The BONuS12 RPTC and DMS gas panel (v.0.3)

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Abstract

A gas panel to distribute and control the gas supply for the BONuS12 Radial Time Projection Chamber (RTPC) and Drift Monitor System (DMS) was built at The College of William and Mary with the advisory of the JLab Detector Support Group (DSG). This note describes its construction and working use.

1 Introduction

The BONuS12 RTPC consists of a 40 cm long cylindrical chamber conformed by different concentric regions. At the center there is a target straw of 3 mm radius filled with Deuterium or Hydrogen at pressure of 7 atm. Next, there is a buffer region, filled with ^{4}He at 1 atm, to minimize the effect of Møller electrons. This region is surrounded by an aluminized mylar foil cylinder of 20 mm radius connected to the ground. Two volumes surround the buffer, standoff and drift region. These volumes are separated by another cylindrical aluminized mylar foil of 30 mm radius, acting as a cathode. Then, a set of three GEM cylindrical foils will amplify the electron signal produced by the ionization of the gas in the drift region. The first GEM, with a radius of 70 mm, acts as the anode of the chamber, producing a radial electric field perpendicular to the beam. The second and third GEM foils have a radius of 73 and 76 mm respectively. Finally, a cylindrical printed circuit board with $\approx$ 18000 sensor pads collects the charged amplified by the GEMs. The whole chamber will be inserted in a solenoid which will produce a magnetic field parallel to the beam. Figure 1 shows a transverse scheme of the RTPC showing the different regions and the ionization process.

The Drift-gas Monitoring System (DMS) is essentially a drift chamber designed to measure the drift-velocity of electrons in the drift-gas mixture. It does this by detecting β electrons radiated by two ^{90}Sr sources in coincidence with ionization electrons that those β's create (see Fig.2). Each β must travel straight up through the hole in the skeleton of the DMS into the drift gas, create an ionization electron in the sensitive region, and be detected at the opposite end by an scintillator-photomultiplier tube combination. The ionization electrons that are created in that sensitive region are forced to move toward the anode via the electric field created by the cathode-anode combination and the field shaping electrodes that ensure the field is uniform in between. By knowing the distance between the sources and the arrival time of ionization electrons at the anode, we can calculate the drift velocity of those electrons. That drift velocity along with readings from attached pressure and temperature sensors, will tell us a bit more about the gas mixture changes and its effect on the velocity.

The construction of the DMS consists of the skeleton, electronics, and sources. The skeleton is made of six detachable Delrin sides held together by screws and maintains its air-tightness by way of rubber gaskets. The cathode, anode, and field-shaping electrodes are made of conducting metals. Those together with the photomultiplier tubes all rely on a high-voltage power supply. Finally the sources are Eckert & Ziegler ^{90}Sr sources that will be housed in a plastic and attached to the DMS in a light-tight manner.

The gas panel described in this note is designed to supply a pre-mixed gas, 20% CO_2 in He, to the standoff and drift volumes of the RTPC, the DMS, and He to the buffer volume. The gas panel concept (figure 3) was designed by George Jacobs from the JLab DSG and assembled at The College of William and Mary (W&M).

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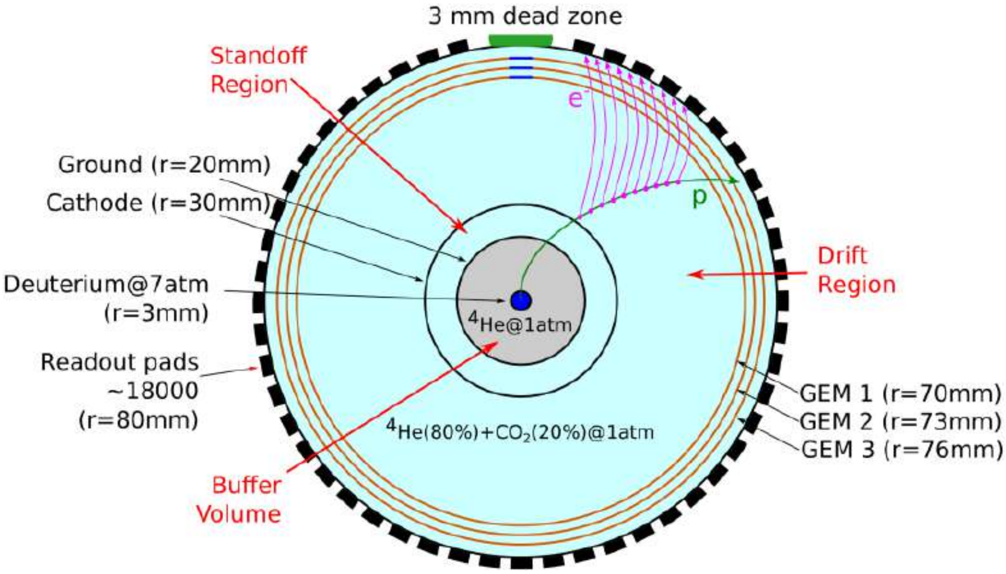

Figure 1: Cross section scheme of the BONuS12 RTPC, showing the concentric gas volume regions and its corresponding gas composition. The regions indicated in red are the volumes gas supply by the gas panel.

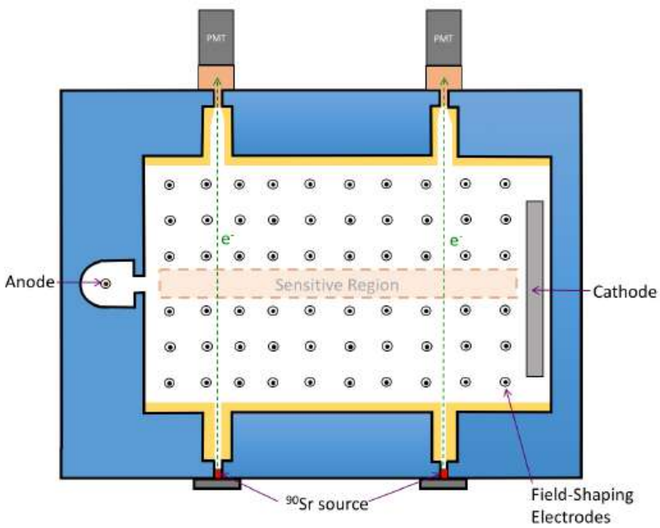

Figure 2: Drift Monitor System concept. (From N. Dzbenski)

2 Description and construction of the Gas Panel

2.1 Gas Line Runs and Connections

There are pre-existing lines running from the target gas pad to the hall that are available. These lines terminate at the downstream end of the space frame. These lines can be diverted to the upstream location or new lines can be run that terminate at the upstream end of the space frame. The RTPC gas is supplied in high pressure, 2000 psi, pre-mix cylinders of 20% CO_2 in He, each containing 220 SCF. Pressure regulators reduce the gas supply pressure to 15 psi for the mass flow controller. Flow limiting orifices limit gas flow in case of component failure. The ^{4}He buffer gas is supplied in high pressure, 3000 psi, cylinders each containing 220 SCF. Pressure regulators reduce the gas supply pressure to 15 psi for the manual flow meter with valve. Flow limiting orifices limit gas flow in case of component failure. Gas for the ^{4}He buffer volume is supplied from the Legacy Hall B He gas distribution system. The ^{4}He gas cylinders are located at the Hall B Gas Shed, Bldg. 96B.

2.2 Description of the gas panel

The gas panel contains the gas system sensors, valves and controls.

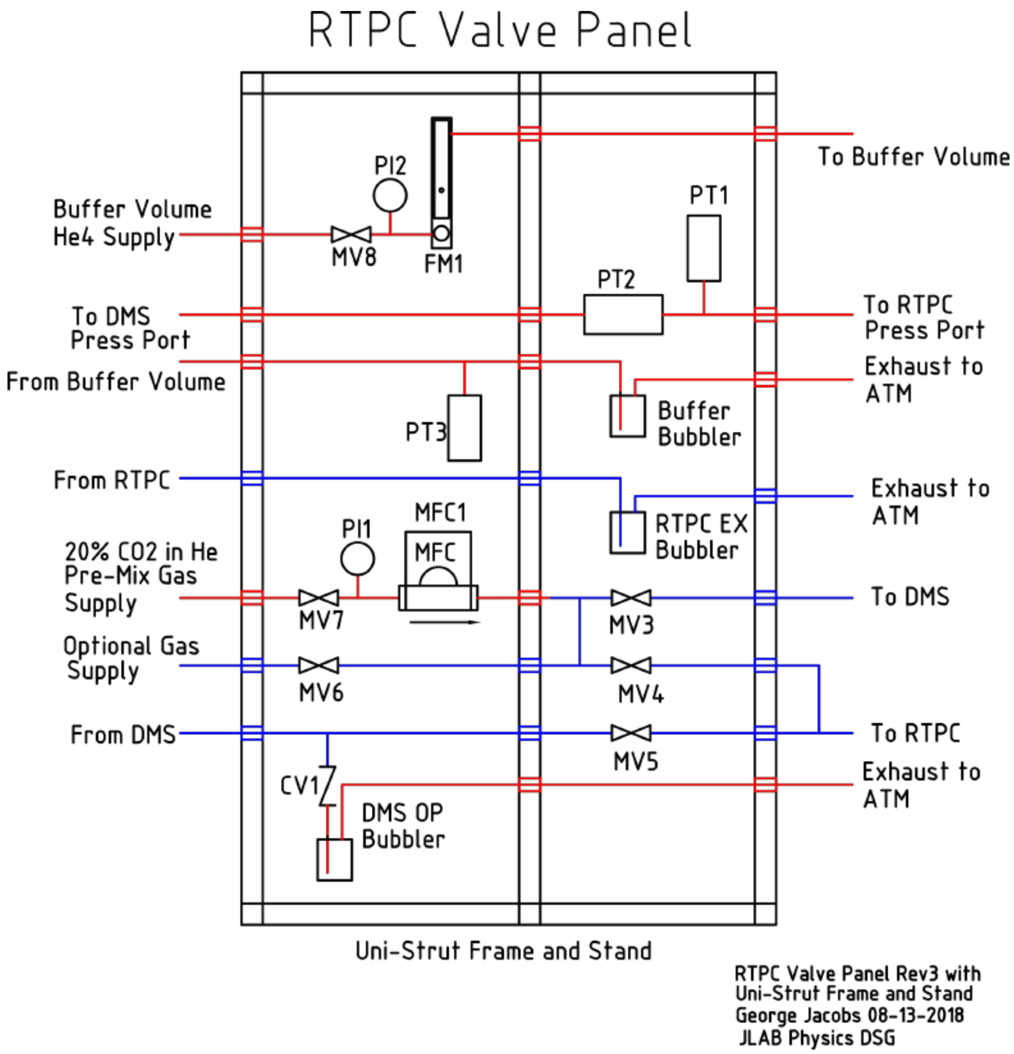

Figure 3: CAD concept of the gas panel designed by G. Jacobs. The red and blue lines indicate the 1/4" and 1/2" tubing, respectively.

The pre-mix gas flow pressure is controlled by a Mass Flow Control (MFC) (MKS GE50A) and is monitored by a pressure gauge at the inlet of the MFC. The gas panel could be isolated from the gas supply closing the valves MV7 and MV8 (see figure 3).

The MFC flows gas to the DMS then to the RTPC. The gas flow can be bypass the DMS manually, operating the valves MV3, MV4 and MV5 (as is explained in section 3.3). A check valve, CV1 limits pressure in the DMS volume to 1 psi in case of human error.

The option of a second or alternate gas supply is provided by a tee connection and isolation valve, MV6.

The He gas to the buffer volume is supplied via the MV8 valve and controlled by the manual flowmeter FM1.

The mineral oil filled bubblers, for the RTPC, DMS and Buffer, act as a check valve to prevent backflow of air into the system while maintaining the desired detector pressure and providing a visual indication of gas flow.

2.3 Construction of the gas panel

The gas panel is built over a Unistrut steel frame of 1300 mm (34") × 863 mm (51,25"). The list of the gas system components is shown in the table 1. The connections are made through copper tubing and stainless steel fitting (table 2) using brass ferrules for the compression fitting (see figure 4).

The arrangement of the components follows the scheme, when possible, from George Jacobs (fig. 3). The MFC, PT1 and PT2 are attached to the frame through metal plates to reduce stress in the copper tubing and add stability of the same. All the compression joints were done following the instructions from the Swagelock manual and verified with the gauge (fig. 5).

Item and number	Model	ID
Mass Flow Controller x1	MKS GE50A013202SBV020	MFC1
Absolute Pressure Sensor x1	MKS AA01A13BAS3B00000	PT1
Differential Pressure Sensor x1	MKS 226A22TBBBBFB4A1	PT2
Differential Pressure Sensor x1	MKS 223BD-00010AABS	PT3
0-60 psi Pres. Gauge x1	Ashcroft 251009 SW 02 L 60#	PI1
0-60 psi Pres. Gauge x1	Ashcroft 20W1005 H 02 L 60#	PI2
Flowmeter x1	Dwyer VA1043	FM1
Overpressure bleed off valve x1	Swagelock SS-4C-1	CV1
Glass Jar with PTFE Plastic Seal x3	McMaster-Carr 4239T33	Bubbler
1/2" ball valve x4	Swagelock SS-8P6T	MV3, MV4, MV5, MV6
1/4" ball valve x2	Swagelock B-42S4	MV7, MV8

Table 1: Main components used in the gas panel, number of them, model and code ID.

Figure 4: Picture of the brass ferrules used with the copper tubing in the gas panel with a stainless steel compression nut.

Figure 5: Picture example of the use of the gauge with the compression component.

All inlets and outlets on the panel are provided with compression fittings to facilitate connections with the tubing.

A picture of the completed panel is shown in the figure 6.

Item and number	Model
1/2” soft coil copper tubing	Mueller ACR Tubing - Grainger 4WTC2
1/4” soft coil copper tubing	Mueller ACR Tubing - Grainger 4WTA8
1/4” Union Tee x4	Swagelock SS-400-3
1/2” Union Tee x2	Swagelock SS-810-3
1/4” Tube Union x4	Swagelock SS-400-6
1/2” Tube Union x2	Swagelock SS-810-6
1/2” OD X 1/4” OD Reducing x1	Swagelock SS-810-6-4
1/4” Union Tee to FNPT x3	Swagelock SS-400-3-4TTF
1/2” Union Elbow x2	Swagelock SS-810-9
1/4” Cap x8	Swagelock SS-400-C
1/2” Cap x6	Swagelock SS-810-C
1/2” Tubing Cushioned Clamp x10	Cush-A-Nator CN08
1/4” Tubing Cushioned Clamp x13	Cush-A-Nator CN04

Table 2: Joint components used in the gas panel, number of them and model.

Figure 6: Completed RTPC and DMS gas panel photo.

3 Use of the gas system

3.1 Controls and Instrumentation

A National Instruments cRio is used to control the MFC and read back the gas system flow and pressure signals. These signals are available on EPICS:

- RTPC Gas Flow (MFC1)
- RTPC Absolute Pressure (PT1)
- DMS-RTPC Differential Pressure (PT2)
- Buffer Differential Pressure (PT3)

The MFC is regulated via the gas system GUI located at Gas shed, L3 space frame, and Fwd Carriage. The EPICS readouts are available from any computer where EPICS can read out.

3.2 Gas System Initial Start-up

The RTPC and DMS must be purged of normal air the first time to be used[1]. Read the whole list of steps below, before start the procedure since they are not strictly sequential. **DO NOT TURN ON THE HV UNTIL THE PROCEDURE IS COMPLETED**.

1. Verify all gas system components, gas lines, RTPC detector and DMS volume are connected as shown in the gas system P&I diagram (fig.3 and fig.7).
2. Verify proper valve lineup for start up in the following order:
   (a) Close or check closed MV1, MV2, MV4, MV6, MV9, and MV10.
   (b) Open or check open MV3, MV5, MV7, and MV8.
   (c) Close the flow meter valve on FM1.
   (d) Open the gas cylinder valves and set the pressure regulators to 15 psi.
   (e) Open MV1, MV2, MV9, and MV10.
3. Set the flows on MFC1 and FM1.
4. Purge the detector and DMS volumes at 100 sccm to 250 sccm for ∼90 min.
5. Once the purge is complete, reduce the detector and DMS flows for data taking.
6. Turn on HV.

3.3 Flow and Pressure Controls

Increase or decrease of gas flow or pressure is done as follows:

- **Detector gas flow control:** Adjust the setpoint of MFC1 (from the gas systme GUI) to increase or decrease gas flow.
- **He buffer gas flow control:** Adjust manually FM1 control valve to increase or decrease flow
- **RTPC gas volume pressure control:** To increase pressure, add oil to the RTPC exhaust gas bubbler. To decrease pressure, remove oil from the bubbler.
- **He buffer pressure control:** To increase pressure, add oil to the buffer exhaust gas bubbler. To decrease pressure, remove oil from the bubbler

To add or remove oil from the bubbler, just unthread the glass jar from the lid.

3.3.1 RTPC and DMS supply

Regulate the flow through the MFC as needed via the gas system GUI. From the DMS, the gas returns to the gas panel and is conducted to the RTPC. The pressure between the DMS and the RTPC is monitored via EPICS by PT1 and PT2 with an extra line between the RTPC, the DMS and the panel.

3.3.2 Bypass DMS

In case of direct supply to the RTPC bypassing the DMS (the gas flow is not stopped), the procedure is as follows:

- open MV4
- close MV3 and MV5

RTPC pressure is still monitored with PT1 since the monitor line between the RTPC and the DMS is not isolated. PT2 will indicate the differential pressure between the RTPC and atmosphere (regulated by DMS bubbler).

[1] it includes when any of the vessels are open to the atmosphere, besides the exhaust connections from the bubblers

3.3.3 Optional gas supply

The optional gas inlet can be used to add an additional MFC to mix in an additional gas in the future if it is determined that it is needed. It can be used as unique source of gas or combined with the existing line (the one attached to MV7). To use such inlet follow the next steps:

- close MV7
- Attach gas source to MV6
- open MV6 (and MV7 in case to use both gas sources)
- Control gas flow using the optional controls (TBD)

3.4 Gas System Shut Down

To shut down and isolate the gas system perform the following actions;

- Close the gas cylinder valves
- Close MV1, MV2, MV9, and MV10

4 Hazards

Portions of the gas system, as shown in figure 7 are considered a pressure system and must satisfy all safety regulations indicated by JLab ES&H. Portions of the gas panel NOT considered a pressure system, after the following components:

- immediately after the flow-meter FM1
- after valve MV3, MV4, MV5.

The RTPC and the DMS are not considered pressurized vessels as pressure is limited by the oil filled bubblers.

The gases to be used are not flammable, so not further consideration is needed.

Although the gas exhaust is conducted to the atmosphere outside the hall, any possible gas leak in the system would not cause a Oxygen Deficiency Hazard (ODH) Risk.

5 Monitoring and Archiving of Drift Gas System

The necessary mass flow rate, differential pressure, and temperature readings for the BONuS12 drift gas system will both be incorporated in the the standard CLAS12 monitoring scheme and archived via EPICS. The associated controllers and sensors will be streamed in to the same cRIO framework that is used for all of the detectors and their auxiliary systems. This information being archived will be useful for analysis and calibration purposes in that it will help in understanding how the RTPC was performing during data taking.

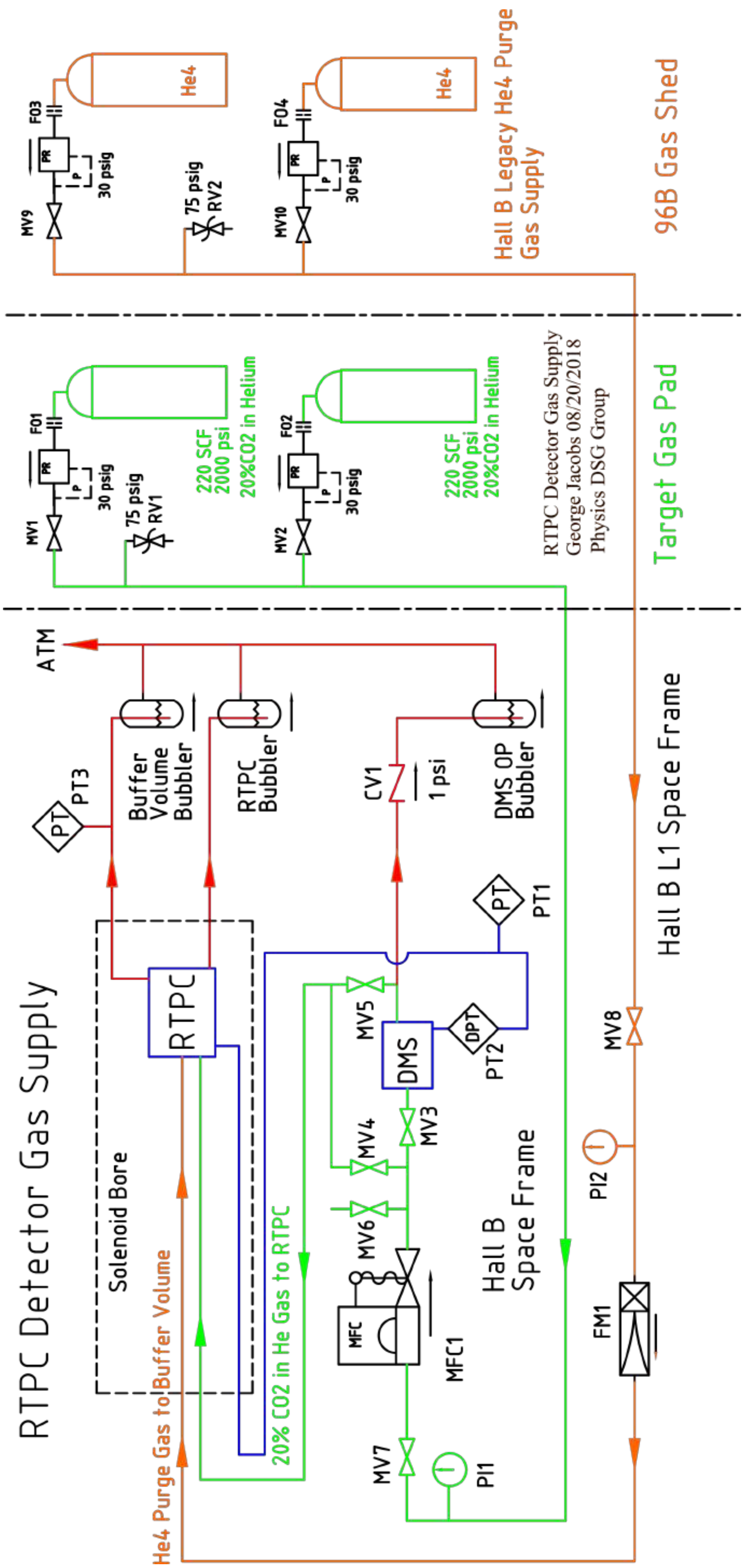

Figure 7: CAD scheme of the complete RTPC and DMS gas system designed by G.Jacobs, including the outdoors section.