Studies on new Eco-gas mixtures for Extreme Energy Events Project

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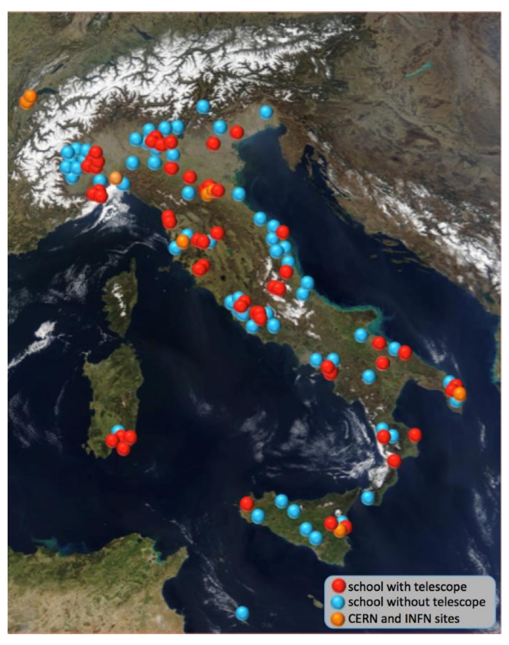
1. Introduction

The Extreme Energy Events (EEE) experiment[1], a joint project of the Centro Fermi and INFN national research institutes, has a dual purpose: a scientific research program for measurements of the cosmic rays fluxes at ground level[2,3,4] and an intense outreach program with an active contribution of students and teachers in the construction and operation of the detectors. The network counts 60 tracking detectors, each made by three Multigap Resistive Plate Chambers (MRPC), operated so far with a gas mixture composed by 98% $C_2H_2F_4$ and 2% SF_6. Given its high Global Warming Potential (GWP), the collaboration started a R&D on alternative mixtures environmentally sustainable. Latest results on $C_3H_2F_4$ + He mixture are presented.

2. The EEE Network

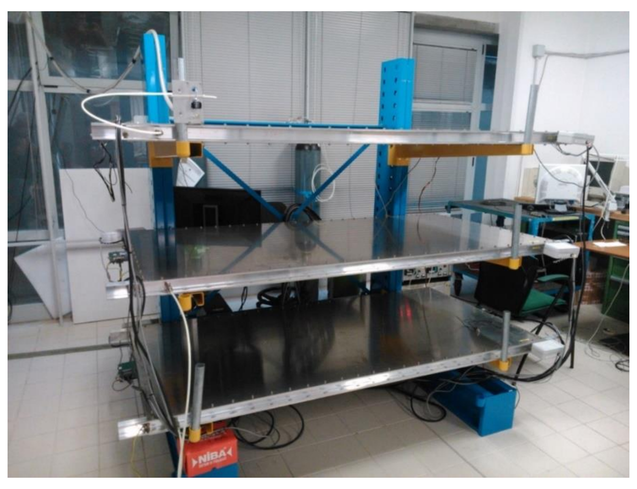


Map of EEE stations

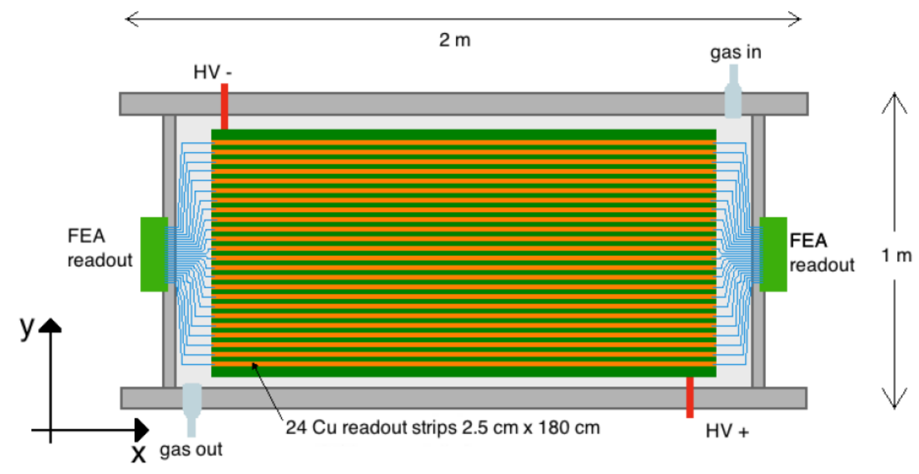
The EEE experiment is based on a network of 60 "telescopes" installed mostly in High Schools all over Italy. The student participate to the construction of the chambers at CERN, to the mounting inside the schools and to the commissioning, operations and monitoring of the detectors all over the yearly data tacking periods.

Data collection, quality monitoring and analysis is centrally performed at CNAF (Bologna)

3. The Telescope



One of the EEE telescopes



Schematic top view of one MRPC with the 24 strips

- 3 MRPCs per telescope, with active surface ~158x82 cm², differentially read out by 24 longitudinal strips. Signal collected at both edges of the strip.
- Front-end and digitization based on NINO ASIC[5] + HPTDC[6].
- Longitudinal coordinate reconstructed by the difference in the arrival times of the signal at the opposite ends of the strip. Transversal coordinate obtained by the strip position.

4. New eco-mixtures

The MRPCs have been fluxed so far with a "standard" gas mixture 98% $C_2H_2F_4$(**R134a**) and 2% SF_6 -> GWP ~ 1430!

Since 2015 the EEE collaboration has undertaken several actions to reduce the gas flow; recently it decided to phase R134a and SF_6 out.

The R&D on new eco-gas mixtures has recently entered its final phase.

Constraints on new mixtures:
- Not toxic/flammable, low cost.
- Compatible with current gas mixers -> only binary mixtures.
- MRPCs must operate below ~20 kV.
- No modification to FE electronics.
- No loss of detector performance.

2 main candidates with $C_3H_2F_4$ (**HFO1234ze**) after preliminary tests:

GWP < 10!!!

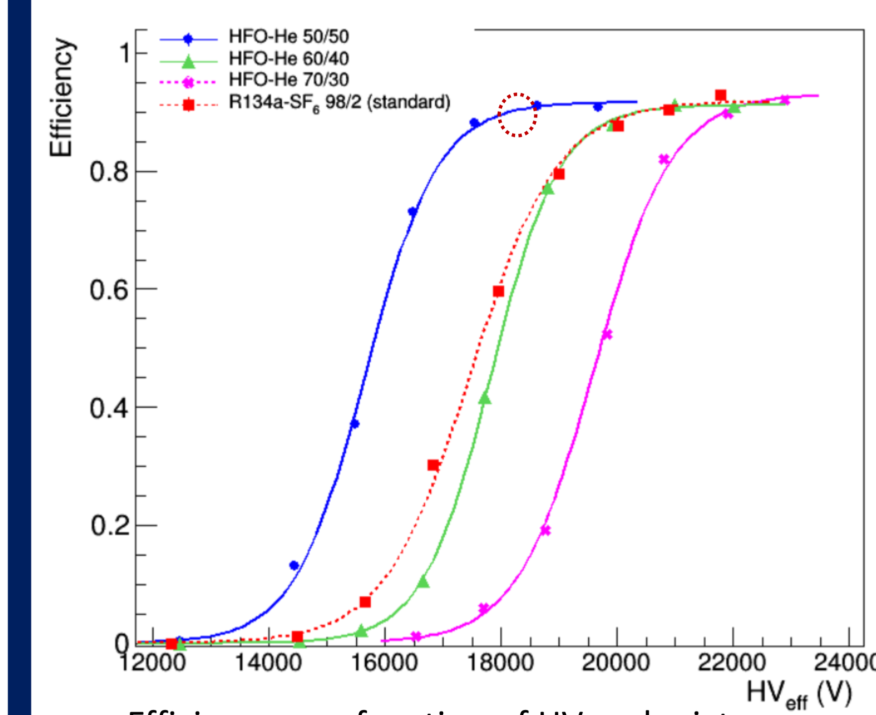
$C_3H_2F_4$ + CO_2

$C_3H_2F_4$ + He (discussed here)

$C_3H_2F_4$+He mixture independently tested on 2 telescopes (Pisa and Cosenza), with very similar results. Gas flux set to have a complete gas volume exchange in the chamber every 3 days, relative gas percentage under study.

5. Efficiency

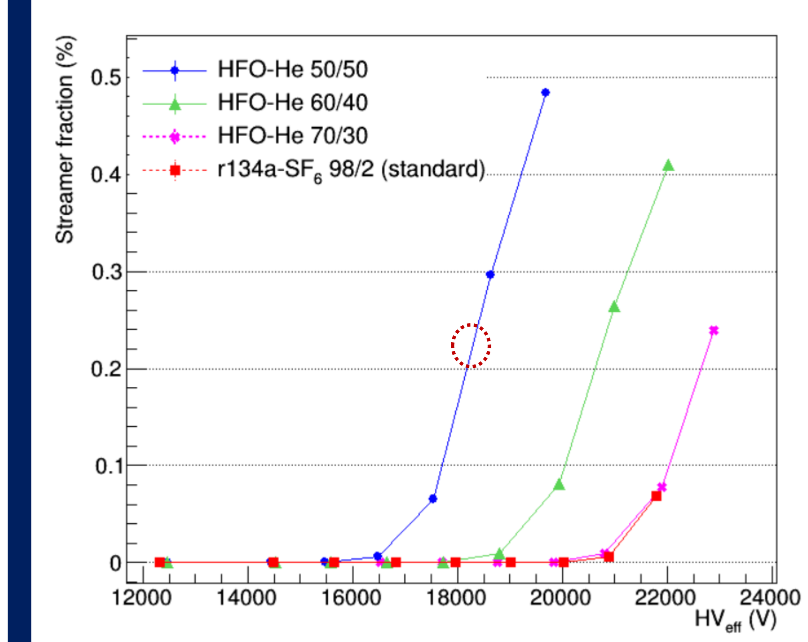
Test setup: 2 chambers operated with "standard" mixture and optimal HV bias, used for trigger and tracking. Third chamber (under test) fluxed with new eco-gas mixture.



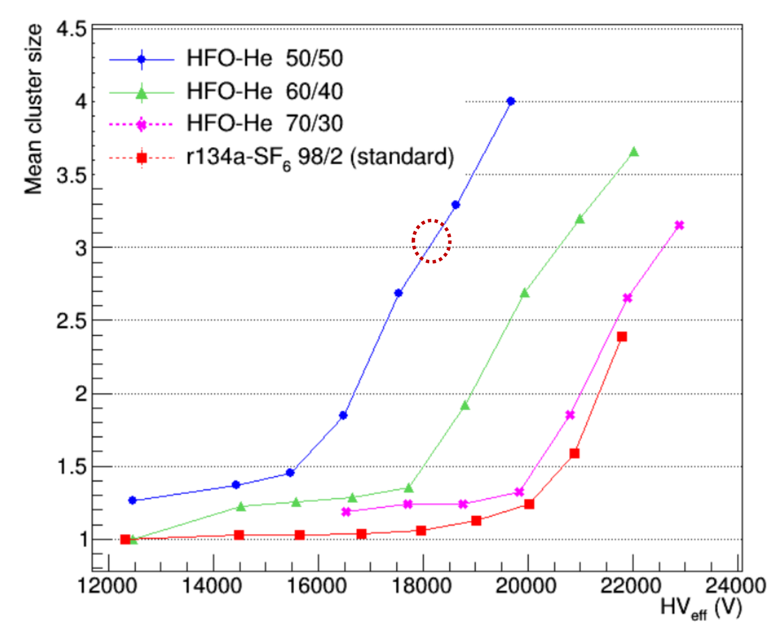
Efficiency as a function of HV and mixture

Offline event selection based on data from the 2 trigger chambers:
- B of reconstructed particle in the 0.85-1.25 range.
- Extrapolated intercept point within the fiducial area on test chamber.
- Track zenithal angle $\theta < 25°$.

Chamber considered efficient if a cluster is found within 10 cm from the extrapolated intercept point



Streamer (cluster size > 3) fraction as a function of HV and mixture



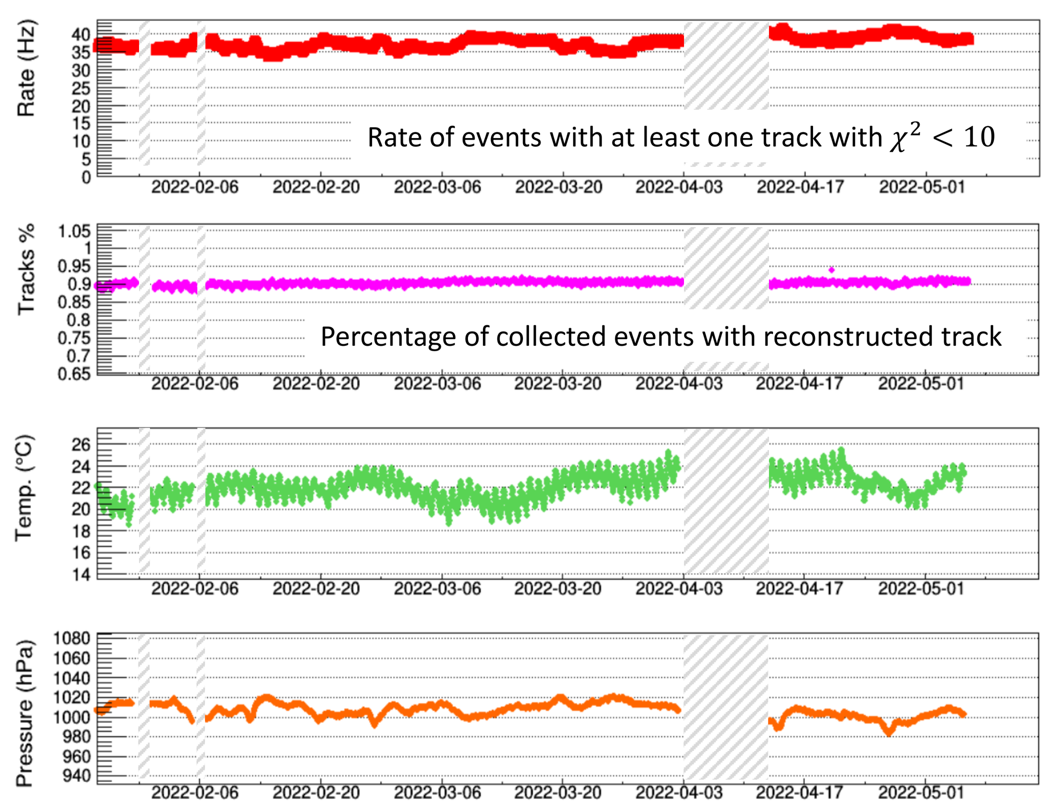
Cluster size as a function of HV and mixture

Example of working point (circled in plots): 18-18.5 kV for $C_3H_2F_4$ + He 50/50

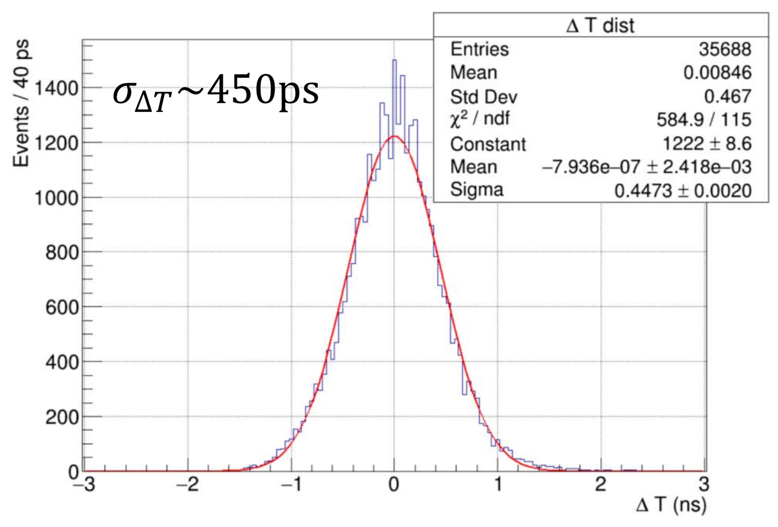
Operating the telescope with $C_3H_2F_4$ + He guarantees the same efficiency at the same operating voltage as the "standard" mixture. Not a problematic increase of streamer fraction and cluster size.

6. Stability & time precision

Test telescopes fluxed for more than three months, all chambers fluxed with new mixture (50/50): very good stability and no degrade of performance. Parameters fully compatible with "standard" mixture.



Interruptions due to efficiency study and telescope maintenance.



Time difference between trigger chambers and tested chamber

- Signal total charge correction (for Time Walk correction) to be applied.
- Optimization of working point and mixture ongoing.

Muon absolute timestamp uncertainty dominated by GPS time precision.

4D (tracking & timing) reconstruction capability maintained with $C_3H_2F_4$ + He

7. Conclusion and outlook

- **Preliminary results indicate that $C_3H_2F_4$ + He mixtures can be effectively used to replace the "standard" mixture, complying with the project requirements and with the advantage of a negligible GWP.**
- **A few more EEE telescopes are starting operations with this mixture to increase the measurements and for HV and gas mixture composition fine tuning.**

[1] M. Abbrescia *et al.*, *Eur.Phys.J.Plus* 128 (2013) 62
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[3] M.Abbrescia *et al.*, *Eur.Phys.J.Plus* 130 (2015) 9, 187
[4] M.Abbrescia *et al.*, *Eur.Phys.J.Plus* 126 (2011) 61
[5] F. Aghinolfi *et al.*, *IEEE Trans.Nucl.Sci.* 51 (2004) 1974-1978
[6] J. Christiansen. https://cds.cern.ch/record/1067476/files/cer-002723234.pdf

15th Pisa Meeting on Advanced Detectors, 22-28 May 2022, La Biodola, Italy