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Performance of multigap resistive plate chambers with pure Freon 134a

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ABSTRACT

The performance of Multigap Resistive Plate Chambers (MRPCs) with pure Freon 134a was investigated. Two types of MRPCs with different number of gaps and different gap width have been studied; one with 10 gaps of 250 μm and the other with 24 gaps of 160 μm. From the beam tests performed at CERN, the time resolution of the MRPCs flushed with pure Freon has been found to be the same as when SF_6 was added to Freon. The 10 gap MRPC has a time resolution better than 50 ps and the 24 gap MRPC has a resolution of 21 ps, at full efficiency and with no streamers. With pure Freon, the streamers start to develop at a lower electric field.

1. Introduction

The Time-Of-Flight (TOF) detector of the ALICE experiment at CERN [1] is based on the Multigap Resistive Plate Chamber (MRPC) technology [2]. It is composed of MRPC strips with 10 gaps of 250 μm. It provides a time resolution of 50 ps and a charged particle detection efficiency of 100% [3]. Recently a new MRPC with 24 gaps of 160 μm has been built and tested [4]. A time resolution of 20 ps has been measured with this 24 gap MRPC. Both the 10 gap MRPC of ALICE-TOF and the new 24 gap MRPC use a mixture of Freon and SF_6.

During the development of the Multigap Resistive Plate Chamber, a three component gas mixture containing Freon ($C_2F_4H_2$), SF_6, and Isobutane (iso-C_4H_{10}) has been used [5,6]. The use of the flammable gas, Isobutane, was found not to be necessary for the 10 gap MRPC [7]. The SF_6 has been used since it was found to suppress the development of streamers [5]. The width of the gap and the material used for construction today, however, are quite different from those of Ref. [5]. Therefore we investigated whether we could also remove the SF_6 from the gas mixture while obtaining similar performance concerning time resolution and efficiency.

In this paper, we present the results of operating the MRPCs mentioned above without SF_6. A comparison of the efficiency, streamer probability, time resolution, and the charge spectrum will be made between Freon-SF_6 mixtures and pure Freon.

2. Experimental setup

The 10 gap MRPC strip was built in a two stack structure as shown in Fig. 1. Each stack consists of five gas gaps (G). The gaps are formed by glass sheets (J) of 400 μm separated by a fishing line of 250 μm diameter. The two outermost glass sheets (K) of a given stack, 550 μm thick, are painted with a resistive coating and are connected to high voltage power supplies of opposite polarities. The anode (F) and cathode (H) pickup electrodes, arranged in two rows, are printed in the vetronite PCBs (D) which are placed next to the high voltage planes. Mylar sheets are used as insulators between the high voltage plane and the vetronite PCB. The size of a pickup electrode is 2.5 cm × 3.7 cm. A 10 gap MRPC strip placed in an aluminum box with a volume of 200 l has been used for this measurement. The time and the width of the signal from a selected channel have been read by a LeCroy oscilloscope.

The 24 gap MRPC has four stacks, each stack consisting of six gas gaps, as shown in Fig. 2. The size of a pickup electrode is 2.45 cm × 7.4 cm and it is read out at both ends. Two 24 gap MRPCs were mounted in parallel in an aluminum box with a gas volume of 30 l.

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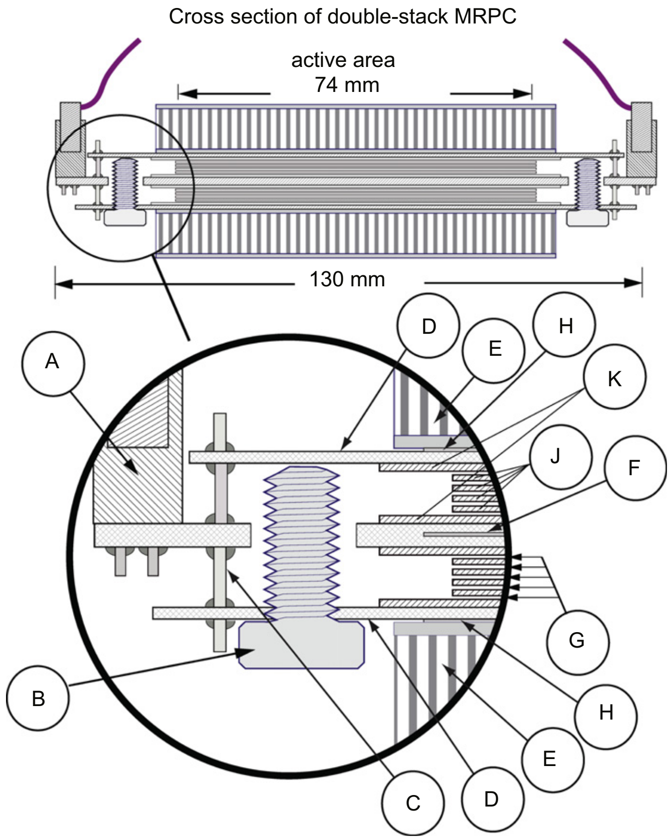

Fig. 1. Structure of the 10 gap MRPC. It consists of two stacks. Each stack has five gaps (G) of 250 μm formed by the four inner glass sheets (J) and two outer glass sheets (K). Also shown in the picture are; flat cable connector (A), nylon screw (B) that holds the fishing-line spacer, pin connector (C) to bring the cathode signal to the central read-out PCB with anode pickup pads (F), honeycomb panel (E), and PCB with cathode pickup pads (H).

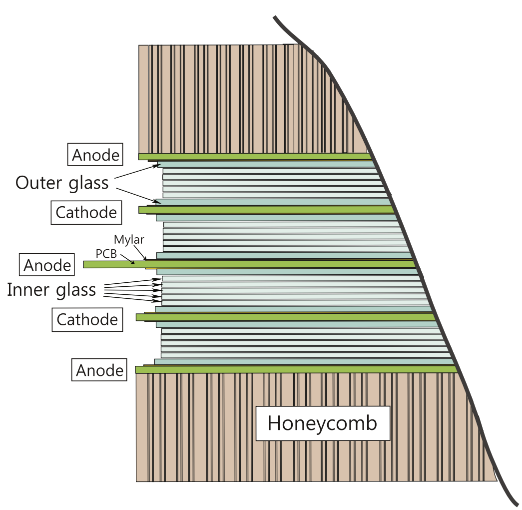

Fig. 2. Structure of the 24 gap MRPC. It consists of four stacks. Each stack has six gaps of 160 μm.

We used an Agilent Infiniium oscilloscope DSO90254A to measure the time and the width of the signals. The beam was centered on a selected strip; the two ends of this strip from both MRPC detectors were connected to the four channels of the oscilloscope using a home made LVDS to NIM converter. The signals from the anodes and cathodes of the MRPC strips were fed to the differential inputs of the NINO preamplifiers-discriminators [8]. The front-end card

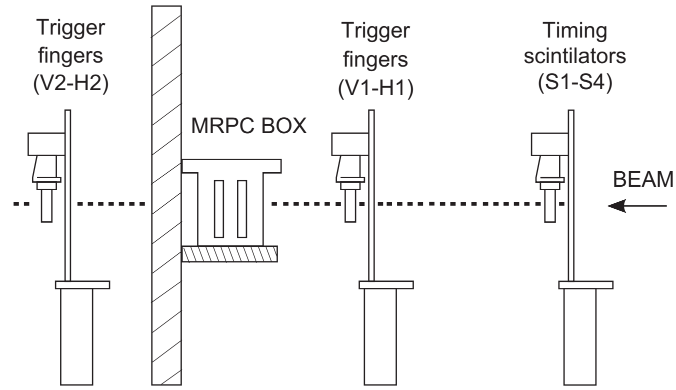

Fig. 3. Schematic of the experimental setup. Three sets of scintillators are used to generate the trigger.

with the NINO chips was placed outside the aluminum box in the case of the 10 gap MRPC. In the case of the 24 gap MRPC, small cards with the NINO chips were attached very close to the MRPC strips inside the aluminum box. During the beam tests, the gas was flushed at a rate of 20 l/h. At the gas outlet of the chambers, the O_2 contamination and the humidity were monitored.

We performed the measurements in three beam test periods. The 24 gap MRPC was tested in July 2009 and the 10 gap MRPC in October 2009 and June 2010. The chambers were mounted in the T10 beam line of the Proton Synchrotron in the East Hall at CERN. The schematic of the experimental setup is shown in Fig. 3. Three sets of scintillators-photomultipliers were used to provide the trigger. The momentum of the beam particles, mainly negative pions, was 5 GeV/*c*.

3. Results

We tested the 10 gap MRPC increasing the fraction of SF_6 from 0% to 10% in 2% steps. At each high voltage point we took two thousand events with which we measured the efficiency, streamer probability, and the time resolution.

The NINO ASIC encodes the input charge into the width of the LVDS output signal. The distribution of the width at various voltages is shown in Fig. 4 for 0% SF_6 and 2% SF_6. At the lowest voltages only one peak is visible, which corresponds to the signal from the avalanche production. As the voltage increases, a second peak is formed and its size increases with the voltage. The distance between these two peaks is fixed at 5 ns approximately. We interpret this second peak as due to the avalanche signal reflected from the input of the PCB containing the NINO chip. The reflected wave travels back to the MRPC where it is reflected again to the NINO input due to imperfect matching of the various transmission lines. The delayed arrival of this reflected signal makes the TOT longer than the original value by a few ns if the reflected signal is big enough to recross the threshold of the NINO discriminator. The measured time difference is consistent with the length (several tens of centimeters) of the flat cables used between the MRPC and the NINO board. Above this second peak, events with a value of TOT larger than 20 ns are observed, which extend to very high values; these events are classified as streamers.

In order to obtain the time resolution, the difference between the arrival time of the beam particle at the 10 gap MRPC and the T0 measured by the scintillators (S1–S4) has been used. The measured time difference has been corrected for slewing using the TOT of the signal. Fig. 5 is a scatter plot showing the correlation between the time difference (ΔT) and the width. Its profile has been fitted with a fifth order polynomial and the correction has been applied to the time difference by subtracting the value of this function at the