Shutter for Neutron Beam Research at Triga Mark II using for the Prompt Gamma Neutron Activation Facility: Modeling and Simulation

ABDESSAMAD DIDI[A,B], HAMID AMSIL[A], HAMID BOUNOUIRA[A], KHALID LARAKI[A], ILYAS AARAB[A,C], HAMID MARAH[A], HASSANE DEKHISSI[B]
[A] National Centre for Nuclear energy, science and. Technology Morocco
[B] Department of Physics, Faculty of Sciences, University of Mohammed Ist, Oujda, Morocco
[C] Departement of Physics, Faculty of Sciences, University of Ibn Tofeil, Kenitra, Morocco

Abstract

This research aims to presents the neutron simulations for the shutter installation using in Prompt-Gamma Neutron Activation Analysis (PGAA) in TRIGA reactor. The results values of this work propose that, a good using of shutter of neutron is more important to improvement the nuclear security protocol at the center.

Keywords: Monte Carlo, MCNP, TRIGA MARK, Neutron Beam, Neutron flux

Introduction

As part of its support to socio-economic actors in the field of material characterization and non-destructive testing, the National Energy Center of Nuclear Science and Technology (CNESTEN) has started in collaboration with the International Atomic Energy Agency (IAEA), a project to install the Prompt-Gamma Neutron Activation Analysis (PGAA) in TRIGA reactor Tangential Channel (NB1).The TRIGA MARK II Nuclear Reactor is a pool type reactor, designed for research; the reactor is a valuable source of neutrons used in various laboratory applications. The most important application of the reactor TRIGA is irradiation in the core or near the core, as an example neutron activation analysis (NAA) [1-3]. Extracting a beam of neutrons from outside the biological shielding of the reactor presents a possibility for research that would otherwise not be feasible for irradiations near of reactor facility. The characteristics such as energy, angle, and content of this external radiation beam can be controlled to some extent and thus allow flexibility for specific applications. Several researchers have published the study of the neutron beam via a collimator and the shutter [4-9]. The aim of this research was to design and build a neutron beam facility to extend the Prompt-gamma neutron activation analysis. In previous research we communicated the collimator and the sapphire as two devices necessary for the orientation of the neutron beam, in this research we approached the shutter as a beam stopper, because each installation of a PGAA system is necessary an ability to stop the neutron or gamma beam coming out of the collimator. In this context we are installing equipment which plays the role of activating and deactivating the beam, therefore a very important role in protecting workers against nuclear radiation when sample changes are made.

The shutter is made up of four cylindrical blocks of materials, these deferent blocks are (Boron Polyethylene for protection against fast neutrons, Solid paraffin is mainly used to absorb all thermal neutrons, Born stainless to attenuate gammas, and Lead on the sides and the top to attenuate all the gamma produced at the shutter level), the blocks are separated by a thin plate of boric acid with a density of 1.5 g/cm^3. The shutter is a system that contains two positions (on/off), which are moved by a pneumatic cylinder (the possibility of closing by gravity is integrated into the event of a power cut or in the event of an emergency closing). The ideal position of the shutter is attached directly to the collimator. The shutter contains the following main elements (frame, movable block, collimator, beam stopper, base plate, pneumatic system, and an electrical system) Figure 1. We have used in this research the code MCNP6.1, developed by Los Alamos National Laboratory, is used worldwide to simulate the transport of neutrons using the Monte Carlo method, this method is well suited to solve complex issues [10-12].

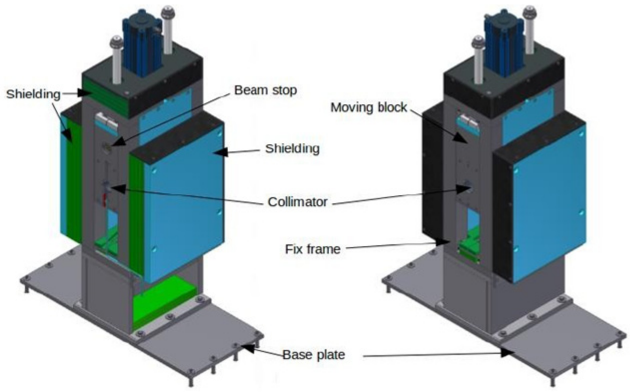

Figure 1. Neutron Beam Shutter for PGAA

Results and discussion

The MCNP model (See Figures 2 and 3) allowed us to determine the attenuation of neutron flux passing through the collimator at each shutter position. These results were introduced to evaluate the neutron current throughout the shutter. In this part we simulated the neutron current through each upper surface outlet from the end of collimator to the end of shutter. Figure 3 shows the shutter geometry with the deferent materials that contains each layer of materials bounded by a surface indicated.
The MCNP model allowed us to determine the attenuation of the neutron flux passing through the shutter at each 1 cm step (See Figure 3). We notice from the figure that the deprived neutrons flux and each deprivation relates to the type of shutter material. From figure 4, there are blue crosses, each cross signifies the limit of a block material, which is why when we find the thin layers of Lead we notice a small peak expressing a lack of flux through this layer.

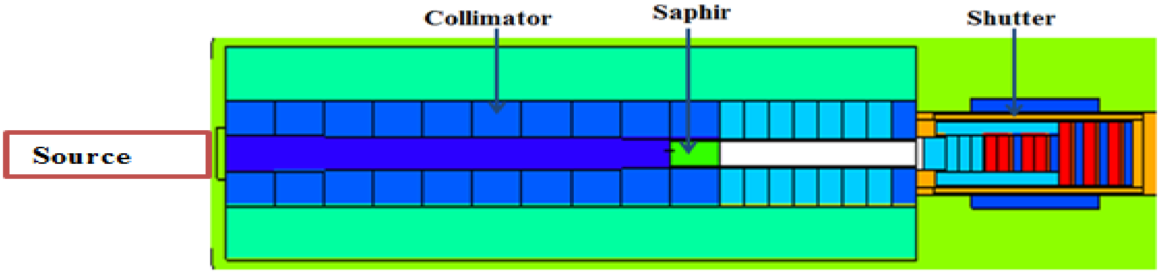

Figure 2. 2D models of collimator and shutter, obtained by the code MCNP

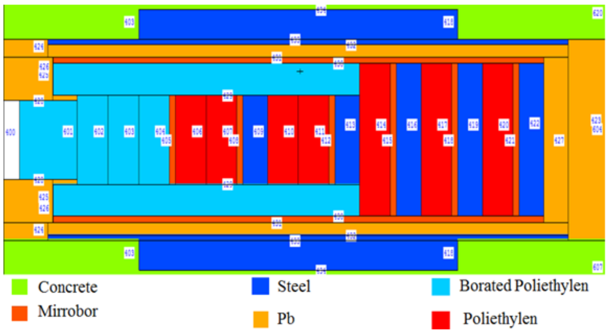

Figure 3. 2D model of the shutter, obtained by the code MCNP

We performed several simulations using the Monte Carlo method in several shutter positions, to know the intensity and the type of neutron flux in each region. Fig. 3 expresses the neutron distribution as a function of the type of neutron (thermal, epithermal and fast). According to Figure 5 which presents the neutron flux as a function of the neutron energy, note that the neutron flux at the entrance of the shutter is more than 110 times more intense than the end of the shutter (510^4 n/cm^2.s at the shutter inlet and 5.10^2 n/cm^2.s at the outlet). Therefore, the neutron flux at the end of the shutter is almost zero. This research describes the modeling and description of the Shutter facility used in PGAA system at CNESTEN.
We have carried out several neutron simulations to take into account the characteristics of the various components of the installation such as the shutter, materials, the neutron beam and shielding.

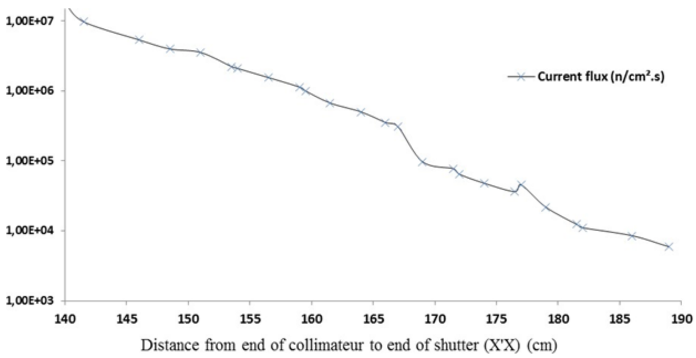

Figure 4. Neutron flux distribution through shutter (n/cm^2.s)

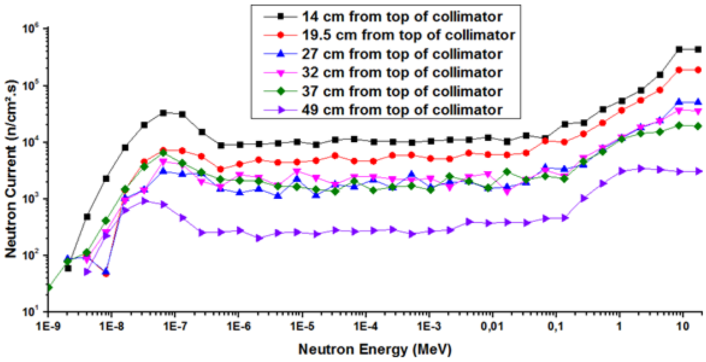

Figure 5. Neutron flux distribution in different shutter position

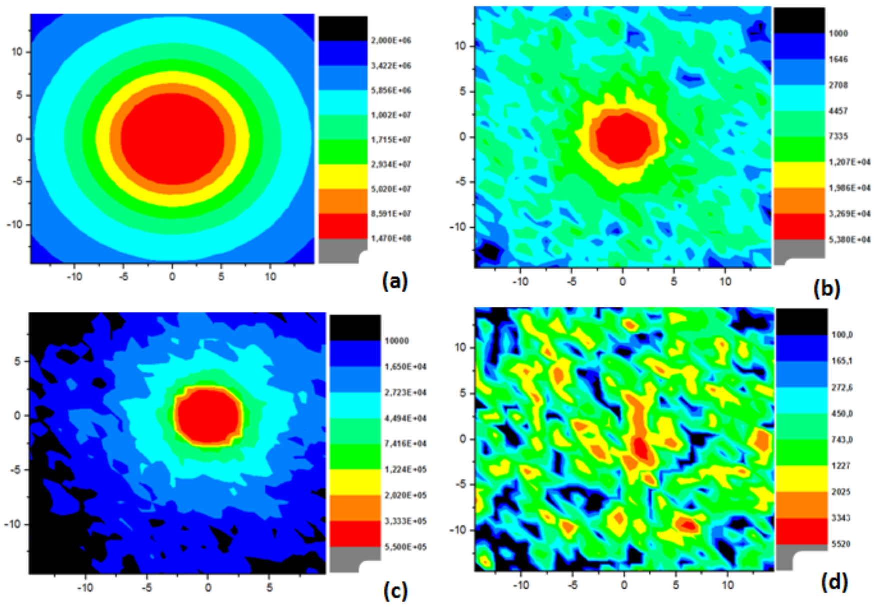

Figure 6. Neutron flux mapping was carried out at 10 cm from the collimator inlet (a), at the end of the collimator (b), at 20 cm from the shutter inlet (c) and 40 cm from the shutter inlet (d)

Neutron flux mapping was carried out at 10 cm from the collimator inlet (a), at the end of the collimator (b), at 20 cm from the shutter inlet (c) and 40 cm from the shutter inlet (d). A working beam facility requires the ability to toggle the beam on and off and protect the beam in both cases. The beam shutter is designed to effectively protect the neutron beam when the attachment is not in use or when sample changes are being made. Based on the results approved during this Monte work, we found that the shutter is designed to shut off all neutrons coming from the reactor core. The results of this work generated by these simulations explain that we will have to add some performance after the shutter to stop the fission gamma from the reactor core which was not taken into account in the design of the shutter. Therefore, recommending the need for additional shielding around the shutter.

Conclusion

In this study, we have shown that the shutter plays an important role in stopping the neutron flux. Based on the results obtained, it is recommended to install a concrete wall opposite the shutter. All this is for quality assurance and safety is well adapted against neutron radiation coming from the collimator.

References

[1] Chahidi, H. and et al. Performance of k0 standardization method in neutron activation analysis using Kayzero for Windows software at the National Center for Energy, Sciences and Nuclear Techniques (CNESTEN Morocco), J. Radioanal Nucl Chem, 2021, 327, pp. 59-64.

[2] Didi, A. and et al. feasibility study for production of oidine-131 using dioxide of tellurium130, International journal of Pharmacy and Pharmaceutical Sciences, 2016, 8, pp. 327-331.

[3] Didi, A. and et al. Toward for production of Molybdenum-99 by irradiation of MoO3 target in a neutron flux, Bangladesh Journal of Medical Science, 2018, 17, pp. 567-572.

[4] Amsil, H. and et al. Conceptual implementation stages for Moroccan PGAA/NI instruments: STAGE I & II. Journal of Neutron Research, 2020, 22, no. 4, pp. 403-415.

[5] Didi, A. and et al. Collimator and sapphire filter using for the prompt gamma neutron activation analysis facility: modelling and simulation, International Journal of Nuclear Energy Science and Technology, 2020, 14, pp. 154-164.

[6] Jalil, A. and et al. Determining PGAA collimator plug design using Monte Carlo simulation, Nuclear Engineering and Technology, 2021, 53, 3, pp. 942-948.

[7] Mghar, M. and et al. Design of a new collimator used in the PGAA nuclear technique, Physics AUC, 2017, 27, 39, pp. 32-40.

[8] Gaibor, L. and et al. Handbook of Prompt Gamma Activation Analysis with Neutron Beams, Chemical Research Centre, Budapest, Hungary, J. Am. Chem. Soc., 2005, 127, 39, pp. 13740-13741.

[9] Didi, A., Amsil, H., Bounouira, H. et al. Improvement of Neutron Safety Performance of Devices Used in the Prompt Gamma Activation Analysis Technique (PGAA) in Morocco: Modeling and Simulation. Moscow Univ. Phys. 76, 398–401 (2021).

[10] Rapport, Direction Etudes et Recherche Scientifiques, Direction des Installations Nucléaires, dossier de sûreté pour l'installation d'un collimateur et d'un shutter dans le canal NB1 du réacteur de recherche du CENM-MAROC, 2019.

[11] MCNP MCNP6 MCNP6TM USER S MANUAL Code Version 6.1.1beta, Los Alamos National Laboratory report LA-CP-14-00745, Rev. 0., (2014).

[12] Goorley, T. and James, M. Initial MCNP6 Release Overview MCNP6 Version 1.0, Los Alamos National Laboratory report LA-UR 13-22934 Los Alamos National Laboratory, 2013.