UNDER PEER REVIEW

Original research papers

Simulation of low energy neutron shielding by GEANT4 and MCNP4C cod

Abstract

Aims/ objectives: In this work neutrons shielding of ^{252}Cf source simulated with GEANT4 program and MCNP4C cod. The relative neutron flux rates are calculated for different materials. Among various physics models of GEANT4 for the hadronic interaction of neutron, we have used the High Precision (HP) model, which is based on the ENDF-V1 data and is able to treat elastic scattering , inelastic scattering , fission, fusion and capture. The simulation results of GEANT4 are compared with the results of MCNP4C.

Keywords: Neutron shielding; Simulation; Geant4; MCNP4C

PACS 28.41.Qb

1 Introduction

Today with the advancement of technology, the use of nuclear technology in various fields of industry, medicine and research...is increasing. Chilton (1984); Gemmell (2005). Gamma rays and neutrons are emitted in various nuclear reactions. These rays have high permeability, while not undermining the beam with appropriate shielding, these can be serious and irreversible horses to human. Gemmell (1989). In particular, construction and design neutron shielding is of vital importance related to health and safety issues. For that reason, the validation of neutron interaction models in simulation is very important.

2 GEANT4

GEANT4 is a general purpose toolkit for Monte Carlo simulation of particle transport in matter. Ivanchenko (2011). GEANT4 is an open-source physics simulation toolkit originally created at CERN

UNDER PEER REVIEW

. It was developed especially for high energy physics. Physicists use simulation to optimize detectors and software algorithms with the goal to measure, with utmost efficiency, marks that previously unobserved particles predicted by new theories would leave in their experimental devices, but nowadays it is widely used for various applications. Its areas of application include high energy, nuclear and accelerator physics, as well as studies in medical and space science. Agostinelli (2003).

2.1 Geometry for neutron source and shield

The geometry of the neutron source shielding is shown in figure 1.The neutron source is ^{252}Cf. The distance between neutron source and shield is 15 cm. The thickness of the shield is chosen to be 5, 10 and 20 cm.

2.2 Hadronic Models

GEANT4 toolkit supports various hadronic models. We use G4HP(High Precision) model which includes four physical processes for neutron elastic scattering, inelastic scattering, fission and capture. G4HP model is a data driven model. The energy coverage of the HP model is from thermal energies to 20 MeV. The HP model is based on the data formats of ENDF-v1. This model includes cross section and final state information for elastic and inelastic scattering, capture, fission **?** and isotope production. Bak (2011).

3 Shielding Materials

Three different shielding materials are used in this work. Concrete is widely used as one of the most common and the most cost-effective elements for the construction of a shield. Gemmell (1989); Sharifi (2003). In order to have a safe biological nuclear power plants, medical, industrial and nuclear research centers, heavy weight concrete(magnetite concrete) that uses heavy natural aggregates such as barites or magnetite or manufactured aggregates such as iron or lead shot is extremely used. Akkurt (2013); Jaeger (1968-75). The main land-based application is for radiation shielding (medical or nuclear). Offshore, heavyweight concrete is used for ballasting pipelines and similar structures. Lee (1986). The components of these shielding material and mass fraction are listed in table 1.

4 MCNP4C

The MCNP Code developed and maintained by Los Alamos National Laboratory is the internationally recognized code for analyzing the transport of neutrons and gamma rays (hence NP for neutral particles) by the Monte Carlo method. The MCNP code can also treat the transport of electrons, both primary source electrons and secondary electrons created in gamma-ray interactions. Briesmeister (2000); Singh (2014).

5 Results

5.1 Neutron flux

We have calculated the neutron flux for different shielding materials and thicknesses. The curves of neutron flux verses energy for different thikness is shown in figures 2, 3 and 4. With the addition of boron increases the efficiency of conventional concrete, because boron element contain a high

UNDER PEER REVIEW

element	concrete	Borated concrete	magnetite concrete
H	0.010	0.09	0.007
B	–	0.018	0.013
O	0.539	0.535	0.350
Na	0.020	0.016	0.014
Al	0.030	0.028	0.020
Si	0.340	0.326	0.020
K	0.010	0.009	–
Ca	0.040	0.038	0.028
Fe	0.020	0.019	0.550

absorption cross section for neutrons of low energy. Heavy concrete is more efficient than concrete and Borated concrete because of its higher density.

5.2 Relative neutron flux rates

The relative neutron flux rate is defined as the neutron flux with the shield to the neutron flux without the shield. In the figures 5, 6 and 7 we compare the simulation results of GEANT4 with the results of MCNP4C and as can be seen there are a good agreement between the results.

6 Conclusion

We have calculated the relative neutron flux rate using GEANT4 and MCNP4C. There is not much difference between the results of GEANT4 and those of MCNP4C. Heavy concrete is more efficient than concrete and Borated concrete because of its higher density.

References

Agostinelli, S. et al.(2003). *Geant4- a simulation toolkit*, *Nucl. Instr. Meth. Phys. Res. A*,*506*, 250-303.

Akkurt I., El-Khayatt A.M. The effect of barite proportion on neutron and gamma-ray shielding. *Annals of Nuclear Energy* , *51*, 5-9.

Bak S. I. et al. *GEANT4 Simulation of the Shielding of Neutrons from* ^{252}Cf, *Korean Physical Society*, August 2071-2074.

Briesmeister,J.F. (2000). *MCNP*^{TM}*-A General Monte Carlo N-Particle Transport Code* , Version 4C, RSICC COMPUTER CODE COLLECTION, LA-13709-M Manual, OAK RIDGE National Laboratory, 2000.

Chilton, A. B., et all. (1984). Principles of Radiation Shielding. Prentice-Hall New York, Englewood Cliffs,.

UNDER PEER REVIEW

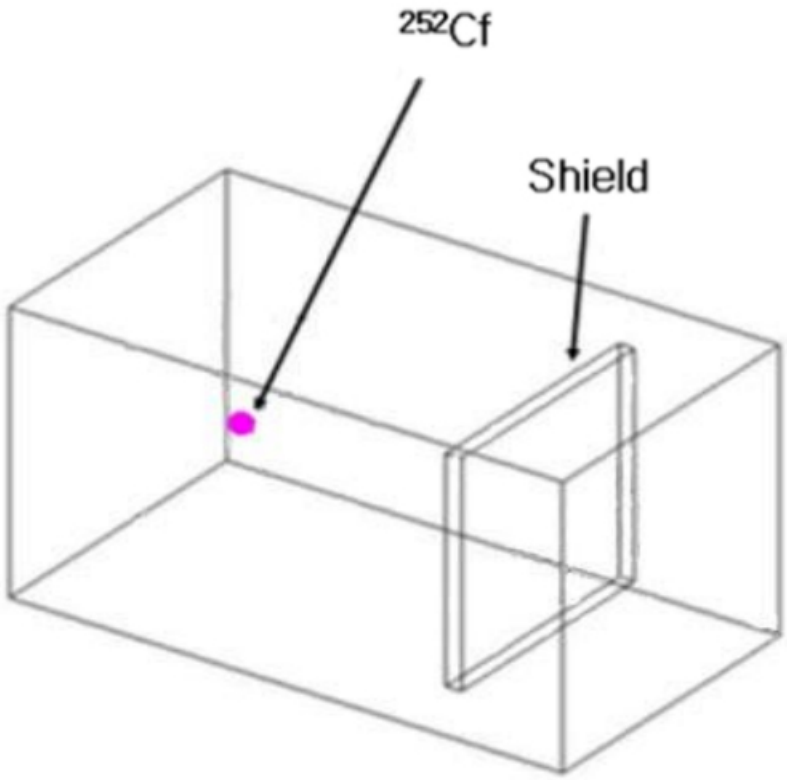

Figure 1: Geometry for neutron source and shield

Gemmell, H. G.; Murray, A. D.(2005). Practical Nuclear Medicine. Springer-Verlag London Press, third edittion 231.

Gemmell, H. G.; Murray, A. D. (1989). Concrete Radiation Shielding. Longman Scientific London,.

Ivanchenko, V. et al.(2011). Recent Improvements in Geant4 Electromagnetic Physics Models and Interfaces, Progress in NUCLEAR SCIENCE and TECHNOLOGY. 2, 898-903.

Jaeger, R.G, 1968-75, Engineering Compendium on Radiation Shielding, Vol. I *Shielding Fundamentals and Methods* ,Vol. II *Shielding Materials and Design*, Vol. III *Shield Design and Engineering*, Springer-Verlag, New York 1968-1975.

Lee D. M. Low-energy neutron shielding, *Los Alamos National Laboratory*, LA-10791-MS.

Sharifi, Sh., et al. Comparison of shielding properties for ordinary, barite, serpentine and steel-magnetite concretes using MCNP-4C code and available experimental results. *Ann. Nucl. Energy* ,*53*, 529-534.

Singh, V.P., Badiger N.M. Gamma ray and neutron shielding properties of some alloy materials. *Ann. Nucl. Energy* 2014, *64*, 301-310.

UNDER PEER REVIEW

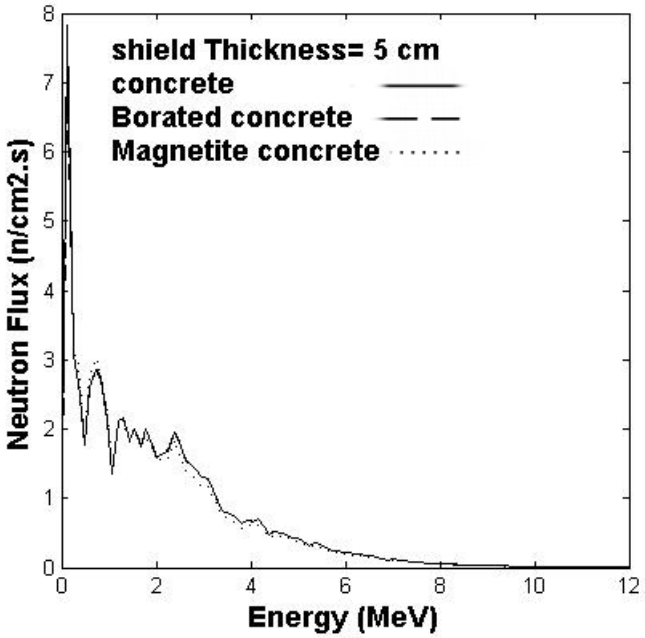

Figure 2: Neutron flux for different materials

UNDER PEER REVIEW

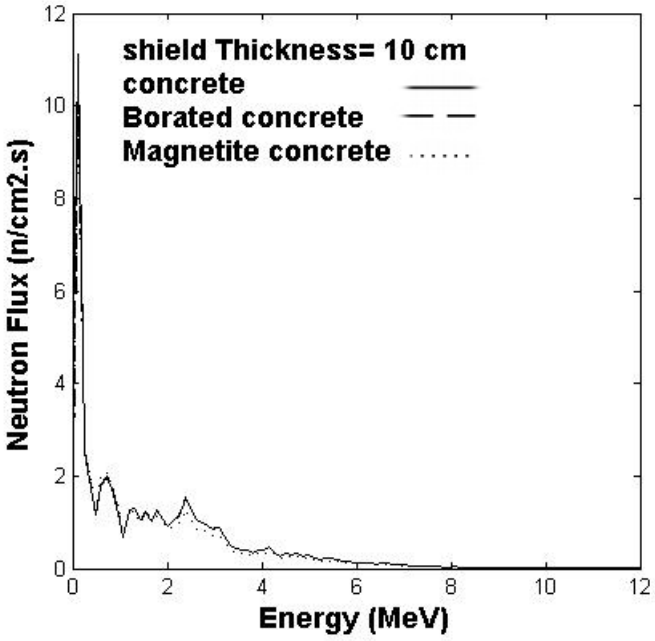

Figure 3: Neutron flux for different materials

UNDER PEER REVIEW

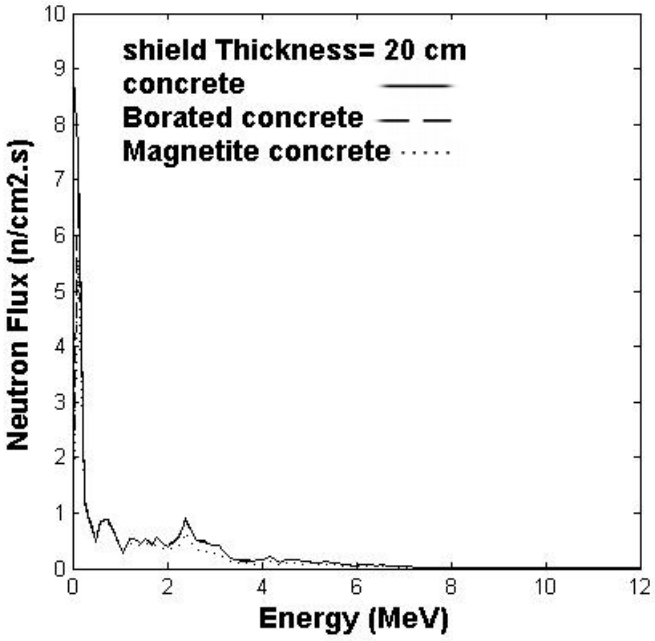

Figure 4: Neutron flux for different materials

UNDER PEER REVIEW

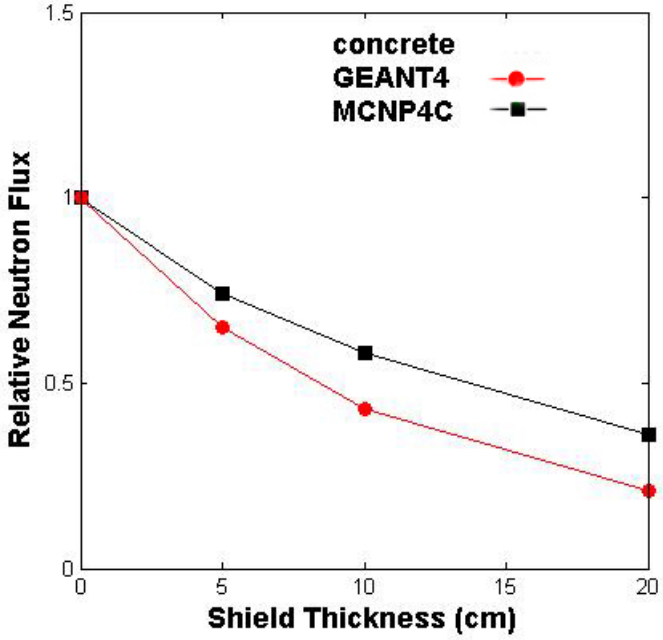

Figure 5: Comparison between the results of Geant4 and MCNP for different concrete

UNDER PEER REVIEW

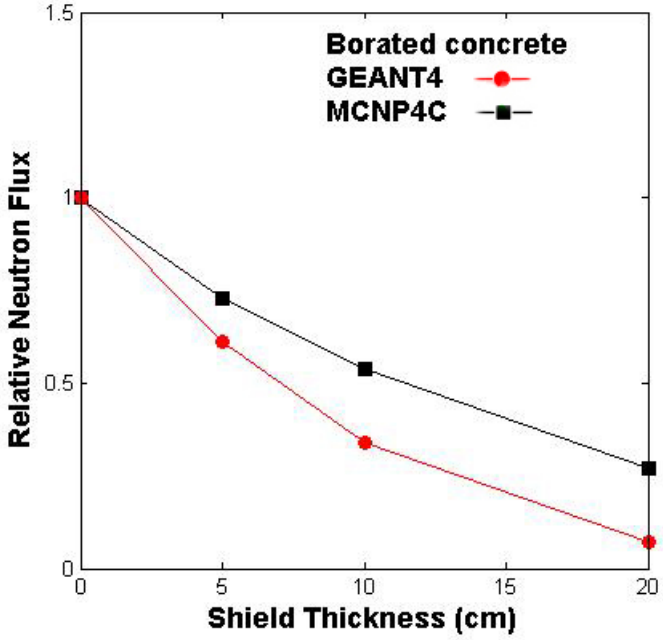

Figure 6: Comparison between the results of Geant4 and MCNP for different concrete

UNDER PEER REVIEW

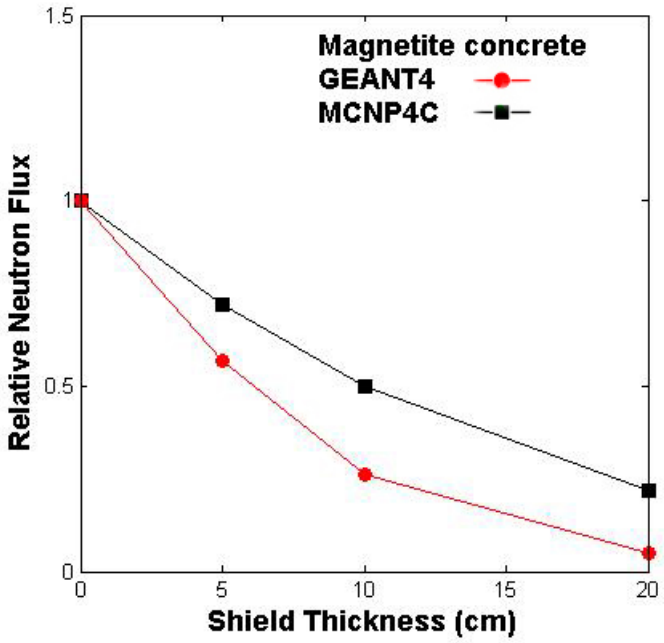

Figure 7: Comparison between the results of Geant4 and MCNP for different concrete