Cooling of the Belle-II PXD detector

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- Outline

Belle-II experiment

Please, change your mind!

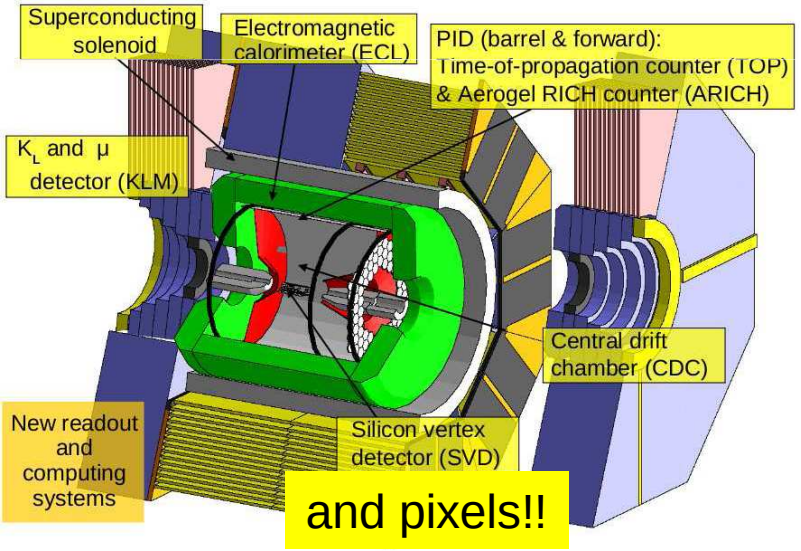
Cooling solution

Summary

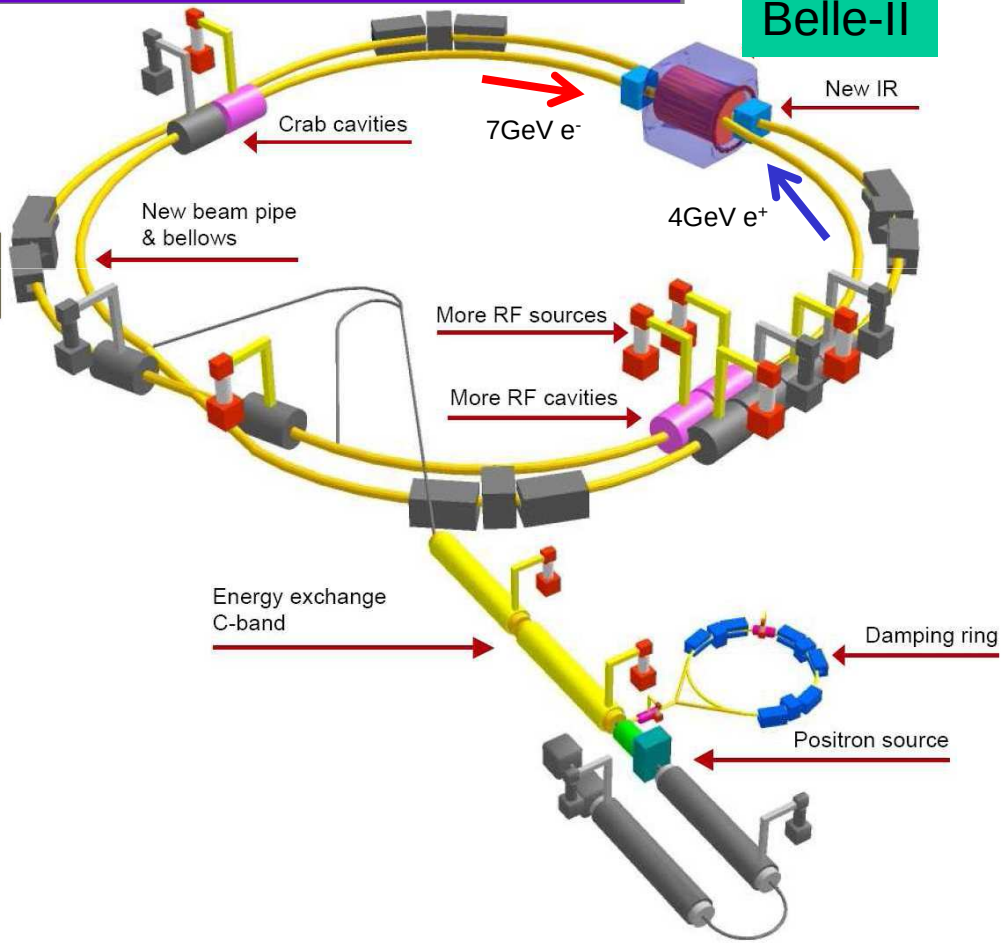
KEKB Upgrade Plan : Super-B Factory at KEK

- *Asymmetric energy e^+e^- collider at E_{CM}=m(ϒ(4S)) to be realized by upgrading the existing KEKB collider.*
- *Initial target: 10 × higher luminosity* ≅ $2\times10^{35}/cm^2/sec$
  → 2×10^9 *BB and* $\tau^+\tau^-$ *per yr.*
- *Final goal:* $L=8\times10^{35}/cm^2/sec$ *and* $\int L\,dt = 50\ ab^{-1}$

Luminosity 50 times larger than Belle
Current 2 times larger



and pixels!!



From ILC to Belle-II

- Belle-II is more challenging rather than ILC in some points

	ILC	Belle-II
Occupancy	0.13 hits/μm^2/s	0.4 hits/μm^2/s
Radiation	< 100 krad/year	> 1Mrad/year
Duty cycle	1/200	1
Frame time	25-100 μs	20 μs (continuous r.o. mode)
Momentum range	All momenta	Low momentum (< 1 GeV)
Acceptance	6º-174º	17º-150º

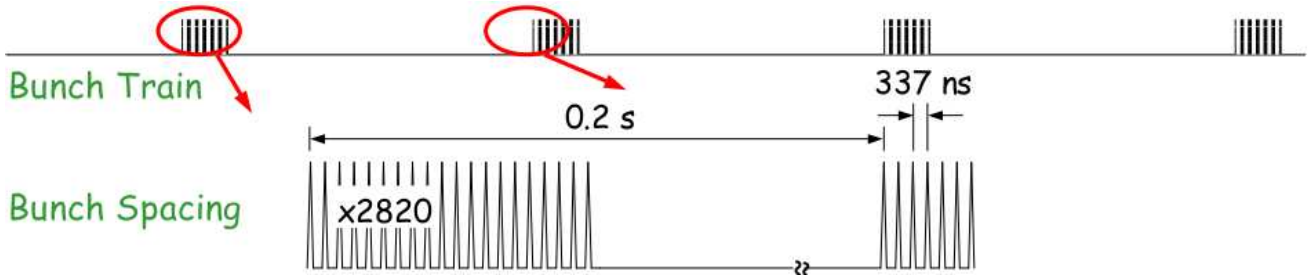
- ILC
  - Excellent single point resolution (3-5 μm) → Small pixel size 25μm^2
  - Low material budget (0.12%X_0/layer)

- Belle II
  - Modest spatial resolution (10μm) → Moderate pixel size (50 x 75 μm^2)
  - Few 100 MeV momenta → Lowest possible material budget (0.15% X_0/layer)

Understanding the cooling

	ILC	Belle-II
Frame time	25-100 μs	20 μs (continuous r.o. mode)

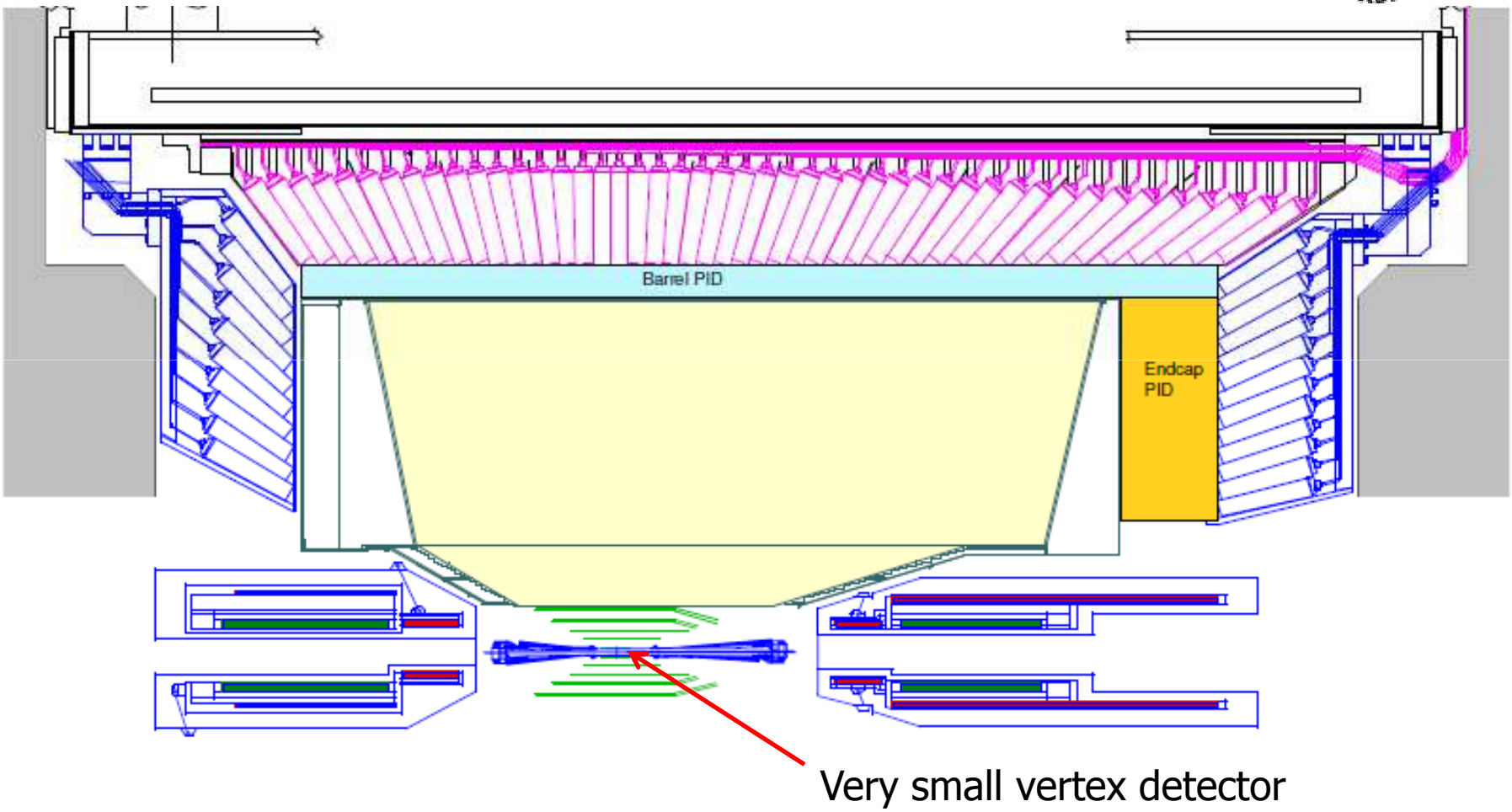
The time structure of the beam is completely different… so the ASICS are powered on all the time and this way not only air cooling but also active cooling is needed…



	ILC	Belle-II
Acceptance	6º-174º	17º-150º

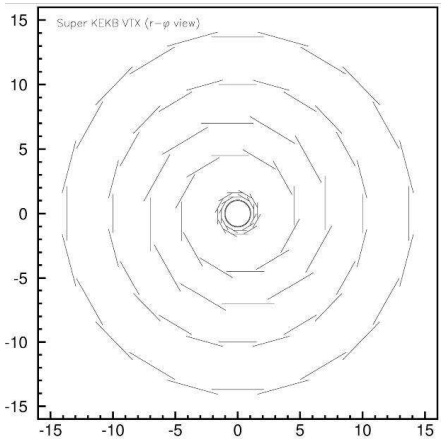
We can benefit of this issue and place all the 'heavy' stuff outside…

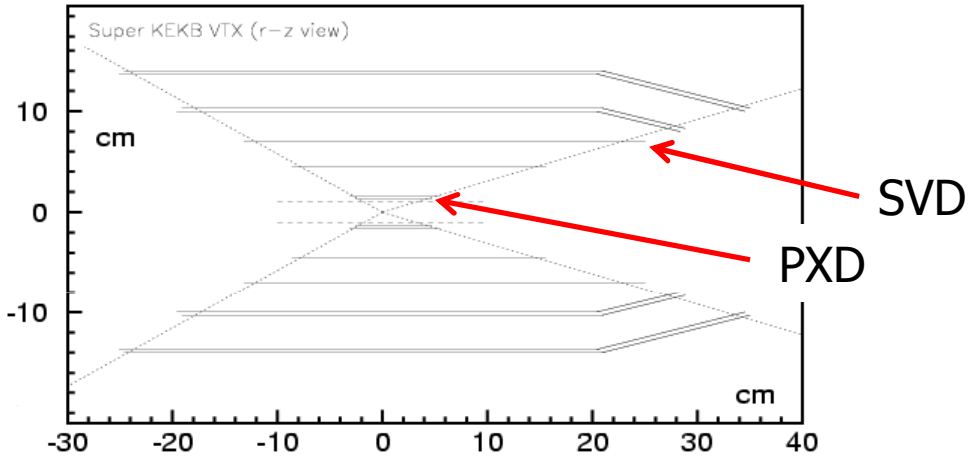
- Belle-II detector



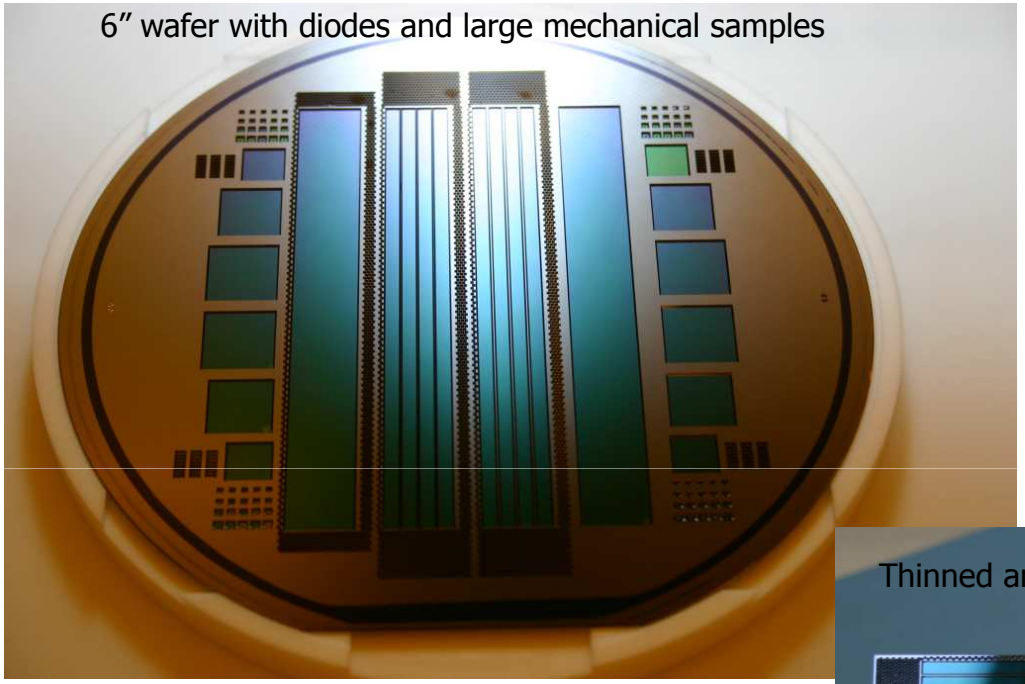
Zooming in…

- 2 thin pixel layers at 1.4 cm and 2.2 cm (subject to optimization)
- 4 layers with double sided Si-strip detectors
- Angular coverage 17°<θ < 155°, slanted at the end

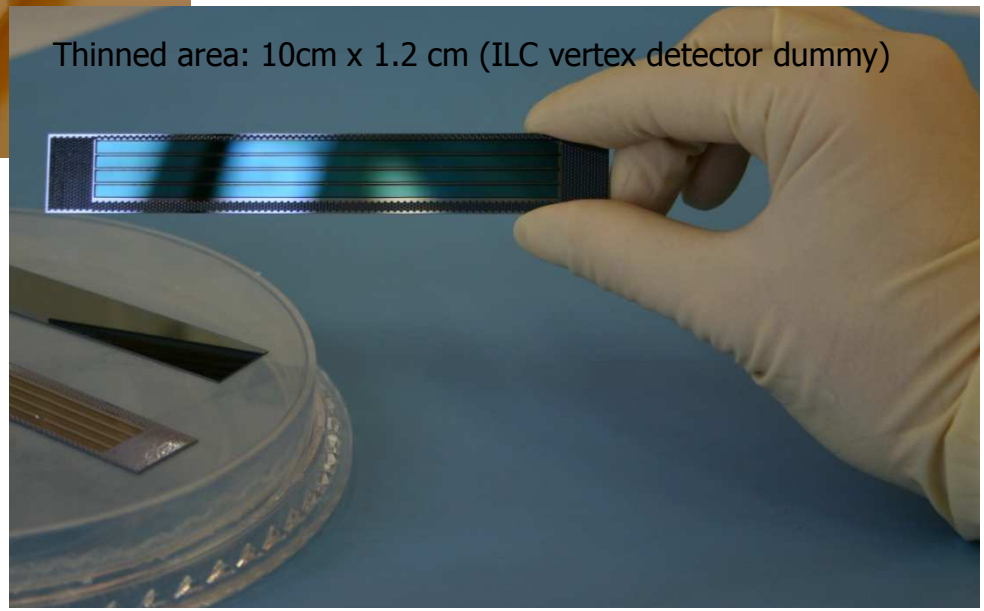




DEPFET Thin sensors



- The stiffness is provided by the frame itself
- No aditional support structure is required

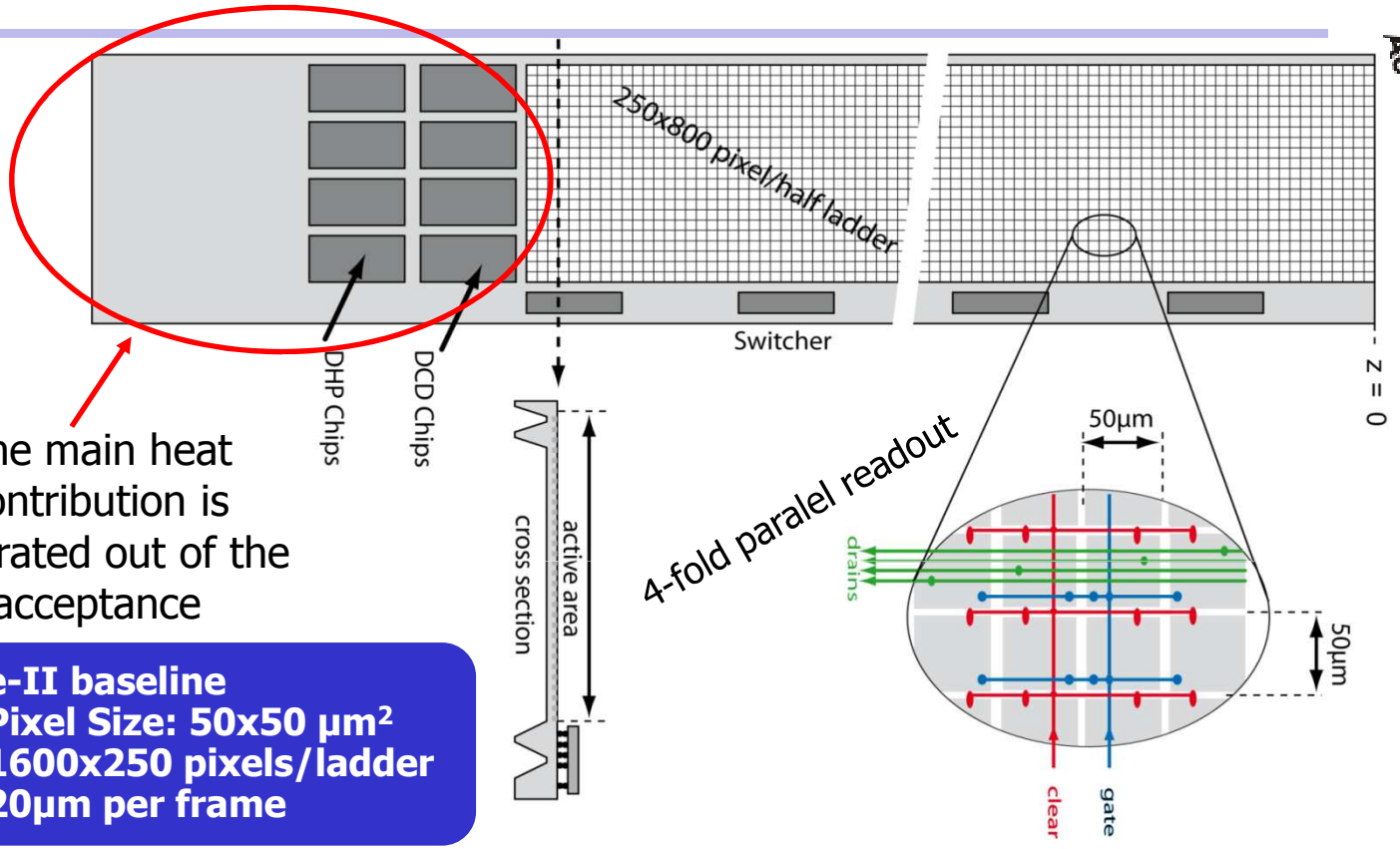


The material budget… a crucial issue!

→ Try to reduce the m.s. contribution

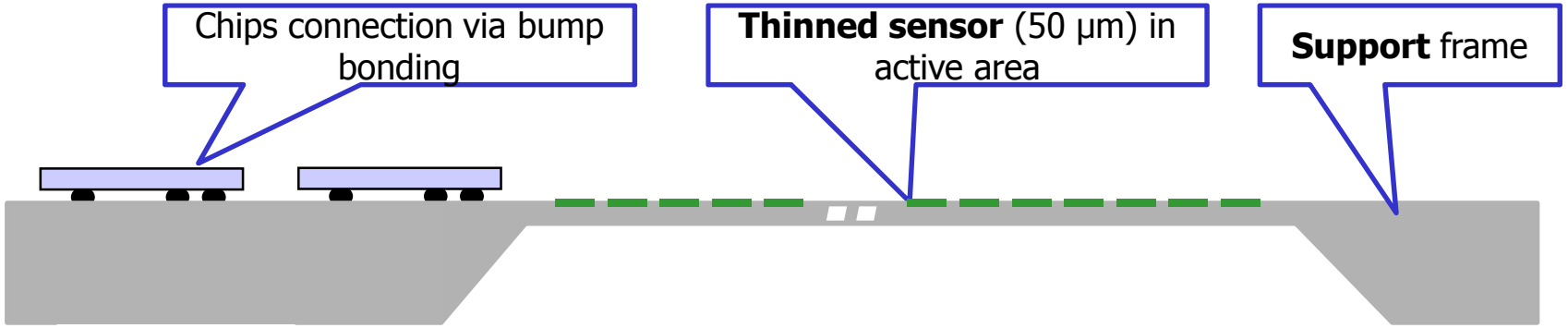
- **Sensor: Thinned down to 50µm**
- **Balconies: Etched grooves**

The Belle-II half ladder

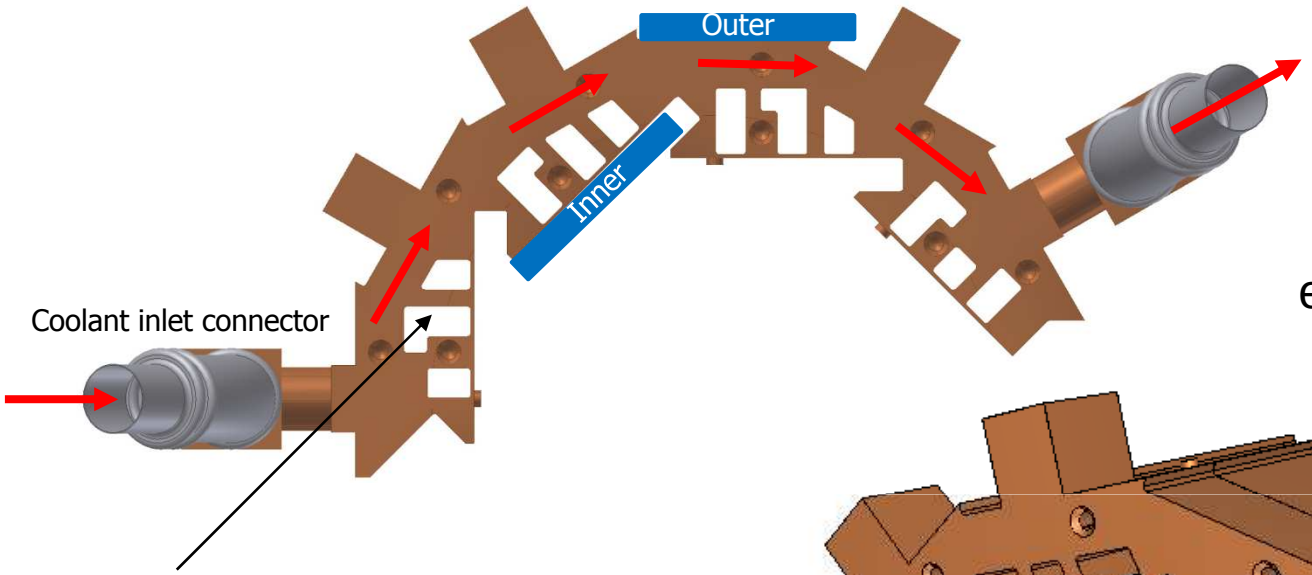


The main heat contribution is generated out of the acceptance

- **Belle-II baseline**
  Pixel Size: 50x50 µm²
  1600x250 pixels/ladder
  20µm per frame

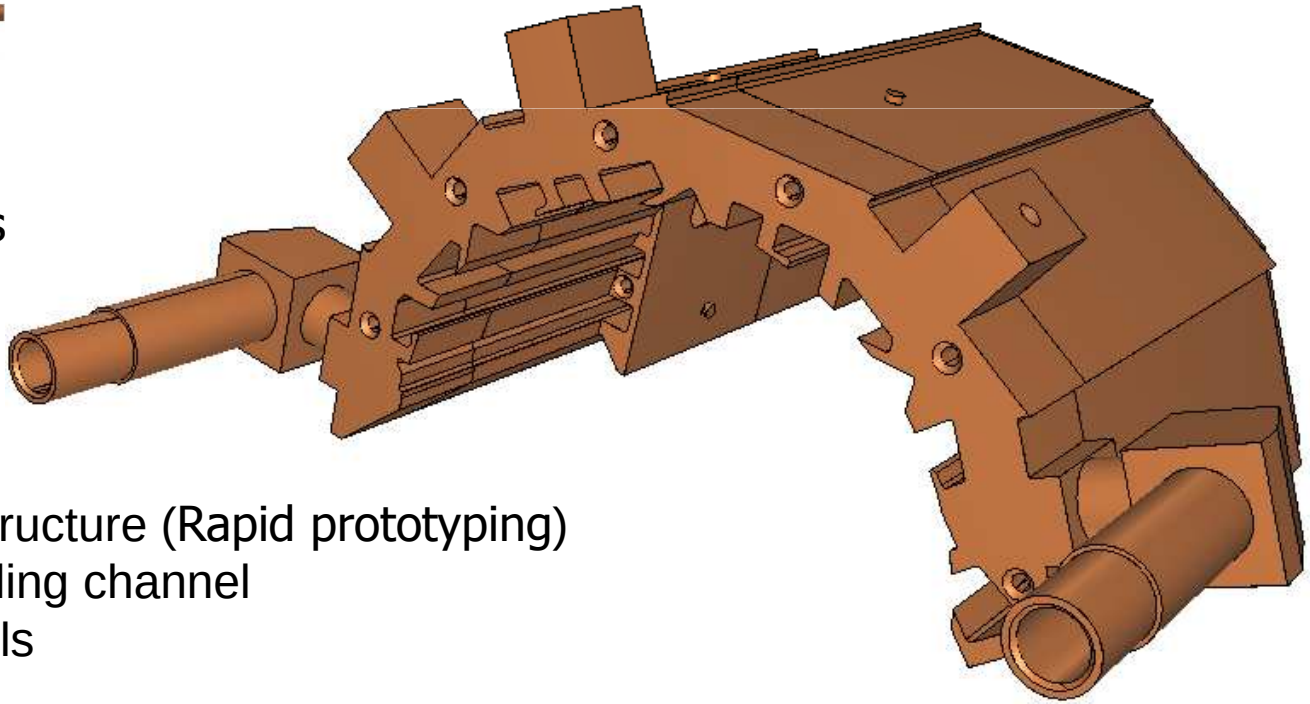


Integrated Support and Cooling Structure (ISCS)



Air cooling channels between ladders

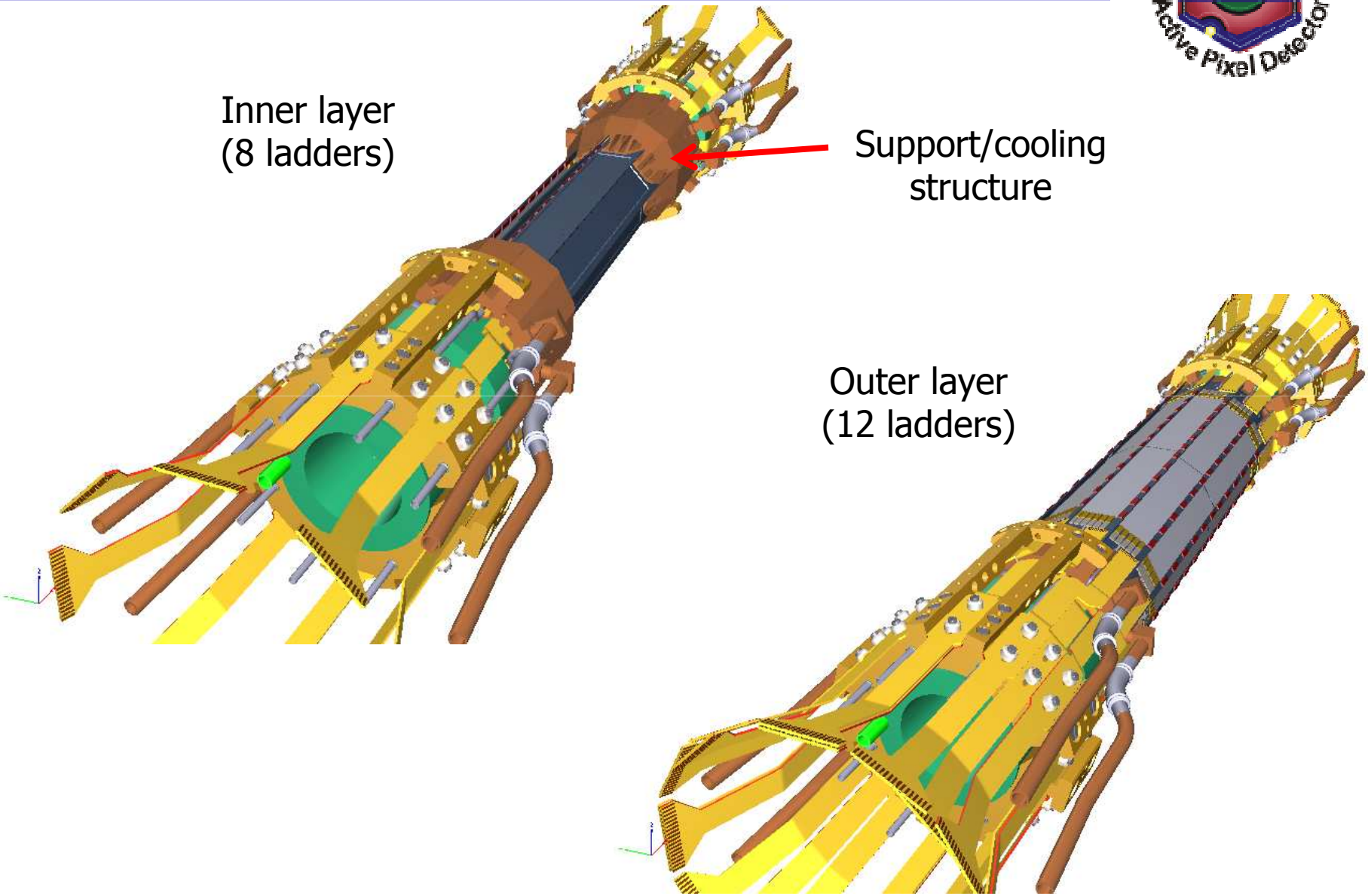
Baseline: CO_2 evaporative cooling



- Half support structure (Rapid prototyping)
- Integrated cooling channel
- Airflow channels

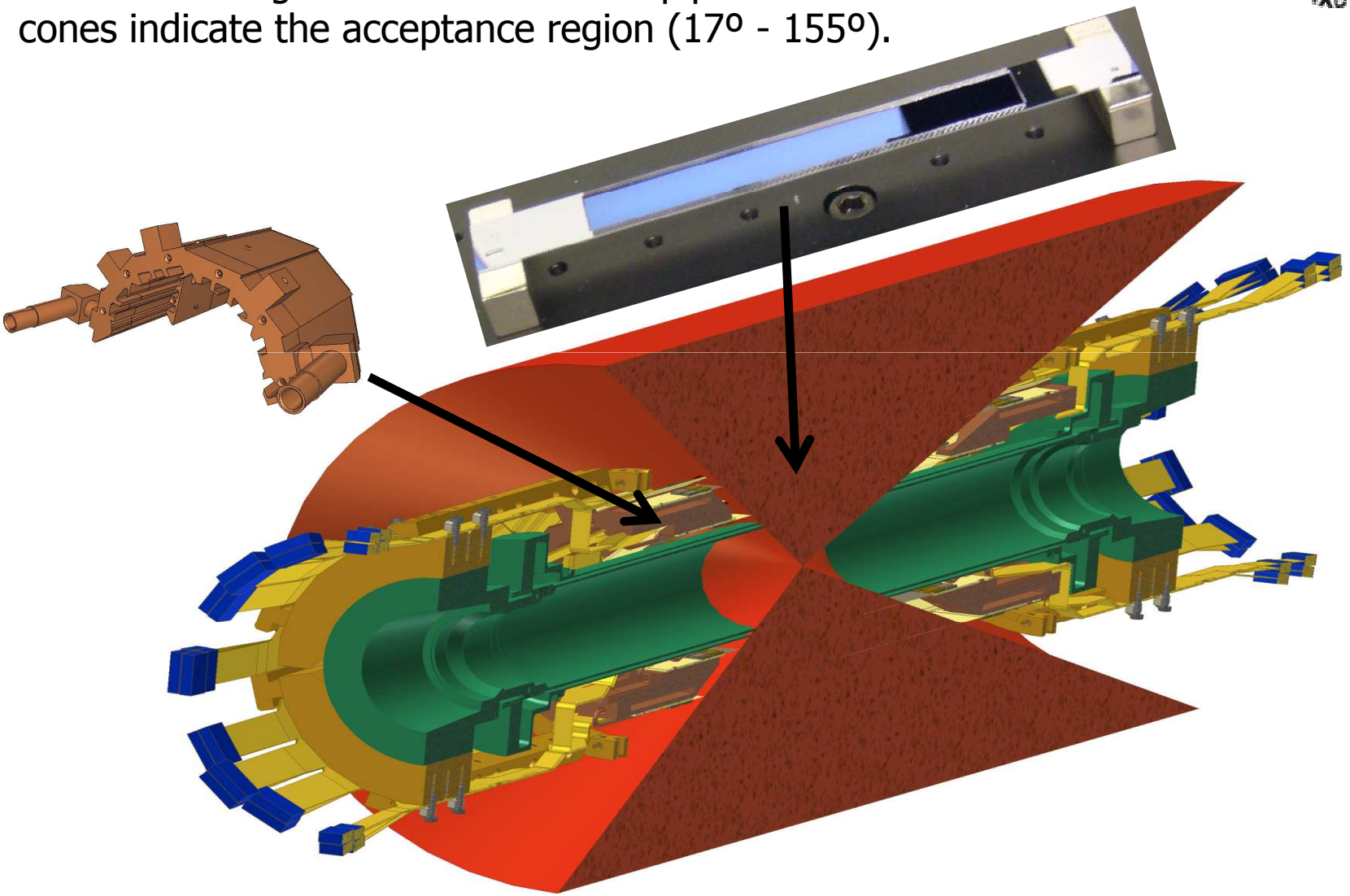
❑ Idea: Remove the heat directly where is produced

- 3D PXD

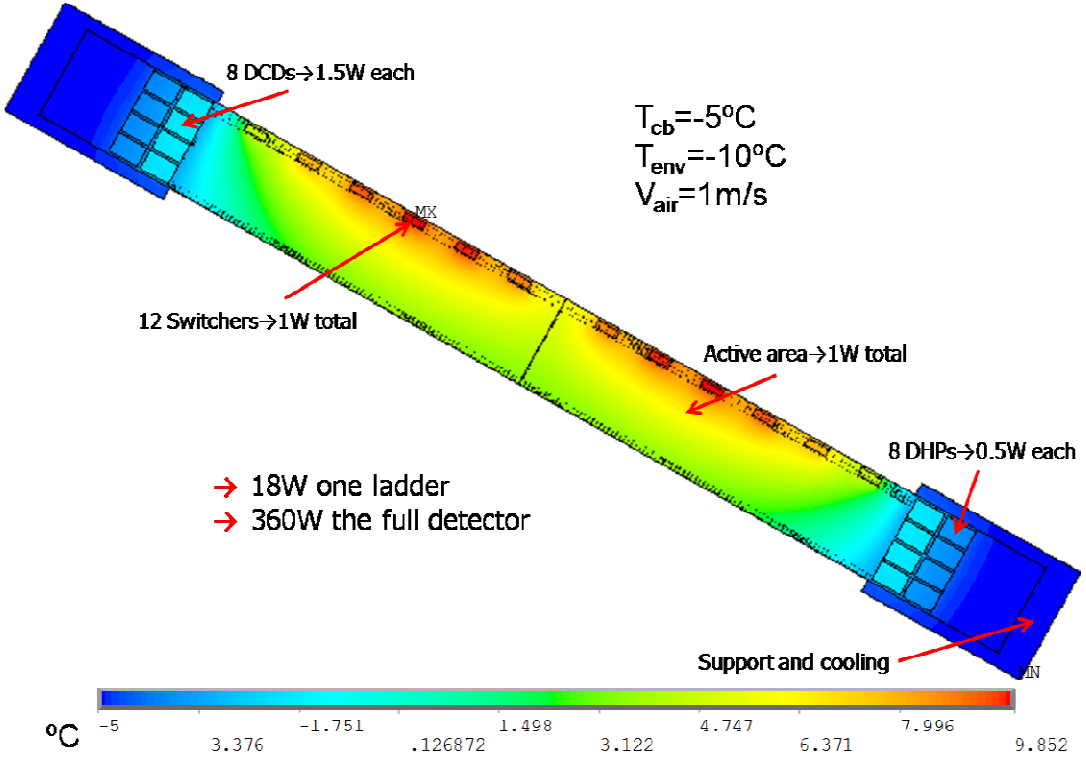

Inner layer
(8 ladders)
Support/cooling
structure
Outer layer
(12 ladders)

Belle-II acceptance

Cut view through detector with beampipe. The red cones indicate the acceptance region (17º - 155º).



Thermal studies

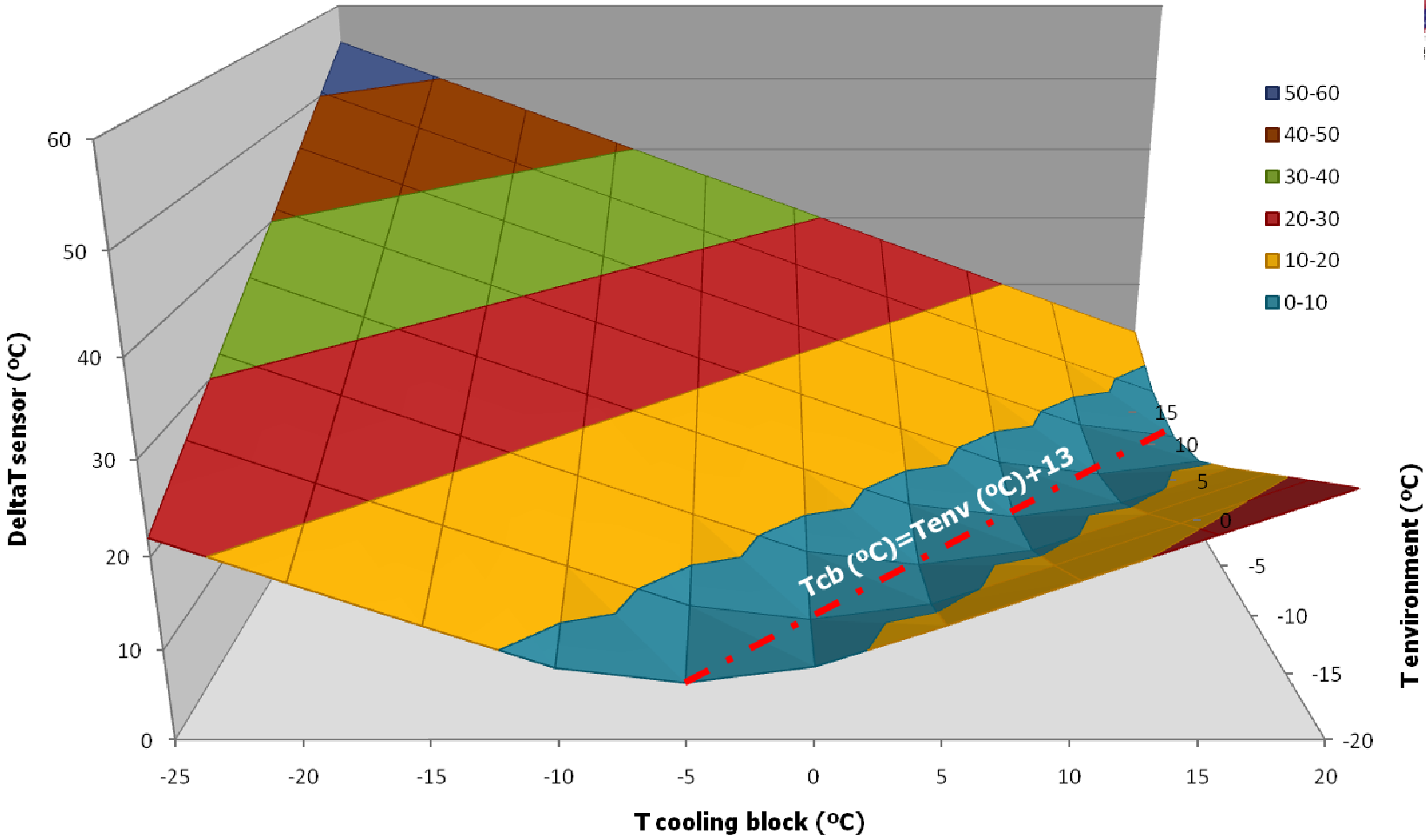


Ladder Belle-II PXD

By means of thermal simulations (cross checked with measurements) we know that:

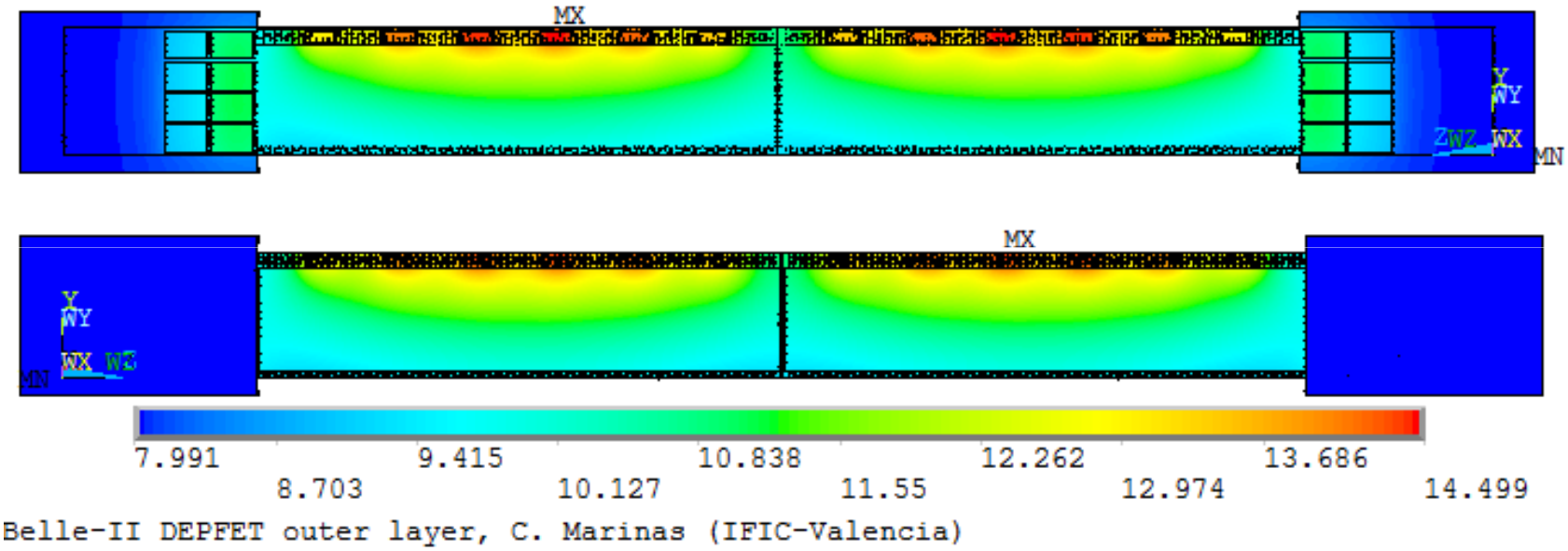
- The end of stave has to be cooled by means of conduction (massive cooling structures at both ends; see previous slide)
- The center of the ladder is an issue for the forced convection

Simulation: Finding a 'Working point'



- 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



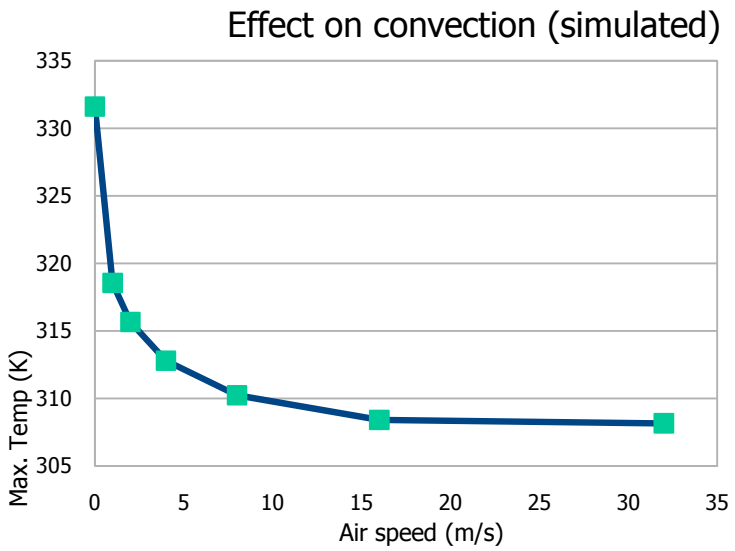
Reasonable environment conditions

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!

Air speed effect



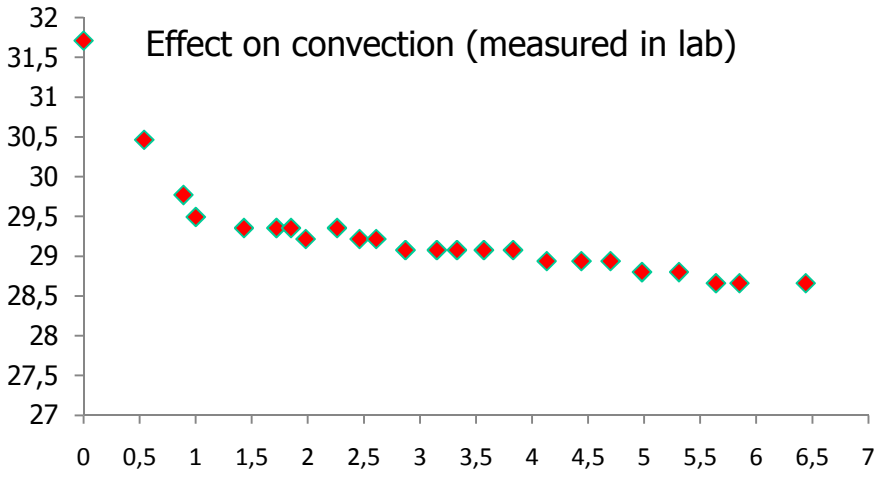
We obtain the same behaviour in both, simulations and measurements

The temperatures can not be compared because of different geometries

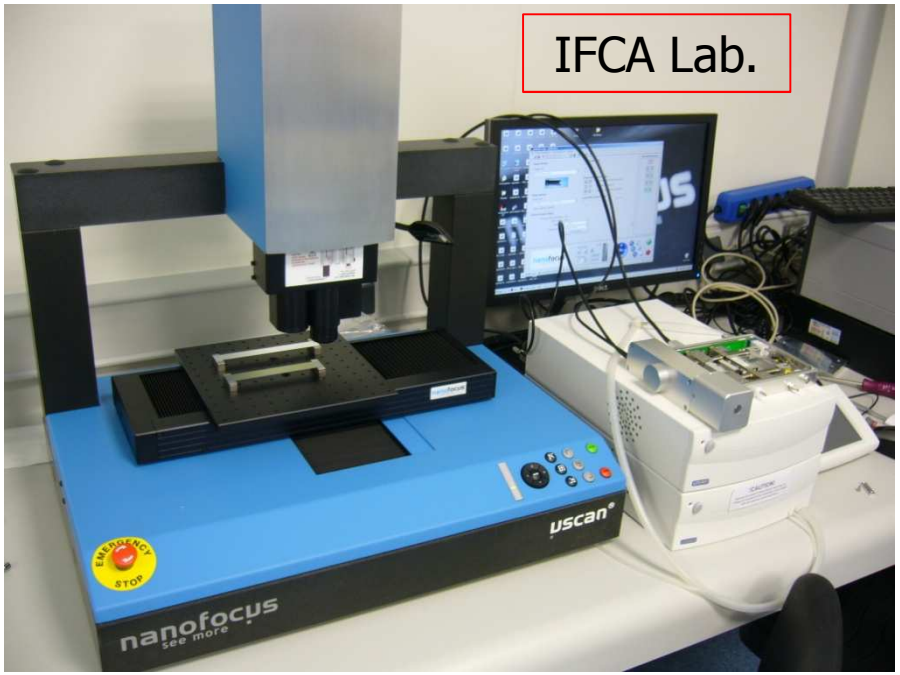
A big mass flow is not needed…

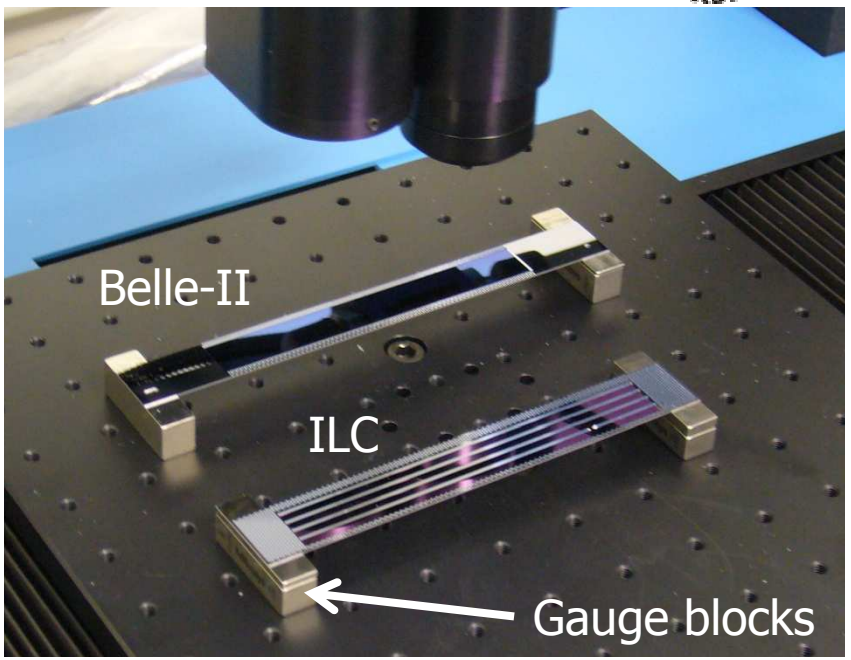
Just a small speed to move the heat out of the central part (~1m/s)

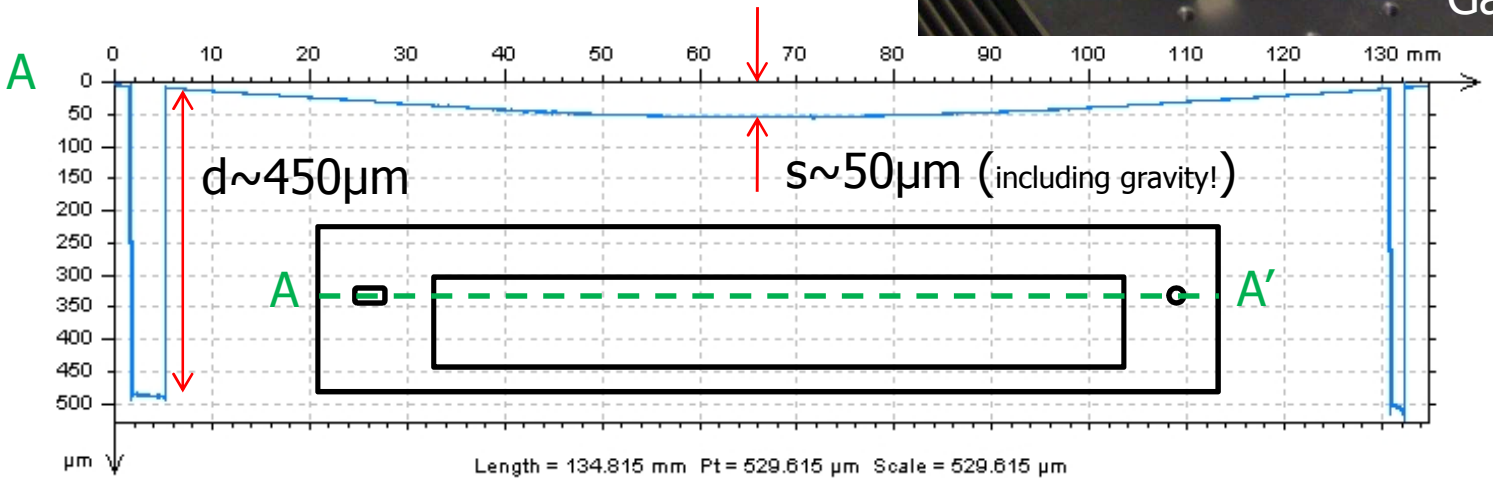
Air cooling solutions are on the way!



- Effect of air cooling: Vibrations (Together with IFCA)

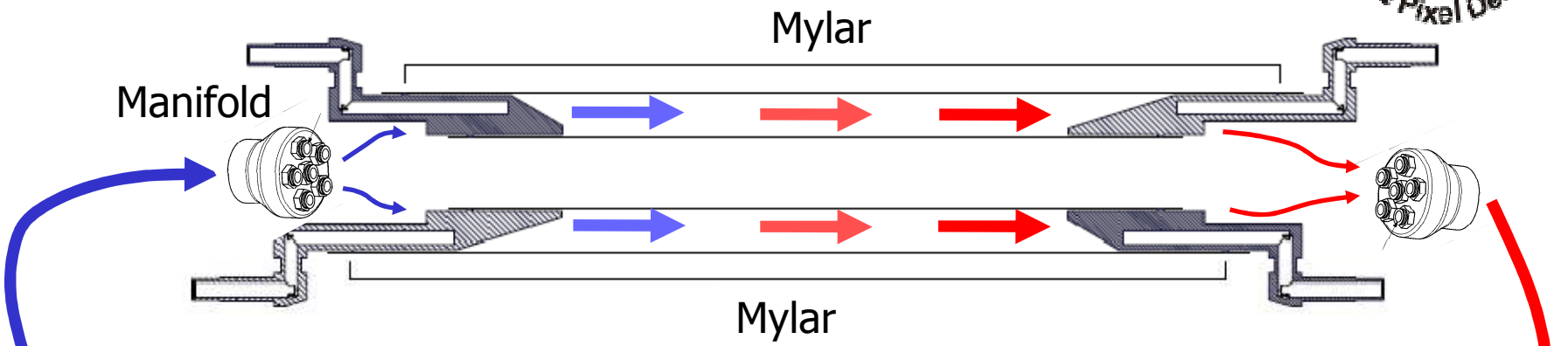






Study thermal stresses is also in the plan

Belle-II PXD Option 1



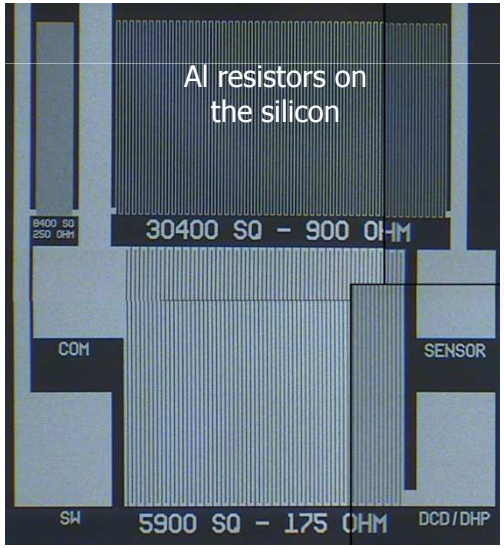
Cold air gun (down to -30ºC)

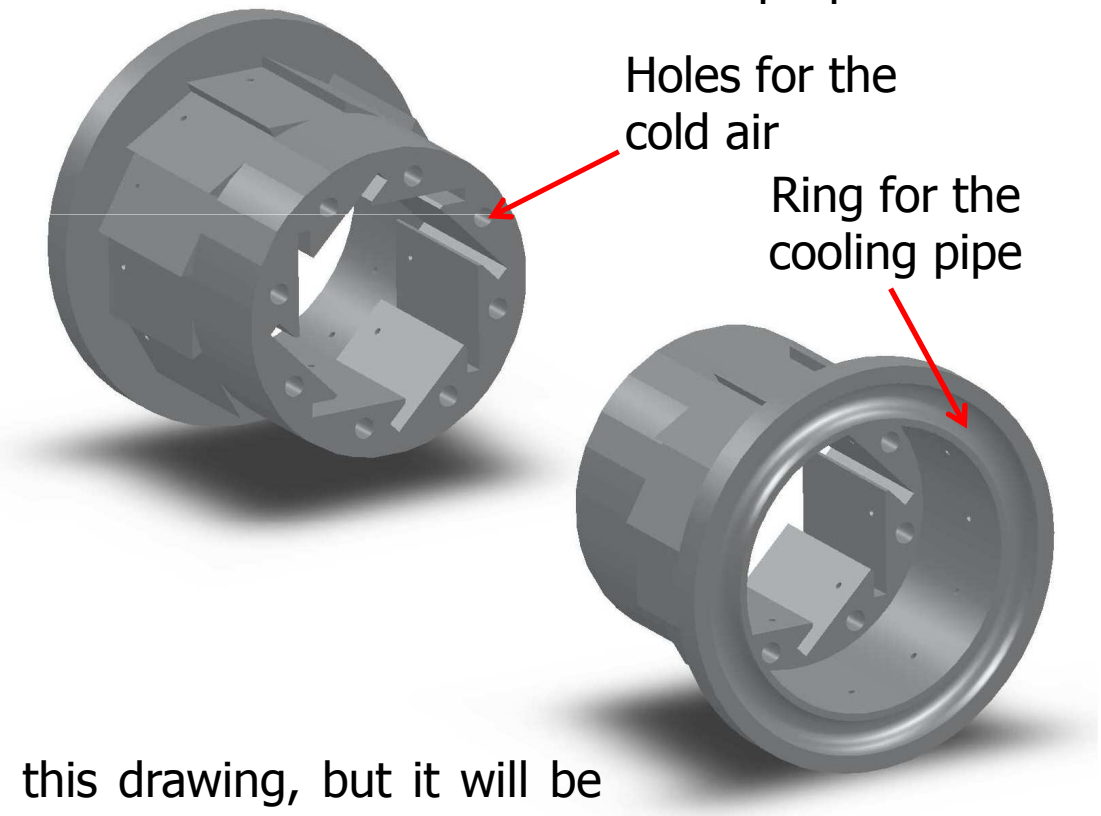
Vacuum

Mockup

Simplified support structure for testing purposes

All these effects will be measured in the lab, with a real mock-up





• The beam pipe is missing in this drawing, but it will be there (with its own temperature ~15ºC) in the final design

AIDA project (Detector R&D)

❑ In the near future, all these thermal and mechanical activities could be performed inside the AIDA project

Aim: Improve common infrastructures required for detector R&D, with trans-national access to beam tests and irradiation facilities → **R&D in detectors**

User communities: SLHC (luminosity-upgraded LHC), future Linear Colliders (ILC and CLIC), future accelerator-driven neutrino facilities or future B-physics facilities (e.g. Super-B).

Groups involved: DESY, Oxford, CEA Saclay, Strasbourg, IFCA, IFIC

Budget 600.000 €

Conclusions

❑ Belle-II detector is foreseen to be installed by the fall of 2013

- ➢ This project boosted the DEPFET development
- ➢ All the 'minor' details are being studied!

❑ Because of the special features of the Belle-II…

CLIC

• the cooling rely on:

- ➢ Conduction at both ends of the staves → CO_2 evaporative cooling
- ➢ Convection in the center of the ladder → Forced cold airflow

To be measured in lab!

• from the mechanics:

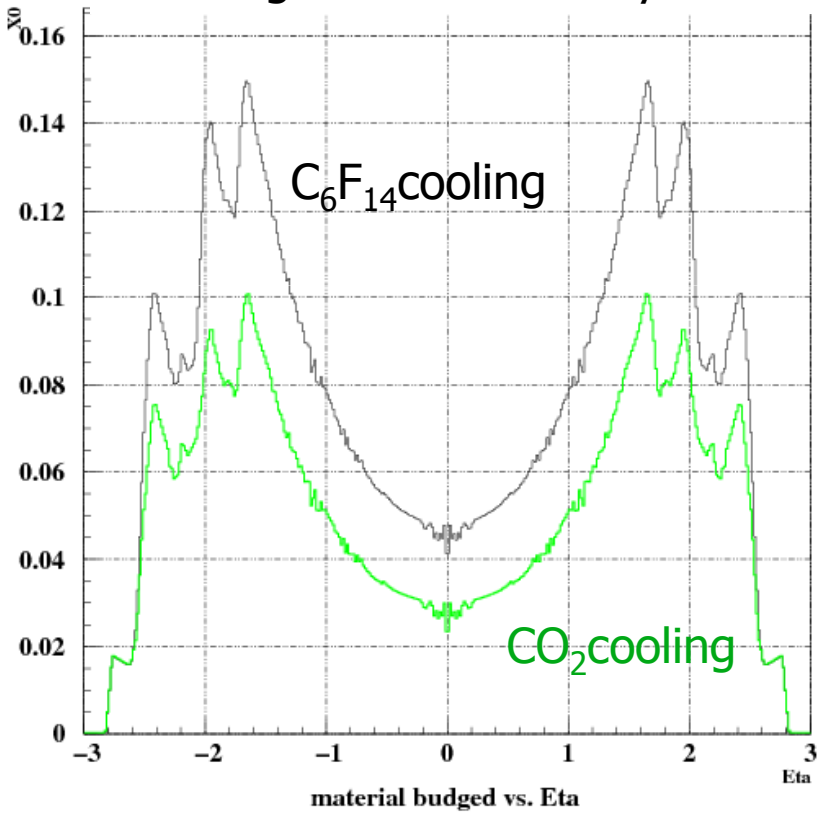
- ➢ The sensor is an all-silicon self support structure, with very low material budget
- ➢ The detector rests on a heavy support/cooling structure outside of the acceptance

CO_2 evaporative cooling

- Cooling loops (radius of 5mm) with very small pipes (outter radius ~1.3mm, wall thickness ~50μm)
- The material budget is reduced
- LHCb, AMS, CMS, ATLAS, industry → Growing interest in this coolant (CO_2)
- Low mass flow needed
- No corrosion

- Bigger engineering studies are required
- High pressures

CMS Material distribution budget for 3 barrel layers



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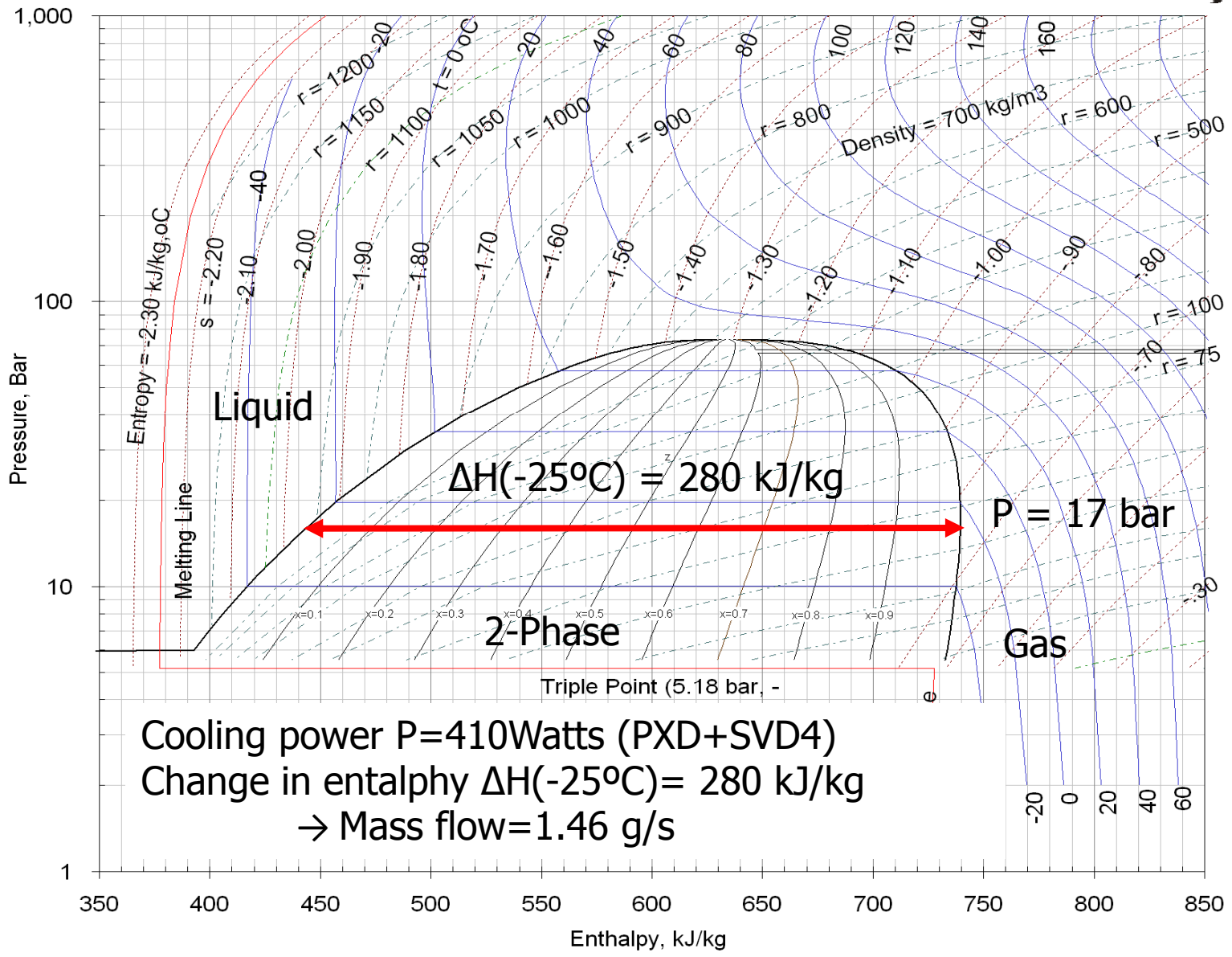
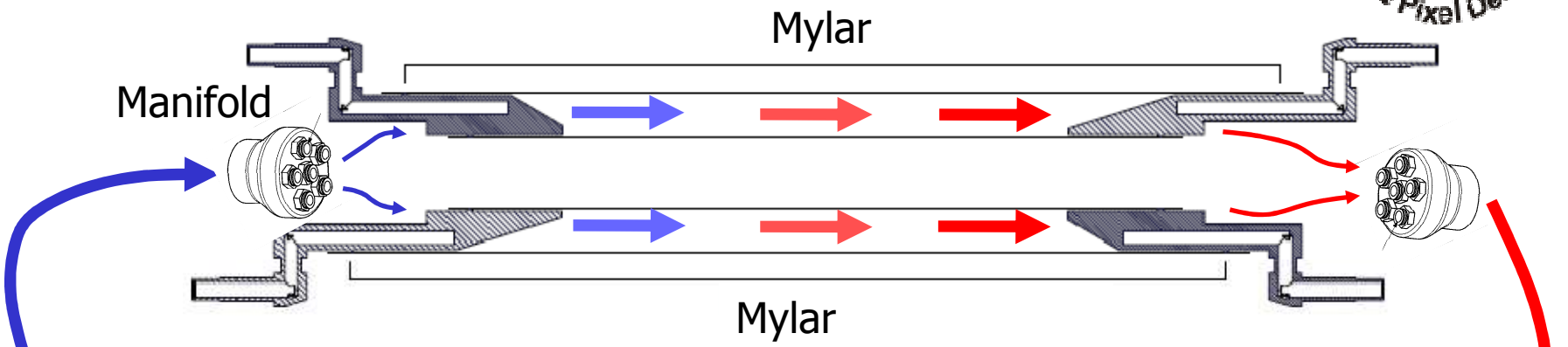
CO_2 Mass flow estimation



Belle-II PXD standalone cooling



Cold air gun (down to -30ºC)

Vacuum

What about the thermal gradient along the ladder?

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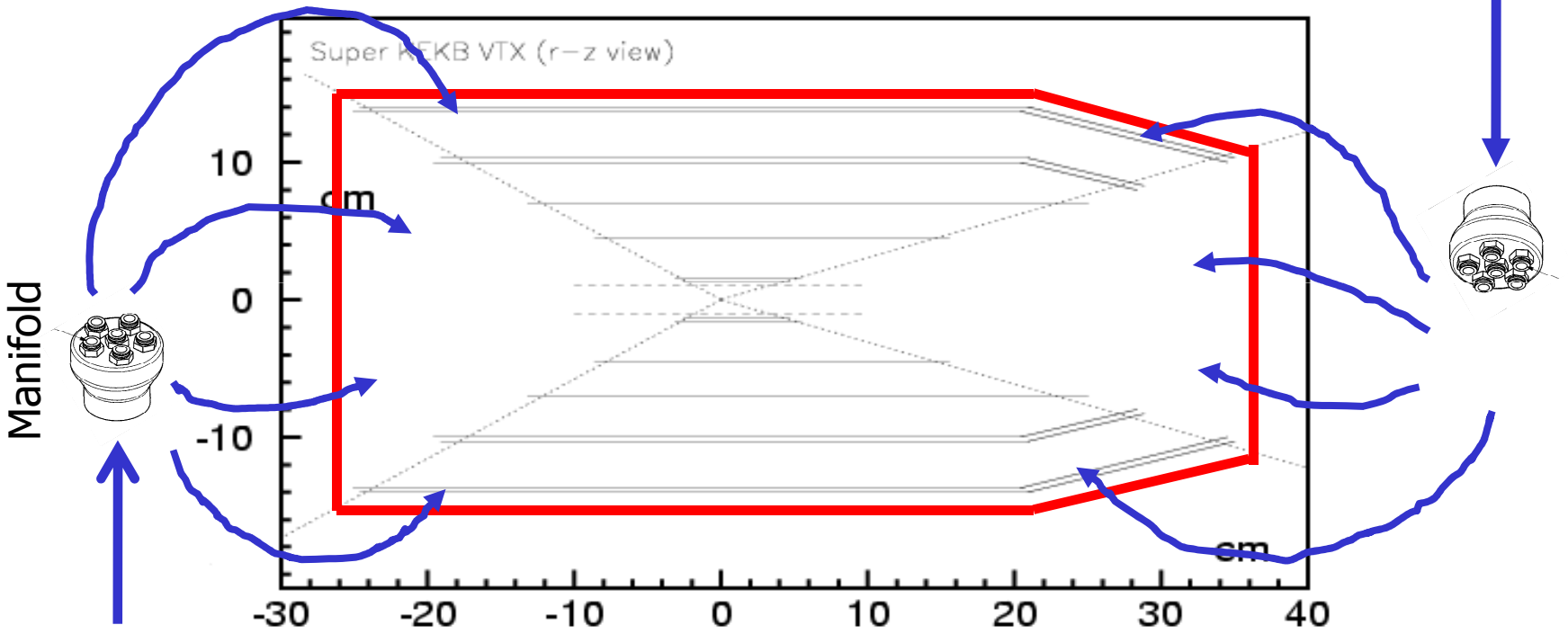
Belle-II PXD-SVD cooling

Fill the chamber with cold air…



Cold air gun

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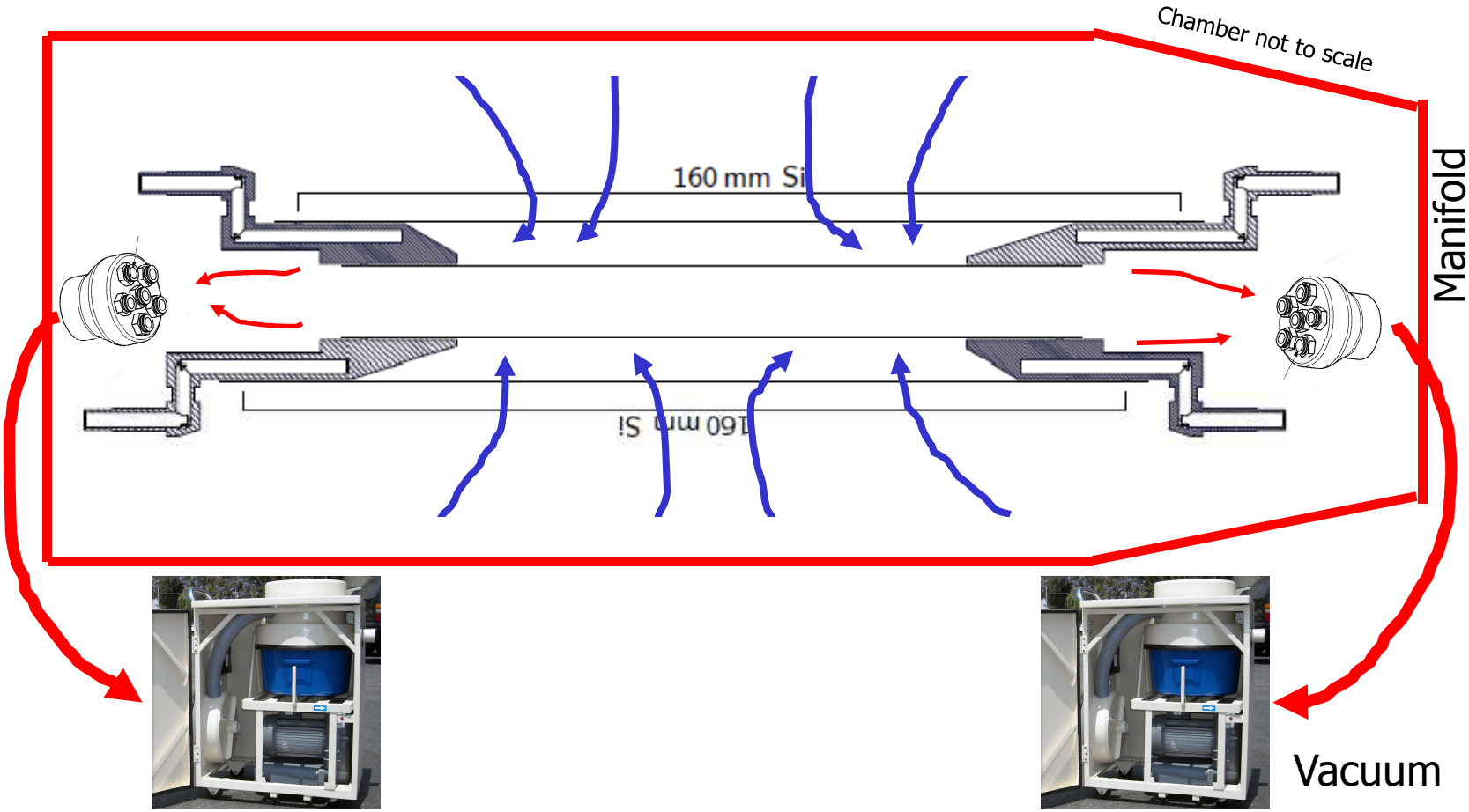
And take the air out from both sides of the PXD, using the holes in the support structure



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