Silicon Tracking and Vertexing
Summary

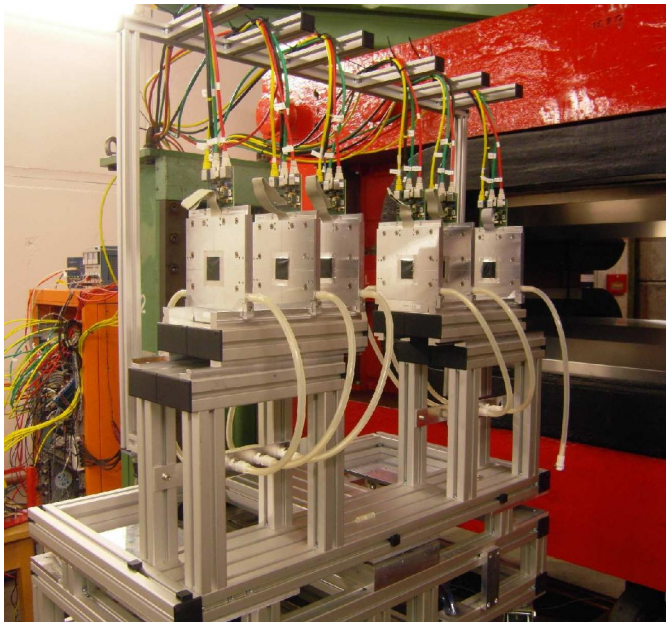
Vertexing & Tracking (R&D 7)

- ✔ Tuesday (R&D 7): Sensors + Simulation
  - ➔ FPCCD sensors + ASICS: Y. Sugimoto, E. Kato
  - ➔ DEPFET: L. Andricek + G. Timón
  - ➔ CMOS Pixel detectors: M. Winter
  - ➔ Chronopixels: N. Sinev
  - ➔ Novel 2D silicon strip detector: F. Muñoz
  - ➔ Geiger Mode APDs: E. Vilella
  - ➔ Large Area Si Tracking: A. Savoy-Navarro
  - ➔ Tracking at UCSC/SCIPP: B. Schumm
  - ➔ Background studies for Vertex and Forward Tracking: J. Trenado.
  - ➔ Tracking performance in CLIC_ILD + CLIC_SiD: M. Hauschild
- ✔ Thursday (R&D 7): Engineering, system issues
  - ➔ Single and Double-sided ladders for ILD vertex: M. Winter
  - ➔ CLIC Vertex detector Mechanics: W. Cooper
  - ➔ Air cooling studies for Vertex Detectors: A. Oyanguren
  - ➔ Structural and Environmental Monitoring of Tracker and Vertex sensors using FOS: D. Moya

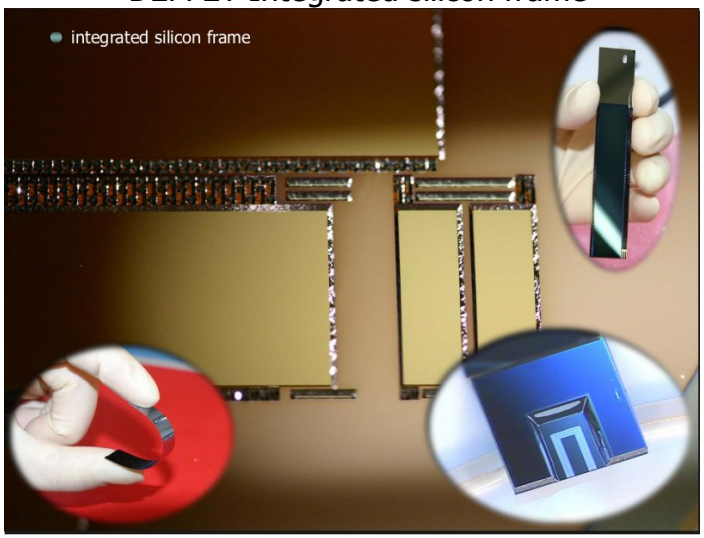
Very impressive work. Impossible to make a summary in 12 minutes.
A personal selection...

Vertex Sensors

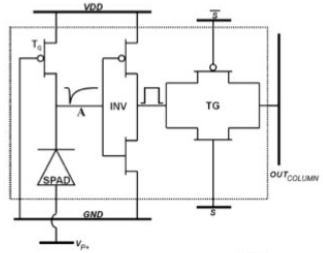
CMOS Pixel Sensors established architecture. EUDET Beam Telescope

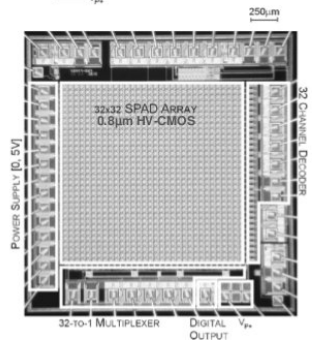


DEPFET Integrated silicon frame



- ✔ 2 sensor types struggling to be ready for starting experiments
  - ➔ (CPS @ Star 2012 and
  - ➔ DEPFET @ Belle II 2015)
  - ➔ Both have been successfully tested with thin sensors (50 um)
- ✔ FPCCD getting ready with some problems with pixel sizes of 6um, but performing well with bigger pixel sizes
  - ➔ Thinning down to 50um OK on prototypes
- ✔ Chronopixels had problems with first prototype. Second prototype should be ready by end of 2011
- ✔ Still some room for "innovation"
  - ➔ Geiger APDs





Tracking

- ✔ Single sided AC-coupled Si micro strips with Resistive coupling

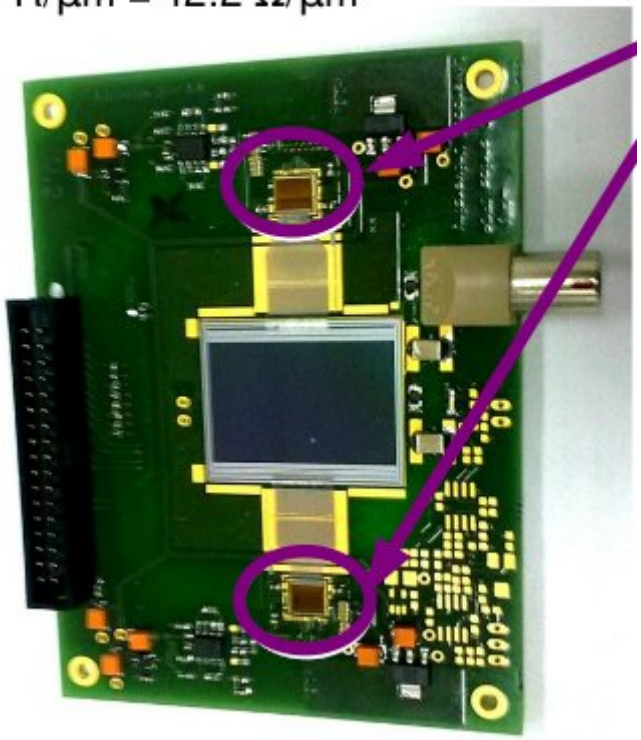
2 different prototypes

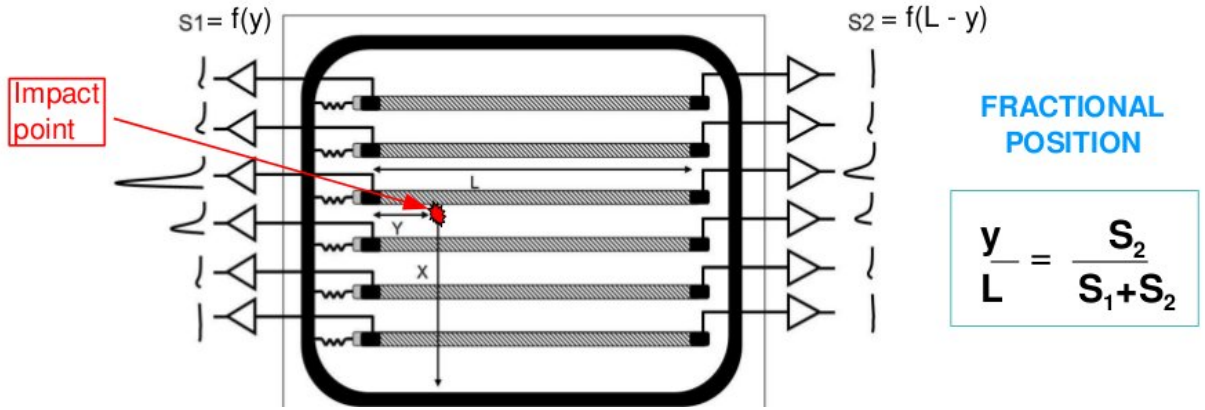
Implant & readout pitch =80 µm

Electrode resistance:

R/µm = 2.8 Ω/µm

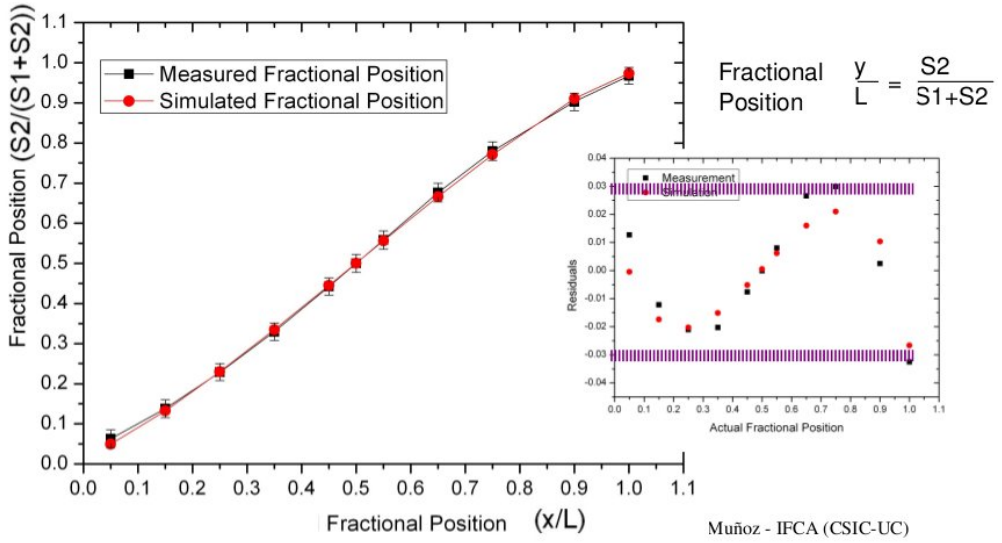
R/µm = 12.2 Ω/µm





FRACTIONAL POSITION

$$\frac{y}{L} = \frac{S_2}{S_1+S_2}$$



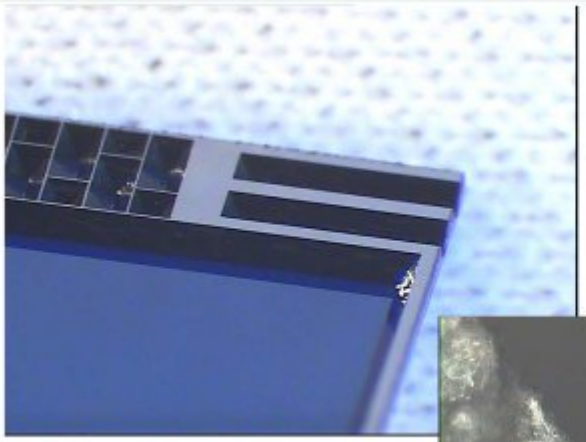
Fractional Position $\frac{y}{L} = \frac{S2}{S1+S2}$

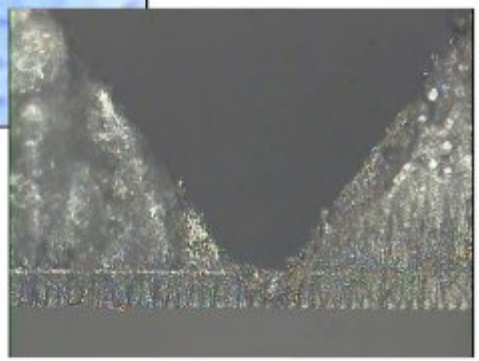
Muñoz - IFCA (CSIC-UC)

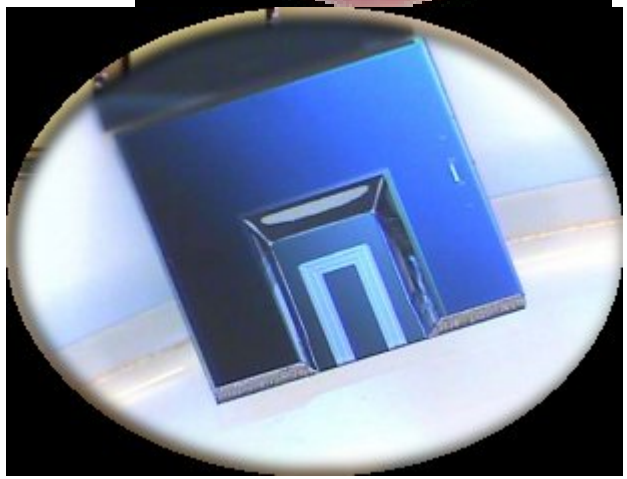
Local supports: DEPFET

- ✔ DEPFET: **does not need it** since it has the integrated silicon frame
- ✔ Can join 2 "half" ladders

- ❑ butt-joint between two half-ladders
- ❑ reinforced with 3 ceramic inserts
- ❑ 2x300μm dead area per ladder
- ❑ mechanical tests → remarkably robust!!
- ❑ bowing: up to 1 mm sagitta (over 10 cm)
- ❑ tension: 40 to 60 N, then the Si broke

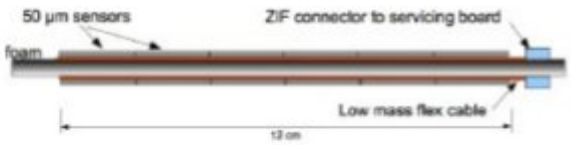


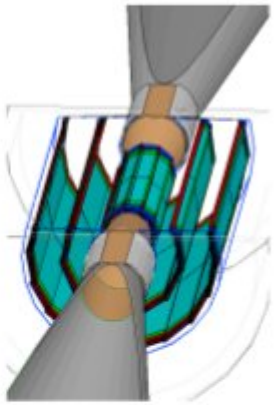




Local Supports: CMOS Pixel Sensors

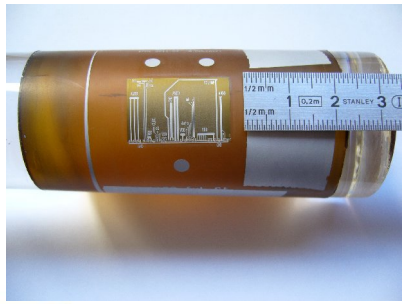
- **Ultra-light double-sided ladder : PLUME project**
  - ✗ Pixelised Ladder using Ultra-light Material Embedding
  - ✗ Objectives :
    - ➔ demonstrate feasibility of 2-sided ladder (0.3 % X0) for the ILD vertex detector by 2012 (DBD)
    - ➔ evaluate benefits of 2-sided concept : σ_{sp}, redundancy, alignment, shallow angle pointing, elongated⊕square pixels
  - ✗ Collaboration : Bristol - DESY - Oxford – Strasbourg

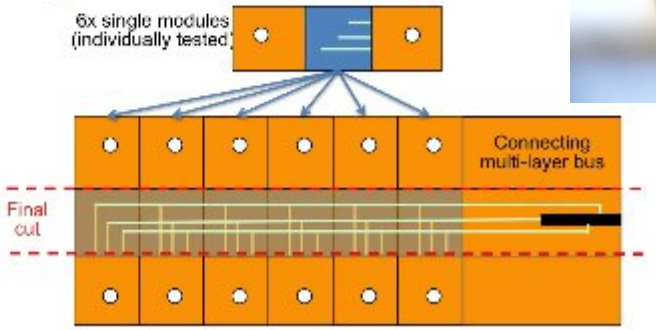




2 Functional ladders produced. Tests show that noise is as single sensors.

- **Unsupported single-sided ladder : SERNWIETE project**
  - ✗ SEnsor Row Neatly Wrapped In an Extra-Thin Envelope
  - ✗ Objectives :
    - ➔ demonstrate feasibility of unsupported concept (≤0.15 % X0)
    - ➔ for the ILD vertex detector by 2012 (DBD)
    - ➔ evaluate thermo-mechanical properties : system integration, curved supports
  - ✗ Context : EU project Had. Phys. 2 (coll. with Univ. Frankfurt & CERN)





Vertex mechanics

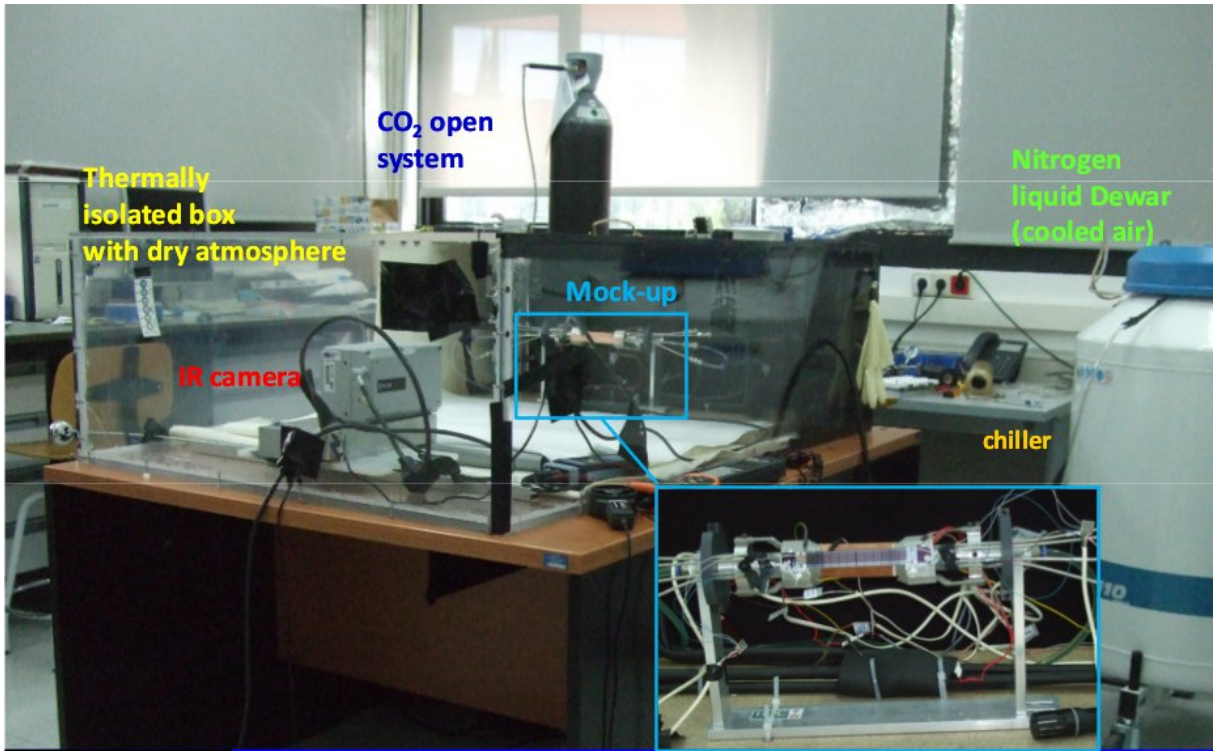
- ✔ Still nothing defined from endplates (barrel, let alone endcaps) to the outside world
  - ➔ No service routing
  - ➔ No location of patch panels
  - ➔ .....
- ✔ A talk of CLIC Vtx mechanics reminded us issues still to be done and highlighted the studies already done.

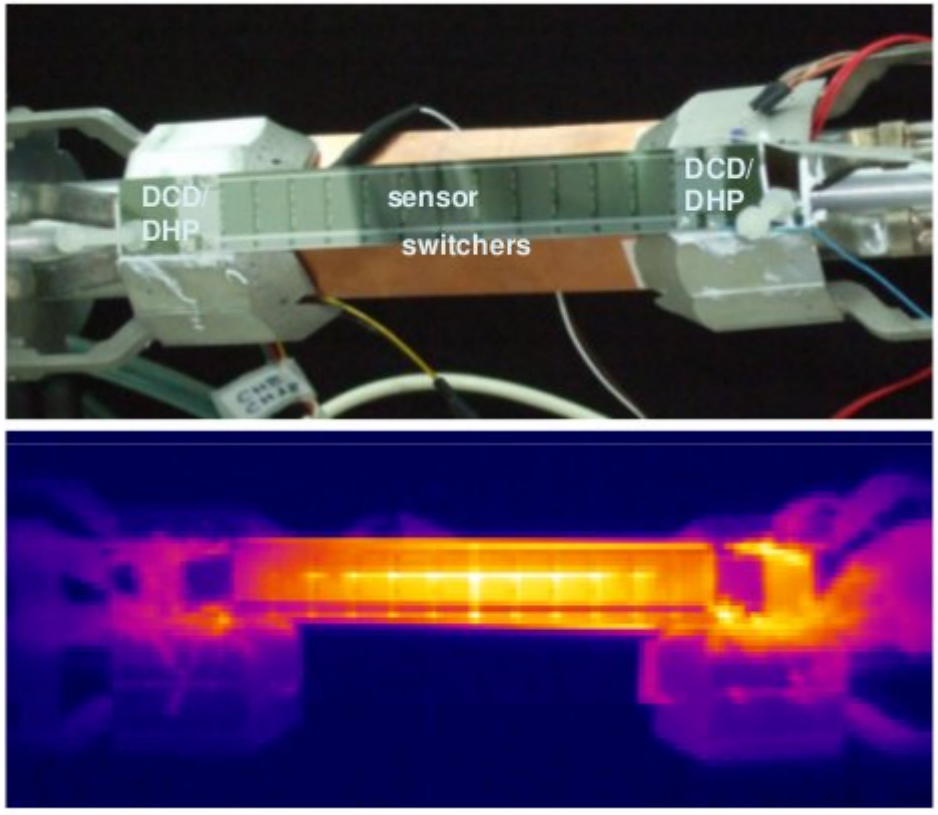
Considerations

- At least twelve factors should be considered in the vertex detector mechanical design:
  - Vertex detector geometry
  - Integration with the beam pipe
  - Integration with the tracker and other sub-detectors
  - Ease of fabrication and assembly
  - Sensor tiling
  - Precision of assembly
  - Stability of support
  - Heat removal
  - Material contributions
  - Power delivery
  - Cabling
  - Servicing
- Only a few of these considerations will be discussed in this talk.
- However, linkages exist among many of them and should not be forgotten or neglected.

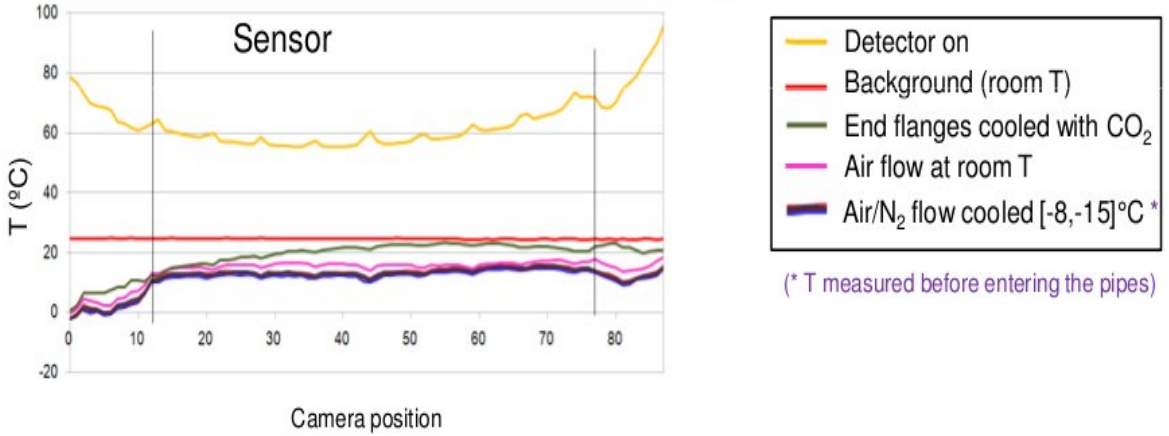
Air cooling

- ✔ Test made with thin DEPFET modules in Belle II "configuration"
  - ➔ End supports cooled with CO2
  - ➔ Cold air flows through channels in supports
- ✔ Message valid for ILC/CLIC:
  - ➔ Convection helps. Do not need very high mass flows: just movement.
  - ➔ How to cool down the air and bring it to the system
- ✔ To be done: vibrations





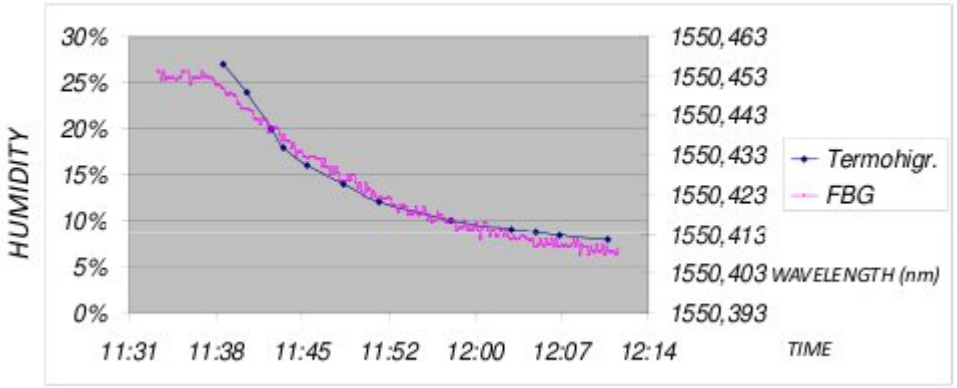
- Sensor region (P~0.5 W x 2): (corrected emmisivity)



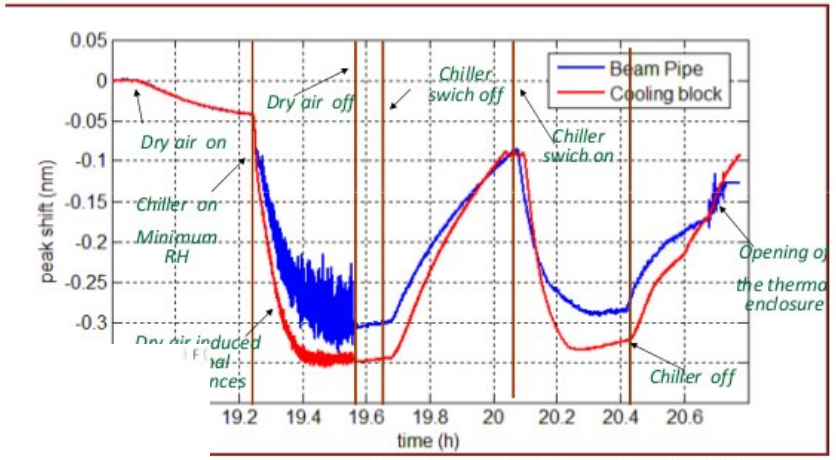
Structural & Environmental monitoring

- ✔ Fiber Optic Sensors an interesting monitoring tool
- ✔ Tests made at previous setup give encouraging results

■ Humidity measurement

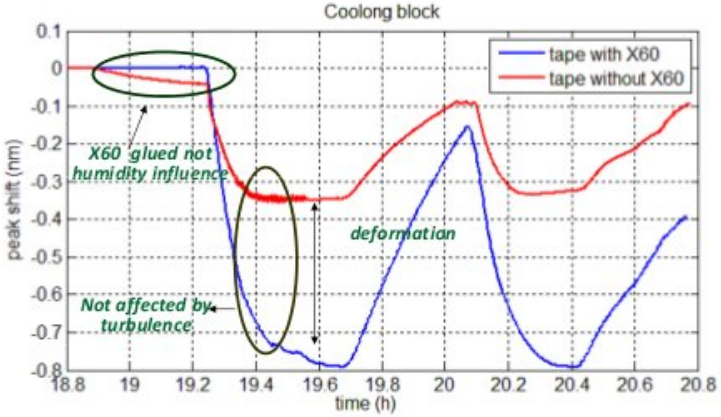


■ Temperature measurement



D.Moya, Tracking-Vertex session, Granada Sept. 29th 2010

■ Strain Measurement



Conclusions

- ✔ A personal selection of highlights shown.
- ✔ They give an idea of the impressive work made towards a real system.
- ✔ The fact that some Vtx technologies are getting ready for other experiments helps in analyzing the details and problems we may find "beyond the sensor"
- ✔ All these efforts are supported by simulation work which has not been show here (see the talks at the R&D 7 sessions)