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PRELIMINARY MCNP-POLIMI SIMULATIONS FOR THE EVALUATION OF THE "FLOOR EFFECT": COMPARISON OF APSTNG AND CF SOURCES

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1. INTRODUCTION

The present simulations performed with the Monte Carlo code MCNP-POLIMI [1] have the scope of evaluating the associated-particle sealed tube neutron generator (APSTNG) for use as an interrogation source in the source-driven noise analysis method for the assay of nuclear materials. In the Nuclear Materials Identification System (NMIS) developed at the Oak Ridge National Laboratory, the time-dependent cross-correlation of the timed neutron source and detector responses is one of the signatures acquired. Previous studies and measurements have demonstrated the sensitivity of this and other related signatures to fissile mass [2-3].

In a recent report [4], we outlined the advantages of the APSTNG interrogation source for use with NMIS when compared with the Cf-252 source. In particular, we showed that when the distance between the source and the sample and the sample and the detectors is large, the APSTNG source outperforms the Cf-252 in sensitivity to fissile mass. This is the case when performing measurements of items that are placed inside containers.
The purpose of this report is to investigate the advantages of using the APSTNG source in reducing the effect of floor reflections in the signatures acquired. To this end, a large number of MCNP-POLIMI Monte Carlo simulations were performed to obtain source-detector covariance functions.

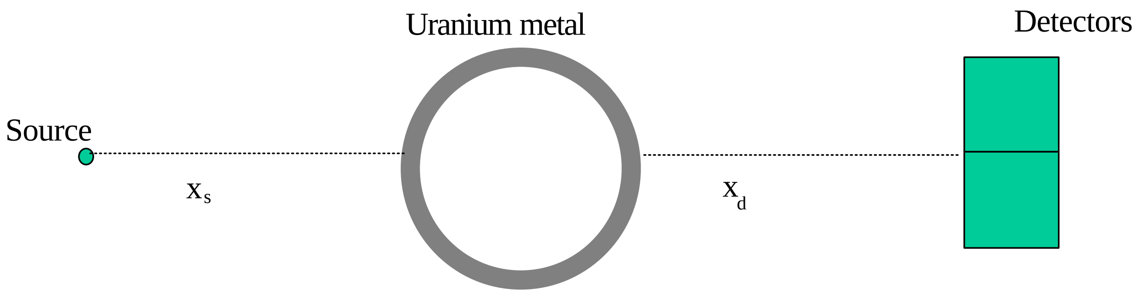
2. MCNP-POLIMI SIMULATIONS GEOMETRY

The results compare the calculated signatures for two sources: (1) a Cf^{252} source in an ionization chamber and (2) an associated particle DT neutron generator of 14.1 MeV neutrons. An associated particle 14.1 MeV neutron generator detects a cone of alpha particles from the DT reaction. Because the 14.1 MeV neutrons are emitted in the opposite direction from the alpha particle, a cone of neutrons is defined and can be aimed at the fissile material. This source has several advantages over Cf^{252}, three of which are: (1) one neutron is emitted per source event so all multiple events come from induced fissions, (2) all neutrons emitted have the same velocity so all transmitted neutrons arrive at the detectors at a known time with all fission neutrons arriving at the detector at later times, and (3) it is directional.

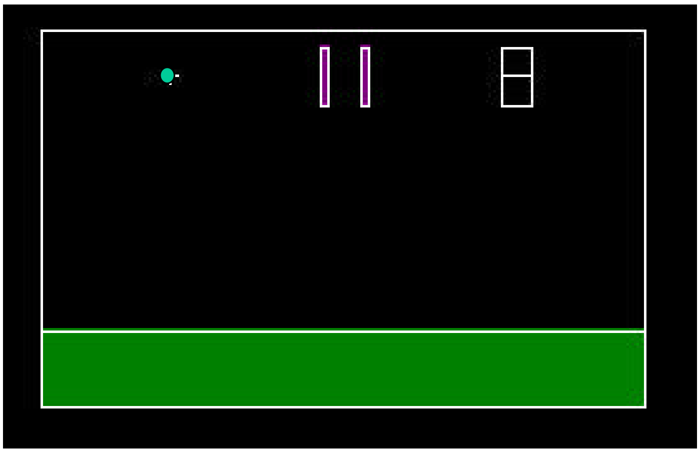
MCNP-POLIMI simulations were performed for the standard uranium metal castings for storage at the Oak Ridge Y-12 plant with the source on one side and four fast plastic scintillation detectors on the opposite side, as shown in Figure 2.1. The casting enrichment is set to 93 wt% U-235 and 0.3 wt% U-235. The detectors, cubes of side 7.62 cm, are placed one on top of the other in a 2x2 array. The distance between the source and the casting, x_s and the distance between the detectors and the castings, x_d in Figure 2.1 are set to 41.7 and 35.5 cm, respectively.
The simulations were repeated for geometries with and without a concrete floor. The floor was placed at a distance of 60 cm from the bottom of the uranium casting and has a thickness of 20 cm. The composition of the concrete is given in Table 3.1. The density of the concrete is set to 2.2994 g/cc.

Table 3.1. Concrete composition (element and wt%).

Element	Wt %
Fe	0.7784
H	0.6187
C	17.52
O	41.02
Na	0.02706
Mg	3.265
Al	1.083
Si	3.448
K	0.1138
Ca	32.13



(a)



(b)

Fig. 2.1. Top (a) and side (b) view of the geometry used in the MCNP-POLIMI simulations. x_s and x_d are the source-to-casting and detector-to-casting distances, respectively. Concrete floor is shown in green (b).

3. SIMULATION RESULTS

The source-detectors covariance functions [$R_{12}(\tau)$] are generated by correlating the source signal with the combined signal from the four detectors, and normalizing to the number of neutrons emitted by the source. The resulting signature represents the number of counts in the detectors correlated with a source event, per source neutron. $R_{12}(\tau)$ is simulated for a measurement with concrete floor and without concrete floor.

Figure 3.1 shows the results of the interrogation of uranium metal castings by the APSTNG source with and without the concrete floor. The signature is characterized by two sharp peaks, and a third, broader distribution. The first peak occurs at a time lag of approximately 12 ns, and is due to the photons that are generated by neutron interactions inside the uranium casting, by induced fission and inelastic scattering. The second peak occurs at a later time, approximately 18 ns. This peak is possibly given by the gamma rays that are generated by neutron inelastic scattering inside the scintillators. The neutron part of the signature has a broad distribution extending from 20 to 60 ns.

The simulations were repeated for a deplete casting (0.2 wt % U-235) and enriched casting (97 wt% U-235). The results show that the presence of the concrete floor has a negligible effect on the acquired signature. The results also show that the use of the APSTNG source enables us to distinguish between the deplete and enriched sample. The differences in the neutron peak are evident after time lag 20 ns.

Figure 3.2 shows the results for the same configuration, and using a Cf-252 source in place of the APSTNG source. Similarly to the previous case, the simulations were repeated for the deplete and enriched casting, with and without concrete floor. The results for the simulations that include the concrete floor show that after time lag 70 ns, a constant background is clearly visible. This is probably given by the neutrons and photons from the source and the sample that interact with the floor and are scattered towards the detectors. Another possible effect is given by inelastic scattering of neutrons inside the concrete floor, which generates gamma rays that in turn are detected by the detectors.

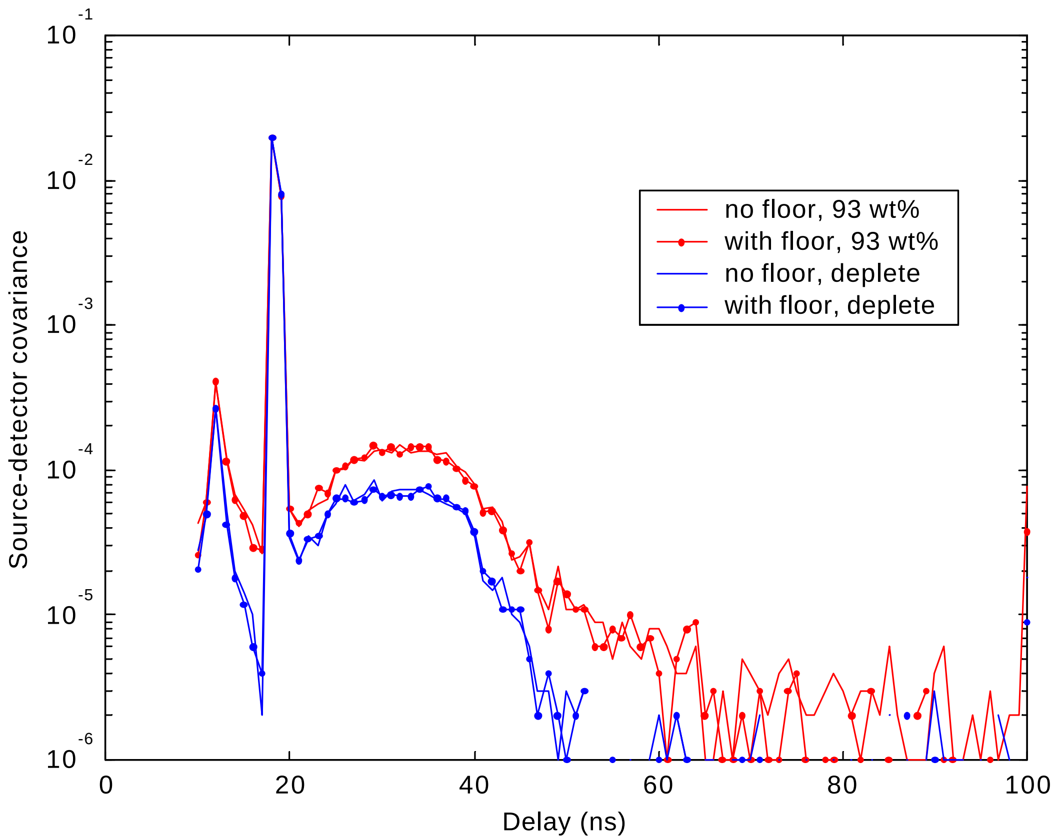


Fig. 3.1. MCNP-POLIMI simulations results for APSTNG source emitting neutrons in the cone towards the sample. The red curves are relative to an enriched (93 wt%) casting, whereas the blue curves refer to a deplete (0.2 wt%) casting. The solid line shows the result with no floor whereas the solid line with dots shows the result with concrete floor. x_s = 41.7 and x_d = 35.5 cm are the source-to-casting and detector-to-casting distances, respectively. Nps=1e6 source particles.

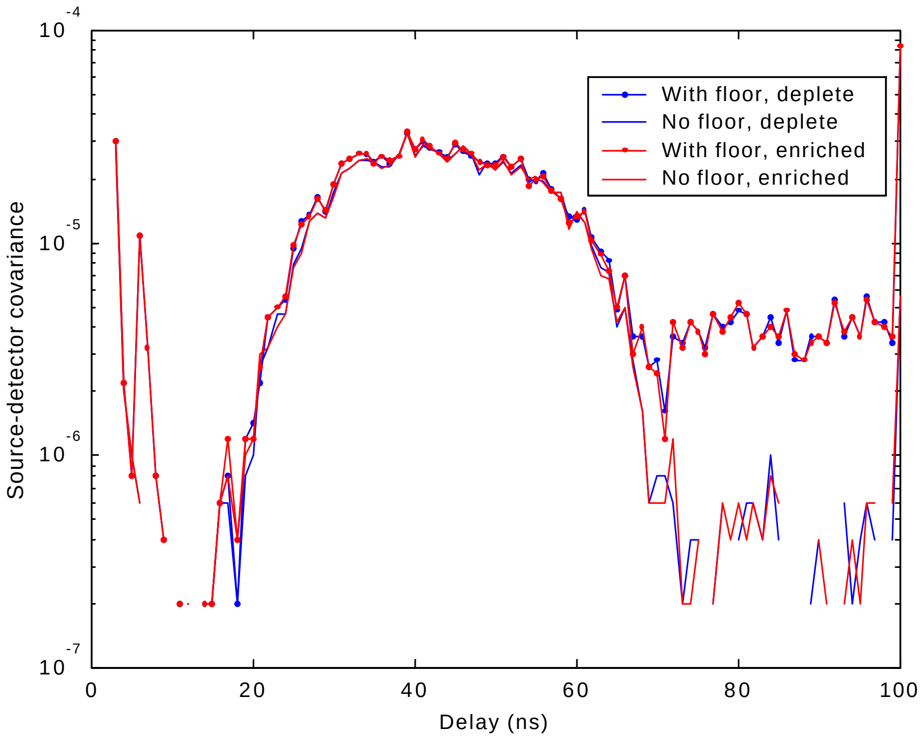


Fig. 3.2. MCNP-POLIMI simulations results for ^{252}Cf source emitting neutrons and photons isotropically. The red curves are relative to an enriched (93 wt%) casting, whereas the blue curves refer to a deplete (0.2 wt%) casting. The solid line shows the result with no floor whereas the solid line with dots shows the result with concrete floor. x_s = 41.7 and x_d = 35.5 cm are the source-to-casting and detector-to-casting distances, respectively. Nps=10e6 source particles.

CONCLUSIONS

The preliminary results discussed in this report show the advantages of using an APSTNG neutron source as the interrogation source in the active assay of a fissile sample when floor reflection is present. The possibility of aiming the source neutrons inside the solid angle towards the fissile sample greatly reduces the effect of the floor. This possibility is particularly relevant when measurements are made on containers that are placed in storage arrays. In this case, the presence of neighboring containers with fissile samples may alter the acquired signature if a non-directional source is used as a trigger.

REFERENCES

1. S.A. Pozzi, E. Padovani, and M. Marseguerra, "MCNP-POLIMI: A Monte Carlo Code for Correlation Measurements", submitted for publication on *Nuclear Instruments and Methods A.*

2. Mihalczo, J.A. Mullens, J.K. Mattingly and T.E. Valentine, Physical Description of Nuclear Materials Identification System (NMIS) Signatures, Y/LB-15,946R4 Oak Ridge Y-12 Plant.

3. Mattingly, T.E. Valentine, J.T. Mihalczo, L.G. Chiang, and R.B. Perez, Enrichment and Uranium Mass from NMIS for HEU Metal, Institute for Nuclear Materials Management, 41st Annual Meeting, July 16-20, 2000, New Orleans, Louisiana.

4. S.A. Pozzi and J.T. Mihalczo, "Preliminary Comparison of Cf-252 and the Associated Particle Sealed Tube Neutron Generator as Interrogation Sources for Uranium Metal Castings", Oak Ridge Y-12 Plant, Y/LB-16,060 (2000).

5 S.A. Pozzi and F.J. Segovia, "^{252}Cf-Source-Correlated Transmission Measurements and Genetic Programming for Nuclear Safeguards", submitted for publication on *Nuclear Instruments and Methods A.*