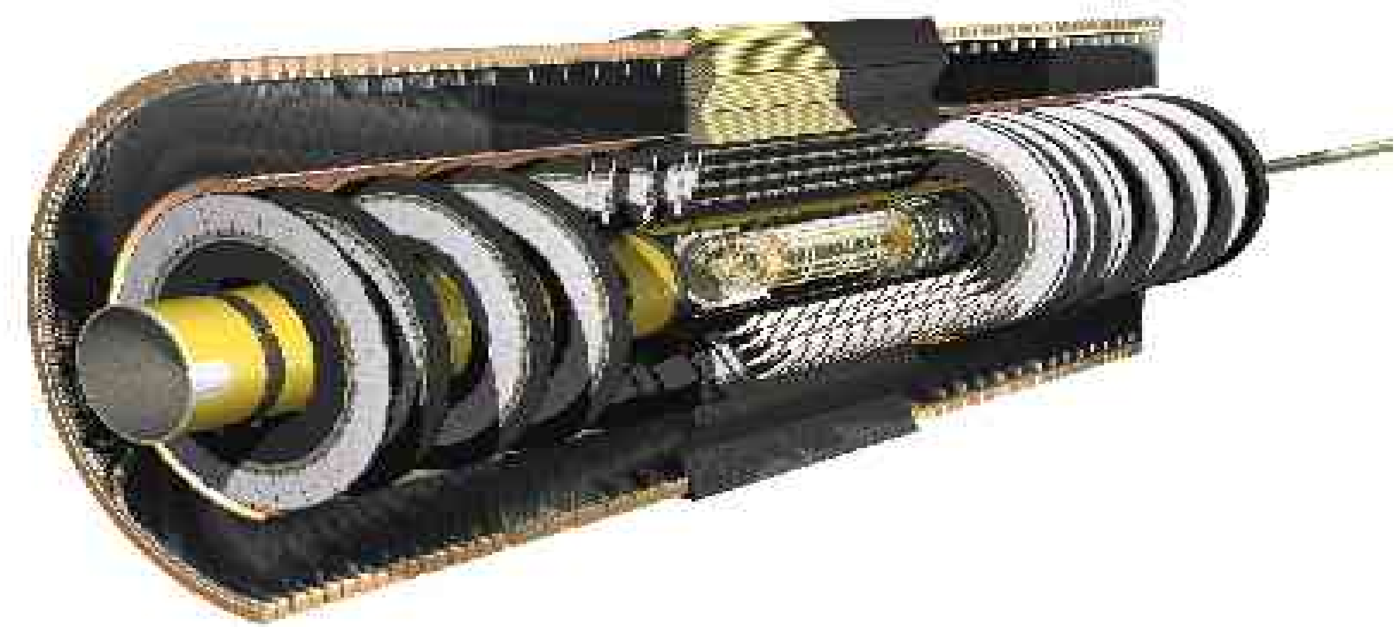
Contribution to the humidity condition supervision in the ATLAS Inner Detector volume



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Oslo, 17. October 2008

Overview

- *Dew point monitor in the exhaust of the N2 volume*
  - *Design*
  - *Installation*
  - *Readout and DCS software*
  - *Commissioning*
- *Humidity measurements in the ATLAS ID general volume*
  - *Classification and Cataloging*
  - *HMX2200 relative humidity sensors*
  - *Monitoring*

N_2 exhaust Dew Point Monitor

- *Purpose*
  - *To x-check the environmental conditions in Pixel, SCT Barrel and SCT End-cap volumes*
  - *Using vradiation hard relative humidity (RH) and temperature (T) senors*
  - *Interfaced with a SIEMENS Simatic S7-300 PLC that takes care of signal processing and sending the processed data to PVSS*
- *General layout*
  - *Sensors are placed in the UX15 detector cavern at the N_2 exhaust*
  - *Conditioning board and PLC are placed in the USA15 controlled area*

RH, T and Dew Point

- *Having RH and T measurement*
- *To calculate Dew Point temperature Td we model of the saturation vapor pressure dependence upon the temperature is needed*
- *We relay on a simple parametrization whose coefficients are computed by fitting the data*

$$P_s = C_1 \cdot \exp\left(\frac{C_2 \cdot T}{C_3 + T}\right)$$

$$P_d = P_s \cdot RH$$

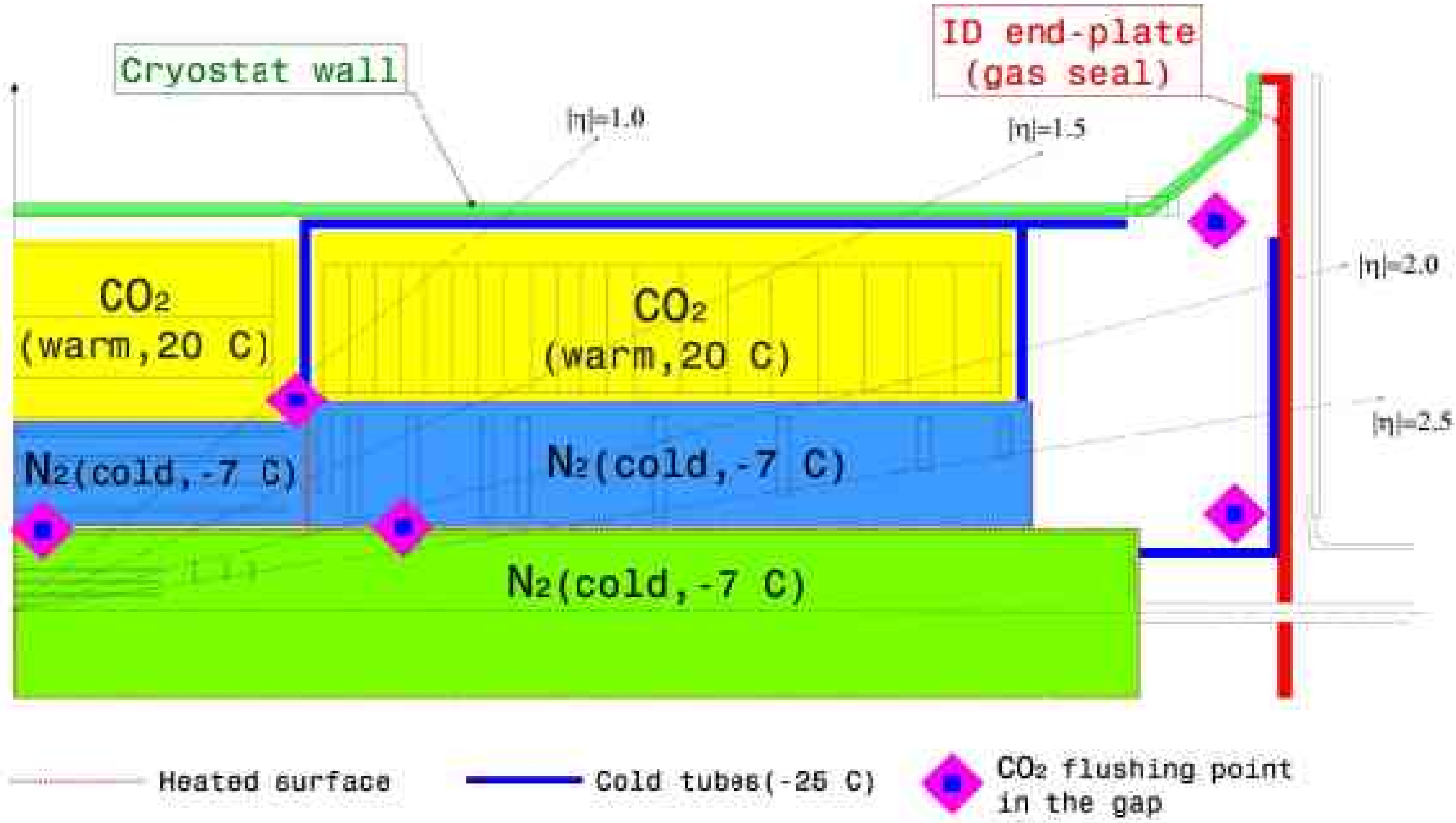
$$T_d = \frac{-ln(P_d/C_1) \cdot C_3}{-ln(P_d/C_1) - C_2}$$

Phase	T [°C]	C_1 [mbar]	C_2 [-]	C_3 [°C]
Ice	-50.9 – 0.0	6.10714	22.44294	272.440
Water	-50.9 – 0.0	6.10780	17.84362	245.425
Water	-0.0 – 100	6.10780	17.08085	324.175

RH basics:

- RH is the ratio between the actual partial vapor pressure Pv and the saturation vapor pressure above water (ice) Ps
- “Dew (Frost) Point temperature Td” it is when Ps(Td)=Pv(Td) and condensation begins:
- Decreasing the temperature below the Dew Point temperature the partial vapor pressure exceeds the saturation value, so condensation occurs until the balance is reached again.

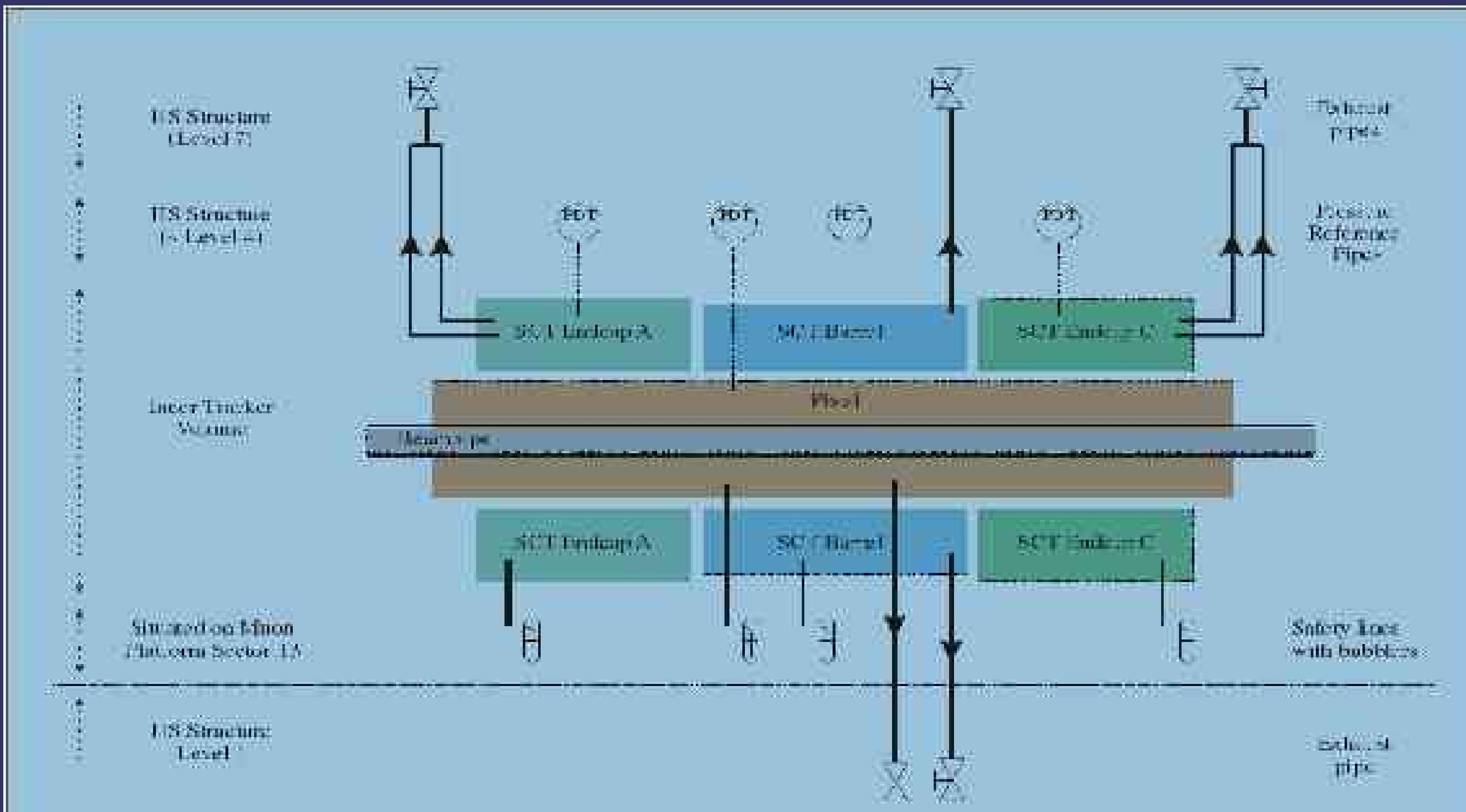
Inner Detector Volume



The inner ATLAS tracker (SCT and Pixel detector) will be cooled down to temperatures of -20°C. To prevent creation of ice the frost point in the environmental gas needs to be below -30°C.

N_2 system

- *Nitrogen flushed through the inner part of the ID (SCT + Pixel) ensures the dry environmental condition inside the Thermal Enclosure*



- *N_2 system: Four manual gas circuits, each of them supplies gas to Pixel, SCT endcap A, SCT endcap C and SCT barrel.*

N_2 system exhaust

N_2 exhaust racks in UX15 cavern at level1 Y.59-04.X1 (left) &

at level 7 Y.62-04.X7 (right)

Operational conditions

➲ ***Requirement for the humidity sensor***

- *1% resolution over a large relative humidity range*
- *especially functional in the low (0-20 %) range*
- *operational at subzero temperatures*
- *radiation hard*
- *with an option to read the sensor with conditioning electronics positioned at a distance of about 100 m*
- *reasonable prise*

A wide array of humidity measurement instrumentation is available due to the importance of humidity control and monitoring in numerous industries. However, very few are operable under the extreme conditions expected.

Humidity sensor

- Choice: HMX2200 by Hygrometrix Inc
- MEMS* piezoresistive strain gauge technology sensor + 8Kbit EEPROM** in a single package
- proved to be quite robust
- while for relatively low cost (due to using semiconductor fabrication techniques)
- radiation hard
- and the performance suited the needs
- provides the T measurement in addition

Navigated by:

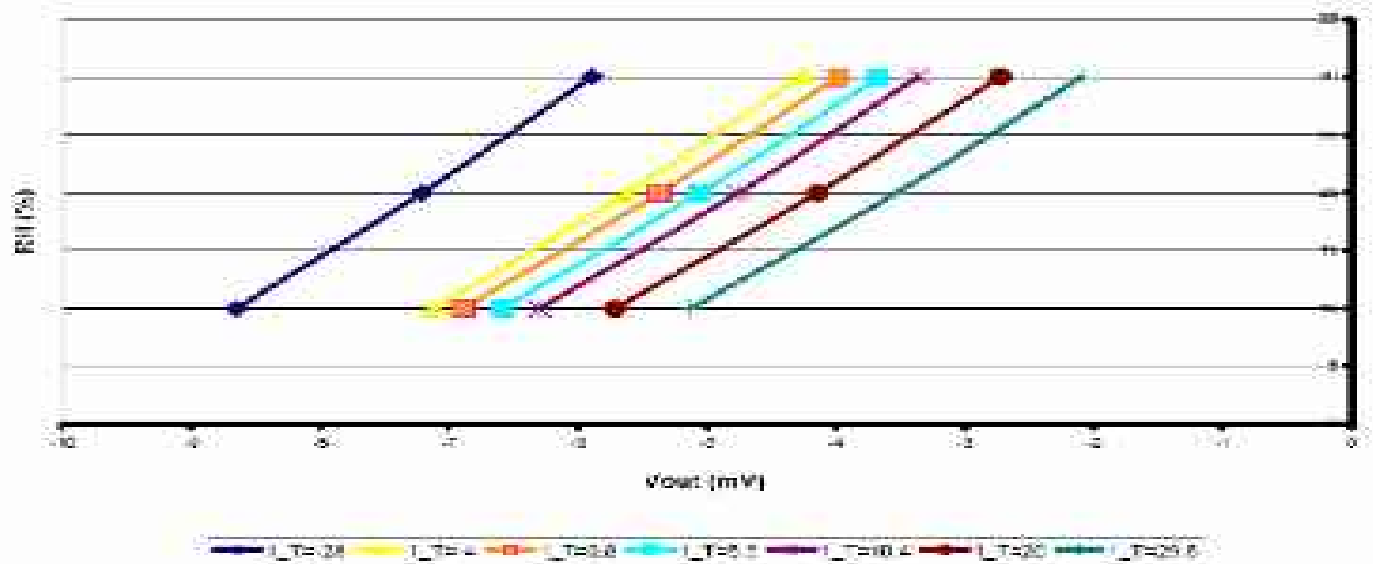
CMS note "The humidity sensors for the CMS Tracker", sensor characteristics provided by the production company

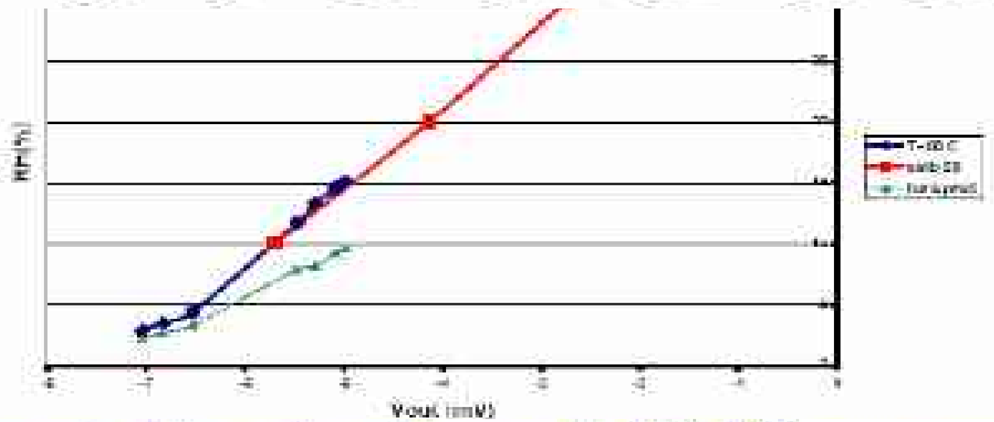
Conditioning circuit that translates the sensor output to a 4-20 mA current (industrial standard) developed in Genova

*MEMS stands for micro-electromechanical system

**EEPROM = electrically erasable programmable read-only memory

HMX calibration in Genova





We want to calculate a dewpoint around -30/-28°.
The T of the gas at the exhaust will be between 18-23°.
If we do not cool the gas this would mean measuring a RH ~< 1%, which can't be measured with humidity sensors that would suit to our application.

Need to Cool down the gas and the sensors at about -5 to 5°

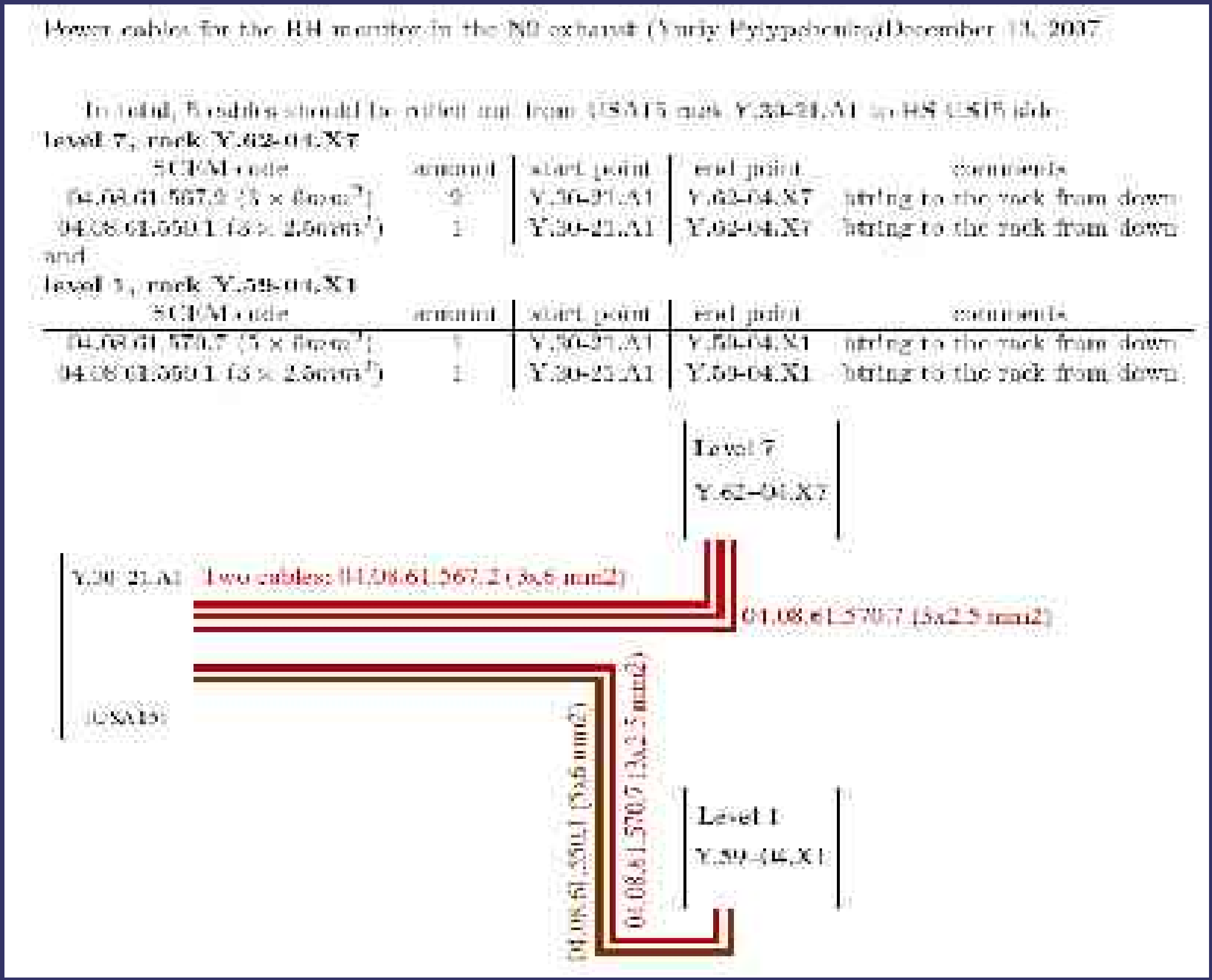
Measurement on confined volume of gas:

- *Sensor enclosed in a box*
- *which collects the gas*
- *and cools it down to the required by precision temperature*
- *Peltier element introduced for cooling purposes*

- *Tests and development in Genova*
- *with the target of 20 l/min at the exhaust*

Power Cables

- *Presence of the cooling elements required additional power cables...*



Power cables for the BH monitor in the N2 exhaust ([illegible]) December 13, 2007

In total, 5 cables should be [illegible] from USA15 rack Y.30-21.A1 [illegible]

level 7, rack Y.62-04.X7

SCEM code	amount	start point	end point	comments
04.08.61.567.2 (5 × 6mm²)	2	Y.30-21.A1	Y.62-04.X7	string to the rack from down
04.08.61.569.1 (5 × 2.5mm²)	1	Y.30-21.A1	Y.62-04.X7	string to the rack from down

and

level 1, rack Y.59-04.X1

SCEM code	amount	start point	end point	comments
04.08.61.570.7 (5 × 6mm²)	1	Y.30-21.A1	Y.59-04.X1	string to the rack from down
04.08.61.569.1 (5 × 2.5mm²)	1	Y.30-21.A1	Y.59-04.X1	string to the rack from down

Thanks a lot to Ole Røhne & Bjørn Samset for the help with moving that heavy stuff around!!!

Sensors setup in UX15

- *Fife "boxes" installed at the end of N_2 exhaust pipes*
- *Thermally isolated"Box"*
  - *hosts HMX and Pt1000 sensors*
  - *equipped with Peltier cooling elements to cool the incoming gas to the required temperature of about -4° C*
  - *electro-valves at the inlet and outlet to control gas flow*
  - *AC fan (ouside of the box) for removing the heat*
    - *required to equip the N_2 exhaust racks with 230 AC V power lines*

Setup in USA15

Rack Y.30-21.A1

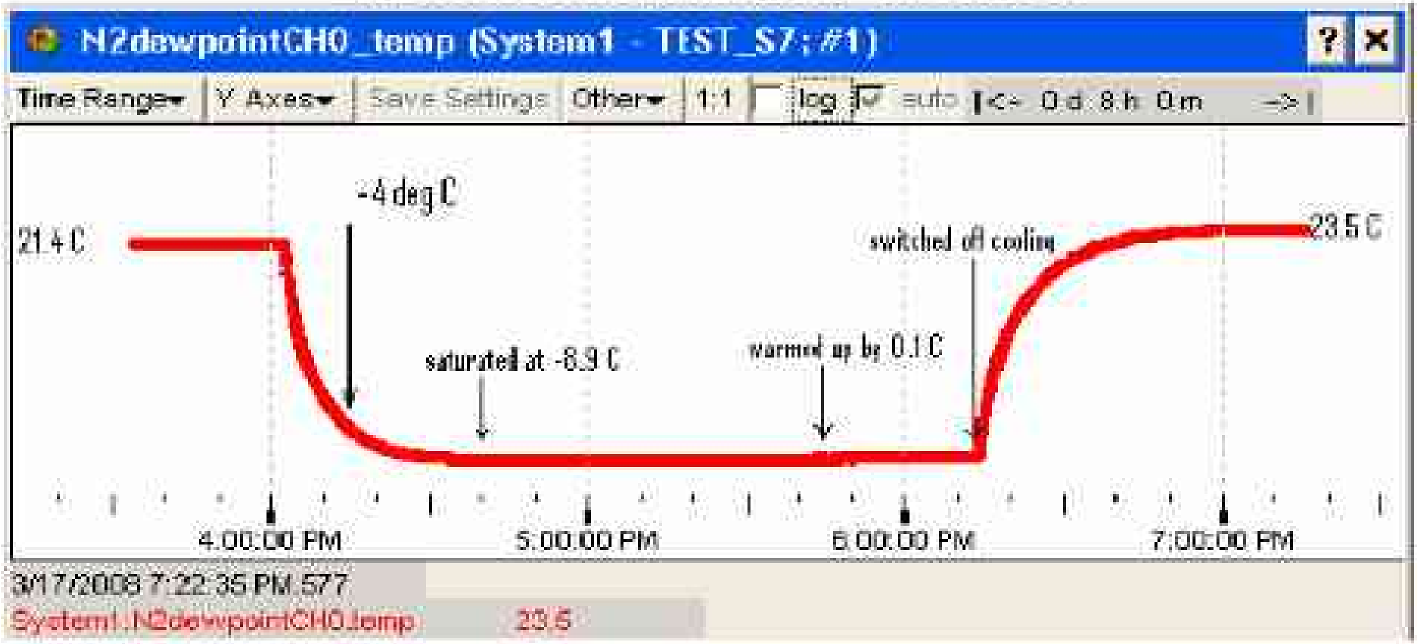
- HMX conditioning board
- 7 additional PS (SIEMENS SITOP Flexi)
  - for 5 Peltier coolers, electro-valves and conditioning board.
- PLC rail with
  - PS, CPU, CP, 2 AI for HMX, 1 AI for Pt1000, 1 DO module for releys
- PLC software:
  - Converts the voltages to T, RH and Dew Point for each measuring point
  - Controls the electro-valves
- PLC is connected to the LCS via Ethernet (IP/TCP)
- Due to specific conditions of ATN PLC can be programmed only with the direct PC connection with PLC USB adapter (EPF property). PC should have STEP7 software installed
- Required to arrange additional 230 VC V power lines to the rack for the installed equipment

It would be impossible without Giovanni, Ettore and Alessandro from Genova as well as W.Iwanski assistance

Installation and Post-installation

- *The system was installed in March 2008*
- *Right after installation and connection it was realized that at the present N2 flow it will not function as planned*

Experience from Monday 17.03.2008

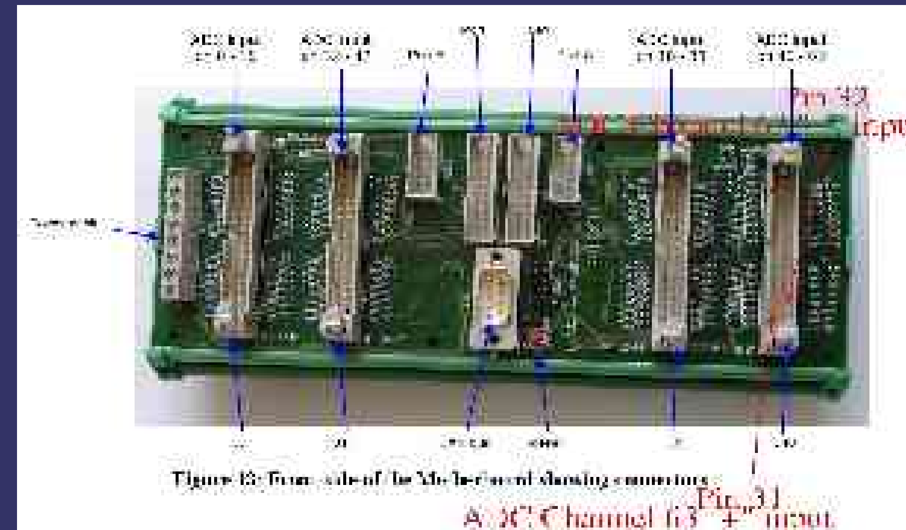


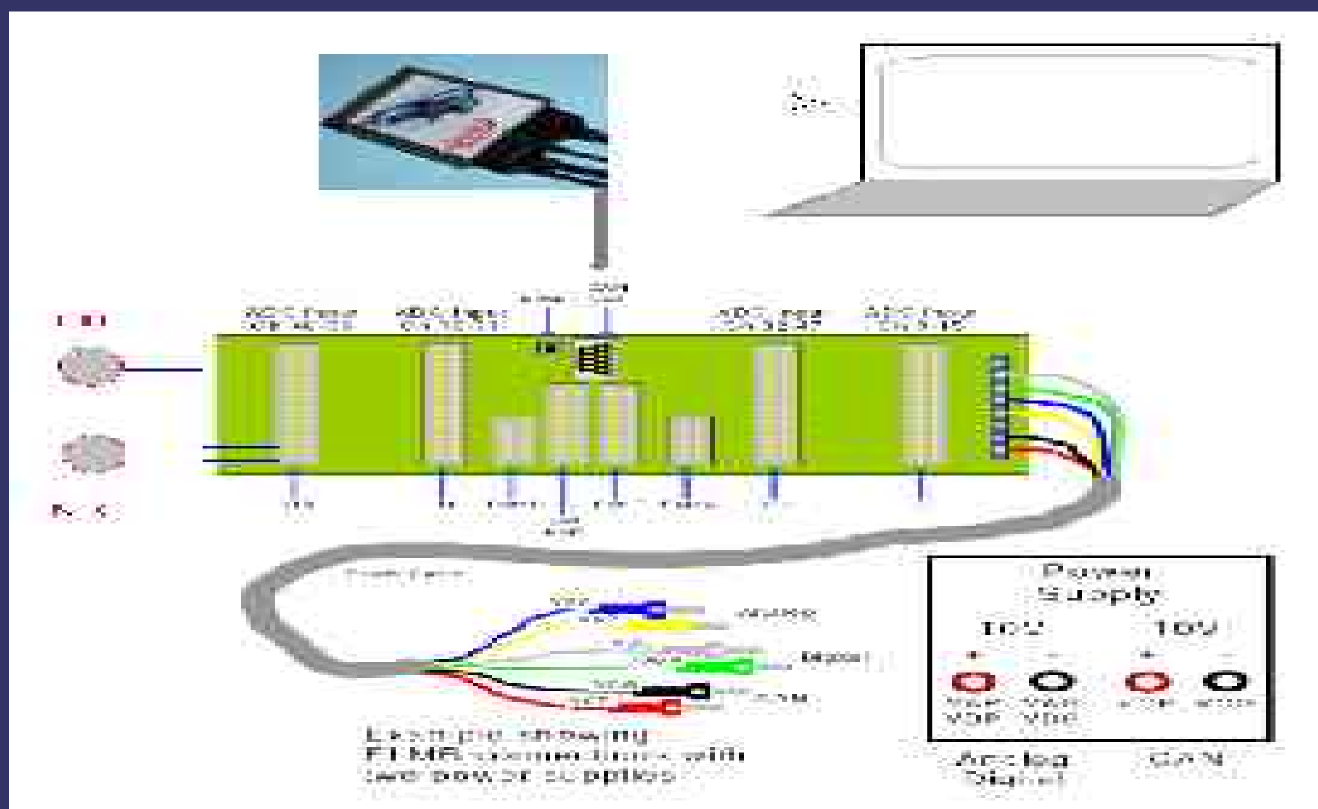
Temperature vs Time

- *in April 2008 valves were taken out, input pipe diameter increased*
- *turning to the measurement on the gas continuous flow (instead that on confined volume of gas).*
- *The flow (~20 l/h) is enough, nevertheless, to measure low dew point*

Local Test Setup

- *To enhance the software development*
  - *ELMB + ELMB Mother board*
  - *NTC and HIH-400 sensors*
  - *Kvaser LapCAN*
  - *HP Laptop runnign Windows XP with installed PVSS*
  - *Laboratory PS*





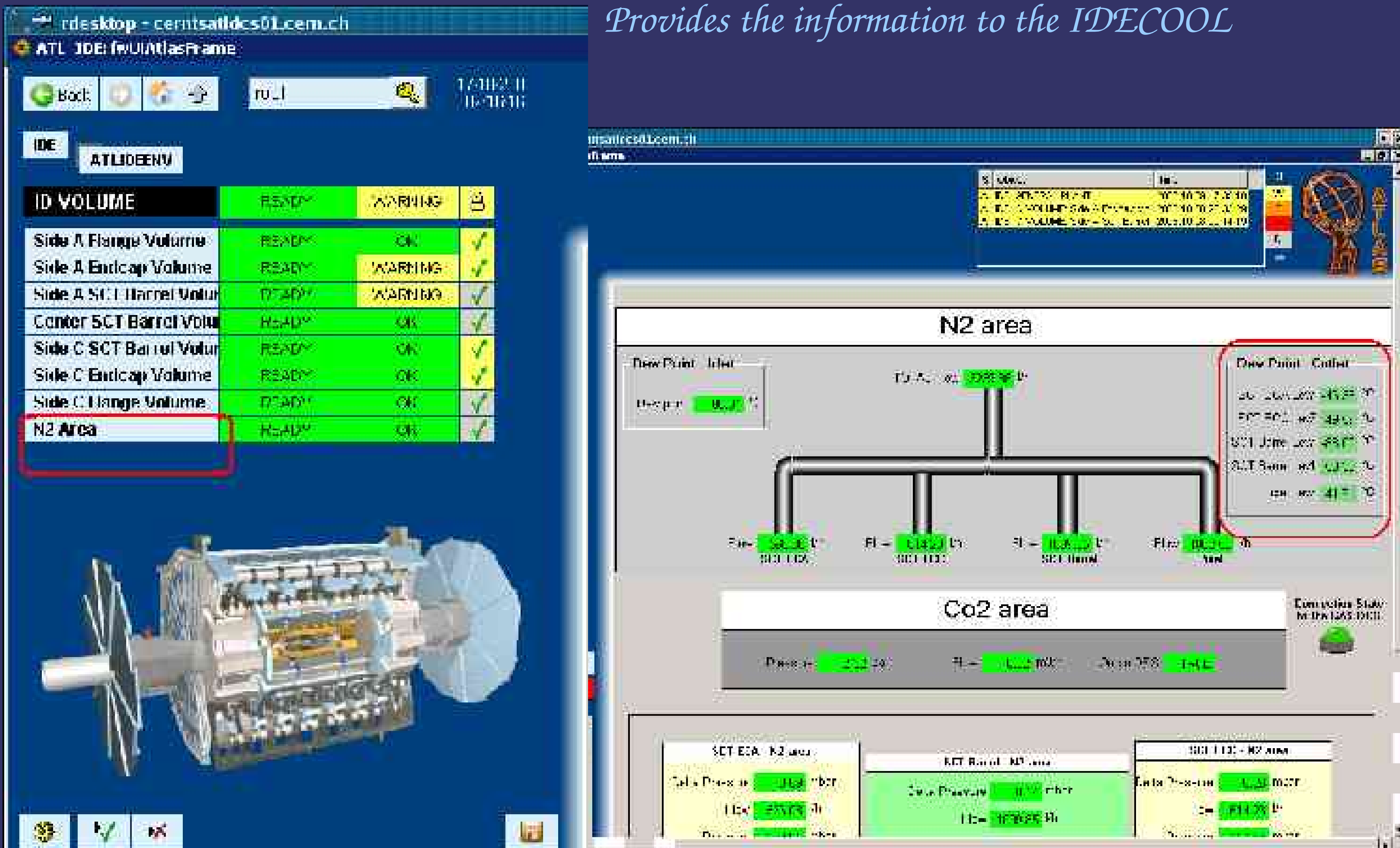
DCS software: PVSS part

- *5 datapoints with 5 DPE in each representing T, RH, DP, V_{RH}, V_T*
- *Connected to the PLC with Native Simatic S7 driver (part of PVSS)*
- *Pulling mode is used; pulling time 5 sec*
- *T, RH and DP values are archived with smoothing*

DCS soft: FSM hierarchy

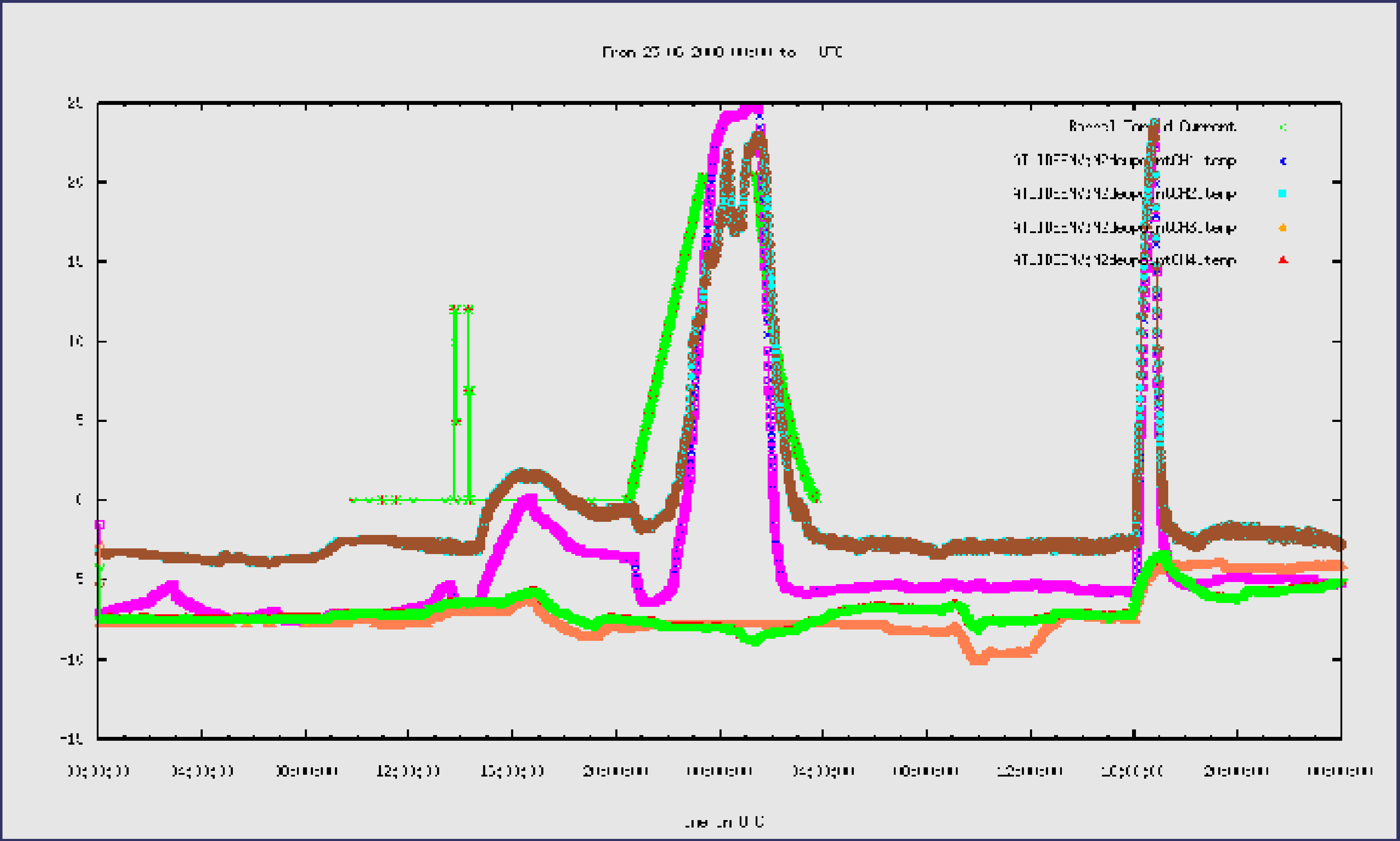
- *Part of the IDEENV FSM (still under development)*

Provides the information to the IDECOOL



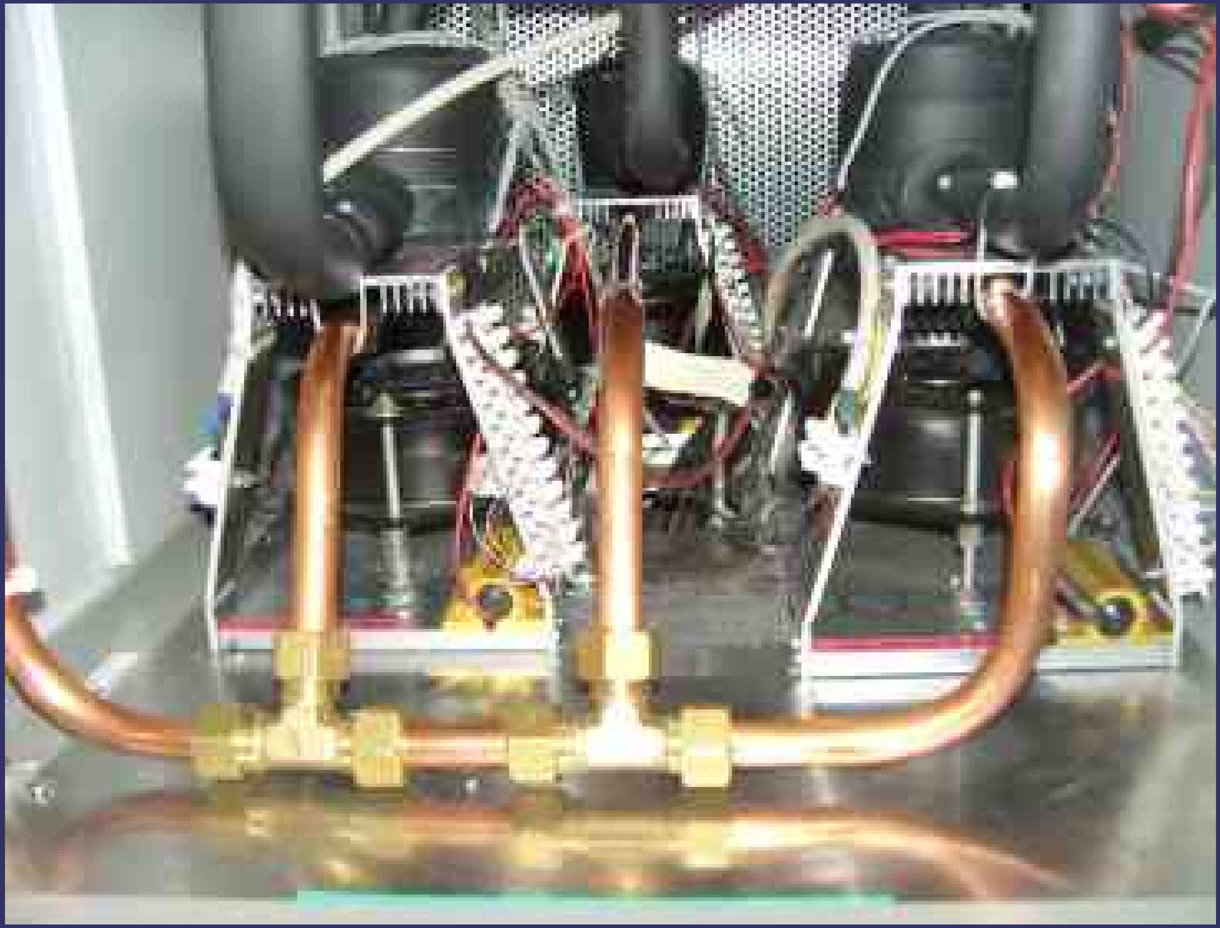
Magnetic Ventilation

- *During magnet tests in July'08 it was observed another drawback of the system: AC fans meant to dissipate heat from the Peltier do not tolerate the Toroidal field.*



Magnetic Ventilation

- *Solution: use compressed air instead of any fans to ensure air ventilation in the N_2 exhaust racks*
- *Would not make it without help of Alex Bitadze, Koichi Nagai and Valery Akhnazarov.*

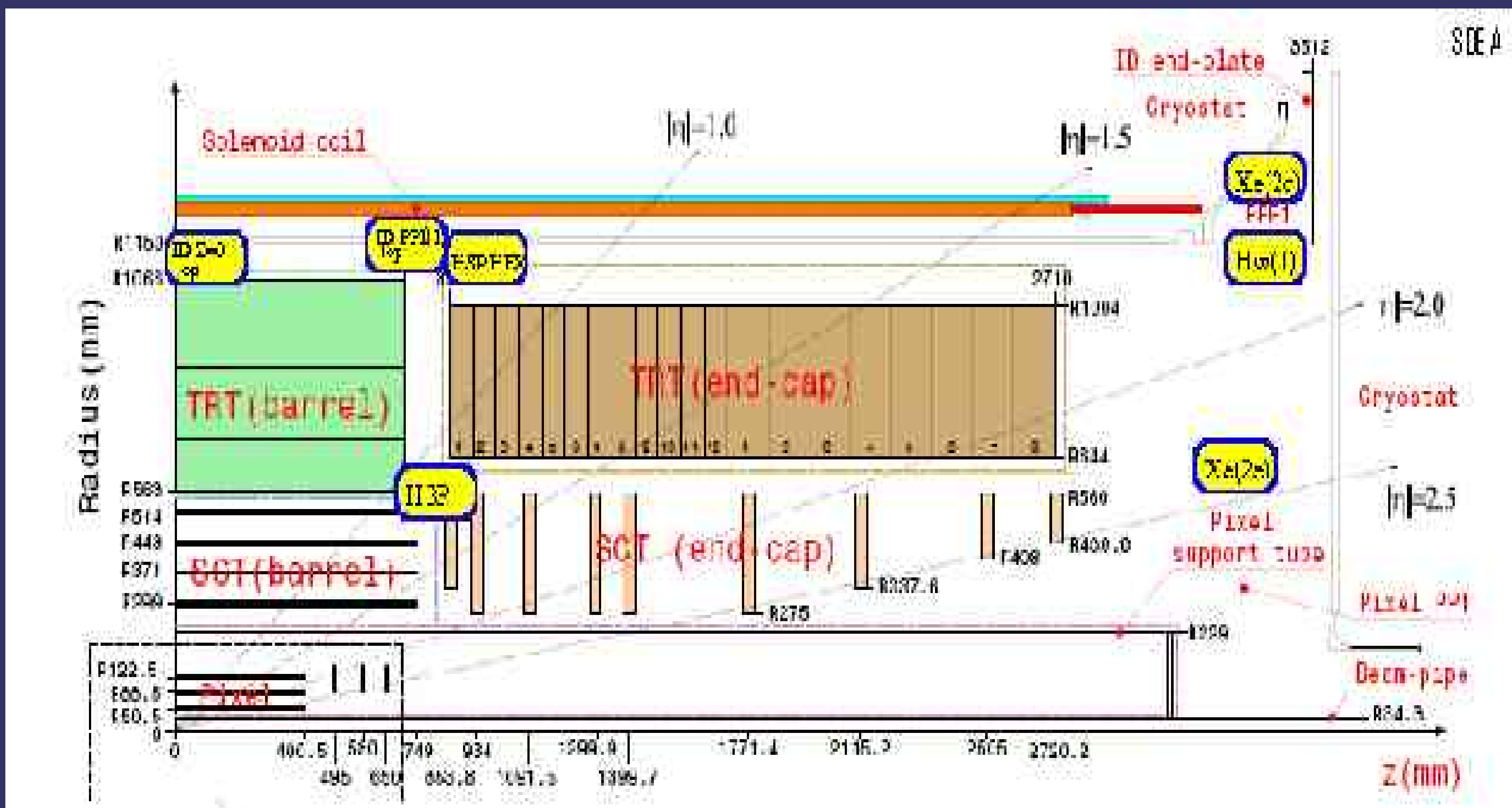


Summary on N2 exhaust Dew Point monitor

- *Commissioning is ongoing, sensor signals look very stable (monitoring basically ch1 performance)*
  - *Despite of the luck of the N2 flow made the system provides reasonavle insight to the env. conditions inside thermal enclosure*
  - *Calibration looks OK . Good correlation with the values from inside the SCT*
  - *Ch4 extensively used by Pixel community as a benchmark*
- *Work on updating the IDEENV FSM tree with dedicated N2 exhaust monitor panels*
- *Some attempts to create documentation in form of EDMS note*

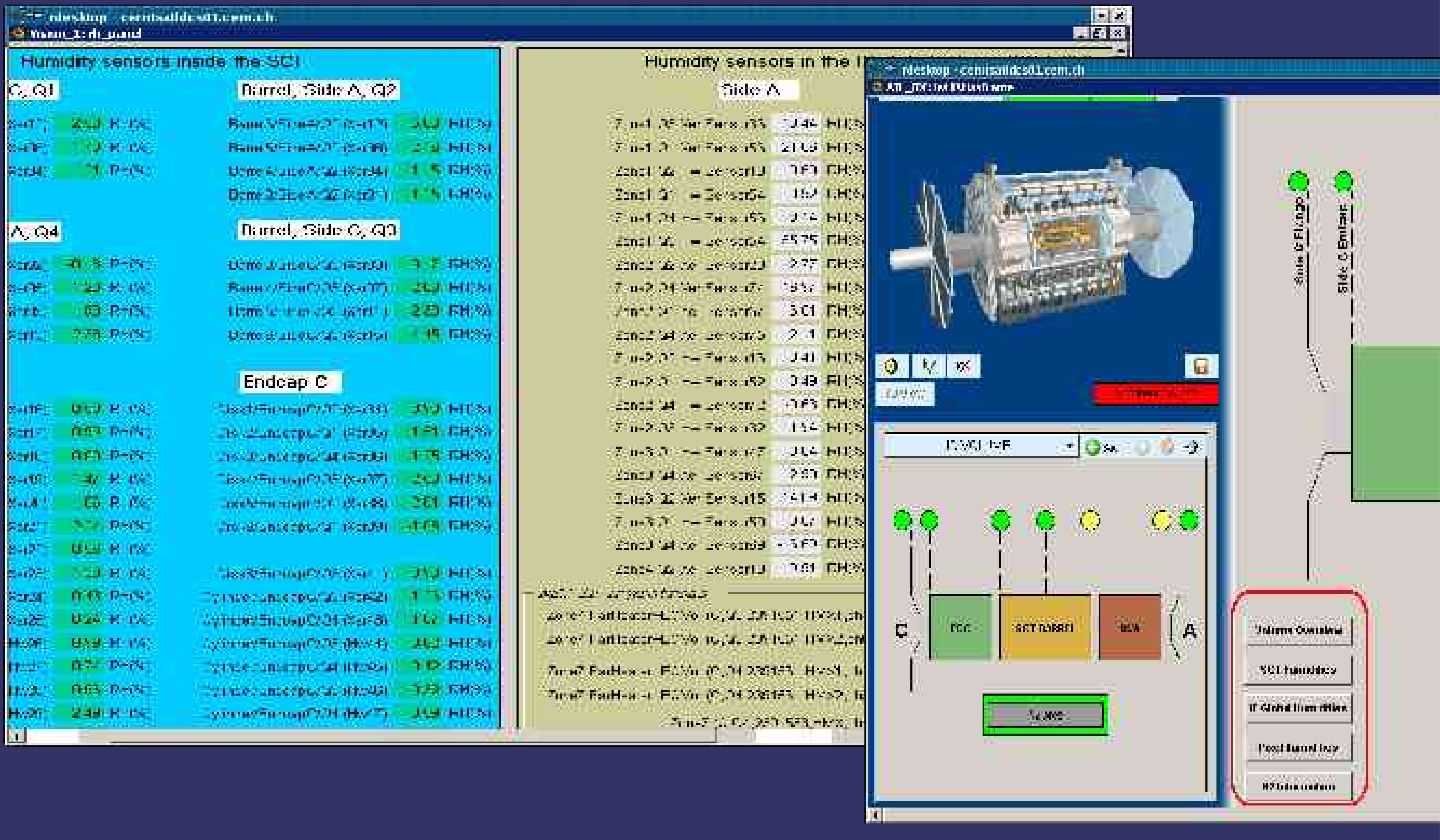
RH in the ID global volume

- *Catalog of all RH sensors in the Pixel, SCT and ID global volumes*
- *Localize the position of the sensors in the ID global*
- *PVSS panel summarizing all RH measurement*
- *Summary page on ATLAS ID Twiki (https://twiki.cern.ch/twiki/bin/view/Atlas/IDHumiditySensors)*



RH in the ID global volume

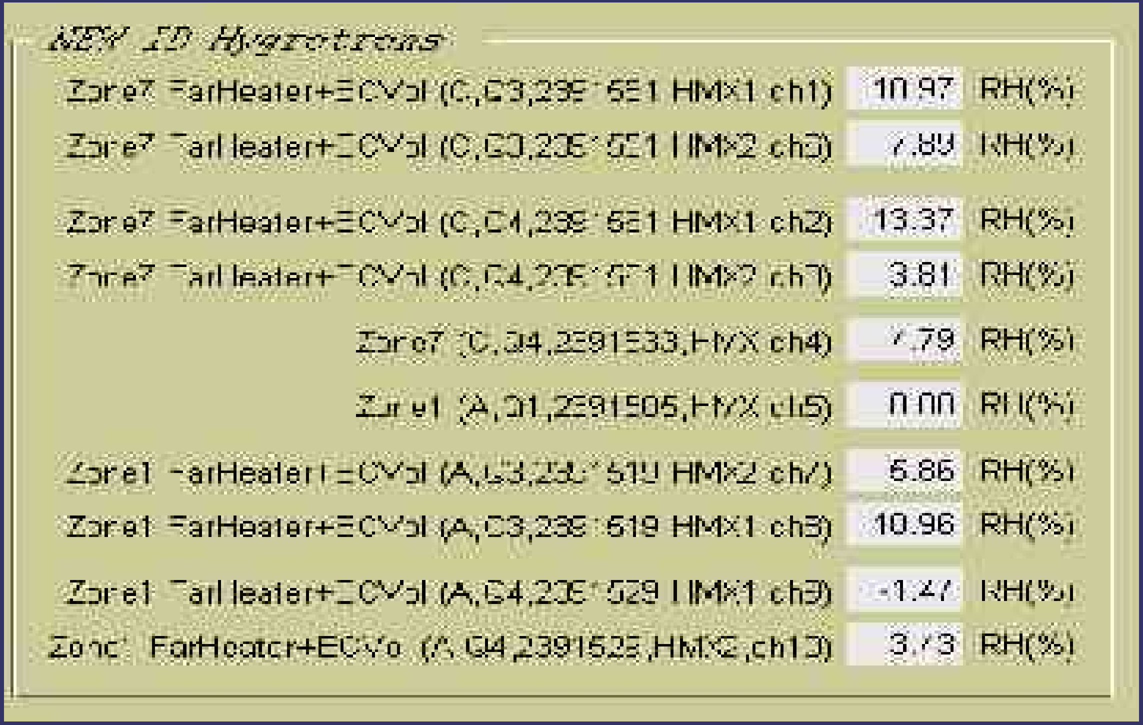
- *PVSS panel to summarize all RH measurement in the ID (except TRT)*
- *Split to three panels (buttons) in the IDEENV*



New RH in the ID global volume

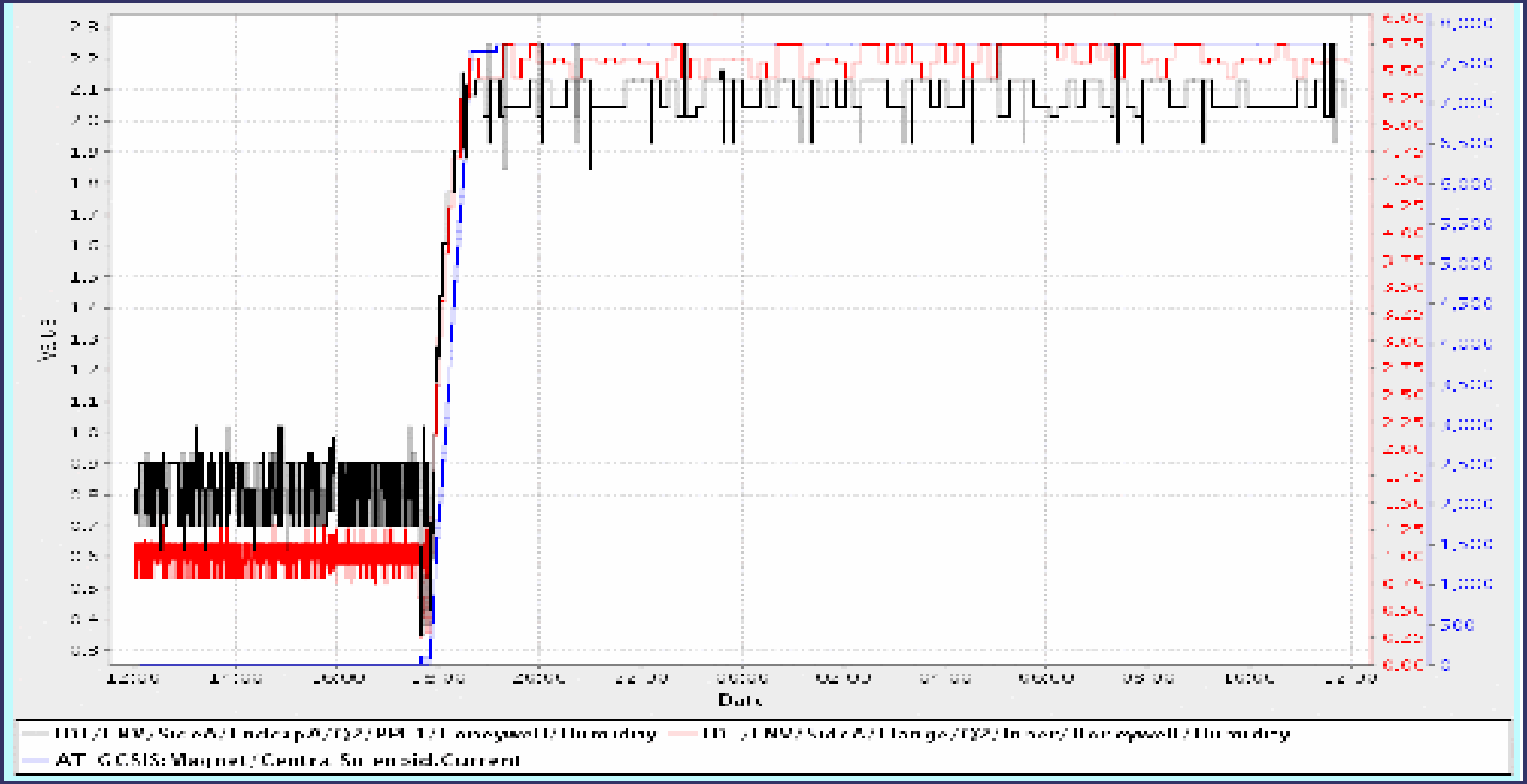
- *Packages with HMX2200 and NTCs installed at the far heaters*
- *HMX signals conditioned with Genova boards are interfaces with the PLC*
  - *additional two AI modules were installed for this purpose in July 2008*
  - *wiring and re-programming PLC to include newcomers*
- *NTC are not connected ---> both RH and T from the same HMX*
- *Added to the IDEENV*

- *Second order polynomial used to compute RH as a function of T and Vout*
- *Polynomial coefficients obtaned from fitting the calibration data provided by supplier*



Summary

- *N2 dew point monitoring system designed, installed and nearly commissioned*
- *RH sensors in the ID volume are cataloged and their performance is under control*
- *Permanent monitoring of the RH and Dew Point in the ID volume*



Summary

- *N2 dew point monitoring system designed, installed and nearly commissioned*
- *RH sensors in the ID volume are cataloged and their performance is under control*
- *Permanent monitoring of the RH and Dew Point in the ID volume*
- *Calibration for new HMX should be x-checked*
- *Possible NTC measurement recovered by using IDEENV ELMB channels*
- *EDMS not on the new HMX connection and calibration*

At the end...

- *During the process of installation and commissioning this place became like a second home :)*

Thanks to Ole, Katarina and Lillian for lending cameras