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Analysis of the Wire Chamber Test Stand (WCTS) Data

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Abstract

CEBAF's (Continuous Electron Beam Accelerator Facility) CLAS (CEBAF Large Acceptance Spectrometer) drift chambers are monitored by the WCTS, which runs CODA (CEBAF Online Data Acquisition) on a Linux operating system. CODA is the data acquisition program for CLAS. The WCTS collects Time-to-Digital Converter (TDC) and Analog-to-Digital Converter (ADC) data from 96 wires.

This project analyzes TDC and ADC data taken by the WCTS, extracts the signal, and determines the mean charge and sigma. Every ADC histogram contains pedestal and noise data. To determine the mean charge and sigma, a program was written using ROOT to fit a Gaussian curve to the pedestal, an exponential function to the noise, and to subtract both these from the histogram. The remaining data are fitted both with a Gaussian and a Landau function. The mean and sigma are determined. Over time, changes in the mean or sigma or both indicate wire-ageing effects or electronic malfunctions or both.

1 Introduction

The CLAS drift chambers track trajectories of charged particles. The drift chambers comprise three regions. Each region is divided into six sectors, each of which consist of two super-layers. These super-layers consist of cells -- 6 field wires surrounding one sense wire in a hexagonal patten [2]. Argon carbon-dioxide (90:10 by volume) is used as the drift gas [1]. Data are collected by CODA run on a Linux operating system.

Drift chambers and associated electronics are subject to ageing effects. Polymer deposits accumulate on wires. As a result, fewer electrons in the gas are ionized. Offsets on hardware may change causing data to vary from run to run. Therefore, drift chambers are monitored using the WCTS to provide advance warning of these effects.

The WCTS collects ADC and TDC data from 96 out of 2204 wires of a given drift chamber to check for wire-ageing effects or electronic malfunctions or both. A trigger schematic of the WCTS is shown in the Appendix (page 15). The mean charge and sigma of the ADC data are monitored. Changes in the mean or spread warn that the drift chamber is not functioning properly.

2 ADC Data Analysis

The raw ADC data from the 96 wires is displayed as 96 histograms using the program **WctsPlotter**. All raw ADC data contain pedestal and noise in addition to the signal. An example of a pedestal is shown in Fig. 1.

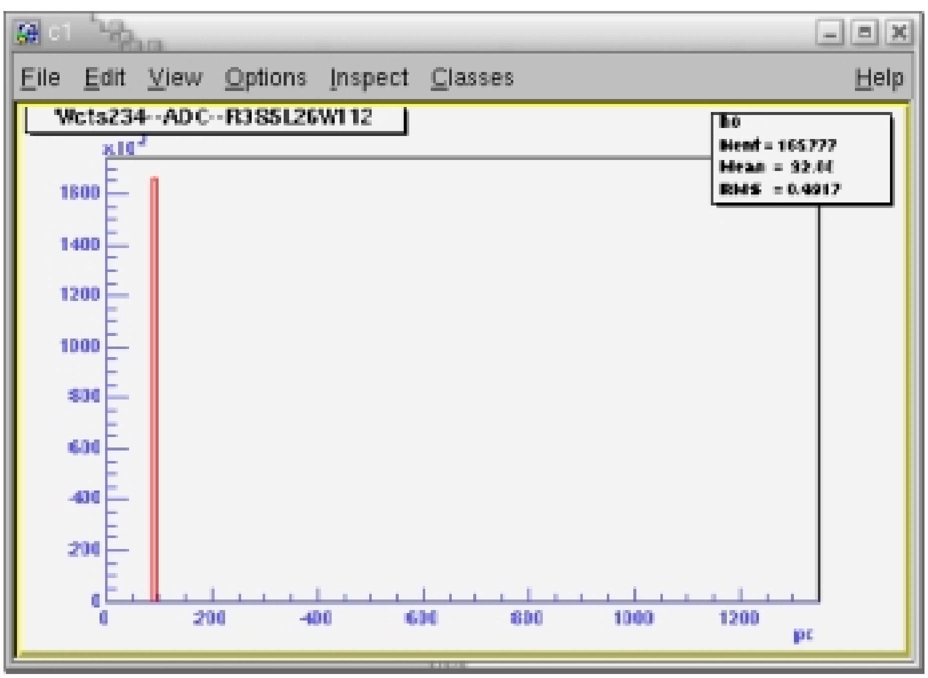


Figure 1. Pedestal ADC data

An ADC histogram from a WCTS data collection is shown in Fig. 2. Ideally, pedestal and signal should be distinguishable. However, in Fig. 2, pedestal and signal data are indistinguishable.

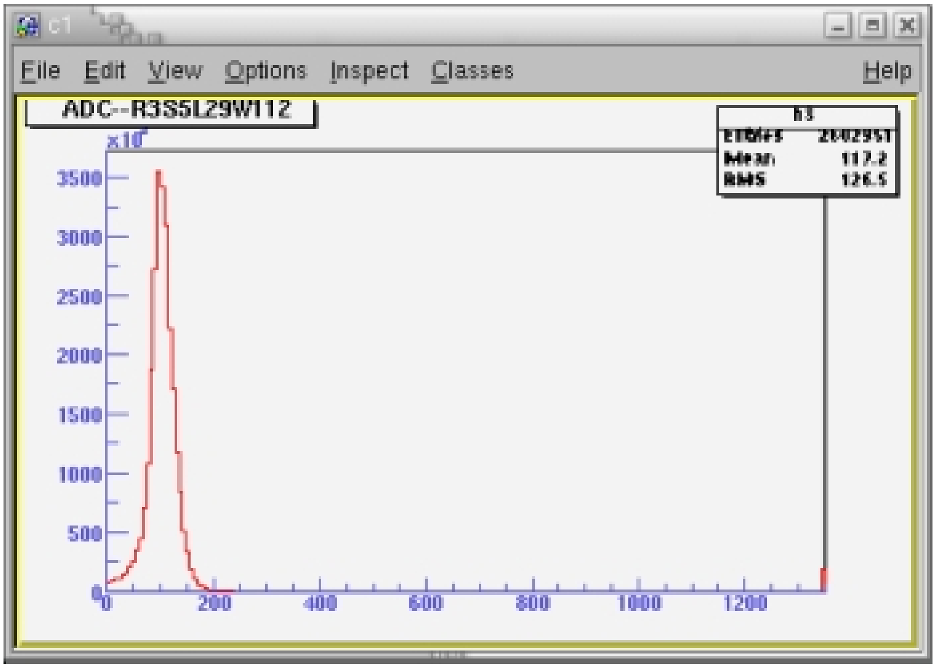


Figure 2. ADC histogram with indistinguishable pedestal and signal data.

To separate the pedestal and signal, the gain of the system was doubled. Fig. 3 shows an ADC histogram for a channel after the gain was doubled. The pedestal and signal have become slightly distinguishable. The pedestal appears to lie between 0 and 100 pC while a peak is seen at 200 pC.

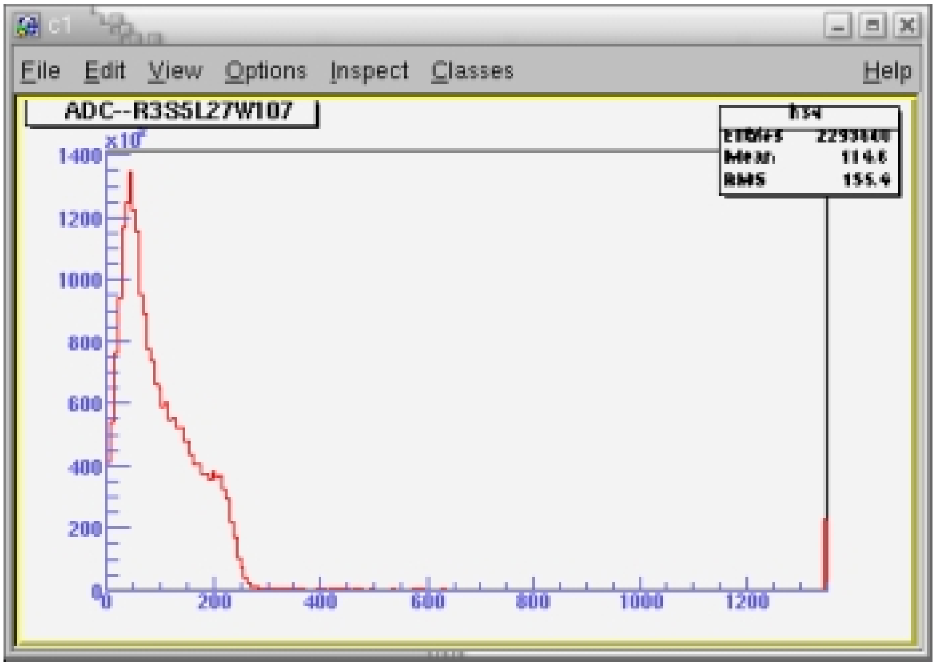


Figure 3. ADC histogram with signal amplified twice that of Fig. 2.

3 ADC Fit and Subtraction Program

Once the WCTS data were collected from the 96 wires, WctsPlotter displays the data as histograms and stores the histograms in a ROOT file. The program **adc_fit_histos.C** is a ROOT macro written in C. A flow chart for **adc_fit_histos.C** is in the Appendix (page 16). The user is prompted for an input ROOT file and the specific channel to be analyzed. The program analyzes the data using the following steps:

Step 1: **adc_fit_histos.C** displays the original ADC histogram for the specified channel. Channel 48 is shown in Fig. 4.

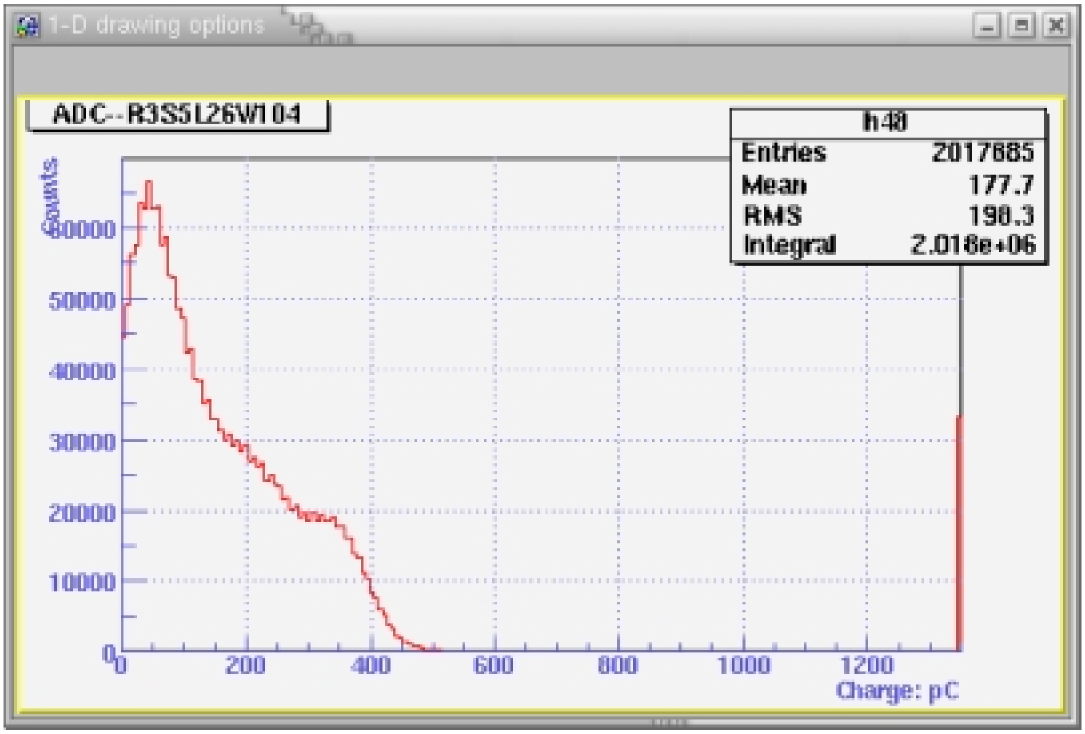


Figure 4. Raw ADC data histogram for Channel 48.

Step 2: Generally the pedestal lies between 0 and 200 pC. Thus, the peak at 50 pC indicates a pedestal. The shape of the pedestal is approximated by a Gaussian curve. The user inputs a fit range and a Gaussian is fitted to the pedestal. The fit is shown in Fig. 5.

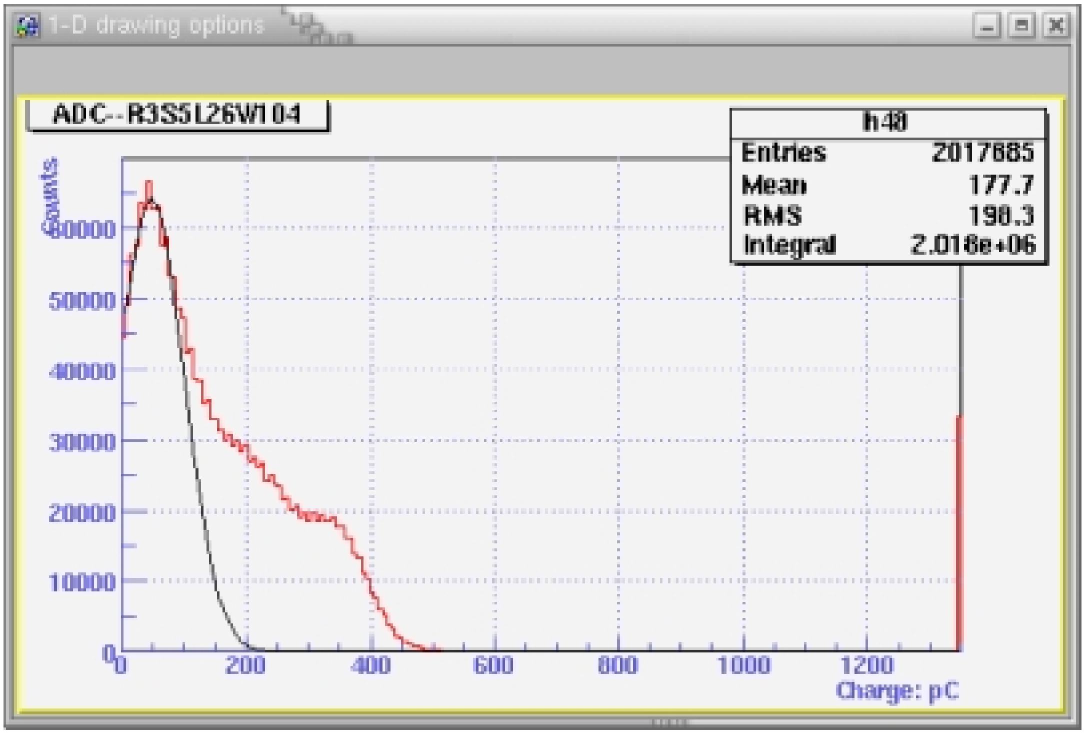


Figure 5. Gaussian fit to the pedestal.

Step 3: The pedestal is subtracted from the histogram in Fig. 6.

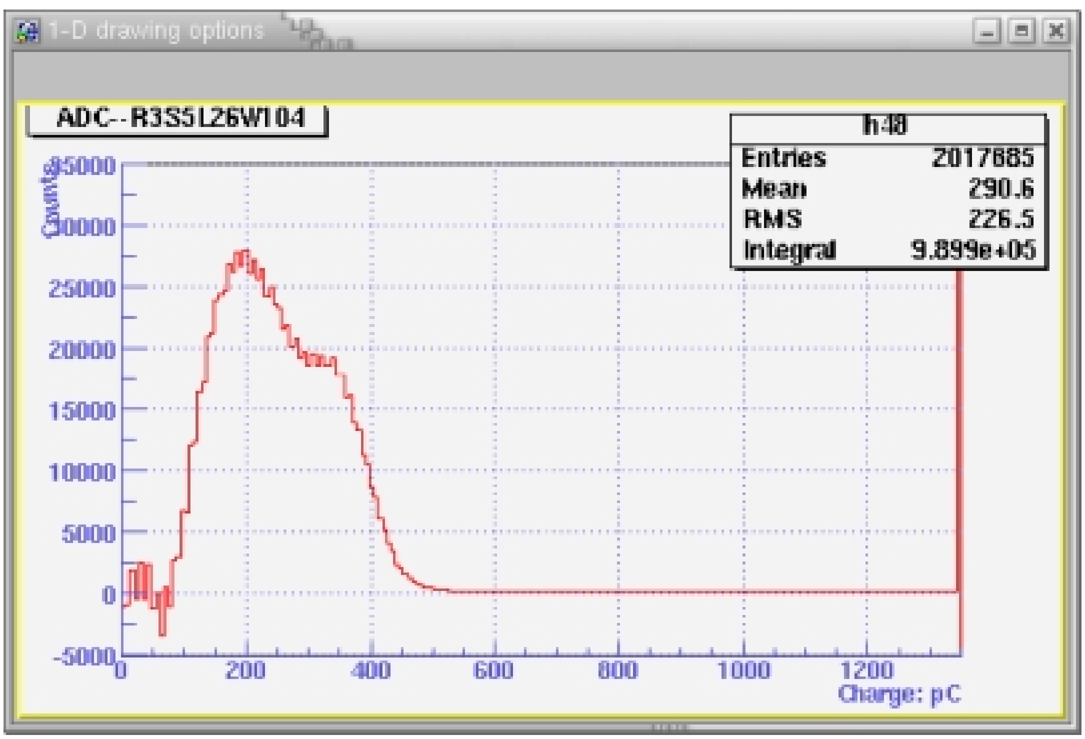


Figure 6. The pedestal is subtracted from the histogram.

Step 4: The histogram is displayed on a log scale to examine the noise data. The noise lies between 600 and 1350 pC. A linear fit models the noise on the log scale, which corresponds to an exponential fit on a linear scale. The exponential fit is made to the noise from 600 to 1350 pC as shown in Fig. 7.

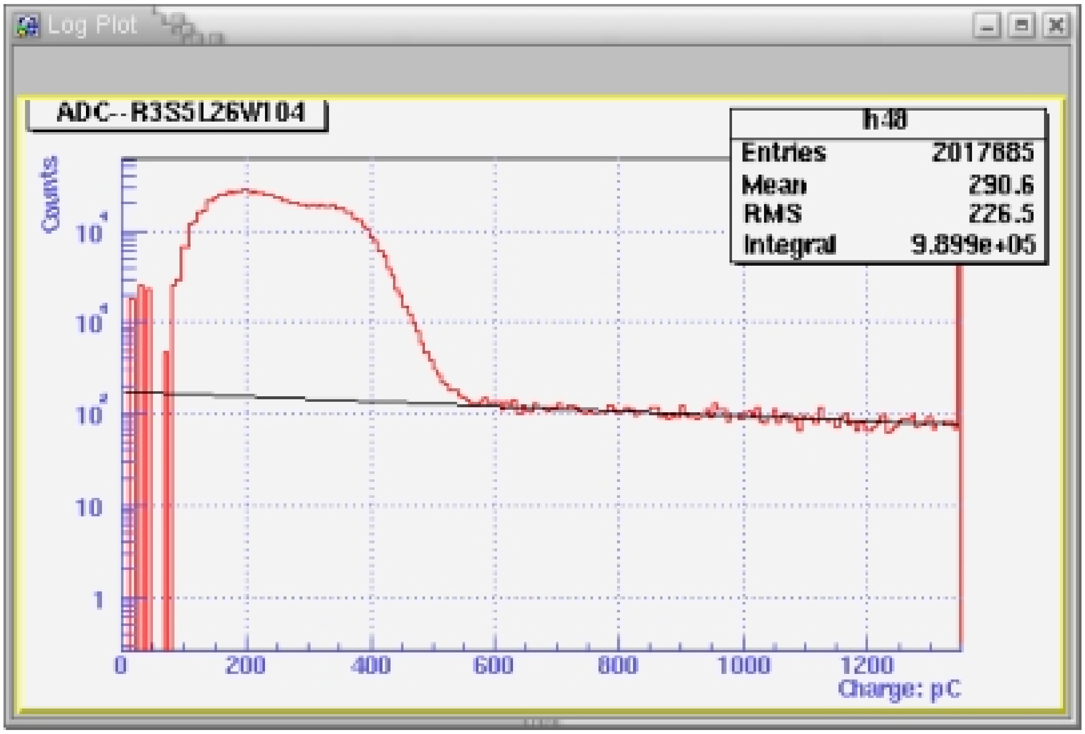


Figure 7. Exponential fit to the noise shown on a log scale .

Step 5: In Fig. 8, the noise data is subtracted from the histogram leaving the signal.

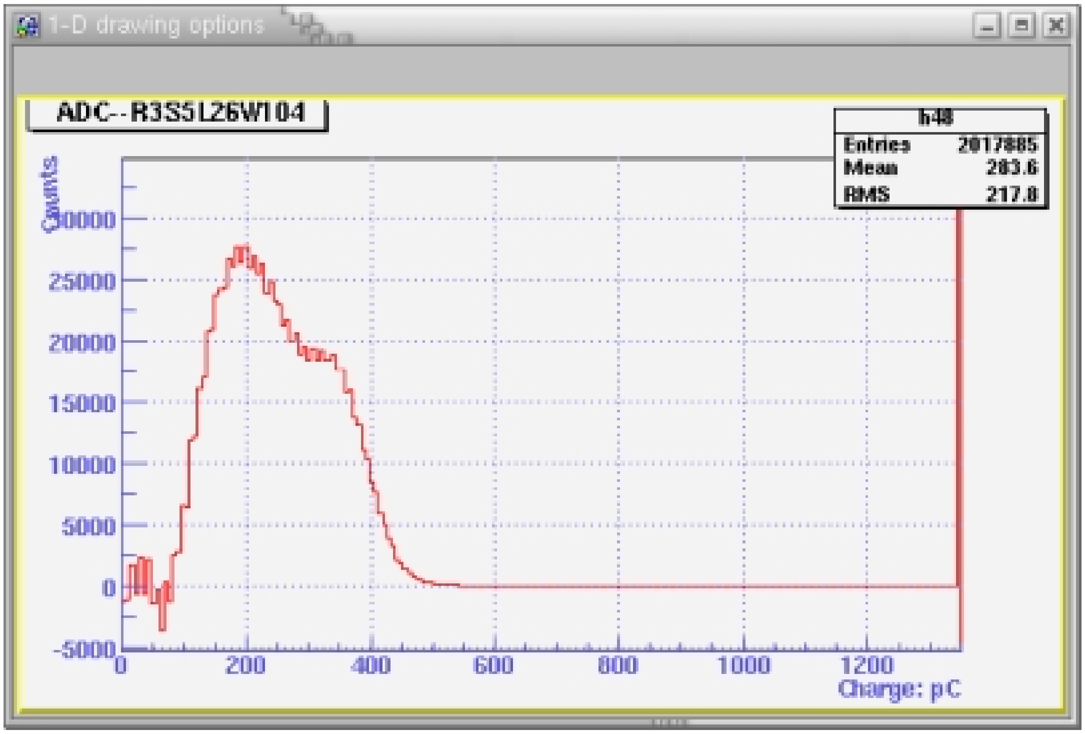


Figure 8. Signal data remaining after pedestal and noise are subtracted.

Step 6: The signal data are fitted with a Gaussian curve. The fit parameters -- in particular, the mean and sigma -- are displayed as well. The ideal signal data distribution is a Landau distribution; however, a Gaussian curve is used for simplicity. The peak of the Gaussian fit is identified as the mean charge.

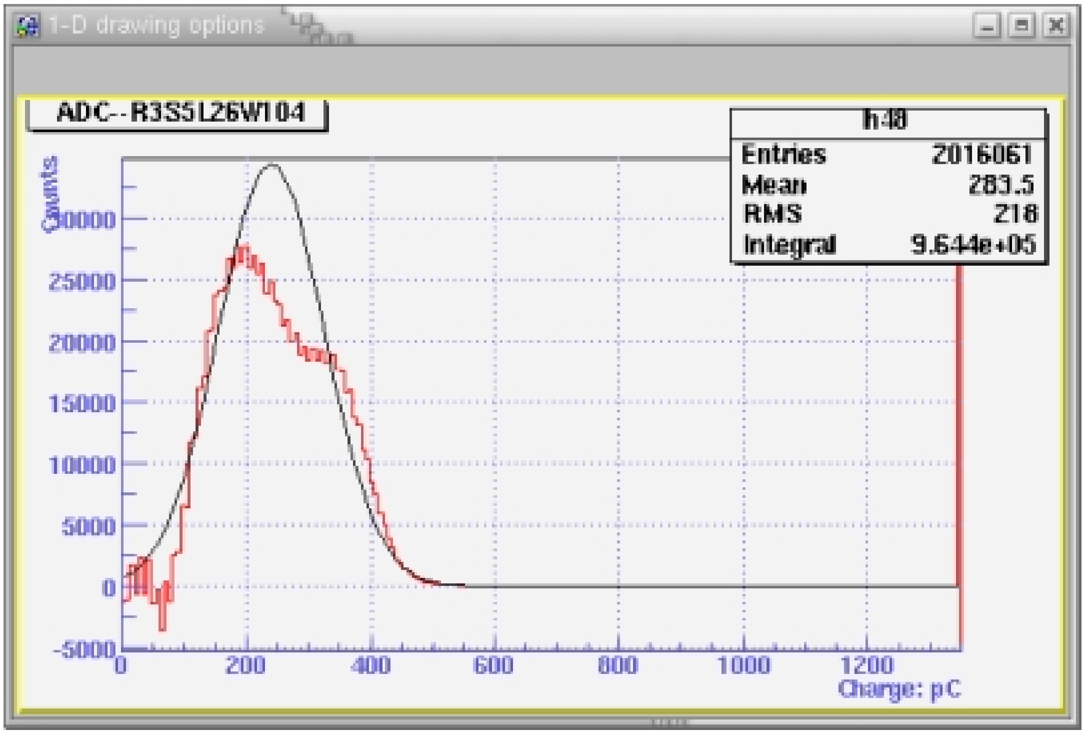


Figure 9. Gaussian fit to the signal data with constant 27000, mean 240, and sigma 95.

The signal should have a single peak, however, the signal has a double peak. Fig. 9 reveals a shortage of high charge data needed to create a single peak. A possible explanation for this cell inefficiency is a problem with the ADC gate timing. ADC data is collected within a gate time of 2 µs. Input pulses that arrive too early have only their tail end inside the gate. These pulses that arrive early were close to the sense wire and therefore are expected to have high charges. Thus, ADC integration of the tail end of these pulses will yield a lower charge than the actual charge.

Step 7: Ideally, the signal resembles a Landau function. A Landau fit to the signal is shown in Fig. 10. The fit parameters are shown and the mean and sigma identified.

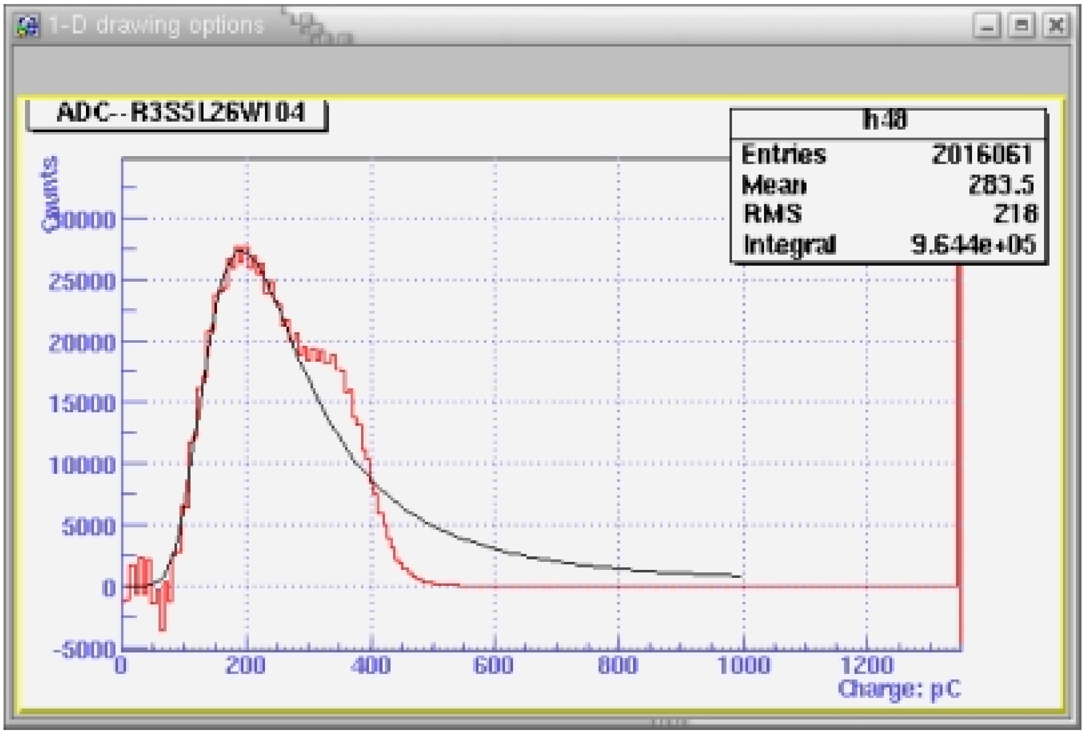


Figure 10. Landau fit to the signal with constant 147313, mean 214, and sigma 50.

The Landau fit also shows a shortage of data above 400 pC and an excess of data with charge between 300 and 400 pC. This finding further supports the conjecture that the ADC gate is not completely integrating signal pulses that arrive early. Only a portion of an early pulse is integrated. As a result, a pulse with high charge is integrated as a lower charge. The pulses with charge 400 pC and above are registered as having a charge between 300 and 400 pC.

4 TDC Data Analysis

The raw TDC data from the 96 wires is plotted on 96 histograms using **WctsPlotter**. Fig. 11 shows the TDC histogram for channel 48. TDC histograms plot shorter drift times to the right end and longer drift times to the left end. The TDC stop is at 0 ns in the histogram -- 3500 ns after the shortest possible drift time. The longest possible drift time is 1500 ns. Good TDC data lie in the range of 2000-3500 ns.

ADC data contain more entries than TDC data because the ADC gate collects data as long as there is a trigger signal. TDC data is collected only when a particle travels through one of the 96 wires being tested by the WCTS and is in coincidence with the trigger signal.

Figure 11. Histogram of raw TDC data for Channel 48.

After both pedestal and noise are subtracted from the ADC histogram, the remaining data should be signal. These data are analyzed further using a C++ program titled **adc_tdc_plots**, which displays a TDC or ADC histogram for events within specified charge and time ranges.

The ADC histogram is examined after Step 5. The signal data lies between 100 and 500 pC. Analyzing TDC data checks for ADC noise in this range. **adc_tdc_plots** displays a TDC histogram for events within the ADC range 100 to 500 pC. The histogram is shown in Fig. 12.

Signal data are defined to be those events which register both a TDC hit between 2000 and 3500 ns and an ADC signal. Thus, the ADC signal data should, in principle, have only TDC data between 2000 and 3500 ns. TDC data between 0 and 2000 ns are identified as noise.

In Fig. 12, the events between 0 and 2000 ns are by definition noise. The program **adc_tdc_plots** then displays an ADC histogram, shown in Fig. 13, for those noise events.

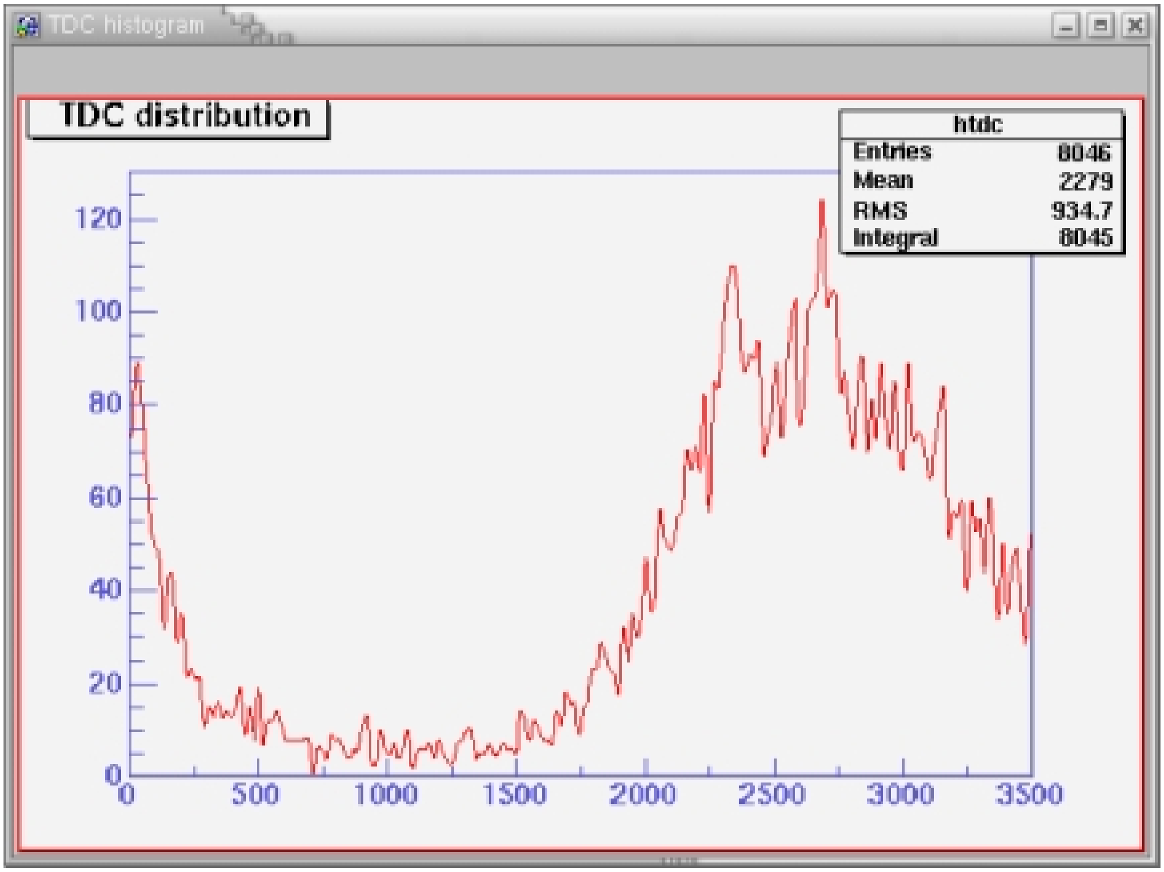


Figure 12. TDC histogram for events of charge 100 to 500 pC.

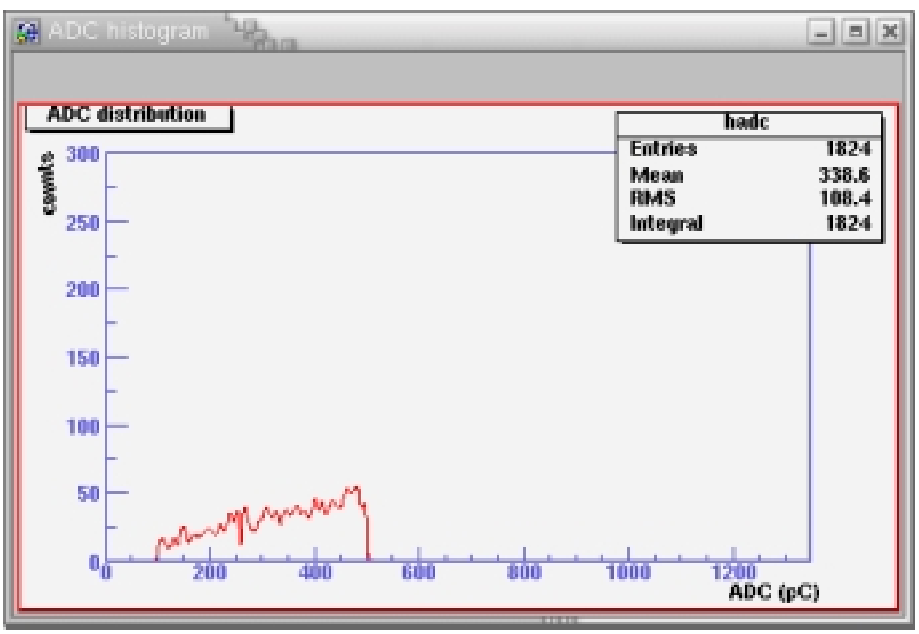


Figure 13. ADC histogram for events with drift time 0 to 2000 ns.

This ADC histogram of this noise data is again subtracted from the signal data (Figure 8) in **adc_fit_histos.C** as shown in Fig. 14.

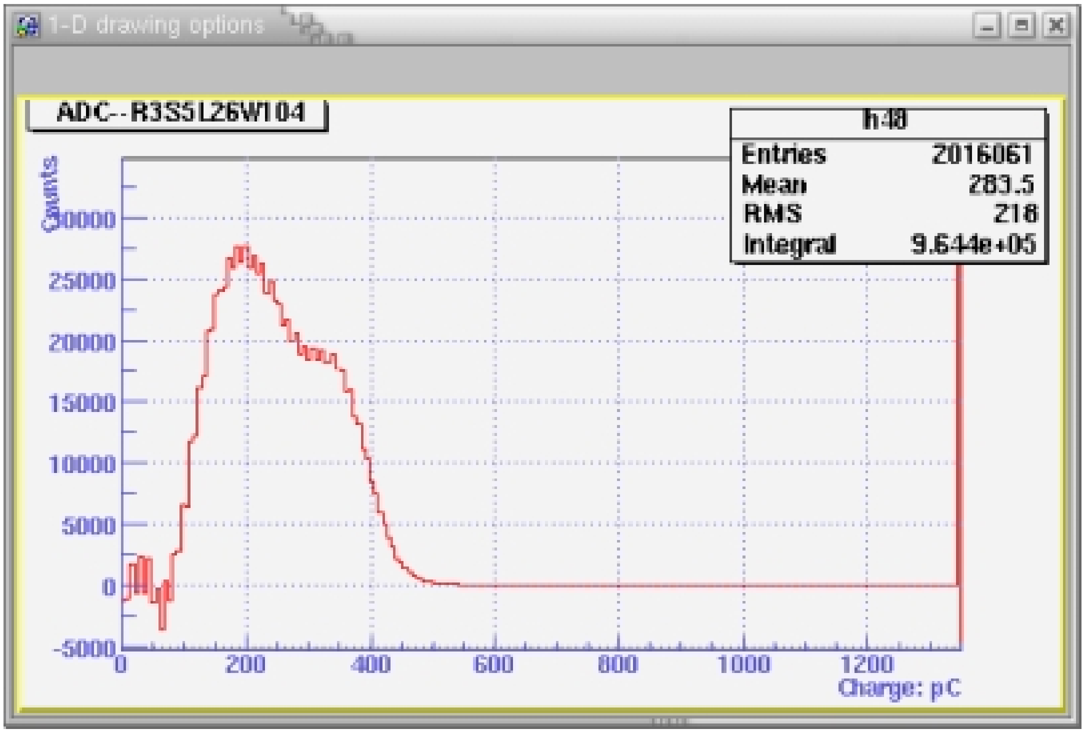


Figure 14. ADC histogram after subtracting Figure 13 from Figure 8.

After this subtraction, a Gaussian and a Landau are fitted to the remaining data using **adc_fit_histos.C**.

5 Conclusions

WCTS data were analyzed to determine the mean charge and sigma of the signal, which will indicate whether or not the drift chamber is functioning properly. To identify the mean, two programs were written to extract the signal from raw data.

The program **adc_fit_histos.C** subtracts the pedestal and noise in an ADC histogram. The remaining data are fitted with a Gaussian and Landau function. Several ADC histograms displaying fits and subtractions for WCTS run 311 are available at http://alexander.jlab.org.

TDC data are analyzed by the program **adc_tdc_plots.cpp**. A TDC histogram is plotted for the ADC signal. The events which register a TDC hit between 0 and 2000 ns are defined to be noise. This noise is subtracted from the ADC signal through **adc_fit_histos.C**.

Software now exists to successfully extract the signal and identify the mean charge and sigma. Changes in the mean or sigma over time indicate drift chamber malfunctions or wire-ageing effects or both. The limitations of the project are the hardware used in data collection: ADC gate timing, varying offsets, and electronic component instability all of which cause errors in data collection.

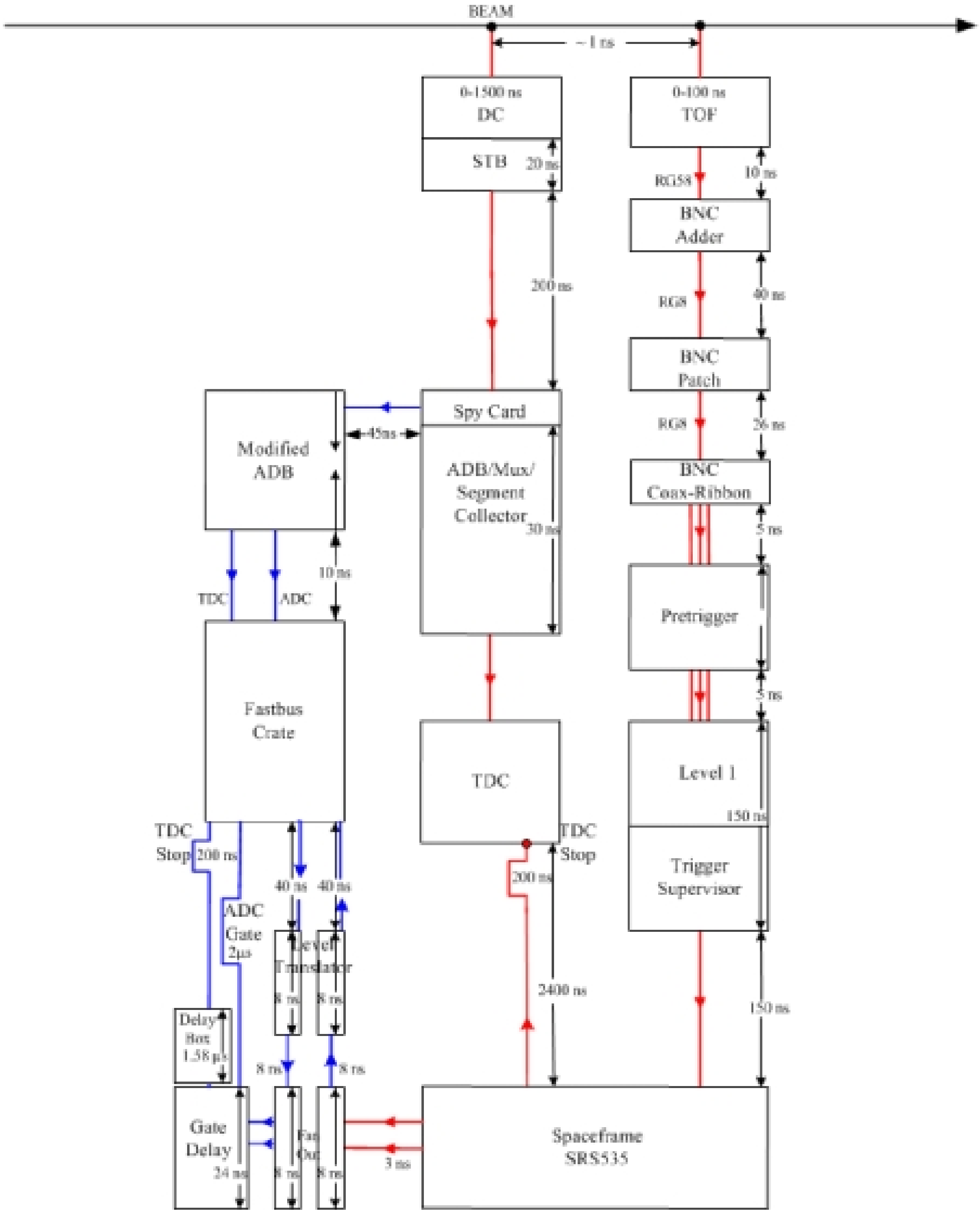
References

[1] M.D. Mestayer et. al., "The CLAS drift chamber system," Nuclear Instruments and Methods in Physics Research A 449 (2000) 81-111, 2000.

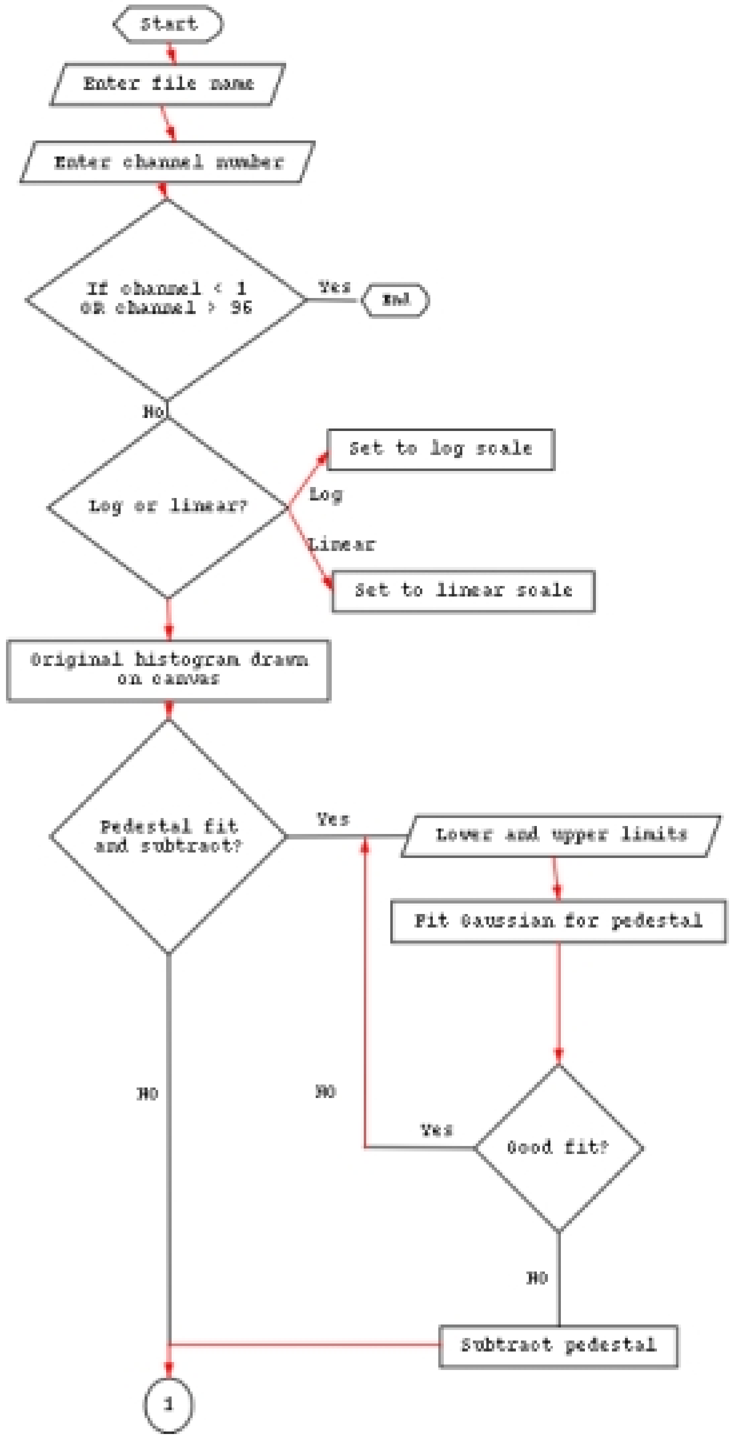
[2] *Experimental Hall B*. Ed. Mark Ito. Jefferson Lab. Jul. 2002 <http://www.jlab.org/Hall-B/>

Appendix

Trigger Schematic



Flowchart of adc_fit_histos.C



Flowchart of adc_fit_histos.C contd.