

CO₂ cooling requirements and related issues

November 16, 2017

Feedback to questions of Paola

Detector power and flow requirements

- UT cooling requirement: documented in [EDMS 1487284](#)

- **With one exception the document is complete and correct**

- Extract: **4.A. Major Detector Thermal Requirements**

The main thermal requirements for the UT Tracker are stated here.

1. **Temperature difference within a given sensor: Not to exceed ΔT of 5 °C**

This is a constraint to limit both the deformation of the sensor due to thermal contraction, and the relevant stresses induced on the sensor by cooling it down.

2. **Maximum temperature for any sensor: To be maintained below -5 °C**

This is a functional requirement for the sensor operation under the worst conditions foreseen in the detector, after maximum irradiation, at the end of its life.

3. **Maximum ASIC temperature: Not to exceed +40 °C**

The electronics readout ASICs should be maintained at the lowest possible temperature compatible with other requirements of the system. The ASIC are the most powerful local heating source in the detector, so that their temperature is the maximum figure present in the detector.

- We say nothing in the specifications about **the lowest temperature in the box** for the various operating modes; we only define the dew-point of the dry air.
- The box has been validated for a temperature of about -10°C. Down to this temperature the aerogel interface between the beam-pipe and the box has also been validated, but not for lower temperatures.
- **It seems now that this cannot be guaranteed for all operating modes**

UT cooling requirements

- Extract:

OPERATIONAL MODES

T_evap, Normal operation	-30 ± 5 °C	cold, max power 5 kW
T_evap, Partial power operation	-30 ± 5 °C	cold, max power 2.6 kW
T_evap, Maintenance	-30 to +15 °C	cold or warm, max power 1.5 kW

1. UT NORMAL OPERATING (DATA-TAKING) MODE,

COLD: $T_{op} = -30 \pm 5 \text{ }^\circ\text{C}$

Conditions. Box halves joined and sealed, electronics fully powered, full cooling to maintain the sensors temperature under $-5 \text{ }^\circ\text{C}$. For normal data-taking.

2. UT PARTIAL-POWER (STAND-BY) MODE,

COLD: $T_{op} = -30 \pm 5 \text{ }^\circ\text{C}$

Conditions. Box halves joined and sealed, with electronics on but operating at partial power, i.e., from 10% to 50% of nominal power. For electronics testing of digital readout alone, analog readout alone, power distribution, and slow control.

Note. The sensors should be kept at a nominal temperature, under $-5 \text{ }^\circ\text{C}$. Although the temperature remains the same here as in normal operating mode, the power load is less. Hence the cooling power required is less, and the mass flow rate can be reduced, if needed, based upon the actual power load in the range given above.

3. UT MAINTENANCE (INSTALLATION/COMMISSIONING) MODE,

COLD OR WARM: $T_{op} = -30 \text{ }^\circ\text{C TO } +15 \text{ }^\circ\text{C (Room Temp., above Dew Point)}$

Conditions. Box halves retracted and sealed (or retracted and unsealed), electronics and cooling on for one half-plane at a time only (refers to in-pit, not on-surface operational modes). For maintenance/commissioning in pit.

We only specify the lowest temperature on the sensors, not inside the box.

Clearly, in particular when the electronics are off and we have a CO_2 temperature of -30°C , the air temperature inside the box will drop to $< -10^\circ\text{C}$.

Common T set point for operation in backup

- Delicate point for the exceptional case where VELO and UT are powered by the same plant and the set-point cannot be changed to a value of -10°C .
 - From the UT-side we have to be avoid problems with the (silica aerogel) interface to the beam-pipe and the resulting temperatures, if the temperature inside the box drops to -25°C .
- **We have to address this issue !**

Options to be discussed

- Related to the design of the box:
 - Add 2 heaters on the side of the box → needs large power (2x~2kW), difficult to bring warm air to the beam-pipe area
 - adding on the outside of the box in certain areas thin heaters (e.g. nickel-chromium-based superalloy on kapton foils, as used in CMS) could be considered
 - These heaters are very thin (~200μm), and thus the impact on the material budget would be small
 - The heaters would be needed in particular close to the beam-pipe → complicated
 - a guided warm airflow in particular in the area between UT and RICH1 could also be considered
 - Space constraints, which should not be underestimated
- From tests on the prototype box we have a better understanding of the thermal behaviour when going down with the air temperature to -20°C.
 - However, the present box has 3cm thick Airex walls (not 2cm, as foreseen in the end)
 - The measurements don't agree with calculations

Options to be discussed

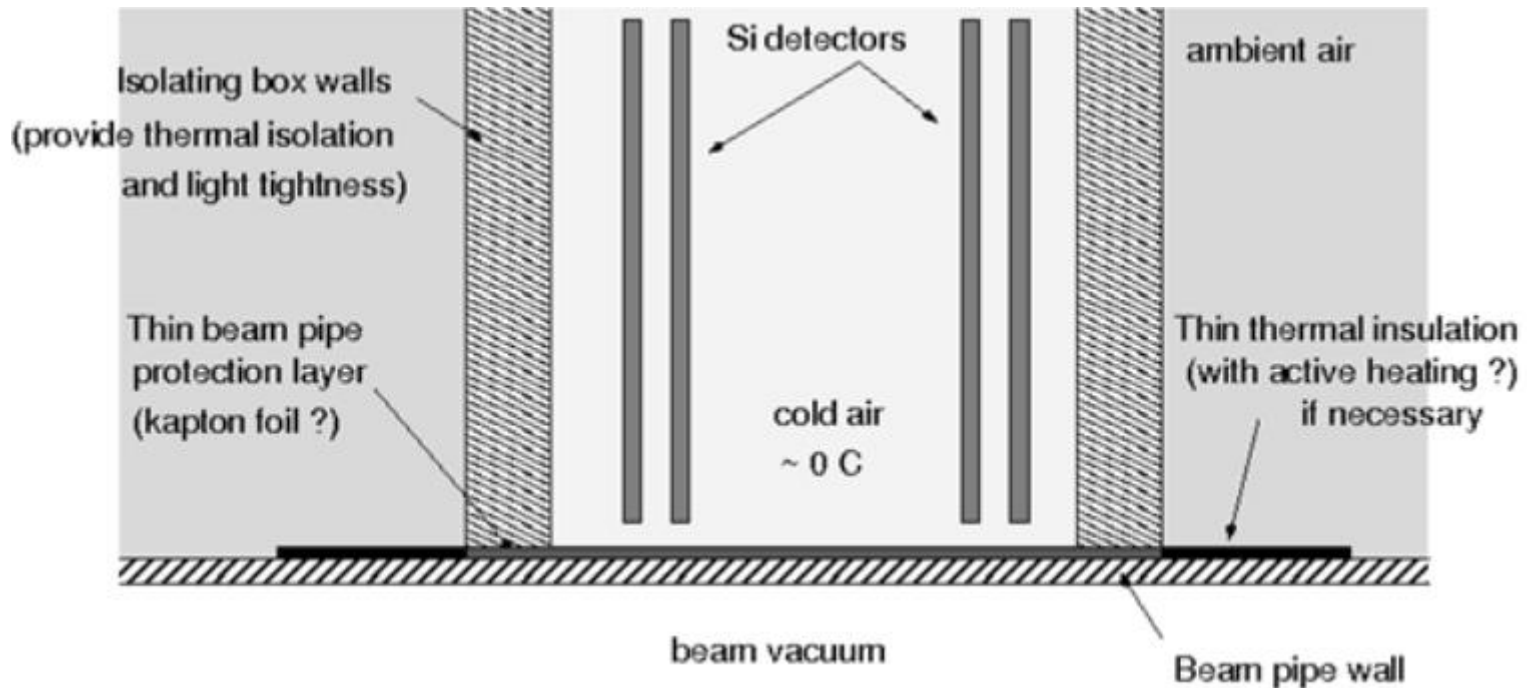
- Changing the P&Id for the cooling system by e.g. introducing a back-pressure-regulator or an impedance to control the temperature for the UT cooling independent of VELO (in case of common operation of the two systems)
- Implications should be discussed

Further questions of Paola

- All parts are qualified for design pressure of 130 bar, i.e. testing pressure of 187 bar
 - This is what we are doing/intend to do
- All sub detectors will provide via DIP a “reading Temperature” which will be used at cooling system start-up to initiate circulation at that T
 - We have various temperature sensors in the system
 - In the detector part of the cooling system (Simone)
 - A system monitoring the ambient conditions in the box (FOS, Gaia/Carlos)
 - Moreover, we have temperature sensors on the staves (Syracuse)

Backup

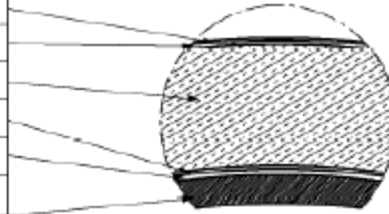
Proposed insulation of UT to the beam-pipe



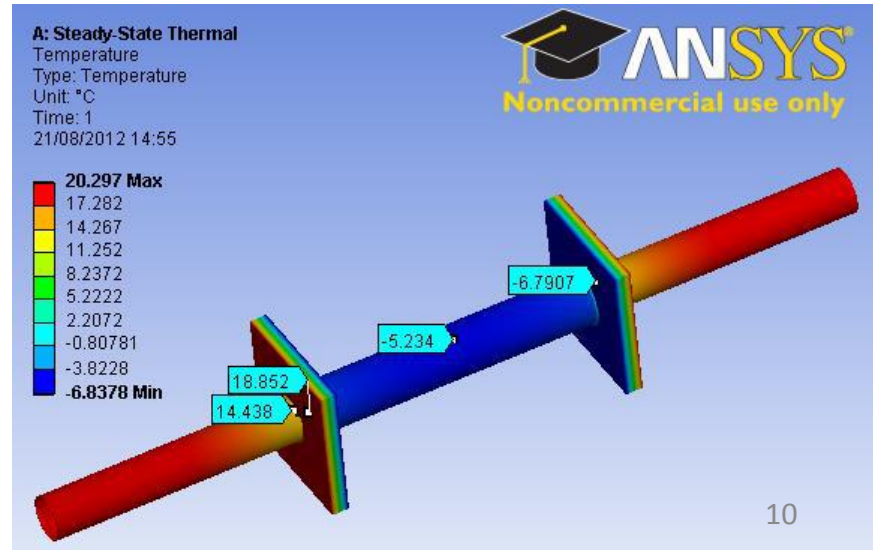
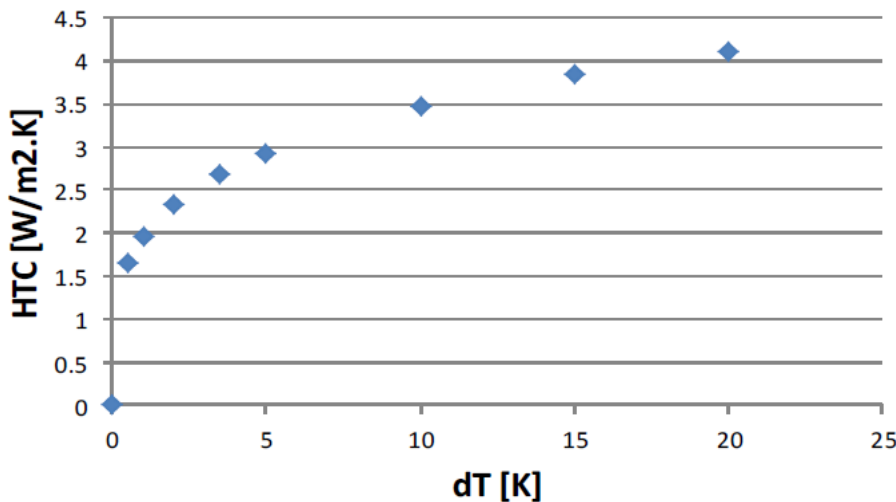
- Advantages of this proposal are:
 - It minimizes the distance between detector modules and the beam-pipe.
 - It minimizes the amount of material and thus interactions and multiple scattering
- This proposal has been summarized in the upgrade Tracker TDR

Silica aerogel based insulation

Description	thickness (mm)	density (g/cm ³)
Aluminium Foil	0.05	2.7
2 layers polyimide tape (Kapton)	2*0.06	1.53
Aerogel insulation (compressed)	4	0.11
2 layers polyimide tape (Kapton)	2*0.06	1.53
heaters	0.2	1.73
vac.chamber wall		



- Calculation of the Heat Transfer Coefficient:
- Thermal conductivity K of aerogel 14.7 mW/mK, and of beryllium 190 W/mK
- Assuming -10°C in the box and 20°C for the beam-pipe, thus a dT of 30°C , the HTC approaches a value of $5\text{W}/\text{m}^2\text{K}$
- 4mm of aerogel have been determined to avoid condensation outside the box through heat-transfer via the beam-pipe (compressed thickness 3.5mm)

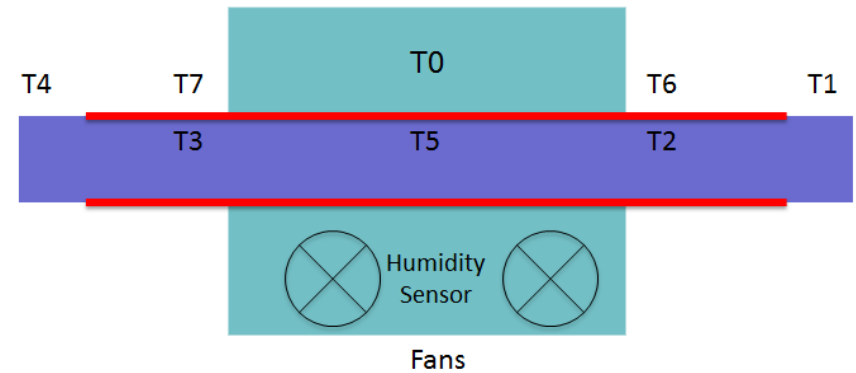


Final validation



Location of temperature sensors

- T0 temperature inside the box
- T1, T4 temperature outside the box
- T2, T3 and T5 on the beam-pipe
- T6 and T7 on the insulation



Results with RH=17% and $T_{\text{box-air}} = -10^{\circ}\text{C}$

