2017 International Nuclear Atlantic Conference - INAC 2017
Belo Horizonte, MG, Brazil, October 22-27, 2017
ASSOCIAÇÃO BRASILEIRA DE ENERGIA NUCLEAR – ABEN

Agência Brasileira do ISBN
ISBN 978-85-99141-07-6

REACTOR IPEN/MB-01 DOSIMETRY USING TLDs

TássioA. Cavalieri[1], Paulo T. D. Siqueira[1] and Hélio Yoriyaz[1]

[1] Instituto de Pesquisas Energéticas e Nucleares (IPEN / CNEN - SP)
Av. Professor Lineu Prestes 2242
05508-000 São Paulo, SP
tassio.cavalieri@usp.br

ABSTRACT

This paper is a preliminary study on the use of reactor IPEN/MB-01 as standard radiation source for mixed field dosimetry studies. As a first step on this attempt, simulations and experiments, evaluating the neutron and gamma field distributions, were performed and compared. TLDs are widely employed in dose measurements and the TLD 100 / TLD 700 pair conforms with ICRU recommendations for mixed field dosimetry. In this study, TLD irradiations were performed in the IPEN/MB-01 nuclear reactor. IPEN/MB-01 reactor is zero power reactor widely used to perform reactor physics experiments. Its neutron flux distribution is well known for a variety of reactor core configurations. However, the photon fluxes are unknown. A series of experiments with TLD 100 and TLD 700 were performed for two different core configurations (rectangular and cylindrical with a central flux trap). Simulations with MCNP5 for these two configurations were also done, and neutron and gamma fluxes distributions along the core were computed. The responses of TLD 100 and TLD 700 were compared with simulated fluxes and showing a good agreement between them. This paper presents the results of the experiments done so far given the status of the study under way in order to couple IPEN/MB-01 and TLD 100 / 700 pair into a mixed field calibration methodology.

1. INTRODUCTION

The IPEN/MB-01 reactor (São Paulo – Brazil) is zero power reactor, i.e. no concern has to be delivered on heat removal, widely used to perform reactor physics experiments, having its neutron flux well determined, both experimentally as by simulations, all over the core for a wide variety of core configurations. However, little attention has ever been paid on gamma flux distribution on its unique, flexible and diverse attainable mixed neutron-gamma fields.

On the other hand, the International Commission on Radiation Units and Measurements, ICRU, recommends the use of a pair of detectors, each of which with distinct responses to the field components, in order to perform mixed field dosimetry[1].
However, except for the gamma component, estimates on detector response to each individual component are seldom achievable. One often evaluates the combined response disregarding their interplay and their dependence on energy, as one usually evaluates components responses for a single mixed radiation field conformation.

This work presents the first results on the use of IPEN/MB-01 as a mixed neutron/gamma radiation source, providing a multitude of neutron/gamma conformations, for evaluation of detector responses. It presents some experimental and calculated results of the neutron and gamma distribution along the reactor IPEN/MB-01 for two distinct core configurations. Neutron and gamma fluxes distribution were calculated for each specific core configuration using MCNP5 [2], a general radiation transport code. For the validation of simulations, data from activation foil of previously works[3] were used. Experimental data were obtained using LiF (TLD 100/TLD700) TLDs pairs placed at different spots in the core.   TLD experimental results were compared to simulations.

2. MATERIALS AND METHOD

2.1. Termoluminescent Dosimeters (TLDs)

The thermoluminescent dosimeters (TLDs) are widely employed for dose measurements in phantom and in vivo due their small dimensions, response reproducibility and relative low cost. The TLDs reduced size makes them ideal for dose measurement inside a reactor. And the TLD 100 / TLD 700 pair meets the criteria of having distinct response for each field component.

TLD 100 and TLD 700 used in this work are from Harshaw®. These TLDs are made of LiF:Mg,Ti with different Li isotopic concentrations and all of them have disk shape whose dimentions are 3mm of diameter and 0.38mm of width.

The difference between these TLDs lays on the relative amount of Li isotopes in their composition. TLD 700 is enriched with ^{7}Li (99.93%) while TLD 100 has Li in its natural isotopic composition, therefore having a higher concentration of ^{6}Li than TLD 700. ^{6}Li has a high thermal neutron cross section and therefore TLD 100 responds to thermal neutrons and gamma radiation, while TLD 700 responds only to gamma radiation.

A single TLD thermal treatment cycle has been followed for both TLD types: 1h in 400°C and 2h in 100°C. A Harshaw 3500 Reader was used to read the TLDs with the following working parameters: 1000V applied voltage; 60°C pre-heat; 400°C final temperature; and 45s reading time lapse.

The TLD glow curve can be divided into two Regions Of Interest (ROI); these ROIs provide different information about the field under these TLDs were irradiated. Figure 1 shows the glow curves for TLD 100 and TLD 700 after they have been irradiated in a mixed neutron gamma field. ROIs 1 is depicted by the region between the vertical lines placed at channels 65 and 110 while ROI2 by the region next to the right, i.e. between channels 110 and 155.

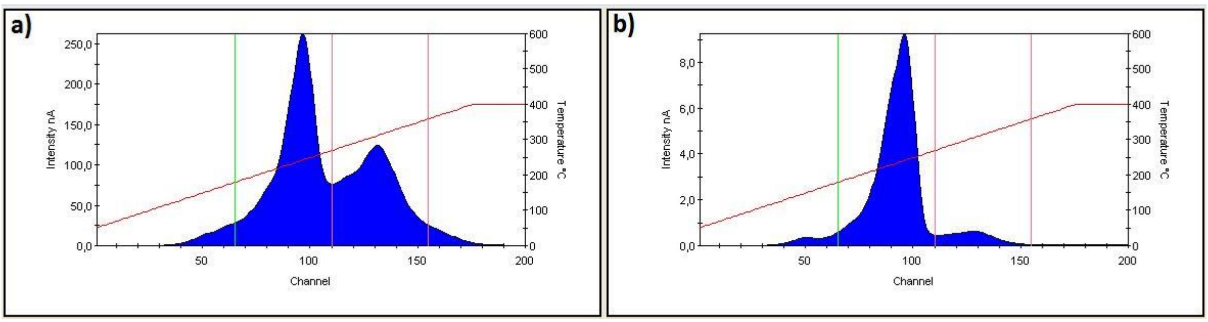

Figure 1: TLDs glow curves. a) TLD 100; b) TLD 700

The ROI 1 of TLD 100 glow curve is a region sensitive to thermal neutron and gamma, while the ROI 2 is a region sensitive only to thermal neutrons. TLD 700 on its turn is sensitive only to gamma radiation, so its glow curve is predominantly in the ROI 1.

2.2. Reactor IPEN/MB-01

The IPEN/MB-01 is zero power nuclear reactor, and its core allows the assembly of different critical arrangements. Its matrix plate, a support apparatus which holds the fuel elements in the reactor core, has 900 holes, spaced 15 mm apart, in a 30x30 arrangement enabling a lot of sorts of fuel distribution to conceive different core configurations[4].

The experiments shown in this work were carried out for two different core configurations were : i) cylindrical with flux trap and ii) rectangular (26x28). Figure 2 shows the schema of these two configurations.

a) b)

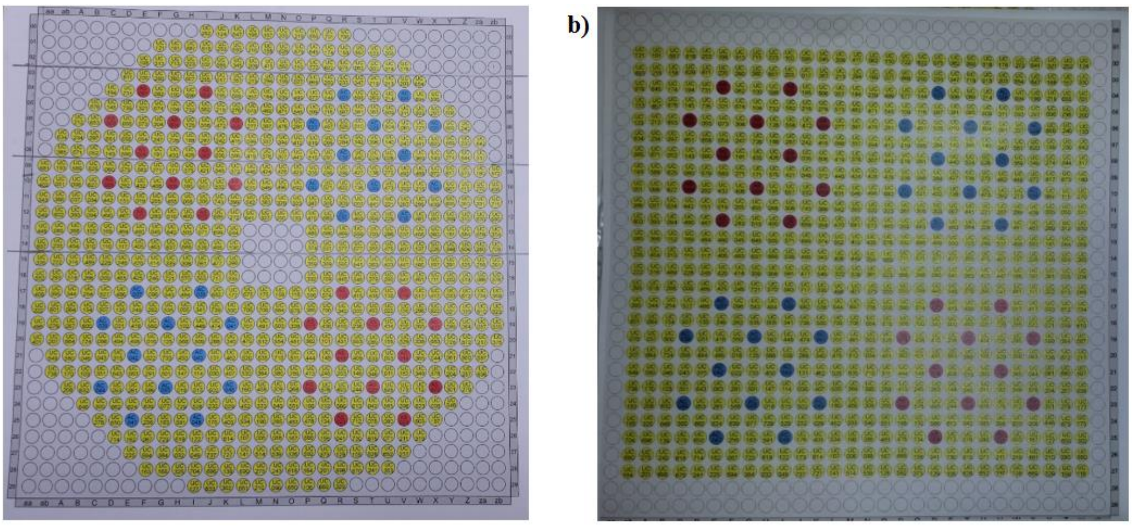

Figure 2: IPEN/MB-01 core configurations: a) cylindrical with flux trap; b) rectangular (26x28)

2.2.1. Irradiations

For each core configuration TLD irradiations were performed by placing TLD sets along the central plane of core reactor. This plane laid between channels 14 and 15 as shown in Figure 3.

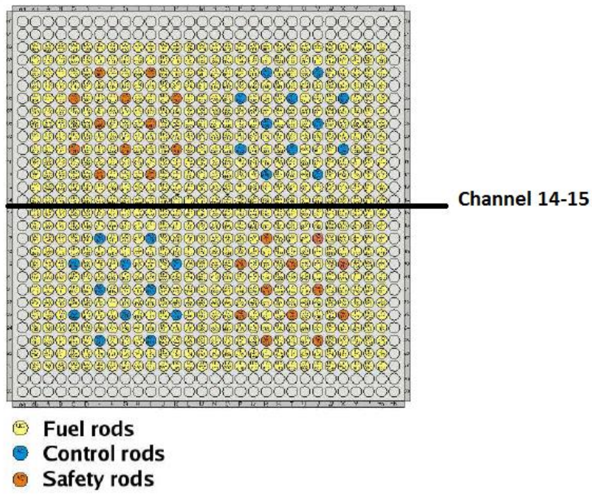

Figure 3: Irradiation channels in IPEN/MB-01 core.

At the fuel central height (273 mm), TLDs sets consisting of x TLD 100 and y TLD 700 were placed at three distinct positions along its horizontal axis. These positions are shown in Figure 4.

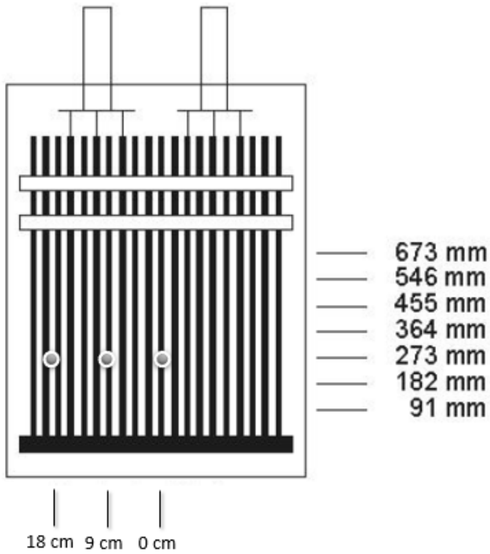

Figure 4: TLDs positions in IPEN/MB-01 [3 – adapted]

Each irradiation was performed for one hour and the reactor operating at 1W thermal power. This set up was chosen due to the possibility of removing the TLDs soon after the reactor was shut down and thus reducing the time which TLDs would exposed to the background radiation coming from the reactor at its cooling down regime.

2.3. Simulation

Simulations were performed with MCNP5 for each core arrangements. For each simulation neutron and gamma fluxes in each point of reactor were calculated. The neutron fluxes were calculated for two neutron energy ranges: thermal neutron (neutrons with energies under 0.625 eV) and epithermal neutron (between 0.625eV and 100 keV).

3. RESULTS

3.1.Simulation Validation

Simulations results of thermal and epithermal neutron fluxes in IPEN/MB-01 reactor core at its rectangular configuration were validated by comparing them with neutron flux data obtained by gold activation foils experiment given by Gonçalves [3]. The comparison between simulation and experimental data is presented at Figure 5.

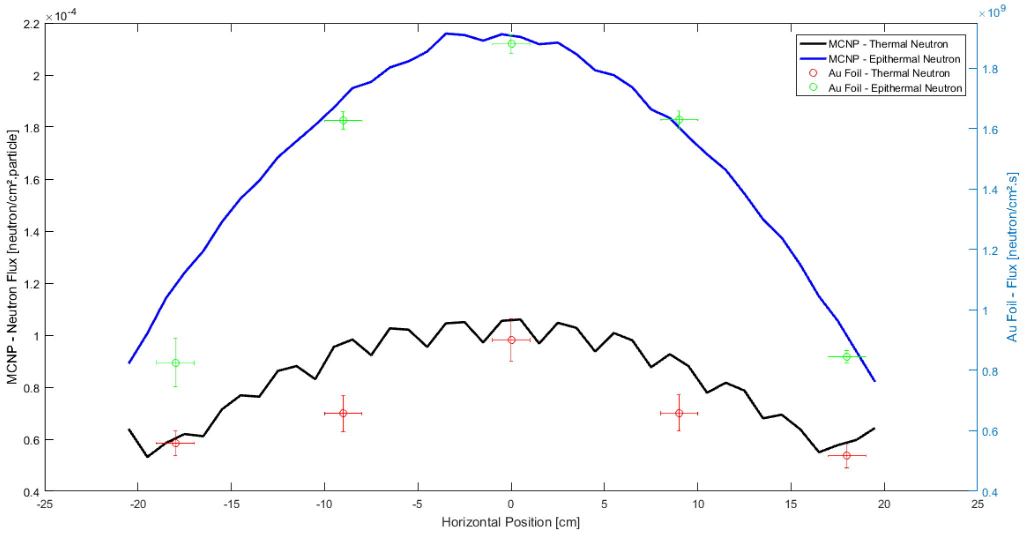

Figure 5: Experimental and simulated neutron flux profiles in IPEN/MB-01.

As one can see in figure 5, calculated and experimental results present a good agreement if one takes into account the experimental uncertainties.

3.2.Neutron and Gamma Fluxes Calculated by MCNP

Simulations with MCNP5 provided neutron (in the two different ranges) and gamma flux distributions along the plane given by channel 14-15. Figures 6 and 7 show the thermal neutron flux distributions calculated (by MCNP) respectively for the rectangular and cylindrical with flux trap configurations. Figures 8 and 9 show the gamma fluxes distributions calculated for both configurations just mentioned.

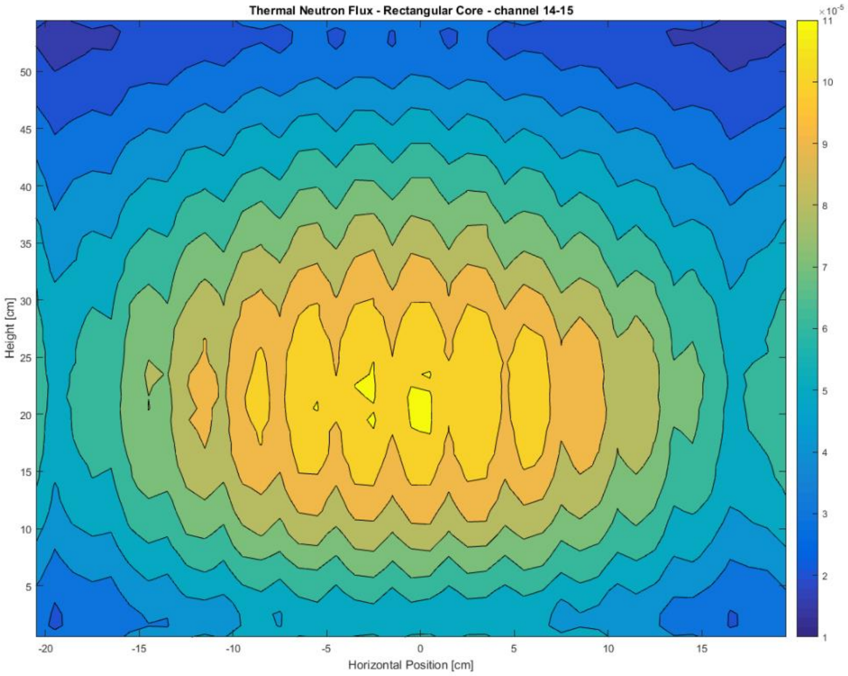

Figure 6: Neutron flux for rectangular core configuration at channel 14-15

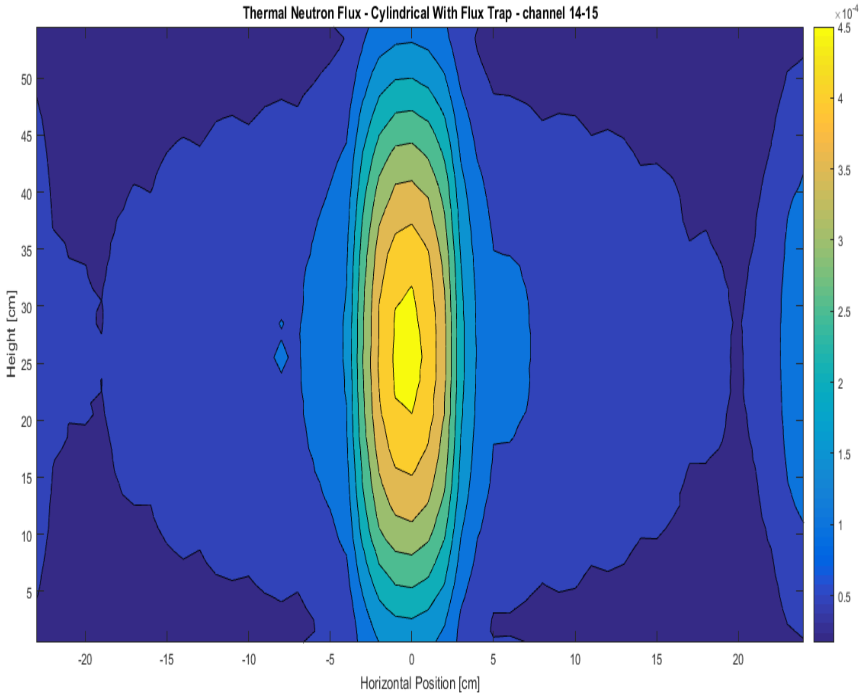

Figure 7: Neutron flux for cylindrical core with flux trap configuration at channel 14-15

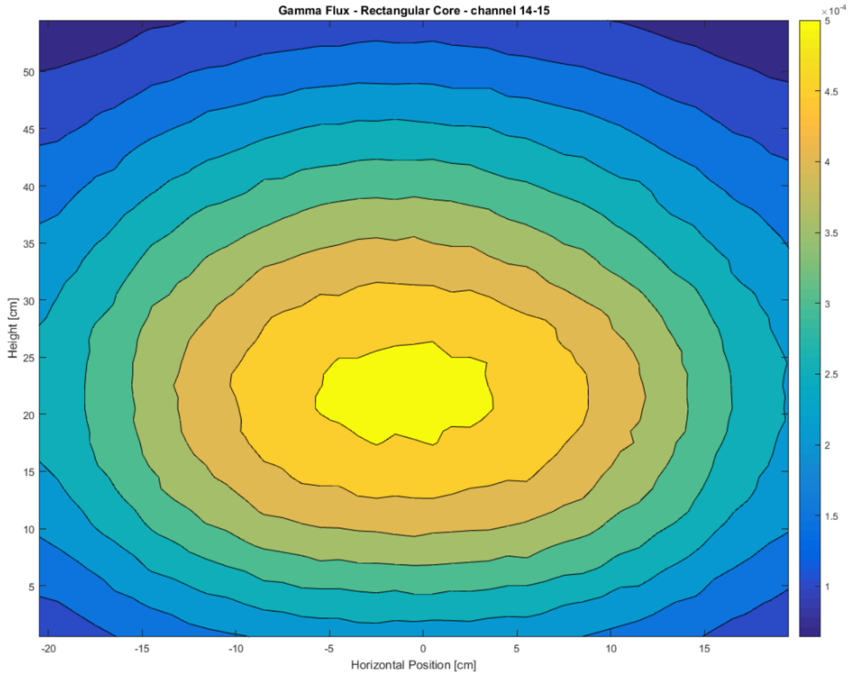

Figure 8: Gamma flux for rectangular core configuration at channel 14-15

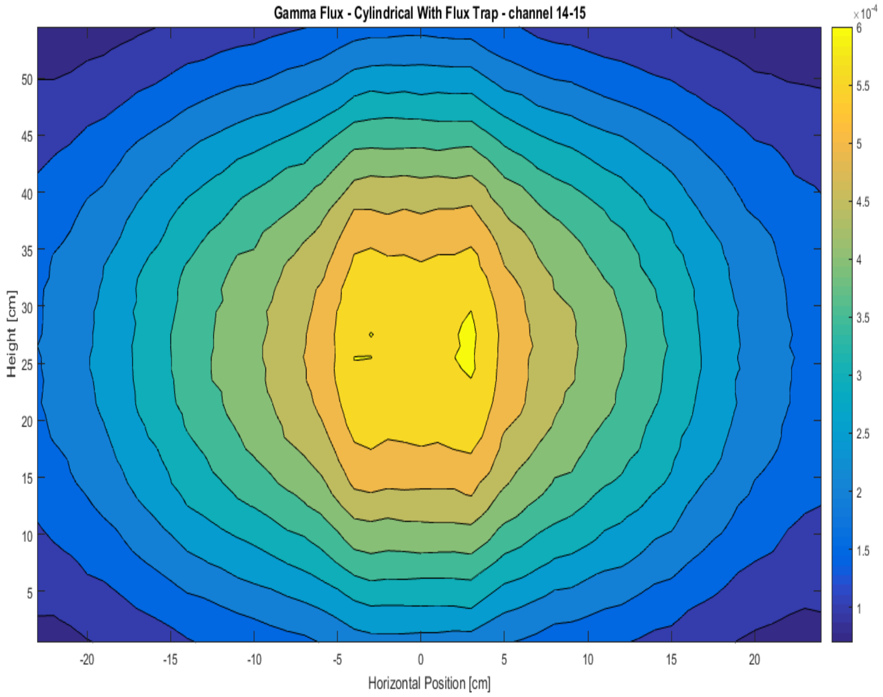

Figure 9: Gamma flux for cylindrical core with flux trap configuration at channel 14-15

3.3.TLDs Response

TLDs responses were compared with the calculated neutron and gamma fluxes at irradiation positions. These comparisons were set to study the interplay of field spectra on the intensity of the TLD ROIs response.

Figures 10 and 11 show these comparison for TLD 100 and TLD 700 for rectangular core configuration.

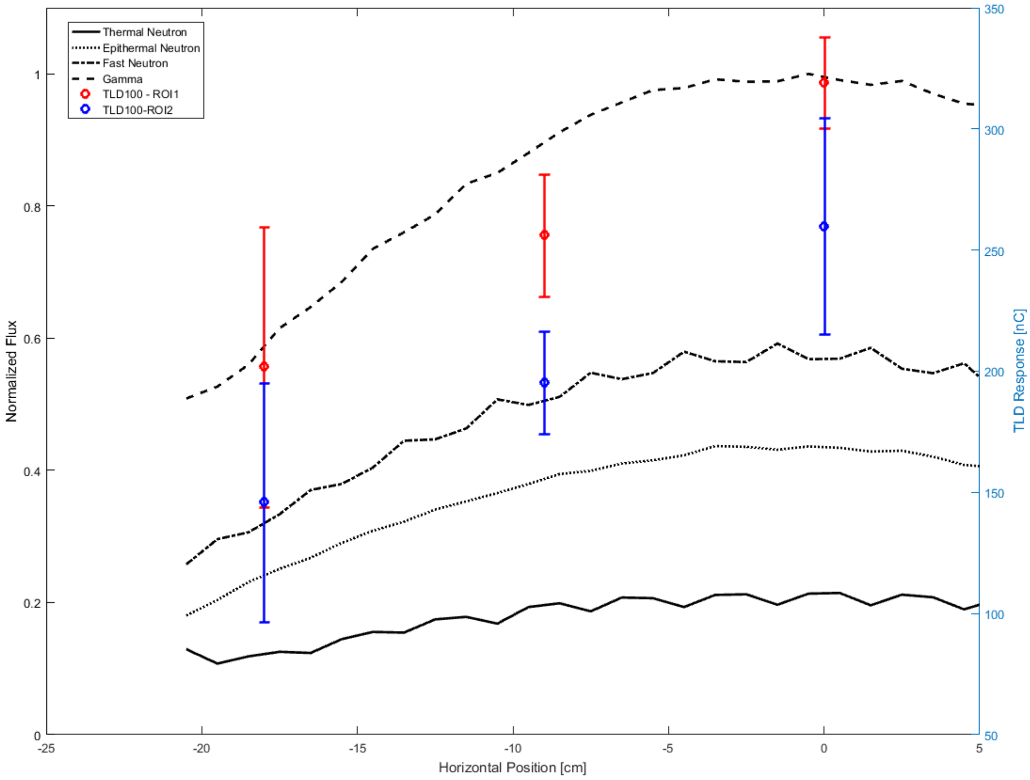

Figure 10: Comparison between TLD 100 response and neutron and gamma flux for rectangular core at channel 14-15

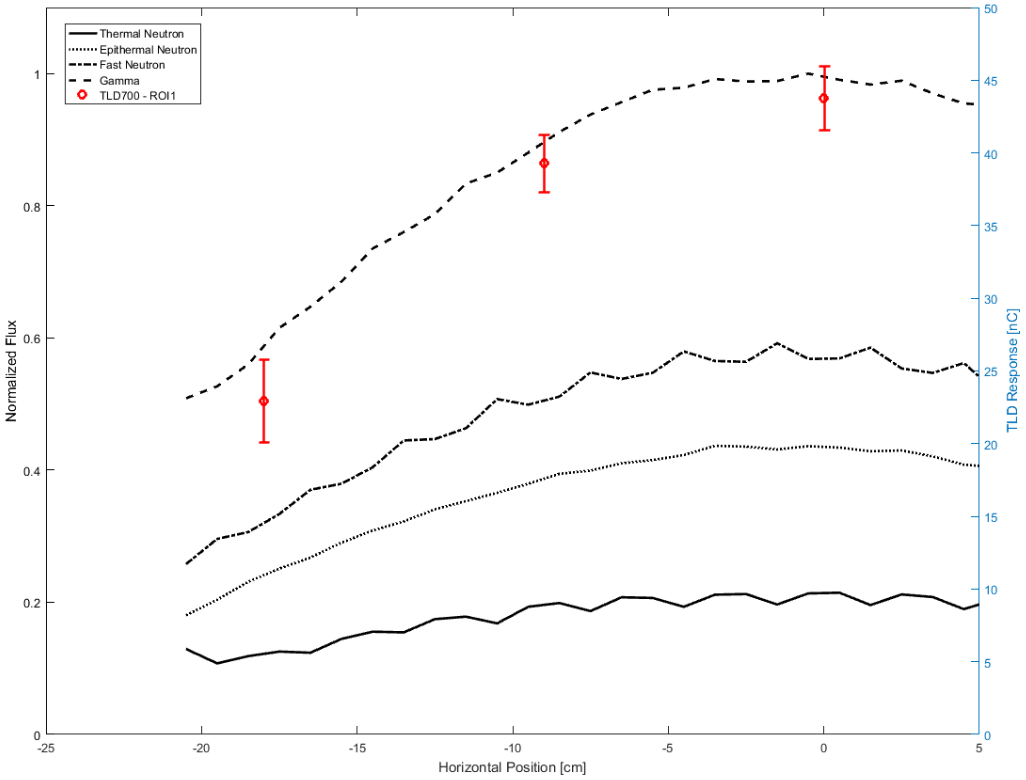

Figure 11: Comparison between TLD 700 response and neutron and gamma flux for rectangular core at channel 14-15

In this case the maximum variation on thermal neutron and gamma flux in TLD position is approximately 60% for both cases.

For TLD 100 ROI 1 the maximum difference in response is approximately 60% too. How TLD 100 ROI 1 response for neutron and gamma radiation it was expected a fall of 60% for this ROI, what was observed. TLD 100 ROI 2 responses only for thermal neutron fall 60% too, what is expected.

The TLD 700 ROI 1 is sensitive preferably to gamma radiation. So, it was also expected a fall of 60%, and the result obtained was 53%.

These TLDs responsesobtained, at first, agree with simulations. However, the dispersion in TLDs response is too high, and more experiments are needed in this configuration. How the fall in thermal neutron and gamma fluxes are similar, in this case it was not possible to study the difference in the TLD 100 ROIs due to different field spectrum.

The cylindrical core arrangements with flux trap provide a great variation at field spectrum, what provide a better data for study of difference in ROIs of TLD 100. Figure 12 and 13 show these comparison for TLD 100 and TLD 700 for cylindrical core arrangement with flux trap.

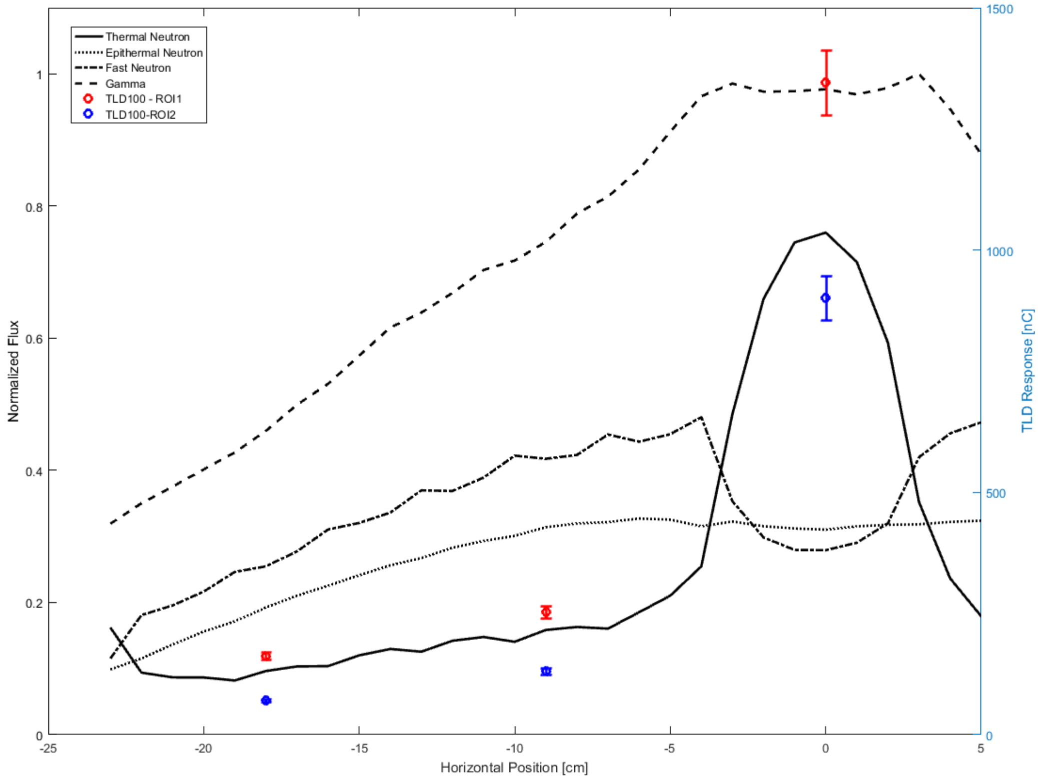

Figure 12: Comparison between TLD 100 response and neutron and gamma flux for cylindrical core with trap at channel 14-15

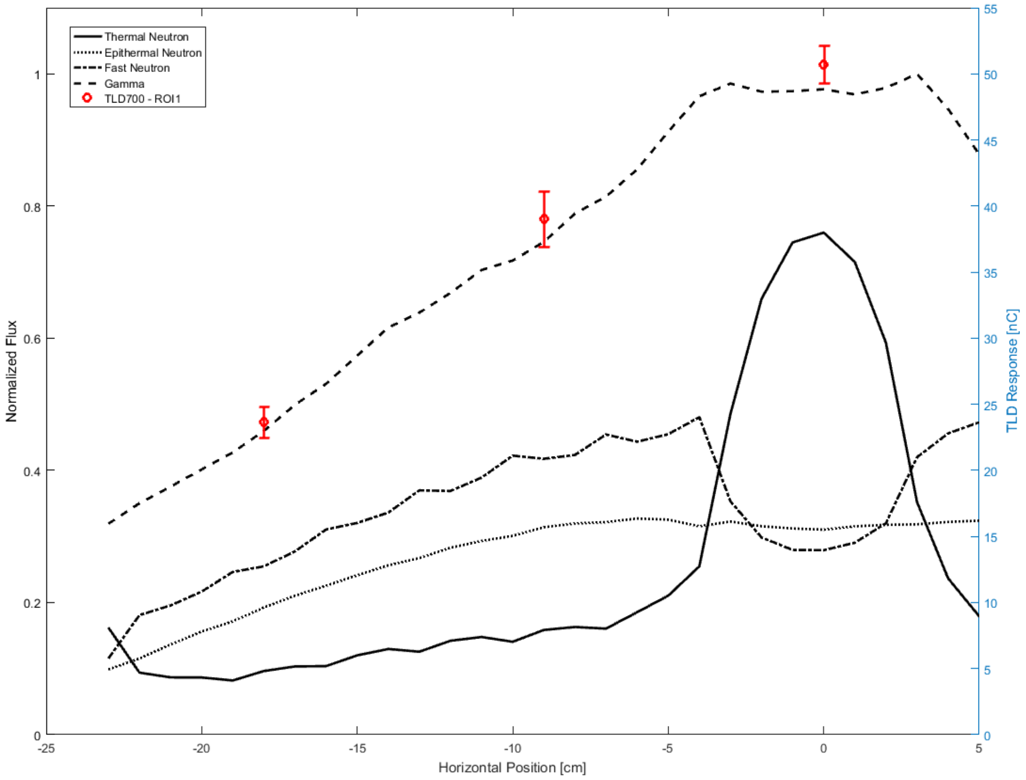

Figure 13: Comparison between TLD 700 response and neutron and gamma flux for cylindrical core with trap at channel 14-15

There are different fields spectrum in cylindrical core with flux trap. In the central region, there is a gain of thermal neutron, that do not have at the lateral. How TLD 100 is sensitive to thermal and gamma radiation, it is observed that its response agrees with the thermal neutrons flux, while TLD 700 response agrees with gamma flux.

The response of TLD 100 ROI 1 is bigger than TLD 700 ROI 1, in the central position of cylindrical core with flux trap this difference is more than 260%. It is proving that TLD 100 is more sensitive to thermal neutron than gamma radiation.

4. CONCLUSION

This work presents the preliminary results in order to evaluate the use of IPEN/MB-01 as a source of different and known mixed neutron/gamma fields.
The results obtained so far seems to corroborate this intent, which would provide different controlled/known irradiation fields, which, by their turn, would allow the study of detector responses and a better use of them.
However, a lot of work is still ahead, as many other experimental data shall be collected along the reactor core as well around its reflector.

ACKNOWLEDGMENTS

The authors would like to acknowledge CNPq for its financial support.

REFERENCES

1. International Commission on Radiation Units and Measurements, *Neutron Dosimetry for Biology and Medicine*, 1984.
2. X-5 Monte Carlo Team, *MCNP - A General Monte Carlo N-Particle Transporte Code*, 2005: Los Alamos.
3. Gonçalves, L.B., *CALIBRAÇÃO DOS CANAIS NUCLEARES DO REATOR IPEN/MB-01, OBTIDA A PARTIR DA MEDIDA DA DISTRIBUIÇÃO ESPACIAL DO FLUXO DE NÊUTRONS TÉRMICOS NO NÚCLEO DO REATOR ATRAVÉS DA IRRADIAÇÃO DE FOLHAS DE OURO INFINITAMENTE DILUÍDAS*, 2008, Instituto de Pesquisas Energéticas e Nucleares: São Paulo/SP.
4. IPEN. *Reator de Pesquisa IPEN/MB-01*. 2017 [cited 2017; Available from: https://www.ipen.br/portal_por/portal/interna.php?secao_id=723.]