Test of new Eco-Gas mixtures for the Multigap Resistive Plate Chambers of the EEE Project

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Abstract

The Extreme Energy Events (EEE) experiment is designed to study cosmic rays via a network of muon telescopes, based on the Multigap Resistive Plate Chambers (MRPC) technology. Since its beginning, the MRPC detectors of the EEE telescopes were filled with a gas mixture of 98% of tetrafluoroethane and 2% of sulfur hexaflyuoride, but recent restrictions on greenhouse gases have prompted the study of the performance of these chambers with new gas mixtures. To this aim, extensive tests of tetrafluoropropene and carbon dioxide or sulfur hexafluoride gas mixtures have been carried out.

Keywords: Multigap Resistive Plate Chambers, Eco Gas testing
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1. Introduction

The 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 56 muon telescopes, based on the MRPCs technology [1, 2, 3]. Due to its wide coverage over the Italian territory (more than 10 in latitude and longitude, covering more than $3x10^5 km^2$), the EEE network is the largest MRPC based system for cosmic rays detection.
Each muon telescope of EEE is made of 3 Multigap Resistive Plate Chambers (MRPC), filled with a mixture of 98 % tetrafluoroethane ($R134a$) and 2 % sulphur hexafluoride (SF_6), at a continuous flow of 2l/h and atmospheric pressure. Recently EU has imposed restrictions and regulation on greenhouse effects, setting up a maximum limit of 150 on Global Warming Potential of gas mixtures.

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To fulfill this restriction, 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.

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 mixtures of tetrafluoropropene ($R1234ze$) and carbon dioxide (CO_2)or sulfur hexafluoride (SF_6), as summarized in Table 1.

Tested Mixtures
Pure $R1234ze$
$R1234ze(90\%) + CO_2(10\%)$
$R1234ze(80\%) + CO_2(20\%)$
$R1234ze(50\%) + CO_2(50\%)$
$R1234ze(95\%) + SF_6(5\%)$
$R1234ze(98\%) + SF_6(2\%)$
$R1234ze(99\%) + SF_6(1\%)$
$CO_2(100\%)$
$CO_2(98\%)+ SF_6(2\%)$

Table 1: Tested gas mixtures

A comparison between the efficiencies obtained for all the considered gas mixtures is shown in Fig. 1, together with the corresponding streamer percentage. The performance of the $R134a$ standard mixture is described by pink empty circles.

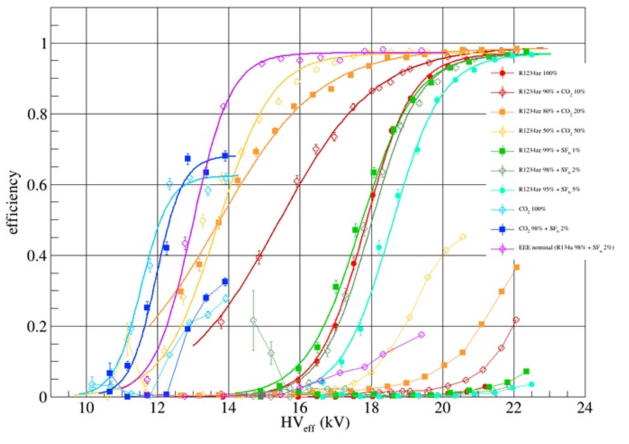

Figure 1: Efficiency and streamer for all the tested gas mixtures

As one can easily see from Fig. 1 the pure tetrafluoropropene $R1234ze$ (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 $R1234ze + CO_2$ have been tested. These mixtures have extremely low values of the GWP (GPW=6 for tetrafluoropropene and GPW=1 for carbon dioxide), then we can combine the mutual percentages of the two gases without any limitations.
The corresponding efficiencies (empty red and crosses, full orange squares in Fig.1) show HV setting points lower than that of pure tetrafluoropropene, with a possibile working point at $17-18$ kV for the $R1234ze(50\%) + CO_2(50\%)$ mixture. On the other hand, the corresponding streamer percentage increases.
Then, to improve this result, we have also considered for testing two mixtures of tetrafluoropropene and sulfur exafluoride, though this last can be used only at very low percentages, due to its high value of the GWP. The corresponding efficiencies, represented in Fig. 1 by the green points, show a still high value of the HV setting point, although the streamer percentage is satisfactory. Actually, the $R1234ze(99\%) + SF_6(1\%)$ mixture seems to be a good candidate to substitute the standard one, but the sulfur exafluoride percentage is still too high to reduce GPW: the obtained results could probably be improved by testing the $R1234ze(99,5\%) + SF_6(0{,}5\%)$ mixture.
We have also considered CO_2-based mixtures (blue points in Fig.1), obtaining the lowest HV setting points, but due to low values of the corresponding efficiencies, these mixtures are not suitable to substitute the standard one.

3. Conclusion

Among the gas mixtures considered in these preliminary tests, the most promising configurations should be $R1234ze(50\%) + CO_2(50\%)$ and $R1234ze(99\%) + SF_6(1\%)$ mixtures. To find the optimum candidate, work is still in progress: we plan to test EEE MRPC detectors with $CF3I$, and $R1234ze(99,5\%) + SF_6(0{,}5\%)$, to find the best substitute for the actual mixture, able to fulfill EU restrictions without compromising the experiment objective.

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