Strategies to reduce the GWP emission in the MRPC array of the EEE experiment

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The EEE Project

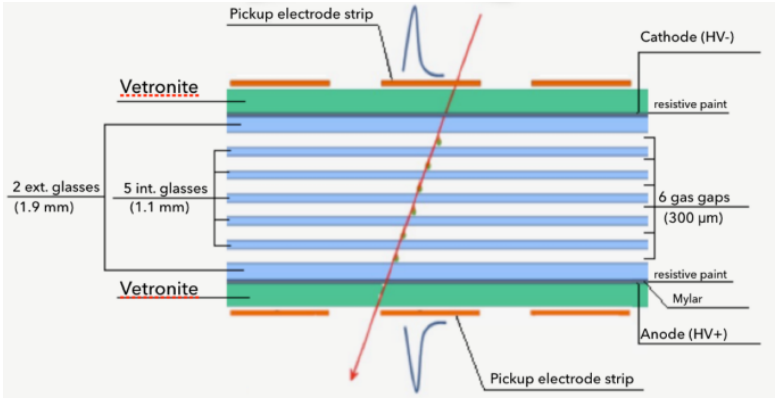
The Extreme Energy Events (EEE) Project : **3 Multigap Resistive Plate Chambers** (**MRPCs**) to detect and track cosmic muons with the aim to study Extensive Air Showers.

11 deg Latitude

10 deg Longitude

55 EEE Station in school buildings
5 at INFN sections
2 at CERN

62 EEE telescopes



- ✓ **Low Rate** : mean muon rate in the EEE detectors ~30 Hz;
- ✓ Large MRPCs 1.58 ×0.82 m^2, readout copper strips;
- ✓ 6 gas gaps: 300 μm spaced by fishing line
  from 2018 : 55 New Chambers → 250 μm gaps;
- ✓ **A mixture of $C_2H_2F_4$, R134a** (98%) **and SF_6** (2%) flowed in daisy chain at the **atmospheric pressure** with a **flow ~ 2 - 3 l/h**;

The EEE Telescopes

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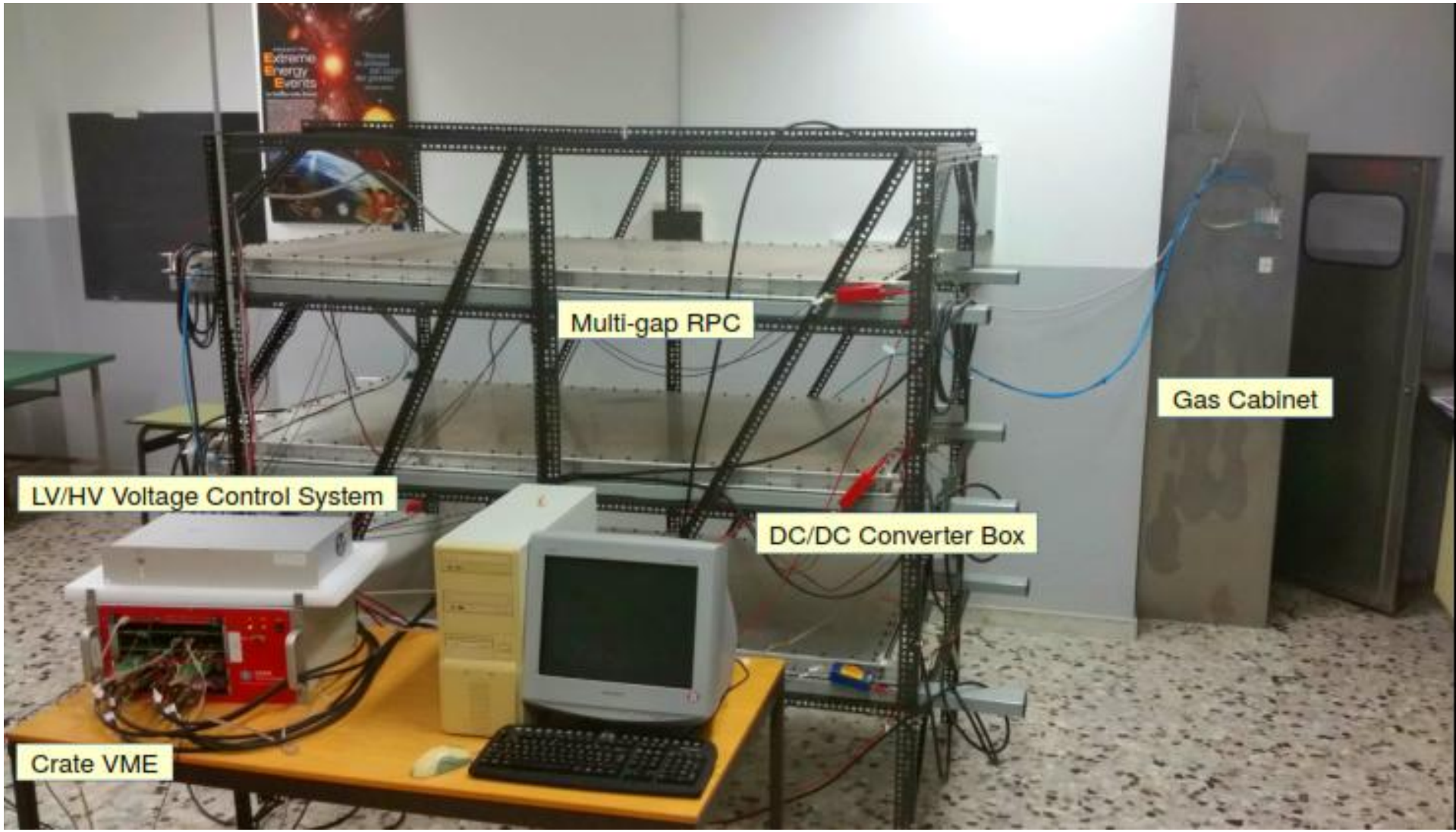
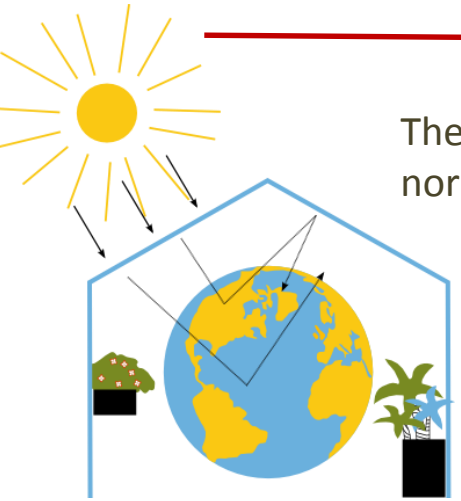
3 Multigap Resistive Plate Chambers (MRPCs) for tracking particles

Large chambers 1.58x0.82 m^2



The GWP reduction



The Global Warming Potential measures the **« greenhouse effect »** of a gas normalized to CO_2.

EU decides to ban the gas mixture with GWP > 150 (2015 → 2020)

Mixture adopted in the EEE MRPCs :
R134a (98%) + SF_6 (2%) → GWP ~1880

62 telescopes with a flow of 2 l/h → ~ 10^6 l/year, 3t /year

(These gases will continue to be available for research purposes but due to the reduced interest from industry their cost largely increased → R134a is now up to 3 times more expensive ~ 50k euro/y)

Our strategies to reduce the GWP emission in the EEE MRPC array

The EEE Collaboration has started 3 important actions:

- Gas recirculation system
- Gas flow reduction
- Eco-friendly gas mixtures

Gas Recirculation System

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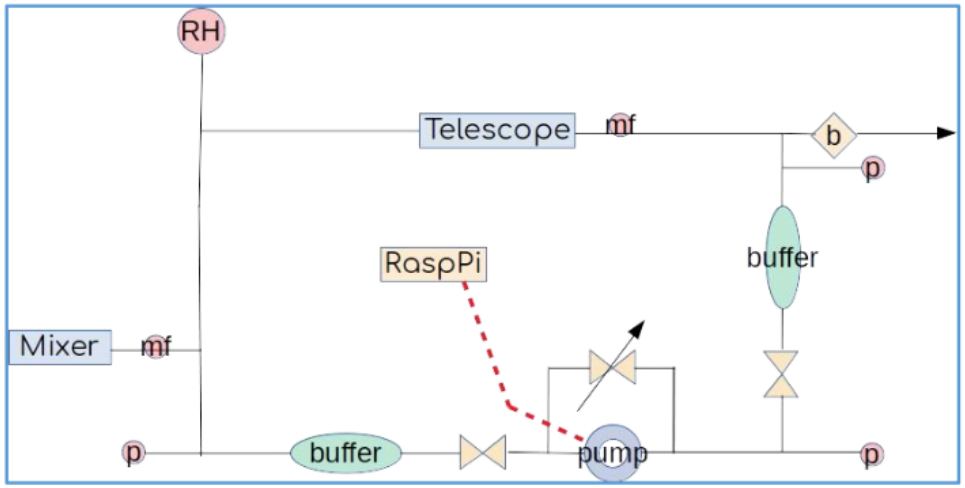
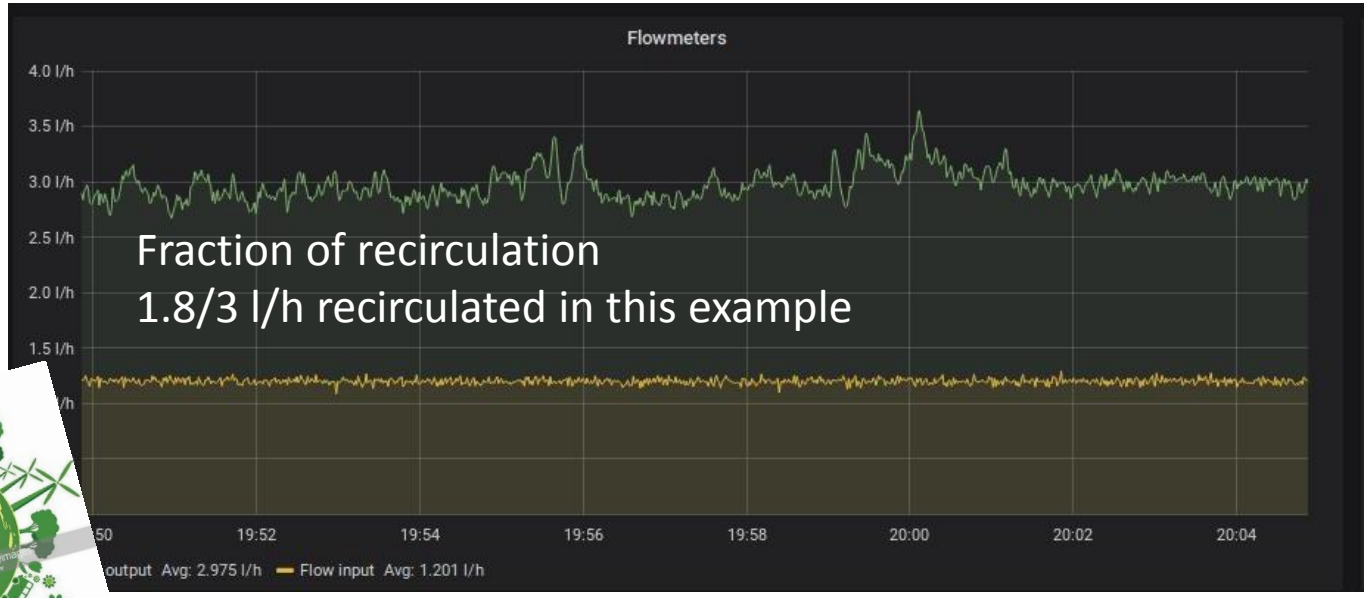
A recirculation system has been installed and under study on a EEE Telescope at CERN (* thanks to CERN Gas Group)

OUR GOAL:
A simple, small, easy-to-use system to be eventually installed in each EEE Station, to be monitored by school teams

The cost of a prototype is ~ 2 keuro → our target is < 1 keuro,





At present the prototype can reuse a flow fraction ~60%

Performance at a Flow ~ 1 l/h

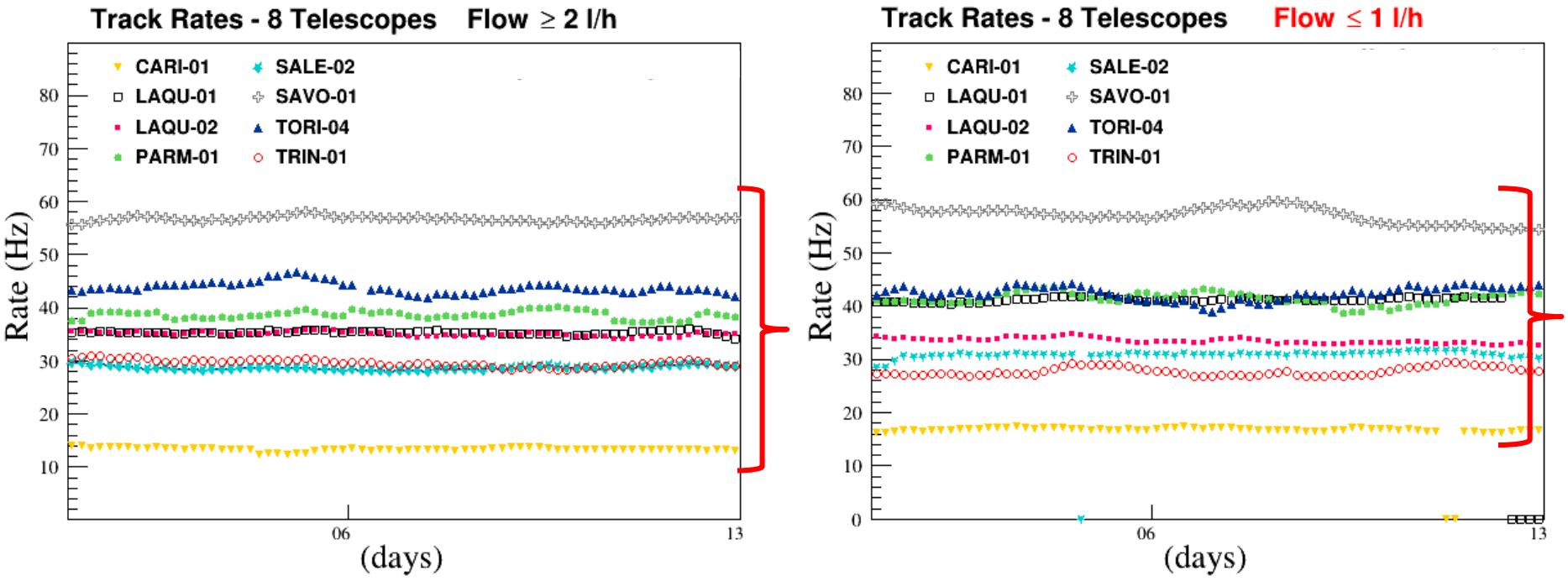
The flow reduction campaign started in September 2019 → stopped in March 2020

from 2-3 l/h -> 1 l/h

when ~65% of the EEE Telescope array was able to operate with a flow ~ 1 l/h

The MRPCs for tracking cosmic muon can operate at a lower flow,
their performance are not affected by flow reduction

Muon track rate



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

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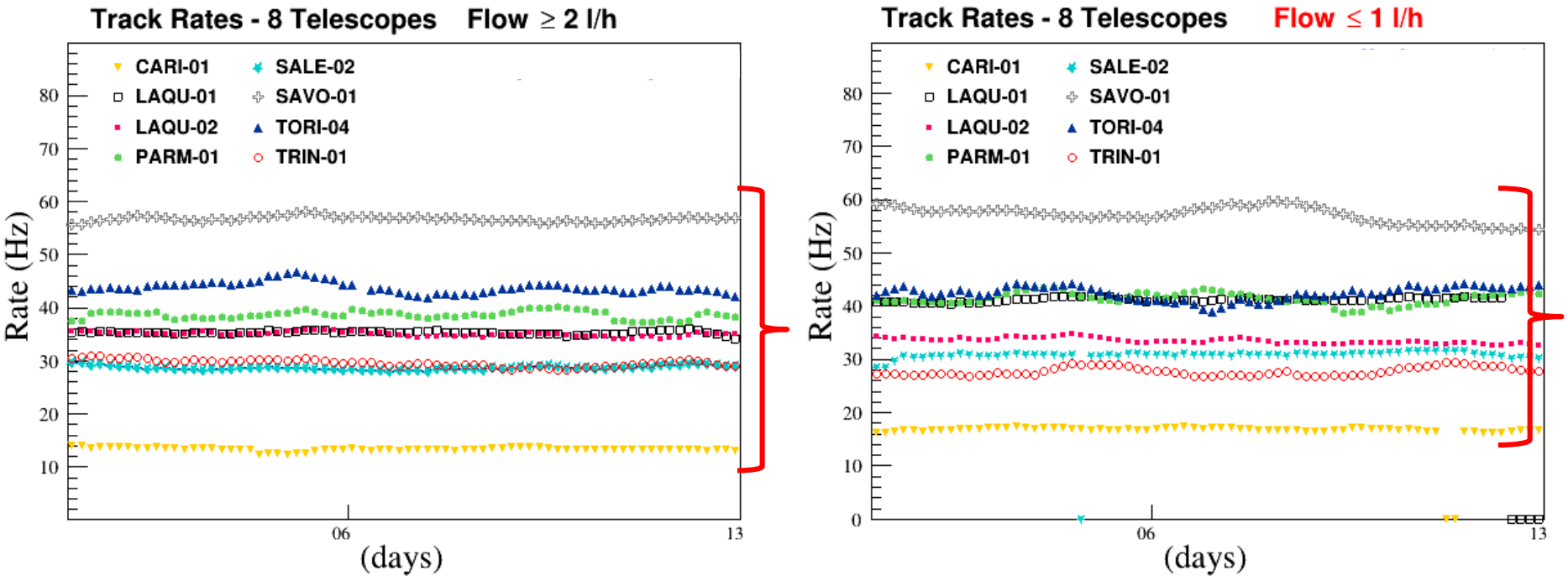

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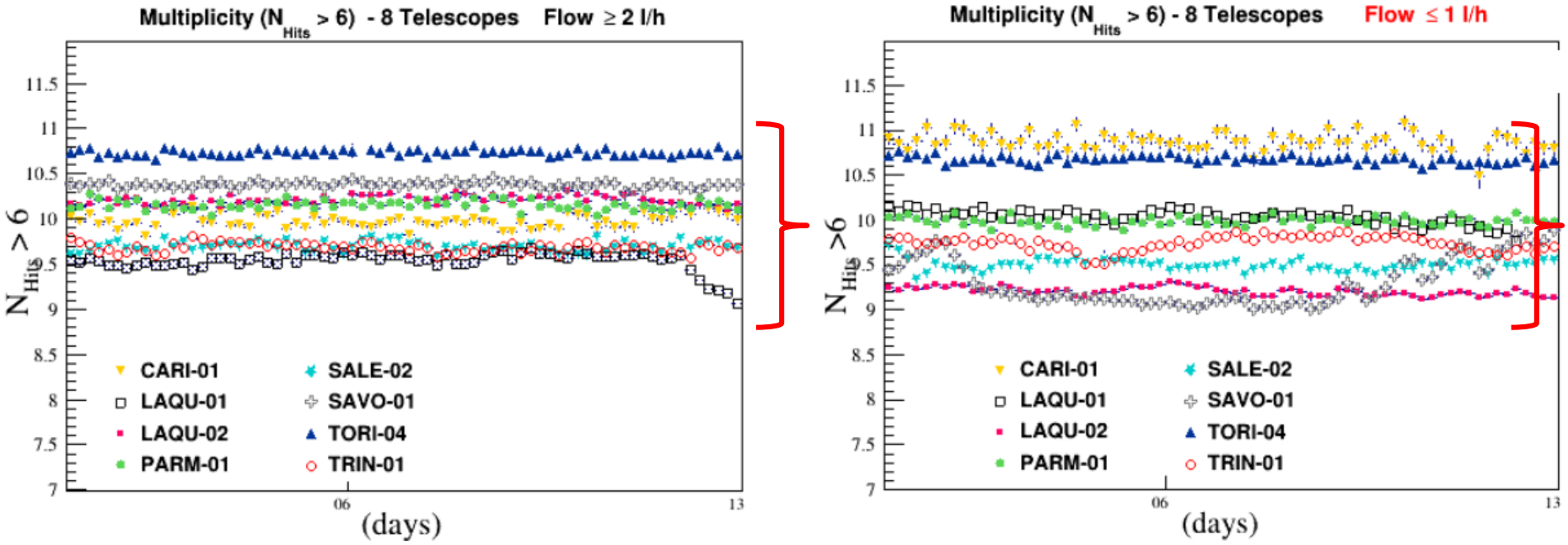
Multiplicity : total number of hits $N_{Hits} > 6$ on the three chambers for each event



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Spatial and Time resolutions are non affected by the flow reduction.
The different value are compatible, considering the different operative condition in the two periods of test.

Average value	*Flow ≥ 2 l/h*	*Flow ~ 1 l/h*
Time Resolution σ_t	237 ± 67 ps	238 ± 40 ps
Longitudinal Res. σ_x	1.48 ± 0.04 cm	1.4 ± 0.1 cm
Trasversal Res. σ_y	0.92 ± 0.01 cm	0.93 ± 0.05 cm

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Eco-Friendly Gases

Several gas mixtures have been tested in the EEE Telescope, with new **MRPCs** (250 μm gaps) **using cosmic muons** (low rate ~ 30 Hz)

The **MRPC efficiency, current, cluster size** has been studied with different **« ecofriendly »** mixtures as a function of applied high voltage

- Pure $C_3H_2F_4$ (R1234ze)
- R1234ze + CO_2
- R1234ze + SF_6
- Pure CO_2
- CO_2 + SF_6

The promising gas mixtures were :

- Pure $C_3H_2F_4$ (R1234ze) → **High cost for** R1234ze ~ 2 × R134a
- R1234ze + SF_6 → High GWP value
- R1234ze + CO_2 → better than pure R1234ze but already expensive

Eco-Friendly Gases

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Updates on Gas studies:

New test mixtures are going to use both **MRPC types : 300/250** µm gaps

- **R1234ze + CO_2** : 50/50 → 90/10
- **R1234ze +** He : 70/30 → 80/20

Ar/ CO_2

R1234ze/ Ne, O_2 … unexplored !!!

Ar, CO_2 and **He** → cheap 30 euro / m^3

TESTs in INFN Laboratories can start the next month.

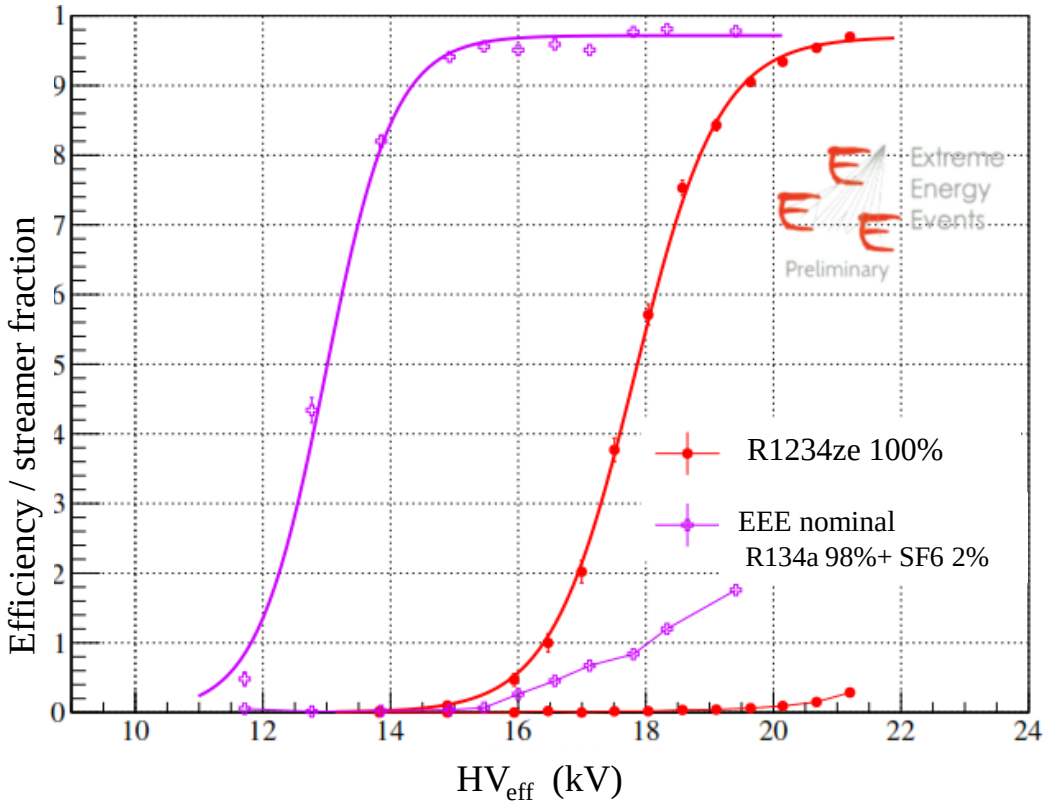
(Bologna + Pisa + Cosenza)

100% Tetrafluoropropene $C_3H_2F_4$

Tetrafluoropropene $C_3H_2F_4$ (R1234ze or HFO) with **GWP = 4** could be a good candidate to substitute R134a ($C_2H_2F_4$, GWP = 1300)

High rate measurements (in RPCs) show good results with mixtures of R1234ze …

Pure R1234ze



- Efficiency vs HV_{eff}
- Streamer fraction :

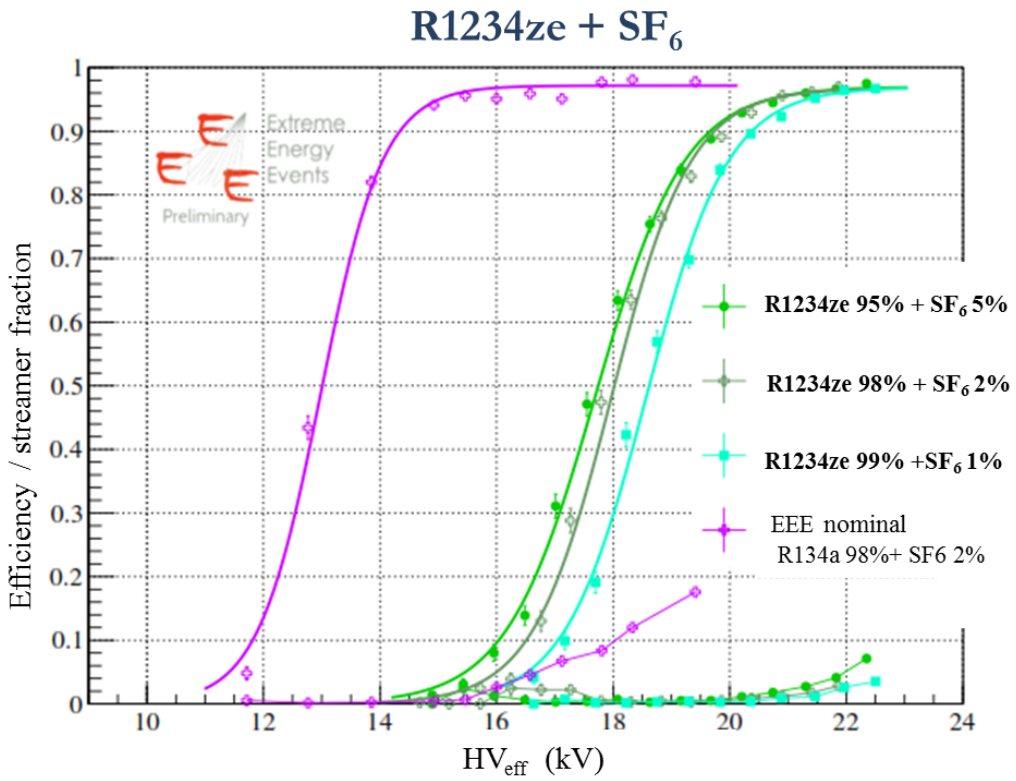
$$S = \frac{\#\ TOT\ Hits\ \ with\ cluster\ size{>}5\ strips}{\#\ TOT\ Hits\ in\ the\ chambers}$$

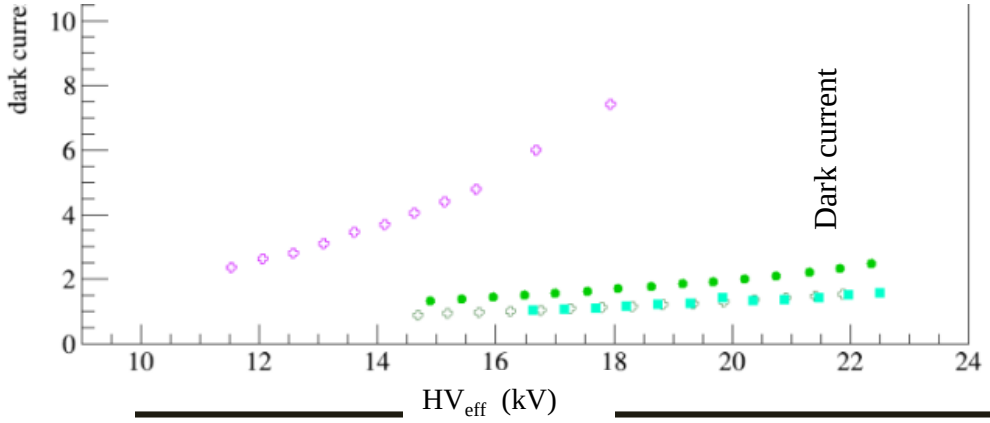
Lower dark currents
Streamers < 5 % → **good quencher**

HV setting point, around 21 kV, **is higher** than the EEE nominal mixture (mean value 16-17 kV with new 250µm-MRPC). It is close to the upper HV limit supplied by DC/DC converters.

Test for eco-mixtures in MRPCs with 300μm gaps

R1234ze + SF_6





SF_6 is very effective quencher also in a small percentage.

- Efficiency vs HV_{eff}
- Streamer fraction :

$$S = \frac{\#\ TOT\ Hits\ \ cluster>5\ strips}{\#\ TOT\ Hits}$$

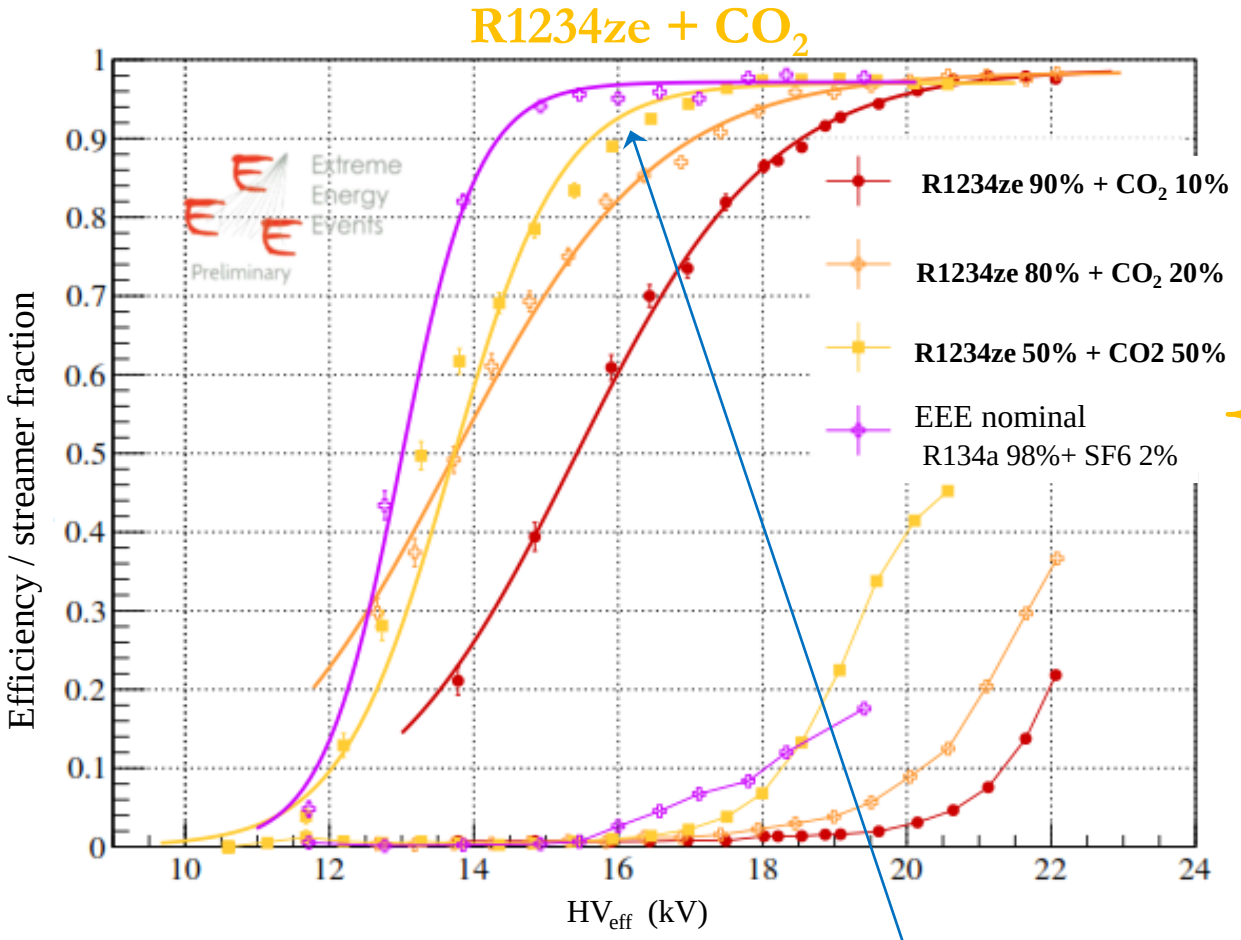
High value of the HV setting point, above the upper HV limit supplied by DC/DC converters.

Noisy is highly suppressed by SF_6.

Due SF_6 very high GWP value (GWP = 23900), its fraction should not exceed 0.5%

R1234ze + CO_2

Mixtures based on Tetrafluoropropene and CO_2 and have been tested in order to decrease the working voltage [very low GWP mixtures: $GWP_{R1234ze} = 6$, $GWP_{CO2} = 1$]



- Efficiency vs HV_{eff}
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The efficiency plateau decreases as the CO_2 fraction increases. For mixture R1234ze **50% + CO_2 50%** →18 kV

The streamer percentage increases.

- **Mixture percentages can be refined -> R1234ze 60% + CO_2 40% or 70%+30%**
- **Test for eco-mixtures in MRPCs with 300μm gaps**

Eco-Friendly Gases

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Ar, CO_2 and **He** → cheap 30 euro / m^3

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Summary

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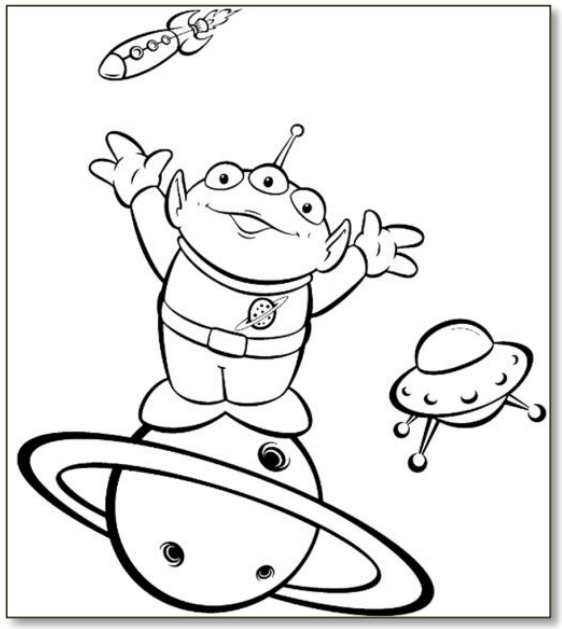
Gas flow reduction	→	At least 65% EEE array is able to use a flow ~1 l/h
Gas recirculation system	→	**Our prototype can reuse a flow fraction ~60%**
Ecofriendly gases	→	**New tests are planned** with **R1234ze + CO_2** and new mixtures will be investigate

The activity to reduce the **Global Warming Potential in the MRPC array of the EEE experiment** interrupted last year, is going to restart!

THANKS FOR YOUR ATTENTION



. . . *Spares*

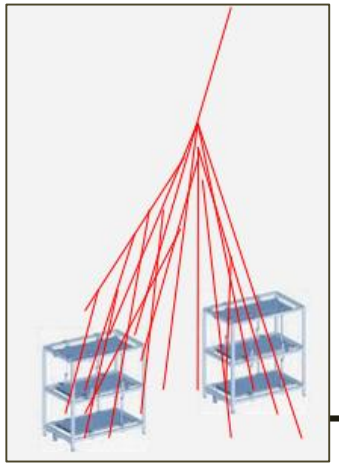
The EEE Project

The Extreme Energy Events (EEE) Project an experiment for the detection of Extensive Air Showers (EAS). It is a joint scientific and educational initiative by CREF in collaboration with INFN and CERN

The detection of an EAS is achieved by measuring the coincidences recorded at the different sites of the EEE Telescopes Array.
It consists of **tracking detectors** hosted in High Schools each made of 3 **Multi-gap Resistive Plate Chambers** (MRPCs).

The Project started in 2004 ⇒ > **62 EEE telescopes** across an overall area of ~ 3 x 10^5 km^2

In 2019 ⇨ 8 new stations



- 55 EEE Station in school buildings
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Telescopes are organized in clusters (10m -4 km d.) and single telescope stations

The EEE Telescopes

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