Test of new eco-gas mixtures for the multigap resistive plate chambers of the EEE project

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A B S T R A C T

The Extreme Energy Events (EEE) experiment is a project by Centro Fermi (Museo Storico della Fisica e Centro Studi e Ricerche “Enrico Fermi”) in collaboration with INFN, CERN and MIUR, designed to study cosmic rays via a network of muon telescopes, based on the Multigap Resistive Plate Chambers (MRPC) technology. Due to its wide coverage over the Italian territory (more than 10 ° in latitude and longitude, covering more than 3x105 km2), the EEE network is the largest MRPC-based system for cosmic rays detection. Each MRPC has 6 gas gaps obtained by a stack of glass plate, spaced 250 μm each, and is equipped with 24 copper strips. Since its beginning, the EEE MRPCs were filled with a gas mixture of 98% of tetrafluoroethane and 2% of sulfur hexafluoride, but recent restrictions on greenhouse gases have prompted the study of their performance with new gas mixtures. To this aim, extensive tests of tetrafluoropropene and carbon dioxide or sulfur hexafluoride gas mixtures have been carried out.

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1. Introduction

The EEE experiment is designed to study cosmic rays via a network of 56 muon telescopes, based on the MRPCs technology [1–3]. Each muon telescope of EEE is made of 3 Multigap Resistive Plate Chambers (MRPC), filled with a mixture of 98% R134a (tetrafluoroethane, C\textsubscript{2}H\textsubscript{2}F\textsubscript{4}) and 2% SF\textsubscript{6} (sulfur hexafluoride), at a continuous flow of 2 l/h and atmospheric pressure. Recently EU has imposed restrictions on greenhouse effects, setting up a maximum limit of 150 on Global Warming Potential of gas mixtures: to fulfill this regulation (for the present gas mixture \( GW P \approx 1900 \)), extensive tests of several gas mixtures with cosmic muons detected by one of the telescopes installed at CERN have been carried out [4]. Results of these tests, focused on the choice of the mixture with better performances, in view of new operating conditions for the EEE telescopes, will be described.

![Fig. 1. Efficiency and streamer for all the tested gas mixtures. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)](image1)

![Fig. 2. Efficiency and streamer for the most promising gas mixtures.](image2)

<table>
<thead>
<tr>
<th>Table 1 Tested gas mixtures.</th>
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<tr>
<td>Pure R1234ze</td>
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<tr>
<td>R1234ze(90%) + CO\textsubscript{2}(10%)</td>
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<tr>
<td>R1234ze(80%) + CO\textsubscript{2}(20%)</td>
</tr>
<tr>
<td>R1234ze(50%) + CO\textsubscript{2}(50%)</td>
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<tr>
<td>R1234ze(95%) + SF\textsubscript{6}(5%)</td>
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<tr>
<td>R1234ze(98%) + SF\textsubscript{6}(2%)</td>
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<tr>
<td>R1234ze(99%) + SF\textsubscript{6}(1%)</td>
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<tr>
<td>CO\textsubscript{2}(100%)</td>
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<tr>
<td>CO\textsubscript{2}(98%)+SF\textsubscript{6}(2%)</td>
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2. MRPC eco gas test results

The detection efficiency, the chamber current and the cluster size have been studied under different conditions as a function of the applied high voltage, for new gas mixtures [4], as summarized in Table 1.

Fig. 1 shows a comparison between the performances of all the considered gas mixtures, with respect to those of the standard one, described by pink empty crosses.

The pure R1234ze (tetrafluoropropene, C\textsubscript{3}H\textsubscript{3}F\textsubscript{3}), described in Fig. 1 by red full points, shows an acceptable streamer percentage, but also a higher HV setting point with respect to the original mixture. To lower the HV setting point, three different mixtures of R1234ze+CO\textsubscript{2} have been tested. Due to their extremely low values of the GWP (GWP=6 for R1234ze and GWP=1 for CO\textsubscript{2}), their mutual percentages can be combined without any limitations. The corresponding efficiencies (empty red and yellow crosses, full orange squares in Fig. 1) show HV setting points lower than that of pure R1234ze, with a possible working point at 17–18 kV for the R1234ze(50%)+CO\textsubscript{2}(50%) mixture. On the other hand, the corresponding streamer percentage increases.

To improve this result we also considered three mixtures of R1234ze+SF\textsubscript{6}, though this last can be used only at very low percentages, due to its high GWP value. The corresponding efficiencies (green points, squares and crosses in Fig. 1), show a still high value of the HV setting point, although the streamer percentage is satisfactory. Actually, the R1234ze(99%)+SF\textsubscript{6}(1%) mixture seems to be a good candidate to substitute the standard one, but the SF\textsubscript{6} percentage is still too high to reduce GWP: the obtained results could be improved by testing the R1234ze(99,5%)+SF\textsubscript{6}(0,5%) mixture. We also considered CO\textsubscript{2}-based mixtures (blue points and crosses in Fig. 1), obtaining the lowest HV setting points, but due to low values of the corresponding efficiencies, these are not suitable to substitute the standard one.

3. Conclusions

The most promising gas mixtures are shown in Fig. 2, but work is still in progress: we plan to test EEE MRPC performances with CF\textsubscript{3}I, R1234ze(99,5%)+SF\textsubscript{6}(0,5%), and R1234ze+He.

References