Progress Towards the Development of Cooling Demonstrator of the CBM Silicon Tracking System

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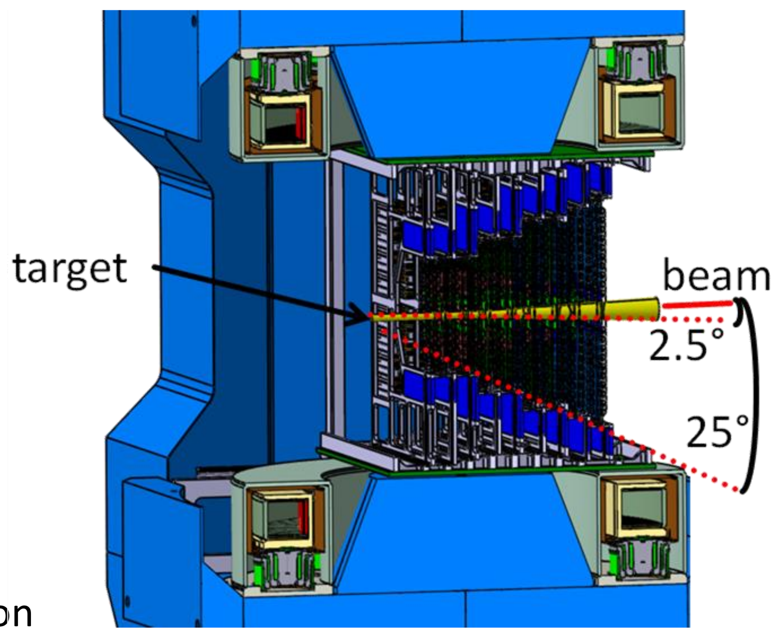
Compressed Baryonic Matter experiment at FAIR

CBM Silicon Tracking System

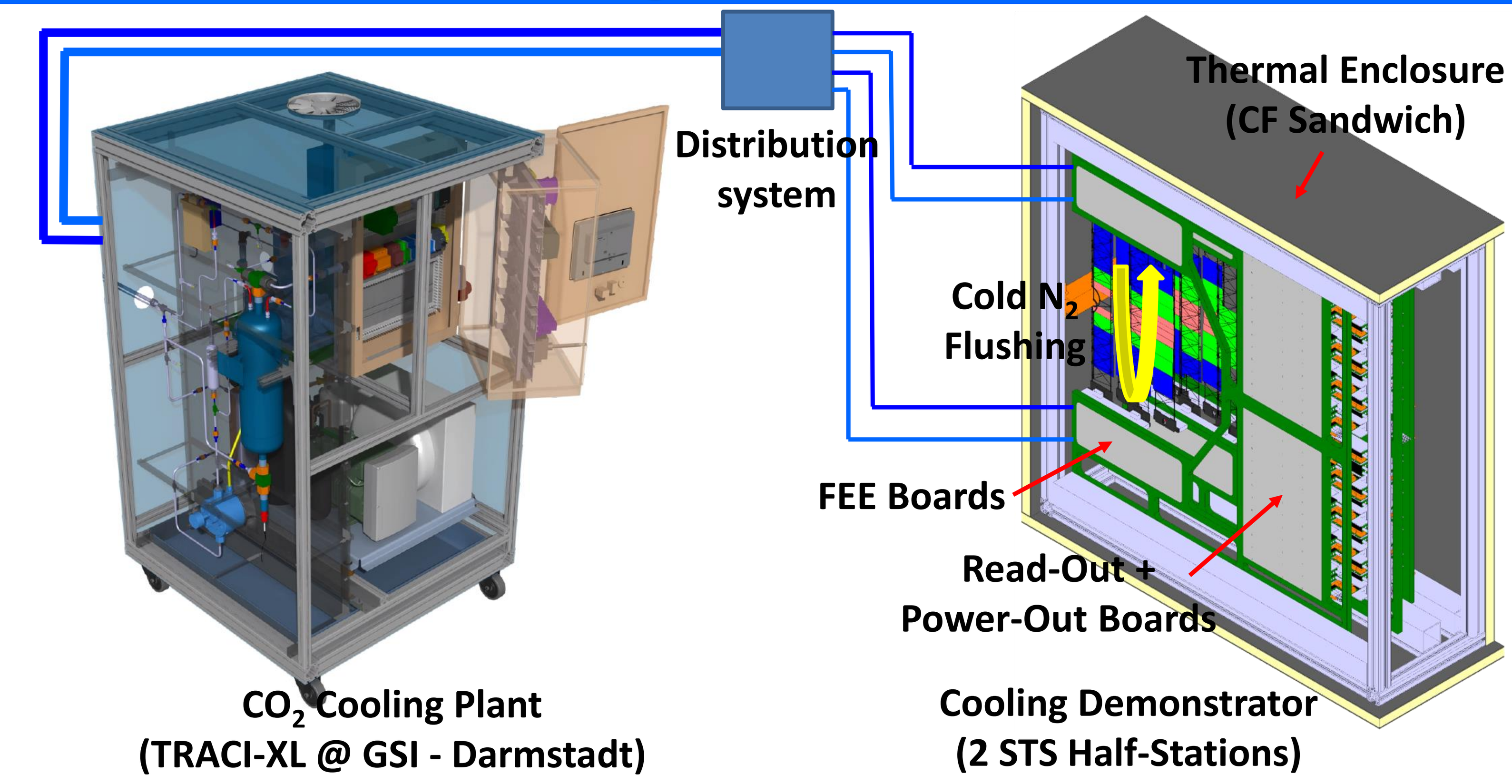
- CBM aims to explore regions of high-baryonic densities of QCD phase diagram
- Requires detection of rare probes
  - → $10^5 - 10^7$ collisions/sec (Au-Au)
  - → Momentum Resolution $\Delta p/p \approx$ 1-2%
  - → High track reconstruction efficiency with pile-up free track point determination
- Silicon Tracking Station: Key to CBM Physics
  - → 8 Tracking Stations inside 1Tm field
  - → 896 double-sided micro-strip sensors
  - → Low Material Budget: 0.3% - 1.5% X_0/station
  - → Radiation tolerance: ≤ 10^{14} n_{eq} cm^{-2} } Sensor temp. ≤ -10°C
  - → Signal-to-noise ≥ 10 }
  - → Self-triggering front-end electronics located outside acceptance } Power dissipation ~40kW in ~2m³
  - → ~1.8 million r/o channels + ~16000 r/o ASICs "STS-XYTER" }



STS in Dipole Magnet

Bi-Phase CO_2 cooling at -25°C for FEE | **Forced N_2 cooling directly for sensors**

Cooling Demonstrator



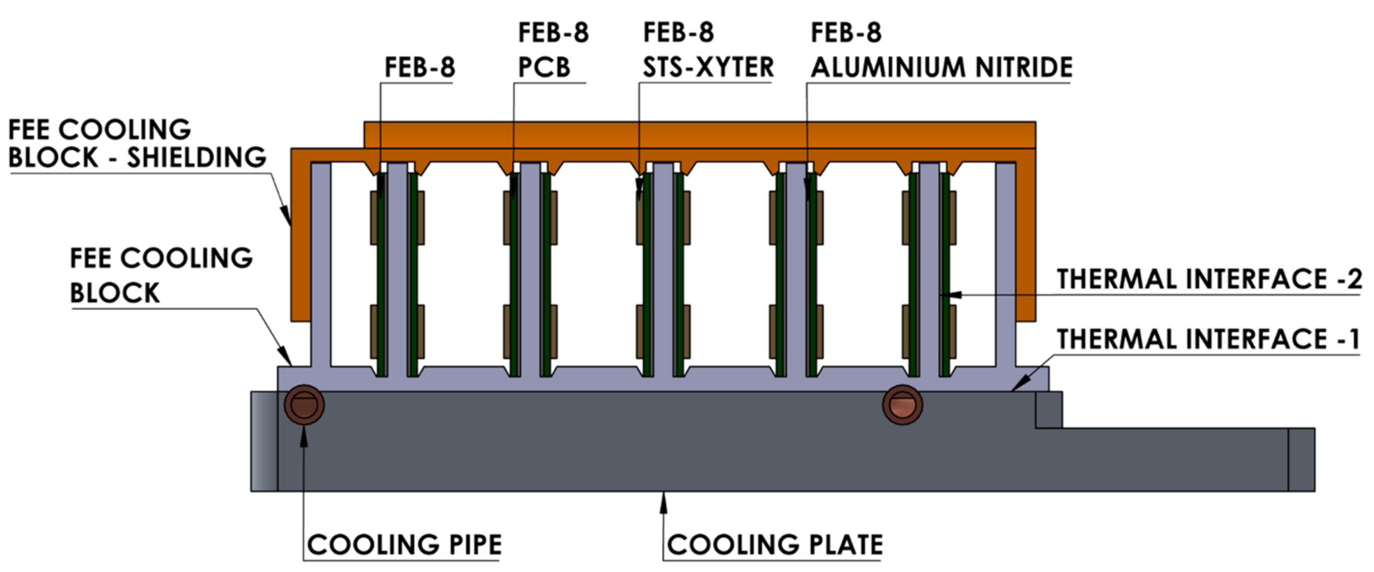
CO_2 Cooling Plant (TRACI-XL @ GSI - Darmstadt)

Cooling Demonstrator (2 STS Half-Stations)

Why Bi-Phase CO_2 ?
- High volumetric HTC → Smaller tubes
- Isothermal evaporation
- High pressure → Thermal Stability

Cooling & Integration Challenges
- Sensor cooling with least X_0/station
- RH << 1% @ 25°C to avoid condensation
- High-density feedthroughs, transfer lines

Front-End Electronics Cooling

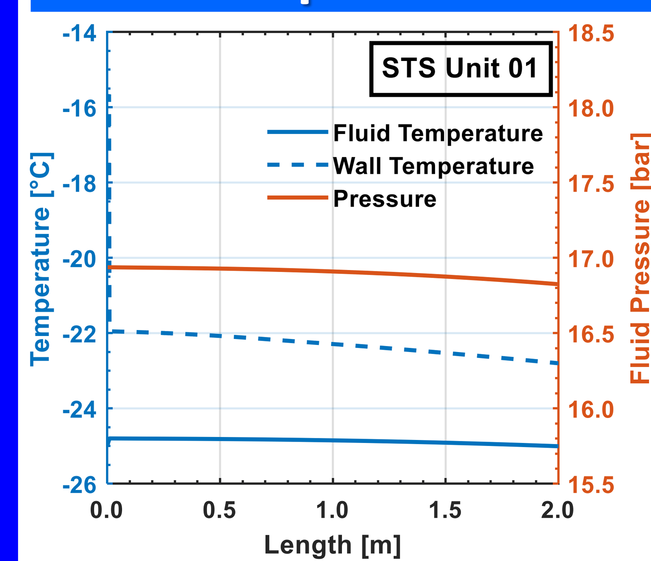


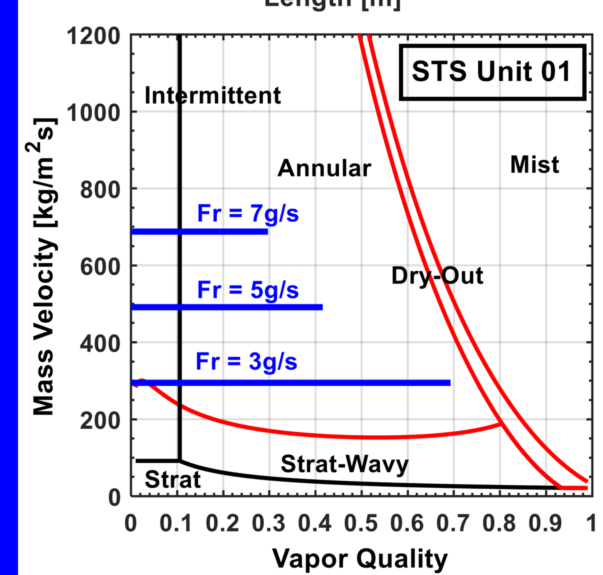
Front-End Electronics Cooling Concept

FEE Cooling Plate (Press-Fitted Tube Channels) PED Compliant @ 100bars

FEE Cooling Block with dummy FEB-8 & PT100 sensors

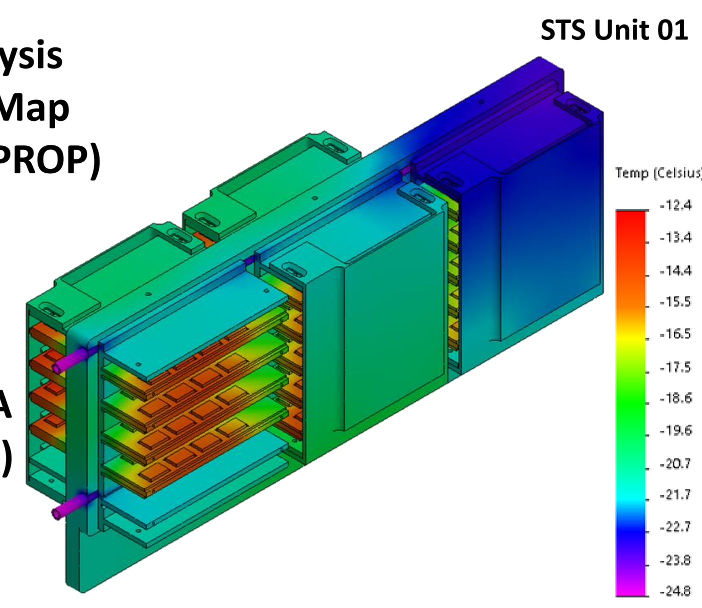
Optimisation of CO_2 Operational Parameters





T-p v/s L Analysis
Flow Pattern Map
(MATLAB + REFPROP)

Thermal FEA (SolidWorks)



Max. FEE temp. < -10°C

Cooling Demonstrator FEE Operational Parameters

T_{CO2} = -25°C, Tube D_{eq} = 3.6mm (O.D. 6mm), L = 2m

Quarter-Station #		P_{FEE} (W)	Fr (g/s)	ΔP (bar)
1	Unit 0	265	3	0.0342
	Unit 1	609.5	7	0.1127
2	Unit 2	344.5	3	0.0459

Optimisation of Thermal Interfaces

- Thermal Interface Materials (TIMs)
  - → Increase area of contact & thermal conductivity
- Relative measurements with water as coolant
  - → Flattening the interfaces (~10µm) improves the results substantially
  - → Good agreement (± 10%) b/w exp. – FEA

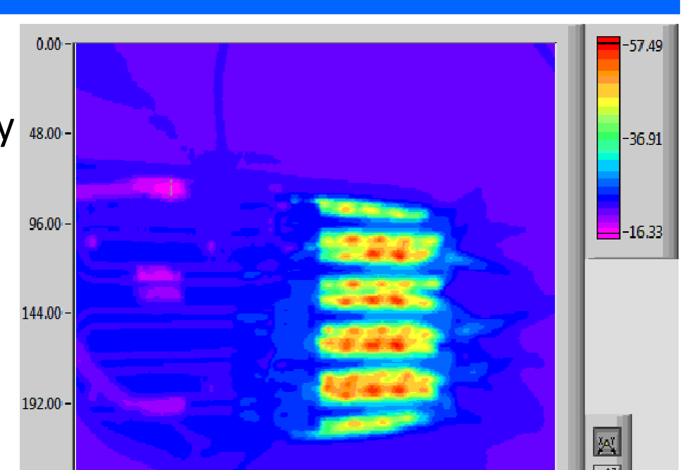
TIM Optimisation

T_{H2O} = 15°C, Q̇ = 160W, Fr = 11.1g/s

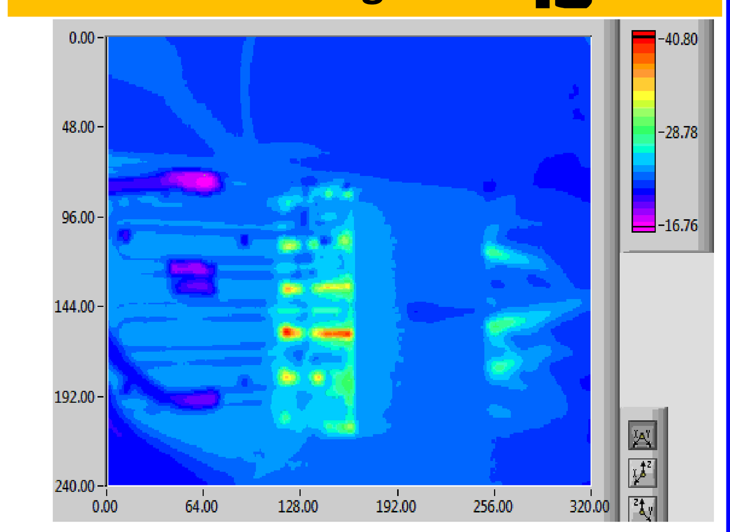
Interface #1	Interface #2	Maximum Fin Temp. (°C) Exp. (PT100)	Thermal FEA
Grease	Grease	29.7	32.0
	C-Foil	29.6	32.0
C-Foil	Grease	33.7	32.1
	C-Foil	33.9	32.1

TIM Properties

	k (W/m·K)	d (µm)	R_Θ (d/k; m²·K/W)
Grease	5.0	30	6.0×10^{-6}
C-Foil	16.0	125	7.8×10^{-6}



Viscous TIM (grease) is better
FEE shielding works



Conclusion and Outlook

- Ongoing R&D for cooling demonstrator with 2 STS Half-Stations
- Bi-Phase CO_2 cooling is an optimal solution for cooling the STS electronics
  - → T-p v/s L analysis + Thermal FEA model developed to computationally characterise FEE cooling setup
  - → Characterization parameters for FEE cooling of first 2 STS Half-Stations with press-fitted tube channels obtained
  - → Experimental verification with CO_2 needed upon cooling plant completion
  - → Thermal interface optimisation shows that using grease increases thermal efficiency
  - → Further options (e.g. Graphite tapes etc) will also be studied
- Forced N_2 cooling on sensors needed to minimise radiation damage
  - → Realisitc mechanical setup with minimum material budget inclusion is desired
- Thermal characterization of HV-LV, optical etc connectors is foreseen
- Operational experiences from mSTS@SIS18 (Aug-Sep'18) for demonstrator integration

References

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