Thermal Design and Test, Design of cold/warm Dry Volume

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2017.10.15-17, BPAC focused review on VXD

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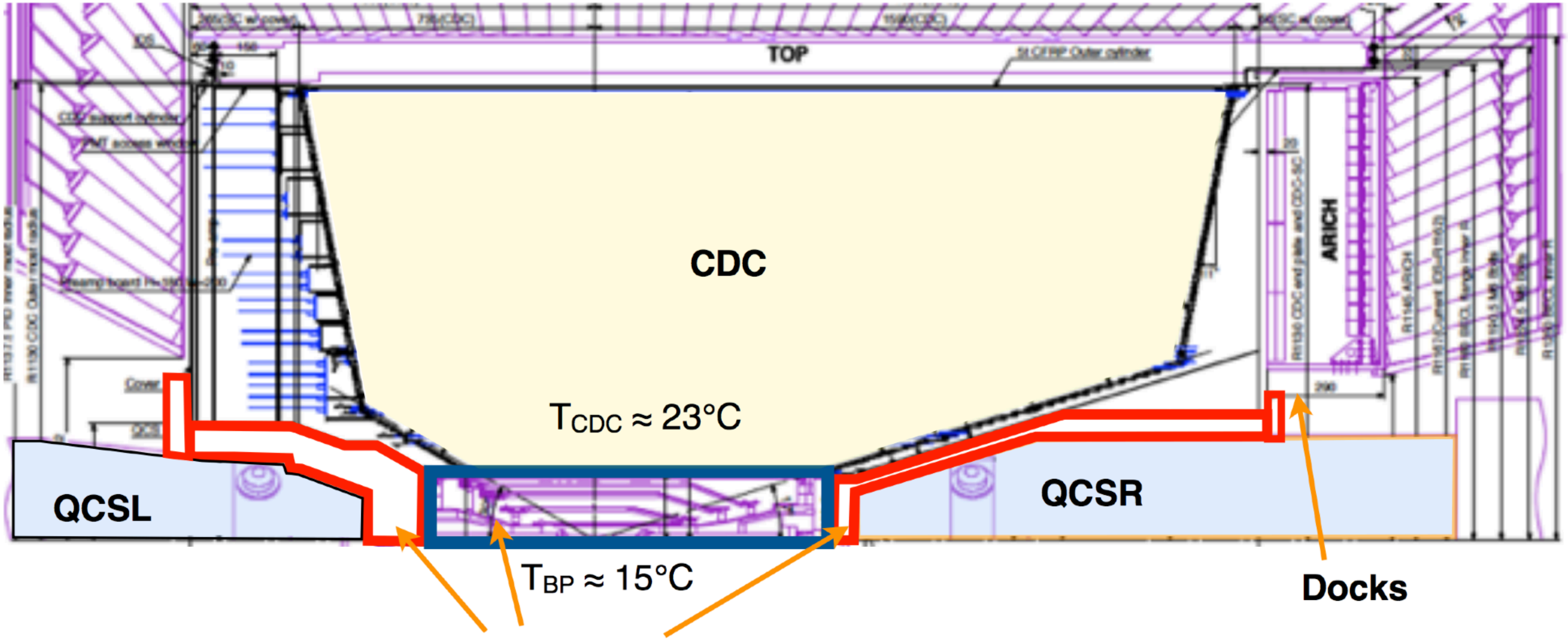
VXD Thermal Environment



"Cold" and "warm" Dry Volumes

VXD Power consumption

- PXD 420W
- SVD 700W
- required cooling capacity of ~ 2-3kW

Constant temperature at inner surface of CDC is essential for stable calibration and dE/dx performance

- minimize thermal impact from VXD

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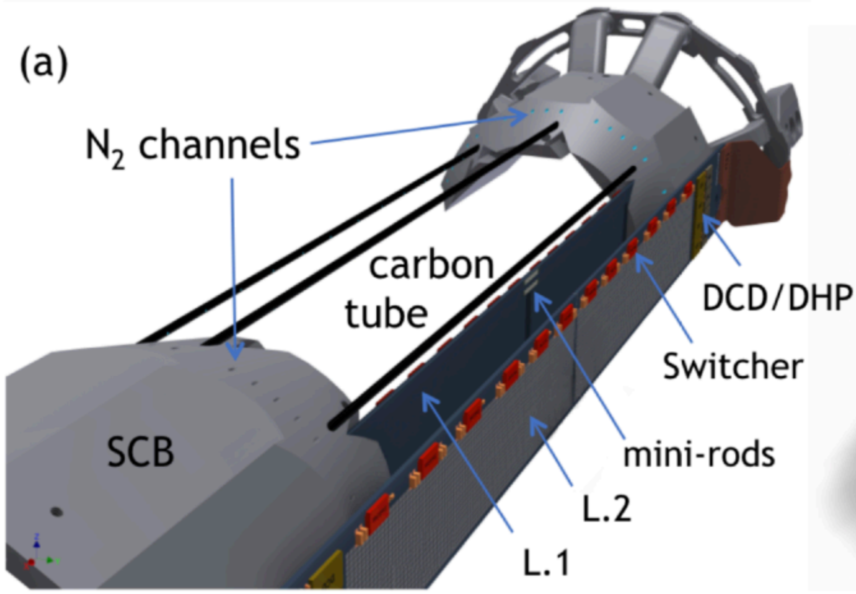
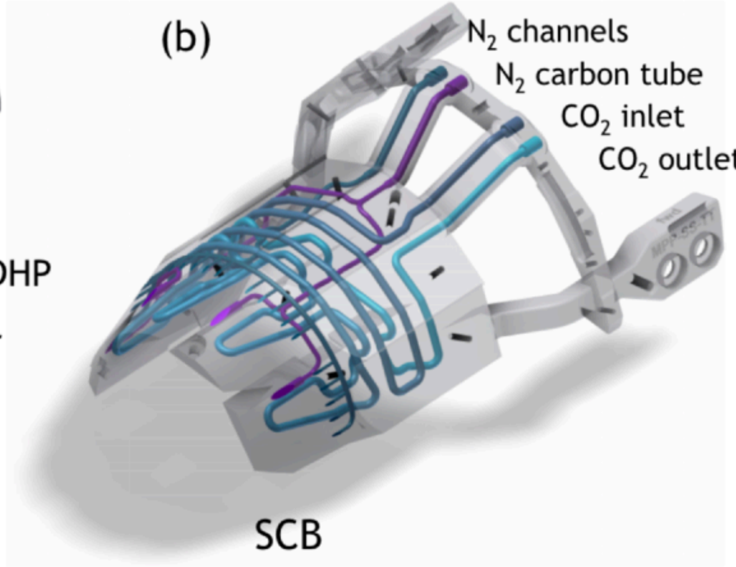
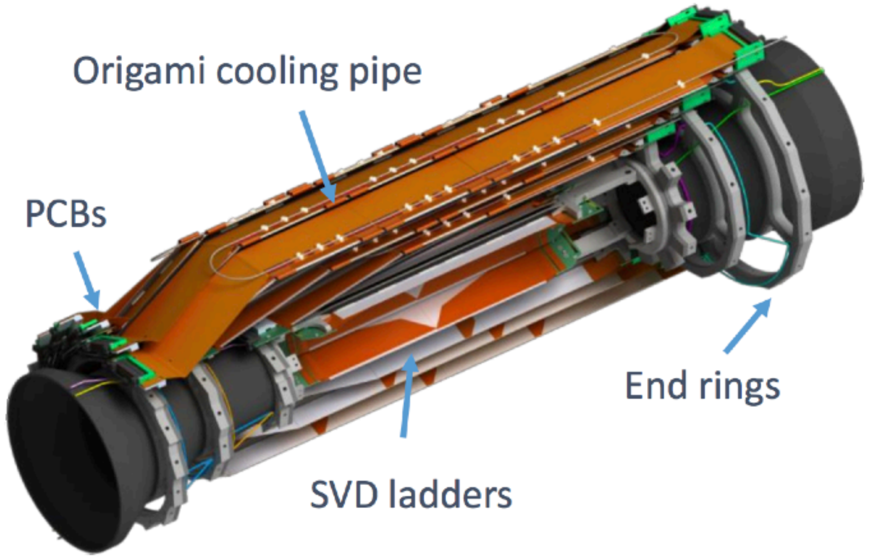
VXD Thermal Design





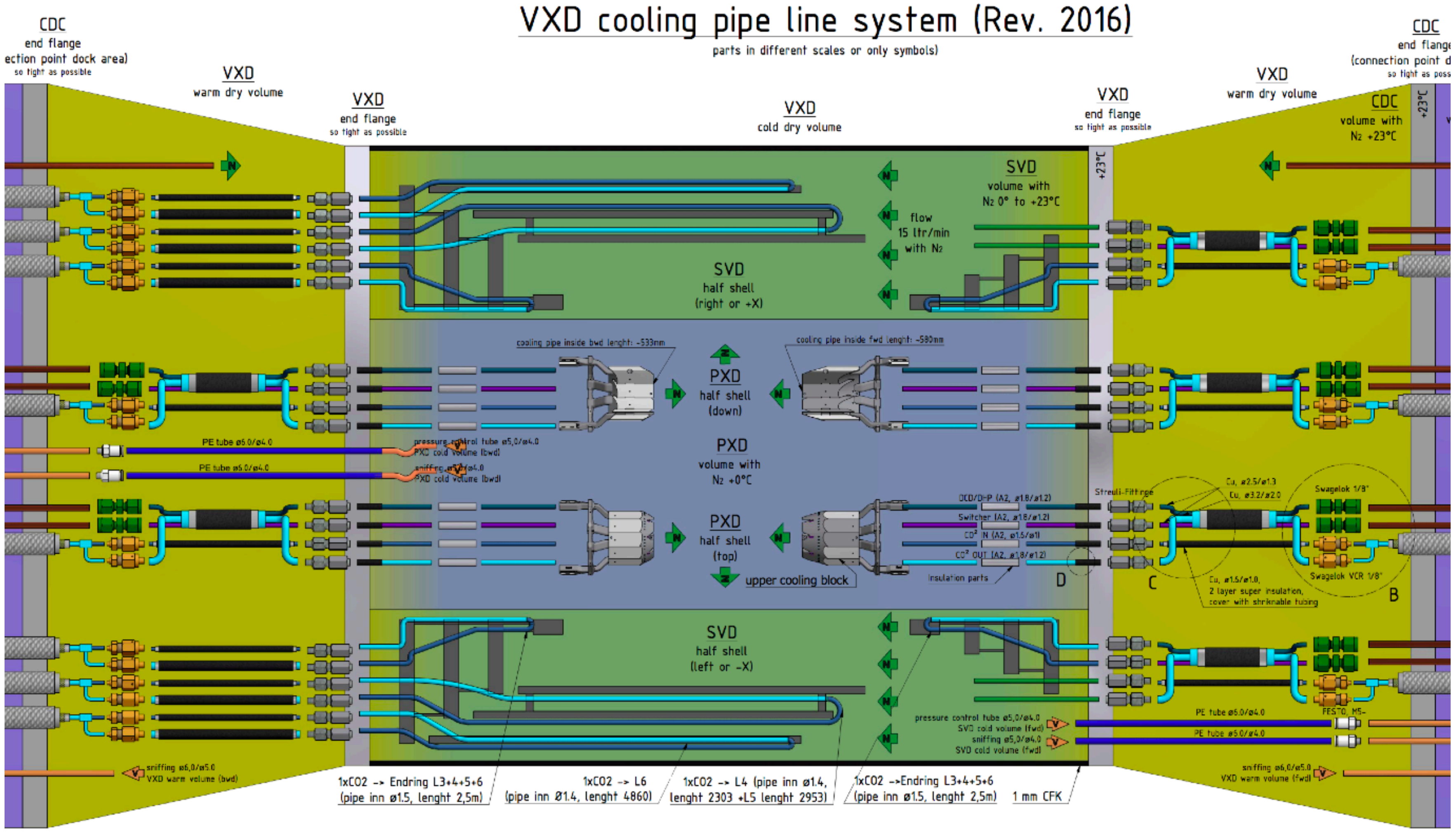


Power consumption

- PXD 420W
- SVD 700W
- required cooling capacity of ~ 2-3kW

In total need 12 independent cooling circuits

- 4 PXD SCBs (105W)
- 4 SVD endrings (93W)
- 4 SVD origami cooling pipes (68/96W)



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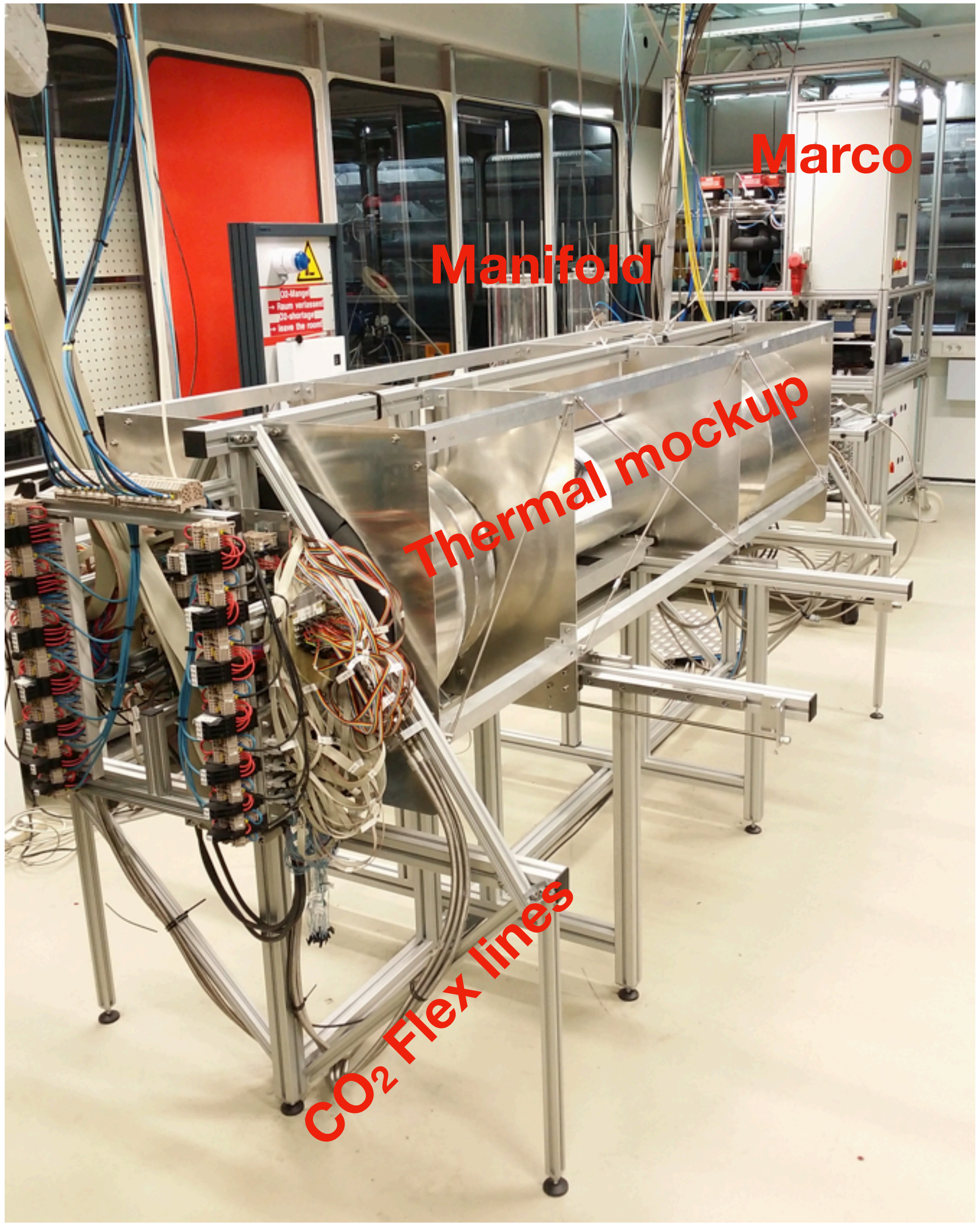
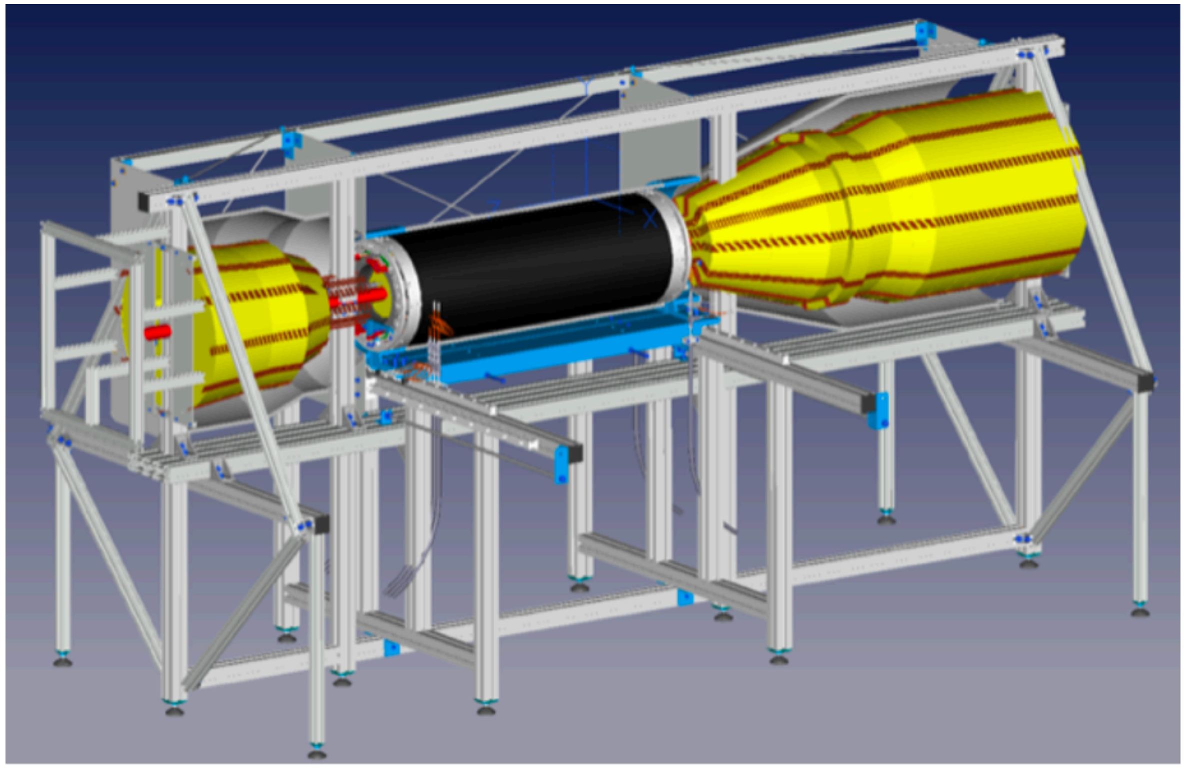
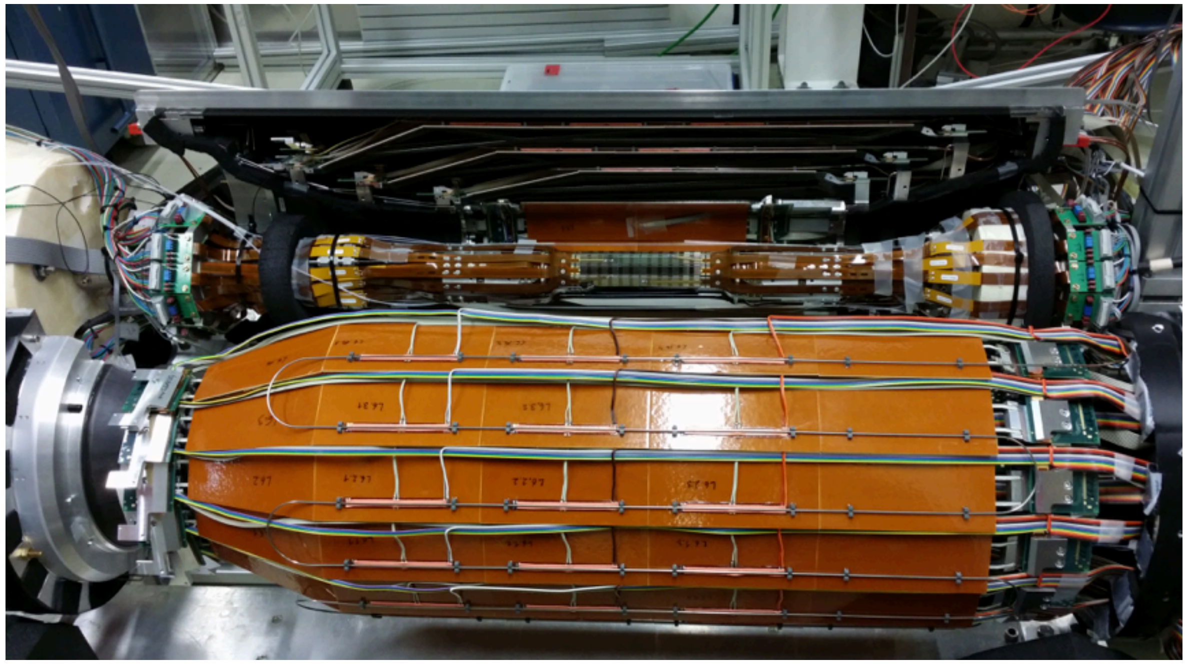
VXD Thermal Mock-up







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Summary of Thermal Results

Executive summary of results from PXD-only studies

- An optimal CO_2 temperature of ~ **-30°C** has been established
- with N_2 flow of 20 L/min to SCBs, temperature on PXD ladders is < **33°C** (DCD/ DHP~**20°C**).
- cooling effect of N_2 rather **independent** of N_2 temperature
- temperature gradient in z-direction in sensitive area **ΔT_z ~ 8°C**
- top-bottom temperature gradient in PXD volume **ΔT_y ~ 5°C**
- 20 L/min N_2 injection induces only **negligible vibrations** of PXD sensors

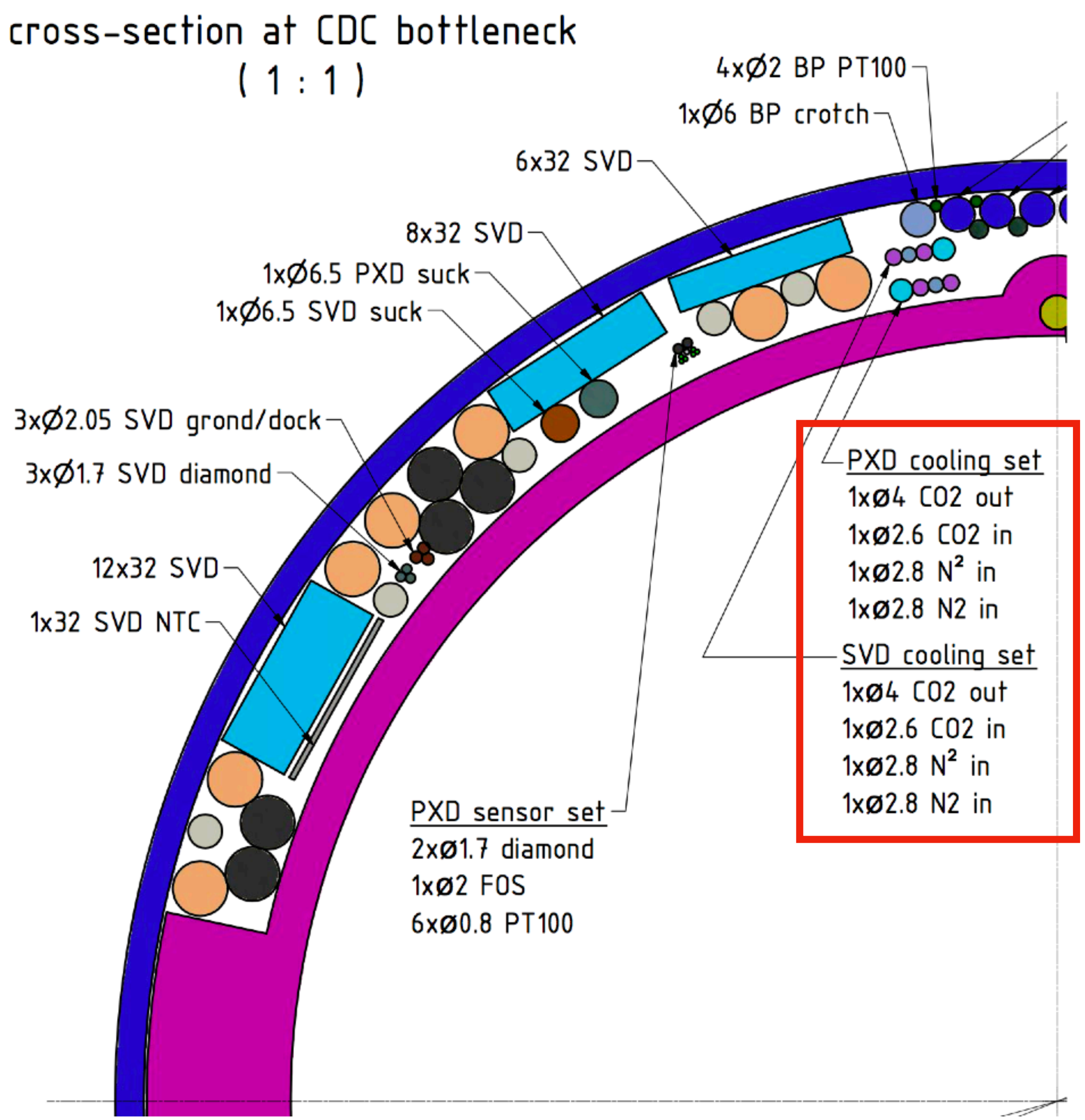
Results from SVD studies

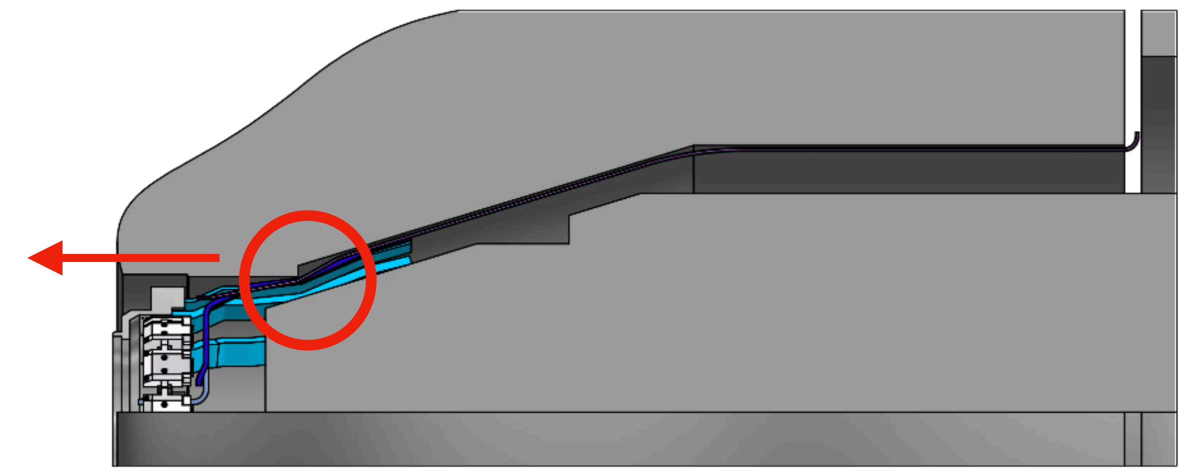
- temperature on SVD is well under control **<30°C** expect L.3
- local high temperature (>**60°C**) observed on L.3, Cu figures are inserted to improve thermal conductivity.
- Heat transport through SVD cables has only **minor effect** on temperature distribution

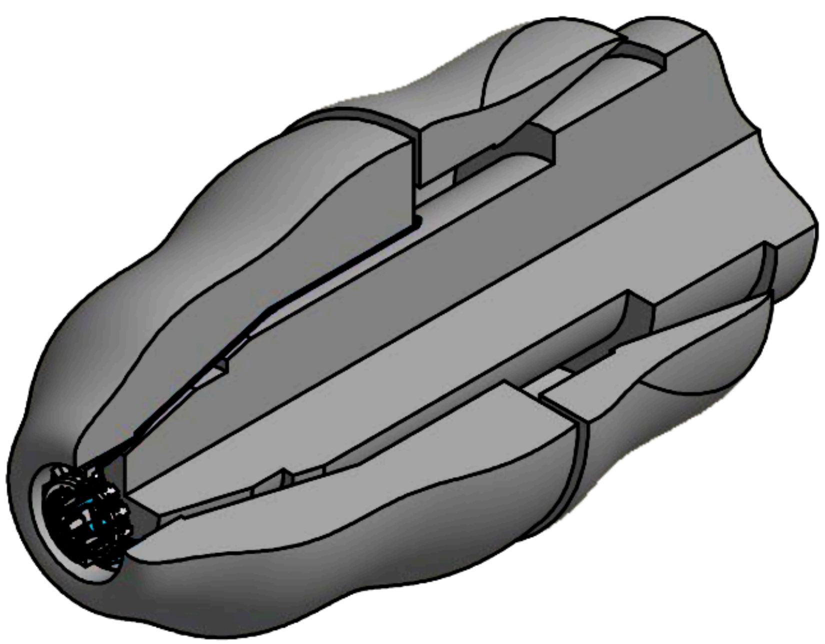
"Cold" and "warm" dry volume

- In VXD volume, the dew point is ~ **-35°C**
- top-bottom temperature gradient on CFRP shield is **ΔT_y ~ 5°C**
- Temperature on CDC inner cylinder range from **15°C** (top) to **8°C** (bottom)
- N_2 injection **~15L/min** into warm dry volume is required to avoid condensation on unprotected CO_2 pipes

CO_2 pipes in Warm Dry Volume







K. Ackermann, MPI, 2015

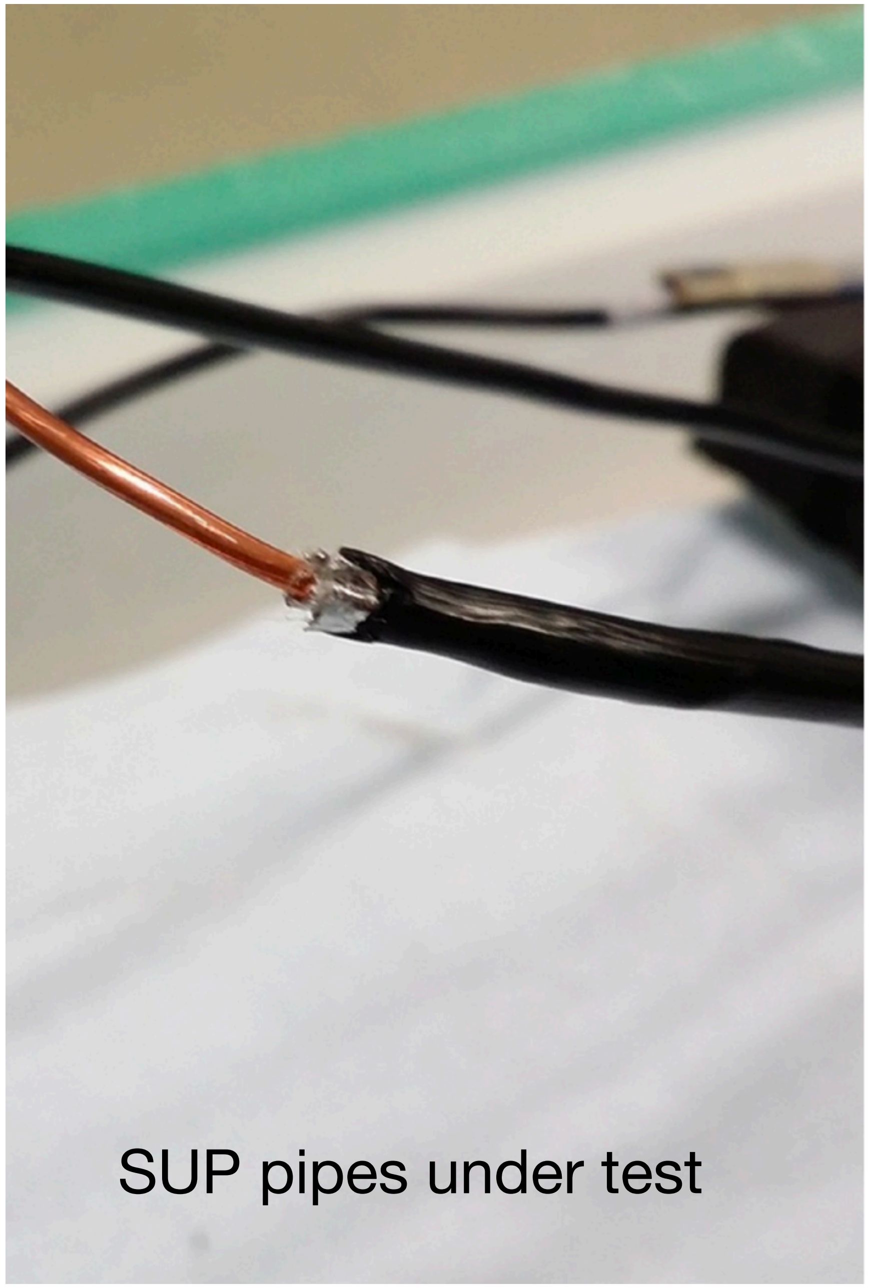
Protection of the CO_2 pipes

- Limited space in warm dry volume
  - no vacuum isolation for CO_2 cooling pipes (OD1.6mm, Cu lines)

- Condensation is unacceptable
  - N_2 injection

Need to protect the cooling pipes
- for thermal and electrical isolation

Different protection scheme were tested at DESY
- (SH) 0.1mm Shrink hose
- (PU) 0.1mm Polyurethane (PU) or PU+Shrink hose
- (SUP) 1mm super isolation (shielding) + Shrink hose


SUP pipes under test

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Thermal tests

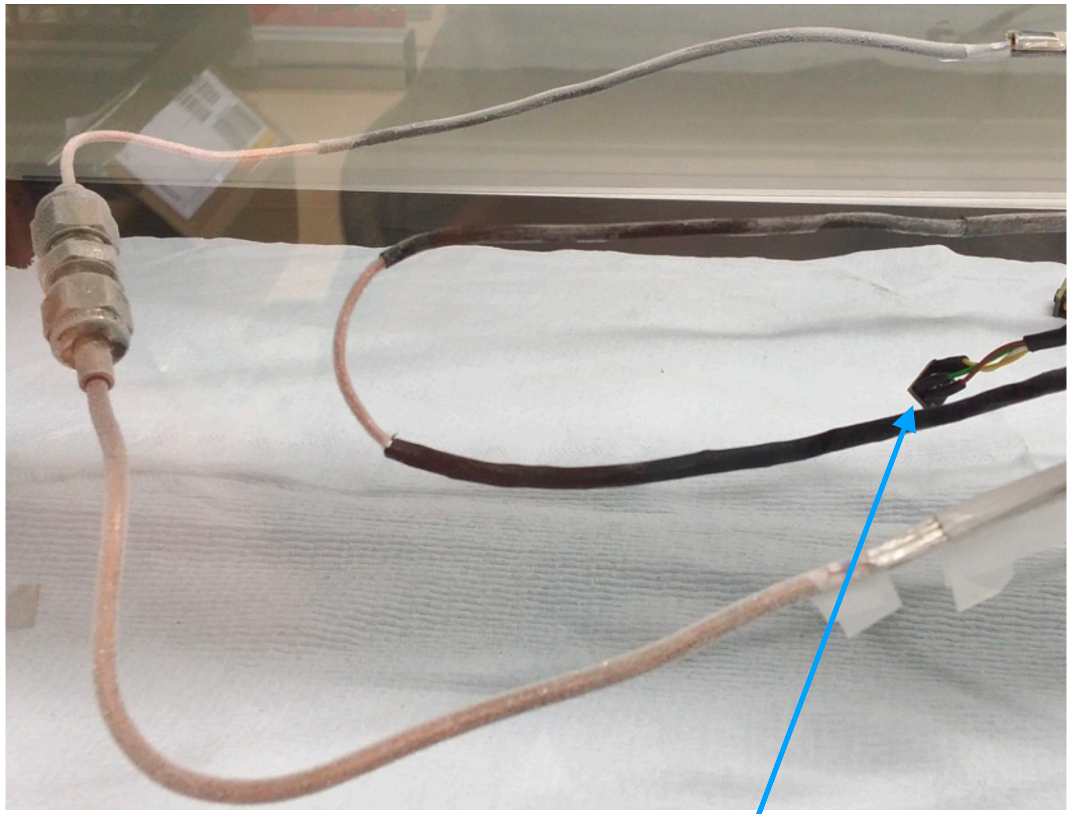
With CO_2 temperature set at -25°C, the environment temperature is about 21°C

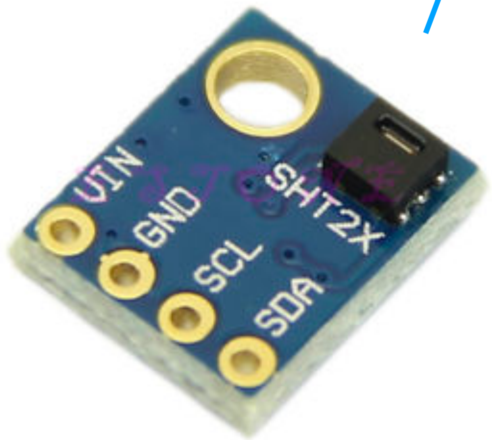
- Surface temperature of

the bare Cu pipes/SH/PU/SUP are
-13/-10/-8/5°C

We increased the humidity (HR)

- when HR ~ 7%, dew point (DP) ~ -16°C,
  condensation appears on Cu pipes
- when HR ~ 11%, DP ~ -11°C,
  condensation on Shrink hose
- when HR ~ 13%, DP ~ -9°C,
  condensation on PU and PU+shrink hose
- when HR ~ **25%**, DP ~ 0°C,
  condensation on **super isolated pipe**





Commercial Humidity and Temperature IC

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CO_2 pipes prepared at DESY

Inflatable seals

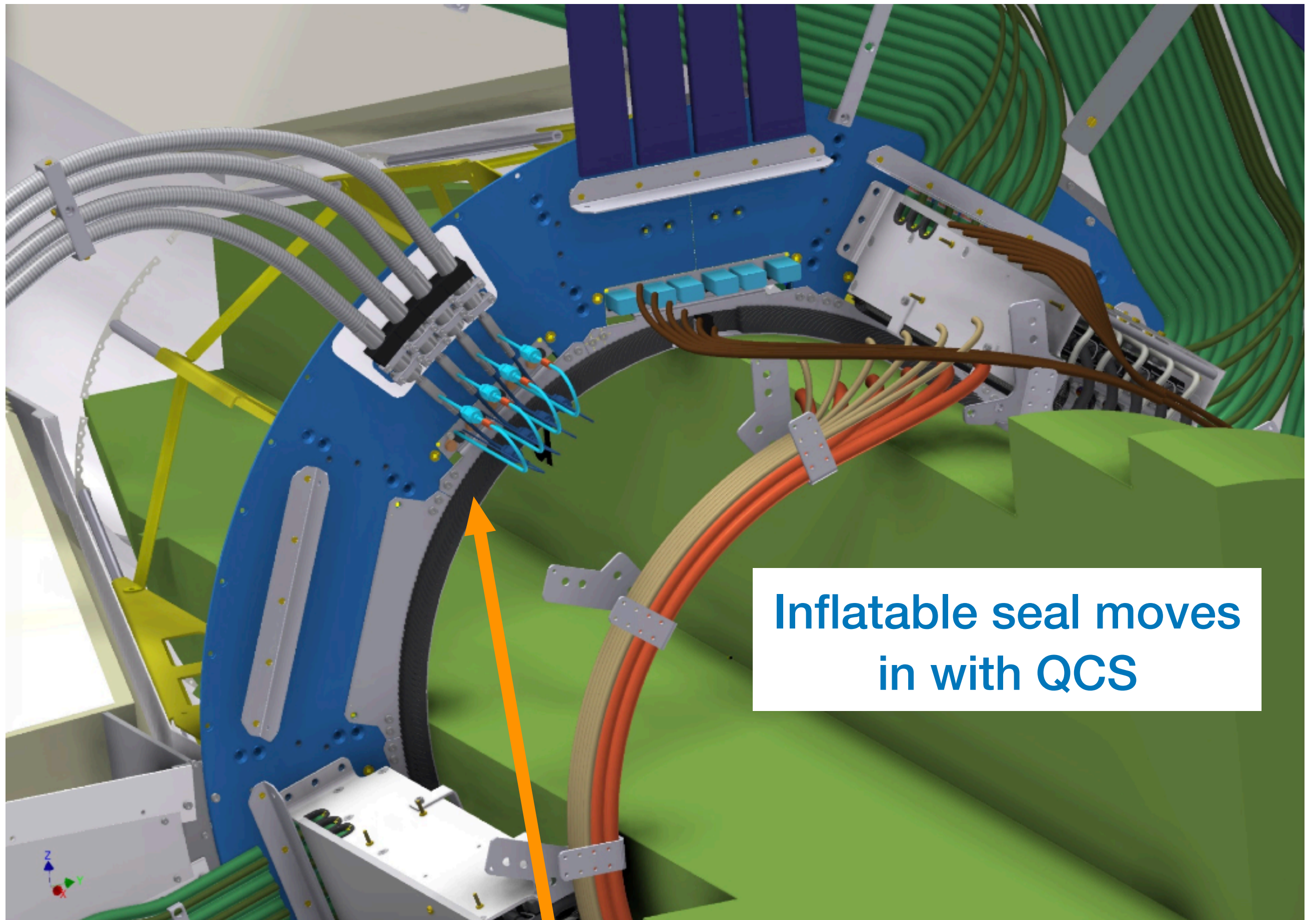
Super isolated CO_2 pipes

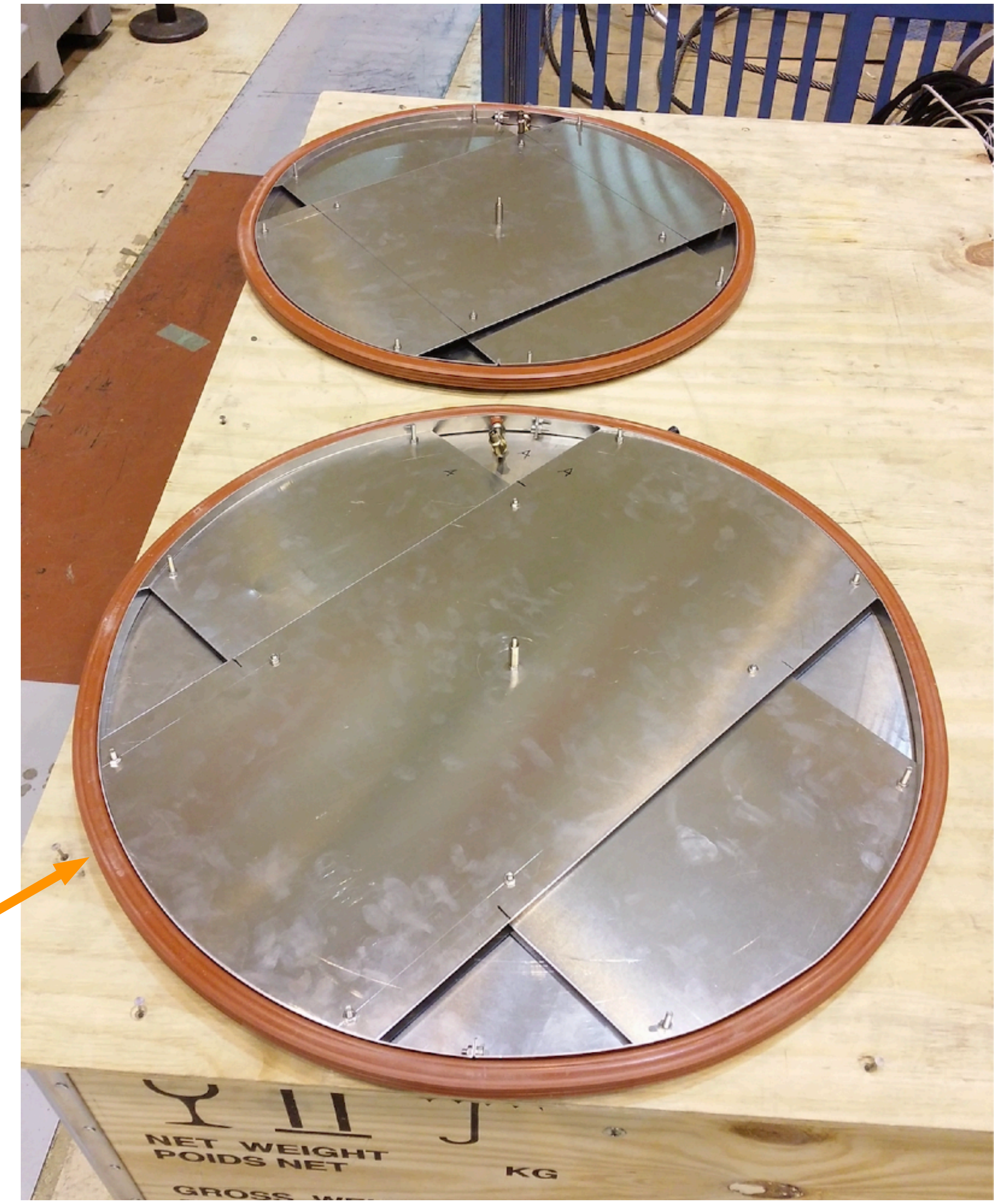
Finalized Super isolated CO_2 pipes (OD 5mm):

PU+shielding+Shrink hose

The pipes have arrived at KEK, together with the inflatable seals.

Close the Dry Volume





The setup to check the BEAST II system before the QCS moves in. Later the seal will be mounted on the QCS.

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Summary

Thermal design and tests:

Various thermal and mechanical tests have been carried out with the full-size thermal mock-up at DESY.

- An optimal CO_2 temperature of ~ -30°C has been established.
- 20 L/min forced N_2 flow to SCBs is required.
- Temperature on the sensors are under control.
- Vibration on PXD ladders is negligible.

Cold/warm dry volume:

- Local dew point in VXD volume reaches -35°C.
- The super isolated CO_2 lines are used in the warm dry volume, the requirement to humidity can be less critical.
- The warm dry volume will be closed with inflatable seals, which will move in together with the QCS.

Backup

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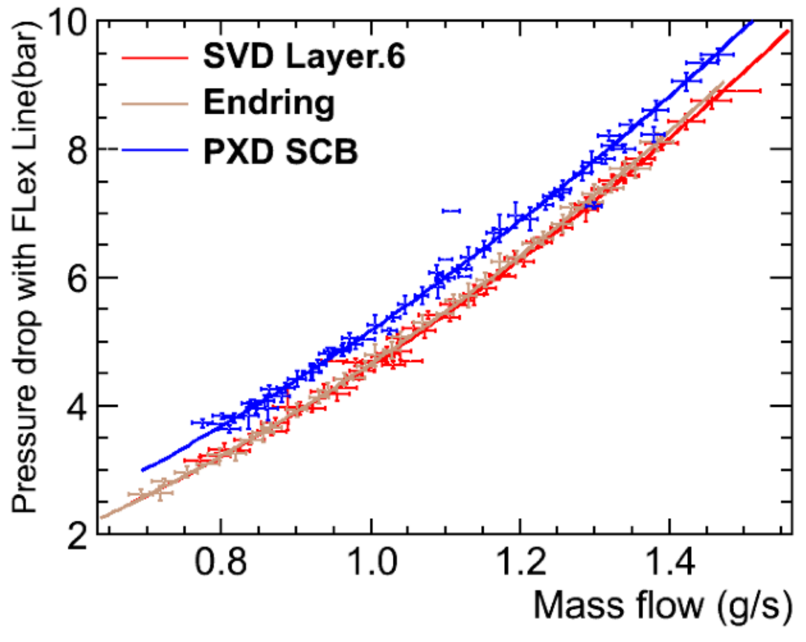
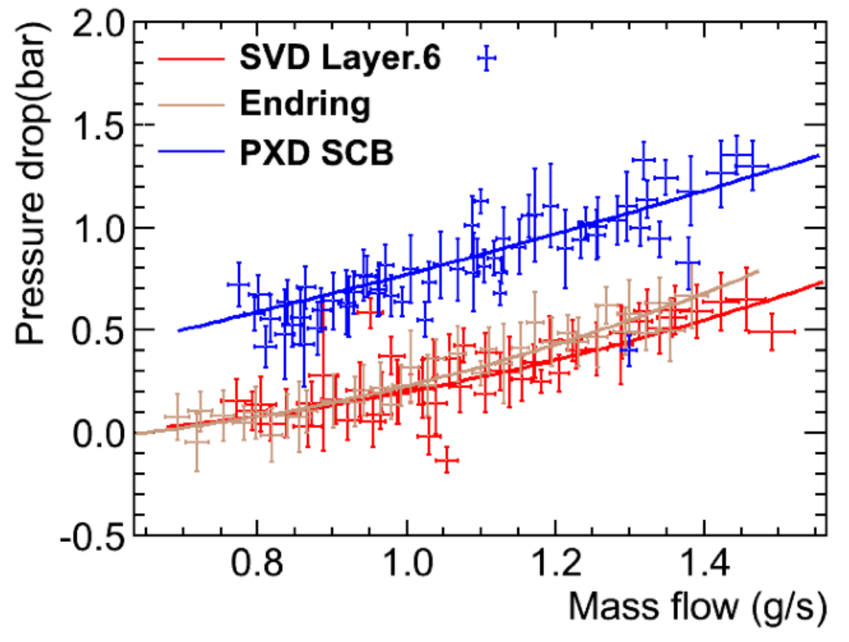
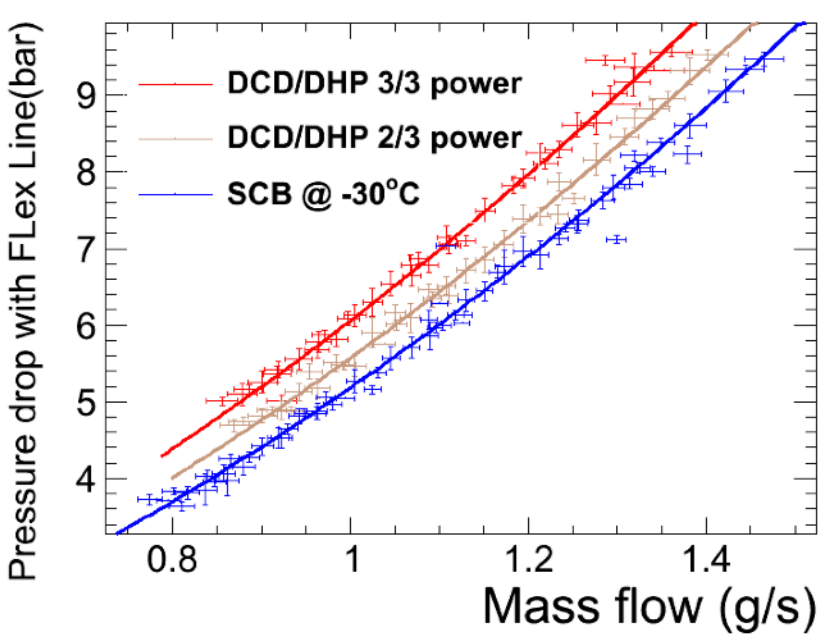
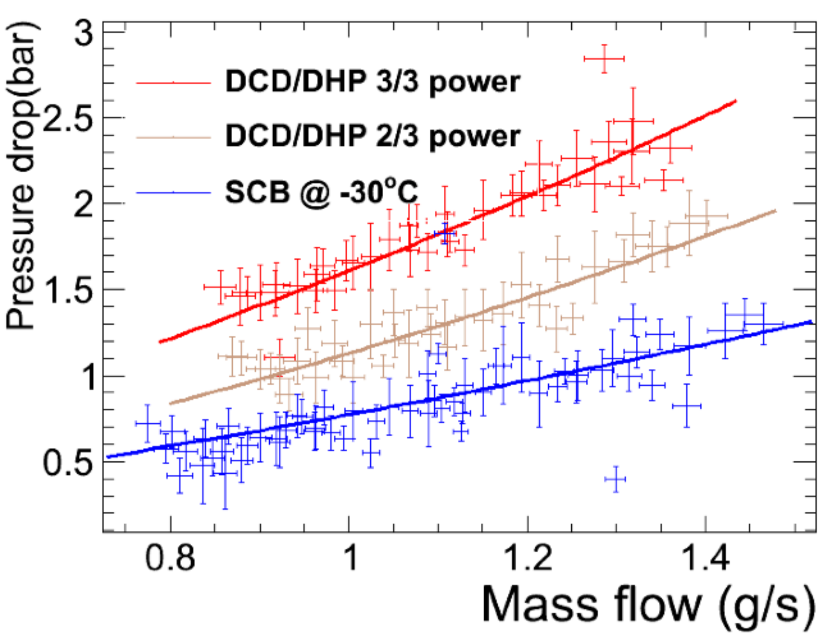
Pressure drop in Cooling Circuit





- The long and thin cooling lines cause pressure drops, which result in temperature gradients.
- Relatively big contribution of pressure drop in transfer flex line, to ensure balanced CO_2 mass flow in each circuit.

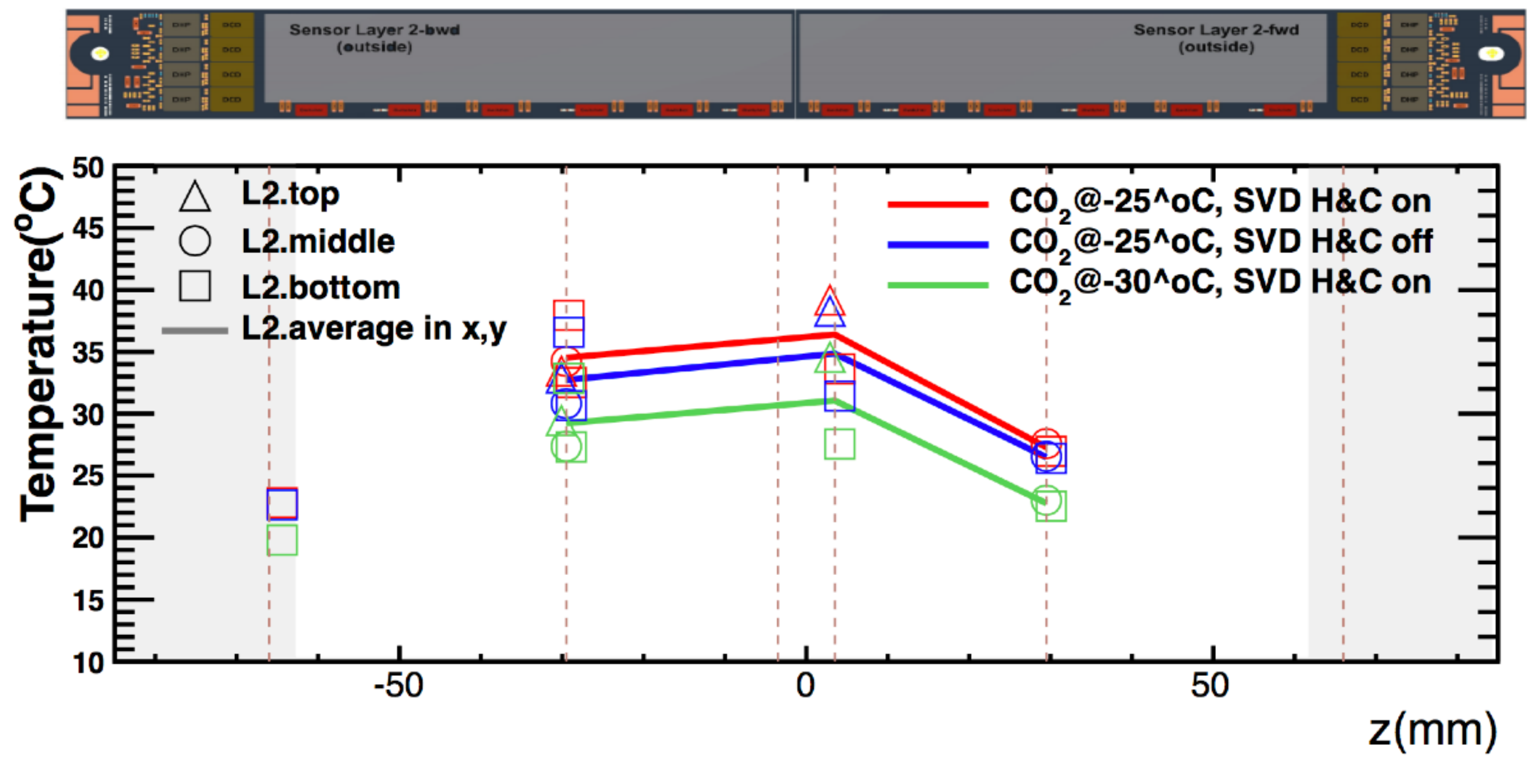


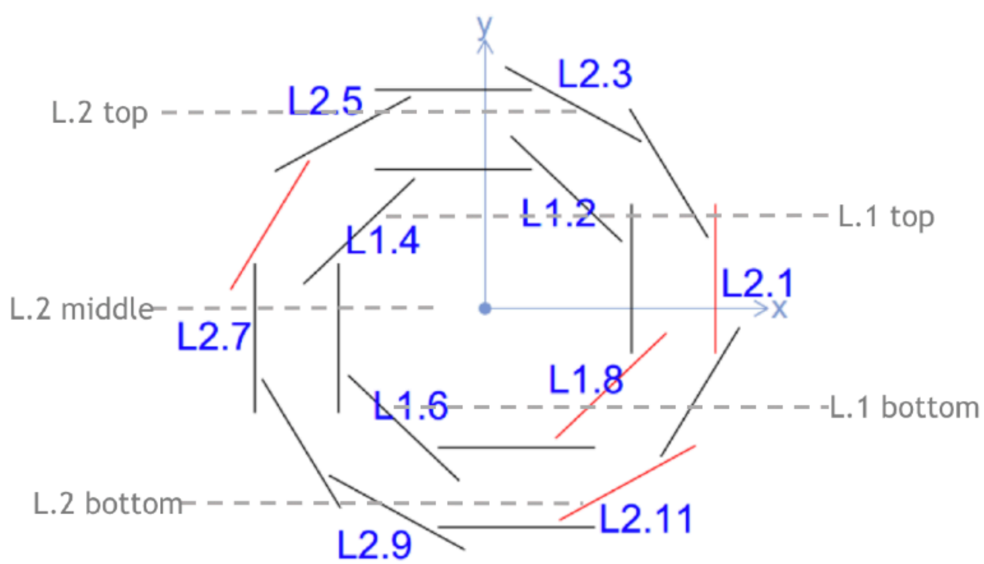


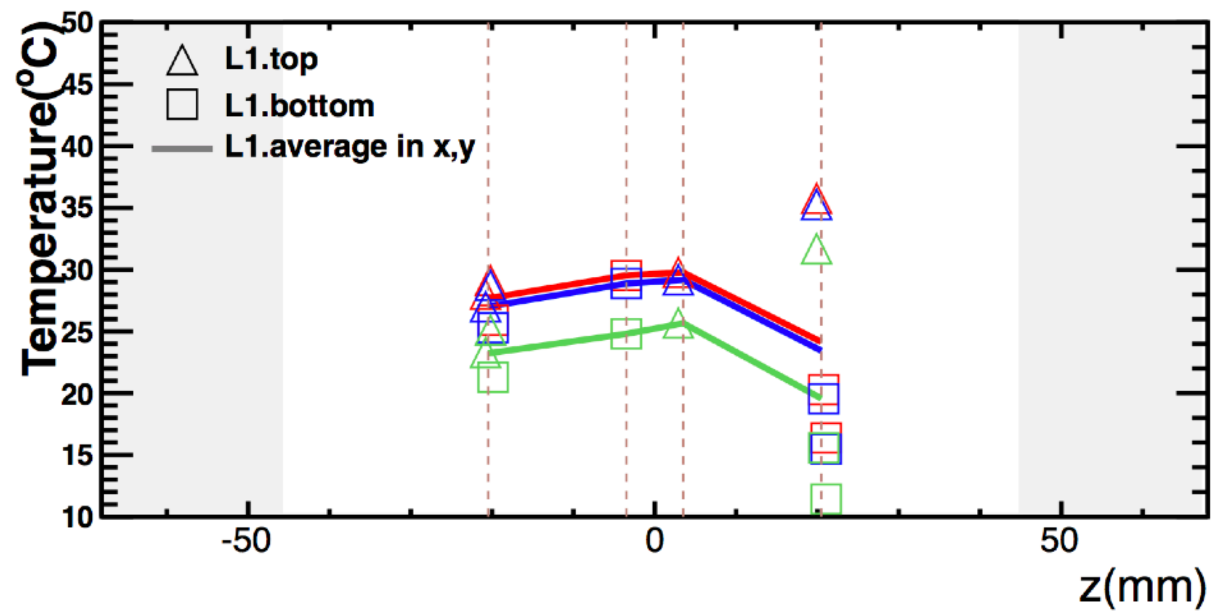
- Additional pressure drop of about 1 bar results from the heat load in PXD ASICs.

Temperature Distribution on PXD

- CO_2@-25/-30°C; N_2 20L/min
- Power consumption*:
  - DCD/DHP 9W, Switcher 1W,
  - matrix 0.5W
- Temperature is monitored by resistance thermometers.
- With SVD cooling and power on, temperature on PXD changes ~2°C.



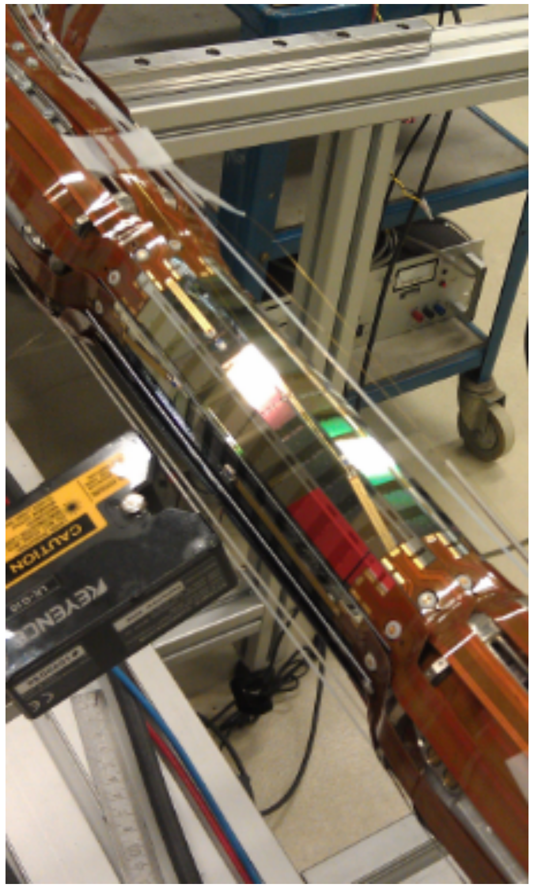




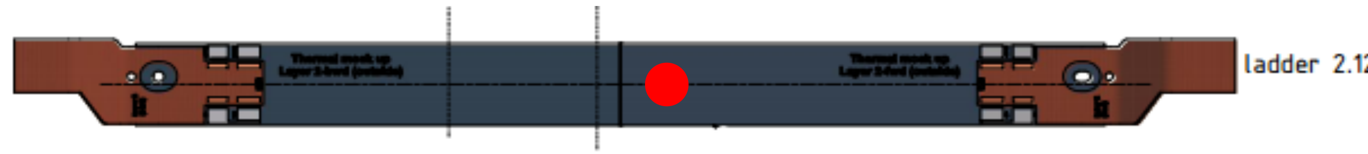
- By changing the CO_2 set point, the temperature distribution gets shifted, while the gradients stay.
- By increasing the N_2 flow, the gradient gets improved.

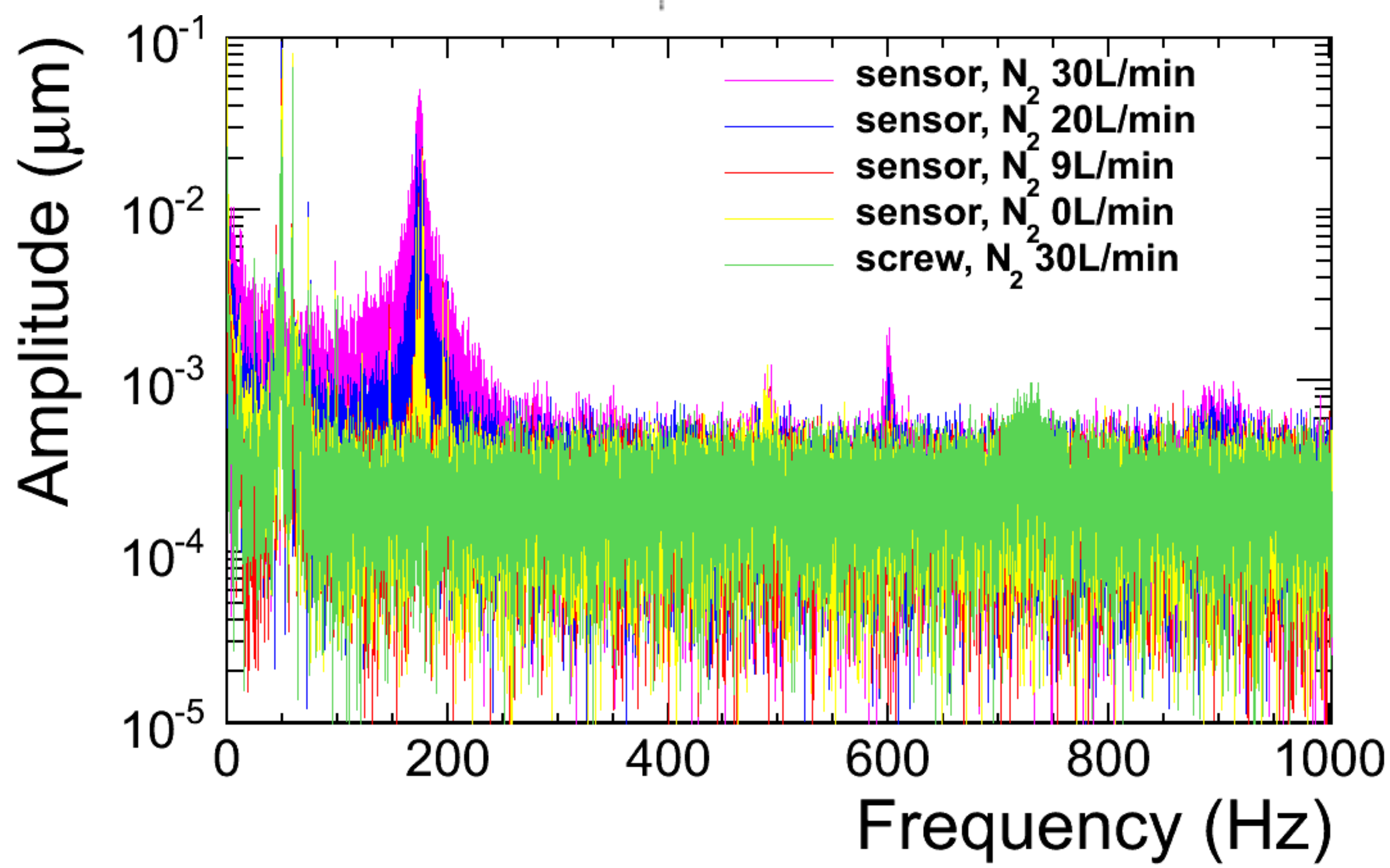
ΔT_Y ~ 5°C, ΔT_Z ~ 8°C

Vibration v.s. N_2 flow

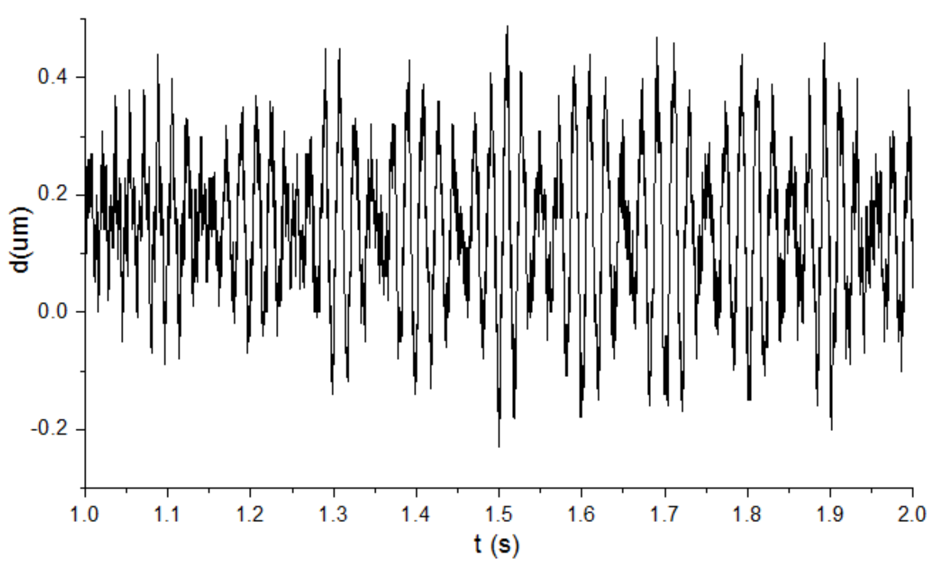


Using non-contact laser displacement sensor



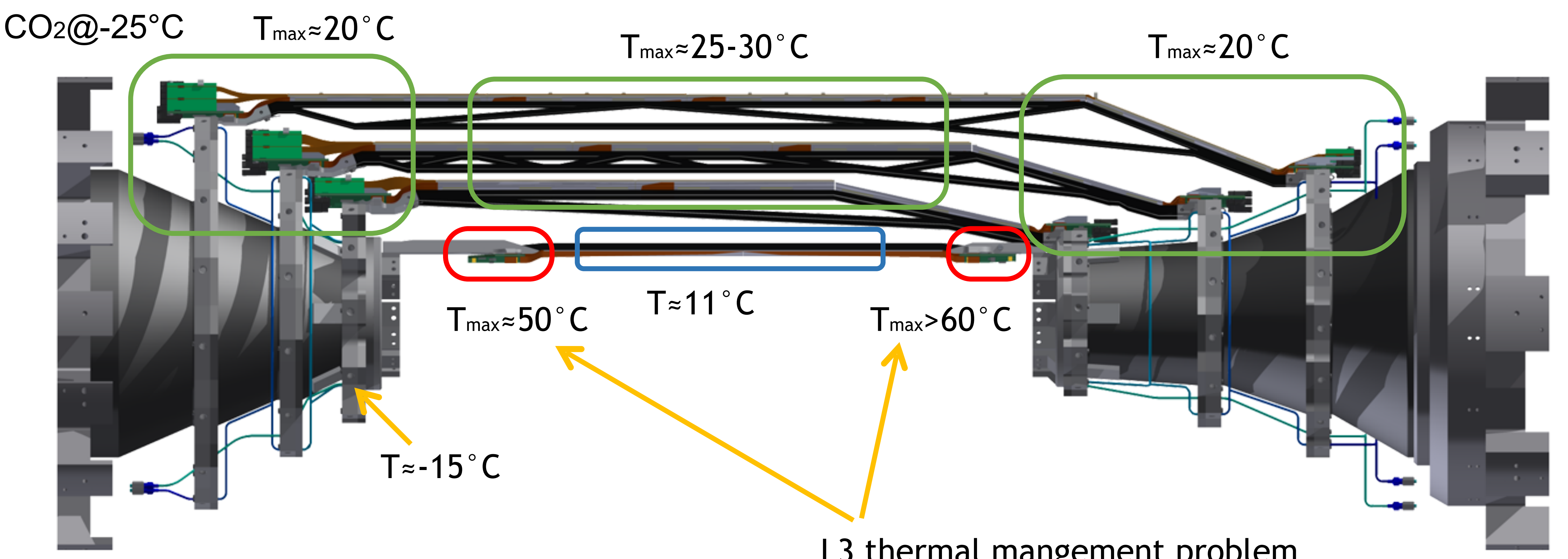


Vibration with RMS amplitude about 0.2um.



- A peak at about 175 Hz is observed, amplitude increases with the flow rate reaching about 0.02μm when 20L/min of N2 is injected.
- Flat background indicated by the measurements at the fixation screws on the SCB.

Temperature in SVD

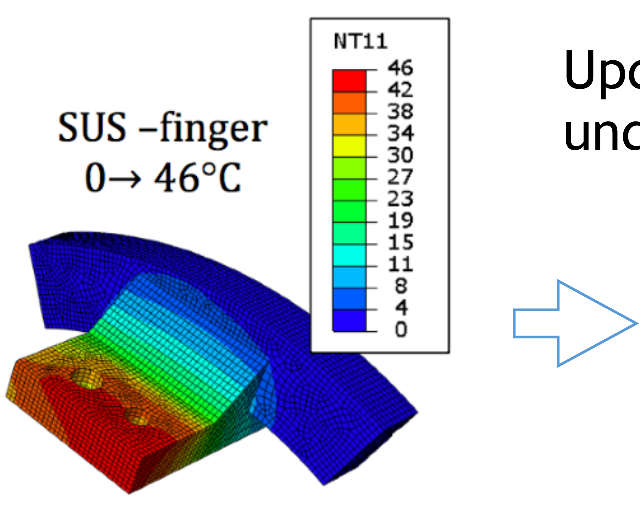


L3 thermal mangement problem

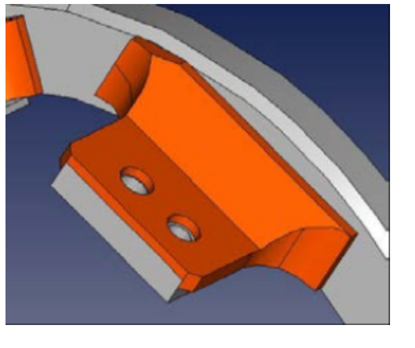
- Finite Element (FE) Simulation indicates most of the gradient (~45°C in FW) is in the endring finger, made of stainless steel.

- Temperature in the middle of L.3 sensors is strongly influenced by PXD, therefore relies on the injected N2 flow.

- For L4/5/6, with nominal load, the maximum temperature on FW/BW edges reaches about 20°C, and module ASICs reach about 25-30°C.



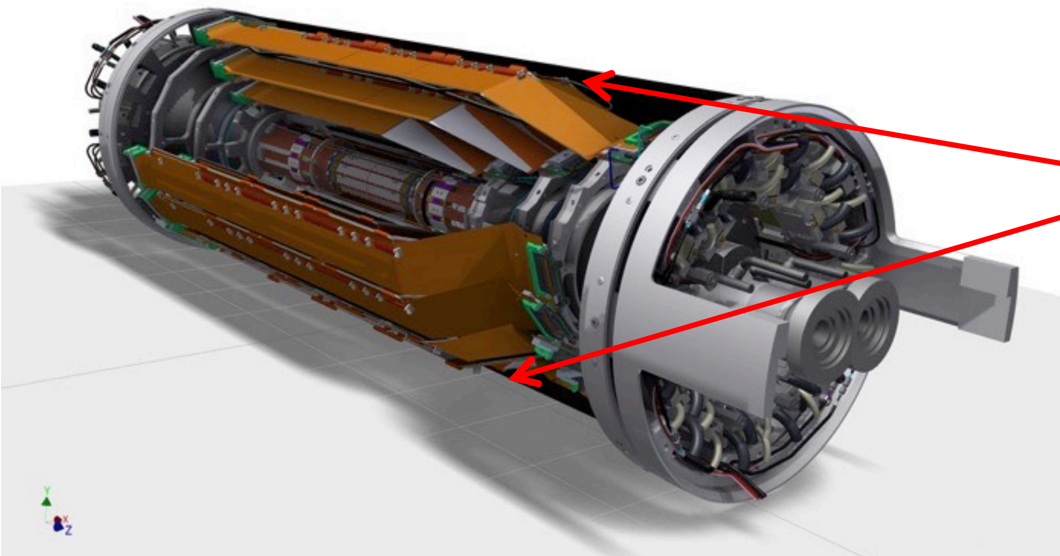
Update with copper insert, under testing in Melbourne.



Temperature in VXD Volume

Temperature on the top/bottom of inner side of VXD CFRP shield and CDC inner surface (Al shield).

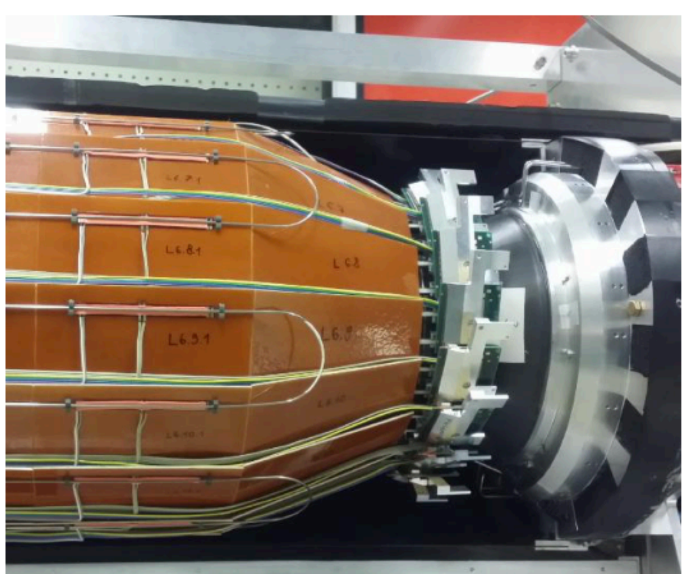
CO_2@-25°C

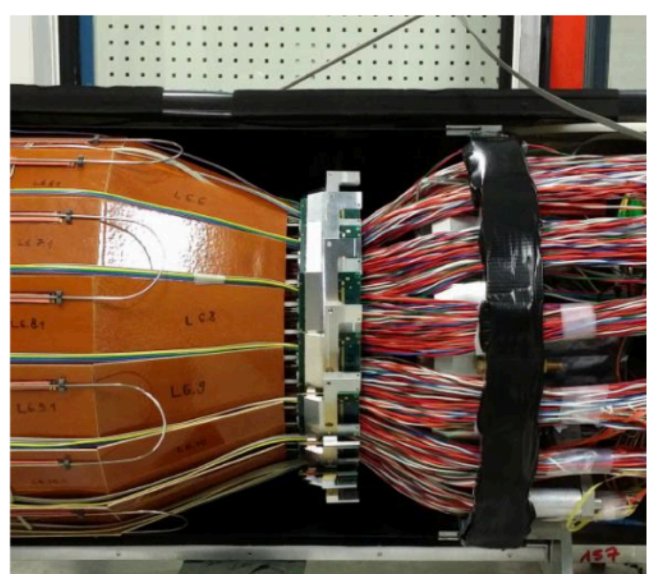


	VXD shield inner surface	CDC inner cover
top	10	15
bottom	4	8

About 6°C's gradient.

Thermal transfer through cables





- Electronic cables are insert to FW +x half endring, contacting L5&6.
- Little influence from cables' thermal conductivity.

Dew Point in Dry Volume v.s. N_2 flow