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A MODEL OF BETA AND GAMMA INTERACTION AND MONTE CARLO CALCULATION USED FOR THE IONIZATION CHAMBER ENERGY DEPENDENT RESPONSE FUNCTION DETERMINATION

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In this paper a model of beta and gamma interaction is described, which was used for the Monte Carlo calculations of the chamber response energy dependence.

Model used in these calculations is applicable for radiation energy range from 10 keV to 10 MeV. Model includes bremsstrahlung effect as well as corrected cross-sections for photoeffect. Results obtained by these calculations were compared with experimentally obtained data.

Introduction

A good gamma and beta interaction model supported by a program based on Monte Carlo method enables calculations in complex situations such as a dose measurements system with ionization chamber. In the exposure dose measurements it is desirable to have ionization chamber with the energy independent response. Due to the fact that usually the construction materials are not air-equivalent, the energy equilibrium of generated electrons is disturbed which necessitates knowledge of the energy dependence of the chamber characteristics before its construction.

Main characteristics of the interaction models

In the used model out of all possible photon interactions only photoeffect, Compton effect and pair-production are taken into account. For the choice of the most probable process in the interaction event it is necessary to calculate total cross sections for different types of interaction. For Compton interaction Klein-Nishina formula for total cross-section [1] was used

$$\sigma_c = 2\pi r_o^2 \frac{1+\alpha}{\alpha^2}\left|\frac{2(1+\alpha)}{1+2\alpha} - \frac{1}{\alpha}\ln(1+2\alpha)\right| + \frac{1}{2}\ln(1+2\alpha) - \frac{1+3\alpha}{(1+2\alpha)^2} \qquad (1)$$

where $\alpha = h_{\nu o}/m_o c^2$.

For photoeffect the following formula for cross section for nonpolarized photons was used

$$\tau_k = \sigma \frac{4\sqrt{2}}{137^4} \frac{Z^5}{\alpha^{3,5}} \qquad (2)$$

where σ - is the Thompson scattering cross section. In order to have cross-section for photoeffect calculated with smaller error it was corrected with available more correct experimental results [2,3,4].

Calculations for the pair production cross-section were done by standard formula [5].

The next step was to choose the value of the variable. For that procedure one has to have a variable probability function, and in our case for Compton interaction variable was the photon scattering angle ϕ, and the probability function was as follows

$$\sigma_c(\phi_o) = \pi r_o^2 \frac{\alpha(1-\cos\phi_o)^2+2(1-\cos\phi_o)}{2|1+\alpha(1-\cos\phi_o)|^2} + \frac{(2\alpha+1)(1-\cos\phi_o)}{\alpha^2|1+\alpha(1-\cos\phi_o)|} +$$

$$+ \frac{1-\cos\phi_o}{\alpha^2} + \frac{\alpha^2-2(\alpha-1)}{\alpha^3} \ln|1+\alpha(1-\cos\phi_o)| \qquad (3)$$

The beta interaction was treated by using model of group collisions. One calculates probability of delta electron and bremsstrahlung photon formation over a chosen segment of the trajectory. The segments of the trajectory were chosen in such a way that the probability of the catastrophic collisions is smaller than 1%. Details of the model are given in reference [6].

Some characteristics of the computer program

Coordinates of the photon and electron momentum are followed in six-dimensional vectors. The initial number of photons was up to 1000 photons. The loss of the photon energy was calculated step by step. Calculational time for 1000 photons was about four hours for CDC-3600.

Because of the large number of beta collisions, as the first step electron interaction matrices were formed. Calculational time for the case of electron energy up to 10 MeV-a and one material was two hours, for CDC-3600.

Results

For the source-chamber geometry shown in Figure 1, we have calculated the electron energy spectrum for graphite chamber (Figure 2) as well as for chamber with air equivalent material (Figure 3). For chamber filled with air the energy deposited in sensitive volume was calculated. In Figure 4 is shown the dependence of the ratio of measured X(E) and "true" $X_o(E)$ exposure for a chamber with air-equivalent walls, as well as the calculated ratio for ^{137}Cs radiation (E=0.663 MeV).

The approximations used in the model were as follows

- cut of energy of photons and electrons was 10 keV
- it was taken that electrons and photons of energies less than 10 keV lose all their energy at the point of interaction
- that the energy spectrum's shape in the sensitive volume was unchanged.

Conclusion

One can consider that the used interaction model, with discussed approximations, is quite acceptable. Model of beta interaction was verified by comparison with experimental results.

In the study to come we are intending to modify and examine the interaction models which will give even better results.

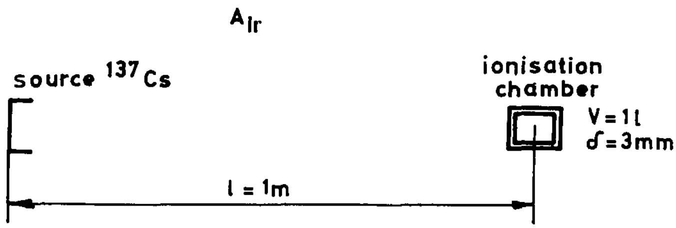

Fig.1. Source-chamber geometry used in the calculations

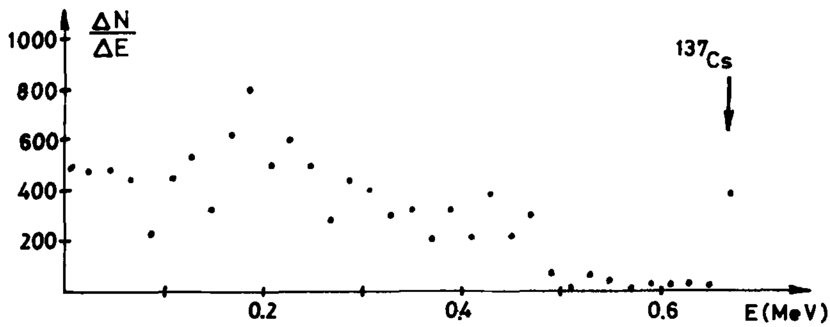

Fig.2. Energy spectrum of the electrons generated in the chamber with carbon walls

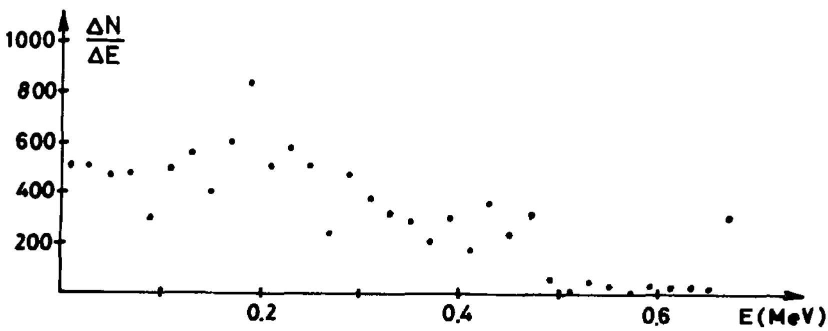

Fig.3. Energy spectrum of the electrons generated in the air-equivalent wall of the chamber

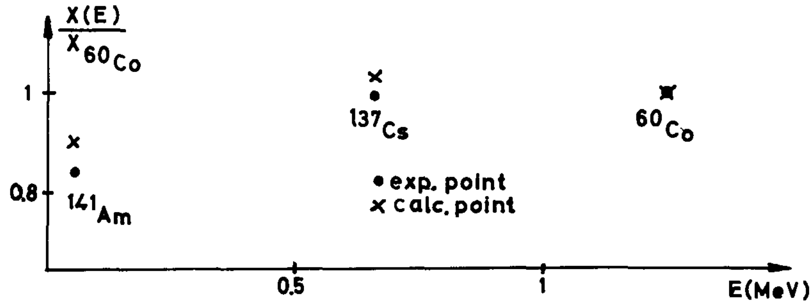

Fig. 4. Ratio $X(E)/X_o(E)$

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