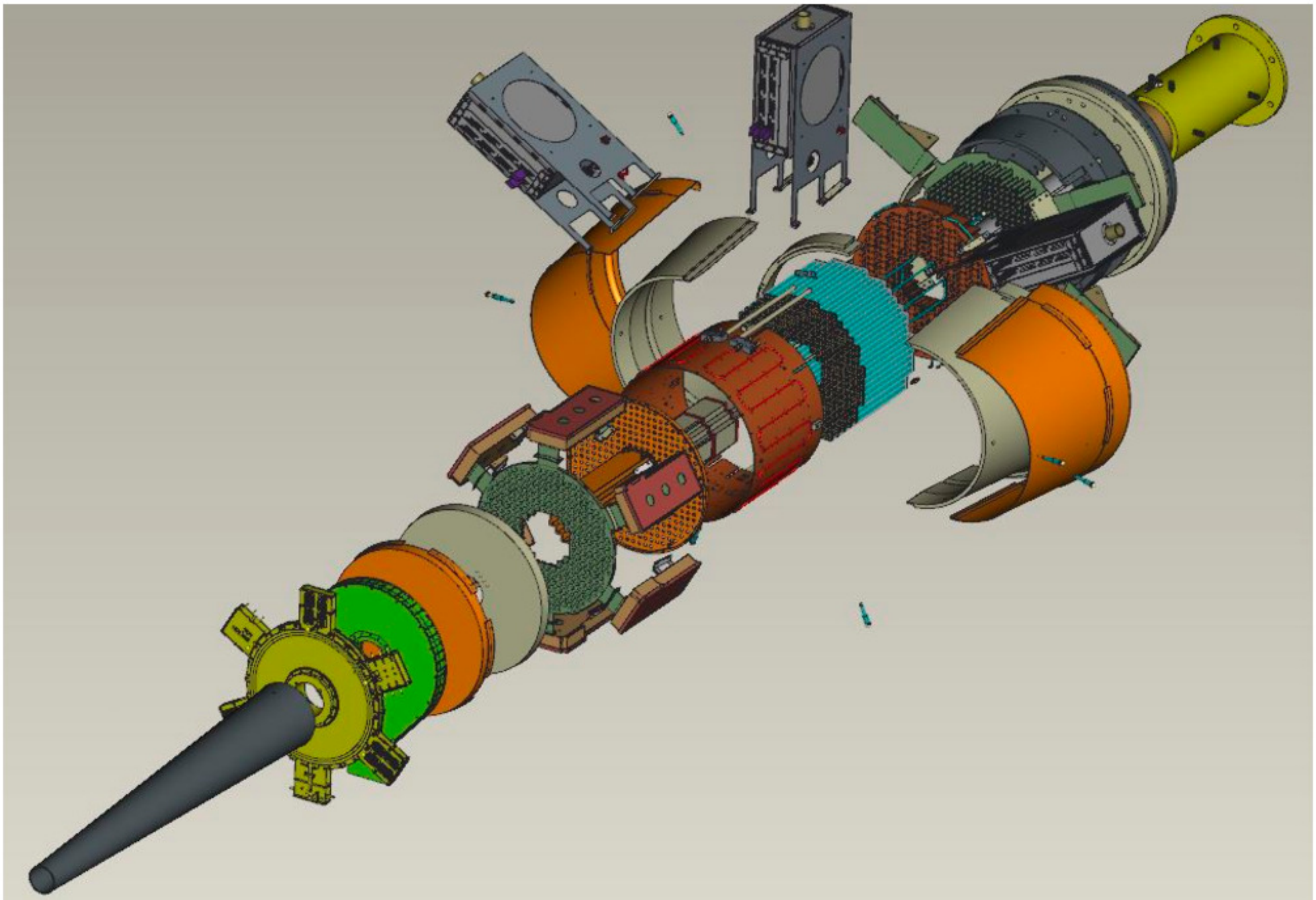
October 28 2016
Version V1.0



CLAS12
Forward Tagger (FT)
Manual of operation

The CLAS12 Collaboration

Abstract

This manual describes how to operate the CLAS12-Forward Tagger (FT).The FT is made by three subsystems: an electromagnetic calorimeter (FT-Cal), a hodoscope (FT-Hodo) and a tracker (FT-Trck). This document is divided in three sections, one for each detector.

Manual for CLAS12 FT-Cal v1.0

October 28, 2016

Contents

1 General description of the FT-Cal

The electromagnetic calorimeter (FT-Cal), installed upstream of the CLAS12 torus magnet (Figure 1), is one of the three subsystem of the CLAS12 Forward Tagger and performs two essential functions for the system: it measures the energy of electrons via the detection of the electromagnetic shower and provides input for the trigger system. The FT-Cal modules are based on rectangular 200 mm long PbWO crystal with a 15x15 mm^2 face wrapped in VM2000 multilayer polymer mirror film. The scintillation light, approximately 120 photons/MeV at 120° C and 170 photons/MeV at 0° C, is read out by a 10x10 mm^2 Hamamatsu S8664-1010 Avalanche Photodiode (APD) with 75% quantum efficiency glued to the rear face surface. The low gain of APDs (150 pC/pC) is compensated with custom-made preamplifier boards, which provide a factor of 600 amplification of the APD signal. In front of the crystals, LEDs are installed to send light into the crystals. These are used in order to check the proper functioning of the FT-Cal and provides complementary information to evaluate gain variations in the various channels of the calorimeter (see Figure 2).

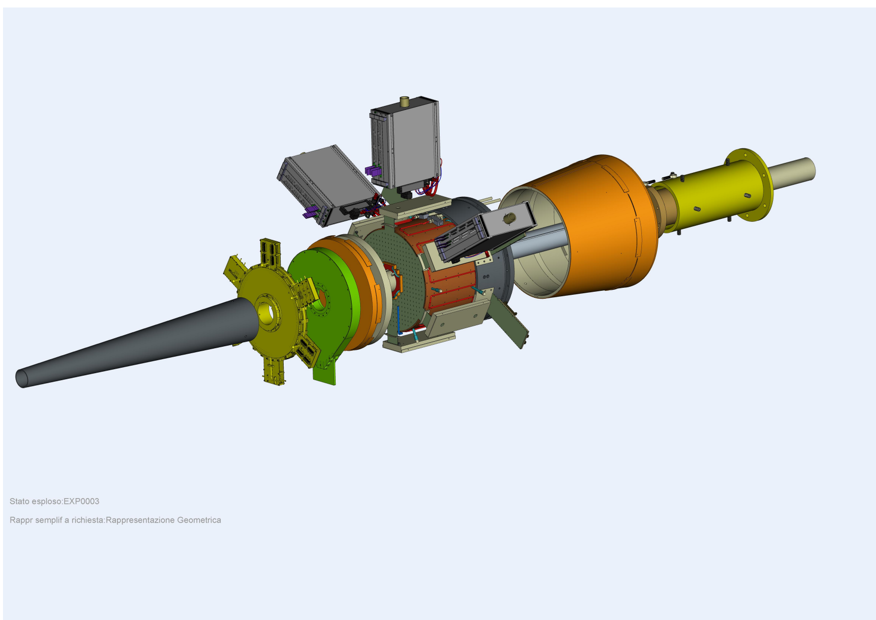


Figure 1: General view of the Forward Tagger(FT); components shown are the tracker, hodoscope and calorimeter respectively.

The FT-Cal is built as a circular matrix of crystals, surrounding the beamline. The 332 modules (Figure 3) are enclosed in a copper structure connected to the calorimeter cooling circuit (<1°C stability and <1°C uniformity) to stabilize the crystal light yield and the operation of the APDs. Two semi-circular printed circuit boards (referred as mother boards) mounted on the back plane with two extensions that exit from the enclosure are used to supply the ±5 V operating voltage for the preamplifiers, the 400 V bias voltage to the APDs, and to read out signals from the APDs. Each half of the FT-Cal is divided into 18 bias voltage groups formed in order to minimize the gain spread of the APD-preamplifier couples. After a 1:1 signal splitter, 1/2 of an amplified APD signal is fed to a single channel of a JLab flash ADC (FADC) board. The FADC boards are high

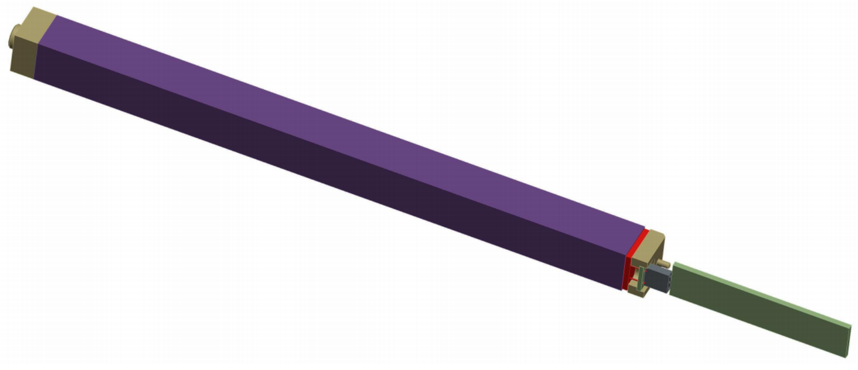


Figure 2: View of an FT-Cal crystal and the amplification chain.

speed VXS modules digitizing up to 16 crystal signals at 250 MHz and storing 4 ns samples with 12-bit resolution. When a trigger is received, the pipeline is read on these boards from 5 samples before and 30 after the trigger time (those values will be adapted during commissioning).

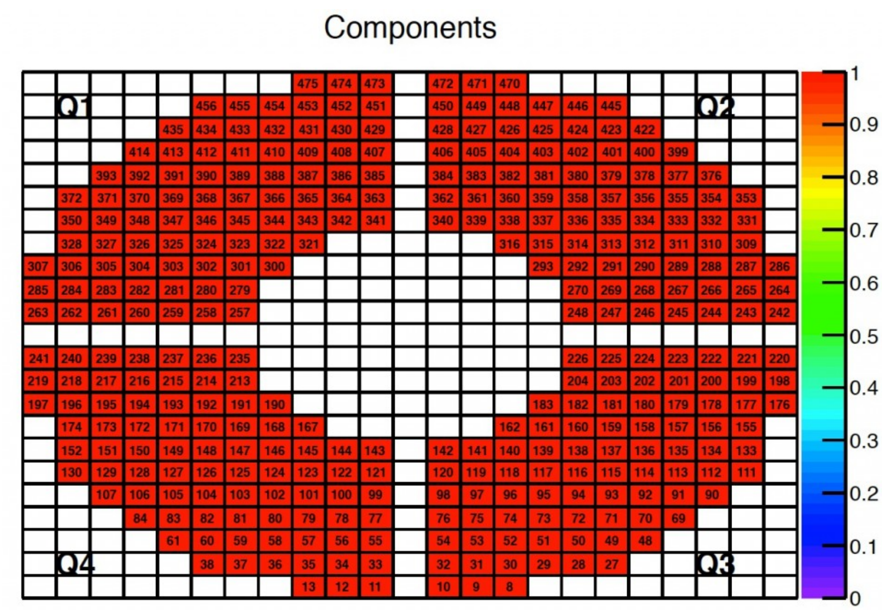
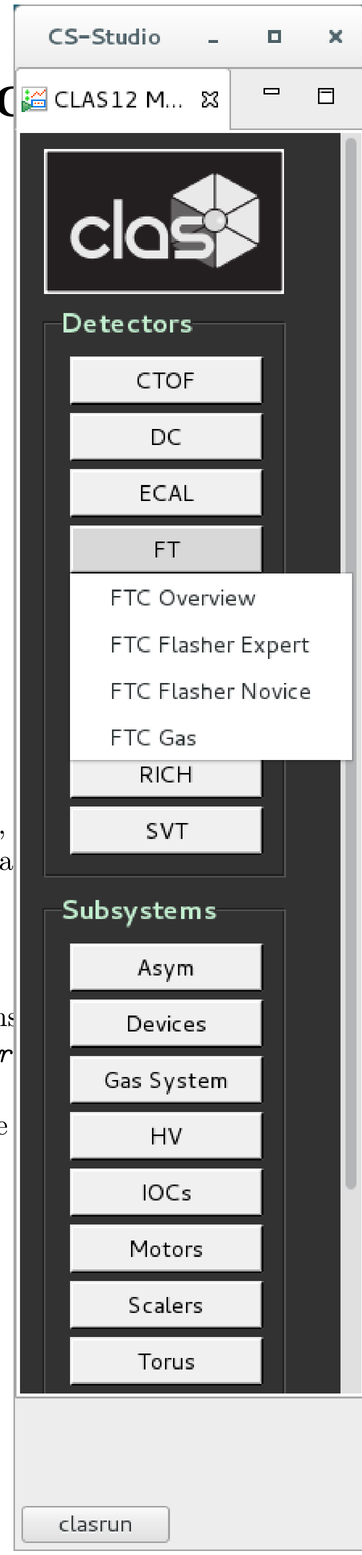


Figure 3: Front view of the FT-Cal crystals layout, with indications of the component number.

Part I

Shift Takers Instruc



All FT-Cal controls are accessible through EPICS, CS window (Figure 4). If not already running, it ca he command

`clas12_epics`

in a terminal on any of the `clonpc##` workstations se.

All shift workers should be using user `clasr` *his document.*

The primary FT-Cal screen is shown in Figure ird CLAS EPICS control GUI.

Figure 4: View of the Hall-B EPICS main window.Menu shown gives access to the HV, LV, Temperature sensors, Chiller, Gas system, and LED flasher.

2 Primary FT-Cal EPICS Screen

This one screen combines all basic FT-Cal EPICS controls and monitoring into one window. It is accessible from the **FT** button in Figure 4. 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 FT-Cal *controls* shift workers should need, which is to turn LV and HV on and off. HV should be turned on always after LV. 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 FT-Cal screen provide access to more detailed or expert screens for the corresponding subsystem.

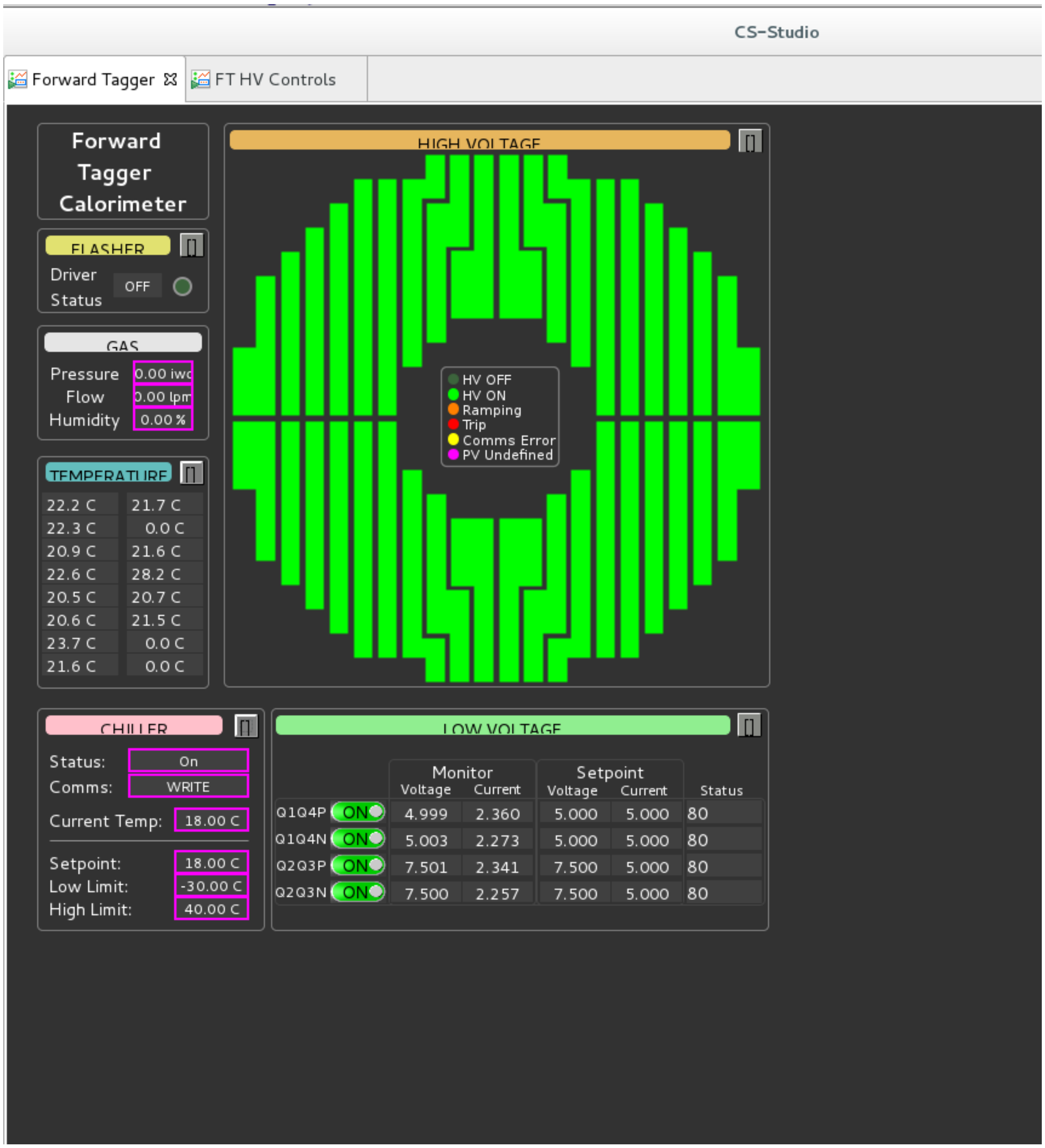


Figure 5: The primary EPICS screen needed for shift workers to monitor FT-Cal.

3 Temperature

The FT-Cal temperature should remain stable within $\pm 0.1^{\circ}$ C in order to avoid gain variation in the system. Cooling controls and monitoring are desribed in this section.

3.1 Temperature Sensors

Sixteen temperature sensors are placed in the FT-Cal enclosure and should be monitored through FT-Cal's main EPICS screen. Figure 6 shows the expert screen accessible via the grey square button in the top right of the temperature section of the main FT-Cal screen. Temperatures at different locations in the calorimeter as shown in Figure 8 are measured by the instruments shown in Figure 9. Variations of one degree C or more during a shift should be reported to FT-Cal expert on call and noted in the log book. The strip charts 7 are accessible from the two buttons in the temperature section of Figure 5 (and also the main CLAS12_EPICS screen in Figure 4)[1].

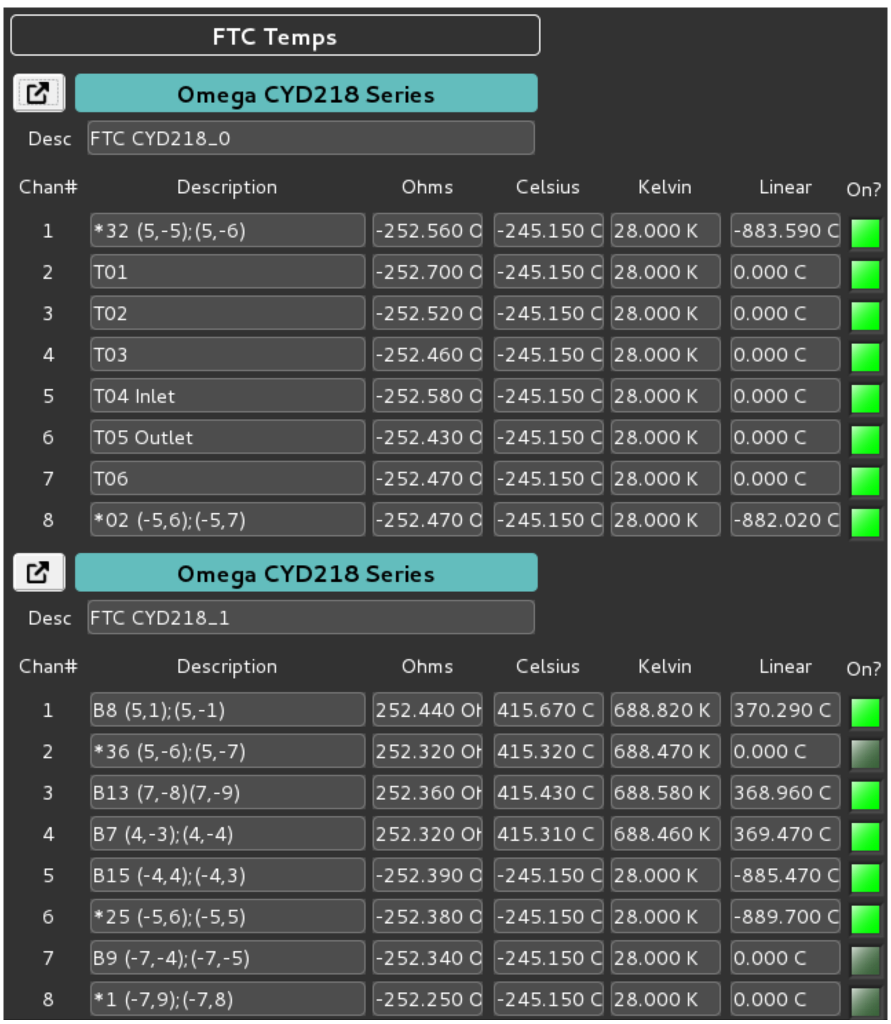


Figure 6: View of the EPICS temperature monitoring window.

[1] To be implemented.

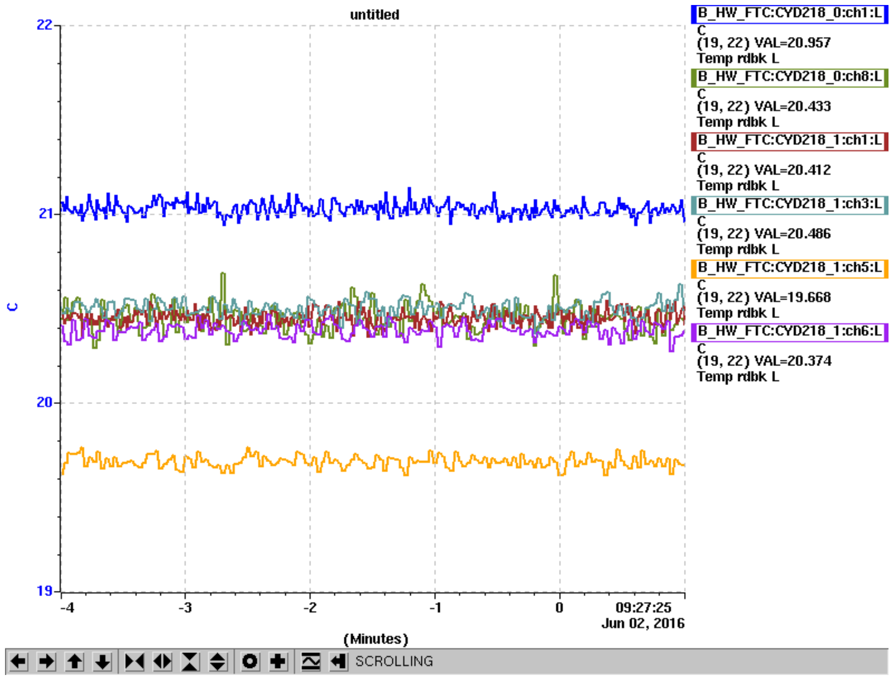


Figure 7: Example view of what the implemented EPICS strip charts will look like

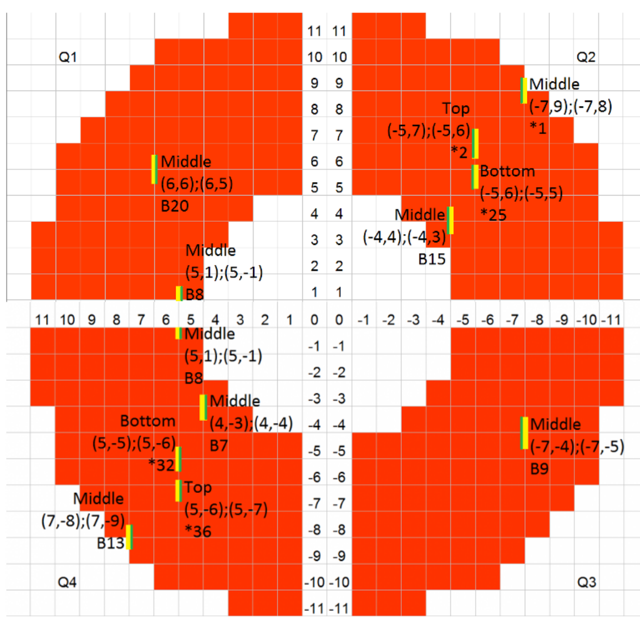


Figure 8: Placement of the Flex PT100's within the FTCal.

Figure 9: View of the temperature modules measuring both the crystal and external temperatures of the FTCal.

3.2 Chiller

The chiller allows to keep the calorimeter at the right temperature and should be ON and set at -3 C at all times. The chiller can be monitored through its webcam and EPICS controls (Figure 10). Shift takers should not attempt to change the chiller settings and call FT-Cal expert in case of problem.

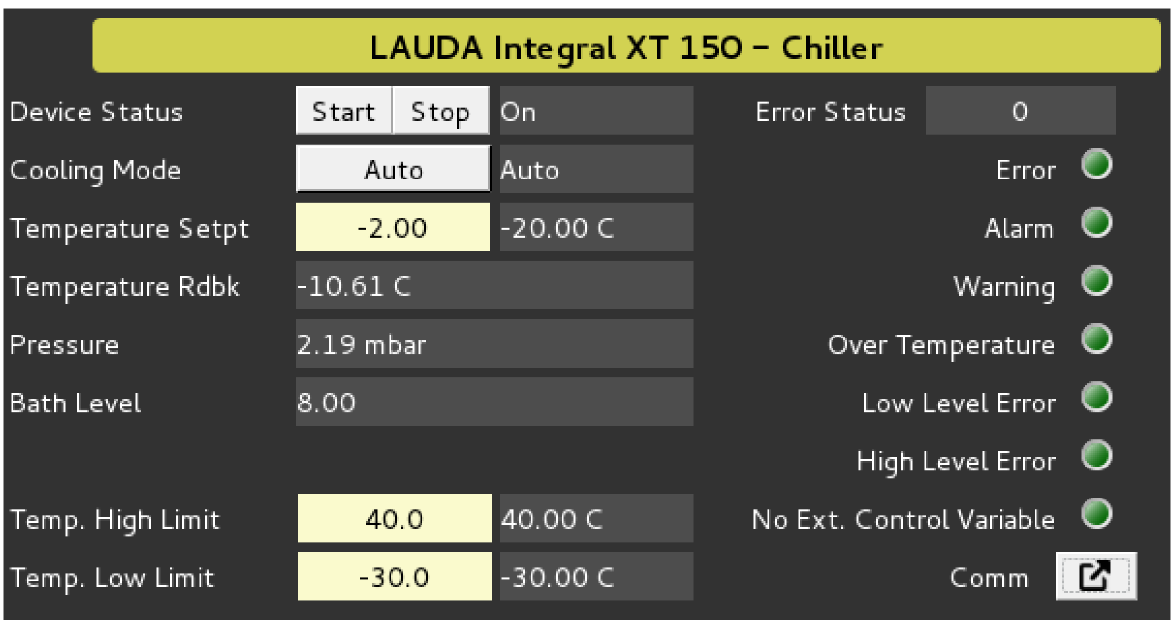


Figure 10: View of the chiller slow control window, for the purpose of live monitoring.

4 Low Voltage

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

LV should be monitored using its portion of the main FT-Cal EPICS screen (shown in Figure 5). The currents driven by the four channels should be similar. Call the FT-Cal expert if this appears not to be ON or shows an abnormal current for any of the channels. *Normal current is between 2.2 and 2.4 A for all channels.*

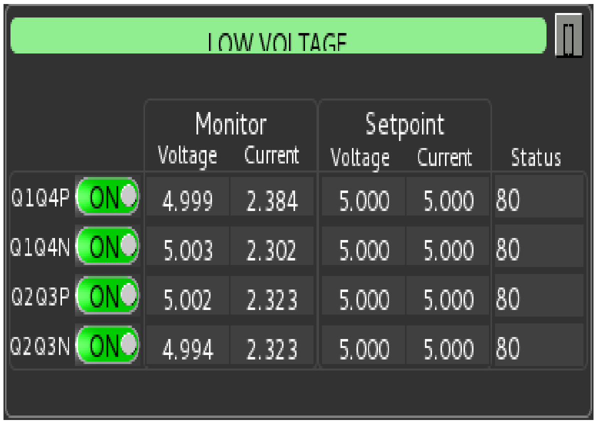


Figure 11: LV controls for the FTCal.

5 High Voltage

5.1 Turning ON/OFF High Voltages

The high voltage supply of the FT-Cal is controlled and monitored using the main FT-Cal EPICS window (Figure 5). It has buttons to ramp up and down the entire calorimeter's high voltages, accessible via the gray square buttom on the top right of the HV section of the main GUI, open windows for individual channel control (Figure 13), and open more detailed expert views.

5.2 HV Current Monitoring

Individual channels' currents can be monitored from the GUI in Figure 13, and strip charts should be open for long term monitoring (see Fig. 12). Jumps or drifts in current of more than 1 A should be noted in the logbook.

5.3 Responding to HV trips

HV problems, in particular trips, are indicated by a red group in the main FT-Cal EPICS GUI (Figure 5). HV trips will also be announced by the alarm handler. During normal operations with HV ON, there should be no red groups in Figure 5 and no ECAL HV alarms. In case of an HV trip, or a red region in Figure 5:

- 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 menu accessiable via the gray square button of the HV section the main FT-Cal EPICS screen (Figure 5).

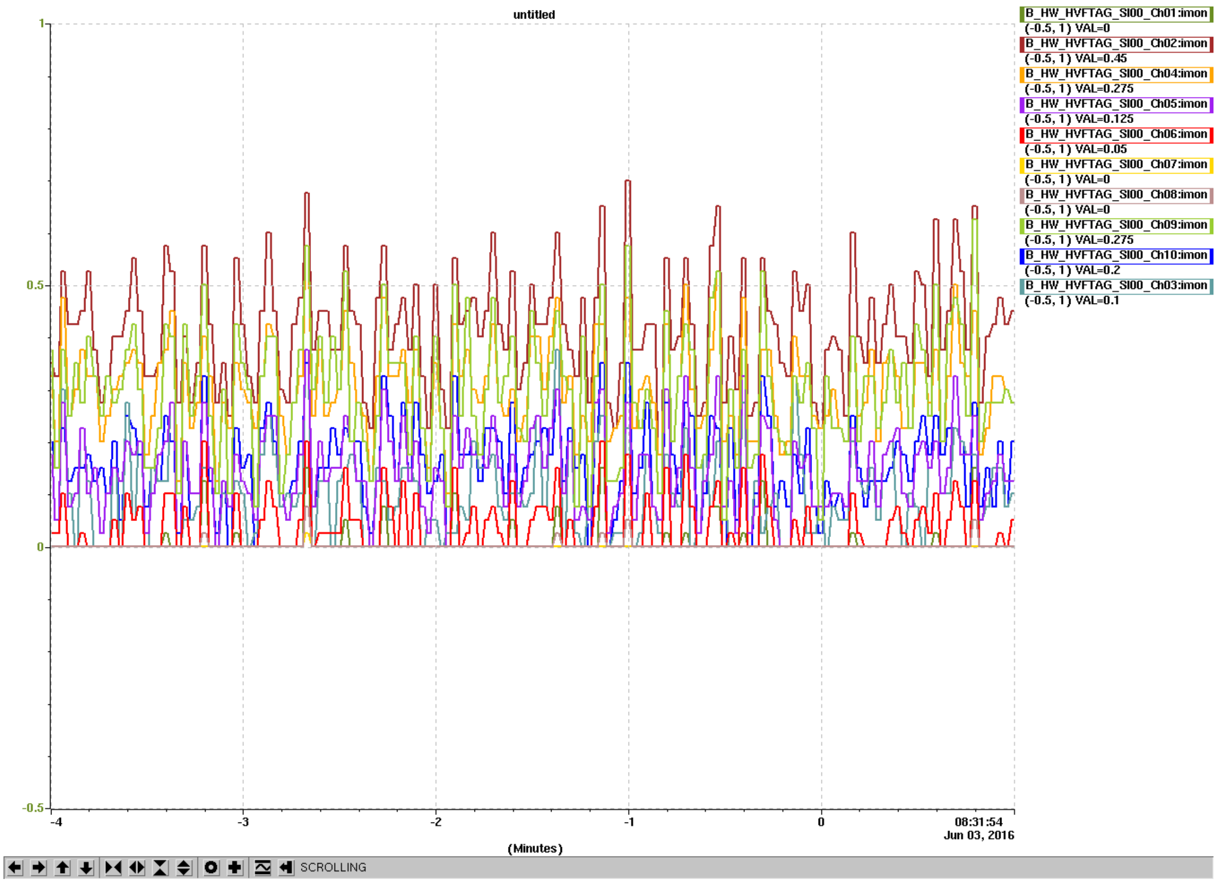


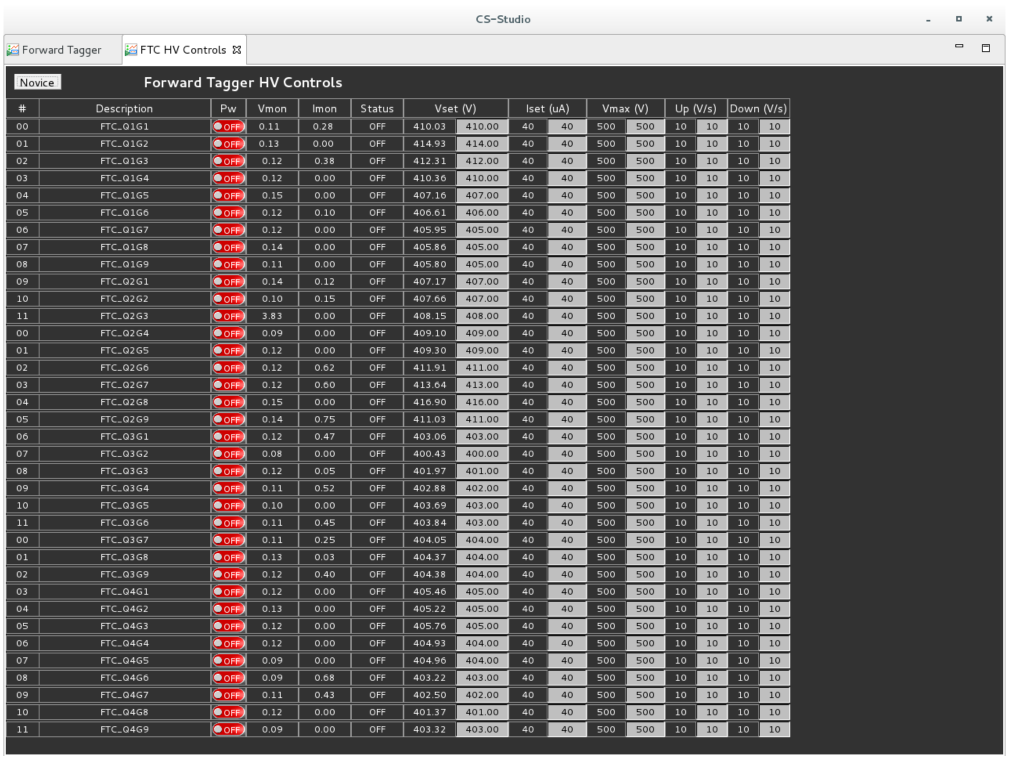
Figure 12: Example HV Current strip chart. This feature will be added soon to the FTCal Epics Gui.

- Record the trip in the log book with precise indication of the group and run number concerned.

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

Note, the HV can take up to 1 minute 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 FT-Cal expert on call.

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



#	Description	Pw	Vmon	Imon	Status	Vset (V)		Iset (uA)		Vmax (V)		Up (V/s)		Down (V/s)	
00	FTC_Q1G1	OFF	0.11	0.28	OFF	410.03	410.00	40	40	500	500	10	10	10	10
01	FTC_Q1G2	OFF	0.13	0.00	OFF	414.93	414.00	40	40	500	500	10	10	10	10
02	FTC_Q1G3	OFF	0.12	0.38	OFF	412.31	412.00	40	40	500	500	10	10	10	10
03	FTC_Q1G4	OFF	0.12	0.00	OFF	410.36	410.00	40	40	500	500	10	10	10	10
04	FTC_Q1G5	OFF	0.15	0.00	OFF	407.16	407.00	40	40	500	500	10	10	10	10
05	FTC_Q1G6	OFF	0.12	0.10	OFF	406.61	406.00	40	40	500	500	10	10	10	10
06	FTC_Q1G7	OFF	0.12	0.00	OFF	405.95	405.00	40	40	500	500	10	10	10	10
07	FTC_Q1G8	OFF	0.14	0.00	OFF	405.86	405.00	40	40	500	500	10	10	10	10
08	FTC_Q1G9	OFF	0.11	0.00	OFF	405.80	405.00	40	40	500	500	10	10	10	10
09	FTC_Q2G1	OFF	0.14	0.12	OFF	407.17	407.00	40	40	500	500	10	10	10	10
10	FTC_Q2G2	OFF	0.10	0.15	OFF	407.66	407.00	40	40	500	500	10	10	10	10
11	FTC_Q2G3	OFF	3.83	0.00	OFF	408.15	408.00	40	40	500	500	10	10	10	10
00	FTC_Q2G4	OFF	0.09	0.00	OFF	409.10	409.00	40	40	500	500	10	10	10	10
01	FTC_Q2G5	OFF	0.12	0.00	OFF	409.30	409.00	40	40	500	500	10	10	10	10
02	FTC_Q2G6	OFF	0.12	0.62	OFF	411.91	411.00	40	40	500	500	10	10	10	10
03	FTC_Q2G7	OFF	0.12	0.60	OFF	413.64	413.00	40	40	500	500	10	10	10	10
04	FTC_Q2G8	OFF	0.15	0.00	OFF	416.90	416.00	40	40	500	500	10	10	10	10
05	FTC_Q2G9	OFF	0.14	0.75	OFF	411.03	411.00	40	40	500	500	10	10	10	10
06	FTC_Q3G1	OFF	0.12	0.47	OFF	403.06	403.00	40	40	500	500	10	10	10	10
07	FTC_Q3G2	OFF	0.08	0.00	OFF	400.43	400.00	40	40	500	500	10	10	10	10
08	FTC_Q3G3	OFF	0.12	0.05	OFF	401.97	401.00	40	40	500	500	10	10	10	10
09	FTC_Q3G4	OFF	0.11	0.52	OFF	402.88	402.00	40	40	500	500	10	10	10	10
10	FTC_Q3G5	OFF	0.10	0.00	OFF	403.69	403.00	40	40	500	500	10	10	10	10
11	FTC_Q3G6	OFF	0.11	0.45	OFF	403.84	403.00	40	40	500	500	10	10	10	10
00	FTC_Q3G7	OFF	0.11	0.25	OFF	404.05	404.00	40	40	500	500	10	10	10	10
01	FTC_Q3G8	OFF	0.13	0.03	OFF	404.37	404.00	40	40	500	500	10	10	10	10
02	FTC_Q3G9	OFF	0.12	0.40	OFF	404.38	404.00	40	40	500	500	10	10	10	10
03	FTC_Q4G1	OFF	0.12	0.00	OFF	405.46	405.00	40	40	500	500	10	10	10	10
04	FTC_Q4G2	OFF	0.13	0.00	OFF	405.22	405.00	40	40	500	500	10	10	10	10
05	FTC_Q4G3	OFF	0.12	0.00	OFF	405.76	405.00	40	40	500	500	10	10	10	10
06	FTC_Q4G4	OFF	0.12	0.00	OFF	404.93	404.00	40	40	500	500	10	10	10	10
07	FTC_Q4G5	OFF	0.09	0.00	OFF	404.96	404.00	40	40	500	500	10	10	10	10
08	FTC_Q4G6	OFF	0.09	0.68	OFF	403.22	403.00	40	40	500	500	10	10	10	10
09	FTC_Q4G7	OFF	0.11	0.43	OFF	402.50	402.00	40	40	500	500	10	10	10	10
10	FTC_Q4G8	OFF	0.12	0.00	OFF	401.37	401.00	40	40	500	500	10	10	10	10
11	FTC_Q4G9	OFF	0.09	0.00	OFF	403.32	403.00	40	40	500	500	10	10	10	10

Figure 13: View of the EPICS FT-Cal HV control window for individual channels.

6 How to switch ON/OFF the FT-Cal

As discussed in the previous Secs. the FT-Cal to operate requires to have the LV, HV and the chiller on. Here below is the sequence of operations required.

6.1 Switching the FT-Cal ON

- From the CLAS12 EPICS control bring the Primary FT-Cal EPICS screen ON (see Sec.2)
- Check temperatures (see Sec.3) and the status of the chiller (see Sec.3.2), if OFF, do not proceed and call the FT-Cal expert.
- Switch the LV ON (see Sec.4)
- Switch the HV ON (see Sec.5) *HV has to be switched ON AFTER LV!*

6.2 Switching the FT-Cal OFF

- From the CLAS12 EPICS control bring the Primary FT-Cal EPICS screen ON (see Sec.2)
- Switch the HV OFF (see Sec.5) *HV has to be switched OFF BEFORE LV!*
- Switch the LV OFF (see Sec.4).
- Leave the chiller ON (see Sec.3.2)

7 Scalers

Rates seen by the FT-Cal are available in the ROOT-based GUI shown in Figure 14, which represent the rates as seen by the FADC electronics.This display is currently not accessible via the main clascss window, however it will be implemented in the final version. The current Scaler Gui is stored on the jlab12daq1 machnine located in the EEL, and has been used for the purpose of channel debugging. These numbers should all remain constant within ~10% during stable beam operation. A color code will help the operator to check the scaler uniformity. A strong increase is the indication of bad beam conditions or the presence of a new source of noise in the FT-Cal system. If the latter case, please contact FT-Cal expert on call.

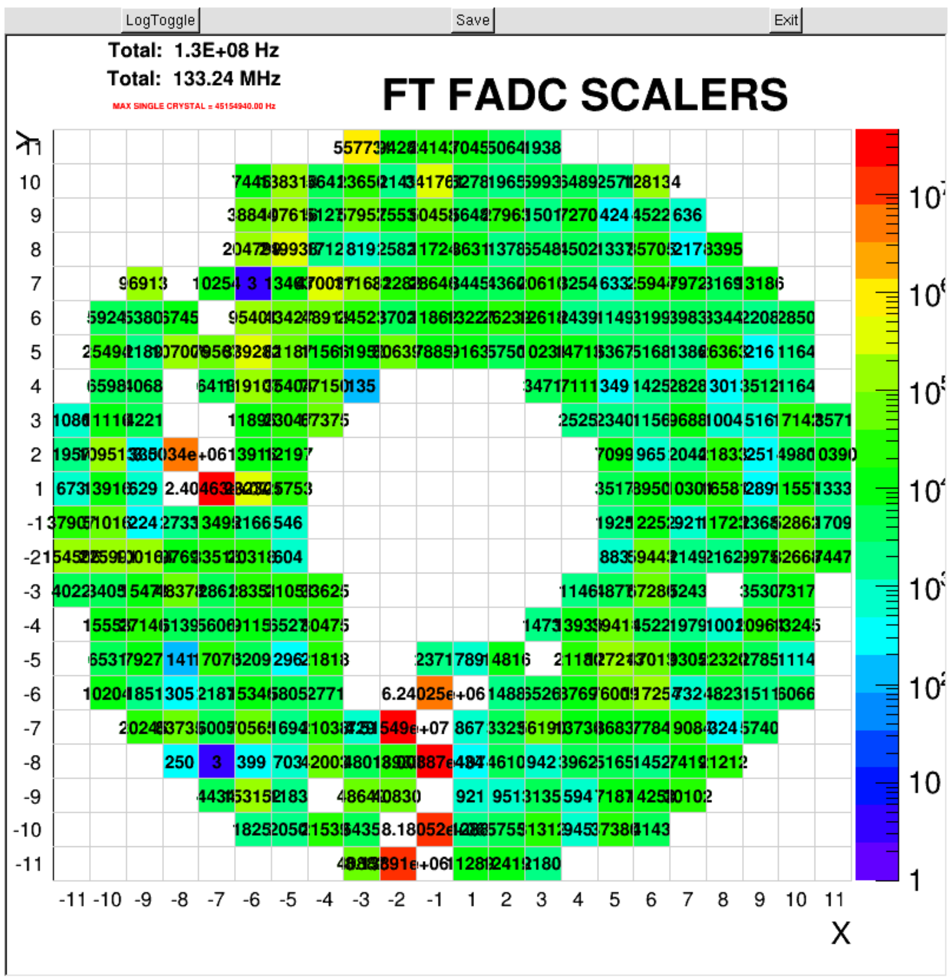


Figure 14: View of the EPICS FADC scalers window (to be updated based on beam-commissioning rates.

8 Strip Charts

The most import quantities to monitor with strip charts are temperature and HV current. The StripTool from MyaViewer shown in Figure 7run by executing the following scripts in a terminal (To Be Implemented):

- `mya_ftcal_all.sh`
- `mya_ftcal_temp.sh`
- `mya_ftcal_curr.sh`
- `mya_ftcal_voltage.sh`

9 Monitoring App

The CLAS12 java monitoring app is used to run full calorimeter reconstruction and calibration on-line 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:

```
clas12-module
```

and choose from the menu the monitoring application you are interested in. Then click the "Et" button to connect to the ET ring and the ">>" to start the event processing.

At the start of every run, the histograms in the monitoring app should be cleared via the "Clear Histograms" button. After a few minutes of beam, the tabs should be cycled through and their plots compared to the reference. Once sufficient statistics are accumulated, snapshot of the relevant panel should be taken and uploaded to the logbook.

10 LED Monitoring

10.1 System operations

The LED system is operated through an EPICS GUI accessible from the main CLAS12 EPICS menu, through FT, then FTC-Flasher Novice (see Figure 15).

Shift takers are requested to operate the system in "Sequence mode" only. To do so, when requested, click on "Initialize Flasher", then verify the TOP frequency is 8000 Hz, and if necessary adjust it trough the proper drop-down menu. Finally, to start the sequence, click on "Start". During such a run the DSC scaler screen and the monitoring app allows to check the proper functioning of the channels.

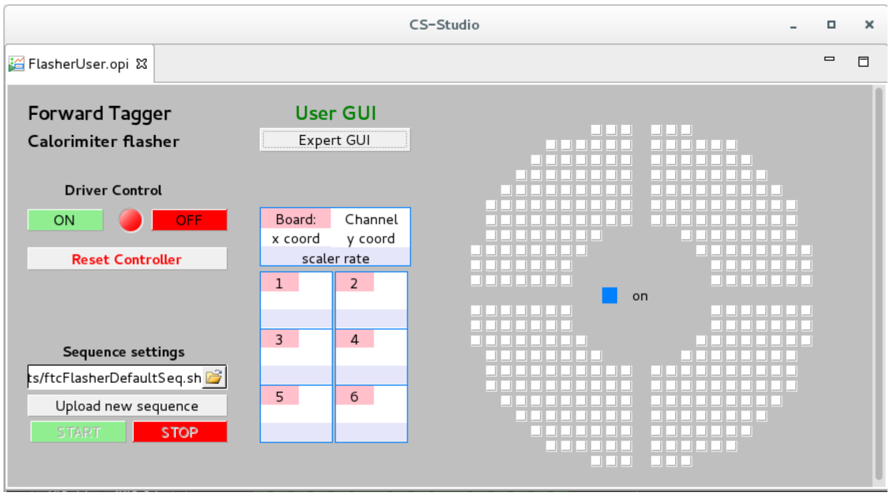


Figure 15: The HPS-ECAL Led monitoring system EPICS GUI.

10.2 Automatic LED Monitoring

A monitoring app is setup to record all channels successfully registered during an LED run. It should be started before the LED sequence is started and viewed afterwards, with the command:

```
clas12-module
```

and selecting the FTCalLEDViewerModule from the menu. Make sure to use the clasrun account before using this command.

10.3 Taking a LED sequence run

The following instructions must be followed to take an LED sequence run. This involves setting the DAQ, starting the LED sequence run, and configure the monitoring app to monitor the data. At the end of the run, the user can upload the relevant information to the CLAS12 conditions database, as well as post a log-entry to the HallB electronic logbook.

10.3.1 Setup

Follow these instructions to setup the system before takin the LED sequence run.
It is critical they are followed in the **exact** order as they are here reporter.

1. **Start the DAQ system:**
    - Identify the machine where the DAQ RunControl is running. If you can't find it anywhere, it is possible the DAQ system has to be initialized from scratch. To do so, refer to the CLAS12 DAQ manual, or contact the DAQ expert.
    - Depending on the DAQ state, different buttons may be visible in the "Transition" area. If the "Configure" button is not visible, click on "Reset", then on "OK".
    - Click on "Configure" to properly set up the run. A "Run Type Configuration" dialog will show up.
      There are two active FT configurations available:
        - FT: this is the standard configuration; all CODA modules are up, FT data are collected and wriitten on disk.
        - FT_NOER: CODA ER module is off, data are collected for on-line analysis but they are not saved on disk.
    - Click on "Download" button. A file-chooser menu will show up.
      Select: clasdev.trg.
      Click on "OK" to close the file-choose menu.
    - Click on "Prestart". Wait until the "GO" button appears, but **do not click on it yet.**
2. **Start the monitoring app:** Use the command outlined in the previous section to start the monitoring app.

   Do this after the run-control shows the "GO" button.

   When the monitoring gui window shows up, click on the *Et* button to connect to the ET ring and on the ">>" button to start the event processing.
3. **Initialize the LED monitoring sequence:**In the EPICS gui, click on "Initialise Flasher", "Start Flasher", then on "!Stop All Seq" (to ensure there are no previous sequences running).

10.3.2 Run start, data taking, and run stop

To start data taking follow these instructions, in the exact order they are reported here.

1. In the RunControl GUI, click on the "GO" button. Wait 10 s, until the message "transition go succeeded" is displayed in the log window and the "END" button displays.
2. In the EPICS gui, click on "Start".

While the LED sequence is running, you can look at the monitoring application to check data being recorded. The event display will show 6 crystals at time with a signal. A full sequence will take $\simeq$ 50 minutes to complete.

The DAQ system is not set up to end the run when the LED sequence is completed. When the sequence is complete:

- The LED system automatically turns off. As a direct consequence of this, no further triggers are sent to the DAQ system

- The data-taking run is **not** ended. This means the DAQ will stay in RUN mode, but no events will be recorded, since there are no triggers.

Use the EPICS gui to periodically check the sequence status, looking at the Sequence Control section (RED is OFF, GREEN is ON). Tipically, a sequence will take $\simeq$ 50 minutes to complete.

The user can confirm the sequence has actually ended by looking at the FT-Cal Event display: no crystals have signal when the sequence is off.

When the sequence is OFF, first turn OFF the controller (LED ON/OFF, click on OFF), then use the DAQ run control to END the run, by clicking on the "End" button.

10.3.3 Analysis at the run end

When the run ends, loop through the different tabs of the monitoring application to check the histograms were correctly filled and the color maps shown in the detector view panel are consistent with previous one. Check in particular that no calorimeter channel in this map is shown as grey that would indicate the channel is dead or the sequence was not complete. In that case contact the FT-Cal expert on call.

Close and restart the monitoring application and analyze the recorded EVIO file by selecting it via the "File" button.

Once the analysis will be completed, loop again through the different tabs of the monitoring application to verify histograms an calorimeter maps. Check the values reported on the "Charge" tab: the average channel response should be in the range $\simeq 20 \div 30$. Make an entry in the e-logbook , reporting the run number and including a snapshot of the "Charge" tab and the LED calibration result file. The path to the latter will be indicated on the terminal from which the monitoring application was started.

TODO: print a reference map and aks the user to compare with that

10.4 Quick 2-Minute Noise Run for Simple Channel Status Check

A quick check of the calorimeter channels functionality can be obtained with a quick LED run. In this case, we simply make use of the LED sync trigger to have data recorded without performing a full LED sequence and check the noise levels recorded for each channels. A channel is operating normally if the noise RMS is within 0.75 and 1.1 mV. Noise below this range may indicate the channel is dead.

In order to perform this check, use the same procedure outline above for the LED sequence run:

1. **Start the DAQ system:**
    - Identify the machine where the DAQ RunControl is running. If you can't find it anywhere, it is possible the DAQ system has to be initialized from scratch. To do so, refer to the CLAS12 DAQ manual, or contact the DAQ expert.
    - Depending on the DAQ state, different buttons may be visible in the "Transition" area. If the "Configure" button is not visible, click on "Reset", then on "OK".
    - Click on "Configure" to properly set up the run. A "Run Type Configuration" dialog will show up. Use the scroll-down menu to select as RunType: FT. This

configuration will also save any data on tape. Use instead: FT_NOER to not save data on tape.
Default is to save data to the tape

- Click on “Download” button. A file-chooser menu will show up.
Select: clasdev.trg.
Click on “OK” to close the file-choose menu.
- Click on “Prestart”. Wait until the “GO” button appears.
- In the RunControl GUI, click on the “GO” button. Wait 10 s, until the message “transition go succeded” is displayed in the log window and the “END” button displays.

2. **Initialize the LED monitoring sequence:**In the EPICS gui, click on “Initialise Flasher”, then on “!Stop All Seq” (to ensure there are no previous sequences running) and finally on “Start”.

3. **Start the monitoring app:**

   - Use the command outlined in the previous section to start the monitoring app. When the monitoring gui window shows up, click on the “Et” button to connect to the ET ring and on the “>> button to start the event processing.
   - Accumulate events for 2 minutes.
   - Go to the “Noise” 16 tab and check the detector view map on the left panel: noise levels are within range if they show in green.
   - Compare the color map with previous ones to verify the presence of new “dead” (blue) or “noisy” channels (orange). Take a snapshot of the panel and make an e-logbook entry with the appropriate comments.

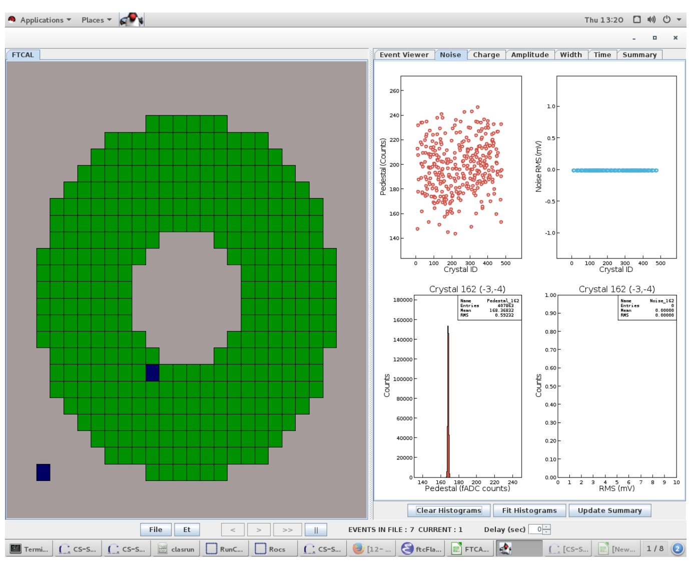


Figure 16: Example Noise map within the LED monitoring Gui. The color of the heat map is determined by the RMS of the mean of the noise of a given channel.

   - If new problematic channels are found, contact the FT-Cal expert on call.

4. **Stop the DAQ:** click on “End Run”.

5. **Stop the LED controller:** end the sequence by clicking on “Stop” and turn off the drivers by clicking on “OFF”.

When the detector will be installed and the conditions DB defined, instructions on how to upload results will be added to this manual.

11 Taking a Cosmic Calibration Run

1. **Start the DAQ system:**
   - Identify the machine where the DAQ RunControl is running. If you can't find it anywhere, it is possible the DAQ system has to be initialized from scratch. To do so, refer to the CLAS12 DAQ manual, or contact the DAQ expert.
   - Depending on the DAQ state, different buttons may be visible in the "Transition" area. If the "Configure" button is not visible, click on "Reset", then on "OK".
   - Click on "Configure" to properly set up the run. A "Run Type Configuration" dialog will show up. Use the scroll-down menu to select as RunType: FT. This configuration will also save any data on tape. Use instead: FT_NOER to not save data on tape. 17

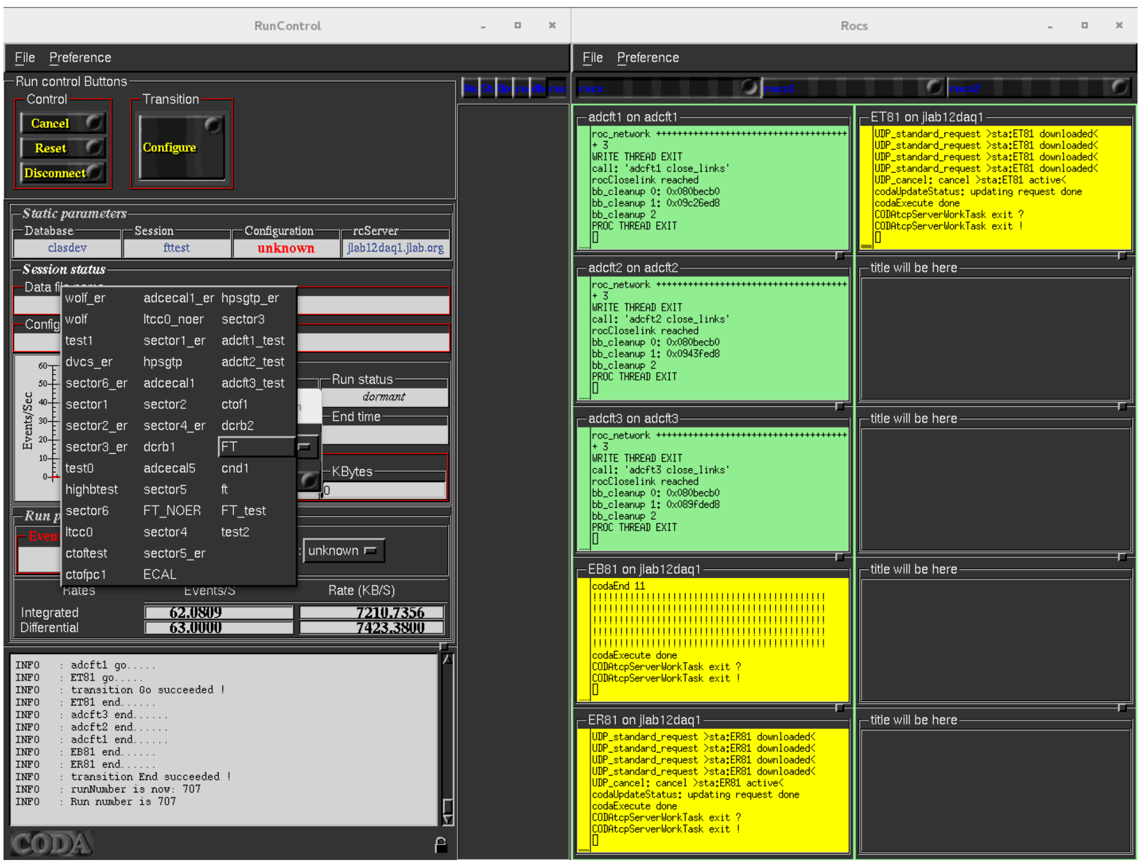


Figure 17: Depending on whether the user would like to record or only view live data, there are two configuration options to choose from. The FT option records data, and the FT_NOER option only shows live events.

   Default is to save data to the tape

   - Click on "Download" button. A file-chooser menu will show up. On the Left pane of the popup window select .../parms/trigger/FT Once within the aforementioned directory Select ft_selftrigger.trg in the Right pane
     Click on "OK" to close the file-choose menu. 18
   - Click on "Prestart". Wait until the "GO" button appears.
   - In the RunControl GUI, click on the "GO" button. Wait 10 s, until the message

Figure 18: Once the configuration has been chosen, the user will then download the corresponding trigger file. In the case of the Forward Tager, this file is accessed by clicking the download button and navigating to .../parms/trigger/FT/ in the left window of the popup, and selecting the file called ft_selftrigger.trg in the right window.

"transition go succeded" is displayed in the log window and the "END" button displays.

2. **Start the monitoring app:**
   - Use the command outlined in the previous section to start the monitoring app. When the monitoring gui window shows up, click on the "Et" button to connect to the ET ring and on the ">> button to start the event processing.
   - Once connected to the ET ring the user will see live events on the Left pane of the monitoring app19, as well as the waveform and tabs to provide further analysis on the Right.

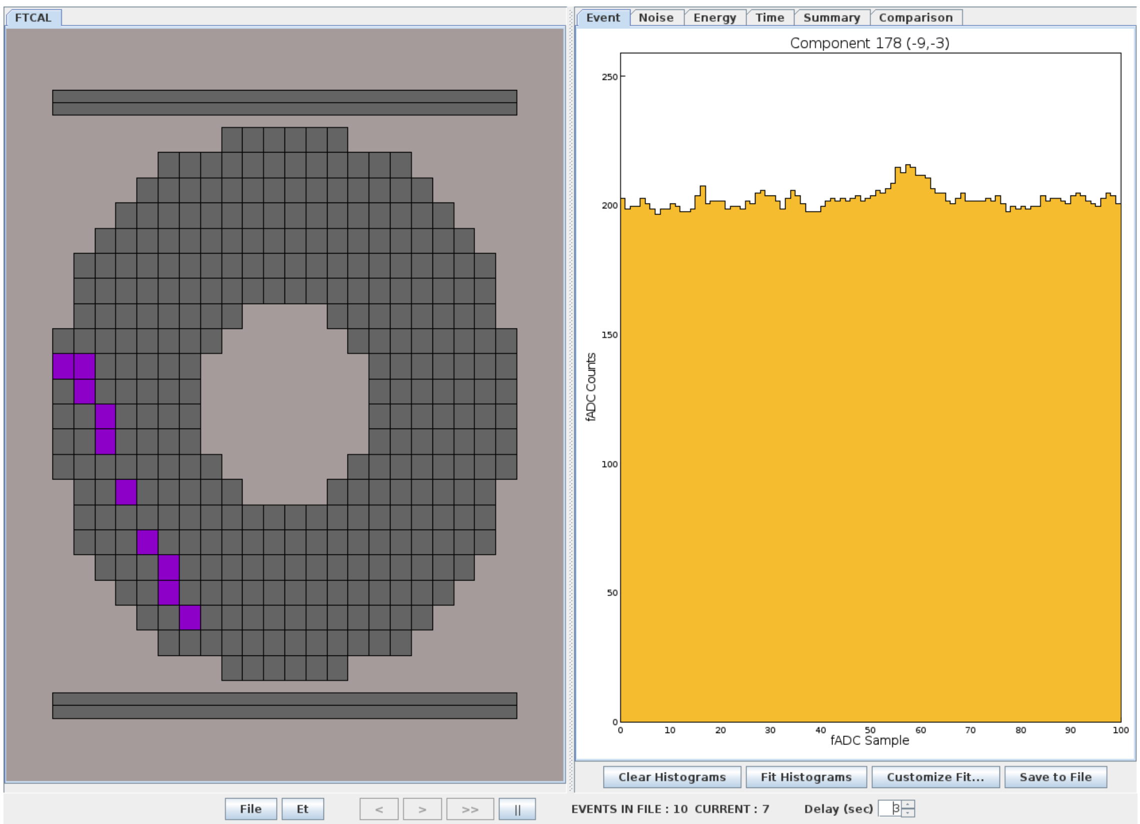


Figure 19: Sample cosmic event showing the channels being activated, as well as a histogram for a selected channel, which shows read waveform.

Part II

FT-Cal Experts Resources

12 Location of FT-Cal Ancillary Systems

- The chiller is located beam-right on Level 2 space frame. 20
- The LED controllers are located in the FT racks under the subway. See Figure 21.
- The FADCs and patch panels occupy the top part of the FT racks under the subway. See Figure 22.
- The HV supply is located beam-left on Level 1 space frame. See Figure 24.
- The LV supply is located in the FT racks under the subway. See Figure 23.

The layout of the FT racks (located under the subway) is shown in Fig. 25.

Figure 20: LAUDA XT150 chiller will be located beam-right on Level 2 space frame.

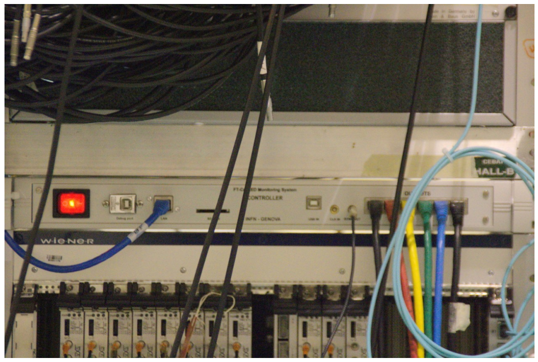


Figure 21: LED flasher controller located in the FT racks under the subway.

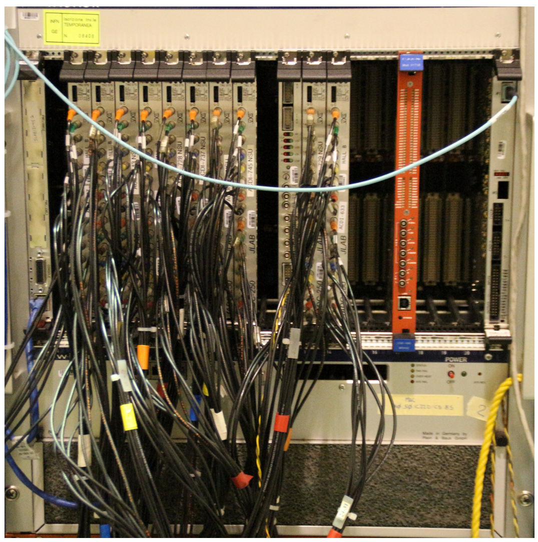


Figure 22: One of the FADC crates for the Forward Tagger located in the racks under the subway. *To be replaced with a picture of the fADC rack in the Hall.*

Figure 23: MPOD crate containing the OMPV.8008 LV supply board located in the FT racks under the subway.

Figure 24: CAEN HV power supply located on the beam-left side of Level 1 Space Frame. Key for on/off is in the lower right corner of the crate.

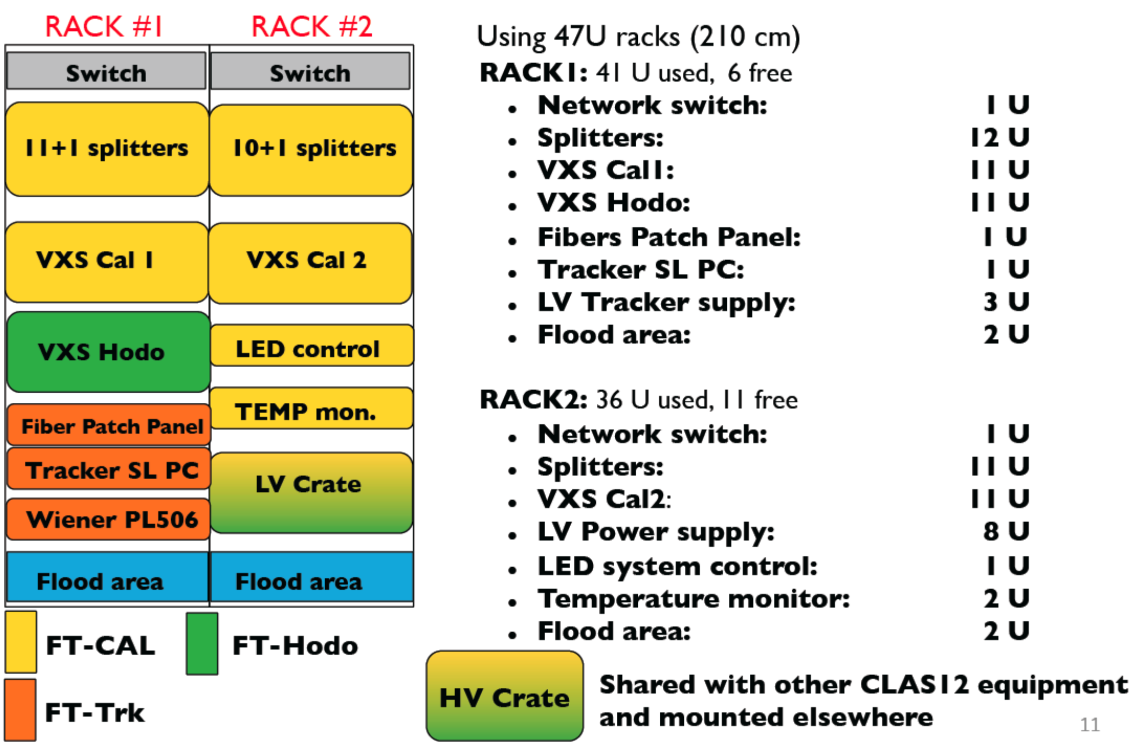


Figure 25: FT electronic racks layout.

13 LV Supply

The low voltage power supply is an Wiener MPOD OMPV.8008. It should be set with all four channels at +5V with their current limits at 5 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 for intense beam operation. If that was the case check, with all power supplies off, that all connection are goods. Then contact run coordinator to see if the current limit should be increased.

13.1 Changing LV Settings

The LV supply can be controlled via its EPICS expert screen (Figure 26), accessible from the grey button in the top right of the LV section of the main FT-Cal EPICS screen (Figure 5). In general the only necessary changes are powering on/off, while voltage and current setpoints are never changed from 5V/5A.

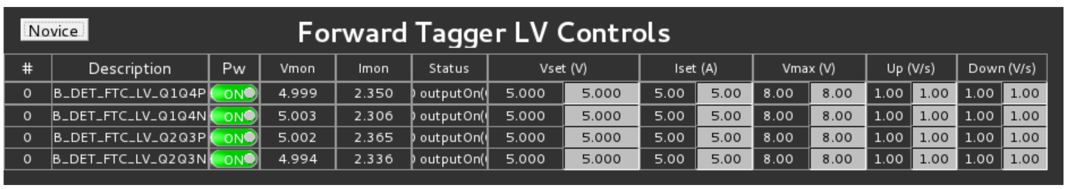


Figure 26: The LV expert EPICS screen in normal operation.

Note, as a safeguard, if one currently tries to use EPICS to set the voltage greater than 5 V or the current greater than 5 A, the request will be ignored by the IOC.

14 High Voltage

14.1 Changing HV Settings

NOTE: Changing voltage settings should be taken care of in coordination with the FT-Cal group (contact M. Battaglieri).

NOTE: The FT-Cal HV groups were renumbered for EPICS, and the correspondence map (Figure 27) is available on the following webpage: https://logbooks.jlab.org/entry/3370066

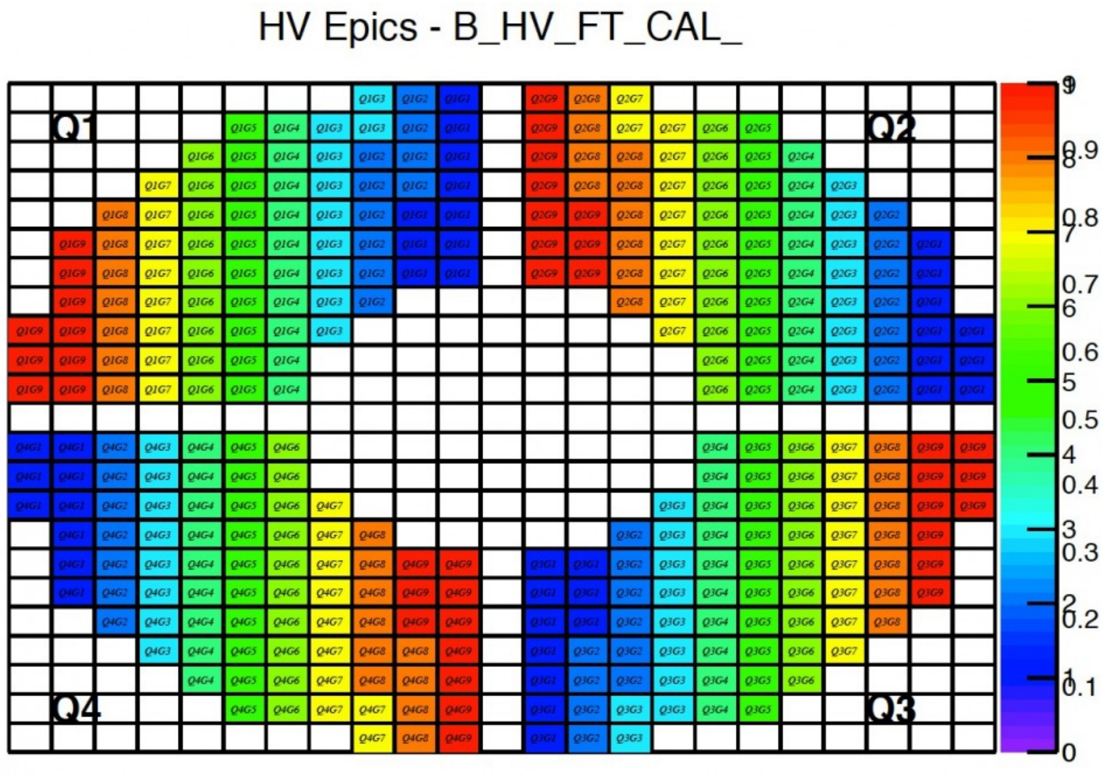


Figure 27: HV channel map for reference.

If for some reason some channels were to drop in gain (or increase) or if the current drawn increases in a group, it might be necessary to change the HV settings in the expert FT-Cal EPICS control (Fig. 13). A modification of the voltage will lead to a modification of the gain used by the trigger system, these values need to be updated at the same time!

14.1.1 HV Save/Restore

A system to save and restore the entire calorimeter's voltage settings is available via the grey button in the HV section of the main Overview page, shown in Figure 5. If the voltage setpoints are changed, a backup should be made of the new settings. This must be run as clasrun user in directory `/usr/clas12/DATA/burt/FTC_HV`. An example of the restore window is shown in Figure 28, which is accessible from the FTC Overview screen shown in Figure 5.

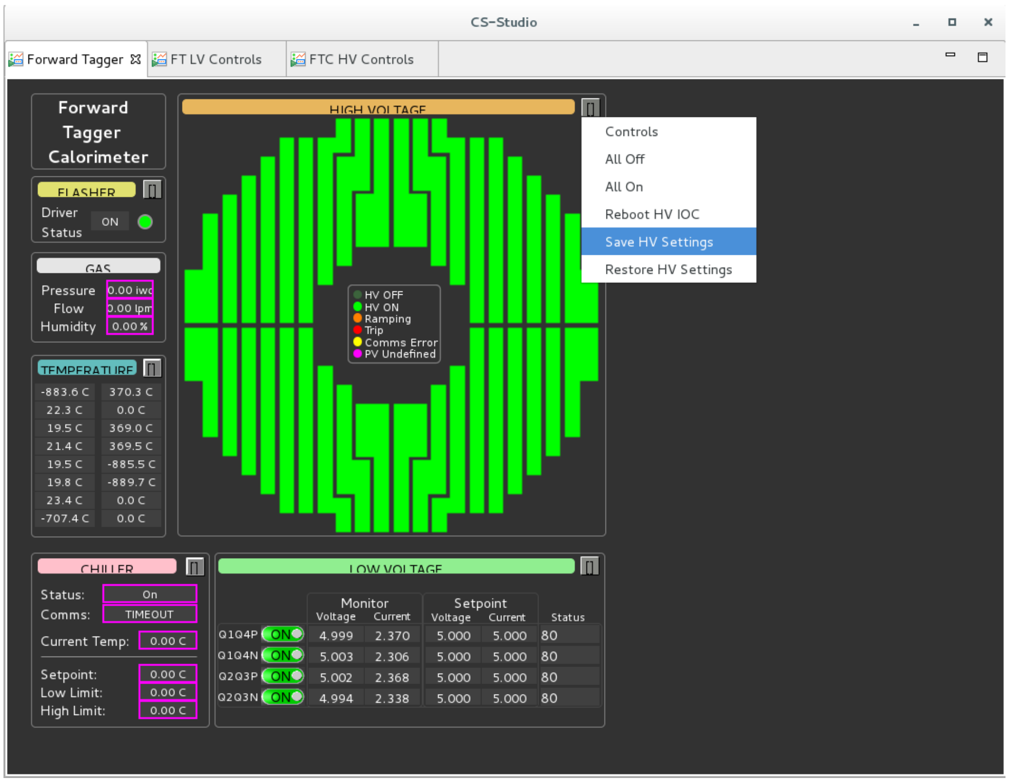


Figure 28: Menu button within the High Voltage section of the FTC Overview window which allows the user to save HV setting. To restore simply use the next option below, within the same menu.

15 Channel Mapping GUI

Channel mapping is available as Annex to this manual.

16 LED system for experts

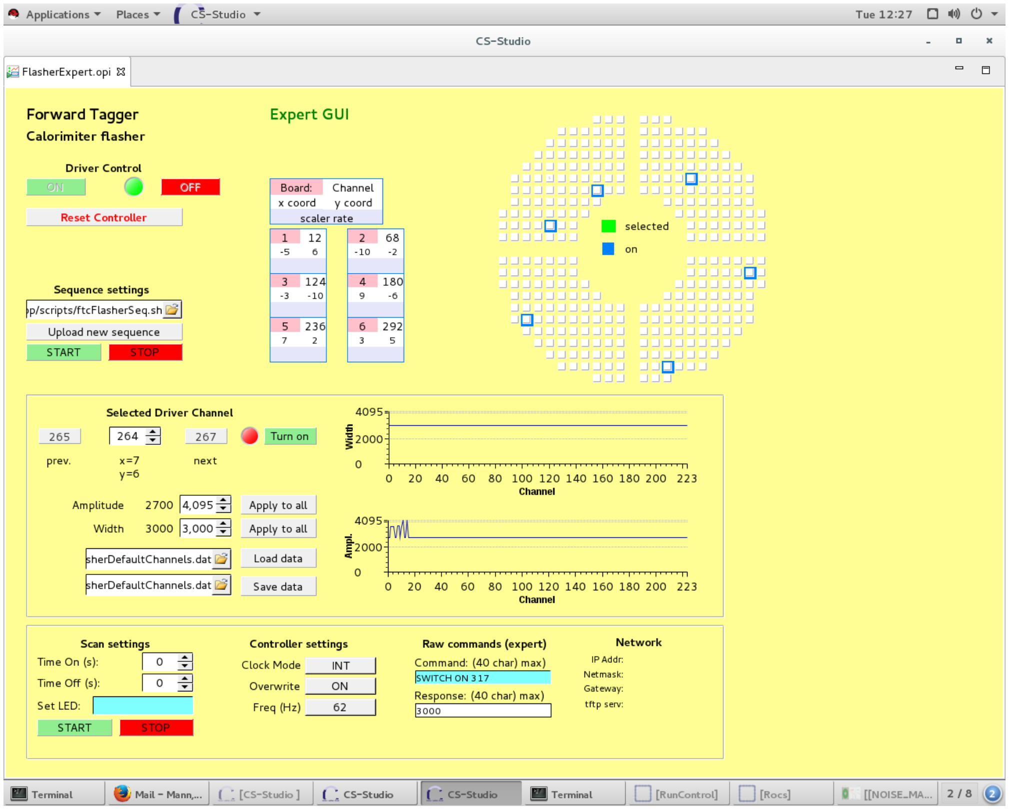


Figure 29: View of the LED flasher expert controls.

1. **Getting There!**
   - Using the Hall-B Epics main window select the option FTC Flasher Expert.4 Within this GUi the user has master control of all the LED Flasher's capabilities. The User may flash groups or single LED's automatically, set LED amplitudes and widths, send raw commands to the flasher, and control various trigger aspects of the flasher.
2. **Novice: Turning on/off**
   - On the Flasher Gui there are two options under driver control "ON" and "OFF". Before starting anything with the LED system make sure the driver control is on, otherwise all commands you send to the GUi will have no effect. Once finished with your work, remember to switch off the system; if this action is not performed you could unwantingly trigger the system (versus a acalibration run), or flash the APD within the FTCal with an LED while taking an actual run. 30
3. **Novice: Visual Map**
   - As with the novice window, the user can select single LED's and mouseover each element to determine the component number and LED driver channel. The only limitation of using this map is that, like with the novice version of this Gui, the user will be unable to set Amplitudes, Widths, or turn individual LED's on. 30
4. **Novice: Sequence**

- As with the novice window the user can also initiatestart and stop a sequence, with the corresponding buttons on the Gui. This sequece flashes a set of 6 LED's (with exception to the first step, in which only 2 a flashed) at a time for a total of 60 seconds. The 3X2 matrix in the middle shows the current LED's being activated as well as their coordinate positions in the FTCal. 30

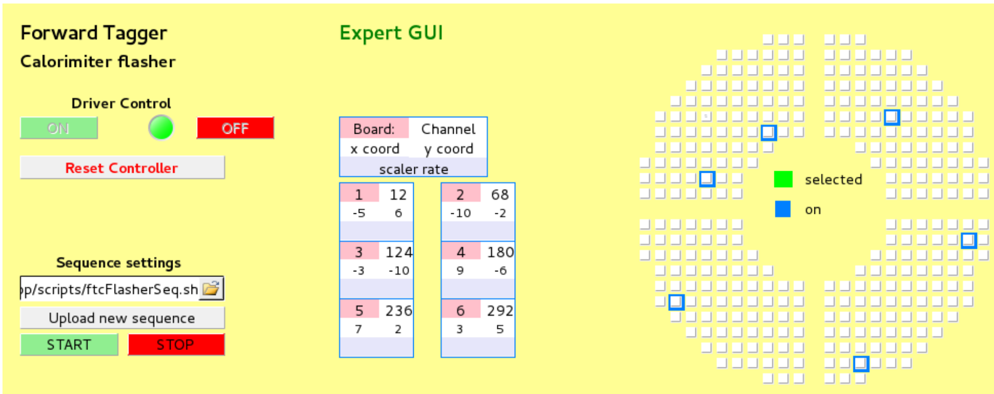


Figure 30: Cropped view of the LED flasher expert controls, showing only the top section.

5. **Expert: Single Selection**
   - In the middle section of the GUi the user will see the options to cycle through each LED in order, starting at (3,11), and transitioning horizontally accross the row when the next LED is selected. Most importantly the user will also be given the opportunity to turn on/off individual LED's for specific channel testing. The numbering system is highlighted in the image below. 31 32
6. **Expert: Amplitudes and Widths**
   - In the middle section of the Gui, the user will also be allowed to alter the flashing LED's amplitude (brightness), and width (the length of the pulse flash); two graphs on the right side of the window display the distribution of amplitudes and widths for all LEDs. If the user would like to save/load their own settings for all LED's the save/load buttons will perform that task. 32
7. **Expert: Scan Setting**
   - ****TO BE ADDED*****
8. **Expert: Controller Setting (Trigger)**
   - Under this column the three buttons displayed allow the user to trigger to the entire system, alter the rates of this trigger, and enable an overwrite function. the two options related to the trigger are: "Clock Mode" and "Freq (Hz)".The final button "Overwrite" allows the user to continually turn on LEDs without having to turn off the previously selected channel. 33
9. **Expert: Raw Commands**
   - In order to use this section the user will need to be familiar with the list of raw commands that the flasher can accept. The list of commands is found on the following WIKI page: https://wiki.ge.infn.it/g3wiki/index.php/Monitoring_system#For_dummies in the section title "List of available commands" 33

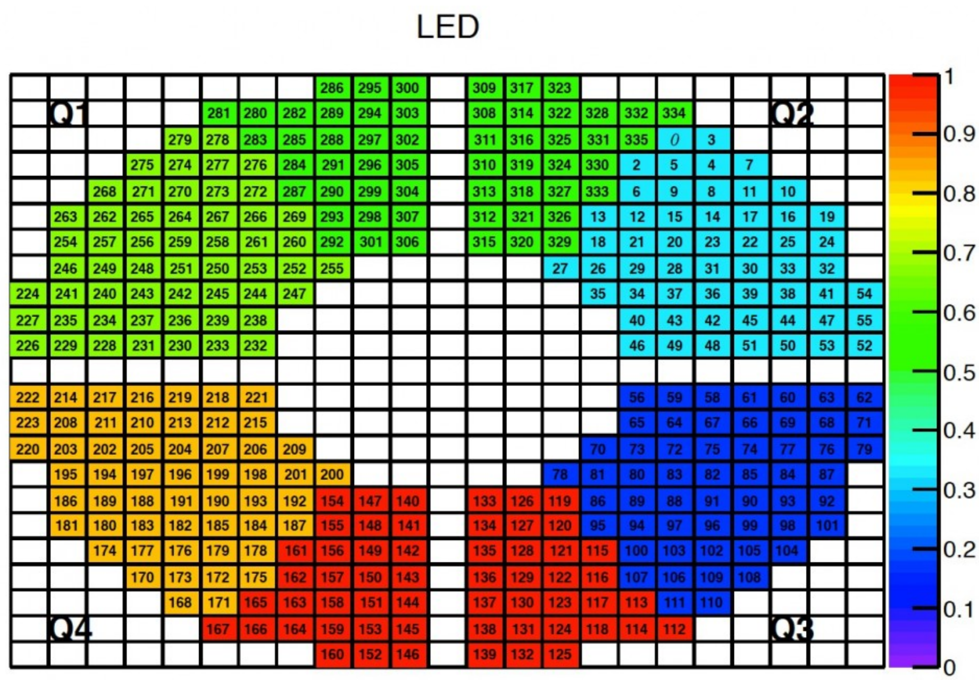


Figure 31: LED number association.

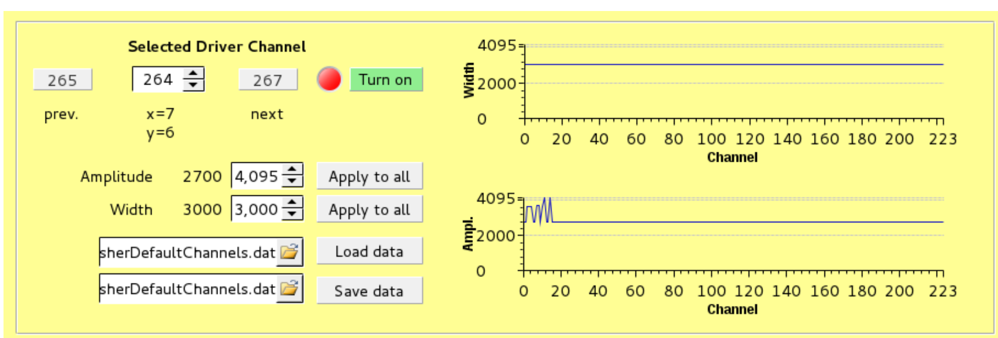


Figure 32: Cropped view of the LED flasher expert controls, showing only the middle section.

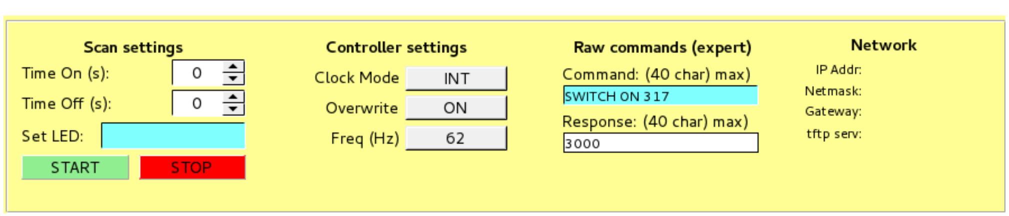


Figure 33: Cropped view of the LED flasher expert controls, showing only the bottom section.

10. **Expert: Network Information**
   - ****TO BE ADDED*****

Manual for CLAS12 FT-Hodo v1.0

FT-Cal On-Call Cell Phone: 757-810-1489
Authors:
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May 31, 2016

Contents

1 General description of the FT-Hodo

The primary task of the Forward Tagger Hodoscope (FT-Hodo) is to separate electron and photon events in the calorimeter. These events cannot be distinguished using information from the FT-Cal alone due to the similarity of their electromagnetic shower shapes. Electrons are identified by observing the presence of a hit in the FT-Hodo array, which is correlated in both position and time with a cluster observed in the calorimeter.

The FT-Hodo provides a highly efficient charged particle signal with a spatial and timing resolution similar to that of the calorimeter. In addition, to minimise possible misidentification of photons the detector is designed to suppress the contribution of false events arising from photon conversion in the FT-Hodo detectors and contributions from "splashback" of the electromagnetic shower created by events depositing energy in the FT-Cal. To do this, a 2 layer design was implemented. The timing resolution of the FT-Hodo is comparable with FT-Cal so as not to compromise the achievable coincidence timing resolution (better than 1 ns). The hodoscope is positioned upstream of the FT-Cal, fitting into a circular disk of diameter 330 mm and depth of 42 mm.

The hodoscope comprises a segmented array of plastic scintillator tiles (Eljen-204), embedded with a wavelength shifting (WLS) fibres, and is read out by 3x3 mm^2 silicon photomultipliers (SiPM) via optical fibres. The plastic scintillators provide fast timing and sufficient resistance to radiation damage for use in the high rate environments of the forward tagger. The scintillation light from the detector elements is transferred away from the hodoscope using embedded WLS fibres, which are fusion spliced to 5m-long optical fibres. The WLS fibres absorb the UV light produced in the plastic scintillator and emit at a larger wavelength (green), which matches well with the optimal quantum efficiency of typical SiPMs. The splicing induces a photon loss of less that 2% whereas the use of optical fibre allows the captured light to be transported with a light loss less that $\sim 40\%$ over the 5 meter path to the SiPM.

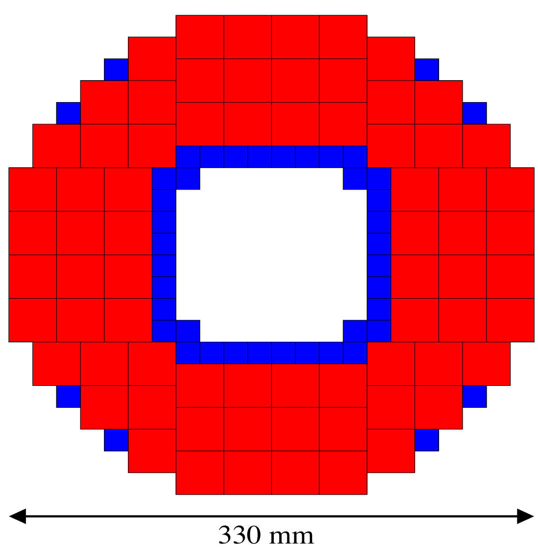


Figure 1: Layout of plastic scintillator detectors in the Forward Tagger hodoscope. Blue squares represent 15 x 15 mm pixels and red 30 x 30 mm.

The hodoscope array is made of two scintillator-tile sizes, 15 x 15 mm – P15, and 30 x 20 mm – P30, which cover a single and an array of four calorimeter crystals respectively. The arrangement of these detector elements that makes up a layer of the hodoscope is shown in Fig. 1. The hodoscope comprises of 2 detector layers, each having 44 P15 and 72 P30 pixels. One layer is made from 7 mm-thick plastic scintillator tiles with the second utilising 15 mm-thick tiles. The two layer resolution is the preferred option for the hodoscope, sine the front thin layer is employed to reduce photon conversion in the hodoscope, while the thicker back layer provides the signal with the most accurate timing information for the event.

2 LED flasher

2.1 Overview

The purpose of the LED flasher is to monitor changes in the transmission of the Hodoscope fibres. The principle of its operation is that pulsed light from an LED of a similar wavelength to that produced in the hodoscope scintillators is conveyed inside the hodoscope, to the enclosed area behind the scintillator tiles, and used to illuminate the part of the wavelength-shifting fibres which is outside the tiles. These absorb some of that light in the same way as they do the scintillation light, re-emit it inside the fibre at a longer wavelength and the light pulse is then transported down the optical fibre to the SiPM sensor at its end. Any changes in the behaviour of the wavelength-shifting fibres or the transmission of the optical fibres, for example due to radiation damage, will affect the read-out signal. A fraction of the emitted light from the LED will be measured directly with a SiPM to provide a calibration reference for each pulse. In order to decouple any possible effects due to the degradation of the flasher fibres, two single fibres of the same material and twice the length are passed from the LED through the hodoscope enclosure, one in each layer, and out to two SiPM sensors. The flasher can be pulsed at any time in a dedicated run. In this way any changes in the flasher signals read-out by the hodoscope fibres can be monitored over time, calibrated to the size and width of the emitted LED pulse and corrected for any degradation due to the flasher fibres themselves.

2.2 The flasher hardware

The hardware comprises an LED light source with peak emission at 420 nm (M420F2, Thorlabs), the light from which is transported along a short optical fibre to a custom-made splitter, whence it travels along optical fibres into the hodoscope enclosure.

The splitter has been custom-made at Glasgow University and consists of a small, light-tight plastic unit which houses a glass diffusing disk positioned in front of the LED fibre, a short cylindrical light-guide and a "top hat" fixture at the end containing the optical fibres. Eight output flasher fibres are fixed inside the rim of the "top hat" in a circle, their open ends meeting the light-guide. Additionally, a calibration fibre and two flasher-monitoring fibres are positioned in the centre of the "top hat", within the protruding cylinder inside which a number of transmission filters reduce the light intensity down to a level that is not damaging to the SiPM sensor. The calibration fibre is connected directly to a SiPM and its signal is used to calibrate the LED pulse read out from the hodoscope channels. The two flasher-monitoring fibres are passed through the hodoscope enclosure, one through each layer, and connected directly to SiPMs. They are made from the same material as the flasher fibres and any changes in the signals sent through them are used to quantify degradation effects of the flasher fibres.

The tips of the flasher fibres have been machined to emit diffuse light homogeneously along their length, illuminating the hodoscope enclosure inside which they are positioned. The configuration can be seen in Fig. **??**, with 6 cm long tips epoxied to the hodoscope lid tangentially in the centre of the hodoscope fibres closer to the neck of the hodoscope and 9 cm long tips epoxied in the equivalent positions further from the neck. Thus, in each of the two layers of the hodoscope, four illuminating tip fibres are fixed to the lid of the hodoscope tracing out a rough circle in the middle of its active part. The illuminating-tip fibres were 6m long, produced by Medlight (cylindrical light diffusers, model RD) with a $500\mu m$ diameter plastic core, clad in transparent PVC plastic (1/1.8 mm inner/outer diameter) sealed at the illuminating end. The part of the fibre which is outside the hodoscope enclosure was additionally sheathed in black plastic tubing to provide a light-seal. The two flasher-monitoring fibres, 12 m long, were made of the same material but without an illuminating end. These were stretched through the two layers of the hodoscope and epoxied to the lid alongside the illuminating tips.

Part I
Shift Takers Instructions

All FT-Hodo controls are accessible through EPICS, from the main HPS_EPICS window (figure 2). If not already running, it can be opened by executing the command

`hps_epics`

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

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

The primary FT-Hodo screen is shown in figure **??** and opened via t

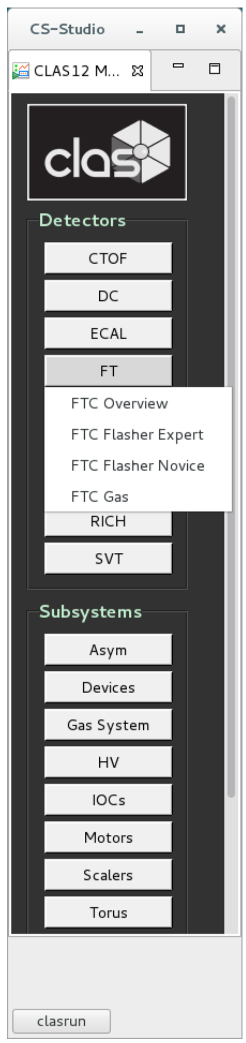


Figure 2: View of the Hall-B EPICS main window.Menu shown gives access to the HV, LV, Temperature sensors, Chiller, Gas system, and LED flasher.

3 Primary FT-Hodo EPICS Screen

4 Low Voltage

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

LV should be monitored using its webcam and its portion of the main ECAL EPICS screen (both shown in figure ??). Call the FT-Hodo 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 3: LV controls for the FTHodo.LV STRIP CHARTS TO BE IMPLEMENTED SOON

5 High Voltage

5.1 Turning ON/OFF High Voltages

The high voltage supply of the FT-Hodo is controlled and monitored using the main FT-Hodo EPICS window (Figure ??). It has buttons to ramp up and down the entire hodoscopes high voltages (labeled **ALL ON** and **ALL OFF**), open windows for individual channel control (figure 4), and open more detailed expert views (e.g. figure 8).

5.2 HV Current Monitoring

Individual channels' currents can be monitoring in figure 4, and strip charts should be open for long term monitoring. The strip charts are accessible from the main FT-Hodo screen (figure ??) under the HV sections' **Monitors** button (and also from the HPS_EPICS screen (figure 2) via the **Strip-Tool** button). An example is shown in figure ??. Jumps or drifts in current of more than 1 A should be noted in the logbook.

5.3 Responding to HV trips

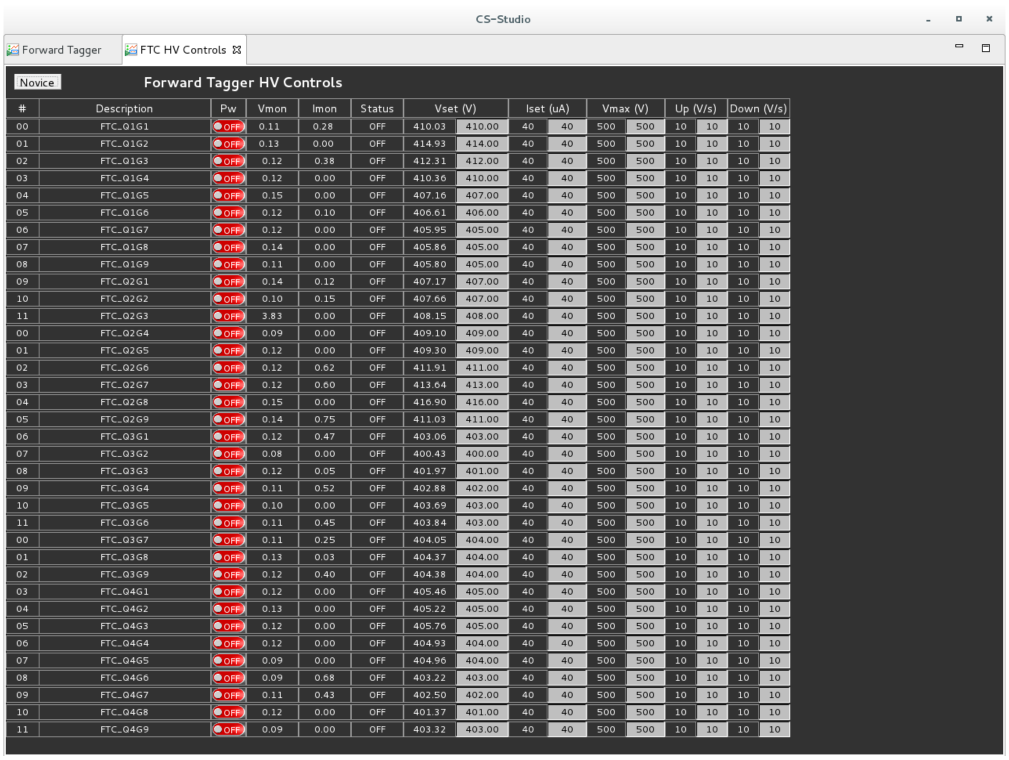
HV problems, in particular trips, are indicated by a red group in the main FT-Hodo EPICS GUI (figure ??). HV trips will also be announced by the alarm handler. During normal operations with HV ON, there should be no red groups in Figure **??** and no ECAL HV alarms. In case of an HV trip, or a red region in Figure **??**:

- Try to reenable the tripped HV group by turning it back on in the EPICS HV control screen (figure 4) accessed via the **Controls** button in the main FT-Hodo EPICS screen (Figure **??**). (An easier alternative is just pressing the **ALL ON** button in the main FT-Hodo EPICS screen.)
- Record the trip in the log book with precise indication of the group and run number concerned.

Contact the ECAL 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 FT-Hodo expert on call.

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



#	Description	Pw	Vmon	Imon	Status	Vset (V)		Iset (uA)		Vmax (V)		Up (V/s)		Down (V/s)	
00	FTC_Q1G1	OFF	0.11	0.28	OFF	410.03	410.00	40	40	500	500	10	10	10	10
01	FTC_Q1G2	OFF	0.13	0.00	OFF	414.93	414.00	40	40	500	500	10	10	10	10
02	FTC_Q1G3	OFF	0.12	0.38	OFF	412.31	412.00	40	40	500	500	10	10	10	10
03	FTC_Q1G4	OFF	0.12	0.00	OFF	410.36	410.00	40	40	500	500	10	10	10	10
04	FTC_Q1G5	OFF	0.15	0.00	OFF	407.16	407.00	40	40	500	500	10	10	10	10
05	FTC_Q1G6	OFF	0.12	0.10	OFF	406.61	406.00	40	40	500	500	10	10	10	10
06	FTC_Q1G7	OFF	0.12	0.00	OFF	405.95	405.00	40	40	500	500	10	10	10	10
07	FTC_Q1G8	OFF	0.14	0.00	OFF	405.86	405.00	40	40	500	500	10	10	10	10
08	FTC_Q1G9	OFF	0.11	0.00	OFF	405.80	405.00	40	40	500	500	10	10	10	10
09	FTC_Q2G1	OFF	0.14	0.12	OFF	407.17	407.00	40	40	500	500	10	10	10	10
10	FTC_Q2G2	OFF	0.10	0.15	OFF	407.66	407.00	40	40	500	500	10	10	10	10
11	FTC_Q2G3	OFF	3.83	0.00	OFF	408.15	408.00	40	40	500	500	10	10	10	10
00	FTC_Q2G4	OFF	0.09	0.00	OFF	409.10	409.00	40	40	500	500	10	10	10	10
01	FTC_Q2G5	OFF	0.12	0.00	OFF	409.30	409.00	40	40	500	500	10	10	10	10
02	FTC_Q2G6	OFF	0.12	0.62	OFF	411.91	411.00	40	40	500	500	10	10	10	10
03	FTC_Q2G7	OFF	0.12	0.60	OFF	413.64	413.00	40	40	500	500	10	10	10	10
04	FTC_Q2G8	OFF	0.15	0.00	OFF	416.90	416.00	40	40	500	500	10	10	10	10
05	FTC_Q2G9	OFF	0.14	0.75	OFF	411.03	411.00	40	40	500	500	10	10	10	10
06	FTC_Q3G1	OFF	0.12	0.47	OFF	403.06	403.00	40	40	500	500	10	10	10	10
07	FTC_Q3G2	OFF	0.08	0.00	OFF	400.43	400.00	40	40	500	500	10	10	10	10
08	FTC_Q3G3	OFF	0.12	0.05	OFF	401.97	401.00	40	40	500	500	10	10	10	10
09	FTC_Q3G4	OFF	0.11	0.52	OFF	402.88	402.00	40	40	500	500	10	10	10	10
10	FTC_Q3G5	OFF	0.10	0.00	OFF	403.69	403.00	40	40	500	500	10	10	10	10
11	FTC_Q3G6	OFF	0.11	0.45	OFF	403.84	403.00	40	40	500	500	10	10	10	10
00	FTC_Q3G7	OFF	0.11	0.25	OFF	404.05	404.00	40	40	500	500	10	10	10	10
01	FTC_Q3G8	OFF	0.13	0.03	OFF	404.37	404.00	40	40	500	500	10	10	10	10
02	FTC_Q3G9	OFF	0.12	0.40	OFF	404.38	404.00	40	40	500	500	10	10	10	10
03	FTC_Q4G1	OFF	0.12	0.00	OFF	405.46	405.00	40	40	500	500	10	10	10	10
04	FTC_Q4G2	OFF	0.13	0.00	OFF	405.22	405.00	40	40	500	500	10	10	10	10
05	FTC_Q4G3	OFF	0.12	0.00	OFF	405.76	405.00	40	40	500	500	10	10	10	10
06	FTC_Q4G4	OFF	0.12	0.00	OFF	404.93	404.00	40	40	500	500	10	10	10	10
07	FTC_Q4G5	OFF	0.09	0.00	OFF	404.96	404.00	40	40	500	500	10	10	10	10
08	FTC_Q4G6	OFF	0.09	0.68	OFF	403.22	403.00	40	40	500	500	10	10	10	10
09	FTC_Q4G7	OFF	0.11	0.43	OFF	402.50	402.00	40	40	500	500	10	10	10	10
10	FTC_Q4G8	OFF	0.12	0.00	OFF	401.37	401.00	40	40	500	500	10	10	10	10
11	FTC_Q4G9	OFF	0.09	0.00	OFF	403.32	403.00	40	40	500	500	10	10	10	10

Figure 4: Cropped view of the EPICS FT-Hodo HV control window for individual channels.

6 Scalers

Rates seen by the FT-Cal are available in the ROOT-based GUI shown in Figure 5, which represent the rates as seen by the FADC electronics. This display is accessible via the main HPS_EPICS window under the **ECAL Scaler GUIs** button, and also by running the command `hps_ecal_scalers` in a terminal. *As of 2016, the discriminators are disconnected and only the FADC rates are accessible.*

One can also see clustering scalers from the DAQ "diaggui" screen (figure **??**), accessible also by the **ECAL Scaler GUIs** button or by executing `diaggui.sh` in a terminal. This GUI indicates the rates of clusters reconstructed by the trigger electronics.

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 FT-Cal system. If the latter case, please contact FT-Cal expert on call.

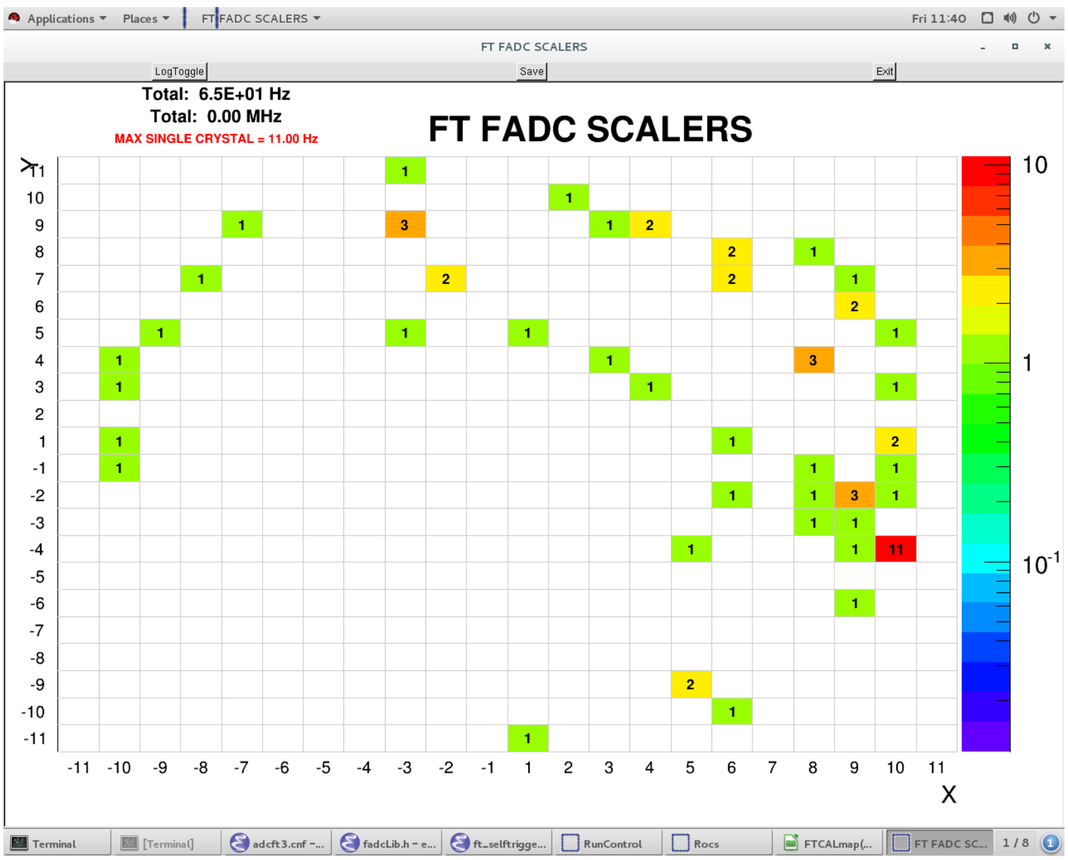


Figure 5: View of the EPICS FADC scalers window.

7 Strip Charts

The most import quantities to monitor with strip charts are temperature and HV current. There are two programs to view strip charts of FT-Cal EPICS variables. The older StripTool shown in figure **??** can be started from the HPS_EPICS gui. The newer MyaViewer (which adds the ability to retrieve archive information) can be run by executing the following scripts in a terminal:

- `mya_ecal_all.sh`
- `mya_ecal_temp.sh`
- `mya_ecal_curr.sh`
- `mya_ecal_voltage.sh`

8 Monitoring App

The monitoring application is based on the common tools developed for CLAS12. It provides many plots to assess detector performance. To start the monitoring app, in a terminal run:

```
startHodoMonitoring
```

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.

The main window is split into two panels 1) the detector view, and 2) data view. The detector view shows the individual tiles in the two hodoscope layers and allows the selection of a specific detector element. It also indicates bad detector elements through colour-coding. The data view shows information collected using the selected detector element.

Part II

FT-Cal Experts Resources

9 Location of FT-Hodo Elements

REMINDER: *Since the FT-Hodo is within 3 feet of the beamline, it needs to be surveyed by RADCON before any work can be done on it.*

- The LED controllers are located at the top of the rack closest to the beamline in the Alcove. item The FADCs and patch panels occupy the rack furthest from the beamline in the Alcove.
- The HV supply is on the Pie Tower in the rack closest to the beamline. See figure **??**.
- The LV supply is on the Pie Tower at the top of the middle rack. See figure 6.

IMAGE.png

Figure 6: Location of Agilent LV power supply near the top of the middle rack in the pie tower. Power switch is circled in red.

Figure 7: Location of the CAEN HV power supply ****LOCATION TBA***. Key for on/off is in the lower right corner of the crate.

10 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.

10.1 Changing LV Settings

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

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 10.1.1), 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`

10.1.1 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 10.3).

10.2 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.

10.3 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.

11 High Voltage

11.1 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 8).

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.

11.2 Changing HV Settings

NOTE: Changing voltage settings should be taken care of in coordination with the FT-Cal group (contact M. Battaglieri). Current setting can be increased in case of need, please document this change in the log book and notify the FT-Cal expert on call.

NOTE: The FT-Cal HV groups were renumbered for EPICS, and the correspondence map (figure 9) is available in the expert FT-Cal HV monitoring window (Figure 8) via the “Expert HV Map” button.

If for some reason some channels were to drop in gain (or increase) or if the current drawn increases in a group, it might be necessary to change the HV settings in the expert FT-Cal EPICS control (Fig. **??**). A modification of the voltage will lead to a modification of the gain used by the trigger system, these values need to be updated at the same time!

11.2.1 HV Save/Restore

A system to save and restore the entire calorimeter’s voltage settings is available via buttons in the ECAL HV expert window in Figure 8. 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 10, which is accessible from the HV expert screen shown in Figure 8.

11.3 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 `hpsrun` on `clonpcNN` by excuting the command:

```
$HOME/.ecalhv/plotEcalHV.py
```

The product should be a plot like figure **??**.

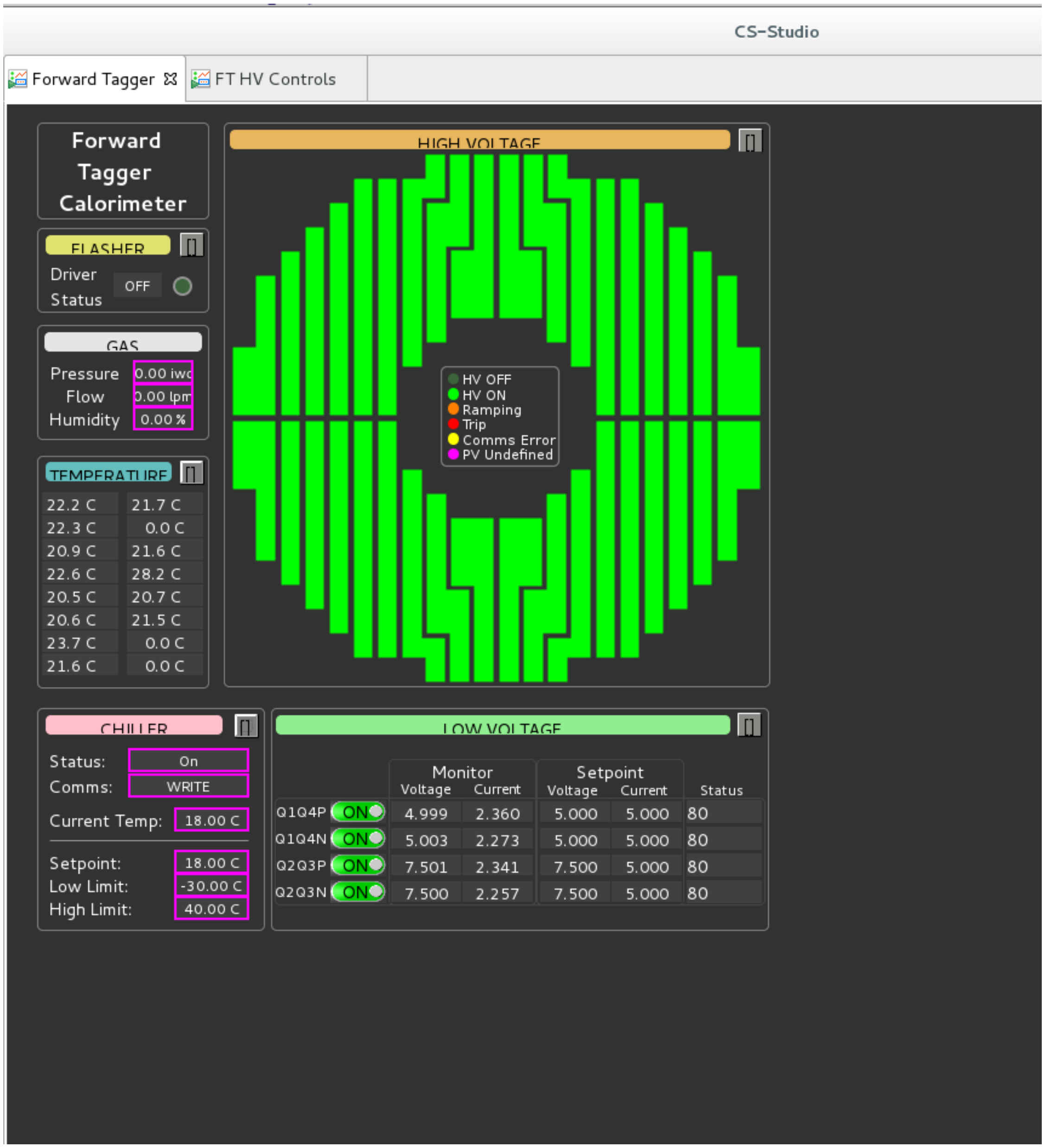


Figure 8: View of the EPICS FT-Cal HV expert monitoring window.

IMAGE.png

Figure 9: HV channel map for reference.

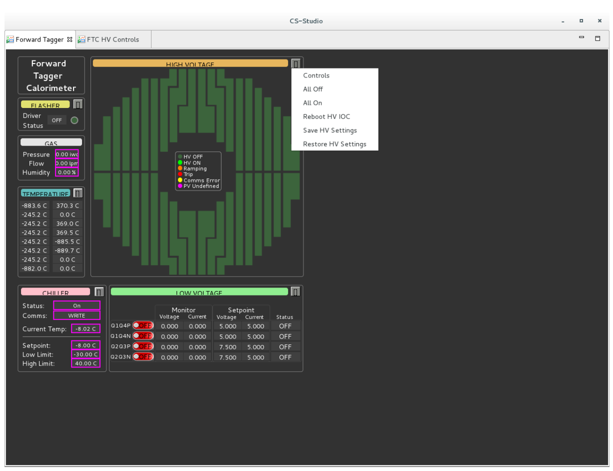


Figure 10: HV menu within EPICS to save/restore HV settings.

12 Channel Mapping GUI

Channel mapping is available in a spreadsheet in the annex pdf on the HPS Run Wiki. It is also available in an interactive GUI (shown in Figure **??**) which can be run by executing

`kylesGui.sh`

in a terminal.

The user can hover over a crystal with the mouse to see all its channel numberings in the table at the bottom of the window. This includes x/y-indices, APD and LED channel numbers, FADC slot/channel, JOUT connector and channel, and HV group. *Note that preamp numbers in this GUI are no longer copmletely correct after their partial replacements prior to the 2015 Engineering Run.*

There is also a filtering option in the **View** menu to highlight all channels corresponding to certain criteria.

13 Opening the Hodoscope

This requires 2 people. Extreme care must be taken for all fibres and cabling during this process.

14 Disconnection of a Channel and Preamplifier Replacement

In last resort, to recover a HV group that is tripping one can disconnect the faulty channel causing trouble. To do so, you need to find exactly which channel is involved! It might be obvious from data, if the channel was already very noisy, else you will have to test the channels of the group one by one. This is a lengthy operation and should only be attempted with the authorization of the run coordinator and in coordination with the FT-Cal Group. It necessitates that the Hall-B crew moves the FT-Cal out of the beam line and to open it.

FORWARD TAGGER TRACKER OPERATION MANUAL V1.0

Table of Contents

1 Introduction

This document details how to operate the Forward Tagger Micromegas detector. The instructions reported in the following are for trained personnel. A shift taker manual will be developed as simplified monitor and control interfaces are developed based on the CLAS12 slow controls system.

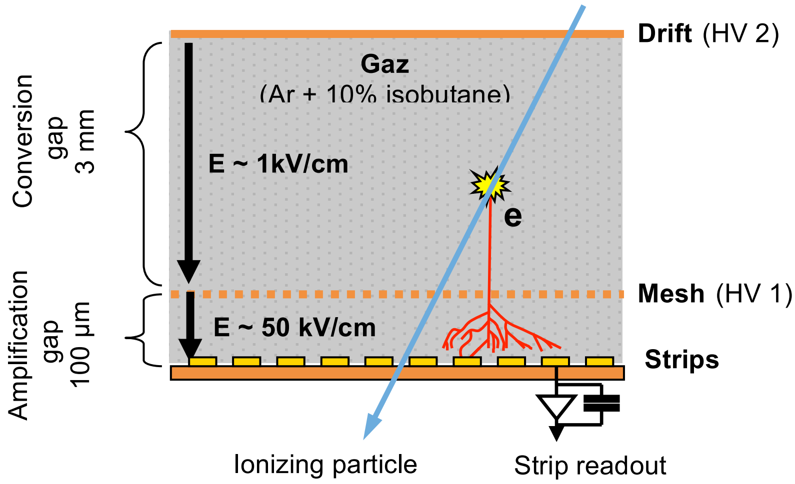


Figure 1 - Schematic of a Micromegas detector

2 System description

2.1 General:

The Forward Tagger Tracker (FT-Trck) is made of Micromegas detectors disposed in four layers. A Micromegas (MICROMEsh GAseous Structure) is a gaseous detector based on a parallel plate electrode structure and a set of microstrips for readout as seen on Fig. 1. The presence of a micromesh between the strips and the drift electrode allows for separating the conversion gap, where particles create primary electrons by interacting with the gas, from the amplification gap, where the primary electrons will create an avalanche in the presence of a high electric field. If this field is high enough compared to the field in the conversion gap, the micromesh is transparent for the electrons, but not for the ions coming from the avalanche. This special feature allows a very fast collection of the ions created in the amplification gap (around 100 ns, compared to several microseconds for a drift chamber). For this reason, Micromegas detectors have a very high-rate capability. The detectors used in the case of FT-Trck have a disk shape.

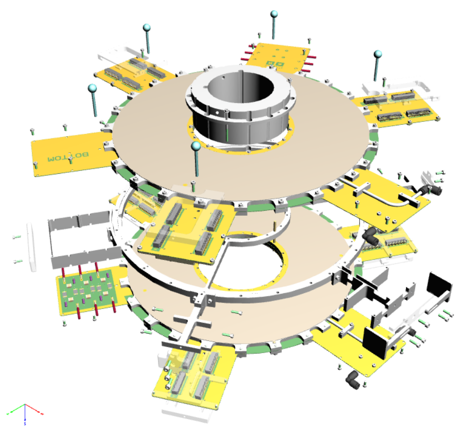


Figure 2 – Exploded view of the Forward Tagger Tracker

The Forward Tagger Tracker is composed of two double-sided Micromegas double-stage gaseous detectors. The detectors are based on the resistive Micromegas technology: a coating of resistive strip material is deposited on the top of the readout strip thus allowing to operate the detectors without spark at high rate; In this configuration the mesh is grounded and the high voltage for amplification is positive on the resistive strips. This technology is also employed in the CLAS12 Central Micromegas tracker. Each detector consist of two planes with strips oriented along the X and Y axis, respectively, separated by 10 mm. Each plane has 768 strips with 560 μm pitch. The FT tracker covers the polar angle region from 2.5 to 4.5 degrees from the target. The gas that will be used is a mixture of 90% of Argon and 10% of isobutane. Fig. 2 shows an exploded view of the FT-Trck.

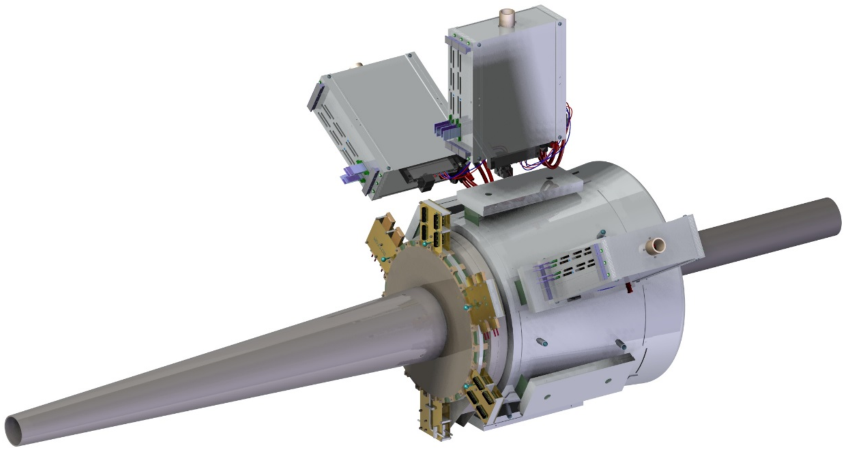


Figure 3 – View of the Micromegas tracker mounted in the Forward Tagger

In order to hold the FT-Trck in the operating position, i.e. in front of the FT hodoscope and calorimeter as shown in Fig. 3, the Micromegas detectors are supported at the center by a stainless steel ring, which is designed to fit onto the FT calorimeter inner support pipe. Three custom crates containing the readout boards are mounted on the calorimeter outer case, as shown in Fig. 3 and 4. The connection between detectors and readout is done using 1.5 m long flex cables.

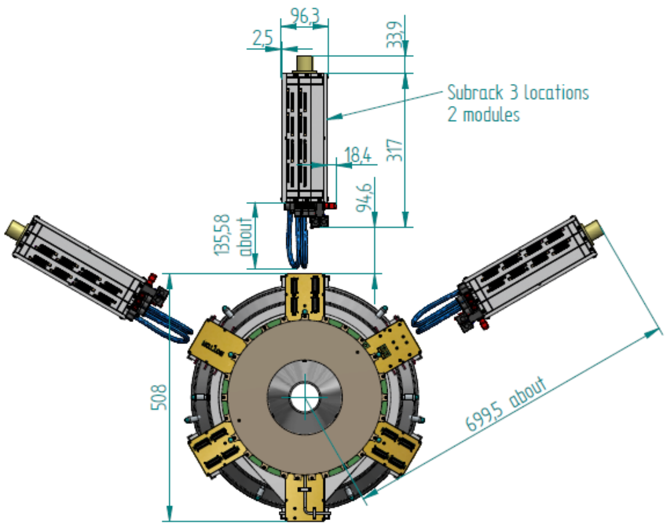


Figure 4 – Front view of the Forward Tagger with the tracker and related electronics

In operation, a Micromegas detector has to be polarized by three high voltages (HV), the two active areas corresponding to the anode and the drift plane (cathode) 5 mm above the anode. The nomenclature used is summarized in Table 1. Each double side detector has an input and an output gas connection.

Naming convention	Detector number	Drift
FTT_X_STRIPS	X	
FTT_X_DRIFT	X	•

Table 1 - Nomenclature of the high voltage for the FT tracker detectors, x=1..4

2.2 Gas:

The Micromegas are continuously flushed with gas in order to keep a good purity and overcome the normal outgassing of the detectors. The gas is Argon with 10% of isobutane. The flow rate is 4 l/h (liter per hour) for the full set of detectors in serial. The gas is rejected outside Hall B.

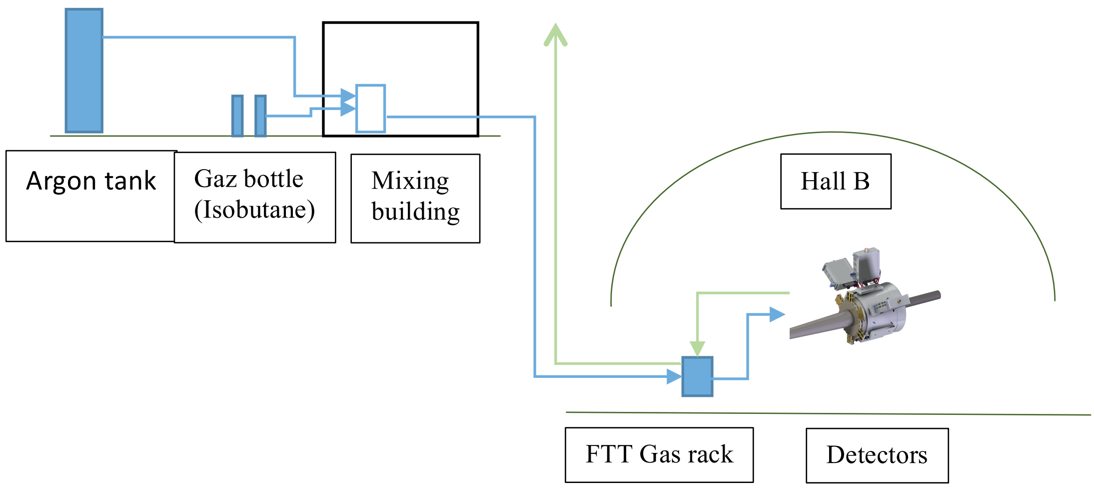


Figure 5 - General view of gas lines

The gas system will be partially shared with the CLAS12 MVT barrel detectors. The gas lines for the all Micromegas detectors are coming from the gas shack. The line for the FT-Trck ends at a gas rack located on the floor at the entrance of Hall B. The rack has a mass flow meter at the entrance and two flow meters at the exit (normal gas exhaust and overpressure). The monitoring of the pressure and of the mass flow meter is done through a 1200 series Siemens PLC. If a difference of flow is found (a leak), the system is stopped and a leak check can be done using rotameter providing gas for a double-sided detectors. Thus while waiting for opportunity to repair the leak, the system can work with a line of double-sided detector disabled.

A gas control panel located in the FT rack under the subway allows operating the gas rack in manual (with fixed values for the flow and pressure) or in automatic (by PLC).

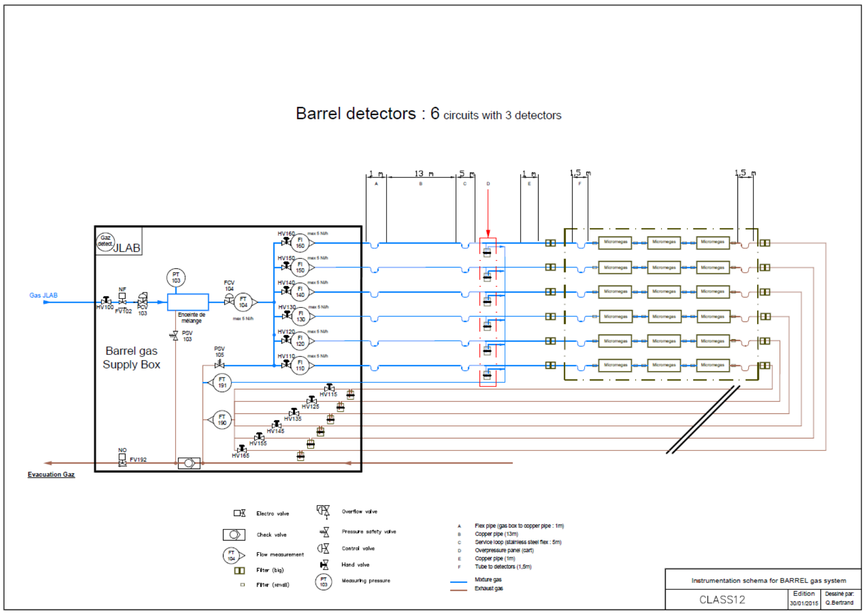


Figure 6 - Schematic of the CLAS12 MVT Barrel gas rack. A similar layout is employed for the FT-Trck gas rack with only one line going to and from the detectors.

2.3 FT tracker readout system

The extremely tight design of the CLAS12 Forward Tagger puts strong constraints on the overall space allocated for the tracker. Consequently, a readout architecture based on the off-detector frontend electronics has been adopted. It is shown on Fig. 3 and 4. Lightweight micro-coaxial cable assemblies with low linear capacitance carry bare unamplified signals to the frontend units (FEU) housed in crates attached to the calorimeter case. The frontend electronics are responsible for the pre-amplification and shaping of the detector signals, for holding the latter in a pipeline waiting for trigger process to yield, for the digitization and compression of the selected event data and for their delivery to the backend electronics. The backend is responsible for data concentration event-wise. It provides an interface with the CLAS12 event building system. It also ensures a fixed latency path between the CLAS12 trigger system and the FEUs. It receives the system clock and trigger from the CLAS12 trigger supervisor and synchronously conveys them to the FEUs over bidirectional optical links.

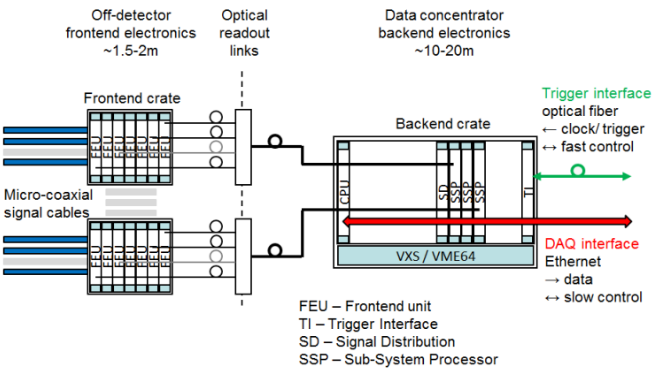


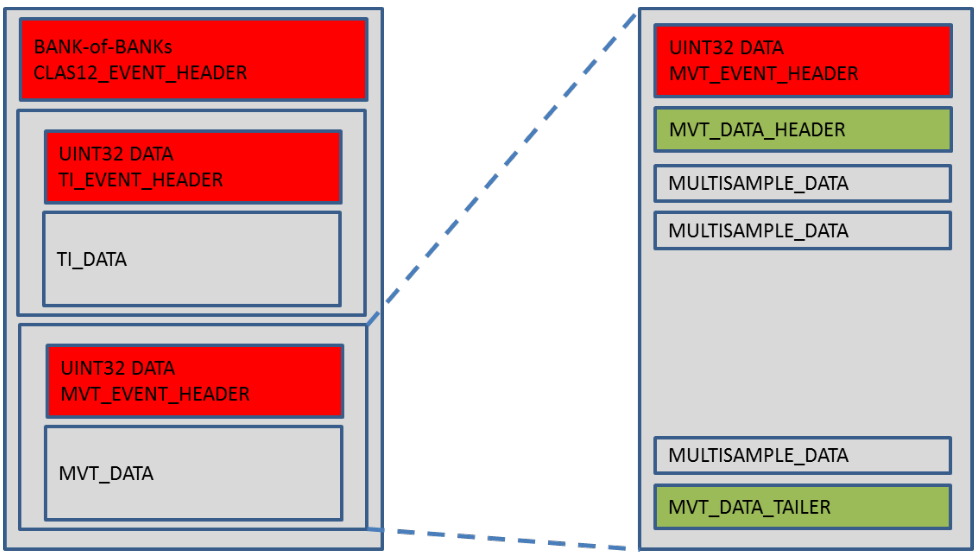
Figure 7 - Schematic of readout system.

To improve FT-Trck readout noise immunity the readout takes advantage of the continuous sampling of detector signals. Pickup noise usually affects groups of neighboring signal lines. It is possible to determine and remove this coherent noise greatly smoothing the induced fluctuations. For each trigger the signal samples are compared to the channel discriminating threshold after the common mode noise subtraction. For channels with charge deposits above the thresholds, a fixed number of consecutive samples are kept for offline analysis. The retained samples describe the signal development in the channel. Fitting their values with a known function allows accurate estimation of deposited charge and of signal timing.

The system is dimensioned to read out the 3K channels of the FT-Trck. The expected 50 MHz physics background results in strip-hit rates of 100 kHz. The readout system is compliant with the CLAS12 requirement of a 20 kHz maximum trigger rate and provides a sufficiently deep data pipeline to cope with a trigger latency as long as 16 µs.

2.4 Data Format

The back end of the data acquisition system of the FT Tracker is based on JLAB standard VME/VXS hardware including TI, SD and SSP boards. Dedicated firmware and software was designed to ensure full compatibility with the CODA DAQ software environment deployed in Hall B. FT tracker data files comply with EVIO requirements. Raw data files can optionally be collected for debugging purposes. Otherwise, the FT tracker data is disentangled event-wise and files are structured following the composite EVIO data format with self-contained description string as follows:



FTT_EVENT_HEADER					
word	**desc.**	32-bits			
0	type	Exclusive length			
	bits	[31:0]			
1	type	tag	pad	type	num
	bits	“” [31:16]	“” [15:14]	“” [13:8]	“” [7:0]

FTT_DATA_HEADER					
word	**desc.**	32-bits			
0	type	Exclusive length			
	bits	[31:0]			
1	type	tag	pad	type	num
	bits	“” [31:16]	“” [15:14]	“” [13:8]	“” [7:0]

Multisample FTT composite data c,i,l,N(s,Ns)					
8 bits	**Back end board ID – Front end board ID**				
	BEU ID [7: 5]		**FEU ID [4 : 0]**		
32 bits	**Event number**				
64 bits	**Timestamp**				
	“00”[63:62]	**BEU time stamp (4ns) [61:16]**	**“0” [15]**	**FEU time stamp (8ns) [14:3]**	**FEU fine time stamp (8ns) [2:0]]**
32 bits	**Number of channels hit**				
16 bits	**Channel ID**				
32 bits	**Number of samples**				
16 bits	**samples**				

FTT_DATA_TAILER					
word	**desc.**	32-bits			
0	type	Exclusive length			
	bits	[31:0]			
1	type	tag	pad	type	num
	bits	“” [31:16]	“” [15:14]	“” [13:8]	“” [7:0]

3 Controls and monitoring

3.1 Detectors high voltage

Each FT Micromegas detector needs two high voltage potentials to operate (+ground); the resistive strips are at a potential of ~ 480 V and the drift at a potential of ~ -600 V.

The high voltage is provided by a CAEN A1536HDM card with four positive and four negative channels. The card is installed in a CAEN crate located on beam-left side of Level 1 space frame and hosting the HV card for the FT hodoscope and calorimeter. From the crate to the detectors, standard high voltage cables are used. The crate is controlled by the EPICS slow control system. The HV system has 3 settings “OFF”, “WAIT”, and “PHYSICS”. In “OFF” state, all the HV are set to 0 V (ground), in

"WAIT" the detectors are polarized but with no gain, and in "PHYSICS" mode the detectors are active and ready to take data.

The detectors HV should always be OFF when the gas mixture is not ok.

3.2 Low voltage for the front end electronics

The frontend electronics is powered from a remote supply placed in in the FT racks under the subway. Voltage drop is ineluctable on the over the long power cables connecting the crates with the power source. Single PL506 modular power supply system from Wiener [Win] is used. It has 4 independent programmable power supply modules with 100 A capability in the output range from 2 to 7 Volts. One module powers one frontend crate. Two 6 mm^2 cross-section power cables and two 1.5 mm^2 sense cables are used to connect a module and a crate. The power cables are chosen with the cross-section exhibiting not more than 1 V drop over the cable length. The sense cables are needed for power regulation. The powering scheme is shown on Fig. 8.

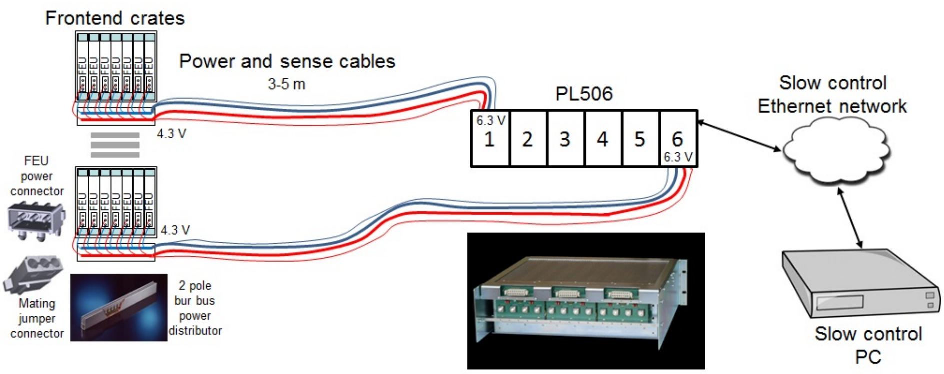


Figure 8 - Powering of the FT tracker front-end electronics

A 2-pole power distribution bus bar from Schroff is attached to each crate [Pbb]. Each of its rails is rated from 60 to100 A, depending on ambient temperature. The power and the sense cables are connected to the rails. Short two-wire jumpers deliver the 4.5 V power from the bust bar to FEU-s. The voltage drop on the jumpers is negligible.

The desired output voltage and current values, as well as the operating temperature range of the PL506 power supply is programmed by a slow control PC via an Ethernet network. The PC also monitors the power supply operation. The SNMP protocol is used for the control and monitoring operations. Each power supply channel is interlocked with the cooling system of the corresponding crate.

3.3 Slow control of the front end electronics

A low level remote slow control of FEU-s is based on the 4-wire JTAG standard. Each FEU has a 24-pin 2 mm connector to access one of its 3 JTAG chains at a time. One of the chains groups a Xilinx XC6VLX75T Virtex-6 FPGA and two associated XCF32P configuration Platform flash PROM-s. This chain allows for remote programming of the FPGA and/or flash PROM-s, as well as for reading FPGA core and IO voltages and its temperature values. The second JTAG chain comprises a single MAX16031 system monitor chip. The power consumption of the module, various onboard generated voltages, the values of three temperature sensors are monitored by this chain. Yet a third JTAG chain includes an auxiliary Xilinx XC9572XL CPLD giving access to the board hardware ID, the FPGA boot status and some other additional information.

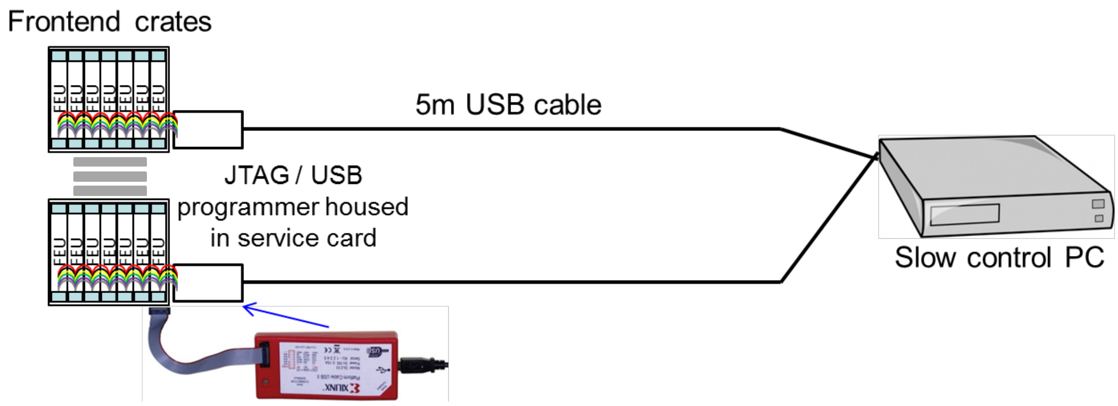


Figure 9 - Slow control for the FTT front-end electronics

The organization of the slow control network proposed for the frontend electronics is sketched on Fig. El3. A Xilinx USB programmer [Prg] is installed in the service card in each frontend crate. A flat ribbon cable jumper carrying the four JTAG signals connects the programmer to all FEU-s in the crate. A 5m long USB cable connects the programmer to the remote slow control PC. The PC controls several USB programmers each connected to a frontend crate.

For monitoring operations, standalone program acting as an EPICS server periodically or on a user request scans a group of FEU-s reading requested information, populating specific databases with it and eventually presenting it in a user readable form. The program allows for remote updates of the FEU firmware as well as for a "cold" restart of the FEUs by rebooting them.

3.4 Front end cooling

Since the front-end electronics is located close to the detectors, in a region with potentially significant stray magnetic field due to the proximity with the CLAS12 magnets, standard fans cannot be used in the FEU crates. Therefore, for every front-end electronics crate, a remote fan is placed 6 m away with a pipe bringing fresh air from the hall and a fan removing the heated air in the hall. An interlock system on the fans will shut down the low and high voltages if the fans are not powered. Additional safety controls on the electronics board prevent the system from overheating.

4 Procedures

4.1 General procedure

Here follows the general procedures for turning ON and OFF the FT-Trck system:

Turning FT-Trck system ON:

1. Turn on gas,
2. Turn on cooling system,
3. Turn on Electronics Low Voltage,
4. Turn on Electronics High Voltage,
5. Take a Pedestal run, check noise levels, write configuration file,
6. Ready for physics.

Turning FT-Trck system OFF:

1. Turn off Electronics High Voltage,
2. Turn off Electronics Low Voltage,
3. Turn off gas,
4. Turn off cooling system.

4.1.1 Installation

The tracker is inserted on the FT support pipe after the installation of the hodoscope. Keys on the tracker and hodoscope support rings and matching keyways on the calorimeter pipe will ensure the relative alignment of the three detectors. A survey is done by JLab engineers using precision targets on the FT-Trck and on the FT-Cal to the absolute position of the whole FT with precision comparable to the tracker resolution.

The FT tracker is tested with its electronics using comic rays in order to check efficiency and noise levels.

4.1.2 Gas On and Gas off

Procedure to turn the gas ON:

The detectors HV must be "OFF" (HV are different when air or Argon are in the detector).

Step 1: purging the detector with argon (to remove air, i.e. oxygen)

1. set the FT-Trck gas control system in manual mode,
2. push the "gas On" button on the FT-Trck gas control system,
3. open the Argon tank valve (in gas shack),
4. open the FT-Trck gas rack valves,
5. flush the in line with 40 l/h of Argon (using the Argon mass flow meter of the mixing unit)
6. open the 2 rotameters of the barrel with 4 l/h each,
7. check the 2 return bubblers for bubble,
8. wait for 4 hours (flush of ~ 4 time the volume, including pipes).

Step 2: flowing detectors with Argon + 10% isobutane (can be done only after Argon purging)

1. set the FT-Trck gas control system in automatic mode,
2. push the "gas On" button on the FT-Trck gas control system,
3. open the Argon tank valve and Isobutane bottle valve,
4. open the FT-Trck gas rack valves,
5. flush the in line with 3.6 l/h of Argon and 0.4 l/h of isobutane (using the mass flow meter of the mixing unit),
6. check the 2 return bubblers for bubble,
7. check the value of the mass flow meter of FT-Trck gas rack (EPICS),
8. wait for 2 hours (flush of ~ 2 time the volume, including pipes),
9. ready for HV ON.

Procedure to put the gas OFF for short time (without Argon purging):

1. push the "gas OFF" button on the FT-Trck gas control system (can be done with EPICS).

Procedure to put the gas ON after short time off (without Argon purging):

1. push the "gas ON" button on the FT-Trck gas control system (can be done with EPICS),

2. wait for 2 hours.

Procedure to put the gas OFF for long time (with Argon purging) or prior dismounting detectors:

The flammable gas mixture must be removed from the detectors and replaced by Argon:

1. set the FT-Trck gas control system in manual mode,
2. push the “gas On” button on the FT-Trck gas control system,
3. open the Argon tank valve (in gas shack),
4. open the FT-Trck gas rack valves,
5. flush the in line with 4 l/h of Argon (using the Argon mass flow meter of the mixing unit),
6. open the 2 rotameters of the barrel with 5 l/h each,
7. check the 2 return bubblers for bubble,
8. wait for 4 hours (flush of ~ 4 time the volume, including pipes),
9. detector purged of flammable gas, ready to be dismounted).

4.1.3 HV on / off

In order to switch the HV on the FT-Trck detectors must have first been flushed with the Ar+10% gas mixture.

To power ON the HV

1. Switch the HV crate ON using the key,
2. Enter the password if necessary,
3. Check the strip value of HV for each channel,
4. Check the strip I max value HV for each channel,
5. Check the value for drift HV,
6. Put ON each positive HV for the strips,
   - wait for HV to establish,
   - check for overcurrent,
7. put ON each negative HV for drift,
   - wait for HV to establish,
   - check for overcurrent.

4.1.4 Powering up and down the FT tracker readout system

The powering scheme of the front-end electronics is shown on Fig. 8. After each general shutdown of the FT-Trck system, it is necessary to power up the PL506 low voltage supply in order to be remotely controlled via the overall CLAS12 slow control network. The frontend cooling system must be up and cooling interlock connector inserted at its front panel to be able to power individual modules supplying frontend crates. The FT-Trck backend electronics, being housed in the JLAB VXS/VME crates, is powered up following the standard procedures. It is preferable to power the FT-Trck backend electronics first, following by the power up of the frontend electronics. The following is the FT-Trck readout activation sequence:

1) Make sure the PL506 power supply is on,
2) Power up FT-Trck backend electronics crate,
3) Start FT-Trck frontend electronics cooling system,
4) Power up individual modules within the PL506 system,
5) Scan all frontend units to check their state.

The power down has to be done in the inversed order, but first one has to make sure that the FT-Trck high voltage is off.

The PL506 low voltage power supply is remotely controlled and monitored via EPICS software. It has four low voltage modules, one per crate plus one spare. The modules are configurable individually, even though their settings are identical. Table 3 lists the configuration parameters and their typical values.

Parameter	Value	Comment
Sense voltage (V)	6	Frontend operating voltage
Current limit (A)	15	2 FEU x 5 A plus power up rush current
Ramp up (V/s)	100	
Ramp down (V/s)	100	
Moderate regulation	set	FTT cables are 15 m long
Min sense voltage (V)	5.8t	Low limit for operating voltage
Max sense voltage (V)	6.2t	High limit for operating voltage
Max terminal voltage (V)	7	Takes into account power drop over the cables
Max current (A)	20	
Max Power (W)	140 W	
Max temperature (°C)	80	

Table 2 - Low voltage configuration parameters

4.2 Interlocks

4.2.1 gas

Gas flows and pressures are controlled by Siemens 1200 series PLC, then sent to EPICS. In case of a global gas leak or overpressure, the PLC will shut down the gas system automatically and send an alarm.

4.2.2 HV

The HV settings should be switch to “OFF” in the following events:

- Electronics is not powered,

- Gas mixture is not the nominal one (pure argon will damage the detector is they stay ON).

4.2.3 LV

In case of HV failure, the LV shuts itself down. Global slow control detects LV failures and/or powers down FEUs. No damage can occur to equipment or personnel.

4.2.4 Electronics Cooling

If the electronics cooling interlock is activated, the LV system is shut down followed by a HV system shut down. In case the interlock fails, the global slow control & local FEU monitoring continues to operate.

4.3 Response to Hall B alarm

4.3.1 Gas system

In case of a fire alarm in the Hall, the gas system will also shut itself down.

4.3.2 HV & LV

In case of a fire alarm in the Hall, the HV and LV systems will shut themselves down in that order.

5 Abbreviations

BEU Backend unit

FEU Frontend unit

JTAG Joint Test Action Group

LVDS Low voltage differential signaling

FT Forward Tagger

FTT or FT-Trck Forward Tagger Micromegas tracker

TI Trigger interface

6 References

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[Feu] I. Mandjavidze, "FEU a frontend unit for Micromegas trackers", User's Manual, March 14, 2016

[Pbb] Schroff, Power distribution bus bars, reference: 20100-008

[Prg] Xilinx, "Platform Cable USB II", DS593, v1.2.1, March 17, 2011

[Win] W-Ie-Ne-R, "PL512/PL506, Modular