# Subject

## Experience of long-term operation under **ALICE** experiment of the automated cooling system of electromagnetic calorimeter **PHOS**

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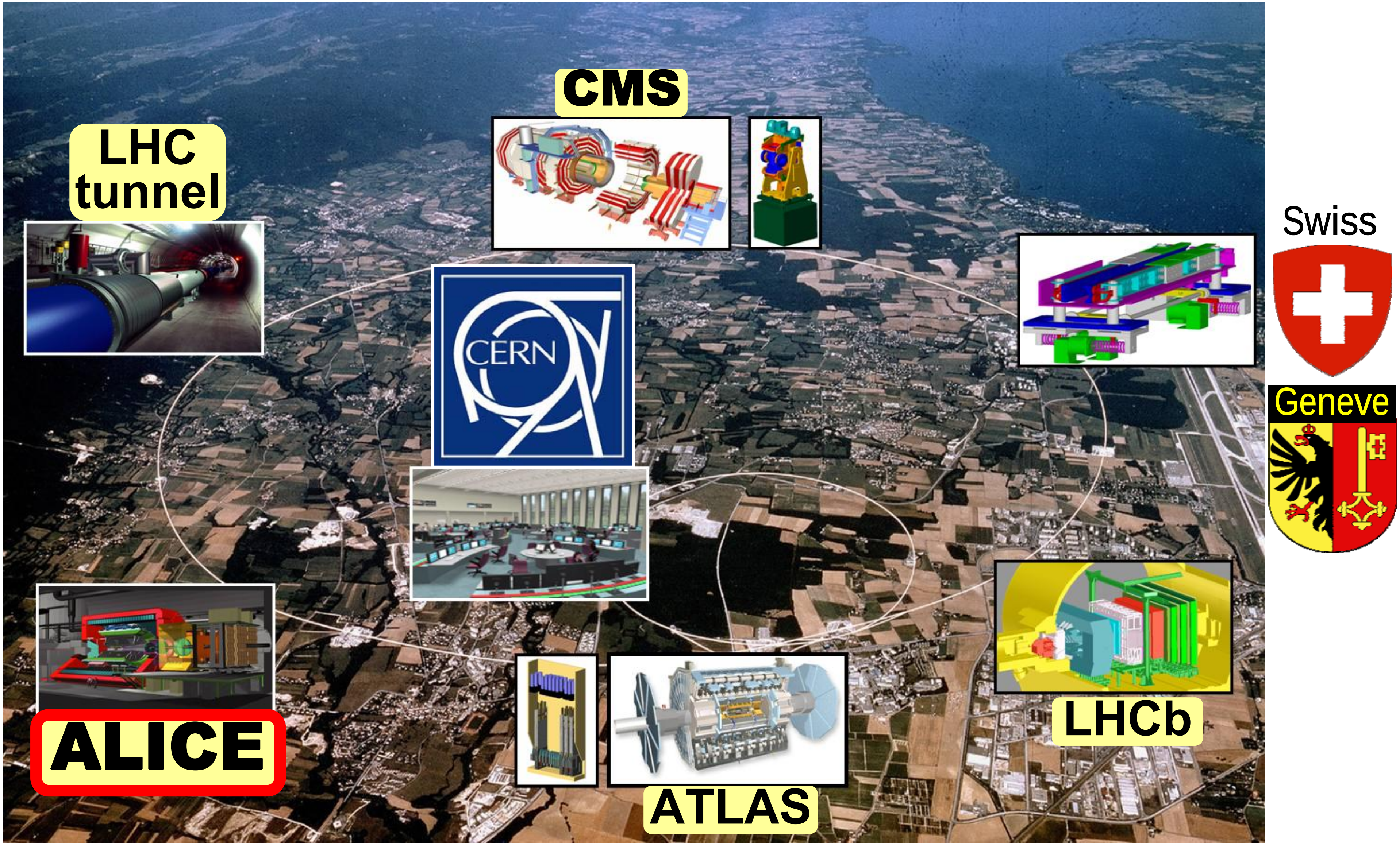
**There are described in brief the system of photon spectrometer PHOS cooling and thermal stabilization system of ALICE experiment as well as the experience of its operation in the experiments on colliding proton and ion beams realized on a Large Hadron Collider. The system has operated more than 20 months in a continuous mode providing the required operating temperature of crystals -25°C and its high stability of ±0.1°C.**

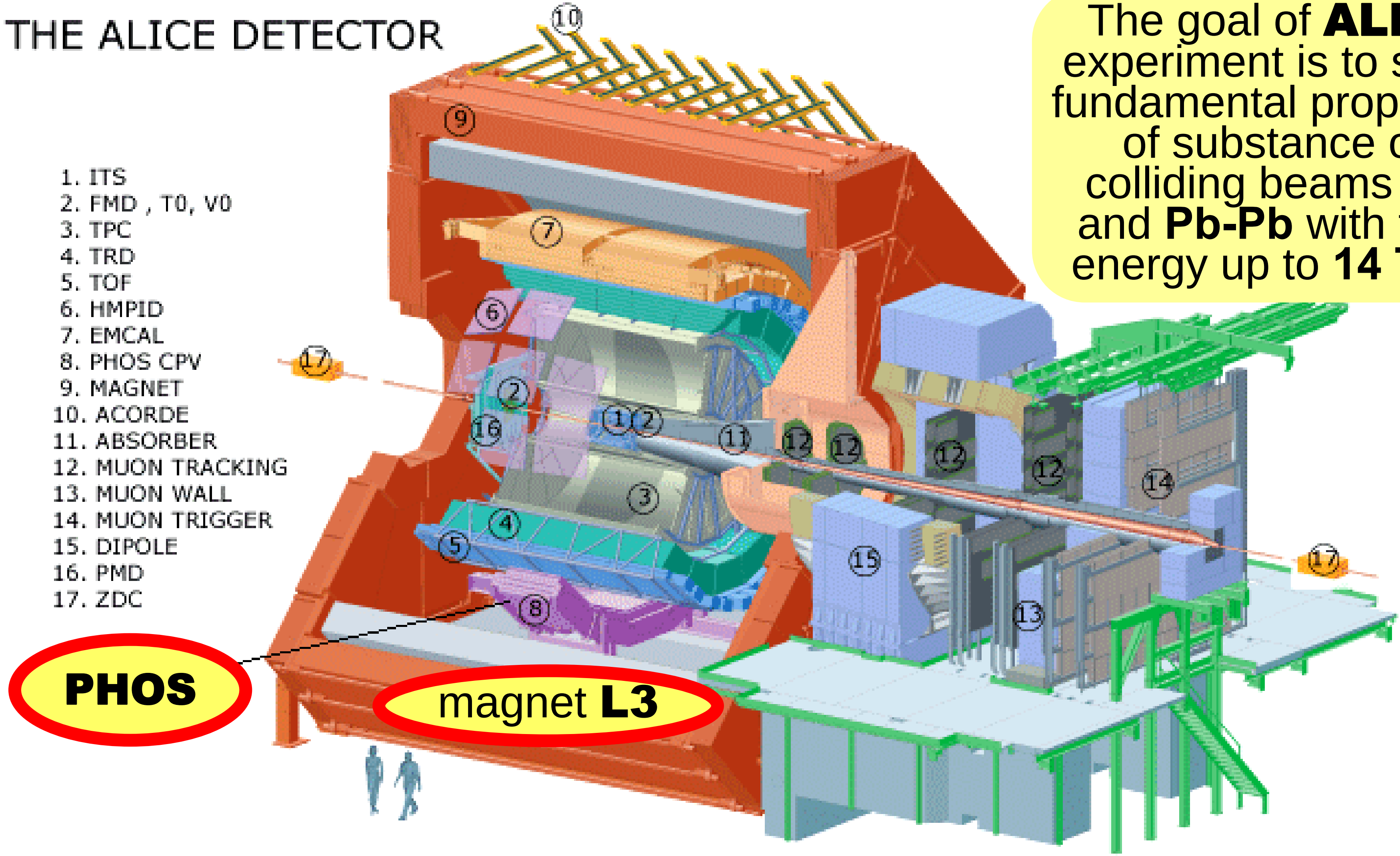
# CERN, LHC, ALICE

**the largest accelerating complex in the world**



# **PHOS** spectrometer in **ALICE** experiment

The goal of **ALICE** experiment is to study fundamental properties of substance on colliding beams **p-p** and **Pb-Pb** with total energy up to **14 TeV**.




**General view of experimental facility ALICE inside a pit UX25, depth ~50 m.**

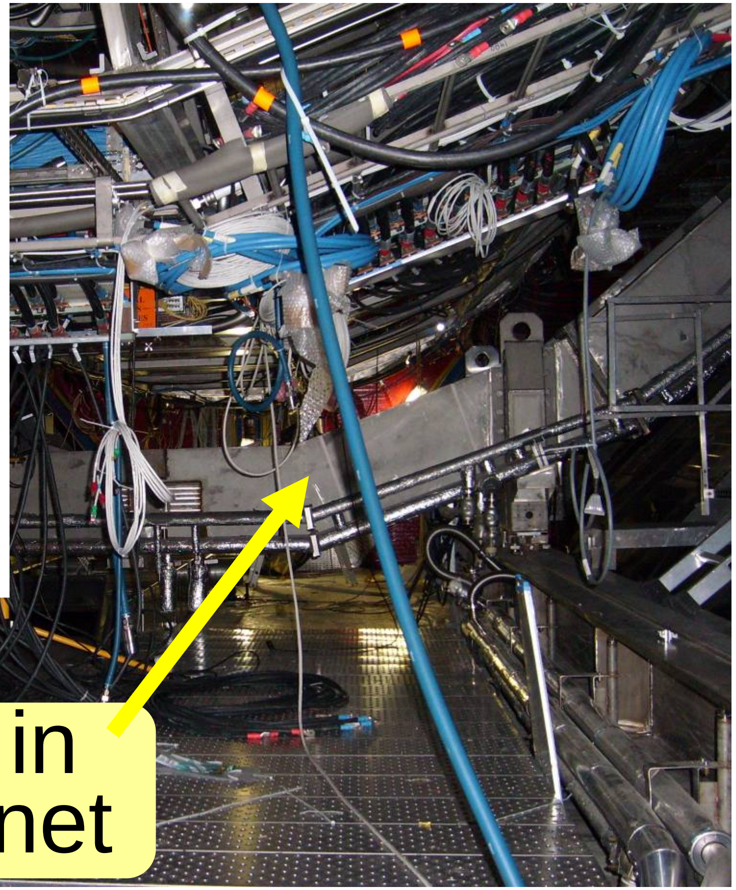
# External view of PHOS

РФЯЦ ВНИИЭФ

Sarov

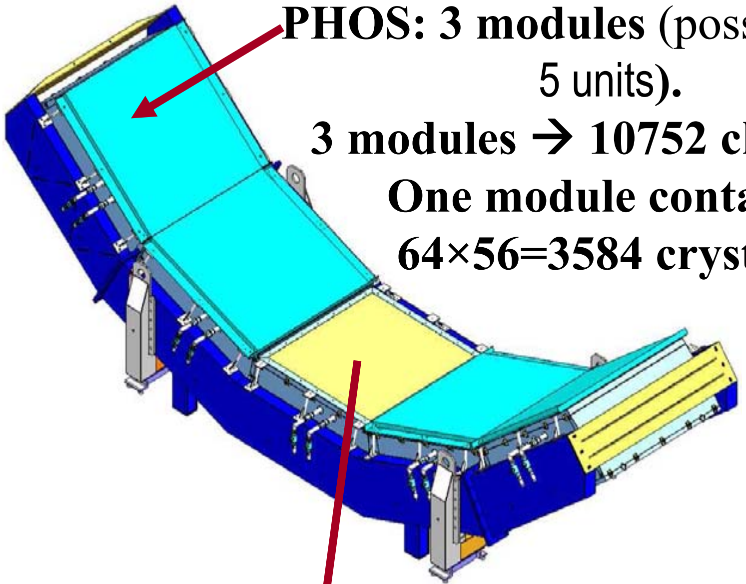
**PHOS** – one of a small number of **CERN** projects where the leading part is played by **Russia**



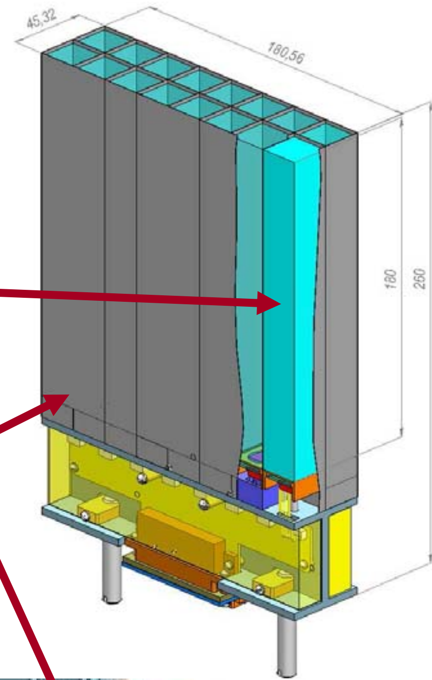


# PHOS spectrometer design

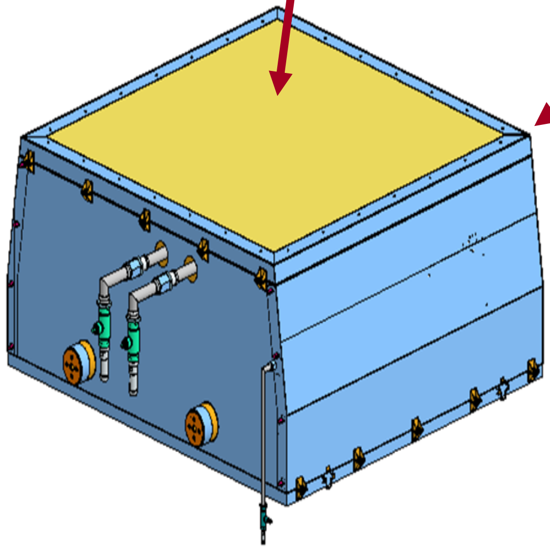
mechanical assemblies and assemblage itself are realized by VNIIEF

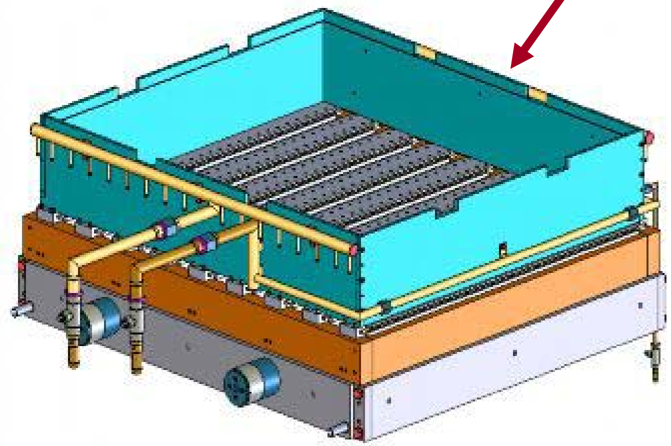


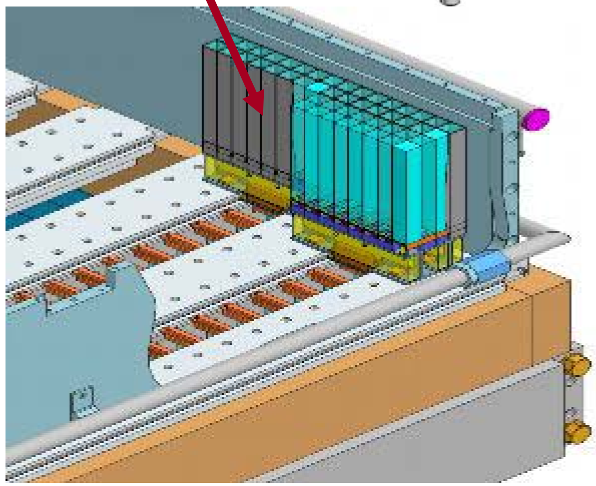
**PHOS: 3 modules** (possible up to 5 units**).**
**3 modules → 10752 channels.**
**One module contains:**
**64×56=3584 crystals.**



**Crystal: PWO** ($PbWO_4$)
**Total volume of PWO: 0.93 m³**
**Total weight of PWO: 7.5 t**
**Sub-assembly: bars 8×2**
**Sealed container**
**Working temperature -25°C**
**Cooling board**

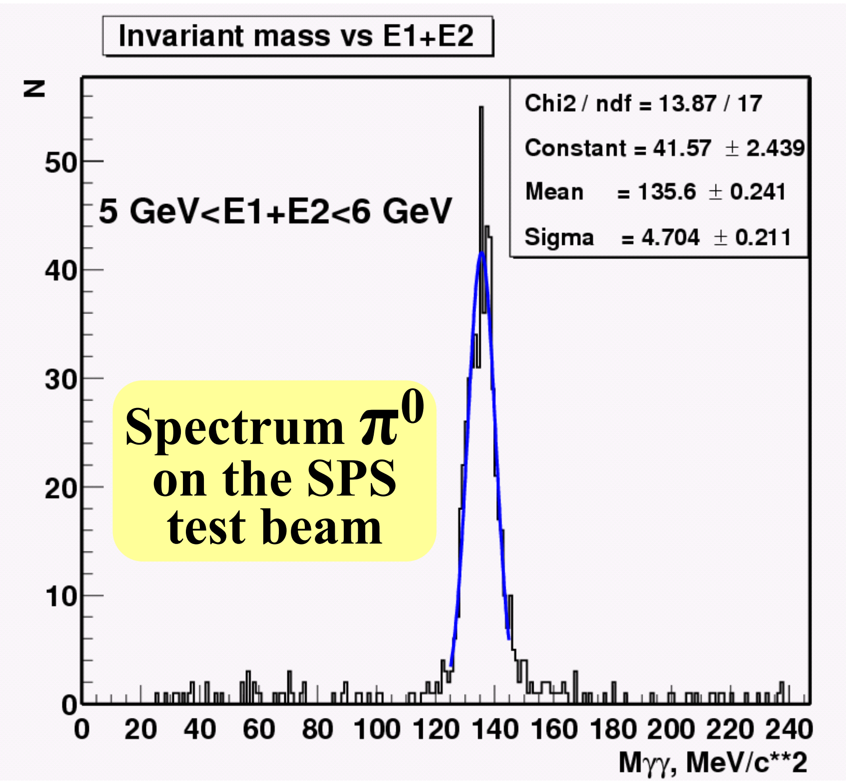


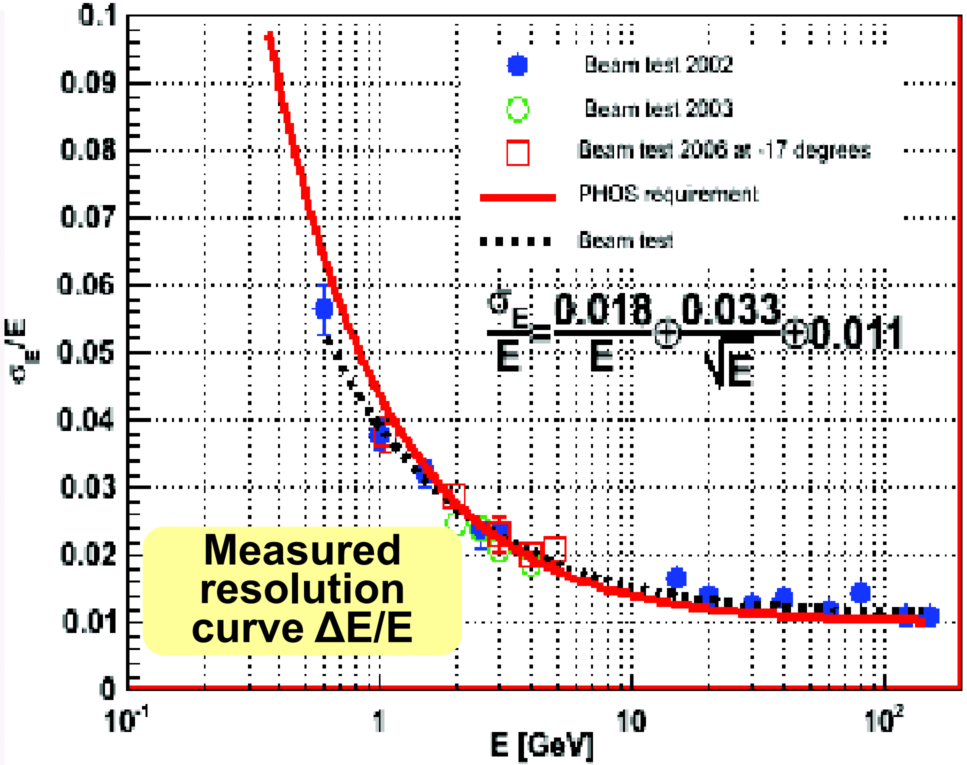




# Energy resolution of **PHOS**

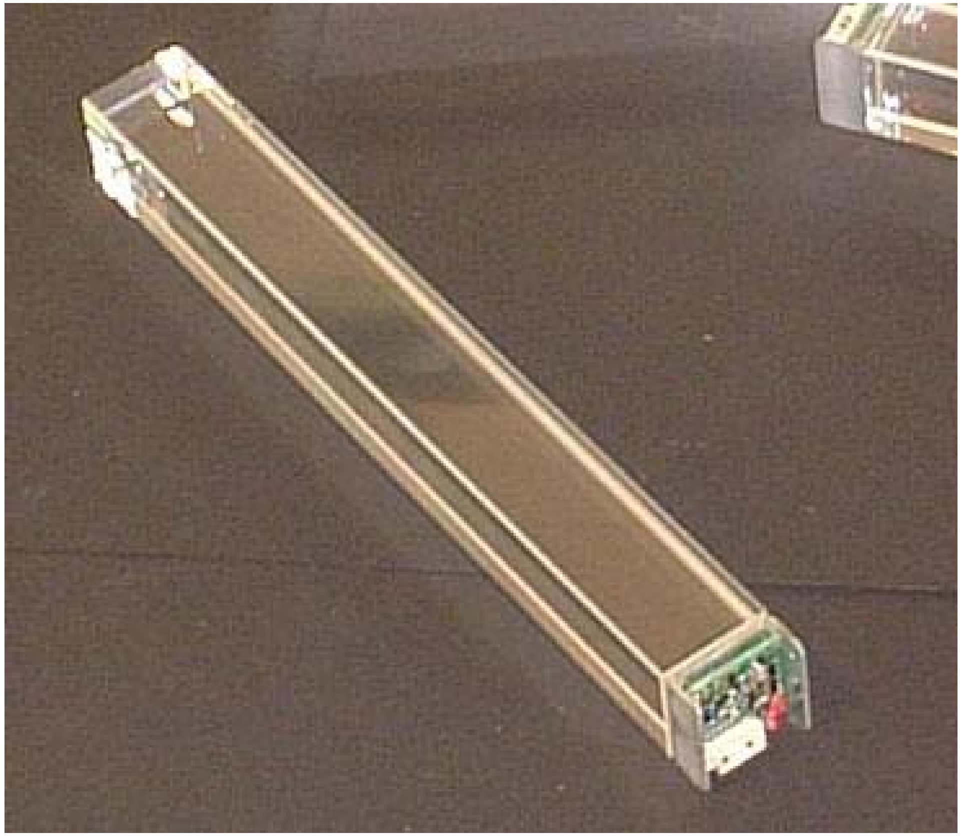
**One of critically significant characteristics of PHOS spectrometer is energy resolution ΔE/E. To meet the experiment conditions there should be ΔE/E=1% at high E values.**



# PWO crystals

## What do we need to achieve resolution ΔE/E = 1 % ?



External view of PWO crystals with a preamplifier at the end

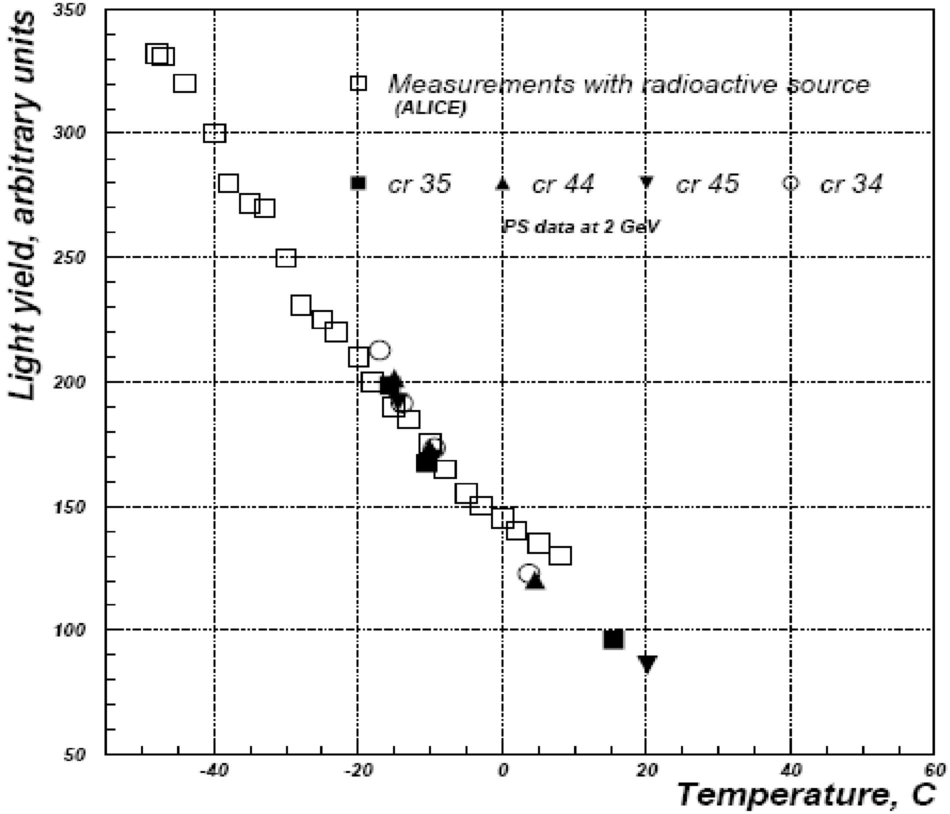
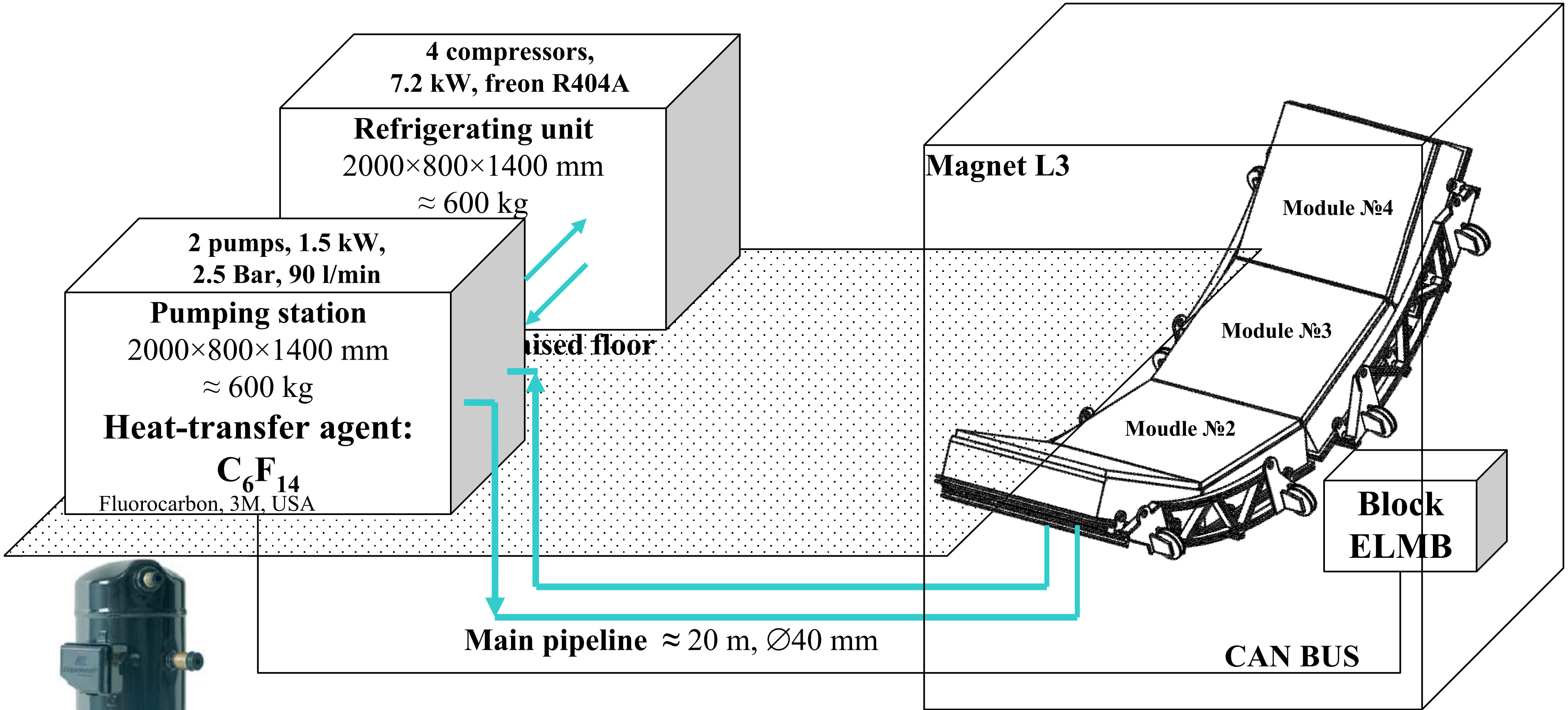



Diagram of PWO crystals light yield dependence on temperature

**Operating temperature -25°C, coefficient ≈ -2.3 % per 1°C.**

**Requirements to stabilization accuracy ± 0.1°C.**

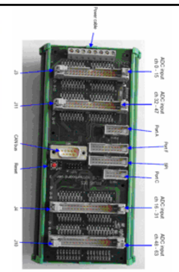
# SCTS – System of PHOS cooling and temperature stabilization




4 compressors

2 pumps

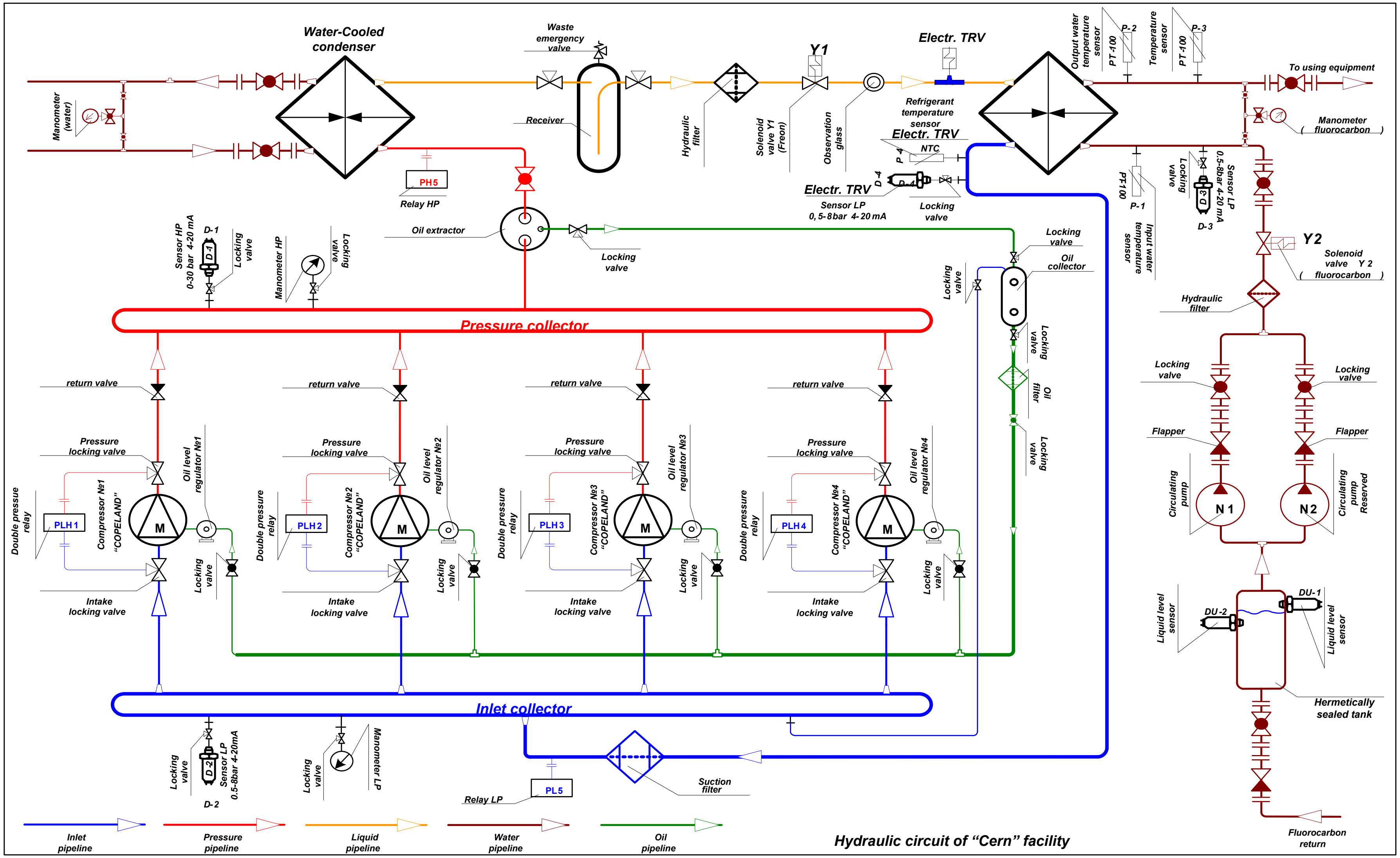
12 modules I-7000



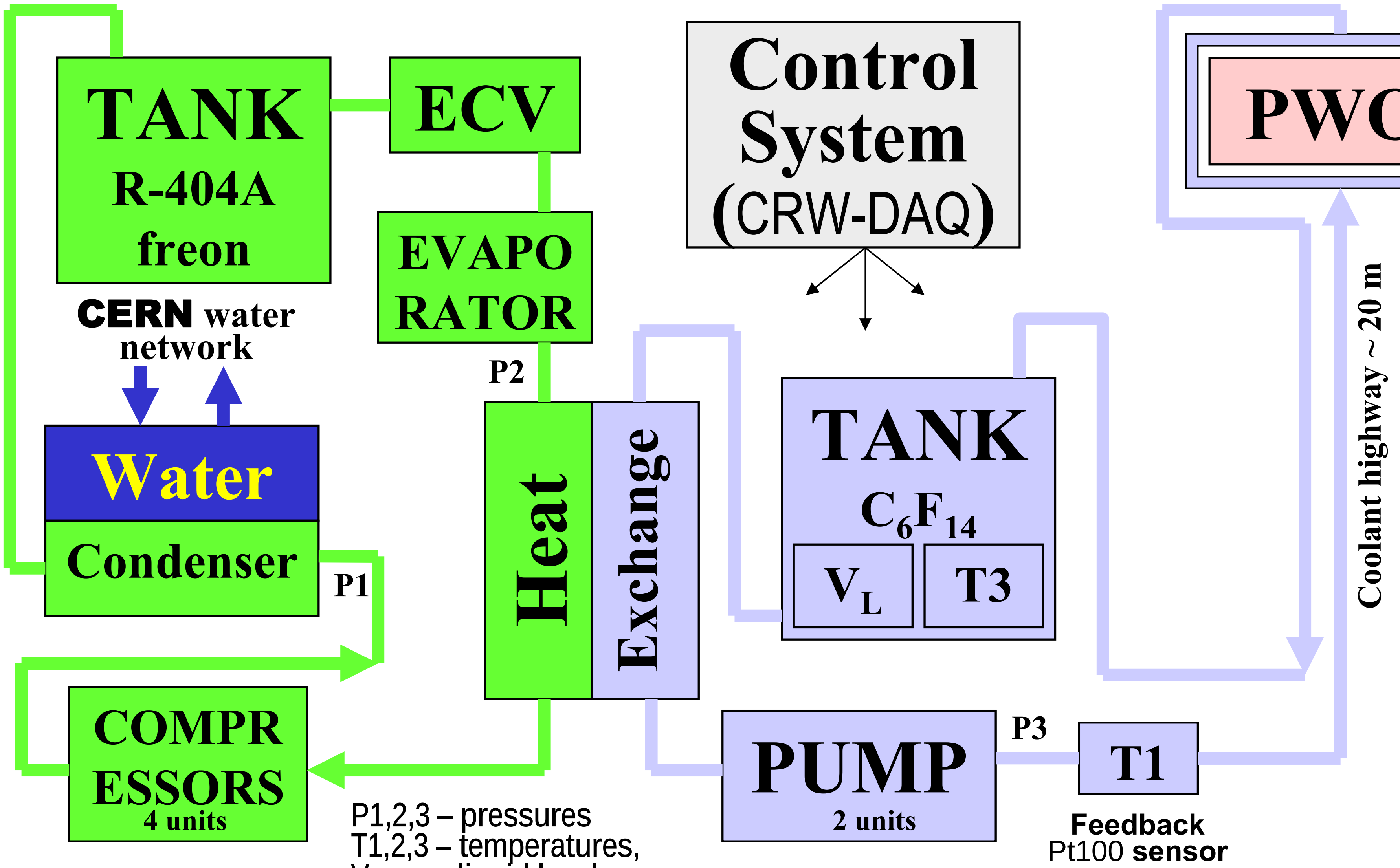
6 ELMB cards

On-board computer

# Schematic hydraulic circuit of the cooling system

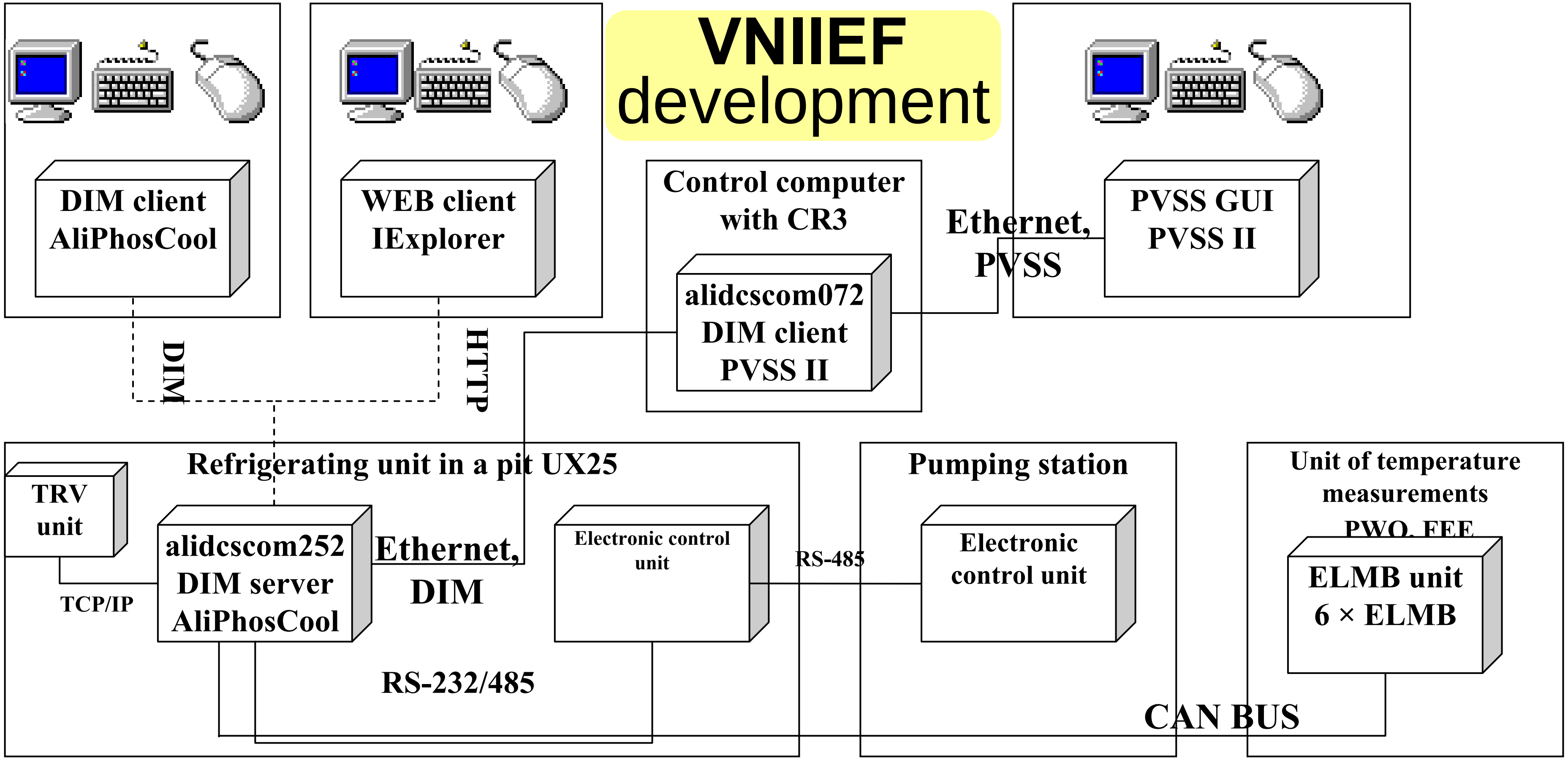


# Structure of **PHOS** detector cooling system




P1,2,3 – pressures
T1,2,3 – temperatures,
$V_L$ – liquid level.

# ACS for SCTS: 175 registration channels, 20 – control channels




**SOFT:** Control: AliPhosCool (CRW-DAQ); GUI: PVSS II SCADA (ETM)

**HARD:** 12×I-7000 (ICP-DAS), 6×ELMB (CERN), EC3-X33 (ALCO), NISE 3100 (NEXCOM)

**NET:** DIM, PVSS, HTTP, TCP/IP, RS-232/485, CAN BUS

# ACS for SCTS: Objectives

- **Remote supervision and control:** access is denied to the pit during the experiment, within months.
- **Condition control and diagnostics:** a large number of different sensors controlling equipment parameters.
- **Manufacturing equipment control:** pumps, compressors, gates, heaters, valves, relays…
- **Interlocking system:** automatic prevention of hazardous modes of equipment operation.
- **Alarm warning system:** locally – with the aid of GUI; at a distance - through automatic distribution of email messages basing on the list of experts
- **Measurement of process-dependent parameters: T**, **P**, liquid flows and levels.
- **High-accuracy measurement of PWO matrix temperature**
- **Stabilization of PWO matrix temperature:** it is required to get the long-term stability **±0.1°C**.
- **Record-keeping of measurements:** > 200 parameters, ≈ 30 GB/year.

# ACS for SCTS: Features

• **Remote access: surveillance and control is available from any place in the world**. The system is controlled during most of the time by the experts from Sarov. The remote access is well protected.

• **High fault-tolerance:** watching timers, duplication of major assemblies of importance, self-recovery after emergency failures, fault-tolerant software (crw-daq).

• **High degree of parallelism:** the task of control is jointly solved through many flows and processes with differentiation of functions.

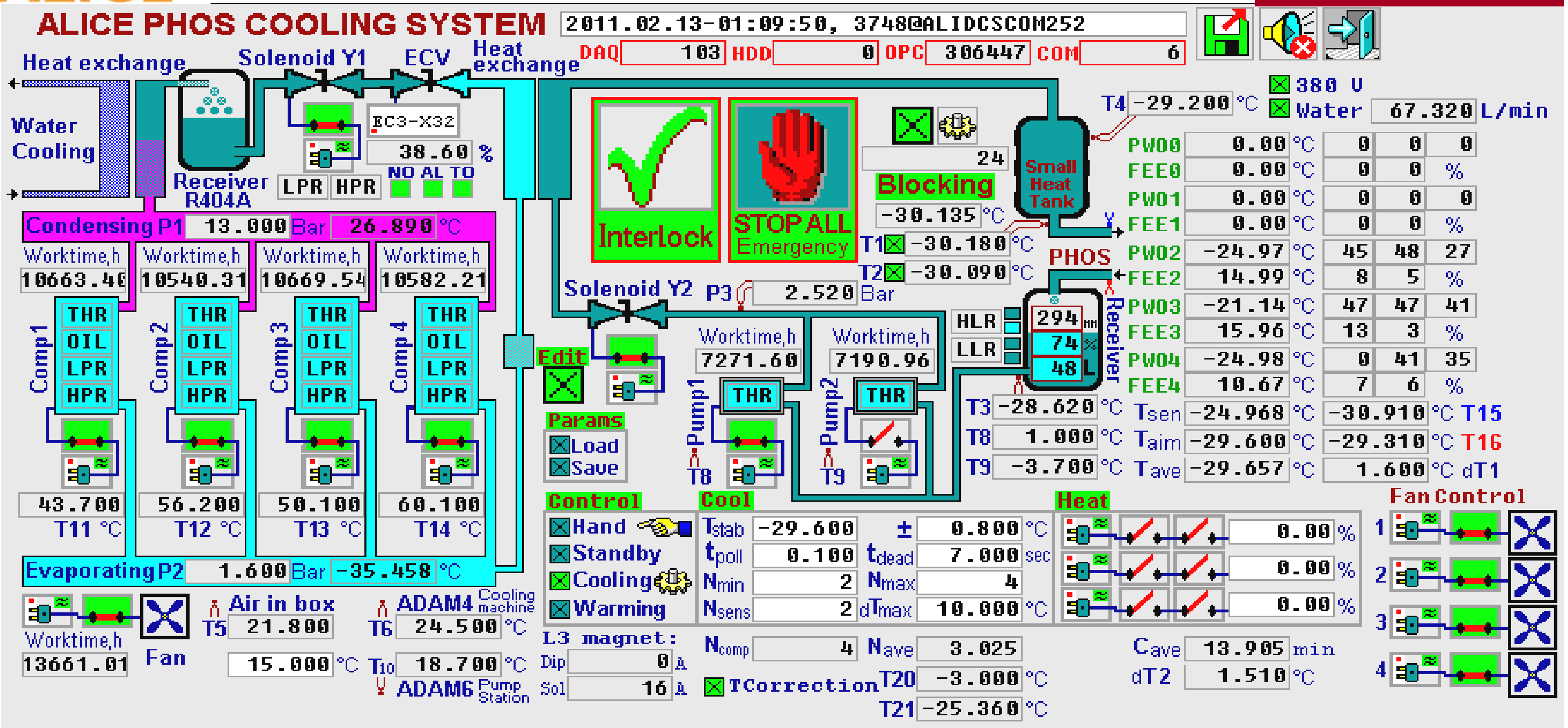
• **Integration to general network system ALICE:** the system is totally integrated to **DCS** with the aid of **DIM**.

• **Developed system of blocking: 37** conditions of blocking to prevent abnormally dangerous conditions of operation.

• **Good warning system:** automatic distribution of email messages according to the list of experts in case of alarms and system critical failures.

# Control program **AliPhosCool**

Created in VNIIEF in order to control **SCTS**



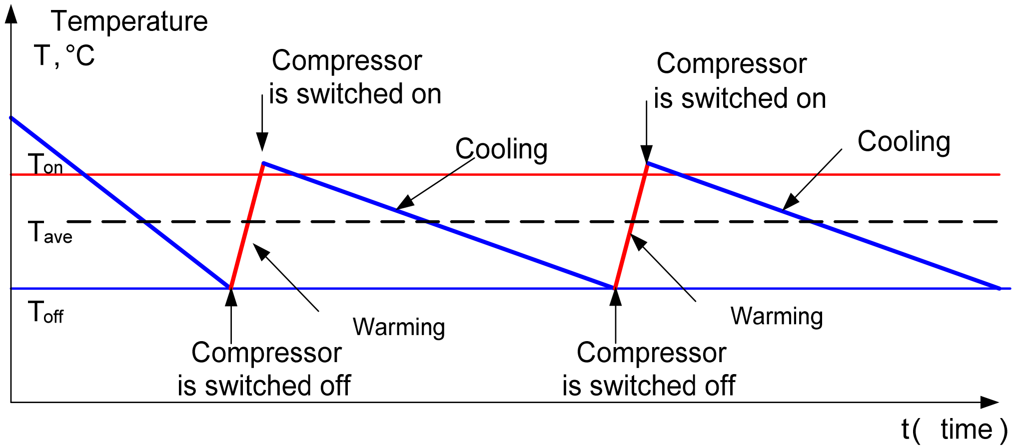

# Designed in the development package **CRW-DAQ**

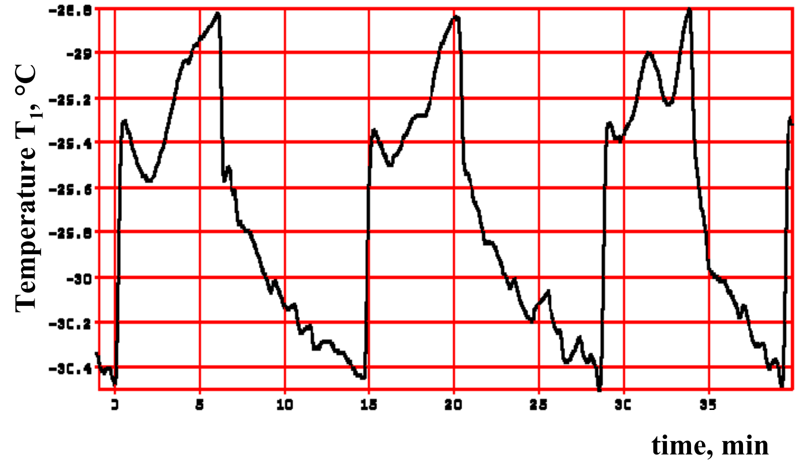
Development of **VNIIEF**

Within **20** months there occurred no failures through SCTS

*crw-daq.ru*

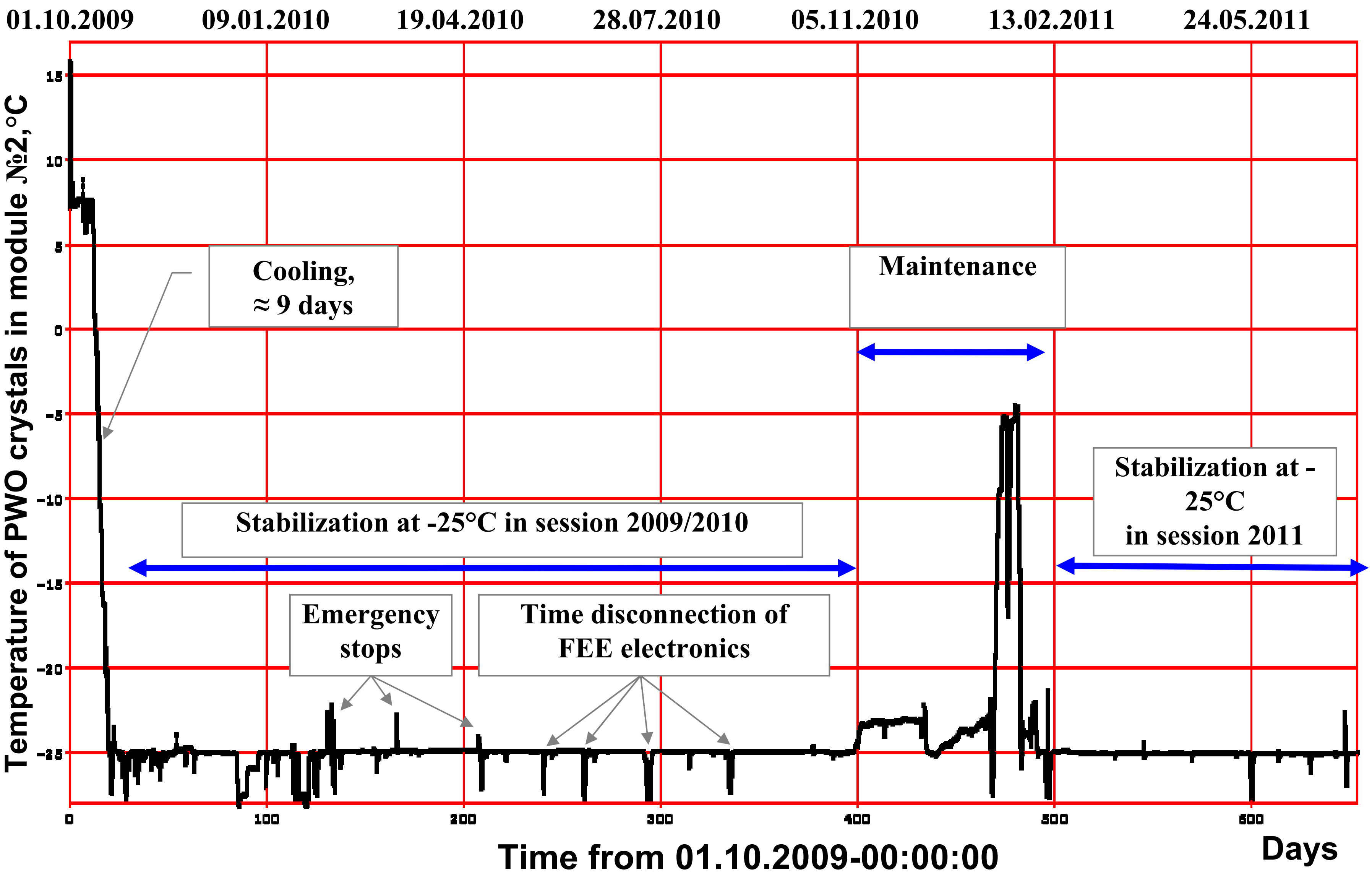
# Algorithm of temperature stabilization



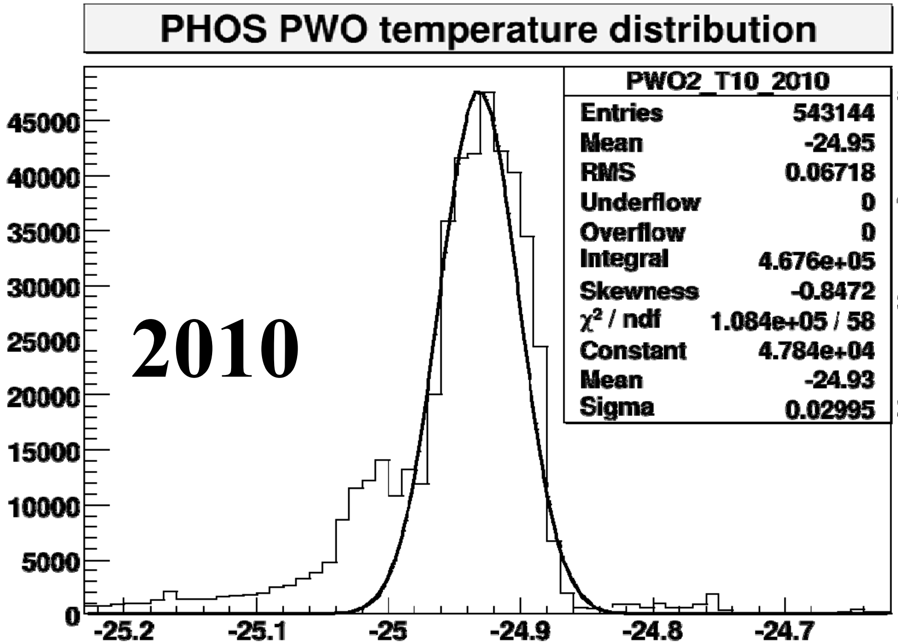



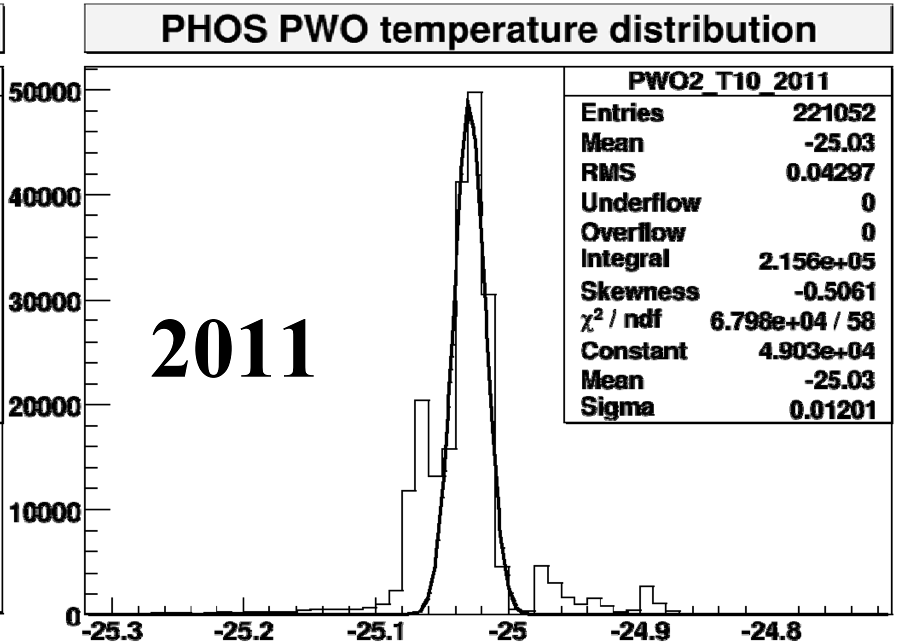

**The principle of temperature stabilization consists in periodic compressor switch-on and switch-off on a feedback signal from sensor $T_1$ measuring the temperature of heat carrier going to the detector cooled modules. The system has got 6 setup variables: task temperature of heat carrier stabilization $T_{stab}$, temperature gap of $\Delta T$ regulation, minimal $N_{min}$ and maximal $N_{max}$ number of working compressors, temperature of TRV overheat $T_{overheat}$ and pressure $P_1$ of freon in a discharge header. The algorithm works the following way. When temperature $T_1$ of the monitoring sensor is higher than the threshold value $T_{on}=T_{stab}+\Delta T$, then, there initiates $N_{max}$ of compressors and heat carrier cooling begins. At the decrease of $T_1$ lower than $T_{off}=T_{stab}-\Delta T$ threshold there works $N_{min}$ of compressors and heat carrier becomes warmer. As a result there occurs a stable dynamic cycle of regulation which period depends on the $\Delta T$ .**

# Expanded diagram of matrix **PWO** №2 temperature in 2009-2011



# Histograms of **PWO** temperature distribution in sessions on **LHC** in **2009/2010** and **2011**



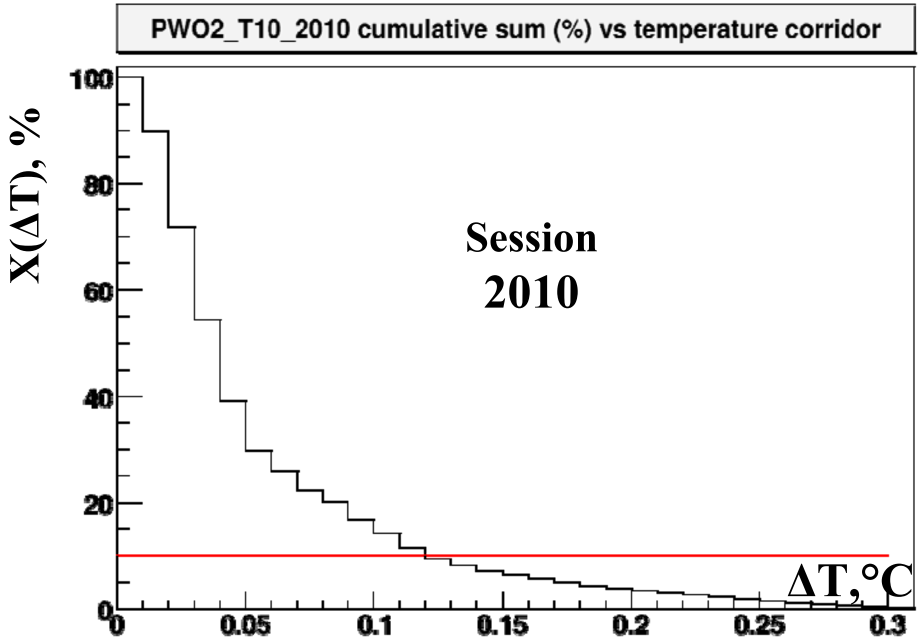

**The histograms of PWO crystals temperature distribution of module №2 in session 2009/2010 (left) and session 2011 (right)**

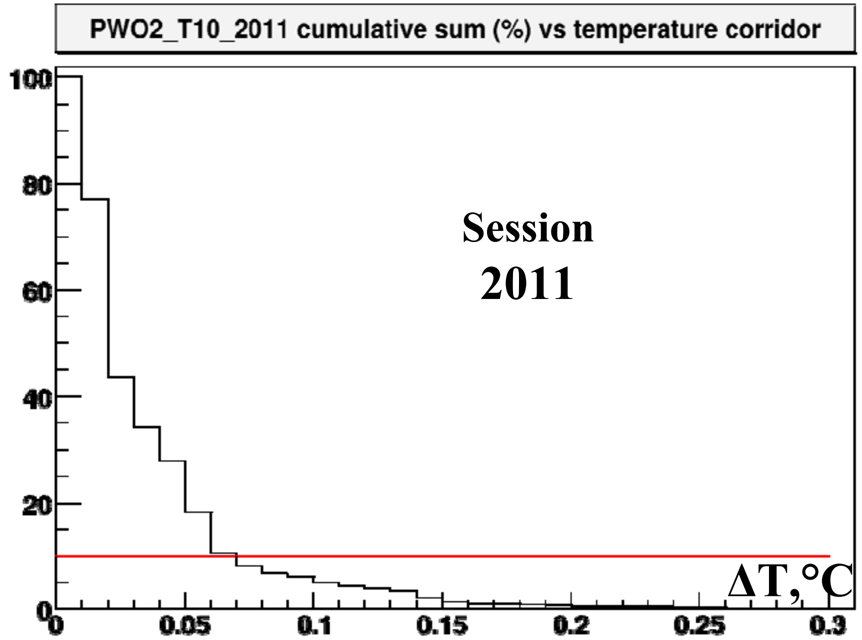
**The count in each channel of histogram is equal to the time in minutes during which the value of temperature was within the range corresponding to this channel**

**Session 2009/2010: -24.95 ± 0.07 °C**

**Session 2011: -25.03 ± 0.04 °C**

# Relative operating time X(ΔT) depending on temperature range ΔT (module №2)



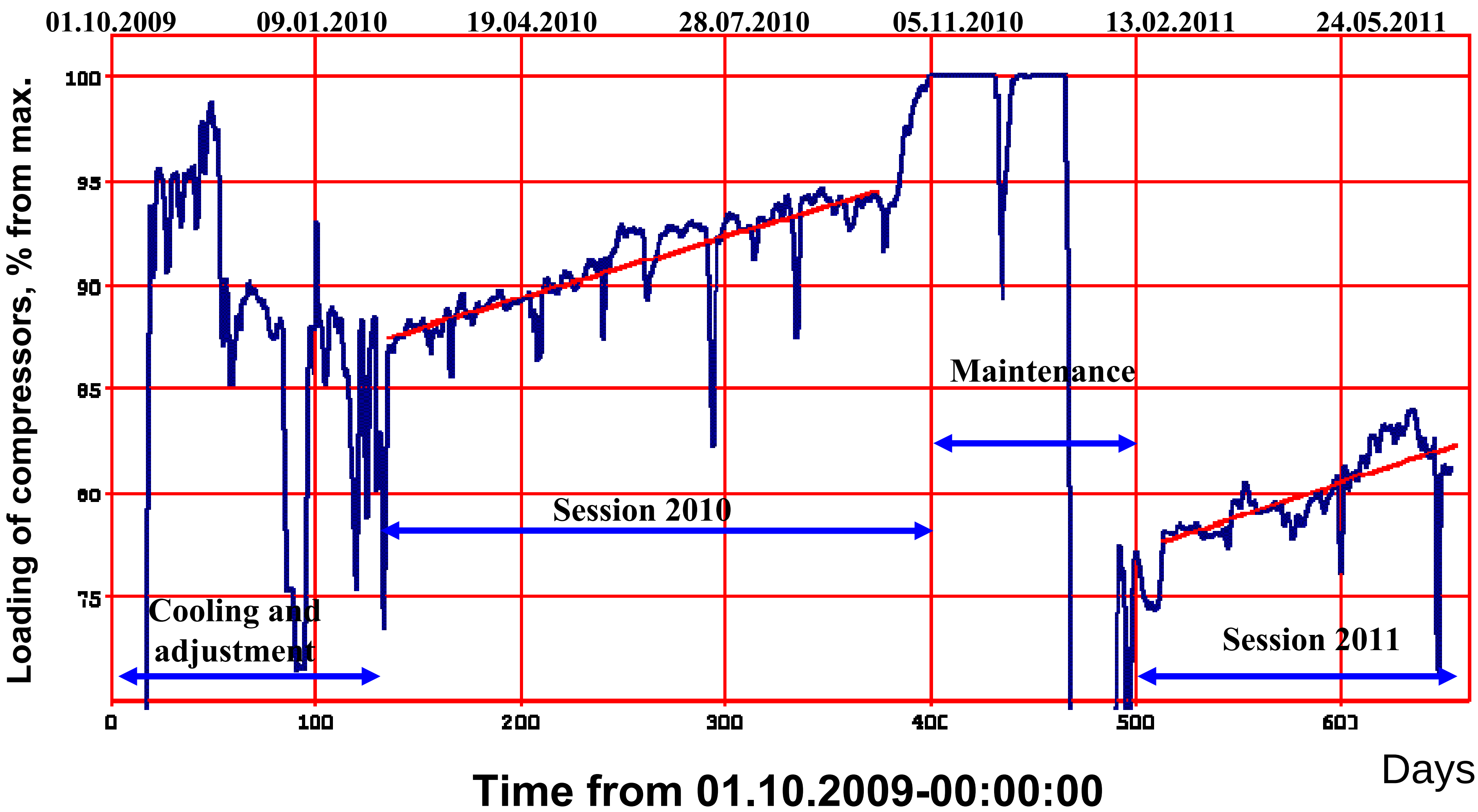

*X(ΔT)* demonstrates time fraction in percent of the total time within which the temperature was beyond the $T_{mean}$±ΔT interval, while the *100-X(ΔT)* value – the fraction of time in per cent during which the temperature was within the $T_{mean}$±ΔT interval.

It is evident from the diagrams that during more than 90% of operating time the PWO crystals in module №2 had the temperature which was not beyond the range

-24.95 ± 0.12°C in session 2009/2011 and

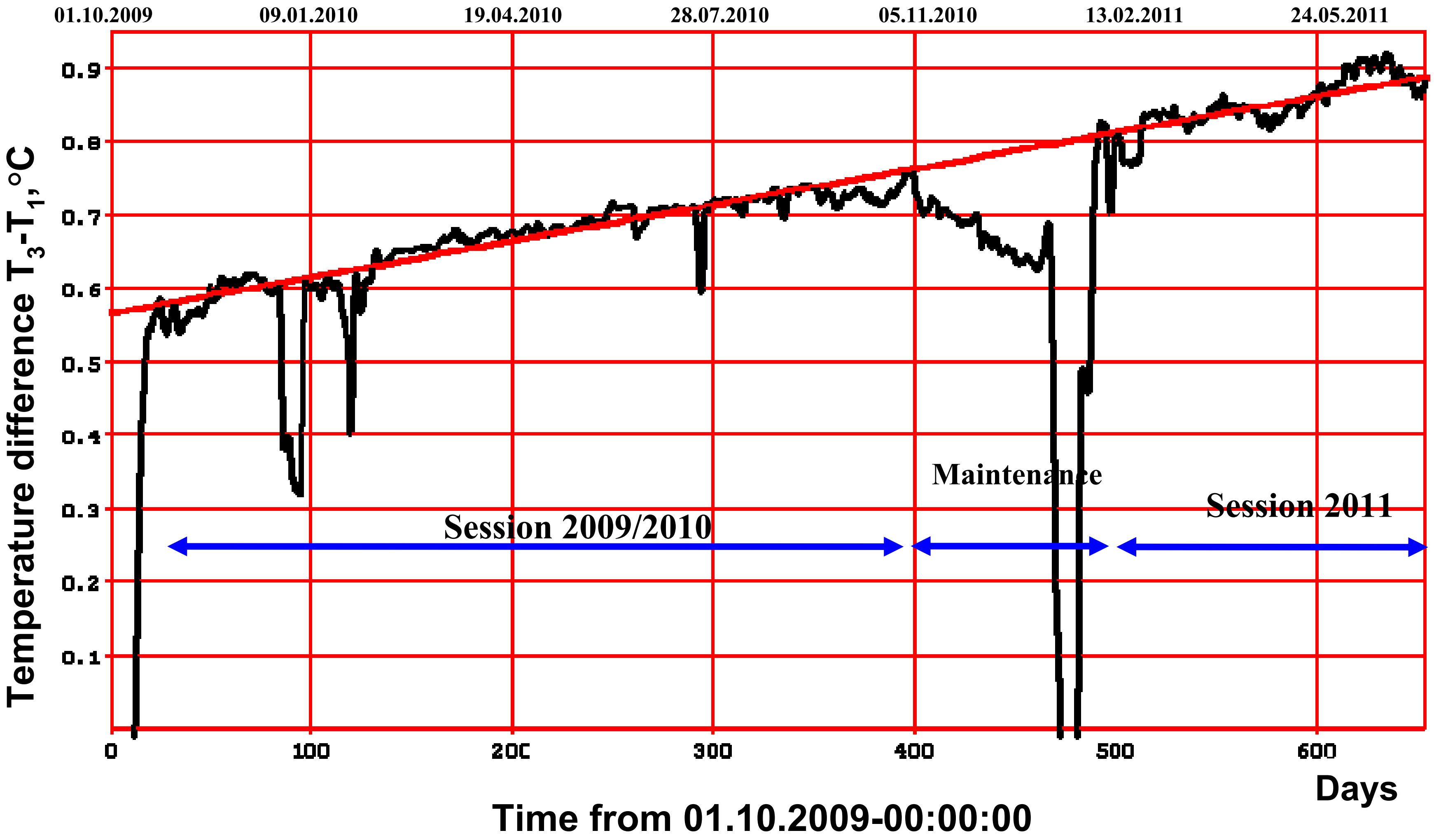
-25.03 ± 0.07°C in session 2011.

# Diagram of average compressors loading during twenty-four hours, in per cent % from the maximal loading




**Loading grew with coefficient ≈ 11 % per year.**

# Diagram of temperature difference $dT=T_3-T_1$ at the input and output of the cooled module




**The difference grew with the coefficient ≈ 0.18°C per year.**

# Conclusions

The assigned task is **accomplished:**

1. **No-failure operation > 20 months**
2. **Session 2009/2010:-24.95 ± 0.07 °C**
3. **Session 2011: -25.03 ± 0.04 °C**

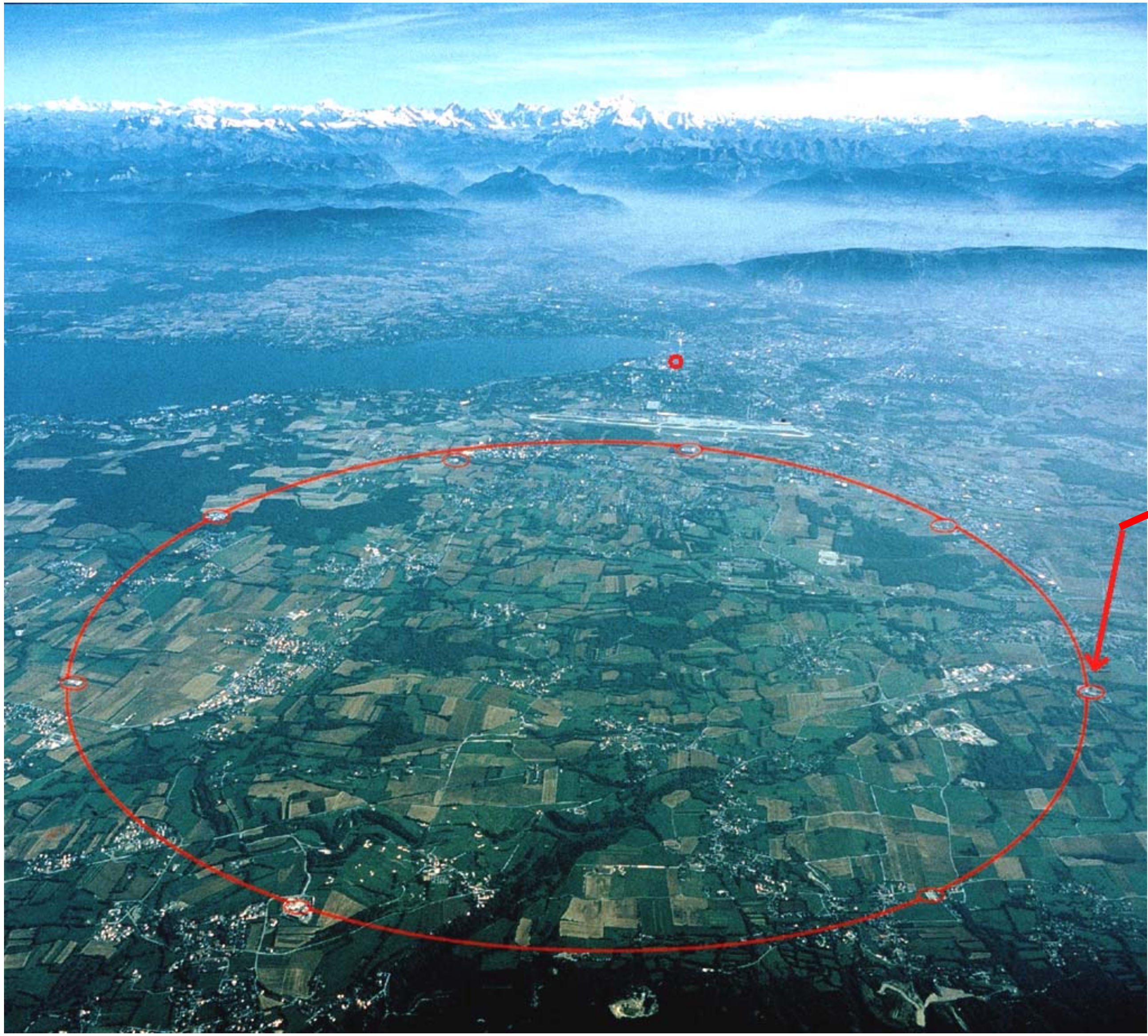
**Discovered features:**

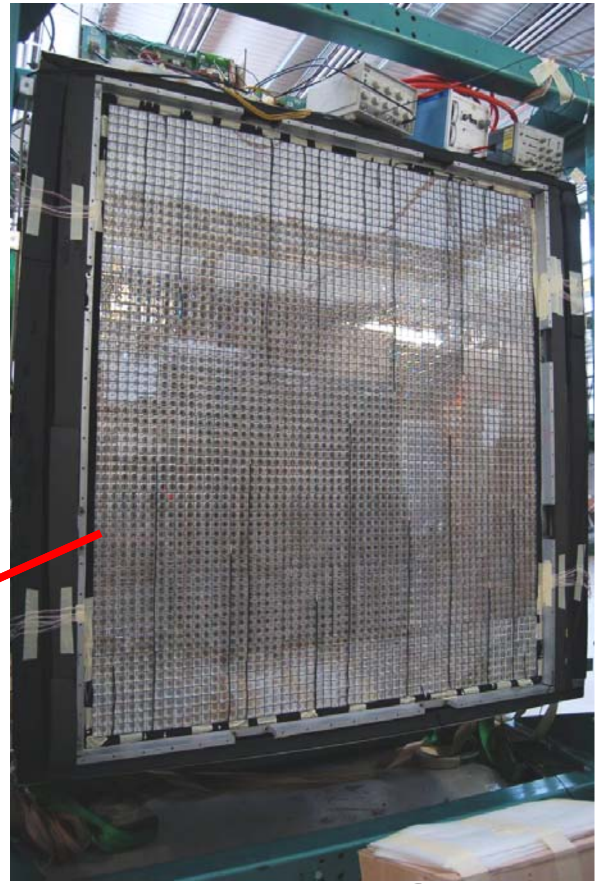
1. **Growth of average loading of compressors - by 11% per year**
2. **Growth of temperature difference at the input and output – by 0.18°C per year**

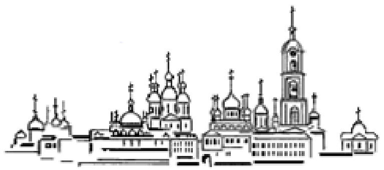
**Possible explanation – heat insulation drench because of atmospheric moisture condensation.**

**→ Periodic replacement of heat insulation is required.**

# Thank you for your attention







Russia

Sarov