ISSN: 2320-5407 Int. J. Adv. Res. 5(3), 1671-1676

Journal Homepage: - www.journalijar.com
INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)
ISSN NO. 2320-5407

Article DOI: 10.21474/IJAR01/3677
DOI URL: http://dx.doi.org/10.21474/IJAR01/3677

RESEARCH ARTICLE

MONTE CARLO MODELING OF A ^{252}CF-BASED DETECTION SYSTEM FOR LANDMINES

Nassreldeen Elsheikh.
Al-Baha University, College of Science &Arts in Al -Mikhwah, Department of Physics, Al-Baha, Saudi Arabia

Manuscript Info

Manuscript History

Received: 12 January 2017
Final Accepted: 04 February 2017
Published: March 2017

Key words:-
Landmines detection, neutron backscattering, Monte Carlo modeling

Abstract

Simulations using Monte Carlo N-particle transport code MCNP5 were carried out to model a ^{252}Cf-based system for detection of buried landmines. The study explores the performance of the neutron backscattering methods in providing elemental characterization for the buried landmine. The net elastically back-scatted (EBS) neutron energy spectra at both fast and thermal neutron ranges were calculated. The net (EBS) neutrons from the major constituent elements of a landmine simulant (TNT) have shown definite structures that can be used for identification of buried landmines.

Introduction:-

The most common explosives used in landmines are TNT ($C_7H_5N_3O_6$) and RDX ($C_3H_6N_6O_6$). As their composition indicates, they are composed of four basic elements: hydrogen, carbon, nitrogen and oxygen. Although many organic materials buried in soil are also composed of the same elements, use can be made of the fact that explosives have concentrations that are different than in soil and in most common organic materials. One way for the detection and identification of explosives is the use of neutrons. Several investigations were carried out on the advantages and limitations of neutron-based techniques used for the detection and identification of anti personnel landmines (e.g. Csikai, 1999, ElAgib and Csikai, 1999, Datema et al., 2000, Hussein and Waller, 2000, Kiraly et al., 2001, Brooks et al., 2004). The incident neutrons will interact with the nuclei of the major chemical elements in the mine (H, C, N and O), emitting elastically backscattered fast and thermal neutrons spectra which can act as fingerprints of the these chemical elements.

The elastically backscattered (EBS) neutrons can be detected by a suitable detector capable of differentiating the EBS neutrons according to their energy and their flux. The concentration of hydrogen, carbon, nitrogen or oxygen can be evaluated by calculating the elastically backscattered net relative yield of the neutrons and observing the different patterns of their energy spectra (Hussein, et al., 2005). One other detection approach based on neutron backscattering is to simply detect the hydrogen content in soil by measurement of thermal backscattered neutrons from hidden explosives. The change in hydrogen concentration in soil can be made by calculating the intensity of low energy neutrons reflected back from soil (Hussein and Waller, 2000). The chemical elements of interest for the detection of explosives require neutron sources of different energies in order to be observed.

Hydrogen is best observed through nuclear reactions initiated from very low energy neutrons. Other elements such as C, N, and O require neutron energies of several MeV to be observed at all. To satisfy this, the required neutron source should produce high energy neutrons for the detection of elements such as C, N, and O, and low energy neutrons for elements such as H (Vourvopoulos and Sullivan, 2006). Such a task can be accomplished with the use of a spontaneous fission source such as ^{252}Cf. The present work was done by considering a simple sample-source-

Corresponding Author:- Nassreldeen Elsheikh.
Address:- Al-Baha University, College of Science &Arts in Al -Mikhwah, Department of Physics, Al-Baha, Saudi Arabia.

detector geometry, simulating the elastically backscattered (fast and thermal) neutrons from the constituent elements of the explosive material and studying the variation in the net flux with the source energy spectrum. Such geometry was chosen in order to tally the EBS fast and thermal neutrons spectra.

MCNP Modeling& calculation procedure:-

Monte Carlo simulation of a land-mine localization device using the neutron backscattering method was reported by Datema et al. (2002). The general-purpose Monte Carlo N-Particle (MCNP) code, as described by the X-5 Monte Carlo Team (2003), was used in the present study. The code accounts for all neutron reactions given in a particular cross-section evaluation (such as ENDF/B-VI). The evaluated data are processed into a format appropriate for MCNP with the help of codes such as NJOY (MacFarlane et al., 1982). Continuous nuclear cross section data based on the ENDF/B-VI were used in the present computations. The net elastically backscattered neutron spectra were computed for the major elements of a landmine when buried in soil. Calculations were performed using a fixed point source with enough histories to have the statistical error less than 2% in all energy bins.

The sample-source-detector geometry used in the present study is shown in Fig. 1.

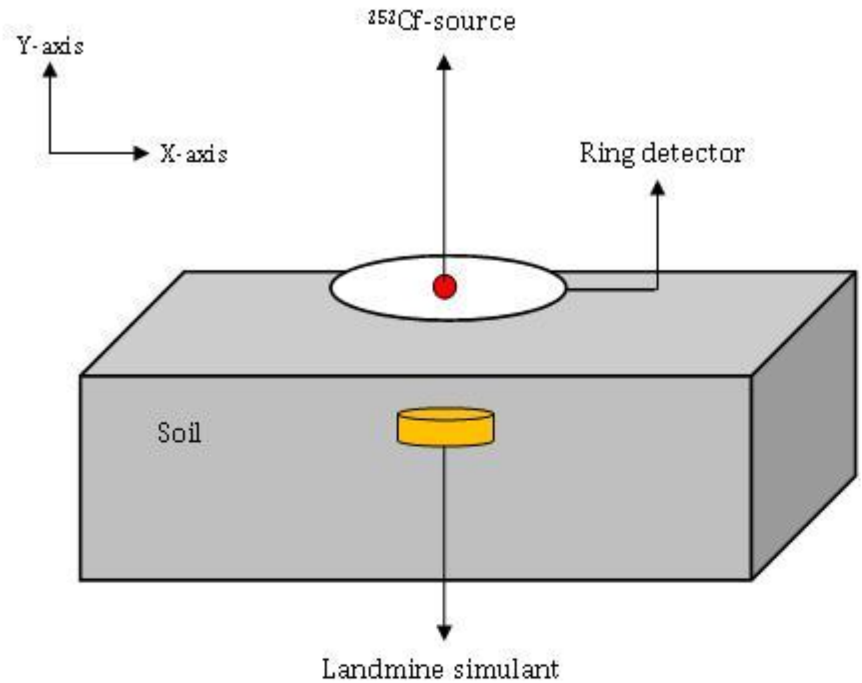

Fig 1:- Geometry used in the MCNP simulations.

The model consists of a soil of dimensions 200cm×150cm×100cm, with the sample as an explosive material in the form of a cylindrical cane TNT of 5cm radius×5cm height, buired 5cm deep in soil. A point neutron isotopic ^{252}Cf source was used in the study. The source was located at vertically above the soil at y= +10cm. Measured and normalized neutron spectra of ^{252}Cf employed in the calculations were taken from Griffith, et al. (1990). A ring detector with 10cm radius was centered on the ^{252}Cf source. This is tally the elastically backscattered (EBS) neutrons from the major constituent elements of the buried landmine. The net elastically backscattered neutrons spectra were calculated by subtracting the background spectrum (soil) from the signal (soil and sample). The calculations were carried out in duration of 100s.

The composition of soil and TNT explosive as modeled in the MCNP simulations is shown in Table 1, with the data taken from Maucec and Rigollet (2004) and Hussein et al. (2005). Mass densities (in g.cm-3) of H (0.02), C (2.23), N (0.81), O (1.14) and Si (2.33), that were used in the MCNP simulations, were taken from the same sources.

Table 1:- Composition of soil and TNT explosive as modeled in MCNP simulation [8,11]

Material / Mass Density (g.cm^{-3})	Elemental Mass Fraction / Mass Density (g.cm^{-3})					
	H	C	N	O	Si	Al
Soil	0.0146			0.5520	0.3607	0.0731
1.12	0.016			0.618	0.404	0.082
TNT ($C_7H_5N_3O_6$)	0.0217	0.370	0.185	0.4229		
1.65	0.0358	0.610	0.306	0.689		

Results and Discussion:-

The net EBS neutron energy spectra from H, C, N, O and landmine stimulant are shown in Figs. 2-6, respectively. Fig. 2 represents the net EBS neutron energy spectra from H. A few peaks of low energy elastically backscattered (LEBS) neutrons are observed in the low neutron energy range (0.022MeV -0.052 MeV). Negative indications are observed, because fast elastically backscattered (FEBS) neutrons are higher from the constituent elements of soil.

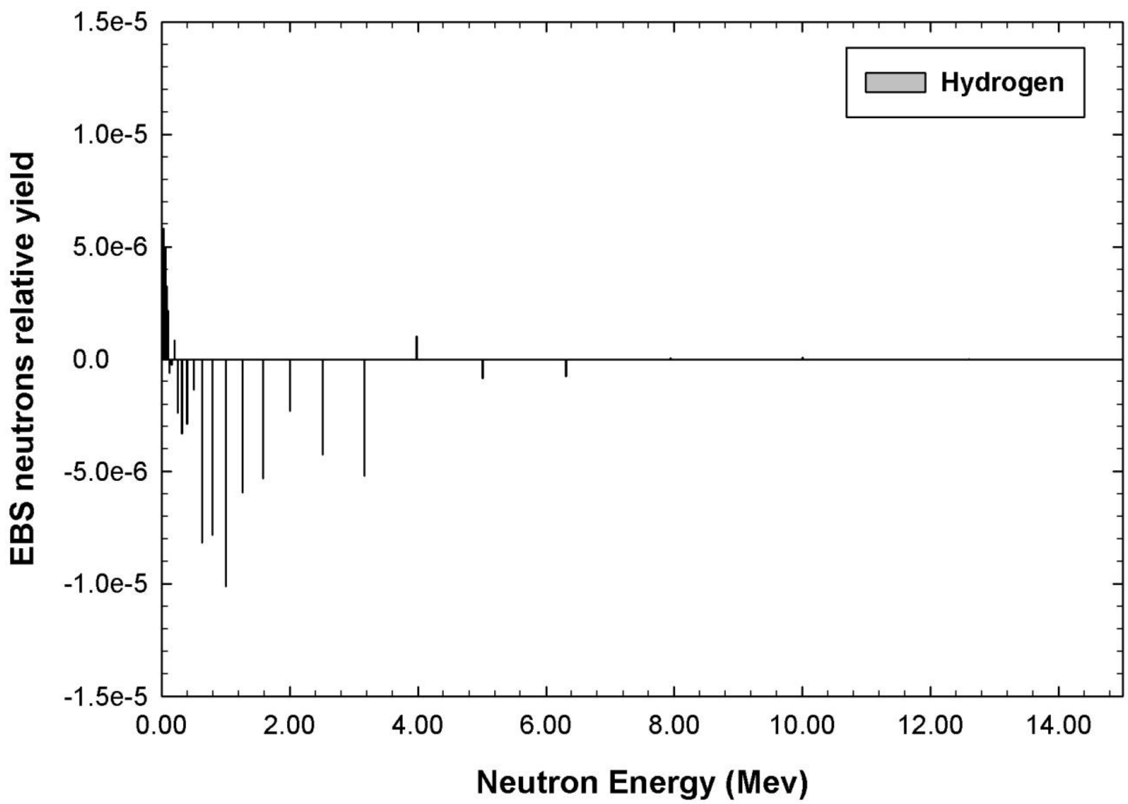

Fig. 2:- The EBS neutron energy spectra from H.

The net EBS neutron energy spectra from C are shown in Fig. 3. More relatively high peaks of LEBS neutrons are observed at the low neutron energy range (0.39MeV-0.64MeV). Compared with H, it is reasonable, since C is less effective as a moderator compared to hydrogen. Relatively high peaks of FEBS neutrons are also observed at the energies 1.58MeV, 2 MeVand 3.51MeV.

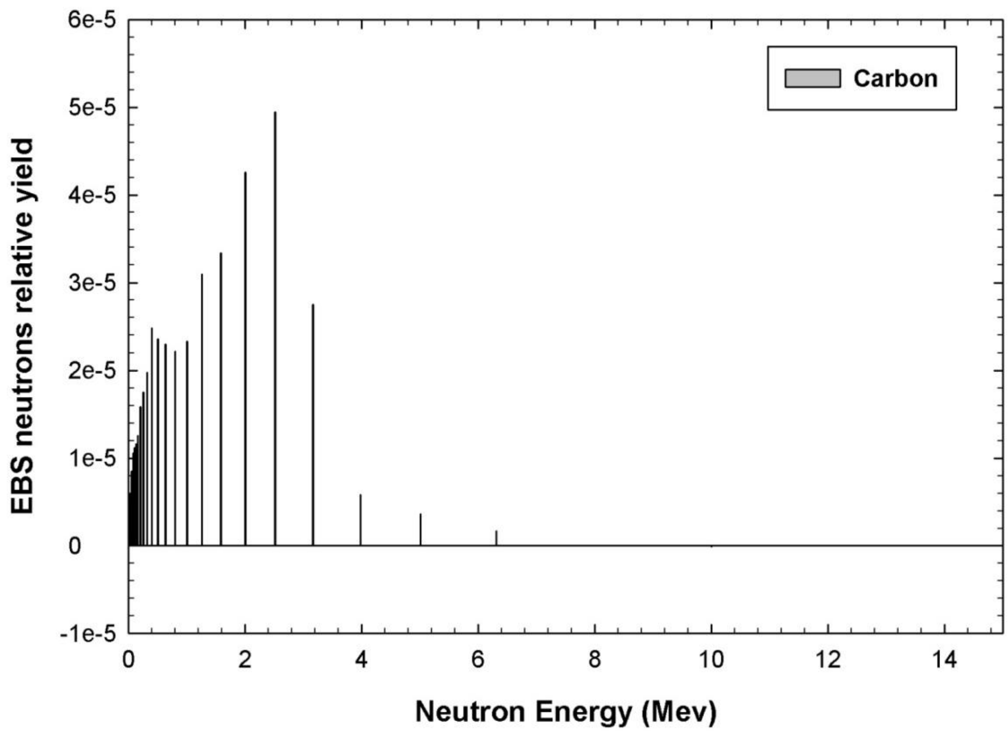

Fig. 3:- The EBS neutron energy spectra from C.

The net EBS neutron energy spectra from N are shown in Fig. 4. Intensive peaks of LEBS neutrons are observed at the low neutron energy range (0.022MeV-0.64MeV). Relatively high peaks of FEBS neutrons are also observed at the energies 1.21 MeV, 2.32 MeV, 3.35 MeV and 3.25 MeV.

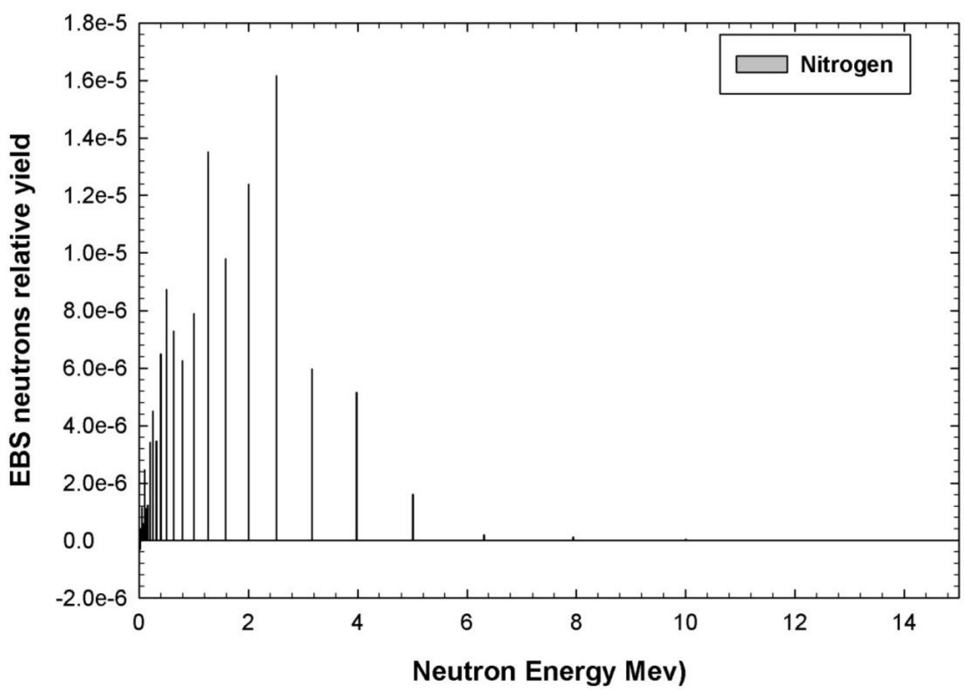

Fig. 4:- The EBS neutron energy spectra from N.

Fig. 5 shows the net EBS neutron energy spectra from O. A high peak of LEBS neutrons is observed at 0.64 MeV. Relatively high peaks of FEBS neutrons are observed at energies 2.33 MeV and 3.27 MeV

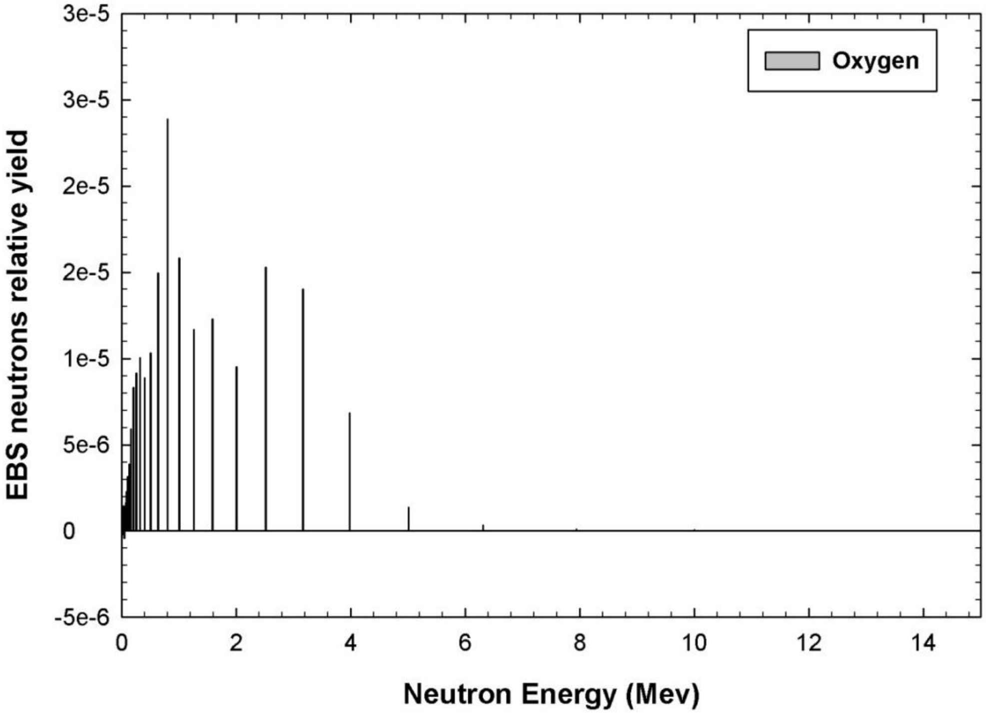

Fig. 5:- The EBS neutron energy spectra from O.

Fig. 6 represents the net EBS neutron energy spectra from landmine. Relatively high peaks of LEBS neutrons are observed at the energies 0.324 MeV, 0.531 MeV and 0.74 MeV. In addition, relatively higher peaks of FEBS neutrons are observed at 3.35 MeV. It is clear from the above results that the EBS neutrons spectra are spread throughout the slow and fast neutron energy regions. Effective detection of such neutron yields can be achieved by employing a detector capable of detecting both slow and fast neutrons.

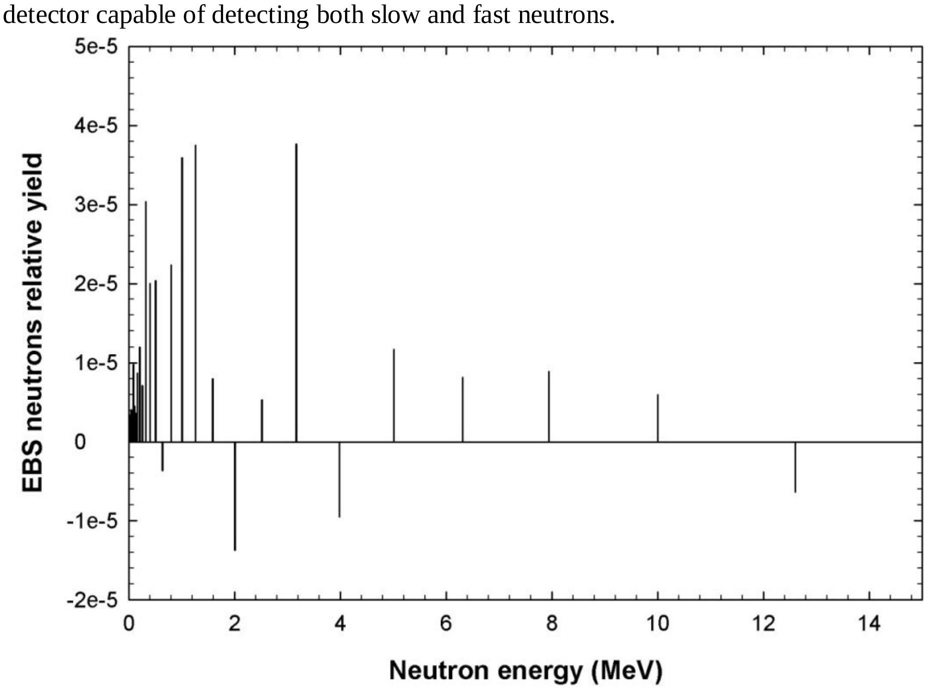

Fig. 6:- The EBS neutron energy spectra from landmine.

Conclusion:-

In the present work, Monte Carlo code was used to model a point ^{252}Cf neutron source centering a ring detector of 10cm radius. The energy spectra of the net EBS neutrons from the major constituent elements of landmine; H, C, N and O were explored. The EBS neutron energy spectra of fast and thermal neutrons of the major constituent elements of landmine stimulant have shown definite and detectable structures that can be used for the identification of a buried landmine.

Acknowledgements:-

The author is grateful to Dr. Ibrahim ElAgib of King Saud University, College of Sciences, Physics & Astronomy Department, for valuable discussions.

References:-

1. Brooks, F.D., Buffer, A., Allie, M.S., 2004. Detection of anti-personnel landmines usingneutrons and gamma-rays. Radiation Physics and Chemistry, 71, 749-757.
2. Csikai, J., ElAgib, I., 1999. Bulk media assay using backscattered Pu-Be neutrons. Nucl.Instrum. Methods A, 432, 410-414.
3. Datema, C.P., Bom, V.R., Van Eijk, C.W.E., 2000. Landmine detection with the neutronbackscattering method. IEEE Nucl. Sci. Conf. Record 1, pp. 5111 – 5114.
4. Datema, C.P., Bom, V.R., Van Eijk, C.W.E., 2002. Experimental results and Monte Carlosimulations of a landmine localization device using the neutron backscattering method. Nucl.Instrum. Methods A, 488, 441-450.7
5. ElAgib, I. and Csikai, J., 1999. Validation of neutron data libraries by backscatteredspectra of Pu-Be neutrons. Nucl. Instrum. Methods A, 435, 456 – 461.
6. Griffith, R.V., Palfalvi, J., Madhvanath, U., 1990. Compendium of neutron spectra anddetector responses for radiation protection purposes. IAEA Technical Report Ser. No. 318,IAEA, Vienna
7. Hussein, E. M. A., Waller, E. J., 2000. Landmine detection: The problem and the challenge. Appl. Radiat. Isot. 53 (4-5), 557-563.
8. Hussein, E.M.A., Desrosiers, M., Waller, E.J., 2005. On the use of radiation scattering for the detection of landmines. Radiation Physics and Chemistry, 73, 7-19.
9. Kiraly, B., Olah, L., Csikai, J., 2001. Neutron-based techniques for detection of explosives and drugs. Radiation Physics and Chemistry, 61, 781-784.
10. MacFarlane, R. E., Muir, D. W. and Boicourt, R. M., 1982. The NJOY nuclear dataprocessing system: users manual. Los Alamos National Laboratory Report LA-9303-M, Vol. I(ENDF-324).
11. Maucec, M., Rigollet, C., 2004. Monte Carlo simulations to advance characterization oflandmines by pulsed fast/thermal neutron analysis. Appl. Radiat. Isot. 61, 35 - 42..
12. Vourvopoulos, G., Sullivan, R. A., 2006. Evaluation of PELAN as a landmine confirmation sensor. Proc. SPIE, Int. Society for Optical Engineering, 6217 I, Art. No. 62171P.
13. X-5 Monte Carlo Team, 2003. MCNP - a general Monte Carlo N-Particle transport code: overview and theory, V. 5, Vol.1., Los Alamos National Laboratory.