Platinum Self-Powered Neutron Detectors

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Introduction

Self-powered neutron detectors (SPNDs) work off the principle of indirect neutron flux measurements via material activation. The emitter in an SPND, shown in figure 1 below, is activated and hence through a series of possible nuclear reactions charged particles are generated. A current Is hence produced, the magnitude of which is proportional to the neutron flux incident upon the SPND.

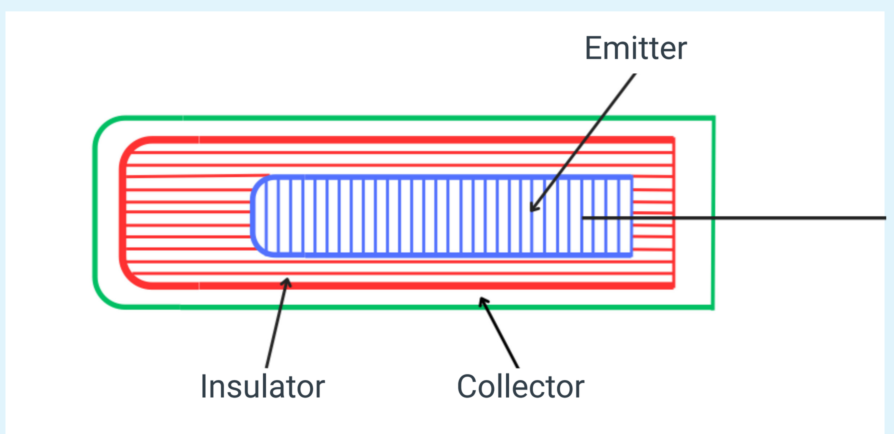


Figure 1: Schematic of SPND [1]

There are two types of SPND categorized from emitter material, and the resulting nuclear reaction which generates a current

- Prompt (^{59}Co, ^{195}Pt)
- Delayed (^{51}V, ^{103}Rh)

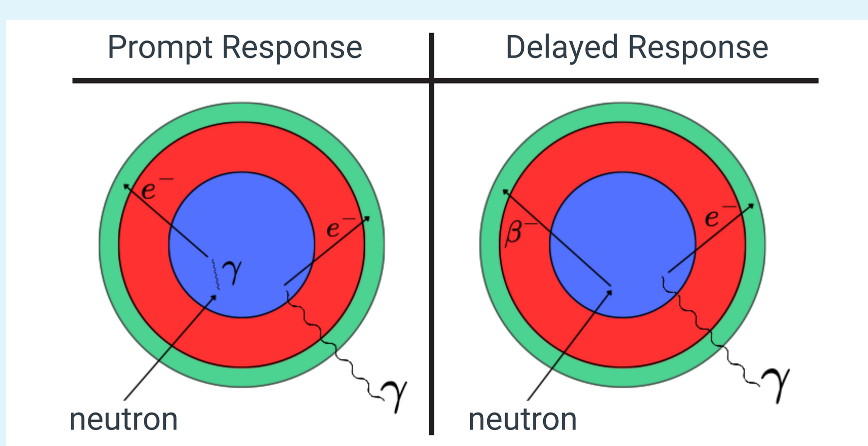


Figure 2: Illustration of different SPND responses.

Prompt SPNDs used in reactor cores for:

- Three-dimensional flux monitoring
- Criticality monitoring
- Control-rod feedback
- Reactor diagnostics

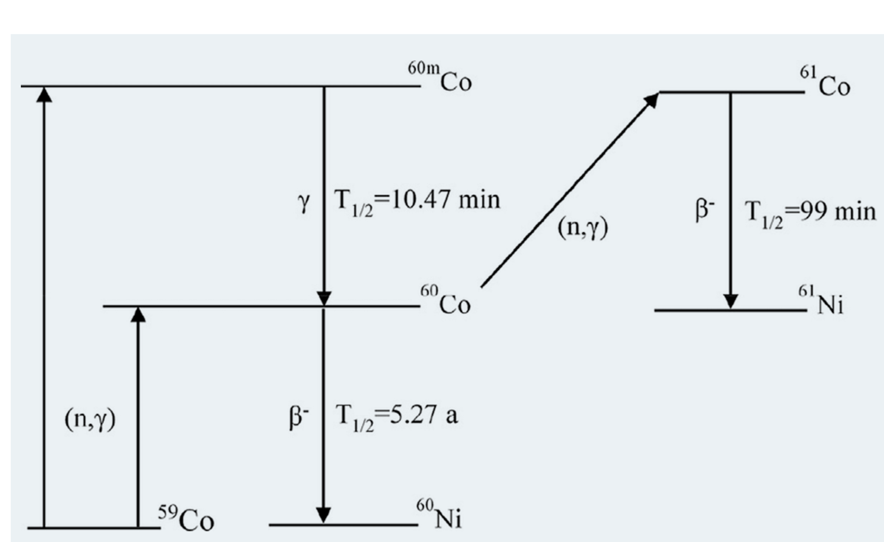
Research Motivation

Many reactors use ^{59}Co SPNDs, which have their own problems:

- Limited lifespan due to buildup of ^{60}Co

High-energy γ produced from ^{60}Co present large issues in handling, processing and disposal

Harsh reactor environment renders other commonly used thermal neutron detectors unfit for use	
^{3}He gas filled detectors Charge integration time too high	^{235}U fission chambers Fissile coating becomes depleted too quickly



Project aim: Investigate the technical feasibility of using a ^{195}Pt emitter SPND in a nuclear reactor due to its beneficial properties; displayed in the table below.

Emitter Material	Detector Response [2]	Activation Cross-Section, (barns) [2]	Resulting Isotope	Half-life [3]	Neutron Capture Q-value (MeV)
^{51}V	99% delayed: (n, β) 1% prompt: (n, γ)(γ, e⁻)	4.9	^{52}V	3.74 minutes	6.69
^{59}Co	Prompt: (n, γ)(γ, e⁻) *Compensation for build up of ^{60}Co required*	37	^{60}Co	5.27 years	6.87
^{103}Rh	Two-fold Delayed: (n, β)	135 (92%) 11 (8%)	^{104}Rh 104mRh	42.30 seconds 4.36 minutes	6.39
^{195}Pt	7% prompt: (n, γ)(γ, e⁻) 93% gamma: (γ, e⁻)	24	^{196}Pt	Stable	7.30

Performance and Testing

MCNP was utilized to track individual particle histories, providing a local solution to the particle transport equation.

^{3}He detectors used to evaluate neutron rate a function of both polythene moderator and borated polythene shield thickness.

Simulations and experimental work were then combined; results displayed in figure 4 below. Simulations and experimental results were then used to characterize neutron lab facility and evaluate significant sources of scattering and shielding within the neutron facility, figure 5 below.

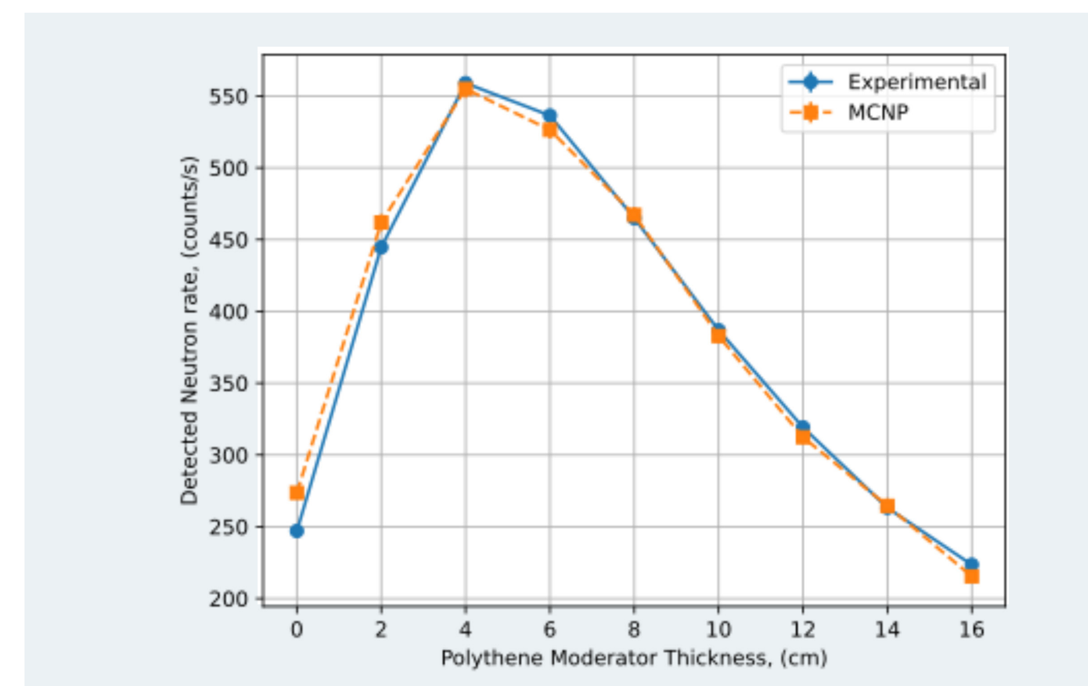


Figure 4: Detected neutron rate as a function of moderator thickness.

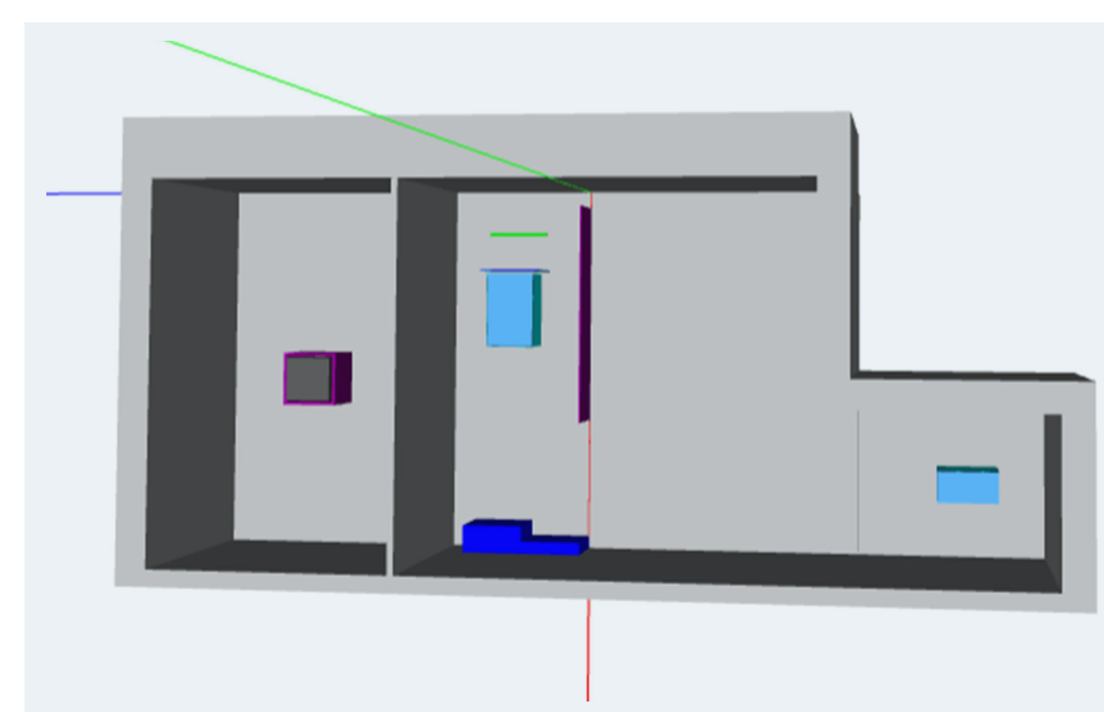


Figure 5: 3D render of neutron facility used in MCNP simulations

Future Work

- Produce isodose map of neutron lab facility.
- Build validated MCNP model of indirect neutron flux measurements using activated samples of given materials such as ^{116}In, ^{197}Au and ^{195}Pt .
- Develop Pulse Shape Analysis (PSA) techniques to differentiate between neutron and photon signals in SPNDs. Hence suppressing background photon signals from prompt and delayed gamma-rays improving reliability for use in reactor cores.

References & Acknowledgements

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