chambers to determine the coordinate along the sensing wire.

– Same concept with conventional microstrips with slightly resistive electrodes



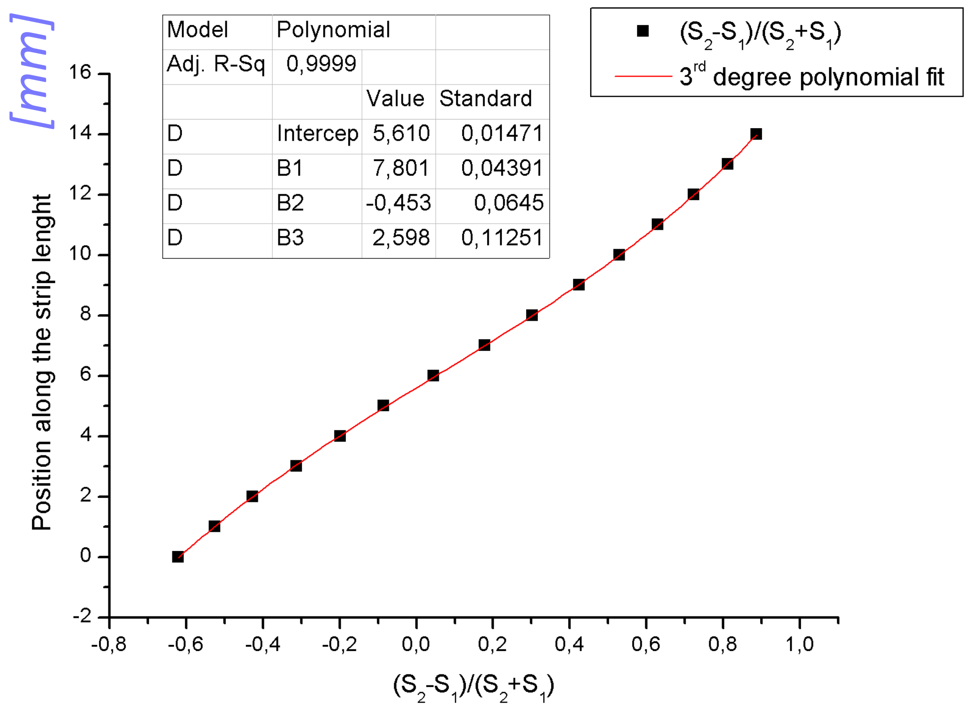
$S_1=f(y)$
$S_2=f(L-y)$

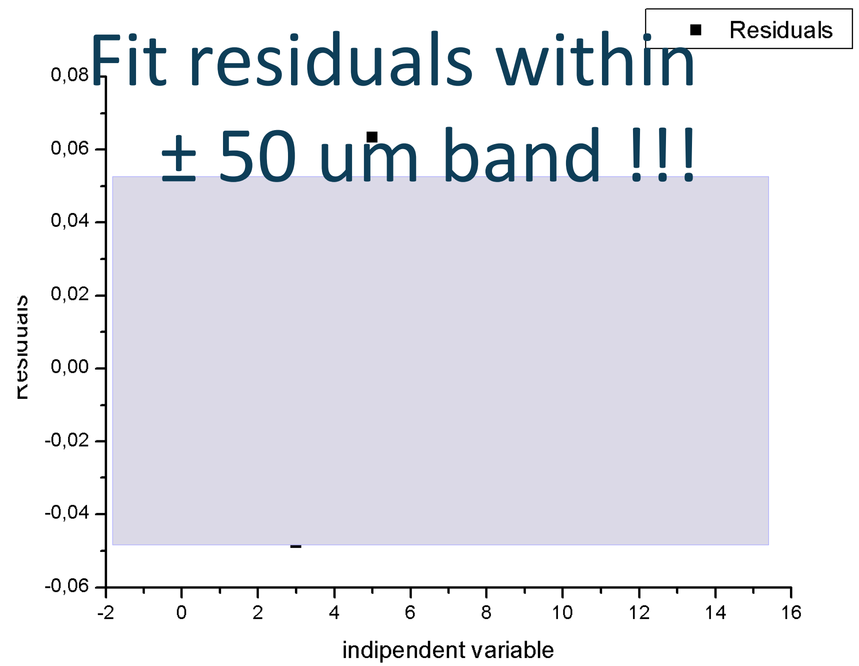


Longitudinal coordinate from Q_{div} (2)

– Naïve computation of position along the strip:

$$y = \frac{Q_{far} - Q_{near}}{Q_{far} + Q_{near}}$$



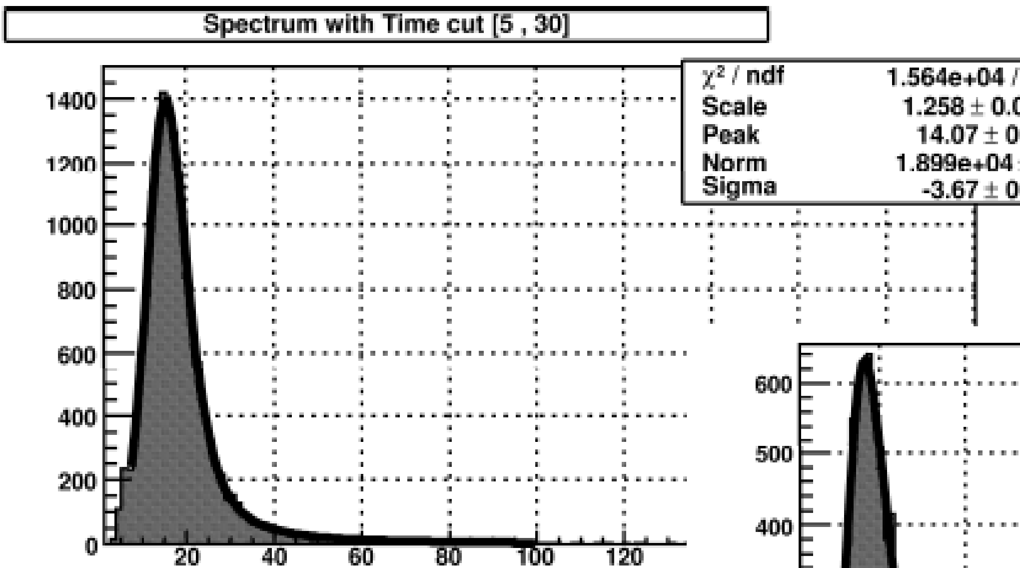


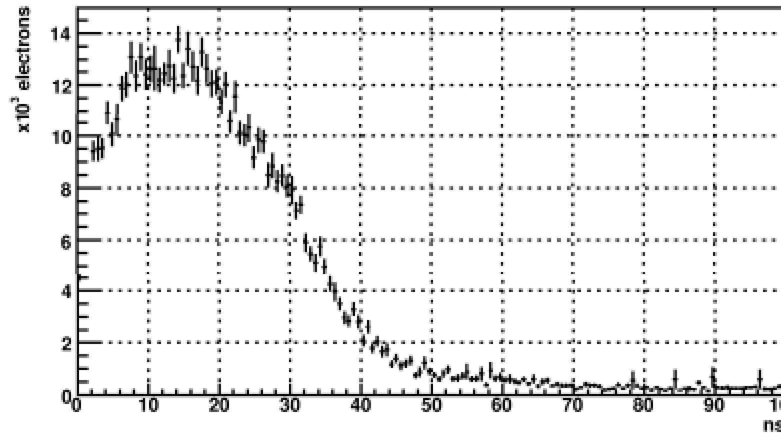
Fit residuals within ± 50 um band !!!

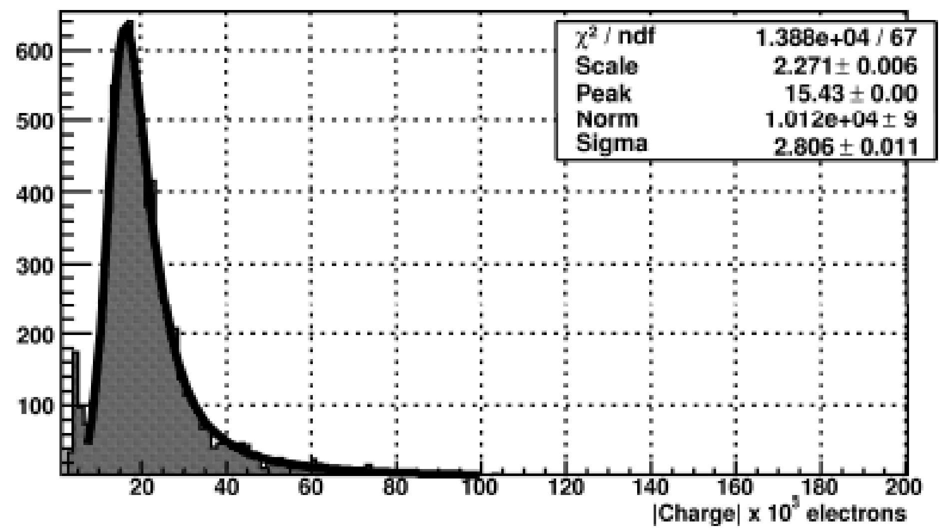
Test Beam @ SPS (3)

Signal Spectrum

& pulse shapes

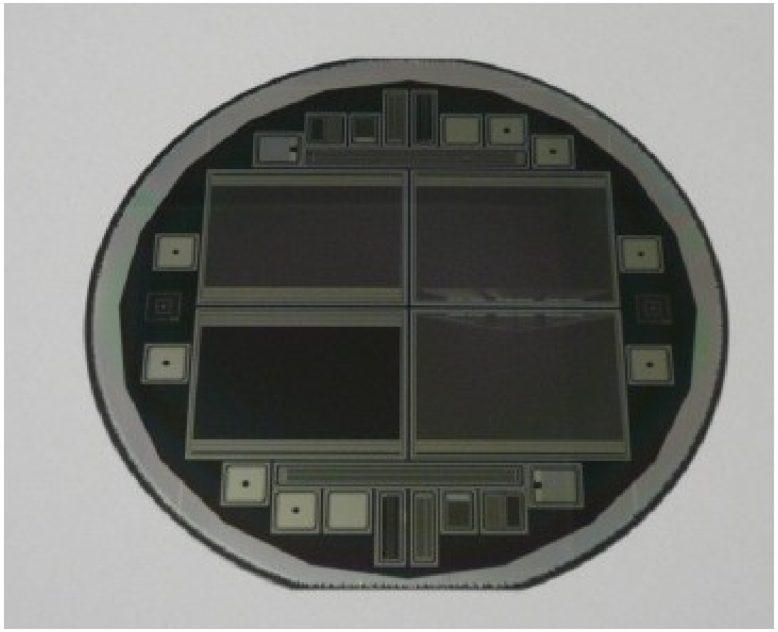


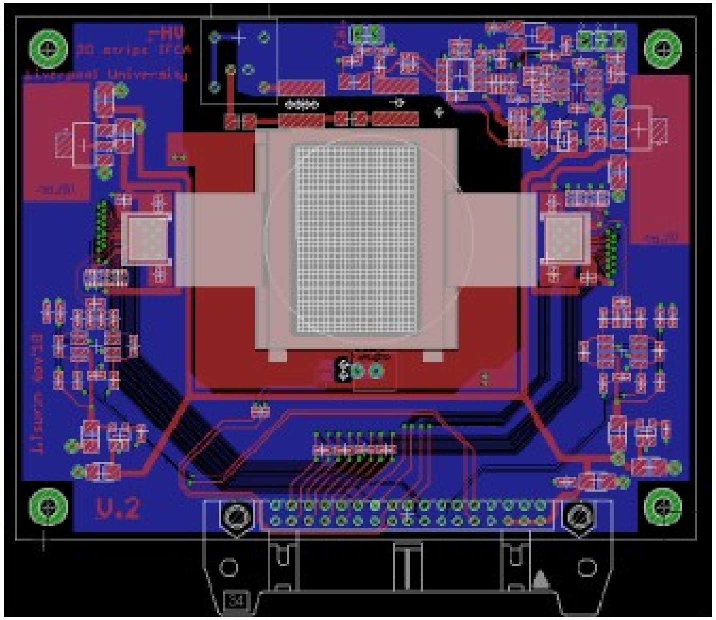




Microstrip electrodes (4)

– 6 new wafers. 1 reference sensor, 1 poly sensor, 2 DML integrated PA sensors (per wafer)
– Reduced polysilicon resistivity (366 and 84 Ohm/□)
– Modified ALIBAVA daughter board for 2 sides read out

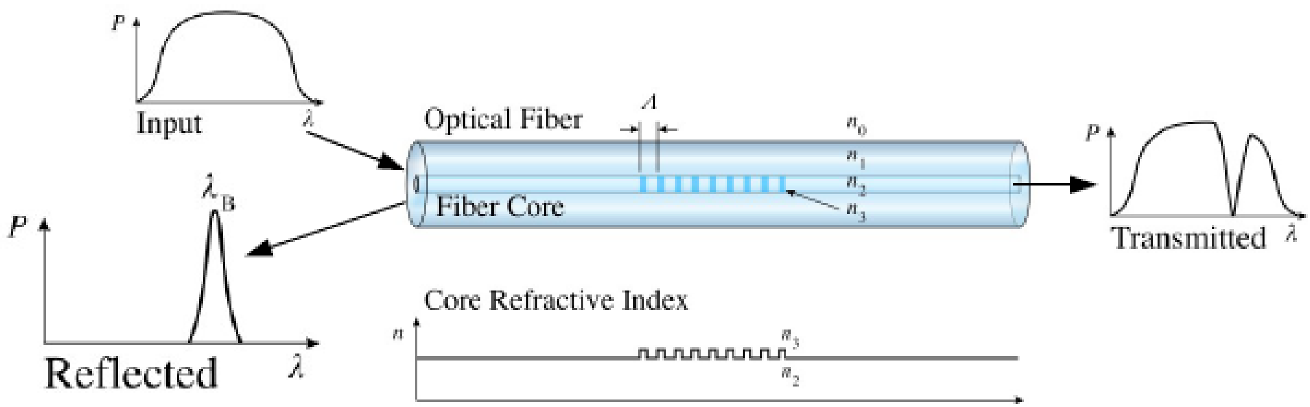




2. Fiber Optics Sensors for HEP

_Fiber Optic Sensor for structural and environmental monitoring of tracker systems

- Gratings can be used as “single wave reflectors” *aka* Bragg reflectors

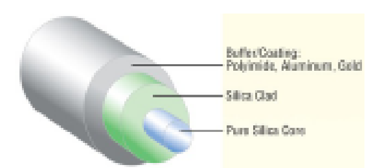


$\lambda_B = 2\, n_{eff}\, \Lambda$

- λ_B is sensitive to strain and T: $\left[\frac{\Delta\lambda_B}{\lambda_B}\right] = C_S\epsilon + C_T\Delta T$ $\begin{cases} \sim 10 \text{ pm/K} \\ \sim 1 \text{ pm}/\mu\varepsilon \end{cases}$

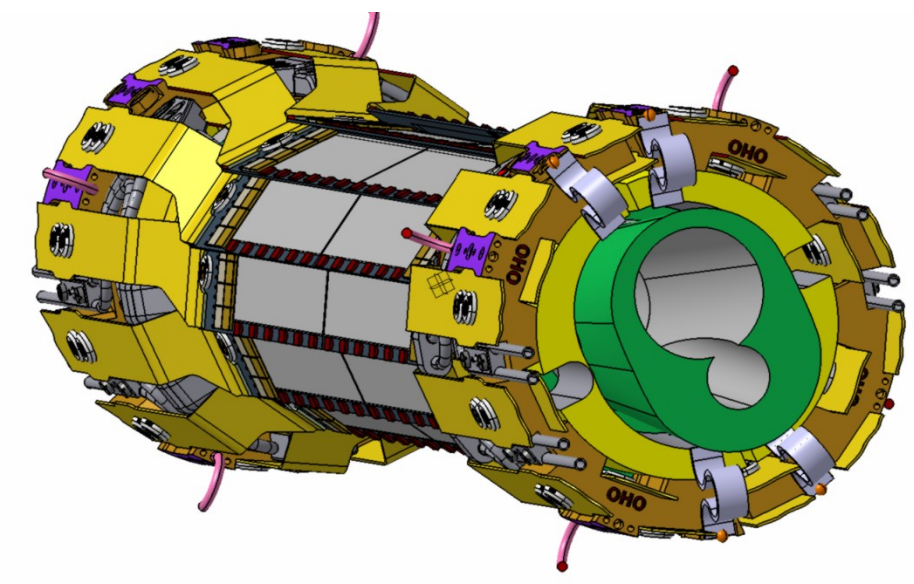
- Bragg reflectors can then be used as sensing elements in optical fibers

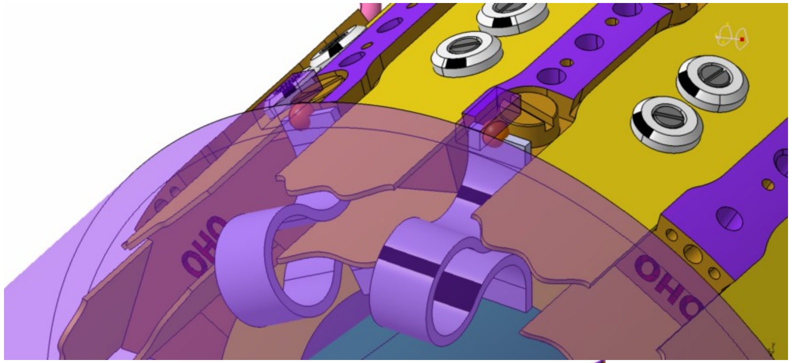
- Other quantities (humidity, %CO2, magnetic field,…) can be measured using coatings sensitive to these measurands.

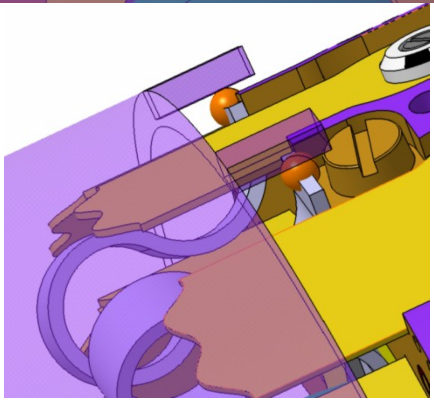


_Fiber Optic Sensor for structural and environmental monitoring of tracker systems (2)

- Application case: development of FOS based displacement sensors for relative monitoring of PXD and SVD Belle-II pixel sub-systems.



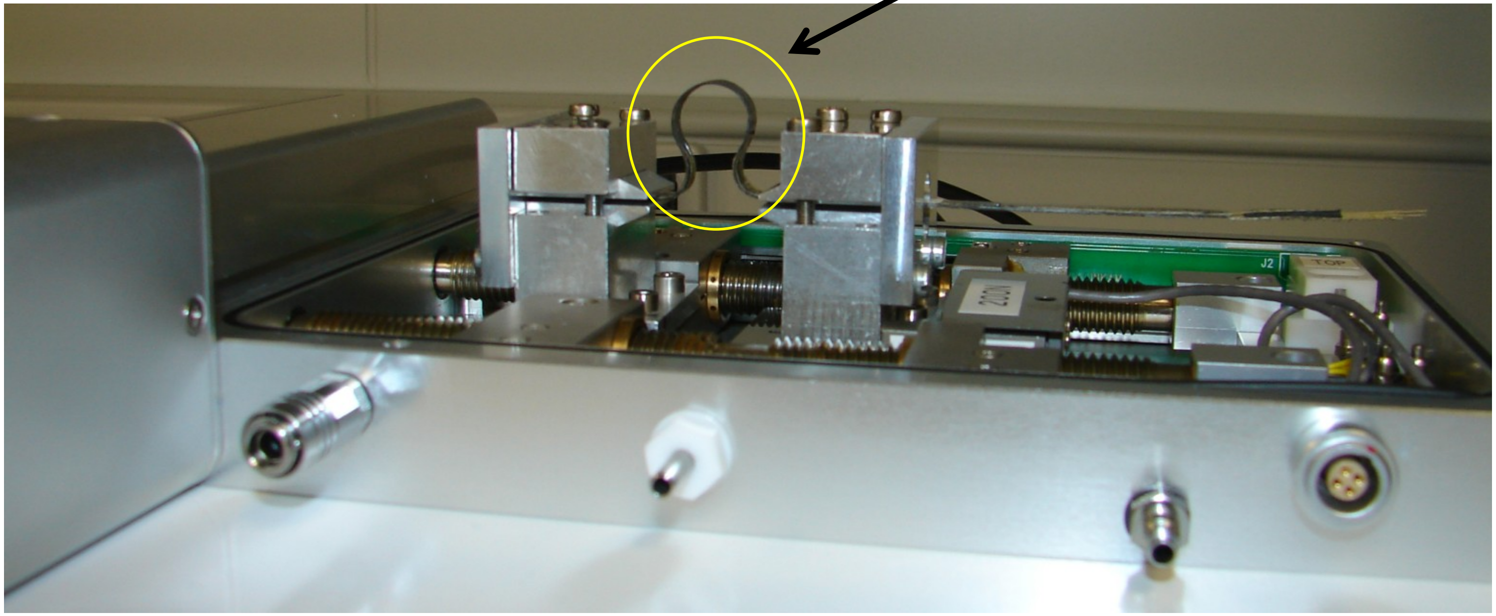




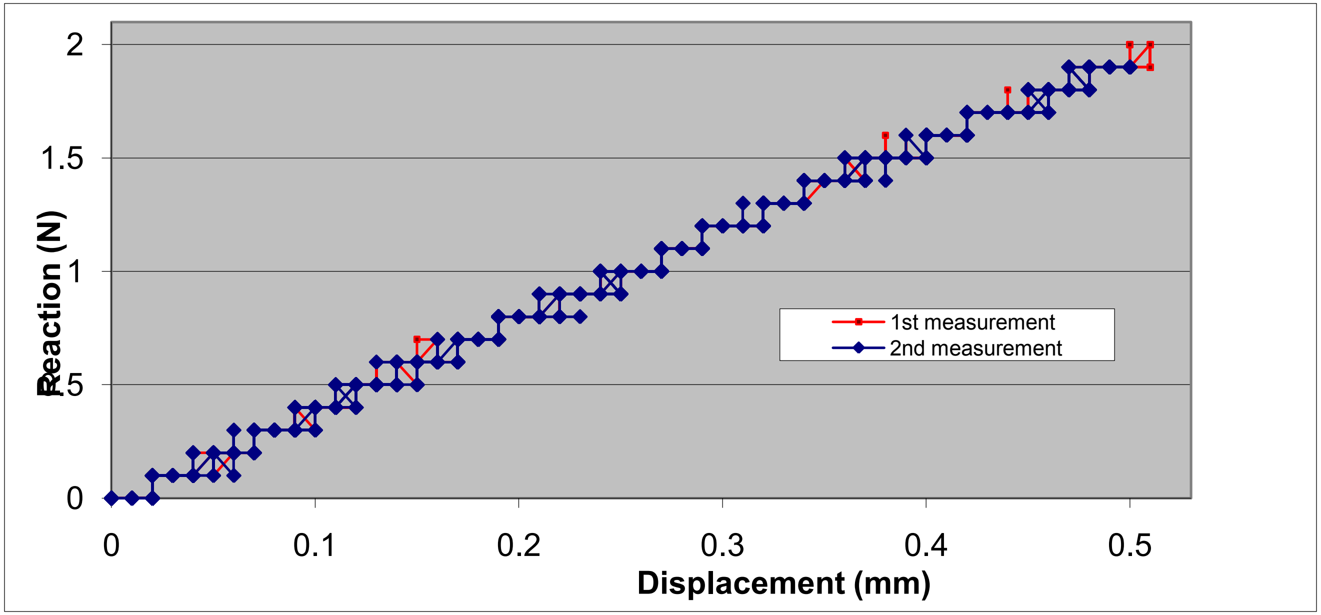
_Omega Shape mechanical mockup calibration

– Two kind of mechanical dummies:
  - Omega shape and S shapes.
  - Composite laminate stack + embedded optical fibers (no sensors)
– A Tensile testing stage was used (displacement+ force sensor)
  - Special grips where manufactured
  - Displacement Range of 500 um.
– Goal: determine the omega reaction force.

Omega Shape



_Omega shape: Reaction Force



configuration	Nº of layers	Max Reaction (Newtons)
Omega	4	0.2
	6	1.9
S-shape	4	0.2
	6	0.6

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Omega Shape: preproduction prototype

- Six layers of unidirectional C.F./G.F. fabric Omega Shape.
  - The laminate stacks will be disposed in a way that the thermal expansion and the humidity induced expansion will be negligible (CTE = $-0.1x10^{-6}$)
  - Three optical Fiber sensors embedded: redundancy, reliability, temperature compensation (if needed).

- The design of the fixation of the omega "foots" depends strongly on the PXD-SVD space constraints.
  - The same thing applies to the final dimensions

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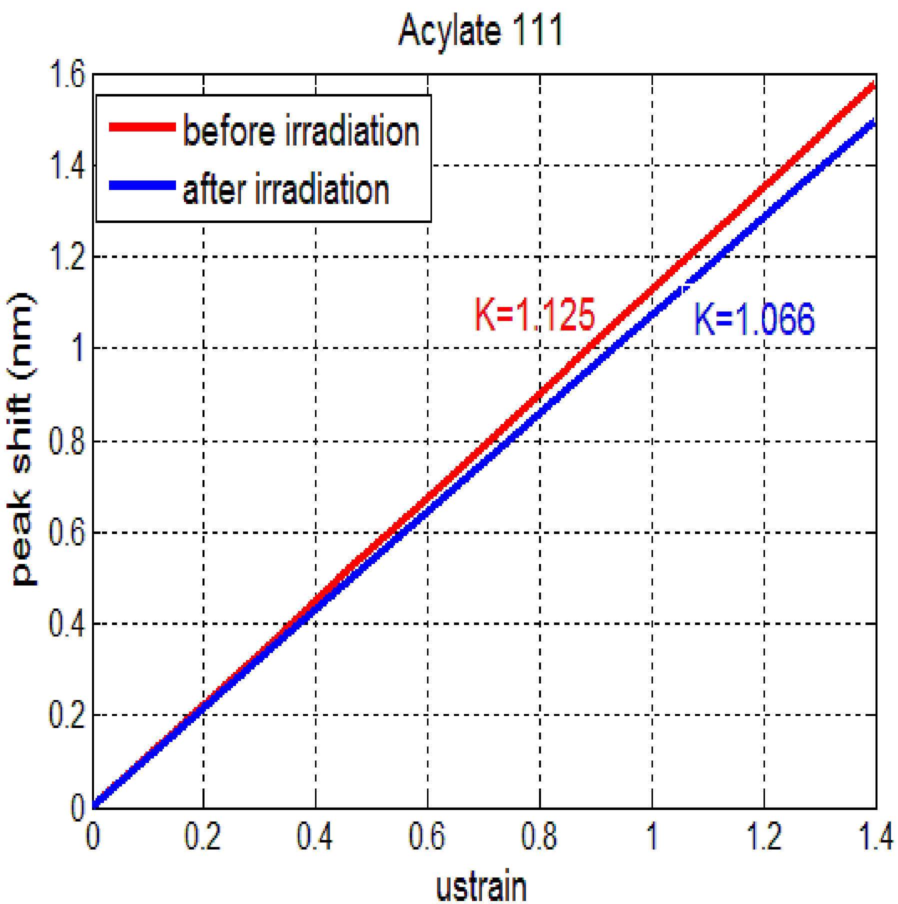
Irradiation effect on FBGs strain response

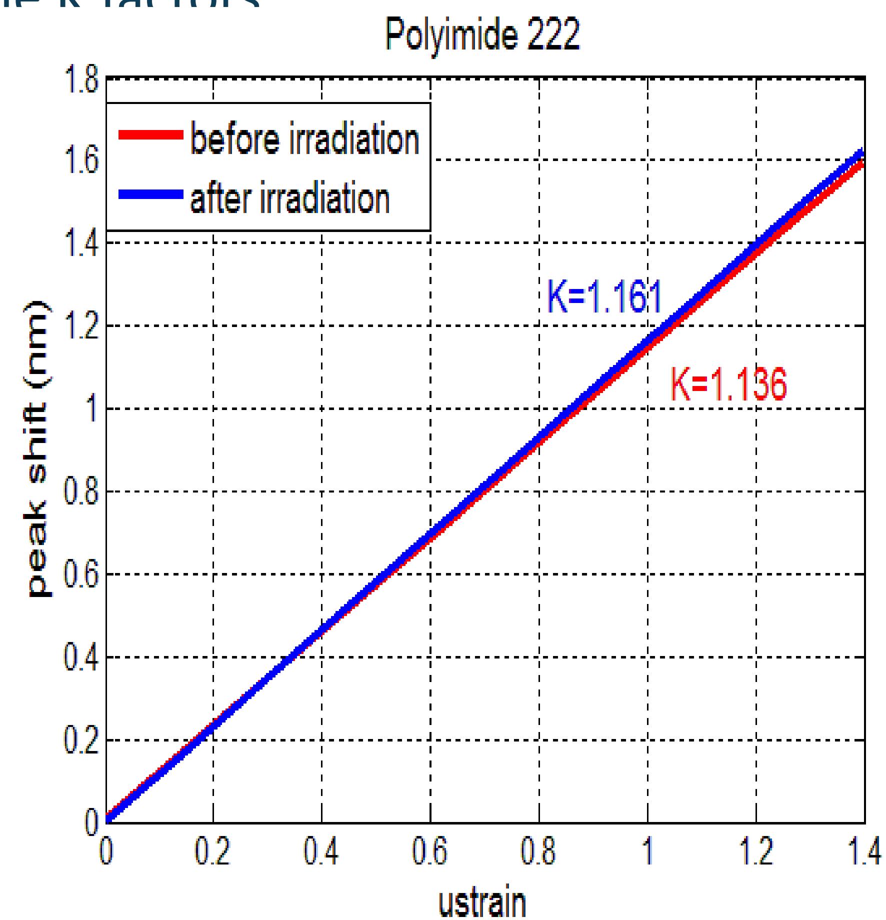
– FBGs sensor strain sensibility is on the basis of the Omega shape concept.
– Several sensor samples irradiated up 1.5 Grad !!!
– The calibration Set-up
  - A carbon fiber tube with thermal expansion near zero and attached to a micrometric stage with a fiber locking system
  - Distance between the end of the carbon fiber tube and fiber locking system is known. Displacement applied by a micrometric stage.
  - Overall precision is two microstrain.

FBGs MECHANICAL CALIBRATION RESULTS

- Mechanical calibration K factor lineal adjustment before and after irradiation.

- the difference below 5% for all the K factors





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FBGs MECHANICAL CALIBRATION RESULTS

Sensor	Coating	Attenuation, dB	Peak Shift, pm	K, pm/usn	K, pm/usn
				before irradiation	after irradiation
111	acrylate	0.42	-3	1.126	1.066
112	acrylate	0.15	-14	1.132	
212	Polyimide(DT)	6.05	140	1.099	1.160
213	polyimide(DT)	6.26	173	1.099	1.164
214	polyimide(DT)	7.16	175	1.104	1.166
221	polyimide(DT)	7.56	158	1.126	1.158
222	polyimide(DT)	6.92	175	1.136	1.161
223	polyimide(DT)	6.92	173	1.136	1.1690
021	ormocer(DT)	6.23	308	1.142	1.1570
022	ormocer(DT)	8.80	379	1.151	1.171
023	ormocer(DT)	5.00	334	1.158	1.182
03	Ormocer (TII)	0.01	206	1.143	1.150
04	Ormocer (TII)	0.03	307	1.151	1.173
05	Ormocer (TII)	0.21	359	1.176	1.175

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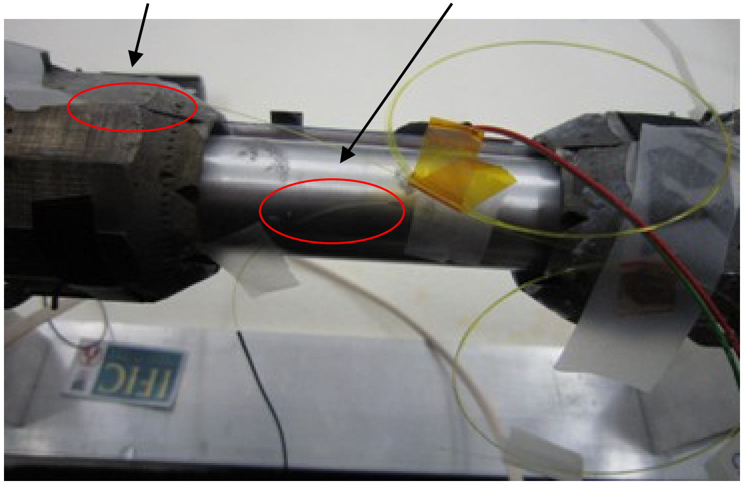
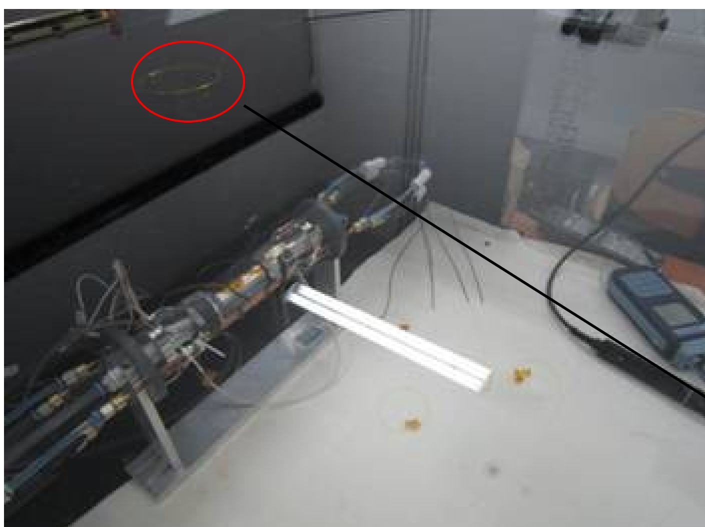
Thermal monitoring of Valencia's Mockup

FBG attached Cooling Block

FBG attached Beam Pipe



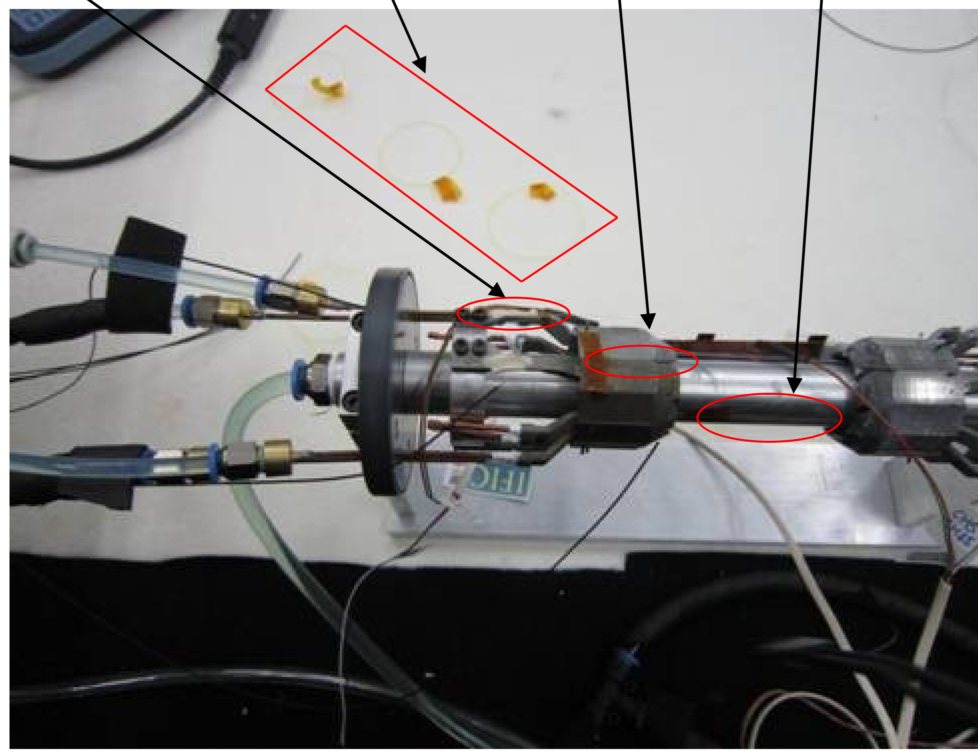


Free FBG inside box

FBG attached Cooling Block

FBG attached Beam Pipe

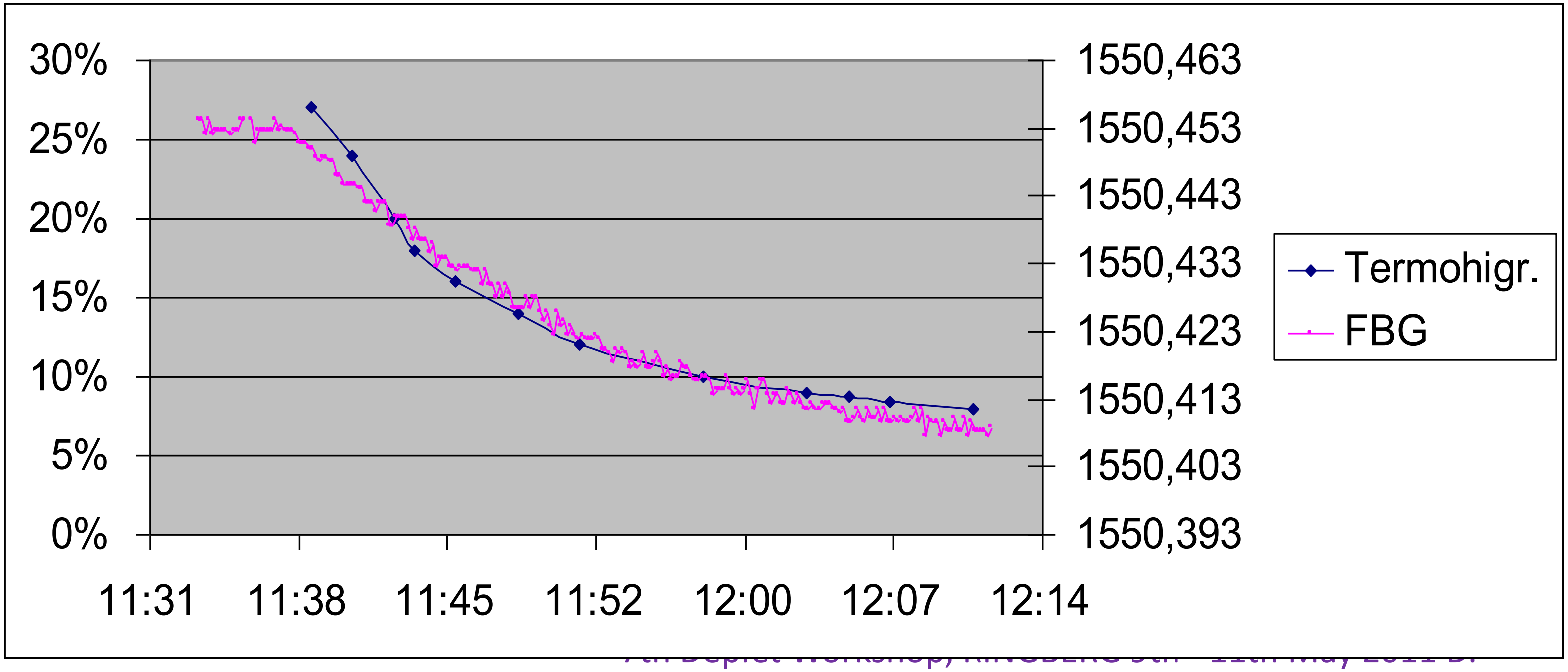
FBG glued X60 Cooling Block



Free FBG outside box

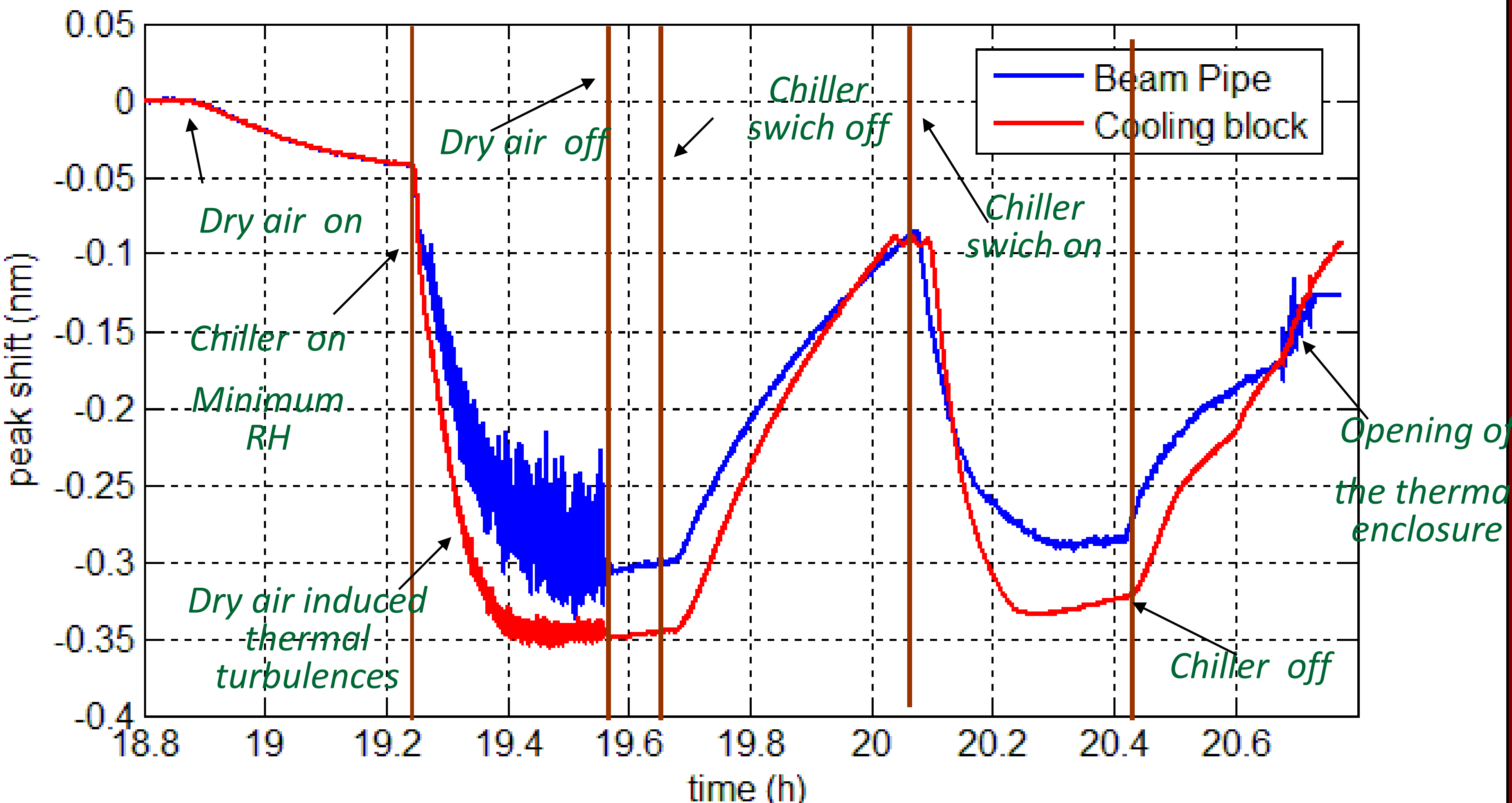
FBG measurement in Valencia Mock-up

- Cooling sequence.
  - First inject dry Air to reduce the relative humidity (8%)
  - Switch on the chillers ($-20^{o}C$) to cold down the cooling block and beam pipe.
- During the first thermal cycle, we saw that the signal of the polyimide coated sensors changed with the relative humidity



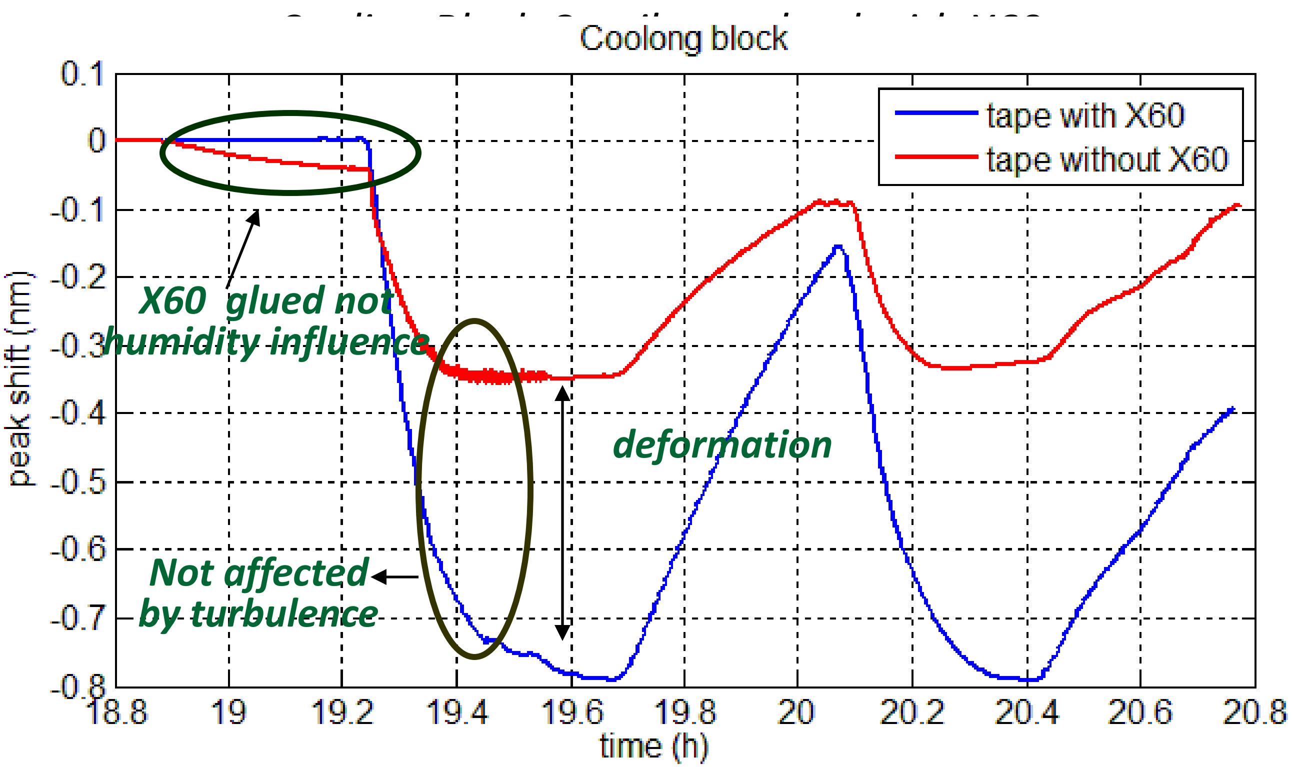
FBG measurement in Valencia Mock-up

- During cooling cycle, several effects were observed



Strain measurement in Valencia Mock-up

- We measure the strain with the FBG glued with X60 to the cooling block.
  - The peak shift is two times of the one measured by the ones attached only by adhesive tape
    - No effect of the humidity.
  - It does not see the quick temperature fluctuations (protected by X60)



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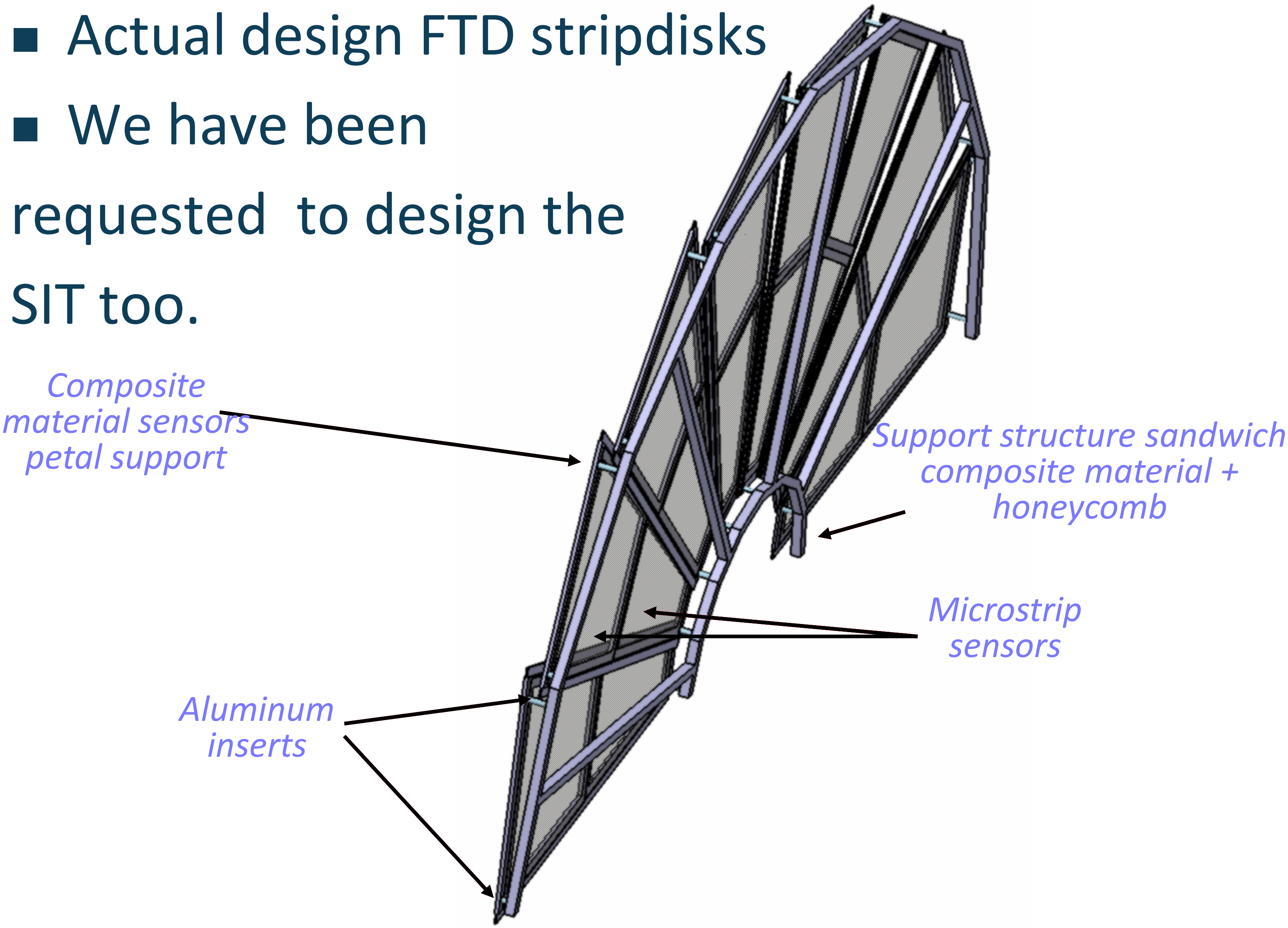
3. ILD Inner silicon tracker:

Mechanical design

Power distribution system.

FTD MECHANICAL DESIGN

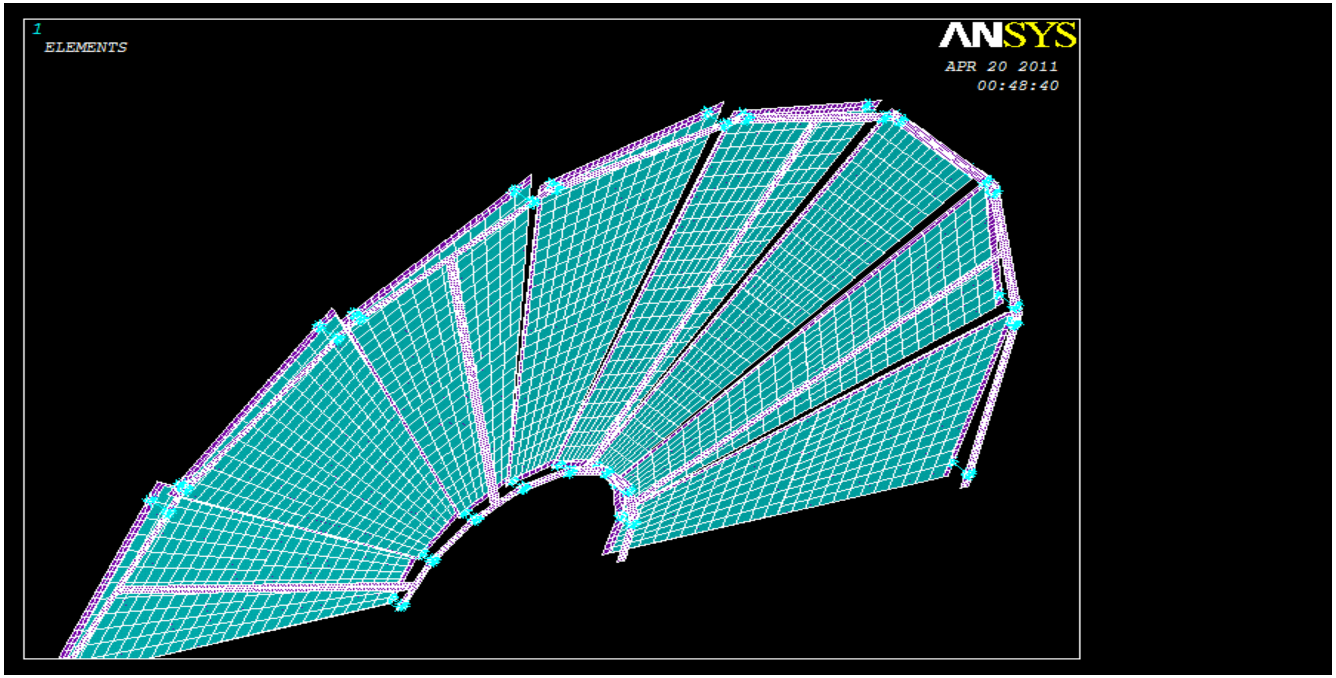
- Actual design FTD stripdisks
- We have been requested to design the SIT too.



- Design validation
  - Ask to composite material manufature experts about the design (Composite material department at INTA, Spanish Aerospace Agency)
  - The two main structures (petals an support rings) can be manufactured in a reasonable way.
  - A first discussion abaut how the two pieces could be manufactured.
  - Proposal to use a high module carbon fiber (M55J), since fragility should not be a big problem with respect to the deformation.

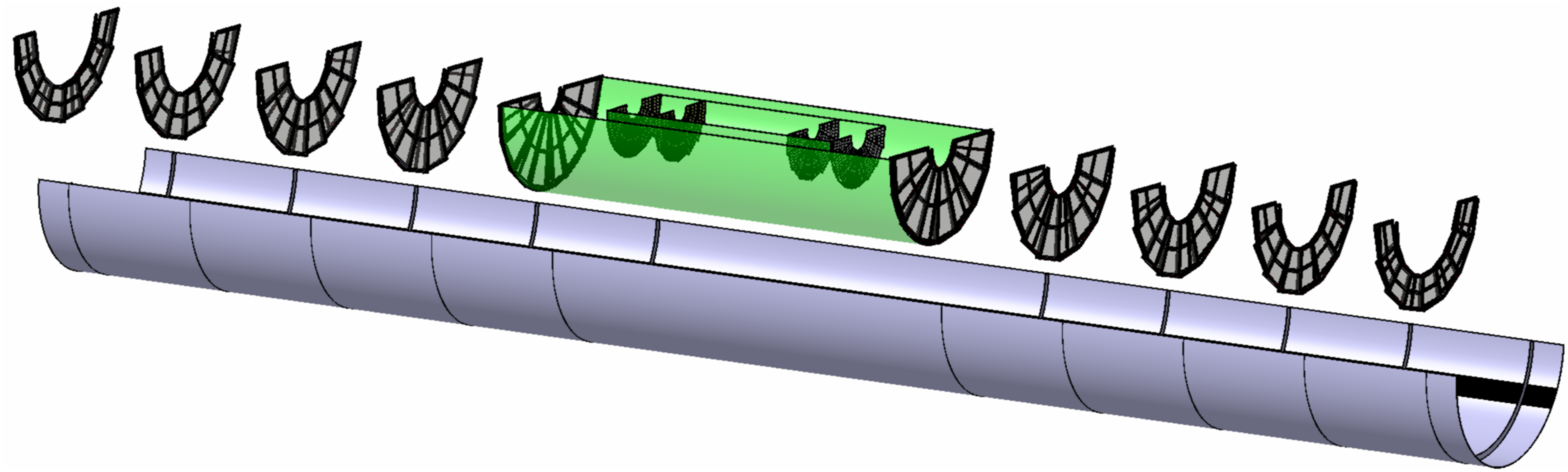
FTD MECHANICAL DESIGN

- Mechanical simulation
  - Starting to create a first naïve model for the simulation
    - Some initial problems
  - Instead of doing a simulation of all the FTD, simulate each modul (Petal, and support isolated)



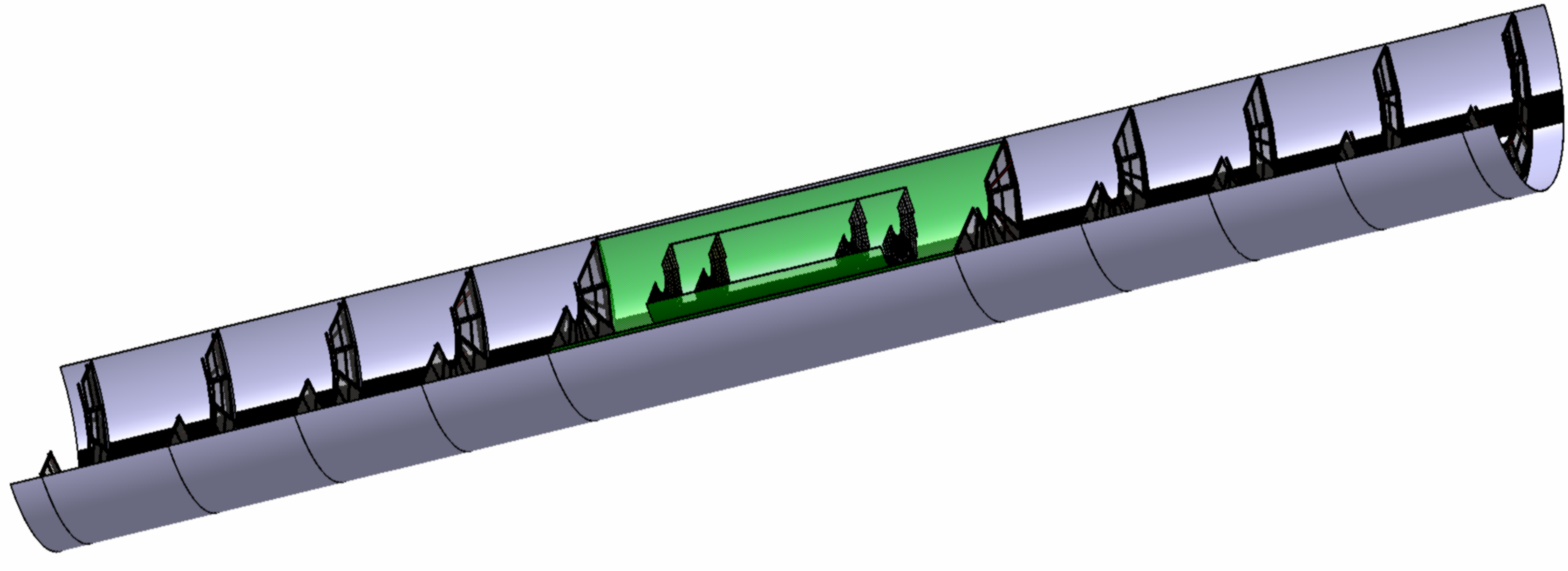
1st ASSEMBLY STEP

Mount the FTD and the SIT dectors



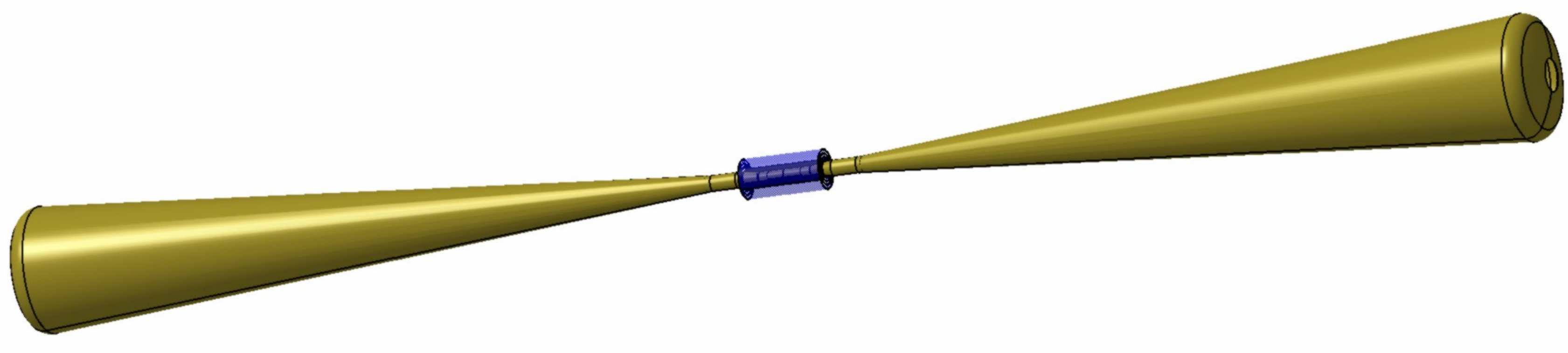
SECOND ASSEMBLY STEP

Assembly half FTD and SIT detector to one half of the inner support



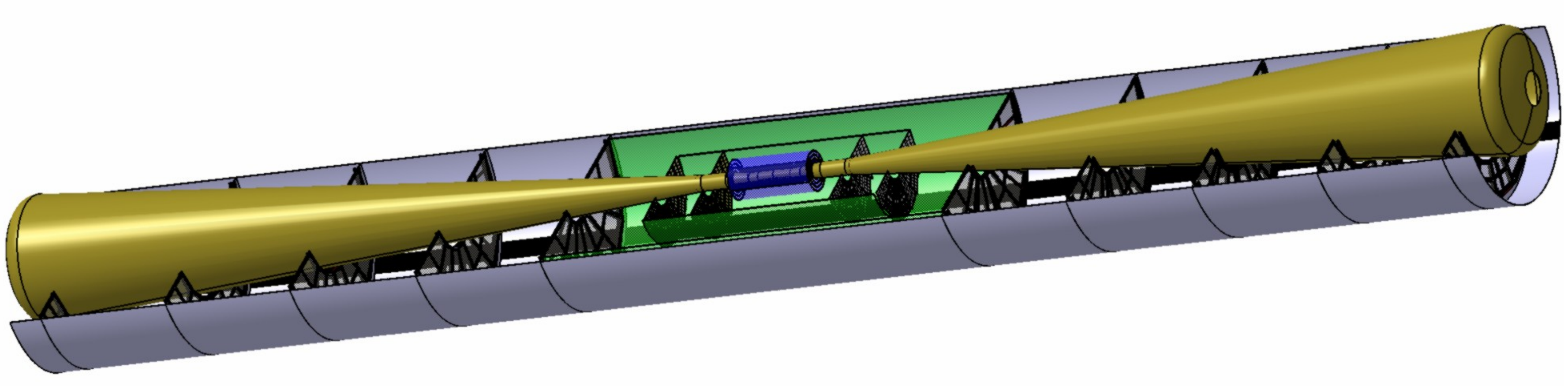
THIRD ASSEMBLY STEP

Assembly the vertex to the Beam Pipe



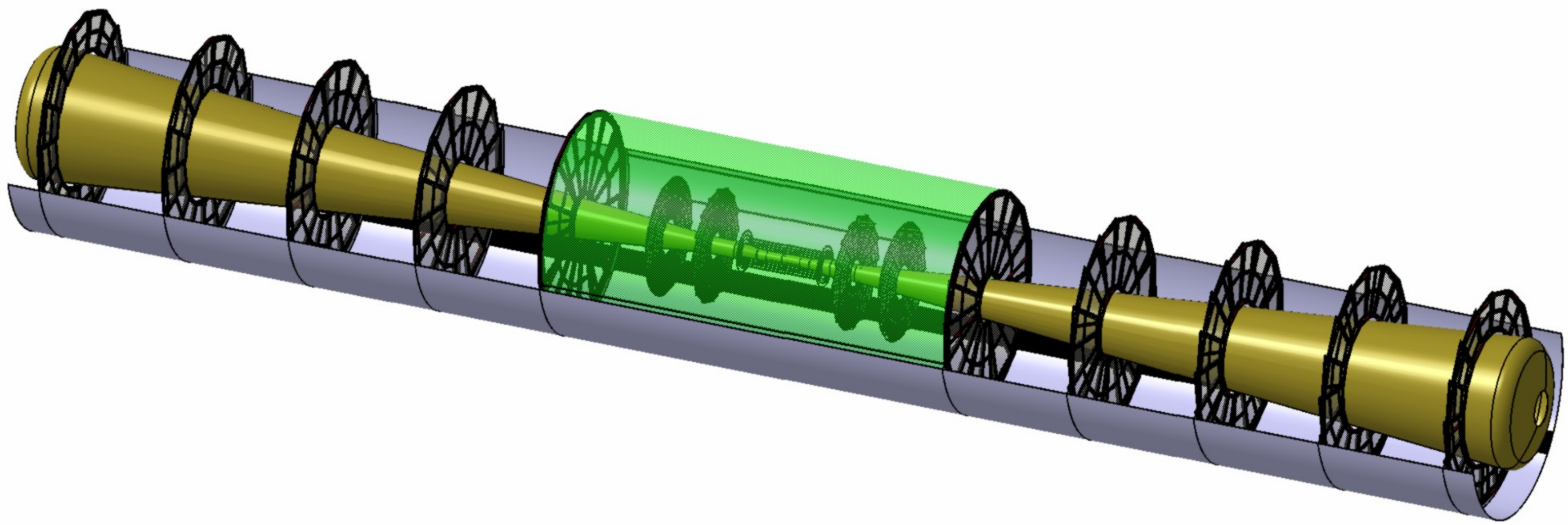
FOURTH ASSEMBLY STEP

Assembly the Beam Pipe to the half detectors an the inner support cylinder



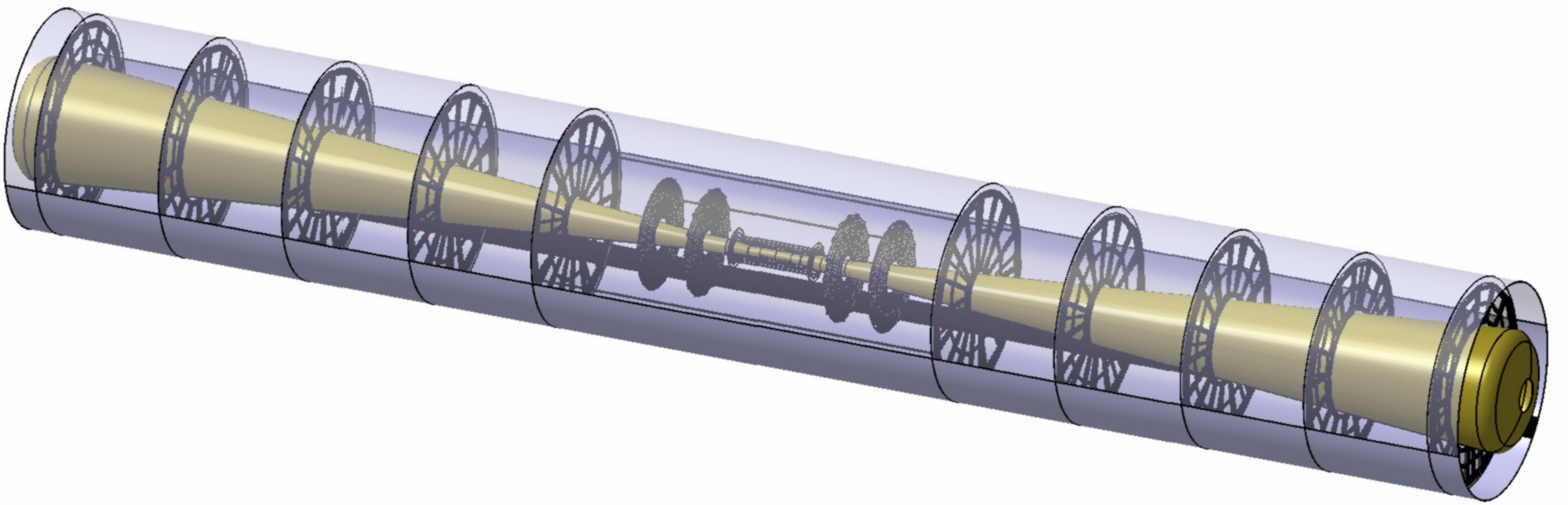
FIFTH ASSEMBLY STEP

Mount the other half of the FTD and SIT detectors



SIXTH ASSEMBLY STEP

Assembly the lass half of the inner support once all the sensors has been referenced by photogrametry or equivalent



Caveat: power distribution & design constrains

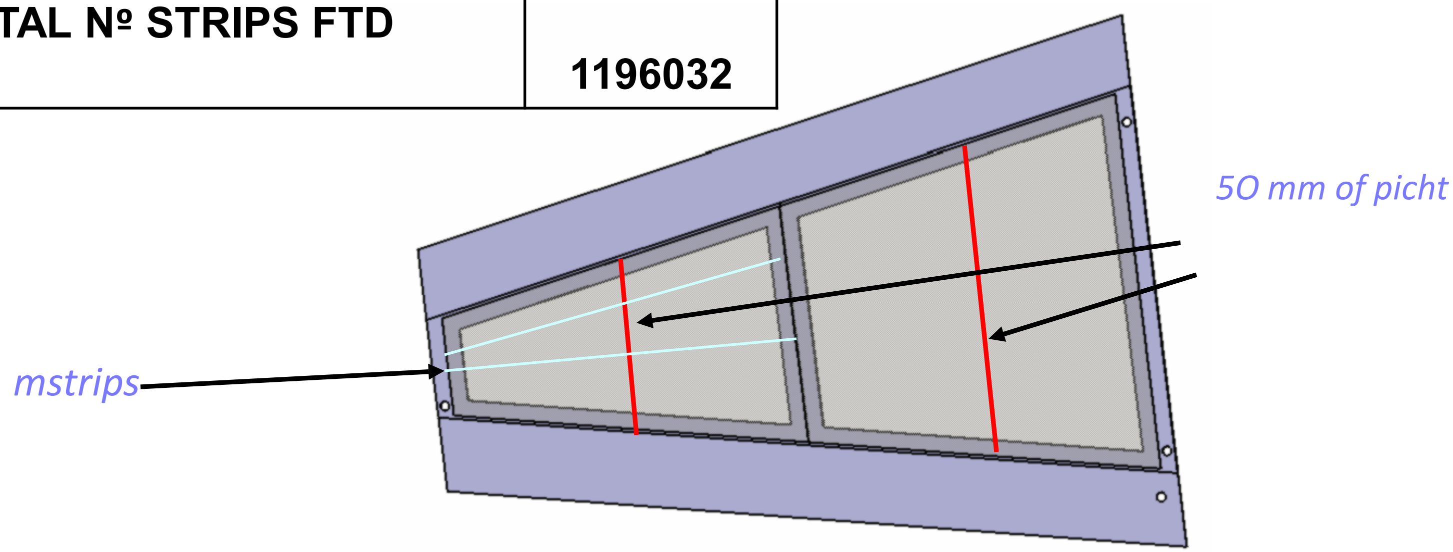
- Power distribution design, several options:
  - **DC-DC converters** (noise source close to FEE, bulky difficult to integrate, see next slides)
  - **Local RAD-hard regulators** (no so bulky, low effiency: strong heat dissipation)
  - **Remote power supply** (requires remote sensing: complex feed-back loop, expensive, high power dissipation on cables, material budget: cooper cable, unclear behavior against power-pulsing-induced transients due to long cables)
- Here, we consider the first option:
  - To accommodate the high consumption (65 A on average per disk)
  - To absorb transients associate to power pulsing system.
  - Synergy with SLHC and new DC-DC hard-rad design.
- Showing a working document more than first version of power distribution system.

POWER DISTRIBUTION

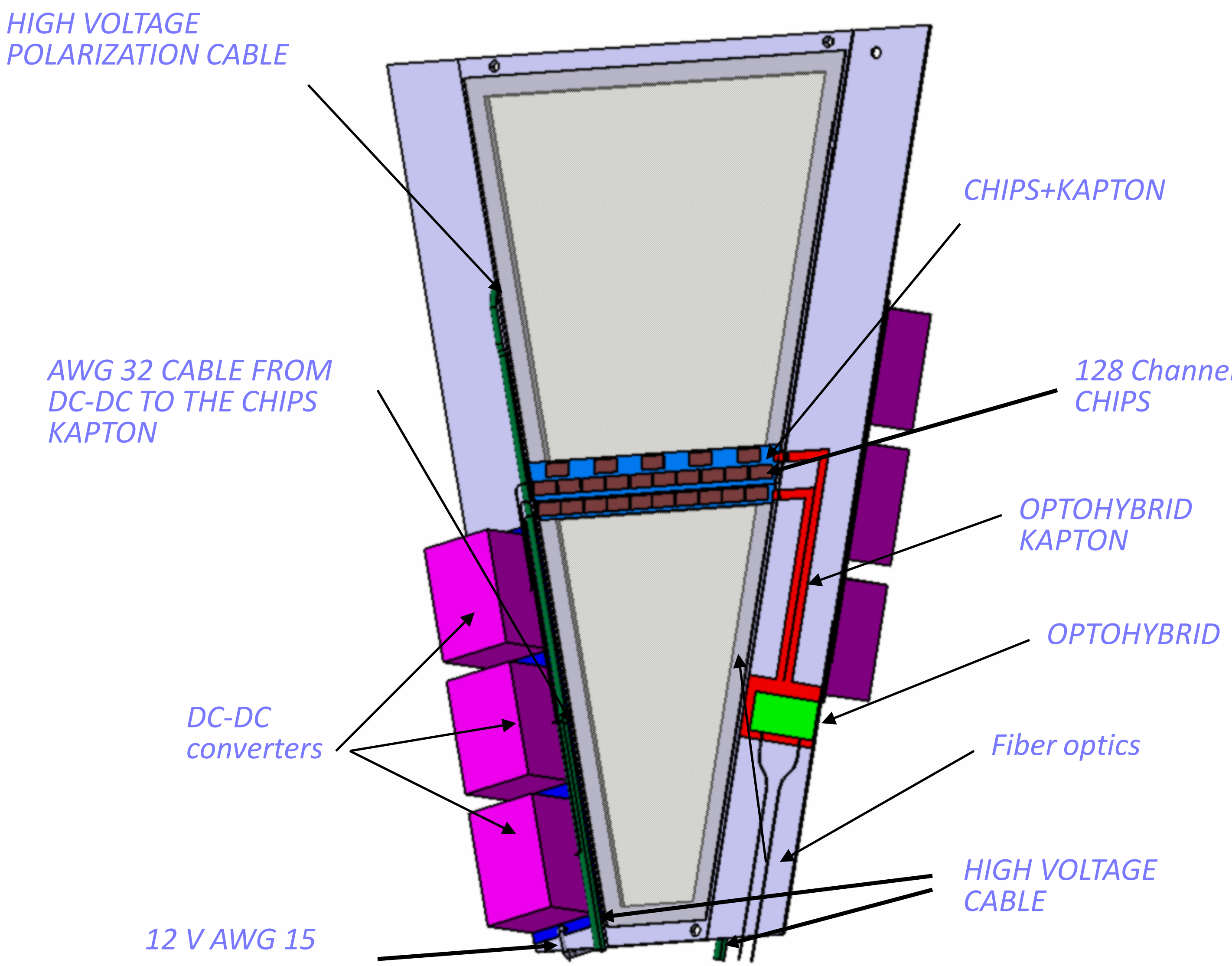
- A first estimation of the Cables , DC-DC converters, r/o chips and OPTOHYBRID including petal’s cable routing, still non optimized
- Input: Nº of channels per sensor assuming a future generation 128 ch r/o chip and optical links
- For the design :
  - The sensors in a 6 inch Wafer
  - Fine Pitch Sensors: 50 mm in the middle height of each sensor

POWER DISTRIBUTION : INPUT

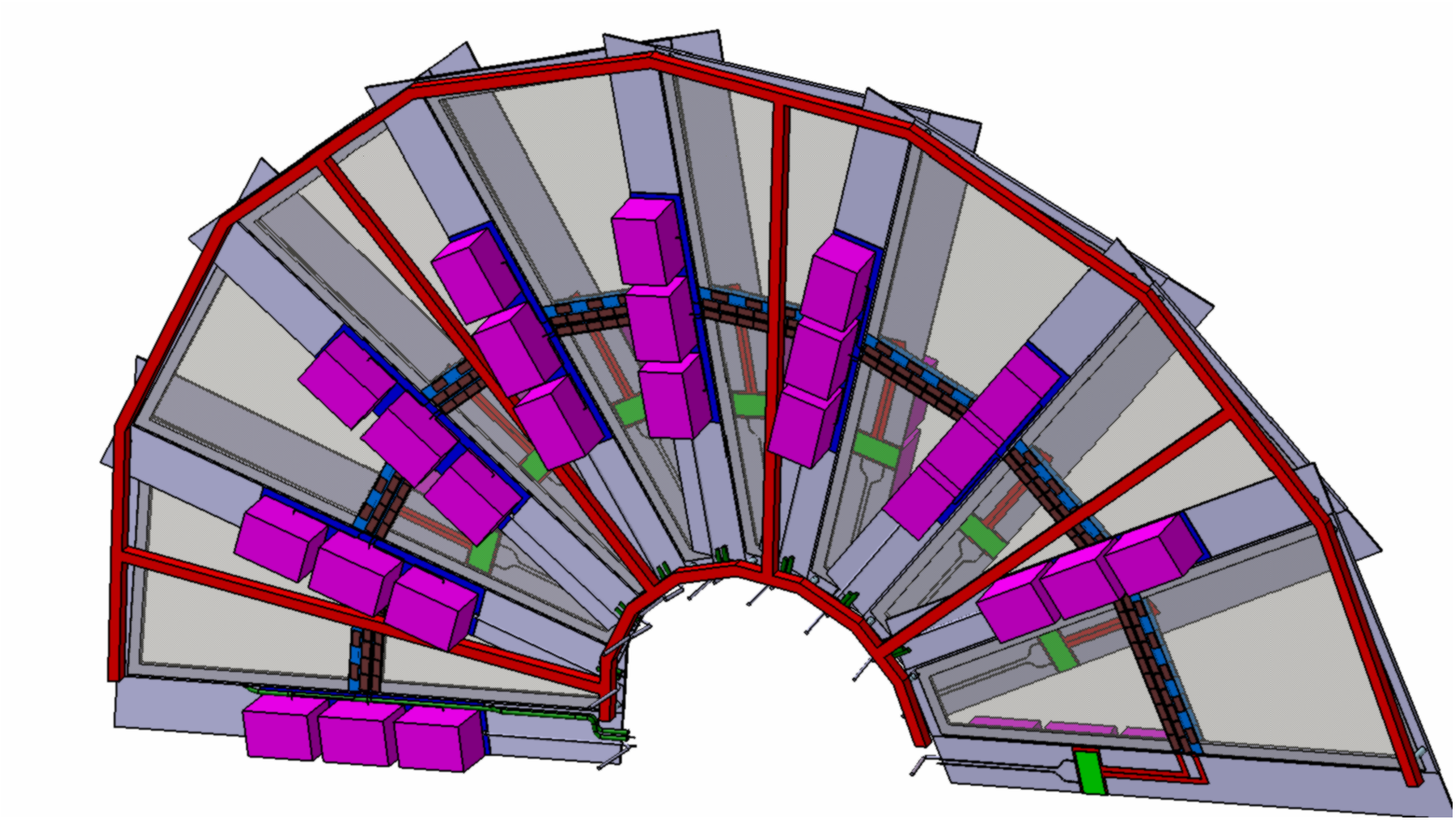
	MIDDLE PITCH									
FTD	FTD3		FTD4		FTD5		FTD6		FTD7	
	TOP	BOT	TOP	BOT	TOP	BOT	TOP	BOT	TOP	BOT
Nº STRIPS PER SENSOR	2048	1280	2048	1280	2304	1536	2304	1792	2304	1792
Nº 256 CHIPS per sensor	8	5	8	5	9	6	9	7	9	7
TOTAL Nº STRIPS	212992		212992		245760		262144		262144	
TOTAL Nº STRIPS FTD			**1196032**							



ELECTRONIC AND CABLE LAYOUT



ELECTRONIC AND CABLE LAYOUT



- DC-DC converters maybe a good solution in terms of power distribution but too much material budget (carefull study is in progress.)

Summary

– Several R&D lines in strong collaboration with other FA network members, our interest is to reinforce it.
– Belle-II appear as an ideal intermediate target for FOS technologies.
– Significant increase of R&D activity and visibility in the design of the ILD inner silicon trackers.
– Two technologies: transparent sensors and FOS sensors currently being transferred to industrial sector (aerospace and civil nuclear industry) via the INNPACTO program.