Thermal Mock-up Status

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DESY

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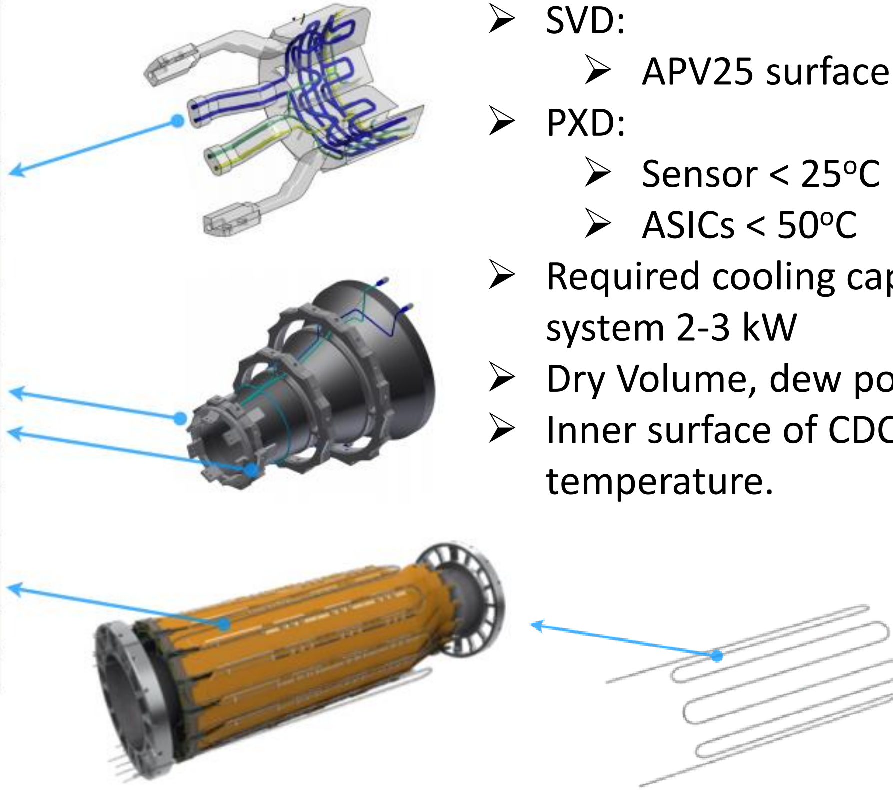
VXD Cooling System

CO_2 Circuit	Detector	Half	Layer	Type	Side	Power [W]
1	PXD	up	1&2	endring	bwd	90
2			1&2	endring	fwd	90
3		down	1&2	endring	bwd	90
4			1&2	endring	fwd	90
					sum PXD	360
5	SVD	left	3-6	endring	bwd	93
6		right	3-6	endring	bwd	93
7		left	3-6	endring	fwd	93
8		right	3-6	endring	fwd	93
9		left	4&5	origami	bwd	68
10		right	4&5	origami	bwd	68
11		left	6	origami	bwd	96
12		right	6	origami	bwd	96
					sum SVD	700
					sum VXD	1060

plus 4 circuits for N_2 supply

plus parasitic heat load from the environment

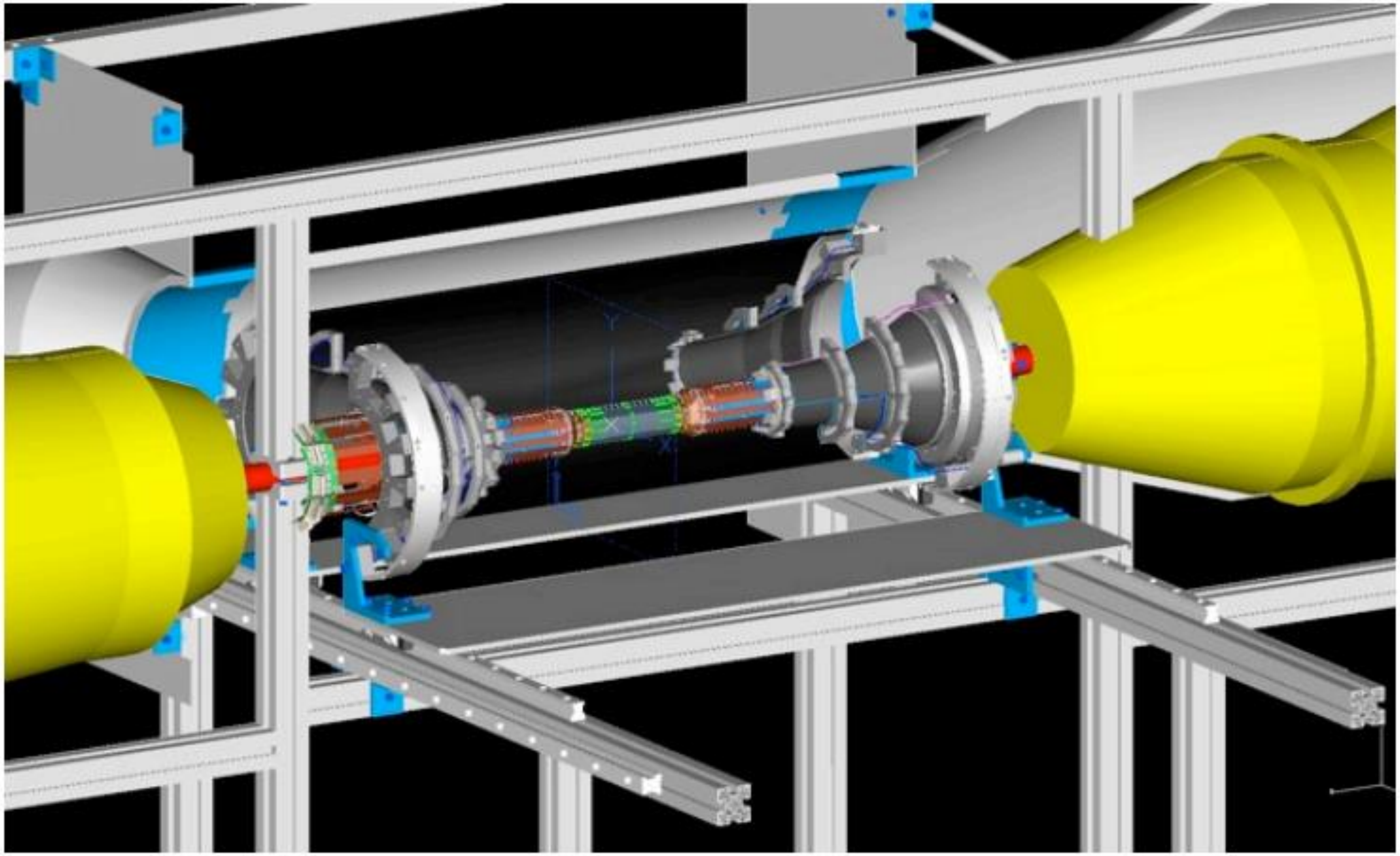


- SVD:
  - APV25 surface@~0°C
- PXD:
  - Sensor < 25°C
  - ASICs < 50°C
- Required cooling capacity of CO2 system 2-3 kW
- Dry Volume, dew point ~ -30°C
- Inner surface of CDC @room temperature.

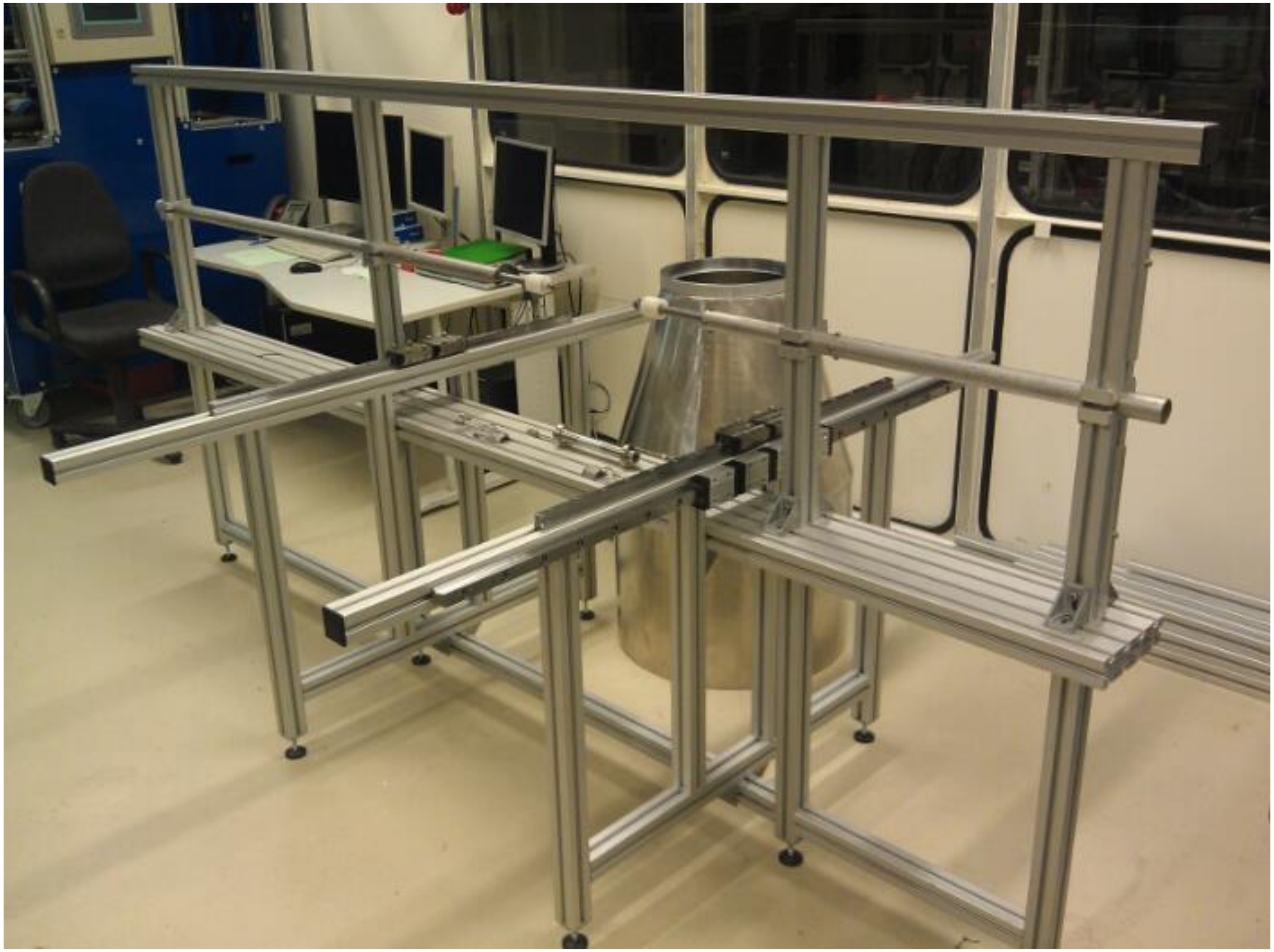
2-phase CO_2 Cooling

- CO_2 is in the two-phase regime – liquid and gaseous state exist simultaneously.
- Heat removal by evaporating liquid CO_2 at the constant temperature and pressure.
- The temperature can be controlled and monitored by the pressure.

Thermal Mock-up

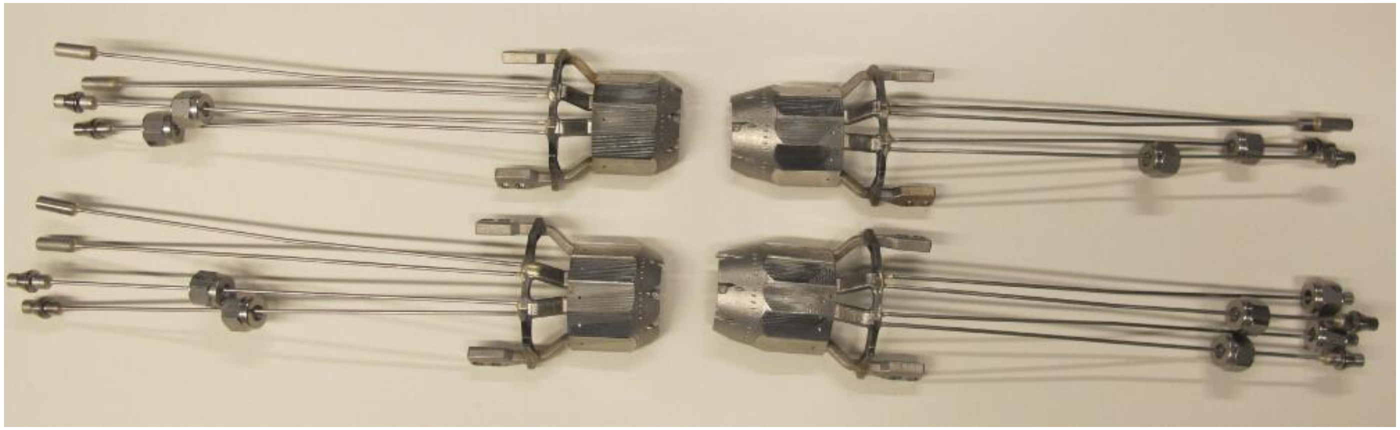


Thermal Mock-up



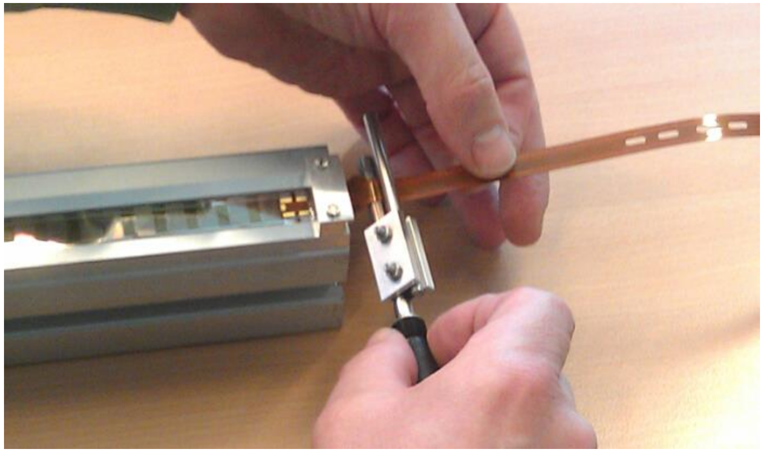
Thermal Mock-up : PXD

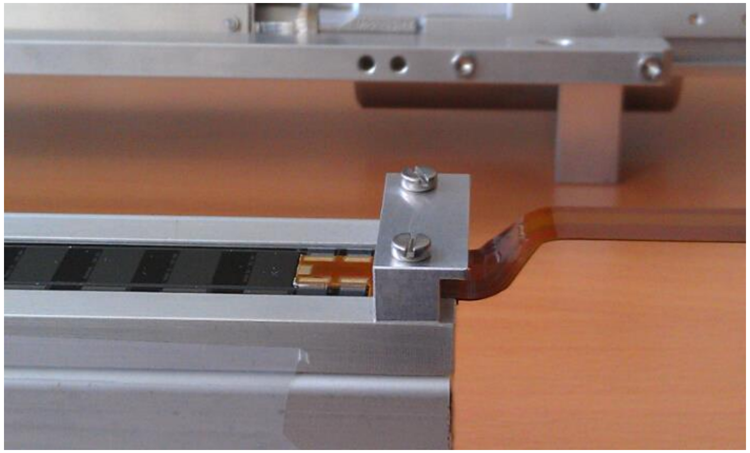
4SCB (Support Cooling Block)

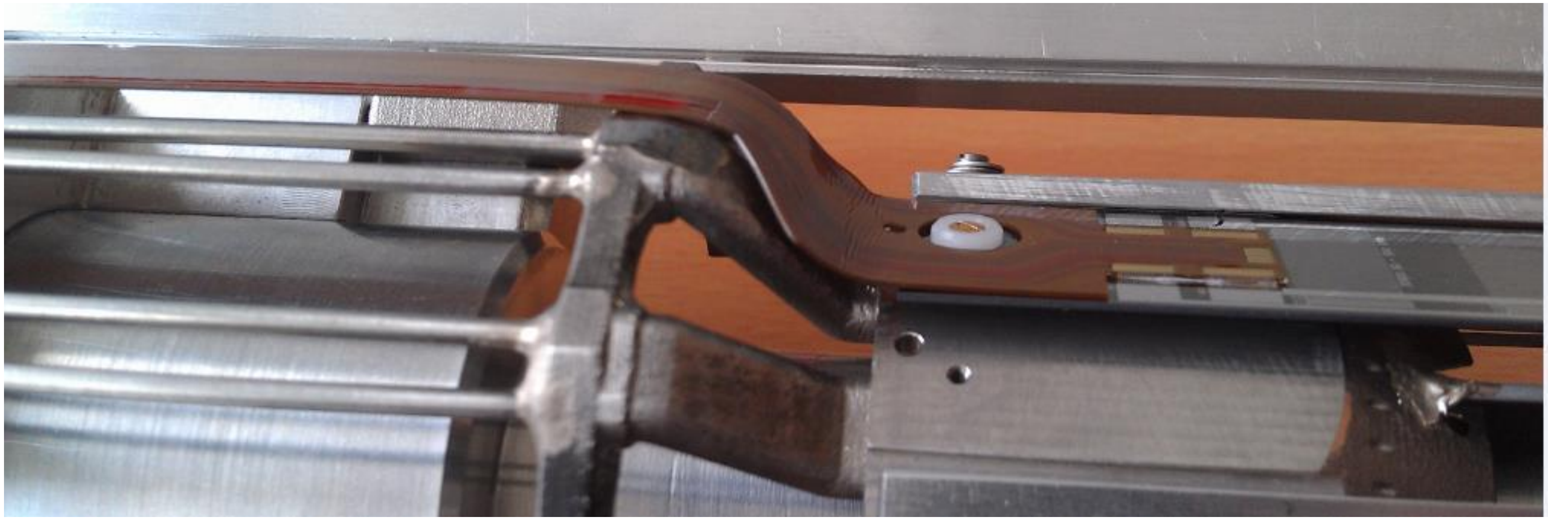


Thermal Dummy Ladders

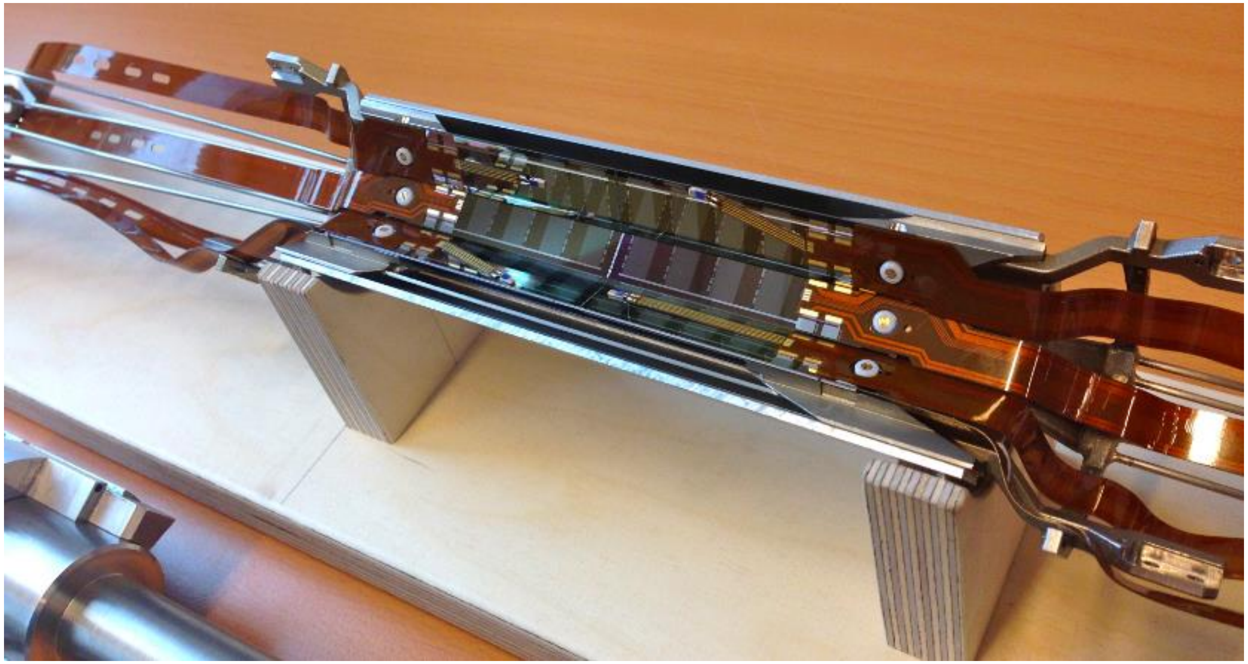
Kapton fiber bending

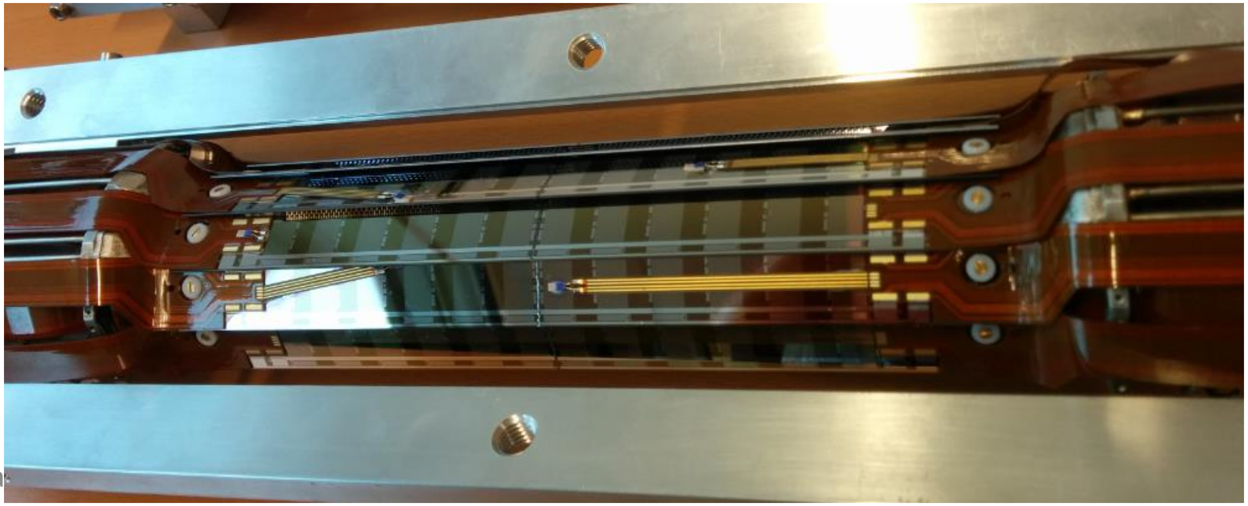




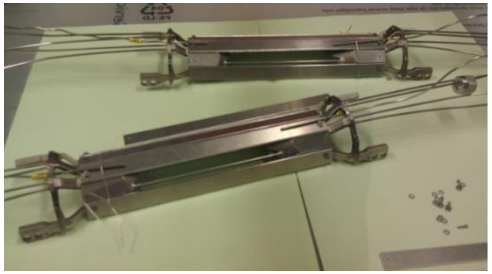


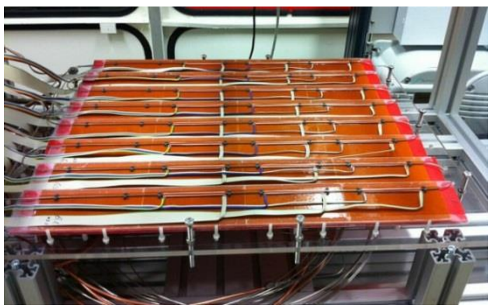
Mount the thermal Dummy Ladders on





Mass flow v.s. Pressure drop



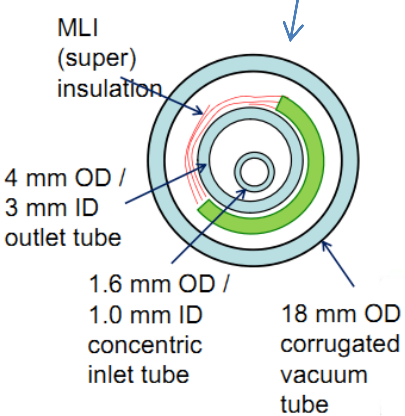


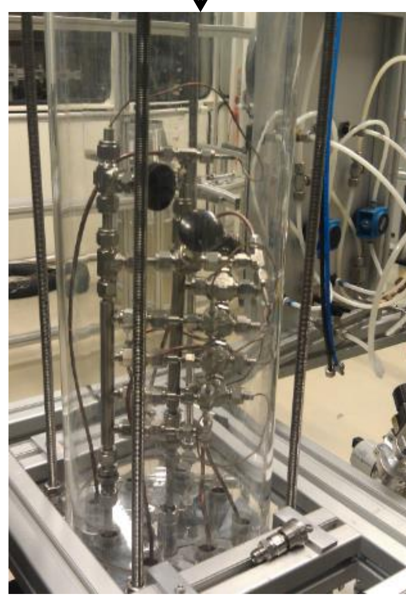
The long and small diameter cooling lines cause relative high pressure drops, which cause temperature gradients. We measure the Pressure Drop to the mass flow in our Mock-up.

8m transfer flex line

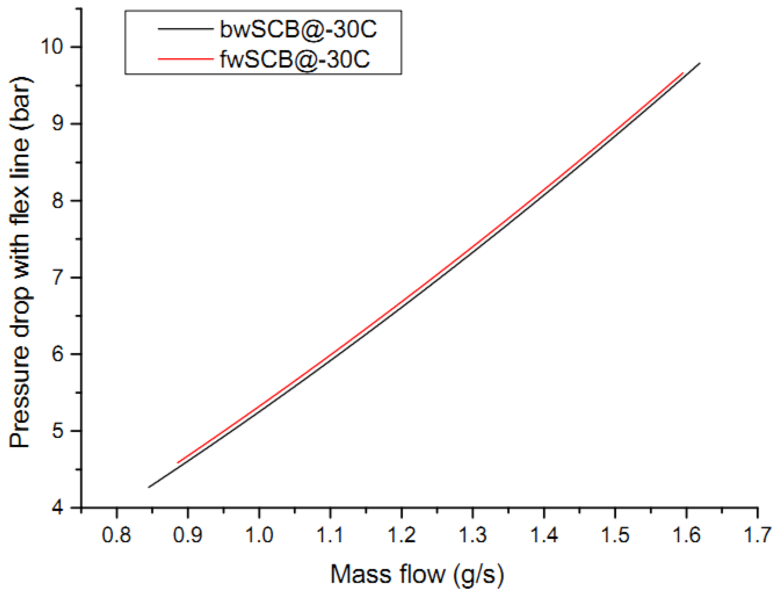
Experimental setup

By pass

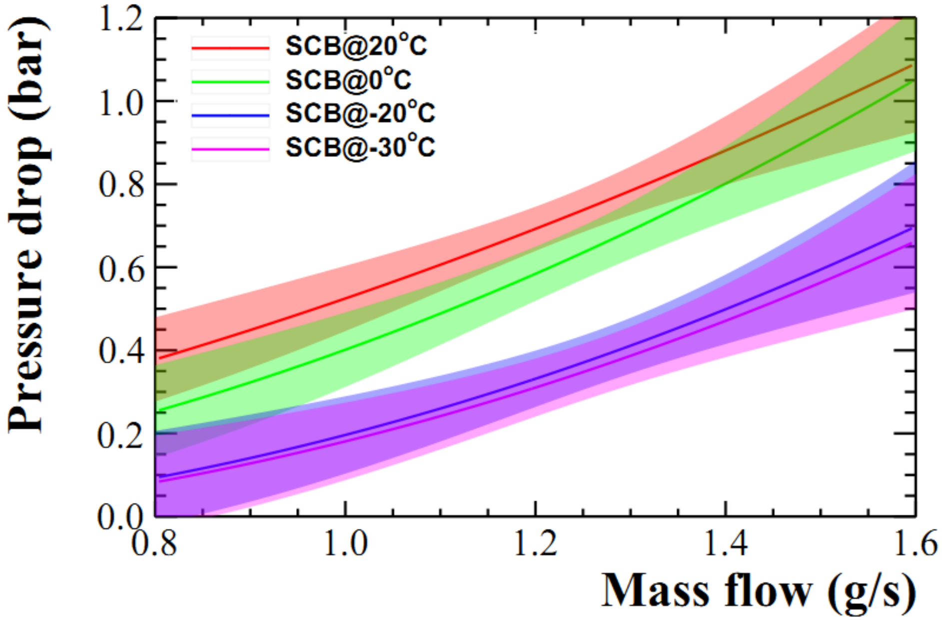




SCB : Mass flow v.s. Pressure drop



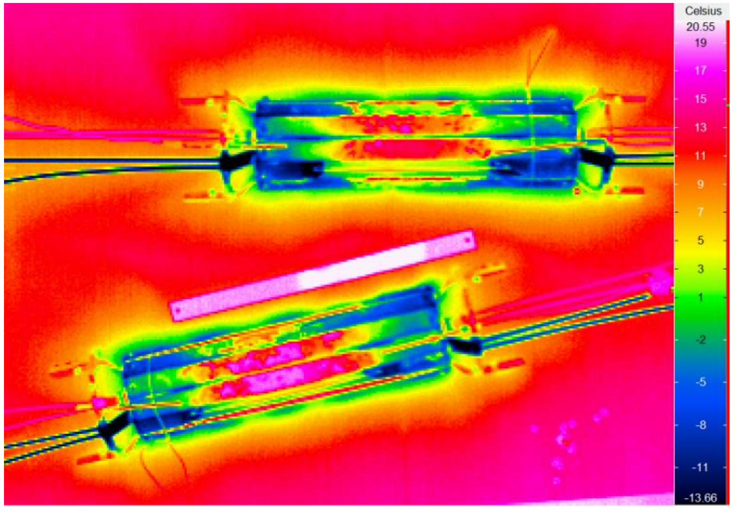
f/b SCB, with flex line.



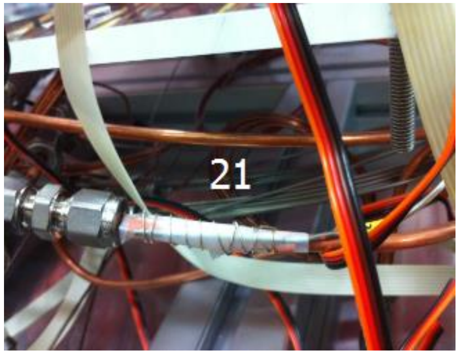
Averaged SCB

- Big pressure drop happens in transfer flex line.
- Small difference of pressure drops in forward/backward SCBs.

Temperature

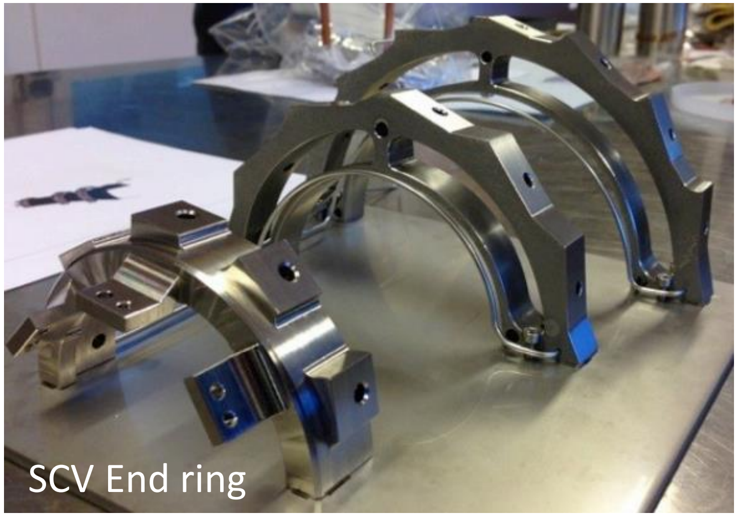


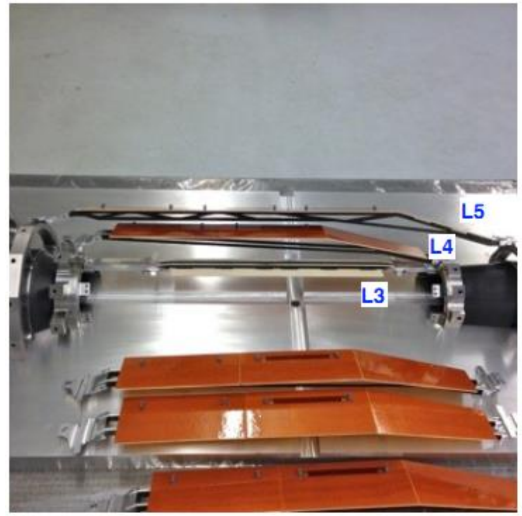
Temperature on SCB surface, when T=-30°C, PT100 gives -24°C, when T=-20°C, PT100 gives -15°C.

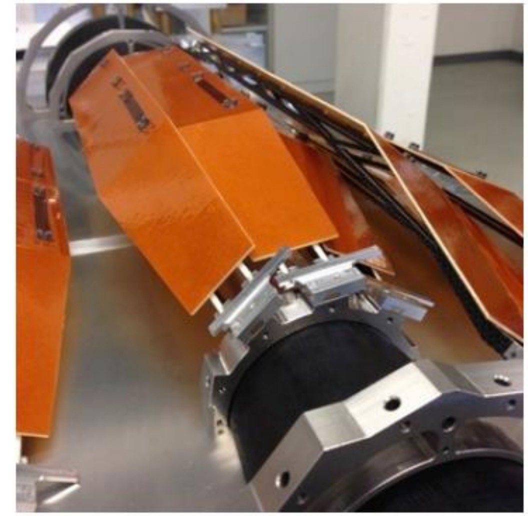


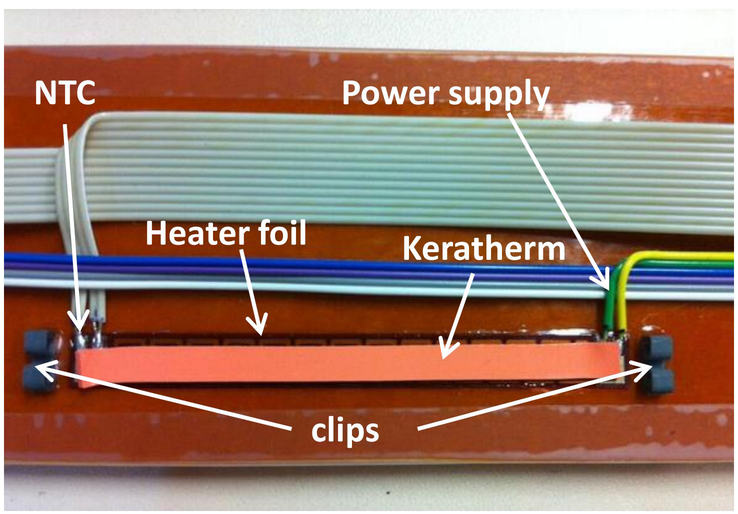
@T=-20°C;
PT100.
20: inlet -16.2°C
(thin pipe gives bad touch to PT100);
21: outlet -18.9°C.

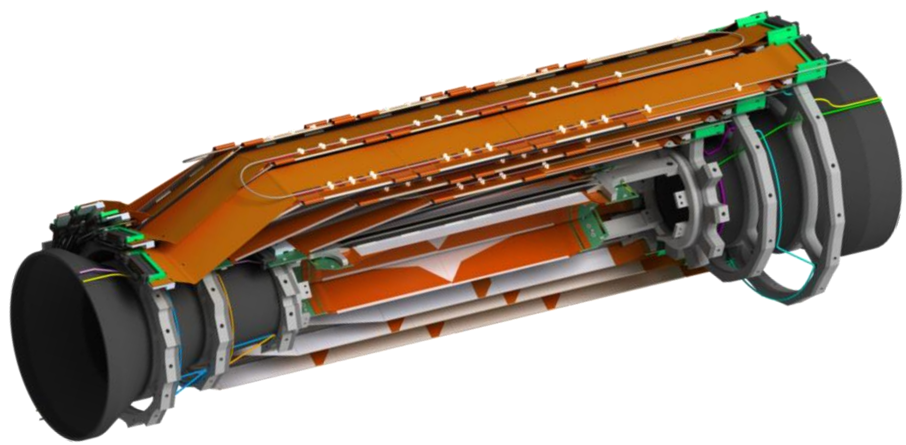
Thermal Mock-up : SVD



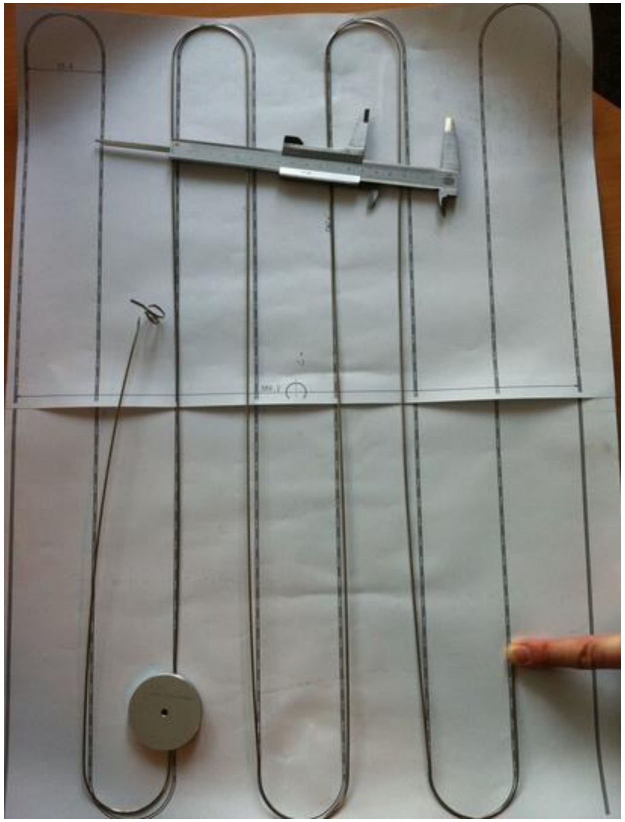


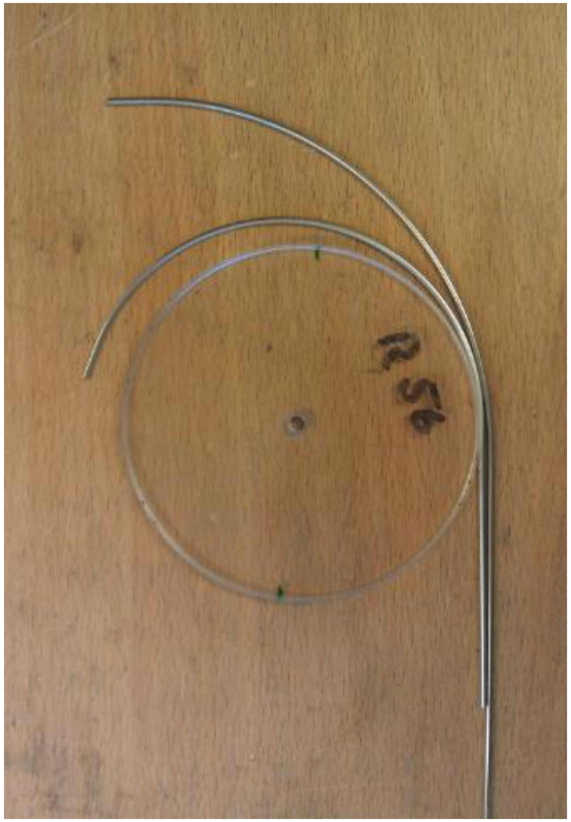






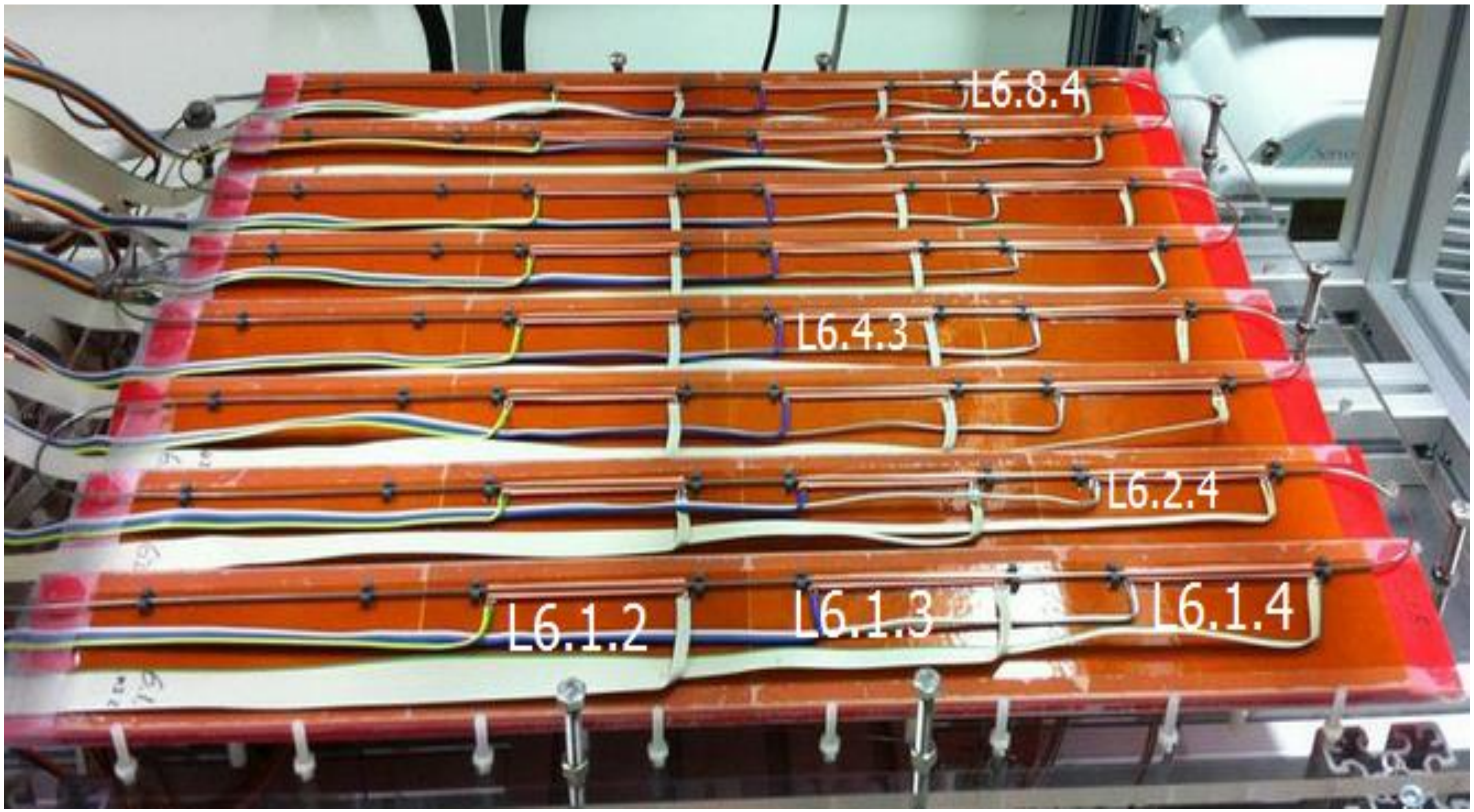
Pipe bending





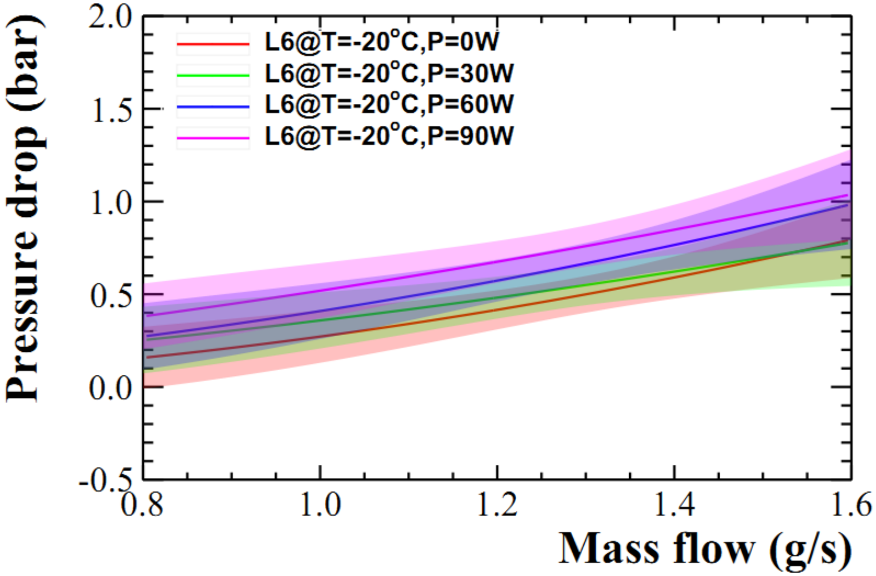
Study of SVD Flat Layer.6

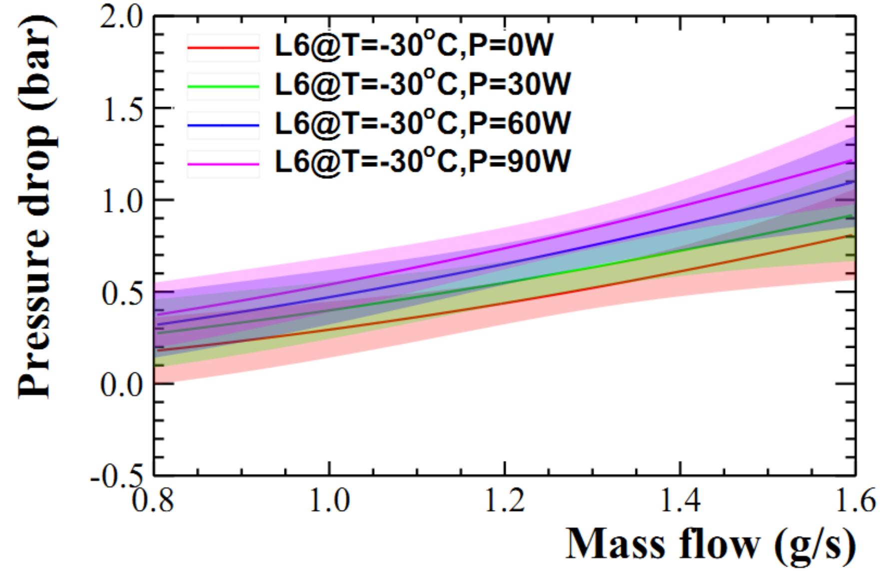
Arrangement → L6.8.x



L6.x.4

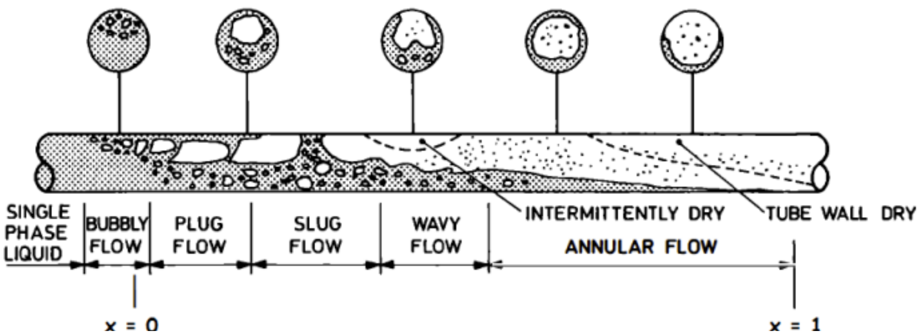
Pressure drop v.s. Mass flow





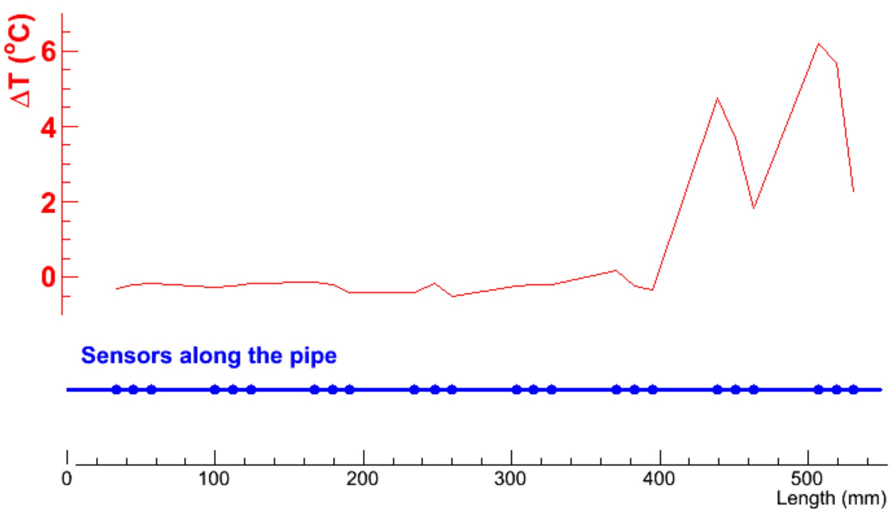
- Higher heat power gives higher pressure drop

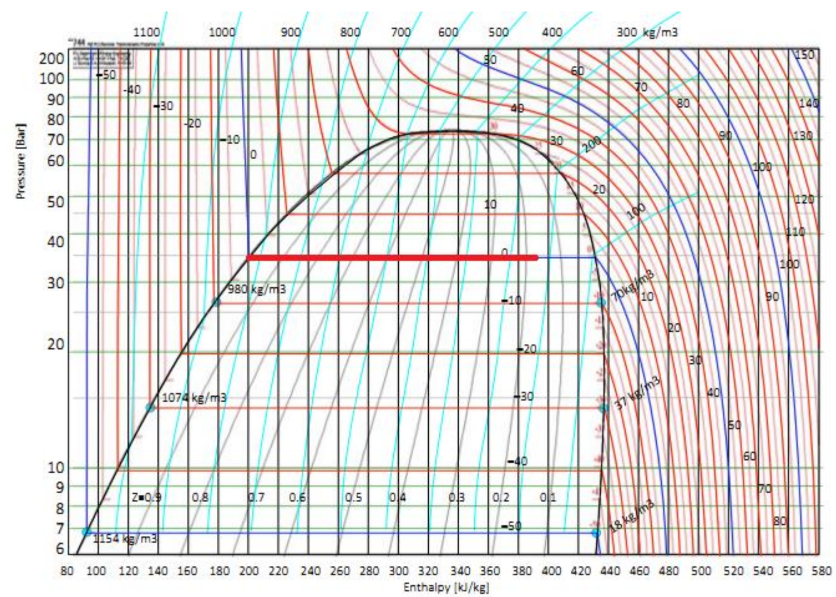
Dry out



Dry out

When the vapor quality gets too high, there will be no liquid film on the capillary walls, then result in a shape increase of the cooling block temperature.





The dry out happens in the last 6 sensors, where the temperature changes 5°C.

Estimate the minimum mass flow

$\Delta P \propto \frac{L}{d^2}$, where L is pipe length, d is diameter.

Assume : pressure drop is due to narrow bends in SCB, and due to pipe length in L.6.

Pressure drop of

Layer 4&5 : $\frac{L4\&5}{L6} * \text{dp}(\text{L6@68W},-20^{o}\text{C})$

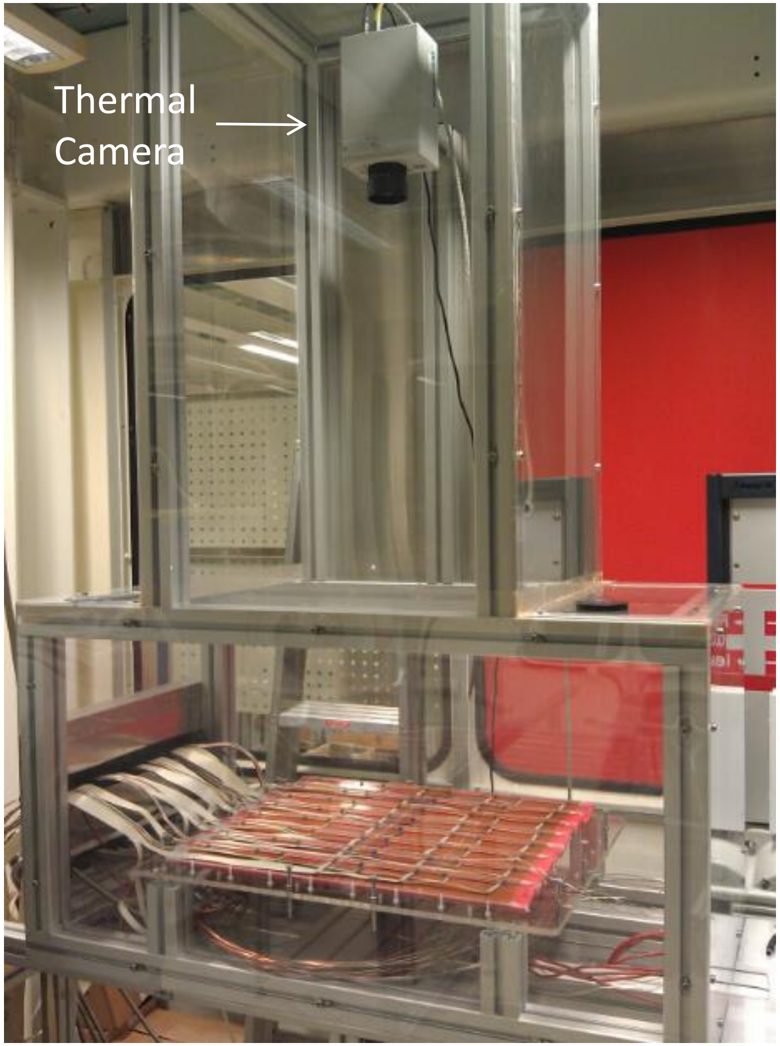
BWD : $\left(\frac{d(scb)}{d(bwd)}\right)^2 * \frac{Nbends(bwd)}{Nbends(scb)} * dp(SCB@90W,-20^{o}\text{C}) + \left(\frac{d(layer6)}{d(bwd)}\right)^2 * \frac{L(bwd)}{L(Layer6)} * dp(L.6@90W,-20^{o}\text{C})$

FWD: similar way

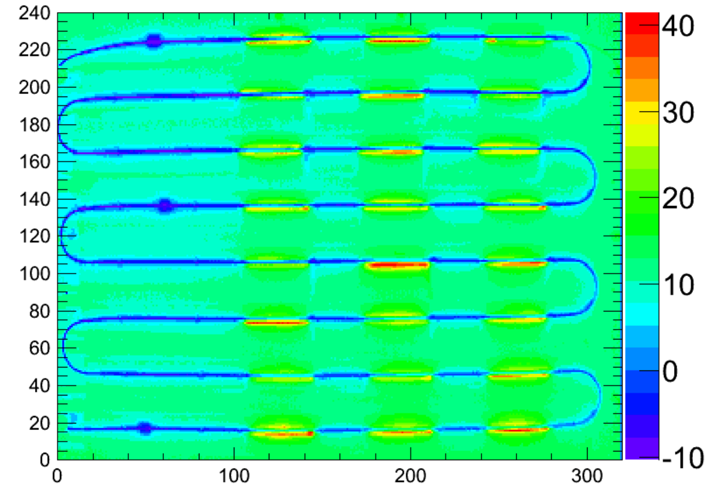
T=-20℃	No.	heat	Min_massflow	Min_pressure drop (w flex line)	Mass flow @dp=1.76 bar (w flex line)
SCB	4	90 W	0.41 g/s	1.76 bar	0.41 g/s
BWD	2	93 W	0.42 g/s	1.49 bar	0.47 g/s
FWD	2	93 W	0.42 g/s	1.43 bar	0.49 g/s
L4&5	2	68 W	0.31 g/s	0.83 bar	0.53 g/s
L6	2	96 W	0.43 g/s	1.33 bar	0.52 g/s

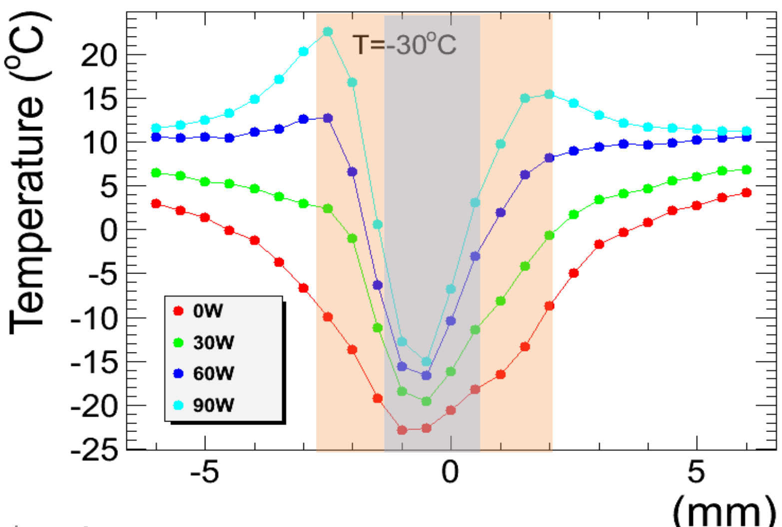
- At T=-20°C, total mass flow for the mockup> 5.66 g/s, gives the pressure drop of 1.76 bar.
- At T=-30°C, total mass flow for the mockup> 5.43 g/s, gives the pressure drop of 1.73 bar.

Temperature



Thermal Camera 320X240



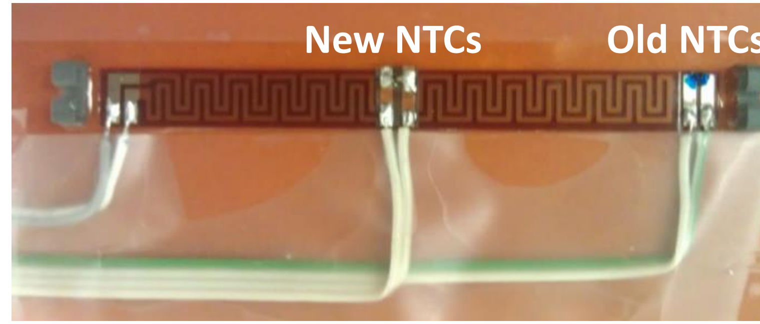


New NTC sensors

For the dummy heater module:

$$\Delta Q_{CO2} + \Delta Q_{ambient} = P\Delta t\ ,\quad \Delta Q/\Delta t = c\Delta T\ ,$$

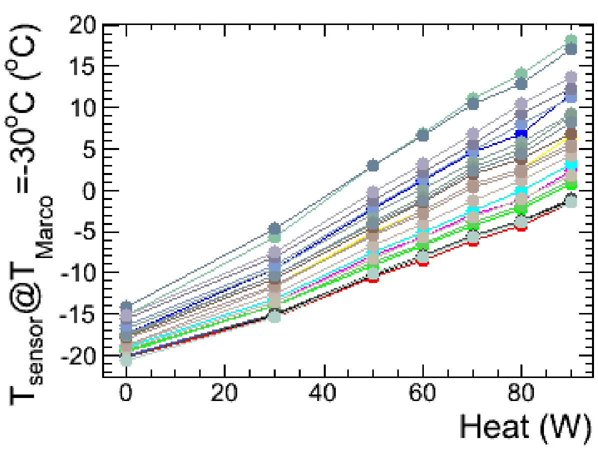
$$\Rightarrow \alpha'(T_{module} - T_{CO2}) + \beta'(T_{module} - T_{ambient}) = P\ .$$

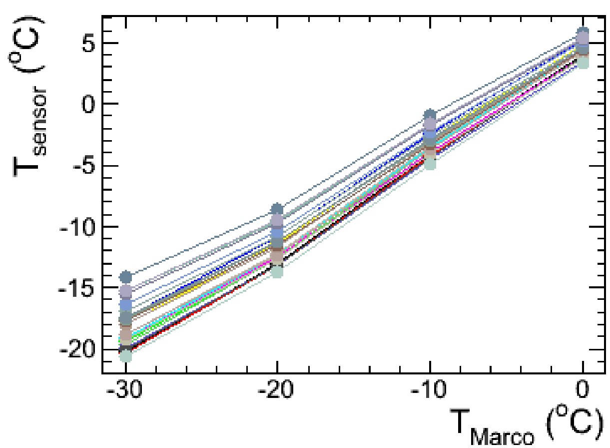


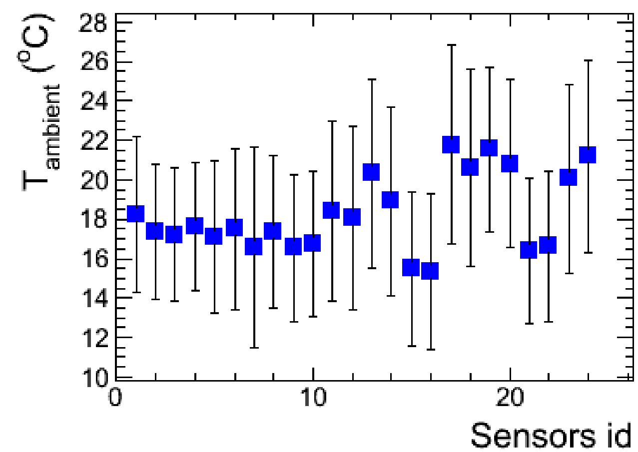
For the NTC sensors:

$$\alpha(T_{NTC} - T_{CO2}) + \beta(T_{NTC} - T_{ambient}) + \gamma(T_{NTC} - T_{module}) = 0$$

$$\Rightarrow \quad T_{NTC} = kP + mT_{CO2} + (1-m)T_{ambient}$$







Summary

What we have learnt

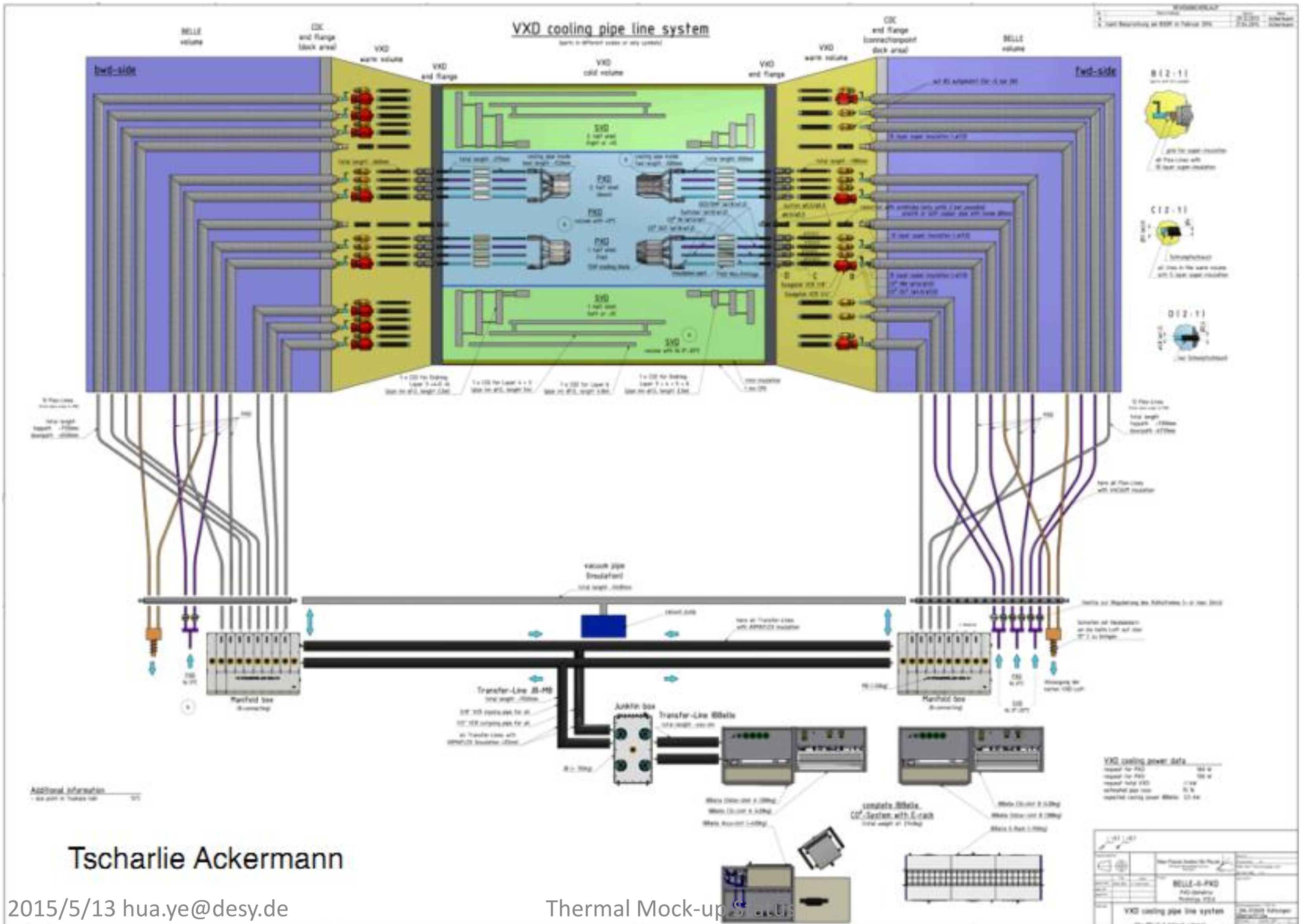
- Pressure drop to mass flow of SCB and Layer.6
- Temperature of dummy heaters.
- Bending work, assembly work ……

Next to do

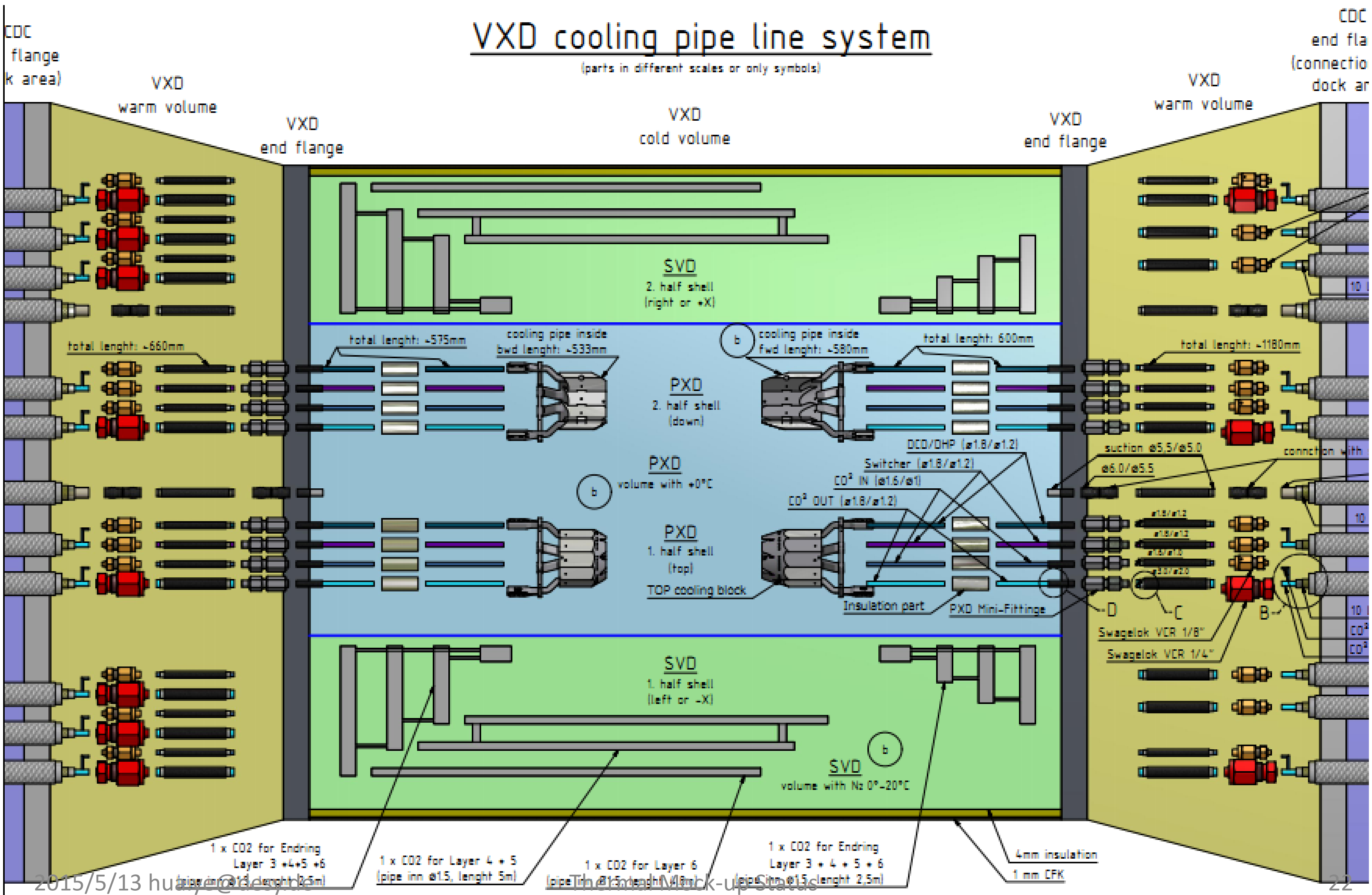
- Build up the thermal mock-up.
- FBG (Fiber Bragg grating) temperature/humidity sensors
- ……

Backup

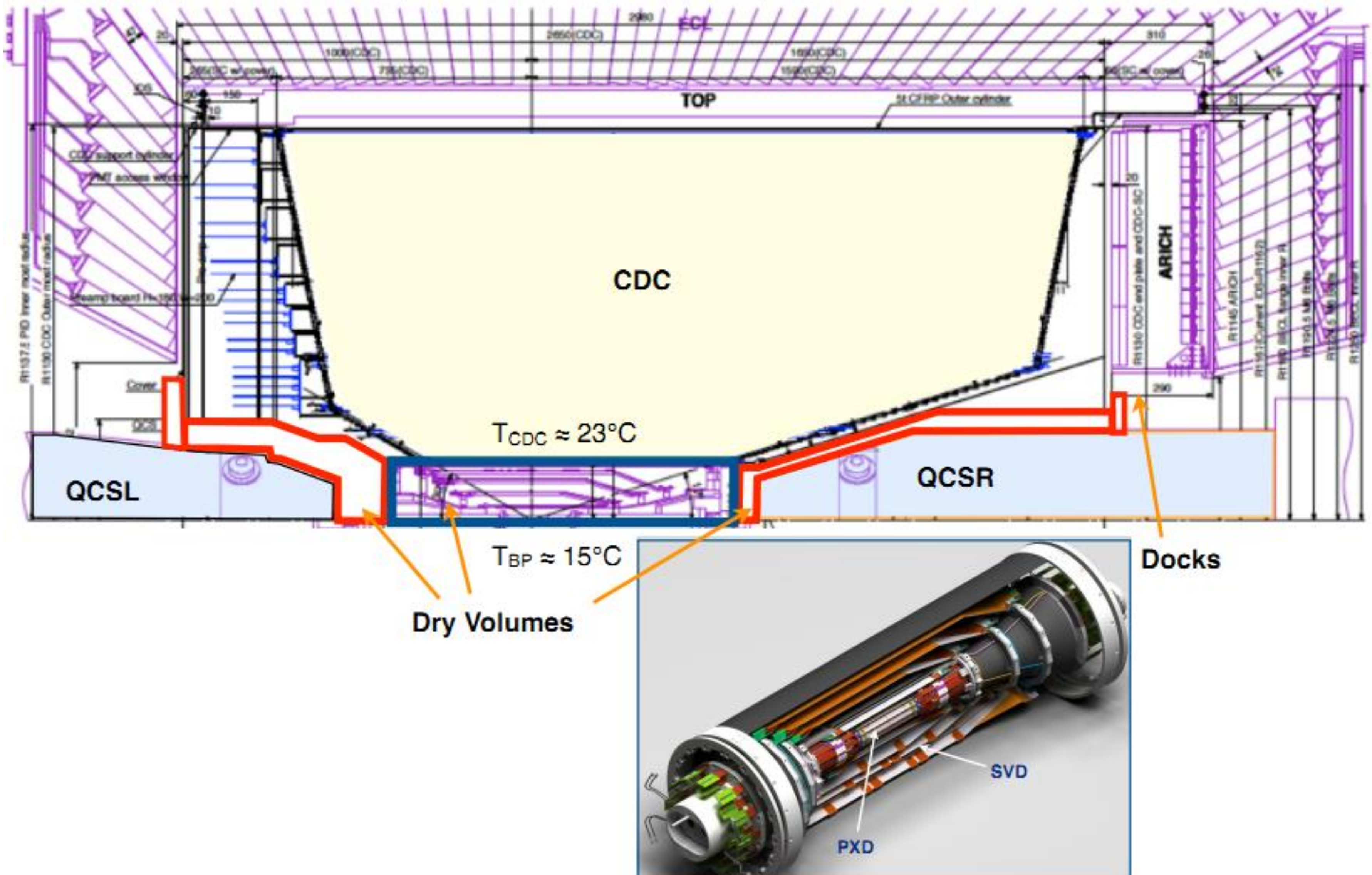
VXD Cooling Pipe Line System



VXD Cooling Pipe Line System



VXD Cooling


TOP
CDC
ARICH
$T_{CDC} \approx 23°C$
QCSL
QCSR
$T_{BP} \approx 15°C$
Docks
Dry Volumes
SVD
PXD