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Performance of Resistive Plate Chamber operated with new environmental friendly gas mixtures

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The Resistive Plate Chamber (RPC) detectors are widely used thanks to their excellent time resolution and low production cost. At the CERN LHC experiments, the large RPC systems are operated in avalanche mode thanks to a Freon based gas mixture containing C2H2F4, SF6 and iC4H10. Unfortunately C2H2F4 and SF6 are considered greenhouse gases with high impact on the environment. Furthermore the C2H2F4 is also subject to European regulations aiming in a gradual phase out from production in the near future that could induce instability on the price and incertitude in the product availability. The search of new environmental friendly gas mixtures is therefore advisable for reducing GHG emissions and costs as well as to optimize RPC performance and possible aging issues.

Several hydrofluorocarbons (HFCs) and hydrofluoroolefins (HFOs) with a global warming potential (GWP) lower than the C2H2F4 have been studied as possible replacement. More than 60 new environmental friendly gas mixtures based on these gases with the addition of inert components have been tested on single-gap RPCs by measuring the detector performance in terms of efficiency, streamer probability, induced charge, cluster size and time resolution. Evaluations of the quenching and electronegative capacities of the selected eco-friendly gas candidates have been deduced by comparison of the RPC performance.

A particular attention has been addressed to the possibility of maintaining the current LHC RPC operation conditions (i.e. currently used applied voltage and front-end electronics) in order to be able to use new gas mixtures for RPC systems even when the common infrastructure (i.e. high voltage and detector components) cannot be replaced.

A complete replacement of C2H2F4 with the HFOs does not give satisfactory results using the current LHC detector front-end electronics and high voltage system. However reasonable avalanche operation is achievable with some of the low GWP HFCs tested. It has been observed that methane (C) and ethane (C2) molecular structures allow direct operation at applied high voltage similar to the ones currently used at the LHC experiments. On the contrary propane or propene structures (C3 without or with double bounds) require the addition of Argon or Helium. Unfortunately mixtures with Argon and Helium show the presence of a large fraction of streamers well above the tolerable limit for safe and long-term operation at the LHC experiments. Encouraging results have been obtained with a partial (50%) substitution of the C2H2F4 with HFO and the addition of small Helium quantity or by using HFCs based gas mixtures. The nowadays RPC gas mixture is therefore not easily substitutable with another 3 gas mixture components but encouraging results have been obtained with a 4-6 gas mixture components. In case of no constrains with the RPC design and infrastructure, operation in avalanche mode with a HFO based gas mixture can be obtained at higher electric field and with a dedicated electronics.

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