# Hall C HMS Scintillator Calibration

Peter Bosted

December 5, 2008

## 1 Introduction

The goal of the HMS scintillator time-of-flight calibration procedure is to determine the parameters that convert the raw TDC (time-to-digital converter) and ADC (analog-to-digital converter) values to relative times that the particle passes through the plane of scintillators in question. There are three main uses for calibrated scintillator times

- Calculating the actual time that a particle passed through each of the drift chambers (DC), relative to the trigger time. This is needed to get an accurate drift time distance from the TDC value of each DC wire that fired. This is calculated in the code `Analyzer/HTRACKING/h_trans_scin.f` as the average of all the corrected scintillator times, corrected using the assumed speed of the particle tot he time it cross the nominal focal plane. Thus, scintillator calibration should be done before DC calibration.

- Calculate the time-of-flight between the two groups of scintillators (X1/Y1 and X2/Y2). This can be used to distinguish protons from kaons, for example.

- Get an accurate time-of-flight from the target to the HMS hut. This can be used in coincidence experiments for much better particle identification due to the much longer flight path. The time of the beam hitting the target must be known from another spectrometer, such as the SOS, SHMS, or BETA.

All the important parameters will be stored in a file such as sane08/replay/PARAM/hhodo.param. If different files are needed for different parts of the experiment, one can make files with names such as sane08/replay/PARAM/hhodo71371.param, and a file such as sane08/replay/DBASE/MAIN_SANE.db can be edited to point to files such as sane08/replay/DBASE/sane71731.param that "include" the relevant calibration files (include hhodo.param) for a given range of run numbers.

The current version of the Analyzer uses the following formula:

$$t_{cor} = t_raw - a - p/b - c/\sqrt{ADC}$$

where $t_raw$ is given by the raw TDC value multiplied by the parameter hscin_tdc_to_time, which must be initialized to a correct value in hhodo.param. For F1 TDCs currently in use, the correct value is 0.0566 in units of nsec/channel. In the above formula, $a$ is shorthand for hhodo_pos_invadc_offset or hhodo_neg_invadc_offset, where pos or neg refers to the "positive" or "negative" PMT at either end of each scintillator bar. The units are in nsec, and typically range from -30 to 30. The parameter $B$ is shorthand for the parameters in hhodo.param named hhodo_pos_invadc_linear and hhodo_neg_invadc_linear, and since the variable $p$ is the calculated path-length along the length of the scintillator bar (in cm) from the PMT to the point where the particle is supposed to have hit the paddle. The units of $b$ are therefore in cm/nsec, and reflect the effective speed of light in the bar. Since the index of refraction of plastic is about 1.4, the maximum value of $b$ should be 30/1.4=21 nsec. Actual values are smaller because the light bounces around in the bar, giving an effective path length that is about $1.4p$. Therefore $b$ should be close to 14 nsec/cm if the fitting procedure is working correctly. The final parameter, $c$, is shorthand for hhodo_pos_invadc_adc and hhodo_neg_invadc_adc, and it's purpose is to correct for "pulse-height slewing" using the ADC value for a particular PMT. Since we used fixed-level discriminators, the TDC will be earlier for big pulse heights than for smaller ones. Since there is some attenuation of the light as it passes through the bar, $p$ and $ADC$ for a given event tended to be somewhat correlated, so that it takes a large number of events and a good range of $p$ to simultaneously determine $b$ and $c$. To obtain better converge, the fitting program sets $b$ to be the same for the positive and negative ends of a given paddle.

# 2 How to perform a new TOF calibration

## 2.1 Name of file that this calibration works with

Figure out which file is going to contain the nominal parameters for the current analysis.

To find this, first figure out what your replay script is setting for the environmental variable `ENGINE_CONFIG_FILE` (normally something like `PARM_FILES/REPLAY.PARM`.

Now look in that file and see what `g_ctp_database_filename` is set equal to (something like `DBASE/MAIN_SANE.db`.

Now look in that file and see what the variable `g_ctp_parm_filename` is set equal to (something like `DBASE/sane_43.param`) for the range of run numbers that includes the one you are going to analyze.

In that file, look for a line like `#include "PARAM/hhodo.param"`. The file hhodo.param is the one that contains everything to do with HMS scintillator tof parameters. If more than one set of parameters is needed for a given experiment, normally we will make several versions, with names like hhodo12345.param, where 12345 is the run used to obtain the coefficients.

## 2.2 Setting starting values

A filter is placed that all raw TDC values must lie between the two parameters `hscin_tdc_min` and `hscin_tdc_max`. Check that the limits include the raw TDC peaks, which you can see in histograms with names like `hscin1x1postdc` which are defined in the include file `HIST/hist.HMS_rawtdcs`. Normally, these only need to be adjusted if there is a major change to hardware (different TDCs) or the trigger.

Set `hstart_time_slop` to 50 nsec.

Set `hscin_tdc_to_time` to value appropriate for TDC being used. For F1 TDCs in current use, the value is 0.0566 nsec/channel.

Normally, set these distance tolerances: `hhodo_slop = 2., 2., 4., 4.` These are in cm. If you find some paddles are missing, you can increase these values to large numbers and figure out what is wrong with the geometry file or the TDC mapping.

Set all other variables to the values used in a recent good run. Generally speaking, this will apply to all the variables discussed in the previous paragraphs as well.

## 2.3 Initial Calibration

After any major hardware or software changes, it is best to do an initial calibration with a large value of the time tolerance variable called `htof_tolerance`. The normal default value should be about 10 nsec (set in hhodo.param). You can over-ride on the command line, though. I recommend using 50 nsec for an initial calibration.

To do a calibration, first pick a run where the HMS has a reasonably uniform distribution of events across the focal plane (ie, not an elastic peak run), and where the particles are dominated by electrons and pions. It is much harder to calibrate with a positive polarity, because one gets not only pions, but kaons, protons, and deuterons in the time-of-flight (TOF_ spectrum. This creates ambiguity in the TOF between S1 and S2, and leads to bad solutions in the fitting. The run should have at least 100,000 electron events (preferably 500,000). Ideally, the singles rates in the scintillator paddles should be well below 1 MHz (see the scaler file output) to avoid accidental hits.

To get the calibration to be active, set `hdumptof=1` on the command line. So, for an initial calibration, one would type something like `./SCRIPTS/replay grun=12345 hdumptof=1 htof_tolerance=50.`

## 2.4 Examine the results

When the replay is finished, you should see two files appear in the directory replay/HTOFCAL (if this directory doesn't exist, should should make one first).

The file htofcal12345.param contains all the tof calibration parameters found by the fit. It also has a copy of all the values that are unaffected by the calibration (such as minimum and maximum raw TDC values). It you are happy with it, copy it over to PARAM/hhodo12345.param and use it for subsequent analysis. If you did an initial calibration with a 50 nsec tolerance, do another one with 10 nsec, to avoid biases that come from accidental hits. Hopefully none of the values will change much. I also like to do a final iteration with 3 nsec tolerance. This tolerance is slightly inefficient, but very good at removing accidental hits for high rate runs.

The file htofcal12345.diag contains diagnostic information that is very useful to find out if there are any problems and if the fit is valid.

Things to look out for include:

- one the first line, ifail should be 0
- the next 51 lines are a summary of the fit parameters found. The first column is the detector number in the internal fitting scheme. S1X are 1 to 16. S1Y is 21 to 30. (so S1Y1 is 21, etc.), S2X is 41 to 56, and S2Y is 61 to 70. The next two columns are the number of hits (meaning both an ADC and TDC value) for the positive and negative ends of detector, respectively. When all is working right, there should be about equal number of hits on each end of each paddle. There should be hits in detectors 1-16, 22-30, 41-56, and 61-70. Generally, S1Y1 doesn't get hits, although it physically exists.
- Columns 3 and 4 are the values of `hhodo_pos_invadc_offset` and `hhodo_neg_invadc_offset`, respectively. Columns 5 and 6 are the `hhodo_pos_invadc_linear` and `hhodo_neg_invadc_linear` values, and the last two columns are the `hhodo_pos_invadc_adc` and `hhodo_neg_invadc_adc` values. See discussion in the Introduction and check they are in the expected range. If not, make an adjustment by hand in the hhodo12345.param file.
- Following this are one-line histograms of the ADC spectra of each paddle. The first column is the internal detector number. The same numbering scheme is used as above, but now values from 1 to 100 are the positive PMTs, and 101 to 200 are the negative ends (so 101 means S1X1neg, etc.). The next 18 columns are the number of counts in bins of 20 channels. Check that all ADC spectra look similar to each other. If not, adjust the HV for that channel. It is important that the peak be well above channel 40, which means the maximum number of hits should not be in columns 2 or 3. Note: there could also be a problem with the pedestal (threshold) file. Make sure the pedestal file is good.
- After that, (`THIST`) there are one-line time-residual plots for each PMT. The first column is the internal detector number (as for the ADCs), and the next 10 columns are the distribution of time differences for that

PMT compared to all others, in bins of 1 nsec. A difference of zero is between columns 6 and 7, so most of the counts should be in these two columns, more or less symmetrically. If you see a peak that is offset, or wider than the others, there probably is some kind of problem with that PMT.

- The last lines of the file (PHIST) are one-line distributions of the path-lengths found for the good events. They should look relatively flat.

### 2.5 Final calibration

If the initial calibration looks good, copy HTOFCAL/htofcal1234.param over to PARM/hhodo12345.param and adjust the data base to use the new file. Do another calibration with htof_tolerance=10., and if all still looks good, one with htof_tolerance=3..

### 2.6 Monitoring calibrations

Do the calibration for a sample of runs with a common set of high voltages, hardware setup, and trigger configuration. Check that the fit values are pretty close tot he ones used for the reference run. If not, try to find where the change occurred by examining the beta spectrum for each run, and seeing where it is gets wider.

Another thing to look at in hhodo12345.param are the values of hhodo_pos_sigma and hhodo_neg_sigma, which give the spread in time differences for a given PMT, in nsec. The default value of 0.1 means a detector did not get enough hits to be fit. The good detectors should be sigmas of 0.3 to 0.4 nsec. In real life, some detectors get values of 1 nsec or larger. If it is a central detector that is getting lots of good hits, this probably means the HV needs to be changed (check the corresponding ADC spectrum). Too small HV gives a large time slewing with the code cannot correct for. Too high a HV gives too many hits, and also pulse height values than can saturate the ADC.'

## 3 How to know if calibration really worked

If the calibration worked right, you should see the following things:

- Look at the histogram `hbeta_notrk`, defined in `HIST/hist.HMS_pid_other`. You should see a nice narrow peak centered on 1 (for electron runs), and also peaks at the expected values for a proton run (i.e. protons, deuterons, and sometimes tritons should be clearly visible). These values of beta don't use the path length correction, by the way, or any other tracking information.

- Check that the `hstart_time1` and `hstart_time2` spectra (defined in `HIST/hist.HMS_scin_timing` are clean and narrow (no double peaks for electron runs), and centered on the value found by the fit (`hstart_time_center` in `hhodo12345.param`).

- Check that the beta spectra using tracks also looks narrow (width less than 0.1) and centered on 1 for electron runs. You can find this as `hsbeta`, `hsbeta-`, and `hclbeta`, defined in `HIST/hist.HMS_pid_other`