Available online at www.sciencedirect.com
SCIENCE DIRECT
Nuclear Instruments and Methods in Physics Research A 508 (2003) 94–97
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
www.elsevier.com/locate/nima

Study of the performance of standard RPC chambers as a function of bakelite temperature

M. De Vincenzi, G. Hull, S.M. Mari*, G. Pellizzoni

Dipartimento di Fisica, Università di Roma TRE and INFN Sezione di Roma TRE, Via della Vasca Navale 84, 00146 Roma, Italy

Abstract

A systematic study of the performance of the Resistive Plate Chambers as a function of the bakelite temperature is presented. The current, the rate and the efficiency were measured in the temperature range 22–40°C. The values of the relative humidity during the data taking were in the range 40–60%. Measurements show a strong dependence of the efficiency on bakelite temperature.

Keywords: Gaseous detector; RPC chambers; Temperature dependence; Resistivity of bakelite; RPC efficiency; RPC performances

1. Introduction

The Resistive Plate Counters (RPC) are widely used in many accelerator and Cosmic Ray experiments because of their good time and spatial resolution and because of their mechanical simplicity. In the next LHC experiments the produced particles rate will reach 1 KHz/cm^2; at this high rate it is important to know the RPC performance as a function of the bakelite properties. The use of RPC in extensive air shower experiments [1] for the detection of the space–time shower profile also requires high performance which can be affected by the temperature of the bakelite. The temperature behavior of the RPC performance is expected to be related to the gas density and to the bakelite electrical properties. The change in the gas density due to small temperature variation can be accounted for by re-scaling the applied high voltage (V) according to the relationship $V = V_0(P_0/P)(T/T_0)$ where P_0 and T_0 are arbitrary standard values. However for wide temperature variation it should be considered that in the ideal gas approximation the parameter which fixes the high voltage is given by $gap \times pressure/temperature$. The effective voltage acting on the gap depends on the bakelite electrical properties (resistivity ρ, dielectric constant ε) which are affected by temperature variation also. In the following the performance of a standard RPC chamber as a function of the temperature is presented. The RPC working parameters (current, time resolution, efficiency) were measured in the temperature range 22–40°C, in the RH range 40–60% and in the atmospheric pressure range 998–1016 mb. The bakelite resistivity of the RPC chambers used in this test is $\rho \sim 10^{12}$ Ω cm.

*Corresponding author.
E-mail address: mari@fis.uniroma3.it (S.M. Mari).

0168-9002/03/$ - see front matter
doi:10.1016/S0168-9002(03)01284-1

2. Experimental setup

The test was carried out using two RPC chambers of the type used by the Argo-YBJ experiment, described elsewhere [2]. Each RPC, which covers an area of $50 \times 50\ \text{cm}^2$, is realized by two bakelite plates of high resistivity ($\rho \sim 10^{12}\ \Omega\ \text{cm}$) where a PVC frame and a 10×10 cm lattice of ~ 8 mm diameter spacers define a gap of 2 mm. The gap was filled with the gas mixture used in the Argo-YBJ experiment: Argon (15%), Isobutane (10%), tetrafluorethane (75%), with an accuracy of about 1%, and the RPCs were operated in streamer mode. The RPC signals are picked up by means of an aluminum pad of $46 \times 46\ \text{cm}^2$ glued on 0.2 mm thick film of Poly-Ethylen-Tereftalate (PET), a grounded aluminum foil was used to shield the RPC and a rigid aluminum structure was used to support the RPC. The pressure on the RPC gap, due to the rigid structure, was $5\ \text{g/cm}^2$. One of the two RPCs (RPC1) was mounted horizontally in an isothermal box where stable temperature condition was obtained and relative humidity has been monitored. The air in the box was continuously circulated in order to avoid local gradients, the temperature in the box was measured by means of four digital thermometers, with an accuracy of 0.1°C, and five transistor with an accuracy of 0.4°C. The temperature was continuously measured during all the tests. A worm-wheel of tubes is used for thermalizing the gas mixture before entering in the RPC1. The temperature of the gas flowing out from the RPCs was also measured. Another RPC (RPC2) was mounted outside the isothermal box and was used as a reference chamber. The trigger of the experiment is defined by the coincidence of three plastic scintillators; in this way muons with a momentum bigger than 0.4 GeV/c are selected and the time accuracy is better than 1 ns. In Fig. 1 a schematic view of the experimental setup is reported.

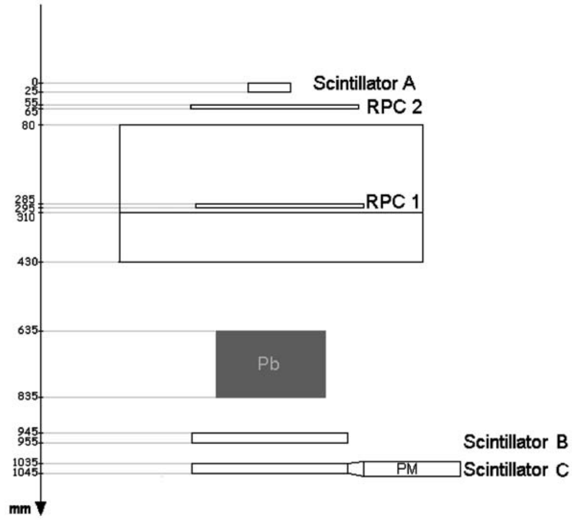

Fig. 1. Schematic view of the experimental setup.

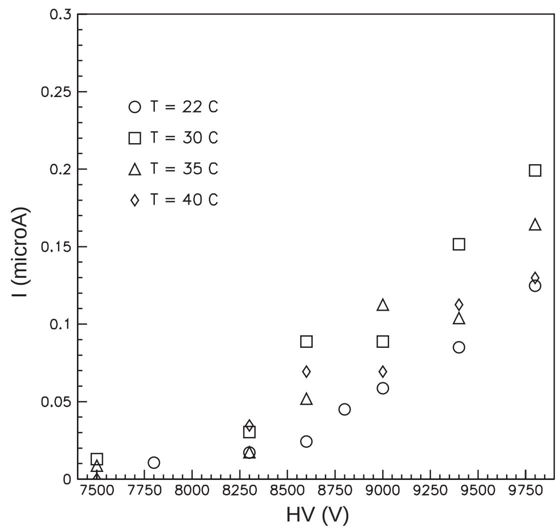

Fig. 2. RPC current as a function of the applied high voltage for all the tested temperatures.

3. RPC performance

The measurements were taken at the temperature: $T = 22°\text{C},\ 30°\text{C},\ 35°\text{C}$, and 40°C. For each temperature about 1000 events were collected in various data sets. The chambers were continuously operated and monitored during the data taking. Measurements of current, efficiency, single rate and time resolution were performed for all the tested temperatures. In Fig. 2 the RPC currents are shown as a function of the applied high voltage for

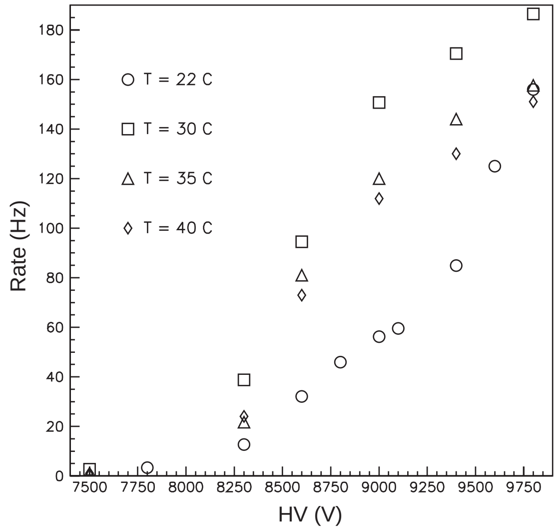

Fig. 3. RPC single rate as a function of the applied voltage for all the tested temperatures.

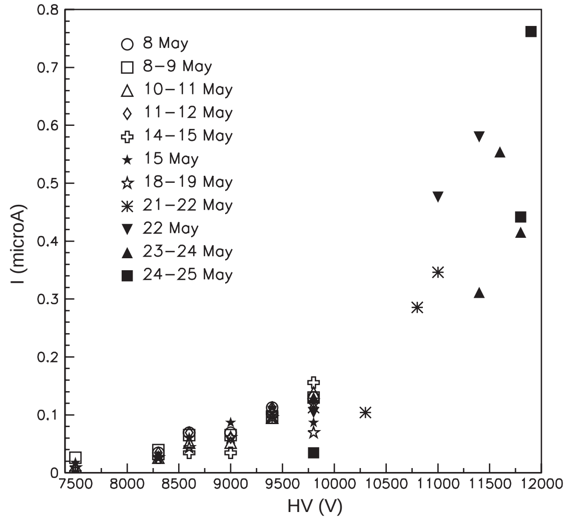

Fig. 5. RPC current as a function of the applied voltage for the data at $T = 40°C$.

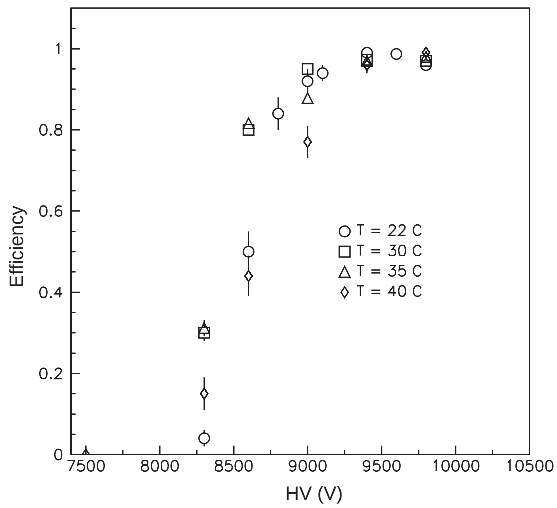

Fig. 4. RPC efficiency as a function of the applied high voltage for all the tested temperatures.

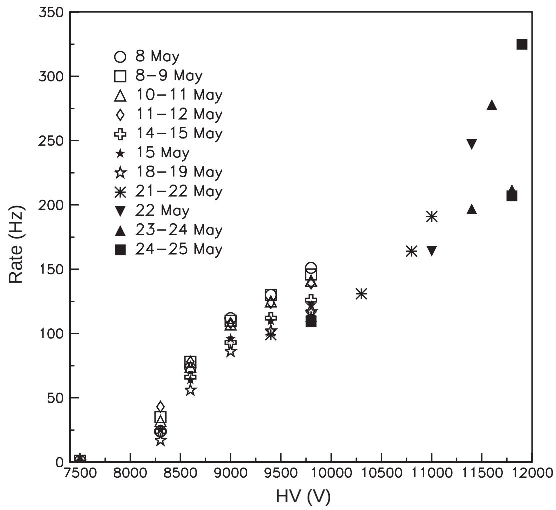

Fig. 6. RPC single rate as a function of the applied voltage for the data at $T = 40°C$.

all the tested temperatures, the current at $T = 40°C$ was reported for the first data set taken at this temperature. Comparing data taken at $T = 22°C$ with those taken at $T \geqslant 30°C$, the current behavior is according to a negative thermal coefficient of the resistivity of the bakelite [3]. The RPC single rate curves for all the tested temperatures are reported in Fig. 3, the data at $T = 40°C$ is related to the first data set. The single rate curves start to rise at the same high voltage values as the current curves do showing the entering in the streamer regime of the chamber. The RPC efficiency was measured for all the tested temperatures by means of three-fold scintillators

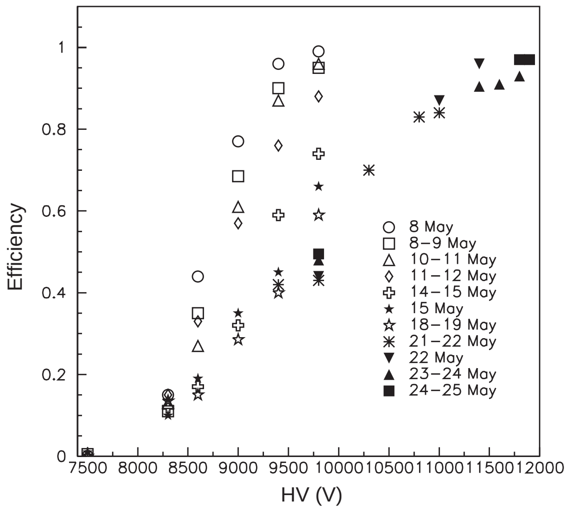

Fig. 7. RPC efficiency as a function of the applied voltage for the data at $T = 40°C$.

coincidence. In Fig. 4 the efficiency vs. voltage curves are reported, all the curves show an efficiency value in the plateau region of about 98% which is the nominal limit due to the geometrical acceptance. In Figs. 5–7 the RPC current, single rate and efficiency are reported for the data sets taken at $T = 40°C$. The plots show that the current, the single rate and the efficiency measured at a fixed voltage are clearly decreasing during the operating period at this temperature value. At the beginning of the data taking at $T = 40°C$ the efficiency reaches a plateau value of 98% as for the $T = 22°C$, $30°C$, and $35°C$ (see Fig. 4); on the contrary the efficiency curves, related to the data taken during the 400 h of the operation at $T = 40°C$, show a drop down of about 40% (see Fig. 7). The efficiency was partially recovered increasing the high-voltage up to 12,000 V, very close to the break down voltage of the material used to built the RPC. The RPC1 was again operated at $T = 30°C$ but the measured efficiency was still 40% demonstrating a permanent efficiency loss. The second RPC (RPC2) was warmed in the isothermal box for 170 h at $T = 40°C$ but with the high-voltage switched off. After this heating cycle, the efficiency was again measured, at $T = 30°C$ reaching 98%. The results on measured efficiency of RPC1 and RPC2 show that the loss of the efficiency of the RPC1 is due to the action of both high voltage and temperature.

4. Conclusion

An extensive study of the RPC performance as a function of the bakelite temperature was performed. The RPC current, single rate and efficiency were measured at temperature values $T = 22°C$, $30°C$, $35°C$, and $40°C$. The efficiency for $T \leqslant 35°C$ reaches the nominal value of 98%. At $T = 40°C$ data show clearly a permanent efficiency loss: after about 400 h at $T = 40°C$, the RPC efficiency drops down to about 40%.

References

[1] C. Bacci, et al., Nucl. Phys. B 85 (2000) 338.
[2] C. Bacci, et al., Nucl. Instr. and Meth. A 443 (2000) 342.
[3] M. Abbrescia, et al., Nucl. Instr. and Meth. A 359 (1995) 603.