FTOF High Voltage Calibrations

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hv-calib.tex

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Abstract

This write-up includes some notes on the high voltage calibration of the PMTs for the CLAS12 Forward Time-of-Flight (FTOF) scintillation counters as well as a lay out of the basic algorithms employed.

1 Introduction

The FTOF PMT high voltage settings are determined through a dedicated calibration run employing cosmic ray muons. The electronics trigger and the data analysis are set up to select those muons that go through the full extent of the counter from the front face to the back face.

Fig. 1 shows different muon tracks passing through the scintillation bar. The ideal case of a normally incident muon passing through the face of the counter is shown in Fig. 1 (left). These minimum ionizing tracks deposit roughly 10 MeV as they pass through the 5-cm thick FTOF panel-1a and panel-2 scintillation bars. (Remember that for minimum ionizing particles $dE/d\rho x = 2$ MeV/g/cm^2.)

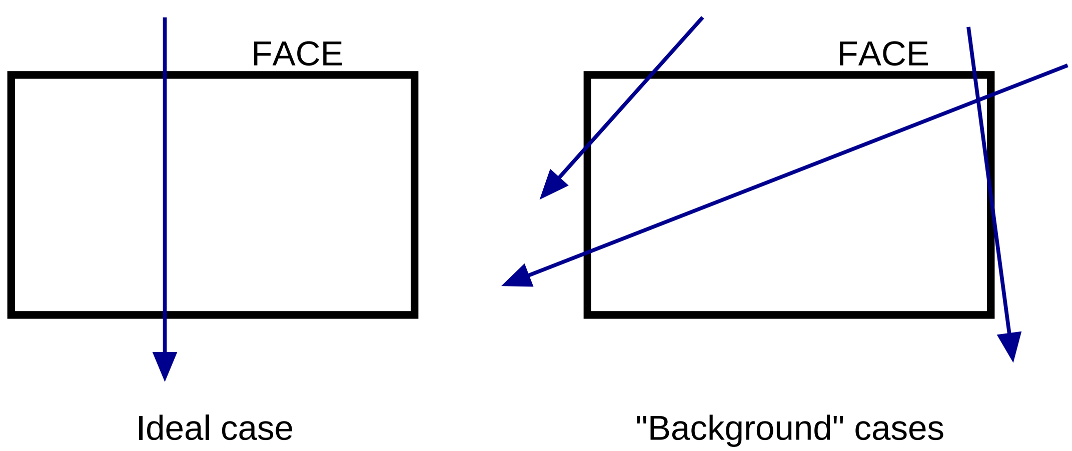

Figure 1: Representation of muon tracks passing through a scintillation bar. (left) Ideal case where the tracks are normally incident on the face of the bar. (right) Background events where the tracks clip the corners of the bar or pass through the side of the bars.

The energy deposited in the scintillator by the muons follows a Landau distribution. The ADC spectrum shows a peak above pedestal for the minimum ionizing muons from tracks close to the ideal case of Fig. 1 (left) as well as background events from tracks like those shown in Fig. 1 (right). The background events above the minimum ionizing peak arise from events with multiple track candidates and events from non-minimum-ionizing tracks.

The energy deposited is recorded by an ADC. For a given scintillation bar, the typical ADC spectrum appears as shown in Fig. 2. These events recorded in the ADC spectrum have been pedestal subtracted.

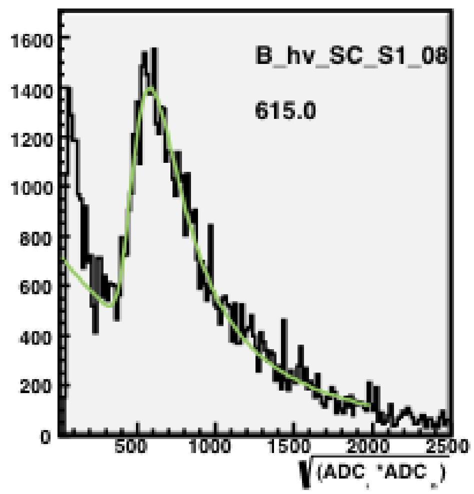

Figure 2: ADC spectrum from a typical CLAS12 FTOF counter showing the minimum ionizing muon peaks at about ADC channel 600.

In reality we combine the information from the left and right PMTs to produce an average ADC spectrum for the counter through the quantity:

$$\overline{ADC} = \sqrt{(ADC_L - Ped_L) \cdot (ADC_R - Ped_R)}. \tag{1}$$

Given the finite dynamic range of the ADC, we have chosen to position the minimum ionizing muon peak in a particular ADC channel (Fig. 2 shows channel 600) so that it is slightly above the pedestal, but leaves sufficient range for the more highly ionizing charged tracks of our typical physics events. The position of the muon peak in the ADC spectrum is set by the PMT HV setting.

It is well known that the PMT gains depends exponentially on the applied voltage. Expressed in a slightly different way, we can relate the PMT gain G_1 at a given voltage V_1 to the gain G_2 at a different voltage V_2 via:

$$\frac{G_1}{G_2} = \left(\frac{V_1}{V_2}\right)^{\alpha}. \tag{2}$$

This is a basic power law form with α representing the power law factor. For the FTOF PMTs, the typical value of α was determined to be 7.2. Rewriting eq.(2) in a slightly different form, we have:

$$\frac{\Delta G}{G} = 7.2\frac{\Delta V}{V}. \tag{3}$$

It is this expression that is the basis for relating the average scintillator $\overline{ADC}$ setting (see eq.(1)) to the PMT HV setting. Expressed slightly differently, eq.(3) tells us how much to increase or decrease the PMT HV settings to put the muon peak in the desired ADC channel.

Note that the gain-matching procedure then amounts to adjusting the HV settings of all PMTs to whatever values are required to position the muon peak for each counter in the desired ADC location.

2 HV Calibration Algorithm

This section details the algorithm for the basic HV calibration code for a given FTOF counter in a series of steps.

♢ **Step #1**:

Form the two basic calibration spectra for each counter. These are the average ADC spectra ($\overline{ADC}$) and the logarithmic ratio of the pedestal subtracted ADC data from the left and right PMTs of a given counter (R).

$$\overline{ADC} = \sqrt{(ADC_L - Ped_L)\cdot(ADC_R - Ped_R)} \tag{4}$$

$$R = \ln\left[\frac{ADC_R - Ped_R}{ADC_L - Ped_L}\right]. \tag{5}$$

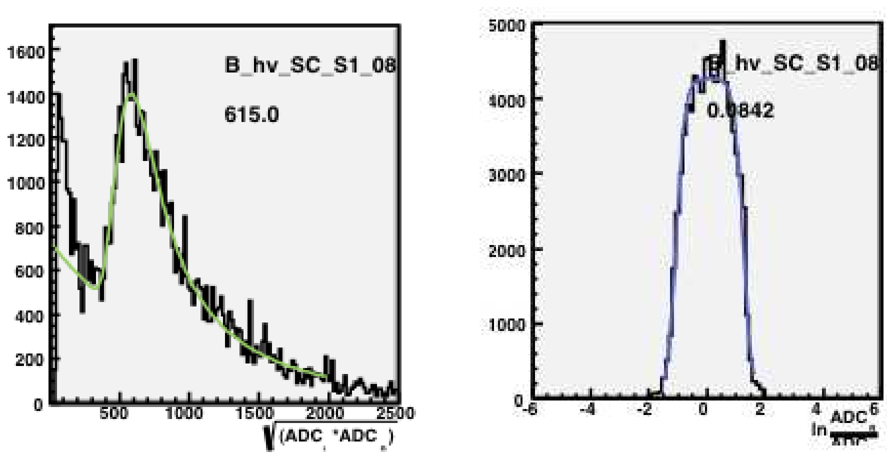

Figure 3: (Left) Average ADC spectrum ($\overline{ADC}$) and (right) log ratio spectrum (R) from a typical CLAS12 FTOF counter.

$\diamondsuit$ **Step #2**:

(i). Fit the $\overline{ADC}$ spectrum to determine the centroid of the muon peak using a Landau function for the muon peak and a polynomial function for the background. Call this value $GAIN\_IN$.

(ii). Fit the R spectrum to determine the centroid. Call this value $CENTROID$.

See the plots in Fig. 3 for fit examples.

$\diamondsuit$ **Step #3**:

Determine the effective centroids of the left and right ADC distributions using the $GAIN\_IN$ and $CENTROID$ values from Step #2.

$$G_L = \frac{GAIN\_IN}{\sqrt{\exp(CENTROID)}}, \qquad \text{effectively } (ADC_L - Ped_L) \tag{6}$$

$$G_R = GAIN\_IN \cdot \sqrt{\exp(CENTROID)}, \qquad \text{effectively } (ADC_R - Ped_R). \tag{7}$$

$\diamondsuit$ **Step #4**:

Compute the desired shifts in voltage using eq.(3).

$$\Delta G_{L,R} = 600.0 - G_{L,R}, \qquad \text{(to put muon peak in ADC channel 600)} \tag{8}$$

$$\Delta V_{L,R} = \frac{V_{L,R}{}^{ORIGINAL} \cdot \Delta G_{L,R}}{G_{L,R} \cdot \alpha}. \tag{9}$$

Thus $V_{L,R}^{NEW} = V_{L,R}^{ORIGINAL} + \Delta V_{L,R}$.

Note: The PMT voltages should be negative, so the final settings from these values will actually be $-V_{L,R}^{NEW}$.

$\diamondsuit$ **Step #5**:

There are a number of sanity checks included in the code to ensure that the $\Delta V_{L,R}$ settings are reasonable.

(i). If ($575 \leq G_{L,R} \leq 625$), do not adjust $V_{L,R}$.

(ii). If $|\Delta V_{L,R}| \geq 250$ V, set $|\Delta V_{L,R}| = 250$ V $\Rightarrow$ maximum allowed voltage change.

(iii). If $V_{L,R}^{NEW} > 2500$ V, set $V_{L,R}^{NEW} = 2500$ V $\Rightarrow$ maximum allowed voltage setting.

3 HV Calibration Code

The HV calibration software for the CLAS TOF system is included in the CVS repository at:

`packages/utilities/sc_calib/hvGUI`

The *c* program code subroutine for the calibration algorithm detailed in Section 2 (from the code doHV.cc) is given below.

```
double doHV::CalNewHV(double old_HV,double GAIN_IN,double centroid,int LEFT_RIGHT)
{
  double G,delG,delV,newHV;
  double alpha = 7.2;

  old_HV = fabs(old_HV);

  //Left Counters
  if (LEFT_RIGHT == 1)
      G = GAIN_IN/sqrt(exp(centroid));
  //Right Counters
  if (LEFT_RIGHT == 0)
      G = GAIN_IN*sqrt(exp(centroid));

  delG   = (600.0-G);
  delV   = (old_HV*delG)/(G*alpha);
  newHV  = (old_HV+delV);

  if(GAIN_IN>=575.&&GAIN_IN<=625.)
    newHV = old_HV;
  if(delV>locMaxDeltaV)
    newHV = old_HV+250.;
  if(delV<-1.0*locMaxDeltaV)
    newHV = old_HV-250.;
  if(newHV>2500.0)
    newHV = 2500.0;

  newHV = -1.0*newHV;
  return newHV;
}
```