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Simulation of Resistive Plate Chamber sensitivity to neutrons

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Abstract

The Resistive Plate Chambers (RPCs) sensitivity to neutrons has been simulated using GEANT code with MICAP and FLUKA interfaces. The calculations have been performed as a function of the neutrons energy in the range 0.02 eV–1 GeV. To evaluate the response of the detector in the LHC background environment, the neutron energy spectrum expected in the CMS muon barrel has been taken into account; a hit rate due to neutrons of about 0.6 Hz cm^{-2} has been estimated for a $250 \times 250\,cm^2$ RPC in the RB1 station. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: Resistive plate chambers; Neutron sensitivity; GEANT-MICAP

1. Introduction

To understand how the neutron background at the Large Hadron Collider (LHC) could affect the functionality of the Resistive Plate Chambers (RPCs) we have estimated the sensitivity of these detectors to neutrons in an energy range from 0.02 eV to 1 GeV. Neutrons were transported by means of the GEANT 3.21 [1] using MICAP interface at low energies ($E_n < 20$ MeV) and the FLUKA one at higher energies.

2. Geometry and sources

The appropriate materials and the geometry of a CMS like double gap RPC [2] (two gaps with common readout strips) and the usual RPC gas mixture (3% iC_4H_{10} 97% $C_2H_2F_4$) were input to the code. Two configurations for a 20×20 cm^2 RPC were studied; materials and their thickness are shown in Table 1.

Two types of neutrons source were chosen: a neutron beam impinging normally on the chamber and an isotropic source evenly distributed on one of the two chamber surfaces (the entering surface in the following; the gap near this surface will be referred as "I" while the other one as "II"). For each source configuration the sensitivity was evaluated at 17 energies: 2×10^{-8}, 1×10^{-7}, 1×10^{-6}, 1×10^{-4}, 1×10^{-3}, 0.1, 0.5, 1, 2,5,10, 25, 50, 100, 250, 500, 1000 MeV. An energy cut at 0.01 eV for neutrons, at 100 keV for protons and at 10 keV both for γ and electrons was applied.

3. Sensitivity

To establish an upper limit for the sensitivity we assumed that each charged particle reaching a gap

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Table 1
Thickness of RPC materials used in the simulation

Material	With PVC thickness (cm)	Without PVC thickness (cm)
Aluminum	0.06	
PVC	1	
Aluminum	0.01	0.06
Polyethylene	0.03	0.03
Bakelite	0.2	0.2
Gas	0.2	0.2
Bakelite	0.2	0.2
Aluminum	0.01	0.01
Bakelite	0.2	0.2
Gas	0.2	0.2
Bakelite	0.2	0.2
Polyetilene	0.03	0.03
Aluminum	0.01	0.06
PVC	1	
Aluminum	0.06	

produces a signal; however, if during the transport of a single neutron, more than one charged particle reaches the same gap, only the "first" one is assumed to produce a detectable signal. Charged particles considered here were electrons, positrons, protons and α.

The single gap sensitivity of the "I" ("II") gap was defined as $N_I/N_n(N_{II}/N_n)$, where N_n is the number of neutrons crossing the entering surface of the chamber and N_I (N_{II}) the number of 'first' charged particles entering the "I" ("II") gap. The double gap sensitivity was defined as $N_{I\text{ or }II}/N_n$ where $N_{I\text{ or }II}$ is the number of the charged particles that enter the first or the second gap; according to this definition the double gap sensitivity is the sum of that of two single gap minus the contribution due to charged particles crossing both gaps.

4. Results

In Fig. 1, the double gap sensitivity as a function of E_n for a 20×20 cm^2 RPC is shown for different geometry and source configurations: RPC "without PVC" and parallel beam, RPC "without PVC" and isotropic source, RPC "with PVC" and

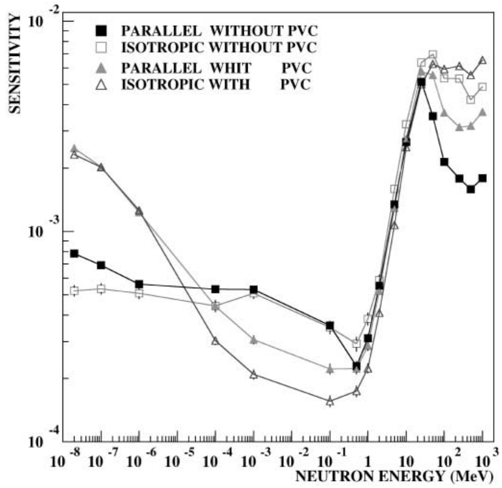

Fig. 1. Double gap RPC sensitivity vs. E_n. Different RPC (20× 20 cm^2) and source configurations are compared: RPC "without PVC" and parallel beam source (full squares), RPC "without PVC" and isotropic source (empty squares), RPC "with PVC" and parallel beam source (full triangles), RPC "with PVC" and isotropic source (empty triangles).

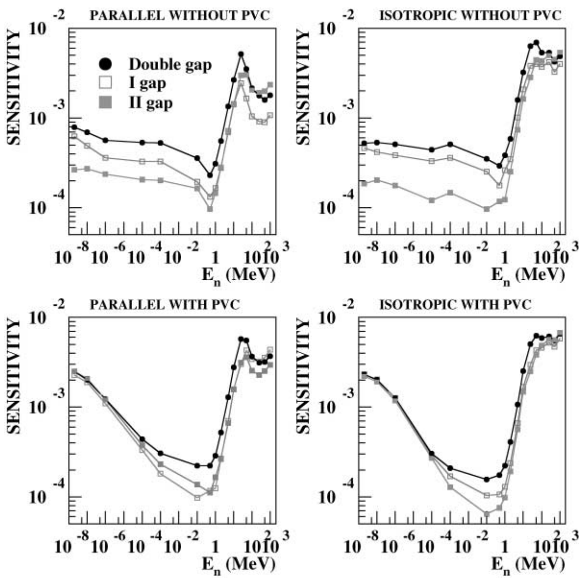

Fig. 2. Double gap RPC sensitivity vs. E_n; the contributions from the gaps "I" and "II" are evidenced for different RPC and source configurations: double gap sensitivity (full circles), gap "I" sensitivity (empty squares), gap "II" sensitivity (full squares).

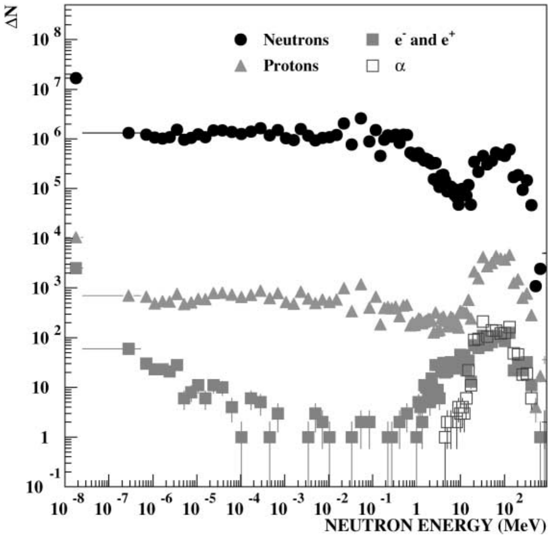

Fig. 3. CMS Muon Barrel (RB1) neutron spectrum (full circles) that enters the RPC. The resulting number of 'first' charged particles entering the gaps is superimposed: electrons and positrons (full squares), protons (full triangles) and α (empty-squares).

parallel beam, RPC "with PVC" and isotropic source.

Starting from 1 MeV the RPC sensitivity is higher for an isotropic source than for a parallel one, and in case of a "with PVC" than a "without PVC".

The presence of PVC rises the sensitivity in the low-energy region ($E_n < 1 \times 10^{-5}$ MeV) where it is mostly due to the γ coming from (n,γ) capture reactions whose cross-section rises at lower neutron energies ($\sigma \propto 1/\sqrt{E_n}$). At higher energies ($E_n > 1$ MeV), the sensitivity rises rapidly and reaches a maximum as a consequence of protons produced by elastic scattering on H and by (n,p) reactions on C, O and Al. In fact for 15 MeV incoming neutrons the produced protons have a range of ≈ 0.2 cm in bakelite which allows them to reach the "I" gap whenever they are produced in the first layer of bakelite of a "without PVC" RPC.

Table 2
RPC sensitivity estimated with a CMS RB1 neutron spectrum[a]

	RPC area (cm^2) 20×20	RPC area (cm^2) 250×250
Sensitivity	0.97×10^{-3}	1.19×10^{-3}
Hit rate Hz cm^{-2}	0.45	0.55

[a] Values are calculated for two RPC sizes; statistical errors are within 1%

Fig. 2 shows the double gap RPC sensitivity ("I or II") and the contributions of the gaps "I", and "II".

5. Conclusions

The method illustrated here might be used to estimate the sensitivity for different experimental environments according to the various neutron spectra. We inputed the expected CMS neutron spectrum [2] reported in Fig. 3 to estimate the RPC sensitivity with an isotropic source; the spectra of the first charged particles (protons, electrons and positrons, and α) crossing the gaps are superimposed; the total sensitivity can be directly calculated from the ratio of the spectra areas; the results are reported in Table 2.

We can conclude that a CMS RB1 chamber will have a hit rate due to neutrons of about 0.6 Hz/cm^2.

References

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[2] CMS Muon Technical Design Report CERN/LHCC/97-32, December 97; ATLAS Muon Technical Design Report CERN/LHCC/97-22, May 97.