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Monte Carlo Simulations of Resistive Plate Chamber for 0.511 MeV Photon with FLUKA

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We report the simulation results of resistive plate chamber for 0.511 MeV photons using FLUKA code. The efficiency of resistive plate chamber is directly related to the number of electrons produced in the gas gap. Therefore, the type of converter materials and thickness are important parameters for resistive plate chamber detection performance. In this work, the FLUKA based simulations for parallel and isotropic photons were operated for detection efficiency by choosing different converter materials and thicknesses.

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1. Introduction

The resistive plate chambers (RPCs) are very successful parallel plate gaseous detectors, since their design in 1981 [1]. The typical RPCs have got two parallel electrodes with high resistivity of about (10^{10}–10^{12}) Ωcm, which are separated to a gas gap of a few mm (Fig. 1). They are widely used in many applications from high-energy physics experiments to medical imaging systems in that good space and time resolution and high efficiency. RPCs perfect time resolution allows being an alternative to the scintillators to measure the time of flight (TOF) of photons.

In the literature, it is possible to find several simulation works both on the RPCs [2–9] and also on other fields [10–13]. In this study, we have focused on the sensitivity of single-gap RPC for 0.511 MeV energy photon source. We have described all possible photon interactions with the different glass electrode materials at the FLUKA simulation program [14]. We used glass electrodes of five different compositions, marked as ordinary glass (1), boro-silicate glass (2), soda-lime glass (3), lead glass (4) and Pyrex (5).

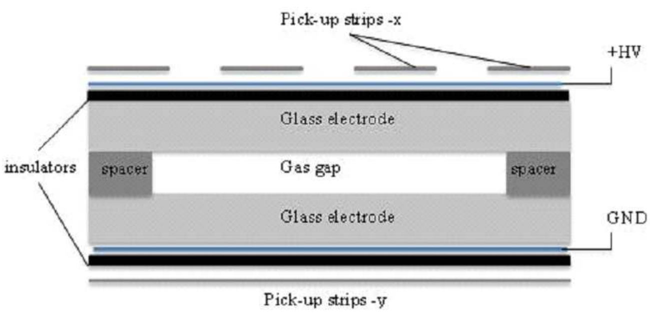

Fig. 1. The schematic illustration of typical RPC design.

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2. The RPC simulation setup

In this work, the FLUKA Monte Carlo code was used. The input file was prepared for the traditional single-gap RPC design, which has the 10×10 cm^2 surface area. The properties of each material are given in Table I. FLUKA inputs have been run for 1, 2, 3, and 4 mm thicknesses of electrodes. In the calculations, the gas gap was taken as 2 mm thick. The physical processes in the gas volume were not considered in this study, only sensitivity of the RPC detector was investigated.

The glass electrodes were exposed to 0.511 MeV energy isotropic and pencil photon beam. Pencil photon beam is perpendicularly impinging on the RPCs surface. The energy cut off 0.01 MeV for electron, 0.001 MeV for photon was applied in the FLUKA input. The simulation was started with 10^7 primary photons. Incoming 0.511 MeV energy primary photons are converted to electron via the interactions of Compton and photoelectric. These possible interactions have been taken into account in our simulation.

TABLE I

Glass electrodes material composition [%].

type	1	2	3	4	5
Na	9.6	3	10	–	2
Si	33.7	26	25	8.1	25
Ca	10.7	–	3	–	–
O	46	60	60	15.6	65
B	–	9	–	–	7
Al	–	2	1	–	1
Mg-	–	1	–	–	
Ti	–	–	–	0.8	–
As	–	–	–	1	–
Pb	–	–	–	75.2	–

3. The simulation results

To investigate the sensitivity, the number of electrons that reach the gas gap for five different glass electrodes and for different thicknesses (1, 2, 3, 4 mm) of them have been calculated. The sensitivity can be defined as $s = N/N_0$, where N_0 is the number of primary photons entering the RPC chamber surface, N is the electron yield in the gas gap. The electron yield is directly related to the photon interactions in the electrode materials. Therefore, the Compton and photoelectric interactions are important at the calculations of simulation for 0.511 MeV energy photons and they have also been taken into account in the FLUKA input files. Also, the calculations were repeated for different thicknesses of materials because thickness affects the number of electrons reaching to the gas gap. In this case, with the increasing thickness, the number of scattering electrons through the electrode material increases. The sensitivity results were given in Table II for isotropic and pencil photon beam. The simulation results show that the photon sensitivity slowly decreases with the increase of the thickness of the electrodes.

TABLE II

FLUKA simulation results for different thicknesses of RPC electrode materials.

Thickness	1	2	3	4	5
isotropic photon source					
1 mm	0.0019667	0.0020048	0.0020021	0.0048322	0.0021491
2 mm	0.0018322	0.0020666	0.0017765	0.0043058	0.0018424
3 mm	0.0016428	0.0018731	0.0017664	0.0030818	0.0017078
4 mm	0.0015717	0.0016231	0.0036583	0.0027186	0.0016297
pencil photon beam					
1 mm	0.0031632	0.0030945	0.0035168	0.0072818	0.0031232
2 mm	0.0038624	0.0030376	0.0033528	0.0078944	0.0031344
3 mm	0.0029728	0.0030328	0.0031688	0.0065056	0.0034696
4 mm	0.0030056	0.0031185	0.0028608	0.0067776	0.0030232

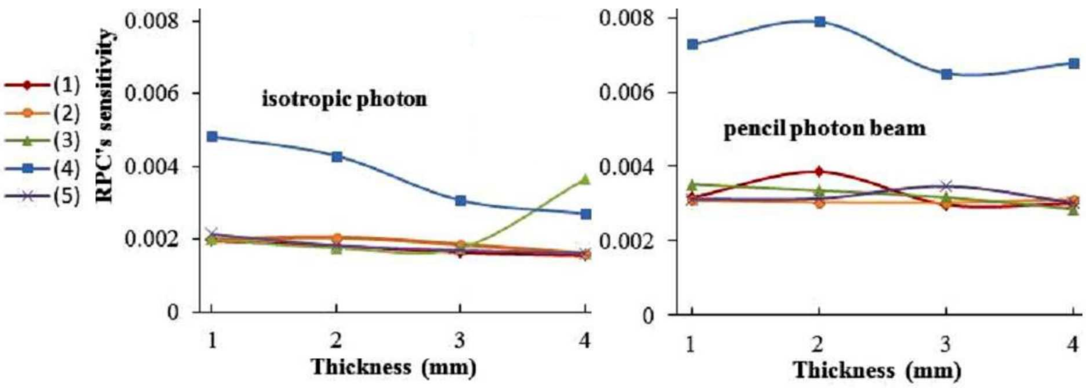

Fig. 2. Variation of RPC sensitivity with thickness of the five different electrode materials calculated by FLUKA for isotropic and pencil photon beam.

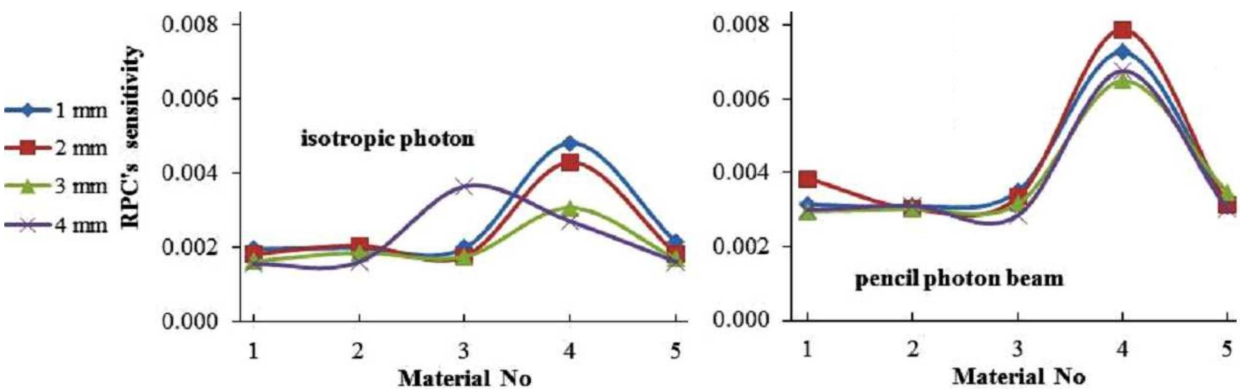

Fig. 3. Variation of RPC sensitivity depending on the type of the glass electrodes as calculated by FLUKA for isotropic and pencil photon beam.

The RPC photon sensitivity obtained by the FLUKA simulation as a function of the material thicknesses was shown in Fig. 2. The highest photon sensitivity was obtained for the glass-lead electrode material with 2 mm thickness. The sensitivity values for all the other electrodes are almost the same. It can be seen that comparatively higher sensitivities were obtained for the pencil photon beam.

It was assigned a number to each electrode material as given in Tables I, II and the sensitivity results depending on the type of glass material were plotted in Fig. 3. The value of sensitivity of material 4 (glass-lead) with 2 mm thickness was obtained as 0.008 for pencil photon source. It was observed that this value dropped to 0.004 for isotropic photon source. The isotropic photons with low energy having lower interaction cross-section lead to decrease in the number of electrons that reach the gas gap so the sensitivity will be decreased.

4. Conclusion

We have presented the simulation results of the photon sensitivity for typical single-gap RPC design. To understand how the electrode material type and thickness can affect the photon sensitivity of RPC, we have chosen five different glass electrodes with 1, 2, 3, and 4 mm thickness in the calculations of FLUKA simulation. In all calculations, we have used the isotropic and pencil photon source with energy of 0.511 MeV. The results show that the sensitivity depends on electrode material type and thickness. The highest sensitivity value was obtained for the glass-lead material with the thickness of 2 mm for pencil photon source. While the values of sensitivity for glass-lead electrode are evidently changed depending on the thickness, the other ones are slowly. The sensitivity value for the pencil photon source was obtained almost twice more than isotropic results.

The single-gap RPC sensitivity for 0.511 MeV photons is very low. In this work, we focused on the glass material type and thickness. In order to improve it, the number of gas gap parameters can be included at the widely used calculations of FLUKA simulation. Currently we are working on simulation including the number of gaps.

Acknowledgments

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