New Eco-gas mixtures for the Extreme Energy Events MRPCs: results and plans

Silvia Pisano*
for the EEE Collaboration

*Museo Storico della Fisica e Centro Studi e Ricerche Enrico Fermi and Laboratori Nazionali di Frascati - INFN
Eco-friendly gas mixture for gaseous detectors: why?

- **Global Warming Potential** (GWP) measures the greenhouse effect of a gas normalized to $CO_2$  
  \( GWP_{CO_2} = 1 \)

- Gas mixtures with **GWP > 150** have been banned by EU

- Present RPCs adopt mixtures with high GWP

Example (EEE nominal): 98% $C_2H_2F_4$ + 2% $SF_6 \Rightarrow GWP = 1889
Ecogas tests within the EEE Project

EEE Project: a network of telescopes based on Multi-gap Resistive Plate Chambers for the detection of Extreme Energy Events in cosmic rays

~ 56 stations

Ecogas mixture tests:

⇒ first tests on MRPCs (together with the ongoing tests at high rate – see Yonwook Baek’s talk)

⇒ first tests at low rate (100 $Hz/m^2$)

⇒ see M. Abbrescia’s talk on the project upgrade
⇒ see D. De Gruttola’s talk on the performances
Recent tests on RPCs at high rate

$C_3H_2F_4$ (tetrafluoropropene, HFO, GWP=6) emerged as a good candidate to substitute $C_2H_2F_4$ (GWP=1300) when combined to $CO_2$ and $CF_3I$ or $SF_6$.

Abbrescia et al. JINST 11 (2016) no.08, P08019
Tests with cosmics at low rates

Open questions from high rate studies:

1. Is it possible to reach a stable **plateau** with eco-friendly mixtures at **low rates**?
2. Can the **streamer percentage** be kept **low** enough?
3. Can the HV-lowering by CO\textsubscript{2} observed at high rate be exploited in EEE MRPCs?
4. Can mixtures containing SF\textsubscript{6} be produced still fulfilling ECO requirements?

⇒ See Yonwook Baek talk
Tests with cosmics at low rates

Tested mixtures

- Pure R1234ze
- R1234ze + CO₂ (90/10 – 80/20 – 50/50)
- R1234ze + SF₆ (98/2 – 99/1)

CO₂-based mixtures

Original mixture: R134a – tetrafluoroethane
GWP=1300

R1234ze (GWP=6) + CO₂ (GWP=1)
- No limitations on percentages
- Streamer % with CO₂ at low rates?
- Lower HV?

R1234ze + SF₆ (GWP=23900)
- SF₆ < 0.5%
- Likely better in terms of streamer %
- HV above the DC/DC limits

Further combinations being tested:
- CO₂-based combinations
- CF3I (trifluoriodometane, GWP<5)
Pure R1234ze

⇒ see D. De Gruttola’s talk for details on performances
⇒ see M. Abbrescia’s talk on efficiency calculation
Pure R1234ze

- Higher HV setting point with respect to standard mixtures
- Streamer percentage under control
- Less noisy behaviour (lower dark currents)
- Stable cluster size
- HV at the limit of the DC-DC converters
Pure R1234ze

- R1234ze 100%
- EEE nominal (R134a 98% + SF₆ 2%)

[Graph showing the relationship between cluster size, HV_eff (kV), and dark rate (Hz/Hz).]
R1234ze + CO₂
R1234ze + $CO_2$

- **Lower HV** setting point with respect to standard mixtures
- However, noisy behaviour observed
- Possible working point under identification (17–18 kV?) for **R1234ze 50% + CO$_2$ 50%** (but streamer component close to diverge)
R1234ze + $CO_2$

- R1234ze 90% + CO$_2$ 10%
- R1234ze 80% + CO$_2$ 20%
- R1234ze 50% + CO$_2$ 50%
- EEE nominal (R134a 98% + SF$_6$ 2%)
R1234ze + $SF_6$
Higher HV setting point with respect to standard mixtures

However, noise is highly suppressed by $SF_6$

**R1234ze 99% + $SF_6$ 1%** ⇒ most promising configuration

- However, $SF_6$ 0.5% max percentage to fullfill UE requirements
- Future tests on **R1234ze 99.5% + $SF_6$ 0.5%**
R1234ze + SF$_6$

- R1234ze 99% + SF$_6$ 1%
- R1234ze 98% + SF$_6$ 2%
- R1234ze 95% + SF$_6$ 5%
- EEE nominal (R134a 98% + SF$_6$ 2%)
$CO_2$-based mixtures
**CO$_2$-based mixtures**

- **Very low** HV setting point with respect to standard mixtures
- **However**, very noisy configuration
- **Efficiency too low** (~0.6)
$CO_2$-based mixtures

- $CO_2$ 100%
- $CO_2$ 98% + SF$_6$ 2%
- EEE nominal (R134a 98% + SF$_6$ 2%)
Conclusions

A **stable plateau** can be reached in the low rate configuration.

\( \text{CO}_2 \) significantly lowers the working point for HV, but is very noisy.

\( \text{CO}_2 \)-based mixtures not efficient.

\( \text{SF}_6 \) is the best candidate as a quencher, but only a very small component is allowed by UE requirements (0.5% max).
Conclusions

- First tests on MRPCs at low rate

- Stable plateau observed ⇒ possible HV working points can be identified

- **R1234ze 99% + $SF_6$ 1%, R1234ze 50% + $CO_2$ 50%** most promising configurations ⇒ under balancing now

- In few months, some stations will be equipped with the best eco-friendly mixtures for testing in full operational mode on a longer time scale
backup
Tests with MRPCs at high rate at CERN

Experimental setup

- T10 East Area
- 7 GeV, 60 mrad, Spill: 0.3 s, max intensity $10^6$ N/s
- Pions (protons and muons also available)
- Nominal $10^3$N/s-$10^4$N/s, 400 events per spill acquired (sw limit)

⇒ See Yonwook Baek talk
Tests with MRPCs at high rate at CERN

95% R124a + 5% $SF_6$ vs. R1234ze + $CO_2$ mixture

⇒ See Yonwook Baek talk

No Plateau At high rates

CO2 lowers the HV → very important for EEE telescopes
Tests with MRPCs at high rate at CERN

95% R134a + 5% $SF_6$ vs. R1234ze + $SF_6$ mixture

⇒ See Yonwook Baek talk
Mean multiplicity

STD vs ECO

HV (kV)

Mean of Multiplicity

- Freon gas 95% + SF6 5%
- ECO gas 100%
- ECO gas 95% + CO2 5%
- ECO gas 90% + CO2 10%
- ECO gas 85% + CO2 15%
- ECO gas 98%+SF6 2%
- ECO gas 99%+SF6 1%
Tests with MRPCs at high rate at CERN

95% R124a + 5% SF₆ (EEE nominal)

Good plateau stability
Low dark currents and rates

⇒ See Yonwook Baek talk
Tests with MRPCs at high rate at CERN: streamer %

Right peaks are considered as anomalous avalanches (streamers?)