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

EVALUATION OF THE INFLUENCE OF THE TH-GEM DETECTOR COMPONENTS IN DOSIMETRIC MEASUREMENTS OF STANDARD MAMMOGRAPHY BEAMS

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ABSTRACT

GEM detectors have found applications in many areas due to their simplicity of construction, low cost, ruggedness and diversity of shape. A dosimeter with these qualities presents utility in several applications, as for example in diagnostic and therapeutic medicine, industrial radiography and nuclear meters. Furthermore, the high sensitivity provided by GEM detectors may extend their applications in low dose dosimetry. Based on these facts, it may be interesting to produce a prototype of a portable TH-GEM type detector with characteristics suitable for dosimetric use in X-rays with low and medium energies. The precise determination of the dosimeter characteristics is very important for laboratories of instrument calibration, as well as to determine how the various components of the detector may influence on the energy deposited in the sensitive volume. In this work, the results obtained about the influence of each one of the components present in this type of detector in standard mammography beams is presented. The code MCNP5 was used. The results allowed the adaptation of the detector to the desired conditions.

1. INTRODUCTION

The need on experimental physics for the determination of the trajectories of subatomic particles has propelled the development of the MultiWire Proportional Chamber - MWPC invented in 1968 by George Charpak, Nobel Prize winner [1]. Microfabrication technology, in particular, has enabled the development of detectors in the concept of MicroPattern Gaseous Detector (MPGD), like: Micro-Strip Gas Chamber (MSGC) [2], MICROMEsh GAseous Structure (MICROMEGAS) [3] and Gas Electron Multiplier (GEM) [4].

The operation of the TH-GEM detector (Thick GEM) is the same of the GEM detectors. The diference is in the structure. The GEM detectors present a micrometric pattern while the TH-GEM presents milimeter patterns. Thus, the TH-GEM detector is an extended scale GEM detector.

The TH-GEM detector, which is the focus of this work, consists in a thin polymeric plate coated on both sides by metallic material. This plate is called amplification plate, and is perforated in a millimeter pattern, and immersed in a rarefied gas. An electrical potential difference is applied between the coatings on both sides of the plate, creating an intense electric field configuration within each orifice, which then acts as a proportional counter, multiplying the electrons released during the induced ionizations by the incident radiation on the gas. An ionization avalanche process is formed, generating a measurable charge, which is collected by a collecting plate for a signal reading [5].

More than one amplification plate can be used in series to further amplify the cascade effect. The physical processes that govern the operation of the GEM detector are the electronic transport in the gas, multiplication of ionizations, charge induction and ion-backflow, all the processes with well-designed models that can be studied through computational simulations.

In this work, results are presented on the evaluation of the influence that each one of the components present in the detector reading in standard mammography beams.

2. MATERIALS AND METHODS

To determine the influence of each component, the MCNP5 (Monte Carlo N-Particle) radiation transport code, developed by the Los Alamos National Laboratory (LANL), was used [6].

The MCNP code works with a system of importance that defines how the particles interact with the medium. By using zero importance in a given environment, particles entering this space will be eliminated. In other words, space with zero importance will behave as an ideal absorber, not generating transmission or scattering. Thus, to evaluate the influence of each component on the detector response, some simulations were performed alternating their importance to zero and comparing them with the value obtained with importance one. The tally used was F8, for photons and electrons, which provides the energy deposited in MeV.

For this some input parameters have to be specified correctly: geometry, materials that compose the detector, experimental setup and characteristics of the radioative sources.

2.1. Geometry and material of TH-GEM detector

For the detector base the polyoxymethylene material was used, density 1.41 g/cm^3. For the entrance window, 6 μm thick aluminum foil was used, density 2.6989 g/cm^3. The amplification and collecting plates were made of fiberglass printed circuit boards, density 2.49 g/cm^3, coated by copper, density 8.96 g/cm^3[6]. The collecting and the amplification plates are separated by spacers of 6.0 mm. The TH-GEM detector was filled by Argon gas, density 1.66201x10^{-03} g/cm^3 [7]. The dimensions are shown in Table 1.

Figure 1 shows the geometry used in the simulation for the TH-GEM detector with the materials of each component. The input window and the copper coating of the printed circuit boards are not visible in the figure. The sensitive volume is the region where the energy deposited in the simulation is obtained. It refers to a parallelepiped in front of the region of the orifices of the amplifier plate. A three-dimensional view is shown in Figure 2.

Table 1: TH-GEM Detector dimensions

Component	Dimension	Value (mm)
Base	Sides	110.03
	Thickness	12.95
	Height	31.67
	Depth	26.39
Collecting plate	Width	59.80
	Length	60.70
	Copper thickness	0.03
	Fiberglass thickness	1.53
Amplification Plate	Width	59.80
	Length	60.70
	Copper thickness	0.03
	Fiberglass thickness	0.50
	Orifice diameter	0.25
	Etched rims diameter	0.50
	Distance between orifices	0.11
Shielding	Sides	110.00
	Thickness	6.00
Input window	Sides	34.50
	Thickness	0.006

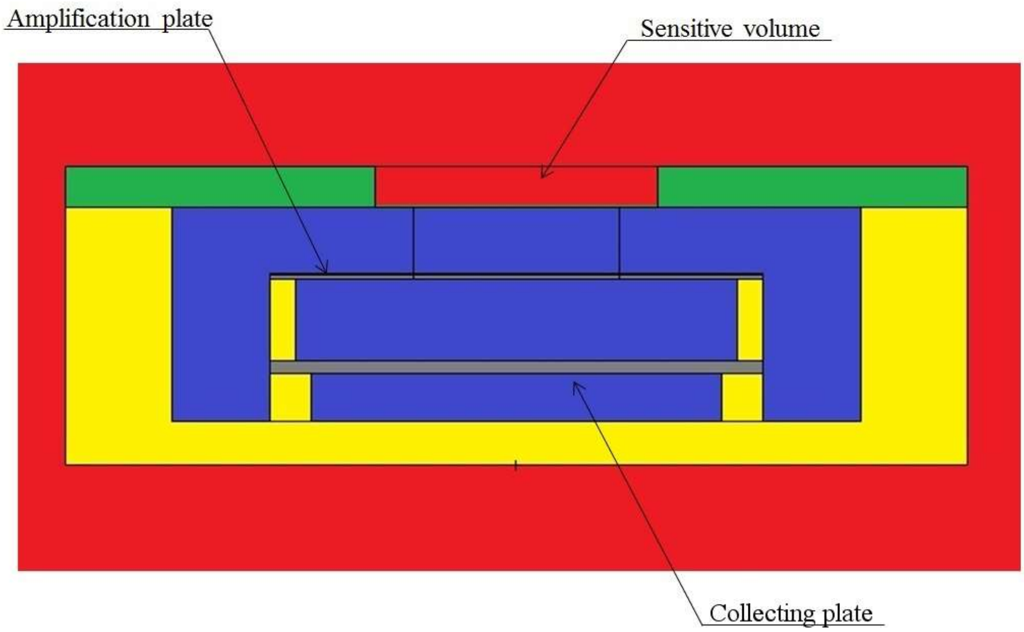

Figure 1 - Transverse section of the TH-GEM detector modelled by the MCNP5 code, visualized with Vised X22S software. The color Red represents dry air; Green: aluminum shielding; Blue: Argon gas filling the detector; Yellow: Poluoxymethylene base and separators; Gray: fiberglass amplification and collecting plate.

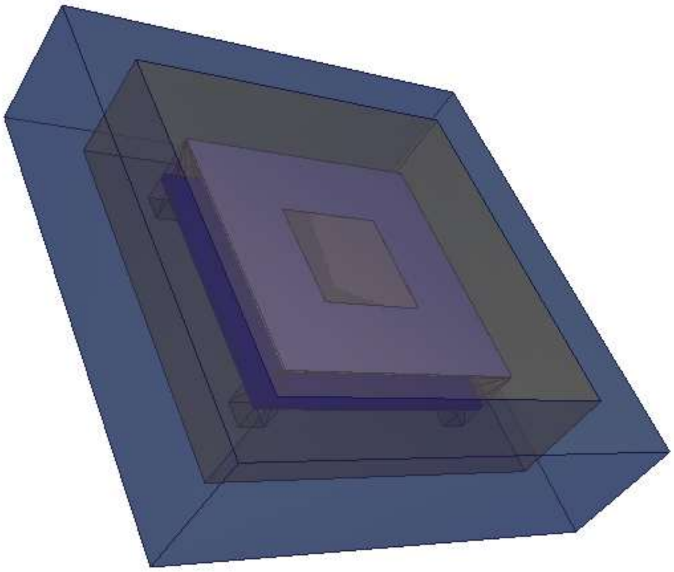

Figure 2 - Three-dimensional view of the TH-GEM detector

2.2. Experimental setup and characteristics of the radioactive source

The radiation beam was simulated in a conical format with a diameter of 12 cm. The focal point of the radiation source was placed at a distance of 100 cm away from the detector input window. The radiation quality used was WMV28, which uses a tube voltage of 28 kV, a current of 10 mA and a filtration of 0.07 mm of molybdenum.

The spectrum was obtained by a semi-empirical model developed to generate the X-ray tube spectra of mammography beams (ranging from 18 kV up to 40 kV tube voltage) using polynomial interpolation [8]. The filter attenuations using the Lambert-Beer law were added to the model and the attenuation coefficients for the filters were obtained by Berger et al. [9]; and Saloman and Hubbell [10].

3. RESULTS

The influence values on the response of the detector for each component obtained are presented in Table 2. It is possible to observe that the TH-GEM detector base, the collecting plate and the shielding present an insignificant influence.

Table 2 – Influence values obtained

Component	Influence (%)
Base	0.09
Collecting plate	0.01
Shielding	1.50
Amplification Plate	44.0

The thickness of the shielding was chosen in order to minimize the radiation transfer to the sensitive volume other than the one incident on the entrance window.

The amplification plate presented a considerable influence. This result can be explained considering that Compton retracted electrons and photoelectrons produced by photon interactions with the amplification plate, contribute considerable to the deposited energy at the sensitive volume of the radiation detector.

4. CONCLUSIONS

That the thickness of the 6mm shielding is ideal in the standard mammography beam. The TH-GEM detector base and the collecting plate presented an insignificant influence on the energy deposited at the sensitive volume of the detector. The amplification plate presented a considerable influence of 44%. This result was expected and was attributed to radiation scattering.

ACKNOWLEDGMENTS

The authors acknowledge the partial financial support from the Brazilian agencies: CNEN, FAPESP, CNPq, CAPES and MCTIC (Project: INCT – Radiation Metrology in Medicine).

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