Cooling System(s) for the Roman Pots of TOTEM experiment

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AGENDA:

1. **Scope of the Research activities (TFP and DAQ group at the Dept. of Applied Physics – F. of Mechanical Engineering, CTU in Prague)**
2. **TOTEM Roman POT cooling system development**
3. **Application of the efficient heat exchangers**
4. **Commissioning matters (ATLAS, TOTEM RP or any other system)**
5. **What we have learned so far**

Scope of the Research activities

- **Main research program for CERN :**
- Cooling system design for electronics application:

ATLAS Inner Detector cooling circuit

Pixel and SCT structures testing (with CPPM Marseille)

- Design, assembly and commissioning of the cooling system realized at CERN in SR1 facility
- Commissioning measurements in the PIT (ATLAS cavern)

TOTEM Cooling system for the Roman POTs

- Overall design, prototype development and verification of the Roman POT thermal mockup
- Commissioning measurements of the 24 RP, prior to the installation in the LHC tunnel; final system commissioning

Cooling systems for tle AFP ATLAS

- Design and basic testing with mockups (AIRCOOLER)

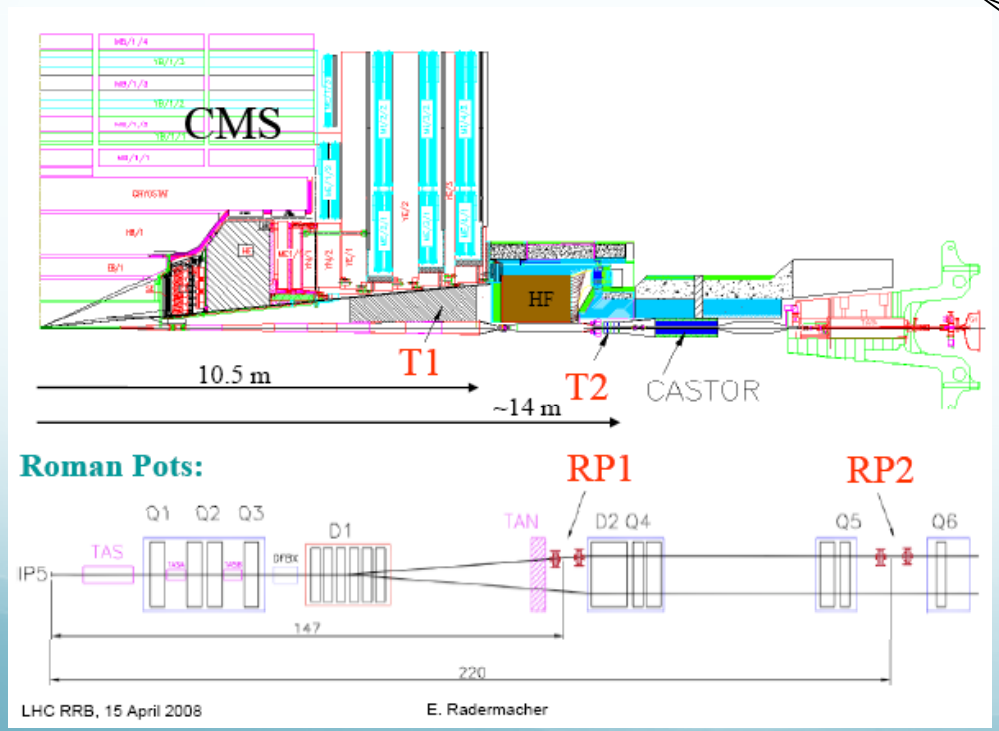
Repair of the Cooling system for ALICE SPD

- Repair of the blocked filters within pixel SPD circuits

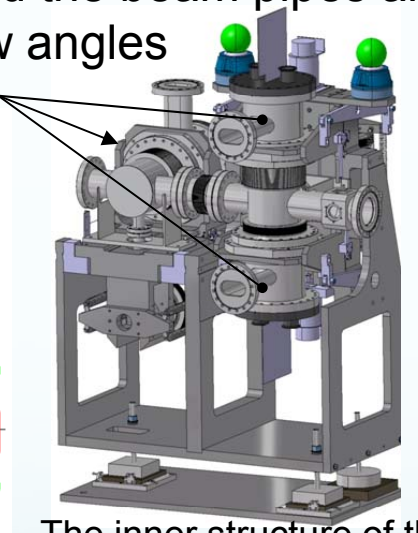
TOTEM Cooling system for the Roman POTs

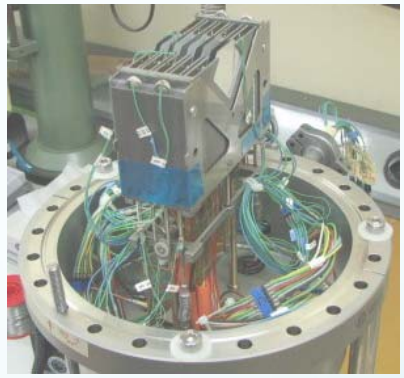
TOTEM Experiment - its main goal is to measure the total cross section, elastic scattering and diffractive processes at the LHC on both sides of the CMS detector. The diffractive processes are detected by two types of tracking telescopes (T1 and T2). To measure the cross section and the elastic and quasielastic interactions a special instrument had to be introduced: The Roman Pot (RP).

24 Roman Pots located in 8 positions around the beam pipes are capable of detecting particles diverted by extremely low angles



Roman Pots

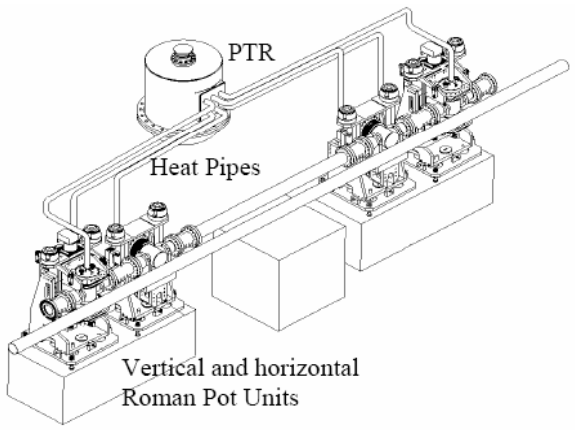




The inner structure of the Roman Pot consists of 10 silicon detectors, each of them is positioned in an electronic board called the “hybrid” with four embedded readout chips. Operation of the detectors requires temperatures below –10 °C. The dissipated heat from the chips reaches ~ up to 3 W per plane.

TOTEM Cooling system for the Roman POTs

We have been asked to develop CS for TOTEM RP in MAY 2006, once the system based upon the heat pipes and pulse tube refrigerator has been ruled out since the changes in specs and strategy



Cooling system lay-out with heat pips and a PTR for an individual roman pot station

Our task was extremely difficult since we have inherited some fixed baselines, time for development was extremely short and nearly no resources were available at the beginning of the work

A new system has been developed by the team of the CTU Prague and the final system for the PIT was designed and installed by TS/CV of CERN

Close cooperation of the CTU and CERN - TS/CV resulted in successful commissioning of the whole system and it is still going on

TOTEM Cooling system for the Roman POTs

An evaporative cooling system circulating fluorocarbon C_3F_8 in 4 main closed loop has been chosen and designed to guarantee a total cooling capacity of 1.2 kW and supply a global mass flow rate of 40 g/s to be uniformly shared between the 24 TOTEM Roman Pots.

Basic phases of the development:

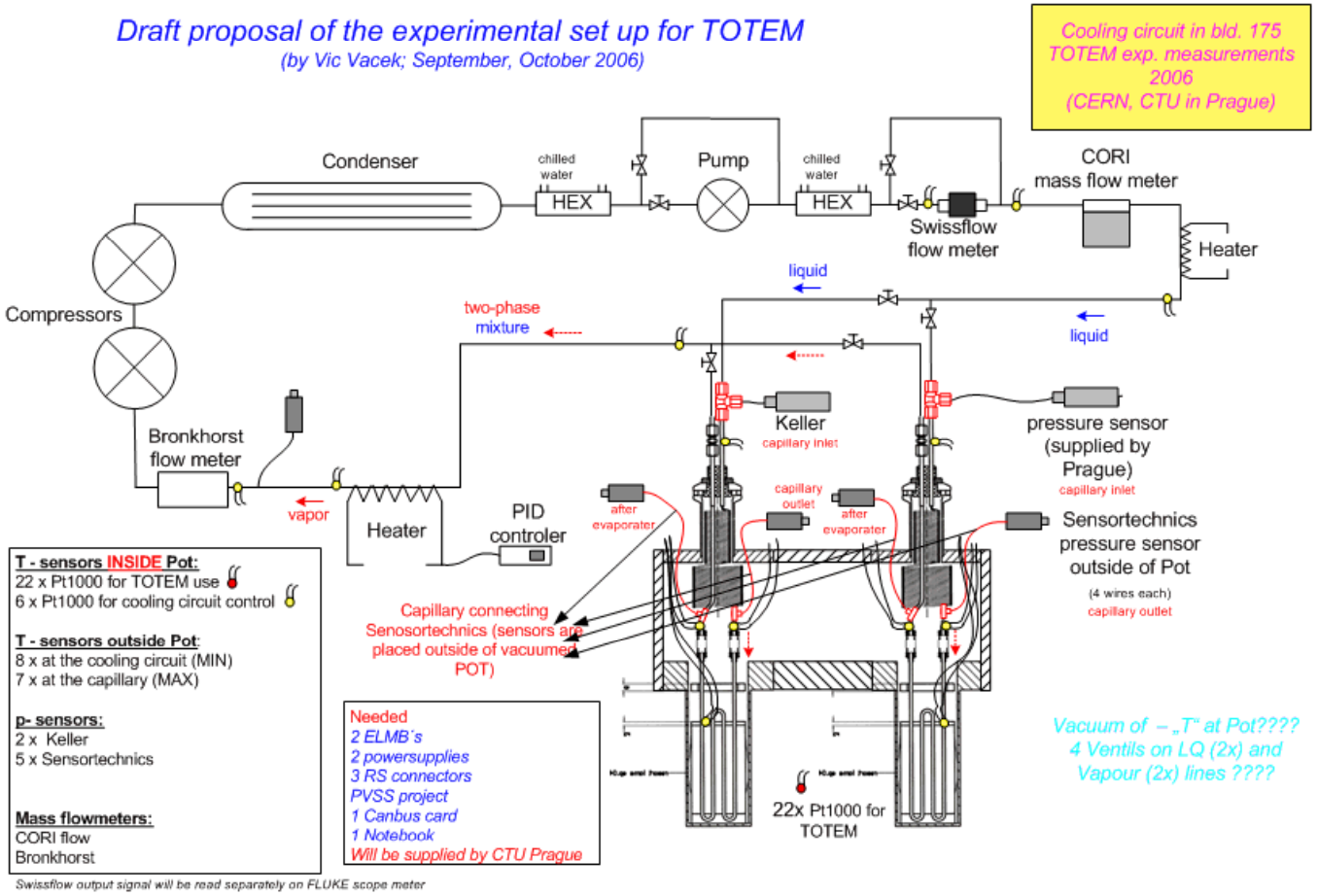
- **Evaluation of the principle (2006-2007)**
- **Thermal mock-up development and testing (2007)**
- **Small commissioning CS design and assembly for individual RP testing at H8 facility at CERN was successfully finished in 2007/08 and is being used and will be upgraded for use in 2013/2014.**

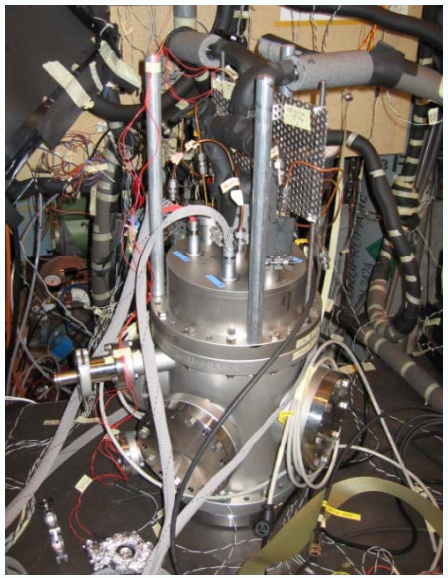
IN PARALLEL:

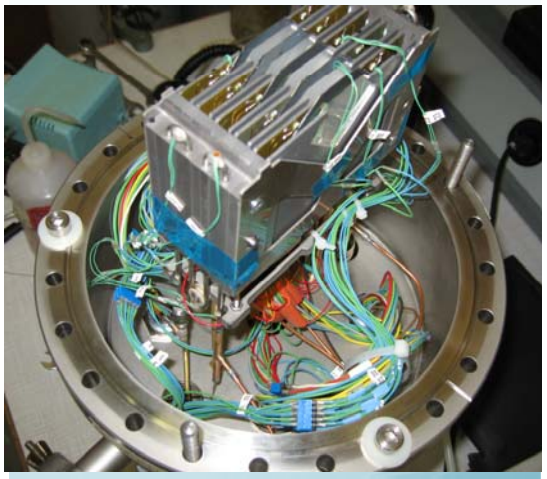
- **Final CS has been designed by TS/CV (2007-2008)**
- **RP TOTEM CS is installed and it has been operated smoothly until this year LS1**

TOTEM Cooling system for the Roman POTs

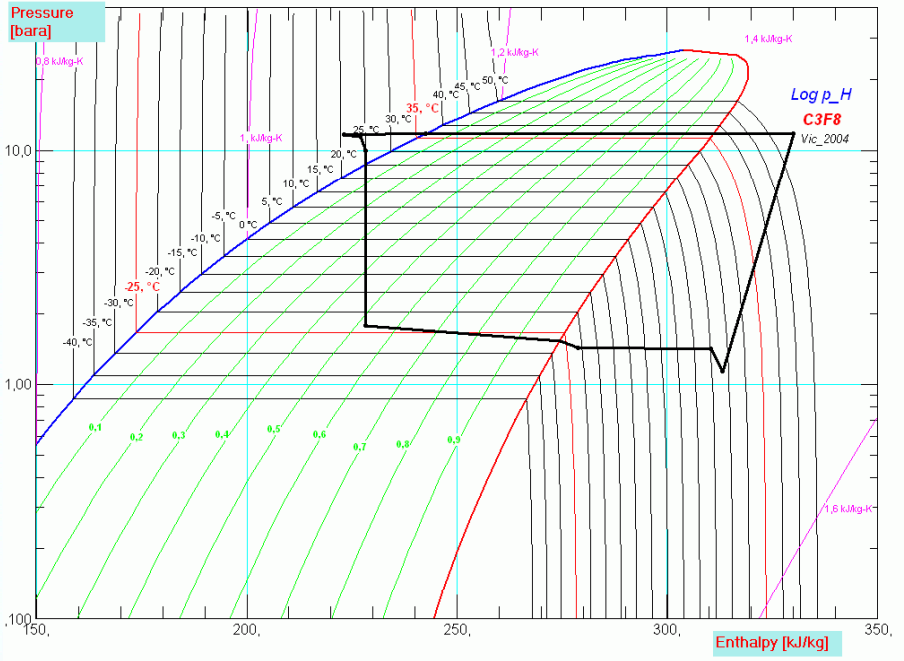
- **Evaluation of the principle (2006-2007)**
- **Thermal mock-up development and testing (2007)**





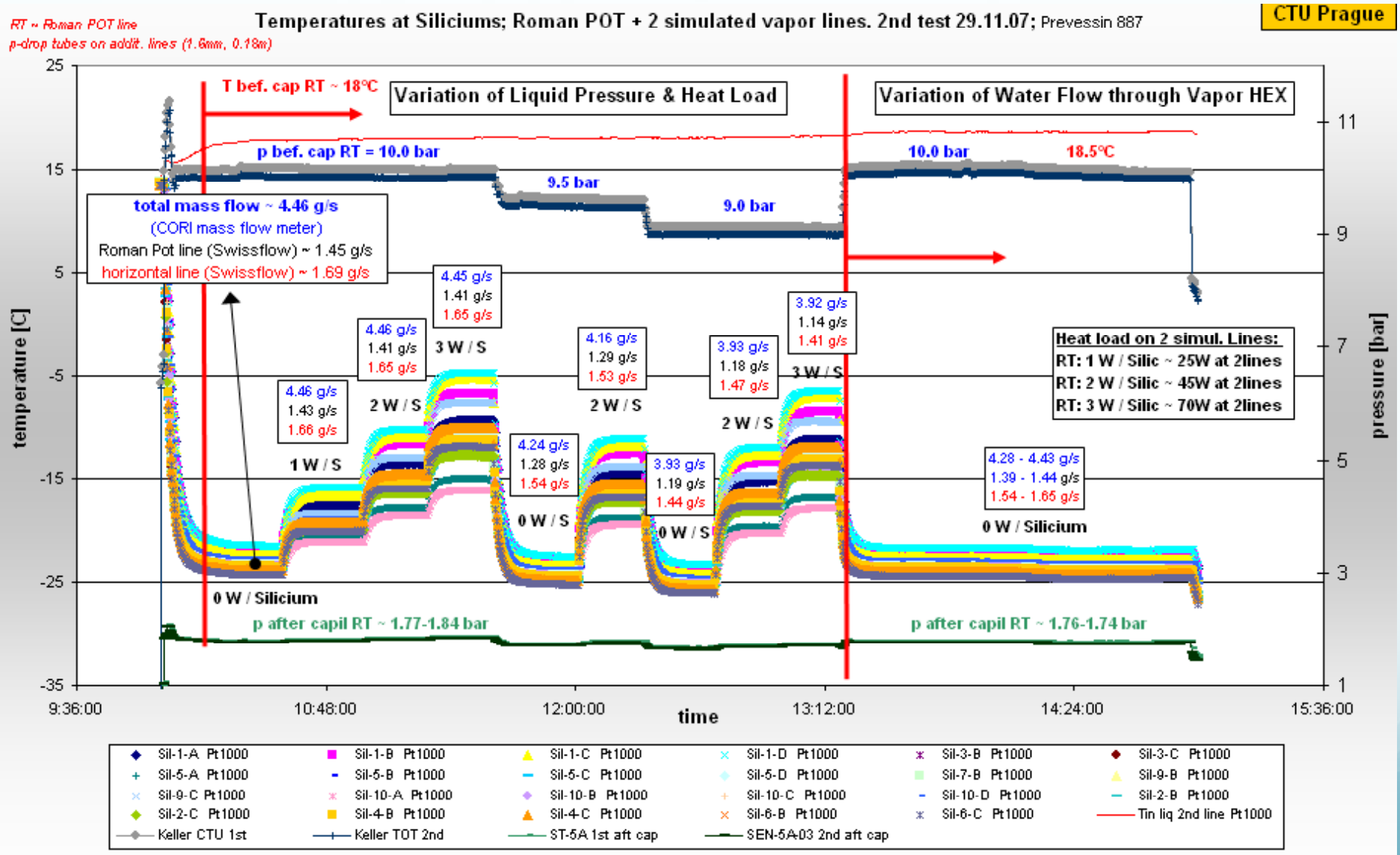


Cooling Circuit in Building 887/H8 - CERN

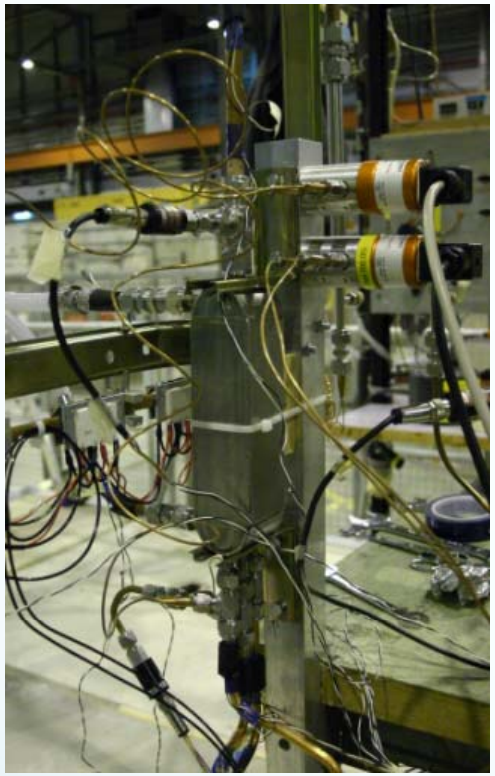


The cooling has been designed, assembled and adjusted by the team from the Department of Applied Physics of the CTU in Prague in 2007 and 2008. It consists of two oil-free compressors, a set of chilled water heat exchangers, a pump and a condenser with PID controlled temperature. The circuit is filled with fluorinert refrigerant R218. The circuit is presently prepared to cool down up to three Roman Pots simultaneously. Several tuning and control devices implemented within the circuit enable to vary a large scale of operational parameters.

Performance of the Cooling Circuit with single POT



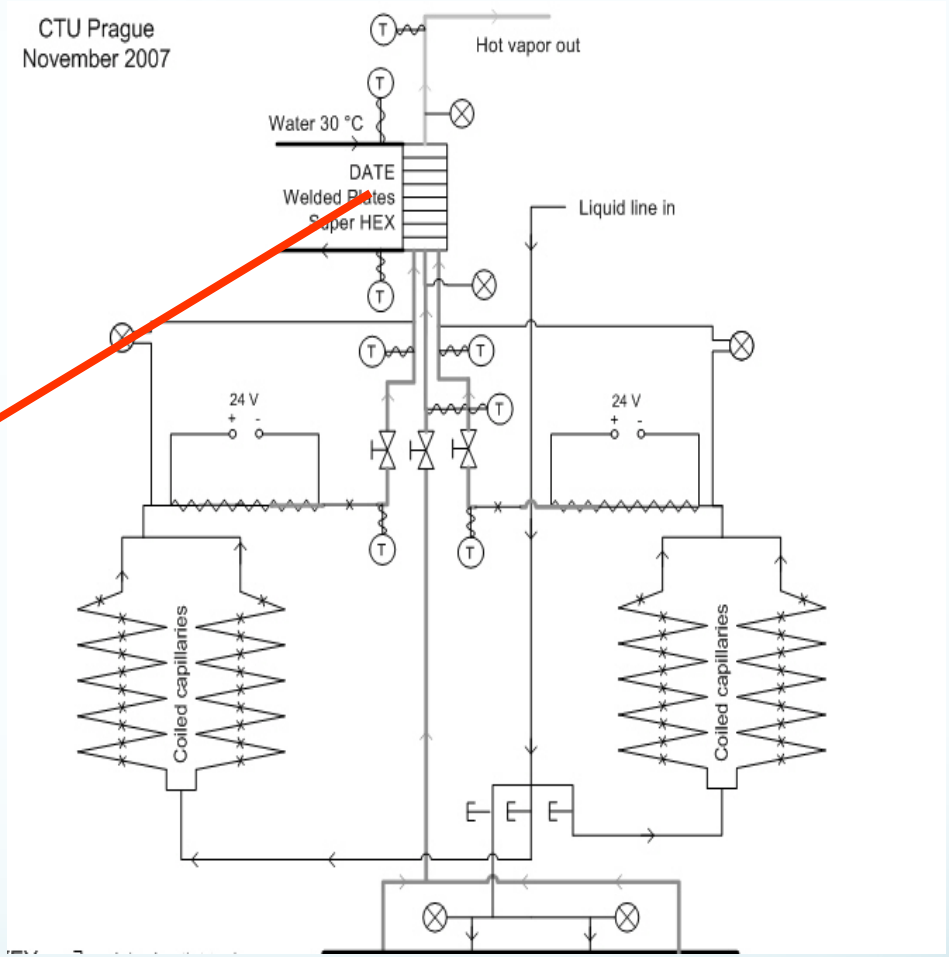
Implementation of the HEX into the cooling circuit



Instrumentation around the HEX,

P, T and flow sensors

The Date–Hex prototype installed into the circuit with installed pipelines

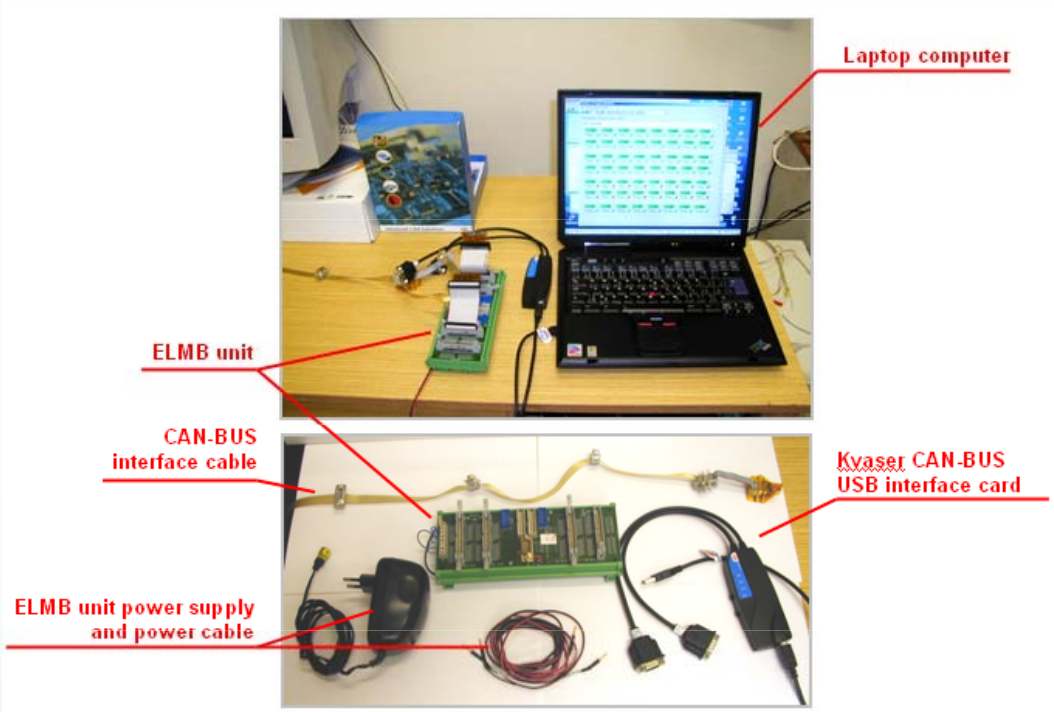


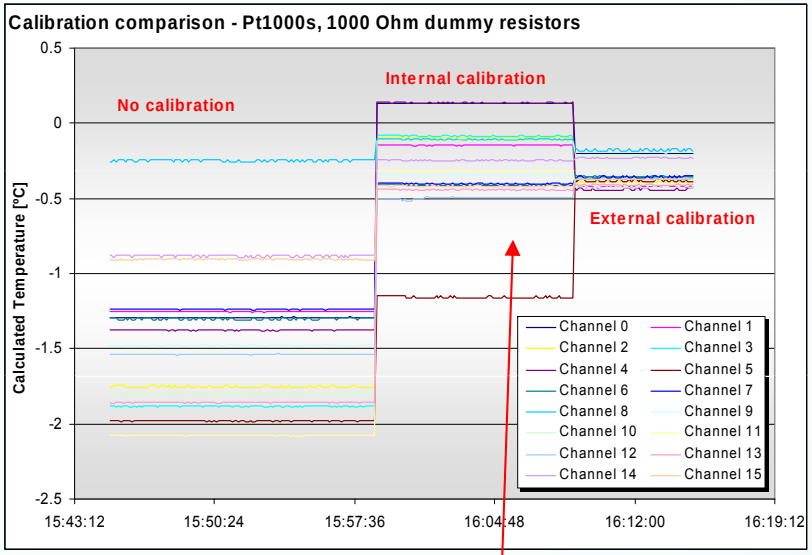
Arrangement for the nominal refrigerant mass flow up to 5 g/s; water flow measured standard with use of float device, while vapor flow was monitored via SWISS-FLOW meters (frequency principle) calibrated prior to measurements

Performance of the HEX (other applications?)

What is needed for smooth commissioning ?

Reliable and robust DAQ system – it is a „must“ for the commissioning

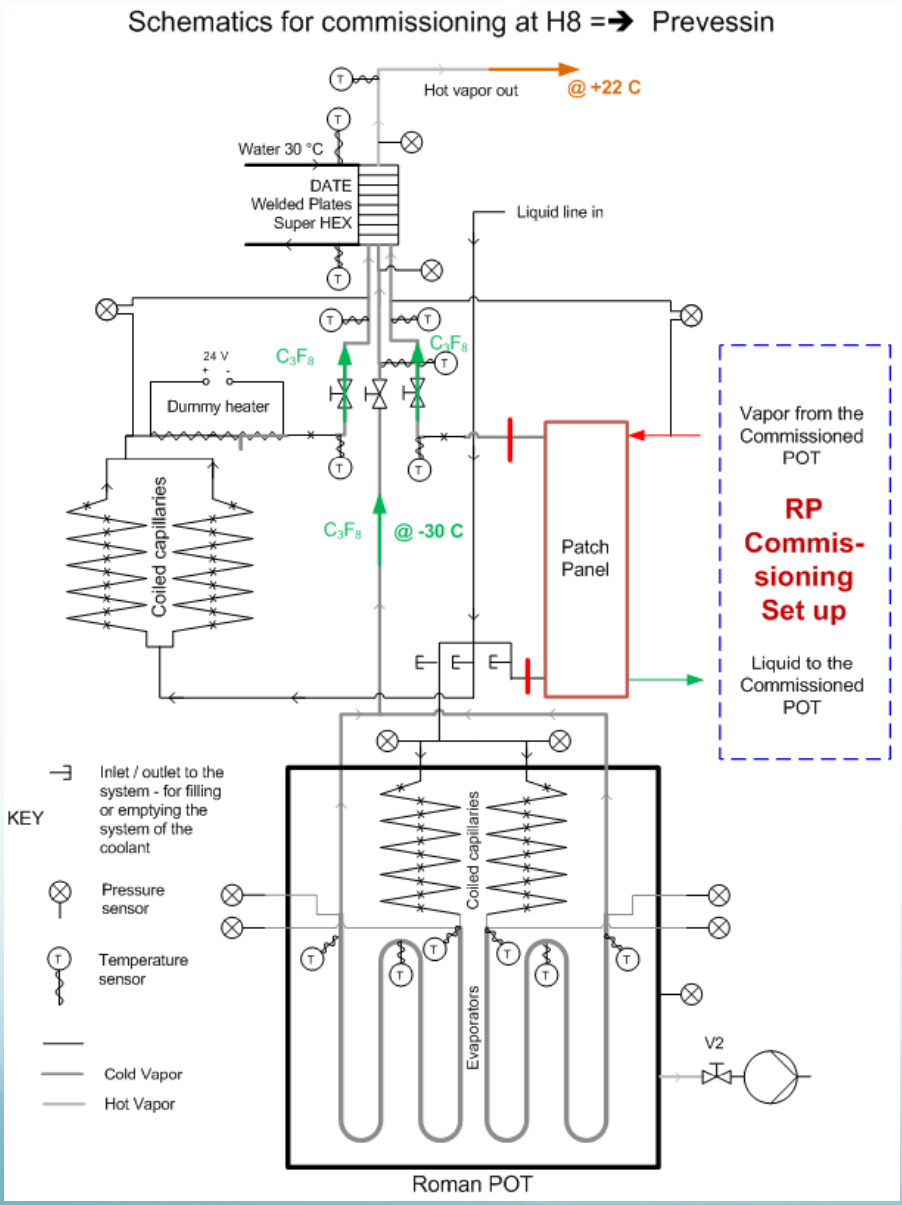




Enhanced accuracy due to the „internal and „external ELMB calibration and proper sensor handling

- Simple version of the mobile DAQ system for commissioning:
- 64 channels (but expandable; low cost per channel)
- Type of the sensors:
- PT 100, PT1000, NTC
- Pressure sensors (voltage signals)
- Humidity sensors (capacitance principle+voltage converter)

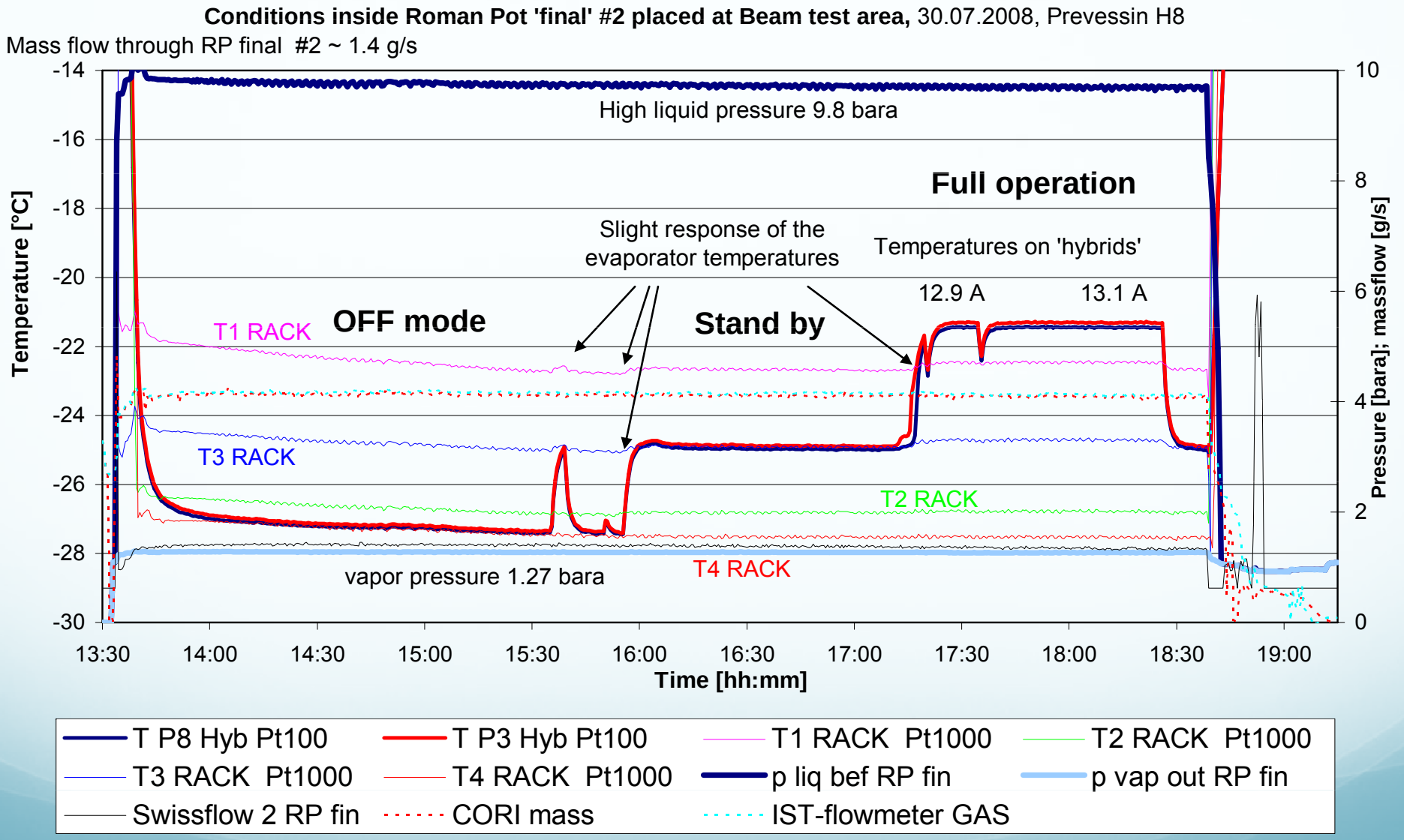
Modifying and tuning Prevessin CS for commissioning purposes



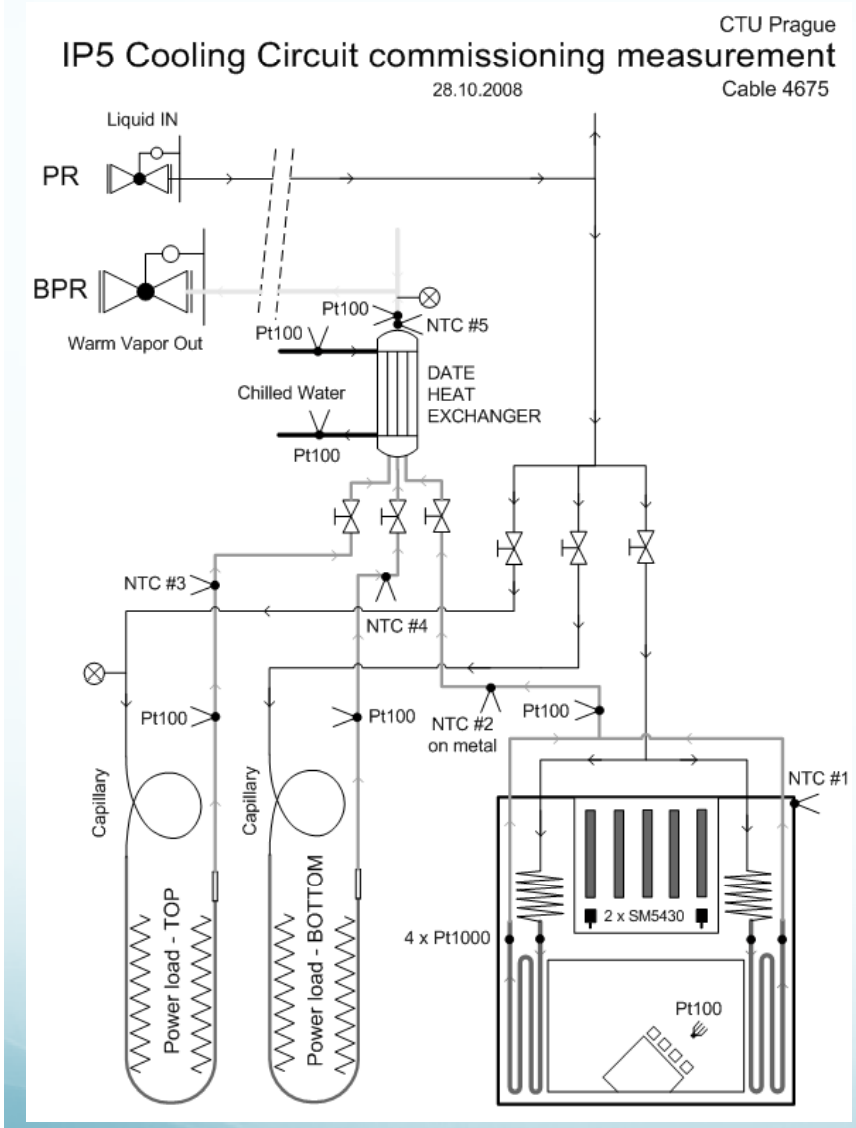
- Cooling System at H8/in Building 887 prepared was prepared
- DAQ and control system was verified and handed to TOTEM
- Patch panel with valves has been added to the system to separate the rack for the Roman POT installed for eventual commissioning

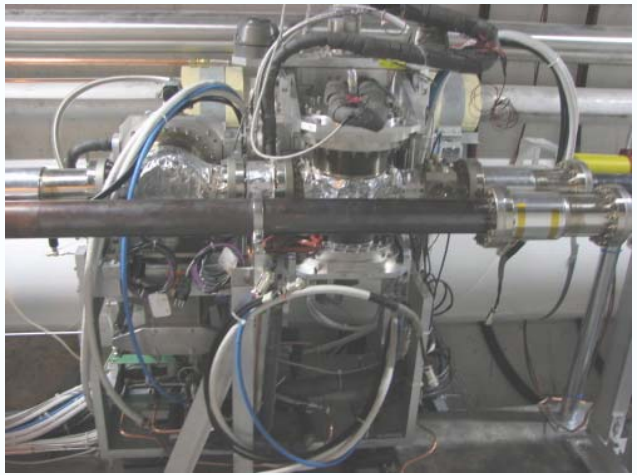
- Patch panel will allow:
  1. an individual manipulation of the RP,
  2. its leak checking
  3. pumping down the separated part of the cooling lines
- and when ready,
  - it can be connected to the CS circulation just through 2 valves
  - **It can serve also for capillary trimming**

Prevessin CS – commissioning results of the RP No. 2

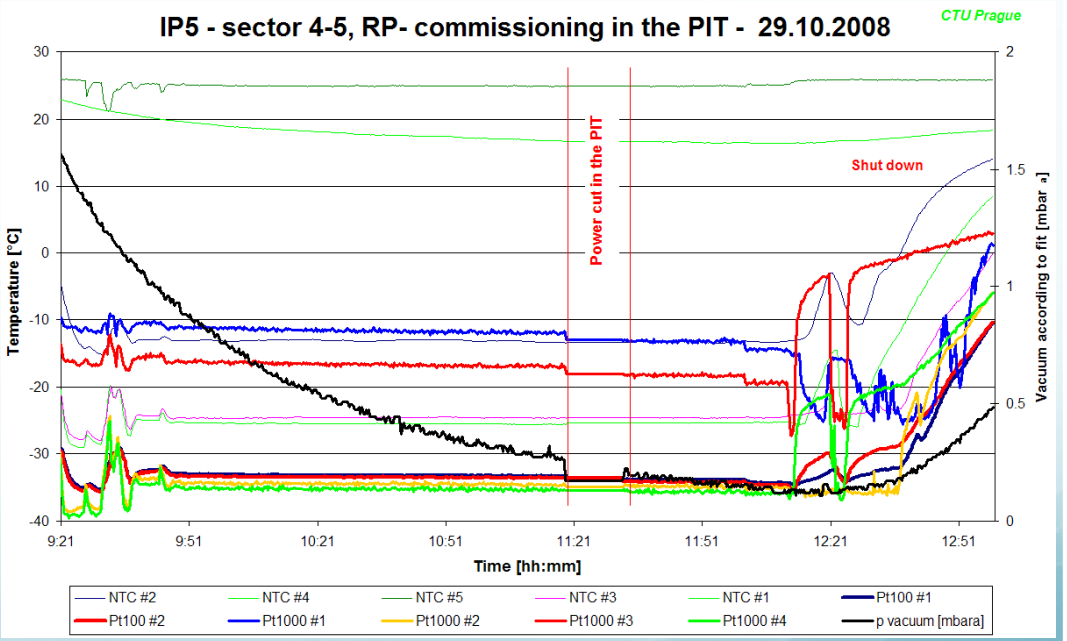


Commissioning in the PIT:





Roman Pot station in the LHC tunnel with one RP and two Dummy loads



Sensors are monitored independently by the PLC and by the ELMB based mini DAQ system

Sumary of the last results from the PIT

Historical Reminders from Sacley 2008 and Cracow 2009, Prague 2009 and CERN 2011 meetings.

Studied and offered options for the AFP cooling system solution, CTU Prague Team (up to now):

1. ***Modified*** *cooling system, which has a base in* ***TOTEM*** *solution (depending on available space for the plant)*
2. *Individual* ***micro-cooling systems*** *close to the each main heat source unit (to be developed – using thermosiphon principle)*
3. *Vortex based* ***dry air cooling system*** *(already tested, two stage system needed, control system under development)*
4. *Modified* ***heat pipes*** ***and*** ***pulse tube refrigerator*** *solution (with use of already gained experience)*

Note for the AFP management:

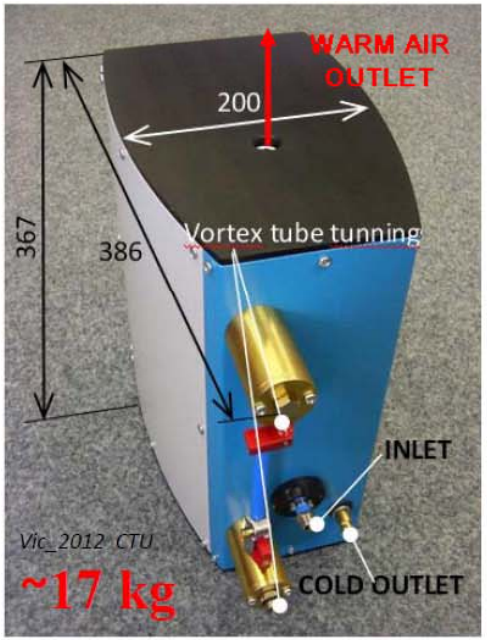
PLEASE, TAKE IN ACCOUNT, THAT THIS SUBJECT (COOLING) WAS UNDERESTIMATED FROM THE POINT OF IMPORATNCE, TIMESCALE AND RESOURCES (BOTH MANPOWER AND BUDGET) NEARLY IN ALL CERN PROJECT SO FAR

Based upon our analyses of options we have proceeded with two (**1. and 3. systems**) preferred solution

Possible alternative or backup also for TOTEM Roman Pot Upgrade

PREFERRED SOLUTIN NO.:1

Prototypes developed, manufactured and delivered by the CTU Prague lab



1st Prototype successfully tested during 2010/11 (350 W) – in our Prague laboratory

2nd Prototype commissioned this year → 2012 (600 W) – in our Prague laboratory

Two AIRCOOLER prototypes are using unique combination of the vortex tubes and heat exchangers to achieve a desired cooling effect.

BOTH PROTOTYPES WERE SUCCESFULLY TESTED AT CERN THIS SUMMER WHEN CONNECTED TO THE AFP THERMAL MOCK-UP (BETWEEN JUNE AND AUGUST 2012)

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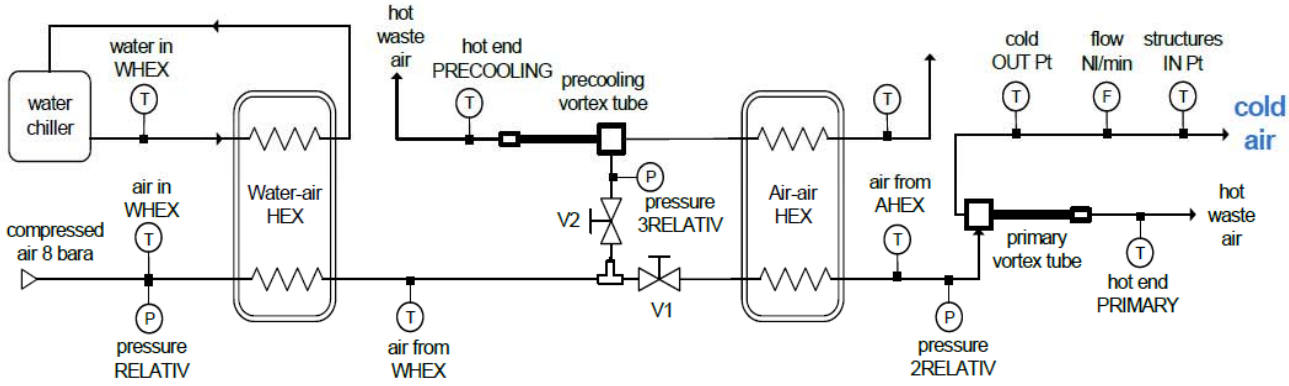
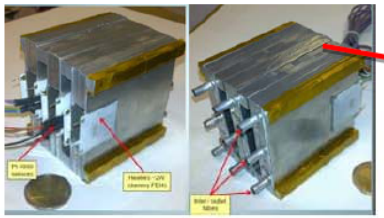
CTU Prague, Vic Vacek *AFP Collaboration meeting, CERN, September 2012*

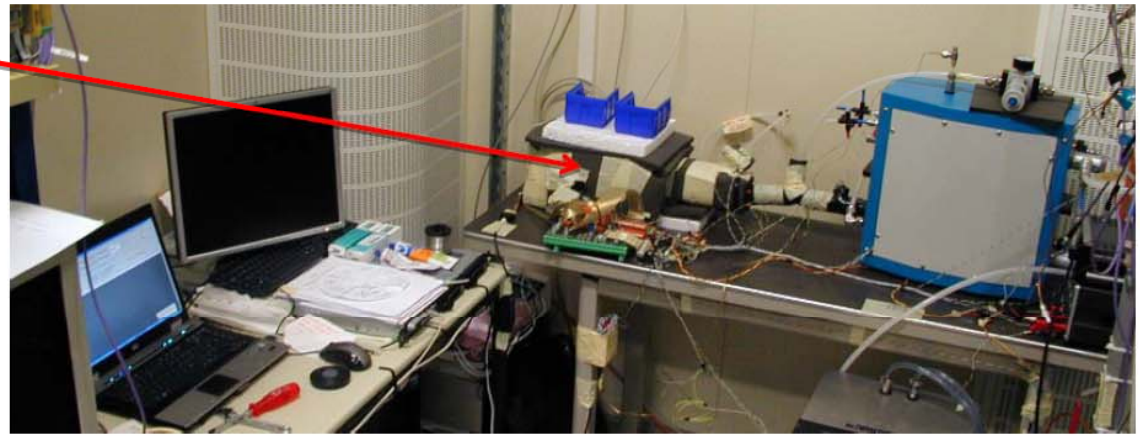
AIRCOOLER TEST SET UP at SR1



Schematics and DAQ sensors mapping around the cooling system setup in SR1 Bldg.

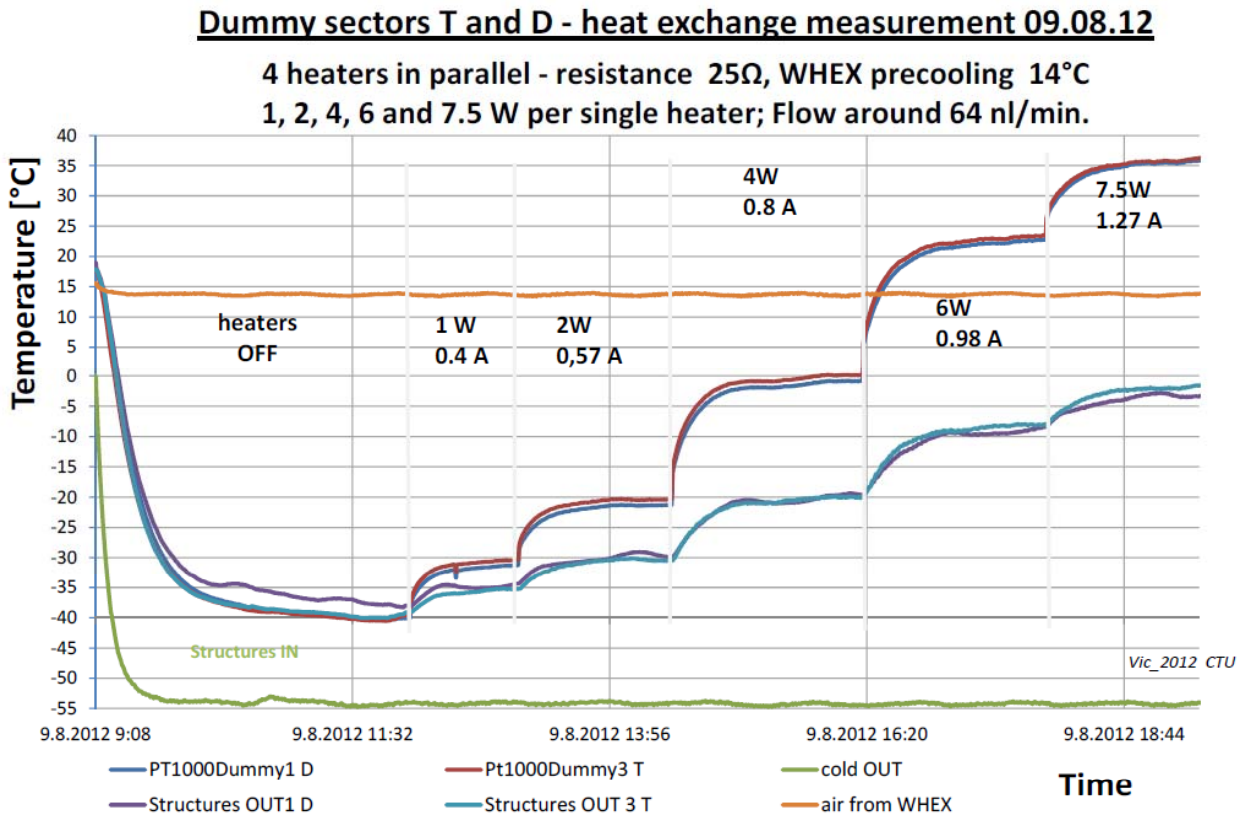


3 different loops were investigated (one smooth tube loop, two with extended surfaces (tube inserts, low profile fins)



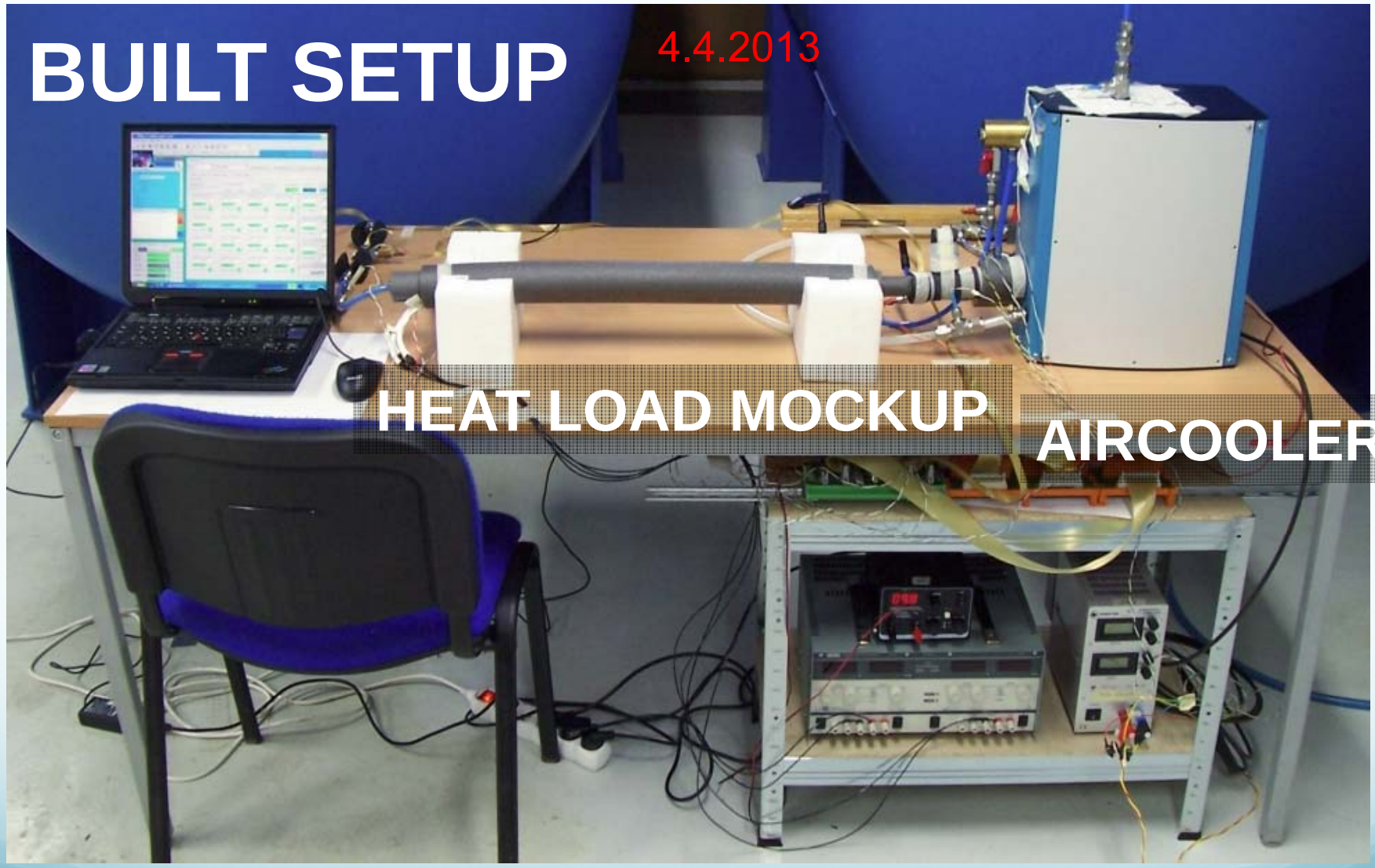
The AFP cooling system setup in SR1 Bldg.

AIRCOOLER TEST SET UP at SR1



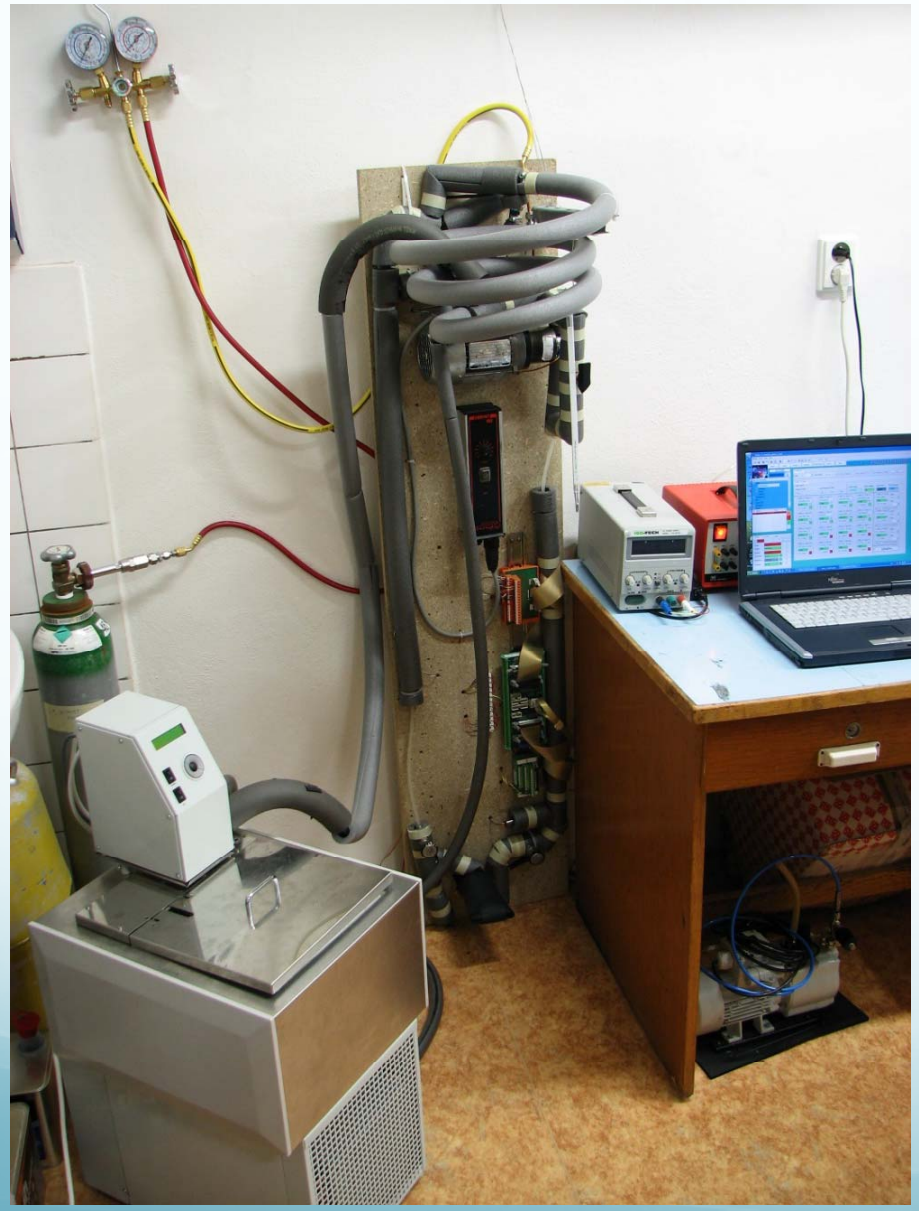
Sample of the typical all day run during commissioning – with various power dissipations (nominal projected value is around 1W) and temperature profiles

Design and Implementation of Measurement Setup for AIRCOOLER I prototype testing at our CTU Lab

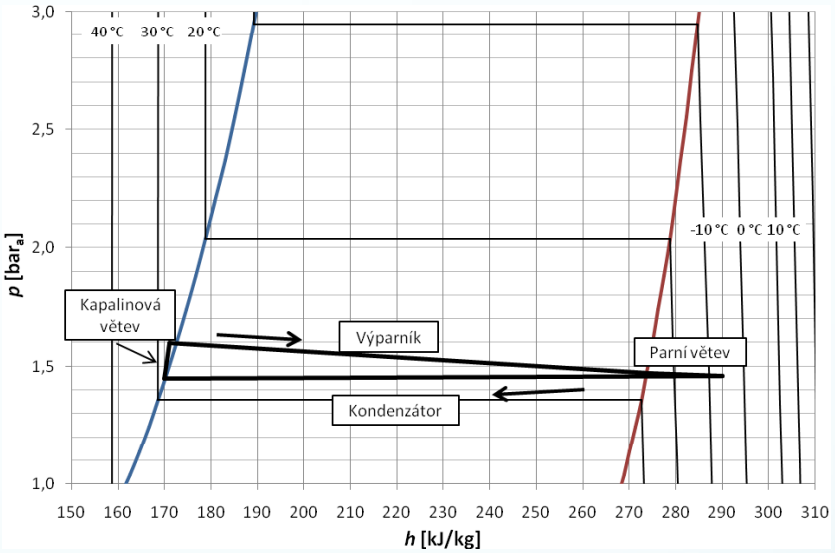


Set up prepared for Control system development and Cooling power measurements

Thermosiphon prototype



Thermosiphon in the CTU Prague Lab under the tests



Positive results from the tests up to 300 W

Similar, but much larger scale is going to be used for ATLAS Inner detector after tle LS1

SUMMARY

- Overall scope of the research activities was outlined – covering last few years
- TOTEM Roman POT cooling system was described and relevant experience from CS design, running and commissioning were presented
- We have several CS alternatives ready for an upgrade
- General comments related to CS of the RP detector applications were introduced
- Once a new RP mechanical design is finalized – implementation of the CS is to be its integral part
- Upgrade of testing rig at H8 is already prepared