

# 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, 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 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 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  $35^\circ$  to  $125^\circ$  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.

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 effective time resolution for each counter along its full length of  $\sigma_{TOF}=80$  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.

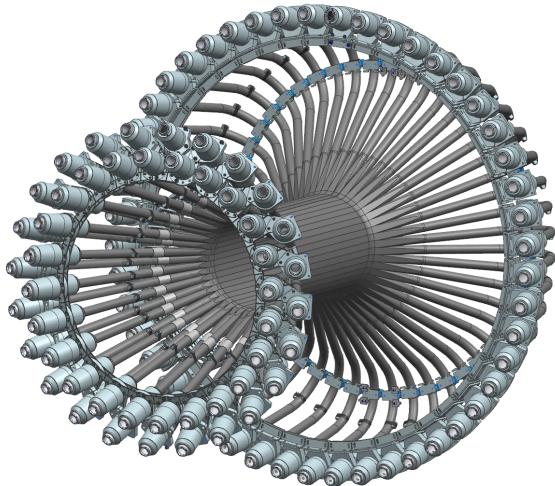


Figure 1: View of the Central Time-of-Flight system for CLAS12 showing the upstream straight light guides, the scintillation bars, and the downstream bent light guides. The PMTs reside within the shield cylinders located at the ends of the light guides.

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. The beamline lies along the symmetry axis of the CTOF barrel pointing downstream (left

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 $\sim 3.4 \times 3 \times 92$ cm <sup>3</sup>
PMTs	Hamamatsu R2083 (H2431-MOD assembly)
Light Guides - Upstream	O.D.=5.08 cm, 1-m-long, focusing design, straight
Light Guides - Downstream	O.D.=5.08 cm, 1.6-m-long, focusing design, bent $135^\circ$
Magnetic Shields	3-layer cylinder: Co-nectic, Hiperm-48, Steel-1008
Design Time Resolution	80 ps
$\pi/K$ separation	$3\sigma$ up to 0.58 GeV
$K/p$ separation	$3\sigma$ up to 0.93 GeV
$\pi/p$ separation	$3\sigma$ up to 1.14 GeV

Table 1: CTOF technical design parameters.

to right in Fig. 3). The nominal position of the center of the CTOF scintillation barrel is roughly 19.3 cm 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 looking downstream.



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.

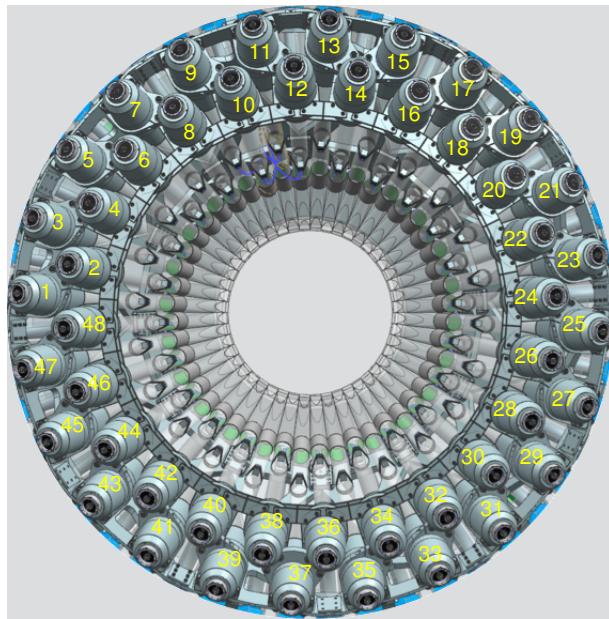


Figure 4: CTOF counter numbering convention seen looking at the upstream end of the detector.

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. 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. Note that the CTOF magnetic shields include compensation coils powered through a dedicated low voltage system (LVPS). However, the coils are not used in nominal beam operations for CLAS12.

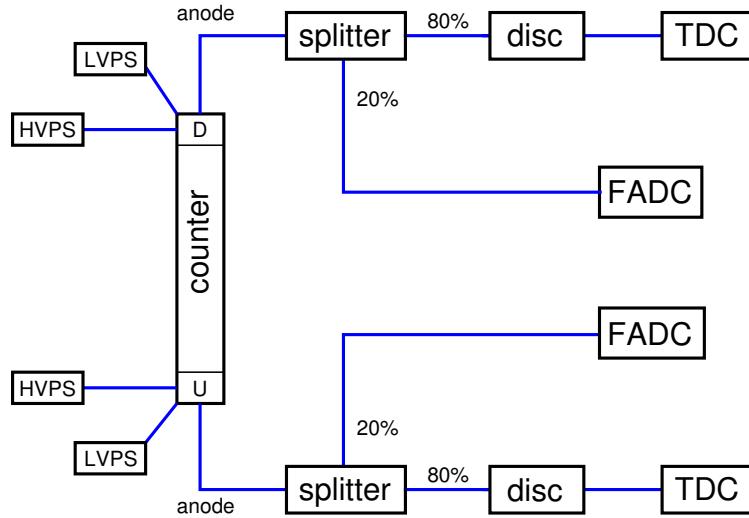


Figure 5: Block diagram for the CTOF system showing the layout of the readout electronics and power connections for a single counter.

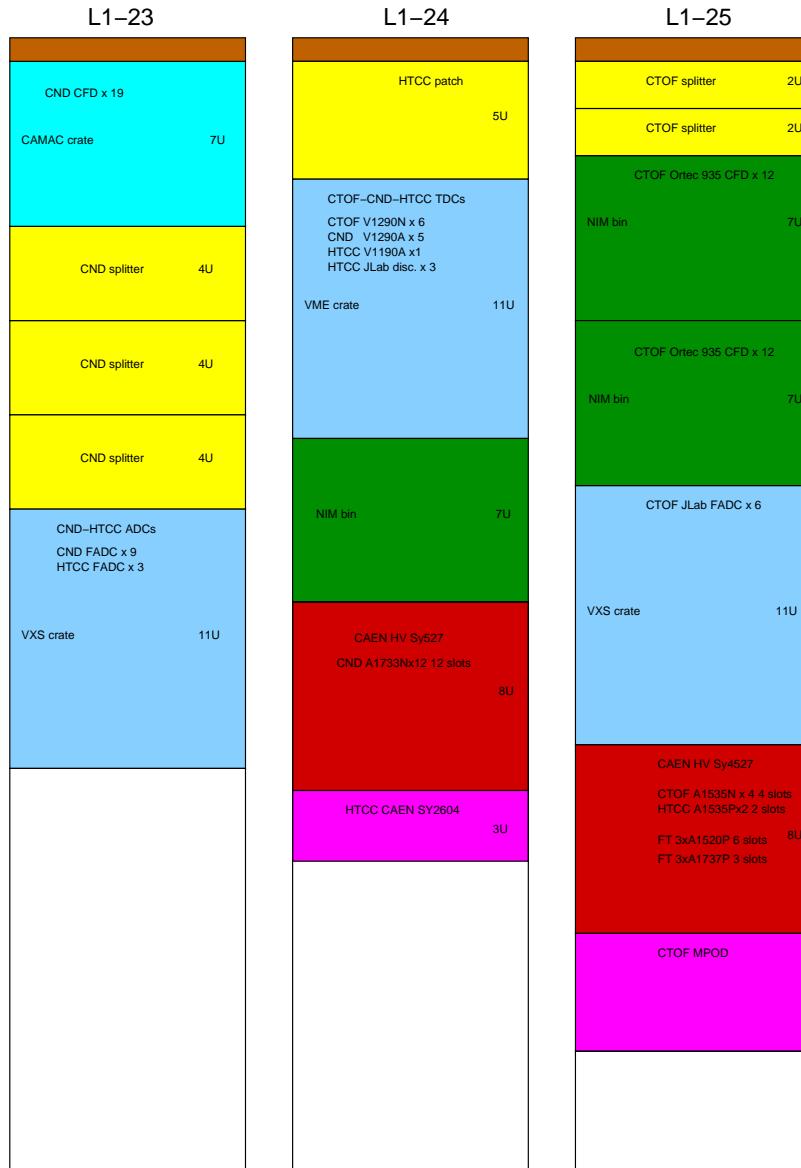


Figure 6: Layout of the electronics for the CTOF, CND, and HTCC NIM and VME electronics on the beam left side of Level 1 of the Space Frame in Hall B. The positions of the HV (SYS1527) and LV (MPOD) mainframes are also shown.

## 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 2.3).

#### 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 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 the HV system is monitored by the alarm handler. 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.

## 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
- HV trip - red
- Communication problem - yellow
- Undefined channel status - magenta

For the shift worker the most common operations are:

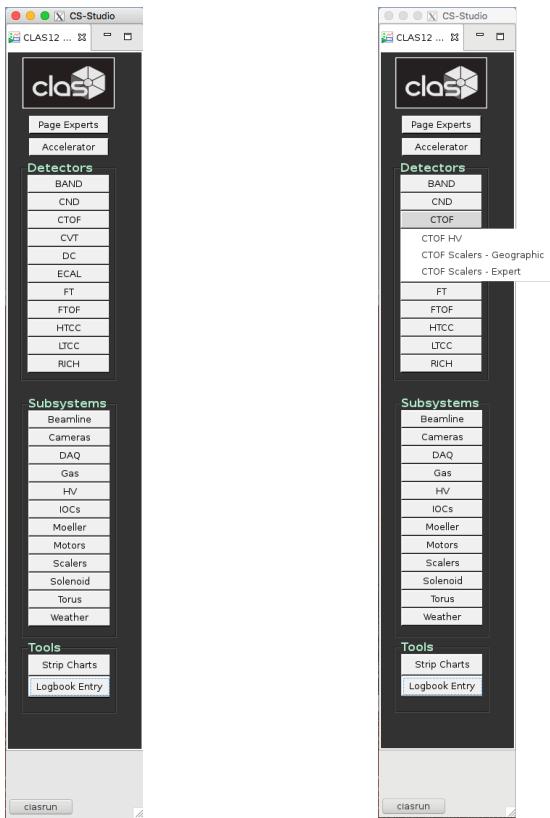


Figure 7: The CS-Studio interface used for the Slow Controls of the CLAS12 detectors and subsystems. (Left) General CLAS12 interface. (Right) Options for the CTOF system.

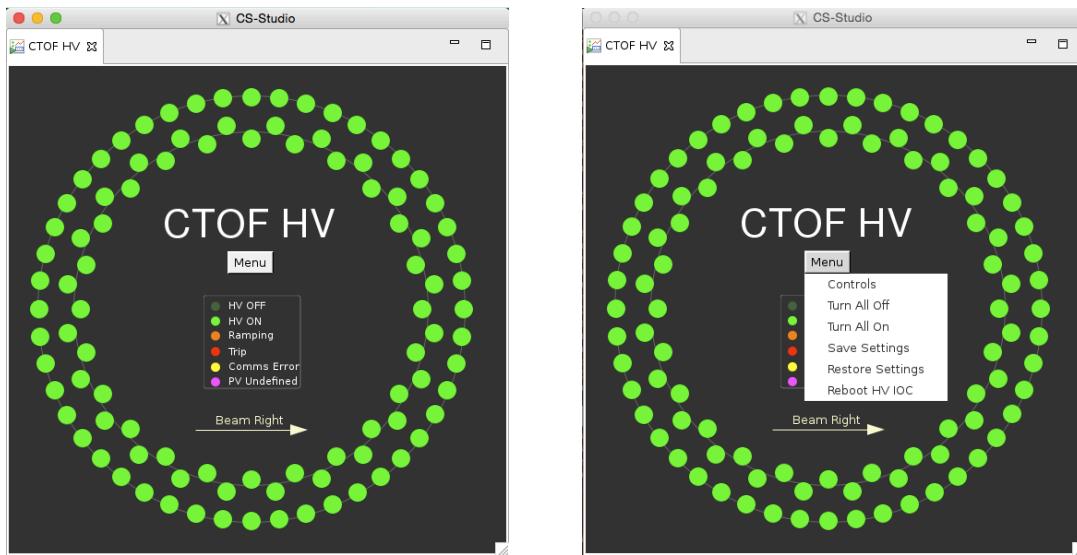


Figure 8: CTOF HV display and control interface. The right figure shows the “Menu” options available.

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.

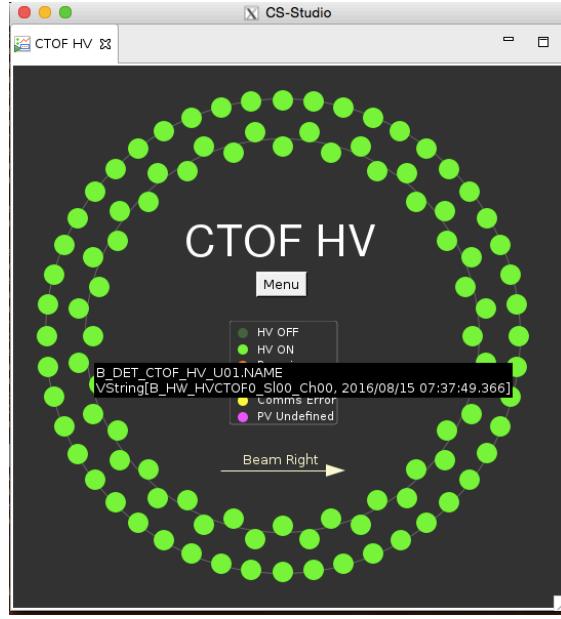


Figure 10: CTOF HV display showing the channel information when the mouse is paused over a PMT circle.

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.

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

CS-Studio

CTOF HV Controls

Expert

#	Description	Pw	Vmon	Imon	Status	Vset (V)	Iset (uA)
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	2033.00	357.00	ON	2034.000	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.

CS-Studio

CTOF HV Controls

Novice

#	Description	Pw	Vmon	Imon	Status	Vset (V)	Iset (uA)	Vmax (V)	Up (V/s)	Down (V/s)
0	CTOF_HV_U01	ON	2112.00	370.50	ON	2113.000	500.00	3000	3000	50 50 100 100
1	CTOF_HV_U02	ON	2135.50	375.00	ON	2137.000	500.00	3000	3000	50 50 100 100
2	CTOF_HV_U03	ON	2165.00	382.50	ON	2166.000	500.00	3000	3000	50 50 100 100
3	CTOF_HV_U04	ON	2163.50	380.00	ON	2165.000	500.00	3000	3000	50 50 100 100
4	CTOF_HV_U05	ON	1955.50	343.00	ON	1956.000	500.00	3000	3000	50 50 100 100
5	CTOF_HV_U06	ON	2070.50	365.00	ON	2072.000	500.00	3000	3000	50 50 100 100
6	CTOF_HV_U07	ON	2148.50	377.50	ON	2150.000	500.00	3000	3000	50 50 100 100
7	CTOF_HV_U08	ON	2142.00	376.50	ON	2143.000	500.00	3000	3000	50 50 100 100
8	CTOF_HV_D01	ON	2077.00	365.00	ON	2078.000	2078.000	500	500	3000 3000 50 50 100 100
9	CTOF_HV_D02	ON	2323.00	406.50	ON	2324.000	2324.000	500	500	3000 3000 50 50 100 100
10	CTOF_HV_D03	ON	2160.50	378.00	ON	2161.000	2161.000	500	500	3000 3000 50 50 100 100
11	CTOF_HV_D04	ON	2033.00	357.00	ON	2034.000	2034.000	500	500	3000 3000 50 50 100 100
12	CTOF_HV_D05	ON	1888.00	332.00	ON	1889.000	1889.000	500	500	3000 3000 50 50 100 100
13	CTOF_HV_D06	ON	2270.50	398.50	ON	2267.000	2267.000	500	500	3000 3000 50 50 100 100
14	CTOF_HV_D07	ON	2305.50	405.50	ON	2306.000	2306.000	500	500	3000 3000 50 50 100 100
15	CTOF_HV_D08	ON	2129.00	374.00	ON	2130.000	2130.000	500	500	3000 3000 50 50 100 100
16	CTOF_HV_U09	ON	1992.50	349.50	ON	1993.000	500.00	3000	3000	50 50 100 100
17	CTOF_HV_U10	ON	2078.00	365.50	ON	2078.000	2078.000	500	500	3000 3000 50 50 100 100
18	CTOF_HV_U11	ON	2141.50	375.00	ON	2142.000	500.00	3000	3000	50 50 100 100
19	CTOF_HV_U12	ON	2070.50	362.50	ON	2071.000	2071.000	500	500	3000 3000 50 50 100 100
20	CTOF_HV_U13	ON	2188.00	382.50	ON	2188.000	2188.000	500	500	3000 3000 50 50 100 100
21	CTOF_HV_U14	ON	2191.50	385.00	ON	2191.000	2191.000	500	500	3000 3000 50 50 100 100
22	CTOF_HV_U15	ON	2188.00	384.00	ON	2188.000	2188.000	500	500	3000 3000 50 50 100 100
23	CTOF_HV_U16	ON	2065.00	361.00	ON	2065.000	2065.000	500	500	3000 3000 50 50 100 100
24	CTOF_HV_D09	ON	2169.00	381.00	ON	2170.000	2170.000	500	500	3000 3000 50 50 100 100
25	CTOF_HV_D10	ON	2187.50	385.00	ON	2187.000	2187.000	500	500	3000 3000 50 50 100 100
26	CTOF_HV_D11	ON	2125.50	375.00	ON	2125.000	2125.000	500	500	3000 3000 50 50 100 100
27	CTOF_HV_D12	ON	1974.00	348.50	ON	1974.000	1974.000	500	500	3000 3000 50 50 100 100
28	CTOF_HV_D13	ON	2064.50	364.00	ON	2063.000	2063.000	500	500	3000 3000 50 50 100 100
29	CTOF_HV_D14	ON	2111.50	373.50	ON	2111.000	2111.000	500	500	3000 3000 50 50 100 100
30	CTOF_HV_D15	ON	2090.50	368.50	ON	2091.000	2091.000	500	500	3000 3000 50 50 100 100

Figure 12: CTOF “expert” channel controls screen.

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.**

### 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 the 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.

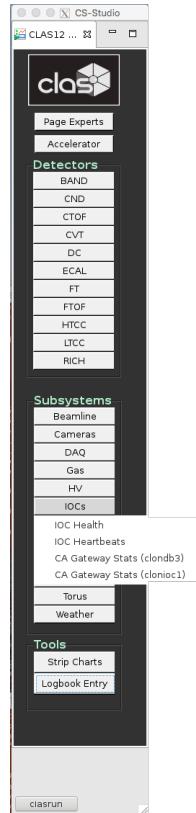


Figure 13: Sub-menu on the primary Slow Controls interface to reboot the IOCs.

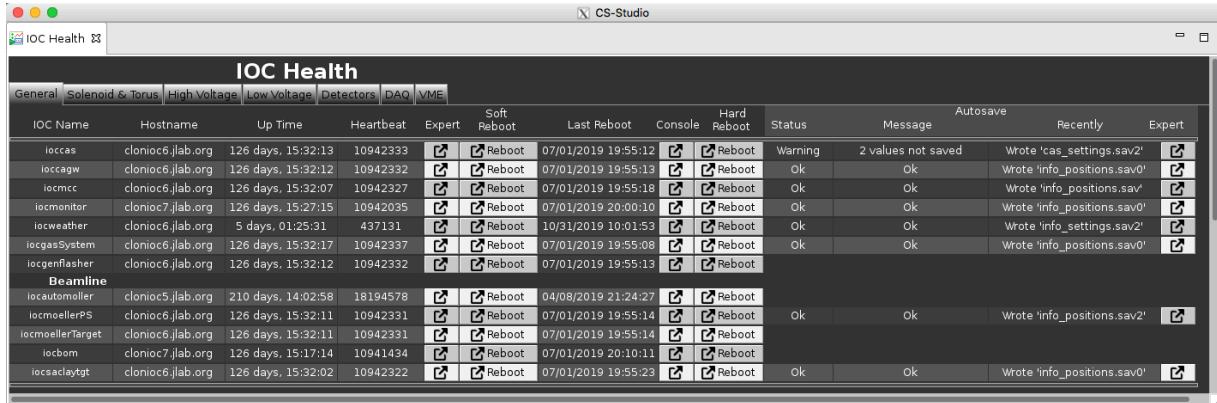


Figure 14: IOC health screen for access to all Hall B IOCs.

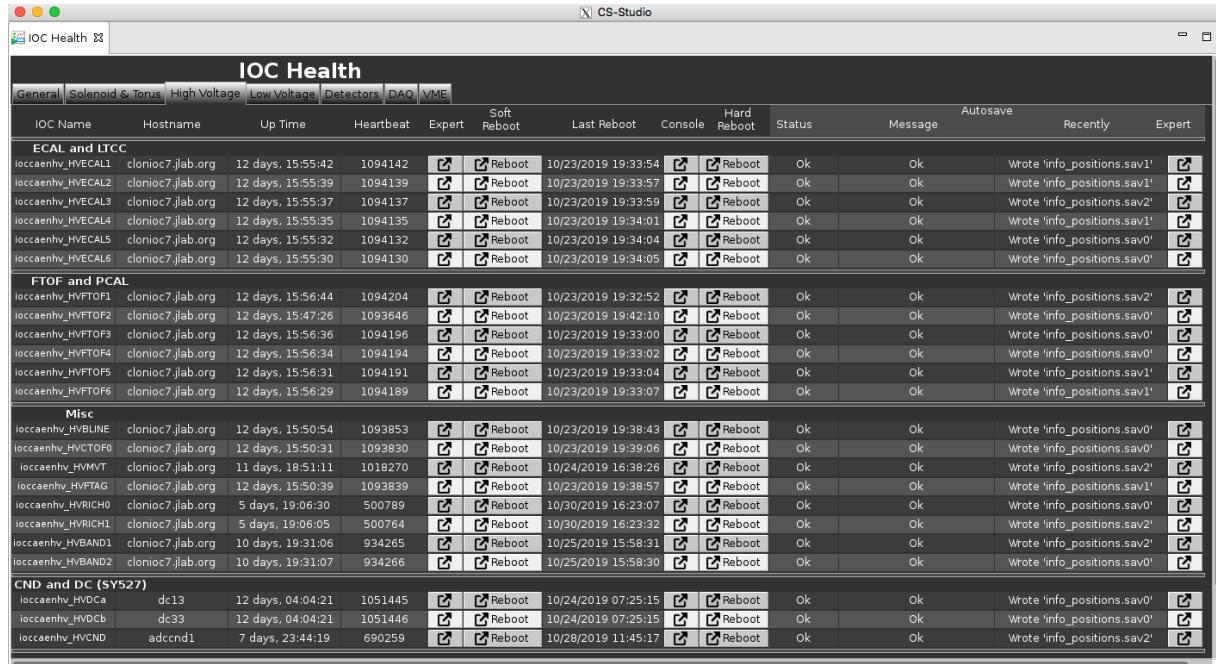


Figure 15: IOC health screen where individual IOCs that control the HV mainframes can be rebooted.

## 2.3 Detector Monitoring

A number of monitoring tools to study the performance of the 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. 16(upper left).

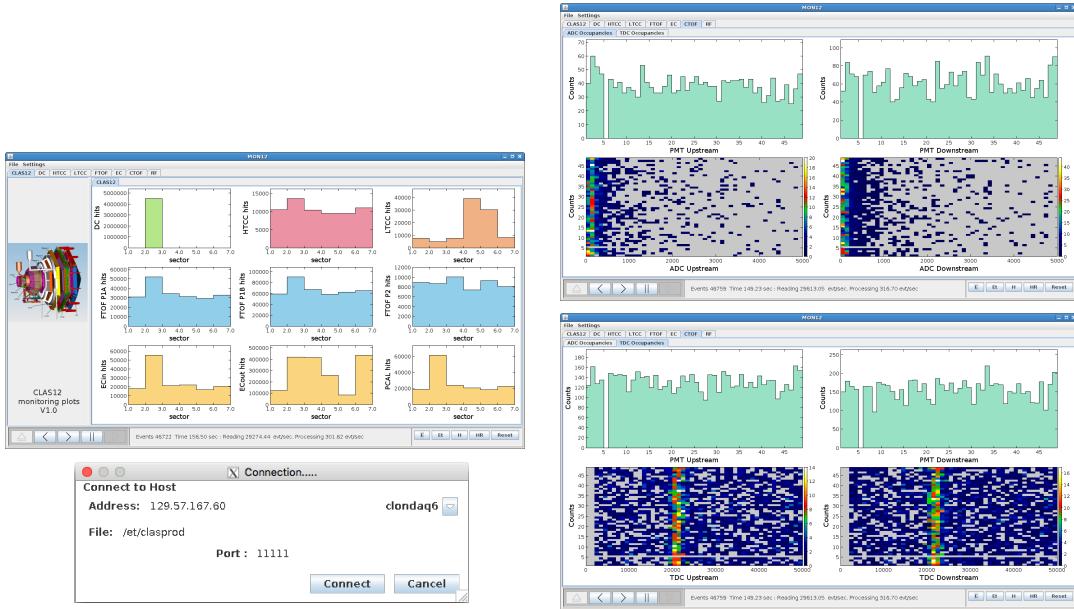


Figure 16: (UL) The main *mon12* display screen showing counts across the different CLAS12 subsystems. (LL) ET connection pop-up screen. (Right) The CTOF ADC and TDC scaler screens within *mon12*.

The *mon12* utility for online data monitoring 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. 16(lower left). 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 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. 16(right).

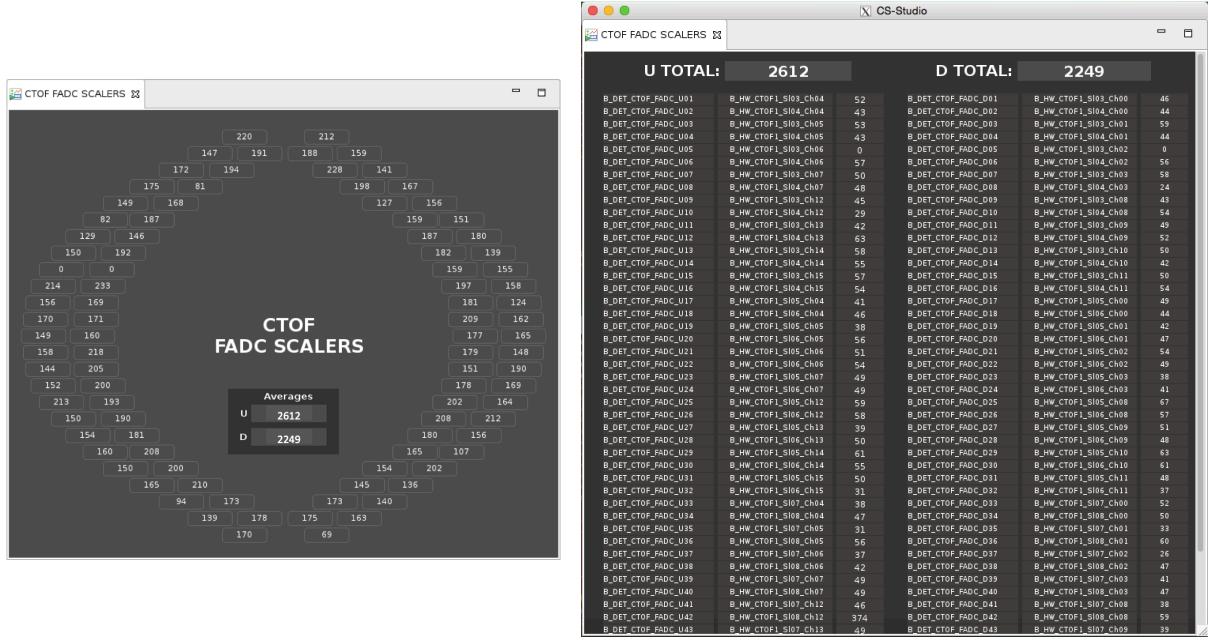


Figure 17: Scaler displays for the CTOF counters from the Slow Controls system showing the two different options, “CTOF Scalers - Geographic” (left) and “CTOF Scalers - Expert” (right). Both displays show the total rate for the upstream and downstream PMTs.

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. 17.

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 3.1.3, 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 (contact the CTOF Group Leader for details);
4. Monitor the system performance with the *ctofmon* expert monitoring suite (see Section 3.1.3);
5. 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 system 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 system 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 is functioning, and that the DAQ system can fully communicate with the readout electronics.

Fig. 18 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 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.

#### 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 [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.**

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

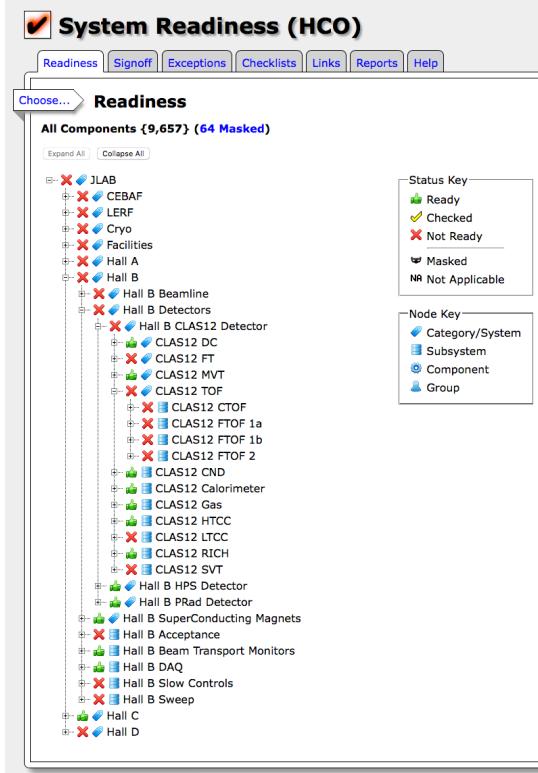


Figure 18: Screenshot of the Hall B hot checkout screen. The CTOF system appears under the “Hall B CLAS12 Detector” and “CLAS TOF” headings. All entries for CTOF have to be verified as functional and all items listed as “Not Ready” must be changed over to “Ready”.

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 Group Leader as soon as is reasonable.

### 3.1.3 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. 19.

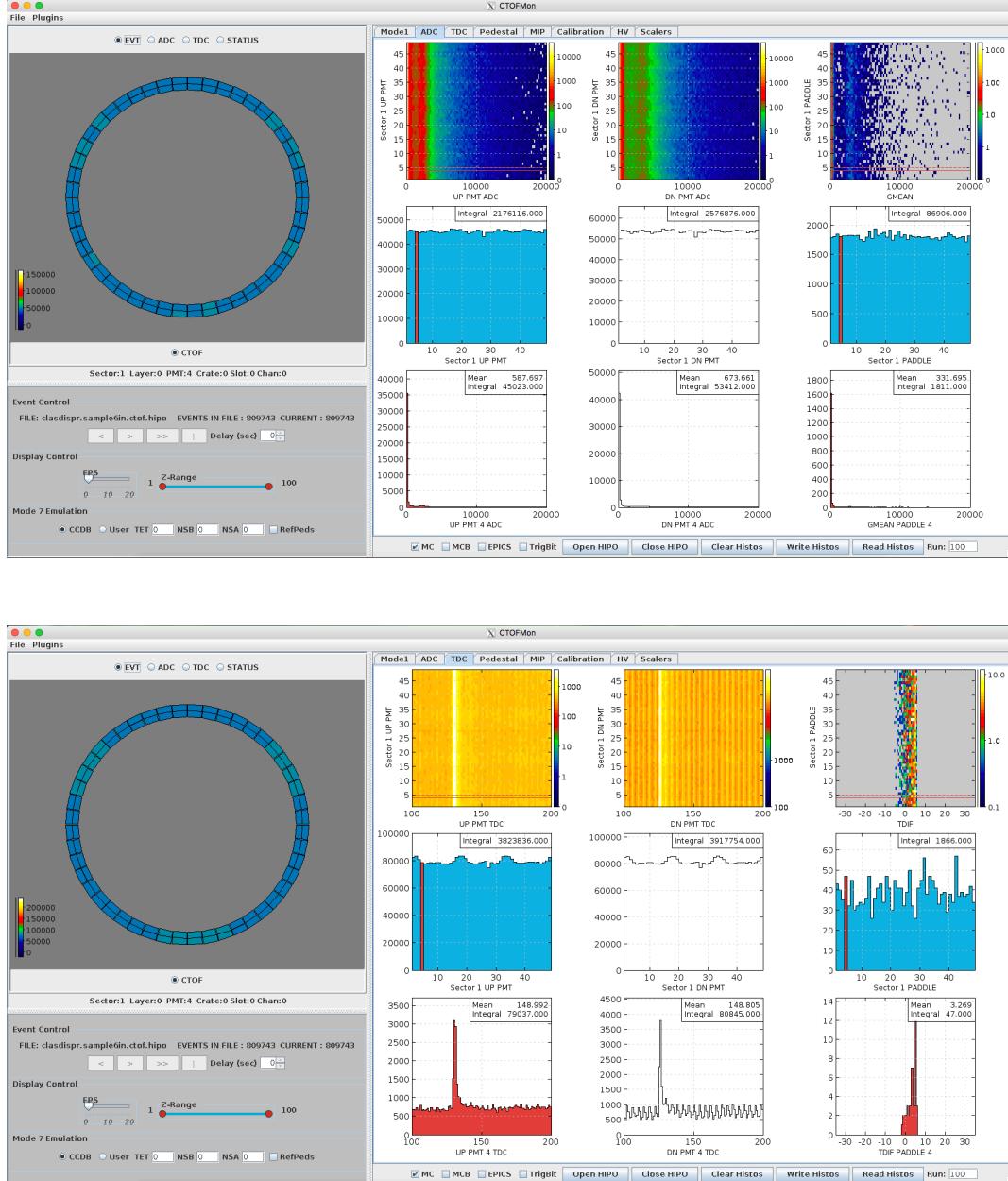


Figure 19: Screens from the *ctofmon* expert monitoring suite.

## 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)
- 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 mainframe 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. 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.
11. 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 using the *ctofmon* system monitoring suite (see Section 3.1.3).
- 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 CTOF Group Leader, 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 or downstream light guides as they are buried within the solenoid and HTCC and ambient light levels are usually very low. However, the long upstream 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. 20 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 20: 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 associated HV distribution box located on the solenoid cart under the upstream end of the CTOF.

### **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 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` or `./loadhvmax`).

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

- $HV_{max}$  values: -2500 V
- $i_{max}$  values: 500  $\mu$ 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 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.

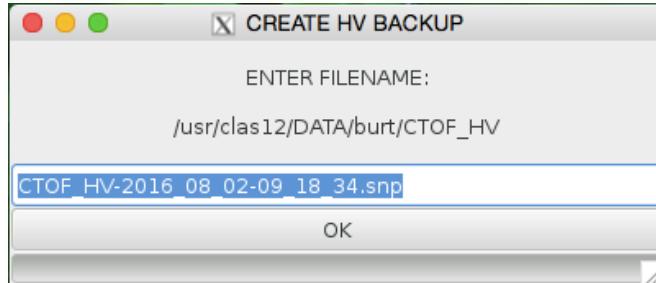


Figure 21: Window that comes up after selecting “Save HV Settings” in Fig. 8(right).

### 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. 21 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. 22 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.

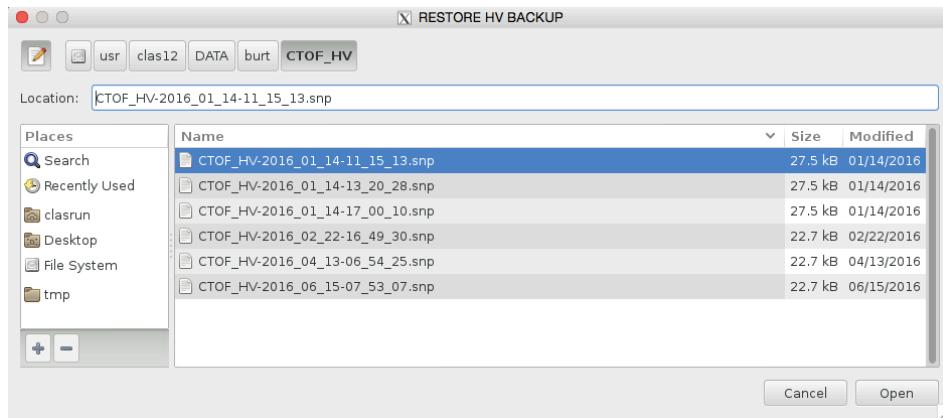


Figure 22: Window that comes up after selecting “Restore HV Settings” in Fig. 8(right).

## 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. 23. The 80% signals run from the splitters to the discriminators. Fig. 24 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. 23). The splitter outputs to the discriminators are through the lemo connectors. Note that the locations of the CTOF electronics crates are shown in Fig. 6

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. 25 and 26 for the TDCs and FADCs, respectively. Fig. 27 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											
<i>CHAN</i>	<i>CHAN</i>	<i>CHAN</i>	<i>CHAN</i>	<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
3	5D	4	7D	3	6D	4	8D	3	21D	4	23D
5	1U	6	3U	5	2U	6	4U	5	17U	6	19U
7	5U	8	7U	7	6U	8	8U	7	21U	8	23U
9	9D	10	11D	9	10D	10	12D	9	25D	10	27D
11	13D	12	15D	11	14D	12	16D	11	29D	12	31D
13	9U	14	11U	13	10U	14	12U	13	25U	14	27U
15	13U	16	15U	15	14U	16	16U	15	29U	16	31U

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>	<i>CHAN</i>	<i>CHAN</i>	<i>CHAN</i>	<i>CHAN</i>
1	33D	2	35D	1	34D	2	36D				
3	37D	4	39D	3	38D	4	40D				
5	33U	6	35U	5	34U	6	36U				
7	37U	8	39U	7	38U	8	40U				
9	41D	10	43D	9	42D	10	44D				
11	45D	12	47D	11	46D	12	48D				
13	41U	14	43U	13	42U	14	44U				
15	45U	16	47U	15	46U	16	48U				

Figure 23: 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 24: 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 25: CTOF VME map for the TDCs.

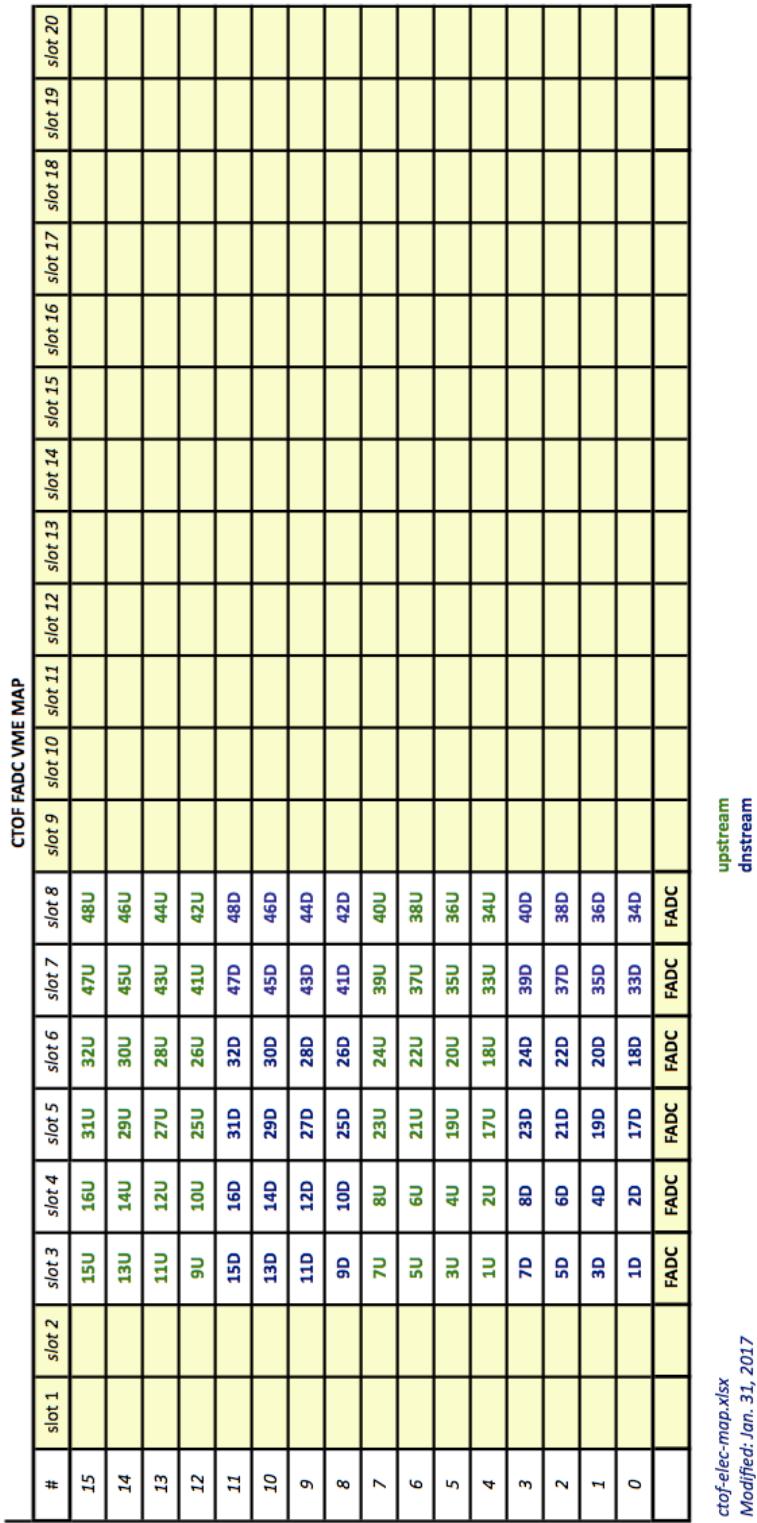


Figure 26: CTOF VME map for the FADCs.

Jan. 31, 2017

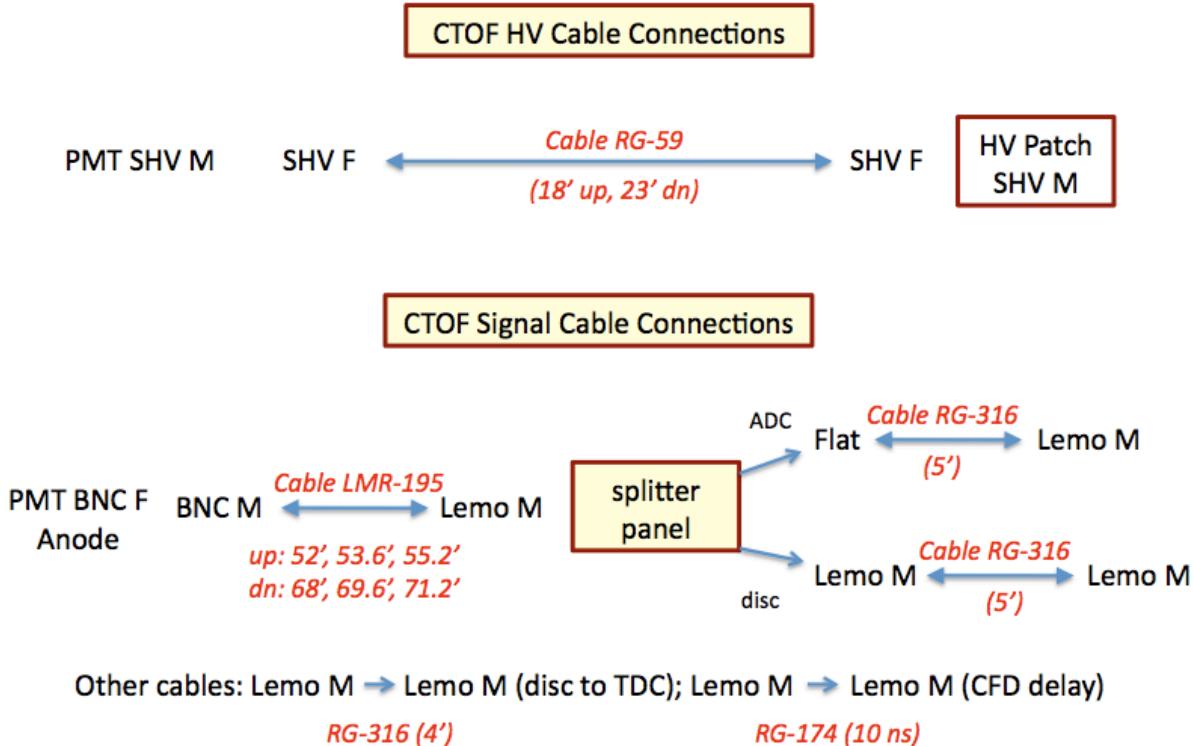


Figure 27: CTOF HV and signal cable connections.

### 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. 28 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. 27 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. 29.

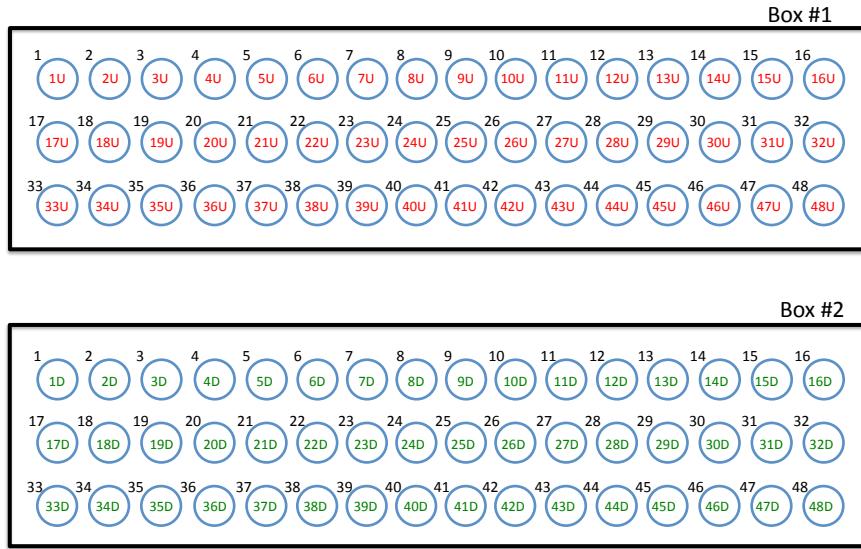


Figure 28: Mapping of the HV channel connections to the HV distribution boxes for the upstream and downstream PMTs.

**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 29: 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.

## 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>