Cooling activities at IFIC (Valencia)

C. Marinas
IFIC-Valencia

4th International Workshop on DEPFET detectors and Applications
4.5.2010

Outline

Summary: Belle-II PXD simulation results

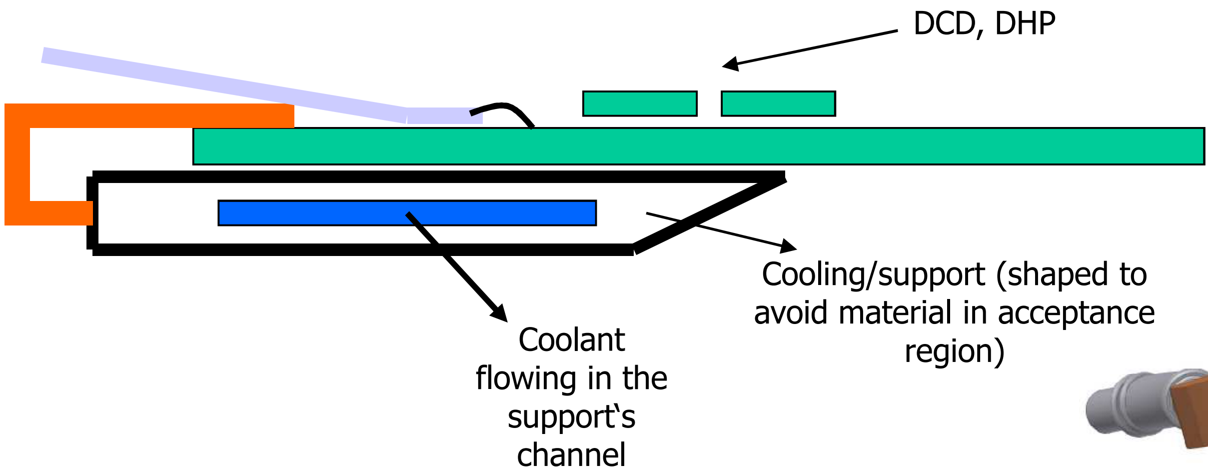
Air cooling problem: The STAR (RHIC) experience

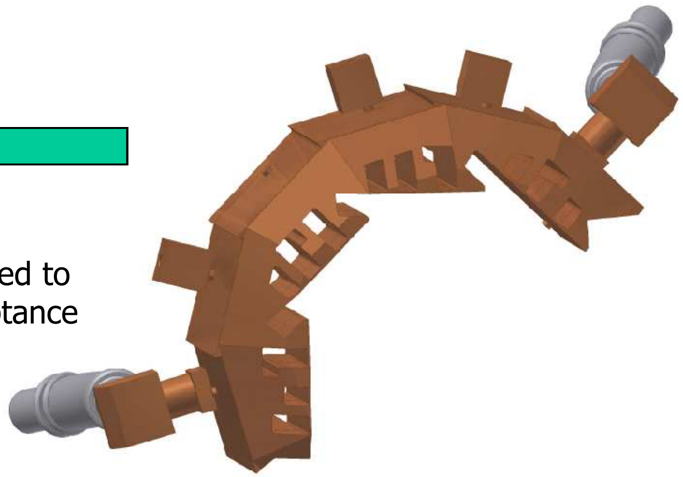
Valencia's Test Bench

SUMMARY: BELLE-II PXD SIMULATION RESULTS

Once upon a time…

1.- A new cooling/support estructure has been designed
-CVD-Diamond not needed anymore





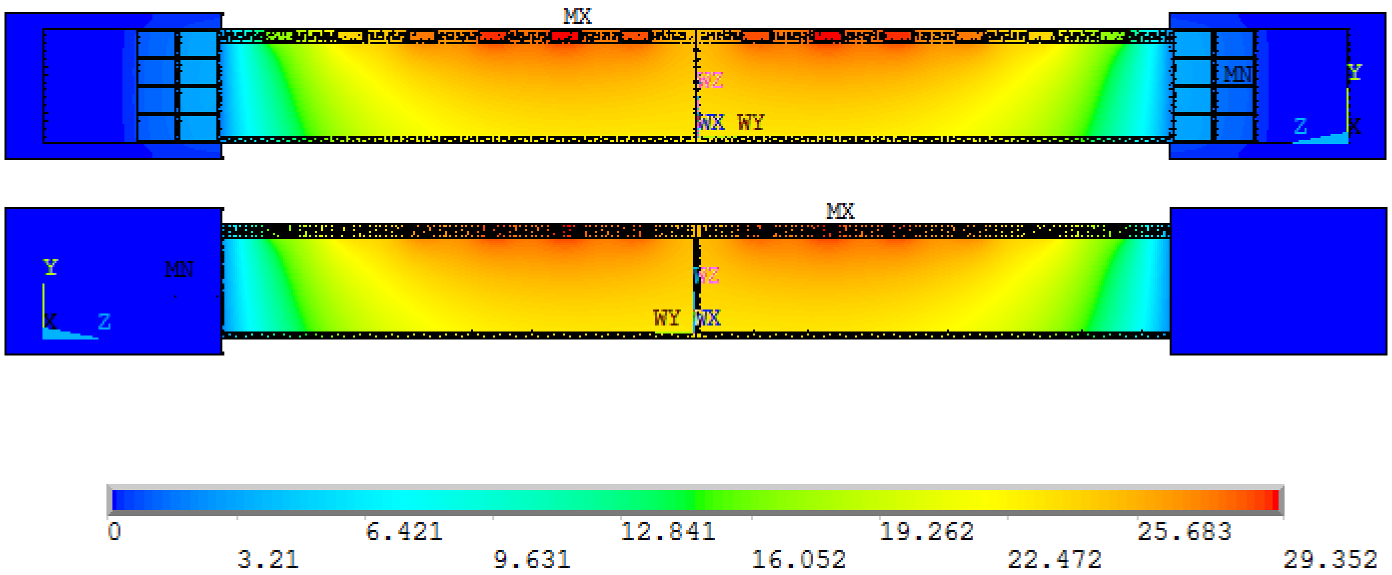
2.- A new simplified cooling solution has been developed
-No TPG strip underneath the SW’s balcony

3.- A more detailed ladder geometry has been simulated
- Etching
- Two halves glued

Carlos.Marinas@ific.uv.es

Outer layer design evolution: the final geometry

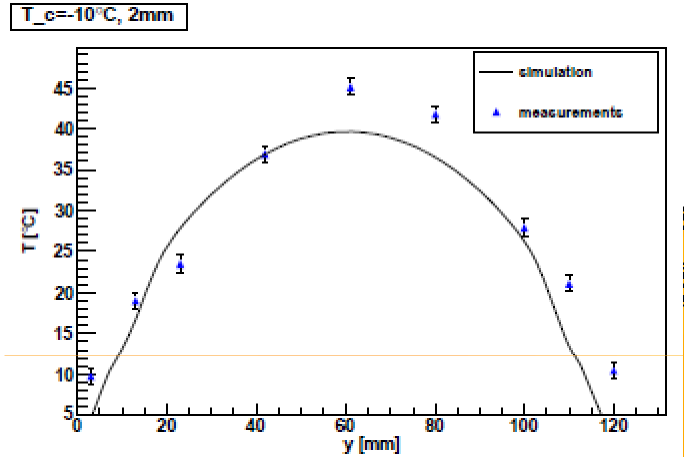
- Ladder → Two half modules glued at the center (etching implemented)
- 12 Switchers
- Ladders connected directly to the cooling block
- New geometry (dimensions) according to the 'final' outer layer design

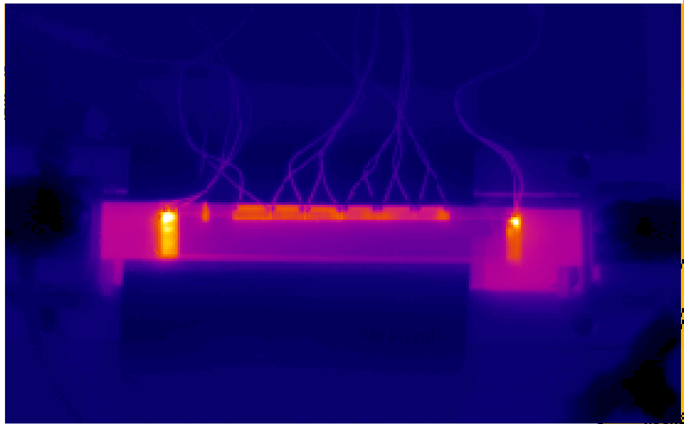


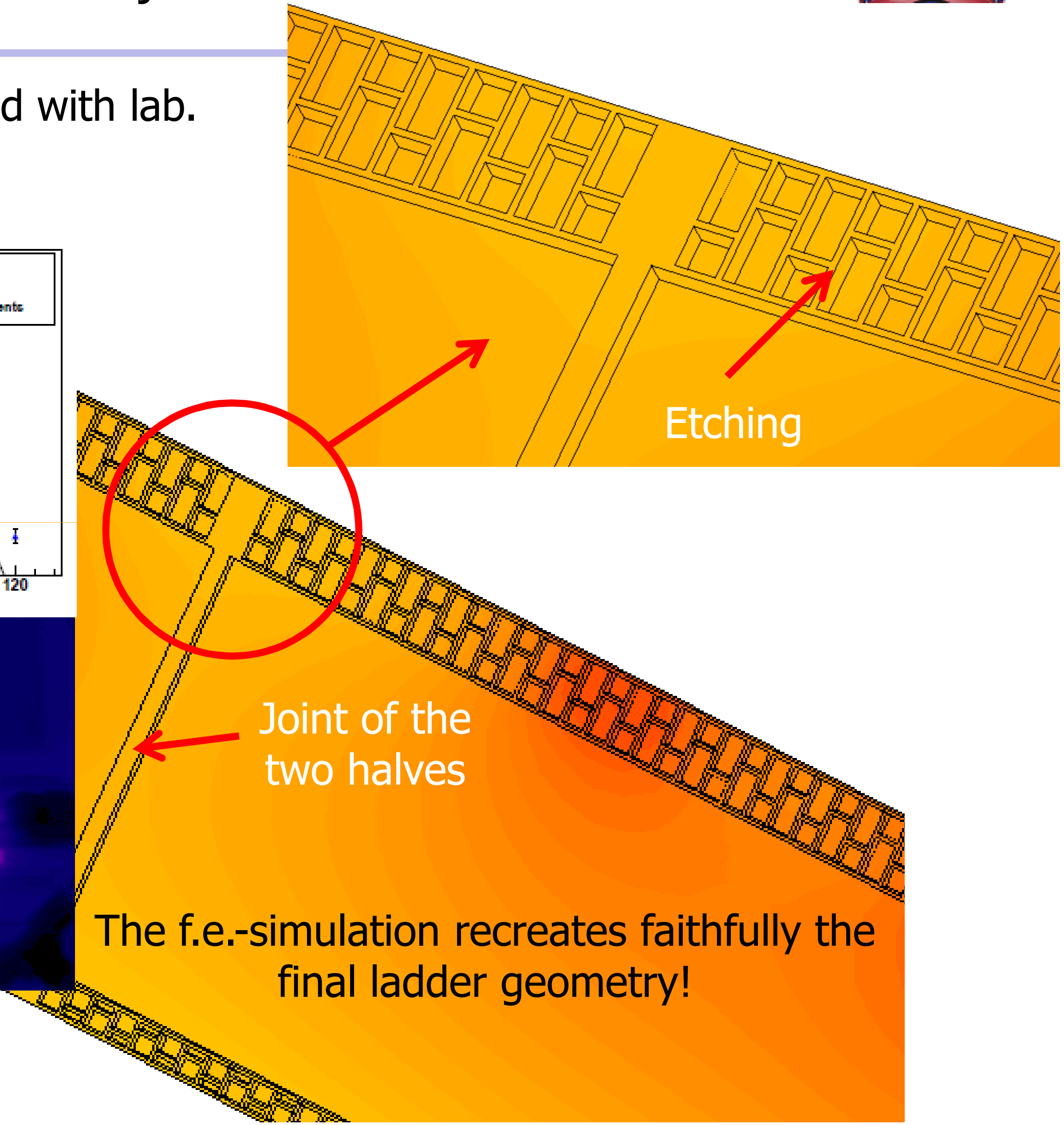
Belle-II DEPFET outer layer, C. Marinas (IFIC-Valencia)

Frame perforation & dead joint

Simulations cross-checked with lab. measurements

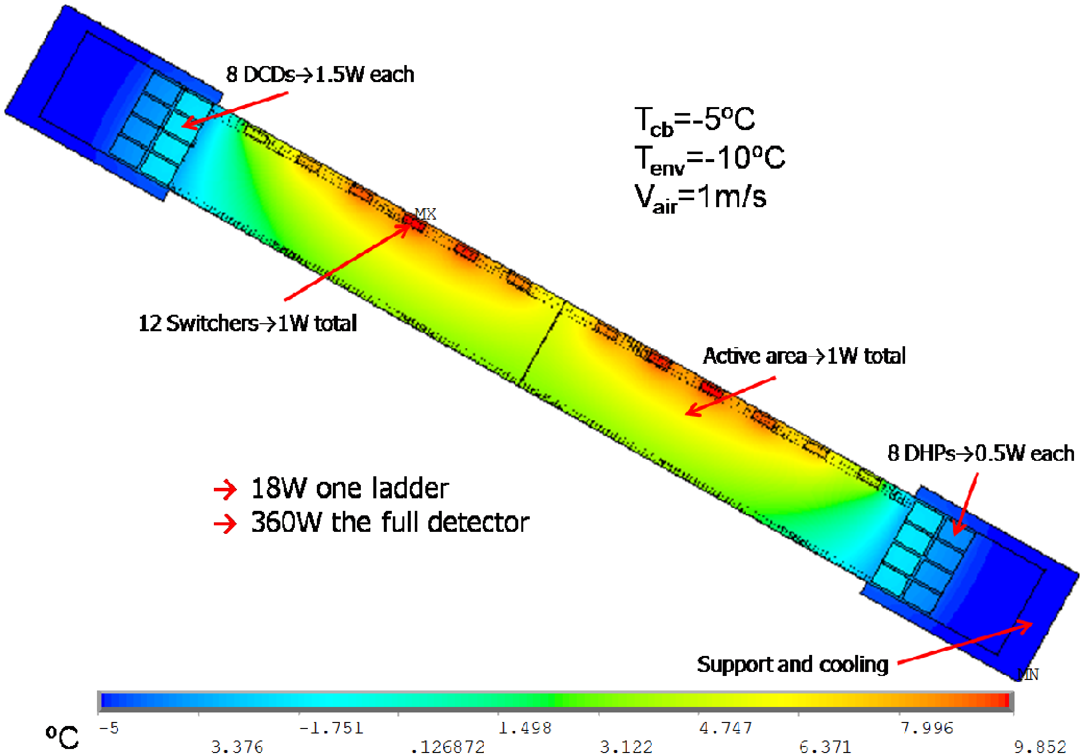






The f.e.-simulation recreates faithfully the final ladder geometry!

Thermal studies



T_{cb}=-5ºC
T_{env}=-10ºC
V_{air}=1m/s

→ 18W one ladder
→ 360W the full detector

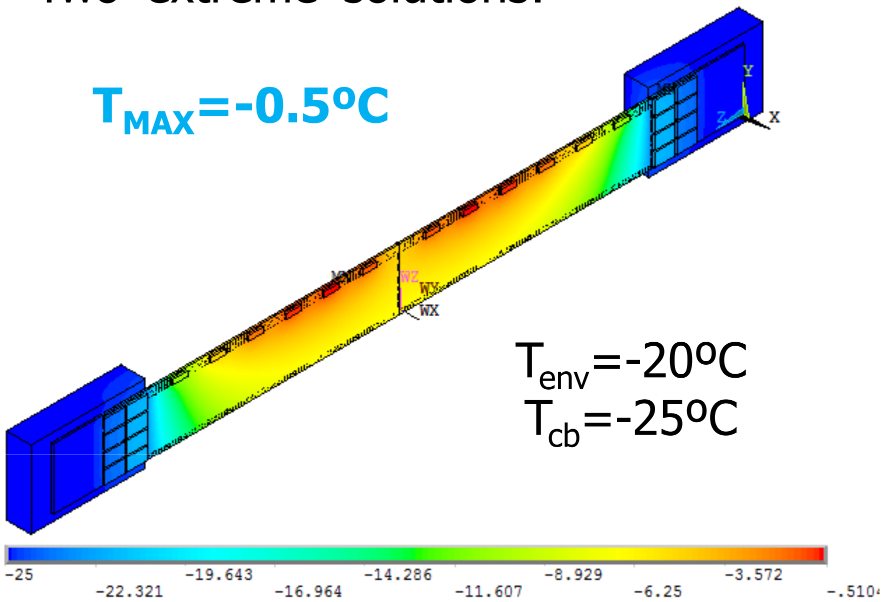
Ladder Belle-II PXD

- Implement the full Belle-II ladder geometry in f.e- software
- Apply the loads to the different elements (DCD,DHP,SW,Sensor)
- Find an optimal cooling solution (find T_{env} and T_{cb}) for the current upper limits on the temperatures:
  - T_{max} (Sensor)<30ºC
  - T_{max} (Chips)<60ºC

Exploring the space T_{env}-T_{cb}

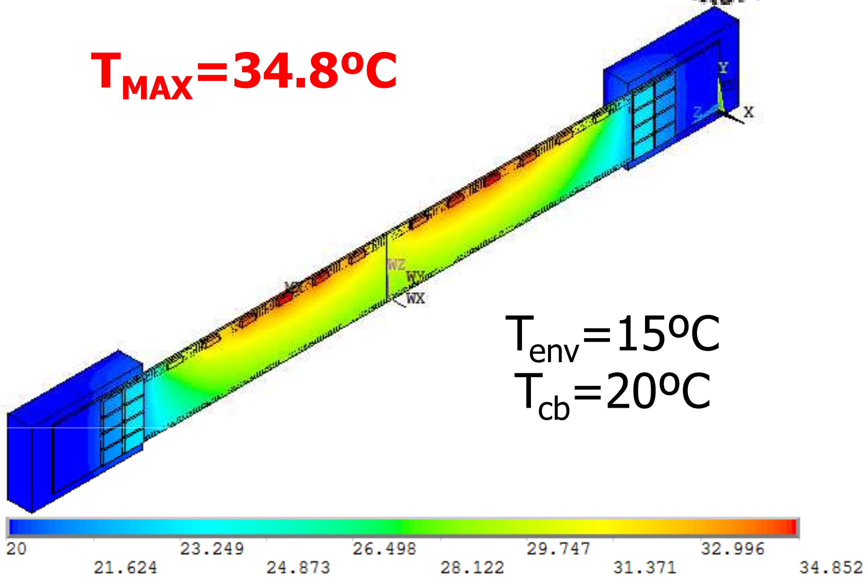
Two 'extreme' solutions:

T_{MAX}=-0.5ºC



T_{env}=-20ºC
T_{cb}=-25ºC

T_{MAX}=34.8ºC

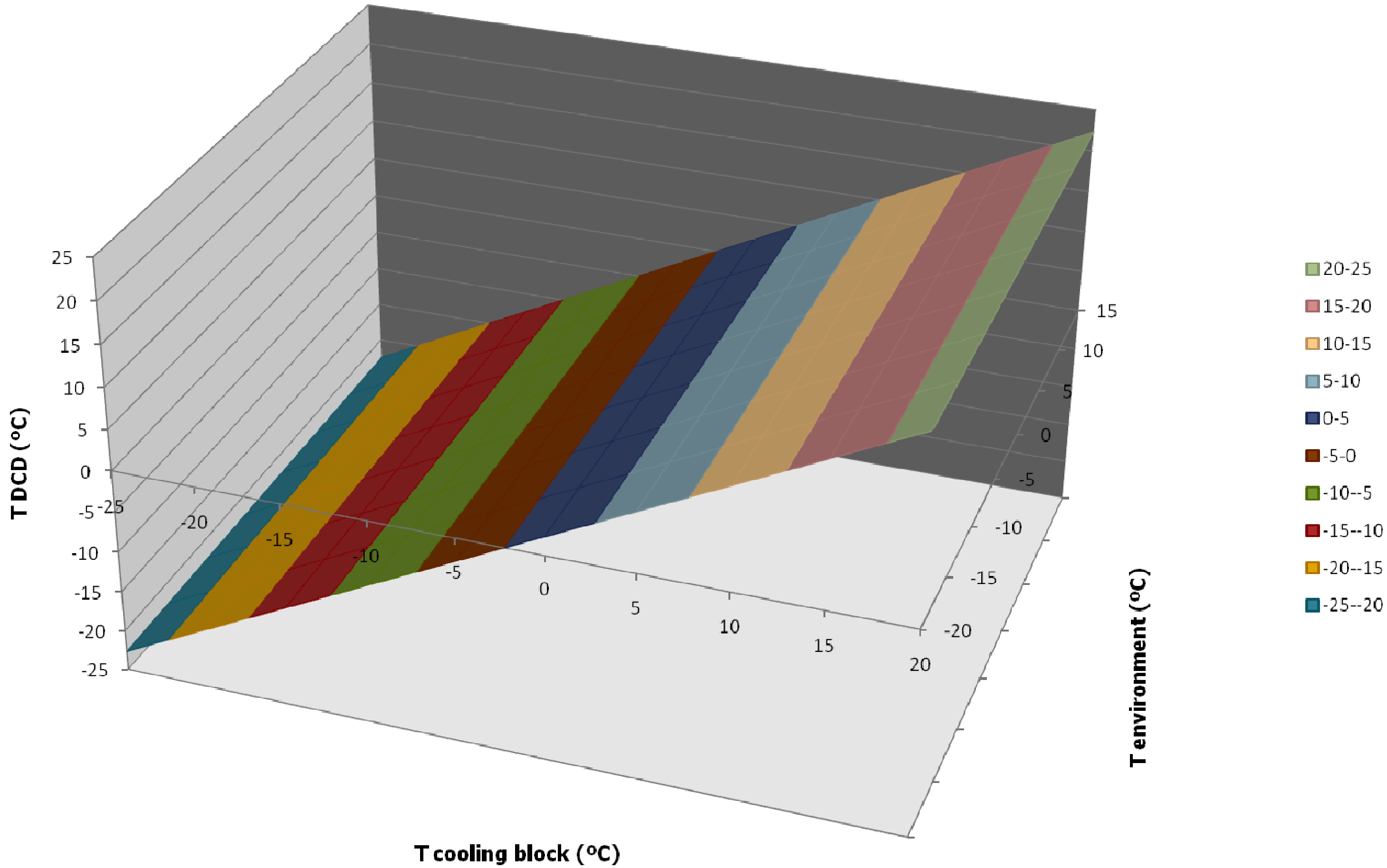


T_{env}=15ºC
T_{cb}=20ºC

Vary $$T_{env} \in [-20^{o}C, +15^{o}C]$$ $$T_{cb} \in [-25^{o}C, +20^{o}C]$$ and see if T_{DCDmax}, T_{SWmax}, $T_{SENSORmax}$ are below the established limits

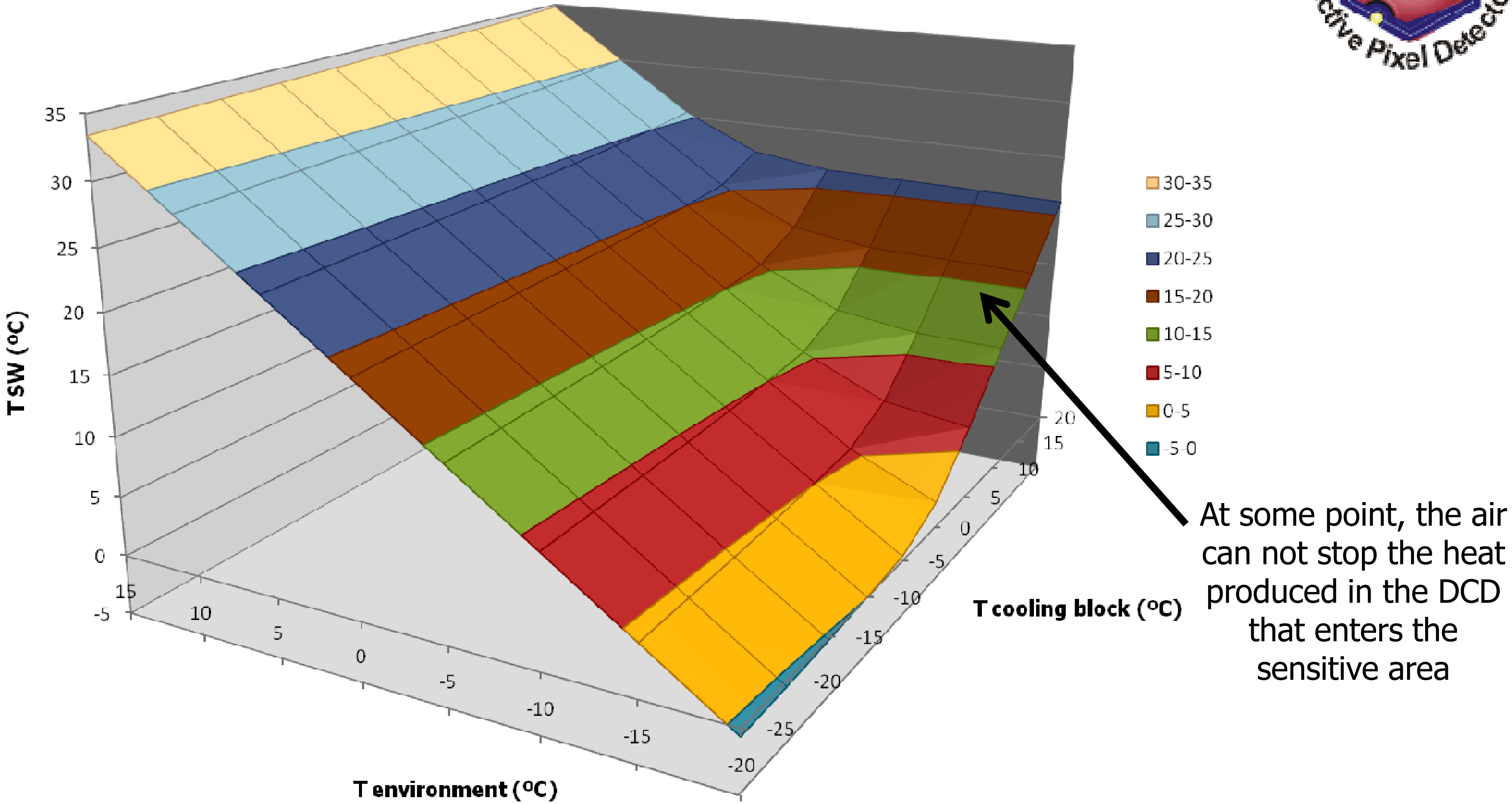
• It was show (simulation and lab measurements) in previous meetings that forced convection is needed: v_{air}=1m/s

Maximum DCD temperature



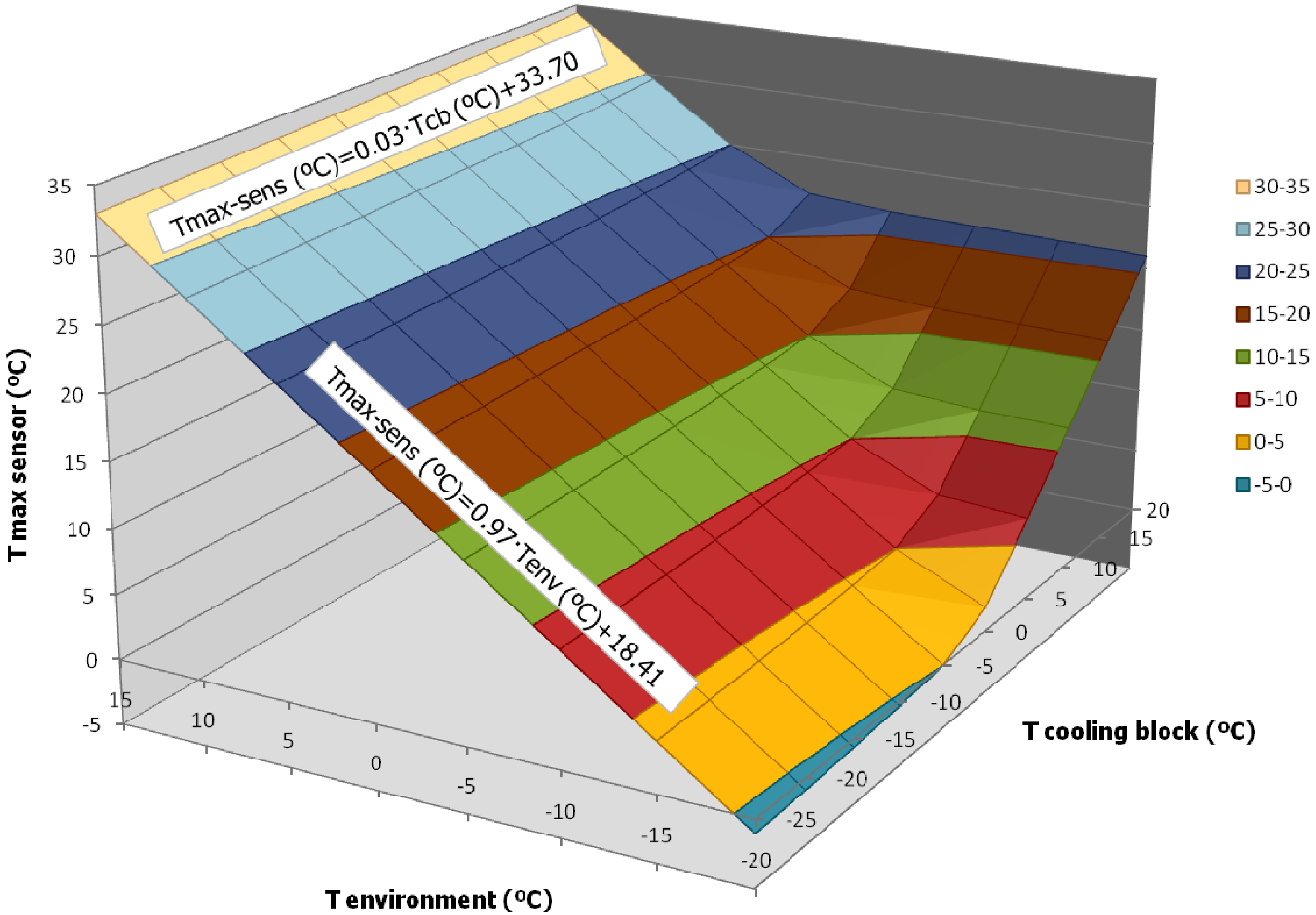
• We are within the temperature limits in this range of temperatures
• As demonstrated in previous simulations, the major influence comes from the cooling block's temperature

Maximum SWITCHER temperature



- We are within the temperature limits in this range of temperatures
- The major influence comes from the environment's temperature

Maximum SENSOR temperature



- We are within the temperature limits in this range of temperatures
- The major influence comes from the environment's temperature

What to do?

According to these simulations, one can choose whichever combinations for the environment and cooling block temperatures (although some of them are close to the sensor imposed limit)

→ These constraints do not allow us to fix a 'working point' for the system…

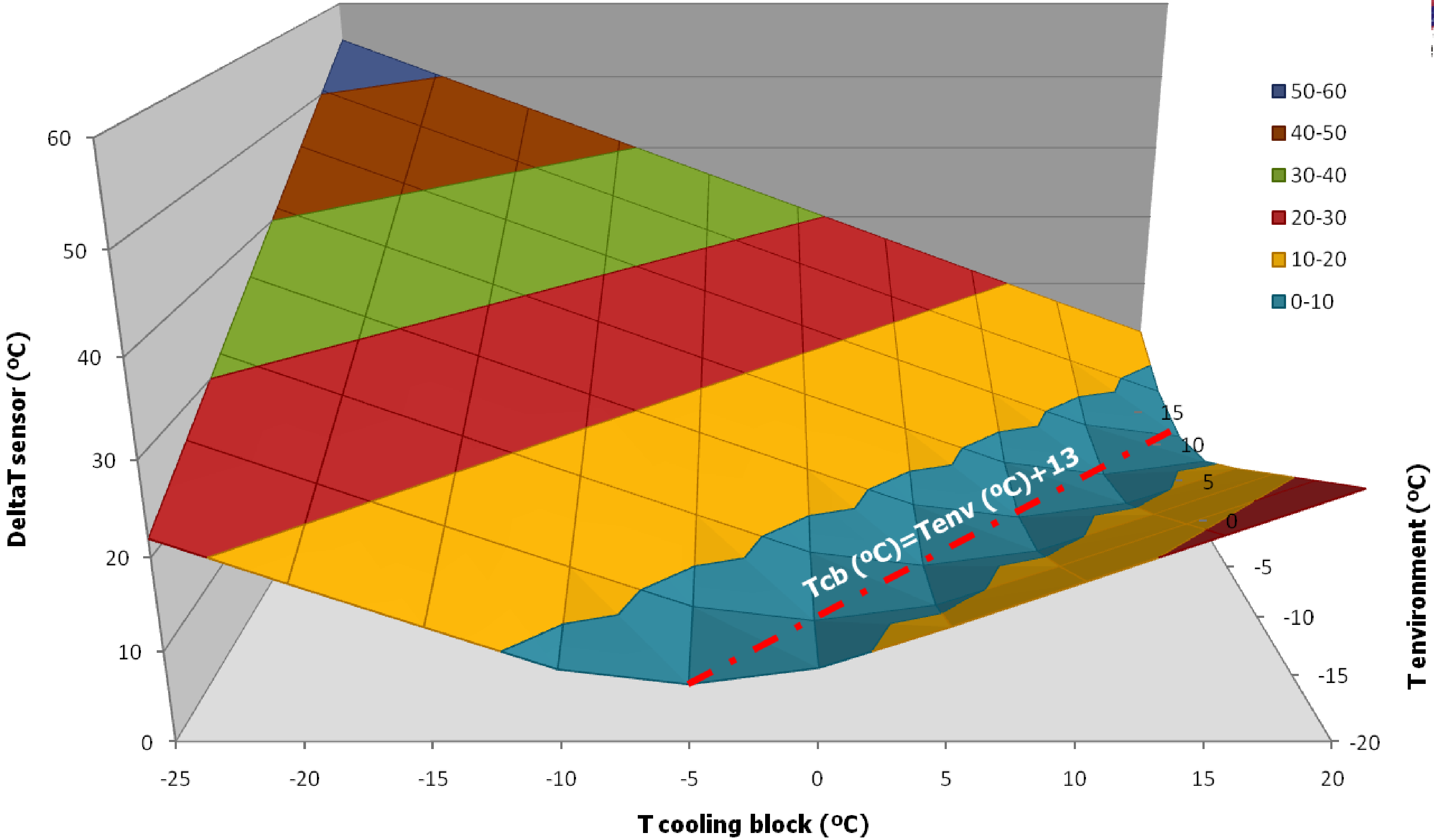
We need some new indicator to decide the temperatures to be applied…

$$\Delta T_{sensor} = T_{max} - T_{min}$$

ΔT_{sensor} has to be minimal in order to:

1.- Have an uniform response of the sensor
2.- Avoid thermal stresses

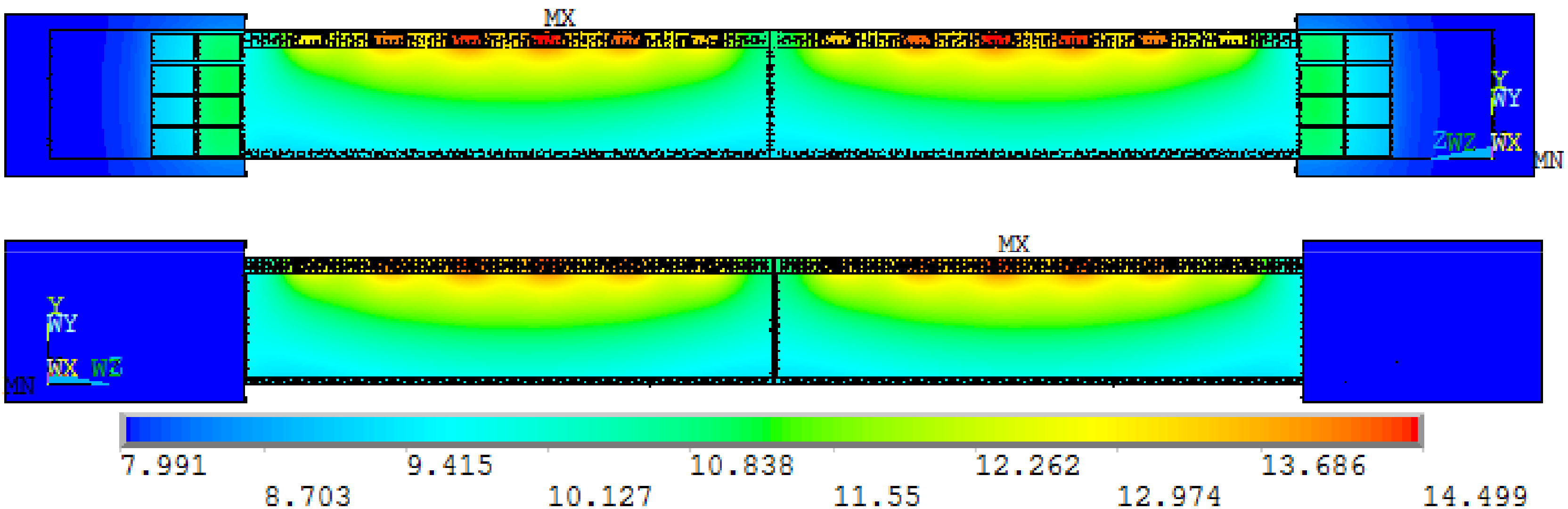
DeltaT$_{sensor}$ (for 50µm!!)



- T_{env}-T_{cb} are not free parameters anymore
- In order to keep the DeltaT$_{sensor}$ minimal, a relation between them is needed
- This relation depends on the sensor thickness!

One possible solution

- With our new thickness baseline d_{Sensor}=75µm



Belle-II DEPFET outer layer, C. Marinas (IFIC-Valencia)

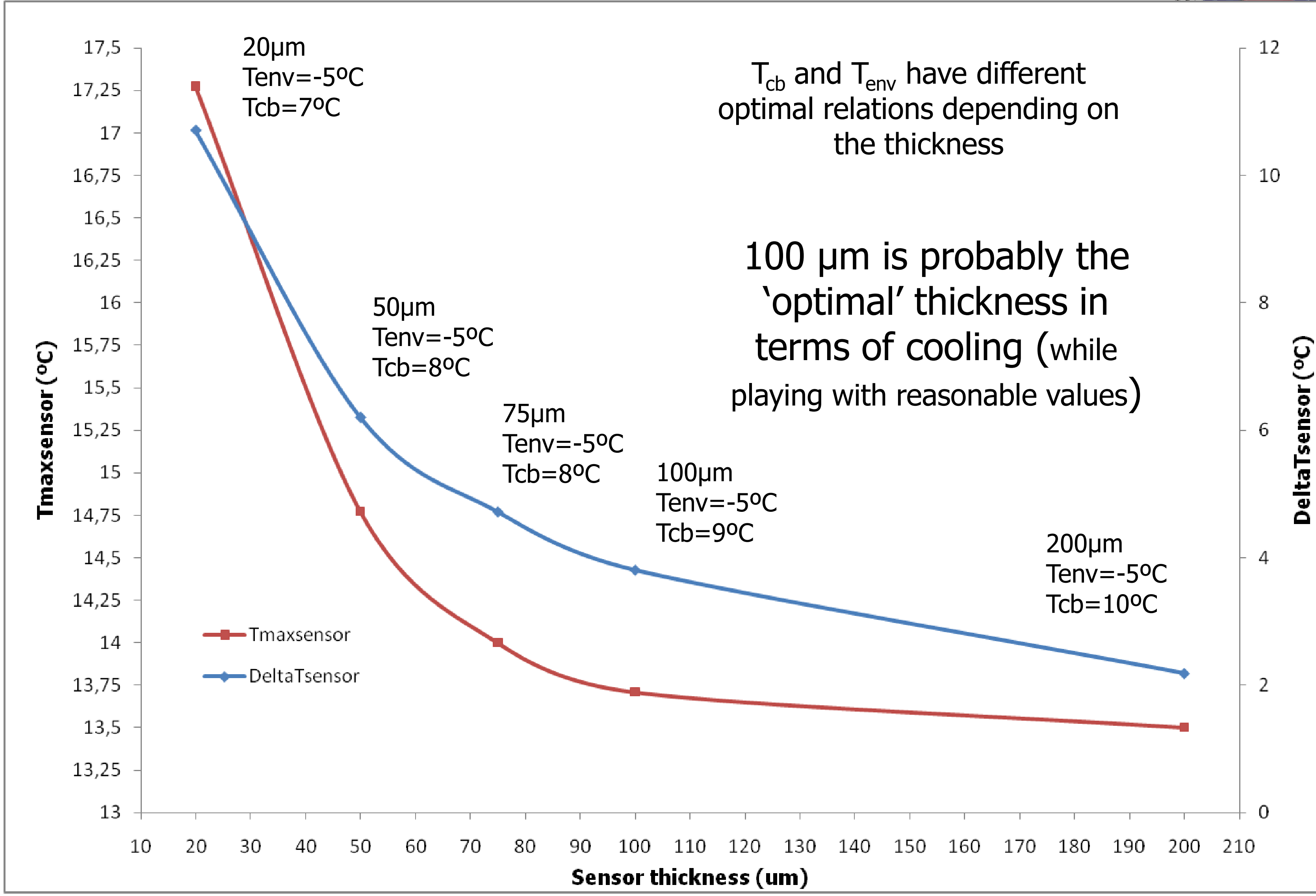
Reasonable environment conditions

T_{env}=-5ºC
T_{cb}=8ºC**

→ $T_{SENSORmax}$=14ºC
DeltaT=4.7ºC

** To achieve this T in the cb, the coolant has to be much colder ~-20ºC or lower! (Karlsruhe meas.)

Sensor thickness



Conclusions

- The final ladder geometry is fully implemented in the f.e.-software

- A big range of combinations have been studied in the T_{env}-T_{cb} parameters space.
  - Altough a big number of valid combinations appeared, the necessity of minimal $DeltaT_{sensor}$ and T_{SENSOR} lead us to:

  - Forced convection with cold gas

  - Rather low temperatures in the cooling blocks

  - If 75 µm, a starting working point could be T_{env}=-5ºC T_{cb}=8ºC (by fixing one of them, the other is already fixed too)

- Although the final sensor thickness must be decided because of the physics performance, under the 'cooling' point of view, 100 µm is the optimal number (going from 100 µm to 200 µm we don't gain that much)

  - Better temperature homogeneity along the sensor
  - Lower maximum temperature achieved in the sensitive area

AIR COOLING PROBLEM: THE STAR (RHIC) EXPERIENCE

➢ Why to study this detector?

- Some time ago, we discovered that forced convection is mandatory.
- Also SVD needs some kind of air flowing
- A common cold dry volume for both detectors was proposed

How to implement the air cooling???

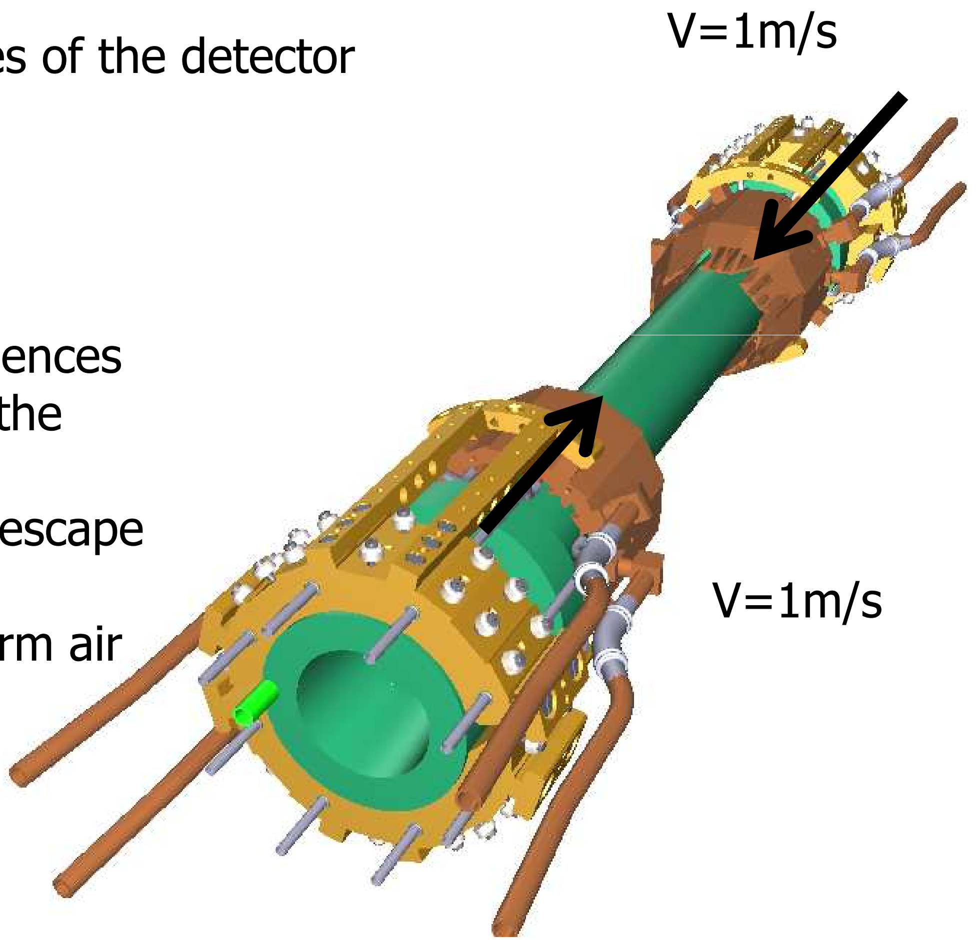
KEK is very worried about this issue…

✓ First proposal:

Blow air from both sides of the detector and leave it to expand

Problems:

- Vibrations and turbulences
- What will happen in the middle?
- Where is the way to escape for the air?
- Do we have an uniform air distribution?

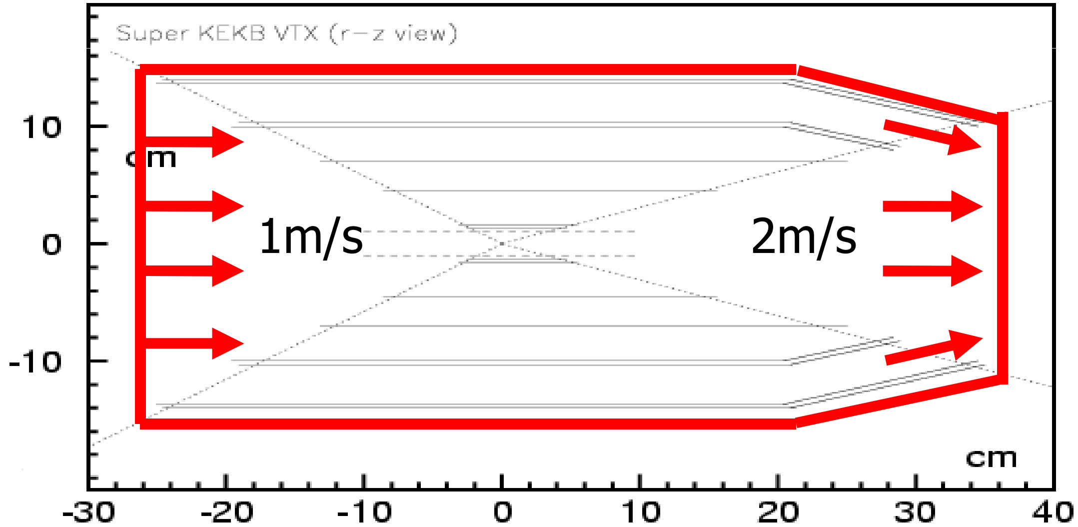


✓ Second proposal:

Build a ‘chamber’ for both detectors together and blow air from one end

Problems:

- Vibrations and turbulences
- The cold air could affect the CDC
- How could we move such ammount of air volume?
- Lack of space for isolation between the SVD and CDC

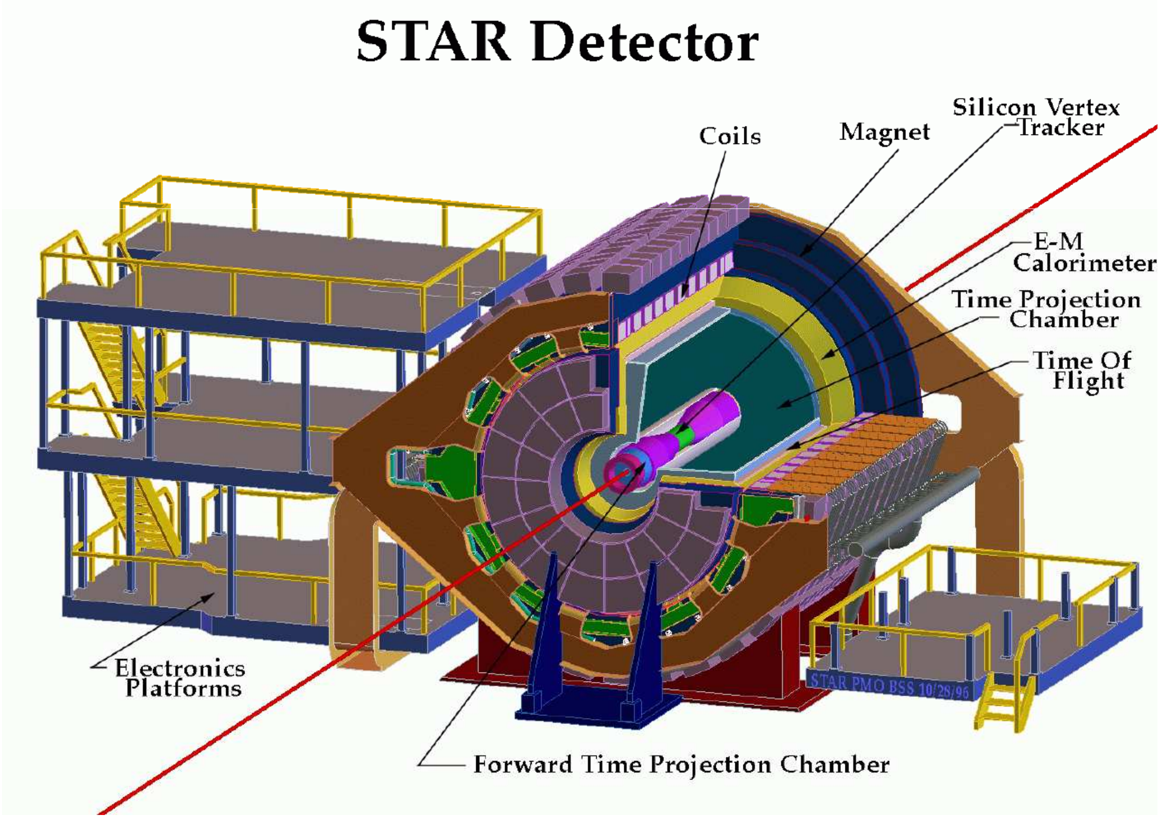


✓ The 'third way':

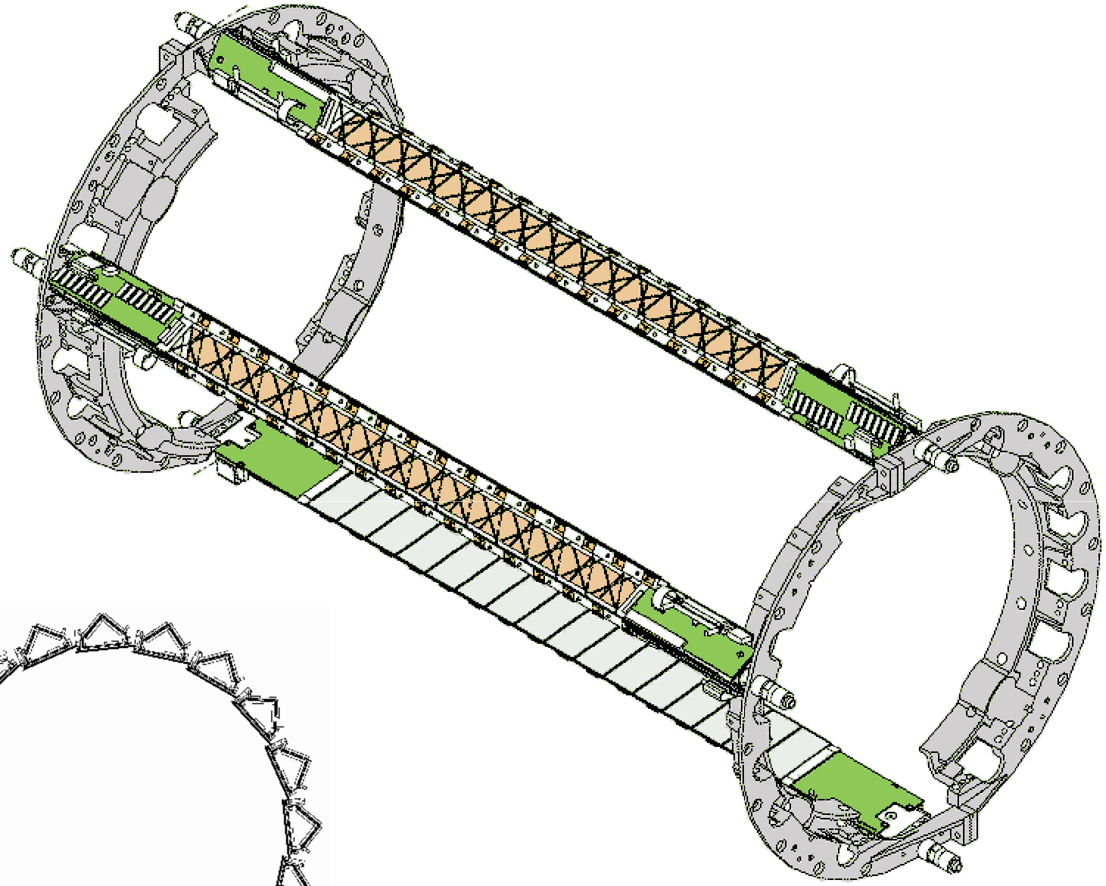
It's an intermediate solution based on the STAR SSD (Silicon Strip Detector) detector at RHIC.

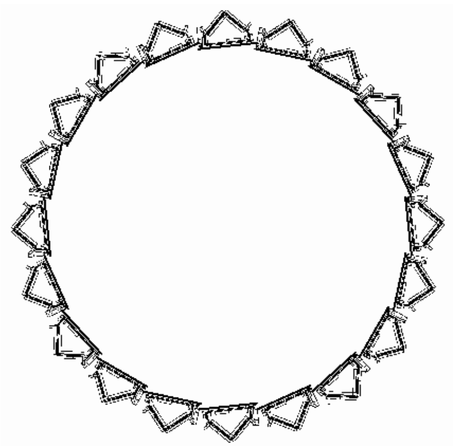
Problems:

• Uniformity of the temperature
• The lack of space is always present…



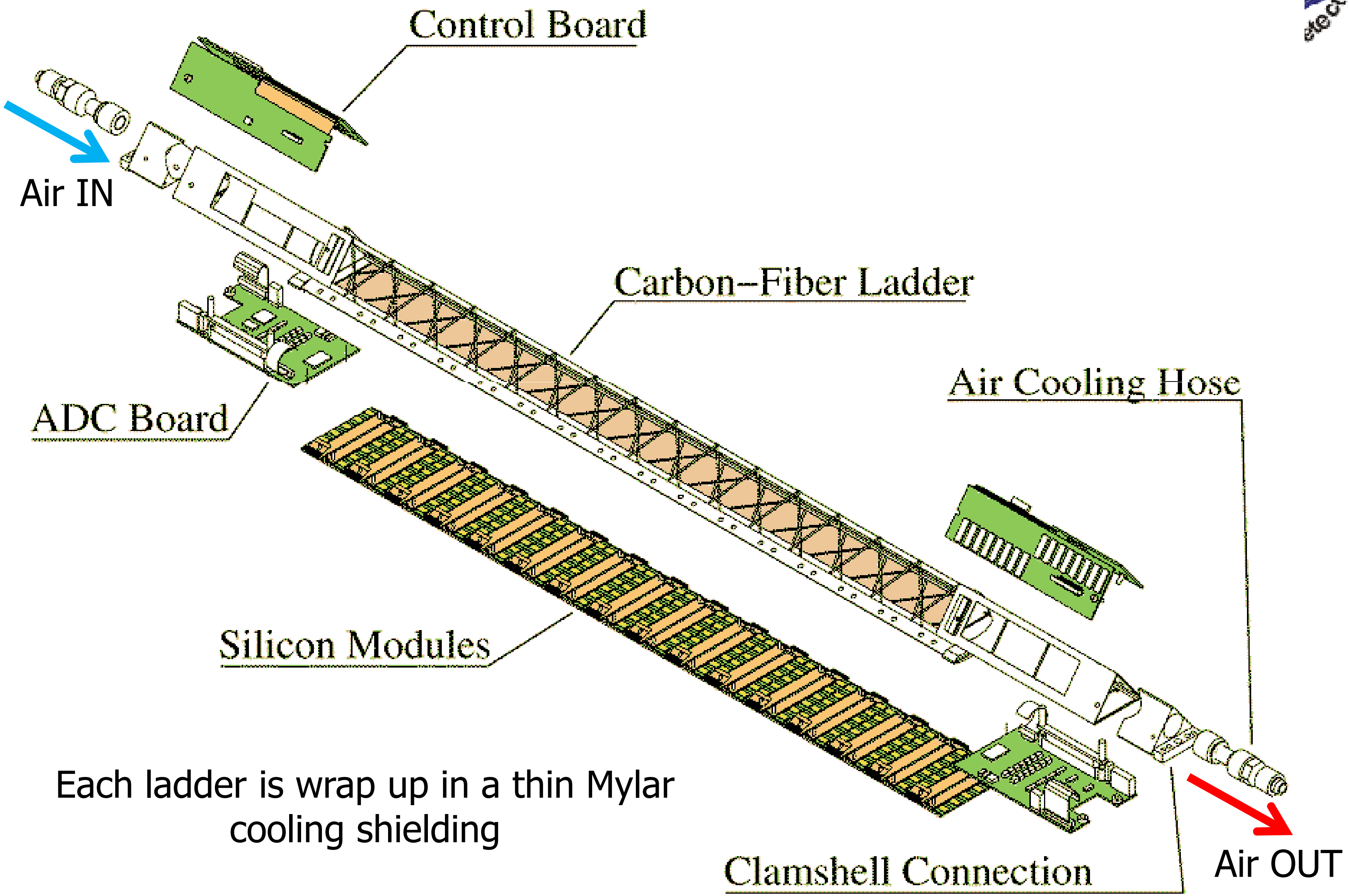
SSD subdetector



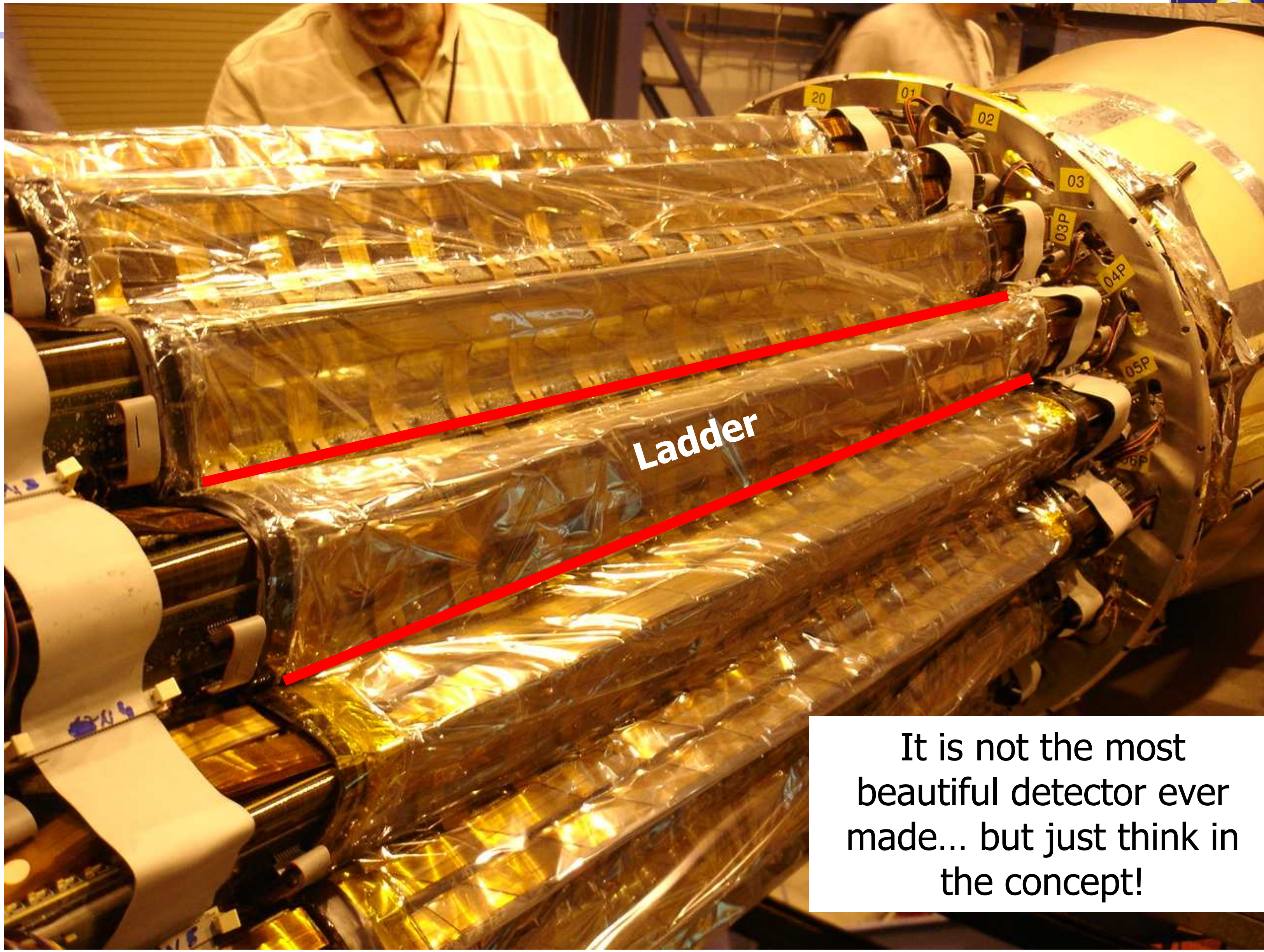


SSD lateral view populated with all the ladders

SSD ladder

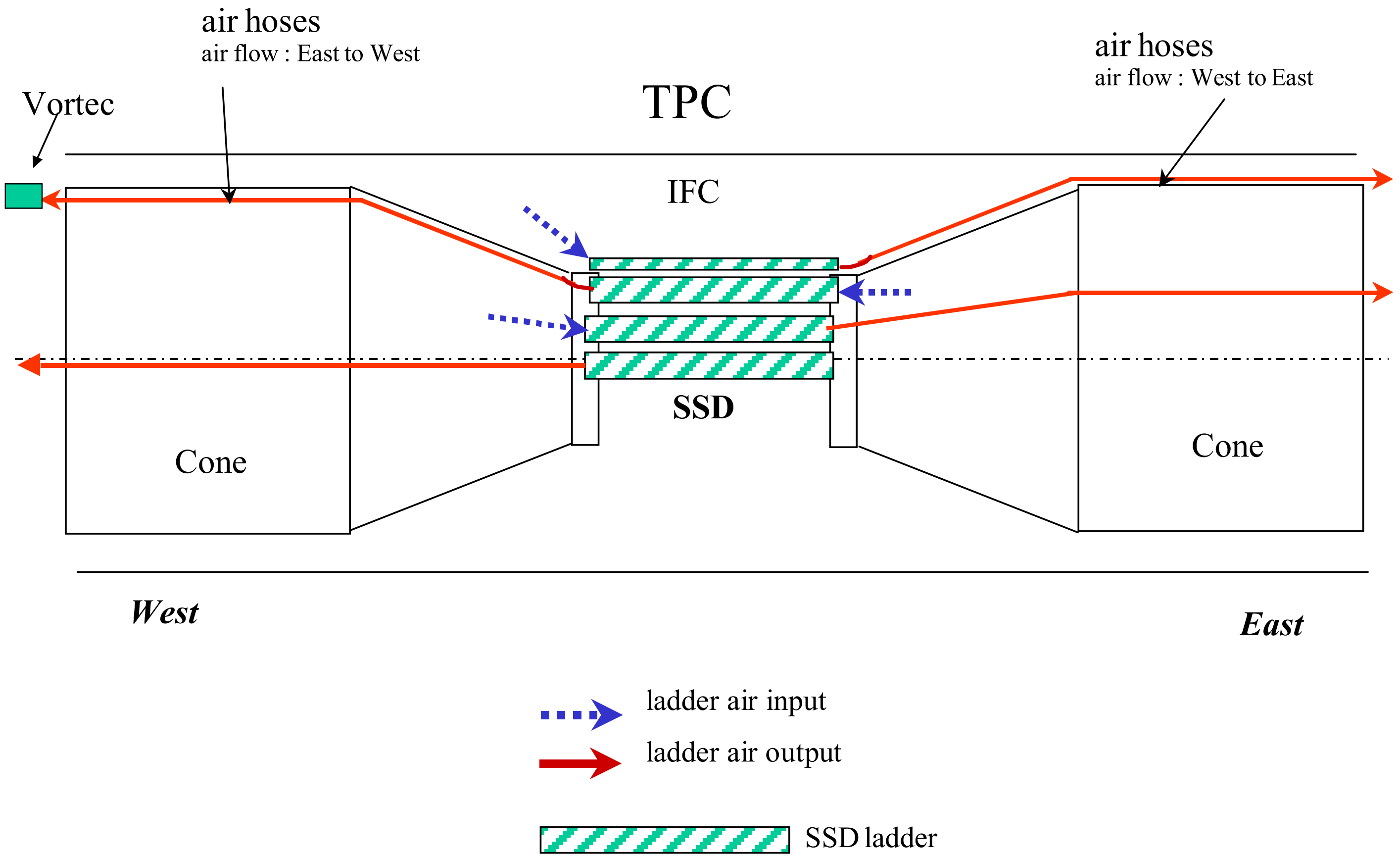


Each ladder is wrap up in a thin Mylar cooling shielding

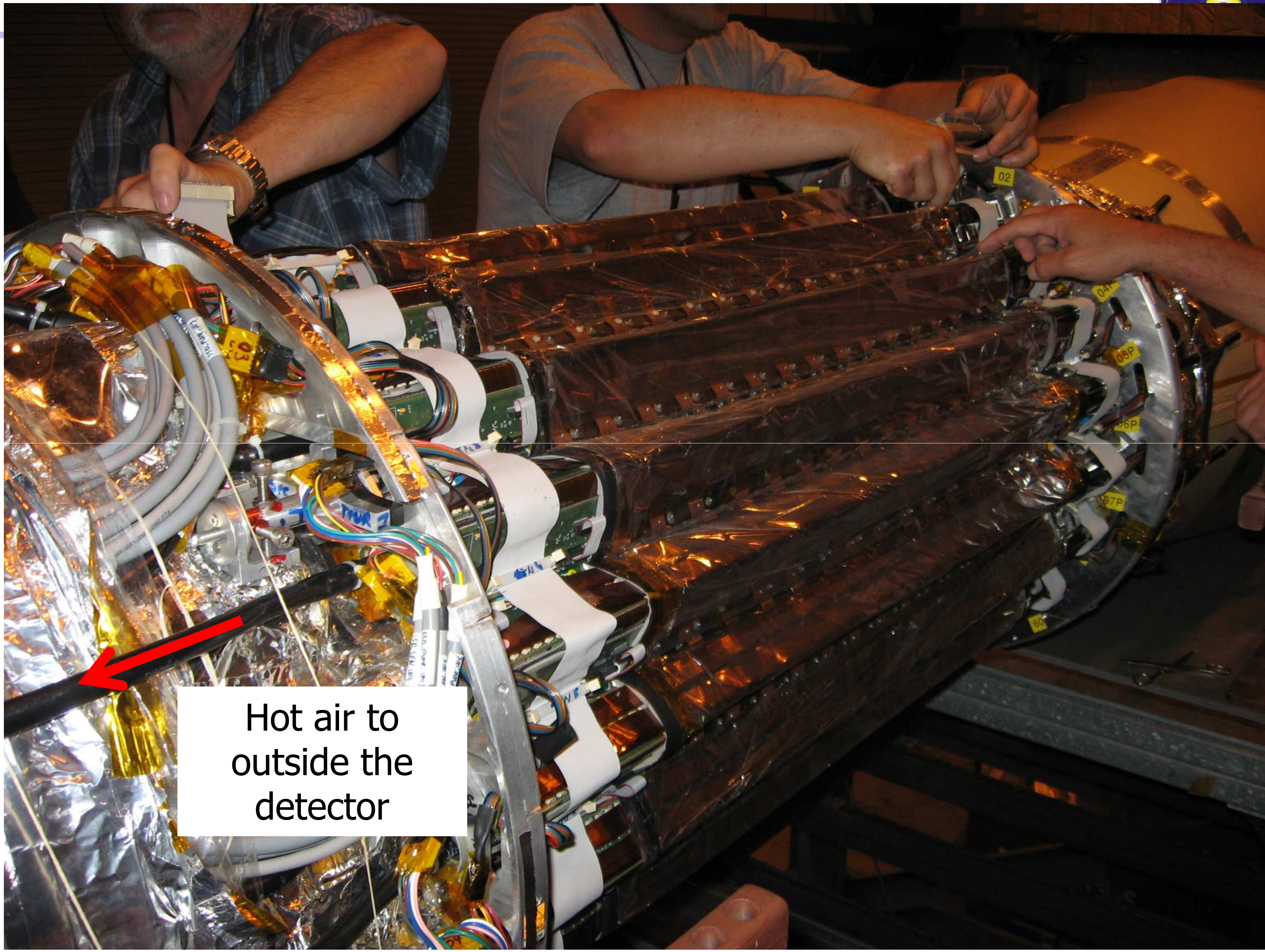


It is not the most beautiful detector ever made... but just think in the concept!

Stand-alone air cooling

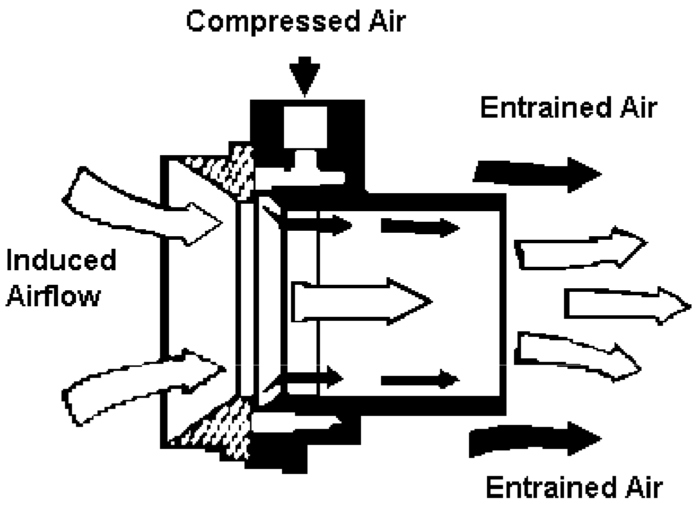


The SSD is cooled down by means of an air flow induced at one end of every ladder and taking the fresh cooled air from the TPC-IFC (Inner Field Cage) through the full volume of the ladder. The air flow is produced by a compressed air (7 bars, produced by a dedicated compressor) running into air flow amplifiers called 'Vortec', that induce an air flow of the order of 1 l/s (< 0.5 m/s) in the ladders.


Hot air to
outside the
detector

Vortec: Transvector airflow amplifier

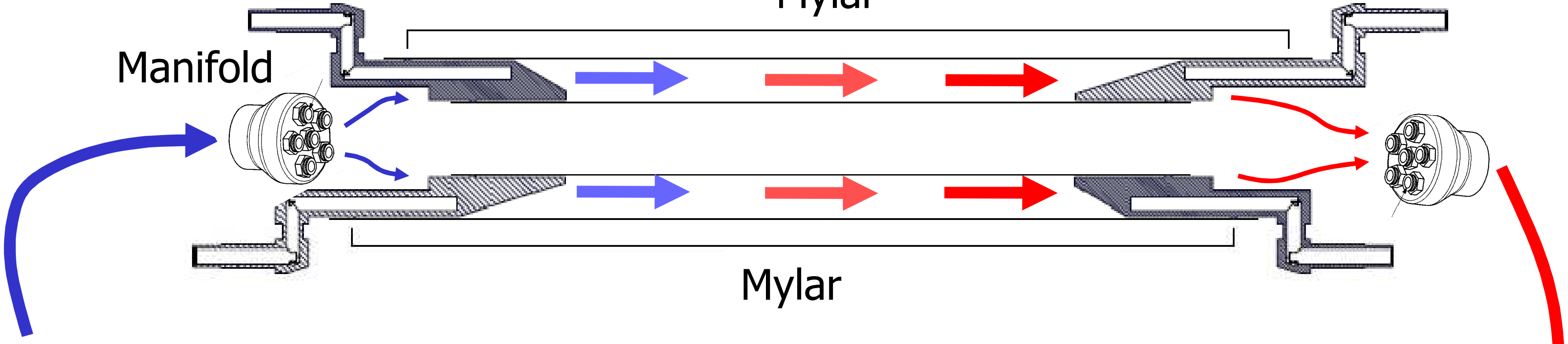
Airflow amplifier principe



The Transvector (an air driven venturi tube) uses the impulse principle to achieve amplified airflow. When compressed air enters the Transvector, it fills a chamber that has only one exit path - a 0.051mm orifice. As the air is forced out of the orifice, it accelerates and collides with surrounding air entraining a great volume of free ambient air. The result is a large volume of input and therefore output air in return for a small amount of compressed air. The induced airflow is the cooling airflow that travels through the ladder

They performed the test with 6.5 bar of transvector compressed air supply; but a Transvector can work very well at 8 bars and therefore increase the airflow in the ladder by 20%.

Belle-II PXD Option 1



Cold air gun (down to -30ºC)

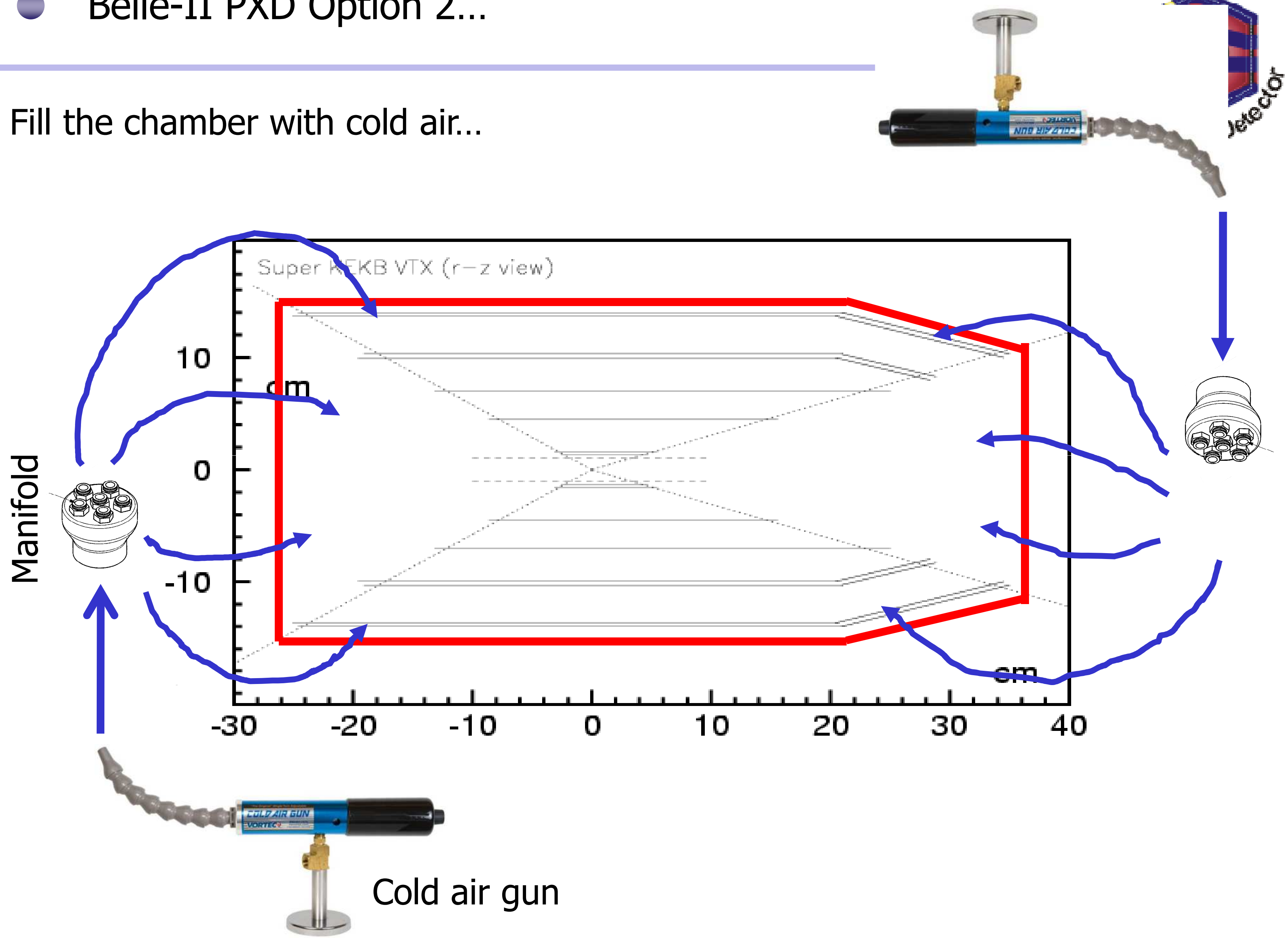
Vacuum

- ✓ This configuration seems more realistic
- ✓ The flow should be 'more' laminar
- ✓ A similar configuration can be used for the SVD

Hard-plumbing to avoid kinks in the pipes
What about the thermal gradient along the ladder???

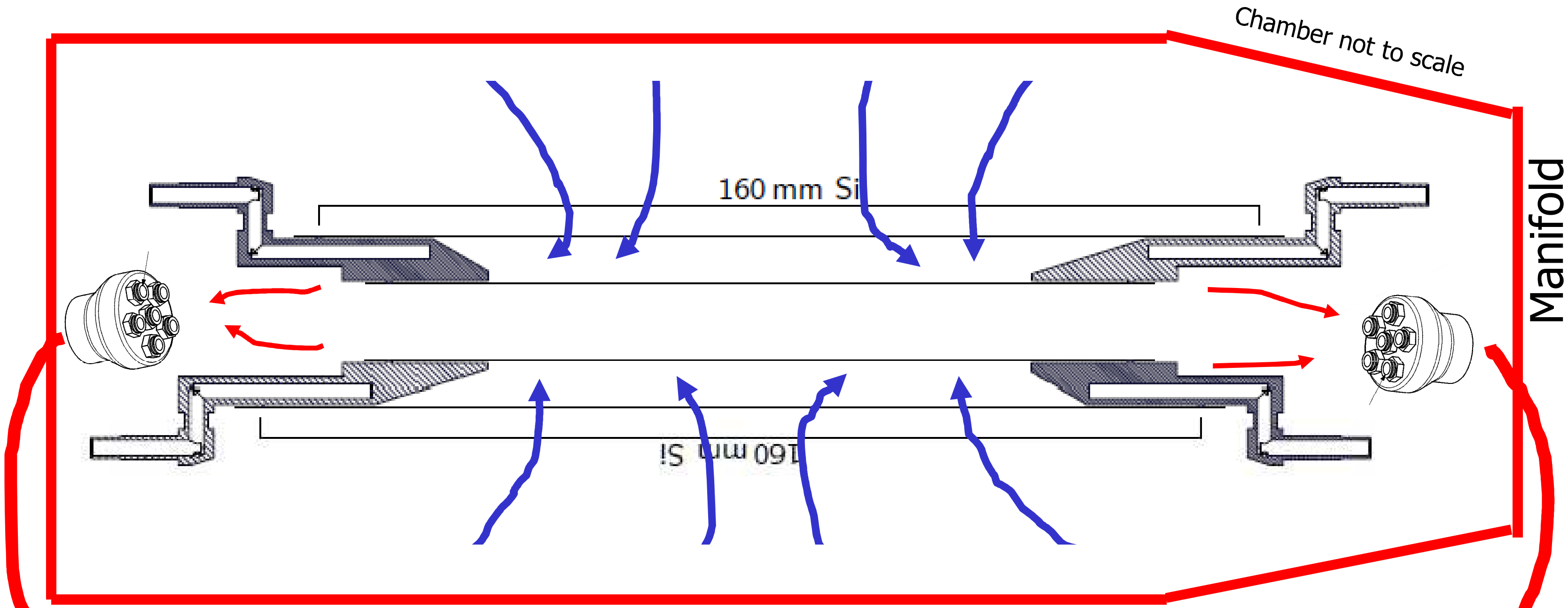
Belle-II PXD Option 2…

Fill the chamber with cold air…



Belle-II PXD Option 2…

And take the air out from both sides, using the holes in the support structure



More homogeneus temperature along the ladder

What about the isolation with the CDC??

Vacuum

Conclusions

- Two air cooling options were presented
- There is no way to simulate this…

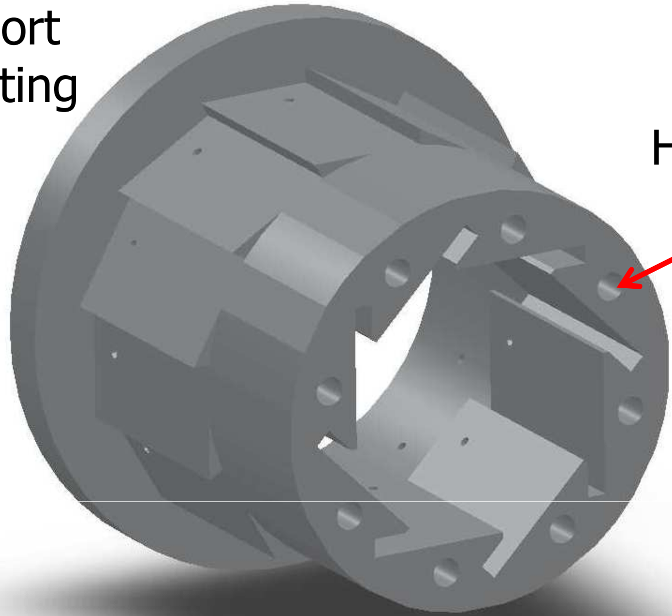
Build a mock-up and measure!

→ See next slide

VALENCIA'S TEST BENCH

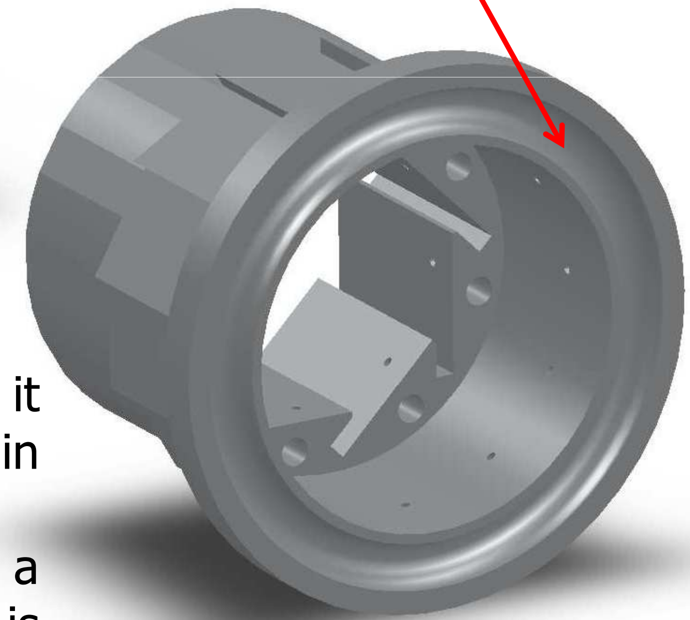
Support structure (a simplified sketch!)

Simplified support structure for testing purposes



Holes for the cold air

Ring to wrap the cooling pipe



- The beam pipe is missing in this drawing, but it will be there (with its own temperature ~15ºC) in the final design
- The cold air will be provided by a coil inside a dewar with liquid nitrogen (the cold air gun is also on the way to Valencia)

❑ Future activities:

• Study of the two air cooling options with dummy ladders created on Al or plastic and only one Belle-II real ladder

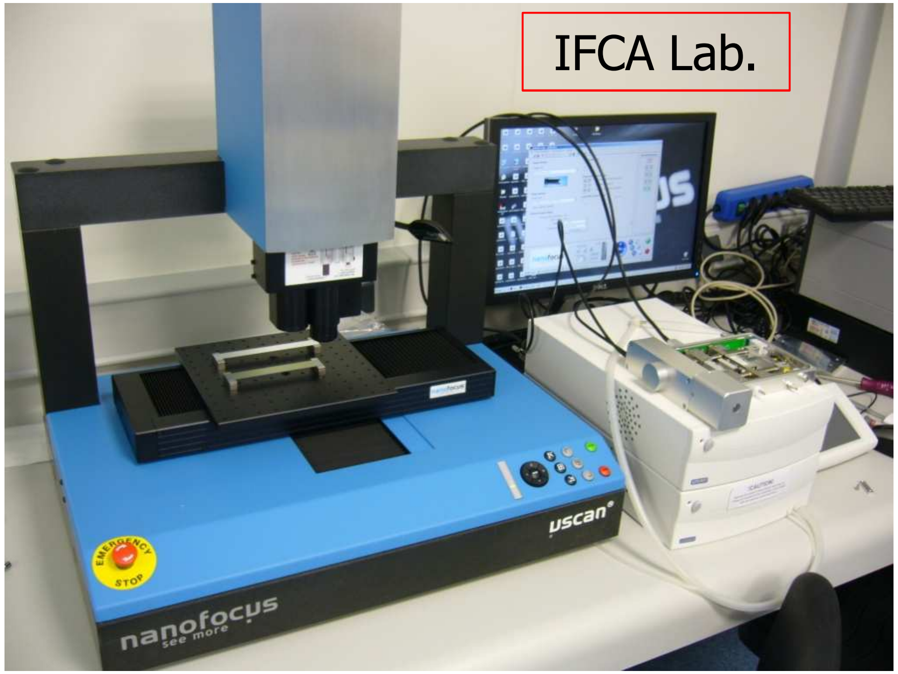
• Once the samples with the resistors integrated ready, include thermal measurements

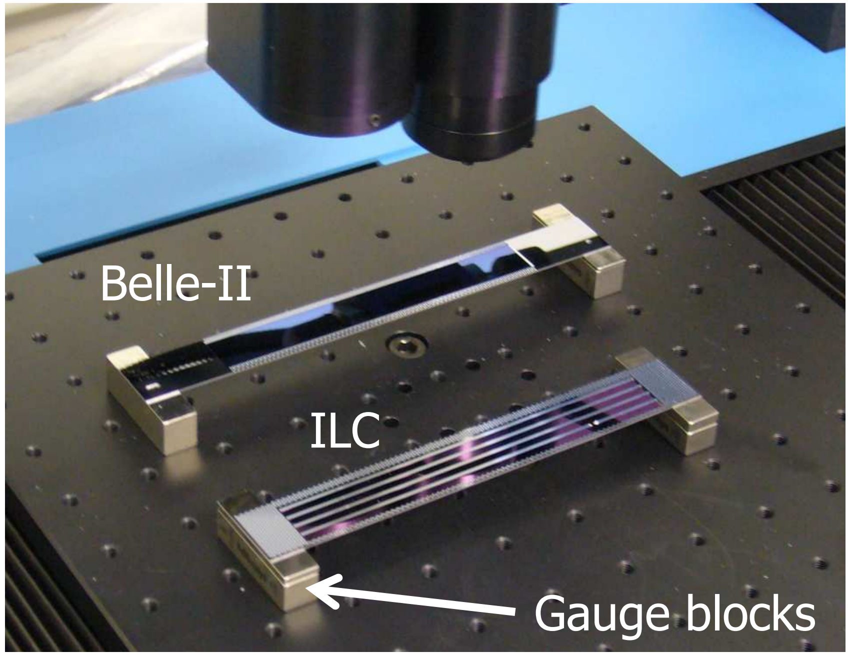
❑ Together with IFCA (Santander) → See I. Vila's talk

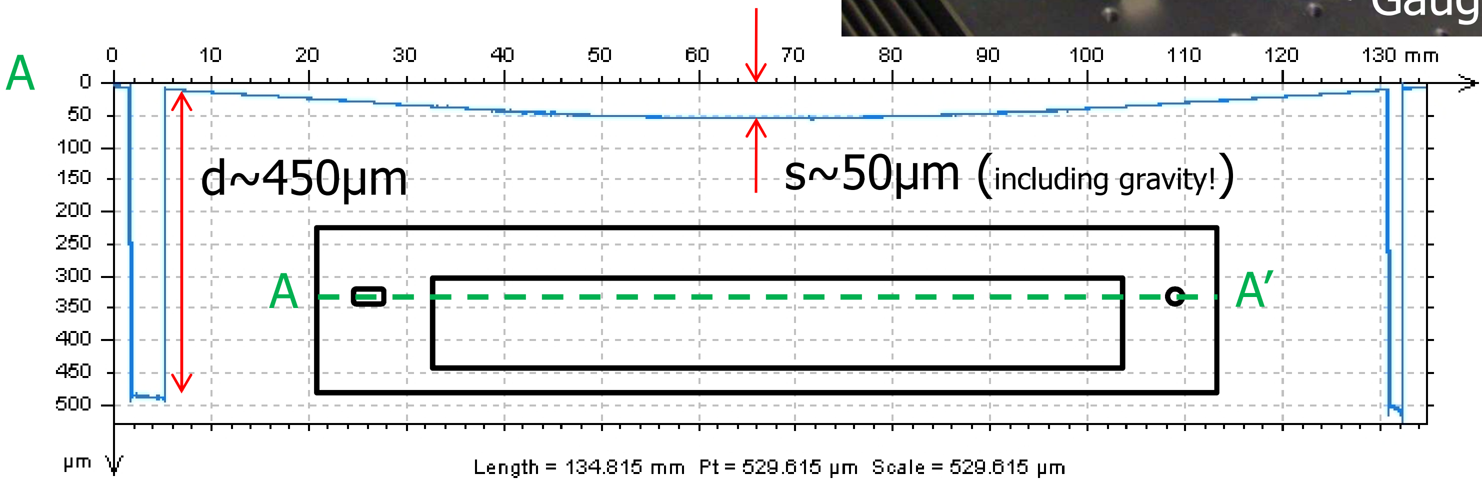
• Vibration measurements
• Temperature deformations
• Thermal stress

• This collaboration has already started

Preliminary measurements (C.Mariñas, D.Moya)





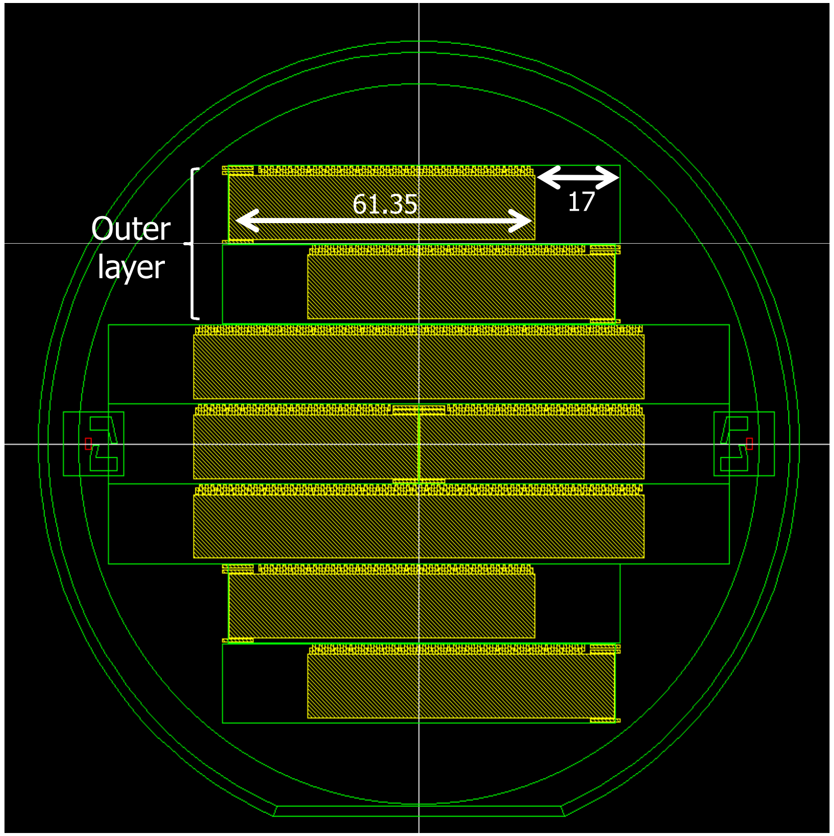


Thank you very much!

Layout for the new mechanical samples

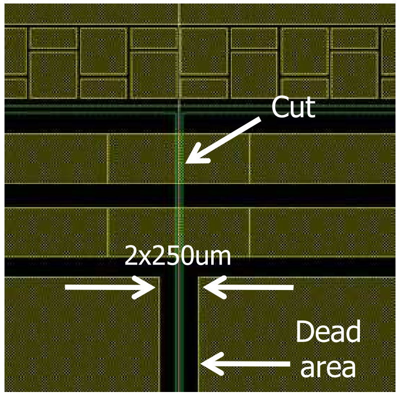
Ladder length=78.35mm
Ladder width=15mm
Length DCD+DHP balcony=17mm
Width Switcher's balcony=2mm

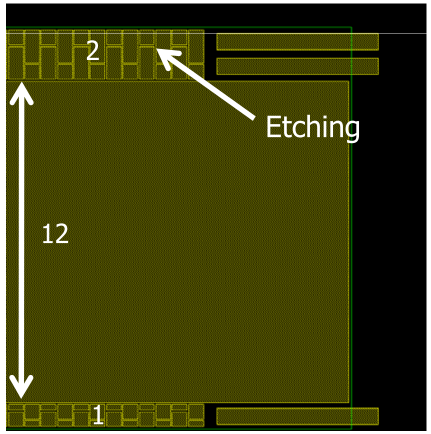
Sensor width=12mm
Sensor length=61.35mm



The geometry is now different

- New ladder dimensions
- Insensitive area to glue both halves
- Etching on balconies to reduce material





Carlos.Marinas@ific.uv.es

•1 EP-50SE rotary screw compressor
•Dimensions : L 53 in, W 42 in, H 72 in
•Weight : 1800 lbs
•Power : 37 kW
•Voltage : 460 V / 60 Hz
•Noise level : 85 dBA

•1 refrigerated dryer TMS80
•Dimensions : L 35 in, W 27 in, H 42 in
•Weight : 407 lbs
•Power : 1.26 kW
•Voltage : 230 V / 1 phase / 60 Hz

•2 filters oil remover IRP 385
•Dimensions : H 25.5 in, diameter 6.1 in
•Weight : 14.3 lbs

Carlos.Marinas@ific.uv.es

Cold
air

Induced
airflow