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Gamma Background Simulation for the RPC Endcap and Barrel regions of CMS/LHC using GEANT4

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We present results for the CMS-RPC sensitivity to gamma rays which were simulated with GEANT4 Monte-Carlo Code. The simulations were performed as a function of gamma energy in a range from 0.007 to 1000 MeV. In order to evaluate the γ-induced rates in the CMS muon system, the gamma spectra expected in the CMS endcap and barrel regions were taken into account. The estimated rates induced by an isotropic gamma source in the ME1, ME2, ME3, and ME4 were 138.0, 42.0, 29.0, and 28.0 Hz/cm^2, respectively, when the GEANT4 standard electromagnetic package was used for the simulations. Whereas, the hit rates estimated for the MB1 and MB4 stations were $\sim$ 0.4 and 1.26 Hz/cm^2, respectively, when the same gamma-ray source and the same GEANT4 package were employed for the simulatiom.

1. Introduction

Resistive Plate Chambers (RPCs) play a significant role in the muon trigger for the future Large Hadron Collider(LHC) experiments[1]. At LHC, the beam provides an energy of about 20 interaction per bunch crossing at beam frequency of 40 MHz. The environment will be strongly influenced by γ- and neutron-induced background whose expected rate varies for modules located in different regions of the CMS detector. The expected overall dose arise by a 10-year exposure ranges from 1 Gy (for the barrel-region detectors) to 100 Gy (for the endcap region detectors).

This high-level of background may introduce a severe radiation damage to all the detectors and the electronic components. Therefore, it is important to constantly monitor their radiation level. The motivation of this study is to estimate the hit rates for the gamma backgrounds which will be present in the CMS endcap- and barrel-region RPCs. The gamma-ray events were generated in the RPC double-gap tri-dimensional geometry by means of GEANT4 Monte Carlo code.

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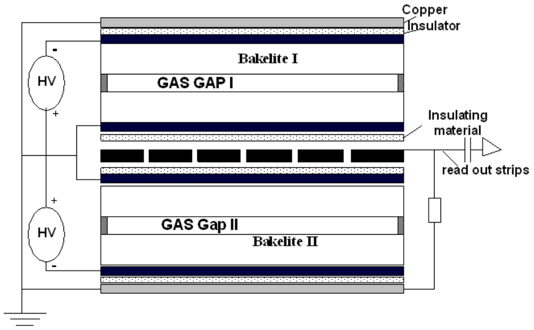

Figure 1. Basic RPC configuration used in the simulation.

2. Monte Carlo Simulation of RPC with GEANT4

As the scale and the complexity of high energy physics experiments increase, simulation studies become more essential to design and optimize the detectors, to develop and test the reconstruction and analysis programs, and to interpret the experimental data. GEANT is a system of detector description and simulation tools that help physicists in such studies. In particular, GEANT4 provides Packages specialized for modeling both electromagnetic and hadronic physics interactions. In the present studies, the results concerning the following GEANT4 electromagnetic Packages will be discussed:

- Standard Energy Package;
- Low Energy Package, based on Livermore data Libraries [2–4].

2.1. GEANT4 Standard Energy Package

The Standard Energy Package[5] provides a variety of models based on approaches to the description of electrons, positrons, photons and charged hadrons interaction in the energy range from 1.0 keV to 100 TeV. These models assume that the atomic electrons are quasi-free, while the atomic nucleus is fixed. The GEANT4 Standard Package is mainly addressed to the high energy physics domain.

2.2. GEANT4 Low Energy Package

The Low Energy Package [5,6] extends the range of accuracy of electromagnetic interactions down to lower energies than the GEANT4 Standard Package. This Low Energy Package exploits evaluated data libraries (EPDL97 [2], EEDL[3] and EADL[4]) which provide data for the calculation of the cross-sections and the sampling of the final state necessary for modeling photon and electron interactions with matter. The current implementation of low energy electron processes can be used down to 250 eV. This Package also handles the ionization by hadrons and ions [7].

3. RPC working principle and its Configuration used in the present work

Resistive Plate Chambers have good time resolutions high detection efficiencies at low costs and with the possibility of being segmented as needed. Fig. 1 shows the structure of double-gap RPC. The double- gap RPC consists of a stack of resistive bakelite plates, separated one from the other by spacers of equal thickness creating a series of gas gaps (two gas gaps of about 0.2 mm). The outer surfaces of resistive material are coated with conductive graphite paint to form the HV and ground electrodes. A non-flammable gas mixture which contains 97% tetra-fluoro-ethane and 3% iso-butane is used. The operation of RPC is easy to explain. A high-energy primary particle passing through the detector ionizes some atoms of the gas. The detector sensitivity is the sum of the contribution of the gas ionization, and the ionization in the electrode layer closer to the gas gaps. The basic structure components of double-gap RPC(e.g., insulator, gas gaps, bakelite electrodes etc) were inserted to the GEANT4 code [1,8]. In the present simulation studies, efficiencies of the RPC has been evaluated as a function of gamma energy in the range from 0.007 to 1000 MeV. Gamma particles were simulated by GEANT4 code using Standard and Low energy electromagnetic Packages.

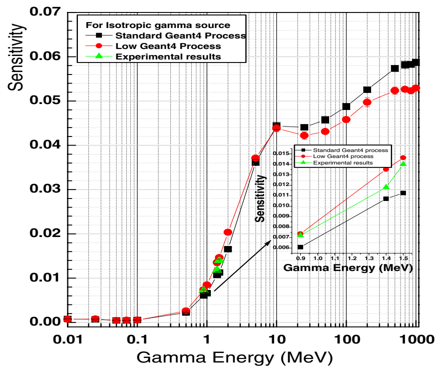

Figure 2. Comparison of GEANT4 Standard and Low electromagnetic processes and measured efficiency for the RPC set-up.

4. Simulation Results

In order to obtain the RPC response or its sensitivity for a gamma ray, we applied the assumption that each produced charged particle generates a signal to the read-out strips, on arriving

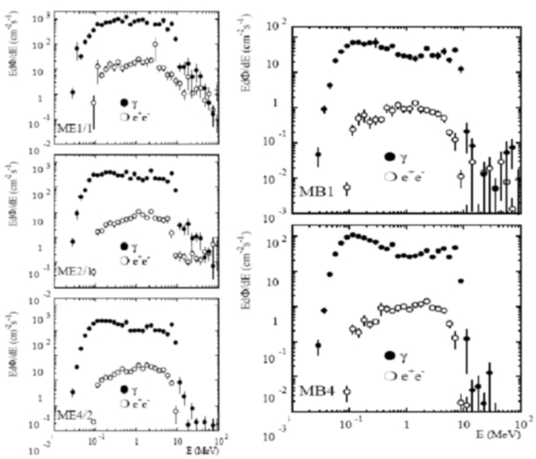

Figure 3. (a)Gamma background spectra in the CSC gas layers of ME1/1, ME2/1, and ME4/2 (left side), (b)Gamma background spectra in the Drift Tubes gas layers of MB1, and MB4 (Right side).

at the RPC gas gap; if more than one charged particle reach the gas gap, only the 1st one is assumed to generate a signal. The sensitivity ε in our code is obtained from; $\varepsilon = N_i/N_o$. Where N_o is number of original primary particles impinging on RPC and N_i is the number of charged particles arriving at any of the two gas gaps. In order to obtain a statistical uncertainty of less than 1%, a large number of photon events, ranging from 10^5 to 10^6, was generated. In order to check the physics models, a comparative simulation was carried out using GEANT4 Standard and Low electromagnetic physics (see Fig. 2).

The results obtained with GEANT3 and GEANT4 are compared with experimental data in Table 1. For the double-gap RPC configuration with 2 mm gas gap, the present simulated gamma sensitivity results are in agreement with the previous GEANT3 simulation results [9]. By employing GEANT4 Standard electromagnetic process simulation code, the double-gap RPC sensitivity for an isotropic γ source is $s_\gamma < 5.9 \times 10^{-2}$ for E_γ < 1000 MeV. Similarly for GEANT4 Low electromagnetic process the double-gap RPC sensitivity for an isotropic γ source is $s_\gamma < 5.29 \times 10^{-2}$ for $E_\gamma < 1000$ MeV.

For simulating the endcap region of the RPC for gamma rays, we applied our preliminary results to Fig. 3(a) of the CMS muon TDR (CERN/LHCC 97-32), which shows the particle spectra in CSC gas layers of ME1/1, ME2/1 and ME4/2. The assumption that we could employ our simulation results shown in Table 2, to these regions is based on the fact that both the CSCs and the RPCs in the endcap area of CMS have same locations. Similarly for barrel area hit rate estimation, we applied the simulation results to Fig. 3(b), which shows gamma background spectra in the drift tube gas layers of MB1 and MB4. The hit rate can be found by employing the same number of particles impinging on the RPC, and thus the sensitivity values were evaluated. In the first step, the obtained sensitivity values were applied at bin by bin to the Fig. 3(a) and Fig. 3(b), and summed up. In the next step, the summed up sensitivities values were divided by the total number of gamma's, which were the average sensitivities in those regions. Finally applying those

Energies	Double-gap RPC Sensitivity		
	Experimental	GEANT3	GEANT4
0.9 MeV	0.72×10^{-2}	0.92×10^{-2}	0.73×10^{-2}
1.4 MeV	1.18×10^{-2}	1.60×10^{-2}	1.3×10^{-2}
1.5 MeV	1.40×10^{-2}	1.90×10^{-2}	1.46×10^{-2}

Table 1
Summary of the experimental and simulated gamma sensitivity results.

results to Fig. 10.6.3 of the CMS muon TDR gave the total hit rate of gamma's in those regions.

Particles	Simulation	Regions	GEANT4 Packages	
			Standard	Low
γ	Sensitivity ($\times 10^{-2}$)	ME1	1.38	1.40
		ME2	1.38	1.50
		ME3	1.15	1.36
		ME4	0.93	1.22
	Rates (Hz/cm^2)	ME1	138.0	140.0
		ME2	42.0	45.0
		ME3	29.0	5.0
		ME4	28.0	33.0

Table 2
CMS/RPC endcap region gamma sensitivity, and background hit rate results.

5. Conclusions

A simulation studies of the RPC's sensitivity for gamma was done, and the results are applied to the CMS/RPC endcap and barrel regions. The present simulated gamma sensitivity results are in good agreement with the experimental results reported in [9, 10]. The obtained results are summarized in Table 1, 2, and 3, in which the gamma sensitivities and their respective energy values are reported for the RPC. According to these numerical values, we can estimate that the CMS endcap ME1, ME2, ME3, and ME4 will have a hit rate due to an isotropic gamma source (using GEANT4 Standard electromagnetic Package) of about 138.0, 42.0, 29.0, and 28.0 Hz/cm^2 respectively. Using the same source and Package for the region of CMS MB1, and MB4, the hit rate would be about 0.4 and 1.26 Hz/cm^2, respectively. Similar characteristics of gamma hit rates have been observed for GEANT4 Low electromagnetic Package.

GEANT4	γ sensitivity		Rates (Hz/cm^2)	
	MB1	MB4	MB1	MB4
Standard	9.74×10^{-3}	7.09×10^{-3}	0.4	1.26
Low	1.25×10^{-2}	9.49×10^{-3}	0.5	1.70

Table 3
CMS/RPC barrel region gamma sensitivity, and background hit rate results.

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