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The radiator gas and the gas system of COMPASS RICH-1

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Abstract

The design of the COMPASS RICH-1 gas system, its operational modes, the cleaning setups for the preparation of the radiator gas and transmission measurement installations are described. The gas system in presently fully operational and satisfactory transmission of VUV light through the radiator gas has been reached.

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Keywords: COMPASS; RICH; C_4F_{10} radiator gas; VUV light transmission

1. Introduction

RICH-1 [1], one of the major detectors of the COMPASS [2] spectrometer, is using 3 m of C_4F_{10}[3] as radiator and MWPC with CsI photocathodes as VUV photon detectors, with a total active surface of about 5.3 m^2. Thin (5 mm) fused silica plates (600 × 600 mm^2) separate the radiator gas vessel and the detector volume. Taking the quantum efficiency of the detector and the fused silica cut-off, the sensitive wavelength range of the system is between 160 and 200 nm, which makes it important to have a clean radiator gas, namely transparent in the VUV region. Two spherical mirror surfaces (20 m^2 total area, focal length 3.3 m) [3] provide focusing on the photon detectors, which are placed outside the spectrometer acceptance. The transparency of the radiator material, which influences directly the number of photons per ring observed, is measured online using a system equipped with a deuterium lamp and a solar-blind photomultiplier. We will further

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[3] 3M performance fluid PF-5040 by Minnesota Mining and Manufacturing Company, 3M Center, St. Paul, MN, USA.

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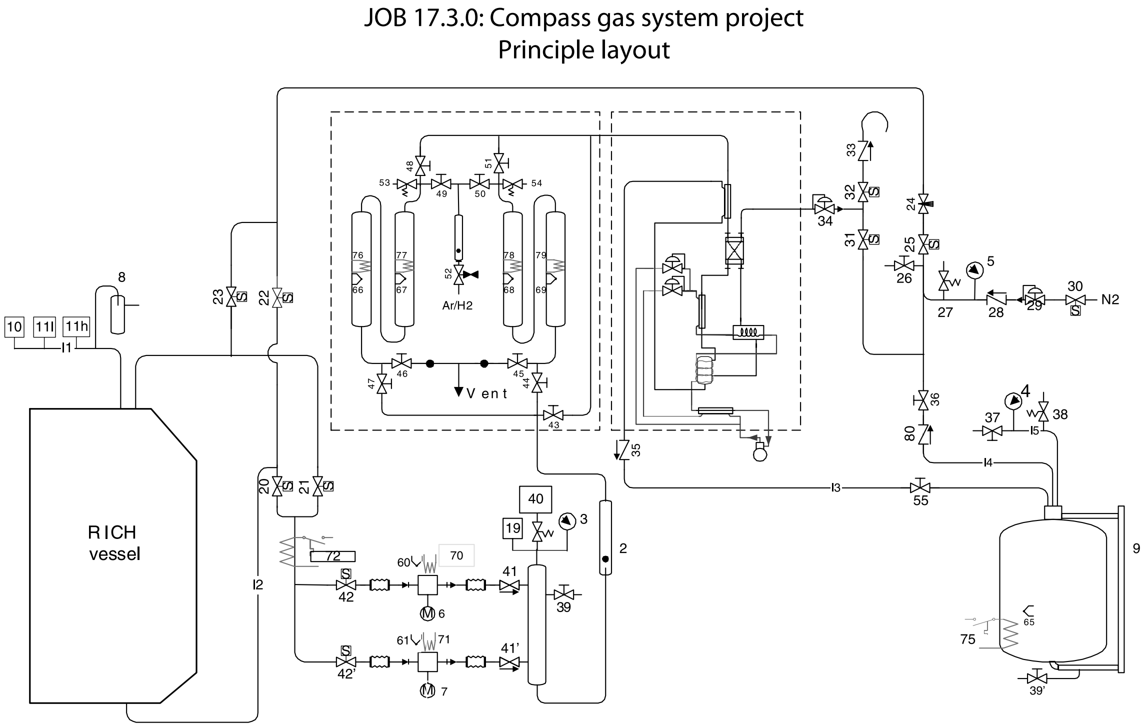

Fig. 1. Schematic diagram of the COMPASS RICH-1 gas system.

report about the gas system, its operational aspects and techniques of gas cleaning.

2. The gas system

The COMPASS RICH-1 gas system (Fig. 1) follows a basic design [4] already used for other RICH detectors (HERA-B [5], CAPRICE [6]). Its main task is to provide, during detector operation, well controlled pressure conditions, within small limits, in the RICH vessel ($\sim 80\ \mathrm{m}^3$) to purify the radiator gas from oxygen and water vapour contaminations and to perform the filling of the vessel and the C_4F_{10} recovery. Its main components are two oil-free compressors,[4] working in parallel, a pressure sensor installed on top of the radiator vessel, a pneumatic valve. The system is complemented by filtering cartridges and a cooling system for N_2 and C_4F_{10} separation. The relative pressure in the vessel is kept constant controlling the input flow by the pneumatic valve which is regulated according to the pressure sensor response. The compressors, aspiring the gas from the vessel, run at constant frequency. They are heated (typically at 50°C) to prevent C_4F_{10} condensation in this section of the gas system, where the pressure can reach 500 kPa. The control of the system is performed via a Programmable Logic Control (PLC).

The choice to regulate the pressure of the gas radiator vessel relatively to the atmospheric pressure is dictated by the two thin vessel walls required in the spectrometer acceptance region. Operational conditions foresee 200 Pa at the upper side of the larger thin wall (corresponding to a relative pressure of 700 Pa at lower side and to 100 Pa on top of the vessel). An upper limit of 300 Pa and a lower limit of -200 Pa for the relative pressure on top of the vessel have been set accordingly to the thin wall structure and the overall vessel mechanical design. If the relative

[4] Haug SOGX 50-D4.

pressure exceeds these limits, the forces generated by the thin wall deformation could induce deformations of the vessel structure, to which the mirror wall is fixed, thus generating mirror misalignment. For pressure values even further from the allowed range, the thin walls risk to be damaged. Moreover, in all operational conditions, only a pressure difference of at most 1000 Pa between the vessel and the photon detector volume is allowed to avoid mechanical stresses on the fused silica plates: this is guaranteed regulating also the photon detector pressure relatively to the atmospheric one. The relative vessel pressure is kept constant within 10 Pa over months of operation. The avoid accidental pressure values outside the allowed range, for example in case of a long power failure, a safety-bubbler, mounted on top of the vessel, will release gas to the atmosphere or let air enter in the vessel.

The radiator gas is circulated at a rate of 3–5 m^3/h through a filter,[5] to prevent building up impurities due to leaks: the global, i.e. vessel and gas system, rate of air input is ~ 3 Pa $\times$ l/s. Two filter cartridges, mounted in parallel, ensure to have at least one operational filter at all times. They can be regenerated in situ.

Before filling and during long shutdown periods, the vessel is flushed with nitrogen. N_2 and C_4F_{10} separation during filling and recovery is based on the different boiling points of the two gases and provided by a cooling system with heat exchangers operating at $-35°C$. During filling and emptying, the pressure in the separator section is kept at 400–500 kPa: nitrogen vented out thus contains $\sim$4–5% residual C_4F_{10}.

The system operation has been stable over periods of months. It is also quite easy, thanks to the simple design principle.

3. Gas quality measurements

The gas system is complemented by monitoring instrumentation, including commercial instrumentation (a hygrometer, an oxygenmeter and a binary gas analyser), a sonar to determine the gas composition by measuring the speed of the sound in the gas [7] and a setup for transparency measurements. This setup allows to perform an integral measurement over the range from 160 nm to 210 nm. The system consists of a stainless-steel transmission cell of 2870 mm length (Fig. 2); at one side a deuterium lamp[6] is attached and on the other side there is a solar-blind photomultiplier tube[7] reading the intensity of the transmitted light. A fused silica window is installed along the light path to match the sensitivity of this measuring system with that of the photon detectors. The measuring cell can be evacuated down to 10^{-3} Pa for normalisation measurements. Alternatively, normalisation can be obtained by flushing the measuring cell with nitrogen.

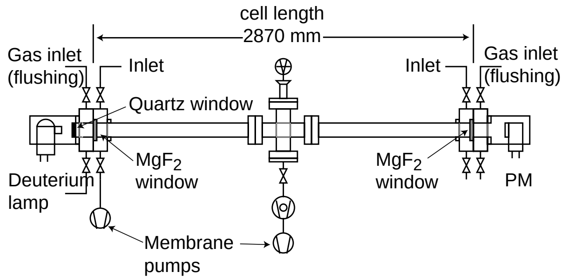

Fig. 2. Schematic drawing of the VUV integral measurement setup.

4. Radiator gas cleaning

C_4F_{10} is intrinsically transparent in the UV region of interest for COMPASS RICH-1, but in the commercially available material strongly VUV absorbing contaminations are present. Therefore gas cleaning is needed before injecting it in the RICH gas system. It is clear from experience that the amount and nature of polluting material traces varies in the different production and delivery batches.

A cleaning system was put in operation in year 2000 and also used in year 2001. Liquid C_4F_{10} is circulated permanently through the filters in a

[5] BASF-Catalyst R13-11 by BASF AG, 67056 Ludwigshafen, Germany.

[6] Hamamatsu L2D2 lamp, type L7295.

[7] Hamamatsu type R7639.

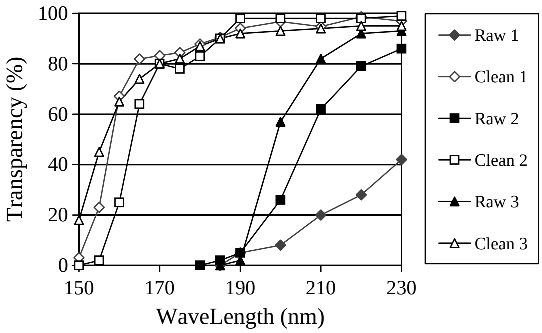

Fig. 3. VUV light transmission through 51 mm of liquid C_4F_{10} scaled to 5 m of gas, 100 kPa, for three different samples. Raw material and clean material transmission are shown.

closed loop. This cleaning system has a direct connection with a cell, 51 mm long, closed by CaF_2 windows, mounted in the vacuum chamber of the CERN reflectometer [8], which has been modified to allow light transmission measurements for COMPASS and ALICE experiments. The VUV light transmission through the liquid (corresponding to more than 7 m of gas path length at atmospheric pressure) can be measured. The normalisation of the measured transmission is performed flushing the cell with clean nitrogen. This set-up makes it possible to monitor on-line the material transparency during cleaning procedure.

In a first stage, different filter materials have been tested: silica gel, activated carbon, 13X molecular sieves and Cu-catalyst, the last one resulting to be the most efficient for the material used during this test phase and it was adopted. It has allowed to obtain light transmission $\geqslant 80\%$ down to 165 nm (Fig. 3) with material loss of 7%. Later, depending on the different material samples, the same light transmission has been obtained with material losses up to 50%. The large variation of loss rates is related to the different amount and nature of contamination impurities: ideally, the choice of the best filter should be sample dependent.

A second cleaning system has been put in operation in year 2002. The material is circulated in closed loop in gas phase through activated carbon filter and 13X molecular sieve, later replaced by 5A molecular sieve. Oxygen is removed in a cool section ($T \sim -60°C$), where C_4F_{10} condensate and the liquid drops return to the bottle, while gas component is vented out. Typical material loss is $\sim 20\%$.

5. Conclusions

Since the 2001 run we have been successfully operating the RICH-1 radiator gas system. The system is stable, robust and easy to operate. After initial difficulties in obtaining the required purity of the material, the needed gas transparency in the VUV-region has been achieved. Integral transmission values of 90% for the average photon path length of 4.5 m have been observed.

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