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Nuclear Instruments and Methods in Physics Research A 508 (2003) 106–109
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
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Ageing tests on the low-resistivity RPC for the ALICE dimuon arm

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For the ALICE Collaboration

Abstract

The trigger for the Dimuon Forward Spectrometer of the forthcoming ALICE experiment at CERN LHC will be provided by low-resistivity, single gap Resistive Plate Chambers working in streamer mode.

Different ageing test were performed to measure and improve the life-time of the detector. Dummy chambers have been built to understand the effects of continuous gas flow upon the Bakelite resistivity: the results concerning our standard gas mixture (49% Ar, 40% forane, 7% isobutane and 4% SF_6) are reported, and compared with the same mixture in which $\sim 1\%$ of water vapor is added. Moreover, two ageing test of 1 month each have been carried out at the Gamma Irradiation Facility at CERN during 2001. The efficiency for cosmic rays under γ irradiation of RPCs coated with different thicknesses of linseed oil was measured. After protracted operation, the detectors have shown an increase of the current and of the background rate. The increase is slower in the chamber with a thicker oil coating.

PACS: 29.40.Gx; 29.40.Cs

Keywords: Resistive plate chambers; Streamer; Ageing

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0168-9002/03/$ - see front matter © 2003 Elsevier Science B.V. All rights reserved.
doi:10.1016/S0168-9002(03)01287-7

1. Introduction

Resistive Plate Chambers [1,2] operated in streamer mode have been chosen as trigger detectors for the ALICE dimuon arm [3,4]. The ALICE RPCs [5] are realized with low-resistivity ($\rho \simeq 10^9\ \Omega$ cm) Bakelite electrodes (coated with linseed oil), to increase their rate capability in order to match the ALICE requirements (100 Hz/cm^2, including a large safety margin). Moreover, they are operated with a quenched gas mixture (49% argon, 40% $C_2H_2F_4$, 7% isobutane and 4% SF_6), in order to reduce the streamer charge. In this paper we will report the results of two ageing tests performed on the detector: one to measure the increase of Bakelite resistivity due to dry gas flow, and the other to check the overall behaviour of the detector after prolonged irradiation with γ rays.

2. Resistivity test

Since the gas mixture tested and adopted for RPC operation does not contain water vapour, it is possible that continuous flow of the gas could lead to a diminution of the Bakelite water content, thus increasing the resistivity of the electrodes and worsening the rate capability. Indeed, an increase of Bakelite resistivity (up to two orders of magnitude) has been measured for a phenolic Bakelite sheet after exposition to prolonged dry gas flow [6].

Since the RPCs are assembled gluing together the Bakelite plates onto the external frame, a direct measurement of the Bakelite plates resistivity without damaging the chamber is impossible. We have, therefore, constructed two dummy RPCs (not connected to HV), which can be opened easily, each made of two 50×50 cm^2 phenolic Bakelite plates (types A and B, coming from two different manufacturers) with a gas gap 3 mm wide. On the side facing the gas gap the plates were coated with undiluted linseed oil.

The two dummy chambers have been fluxed for 4 months with our standard gas mixture: one with the dry mixture, and the other one with a humid mixture with about 1% of water vapour, which was added by previously passing the mixture through a bubbler filled with water at 10°C. The gas flow amounted to 30 cm^3/min.

The dummy chambers were opened from time to time, to measure the resistivity of the Bakelite sheets in five different points. The results of the measures for the two types of Bakelite are similar and are shown in Fig. 1 for type A Bakelite and in Fig. 2 for the type B. The resistivity of the dummy electrodes fluxed with the dry gas mixture increased by more than a factor 2, while the one of the humid-fluxed sheets remained basically unchanged.

3. Ageing tests

In the ALICE environment, the RPCs will be exposed to different counting rates, depending on the interaction type. Present simulations predict a maximum counting rate of $\sim$40 Hz/cm^2 in Ar–Ar, $\sim$10 Hz/cm^2 in p–p and 5 Hz/cm^2 in Pb–Pb collisions.

To simulate the effects of years of operation in the ALICE environment, we exposed some 50×50 cm^2 prototypes to the γ flux from the ^{137}Cs

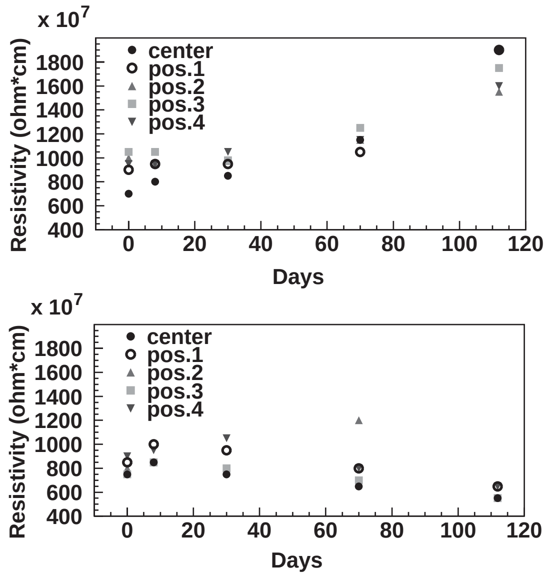

Fig. 1. Measures of resistivity on different zones of the type A dummy electrodes: 'dry' (top) and 'humid' (bottom).

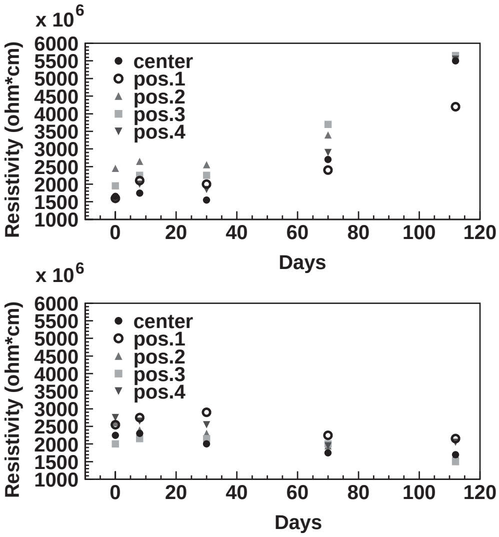

Fig. 2. Measures of resistivity on different zones of the type B dummy electrodes: 'dry' (top) and 'humid' (bottom).

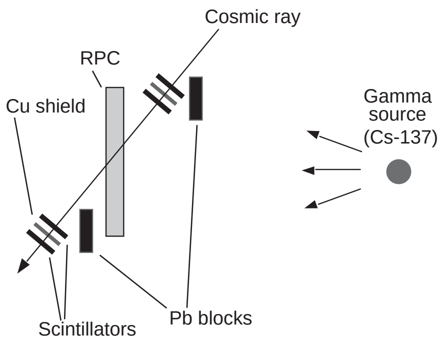

Fig. 3. Set-up for the ageing tests at GIF.

source of the Gamma Irradiation Facility at CERN [7].

3.1. Set-up of GIF tests

The aim of the tests is to monitor the efficiency of the detectors for cosmic ray detection under γ irradiation. The experimental set-up is shown in Fig. 3: the chambers are placed vertically inside a frame which also supports two pairs of $50 \times 10\ cm^2$ scintillators, partially superimposed and shielded from the radioactive source by an array of lead blocks. The four-fold scintillator coincidence selects a $30 \times 10\ cm^2$ zone on the detectors and is used for cosmic rays identification.

The RPCs are made with Bakelite ($\rho = 1.5 \times 10^9\ \Omega$ cm) covered with a melamminic layer on the side facing the gas, and are equipped with vertical strips 2 cm wide: 16 strips are centred on the area individuated by the coincidence of the scintillators, and are read out by means of single-threshold on-board discriminators. The ORs of the strips are used to estimate the counting rate induced on the detector, and, in coincidence with the trigger, to monitor the chamber efficiency.

The HV value was set at 200 V above the knee of the efficiency plateau. We noted periodically the values of the current drawn from the detectors, together with the environmental conditions: temperature, atmospheric pressure and humidity. From time to time, the radioactive source was shut off for a few minutes, to measure the dark current and the single rate. The γ-induced counting rate varied between 70 and 150 Hz/cm^2.

3.2. February 2001 test

In February 2001 we tested two detectors, one with a thin linseed oil coating (3–5 μm) and the other without linseed oil.

Before irradiation, the dark current (with source off) of the oiled RPC was about 2 μA at 9000 V and the single rate was about 0.1 Hz/cm^2; at the end of the irradiation run the oiled detector accumulated an integrated charge of $\sim 30\ mC/cm^2$, and the dark current reached a value of more than 40 μA at 9200 V, while the counting rate at the same HV was $\sim 3.5\ Hz/cm^2$.

Concerning the working current (i.e. the current under γ irradiation), at the beginning of the test at a counting rate of 57 Hz/cm^2 the chamber drew 80 μA. At the end of the test, however, at a counting rate of 65 Hz/cm^2 the chamber current increased to ~ 160 μA.

The non-oiled RPC did not even reach a full-efficiency plateau. The initial values of dark current and single rate were, respectively, 2.5 μA and 1.2 Hz/cm^2; after 45 h of operation with an average counting rate of 50 Hz/cm^2 the dark current at 9000 V was more than 200 μA, with a single rate of 8.4 Hz/cm^2.

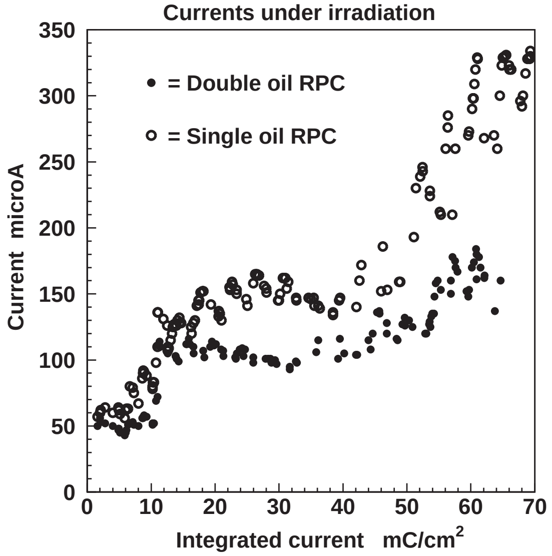

Fig. 4. Currents under irradiation drawn by the double-oiled (full circles) and single-oiled (open circles) RPC. The vertical line marks the change of the counting rate.

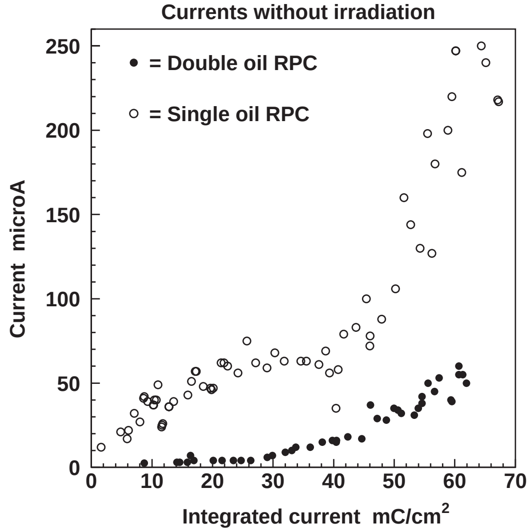

Fig. 5. Dark currents of the double-oiled (full circles) and single-oiled (open circles) RPC.

3.3. June 2001 test

The results of the February test indicate that the chamber without oil coating is more exposed to ageing problems. Moreover, an RPC prototype with a thicker oil coating, which was tested for a week at GIF in January, 1999 with a higher counting rate (~ 300 Hz/cm^2), did not undergo a similar performance deterioration. For these reasons, we decided to test for 1 month (with the same experimental set-up) an RPC with a double oil coating, i.e. an RPC in which the oiling process was performed twice. The counting rate on the detectors in the initial phase was about 60 Hz/cm^2, and after ~ 10 mC/cm^2 it was raised up to 110 Hz/cm^2. Fig. 4 shows the current drawn under irradiation by both the single- and double-oiled RPC which were tested at the same time. The dark currents of both detectors is plotted in Fig. 5. As is apparent in particular from Fig. 5 the operation characteristics of the double-oiled chamber are more stable under irradiation. Both chambers were fully efficient until the end of the ageing run, with a small decrease of the efficiency for the single-oiled one.

References

[1] R. Santonico, R. Cardarelli, Nucl. Instr. and Meth. 187 (1981) 377.
[2] R. Santonico, R. Cardarelli, Nucl. Instr. and Meth. A 263 (1988) 20.
[3] ALICE Technical Proposal, CERN/LHCC 95-71.
[4] ALICE Forward Muon Spectrometer Technical Design Report, CERN/LHCC 99-22.
[5] R. Arnaldi, et al., Nucl. Instr. and Meth. A 451 (2000) 462.
[6] I. Crotty, et al., Nucl. Instr. and Meth. A 360 (1995) 512.
[7] S. Agosteo, et al., Nucl. Instr. and Meth. A 452 (2000) 94.