INTERNATIONAL WORKSHOP
ON FUTURE LINEAR COLLIDERS

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Air cooling for Vertex Detectors

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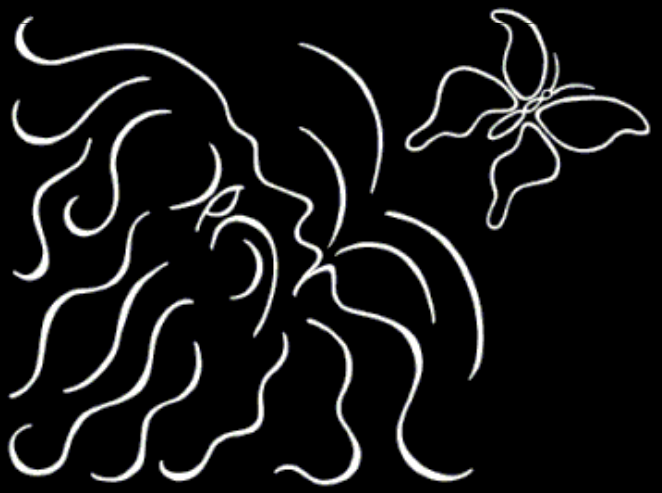


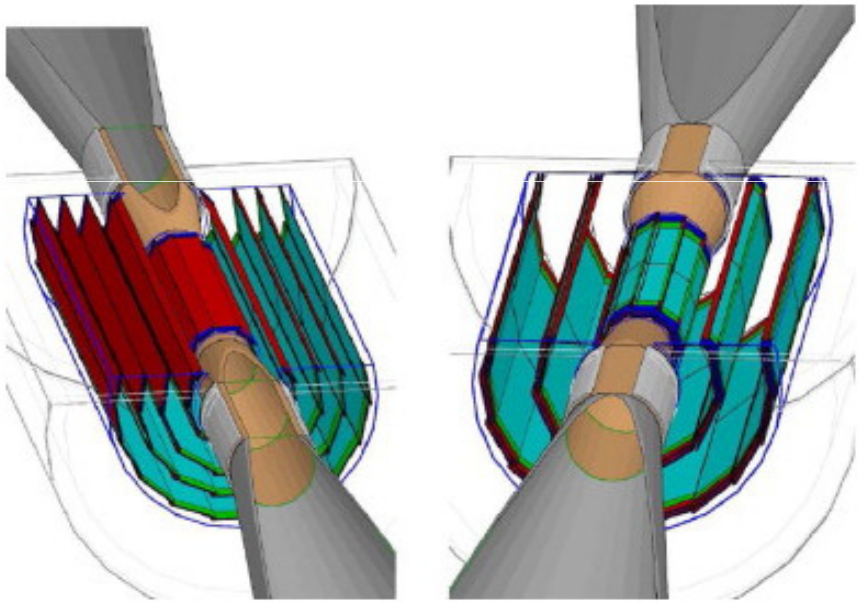
Outline

- Introduction
- PXD Mock-up for Belle-II
- Air flow cooling
- Conclusions
- Prospects

Introduction

- Vertex Detector requirements for Future Linear Colliders:

→ High point resolution (< 5 μm)
→ Low material budget (X_0~0.3%)
→ High radiation tolerance (~kRad/year)
→ Fast integration time (25-100 μs)
→ Low occupancy (<1%)
→ Low power consumption (~mW/cm^2)



→Proper mechanical design, support and cooling is key for achieving low material budget and due power dissipation

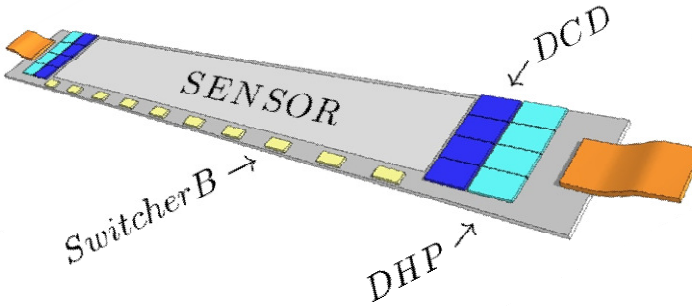
PXD Mock-up

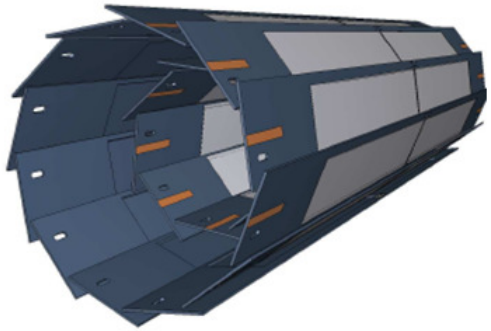
- Purpose:

Test the mechanical design and cooling for the PXD detector at Belle-II (DEPFET sensors, remind Laci's talk on Tu. R&D7)

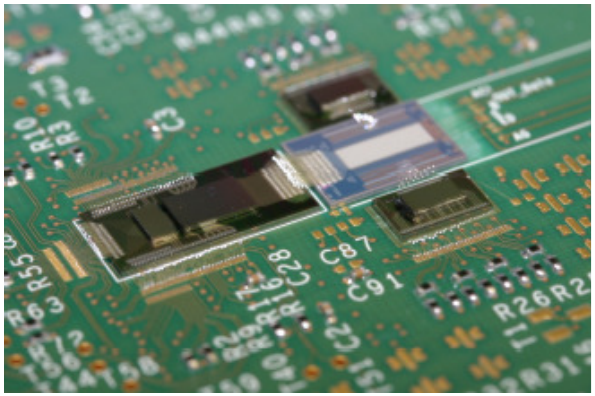
BELLE-II: 2 layers with 8 (inner) + 12 (outer) ladders (r=14,22mm)

ILC: 5 layers with 10/11/12/16/20 ladders (r=15 - 60mm)





Prototype DEPFET pixel sensor and readout

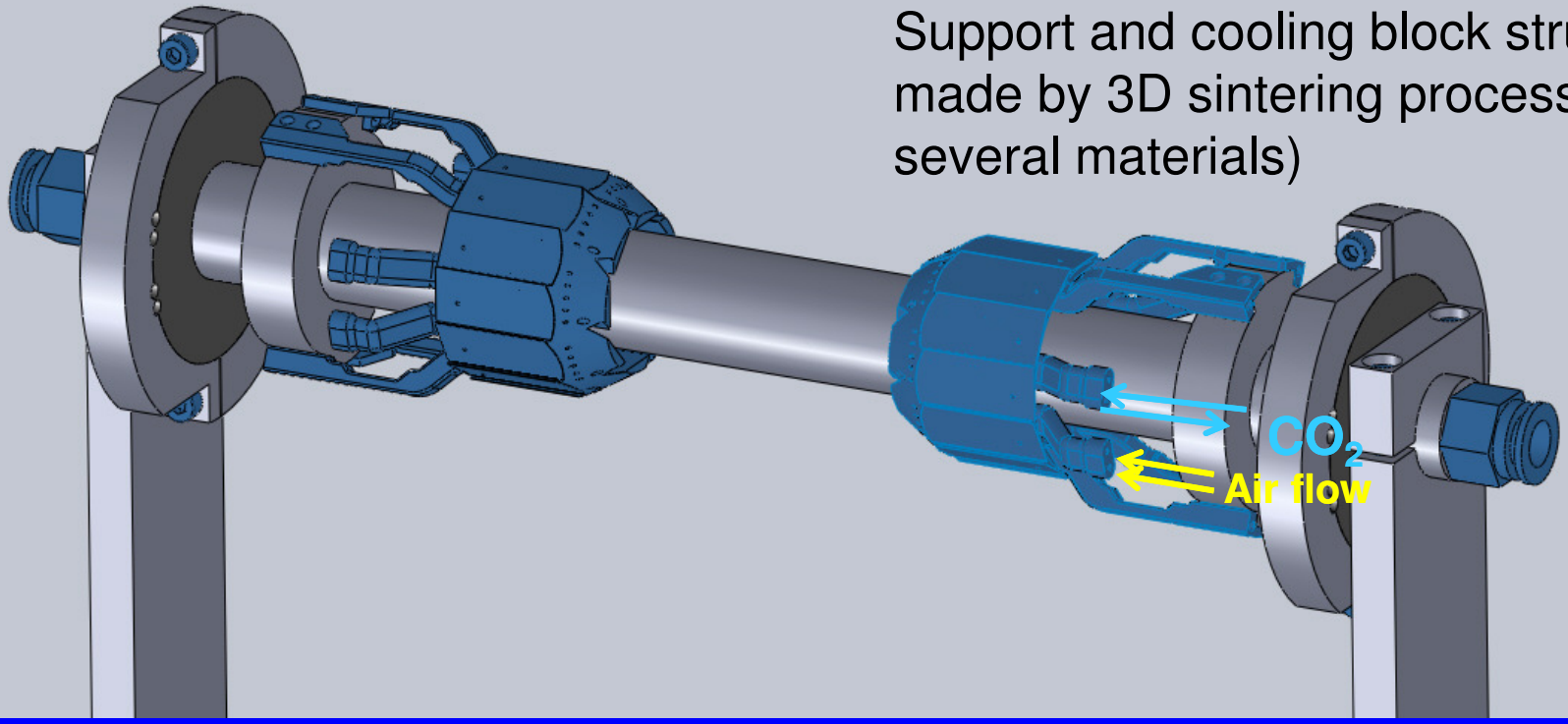


- PXD @ Belle-II vs ILC:

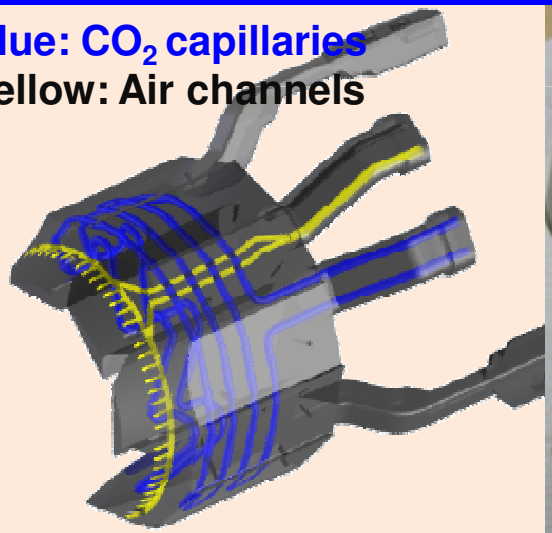
	Belle-II	ILC
Point resolution	10 μm	5 μm
Material budget	~ 0.1% X_0	~ 0.1% X_0
Radiation tolerance	>1 MRad/year	<100 kRad/year
Frame time	10 μs	25-100 μs
Occupancy	0.4 hits/μm²/s	0.13 hits/μm²/s
Power consumption	18 W/ladder (360W entire detector)	5W entire detector (duty cycle 1:200)

PXD Mock-up

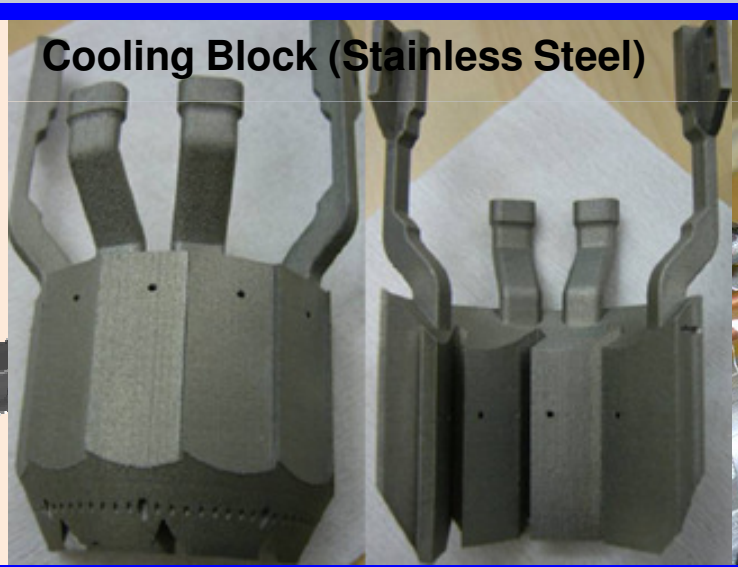
Support and cooling block structures made by 3D sintering process (testing several materials)



Blue: CO_2 capillaries
Yellow: Air channels



Cooling Block (Stainless Steel)



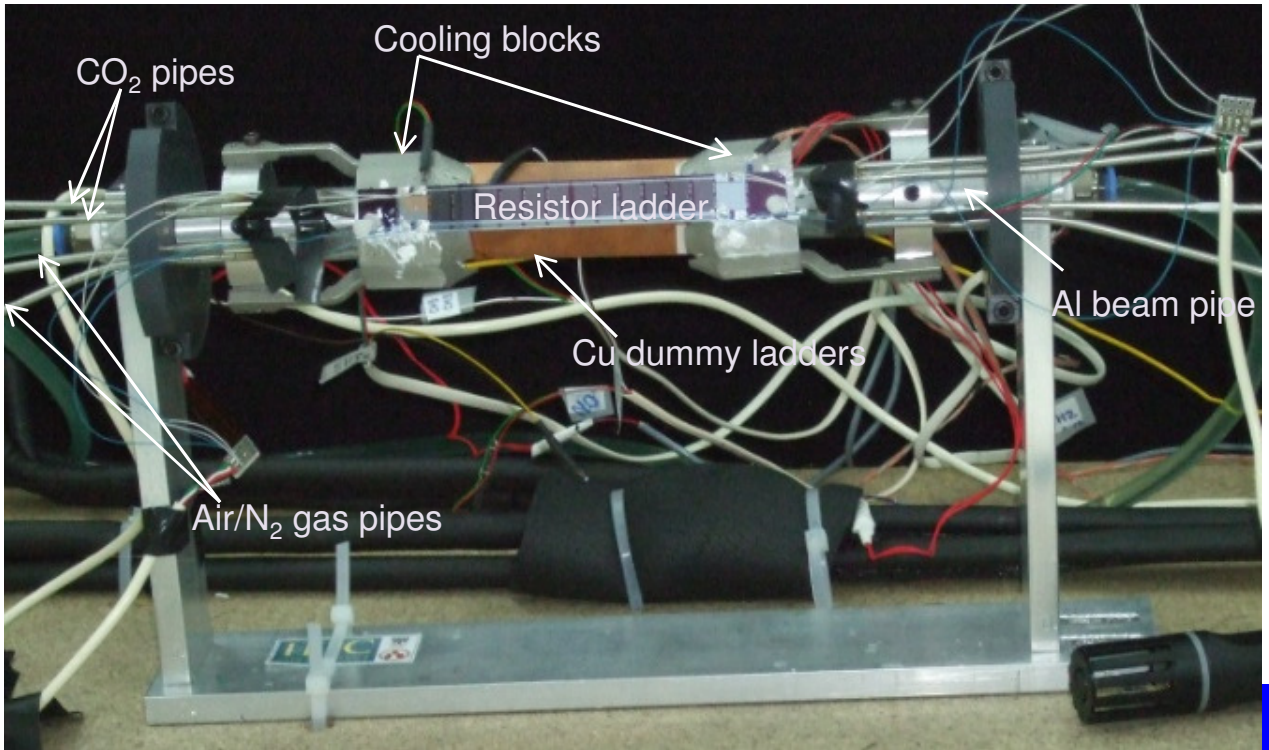
DEPFET resistor samples

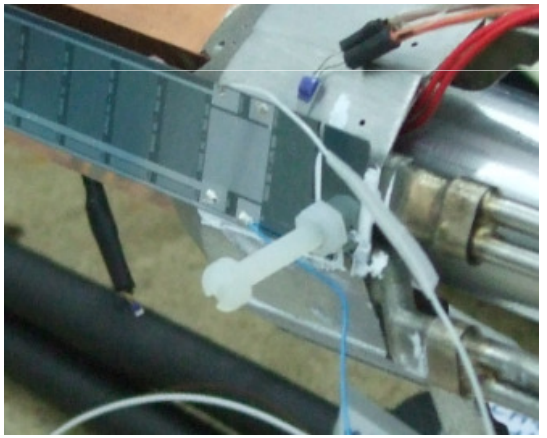
PXD Mock-up

- Mock-up setup:

- Cooling blocks, cooled down with CO_2 (~12bar→ T~-30°C)
- Dry air/N_2 gas flow (v =2 m/s, T= -15 – 25°C *) (cooled down with N_2 liquid atmosphere)
- Dummy ladders: → Cu and Al ladders with heaters (inner and outer ladders).
  - Power dissipated along ladder: 1-4 W → T ~ 30°C-60°C

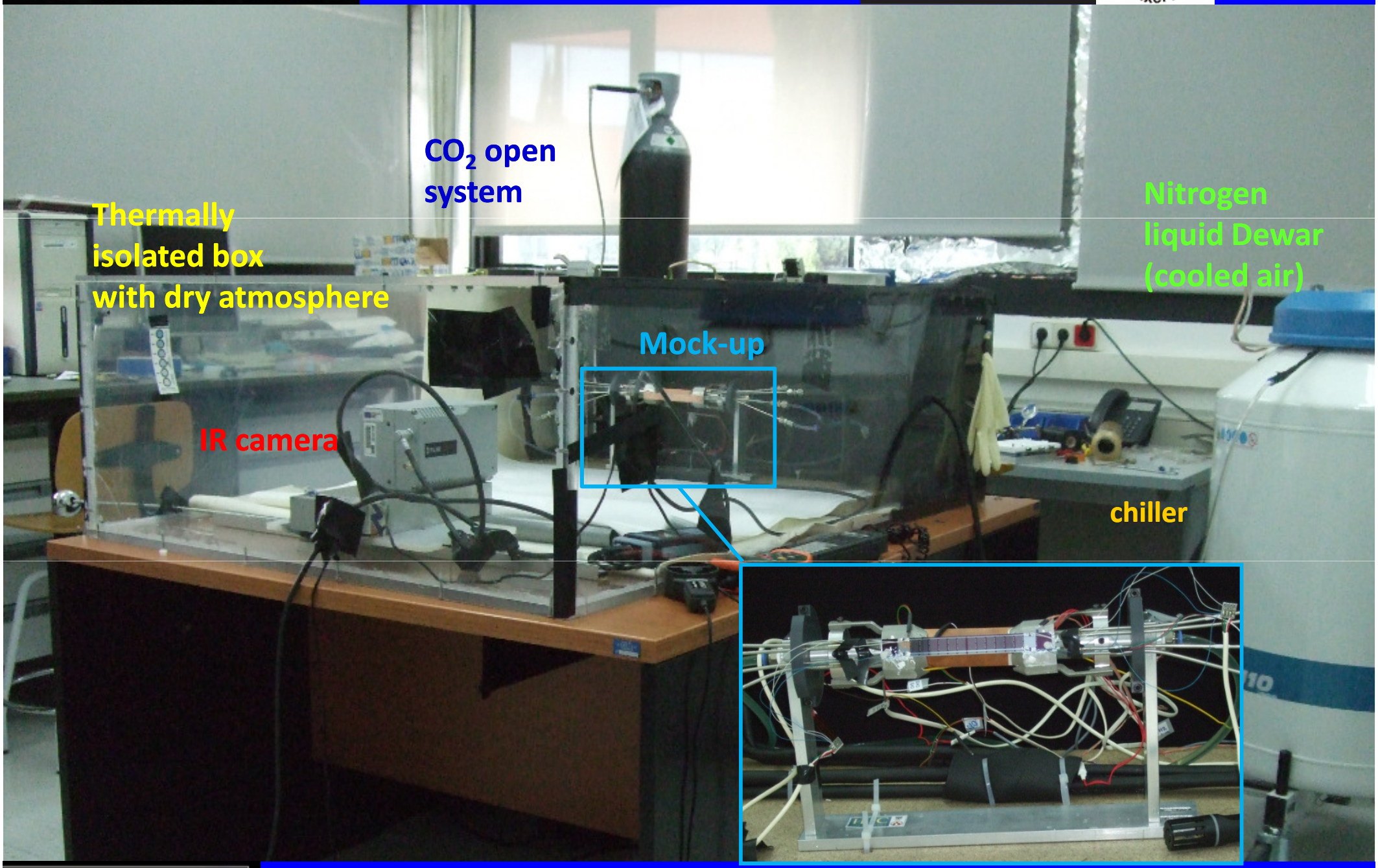
→ Resistor Si samples
  - Power dissipation: Sensor: P ~ 0.5 - 1 W
    Switchers: P ~ 0.25 - 0.5 W
    DCDs/DHPs: P ~2.5 - 8 W





(*before entering the pipes)

PXD Mock-up


CO_2 open system
Thermally isolated box with dry atmosphere
Nitrogen liquid Dewar (cooled air)
Mock-up
IR camera
chiller

Air cooling

- Method:

- Measure temperature along inner and outer ladders and in the cooling blocks with an IR camera (properly calibrated) and PT'100 probes

- Studies:

CO_2 cooling:

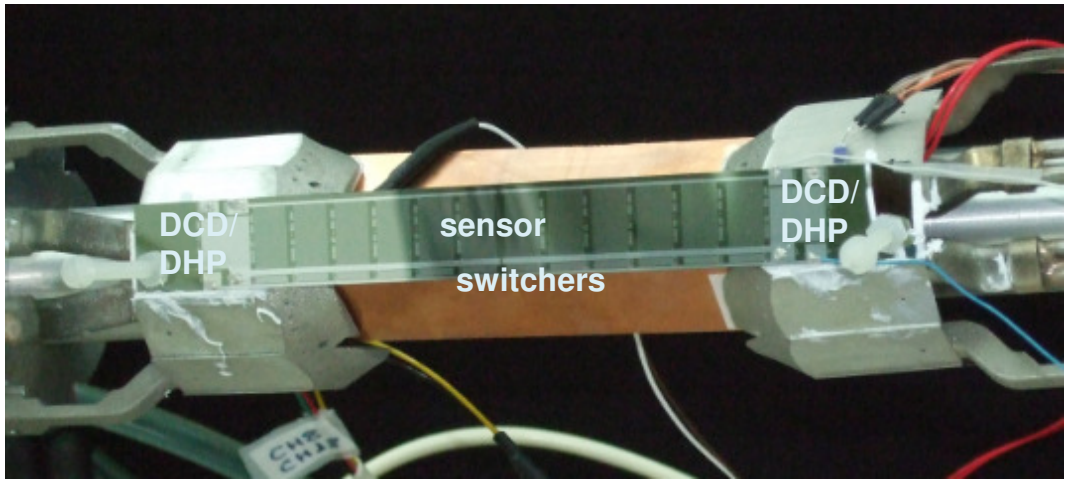
→ Cooling Block temperature

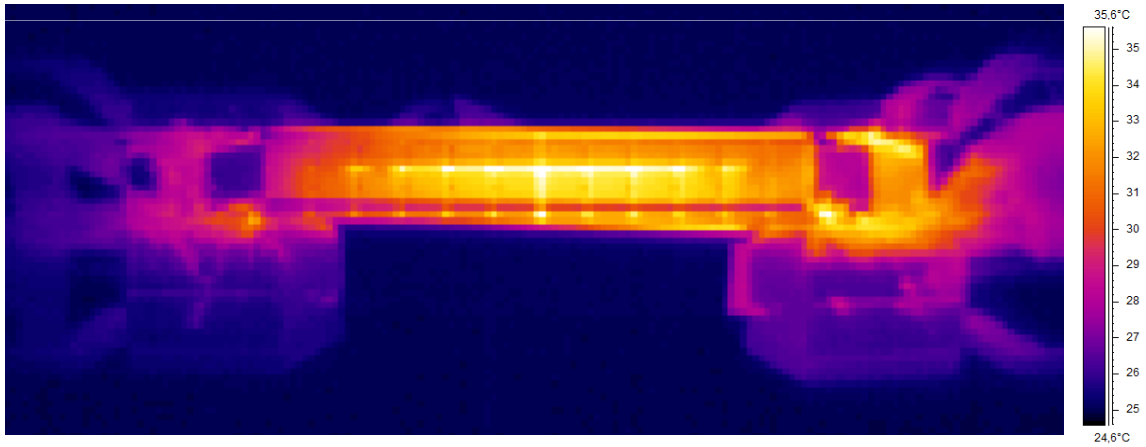
→ Power dissipation (DCDs/DHPs)

Air flow cooling:

→ Air velocity

→ Power dissipation (sensor and switchers)

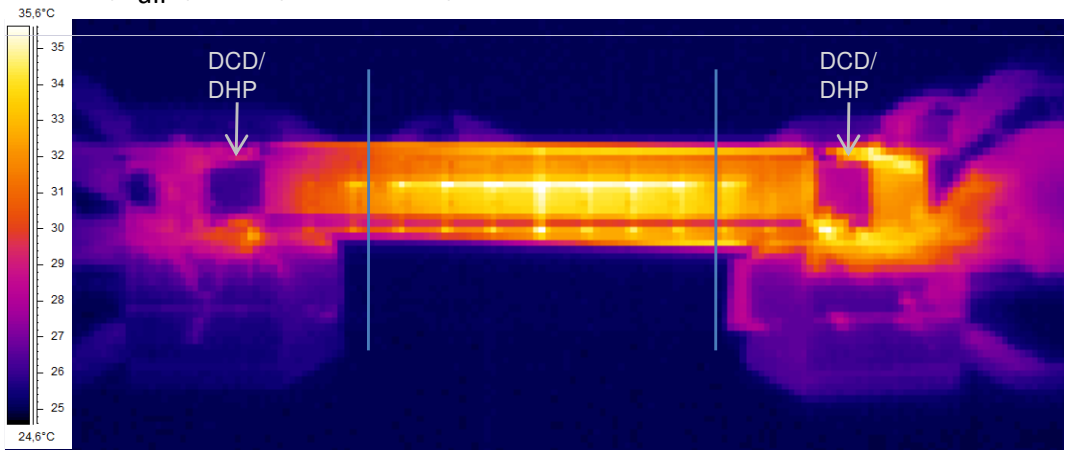


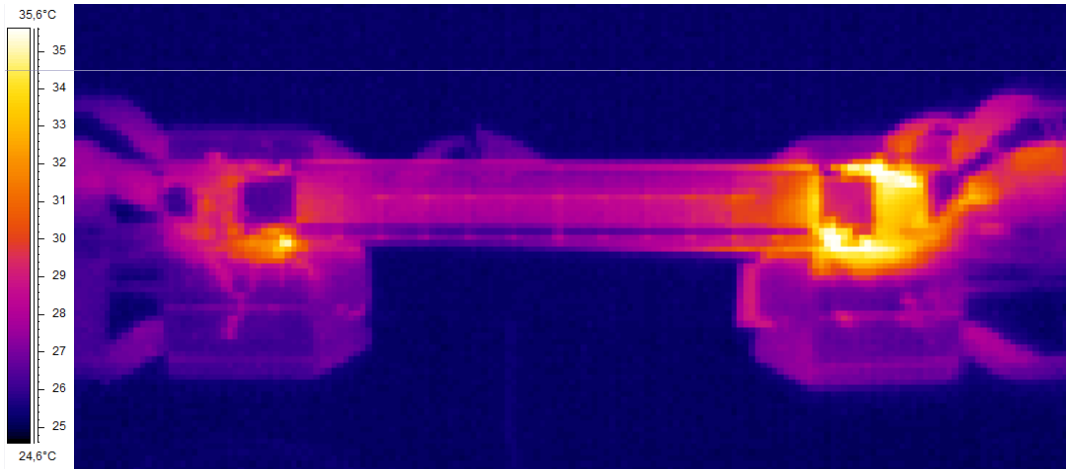


Air cooling

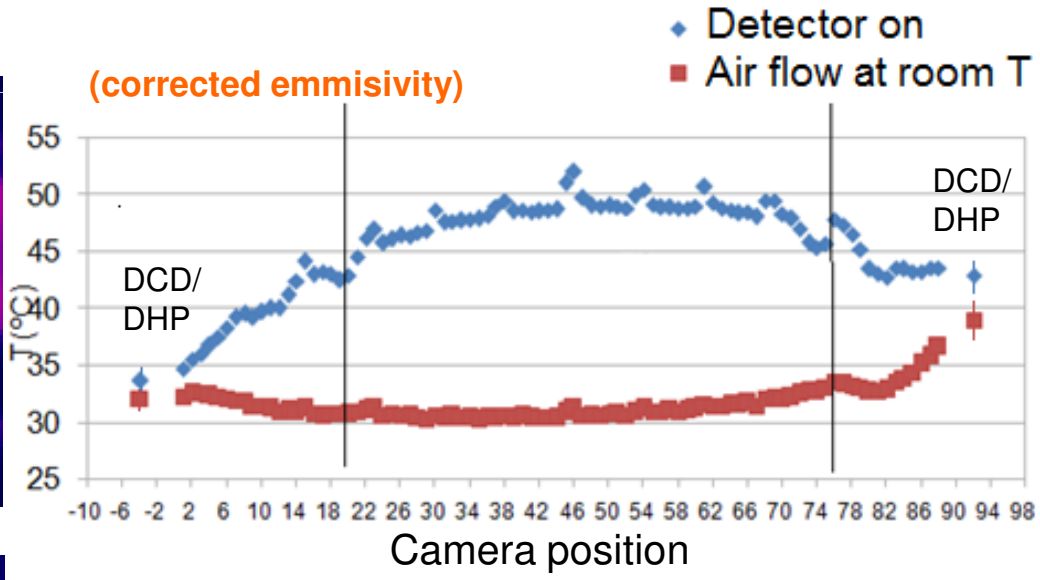
- Results:

- Effect of blowing dry air at room temperature (25°C):
(v_{air} (inlet) ~ 2 m/s)





Sensor: P ~ 1 W x 2
Switchers: P ~ 0.25 W (left switcher off)
DCDs/DHPs: P ~2.5 W x 2



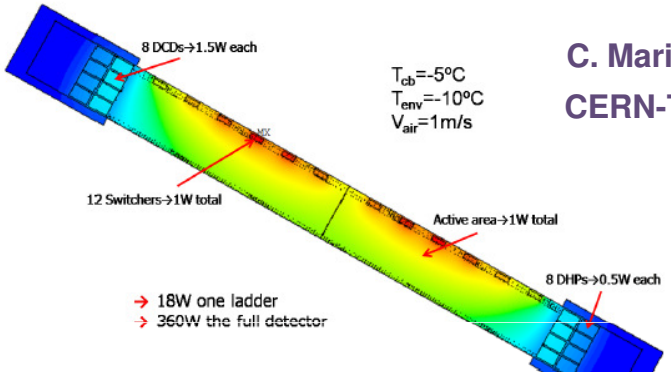
-The air flow (at room T) decreases and homogenizes the temperature along the detector.
→ Decreases T ~ 15° C
→ Max ΔT along the ladder 18°C→ 8°C

Air cooling

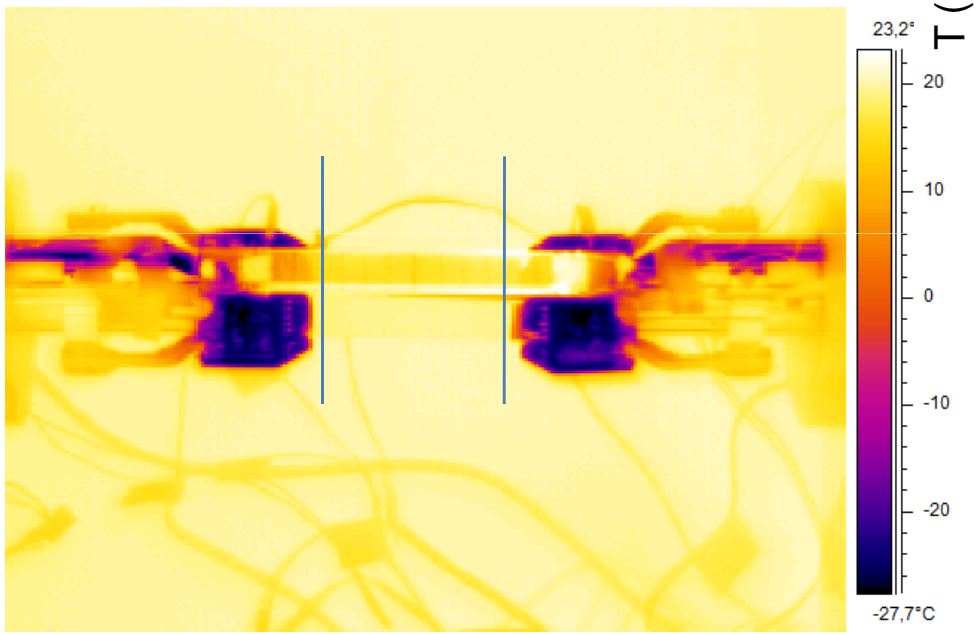
- Results:

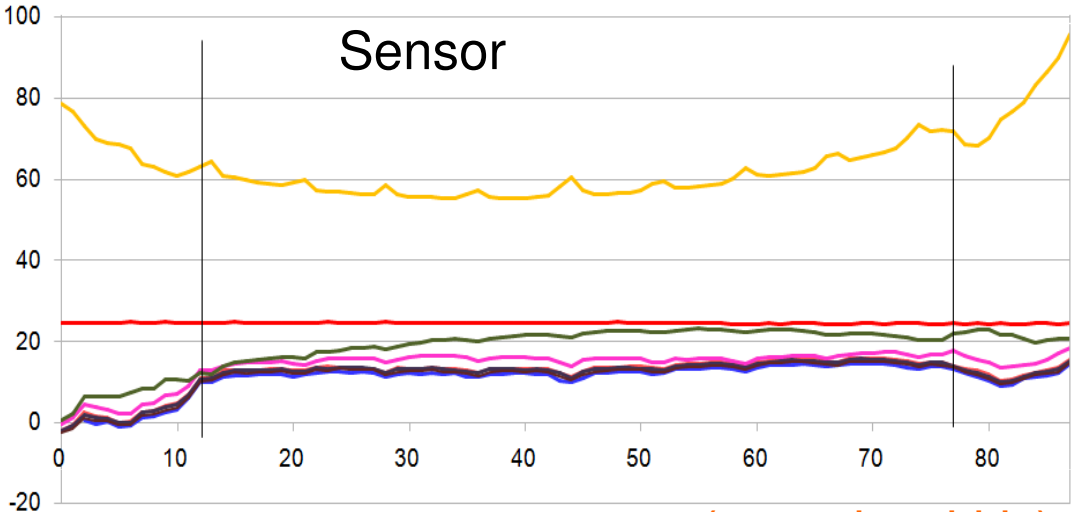
- Cooling down the cooling blocks with CO_2 and blowing dry air/ N_2 gas at several temperatures

Sensor: → P ~ 0.5 W x 2
Switchers: → P ~ 0.5 W
DCDs/DHPs: → P ~ 8 W x 2



C. Mariñas simulation
CERN-THESIS-2011-101





(corrected emmisivity)

Camera position

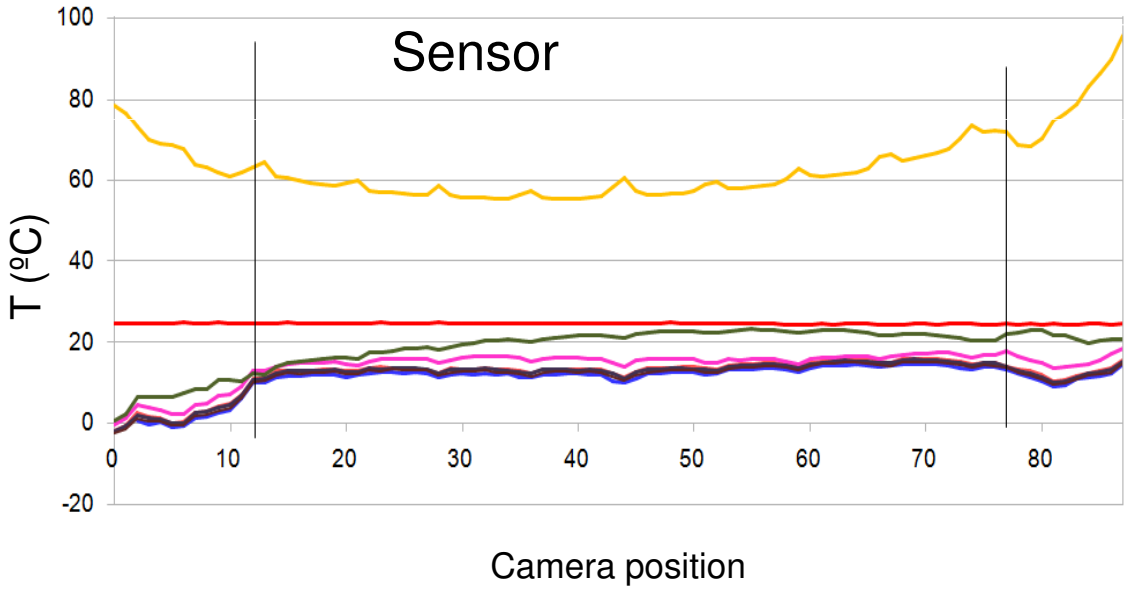
- Detector on
- Background (room T)
- End flanges cooled with CO_2
- Air flow at room T
- Air/N_2 flow cooled [-8,-15]°C *

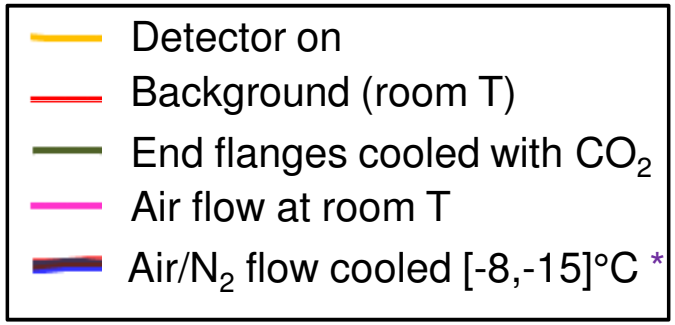
(* T measured before entering the pipes)

Air cooling

- Results:

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





(* T measured before entering the pipes)

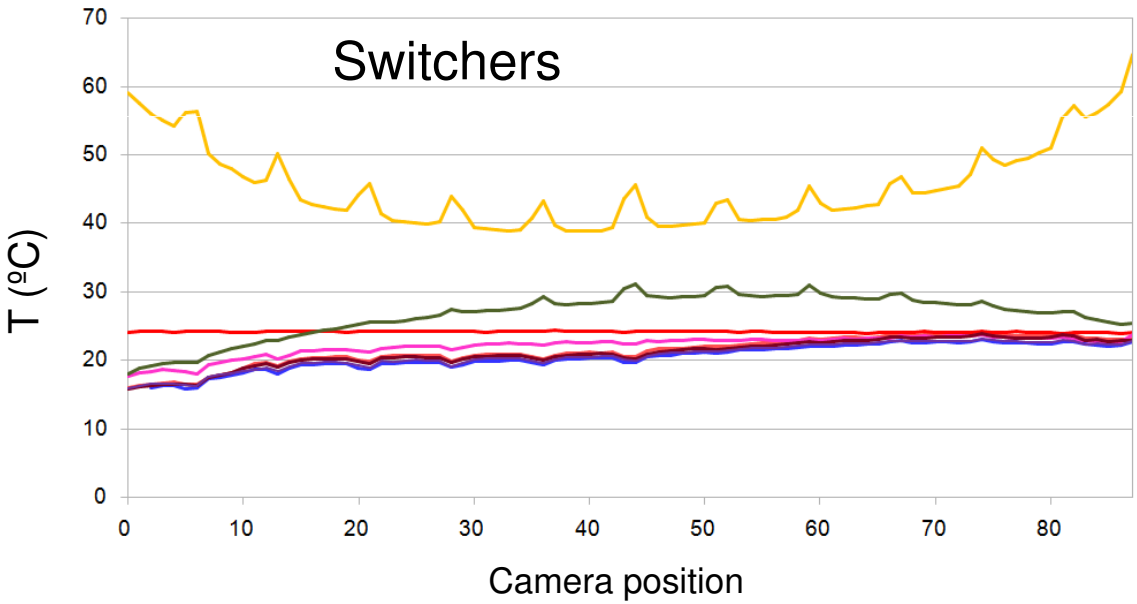
- Temperature for the sensor when switching on the detector: ~ 60 °C
- Cooling the endflanges (CO_2): **T sensor< 25 °C** (~ room T)
- Blowing air at room T → **T sensor < 20 °C** and homogeneous
- Blowing cooled air (-8,-15) °C → **T sensor ~ 15 °C** and homogeneous
- ΔT_{max} along the sensor **~ 10 °C**

Air cooling

- Results:

- Switchers region (P~0.5 W):

(corrected emmisivity)



- Detector on
- Background (room T)
- End flanges cooled with CO_2
- Air flow at room T
- Air/N_2 flow cooled [-8,-15]°C *

(* T measured before entering the pipes)

(Only right switcher was operating)

- Temperature for the switchers when the detector is switched on ~ 40 °C
- Cooling the endflanges (CO_2): **T switchers ~ 20-30 °C** (~ room T)
- Blowing air at room T → **T switchers < 25 °C** and homogeneous
- Blowing cooled air (-8,-15) °C → **T switchers < 25 °C** and homogeneous
- Small ΔT_{max} along the detector **< 10 °C**

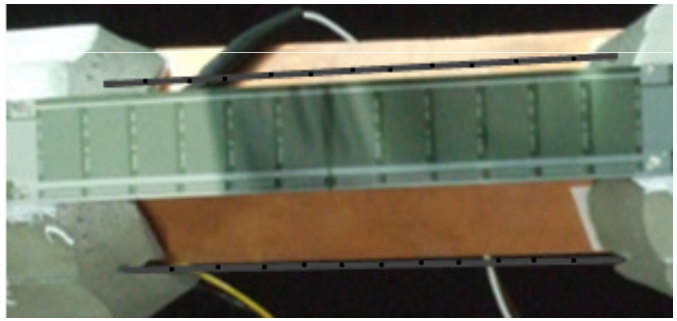
Conclusions

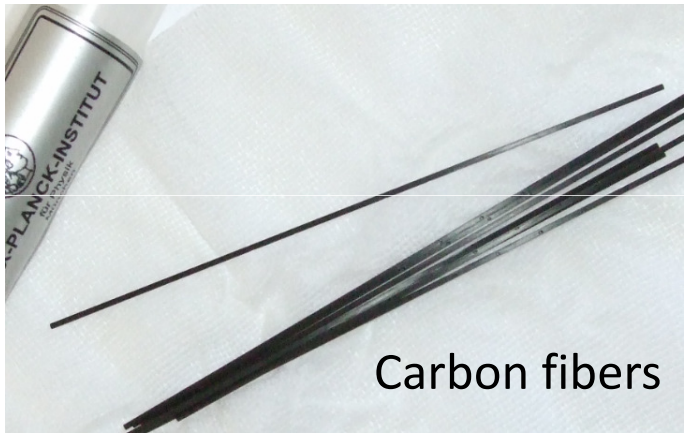
- PXD Mock-up setup to study the cooling for Belle-II
- At present, all tests of air cooling show:
  - Significant effect of air cooling even at room T (ΔT=15°C for P ~2.5W)
  - Cooled air flow decreases the ladder temperature below ~20°C
  - ΔT_{max} along the ladder less or around 10°C (with cooled endflanges)
- Results may be suitable for ILC. Some issues:

  How is the air/N_2 delivered? (supporting disks?)

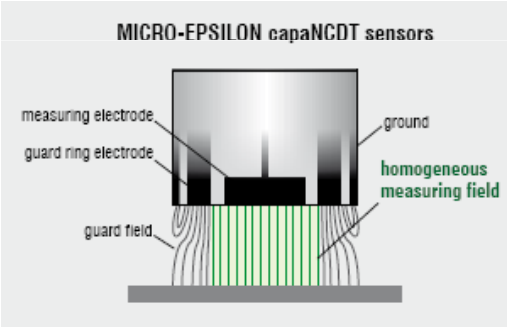
  How is the air/N_2 cooled (if needed)?

- Test air flow effect in the inner ladders (mainly for the switchers) through carbon fibers

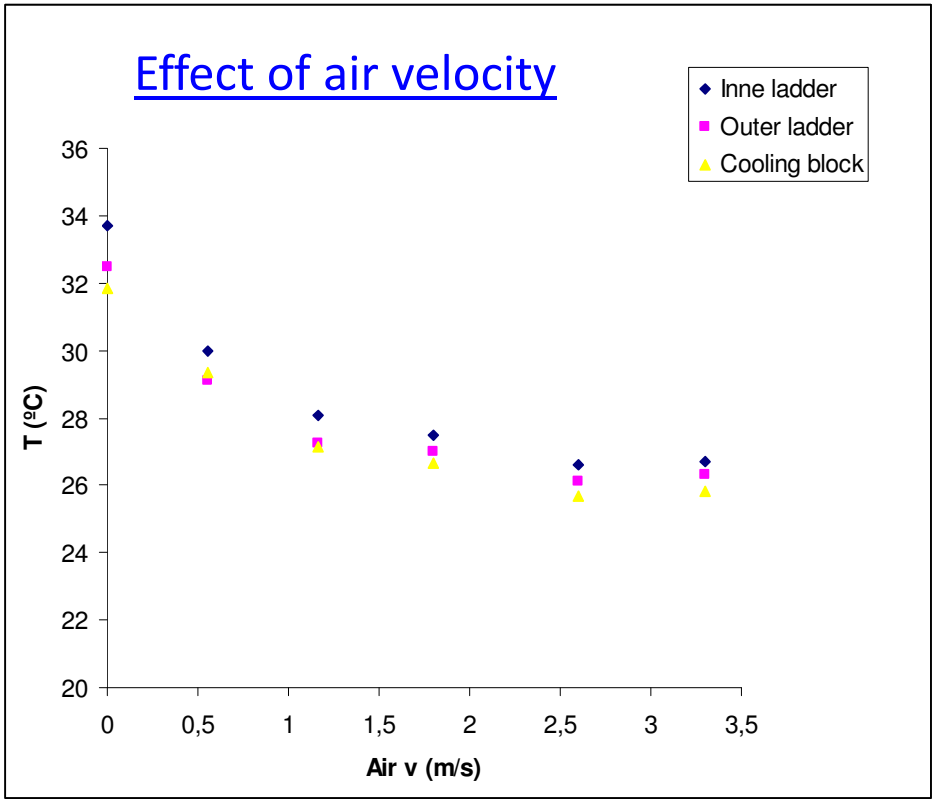




- Test possible vibrations in the detectors due to the air flow (Capacitive Non-Contact Displacement detectors)



- Results:

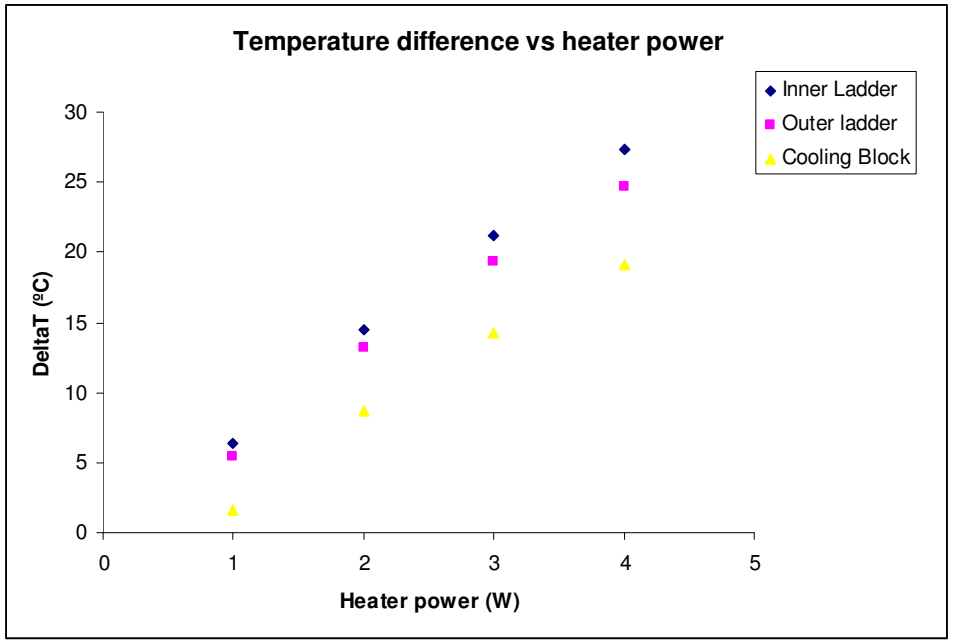


- It is enough to have a very low speed air flow (inlet) to achieve a proper heat dissipation in the ladder (1 W→ΔT~ 6-7°C)

(Expected behaviour from C. Mariñas simulations, CERN-THESIS-2011-101)

Power dissipation:

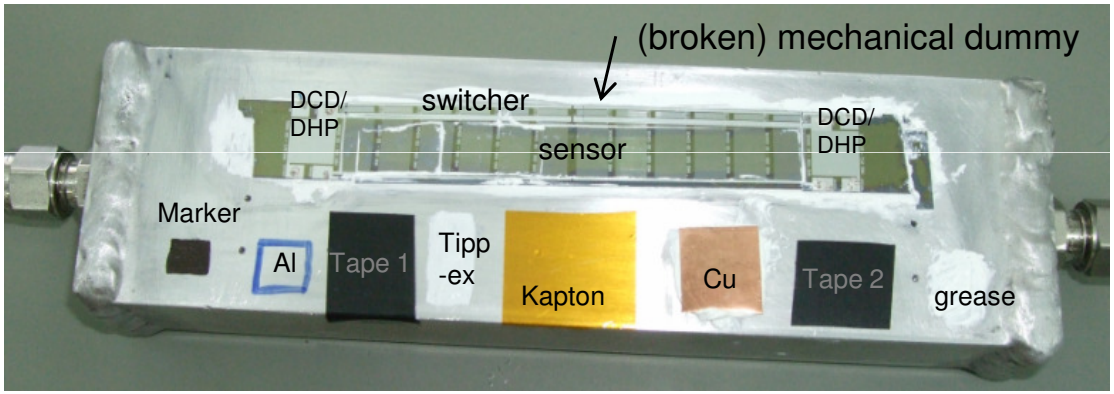
ΔT=object T without air – object T when having a room T air flow (v ~ 2m/s).

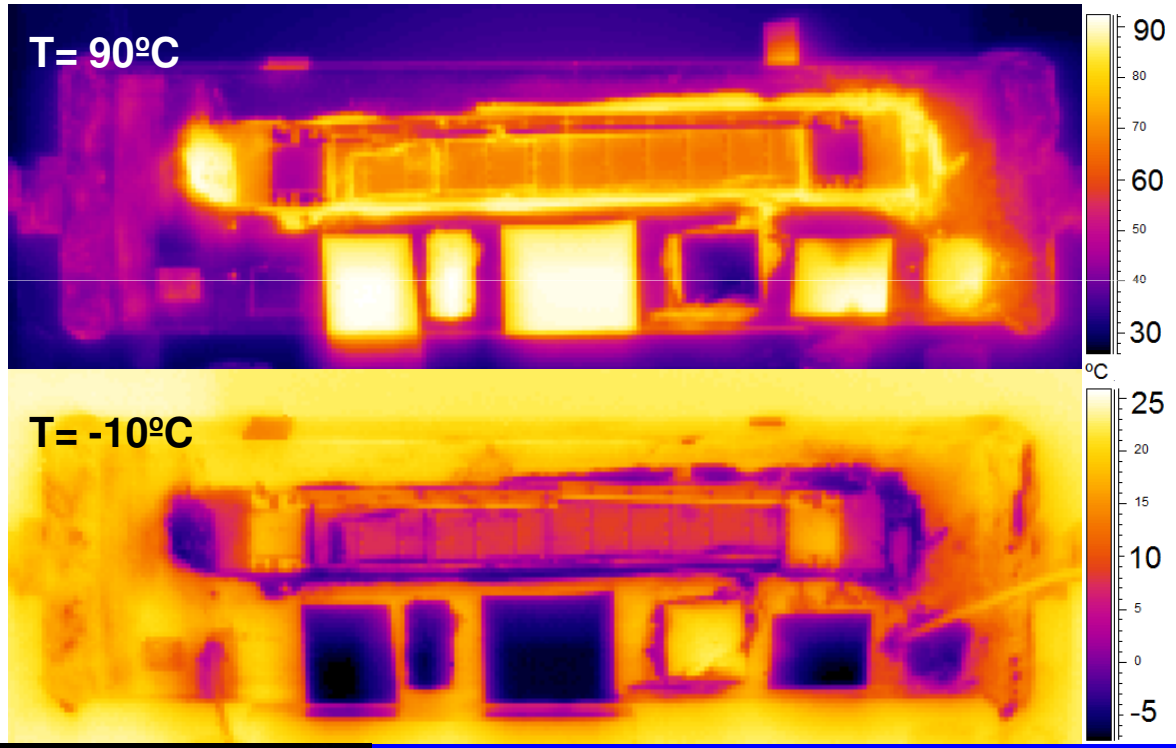


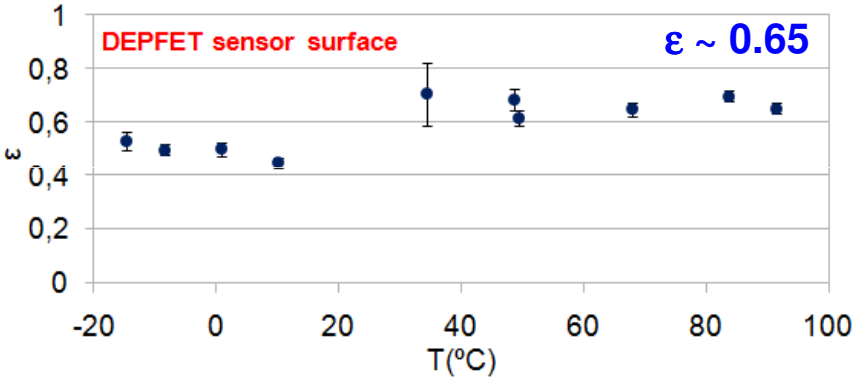
- Power dissipation increases as power (i.e. heating) increases

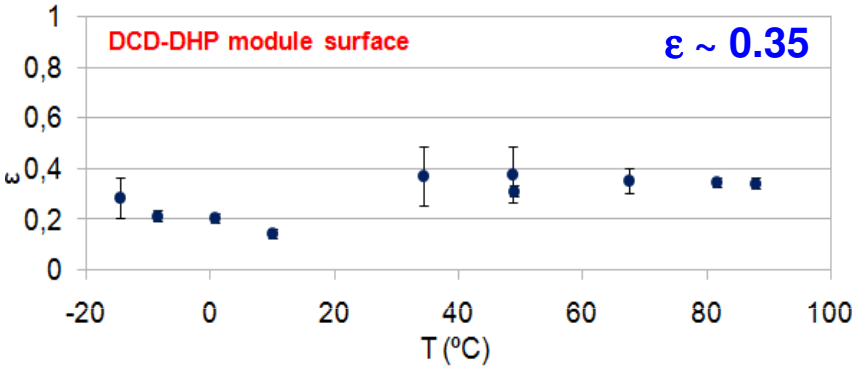
Calibration tool for the IR camera: (ε depends on the material)

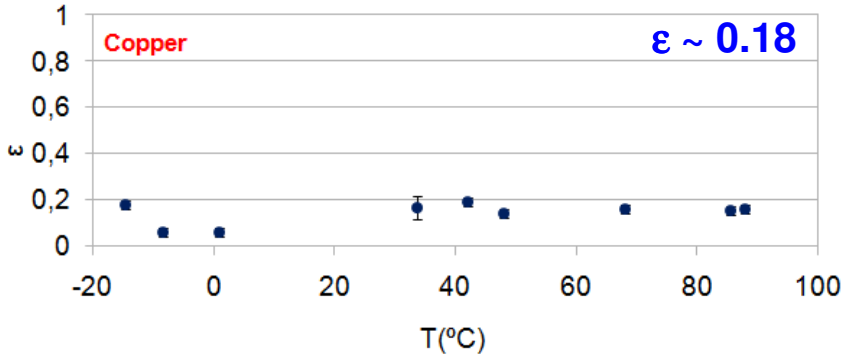
Al box filled with coolant: cooled down with chiller, heated with heaters. Study material ε



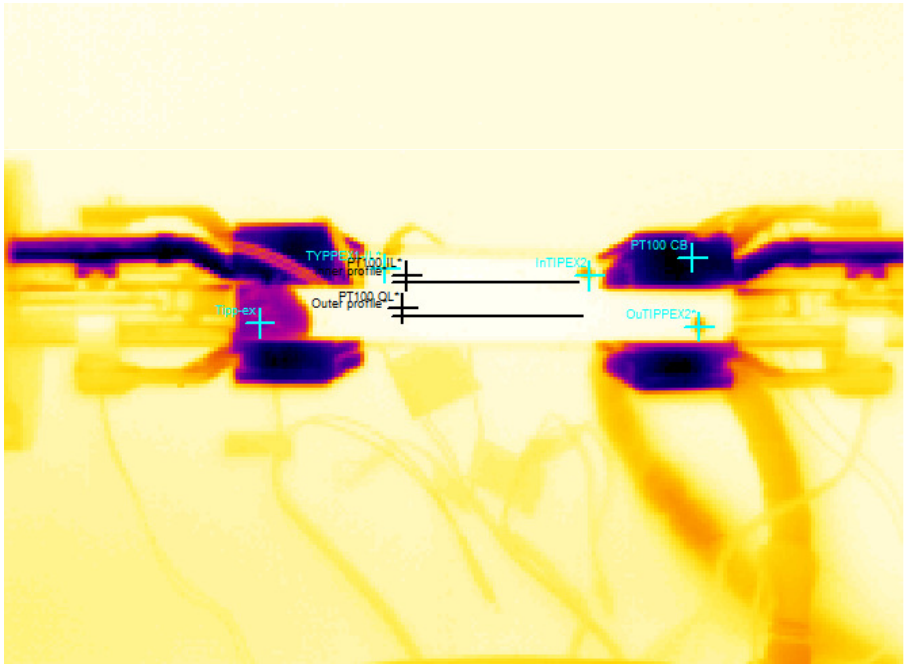


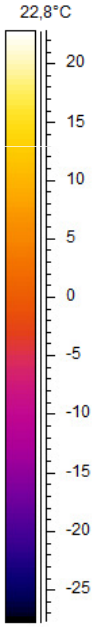


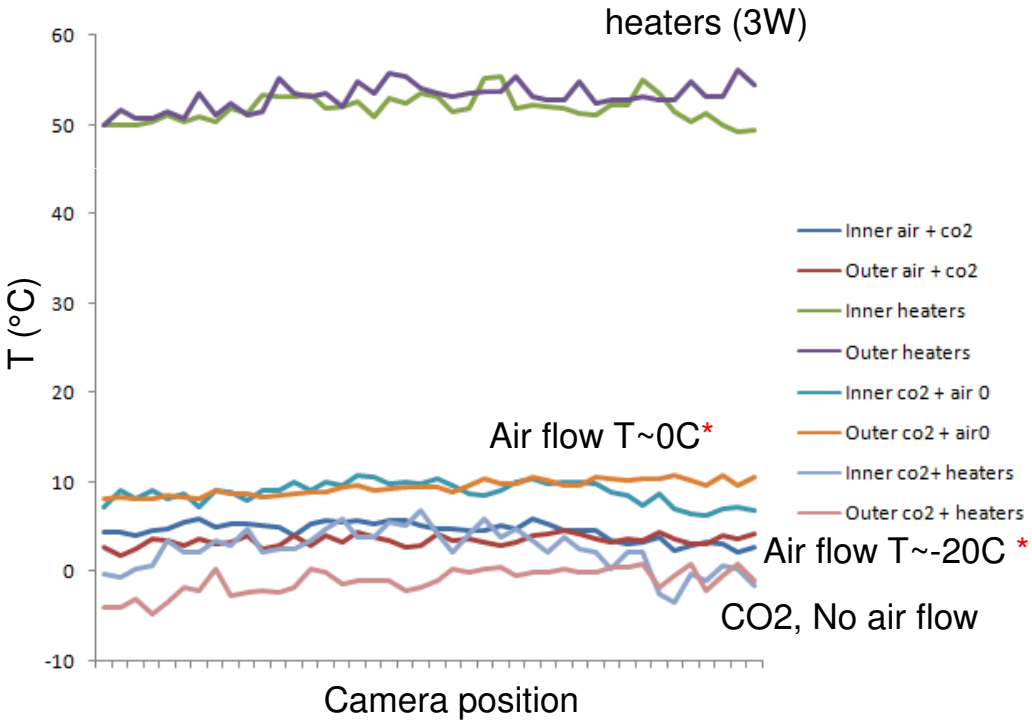




- Inner ladder:



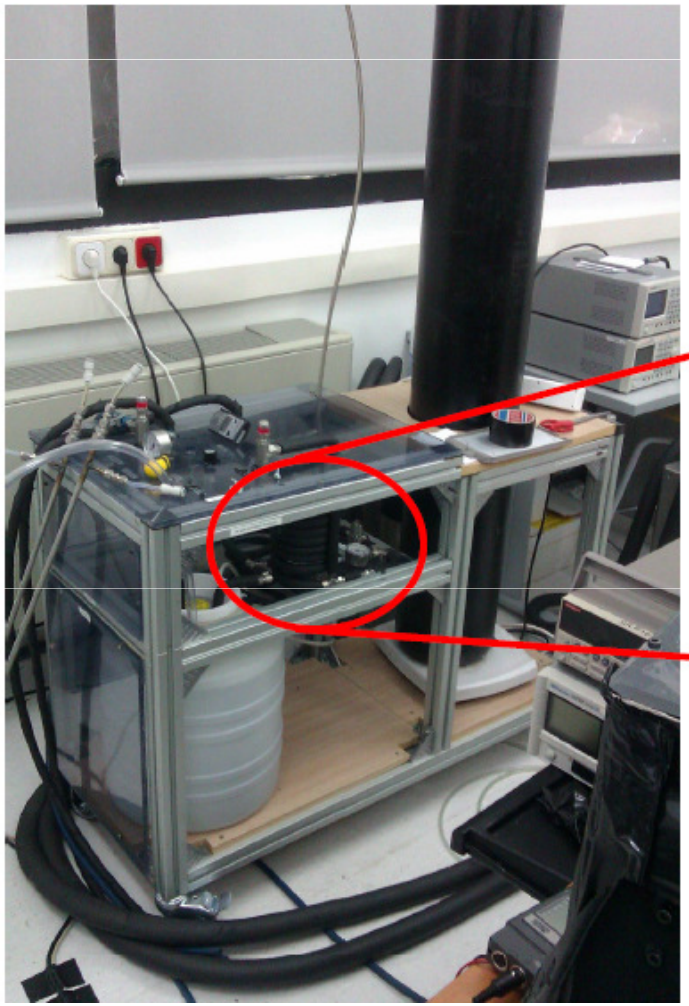


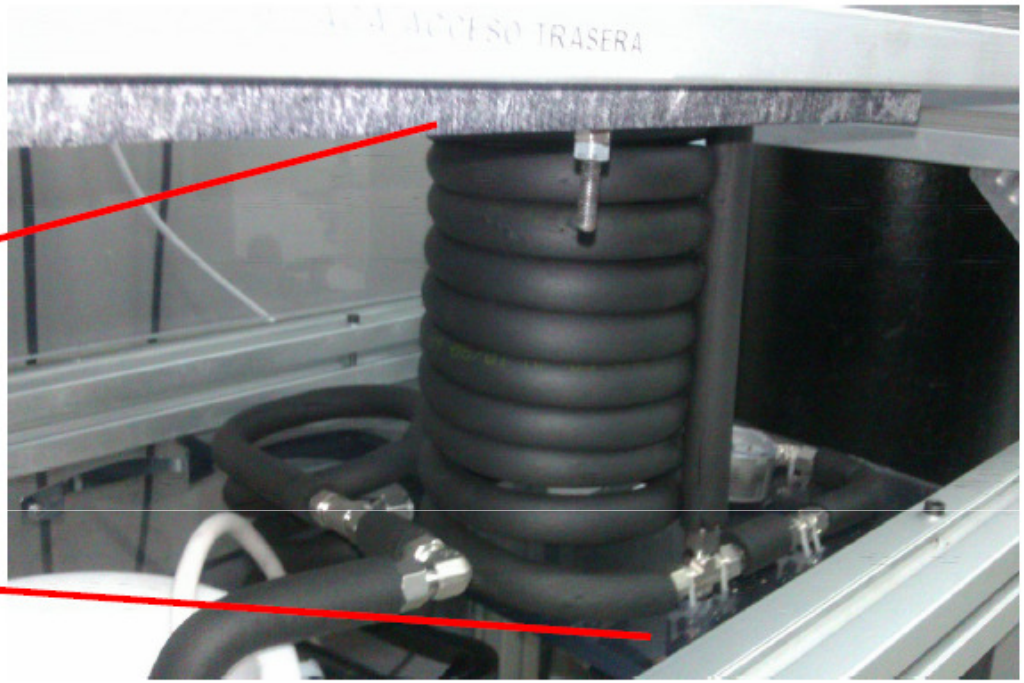


* entering in the box; T in the CB?

- Air flow cooling with the CO_2 return

Until now, air or N_2 gaseous cooled down by the atmosphere inside the liquid N_2 Dewar (-80°C). New CO_2 exchanged system to cool down the air flow in place (to test).





1.5m pipe coil at the CO_2 return to cool down the air:
Air flow temperature in the outlet ~ -5 - 0 °C

- Dummy ladders: