STUDY OF PLASTIC SCINTILLATOR DETECTOR FOR BETA AND GAMMA RADIATION MEASUREMENT

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RESUMO

Sistemas de detecção de radiação beta são utilizados em diferentes áreas, tais como: ambiental, indústria, medicina e protecção radiológica. No projeto e montagem de um sistema de detecção de radiação beta, a espessura do detector cintilador plástico é determinada para a maior energia observada de partículas carregadas. As combinações de detectores de radiação gama e beta têm sido usados em sistemas de coincidência, tendo como objetivo a sua aplicação, onde um baixo nível de radiação de fundo é necessário. Os detectores cintiladores plásticos são usados em sistemas de medição, acoplados a outros tipos de detectores, ou projetos com detectores de diferentes espessuras. No curso "Fundamentos teóricos e práticos da instrumentação usada na aquisição de dados nucleares", foi realizada uma experiência para determinar qual espessura deverá ser utilizada para a medição beta ou gama. Os autores são professores, colaboradores e estudantes do curso que visa ensinar como utilizar os instrumentos nucleares de laboratório e realizar experimentos para obtenção de parâmetros nucleares. É um dos cursos oferecidos pelo programa de pós-graduação do Instituto de Pesquisas Energéticas e Nucleares (IPEN-CNEN / SP).
Palavras-chave: instrumentação nuclear, detectores nucleares, detecção beta e gama, cintilador plástico.

ABSTRACT

Beta radiation detection systems are used in different fields, such as: environment, industry, medicine and radiation protection. In the project and assembly of a beta radiation detection system, the thickness of the plastic scintillator detector is determined by the range of the largest charged particle energy to be observed. The combinations of beta and gamma radiation detectors have been used in coincidence systems, having as a goal their application where a low level of background radiation is necessary. Plastic scintillator detectors are used in systems of measurements, coupled to other detector types, or assemblies with detectors of different thicknesses.
In the "Theoretical and practical fundamentals of the instrumentation used in nuclear data acquisition" course, an experiment to determine what thickness should be used for beta or gamma measurement was carried out. The authors are teachers, collaborators and students of the course, which seeks to teach students how to use the laboratory nuclear instruments and carry out experiments to obtain nuclear parameters. It is one of the courses offered by the Nuclear and Energy Research Institute (IPEN–CNEN/SP) postgraduate programs.
Keywords: nuclear instrumentation, nuclear detectors, beta and gamma detection, plastic scintillator.

1. INTRODUCTION

Beta radiation detection systems are used in different fields, such as: environment, industry, medicine and radiation protection [1]. In the project and assembly of a beta radiation detection system, the thickness of the plastic scintillator detector is determined by the range of the largest charged particle energy to be observed. The scintillator detectors can be made with a larger thickness, when there is interesting in the gamma radiation detection or when this does not constitute a problem for the measurement being carried out. Beta detection systems have been developed and tested in several laboratories for application in environmental measures, for which a low background radiation is necessary. The combination of beta and gamma radiation detectors has been used in coincidence systems, having as a goal its application where low level of background radiation is necessary. Plastic scintillator detectors are used in measurements systems, coupled to other detector types or assemblies with detectors of different thicknesses [2]. The plastic scintillator detectors present the advantage of being mechanically resistant, not hygroscope and obtainable in several dimensions. This allows to make detection of different thicknesses and to evaluate their response in the radiation detection. The plastic detector used in this work is of the type NE-110. Since the organic elements of this detector contain basically Hydrogen and Carbon, which possess low atomic number in the interaction with the gamma radiation, the Compton effect prevails. Consequently, it presents low energetic resolution [3].

The objective of this work was: (1) to determine the optimized thickness for beta radiation detection with low interference of the gamma radiation (background), (2) to determine the optimized thickness for gamma radiation detection. Those responses can be used in the assembly of a coincidence system for beta detection with low background radiation, using lead block as passive shield and a large scintillator as an active shield, (3) to instruct students in assembly processes coupling scintillator crystals and photomultipliers and analyzing the interaction of radiation with matter in accordance with the thickness of the crystal.

2. MATERIALS AND METHOD

The Plastic Scintillator used in this work was produced in the detectors laboratory of Radiation Technology Center (CTR) of Nuclear and Energy Research Institute – IPEN/CNEN –SP, by polymerization of styrene monomer solutions, containing 0.4% of 2.5-diphenyloxazole (PPO) and 0.04% of 1.4-bis (5-phenyloxazol-2-yl) benzene (POPOP). The effectiveness of purification was evaluated by transmittance measurements in the wavelength range 300-800 nm [4]. The block of plastic scintillator was manufactured in order to obtain detectors of different thicknesses. Various detector thicknesses were used to study the best relationship between efficiency of beta and gamma detection. Gamma sources (^{137}Cs) and beta source (^{90}Sr/^{90}Y) were used.

A plastic scintillator detector system consists, basically, of a combination of a scintillation sensor, a photomultiplier tube and associated electronic circuit for detection and measurement of ionizing radiation.

In all types of scintillator detectors, the properties that should be considered in their production are:

• High transparency to own fluorescent light;
• Short decay time of flicker, nanosecond (10^{-9} s);
•Wavelength compatible with the fluorescence quantum efficiency of the sensor (photomultiplier tubes, photodiodes), as shown in Figure 1;

• Absence of phosphorescence in normal work conditions and the possibility of making large and transparent detectors.

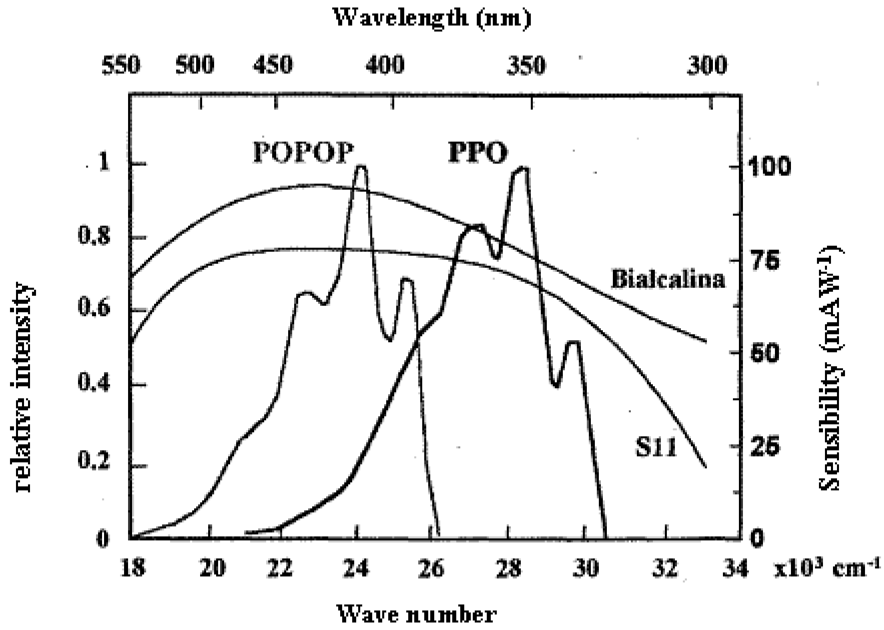
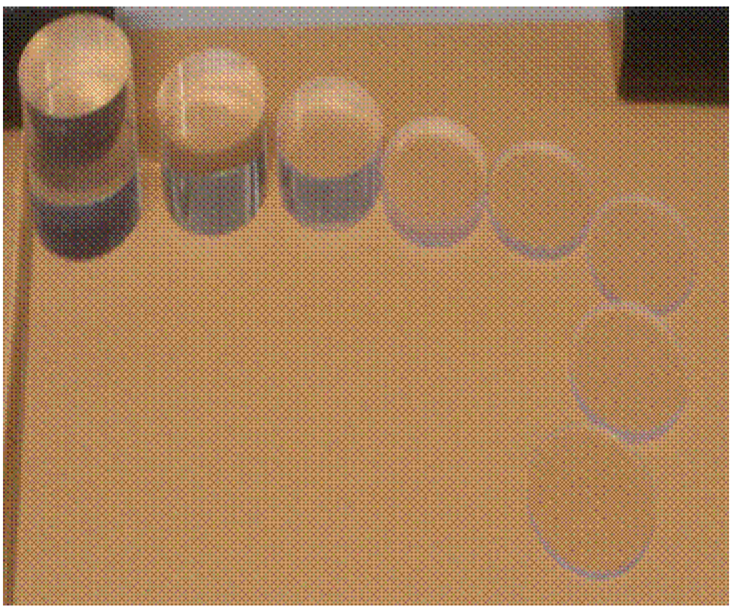


Figure 1. Fluorescence spectrum of the PPO and POPOP scintillator and the photomultiplier response spectrum. [5]

In the experiment, plastic scintillators with eight different thicknesses were used (Figure 2).



Scintillator Thickness (mm)
2.43
2.93
3.99
5.02
9.42
19.11
29.50
48.80

Figure 2. Scintillator detectors.

In Figure 3, photomultiplier and radioactive sources of ^{90}Sr and ^{137}Cs, used in the experiment, are showed (Figure 3).

Figure 3. Photomultiplier and sources.

The photomultiplier was connected to a preamplifier and the high voltage and other electronic modules for the experiment (Figure 4).

Figure 4. Used instrumentation

The optical coupling made between the photomultiplier and the plastic scintillator is an important process for the proper functioning of the system. For this purpose, it is used a silicone grease that serves to prevent any kind of air bubble between the two surfaces that could change the measurement results (Figure 5).

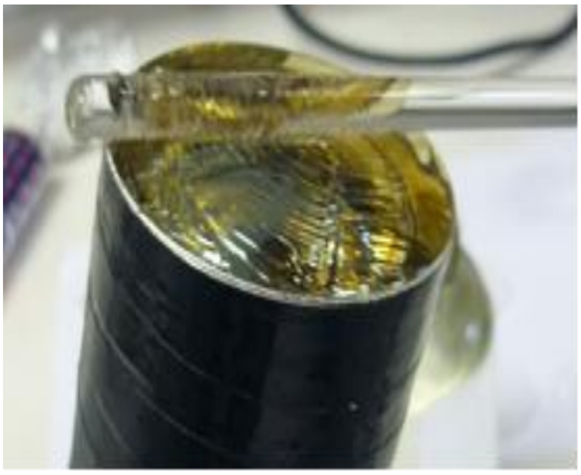


Figure 5. Optical coupling with silicon grease.

3. RESULTS

The Figure 6 presents the relationship between the counts and the scintillator thickness, using gamma and beta radiation sources.

The best thickness determined for the beta radiation was 2.43 mm and, for the gamma radiation, was 50 mm.

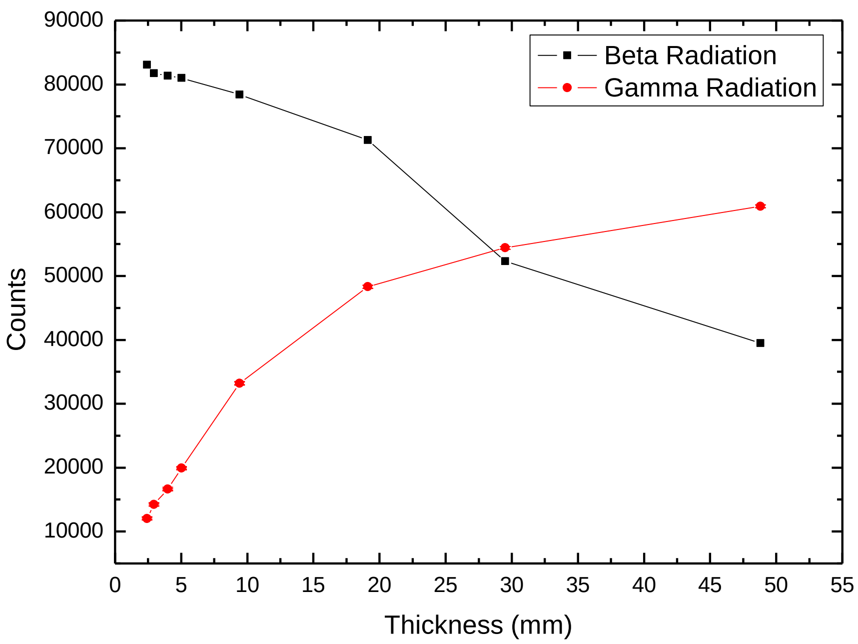


Figure 6. Response of the different scintillator thickness to gamma and beta radiation.

4. CONCLUSIONS

The objectives were achieved. The optimized thickness of the scintillator crystal for beta and gamma radiation was determined. Therefore, in order to obtain a minimum background value for the beta measurements, anti-coincidence between the main detector (2.43 mm thickness) and secondary detector for gamma radiation (well type plastic scintillator detector thickness 50 mm) was designed.

The students of the course "Theoretical and practical fundamentals of the instrumentation used in nuclear data acquisition" presented good results to the experimental and theoretical components involved in this work.

5. REFERENCES

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