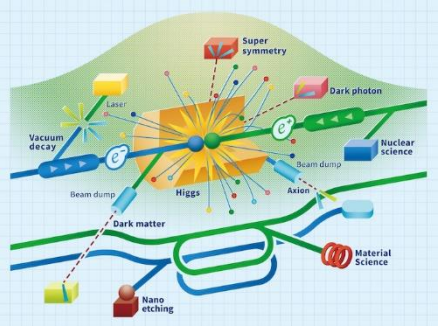
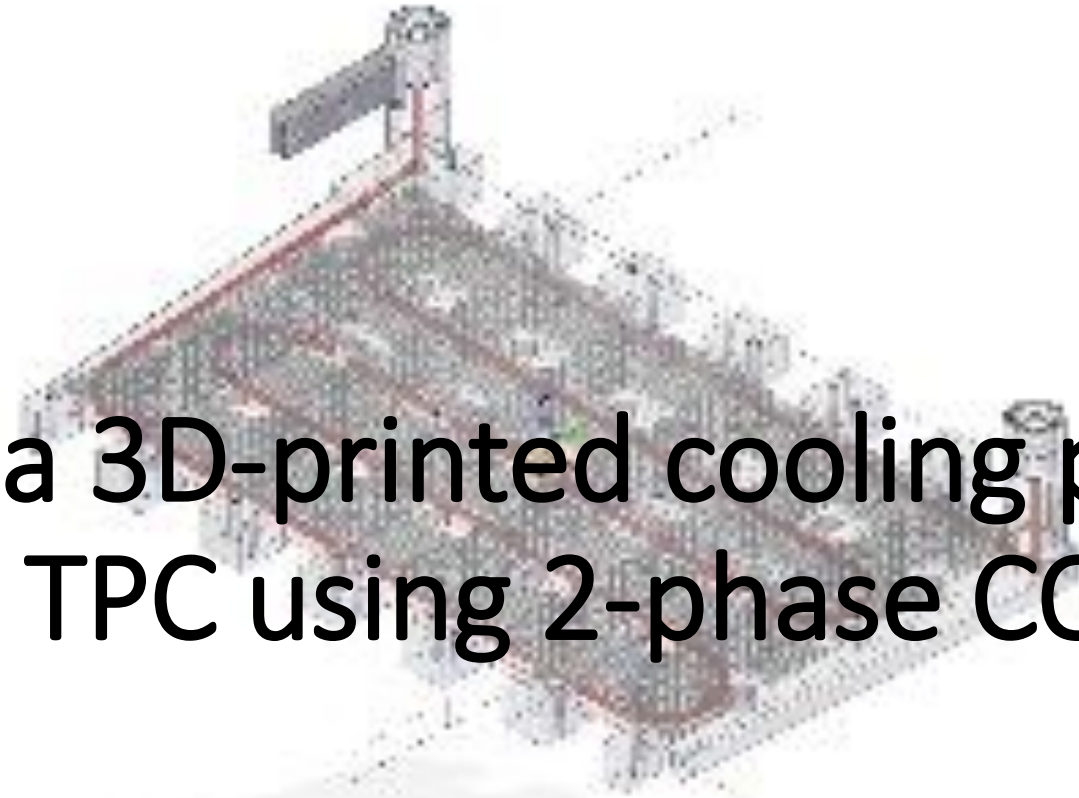


ILCX2021 ILC Workshop on Potential Experiments



Test of a 3D-printed cooling plate for a TPC using 2-phase CO2

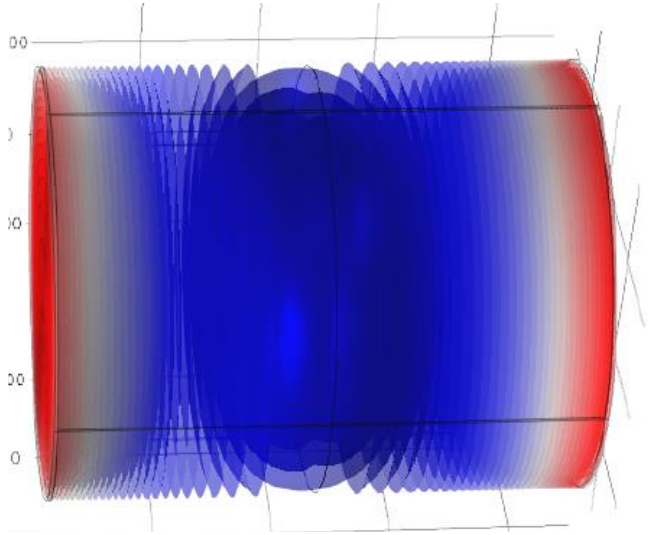
David ATTIE, Paul Colas, Ralf Diener, Serguei Ganjour, Oliver Schaefer, Olivier Tellier

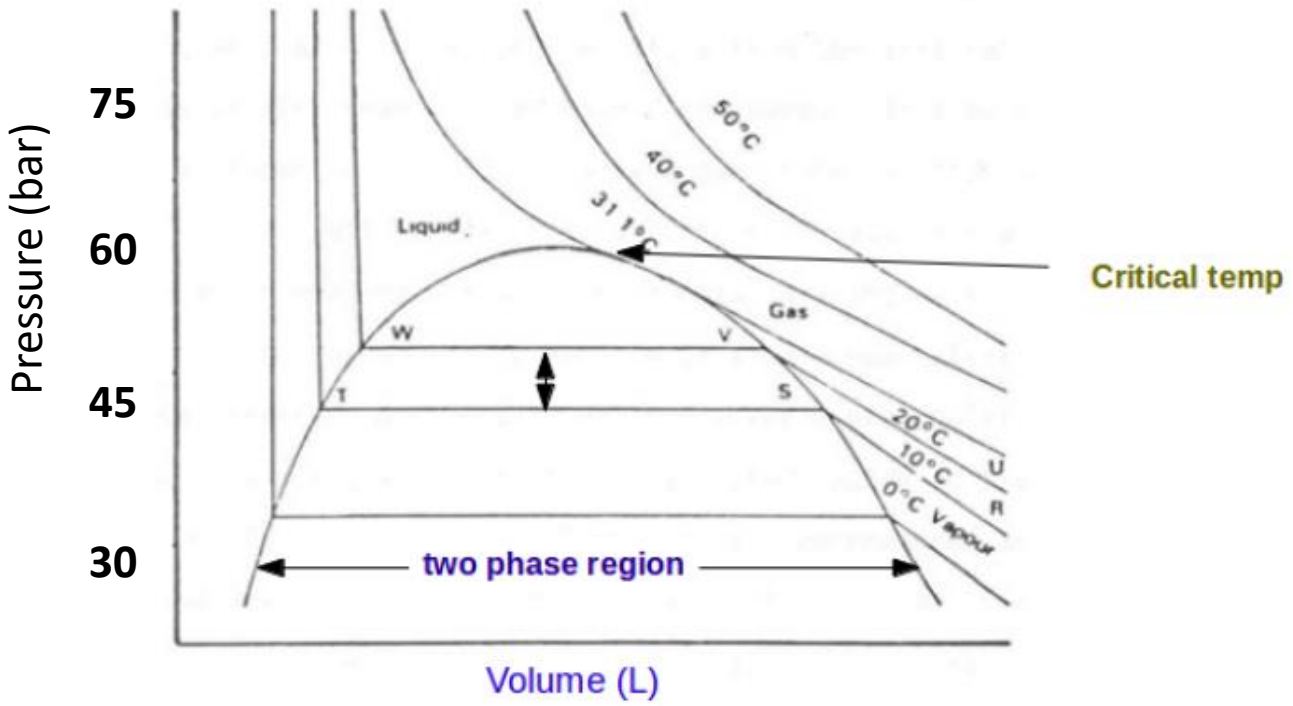
Université Paris Saclay and DESY

TPC cooling

- TPC endcap needs cooling (6kW per endcap in the pad design, an order of magnitude more in the pixel option, both could be mitigated by power switching).
- This must be done in a very uniform way
- To avoid temperature gradients in the gas, the cooling must be done at room temperature. This also avoids condensation.
- A known way to remove efficiently heat at room temperature is to use 2-phase CO2 at high pressure.
- Other advantages are : low viscosity of CO2, not risk of water leak,…
- At 60 bar the temperature is about 20°C, at 15 bar it is -20°C (used for Si detectors)

Simulation without cooling 72°C to 32°C

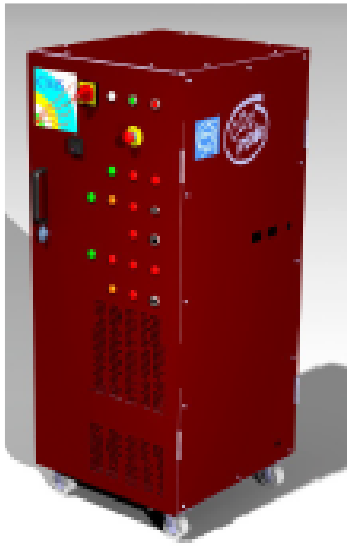




2 phase CO2 cooling : TRACI

Transportable Refrigeration Apparatus for CO2 Investigation (TRACI)

Designed by a Nikhef-CERN collaboration (Bart Verlaat, T. Szwarc, L. Zwalinski,…)
1 unit purchased by KEK and installed at DESY



Refrigerent power ~300 W
1 kg of CO2
Nominal flow rate 2.5 g/s

Measurement and simulation of two-phase CO_2 cooling in Micromegas modules for Large Prototype TPC

Deb Sankar Bhattacharya[a,b,c,*], David Attie[b], Paul Colas[b], Supratik Mukhopadhyay[a], Nayana Majumdar[a], Sudeb Bhattacharya[a], Sandip Sarkar[a] and Aparajita Bhattacharya[c]

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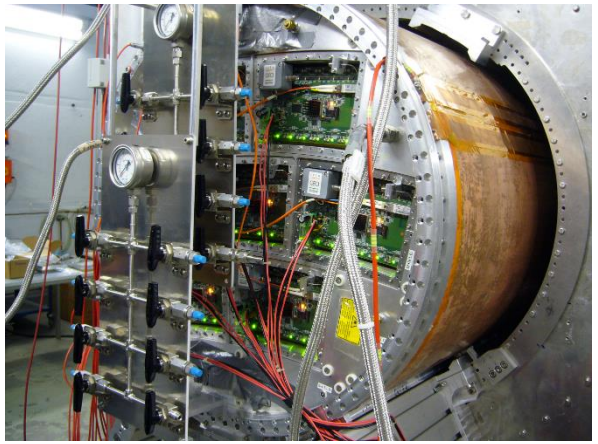
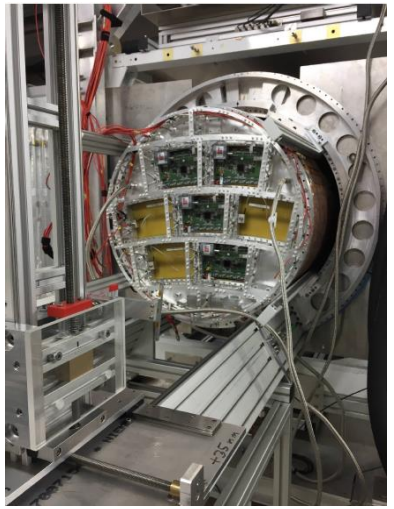
[b]DSM/IRFU/SPP, CEA, Saclay, 91191 GIF SUR YVETTE, France
[c]Department of Physics, Jadavpur University, Kolkata 700032, India.
E-mail: dsb.physics@gmail.com

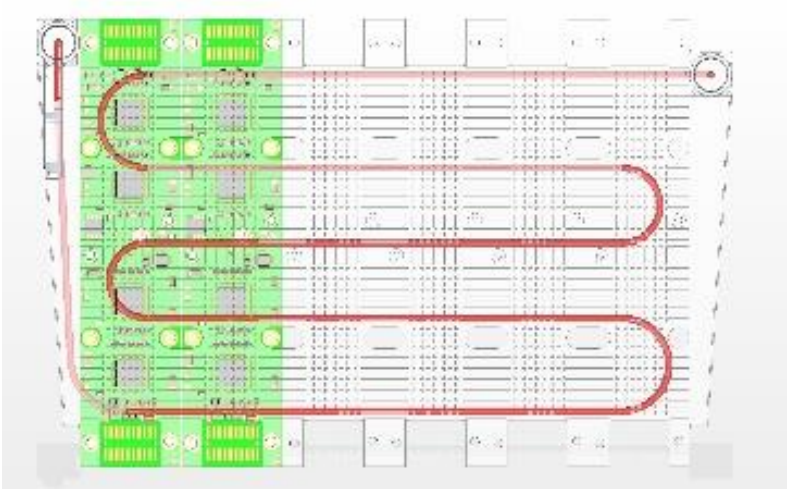


7-module Test in parallel in 2015 and 4-module test in one loop in 2018.



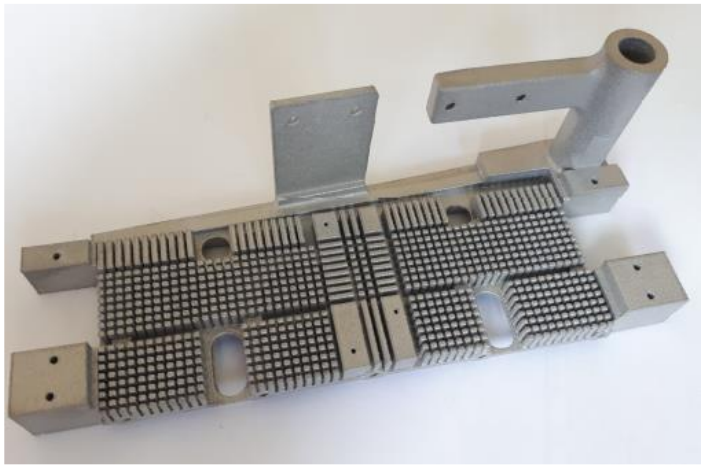
Implementation with a stainless-steel pipe (2013-2018)

Now integrated 3D-printed cooling plate in Aluminum (2019-2021)



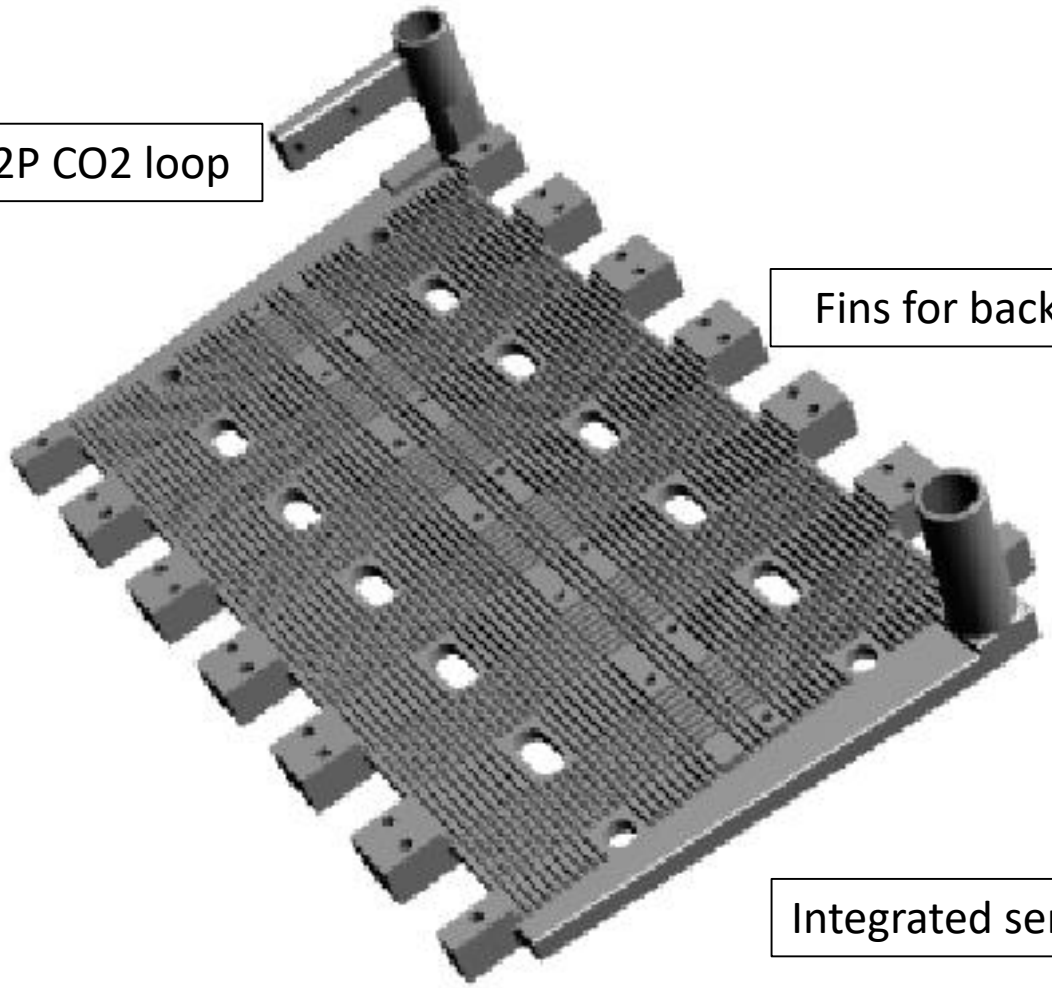
1/10 prototype
2019

Integrated serpentine
Drastic safety measures
for Al 3D printing
(flamable Al powder)



Monolithic cooling plate in 3D printing

Connectors to 2P CO2 loop



Fins for backup air-cooling

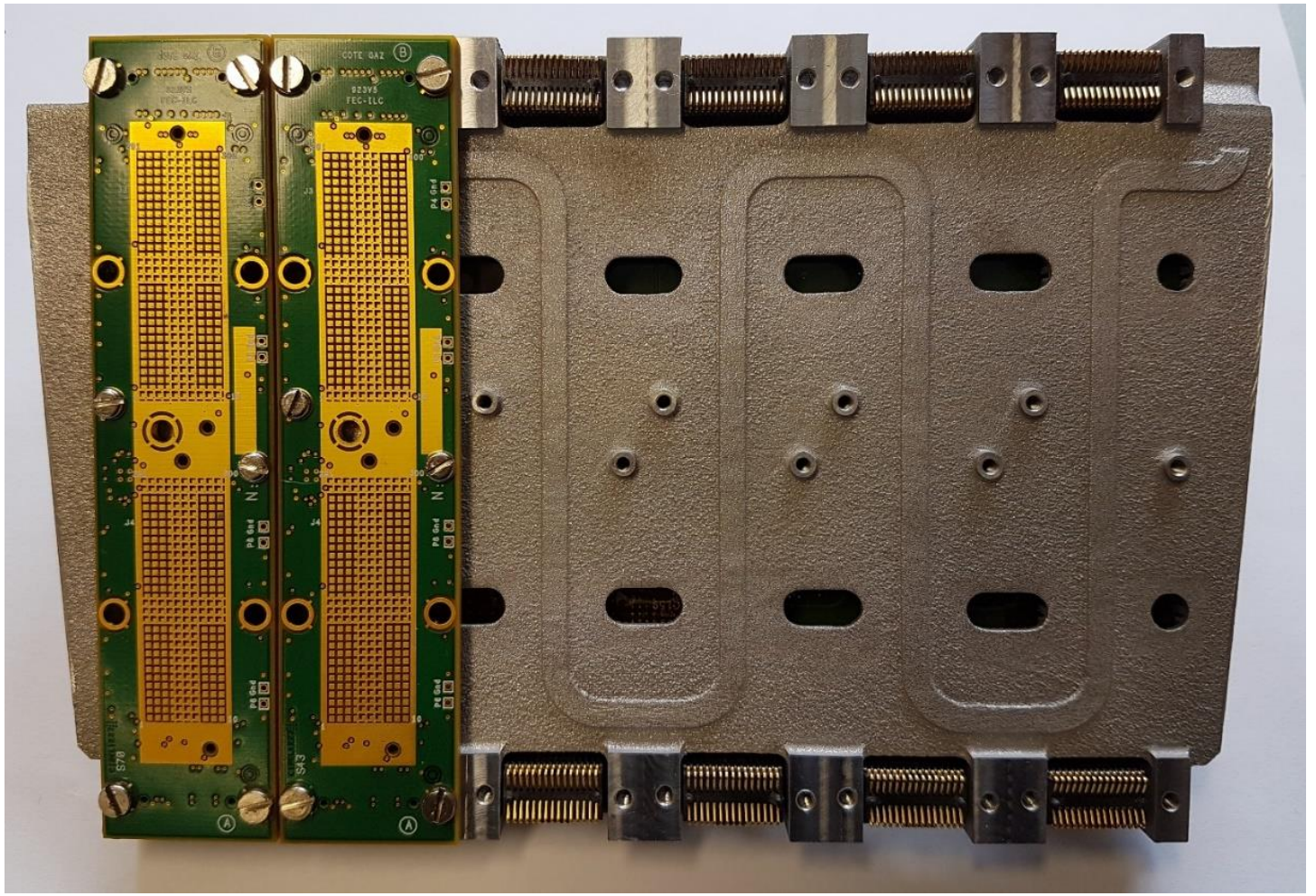
Integrated serpentine

Realized at Saclay within a R&D project on metallic additive manufacturing (COSTARD)
Tested at DESY in October 2021

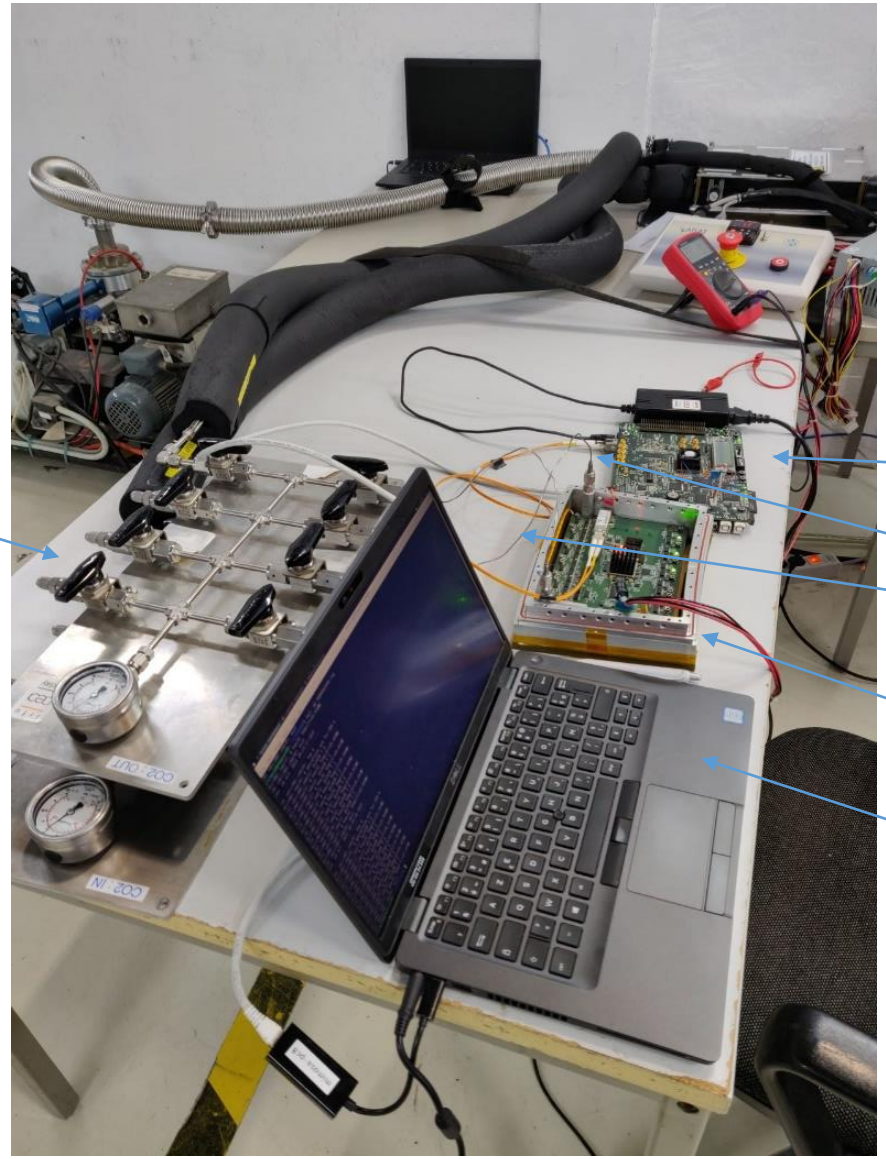
M. Riallot, O. Tellier, Y. Jan

Mounting test : Cooling plate equipped with 2 Front-End Electronic Cards out of 6

Each Front-End card and the mezzanine module card (which includes ADC, FPGA and voltage regulators) are monitored in temperature using probes.



Experimental setup



To and from TRACI

Manifold with manometers and valves

DAQ back-end

Capillaries for 2-phase CO2

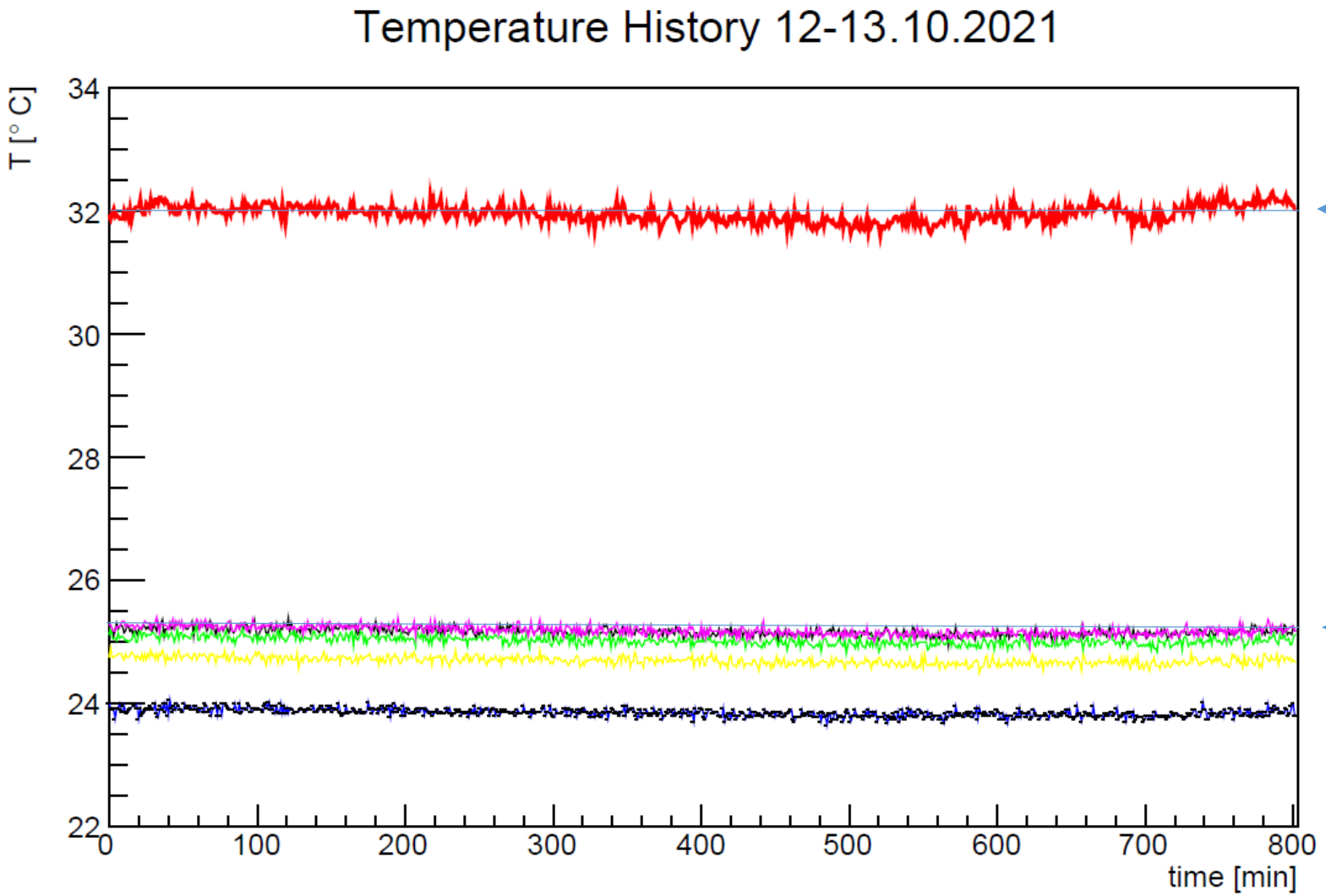
Integrated detector Module

DAQ laptop

Thanks to Frauke Polbotszki for her help with TRACI

Flow : 2.5 g/s

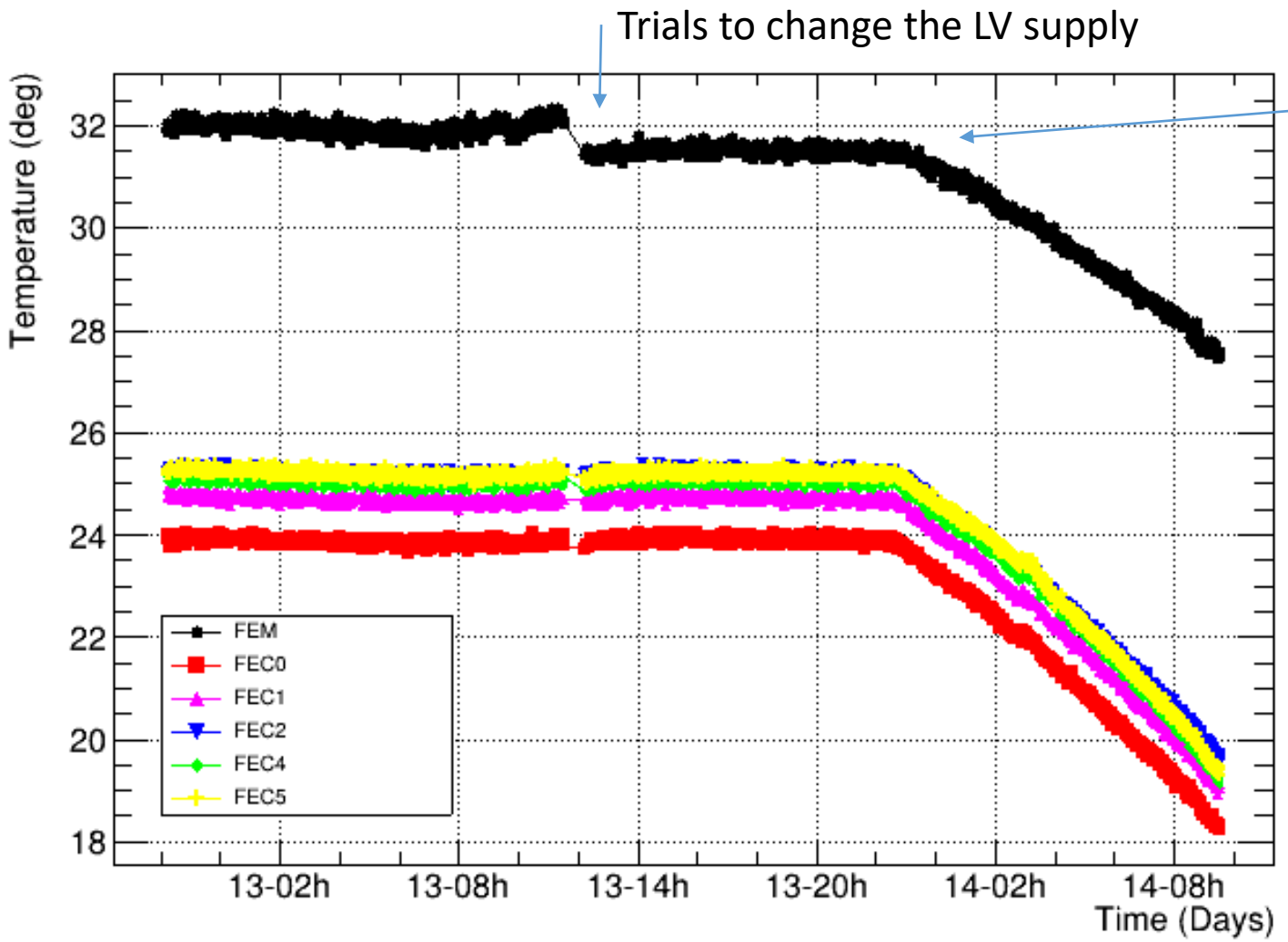
Temperatures were 50° before cooling and lowered to 25° with cooling



Mezzanine Stable within 0.2°C

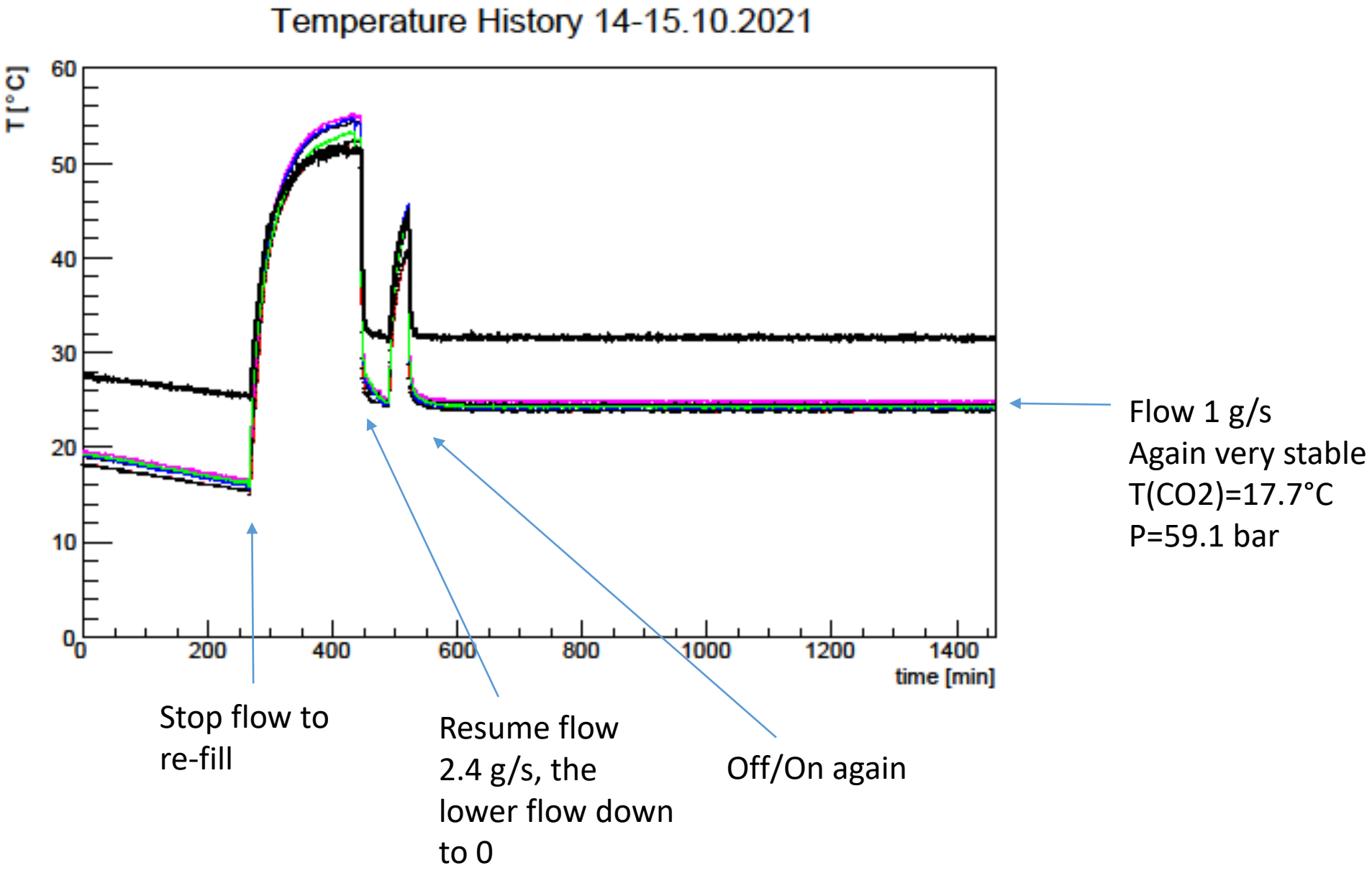
Front-end cards Stable within 0.1°C

Temperature stable during 25 hours



Temperature and pressure lowered by itself (probably due to a CO2 leak)

Re-fill in CO2


Temperature History 14-15.10.2021
T [°C]
60
50
40
30
20
10
0
0
200
400
600
800
1000
1200
1400
time [min]
Flow 1 g/s
Again very stable
T(CO2)=17.7°C
P=59.1 bar
Stop flow to re-fill
Resume flow 2.4 g/s, the lower flow down to 0
Off/On again

Implementation in ILD TPC

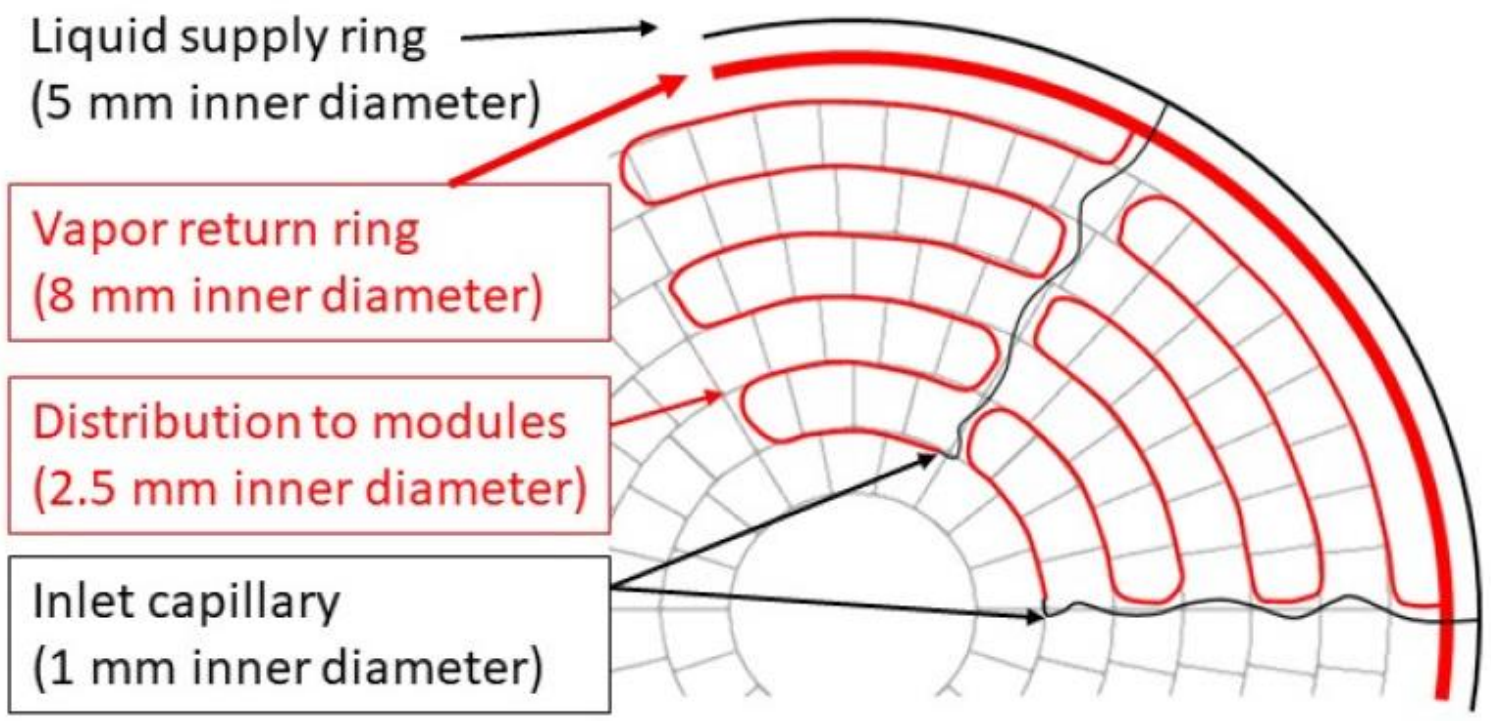


Figure 6.18. Sketch of a TPC cooling system with tube routing on the TPC end plate. Figure courtesy of Bart Verlaat, Nikhef.

With the Lukasz 2kW compressor, 3 units per endplate would be sufficient

CONCLUSIONS

- Successful test of a new 3D-printed cooling plate for CO_2
- Simpler than a pipe
- Efficient back-up air cooling

- Ready to provide the cooling for the common LCTPC module

- Next : try it with Lukasz, the next generation after TRACI, more powerful (2 kW) : can cool 80 modules of the present size : 3 Lukasz per endcap are enough.