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LHCb RICH Gas System Proposal

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Abstract

Both LHCb RICH will be operated with fluorocarbon as gas radiator. RICH 1 will be filled with $4m^3$ of C_4F_{10} and RICH 2 with $100m^3$ of CF_4. The gas systems will run as a closed loop circulation and a gas recovery system within the closed loop is planned for RICH 1, where the recovery of the CF_4 will only be realised during filling and emptying of the detector. Inline gas purification is foreseen for the gas systems in order to limit water and oxygen impurities.

1 Introduction

The RICH system has the task of identifying charged particles over the momentum range 1-150 GeV/c, within an angular acceptance of 10-300mrad. Particle identification is crucial to reduce background in selected final states and to provide an efficient kaon tag. To achieve this goal, the system consists of an upstream detector (RICH 1) with aerogel and a gas radiator and a downstream detector (RICH 2) with a gas radiator only. The RICH 1 radiator with its volume of 4 m^3 will use C_4F_{10}. RICH 2 will be filled with 100m^3 of CF_4 [1]. Both radiators remain gaseous at normal temperature and pressure.
The oxygen and water content of the Cherenkov gas are not critical parameters, but should not exceed 100-200 ppm.
Residual nitrogen has an effect on the refraction index and should therefore be kept constant and below 1%.
The gases are circulated in a close loop with an expected flow rate of 10% of the total gas volume. CF_4 and C_4F_{10} are expensive gases, which makes a recovery system indispensable.
The main parameters for the RICH gas system design are listed in *Table 1*.

		RICH 1	**RICH 2**
Gas		*C_4F_{10}*	*CF_4*
Volume		*4 m^3*	*100 m^3*
Flow rate		*0.4 m^3/h*	*10 m^3/h*
O2 impurity		*~100-200ppm*	
H2O impurity		*~100-200ppm*	
N2 impurity		*≤ 1%*	
Relative pressure stability	at running	*< 0.5 mbar*	
	filling / emptying	*± 1-2 mbar*	
Gas price **(as today)**		*930 CHF/m^3*	*305 CHF/m^3*
Melting point (1bara)		*-128.2°C*	*-183.6°C*
Boiling point (1bara)		*-1.9°C*	*-128°C*

Table 1: Basic parameters for the two RICH gas systems.

2 Gas Circulation

The circulation loop for the RICH 1 and -2 detector is distributed over three different areas:

- the SGX building contains the primary gas supply, the purifier, the gas analyser , the compressor (RICH 1) and the separation plant
- the accessible service area behind the radiation wall in the UX cavern accommodates the flow regulation, the compressor (RICH 2) and the emergency back-up system
- the experimental area houses the detector with the remotely read pressure sensors

2.1 RICH 1 gas system

The RICH 1 gas will be circulated in a closed loop with an inline liquefaction of the return gas to separate volatile impurities (*Figure 1*).
To reduce water impurities, inline gas purification with a molecular sieve will be implemented. The purifier will be placed in the gas building at the surface before the gas will be transferred to the underground cavern. A gas analysis is performed before and after the gas purification.
A pump in the return line allows the gas to be compressed before entering the separation plant. Behind the compressor the C_4F_{10} will be liquid and for this reason the compressor has to be placed in the SGX building at the surface. To stabilise the pressure in the RICH detector, the pump will be driven by a frequency regulator controlled by a pressure sensor on the detector.

2.2 RICH 2 gas system

As for the RICH 1 detector the RICH 2 gas system will be circulated in a closed loop, but with a separation plant in parallel only used during filling and emptying the detector (*Figure 2*). CF_4 recovery is in particular useful for filling and emptying of the large RICH 2 volume. During physics period the CF_4 gas system runs in a closed loop circulation without liquefaction using filters for water removal.
The RICH 2 consists of one gas volume with two gas inlets and two outlets, where one of each will be placed at the top, the other two at the bottom of the detector.
The gas from the distribution system will be pumped back to the surface and recycled through the purifiers. The pressure regulation can be performed either by a control valve in parallel with the compressor or by frequency controlled pump. A buffer volume in the RICH 2 gas circuit is needed in order to react on fast changes of the atmospheric pressure.

2.3 Filling and emptying of the RICH

Two gas inlets and two gas outlets, one of each at the bottom and on top of the detector, connect the distribution rack to the radiator, thus the high density freon gas can be filled from the bottom and the lower density nitrogen as purging gas from the top. Before the start up and during shutdown periods both RICH detectors will be filled with nitrogen gas. During the filling of the RICH 2 detector the fluorocarbons will replace the nitrogen and the return gas will be circulated through the separation plant. This gives the possibility to recover the fluorocarbon from the return gas and to vent only the nitrogen and oxygen. RICH 2 will be switched in a close loop system as soon as the impurities in the fluorocarbon are under the given level. The recovered CF_4 will be compressed and filled in a battery for later use.
To prepare the RICH for the shutdown periods, the fluorocarbons have to be replaced by the nitrogen. The gas system has to be switched from the closed gas circulation to the open system to allow the recovery of gases through the recovery plant. Again he fluorocarbons will be collected in the gas battery.

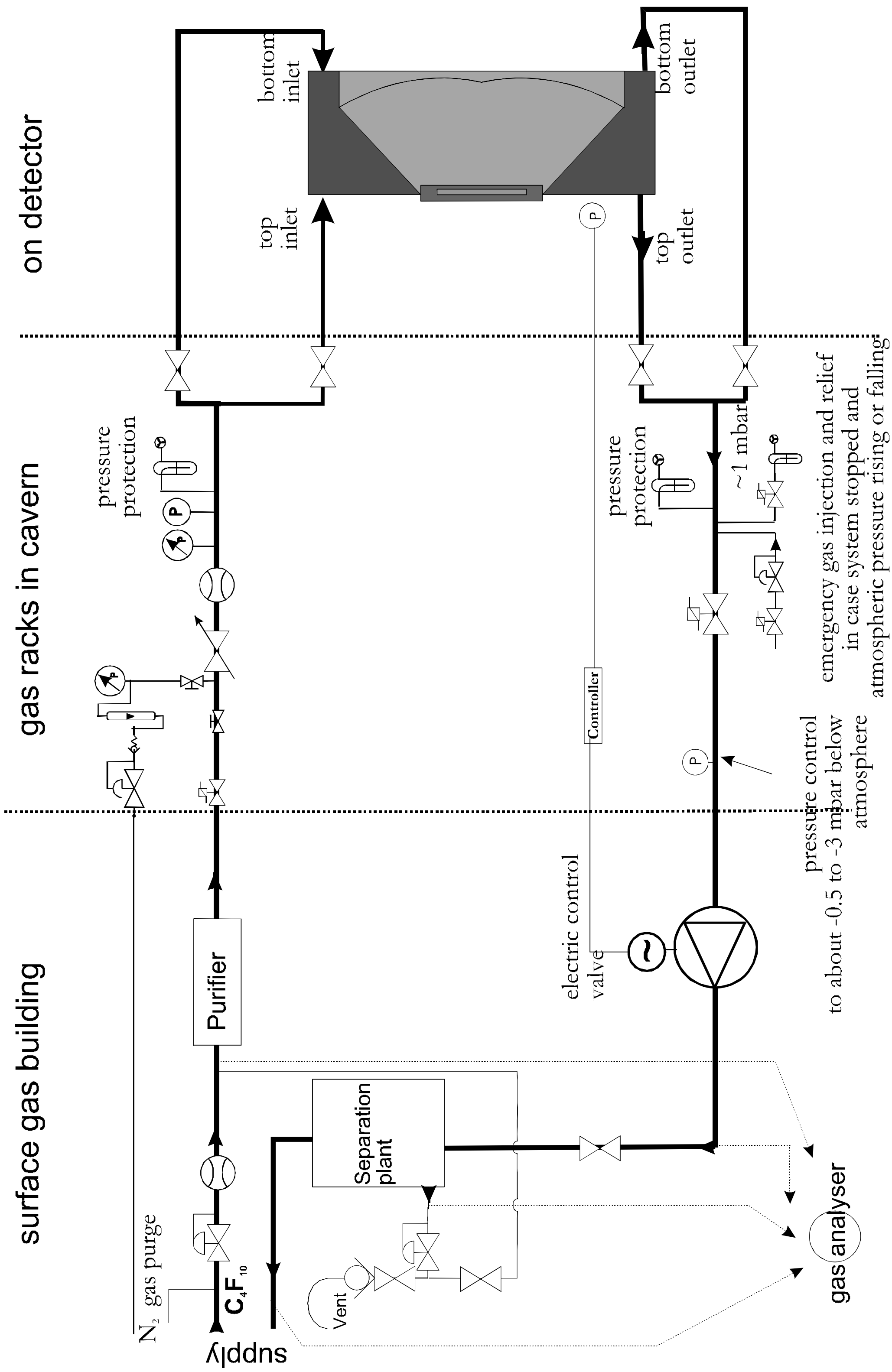

Figure 1: RICH 1 gas distribution system

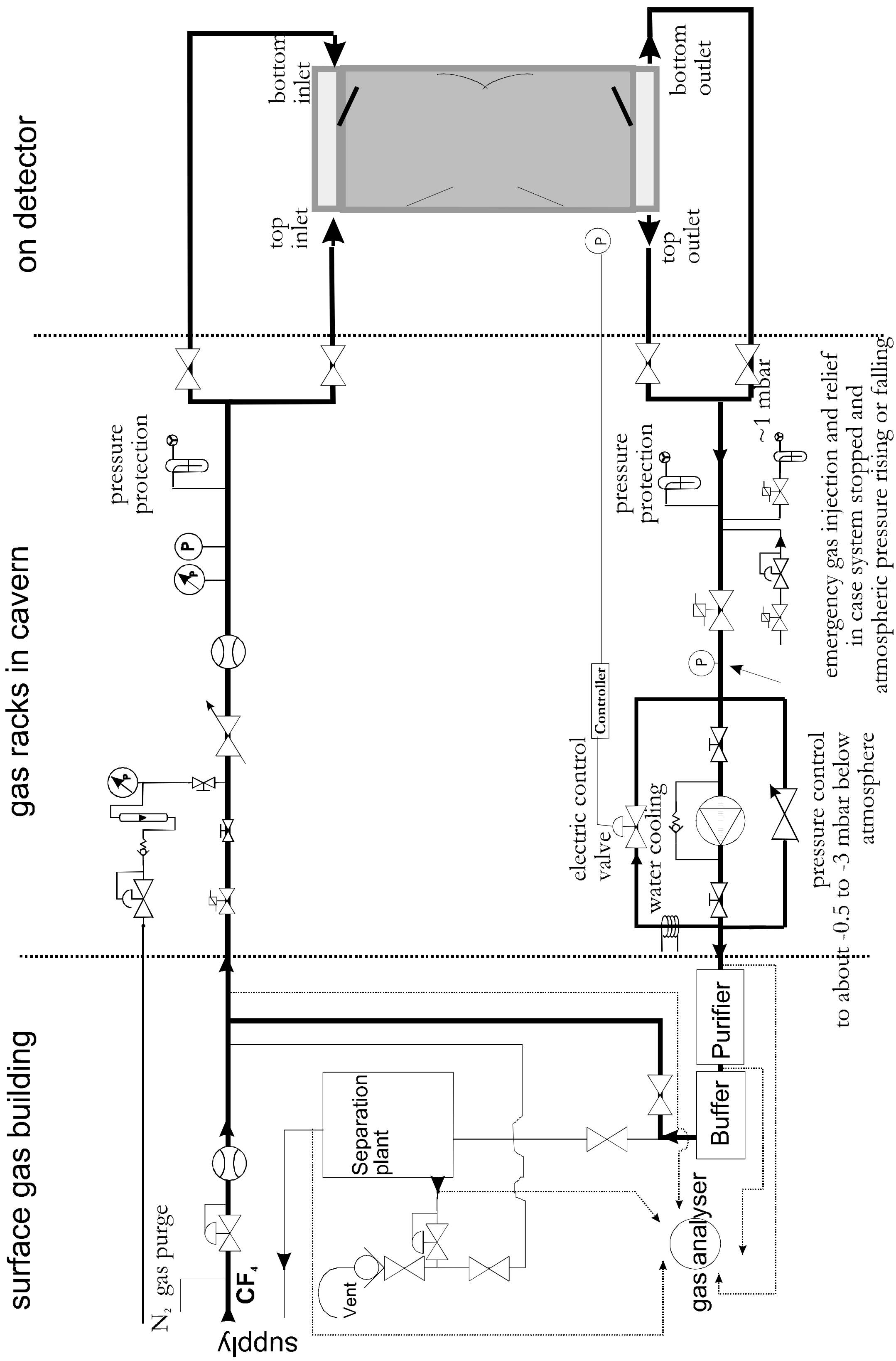

Figure 2: RICH 2 gas distribution system

3 Piping

The existing DELPHI supply and return pipes between the SGX building and the UX cavern will be reused by the LHCb experiment and hence for the two RICH systems. These pipes are all stainless steel with welded connections. For RICH 1 a 35mm heated input tube and a 22mm heated return line and for RICH 2 a 35mm input and return line are reserved.

The gas pipes from the hall entrance to the gas distribution racks behind the radiation shield and from the distribution racks to the detector have to be implemented.

4 Gas purification

Most close loop circulation systems need gas purification in the return line in order to reach high regeneration rates and low fresh gas flows. The principle impurities, which accumulate in recirculation systems, are sub-components from air introduced by leaks of the detector itself or in the gas circuit near the compressor where the pressure is very low.

The wave length acceptance window for the photon detector is from about 800 nm to about 200 nm. Oxygen and water does not have an appreciable absorption coefficient for wavelengths > 200 nm. See *figure 3* where the absorption coefficient is given in units of cm^{-1}. The mean path length for a Cherenkov photon in RICH 2 is about 10 m. It has been decided that the oxygen and water content in the Cherenkov gas should not exceed 100-200 ppm.

Water can easily be taken out to a level well below 0.1 ppm using molecular sieve. 13 Angstrom molecular sieves, together with activated carbon, have been used successfully in the DELPHI RICH fluid system to remove trace gases that absorb photons in the wave length window above 170 nm. Molecular sieves (3Å or 4Å (C_4F_{10}, CF_4) and 13X (C_4F_{10})) will be implemented in the RICH gas systems. Activated carbon will be added if it is needed Oxygen will be removed by the separation system.

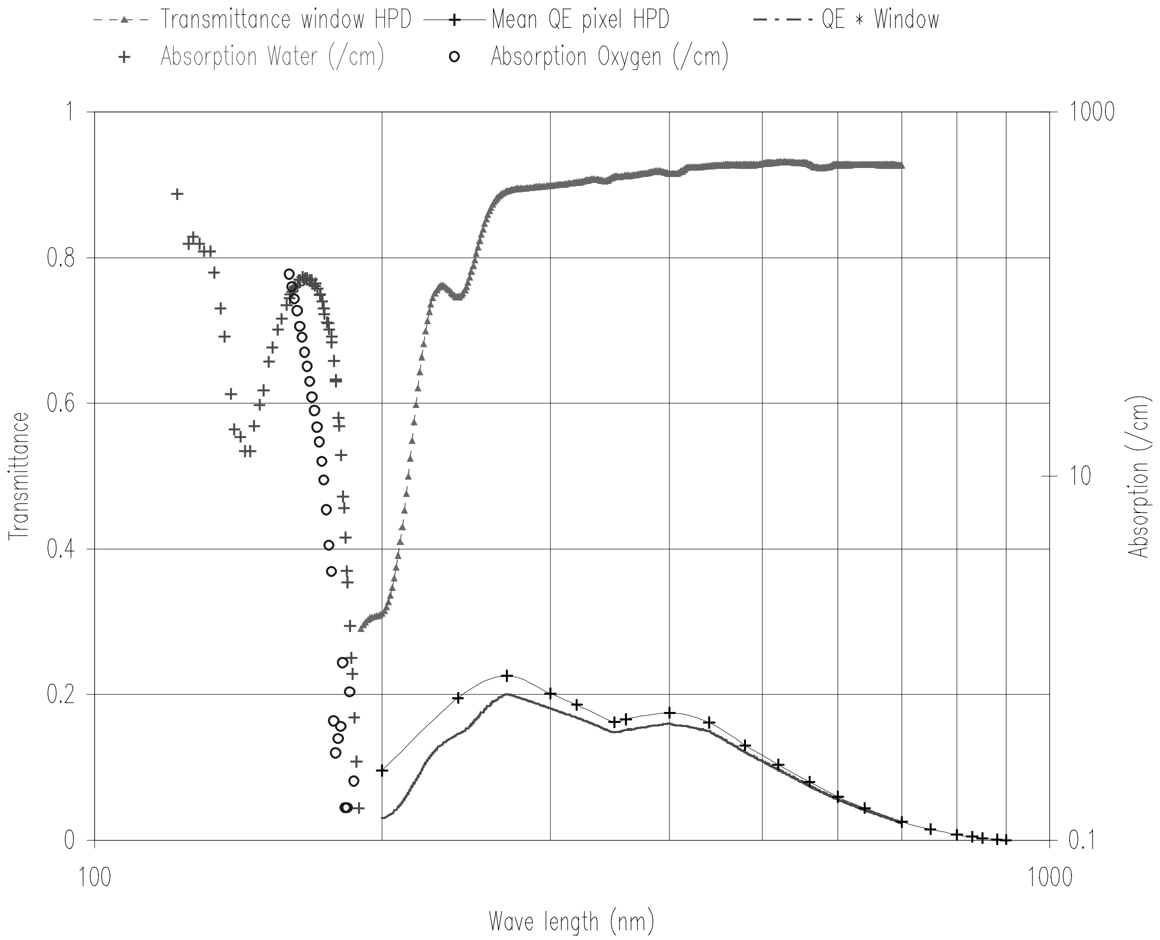

Figure 3: Transmission and absorption coefficient data for the LHCb RICH

5 Fluorocarbon recovery

To recover the fluorocarbons of the RICH 1 and RICH 2 detectors a recovery plant is recommended. In order to make the C_4F_{10} and CF_4 re-usable for the RICH systems, it must be separated mainly from the nitrogen contamination.

5.1 *Recovery plant for RICH 1*

The main task of the separation plant (*Figure 4*) is to liquefy the C_4F_{10} gas while the nitrogen and oxygen remains gaseous. This allows to collect the C_4F_{10} and to release the nitrogen and oxygen gas.

The C_4F_{10} will enter the separation system together with the nitrogen and oxygen impurities and will be pre-cooled while passing the return gas through two heat exchangers. In order to liquefy the C_4F_{10} completely it will be cold down to -50°. The pure C_4F_{10} will be collected and transferred to a reservoir, which serves as gas supply for the RICH 1 gas system.

The nitrogen and oxygen gas will leave the system through the exhaust.

5.2 Recovery plant for RICH 2

The boiling point of CF_4 is much lower than the one of C_4F_{10} and liquid nitrogen has to be used to liquefy the CF_4 efficiently. Before liquefying the fluorocarbon, the gas has to be filtered from water to avoid freezing of the separation plant.
Outside of the separation plant, the liquid CF_4 will be evaporated and compressed to 200 bars into a gas battery for later use, the oxygen and nitrogen will be vented through the exhaust line. The container that covers the recovery plant, will be kept at a pressure of 50 mbar to sustain good isolation of the system. (*Figure 5*)

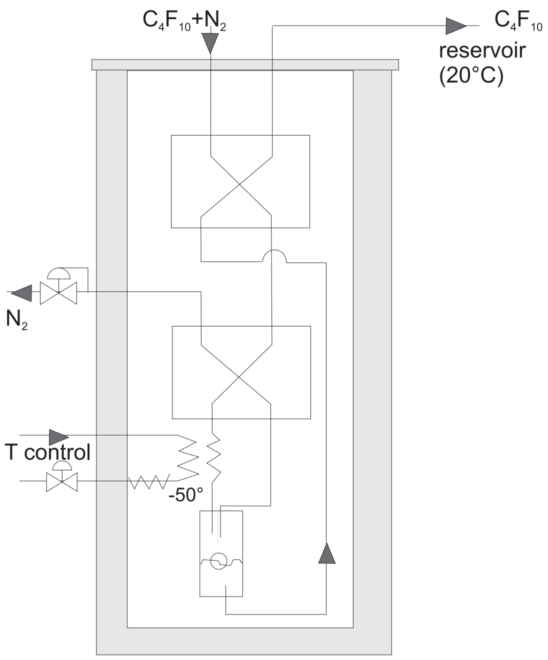

Figure 4: Separation plant for the RICH 1 detector, an isolated cold box

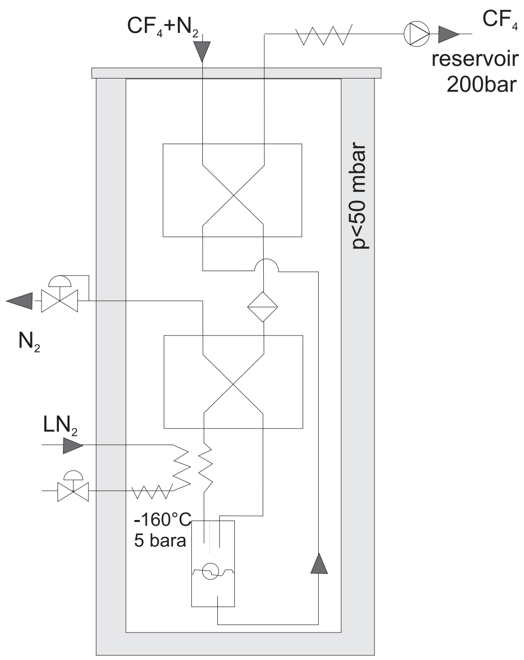

Figure 5: Separation plant for the RICH 2 detector, housed in a cryogenic vessel under vacuum.

6 Gas control

The gas control will follow the general recommendations of the Joint-Control-Project of the four LHC experiments (JCOP). In particular, the production of gas control systems will be prepared using the industrial software development standard PSS05. In the first step of this framework, a User Requirement Document is prepared at the moment, which captures as many details as possible. The hardware architecture of the gas control equipment favours Programmable Logic Controllers (PLC) as front-end computers. This allows secure, standalone solution which are independent of generally used computer networks. Signals from sensors and actuators will be transmitted via a fieldbus to the PLCs. On a higher level, users will be able to interact with the gas control system via a Graphical User Interface dedicated for gas. Also here, general recommendations for SCADA systems from JCOP will be followed. This will ensure and facilitate the integration of the gas control system into the general LHCb Detector Control System.

7 Reference

[1] LHCb Technical Proposal, The LHCb Collaboration, CERN/LHCC 98-4 (February 1998)