Available online at www.sciencedirect.com

SCIENCE DIRECT

Nuclear Instruments and Methods in Physics Research A 550 (2005) 116–126

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

www.elsevier.com/locate/nima

Cosmic ray tests of double-gap resistive plate chambers for the CMS experiment

M. Abbrescia[a], E. Cavallo[a], A. Colaleo[a], G. Iaselli[a], F. Loddo[a], M. Maggi[a,*], B. Marangelli[a], S. Natali[a], S. Nuzzo[a], G. Pugliese[a], A. Ranieri[a], F. Romano[a], R. Trentadue[a], N. Cavallo[c], G. Comunale[c], P. Paolucci[c], D. Piccolo[c], C. Sciacca[c], G. Belli[b], C. De vecchi[b], R. Guida[b], S.P. Ratti[b], C. Riccardi[b], P. Torre[b], P. Vitulo[b], Y. Ban[d], J. Cai[d], H. Liu[d], S. Qian[d], Q. Wang[d], Y. Ye[d], J. Ying[d], A. Dimitrov[e], I. Glushkov[e], L. Litov[e], I. Nasteva[e], B. Pavlov[e], P. Petkov[e], T. Anguelov[f], V. Genchev[f], P. Iaydjiev[f], B. Panev[f], S. Stoykova[f], G. Sultanov[f], R. Trayanov[f], P. Vankov[f]

[a]*Dipartimento Interateneo di Fisica and Sezione INFN, Bari, Italy*
[b]*Dipartimento di Fisica Nucleare e Teorica and Sezione INFN, Pavia, Italy*
[c]*Dipartimento di Fisica Nucleare e Teorica and Sezione INFN, Napoli, Italy*
[d]*Peking University, China*
[e]*Atomic Physics Department, Faculty of Physics, University of Sofia, Bulgaria*
[f]*INRNE, BAS, Sofia, Bulgaria*

Received 11 April 2005; received in revised form 2 June 2005; accepted 8 June 2005

Abstract

The CMS Barrel resistive plate chambers quality tests are performed at three different sites (Bari, Pavia and Sofia), where equivalent software and hardware tools are used. Data from the first 210 detectors are available for a comprehensive analysis. The paper describes the general experimental set-up, the test procedure and the cosmic muon test results. The muon trajectory reconstruction algorithm, used for precise studies, is presented. The criteria to accept or reject a detector are also given. The CMS final-design chambers show an average efficiency greater than 95%.

PACS: 29.40.C

Keywords: RPC; Muon system; CMS; Trigger

*Corresponding author. Tel.: +39 080 5442181.
E-mail address: Marcello.Maggi@ba.infn.it (M. Maggi).

0168-9002/$ - see front matter
doi:10.1016/j.nima.2005.06.074

1. Introduction

Future CERN LHC experiments will adopt resistive plate chambers (RPC) in their trigger systems [1–3]. RPCs [4] are gaseous parallel-plate detectors with time resolution competitive to that of scintillators (~1 ns) and good spatial resolution (~1 cm) [2]. Signals are induced on a read-out stripped plane outside the gas volume.

The basic constituent of the CMS RPC chamber is the so-called *single-gap*. It is made of two parallel high-resistivity bakelite plates ($\sim 10^{10}\,\Omega\,\mathrm{cm}$) which form a 2 mm gas gap. In particular, CMS will use double-gap RPCs [1] operated in avalanche mode (reduced gas gain) [2] to ensure high rate capability ($\sim 1\,\mathrm{kHz/cm^2}$). A *double gap* consists of two *single gap*s put one on top of the other with common read-out copper strips in the middle. The signal is induced by the two avalanches simultaneously leading to an improved detection efficiency [5] being the sum of two *single gap* signals.

Each Barrel chamber consists of two *double gap*s, named forward (FW) and backward (BW). These are held together by aluminum profiles.

Among all 480 chambers foreseen to complete the entire Barrel RPC system more than 200 have already been accepted.

2. Experimental set-up

The experimental areas for RPC cosmic ray tests are located in Bari (Physics Department and INFN unit), Pavia (Physics Department and INFN unit) and Sofia (INRNE) [6]. Special halls are equipped with cranes, low- and high-voltage power supplies, gas-distribution lines, weather stations and data acquisition systems.

Cosmic ray test facilities are operational in all sites. They consist of metallic towers where chambers can be placed horizontally and read out in coincidence with the passage of triggering muons. A maximum of ten chambers at Bari site and five at Pavia and Sofia sites can be tested simultaneously. Temperature in the halls is kept constant by an air-conditioning systems.

The experimental set-up for one cosmic ray muon test stand consists of a muon trigger system that is provided by a set of scintillators located on the top and bottom of the test tower. It is based on two double layers of scintillators covering an area of $125 \times 44\,\mathrm{cm}^2$. Fig. 1 shows the scintillator locations: S1, S2 on top and S3, S4 at the bottom of the tower. They are all connected in logical AND. Small ($60 \times 40\,\mathrm{cm}^2$) plastic scintillators, V1 and V2, which are placed on the top of the tower at a distance of 50 cm from the muon trigger system, are also used to veto electromagnetic showers. The overall trigger signal, used after noise discrimination, follows the logic $T = (S1 \cap S2 \cap S3 \cap S4) \cap (\overline{V1 \cup V2})$. The trigger system is supported by a mechanical structure which allows one-dimensional displacement of the scintillators along the strip length to cover either the FW or the BW part of a chamber.

The gas system is based on a series of three *Bronkhorst Hi-Tec* EL-FLOW® mass flow meter/controllers F-201C. The gas mixture is composed of 96.2% $C_2H_2F_4$, 3.5% *iso*-C_4H_{10} and 0.3% SF_6 and it is distributed via parallel system to the chambers. Water vapors are also added to humidify the operating gas within 40–45%. The gas composition is monitored and known with a relative precision better than 1%.

The High-voltage (HV) power supply distribution is based on the Universal Multichannel CAEN-SY1527 unit which has internal processor and network connection. A dedicated

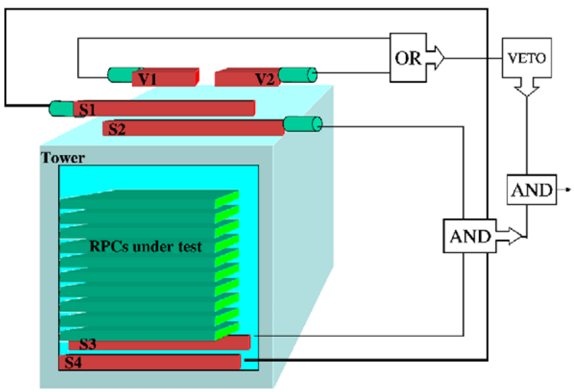

Fig. 1. Experimental set-up and trigger logic scheme.