

Update on Micro-channel cooling inside silicon sensors



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(1)



(2)



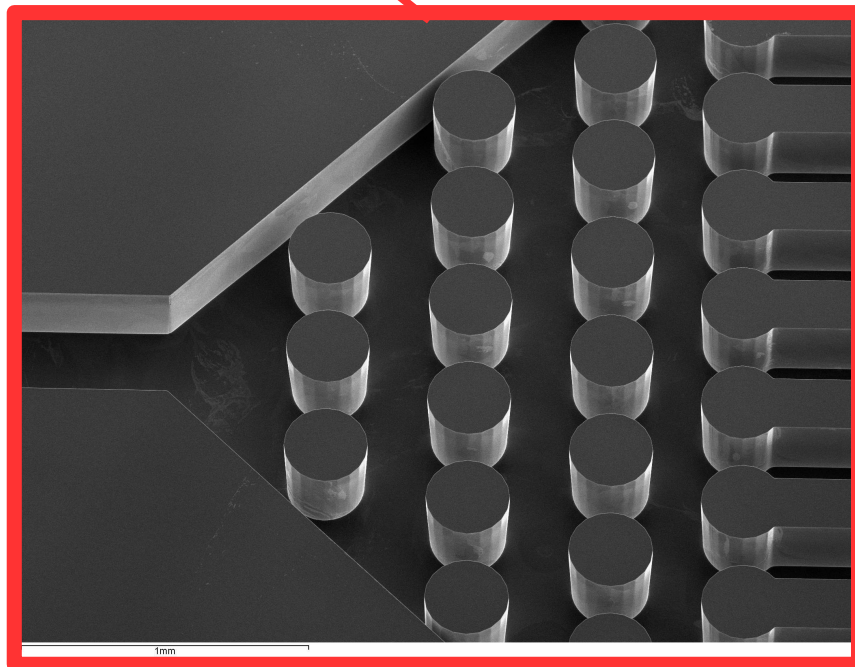
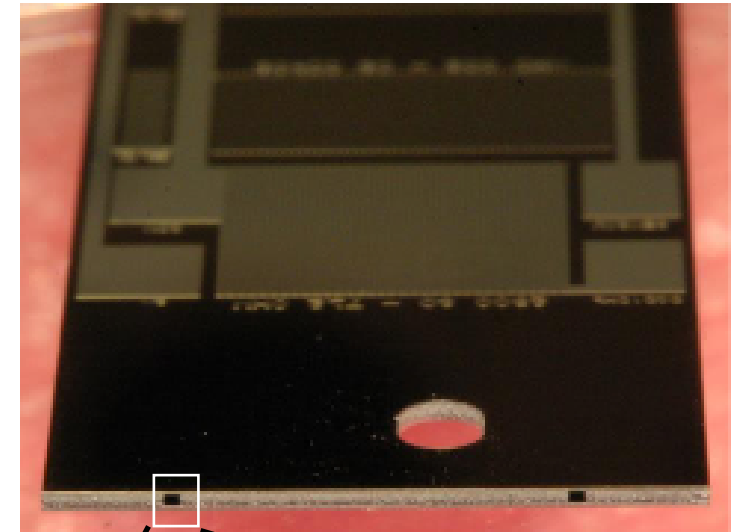
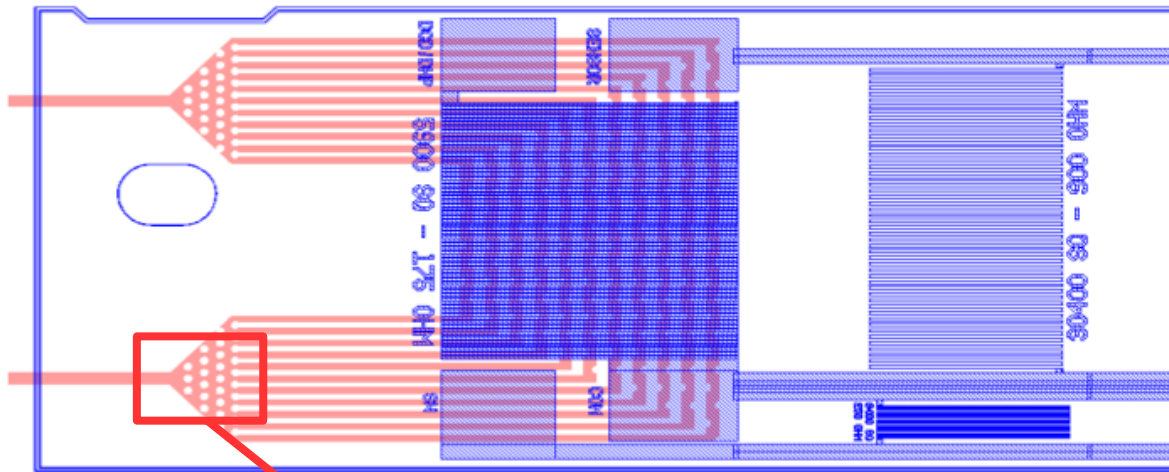
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Outline

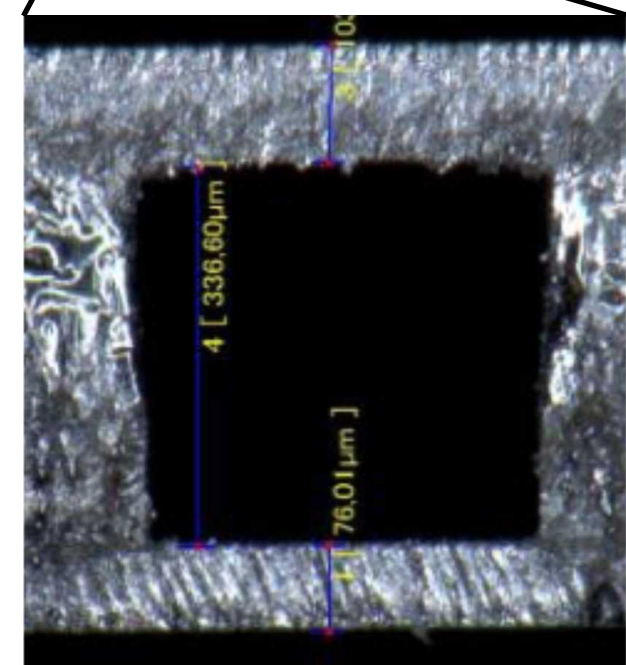
- 1- Introduction of the setup
- 2- Past results and main issues to address
- 3- Present results and mcc optimization
- 4- Summary

Introduction

The resistive dummies with integrated micro-channels based in DEPFET layout design:



Micro-channel pattern in handle wafer



Inlet and outlet: ~380 x 340 μm

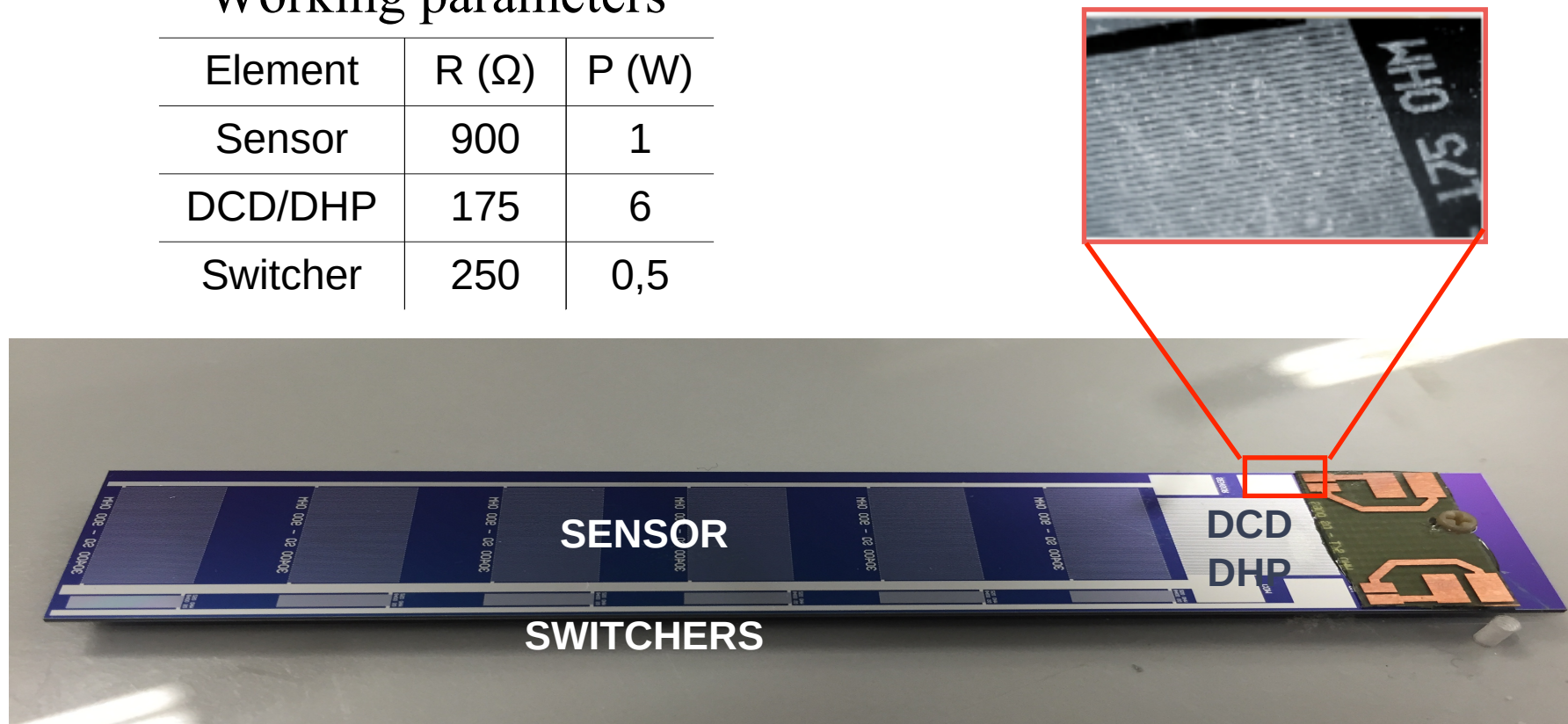
Introduction

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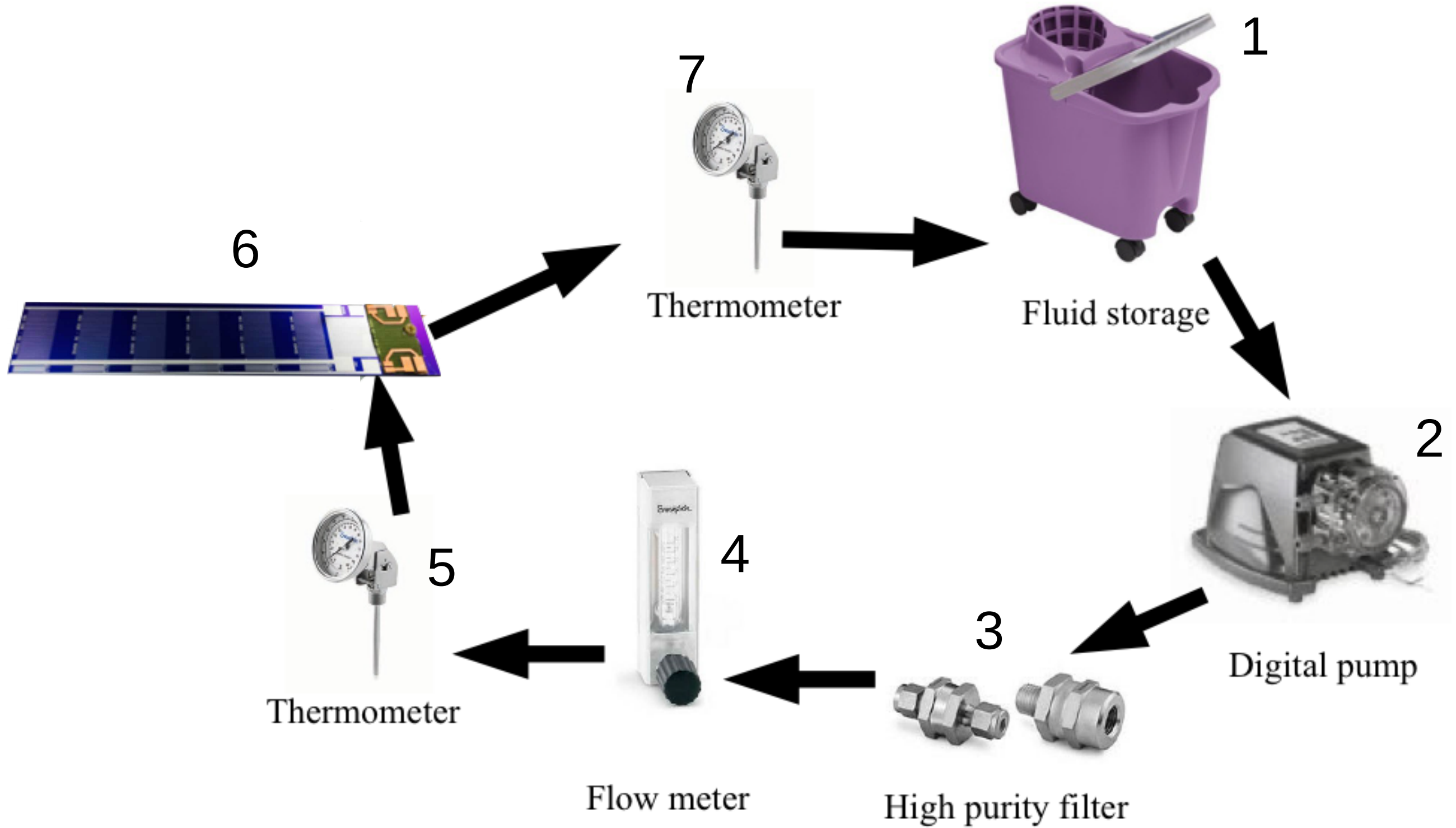
- Si modules with the designed dimensions of the DEPFET detectors
- Homogeneous thickness (thinned sensor area not needed)
- Modules do **not include** the **real electronics**
- Aluminum layer with resistor meanders on thin top wafer -> **simulate the power distribution**

Working parameters

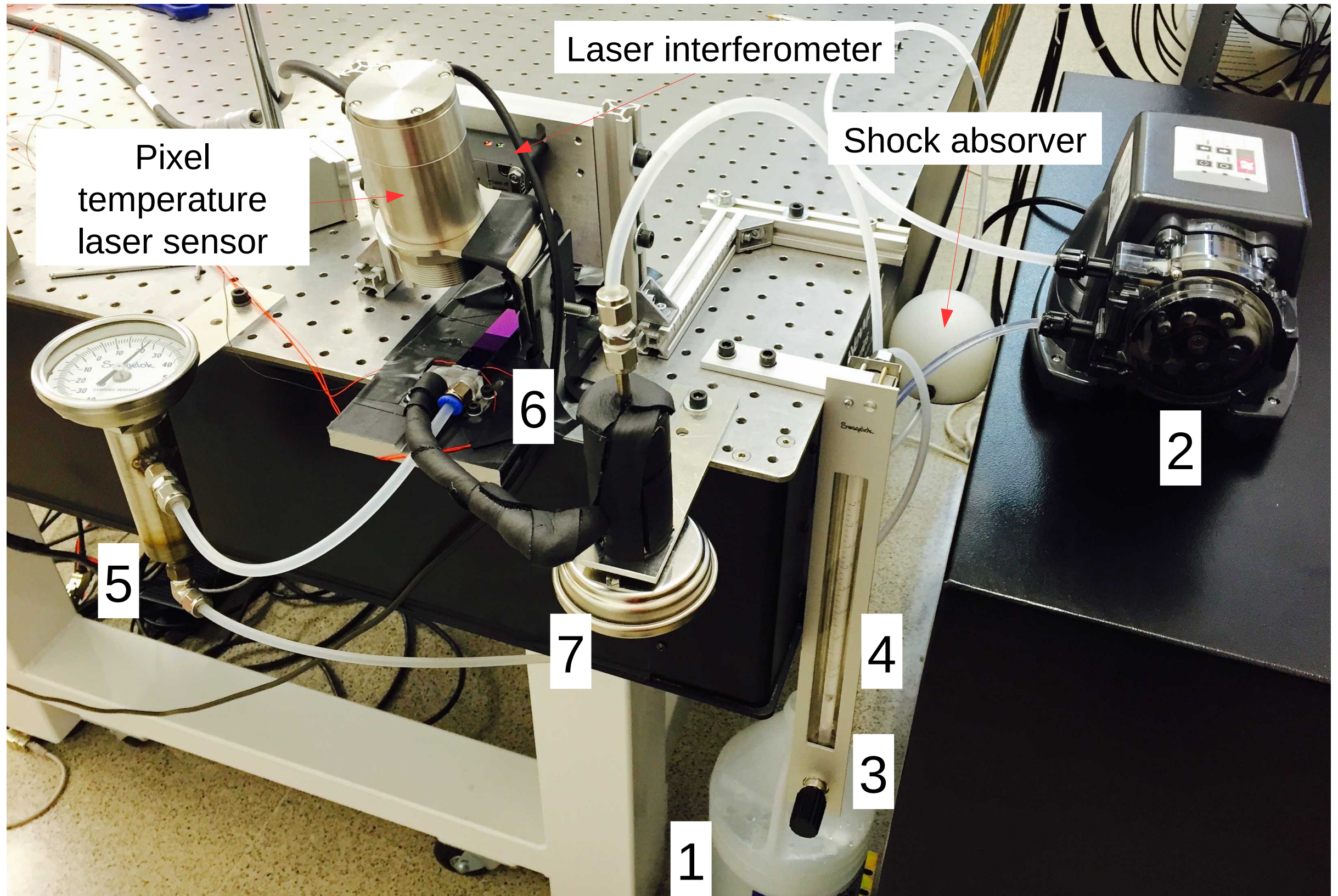
Element	R (Ω)	P (W)
Sensor	900	1
DCD/DHP	175	6
Switcher	250	0,5



Introduction

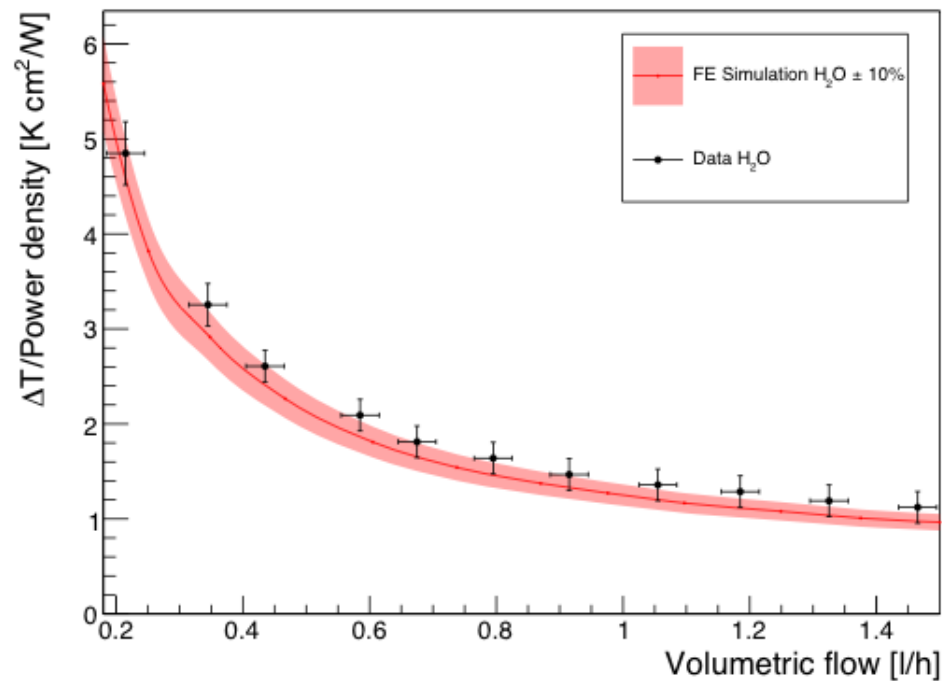


Introduction

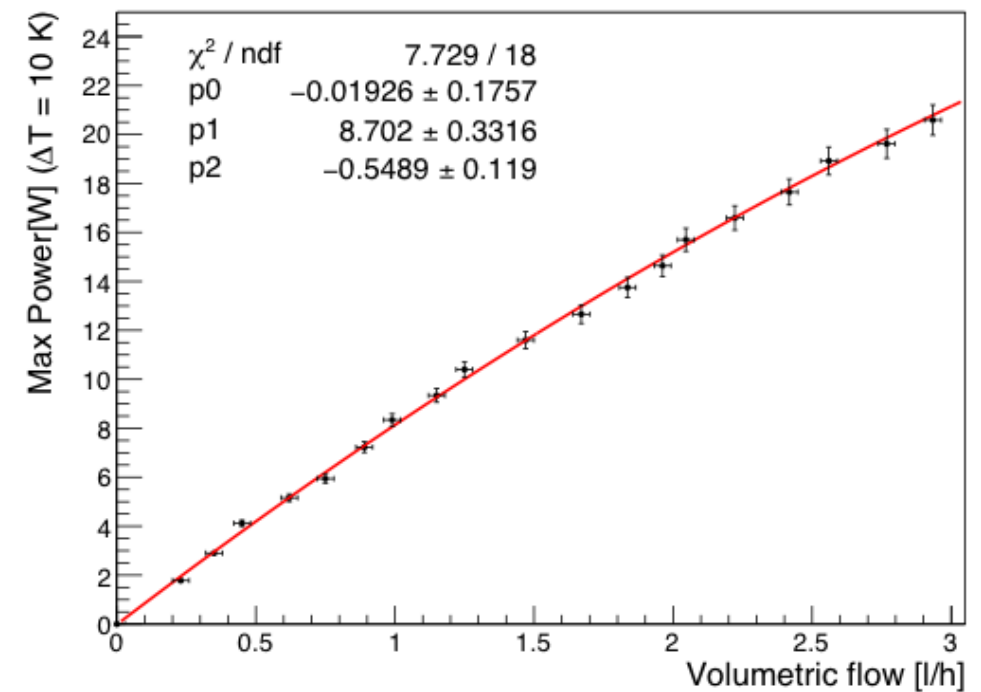


Past results

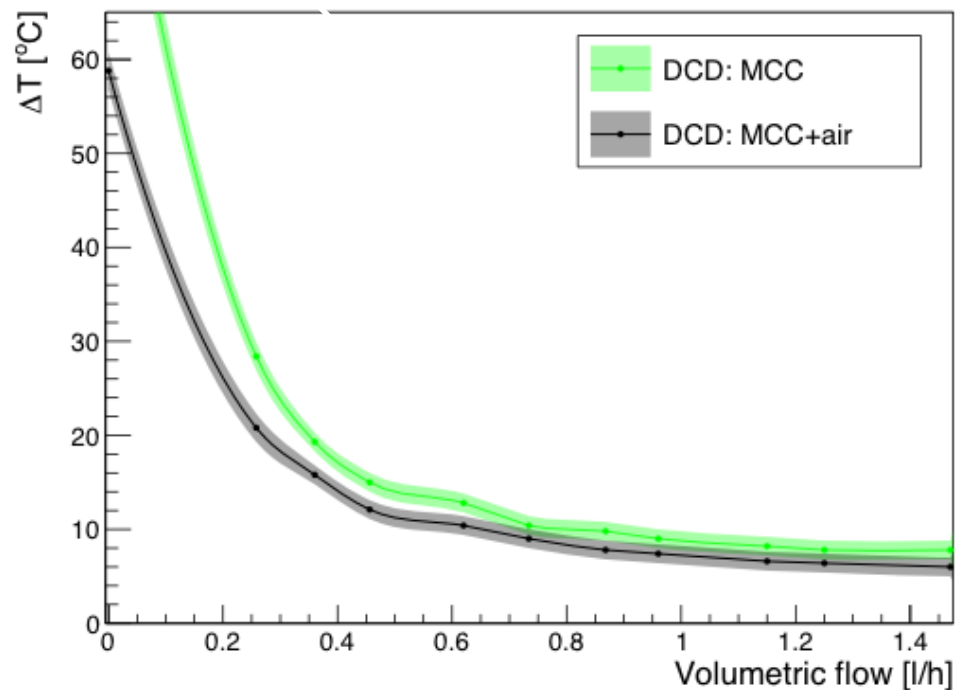
TFM: lab vs sim results



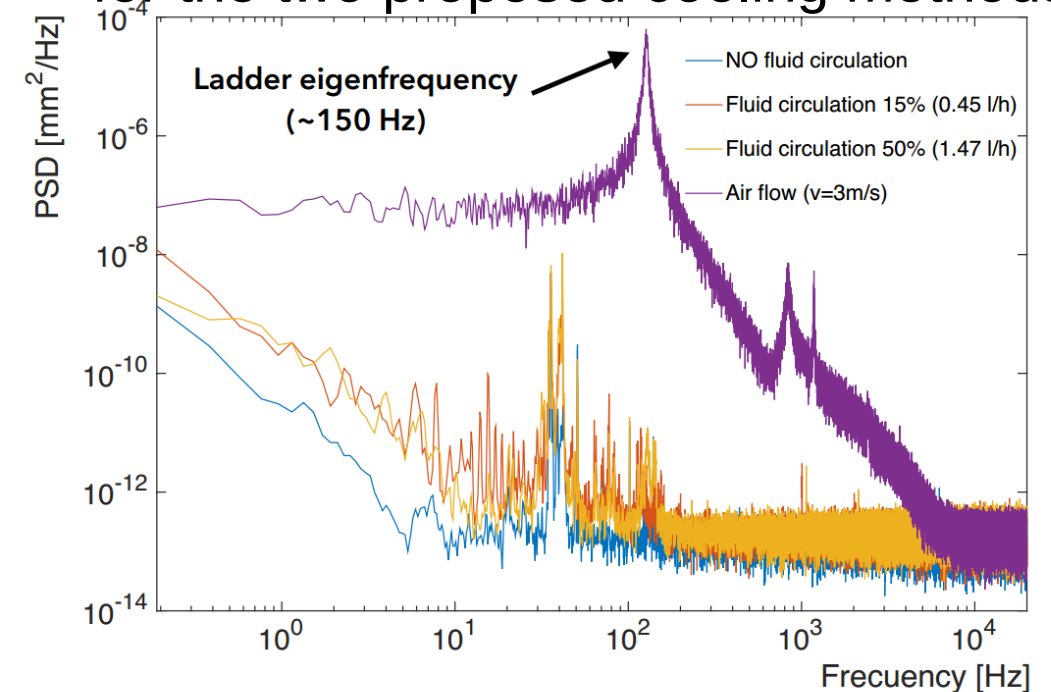
Max. power for $\Delta T=10\text{K}$



Difference between mcc and mcc+air



First frequency mode and deformation influence for the two proposed cooling methods



More information available in [JINST, Volume 11, June 2016](#)

MCC optimization

- New issues arised:

Problems	Solution
High amount of material for connexion between tubes and silicon microchannel ladder	

MCC optimization

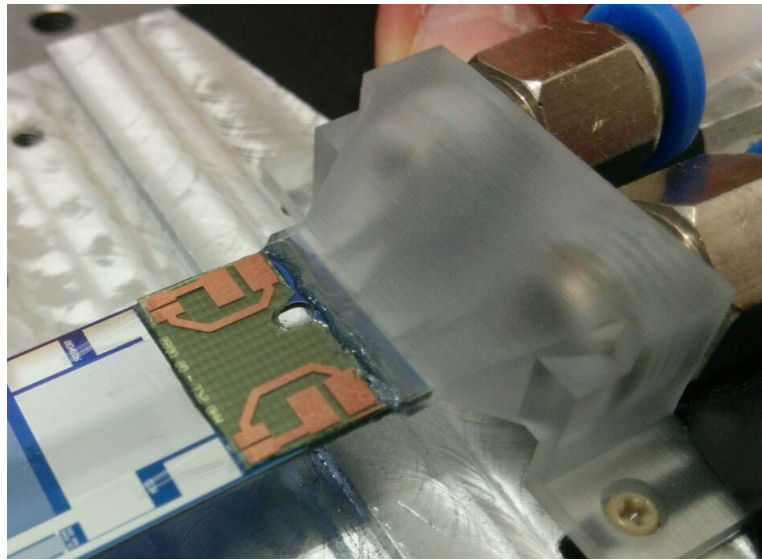
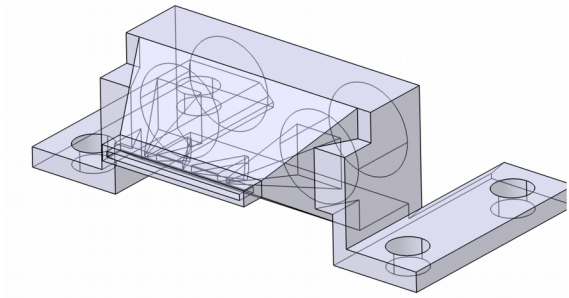
- New issues arised:

Problems	Solution
High amount of material for connexion between tubes and silicon microchannel ladder	Connector optimization

MCC optimization: material budget

Past (A long time ago,...)

(0.81% X/X_0)

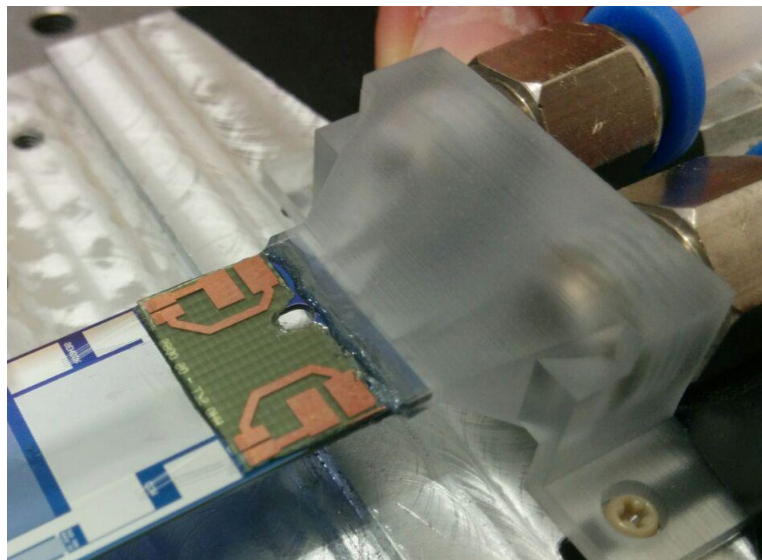
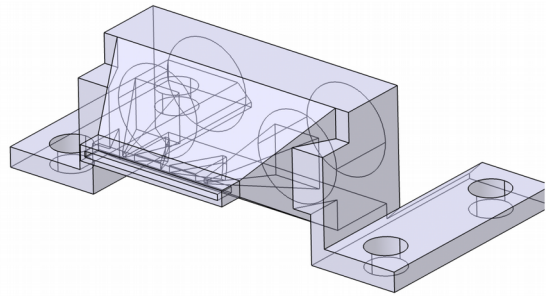


- First successful attempt
- Huge amount of material used:
connector and metal fittings
- Mechanical fitting
- Non high performance glue

MCC optimization: material budget

Past (A long time ago,...)

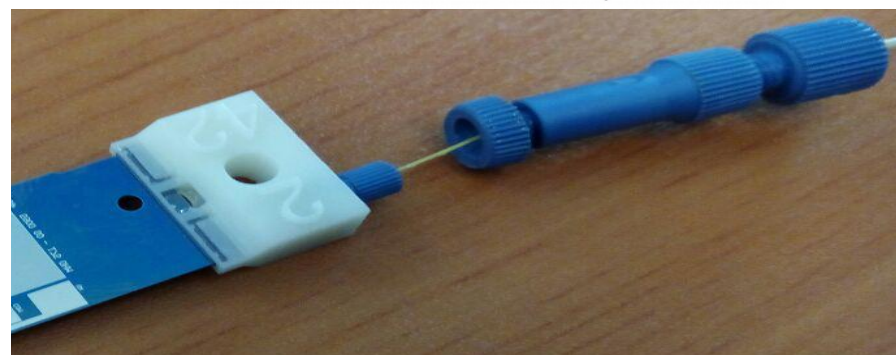
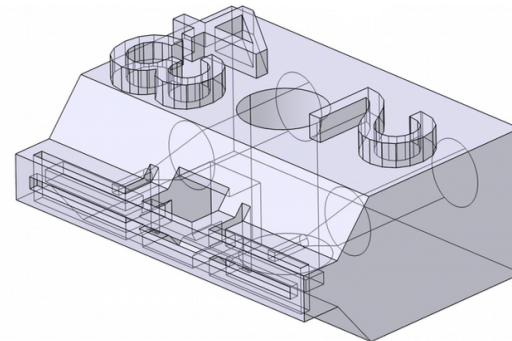
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Past (A not so long time ago)

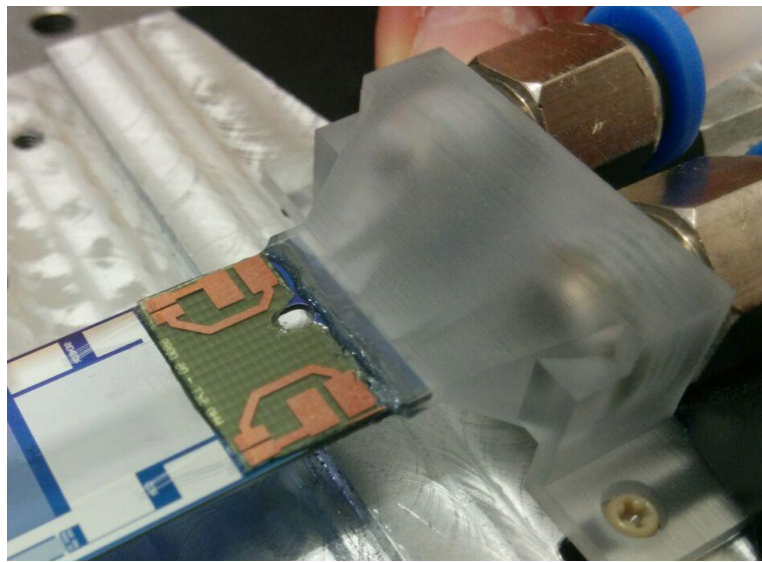
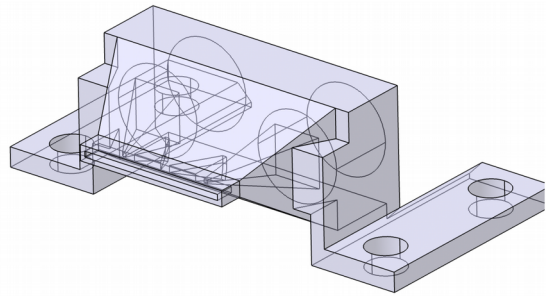
(0.2% X/X_0)



- Low amount of material used: connector and peek fittings
- Mechanical fitting
- High performance glue Araldite 2020 → low viscosity → clogging

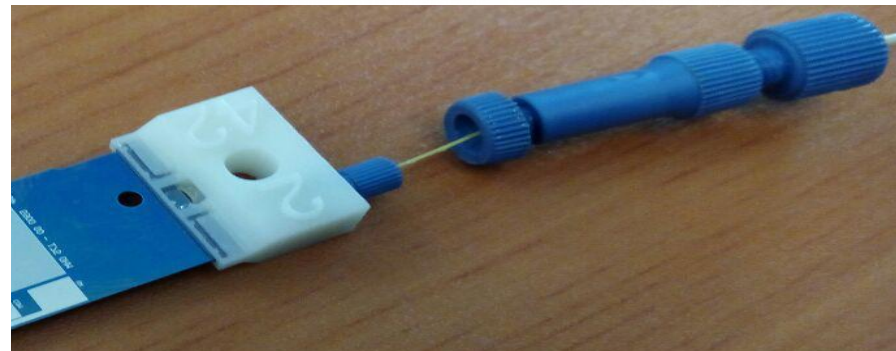
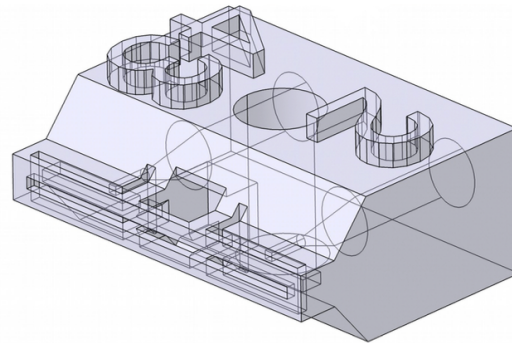
MCC optimization: material budget

Past (A long time ago,...)
(0.81% X/X_0)



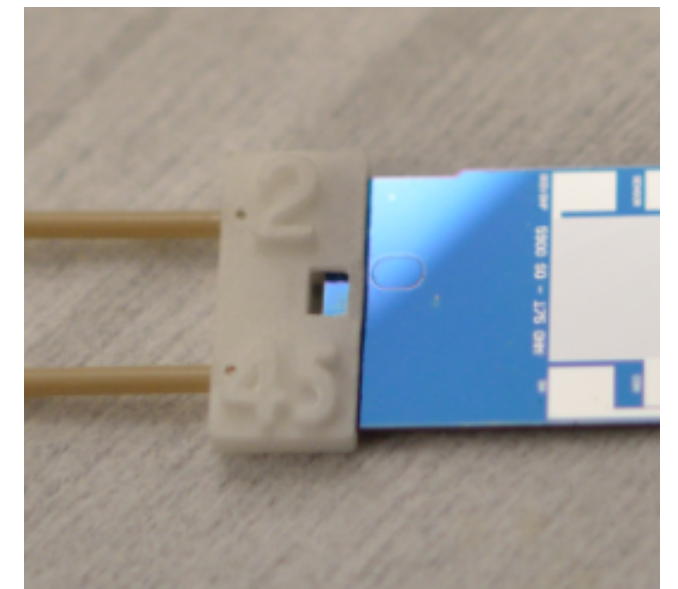
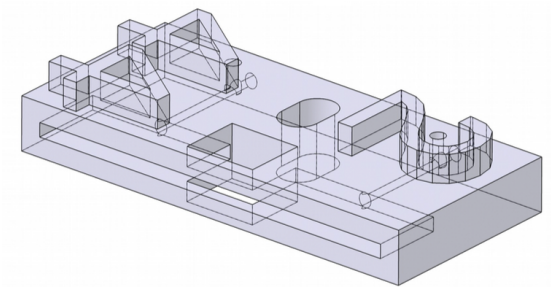
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- Non high performance glue

Past (A not so long time ago)
(0.2% X/X_0)



- Low amount of material used: connector and peek fittings
- Mechanical fitting
- High performance glue Araldite 2020 → low viscosity → clogging

Present
(0.05% X/X_0)



- Low amount of material used: connector and peek fittings
- Chemical fitting
- High performance glue Araldite 2011 → high viscosity → no clogging

MCC optimization

- New issues arised:

Problems	Solution
High amount of material for connexion between tubes and silicon microchannel ladder	Connector optimization
3D printed materials radiation resistance is unknown	

MCC optimization

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Problems	Solution
High amount of material for connexion between tubes and silicon microchannel ladder	Connector optimization
3D printed materials radiation resistance is unknown	Ultimate tensile strength test needed for different irradiated samples

MCC optimization: connectors material

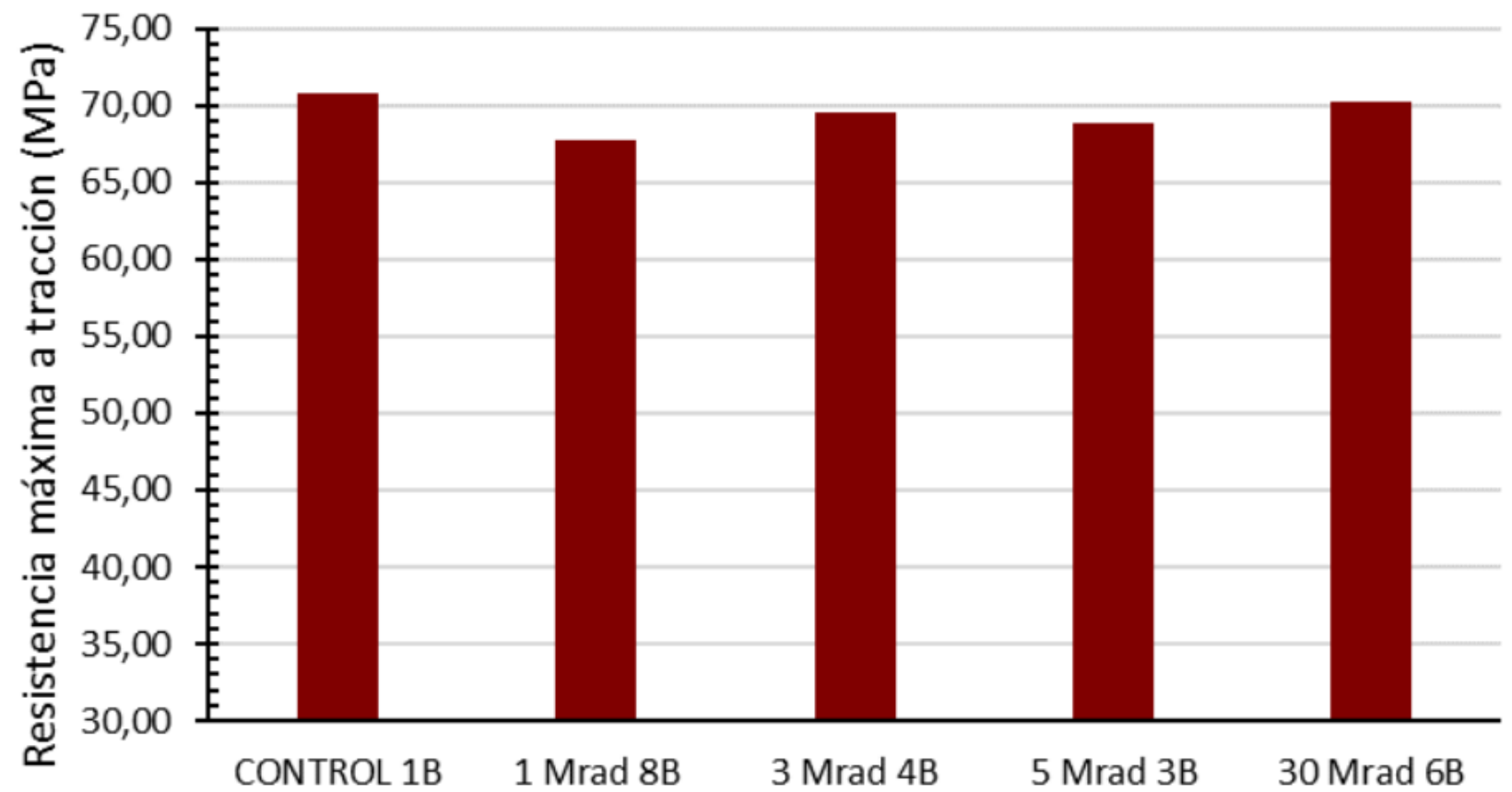
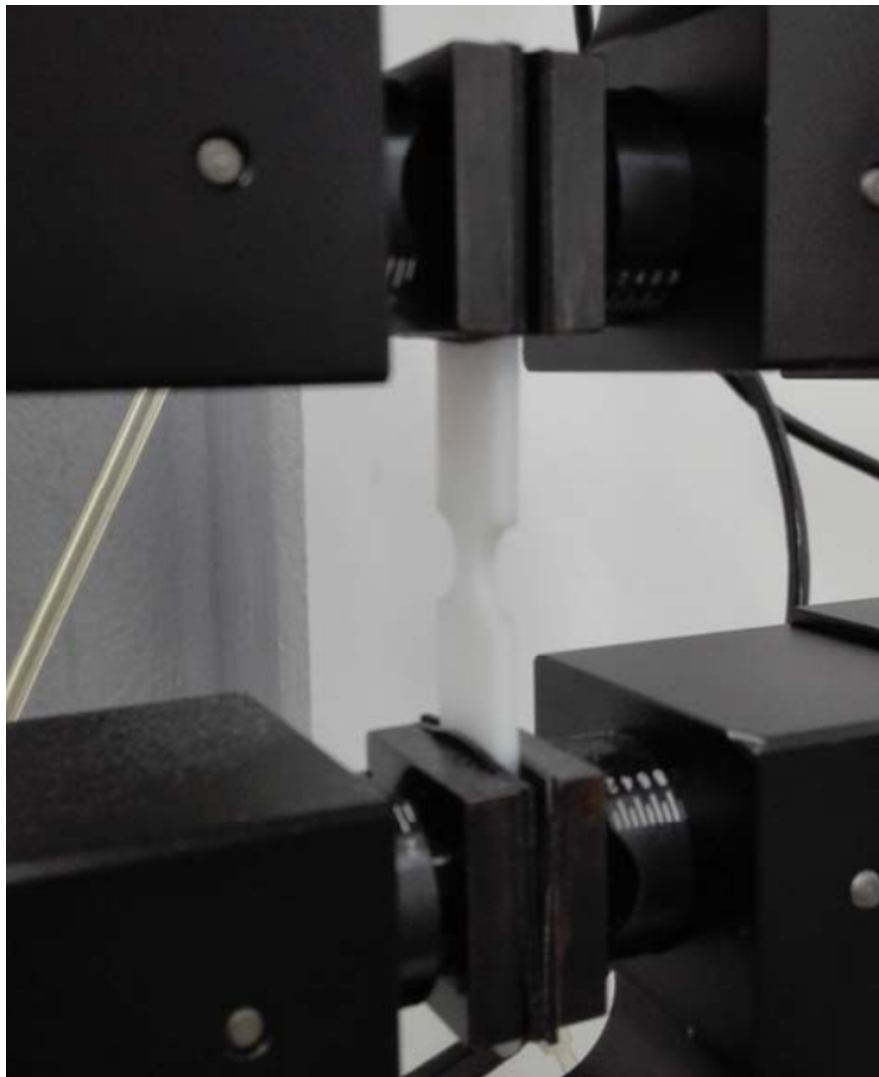


Different radiations levels

Two type of radiation:

- Neutrons
- **X-Rays**

MCC optimization: connectors material



MCC optimization

- New issues arised:

Problems	Solution
High amount of material for connexion between tubes and silicon microchannel ladder	Connector optimization
3D printed materials radiation resistance is unknown	Ultimate tensile strength test needed for different irradiated samples
Manual gluing process which brings to a dependency of random factors: subtle manipulation, luck,	

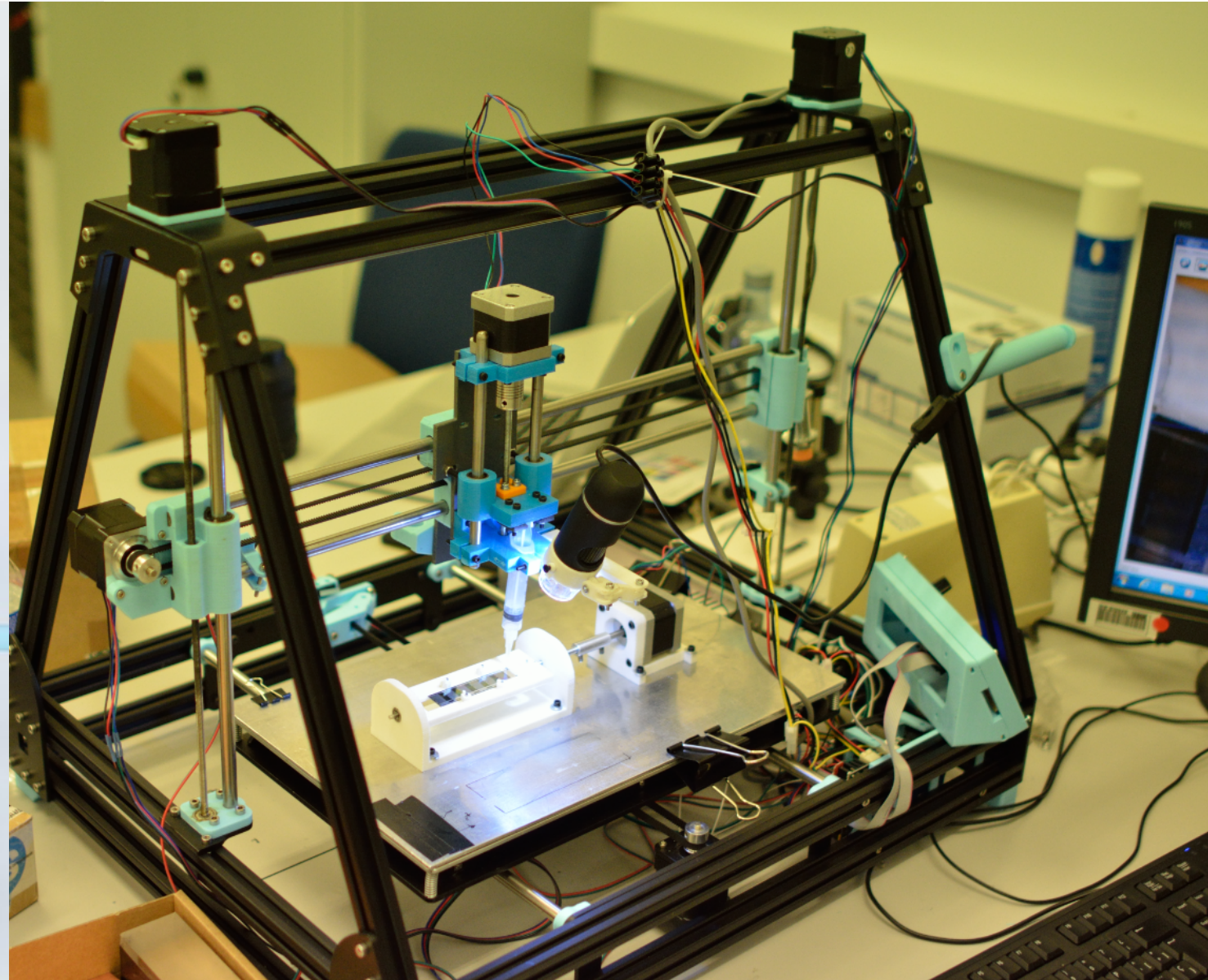
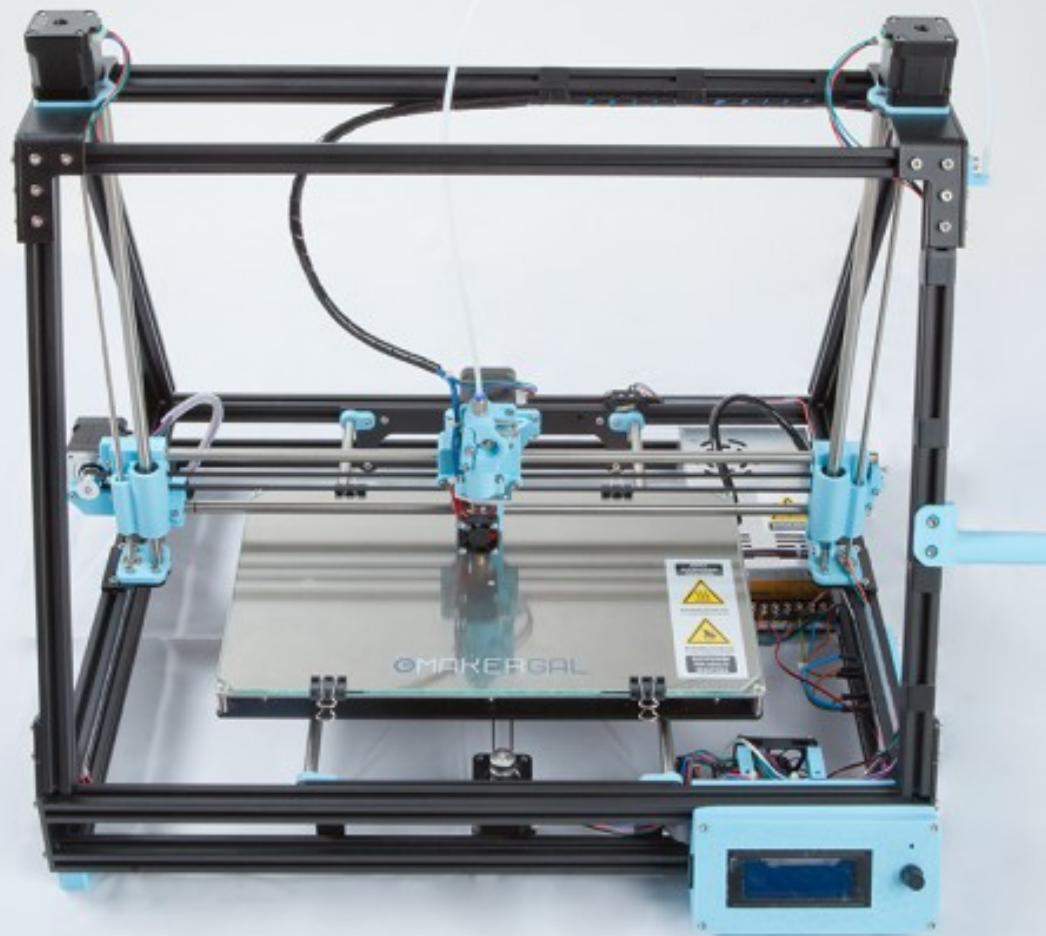
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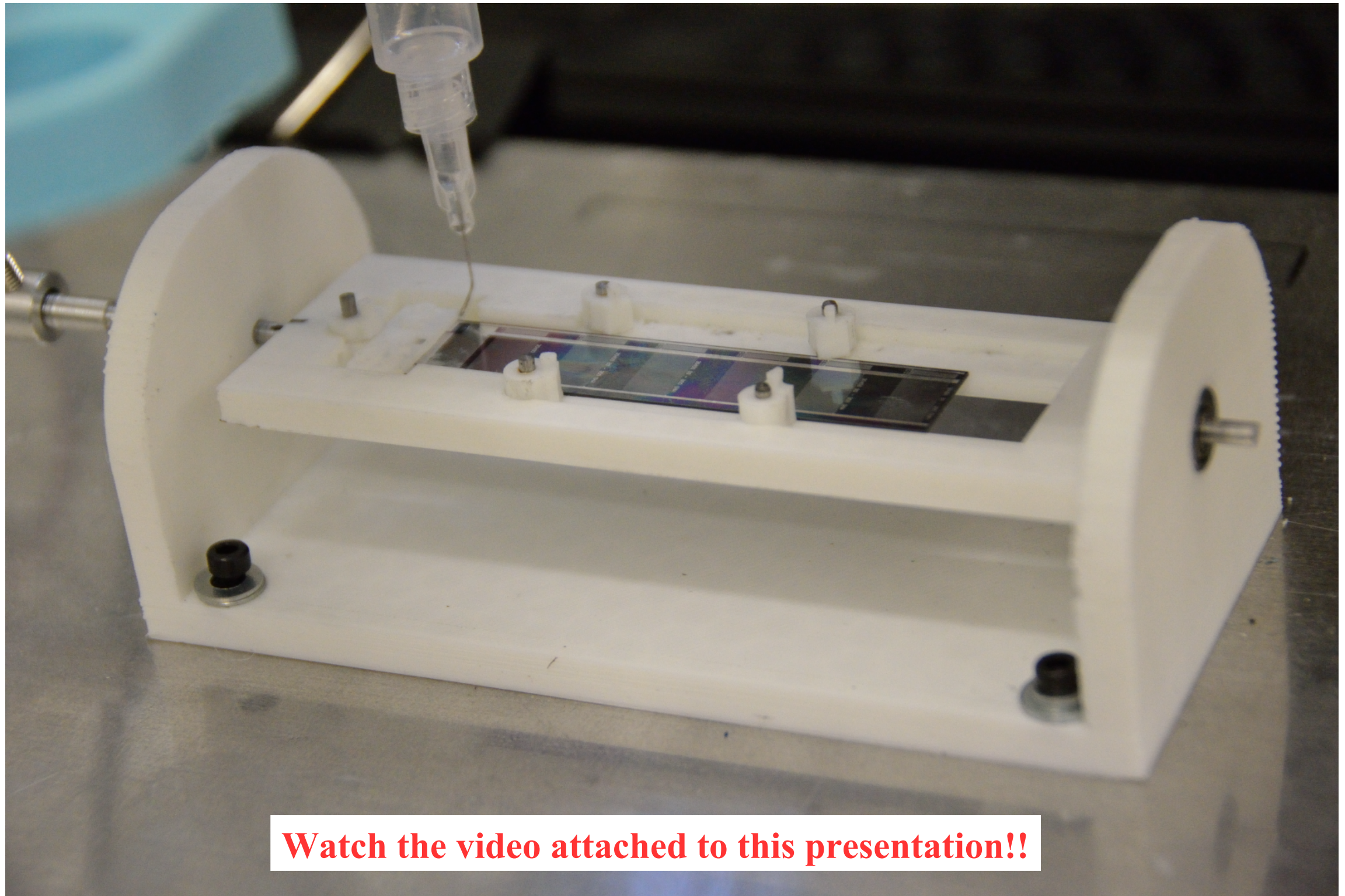
MCC optimization: automatization

Mendel Max 3D XL



- Low cost machine
- Open hardware and software
- Needing to adapt tooling for needle and glue syringe

MCC optimization: automatization



MCC optimization

- New issues arised:

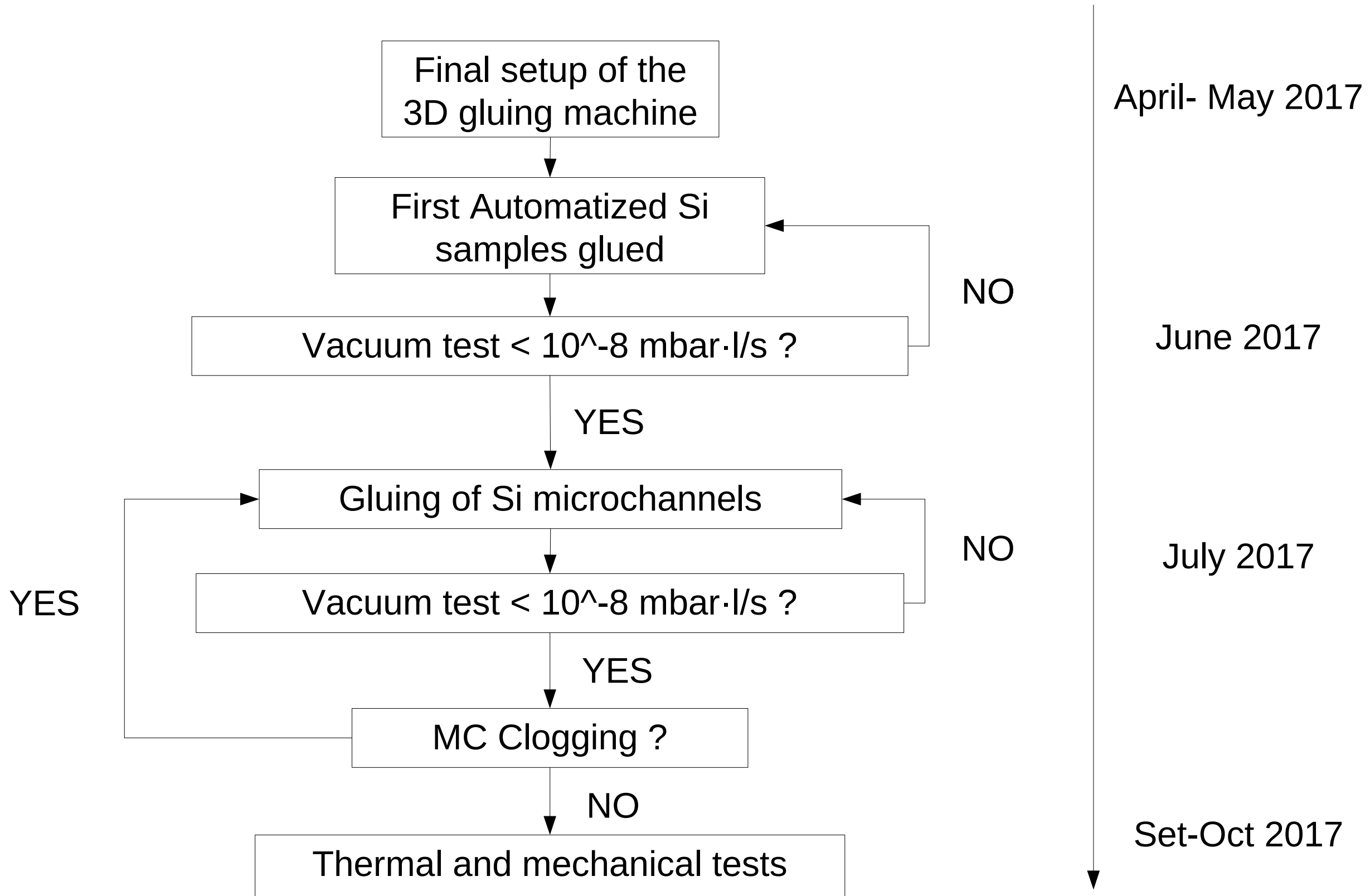
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“Leak quality” unknown	

MCC optimization

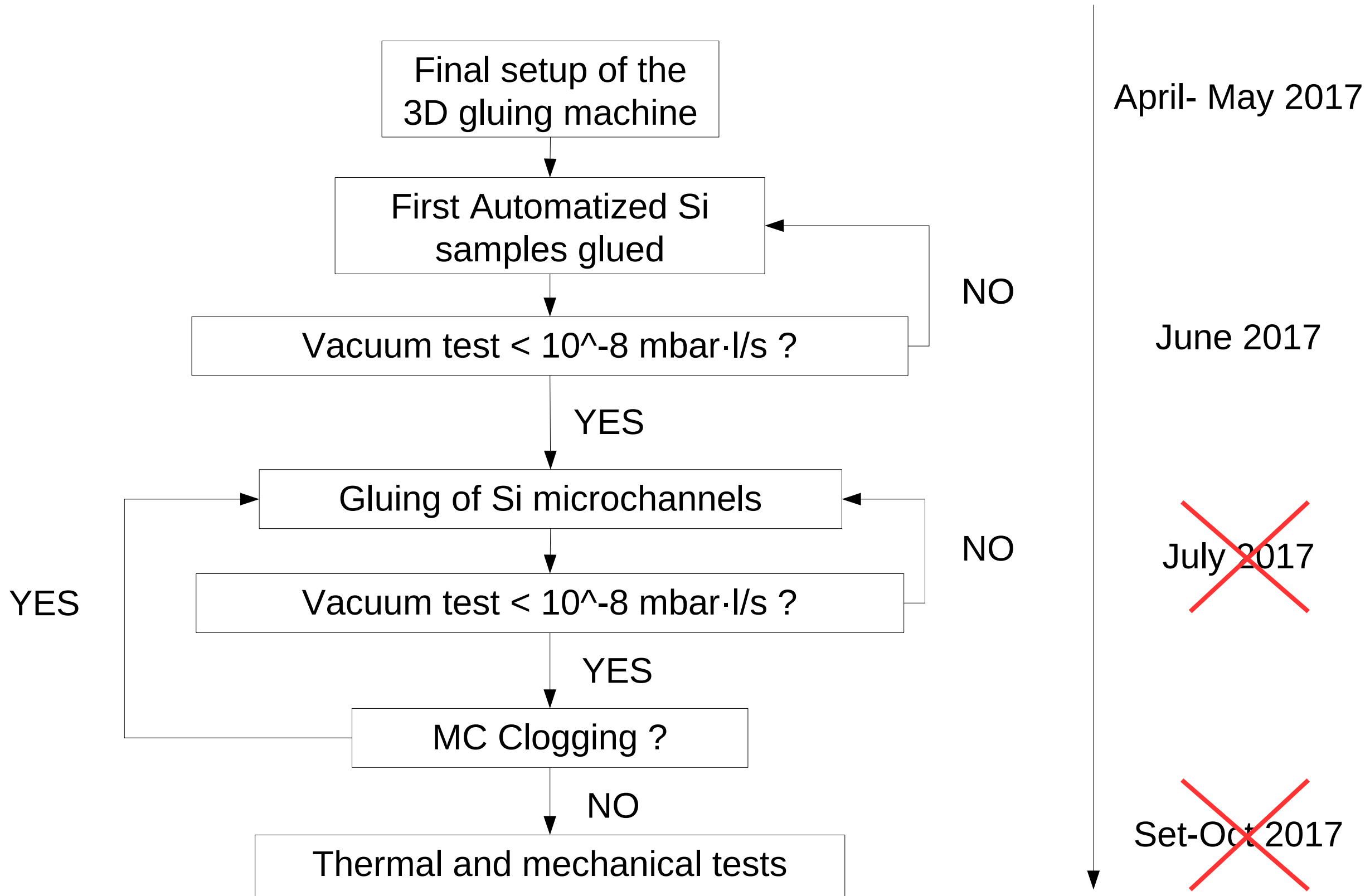
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“Leak quality” unknown	Vacuum test to validate before fluid flows through microchannels

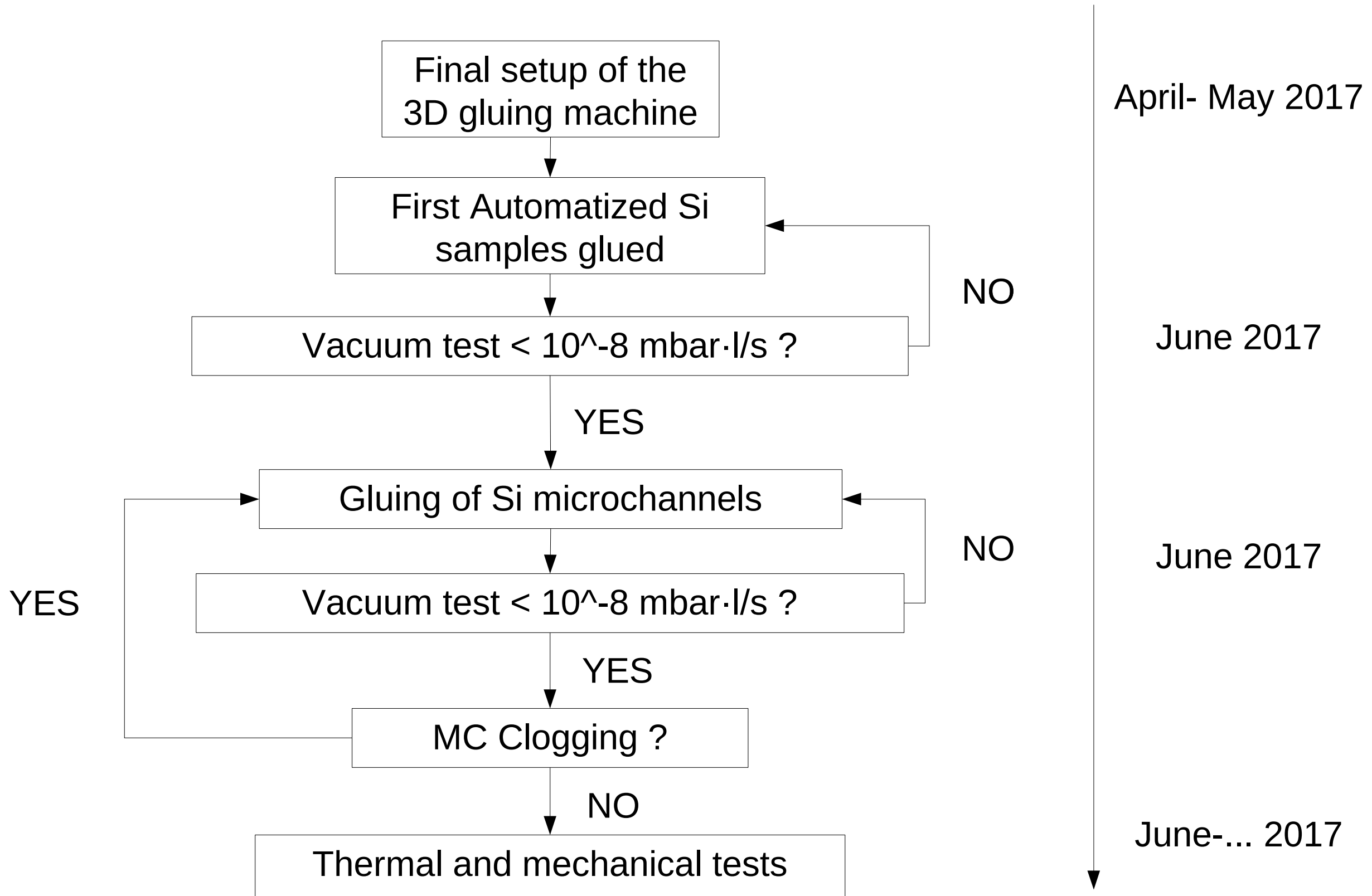
MCC optimization: Vacuum test



MCC optimization: Vacuum test



MCC optimization: Vacuum test



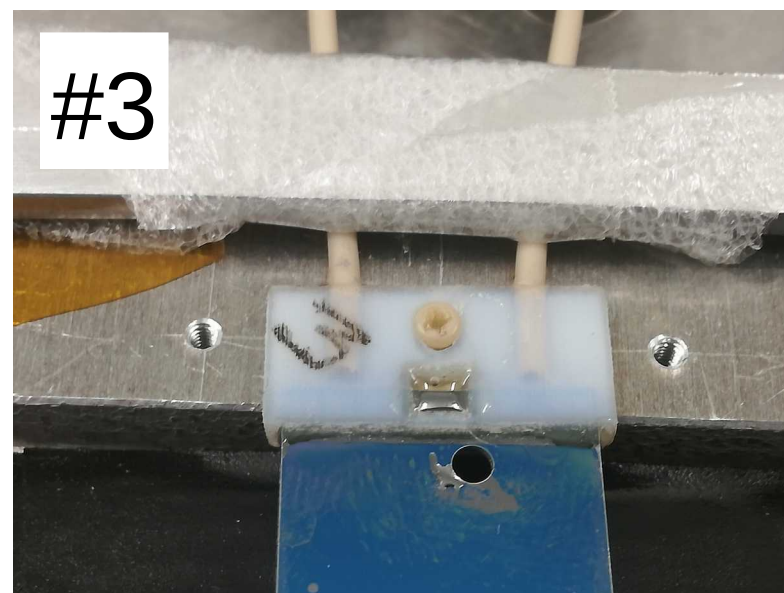
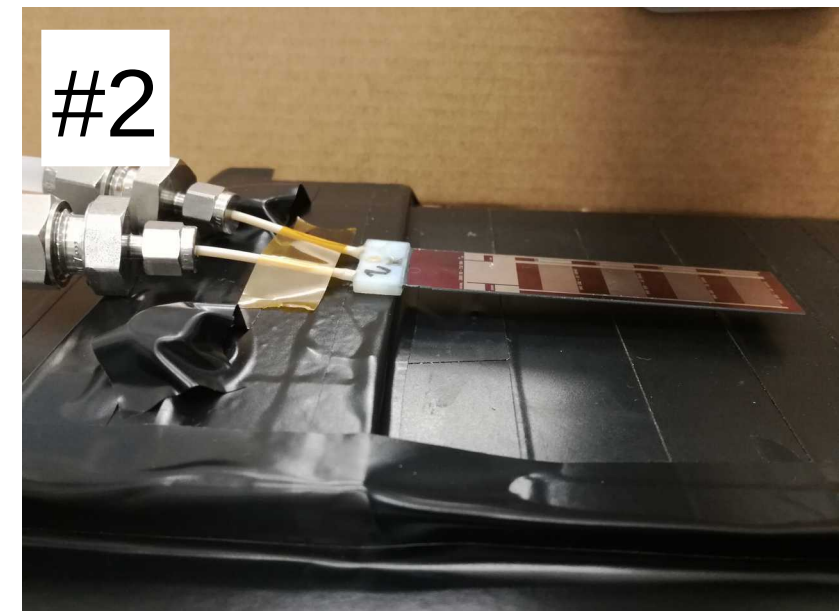
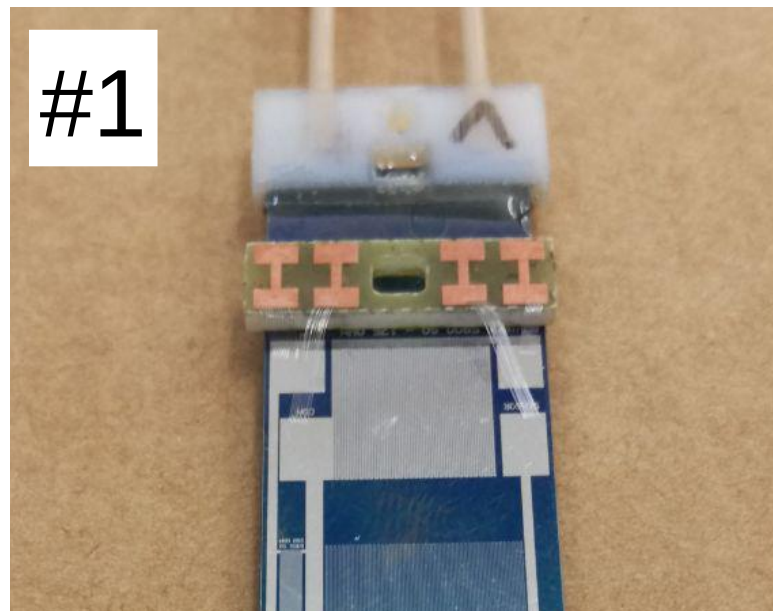
MCC optimization: Vacuum test



MCC optimization: Vacuum test



Sample number	#1	#2	#3	#4
Vacuum test [mbar l/h]	$5,5e^{-9}$	$9,0e^{-9}$	$8,6e^{-9}$	$6,1e^{-9}$



MCC optimization

- New issues arised:

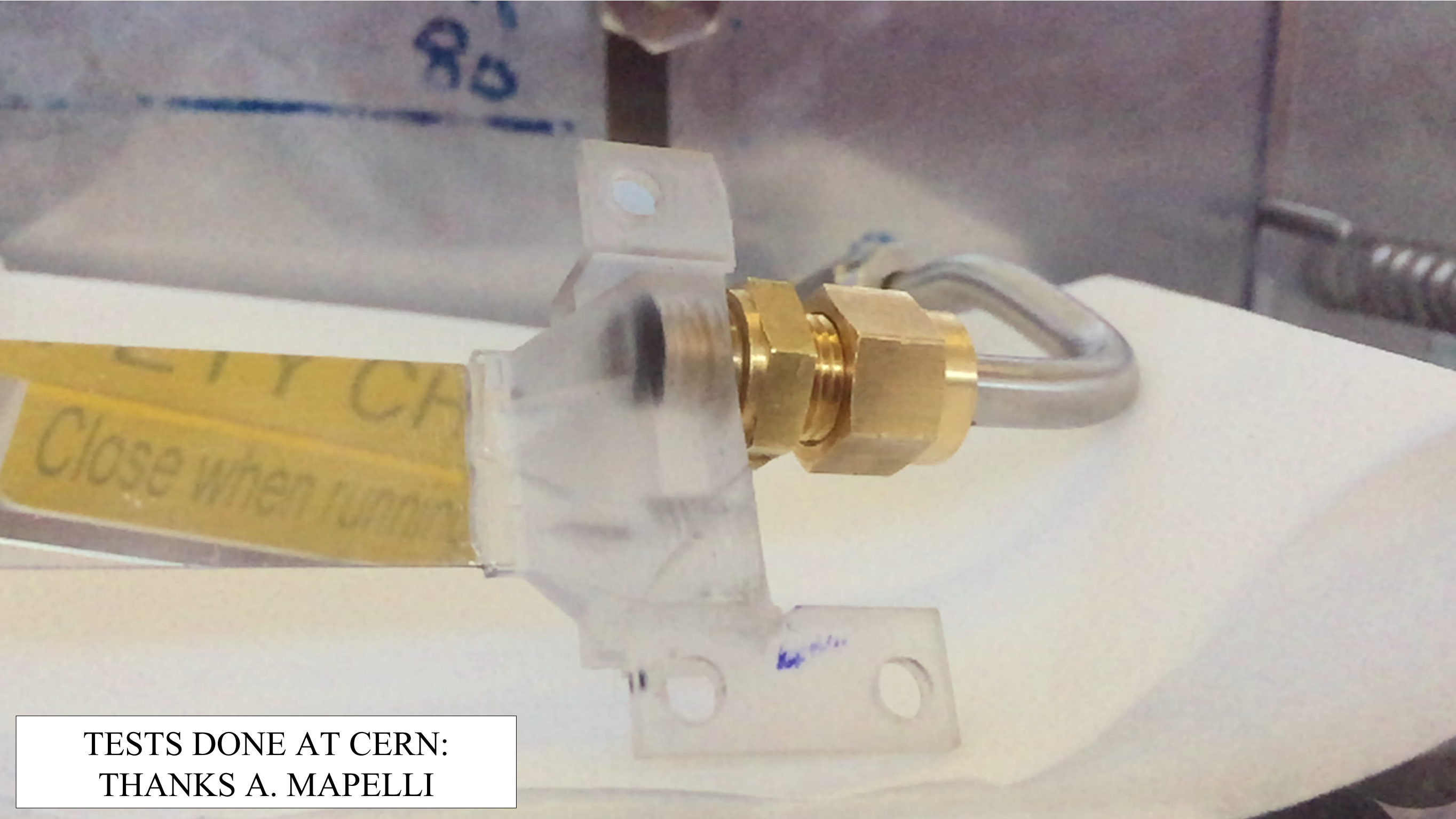
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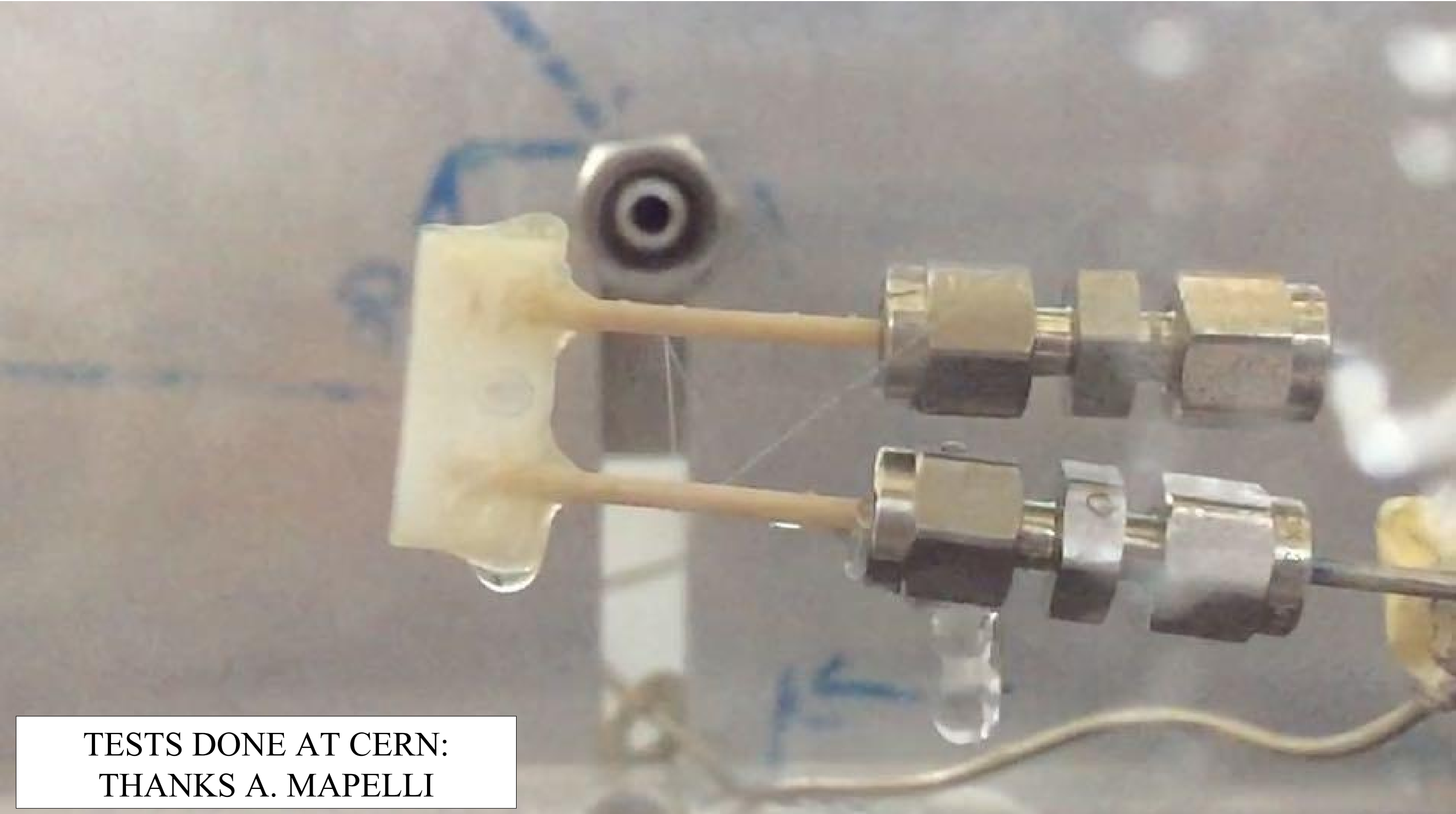
MCC optimization: pressure test



TESTS DONE AT CERN:
THANKS A. MAPELLI

180 bar achieved

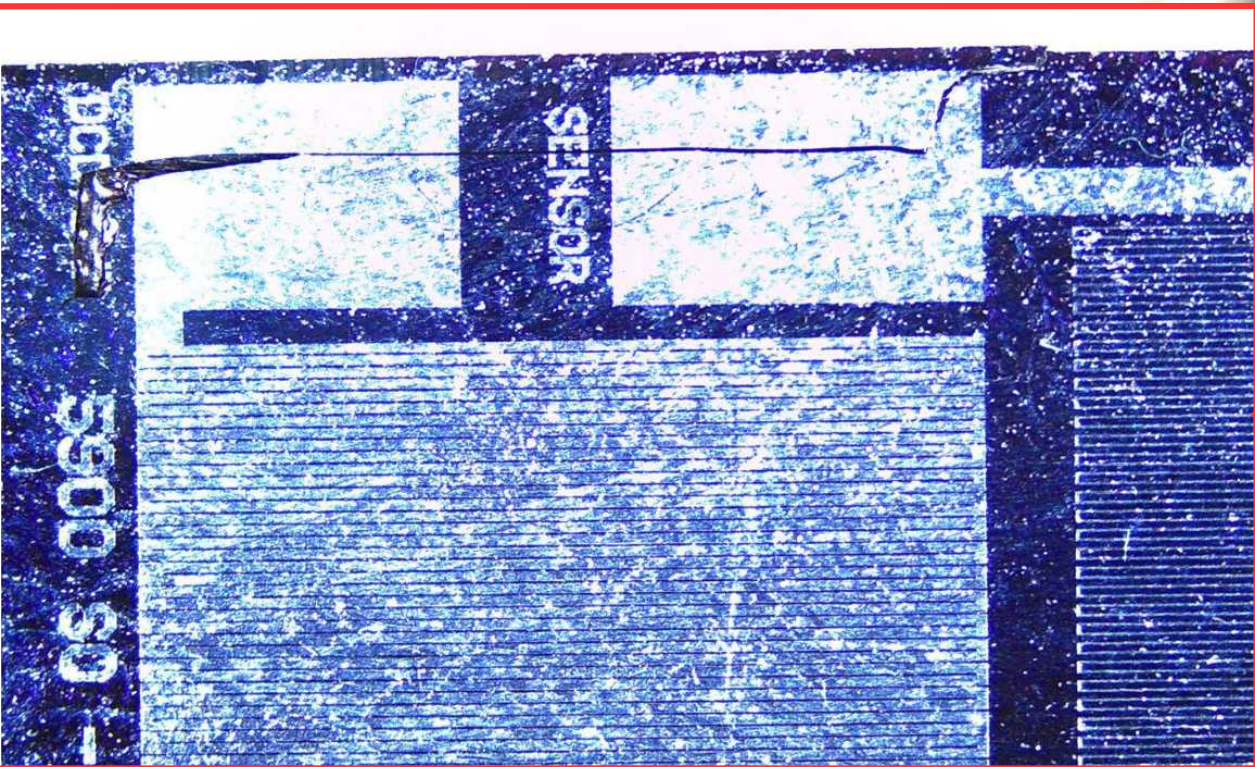
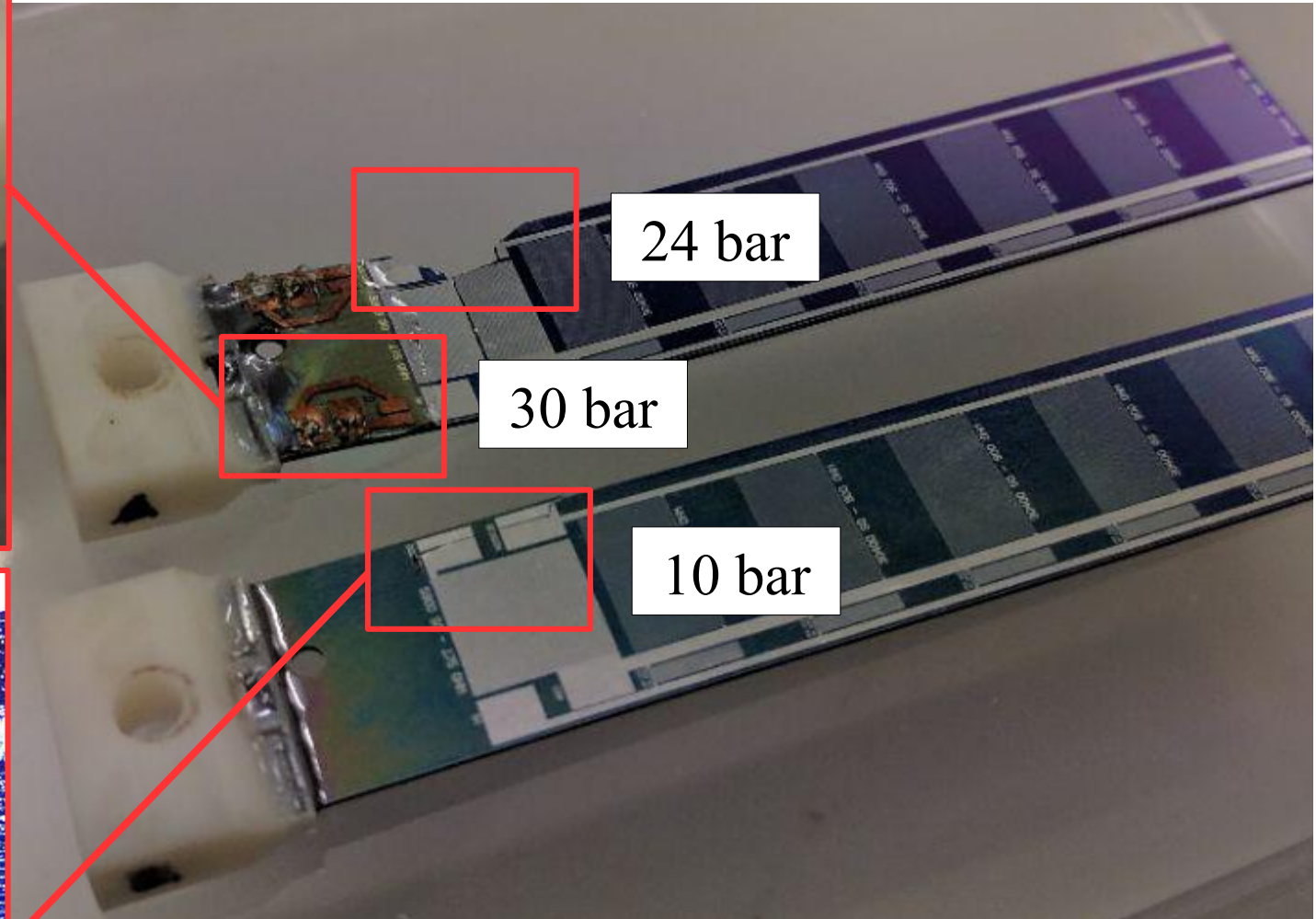
MCC optimization: pressure test



TESTS DONE AT CERN:
THANKS A. MAPELLI

50 bar achieved

MCC optimization: pressure test



MCC optimization

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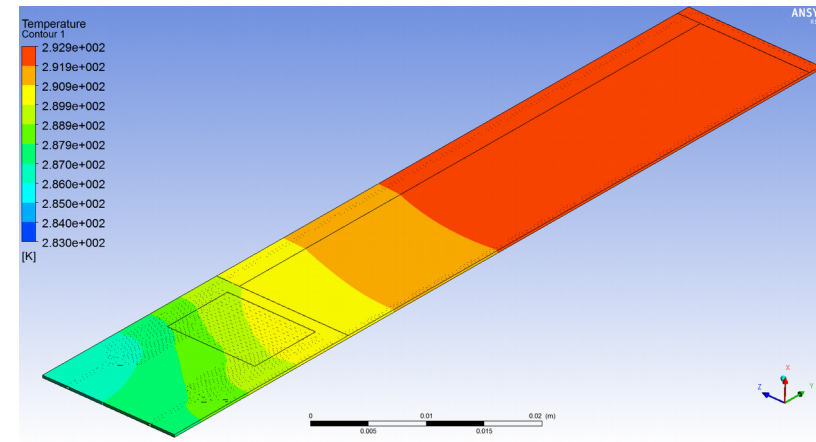
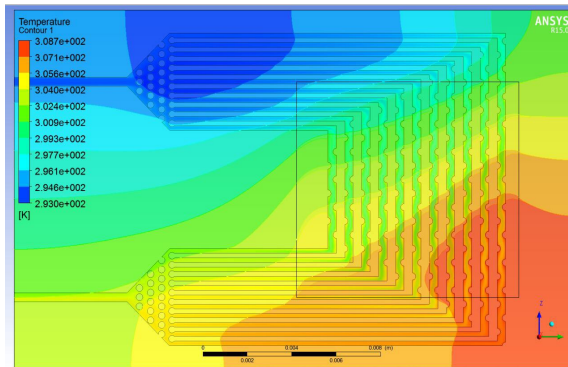
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Unknown pressure resistance of 3D printed material and silicon microchannels	Pressure testing samples
Thermal gradient in sensor area and no cooling in switchers and sensor region	

MCC optimization

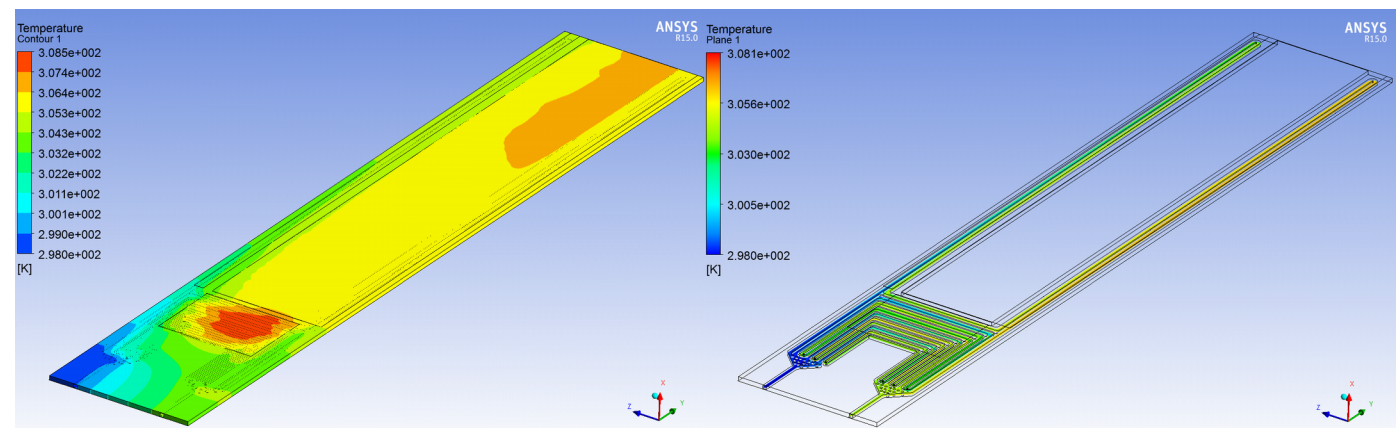
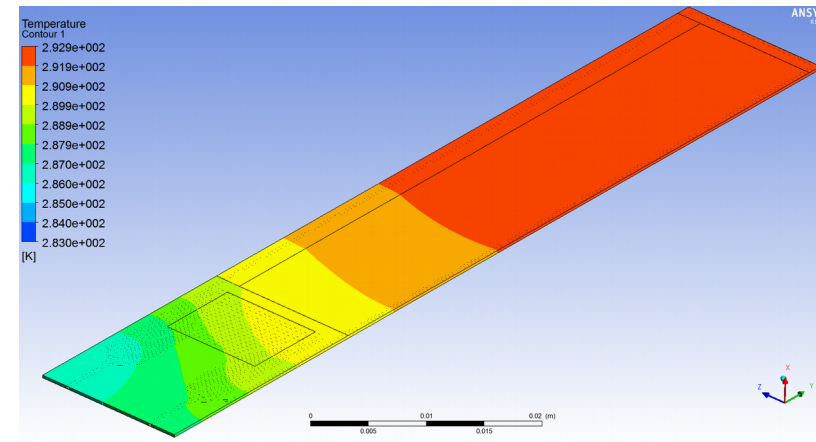
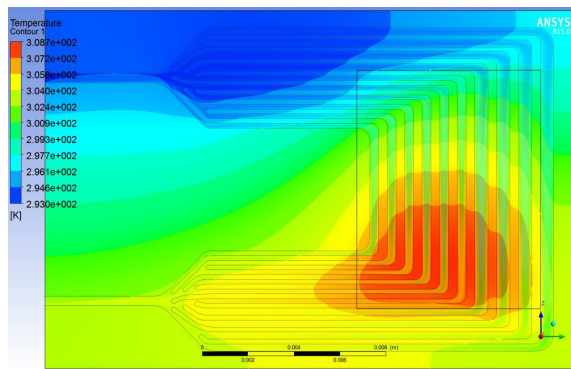
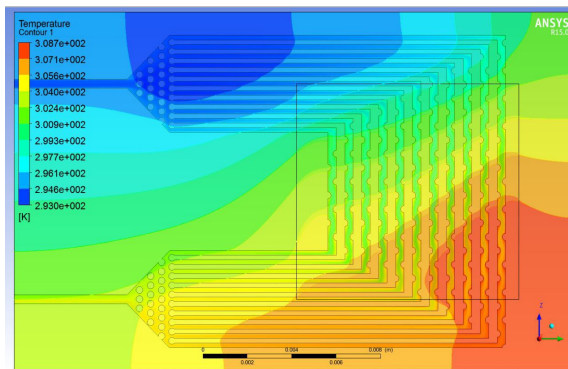
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Thermal gradient in sensor area and no cooling in switchers and sensor region	Microchannel new layout

MCC optimization: new channels layout



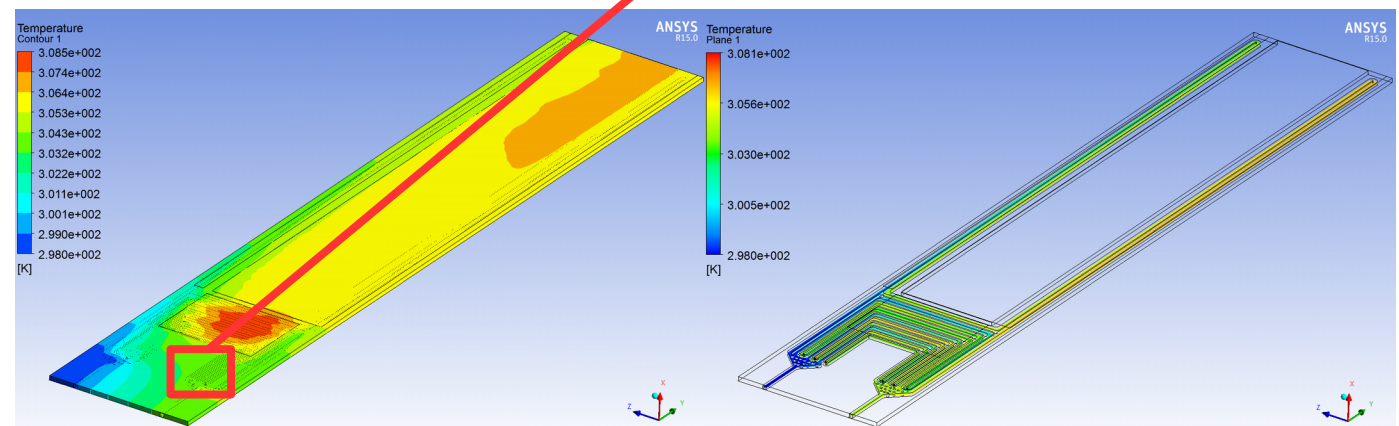
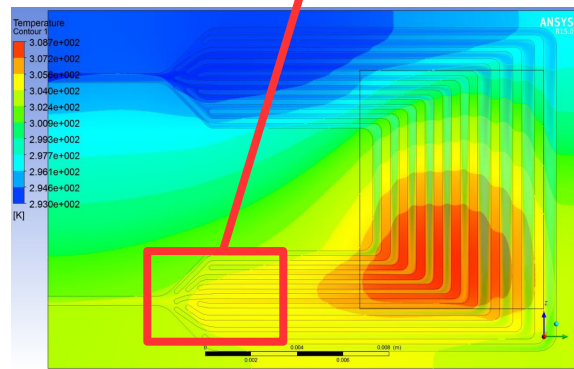
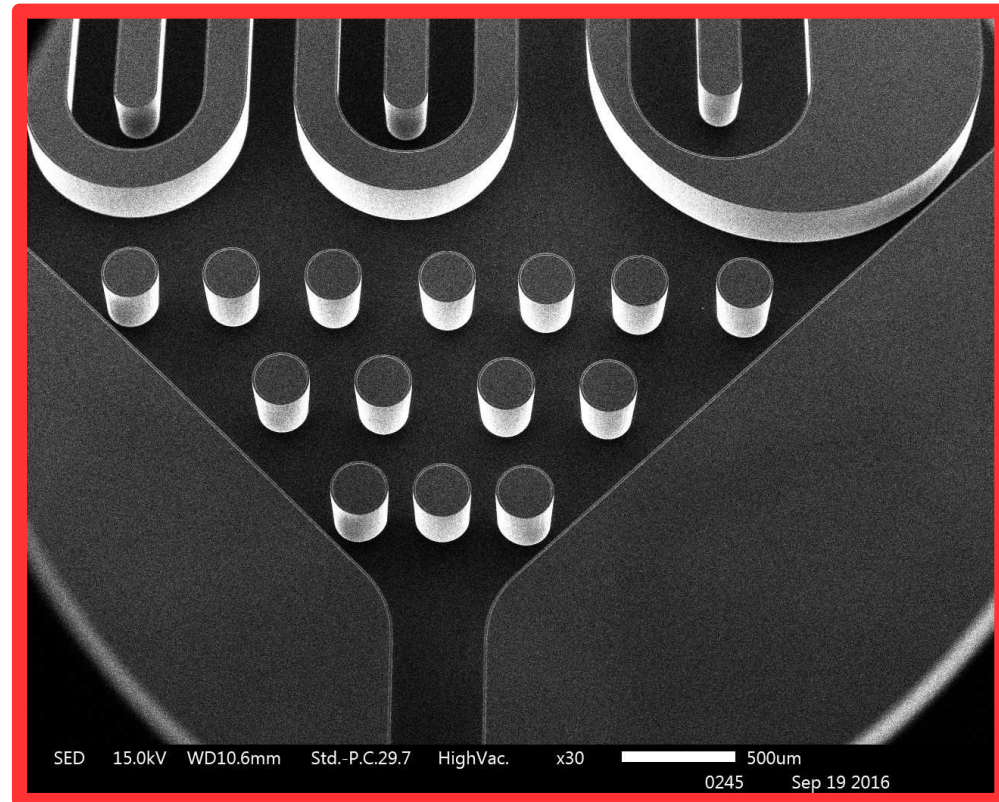
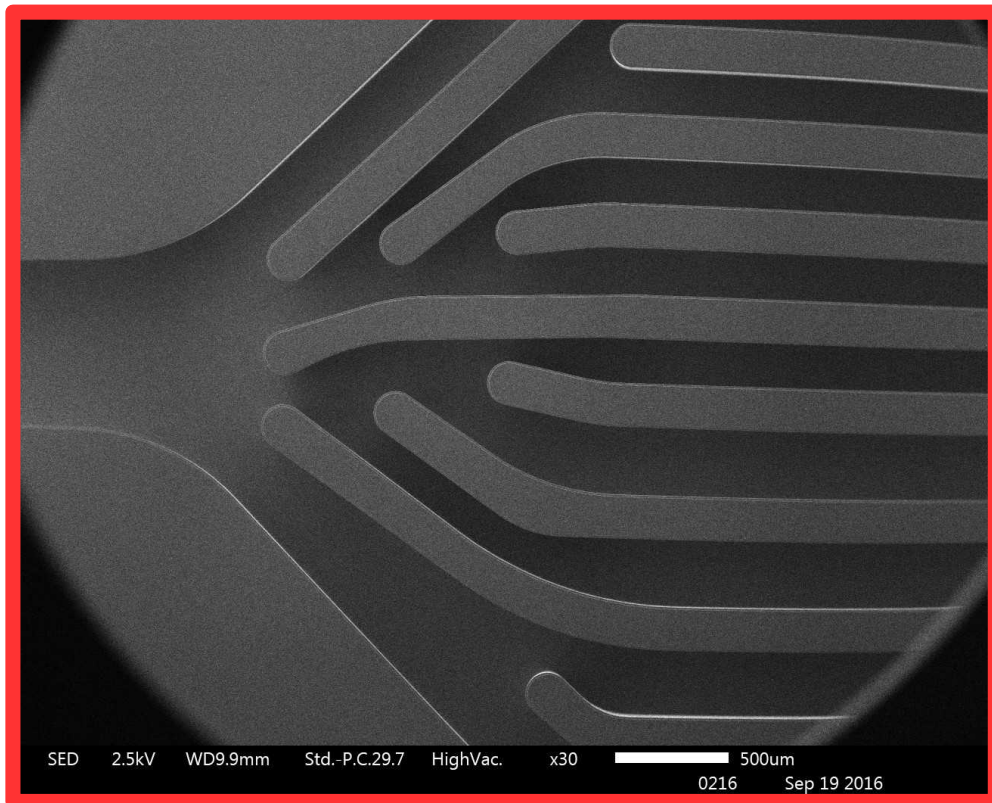
MCC optimization: new channels layout



New mcc layout have been manufactured:

- Optimized layout for mcc: simulations predict better performance
- Mcc along all the heat sources

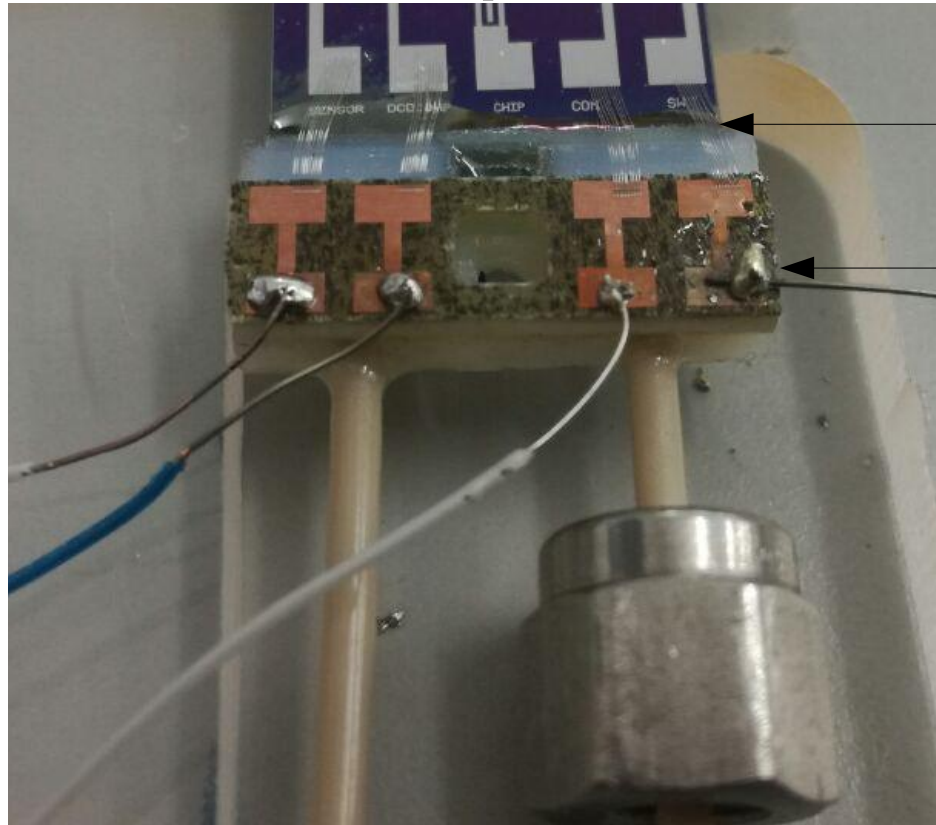
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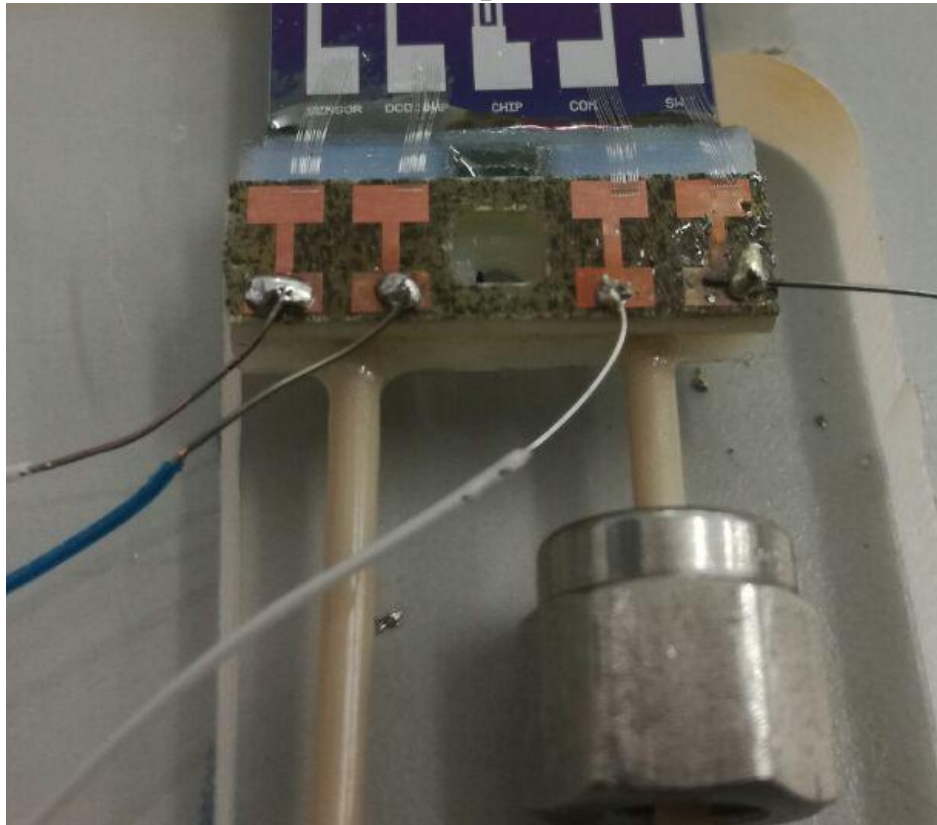
MCC optimization: new channels layout



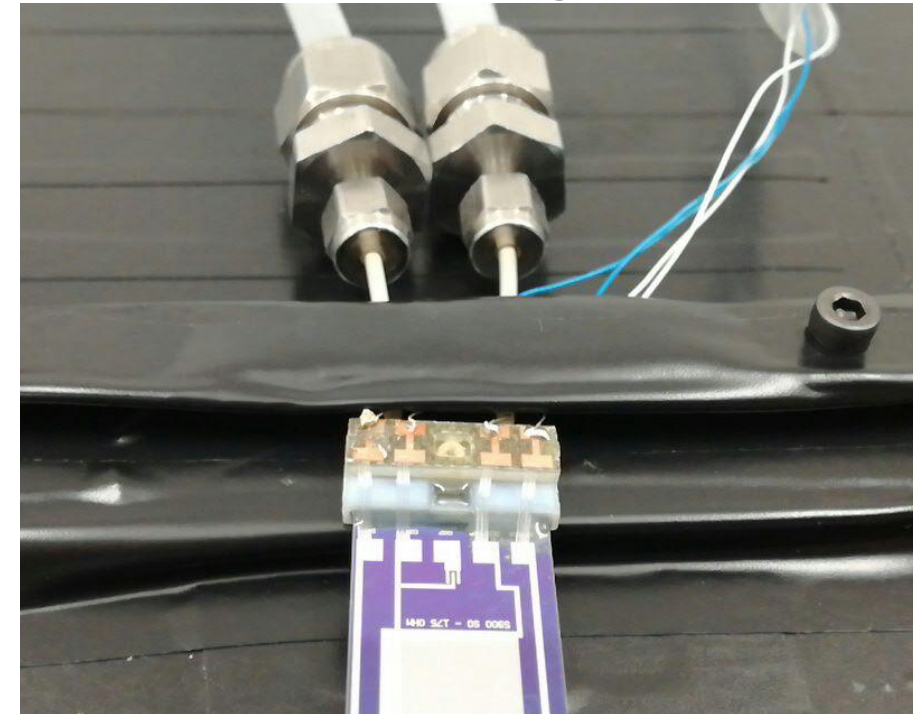
Wirebonding

Cable welding

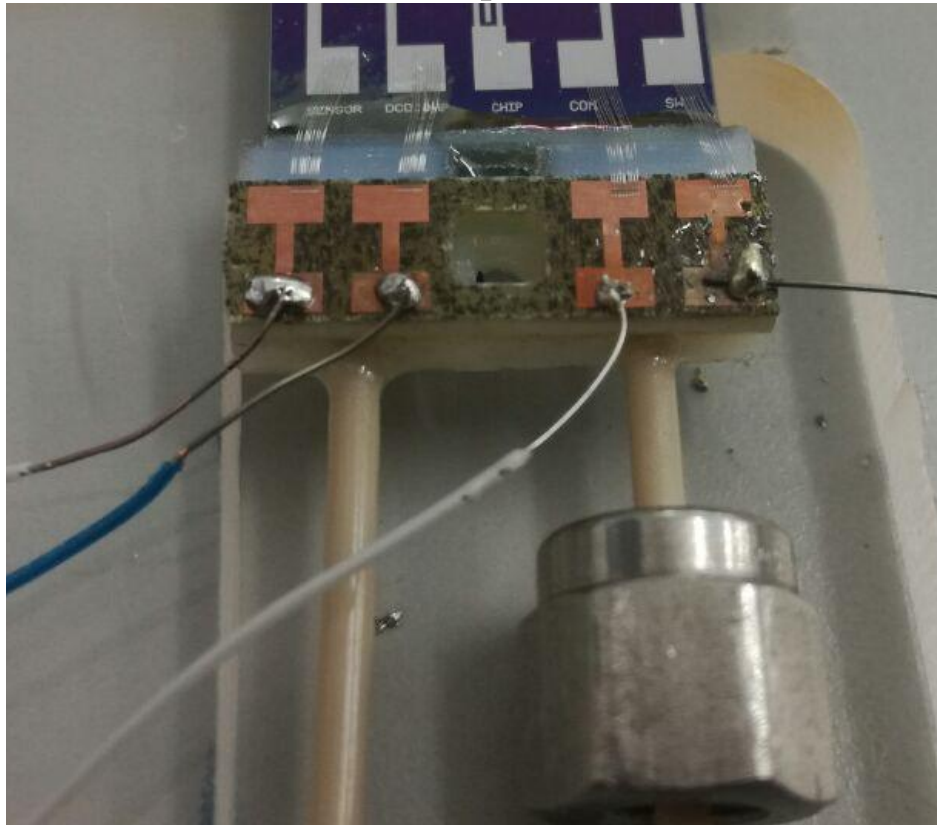
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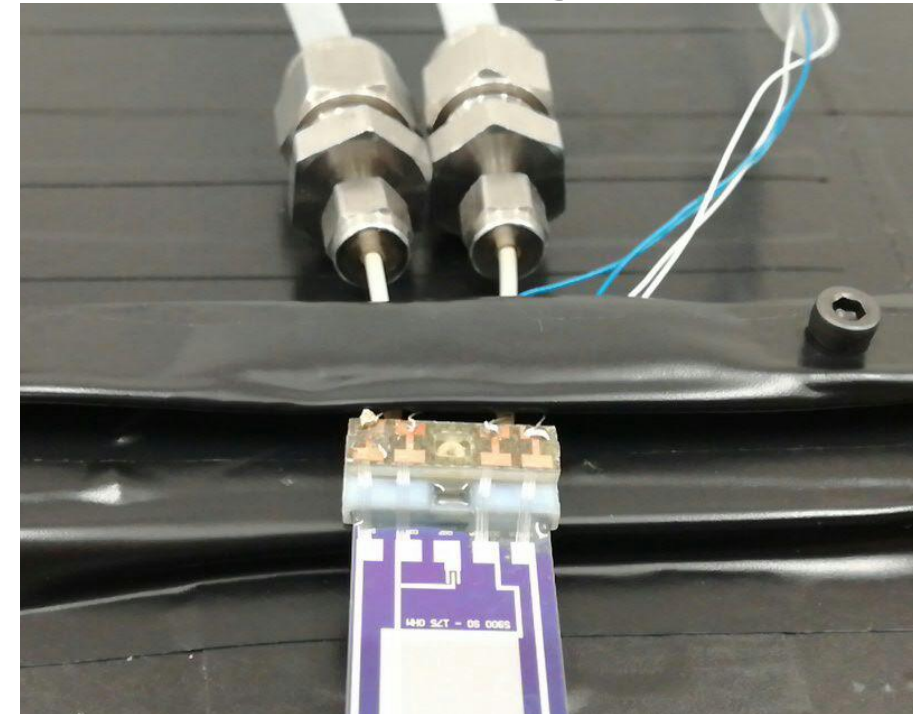
Tubes fittings



MCC optimization: new channels layout



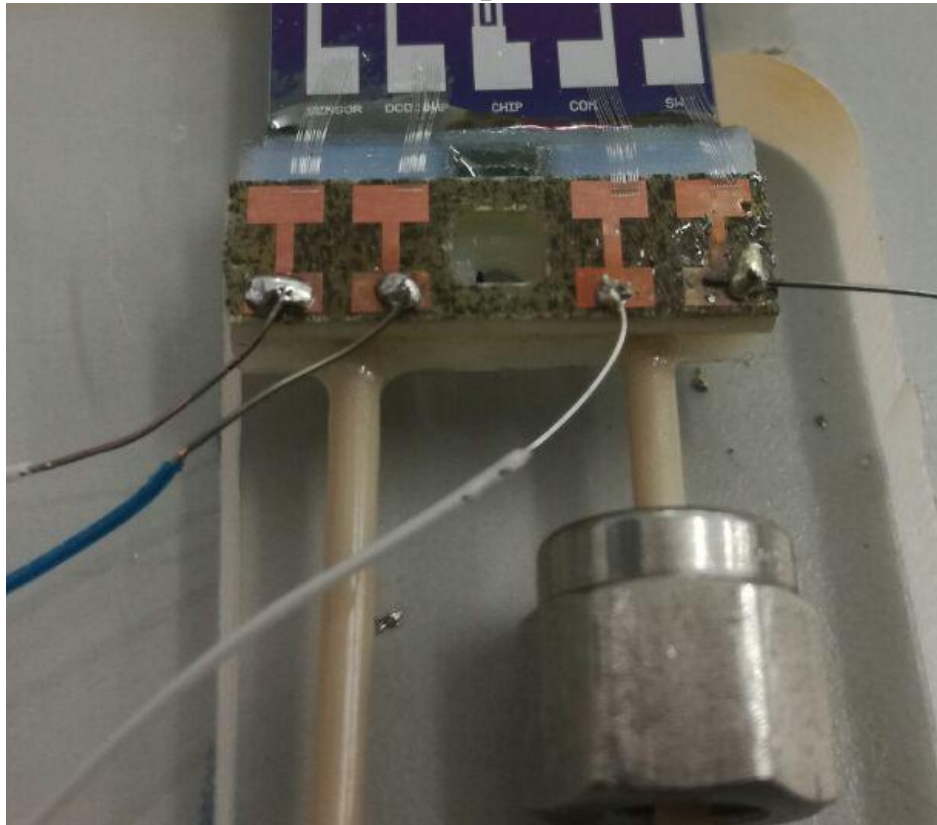
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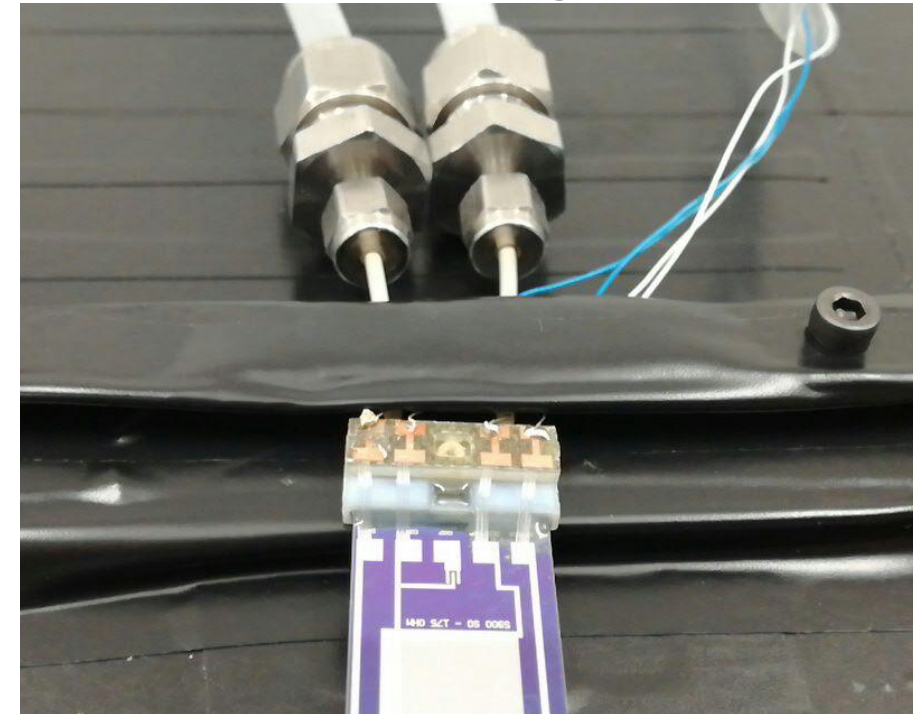
Power
Connexion



MCC optimization: new channels layout



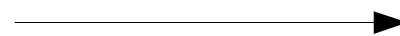
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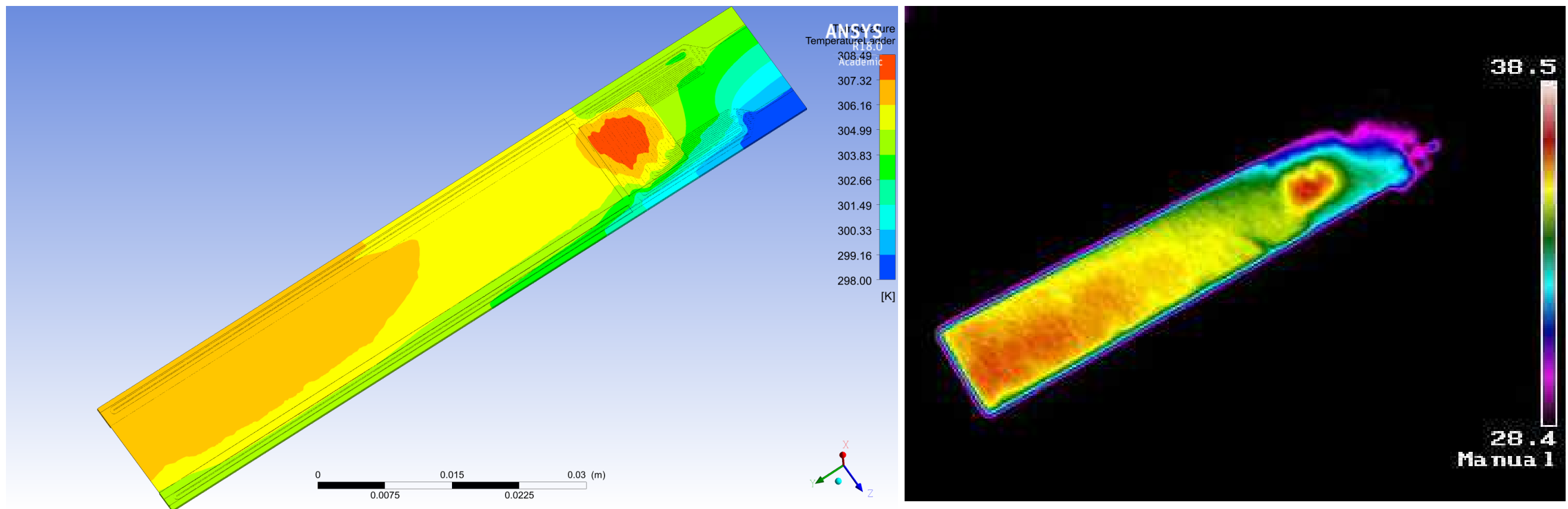
Power
Connexion



Black box

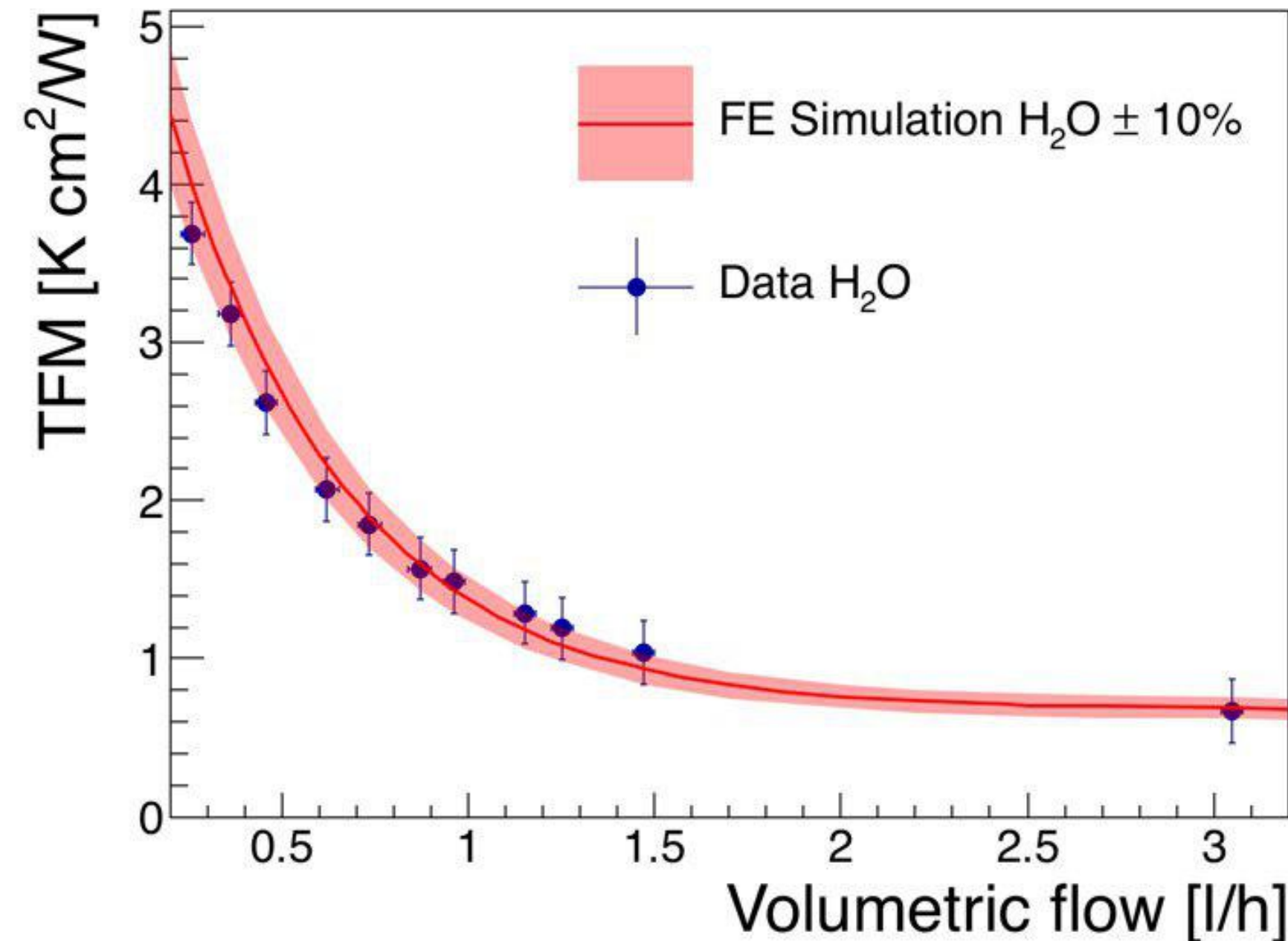
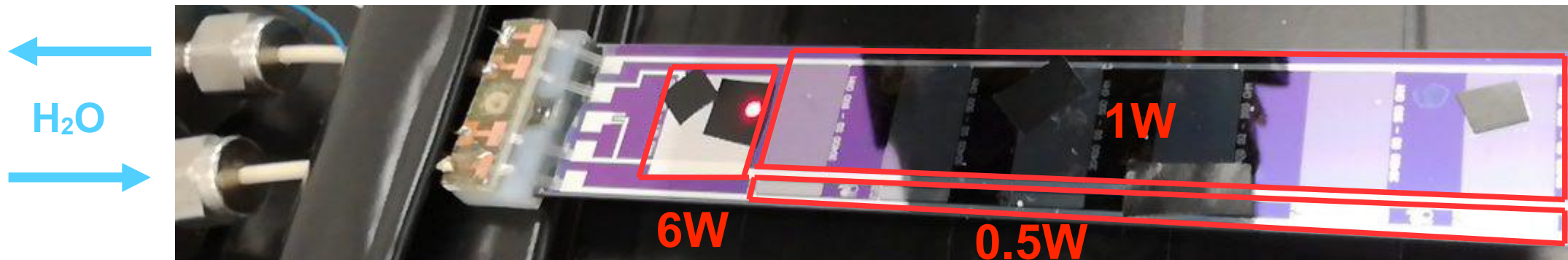


MCC optimization: new channels layout



- Inlet in the simulation is the outlet in the test
- Thermal camera inside black box
- Simulation $\Delta T=10,5K$ and test $\Delta T=10,1K$

MCC optimization: new channels layout



Test accuracy:

- Vol. Flow: +/- 0.04 l/h
- Temperature: +/- 1K
- Power: +/- 1% W

Simulation accuracy:

- No radiation
- Infrarated HTC
- Positioning of the measuring point

Mcc dummy cooled non-stop for 2 days with no leaks and no clogging

Good agreement with FE simulation within 10% error

In low Vol. Flow, tests are very sensitive to the Vol. Flow error

In high Vol. Flow, test are very sensirive to the Temp. error

(still) Future work

- More accurate measurements (those are very preliminary)
- Other fluids
- Test bumpbondigs chips
- Test active sensors
- Flex cable for powering
- Optimize amount of glue
- Are irradiated material results acceptable??

Summary

- Microchannels new layout designed, manufactured and working as expected
- Gluing repeatability obtained by hacking a 3D printer machine
- Optimization (material budget, integration) and validation (pressure, radiation hardness) of the 3D printed connector done
- In plane mcc connexion is possible maintaining low material budget
- 3D gluing machine vacuum tests under 10^{-8} mbar l/s
- Pressure test done in 3D printed material for connector and microchannels