Visit to CERN's CO2 Cooling Installations

- Visit organized by Immanuel Gfall (Vienna)

  → LHCb experiment (running CO2 plant)

  → CERN cryolab, visit CO2 test installations (Hans Postema)

- Aim:

  → Familiarize with evaporative cooling systems

  → prepare for decision on PXD cooling

- Participants: I. Gfall, H.J. Simonis, T. Weiler, C. Marinas, H.G. Moser, C. Kiesling

Cooling Issues for the PXD

- Water cooling for the PXD EOS may not be sufficient

  → underpressure system required

  → copper cooling block mechanically problematic

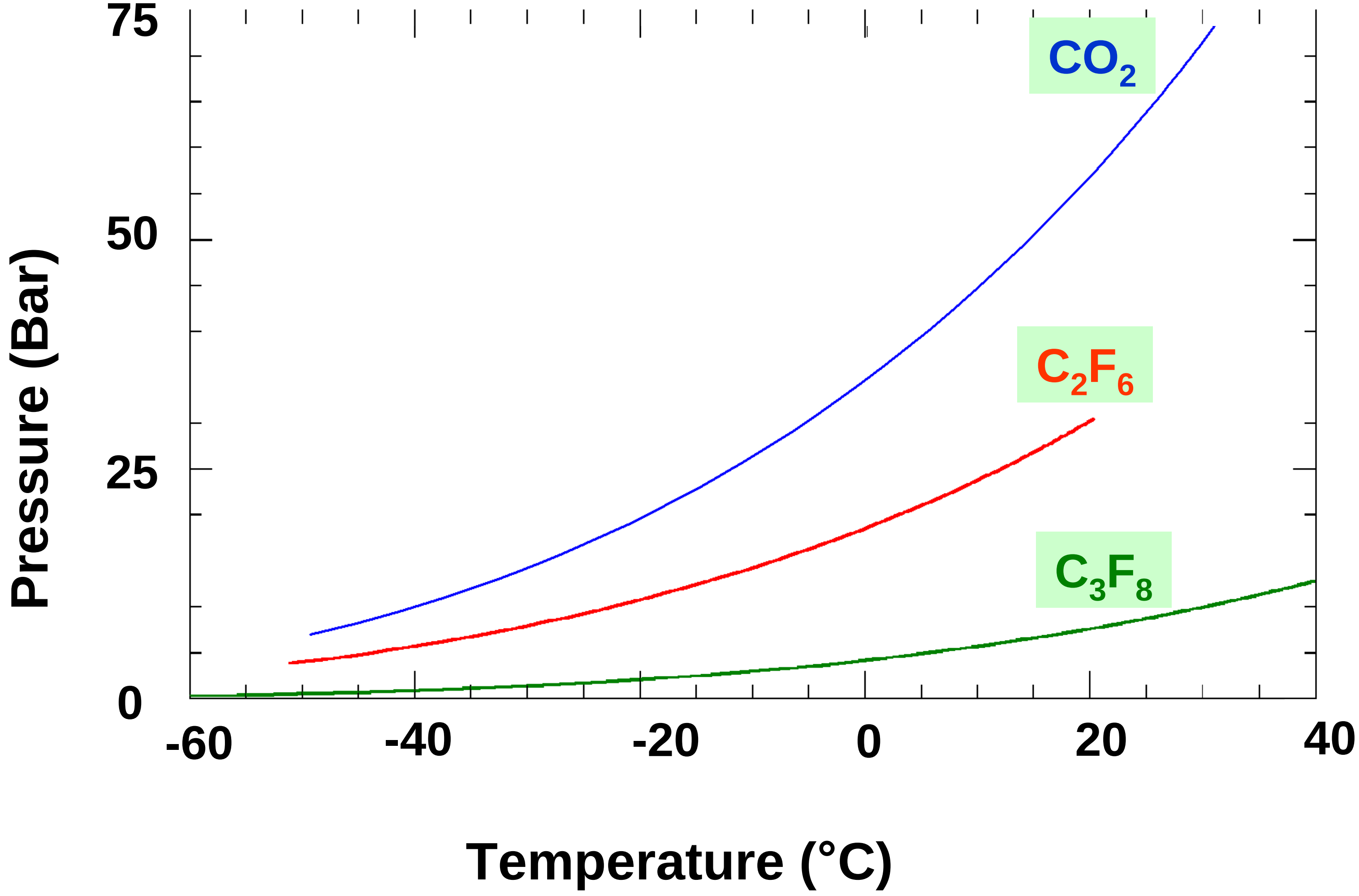
- Option for common (PXD + SVD) cooling system discussed during the Prague meeting → evaporative systems

- CO2 seems preferred option for SVD (Origami scheme)

- C3F8 (a la ATLAS) is an alternative (?)

Saturation curves in the PT Diagram for CO_2, C_2F_6 & C_3F_8

(3 used or considered refrigerants at CERN)



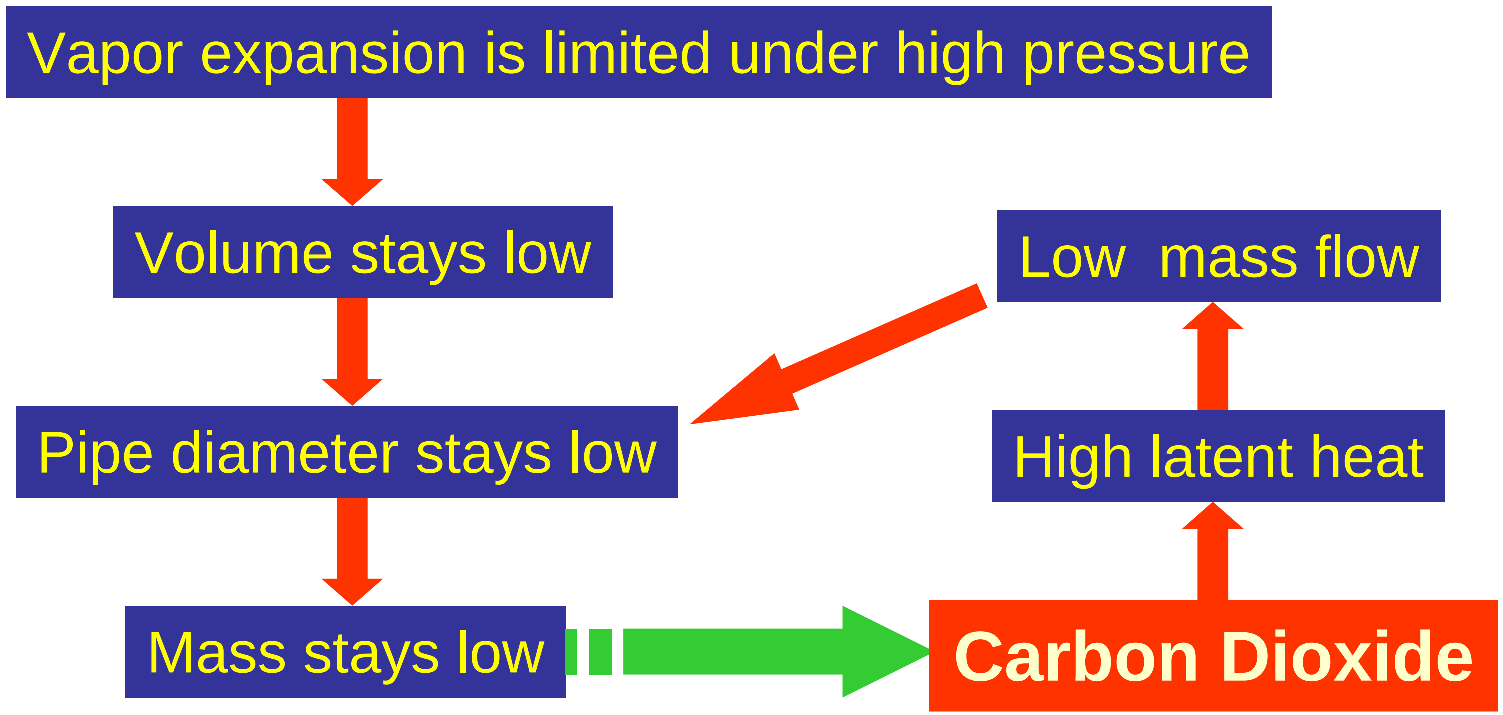
foils from
Bart Verlaat
Nikhef

Hans Postema
CERN

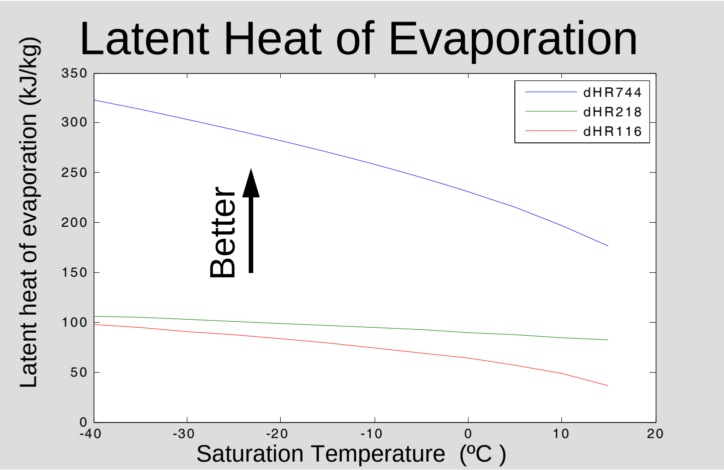
The easiest way of cooling is:

Evaporate at high pressure!

Why?



Property comparison

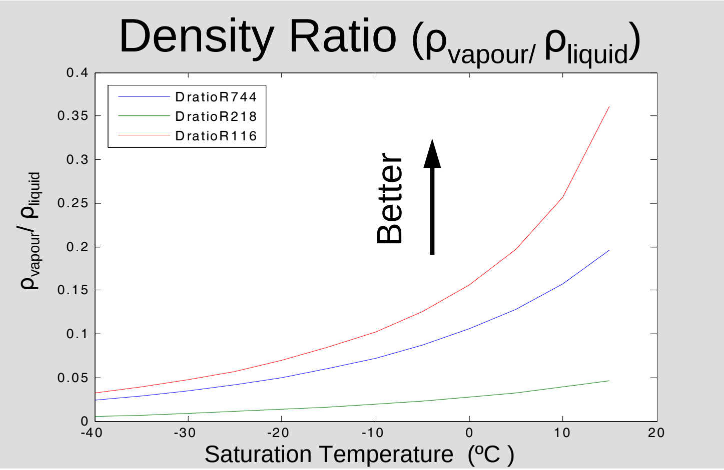


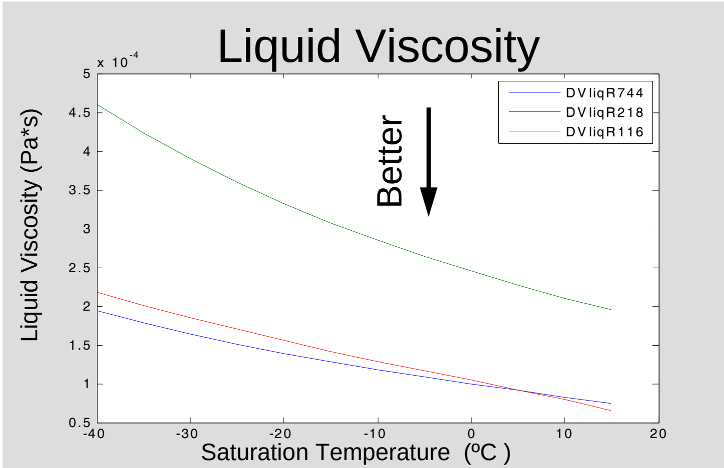
Refrigerant “R” numbers:

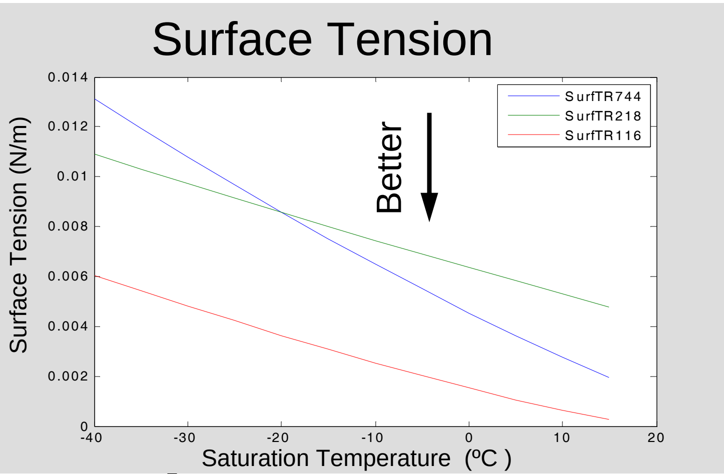
R744=CO_2

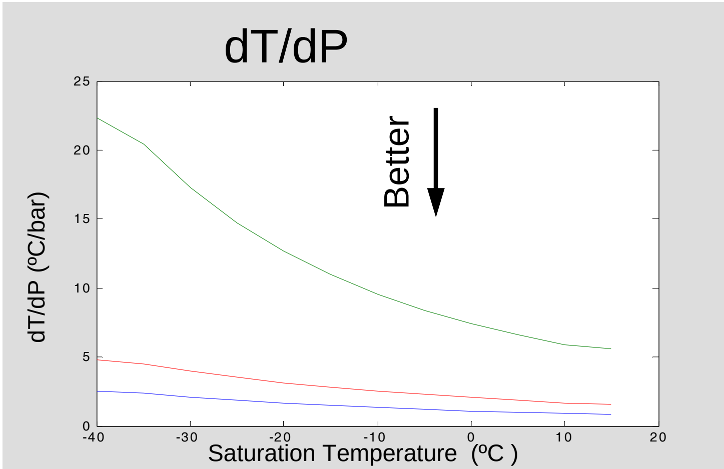
R218=C_3F_8

R116=C_2F_6





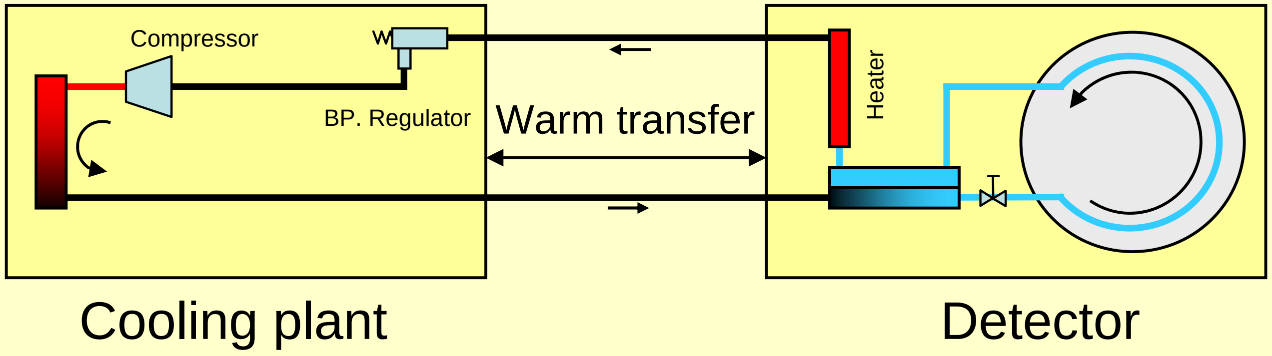


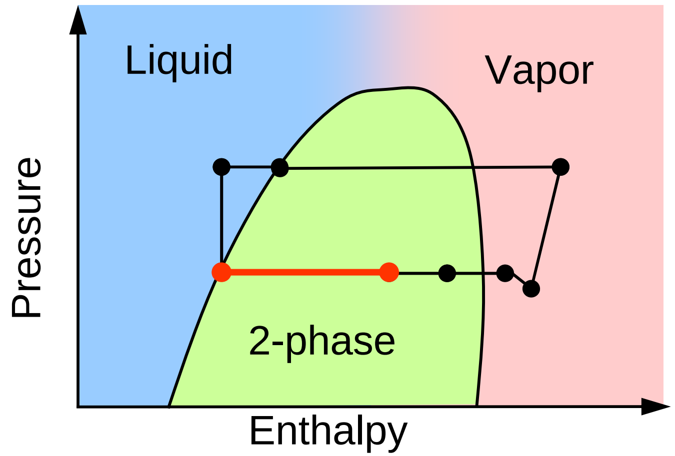


Evaporative cooling principles at LHC

Atlas Inner Detector: **Vapor compression system**

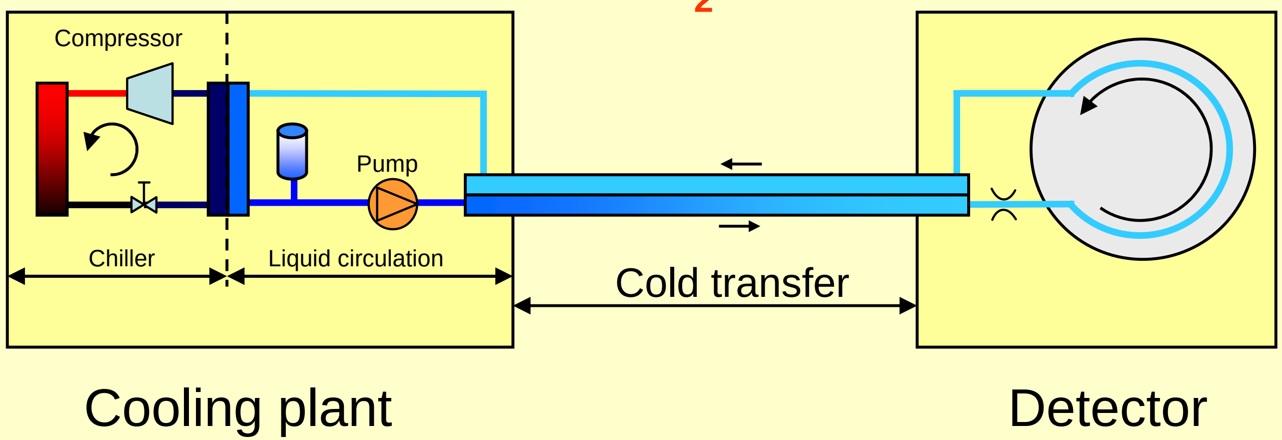
Fluid: C_3F_8

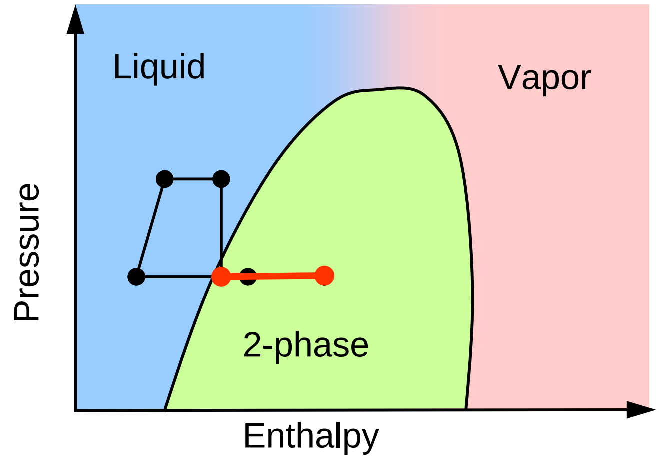




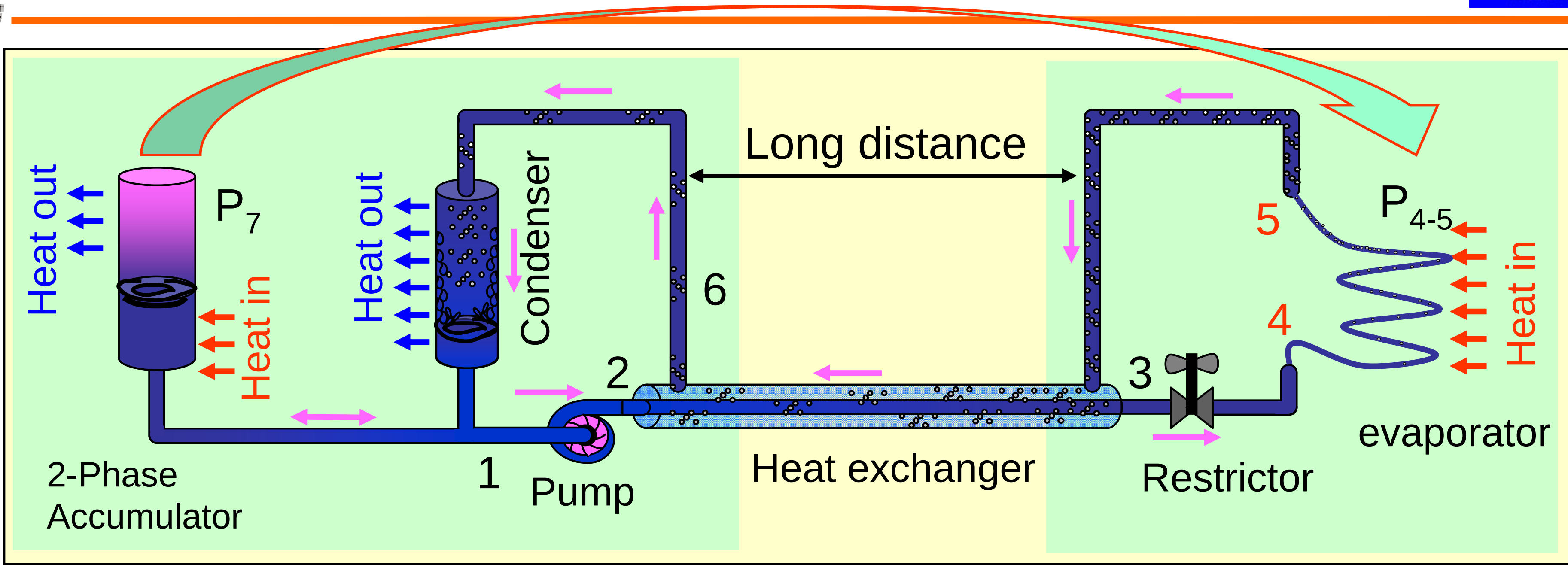
LHCb-VELO: **2PACL pumped liquid system**

Fluid: CO_2



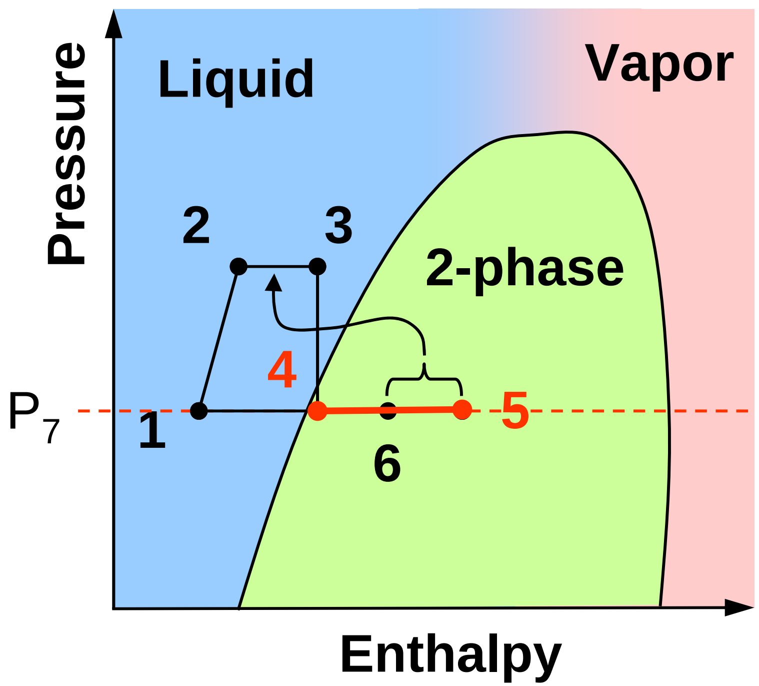


The 2-Phase Accumulator Controlled Loop



2PACL principle ideal for detector cooling:

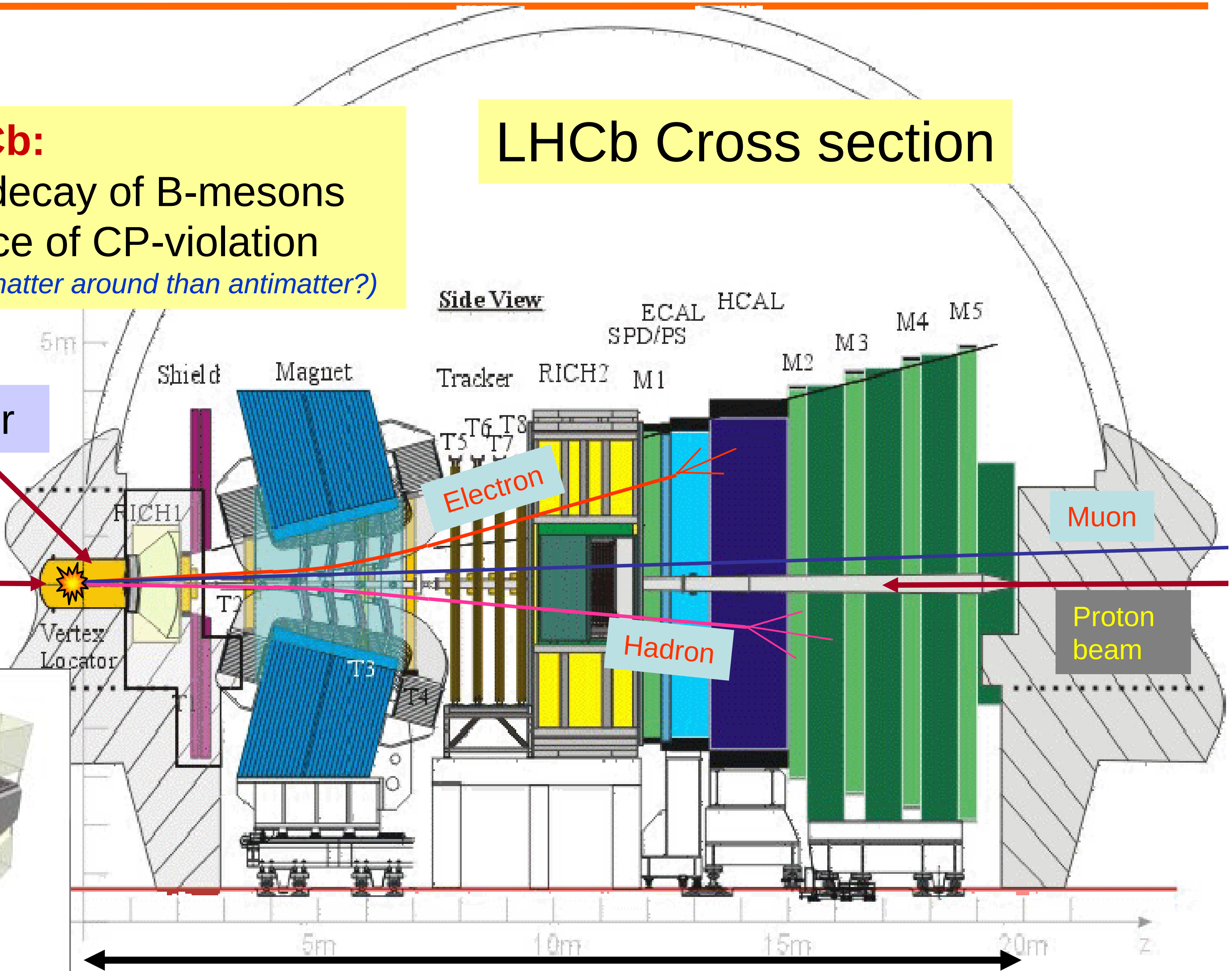
- Liquid overflow => no mass flow control
- Low vapor quality => good heat transfer
- No local evaporator control, evaporator is passive in detector
- Very stable evaporator temperature control at a distance ($P_{4-5} = P_7$)



LHCb Detector Overview

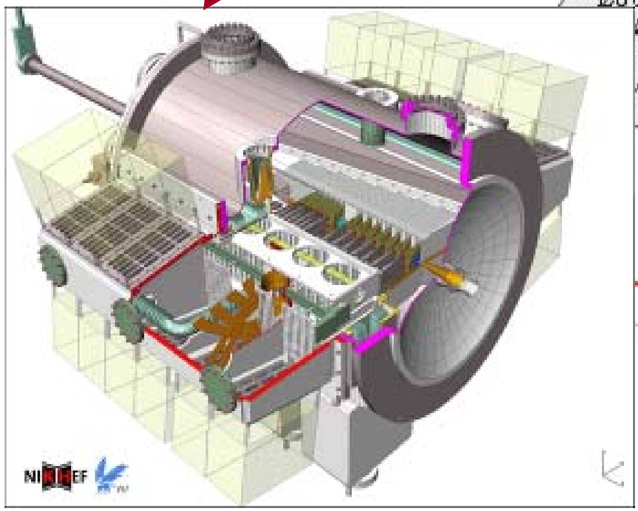
Goals of LHCb:
Studying the decay of B-mesons to find evidence of CP-violation
(Why is there more matter around than antimatter?)

LHCb Cross section



20 meter

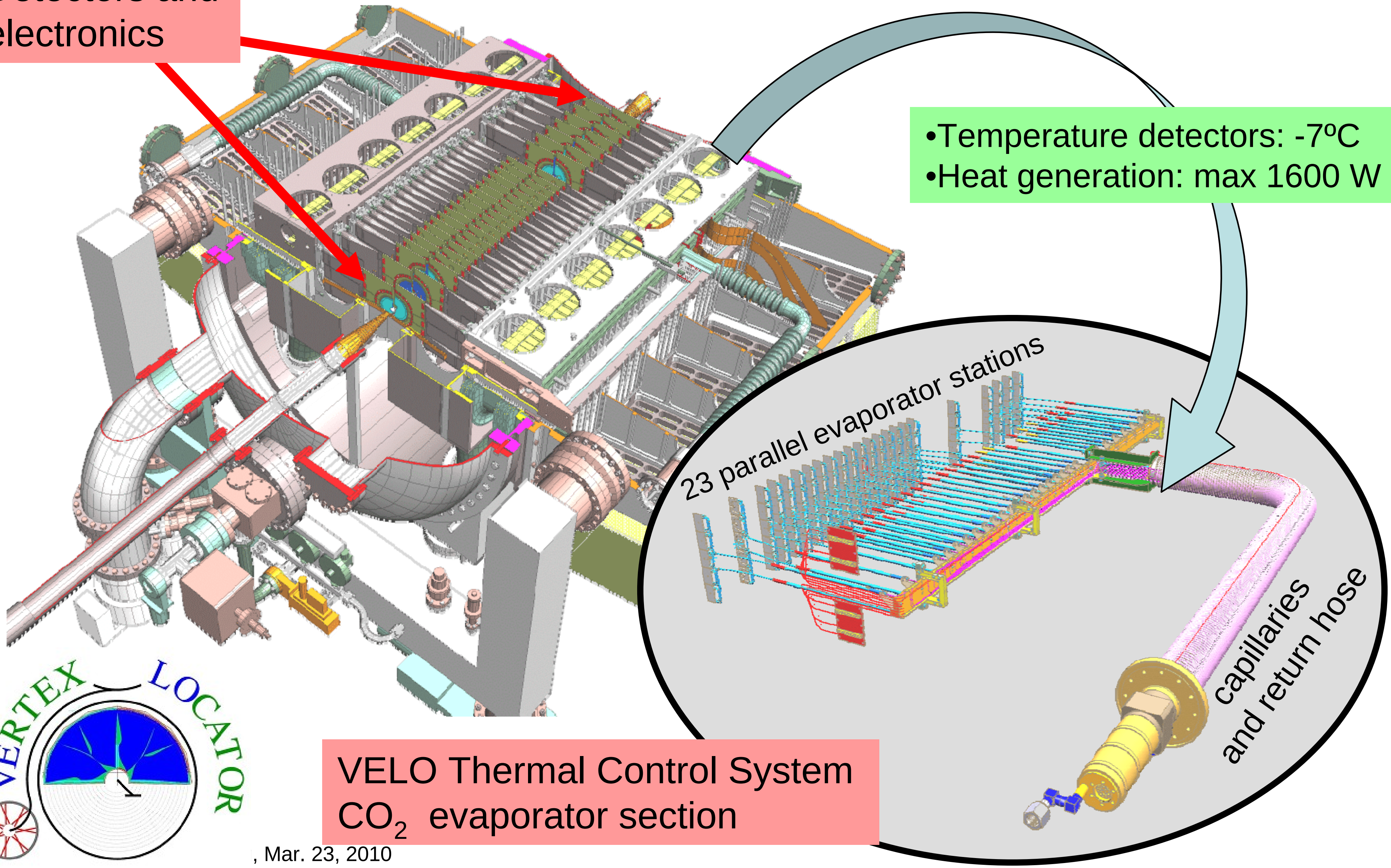
Vertex Locator



The LHCb-VELO Detector

(VErtex Locator)

Detectors and electronics



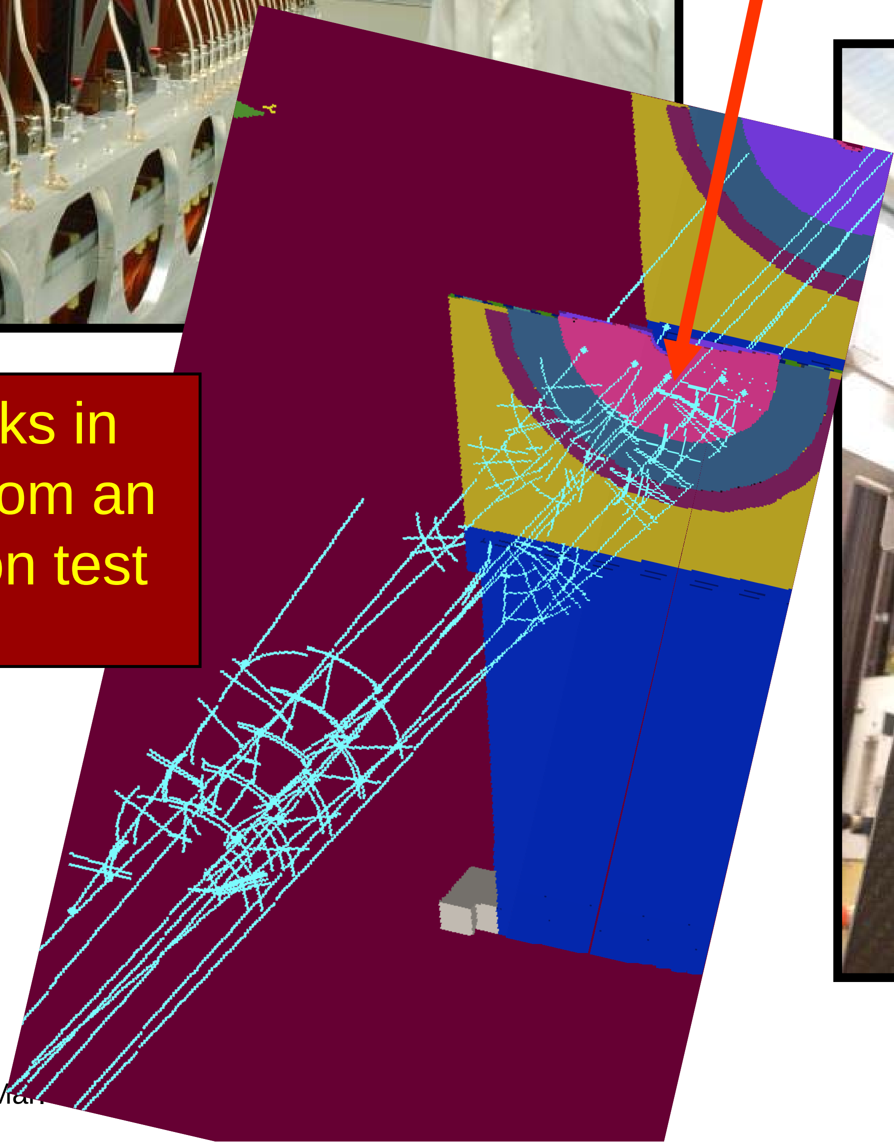
- Temperature detectors: -7ºC
- Heat generation: max 1600 W

VELO Thermal Control System
CO_2 evaporator section

The Velo Detector

Detection Silicon

Heat producing electronics



Particle tracks in the VELO from an LHC injection test *(22 august '08)*

CO_2 evaporator
(Stainless steel tube casted in aluminum)

BVERLAAT@NIKHEF.NL

VELO Cooling Challenges

- VELO electronics must be cooled in vacuum.
  - Good conductive connection
  - Absolutely leakfree
- Maximum power of the electronics: 1.6 kW
- Silicon sensors must stay below -7°C at all times (on or off).
- Adjustable temperature for commisioning.
  - -5°C to -30°C (Nominal irradiated -25°C)
- Maintenance free in inaccessable detector area

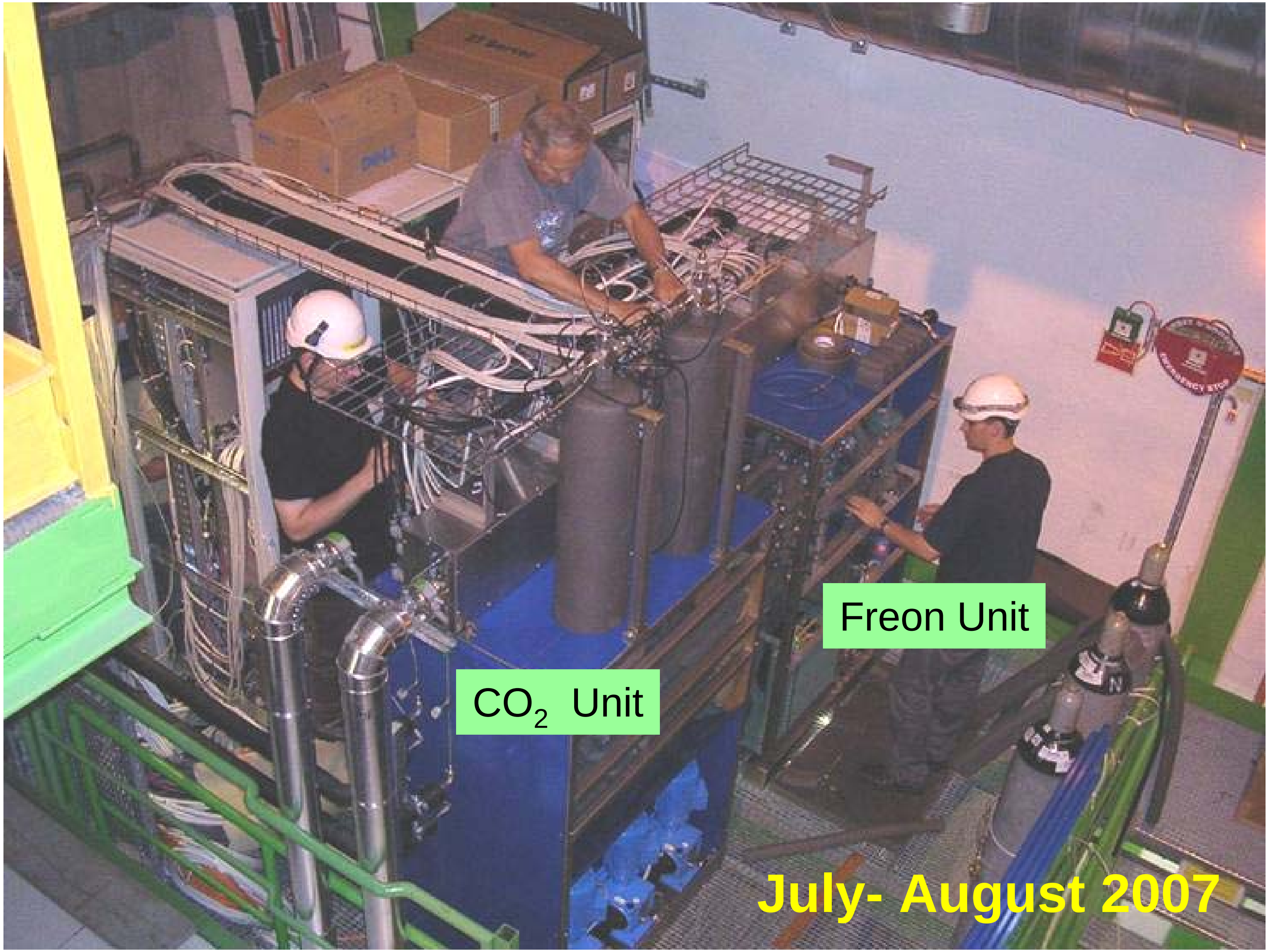
… sounds very similar to PXD requirements

VTCS construction

Velo Thermal Control System

- CO_2 2PACL's
  - Stainless steel piping with:
    - (Orbital) Welding
    - Vacuum Brazing
    - Swagelok Cajon VCR fittings and line components
  - Lewa liquid CO_2 pump (100 bar)
  - In house designed accumulator (130 bar)
  - Reinforced SWEP condenser (130 bar)
    - Now commercially available at SWEP.
  - 55 meter concentric transfer line
  - Aluminium casted cooling blocks
- Chillers designed in house with standard commercial chiller components.
  - Copper piping with hard solder joints
  - Danfoss line components
  - Bitzer compressors
  - SWEP heat exchangers
- Siemens S7-400 series Programmable Logic Controller (PLC)

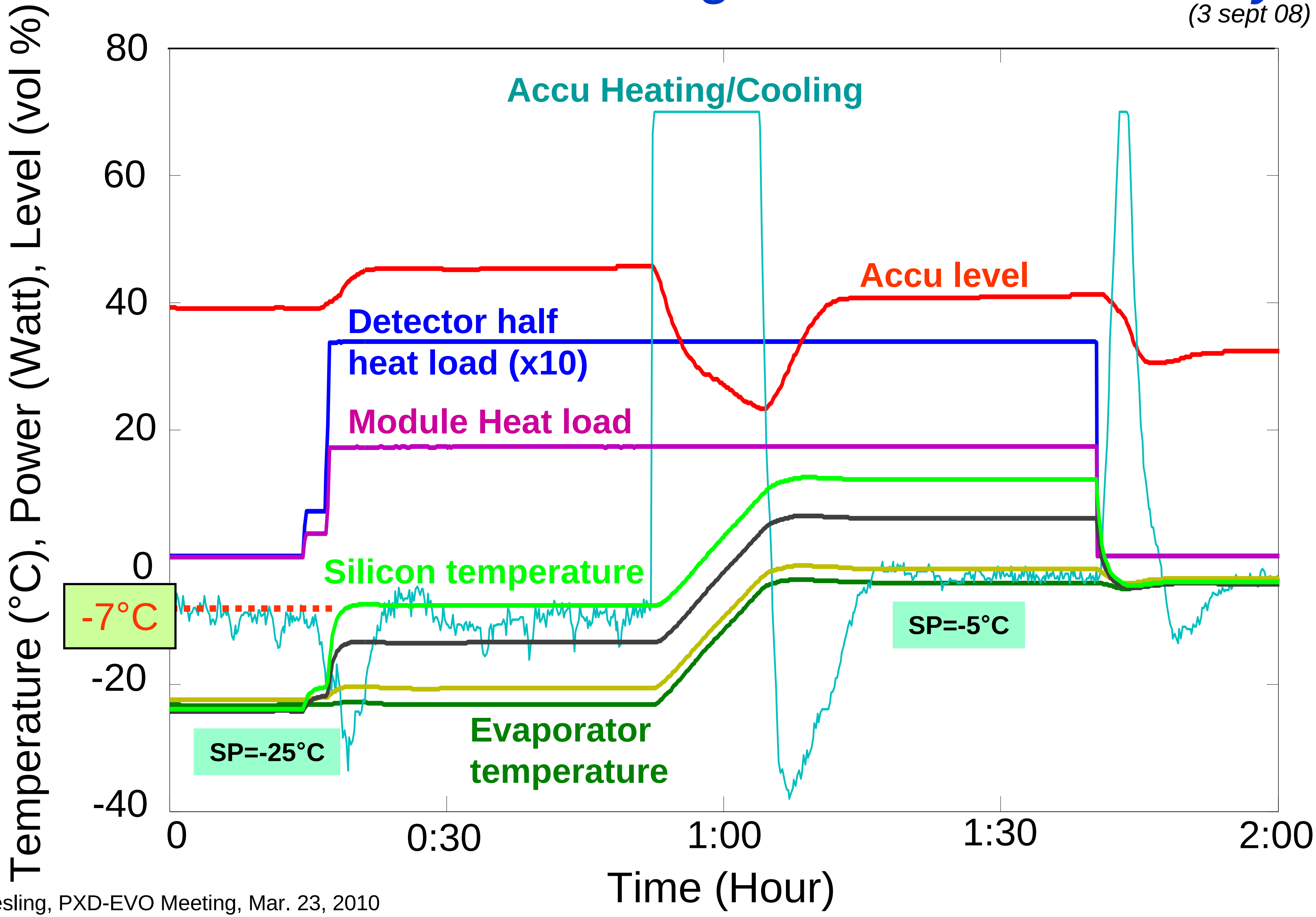
VTCS Units Installed @ CERN



24 June '08: After a succesful commisioning of the detector at -25°C, the setpoint is increased to -5°C.

And has been running since then smoothly!

(3 sept 08)



Visit to the CERN Cryolab (Hans Postema)

CMS Upgrade CO2 project, participants:

- RWTH Aachen – Lutz Feld, Michael Wlochal, Jennifer Merz
- IPN Lyon – Nick Lumb, Didier Contardo
- University Karlsruhe – Wim de Boer et al.
- Fermilab – Simon Kwan, Richard Schmitt, Terry Tope, Kirk Arndt

CMS Upgrade CO2 project, participants (2)

- PSI – Roland Horisberger
- CERN Cryolab – Friedrich Haug, Jihao Wu, Torsten Koettig, Christopher Franke
- University Esslingen – Walter Czarnetzki, Stefan Roesler
- CERN DT group – Joao Noite, Antti Onnela, Paolo Petagna, Paola Tropea,

CMS Upgrade CO2 project, participants (3)

- NIKHEF Atlas – Bart Verlaat, Auke-Pieter Colijn
- SLAC Atlas – Marco Oriunno
- CERN Atlas – Danilo Giugni, Jan Godlewski, Jose Direita
- EPFL Lausanne – John Thome et al.
- CERN CMS – Duccio Abbaneo, Hans Postema

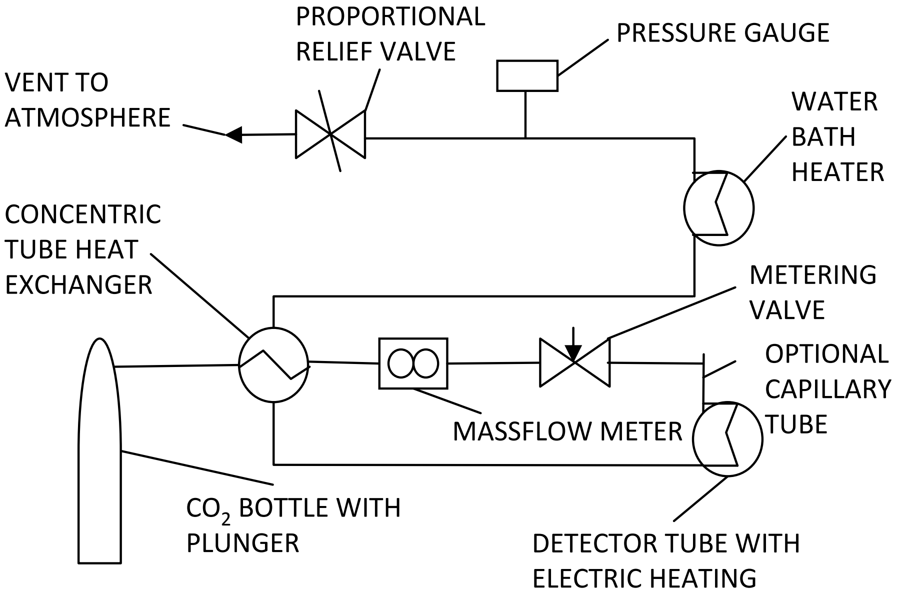
CO2 Full scale setup

- Following the example of the LHCb cooling plant, we will build a full scale setup for testing purposes
- Setup based upon CMS-TEC cooling plant provided by Karlsruhe
- R404 chiller has cooling power of 4 kW at -35 C
- System uses Lewa pump and SWEP heat exchanger also provided by Karlsruhe

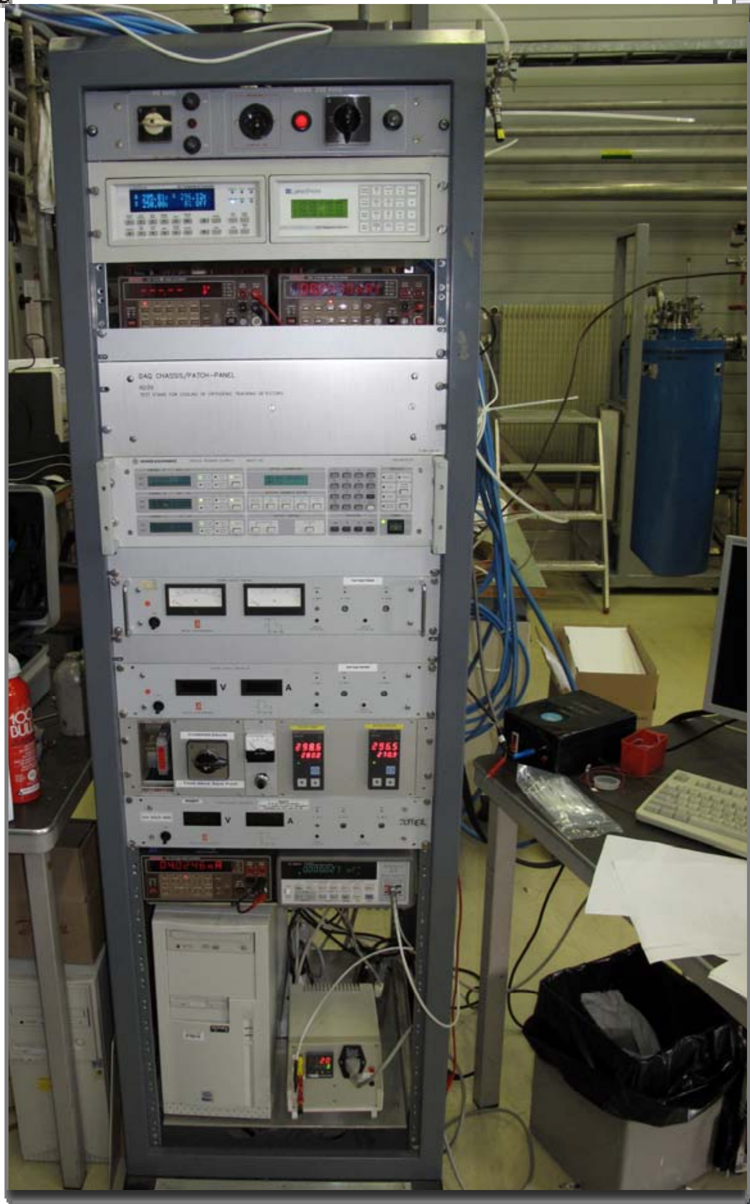
CO_2 Cooling Test Status

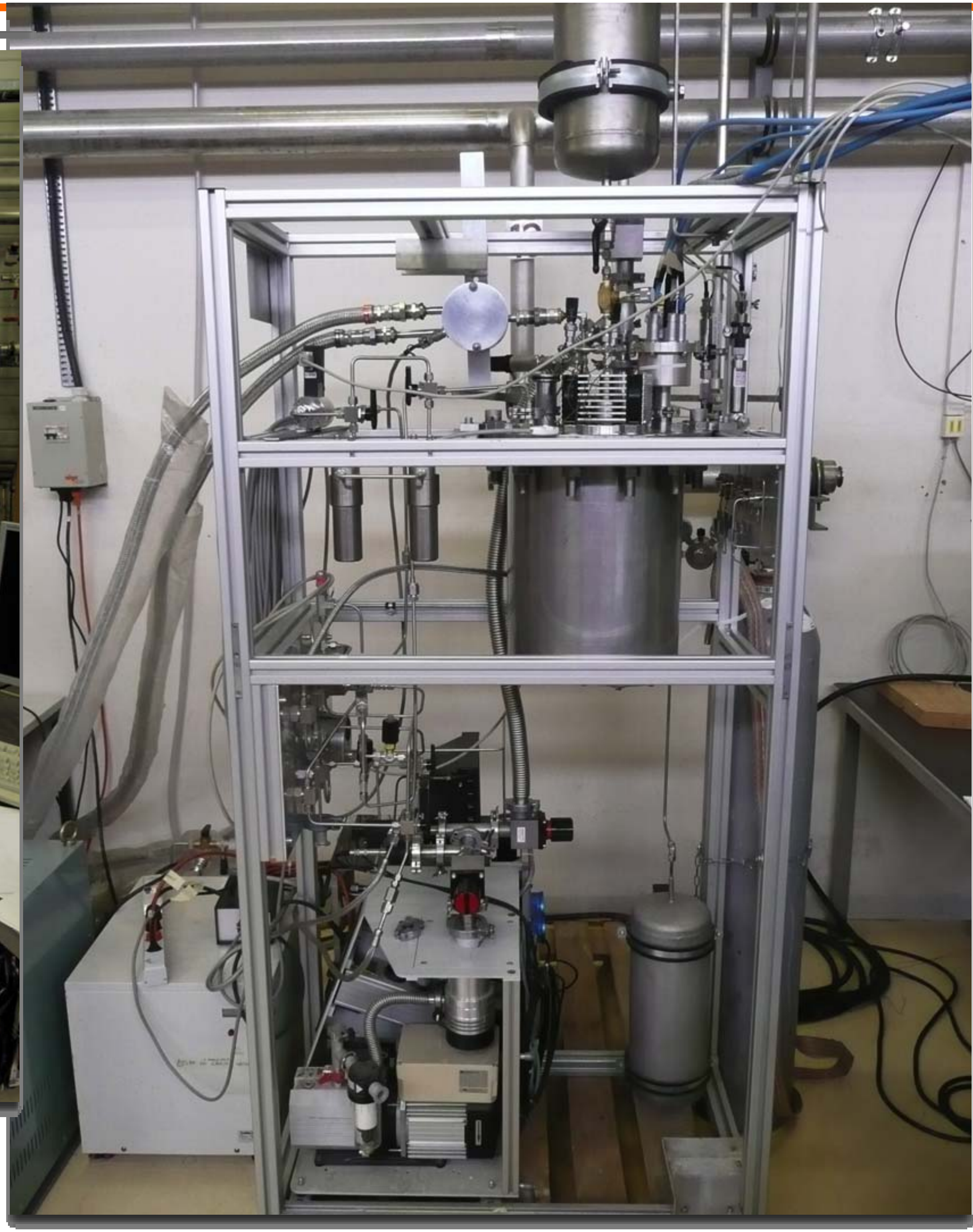
- 1.4mm ID, 5.5m length cooling pipe tested in different heat loads and flow conditions.
- Available empirical models for two phase pressure drop prediction were used and compared with experimental data.
- Upgrades on the test setup are being made in order to improve the measurements.
- Pixel cooling pipe mockup provided by PSI will be tested during the following weeks.

CO_2 Cooling Test Setup



Test setup





Test Setup

Operating temperatures -40°C to -5°C

Mass flow up to 1.5 g/s

Heat flux at test section up to 30 kW/m²

Tube diameter (test section) up to 2.0 mm

Design pressure of the setup 100 bar

Cooling power Pulse Tube Cryocooler 150W@225K

Insulation vacuum $5 \cdot 10^{-5}$ mbar

Conclusions

- Evaporative Cooling seems very attractive
- Many groups are working on the field of CO_2 cooling („trendy“)
- C_3F_8 has no clear advantages
- CO_2 engineering is essentially done, plants of the size required for SVD/PXD exist (order kW cooling power)
- NIKHEF group is very supportive (get blue prints from Braat Verlaat)
- Common project with Vienna seems advantageous
- Next steps: visit to Amsterdam (Braat) together with engineers

  test system to be created within SVD/PXD group