Applications of Digital Pulse Acquisition Systems and Software Defined Electronics (SDE) in Advanced Teaching Labs

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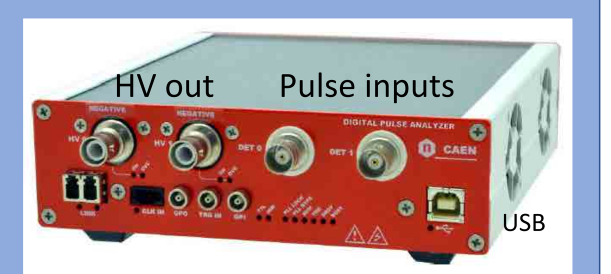
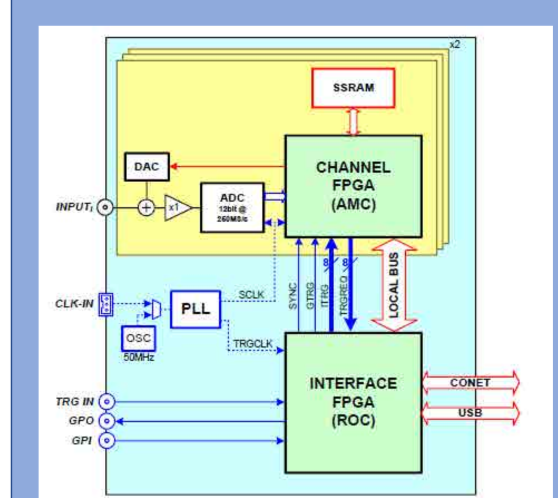
Abstract:

The CAEN DT5790N is a digital acquisition system which houses two high voltage supplies and two highspeed (12 bits, 250MHz) waveform (pulse) digitizers. These in tandem with the use of post processing software combine to produce a Software Defined Electronic (SDE) system that can be used in several advanced teaching lab experiments. FPGAs and built-in software can be used to display the pulse waveform and produce a time-stamped output (4 ns intervals) in a text list for post processing, e.g. via MATLAB, Python, LabVIEW, ROOT, BASIC, etc. The SDE can then be reconfigured as needed and used to run many nuclear and other experiments in an advances teaching lab course. This serves to expose students to modern state-of-the-art data acquisition technology. Experiments such as Fission Neutron Time-of-Flight, Compton Scattering, Co-60 Gamma Coincidence, Na-22 Gamma-Gamma Annihilation. Muon Lifetime, etc. are well suited for SDE. The SDE system also provides a very adaptive and cost-effective substitute for NIM or CAMAC electronics as SDE can be easily set up with only a single digitizer box and a computer for many different experiments. Typical data using the SDE applications we have developed for several advanced teaching lab experiments will be shown. Several other digitizers similar to the CAEN unit are also available for SDE.

Internal Interface:



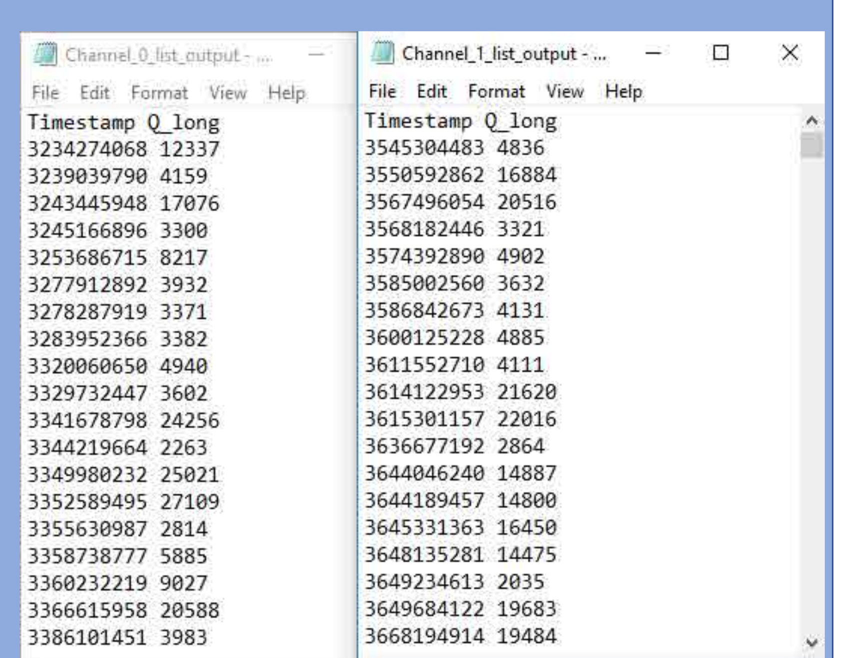
The CAEN DT5790N digitizer/HV supply contains user-programmable FGPAs for each of the output channels. These can be configured though configuration files which write logic to the channels registers in order to perform acquisition that involves pulse discrimination or coincidence timing. Custom software can be written to control the DT5790N, though CAEN also provides user



friendly DPP_PSD control software which can also be used to run data acquisition. This software has a built in oscilloscope mode and energy histogram mode which are both useful for post processing. [1][2]

SDE Post Processing:

The SDE method used for most of the experiments is through the use of the text list dumping functionality of the DPP-PSD Control software provided by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File Edit Format View Help

Timestamp	Q_long
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3253686715	8217
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3278287919	3371
3283952366	3382
3320060650	4940
3329732447	3602
3341678798	24256
3344219664	2263
3349980232	25021
3352589495	27109
3355630987	2814
3358738777	5885
3360232219	9027
3366615958	20588
3386101451	3983

Channel_1_list_output - ...

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Timestamp	Q_long
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3550592862	16884
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3574392890	4902
3585002560	3632
3586842673	4131
3600125228	4885
3611552710	4111
3614122953	21620
3615301157	22016
3636677192	2864
3644046240	14887
3644189457	14800
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3648135281	14475
3649234613	2035
3649684122	19683
3668194914	19484

CAEN. Thus, whenever the FPGAs trigger an output event, information about the triggered event is then written to a specified PC .txt file. This is shown in the example for two gamma ray detectors with coincident events.

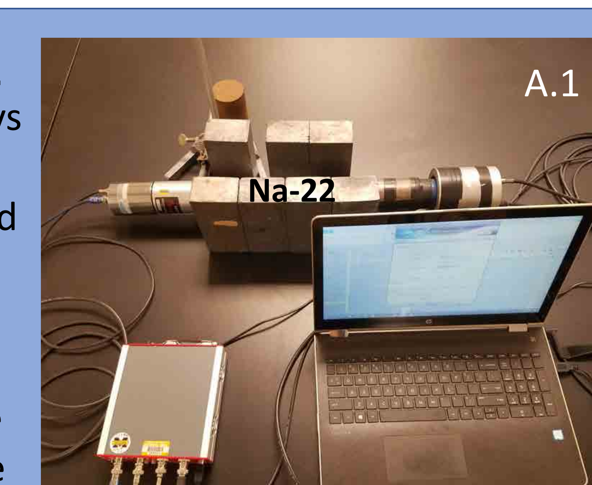
Experiments with SDE software developed are the following: Na-22 Gamma-Gamma Coincidence, Compton Scattering, Muon Lifetime,Cf-252 Fission Neutron Time of Flight.

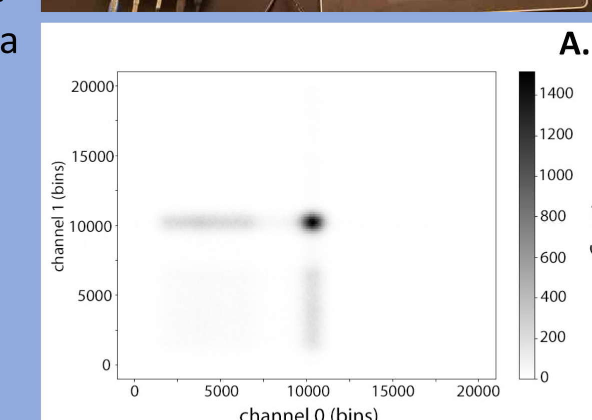
Experiments planned to develop SDE include: Co-60 coincidence, Neutron Activation, Ba-137 half life, HP Gamma Spectroscopy, and others.

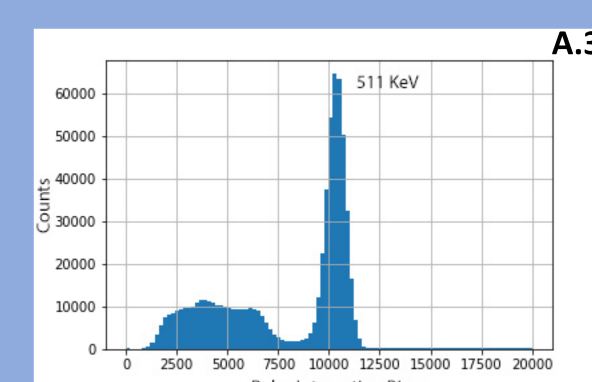
Na-22 Gamma-Gamma Coincidence

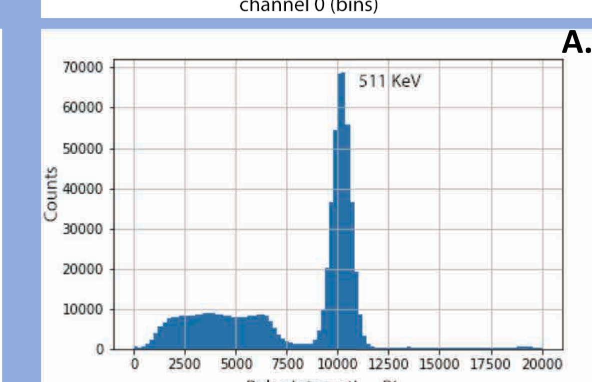
To measure the two back to back 511 KeV gamma rays produced by Na-22 positron annihilation using SDE we used two NaI(Tl)+PMT detectors connected and powered by the CAEN DT5790N. This is connected by USB to a laptop running the DPP-PSD control software, as seen in Figure A.1. The two channel FPGAs were configured to run coincidence, thus the event trigger to write the time stamped PMT anode pulse integrals to the .txt list PC file only occurs when both channels trigger an event within a 40ns window. Post-processing software written in Python 3.6 was then used to generate 2D plots where the coincident gammas along with random coincident events can be displayed with the coincident gamma photo-peaks and Compton events in the detectors.

Figure A.2 shows the 2D coincidence plot whereas Figures A.3 and A.4 show the energy histogram of channel 0 and channel 1 respectively



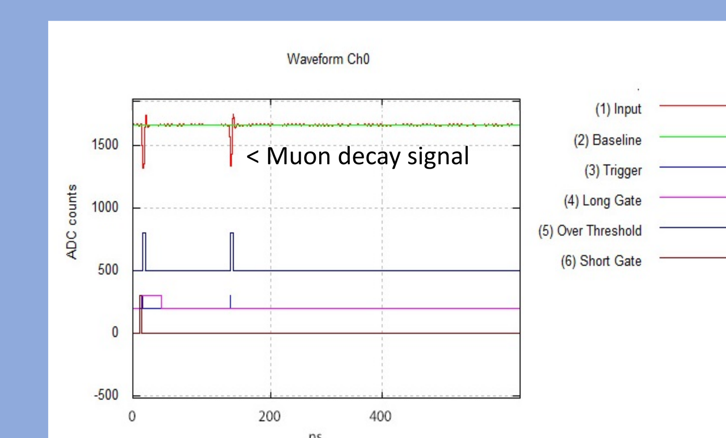


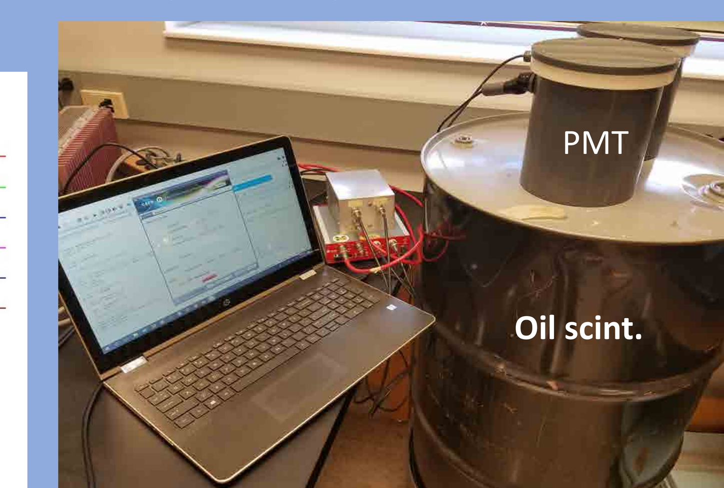


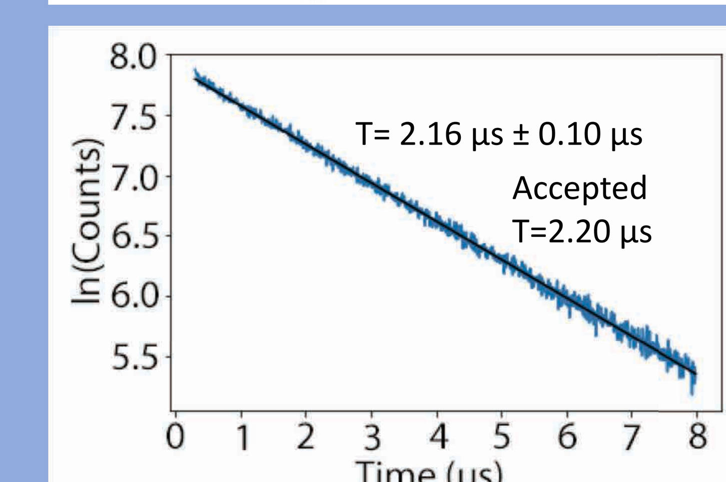


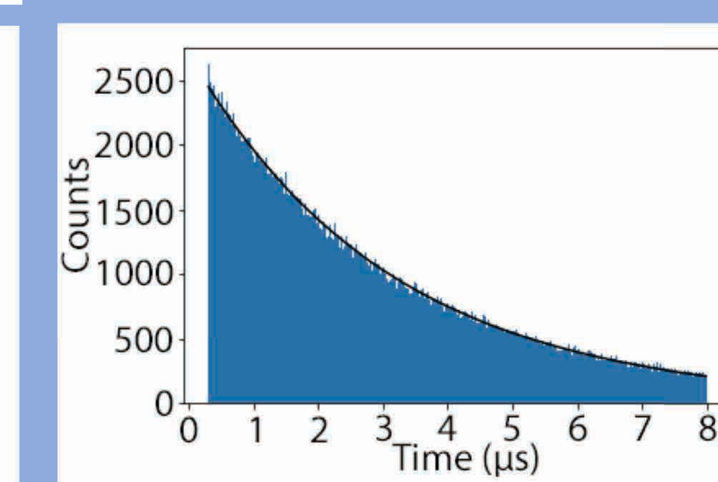
Muon Lifetime

The muon decay detector from an existing Muon Lifetime experiment consists of a large 55 gallon drum of mineral oil scintillator with large PMTs. It was updated with the digitizer and SDE. The figure shows coincident PMT pulses: the digitized incident muon signal, followed by the muon decay signal. SDE post processing yields 2.16 μs ± 0.10 μs for the muon mean lifetime, in agreement with the known value.



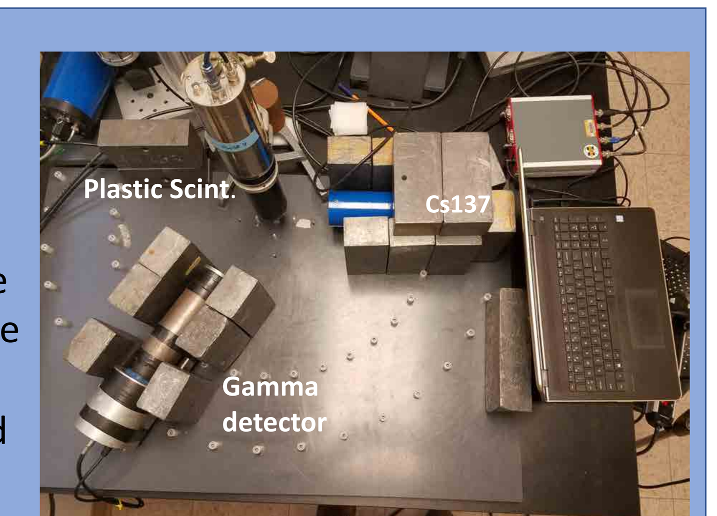




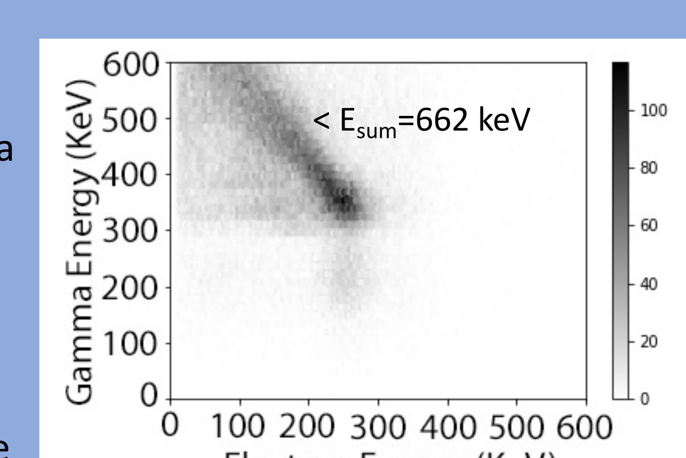


Compton Scattering

. A standard set up was used, with a plastic scintillator and PMT serving as the low-Z scattering medium and a NaI(Tl) with PMT serving as the detector for the scattered coincident gamma ray. The coincidence window and energy calibrations are done as previously described and similar post-processing software used to generate 2D plots of coincident and non-coincident scattered gamma rays and electrons as a function of gamma ray emission angle. In this case there is a direct correlation between these energies and the gamma-ray scattering angle via the well-known Compton relation which requires that the summed energy is equal to the incident gamma ray energy, in this case 662 KeV (Cs-137).

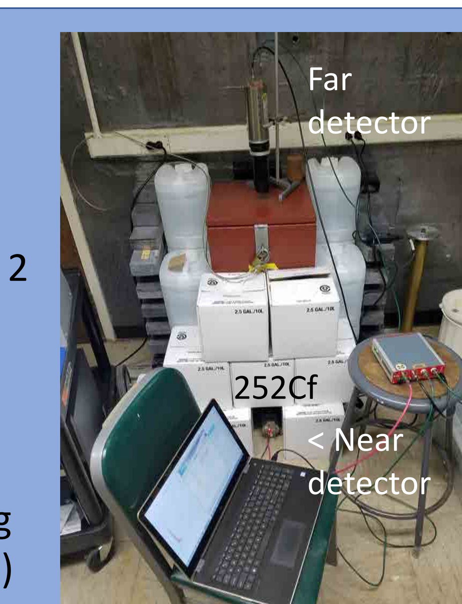


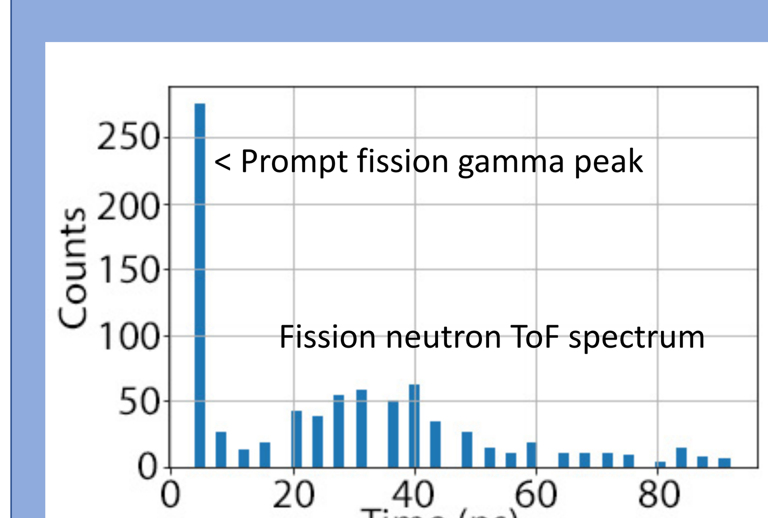
After calibrating the detectors with gamma -ray sources, data was obtained over a range of gamma angles with ca. 2 in by 2 in. dia. plastic and NaI(Tl) detectors using a collimated Cs-137 source. As can be seen the 2D data taken at various angles as expected follow a diagonal path corresponding to 662 keV summed energy. The angular distribution of Compton scattering also can be measured at the same time.

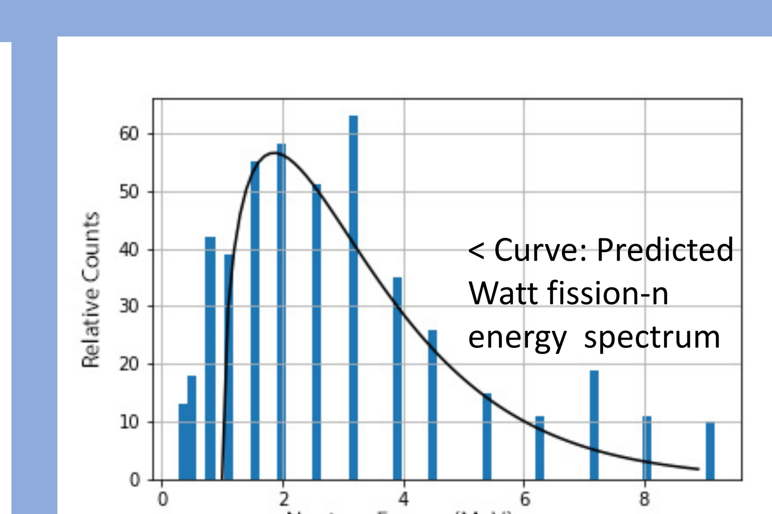


Fission Neutron Time-of-Flight

This experiment is done with a depleted oil well-logging sealed 252CF spontaneous fission source. The set up is again from an existing experimental as described in [3]. The SDE version replaces the analog electronics (NIM or CAMAC) with the CAEN 2 channel digitizer/HV supply operating in time-stamped list mode. In this mode the signal from the start and stop plastic scintillators are recorded in the PC as a list of pulse integrals stored with a time stamp in 4 nsec intervals (see above). A custom SDE program simulating coincidence and time-to-analog (TAC) modules is then used to determine the time of flight (ToF) of the detected neutrons and gamma rays at the far detector placed ca. 1 m away from the detector near the fission source.







References:

[1] CAEN UM3188 DT5790-Digital Pulse Analyzer Manual rev0

[2] CAEN UM2580 DPSD User Manual rev9

[3] F. D. Becchetti, M. Febbraro, R. Torres-Isea, M. Ojaruega, L. Baum “252Cf fission-neutron spectrum using a simplified time-of-flight setup: An advanced teaching laboratory experiment” [AmJPhys **81(**2013)112]

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