



# CO<sub>2</sub> cooling of an endplate with Timepix readout

Bart Verlaat, Nikhef

*LCTPC collaboration meeting*  
*DESY, 22 September 2009*

# Contents

- Introduction to CO<sub>2</sub> Cooling
- Overview of the current CO<sub>2</sub> systems in HEP
- CO<sub>2</sub> cooling for LCTPC
- Conclusions

# Why is evaporative CO<sub>2</sub> cooling good for HEP detectors?

CO<sub>2</sub> allows small tubing

*Why?*

Large latent heat & Low viscosity & High pressure

Allow low flow

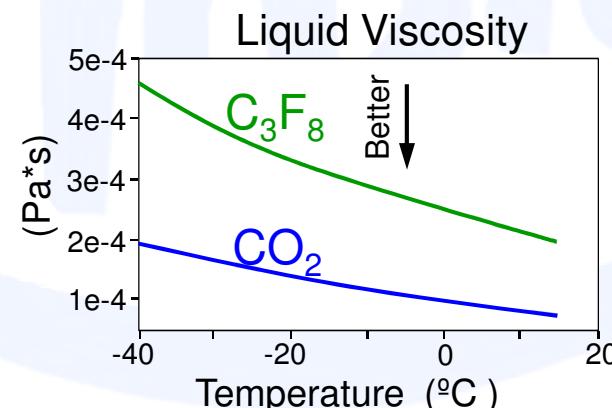
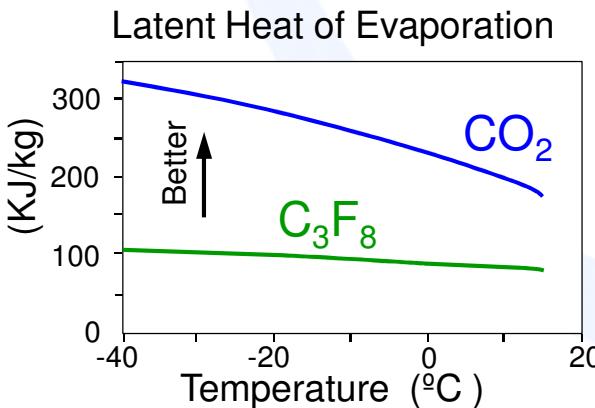
Low pressure drop

Allow high pressure drop

Low pressure drop

Lower pressure drop

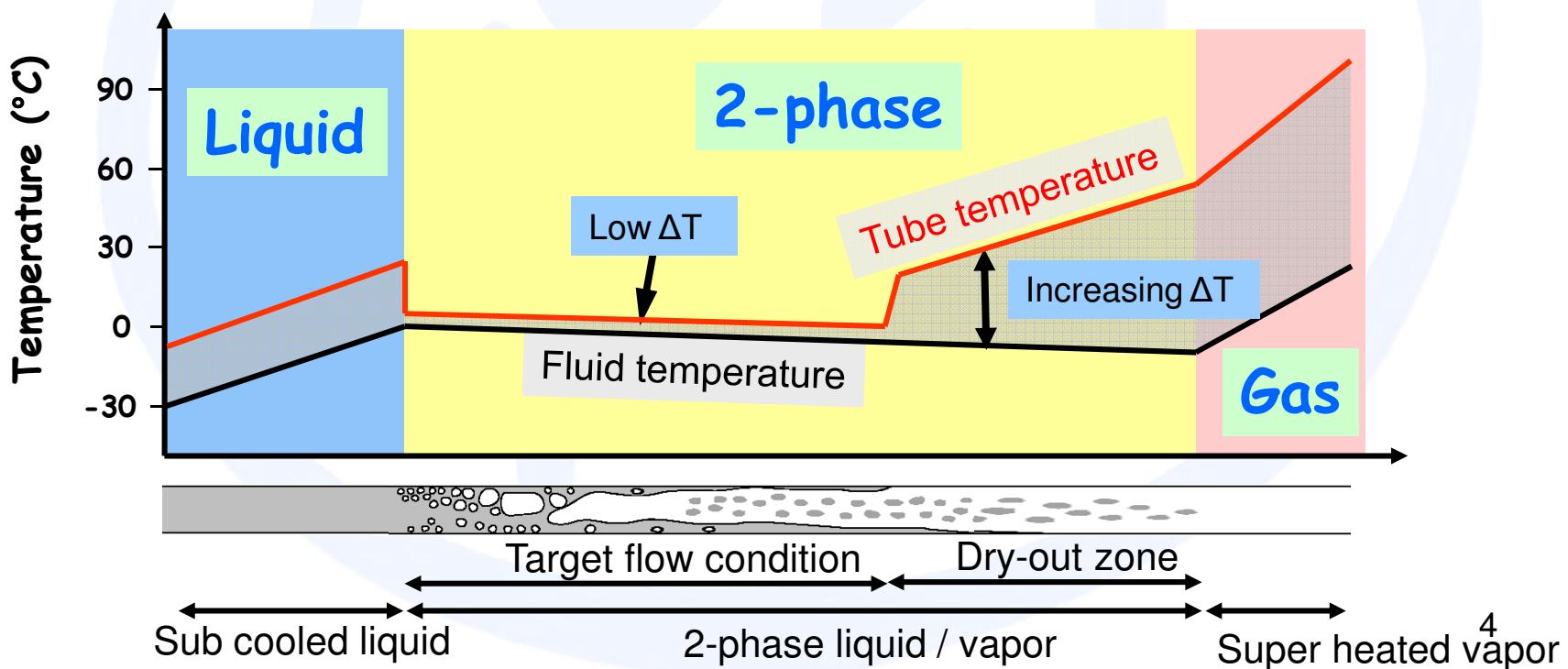
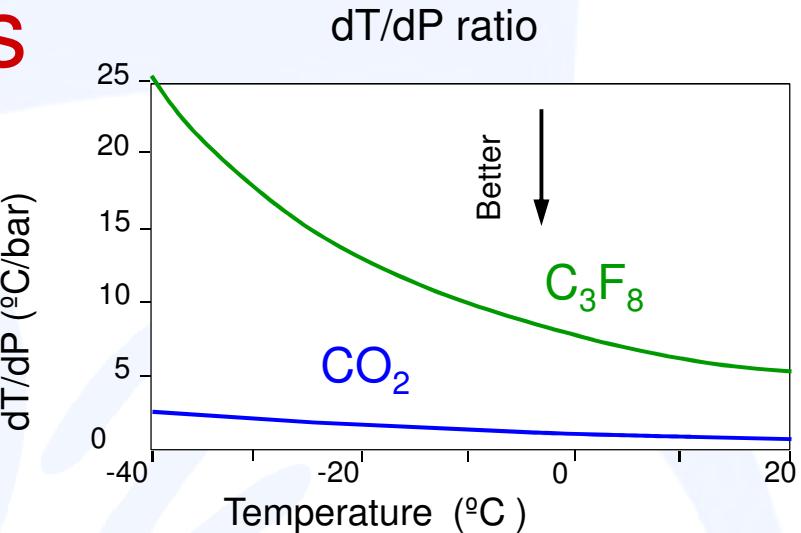
Allow high pressure drop



Allow very small tubing

# Temperature gradients in cooling tubes

Low  $dT/dP$  ratio due to high pressure → **High pressure is good!**

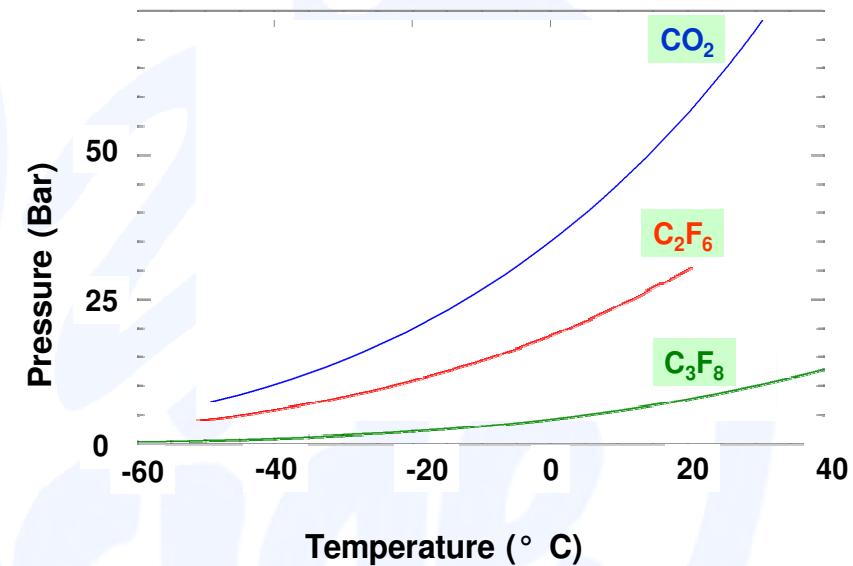
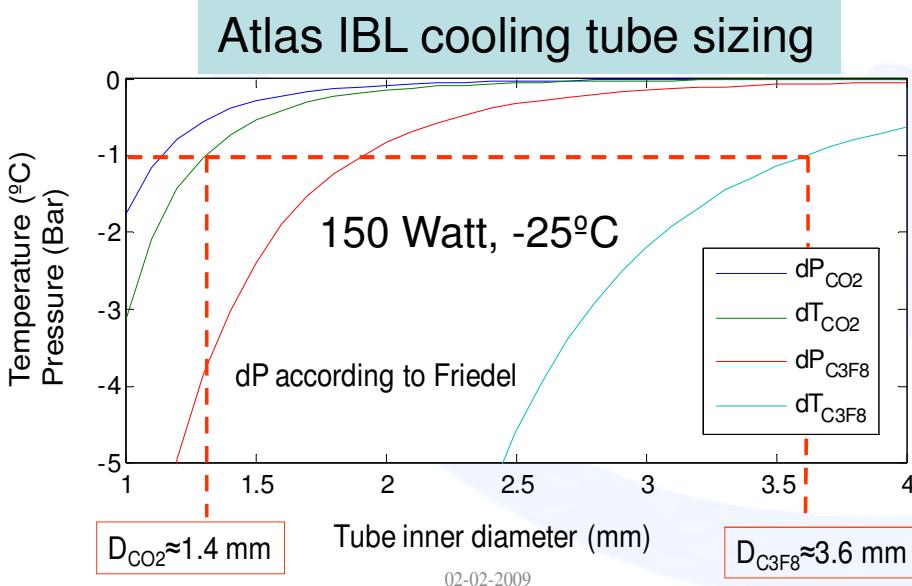


# CO<sub>2</sub> safety issues

Pressure Equipment Directive (PED):

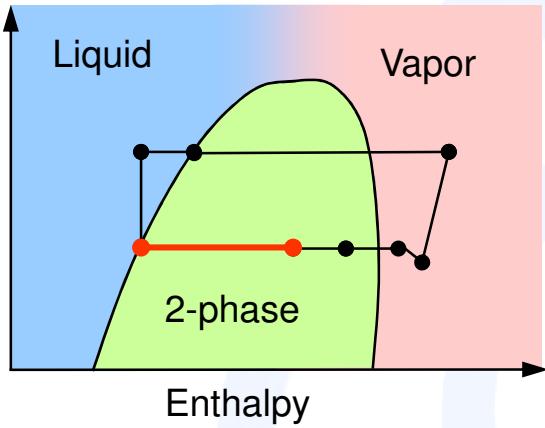
- Stored energy determines the safety class.
- Stored Energy = Pressure x Volume

CO<sub>2</sub> is environmental friendly, non-toxic and cheap

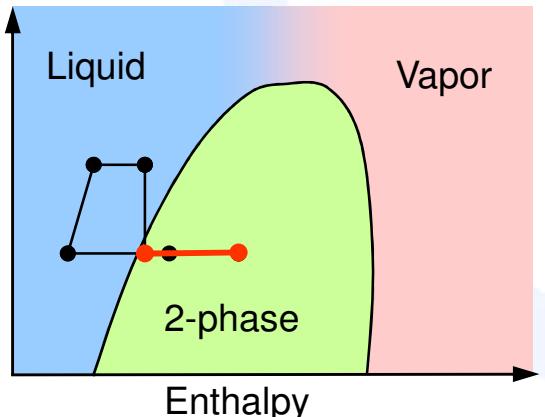
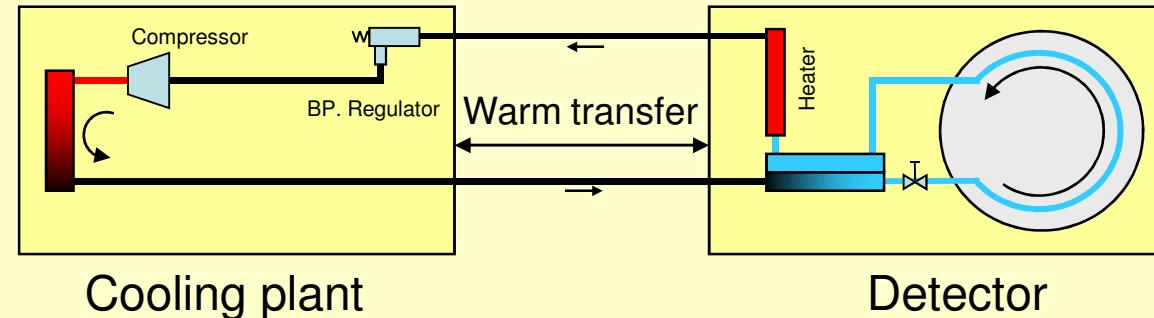


	ID	Pressure at 30°C	Stored energy
CO <sub>2</sub>	1.4mm	72.1 bar	11.1 J/m
C <sub>3</sub> F <sub>8</sub>	3.6mm	9.9 bar	10.1 J/m

# How to get the ideal 2-phase flow in the detector?

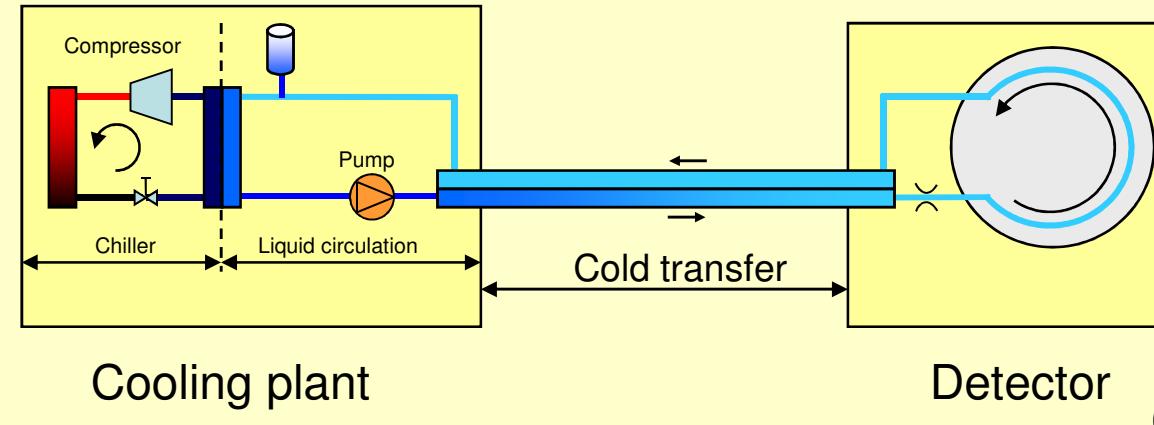


Traditional method: **Vapor compression system (Atlas)**



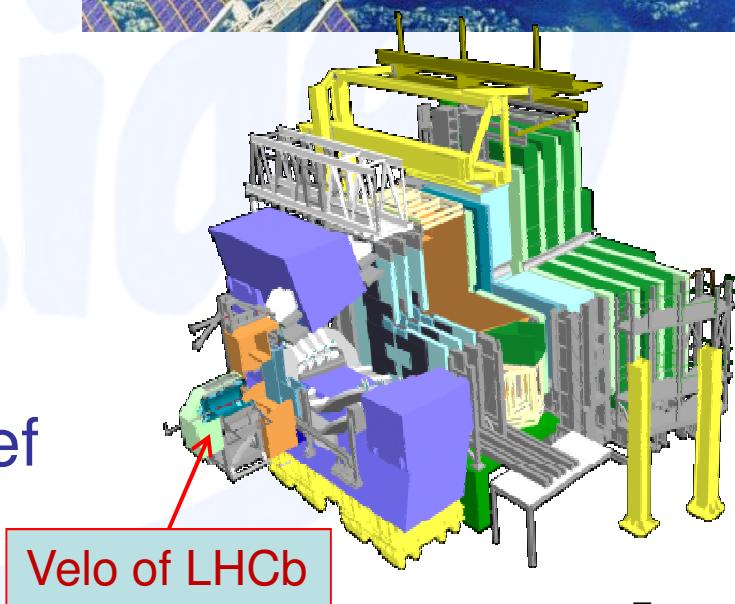
2PACL method:  
**(LHCb)**

**Pumped liquid system**



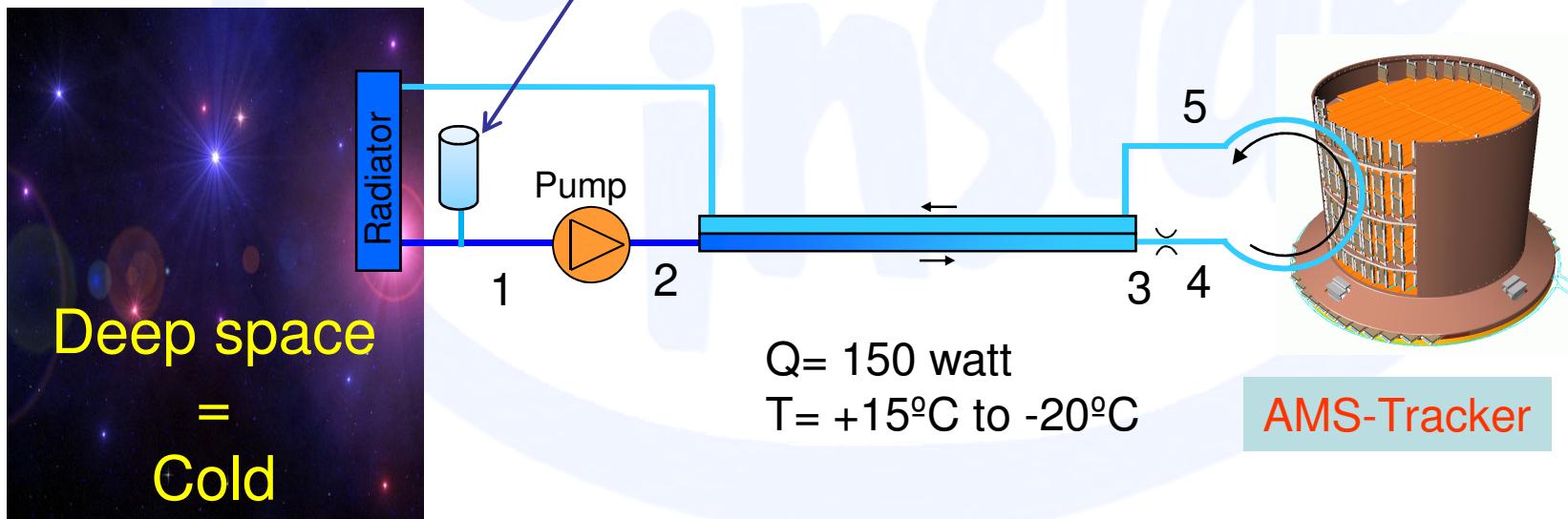
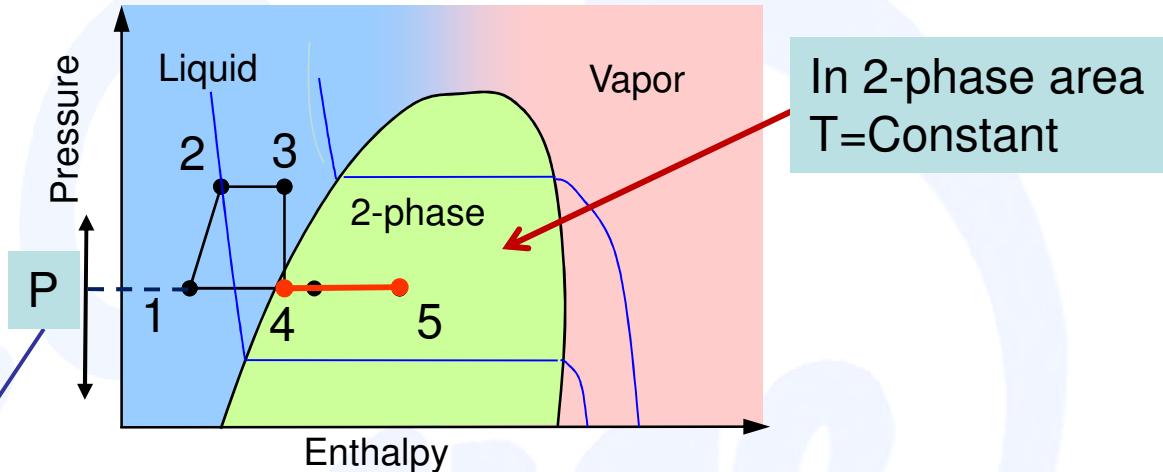
# CO<sub>2</sub> systems in HEP

- 2 CO<sub>2</sub> cooling systems have been developed for HEP detectors so far.
  - AMS-TTCS (Tracker Thermal Control System)
    - Q= 150 watt
    - T=+15°C to -20°C
  - LHCb-VTCS (Velo Thermal Control System)
    - Q=1500 Watt
    - T= +8°C to -30°C
- Both systems are based on the **2PACL** principle invented at Nikhef



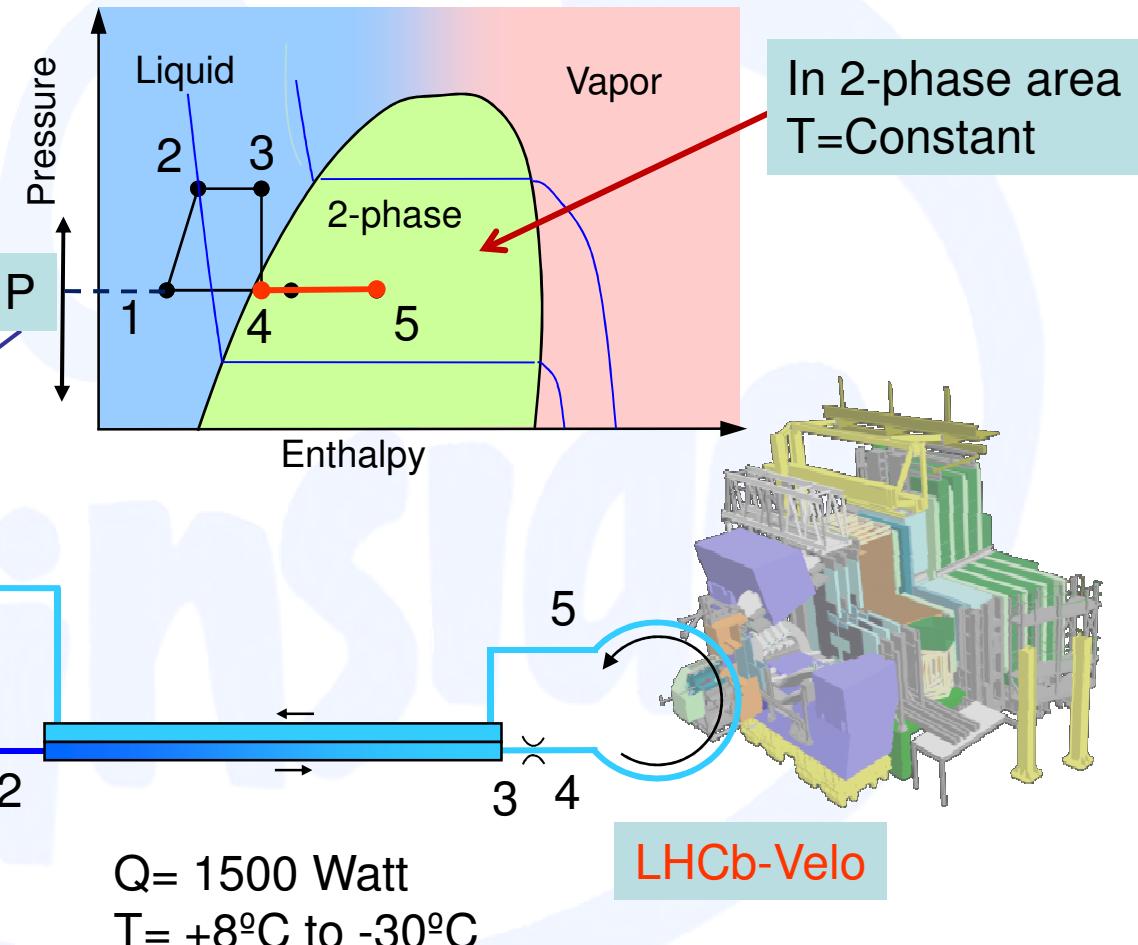
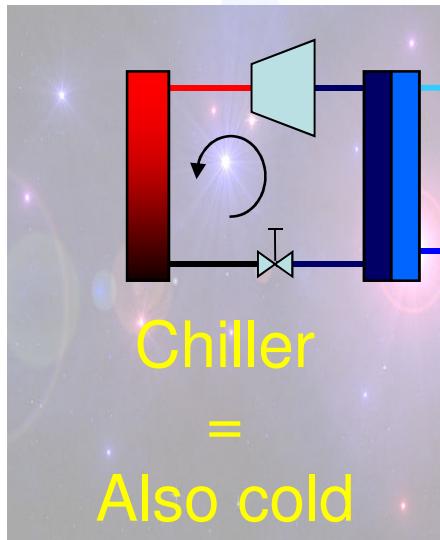
# 2-Phase Accumulator Controlled Loop (2PACL)

- 2PACL was developed for the AMS-TTCS
- 2PACL also implemented in LHCb-VELO

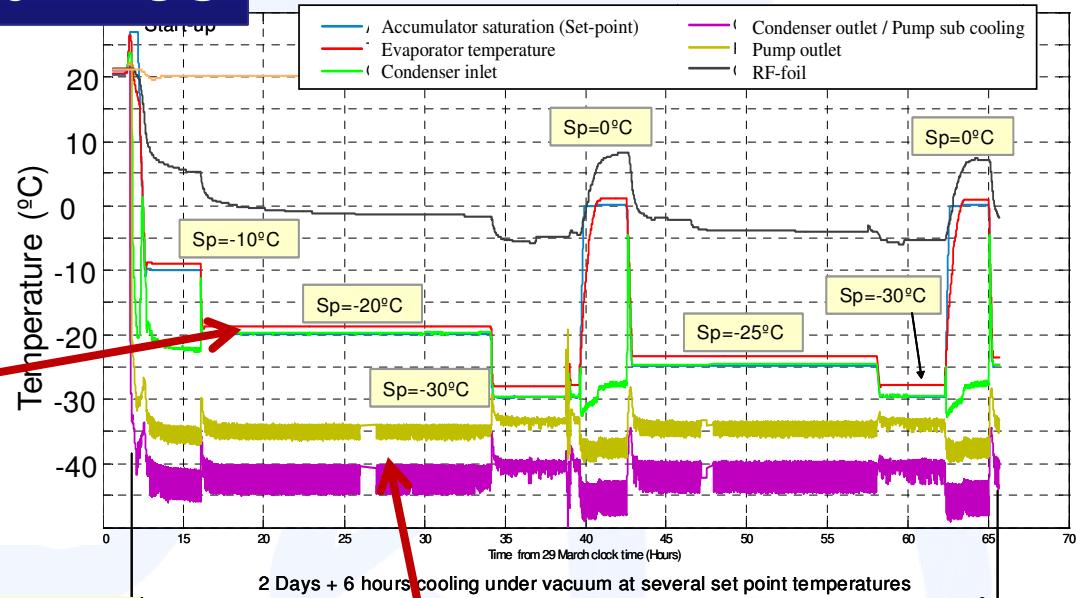


# 2-Phase Accumulator Controlled Loop (2PACL)

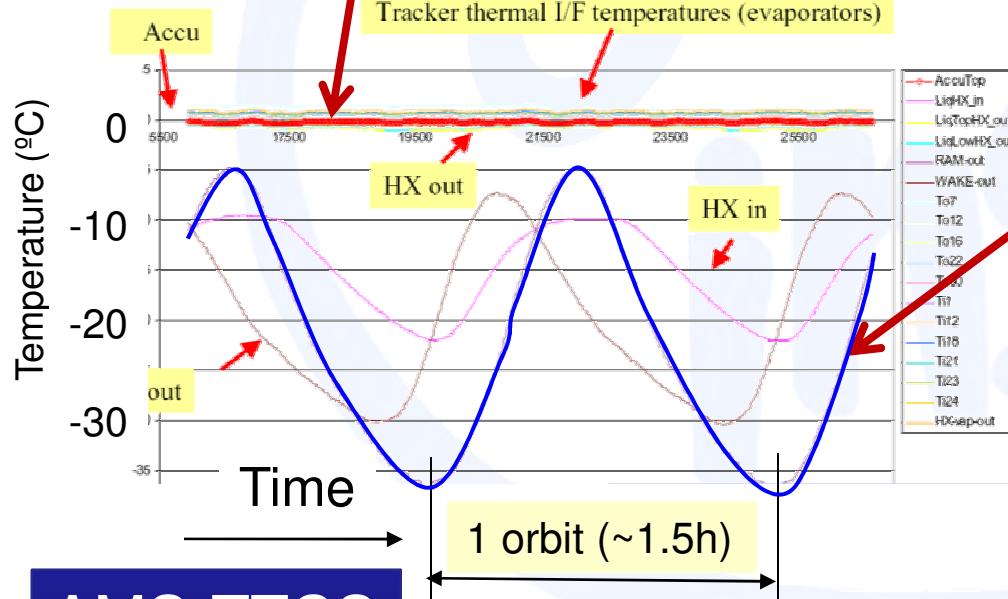
- 2PACL was developed for the AMS-TTCS
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# LHCb-VTCS



Accumulator temperature  
= Cooling tube temperature



Temperature of the chiller

Temperature of space radiator

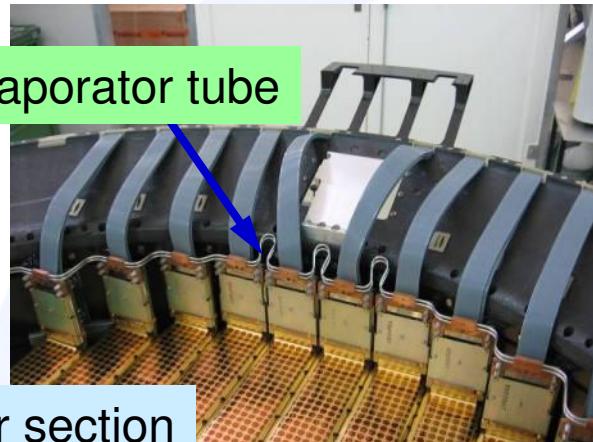
The cooling tube temperature is:

- Easy to control
- Very stable
- Independent of primary cooler temperature

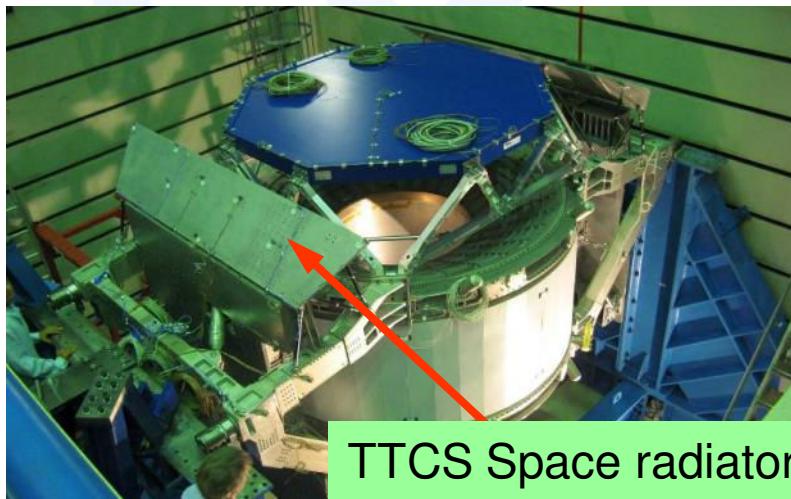
# The AMS-Tracker Thermal Control System (AMS-TTCS)



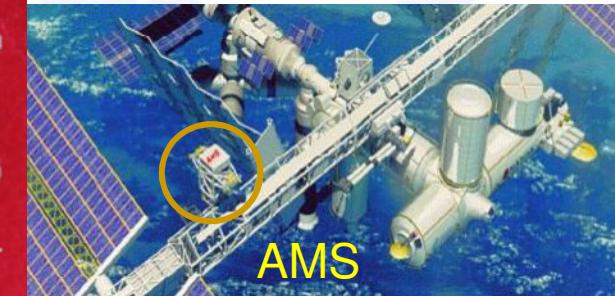
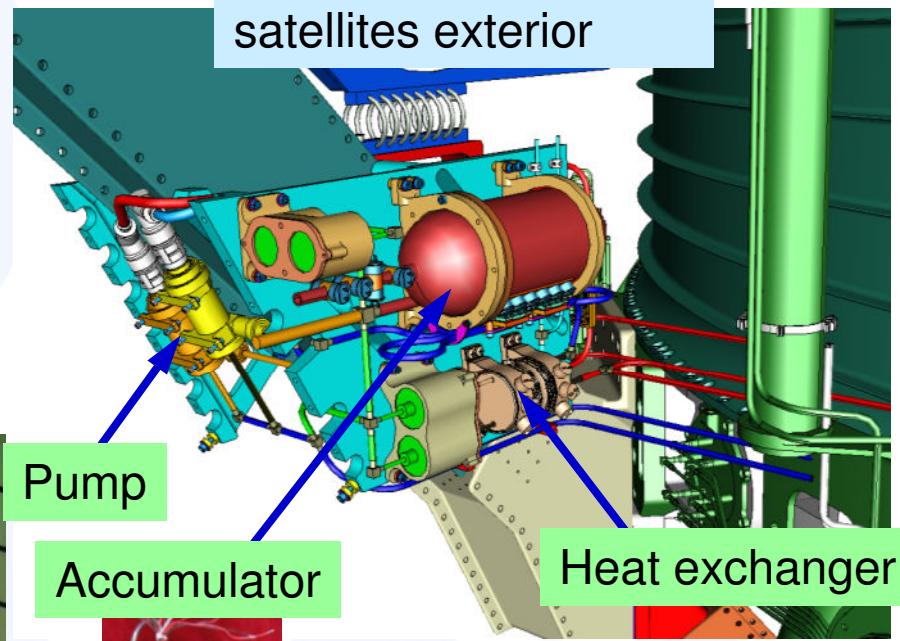
Evaporator tube



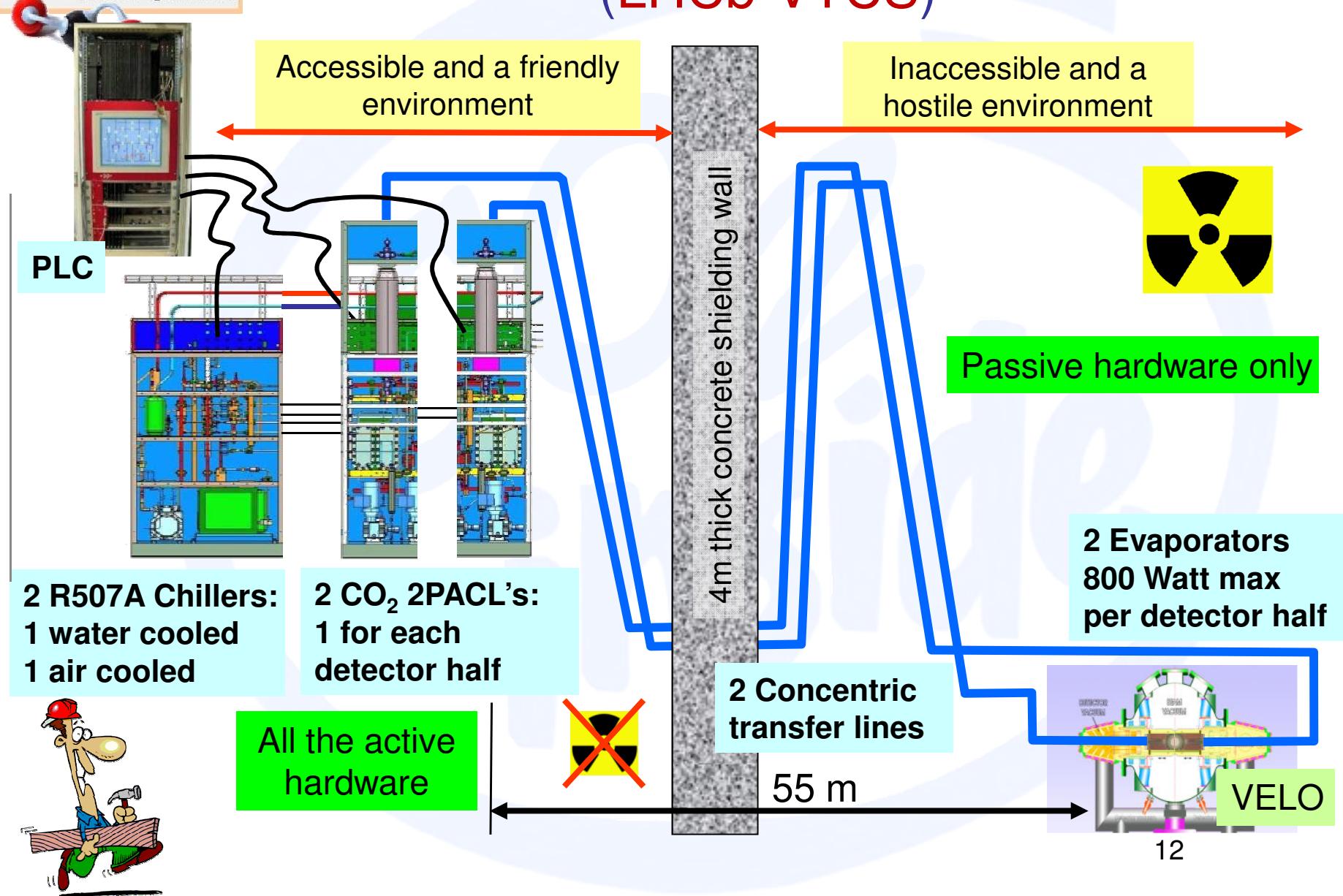
Evaporator section



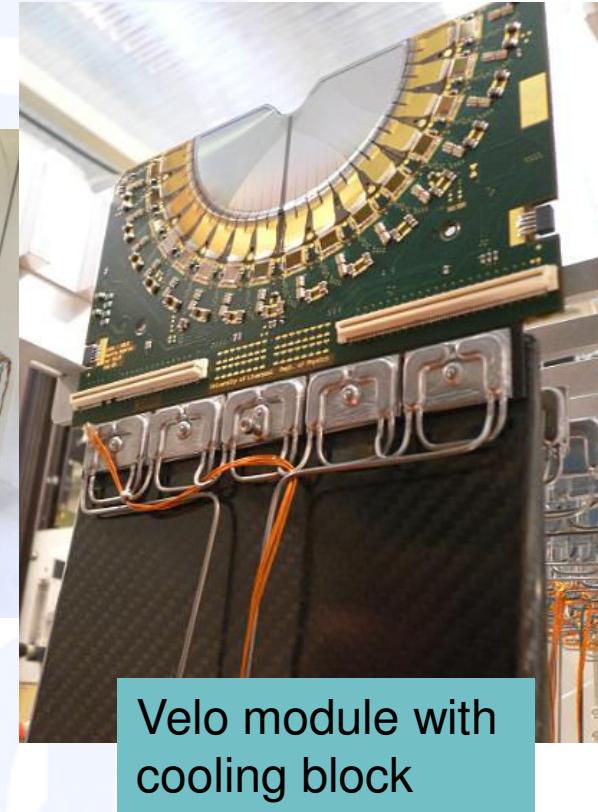
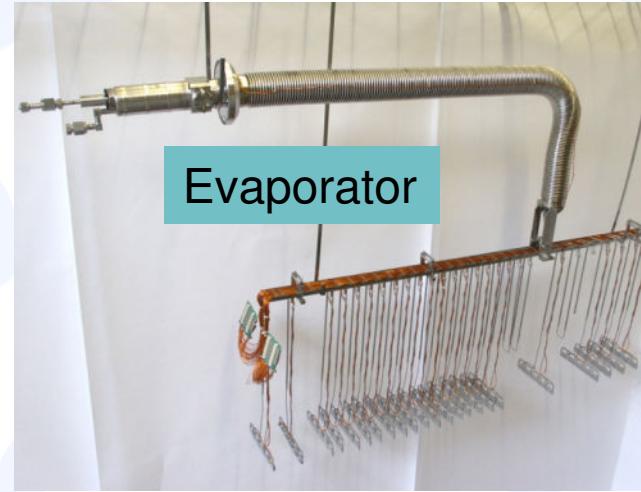
Component box on satellites exterior



# The LHCb-Velo Thermal Control System (LHCb-VTCS)

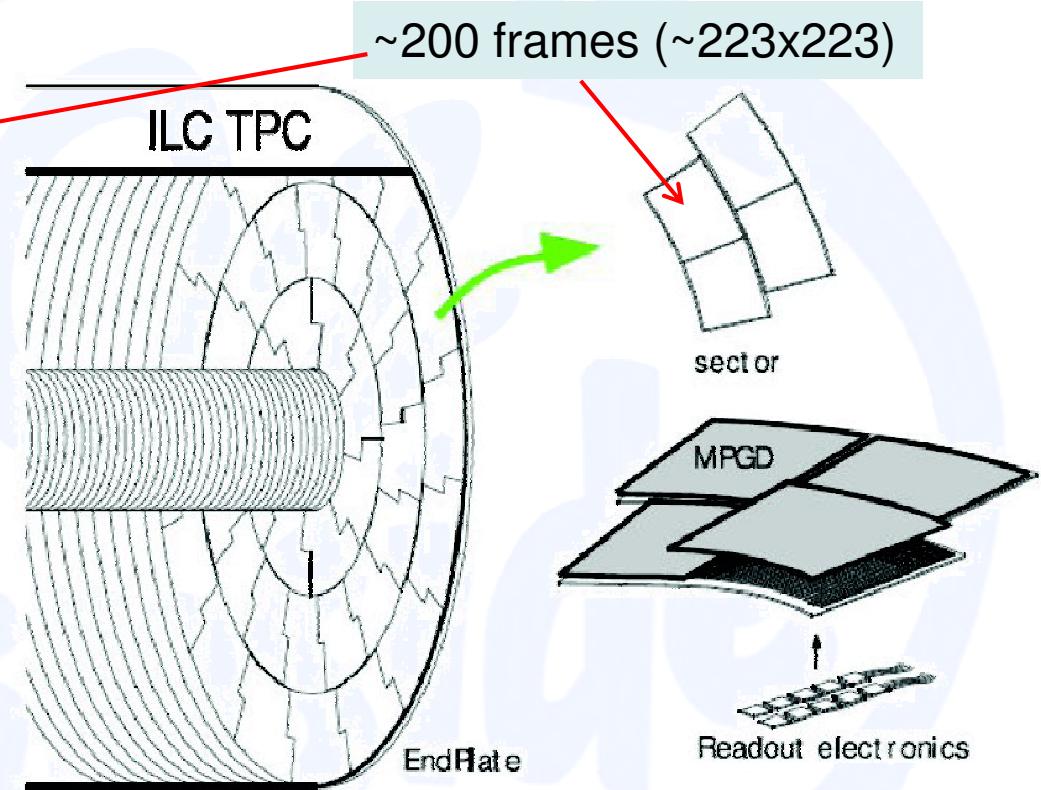
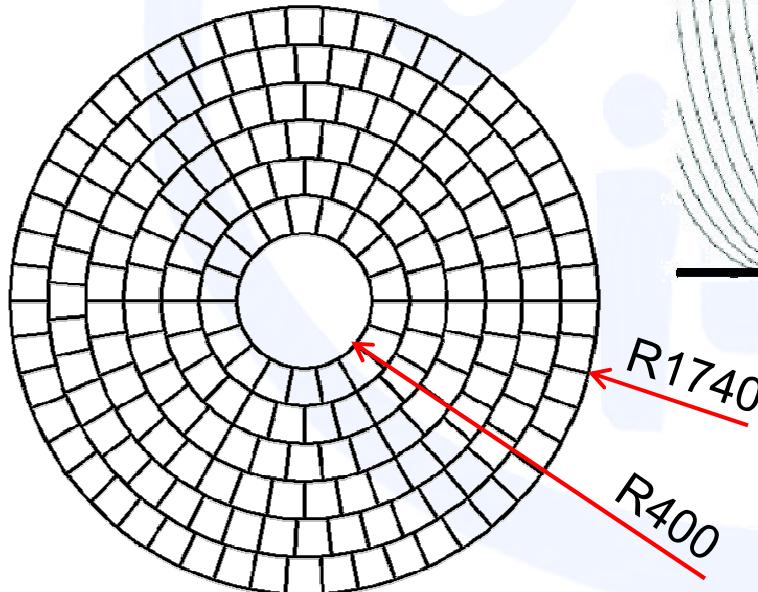
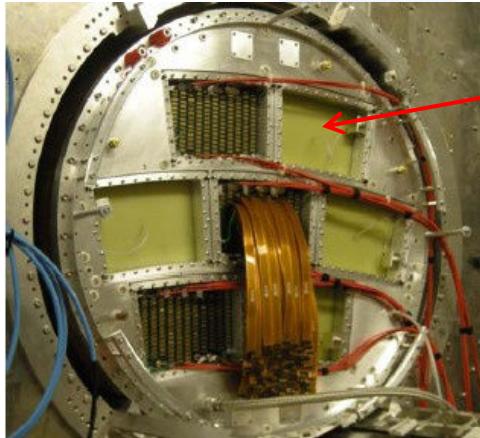


# The LHCb-Velo Thermal Control System (LHCb-VTCS)



# Calculation of a LCTPC cooling tube

## *Assumed TPC endplate layout*

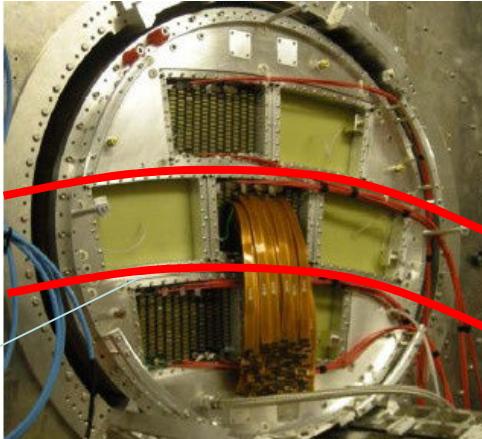


$\text{Area} \approx 9\text{m}^2 \approx 5000\text{chips/m}^2$   
 Heat load  $\approx 5\text{kW/m}^2$   
 Duty cycle  $\approx 2\%$   
 Total power  $\approx 1\text{kW}$   
 Power per frame = 5 watt  
 Cooling temperature =  $20^\circ\text{C}$

# Temperature gradients

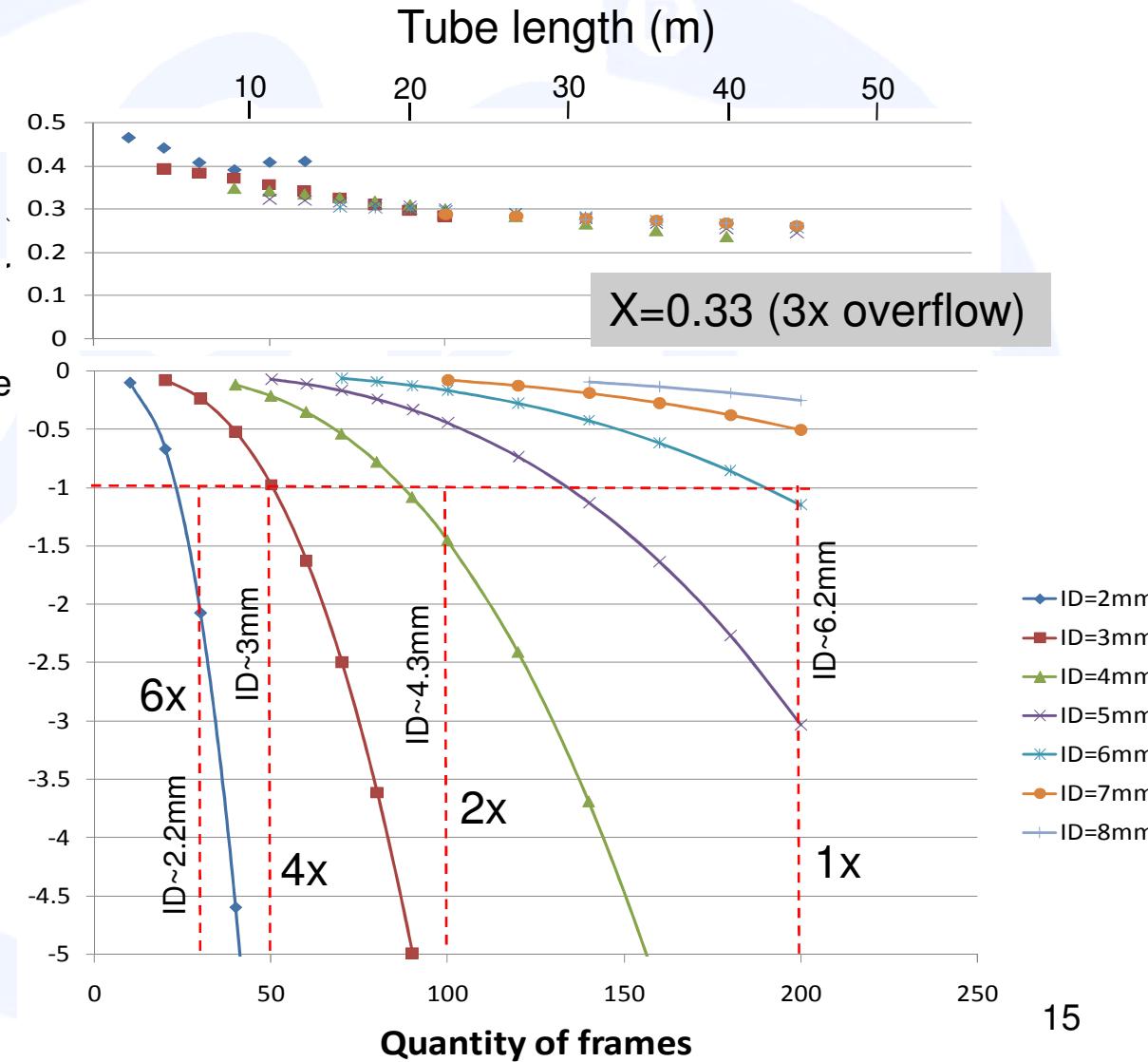
(As function of cooling tube diameter and length)

Radial temperature gradient ( $^{\circ}\text{C}$ )  
*(Heat transfer end of tube)*



Longitudinal temperature gradient ( $^{\circ}\text{C}$ )  
*(Pressure drop)*

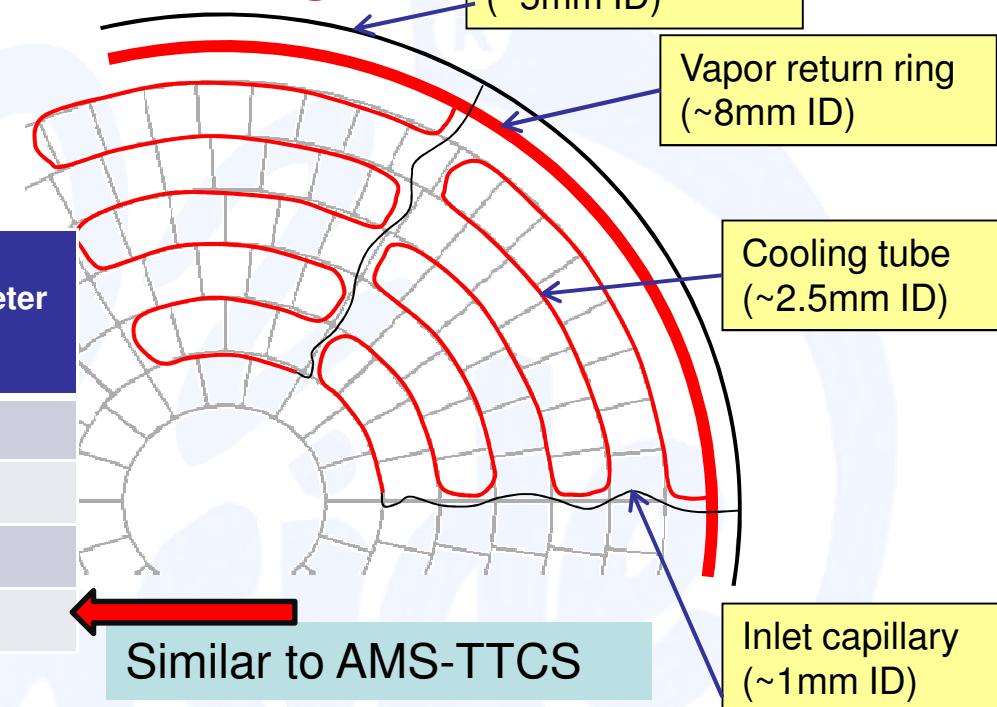
Power per frame = 5 watt  
Frame length = 223mm  
Heat load = 22.5 Watt/m



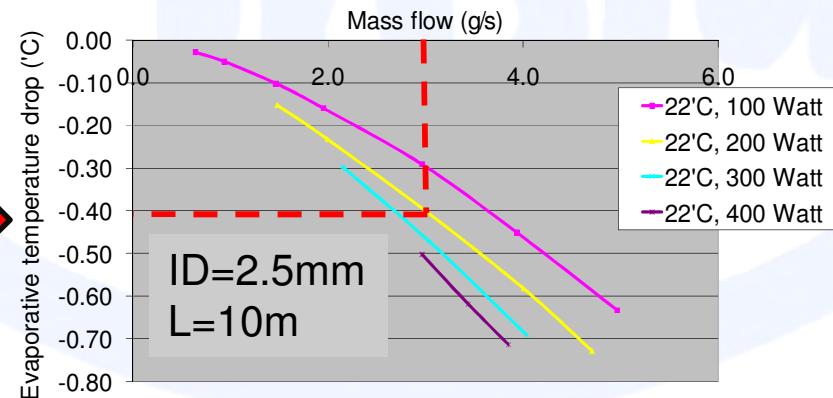
# TPC end plate cooling tube routing

Possible layout of the 6 loops option

	Qty Frames / loop	Heat load per loop (W)	Tube length (m)	Inner diameter (mm)
1 loop	200	1000	48m	6.2
2 loops	100	500	24m	4.3
4 loops	50	250	12m	3
6 loops	34	171	8m	2.2

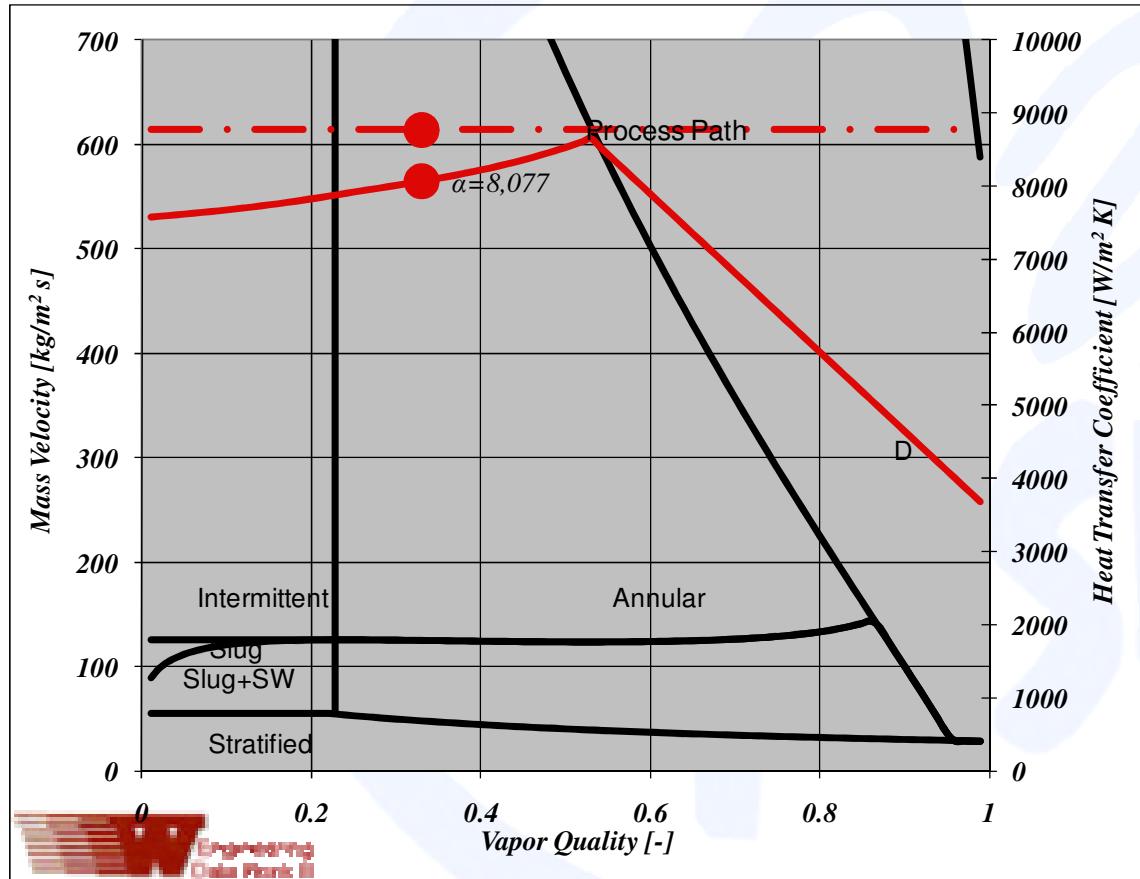


AMS test data (2001)  
0.4°C temperature gradient



# LCTPC cooling tube performance

## (6 parallel loops)

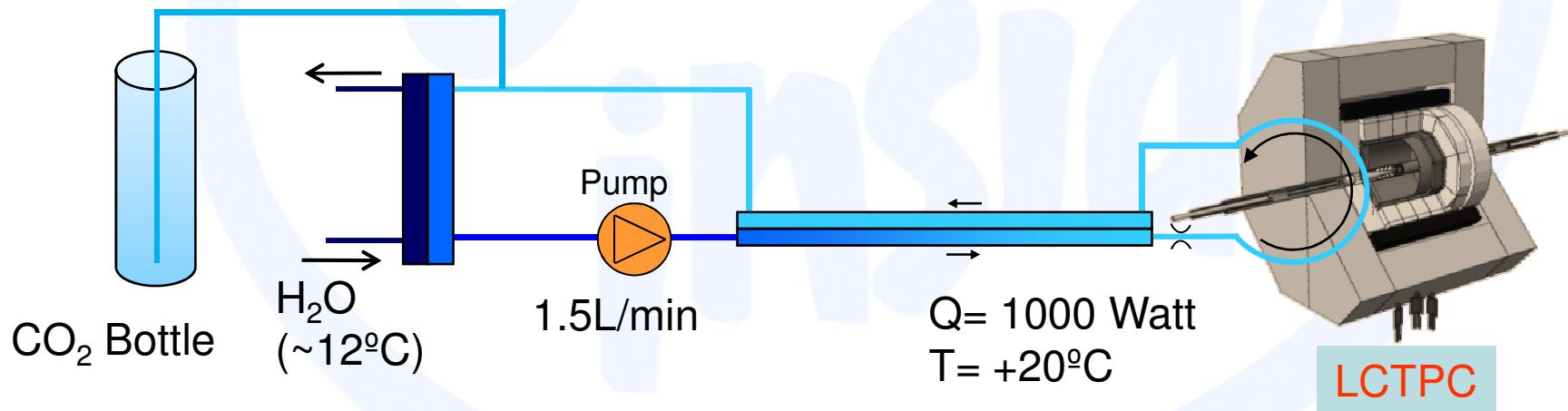


# 2PACL for LCTPC

## Warm 2PACL very simple

- Accumulator is  $\text{CO}_2$  bottle @ room temperature
- Cold source is cold water

**Bottle temperature = Detector temperature**



AMS-TTCS was tested in the same way  
(Cold test done with bottle outside in winter)

# Conclusions

- $\text{CO}_2$  cooling seem feasible for LCTPC
- A 6 loop option looks reasonable
  - Inner diameter 2.5mm
  - Length ~8m
  - Gradient < 1°C
  - Heat transfer ~8000W/m<sup>2</sup>K
  - Already tested for AMS-TTCS
- A room temperature  $\text{CO}_2$  cooling system easy to realize.
  - Pump (LEWA LDC-1 with damper)
  - Heat exchanger (SWEP BDW16 DW-U)
  - Transfer tube (Concentric pipe in pipe)
  - Cold water (Available standard in lab)
  - Bottle (You get it for free if you order  $\text{CO}_2$ )