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Bi-Phase CO_2 cooling of the CBM Silicon Tracking System (STS) detector

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Cooling Challenges

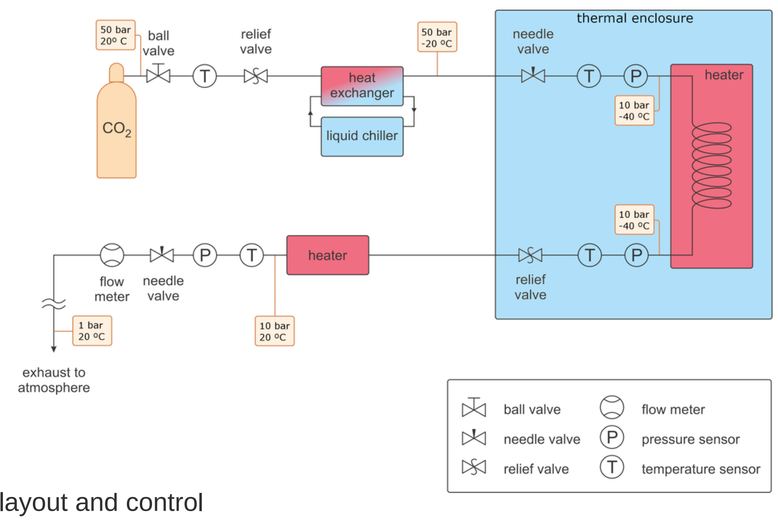
To avoid thermal runaway the silicon sensors have to be kept at -5˚C. This is quite challenging as about 50 kW of heat is dissipated from the STS Front-End-Boards (FEB) and Read-Out-Boards (ROB) into a rather small volume with very limited space for heat exchanger plates. We use bi-phase CO_2 cooling due to its superior volumetric heat transfer coefficient, which is about an order of magnitude better than conventional freons.

Within this project we have:

- built an open CO_2 cooling system for testing heat exchanger efficiencies;
- tested different designs of FEB box and measured the temperature distribution when attached to a heat exchanger;
- compared with Solid Works FEM simulations;
- built a sophisticated 1 kW closed CO_2 system (TRACI XL);
- TRACI XL will be used to test a quarter station with heat load of up to 1 kW.

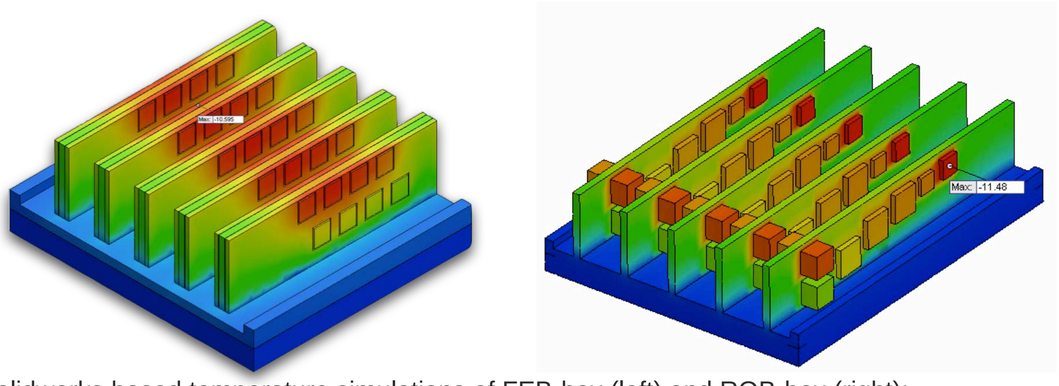
FEB-Box and ROB-Box cooling R&D

Open Blown CO_2 cooling system



- simple layout and control
- allows basic tests of CO_2 cooling efficiencies of different heat exchanger designs

FEM Calculations of Temperature Distribution



- Solidworks based temperature simulations of FEB-box (left) and ROB-box (right);
- allows to experiment and fine-tune parameters;
- evaluation of cooling for front-end boards for different shelve thicknesses;

R&D results

Power Applied, W	Maximum temperature, ˚ C		
	1mm	2mm	3mm
140 W	15	-14.2	-22.6
200 W	24	0.2	-15

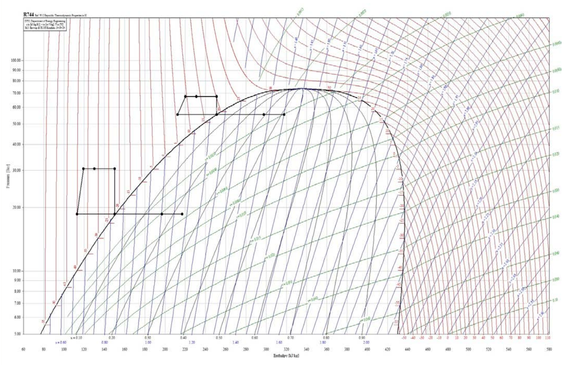
Experimentally measured maximal temperature on the FEB box in dependence of power applied and shelve thickness

Maximum temperature, ˚ C		
T, coolant	T@200W	T@140W
-40	-10.6	-12.7
-30	-4.9	-9.9
-20	0.8	-4.1
-10	6.5	1.58

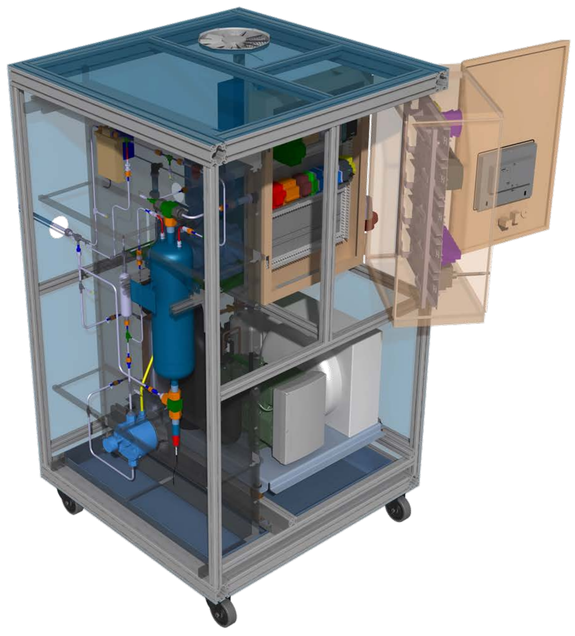
Result of simulations showing the expected maximal temperature on the FEB box in dependence of initial coolant temperature and power applied

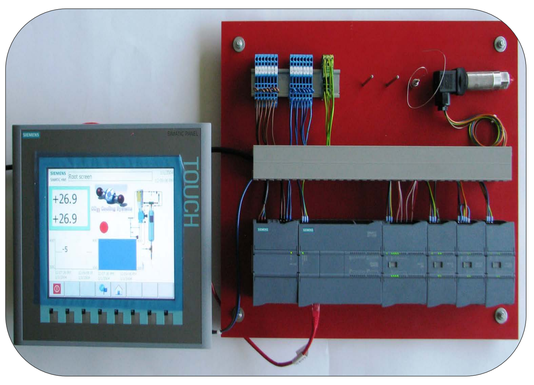
3mm FEB-box design is sufficient to completely remove the heat from the front-end electronics.
Simulated 1mm ROB-box design already allows to keep the read out electronics at -11 ^{0} C.

TRACI-XL, a 1 kW CO_2 Cooling Plant

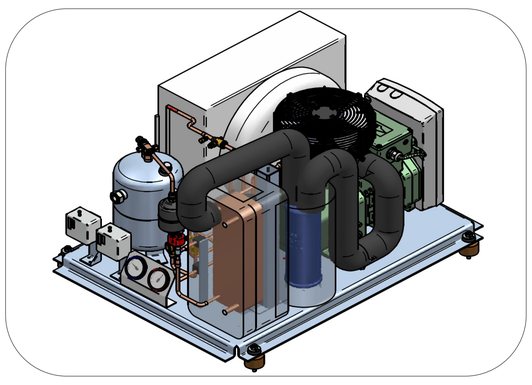


TRAXI XL provides liquid CO_2 in the temperature range from -40^{0}C to 5^{0}C at the bi-phase boundary. The diagram shows two possible **thermodynamical cyles**, the latent heat will be used in the heat exchanger for cooling up to 50% vapor quality.

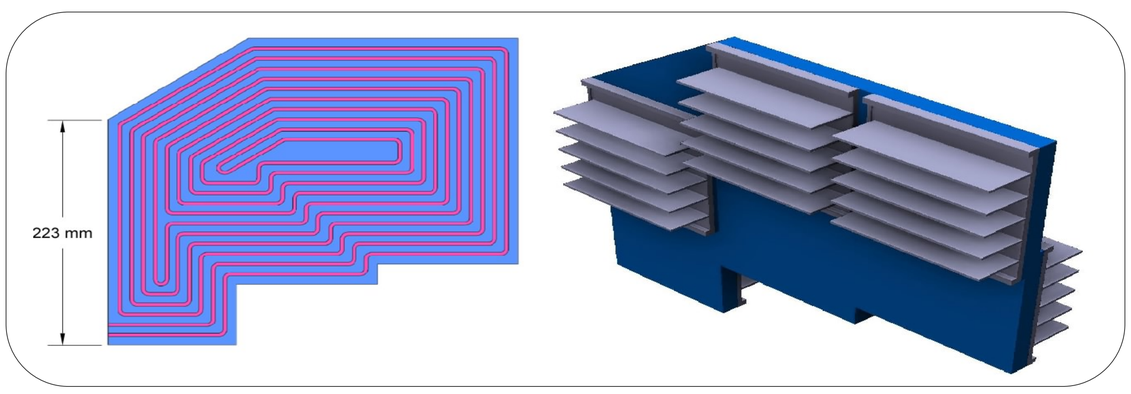




The cooling plant is fully controlled by a standard **PLC Siemens S1200**.



The CO_2 gas-liquid mixture is re-liquefied in a **condensing unit** which uses R404A (freon) as secondary coolant at a minimum temperature of -45ºC in the low pressure side.



Traci XL will be used to test the cooling efficiency of a 1 kW quarter station cooling demonstrator. **Heat exchangers** (in blue) take the thermal load form the front-end electronics. The left side figure shows the channels for the liquid CO_2 flow in the heat exchanger; the right side figure show the cooling plate with shelves for the front end boards attached.