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Monte Carlo study of detection systems of explosives and illicit substances using a D-D neutron generator

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Abstract

Prompt gamma neutron activation analysis (PGNAA) using a Deuterium-Deuterium (D–D) neutron generator, is one of the most promising method to detect explosives and illicit substances. Using Monte Carlo methods with MCNP6 code, a model of a DD Generator (DD-110 Adelphi Technology [1]) has been built with one or two NaI(Tl) detectors of 1.5" x 1" size in order to determine an optimal configuration. Several calculations have been performed to analyse the detection power for samples of different explosives: RDX, Ammonium Nitrate, land mines, military and homemade explosives, have been selected. Different models have been made varying moderator and shielding thicknesses (polyethylene and lead) and we conclude that the configuration with 10 cm thickness of polyethylene, is the best configuration to obtain a neutron thermal flux appropriate for detection of these simulated samples of explosives.

Introduction

D-D Neutron generator: Fusion of light nuclei is the most common approach used with particle accelerators to generate neutrons; the most common of these reactions used for producing neutron are listed in the **Table 1**. While other reactions also exist and have been used with accelerators these are the ones that have been found to be the most useful, the easiest to employ, and the most efficient for the purpose [2]. Polyethylene ($(CH_2)_n$), is an effective neutron shielding material for neutrons and displays excellent attenuation behavior because of its hydrogen content (14% by weight) and its density. In polyethylene, the hydrogen capture of thermal neutrons is through the $^1H(n, \gamma)^2H$ reaction which has a cross section of 0.33 barn for neutrons in thermal equilibrium at room temperature (En = 0.027 eV) [3].

Materials and Methods

Is in development a system of detection based through the use of the reaction Deuterium-Deuterium (D-D), the when generate neutrons in the reaction, through these system has been simulation with the use of the code Monte Carlo, the process is the detection of explosives, identificating the elementals compounds of the sample in the reaction of the thermic neutrons, as the issue gamma fast of 10.82 MeV in the nitrogen [4]. The main problem, is the differentiation of the materials elements considered parasites, in the identification of the amount of hidden explosives [5].

Reaction	Q Value [MeV]	Minimum Product Energies [MeV]
$H^2 + H^2 = He^3 + n$	+3.269	$He^3 = 0.82$ $n = 2.45$
$H^2 + H^3 = He^4 + n$	+17.589	$He^4 = 3.54$ $n = 14.05$
$H^1 + Li^7 = Be^7 + n$	-1.644	$Be^7 = 0.21$ $n = 0.03$
$H^2 + Li^7 = Be^8 + n$	+15.031	$Be^8 = 1.68$ $n = 13.35$
$H^1 + Be^9 = B^9 + n$	-1.850	$B^9 = 0.18$ $n = 0.023$
$H^2 + Be^9 = Be^{10} + n$	+4.361	$B^{10} = 0.40$ $n = 3.96$

Table 1.- Common nuclear reactions used to produce neutrons in particle accelerators

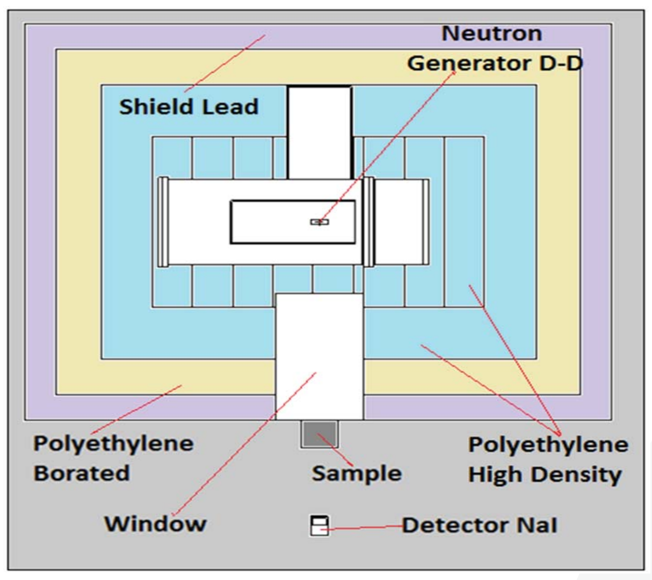

Figure 1.- MCNP geometry of the explosives detection system based on a D-D neutron generator and 1.5" x 1 NaI detector

Results

energy (MeV)	Neutron flux (n cm-2 s-1)
2,50E-02	1,33E+05
1,00E+00	3,97E+05
2,50E+00	1,33E+05
TOTAL	6,62E+05

Table2.- Calculated neutron flux at the sample position for a 1,0E+11 n/s neutron generator output.

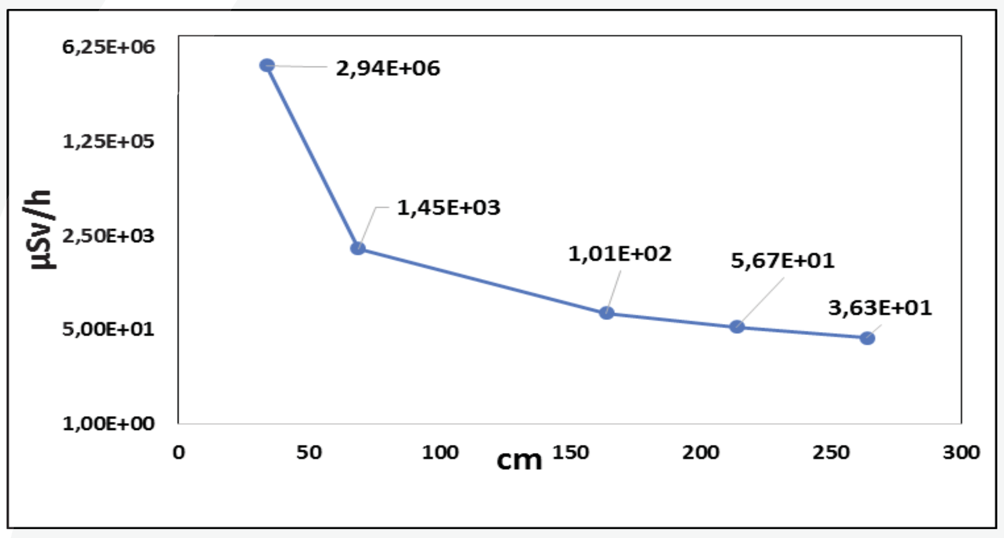

Figure 5.- Neutron dose equivalent rate (µSv/h) due to the explosive detection system at points 0.5 1.0 1.5 and 2.0 m, corresponding to figure 2.

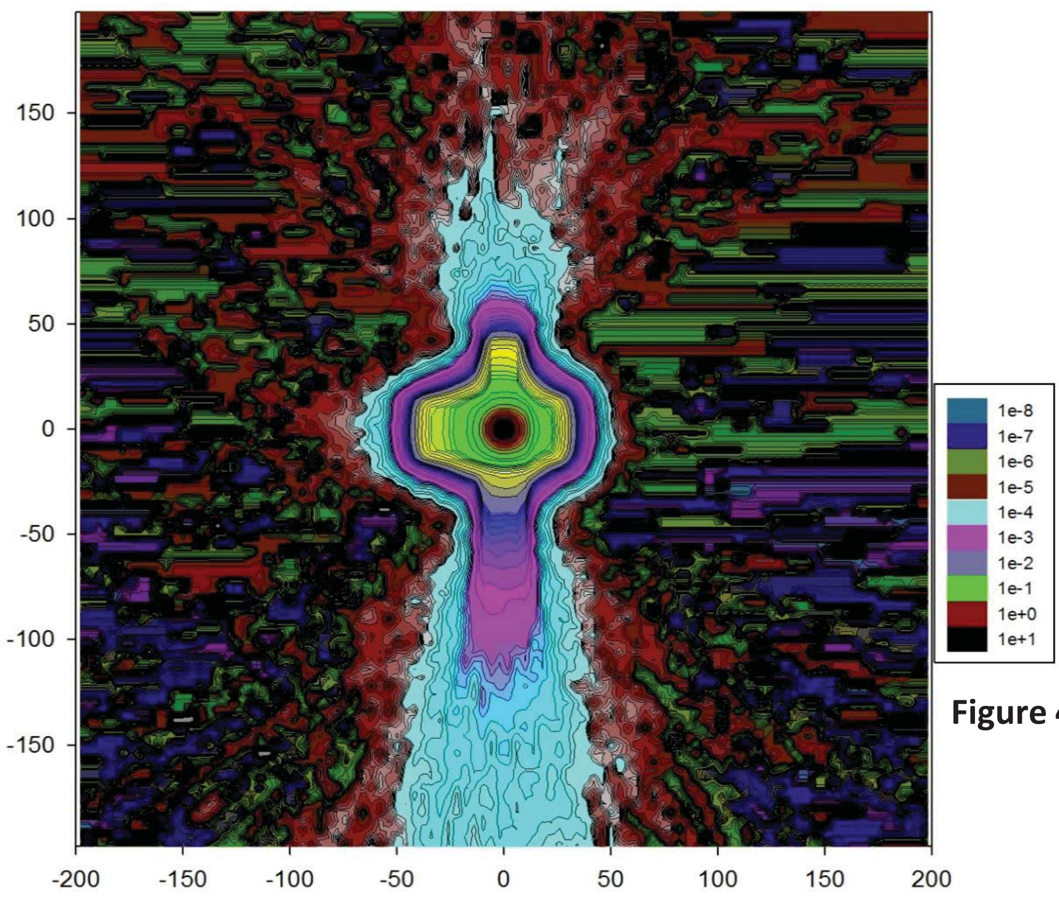

Figure 2.- Scheme neutron dose equivalent rate (µSv/h) due to the explosive detection system at points 0.5 1.0 1.5 and 2.0 m, corresponding to figure 1 configuration.

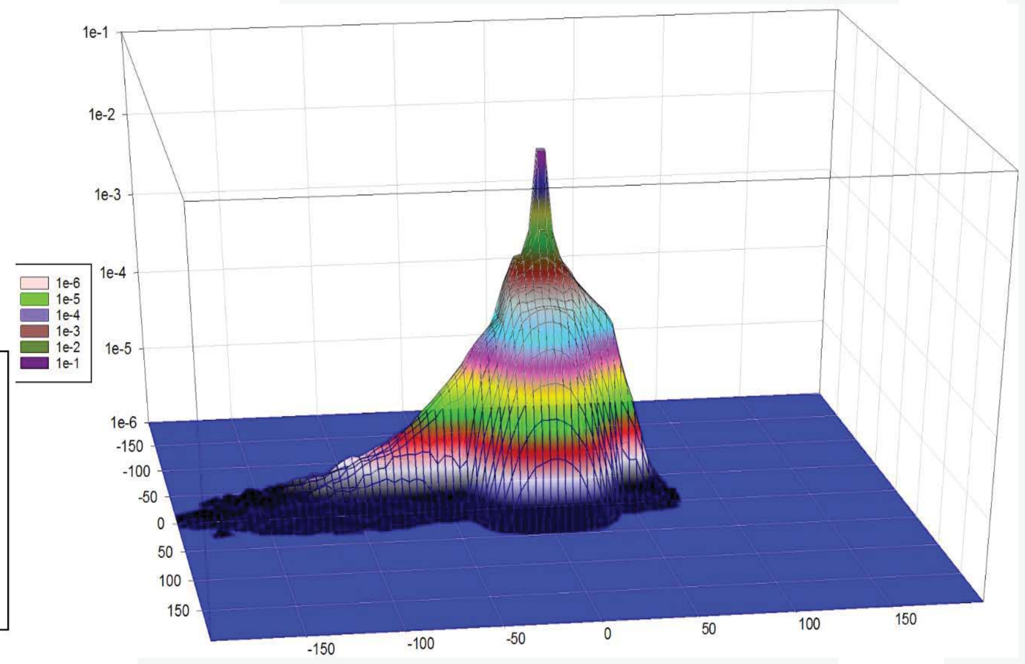

Figure 4.- Neutron flux as a function of distance from neutron generator (cm)

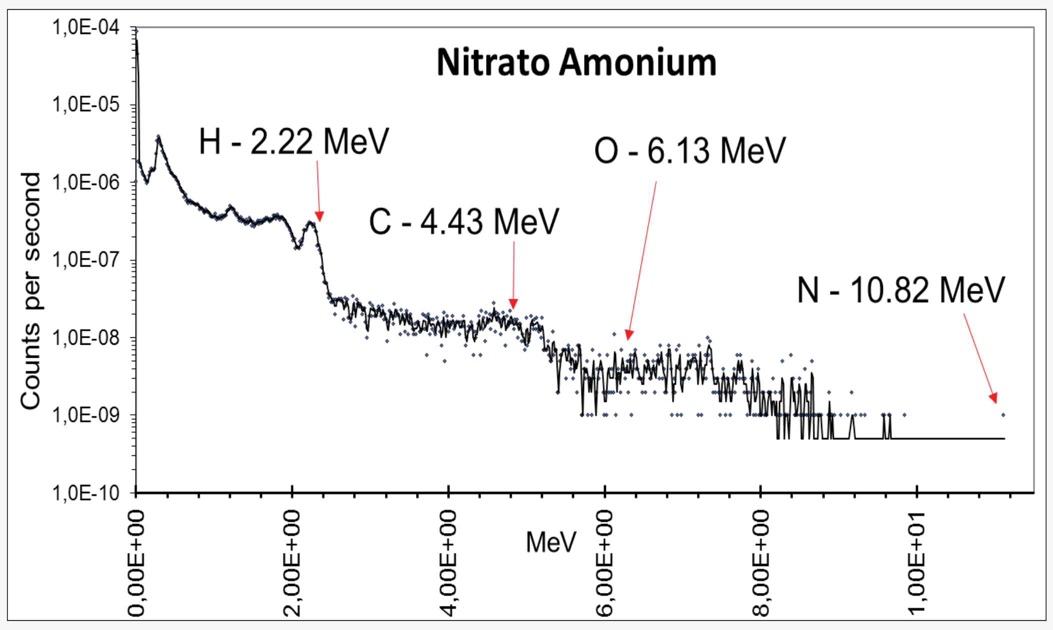

Figure 6.- Gamma ray spectrum from an activated Nitrate Ammonium sample through MCNP6.

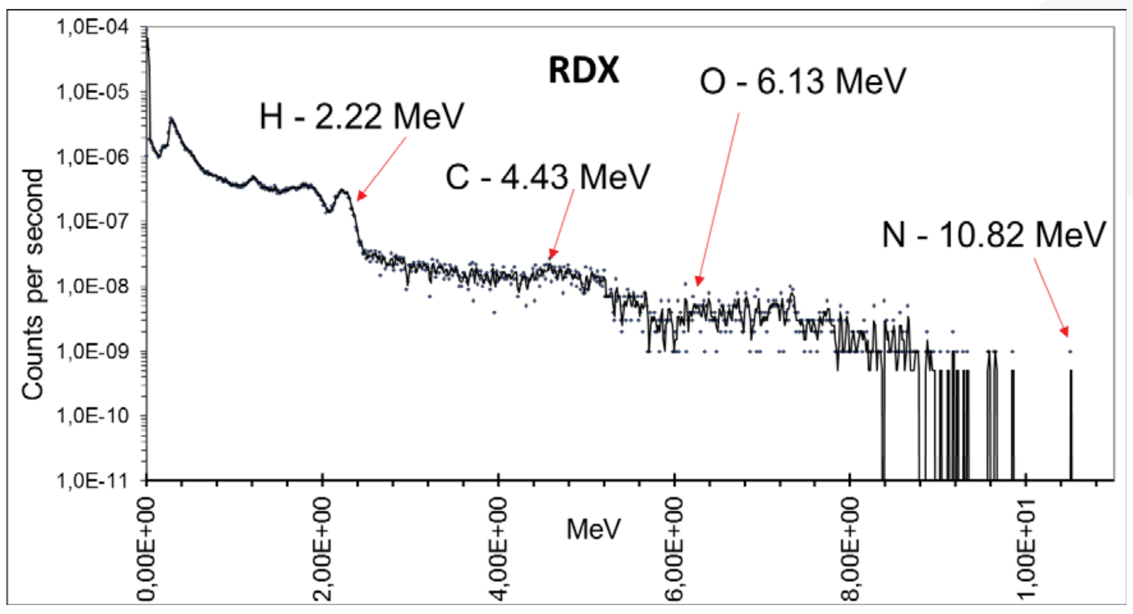

Figure 3.- Gamma ray spectrum from an activated RDX sample through MCNP6.

The determination of the H, C, N and O in samples through of use of a source of neutrons, provide an invaluable tool in the identification of substances in samples and baggage. A neutron beam interacts with the sample and the amount of H, C, N and O. [6] can be determined through the emission of gamma rays and their energy spectra.

Conclusions

An explosive detection system based on a D-D neutron generator has been conceptually designed incorporating reliable and effective radiation shielding of the gamma-ray detector using MCNP6. The detection of explosives using thermal neutrons is primarily based on the identification of nitrogen through its 10.82 MeV capture ɣ-ray. The 2.5 MeV neutrons produced from the D-D neutron generator with an output of 1.0E+11 n/s could be used to detect explosives with an NaI detector.

References

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