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Signal Discrimination in Thinned Silicon Neutron Detectors using Machine learning

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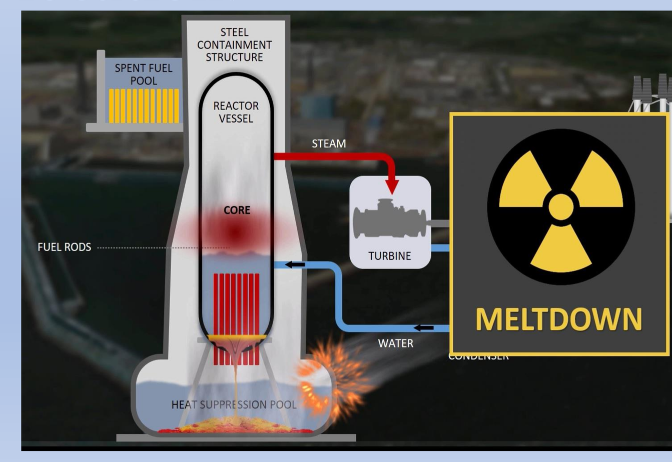
Introduction

High gamma backgrounds can pose a significant source of interference in solid-state neutron detectors making the neutron flux approximation inaccurate.
This work focuses on optimizing a thin sensor thickness to enhance the neutron capture rate and reject gammas, and analysis of multiple input source through the differentiation of signals using pattern recognition.
Gamma isotopes and neutron spectrums have been simulated using **GEANT4 + Electronic noise estimation**. Different machine learning tools have been considered to discriminate different gamma and neutron sources, including **PCA, RNN, SVM, KNN, ResNet** and others.

Motivation and background

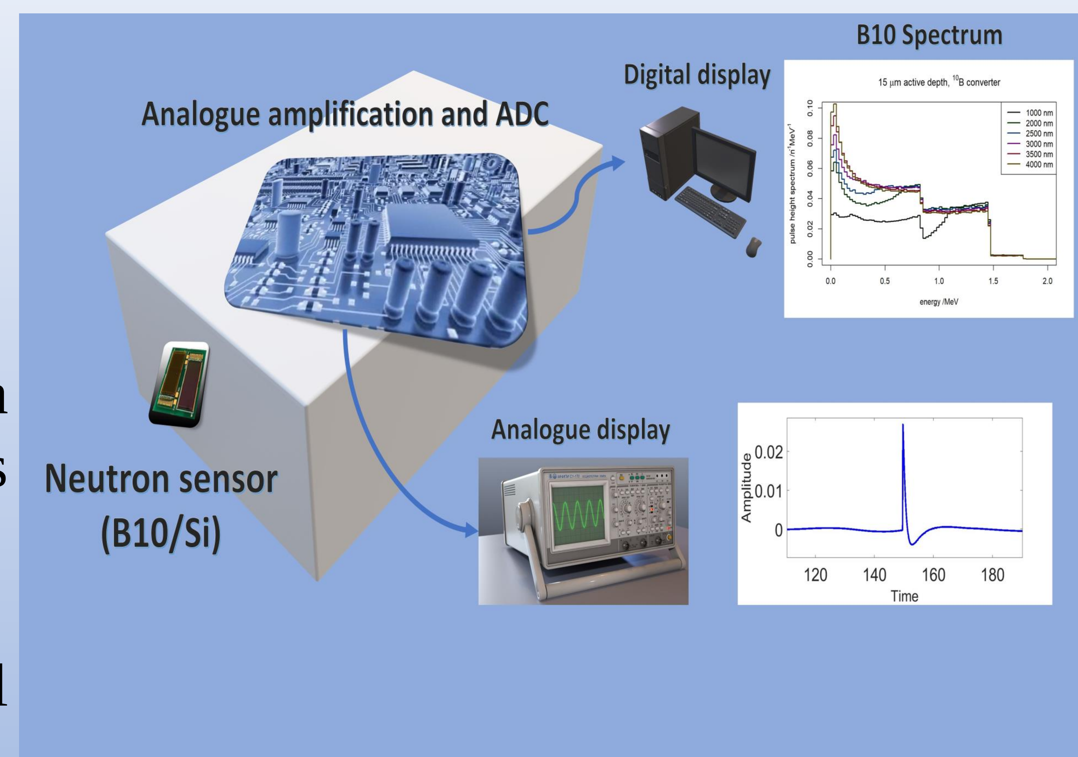
Three of the six reactors units at Fukushima suffered a partial meltdown following the 2011 tsunami.
Decommissioning challenges:
1- Finding **the location of the neutron sources** around the melted units in high gamma background
2- Estimate the **neutron flux around the location**.
3- **Reducing the gamma interaction by** the nature of the sensor design.
4- Applying advanced and trained **machine learning methods to differentiate gamma and neutron flux**.



Methodology and experimental design

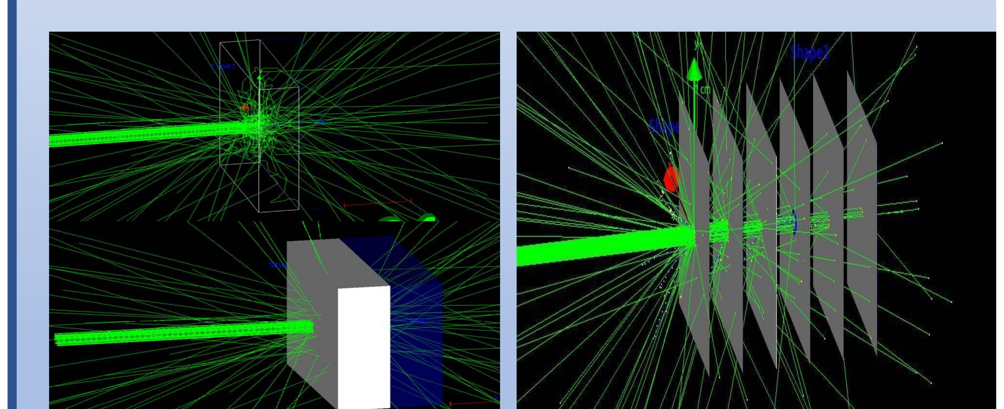
1- B10 based sensor, to **stop neutrons and reject gamma.**
2- Hybride CdTe/CZT sensor-based gamma detection
3- PCB electronics, for **amplification and ADC conversion.**
4- Computer software, for **digital reading, Pileup correction and machine learning discrimination**.

A B10/ thin Si has been optimized to increase the sensitivity level of the senor and reject gamma interaction. **GEANT4 has been used to find the optimal converter thickness (2um)**. Other crystals including CsI, CdTe and CZT have been tested to collect gamma and neutron spectrums.
Charge amplifier has been used to enhance the signal gain before the ADC conversion step.
Filterbank, digital filters and wavelet transform approaches have been used to denoise the digital signal and correct the Pileup events.
Deep neural network has shown an impressive improvement in segmentation and classification tasks. Convolutional or recursive mode of neural network can be used in this work to classify neutrons from gamma hits.

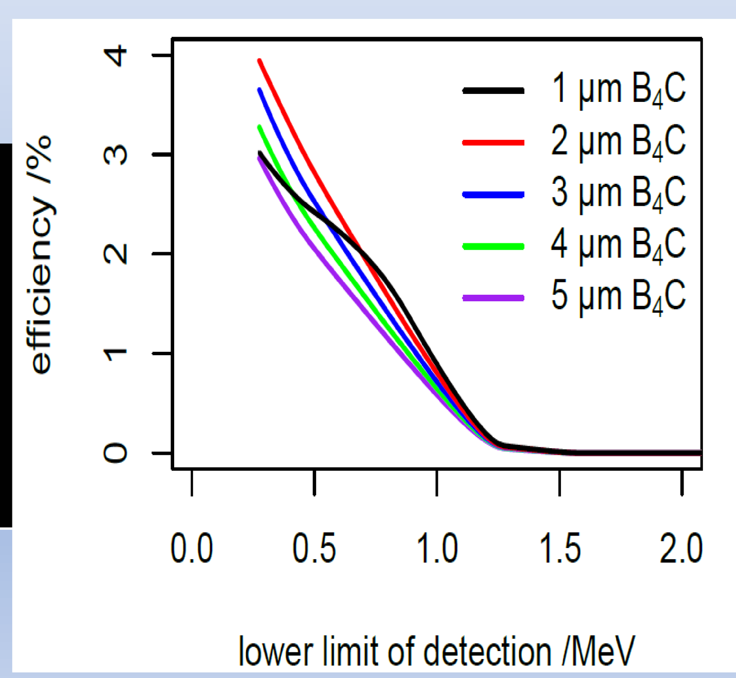


Results

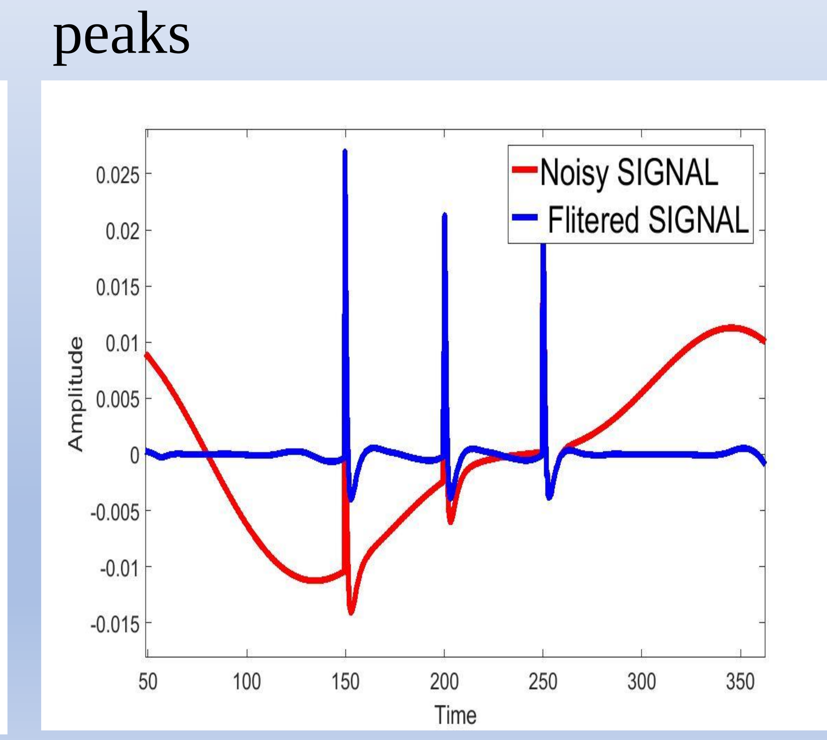
GEANT4 geometry design for single and six-layers B10/SiC sensor defining sensitivity vs



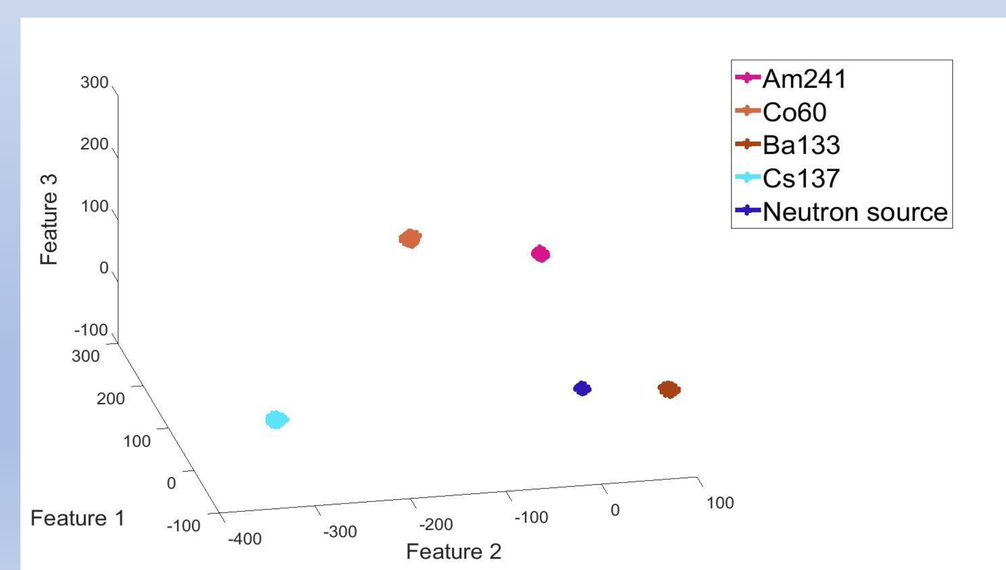
B10 based absorber optimized thickness (2 um)



Wavelet transform to remove noise and detect peaks



Low grade CdTe crystal has been used to collect gamma and neutron spectrums. A classification method based on principle component analysis and recursive neural network has been used to find the 3D feature map below.



Discussion and Conclusion

The discrimination of differing emitters of ionising radiation is becoming important and has a number of applications. Historically, radiation In this work a range of detectors have been used that respond to a multiple of radiation types and advanced real time signal processing used to identify the radiation type. The results show that an understanding of the physics of the complete system allows advanced algorithmic processing to enhance radiation and isotopic identification This work has **the novelty in the design and physics of the detector, the electronics and the application of machine learning applications to locate, separate and identify the neutron and gamma sources**.