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RPC γ sensitivity simulation

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Abstract

A method to simulate the Resistive Plate Chambers (RPCs) γ sensitivity has been developed using a Monte Carlo code. The sensitivity has been evaluated as a function of the γ energy in the range 0.1–100 MeV and for different spectra. To evaluate the response of the detector in a Large Hadron Collider (LHC) background environment the γ energy spectrum expected in the CMS muon barrel has been taken into account and the RPC γ sensitivity evaluated as a function of the detector size. © 2000 Elsevier Science B.V. All rights reserved.

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1. Introduction

Several studies [1,2] have shown that Resistive Plate Chambers (RPCs), as well as other detectors at the Large Hadron Collider (LHC), will work in a hostile radiation background mostly made of γs and neutrons. To understand how this background could affect the detectors functionality we need to know their sensitivity to these kinds of radiation. The aim of this paper is to estimate the RPCs γ sensitivity in an energy range from 0.1 to 100 MeV. To transport γs and electrons in a tridimensional geometry the Monte Carlo code MCNP-4B [3] was used.

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2. Geometry and sources

The appropriate materials and the geometry of a CMS-like double-gap RPC [1,2] were input to the code. We assumed moreover the usual RPC gas mixture.[1] To assure a good mechanical rigidity, standard RPCs were usually assembled with an external (preloaded) plate made of a thin (100 μm) aluminum layer glued to a PVC foam (1 cm); CMS-like double-gap RPCs subtitute this external plane with commercial (preloaded) aluminum bars transversally fixed along the detector surfaces. Since the RPC sensitivity is correlated to the quantity of matter crossed by the incident γs both configurations were first studied and the results

[1] 3% iC_4H_{10}–97% $C_2H_2F_4$.

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compared. In the following the first configuration will be referred to as *with* PVC while the latter to as *without* PVC.

The γ source was chosen to be (a) an isotropic source evenly distributed on the entering surface of the chamber; (b) a γ beam impinging normally on the chamber.

For each source configuration, the sensitivity was evaluated at 11 points: 0.1, 0.2, 0.4, 0.662 (^{137}Cs), 1.25 (^{60}Co), 2, 5, 10, 25, 50 and 100 MeV. An energy cut at 0.001 MeV for both γ and electrons was also applied.

3. Sensitivity

Signals in RPCs exposed to γs are expected to be generated by photoelectric, Compton and pair-production reactions according to the γ energy. The relative contribution of the three processes, in terms of first-produced electrons, is shown in Fig. 1. To establish an upper limit for the sensitivity we assumed each electron reaching a gas gap as producing a signal; however, if during the transport of a single photon, more than one electron reaches the same gap, only the first one is assumed to produce a detecting signal; this assumption is supported by the fact that the time duration of this process, since the source photon extraction, is at maximum of the order of few nanoseconds. Moreover, any cluster size contribution was not taken into account.

Three separated classes of signals were counted: signals only in the first gap, signals only in the second gap and simultaneous signals in both gaps.

According to all the above assumptions, the RPC γ sensitivity ε was defined as $\varepsilon = N_e/N_\gamma$, where N_γ is the number of photons crossing the entering surface of the chamber and N_e the number of the first electrons (for each history) that enter only the first gap, only the second gap or both. As mentioned ε was evaluated as a function of the γ energy E_γ.

Simulated γ RPC sensitivity as a function of E_γ for different RPC and source configurations are compared in Fig. 2. The results show that below about 2 MeV the sensitivity does not depend on the source and RPC configuration; above this energy the RPC sensitivity is higher for an isotropic source ((a) and (c)) than for a parallel beam ((b) and (d)). In the first case indeed (isotropic source), photons entering the chamber sideways have a higher interaction probability.

It would be interesting to visualize which is the relative contribution of the signal classes to the

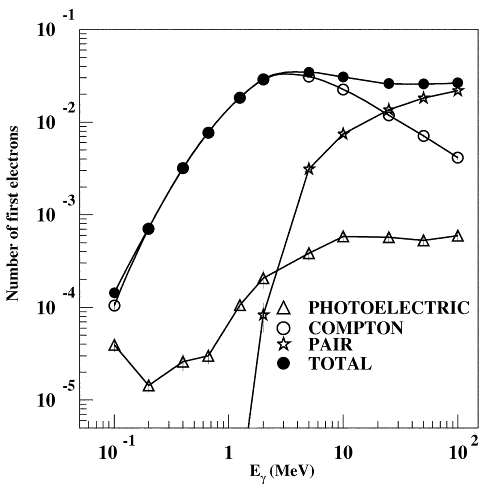

Fig. 1. Number of first electrons crossing a *without* PVC $20 \times 20\,\text{cm}^2$ RPC gap vs. γ energy. The relative contributions due to photoelectric effect, Compton scattering and pair-production are evidenced.

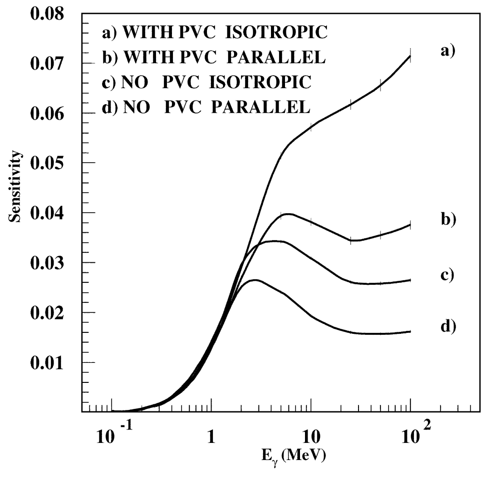

Fig. 2. Simulated γ RPC sensitivity vs. E_γ. Different RPC and source configurations are compared: (a) RPC *with* PVC and isotropic source; (b) RPC *with* PVC and parallel beam source; (c) RPC *without* PVC and isotropic source; (d) RPC *without* PVC and parallel beam source.

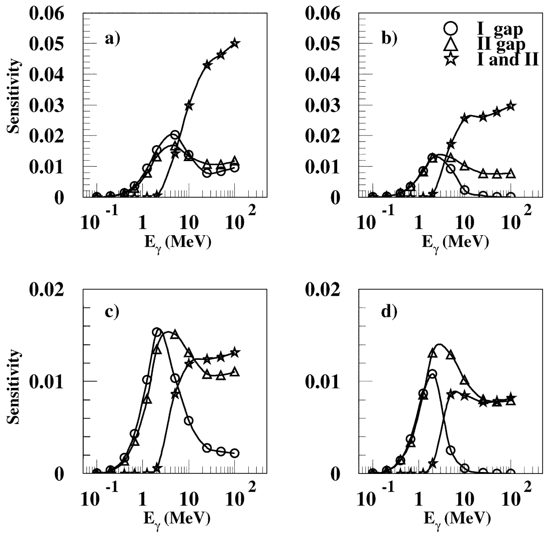

Fig. 3. γ RPC sensitivity vs. E_γ. The separated contributions from the three classes (as specified on the text) are evidenced for different RPC and source configurations: signals from the first gap (open circles), signals from the second gap (open triangles), signals from both gaps (open star); (a) isotropic source *with* PVC, (b) parallel beam *with* PVC, (c) isotropic source *without* PVC, (d) parallel beam *without* PVC.

sensitivity curves shown in Fig. 2. This is done in Fig. 3 where the γ sensitivity due to signals from one gap only, from the other gap only and from both gaps are evidenced. The preceding figures were obtained by considering a double-gap $20 \times 20\ \mathrm{cm}^2$ RPC. However, the CMS and the ATLAS experiments will use large area RPCs and their γ sensitivity might be different according to the detector size. We studied this possibility by estimating the sensitivity as a function of the detector area; the results, for an isotropic source, are shown in Fig. 4 for four different energies. As one can see the sensitivity increases with the size of the RPC and its slope, at a fixed RPC area, increases with energy. As an example a RPC like those used in the first station of the CMS muon barrel (typically about $5\ \mathrm{m}^2$ large) reaches 90% of its full sensitivity at about 1.25 MeV while at 100 MeV the sensitivity curve is still increasing.

For a parallel beam source (not shown in figure) the sensitivity is instead independent from the detector area.

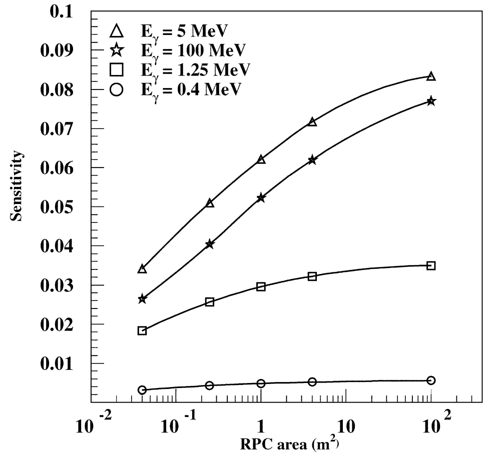

Fig. 4. γ sensitivity as a function of the RPC area; curves corresponding to only four energies are displayed: 0.4, 1.25, 5, and 100 MeV.

4. Conclusions

The method illustrated in this paper might be used to estimate the sensitivity for different experimental environments according to the various γ spectra. As an example we used the CMS photon spectrum [1,2] of Fig. 5 to estimate the RPC γ sen-

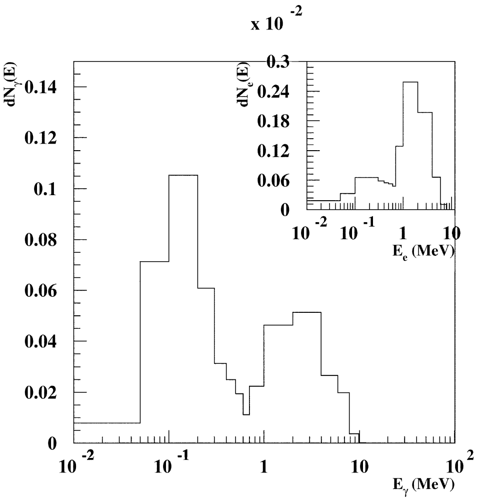

Fig. 5. CMS Muon Barrel (MB1) γ spectrum that enters the RPC. The upper frame shows the resulting electrons spectrum into the gaps.

Table 1
Total RPC sensitivity estimated with a CMS MB1 γ spectrum[a]

	RPC area (cm^2) 20×20	RPC area (cm^2) 250×250
I gap	0.75×10^{-2}	1.00×10^{-2}
II gap	0.64×10^{-2}	0.94×10^{-2}
I and II gaps	0.18×10^{-2}	0.26×10^{-2}
Total	1.57×10^{-2}	2.20×10^{-2}

[a] Values are calculated for two RPC sizes and for each signal class (as explained in the text). Statistical errors are within 1%.

sitivity with an isotropic source. The spectrum of the first electrons crossing the gaps is plotted in the inserted frame; the total sensitivity can be directly calculated from the ratio of each spectrum area. The numerical values are summarized in Table 1 where the total γ sensitivity and the signal classes contribution are reported for two values of the RPC area. According to these values and to the above spectrum, one can estimate in the CMS MB1 stations a RPC hit rate due to γ of about 10 Hz/cm^2.

References

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