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Experimental results on RPC neutron sensitivity

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Abstract

RPC neutron sensitivity has been studied during two tests done with different neutrons energies. In the first test, neutrons from spontaneous fission events of ^{252}Cf were used (average energy 2 MeV); while in the second test neutrons were produced using a 50 MeV deuteron beam on a 1 cm thick beryllium target (average energy 20 MeV). Preliminary results show that the neutron sensitivity in double gap mode is $(0.52 \pm 0.03) \times 10^{-3}$ at about 2 MeV and $(5.3 \pm 0.5) \times 10^{-3}$ at about 20 MeV.

Keywords: Resistive plate chamber; Gamma sensitivity; Neutron sensitivity; Compact muon solenoid

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1. Introduction

Resistive Plate Chambers (RPCs) have been chosen as a part of the muon subdetector for the CMS experiment at the Large Hadron Collider (LHC). The nominal LHC luminosity, 10^{34} cm^{-2} s^{-1}, combined together with the 7 TeV proton beam energy will create a very hostile radiation environment mostly made of neutrons and gamma rays where RPCs will work.

Neutron background energy range, in the regions of the muon stations, is between few meV (thermal neutrons) and 1 GeV. Gamma radiation is mainly due to neutron radiative capture and the energy range starts from virtually zero up to 10 MeV [1].

The RPC detector used during the two tests was a double gap bakelite RPC made of two single gaps with central common read-out strips and independent HV connections. One of the two gaps underwent the traditional treatment of the electrodes with linseed oil. The active area was about 35×35 cm^2. The chamber was equipped with standard RPC front-end board (FEB) and the charge threshold was set to 100 fC [2].

Tests done in our laboratory, on the same RPC, have shown that the detector works in avalanche mode with an efficiency higher than 95% and an applied HV between 9.6 and 9.8 kV. The OR of all the strips was taken as the RPC response.

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2. RPC neutron sensitivity at 2 MeV

During the first test neutrons from spontaneous fissions of ^{252}Cf were used. The RPC under test was placed 30 cm from a ^{252}Cf source. Fission events were counted by detecting the prompt gamma radiation, accompanying the fission, by mean of two BaF_2 scintillators. During fission events there is on average an almost isotropic emission of 3.8 prompt neutrons and 10.3 prompt gammas; the neutrons energy spectrum is shown in Fig. 1(a). Further description of radiation emitted from a ^{252}Cf source can be found elsewhere [3–5].

The RPC was considered efficient to the fission event when a detector signal appears in coincidence with the trigger signal, given by the coincidence of the two BaF_2 scintillators, inside a 50 ns gate. In this way, only the prompt radiation was able to contribute to the measured rate. The direct experimental result is a measure of the probability to reveal the ^{252}Cf spontaneous fission event with the RPC detector. Accidental coincidences between the trigger signal and the RPC signal, due to the detector noise, have been studied using a random trigger and their contribution subtracted.

Shielding techniques were employed to isolate, as well as possible, neutron and gamma components. Shields were made with lead and polyethylene (PE) slabs of different thickness. Experimental data were analysed as a function of the number of effective neutron interaction lengths defined by $X_{\mathrm{eq}} = X_{\mathrm{Pb}}/\lambda^*_{\mathrm{Pb}} + X_{\mathrm{PE}}/\lambda^*_{\mathrm{PE}}$, where X_{Pb} and X_{PE} represent lead and PE thickness in the considered shield, λ^*_{Pb} and λ^*_{PE} are the corresponding neutron effective interaction lengths that take into account the shielding configuration effects on the neutron attenuation. However, using only the experimental data, it is not possible to distinguish between a signal coming from a neutron interaction inside the RPC and a signal coming from other sources: prompt gamma, secondary gamma (produced by neutron interaction outside the RPC) and electron–positron. For this reason the experimental set-up has been simulated using the GEANT 3.21 code. In the simulation, each signal generated into a gap was assigned to the corresponding particles entering the RPC detector. Then, simulation results were used to separate neutron and gamma contribution in the experimental data and, finally, to extract the neutron and gamma sensitivities (more details will be available in a forthcoming paper).

Sensitivity results are shown in Table 1. For prompt gammas that reached the detector surface a significant change in their average energy has been found due to the hardening of the gamma spectrum with the thickness of the shielding material. For this reason two values are given in Table 1. For prompt neutrons and secondary gammas a fit was done using data from all

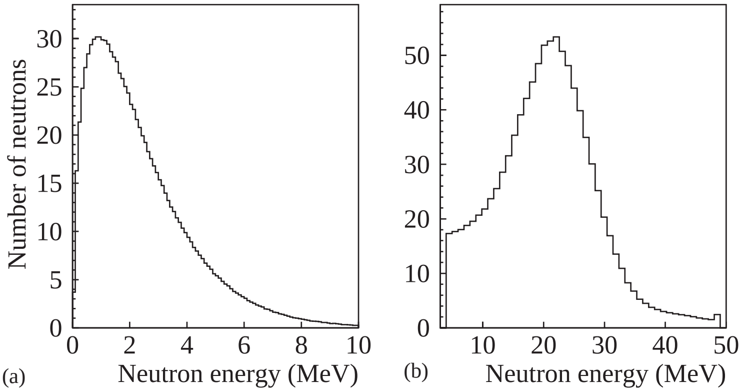

Fig. 1. (a) Prompt neutrons spectrum from ^{252}Cf spontaneous fission events; (b) neutrons energy spectrum from the reaction $^9\mathrm{Be} + \mathrm{d} \rightarrow \mathrm{n} + X$.

Table 1
Summary of the neutron and gamma sensitivity results

Single gap	Sensitivity ($\times 10^{-2}$)	⟨Energy⟩ (MeV)
Prompt γ	0.41 ± 0.04	0.9
Prompt γ	0.81 ± 0.05	1.5
Secondary γ	0.71 ± 0.04	1.4
Neutron	0.028 ± 0.003	1.9
Double gap	**Sensitivity ($\times 10^{-2}$)**	**⟨Energy⟩ (MeV)**
Prompt γ	0.72 ± 0.06	0.9
Prompt γ	1.42 ± 0.07	1.5
Secondary γ	1.19 ± 0.05	1.4
Neutron	0.052 ± 0.003	1.9

configurations since the average energy does not depend on X_{eq}.

3. RPC neutron sensitivity at 20 MeV

During the second test neutron production was based on the reaction $^{9}\text{Be} + \text{d} \rightarrow \text{n} + X$, using a 50 MeV deuterons beam accelerated by the Louvain-la-Neuve cyclotron on a 1 cm beryllium target. The quantity X represents the other particles produced by the deuterons interactions in the beryllium target. Further informations on beam characteristics can be found in Ref. [6]. The absolute flux has been estimated with a relative error of about 20%. The overall neutrons production yield is 6.6×10^{11} neutrons $\mu\text{C}^{-1}\,\text{sr}^{-1}$. Neutron energy spectrum is shown in Fig. 1(b). The average energy is 20 MeV. The RPC detector was placed 91 cm from the beryllium target and was centred with respect to the beam axis.

Neutron sensitivity was measured by evaluating the increase in the RPC counting rate in the case of beam on with respect to the case of beam off. The counting rate with beam off can be attributed to the detector noise.

For the measurement of RPC neutron sensitivity it is very crucial the knowledge of the presence of other particles in the beam (in our case there were mainly protons, electrons and gammas [6]). Neutron sensitivity can be written as $S_n = \text{Rate}/\phi_n - S_\gamma * \phi_\gamma/\phi_n - S_{ch} * \phi_{ch}/\phi_n$, where ϕ_n, ϕ_γ, ϕ_{ch} are the estimated neutron, gamma and charged particles fluxes at the RPC position, while S_n, S_γ, S_{ch} are the RPC sensitivities relative to the same radiations. The beam contamination effect (described by the second and the third term) has been evaluated by means of a simulation study based on the GEANT code. Contributions coming from protons and electrons have been found to be negligible. Gamma contribution was of the order of 0.50×10^{-3} for double gap mode.

Table 2
Summary of the RPC neutron sensitivity results at 20 MeV

	Sensitivity ($\times 10^{-3}$)
Gap II (oiled)	3.0 ± 0.3
Gap I (non-oiled)	2.6 ± 0.3
Double gap	5.3 ± 0.5

Neutron sensitivity results at the working point, after beam contamination subtraction, are shown in Table 2. The main contribution to the estimated error comes from the systematic error on the measured neutron yield, as reported before.

4. Conclusions

RPC neutron sensitivity has been studied at two different energies and preliminary results are summarized in Tables 1 and 2. In double gap mode neutron sensitivity is $(0.52 \pm 0.03) \times 10^{-3}$ and $(5.3 \pm 0.5) \times 10^{-3}$ at average energy of 2 and 20 MeV, respectively. Fig. 2 shows a comparison between the experimental data and the simulation results on neutron sensitivity as a function of the neutron energy. Horizontal bar of the experimental points in Fig. 2 indicate the neutron energy range during the test. A good agreement between experimental data and simulated results is noticed in all cases: oiled gap, non-oiled gap and double gap.

Gamma sensitivity measurement obtained during the first test, with a ^{252}Cf source, has been reported in Table 1 and is always greater than neutron sensitivity.

As expected, double gap sensitivity is about twice the single gap sensitivity.

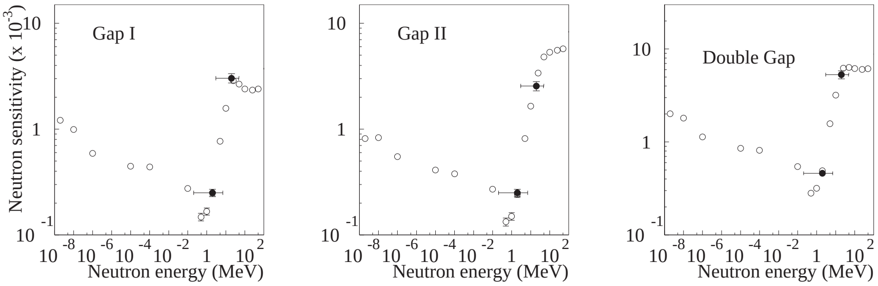

Fig. 2. RPC neutron sensitivity: comparison between experimental data (full circles) and simulation results (open circles).

Both neutron and gamma sensitivity has been found to be independent of the electrodes internal surface treatment with linseed oil.

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