CRYOGENICS OPERATIONS 2008

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Continuous Operation of Liquefied Noble Gas Calorimeters at CERN

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on behalf of the NA62 and ATLAS collaborations

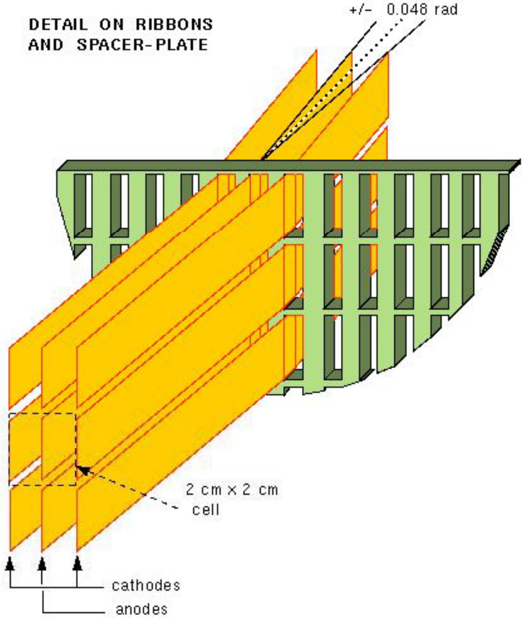
Why Calorimetry at CERN?

The Liquefied noble gas calorimeters at CERN are used to measure the energy of particles created when a beam hits a fixed target, or created during the interaction between two particles in two crossing beams.

Principle: incoming particle is ionising atoms of the liquid present in the calorimeter. The number of electrons created depends on the energy of the incoming particle. The calorimeter is divided in a large number of high voltage cells. Electrons generated in the calorimeter are accelerated by the electric field and create an electrical current.

To have a liquefied noble gas calorimeter of high performance:

- stable temperature (sensitivity: 2%/K) and small gradients (ATLAS < 0.3 K)
- high purity liquid (no electro negative products)
- HV cells should be as small as possible to have a good space resolution
- no bubble formation (HV breakdown)
- stochastical processes, very long operation time
- heavy (dense) liquids, eventual safety risks



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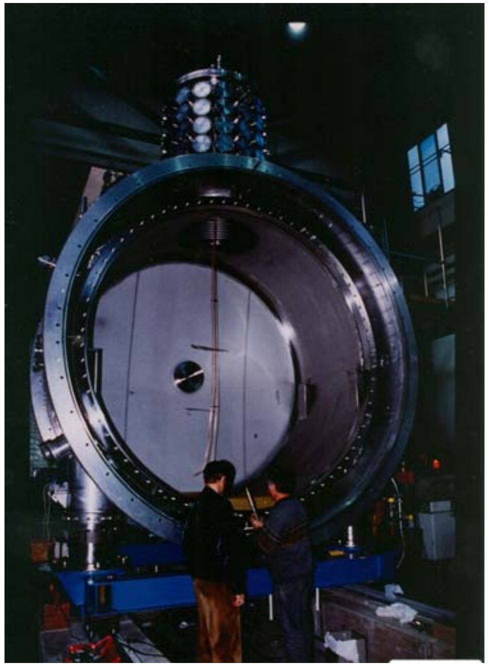
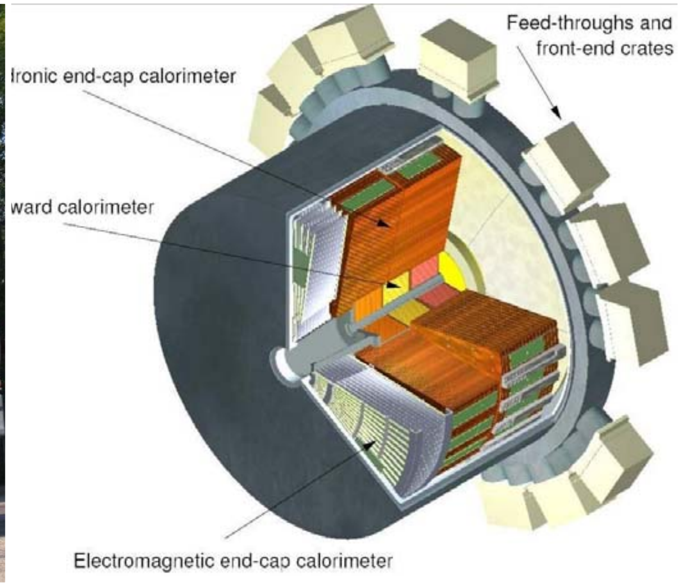
NA62 liquid krypton calorimeter

- a 9000 litre liquid krypton calorimeter;
- an open detector structure, natural convection prevents significant stratification in the krypton;
- re-liquefaction of evaporating krypton is made outside of the calorimeter, providing purification of the gaseous krypton on-line;
- total of 10000 litre of krypton stored in system (price 1993: 460$/liter), storage only possible in liquid phase;
- signal and high voltage cables enter the calorimeter via the gas phase
- system in operation since 1996, warmed up once (1997), since then in continuous operation.



ATLAS liquid argon calorimeter

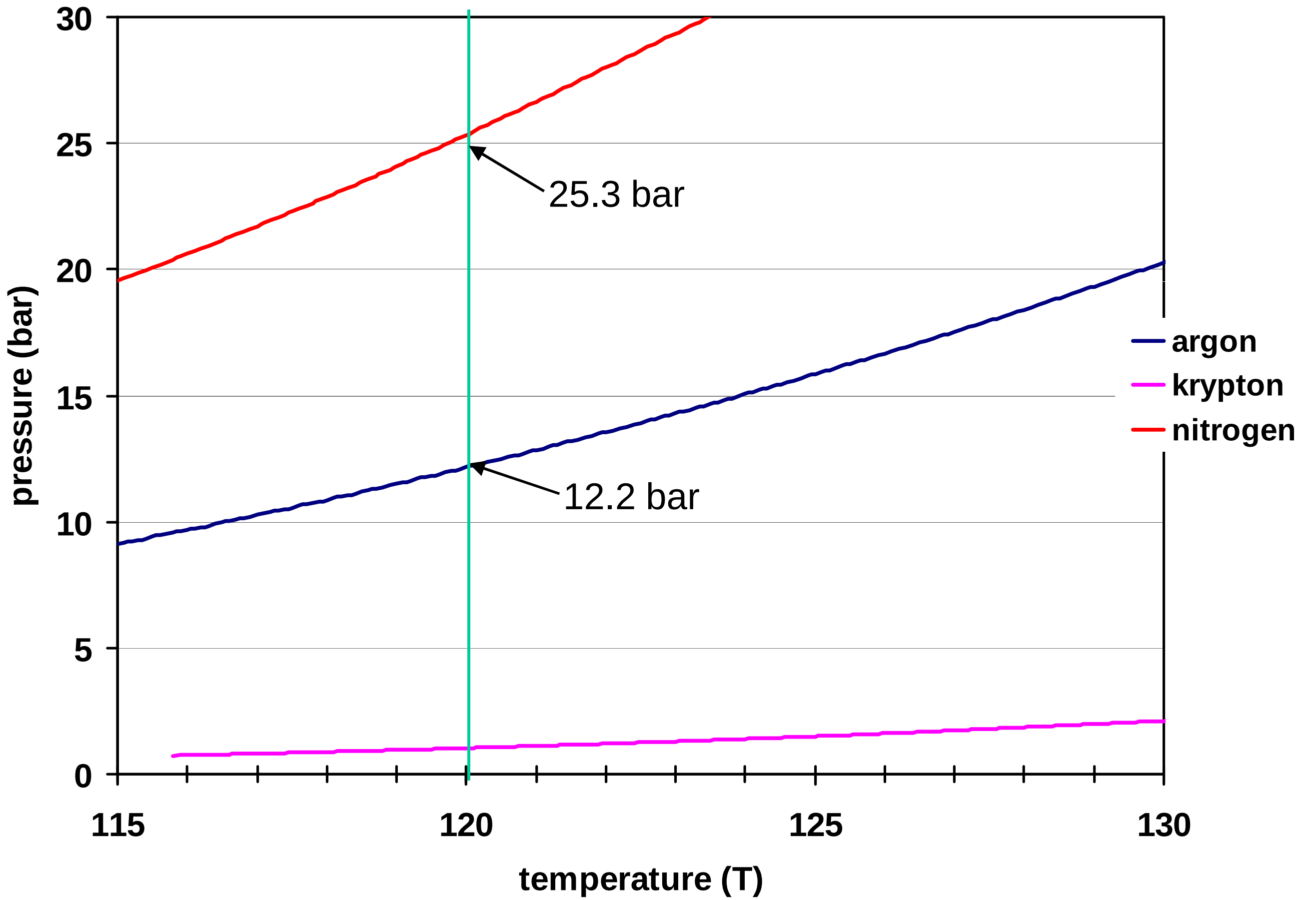
- a 78 m3 liquid argon calorimeter housed in three independent cryostats (two end-caps and one barrel);
- a closed detector structure, so no natural convection, heat exchangers have to be placed close to the active detector volume (mass calorimeter: 548 t)
- no possibility for an on-line purification process
- total of 100 m3 of high purity argon present in system (price 2005: 1 CHF/litre);
- signal and high voltage cables enter the calorimeter via the liquid phase (256000 signal wires)
- complete system operational since 2007
- ATLAS lifetime (continuous operation: about 15 year)



How to cool the NA62 calorimeter

The pressure above the liquid krypton bath is regulated at 1.15 bar (Tsat = 121.5 K). Triple point krypton 115.8 K.

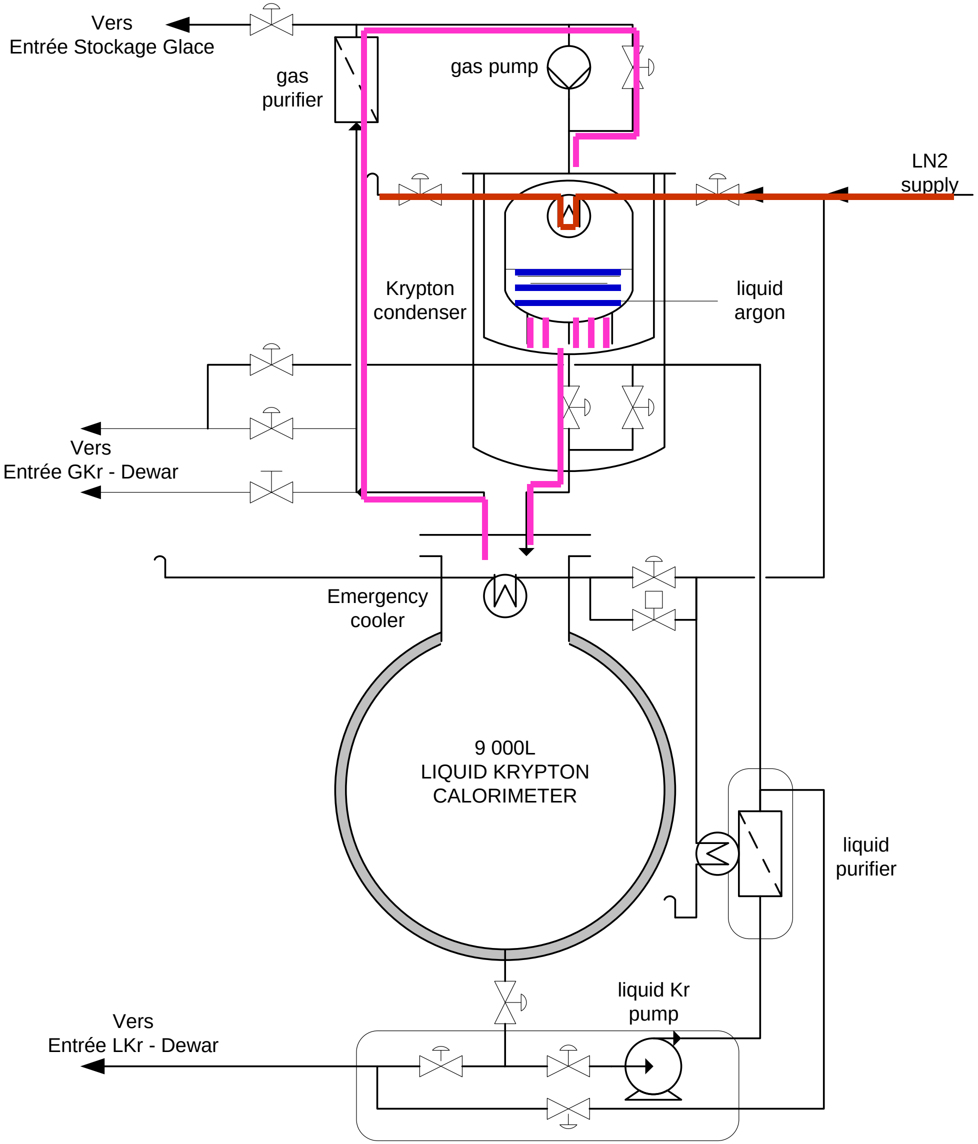
Which cooling liquids could be used for this calorimeter? (no dependence from "machinery")



How to cool the NA62 calorimeter

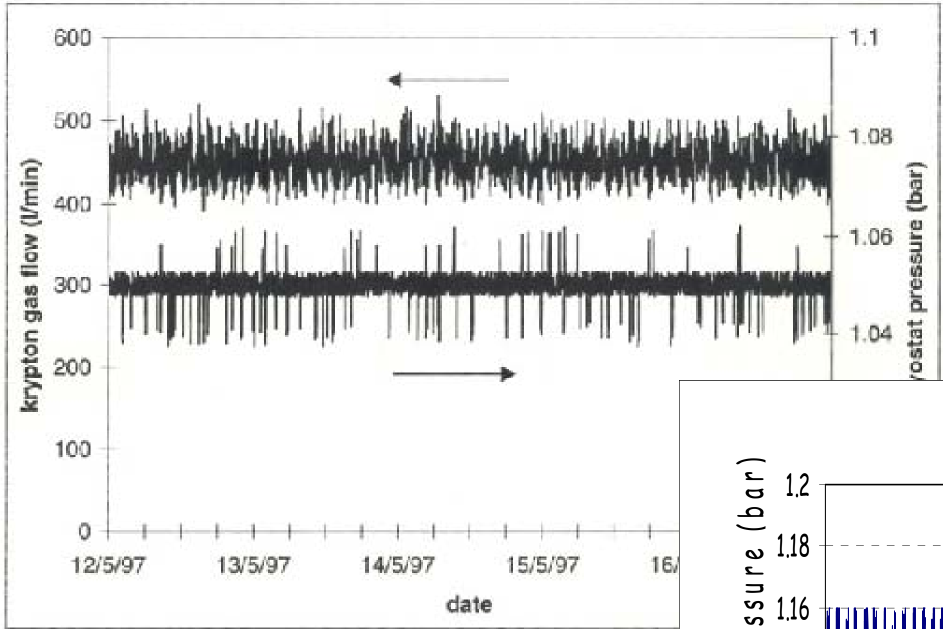
Solution: an intermediate "argon cooler":

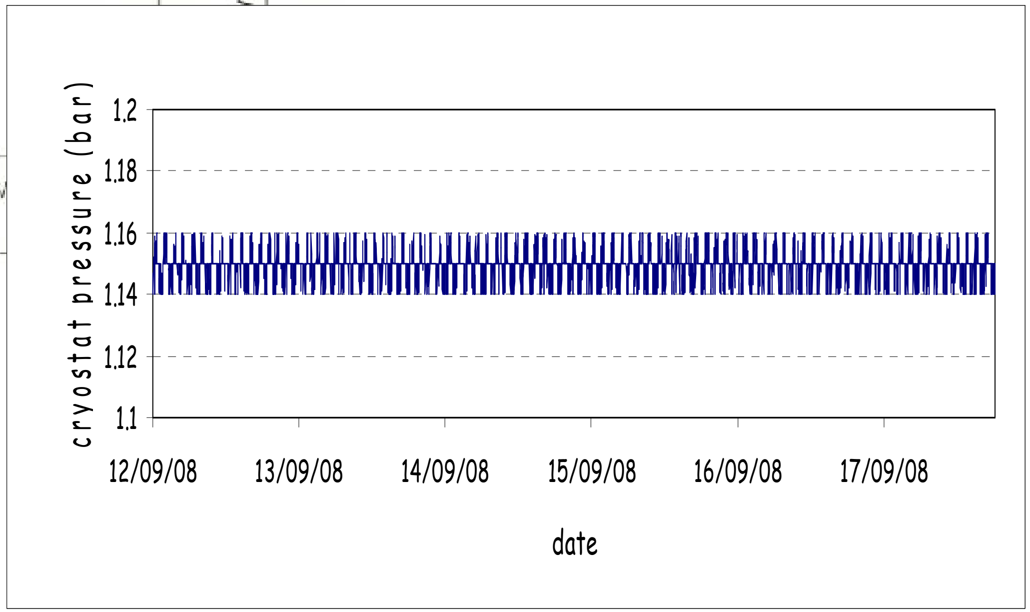
- an argon bath is kept at about 12.2 bar, by passing a saturated liquid nitrogen flow through a heat exchanger placed in the gas phase above the bath (argon triple point: 83.8 K);
- gaseous krypton condenses on the outside surface of the argon bath, and leaves the argon cooler in liquid phase at a temperature of about 120 K.



Final result NA62 cooling

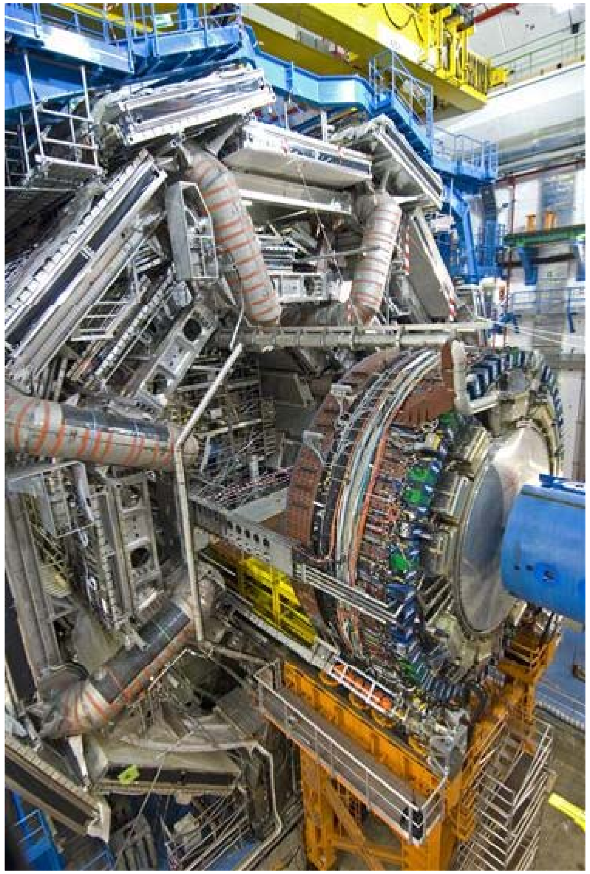
The pressure in the krypton bath is stabilized within ±10 mbar for periods up to several years

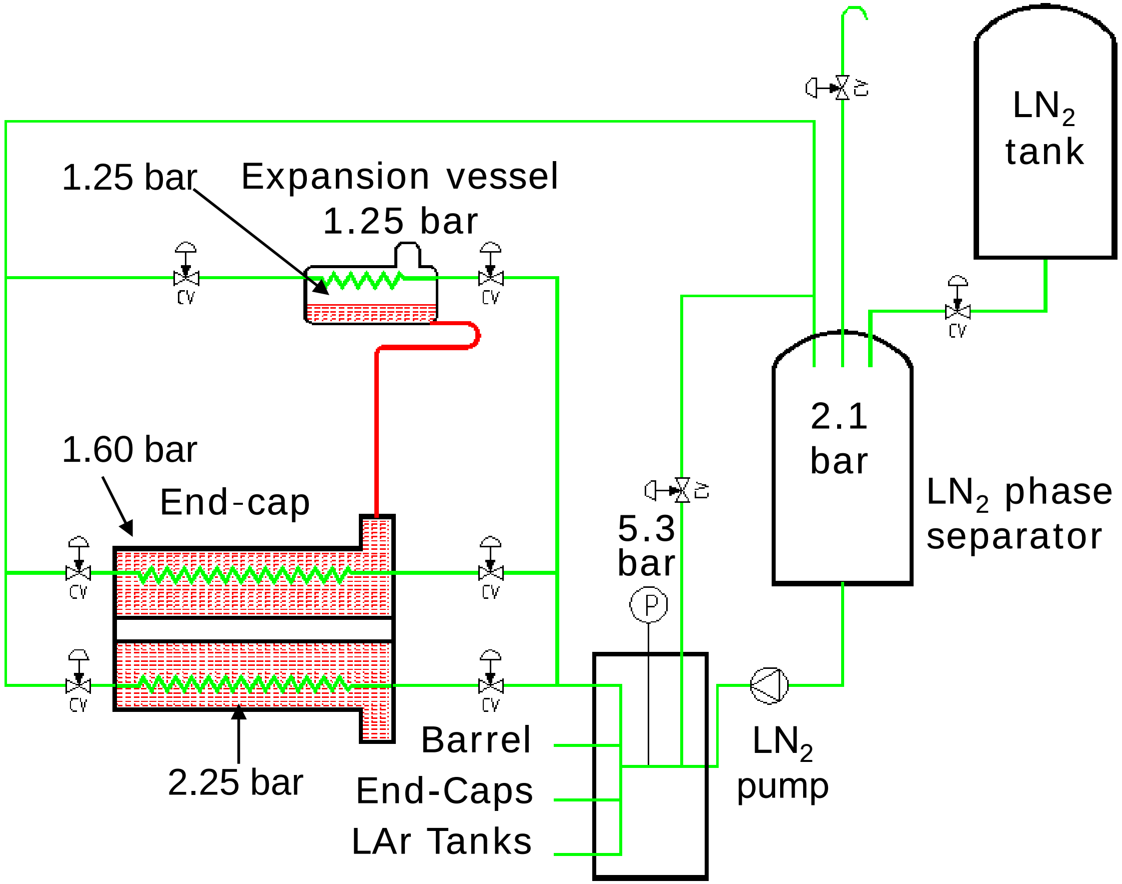




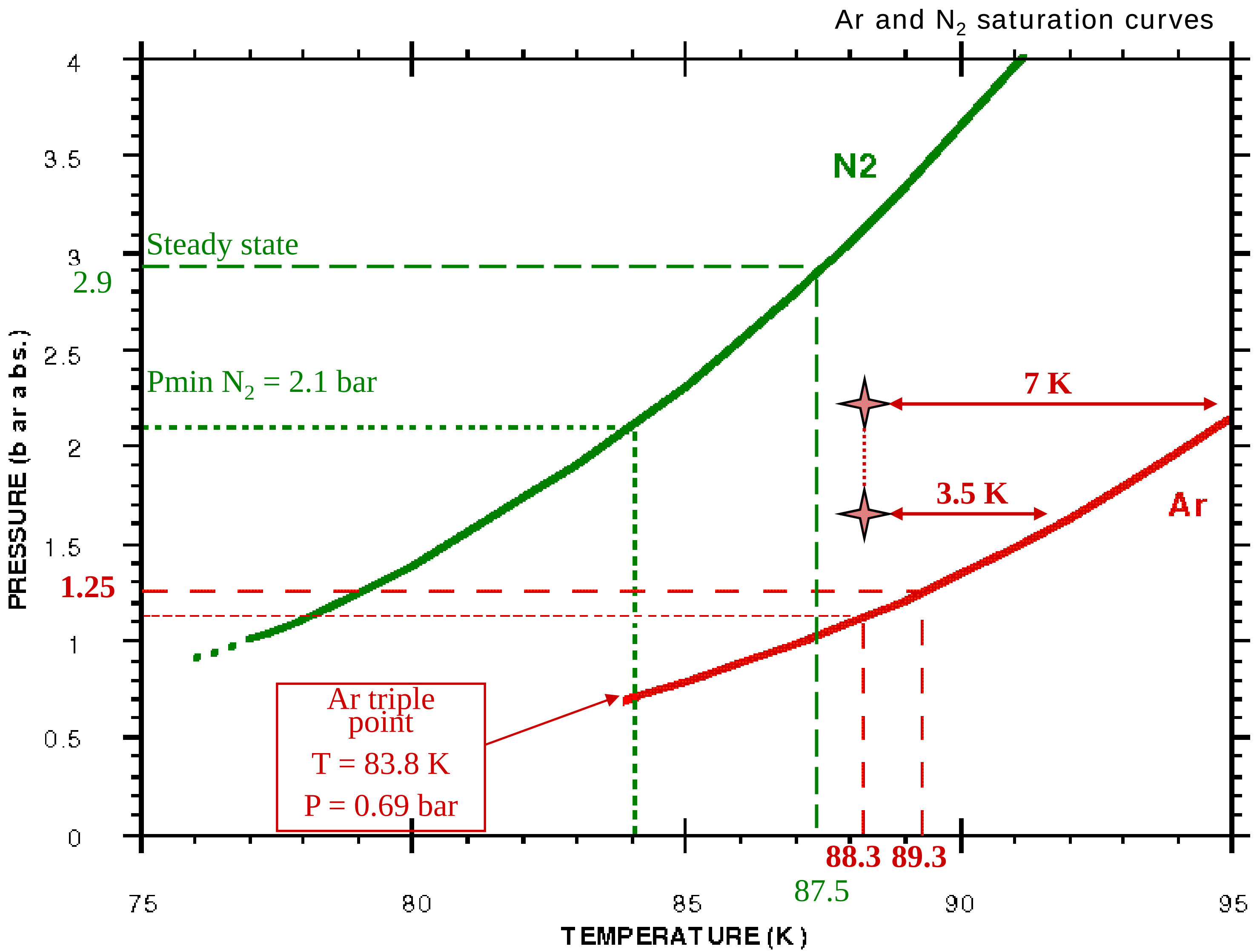
How to cool the ATLAS calorimeter?

The argon gas pressure in the expansion vessel is regulated at 1.25 bar (Tsat 89,3K), while the temperature in the liquid argon bath is regulated to 88.3 K. This creates a subcooling of the argon bath between 3,5 K and 7 K depending on the hydrostatic pressure in the argon bath.





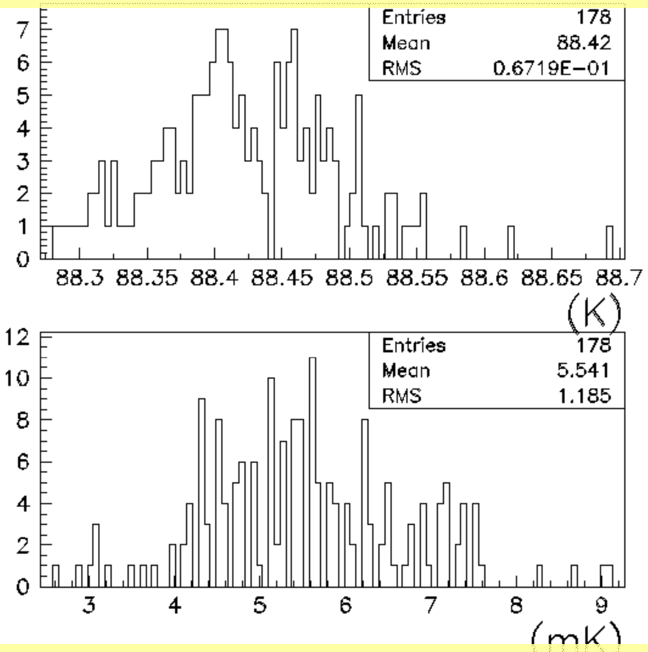
How to cool the ATLAS calorimeter?



ATLAS stable state conditions

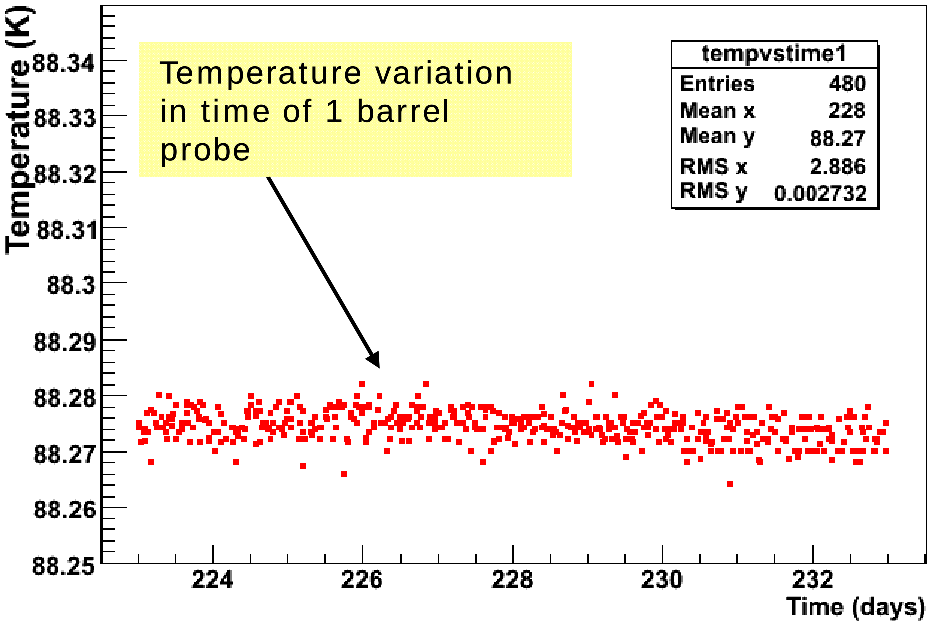
The barrel cryostat is now in a stable situation for over two years:

Statistical occurrence of barrel mean T



Stability measurements in barrel over 24 h

Probe #85 (Barrel)



Impurity level of argon: < 0.02 ppm oxygen equivalent

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How to prepare for long term continuous operation

Valid for the ATLAS and for the NA62 installation:

1. The simplest cooling principle possible has been implemented (evaporation of liquid nitrogen supplied by storage tanks and for ATLAS also by a refrigerator. System operation based on simple pressurization and/or gravity process)
2. Systems have very reliable power supplies, with the lowest consumption possible (EDF / EOS / Diesel system1 / Diesel system 2 / UPS)
3. Systems have back up compressed air supply
4. Systems have back up cooling water supply
5. Systems have redundant or “prepared” PLC’s
6. Systems have a very reliable alarm system
7. Once stable, no more changes are made to the system!!

Foreseeable problems:

1. Regulation of system is anyway changed!!!!
2. Upgrade of PLC software
3. Interference coming from the environment

How to prepare for long term continuous operation

Results NA62:

1. NA62 started running in 1996:
2. Since then only two “experts” involved in the operation of the system (24h/24h, 365d/year)
3. One major power cut lasting 9 hours. The UPS system has supplied power over this complete time interval
4. No krypton has been lost
5. No data taking time has been lost because of cryogenic problems
6. Control system has been upgraded this year (new PLCs, new power distribution, new program etc.), while cryostat was kept operational
7. Operation is now taken over by a section in charge of operating several cryogenic plants

How to prepare for long term continuous operation

Results ATLAS :

1. Cryogenic system is now running for over two years in experimental area;
2. No more direct access to cryostats
3. System survived severe power problems (no electrical network, no diesel network, depending on UPS) without any interference;
4. No argon has been lost
5. Minimum monitoring time is needed from operation section.