20TH INTERNATIONAL WORKSHOP ON DEPFET DETECTORS AND APPLICATIONS

INTEGRATED COOLING CHANNELS IN POSITION-SENSITIVE SILICON DETECTORS

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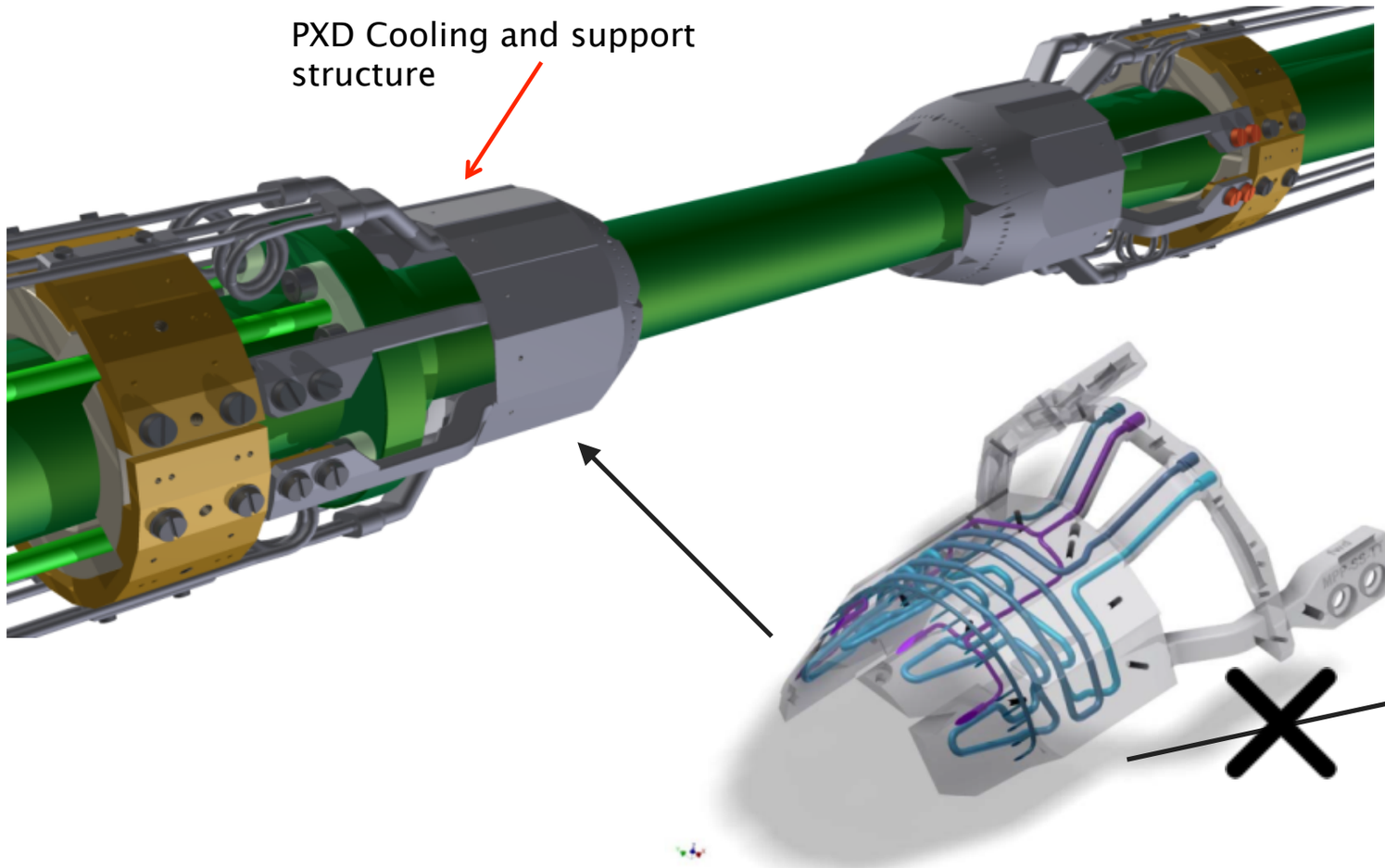
MCC CASE FOR PHYSICS DETECTORS

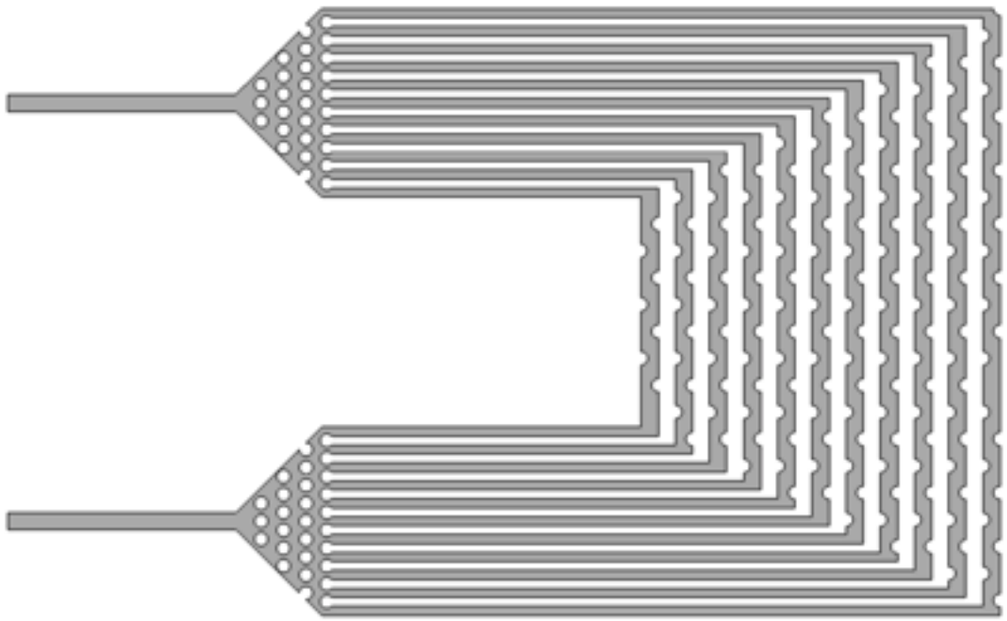


- Belle II **cooling structure would be too massive** to higher acceptance detectors like ILC.

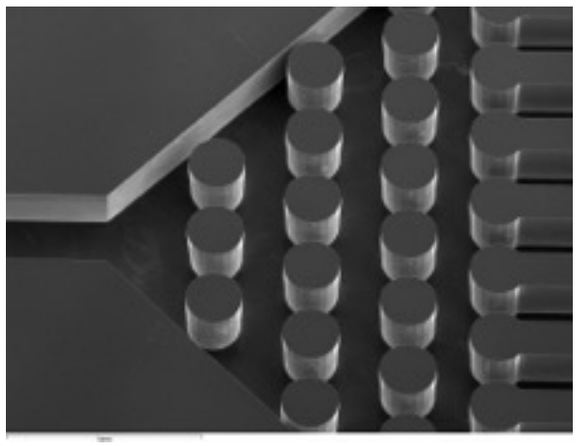
	Belle II	ILC
Acceptance	17º-155º	6º-174º
Material budget	0.21% X_0 per layer	0.12% X_0 per layer
Resolution	15 μm (50x75 μm^2)	5 μm (20x20 μm^2)

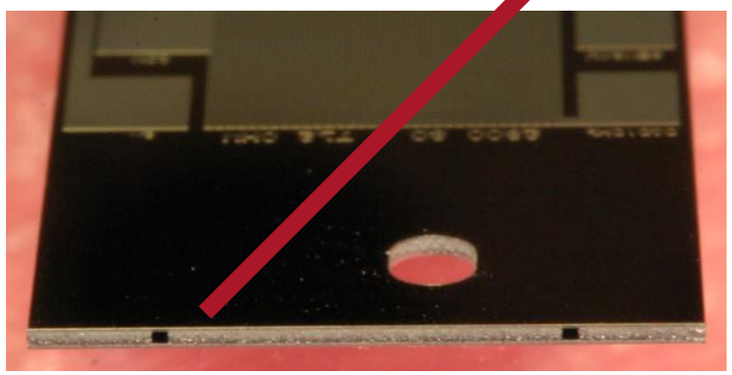
MCC DEPFET-LIKE MODULE: PRODUCTION

- An integrated cooling channel is designed for a DEPFET module, focusing in the EOS.
- The MCC production adds one extra step to the chain: etching the μ-channel in the handle wafer.

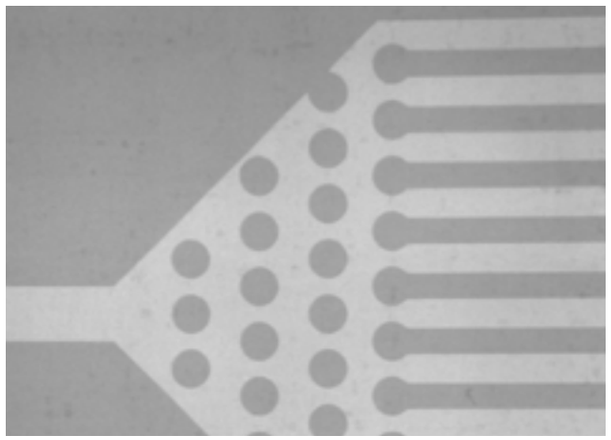


Handle before bonding





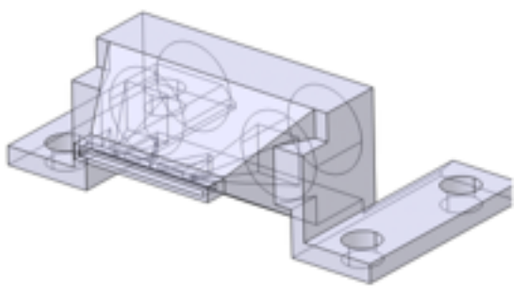
Dummy X-ray

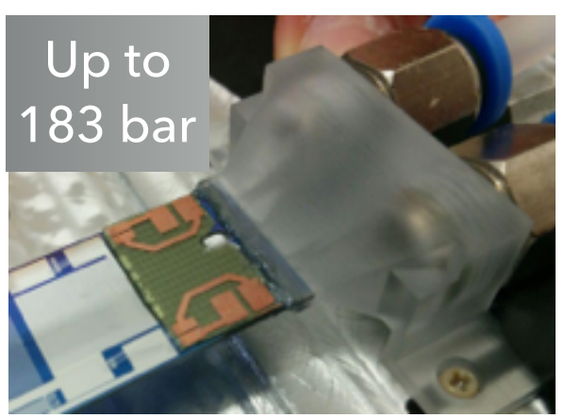


MCC DEPFET-LIKE MODULE: CONNECTORS

In order to feed the cooling circuit a number of connectors to interface with commercial fitting elements have been designed:

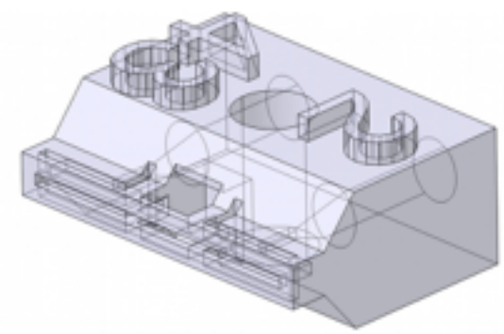
Past (0.81% X/X_0)

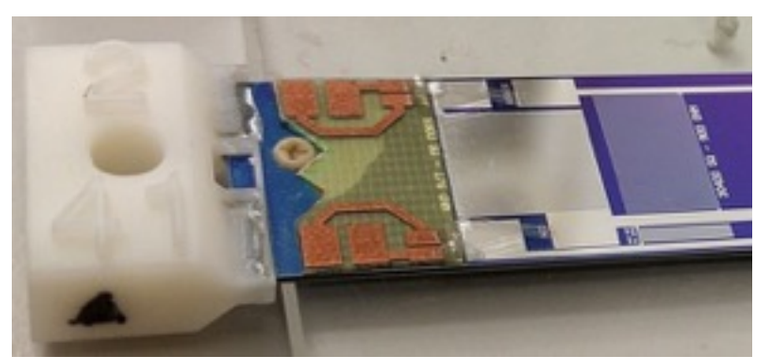




- **Self aligning connector**

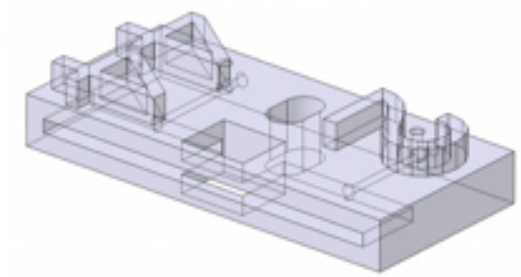
Present (0.2% X/X_0)

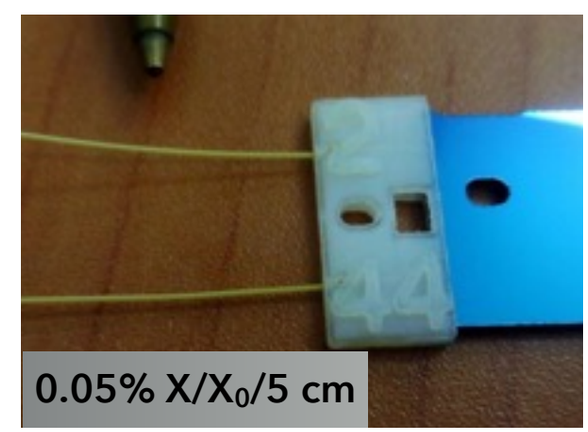




- **3D-printed (15 μm precision)**

Future (0.05% X/X_0)

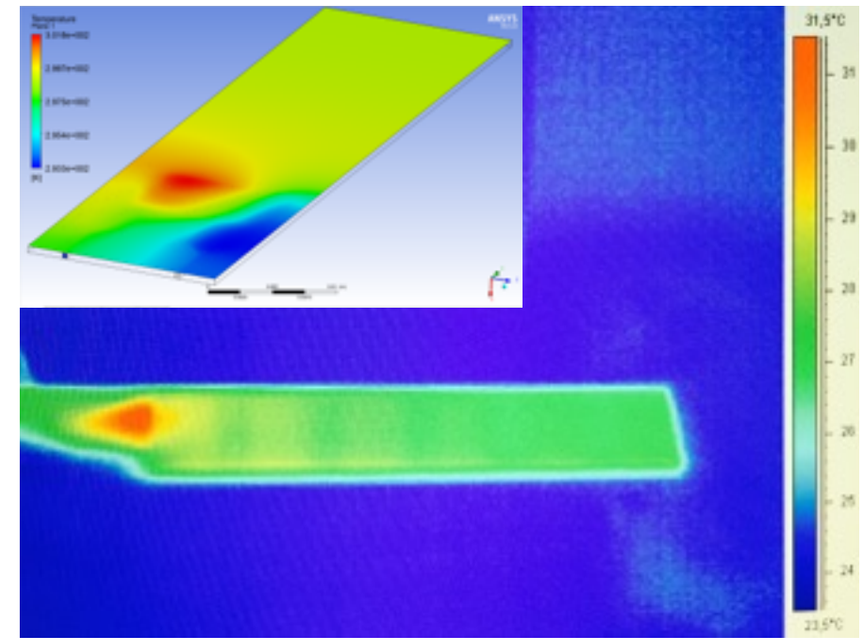




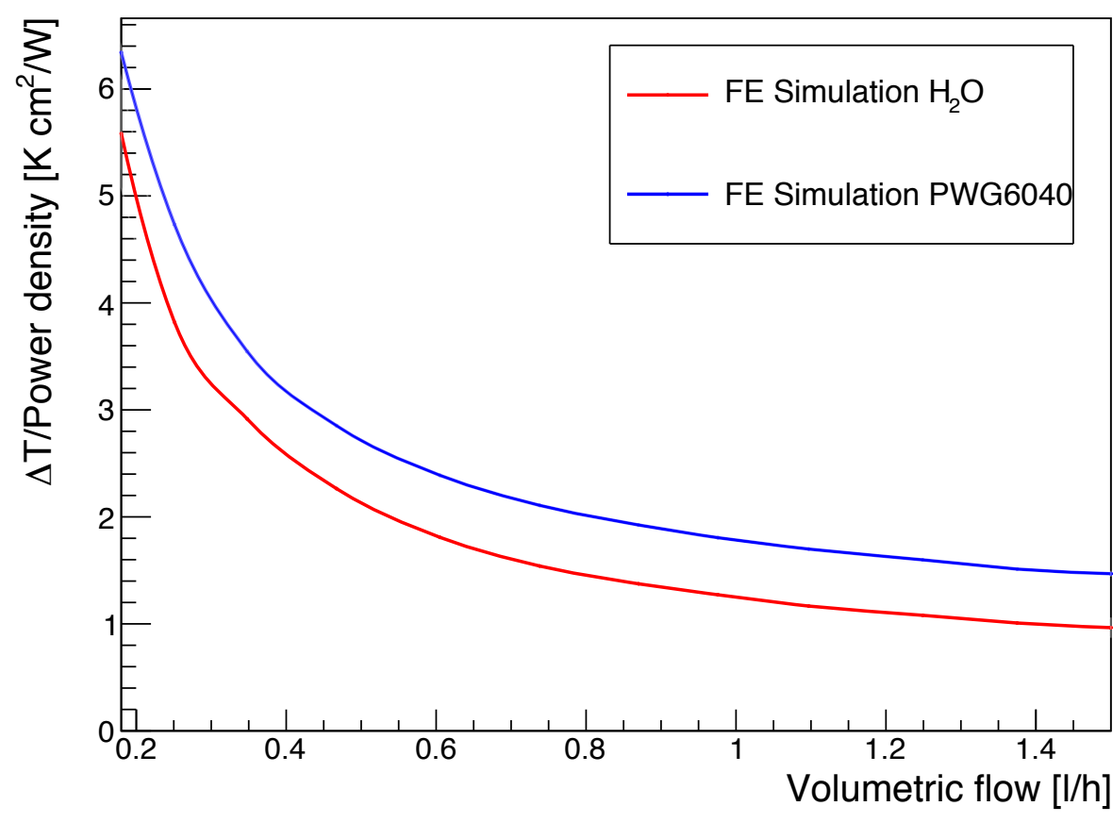
- **Glue sealed**

FINITE ELEMENT SIMULATION (I)

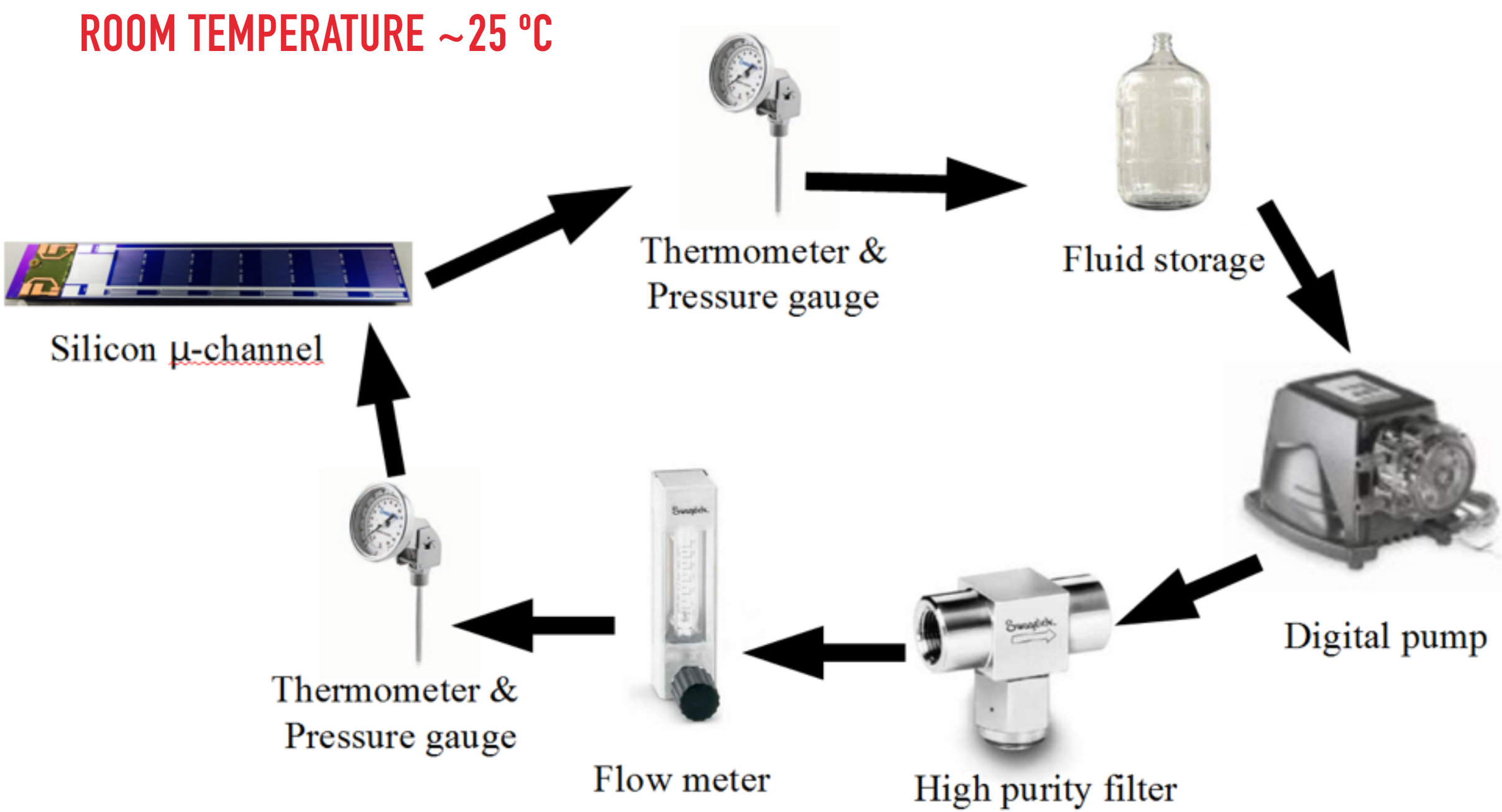
TEMPERATURE = 25 ºC



- Low-cost mono-phase cooling liquid: H_2O.
- Low volumetric flows (~1 l/h) and low pressure (< 1 bar) are enough to dissipate 6 W in the EOS.
- Possibility to use CO2 at high pressure, but not necessary at the power densities studied.

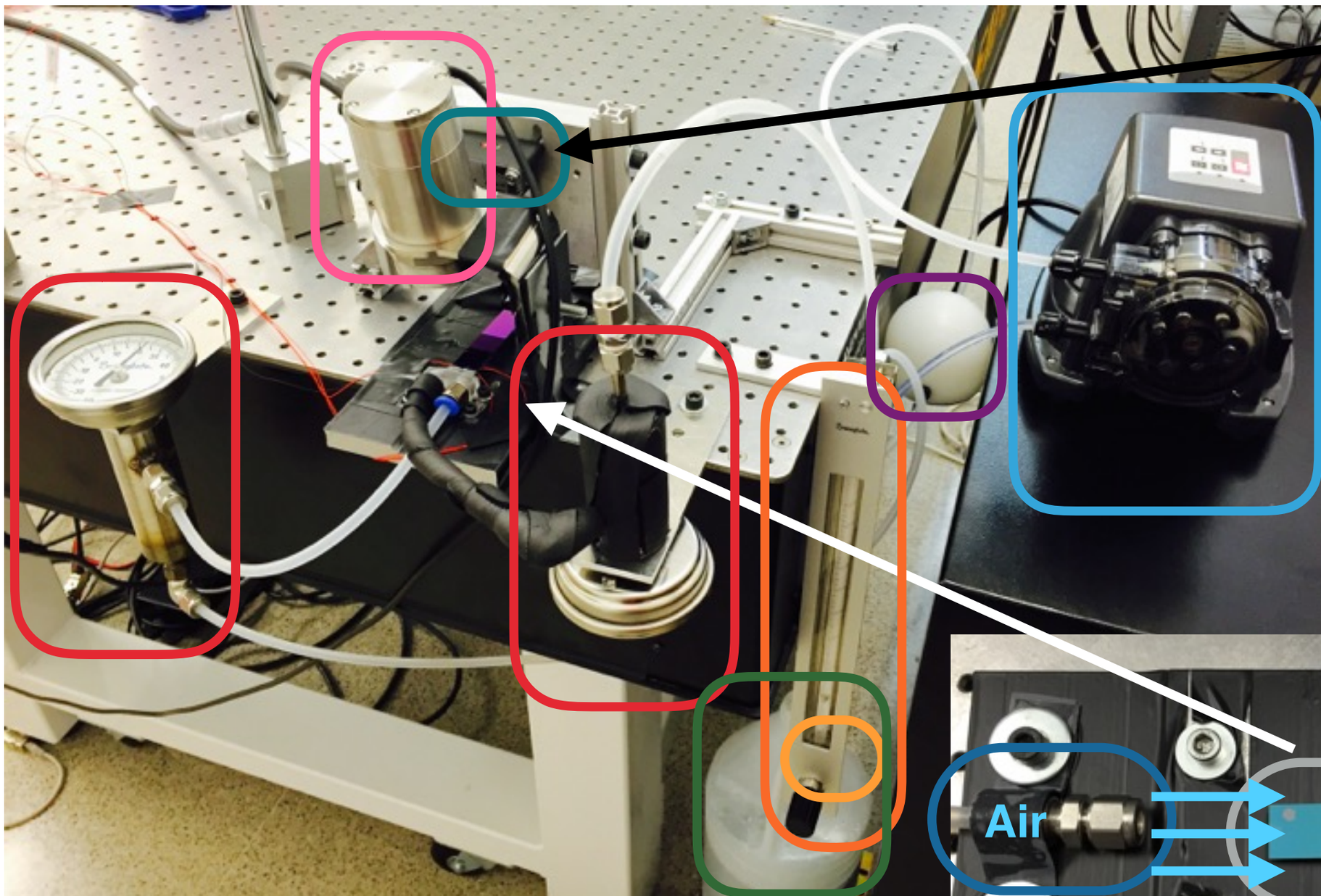


EXPERIMENTAL SETUP: SCHEME



EXPERIMENTAL SETUP: REALITY

INTERFEROMETER @ 50 KHZ INFRARED LASER FLOWMETER



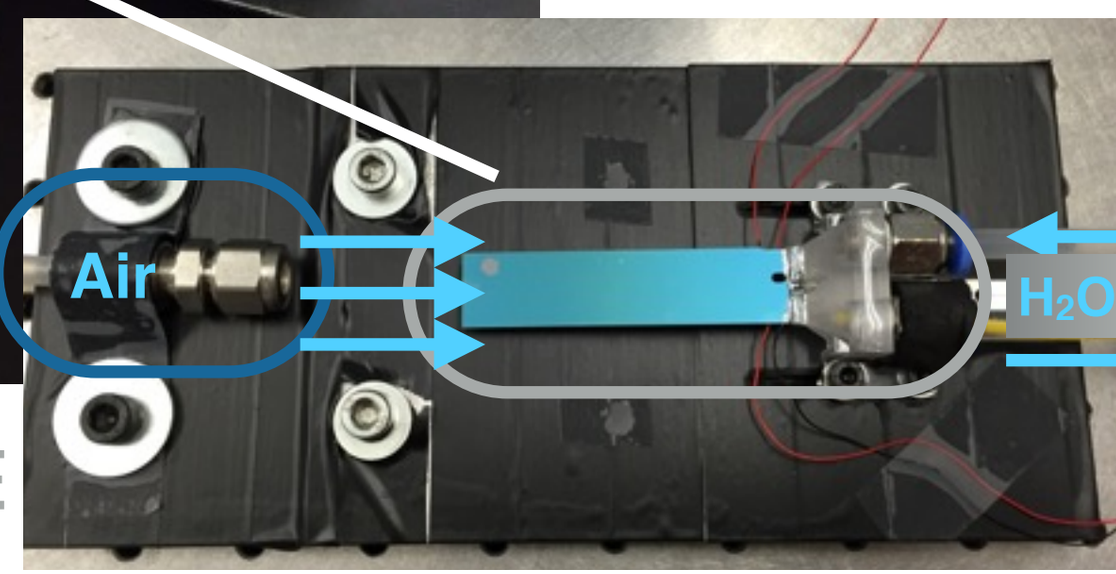
PURITY FILTER

SHOCK ABSORBER

PERISTALTIC PUMP

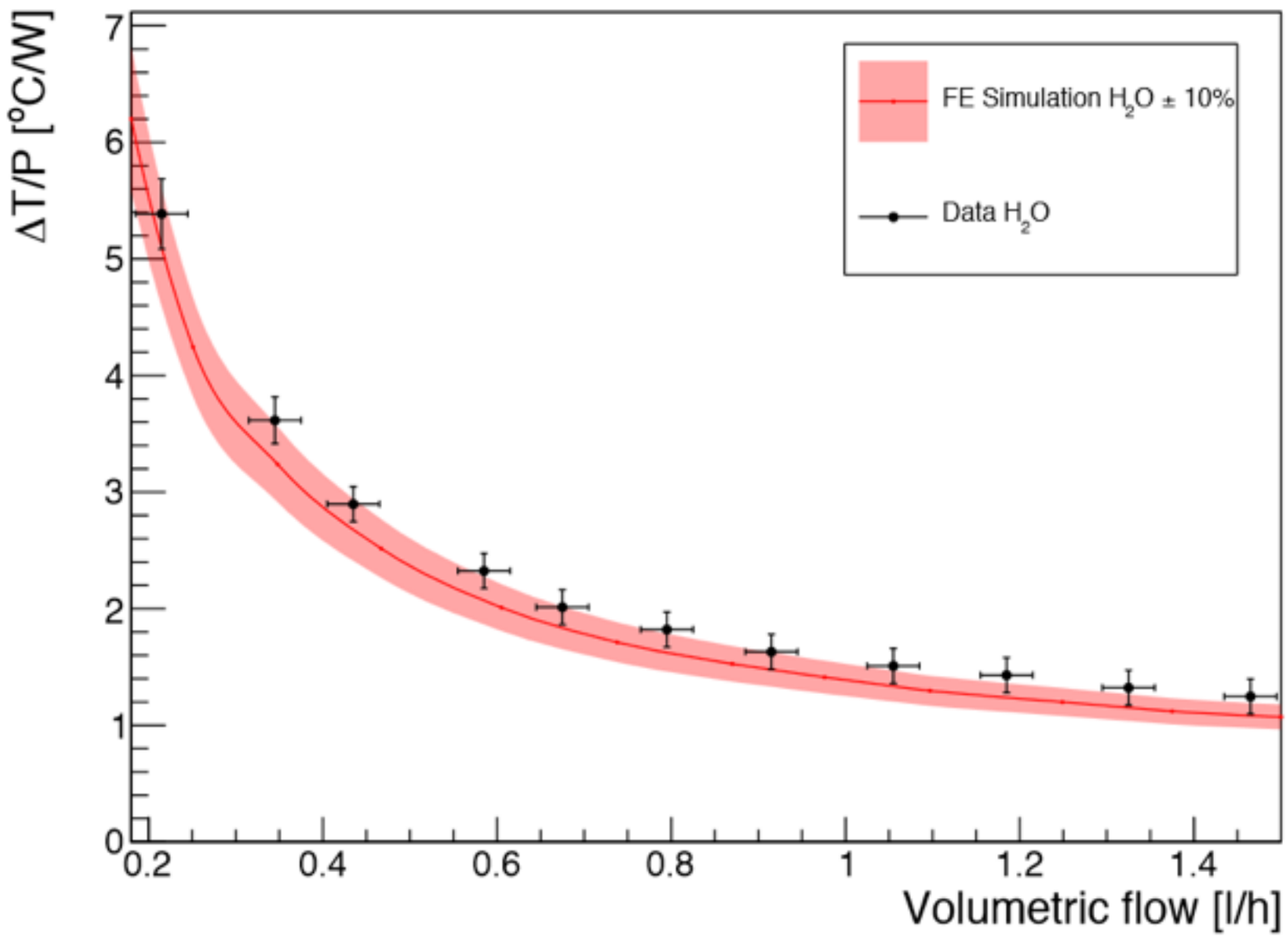
WATER STORAGE

AIR COOLING



TERMOMETERS CLAMPED-FREE MCC SI MODULE

RESULTS: THERMAL PERFORMANCE (I)



Errors:

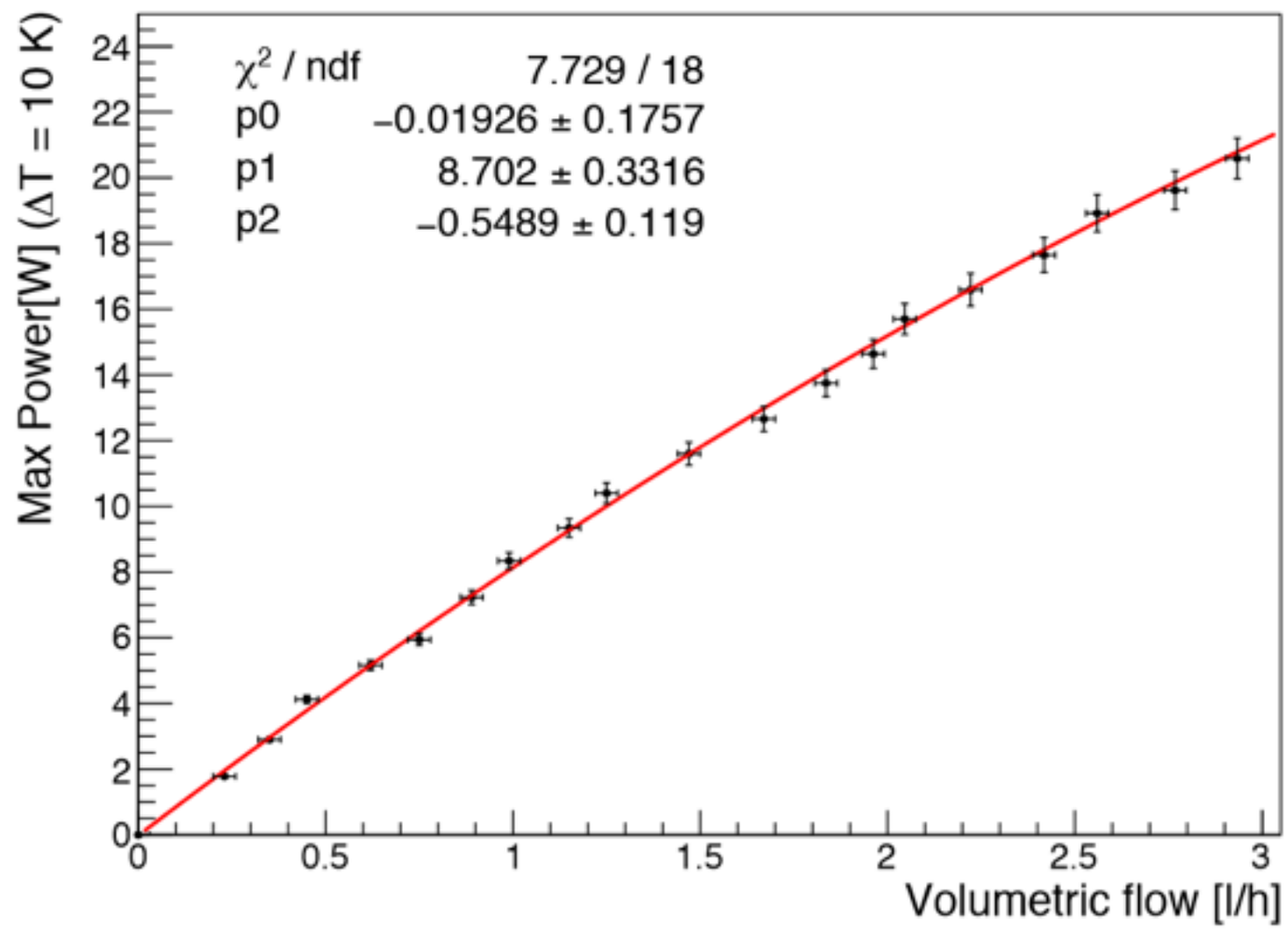
- **P: ±1% W**
- **T: ±1 °C**
- **Flow: ±0.03 l/h**

- **MCC dummy cooled non-stop for a week with no leaks and no clogging.**
- **Good agreement with the FE simulation (within 10% error).**

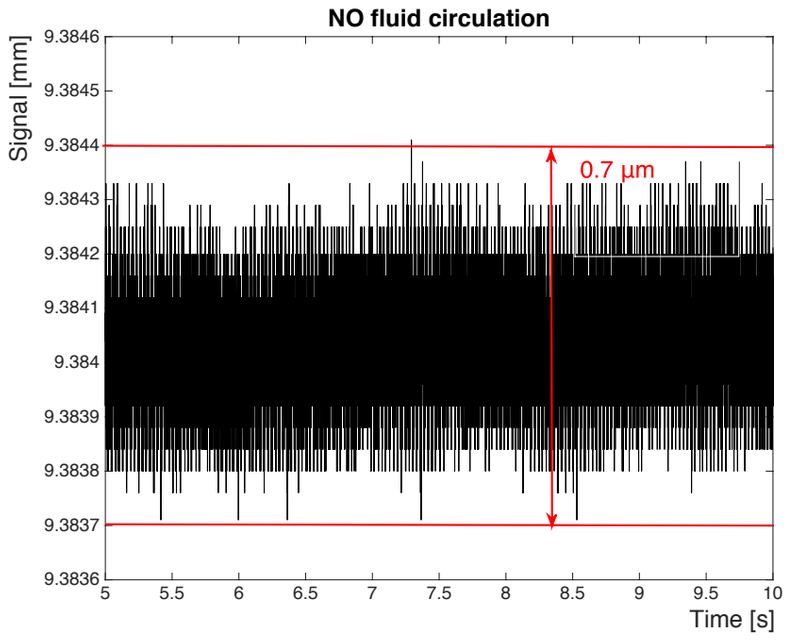
RESULTS: THERMAL PERFORMANCE (II)

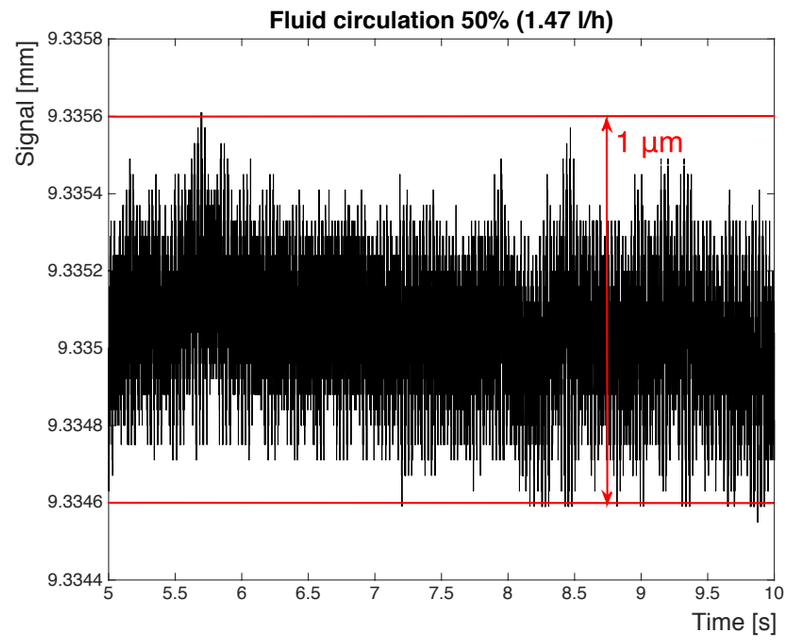
Max. power supported for **ΔT of 10 °C** as a function of the volumetric **flow**:

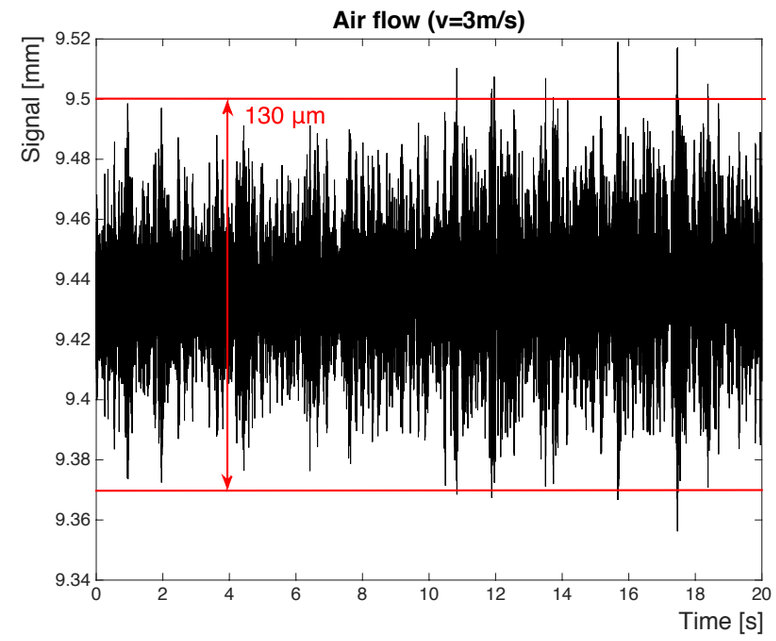
- Power **capped at** max. pump power **~3 l/h**
- Low pressure measured: **0.2 - 1.5 bar**



RESULTS: MECHANICAL IMPACT (I)







No fluid circulation and no air flowing

Peak to peak of the signal ~0.7 µm
RMS ~0.3 µm

Fluid circulation (1.47 l/h)

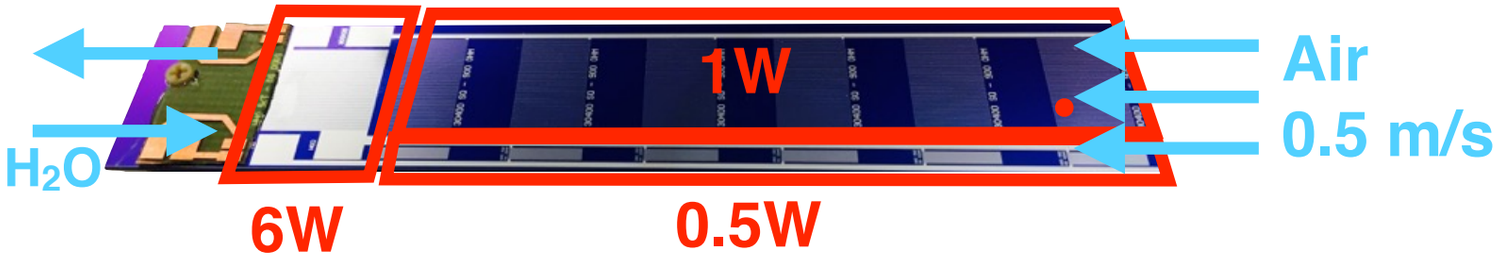
Peak to peak of the signal ~0.1 µm
RMS ~0.4 µm

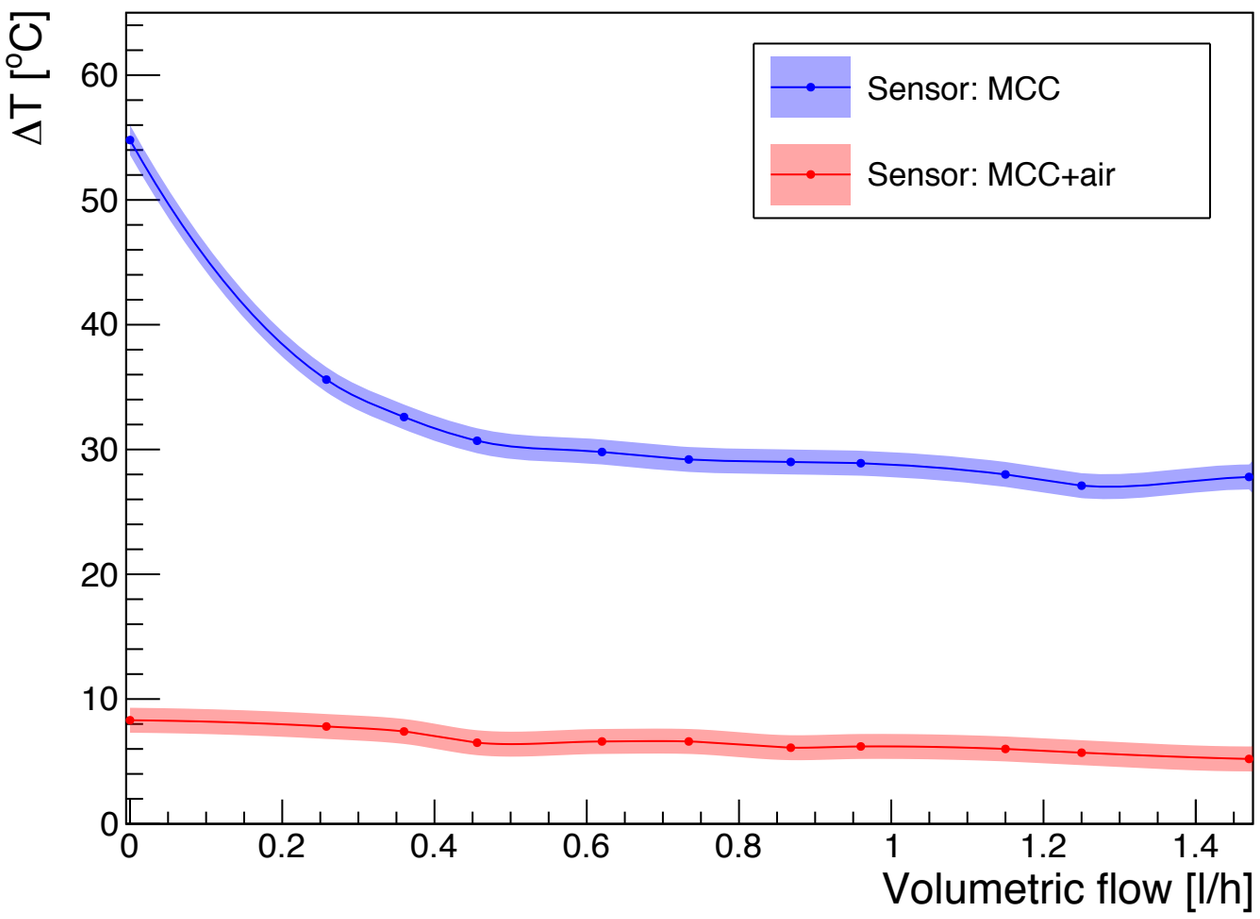
Air flowing (3 m/s)

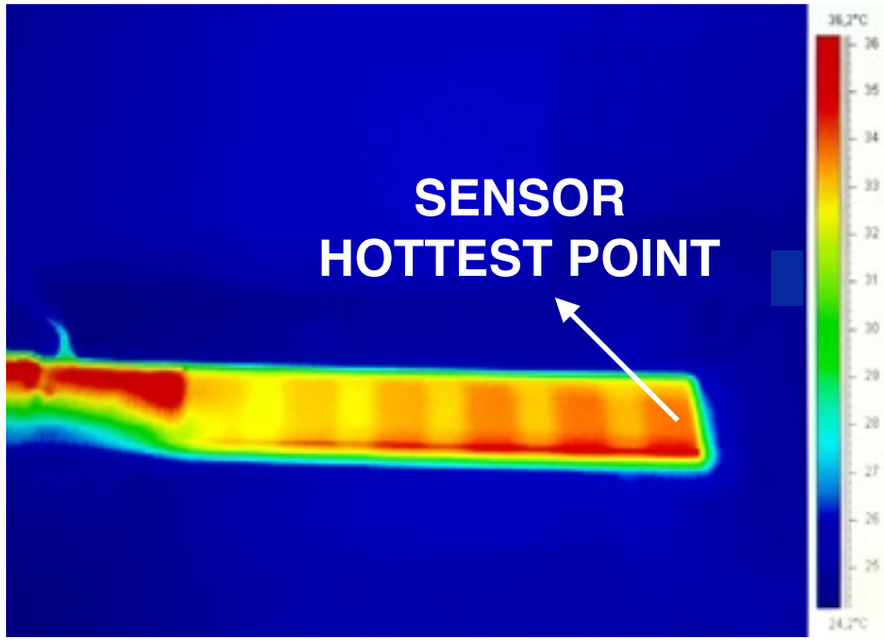
Peak to peak of the signal ~130 µm
RMS ~57 µm

MCC has no significant impact on mechanical stability in the clamped-free configuration but air deformations are over 100 µm for v = 3 m/s.

WHOLE POWERED MODULE: HYBRID APPROACH



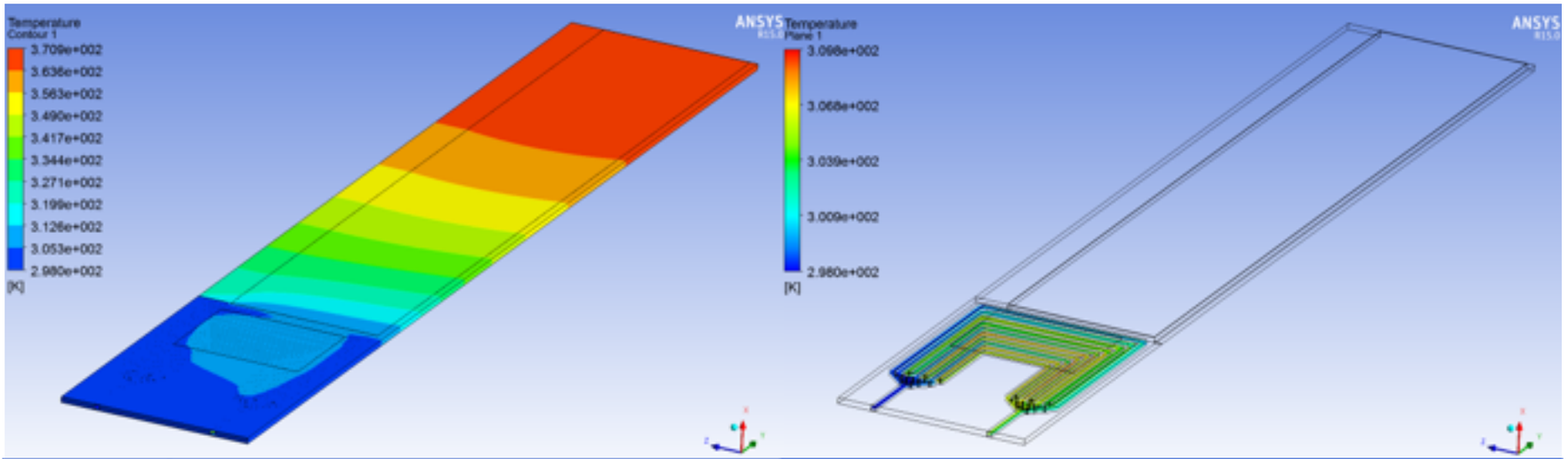




- Big difference between MCC and MCC+air at the sensor area hottest point.
- Nearest regions to air input are efficiently cooled even with low air flow.
- MCC has less impact in away points as expected and great cooling locally.

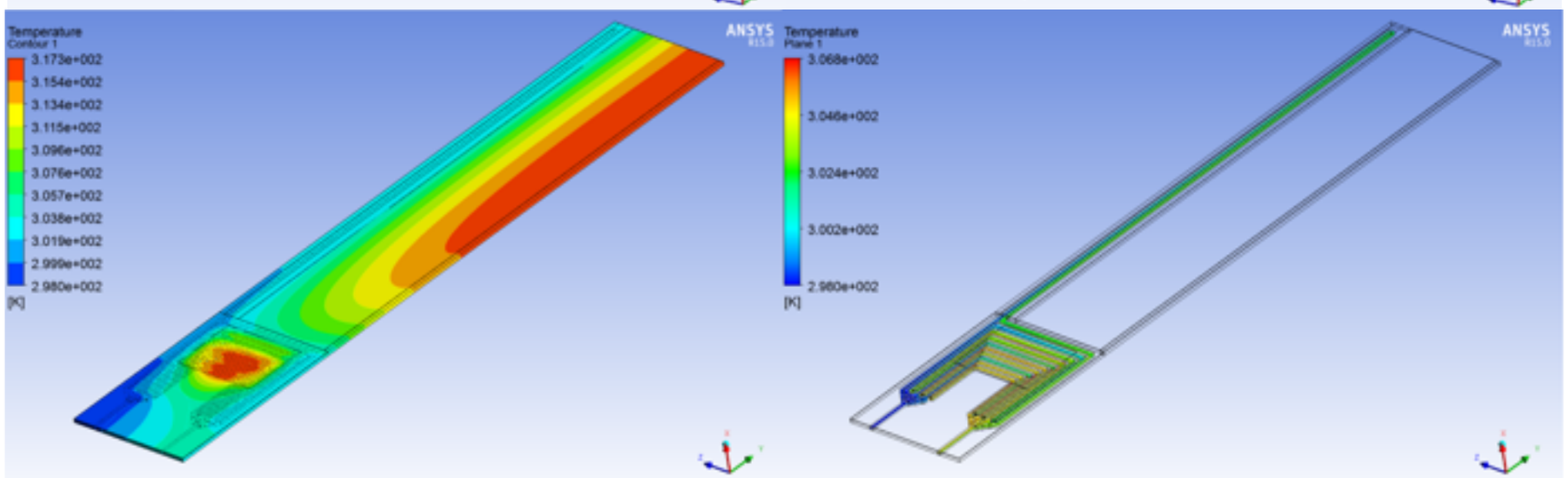
Cooling strategy: micro-channels running under the front end and gentle air flow on the sensor part.

WHOLE POWERED MODULE: MCC ALTERNATIVES



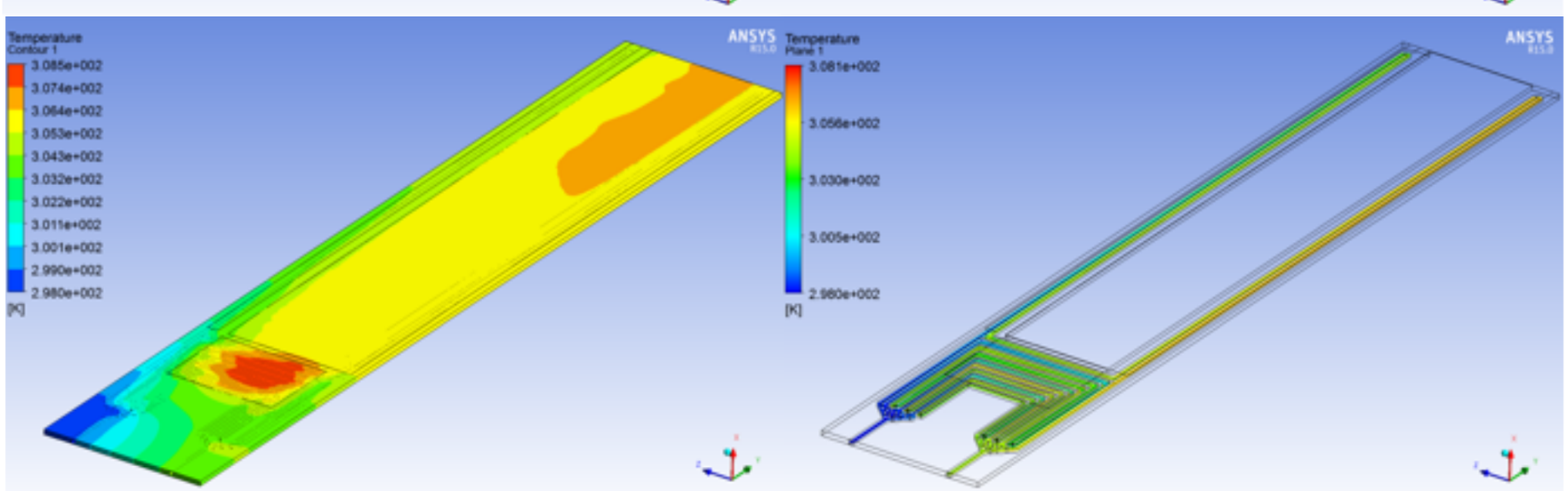
Standard MCC layout

ΔT = 73 K



Standard MCC layout + channel below switchers

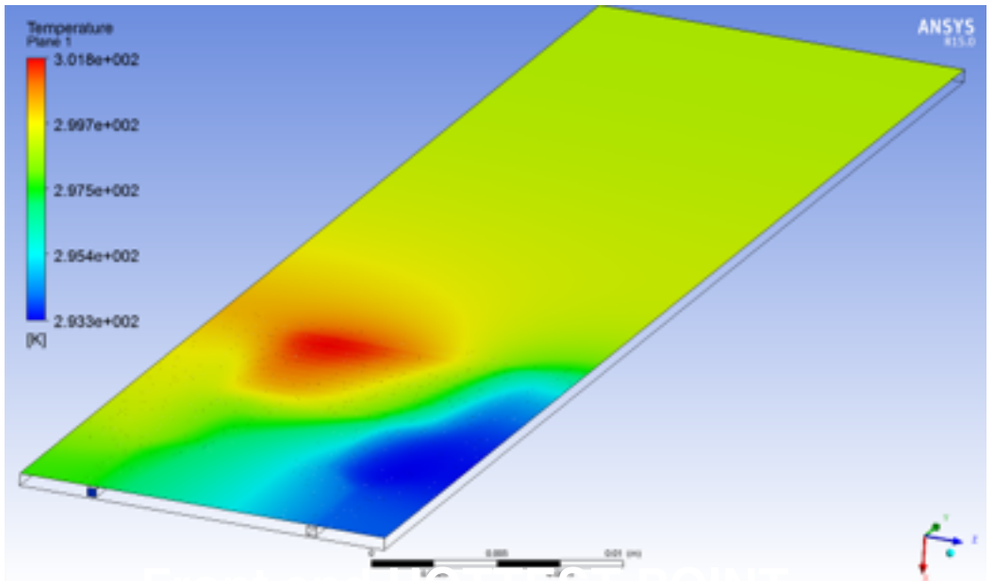
ΔT = 15 K

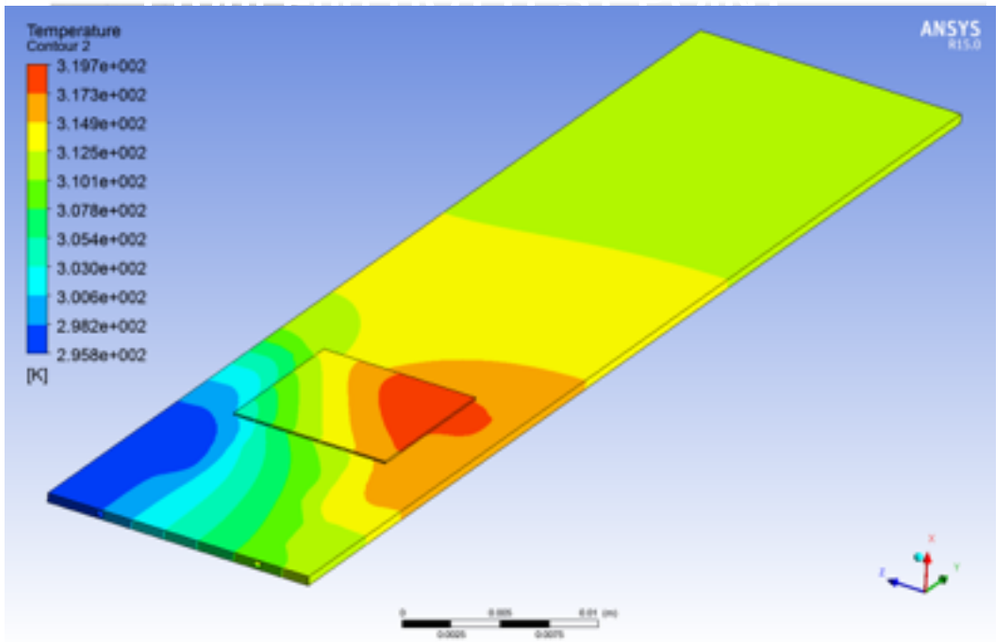


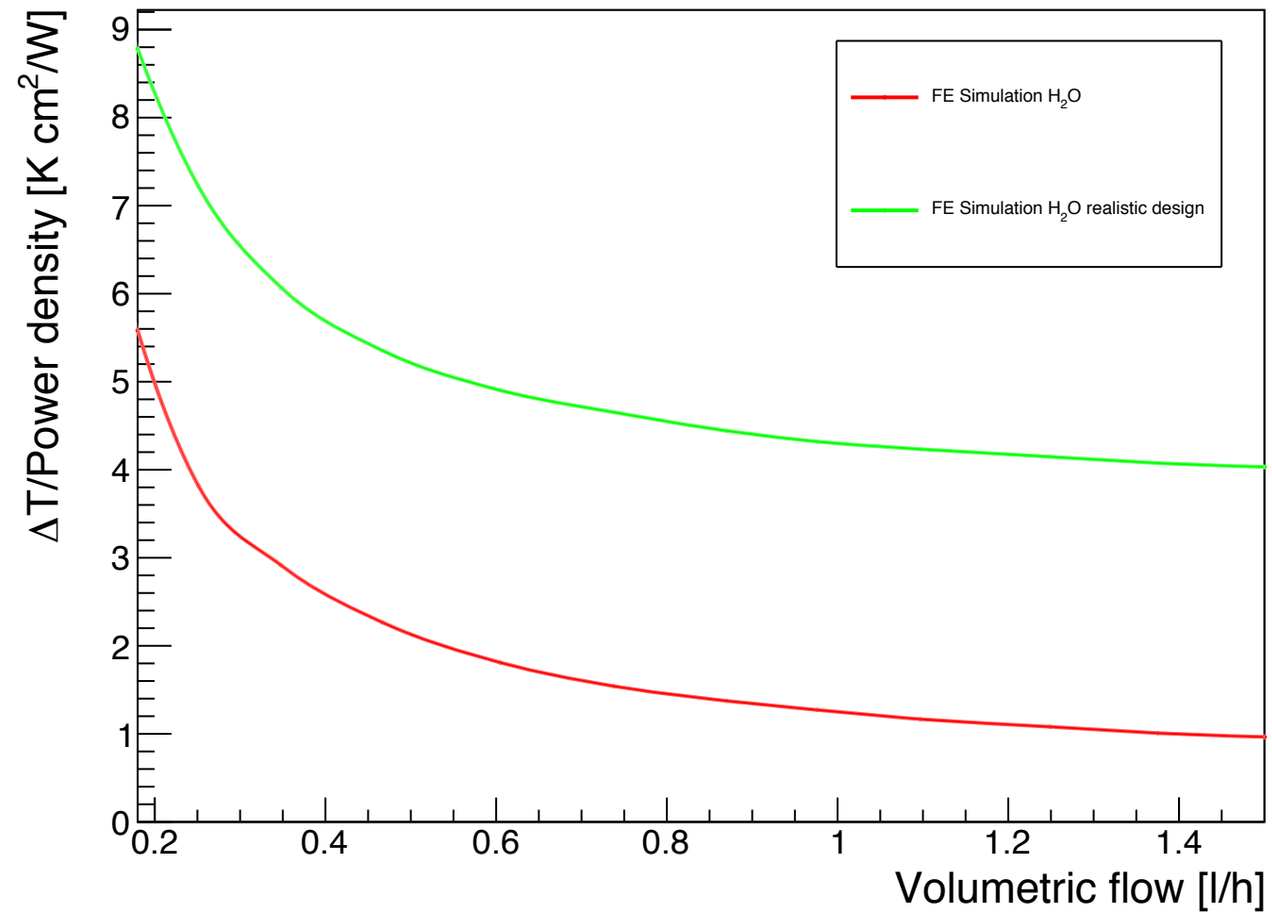
Standard MCC layout + channel below switchers + channel in the balcony

ΔT = 5 K

MORE REALISTIC APPROACH: BUMPS





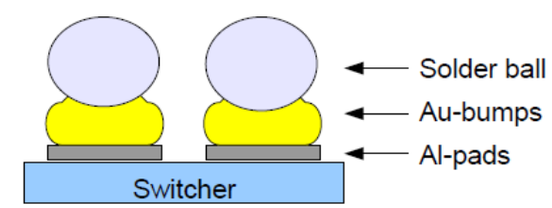


Realistic design

300 µm Si ASICS +

100 µm Bump-boundings

thermal resistivity of 6 W/m·K



Carlos Mariñas PhD Thesis

In the realistic design the power dissipation is degraded

NEXT STEPS

- Test the radiation resistance of the 3D-printed connectors.
- Repeat the thermo-mechanical measurements for the new designs of the connectors.
- Reproduce the study for the more realistic approach, with bumped resistors instead of printed ones.
- Produce and test the thermo-mechanical properties of the whole powered modules of the new MCC alternative layouts.

SUMMARY

- MCC shows very efficient local cooling, up to 25 W/cm^2 for $\Delta T \sim 10°$ C using low pressure mono-phase cooling liquid.
- The thermal measurements agree with the FE simulation.
- MCC has negligible impact on the module mechanical stability.
- Three in-plane connector concepts have been designed and manufactured, going towards less massive connectors.
- MCC modules have been successfully assembled (in 3/3), operated non-stop for a week, and supporting pressures up to 183 bars.
- These features qualify MCC as a real option for silicon detectors in physics.

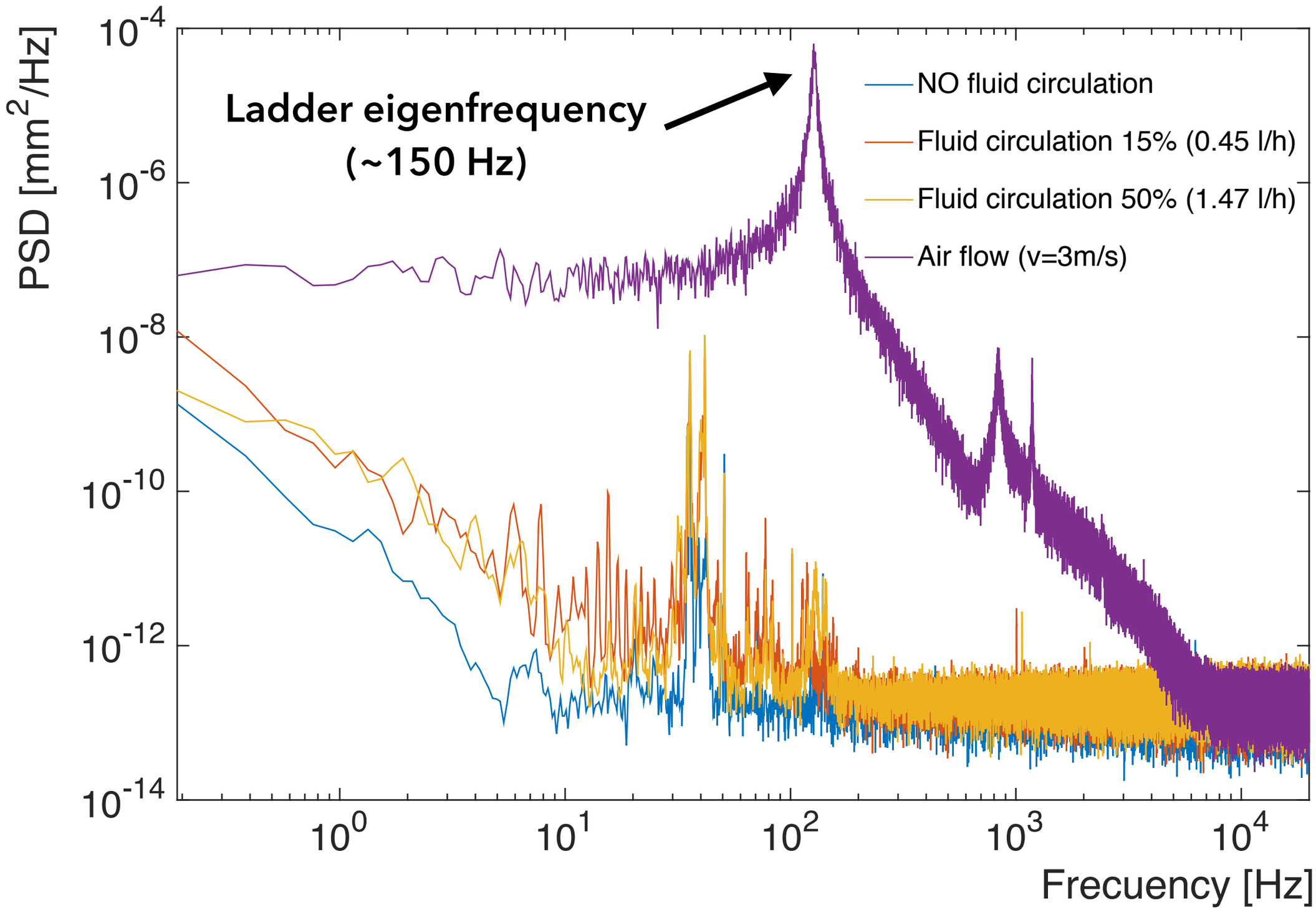
THANKS FOR YOUR ATTENTION

THIS STUDY IS SUPPORTED BY THE AIDA2020 THERMO-MECHANICAL PACKAGE

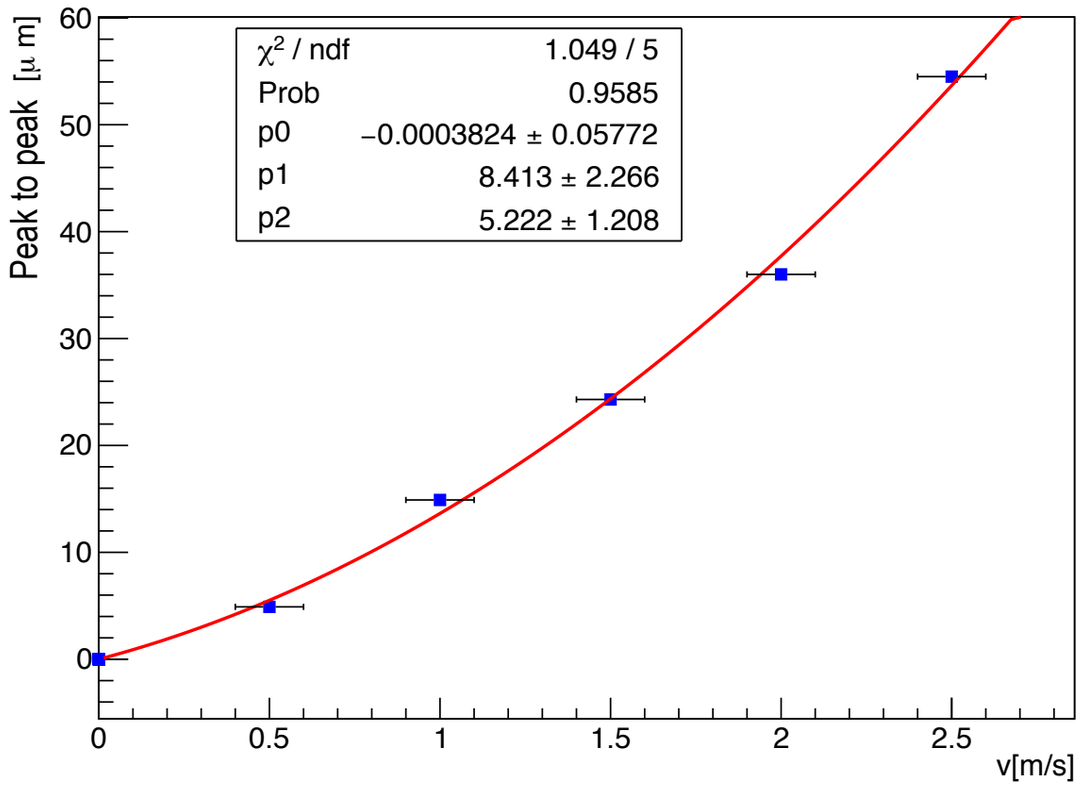
MORE INFORMATION AVAILABLE AT ARXIV:1604.08776

BACKUP

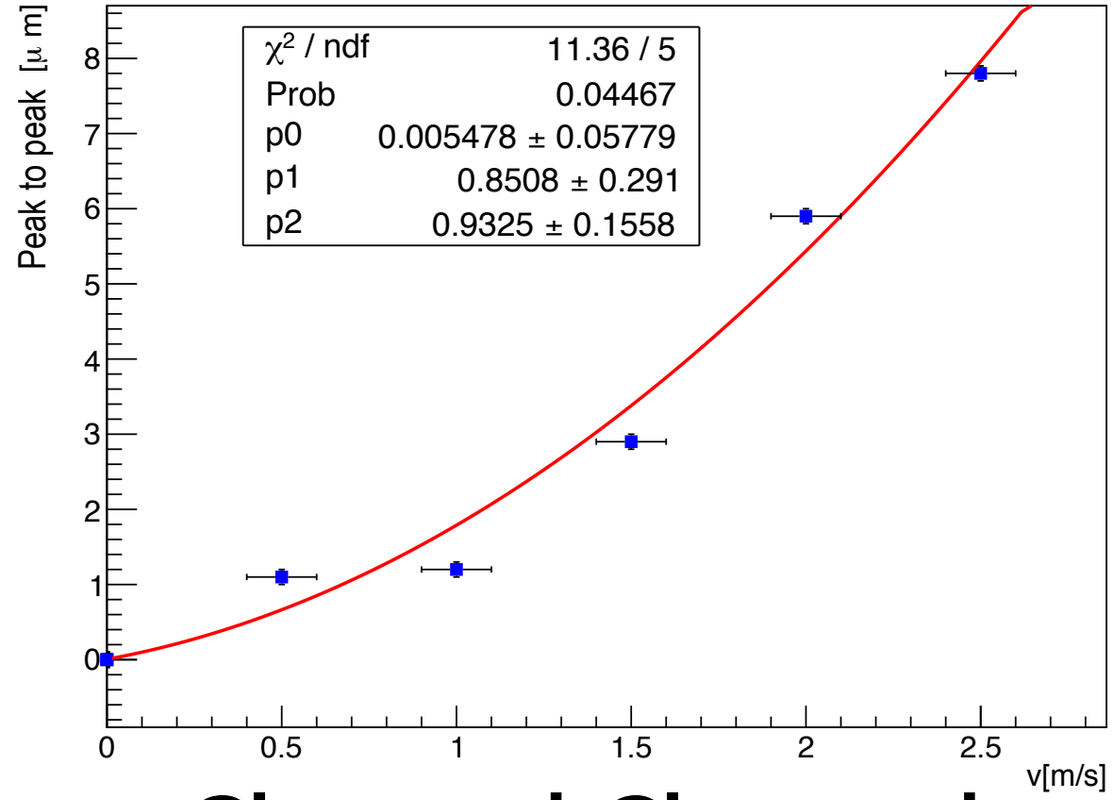
VIBRATION'S SPECTRAL POWER DENSITY



VIBRATION AMPLITUDE VS. AIR SPEED



Clamped-Free



Clamped-Clamped

- **Peak-to-peak amplitude is the change between peak (highest amplitude value) and trough (lowest amplitude value)**
- **RMS ≃ (PeaktoPeak/2) * 0.707 (approximation)**
- **For v= 2.5 m/s the amplitude of vibration is:**
  - **~19 μm for clamped-free configuration**
  - **~2.8 μm for clamped-clamped configuration**