

For Publisher's use

v1.0 - 7th December 1998.Ω00
i00

RESISTIVE PLATE CHAMBERS IN HIGH ENERGY EXPERIMENTS

SERGIO P. RATTI*

*Dip. di Fisica Nucleare and Sezione I.N.F.N. I27100 Pavia (Italy)**E-mail: ratti@pv.infn.it*

The Resistive Plate Chamber (hereafter referred to as RPC) has been first developed by R. Santonico and his group¹ since the late seventies. They have been employed in several experiments at nuclear reactors², fixed target accelerators^{3,4}, colliders^{5,6} as well as in cosmic rays^{7,8}.

In order to properly perform their functions, RPC's have to undergo a series of restricting working conditions, mostly connected to the severe radiation background environment in which they are designed to work.

The RPC is a very successful wireless detector which is able to ensure both a high efficiency and a fast response. The absence of wire technologies and the cheap material employed makes the cost production very low so that it can be used to build very large area detectors. A large RPC can have a sensitive area as large as $2m \times 2.5m$. In addition it can be operated in a low gas gain regime, providing a high rate capability. Finally it can provide time of flight measurements as well as position measurements.

1 RPC's for LHC: performances and requirements

The RPC's play a significant role in the muon triggers of experiments designed at the future high energy colliders, particularly the CERN Large Hadron Collider (hereafter referred to as LHC)^{9,10,11}. At this collider, the beam provide an average of 20 interaction per bunch crossing at a beam frequency of 40 MHz.

*Co-authors are: S.Altieri, G.Belli, G.Bruno, R.Guida, M.Merlo, S.P.Ratti, C.Riccardi, P.Torre, P.Vitolo (INFN and Univ. of Pavia), M.Abbrescia, A.Colaleo, G.Iaselli, F.Loddo, M.Maggi, B.Marangelli, S.Natali, S.Nuzzo, G.Pugliese, A.Ranieri, F.Romano (INFN, Politechnique and Univ. of Bari)

The environment will be heavily contaminated by γ ray and neutron backgrounds whose rate could vary -in different regions of the detectors- from ≈ 1 to $\approx 10^3$ Hz/cm^2 . The overall doses during a 10 year exposure may vary in the range 1 Gy (barrel region) and 100 Gy (endcup region).

To meet this requirements the detector must provide a fast trigger with an overall time tolerance range $\sigma_{tot} \leq 3ns$; it has to have a low sensitivity to both γ rays and neutrons. Finally the radiation damage on *all* detector's components should be adequately affordable.

2 Rate Capability and Timing Properties

A prototype of a double gap ($2.0m \times 2.5m$) RPC -with single gap readout- to be inserted into the CMS muon trigger system has been exposed to a $20Ci$ ^{137}Cs source at the CERN γ irradiation facility (GIF).

A $200GeV/c$ muon beam could be used to trigger the RPC in different γ background conditions. Different absorbers could be inserted between the source and the RPC inducing into the the RPC readout different overall hit counting rates with beam off. We selected two absorbers: one corresponding to a hit rate of $180 Hz/cm^2$, the other to $550 Hz/cm^2$ which is estimated to be safely larger than the one to the expected due to the background at the worst RPC position in the barrel region of CMS.

In fig.s 1 the results shown are twofold: fig. 1a shows the efficiency curves (ϵ vs. HV) in two different background conditions, compared to the no background (no osurce) situa-

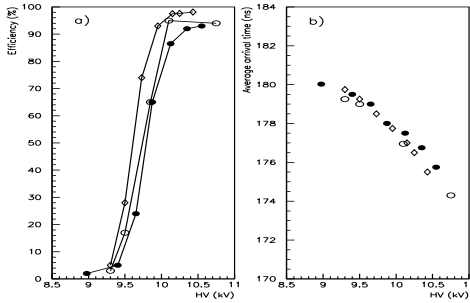


Figure 1. a- Efficiency vs. high voltage of a double gap RPC ($2.0m \times 2.5m$) in different background conditions; b- average arrival time; c- time resolution. \circ : no source; \circ : background hit rate 180 Hz/cm^2 ; \bullet : background hit rate 550 Hz/cm^2 .

tion, while fig.s 1b,c show the time properties of the detector. From fig. 1b one sees that the average arrival time undergoes a time walk $\Delta\tau < 6ns$ over a high voltage range of $\approx 1.7KV$ from 9.0 KV to 10.7 KV. Fig. 1c shows on the other hand that the worse intrinsic time resolution σ_τ , over the same high voltage range in the same experimental conditions is $\sigma_\tau < 1.4ns$.

3 RPC Sensitivity to γ Rays and Neutrons

The RPC detector has to have low sensitivity to both γ rays and neutrons. A Monte Carlo algorithm has been employed to simulate two different situations, i.e: exposure of a fully assembled RPC -including holding frames, electrodes, finishing foam- to:

1- isotropic flux of γ 's or, separately, neutrons, evenly distributed on the chamber surface;

2- a parallel beam perpendicularly impinging the whole chamber surface.

The package MCNP-4b developed by the Los Alamos Nat'l Laboratory¹² was used for the γ 's simulation, while GEANT was used for the neutron's simulation (MICAP for $E_n < 20MeV$ and FLUKA for higher ener-

gies were used as interface for cross sections).

The major assumption is that each produced charged particle reaching the RPC gas gap produces a signal into the readout output; if during any primary particle transport more than one charged particle reaches the gas gap, only the first is assumed to produce a signal.

The double gap sensitivity to γ rays is well below 8×10^{-2} for $E_\gamma < 100MeV$. The sensitivity is defined as: $s = N_I/N_o$, where N_I is the number of charged particles reaching any of the two gas gaps and N_o is the number of original primary particles impinging the chamber. If we use the simulated γ sensitivity and the expected γ spectrum in the region of the first RPC layer in the central barrel of the CMS setup, we get an expected hit rate in the RB1 region⁹ of $\approx 5 \text{ Hz/cm}^2$.

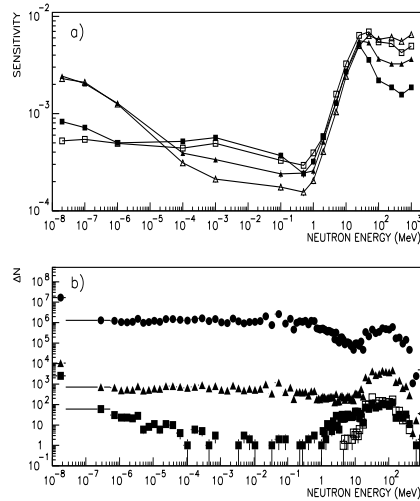


Figure 2. a- RPC neutron sensitivity vs. neutron energy. Full symbols for parallel beam; open symbols for isotropic beam. Squares: RPC without PVC foam; triangles: RPC with PVC foam. b- Charged particle spectra produced by primary neutrons into an RPC gas gap in the CMS barrel region, compared to the simulated neutron spectrum (full circles) in the RB1 region. Full squares: e^+/e^- ; open squares: α particles; full triangles: protons.

The same definition of s holds for neu-

trons. The simulation program for a neutron source is more complex as it implies the use of neutron interaction cross sections for several nuclei and several energies.

The results obtained in this case are shown in fig.s 2. Fig. 2a shows the RPC sensitivity obtained in the conditions detailed in points 1- and 2- above, with or without PVC finishing foam. The sensitivity for $E_n < 10^{-5} MeV$ is mostly due to γ 's coming from (γ, n) capture reactions whose cross section increases with decreasing energy ($\sigma \sim 1/\sqrt{E_n}$): thus the presence of the foam enhances s . The values, however remains below 2×10^{-3} for $E_n < 1 MeV$. At higher energies the sensitivity reaches a maximum around $E_n \sim 50 MeV$ around $s \sim 7 - 8 \times 10^{-3}$. At $\geq 15 MeV$ incoming neutrons the produced protons have a residual range of about 2 mm in bakelite so that they can easily reach the gas gap.

Similar to the γ case, if we use the simulated neutron sensitivity and the expected neutron spectrum of fig. 2b we get an expected hit rate in the RB1 region⁹ of $\approx 0.6 Hz/cm^2$.

4 Front End Chip Radiation Damage

Intense radioactive environments may damage not only the material used to build the detector (namely, bakelite) but, most important, the components of the Front End (F.E.) electronic readout chips and boards which are located very close to the detector itself. The bakelite can easily stand high doses without changing its resistivity characteristics¹³. From this point of view a must is to keep the operating temperature under control. The damage to electronic components can be either severely disruptive (dislocations or threshold total dose effects) or reversible as typically may be a *single event upset* produced by spurious transient hits. This phenomenon has been studied by

exposing 4 F.E. final production 8 channel chips to the intense fluence of the 250 kW Triga Mark II reactor of the University of Pavia and by measuring reactor on/off hit rates. The measured neutron flux was about $6 \times 10^5 n/cm^2s$ and the neutro energy in the range $0.4 eV - 10 MeV$. The average chip rate remains stable for fluences up to 10 LHC year equivalent in the range $1.9 - 2.5 \cdot 10^{-3} Hz/channel$.

5 Mass Production Quality Control

Finally we tested the electrical resistivity of the first 10% mass production of bakelite-electrodes. The allowed values may range from $1to6 \cdot 10^{10} \Omega cm$. Of the total 400 slabs produced about 77% have ρ in the range $1to4 \cdot 10^{10} \Omega cm$ and about 8% are to be discarded. We will however use slabs of higher resistivity in the construction of the double gap RPC placed in regions of lower background level.

References

1. R.Santonico, R.Cardarelli, N.I.M. **A187**, 337 (1981) ;
2. E.Calligarich et al., N.I.M. in Phys. Res. **A337**, 350 (1994);
3. G.Cataldi et al., N.I.M. **A344**, 350 (1994);
4. P. Sheldon et al. Sci. Acta **11**, 437 (1996);
5. Babar Coll. TDR, (march 1995);
6. R.deAsmundis et al., Sci. Acta **11**, 139 (1996);
7. C.Bacci et al., N.I.M. **A443**, 342 (2000);
8. P.O.Mazur, Sci. Acta **11**, 331 (1996);
9. ARGO Coll., Nucl.Phys.Proc.Suppl. **78**, 38 (1999);
9. CMS: Muon Project TDR, CERN/LHCC/97-32 (1997);
10. ATLAS: Muon Spectrometer TDR CERN/LHCC/97-22 (1997)
11. LHCb: Technical Proposal CERN/LHCC/98-04 (1998);
12. MICAP Los Alamos report;
13. M.Abbrescia et al., RPC Barrel E.D.R., CMS doc. 1999/43 (1999).