



# Sweeper Thick and Thin Scintillator Calibration

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## 1 Introduction

This document is intended to guide you through the process of correcting for position dependence of the thick and thin scintillators. This calibration should be performed after the Time of Flight calibration and the CRDC position calibrations. The first task in this guide is to calibrate the individual PMTs to correct for gain differences. After that, any remaining dependence is corrected for by introducing an equation into the energy spectra.

### 1.1 Setup

Open Tandem Spectcl and type in source `tcl/thick_thin_cal/thick_thin_pos_source.tcl` in order to create the pseudos for the thick x, thick y, thin x, and thin y positions. This file calculates the positions of particles on the thick and thin detectors based on their positions on the CRDCs. After that, go into your GUI and load the definition file.

The run list will be referenced several times in order to find appropriate runs to perform your calibration on. You may want to print it out for reference.

## 2 Time Dependence on PMTs

The first task is correcting for the different gains of the individual photomultiplier tubes. In order to calibrate the PMTs, the time to each tube must be known to be the same. Therefore, only particles impacting on the center of the detectors can be considered. You can cut out other particles by gating on the center of the thick and thin detectors. From there the distance to each photomultiplier tube is equal, so for any particle impacting within this region, the energy signal on each PMT should be the same. Due to differences in the gain, though, they will not be. You must correct the individual tubes with respect to one another.

### 2.1 Finding a centered beam

Create a spectrum for `thick.xpos` versus `thick.ypos`. You can do this in the spectra tab of your GUI. For *Spectrum Type* select *2D*. Under *Spectrum Name*, type in a descriptive name like `thick_xpos_vs_ypos`. Under *X Parameter*, type in `thick.xpos` and under *Y Parameter*, type in `thick.ypos`. For both the X and Y parameters, *Low* should be set to  $-200$ , *High* to  $200$ , and *Bins* to  $401$ . Press the *Create/Replace Spectra* button to create the spectra, and click *Update Spectrum List* at the bottom of the GUI.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
33	1029	DB	6-Aug	thin Ex.1	thin	n/a	-2.9522		305	tuning		Focus Check						
34	1030	DB	6-Aug	thin Ex.1	thin	n/a	sweep		305?	CRDC1 Mask		spstg16 crashed						
35	1031	DB	6-Aug	thin Ex.1	thin	n/a	sweep		305?	CRDC1 Mask		CRDC calc						
36	1032	DB	6-Aug	thin Ex.1	thin	n/a	sweep		305?	CRDC2 Mask		CRDC calc						
37	1033	WAP	15.10	6-Aug	thin Ex.1	thin, conc	D.S=2 1-fold		-4.5453	matched?	188	production						
38	1034	WAP	16.00	6-Aug	thin Ex.1	thin, conc	D.S=2 1-fold		-4.5433	matched?	188	production						
39	1035	WAP	17.00	6-Aug	thin Ex.1	thin	1-fold		-4.0039	2.369	188	thickness						188 and Dia
40	1036	WAP	17.04	6-Aug	thin Ex.1	thin	1-fold		-3.8184	2.292	188	thickness						188 and Dia
41	1037	WAP	17.05	6-Aug	thin Ex.1	thin	1-fold		-3.8184	2.292	188	thickness						188 and Dia
42	1038	WAP	17.08	6-Aug	thin Ex.1	thin	1-fold		-3.8184	2.292	188	thickness						188 NO Dia
43	1039	WAP	17.20	6-Aug	thin Ex.1	thin	1-fold		-4.375	2.54	94	thickness						94 NO Dia
44	1040	WAP	17.28	6-Aug	thin Ex.1	thin	1-fold		-3.0731	2.01	305	thickness						305 NO Dia
45	1041	WAP	17.36	6-Aug	thin Ex.1	thin	1-fold		-4.7437	2.71	none	thickness						NO Dia
46	1042	WAP	17.39	6-Aug	thin Ex.1	thin	1-fold		-4.7437	2.71	coll	tuning						NO Dia
47	1043	WAP	17.43	6-Aug	thin Ex.1	thin	1-fold		-4.7437	2.71	none	efficiency						Dia. in
48	1044	WAP	17.51	6-Aug	thin Ex.1	thin	1-fold		sweep	n/a	none	tuning						Dia. in
49	1045	WAP	18.04	6-Aug	thin Ex.1	thin	1-fold		-4.9425	2.76	none	tuning						Dia. in
50	1046	WAP	18.06	6-Aug	thin Ex.1	thin	1-fold		-4.9382	2.646	none	tuning						Dia. in
51	1047	WAP	18.11	6-Aug	thin Ex.1	thin	1-fold		-4.3555	2.527	none	tuning						Dia. in
52	1048	WAP	18.18	6-Aug	thin Ex.1	thin	1-fold		-4.3555	2.527	none	tuning						Dia. in
53	1049	WAP	18.23	6-Aug	thin Ex.1	thin	1-fold		-4.3524	2.408	none	tuning						Dia. in
54	1051	WAP	18.27	6-Aug	thin Ex.1	thin	1-fold		-4.342	2.52	coll	tuning						NO Dia
55	1051	WAP	18.32	6-Aug	thin Ex.1	thin	1-fold		-4.8419	2.761	coll	tuning						NO Dia
56	1052	MK	19.15	6-Aug	thin Ex.1	thin	1-fold		-5.0146	2.85	188	production						
57	1053	JM	19.35	6-Aug	thin Ex.1	thin	1-fold		-5.0153	2.85	188	production						
58	1054	MK	6-Aug	thin Ex.1	thin	1-fold			-4.7363	2.7075	188	production						
59	1055	MK	6-Aug	thin Ex.1	thin	1-fold			-4.7363	2.7075	188	production						
60	1056	JM	6-Aug	thin Ex.1	thin	1-fold			-4.7363	2.7075	188	production						
61	1057	MK	6-Aug	thin Ex.1	thin	1-fold			-4.7363	2.7075	188	production						
62	1058	MK	6-Aug	thin Ex.1	thin	1-fold			-4.454	2.57	188	production						
63	1059	MK	6-Aug	thin Ex.1	thin	1-fold			-4.454	2.57	188	production						
64	1060	MK	6-Aug	thin Ex.1	thin	1-fold			-4.317	2.5089	188	production						
65	1061	WAP	7-Aug	thin Ex.1	thin	1-fold			-4.317	2.5089	188	production						
66	1062	WAP	7-Aug	thin Ex.1	thin	1-fold			-4.3481	2.523	188	production						
67	1063	WAP	7-Aug	thin Ex.1	thin	1-fold			-4.3481	2.523	188	production						
68	1064	WAP	7-Aug	thin Ex.1	thin	1-fold			-4.8175	2.749	188	production						the last sweeps without
69	1065	JDH	7-Aug	thin Ex.1	thin	1-fold			-4.8175	2.749	188	production						
70	1066	NF	7-Aug	thin Ex.1	thin	1-fold			-4.8169	2.749	188	production						
71	1067	NF	7-Aug	thin Ex.1	thin	1-fold			-4.8169	2.749	188	production						
72	1068	JB	7-Aug	thin Ex.1	thin	1-fold			-4.8163	2.749	188	production						
73	1069	NF	7-Aug	thin Ex.1	thin	1-fold			-4.8169	2.749	188	production						
74	1070	JB	7-Aug	thin Ex.1	thin	1-fold			-4.8169	2.749	188	production						
75	1071	JB	7-Aug	thin Ex.1	thin	1-fold			-4.8169	2.749	188	production						
76	1072	JB	7-Aug	thin Ex.1	thin	1-fold			-4.8169	2.749	188	production						
77	1073	JB	7-Aug	thin Ex.1	thin	1-fold			-4.8169	2.749	188	production						
78	1074	WAP	7-Aug	thin Ex.1	thin	1-fold			sweep	305	CRDC1 Mask							
79	1075	WAP	7-Aug	thin Ex.1	thin	1-fold			sweep	305	CRDC2 Mask							

### 2.1.1 Andgates

It may also be necessary to create a gate that removes any artificial features in the spectrum. If this becomes necessary, create a fragment gate and a gate which removes any artificial features. Construct an and gate combining them. You can do this under the gates tab of your GUI. Type the name of your and gate into the box under *Create/Replace* . Under *Gate Select* , type the names of your two gates, making sure to leave a space between them. In the upper right hand corner, select the gate type and. Now create your gate by clicking *Create/Replace*.

### 2.1.2 Gate Application

Now apply your gate to the `xpos vs. ypos` spectrum. This can also be done in the GUI. Select *Gate* in the middle right of the *Spectra* tab and pull down until you find your gate. Now select your spectrum from the list and click *Apply*.

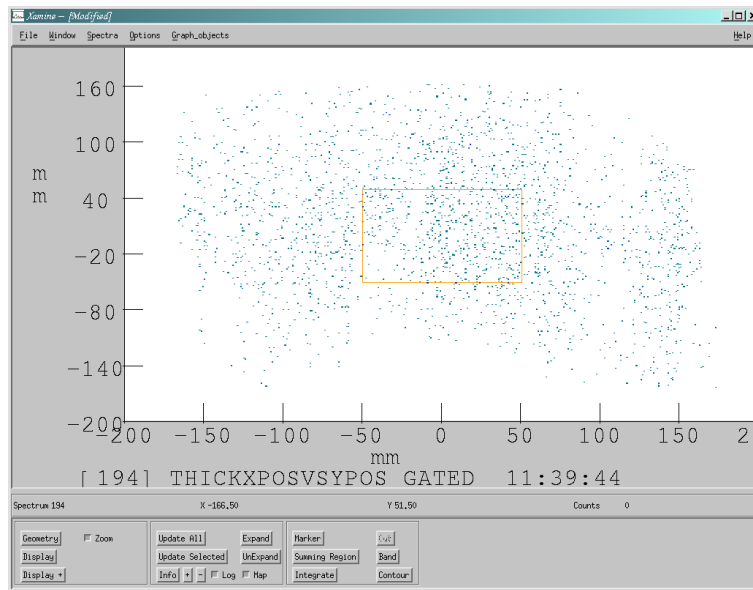
### 2.1.3 Runlist

After this, you can reference the run list to find a production run with a magnetic field that focuses your fragment on the center.

There are a few different types of runs that you will use for calibration. In a sweeper run, the beam moves in a straight line in the x direction across the target. This gives the user a good idea as to what the energy distribution should look like in the x direction. In a production run, the beam hits a target, and the set magnetic field of the sweeper causes different particles to impact the detectors at different positions. In a no target run, the sweeper magnet maintains a constant magnetic field, which places the beam at a single position on the detector.

You will use different types of runs in calibrating the different detectors. The most heavily populated isotope is unreacted beam, and should be used when possible. However, it can only be used to calibrate the thin detector because the thin detector stops particles larger than  $Z=15$ . In order to calibrate the thick scintillator, you must use a lighter particle such as those produced on a target. Choose one that is produced in abundance. In calibrating the PMTs, it is best to use runs centered about 0 in both the X and Y directions. Therefore, you will use a production run for the thick scintillator, and a no target run for the thin scintillator.

A little guess and check may be needed to find a run that focuses your particle well. When you have found an appropriate run, gate on the center. A contour gate from  $-50$  to  $50$  in both the X and Y directions should give you enough points to work with. You want the smallest gate possible while still retaining enough points to work with.

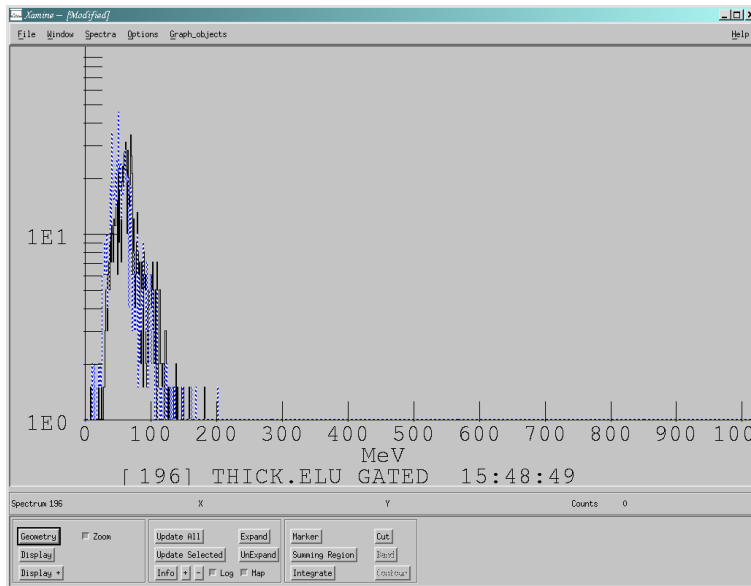


You now want to create an and gate combining the isotope gate and the center position gate.

Create spectra identical to `thick.Eld`, `thick.Elu`, `thick.Erd`, and `thick.Eru`. Name them something along the lines of `thick.Eld_gated`. Apply the new and gate to them.

## 2.2 Changing the Variables

Now, you must change the slopes and offsets for the different PMTs so that they match each other. Bring all four gated spectra up in Xamine. Attach the same run you gated on earlier. Select one spectrum to use as your base for correcting the others. Superimpose one of the other spectra onto that one. You can do this by clicking on the spectrum you are using as a base and clicking the drag down menu *Spectra* at the top of the Xamine window. Select *Superimpose*. From the list it gives you, select the spectrum you would like to correct. Click *OK*. The spectrum should now be superimposed upon your base.



## 2.2.1 Displaying the Variables

In your GUI, go to the variables tab. Make sure these variables are displayed:

```

user.e.thick_ld.offset
user.e.thick_ld.slope
user.e.thick_lu.offset
user.e.thick_lu.slope
user.e.thick_rd.offset
user.e.thick_rd.slope
user.e.thick_ru.offset
user.e.thick_ru.slope

```

If they are not, select a slot for the variable by clicking a diamond to select the corresponding slot, and selecting the appropriate variable from the drop down list, *Variables*, which is located at the top left in the GUI. The spectra you are using, such as `thick.Eld`, are the calibrated versions of other spectra like `thick.deld`. `thick.deld` is in units of channels while `thick.Eld` is in units of nanoseconds. The calibration process changes channels to nanoseconds with the relation  $y = mx + b$ . The slope variable will change the spread of a spectrum while the offset will change the time offset. `thick.Eld` and its counterparts for the other tubes will then be used to calculate `user.e.thick_total.cal`. This parameter is the total calibrated energy, and will be used in the second part of calibration as well as your analysis.

Your variable file needs to be saved as something new after you implement your new variables. You can do this at the bottom of the page.

## 2.2.2 Finding the Variables

Now change your variables so that the two graphs match up as well as possible. You will need to click *Update Spectra* on the GUI whenever you change your variable values. Also, do not forget to *Clear Spectra* in the tandem window whenever you have implemented a new correction factor. A good way to find the

correct variables may be to first find the ratio between the widths of the spectra and use that as the slope variable. You should then be able to attach the run again and locate the offset easily.

## 2.3 Finishing

When you are finished, save your altered definition file with a new name, and reference this one from now on.

# 3 Position Dependence on Energy

Though you have calibrated the PMTs, there may still be a position dependence on energy. Source the file `tcl/thick_thin_cal/thick_thin_xpos_ypos.tcl` to create your position versus energy pseudos and spectra for both the calibrated and uncalibrated cases. The spectra created are as follows:

```
thick_xpos_uncal
thick_ypos_uncal
thin_xpos_uncal
thin_ypos_uncal
thick_xpos_cal
thick_ypos_cal
thin_xpos_cal
thin_ypos_cal
```

However, the calibration variables for the calibrated case still need to be set.

## 3.1 Selecting a run and an isotope

You can gate on the same fragment you used to calibrate the PMTs. Apply the gate to your `thick_xpos_uncal` and `thick_xpos_cal` spectra.

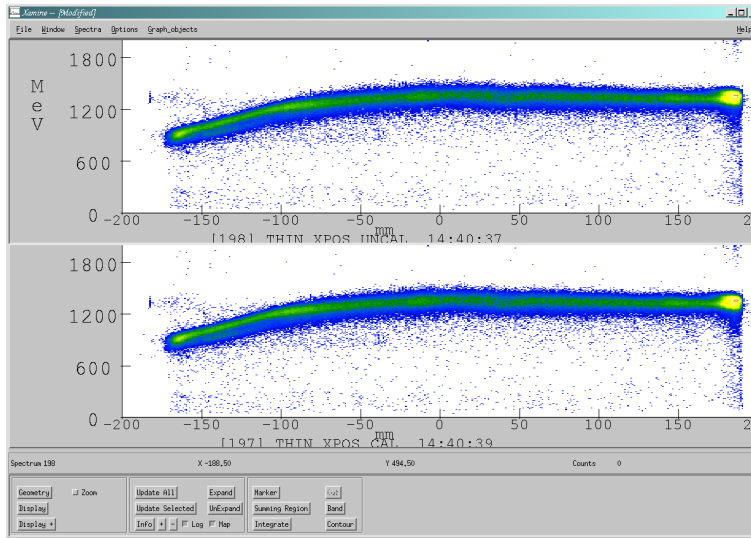
In the run list, find a production run to attach to `spectcl`. You will use this run to calibrate the thick X position. It may be necessary to attach more than one run in order to see the line of best fit clearly.

### 3.1.1 Display

In Xamine, set the configuration to display uncalibrated and calibrated runs for thick X. You will need 2 cells. Display:

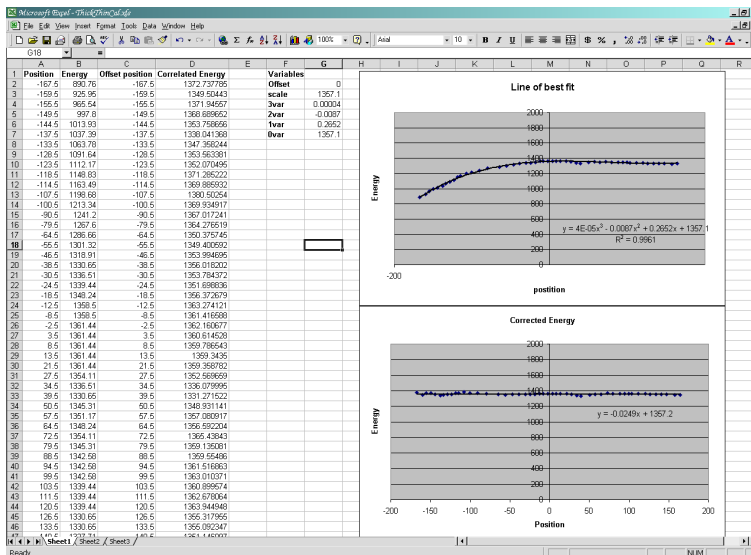
```
thick_xpos_uncal
thick_xpos_cal
```

Your calibrated and uncalibrated spectra will look identical until you find the calibration coefficients. A spectrum with no position dependence will appear as a straight line across the graph. It is likely, however, that there is a position dependence in your spectra. This must be corrected for. You need to find an equation that cancels out the position dependence in your spectra.



### 3.2 Correction Factors in Excel

Load the Excel file, `ThickThinCal.xls` which should be located in your experiment folder. This file takes your spectrum and finds an equation to flatten it out. First, it finds the line of best fit for your position versus energy data. It uses a third order equation of the form  $a(x - x_0)^3 + b(x - x_0)^2 + c(x - x_0) + d$  to fit your line. Then, it requires the user to enter the coefficients of the variables into the appropriate cells. The file then takes the inverse of this equation and multiplies it back by the Energy to find a corrected graph.



When your data has finished running in, (or, if it's a long set, a representative portion) click on the `thick_xpos_uncal` graph in your Xamine window. Move the cursor over the thickest part of your line, and enter several representative data points into the excel file. The file allows for 50 points, but as few as 15 should work. The top chart will display your points and the line of best fit for them. The bottom chart displays your corrected spectrum. You should now save your excel spreadsheet as something new.

### 3.2.1 Correcting for Position Dependence

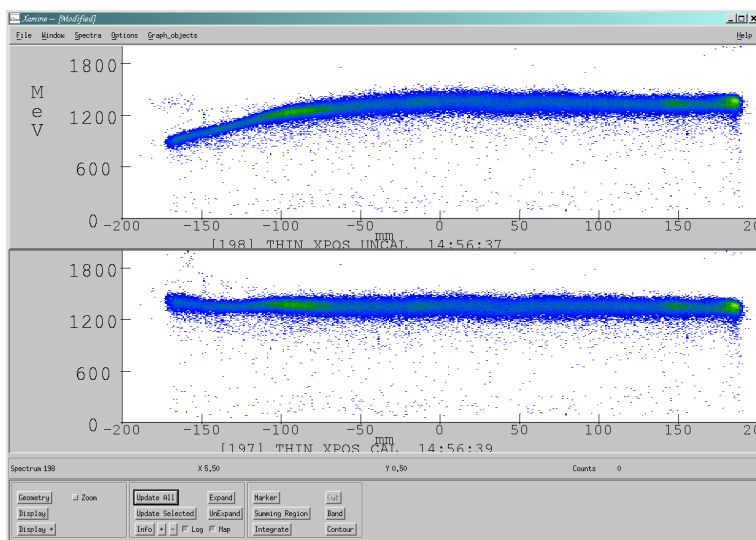
You need to manually change the coefficients for the equation of the bottom graph. You can do this in the *Variables* column. Leave the *Offset* and *Scale* alone for now. The coefficient for the third order variable,  $a$  in the above equation, goes into the spot for  $3var$ , second coefficient into  $2var$ , and so on. Your *Corrected Energy* graph should now look about flat. However, since we have essentially taken one equation and multiplied it by its inverse, the magnitude of the graph should be about 1. Use the *Scale* variable to change it to a magnitude similar to that of the top graph. The offset value is used to adjust the first graph in an attempt to find an even better fit, and thus find the flattest line possible for the second graph. However, the values for your line of best fit will change as your offset does, so do not forget to change your coefficients.

### 3.3 Setting the Variables

Once you have found a satisfactory fit, record the values for each variable. You will need them later. Now go back into your Tkcon window and type `set thick_xpos_3order_var xxx` where xxx is the value you found in Excel. Do this for the rest of your variables:

```
set thick_xpos_2order_var xxx
set thick_xpos_1order_var xxx
set thick_xpos_0order_var xxx
set thick_xpos_scale_set xxx
set thick_xpos_offset xxx
```

Now, if you *Clear Spectra* and source your run again, your `thick_xpos_cal` graph in Xamine should be flat.



### 3.4 Calibrating the Other Spectra

The process for calibrating `thin_xpos` is virtually identical to that of calibrating `thick_xpos`, except that you should use a sweeper run. A sweeper run gives the best position dependence information for this detector in this direction.

When finding your values for `thick_xpos`, you should try to find a run that is unfocused in the Y direction. Production runs are often good for this. Remember that unreacted beam does not often get through the thin detector, and you will have to gate on a lighter isotope. You can use the same gate you used for `thick_xpos`.

The procedure for correcting `thin.ypos` differs from the procedure for correcting `thick.ypos` in only one way. Unreacted beam larger than  $Z=15$  is detected on the thin scintillator and should be used if possible in order to maximize the number of data points available.

### **3.5 finishing**

When you have set all your variables, open the file `thick_thin_xpos_ypos.tcl`. At the top, set the variables to their new values, save it with a new name, and source that file from now on.