Manual for CLAS12
Ring Imaging Cherenkov Counter

RICH On-Call Cell Phone: 757-810-1489
Authors:
M. Contalbrigo (mcontalb@jlab.org)
V. Kubarovsky (vpk@jlab.org)
M. Mirazita (mirazita@jlab.org)

May 27, 2016

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 σ 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.

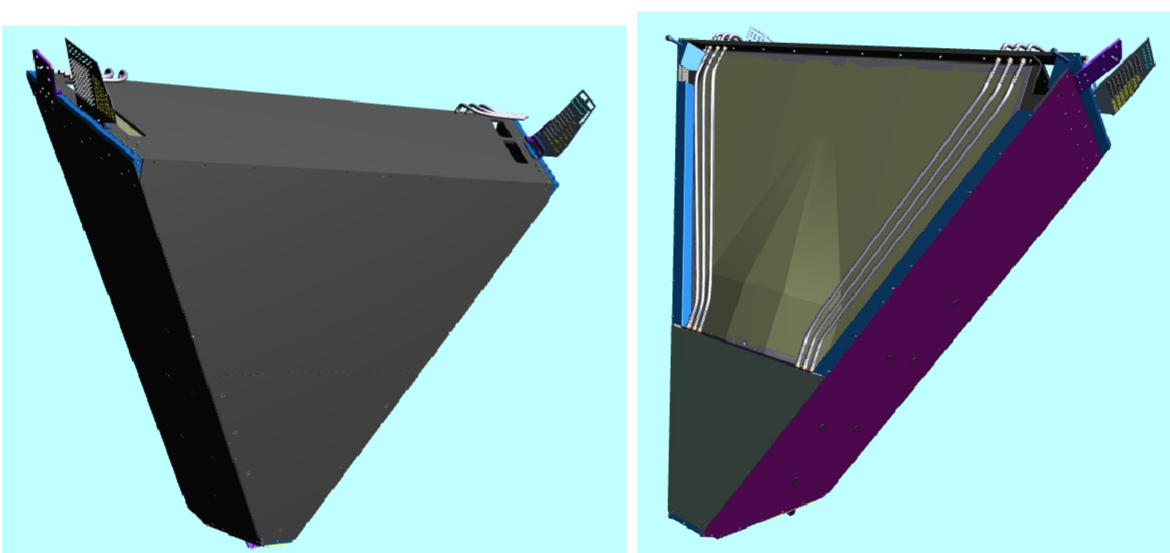


Figure 1: Back and frontal drawings of the RICH module.

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).

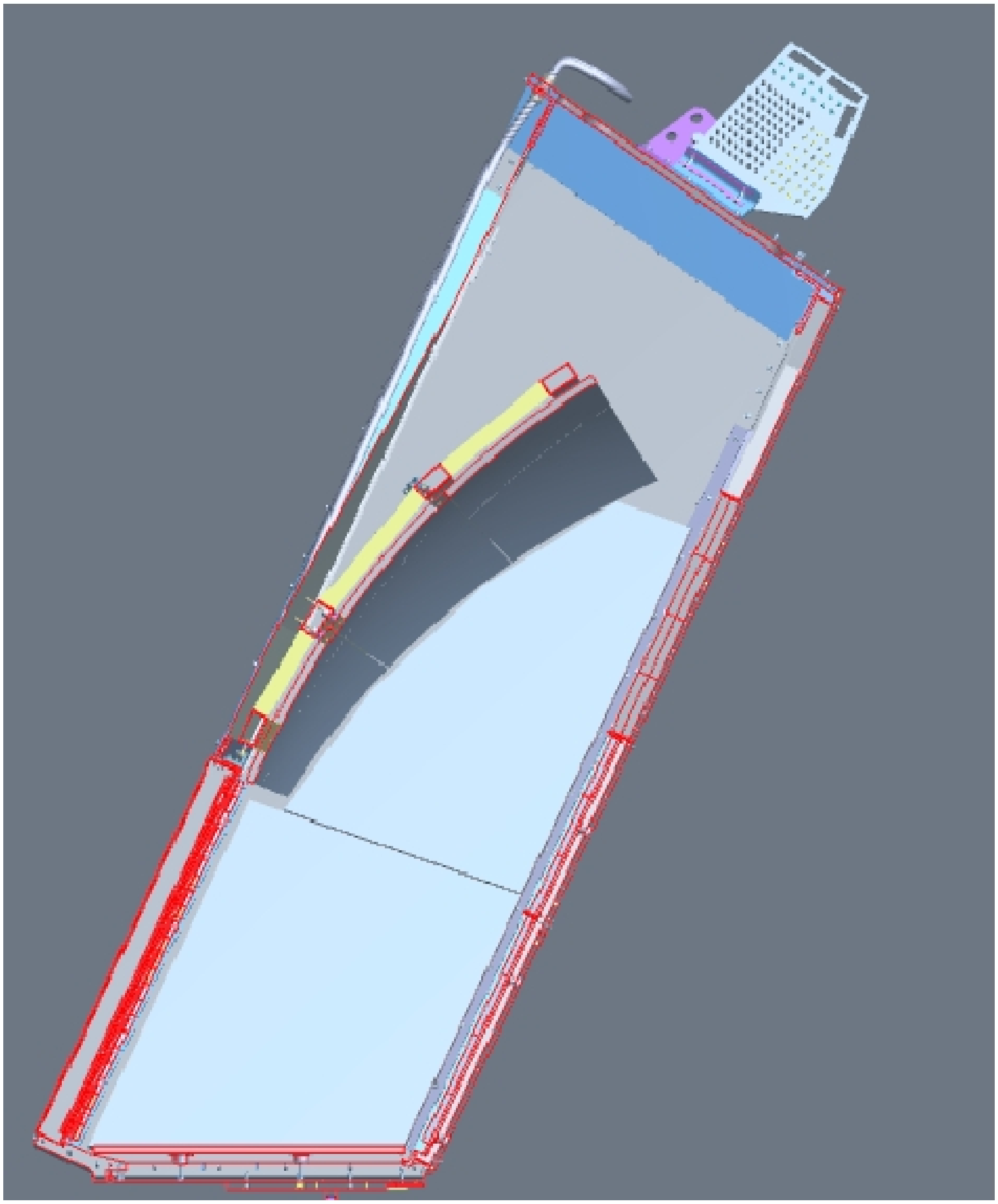


Figure 2: Cross section of the RICH.

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 Hamamatsu H8500 and H12700 MAPMTs, 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. The FEE is organized in tiles serving groups of two or three MAPMTs. Each tile is composed by an adapter board, an ASIC board housing the MAROC3 chip for the MAPMT readout and an FPGA in charge to configure the chip and to ensure the connection with the DAQ systems via optical link. There is one MAROC3 chip per MAPMT and one FPGA per tile. The total number of tiles is 138.

2 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.

2.1 The Nitrogen 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 6 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. 3. 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 4, we report the list of the components of the system.

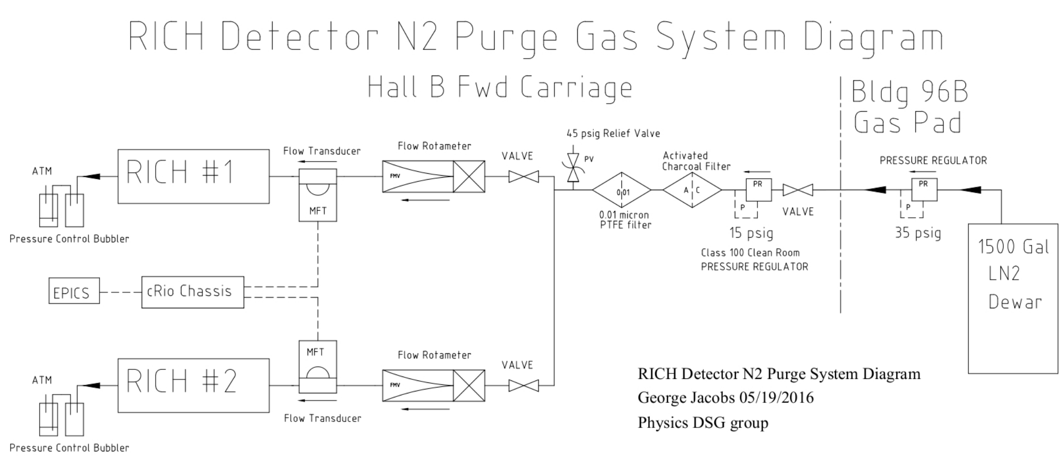


Figure 3: Schematic of the nitrogen supply system.

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

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 4: Complete list of the components of the nitrogen supply system.

- 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.

2.2 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 ^{o}C, 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 minimum capacity of each compressor must be 600 l/min, 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 ^{o}C
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 5 and the list of its components is reported in figure 6. 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.

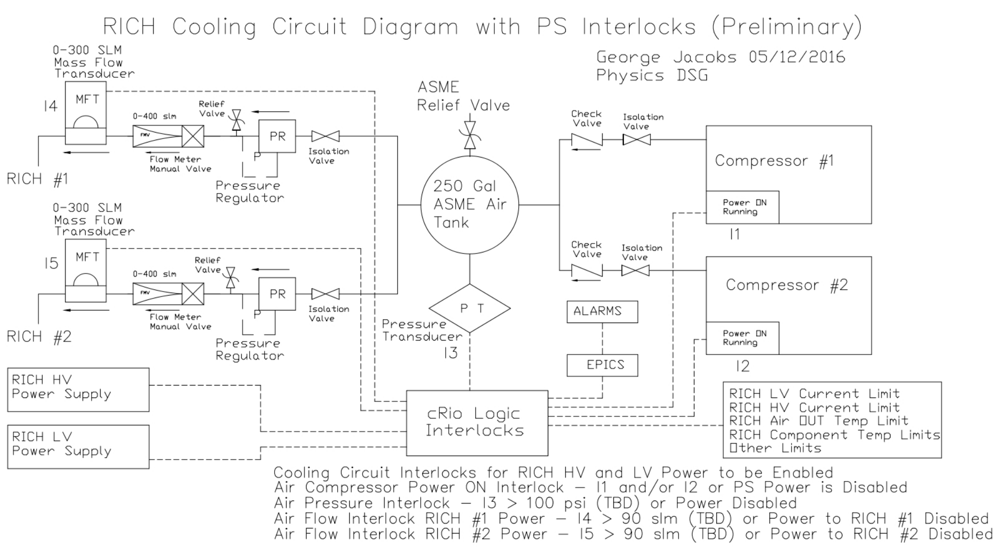


Figure 5: Schematic of the cooling system and interlocks.

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 6: Complete list of the components of the cooling system and interlocks.

Part I
Shift Takers Instructions

All RICH controls will be accessible through EPICS, from the main CLAS_EPICS window (figure 7). 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 8 and opened via the **RICH** button in the right side of the main CLAS EPICS screen (figure 7).

From the main CLAS_EPICS window you can also access individual screens with more controls and details, **Temperature monitoring** in *Miscellaneous* then *RICH Temperature*, the **RICH chiller** in *Devices* then *Chiller (RICH)*, the **Scalers** in *RICH Scaler GUI*, the **RICH high voltage** in *Voltages* then *RICH HV*.

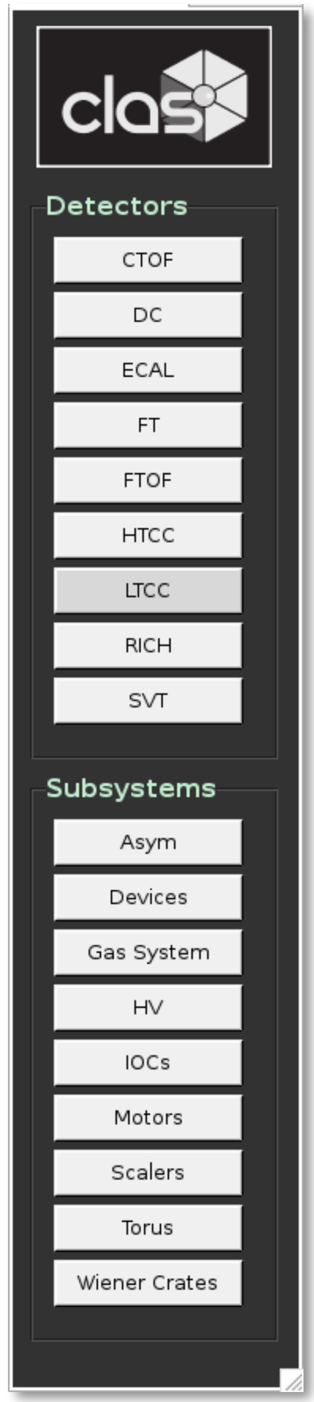


Figure 7: View of the Hall-B EPICS main window.

3 Primary RICH EPICS Screen

This one screen combines all basic RICH EPICS controls and monitoring into one window. It is accessible from the **RICH** button in figure 7. This includes embedded versions of the dedicated screens in the following sections: temperature sensors, chiller, 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, as well as cctv webcams, for additional *monitoring* in the following sections.

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

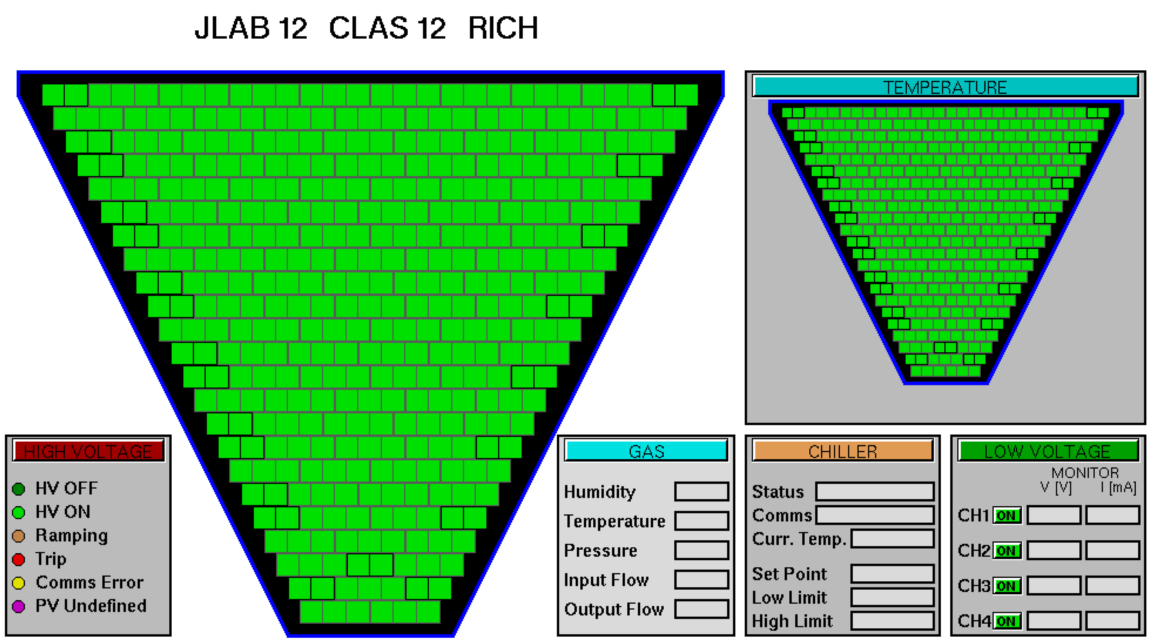


Figure 8: The primary EPICS screen needed for shift workers to monitor RICH.

4 Temperature

The RICH temperature should remain stable. Cooling controls and monitoring are described in this section.

4.1 Temperature Sensors

Eighteen temperature sensors are placed in the RICH enclosure and should be monitored through RICH's main EPICS screen and the strip charts shown in in figure 9. Variations of two degrees F or more during a shift should be reported to RICH expert on call and noted in the log book. The strip charts are accessible from the two buttons in the temperature section of Figure 8 (and also the main CLAS_EPICS screen in Figure 7).

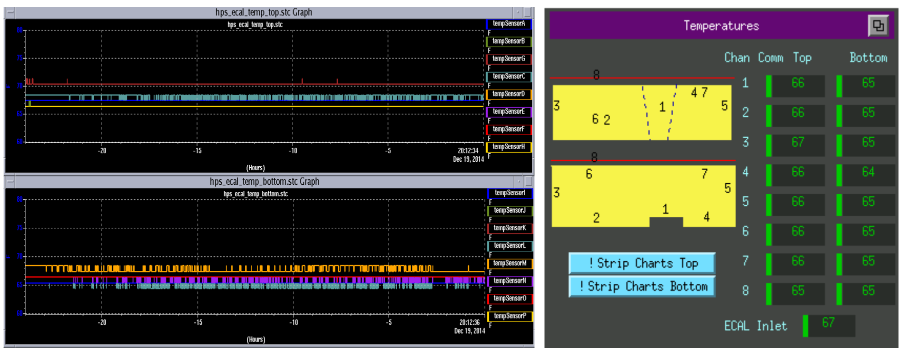


Figure 9: View of the EPICS temperature monitoring strip charts (left) and the temperature portion of the main RICH EPICS screen (right).

4.2 Cooling System

The cooling allows to keep the calorimeter at the constant temperature and should be ON at all times. The cooling system can be monitored through its webcam and EPICS controls (figure 10). Shift takers should not attempt to change the cooling system settings and call RICH expert in case of problem. The webcam is accessible in a web browser via the url `cctv10.jlab.org` and the "Monitoring" tab on the **CLAS Run Wiki**.

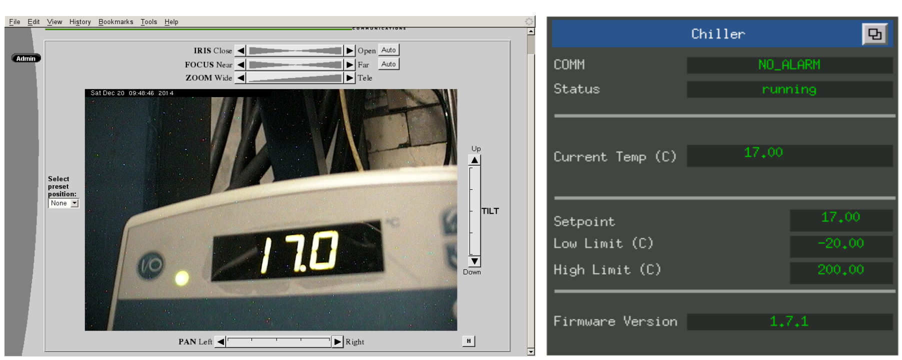


Figure 10: View of the chiller's `cctv10.jlab.org` webcam (left) and its portion of the main RICH EPICS window (right).

5 Low Voltage

The low voltage power supply must be on before HV is turned on, and changing its settings requires contact with an RICH-expert.

LV should be monitored using its webcam and its portion of the main RICH EPICS screen (both shown in figure 11). Call the RICH expert if this appears not to be ON or shows an abnormal current for either of its two channels. *Normal current is between 4.0 and 4.2 A for both channels.* This webcam is accessible via the url `cctv11.jlab.org` in a web browser and the "Monitoring" tab on the main **HPS Run Wiki**.

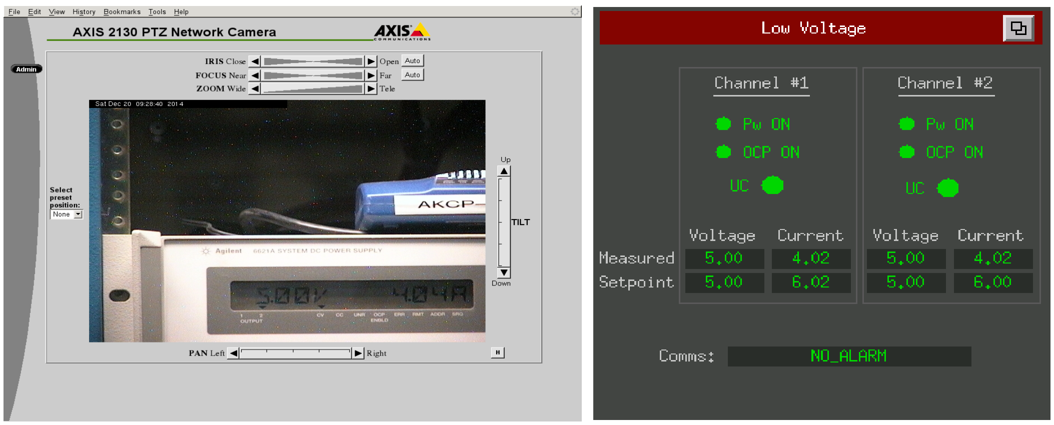


Figure 11: View of the LV suuply by webcam (`cctv11.jlab.org`) and its portion of the main RICH EPICS screen.

6 High Voltage

6.1 Turning ON/OFF High Voltages

The high voltage supply of the RICH is controlled and monitored using the main RICH EPICS window (Figure 8). It has buttons to ramp up and down the entire calorimeter's high voltages (labeled **ALL ON** and **ALL OFF**), open windows for individual channel control (figure 13), and open more detailed expert views (e.g. figure 16).

6.2 HV Current Monitoring

Individual channels' currents can be monitoring in figure 13, and strip charts should be open for long term monitoring. The strip charts are accessible from the main RICH screen (figure 8) under the HV sections' **Monitors** button (and also from the HPS_EPICS screen (figure 7) via the **Strip-Tool** button). An example is shown in figure 12. Jumps or drifts in current of more than 1 A should be noted in the logbook.

6.3 Responding to HV trips

HV problems, in particular trips, are indicated by a red group in the main RICH EPICS GUI (figure 8). HV trips will also be announced by the alarm handler. During normal

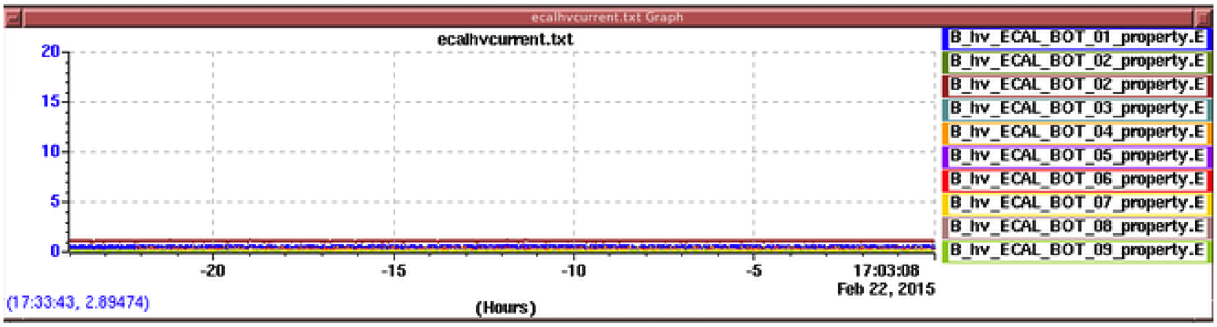


Figure 12: HV Current strip charts.

operations with HV ON, there should be no red groups in Figure 8 and no RICH HV alarms. In case of an HV trip, or a red region in Figure 8:

- Try to reenable the tripped HV group by turning it back on in the EPICS HV control screen (figure 13) accessed via the **Controls** button in the main RICH EPICS screen (Figure 8). (An easier alternative is just pressing the **ALL ON** button in the main RICH EPICS screen.)
- Record the trip in the log book with precise indication of the group and run number concerned.

Contact the RICH expert on-call in case of uncertainty.

Note, the HV can take up to 3 minutes to turn back on so you should end the current run and begin a new one when the high voltage is back on. If you cannot get a HV group to work contact the RICH expert on call.

If you encounter more than two HV trips during your shift for the same group, you should notify the RICH Expert.

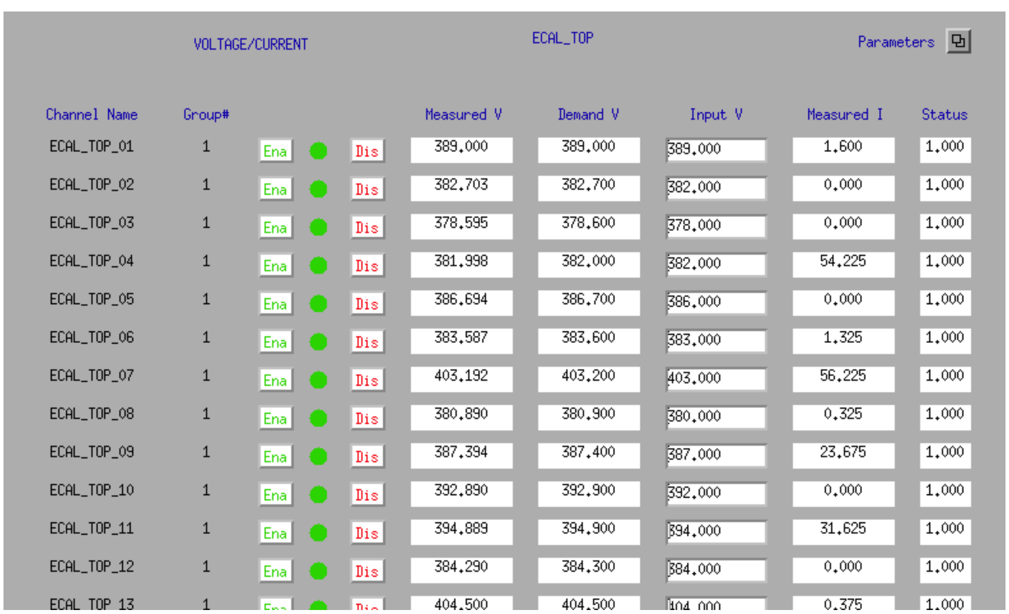


Figure 13: Cropped view of the EPICS RICH HV control window for individual channels.

7 Scalers

Rates seen by the RICH are available in the ROOT-based GUI shown in Figure 14, which represent the rates as seen by the RICH electronics. This display is accessible via the main CLAS_EPICS window under the **RICH Scaler GUIs** button, and also by running the command `clas_rich_scalers` in a terminal.

These numbers should all remain constant within ~10% during stable beam operation. A strong increase is the indication of bad beam conditions or the presence of a new source of noise in the RICH system. If the latter case, please contact RICH expert on call.

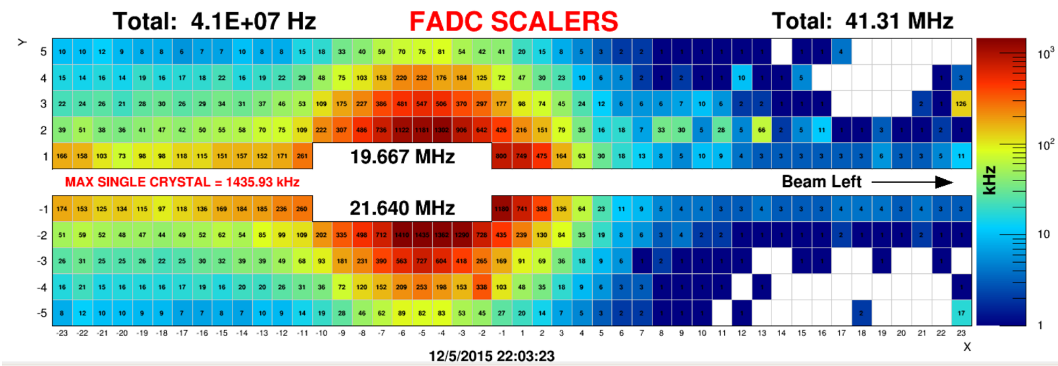


Figure 14: View of the EPICS RICH scalers window.

8 Strip Charts

The most import quantities to monitor with strip charts are temperature and HV current. The MyaViewer (which adds the ability to retrieve archive information) can be run by executing the following scripts in a terminal:

- `mya_rich_all.sh`
- `mya_richl_temp.sh`
- `mya_rich_curr.sh`
- `mya_rich_voltage.sh`

9 Monitoring App

The hps-java monitoring app is used to run full calorimeter reconstruction on live events from the daq on the ET ring. It provides many plots to assess detector performance. To start the monitoring app, in a terminal run:

```
startRICHMonitoring
```

Then click the "connect" button to connect to the ET ring.

At the start of every run, the monitoring app should be disconnected and reconnected to the ET ring. After a few minutes of beam, the tabs should be cycled through and their plots compared to the reference. Once sufficient statistics are accumulated, the plots should be saved as a pdf and uploaded to the logbook.

Part II
RICH Experts Resources

10 Cooling system

High capacity air compressors supply clean dry air at room temperature to cool the electronics package inside the detector. The plan is to have 2 compressors in parallel charging a 1000 liter capacity air tank. Air pressure is reduced to supply manual valve flow meters, one per detector. In the case of a power outage, the air tank should contain sufficient air to remove the latent heat of the electronics package.

Powering up the electronics package inside the RICH without cooling may result in severe damage or fire. Interlocking RICH HV and LV power supply operation to proper cooling circuit operation eliminates this hazard. The interlocks perform two functions in the case of a cooling system fault

- Turn off power to the electronics package.
- Prevent energizing the electronics package.

There are 3 cooling circuit interlocks.

- Air Compressor Operation: minimum one compressor operating.
- Minimum Air Pressure in Tank.
- Minimum Cooling Air Flow.

All three interlocks must be true in order for the electronics package to have power.

The cooling system can be controlled through EPICS (10).

10.1 Rebooting the Cooler system After Power Failure

If the cooler system loses power while in local mode, the "power" button must be pressed manually to restart it after power is restored. In case it loses power while in remote mode, a procedure is necessary to reset it after power is restored:

1. Hold the "up" and "down" arrow buttons simultaneously for 10 seconds.
2. Press the "computer" button to go into local mode.
3. Press the "power" button to turn it off.
4. Press the "power" button to turn it on.
5. Press the "computer" button to return to remote mode.

10.2 Restarting the Cooler System IOC

Chiller IOC runs in "procserv", a wrapper that automatically runs and restarts services and provides access to them via telnet. To restart the chiller's IOC:

1. '`softioc_console iocchiller`' and type user's password if necessary.
2. '`ctrl-x`' to restart the IOC

3. `ctrl-]` to quit to telnet
4. `quit` to exit telnet

Don't leave a terminal open connected to this telnet session.

10.3 Restarting the Temperature Monitoring IOC

Thermocouples are used to monitor the temperature inside and outside the calorimeter. To restart the IOC that reads these:

1. `softioc_console ioctempSens` and type user's password if necessary.
2. `ctrl-x` to restart the IOC
3. `ctrl-]` to quit to telnet
4. `quit` to exit telnet

Don't leave a terminal open connected to this telnet session.

11 LV Supply

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.

11.1 Changing LV Settings

The LV supply can be controlled via its EPICS expert screen (figure 15), accessible from the grey button in the top right of the LV section of the main ECAL EPICS screen (figure 8). In general the only necessary changes are powering on/off, while voltage and current setpoints are never changed from 5V/6A.

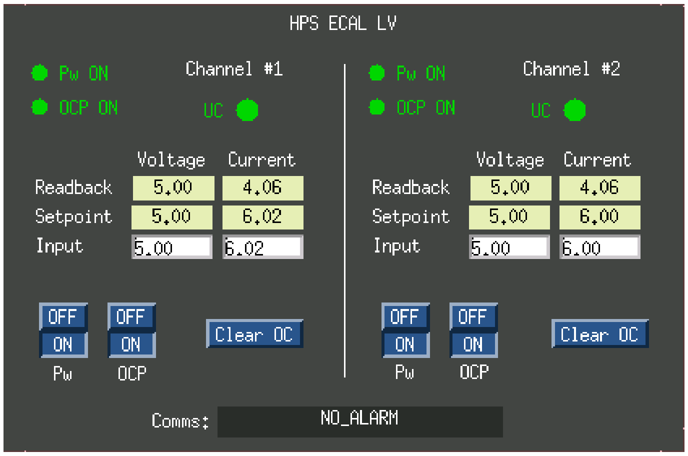


Figure 15: The LV expert EPICS screen in normal operation.

Note, as a safeguard, if one currently tries to use EPICS to set the voltage greater than 5 V or the current greater than 6 A, the request will be ignored by the IOC. Overriding these limits can currently only be done either via local control (Section 11.1.1), or by setting new values for the limits via `caput`. The corresponding PVs are:

- `HPSECALLV:i1set:DRVH`
- `HPSECALLV:i2set:DRVH`
- `HPSECALLV:v1set:DRVH`
- `HPSECALLV:v2set:DRVH`

11.1.1 Local Operation

The LV supply can also be controlled manually in the hall via buttons on its front panel. However, when in remote mode (denoted by the “RMT” marker in its LCD display), local operations require pressing the “LCL” button first, then quickly pressing the desired operation button before remote mode is automatically reenabled by the IOC. Completely disabling this “feature” requires stopping the IOC (see section 11.3).

11.2 Restarting the LV IOC

To restart the IOC:

1. ‘`softioc_console iocA6621`’ and type user’s password if necessary.
2. ‘`ctrl-x`’ to restart the IOC
3. ‘`ctrl-]`’ to quit to telnet
4. ‘`quit`’ to exit telnet

Don’t leave a terminal open connected to this telnet session.

11.3 Disabling the LV IOC

To disable the IOC:

1. ‘`softioc_console iocA6621`’ and type user’s password if necessary.
2. ‘`ctrl-t`’ to toggle auto-restart
3. ‘`ctrl-x`’ to kill the IOC
4. ‘`ctrl-]`’ to quit to telnet
5. ‘`quit`’ to exit telnet

Don’t leave a terminal open connected to this telnet session.

12 High Voltage

12.1 Restarting the HV IOC

Occaissonaly the soft IOC for the HV needs to be manually restarted. Symptoms of this condition include errors messages from EPICS when trying to turn on/off voltages and white blocks in the main HV screen (figure 16).

To restart the IOC:

1. '`softioc_console iocecalVoltages`' and type user's password if necessary.
2. '`ctrl-x`' to restart the IOC
3. '`ctrl-]`' to quit to telnet
4. '`quit`' to exit telnet

Don't leave a terminal open connected to this telnet session.

Note, this IOC always needs to be restarted if the HV CAEN mainframe is power cycled.

12.2 Changing HV Settings

NOTE: Changing voltage settings should be taken care of in coordination with the RICH group.

NOTE: The RICH HV groups were renumbered for EPICS, and the correspondence map will be available in the expert RICH HV monitoring window (Figure 16) via the "Expert HV Map" button.

12.2.1 HV Save/Restore

A system to save and restore the entire RICH's voltage settings is available via buttons in the RICH HV expert window in Figure 16. If the voltage setpoints are changed, a backup should be made of the new settings. This must be run as a user in group `clas-4`; user `hpsrun` does not have sufficient priveleges to save/restore voltage settings. An example of the restore window is shown in figure 18, which is accessible from the HV expert screen shown in Figure 16.

12.3 Long Term HV monitoring

An hourly snapshot of HV currents is stored by a cron job (and in the EPICs and MYA databases). Currently the easiest way to view it is as user `clasrun` on `clonpcNN` by excuting the command:

```
$HOME/.ecalhv/plotRICHHV.py
```

The product should be a plot like figure 19.

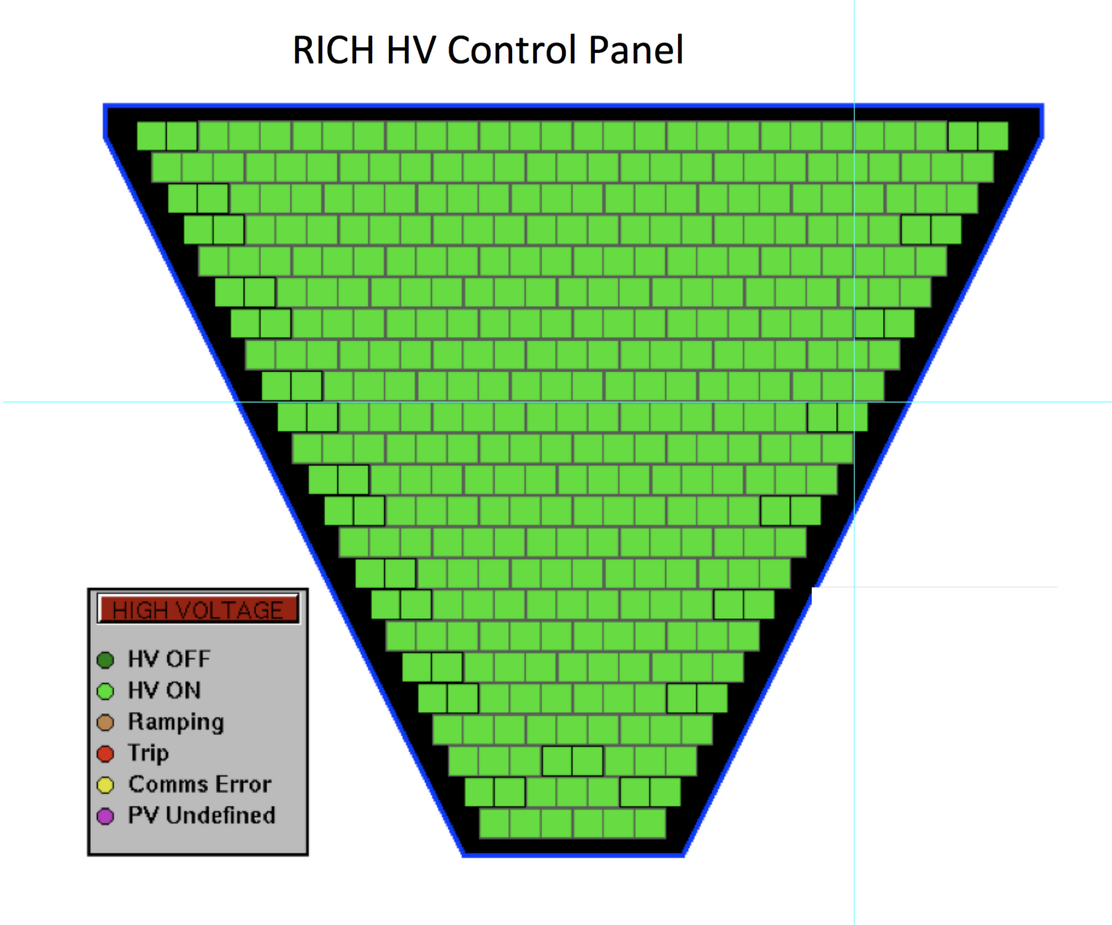
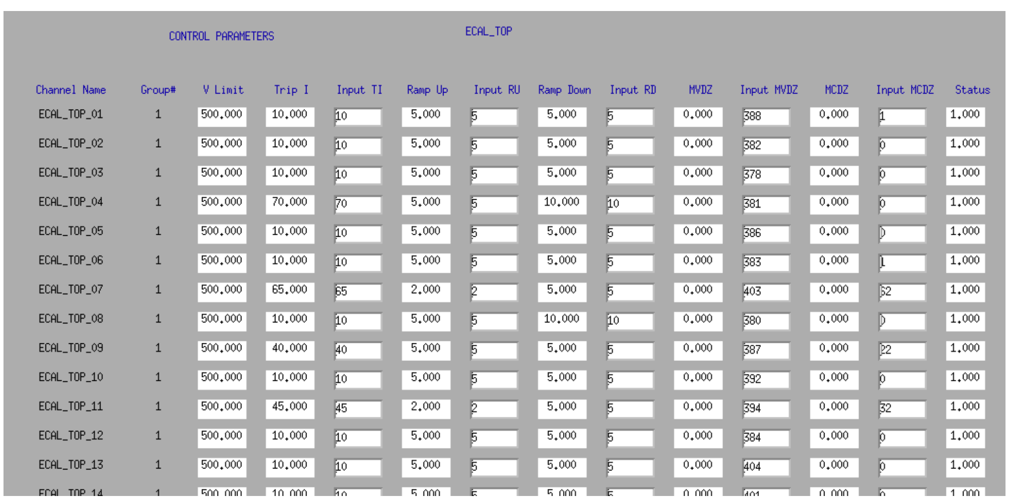


Figure 16: View of the EPICS RICH HV expert monitoring window.



CONTROL PARAMETERS ECAL_TOP

Channel Name	Group#	V Limit	Trip I	Input TI	Ramp Up	Input RU	Ramp Down	Input RD	MVDZ	Input MVDZ	MCDZ	Input MCDZ	Status
ECAL_TOP_01	1	500.000	10.000	10	5.000	5	5.000	5	0.000	388	0.000	1	1.000
ECAL_TOP_02	1	500.000	10.000	10	5.000	5	5.000	5	0.000	382	0.000	0	1.000
ECAL_TOP_03	1	500.000	10.000	10	5.000	5	5.000	5	0.000	378	0.000	0	1.000
ECAL_TOP_04	1	500.000	70.000	70	5.000	5	10.000	10	0.000	381	0.000	0	1.000
ECAL_TOP_05	1	500.000	10.000	10	5.000	5	5.000	5	0.000	386	0.000	0	1.000
ECAL_TOP_06	1	500.000	10.000	10	5.000	5	5.000	5	0.000	383	0.000	1	1.000
ECAL_TOP_07	1	500.000	65.000	65	2.000	2	5.000	5	0.000	403	0.000	62	1.000
ECAL_TOP_08	1	500.000	10.000	10	5.000	5	10.000	10	0.000	380	0.000	0	1.000
ECAL_TOP_09	1	500.000	40.000	40	5.000	5	5.000	5	0.000	387	0.000	22	1.000
ECAL_TOP_10	1	500.000	10.000	10	5.000	5	5.000	5	0.000	392	0.000	0	1.000
ECAL_TOP_11	1	500.000	45.000	45	2.000	2	5.000	5	0.000	394	0.000	32	1.000
ECAL_TOP_12	1	500.000	10.000	10	5.000	5	5.000	5	0.000	384	0.000	0	1.000
ECAL_TOP_13	1	500.000	10.000	10	5.000	5	5.000	5	0.000	404	0.000	0	1.000
ECAL_TOP_14	1	500.000	10.000	10	5.000	5	5.000	5	0.000	401	0.000	0	1.000

Figure 17: Cropped view of the EPICS HV expert control window. It is accessed from the parameters button in the RICH HV control screen 13

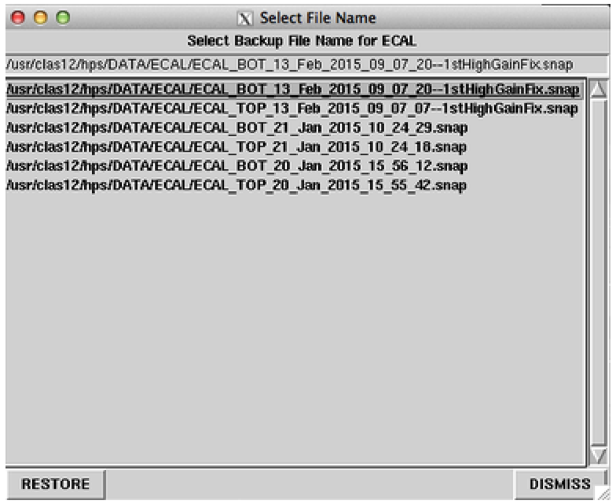


Figure 18: The gui interface to save/restore HV settings.

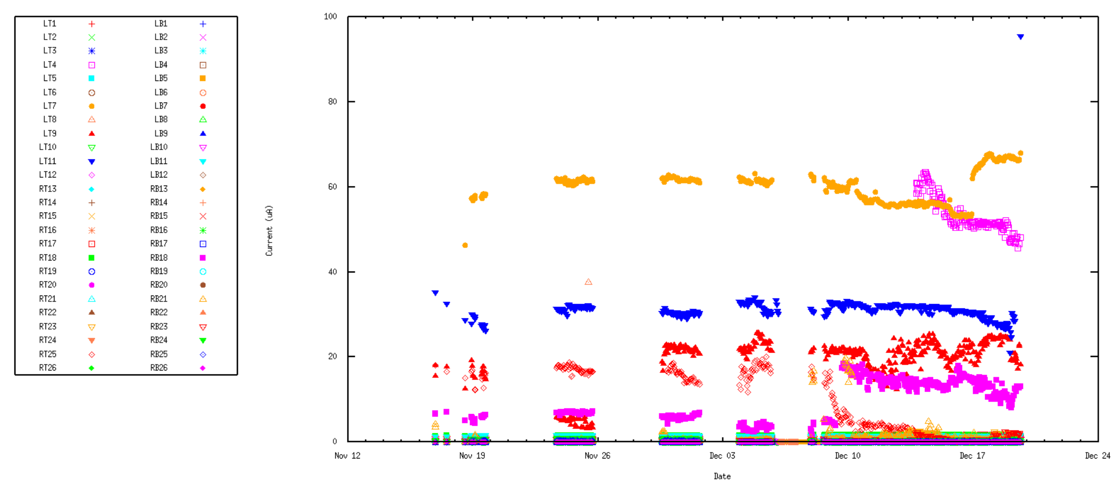


Figure 19: Expert HV current history.