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Instruments that advance the art

Pixie-4e Customization for SAUNA

1 Overview

This document describes the customization in Pixie-4 Express software for the SAUNA application. Changes have been made to the Igor user interface (Pixie Viewer) and the on-board DSP code to

- control run start/stop times and cycle through various run periods
- acquire 2D spectra of beta/gamma energies and 1D spectra of gamma, beta sum, and beta singles energies on the Pixie-4e module
- compute and increment a POS quality control histogram
- display 1D and 2D spectra and export as text files.

2 Setting up

The SAUNA specific functions are available if the procedure file "User_SAUNA.ipf" is loaded into the Pixie Viewer instead of the default "User.ipf". There are no changes to firmware, DSP code or C library, however the spectrum memory read from the module has to be treated differently to extract the individual spectra.

Normally, the Pixie-4 SAUNA software is distributed as an add on to the generic Pixie-4 Express release. The release zip file contains

- a specific Pixie Viewer file "Pixie_SAUNA.pxp": copy to top level installation folder (where other .pxp files are located)
- User_SAUNA.ipf: copy to top level installation folder (where other .pxp files are located)
- manuals: copy to "doc" folder
- settings (*.set): copy to "configuration" folder.

  To start working with the Pixie-4e, double click on the file "Pixie_SAUNA.pxp". After Igor startup, the Pixie Viewer will display a panel where chassis type and slots occupied by the Pixie-4e modules can be entered, and from where the module can be rebooted by clicking the "Start Up System" button. From then on, setting up the modules for gain, offset and filter parameters is the same as described in the User Manual and online help.

3 Data Acquisition

3.1 Setup

The SAUNA code variant expects the gamma detector to be connected to channel 1, the beta detectors connected to channel 2 and 3.

3.2 SAUNA Acquisition Controls (Igor)

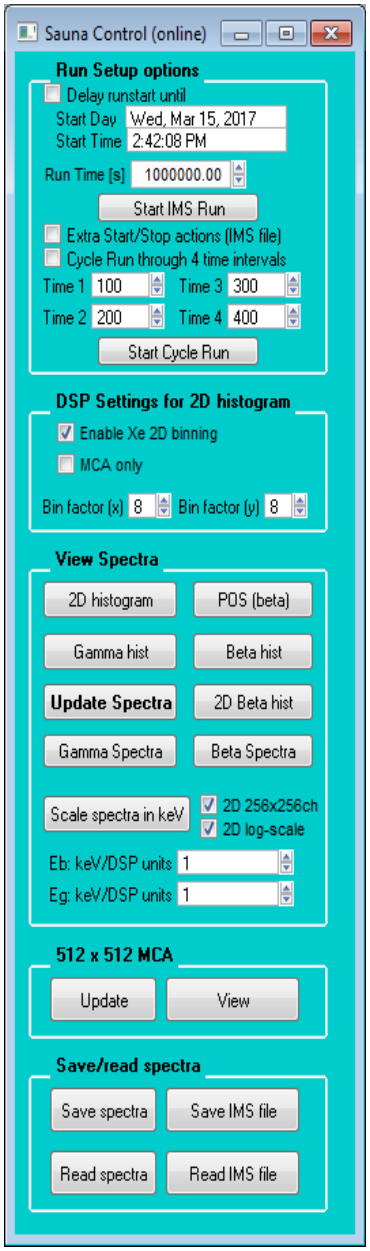


Figure 1: SAUNA control panel in Igor

To support the run start/stop schedule of the SAUNA application, two functions were added to the Pixie Viewer: an option to delay the runstart until a specific date and time, and an option to cycle through runs of different duration. These functions can be controlled in the "Sauna Control" panel shown in figure 1. The panel can be opened by selecting "SAUNA Online Analysis" from the XIA menu in the top menu bar.

In the panel, the SAUNA options can be enabled by checking the corresponding check boxes and entering time/date and/or cycle run times in the control fields. A cycle run must be started by clicking the "Cycle Run" button in the Sauna Control panel, a delayed run is started by clicking the usual "Start Run" button in the "Run" tab of the main Pixie-4 run control panel. A new DSP setting checkbox now allows suppression of list mod data, saving only MCA data.

The SAUNA panel also has buttons to open 1D and 2D spectra and histograms, which can be updated (read from the module) by clicking the "Update Spectra" button. The 2D spectrum shows 256 x 256 bins of gamma energy vs beta energy; the bins are colored according to the number of counts they contain. The coloring can be selected as log scale or normal scale by checking the corresponding checkbox in the SAUNA panel. In addition there is a 256 bin POS quality control histogram showing the ratio

$$R = ((Beta1-Beta2)/(Beta1+Beta2) +1)*128$$

computed and incremented for each event, and a further 2D histogram of Beta1 vs Beta2.

To zoom in or otherwise modify the plots, the default Igor graph control functions can be used. To scale the energy axes in keV, enter a calibration constant in the field "keV/DSP units" and click the "Scale Spectra …" button. For example, if a 662 keV peak appears at a bin

300 in the 1D spectrum, the constant would be 662/300 = 2.2. Spectra can be written to and read from file with corresponding buttons.

3.3 SAUNA Acquisition Parameters

3.3.1 Runtype and Output Options

The Pixie-4e default mode of operation (Runtype 0x400) is to capture data records for each detected rising edge, and (in list mode) store them as single channel event records. This is the most general way and allows acquisition closely following pulses. For coincidence data acquisition, it is often more convenient to run in "group" or "coincidence" mode (Runtype 0x402), which captures 4-channel event records for easier extraction of coincidences.

For SAUNA operation, Runtype 0x402 should be used. This is a list mode run type that normally generates 4-channel event records (with optional waveforms). Additionally, MODCRSA bit 0 should be set (Option "allow only one record per CW" in Igor's Coincidecne tab) to avoid multiple events from delayed coincidences.

If waveforms are of no interest, waveforms should be set to zero length (the "Trace Length" in Igor's Waveform tab). If no list mode data should be recorded at all (MCA only mode), bit 1 in the DSP variable MODCSRB must be set (equivalent to setting bit 1 in the C library variable MODULE_CSRB or checking the "MCA only" in the SAUNA control Panel).

3.3.2 Histogramming Parameters

The standard Pixie-4e FW/SW accumulates four 32K spectra, one for each channel. Channel 0's spectrum starts at memory location 0, channel 1 at location 32K, and so on. The number of used bins per spectrum is controlled by the DSP variable LOG2EBIN (mapped to the "Binning Factor" in Igor's Advanced tab, or the variable BINFACTOR in the C library). If BINFACTOR is set to N, 2^N bins are combined into one. Since energies are computed to 16bit numbers (allowing in principle spectra with 64K bins), BINFACTOR = 2 produces 16K spectra, BINFACTOR=3 produces 8K spectra etc.

In the SAUNA operation code, the MCA binning mode has been modified to instead accumulate the following spectra:

i) an 8K spectrum of gamma singles (ch.1), starting at location 0,

ii) an 8K spectrum of the beta sum (ch.2+ch.3), starting at location 8K,

iii) an 8K spectrum of ch.2 only, starting at location 16K,

iv) an 8K spectrum of ch.3 only, starting at location 24K,

v) a 256 bin spectrum of the POS ratio R, starting at location 32K,

vi) a 128 x 128 2D beta-beta spectrum, starting at location 48K, and

vii) a 256 x 256 2D gamma-beta spectrum, starting at location 64K.

viii) a 512 x 512 2D gamma-beta spectrum, starting at location 0 of the second page of the MCA memory.

To enable the SAUNA 2D binning mode, bit 8 in the DSP variable MODCSRB must be set (equivalent to setting bit 8 in the C library variable MODULE_CSRB or checking the "Enable Xe 2D binning" in the SAUNA control Panel). To ensure proper binning of the spectra,

BINFACTOR should be set to 3 and 8, respectively. Table 1 lists which channel's BINFACTOR controls which spectrum.

It is sometimes useful to set BINFACTOR to a smaller number than the default. For example, in the above 2D spectrum a peak from Cs137 at 662 keV will appear at bin 100 if Pixie-4e gain and PMT bias are such that the full dynamic range of the Pixie-4e is 1.7 MeV. (This means the largest pulse – from zero to max. ADC range – is computed to have a pulse height of 65535 in DSP units, is divided by 2^8 for binning to fall in bin 255, and happens to have an energy of 1.7 MeV). If only energies of say up to 850 keV are of interest, BINFACTOR can be reduced to 7 so that there is more detail in the spectrum. The 662 keV peak will then fall at bin 200 and more detail is available for lower energies. However, pulses with energy above 850 keV will not be binned into the spectrum, even though they are in range for the acquisition.

3.3.3 Summary of Input Parameters

Table 1: Input Parameters

C library variable	DSP variable	Spectrum (ref)	Default	Notes
BINFACTOR, channel 0	LOG2EBIN 0	Beta sum (ii)	3	
BINFACTOR, channel 1	LOG2EBIN 1	Gamma singles (i)	3	
BINFACTOR, channel 2	LOG2EBIN 2	Beta singles, ch. 2 (iii)	3	
BINFACTOR, channel 3	LOG2EBIN 3	Beta singles, ch. 3 (iv)	3	
USER_IN (module)	USERIN	2D, beta-axis (vi, vii, viii)	8	Increased by 1 for vi Decreased by 1 for viii
USER_IN +1 (module)	USERIN+1	2D, gamma-axis (vii, viii)	8	Decreased by 1 for viii
MODULE_CSRA	MODCSRA		1	Set bit 0 to capture only one 4-channel event per coincidence window.
MODULE_CSRB	MODCSRB		256	Set bit 1 to suppress LM data Set bit 8 to enable 2D Xe binning
RUN_TYPE	RUNTYPE		0x402	Must also specify 0x402 in API functions call

In Igor, BINFACTOR for channel 0-3 and the MODULE_CSRB bit 8 are set by running the macro "SAUNA_Apply2D_settings" from the top menu bar (a shortcut to setting each in the panels). USERIN and USERIN+1 can be set from the "Sauna Control" panel (binfactor (x/y)).

3.4 Output Data

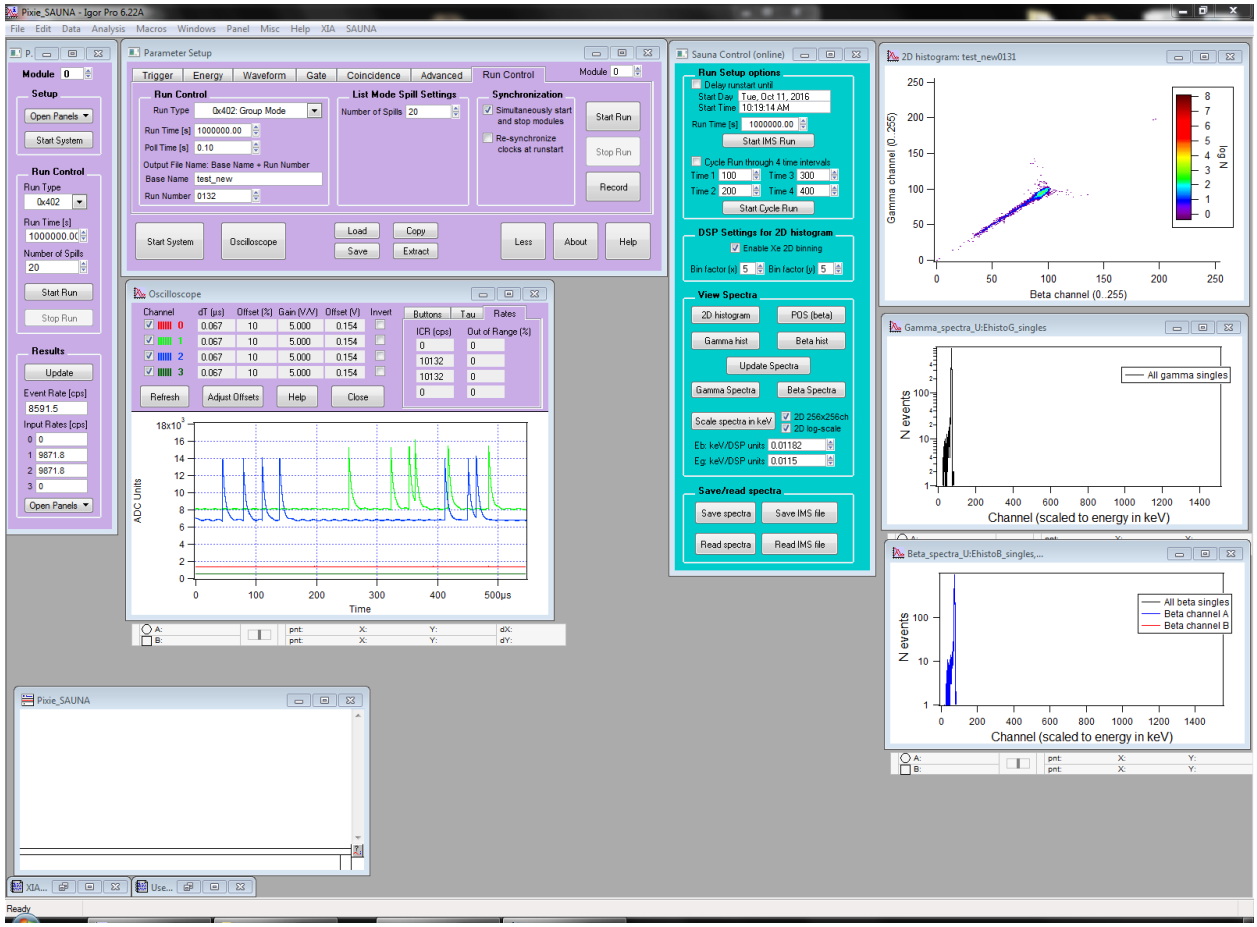
The spectrum data i) to vii) can be read from Pixie-4e MCA memory as usual, using runtask 0x9001. The recommended operation is to always read all 128K of spectrum memory, save the data to file, and then distribute to the various spectra using the following location information:

Spectrum	**Starting location in memory or file**	
Gamma singles, ch.1	0	
Beta sum	8K	
Beta singles, ch. 2	16K	
Beta singles, ch. 3	24K	
POS spectrum	32K	
2D beta-beta spectrum	48K	
2D gamma-beta spectrum	64K	

The 2D gamma-beta spectrum is organized as follows: word 0 of the 2D spectrum is bin (Eg, Eb) = (0,0), word 1 is (0,1), word 255 = (0,255), word 256 = (1,0), word 512 = (2,0), word 65535 = (256,256). In other words, for an event with energies Eg and Eb, word number (256*Eg + Eb) is incremented. Eg and Eb refer to the energy in DSP units after dividing by $2^{\text{BINFACTOR}}$. The order for the 2D beta-beta spectrum follows the same principle.

The spectrum data for viii) requires calling runtask 0x9005, to read data from the second page of the on-board MCA spectrum (for extended 2D data). The data is organized equivalent to the 256x256 bin gamma-beta spectrum. The spectrum starts at location 0 and uses all 256K bins of the MCA memory page.

4 Test Setup



A basic test of the SAUNA function and features uses pulses generated by a random pulser split for the gamma channel (ch.1) and one beta channel (ch.2). Settings are deliberately de-optimized to broaden peaks and occasionally miss events. The result is shown in the screenshot below:

- The oscilloscop plot shows the random and/or periodic pulses from signal source
- the gamma spectrum shows the broad peak for ch.1
- the beta spectra show a peak for beta A and a no peak for beta B. The beta sum is identical to beta A.
- The 2D spectrum shows a diagonal line for Egamma = Ebeta, with tail due to the de-optimized setting.

5 Substituting Channel 0 for Bad Channels

Currently not supported for Pixie-4 Express

In version 2.72, three DSP code variants are added to substitute channel 0 for a possible bad channel *N* = 1, 2, or 3. This is accomplished by writing channel 0's measured energy value into the histogram for channel *N*, and overwriting channel *N*'s run statistics with those from channel 0. The modification does NOT change

- ICR and out of range (shown in the oscilloscope)
- List mode traces
- oscilloscope traces
- input parameters like gain, offset,threshold, trigger settings.

To make the substitution for channel *N*, go though the following steps:

1. Save the settings to a file e.g. SAUNA_swapch.set.
2. Change the DSP bin file from SNAcode.bin to SNAcode0TO*N*.bin.
3. Reboot the Pixie module, loading the new .set file
4. Change detector cable from channel *N* to channel 0.
5. Copy all settings from channel *N* to channel 0. Use of the copy/extract buttons is recommended. Verify the detector signal is visible in channel **0** and that it is in range.
6. Save settings to a new file, e.g. SAUNA_0toN.set
7. Take data as in any normal run. In the run statistics, channel 0's input count rate etc will be duplicated to channel *N*. Spectra should appear unchanged to before the substitution.

6 Code Versions and Variants

This documentation refers to the following code version and variant:

1. Igor: The SAUNA code relies on Pixie-4 Igor software version 4.39, calls to user variants: version 0x105.
   The user variant of the Pixie-4 Igor interface is 0x110 (i.e. customized for application xenon monitoring, SAUNA). The version of the Igor user code is 0x000D, i.e the 12th update. This code is contained in the Igor procedure file User_SAUNA.ipf
2. C library: The SAUNA code relies on the generic Pixie-4e C library version 4.39, build 0x320A or 0x640A. No modifications for SAUNA are added.
   When compiling with the mingw32 compiler, add compiler switch COMPILE_TOOL_MINGW32 to the makefile
3. DSP: The SAUNA code relies on the generic Pixie-4e DSP code version 0x439. The DSP code modifications are *not* implemented in the user-accessible file user.dsp. The DSP user code version should be ignored.
4. Additional DSP variants are provided to substitute channel 0 for channels 1,2, or 3. The code files are names SNAcode0TON.bin, N = 1,2,3. They are identified as DSP build 0x23N2.

5. Firmware: C library: The SAUNA code relies on the generic Pixie-4e firmware version 0x0438 (Fippi) and 0xA551 (System). No modifications for SAUNA are added.

7 Known Bugs

This is a beta release, please test and comment.

8 Updates:

10/9/09: fixed bug in DSP parameter download from Igor (wrong Igor function name) updated version of the Igor user code to 0x0006

9/25/09: fixed bug in DSP causing "mirroring in" of events outside 2D histogram

1/26/10: updated binning to include 2D beta-beta spectrum.

3/22/12: Updated release to be compatible with latest general purpose release (v2.40) which is compatible with Windows 7 (32 bit). No change in SAUNA code, minor edits in documentation (e.g. add test setup, update version numbers)

4/10/12: Updated release for bug fixes in general release 2.43 (Fippi Firmware, DSP and C library rebuild)

2/1/14: Revision of User ipf function calls (initialize path/file names)

6/3/16: Add DSP variants to substitute channel 0 for channels 1,2, or 3. Also includes a bug fix in the main code to avoid boot crashes in Windows 7 (64bit) and to improve polling timing during the run.

10/12/16: Port and update to Pixie-4 Express. Changes include:

- Pixie-4 settings files (from version 2.7x and before) are not compatible with Pixie-4 Express software (version 4.x)
- DSP settings are immediately update, no need for read/apply button (removed from "Sauna Control" panel.
- Run Type must be 0x402.
- SAUNA binning is included in standard Pixie-4e DSP code; only settings files and the Igor user procedure file (User_SAUNA.ipf) are SAUNA specific.
- Instead of specifying clover binning mode (bit 3 in the DSP variable MODCSRA and "Sum channels" checkbox in the Pixie Viewer Coincidence Tab), Xe 2D binning mode must be specified (bit 8 in the DSP variable MODCSRB). A corresponding checkbox has been added to the Sauna Control" panel.
- We recommend checking the box "Allow only one record per CW" in the Pixie Viewer Coincidence Tab since otherwise every detected rising edge will create a full 4-channel record with mostly zero energies (intended for very fast coincidences or multiple coincidences within a single coincidence window).

May/June 2017:	Various bug fixes and driver updates. Includes correction of POS spectrum (257 bins), binning control of the 2D beta spectrum, and added option to suppress list mode data.