Study on the Methodology of Fast Neutron Detection Based on Plastic Scintillators for Safeguards Research

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1. Introduction

Safeguards is a fundamental approach to verify the diversion of special nuclear materials (SNM), e.g., ^{235}U or plutonium. Traditionally He-3 based thermal neutron detectors has been used for nuclear material accountancy (NMA) because of its high detection efficiency. However the He-3 gas became an uneconomical measure as demand increased, so fast neutron detection was focused as a substitutive technique. This is because fast neutron detection has potential advantages compared to the thermal system. Therefore we have tried to design and optimize an advanced nuclear material accounting system.

2. Comparison to the conventional system

2.1 Properties of the Conventional Thermal System

Over 50-years, He-3 based thermal neutron detection has been considered as standard for NMA. This is because it has high neutron detection efficiency (≈ 50%), very low gamma sensitivity, high reproducibility of results (± 0.15%), and simple operation (≈ 10 mins). However information of prompt neutrons with respect to fission event is not available because of moderation process. This also make measurement system to take longer time for each single event. Also thermalized neutrons are relatively slower than prompt neutron, so longer gate time (≈ 50 μs) for coincidence accounting is required. This point can be a source of measurement uncertainty as a result of counting neutrons uncorrelated with fission events; such as scattered neutrons. Therefore the thermal system could not be appropriate for larger samples.

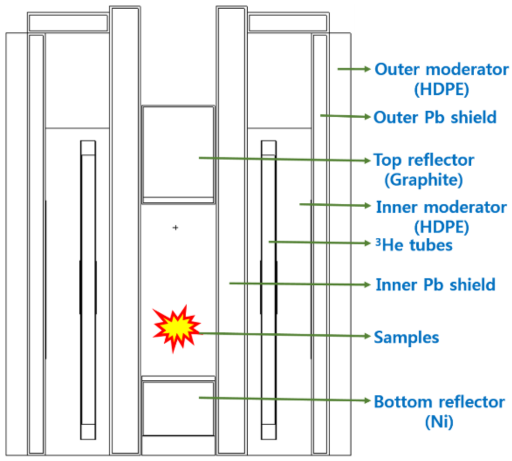

Fig. 1. Well-type He-3 proportional counter modelling.

2.2 Properties of fast neutron detection

The fast neutron detection is possible to deduce fission informative data from prompt neutrons because no moderation process is needed [1]. Also lower random uncertainty could be achieved [2] because of much shorter gate time (≈ 50 ns). Therefore, fast system might show higher precision for large samples even with shorter measurement time. Nevertheless one fatal limitation is very high gamma sensitivity which distorts neutron induced signals to be indistinguishable from gamma induced signals. However this can be mitigated through pulse analysis algorithms called pulse shape discrimination (PSD).

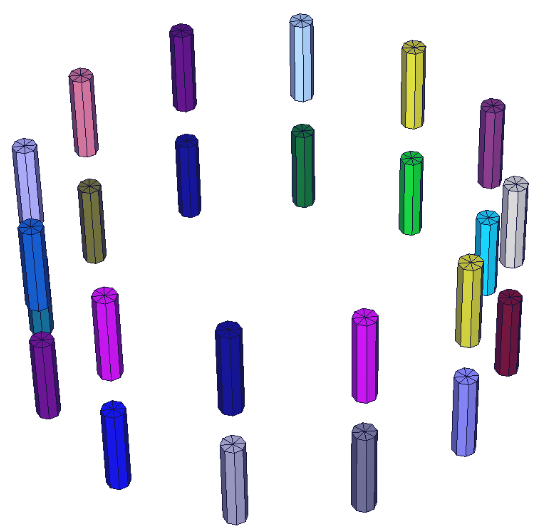

Fig. 2. Well-type plastics detectors modelling using MCNP.

Table 1. Properties of EJ-299-33 Plastic Scintillator

Properties	EJ-299-33 Plastics
Light Output (% Anthracene)	56
Scintillation Efficiency (Photons/1 MeV e-)	8600
Wavelength of Maximum Emission (nm)	425
H : C Ratio	0.927
PSD	Capable

3. Methodology

We are planning to conduct both experimental and computational approaches for this research. For the experiment, EJ-299-33 plastic scintillation detector was selected, and the critical reason is its PSD capability. In addition, plastics have geometrical flexibility with relatively stable chemical, mechanical properties. The optimization process will be achieved via Monte Carlo Neutron Particle code (MCNP 6.2 version). We considered Geant4.10.2 with a specific data card, FREYA (Fission Reaction Event Yield Algorithm) which is a fission event generator to model complete fission events [3].

4. Conclusion

We studied methodology for the future research with plastics based fast neutron measurement for the purpose of safeguards. We have designed our own fast neutron detection system with using Monte Carlo code, and optimization procedure is needed. Considerable further tasks should be analytic comparison to other fast systems, and categorization of diverse PSD techniques with analysis of their performance dependent of other options consisting measurement system. There is indeed no commercial applications of fast neutron detection for safeguards, so there are a lot of future works. Finally this research will be highly contributive for IAEA safeguards impregnability.

ACKNOWLEDGEMENT

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