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# Ecological transition for the gas mixtures of the MRPC cosmic ray telescopes of the EEE Project

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Abstract: The Extreme Energy Events (EEE) Collaboration is fully involved in an ecological transition. The use of the standard gas mixture, $C_2H_2F_4$ + $SF_6$, has stopped in favor of an alternative green mixture based on $C_3H_2F_4$ with the addition of He or $CO_2$. The choise of these new mixtures is motivated by the significant lower Global Warming Potential (GWP) to reduce the emission of gases potentially contributing to the greenhouse effect. The EEE experiment consists of 61 muon telescopes based on Multigap Resistive Plate Chambers (MRPCs), each telescope composed of 3 chambers filled with gas. Several EEE detectors are today completely fluxed with the new ecological mixture. This contribution will report recent results about the telescope performance obtained from studies with the eco-friendly alternative mixture carried out in the last years.

Keywords: Gaseous detectors; Large detector systems for particle and astroparticle physics; Particle tracking detectors (Gaseous detectors)

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## Contents



## 1 Introduction

The EEE Project aims to study cosmic rays by detecting secondary muons on the Earth surface generated by primary cosmic rays interaction in atmosphere. The Project has also with an educational purpose with the direct involvement of Italian high school students and teachers in all the phases of the experiment [1]. The EEE network is the largest MRPC-based system consisting of 61 tracking detectors (telescopes). The EEE detectors are installed in Italian high-school buildings and physics laboratories, spanning an area of more than $10^5$ km$^2$ (figure 1).


**Figure 1.** Map of EEE telescopes and schools participating in the EEE Project. In red and light blue respectively schools with and without the telescope, in orange research centres equipped with telescopes.

The telescopes are GPS synchronised for offline analysis on time correlated events.

The EEE gas detector is composed of 3 large area $(0.82 \times 1.58)$ m$^2$ MRPCs (figure 2) operating in avalanche mode, each chamber has six 300 µm gas gaps (250 µm in the new chambers built in the EEE upgrade phase since 2017) [2].

The standard gas mixture used to flux the chambers consisted of 98% $C_2H_2F_4$ + 2% $SF_6$ that are Green House Gases (GHG). The EEE Collaboration has pursued a path to reduce its GHG emissions searching for an ecological mixture to replace the previous one without affecting the detector performance [3, 4]. The new mixture has to be compatible with the hardware of the experimental setup and obviously satisfy the safety requirements. Specifically, the mixture has to be characterized by a working point up to 20 kV and can only be binary, since each EEE station is equipped with only two flowmeters, which cannot be replaced in the whole array, as the costs would be too high. In

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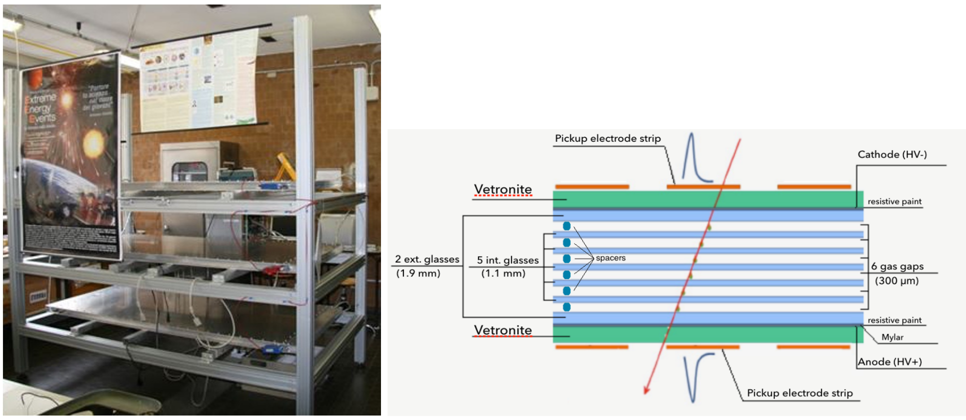


**Figure 2.** EEE telescope (left). Inner structure of a MRPC (right).

addition the eco-mixture has to meet a few criteria: compared to the previous one, it needs to have similar performance and a lower GWP that is the index used to quantify the impact of GHG, each gas has a specific GWP normalized to $CO_2$ which has a value equal to 1. The GWP of the EEE standard mixture is a combination of the value of its main component $C_2H_2F_4$ (tetrafluoroethane), which is 1430, and of the quencher, $SF_6$ (sulfur hexafluoride), equal to 23600; the resulting GWP is 1880, out of the range allowed by the EU regulations banning gases with an index greater than 150. Although research activities exempted from the regulation, the EEE Collaboration decided to start a transition towards a green mixture and the muon telescopes are today fluxed with an eco-friendly gas mixture.

## 2 Eco-friendly mixture

The search for an eco-friendly gas mixture for the cosmic rays telescopes of the EEE experiment led to replace $C_2H_2F_4$ with $C_3H_2F_4$ (HFO1234ze — tetrafluoropropene), characterized by a significantly lower GWP, equal to 6. Potentially a mixture made of 100% of $C_3H_2F_4$ would not require a quencher, however the operating voltage would be too high for the EEE power supply (upper limit 20 kV). In order to reduce the operating voltage, a small percentage of Helium is added to the mixture [5]. The choice of the eco-friendly mixture was driven by the results of an extensive set of tests [6]. Quite a number of mixtures based on $C_3H_2F_4$ with different percentages of He have been tested in order to optimize the HV curve. An example is shown in figure 3, the efficiency test curves of the telescope installed in Pisa INFN Laboratory (named PISA-01) are shown, comparing the standard mixtures with several percentages of $C_3H_2F_4$ and He. The results show that the EEE detectors can be operated with a mixture made of these two gases without any loss in performance [7].

The triple coincidence data acquired with this new eco-friendly mixture shows the expected angular distribution (the zenithal angle of the reconstructed tracks and the angle with respect to the long side of the telescopes) compared with the data collected with the standard mixture [3]. Figure 4 show the trigger rate and fraction of reconstructed tracks, identified by a $\chi^2 < 10$, for the SALE-02 EEE telescope with a good rate stability and no degradation in terms of cosmic track reconstruction.

The change in the mixture does not affect the detector's performance: the trend is approximately constant on the whole data taking period.

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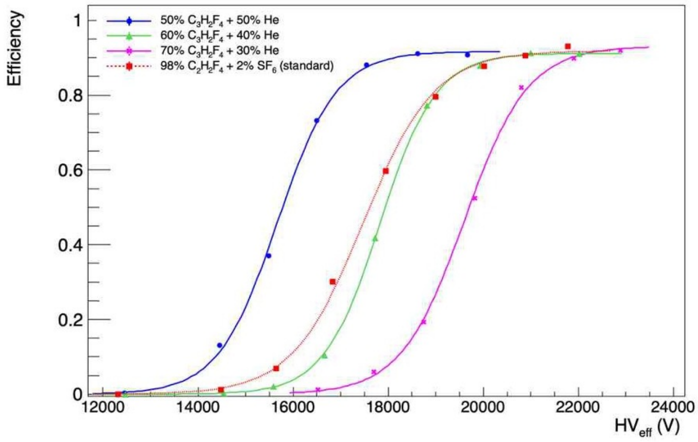


**Figure 3.** Efficiency curves as function of the applied voltage for the chamber filled with the eco-mixture made of $C_3H_2F_4$ and different percentages of Helium. Dashed red line represents the “standard” mixture, solid lines are used for the $C_3H_2F_4$ + He mixtures.

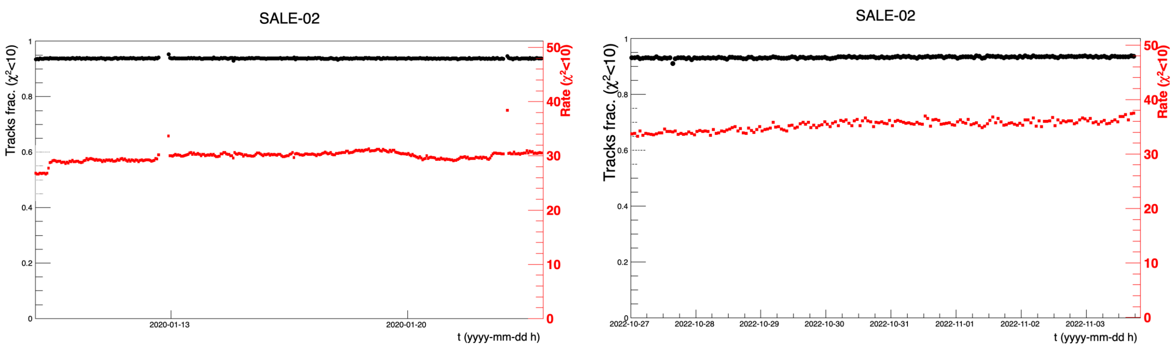


**Figure 4.** Trigger rate in red and fraction of reconstructed tracks in black for the SALE-02 EEE telescope with the standard mixture (left) and with the eco-mixture (right).

The EEE detectors fluxed with the new ecological mixture are: BOLO-02, CAGL-01, CARI-01, CATZ-01, LNLE-01, PISA-01, REND-01, SALE-02, SALE-03.

## 3 Conclusions

The EEE Collaboration is carrying out an ecological transition to replace the gas mixture used in the muon tracking detectors. Several stations are today in acquisition with the eco-friendly gas mixture made of $C_3H_2F_4$ + He, with satisfactory performance for the physics aims of the experiment and the long term data taking is ongoing. The eco-friendly gas mixture currently used guarantees a significant reduction of GWP providing similar performance at the same operating voltage as the standard mixture and no hardware changes are needed. The encouraging results from the R&D on ecological gas mixture carried out in controlled laboratories (CERN and INFN), are now confirmed also in a not controlled environment, as shown from results presented hereby (telescope in a school building). More telescopes are gradually restarting the data taking with new eco-gas mixture. Other mixtures, based on $C_3H_2F_4$ and $CO_2$ are under investigation.

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