

Forward Time-of-Flight System Operations Manual

D.S. Carman, Jefferson Laboratory

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Abstract

This document provides an overview of the CLAS12 Forward Time-of-Flight (FTOF) System and serves as an Operations Manual for the detector. Instructions are provided for shift workers related to the basic steps of operating and monitoring the HV controls, monitoring the detector system and responding to alarms, and knowing when to contact the on-call personnel. More complete details are also provided for FTOF system experts regarding the channel mapping to the readout electronics, the cable connections and routing in Hall B, higher-order high voltage system operations, and detector servicing. This document also provides references to the available FTOF documentation and a list of personnel authorized to perform FTOF system repairs and to modify system settings.

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1 FTOF Overview

The Forward Time-of-Flight (FTOF) system is a major component of the CLAS12 Forward Detector that is used to measure the flight time of charged particles emerging from beam-related interactions in the target. The average path length from the target to the FTOF counters is roughly 6 - 7 m. The system requirements include excellent timing resolution for particle identification and good segmentation to provide for flexible triggering options. The system specifications call for an average time resolution of $\sigma_{TOF}=80$ ps at the more forward angles of CLAS12 ($\theta < 35^\circ$) and 150 ps at larger angles ($\theta > 35^\circ$). The system must also be capable of operating in a high-rate environment. At the nominal CLAS12 operating luminosity of $1 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$, the average rate per scintillation counter approaches 1 MHz.

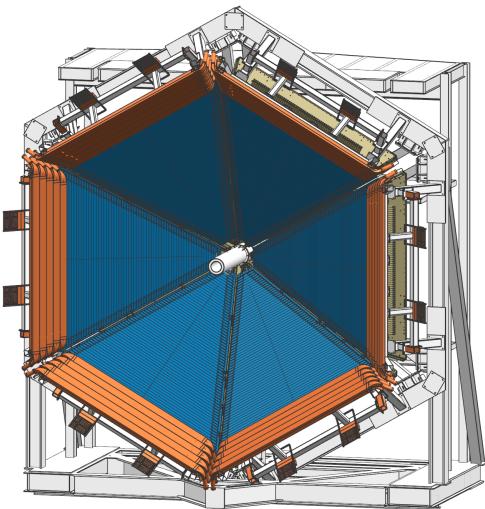


Figure 1: View of the FTOF for CLAS12 highlighting the location of the counters. The panel-1b arrays are shown in orange and the panel-2 arrays, mounted around the perimeter of the Forward Carriage, are shown in red. The panel-1a arrays are mounted immediately downstream of the panel-1b arrays, and are not visible in this picture. The Forward Carriage is roughly 10 m in diameter.

The CLAS12 spectrometer in the forward direction is built around a six-coil superconducting toroidal magnet that divides the active detection area into six 60° -wide azimuthal regions called sectors. In each of the six sectors of the CLAS12 Forward Detector, the FTOF system is comprised of three arrays of counters, referred to as panels, named panel-1a, panel-1b, and panel-2. Each panel consists of a set of rectangular scintillators with a PMT on each end. Panel-1 includes the sets of counters located at forward angles (roughly 5° to 35°) (where two panels are used to meet the 80 ps average time resolution requirement) and panel-2 includes the sets of counters at larger angles (roughly 35° to 45°). The positioning and attachment of the FTOF detector arrays on the Forward Carriage of CLAS12 are shown in Fig. 1. Each of the six panel-1a arrays contains 23 counters, each of the six panel-1b arrays contains 62 counters, and each of the six panel-2 arrays contains 5 counters.

Figure 2 shows the sector naming and identifier conventions for the FTOF system, as well as the definitions of the left and right sides of each sector. A summary of the FTOF technical parameters is given in Table 1.

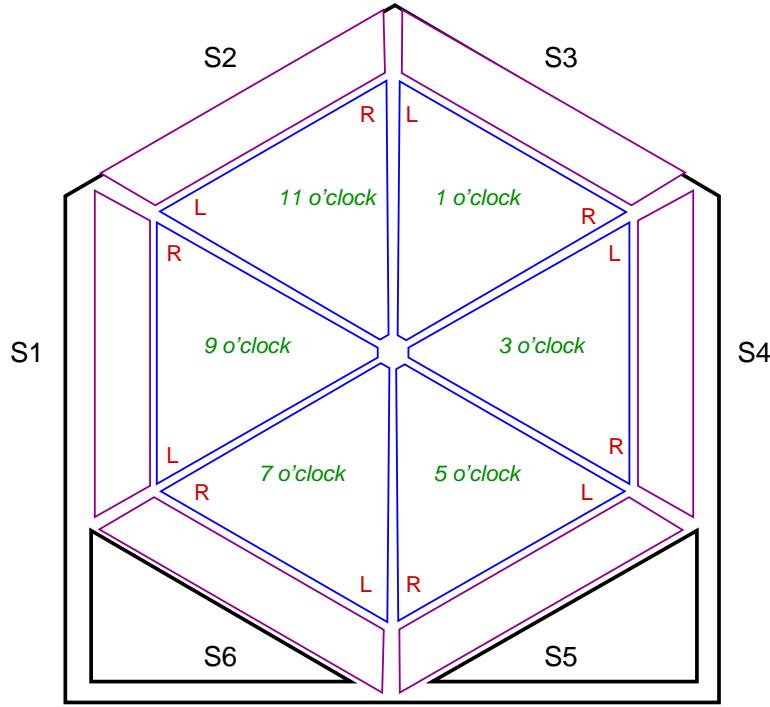


Figure 2: Schematic view of the Hall B Forward Carriage looking downstream along the electron beamline showing the sector naming convention, the definitions of the left (L) and right (R) sides of each sector, and the clock position identifier. The electron beam goes into the page such that S1 is on beam left and S4 is on beam right.

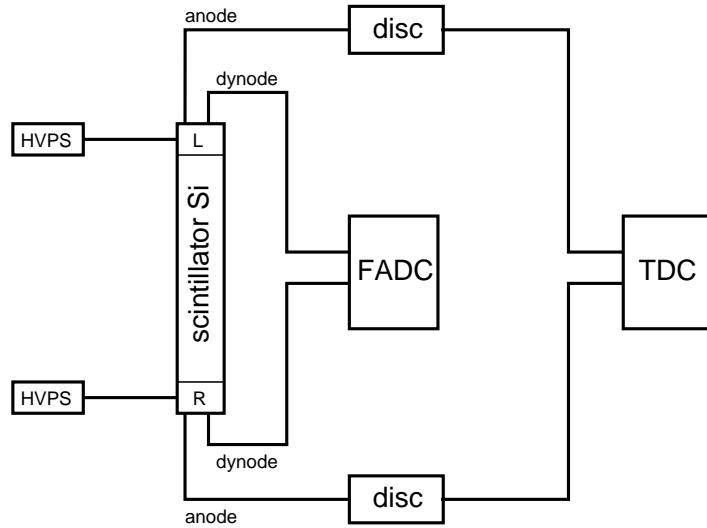


Figure 3: Block diagram for the FTOF system showing the layout of the readout electronics and HV connections for a single representative counter.

Parameter	Design Value
Panel-1a	
Angular Coverage	$\theta = 5^\circ \rightarrow 35^\circ, \phi : 50\% \text{ at } 5^\circ \rightarrow 85\% \text{ at } 35^\circ$
Counter Dimensions	$L = 32.3 \text{ cm} \rightarrow 376.1 \text{ cm}, w \times h = 15 \text{ cm} \times 5 \text{ cm}$
Scintillator Material	BC-408
PMTs	EMI 9954A, Philips P2262
Design Resolution	90 ps \rightarrow 160 ps
Panel-1b	
Angular Coverage	$\theta = 5^\circ \rightarrow 35^\circ, \phi : 50\% \text{ at } 5^\circ \rightarrow 85\% \text{ at } 35^\circ$
Counter Dimensions	$L = 17.3 \text{ cm} \rightarrow 407.9 \text{ cm}, w \times h = 6 \text{ cm} \times 6 \text{ cm}$
Scintillator Material	BC-404 (#1 \rightarrow #31), BC-408 (#32 \rightarrow #62)
PMTs	Hamamatsu R9779
Design Resolution	60 ps \rightarrow 110 ps
Panel-2	
Angular Coverage	$\theta = 35^\circ \rightarrow 45^\circ, \phi : 85\% \text{ at } 35^\circ \rightarrow 95\% \text{ at } 45^\circ$
Counter Dimensions	$L = 371.3 \text{ cm} \rightarrow 426.1 \text{ cm}, w \times h = 22 \text{ cm} \times 5 \text{ cm}$
Scintillator Material	BC-408
PMTs	Photonis XP4312B, EMI 4312KB
Design Resolution	145 ps \rightarrow 160 ps

Table 1: Table of parameters for the scintillation bars, PMTs, and counters for the FTOF panel-1a, panel-1b, and panel-2 arrays.

A block diagram of the readout electronics for one counter of the FTOF system is shown in Fig. 3. The PMT anode outputs are connected to JLab VME leading edge discriminators and CAEN VME TDCs. Both high resolution TDCs (25 ps LSB CAEN 1290A) and lower resolution TDCs (100 ps LSB CAEN 1190A) are employed, where the lower resolution TDCs are associated with the longer counters at large polar angles for panel-1a, panel-1b, and panel-2. The PMT dynode outputs are connected to JLab 250 MHz VME flash ADCs.

The electronics for each sector are located behind the detectors on the three levels of the Forward Carriage as follows:

- FTOF S1: FC Level 2 South
- FTOF S2: FC Level 3 South
- FTOF S3: FC Level 3 North
- FTOF S4: FC Level 2 North
- FTOF S5: FC Level 1 North
- FTOF S6: FC Level 1 South

Note that “South” refers to beam left and “North” to beam right (closer to the Pie Tower). Figure 4 shows the rack locations for the FTOF VME electronics and signal cable patch panels.

The high voltage (HV) power supplies for each FTOF sector are either CAEN 1527LC mainframes or CAEN 4527 mainframes outfitted with negative polarity 24-channel A1535N modules. The HV mainframes that power the FTOF system are actually shared between

the FTOF and the PCAL. The FTOF boards occupy slots #0 to #7 of each mainframe and the PCAL boards occupy slots #8 to #15 of each mainframe. The supplies are named HVFTOF n , $n=1 \rightarrow 6$ (i.e. HVFTOF1 \rightarrow HVFTOF6). Figure 4 shows the locations of the HV mainframes for each of the FTOF sectors on the Forward Carriage.

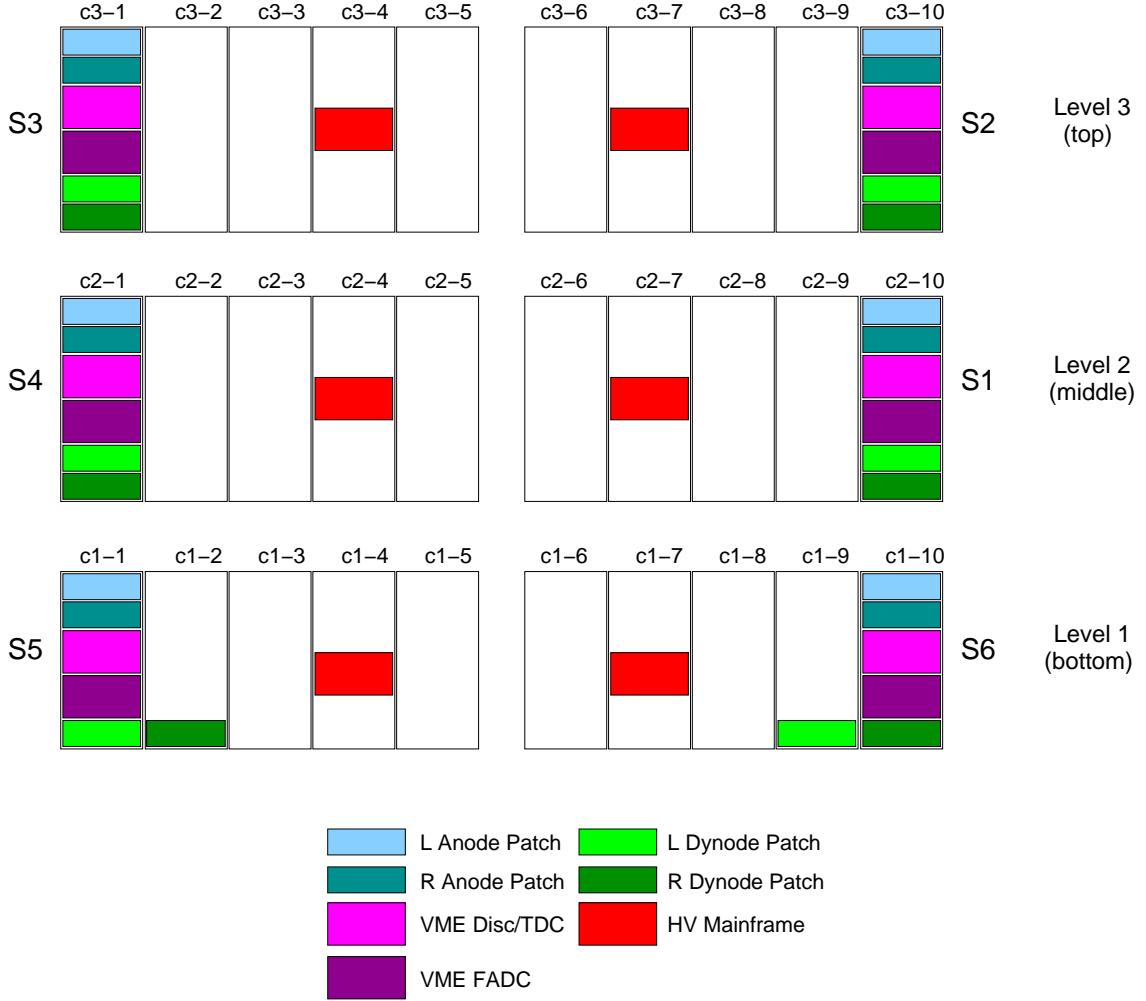


Figure 4: Forward Carriage layout of the FTOF VME electronics, signal cable patch panels, and HV power supplies in the electronics racks on each of the three levels. The rack names on each level (c1, c2, and c3) are numbered 1 through 10. This view is looking upstream. Note: The racks on Level 1 are 180 cm tall and those for Levels 2 and 3 are 210 cm tall. For this reason, the dynode patch panels are split into two neighboring racks on Level 1.

2 Information for Shift Workers

2.1 Shift Worker Responsibilities

The shift worker in the Hall B Counting House has five responsibilities with regard to the FTOF system:

1. Updating the Hall B electronic logbook with records of problems or system conditions (see Section 2.1.1);
2. Contacting FTOF system on-call personnel for any problems that are discovered (see Section 2.1.2);
3. Responding to FTOF system alarms from the Hall B alarm handler (see Section 2.1.3);
4. Turning on or off the high voltage for the FTOF system using the HV control interface (see Section 2.2);
5. Monitoring the hit occupancy scalers for the system (see Section 2.3).

2.1.1 Updating the Logbook

The electronic logbook (or e-log) [1] is set up to run on a specified terminal in the Hall B Counting House. Shift workers are responsible for keeping an up-to-date and accurate record of any problems or issues concerning the FTOF system. For any questions regarding the logbook, its usage, or on what is considered to be a “logbook worthy” entry, consult the assigned shift leader.

Note the shift worker should follow all posted or communicated instructions about entering FTOF monitoring histograms or scaler information into the e-log. This is typically done (at least) once per 8-hour shift as directed on the shift checklist.

2.1.2 Contacting FTOF System Personnel

As a general rule, shift workers should spend no more than 10 to 15 minutes attempting to solve any problem that arises with the FTOF system. At that point they should contact the assigned FTOF on-call expert either to provide advice on how to proceed or to address the problem. **The FTOF on-call phone number is (757)-344-7204.**

This document is divided into sections for shift workers and for FTOF system experts. However, only FTOF system experts (as listed in Section 5) are authorized to make changes to the FTOF parameter settings, to work on the hardware or electronics, or to modify the data acquisition (DAQ) system settings. This division between shift worker responsibilities and expert responsibilities is essential to maintain in order to protect and safeguard the equipment, to ensure data collection is as efficient as possible, and to minimize down time. If the shift worker has any questions regarding how to proceed when an issue arises, the shift leader should be consulted.

2.1.3 Hall B Alarm Handler

The BEAST alarm handler system running in the Counting House monitors the entire Hall B Slow Controls system. This includes the HV and low voltage (LV) systems, gas systems, torus and solenoid controls, subsystem environment controls (*e.g.* temperature, humidity), and pulser calibration systems (among several others). The system runs on a dedicated terminal in the Counting House. One of the main responsibilities of the shift worker is to respond to alarms from this system, either by taking corrective action or by contacting the appropriate on-call personnel. Instructions and details on the alarm handler for Hall B are given in Ref. [2].

The only element of the FTOF system monitored by the alarm handler is the HV system. Any time a channel trips off an alarm will sound. The alarm handler will identify the specific channel (or channels) that have tripped. These channels can be reset either through the alarm handler or through the nominal FTOF HV control screens. These channels should be reset only after ensuring that whatever condition caused the trip (*e.g.* bad beam conditions) has been addressed.

2.2 High Voltage Controls

The FTOF HV is controlled through the Hall B CS-Studio suite, which is an Eclipse-based collection of tools used as an interface to the EPICS Slow Controls system. To start the user interface on any terminal in the Hall B Counting House, enter the command “clascss”. Figure 5(left) shows the control panel that is launched.

To bring up the FTOF HV controls, click on the “FTOF” button on the subsystem list. This pops up a sub-menu of all Slow Controls subprograms for the FTOF system (see Fig. 5(right)). Clicking the mouse on the “FTOF HV” option brings up the HV control interface for the FTOF system as shown in Fig. 6. This interface allows for HV operations at a number of functionality levels:

- All channels in the full FTOF system
- All channels in a single FTOF sector (panel-1a, panel-1b, panel-2)
- All channels in a single sector for a given panel
- A single PMT in the FTOF system

The HV Control Interface screen (see Fig. 6) also provides a color key to indicate the channel status:

- HV off - no highlight color (channel color dark green)
- HV on - bright green
- HV ramping up or ramping down - orange
- HV trip - red

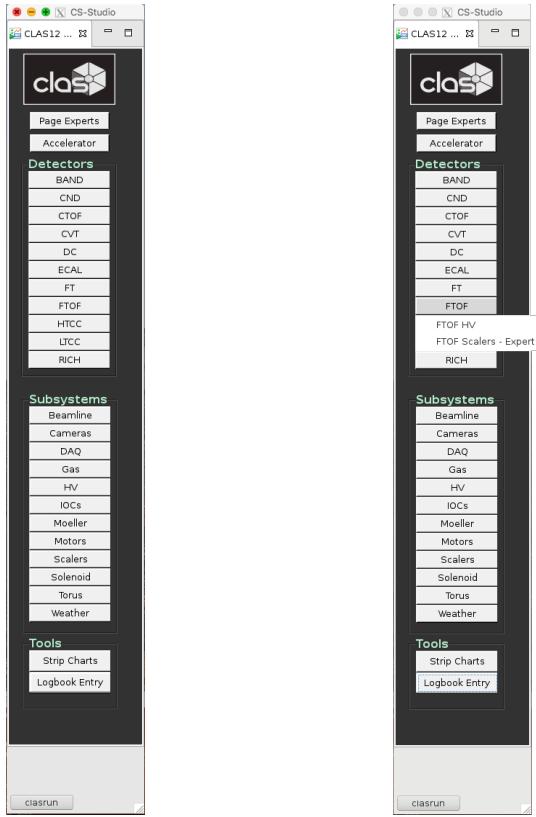


Figure 5: The CS-Studio interface used for the Slow Controls of the CLAS12 detectors and subsystems. (Left) General CLAS12 interface. (Right) Options for the FTOF system.

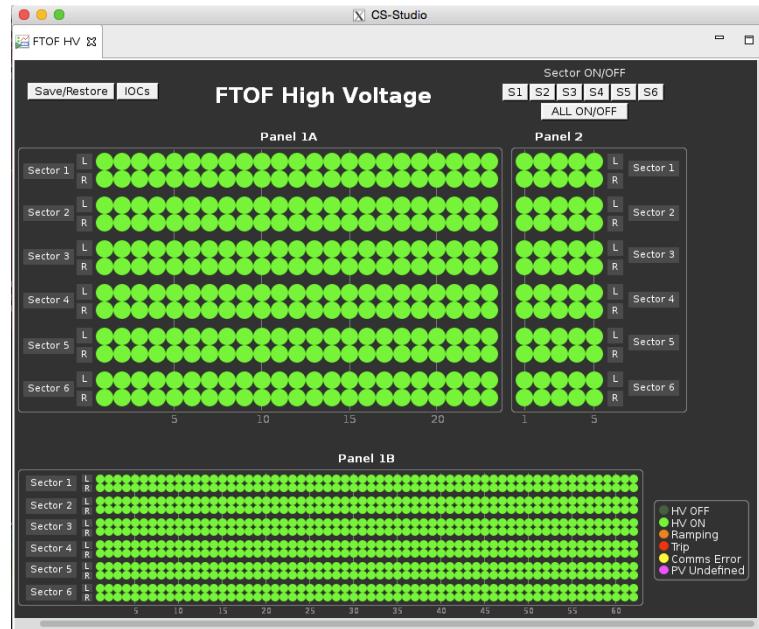


Figure 6: FTOF HV display and control interface.

- Communication problem - yellow
- Undefined channel status - magenta

For the shift worker the most common operations are:

1. To turn the HV for all system PMTs on or off. This is accomplished by clicking the button in the upper right corner “ALL ON/OFF”. This pops up a sub-menu with the relevant options “Turn All Off” and “Turn All On”.
2. To turn individual PMTs on or off. This is accomplished by clicking on the circle representing the channel of interest. This brings up a control screen for the channel of interest as shown in Fig. 7. Clicking on the button in the “Pw” (Power) column toggles the channel HV on and off.
3. To turn the HV for all PMTs in a single sector on or off. This is accomplished by clicking on the sector button in the upper right corner ($S_1 \rightarrow S_6$) (see Fig. 6). This pops up a sub-menu with the relevant options “Turn Sector XX Off” and “Turn Sector XX On”.
4. To turn the HV for all PMTs in a given panel and sector on or off. This is accomplished by clicking on the Sector button (Sector 1 \rightarrow Sector 6) next to the panel of interest. This pops up a sub-menu with the relevant options as shown in Fig. 8.



Figure 7: FTOF HV display for single channel parameters.

Note that hovering the mouse pointer on a circle representing a PMT brings up EPICS information on that channel as shown in Fig. 9.

If the “Open Channel Controls” option shown in Fig. 8 is selected, a “novice” window is opened as shown in Fig. 10. This window shows the monitored channel voltages and currents (V_{mon} (V) and I_{mon} (μ A)), the channel statuses (OFF, ON), and the set channel voltages and currents (V_{set} (V) and I_{set} (μ A)). If desired, shift workers can toggle the HV settings for single channels on or off through this interface.

In the upper left corner of this “Channel Controls” window is a button marked “expert” that brings up the window shown in Fig. 11. This allows changes to the system settings for the maximum channel current, maximum channel voltage setting, and the channel HV ramp up and ramp down rates. Clicking on the “novice” button in the upper left corner toggles between the expert and novice screens. **The expert screen should only be used by the list of authorized FTOF personnel given in Section 5.**

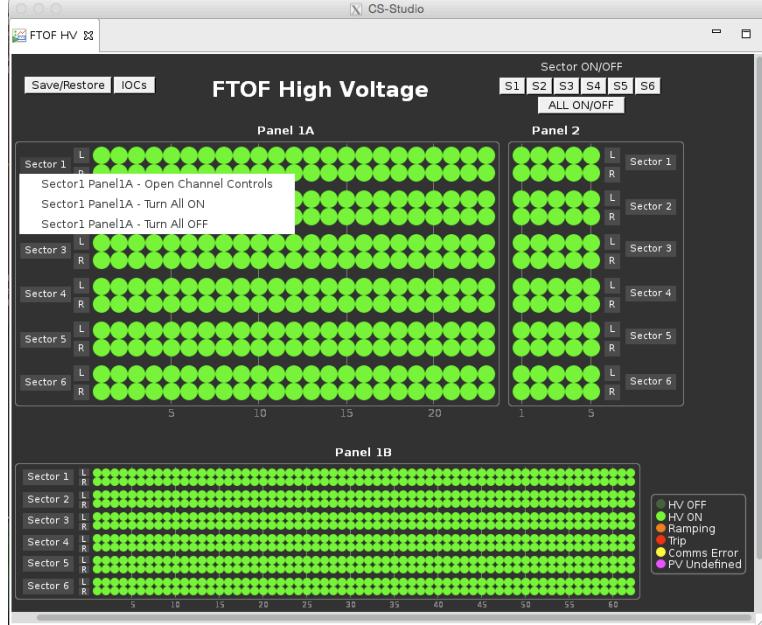


Figure 8: FTOF HV display and control interface to open channel controls for a given panel and sector.

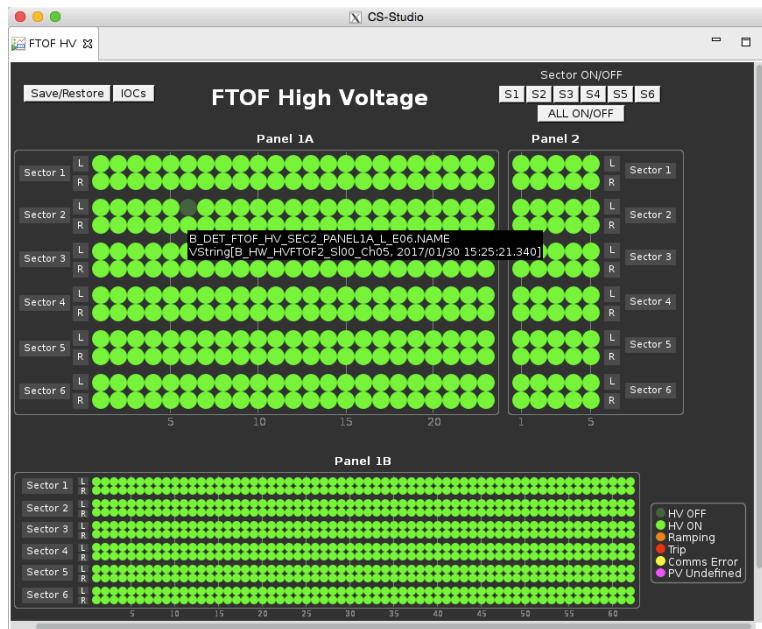


Figure 9: FTOF HV display showing the channel information when the mouse is paused over a PMT circle.

CS-Studio

FTOF HV SEC1 PANEL1A

Expert

#	Description	Pw	Vmon	Imon	Status	Vset (V)	Iset (uA)
1	FTOF_HV_SEC1_PANEL1A_L_E01	ON	1631.00	262.00	ON	1630.000	500.0
1	FTOF_HV_SEC1_PANEL1A_R_E01	ON	1622.50	257.50	ON	1623.000	500.0
2	FTOF_HV_SEC1_PANEL1A_L_E02	ON	1730.50	287.50	ON	1730.000	500.0
2	FTOF_HV_SEC1_PANEL1A_R_E02	ON	1723.00	288.50	ON	1724.000	500.0
3	FTOF_HV_SEC1_PANEL1A_L_E03	ON	1600.50	253.50	ON	1600.000	500.0
3	FTOF_HV_SEC1_PANEL1A_R_E03	ON	1718.50	286.00	ON	1719.000	500.0
4	FTOF_HV_SEC1_PANEL1A_L_E04	ON	1622.00	248.00	ON	1622.000	500.0
4	FTOF_HV_SEC1_PANEL1A_R_E04	ON	1622.50	269.00	ON	1623.000	500.0
5	FTOF_HV_SEC1_PANEL1A_L_E05	ON	1600.00	255.00	ON	1600.000	500.0
5	FTOF_HV_SEC1_PANEL1A_R_E05	ON	1540.00	250.50	ON	1540.000	500.0
6	FTOF_HV_SEC1_PANEL1A_L_E06	ON	1655.50	264.00	ON	1655.000	500.0
6	FTOF_HV_SEC1_PANEL1A_R_E06	ON	1991.00	358.00	ON	1992.000	500.0
7	FTOF_HV_SEC1_PANEL1A_L_E07	ON	1760.50	296.50	ON	1760.000	500.0
7	FTOF_HV_SEC1_PANEL1A_R_E07	ON	1801.00	309.50	ON	1801.000	500.0
8	FTOF_HV_SEC1_PANEL1A_L_E08	ON	1856.00	330.00	ON	1855.000	500.0
8	FTOF_HV_SEC1_PANEL1A_R_E08	ON	1834.50	316.00	ON	1835.000	500.0
9	FTOF_HV_SEC1_PANEL1A_L_E09	ON	2092.00	364.50	ON	2092.000	500.0
9	FTOF_HV_SEC1_PANEL1A_R_E09	ON	1760.00	299.00	ON	1761.000	500.0
10	FTOF_HV_SEC1_PANEL1A_L_E10	ON	1815.50	308.50	ON	1816.000	500.0
10	FTOF_HV_SEC1_PANEL1A_R_E10	ON	2020.00	362.50	ON	2021.000	500.0
11	FTOF_HV_SEC1_PANEL1A_L_E11	ON	1665.00	271.00	ON	1665.000	500.0
11	FTOF_HV_SEC1_PANEL1A_R_E11	ON	2025.00	356.00	ON	2026.000	500.0
12	FTOF_HV_SEC1_PANEL1A_L_E12	ON	1877.00	326.50	ON	1877.000	500.0
12	FTOF_HV_SEC1_PANEL1A_R_E12	ON	2008.50	360.50	ON	2009.000	500.0
13	FTOF_HV_SEC1_PANEL1A_L_E13	ON	2126.00	382.00	ON	2126.000	500.0
13	FTOF_HV_SEC1_PANEL1A_R_E13	ON	1845.00	313.00	ON	1846.000	500.0
14	FTOF_HV_SEC1_PANEL1A_L_E14	ON	1835.00	305.50	ON	1835.000	500.0
14	FTOF_HV_SEC1_PANEL1A_R_E14	ON	1824.00	303.50	ON	1825.000	500.0
15	FTOF_HV_SEC1_PANEL1A_L_E15	ON	2036.00	361.00	ON	2035.000	500.0
15	FTOF_HV_SEC1_PANEL1A_R_E15	ON	2091.00	375.50	ON	2091.000	500.0
16	FTOF_HV_SEC1_PANEL1A_L_E16	ON	1758.50	315.00	ON	1758.000	500.0

Figure 10: FTOF “novice” channel controls screen.

CS-Studio

FTOF HV SEC1 PANEL1A

Novice

#	Description	Pw	Vmon	Imon	Status	Vset (V)	Iset (uA)	Vmax (V)	Up (V/s)	Down (V/s)
1	FTOF_HV_SEC1_PANEL1A_L_E01	ON	1631.000	262.00	ON	1630.000	500	500	2500	2500
1	FTOF_HV_SEC1_PANEL1A_R_E01	ON	1622.500	257.50	ON	1623.000	500	500	2500	2500
2	FTOF_HV_SEC1_PANEL1A_L_E02	ON	1730.000	287.50	ON	1730.000	500	500	2500	2500
2	FTOF_HV_SEC1_PANEL1A_R_E02	ON	1722.500	288.00	ON	1724.000	500	500	2500	2500
3	FTOF_HV_SEC1_PANEL1A_L_E03	ON	1600.500	253.50	ON	1600.000	500	500	2500	2500
3	FTOF_HV_SEC1_PANEL1A_R_E03	ON	1718.500	286.00	ON	1719.000	500	500	2500	2500
4	FTOF_HV_SEC1_PANEL1A_L_E04	ON	1622.000	248.00	ON	1622.000	500	500	2500	2500
4	FTOF_HV_SEC1_PANEL1A_R_E04	ON	1622.500	269.00	ON	1623.000	500	500	2500	2500
5	FTOF_HV_SEC1_PANEL1A_L_E05	ON	1600.000	255.50	ON	1600.000	500	500	2500	2500
5	FTOF_HV_SEC1_PANEL1A_R_E05	ON	1540.000	250.50	ON	1540.000	500	500	2500	2500
6	FTOF_HV_SEC1_PANEL1A_L_E06	ON	1655.500	264.00	ON	1655.000	500	500	2500	2500
6	FTOF_HV_SEC1_PANEL1A_R_E06	ON	1991.000	358.00	ON	1992.000	500	500	2500	2500
7	FTOF_HV_SEC1_PANEL1A_L_E07	ON	1760.500	296.50	ON	1760.000	500	500	2500	2500
7	FTOF_HV_SEC1_PANEL1A_R_E07	ON	1801.000	309.50	ON	1801.000	500	500	2500	2500
8	FTOF_HV_SEC1_PANEL1A_L_E08	ON	1856.000	330.00	ON	1855.000	500	500	2500	2500
8	FTOF_HV_SEC1_PANEL1A_R_E08	ON	1834.500	316.00	ON	1835.000	500	500	2500	2500
9	FTOF_HV_SEC1_PANEL1A_L_E09	ON	2092.000	364.50	ON	2092.000	500	500	2500	2500
9	FTOF_HV_SEC1_PANEL1A_R_E09	ON	1760.000	299.00	ON	1761.000	500	500	2500	2500
10	FTOF_HV_SEC1_PANEL1A_L_E10	ON	1815.500	308.50	ON	1816.000	500	500	2500	2500
10	FTOF_HV_SEC1_PANEL1A_R_E10	ON	2020.000	362.50	ON	2021.000	500	500	2500	2500
11	FTOF_HV_SEC1_PANEL1A_L_E11	ON	1665.000	271.00	ON	1665.000	500	500	2500	2500
11	FTOF_HV_SEC1_PANEL1A_R_E11	ON	2025.000	356.00	ON	2026.000	500	500	2500	2500
12	FTOF_HV_SEC1_PANEL1A_L_E12	ON	1877.500	326.50	ON	1877.000	500	500	2500	2500
12	FTOF_HV_SEC1_PANEL1A_R_E12	ON	2008.500	360.50	ON	2009.000	500	500	2500	2500
13	FTOF_HV_SEC1_PANEL1A_L_E13	ON	2126.000	382.00	ON	2126.000	500	500	2500	2500
13	FTOF_HV_SEC1_PANEL1A_R_E13	ON	1845.000	313.00	ON	1846.000	500	500	2500	2500
14	FTOF_HV_SEC1_PANEL1A_L_E14	ON	1835.000	305.50	ON	1835.000	500	500	2500	2500
14	FTOF_HV_SEC1_PANEL1A_R_E14	ON	1824.000	303.50	ON	1825.000	500	500	2500	2500
15	FTOF_HV_SEC1_PANEL1A_L_E15	ON	2036.000	361.00	ON	2035.000	500	500	2500	2500
15	FTOF_HV_SEC1_PANEL1A_R_E15	ON	2091.000	375.50	ON	2091.000	500	500	2500	2500
16	FTOF_HV_SEC1_PANEL1A_L_E16	ON	1758.500	315.00	ON	1758.000	500	500	2500	2500

Figure 11: FTOF “expert” channel controls screen.

2.2.1 Resetting the IOCs

If there is a controls problem indicated by the appearance of yellow or magenta channels in Fig. 6, which typically appears for all PMTs in a given sector, the usual cause is an issue of communication between the IOC computer and the HV mainframe. To reboot the IOC for a given sector, click on the “IOCs” button on the Slow Controls panel within the “Subsystems” portion of the interface. Figure 12 shows the options that appear on the sub-menu that pops up. On this menu, select “IOC Health” to open the control window shown in Fig. 13. Clicking on the “High Voltage” tab along the top of the screen brings up the screen for the IOCs that control the HV mainframes as shown in Fig. 14. Click on the “Reboot” button (under the “Soft Reboot” column) for the HV supply that has the IOC communication problem. The reboot will take less than two minutes to complete and the yellow or magenta communication problem channel indicators should all disappear. Note that the IOCs can be also rebooted through the FTOF channel control screen shown in Fig. 6. Click on the “IOCs” button in the upper left corner and then click on the “Reboot” button for the sector of interest. If rebooting the IOC does not solve the problems, contact the Slow Controls system expert.

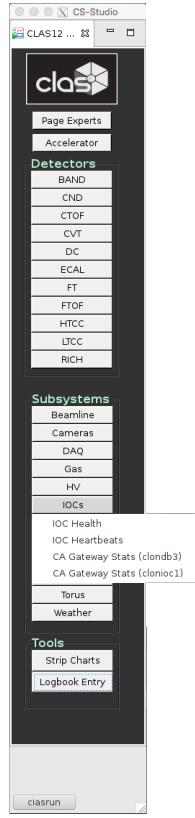


Figure 12: Sub-menu on the primary Slow Controls interface to reboot the IOCs.

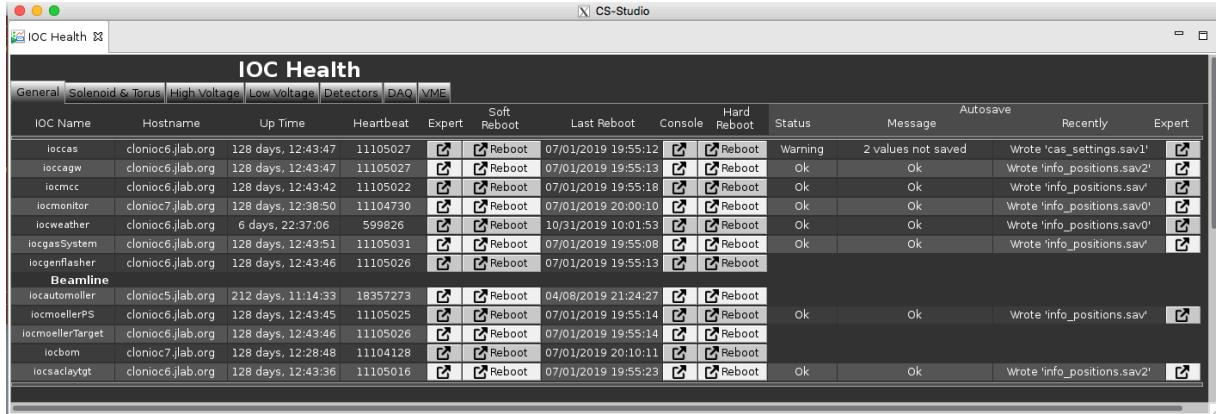


Figure 13: IOC health screen for access to all Hall B IOCs.

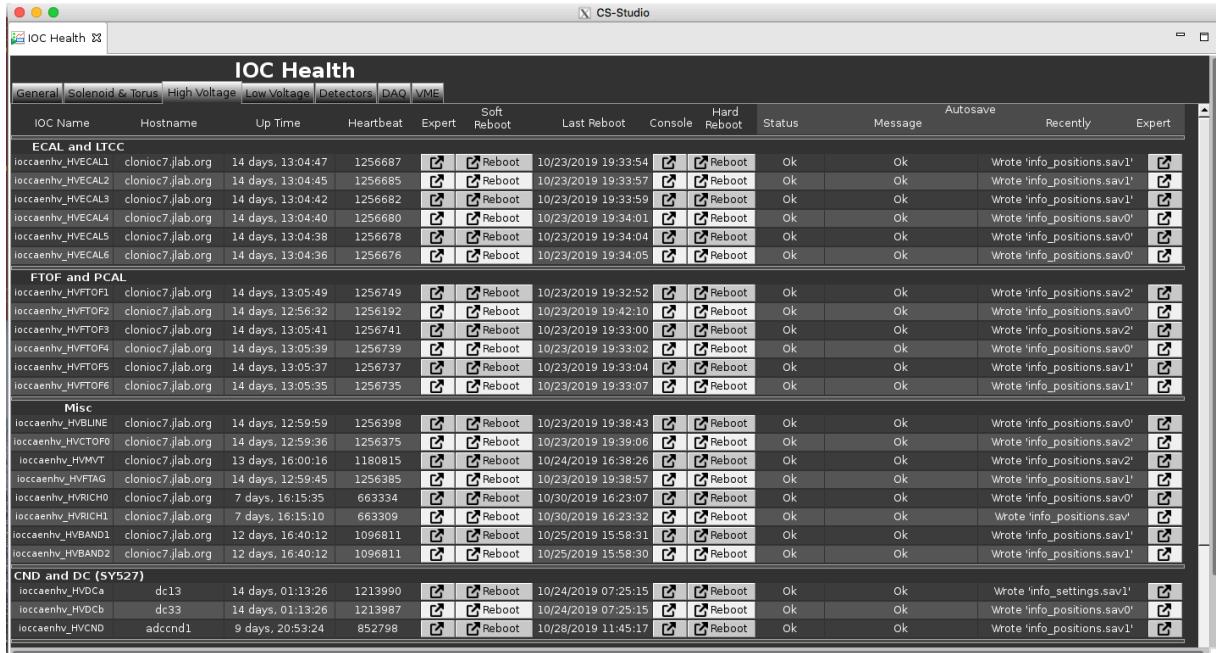


Figure 14: IOC health screen where individual IOCs that control the HV mainframes can be rebooted.

2.3 Detector Monitoring

A number of monitoring tools to study the performance of the FTOF detector system have been prepared. One of the most basic and powerful tools, however, is a simple display of the system scalers.

The primary system for viewing the FTOF scalers in the Hall B Counting House is the *mon12* utility. Typing “*mon12*” on any terminal in the Counting House will bring up the screen shown in Fig. 15(left).

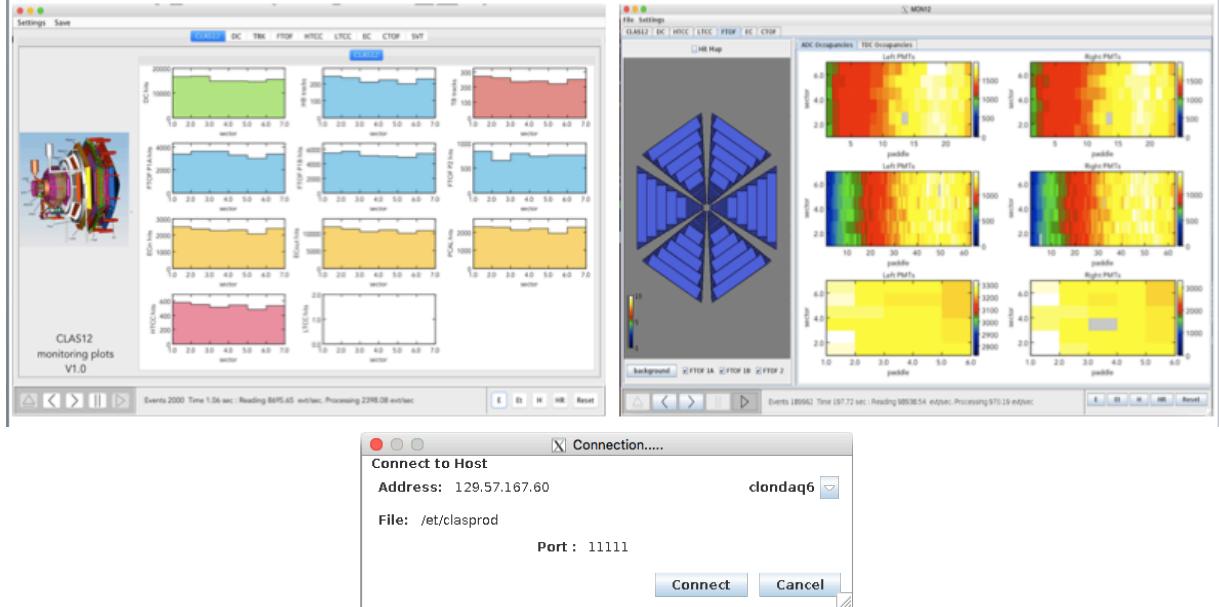


Figure 15: (Left) The main *mon12* display screen showing counts across the different CLAS12 subsystems and sectors. (Right) The FTOF scaler screen within *mon12*.

The *mon12* utility requires the data acquisition system to be operating to display the scaler counts. If a run is in progress, scaler accumulation will begin by selecting the event source from the Event Transfer (ET) ring. This is done by clicking on “ET” in the lower right corner of the *mon12* screen. This will pop-up the window shown in Fig. 15(bottom). To proceed select the appropriate computer (*clondaq6*) from the drop-down menu and then click “Connect”. Finally, click on the “play” button (the rightward triangle in the lower left of the *mon12* screen). The FTOF scalers for panel-1a, panel-1b, and panel-2 for each sector can be viewed for either the FADCs or the discriminators on the FTOF tab by selecting the appropriate source. This brings up the FTOF *mon12* display shown in Fig. 15(right).

The second manner in which to view the FTOF system scalers is through the CLAS12 Slow Controls system. Shown in the options for the FTOF system in Fig. 5(right) is an option to view the FTOF scalers from the TDCs or FADCs. Selecting the option “FTOF Scalers - Expert” brings up a screen such as that shown in Fig. 16. This screen shows the different scaler sources separately for each sector. The sector to display is selected by clicking on the “Sectors” button in the upper left corner. A different display of the same information can be selected by clicking on the “Hardware View” button. The scalers shown in this display count independently of the data acquisition system.

Scalers		Yield		TDC AQC/TOT		TDC TOT		FTOF		Rate		Yield		TDC AQC/TOT		TDC TOT		FTOF		Rate									
10.1.1	5358	6395	39607	372	38	25	10.8 ± 0.1	66515	7161	4198	214	10	25	10.4 ± 0.1	424568	339978	399519	216	18	25	14.7 ± 0.1	155598	124924	9398	237	10	25		
10.1.2	5352	7432	5114	298	38	25	10.9 ± 0.2	10659	8008	4772	389	10	25	10.5 ± 0.2	128458	239484	165154	212	18	25	14.7 ± 0.1	279589	240095	185857	221	18	25		
10.1.3	5352	3732	3732	298	38	25	10.9 ± 0.2	11730	11730	11730	11730	10	25	10.4 ± 0.2	128458	239484	165154	212	18	25	14.7 ± 0.1	281521	240112	185857	221	18	25		
10.1.4	20833	39586	21463	218	38	25	10.8 ± 0.4	29517	32314	21487	294	10	25	10.4 ± 0.4	311443	364937	189776	212	18	25	14.7 ± 0.4	448398	553232	223165	218	18	25		
10.1.5	5352	6395	46848	46848	298	38	25	10.8 ± 0.4	105509	105509	105509	105509	10	25	10.4 ± 0.4	128458	239484	165154	212	18	25	14.7 ± 0.4	594479	467269	274266	218	18	25	
10.1.6	33435	108483	105659	226	38	25	10.8 ± 0.4	97259	118859	105659	226	10	25	10.4 ± 0.4	128458	364945	203095	240	18	25	14.7 ± 0.4	594479	553232	223165	218	18	25		
10.1.7	20835	167484	161659	181	38	25	10.8 ± 0.7	126192	166264	87566	231	10	25	10.4 ± 0.7	311443	483121	279493	237	18	25	14.7 ± 0.7	448398	672740	216537	215	18	25		
10.1.8	5352	6395	39607	372	38	25	10.8 ± 0.7	105509	105509	105509	105509	10	25	10.4 ± 0.7	128458	364945	203095	240	18	25	14.7 ± 0.7	594479	553232	223165	218	18	25		
10.1.9	276455	280821	134656	174	38	25	10.8 ± 0.9	105509	161644	222126	372	10	25	10.4 ± 0.9	311443	399324	296420	282	18	25	14.7 ± 0.9	523485	529512	276579	217	18	25		
10.1.10	22487	297898	170727	211	38	25	10.8 ± 0.9	140951	250454	371483	295	10	25	10.4 ± 0.9	311443	556363	205131	224	18	25	14.7 ± 0.9	602227	280867	181	18	25			
10.1.11	5352	6395	39607	372	38	25	10.8 ± 0.9	105509	105509	105509	105509	10	25	10.4 ± 0.9	128458	364945	203095	240	18	25	14.7 ± 0.9	594479	553232	223165	218	18	25		
10.1.12	299322	377981	179427	219	38	25	10.8 ± 0.9	105509	161644	193311	141	10	25	10.4 ± 0.9	311443	483123	279493	237	18	25	14.7 ± 0.9	648498	526292	243118	242	18	25		
10.1.13	20833	268975	164751	260	38	25	10.8 ± 0.9	271148	311404	167319	212	10	25	10.4 ± 0.9	311443	475553	349393	218	18	25	14.7 ± 0.9	594479	553232	223165	218	18	25		
10.1.14	5352	6395	39607	372	38	25	10.8 ± 0.9	105509	105509	105509	105509	10	25	10.4 ± 0.9	128458	364945	203095	240	18	25	14.7 ± 0.9	594479	553232	223165	218	18	25		
10.1.15	297735	379525	226605	218	38	25	10.8 ± 0.9	276115	359325	224524	223	10	25	10.4 ± 0.9	311443	759395	397549	247	18	25	14.7 ± 0.9	669592	623552	271052	225	18	25		
10.1.16	320129	425752	223159	186	38	25	10.8 ± 0.9	279113	310158	244278	223	10	25	10.4 ± 0.9	311443	494213	189578	217	18	25	14.7 ± 0.9	371087	82471	24476	200	18	25		
10.1.17	5352	6395	39607	372	38	25	10.8 ± 0.9	105509	105509	105509	105509	10	25	10.4 ± 0.9	128458	364945	203095	240	18	25	14.7 ± 0.9	594479	553232	223165	218	18	25		
10.1.18	320129	365688	328752	214	38	25	10.8 ± 0.9	361170	346519	245519	193	10	25	10.4 ± 0.9	311443	473154	196493	258	18	25	14.7 ± 0.9	648220	604049	243030	245	18	25		
10.1.19	348759	525929	260675	186	38	25	10.8 ± 0.9	302606	311656	232322	193	10	25	10.4 ± 0.9	311443	468651	205193	185	18	25	14.7 ± 0.9	741030	600162	268309	185	18	25		
10.1.20	5352	6395	39607	372	38	25	10.8 ± 0.9	105509	105509	105509	105509	10	25	10.4 ± 0.9	128458	364945	203095	240	18	25	14.7 ± 0.9	594479	553232	223165	218	18	25		
10.1.21	420881	474844	260650	186	38	25	10.8 ± 2.3	366946	517151	239483	212	10	25	10.4 ± 2.3	311443	421665	451356	191182	201	18	25	14.7 ± 2.3	653224	470564	189578	218	18	25	
10.1.22	376455	448326	260650	186	38	25	10.8 ± 2.3	366946	517151	239483	212	10	25	10.4 ± 2.3	311443	421665	451356	191182	201	18	25	14.7 ± 2.3	653224	470564	189578	218	18	25	
10.1.23	376455	376455	448326	271159	186	38	25	10.8 ± 2.3	366946	517151	239483	212	10	25	10.4 ± 2.3	311443	421665	451356	191182	201	18	25	14.7 ± 2.3	653224	470564	189578	218	18	25
10.1.24	376455	376455	448326	271159	186	38	25	10.8 ± 2.3	366946	517151	239483	212	10	25	10.4 ± 2.3	311443	421665	451356	191182	201	18	25	14.7 ± 2.3	653224	470564	189578	218	18	25
10.1.25	420881	448326	376455	211	38	25	10.8 ± 2.3	408177	515789	238414	222	10	25	10.4 ± 2.3	311443	421665	451356	191182	201	18	25	14.7 ± 2.3	653224	470564	189578	218	18	25	
10.1.26	421424	614071	341109	216	38	25	10.8 ± 2.7	509127	515857	312184	187	10	25	10.4 ± 2.7	410559	339784	239395	686355	257	18	25	14.7 ± 2.7	394123	424056	89862	242	18	25	
10.1.27	421424	614071	341109	216	38	25	10.8 ± 2.7	509127	515857	312184	187	10	25	10.4 ± 2.7	410559	339784	239395	686355	257	18	25	14.7 ± 2.7	394123	424056	89862	242	18	25	
10.1.28	5352	6395	39607	372	38	25	10.8 ± 2.7	105509	105509	105509	105509	10	25	10.4 ± 2.7	128458	364945	203095	240	18	25	14.7 ± 2.7	594479	553232	223165	218	18	25		
10.1.29	495355	574843	378173	184	38	25	10.8 ± 2.7	429527	651935	374413	218	10	25	10.4 ± 2.7	411548	337751	279773	95464	281	18	25	14.7 ± 2.7	323594	174625	59323	243	18	25	
10.1.30	527448	606570	370480	200	38	25	10.8 ± 2.7	506490	651935	374413	218	10	25	10.4 ± 2.7	510972	664490	281388	224	10	25	14.7 ± 2.7	301857	359150	224165	253	10	25		
10.1.31	473355	574843	378173	184	38	25	10.8 ± 2.7	429527	651935	374413	218	10	25	10.4 ± 2.7	411548	337751	279773	95464	281	18	25	14.7 ± 2.7	323594	174625	59323	243	18	25	
10.1.32	473355	574843	378173	187	38	25	10.8 ± 2.7	429527	651935	374413	218	10	25	10.4 ± 2.7	411548	337751	279773	95464	281	18	25	14.7 ± 2.7	323594	174625	59323	243	18	25	
10.1.33	473355	574843	378173	187	38	25	10.8 ± 2.7	429527	651935	374413	218	10	25	10.4 ± 2.7	411548	337751	279773	95464	281	18	25	14.7 ± 2.7	323594	174625	59323	243	18	25	
10.1.34	5352	6395	39607	372	38	25	10.8 ± 2.7	105509	105509	105509	105509	10	25	10.4 ± 2.7	128458	364945	203095	240	18	25	14.7 ± 2.7	594479	553232	223165	218	18	25		
10.1.35	5352	6395	39607	372	38	25	10.8 ± 2.7	105509	105509	105509	105509	10	25	10.4 ± 2.7	128458	364945	203095	240	18	25	14.7 ± 2.7	594479	553232	223165	218	18	25		
10.1.36	5352	6395	39607	372	38	25	10.8 ± 2.7	105509	105509	105509	105509	10	25	10.4 ± 2.7	128458	364945	203095	240	18	25	14.7 ± 2.7	594479	553232	223165	218	18	25		
10.1.37	5352	6395	39607	372	38	25	10.8 ± 2.7	105509	105509	105509	105509	10	25	10.4 ± 2.7	128458	364945	203095	240	18	25	14.7 ± 2.7	594479	553232	223165	218	18	25		
10.1.38	5352	6395	39607	372	38	25	10.8																						

review is referred to as “hot checkout”. The hot checkout is an online checklist [3] for each subsystem that includes a sign-off for all hardware elements of the system (*e.g.* HV, LV, detectors, gas, pulser). For the FTOF system, the hot checkout includes verification that all detectors are operational, that the Slow Controls system for the HV is functioning, and that the DAQ system can fully communicate with the readout electronics.

Figure 17 shows a screenshot of the hot checkout interface. Under the heading “Hall B CLAS12 Detector”, all entries for FTOF (located within the “CLAS12 TOF” subheading) must be verified as ready. Note that often as part of the system checkout before the start of a run period, an initial cosmic data run is completed. Reminders to complete the system hot checkout will be sent out shortly before the start of a given run period with the required deadline for completing the work.

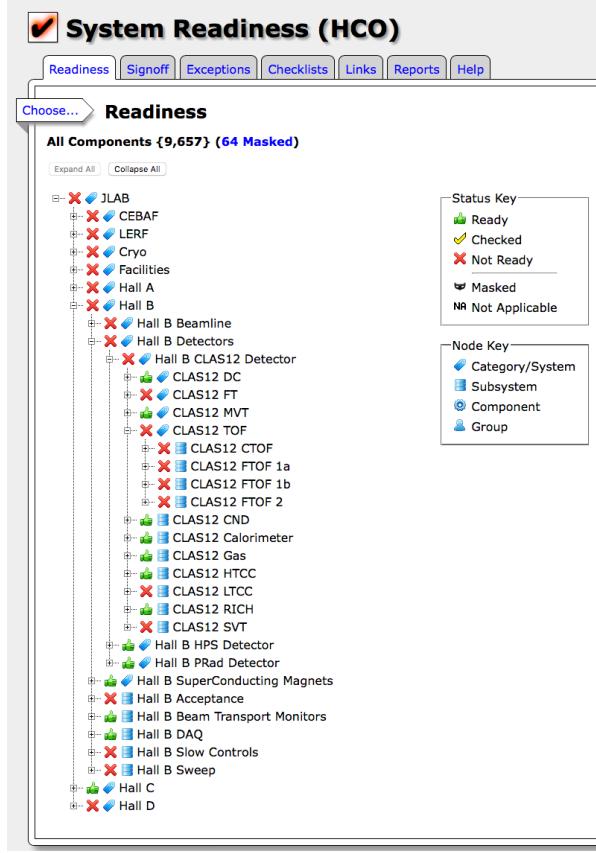


Figure 17: Screenshot of the Hall B hot checkout screen. The FTOF system appears under the “Hall B CLAS12 Detector” and “CLAS TOF” headings. All entries for FTOF have to be verified as functional and all items listed as “Not Ready” must be changed over to “Ready”.

3.1.2 On-Call Responsibilities

Each system Group Leader will organize a list of on-call experts who will take responsibility for carrying a cell phone to allow 24-hour access to experts who can address any problems that arise during a beam running period. The phone numbers of all subsystem experts are posted on the run page [4]. Any problems that cannot be quickly solved by the shift workers,

where quickly amounts to 10 – 15 minutes, should result in a call to the relevant expert cell phone. **The FTOF on-call phone number is (757)-344-7204.**

The on-call experts can often diagnose problems over the telephone, but there are times when they will have to go to the Counting House to more fully address an issue. One of the important responsibilities of the on-call experts is to make practical decisions regarding which problems require access to Hall B for immediate attention and which can be delayed to periods when the accelerator is down or other work is scheduled in the hall. For the FTOF system, usually problems with a single channel are not important enough to stop the data acquisition. The normal mode of operation after initial investigation of a bad channel is to turn off the HV for that channel until access can be made for a more detailed investigation. This work should be coordinated with the Run Coordinator.

Note: It is the responsibility of the FTOF on-call expert to review all issues that they cannot resolve with the FTOF subsystem Group Leader as soon as is reasonable. Each call to the FTOF on-call phone should be logged to the TOF on-call wikipage [5] with a description of the issue and a note on its resolution. This archive can be used as a resource for when problems arise.

3.1.3 Expert Monitoring Suite

The expert monitoring suite for the FTOF system is called *ftofmon*. This code suite is brought up on any Counting House computer by typing “*ftofmon*”. The suite allows monitoring of the following system quantities:

- FADC Mode 1 time slices
- Channel ADCs and TDCs
- Pedestal centroids and widths
- MIP responses
- HV settings
- Scalers

The suite runs from EVIO or HIPO input files or by attaching directly to the DAQ ET ring. The suite can also read and display input histogram files. Screen captures of the suite are shown in Fig. 18.

3.2 System Failure Modes

For the FTOF detector, there are a number of usual “failure” modes with which the system expert should be familiar. These include the following:

- Bad HV board (see Section 3.2.1)
- Bad HV mainframe (see Section 3.2.2)

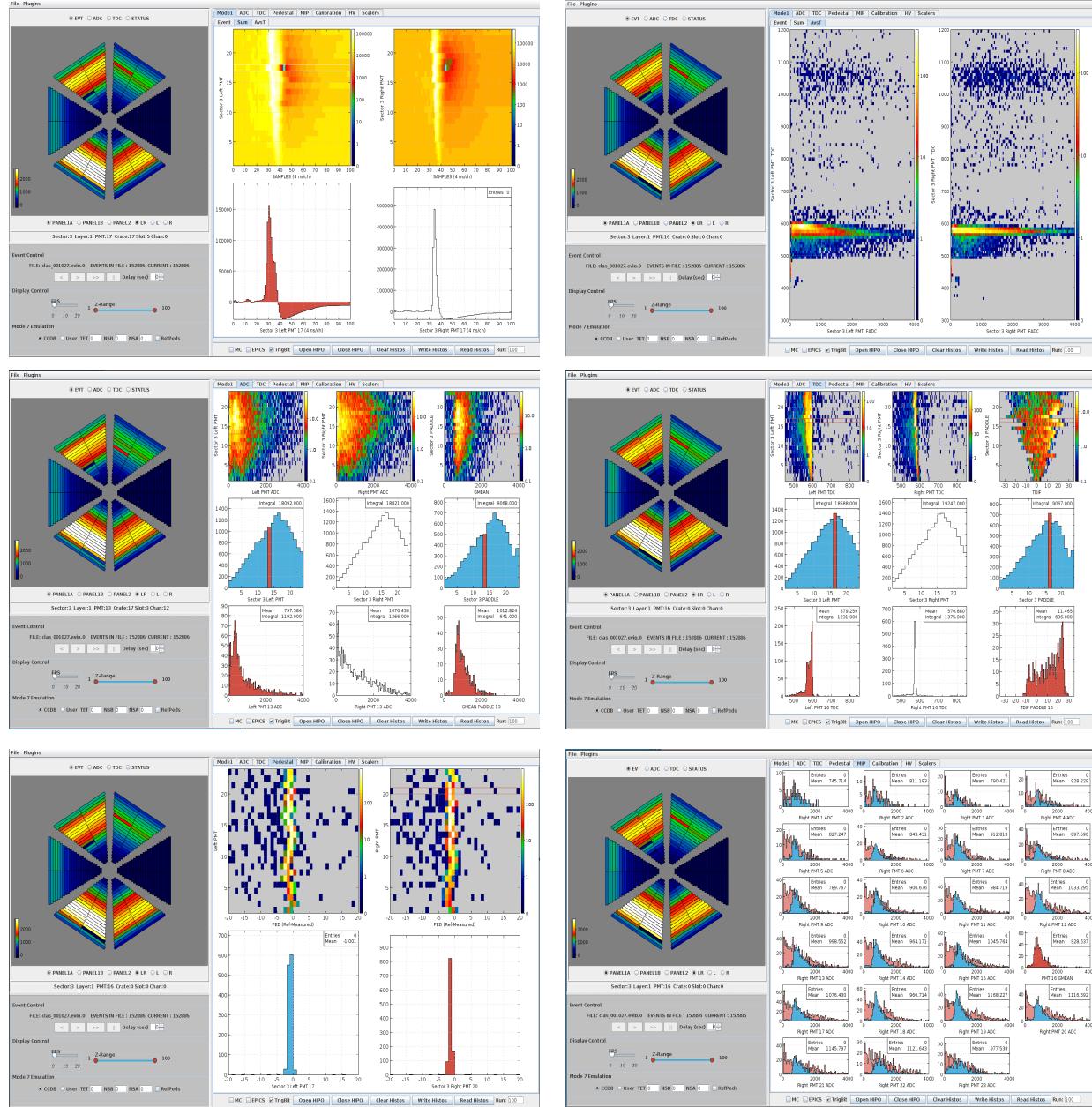


Figure 18: Various screens from the *ftofmon* expert monitoring suite.

- Sudden ADC gain shift (see Section 3.2.3)
- High PMT dark current (see Section 3.2.4)
- Missing anode or dynode signal (see Section 3.2.5)
- Bad PMT (see Section 3.2.6)
- Readout electronics issues (see Section 3.2.7)
- IOC issues (see Section 3.2.8)

3.2.1 Bad HV Board

The evidence for a bad HV board (A1535N) is either that the 24 channels associated with a single board won't ramp up to full voltage before tripping off or bad voltage regulation. For the case of bad voltage regulation, the channels ramp up to full voltage but then fluctuate about the demand voltage setting by up to several hundred volts. Before deciding whether a HV board is bad, some investigation should be completed to ensure that a single HV channel is not causing the problems with the board, which could point to a problem with the PMT or voltage divider. If a board is deemed bad and needs to be replaced, the following steps are necessary:

1. Using the HV control interface, ensure that all HV channels controlled by the main-frame are turned off. Remember that for each sector the HV mainframe for the FTOF also includes the PCAL.
2. Take a spare A1535N board from the storage area in the back room of the Counting House.
3. Turn the front panel key on the HV supply to the “off” position and toggle the main power switch to “off” on the back of the HV supply.
4. On the back of the supply, remove the Radiall connector on the bad board.
5. Pull out the bad board, being careful of the Radiall connectors on the neighboring boards.
6. Install the new board and reconnect the Radiall connector.
7. Be sure to take out the 50Ω lemo interlock terminator from the old board and plug into the same connector on the new board.
8. Toggle the main power switch to “on” and turn the HV power supply on using the key on the front panel, putting the key in the “local” position.
9. Restore the most recent backup parameter settings for the HV mainframe described in Section 3.3.2. Note that only the parameters associated with the swapped board should need to be restored. It is important to note as well that the “BURT” backup file does

not include the parameters for the maximum high voltage settings for the channel. These must be reset for the swapped out board to the nominal values (-2.5 kV for panel-1a and panel-2 channels, -2.0 kV for panel-1b channels). See instructions in Section 3.3.1. These values can also be set channel-by-channel using the FTOF expert channel controls screen discussed in Section 2.2.

10. Leave the bad board on the RadCon survey table in Hall B (floor level on south side of Forward Carriage) attaching a RadCon tag with a contact listing for the Fast Electronics Group. Send an email to the Fast Electronics Group to pick up the module for testing/repairs.
11. If beam conditions are acceptable, turn on the HV for the FTOF and PCAL channels. Be sure to check with the shift leader before energizing the supply.

3.2.2 Bad Mainframe

From time to time the CAEN mainframes will go bad and need to be serviced in situ or replaced entirely with a spare. If the entire mainframe must be replaced, this can be a fairly significant undertaking and should not be considered without certainty that the problem is actually the mainframe. The final determination regarding the status of the hardware should be made in consultation with the Slow Controls expert after a number of different checks are made.

The basic procedure to swap out a mainframe is as follows:

1. Using the HV control interface, ensure that all HV channels controlled by the mainframe are turned off. Remember that for each sector the HV mainframe for the FTOF also includes the PCAL.
2. Turn the front panel key on the HV supply to the “off” position and toggle the main power switch to “off” on the back of the HV supply.
3. The modules are typically pulled out of the back of the mainframe leaving the Radiall connectors attached. Before pulling the modules from the mainframe, be sure that they are clearly labeled so that they can be put back into their assigned slots.
4. Unplug the power cord from the mainframe.
5. Remove the mainframe from the rack and place it on the RadCon survey table (floor level south side of Forward Carriage) attaching a RadCon tag with contact information listing the Fast Electronics Group. Send email to the Fast Electronics Group to pick up the mainframe for testing/repairs.
6. Install a spare mainframe in the rack, install the boards into their assigned slots, and connect the power cord to the mainframe.
7. Toggle the main power switch to “on” and turn the HV power supply on using the key on the front panel, putting the key in the “local” position.

8. Contact the Slow Controls expert to set up communication to the mainframe.
9. When communication is restored, check the channel settings for all boards to be sure that they are correct before turning on the HV. If there are questions regarding the PCAL settings, contact the ECAL expert. As the channel settings are stored on the individual boards, the parameters should be restored without user intervention. However, if necessary, restore the parameter settings as described in Section 3.3.2, making sure that the maximum high voltage limits for each channel are correct (-2.5 kV for panel-1a and panel-2, -2.0 kV for panel-1b).
10. If beam conditions are acceptable, turn on the HV for the FTOF and PCAL channels. Be sure to check with the shift leader before energizing the supply.

3.2.3 Sudden Gain Shift

Sometimes a sudden gain shift can appear in the ADC spectrum for a given counter. There are a number of possible causes for such a condition.

- Problematic PMT/Voltage Divider - sometimes gain shifts can be attributed to a problem with a PMT or voltage divider that requires adjustment of the HV settings. Of course, PMT aging effects also typically lead to a reduced gain that requires an increase of the HV. Such issues are typically seen as slow drifts of the response with time.
- DAQ Problems - the most common cause for an apparent sudden gain shift in the ADC spectra for a counter is due to problems with the FADC settings. Such problems can typically be diagnosed from pedestal shifts or widened pedestals. The pedestals can be checked using the *ftofmon* system monitoring suite (see Section 3.1.3). Note that as the panel-1a and panel-2 dynode signals used for the FADC inputs are bipolar pulses (see Section 3.2.5), issues with shifts in the signal summing region can have a dramatic impact on the FADC spectra.
- Bad Inverters - the panel-1b dynode signals, which are used for the input to the FADCs, are nominally positive polarity pulses that are sent through an in-line inverter attached to the Forward Carriage patch panel (see Section 3.4.2). These inverters occasionally go bad and can be diagnosed comparing the signal on either side of the inverter. Bad inverters should be replaced with new spare inverters contained in the FTOF storage cabinets on the upper level of the Pie Tower.
- Light Leak - it is possible that a gain shift can be due to a light leak on the counter. Note that issues with hardware damage are less likely for the panel-1a and panel-1b counters as they are buried between the LTCC/RICH detectors and the calorimeters. Of course, the panel-2 counters are more exposed and hardware issues can either be explored by looking at signals or measuring dark currents at the voltage dividers, the local disconnect patch panels, or the electronics patch panels. The panel-2 detectors themselves can be explored using access with manlifts as necessary, coordinating work through the FTOF Group Leader, the Run Coordinator, and the Hall B Work Coordinator.

- PMT Saturation - In conditions of excessively high rates, the PMT can become current limited and the ADC signals can become distorted and shifted to lower gains. Be sure that bad beam or high rate conditions are not responsible for the issues seen.

3.2.4 High PMT Dark Current

High PMT dark currents can be seen through increased counting rates in the channel scaler displays or in distorted ADC spectra. The dark currents can be measured at either the local disconnect or the electronics patch panels. There are three likely causes for high PMT dark currents:

1. Bad PMT - At times when a PMT goes bad, its dark current can increase. Typical FTOF PMT dark currents are at the level of 50 nA or less. If a bad PMT has been identified, it can only be worked on during designated FTOF servicing periods. However, the usual procedure is to leave the PMT energized and live with the increased dark current unless the higher currents cause the HV supply channel to trip or the HV board to become unstable. If the channel HV needs to be “turned off”, change $V_{set}=0$. The logbook (HBLOG and HBTOF) should be updated and the HV setting configuration should be saved as the nominal setting.
2. Light Leak - A light leak in the counter wrapping will also lead to higher dark currents. The issue of light leaks is not expected to be an issue for the panel-1a and panel-1b counters as they are buried within the detectors on the Forward Carriage and ambient light levels are usually very low. However, the panel-2 counters are more exposed. Light leaks can be repaired during opportunities when the Forward Carriage is moved away from the torus magnet into its maintenance position.
3. Reflective Layer Wrapping Problems (panel-1b only) - There is an issue with the wrapping of the reflective layer on some of the panel-1b counters that has been seen to lead to “super-hot” PMTs, with dark currents up to 100 μ A. There are several PMTs that have a history of showing such high currents, but occasionally a PMT that had been operating without issue, can suddenly show very large currents. Sometimes the current draw will monotonically reduce over the period of several hours. These PMTs will remain at low currents as long as the HV is not turned off. Sometimes, the currents remain high regardless of how long they are energized. In such cases, judgment should be exercised as to whether to leave the channel on or off. If the channel is turned off (by changing $V_{set}=0$), the HV setting configuration should be updated and saved.

3.2.5 Missing Anode or Dynode Signal

Each FTOF PMT has two signal outputs, an anode and a dynode. On average, the anode signal is roughly three times larger in amplitude compared to its corresponding dynode signal. For the PMTs of panel-1a and panel-2, the anode is a negative polarity signal and the dynode is a bipolar signal (negative polarity primary pulse with a positive polarity overshoot and tail). For the panel-1b PMTs, the anode is a negative polarity pulse and the dynode is a positive polarity pulse. Note that in-line signal inverters at the Forward

Carriage patch panels invert the panel-1b dynode pulse polarity to be negative. Scope images of representative FTOF PMT anode and dynode pulses are shown in Fig. 19.

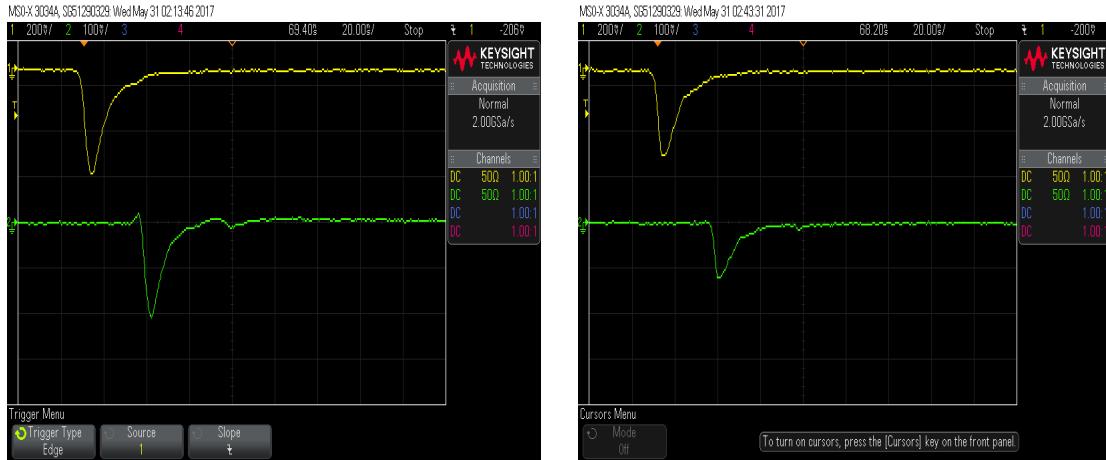


Figure 19: Scope traces for anodes (yellow) and dynodes (green) for typical PMT pulses for panel-1a (left) and panel-1b (right).

Occasionally a signal will disappear from the FTOF monitoring plots. In such a situation, further investigation will be necessary.

- If both anode and dynode signals are missing, this could be due either to a problem with the HV, the VME crate (which would affect an entire board or entire sector), or the PMT itself. If the problem is with the HV board, it should be replaced as detailed in Section 3.2.1. PMT problems are typically apparent as the nominal PMT signal (see Fig. 19) is absent, severely distorted, or replaced by high frequency noise.
- If one signal (anode or dynode) is present for the PMT and the other is missing, this could be a bad cable connection anywhere from the voltage divider to the input to the electronics. The way to diagnose is to use an oscilloscope to look at the signal at each accessible junction point. If the signal is missing from the monitoring data but is seen to be good at the input to the FADC and TDC, contact the DAQ expert for help.
- If the dynode signal is missing from panel-1b, this is likely caused by a bad signal inverter (see Section 3.2.3).
- If either the anode or dynode signal is missing from a panel-1a or panel-2 PMT and the cabling checks out, the problem is likely due to a bad component on the voltage divider. In such a case the channel must be “turned off” by setting $V_{set} = 0$ (with HV channel parameters updated - see Section 3.3.2). Repairs can only be made during a designated FTOF repair cycle.
- If the PMT HV is on but the supply current reads 0, this is likely due to a bad HV cable or connection, or an issue with the HV distribution box.

- Groups of missing signals for consecutive electronics channels are likely due to an unplugged or partially unplugged ribbon cable at the input to the TDC or the output from the discriminators.

3.2.6 Bad PMT

One of the most common failure modes of a PMT is a gradual loss of gain over the period of several years. This can be compensated by adjusting the HV to maintain the gain setting. The PMTs used in the FTOF system have maximum voltage ratings of -2500 V for the PMTs in panel-1a and panel-2, and -2000 V for the PMTs in panel-1b. Once the PMT HV is set to its maximum value and the gain falls below the nominal setting, the PMT should be flagged for replacement during the next servicing opportunity.

3.2.7 Readout Electronics Issues

Readout electronics issues, typically associated with all channels associated with a given discriminator board, TDC board, or FADC board, once diagnosed should be brought to the attention of the DAQ system expert for further diagnosis and attention.

3.2.8 IOC Issues

Loss of communication between the IOC and the HV mainframe is seen by a yellow or magenta color status for all HV channels in a given sector. The IOC should be rebooted following the instructions given in Section 2.2.1. If rebooting the IOC does not solve the problems, contact the Slow Controls system expert.

3.3 HV System Operations

3.3.1 Setting HV Channel Parameters

The CS-Studio program is used to monitor the HV settings of the FTOF system and to toggle the HV off and on for individual or multiple channels in the system. To set the channel values, restore the most recent saved “BURT” backup file (see Section 3.3.2 for details). Note as well that the channel parameters can also be set using control scripts. From the computers in the Hall B Counting House, the scripts are in the sector subdirectories located in the path: `/home/clasrun/ftof/hv/sn`, with $n = 1 \rightarrow 6$ for FTOF S1 → S6. There are seven scripts available for each FTOF sector:

- `loadhvmax-sn`: Contains the maximum HV limits for each supply channel (units = V)
- `loadi0-sn`: Contains the maximum current limits for each supply channel (units = μ A)
- `loadpw0-sn`: Turns all FTOF channels off
- `loadpw1-sn`: Turns all FTOF channels on
- `loadrup-sn`: Sets the voltage ramp up rates for each supply channel (units = V/s)

- *loadrdn-sn*: Sets the voltage ramp down rates for each supply channel (units = V/s)
- *loadtrip-sn*: Sets the maximum time duration for an over-current condition before the channel trips (units = s)

The scripts are run from any of the DAQ machines in the Counting House (using *e.g.* the commands *sh loadhvmax-s1* or *./loadhvmax-s1*).

The nominal settings for the HV channel parameters are as follows:

- HV_{max} values: panel-1a, panel-2: -2500 V, panel-1b: -2000 V
- i_{max} values: 500 μ A
- HV ramp up rate: 50 V/s
- HV ramp down rate: 100 V/s
- Over-current duration before trip: 1 s

The scripts to set the channel HV values are created by the HV calibration program. Before changing the HV values for any channel in the FTOF system, the existing parameter settings must be saved to a backup file (see Section 3.3.2).

Although not the recommended way to set the HV supply channel parameters, there is the option to adjust settings channel-by-channel using the HV “expert” screen shown in Fig. 11. Here the parameters, V_{set} , I_{set} , V_{max} , and the HV ramp up and ramp down rates, can be entered directly into the parameter field. However, it is imperative that the script settings detailed above be kept fully up to date as they represent the system archive values. This “expert” screen should most properly be used only for viewing the channel parameter set values.



Figure 20: Sub-menu of the FTOF HV control screen for “Save/Restore”.

3.3.2 HV Save and Restore

The FTOF HV interface allows all system channel settings (except for the maximum channel HV settings) to be saved into a file or loaded from an archived file by clicking on the “Save/Restore” button in the upper left corner of the main HV screen (see Fig. 6). The files created are referred to as “BURT” backup files, where BURT is an acronym for “Backup and Restore Tool”. BURT is a utility for saving the HV system settings into an ASCII file

readable by the EPICS Slow Controls system. The save files are stored on the DAQ machines in the Hall B Counting House at: `/usr/clas12/DATA/burt/FTOF_HV`.

After clicking on the “Save/Restore” button, a sub-menu appears as shown in Fig. 20 to select “Save Settings” or “Restore Settings”. Clicking on “Save Settings” brings up a window “CREATE HV BACKUP” as shown in Fig. 21 showing the save file path and the selected file name that contains the system name along with the date and time. If the “Restore Settings” option is chosen, the window shown in Fig. 22 comes up showing the saved FTOF HV restore files available from which to select. Selecting a file and clicking on “OK” at the bottom of the window loads all channel parameters for the full HV system. Note that a new backup file should be created whenever any HV settings have changed, including HV values, channel parameter settings, and channel on/off settings.

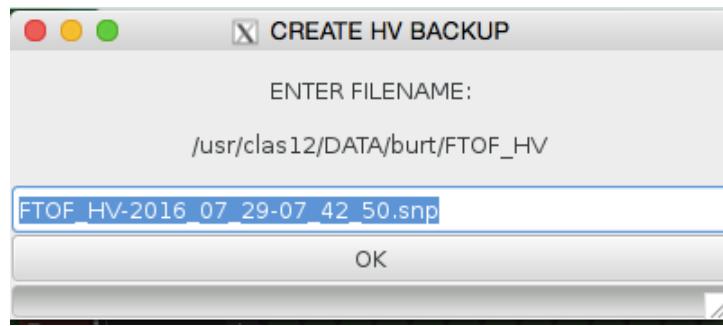


Figure 21: Window that comes up after selecting “Save Settings” during a “Save/Restore” operation (see in Fig. 5(right)).

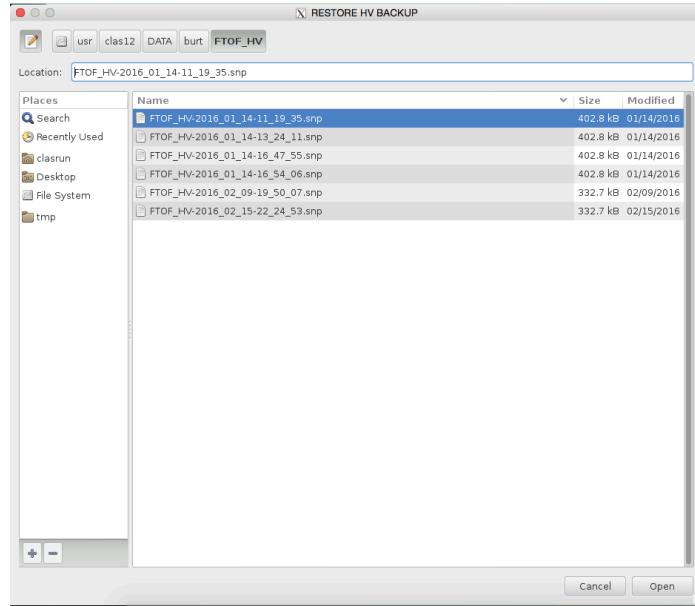


Figure 22: Window that comes up after selecting “Restore Settings” during a “Save/Restore” operation (see in Fig. 5(right)).

3.4 Cabling Details

3.4.1 Signal Cable Maps

The FTOF channel connections to the VME readout electronics are mapped in such a way that neighboring PMTs are not connected to neighboring electronics inputs. This scheme was devised to reduce any electronics noise coupling (*i.e.* cross-talk). The VME electronics channel mapping is shown in Fig. 23 for the FADCs, in Fig. 24 for the discriminators, and in Fig. 25 for the TDCs.

3.4.2 Signal Cable Layout

The anode and dynode signal cables for each PMT run from the voltage divider to a local disconnect patch panel located behind the panel-2 arrays in each sector. A schematic diagram of this patch panel is shown in Fig. 26. These cables vary in length from 12 ft to 23.25 ft. Note that there are two local disconnect patch panels for each FTOF sector, one for the left anode and dynode cables and one for the right anode and dynode cables. The signal cables for each sector are then strung to the Forward Carriage electronics to a second set of patch panels via 35 ft-long cables. A schematic diagram of these so-called electronics patch panels is shown in Fig. 27. The signals are then run from these patch panels to the discriminators (for the anode signals) and to the FADCs (for the dynode signals) via 5 ft-long cables. Note, as stated in Section 3.2.5, the dynode signals for panel-1b emerge with positive polarity from the voltage dividers. To invert the signal polarity to be compatible with the readout electronics, an in-line inverting transformer (Phillips Scientific Model #460) is connected to the electronics patch panel for each channel. Figures 30 and 31 in Section 3.4.5 give schematics for the cable and connector types for each segment of the connections from the voltage divider to the readout electronics for the counters in FTOF panel-1a, panel-1b, and panel-2.

3.4.3 HV Cable Layout

The high voltage cables for each PMT run from the voltage divider to a local disconnect HV distribution box located behind the panel-2 arrays in each sector next to the signal cable local disconnect patch panels. Note that there are four HV distribution boxes for each sector, two for the left PMTs and two for the right PMTs of each sector. Figure 28 shows the layout of the two HV distribution boxes for the left and right PMT HV connections (with left and right defined as in Fig. 2). The output of each HV distribution box is a pair of 35-ft-long multi-conductor cables, each containing 24-channels, with a Radiall connector to mate with the HV A1535N board input connector. See Figs. 30 and 31 in Section 3.4.5 for schematics of the cable and connector types for each segment of the HV connections from the voltage divider to the HV power supplies for the counters in FTOF panel-1a, panel-1b, and panel-2. The HV power supply channel assignments for each sector are nominally given as shown in Fig. 29.

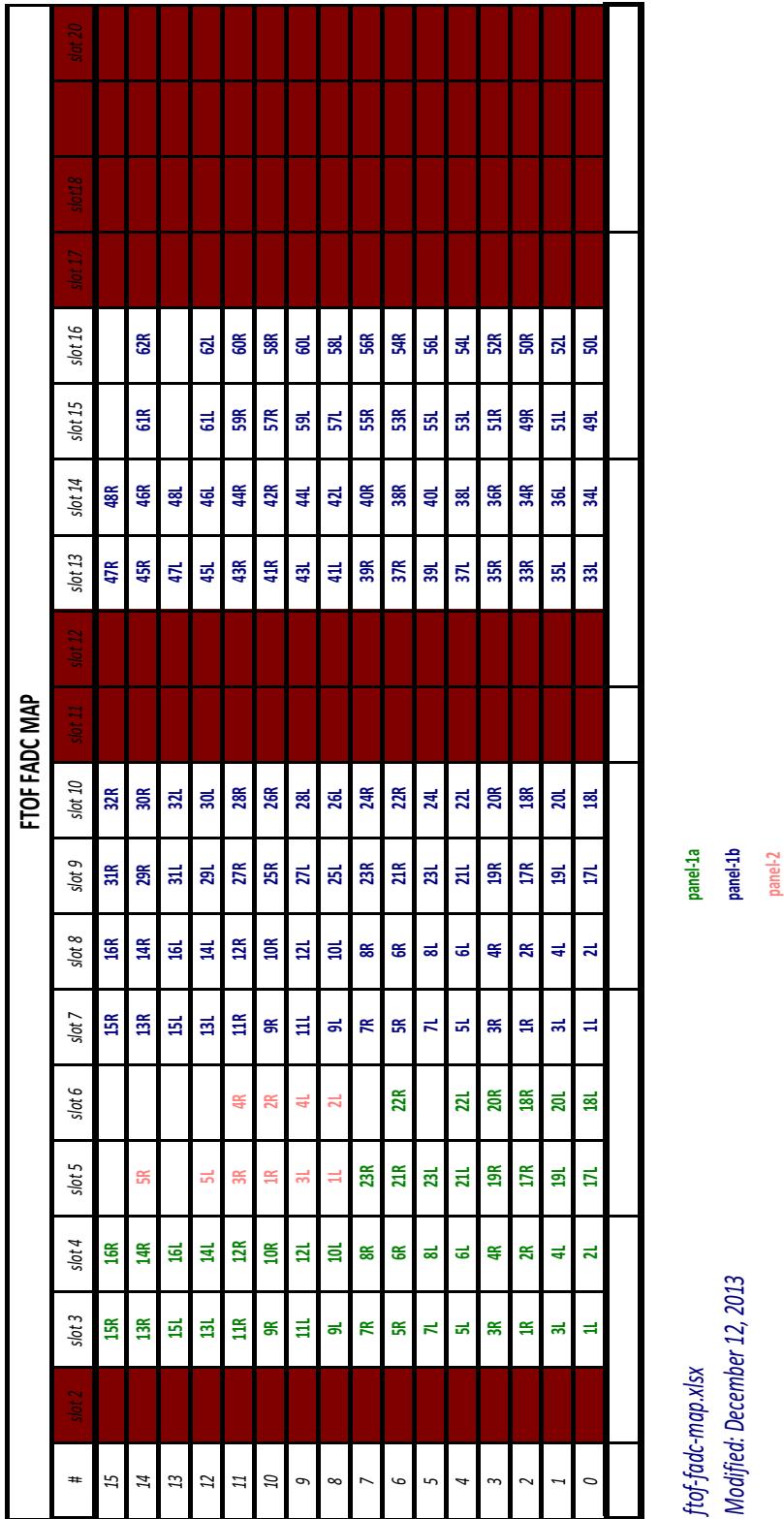


Figure 23: Electronics map for each sector for the input connections to the FTOF VME FADCs.

		FTOF DISCRIMINATOR MAP																			
#		s/ot 2	s/ot 3	s/ot 4	s/ot 5	s/ot 6	s/ot 7	s/ot 8	s/ot 9	s/ot 10	s/ot 11	s/ot 12	s/ot 13	s/ot 14	s/ot 15	s/ot 16	s/ot 17	s/ot 18	s/ot 19	s/ot 20	
1		1L		2L		17L		18L	1L	2L		17L		18L	33L		34L	49L		50L	
2		3L		4L		19L		20L	3L	4L		19L		20L	35L		36L	51L		52L	
3		1R		2R		17R		18R	1R	2R		17R		18R	33R		34R	49R		50R	
4		3R		4R		19R		20R	3R	4R		19R		20R	35R		36R	51R		52R	
5		5L		6L		21L		22L	5L	6L		21L		22L	37L		38L	53L		54L	
6		7L		8L		23L		7L	8L	9L		23L		24L	39L		40L	55L		56L	
7		5R		6R		21R		22R	5R	6R		21R		22R	37R		38R	53R		54R	
8		7R		8R		23R		7R	8R	9R		23R		24R	39R		40R	55R		56R	
9		9L		10L		1L		2L	9L	10L		25L		26L	41L		42L	57L		58L	
10		11L		12L		3L		4L	11L	12L		27L		28L	43L		44L	59L		60L	
11		9R		10R		1R		2R	9R	10R		25R		26R	41R		42R	57R		58R	
12		11R		12R		3R		4R	11R	12R		27R		28R	43R		44R	59R		60R	
13		13L		14L		5L		13L	14L	15L		29L		30L	45L		46L	61L		62L	
14		15L		16L						16L		31L		32L	47L		48L				
15		13R		14R		5R		13R	14R	14R		29R		30R	45R		46R	61R		62R	
16		15R		16R					15R	16R		31R		32R	47R		48R				
		DISC		DISC		DISC		DISC	DISC	DISC		TDC		DISC	TDC		DISC	DISC		DISC	

ftof-disc-map-v2.xlsx
Modified: February 11, 2016
 panel-1a
 panel-1b
 panel-2

Figure 24: Electronics map for each sector for the input connections to the FTOF VME discriminators.

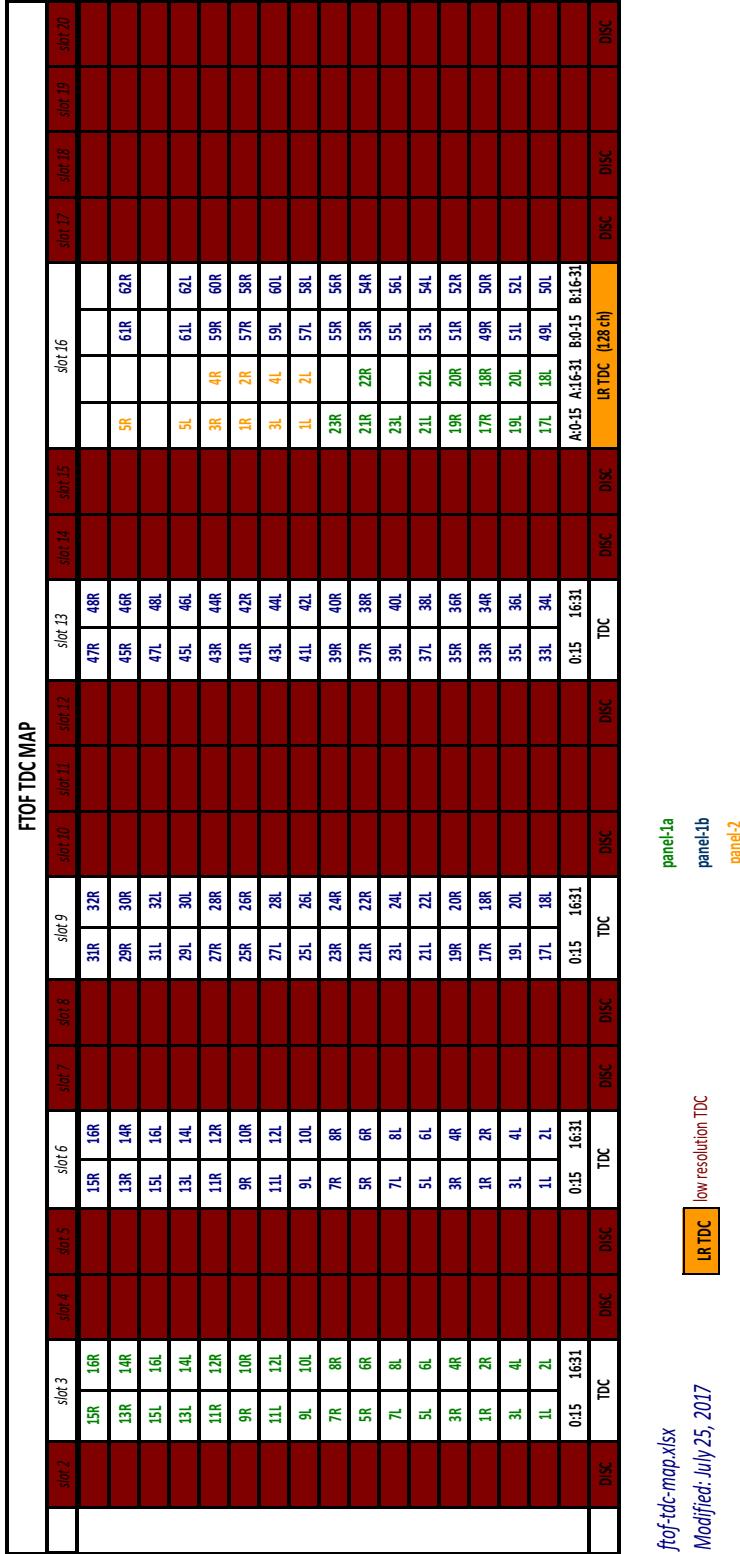


Figure 25: Electronics map for each sector for the input connections to the FTOF VME TDCs.

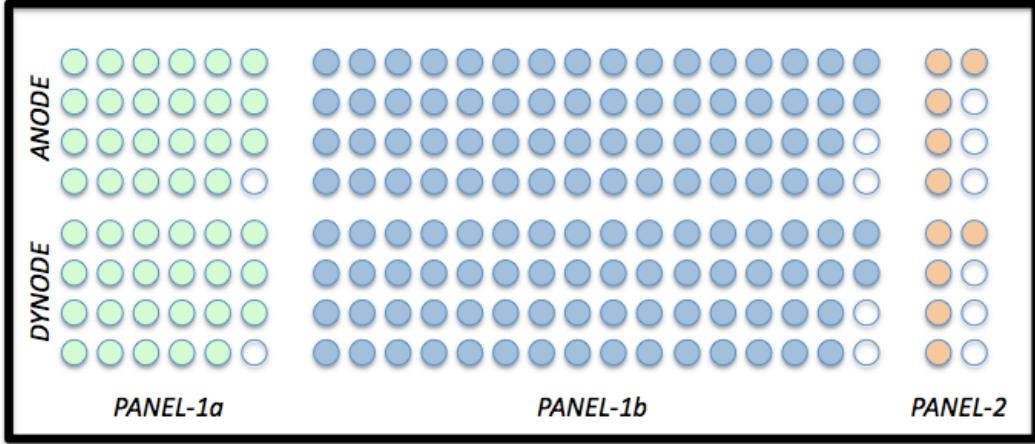


Figure 26: Schematic of the signal cable local disconnect patch panels positioned just behind the panel-2 FTOF counters for each Forward Carriage sector. For each sector there are two such patch panels associated with the left and the right sides of the counter (as defined in Fig. 2). The white filled circles are unused connectors.

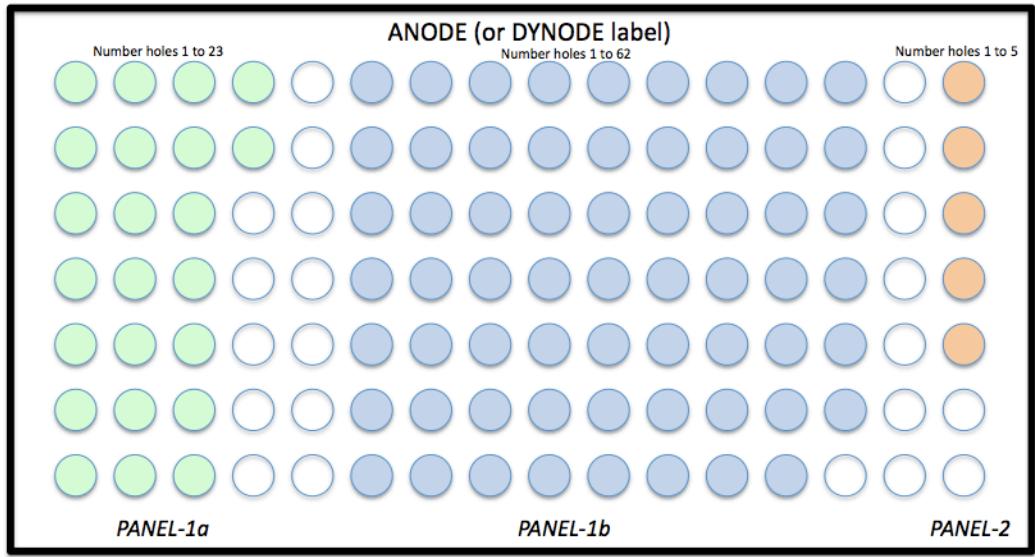


Figure 27: Schematic of the signal cable electronics patch panel located on the Forward Carriage. There are four such panels for each sector for the anode left/right and dynode left/right connections. The white filled circles are unused connections.

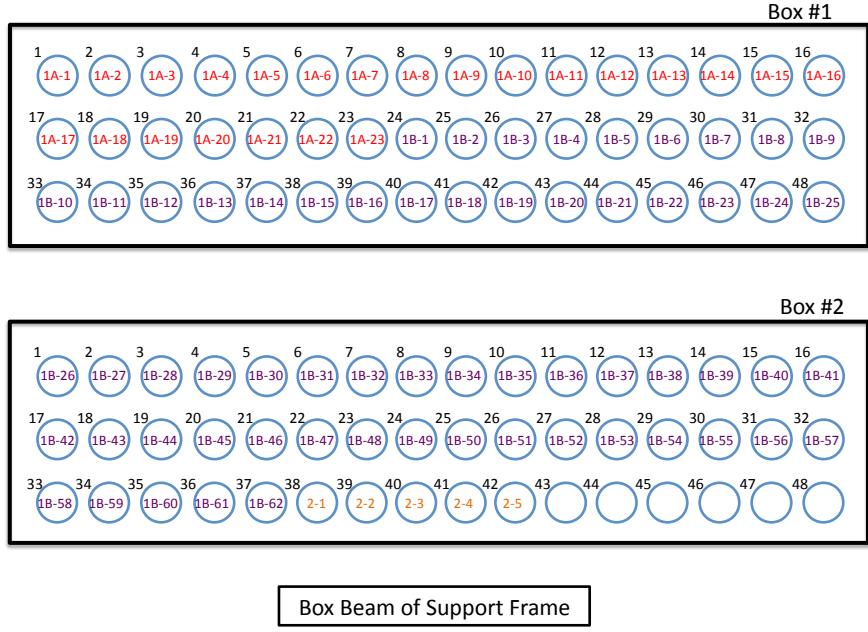


Figure 28: Mapping of the HV channel connections to the HV distribution boxes for each sector. Each sector is connected to four HV distribution boxes, two for the left side PMTs and two for the right side PMTs. Note: The box beam that supports the panel-2 arrays and the patch panels themselves is located under the second box.

FTOF HV Mapping
ftof-hvmap.xlsx
1/6/16

Slot / Ch	Det.														
0:00	1a-1L	1:00	1b-2L	2:00	1b-26L	3:00	1b-50L	4:00	1a-1R	5:00	1b-2R	6:00	1b-26R	7:00	1b-50R
0:01	1a-2L	1:01	1b-3L	2:01	1b-27L	3:01	1b-51L	4:01	1a-2R	5:01	1b-3R	6:01	1b-27R	7:01	1b-51R
0:02	1a-3L	1:02	1b-4L	2:02	1b-28L	3:02	1b-52L	4:02	1a-3R	5:02	1b-4R	6:02	1b-28R	7:02	1b-52R
0:03	1a-4L	1:03	1b-5L	2:03	1b-29L	3:03	1b-53L	4:03	1a-4R	5:03	1b-5R	6:03	1b-29R	7:03	1b-53R
0:04	1a-5L	1:04	1b-6L	2:04	1b-30L	3:04	1b-54L	4:04	1a-5R	5:04	1b-6R	6:04	1b-30R	7:04	1b-54R
0:05	1a-6L	1:05	1b-7L	2:05	1b-31L	3:05	1b-55L	4:05	1a-6R	5:05	1b-7R	6:05	1b-31R	7:05	1b-55R
0:06	1a-7L	1:06	1b-8L	2:06	1b-32L	3:06	1b-56L	4:06	1a-7R	5:06	1b-8R	6:06	1b-32R	7:06	1b-56R
0:07	1a-8L	1:07	1b-9L	2:07	1b-33L	3:07	1b-57L	4:07	1a-8R	5:07	1b-9R	6:07	1b-33R	7:07	1b-57R
0:08	1a-9L	1:08	1b-10L	2:08	1b-34L	3:08	1b-58L	4:08	1a-9R	5:08	1b-10R	6:08	1b-34R	7:08	1b-58R
0:09	1a-10L	1:09	1b-11L	2:09	1b-35L	3:09	1b-59L	4:09	1a-10R	5:09	1b-11R	6:09	1b-35R	7:09	1b-59R
0:10	1a-11L	1:10	1b-12L	2:10	1b-36L	3:10	1b-60L	4:10	1a-11R	5:10	1b-12R	6:10	1b-36R	7:10	1b-60R
0:11	1a-12L	1:11	1b-13L	2:11	1b-37L	3:11	1b-61L	4:11	1a-12R	5:11	1b-13R	6:11	1b-37R	7:11	1b-61R
0:12	1a-13L	1:12	1b-14L	2:12	1b-38L	3:12	1b-62L	4:12	1a-13R	5:12	1b-14R	6:12	1b-38R	7:12	1b-62R
0:13	1a-14L	1:13	1b-15L	2:13	1b-39L	3:13	2-1L	4:13	1a-14R	5:13	1b-15R	6:13	1b-39R	7:13	2-1R
0:14	1a-15L	1:14	1b-16L	2:14	1b-40L	3:14	2-2L	4:14	1a-15R	5:14	1b-16R	6:14	1b-40R	7:14	2-2R
0:15	1a-16L	1:15	1b-17L	2:15	1b-41L	3:15	2-3L	4:15	1a-16R	5:15	1b-17R	6:15	1b-41R	7:15	2-3R
0:16	1a-17L	1:16	1b-18L	2:16	1b-42L	3:16	2-4L	4:16	1a-17R	5:16	1b-18R	6:16	1b-42R	7:16	2-4R
0:17	1a-18L	1:17	1b-19L	2:17	1b-43L	3:17	2-5L	4:17	1a-18R	5:17	1b-19R	6:17	1b-43R	7:17	2-5R
0:18	1a-19L	1:18	1b-20L	2:18	1b-44L	3:18		4:18	1a-19R	5:18	1b-20R	6:18	1b-44R	7:18	
0:19	1a-20L	1:19	1b-21L	2:19	1b-45L	3:19		4:19	1a-20R	5:19	1b-21R	6:19	1b-45R	7:19	
0:20	1a-21L	1:20	1b-22L	2:20	1b-46L	3:20		4:20	1a-21R	5:20	1b-22R	6:20	1b-46R	7:20	
0:21	1a-22L	1:21	1b-23L	2:21	1b-47L	3:21		4:21	1a-22R	5:21	1b-23R	6:21	1b-47R	7:21	
0:22	1a-23L	1:22	1b-24L	2:22	1b-48L	3:22		4:22	1a-23R	5:22	1b-24R	6:22	1b-48R	7:22	
0:23	1b-1L	1:23	1b-25L	2:23	1b-49L	3:23		4:23	1b-1R	5:23	1b-25R	6:23	1b-49R	7:23	

1a = panel-1a
1b = panel-1b
2 = panel-2
The layout of the 6 FTOF HV crates (one for each sector) is identical

Figure 29: HV mainframe FTOF channel assignments for each sector.

3.4.4 Altering Cable Maps

The nominal procedure if there is a problem with a VME electronics board is to replace the board with a spare unit. However, for testing purposes, it might be necessary to change a signal input at the FADC, discriminator, or TDC to an unused channel. This work must always be done in coordination with the DAQ system expert in order to update the channel map used as input to the translation table. This operation is not something that is normally done and should not be attempted by shift workers or FTOF experts as it could lead to problems decoding the data.

Problems with channels within the HV system including the HV distribution box or a A1535N card are reasonably common. The standard procedure when there is a problem with a CAEN HV board is to swap out the problematic board with a spare (see Section 3.2.1). If there is a problem on the HV distribution box on either the left or right side of a sector, there are six spare HV channels that are available. These are detailed in Section 3.4.3. If one of these spare channels is to be used, the first step before disconnecting any system HV cables is to be sure that the channel HV is turned off for the channel to be moved. The SHV cable can then be moved to one of the open connectors on the HV distribution box shown in Fig. 28. In order to update the HV channels map, contact the Slow Controls expert.

3.4.5 Cable Connections

In order to better understand the signal and high voltage cabling scheme for the FTOF system, Figs. 30 and 31 show for panel-1a, panel-1b, and panel-2 the cable and connection types from the counter PMTs to the Forward Carriage electronics and power supplies.

3.5 Detector Repairs and Servicing

Repairs and servicing on the FTOF detectors themselves, specifically panel-1a and panel-1b, are highly involved and inherently risky operations. As the counters themselves are structurally robust, no mechanical problems are expected with them during the lifetime of CLAS12. However, PMTs do occasionally go bad due to gain reductions as a function of time and need to be replaced. In addition, voltage dividers can also sometimes go bad due to failed components (particularly with the older custom-made panel-1a and panel-2 voltage dividers). In order to replace a PMT or a voltage divider on either panel-1b or panel-1a, the entire panels have to be removed from the Forward Carriage and placed on the floor of Hall B. This involves removal of the associated LTCC or RICH detector and either one or both FTOF arrays depending on which array (panel-1a or panel-1b) needs servicing. Such an operation would never be done to repair a single bad element due to the effort and the risk involved. Of course, PMT and/or divider replacement for the panel-2 counters can be performed in situ using a ladder or a manlift (depending on the PMT location). All FTOF detector repairs will be organized through the FTOF Group Leader in conjunction with the Hall B Work Coordinator to be scheduled during a planned down time for Hall B.

Aug. 9, 2012

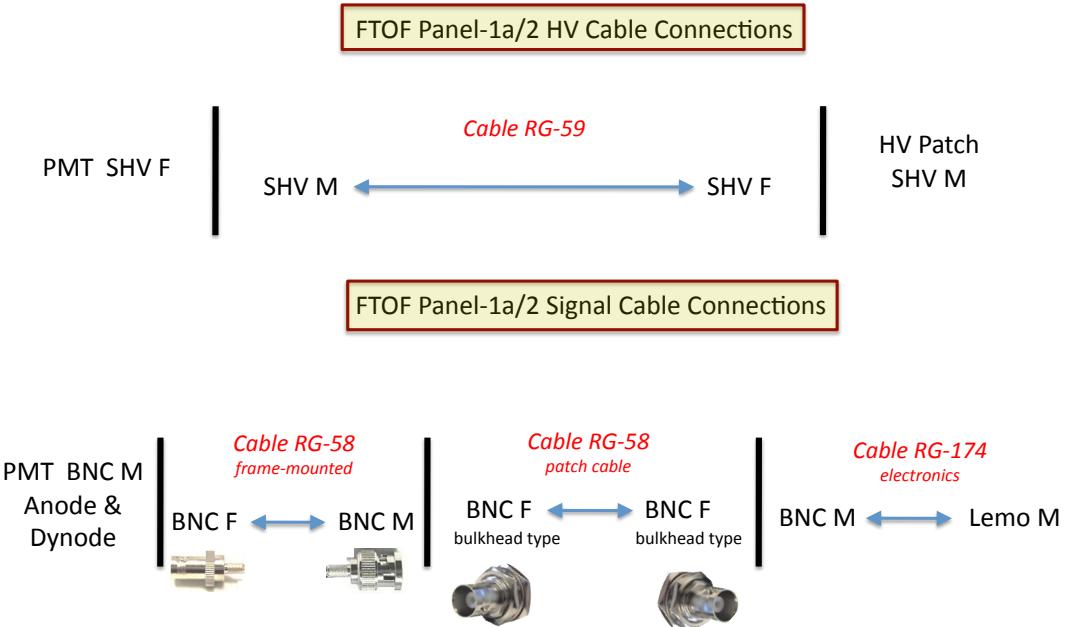


Figure 30: FTOF panel-1a and panel-2 HV and signal cable connections.

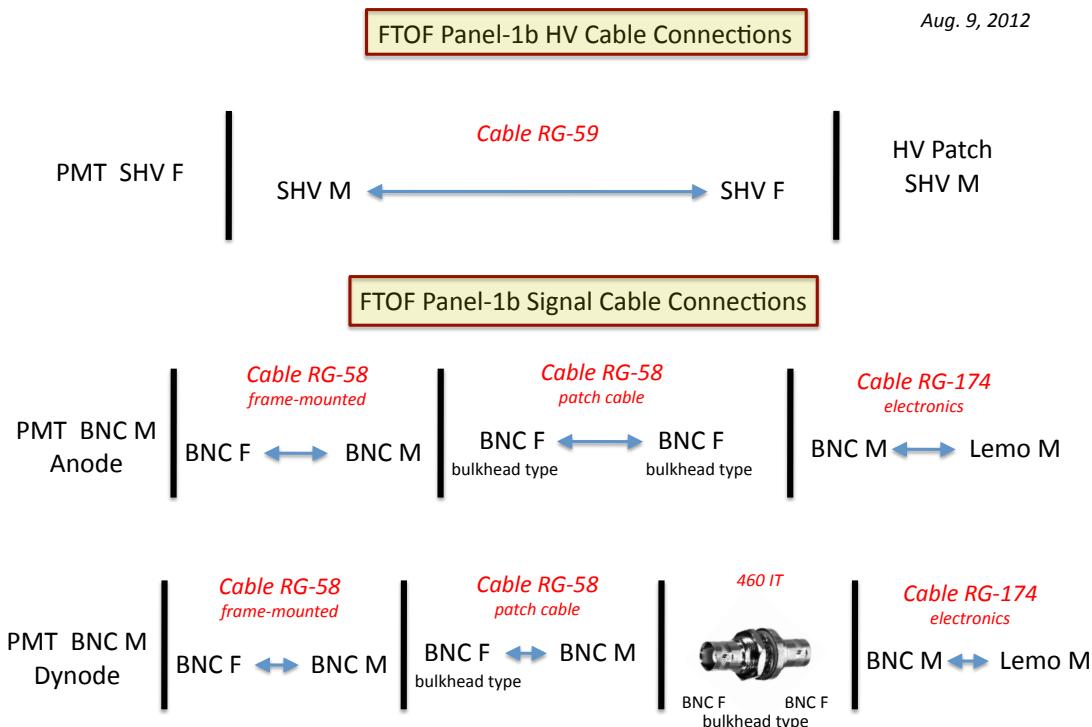


Figure 31: FTOF panel-1b HV and signal cable connections.

4 Documentation

All current documentation for the FTOF system is located on the official FTOF web page [6]. A number of basic subsystem documents can be found there including:

- FTOF System Operations Manual (this document)
 - The source files for the FTOF System Operations Manual are located on the github repository at: *JeffersonLab/clas12-manuals/ftof*
- FTOF Geometry Document
- FTOF Calibration Constants
- FTOF Monte Carlo Simulation Details
- FTOF Reconstruction Document
- FTOF Calibration Algorithms
- FTOF Calibration Tutorial
- Assorted photographs of the detector hardware

If you have any questions related to any of the FTOF system documentation, please contact the FTOF Group Leader.

5 FTOF Authorized Personnel

Beyond turning on/off the FTOF system HV and monitoring the system scalers, all other operations and repairs are only to be carried out by the list of authorized personnel shown in Table 2. The list of authorized personnel for FTOF can only be modified by the FTOF Group Leader.

Name	Telephone	email	Area
Daniel S. Carman	(757)-269-5586	carman@jlab.org	FTOF Group Leader Hardware, Software
Cole Smith	(757)-269-5307	lcsmith@jlab.org	Hardware, <i>ftofmon</i>
Sergey Boyarinov	(757)-269-5795	boyarinov@jlab.org	DAQ
Nathan Baltzell	(757)-269-5902	baltzell@jlab.org	Slow Controls

Table 2: FTOF detector authorized personnel.

References

- [1] Hall B Electronic Logbook: <https://logbooks.jlab.org/book/hblog>
- [2] Hall B BEAST alarm handler:
https://clasweb.jlab.org/wiki/index.php/Slow_Control_Alarms
- [3] Hot Checkout page: <http://accweb.acc.jlab/hco/readiness> (also accessible from the “Shift Documentation” tab on the Run Page wiki [4])
- [4] Hall B current run information page:
<https://www.jlab.org/Hall-B/run-web/>
- [5] https://clasweb.jlab.org/wiki/index.php/TOF_on-call
- [6] FTOF web page: <https://www.jlab.org/Hall-B/ftof>