Manual for CLAS12
Ring Imaging Cherenkov Counter

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Contents

1 General description of the RICH

The first module of the CLAS12 Ring Imaging CHerenkov (RICH) detector is installed on the forward carriage in Sector 4, downstream of the third region of drift chambers and just before the Time-Of-Flight (TOF) system. A second RICH module is foreseen for the starting of operation with transversely polarized target. It's goal is to provide identification of kaons with respect to pions and protons in the momentum range between 3 and 8 GeV/c and for polar angles up to 25°, achieving a 4σ-level separation in the corresponding Cherenkov angle distributions. The RICH design incorporates aerogel radiators, visible light photon detectors, and a focusing mirror system which is used to reduce the detection area instrumented by photon detectors to about 1 m^2. Multi-anode photomultiplier tubes (MAPMTs) Hamamatsu H8500 and H12700 provide the required spatial resolution and match the aerogel Cherenkov light spectrum (visible and near-ultraviolet region).

The RICH is composed by a large trapezoidal box made in aluminum and carbon fiber, with smaller base of about 0.3 m, a larger base of about 4.2 m, a height of about 3.7 m and a depth of about 1.2 m. The total weight is approximately 900 Kg. Two drawings of the RICH box frontal and backward views are shown in figure 1.
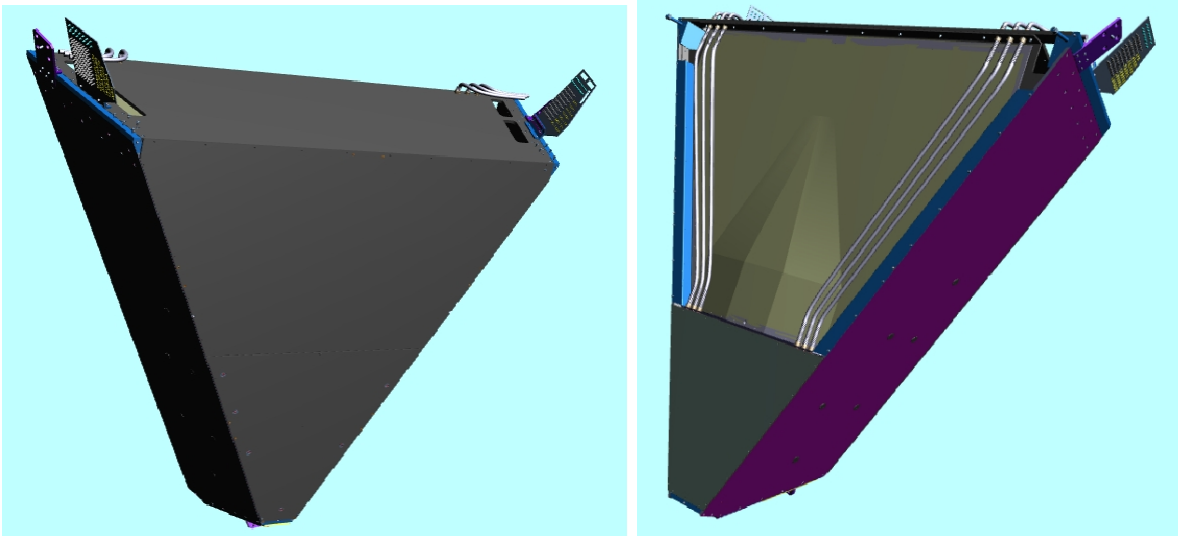

Figure 1: Back and frontal drawings of the RICH module.

Inside the RICH box, a number of active elements are installed, namely:

- the aerogel radiator;

- the planar and spherical mirrors;

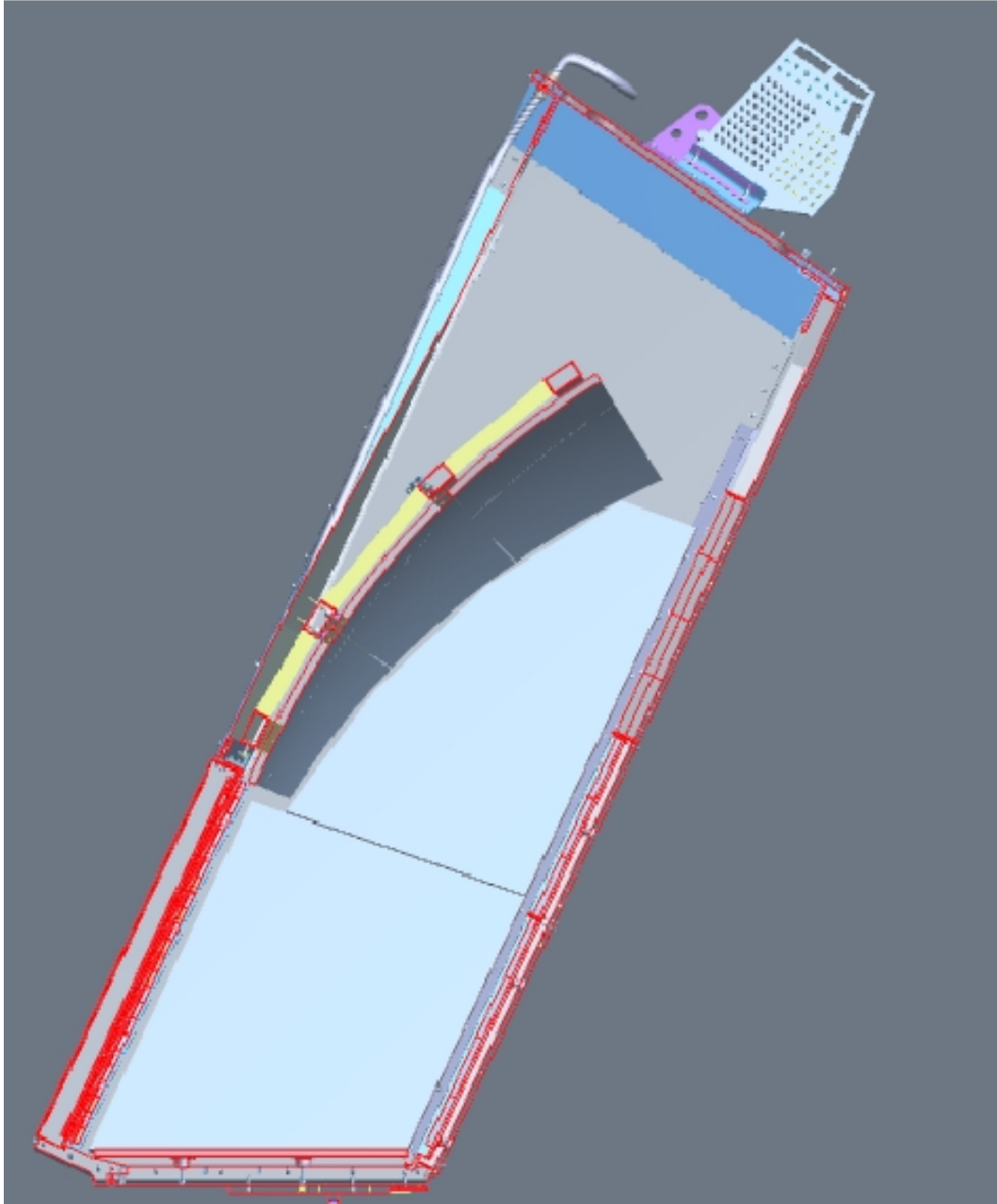- the MAPMTs and the readout Front-End Electronics (FEE).

Figure 2: Cross section of the RICH.

A cross section of the RICH showing the inner elements is shown in figure 2.

The aerogel is an igrophilic material that absorbs water from the environment humidity, resulting in a reduction of its optical performance. For this reason, a strict protocol to handle it has been established during the test and assembly. In addition, the RICH box volume is fluxed with dry nitrogen, in order to prevent water absorption during the operation of the detector.

The detection of the Cherenkov photon is achieved by means of 391 Multi-Anode PhotoMultiplier Tubes (MAPMTs) and the Front-End Electronics (FEE), mounted on a triangular box, about 1.7 m wide, 1.3 m high and about 10 cm thick, that is installed on the lower back of the RICH module.

2 The RICH Electronics

2.1 Photodetectors and Front-End electronics

The Cherenkov photons are detected by using 391 MAPMTs Hamamatsu H8500 and H12700. They are mounted on a carbon fiber panel installed on the lower back of the RICH and that also host the Front-End electronics.

Photodetectors and Front-End electronics are organized in tiles housing groups of 2 or 3 MAPMTs, see Fig. 3 for the 2 MAPMT case. There are 23 tiles with 2 MAPMTs and 115 tiles with 3 MAPMTs. Each tile is composed by an adapter board, an ASIC board and a FPGA board.

The adapter board ensure the connection between the MAPMTs and the ASIC board and also supplies the HV to the MAPMTs. The ASIC board houses the MAROC3 chips, one per MAPMT. The Multi Anode Read Out Chip (MAROC3) is a 64 channel Application Specific Integrated Circuit (ASIC), able to discriminate the 64 channels PMT output signals and produce 64 corresponding binary outputs. The chip provides single channel adjustable gain in the range between 0 and 4 and one adjustable threshold level. The MAROC3 chip is configured, controlled and readout by an FPGA, that also provide the LV supply to the ASIC board and the interface with the CLAS12 DAQ via optical link.
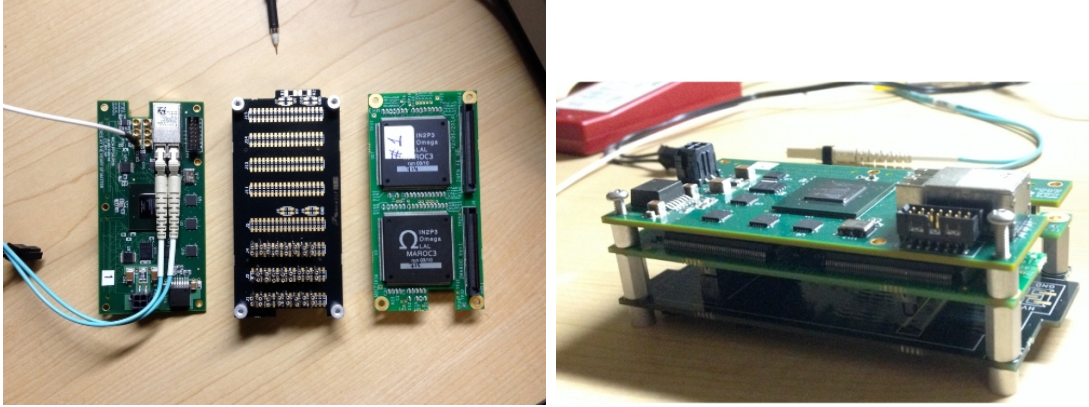

Figure 3: The RICH electronic boards for the 2 MAPMT case (left) and the tile fully assembled (right).

The list of the components of the RICH readout electronics is reported in figure 4.
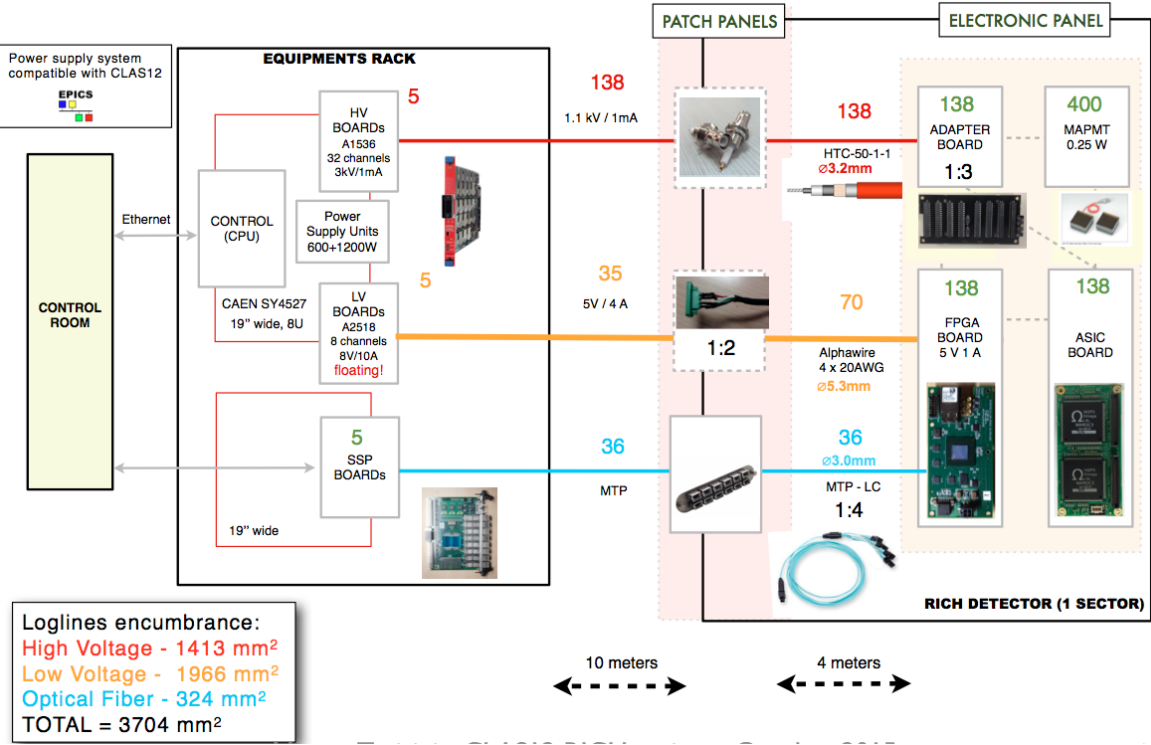
Figure 4: Sketch of the RICH services: LV, HV supply lines and DAQ optical link.

2.2 HV and LV Power Supply

The low voltage and high voltage power supply is a CAEN SY4527, see Fig. 5.

The unit supplies LV and HV power to 138 electronics tiles (RETile), 115 housing 3 MA-PMTs (RETile-3x) and 23 housing 2 MA-PMTs (RETile-2x). It runs on EPICS for Slow-Control with same procedures and controls already developed for other detectors (i.e. HPS ECAL). It houses:

Nr.	Item	Unit	Comment
1	Control board	A4528	With software libraries (EPICS, OPC Server)
1	Power unit	A4533	1800 watt in total at 220 Volt AC
5	HV Board	A1563	32 channels, 3kV/1mA, Common Floating Return
5	LV Board	A2518	8 channels, 8V/10A, Individual Floating
5	Adapter	A647	Radiall (dense) to SHV (robust)

Each HV channel connects one RETile. The HV runs on 138 RG58 cables towards the patch panels mounted on the RICH case, and on 138 HTC-50-1-1 cables inside the RICH volume. The HV should be set between 1000 V (nominal) and 1100 V (maximum). The single channel current dependes on the number of served MA-PMTs and should range between 0.5 (RETile-2x) and 0.8 mA (RETile-3x).

Each LV channel serves four RETiles. The LV runs on 35 AWG16 cables towards the patch panels connectors (Phoenix 8A) where it is 1:4 splitted into 138 AWG20 copper cables, one per RETile. To provide the wanted 5 V at the electronics, the LV should be set in the range between 5.1 and 5.4 V, corresponding to the voltage at the patch panel where sense wires provide feedback for LV stabilization. The LV current
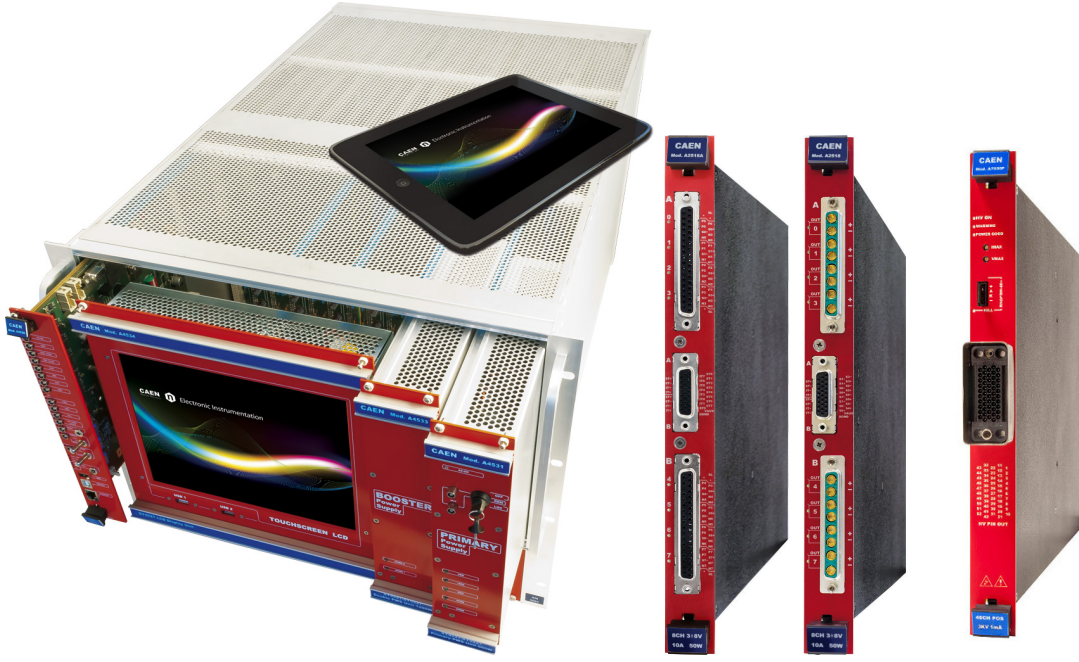
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Figure 5: The CAEN SY4527 power supply.

per channel should be around 4 A as it supplies about 1 A per RETile. The low voltage supply line is designed to not have difficulties to get the wanted voltage because of high current. If that is the case contact run coordinator or RICH electronic experts.

3 The RICH Gas Systems

The RICH is served by two different gas systems, one for the supply of the nitrogen to be fluxed inside the RICH box and one for the cooling of the FEE. Both systems are managed through controls and monitors integrated in the CLAS12 slow-control software. The two systems have been dimensioned in such a way that they will be able to serve two RICH modules.

3.1 The Nitrogen System

In order to preserve the aerogel optical performance, the RICH inner volume must be kept dry by fluxing nitrogen. The nitrogen system supplies the amount of gas necessary to fill the box (about 5 cubic meters) and to compensate for the gas leakage. A complete refill of the volume per day is expected under normal operating conditions. A slight overpressure of 0.5 mbar, controller by a bubbler, prevents the contamination from the outside air. The system is shown in Fig. 6. It is based on a 1500 gallons dewar of liquid nitrogen connected to the RICH box through a on/off valve with a pressure regulator, a 0.01 micron filter and an activated charcoal filter to remove all the impurities, and a flow rotameter and a flow transducer for flow control. In figure 7, we report the detailed list of the components of the system.

The nitrogen gas line control panel is located in the top level of the forward carriage close to the RICH air-cooling tank, see Fig. 8. It allows to isolate the nitrogen line to
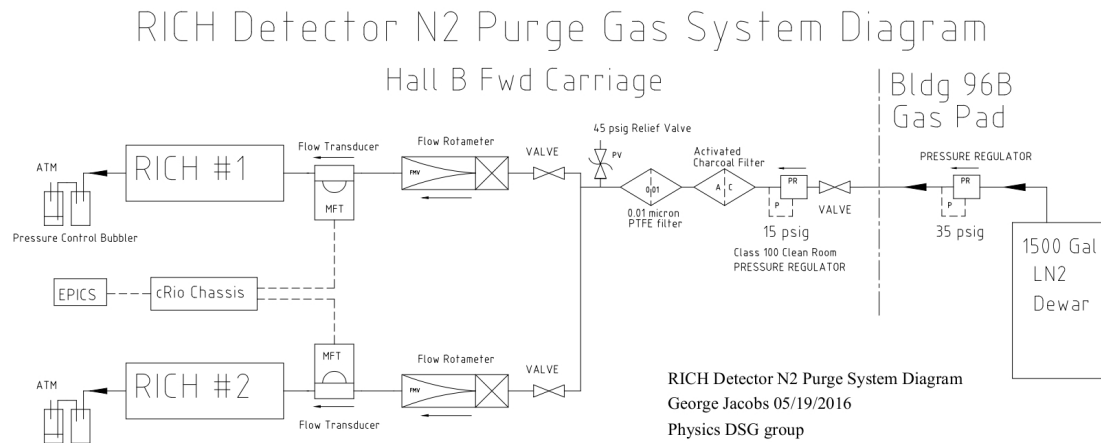
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Figure 6:   Schematic of the nitrogen supply system.

Component	Part Number	Details	Units Required
N2 supply shut off valve	1/2" SS ball valve	On Hand	3
High Purity Pressure Regulator	McMaster Carr part# 4238K42	Class 100 Clean Room press reg	1
pressure gauge for regulator	McMaster Carr part # 4238k47	Class 100 Clean Room press gauge	1
activated charcoal filter	Praxair part # PRSSG6140-3	filter housing with activated charcoal element	1
0.01 micron Teflon Membrane line filter	Praxair part # PRS5103	Teflon Membrane line filter, 0.01 micron	2
replacement activated charcoal filter	Praxair part # PRSSG6143	replacement filter	1
relief valve	circle seal part # D520T1-2M-45	45 psi poppet relief valve	1
rotometer	Dwyer part# RMB-49-SSV	0.0-5.0 SCFH (2360 sccm), SS valve	2
Mass Flow Transducer	MKS part# GM50A13503SB3020	5000 sccm range, 1/4" swagelock fittings, 0-5 vdc analog, 15 p	3
Pressure Control Bubbler and oil trap bubbler assemblies			2
Mason Jars	McMaster Carr part # 3231T44	quart size, vacuum sealable wide mouth jar	4
1/2" bulkhead fittings	Swagelock parts #B-810-61	Szwagelock 1/2" bulkhead fitting	8
1/2" SS tubing for dip tubes and bubbler to oil trap connection		on hand	2
1/2" 90 degree fittings	Swagelock part# B-810-9	Swagelock 90 degree elbow	8
Black nylon tubing	McMaster Carr part # 5112K56	1/2" OD black nylon tubing	200
misc fittings, ferrules, unions, tees, etc	swagelock fittings	Required to connect lines to components	1
Cush clamps, misc brackets, mounting hardware, unistrut	various	Required to mount components, strain relief	1

Figure 7:   Complete list of the components of the nitrogen supply system.

either of the RICH modules for maintenance. The pressure regulator reduces the input pressure to the 15 psig required for the correct functioning of the flow meters. The MFT flow transducer are used by the slow control to monitor the N_2 flow in input to the RICH module.

The slow control checks online the correct functionality of the system, i.e.:

- pressure in the nitrogen circuit;

- flow inside the RICH box;

- temperature and humidity of the gas fluxed inside the RICH box.

RICH N2 Purge Circuit Valve Panel

2-23 slm
Flow
Meter

2-23 slm
Flow
Meter

VALVE

Pressure

VALVE

0.01 micron
PTFE Filter

45 psig
Relief Valve

Activated
Charcoal Filter

MFT

MFT

Flow Transducer
0-20 slm

Pressure
Regulator
15 psig

To RICH #2

To RICH #1

RICH N2 Purge Circuit Valve Panel
George Jacobs 06/01/2016
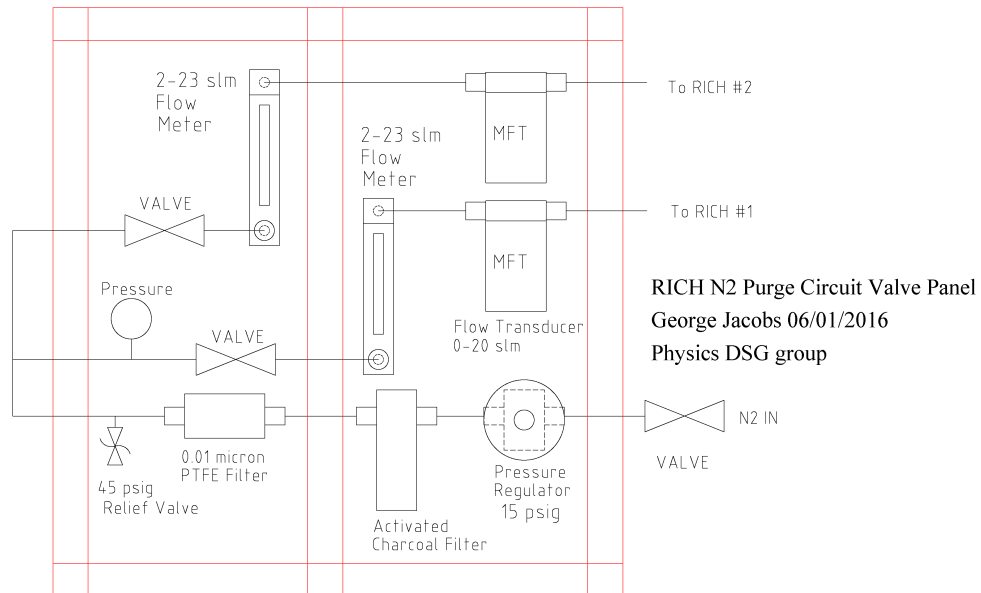Physics DSG group

N2 IN

VALVE

Figure 8:   Schematic of the control panel of the nitrogen circuit.

The shift worker is not supposed to change any setting of the nitrogen line, but to control the stability of the system. Any variation bigger than 0.5 psig in the nitrogen line, 1 slm in the flow or 0.5 % in humidity should be reported to RICH expert on call and noted in the log book.

3.2 The Cooling System

One tile with two or three MAPMs produces about 3.35 or 3.8 W of heat load, respectively. The total load in the whole FEE box is about 500 W. This heat load must be dissipated far from the CLAS12 detectors in order to keep the surroundings of the FEE box at a temperature below 40 ⁰C, the safety limit imposed by the TOF detector which is few cm downstream of the RICH.

The FEE RICH cooling system is based on two high capacity air compressors that supply clean dry air at room temperature. The capacity of each compressor must be large enough so that, in case of failure of one of the two, the other has sufficient capacity to supply the necessary cooling power to two RICH modules. The compressors charge a 1000 liter capacity air tank. Air pressure in the air-cooling circuit is reduced to supply manual valve flow meters to define the air flow entering the RICH enclosure. In the case of a power outage, the air tank should contain sufficient air to remove the latent heat of the FEE package. The characteristics of the compressors are shown in table 1.
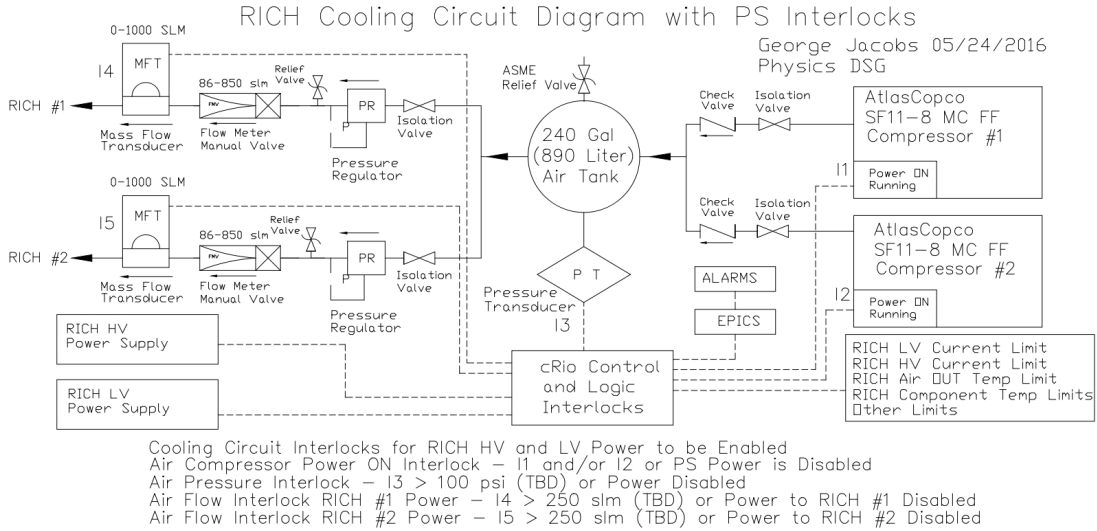
Figure 9: Schematic of the cooling system and interlocks.

Dimensions	1.4 x 0.7 x 1.8 m^3
Weight	515 kg
Max Flow rate	1200 l/min
Dew point	3 ⁰C
Electric power	10.4 kW
Noise press	60 dB (A)

Table 1: The characteristics of the ATLAS Copco SF11-8 MC FF compressors.

Powering up the electronics package inside the RICH without cooling may result in severe damage of the RICH and of other detectors or even fire. To eliminate this hazard, the RICH HV and LV power supply operations are interlocked to the proper functioning of the cooling system.

A schematic of the RICH cooling system with the interlock circuits is shown in figure 9 and the list of its components is reported in figure 10. It includes a number of temperature sensors installed inside the electronics box, air flow transducers connected to the inlets and pressure transducer on the air tank. The interlock performs two functions in case of a cooling system failure.

- turn off power to the electronic package;

- prevent energizing the electronics package.

There are three cooling cicuit interlocks. A first interlock requires the minimum of one compressor correctly functioning. The second interlock requires a minimum air pressure in the tank. The third interlock require a minimum air flow inside the RICH box. All three interlocks must be true in order for the electronics package to have power.

Component	Part Number	Details	Units Required
Air Tank Pressure Transducer (I3)	MKS 722B24TBA2A	range 400 psi, 1/2" tube, 0-10 vdc out, 9 pin D type,	1
Air Flow Transducer (I4 and I5)	MKS 0579A 01332LS3BV	range 0-300 slm, 1/2" swagelock fitting, 15 pin D type	3
Flow Control Rotameter	Dwyer RMC-121-SSV	0-10 scfm (283 slm), SS control valve	2
High Purity Pressure Regulator	McMaster Carr part # 49305K23	5-55 psi range, 1" FPT	2
Local Pressure Gauges – Tank	McMaster Carr part # 4000k791	0-200 psi	1
Local Pressure Gauges – Supply	McMaster Carr part # 4000k721	0-100 psi	2
Check Valves	Swagelock # SS-CHS16-1	1" valve, 1 psid	2
Fittings Estimate	TBD	Compression and pipe fittings	30
Isolation Valves	In House Supply	Valves are on hand and available	0
SS piping	1" SS tubing	Estimate Required	
Fittings	Pipe Fitting to connect tubing	Estimate Required	
ASME Relief Valve for Tank	Requires Analysis	Pressure System Requirements	1
Relief Valves for Supply	Requires Analysis	Pressure System Requirements	2
Compressor Running Transducer	Atlas Copco	Atlas Copco	2
Air Supply Flex Lines	TBD	Need Layout with Routing to Estimate lengths	
Detector Air Out Temp Sensor	TBD	RICH group	2
Detector Air In Temp/H2O	TBD	RICH group /DSG	2
Compressors	RICH Group	Atlas Copco	2
ASME Air Tank	RICH Group	ASME Tank	1

Figure 10: Complete list of the components of the cooling system and interlocks.

The slow control checks online the correct functionality of the system, i.e.:

- pressure in the tank and in the circuit;

- flow inside the RICH box;

- temperature and humidity inside the FEE box.

The shift worker is not supposed to change any setting of the nitrogen line, but to control the stability of the system. Any variation bigger than 1 psig in the air-cooling line, 10 slm in the flow or 2 % in humidity should be reported to RICH expert on call and noted in the log book.
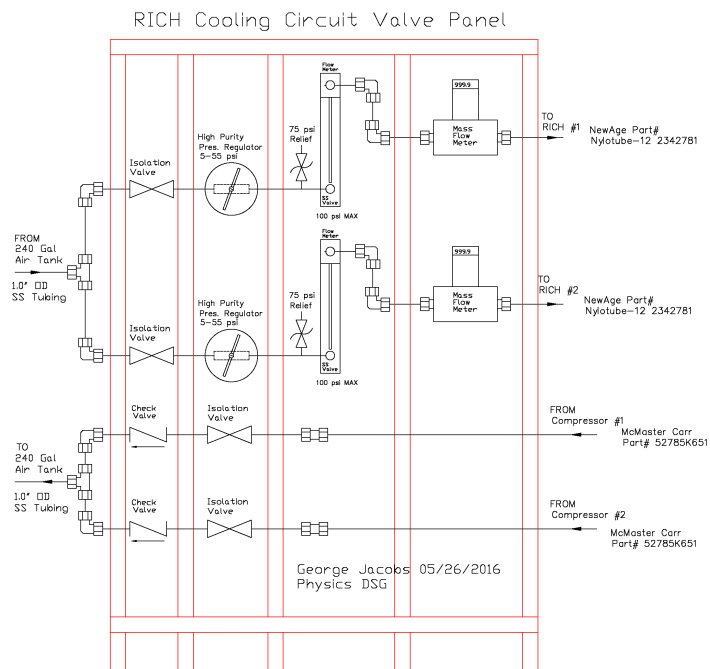
Figure 11: Schematic of the control panel of the nitrogen line.

4 The RICH monitors

In this section, we illustrate the general scheme for the RICH operation and monitor controls. The RICH slow controls are currently under development. Since the RICH uses hardware systems that are also used for other CLAS12 detectors, in some case the GUIs and screenshots showed here are taken from the slow control of detectors that use the same hardware.

4.1 RICH controls

All RICH controls will be accessible via EPICS, from the main CLAS_EPICS window (figure 12). If not already running, it can be opened by executing the command

<center>clas_epics</center>

in a terminal on any of the `clonpc##` workstations in the Hall-B counting house.

All shift workers should be using user **clasrun** *for all instructions in this document.*

The primary RICH screen is shown in figure 13 and opened via the **RICH** button in the right side of the main CLAS EPICS screen (figure 12).

From the main CLAS_EPICS window you can also access individual screens with more controls and details, **Gas system monitoring** in *Gas System* then *RICH gas System*, the **RICH compressors** in *Devices* then *RICH Devices*, the **Temperature monitoring** and **Scalers** in *RICH Scaler GUI*, the **RICH high voltage** in *HV* then *RICH HV*.
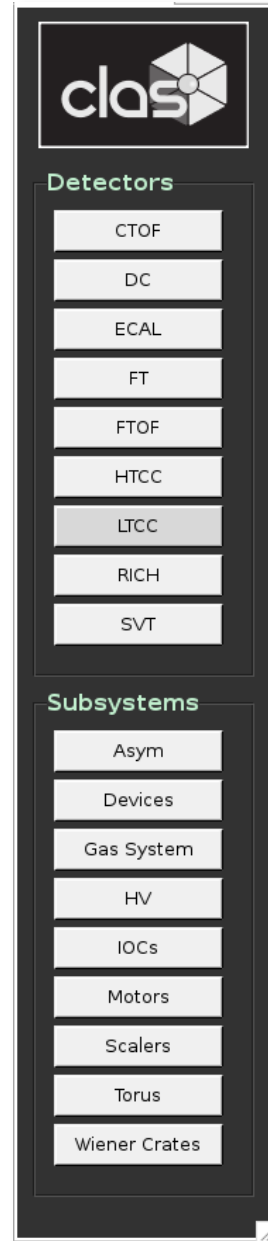
Figure 12:   View of the Hall-B EPICS main window.

The main RICH screen combines all basic RICH EPICS controls and monitoring into one window. It is accessible from the **RICH** button in figure 12. This includes embedded versions of the dedicated screens in the following sections: temperature sensors, air-cooling compressors, and low and high voltage.

This screen provides the only RICH *controls* shift workers should need, which is to turn HV on and off via the red and green **ALL ON** and **ALL OFF** buttons. However, this should be supplemented by the strip charts for temperature and HV current.

The buttons in the top of each section of this main RICH screen provide access to more detailed or expert screens for the corresponding subsystem.
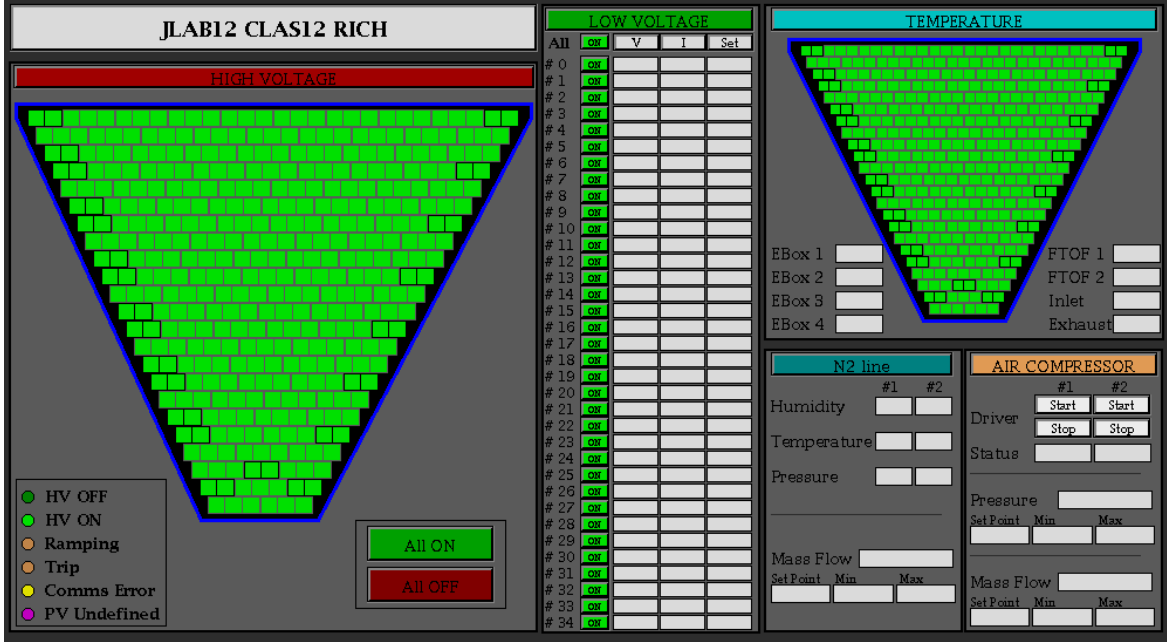

Figure 13: The primary EPICS screen needed for shift workers to monitor RICH.

4.2 Temperature Sensors

The RICH DAQ records the temperature of each of the 138 FPGA chips every few seconds. Several temperature sensors are placed in sensitive positions of the RICH enclosure and should be monitored through RICH's main EPICS screen and the strip charts shown in figure 14. The strip charts are accessible from the button in the temperature section of Figure 13.

Variations of two degrees F or more during a shift should be reported to RICH expert on call and noted in the log book.

4.3 Cooling System

The cooling allows to keep the RICH electronic panel at the constant temperature and should be ON at all times. In orther to prevent temperature stress on RICH components and adjacent detectors, an interlock prevent the HV and LV power to be active without a properly functioning cooling. As other gas systems in Hall-B, the cooling circuit is
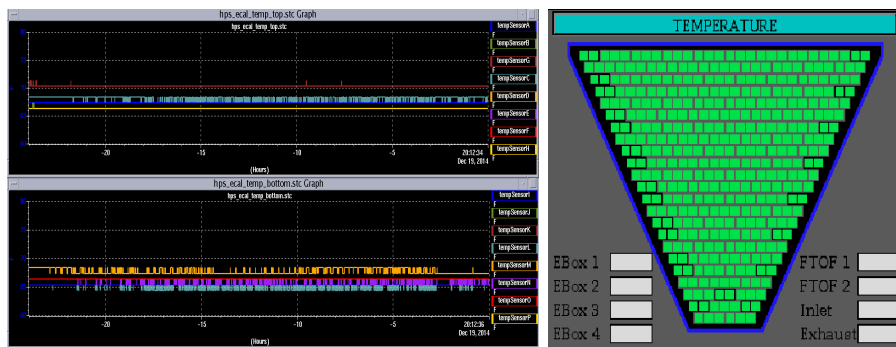
Figure 14: View of the EPICS temperature monitoring strip charts (left) accessible via the top button of the temperature portion of the main RICH EPICS screen (right).
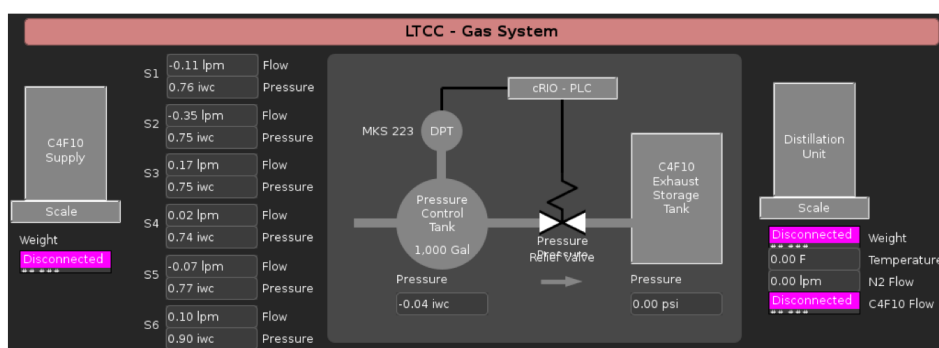

Figure 15: View of the epics window monitoring the LTCC gas line.

Figure 16: View of the air-cooling compressor (left), its control display (center) and the relative portion of the main RICH EPICS window (right).

controlled via a cRio device, see for reference the LTCC monitor in figure 15, and can be monitored through the EPICS controls (figure 16).

Shift takers should not attempt to change the cooling system settings and call RICH expert in case of problem.

4.4 Nitrogen Circuit

A clean and dry nitrogen atmosphere is required inside the RICH vessel to preserve the aerogel optical performace. The nitrogen circuit provides a clean and dry flow and should be ON at all times. As other gas systems in Hall-B, the nitrogen circuit is controlled via a cRio device and can be monitored through the EPICS controls (figure 13).

Shift takers should not attempt to change the nitrogel system settings and call RICH expert in case of problem.

4.5 Low Voltages

The low voltage supply of the RICH is controlled and monitored using the main RICH EPICS window (Figure 13). It has buttons to ramp up and down a single channel or the entire RICH LV voltages (labeled **ALL ON** and **ALL OFF**), open windows for individual channel setting (see for reference the Drift Chamber monitor in figure 17), and open more detailed expert views.

Figure 17: Cropped view of the EPICS LV control window for individual channels of the CLAS12 Drift Chambers.

Shift takers should follow the instruction under "RICH operations" to operate the RICH low voltages.

4.6   High Voltages

The high voltage supply of the RICH is controlled and monitored using the main RICH EPICS window (Figure 13). It has buttons to ramp up and down the entire RICH voltages (labeled **ALL ON** and **ALL OFF**), open windows for individual channel control, and open more detailed expert views.

Shift takers should follow the instruction under "RICH operations" to operate the RICH high voltages.

5 The RICH operation

The procedures to safely operate the RICH are under development and will be fully tested before entering the experimental hall. Here the preliminary versions are described.

5.1 Turning ON

The sequence of actions is

1. Check the air compressor status display on the main RICH EPICS window (Figure 13): at least one compressor should be ON, the pressure and mass flow measured values should be within the working range and close to the set values.

2. Check the temperature status display to exclude alarming conditions. The temperature indicate by the sensors should be within 5 degrees from the Hall-B temperature if the RICH was off for more than 1 day.

3. Turn ON the low voltages, either channel by channel or all together.

4. Check the temperature status display. The single chip and the sensors should increase in temperature and slowly reach an equilibrium. The sensor in the air circuit and at the TOF should all be below 40 degrees Celsius. The sensors within the RICH FEE box should be between 40 and 50 degrees Celsius. The single chip temperature should be between 50 and 60 degrees Celsius.

5. Turn ON the high voltages. All PMT should reach the working condition (green color) within about 1 minute.

5.2 Turning OFF

The sequence of actions is

1. Check the main RICH EPICS window (Figure 13) and note in the loogbok any non standard condition. In the temperature status display, the sensors in the air circuit and at the TOF should all be below 40 degrees Celsius. The sensors within the RICH FEE box should be between 40 and 50 degrees Celsius. The single chip temperature should be between 50 and 60 degrees Celsius. In the air compressor status display at least one compressor should be ON, the pressure and mass flow measured values should be within the working range and close to the set values.

2. Turn OFF the high voltages. All PMT should reach the idle state (grey color) within about 1 minute.

3. Turn OFF the low voltages, either channel by channel or all together.

4. Check the temperature status display. The temperature should start to slowly decrease. No chenge is expected in the pressure and in the mass flow of the cooling circuit.

5.3   HV Trips

In case of HV trips, the sequence of actions is

1. Check in the strip chart the last value of the current for the tripped channel and record it in the logbook, together with the time and channel ID.

2. Turn ON the channel, either with the single channel controls in the submenu or with the "All ON" button in the main EPICS window.

3. Monitor the current for at least 1 minute.

4. In case of unexpected behaviour or repeated trips, call the RICH expert.

5.4   LV Trips

In case of LV trips, the sequence of actions is

1. Check in the strip chart the last value of the current for the tripped channel and record it in the logbook, together with the time and channel ID.

2. Check in the strip chart the last temperature value for the tripped channel and record in the loogbok.

3. Turn ON the channel, either with the single channel controls in the submenu or with the "All ON" button in the main EPICS window.

4. Monitor the current and temperature for at least 1 minute.

5. In case of unexpected behaviour or repeated trips, call the RICH expert.