UNFOLDING OF AM-BE NEUTRON SPECTRUM USING MACHINE LEARNING

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PAPER ANALYSIS

Energy Calibration of EJ-301 Liquid Scintillation Detector using Unfolding Methods for Fast Neutron Measurement

Introduction

- Fast neutrons are the most dominant contributors to the background in the field of rare event search experiments. Thus studying their response is essential.
- The procedure for calibrating EJ-301 liquid scintillation detectors to fast neutron energies using unfolding methods is described in the article. It also covers experimentation and simulation of the EJ-301 liquid scintillation detector.
- In order to get the input Am-Be neutron energy spectrum and calibrate the detector 43 to the neutron energy scale, several unfolding techniques are utilized.

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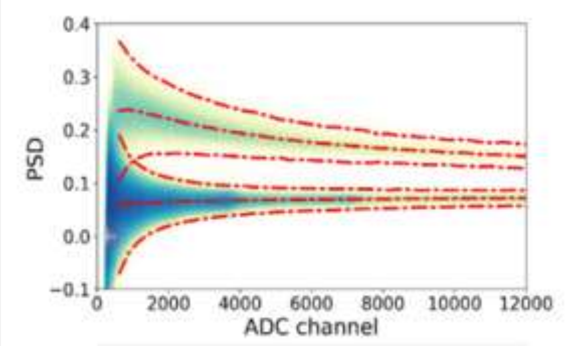
Detector Specifications

- A Photo Multiplier Tube (PMT) is linked to a liquid scintillation detector as a part of the experimental set-up.
- Using a waveform digitizer and DPP-PSD Control Software is used to calculate PSD parameter:
  - PSD = Charge stored in tail/Charge stored in entire pulse
- To get the best Figure Of Merit (FOM) value, the anode voltage was maintained at +750V, which is a measure of PSD quality. With an energy threshold of 275 keV, the FOM value achieved was 1.14.



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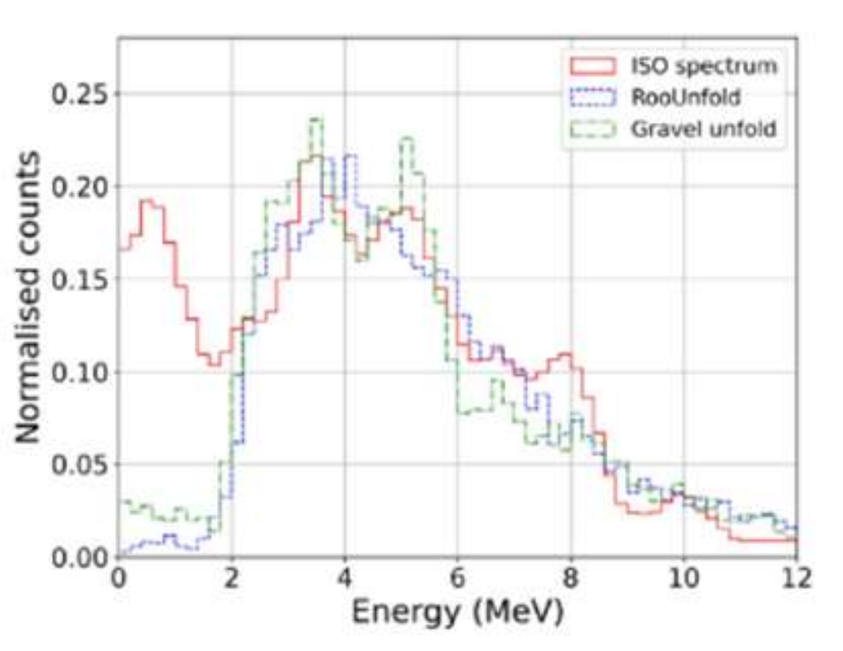
Results

- Using the detector response data gathered during an experiment, the unfolding approach reconstructs the energy spectrum radiated by a radioactive source.
- 240 neutron response functions with fixed energy ranges of 0.05 MeV to 12 MeV are used in the simulation. The light output of the detector for incident neutrons with a specific energy distribution, can be written as:

$$N = R * \phi \quad (1)$$

where, N represents the detector response in terms of optical photons collected at photo cathode. ϕ is the incident spectrum of the radioactive source at the detector and R is the response matrix.

- There are various methods to achieve this, but in this paper, two specific methods - Gravel iterative and RooUnfold - are employed for unfolding.



Unfolded Neutron spectrum

OBJECTIVES

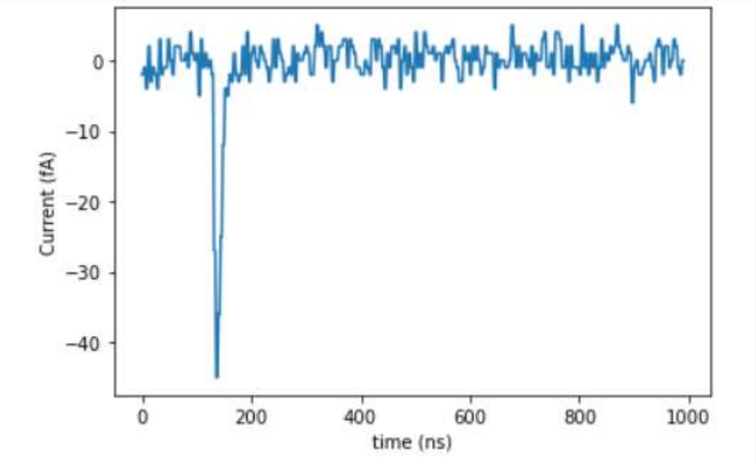
- Analysis of Relevant Research Papers.
- Recording experimental data and assembling a template of pulse shape for different ADC Channels.
- Applying t-SNE to the PSD plots to see if classification is possible for ADC Channels below 740.

EXPERIMENT
APPARATUS AND SOFTWARE

- EJ-301 Liquid Scintillation Detector
- V1370 Waveform Digitizer
- N1470 Power Supply
- CAEN DPP-PSD Control Software
- Am-Be Neutron Source

EXPERIMENT
DATA ACQUISITION

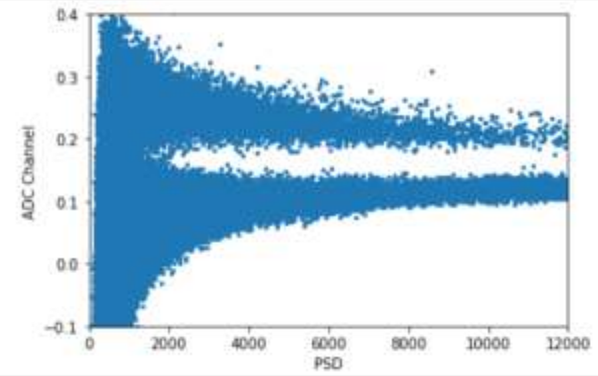
- To apply t-SNE or any classification algorithms, we need specific pulse parameters, like rise time, fall time, and pre-pulse STD, amongst others.
- For the above parameters, we need to assemble a pulse template, i.e., document pulse shapes for different ADC Channels and check energy dependence of pulse shape and pulse height.
- To plot pulse shape at different ADC Channels, we place the source at a distance of 6cm from the detector and use the DPP-PSD Control Software in Oscilloscope mode. This returns the current detected by a the detector at different instances of time.
- We manually set the detector to record data for around 1000 ns for each pulse, post-trigger.



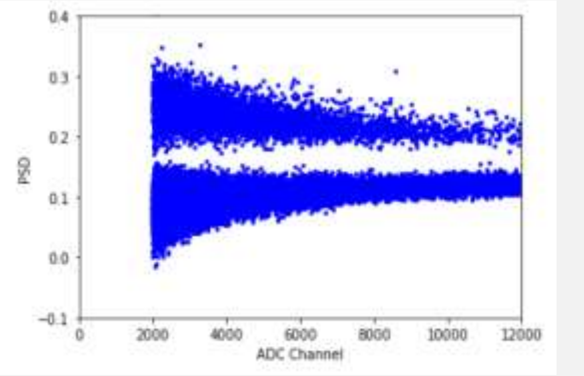
A single pulse detected in Oscilloscope mode

EXPERIMENT
PULSE TEMPLATE

- Integrate the current to find the charge accumulated in the tail of the pulse and calculate PSD parameter for all individual pulses. We plot the PSD to achieve one quite similar to the one achieved by the research group at NISER.
- Determine an ADC channel from where there is a clear separation between neutron and gamma pulses. Consequently, we place a cut at 2000 ADC channel.
- Separate the neutron and gamma pulses.
- Isolate neutron and gamma pulses at different ADC channels, with a bin size of 100 ADC Channels.
- Normalize and average the pulses in these bins and are thus able to observe pulse behaviour for different ADC Channels.



(1)



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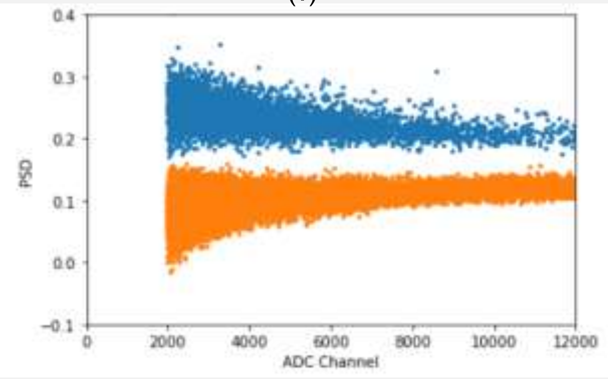

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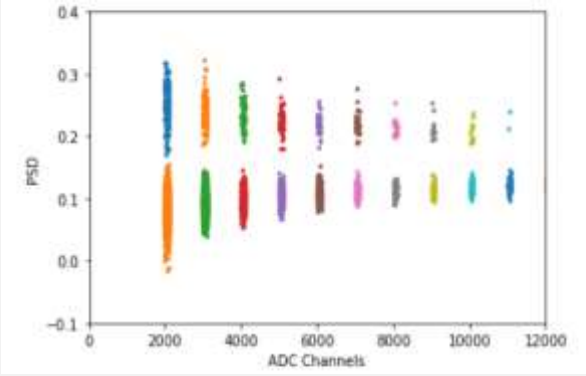

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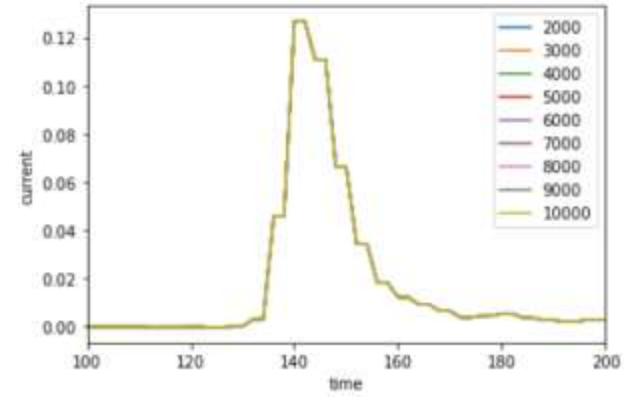
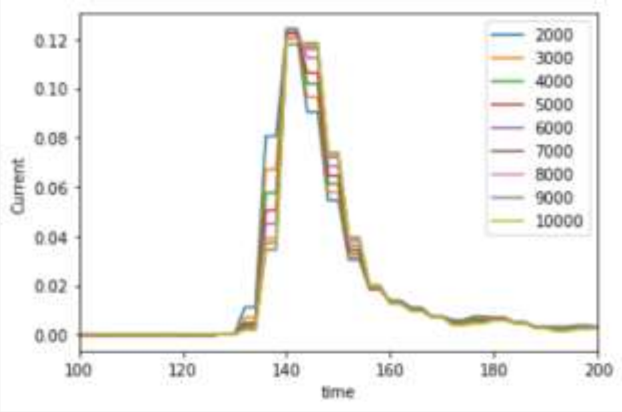
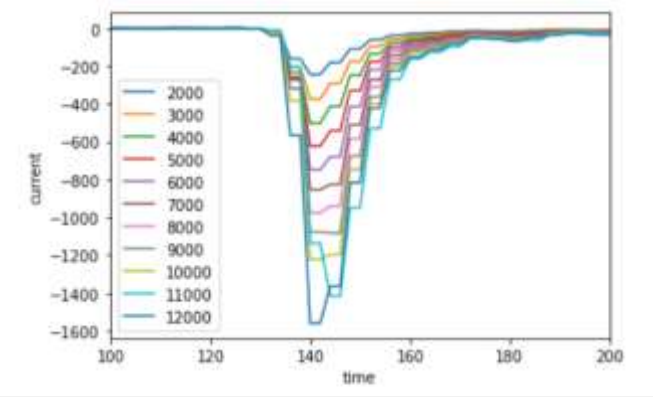
EXPERIMENT
PULSE TEMPLATE



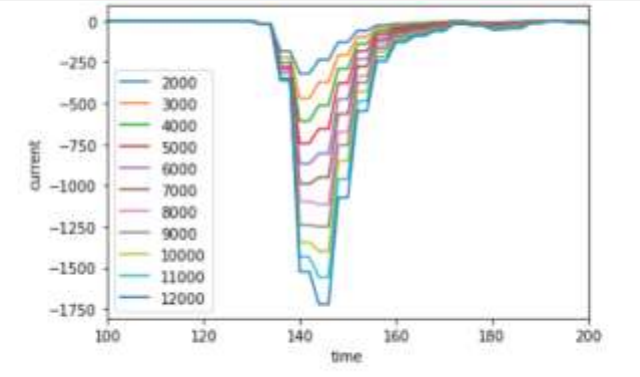
Normalised gamma pulse



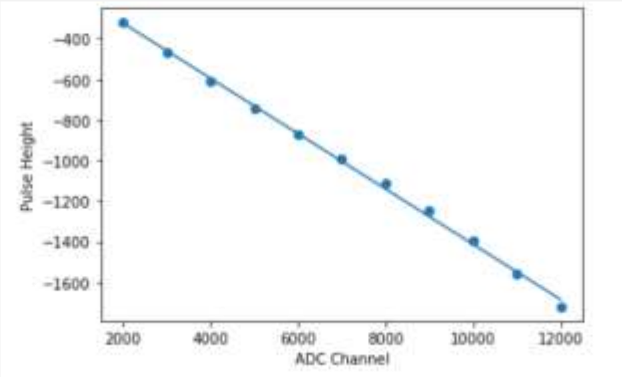
Normalised neutron pulse



Average neutron pulse



Average gamma pulse



Relation between pulse height and ADC Channel

- Pulse shape is not energy dependent.
- Pulse height is energy dependent.
- Energy dependence of pulse height is linear.

FURTHER PLANS

- Calculation of pulse parameters from the pulse template.
- 2. Application of t-SNE to check whether classification is possible below 740 ADC Channel.
- 3. Applying classification algortihms to achieve a well-separated neutron and gamma response.
- 4. Unfolding of neutron spectrum and validating it against the ISO spectrum.