# 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 at a $4\,\sigma$ level in the momentum range between 3 and 8 GeV/c for polar angles up to $35^o$. 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.
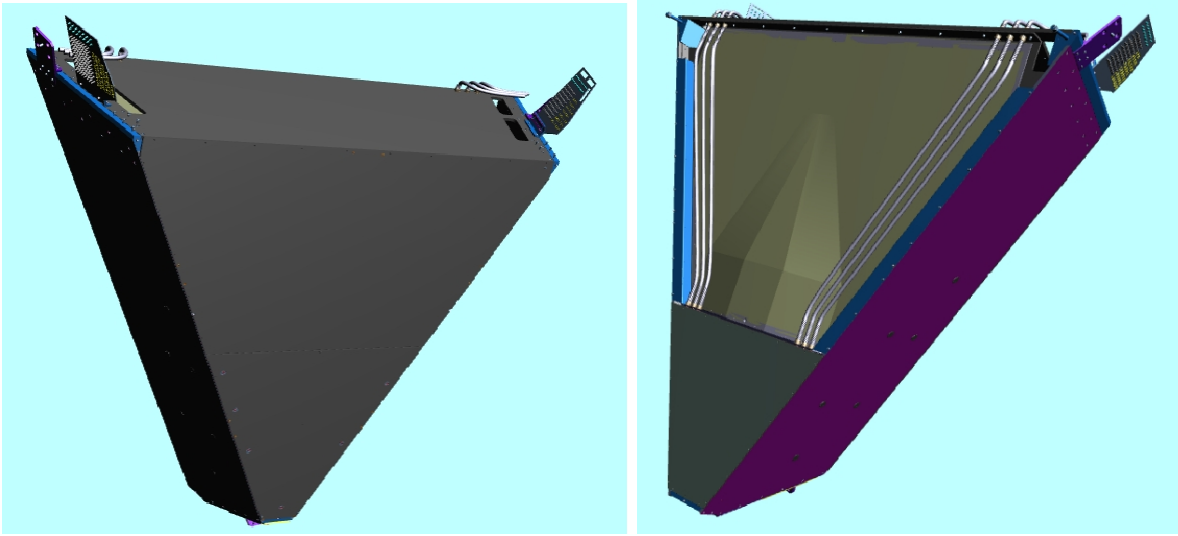
Figure 1: Back and frontal drawings of the RICH module.

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

- the aerogel radiator;

- the planar and spherical mirrors;

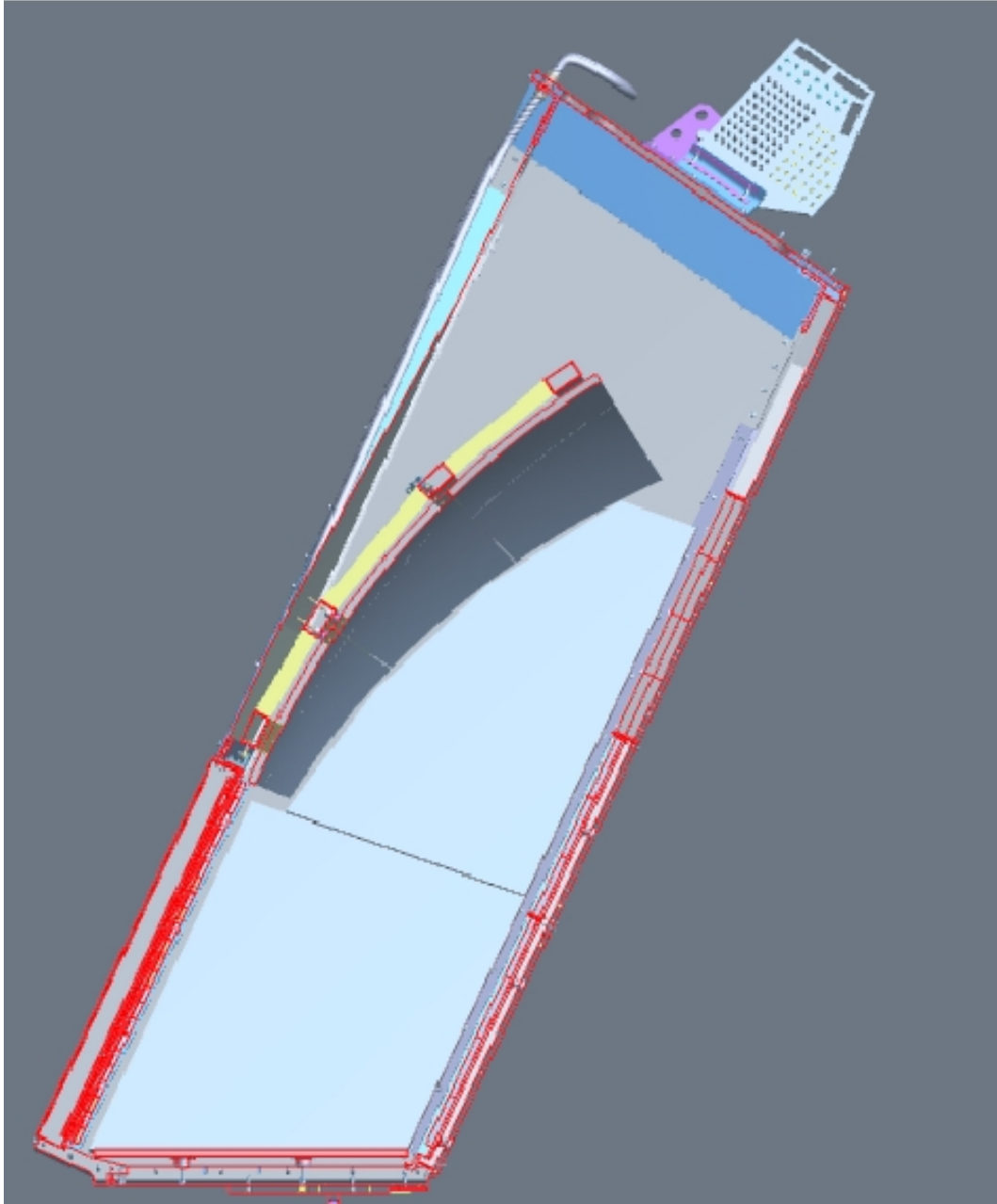- the MAPMTs and the readout Front-End Electronics (FEE).

Figure 2: Cross section of the RICH.

A cross section of the RICH showing the inner elements in 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 3 MAPMT case. There are 23 tiles with 2 MAPMTs and 113 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 the ASIC board and the interface with the DAQ via optical link.
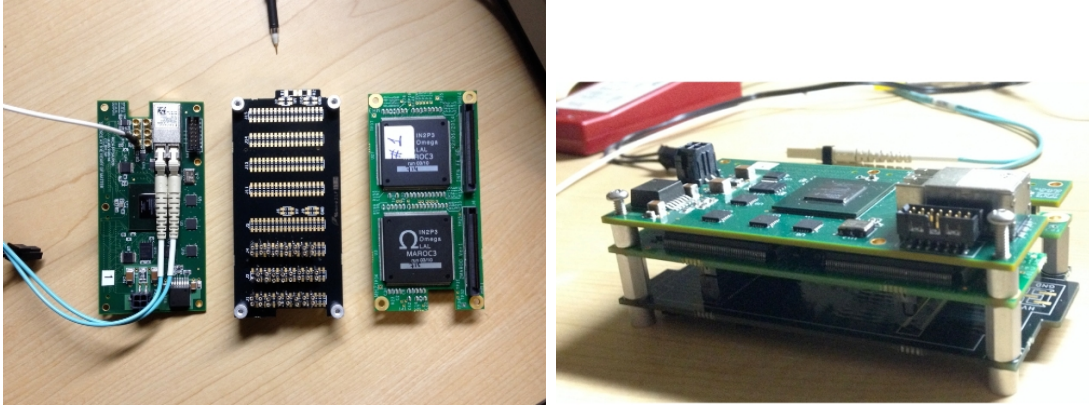


Figure 3:   The RICH electronic boards for the 2 MAPMT case (left) and the tile fully assembled (right).

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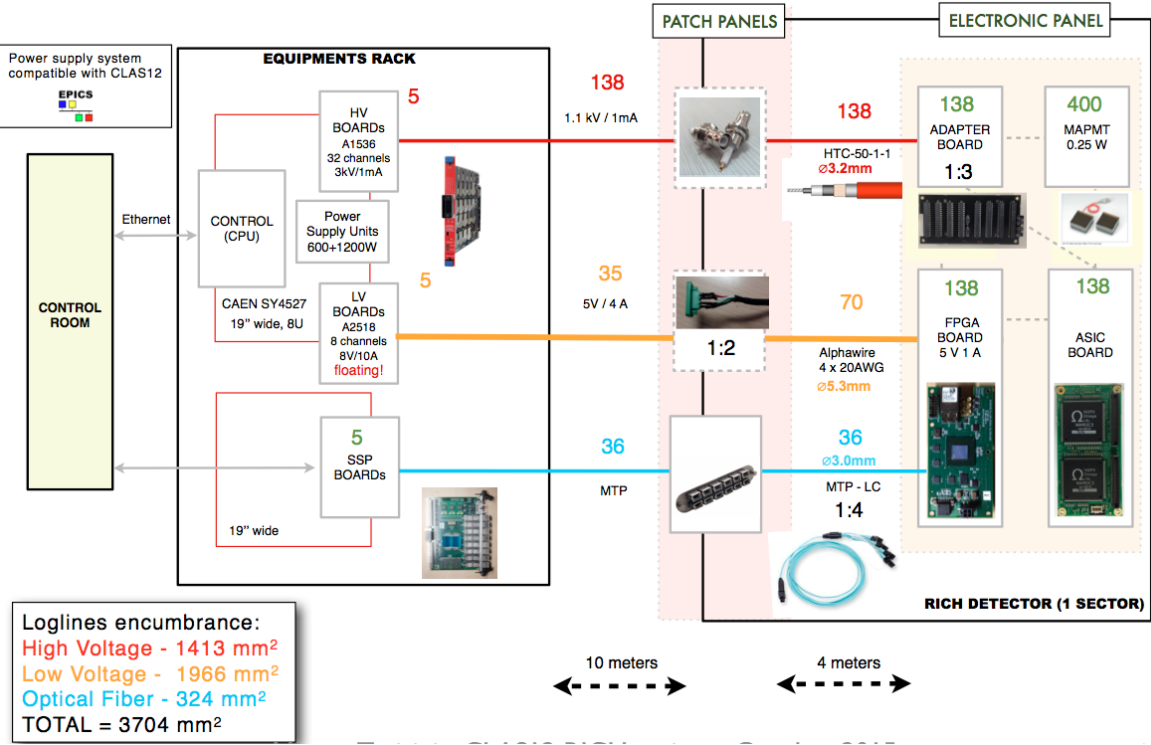
Figure 4: Sketch of the RICH services: LV, HV supply lines and DAQ optical link.

## 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 30 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
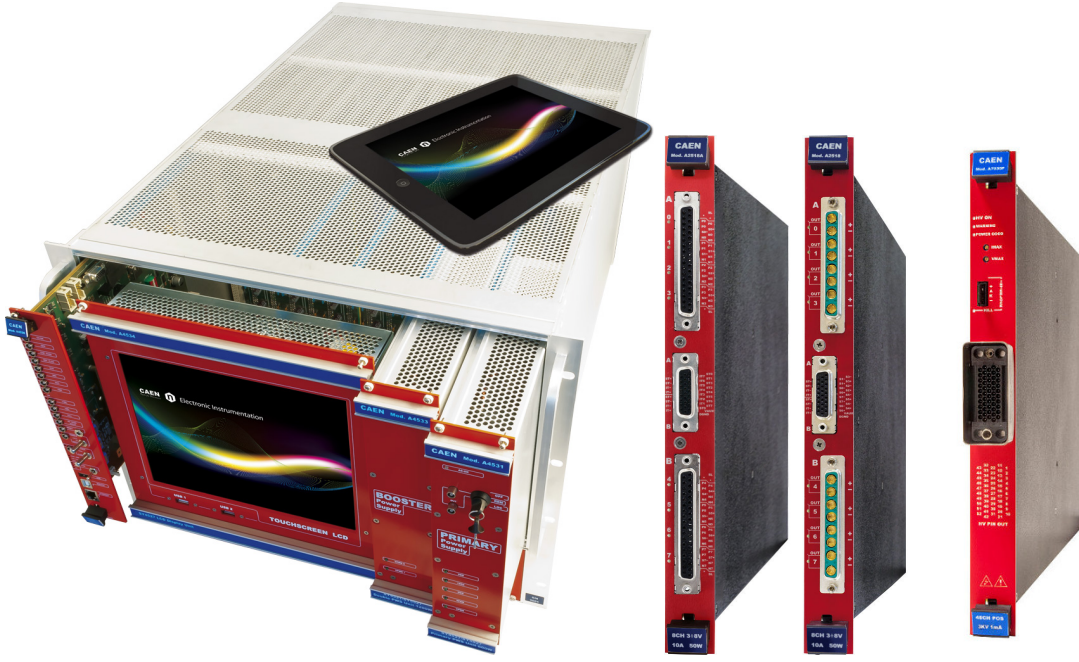
Figure 5:  The CAEN SY4527 power supply.

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.

The low voltage power supply is an Agilent 6621. It should be set with both channels at +5V with their current limits at 6 A, while external wiring inverts one channel to create a bipolar ±5V supply. The low voltage supply might have difficulties to get to full voltage because of high current. If that was the case check, with all power supplies off, that all connection are goods. Then contact run coordinator to see if LV power supply addition is possible.

# 3    The RICH Gas Systems

The RICH is serviced 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 software. The two systems have been dimensioned in such a way that they will be able to serve two RICH modules.

## 3.1    Nitrogen Purge System

In order to preserve the aerogel optical performance, the RICH box environment 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 prevents from the contamination from the outside air. The system is shown in Fig. 14. 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 to remove all the impurities and flow-meters. In figure 7, we report the list of the components of the system.
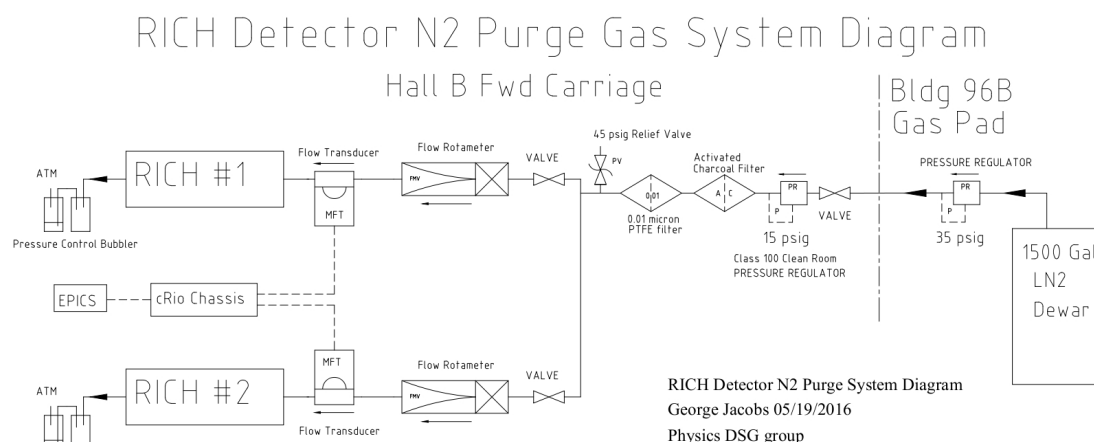


Figure 6: Schematic of the nitrogen supply system.

| 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.

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

- Minimum pressure in the liquid nitrogen dewar;

- Minimum flow inside the RICH box;

- Purity of the gas fluxed inside the RICH box.

In the case of failure of the purity control, the valve is automatically turned off and the flow stopped, to prevent possible damage to the aerogel.

## 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 514 W. This heat load must be dissipated far from the CLAS12 detectors in order to keep the FEE box temperature below 40 $^oC$, 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 is reduced to supply manual valve flow meters. 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.

| Dimensions | 1.4 x 0.7 x 1.8 m$^3$ |
|---|---|
| Weight | 515 kg |
| Max Flow rate | 1200 l/min |
| Dew point | 3 $^oC$ |
| 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 8 and the list of its components is reported in figure 9. It includes a number of temperature sensors installed inside the electronics box, air flow transducers and high purity pressure regulators connected to the inlets and a local pressure regulators 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.

# 4  The RICH monitors

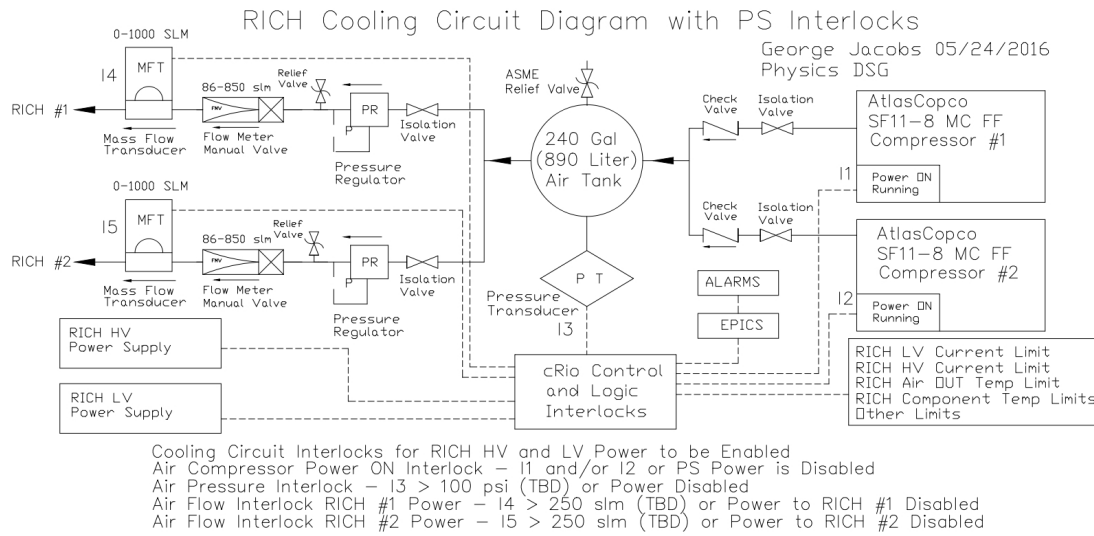In this section, we illustrate the general scheme for the RICH operation and monitor controls.

Figure 8: Schematic of the cooling system and interlocks.

| 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 9: Complete list of the components of the cooling system and interlocks.

## 4.1 RICH EPICS



All RICH controls will be accessible through EPICS, from the main CLAS_EPICS window (figure 10). If not already running, it can be opened by executing the command

```
clas_epics
```

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 **??** and opened via the **RICH** button in the right side of the main CLAS EPICS screen (figure 10).
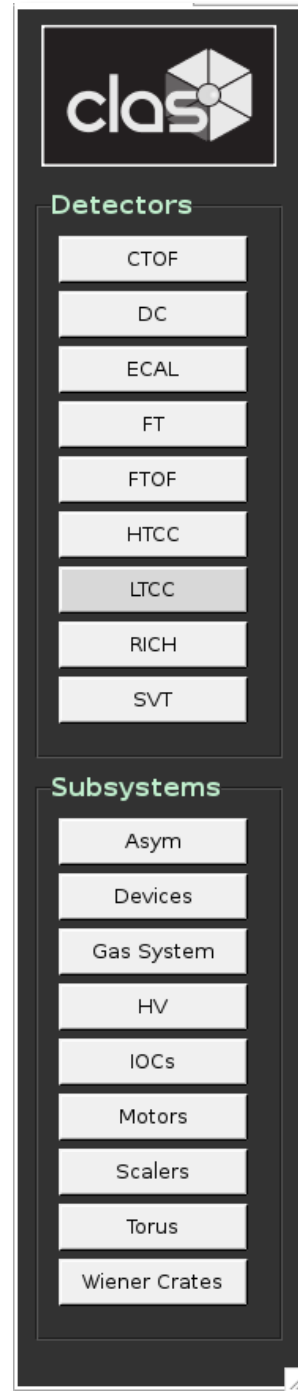
Figure 10: View of the Hall-B EPICS main window.
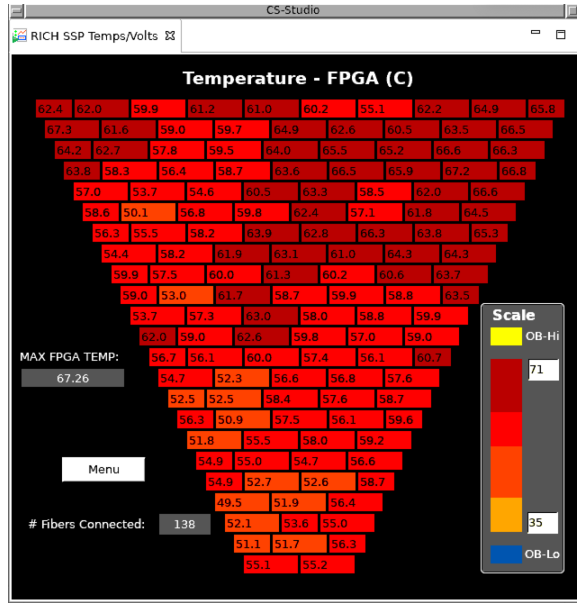
Figure 11: RICH FPGA temperature in $C$.
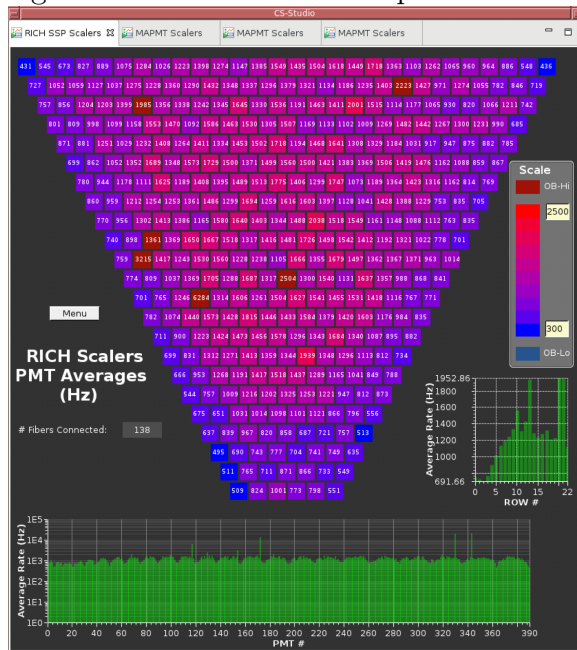


Figure 12: Average MAPMT's pixels in Hz.

The main RICH screen combines all basic RICH EPICS controls and monitoring into one window. It is accessible from the **RICH** button in figure 10. This includes embedded versions of the dedicated screens in the following sections: temperature sensors, air-cooling compressors, nitrogen purge system 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.

## 4.2 Main Slow Control RICH Screens

The RICH DAQ records the temperature of each of the 138 FPGA chips every few seconds. The normal RICH temperature map is presented in Figure **??**. The average over 64 pixels of the MAPMT rate is presented in Figure **??**. The maximum temperature is under EPICS control. The RICH alarm will go off in case the temperature will be go over 75C, that is software

## 4.3 Air 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 controlled via a cRio device and can be monitored through the EPICS controls (figure 13). Shift takers should not attempt to change the cooling system settings and call RICH expert in case of problem.
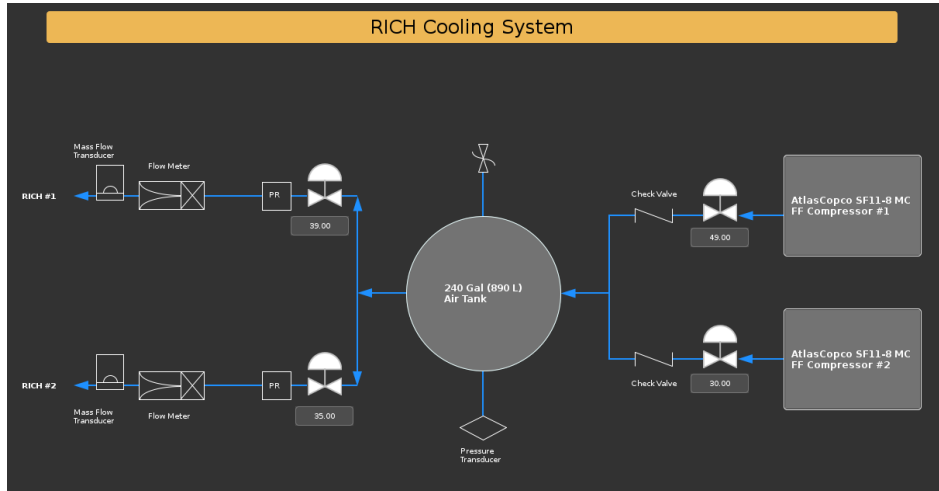


Figure 13: RICH air cooling system control.

## 4.4 Nitrogen Purge System

In order to preserve the aerogel optical performance, the RICH box environment must be kept dry by fluxing nitrogen. The EPICS control screen is shown on Fig. 14.
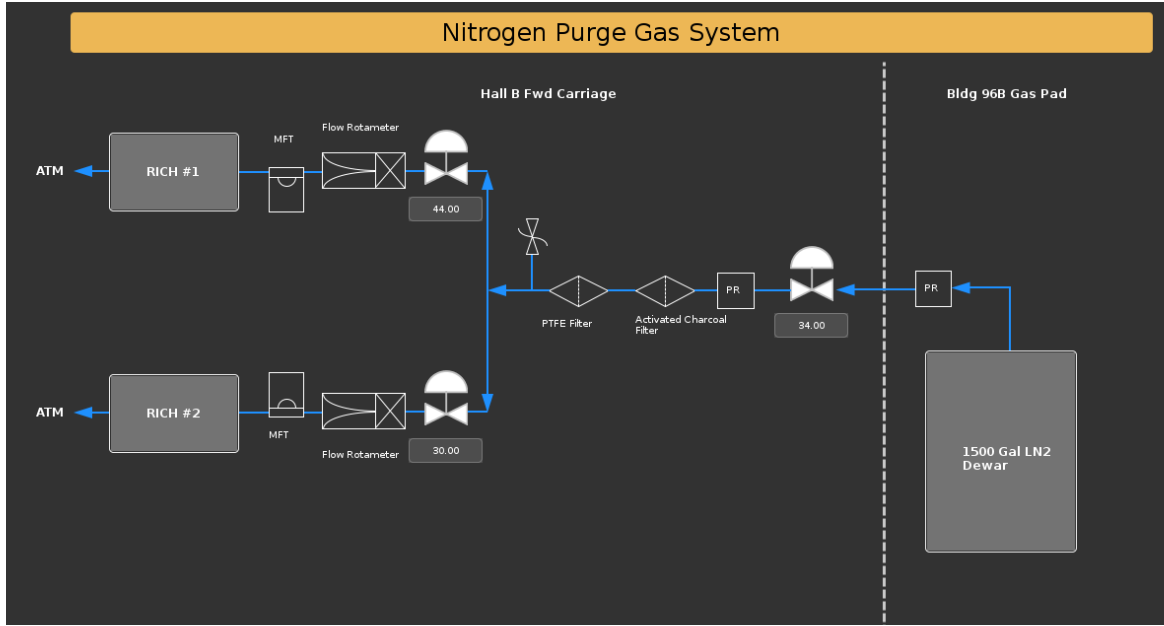
Figure 14:  RICH nitrogen supply system control.

## 4.5   Low Voltage Control

The low voltage supply of the RICH is controlled and monitored using the main RICH EPICS window (Figure  **??**).  It has buttons to ramp up and down the entire RICH voltages (labeled **ALL ON** and **ALL OFF**), open windows for individual channel control (see figure 15), and open more detailed expert views.



Figure 15:  Cropped view of the EPICS LV control window for individual channels of the RICH detector.

## 4.6   High Voltage Control

The high voltage supply of the RICH is controlled and monitored using the main RICH EPICS window (Figure  **??**).  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 (see Fig. 16).

| Description | Pw | Vmon | Imon | Status | Vset (V) | | Iset (uA) | | Vmax (V) | | Up (V/s) | | Down (V/s) | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| HV_ROW1_PANEL1 | ON | 100.00 | 5.30 | ON | 100.00 | 100 | 5 | 5 | 200 | 200 | 10 | 10 | 14 | 15 |
| HV_ROW1_PANEL2 | ON | 101.00 | 5.20 | ON | 101.00 | 100 | 5 | 5 | 199 | 200 | 10 | 10 | 15 | 15 |
| HV_ROW1_PANEL3 | ON | 103.00 | 5.20 | ON | 103.00 | 100 | 5 | 5 | 201 | 200 | 10 | 10 | 15 | 15 |
| HV_ROW1_PANEL4 | ON | 101.00 | 5.00 | ON | 100.00 | 100 | 5 | 5 | 202 | 200 | 10 | 10 | 15 | 15 |
| HV_ROW1_PANEL5 | ON | 102.00 | 4.99 | ON | 102.00 | 100 | 5 | 5 | 202 | 200 | 10 | 10 | 15 | 15 |
| HV_ROW1_PANEL6 | ON | 100.00 | 5.00 | ON | 100.00 | 100 | 5 | 5 | 201 | 200 | 9 | 10 | 14 | 15 |

Figure 16: Cropped view of the EPICS HV control window for individual channels of the RICH detector.