

# Central Time-of-Flight System Operations Manual

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## **Abstract**

This document provides an overview of the CLAS12 Central Time-of-Flight (CTOF) 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 system and shield compensation coil 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 CTOF system experts regarding the channel mapping to the read-out electronics, the cable connections and routing in Hall B, higher-order high voltage system operations, operations of the Light Monitoring System, and detector servicing. This document also provides references to the available CTOF documentation and a list of personnel authorized to perform CTOF system repairs and to modify system settings.

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# 1 CTOF Overview

The Central Time-of-Flight (CTOF) system is a major component of the CLAS12 Central Detector used to measure the flight time of charged particles emerging from beam-related interactions in the target. The CTOF system spans laboratory angles from 35° to 125° and surrounds the experimental target at a radial distance of 25 cm. The CTOF detector consists of 48 92-cm-long scintillation bars that form a hermetic barrel. The barrel is positioned inside of the 5 T superconducting solenoid magnet. Each counter is read out on its upstream and downstream ends using photomultiplier tubes (PMTs) through long light guides to position the field-sensitive PMTs in reduced field regions. However, even in these positions, the PMTs reside in inhomogeneous fringe fields from the magnet at levels as large as 1 kG. In order for the PMTs to operate properly at their design specifications for gain and timing resolution, the magnetic field about the PMTs needs to be reduced to a level below 1 G. Hence the CTOF PMTs must be operated within specially designed magnetic shields with compensation coils.

The requirements for the CTOF system (shown in Fig. 1) include excellent timing resolution for particle identification and good segmentation to minimize counting rates. The system specifications call for an average time resolution for each counter along its full length of  $\sigma_{TOF}=65$  ps. The system must also be capable of operating in a high-rate environment at the nominal CLAS12 luminosity of  $1 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$ . A summary of the CTOF technical parameters is given in Table 1.

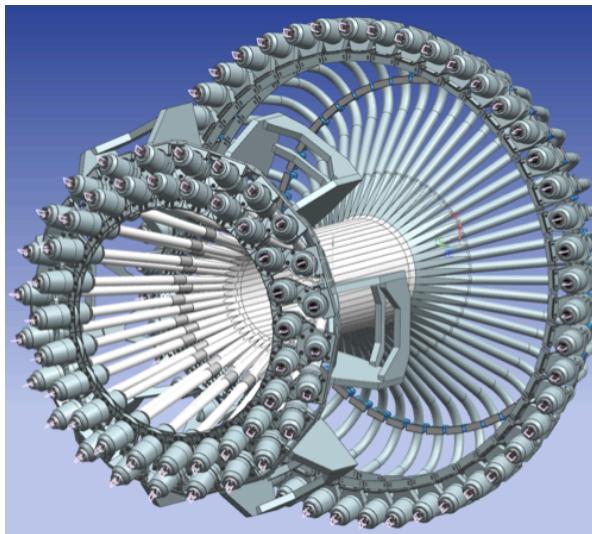


Figure 1: View of the Central Time-of-Flight system for CLAS12 showing the upstream straight light guides, the scintillation bars, and the downstream bent light guides. The PMTs reside within the shield cylinders located at the ends of the light guides.

The CTOF scintillation barrel is composed of 48 wedge-shaped counters of two slightly different designs that alternate in azimuth. A pair of neighboring CTOF counters is shown in Fig. 2. The difference between the two designs is in the pitch angle of the upstream straight light guide and the upstream end of the scintillation bars where they attach to this light guide. The CTOF detector is mounted within the CLAS12 solenoid as shown in Fig. 3.

Parameter	Design Value
Counters	48 BC-408 counters forming a hermetic barrel; double-sided readout
Angular Coverage	$\theta: (35^\circ, 125^\circ)$ , $\phi: (-180^\circ, 180^\circ)$
Counter Dimensions	Trapezoidal cross section $\sim 3 \times 3 \times 92 \text{ cm}^3$
PMTs	Hamamatsu R2083 (H2431-MOD assembly)
Light Guides - Upstream	O.D.=2", 1-m-long, focusing design, straight
Light Guides - Downstream	O.D.=2", 1.6-m-long, focusing design, bent 135°
Magnetic Shields	3-layer cylinder: Co-nectic, Hiperm-48, Steel-1008; compensation coils around inner Co-nectic layer
Design Resolution	65 ps
$\pi/K$ separation	$3.3\sigma$ up to 0.64 GeV
$K/p$ separation	$3.3\sigma$ up to 1.00 GeV
$\pi/p$ separation	$3.3\sigma$ up to 1.25 GeV

Table 1: CTOF technical design parameters.

The beamline lies along the symmetry axis of the CTOF barrel pointing downstream (left to right in Fig. 3). The nominal position of the center of the CTOF scintillation barrel is roughly 7.6 m upstream of the CLAS12 origin. Fig. 4 shows the CTOF naming convention with counter #1 located just above the 9 o'clock position and increasing in number going clockwise around the detector.

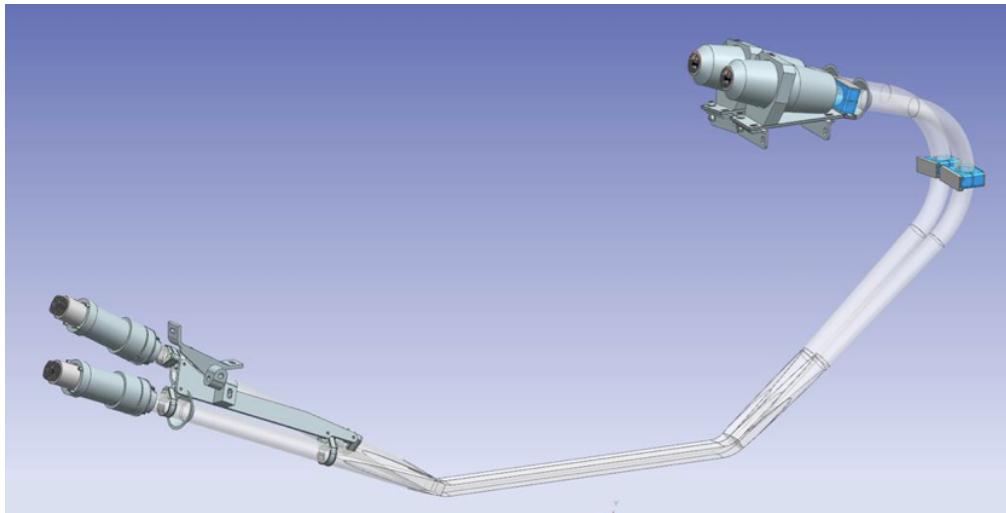


Figure 2: A pair of neighboring CTOF counters with two slightly different designs for the upstream light guide and the upstream end of the scintillation bars.



Figure 3: CTOF mounted within the CLAS12 solenoid in a cut view where the beam axis runs along the CTOF barrel symmetry axis with the beam entering from the left.

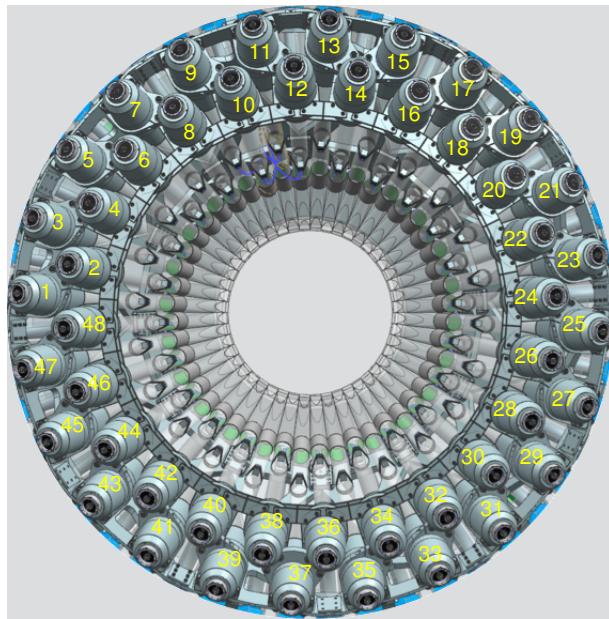


Figure 4: CTOF counter numbering convention seen looking at the upstream end of the detector.

A block diagram of the readout electronics and power connections for one representative counter of the CTOF system is shown in Fig. 5. The PMT anode outputs are connected to one of two UVa 80-20 splitter boxes. The 80% output goes to an Ortec 935 NIM CFD and then to a CAEN 1290A 25 ps LSB VME TDC. The 20% output goes to a JLab 250 MHz VME flash ADC. The high voltage (HV) power supply for the CTOF counters is a CAEN SY1527 mainframe outfitted with four negative polarity 24-channel A1535N modules that is shared with the HTCC system and several beamline devices. The CTOF HV modules occupy slots #0 to #3 in the mainframe. The LV power supplies for the CTOF magnetic shield compensation coils are Wiener MPV8016I modules in an MPOD-mini crate. Fig. 6 shows the locations of the CTOF electronics and power supplies in the electronics racks on the beam left side of Space Frame Level 1.

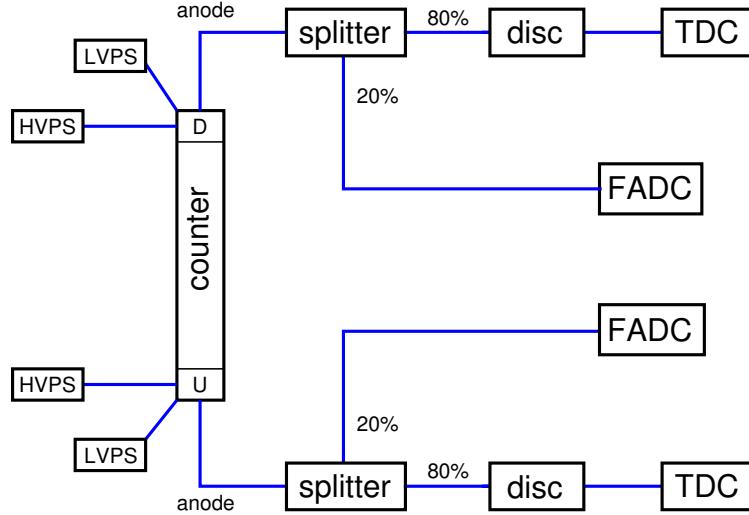


Figure 5: Block diagram for the CTOF system showing the layout of the readout electronics and power connections for a single counter.

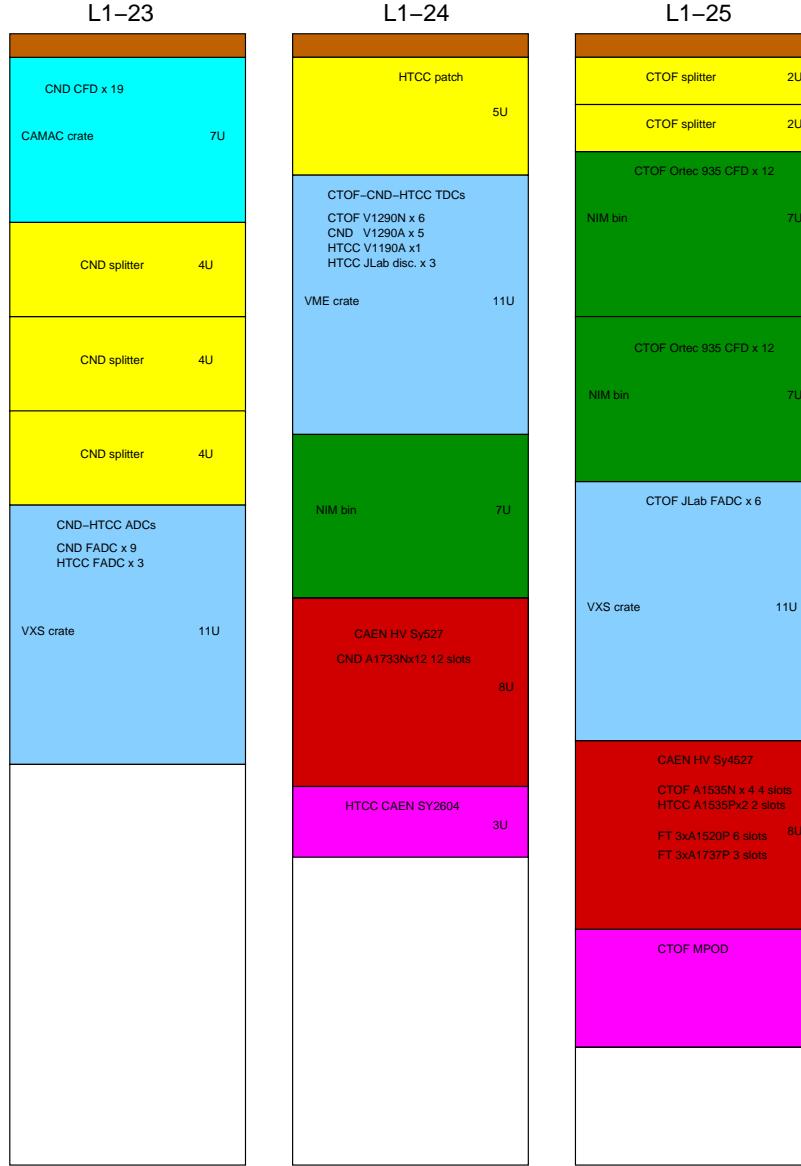


Figure 6: Layout of the electronics for the CTOF, CND, and HTCC NIM and VME electronics on the beam left side of Level 1 of the Space Frame in Hall B. The positions of the HV and LV mainframes are also shown.

## 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 CTOF system:

1. Updating the Hall B electronic logbook with records of problems or system conditions (see Section 2.1.1).
2. Contacting CTOF system on-call personnel for any problems that are discovered (see Section 2.1.2).
3. Responding to CTOF system alarms from the Hall B alarm handler (see Section 2.1.3).
4. Turning on or off the high voltage (HV) for the CTOF system using the HV control interface (see Section 2.2).
5. Monitoring the hit occupancy scalers for the system (see Section 2.4).

#### 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 CTOF 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 CTOF 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 CTOF 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 CTOF system. At that point they should contact the assigned CTOF on-call expert either to provide advice on how to proceed or to address the problem. **The CTOF on-call phone number is (757)-344-7204.**

This document is divided into sections for shift workers and for CTOF system experts. However, only CTOF system experts (as listed in Section 5) are authorized to make changes to the CTOF parameter settings, to work on the hardware or electronics, or to modify the DAQ system software. 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].

For the CTOF system there are two elements that are monitored by the alarm handler. The first 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 CTOF 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. The second CTOF element monitored by the alarm handler is the power status of the LV power supply for the magnetic shield compensation coils. An overcurrent or overtemperature condition at any monitored point in the system will cause the LV power supply to trip off. These conditions are not expected to occur during normal operation of the compensation coil system. If such an alarm condition occurs, the CTOF on-call expert should be contacted to investigate and restore the system.

## 2.2 High Voltage Controls

The CTOF 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*. Fig. 7(left) shows the control panel that is launched.

To bring up the CTOF HV controls, click on the “CTOF” button on the subsystem list. This pops up a sub-menu of all Slow Controls subprograms for the CTOF system (see Fig. 7(right)). Clicking the mouse on the “CTOF HV” option brings up the HV control interface for the CTOF system as shown in Fig. 8(left). This interface allows for HV operations at two functionality levels:

- All channels in the full CTOF system
- A single PMT in the CTOF system

The HV Control Interface screen (see Fig. 8) 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

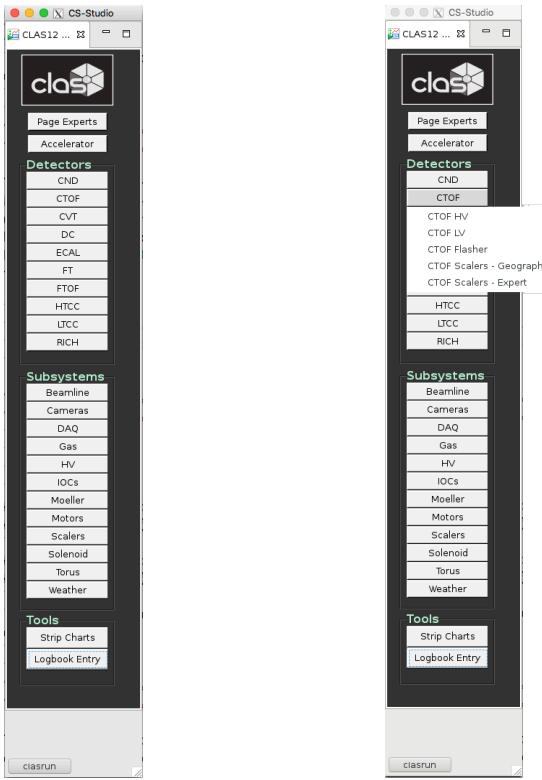


Figure 7: The CS-Studio interface used for the Slow Controls of the CLAS12 detectors and subsystems. (Left) General CLAS12 interface. (Right) Options for the CTOF system.

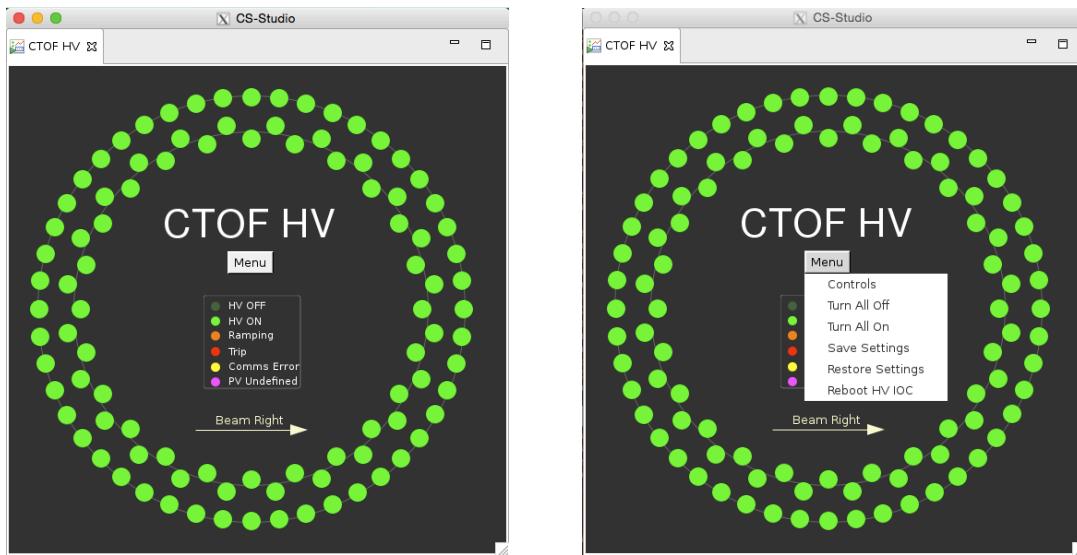


Figure 8: CTOF HV display and control interface. The right figure shows the “Menu” options available.

- HV trip - red
- 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 “Menu” button in the middle of the display. This pops up a sub-menu with the relevant options “Turn All Off” or “Turn All On” (see Fig. 8(right)).
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. 9. Clicking on the button in the “Pw” (power) column toggles the channel HV on and off.



Figure 9: CTOF HV display for single channel parameters.

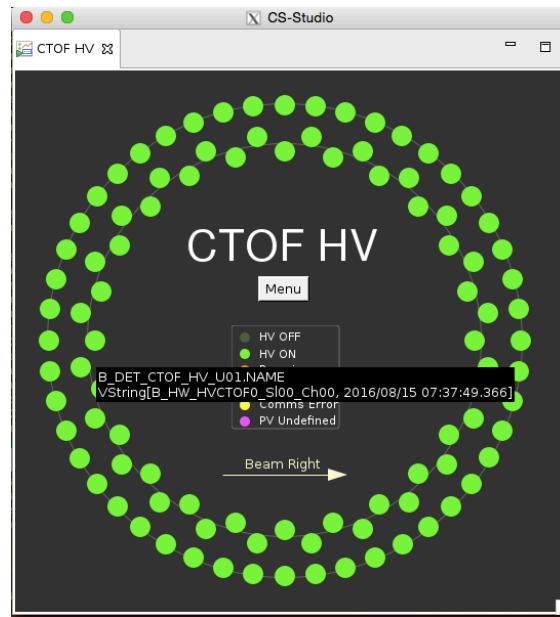


Figure 10: CTOF HV display showing the channel information when the mouse is paused over a PMT circle.

Note that hovering the mouse pointer on a circle representing a PMT brings up information on that channel as shown in Fig. 10.

If the “Controls” option shown in Fig. 8(right) is selected, a “novice” window is opened as shown in Fig. 11. This window shows the monitored channel voltage and current ( $V_{mon}$  (V) and  $I_{mon}$  ( $\mu$ A)), the channel status (OFF, ON), and the set channel voltage and current ( $V_{set}$  (V) and  $I_{set}$  ( $\mu$ A)). If desired, shift workers can toggle the HV settings for single channels on or off through this interface.

The screenshot shows a software window titled "CTOF HV Controls" within "CS-Studio". The window has a tab bar with "Expert" and "Novice" tabs, and the "Novice" tab is currently selected. Below the tabs is a table with 30 rows, each representing a channel. The columns are labeled "#", "Description", "Pw", "Vmmon", "Imon", "Status", "Vset (V)", and "Iset (μA)". The "Status" column contains green "ON" buttons. The "Vmmon" and "Imon" columns show numerical values for each channel. The "Vset" and "Iset" columns also show numerical values, likely representing the target settings for each channel.

#	Description	Pw	Vmmon	Imon	Status	Vset (V)	Iset (μA)
0	CTOF_HV_U01	ON	2112.00	370.50	ON	2113.000	500.0
1	CTOF_HV_U02	ON	2135.50	375.00	ON	2137.000	500.0
2	CTOF_HV_U03	ON	2165.00	382.50	ON	2166.000	500.0
3	CTOF_HV_U04	ON	2163.50	379.50	ON	2165.000	500.0
4	CTOF_HV_U05	ON	1955.50	343.00	ON	1956.000	500.0
5	CTOF_HV_U06	ON	2070.50	365.00	ON	2072.000	500.0
6	CTOF_HV_U07	ON	2148.50	377.50	ON	2150.000	500.0
7	CTOF_HV_U08	ON	2142.00	376.50	ON	2143.000	500.0
8	CTOF_HV_D01	ON	2077.00	365.00	ON	2078.000	500.0
9	CTOF_HV_D02	ON	2323.00	406.50	ON	2324.000	500.0
10	CTOF_HV_D03	ON	2160.50	378.00	ON	2161.000	500.0
11	CTOF_HV_D04	ON	2093.00	357.00	ON	2094.000	500.0
12	CTOF_HV_D05	ON	1888.00	332.00	ON	1889.000	500.0
13	CTOF_HV_D06	ON	2270.50	398.50	ON	2267.000	500.0
14	CTOF_HV_D07	ON	2305.50	405.50	ON	2306.000	500.0
15	CTOF_HV_D08	ON	2129.00	374.00	ON	2130.000	500.0
16	CTOF_HV_U09	ON	1992.50	349.50	ON	1993.000	500.0
17	CTOF_HV_U10	ON	2078.00	365.50	ON	2078.000	500.0
18	CTOF_HV_U11	ON	2141.50	375.00	ON	2142.000	500.0
19	CTOF_HV_U12	ON	2070.50	362.50	ON	2071.000	500.0
20	CTOF_HV_U13	ON	2188.00	382.50	ON	2188.000	500.0
21	CTOF_HV_U14	ON	2191.50	385.00	ON	2191.000	500.0
22	CTOF_HV_U15	ON	2188.00	384.00	ON	2188.000	500.0
23	CTOF_HV_U16	ON	2065.00	361.00	ON	2065.000	500.0
24	CTOF_HV_D09	ON	2169.00	381.00	ON	2170.000	500.0
25	CTOF_HV_D10	ON	2187.50	385.00	ON	2187.000	500.0
26	CTOF_HV_D11	ON	2125.50	375.00	ON	2125.000	500.0
27	CTOF_HV_D12	ON	1974.00	348.50	ON	1974.000	500.0
28	CTOF_HV_D13	ON	2064.50	364.00	ON	2063.000	500.0
29	CTOF_HV_D14	ON	2111.50	373.50	ON	2111.000	500.0
30	CTOF_HV_D15	ON	2090.50	368.50	ON	2091.000	500.0

Figure 11: CTOF “novice” channel controls screen.

In the upper left corner of this HV Controls window is a button marked “expert” that brings up the window shown in Fig. 12. This window 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 authorized CTOF personnel listed in Section 5.**

#	Description	Pw	Vmon	Imon	Status	Vset (V)	Iset (uA)	Vmax (V)	Up (V/s)	Down (V/s)
0	CTOF_HV_U01	ON	2112.000	370.50	ON	2113.000	2113.000	500	500	3000 3000 50 50 100 100
1	CTOF_HV_U02	ON	2195.500	375.00	ON	2137.000	2137.000	500	500	3000 3000 50 50 100 100
2	CTOF_HV_U03	ON	2165.000	382.50	ON	2166.000	2166.000	500	500	3000 3000 50 50 100 100
3	CTOF_HV_U04	ON	2163.500	380.00	ON	2165.000	2165.000	500	500	3000 3000 50 50 100 100
4	CTOF_HV_U05	ON	1955.500	343.00	ON	1956.000	1956.000	500	500	3000 3000 50 50 100 100
5	CTOF_HV_U06	ON	2070.500	365.00	ON	2072.000	2072.000	500	500	3000 3000 50 50 100 100
6	CTOF_HV_U07	ON	2148.500	377.50	ON	2150.000	2150.000	500	500	3000 3000 50 50 100 100
7	CTOF_HV_U08	ON	2142.000	376.50	ON	2143.000	2143.000	500	500	3000 3000 50 50 100 100
8	CTOF_HV_D01	ON	2077.000	365.00	ON	2078.000	2078.000	500	500	3000 3000 50 50 100 100
9	CTOF_HV_D02	ON	2323.000	406.50	ON	2324.000	2324.000	500	500	3000 3000 50 50 100 100
10	CTOF_HV_D03	ON	2160.500	378.00	ON	2161.000	2161.000	500	500	3000 3000 50 50 100 100
11	CTOF_HV_D04	ON	2033.000	357.00	ON	2034.000	2034.000	500	500	3000 3000 50 50 100 100
12	CTOF_HV_D05	ON	1888.000	332.00	ON	1889.000	1889.000	500	500	3000 3000 50 50 100 100
13	CTOF_HV_D06	ON	2270.500	398.50	ON	2267.000	2267.000	500	500	3000 3000 50 50 100 100
14	CTOF_HV_D07	ON	2305.500	405.50	ON	2306.000	2306.000	500	500	3000 3000 50 50 100 100
15	CTOF_HV_D08	ON	2129.000	374.00	ON	2130.000	2130.000	500	500	3000 3000 50 50 100 100
16	CTOF_HV_D09	ON	1992.500	349.00	ON	1993.000	1993.000	500	500	3000 3000 50 50 100 100
17	CTOF_HV_D10	ON	2078.000	365.50	ON	2078.000	2078.000	500	500	3000 3000 50 50 100 100
18	CTOF_HV_D11	ON	2141.500	375.00	ON	2142.000	2142.000	500	500	3000 3000 50 50 100 100
19	CTOF_HV_D12	ON	2070.500	362.50	ON	2071.000	2071.000	500	500	3000 3000 50 50 100 100
20	CTOF_HV_D13	ON	2188.000	382.50	ON	2188.000	2188.000	500	500	3000 3000 50 50 100 100
21	CTOF_HV_D14	ON	2191.500	385.00	ON	2191.000	2191.000	500	500	3000 3000 50 50 100 100
22	CTOF_HV_D15	ON	2188.000	384.00	ON	2188.000	2188.000	500	500	3000 3000 50 50 100 100
23	CTOF_HV_D16	ON	2065.000	361.00	ON	2065.000	2065.000	500	500	3000 3000 50 50 100 100
24	CTOF_HV_D09	ON	2169.000	381.00	ON	2170.000	2170.000	500	500	3000 3000 50 50 100 100
25	CTOF_HV_D10	ON	2187.500	385.00	ON	2187.000	2187.000	500	500	3000 3000 50 50 100 100
26	CTOF_HV_D11	ON	2125.500	375.00	ON	2125.000	2125.000	500	500	3000 3000 50 50 100 100
27	CTOF_HV_D12	ON	1974.000	348.50	ON	1974.000	1974.000	500	500	3000 3000 50 50 100 100
28	CTOF_HV_D13	ON	2064.500	364.00	ON	2063.000	2063.000	500	500	3000 3000 50 50 100 100
29	CTOF_HV_D14	ON	2111.500	373.50	ON	2111.000	2111.000	500	500	3000 3000 50 50 100 100
30	CTOF_HV_D15	ON	2090.500	368.50	ON	2091.000	2091.000	500	500	3000 3000 50 50 100 100

Figure 12: CTOF “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. 8, which typically appears for all CTOF PMTs, the usual cause is an issue of communication between the IOC computer and the HV mainframe. To reboot the IOC, click on the “IOCs” button on the Slow Controls panel within the “Subsystems” portion of the interface (see Fig. 7). Fig. 13 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. 14. Clicking on the “High Voltage” tab along the top of screen brings up the screen for the IOCs that control the HV mainframes as shown in Fig. 15. Click on the “Reboot” button for the HV supply HVCTOF0 (under the “Soft Reboot” column). 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 CTOF channel control screen shown in Fig. 8(right). Click on the “Reboot HV IOC” button and answer “Yes” on the dialog box that comes up. If rebooting the IOC does not solve the communication problems, contact the Slow Controls system expert.

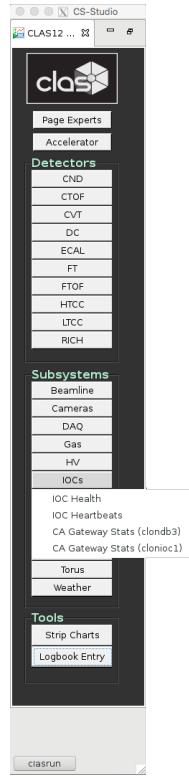


Figure 13: Sub-menu on the primary Slow Controls interface to reboot the IOCs.

IOC Health													
General	Solenoid & Torus	High Voltage	Low Voltage	Detectors	DAQ	VME							
IOC Name	Hostname	Up Time	Heartbeat	Expert	Soft Reboot	Last Reboot	Console	Hard Reboot	Status	Message	Autosave	Recently	Expert
loccas	clonioc1.lab.org	24 days, 18:45:12	2141112	[ ]	[ ] Reboot	06/22/2018 14:25:08	[ ]	[ ] Reboot	Warning	2 values not saved	Wrote 'info_settings.sav'	[ ]	
locaggw	clonioc1.lab.org	24 days, 18:45:12	2141112	[ ]	[ ] Reboot	06/22/2018 14:25:08	[ ]	[ ] Reboot	Ok	Ok	Wrote 'info_positions.sav'	[ ]	
locmc	clonioc1.lab.org	24 days, 18:45:11	2141111	[ ]	[ ] Reboot	06/22/2018 14:25:09	[ ]	[ ] Reboot	Ok	Ok	Wrote 'info_positions.sav'	[ ]	
iocmonitor	clonioc2.lab.org	56 days, 15:55:12	4895712	[ ]	[ ] Reboot	05/21/2018 17:15:08	[ ]	[ ] Reboot	Ok	Ok	Wrote 'info_positions.sav'	[ ]	
iocweather	clonioc1.lab.org	24 days, 18:45:09	2141109	[ ]	[ ] Reboot	06/22/2018 14:25:10	[ ]	[ ] Reboot	Ok	Ok	Wrote 'info_positions.sav'	[ ]	
ioctgasSystem	clonioc1.lab.org	24 days, 18:45:13	2141113	[ ]	[ ] Reboot	06/22/2018 14:25:07	[ ]	[ ] Reboot	Ok	Ok	Wrote 'info_positions.sav'	[ ]	
ioctmollerPS	clonioc1.lab.org	24 days, 18:45:12	2141112	[ ]	[ ] Reboot	06/22/2018 14:25:08	[ ]	[ ] Reboot	Ok	ok	Wrote 'info_positions.sav'	[ ]	
ioctmollerTarget	clonioc1.lab.org	24 days, 18:45:12	2141112	[ ]	[ ] Reboot	06/22/2018 14:25:08	[ ]	[ ] Reboot	Ok	ok	Wrote 'info_positions.sav'	[ ]	
ioscadaytgt	clonioc1.lab.org	24 days, 18:45:09	2141109	[ ]	[ ] Reboot	06/22/2018 14:25:11	[ ]	[ ] Reboot	Ok	ok	Wrote 'info_positions.sav'	[ ]	

Figure 14: IOC health screen for access to all Hall B IOCs.

CS-Studio

The screenshot shows a window titled "IOC Health" with a tab bar at the top containing "General", "Solenoid & Torus", "High Voltage", "Low Voltage", "Detectors", "DAQ", and "VME". The "High Voltage" tab is selected. Below the tabs is a table with the following columns: IOC Name, Hostname, Up Time, Heartbeat, Expert, Soft Reboot, Last Reboot, Console Reboot, Hard Reboot, Status, Message, Autosave, Recently, and Expert.

**ECAL and LTC**

ioccaenhv_HVECAL1	clonioc2.jlab.org	38 days, 18:14:51	3348891	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	06/08/2018 14:57:11	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	ok	ok	Wrote 'info_positions.sav2'	<input checked="" type="checkbox"/>
ioccaenhv_HVECAL2	clonioc2.jlab.org	39 days, 19:01:38	3438098	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	06/07/2018 14:10:24	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	ok	ok	Wrote 'info_positions.sav2'	<input checked="" type="checkbox"/>
ioccaenhv_HVECAL3	clonioc2.jlab.org	39 days, 19:01:35	3438095	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	06/07/2018 14:10:27	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	ok	ok	Wrote 'info_positions.sav1'	<input checked="" type="checkbox"/>
ioccaenhv_HVECAL4	clonioc2.jlab.org	39 days, 19:01:33	3438093	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	06/07/2018 14:10:29	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	ok	ok	Wrote 'info_settings.sav2'	<input checked="" type="checkbox"/>
ioccaenhv_HVECAL5	clonioc2.jlab.org	39 days, 19:01:29	3438089	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	06/07/2018 14:10:33	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	ok	ok	Wrote 'info_positions.sav1'	<input checked="" type="checkbox"/>
ioccaenhv_HVECAL6	clonioc2.jlab.org	39 days, 19:01:27	3438087	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	06/07/2018 14:10:35	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	ok	ok	Wrote 'info_positions.sav2'	<input checked="" type="checkbox"/>

**FTOF and PCAL**

ioccaenhv_HVFTOF1	clonioc2.jlab.org	39 days, 19:01:25	3438085	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	06/07/2018 14:10:37	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	ok	ok	Wrote 'info_positions.sav1'	<input checked="" type="checkbox"/>
ioccaenhv_HVFTOF2	clonioc2.jlab.org	39 days, 19:01:23	3438083	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	06/07/2018 14:10:39	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	ok	ok	Wrote 'info_positions.sav2'	<input checked="" type="checkbox"/>
ioccaenhv_HVFTOF3	clonioc2.jlab.org	39 days, 19:01:19	3438079	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	06/07/2018 14:10:45	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	ok	ok	Wrote 'info_positions.sav1'	<input checked="" type="checkbox"/>
ioccaenhv_HVFTOF4	clonioc2.jlab.org	39 days, 19:01:17	3438077	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	06/07/2018 14:10:48	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	ok	ok	Wrote 'info_settings.sav0'	<input checked="" type="checkbox"/>
ioccaenhv_HVFTOF5	clonioc2.jlab.org	39 days, 19:01:14	3438074	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	06/07/2018 14:10:48	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	ok	ok	Wrote 'info_positions.sav2'	<input checked="" type="checkbox"/>
ioccaenhv_HVFTOF6	clonioc2.jlab.org	39 days, 19:01:13	3438073	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	06/07/2018 14:10:49	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	ok	ok	Wrote 'info_positions.sav0'	<input checked="" type="checkbox"/>

**Misc**

ioccaenhv_HVBLINE	clonioc2.jlab.org	24 days, 18:52:35	2141554	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	06/22/2018 14:19:28	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	ok	ok	Wrote 'info_positions.sav1'	<input checked="" type="checkbox"/>
ioccaenhv_HVCTOF0	clonioc2.jlab.org	4 days, 19:17:24	415043	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	07/12/2018 13:54:39	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	ok	ok	Wrote 'info_positions.sav2'	<input checked="" type="checkbox"/>
ioccaenhv_HVMY1	clonioc2.jlab.org	24 days, 18:52:34	2141554	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	06/22/2018 14:19:28	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	ok	ok	Wrote 'info_positions.sav2'	<input checked="" type="checkbox"/>
ioccaenhv_HVTAG	clonioc2.jlab.org	10 days, 18:03:34	929014	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	07/06/2018 15:08:28	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	ok	ok	Wrote 'info_positions.sav1'	<input checked="" type="checkbox"/>
ioccaenhv_HVRICH	clonioc2.jlab.org	46 days, 13:14:41	4022080	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	05/31/2018 19:57:22	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	ok	ok	Wrote 'info_positions.sav2'	<input checked="" type="checkbox"/>
ioccaenhv_HVRICH1	clonioc2.jlab.org	27 days, 18:16:43	2398603	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	06/19/2018 14:55:19	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	ok	ok	Wrote 'info_settings.sav2'	<input checked="" type="checkbox"/>

**CND and DC (SY527)**

ioccaenhv_HVDCA	dc13	5 days, 19:56:04	503750	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	07/11/2018 13:15:58	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	ok	ok	Wrote 'info_positions.sav2'	<input checked="" type="checkbox"/>
ioccaenhv_HVDCB	dc33	5 days, 19:56:49	503803	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	07/11/2018 13:15:12	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	Warning	1683 values not saved	Wrote 'info_settings.sav1'	<input checked="" type="checkbox"/>
ioccaenhv_HVCND	adccnd1	5 days, 19:56:07	503766	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	07/11/2018 13:15:55	<input checked="" type="checkbox"/> <input type="checkbox"/> Reboot	ok	ok	Wrote 'info_positions.sav0'	<input checked="" type="checkbox"/>

Figure 15: IOC health screen where individual IOCs that control the HV mainframes can be rebooted.

## 2.3 Low Voltage Controls for Shield Compensation Coils

The PMT active magnetic shield layer consists of two independent coils, the first  $z_1$  of 90 turns placed about the middle of the PMT accelerating structure and the second  $z_2$  of 60 turns placed about the PMT photocathode (see Fig. 16). Note that the coils are not typically energized during CTOF operations even with the solenoid at full field. If it is necessary to energize them, this will noted on the run web page [3].

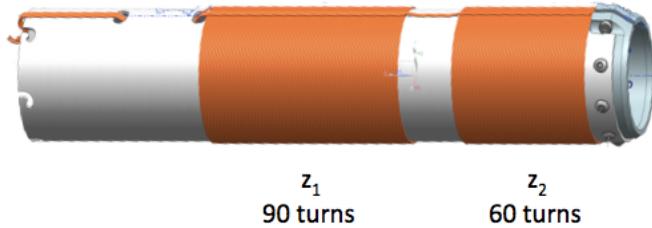


Figure 16: Model layout of the compensation coils on the shield mandrel showing the coil  $z_1$  with 90 turns and coils  $z_2$  with 60 turns.  $z_1$  spans the middle to back part of the PMT dynode structure and  $z_2$  spans the region about the PMT photocathode.

For the CTOF shields the compensation coils  $z_1$  and  $z_2$  are independently controllable. The LV power supply for the coils is a Wiener MPOD mini-crate outfitted with two MPV8016I modules. Each module has eight channels that can individually provide up to 50 W per channel with a maximum current of 5 A. The power supply is connected to the coils via 52 - 68 ft long cables. Each supply channel feeds 12 coils. The system has been tuned for six different values of currents in  $z_1$  and  $z_2$  corresponding to the upstream low-pitch angle shields, the upstream high-pitch angle shields, and the downstream shields. Fig. 17 shows the power circuit layout.

Although the Wiener MPOD system can provide up to 5 A per channel, the coil currents have never had to go above the level of 0.5 - 1 A. In this current regime the coil system remains at room temperature. During operation of the coil power supply in Hall B, a temperature interlock circuit protects the coils from overheating. An over-temperature condition shuts down the Wiener LV supply whose status is monitored by the Hall B alarm handler.

The Wiener MPOD power supply control interface is brought up through the CTOF control panel shown in Fig. 7 by clicking on the option “CTOF LV”. The screen that comes up is shown in Fig. 18. Note that a communication problem between the controls and the power supply would be indicated by magenta colors on the associated channels. To reboot the IOC, follow the instructions in Section 2.2.1. If problems with communications remain after rebooting the IOC, contact the Slow Controls expert.

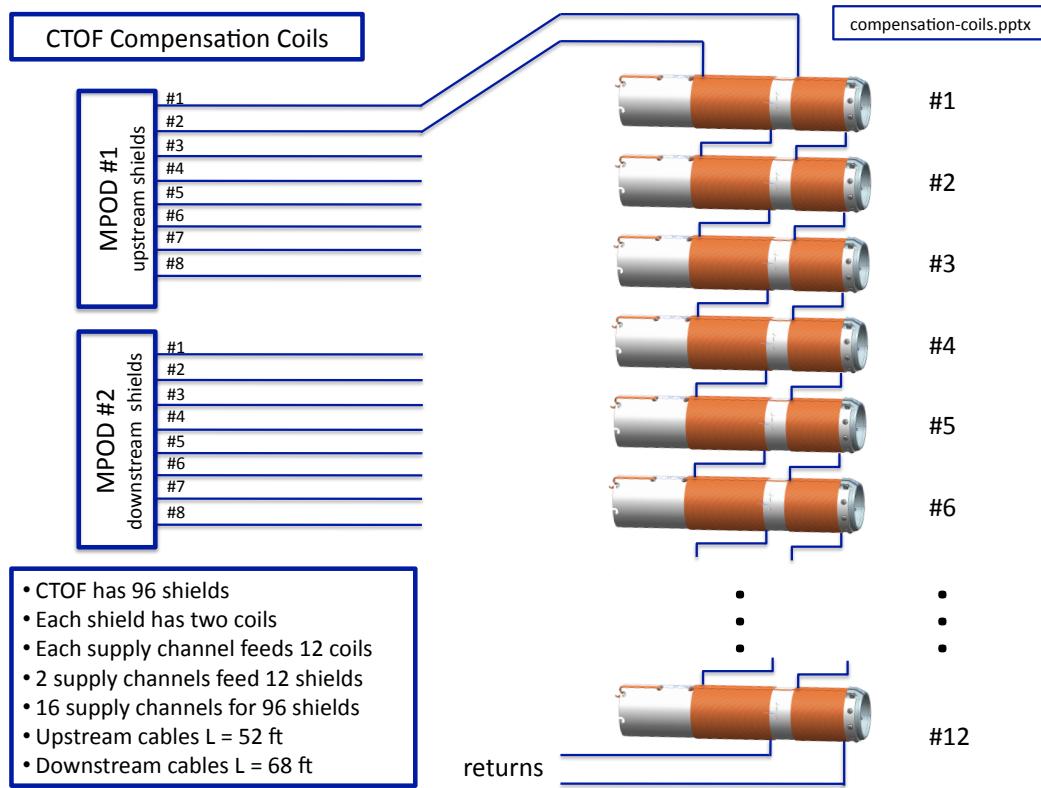


Figure 17: Layout of the power circuit for the CTOF magnetic shield compensation coils.

CTOF Low Voltage															
#	Description	Pw	Vmon	Imon	Status	Vset (V)		Iset (A)		Vmax (V)		Up (V/s)	Down (V/s)	CFG	Itrip (A)
1	B_DET_CTOF_LV_01	ON	0.198 V	1.000 A	CC	2.000	2.000	1.0	1.0	16.0	16.0	100	100	100	5.1
2	B_DET_CTOF_LV_02	ON	0.271 V	0.998 A	CC	2.000	2.000	1.0	1.0	16.0	16.0	100	100	100	5.1
3	B_DET_CTOF_LV_03	ON	0.220 V	1.001 A	CC	2.000	2.000	1.0	1.0	16.0	16.0	100	100	100	5.1
4	B_DET_CTOF_LV_04	ON	0.183 V	1.001 A	CC	2.000	2.000	1.0	1.0	16.0	16.0	100	100	100	5.1
5	B_DET_CTOF_LV_05	ON	0.243 V	1.002 A	CC	2.000	2.000	1.0	1.0	16.0	16.0	100	100	100	5.1
6	B_DET_CTOF_LV_06	ON	0.225 V	0.999 A	CC	2.000	2.000	1.0	1.0	16.0	16.0	100	100	100	5.1
7	B_DET_CTOF_LV_07	ON	0.245 V	1.003 A	CC	2.000	2.000	1.0	1.0	16.0	16.0	100	100	100	5.1
8	B_DET_CTOF_LV_08	ON	0.245 V	1.001 A	CC	2.000	2.000	1.0	1.0	16.0	16.0	100	100	100	5.1
9	B_DET_CTOF_LV_09	ON	0.238 V	1.000 A	CC	2.000	2.000	1.0	1.0	16.0	16.0	100	100	100	5.0
10	B_DET_CTOF_LV_10	ON	0.283 V	1.000 A	CC	2.000	2.000	1.0	1.0	16.0	16.0	100	100	100	5.0
11	B_DET_CTOF_LV_11	ON	0.250 V	1.002 A	CC	2.000	2.000	1.0	1.0	16.0	16.0	100	100	100	5.0
12	B_DET_CTOF_LV_12	ON	0.251 V	1.000 A	CC	2.000	2.000	1.0	1.0	16.0	16.0	100	100	100	5.0
13	B_DET_CTOF_LV_13	ON	0.215 V	1.001 A	CC	2.000	2.000	1.0	1.0	16.0	16.0	100	100	100	5.0
14	B_DET_CTOF_LV_14	ON	0.208 V	1.001 A	CC	2.000	2.000	1.0	1.0	16.0	16.0	100	100	100	5.0
15	B_DET_CTOF_LV_15	ON	0.211 V	0.999 A	CC	2.000	2.000	1.0	1.0	16.0	16.0	100	100	100	5.1
16	B_DET_CTOF_LV_16	ON	0.209 V	0.999 A	CC	2.000	2.000	1.0	1.0	16.0	16.0	100	100	100	5.0

Figure 18: Low voltage system control interface model for the CTOF compensation coils.

## 2.4 Detector Monitoring

A number of monitoring tools to study the performance of the CTOF 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 CTOF 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. 19(left).

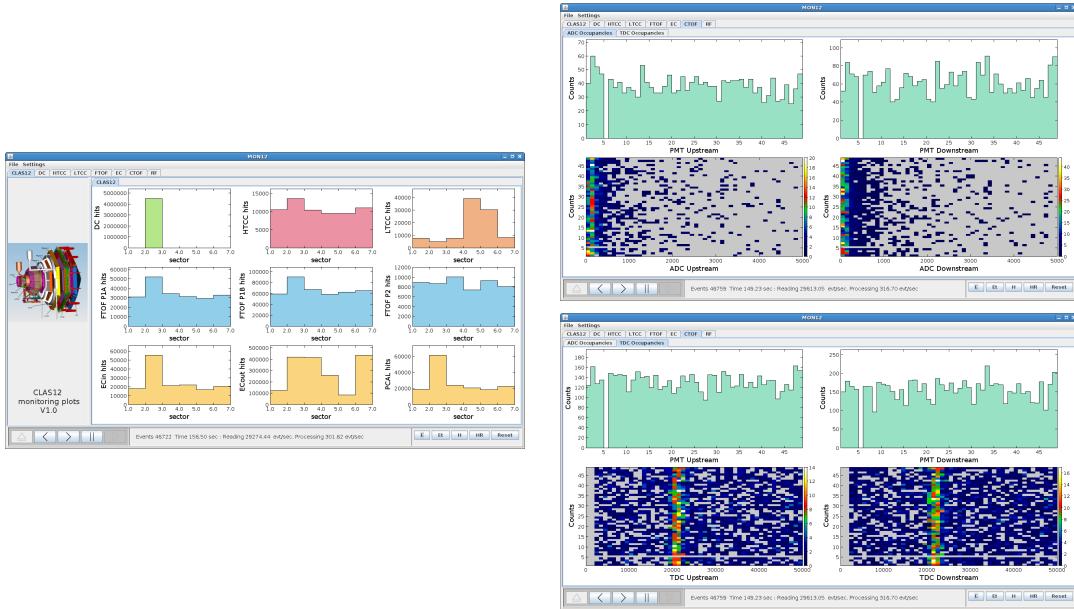


Figure 19: (Left) The main *mon12* display screen showing counts across the different CLAS12 subsystems and sectors. (Right) The CTOF ADC and TDC scaler screens within *mon12*.

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 (either the ET or HIPO rings or EVIO or HIPO data files in the lower right of the screen) and then clicking on the “play” button (the rightward triangle in the lower left of the screen). The CTOF scalers are available for both the FADC and TDC channels by clicking on the CTOF tab and selecting either sub-tab “ADC Occupancies” or “TDC Occupancies” as shown in Fig. 19(right).

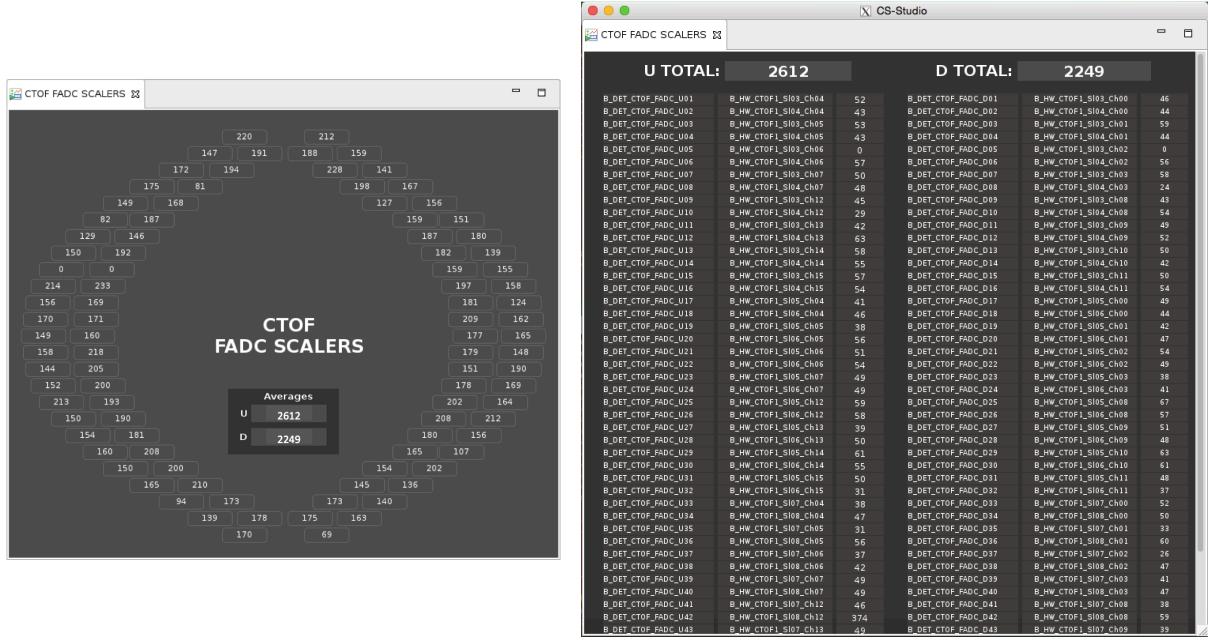


Figure 20: Scaler displays for the CTOF counters from the Slow Controls system showing the two different options, “CTOF Scalers - Geographic” (left) and “CTOF Scalers - Expert” (right). Both displays show the total rate for the upstream and downstream PMTs.

The second manner in which to view the CTOF system scalers is through the CLAS12 Slow Controls system. Shown in the options for the CTOF system in Fig. 7(right) is an option to view the CTOF scalers from the FADCs. Note that there are presently two different options for displaying the same information, “CTOF Scalers - Geographic” and “CTOF Scalers - Expert”. Selecting these options brings up the screens as shown in Fig. 20.

The final manner in which to monitor the performance of the CTOF hardware is through the expert monitoring suite *ctofmon*. Details on this suite are provided in Section 3.1.5, however this suite is mainly intended for CTOF system experts.

## 3 Information for Subsystem Experts

### 3.1 Subsystem Expert Responsibilities

The CTOF subsystem experts have several key responsibilities:

1. Complete hot checkout sign-off before the start of each run period (see Section 3.1.1).
2. Respond to calls on the on-call phone to resolve issues with the CTOF system during data taking (see Section 3.1.2).
3. Take periodic HV gain calibration runs and adjust the system HV settings (see Section 3.1.3).
4. Take periodic LMS performance runs (see Section 3.1.4).
5. Monitor the system performance with the *ctofmon* expert monitoring suite (see Section 3.1.5).
6. Make repairs to the hardware during maintenance periods (see Section 3.2).

#### 3.1.1 Hot Checkout

Prior to the start of each beam running period, each subsystem Group Leader is responsible to review the components of their systems to be sure that they are fully operational. This review is referred to as “hot checkout”. The hot checkout is an online checklist [4] for each subsystem that includes a sign-off for all hardware elements of the system (e.g. HV, LV, detectors, gas, pulser). For the CTOF system, the hot checkout includes verification that all detectors are operational, that the Slow Controls system for the HV and LMS is functioning, and that the DAQ system can fully communicate with the readout electronics. It also includes checkout that the LV power supply system and the shield temperature readout are operational.

Fig. 21 shows a screenshot of the hot checkout interface. Under the heading “Hall B CLAS12 Detector”, all entries for CTOF (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 HV gain calibration is completed (see Section 3.1.3) and an LMS performance scan is taken (see Section 3.1.4). 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.

#### 3.1.2 On-Call Responsibilities

Each subsystem 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 [3]. Any problems that cannot be quickly solved by the shift workers, where quickly amounts to 10 to 15 minutes, should result in a call to the relevant expert cell phone. **The CTOF on-call phone number is (757)-344-7204.**

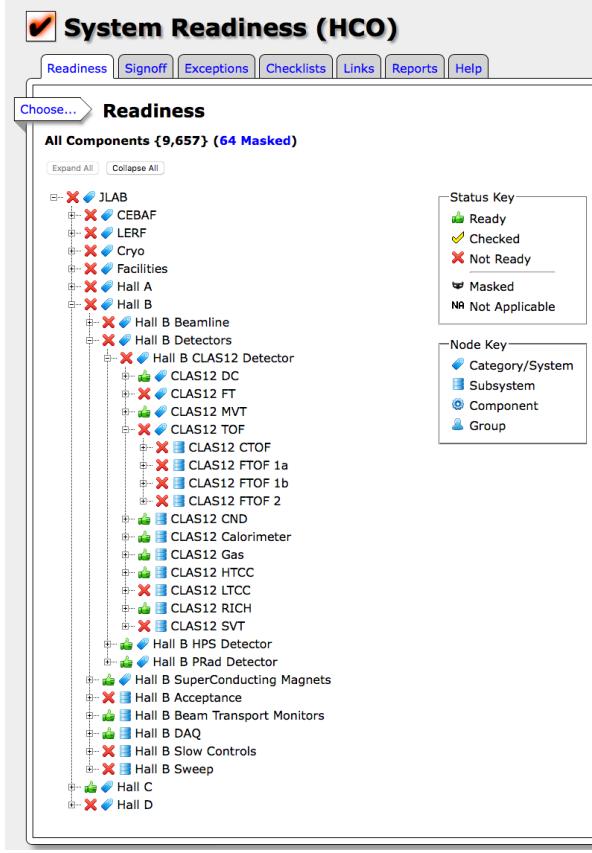


Figure 21: Screenshot of the Hall B hot checkout screen. The CTOF system appears under the “Hall B CLAS12 Detector” and “CLAS TOF” headings. All entries for CTOF have to be verified as functional and all items listed as “Not Ready” must be changed over to “Ready”.

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 CTOF 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. Access to PMTs for service must be done only when the solenoid is off.

Note: It is the responsibility of the CTOF on-call expert to review all issues that they cannot resolve with the CTOF subsystem Group Leader as soon as is reasonable.

### 3.1.3 HV Gain Calibrations

The HV gain calibrations for the CTOF system are typically completed before the start of each run period, as well as several times during the run period when there is opportunity.

The HV gain calibration procedure employs a special cosmic ray trigger defined by the CTOF system. The ADC spectra for each counter are fit to determine the minimum ionizing particle peak position. The end result of the gain calibration amounts to adjusting the system HV settings to position the ADC peaks at their assigned locations corresponding to a specific PMT gain.

The calibration suite for the CTOF system is used to calibrate the PMT gains and the output is a table of PMT HV settings in the appropriate file format that are downloaded into the HV power supplies. This calibration suite is also used to determine the parameters to optimize the timing resolution of the system. Full documentation on using the CTOF calibration suite, including a tutorial for using the code, is included on the CTOF web page [5].

### 3.1.4 LMS Scans

The CTOF Light Monitoring System (LMS) consists of an optical fiber coupled to the light guide near each PMT. The light source is an LED board that is driven by a JLab-designed VME pulser board [6]. The LED source is coupled to the fiber array through a small focusing Acrylic light guide. Note: At the present time the LMS fibers are not connected to the CTOF counters. [Therefore no LMS scans can be acquired. The remainder of this section is included only for completeness.]

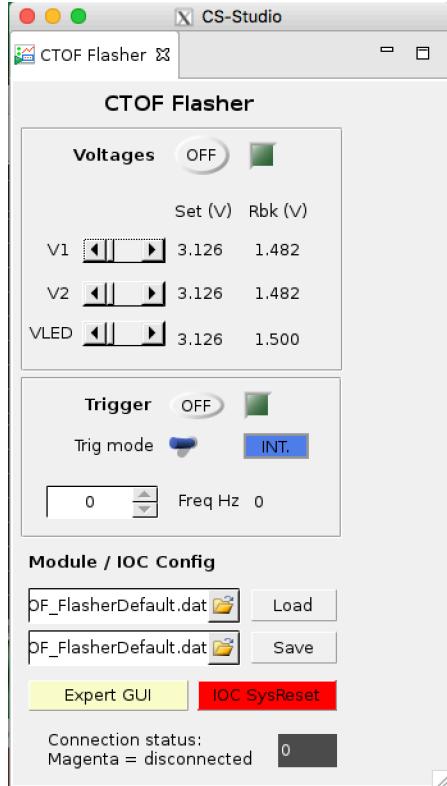


Figure 22: Pulser control interface screen for the CTOF LMS.

The LMS scan sequence amounts to taking six separate data runs adjusting the LED

light amplitude in discrete increments to vary the intensity over the full dynamic range of the FADC. This interface is brought up by clicking on the “CTOF Flasher” option from the CTOF sub-menu shown in Fig. 7. Note that the pulser board has two outputs, one for the CTOF system and one for the HTCC system. Fig. 22 shows the control interface. The intensity scan is controlled by adjusting VLED from 3.5 V to 6.0 V in 0.5 V steps. The nominal pulser frequency for the scan is 1 kHz. Problems with communication between the LMS controls and the pulser board are indicated by a magenta color on the interface. If these are present, that is an indication that the associated pulser IOC needs to be rebooted (see Section 2.2.1). Contact the Slow Controls expert if there are any communication problems that are not remedied after an IOC reboot.

### 3.1.5 Expert Monitoring Suite

The expert monitoring suite for the CTOF system is called *ctofmon*. This code suite is brought up on any Counting House computer by typing “*ctofmon*”. 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. 23.

## 3.2 System Failure Modes

For the CTOF 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)
- Sudden ADC gain shift (see Section 3.2.3)
- High PMT dark current (see Section 3.2.4)
- Missing or bad signal (see Section 3.2.5)
- Bad PMT (see Section 3.2.6)

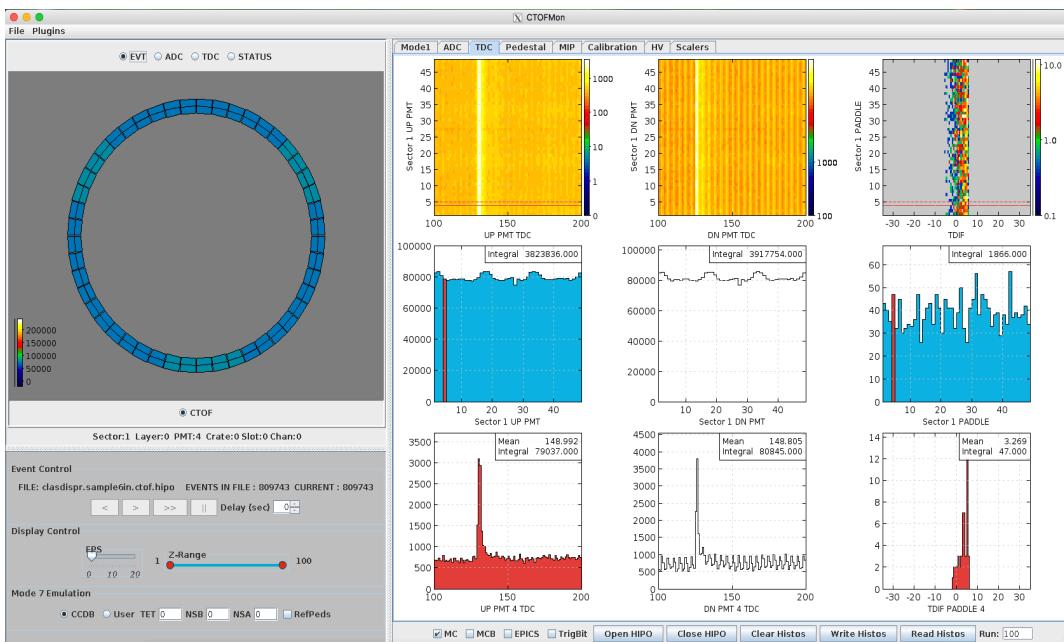
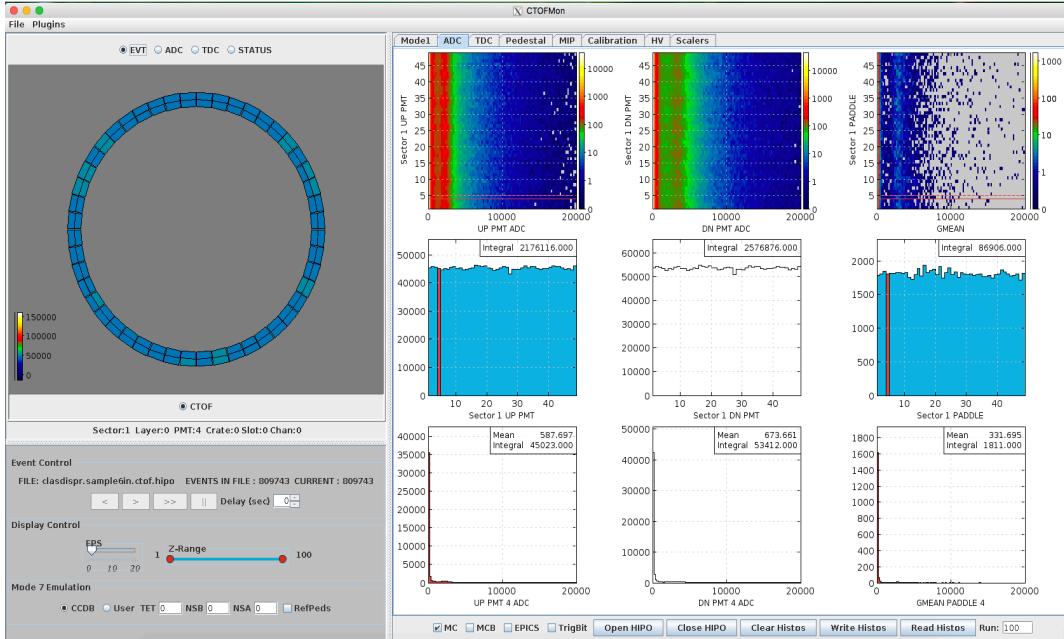


Figure 23: Screens from the *ctofmon* expert monitoring suite.

- 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 the HV mainframe for the CTOF also includes the HTCC and some beamline devices.
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  $50 \Omega$  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). See instructions in Section 3.3.1. These values can also be set channel-by-channel using the CTOF expert channel controls screen discussed in Section 2.2.
10. Enter information on the new board and the old bad board into the Hall B equipment database (see the Appendix).

11. Leave the bad board on the RadCon survey table in Hall B 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.
12. If beam conditions are acceptable, turn on the HV for the CTOF, HTCC, and beamline device 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 the HV mainframe for the CTOF also includes the HTCC and some beamline devices.
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 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 HTCC settings, contact the HTCC expert. If there are questions regarding the beamline device settings, contact the beamline 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).

10. If beam conditions are acceptable, turn on the HV for the CTOF, HTCC, and beamline device 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 spectra 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 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 by taking FADC data in “raw mode” using the *ctofmon* system monitoring suite (see Section 3.1.5).
- Light Leak - it is possible that a gain shift can be due to a light leak on the counter. The detectors themselves can be checked as necessary, coordinating work through the Run Coordinator and the Hall B Work Coordinator.
- PMT Saturation - In conditions of excessively high rates, the PMTs 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 splitter boxes (nominal measurement location) or at the PMT output (if the solenoid is off and access is possible). There are two likely causes for high PMT dark currents:

1. Bad PMT - At times when a PMT goes bad, its dark current can increase. Typical CTOF PMT dark currents are at the level of 50 nA or less. If a bad PMT has been identified, it can be replaced during a scheduled Hall B access. 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 should be updated and the HV setting configuration with the channel off should be saved as the nominal setting.
2. Light Leak - A light leak in the counter wrapping can also lead to higher dark currents. The issue of light leaks is not expected to be an issue on the scintillation bars as they are buried within the solenoid and ambient light levels are usually very low. However, the long upstream and downstream light guides are more exposed. Light leaks can be investigated and repaired during a scheduled Hall B access.

### 3.2.5 Missing or Bad Signal

Each CTOF PMT has a single anode signal output. This signal is a negative polarity pulse as shown in Fig. 24 for a representative pulse from one of the counters. Occasionally a signal channel will disappear from the CTOF monitoring plots. In such a situation, further investigation will be necessary.



Figure 24: Scope traces of a representative anode pulse for the upstream and downstream PMTs of a CTOF counter.

- If a signal channel is missing, this could be due either to a problem with the HV, the VME crate (which would affect an entire board), 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 is absent, severely distorted, or replaced by high frequency noise.
- If a signal channel 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.
- A common reason why a PMT signal is seen to have a high frequency noise component (called ringing) is due to a loose signal cable connector associated with the RG-174 or RG-316 cables. In such a case ensure that the connector barrel is screwed on tightly to the connector threads.
- 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.

### 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 CTOF system have a maximum voltage rating of -2500 V. 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. Note that the serial numbers for the removed and replacement PMTs should be recorded in the CTOF PMT database. The removed PMTs should be cleared by survey and given to the CTOF Group Leader for further evaluation.

### 3.2.7 Readout Electronics Issues

Readout electronics issues, typically associated with all channels associated with a given discriminator module, 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 the HV channels on the CTOF HV display (see Section 2.2). 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 CTOF 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 located in the path: `/home/clasrun/ctof/hv`. There are seven scripts available for setting the CTOF HV parameters:

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

- *loadtrip*: Sets the maximum time duration for an overcurrent 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* or *./loadhvmax*).

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

- HV<sub>max</sub> values: -2500 V
- i<sub>max</sub> values: 500  $\mu$ A
- HV ramp up rate: 50 V/s
- HV ramp down rate: 100 V/s
- Overcurrent 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 CTOF 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. 12. 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.

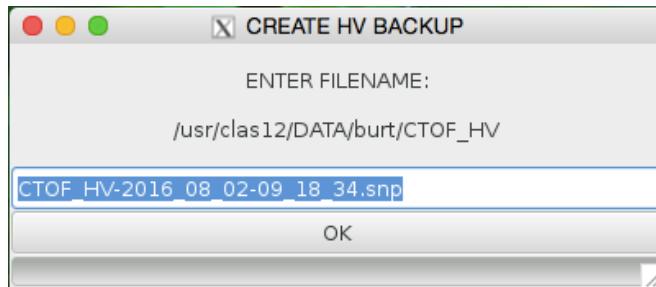


Figure 25: Window that comes up after selecting “Save HV Settings” in Fig. 8(right).

### 3.3.2 HV Save and Restore

The CTOF 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 either on “Save HV Settings” or “Restore HV Settings” on the CTOF Menu screen (see Fig. 8(right)). 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 EPICS variables 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/CTOF_HV`.

Clicking on “Save Settings” brings up a window “CREATE HV BACKUP” as shown in Fig. 25 showing the save file path and the pre-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. 26 comes up showing the saved CTOF 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, or channel on/off settings.

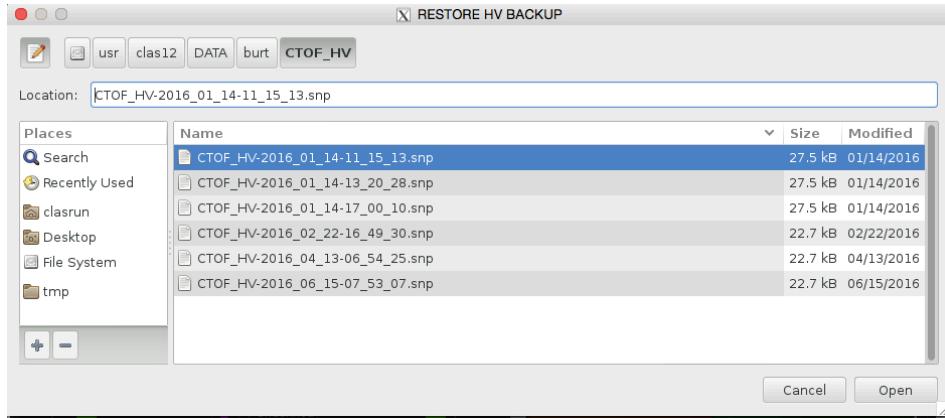


Figure 26: Window that comes up after selecting “Restore HV Settings” in Fig. 8(right).

## 3.4 Cabling Details

### 3.4.1 Signal Cable Connections

The signal cables for each PMT run from the voltage divider to one of two UVa 80-20 signal splitters. A schematic diagram of the splitter connections is shown in Fig. 27. The 80% signals run from the splitters to the discriminators. Fig. 28 shows the signal mapping to the discriminators. The discriminator outputs are then connected to the TDCs. The 20% signals run from the splitters to the FADC inputs. The splitter outputs to the FADCs are through 34-pin connectors for each of the six groups (see Fig. 27). The splitter outputs to the discriminators are through the lemo connectors.

The CTOF 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 Figs. 29 and 30 for the TDCs and FADCs, respectively. Fig. 31 gives schematics for the cable and connector types for each segment of the connections from the voltage divider to the readout electronics for the CTOF counters.

UPPER SPLITTER				LOWER SPLITTER											
<i>CHAN</i>	<i>CHAN</i>	<i>CHAN</i>	<i>CHAN</i>	<i>CHAN</i>	<i>CHAN</i>	<i>CHAN</i>	<i>CHAN</i>								
1	1D	2	3D	1	2D	2	4D	1	17D	2	19D	1	18D	2	20D
3	5D	4	7D	3	6D	4	8D	3	21D	4	23D	3	22D	4	24D
5	1U	6	3U	5	2U	6	4U	5	17U	6	19U	5	18U	6	20U
7	5U	8	7U	7	6U	8	8U	7	21U	8	23U	7	22U	8	24U
9	9D	10	11D	9	10D	10	12D	9	25D	10	27D	9	26D	10	28D
11	13D	12	15D	11	14D	12	16D	11	29D	12	31D	11	30D	12	32D
13	9U	14	11U	13	10U	14	12U	13	25U	14	27U	13	26U	14	28U
15	13U	16	15U	15	14U	16	16U	15	29U	16	31U	15	30U	16	32U

Figure 27: Layout of the connections to the two CTOF signal splitters.

CTOF TEST DAQ NIM BIN CFD MAP

UPPER NIM BIN CFDs												
#	slot 1	slot 2	slot 3	slot 4	slot 5	slot 6	slot 7	slot 8	slot 9	slot 10	slot 11	slot 12
1	1D	1U	9D	9U	2D	2U	10D	10U	17D	17U	25D	25U
2	3D	3U	11D	11U	4D	4U	12D	12U	19D	19U	27D	27U
3	5D	5U	13D	13U	6D	6U	14D	14U	21D	21U	29D	29U
4	7D	7U	15D	15U	8D	8U	16D	16U	23D	23U	31D	31U

LOWER NIM BIN CFDs												
#	slot 1	slot 2	slot 3	slot 4	slot 5	slot 6	slot 7	slot 8	slot 9	slot 10	slot 11	slot 12
1	18D	18U	26D	26U	33D	33U	41D	41U	34D	34U	42D	42U
2	20D	20U	28D	28U	35D	35U	43D	43U	36D	36U	44D	44U
3	22D	22U	30D	30U	37D	37U	45D	45U	38D	38U	46D	46U
4	24D	24U	32D	32U	39D	39U	47D	47U	40D	40U	48D	48U

*ctof-elec-map.xls*  
*Modified: Nov. 4, 2017*

**upstream**  
**dnstream**

Figure 28: Mapping of the CTOF counters to the CFDs.

		CTOF TDC VME MAP																			
#	slot 1	slot 2	slot 3	slot 4	slot 5	slot 6	slot 7	slot 8	slot 9	slot 10	slot 11	slot 12	slot 13	slot 14	slot 15	slot 16	slot 17	slot 18	slot 19	slot 20	
15		15U	16U	31U	32U	47U	48U														
14		13U	14U	29U	30U	45U	46U														
13		11U	12U	27U	28U	43U	44U														
12		9U	10U	25U	26U	41U	42U														
11		15D	16D	31D	32D	47D	48D														
10		13D	14D	29D	30D	45D	46D														
9		11D	12D	27D	28D	43D	44D														
8		9D	10D	25D	26D	41D	42D														
7		7U	8U	23U	24U	39U	40U														
6		5U	6U	21U	22U	37U	38U														
5		3U	4U	19U	20U	35U	36U														
4		1U	2U	17U	18U	33U	34U														
3		7D	8D	23D	24D	39D	40D														
2		5D	6D	21D	22D	37D	38D														
1		3D	4D	19D	20D	35D	36D														
0		1D	2D	17D	18D	33D	34D														
		TDC	TDC	TDC	TDC	TDC	TDC														

upstream  
dnstream

ctof-elec-map.xlsx  
Modified: Jan. 31, 2017

Figure 29: CTOF VME map for the TDCs.

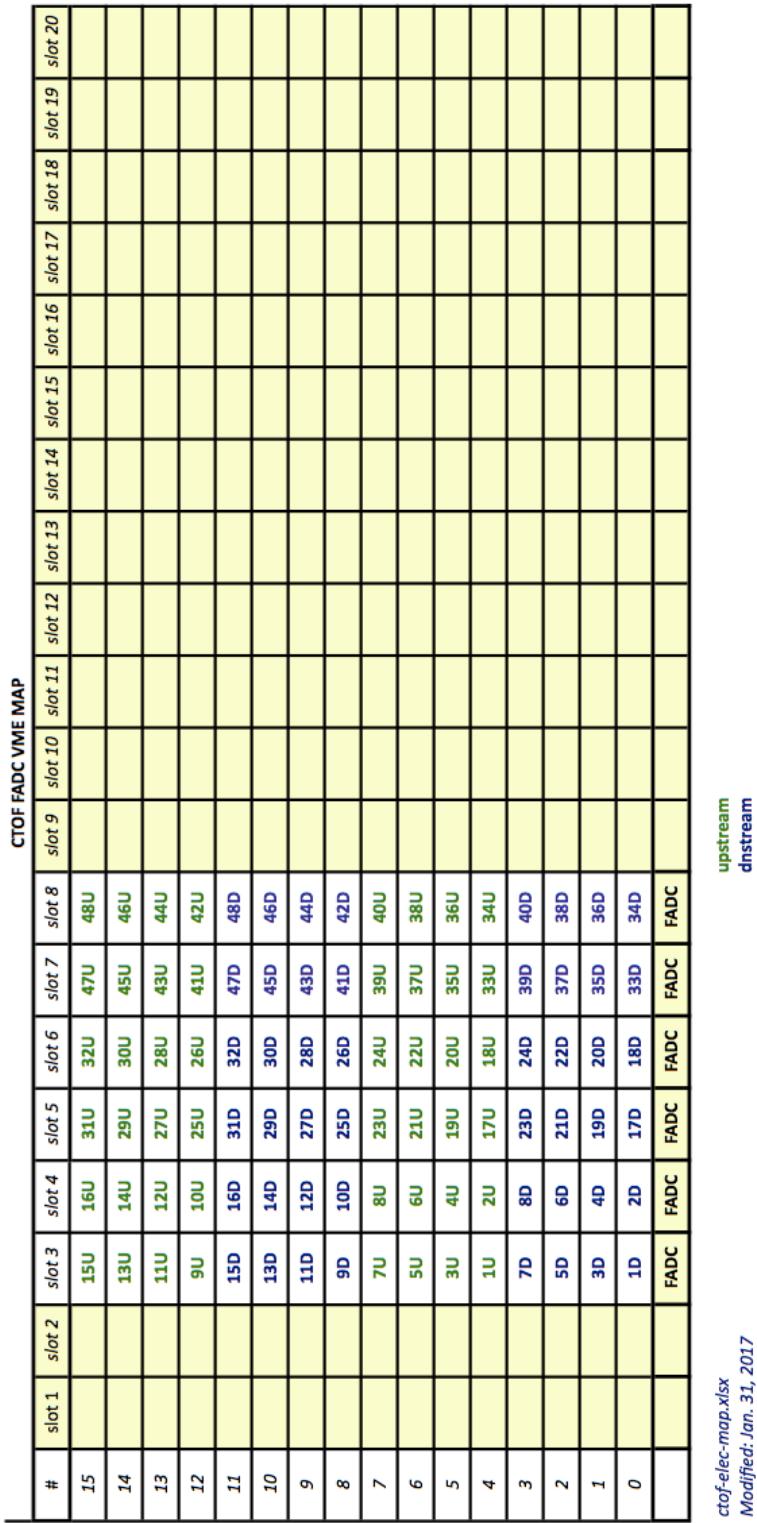


Figure 30: CTOF VME map for the FADCs.

Jan. 31, 2017

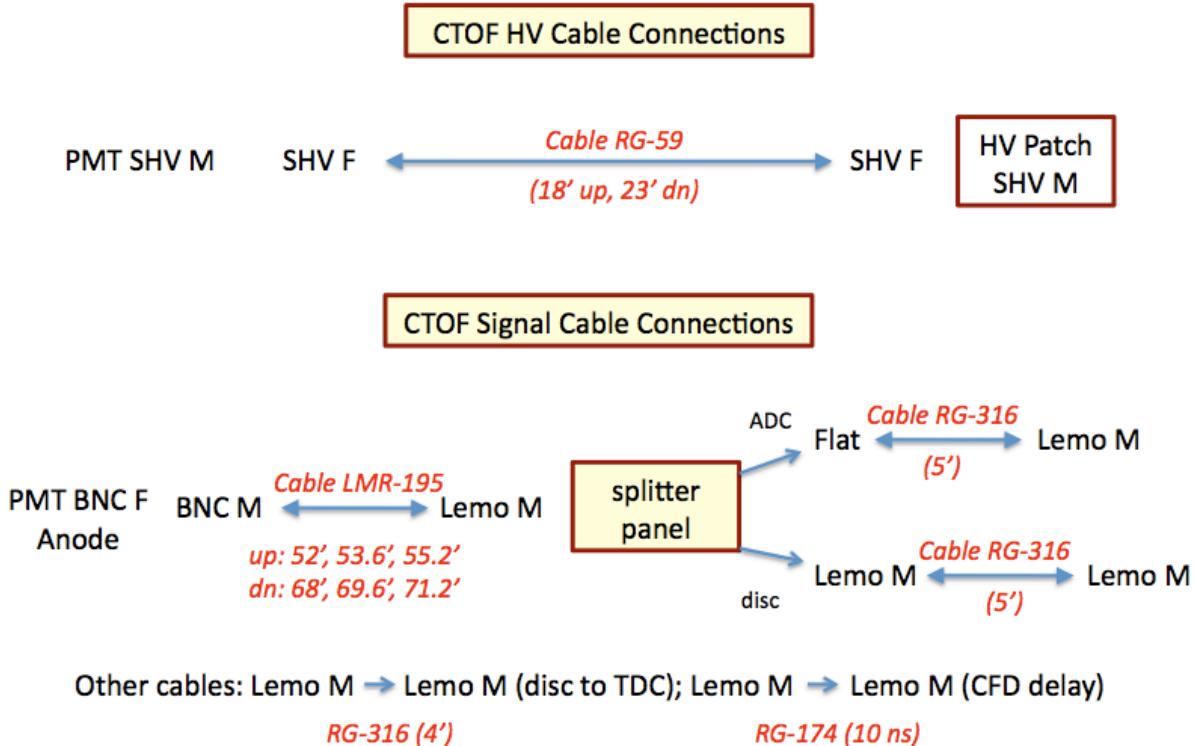


Figure 31: CTOF HV and signal cable connections.

### 3.4.2 HV Cable Layout

The high voltage cables for each PMT run from the voltage divider to one of two HV distribution boxes located on the solenoid cart. Fig. 32 shows the layout of the two HV distribution boxes for the upstream and downstream PMT HV connections. The output of each HV distribution box is a pair of 55-ft-long multi-conductor cables, each containing 24-channels, with a Radiall connector to mate with the HV A1535N board input connector. See Fig. 31 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 CTOF. The HV power supply channel assignments for each sector are nominally given as shown in Fig. 33.

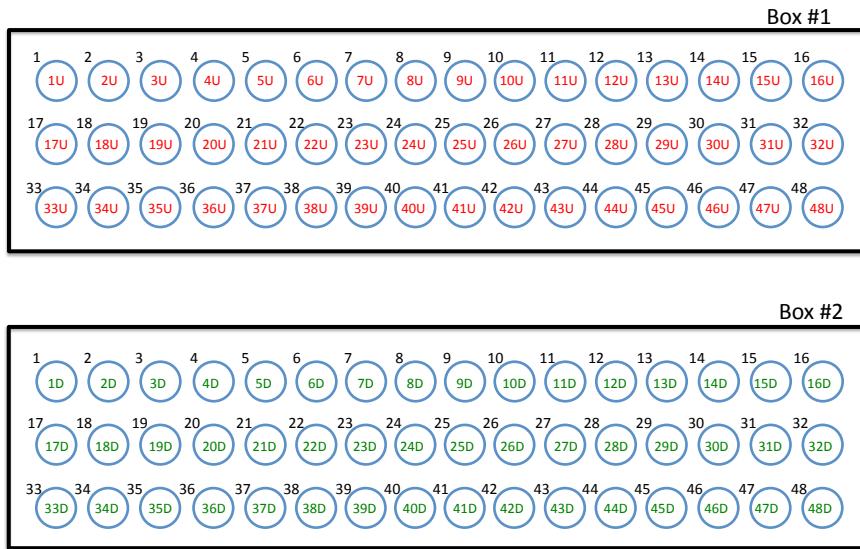


Figure 32: Mapping of the HV channel connections to the HV distribution boxes for the upstream and downstream PMTs.

CTOF DAQ TEST HV MAP

Counter	Slot	Channel
D1 → D24	SI 0	Ch 0 → 23
D25 → D48	SI 1	Ch 0 → 23
U1 → U24	SI 2	Ch 0 → 23
U25 → U48	SI 3	Ch 0 → 23

*ctof-elec-map.xlsx*

*Modified: Oct. 31, 2017*

Figure 33: HV mainframe CTOF channel assignments.

### **3.4.3 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 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 CTOF experts as it could lead to problems decoding the data.

Problems with channels within the HV system are more common issues as channels on the HV distribution box or on a A1535N card are reasonably common. The standard procedure when there is a problem with a CAEN HV board is to swap out the board (see Section 3.2.1). If there is a problem on the HV distribution box for either the upstream or downstream PMTs, the box would have to be swapped out with a spare unit. The first step before disconnecting any system HV cables is to be sure that the associated HV channels are turned off. The SHV cables can then be disconnected. If there is a need to update the HV channels map, contact the Slow Controls expert.

## **3.5 Detector Repairs and Servicing**

Repairs and servicing on the CTOF detectors themselves are highly involved operations. If there were a problem with the scintillation bars or a glue joint, it might be the case that the counters would have to be removed from the solenoid. However, PMTs that go bad can be replaced relatively easily. In addition, voltage dividers can also sometimes go bad due to failed components. All work on the CTOF detectors must be coordinated with the CTOF Group Leader and the Hall B Work Coordinator during an access period with the solenoid turned off.

## 4 Documentation

All current documentation for the CTOF system is located on the official CTOF web page [5]. A number of basic subsystem documents can be found there including:

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

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

## 5 CTOF Authorized Personnel

Beyond turning on/off the CTOF 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 CTOF can only be modified by the CTOF Group Leader.

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

Table 2: CTOF detector authorized personnel.

## 6 Appendix: Hall B Instrumentation Database

When electronics modules or HV modules are removed from Hall B and replaced during servicing with new boards, the information regarding both the old board and the new board needs to be entered into the Hall B Instrumentation Database. This database is accessed online at <http://clonwiki0.jlab.org> by clicking on the “Hall B Inventory” link. This brings up the access screen shown in Fig. 34. To enter information for the old component, search for it in the database using its property tag information. When the item shows up, click on the “Action” button for “Modify this item”. Be sure to change the location of the item to “Hall B Underground/RadCon Table” and change the status of the item to “Action needed/Broken”, as well as to leave the item on the RadCon survey table in Hall B. By entering this information, email will be sent to the property custodian to pick up the item for servicing. For the new component, be sure to also change the location as appropriate using the same approach.

The screenshot shows a web-based inventory system for Hall B equipment. The top navigation bar includes links for DSC, ESPN, CNN, Hall B, Insight, Minutes, FTOF, CTOF, Dictionary, and Links. The main title is "JInventory database in use by CUE user 'carman' with 'read/write' access". Below the title, there are search and filter options: "Item ID:", "Housing Parent | Ancestor:", "Property Tag:", "Short name and description:", "Brand-Format-Model: -- all --", "Reset >>", and "Search >>". A pagination link "1 2 3 4 5 6 Next >> [202]" is also present. The total number of items meeting search criteria is 2016. The main content area displays a table of equipment items:

Check	Property Tag (Serial number)	ID	Short name	Description	Housing	Custodian	Insert Date	Action
<input type="checkbox"/>	BI000471 (CEM-TI-204)	6275	TI board	JLAB TI	Hall B underground (5168) PI (Pie Tower) (5177) PI2-5 (rack) (5215) VME64x crate (5585) * slot 8	Sergey Boyarinov	2016-07-25 10:40:15	
<input type="checkbox"/>	BI000470 (CEM-TI-210)	6274	TI board	JLAB TI	Hall B underground (5168) PI (Pie Tower) (5177) PI2-5 (rack) (5215) VME64x crate (5585) * slot 15	Sergey Boyarinov	2016-07-25 10:37:23	
<input type="checkbox"/>	BI000469 (CEM-TI-207)	6273	TI board	JLAB TI	Hall B underground (5168) FC (Forward Carriage) (5169) C1-2 (rack) (5189) VME64x crate "tdpcal5" (4353) * slot 21	Sergey Boyarinov	2016-07-20 14:25:22	
<input type="checkbox"/>	BI001406 (B55561)	6272	LeCroy VME board 1182	LeCroy VME board 1182 ADC	Bldg. 90 (EEL) (5173) 208A (room) (5252) WIENER VME Mini Crate (6267) * Slot 6		2016-06-27 15:51:23	
<input type="checkbox"/>	PP0M0712 (233)	6270	TDC 32 ch.	CAEN V775	Bldg. 90 (EEL) (5173) 208A (room) (5252) WIENER VME Mini Crate (6267) * Slot 6	Sergey Boyarinov	2016-06-27 15:46:32	
	BI001405	6269	Multicount DDC 32 ch.	CAEN V773	Bldg. 90 (EEL) (5173)	Sergey	2016-06-27	

Figure 34: Hall B equipment database web page.

## 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](https://clasweb.jlab.org/wiki/index.php/Slow_Control_Alarms)
- [3] Hall B current run information page:  
<https://www.jlab.org/Hall-B/run-web/>
- [4] Hot Checkout page: <http://accweb.acc.jlab/hco/readiness> (also accessible from the “Shift Documentation” tab on the Run Page wiki [3])
- [5] CTOF web page: <http://www.jlab.org/Hall-B/ctof>
- [6] JLab Fast Pulser Board Manual:  
[http://www.jlab.org/Hall-B/ctof/lms/FastLEDPulser\\_Description\\_InstructionsDRAFT1.pdf](http://www.jlab.org/Hall-B/ctof/lms/FastLEDPulser_Description_InstructionsDRAFT1.pdf)