Extreme Energy Events — Science inside Schools | Dipartimento di Fisica E.R. Caianiello | TIPP 2021 International Conference on Technology and Instrumentation in Particle Physics | INFN | Università degli Studi di Salerno

Performance of the Multigap Resistive Plate Chambers of the Extreme Energy Events Project

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The EEE Project

The Extreme Energy Events (EEE) Project is designed to detect and study high-energy Cosmic Rays (CR). It is a network of several muon telescopes based on Multigap Resistive Plate Chambers (MRPC) synchronized by GPS. The EEE network is composed of 61 muon telescopes organized in clusters and single telescope stations installed in Italian High Schools, built and operated by students and teachers, constantly supervised by researchers. The unconventional working sites are a unique test field for checking the robustness and the low-ageing features of the MRPC technology for particle tracking and timing purposes.
In order to reduce GreenHouse Gases (GHG) emissions, without affecting MRPC excellent performance, the EEE Collaboration is currently studying alternative mixtures environmentally and economically sustainable.

Muon rate in the EEE detectors ~ 30 Hz

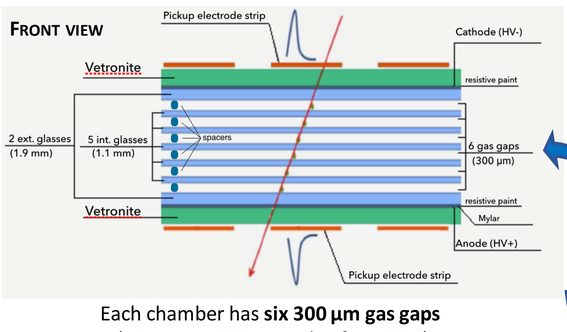
The EEE network is the largest MRPC – based system for cosmic rays detection covering more than 3x10$^5 km^2$

DATA are transferred and stored at INFN computer centre **(CNAF)**

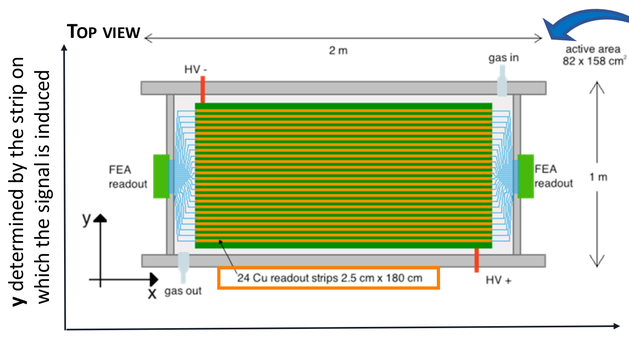
EEE telescope

Each telescope is composed of 3 large area (1.58 × 0.82 m^2) **MRPCs**

High Voltage (HV) up to **20 kV** (avalanche mode) provided by 2 DC/DC converters



Each chamber has **six 300 µm gas gaps** (250 µm in EEE upgrade after 2017) equipped with **24 readout copper strip electrodes** (180 cm x 2.5 cm spaced by 7 mm)



x determined by measuring the difference between the arrival time of the signal at the two ends of the strip

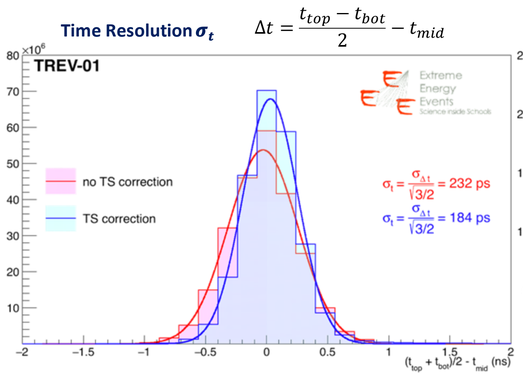
Chambers are filled with a flow of ~ 2 - 3 l/h at atmospheric pressure with a mixture of 98% tetrafluoroethane and 2% sulfur hexafluoride :

$C_2H_2F_4$ (98%) + SF_6 (2%)

Performance

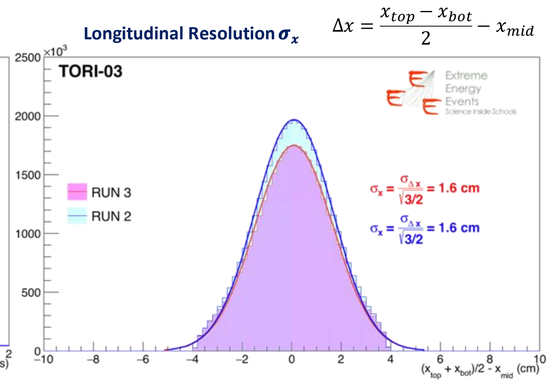
The time resolution is obtained by measuring the hit time on the top and bottom chambers and using these values to determine the expected time on the middle chamber. This value is then compared with the hit time measured on the middle chamber. The width of the obtained distribution is proportional to the time resolution of the telescope. The same strategy is used for the spatial resolution [2].

Time Resolution σ_t $\quad \Delta t = \frac{t_{top} - t_{bot}}{2} - t_{mid}$



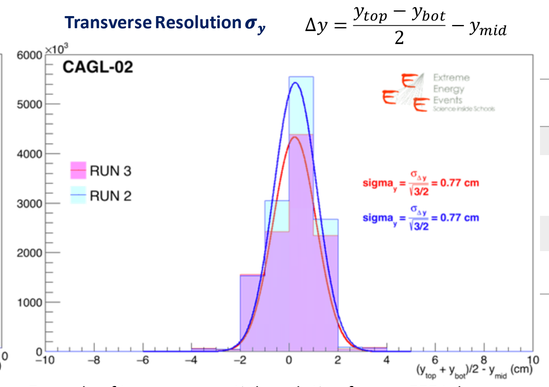
Example of time distributions for one EEE telescope (**TREV-01**, Veneto Region). To be noted that applying Time Slewing (TS) correction improves the resolution by ~ 20%

Longitudinal Resolution σ_x $\quad \Delta x = \frac{x_{top} - x_{bot}}{2} - x_{mid}$



Example of longitudinal spatial resolution for one EEE telescope (**TORI-03**, Piedmont Region) obtained from two subsamples of the data used for the whole analysis.

Transverse Resolution σ_y $\quad \Delta y = \frac{y_{top} - y_{bot}}{2} - y_{mid}$



Example of transverse spatial resolution for one EEE telescope (**CAGL-02**, Sardinia Region) obtained from two subsamples of the data used for the whole analysis.

Average value	
Time Resolution σ_t	238 ±40 ps
Longitudinal Res. σ_x	1.47 ±0.23 cm
Transverse Res. σ_y	0.92 ±0.02 cm
Efficiency ε	93%

Global Warming Potential (GWP)

GWP measures the greenhouse effect of gas normalized to CO_2 ($GWP\ CO_2$=1)

The mixture $C_2H_2F_4$ (98%) + SF_6 (2%) presently adopted in the EEE telescopes has a GWP of ~ **1880**

EU regulations [1] set an upper limit to *GWP* allowed in gas-operated devices

GWP > 150 have been banned by EU

Steps to reduce GWP

1 Gas Recirculation System

Work in progress!

A recirculation system has been installed on a EEE Telescope at CERN and investigation on it is ongoing

The prototype can reuse a flow fraction ~ 60%

MRPCs Tightness Gas Test

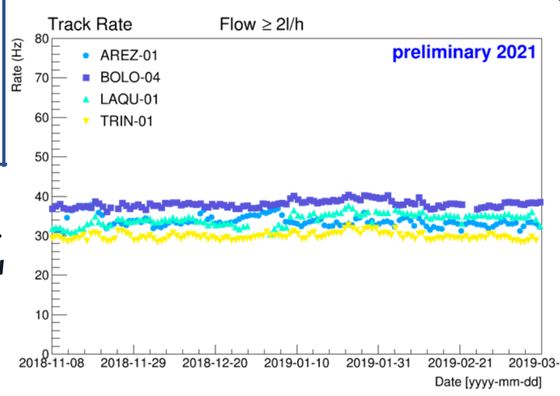
The gas flow reduction has been preceded by a campaign aimed to eliminating any leak in the gas line.

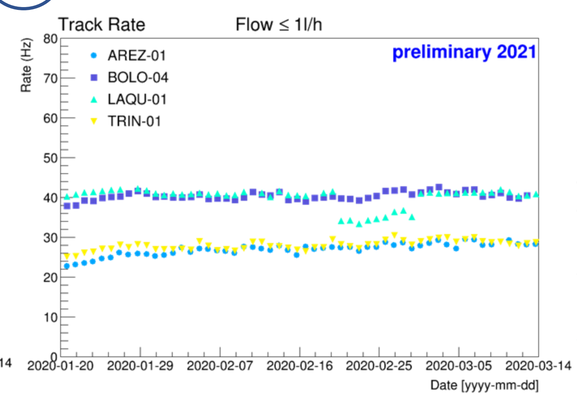
A chamber is accepted if the leakage rate at ΔP_{atm} ~1 mbar is lower than the maximum value: dV/dt = 0.1 l/h [3].

MRPCs with a leakage rate > 0.1 l/h have been cured

The EEE MRPCs can operate at a LOWER flow

2 Gas flow reduction





Remarkable stability considering the different conditions of temperature, external pressure, efficiency fluctuations in a different time lapse between the two data samples.

FLOW REDUCTION
2-3 l/h → ~ 1 l/h

The flow reduction campaign
→ started in September 2019
→ stopped in March 2020 due to Covid-19

~ **65%** EEE detectors with a flow ~ 1 l/h

~ 50% OF GAS WASTE REDUCTION

3 Eco - friendly gas mixtures

Mixtures based on Tetrafluoropropene ($C_3H_2F_4$) with different percentages of CO_2 and SF_6 have been tested in order to optimize the HV curve.
Efficiencies and streamer percentages for the different mixtures are shown below [4].

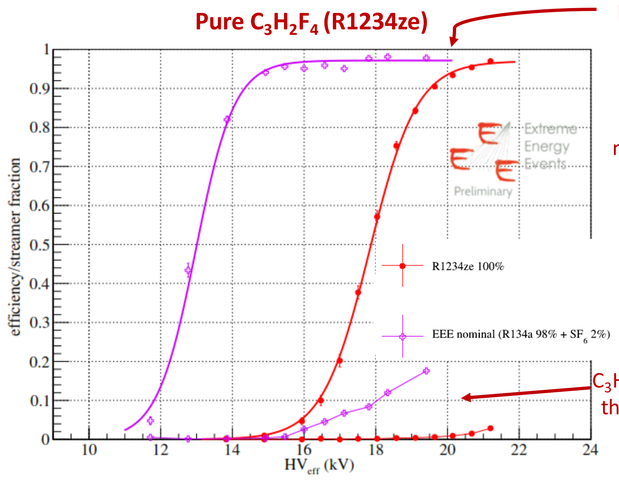
Tested gas mixtures

- *Pure (100%) $C_3H_2F_4$ (R1234ze)*
- *R1234ze (90-80-50)% + CO_2 (10-20-50)%*
- *R1234ze (5-98-99)% + SF_6 (5-2-1)%*
- *Pure CO_2*
- *CO_2 + SF_6*

→ DISCARDED — Too low efficiency - highly noisy

$C_3H_2F_4$ (GWP = 6) is a good candidate to substitute **$C_2H_2F_4$ (GWP = 1430)**

Pure $C_3H_2F_4$ (R1234ze)

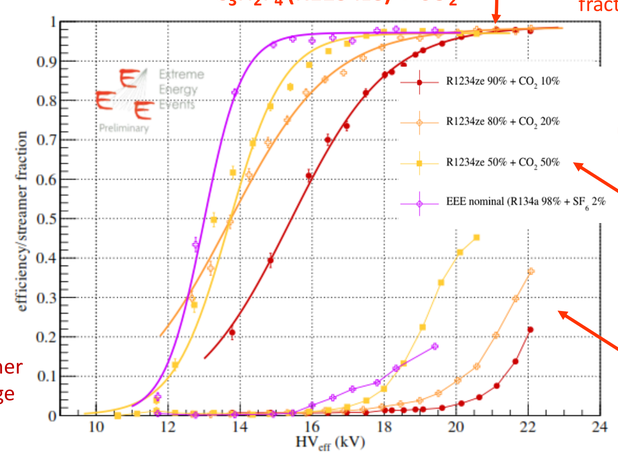


Higher HV working point ~ 21 kV with respect to standard mixtures (~ 16-17 kV with new 250 µm-MRPC)

$C_3H_2F_4$ ia a good quencher the streamer percentage is under control

Streamer fraction $= \frac{\#TOT\ Hits\ with\ cluster\ size > 5\ strips}{\#TOT\ Hits\ in\ the\ chambers}$

$C_3H_2F_4$ (R1234ze) + CO_2



The efficiency plateau decreases as the CO_2 fraction increases

For mixture $C_3H_2F_4$ 50% + CO_2 50% **18 kV** is a good point similar to EEE mixture BUT Streamer percentage too high

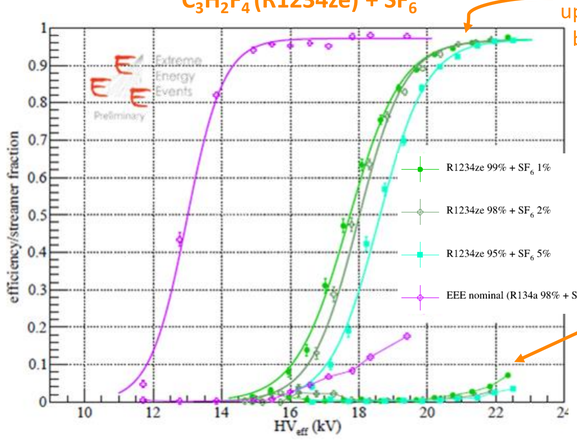
Noisy behaviour

$C_3H_2F_4$ 60% + CO_2 40%
$C_3H_2F_4$ 70% + CO_2 30%

New percentages can be studied

SF_6 is a very effective quencher also in a small percentage

$C_3H_2F_4$ (R1234ze) + SF_6



High value of the HV setting point, above the upper HV limit supplied by DC/DC converters

Noisy is highly suppressed by SF_6

SF_6 percentage still too high for GWP requirements

Due SF_6 high GWP value (23900) its fraction should not exceed **0.5 %**

$C_3H_2F_4$ 99.5% + SF_6 0.5% (GWP ~ 125)

Conclusions and Outlook

- Tests with new percentages of R1234ze + CO_2 and R1234ze + SF_6 are ongoing
- New tests will be performed on both MRPCs types: 300/250 µm gaps
- A few stations are being equipped with all proposed eco-friendly mixtures for tests in full operational mode on a longer time scale
- Flow reduction is well advanced: the final goal to run 100% of the array at 1 l/h can be easily achieved
- Optimization of the recirculation system is ongoing

The EEE Collaboration actions to reduce the **Global Warming Impact in the MRPC array of the EEE experiment is progressing!**

References

[1] Regulation (EU) No 517/2014 of the European Parliament and of the Council on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006.

[2] M. Abbrescia, et al. (EEE collaboration), The extreme energy events experiment: an overview of the telescopes performance - J. of Instrum. 13 (2018) P08026.

[3] M.P. Panetta et al. (EEE Coll.) Strategies to reduce the enviromental impact in the MRPC array of the EEE experiment - J. of Instrum. 15 (2020) C11011.

[4] S.Pisano et al. (EEE Coll.) - J. of Instrum. 14 (2019) C08008, doi:10.1088/1748-0221/14/08/C08008.