Two phase CO2 cooling

for Micromegas Modules

Deb Sankar Bhattacharya

irfu
cea
saclay

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Overview :

- The electronics
- Large Prototype TPC for ILC
- Requirement for cooling and why CO_2 cooling
- How cooling is done
- Results of cooling
- Future plans

The AFTER electronics is applied for Micromegas readout

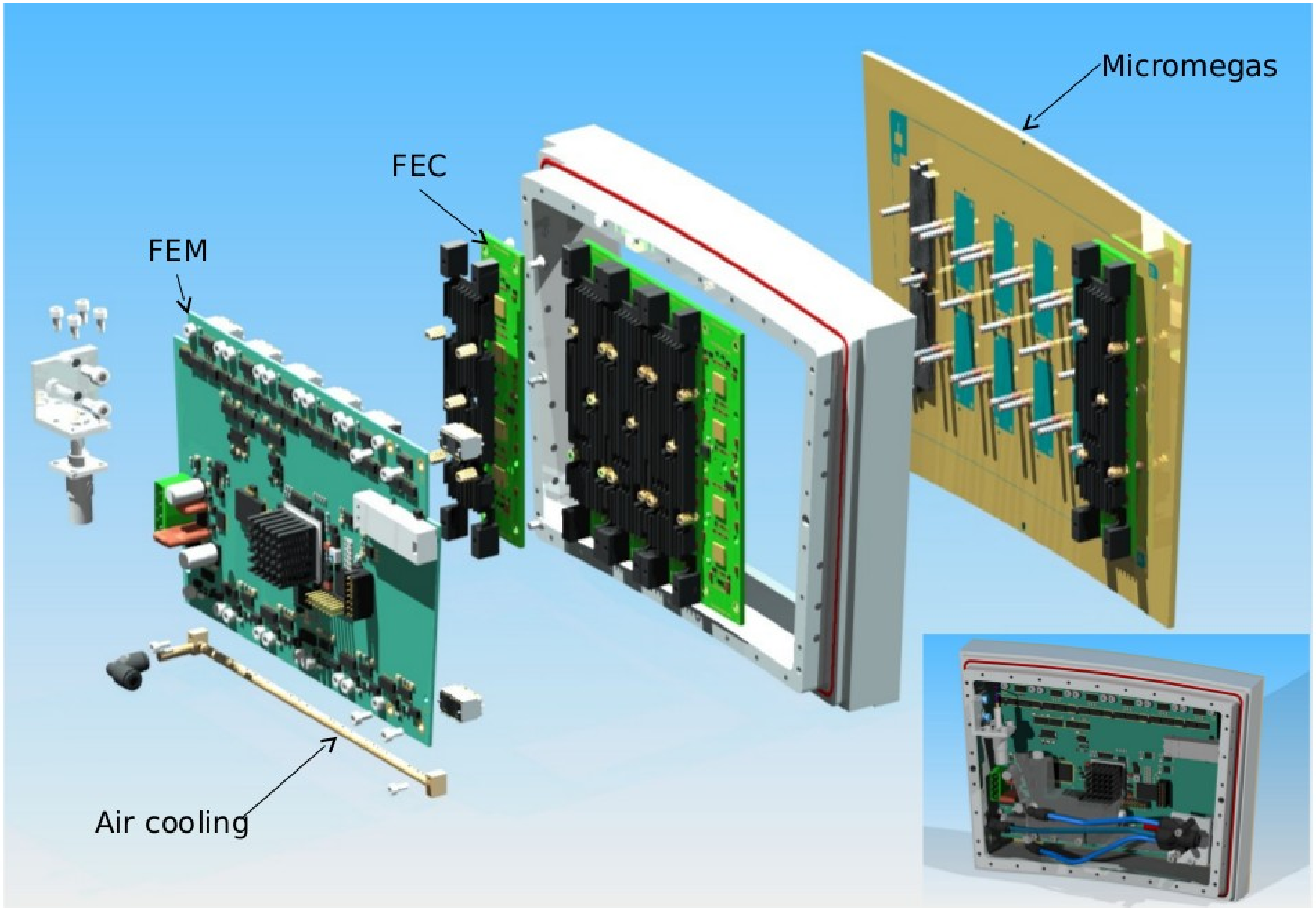
6 FECs, 1 FEM, 24 Chips, 1728 ch

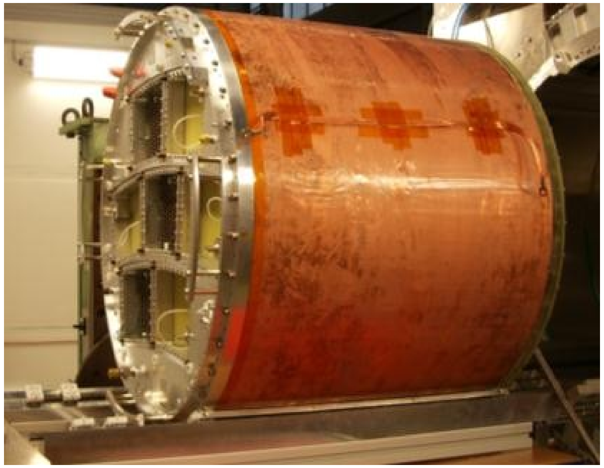
24 rows with 72 pads

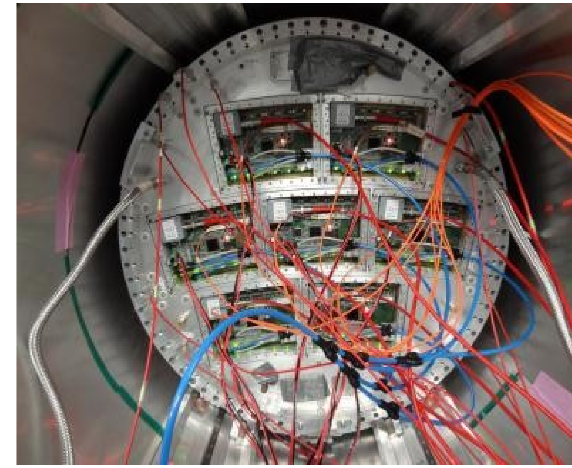
3/7 mm2 pad

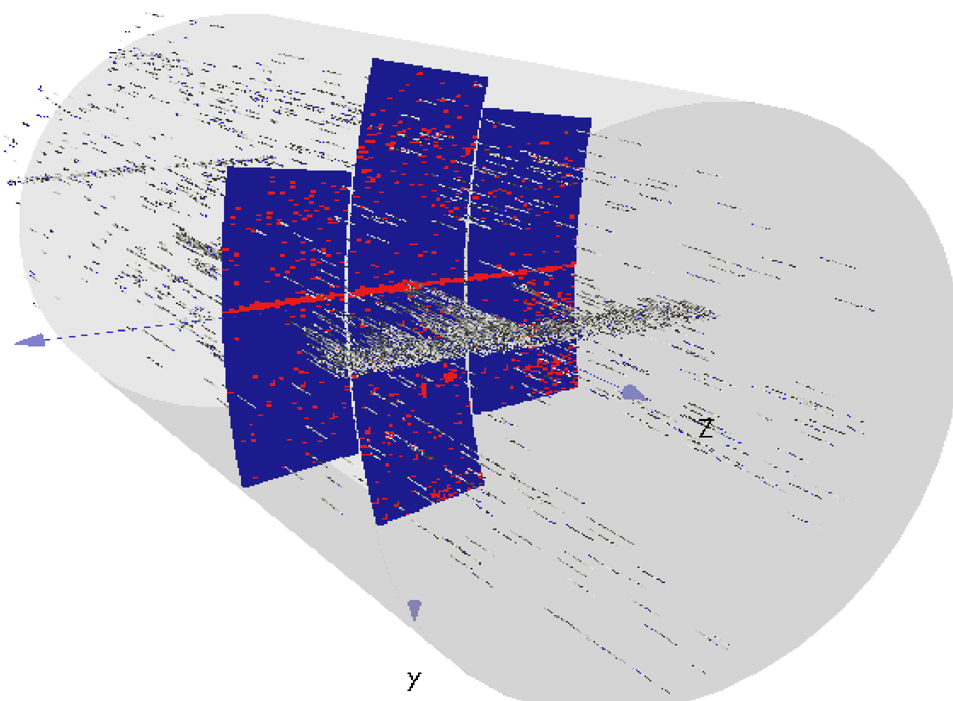
1728 pads per module

resistive foil to spread charge





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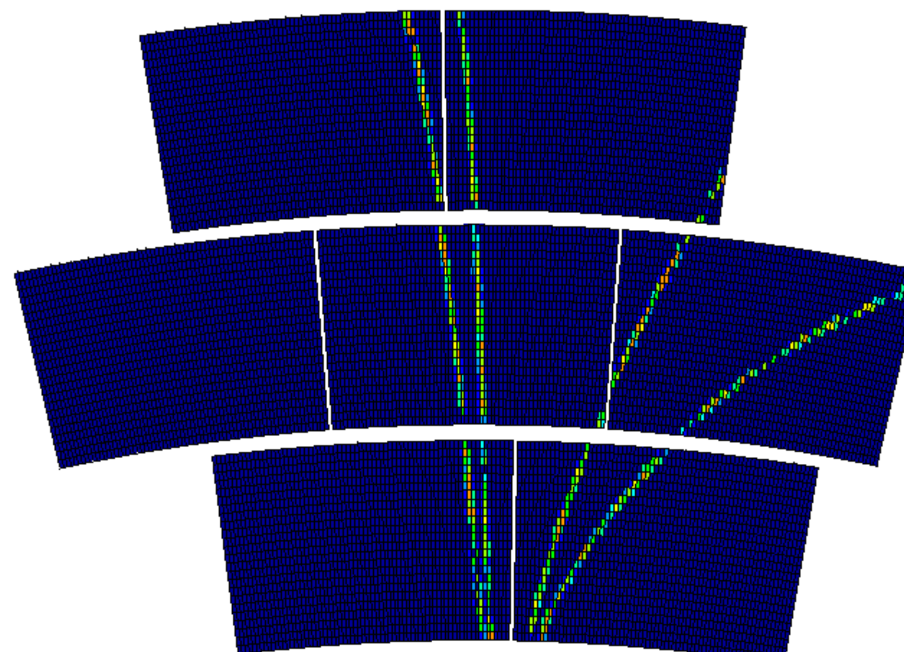


Requirement For Cooling

The electronics runs at 5 Volt and consumes power nearly 26 Watts

6 FECs	ASICs = 12 Watts Power Regulators = 7 Watts	19 Watts
FEM		3.5 Watts
FPGA		3.5 Watts
Total		**26 Watts**

Requirement For Cooling

This power consumption rises up temperature of the Module up to 60 degrees

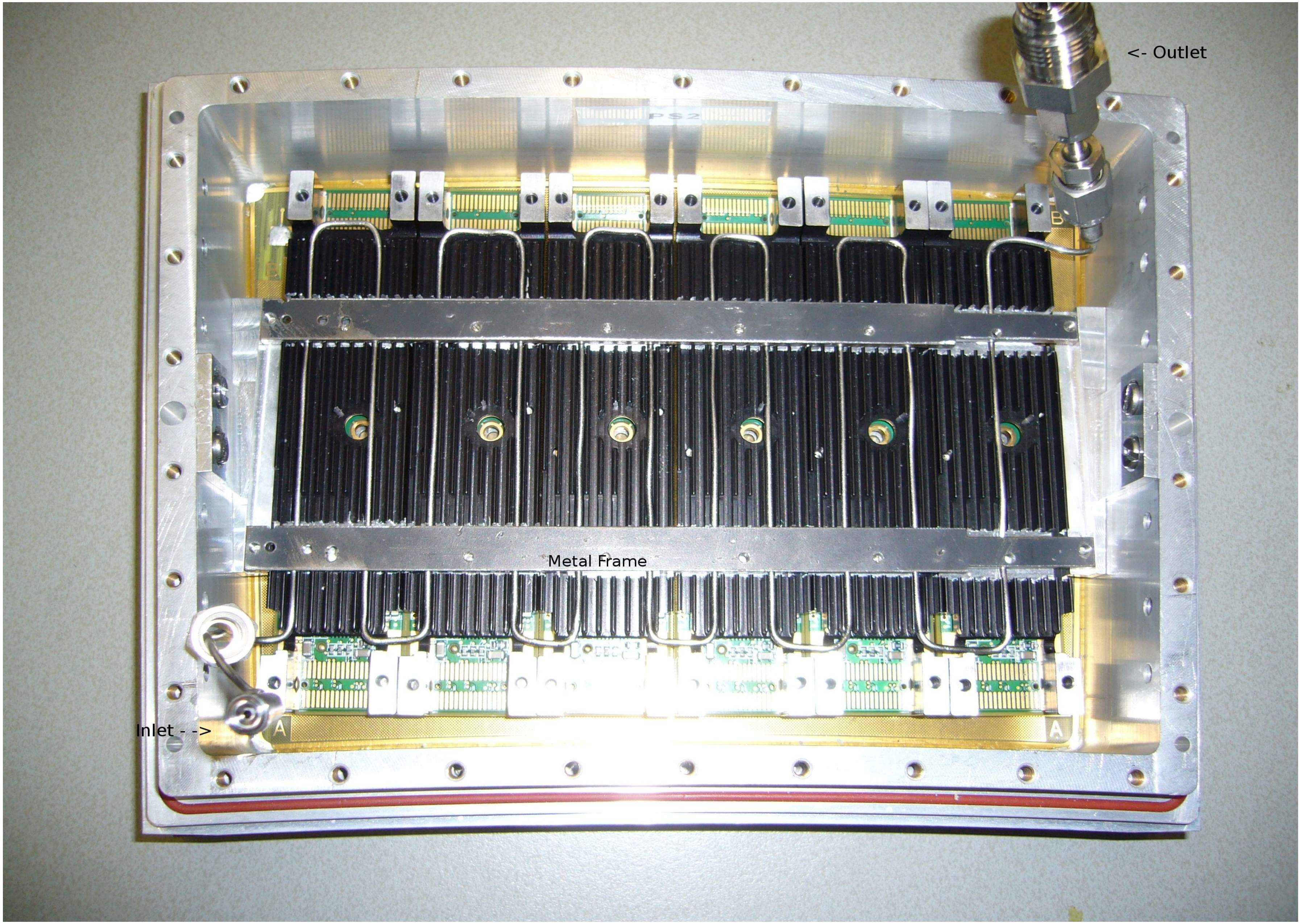
Growth of temperature results in:

- possibility of damage in electronics, if left running for hours without cooling
- heating up of pad plan

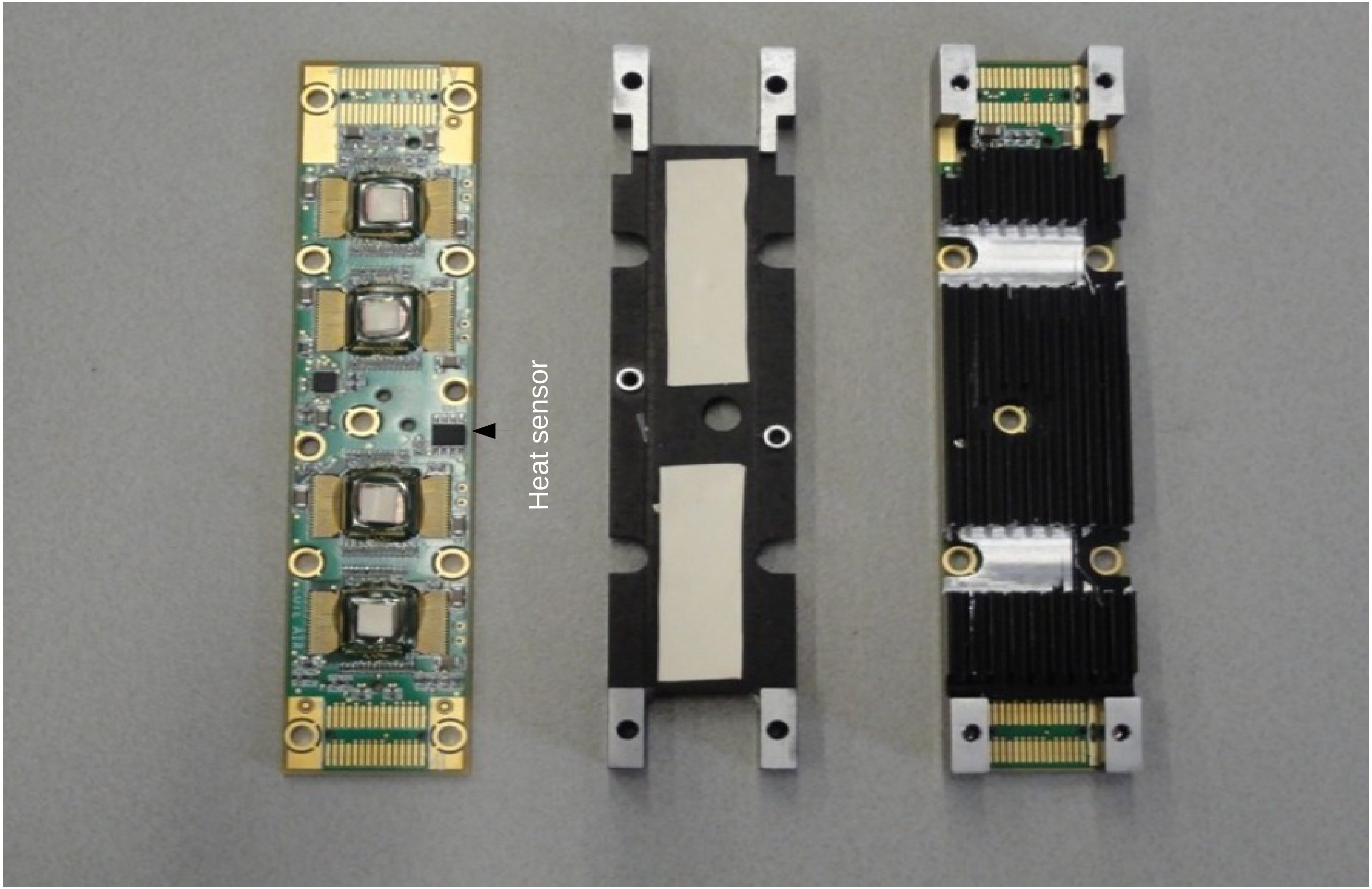
and hence convection current in TPC gas

Conclusion: 'proper cooling is necessary'

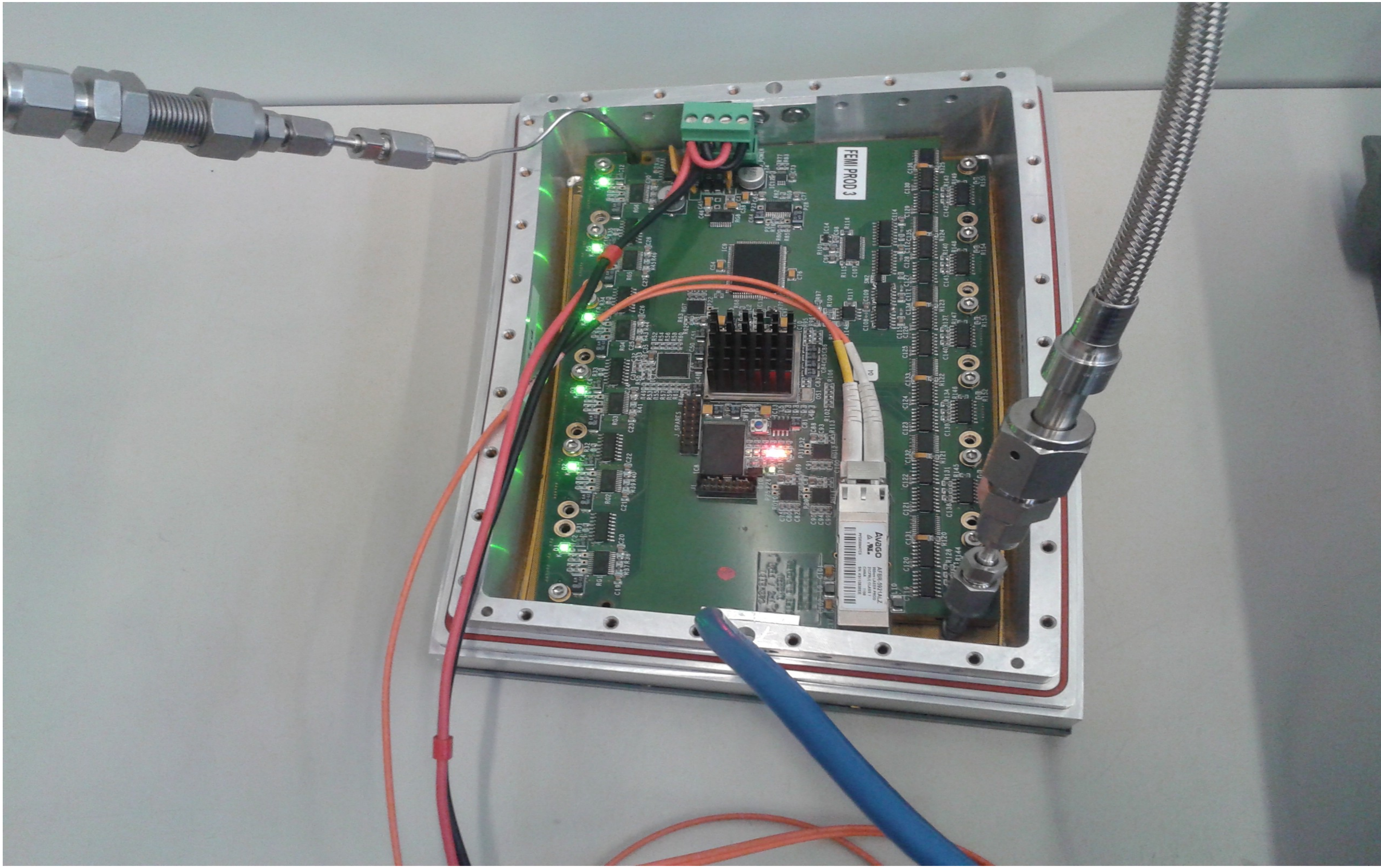
This Cooling circuit inserted inside the Module



FEC and the Radiator.   Each FEC contains one heat Sensor.



A test of the cooling circuit has been carried out at NIKHEF during 02/Dec/2013 to 04/Dec/13



The CO2 cooling system used at NIKHEF

At NIKHEF

Transportable Refrigeration Apparatus for CO_2 Investigation

or

'TRACI'

(Purchased by KEK)

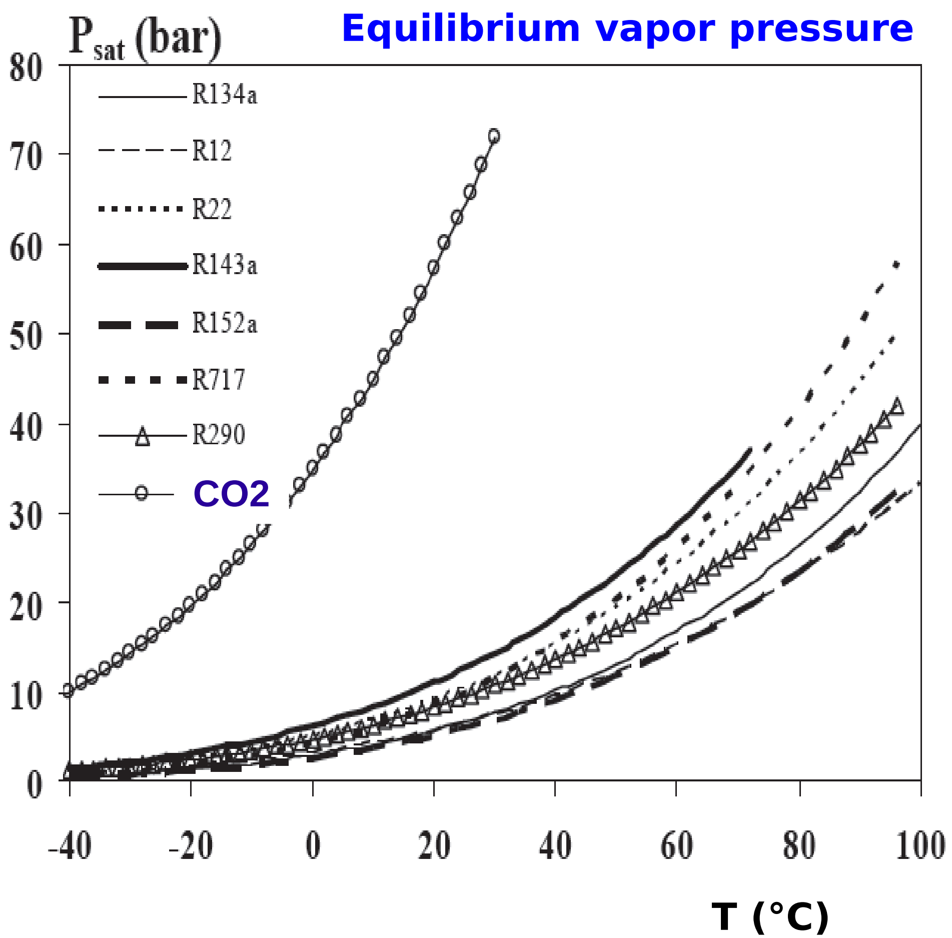
Can Circulate Liquid CO_2

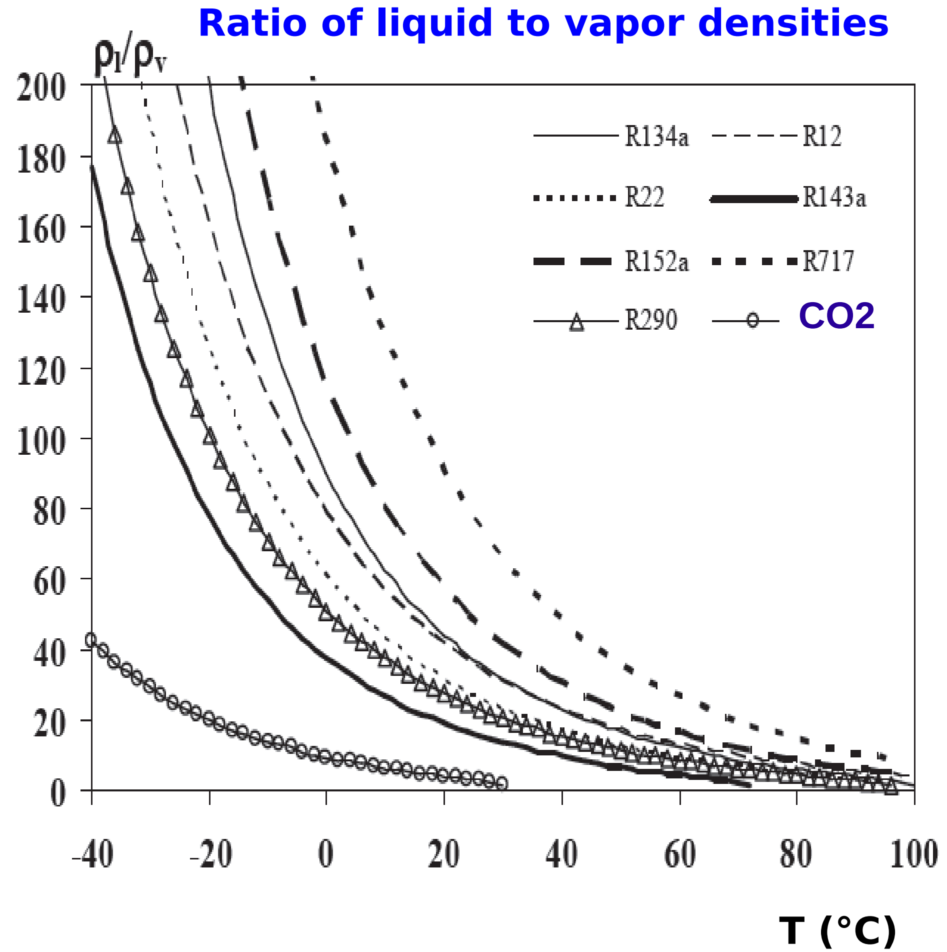
- at different pressures, hence, at different vapor temperatures.
- and at different flow rates.
- cooling power: '100 watts - 250 watts'.
- cooling ranges form “ -40 °C to +20 °C.

Why CO_2 as a refrigerant ?

Higher slope of the vapor pressure curve means that ΔP in the system is smaller.

Low ratio of liquid to gas densities results in a more homogenous two-phase flow (Pettersen 2002).



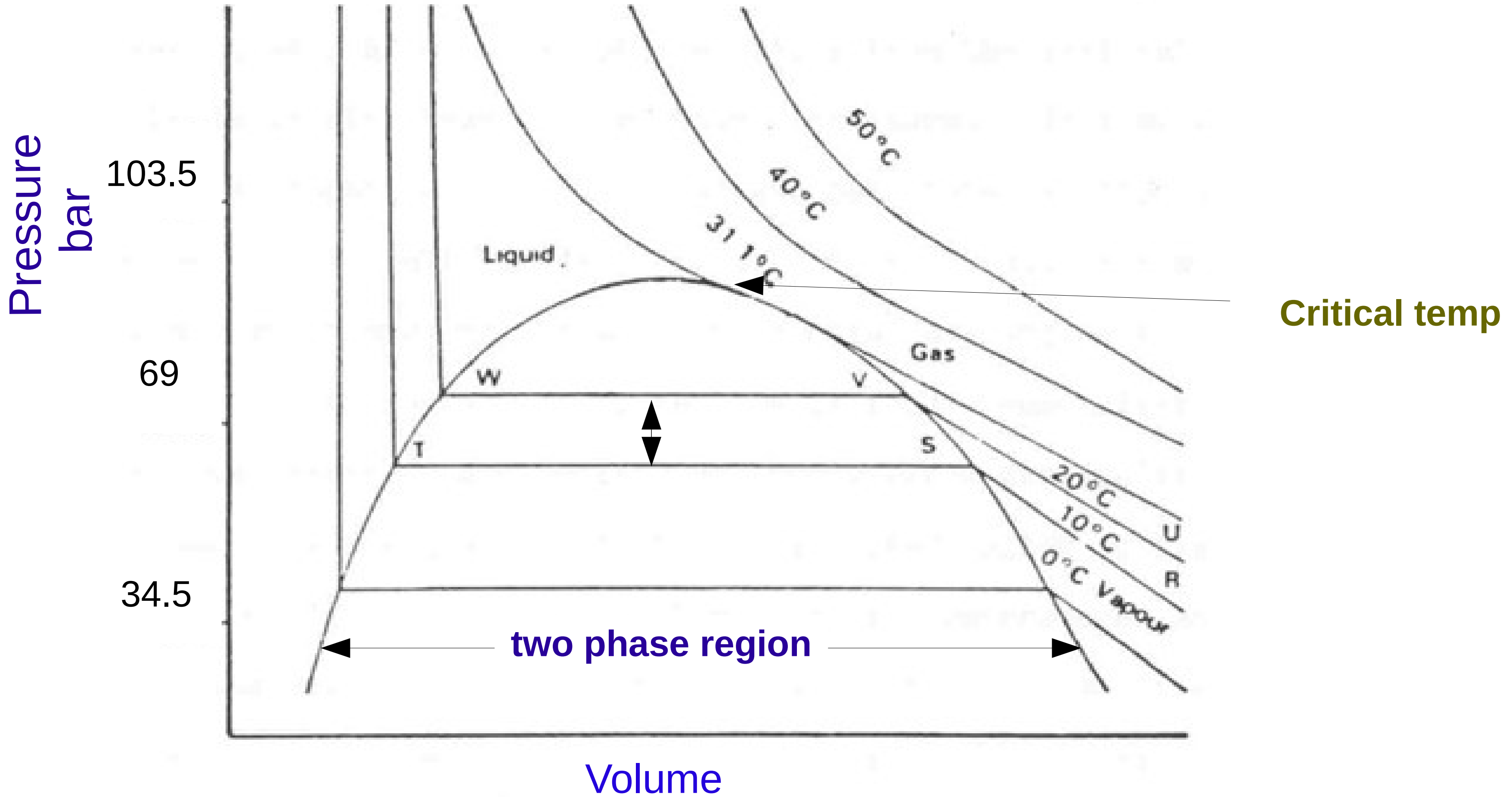


Why two phase cooling ?

Liquid CO_2 has large latent heat → low flow rate

Low viscosity → uniform flow

Evaporative CO_2 cooling → allows small tubing

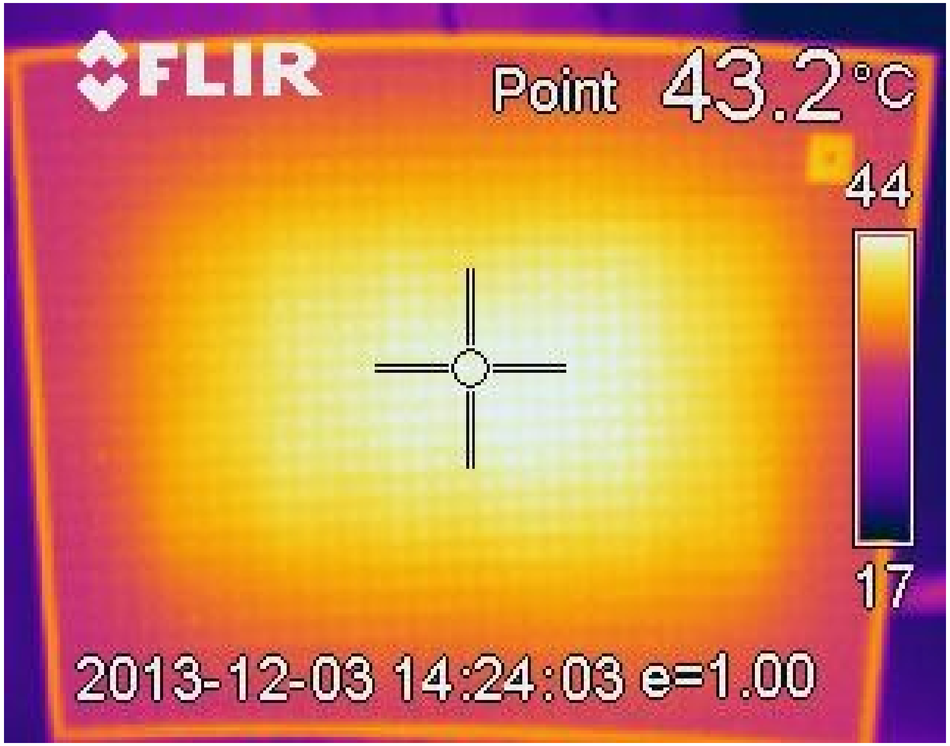


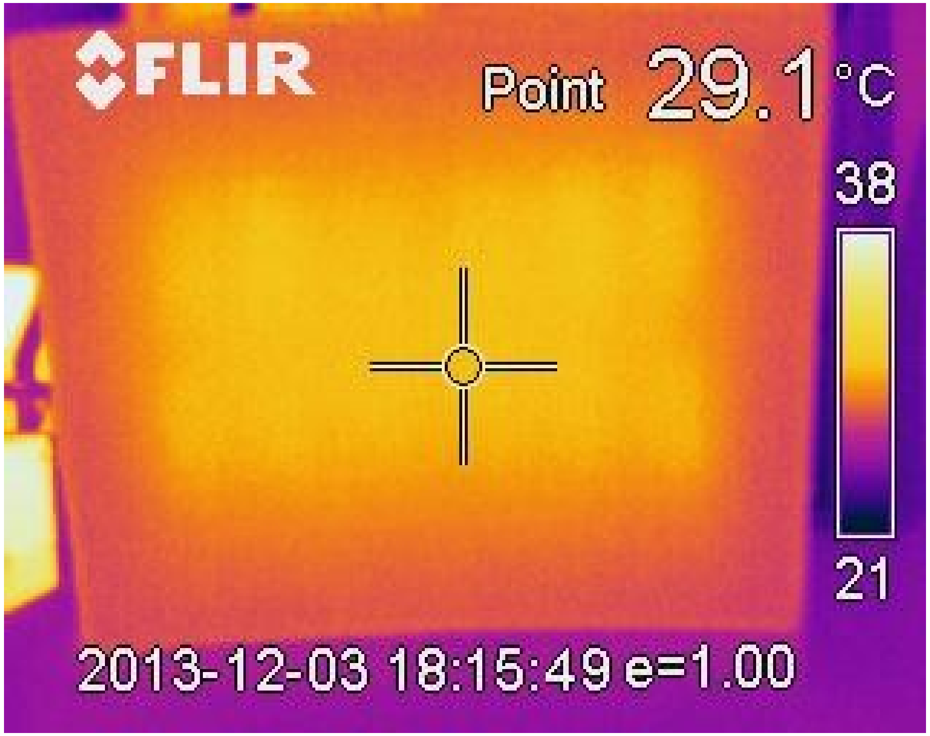
Temperature difference with and without cooling*

FECs and FEMI	Temp (°C) Without cooling	Temp (°C) With cooling
FEC 0	55	35
FEC 1	58	34
FEC 2	61	33.5
FEC 3	62	34.5
FEC 4	60	34
FEC 5	55.5	33.5
FEMI	54.5	37

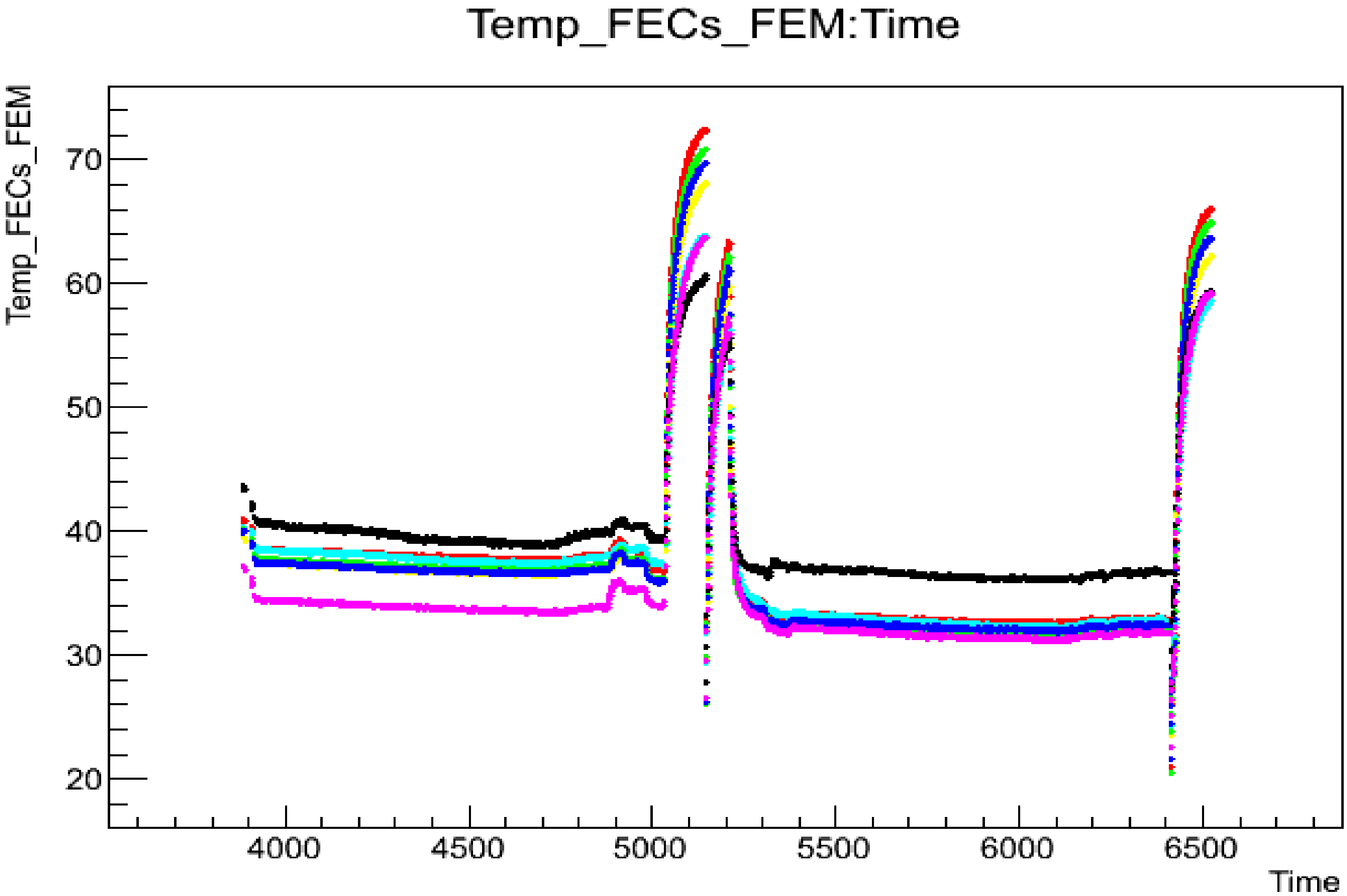
***At Out-Pressure=45 bar, In-Pressure=55.2 bar, Temp 10.0 °C, Flow rate=2.0 gm/sec**

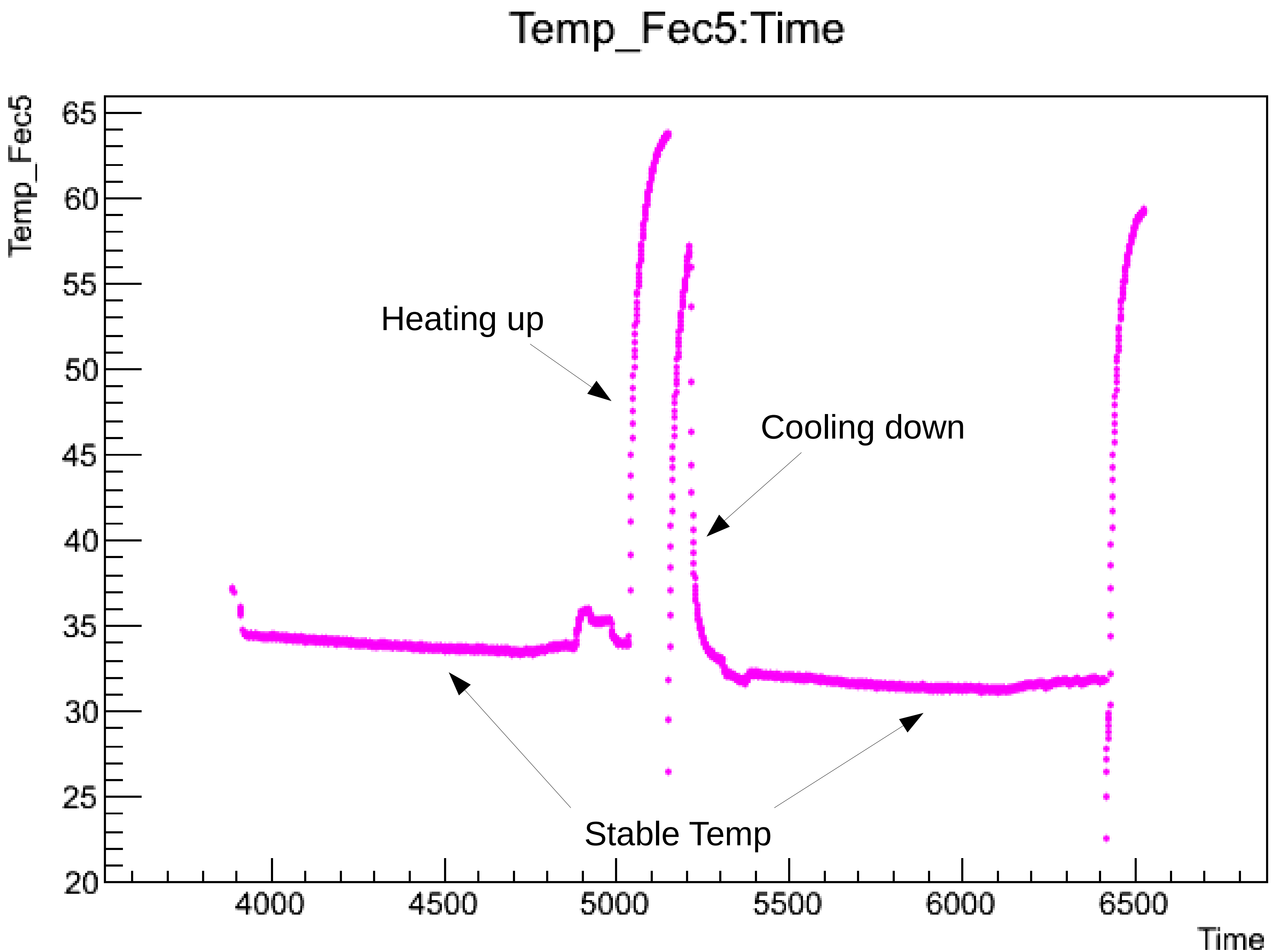
Infrared images of the module without and without cooling





Temperature profile for all the FECs and the FEMI

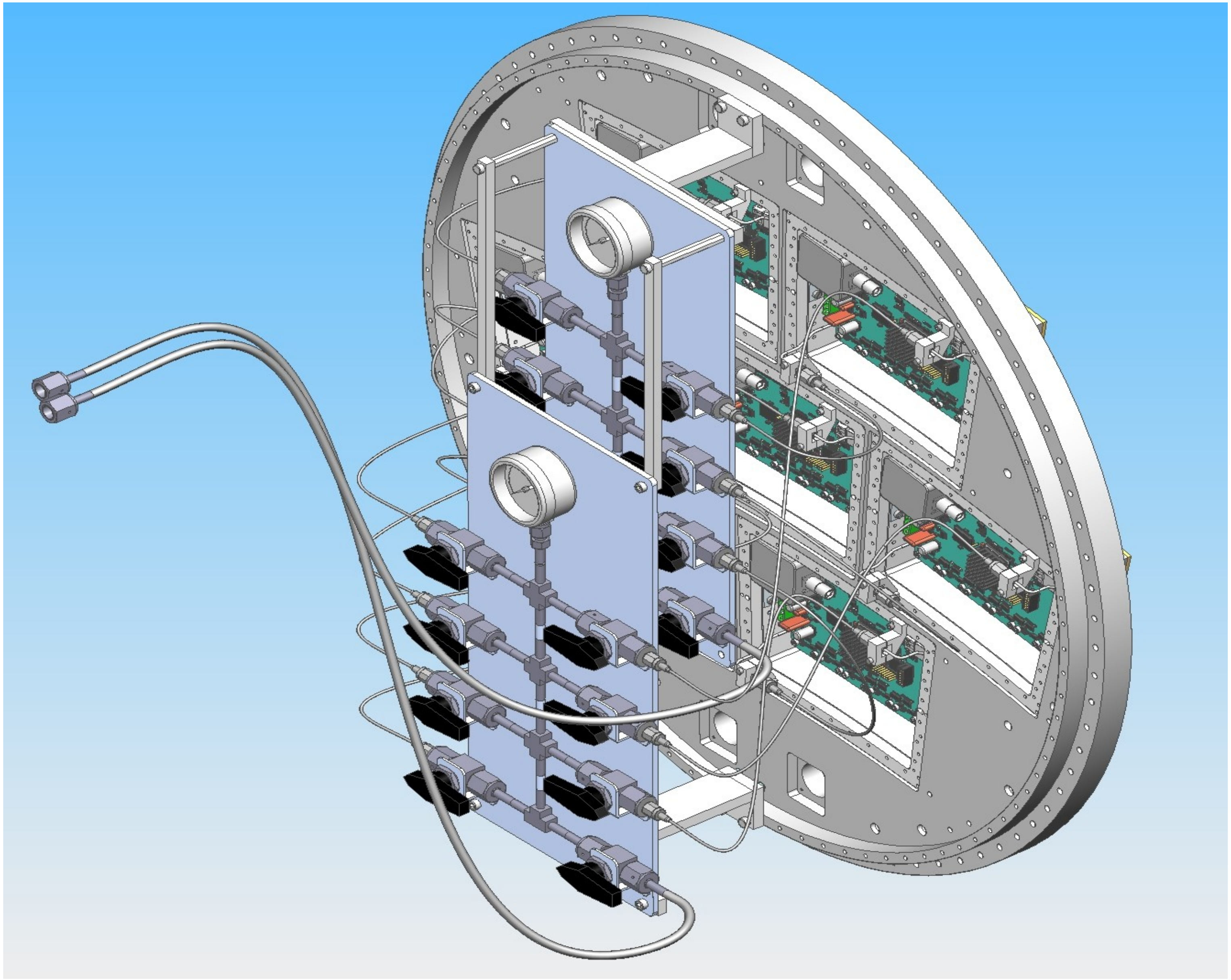



Temp_Fec5:Time
Temp_Fec5
65
60
55
50
45
40
35
30
25
20
4000
4500
5000
5500
6000
6500
Time
Heating up
Cooling down
Stable Temp

Conclusions and future plan

- the temperature profiles show that cooling can stabilize temperature at 31 to 33 degree.
- better thermal contact with the cooling tubes and heat radiators will increase the performance.
- we are planing to apply this cooling model to all 7 modules in parallel for our next data taking at DESY starting from 17 Feb 2014 .

Future Plan



Thank You

Back Up Slides

Temperature vs Drift velocity