Detection of Highly Enriched Uranium using Tagged Neutron (14MeV) based Active Interrogation

Saroj Bishnoi[1]*, R. G. Thomas[2], P. S. Sarkar[1], A. Saxena[2], Amar Sinha[1]
[1]*Neutron and X-Ray Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA*
[2]*Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA*

* *email: saroj@barc.gov.in*

Introduction

Illegal trafficking of special nuclear materials (SNM) in portal containers is a major security concern now days as they can be used for various nefarious activities including terrorism. To prevent this, screening of containers are in general a used practice. Among the available techniques, passive non-destructive detection of naturally emitted gamma and/or neutrons from fissionable materials can be of first choice due to its simpler approach of deployment. But as spontaneous signatures are very low in intensity they are combined with various active neutron interrogation techniques for obtaining low false positive rate in cases. This paper deals with the study of detection of SNM by neutron interrogation by Monte Carlo simulation. The active inspection system is based on the Associated Particle Technique (APT) [1] in which the interrogated neutrons are tagged with the corresponding alpha particles in DT neutron generator and detected gamma rays are correlated in a time of flight mechanism to ascertain the position of the fissionable material. Fission induced by neutrons in SNM produces high gamma ray multiplicity, whereas nonnuclear materials mainly produce single (gamma) events. To study the performances of an active interrogation system using tagged neutron, simulations were performed with GEANT4 version 10.1 code [2] with the inclusion of Fission Reaction Event Yield Algorithm (FREYA) [3,4] integrated into the LLNL Fission Library. It records hits for each neutron history with the relevant parameter information. The output data files are post-processed with a specific tool developed with ROOT data analysis software. Various matrix compositions, suspicious items, SNM shielding and positions inside the container, are under study to assess the performance and limitations of tagged neutron technique based system.

In the following, we show that detection and 3-D reconstruction of Lead shielded Highly Enriched Uranium (HEU) in a container is possible through active interrogation using tagged neutrons by using the additional information of gamma ray energy and multiplicity. High multiplicity is a signature for the presence of special nuclear materials. We describe the development of methodology of modeling associated particle technique and reconstruction of object position.

Simulation methodology

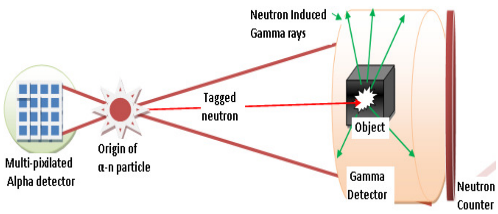

Fig. 1: Schematics of Simulated geometry for SNM detection

Monte Carlo based GEANT 4 10.1 code has been chosen for simulation. The recently implemented FREYA algorithm enables the emission of completely correlated fission secondary's from individual realizations of fission processes on an event-by-event basis for the following isotopes neutron-induced fission :^{233}U, ^{235}U,and ^{239}Pu, up to E_n= 20 MeV and spontaneous fission: ^{252}Cf, ^{238}U, ^{240}Pu, ^{244}Cm. The modeling process of associated particle technique involved various stages. Firstly, DT neutrons and associated α-particles are generated from a point source in opposite direction using random number generator. The emission angle of particle was restricted within less then equal to 10 degree in z-direction to reduce computation time such that there is sufficient particle intensity at experimental chamber for interaction with the sample. The schematic of the simulation is shown in Fig. 1. A multi-pixel alpha detector (size 5x5 cm^2) is placed at 13 cm and on the opposite side in the path of neutron beam a neutron detector of 30 cm diameter placed at 130 cm from the target (DT neutron generator). Also a large size gamma detector (length - 50 cm and diameter - 30 cm) was placed at distance of 100 cm from the target. All three detectors were made sensitive for hit collections. From hits, the information regarding alpha particle positions (x,y,z), alpha distribution detected in coincidence with gamma, gamma energy spectra, time of flight (α-gamma), gamma multiplicity and transmitted neutrons distribution were recorded. Using these parameters, position of neutron interaction was constructed and 2-D and 3-D image of investigated object was obtained. At the same time the transmitted neutron object image were also generated for comparison.

SNM detection and analysis

As a feasibility test, a highly enriched uranium (HEU-20%) sample (5kg) encapsulated inside 2cm thick wall lead box was positioned in the path of tagged neutron beam at distance of 100cm from the neutron emitting point. 10^6 particle histories were run for this simulation and processed. The results are shown below. Fig. 2 shows the reconstructed image without any selection on gamma energy and/or multiplicity distributions. In Fig. 3, the reconstructed images are shown after selecting the gamma ray energies < 0.5 MeV and a multiplicity gate 4-11. It can be seen that the gate in gamma ray energy and multiplicity clearly allows the identification of the SNM (HEU) hidden inside the Lead box which otherwise was not detectable either in 2-D or 3-D.

Result and discussion

Simulation study regarding detection of HEU in a Lead shielded condition was carried out successfully and its 3-Dimensional image was also reconstructed with tagged neutron technique. It is found that the application of selection of gamma energy and multiplicity uniquely identifies and reconstructs Lead shielded SNM 3-Dimensionally with the API technique. In future various other configurations and sensitivity scenarios will be carried out with suitable experimental verification.

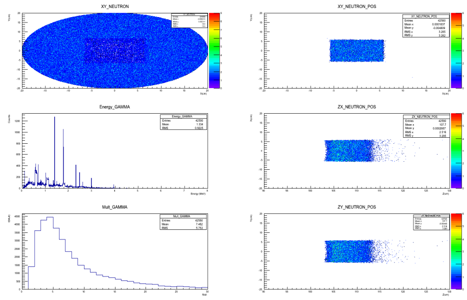

Fig2: Reconstructed image without any gamma energy or multiplicity selection.

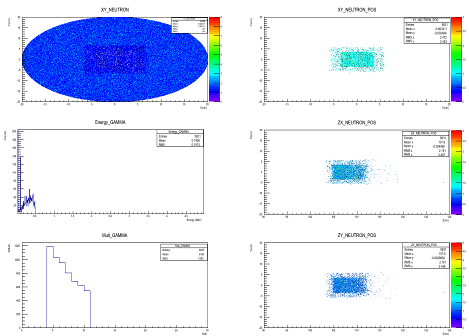

Fig3: Reconstructed object image with energy and multiplicity selection

Different plots in the fig2-3 are correspond to: XY_ NEUTRON= transmitted neutron mage (2D) of object, XY_NEUTRON_POS = constructed 2D image of xy object position, ZX_NEUTRON_ POS=constructed 2D image of zx object position, ZY_NEUTRON_POS = constructed 2D image of zy object position, Energy_ GAMMA = gamma energy spectra from object after neutron interaction, Muil_GAMMA = multiplicity of gamma observed from sample after neutron interaction

References

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