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Level One Trigger Monitor for the CLAS Detector at Jefferson lab

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Abstract

The level one trigger (TLV1) monitor for the CEBAF Large Angle Spectrometer (CLAS) provides real-time results of all level one trigger inputs. TLV1 software is capable on-line analysis by using data from the Event Transfer (ET) system, and off-line analysis by processing data from a file. The Application Program Interface (API) for the crate can be run in the Hall B counting house or on-site at Jefferson Lab. Information from TLV1 enables one to determine efficiencies of the level one trigger inputs.

CLAS

The CEBAF Large Acceptance Spectrometer (CLAS) at Jefferson Lab is a magnetic toroidal multi-gap spectrometer used to study the structure of atomic particles. CLAS consists of drift chambers (DC) to determine the path of charged particles, gas Cherenkov counters (CC) for electron identification, scintillation counters for the measurement of time-of-flight (TOF), and electromagnetic calorimeters (EC) and Large angle calorimeters (LAC) that identify showering particles. A side view of CLAS is given in Figure 1.

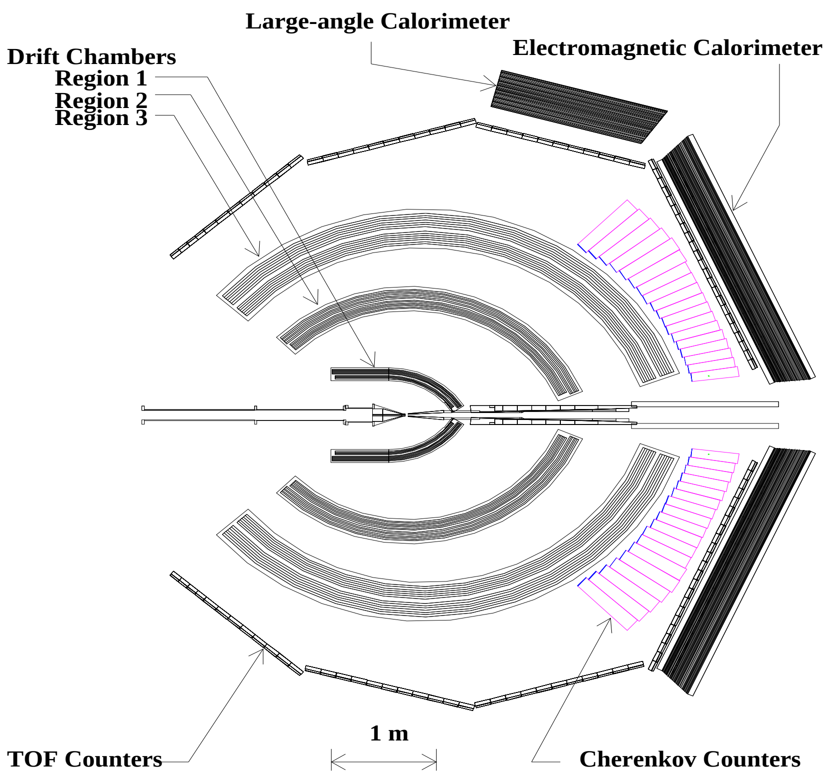

Figure 1: A mid-plane slice of the CLAS detection system. The level one trigger inputs consist of the Time-of-Flight counters, Cherenkov counters, Electromagnetic calorimeters and the Large-angle calorimeters

Level One Trigger

Experimenters want the the capability of multiple independent triggers on events with up to three tracks. To simultaneously meet these demanding requirements, the level one trigger uses a geometry-based, high speed, pipelined, triple-memory lookup. The underlying idea of the trigger design is to use the pattern of hits in the scintillator counters, Cherenkov counters and the electromagnetic calorimeters to find events. The front-end electronics in each sector produce signals from the TOF scintillators (32 signals per sector), CC (16 per sector), and the EC (6 per sector). Sectors 1 and 2 only consist of 2 additional signals from the LAC. Each of these signals indicate an energy deposition over a programmable threshold [1].

TLV1

The trigger level one (TLV1) crate is located on the third platform of the forward carriage of CLAS. TLV1 was designed to monitor all inputs to the level one trigger of CLAS. The crate provides the ability to determine trigger efficiency and detect problems with the level one trigger while data is being collected. TLV1 uses time-to-digital converters (TDCs) to record the rising and falling edges of input signals to the level one trigger. Without the TLV1 crate, knowledge of which inputs actually issued the trigger are unknown.

Installation and Testing

TLV1 is made up of a FASTBUS crate with 6 LeCroy 1877s TDCs. The majority of the level one trigger inputs are located on the second platform of the forward carriage of CLAS. Approximately 800 feet of cable was needed to get all of the trigger bit information to the TLV1 crate.

The LeCroy Model 1877s provides 96 channels of either Common Start or Common Stop multi-hit Time-to-Digital Conversion. All inputs are differential ECL. Each channel can store up to 16 hits within a 32 μs full scale range. The full scale range may be programmed from 0 to 32 μs. Control registers configure the TDC to report either the time of the rising edges, falling edges or both [2].

The TDCs in TLV1 have been configured to work in common stop mode. They have been programmed to record 2 hits and both edges. This allows the crate to record the rising and falling edge of the input signal to the level one trigger. The range of the TDCs were programmed to retrieve 1200 ns from their buffer. In order to view additional signals that may have appeared after the level one trigger has issued a stop, the stop cable for the crate was made long enough to provide a 120 ns delay in the signal to the crate.

There are 80 channels (5 modules with 16 channels each) available per sector for inputs to the level one trigger. The TDCs in TLV1 have 96 channels, 6 modules with 16 channels each, available for inputs. The input configuration of the level one inputs to the TLV1 TDCs are shown in table 1.

Sector 1 TOF double	Sector 2 TOF triple	———	Sector 4 EC	Sector 5 CC	Misc bits
Sector 1 TOF triple	Sector 2 LAC	Sector 3 EC	Sector 4 CC	Sector 6 TOF double	Misc bits
Sector 1 LAC	Sector 2 EC	Sector 3 CC	Sector 5 TOF double	Sector 6 TOF triple	———
Sector 1 EC	Sector 2 CC	Sector 4 TOF double	Sector 5 TOF triple	———	———
Sector 1 CC	Sector 3 TOF double	Sector 4 TOF triple	———	Sector 6 EC	———
Sector 2 TOF double	Sector 3 TOF triple	———	Sector 5 EC	Sector 6 CC	———

Table 1: The connection configuration of the TDCs in TLV1. Each column represents a single TDC module and its six inputs (16 channels each). The horizontal lines in the table represent a slot in the TDC where no connection is made.

The EC and TOF systems use two separate identical output drivers to generate their trigger signals. One output provides a signal to the level one trigger, and the other output is used to drive a signal to a scaler crate. To prevent any signal degradation to the level one trigger, the inputs to the TLV1 crate were taken from the scaler inputs.

The CC system has only one output driver for generating its trigger signals; therefore, the inputs to TLV1 had to be taken from the inputs to the level one trigger. The CC system does not send a signal to a scaler crate. If the Cherenkov system had already been providing a signal to the level one trigger and a scaler crate, the addition of TLV1 would have required special accommodations.

Because additional connectors and cable length were being added to the existing scaler inputs, the output drivers were first tested in the lab to ensure they could handle the additional cable lengths and the added termination from the TLV1 TDCs. A configuration was setup to simulate the installation of the TLV1 crate in the hall. Some signal degradation and reflections were viewable on an oscilloscope with the addition of TLV1, but the signal loss was not significant enough to cause any problems with the current configuration. Figure 2 shows the effects of adding the TLV1 crate in addition to the pre-existing scaler configuration. Approximately a 50 ns delay in the signal to the TLV1 crate can also be seen. This is because the scaler crate is located a short distance from the trigger inputs and has a cable length of about 5 feet. The TLV1 crate is located on the floor above the trigger inputs and has a cable length of about 35 feet.

Since one of the goals of TLV1 is to display the inputs to the level one trigger as they are seen by the trigger, the time at which the signals are seen in the TLV1 analysis need to reflect the time at which they are seen at the level one trigger. This was done by measuring the delay in the cable lengths of TLV1 and those of the level one trigger. The difference in propagation delays is then adjusted in the software analysis of the crate. The delay in the cables was measured after completing the installation of the crate to ensure that the times reflected the actual cable lengths.

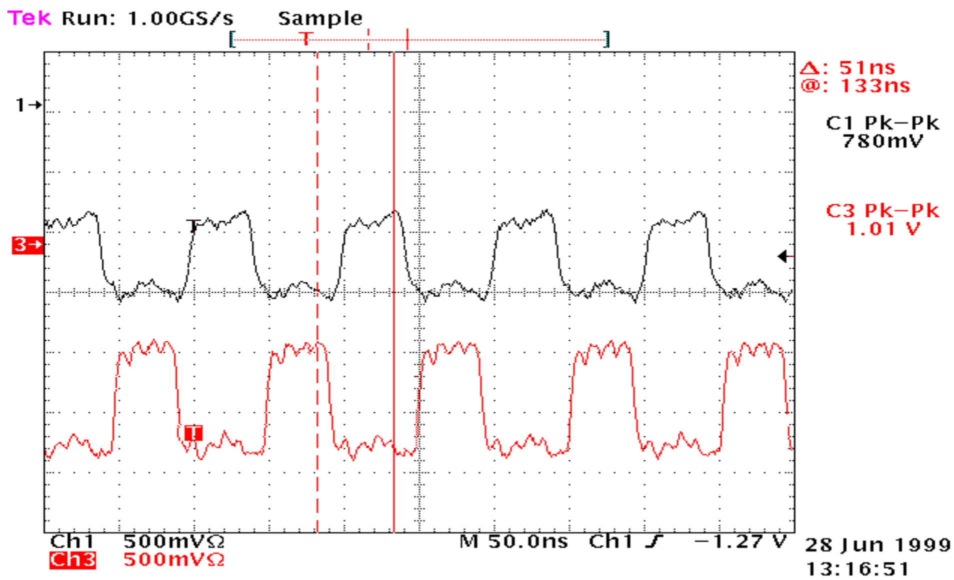

Figure 2: Signal of the current configuration with the addition of TLV1. The top signal is seen by the TLV1 TDCs and the lower signal is seen by the scaler inputs. Approximately a 50 ns delay is apparent in the signal to the TLV1 crate.

Analysis Software

The analysis software for the crate was written using the C++ programming language. The analysis software was written to support the Linux and Solaris operating systems. The Linux operating system was supported because of its large use at the lab. The Solaris operating system was supported because all system monitoring software is done in the hall B counting house using the Solaris platform.

The CERN ROOT analysis software is used to generate the histograms and the GUI interface for the crate. The ROOT system is an object oriented framework for large scale data analysis [3]. ROOT is written in C++ and made it easy to integrate into the analysis software developed for the crate.

The bank name used to record the data collected with the crate and is called the TLV1 bank. The bank consists of a single memory word format with two short integers (id and value). The id is configured as follows: (id = detector $*$ 256 + channel). The detector is composed of 4 different num-

Table 2: The delay measured for the time-of-flight cables.

TOF Sector	TLV1		Level One	
	Double	Triple	Double	Triple
1	60 ns	60 ns	20 ns	20 ns
2	60 ns	61 ns	20 ns	20 ns
3	60 ns	61 ns	20 ns	20 ns
4	71 ns	71 ns	20 ns	20 ns
5	71 ns	70 ns	20 ns	20 ns
6	70 ns	70 ns	20 ns	20 ns

Table 3: The delay measured for the Cherenkov cables.

CC Sector	TLV1	Level One
1	38 ns	38 ns
2	38 ns	38 ns
3	39 ns	38 ns
4	39 ns	38 ns
5	39 ns	38 ns
6	38 ns	26 ns

bers. These numbers are assigned to the different detectors as follows: CC = 1, TOF = 2, EC = 3 and the LAC = 4. The channel number reflects which input channel for that detector the data corresponds to. The value stores the time recorded by the TDC. The TDCs record times in units of half of a nano-second. Therefore, the data in value should be divided by 2 in order to get the obtain time intervas in nano-seconds.

Trigger inputs

Each sector of the time-of-flight system uses 57 scintillator strips with a photo-multiplier tube (PMT) at each end. These are divided over four panels and surround the CLAS detector. 1–23 are mounted on panel 1 and are referred to as the forward angle counters and cover a range of 8^o to 45^o. The

Table 4: The propagation delay measured for the electromagnetic calorimeter cables.

EC Sector	TLV1	Level One
1	60 ns	7 ns
2	59 ns	7 ns
3	59 ns	7 ns
4	59 ns	7 ns
5	59 ns	7 ns
6	59 ns	7 ns

Table 5: The propagation delay measured for the large angle calorimeter cables.

LAC Sector	TLV1	Level One
1	72 ns	6 ns
2	72 ns	11 ns

remaining counters are considered large angle counters and cover a range of 45^o to 142^o. The last 18 counters are paired into 9 logical counters. This grouping results in the system having a total of 48 logical counters [4].

The signals from the PMTs are sent to an analog-to-digital converter (ADC) and a TDC. The information from the ADC is used to determine the amount of energy deposited into the scintillator material, and the TDC information is used to determine where the particle hit the scintillator. The total energy is then the square root of the left times the right ADC. The location is then the left minus the right TDC time.

The time-of-flight system accounts for 32 channels of input per sector to the level one trigger. The first 16 channels are made up by overlapping counters 1–17. Each channel represents the sum of two counters (i.e. 1–2, 2–3, . . . , 16–17) and are referred to as the double inputs. The remaining counters overlap to make up the last 16 channels of input to the level one trigger. These channels are the sum of three counters (i.e. 17–18–19, 19–20–21, . . . , 47–48) and are referred to as the triple inputs.

The Cherenkov counters make up another 16 inputs per sector to the level one trigger. The Cherenkov detectors serve the functions of triggering on electrons, and separating electrons from pions [5]. The Cherenkov is divided into 18 regions. Each region has a PMT on left and right side which generate 36 signals for the level one trigger.

The electromagnetic calorimeters generate an additional 6 channels of input per sector. The calorimeters are made up of a lead-scintillator sandwich design consisting of alternating layers of scintillator strips and lead sheets. There are 39 layers in the sandwich, each consisting of a scintillator followed by a lead sheet. For the purpose of readout, each scintillator layer is sliced into 36 strips, with the slice orientation rotated by 120° in each consecutive layer. Thus there are three orientations (labeled U, V and W), each containing 13 layers. Each view is further subdivided into an inner 5 layer and an outer 8 layer stack. Each module thus requires 36(strips) $\times$ 3(views) $\times$ 2(stacks) for a total of 216 PMTs per sector [6]. The large angle calorimeters also contribute another 2 channels to the level one trigger. However, they are located in sectors 1 and 2 only.

Level One Analysis

The level one trigger can be set up to use multiple trigger configurations. Trigger configurations are arranged to meet the needs of an experiment. During photon experiments, the trigger typically requires a coincidence betweet the tagger, start counters and the time-of-flight system or electromagnetic calorimeters. In electron experiments, the trigger is usually set up as a coincidence between the Cherenkov counters and the electromagnetic calorimeters.

Photon experiments

After completing the installation of TLV1, the first set of experiments performed at the lab were photon experiments. These experiments use the TOF and EC in their trigger configurations. The first results inspected from the crate were the times of the input signals to the level one trigger. This data shows the rising and falling edges of the inputs to the trigger.

Because the TDCs work in common stop mode, the timing information appears in reverse order. When reading the timing information from the crate, it needs to be understood that at time equal to 0 is when the TDCs received their stop signal. At this time, the TDCs read back 1200 ns into their buffers. The first peak closest to 0 represents the falling edge of the input signal. The second peak farthest from 0 represents the rising edge of the input signal.

TOF system

Figure 3 shows the timing plots made for the TOF during a photon experiment. These plots are the result of all 32 input channels for the TOF system. Only 600 ns of the 1200 ns read out by the TDCs is used to make these plots. This gives a general overview of the TOF trigger inputs and is also useful in determining the pulse width of the input signals.

More detailed information on individual channels is accomplished by generating a two dimensional plot. Figure 4 shows a two dimensional plot of the TOF trigger inputs. This represents the time versus channel of the inputs to the level one trigger. The vertical axis represents the 32 channels of input, and the horizontal axis represents the time when the edge transition was seen. This plot allows users to see the results of each individual input channel.

The trigger from the TOF counters is initiated by events that deposit energy in the scintillators greater than some preselected value. The PMT dynode pulses go to a pretrigger circuit where two signals are produced. One of these signals goes to the level one trigger, and the second is a gate pulse which is used to accept the corresponding signals of the low-level discriminators [4]. The anode pulse is sent to the ADCs and TDCs. The efficiency plot helps to determine if the connections between the PMT and hardware are working correctly.

With the information collected by the TLV1 and SC banks, enough data is available to determine the trigger efficiency for the time-of-flight system. This is done by making two separate plots and dividing them to make a third plot. The first plot is made by collecting data from the SC banks. The information from the SC bank is used to determine if the energy deposited in the scintillator was sufficient to generate a trigger event. The second plot uses the same information that was used to make the first plot. However, in addition to the information from the SC bank, this plot uses the information from the TLV1 bank to determine if the scintillator actually generated a trigger event. The third plot is then the second plot divided by the first plot to give the efficiency of each scintillator in the system.

The first plot requires that both the left and right ADCs are greater than 10 counts after subtracting the pedestal values. Then the $\sqrt{\text{left\_adc} \times \text{right\_adc}}$ is done to determine the energy deposited in the scintillator. It also requires that both the left and right TDCs are greater than 10 and less than 4000. The requirements of greater than 10 ensure that data in the TDC is not zero, and the requiring the TDCs to be less than 4000 ensures that the TDC did not overflow.

The second plot is made by taking the same data collected to make the first plot, but then adding the information from the TLV1 banks. The information collected from the TLV1 banks is used to determine if the scintillator(s) issued a trigger bit. Figure 5 shows the results of this plot. This plot gives a good overview of how the different counters in each sector are contributing to the level one trigger inputs. This is also helpful in determining which counters may have a dead or dying PMT and/or a bad connection to an ADC or TDC.

Figure 6 shows the result of dividing the two plots. The majority of the counters in the TOF system have an efficiency greater than 98%. This plot is a good representation to show that the connections between the PMTs and the hardware are in good working order. However, this plot does not show the effects of a dying PMT. The results of a dying PMT are better be seen in figure 5. The efficiency plots are a unique part of the TLV1 analysis. Before the installation of TLV1, the trigger bit information was not available.

The information from the TLV1 crate is also used to generate a trigger distribution plot for the different systems. These plots represent the number of hits for each input channel to the level one trigger. Figure 7 shows the distribution of the 32 channels in the TOF system. These plots are also useful in identifying hot channels in the level one trigger.

Electromagnetic Calorimeters

Figure 8 shows the timing plots made for the EC system during the same photon experiment. These plots are the results of all 6 channels for the EC system. Again only 600 ns of the 1200 ns read out by the TDCs is used to make these plots. This plot shows a general overview of the EC trigger inputs. The pulse width of the input signal can also be determined from looking at the timing plots.

More detailed analysis on the individual input channels from the EC is done by making a two dimensional plot. The plot shows the time versus input channel. The time of the edge transition is represented on the horizontal axis, and the input channel is represented on the vertical axis. Figure 9 shows the results of making the two dimensional plot of the EC trigger inputs.

Trigger distribution plots are also made for the EC system. Figure 10 shows the distribution of the 6 channels in the EC system. Sector 1 shows an input signal in channel 9 which is not apparent in the remaining sectors. This signal is produced by a 10 MHz clock. This channel is not used by the EC system and does not issue any trigger events. This is prevented in the level one trigger programming by reading these unused channels as don't care conditions.

Electron Experiments

During electron experiments, the analysis of the Cherenkov detectors were possible. In electron experiments, the times generated by the CC and the EC are of interest because a trigger is issued when there is coincidence between the CC and EC systems. In the event that the trigger may not be functioning correctly, the times from the CC and EC can be compared to ensure that they are forming a coincidence. This is easily done with the timing plots generated by the TLV1 analysis software. The plots can be printed onto a transparency and then layered one over the other to analyze their timing windows. The time at which their signals show up at the level one trigger can be determined as well as the pulse width.

The timing plots for the CC are the sum of all 6 input channels to the level one trigger. Figure 11 shows the timing plots made for the CC system using data from the TLV1 crate. This information can also be used to find the pulse width of the input signal. The pulse width for the CC input signal is approximately 60 ns.

More detailed information on individual channels is also accomplished by generating a two dimensional plot. Figure 13 shows a two dimensional plot of the CC trigger inputs. This plot represents the time versus the input channels to the level one trigger. The vertical axis represents the time when the edge transition was seen by the TLV1 crate. This plot gives users the ability to see the results of the individual input channels.

The efficiency plots for the CC are made in a similar fashion as those for the TOF system. The efficiency plot is the result of dividing two histograms. The first histogram is made using the information collected with the CC banks. This plot is made by finding out which counters in the Cherenkov should have generated a trigger hit. Then the second histogram is made by using the same information to make the first plot, but also requiring that the counter actually generated a trigger hit. A hit is determined by finding if the counter has information in the TLV1 bank for that event. The efficiency plot is the result of dividing the second histogram by the first. Figure 14 shows the second histogram that is created by using the data from the CC and TLV1 banks. This plot is also useful in showing how the different counters are contributing to the level one trigger inputs.

Figure 15 shows the result of dividing the two histograms. The majority of the Cherenkov counters have an efficiency greater than 95%. This plot is also a good representation for showing that the connections between the PMTs and the hardware is in good working condition.

A trigger hit distribution plot is also made for the CC system. This plot shows the number of hits for each channel in the system. Trigger bits 1–8 represent the left PMTs, and trigger bits 9–16 represent the right PMTs. These plots are useful in determining if the CC has a hot channel in the system. Figure 16 shows the distribution of the 16 channels in the CC system.

The TLV1 GUI

The TLV1 GUI is the front end for the crate. This provides any user with the ability to view the data collected with the TLV1 crate. The user has the option to look at data from a file or the event transfer (ET) system. The ET system provides the program with the data as it is being recorded. This is how the analysis code gets the data it needs for viewing the immediate results of the level one trigger. The ability to view information from a data file is also very important because it allows users to study the trigger after the data has already been taken.

Figure 17 shows the interface presented to the user when the GUI is first started. There are three menu bar items available to the user: File, which gives the user the option to print histograms to a postscript file or exit the program. StartRun, which gives the user the option of processing data from a file or the ET system. ChangeView, which gives the user the ability of selecting the different histograms generated by the analysis software.

After starting the program, the user has three options available to them. They process data from a file, process data from the ET system or exit the program. The remaining options are unavailable at this time. If the user is interested in looking at data file's, the option Enter File Names should be selected. After selecting this option, the user is presented with a dialog box which allows them to enter up to five file names (the full path is expected). Figure 18 shows the dialog box used to enter the file names. After entering the file names, the user will need to select the Begin Run option to start processing the different files.

If the user is interested in the performance of the level one trigger while data is being taken, the option Process ET events under the StartRun menu item should be selected. If the Process ET events is selected, the program will begin processing data immediately and does not require any further input from the user.

Once the program begins looping over data events, the different histograms under the ChangeView menu item can be selected. The histograms in the analysis software have been arranged to reflect the view of the CLAS detector. After the program has begun, the histograms will be present in the main body of the interface. To stop the analysis software, the option End Run should be selected under the StartRun menu item. After halting the program, the user is allowed to continue changing the view of the different histograms. This allows them to select different histograms for printing.

Summary

The level one trigger monitor for CLAS was designed to provide instant results of the level one trigger inputs. This gives collaborators the ability to study inputs to the trigger while the data is being taken. The analysis software has been designed to provide on-line and off-line analysis for the level one trigger. The software has been developed to run in the hall B counting house or on-site at Jefferson Lab. This gives collaborators the flexibility to be located anywhere on-site at Jefferson Lab and have the ability to obtain immediate results of the level one trigger inputs.

Acknowledgements

There were several people who were of great contribution to the completion of this project. Karen Hokansson made it possible to have office space and a computer while working at the lab. Chris Cueves answered many of the hardware related questions and made several trips to the hall to give advice while trouble shooting problems with the crate. Vardan Gyurjyan was very helpful in pointing out many of the sofware related problems. The fast electronics shop Mark Taylor, Bill Gunning, Jeff Wilson and Delisa Smith helped to fabricate hardware necessities and to provide technical assistance. This work was supported in part by the NSF.

References

[1] David C. Doughty Jr., James Englert, Russell Hale, Stephan Lemon, Patrick Leung, Christopher Cuevas and Donald Joyce "A VXIbus Based Trigger for the CLAS Detector at CEBAF," CLAS-NOTE-91-017, 1991.

[2] Model 1877S 96 Channel Fastbus Time-to-Digital Converter, Functional Description, LeCroy Corporation, May, 1997.

[3] Rene Brun, Fons Rademakers, "ROOT – An Object Oriented Data Analysis Framework," CERN Program Library, 1996.

[4] E.S. Smith, T. Carstens, J.Distelbrink, M. Eckhause, H. Egiyan, L. Elouadrhiri, J. Ficenec, M. Guidal, A.D. Hancock, F.W. Hersman, M. Holtrop, D.A. Jenkins, W. Kim, K. Loukachine, K. MacArthur, C. Marchand, B. Mecking, G. Mutchler, D. Schutt, L.C. Smith, T.P. Smith, S. Taylor, T.Y. Tung, A. Weisenberger, and R.E. Welsh "The Time-of-Flight System for CLAS" Nuclear Instruments and Methods in Physics Research, March 10, 1999.

[5] G. Adams, V. Burkert, T. Carstens, V. Frolov, G. Jacobs, M. Kossov, M. Klusman, B. Dross, J. Napolitano, J.W. Price C. Riggs, M.kossov, S. Majewski, Y. Sharabian, A. Stavinsky, C. Smith, P.Stoler, W. Tuzel, A. Vlassov, A. Weisberger, M. Witkowski, B. Wojtekhowski, C. Zorn "The CLAS Čherenkov Detector," accepted for publication by Nuclear Instruments and Methods in Physics Research.

[6] M. Amarian, G. Asryan, K. Beard, W. Brooks, V. Burkert, T. Carstens, A. Coleman, R. Demirchyan, Yu. Efremenko, H. Egiyan, K. Egiyan, H. Funsten, V. Gavrilov, K. Giovanetti, R.M. Marshall, B. Mecking, H. Mkrtchan, R.C. Minehart, M. Ohandjanyan, Yu. Sharabian, L.C. Smith, S. Stepanyan, W.A. Stephens, T.Y. Tung, C. Zorn "The CLAS Forward Electromagnetic Calorimeter," accepted for publication by Nuclear Instruments and Methods in Physics Research.

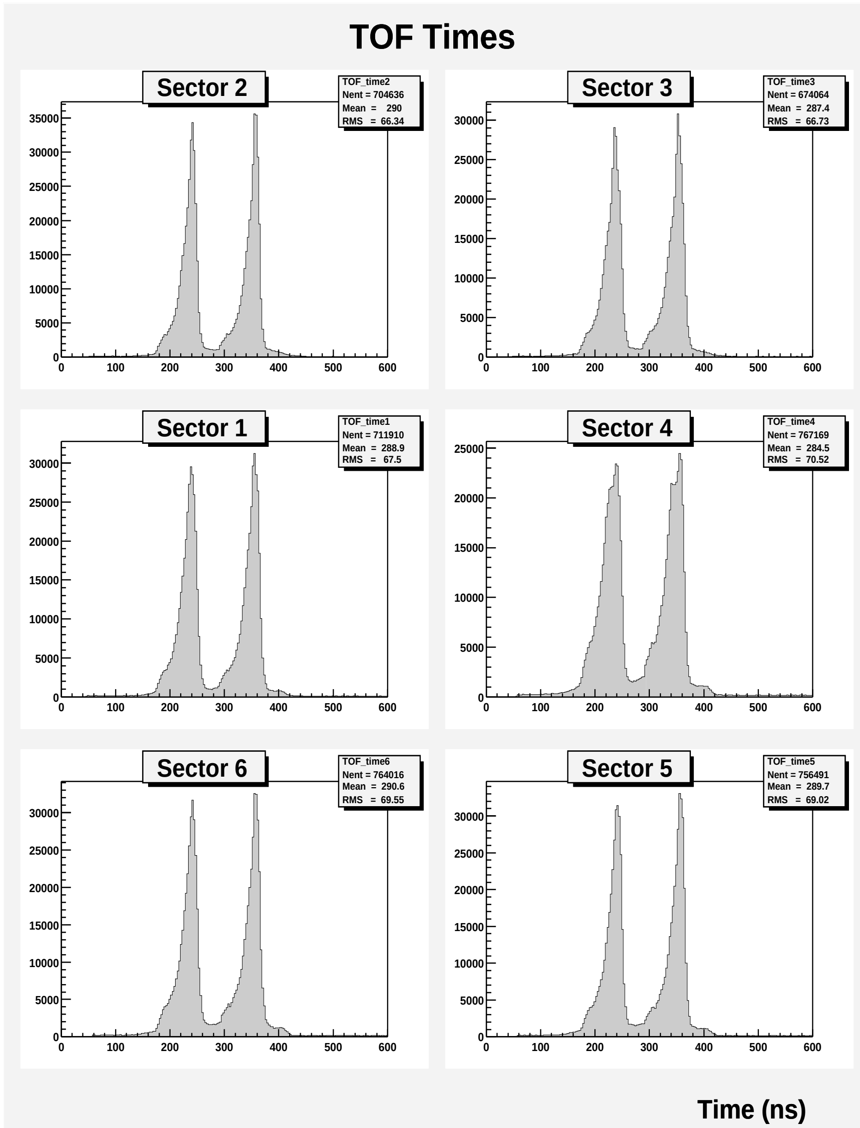

Figure 3: Timing plots for the TOF counters. The sectors are arranged as if looking at the CLAS detector. The TDCs in TLV1 work in common stop mode. The time at 0 ns represents when the TDCs received their stop signal. At this time, the data is then read out of the TDC buffer. As a result, the TDCs should be interpreted in reverse order. The peak closest to 0 represents the falling edge of the input signal, and the peak farthest from 0 represents the rising edge of the input signal. As can be seen, the pulse width of the input signal is approximately 115 ns. This plot is the result of all 32 channels per sector from the TOF into the level one trigger.

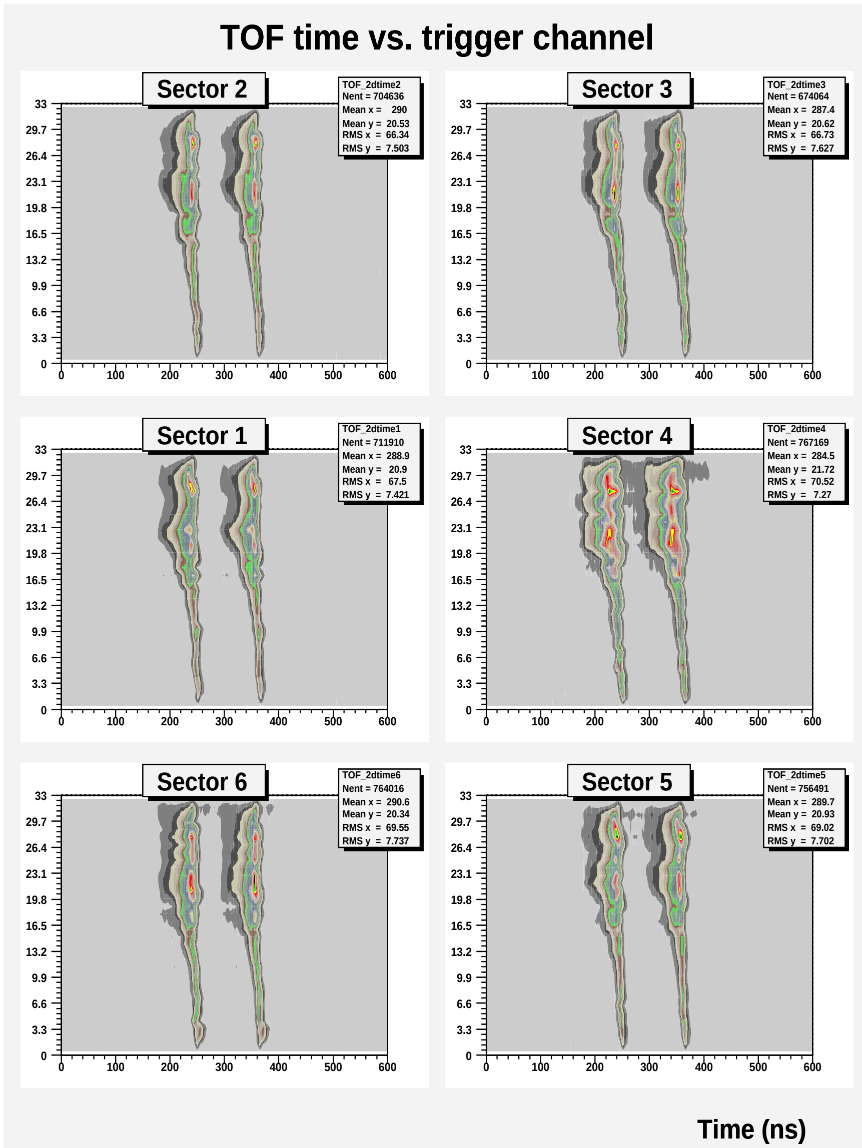

Figure 4: Two dimensional plot for the TOF counters. This plot shows the input channels versus time. This plot gives a good representation of the individual channels into the level one trigger. The vertical axis represents the 32 channels of input from the TOF, and the horizontal axis represents the time of the edge transition at the level one trigger. The deviation in times seen in the larger angle inputs is the effect of a neutral trigger that was used during the photon experiment.

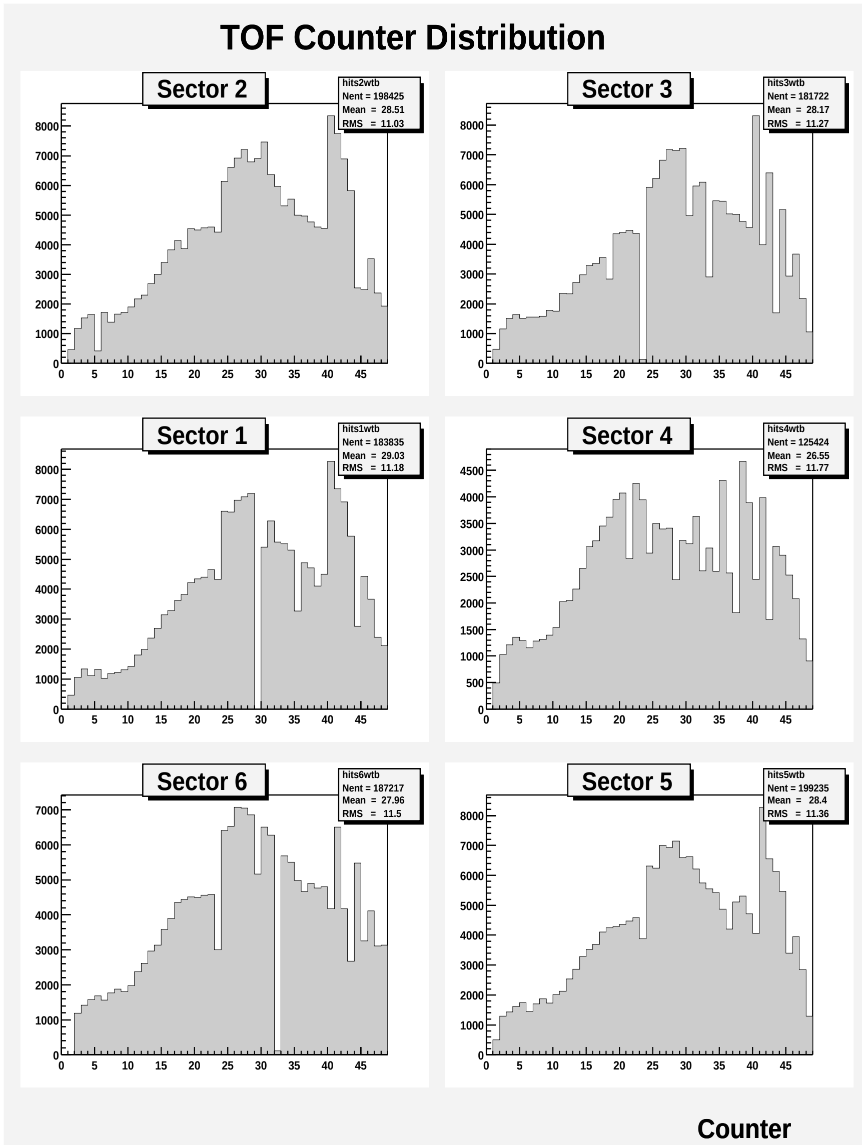

Figure 5: TOF counter distribution plot. There are 48 scintillator counters in the TOF time-of-flight system. This plot shows the results of the TOF counter trigger hit distribution. The number of times each counter has generated a trigger event is represented on the vertical axis. The horizontal axis represents the counter number for that sector. The Plots are arranged as if looking at the CLAS detector. These plots are also useful for detecting dead counters in the system.

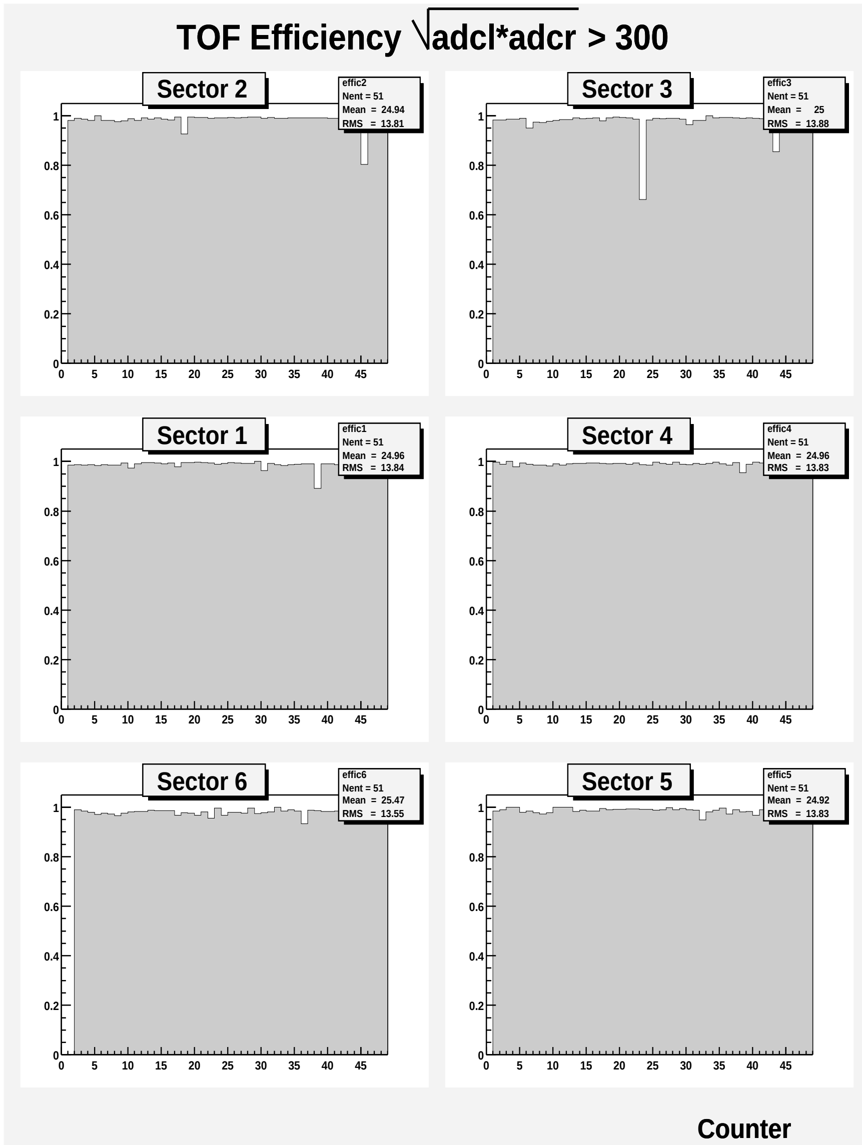

Figure 6: Efficiency plots for the TOF. The efficiency plots are the result of dividing two histograms. The first histogram is made by collecting information from the SC banks to determine if a counter should have generated a trigger event. Then a second histogram is made with the same information in the first plot, in addition, the second plot then checks the TLV1 bank to verify that the counter actually generated a trigger event. The second plot is divided by the first plot to generate the efficiency histogram. The results of the TOF show that the majority of the counters have an efficiency greater than 95%.

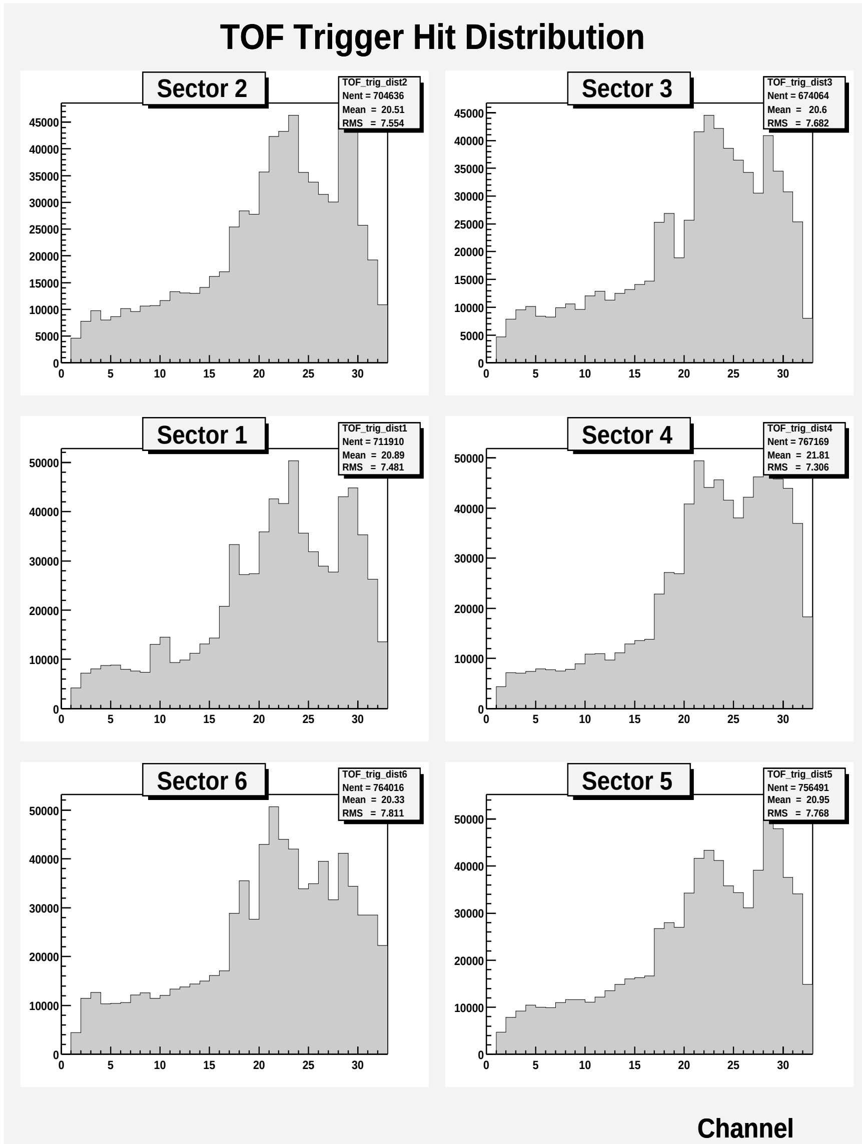

Figure 7: Trigger hit distribution for the TOF. This histogram shows the number of times that each input channel to the level one trigger generated a trigger event. The horizontal axis represent the channel number (1–32 for the TOF), and the vertical axis represents the number of trigger events for that channel. These plots are also useful in detecting hot channels to the level one trigger inputs.

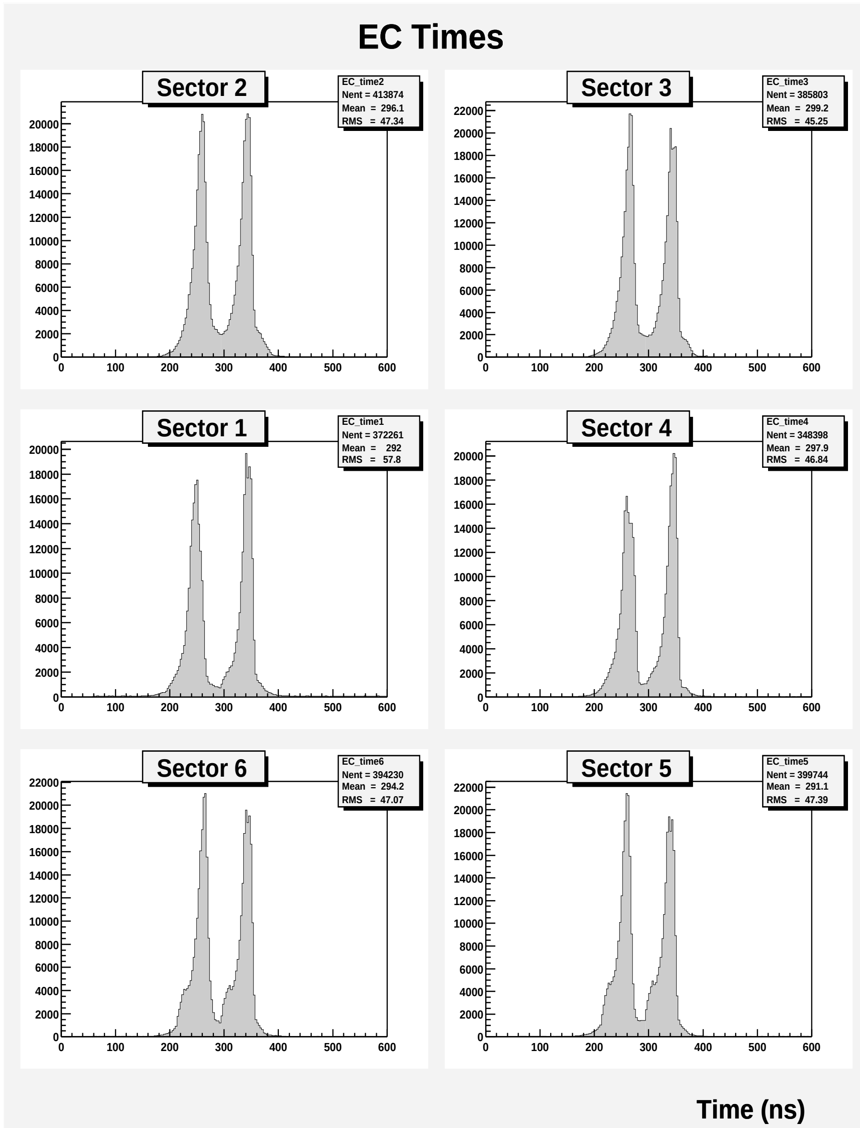

Figure 8: Time plots for the EC. Time 0 represents the time at which the TDCs received their stop signal. The peaks represent the rising and falling edges of the input signals to the level one trigger. The peak on the left represents the falling edge of the input signal, and the peak on the right represents the rising edge of the inputs signal. The pulse width can also be approximated from this plot. This plot shows that the pulse width is approximately 85 ns. These histograms represents all 6 channels of inputs from the EC during a photon experiment.

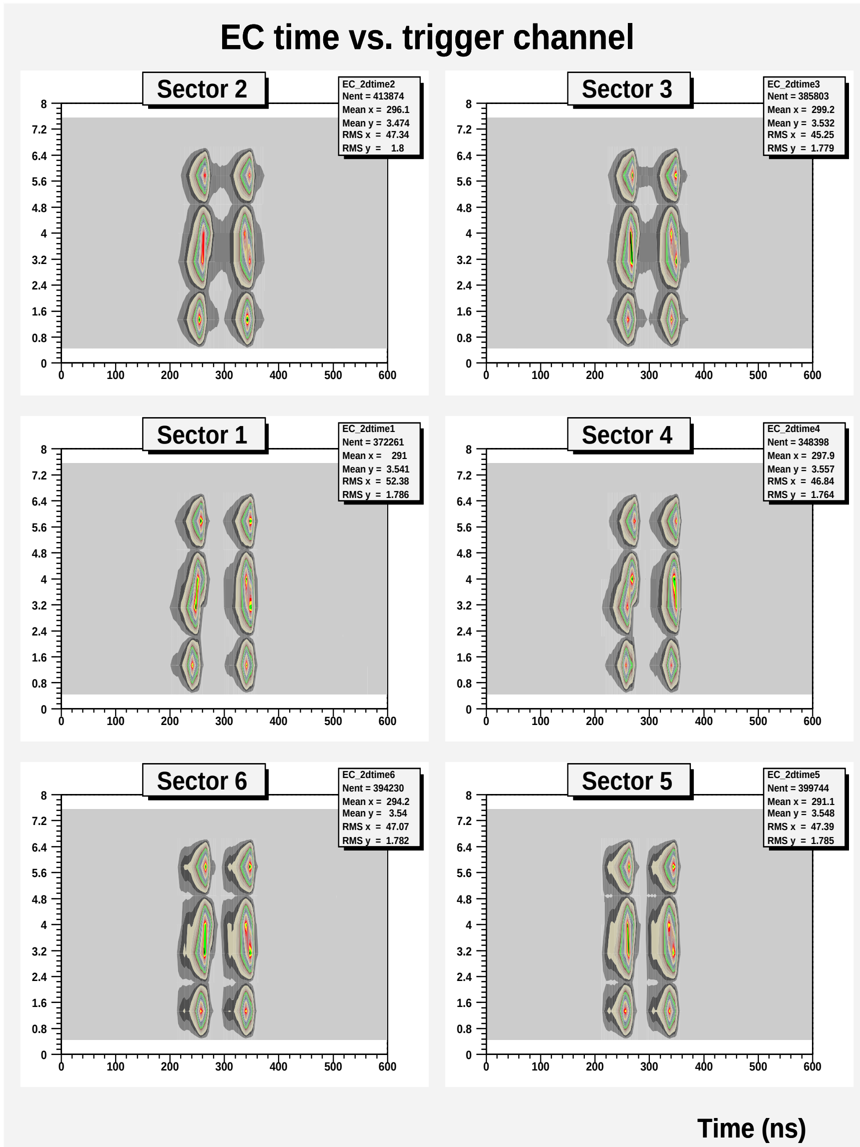

Figure 9: Two dimensional plot for the EC. This plot shows the input channels versus time. This plot gives a good representation of the individual channels into the level one trigger. The vertical axis represents the 6 channels of input from the EC, and the horizontal axis represents the time of the edge transition at the level one trigger.

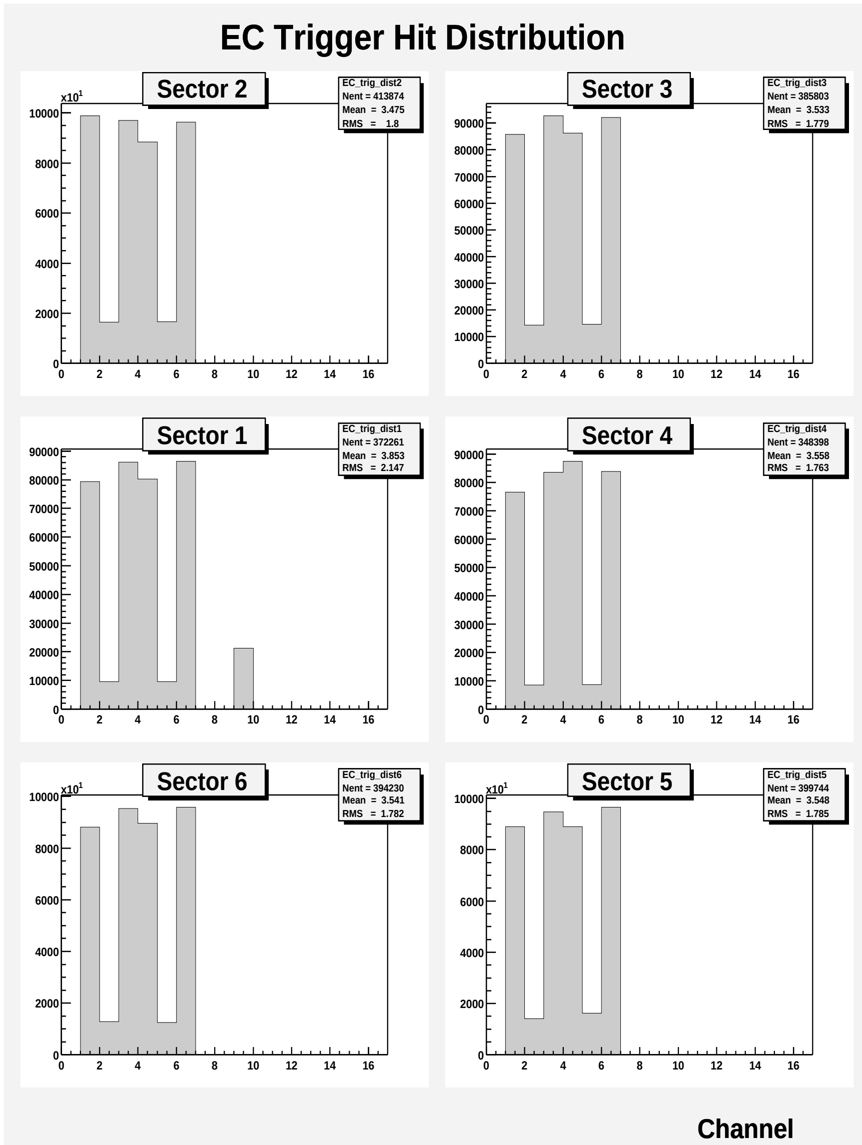

Figure 10: Trigger hit distribution for the EC. This plot shows the number of trigger hits for each input channel of the EC. Channel 9 in sector 1 shows an input signal to the level one that is not apparent in the remaining sectors. The EC uses only 6 channels of input for its level one trigger inputs. This channel is used to carry a 10 MHz clock signal. In the programming of the level one trigger, this channel is seen as a don't care condition and is ignored by the trigger.

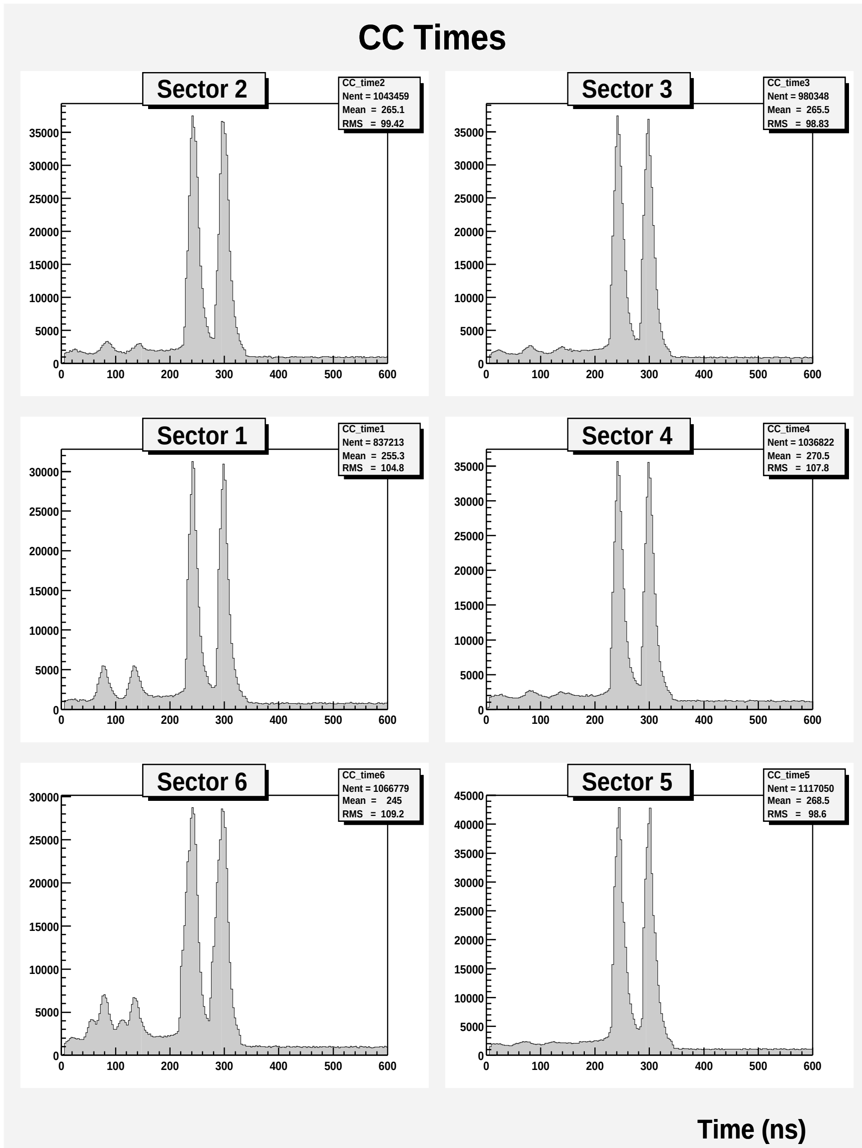

Figure 11: Time plots for the CC. Time 0 represents the time at which the TDCs received their stop signal. The two peaks represent the rising and falling edges of the input signals to the level one trigger. The peak to the left represents the falling edge of the input signal, and the peak to the right represents the rising edge of the input signal. The pulse width can also be approximated from this plot. This plot shows the pulse width is approximately 60 ns. These histogram represents all 16 channels of input for the CC.

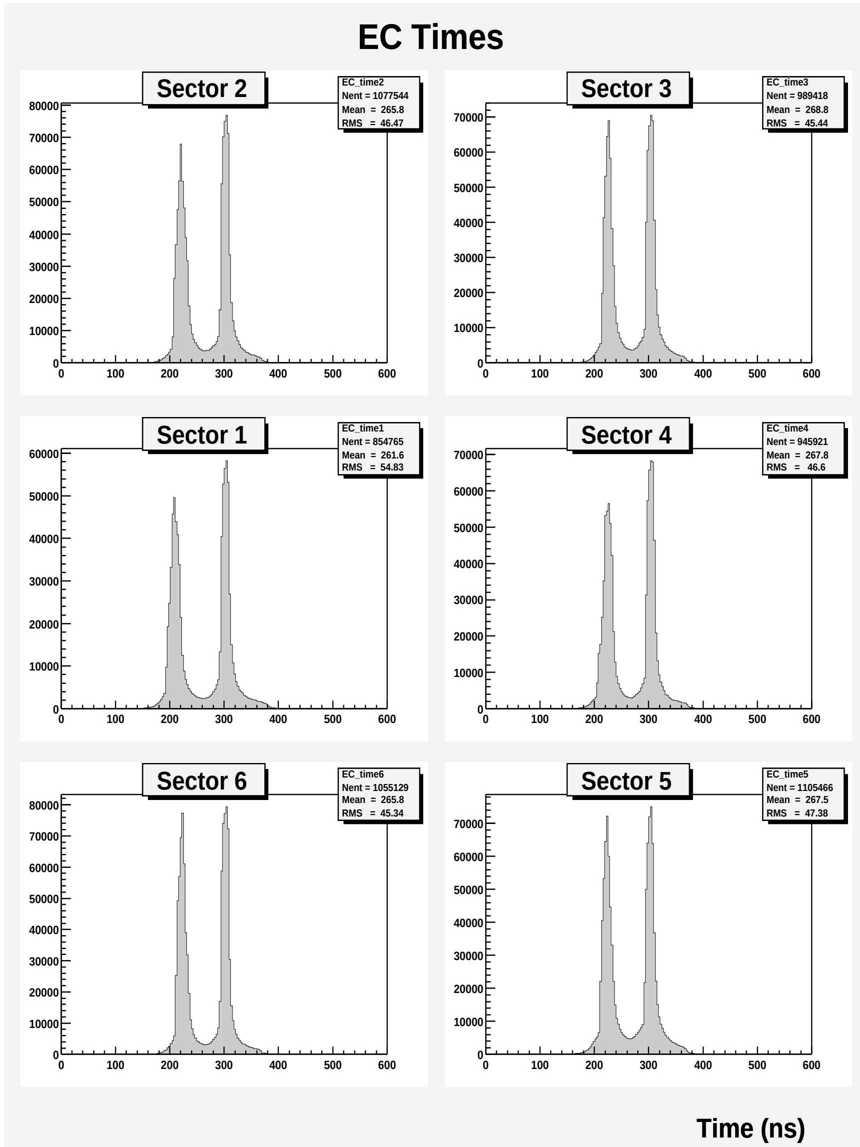

Figure 12: Time plots for the EC during an electron experiment. The two peaks represent the rising and falling edges of the input signals to the level one trigger. During electron experiments, the trigger is a coincidence between the EC and CC. These plots can be printed to an overhead and layered one over the other to determine the times at which each pulse is seen at the level one trigger.

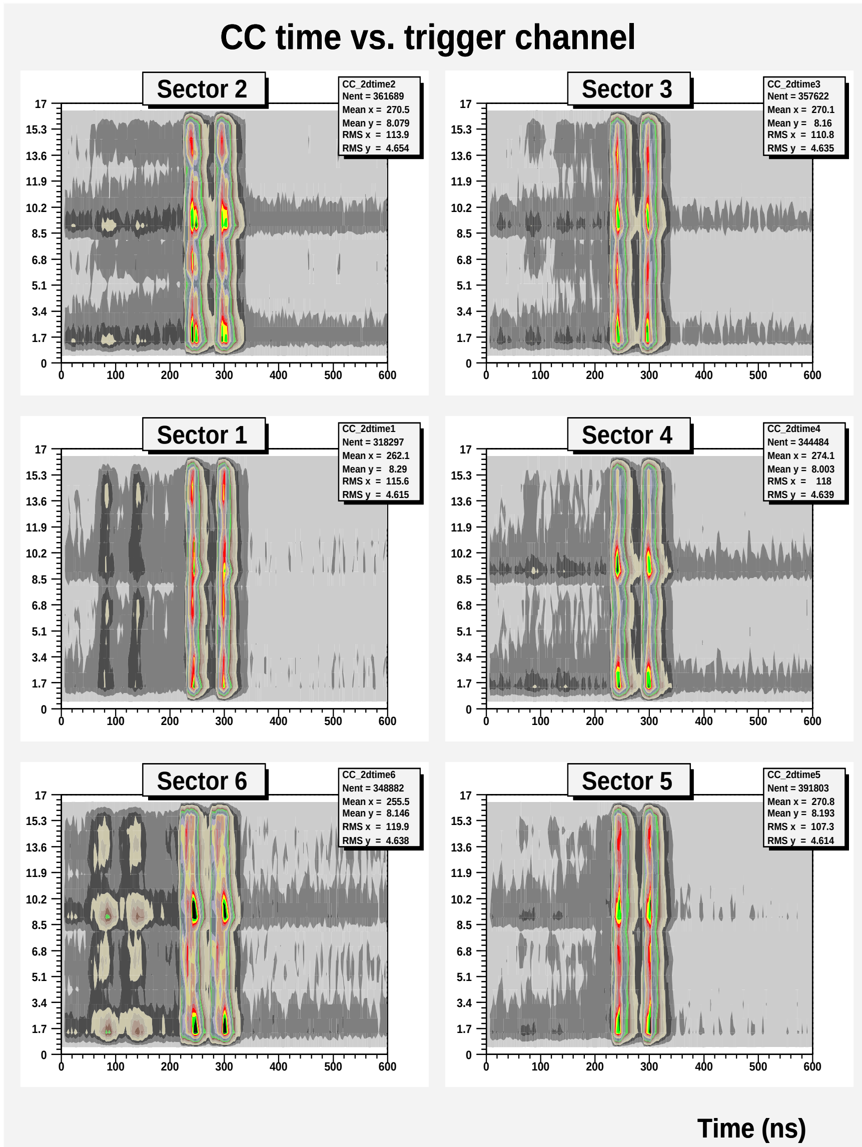

Figure 13: Two dimensional plot for the CC. This plot shows the input channels versus time. This plot gives a good representation of the individual channels into the level one trigger. The vertical axis represents the 16 channels of input from the CC, and the horizontal axis represents the time of the edge transition at the level one trigger.

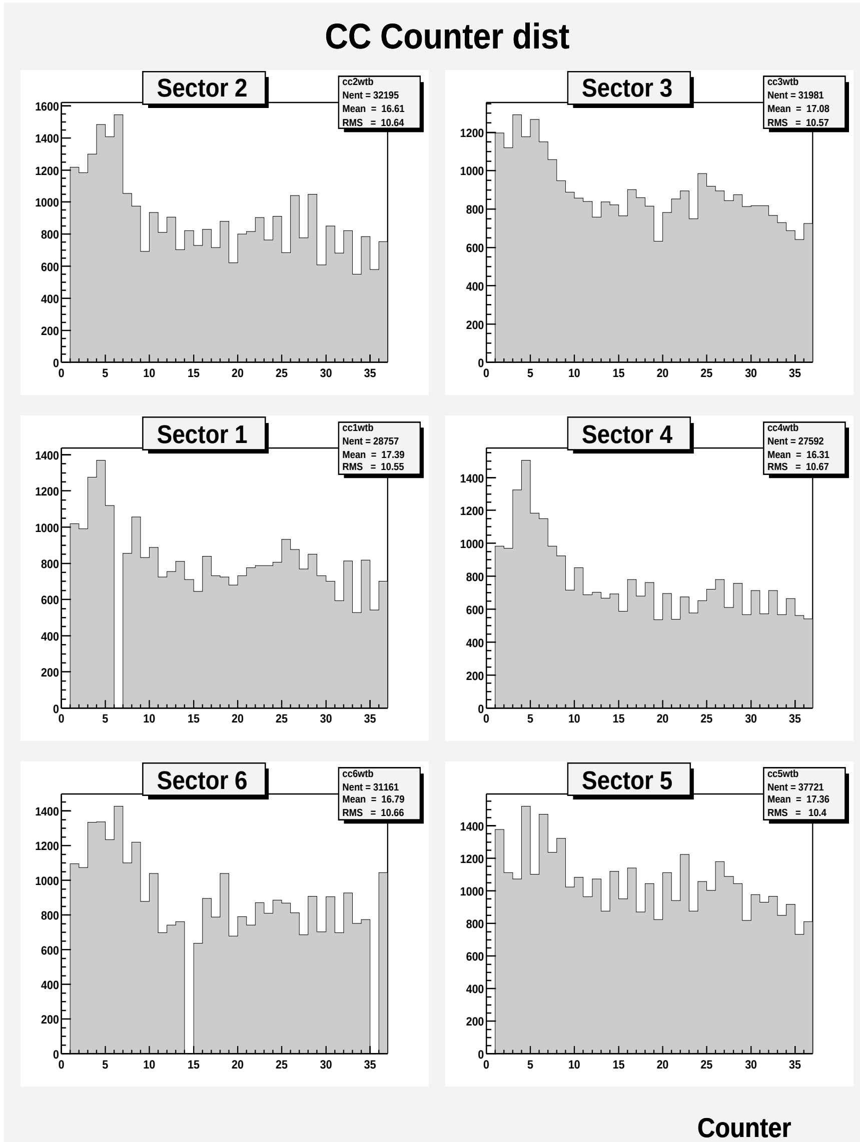

Figure 14: Counter distribution plots for the CC. There are 18 counters in the CC. Each counter has a left and right PMT. The PMTs form their own inputs to the level one trigger. The left PMTs are represented with odd numbers, and the right PMTs are represented with even numbers. This plot shows the number of trigger events generated by each of the PMTs. This plot is also useful in finding dead PMTs in the system. Sector 1 shows a dead PMT in counter 3R, and sector 6 shows dead PMTs at 7R and 18L. The number of times each counter has generated a trigger event is represented on the vertical axis.

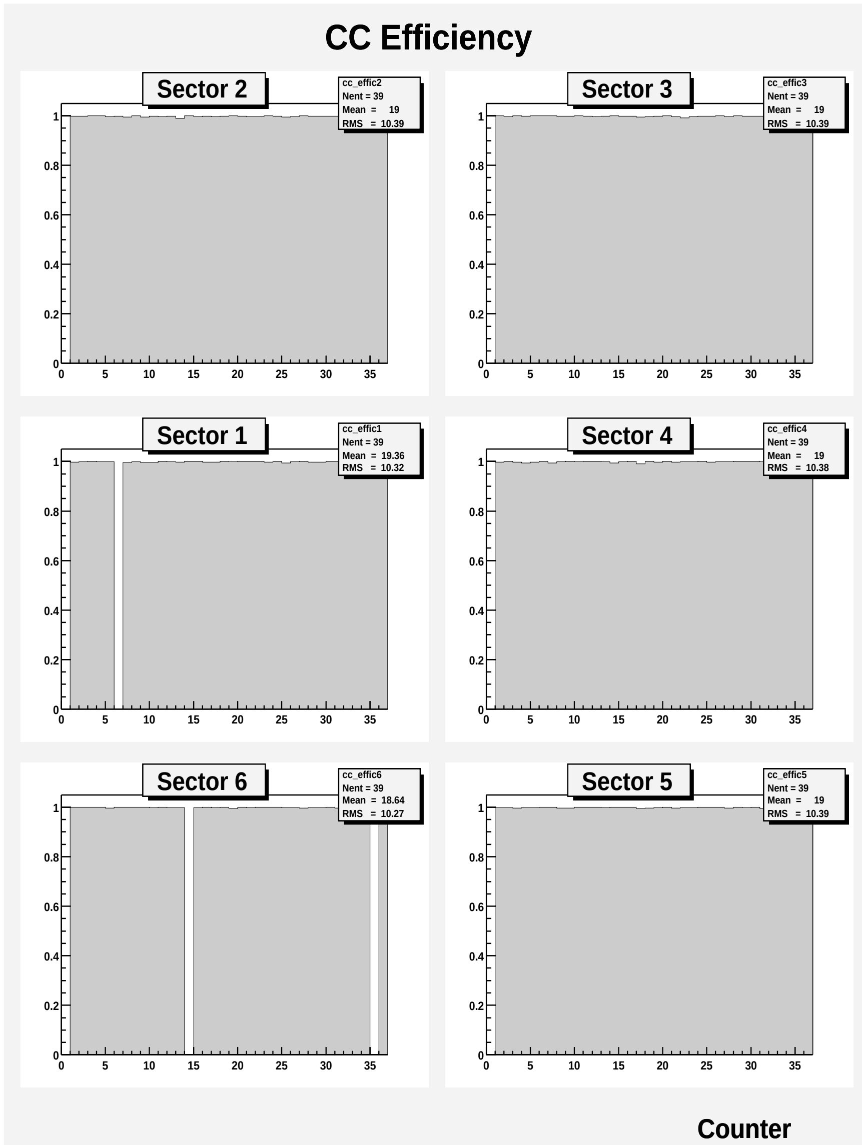

Figure 15: Efficiency plots for the CC. The efficiency plots are the result of dividing two histograms. The first histogram is generated by collecting information from the CC banks and determining if a counter should have generated a trigger event. Then a second histogram is generated by using the same information to create the first, in addition, the second histogram is generated by looking in the TLV1 bank to determine if that counter actually generated a trigger event.

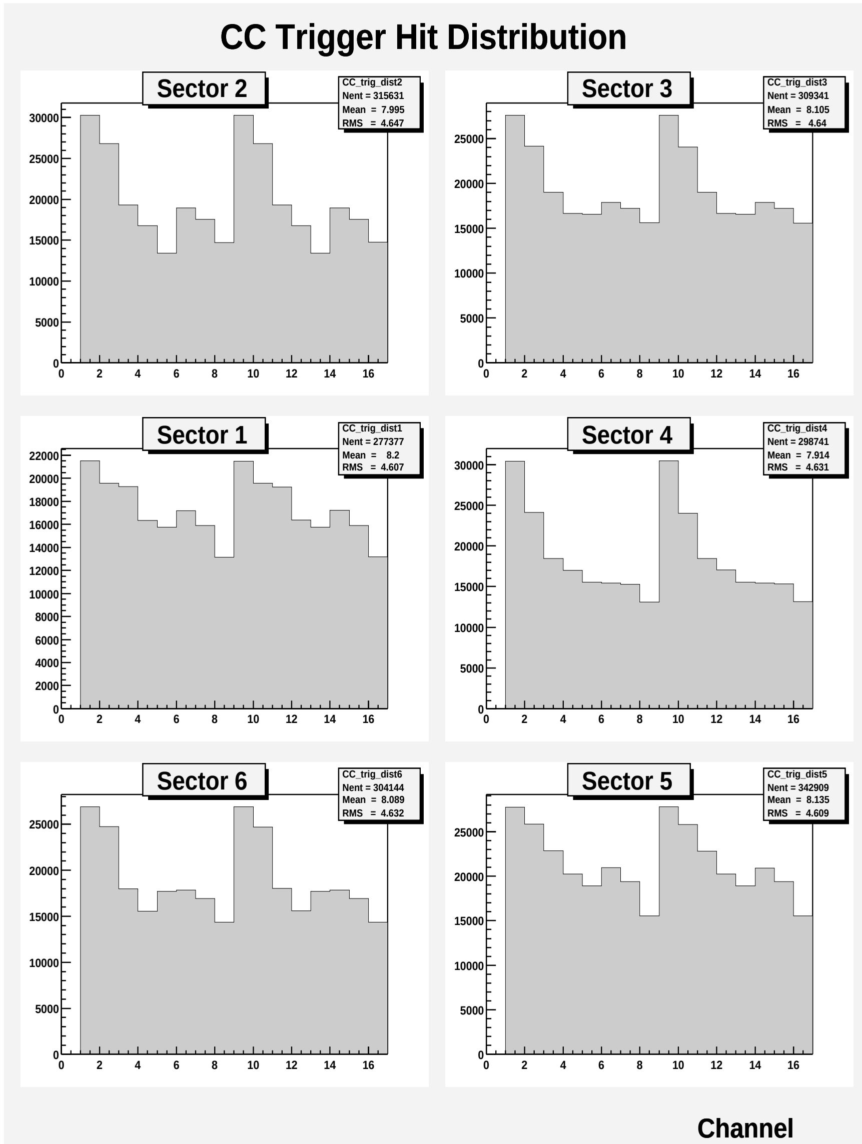

Figure 16: Trigger hit distribution for the CC. This plot shows the 16 channels of input from the CC to the level one trigger. The input channels 1–8 represent the summing of the left PMTs, and input channels 9–16 represent the summing of the right PMTs. The larger counter numbers represent the larger angle counters, and as a result, they have fewer hits than the lower angle counters.

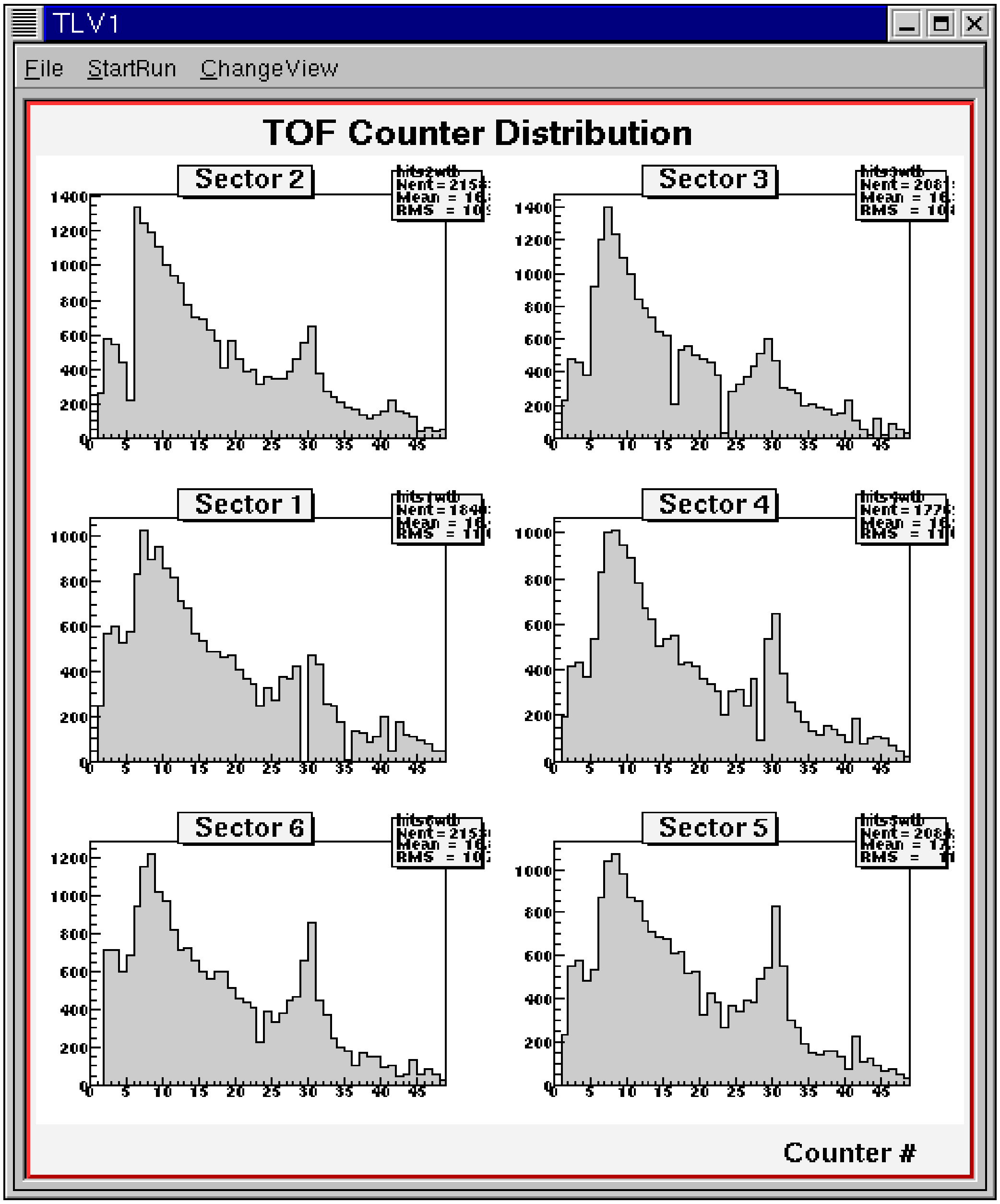

Figure 17: The TLV1 GUI interface. This is the interface presented to the user when the application is first started. All options available to the user are listed under the three different menu items.

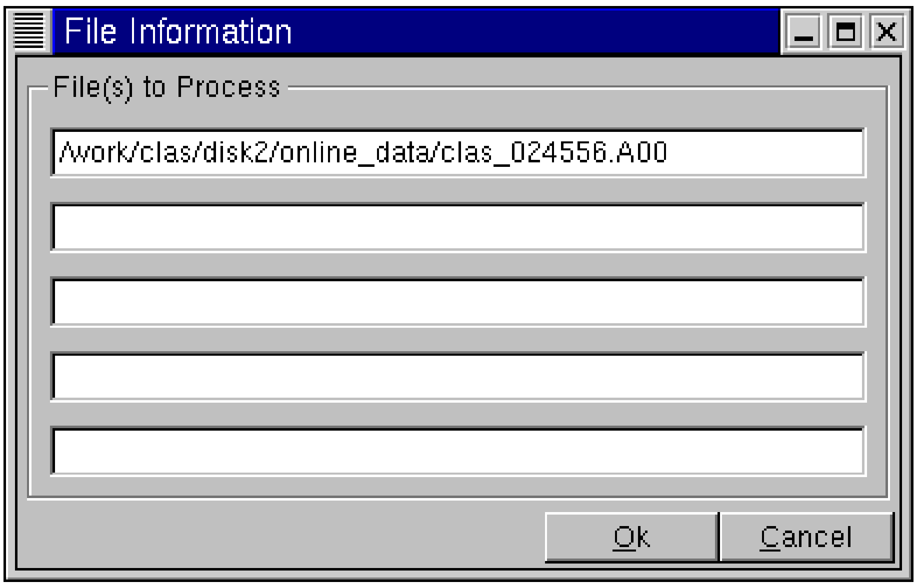

Figure 18: The file name dialog box for the TLV1 analysis software. This is the dialog box presented to the user for entering up to five file names. The file names can be up to 128 characters long. The files are processed in the order in which they are entered.