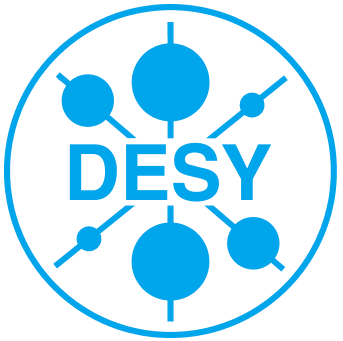


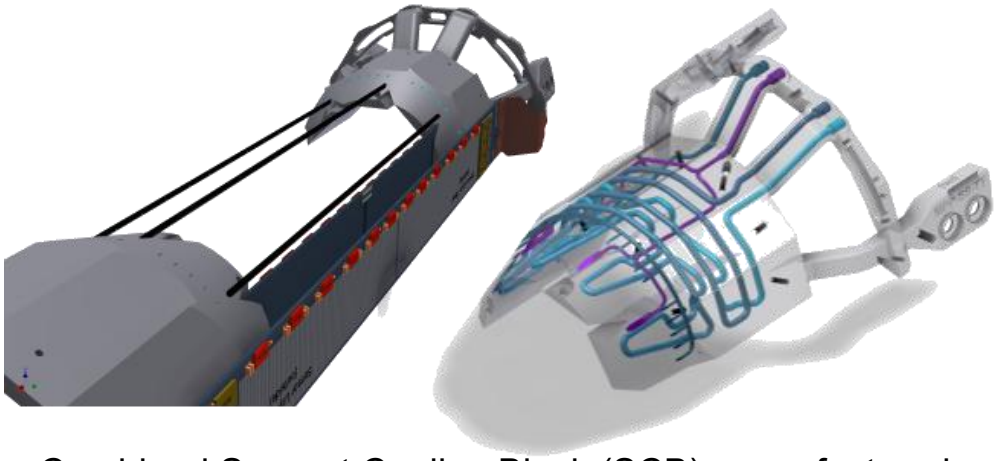
Thermal Test of the Belle II Vertex Detector

H.Ye, C.Niebuhr, R.Stever, K.Gadow, C.Camien

DESY Belle II group

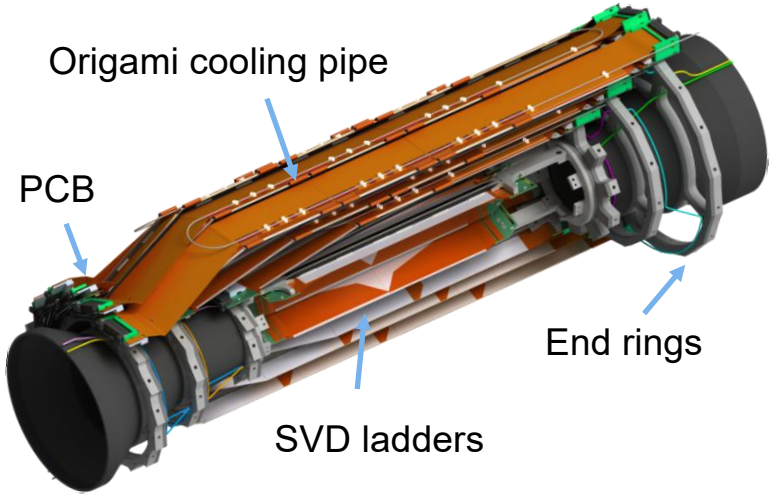
VXD Cooling System

Cooling of the PXD



Combined Support Cooling Block (SCB), manufactured using 3D printing technology, with CO_2 and N_2 channels inside.

Cooling of the SVD



Requirements

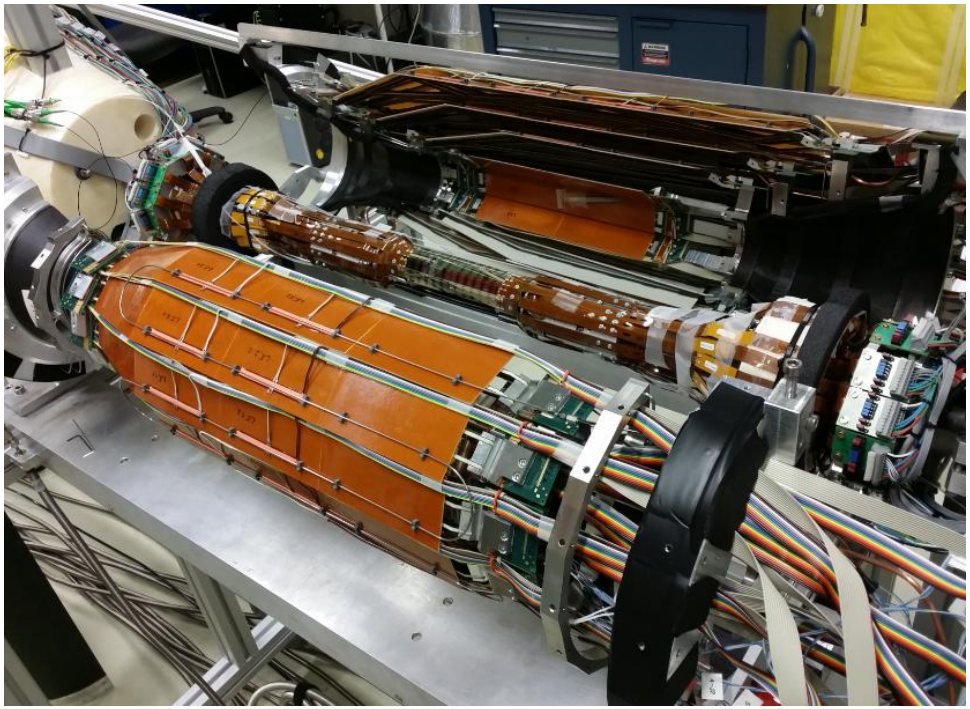
- ❑ PXD: Sensor < 25°C to minimize shot noise due to leakage current; A Sics < 50°C to avoid risk of elector-migration.
- ❑ SVD: APV25 readout chips surface@~0°C for SNR improvement.
- ❑ Power consumption: PXD 360W; SVD 700W, together with the heat load through 9m of vacuum isolated flex lines; required cooling capacity of 2-3kW.
- ❑ VXD needs to be thermally isolated against CDC and beam pipe. Room temperature at the inner surface of CDC is required for stable calibration and DE/dz performance

VXD Thermal Mockup @DESY

Full VXD mock-up is ready, measurements are ongoing.

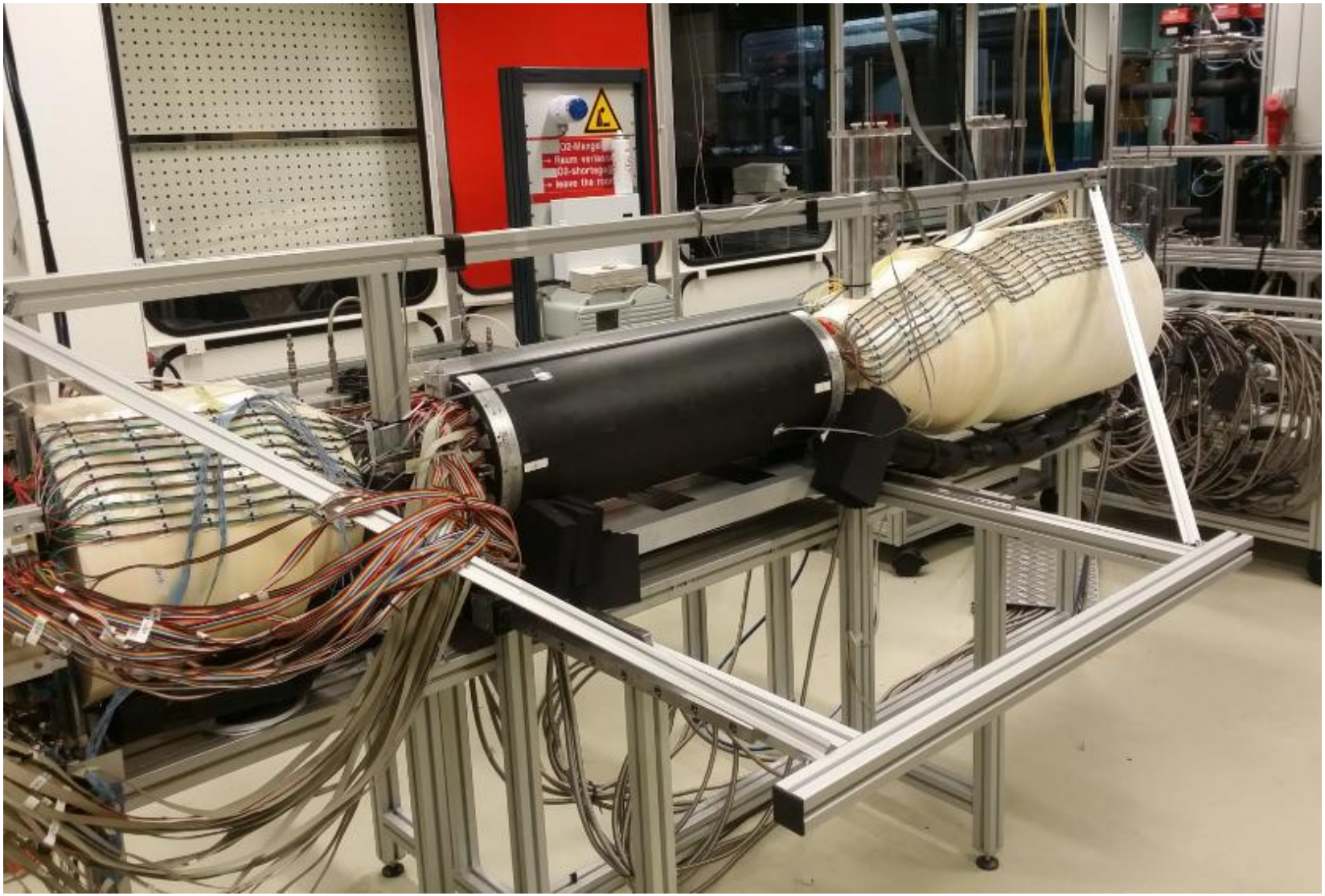
- ✓ 12 cooling circuits
  - ✓ 4 PXD
  - ✓ 4 endrings
  - ✓ 4 origami cooling pipes
- ✓ about 1kW heat load in VXD detector.
- ✓ Half of the designed power applied to L.3

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
designed heat power					sum SVD	700
					sum VXD	1060

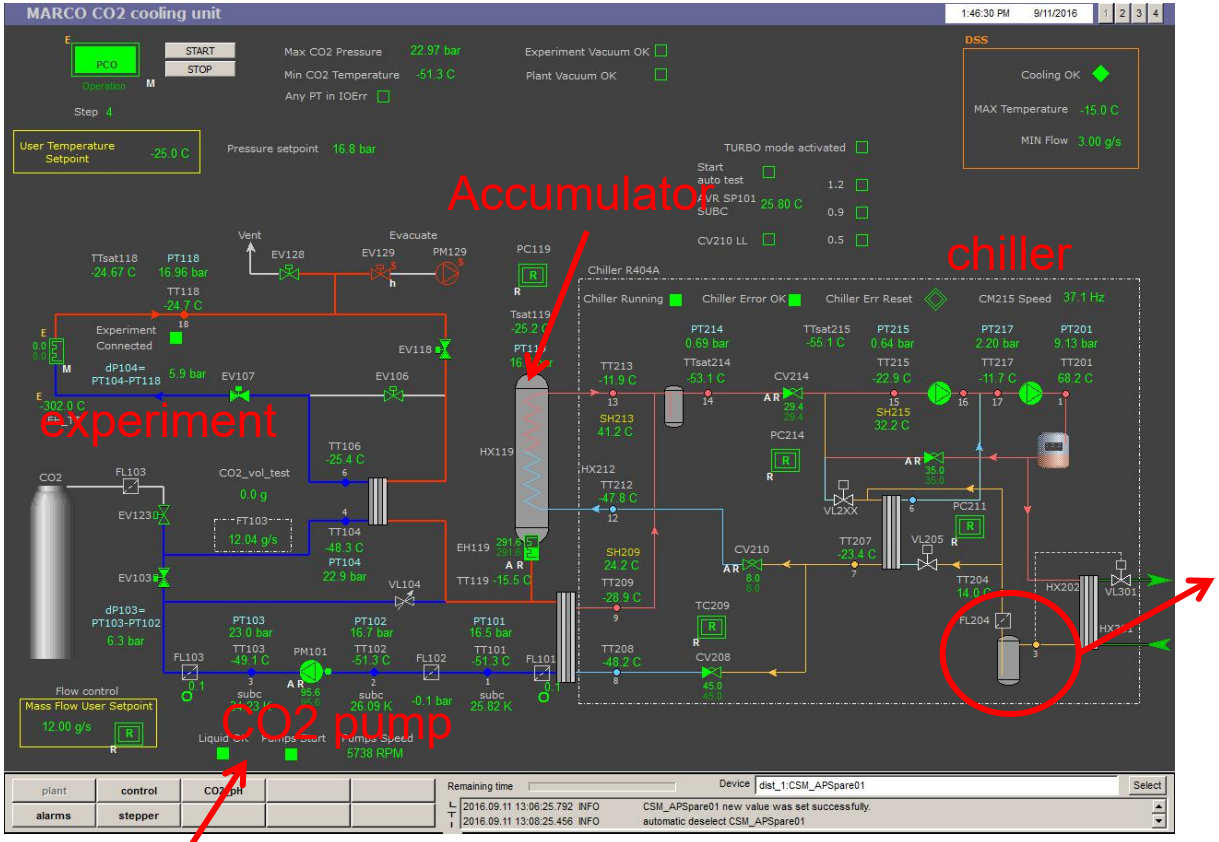


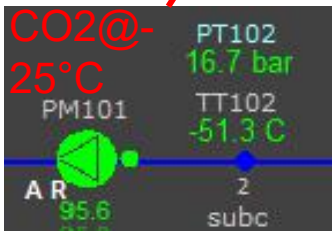
pic in July.2016, +x half of L.6 was missing.

VXD Thermal Lockup @DESY



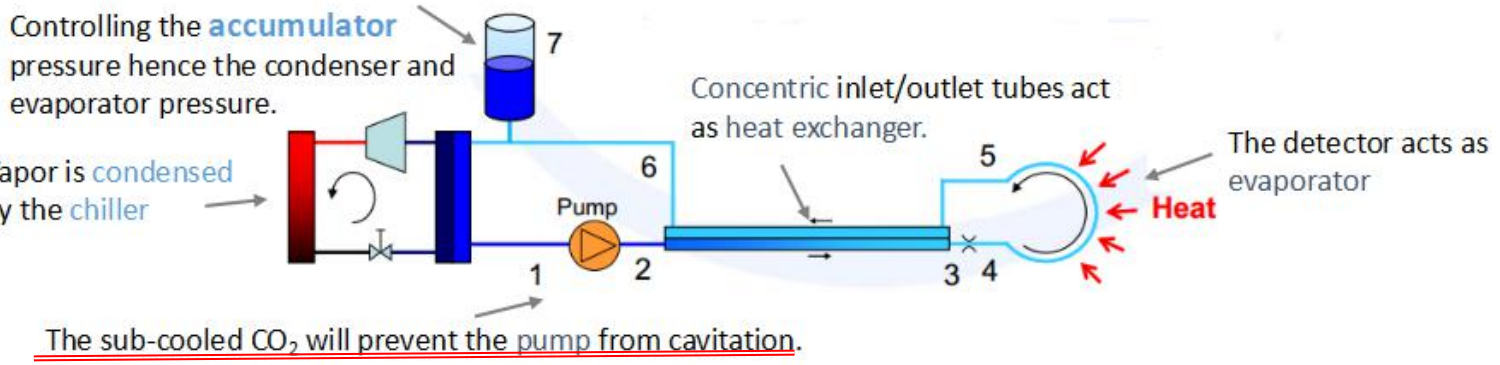
Status of MARCO

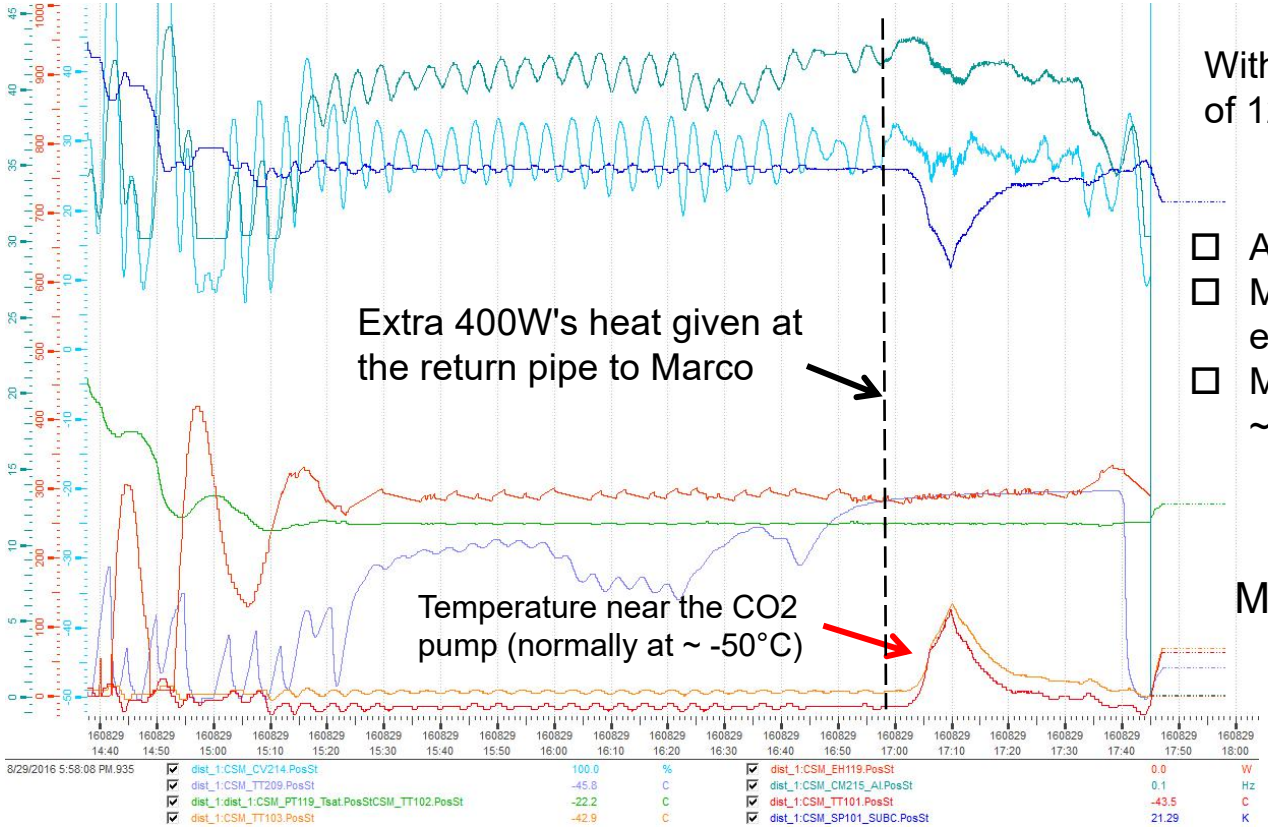




8.5kg coolant (R404a) is filled.
A leak point found in coolant accumulator, annual checks are necessary.

Status of MARCO





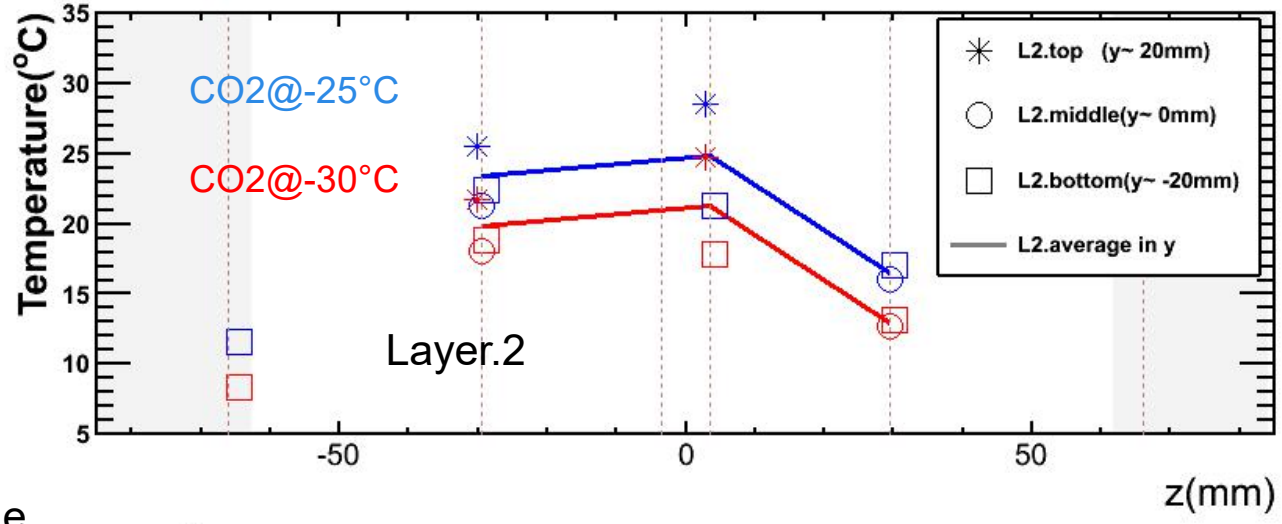
With all 12 cooling circuits, mass flow of 12g/s and 1kW power to VXD

- All copper cooling pipes are isolated.
- Marco works well when CO2@-25°C, even with 300W's extra heat.
- Marco will lose sub-cooling in ~30min when CO2@-30°C.

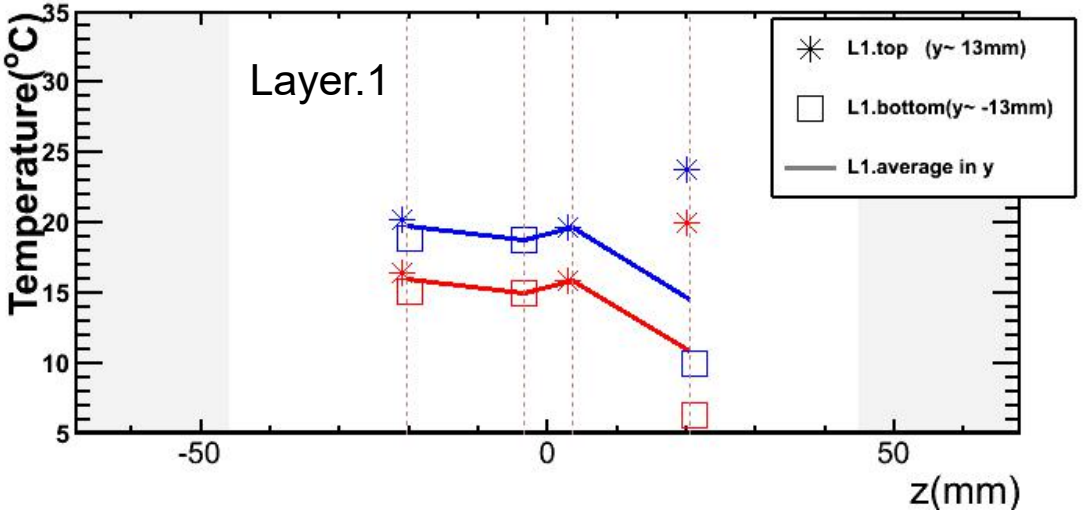
Marco's capacity is reached.

Temperature on PXD in VXD Volume

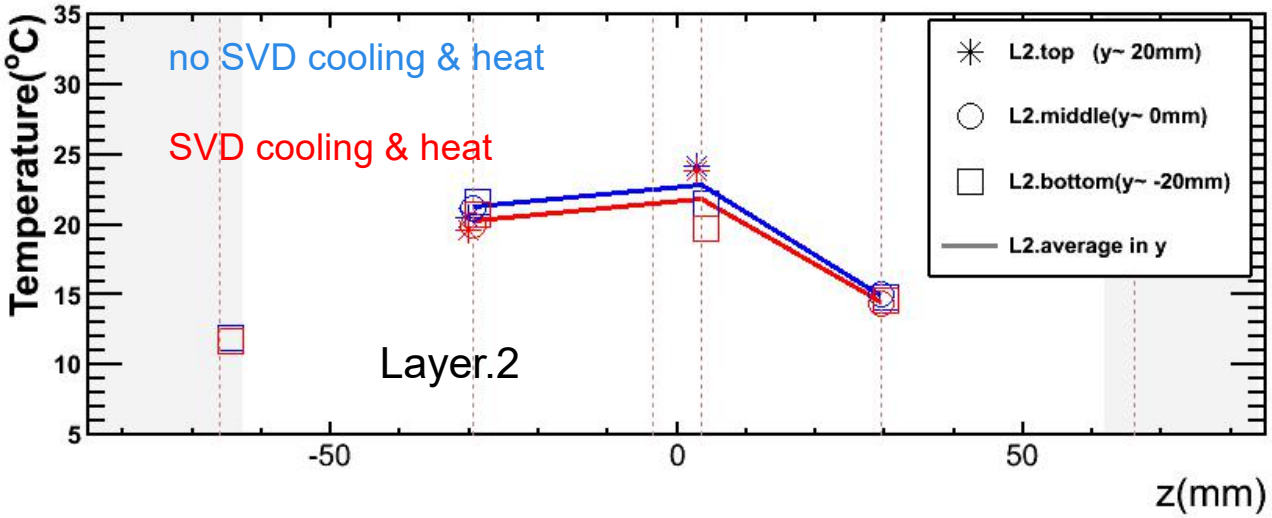
N_2 20L/min



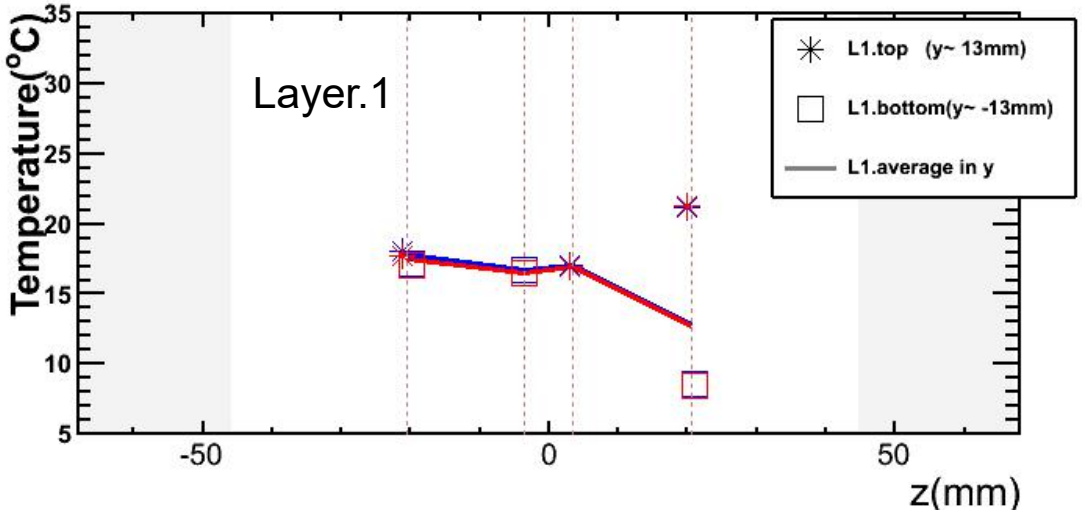
Quick test indicates the asymmetric temperature along the PXD ladder is due to the heat dissipation in the volume (more space in FW side).



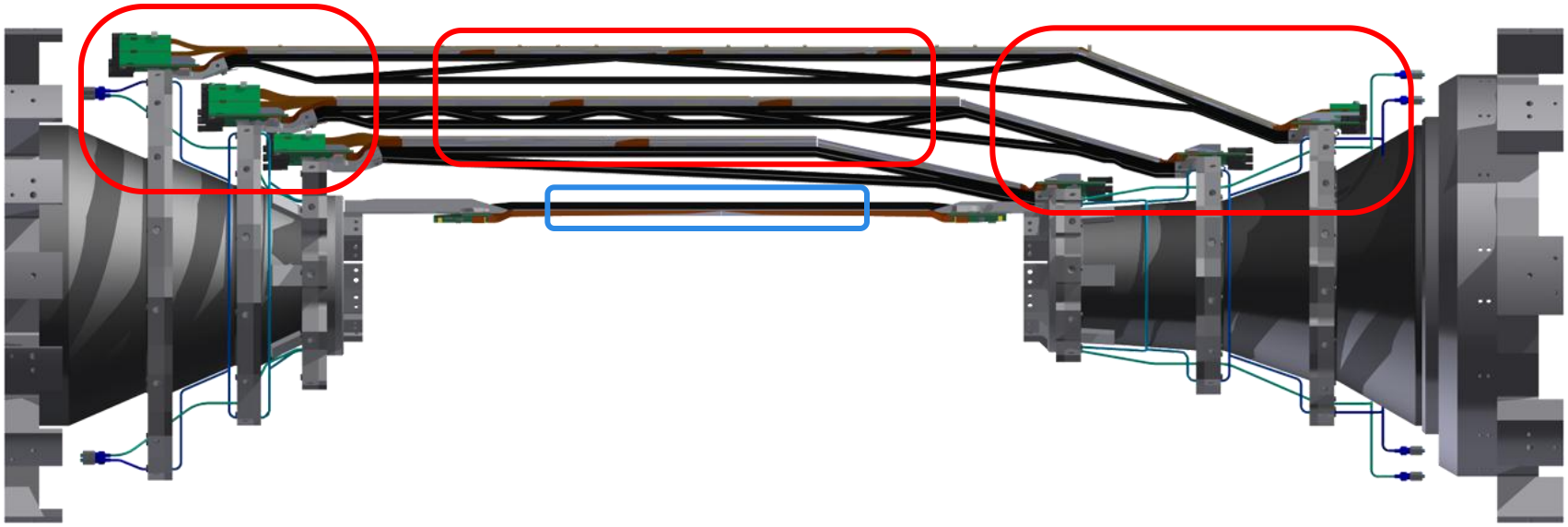
Temperature on PXD in VXD Volume



With SVD cooling and heating on, temperature on PXD changes ~1-2°C.



Temperature on SVD ladders

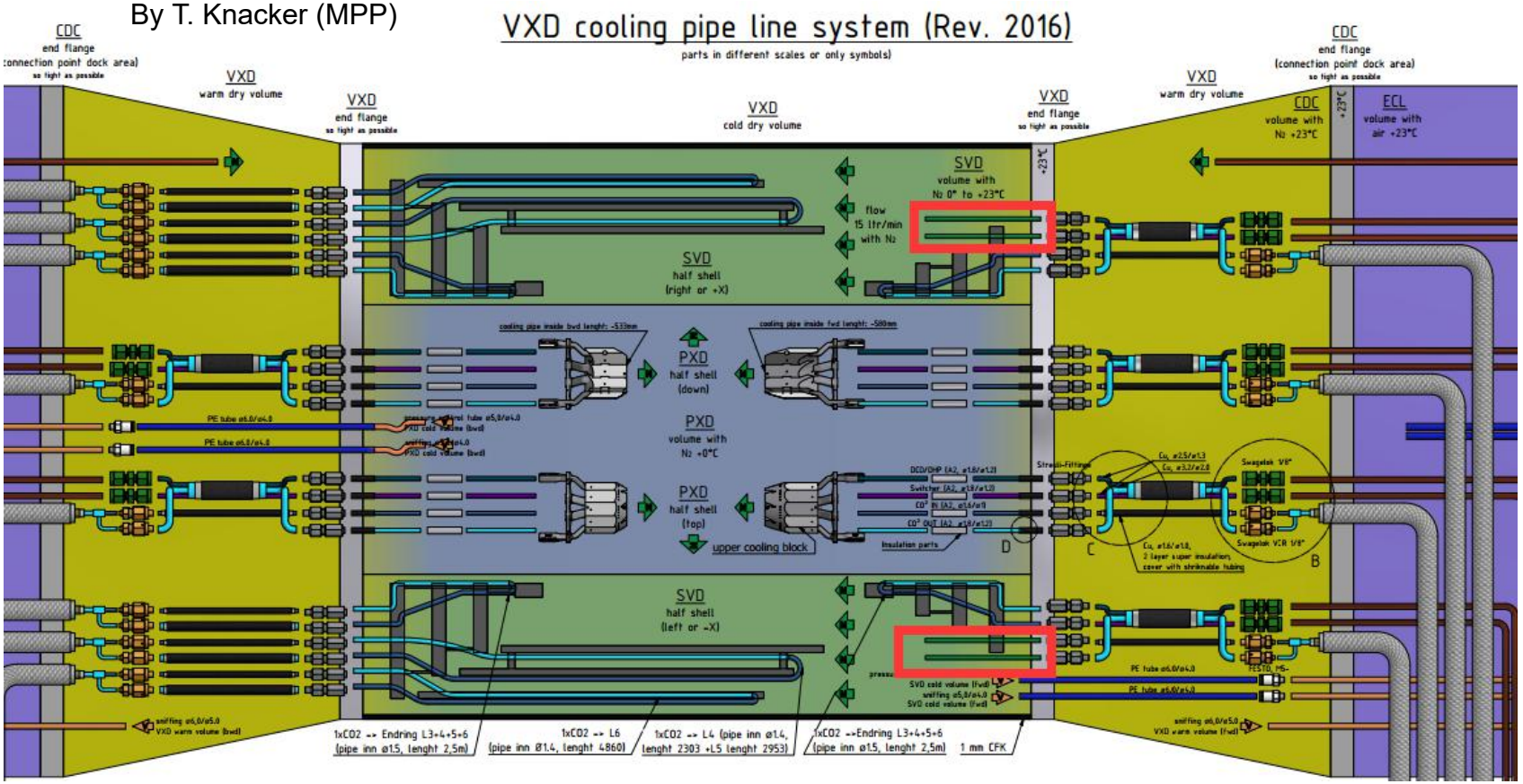


CO2@-25°C:
Temperature in the middle of L.3 sensor is 11°C, it's dominated by PXD, therefore also relies on the injected N_2 flow.

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

Belle II VXD Cooling Pipe Line System

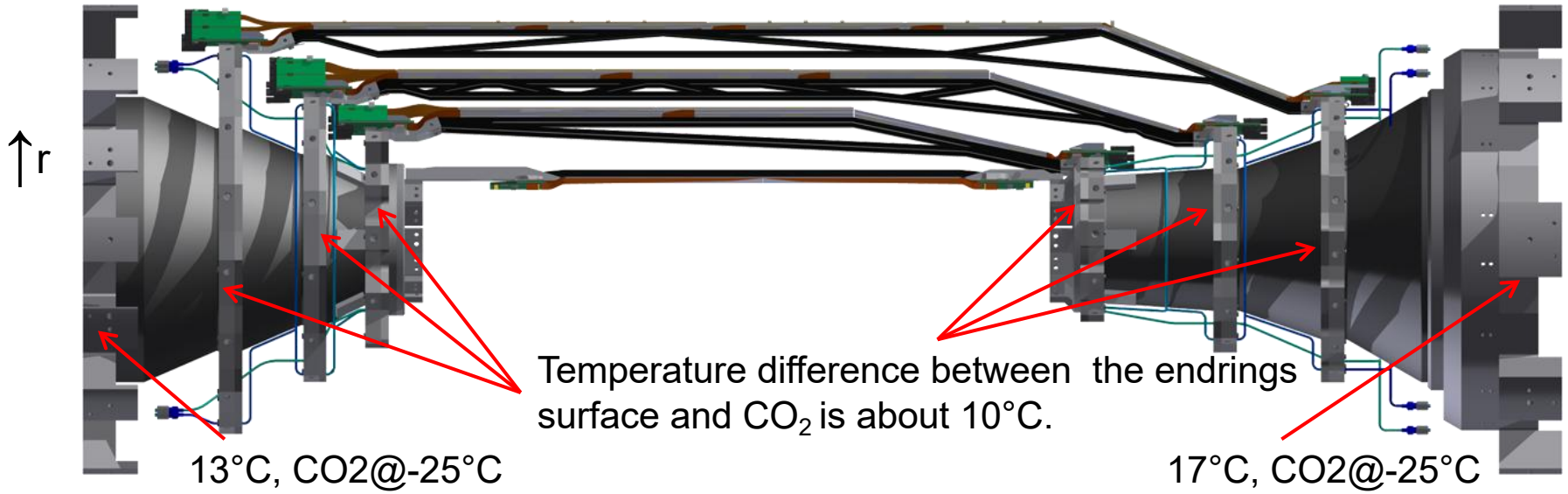
By T. Knacker (MPP)



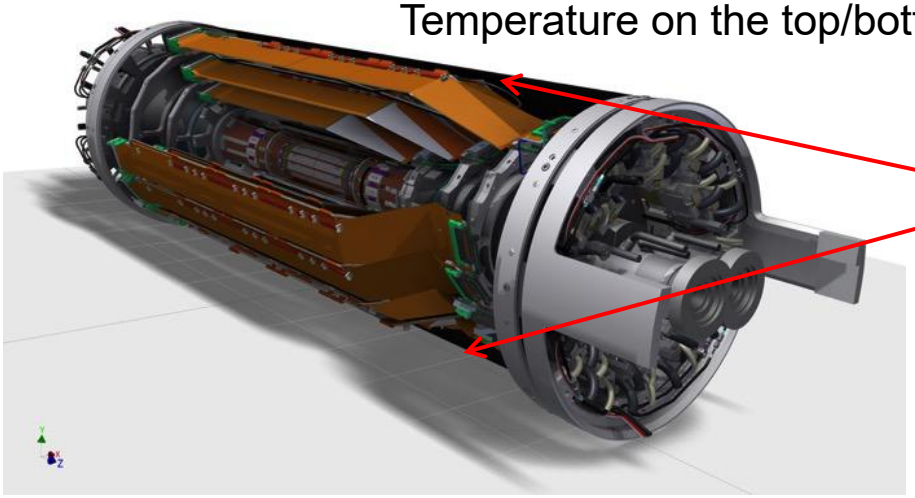
Two N2 lines were installed in FW side, to introduce N_2 , With the flow of 30L/min,

- ☐ Temperature gradient on top and bottom of inner side of CFRP shield improves about 2°C;
- ☐ Temperature on L.6 gets balanced (~1-2°C);
- ☐ Rare influence to other SVD layers and PXD.

Endings and CFRP shield



Temperature on the top/bottom of inner side of CFRP shield .



20L/min N2 to SCB, additionally 30L/min was introduced to SVD.

CO2@ -25°C	heat off	heat on	SVD N2 30L/min
top	11	16	16
bottom	3	10	12

About 5°C's gradient.

N_2 flow@Thermal Mock-up

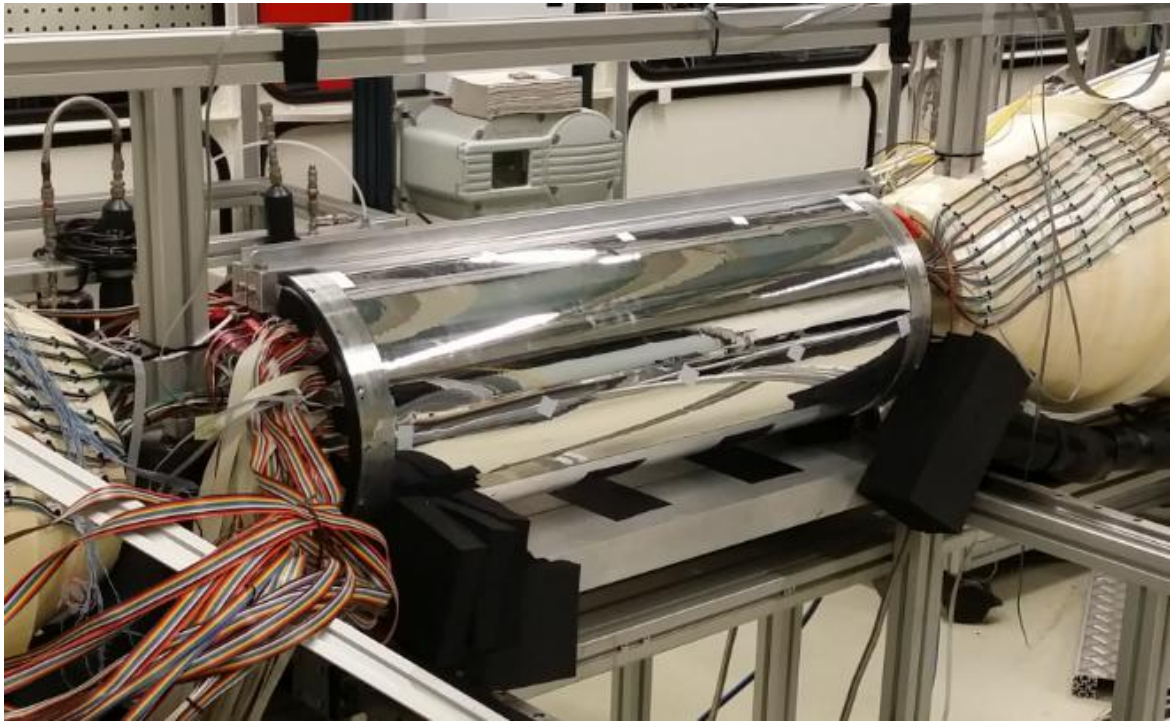
- DESY mock-up is built to study the thermal performance of VXD in Phase 3.
  - PXD : ≥ 20L/min is required for sensor cooling.
  - SVD : 10~30L/min, will improve the temperature gradient on the VXD shield, mainly for protecting the detector from condensation.

Pressure drop in N2 lines at DESY mock-up

- 4 parallel 8m, ID 2mm copper lines, connecting to SCBs.
  - corrected flow : 20L/min, Δp= 1.15bar
  - corrected flow : 30L/min, Δp= 1.95bar

Thermal radiation in environment

A reflecting foil covers the out surface of VXD shield.



With the foil,

- ☐ Temperature on the inner/outer serface of CFRP shield decrease ~0.5°C,
- ☐ No influence to the the ladders.

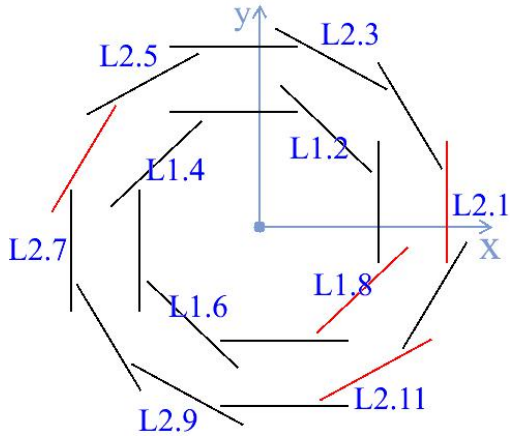
Summary

- Marco almost reaches its capacity with 12 cooling circuits, 12g/s mass flow and CO_2 set point at -25°C.
- With N_2 flow of 20L/min to PXD, temperature on PXD ladders is < 25°C.
- Temperature at SVD ladders (except L.3 ASICs) is 25-30°C.
- Temperature on the inner side of CFRP shield is ~15°C with the gradient of ~5°C. After introducing 30L/min N_2 flow in FW SVD N_2 pipes, this gradient improves ~2°C, not much influence to the temperature on detector.

Backup

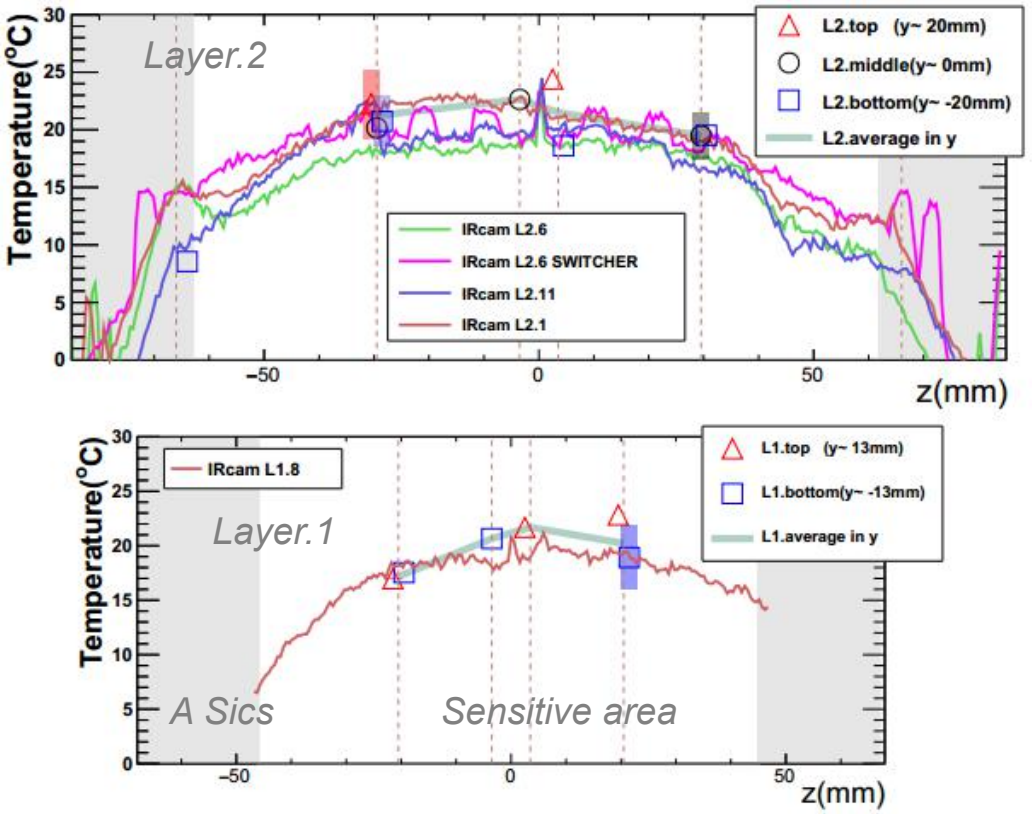
Thermal Mock-up Studies@DESY: Temperature on PXD

A plastic cylinder (ID 18cm, length 70cm) act as dry volume.



$\Delta T_Y \sim 5^oC$,
due to higher density of cold N_2 .
$\Delta T_Z \sim 7^oC$

CO_2@-30°C; N_2 23L/min

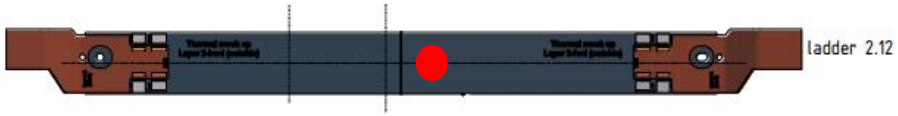


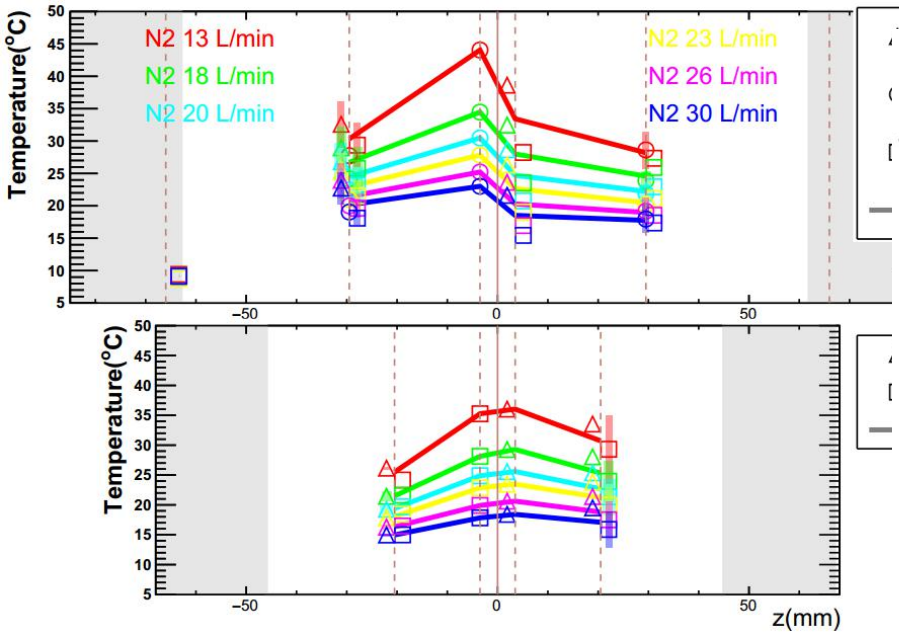
In VXD volume, the temperature improves about 2-3°C because of better heat dissipation。.

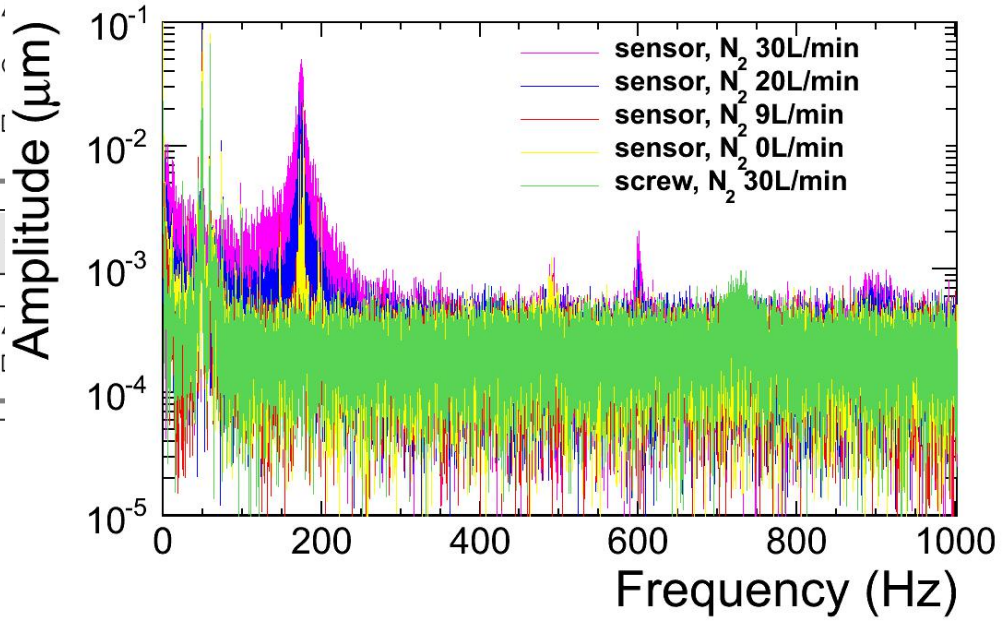
Figure 5: The temperature distribution of PXD ladders along the z-direction. BW(FW) is on the left(right) side. The gray areas indicate the regions of DCD/DHP, while the 75μm thick sensitive area is shown in the center. The thick solid line indicates the averaged temperature along z-direction measured from the Pt100s. Different markers show the average temperature in y-direction at certain position along z-axis, the error bar on the marker represents the temperature range in x-direction. Thin solid lines show the temperature distribution measured by the IR camera on selected ladders.

Air cooling to PXD

CO_2@-30°C, full heat load to PXD.



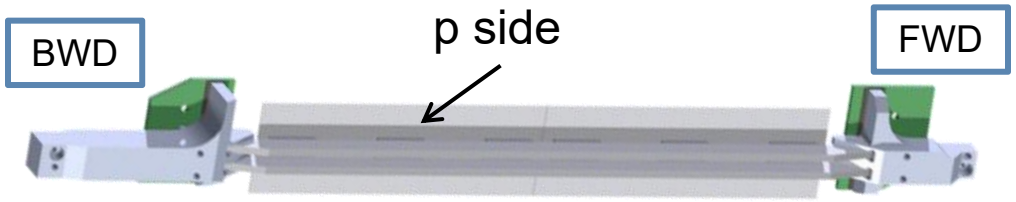




Larger N2 flow improves the temperature gradient.

- 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.

SVD L3 bridge



With nominal load of 8.4W/ladder (FW/BW each side 6 APV25 ~2.1W), max. temperature on p-side Apes is 70°C above cooled ending base temperature. N-side Apes ~ 10°C higher than the p-side ones

With nominal load to L.3
T(L3.3)

BW	Max(°C)	FW	Max(°C)
top(p-side)	28	top	41
bottom(n-side)	50	bottom	60

Modification in BW/FW - preliminary (by K. Gamow from DESY)