CO2 Cooling

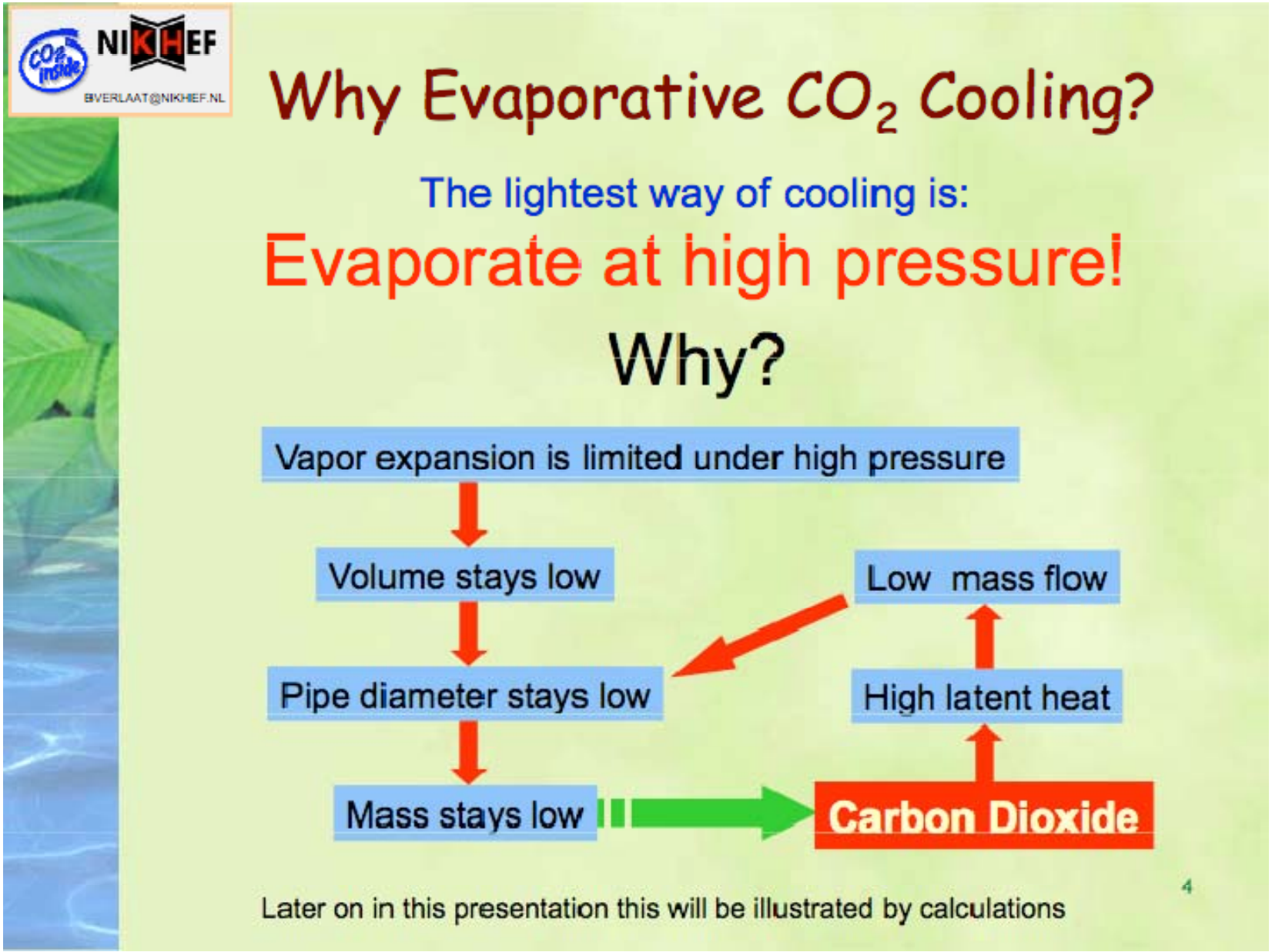
For the CMS Pixel detector

Advantages

- LHCB has chosen CO2, with the following arguments:
- Radiation hard
- Has excellent thermodynamic properties for micro-channels.
- Low dT/dP
- Low mass
- Low liquid/vapour density ratio
- Low viscosity
- High latent heat
- High heat transfer coefficient

Pressure advantage

- Intuitively, higher pressures seem a disadvantage but:
- Gas flow at higher pressures needs smaller pipe diameters
- Pressure drops due to flow become less significant, allowing smaller pipes
- Small pipes can easily support the required pressures


NIKHEF
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Why Evaporative CO_2 Cooling?
The lightest way of cooling is:
Evaporate at high pressure!
Why?
Vapor expansion is limited under high pressure
Volume stays low
Low mass flow
Pipe diameter stays low
High latent heat
Mass stays low
Carbon Dioxide
Later on in this presentation this will be illustrated by calculations

Pressure values

- At 20 degrees C – two phase at 57 bar
- At -12 degrees C – two phase at 25 bar
  - Corresponds to detector operation
- At +5 degrees C – two phase at 40 bar
  - Corresponds to detector storage using the standard chilled water to cool the reservoir.

Existing Supply pipes

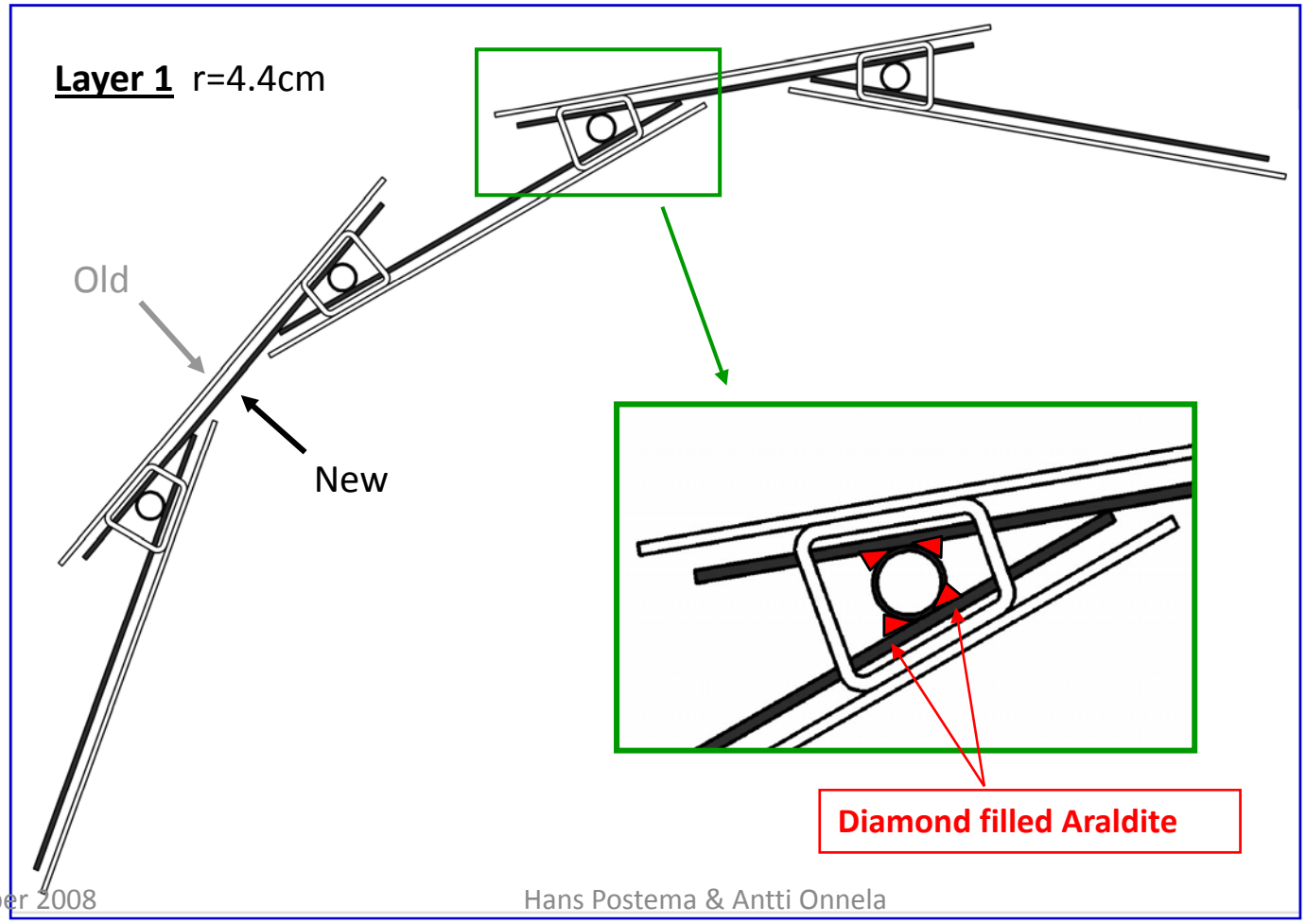
- It is virtually impossible to replace the existing tracker supply lines
- The installed pipes reach the elastic limit at approximately 150 bar (measured at CERN)
- Operation at 40 bar seems feasible

- Safety aspects need to be studied

Modified Mechanics for CO_2 Cooling

Cooling pipes stainless steel. Diameter d = 1.50 mm and wall thickness t = 50 µicrons

$$p_{\max} = 2 \cdot \varepsilon_{yield} \cdot \left(\frac{t}{d} \right)$$ → p_{max} = 275 bar safety factor 3 → **p_{op} = 90bar**



Modified Mechanics for CO_2 Cooling (2)

- Biphase CO_2 cooling allows long cooling loops (~2-3m) with very small diameter pipes (~ 1mm) for thermal loads of ~ 100 W

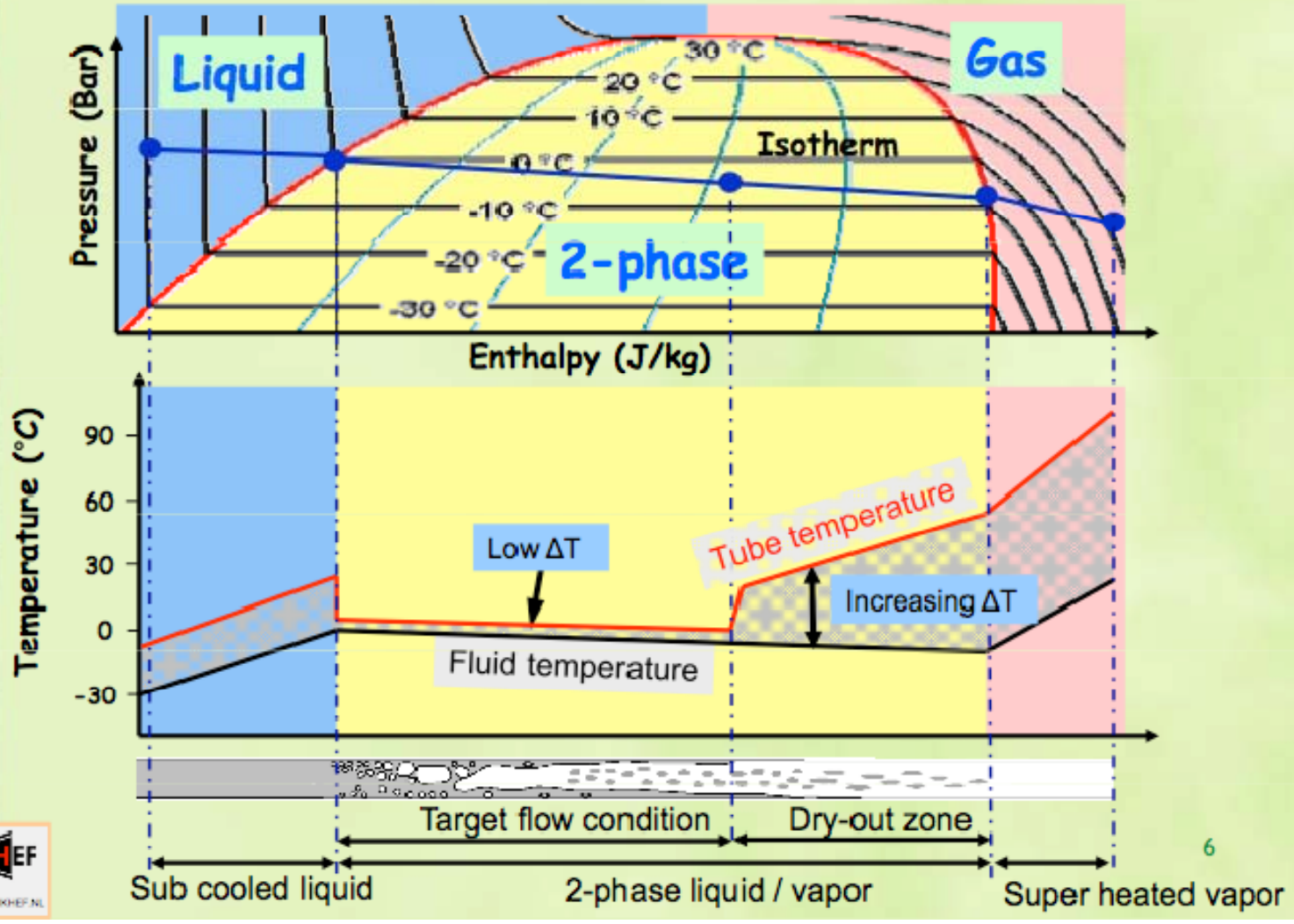
- Present C_6F_{14} monophase has parallel cooling pipes with manifold and large crosssection silicon hoses for feed and drain in front of FPIX tracking region.

- New CO_2 allows serialized pipes without pressure drop problems and therefore reduces resident cooling liquid by large factor.

- Density of liquid CO_2 is ~ 1.03 g/cm^3 compared to 1.76 g/cm^3 of C_6F_{14}

What happens inside a cooling tube?

Heating a flow from liquid to gas



New cooling pipe

- Estimates by Bart Verlaat from NIKHEF allow for a 5.5 m long cooling pipe with a diameter of 1.5 mm
- This avoids all the manifolding in the detector
- The calculated pressure drop along the 5.5 m is 2 bar giving a dT of 3 degrees C
- But calculating 2-phase flow in small tubes is known to be very difficult

R & D

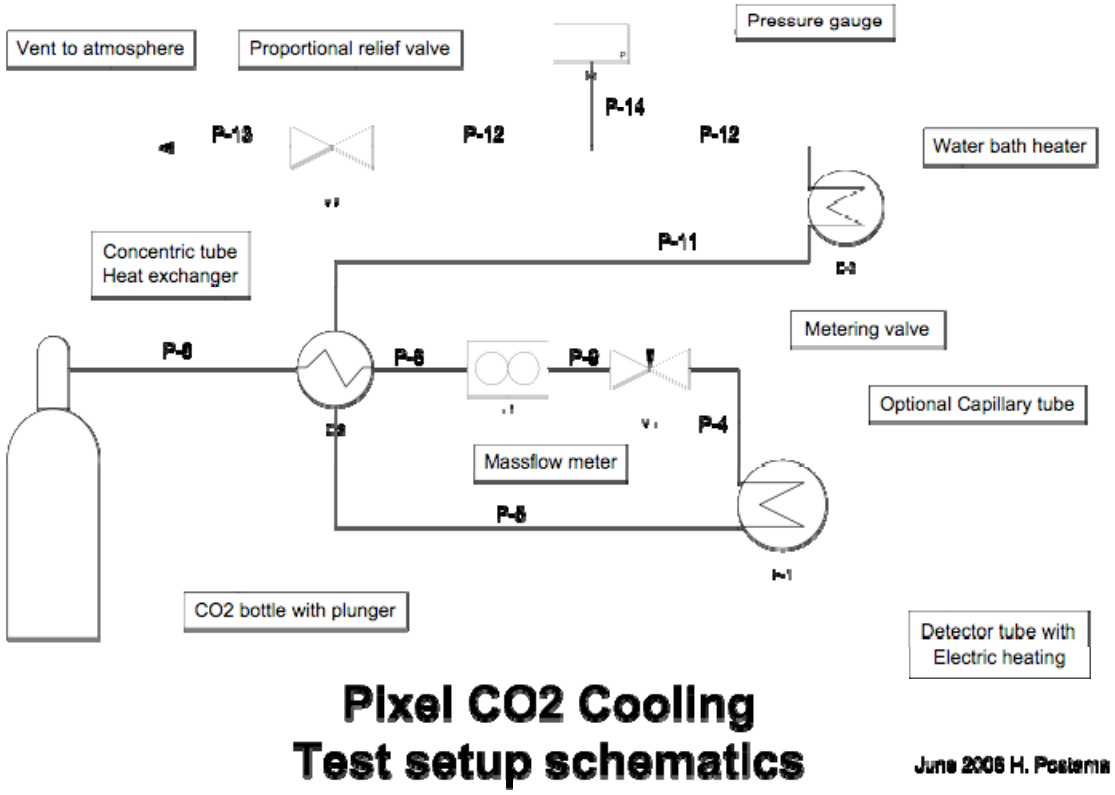
- At present everything indicates that this cooling method is feasible
- A simple test setup can increase the confidence level and can show that the concept is correct
- More sophisticated research is important to assure a full understanding of the system and optimize the design details as well as the operating parameters

Next steps

- Aachen as well as Lyon seem very interested in starting conceptual design verification test (see next slide)

- CERN Cryolab has already started to work on a test setup for high precision measurements and a full characterization of CO2 flow in small tubes

Design verification



Acknowledgements

- Several slides in this presentation are borrowed from:
  - CO2 cooling for HEP experiments – Bart Verlaat – TWEPP-2008
  - Pixel detector CO2 cooling – Roland Horisberger