FOS monitoring for Off-beam infrastructure

AIDA 2nd Annual meeting WP9.3

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Outline

- Off-beam infrastructure: Initial proposal
- Fiber Optical Sensors (FOS) Thermo-mechanical monitor.
- Application to Belle II pixel detector.
- Summary

Initial proposal…

Functions

The main purpose of this thermo-mechanical infrastructure is the study of the mechanical behavior of such systems. To that end several cooling systems should be made available (CO_2 for active cooling systems or cooling by convection using dry gases at different temperatures and speeds). The system should be able to allow for

- studies of deformations induced by thermal cycles ,
- thermal stresses due to asymmetric thermal loads as well as
- the effect on mechanical stability of the support structures and the very thin sensors when cooling by forced convection,
- identify and anticipate possible mechanical resonant Lorentz forces induced by power cycling and control signal schemes.

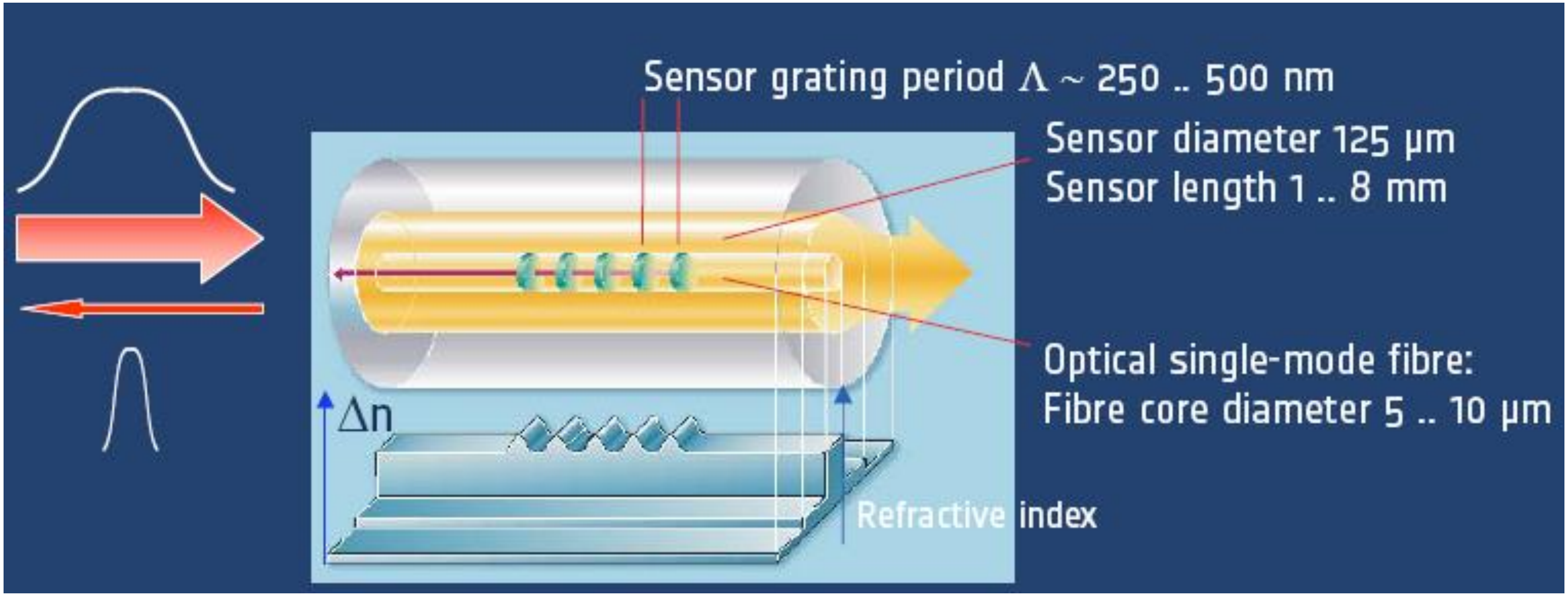
… and proponents

Subtask 9.3.2 (CEA, CNRS-IPHC, CSIC-IFIC, CSIC-IFCA, DESY, UOXF): The operation of detectors with a spatial resolution of a few microns poses very stringent requirements on the overall detector design, in particular on the support, cooling and detector services. This task foresees the development of an infrastructure that allows to evaluate the thermo-mechanical performance of fully integrated detector prototypes under a realistic power load. A set-up, consisting of the most advanced optical instruments and thermal imaging techniques, allows monitoring of minute deformations and misalignment of prototypes in an environment that closely mimics that of the experiment.

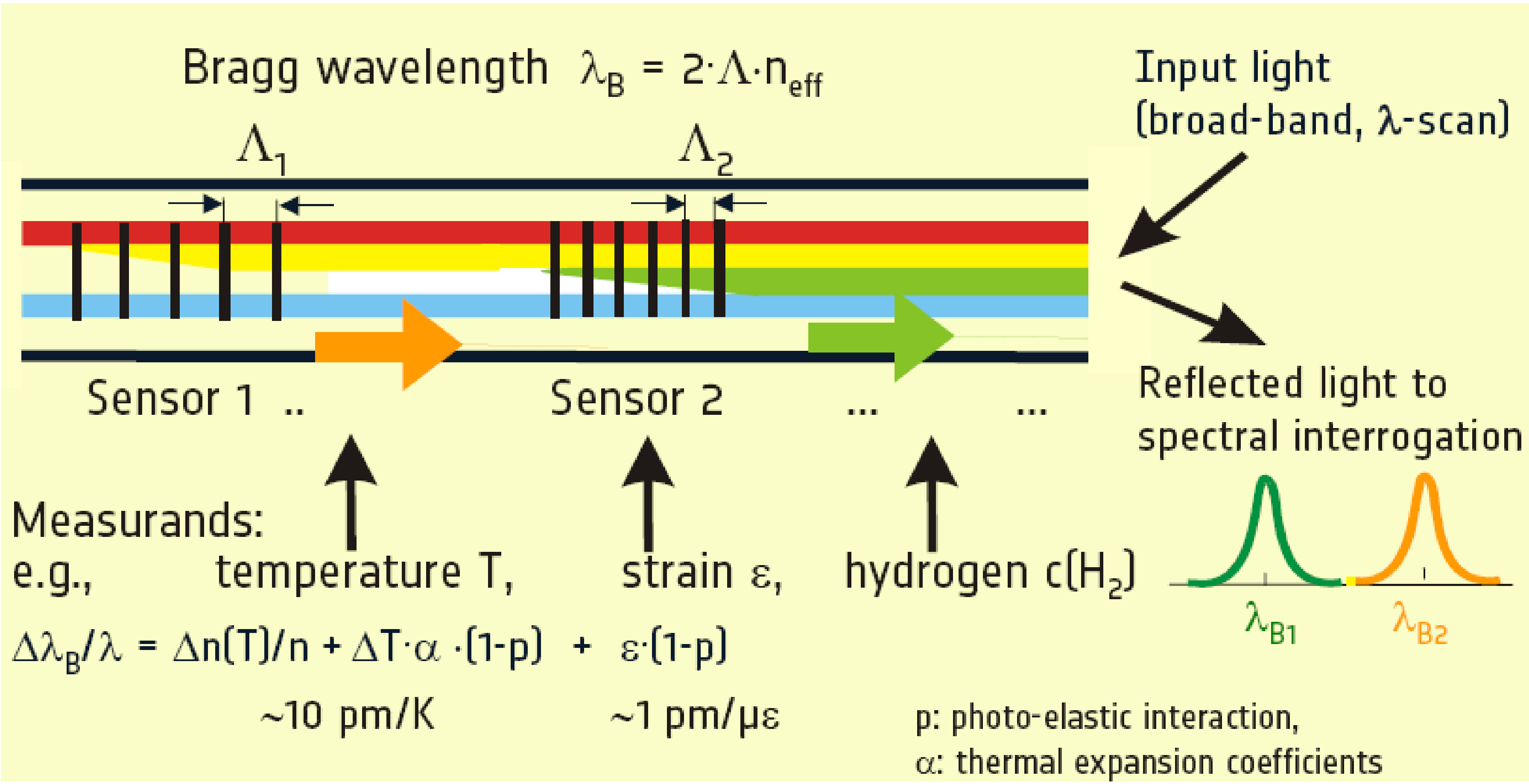
– In this talk I will report on the CSIC-IFIC and CSIC-IFCA activities on the development and commissioning of a FOS based monitor first used to assess the cooling method for the BELLE –II vertex detector

FOS 101 – FBG Strain transducer

– Keep in mind: Physically, FGB sensors have a section of an optical fiber with a length of few millimeters.



FOS 101 (2) – Multiplexing



FOS 101 (and 3) – Advantages

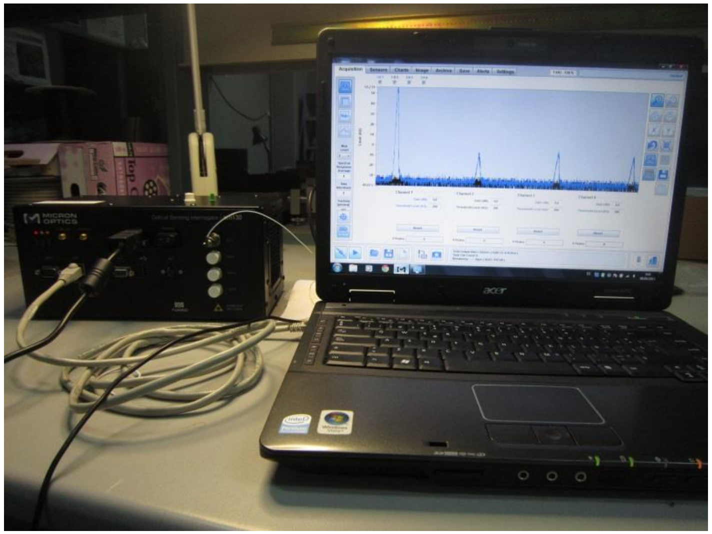
General attributes of fibre optic sensors:

- Immunity against, i.e., applicable in
  - Electro-magnetic fields, high voltage, lightning
  - Explosive or chemically aggressive + corrosive media
  - High and low temperatures
  - Nuclear / ionising radiation environment (to be specified)
- Light-weight, miniaturised, flexible; low thermal conductivity
- Non-interfering, low-loss, long-range signal transmission ("Remote Sensing")

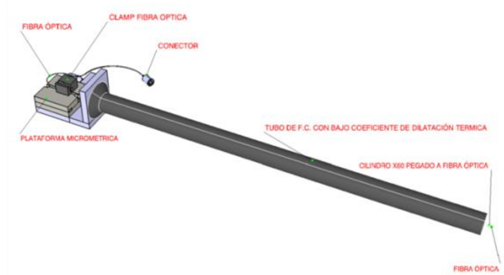
Specific FBG attributes:

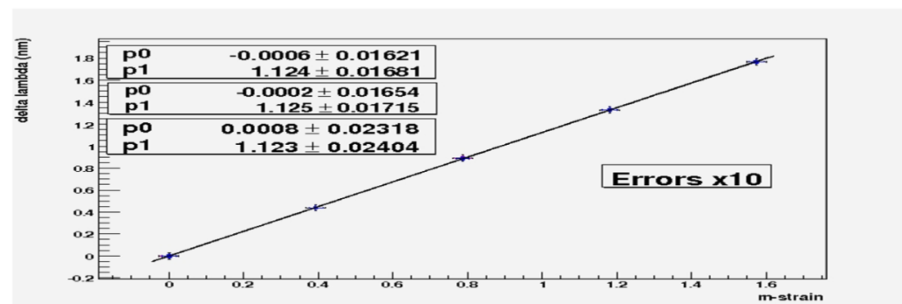
- Multiplexing capability ("Sensor Networks")
- Embedding in composite materials ("Smart Structures")
- Wavelength encoded – transferable measurement, neutral to intensity drifts
- Mass producible at reasonable cost
- Durable to high strain 5..6% ("Draw Tower Gratings", with any kind of coating)
- High and low temperatures (4 K .. 900 °C)

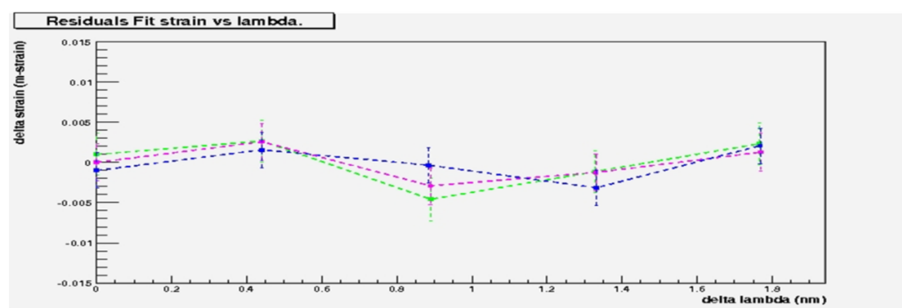
Sensors and Interrogation electronics specification and calibration



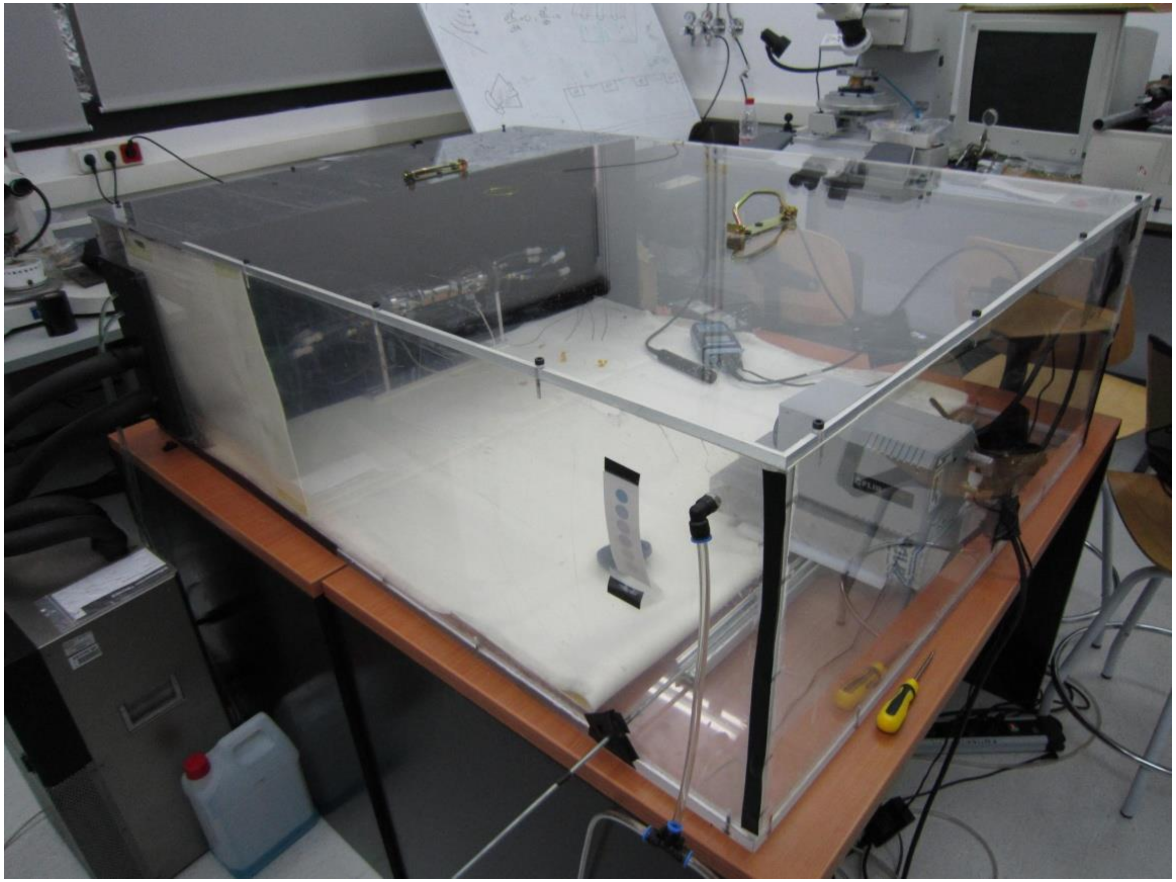
- General purpose sensors acquired and calibrated
- Interrogating electronics selected and dedicated





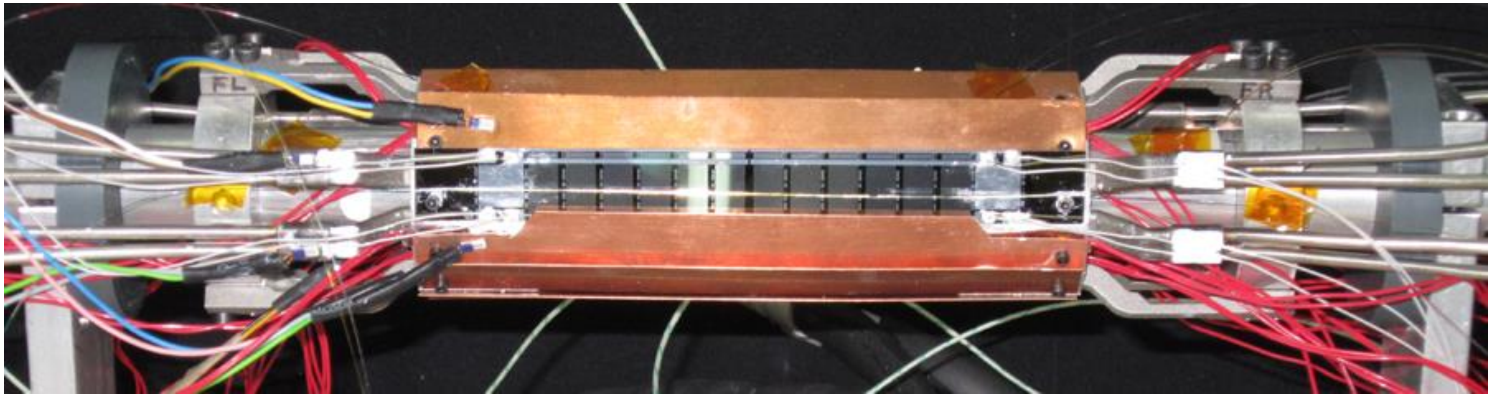


Commissioning: Belle – II PXD Thermo-mechanical Mock-up



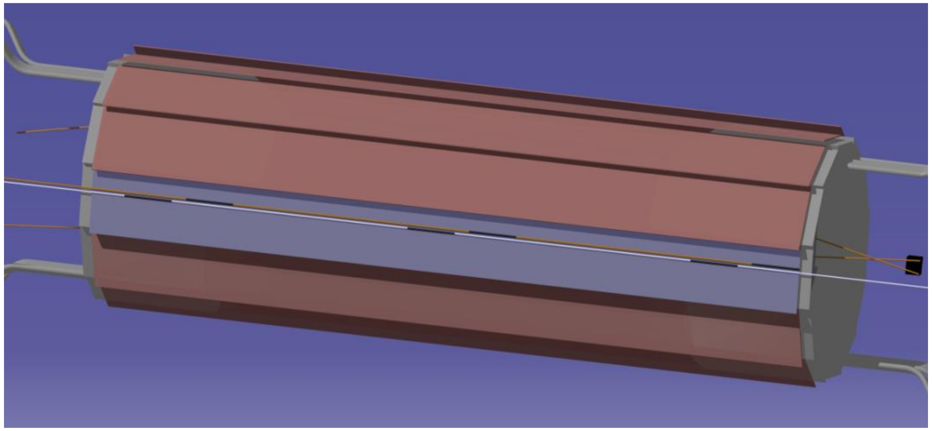
Belle – II PXD Thermal Mockup

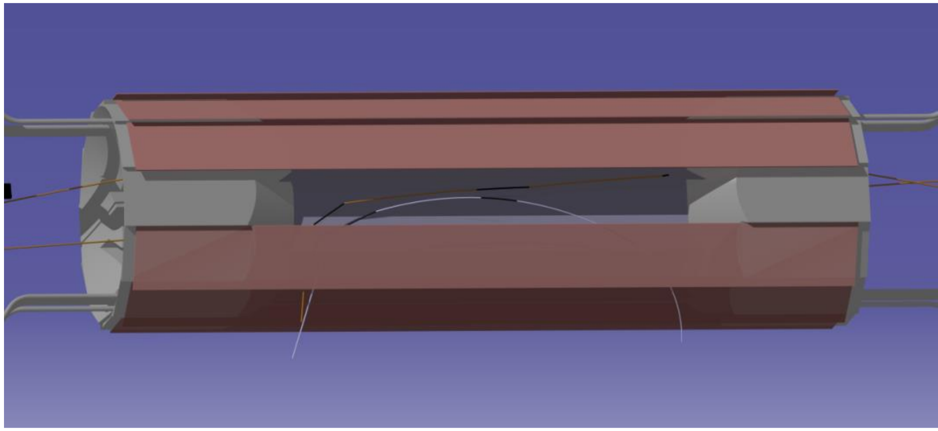
- Fully enclosed volume with Cu dummies and Si resistive sample in outer layer, using new Stainless steel CBs.



- 24 resistive heaters (6.35 mm x 12.70 mm) simulating DCD-DHP dissipation (8W per heater, 192W total)
- N_2 gas cooled down to ~0ºC through Cu coil in LN2 Dewar atmosphere
- Two phase CO_2 cooling (T~-35ºC)
  - BP cooled down to 15ºC (Liquid coolant)

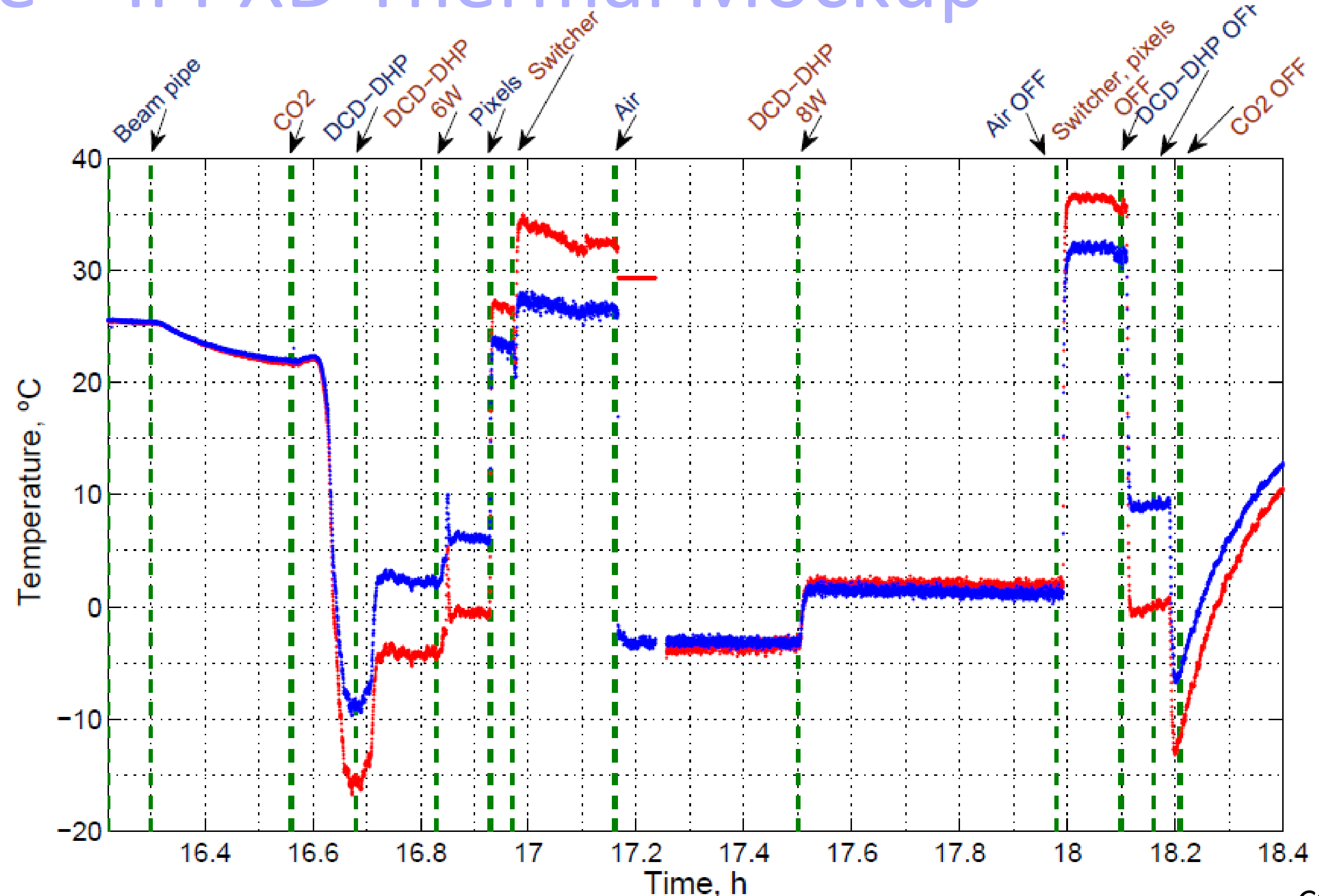
Belle – II PXD Thermal Mockup

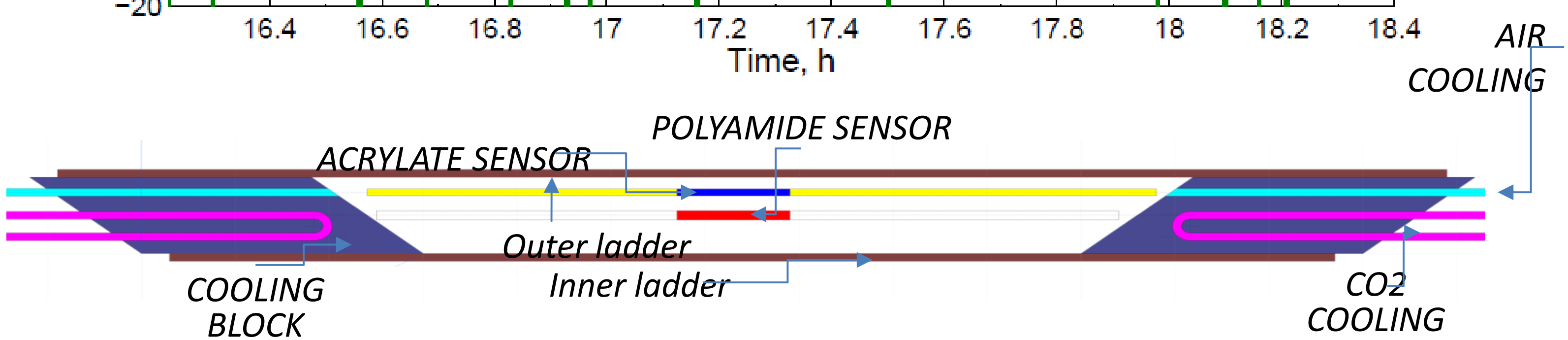




- IFCA FBG sensors (Acrylate and polyamide pairs)
  - Between BP and inner layer
  - Between inner and outer layer
  - Over outer layer
    - On Cu ladders
    - On the Si ladder

Belle – II PXD Thermal Mockup





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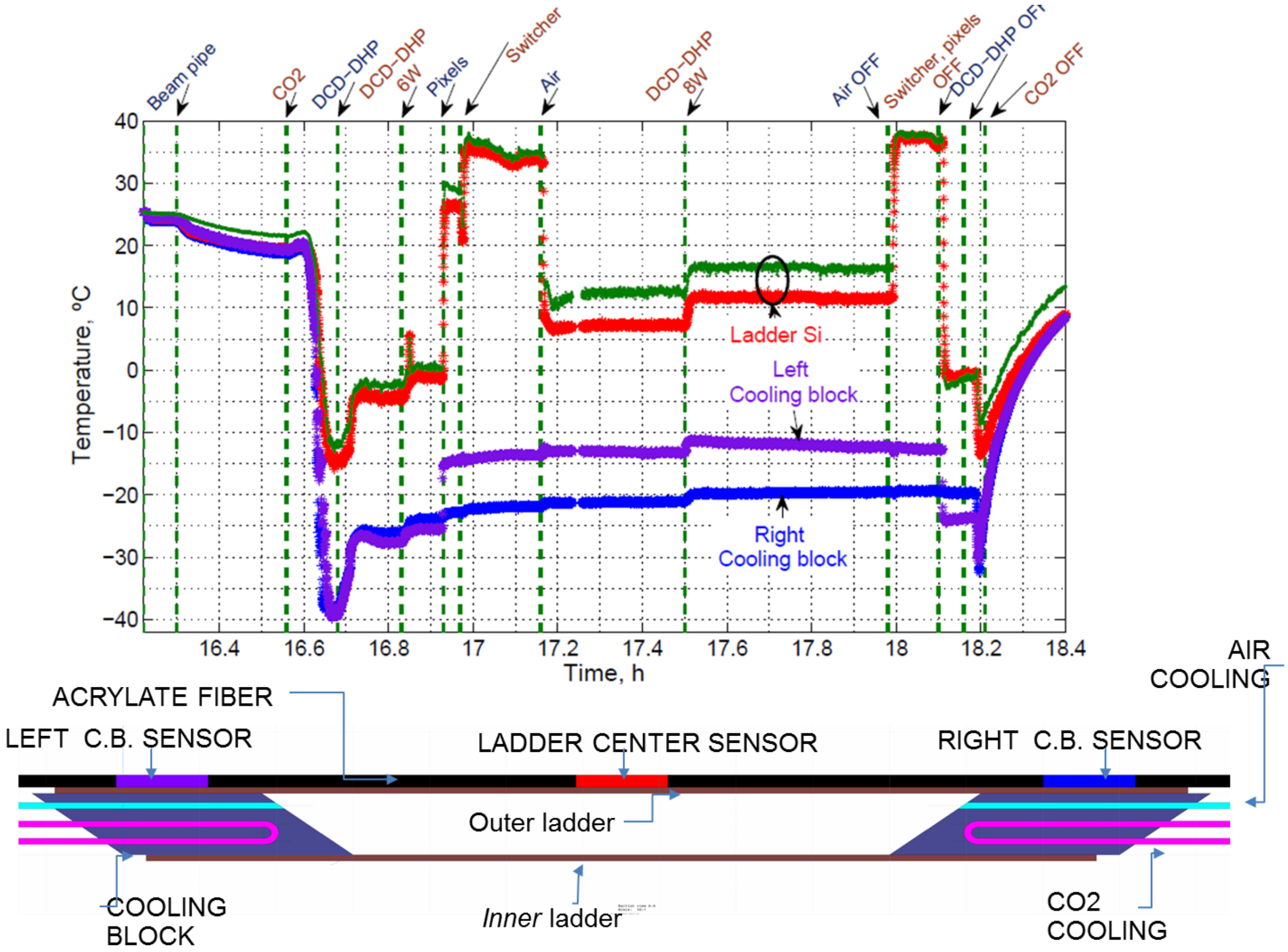
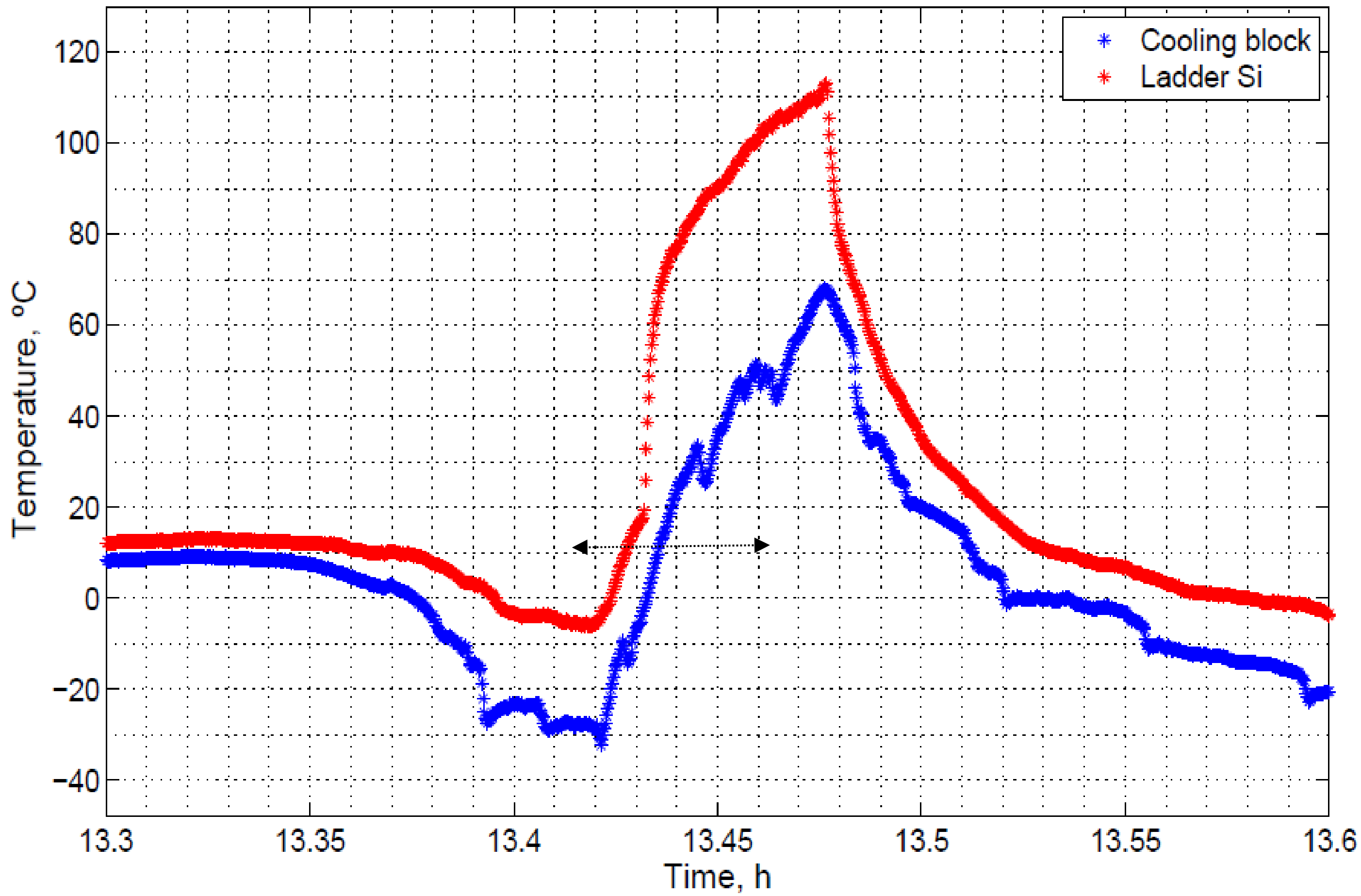
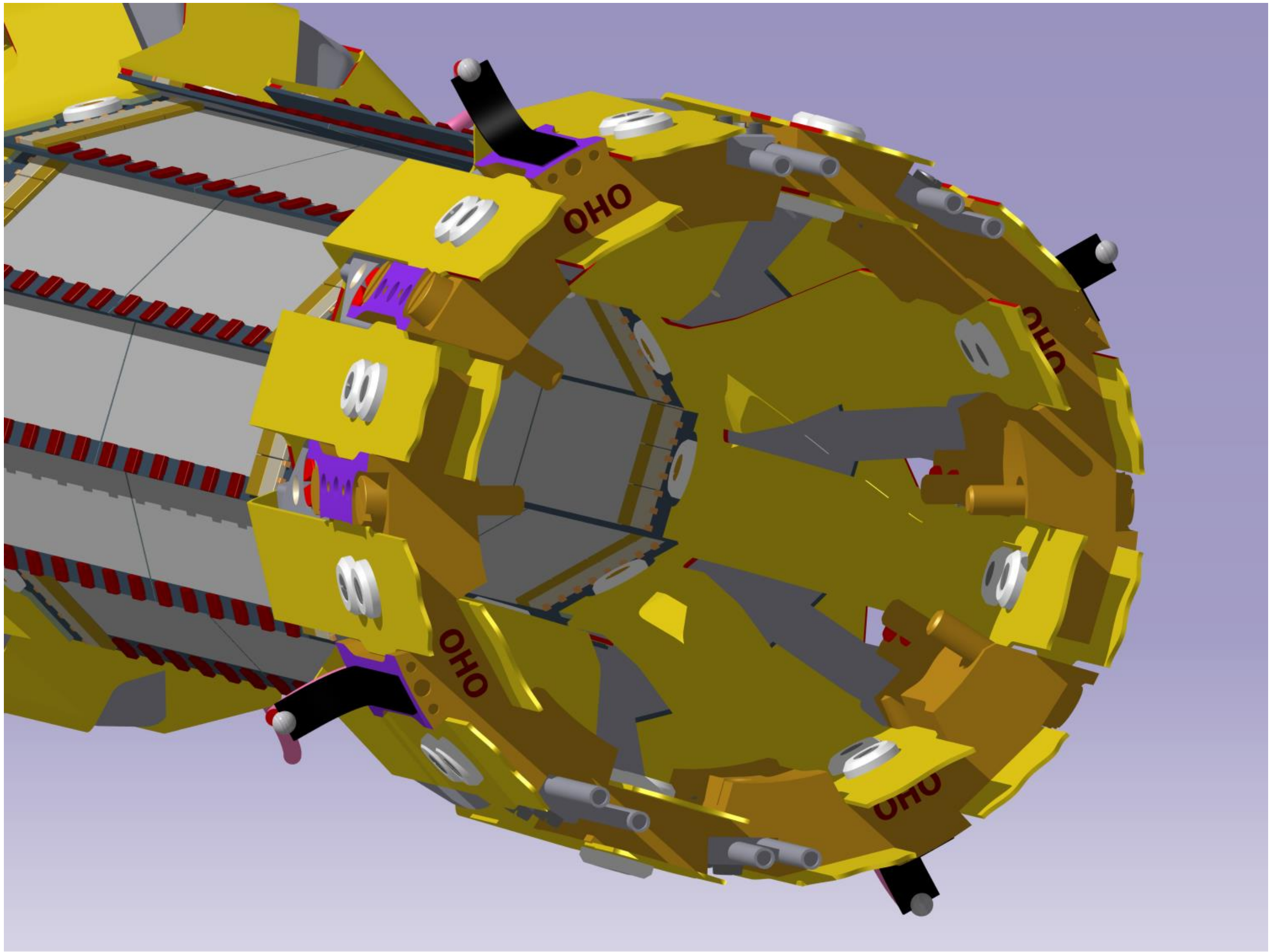


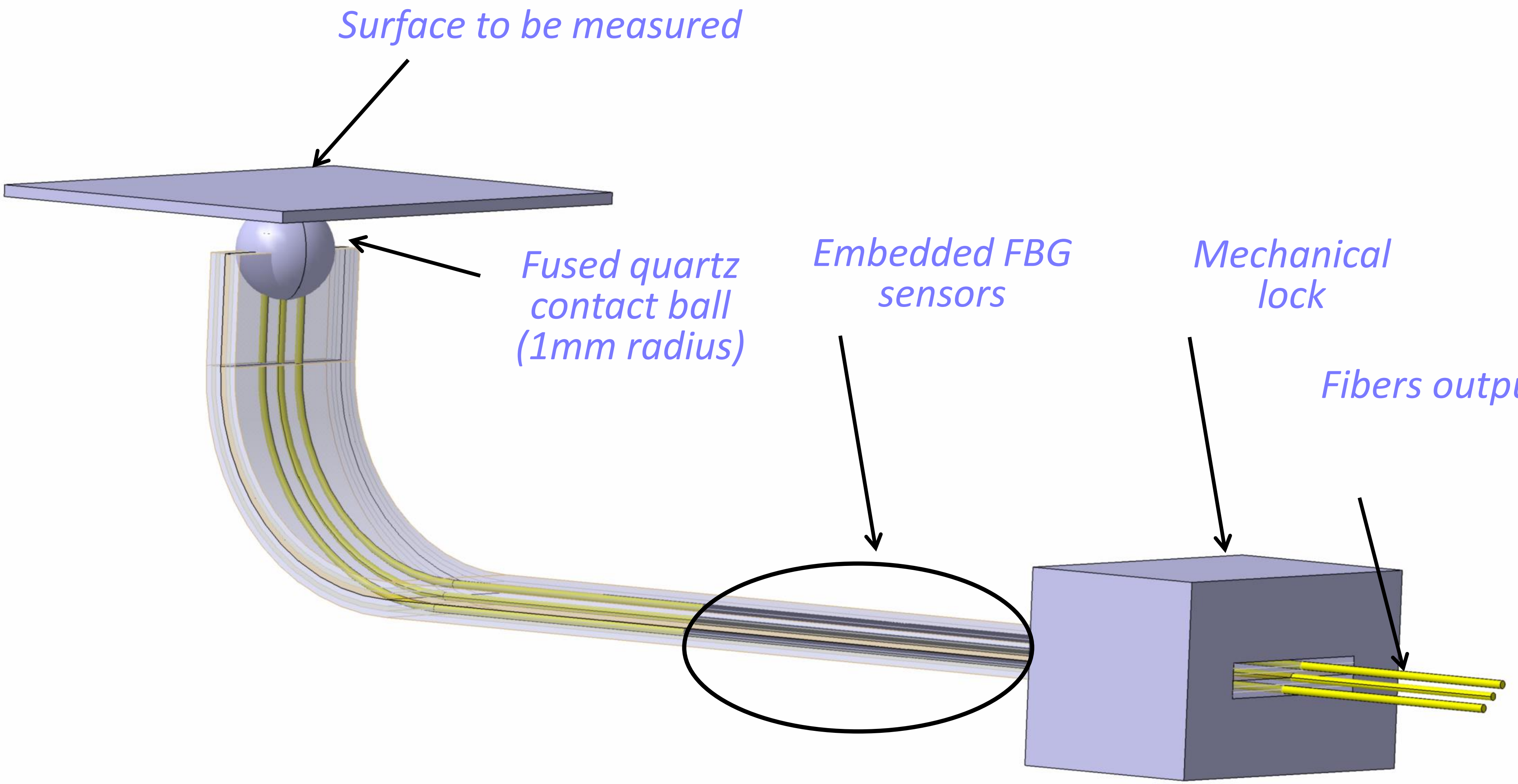
Belle – II PXD Thermal Mockup



PXD vs SVD displacement monitoring: An application specific transducer

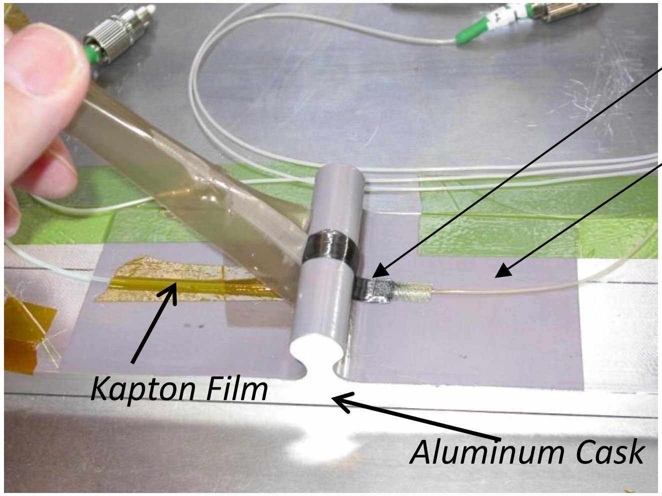


A FOS-based miniature transducer (T, ε)



Omega Shapes an L-shapes Manufacture Process

Omega Shape

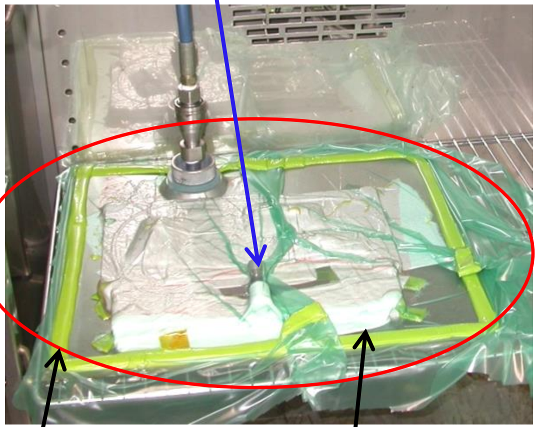


Omega CFRP layout

FO output

Aluminum support base

Omega Shape

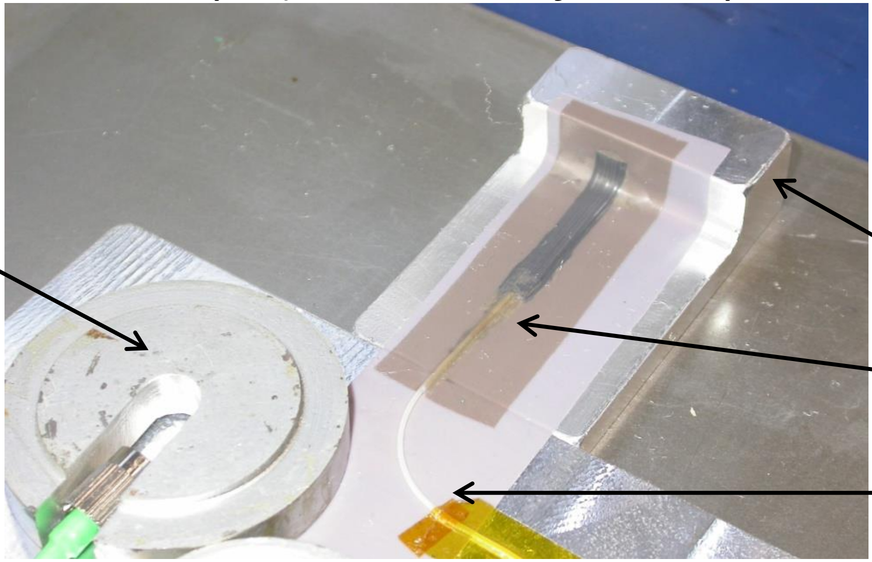


All inside an oven

Vacuum bag

L-Shape (same manufacture process)

Steel cask for connectors protection



Aluminum Cask

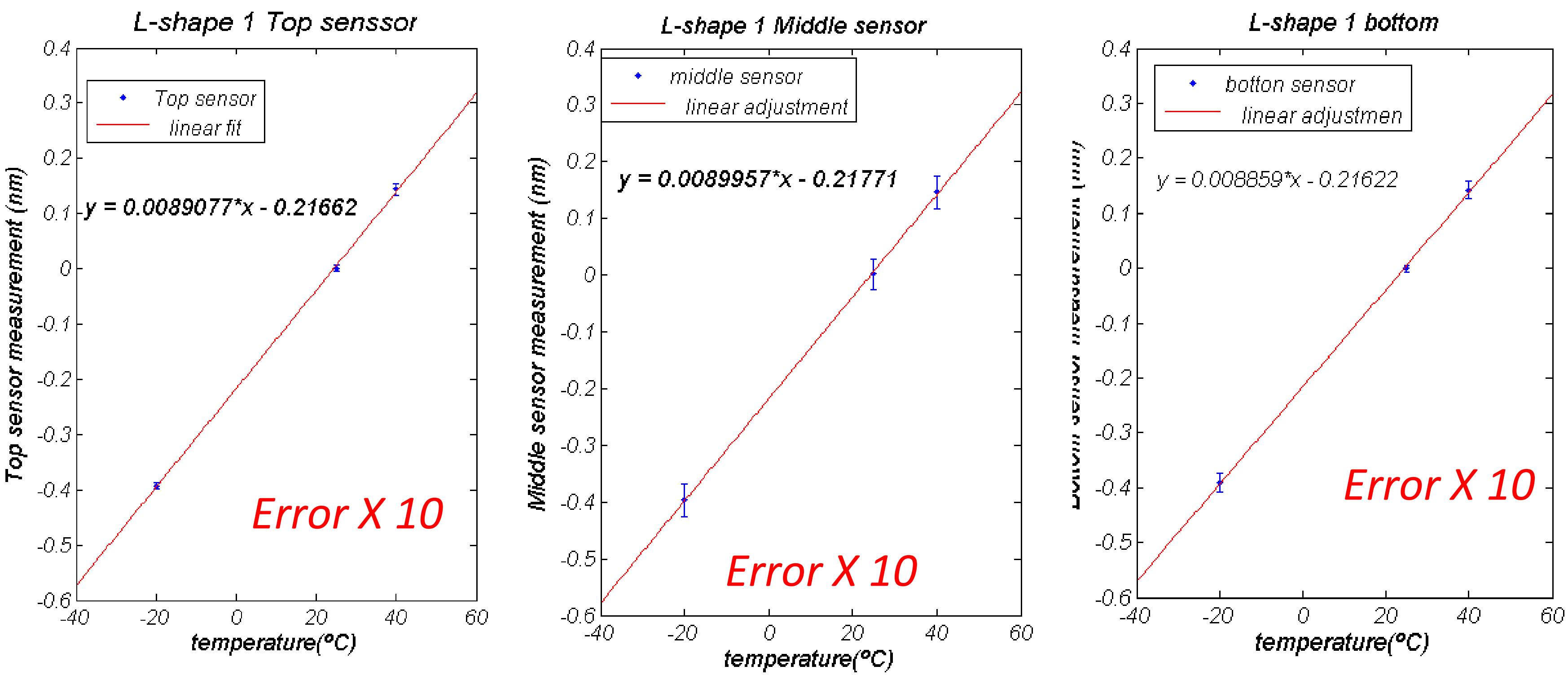
FO output

Kapton Film

Thermal calibrations and temperature compensation

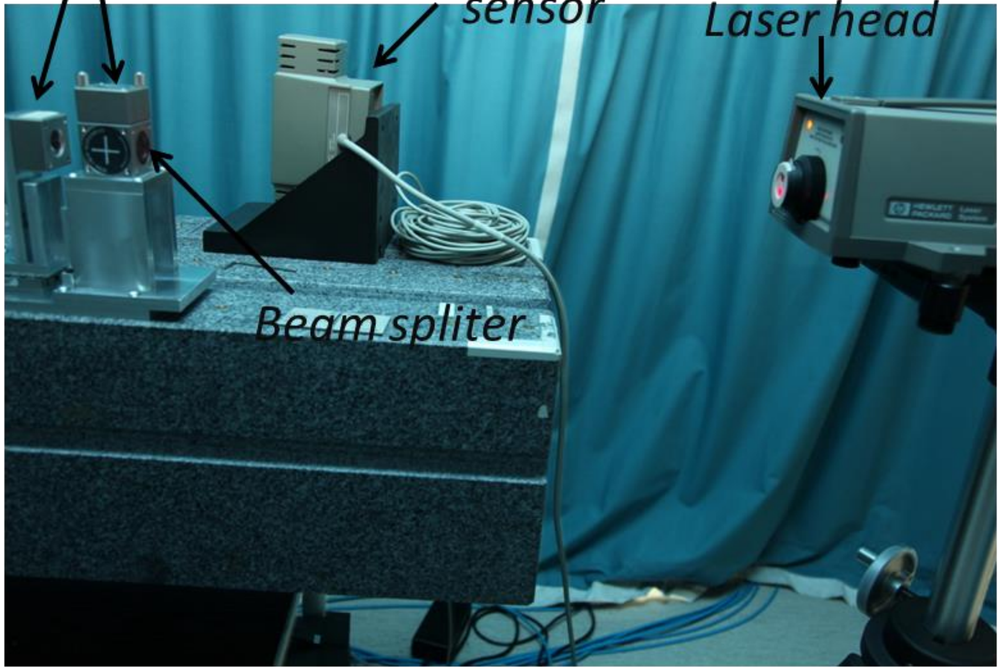
- Omega and L-shapes were calibrated using a SIKA thermocouples calibrator. They were calibrated to three different temperatures, and the calibration was repeated three times.
- The sensitivity of three sensors was constant and near the same (difference<0.6%)

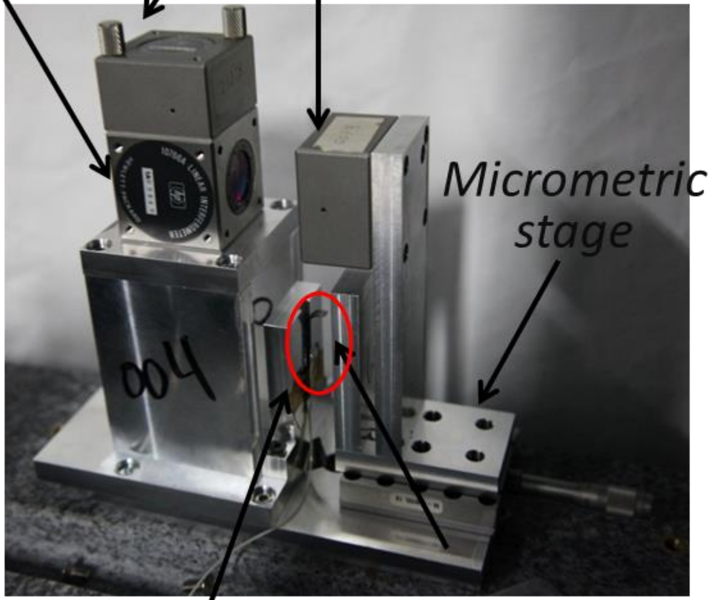
Maximum error < 3 pm (0.3 ºC)



- Trivial approach to temperature compensation with subtraction of top and bottom sensor readout

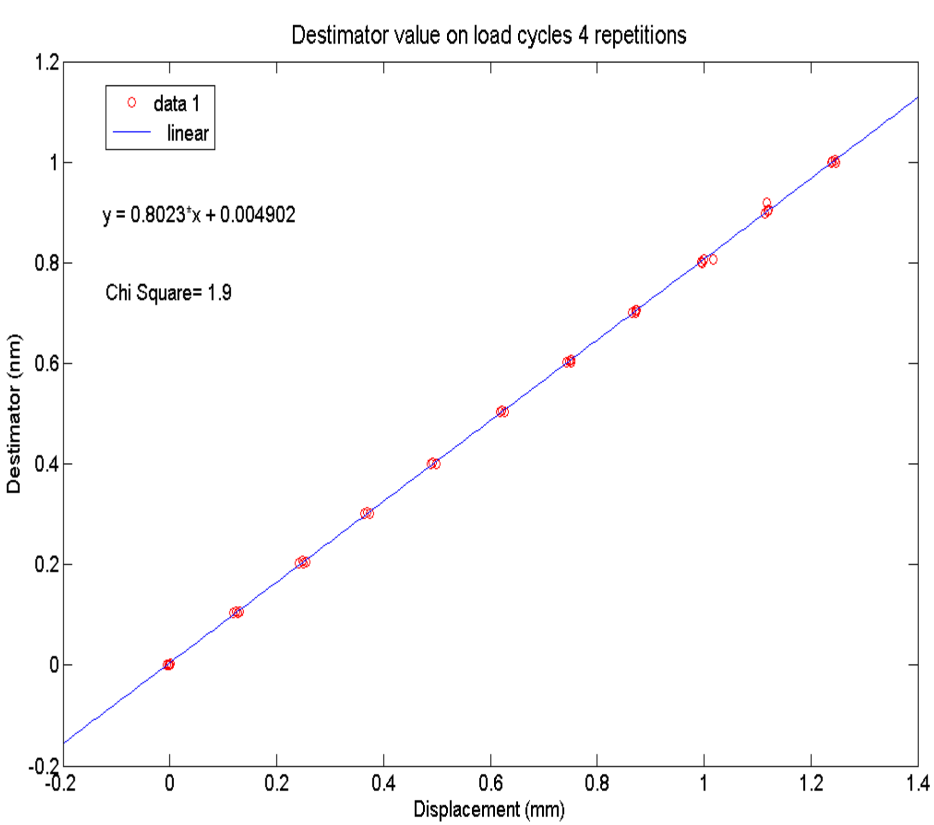
Interferometric displacement calibration

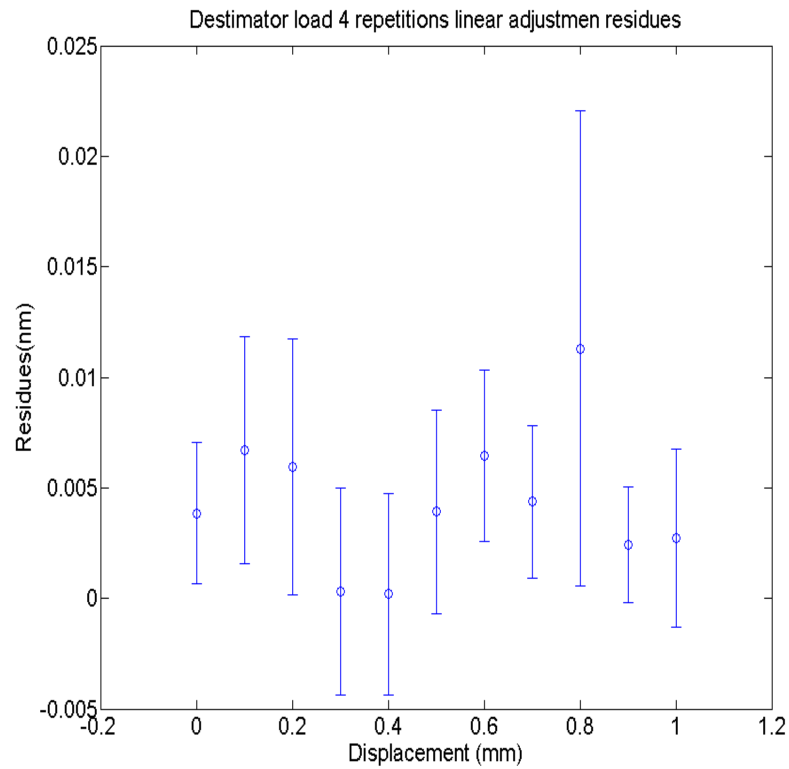




david.moya moyad@ifca.unican.es, 3rd PXD-SVD Workshop, Feb 3-6th,2013, Wetzlar. 12

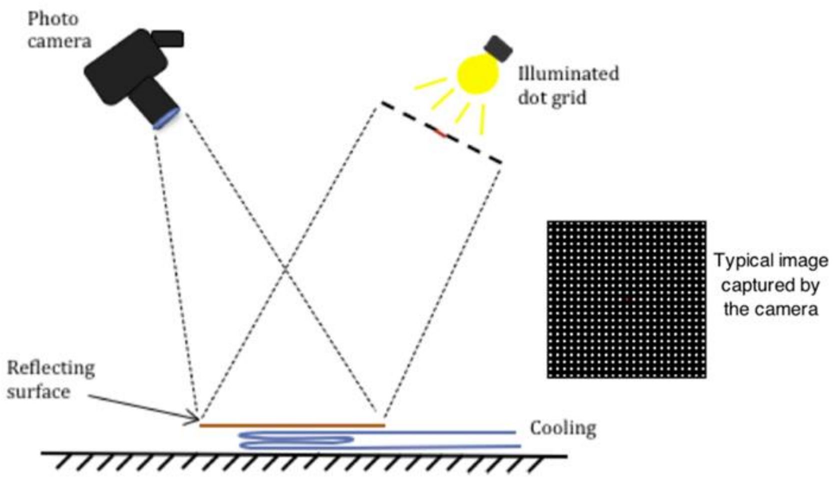
Displacement Interferometric calibration

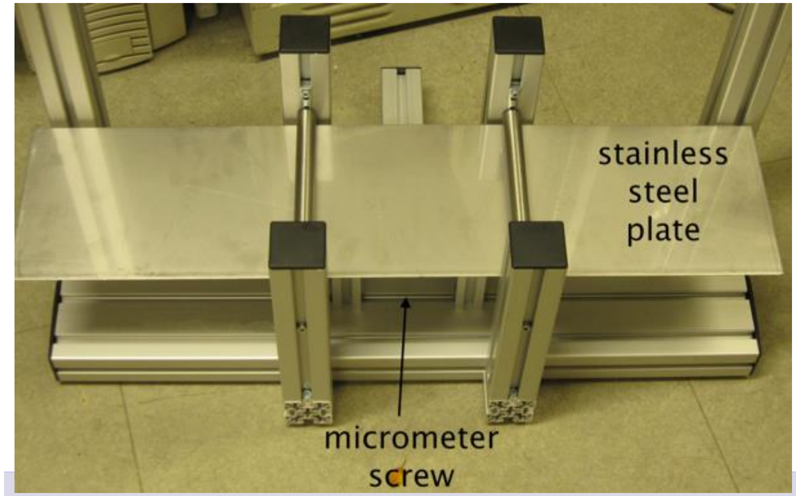




Moving to DESY - Cross calibration

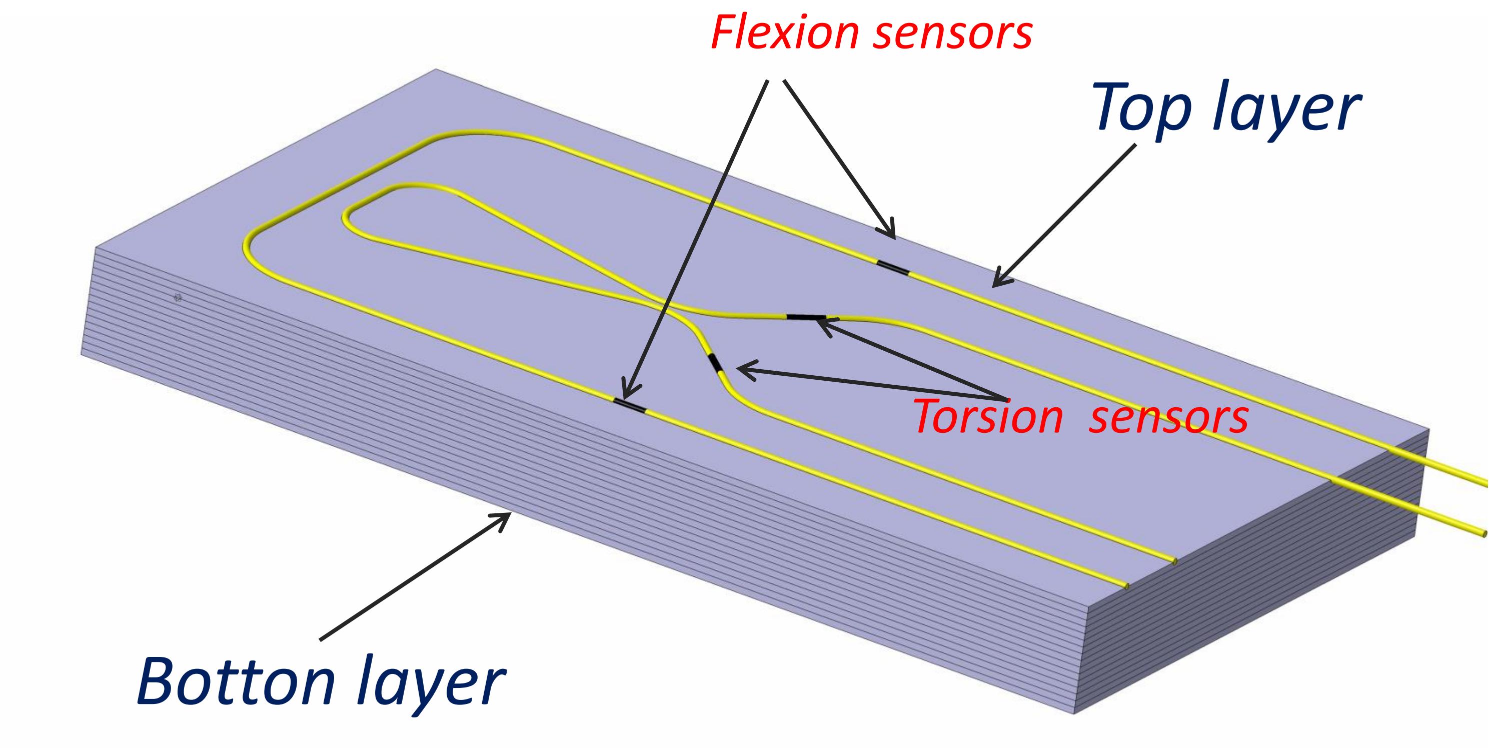
- *By the middle of this year the Aida Project Deliverable Thermo-mechanical set-up will be available at DESY to be used by all de HEP community*
  - *A displacement measurement optical system integrated*
- *Planning to have this year, an FBG sensors interrogation unit installed in this Set-Up to be used by all the community (ILD, LHC, Belle II…) to measure sensors deformation, integrated in detectors mock-ups.*
- *Our idea is to manufacture 1-2 sheets of composite material with FBG sensors embedded and compare its flexion and torsion deformation measurements with the optical displacement sensing device measurements.*





Cross calibration of plate demostrator @ DESY

- The First step is to manufacture and test this self monitoring structures
- This demonstrator is a CFRP plate with ten FBG sensors (five per side) embedded at a define position, allowing us to measure deformations under Torsion and Flexion loads, and temperature (Each sensor position optimized to measure one of these deformations).When a torsion or a flexion load is applied to the sheet, we know from simulations the expected measured value of each sensor.



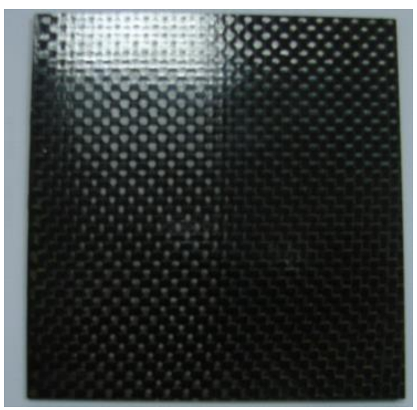
Cross calibration of plate demostrator @ DESY

- *On September 2012 some samples manufactured at INTA (with different carbon fiber and glass fiber materials and finishing) where sent to study the reflectivity.*

Glass fiber fabric

Unidirectiona carbon fiber

Fabric carbon fiber



Polished Unidirectionalcarbon fiber

- *None of this samples was optimal to be measured with the DESY optical system.*

Cross calibration of plate demostrator @ DESY

- *New samples were sent in December 2012 to see if they could be mesured with the optical system. This time samples were coated (alluminun , coopper layers and gel coat).*

Gel Coat

Aluminum layer

Tesa

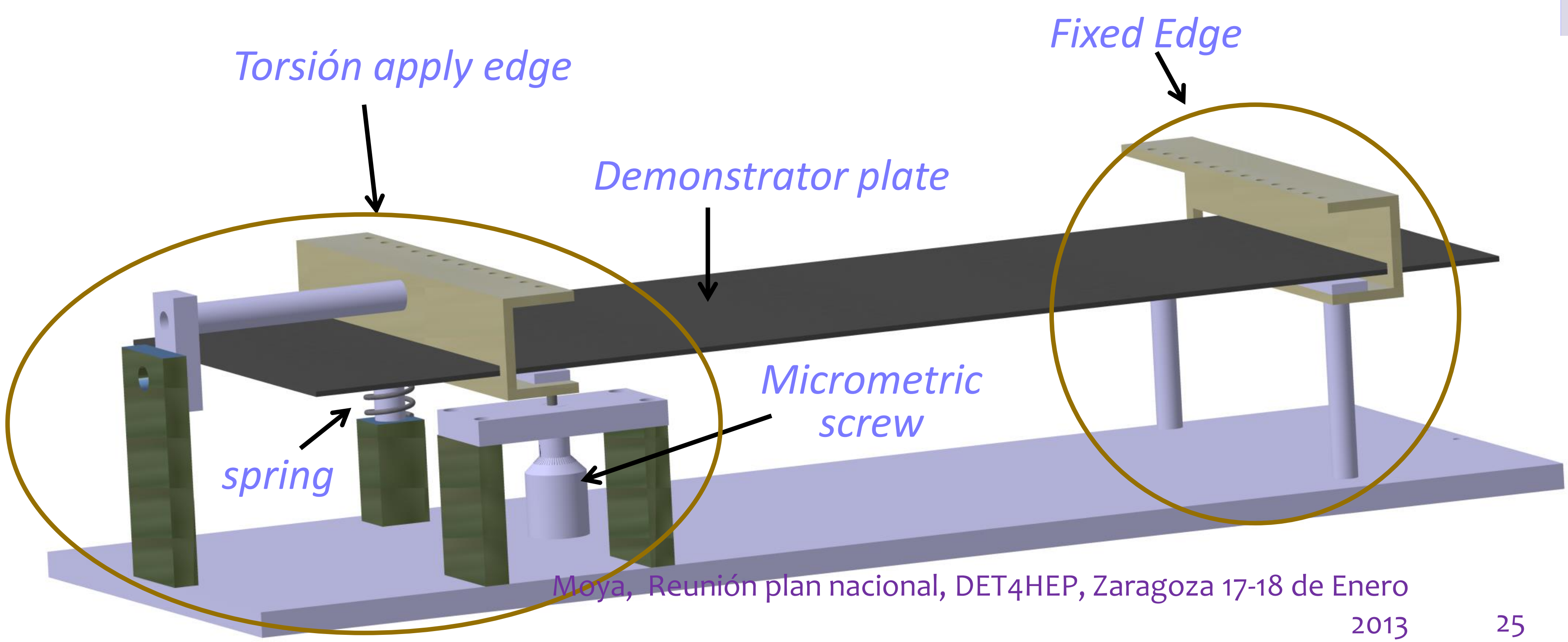
Cooper

- *The optical system was not able to see optical spots in these surfaces. Studying new possible surface coating.*

New approach for cross calibration

– Next steps.

- Manufacture a first technological demonstrator .
- Design and manufacture torsion and flexion calibration systems
- Calibrate the technological demonstrator using profilometer (< 1 um accuracy) or CMM (< 10 μm accuracy).
- Continue studying surface finishing for DESY thermo-mechanical set-up crosscheck



Summary

IFCA

- A FOS-based structural and environmental monitor system as part of the AIDA's offline infrastructure is already available.
- First application cases: Belle-II thermal mockup, displacement sensors, cross –calibration optical setup at DESY.
- System ready for installation at DESY to be part of the Belle-II integrated test beam.
- Welcome other interested groups to workout a dedicated solution to their monitoring needs.

THANK YOU