Outer tracker SiPM,

A view on the thermal issues and cooling solutions

Workshop on SiPM cooling for Fiber Tracker

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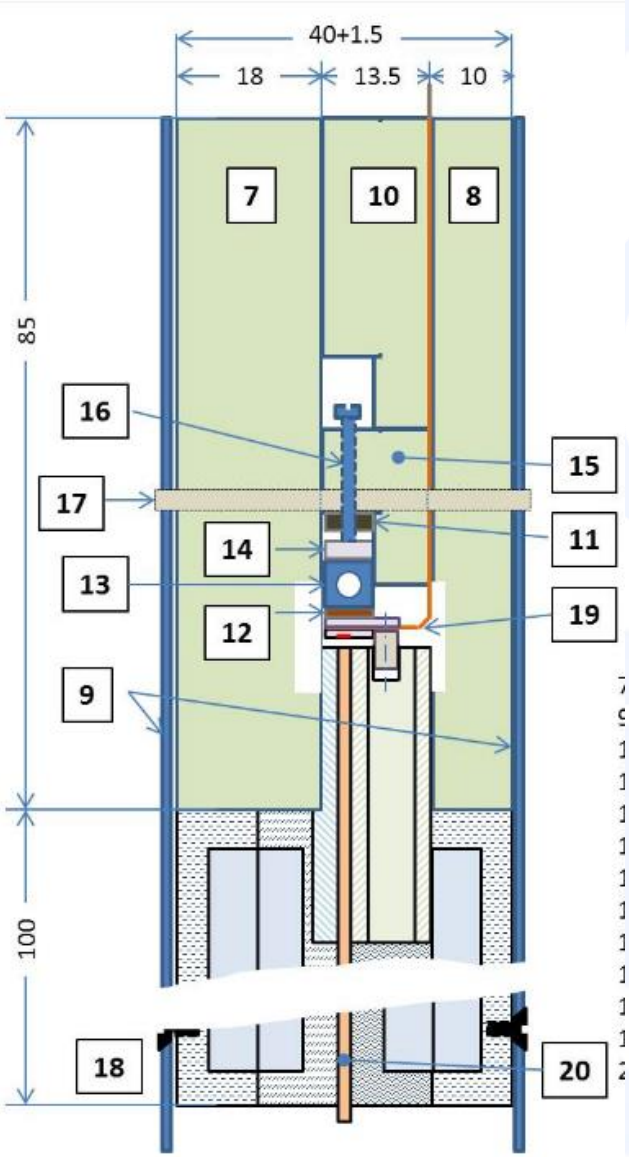
SiPM thermal issues

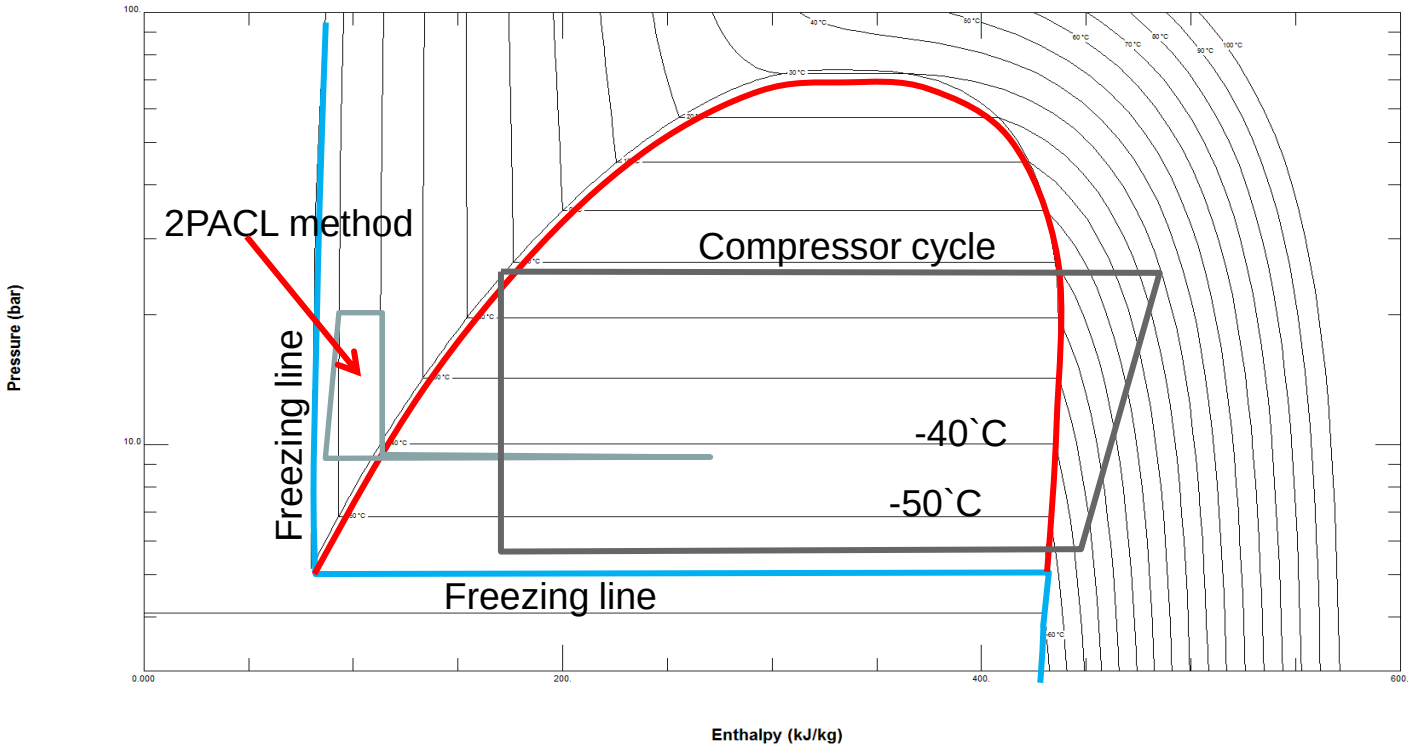


- -50ºC cooling should not be the challenge, enough "commercial" options seem to be available.
- To my point of view the challenge is the overall thermal design.
  - No space for good insulation.
  - Thermal design is the driving design factor for the mechanics.
  - Sophisticated insulation methods or materials needed.

Cooling fluids.

- WRT cooling in inner detectors:
  - SiPM has a relative low heat load
  - SiPM has relative much space and no low mass requirement.
    - Tubes can be larger
  - Is radiation an issue?
    - Can we use more common refrigerants used in refrigeration?
- 2-phase or single phase?
  - Single phase has cold lines, is there space for insulation?
  - 2-phase can have warmer in or outlets and can be designed with less or no insulation

CO_2 cooling



- CO2 freezes at -56^{0}C
- 2PACL cycle (LHCb/Atlas/CMS) needs sub cooled liquid.
  - Practical lower limit: -40^{0}C
  - Oil free
  - Cold lines
- Compressor cycle can be an option
  - Lower temperature possible -50^{0}C
  - Commercial available if oil is allowed
  - Oil free requires a not standard compressor
  - Warmer lines

Fluid comparison

	P @ -50 °C (bar)	Freezing point (°C)	Latent heat (J/g)	GWP
C3F8	0.53	-147.7	110	8830
C2F6	3.7	-100	112	12200
CO2	6.8	-56.6	339	1
N2O	6.5	-90.8	326	298
R404a	0.84	<-105	203	3300
R508b	5.9	<-140	138	13400
R125	0.92	-100.6	165	3500

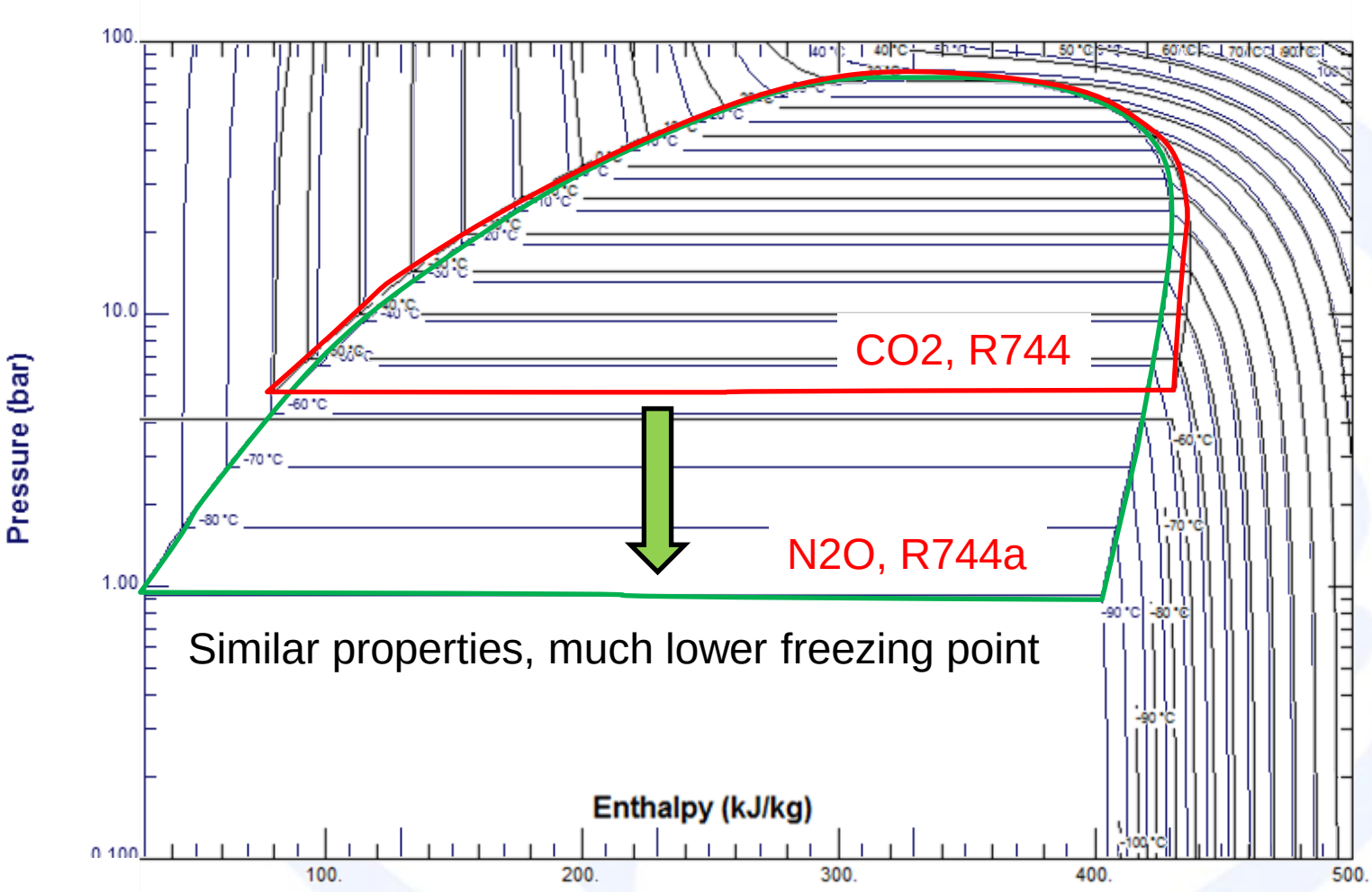
Commercial choice for low temperatures → R508b

N_2O has most properties similar to CO_2, except the freezing point…
N_2O=R744a=Laughing gas, CO_2=R744

Fluids with high pressures can also be pumped in a 2PACL (oil free, more stable)

A 2PACL system is very stable and easy to control. Operation with N2O should be okay as it is similar to CO2.

R744 vs R744a



Is a 2PACL with N2O an option? I have no idea about the impacts such as safety, radiation hardness etc. Thermally it looks interesting. N2O is used to foam cream, so it is not too bad I guess

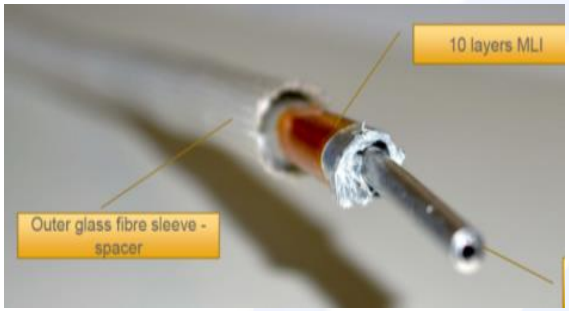
Other commercial cooling options

- R404a in a 2-stage compressor cycle
  - Disadvantage: low pressure, oil.
- R508b + R404a in a cascade system. (Cascade R404a with CO_2 also possible)
  - Disadvantage: oil
- Liquid brine
  - Disadvantage: Dirty fluids.

Known CERN cooling solutions:

- C3F8
  - Too low pressure 0.5 bar @ -50^{0}C.
- C2F6
  - Could be a good candidate, pressure reasonable.
    - 3.7 bar@-50^{0}C
  - Compressor seem not standard.
  - Expensive fluid
- FC Blends
  - I don’t see any reason for a blend, no pressure issue like in Atlas.
- FC liquid brines
  - Personally no experience, but seems like a known technology.
  - Cold lines

Flexible vacuum insulation (Atlas IBL)



- 16mm flexible vacuum below
- 4mm*0.5mm + 1.6x0.3mm concentric tube with CO_2
- 12m long
- Flexible (like a cable)
- -40 ^{0}C inside, 18^{0}C outside
- Up to 300 watt cooling