Advancement and Innovation for
Detectors at Accelerators

Micro-channels for the Higgs factory?

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In collaboration with CNM Barcelona, inputs on Belle 2 from Carlos Mariñas

DRD day IFIC March ‘26 (meeting clashes with DRDC review)

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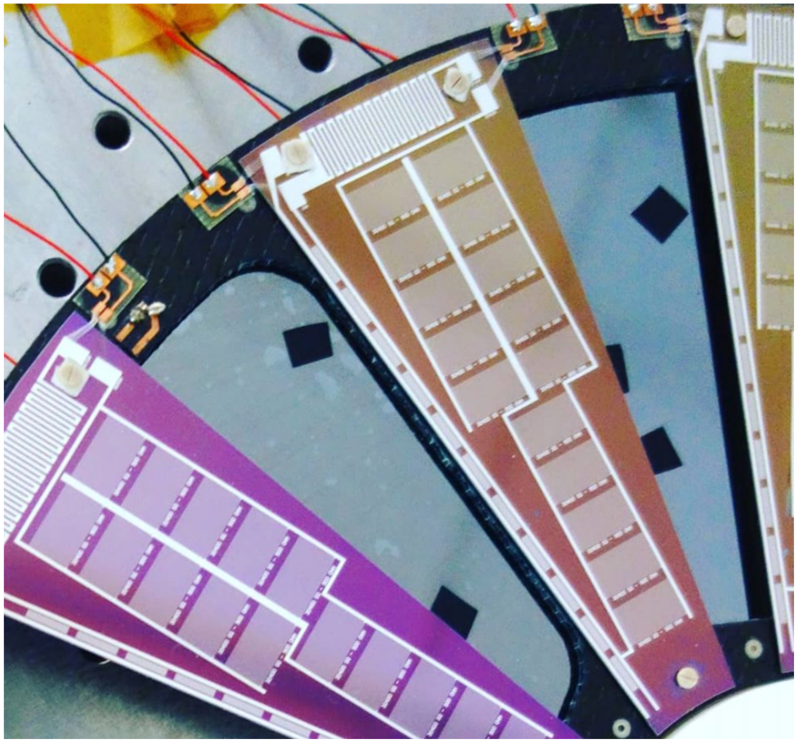
Mechanical studies



Master’s thesis Yamal Naser Requena

Analytical expressions

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ANSYS FEA

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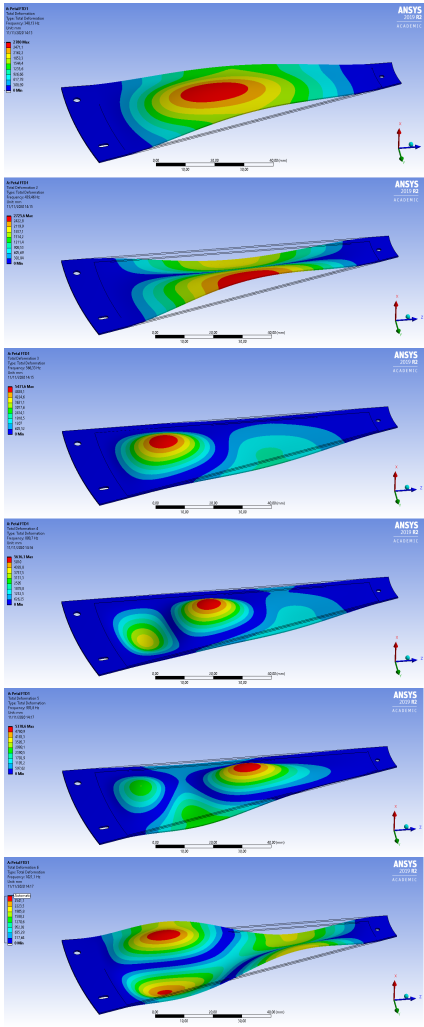
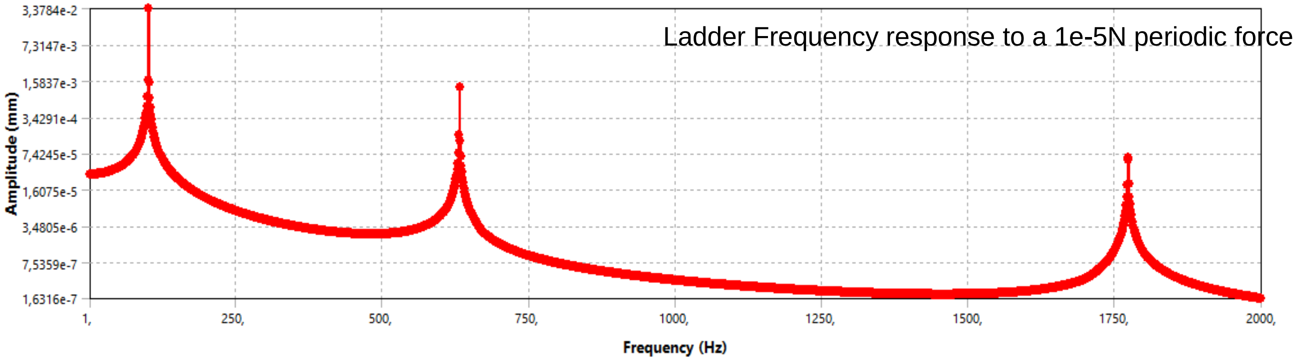
Measurements

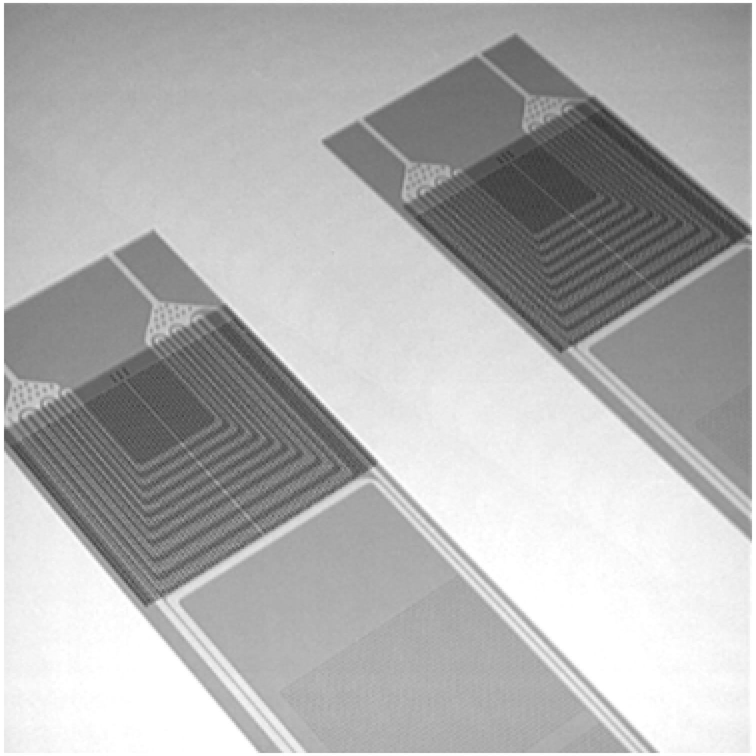
Extend to more realistic vibration loads (air flow, cavern floor, earthquake)




Ladder Frequency response to a 1e-5N periodic force

Micro-channel cooling

- Work with MPG-HLL to develop integrated micro-channels in detector-grade Silicon (DEPFET)
- PoS VERTEX 2016 (2017) 037
- JINST 11 (2016) P016018
- Develop an in-house low-temperature bonding process – qualify within AIDAinnova at CNM and HLL
- Long-term goal: enable micro-channel integration as a post-processing step for CMOS sensors



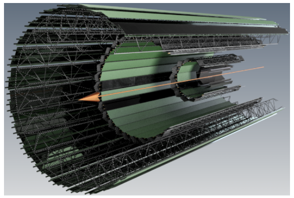
Micro-channels cooling circuit in detector-grade silicon ladders

Global R&D landscape

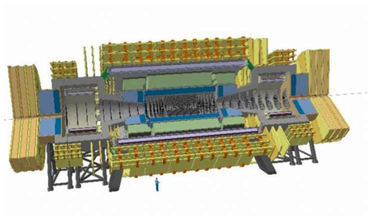
- detector R&D time-line

Future Projects Timeline

Agreed Working Hypothesis



Belle II upgrade (circa 2027):
https://arxiv.org/pdf/2203.11349.pdf



< 2030	2030-2035	2035-2040	2040-2045	> 2045
SPS fixed target Other fixed target, FAIR (hep) BELLE II ALICE LS3 PIP-II/LBNF/DUNE/Hyper-K	ALICE 3 LHCb (≥ LS4) EIC LHeC	ILC	FCC-ee CLIC	FCC-hh FCC-eh Muon Collider

- aim at the vertex detectors of Belle 2 and the Higgs factory
- intermediate-timescale projects are stepping stones

The Higgs factory is maybe not the first application you’d think off for micro-channels

--- Power density (100 mW/cm2) and requirements (room temp) not very severe

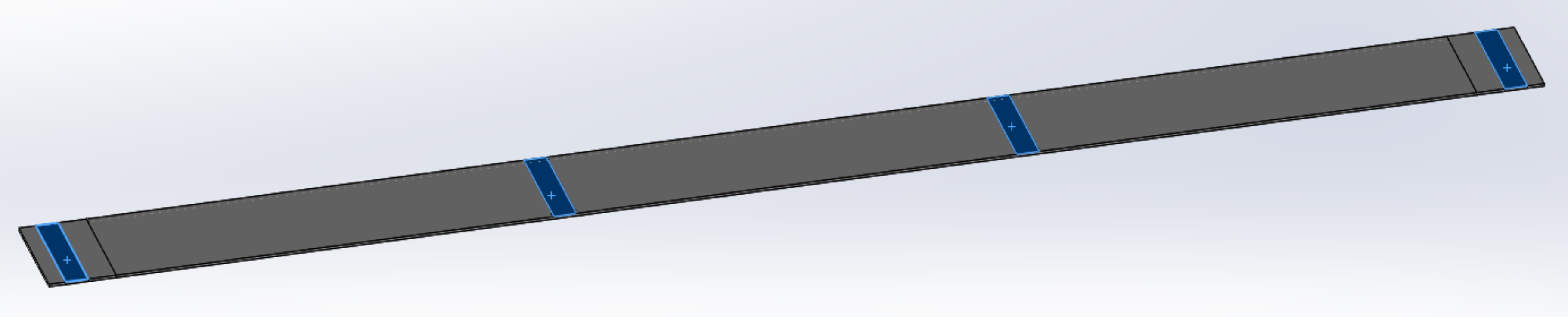
But…

--- Circular colliders (CEPC/FCCee) are DC machines: no power pulsing

--- Active cooling required for beam pipe and competitive for vertex detector ladders

--- Integrated solutions with minimal pressure have ~0 impact on material

FCCee ladder design

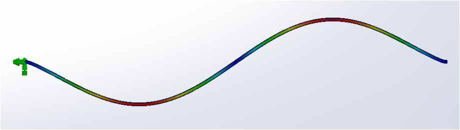


- 260x20 ladder (FCCee dimensions), 50 um thick sensor and 500 um frame
- Use eigenfrequencies as figure-of-merit for mechanical stiffness
- Conclusion: need reinforcement from out of the ladder plane

ALICE's bent vertex detector achieves a similar rigidity as the solution with 4 support points

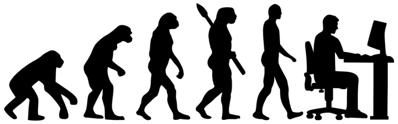
	IT01	IT02 – 3ps	IT03 – 4ps
Mode 1	67	264	584
Mode 2	184	270	589
Mode 3	212	447	608
Mode 4	356	447	799
Mode 5	380	713	814
Mode 6	575	722	837

Eigenfrequencies (in Hz)



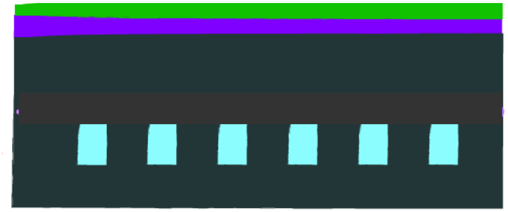
2-3-4 points of support

MCC evolution: integrated cooling



Hybrid pixel detector &
micro-channel cooling plate

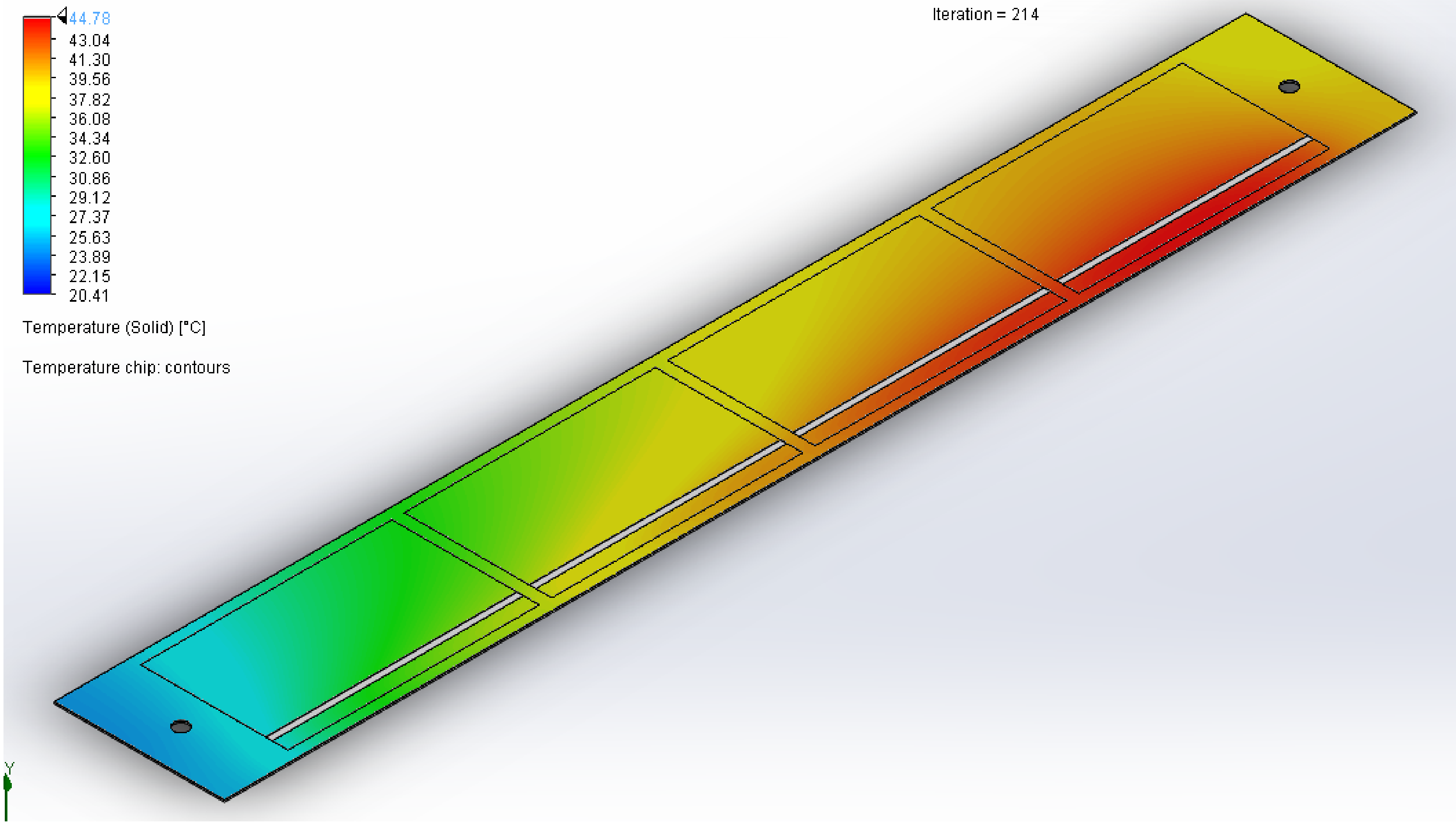
Monolithic CMOS detector



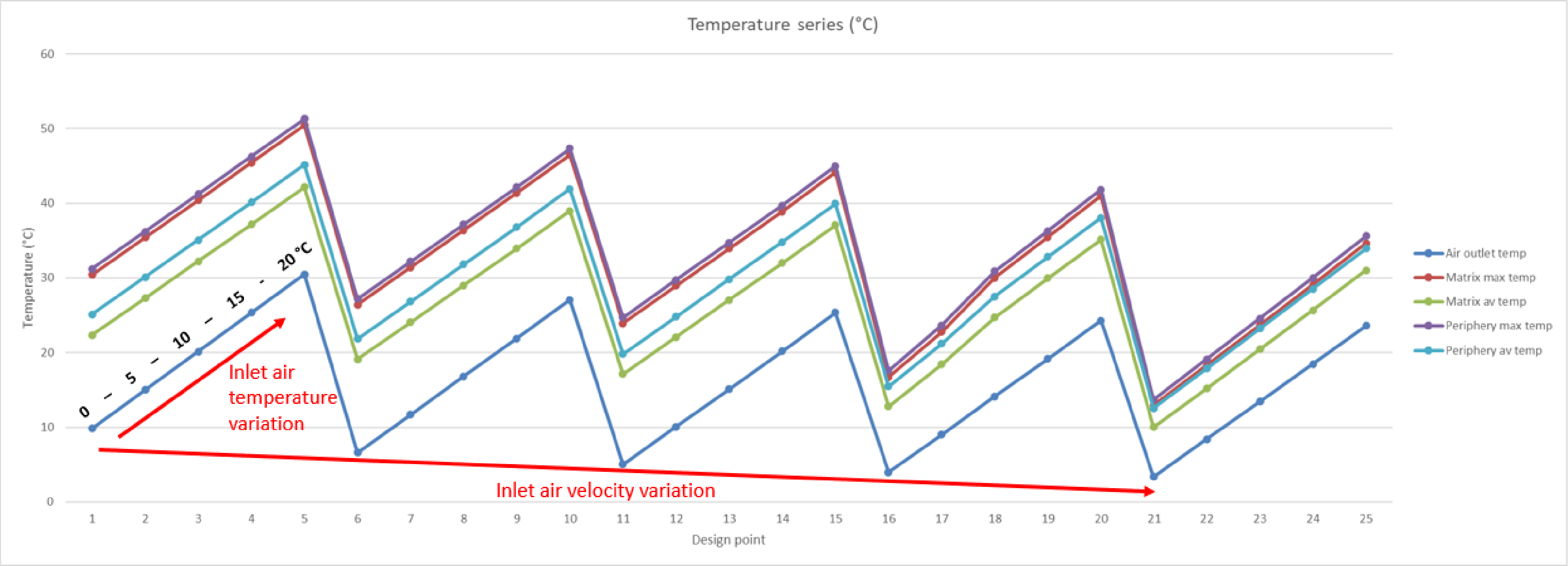
Monolithic CMOS detector
with integrated micro-channels

Design point - 20 °C - 8 m/s

Belle 2 iVTX ladder scaled to FCCee dimensions. Air cooling: 20 °C at 8 m/s. Tmax = 45 °C.



Results – parametric study

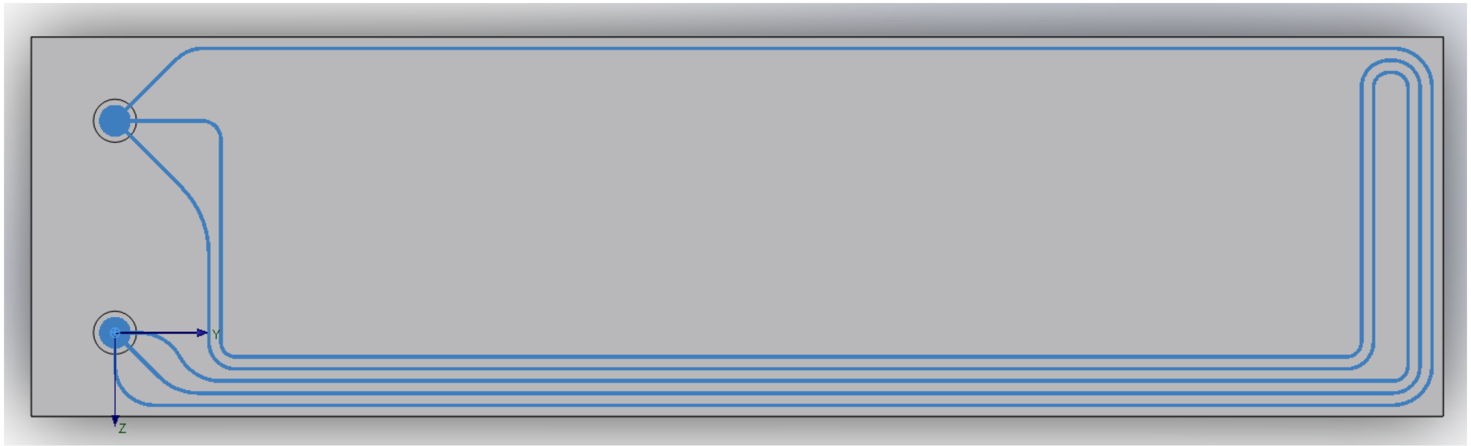


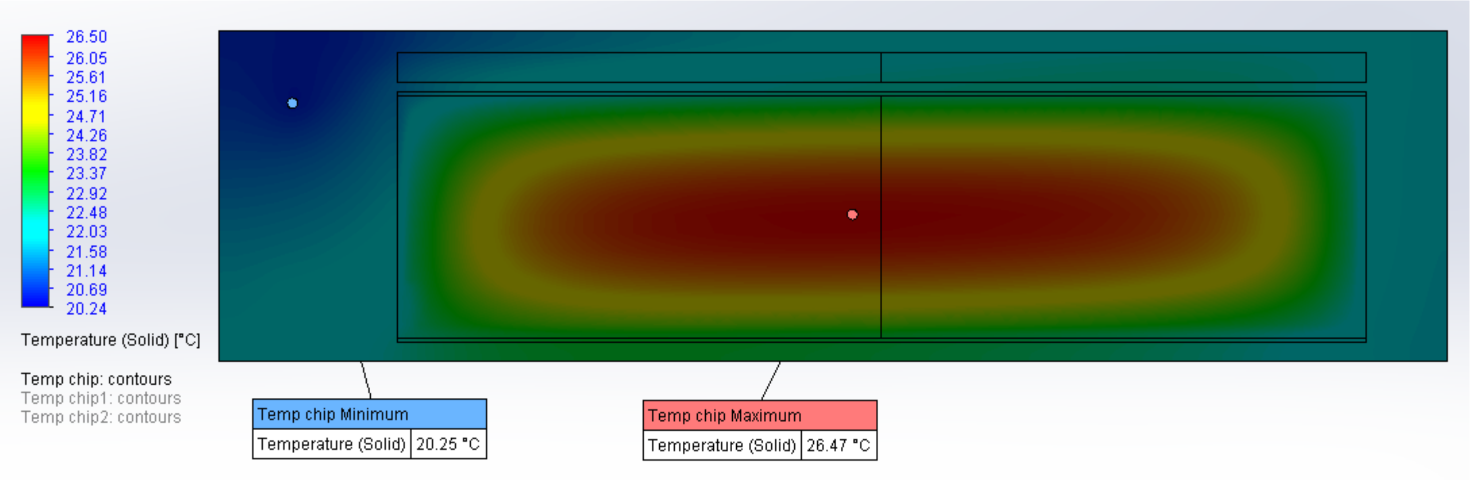
- Air inlet temperature: 0 – 5 – 10 – 15 - 20 °C (bottom to top trend)
- Air inlet velocity: 4 – 6 – 8 – 10 – 12 m/s (left to right trend)

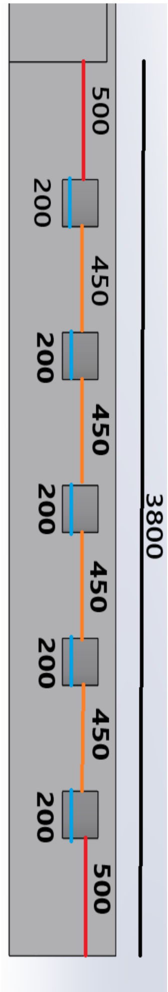
Apparently, none of the combinations satisfy the requirement of $\Delta T < 5^o$ C

Prototype design (to be fabricated at CNM):

- 76 x 20,4 x 0,6 mm (compatible with 4” wafers).
- Thinned to 50 um under the pixel matrix.
- Consumption on pixel matrix: 0,913 W. Consumption periphery: 1,311 W.







Micro-channel cooling

- The AITANA https://aitanatop.ific.uv.es/ group is involved in Higgs factory detector concept (ILD) since a long time
- PRELIMINARY simulation studies: A cooling solution for the Higgs factory vertex detector based on integrated micro-channels and air cooling can offer competitive performance at small impact in material
- Demonstrator prototypes in production at CNM with a fully CMOS-compatible wafer bonding technology (eutectic bonding successfully demonstrated in AIDAinnova; production ongoing end ‘25 – early ‘26)
- Activity overlaps with FCCee design work in DRD8.1