dRICH cooling

for SiPMs and FEEs

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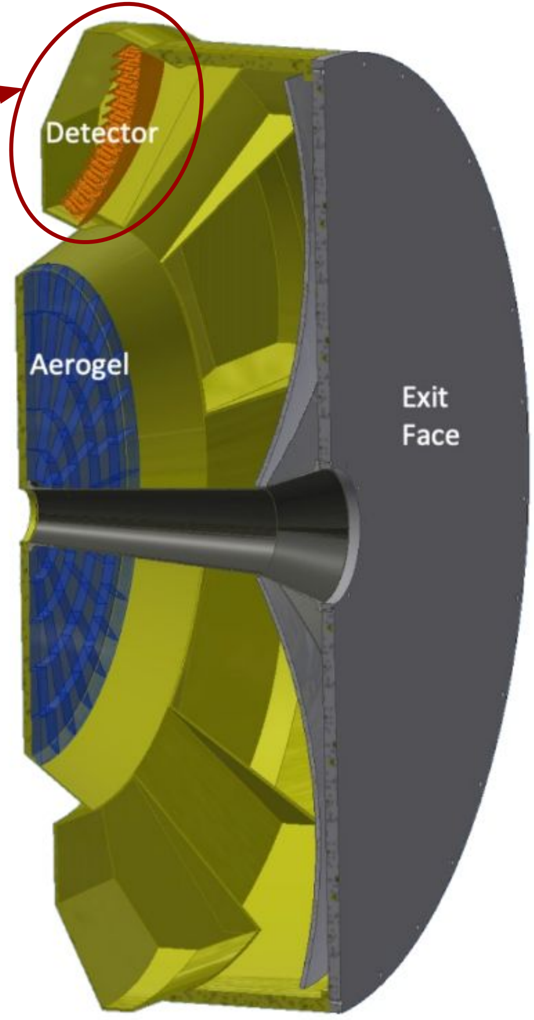
dRICH cooling needs

this talk is about cooling needs inside dRICH readout box



- **keep SiPM sensors at T = -40 C**
  - ~ 3.3 m^2 of silicon photodetectors
  - thermally insulated from gas radiator
- **remove heat generated by front-end electronics**
  - ~ 320 k channels of TDC electronics
  - ~ 1.2 k readout FPGAs

previous TIC presentation: 11 September 2023

SiPM cooling needs

slide from TIC presentation
11 September 2023

- **goal is to be able to cool SiPM down to T = -40 C**
  - even lower if manageable
- **SiPMs do not heat up very much**
  - assuming maximum acceptable DCR: 300 kHz
  - assuming a SiPM sensor with large gain: $5\ 10^6$
  - assuming a SiPM sensor with large bias voltage: 50 V (at low temperature)
  - current drawn by a single sensor: 250 nA
- **256 SiPM for each PDU → 60 uA / PDU**
- **200 PDU for each dRICH sector → 12.5 mA / sector**
- **6 sectors → 75 mA**
- **total power consumption when operated at 50 V is at most ~ 5 Watts**
  - even after irradiation
- **SiPM cooling looks basically like a thermostatic exercise, but**
  - of course it is not that simple because the environment around is not vacuum
  - and there are heat sources nearby (electronics)
- **a proper engineering calculation is needed to define all specs**
  - including flow of circulation fluid

no significant updates here
numbers are still valid

Electronics cooling needs

slide from TIC presentation
11 September 2023

- **goal is to remove the heat generated by the electronics**
  - estimates below are based on current prototype electronics
  - there is no prototype RDO, so there is a bit of a guesswork here
- **1 PDU = 4 FEBs + 1 RDO**
  - current proto-FEB consumes ~ 1.5 W power
  - ~~assume RDO consumes ~ the same (let's put 2 W)~~
  - ~~1 PDU = 8 W~~
- **200 PDU for each dRICH sector → ~~~ 1.5 kW / sector~~**
- **6 sectors → ~~10 kW~~**
- **how to remove that heat?**
  - forced air circulation inside the readout box
    - this might bring heat towards SiPM
    - but also have beneficial effect of keeping quartz window "at room temperature"
  - water-cooling? needs piping and fingers on hot chips
    - perhaps possible, but very little space in the readout box
- **a proper engineering calculation is needed to define all specs**

no updates on FEB power consumption

advances in RDO studies for prototyping current estimate is more realistic and shows larger RDO power consumption

the initial 2 W power consumption for RDO have been underestimated because the board was thought could be based only on a PolarFire FPGA, whereas the current baseline also has a Xilinx Artix Ultrascale+

Electronics cooling needs

updated slide

- **goal is to remove the heat generated by the electronics**
  - estimates below are based on current prototype electronics
  - there is no prototype RDO, so there is a bit of a guesswork here
- **1 PDU = 4 FEBs + 1 RDO**
  - current estimate for FEB consumption: ~ 1.5 W
  - current estimate for RDO consumption: ~ 5 W
  - 1 PDU = ~ 11 W
- **200 PDU for each dRICH sector → ~ 2.2 kW / sector**
- **6 sectors → 13 kW**
- **how to remove that heat?**
  - forced air circulation inside the readout box
    - this might bring heat towards SiPM
    - but also have beneficial effect of keeping quartz window “at room temperature”
  - water-cooling? needs piping and fingers on hot chips
    - perhaps possible, but very little space in the readout box
- **a proper engineering calculation is needed to define all specs**

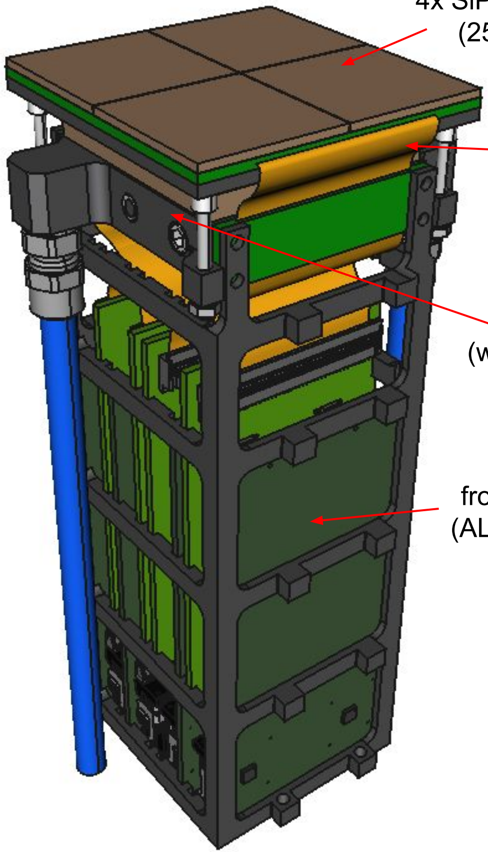
no updates on FEB power consumption

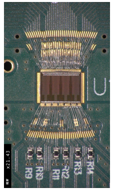
advances in RDO studies for prototyping
current estimate is more realistic and
shows larger RDO power consumption

notice that power consumption depends
also on details of LV power distribution,
primary power supply channels and
auxiliary components (i.e. LDO) that
have to be chosen wisely to optimise
performance, power consumption
and have to be radiation tolerant

this is the current best guess

EIC ePIC-dRICH SiPM photodetector prototype



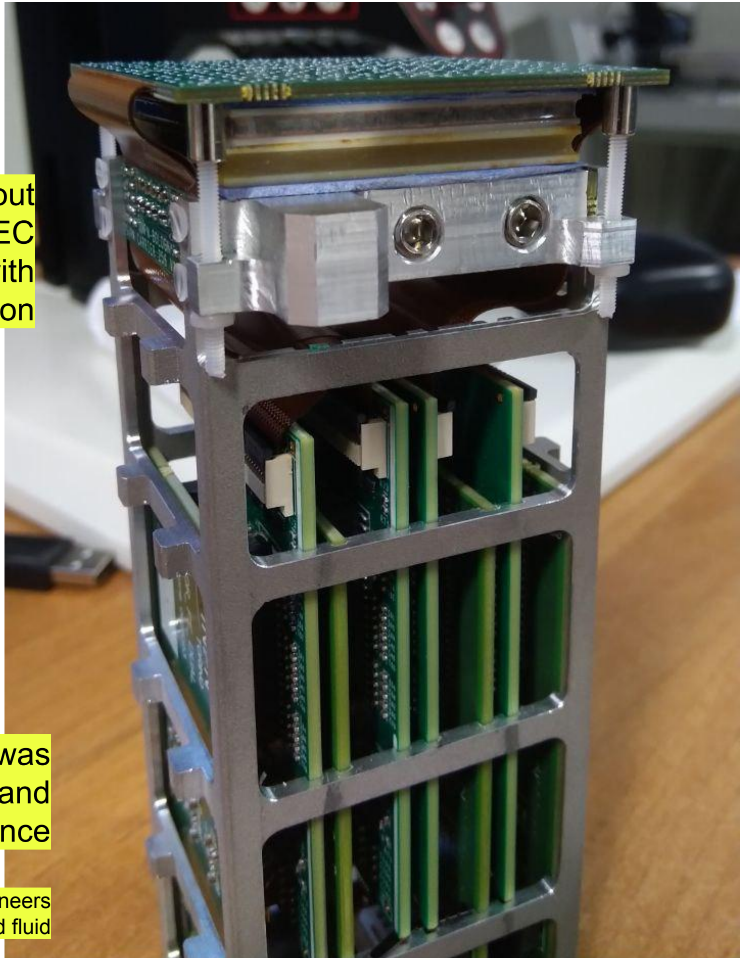


PhotoDetector Unit (PDU)

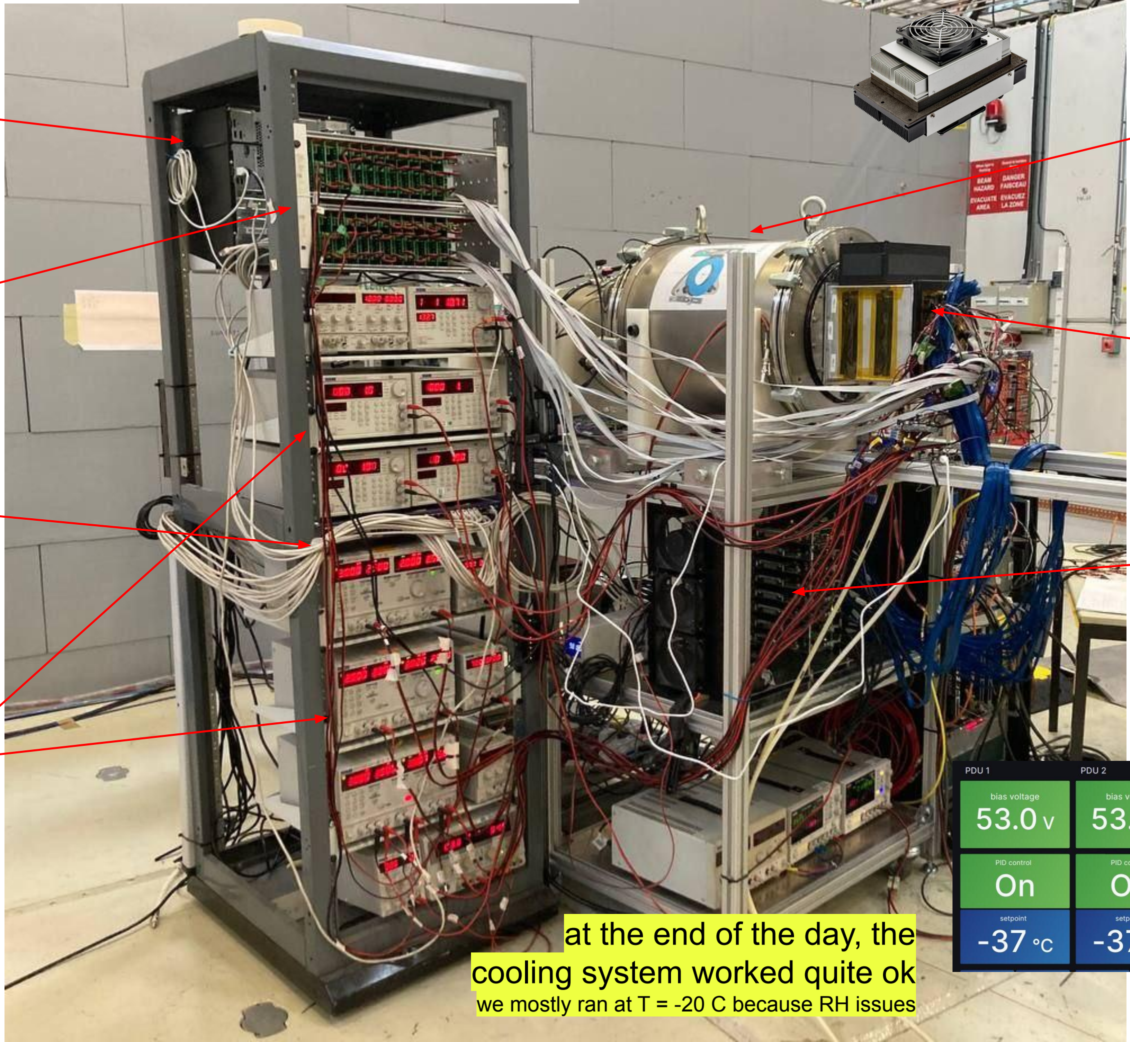
current prototype layout employs two stacked TEC (Peltier) modules with water-cooling recirculation

design of the cooling system was a bit of a guesswork and extrapolation of past experience

future iterations will need involvement of engineers and engineering studies of thermal and fluid



October 2023 CERN PS beam test



DAQ and DCS computers

auxiliary control electronics crates

gigabit ETH switch for DAQ and DCS

low voltage and high voltage power supplies

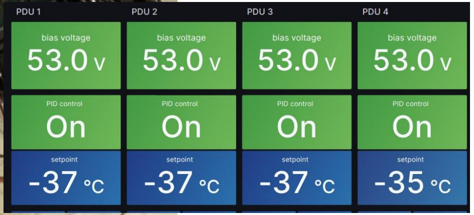
dRICH prototype

SiPM photodetector readout box

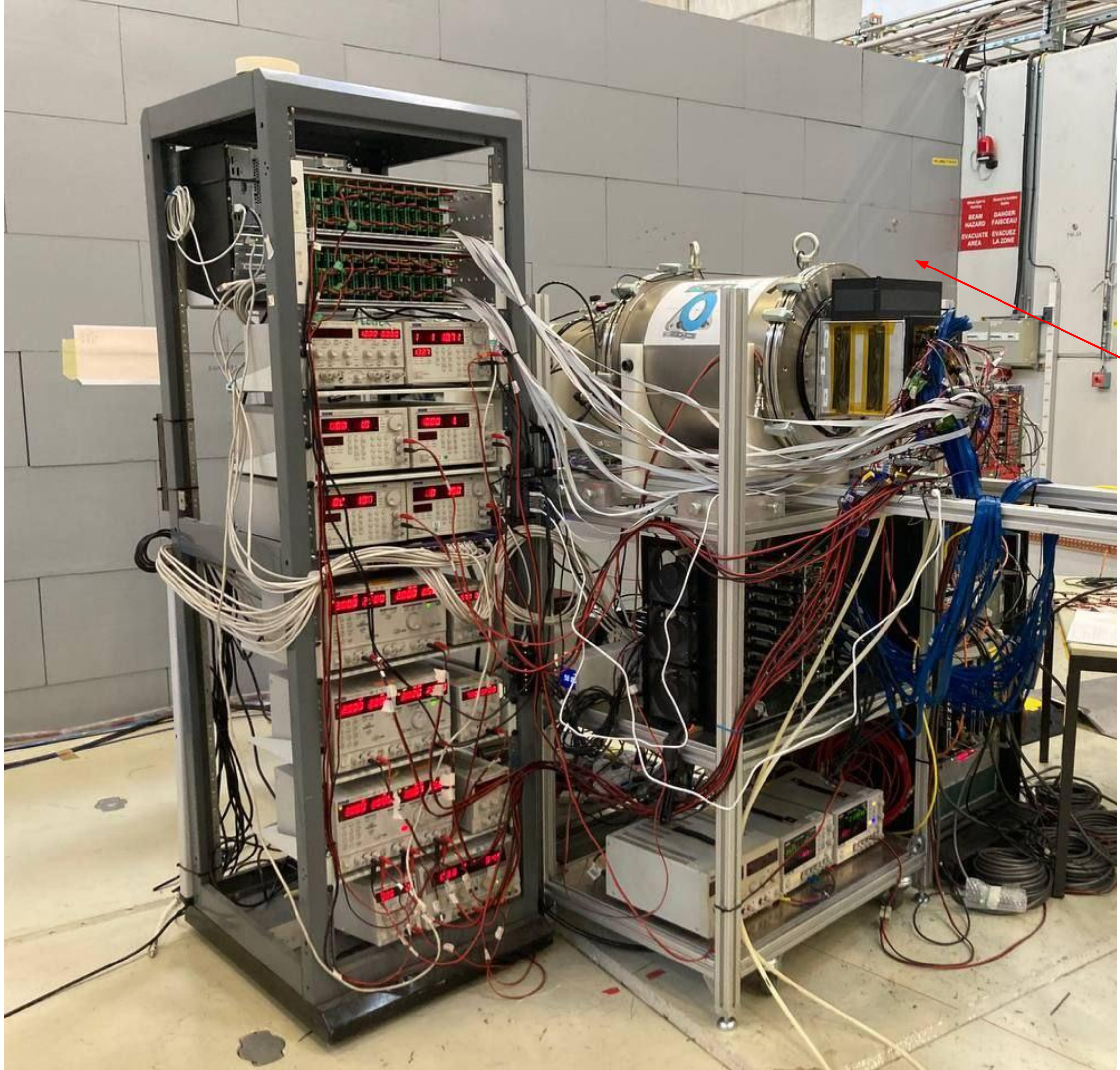
DAQ FPGAs and clock distribution

at the end of the day, the cooling system worked quite ok

we mostly ran at T = -20 C because RH issues



SiPM at low temperature



FEE cooling with TEC heat pump and air circulation cooling

was not yet mounted when this picture was taken

The AA-060-24-22 is an Air-to-Air Thermoelectric Cooler Assembly that uses impingement flow to transfer heat.

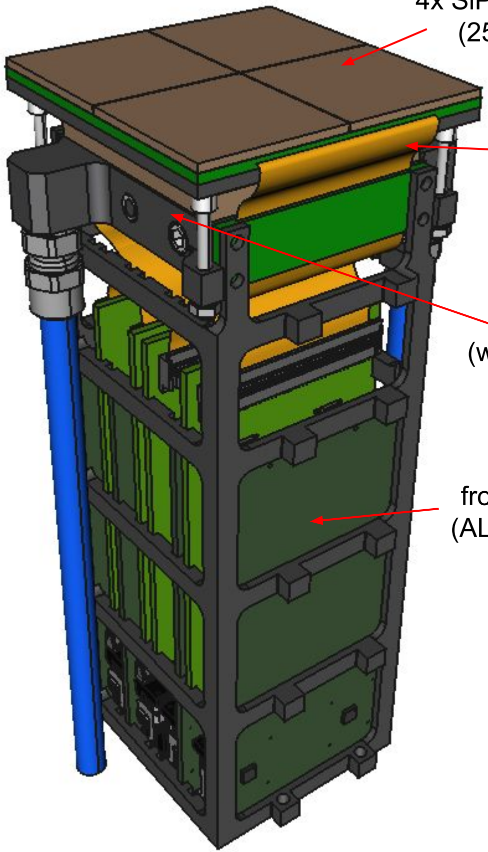
EIC ePIC-dRICH SiPM photodetector prototype

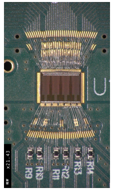
4x SiPM matrix arrays
(256 channels)

flex PCB

cooling stack
(water-cooled Peltier)

minicrate with
fron-end electronics
(ALCOR ASIC inside)



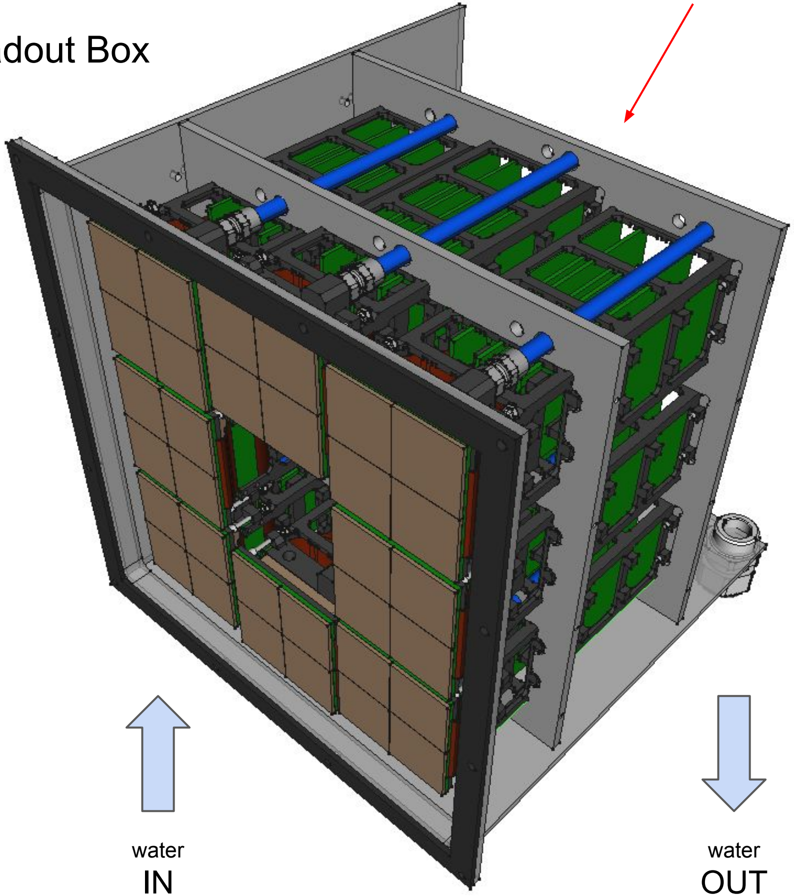


PhotoDetector Unit (PDU)

each PDU has in and out pipes
connected to manifolds

Readout Box

cables and services
(not shown)

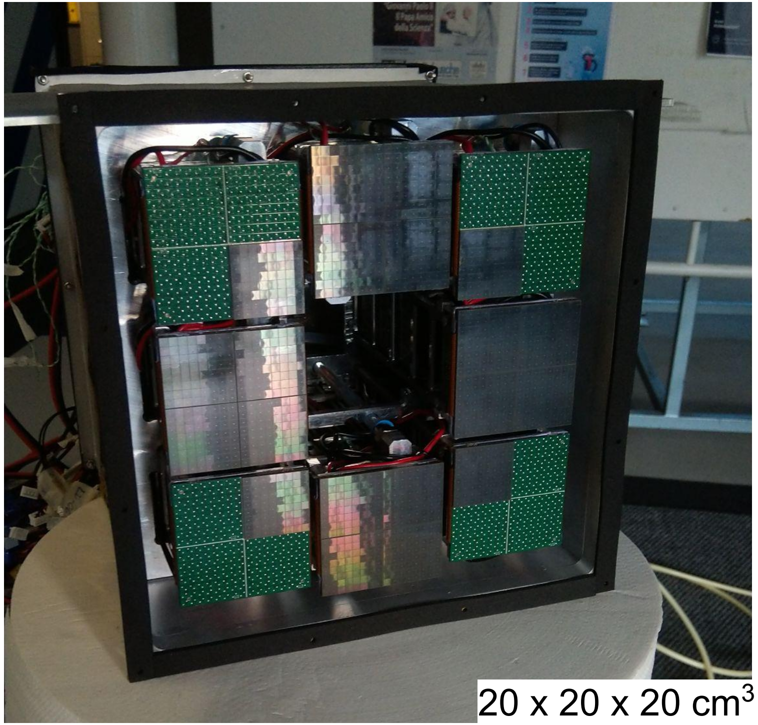


water
IN

water
OUT

EIC ePIC-dRICH SiPM photodetector prototype

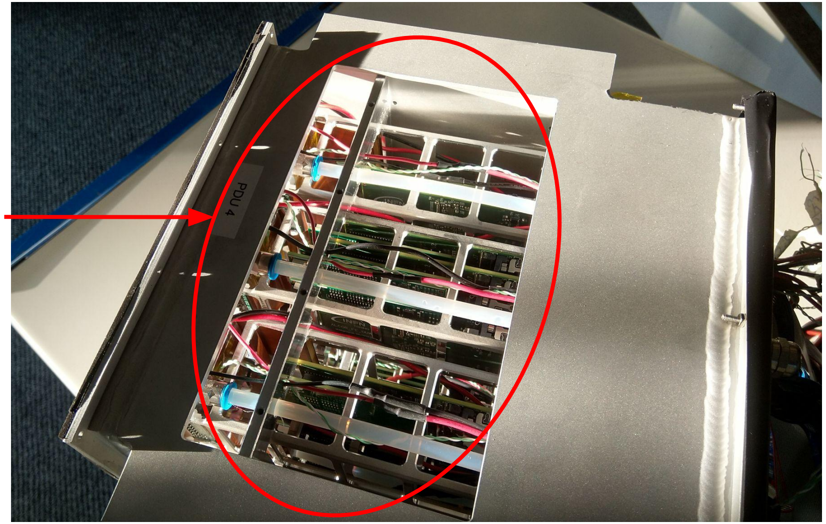
Readout Box (front)



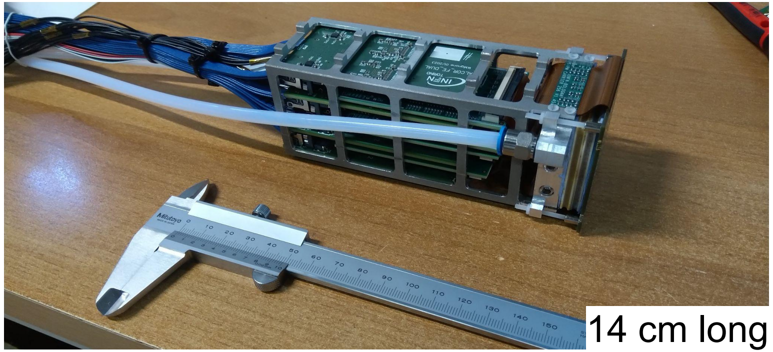
20 x 20 x 20 cm^3

hole for FEE cooling air flow

Readout Box (top)



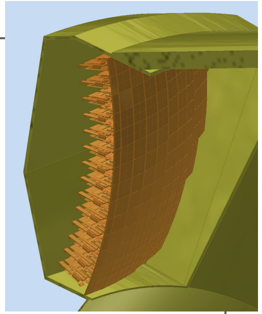
PDU

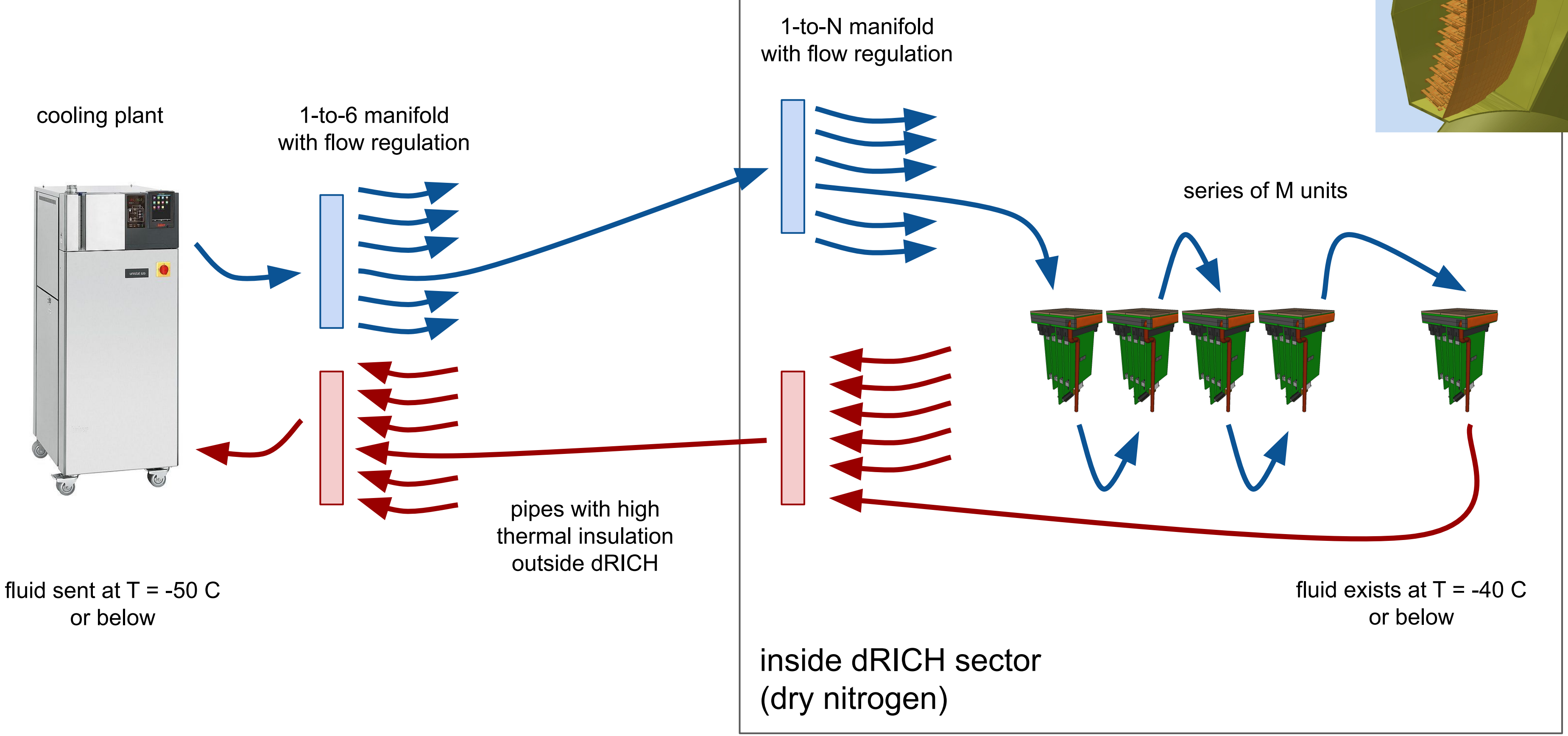


14 cm long

SiPM cooling layout

guesswork for possible pipe routing and system





Fluid-cooling the SiPM

the baseline plan is to get rid of the Peltier modules and cool only with fluid

external chiller with fluid recirculation (ie. siliconic oil)

the chiller here one is just a commercial example

cooling and heating capacity

could use heating capability for annealing? must be demonstrated to be feasible

cooling capacity at -40 C is large (1.5 kW)

huber

General & Temperature Control

Temperature range	-55...250 °C
Temperature stability	±0,01 K

Heating / cooling capacity

Heating capacity	6 kW								
Cooling capacity	250	200	100	20	0	-20	-40	-50	°C
	6	6	6	6	6	4,2	1,5	0,65	kW

Fluid-cooling the SiPM

we purchased a recirculation chiller system
with silicone fluid and insulated piping

SilOil M60.115/200.05 is a low-viscosity silicone fluid which, as a result of its special property profile, is particularly suitable for use as a cold and heat transfer medium in cryostats, thermostats and heat transfer installations.

General & Temperature Control

Temperature range	-55...200 °C

Heating / cooling capacity

Heating capacity	2,4 - 3 kW

Cooling capacity

100	20	0	-20	-40	°C
1,5	1,5	1,5	1	0,3	kW

Circulation pump

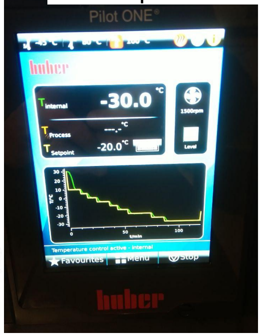
Delivery capacity pressure pump max.	25 l/min; 0,7 bar
Delivery capacity suction pump max.	18,5 l/min; 0,4 bar

Fluid-cooling the SiPM

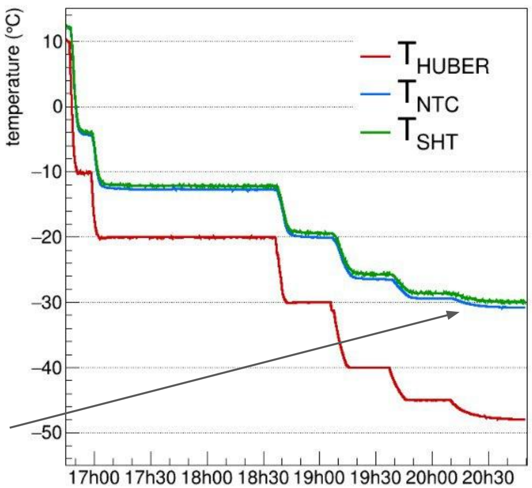
first very preliminary tests on single PDU encouraging, although with some issues to tackle

- rework needed to seal fluid leaks (need to find proper sealant)
- need to understand pump behaviour

chiller operated at low T



temperature sensors



although with a large T difference wrt. the bath temperature eventually we reached T = -30 C

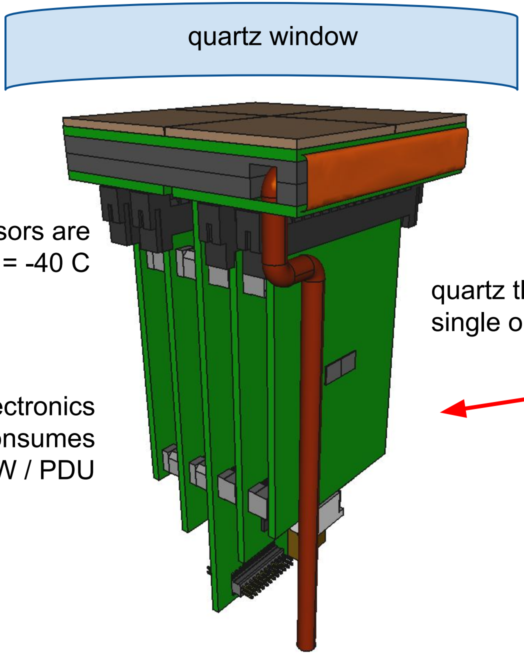
detector in a "dry bag"

The quartz window

an area where there is need of Ansys

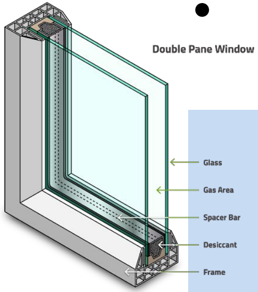
separate readout volume from gas-radiator volume

- gas types are different (N_2 vs. C_2F_6)
- limit temperature gradients in the gas radiator

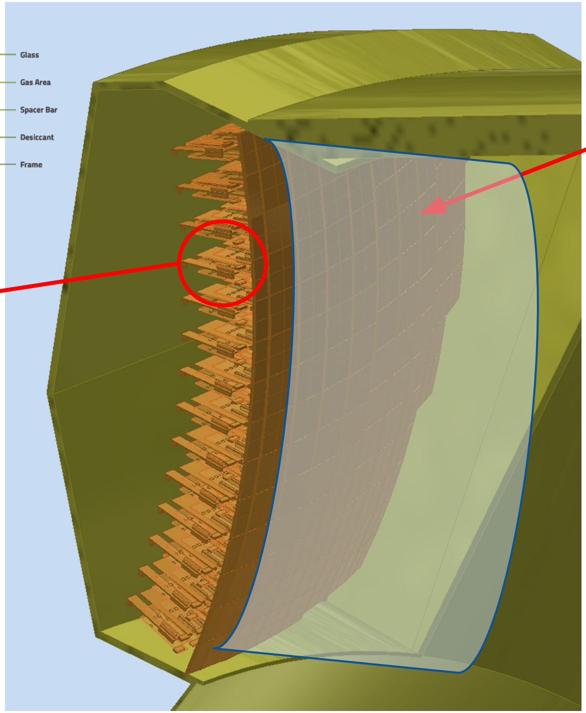


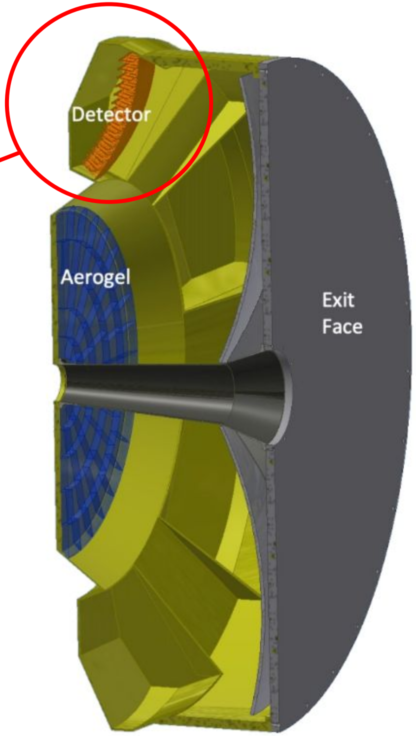
sensors are at T = -40 C

electronics consumes 10 W / PDU



quartz thickness?
single or double pane?





how does the temperature look like behind the window?
how thick do we need it? single vs. double window?

what if there is air circulation in the readout box?
can we "dump" gradients in the gas with gas circulation in the volume?

need engineering support from the project for engineering simulations to be compared to test-bench lab measurements

Summary and next steps (in next slide)

slide from TIC presentation
[11 September 2023]

- **ideas on how to cool the SiPM are there**
  - target to cool down to T = -40 C
  - TEC Peltier-based cooling used in current prototype units works
  - confident that a fully fluid-based cooling concept will work (we want to avoid Peltier in experiment)
- **in principle a modest chiller should be sufficient for SiPM cooling**
  - if one only accounts for the SiPM heat generation
  - but we need to transport fluid (losses)
  - must take into account the environment inside the readout box
  - we need calculations
- **SiPM electronics generates ~ 13 kW across the whole dRICH**
  - ~ 2.2 kW from within each readout box
- **need support from project engineers for cooling calculations / simulations**
  - we will prepare test benches for measurements to be compared to Ansys
  - very important also to assess the impact on the gas radiator (see PID review)

Next steps

- **very important to assess the impact on the gas radiator (see PID review)**
  - we need to assess this as **high priority**
- **temperature measurements using dRICH PDU prototype as mock-up**
  - original (Marco's) plan was to do measurements during October beam test
    - install temperature sensors to measure gradients generated by SiPM cooling
    - we needed to ditch the plan because we did not "own" the beam test area (we were parasitic users) and could not always access the beam test area at our wish (therefore we focused on the test of the new SiPM readout)
  - we scheduled to perform these temperature measurements in March in our labs
    - these could be used as input / feedback to engineering calculations
- **measurements with the real-scale dRICH prototype**
  - advanced and more realistic determination of temperature gradients
  - can make use of various mock-ups
    - quartz window configurations
    - air circulation
    - …