# Proposed New Different Coincidence Neutron Detection Systems using Monte Carlo Simulation

*Presented by*

**Rasha El-Tayebany**

# Outline

- Introduction
- Detectors and Interrogation sources
- Coincidence Neutron systems simulation
- Results and Discussion
- Conclusion
- References

# Introduction

- Neutron coincidence and multiplicity detectors are widely used in measuring and verifying nuclear material for safeguards purposes. Monte Carlo codes could be used to simulate detectors in order to aid in calibration, design, optimization, and analysis of the detection system. On the other hand, it could be used to predict the behavior of particles and radiation within detectors or proposed new systems.

- Simulation must take into account factors such as neutron source spectrum, direction, fission neutron multiplicity, and the detection of thermalized neutrons by proposed counters. In many cases where for example either representatives reference materials are non-existent or regular measurements not available, Monte Carlo simulation codes may be the best possible solution [1-5].

In this work, new designs for coincidence neutron detection systems were proposed with different neutron detectors **($^{3}He$, Ar and $BF_3$)** and calculations. The simulated systems include special nuclear material (SNM) with changing the neutron sources such as; **AmLi, AmBe and $^{252}Cf$**. The aim of this work is determination of the coincidence system efficiency and neutron distribution fluence for each proposed system in active mode. The results of the proposed systems were studied and compared to the active-well neutron coincidence counter (AWCC) which is employed in uranium testing using the code Monte Carlo N-Particle eXtended **(MCNPX).**

# Detectors and Interrogation sources

# Neutron detectors

- $^3He$ Gas filled Detectors
- $BF_3$ proportional counter
- Ar Gas filled Detectors

# $^{3}$He Gas filled Detectors

1. large neutron cross-section, and
2. relatively insensitive to gamma-rays
3. neither toxic nor corrosive
4. can withstand extreme environments
5. can be operated at a lower voltage than some of the alternative proportional counters [6]

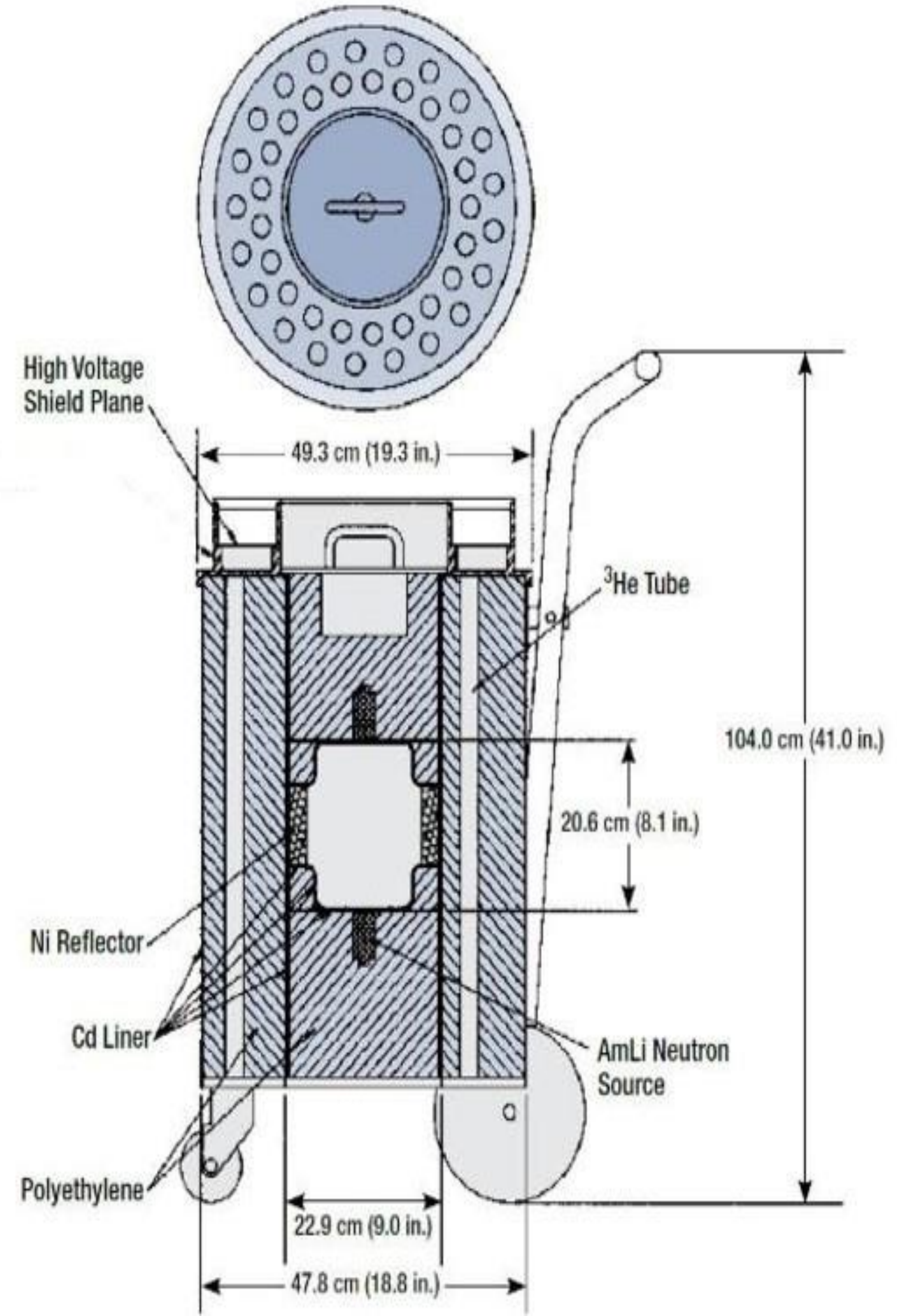
# Disadvantage

The amount of $^{3}He$ worldwide is very limited and there is no longer enough available to fill the demand.

# $BF_3$ proportional counter

1. As $BF_3$ is much more available than $^3He$
2. $n + {}^{10}B \rightarrow 2\alpha$ (2.31 and 2.79 MeV)
3. quickly interacts with gas molecules to produce electron–ion pairs
4. good deposition of energy by the neutrons

# active-well neutron coincidence counter (AWCC)

# AWCC system

a high-density polyethylene ring in which 42 He-3 thermal-neutron detectors are mounted in two concentric circles.

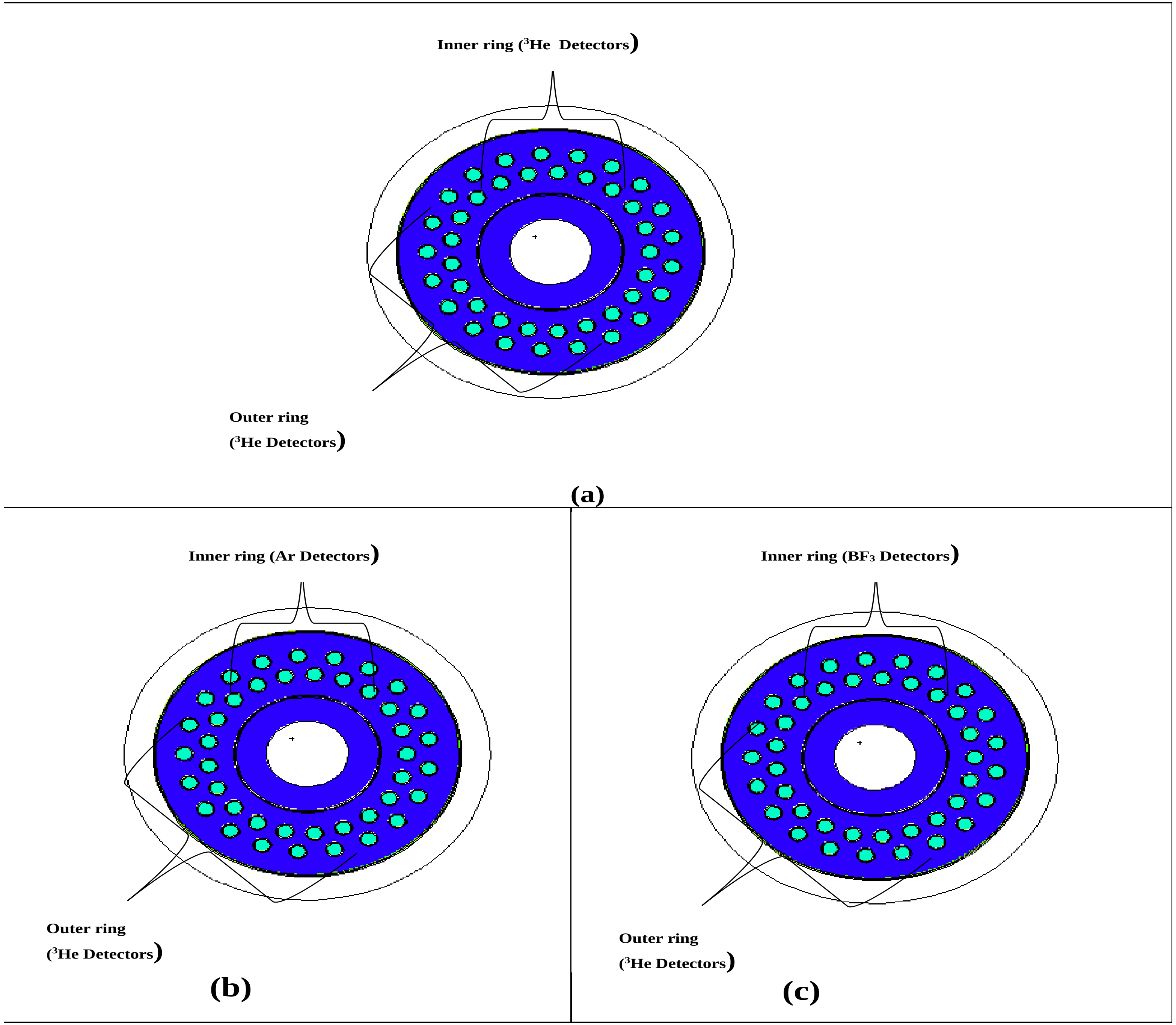
The output pulses are analyzed by the neutron analysis shift register [model JSR-14]

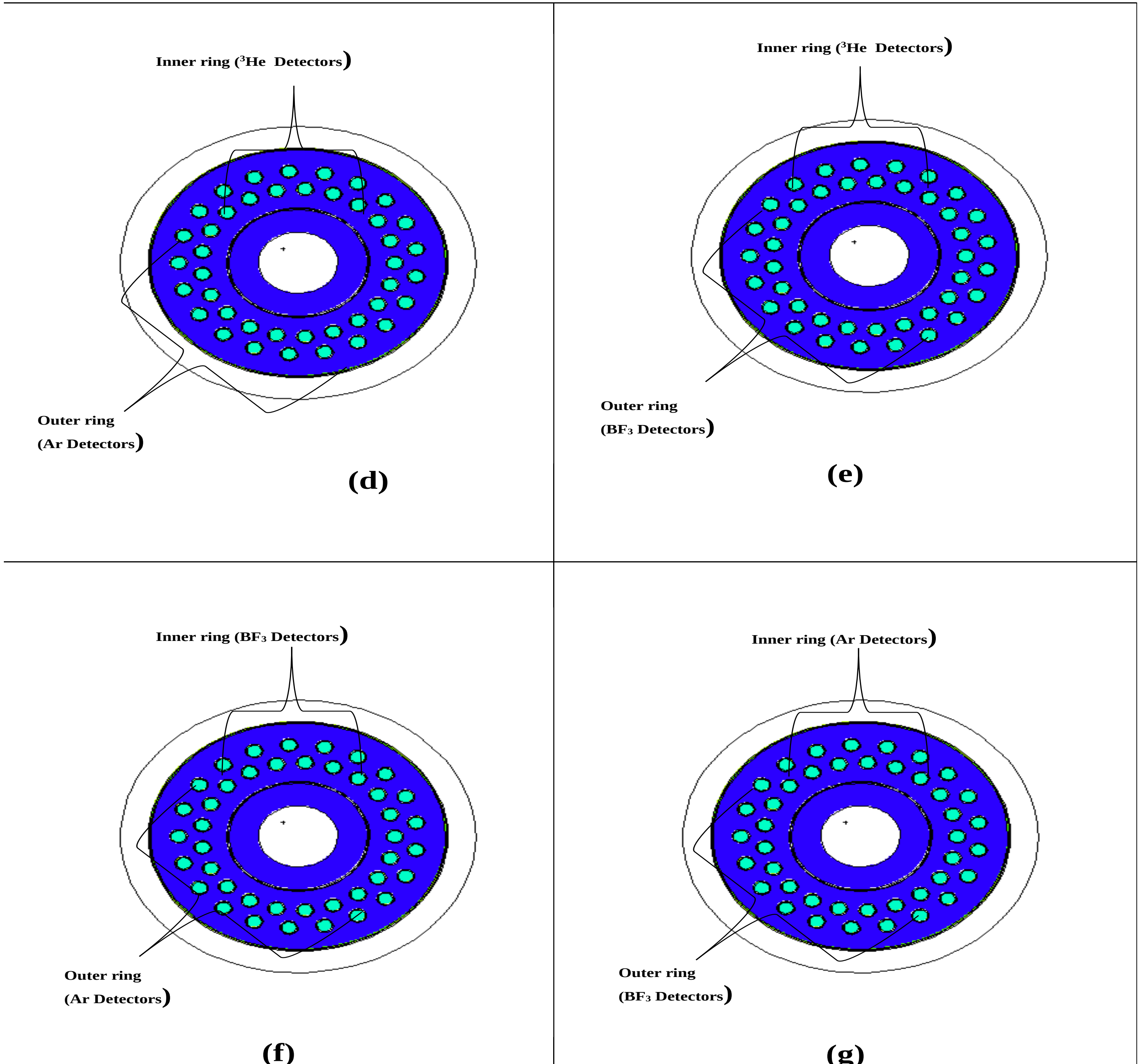
Each source is kept in a stainless-steel container.

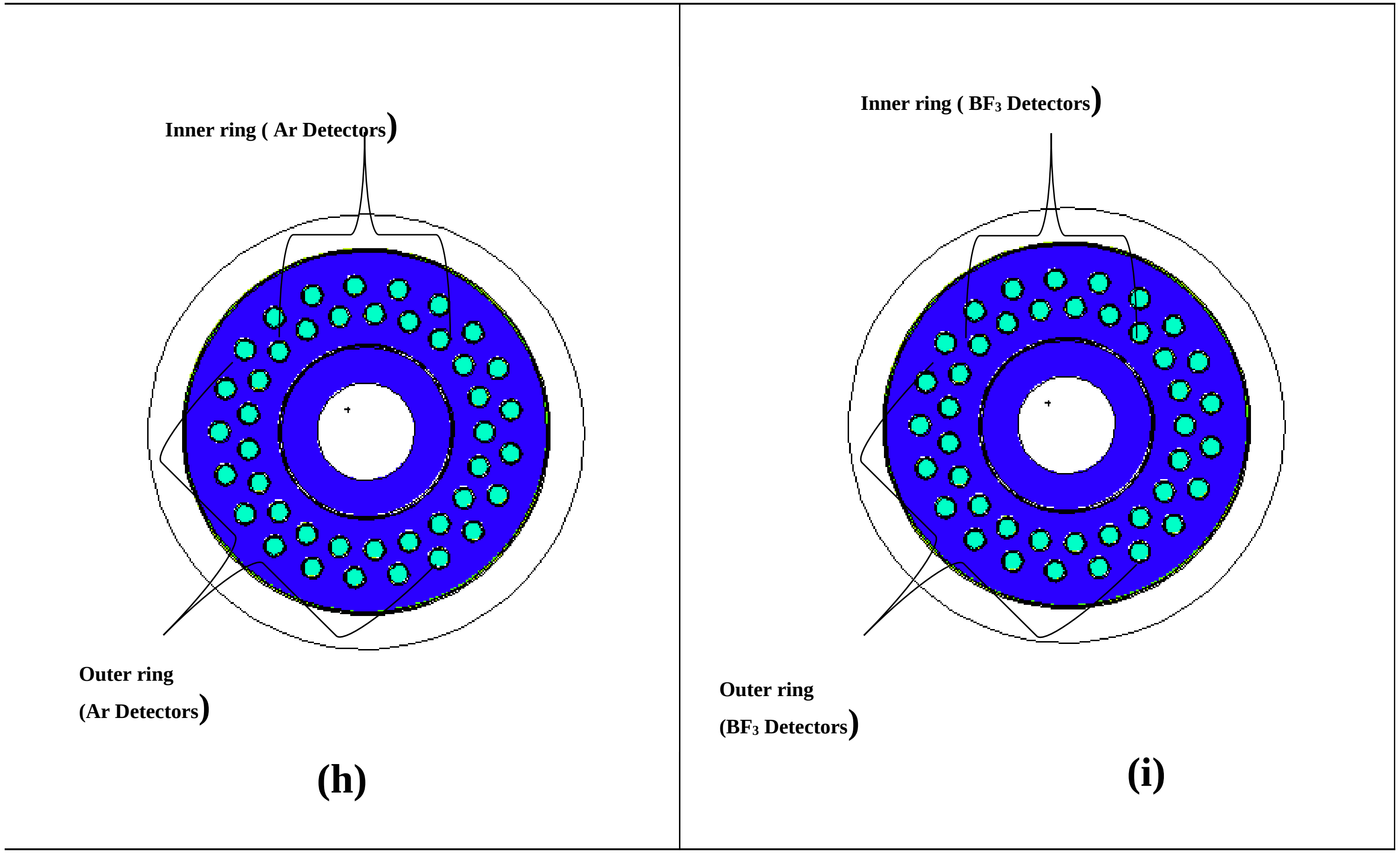
The detectors
6- groups of 7- tubes each.
single preamplifier/ amplifier/discriminator board

The system uses 2- AmLi neutron sources (5 x$10^4$ n/s emission rate each) to activate thermal fission in assayed samples.

A tungsten shield is placed around each source to reduce the g-ray emission [6-8]

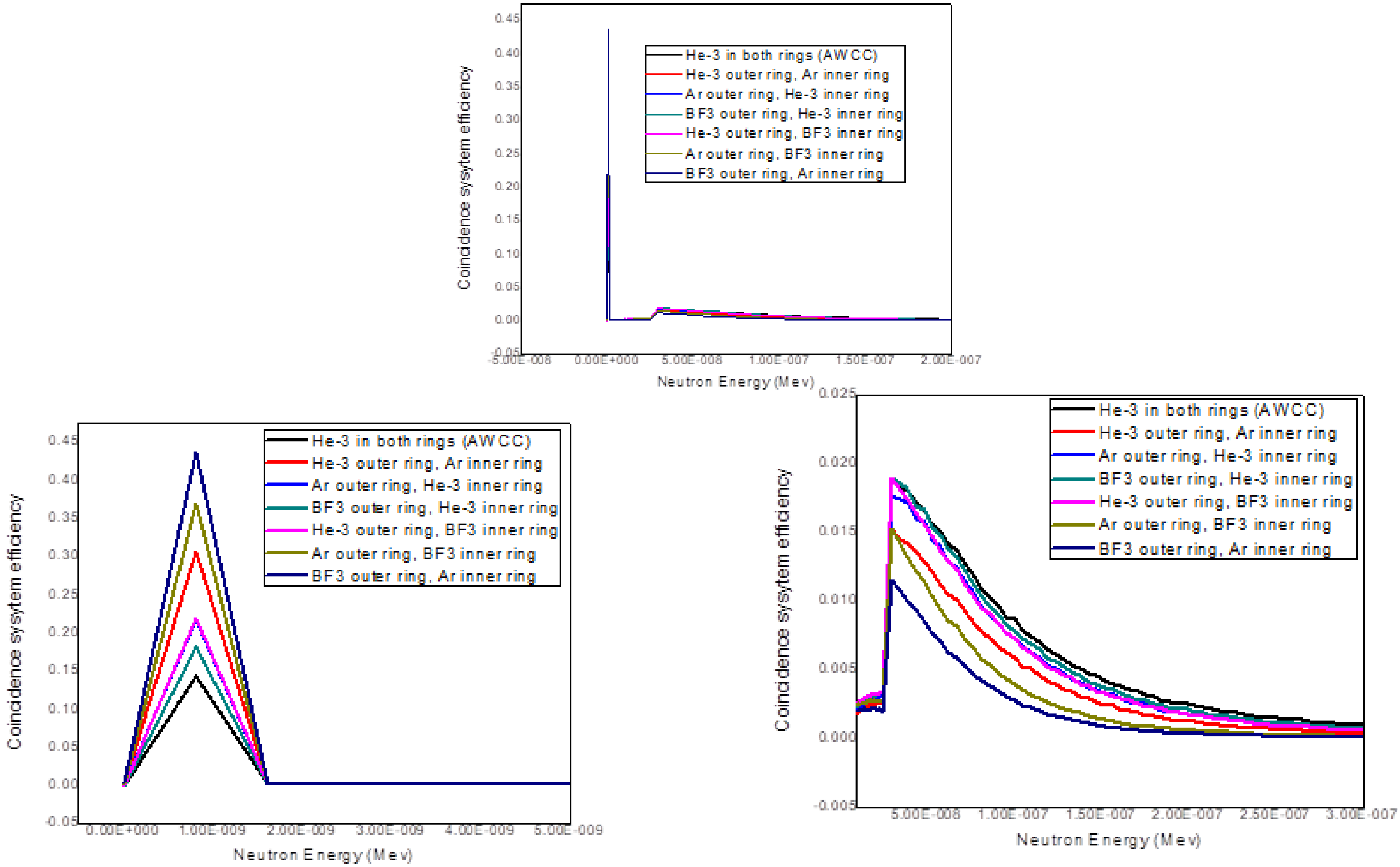

Inner ring (³He Detectors)
Outer ring
(³He Detectors)
(a)
Inner ring (Ar Detectors)
Outer ring
(³He Detectors)
(b)
Inner ring (BF₃ Detectors)
Outer ring
(³He Detectors)
(c)


Inner ring (3He Detectors)
Outer ring
(Ar Detectors)
(d)
Inner ring (3He Detectors)
Outer ring
(BF3 Detectors)
(e)
Inner ring (BF3 Detectors)
Outer ring
(Ar Detectors)
(f)
Inner ring (Ar Detectors)
Outer ring
(BF3 Detectors)
(g)


Inner ring ( Ar Detectors)
Outer ring
(Ar Detectors)
(h)
Inner ring ( $BF_3$ Detectors)
Outer ring
($BF_3$ Detectors)
(i)

# F8 Ungated Coincidence tally

The calculations do not include the “accidental coincidence rate,” which is, in any case, subtracted to produce the measured value. This is **a significant advantage** for the precision of the calculation compared with the precision of an actual measurement.


He-3 in both rings (AWCC)
He-3 outer ring, Ar inner ring
Ar outer ring, He-3 inner ring
BF3 outer ring, He-3 inner ring
He-3 outer ring, BF3 inner ring
Ar outer ring, BF3 inner ring
BF3 outer ring, Ar inner ring
Coincidence system efficiency
Neutron Energy (Mev)
-5.00E-008
0.00E+000
5.00E-008
1.00E-007
1.50E-007
2.00E-007
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
He-3 in both rings (AWCC)
He-3 outer ring, Ar inner ring
Ar outer ring, He-3 inner ring
BF3 outer ring, He-3 inner ring
He-3 outer ring, BF3 inner ring
Ar outer ring, BF3 inner ring
BF3 outer ring, Ar inner ring
Coincidence system efficiency
Neutron Energy (Mev)
0.00E+000
1.00E-009
2.00E-009
3.00E-009
4.00E-009
5.00E-009
He-3 in both rings (AWCC)
He-3 outer ring, Ar inner ring
Ar outer ring, He-3 inner ring
BF3 outer ring, He-3 inner ring
He-3 outer ring, BF3 inner ring
Ar outer ring, BF3 inner ring
BF3 outer ring, Ar inner ring
Coincidence system efficiency
Neutron Energy (Mev)
0.025
0.020
0.015
0.010
0.005
0.000
-0.005
5.00E-008
1.00E-007
1.50E-007
2.00E-007
2.50E-007
3.00E-007

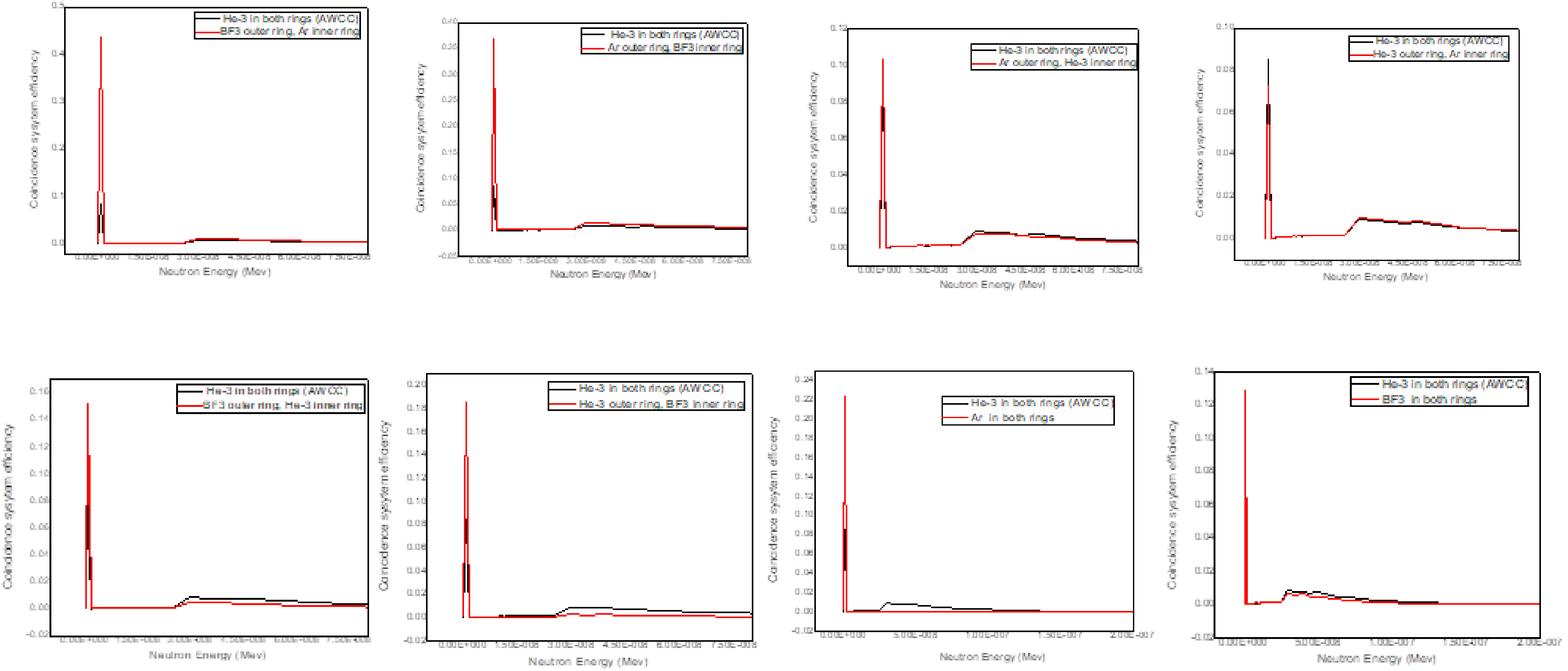



**Fig.(5) Neutron distribution using AmLi source**

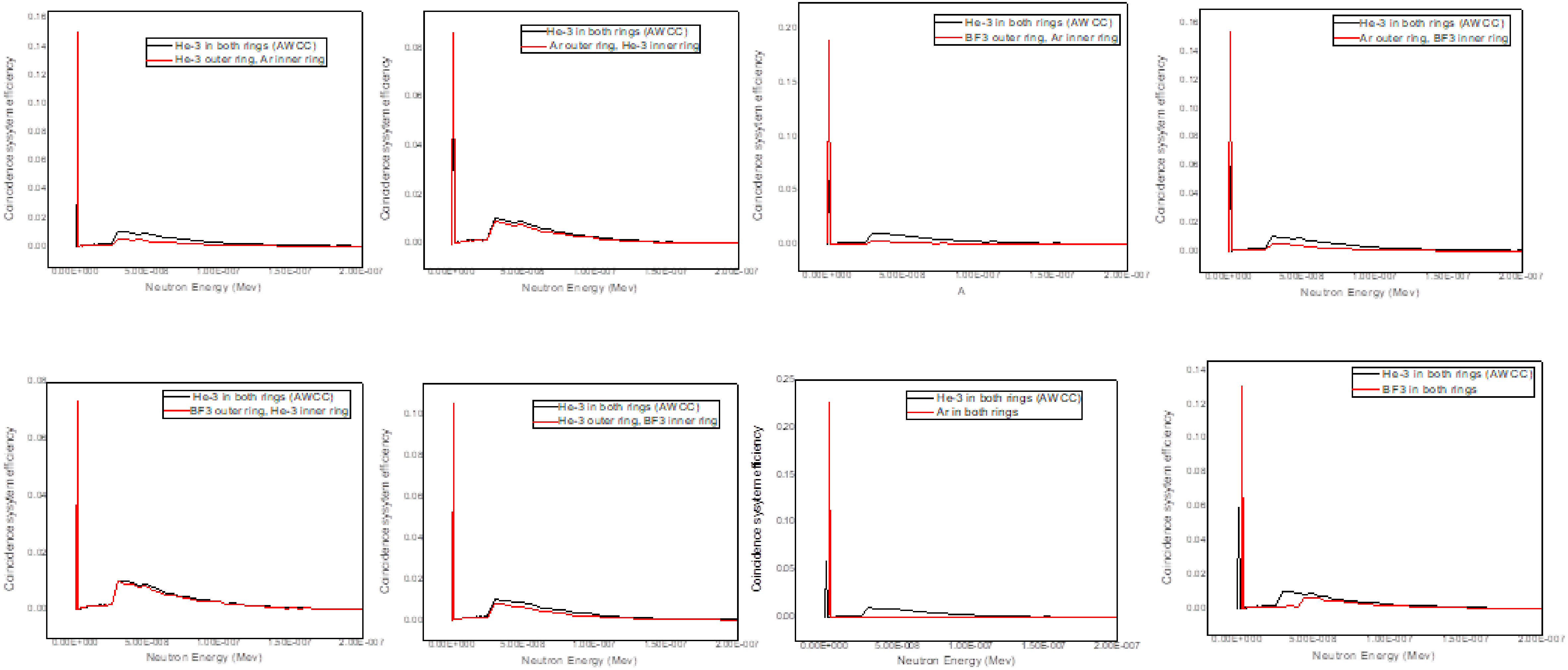



**Fig.(6) Neutron distribution using AmBe source**

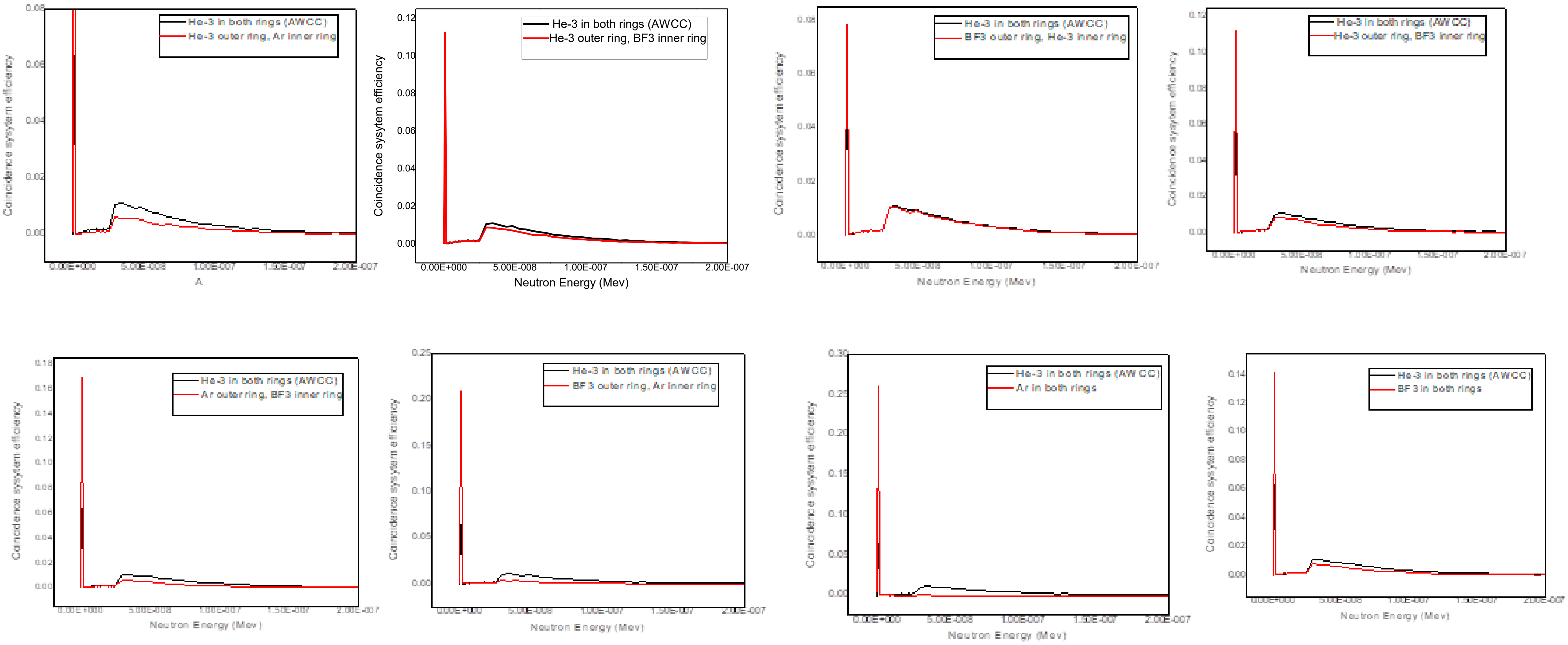



**Fig.(7) Neutron distribution using 252Cf source**

# conclusion

- In order to produce the released particles employed as signs in the assay of particular nuclear material, these models simulate coincidence neutron systems.

- The models were evaluated by comparing their coincidence efficiency systems to the active-well neutron coincidence counter (AWCC) using typical safeguards detectors and the simulation of nuclear data for SNM.

- The three different neutron sources were used (AmLi, AmBe, and $^{252}Cf$).

- The comparison was carried out between the standard model of AWCC and the proposed systems in the energy range which covered the thermal neutron region (0-0.025) eV.

- No single model performed noticeably better than the others and we could recommend using any one of the proposed designs to replace AWCC. However, each difference's impacts have been described and should be taken into consideration while selecting a model.

# References


1. P. Peerani, G. Bosler, I. Cherradi and P. Schwalbach. “Computational Calibration of Neutron Collars for the Verification of HEU Fuel Elements”, Proceeding of the 45th INMM Annual Meeting, Orlando (FL), 18-22 July 2004.
2. H. Tagziria, P. Peerani, W. Koehne and P. Schwalbach, “On-line verification of MOX Fuel Magazines Using Monte Carlo Simulation”, Esarda symposium, London May 2005.
3. P. Peerani, H Tagziria and M. Looman, “Real time simulation of neutron counters, Radiation Measurements 43 (2008) 1506-1510.
4. H. Tagziria, P. Peerani, P. de Baere and P. Schwalbach H. “Monte Carlo Modelling of a Neutron Coincidence Counter for the Verification of $PuO_2$ cans”, Nuc. Ins. & Meth. A580 (2007) 377-379.
5. Marc Looman, Paolo Peerani, Hamid Tagziria, Monte Carlo simulation of neutron counters for safeguards applications, Detectors and Associated Equipment, Volume 598, Issue 2, 11 January 2009, Pages 542-550.
6. CANBERRA, Model JCC-51, Active well neutron coincidence counter, User’s Manual, USA, 1998.
7. CANBERRA, Neutron coincidence counter checklist, 3 He Tube Data Sheets, USA, 1998.
8. CANBERRA, Model JSR-14, Neutron analysis shift register, User’s Manual, USA, 1997.


THANK YOU!