MoNA Calibration Guide

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1 Introduction

The follow chapters describe how to prepare the MoNA detector for an experiment using a suite of fitting programs and procedures.

The MoNA setup file called `MoNA_setup_run.tcl` in the `~/mona/config` directory contains the important flags to set to `"true"` after each successive calibration or fitting procedure is finished. They are:

```
QDC_thres_flag
QDCfitted
TDCfitted
Xposfitted
Tmean_indie_offset
```

Start by opening `MoNA_setup_run.tcl` and editing these flags to "false", then saving.

1.1 Proper Links

Since the fitting codes run in a different directory from the configuration files, some linked files and directories are installed. In general the whole `~/mona` directory tree is copied from the preceding experiment and includes the wrong directory links and old calibration values. They must be checked to ensure they link to the proper destination. The command `>ls -la` can be used to double check if the links are set properly. The following commands should be done when first setting up a new experimental account, and to correct any old or mislabelled links.

1.1.1 TDC Calibration Links In the `~/mona/contrib/tcal` directory the TDC calibration code looks for the TDC spectra written after reading a time calibration run. A link to the `/spectcl/spectra` directory is used:

```
> rm monatcaldata
> ln -fs ~/mona/daq/spectcl/spectra monatcaldata
```

The code then saves the TDC slope values to the MoNA configuration directory, so a link needs to made to it:

```
> rm spectclconfig
> ln -fs ~/mona/config spectclconfig
```

1.1.2 HV, and QDC Calibration Links In the `~/mona/contrib/hvfit` directory the high voltage gain matching code needs to input the MoNArawQDCcosmics.asc file created in SpecTcl from a cosmic background run. A link needs to be set:

```
> rm monacosdata
> ln -fs ~/mona/daq/spectcl/cosmics monacosdata
```

The gain matching code also needs to output the new voltage file to right directory:

```
> rm hvfiles
> ln -fs ~/mona/hv_control/hv_files hvfiles
```

The QDC calibration code runs from the `~/mona/contrib/hvfit` directory also and outputs the QDC slope and offset values to the MoNA configuration directory. So a third link is needed here:

```
> rm spectclconfig
> ln -fs ~/mona/config spectclconfig
```

2 High Voltage Gain Matching

The phototubes (PMT's) of each MoNA detector bar may vary in their sensitivity for a given voltage setting. If one tube is more sensitive than another, a standard flash of light emitted from varying places along the bar will not be detected with uniform efficiency. If a weak light flash occurs nearer the more sensitive tube, that tube has a good chance of detecting it. However, the other, less sensitive tube may not detect it due to the fact that the light signal attenuates on its journey across the bar, and therefore becomes even weaker. This will cause low energy hits to be detected with non-uniform efficiency across the length of the bar because both tubes must fire for an event to be considered good. Therefore, data taken in that particular detector bar will be skewed. To solve this problem, the voltage levels of the two PMT's of each MoNA bar must be gain matched. Each tube must have its voltage level matched with the other in such a way as to ensure uniform detection efficiency across the bar. Gain matching is done using a routine that finds the position of the cosmic peak from a particular run and determines and executes the best adjustment in the voltages of the tubes to properly gain match the detector. Because these adjustments are the program's best guesses, multiple iterations of the gain matching process must be completed before the PMT voltages are accurately matched.

2.1 Getting Started

1. Open up two terminal windows, one to a *spice* machine, and another connected to *spdaq16*.
2. In the *spdaq16* terminal go to the `~/mona/hv_control` directory.
3. To make sure all of MoNA is turned type:

   ```
   > ./Vallon.scr
   ```

2.2 Take Cosmic Data

1. Let the voltages settle for a few minutes.

2. Be sure you are in the `hv_control` directory of the *spdaq16* terminal by using the command `> pwd`.

3. Now you must read out the current voltages into `hv_files/Vout_current.tcl` and copy them into `hv_files/Cosmic_volts.tcl` file by the commands:

   ```
   > ./Vout.scr
   > ./Vcopy.scr
   ```

4. Record a two-hour or longer run[1] of cosmic ray data with all detector bars. Use MoNA multiplicity set to `1-fold` and select self-trigger and self-stop on the XLM control.

5. Open MoNA SpecTcl[5] in the *spice* terminal window or from a Data U. machine.

6. In the SpecTcl Control window, click *Create Raw Spectra*.

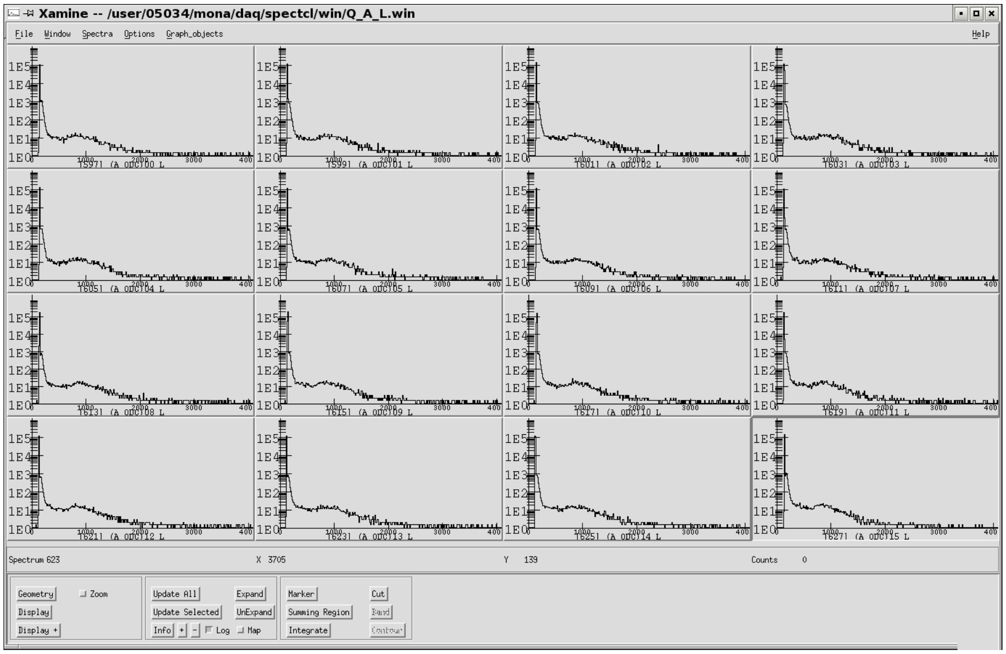
7. Then choose *Attach to File*, and select the run file recorded in step 1.

8. In Xamine go select `Window -> Read Configuration`, and pick one of the `/win/Q_x_x.win` window settings.

9. Allow SpecTcl to analyze all the buffers to ensure sufficient statistics for the cosmic peak fitting program. When the data is read in, click *Update All* in Xamine.

[1]This must be a new recorded run for each iteration

10. Look through the spectra in Xamine to make sure the data is usable (i.e. that there is a cosmic peak in each of the spectra). Select all the `/win/QDC.win` files to view all the QDC raw spectra. The spectra should look like this:



with a pedestal peak near channel 100 and a cosmic muon bump (three orders of magnitude smaller) near channel 900. If there is a problem with one of the bars, double check that the voltage is on and that the inverter box is getting a good dinode signal from the PMT then inverting it for the QDC.

11. In the SpecTcl window, choose *Write Cosmic Spectra* to perform an `swrite` command on all raw QDC spectra. This also reads in the last `Cosmic_Volts.tcl` file and labels each spectra with the proper high voltage channel.

12. In the *spdaq16* terminal window, change directories:

```
> cd ~/mona/contrib/hvfit
```

2.3 Voltage Matching Code

1. Now you run the high voltage fitting code[4] by typing the `> ./hv.sh` command. This runs a shell script that executes the program `fit_mona_spectra.f`.

2. When the process completes, there will be a listing of information about each channel and the changes that have been made. The six numbers are (left to right):

```
   1.HV channel    2.Muon Peak bin    3.Pedestal bin
4.Difference(#2 - #3) 5.Current HV setting 6.New HV setting
```

   The process also saves the new high voltage settings and links them to `/hv_files/QDCfittedHV.tcl`.

3. By just carefully viewing the listed numbers from the output of the `fit_mona_spectra` code we can determine if everything went smoothly without *TopDrawer*.

4. Make sure that the numbers in column 4 are all about 800 and match column 2 minus column 3.
5. Check that the new voltages settings in column 6 are not too different from those in column 5.
6. If you are familiar with the program *TopDrawer*, try the next four listed items; otherwise, you're done with this part.
7. Try to open *TopDrawer* by typing:

   ```
   >  td spectratest.tdr
   ```

   in the spice terminal window.
8. Press `Enter` each time you wish to change to the next set of 8 plots displayed. Each time you do this, the word pause will appear in the spice window.(Note: There are 288 spectra, so there will be over 30 *TopDrawer* screens to look through).
9. Look for a peak that appears around bin 800 and 2 white fit lines; one a gaussian fit to the peak and the other an exponential fit to the background (it appears as a straight line in the logarithmic scale).
10. When the last set has been viewed, pressing `Enter` will close *TopDrawer*.

2.4 Setting New Voltages

1. Now you must apply the new high voltage settings by first going back to the *spdaq16* terminal window and changing directories to `~/mona/hv_control`.
2. Now source the new voltage values into the HV channels by typing:

   ```
   > ./Vfitted.scr
   ```

Repeat Sections 2.2, 2.3, and 2.4 until performing another iteration would not significantly change the voltages, then move on to the QDC calibration procedure. Usually, twice is good enough if starting from voltages previously fitted for another experiment.

3 QDC Calibration

QDC calibration should only be completed after the high voltage channels are fitted following the *High Voltage Gain Matching* directions from section 2. It is important to know the light-energy deposited by a scattered neutron event, and also important to suppress the null-result QDC pedestal events from swapping the Readout. Since every QDC has 32 channels and each pedestal is a positive bin value, all channels will readout if just one creates a valid trigger for that layer.

3.1 Calibration Steps

1. Edit and save `MoNA_setup_run.tcl` with the QDC flag:

   ```
   QDCfitted
   ```

   set to `"true"`.

2. Repeat the *Take Cosmic Data* section from Chapter 2.2, and make sure the recorded run in step 4 is brand new and was not used for voltage gain matching.

3. You need to execute the `calib.sh` shell script to perform the calibration. To do this, make sure you are in the `~/mona/contrib/hvfit` directory.

4. Run the calib.sh program by typing the `> ./calib.sh` command.

5. When the code is finished, information about each channel will displayed. As on the screen, from left to right, the seven numbers correspond to the following:

```
1.HV Channel 2.Muon Peak bin 3.Pedestal bin 4.Diff(#2-#3)
    5.QDC Threshold   6.QDC Slope   7.QDC Offset
```

6. Note that the QDC calibration code is:

```
QDC_Cal = (QDC_raw + QDC_offset) * QDC_slope
```

   so the QDC offset is in units of raw bins and the QDC slope is in units of MeVee/bin. This is fitted to set the muon peak at 20.5 MeVee and the pedestal to zero.

7. Make sure that the numbers in column 4 are all about 800 and match column 2 minus column 3.

8. Check that the QDC threshold values are about:

```
QDC Threshold = ( (Pedestal bin + 3) / 16 ) + 1
```

9. Check that the QDC offset values are the same as the Pedestal Peak values.

10. Check that the QDC slope values are all about 0.028.

11. If the preceding checks are not confirmed then the *High Voltage Gain Matching* directions must be re-done.

12. This program also saves the new slope/offset data in: `~/mona/config` and links to `QDCfittedTHRE.tcl` and `QDCfittedSLOOFF.tcl`.

13. Enter the `~/mona/config` directory and check to see that there are current threshold and slope/offset files, based on the date and time of completion by using the command:

```
> ls -la
```

14. Edit and save `MoNA_setup_run.tcl` with the QDC flags:

```
QDC_thres_flag
```

   set to `"true"`.

You are now ready to run an experiment with voltage-matched PMT's and calibrated QDC parameters. The next time you take data, the QDC's will ignore values less than the threshold, so no pedestals are read. The energy of lost events due to the pedestal suppression will be between 4 to 19 channels, which is less than 0.5 MeVee. Also, the QDC calibrated spectra will be fitted for 20.5 MeVee at the muon peak, and zero for the where the pedestal was.

4 TDC Calibration

MoNA uses time-to-digital converters (TDC's) to set timing coincidences for events that occur in the array. In a sense, they are ”fancy stop watches” for the detector. When a TDC channel receives a pulse from the anode of a PMT of a particular detector bar, it begins charging a capacitor. When the delayed logic stop occurs, the capacitor stops charging, and the amount of charge on the capacitor corresponds to the time the TDC was charging. However, each TDC does not charge at exactly the same rate as another, so the rate at which two different TDC channels charge will give different times for identical time events. This presents a problem that must be overcome with a calibration. The time calibrator (NIM box), which is physically daisy-chained to each of the TDC channels at the beginning of the process, gives precise signal spikes at equal and adjustable intervals over a predetermined and adjustable range. These signals give a standard by which to calibrate the TDC's to ensure proper timing for events that occur in MoNA. Since the same TDC channels are used from one experiment to the next this calibration is not needed for every experiment.

4.1 Record Time Calibration Run

Before any fitting code can find the right TDC slope, a run must be recorded using the *Ortec* NIM Time Calibrator module connected through a NIM threshold discriminator and then to the test inputs of the MoNA CFD's. This setup has been connected, and only needs the time calibrator module installed to run again.

1. In the directory `mona/config`, open the file `MoNA_setup_run.tcl` and edit and save the desired range for the width of the TDC window (in nanoseconds) under `Global Settings` where you find the command `set range`. The range is the total time that spans all 4095 channels; it can be set between 140 and 1200 ns.[2] Also, make sure the `TDCfitted` flag is set to `"false"`.
2. Set both the range and the increment in the time calibration module (model 462, in the NIM crate) to the correct settings, and turn it on. The increment, period, or `delta t` is how often the TDC records a spike. The range should be set equal to or close than the range set in step 1.
3. Give a meaningful name to TDC calibration the run in the Readout window. For example:

   `TDC cal, Trange 350ns, Tdelta 40ns`
4. Plug the *start* output of the time calibrator into the *CFD test input* discriminator channel on the left of the NIM crate, and double check that this signal is routed to all CFD *test* inputs.
5. Plug the *stop* output of the time calibrator into the *TDC test input* discriminator channel on the left of the NIM crate, and double check that this signal is routed to all TDC *common* inputs.
6. Make sure all the CFD's are running by checking their output (*OR*) lights to see them blinking fast.
7. Record a short 10 minute run with all detector bars. Use MoNA multiplicity set to `1-fold` and select self-trigger on the XLM control. Do not select self-stop, the time calibrator must send the both the start and the stop signals.
8. Open MoNA SpecTcl[5] in the *spice* terminal window or from a Data U. machine.
9. In the SpecTcl Control window, click *Create Raw Spectra*.
10. Then choose *Attach to File*, and select the run file recorded in step 1.

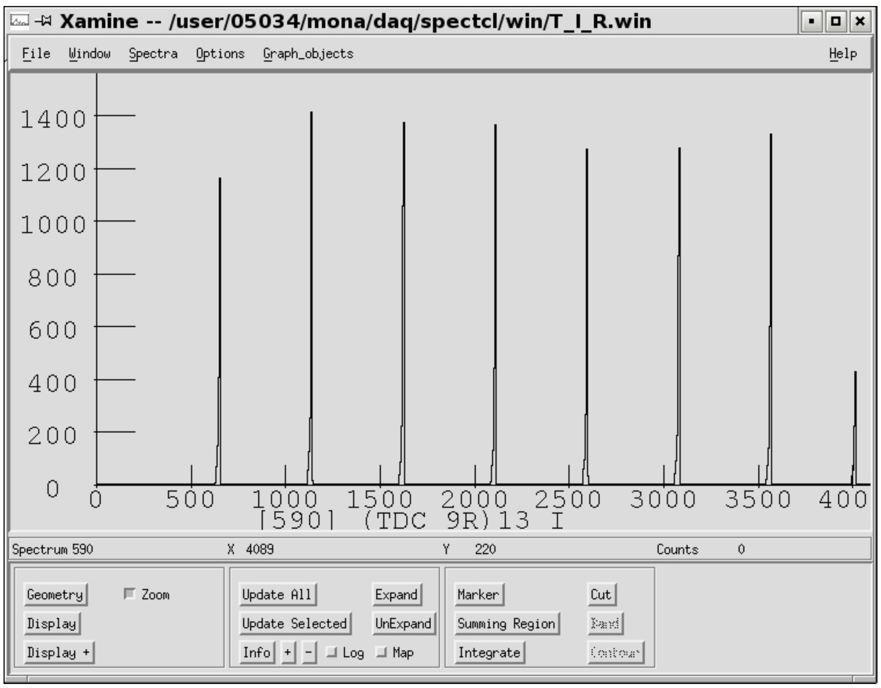
[2] Traditionally, we have used 350 ns for the TDC full scale.

11. In Xamine go select `Window -> Read Configuration`, and pick one of the `/win/TDC.win` window settings.

12. Allow SpecTcl to analyze all the buffers to ensure sufficient statistics for the TDC fitting program. When the data is read in, click *Update All* in Xamine.

13. Look through the spectra in Xamine to make sure the data is usable (i.e. that there are evenly spaced spikes in each of the spectra). Each spike must have more than 300 counts to get recognized by the calibration code. Select all the `/win/TDC.win` files to view all the raw TDC spectra. Pay special attention to some of the inner most MoNA bars like D7 to G9 and see if any are double-peaked. A suitable threshold value must be less than any double-peaked count. The fitting code will take any channel above threshold preceded by a channel below threshold and fit it to the next incremental period. Running the code with a threshold that runs through a double-peaked spike will cause the fitted slope to be very wrong.

    This is a sample spectrum with the delta time set to 40 ns and a range of 350 ns:



14. Select *Write Any Spectra* in the SpecTcl Control window.

15. From the pop-up window, open *Spectrum List* and select all the TDC data spectra (there should be 320 total). Click *Accept and Close*.

16. Name the spectra file including the range and period you've chosen. Make sure that the ASCII is selected.

17. Click *Write Spectra*.

4.2 Running Calibration Code

Running the `tdc_calib.f` code by sourcing the `test.sh` script will save a `slope_offset_datetime.tcl` file in the `contrib` and `mona/config` directories. It will also automatically link the latest one to

`MoNA_TCAL_dynamic_var.tcl` to get used when running SpecTcl. The offset values for the TDC parameters are not very meaningful and set to 100 channels.

1. Log onto a *spice* machine as the experimental account with SSH Secure Shell and type

   ```
   > cd ~/mona/contrib/tcal/monatcaldata
   ```

2. Use the `ls -la` command to reveal your spectra file, most likely among several others.

3. Type `cd ..` to back up a directory.

4. Now open to edit the `test.sh` script. It should look similar to this: [3]

   ```
   #!/bin/sh
   ./tdc_calib <<EOF
   monatcaldata/Tcal_run1002_350_40.asc
   n
   test.tdr
   40.
   1. 3840.
   300.
   EOF
   ln -sf slope_offset_‘cat datetmp.txt‘.tcl slope_offset_latest.tcl
   # exit
   cp slope_offset_‘cat datetmp.txt‘.tcl spectclconfig/.
   ln -sf slope_offset_‘cat datetmp.txt‘.tcl  \
      spectclconfig/MoNA_TCAL_dynamic_var.tcl
   exit
   #
   ```

5. On line 3 of the script, change the filename after the `monatcaldata` directory to the one you desire to calibrate (the filename should correspond to the name of the file you just checked in step 2).

6. The first number under `test.tdr` should be changed to the calibration period (or `delta t`) that the run was taken with in nanoseconds. On the next line, the 1. stands for the first channel and 3840. refers to the number of usable bins (255 less than the total 4095).[4]

7. The 300. stands for the threshold. If a channel contains more than 300 counts the program recognizes it as a peak. Edit this value to one that is suitable for your run.

8. Make sure the `exit` command underneath the count threshold is commented out of the executable program file by placing the pound symbol, #, in front of it.

9. Save your changes and exit the editor.

[3]The *’cat datetmp.txt’* is a date-time stamp created by the code as a series of numbers MMDDYYHHMMSS to include in these file names.

[4]More details about the script can be found in Ref[4].

10. Run the `tdc_calib.f` code by typing:

    ```
    > ./test.sh
    ```

    in the *spice* window.

11. A long list of values and calibrating points will be printed to the screen, you can scroll up through some of the bars, but most shells don't scroll back far enough to see the fitting points for all 320 TDC channels.

12. If you are familiar with the viewer program *TopDrawer*, try running it by using the `td test.tdr` command. Then don't touch anything. To cycle through the graphs, press enter. Don't click on any of the windows. You must be in the shell window to cycle through but can't overlap the black graphs because each graph needs to be viewed. Verify that the points are evenly spaced by the specified increment and linear along the regression line. The vertical axis is the channel number and the horizontal axis spans the range setting in nanoseconds.

13. If a linear fit line seems to deviate from the line of points, you may need to start over with recording a new time calibration run.

14. You can check the slopes by opening the `slope_offset_latest.tcl` file and seeing if the slope values are close to `(range in ns)/4096`. A range of 350 ns should have a slope near 0.08-9 ns/channel.

15. If the fitted slope are not near the range divided by 4095, you may need to start over with recording a new time calibration run, or re-running the fitting code with a different threshold value.

4.3 File Names

As you can see the calibration file is saved in `~/mona/config` with no easy name to describe what it contains and the `MoNA_TCAL_dynamic_var.tcl` link always points to the latest calibration created. You may want to reset this link to a file run earlier and/or rename calibration files to ones with meaningful labels using the `ln -sf` or `cp` commands. Make sure the `MoNA_TCAL_dynamic_var.tcl` link points to the correct file for your experimental runs.

Now you can reopen `MoNA_setup_run.tcl` and edit the `TDCfitted` flag to `"true"`.

5 X Position Calibration

The X position calibration may be done after an experiment is finished as long as a sufficiently long recorded run is taken at the end of the experiment, but some position and energy spectra during the experiment may look strange if this is not done before hand. MoNA must be gain matched and the QDC and TDC slope/offset values must be fitted.

MoNA is a high efficiency neutron detector. Through measuring the position of the particle (neutron or other particle) it becomes possible to know the particle's path and thus extrapolate its energy. In order to do this properly the X-position parameter must be properly calibrated. By noting the difference in time signals from the photomultiplier tubes at each end of a certain MoNA bar, we can produce a spectrum that displays the difference in the time signals (in nanoseconds) between the right and left sides of that bar. By performing this calibration, the user transforms the time difference spectrum in nanoseconds into a position spectrum in centimeters. This is very useful in reconstructing events when analyzing data. Another important reason for this is that the kinetic energy of the neutrons are calculated from `KE=1/2*(n_mass)*(dist./time)^2`. An accurate determination of the energy requires one to know the full 3d position of a hit in any given bar.

5.1 Record Cosmic Run

Before any fitting code can find the correct X position slope and offset values, an long cosmic-ray run must be taken. This new run requires the previous calibrations to be preformed first.

1. Record an overnight (12 hours) run of cosmic ray data with all detector bars. Use MoNA multiplicity set to `1-fold` and select self-trigger and self-stop on the XLM control. Also be sure that you are using calibrated slope/offset values for both the QDC and TDC parameters and check that the calibration flags in `MoNA_setup_run.tcl`:

   ```
   QDC_thres_flag
   QDCfitted
   TDCfitted
   ```

   are set to `"true"`, while `Xposfitted` is set to `"false"`.

2. Open MoNA SpecTcl[5] in the *spice* terminal window or from a Data U. machine.

3. In the SpecTcl Control window, click *Create Pseudo Spec*.

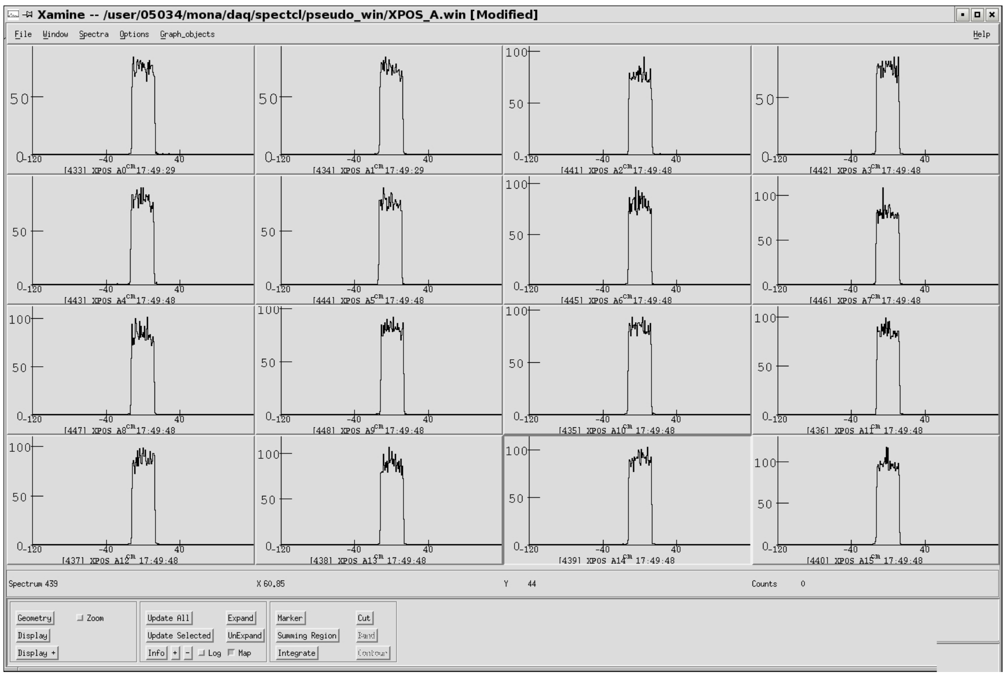
4. In order to avoid any time walk that may occur with near-CFD-threshold events, you must apply a high-Qmean gate (from 8 to 120 MeVee) to each Xpos spectra. Do this by clicking *Apply Qgate to Xpos*. See Ref[3] for a detailed discussion on the CFD walk issue.

5. Then choose *Attach to File*, and select the run file recorded in step 1.

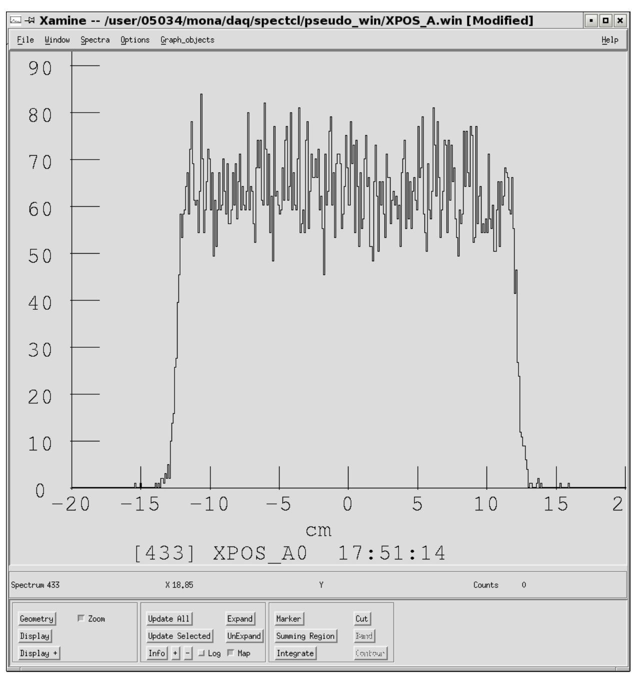
6. In Xamine go select `Window -> Read Configuration`, and pick one of the `/pseudowin/Xpos.win` window settings.

7. Allow SpecTcl to analyze all the buffers to ensure sufficient statistics for the Xpos fitting program. This may take over a half hour since the run was so long. When the data is read in, click *Update All* in Xamine.

8. Look through the spectra in Xamine to make sure the data is usable (i.e. that the edges of the Xpos spectra look sharp). Since the `Xposfiited` flag was set to `"false"`, all the Xpos spectra will display the time difference (a width of about 25 ns), even though the spectra are still labelled with cm. Select all the `/pseudowin/Xpos.win` files to view all the Xpos spectra. The spectra should look like this:



9. Here is an expanded view of A0:



10. Once the file is done loading, and the spectra look okay, push the *Write Xpos Spectra* button in the SpecTcl Control window.

11. When the TkCon confirms the `MoNAxposCosmics.asc` file is written, press the *Calibrate Xpos* button.

12. The TkCon window will scroll through a list of the values fitted for each bar. Scan the output and check that all the parameters have a reasonable slope value (near 8.0).

13. Reopen `MoNA_setup_run.tcl` and change the `Xposfitted` flag to `"true"`, and save.

14. Close SpecTcl and reopen it. The proper calibration will now be sourced to the program. If done properly, the width of an Xpos spectra of cosmic ray data from step 1 should be 200 cm and it should be centered about zero.

6 Independent Tmean Offsets

Setting the independent Tmean offsets may be done after an experiment is finished as long as a sufficiently long recorded run is taken at the end of the experiment, but some timing and energy spectra during the experiment may look strange if this is not done before hand. MoNA must be gain matched and the QDC,TDC and Xpos slope/offset values must be fitted.

Since the various triggering signals to the TDC's are not individually wired but instead chained, the time for each TDC is slightly different. Even though all the PMT's have been gain matched, they still experience slightly different amplifying times. These inconsistences lead to small, but significant, shifts in the average time calculated from the two TDC parameters (Tmean). In this process we will record cosmic rays passing through MoNA and gate on events that pass nearly straight down. The speed of cosmic ray muons are very nearly 29.98 cm/ns (speed of light, c; the value of 29.8 cm/ns is used as the speed of the muons in calculations). So, if we look at the Tmean values for these events between two bars, we can calculate the proper time offset of these two bars relative to each other. If we gate on only muons travelling nearly straight down, the time difference is 0.344 ns for a 10 cm bar (10.26 cm is used as the dimensions of the bar because of tape and gaps between bars). If we use bar A8 as our reference (A8 offset is set to 0), the whole MoNA array, each bar, can then be set to have the proper time offsets. The Tmean differences between bars are calculated through pseudo parameters and the values read by a code from their spectra.

6.1 Finding Independent Offsets

Before any offset values can be calculated, a long cosmic-ray run must be taken. This new run requires the all previous calibrations to be preformed first.

1. Record an overnight (12 hours) run of cosmic ray data with all detector bars. Use MoNA multiplicity set to `3-fold, cosmics` and select self-trigger and self-stop on the XLM control. Also be sure that you are using calibrated slope/offset values for both the QDC and TDC parameters and check that the calibration flags in `MoNA_setup_run.tcl`:

   ```
   QDC_thres_flag
   QDCfitted
   TDCfitted
   Xposfitted
   ```

   are set to `"true"`, while `Tmean_indie_offset` is set to `"false"`.

2. Open MoNA SpecTcl[5] in the *spice* terminal window or from a Data U. machine.

3. From the TkCon window type:

   ```
   % source ~/mona/contrib/tmean_offset_cal/source.tcl
   ```

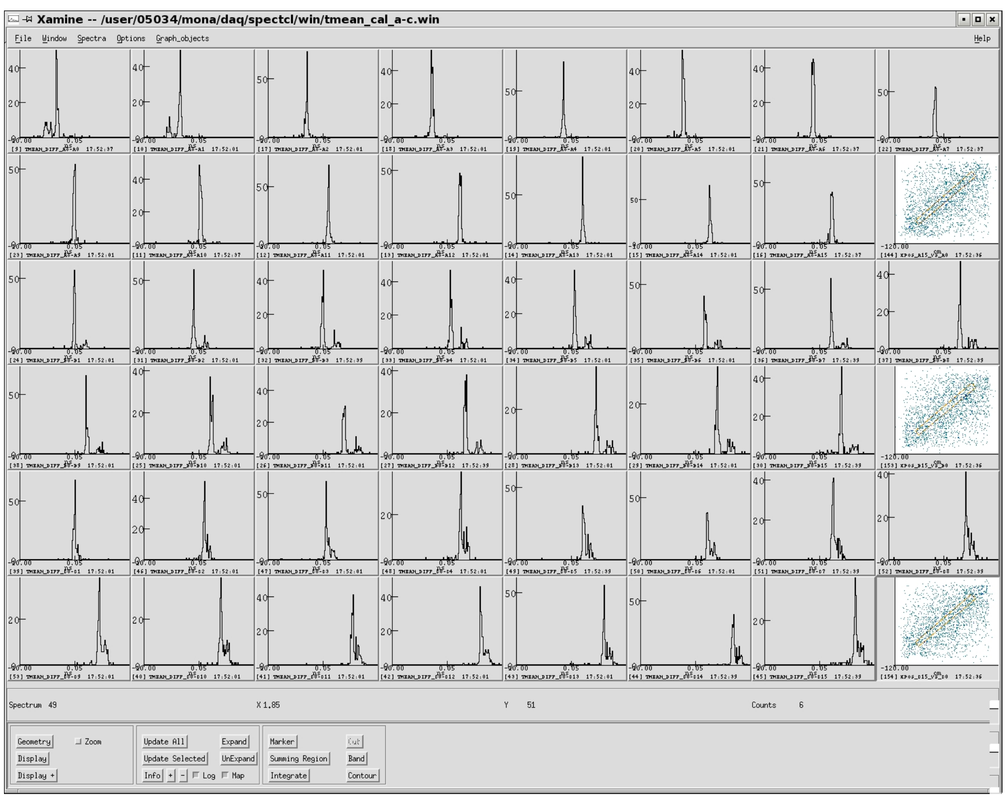
   This will execute all the necessary `tcl` code to create the proper pseudos, make the straight-down gates, and apply them to the new parameters.

4. Then choose *Attach Multiple*, and select all of the run files recorded in step 1. Or using the `attach -pipe cat` command in the TkCon window, manually type in all of the run files recorded in step 1 then select *Start Analysis*.

5. In Xamine select `Window -> Read Configuration`, and pick one of the three `/win/tmean_cal_x-x.win` window settings to view the spectra.

6. Allow SpecTcl to analyze all the buffers to ensure sufficient statistics. This may take overnight since the run was so long. When the data is read in, click *Update All* in Xamine.

7. Look through the spectra in Xamine to make sure the data is usable (i.e. that there is a distinct peak in each Tmean-difference spectrum).



8. Write all tmean_diff spectra using the *Write Tmean_offsets Spec* button on the MoNA SpecTcl window.

9. Open a *spice* terminal window and from directory `~/mona/contrib/tmean_offset_cal` open `MoNA_Tmean_indie_offsets`. This will open the executable that will calculate the Tmean independent offsets. It calculates these by finding a gravity fit (weighted average) 0.3 ns to either side of the peak bin (measured). The program assumes the x axis (in ns) is symmetric about 0 (i.e. -10 to +10 ns).

   For layer A the offsets for bar, N, are:

   ```
   Offset = -[Theory(A8-AN) - Measured(A8-AN)]
   ```

   For the cross terms (e.g. A15-B0) the offsets for layer, X, are:

   ```
   Offset = [Theory(A15-X0) - Measured(A15-X0)] - Offset(A15-A8)
   ```

   For all other layers the offsets for layer, X, and bar, N, are:

   ```
   Offset = Offset(A15-X0) - [Theory(X0-XN) - Measured(X0-XN)]
   ```

10. Edit `MoNA_setup_run.tcl` and save with `Tmean_indie_offset` set to `"true"` to read the `MoNA_Tmean_indie_offsets.tcl` file during next start up.

11. If you now restart SpecTcl and repeat steps 3-7, the peaks in each spectra should show up right at the `theoretical` values listed in the file `Tmean_offsets_theoretical`. In between steps 3 and 4 you must reread the independent offset file you just made (since the first line of `source.tcl` reads in a blank set of offsets).

    ```
    % source $env(MONA_CONFIGDIR)/MoNA_Tmean_indie_offsets.tcl
    ```

12. If you would like to redo the Tmean independent offsets, you must delete or rename the file `~/config/MoNA_Tmean_indie_offsets.tcl` before executing the code again.

Double check that all the calibration flags in `MoNA_setup_run.tcl` (mentioned in Chapter 1) are set to ”true”. For future runs, MoNA is now calibrated with data specific for the experiment.

References

[1] R. Fox, *SpecTcl - User's Guide* October 28, 2003. NSCL. http://docs.nscl.msu.edu/daq/spectcl/users_guide.htm

[2] J. Miller, M. Strongman, L. Elliott, D.B. Hecksel, M.M. Kleber, P.J. Voss, T. Pike, R. Pepin, A. Ratkiewicz, W.A. Peters, D. Albertson *MoNA Calibration* 2006. NSCL. `/projects/proj1/mona/reports`

[3] G. Christian, W.A. Peters, *MoNA Position Calibration* 2005. NSCL. `/projects/proj1/mona/reports`

[4] K. Yoneda, W.A. Peters, *MoNA Fitting Codes* 2004. NSCL. `/projects/proj1/mona/reports`

[5] A. Ratkiewicz, W.A. Peters, *MoNA SpecTcl Guide* 2006. NSCL. `/projects/proj1/mona/reports`

[6] W.A. Peters, *Tandem SpecTcl Guide* 2006. NSCL. `/projects/proj1/mona/reports`