U.S. DEPARTMENT OF ENERGY

PNNL-27615

Radiation Detection and Nuclear Security Summer School

Activity 3A: Pulse Shape Discrimination and Fast Neutron Detection

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June 2018

Pacific Northwest NATIONAL LABORATORY

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Pacific Northwest National Laboratory
Richland, Washington 99352

1 Pulse shape discrimination and fast neutron detection

ADVANCE PREPARATION:

1. Read Knoll, pp. 569-582 (ch 16. fast neutron detection), 225-235 (ch 8. scintillation detectors). 700-701 (additional PSD)

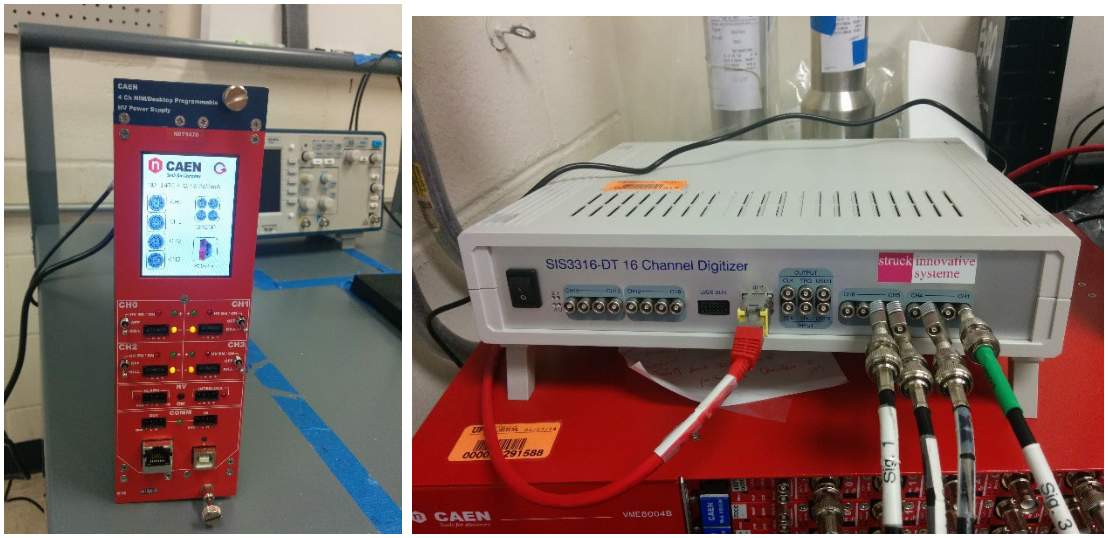
THE NEUTRON SOURCE:

The source of neutrons used will be a ^{252}Cf source that contains about 1/3 of a microgram. 97% of decays are alpha decays while about 3% are spontaneous fission events emitted with an approximate Maxwellian/Watt spectrum. These neutrons are formed with a spread of kinetic energies ranging up to about 10 MeV (see lecture notes).

DETECTORS:

The detector we will use is a EJ-309 liquid scintillation detector. This contains a hydrocarbon liquid with a PMT, which is powered with a standalone negative high voltage supply. The digitizer is controlled by a computer program. The program is controlled with several options in an input script. You will have at your disposal a matlab script that can read in pulses and store them on your computer. That same script can also be used to calibrate the detector.

HIGH VOLTAGE: The scintillator PMTs should not exceed -2000 V.



Power supply (example) and Struck SIS3316-DT 16 Channel digitizer.

PROCEDURE:

EJ 309 Scintillation detector
(a) Calibration
We want to calibrate the detector to have a Compton edge of cesium 137 at 0.35 volts. This achieved using the matlab calibration script “calibration_read.m”. The same script will be used to read the various collected data sets.

The detector will be powered by negative high voltage from a standalone HV-power supply that is operated by touchscreen for up to 4 detectors (one will be used in this lab).

The detector output signal (“anode”) will be connected via BNC cable to a LEMO connector and then to the grey digitizer (any channel).

Using the “sis3316_test_new.exe” program, and the accompanying “sis3316.i” input script we shall collect a few pulses to verify that the detector is operating. At this stage we use a nearby Cs-137 source with the detector.

Once you see pulses take a data set of at least 20 000 pulses and run the “calibration_read.m” script to determine the current Compton edge value. Keep adjusting the voltage until a 0.35 V Compton edge is achieved (higher voltage will move it up and vice versa). What is a reasonably detection threshold in volts? What gamma-ray energy would that correspond to?

(b) Background measurement.
Take a background measurement of at least 10 000 pulses.
Where should we place the sources during this measurement? Why is the background rate so high?

(c) Measurements of neutron and gamma-ray radiation
1. Using an instructor supplied Cf-252 source take on the order of 100 000 pulses of combined neutron and gamma-ray data.
2. Using various gamma-ray energy sources take a measurement of 20 000+ gamma-ray pulses. (where/how should the neutron source be located/shielded at this time?)

3. Using shielding try to collect *ONLY* neutron data. What shielding should be used? At what location should the shielding be placed? (Collect 20 000+ pulses).

(d) instructor demonstration of tail-to-total pulse shape discrimination (PSD)

ANALYSIS:

1. Using the matlab script obtain the raw pulse waveforms from the 4 measurements (BG, neut+γ, neut, γ).
2. Correcting for highly energetic cosmic rays in the data might be a good idea. Those pulses would be larger than the maximum recordable value of the digitizer and would then be distorted.
3. Apply a PSD algorithm to the waveforms, similarly to the instructor shown tail-to-total demonstration (has to be an algorithm other than the traditional tail-total integration comparison). You should see some separation in the combined data and can verify the PSD algorithm with the "pure" separate gamma-ray and neutron data sets. (Do you expect perfect agreement in either case)?
4. Explain your algorithm and its origin (created by you, obtained from references etc?)
5. Once you have a functioning PSD algorithm I want you to obtain the *background corrected* neutron and gamma-ray rate from the Cf-252 source. Note that there is a timing vector generated by the matlab script ("time_t") which lists times of the each pulse in units of 4ns. The values are generated by the computer and will not restart with each measurement.
6. Estimate the fractional contribution to NSC background dose from gamma-rays vs fast neutrons assume no other radiations exist). You can assume a W_R-factor (used to be Q-factor) of 10 for neutrons and a W_R -factor of 1 for gamma-rays.

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