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Nuclear Instruments and Methods in Physics Research A 533 (2004) 154–158

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

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Test of large area glass RPCs at the DAΦNE Test Beam Facility (BTF)

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Abstract

The CaPiRe program has been started to develop a new detector design, in order to produce large areas of glass Resistive Plate Chambers (RPC) detectors, overcoming the previous limitations. As a first step we produced our glass RPC detectors ($1\,\mathrm{m}^2$) at General Tecnica exploiting their standard procedures, materials and production techniques simply using 2 mm glass electrodes instead of the bakelite ones. A set of RPC was produced by using pre-coated (silk screen printed) electrodes, while others were produced with the standard graphite coating. All the detectors, together with four old Glass RPC acting as reference, were tested at the DAΦNE Test Beam Facility with 500 MeV electrons in order to study the efficiency in different positions inside the detectors (i.e. near spacers and edges) and to study the detector behavior as a function of the local particle rate.

PACS: 29.40.Cs

Keywords: RPC; Production; Rate capability

1. Introduction

Resistive Plate Chambers (RPC) have been widely employed both in high energy physics and

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doi:10.1016/j.nima.2004.07.019

cosmic ray experiments [1]. Glass RPCs [2,3] are derived from RPC by substituting the bakelite electrodes with commercial float glass electrodes having high resistivity ($10^{12}\,\Omega\,\text{cm}$). Compared to bakelite, float glass turns out to be more suitable since its volume resistivity is stable over a long period [4]. Moreover, due to glass intrinsic qualities of homogeneity and planarity, surface treatment (i.e. linseed oil) is not needed. Conversely, the window float glass relatively high bulk resistivity could be a limitation for streamer mode operation in high particle rate applications. Moreover, the ageing due to the fluorine compounds like $C_2H_2F_4$ that are present in RPC gas mixtures can be particularly effective due to the etching of the glass electrodes by HF produced under electrical discharge in presence of even low water vapor contamination. Hence operational conditions of glass RPC have to be widely studied and understood in order to allow long term safe operation and eventually to improve the rate capability of the considered detectors. New proposed neutrino experiments will need huge active detector areas, therefore glass RPCs have to be designed in order to allow large-scale production. Indeed, industrial mass production have to be standardized in order to have homogeneous, affordable and reproducible detectors. Previous [3] detectors were produced in small series, although a large amount of detectors was produced [5], they were manually assembled, and glass RPCs have not yet reached the requested level of engineering as it has already been done for the bakelite detectors. In spite of this, a wide range of industrial glass treatments are already available both from glass and automobile industries. We are trying to import and adapt such techniques for glass RPC large-scale production and on the other hand we will modify design and employed materials to fit into standard industrial production techniques. In the frame of this activity, a remarkable improvement has been obtained introducing a new acrylic resistive varnish containing conducting pigments (metal-oxides) and silk screen printing techniques for RPC resistive electrodes production [6].

As a first step on the way to set a new detector design, we produced our glass RPC detectors ($1\,\text{m}^2$) at General Tecnica exploiting their standard procedures, materials and production techniques simply using 2 mm glass electrodes instead of the bakelite ones. A set of RPC was produced by using pre-coated (silk screen printed) electrodes, while others were produced with the standard graphite coating. All the detectors were tested at the DAΦNE Test Beam Facility with 500 MeV electrons in order to study the efficiency in different positions inside the detectors (i.e. near spacers and to study the detector behavior as a function of the local particle rate).

2. Glass RPC prototypes

As a first step on way to develop large area automatically assembled RPCs, four glass RPCs have been built using a pair of commercial float glass electrodes 1000 mm wide, 2.0 mm thick and 1000 mm long. The room temperature volume resistivity of this glass is about $5 \times 10^{12}\,\Omega\,\text{cm}$. This value turns out to be suitable for operation in streamer mode in low particle rate environments. Cylindrical polycarbonate spacers (10 mm in diameter, 100 mm distant from each other) are inserted in the gap in order to ensure the 2 mm distance between the electrodes.

A water-based graphite varnish (3 RPCs, called GT1, GT2 and GT3 in the following) or the new screen printed acrylic varnish (1 RPC, called GT0 in the following) are applied to the external surfaces of the glass to provide the high voltage supply. The surface resistivity of the coating is about $200–400\,\text{k}\Omega/\square$ in order to ensure both a uniform HV distribution on the whole electrode and the transparency in order to perform the read-out by means of external 3 cm strips. One of the glass plates is connected to the ground, the other to the high voltage. The high-voltage plate has been electrically insulated by means of an external Mylar film. External 3 cm pitch pick-up strips have been applied on the HV side of the detector. As a reference we also used four old GRPC [7] (called GSC in the following) with a total active area of $1100 \times 1000\,\text{mm}^2$.

3. Experimental setup

The Beam Test Facility (BTF) at Laboratori Nazionali di Frascati [8] is a e^+/e^- test-beam facility designed to provide a defined number of particles in a wide range of multiplicities (current/pulse:1–10^{10} particles) and energies (e^+: 25–550 MeV; e^-: 25–800 MeV). The BTF is part of the DAΦNE accelerator complex, consisting of a double ring electron–positron collider, a high current linear accelerator (LINAC), an intermediate damping ring (Accumulator) and a system of 180 m transfer lines connecting the four machines. The LINAC delivers electrons with energy up to 800 MeV, with a typical current of 500 mA/pulse, or positrons with energy up to 550 MeV, with a typical current of 150 mA/pulse; the pulse duration can be adjusted in the range 1–25 ns with a maximum repetition rate of 50 Hz. The features described above qualify the BTF as a powerful tool for detector calibration, efficiency measurements and local ageing studies at higher intensities. Regarding our glass RPC, it was possible to perform detailed efficiency measurements (in single electron mode) at different particle rates and with the beam spot impinging on the detector in different positions. The detector under test were mounted in the experimental hall, orthogonally to the beam line, on a trolley with adjustable x–y position at ≈ 30 cm from the end of the beam pipe. A scintillation counter ($20 \times 20\,\mathrm{cm}^2$) was positioned upstream for later data selection. The lead/scintillating fibers calorimeter ($15 \times 15\,\mathrm{cm}^2$, $\Delta E/E \approx 7\%$ at 500 MeV), available at the BTF, was positioned 1.5 m downstream to measure the particle multiplicities. External readout, 3 cm pitch, strip planes were positioned on only one side of the detectors providing the horizontal coordinate. Digital read-out cards were mounted on one side, analog read-out cards, summing the charge of eight strips, were mounted on the other side providing also strip termination.

4. Experimental results

In this paper results on the measurements performed operating our detector in streamer mode with a gas mixture of argon (48%), $C_2H_2F_4$ (48%) and iso-butane (4%) are presented. The beam settings were chosen in order to provide 500 MeV single e^-; the repetition rate was varied between 1 and 24 Hz. Two different beam settings provided two different beam spots having, respectively, $\sigma_x \approx 20$ mm, $\sigma_y \approx 2$ mm (de-focused) and $\sigma_x \approx \sigma_y \approx 2$ mm (focused). The data analysis has been performed on the data collected from the analog cards. Single electrons hitting the RPC detectors were selected by means of the scintillation detector and the scintillating fibers calorimeter positioned respectively in front and behind the glass RPC under test. Only the events within the single particle peak for both detectors have been considered. Efficiencies were calculated by looking for signals over the pedestal that is clearly distinguishable from the single streamer peak. The efficiency plateaux obtained with the analysis procedure described above for the four considered glass RPCs are shown in Fig. 1. The difference between the plateaux of the new RPCs (GT) and the reference one (GSC) is about 100 V, due to intrinsic differences of the detectors. The two RPC GT1 and GT2 were switched on for the first time two days before while the other two had been previously operating for one month. Dark currents were on average $2\,\mu\mathrm{A/m}^2$ at 7800 V for all the detectors. The measurements were performed with the detector at a temperature of 25° and beam settings (2 cycles/s, "de-focused") corresponding approximately to a local particle rate of $0.2\,\mathrm{Hz/cm}^2$.

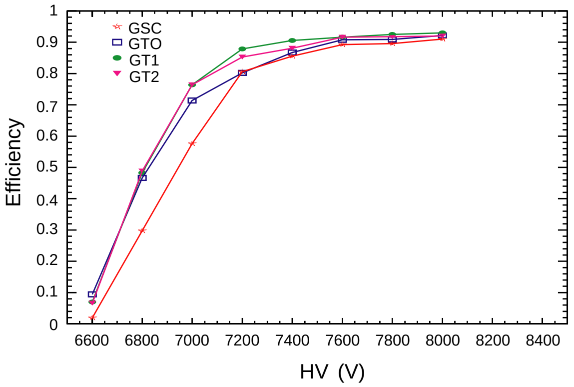

Fig. 1. Efficiency plateaux.

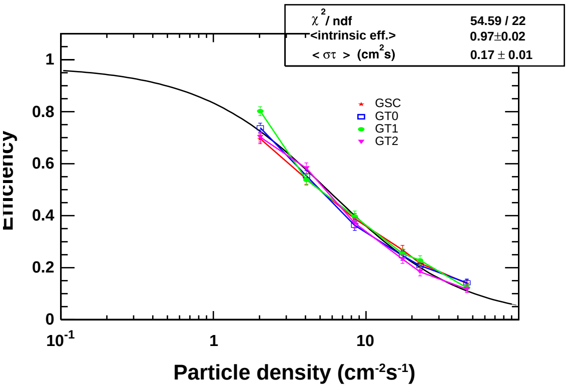

Fig. 2. Efficiency versus particle density, HV = 8200 V.

In order to check the rate capability of our detectors, a set of measurements with the beam set in single electron "focused" ($\sigma_x \approx \sigma_y \approx 2\,\text{mm}$) mode and varying the repetition rate up to 24 Hz have been performed. The measured behaviors are shown in Fig. 2. All curves have been fitted with the function $\varepsilon = \varepsilon_0/(1 + f\varepsilon_0\sigma\tau)$, where ε_0 is the efficiency at zero particle rate, f is the particle rate, σ is the area of the RPC deaden by the discharge and τ is the recovery time. The reported particle densities were calculated considering the true average number of electrons/cycle (according to a Poisson distribution) and converting the approximately Gaussian distribution of the beam into a uniform distribution with the same standard deviation. An efficiency $\varepsilon > 90\%$ for particle densities $f < 0.42\,\text{cm}^{-2}\,\text{s}^{-1}$ has been estimated from the fit. The $\sigma\tau$ value obtained from the fit turns out to be compatible with the resistivity of glass electrodes and operating conditions. This is the first direct measurements of RPC's local rate capability. Our data do not allow to reach the efficiency plateau because lower particle density values can be obtained only using the "defocused" beam having a not well-understood shape. This can also be ascribed to the acceptance and the spatial resolution of our experimental setup. Experimental results obtained with the two considered beam configurations cannot be put in a direct relationship. The GT3 RPC was never exposed to the beam, it was mounted in a cosmic ray telescope and operated with the same gas mixture. The efficiency plateau is shown in Fig. 3.

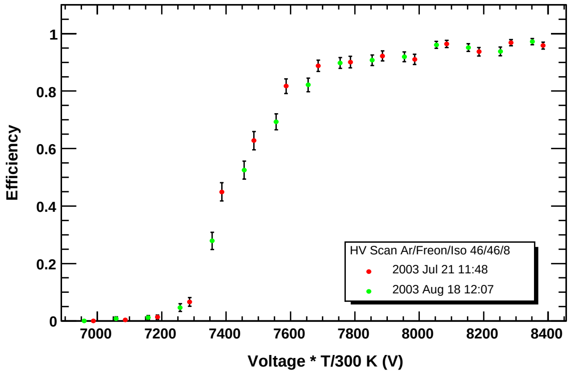

Fig. 3. Cosmic rays efficiency plateau of GT3.

5. Conclusions

A sample of glass RPCs was produced industrially in a fully automated way. The detectors exhibited, during the test performed at BTF and with cosmic rays, a behavior at least comparable to the reference detectors. Cleanliness during production process will have to be improved in order to lower single counting rates and dark currents that can be critical in new glass RPC (high bulk resistivity). Further tests will be performed at BTF and with cosmic rays on more detectors. Spatial resolution will be improved in order to better evaluate the particle density, time measurements will be introduced and different operating conditions will be exploited.

Acknowledgements

The authors would like to thank L. Daniello and G. Giuliani for their help during the setup.

This work has been supported by Istituto Nazionale di Fisica Nucleare (INFN).

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