CBM RICH PROTOTYPE GAS SYSTEM

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1. Introduction

The Compressed Baryonic Matter (CBM) experiment is a heavy-ion experiment at the future FAIR facility being designed to explore the intermediate range of the QCD phase diagram in the beam energy range from 10 to 45 A GeV. With its physics program, CBM will investigate properties of the dense baryonic matter and the expected phase transition between the hadronic and partonic matter. Among the key observables are the low-mass vector mesons and the charmonium decaying into lepton pairs. In CBM, electrons with energies lower than 8 GeV/c will be identified by a RICH detector, which is being developed at several laboratories. In addition, the detector will improve the kaon/pion separation at the momenta higher than 4 GeV/c.

The concept of the RICH detector involves CO_2 as the radiator gas, spherical glass mirrors reflecting the Cherenkov radiation to an array of Multianode Photomultipliers as photo detectors. The CO_2 gas has been chosen because it has the Lorentz factor of 33.3, the radiation length of 183 m and the pion momentum threshold for Cherenkov light production of 4.65 GeV/c, thus representing a very good compromise to fulfill the CBM RICH requirements.

The RICH detector requires stable differential pressure of the CO_2 gas above the atmospheric pressure, as many of gaseous detectors, which requires to ensure mechanical stability of the detector volume. The radiator gas must be free of moisture and oxygen. Additional measurements should be carried out to investigate temperature influence on the detector performance.

2. Gas system design

The primary purpose of the CBM RICH Prototype gas system (Fig. 1) [1] is to provide pure CO_2 gas to the RICH prototype at the correct differential pressure. Its design is based on the gas systems for the STAR and PHENIX experiments at BNL [2–4]. The system operates nominally as a closed circuit gas system with the majority of gases recirculating through the prototype. During the normal operation, the fresh gas is added with a Burkert 8711 mass flow controller FM1. To support constant differential pressure at the 2 mbar level measured with the pressure transmitter PT4, the control system will change the flow through the FM1 controller. If the differential pressure is increasing, the gas flow through FM1 will be reduced. And vice versa, in the case of a differential pressure drop, the flow through FM1 will be increased. The gas system can be operated in an open configuration for purging.

A bypass valve (BMV1) is manually adjusted to enable the optimum flow rate through the prototype. The purity of the recirculating gas is monitored using Panametrics Oxygen (O2X1) and Humidity (MMS35) analysers. A fraction (up to 30 %) of the recirculating gas can be passed through the purifier and dryer to remove oxygen and moisture. There is a possibility to check the gas purity with the analysers after the purifier and dryer to determine their saturation.

The Purifier is filled with active copper. Its operating and regenerating temperature is 220 °C. A Temperature Indicating Controller TIC1 supports this temperature level. The mixture CO_2 + 5 % H_2 can be used to regenerate the Purifier. The oxygen content after the purifier is about 2–3 ppm. The Dryer is filled with NaX (13X) molecular sieves. Its normal operating temperature is 22 °C. The water content at this temperature is 1–2 ppm in the Dryer output flow. The regeneration of the Dryer is performed at 350–400 °C supported with the TIC2.

A computer driven data acquisition/control system monitors all the process variables and provides stabilization of the RICH prototype differential pressure. The computer system flags the quantities which fall outside of the predefined limits and initiates corrective actions. Using data from the TT1, PT4 and BP (Barometric Pressure) sensors, the computer system estimates the value of the CO_2 refraction index.

The gas system is assembled in a single 19″ rack and can be easily transported with the RICH prototype. It can also be used in the future for the complete RICH detector with minor changes.

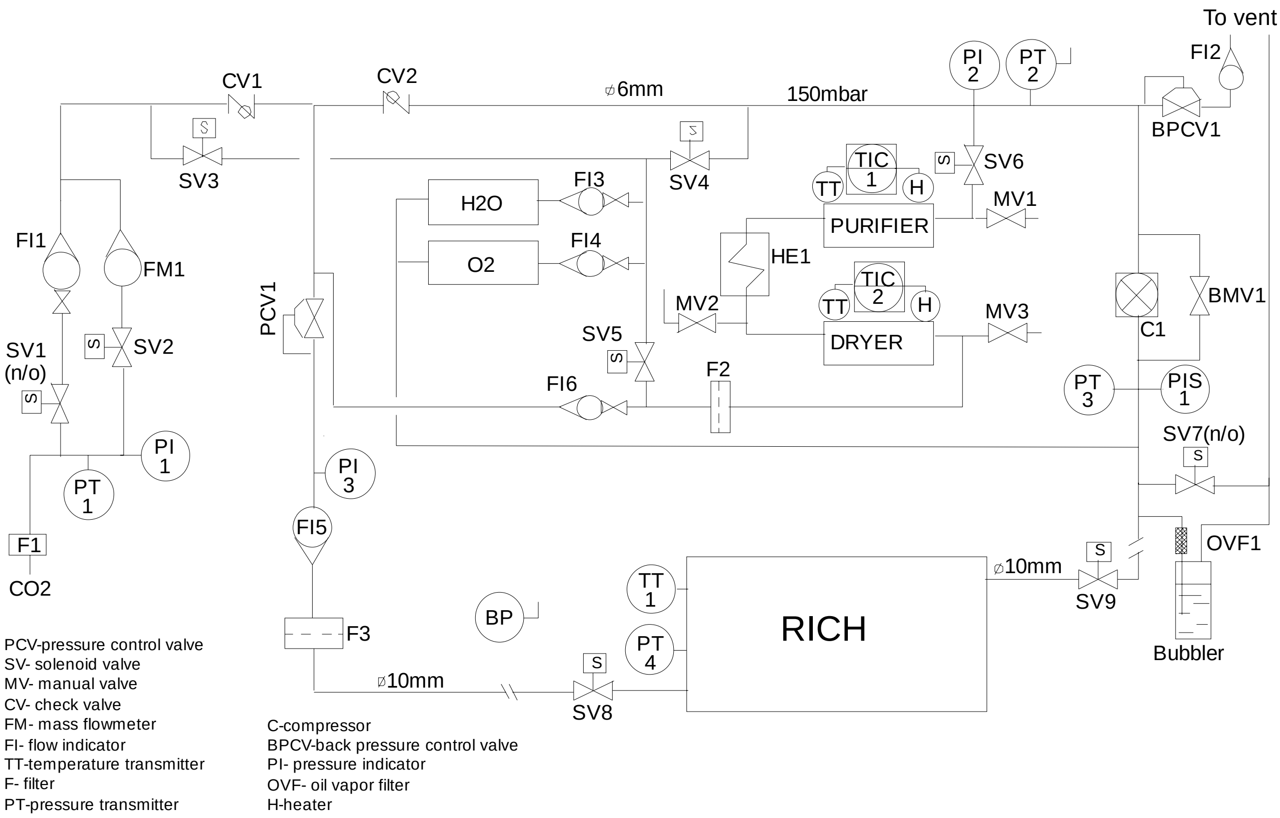

Fig. 1. CBM RICH Prototype gas system

3. Slow control subsystem

The CBM RICH gas system is controlled by a custom slow control subsystem [5] that is based on the data acquisition DAQ32 module [6]. This module was designed for controlling small cryogenic and gas supply systems. It provides reading of up to 32 sensors with industrial standard voltage or current outputs. The device precision is 0.004 % of the measurement scale, which can be selected from the range of +(0–4) V, ± 5 V, +(0–10) V, ± 10 V. The module is also equipped with 16 buffered digital outputs to control acting devices like solenoid valves or compressors, and 4 analog voltage outputs for flow controllers or heaters. Such input-output channel density allows to control small systems like the CBM RICH gas system with a single module.

The variety of data exchange interfaces simplifies the connection of the instrument to an external control system or to a computer. Flexible controller firmware allows implementing the necessary control algorithms like the PID regulation, directly in the firmware. Two of these modules (one working and one spare) are mounted in the gas system rack.

Control computer software [7] has been developed for the Windows platform. It provides reliable data acquisition, automated handling of alarm conditions and manual control of the gas system. All the alarm events and system variables are logged into a database. The software is split into multiple processes that communicate, making use of special operating system kernel objects.

The main process reads all the sensor values and passes them to other processes. In order to make the software more reliable, it has been divided into two threads: one for the Graphical User Interface (GUI) and one for the data acquisition. The GUI thread shows all the gas system parameters including the valve states in the main window. The operator can also use the controls to manage the system manually, as well as adjust the alarm parameters.

The DAQ thread acquires all the process variables, writes them into shared memory and checks the alarm conditions. Every alarm setting contains an alarm threshold, an alarm message and a control template. The template indicates the alarm set and the release actions for every controlled device, *e.g.*, a valve or a compressor. The system makes corrective actions automatically and alerts the operator about the problem. Alarm control templates provide the user with a high degree of flexibility when setting up the system. All the process variables are written into the MS Access database with a specified period. In the case of an alarm trigger, the current values are written out in turn. All the alarm events and software messages are logged into the same database.

It is also useful to have a fast access to particular data and to plot the results during the gas system operation. A special tool (DBViewer) has been developed to work with the gas system database. It provides visualization of the data for any gas system process variable and exports the data from the database to an MS Excel file or tab-delimited text file for further analysis.

One more program has been designed for visualization of the actual state of the system. This program (Charts) displays up to ten selected parameters in the time chart format. Besides, it can be used for a tabular display of the process variables, with extra alarm signals for every parameter in the table. In addition, the TCP/IP client/server is implemented in the Charts software so that it can be used remotely to monitor the system under control.

The gas system control software was successfully used in nine gas systems [2, 3] for several detectors in the STAR and PHENIX experiments at RHIC.

4. Test beam results

During the test beam run in October 2011 at CERN, we had a good opportunity to test the gas system. The major task was to check the differential pressure stability of the RICH prototype in the recirculation mode during stable operation. Figure 2 features the results of our pressure regulation. Obviously, the differential pressure of the RICH prototype was stable at 2.0 ± 0.1 mbar, although the barometric pressure PTB varied in the range of 22 mbar. We can see the same results for the STAR and PHENIX gas systems [2–4], in spite of different control technique. For the STAR and PHENIX gas systems, mass controllers were used to prepare a fresh mixture with a very stable content. The fresh mixture was added to the system gas at a constant flow, and therefore the pressure of the detector was stabilized using a dedicated PID-controller in the recirculation mode.

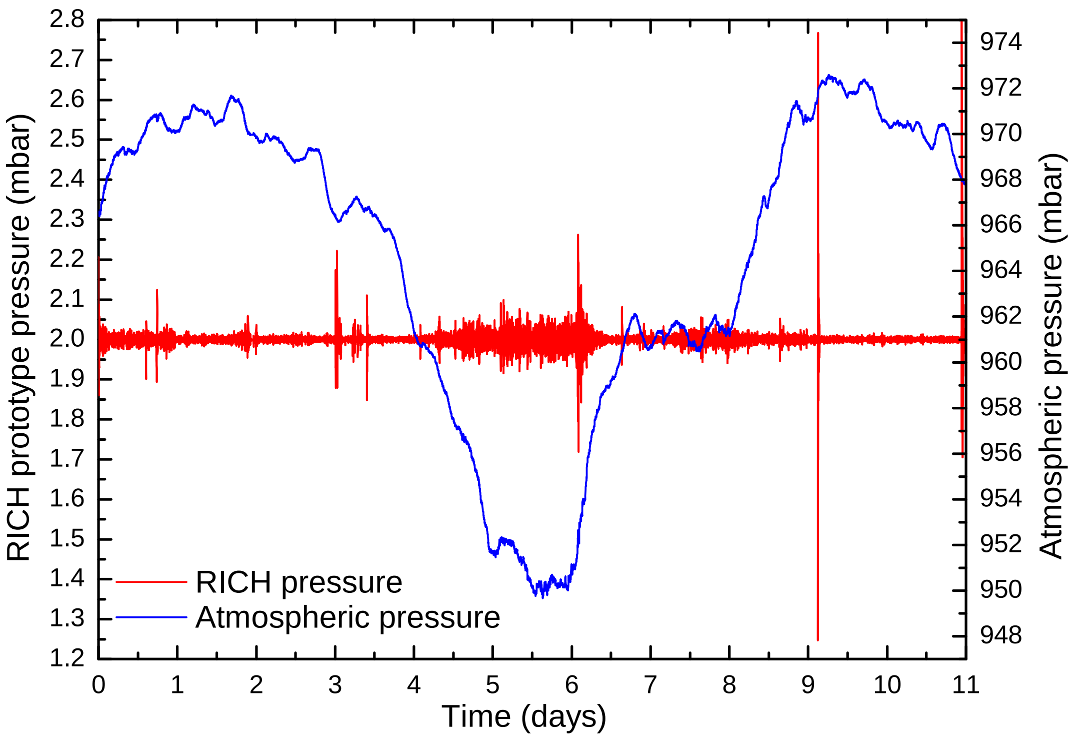

Fig. 2. Detector differential pressure (red line) and the atmospheric pressure (blue line)

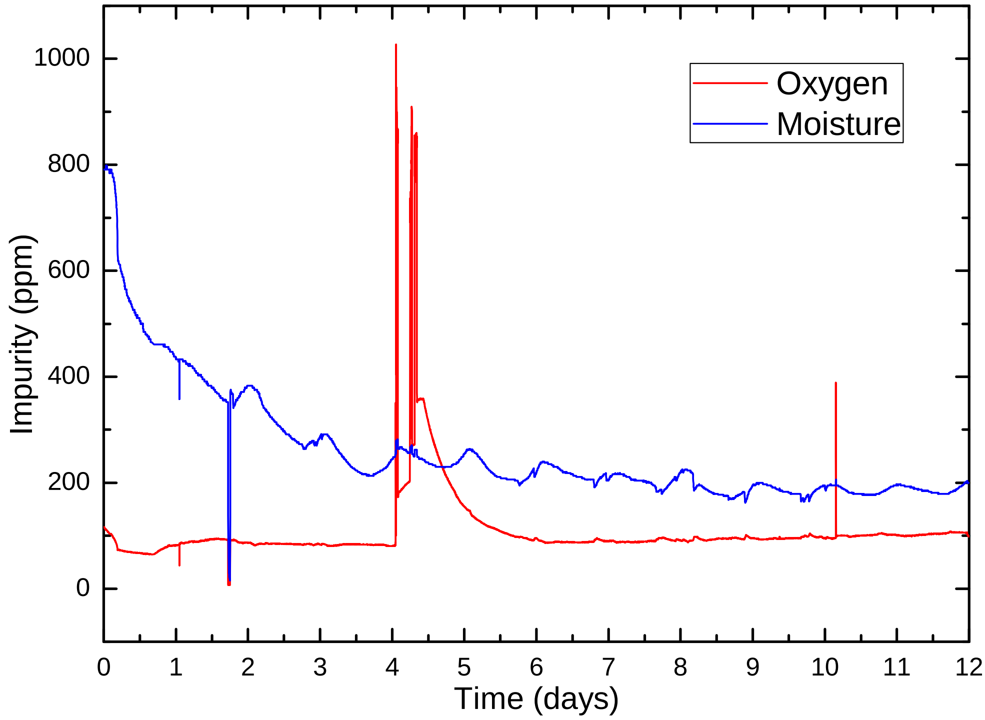

Fig. 3. Oxygen (red line) and moisture (blue line) content

The efficiency of the gas system Dryer and Purifier was also checked. Test results are shown in Fig. 3. It should be mentioned that the inner RICH prototype surface was not treated with a special cleaning process, and we had a lot of water and oxygen adsorbed by the walls of the RICH vessel and the inner structure elements. Even at these conditions, both the Dryer and Purifier had enough efficiency to remove moisture and oxygen to the required level.

The gas system was also used to add a certain amount of oxygen in order to check the detector operation at a higher oxygen content (the spikes in the oxygen line on the fourth day in Fig. 3). The oscillations of the moisture content are caused by daily temperature changes in the hall.

In general, the gas system provided stable operation with stabilization of all the required gas parameters in the RICH prototype. It was reliably operated by the control system, providing all the system parameters to the external slow control system. The RICH prototype vessel (3.5 m^3) was checked for leaks prior to the beam time. Measuring the pressure decrease in the vessel, we have estimated the leak rate to be below the sensitivity of the gas system ($\leq$ 50 sccm).

References

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