Pixie-4 Express

Software Manual

- Coincident Energy Plots -

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Safety

Please take a moment to review these safety precautions. They are provided both for your protection and to prevent damage to the Pixie module and connected equipment. This safety information applies to all operators and service personnel.

Specific Precautions

Observe all of these precautions to ensure your personal safety and to prevent damage to either the Pixie module or equipment connected to it.

Power Source

The Pixie module is powered through a PXI Express (PXIe) chassis. Please refer to the chassis manual for the correct AC voltage connections. The chassis must be powered down to insert and remove the module.

User Adjustments/Disassembly

To avoid personal injury, and/or damage, always turn off power before accessing the Pixie module's on-board switches and jumpers.

Detector and Preamplifier Damage

Because the Pixie module does not provide power for the detector or preamplifier there is little risk of damage to either resulting from the Pixie module itself. Nonetheless, please review all instructions and safety precautions provided with these components before powering a connected system.

Voltage Ratings

Signals on the analog inputs (gold SMA connectors) must not exceed ± 3.5V. Exceptions apply for certain attenuation and termination settings, see Appendix.

Signals on the digital inputs (gold MMCX connector and 10-pin 2mm har-link connector) must not exceed 3.3V.

Servicing and Cleaning

To avoid personal injury, and/or damage to the Pixie module or connected equipment, do not attempt to repair or clean these units. These modules are warranted against all defects for one (1) year. Please contact the factory or your distributor before returning items for service.

Warranty Statement

XIA LLC warrants that this product will be free from defects in materials and workmanship for a period of one (1) year from the date of shipment. If any such product proves defective during this warranty period, XIA LLC, at its option, will either repair the defective products without charge for parts and labor, or will provide a replacement in exchange for the defective product.

In order to obtain service under this warranty, Customer must notify XIA LLC of the defect before the expiration of the warranty period and make suitable arrangements for the performance of the service.

This warranty shall not apply to any defect, failure or damage caused by improper uses or inadequate care. XIA LLC shall not be obligated to furnish service under this warranty a) to repair damage resulting from attempts by personnel other than XIA LLC representatives to repair or service the product; or b) to repair damage resulting from improper use or connection to incompatible equipment.

THIS WARRANTY IS GIVEN BY XIA LLC WITH RESPECT TO THIS PRODUCT IN LIEU OF ANY OTHER WARRANTIES, EXPRESSED OR IMPLIED. XIA LLC AND ITS VENDORS DISCLAIM ANY IMPLIED WARRANTIES OF MERCHANTABILITYOR FITNESS FOR A PARTICULAR PURPOSE. XIA'S RESPONSIBILITY TO REPAIR OR REPLACE DEFECTIVE PRODUCTS IS THE SOLE AND EXCLUSIVE REMEDY PROVIDED TO THE CUSTOMER FOR BREACH OF THIS WARRANTY. XIA LLC AND ITS VENDORS WILL NOT BE LIABLE FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES IRRESPECTIVE OF WHETHER XIA LLC OR THE VENDOR HAS ADVANCE NOTICE OF THE POSSIBILITY OF SUCH DAMAGES.

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Manual Conventions

The following conventions are used throughout this manual

Convention	Description	Example
»	The **»** symbol leads you through nested menu items and dialog box options.	The sequence **File»Page Setup»Options** directs you to pull down the **File** menu, select the **Page Setup** item, and choose **Options** from the sub menu.
Bold	Bold text denotes items that you must select or click on in the software, such as menu items, and dialog box options.	...click on the **MCA** tab.
[Bold]	Bold text within [ ] denotes a command button.	**[Start Run]** indicates the command button labeled Start Run.
`monospace`	Items in this font denote text or characters that you enter from the keyboard, sections of code, file contents, and syntax examples.	`Setup.exe` refers to a file called "setup.exe" on the host computer.
"window"	Text in quotation refers to window titles, and quotations from other sources	"Options" indicates the window accessed via **Tools»Options**.
Italics	Italic text denotes a new term being introduced , or simply emphasis	*peaking time* refers to the length of the slow filter. ...it is important first to set the energy filter Gap so that SLOWGAP to *at least one unit greater than* the preamplifier risetime...
<Key> <Shift-Alt-Delete> or <Ctrl+D>	Angle brackets denote a key on the keybord (not case sensitive). A hyphen or plus between two or more key names denotes that the keys should be pressed simultaneously (not case sensitive).	<W> indicates the W key <Ctrl+W> represents holding the control key while pressing the W key on the keyboard
Bold italic	Warnings and cautionary text.	***CAUTION:*** *Improper connections or settings can result in damage to system components.*
CAPITALS	CAPITALS denote DSP parameter names	SLOWLEN is the length of the slow energy filter
SMALL CAPS	SMALL CAPS are used for panels/windows/graphs in the GUI.	…go to the MCADISPLAY panel and you see…

1 Introduction

The Pixie-4 Express is designed, among other things, to acquire list mode data from coincident events in multiple radiation detectors. The methods to set up and acquire such coincident data, and basic functions to view results, are described in the Pixie-4 Express User's Manual. More advanced functions to display coincident events, including the generation of 2D energy spectra, are provided as a set of add-on procedures to the Pixie Viewer interface. These functions are described in this document.

1.1 Pixie-4 Express Coincident Energy Plotting Functions

- Plotting of Ey vs Ex scatter plots (x,y = channel 0,1,2,3 of the same module)
- Histogramming of data into Ey vs Ex 2D histograms
- Definition of region of interest (ROI) in the histogram
- Extraction of ROI sum and 1D projections
- Export as ASCII text and other formats
- TDC histograms (offline)

1.2 System Requirements

The advanced energy plotting functions require the Pixie Viewer software (version 4.21 or higher) and Wavemetrics' Igor Pro (version 6.22 or higher).

High resolution histograms require significant PC memory and processing power.

1.3 Software Overview

The advanced energy plotting functions are contained in an Igor procedure file (ipf). After starting the Pixie Viewer as described in the User's Manual, the procedure file must be loaded to make use of the functions. See section 2 for details.

The functions operate on list mode data files acquired previously. They can (currently) not be used for processing during acquisition, but are fully functional in offline mode.

All controls are consolidated in two plots, the 2D SPECTRUM, shown in Figure 4-1 and the TIME DIFFERENCE panel, shown in Figure 4-3.

1.4 Support

Please read through this manual before contacting us. Contact information is listed in the first few pages of this manual.

1.5 Principle of Operation

When trying to measure time and energy of pulses from different detector channels that are "related" and belong to a common multi-channel event, a fundamental problem is to decide what is "related". A seemingly simple approach might be to consider all pulses arriving within a short coincidence window (CW) as a group and consider them related. However, this approach becomes difficult if there are multiple pulses within a CW in a single channel – which of the pulses should be used and/or how to report multiple times and energies per CW. Furthermore, closely following pulses can create a series of overlapping the CW, where an individual pulse may belong to several CW records.

In the Pixie-4e, we therefore implemented the concept that an event record is captured for every detected rising edge. This is the most general case and ensures all possible data is captured (for example a time stamp and energy value for each pulse). The problem then becomes one of relating the different records to each other. In the general purpose run type 0x400, each record is for a single channel only, which would require some time sorting between the channels. In the "group mode" run type 0x402, each record contains data from all 4 channels. This eliminates the need to sort the channels, and the following discussion is for data acquired with this run type. The event record includes flags to indicate which channel actually saw a pulse in the current record (hit). For those channels that did not see a pulse, previous energies and time stamps are repeated.

From the data of each 4-channel record, one can then compute the time difference between two channels.

1. If the pulses were truly simultaneous for purposes of data acquisition (i.e. within 1-2 processing clock cycles of 8ns), both channels are flagged as hit, and the time stamp difference is those 1-2 cycles.
2. If only one channel is hit, the time stamp difference is the time from the hit channel's rising edge to the last previous rising edge of the channel that is not hit, i.e. always looking back in time.
3. If none of the channels is hit, the time stamp difference is from two previous pulses (the record has been captured based on the trigger from a third channel). This means the difference repeats and should not be included in any timing histograms. The hit flags can be used to recognize this case.
4. To compute time difference between two pulses of the same channel, use two subsequent records – if the time stamp difference is nonzero, it is the time between two real pulses.

The time differences computed in this way can then be directly be binned into a histogram. To plot energies, specifically energy sums or related energies from two channels, a CW cut has to be applied, for example Esum = 0 if Tdiff > CW. Still open is the question on how to histogram Esum for multiple records within a CW to avoid double counting.

2 Installation

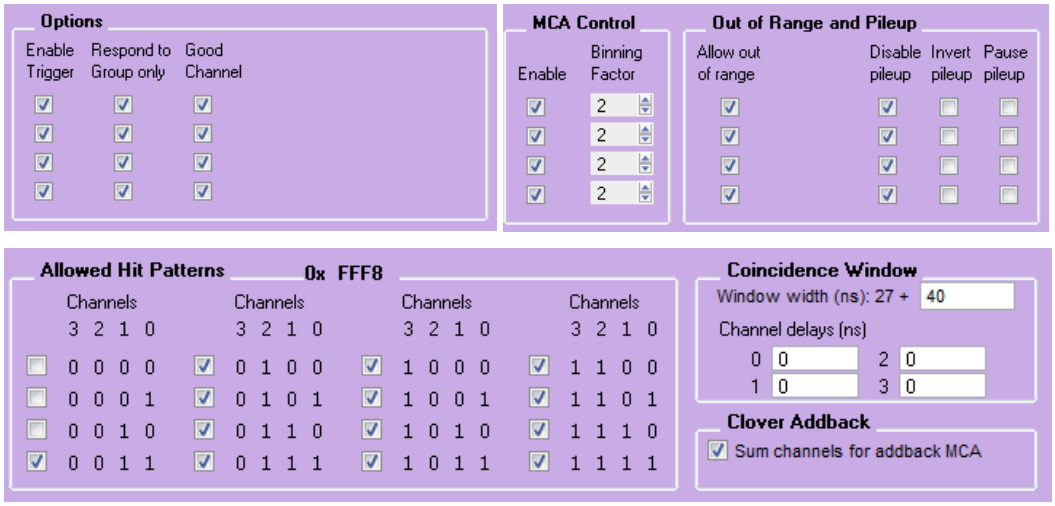
To install the advanced functions, go through the following steps

- Install Igor Pro and the Pixie Viewer software as described in the User's Manual
- Copy the files `XIA_E2D.ipf` and `Pixie_Ecoinc.pxp` into the top level folder of the Pixie software distribution, typically C:/XIA/Pixie4e
- Open the Pixie Viewer variant by double clicking `Pixie_Ecoinc.pxp`
- Initialize the variant specific global variables by selecting top menu **XIA » 2D MCA initialize globals**
- In the PIXIE START UP panel, click **[Start Up System]** or **[Offline Analysis]** to initialize the software.
- Open the 2D SPECTRUM display by selecting top menu **XIA » 2D MCA**
- Open the TIME DIFFERENCE panel by selecting top menu **XIA » Timing**

3 Data acquisition settings

For the coincidence energy functions, the data must be acquired in run type 0x402. Please see section 4.2.1 of the user manual for details. In particular, please remember that the following options must be enabled in the settings:

- enable group trigger for all channels to record data synchronously
- same trace length and energy filter length for all channels
- MCA binning factor should be 2 or more to ensure the energies are binned into the 16Ki MCA without being cut off
- enable option for MCA sum histogram



The options of gating, vetoing, accepting out-of-range or piled up pulses apply to the whole set of 4 channels. So for example, if one out of 4 channels is piled up, nothing is recorded for any channel unless pileup rejection is turned off for that channel. It is best to disable pileup rejection and allow out of range events initially.

The coincidence settings can be freely selected: If only real coincidences are of interest, check only the boxes in the coincidence tab that match the desired hit pattern and set the **Window Width** appropriately to the experiment (e.g. accommodating cable delays, time of flight delays, etc.). The Pixie module will then only record those events. But if file size and throughput are of no importance, it is equally possible to record all events (**Allowed Hit Patterns** = 0xFFFE) and have the offline routines filter out coincidences.

All other settings function as in the standard data acquisition, i.e. ensure gain and offsets are set properly, decay time tau is correct, etc.

4 Offline Analysis

The 2D SPECTRUM display is shown in Figure 4-1. Controls in the upper section of the display are used to select a file and read data from it, to set the display parameters, to open further plots, and to analyze and export the data. These controls will be described in the following sections.

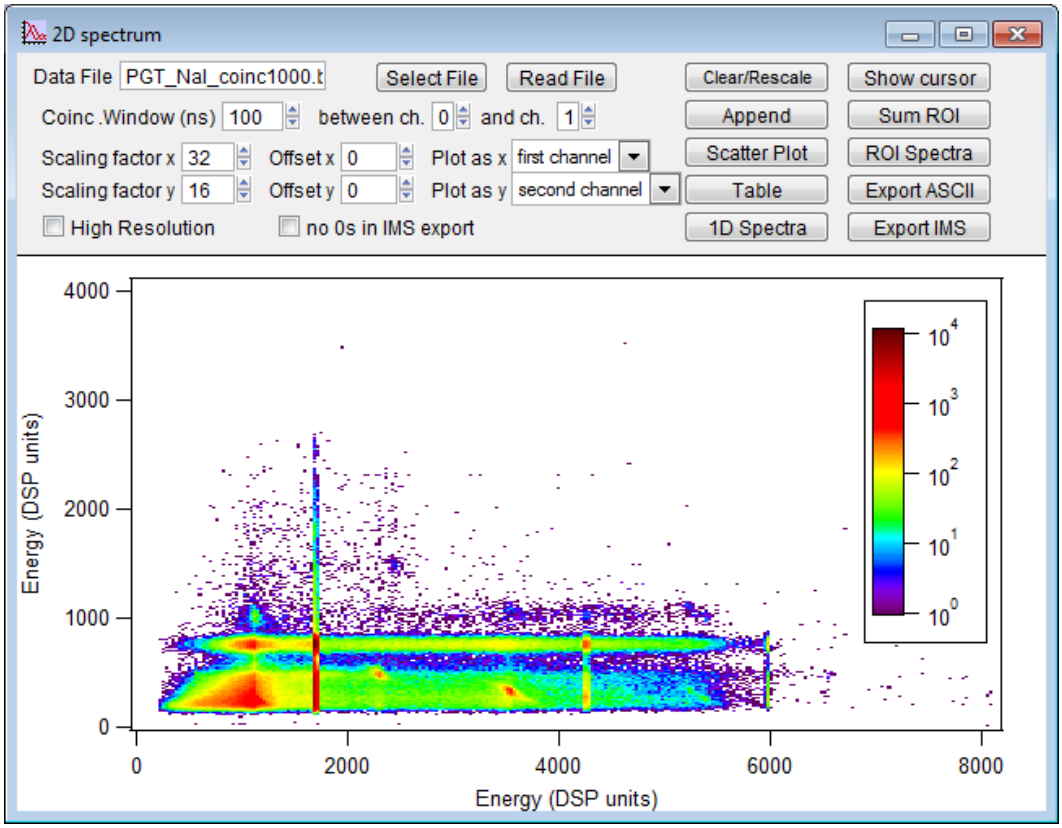


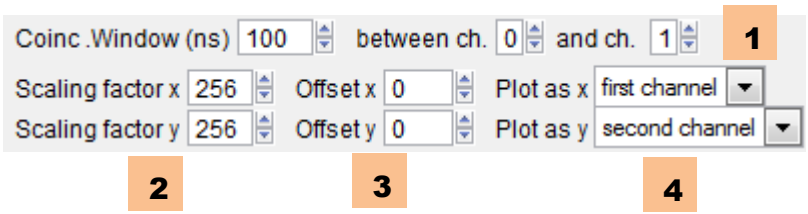
Figure 4-1: The 2D SPECTRUM display. Data shown is from a coincidence setup of a HPGe detector and a NaI detector with a Na-22 source

4.1 File I/O

The name of the file to plot can be entered directly in the **Data File** control field, or can be selected in a dialog by clicking on the **[Select File]** button. These are the same controls as in the LIST MODE TRACE display of the Pixie Viewer. After selecting the file name, the **[Read File]** button must be clicked to extract the energy data from the file and load it into a local array in Igor.

4.2 Histogramming Parameters

The data loaded from the file is a list of energies and time stamps. To process this list into a histogram, first specify the following parameters



1. Define the channels to plot (0..3) and the window (in ns) for which events are considered coincident.
   Note: The coincidence window in the PARAMETER SETUP panel is used for data acquisition – events further apart than specified are not recorded. The coincidence window specified here is for plotting recorded events in the 2D energy spectrum.
2. Specify the scaling factor to map the DSP energy range into the histogram bins. The DSP energy can range from 0 to 65535. To map the full range into the default 256 bins in each direction, choose a scaling factor of 256 for both x and y. If the measured energies are less than 65535, decrease the scaling factor to "zoom in" to a certain region of interest,
3. Specify the offset applied to the DSP energy before scaling. An offset of 0 means energy 0 falls to bin 0 of the histogram, and the maximum energy in the histogram is 65536/scaling factor. If only energies over a certain value should be displayed, enter that value as the offset. For example, offset 1000 will map the energy rage from 1000 to (65536/scaling factor +1000) to bins 0 to 256.
4. Specify which channel to plot as x and y. Choices are the energies of the first (left) or second (right) channel specified under 1. or the time difference between them.
   As described in section 1.5, only energies of *related* events are plotted, i.e., the pulses occurred within the specified coincidence window in the 2 channels. In other words, plotting of energies in a 2D MCA includes specification of the 2 channels, computation of the time difference as described above, and then plotting only those events with Tdiff < CW in the 2D histogram.

After changing any of the parameters, click **[Clear/Rescale]** to initialize the histogram, then click **[Append]** to process the list of energies into the histogram. Additional data files can be appended into the histogram by selecting the new file(s) and clicking **[Append]** without **[Clear/Rescale].**

For higher resolution data, check the **High Resolution** box. This changes the number of bins from 256 x 256 to 4096 x 1024. Display updates may become quite slow on low performance PCs.

4.3 Additional Plots

There are 3 additional plots and tables to view the data:

- Click on **[Table]** to open a table of the energy lists. Table rows correspond to the event number in THE LIST MODE TRACE display.
  The data in the table is updated every time the **[Read File]** button is clicked. The values for energy, TrigTime, and LocalTime are as read from the file, no scaling or offset is

applied. The time differences (TdiffA-C) and x/y values to plot (ETx, ETy) are updated on [**Clear/Rescale**].

- Click on **[1D spectra]** to open a new plot with projections of the 2D histogram to the axes.
  The data in the plot is updated every time the **[Append]** button is clicked. The values are scaled and offset the same as the 2D spectrum.

- Click on **[Scatter Plot]** to open a plot of the entries in the energy list as x vs y (Figure 4-2). The data in the plot is updated every time the **[Read File]** button is clicked. The values are as read from the file, no scaling of offset is applied. If the x and y channels are changed, close and re-open the plot.
  Each event is a point in the plot. If the Igor cursor is placed on a point, the information at the bottom of the plot shows point number, x, and y. The point number matches the event number in THE LIST MODE TRACE display.

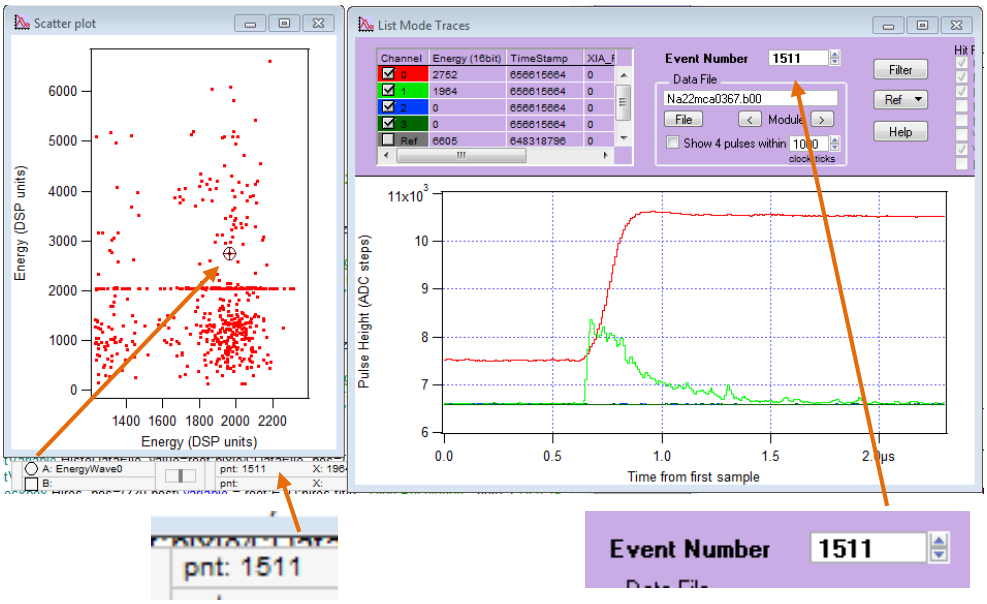
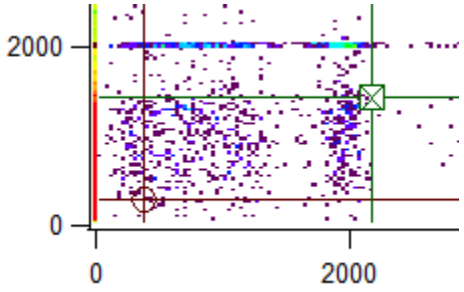


Figure 4-2: Scatter plot of Ey vs Ex and matching event in the LIST MODE TRACE panel

4.4 Analysis and Export

Four buttons allow the following actions:

- Click on **[Show cursor]** to add two cursors to the 2D spectrum plot. The area between the cursor lines forms the region of interest (ROI)



- Click on **[Sum ROI]** to sum the counts from all bins inside the ROI. The result is printed in the Igor command line window (press <ctrl>-j to bring to front)
- Click on **[ROI Spectra]** to open a new plot with the projections of the ROI to the x and y axis
- Click on **[Export ASCII]** to export the 2D histogram data and 1D projections to a plain text file. The file will include header lines and scaling information for the local array in Igor
- Click on **[Export IMS]** to export the 2D histogram data and 1D projections to a text file formatted as IMS 2.0 spectrum data.
  If the **no 0s** box is checked, the 2D histogram is reported as a list of bins with position x, y and counts, omitting bins with zero counts. This is useful to reduce zero data in high resolution spectra.

4.5 Time Histograms

The TIME DIFFERENCES panel (Figure 4-3) allows to define three time differences (TdiffA-C), i.e. the channels between which to compute time differences and the binning parameters of the time histogram. Clicking [**Read Timing Data from binary file**] will

- extract times and energies from the list mode data file
- compute the time differences TdiffA, TdiffB, TdiffC for the specified channels (in nanoseconds)
- bins the Tdiffs into histograms with the specified number of bins and bin size.

A table showing energies, event time stamp (TrigTime), local time stamps and the Tdiffs is opened with the button [**Open TS table]**. (The table also shows the x and y energy or time for the 2D histogram.) A plot of the histograms is opened with the button [**Display Tdiff histograms**].

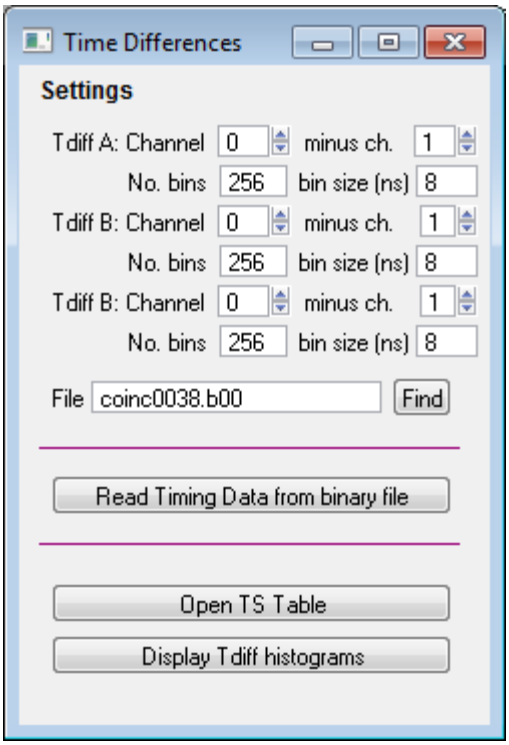


Figure 4-3: The TIME DIFFERENCE panel. Three time differences can be defined between any 2 channels and histogrammed.

5 Examples

5.1 Delayed Pulser

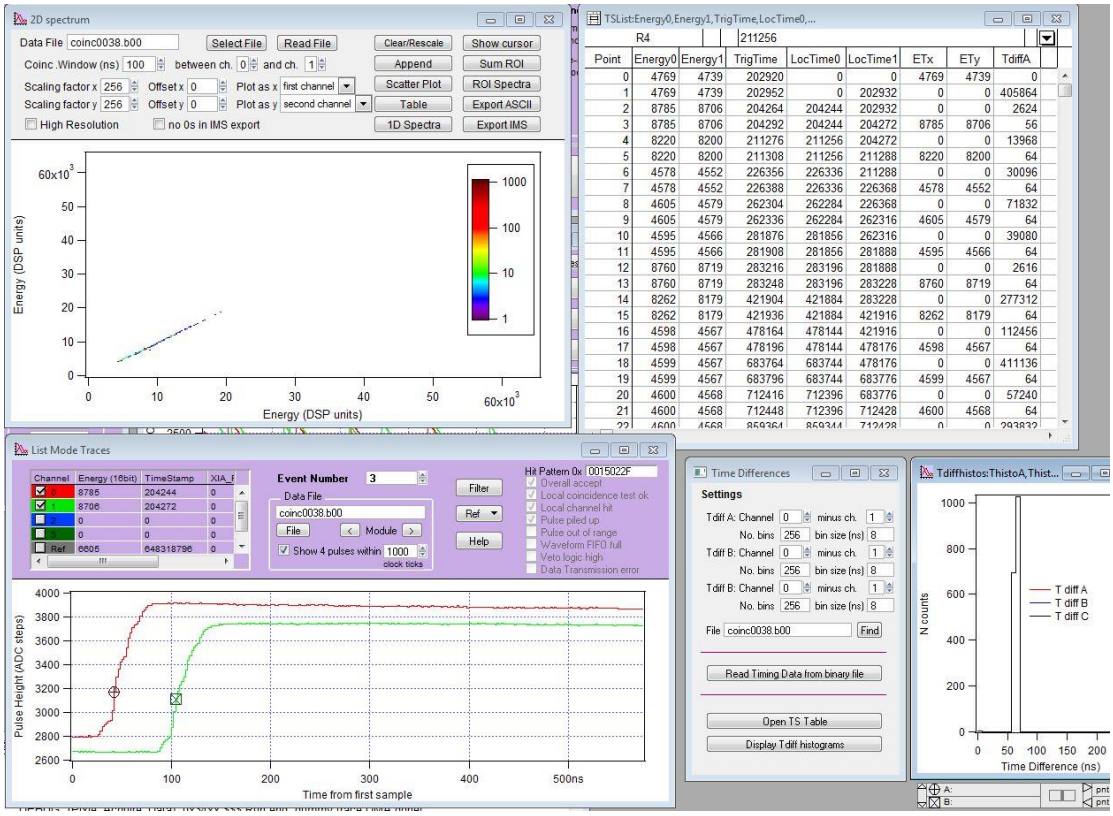


Figure 5-1: Screenshot from pulser example.

A first example of the functionality is illustrated in the screenshot above. A signal from a pulser was fed into channel 0 and (delayed) into channel1. Data was acquired in run mode 0x402.

For histogramming, time differences were chosen to be computed between channel 0 and 1 (smaller panel lower right). Clicking “Read Timing Data …”

- Extracts times and energies from the list mode data file
- Computes the time differences TdiffA, TdiffB, TdiffC for the specified channels (in ns)
- Bins the Tdiffs into histograms with the specified number of bins and bin size.

The results are shown in the TSLIST table and the TDIFFHISTOS plot.

For the 2D histogram, a coincidence window of 100ns was chosen for channel 0 and 1. Energies from first channel is plotted vs the x axis, energies from the second channel vs

the y axis. Clicking the button "Read File" does the same 3 steps as above[1], and also populates the values for x and y to plot in the 2D histogram (ETx and ETy) IF the time difference is smaller than the CW.

As an example, consider event #3 shown in the list mode trace display. It was triggered by ch.1. The hit pattern is 0x00110**2**2F – bit 9 flags ch.1 as hit. This is the delayed channel, and so ch.0 was captured showing an earlier rising edge. The time stamp for event capture is 204292 (TrigTime[3] in the table). The local trigger time for ch.1 for this event is 204272 for ch.1 – 20 ticks earlier since the trigger distribution takes a few clock cycles. The local trigger time for ch.0 is 202244, but this corresponds to the earlier rising edge in this channel; it is repeated from event 2. (Event 2 was captured at 204264, 20 ticks after the rising edge in ch.0). The time difference between ch.1 (event 3) and the last previous rising edge in ch.0 (event 2) is thus 204272-202244=28 ticks or 56 ns. Since it is less than the specified CW of 100ns, ETx and ETy are populated with the energies of ch.0 and ch.1, respectively. (In event 2, the time difference between the pulse in ch.0 (which triggered event 2) and ch.1 (which was not hit in event 2) is larger than 100ns and so the ETxy are set to zero.) Event 3 thus increments a bin at (8785, 8706) in the 2D MCA.

5.2 HPGe and NaI with Na-22 source

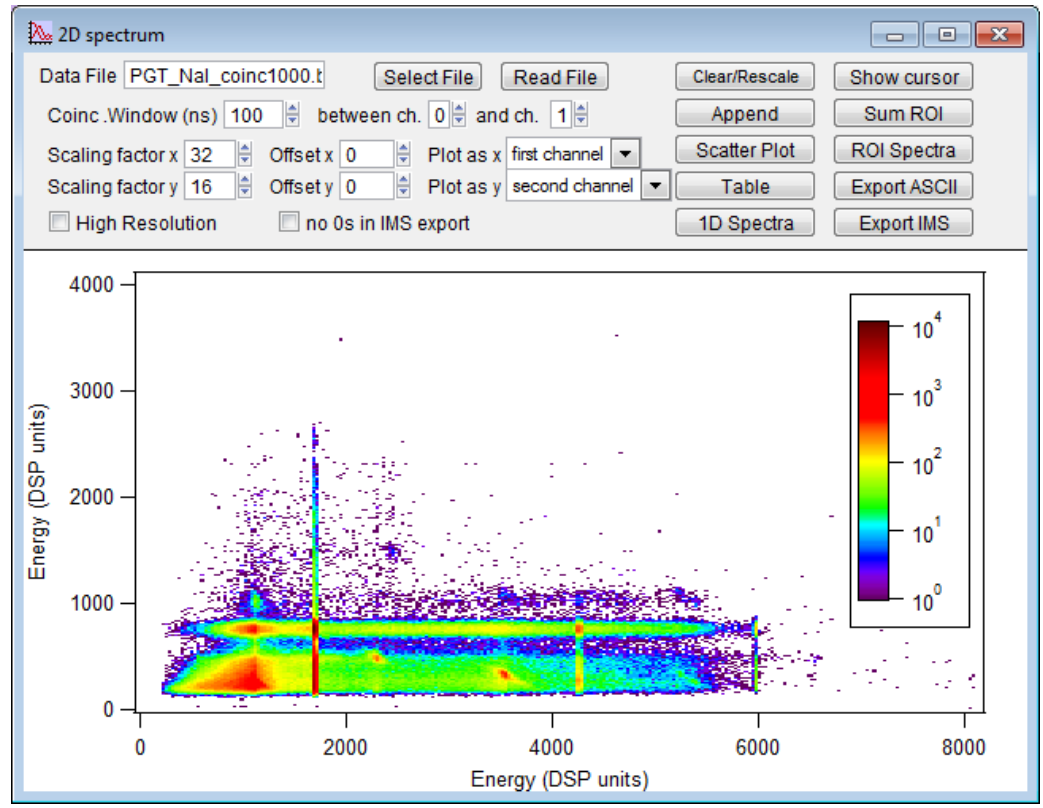
A second example is shown in Figure 5-2. The data was acquired using a HPGe and a NaI detector, with a Na-22 source between them. Prominent lines are at E ~4500 DSP units (1.2MeV) and E~1800 DSP units (511 keV) for HPGe on the x-axis, and E ~800 DSP units (511 keV) for NaI on the y-axis. The (511/511) keV coincidence peak is the area with the highest counts. The acquisition recorded only events where both channels had a hit within 40 ns. The detectors are small, so diagonal lines of constant energies from Compton scatter between detectors are not visible.

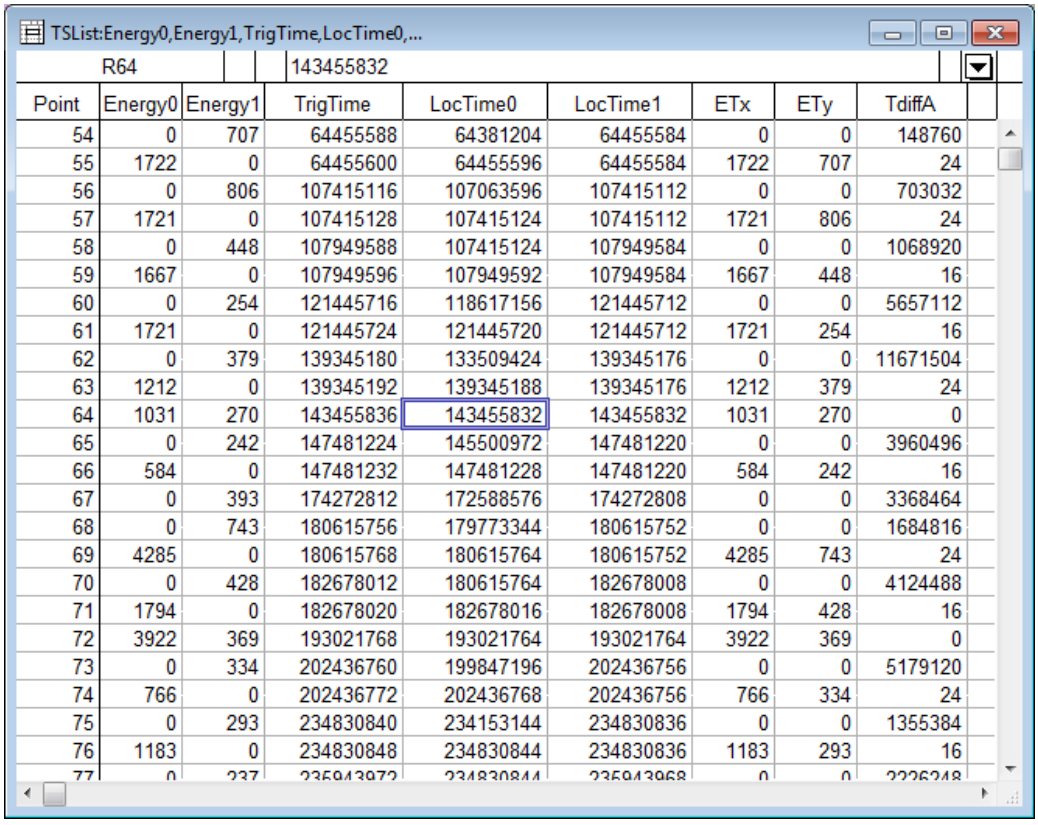
The list of events in the TSLIST table shows events of type 1. and 2. defined in section 1.5:

- In event 64, channel 0 and 1 have exactly the same time stamp, and only one event is recorded. TdiffA=0 and both energy columns have nonzero entries (4053 and 762). This is an event of type 1.
  Note that the TrigTime is 4 ticks later than the local times, as this is the time the event as a whole registered in the logic.
- In event 68, the pulse in channel 1 arrived at local time 18**52 and triggered acquisition at TrigTime 18**56. For channel 0, the local time shows the timestamp from the last rising edge at 17**44. Event 68 is thus not in coincidence with a *preceding* event and ETx, Ety are zero.
  Event 69 however is the pulse from channel 0 at local time 18**64, 12 ticks (24ns) after event 68. Channel 1's local time still shows 18**52 and so the time difference in event 69 to the *preceding* event is computed to be less than the specified 100ns and this is a valid event of type 2. ETx = 4285 is the energy reported for channel 0 in event 69, ETy = 743 is the last valid energy reported before that in channel 1, i.e. the value from event 68. [2]

[1] Both "Read File" and "Read Timing Data …" do the same thing

[2] Timestamps repeat values from previous events for those channels triggered by another channel, but energies are set to zero. This is done since "0" is a valid time stamp, but E=0 marks events with no valid energy.





Point	Energy0	Energy1	TrigTime	LocTime0	LocTime1	ETx	ETy	TdiffA
54	0	707	64455588	64381204	64455584	0	0	148760
55	1722	0	64455600	64455596	64455584	1722	707	24
56	0	806	107415116	107063596	107415112	0	0	703032
57	1721	0	107415128	107415124	107415112	1721	806	24
58	0	448	107949588	107415124	107949584	0	0	1068920
59	1667	0	107949596	107949592	107949584	1667	448	16
60	0	254	121445716	118617156	121445712	0	0	5657112
61	1721	0	121445724	121445720	121445712	1721	254	16
62	0	379	139345180	133509424	139345176	0	0	11671504
63	1212	0	139345192	139345188	139345176	1212	379	24
64	1031	270	143455836	143455832	143455832	1031	270	0
65	0	242	147481224	145500972	147481220	0	0	3960496
66	584	0	147481232	147481228	147481220	584	242	16
67	0	393	174272812	172588576	174272808	0	0	3368464
68	0	743	180615756	179773344	180615752	0	0	1684816
69	4285	0	180615768	180615764	180615752	4285	743	24
70	0	428	182678012	180615764	182678008	0	0	4124488
71	1794	0	182678020	182678016	182678008	1794	428	16
72	3922	369	193021768	193021764	193021764	3922	369	0
73	0	334	202436760	199847196	202436756	0	0	5179120
74	766	0	202436772	202436768	202436756	766	334	24
75	0	293	234830840	234153144	234830836	0	0	1355384
76	1183	0	234830848	234830844	234830836	1183	293	16

Figure 5-2: Screenshot from HPGe-NaI example.