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Timing and charge measurement of glass RPC detector with CO2 based gas mixtures

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Resistive Plate Chambers (RPCs) are versatile detectors widely used in HEP experiments due to their excellent timing resolution and efficiency. However, conventional gas mixtures used in RPCs include C2H2F4 and SF6, freon-based gas mixtures with high global warming potential (GWP). So, a transition to eco-friendly gas is necessary to reduce the environmental impact and long-term operation of RPC detectors. In this study, we present efficiency, timing and charge response measurements of glass RPC detector under different CO2 compositions. Measurements have been conducted on single gap detector using a VME-based data acquisition system.

Summary (500 words)

Resistive Plate Chambers (RPCs) are gaseous detectors widely employed to detect charge particles due to their excellent time resolution and high efficiency. Often, they are used in large-scale high-energy experiments as they cover large regions at a relatively lower cost. Currently operating RPCs primarily run on a three-gas mixture composition, in which freon (R134a) is used as the main primary ionization gas, isobutane (iC4H10) is used to absorb photons, and SF6 is used to quench excess electrons. The optimal gas mixture—which is regarded as the RPC magic ratio—is R134a: iC4H10: SF6 = 94.7: 5: 0.3. But, among these, both R134a (i.e. C2H2F4) and SF6 are greenhouse gases having significant global warming potentials (GWPs) of 1430 and 22800, respectively.

Given that these detectors are utilized in large quantities, even a small amount of leakage at the detector level can significantly impact the environment. Apart from this, the increasing restrictions and regulations will increase the cost of these gases, increasing the overall expense of the experiment, and it appears that these F-based gases will be outright prohibited in a few years. Therefore, we'll need to find other gases that allow RPC detectors to perform just as well as they did with F-based gases. To address these concerns, we have introduced CO2 to our RPC detectors in the current phase, which will assist in lowering the quantity of F-based gases that emerge from the chambers. So, this study investigates the viability of CO2-based gas mixtures as an environmentally acceptable substitute for traditional RPC gas mixtures.

RPC detector's efficiency, time resolution, and charge characteristics have been studied using different CO2 percentages. Additionally, a standard gas mixture is used to compare these performance markers. Experimental measurements are carried out on a single-gap glass RPC detector under cosmic ray background. Signals from the detectors are retrieved on copper read-out strips of size 30 cm X 2.8 cm. The chamber under investigation has been placed between the set of three plastic scintillators coupled to photomultiplier tubes. Each scintillator's output pulse has been fed into a CAEN V814 Leading Edge Discriminator for digital conversion and noise rejection. A three-fold coincidence signal was generated using a CAEN V976 logic unit. This trigger signal also serves as the START command for the CAEN V775 Time-to-Digital Converter (TDC). The raw output signals of the RPC are amplified by charge sensitive pre-amplifiers. The output of which is again sent to the CAEN V814 module, and the further discriminated signal is used as a STOP command for the TDC module. In order to study charge spectra under different CO2 gas compositions, a CAEN V965A Charge-to-Digital Converter (QDC) has been employed.

The study's outcome will provide insights into the feasibility of using CO2-based gas mixtures in RPC detectors. Time and charge spectra, in conjunction with efficiency data, will provide valuable information about detector performance. In conclusion, this study is a positive step towards replacing F-based gases in RPC detectors with more environmentally friendly gas options.

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