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Nuclear Instruments and Methods in Physics Research A 581 (2007) 206–208
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
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# Glass resistive plate chambers in the OPERA experiment

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Available online 31 July 2007

**Abstract**

OPERA is an underground neutrino oscillation experiment to search for $\nu_\tau$ appearance from a pure $\nu_\mu$ beam produced at CERN. To flag the events due to the neutrino interactions with the rock surrounding the OPERA detector, a large VETO system, based on the use of Glass Resistive Plate Chambers (GRPC) has been realized. We describe the detectors, the tests performed before the installation in the underground laboratories and the monitor system for the water pollution in the GRPC gas mixture.


## 1. Introduction

The CNGS (CERN Neutrinos to Gran Sasso) long baseline project is focused on the appearance of $\nu_\tau$ in a $\nu_\mu$ beam to explicitly prove the $\nu_\mu \to \nu_\tau$ nature of the atmospheric oscillation. The OPERA experiment is placed in the Gran Sasso underground laboratory, 732 km from CERN. The CNGS beam is a wide band neutrino beam optimized for $\nu_\tau$ appearance with a mean neutrino energy of 17 GeV. The OPERA experiment [1] is based on the direct observation of the $\nu_\tau$ decay topology. The basic target unit is a brick of $10.2 \times 12.7 \times 7.5\,\mathrm{cm}^3$ made of 56 lead plates(1 mm thick) and 57 emulsion films (about 200 000 bricks in total). The bricks are arranged in two modules, each one composed of 31 vertical walls. Planes of scintillator strips allow to localize the neutrino interactions and select the corresponding bricks. To identify muons and measure their momentum and charge, each target block is followed by a spectrometer equipped with 22 planes of Resistive Plate Chambers (RPC) with bakelite electrodes [2,3]. The measurement of the muon momentum is complemented by six sections of drift tubes for precision tracking through the magnetic field. A large number of CNGS neutrinos interact with rocks and concrete around the OPERA detector; part of secondaries issued from these interactions enter the detector, and may induce false triggers leading to a large amount of erroneous brick extractions and subsequent scanning. For this reason a VETO system based on the use of glass RPCs (GRPC), has been installed upstream of the OPERA apparatus.

## 2. The VETO system of the OPERA experiment

Resistive Plate Chambers are gas detectors composed of two parallel plates generating a uniform electric field. When a particle ionizes the gas between the electrodes, an avalanche process occurs. If the electric field is intense enough, the avalanche reaches the critical size and generates the streamer, a plasma filament between the electrodes, producing an intense current pulse.

As shown in Fig. 1, the RPCs of the VETO have glass electrodes 3 mm thick, with a volume resistivity of about $5 \times 10^{12}\,\Omega\,\mathrm{cm}$ at 20 °C. The high voltage on the electrodes is distributed by means of a resistive coating (surface resistivity $\sim 400\,\mathrm{k}\Omega/\square$). The distance between the spacers has been chosen taking into account the requirement of a minimal dead area and the effect of the deformation produced by the electric field and the gas pressure. In the

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doi:10.1016/j.nima.2007.07.065

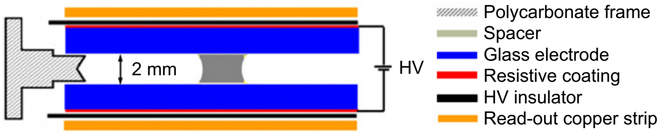


Fig. 1. Schematic drawing of a Glass Resistive Plate Chamber.

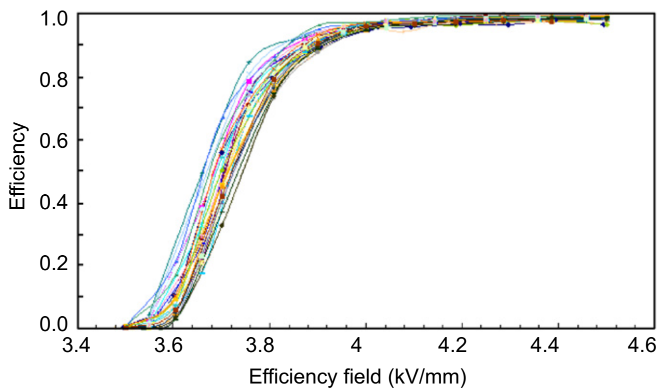


Fig. 2. Efficiency as a function of the nominal electric field $E_0 = V_0/g$, for 32 GRPCs. All the chambers show a similar behaviour reaching the full efficiency for $E > 4.0$ kV/mm. $Ar/C_2H_2F_4/Iso - C_4H_{10}/SF_6 = 48/47/4/1\%$.

VETO GRPC the spacers are 20 cm apart (0.25% dead area, maximal glass sag ~10 μm) [4].

The quality controls on the GRPCs of the OPERA experiment are made in a dedicated external hall at the LNGS [5]. Mechanical properties are first investigated in a fully automatized station, measuring the gas leakage and checking the gluing of the spacers.

Fig. 2 shows the efficiency curves of 32 Glass RPCs as a function of the nominal electric field $E_0 = V_0/g$, where $V_0$ is the applied voltage and $g$ is the nominal distance ($\equiv$ 2 mm) between the electrodes.

Fig. 3(a) shows the efficiency map at $E_0 = 4.4$ kV/mm with a granularity of $3.5 \times 3.5\,\mathrm{cm}^2$. The position of the spacers is clearly visible in the map. The efficiency strongly depends on the electric field for $3.6\,\mathrm{kV/mm} < E_0 < 3.9\,\mathrm{kV/mm}$ (see Fig. 2). Therefore, as the electric field is inversely proportional to the gap value, it is possible to estimate the gap uniformity by means of a local efficiency measurement. Fig. 3(b) shows the efficiency map of a single detector for $E_0 = 3.75$ kV/mm (overall efficiency ~50%). The behaviour of the local efficiency suggests a gap uniformity at the level of ~2% (r.m.s.), probably limited by the float glass technology.

The VETO consists of two $1004 \times 923\,\mathrm{cm}^2$ GRPC planes, each one made of 32 chambers organized into eight rows. As shown in Fig. 4, a row has four chambers, three of them are 2.60 m long and 1.14 m high, while the fourth is slightly smaller ($2.40 \times 1.14\,\mathrm{m}^2$).

Each plane has a distribution system with 8-fold parallel channels, each one equalized by a flow resistor (needle) inserted in series upstream of each line (see Fig. 4). Its

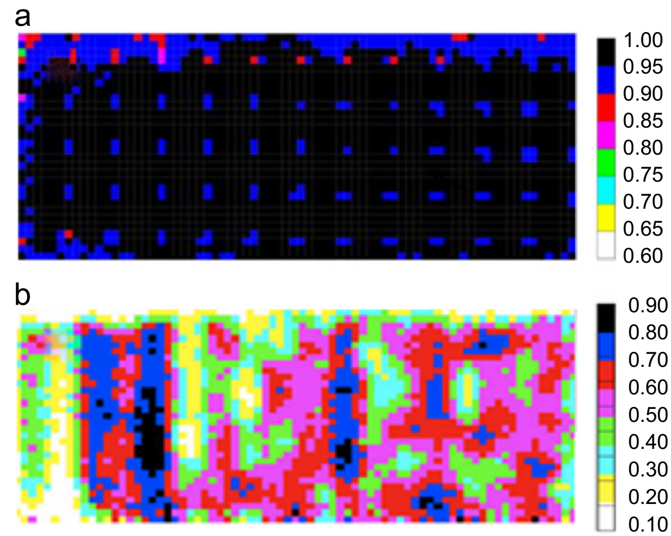


Fig. 3. (a) Efficiency map of a single GRPC at $E_0 = 4.4$ kV/mm. The spacer dead area determines the lower efficiency in correspondence of their location. (b) efficiency map at 3.75 kV/mm: as the efficiency strongly depends on the gap value, the effect of local variation of the distance between the electrodes is clearly visible. $Ar/C_2H_2F_4/Iso - C_4H_{10}/SF_6 = 48/47/4/1\%$.

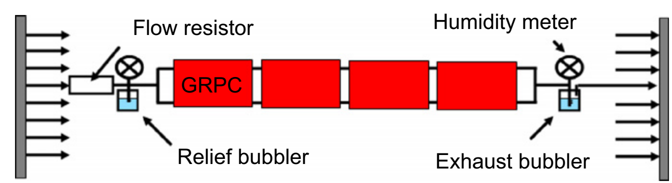


Fig. 4. Gas distribution in the VETO system (see text).

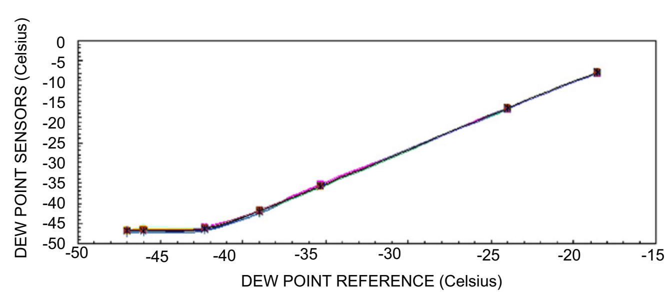


Fig. 5. Calibration curves for all the 32 Honeywell HiH-4602-C sensors with respect to the MTS5(GE Panametrics) hygrometer ($\equiv$ reference).

impedance is about 100 times larger than a row of four GRPC. The relief bubbler protects the detectors from overpressure.

The GRPC is relatively robust except for water vapour contamination [6,7] in the gas mixture. For this reason the gas distribution is made of stainless steel and tygon r2075 pipelines to minimize the water content in the gas flowing through the detectors. To control the humidity level inside the detectors, a monitoring system has been developed. It consists of 32 hygrometers (Honeywell HiH-4602-C) read out by a National Instruments Field Point system. The

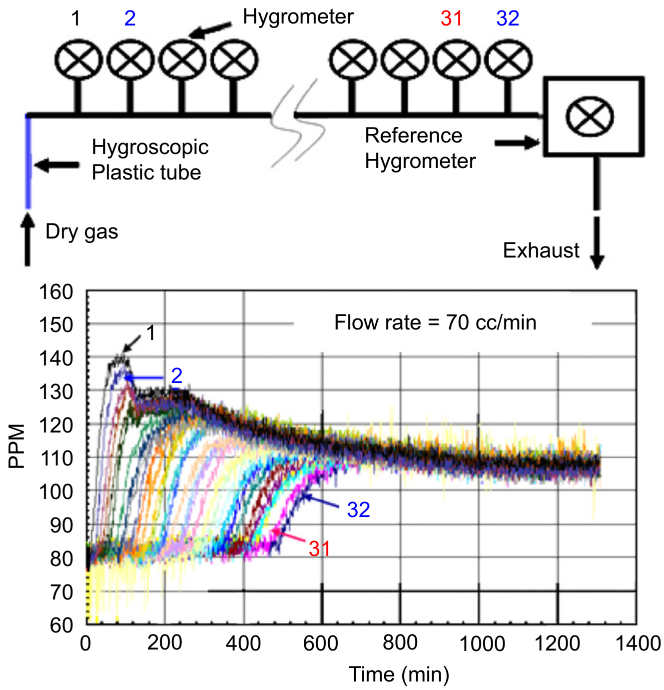


Fig. 6. Top: Experimental setup used for the calibration. Bottom: response of the 32 hygrometers after the insertion of 10 cm plastic tube inside a stainless steel line.

system has been calibrated by using the MTS5(GE Panametrics) hygrometer as a reference.

Fig. 5 shows the preliminary calibration of the 32 hygrometers mounted in the VETO system. All the sensors show a similar behaviour with a linear response for a value of the dew point higher than −42 °C.

Fig. 6 shows the experimental setup used for the calibration measurement. Also shown is the response of all the 32 sensors after the insertion of the plastic tube. It is apparent how the humidity cloud propagates from the first to the last sensor.

## 3. Conclusion

The VETO system of the OPERA experiment is based on the use of Glass RPCs. As the spectrometers are equipped with bakelite RPC, this experiment represents a unique opportunity to compare their performance under the same working conditions. This is of great interest in view of future underground experiments based on the use of RPC detectors, like the Indian Neutrino Observatory (INO) [8] in which about 100 000 m$^2$ of GRPC are foreseen.

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