Status of Electronics Upgrades to the LANL Green is Clean Phoswich Detector Systems – 16419

Randy Lucero *, Felicia Archuleta **, Wynn Christensen **, Lucas Gallegos **,
Kathleen Gruetzmacher **, Wolfgang Hennig ***

* Pajarito Scientific Corporation
** Los Alamos National Laboratory
*** XIA LLC

ABSTRACT

Los Alamos National Laboratory radiological facilities produce low-density room trash that, in many cases, is not contaminated with radioactivity. It has been estimated that 50 to 90% of low-density room trash is free of radioactive contamination and eligible for inclusion in LANL's Green is Clean (GIC) program. The GIC program is a verification program for non-regulated waste from radiation controlled areas that has been actively segregated as nonradioactive through the use of the waste generator's acceptable knowledge.

The GIC program has employed two large area Phoswich gamma ray detector systems (HERCULES and ZEUS) to assay and verify that GIC candidate waste meets free release disposal requirements. The large area (127 cm2) Phoswich detectors consist of a thin NaI front crystal (3 mm thick) that is optically coupled to a thick CsI back crystal (50 mm thick). The crystals are set in an oxygen-free high-conductivity copper housing with a very thin (0.025mm) aluminum entrance window. The scintillation properties of the two crystals are different enough to allow the system's electronic components to identify the origin of any pulse. The original systems utilize Nuclear Instrumentation Module (NIM) electronics to process the detector signals. These electronic modules provide the buffering, amplification, and pulse shape analyzer needed for the proper presentation of signals to the custom Phosmux router module. The router module separates the sodium iodide and cesium iodide signals by their rise times and transfers this information into the computer-mounted multichannel analyzer, a Canberra Model S-100 system. While these NIM Bin counting electronics configurations have been effective for approximately 20 years of operation, they are bulky requiring numerous modules per detector and the important Phosmux module is no longer manufactured by LANL.

Modern advancement of commercial counting electronics now offer more compact options for equivalent detector signal processing. A pulse shape discriminator module, the DGF Pixie-4, made by XIA LLC, has been identified that can replace the majority of the original NIM bin electronics in a much more compact chassis – one Pixie-4 replaces four NIM amplifiers and four NIM PSAs and fits in a small National Instruments™ chassis. Thus, LANL has initiated a system upgrade project to replace the historic NIM electronics with the XIA Pixie4 and associated configuration software. The hardware for one Phoswich systems has been procured for the project and the configuration software, customized for the LANL Phoswich detector application, has been written by

the manufacturer. Initial setup and optimization of the Pixie-4 configuration has been performed. Qualitative and quantitative baseline comparisons to the NIM electronics has been performed. Good agreement of key low energy gamma lines between the systems has allowed "Proof of Concept" to be concluded. Further optimization and performance evaluations are in progress. Modifications to the LabVIEW™ based operating software (originally written by VI Control Systems Ltd.) are being performed by a LANL LabVIEW™ programmer to accommodate the electronics upgrade. A new LabVIEW™ interface to control the Pixie-4 has already been developed. Final optimization and testing, formal software QA, and revisions to operating procedures are in progress to achieve completion of the GIC system upgrade project.

INTRODUCTION

The Los Alamos National Laboratory (LANL) Green Is Clean (GIC) program is designed to reduce the amount of non-radioactive waste that is sent to low-level radioactive waste disposal facilities. Up until 1994, when the concept of "Green Is Clean" was introduced at LANL, waste generated in a LANL radiological control area (RCA) was considered to be at least "suspect" radioactive waste. Many LANL radiological facilities produce low-density room trash that, in many cases, is in fact not contaminated with radioactivity. This low-density trash consists of items such as plastic, paper, gloves, protective clothing, tape, and cardboard. It has been estimated that 50 to 90% of low-density room trash is free of radioactive contamination and eligible for inclusion in LANL's Green is Clean (GIC) program. The GIC program is a verification program for non-regulated waste from RCAs that has been actively segregated as nonradioactive through the use of the waste generator's acceptable knowledge (AK) [1].

The GIC program has most recently employed two large area Phoswich gamma ray detector systems (HERCULES and ZEUS) to assay and verify that GIC candidate waste meets free release disposal requirements [2], [3]. Fig. 1 shows the HERCULES and ZEUS systems.

Both systems utilize large area (12,668 mm2) Phoswich detectors that consist of a thin NaI front crystal (3 mm thick) that is optically coupled to a thick CsI back crystal (50 mm thick). The crystals are set in an oxygen-free high-conductivity copper housing with a very thin (0.0254 mm) aluminum entrance window. The scintillation properties of the two crystals are different enough to allow the system's electronic components to identify the origin of any pulse. HERCULES and ZEUS are designed to use three and four Phoswich detectors, respectively. Fig. 2 shows the Phoswich detectors inside the cavity of the ZEUS system. The GIC systems accommodate bagged and boxed GIC waste packaged to fit inside the waste chamber.

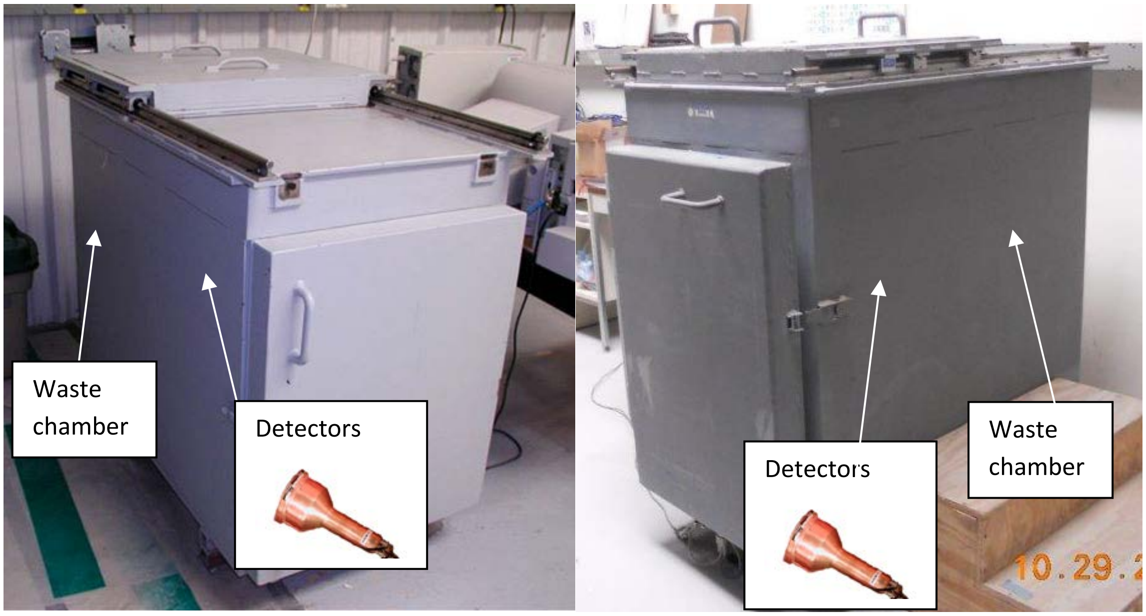


Fig. 1. The HERCULES (left) and ZEUS (right) systems

Fig. 2. Phoswich detectors in the ZEUS system

The counting electronics originally used to operate the systems are based on the Nuclear Instrumentation Module (NIM) standard. While NIM modules are still commercially manufactured and supported, the NIM chassis required for the numerous NIM modules needed to operate the systems are bulky and heavy. Modern advancement of commercial counting electronics now offer more compact options for equivalent detector signal processing. With the advent of the more compact digital counting electronics, it is possible that the NIM standard will become obsolete. Thus, the WM-SVS team at LANL who operates the GIC systems has established a project to evaluate a commercially available module called the Pixie-4 made by XIA LLC that may replace the NIM electronics.

NIM BIN CONFIGURATION

In the NIN Bin configuration, each detector is equipped with a Canberra Model 2005 preamplifier and two NIM modules: an ORTEC® Model 572 amplifier and an ORTEC® Model 552 pulse shape analyzer (PSA). These electronic modules provide the buffering, amplification, and PSA needed for the proper presentation of signals to a custom router module designed by LANL, which separates the sodium iodide and cesium iodide signals by their rise times and transfers this information into the computer-mounted multichannel analyzer, a Canberra Model S-100 system. The choice of the Canberra S-100 multichannel analyzer board mounted in the IBM compatible computer was driven by the availability of support software at the time of the original development. With the windows compatible software, it was a straightforward task to provide the custom analysis of the data in real-time. However, the selection of the S-100 board dictated the requirements for the analog-to-digital (ADC) module, which had to be compatible with the S-100. A Canberra Model 8706 NIM module was used. In order to use a single ADC module for multiple dual-crystal detectors while preserving the individual signals from each of the detectors, a custom multiplexer module to handle the data was designed and developed by LANL – the Phosmux multiplexer. The ORTEC® Model 552 PSA is a single-width NIM module. For this application it accepts as input the bipolar output of the spectroscopy amplifiers (ORTEC® Model 572) and provides two outputs necessary for the custom multiplexer unit: (1) an A signal, which occurs at the 90% point on the trailing edge of the positive lobe, and (2) a B signal, which occurs as the bipolar pulse passes through zero. These A and B signals when properly gated allows the discrimination of the NaI and CsI signals and the rejection of coincident events. Fig. 3 shows the HERCULES system NIM counting electronics.

Fig. 3. The HERCULES NIM Bin electronics

The computers that house the S-100 and operate the systems are over 15 years old, run the Windows98 operating system and are in obvious need of replacement. Also, LANL no longer has the ready capability to manufacture new or replacement Phosmux multiplexers. The HERCULES system is currently fully operational with existing NIM Bin electronics. The ZEUS system is not currently operational with the NIM Bin electronics. ZEUS's electronic components serve as backups for the HERCULES system.

PIXIE-4 PXI CONFIGURATION

The Pixie-4 Digital Gamma Finder (DGF) made by XIA LLC is a 4-channel all-digital waveform acquisition and spectrometer card based on the CompactPCI/PXI standard for fast data readout to the host.

The DGF family of digital pulse processors features unique capabilities for measuring both the amplitude and shape of pulses in nuclear spectroscopy applications. The DGF architecture was originally developed for use with arrays of multi-segmented HPGe gamma-ray detectors [4]. It combines spectroscopy with waveform capture and on-line pulse shape analysis. The Pixie-4 accepts signals from virtually any radiation detector and has been applied to the Phoswich detector signals [5]. Incoming signals are digitized by 14-bit 75 MSPS ADCs. Waveforms of up to 13.6 μs in length for each event can be stored. The waveforms are available for onboard pulse shape analysis, which can be customized by adding user functions to the core processing software. Waveforms, timestamps, and the results of the pulse shape analysis can be read out by the host system for further off-line processing. Pulse heights are calculated to 16-bit precision and can be binned into spectra with up to 32K channels.

The Pixie-4 module is housed in a 6-slot National Instruments™ PXI chassis and is intended to replace the NIM Bin amplifiers, PSAs, ADCs and the custom Phosmux module. The Canberra Model 2005 preamplifiers are still required and used on each detector. The 12V power to the pre-amplifiers in the NIM configuration is being provided by the ORTEC® 572 amplifiers, which means in order to entirely replace the amplifier and move away from the NIM standard, an alternate 12V pre-amp power supply is required. The HV to the detectors in the NIM configuration is from a HV power supply mounted in the NIM Bin. However, the power supply can operate externally from the NIM Bin and doesn't mandate the use of the NIM standard. Ideally, all of the replacement electronics would be PXI based and housed in the same PXI chassis as the Pixie-4 module for compactness. Alternatives for both the pre-amplifier power and HV are preferred as part of the system upgrades. The XIA PXI Power Distribution Module (PDM) and the ISEG EHQ-102 PXI HV module are being tested for the pre-amplifier power and the HV power, respectively. Both modules fit in the 6-slot National Instruments™ PXI chassis used. Fig. 4 shows a Pixie-4 module and the full PXI electronics configuration being tested.

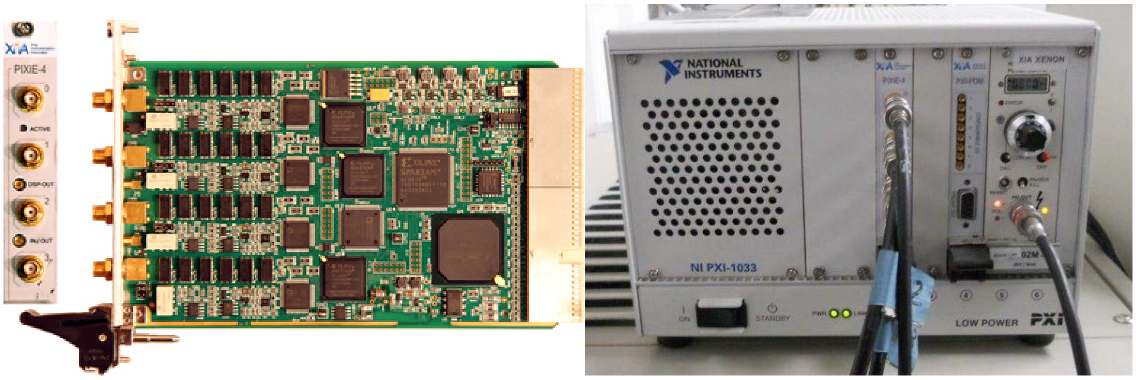


Fig. 4 Pixie-4 and PXI electronics configuration

Modern desktop PCs running 64-bit Windows 7 Enterprise have been set up for the operation of each GIC system. Running on each data acquisition computer (DAC) is the XIA Pixie Viewer software. The Pixie Viewer is the manufacturer's graphical user interface to set up and run the Pixie-4 modules, and is based on WaveMetrics' IGOR Pro software.

PIXIE-4 PHOSWICH DETECTOR CUSTOMIZATION

Digital Signal Processor

The digital signal processor (DSP) controls the operation of the Pixie-4, reads raw data from the Real Time Processing Units (RTPU), reconstructs true pulse heights, applies time stamps, prepares data for output to the host computer, and increments spectra in the on-board memory. The host computer communicates with the DSP, via the PCI interface, using a direct memory access (DMA) channel. The host sets variables in the DSP memory and if necessary calls DSP functions to apply them to the hardware.

In order to discriminate the NaI and CsI signals of the Phoswich detectors, the Pixie-4 DSP had to be customized for the LANL GIC system upgrade project. The custom code analyzes NaI/CsI Phoswich waveforms and allows setting of an upper and lower rise time (RT) threshold and/or pulse shape ratio to categorize pulses as NaI (fast) or CsI (slow) which are then binned into separate MCA spectra. When a pulse is detected and validated by the trigger and pileup circuits of the Pixie-4 in standard operation, the on-board DSP reads out timestamps, raw energy filter values, and (if selected by the user) up to 13µs of pulse waveforms. The energy filter values are used to compute the energy E of the pulse. In this modified code, the DSP processes waveforms to compute a) the rise time RT of the pulse and b) a sum P over the initial portion of the pulse. RT and the ratio P/E are tested against upper and lower thresholds defined by the user. Depending on the outcome of the tests, the event energy is histogrammed into a "NaI" spectrum, a "CsI" spectrum, or an "in-between" coincidence spectrum. Fig. 5 shows the PSum/E vs RT plot for a Phoswich detector for a Co-57 check source measurement.

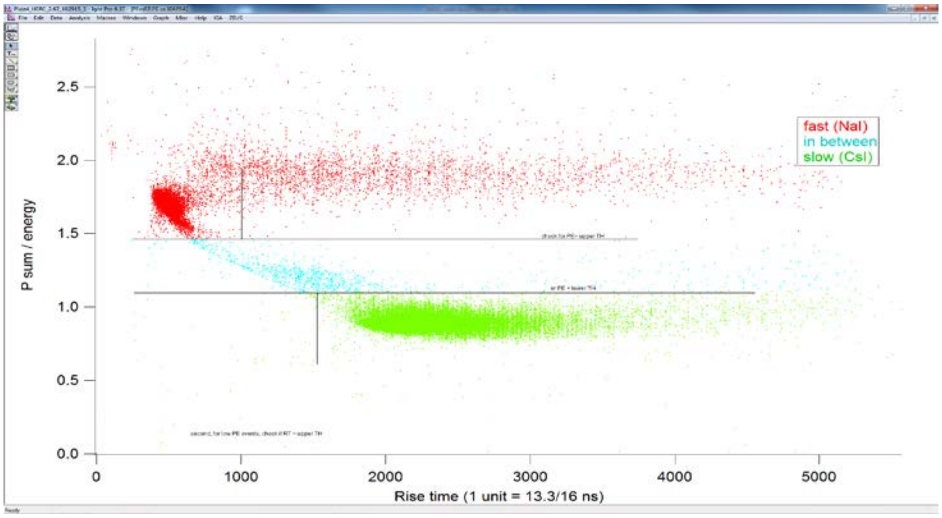
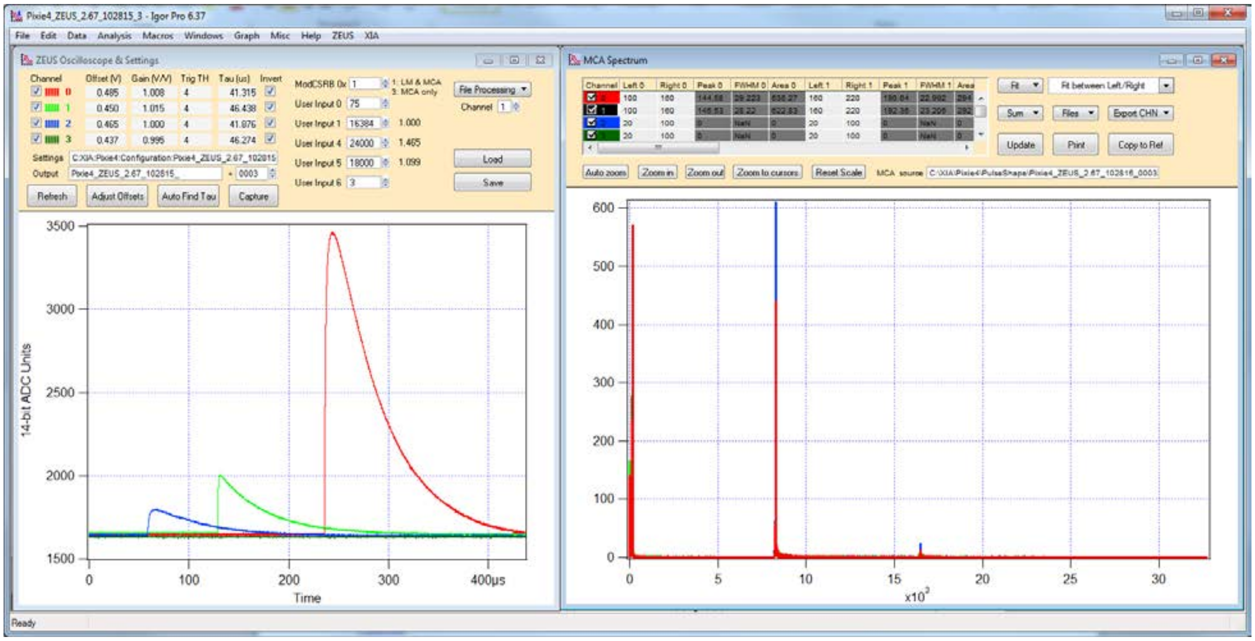


Fig. 5 PSum/E scatter plot for Co-57 source measurement

Pixie Viewer

Custom features to the Pixie viewer were also added for the GIC Phoswich detector application. This included 1) customizing the “User_Control” panel to set the PSum/E input parameters and mode of signal separation, 2) expanding the “Oscilloscope & Settings” panel to combine key controls and specification of input parameters, 3) modifying the MCA display to show the triple spectra for multiple detectors and include a function to export spectra to ORTEC® “chn” format. Fig. 6 shows the customized Oscilloscope and Settings panel and the MCA display for a Co-57 source measurement.



Channel	Offset (V)	Gain (V/V)	Trig TH	Tau (us)	Invert
☑ 0	0.485	1.008	4	41.315	☑
☑ 1	0.450	1.015	4	46.438	☑
☑ 2	0.465	1.000	4	41.076	☑
☑ 3	0.437	0.995	4	46.274	☑

Settings: C:XIA:Pixie4:Configuration:Pixie4_ZEUS_2.67_102815
Output: Pixie4_ZEUS_2.67_102815_ + 0003

ModCSRB 0x: 1 (1: LM & MCA, 3: MCA only)
User Input 0: 75
User Input 1: 16384 1.000
User Input 4: 24000 1.465
User Input 5: 18000 1.099
User Input 6: 3
Channel: 1

Channel	Left 0	Right 0	Peak 0	FWHM 0	Area 0	Left 1	Right 1	Peak 1	FWHM 1	Area
☑ 0	100	160	144.58	29.223	636.27	160	220	180.64	22.982	294
☑ 1	100	160	146.53	28.22	622.83	160	220	182.36	23.206	292
☑ 2	20	100	0	NaN	0	20	100	0	NaN	0
☑ 3	20	100	0	NaN	0	20	100	0	NaN	0

MCA source: C:\XIA\Pixie4\PulseShape\Pixie4_ZEUS_2.67_102815_0003

Fig. 6 Customized Oscilliscope & Settings panel and MDA display

PROJECT STATUS

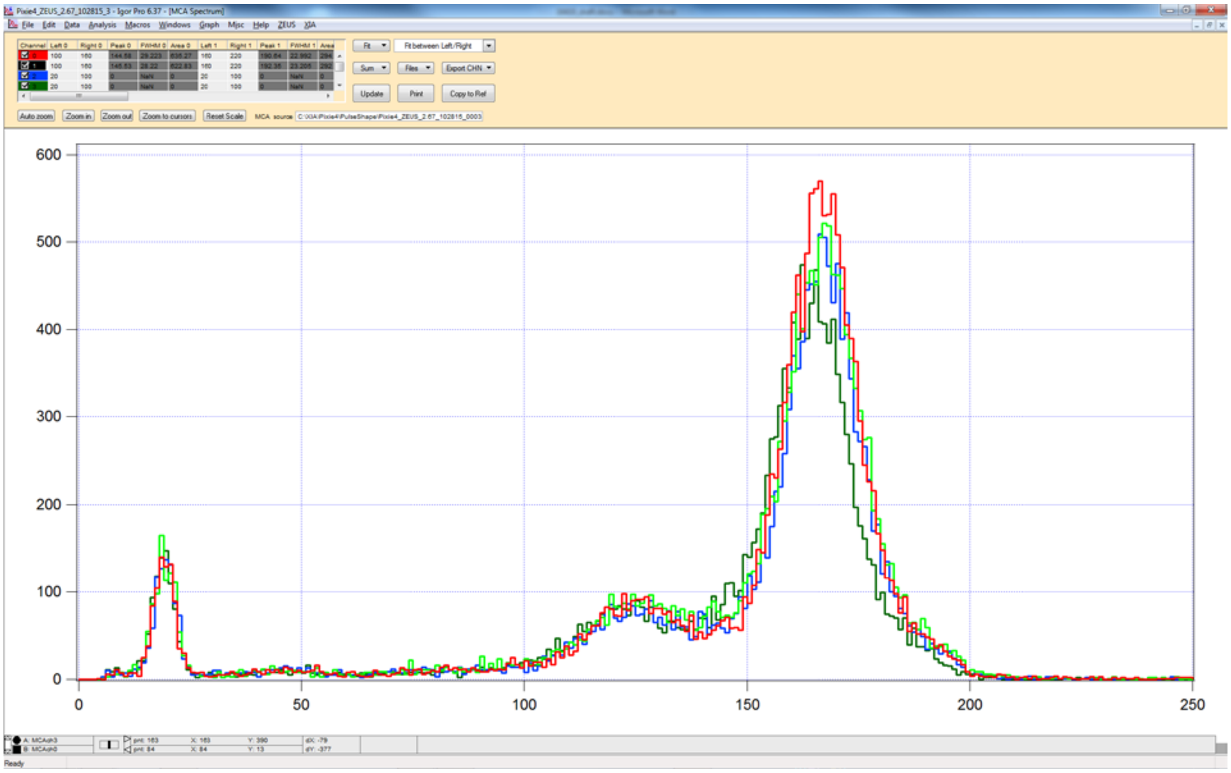
As of the end of 2015 the customization of the Pixie-4 DSP code and Viewer are believed to be complete and adequate to perform comparable NaI and CsI signal discrimination and coincidence rejection to that of the NIM Bin electronics. One complete PXI Pixie-4 upgrade electronics system has been configured and initial experiments on the ZEUS detector system have been done to optimize the operating parameters. Initial indications are that the PXI mounted HV and pre-amplifier modules will work with the Pixie-4 in a single chassis to power multiple detectors in series. Also, since ZEUS is not functioning with the NIM Bin electronics, the PXI Pixie-4 electronics have been connected to the HERCULES detectors for direct comparisons of the same detectors on the two different electronics configurations.

ZEUS Spectra

Initial experiments with the Pixie-4 electronics on the ZEUS detectors have proven to be promising after significant efforts optimizing the Pixie-4 operating parameters for the GIC Phoswich application. Using the PSum/E ratio as the primary means to separate the NaI and CsI signal and reject “in-between” coincidence events, separated spectra were achieved using Co-57 check sources. Each detector had a Co-57 source of similar activities placed approximately 3 inches in front of the detector face.

Each detector is allocated 32K bytes (or channels) of spectrum memory. The fast NaI events are histogrammed into channels 0 to 8191, the slow CsI events are histogrammed into channels 8192 to 16384 and the “in-between” events are histogrammed into channels 16386 to 24577. The last 8K channels of the 32K spectrum memory for each detector are unused. The gains on the detectors have been set so that the NaI spectra are at 0.75keV/chn. Qualitatively, as expected for good NaI and CsI separation, the NaI spectra have both the 14.4keV and 122keV Co-57 gamma ray peaks while the CsI spectra have only the 122keV peak. The “in-between” events represent events where photons interact in both the NaI and CsI media in coincidence producing an intermediate rise time pulse shape – i.e., not fast, not slow but “in-between”. Rejecting these events improves the system detection limits by reducing background primarily in the lower end of the NaI spectra. Fig. 8 shows the NaI spectrum while Fig. 9 shows the CsI and “in-between” spectra for each of the four ZEUS detectors for Co-57. All the histogram’s x-axes are in units of channel number. So with the electronics gain settings such that the energy conversion factor is 0.75 keV per channel for the NaI portion of the spectrum, the NaI 122keV Co-57 peak is set to be at channel 163 by adjusting the detector gain. The CsI energy calibration (keV/channel) is then determined by mathematical correlation using a simple linear function.

The NaI and CsI spectrum views zoom into the section of spectra where there are peak formations. Again, the NaI spectrum exhibits both the high yield 14.4keV and 122keV Co-57 gamma ray peaks, while the CsI spectrum exhibits only the 122keV Co-57 gamma ray peak. This is because the lower energy 14.4keV gamma rays predominantly interact by photoelectric absorption in the NaI detector medium and are not passing through to the CsI detector medium. Whereas, the 122keV gamma rays are energetic enough for some of them to pass through the NaI detector medium without interaction into the CsI detector medium for photoelectric absorption. The peak(s) at *relative* channel position 88 (approx.) in the in-between spectra line up reasonably well the CsI 122keV gamma ray *relative* channel position, so the "in between" spectra may capture some of the CsI events, but also contain coincident NaI/CsI events that would contribute to the NaI background without separation.



Channel	Left 0	Right 0	Peak 0	FWHM 0	Area 0	Left 1	Right 1	Peak 1	FWHM 1	Area
☑ 0	100	160	144.58	29.223	835.27	160	220	190.64	22.992	294
☑ 1	100	160	145.53	28.22	822.83	160	220	192.35	23.206	292
☑ 2	20	100	0	NaN	0	20	100	0	NaN	0
☑ 3	20	100	0	NaN	0	20	100	0	NaN	0

MCA source: C:\XIA\Pixie4\PulseShape\Pixie4_ZEUS_2.67_102815_0003

pnt: 163 X: 163 Y: 390 dX: -79
pnt: 84 X: 84 Y: 13 dY: -377

Fig. 8 NaI spectra for the four ZEUS detectors (energy range ≈ 0-200keV displayed)

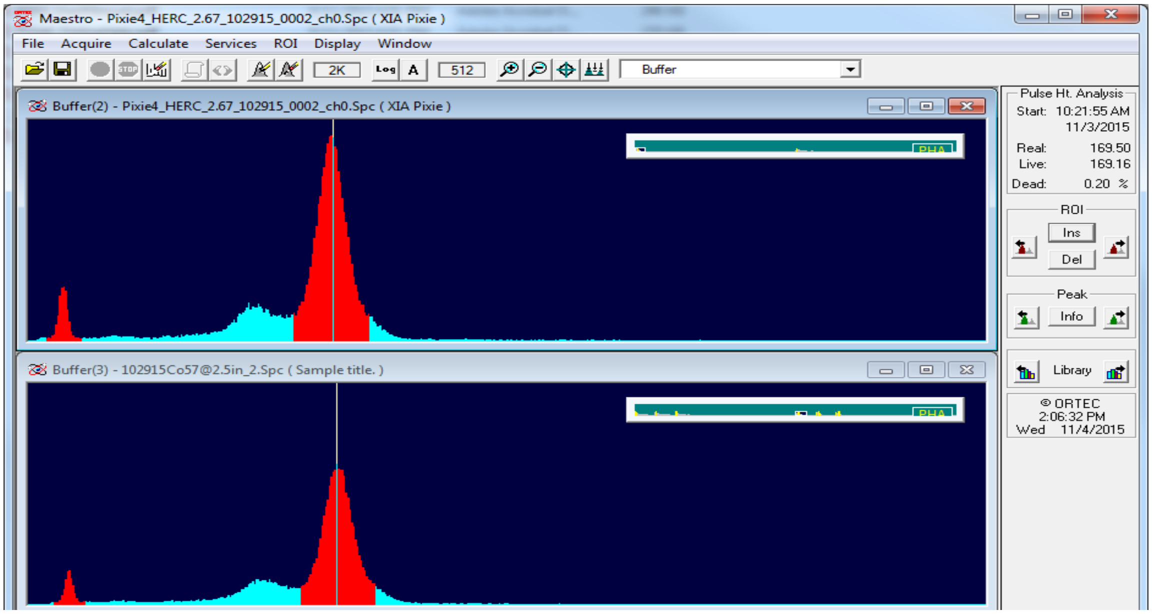
Fig. 9 CsI and "in-between" spectra for the four ZEUS detectors (energy range ≈ 0-200keV displayed)

A key finding with the custom DSP PSum/E gating was that the same digital lower and upper parameters seemed to work on all the detectors to successfully discriminate the NaI and CsI signals. Whereas with the NIM Bin configuration each detector had to be independently set with the Phosmux and the PSAs to optimize each detector's gating.

HERCULES NIM AND PIXIE-4 Spectrum Comparisons

For further evaluation of the Pixie-4 PXI upgrade electronics, experiments have been performed on the HERCULES system. Data was separately acquired with both electronics configurations connected to the same HERCULES detectors with 1) Co-57 sources of similar activity at approx. 2.5 inches in front of each detector and 2) Am241/Cs-137 source combination positioned at the back of the chamber wall in line with the middle detector. A 200 sec real time was set for all measurements. Care was taken to ensure that the sources were at the same locations for the NIM Bin and the Pixie-4 measurements. Two measurements were performed for each electronics configuration with each source loading.

For qualitative reference, for a Co-57 source measurement, the NaI portion of the spectrum for detector 1 for both the NIM Bin configuration and the Pixie-4 configuration are shown together in Fig. 10 – the top spectrum is from the Pixie-4 configuration. Similarly, the CsI portion of the spectrum for detector 1 for both the NIM Bin configuration and the Pixie-4 configuration are shown together in Fig. 11. Similar NaI and CsI peak separation and peak ratios can be observed in the qualitative comparisons.


Maestro - Pixie4_HERC_2.67_102915_0002_ch0.Spc (XIA Pixie)

Buffer(2) - Pixie4_HERC_2.67_102915_0002_ch0.Spc (XIA Pixie)

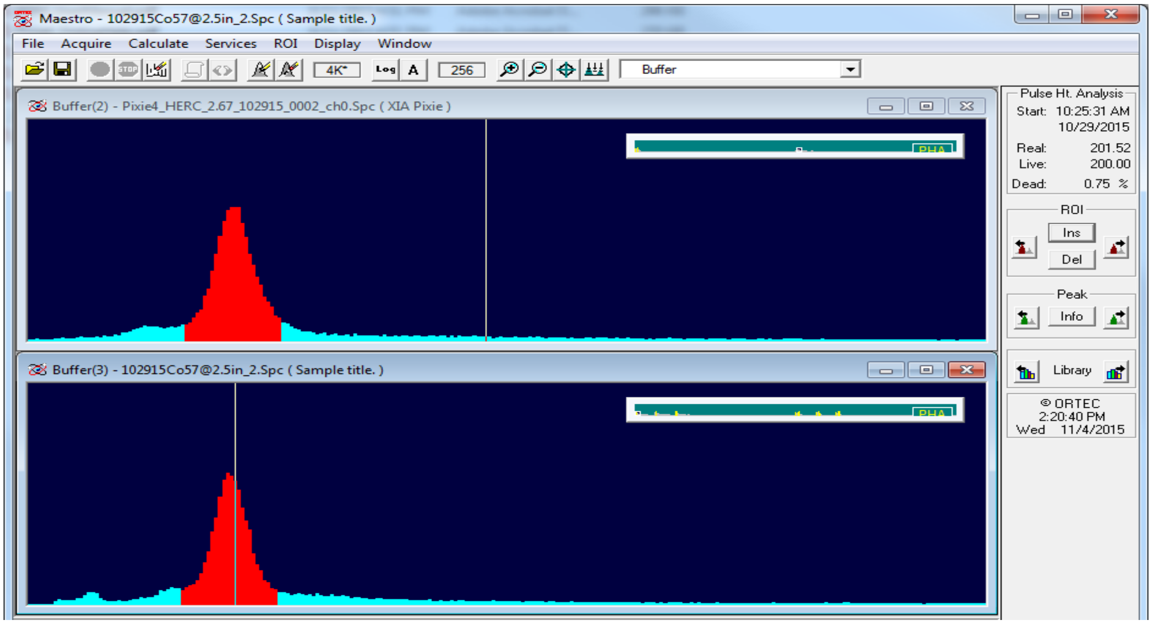
Buffer(3) - 102915Co57@2.5in_2.Spc (Sample title.)

Pulse Ht. Analysis
Start: 10:21:55 AM
11/3/2015
Real: 169.50
Live: 169.16
Dead: 0.20 %

© ORTEC
2:06:32 PM
Wed 11/4/2015

Fig.10 Pixie-4 (top) and Nim Bin (bottom) NaI spectra with Co-57 source

For a quantitative evaluation, NaI and CsI peak resolutions (FWHM channels) and raw efficiency (gross counts) values were calculated and tabulated for both of the electronics configurations and compared. In all cases, the regions of interest (ROIs) for the peaks were set between 2 and 3 FWHM units in order to fully capture the peaks. The MAESTRO® program was used to calculate all of the ROI peak data. Tables I and II shows the average resolution tabulations for all three detectors for the Co-57 and Am-241/Cs-137 measurements, respectively.


Maestro - 102915Co57@2.5in_2.Spc (Sample title.)
Buffer(2) - Pixie4_HERC_2.67_102915_0002_ch0.Spc (XIA Pixie)
Buffer(3) - 102915Co57@2.5in_2.Spc (Sample title.)

Pulse Ht. Analysis
Start: 10:25:31 AM 10/29/2015
Real: 201.52
Live: 200.00
Dead: 0.75 %

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2:20:40 PM
Wed 11/4/2015

Fig.11 Pixie-4 (top) and NIM Bin (bottom) CsI spectra with Co-57 source

TABLE I. FWHM tabulations and comparisons for the Co-57 counts

	FWHM NIM (# ch)			FWHM Pixie-4 (#ch)			Comparison (%diff)		
	NaI		CsI	NaI		CsI	NaI		CsI
	14.4keV	122keV	122keV	14.4keV	122keV	122keV	14.4keV	122keV	122keV
Det 1	4.8	16.3	9.4	5.0	15.8	10.2	4.9%	-3.5%	8.2%
Det 2	5.8	26.6	10.3	5.9	25.8	11.6	1.7%	-2.8%	12.4%
Det 3	5.4	17.5	9.9	5.9	17.9	12.2	9.7%	2.0%	23.5%
						AVG	5.5%	-1.4%	14.7%

TABLE II. FWHM tabulations and comparisons for the Am-241/Cs-137 counts

	FWHM NIM (# ch)			FWHM Pixie-4 (#ch)			Comparison (%diff)		
	NaI		CsI	NaI		CsI	NaI		CsI
	X-ray	59.5keV	662keV	X-ray	59.5keV	662keV	X-ray	59.5keV	662keV
Det 1	7.8	9.8	22.7	9.7	9.9	24.2	24.2%	1.5%	6.5%
Det 2	8.5	17.0	26.0	9.9	16.1	27.0	16.4%	-4.9%	3.9%
Det 3	10.0	11.6	25.3	9.9	11.5	27.1	-0.5%	-0.7%	6.9%
						AVG	13.4%	-1.4%	5.8%

The NaI 122keV peak serves as a good baseline peak for comparison of resolution, since it was used as a key reference peak in the initial optimization of the Pixie-4 operating binning factor and gain energy calibration (0.75keV/ch). The NaI 122keV peak Pixie-4 resolutions are in good agreement with the NIM resolutions – the three detector average FWHM variation was 2%. The 59.5keV Am-241 peak resolutions were also in good agreement – the three detector average FWHM variation was also 2%. In whole, more variation was seen with the other peaks compared, but the detector average variations were all within 15%. It is worth noting that resolution (FWHM) calculations in MAESTRO® can vary significantly with even slight variations in the ROI defined and used, particularly for low-resolution detectors like Phoswich detectors. With that considered, some of the FWHM variations are due to differences between the Pixie-4 spectrum ROIs and the NIM spectrum ROIs. Also with the NIM electronics, slight gating drifts can significantly change the low energy gamma rays peak shapes and amplitudes – this may also account for some of the low energy gamma ray resolution variations.

Tables III and IV shows the average gross count rate tabulations (for both electronics configurations) and all three detectors for the Co-57 and Am-241/Cs-137 measurements, respectively.

TABLE III. Gross peak count tabulations and comparisons for Co-57

	Gross Counts NIM			**Gross Counts Pixie-4**			**Comparison (%diff)**		
	NaI		CsI	NaI		CsI	NaI		CsI
	14.4keV	122keV	122keV	14.4keV	122keV	122keV	14.4keV	122keV	122keV
Det 1	3288	46025	30936	3738	45122	24599	14%	-2%	-20%
Det 2	2375	57216	34027	3339	55511	29386	41%	-3%	-14%
Det 3	4327	53390	34922	4318	52623	31601	0%	-1%	-10%
						AVG	18%	-2%	-15%

TABLE IV. Gross peak count tabulations and comparisons Am-241/Cs-137 counts

	Gross Counts NIM			**Gross Counts Pixie-4**			**Comparison (%diff)**		
	NaI		CsI	NaI		CsI	NaI		CsI
	X-ray	59.5keV	662keV	X-ray	59.5keV	662keV	X-ray	59.5keV	662keV
Det 1	6319	7873	5734	6717	7858	4242	6%	0%	-26%
Det 2	5456	9509	6327	6903	9106	5396	27%	-4%	-15%
Det 3	6761	7770	5647	6342	7813	5188	-6%	1%	-8%
						AVG	9%	-1%	-16%

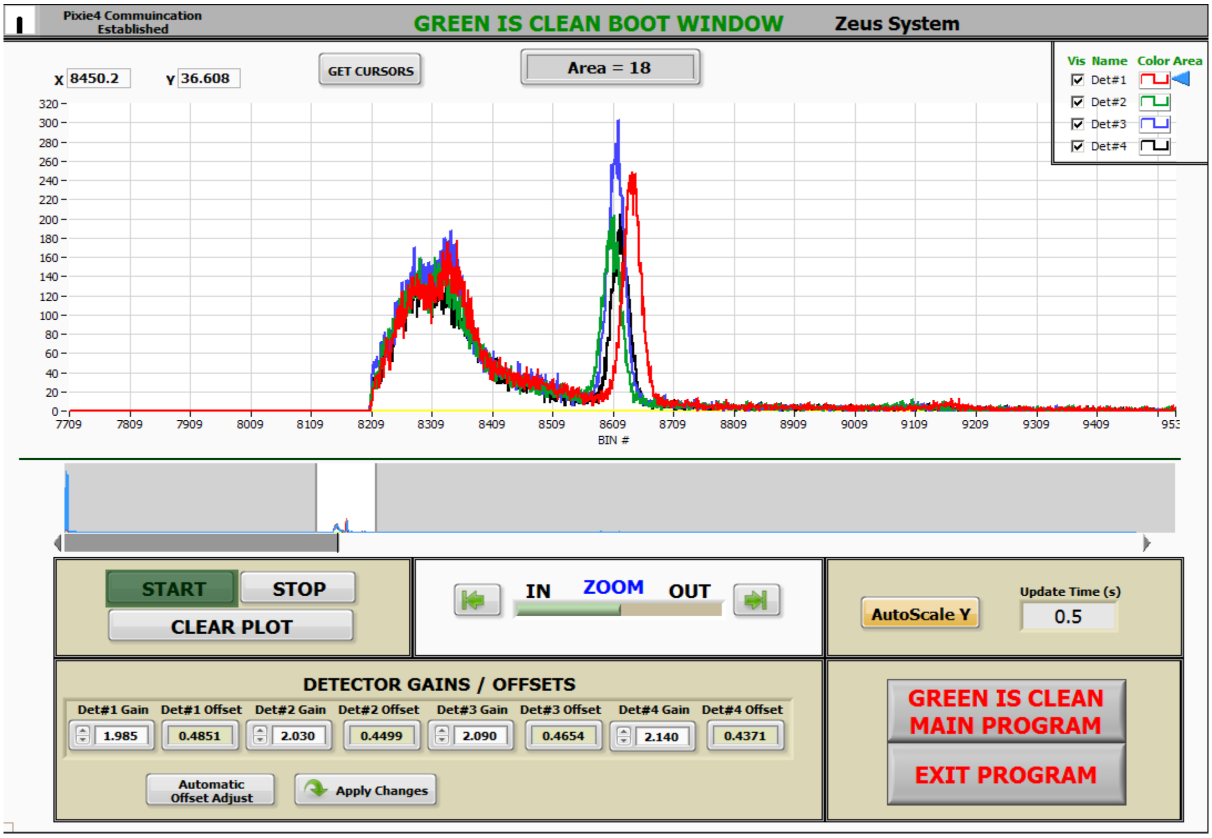
For the efficiency comparisons, again the NaI 122keV is again used as a baseline reference peak since it is used for energy calibration. The NaI 122keV peak Pixie-4 efficiencies are in good agreement with the NIM efficiencies – the three detector average gross counts variation was 2%. The 59.5keV Am-241 peak efficiencies were also in good agreement – the three detector average gross counts variation was 1%. For the low energy NaI peak regions (14.4keV and Am-241 X-ray) the Pixie-4 efficiencies were similar to, but on average higher than the NIM efficiencies by 18% and 9%, respectively. For the CsI 122keV and 662keV energy peak regions the Pixie-4 efficiencies were also similar to, but on average lower than the NIM efficiencies by 15% and 16%, respectively. Some of the efficiency variations are due to differences between the Pixie-4 spectrum ROIs and NIM spectrum ROIs. Gating drifts in the NIM electronics and Pixie-4 gating settings may also be contributing factors. A key goal for the effectiveness of the GIC systems in the upgrade process is to maintain low detection limits (sensitivity) for the low energy NaI regions where TRU contamination in GIC waste are detected. Part of achieving this is having equivalent or higher NaI low energy efficiencies with the upgraded systems. This is the case with the initial evaluation data allowing us to conclude “Proof of Concept” for the Pixie-4 upgrade electronics. Maintaining sensitivity levels for the higher energy CsI regions is also desirable (but not as critical as the low energy NaI regions), so continued evaluation of current and new data, and efforts to further optimize the Pixie-4 operational parameters is planned and in progress.

GIC LabVIEW™ Production Operations Software

While the custom ZEUS/HERCULES Pixie Viewer has proven to be suitable for development and optimization of the Pixie-4 module settings, daily waste processing operations with the NIM Bin configuration have always been done using a LabVIEW™ software user interface. The LabVIEW™ operations software is tailored for production work directed by site operating procedures and is well established. So a final step in the GIC system upgrades is to adapt the GIC LabVIEW™ operations software to be compatible with the signal outputs from the Pixie-4 configuration. This effort has been initiated with the help of a LANL LabVIEW™ programmer through interdivision cooperation. The original LabVIEW™ software was written by a commercial vendor, VI Controls Systems, Ltd., who still supports the project as needed.

A key challenge with the transition to the Pixie-4 configuration is dealing with the different spectrum outputs from the different MCA softwares. The original Canberra Genie2K MCA software communicating with the S100 card histogrammed the signal from all detectors into a single 16K spectrum. The first 8192 channels were assigned to all the CsI events and the second 8192 channels were assigned to all the NaI events. No histogramming of the “in-between” events was performed. Up to eight detectors each with a CsI and NaI separation could be accommodated with this setup – 1024 channels to each separated NaI and CsI detector signal. The LabVIEW™ software communicates with Genie2K while it runs in the background. Differently, with the Pixie-4 configuration, each detector has a 32K spectrum with the NaI events being assigned the first 8192 channels and the CsI events being assigned the second 8192 channels. A single Pixie-4 module can accommodate up to four Phoswich detectors. Four detectors is the current maximum for the ZEUS system, but more detectors could be accommodated with the introduction of additional Pixie-4 modules.

Thus, a new translation of the incoming Pixie-4 spectra had to be developed. This has been achieved with a supplemental LabVIEW™ user interface called the “GIC Main Boot VI”. This replaces the Genie2K MCA software and communicates directly with the Pixie-4 module primarily through a LabVIEW™ compatible “.dll” control file and a pre-optimized parameter settings file. However, Pixie-4 gains and offsets can be adjusted through the “GIC Main Boot VI”. Fig. 12. shows the window of the of the “GIC Main Boot VI” in its current state. In the graphic, a zoomed in portion of the CsI spectrum is displayed in the top portion of the window with the x-axis indicating bin (or channel) number. The middle portion of the window shows the full 32K spectrum for each detector and the section of the spectrum displayed in the top portion. The bottom portion of the window includes data acquisition, spectrum view, and gain and offset adjustment controls. Work to integrate the main boot interface with the rest of the original operations user interface and algorithms is also in progress. Formal software QA activities and documentation, as well as revisions to the applicable operating procedures is part of LabVIEW™ operating software upgrade and is in progress.



x 8450.2
y 36.608
Area = 18

☑ Det#1 🟥
☑ Det#2 🟩
☑ Det#3 🟦
☑ Det#4 ⬛

Update Time (s) 0.5

Det#1 Gain	Det#1 Offset	Det#2 Gain	Det#2 Offset	Det#3 Gain	Det#3 Offset	Det#4 Gain	Det#4 Offset
1.985	0.4851	2.030	0.4499	2.090	0.4654	2.140	0.4371

Fig.12 The GIC Main Boot VI

CONCLUSION

The GIC Phoswich detector systems HERCULES and ZEUS developed in the late 1990s have been a vital part of the GIC program at LANL over the past twenty years. The HERCULES system is still operating using the original developed NIM Bin electronics configuration, but many components of the system are aged and may soon become obsolete. LANL has not maintained the ability to build additional or replacement Phosmux multiplexers and so it is effectively obsolete. In order to preserve the long term functionality of the GIC Phoswich systems, an upgrade project has been initiated. Alternate more compact commercial PSD electronics have been identified, procured and configured and optimization and testing has started. All of the electronic components including the Pixie-4, HV and pre-amp power modules are working in a single PXI chassis to run multiple Phoswich detectors. Initial qualitative experiments on the ZEUS showed that the PSum/E waveform analysis method with the Pixie-4 is effective in separating out the NaI and CsI signals in the Phoswich detectors. Quantitative comparisons on the HERCULES system with both the NIM and Pixie-4 electronics show good resolution and efficiency agreement (<2%) between the systems for the primary NaI 122keV reference peak, but some larger magnitude variations were observed for other peaks compared. Further evaluation of the differences and operating parameter optimization of the new counting electronics is planned and in progress, but “Proof of Concept” has been established for the tested Pixie-4 configuration. Upgrade modifications of the LabVIEW™ based daily operating software to accommodate the new Pixie-4 spectrum format and integrate it into the software algorithms is required and occurring in parallel with further Pixie-4 module testing and optimization. Remaining activities toward completion of the upgrade project will focus on final Pixie-4 optimization and testing, adaptation of the LabVIEW™ operating software, software QA, and operating procedure revisions.

REFERENCES

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