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

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# Eco-friendly gas mixture for gaseous detectors: why?

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- **Global Warming Potential** (GWP) measures the greenhouse effect of a gas normalized to $CO_2$ (GWP=1)
- Gas mixtures with **GWP > 150** have been banned by EU
- Present RPCs adopt mixtures with high GWP

Example: 98% $C_2H_2F_4$ + 2% $SF_6$ ⇒ **GWP = 1889**

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# Ecogas tests within the EEE Project

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

~ 50 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

⇒ see M. Abbrescia's talk on the project upgrade
⇒ see D. De Gruttola's talk on the performances

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# Recent tests on RPCs at high rate

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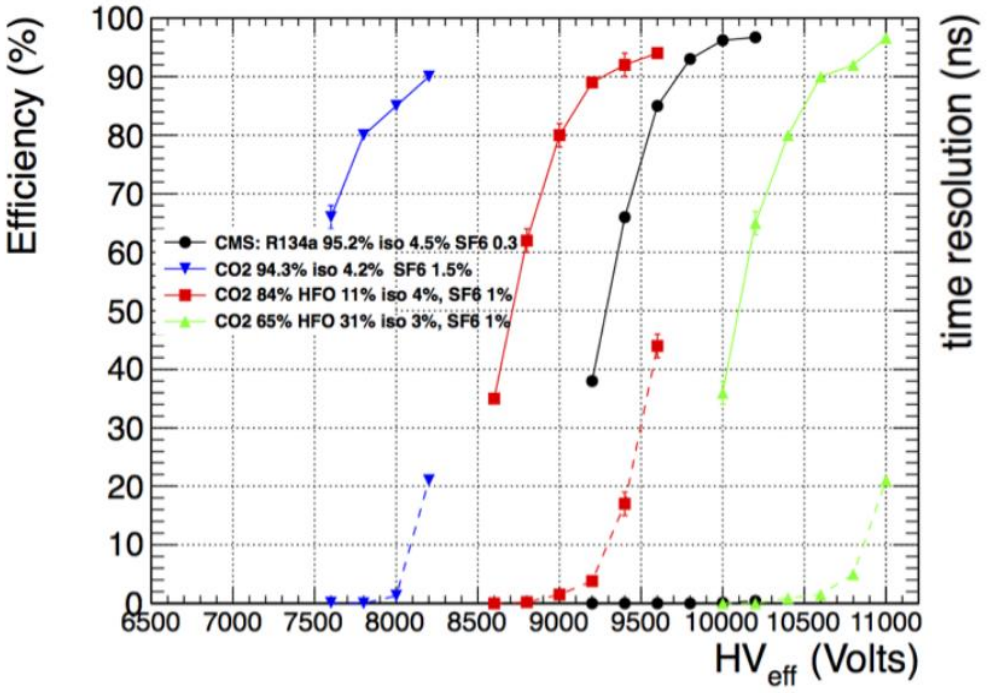
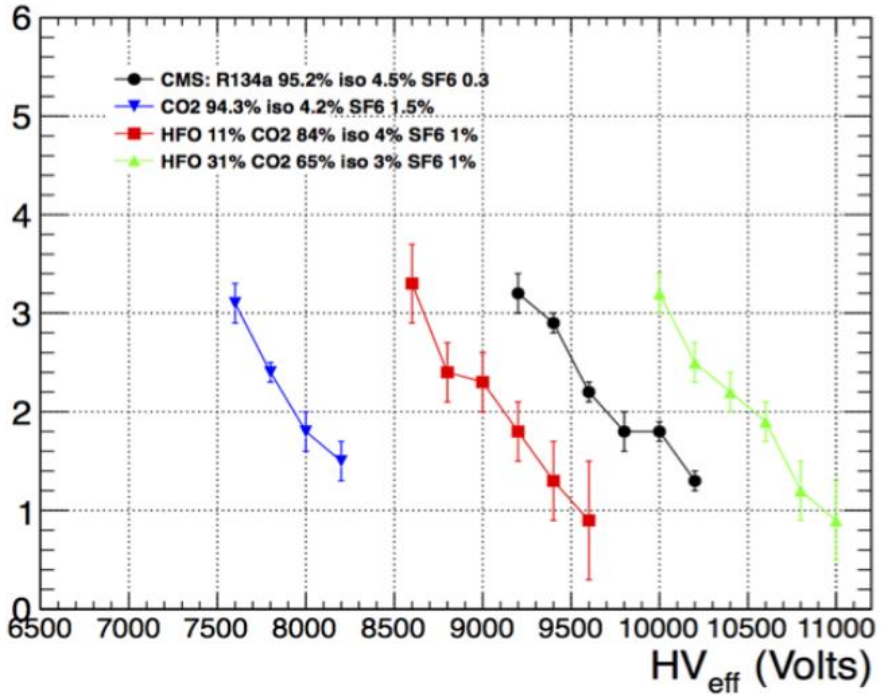
$C_3H_4F_4$ (tetrafluoropropene, HFO, GWP=4) emerged as a good candidate to substitute $C_2H_2F_4$ when combined to $CO_2$ and $CF_3I$ or $SF_6$




Abbrescia et al. JINST 11 (2016) no.08, P08019

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# Tests with MRPCs at high rate at CERN

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⇒ See Yonwook Baek talk

## Experimental setup

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

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# Tests with MRPCs at high rate at CERN

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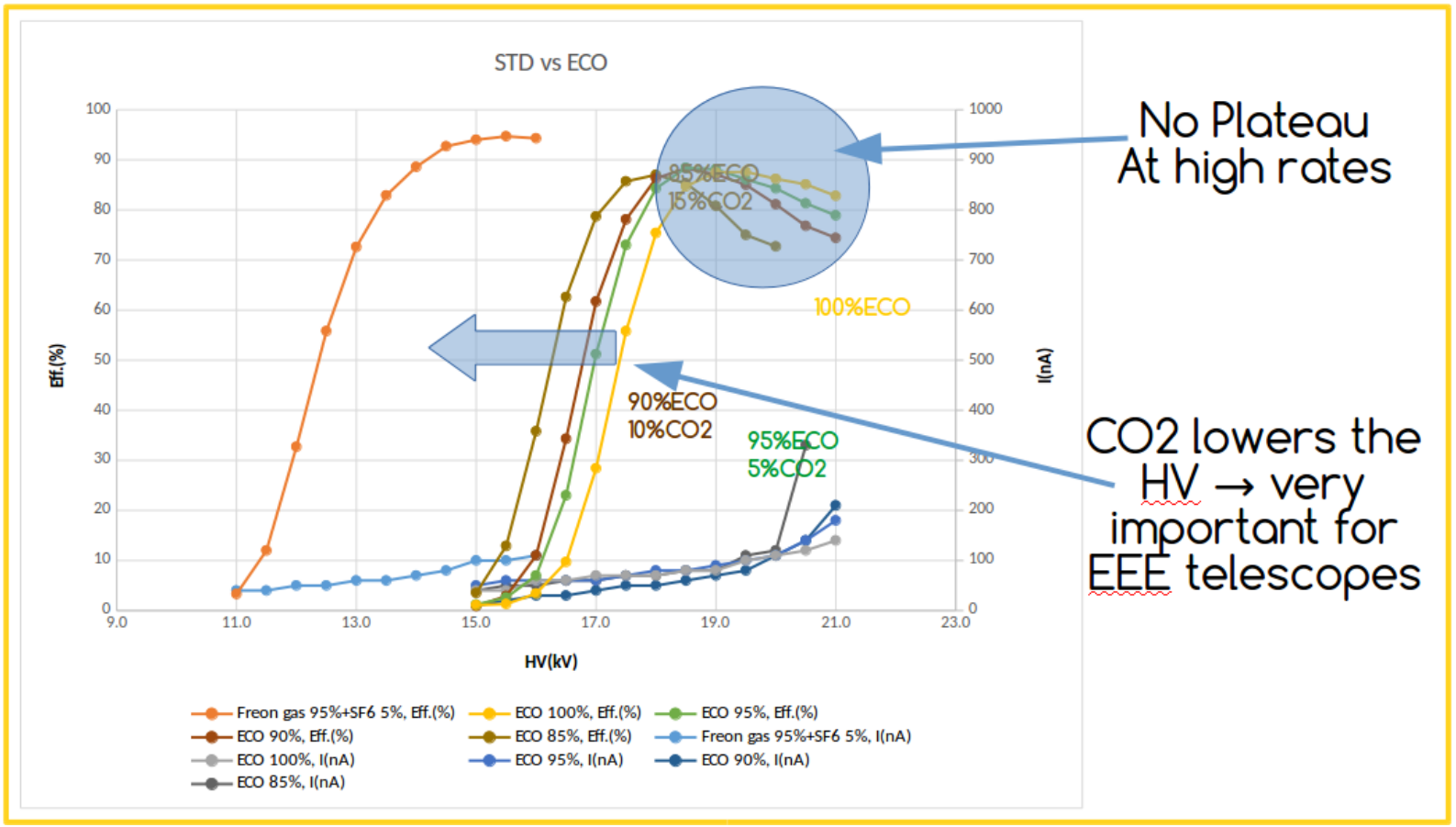
⇒ See Yonwook Baek talk

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



# Tests with MRPCs at high rate at CERN

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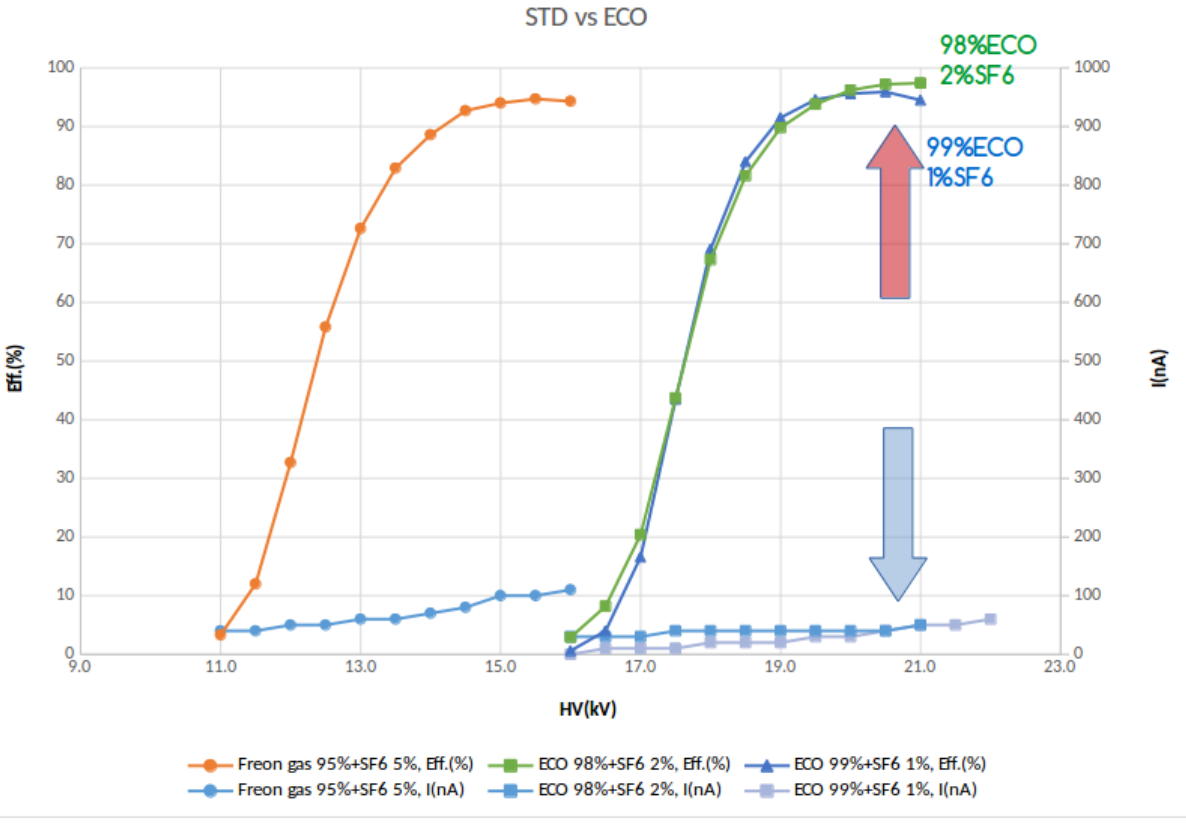
⇒ See Yonwook Baek talk

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

R1234ze raises the HV

SF6 works fine as a quencher



# Tests with cosmics at low rates

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Main **open questions** to be addressed:

1. Is it possible to reach a stable **plateau** with $CO_2$ at **low rates?**
2. Can the **streamer percentage** be kept **low** enough?
3. Can the HV-lowering by $CO_2$ observed at high rate be exploited in EEE MRPCs?
4. Can mixtures containing $SF_6$ be produced still fullfilling ECO requirements?

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# Tests with cosmics at low rates

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**Original mixture: R134a – tetrafluoroethane**
**GWP=1300**

**R1234ze (GWP=4) + $CO_2$ (GWP=1)**
- streamer % with $CO_2$ at low rates?
- lowering HV at plateau with $CO_2$?

**R1234ze + $SF_6$ (GWP=24000)**
- likely better in terms of streamer %
- HV above the DC/DC limits

Other proposals for future tests at low rates:
- trying new mixtures. Examples: Quenchers: CF3I
- both mixtures: adding a third gas for lowering the plateau HV ($He_4$)

Tested mixtures

Pure R1234ze

R1234ze + $CO_2$
(90/10 – 80/20 – 50/50)

R1234ze + $SF_6$
(98/2 – 99/1)

$CO_2$-based mixtures

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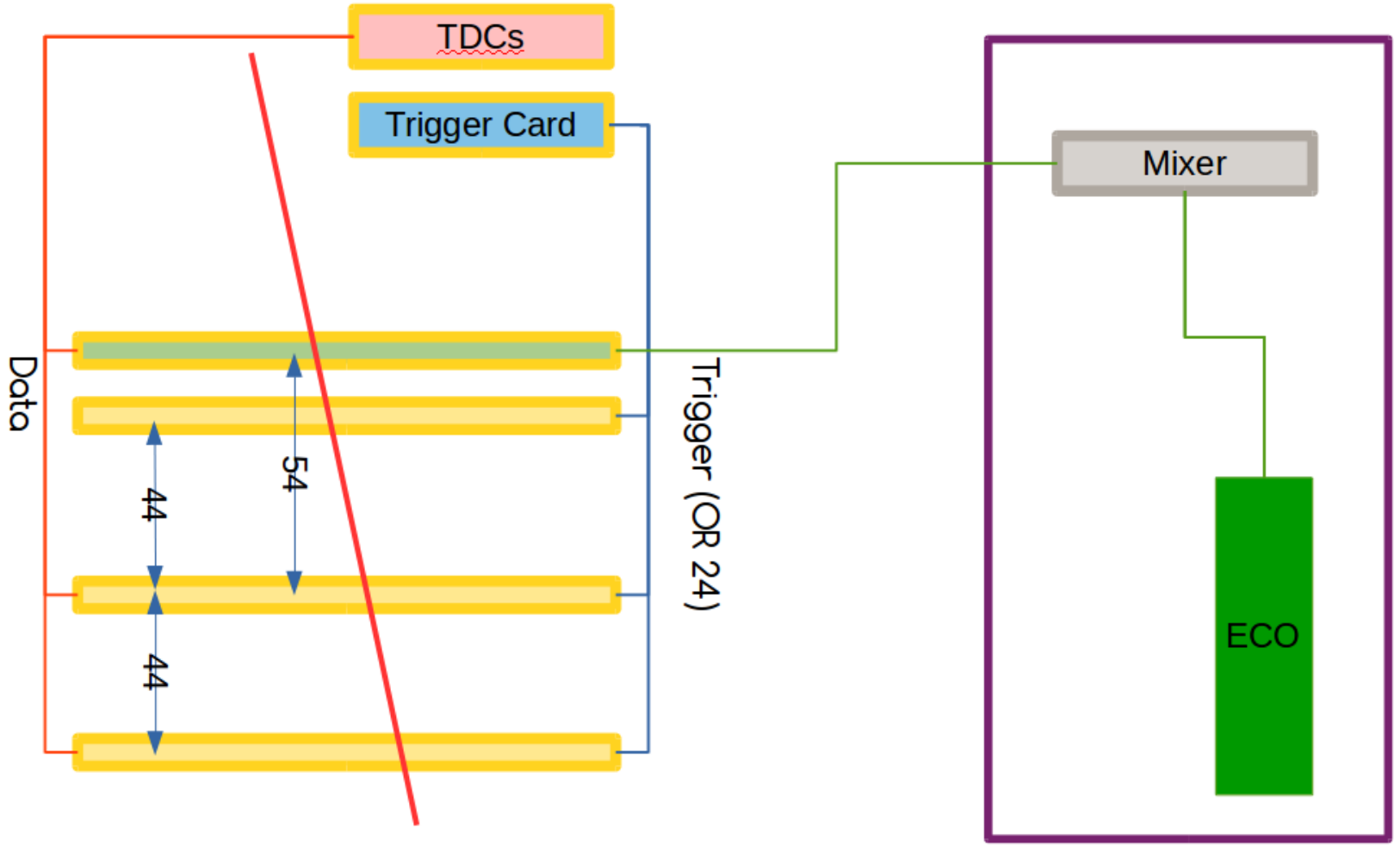
# Pure R1234ze



# Pure R1234ze

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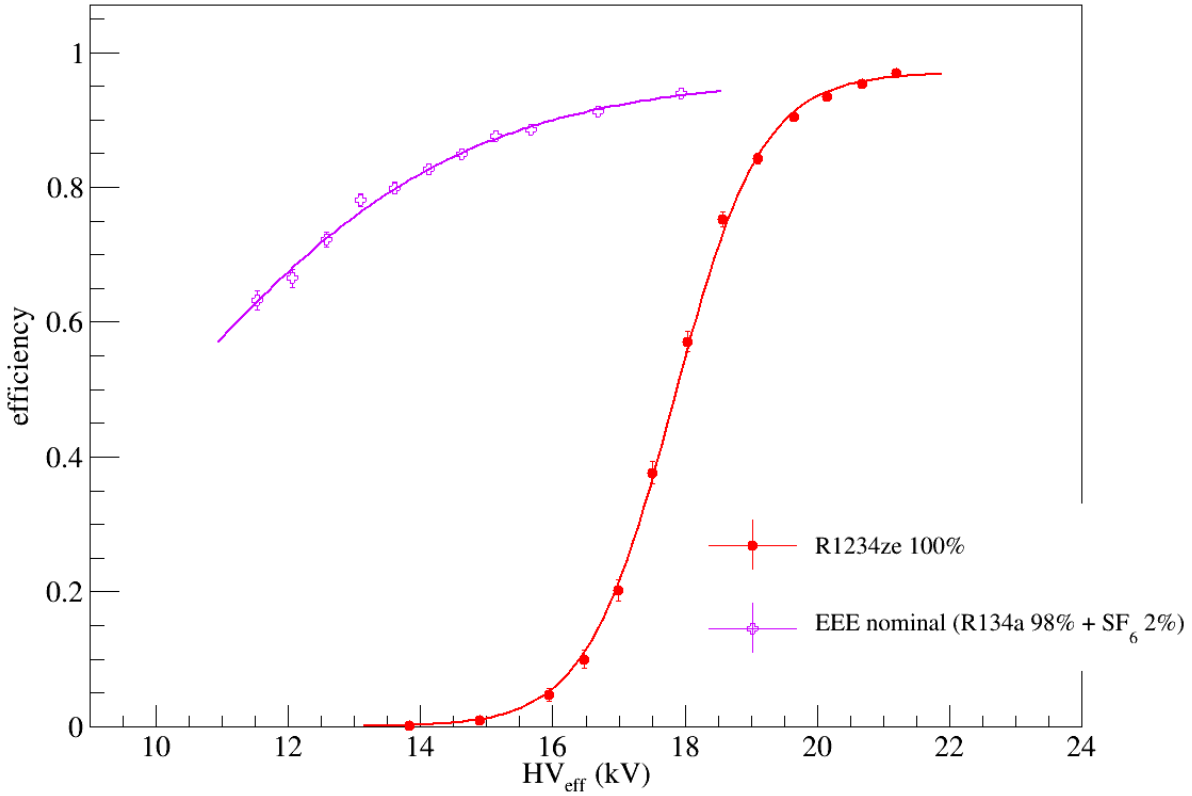


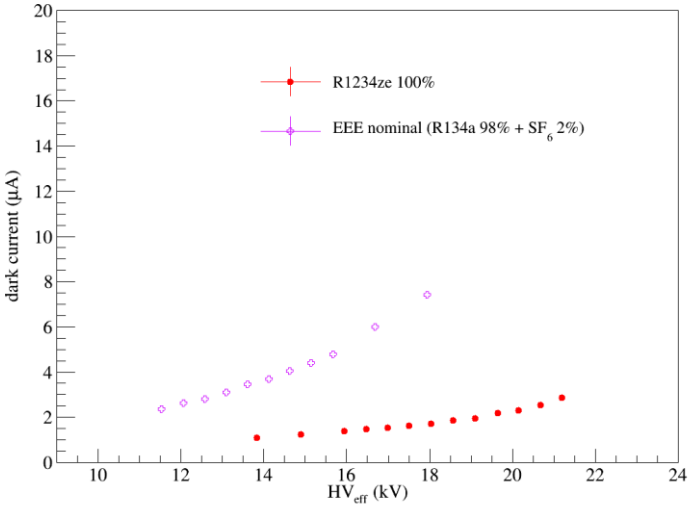


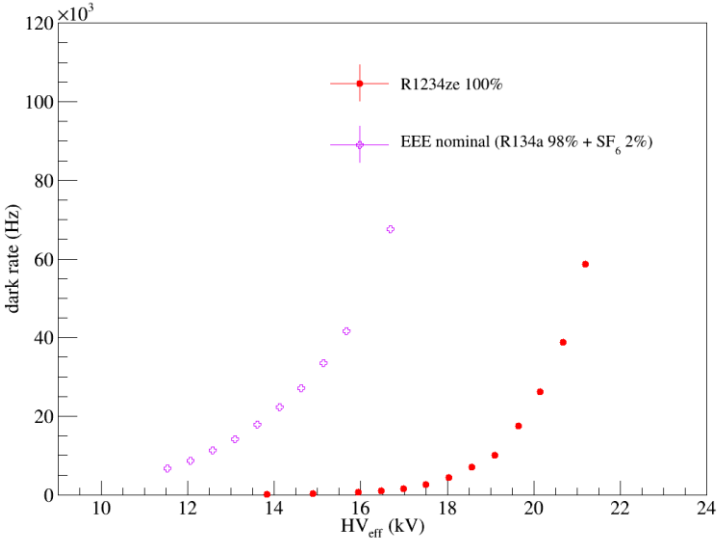


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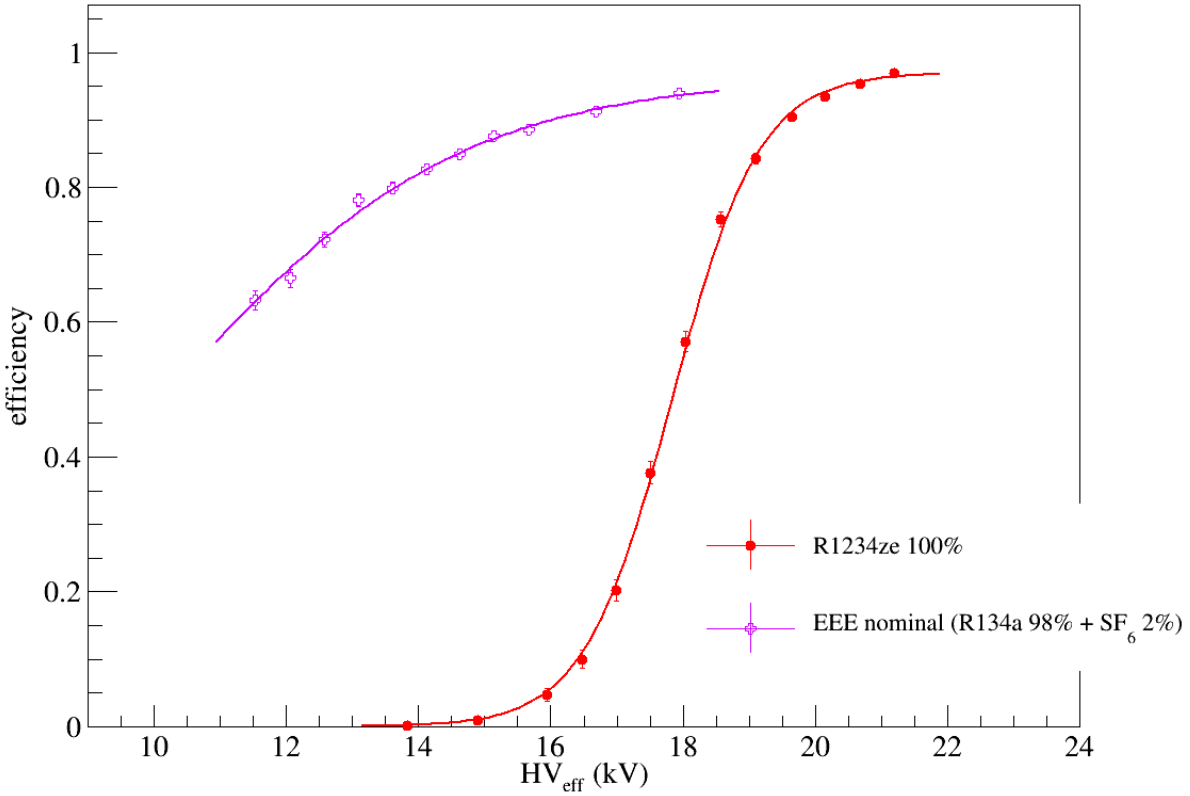
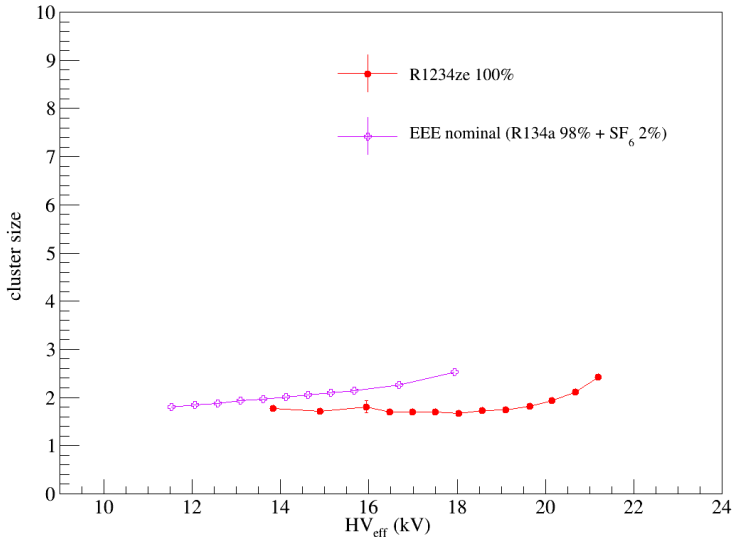
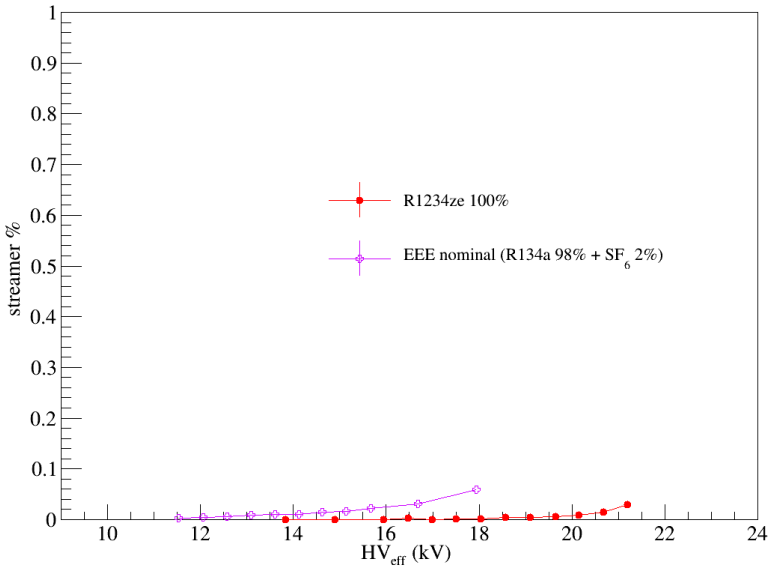
# Pure R1234ze



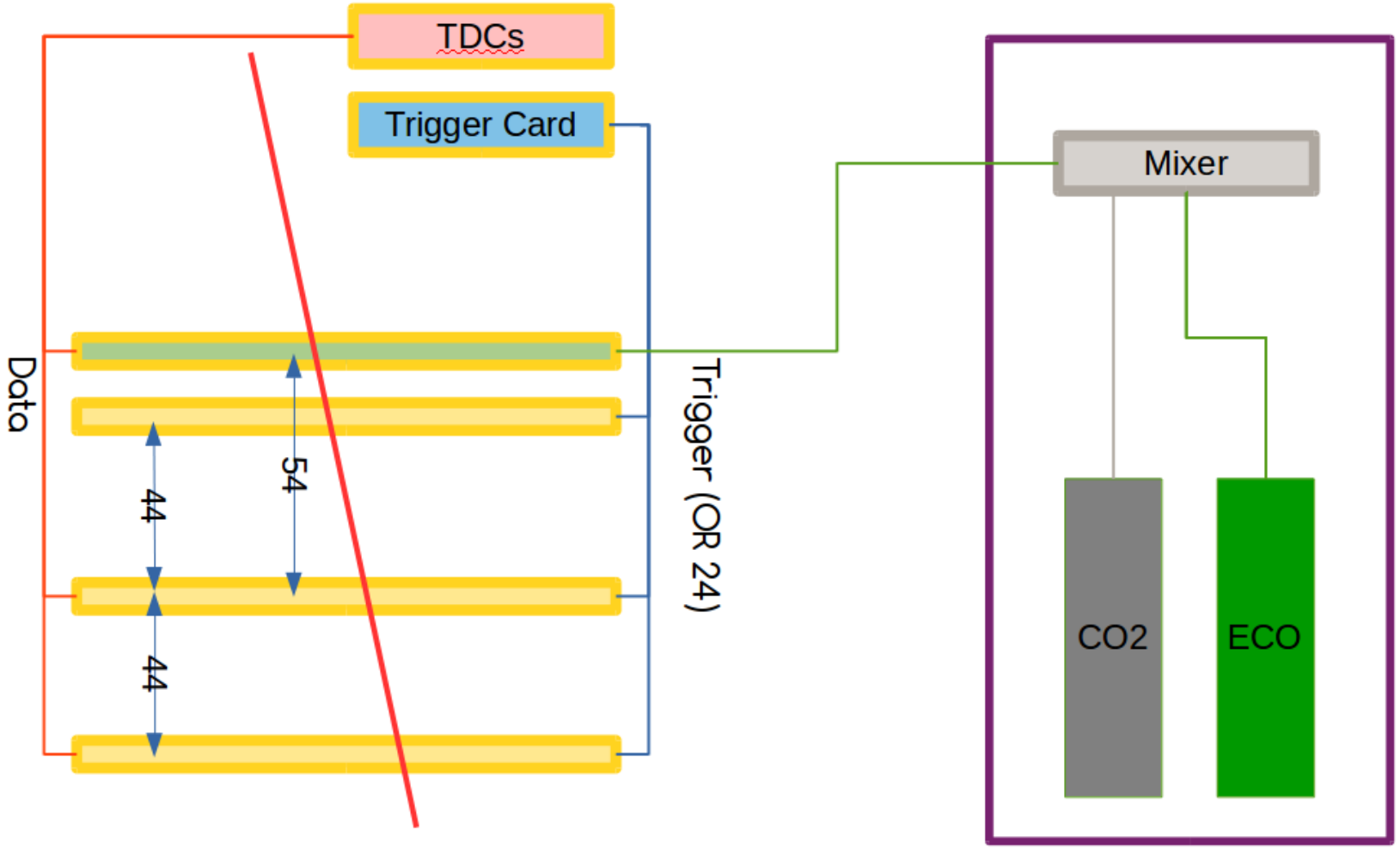



# Pure R1234ze

- Higher HV setting point with respect to standard mixtures
- Less noisy behaviour (lower dark currents)
- Stable cluster size
- Very low streamer percentage

# R1234ze + $CO_2$



# R1234ze + $CO_2$

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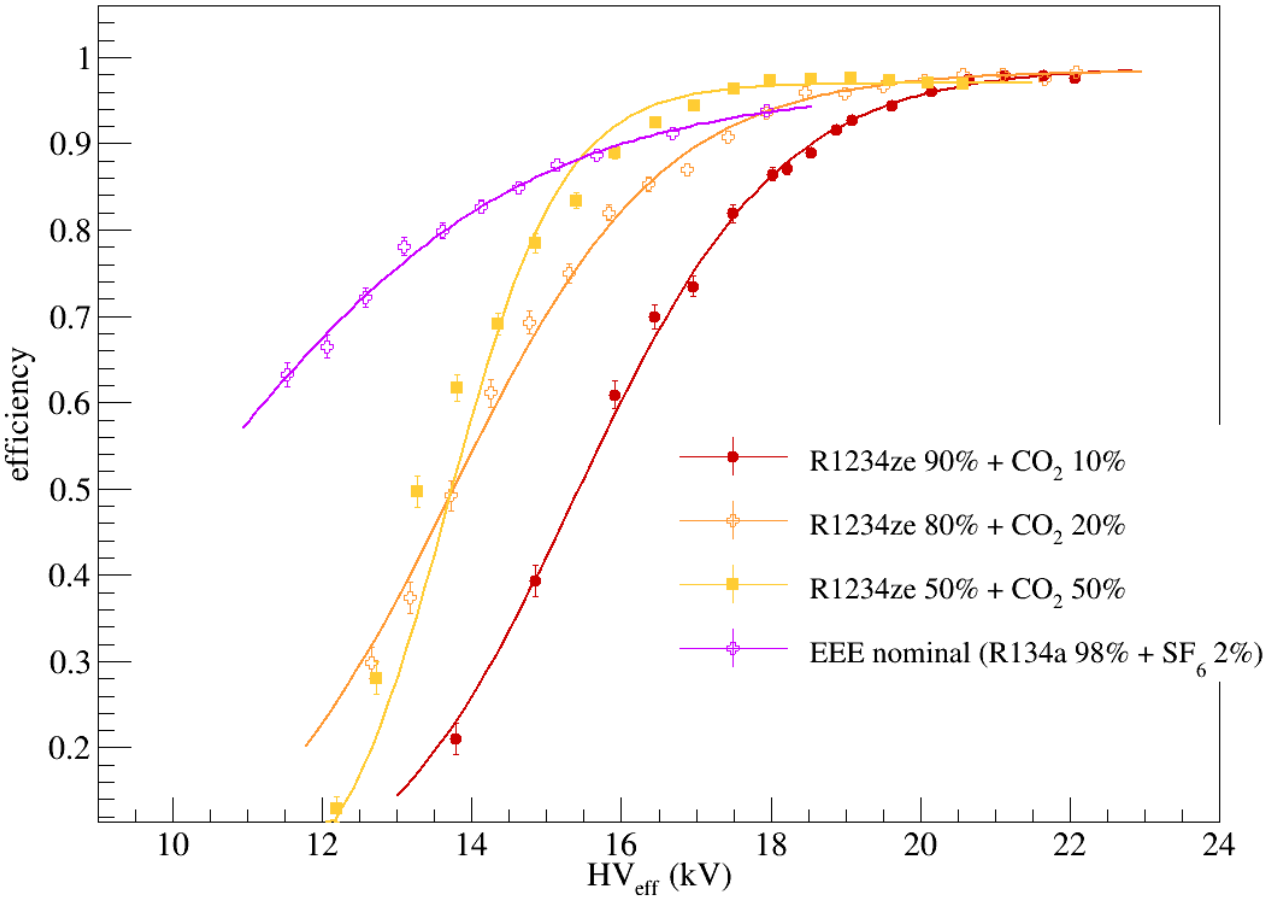


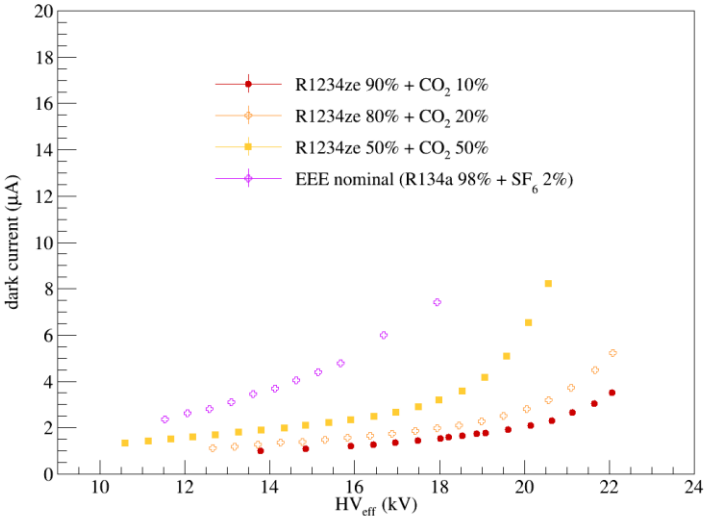


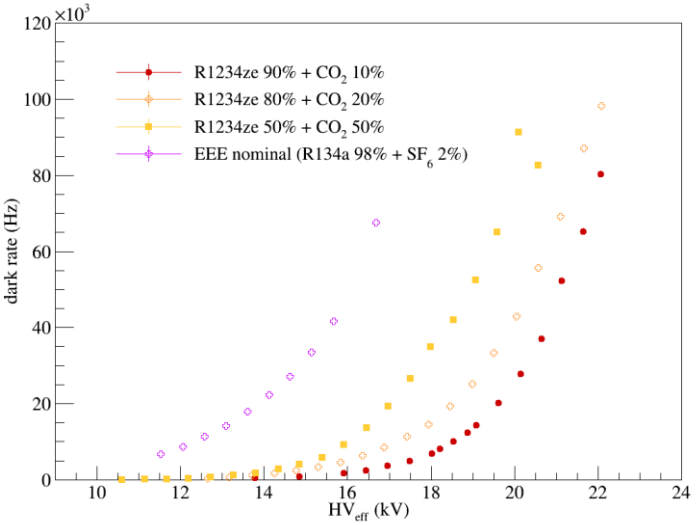


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# R1234ze + $CO_2$

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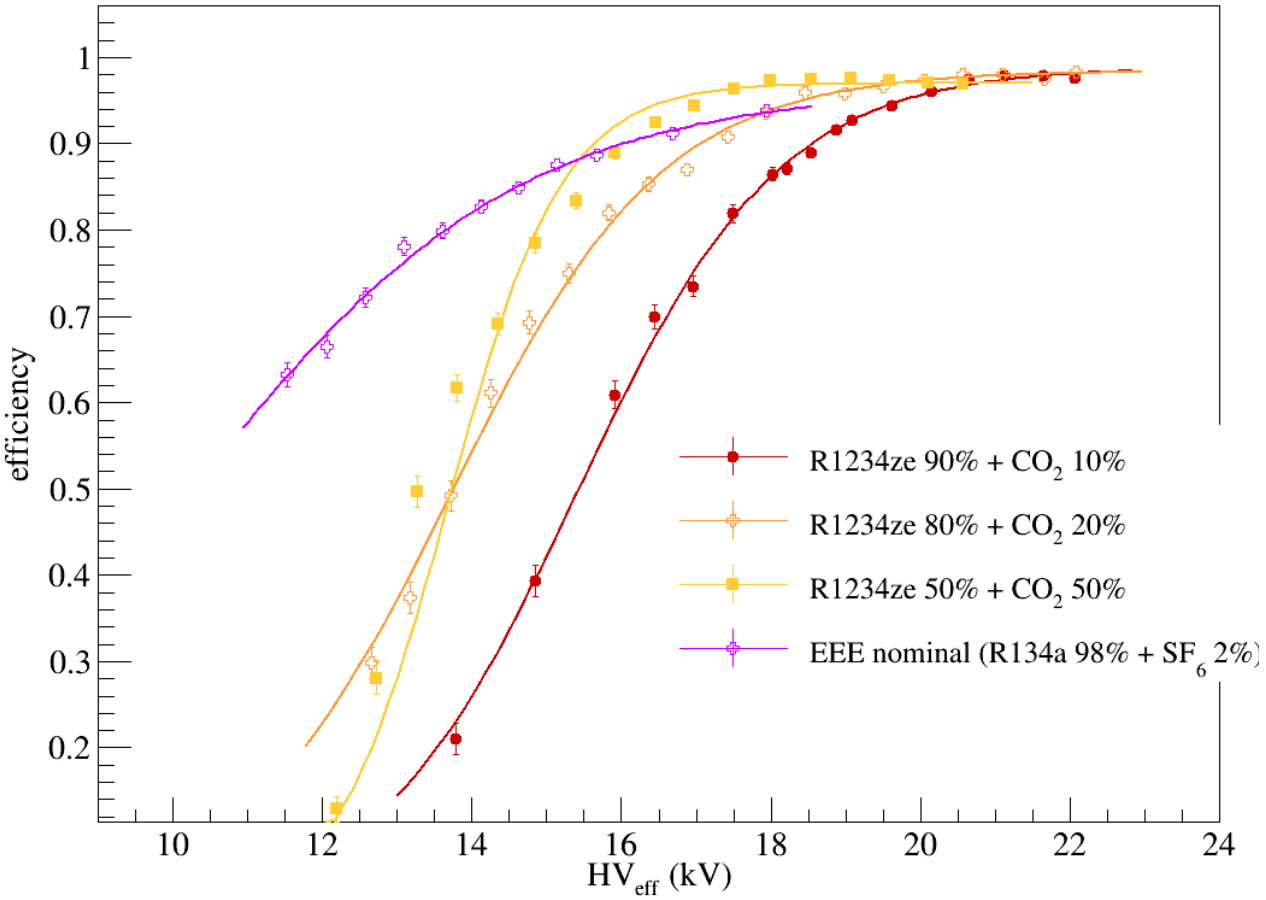


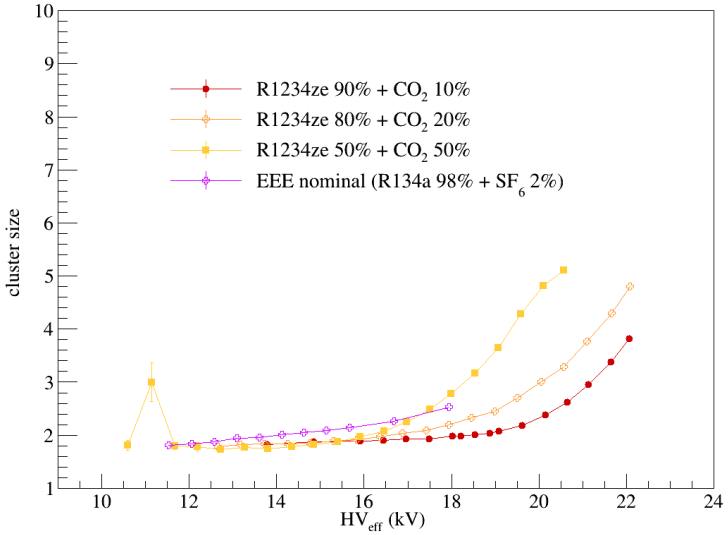


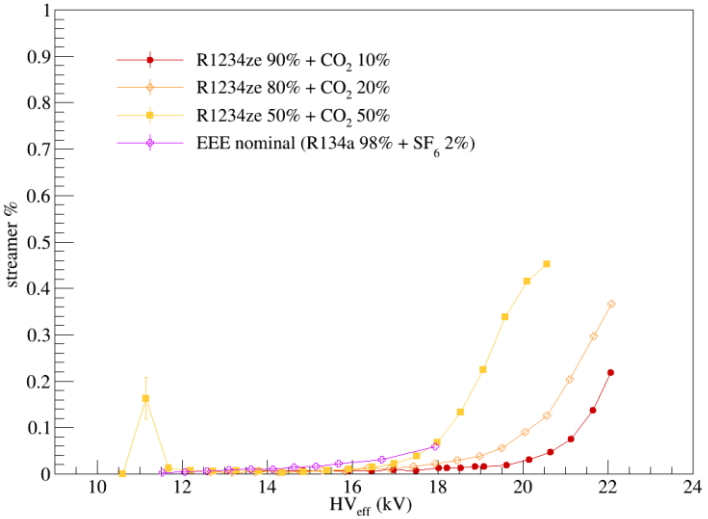


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# R1234ze + $CO_2$

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- **Lower** HV setting point with respect to standard mixtures
- However, noisy behaviour observed
- Possible working point under identification
  - especially true for **R1234ze 50% + $CO_2$ 50%** (but streamer component close to diverge)
  - Possible working point around 19 kV?

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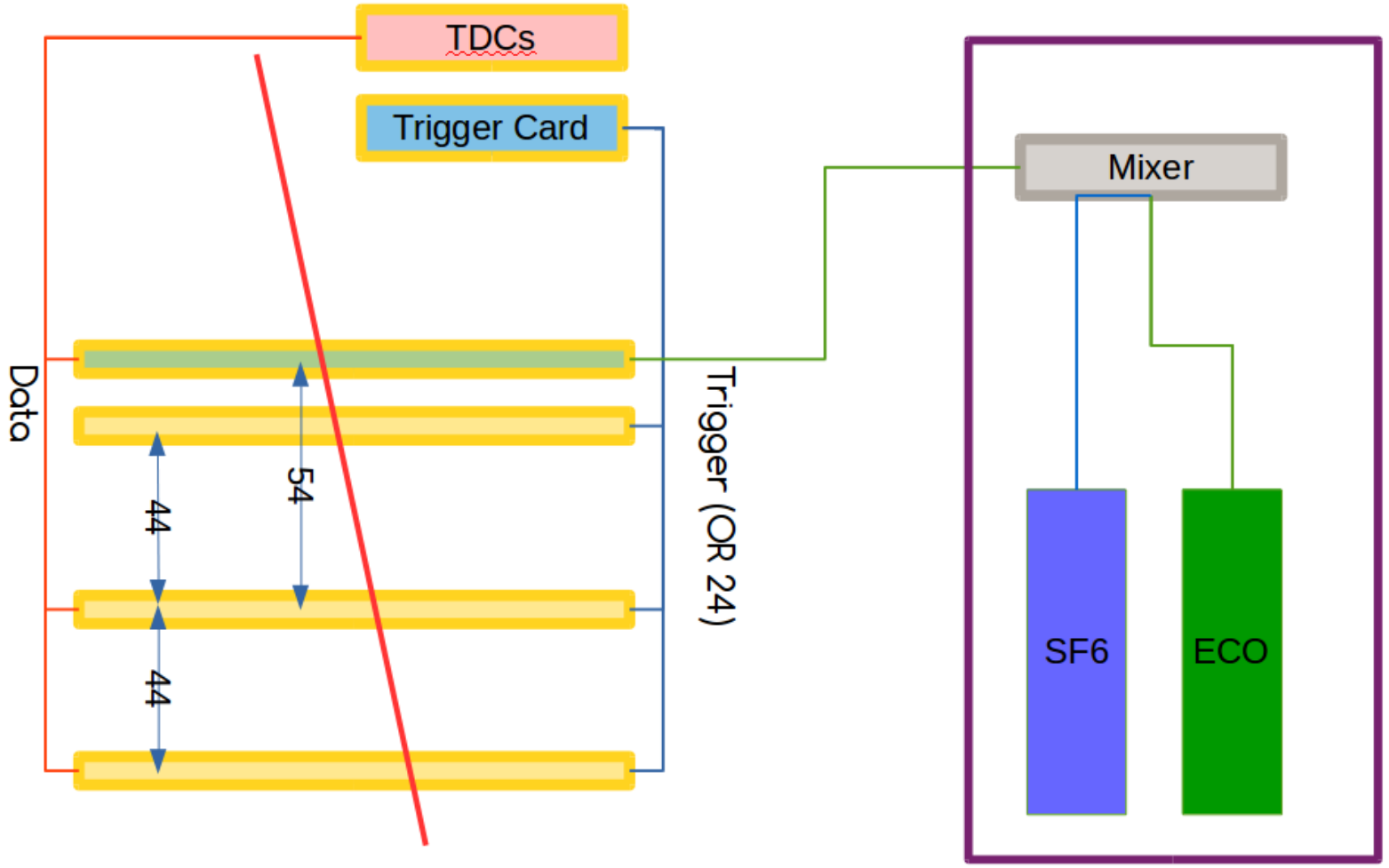
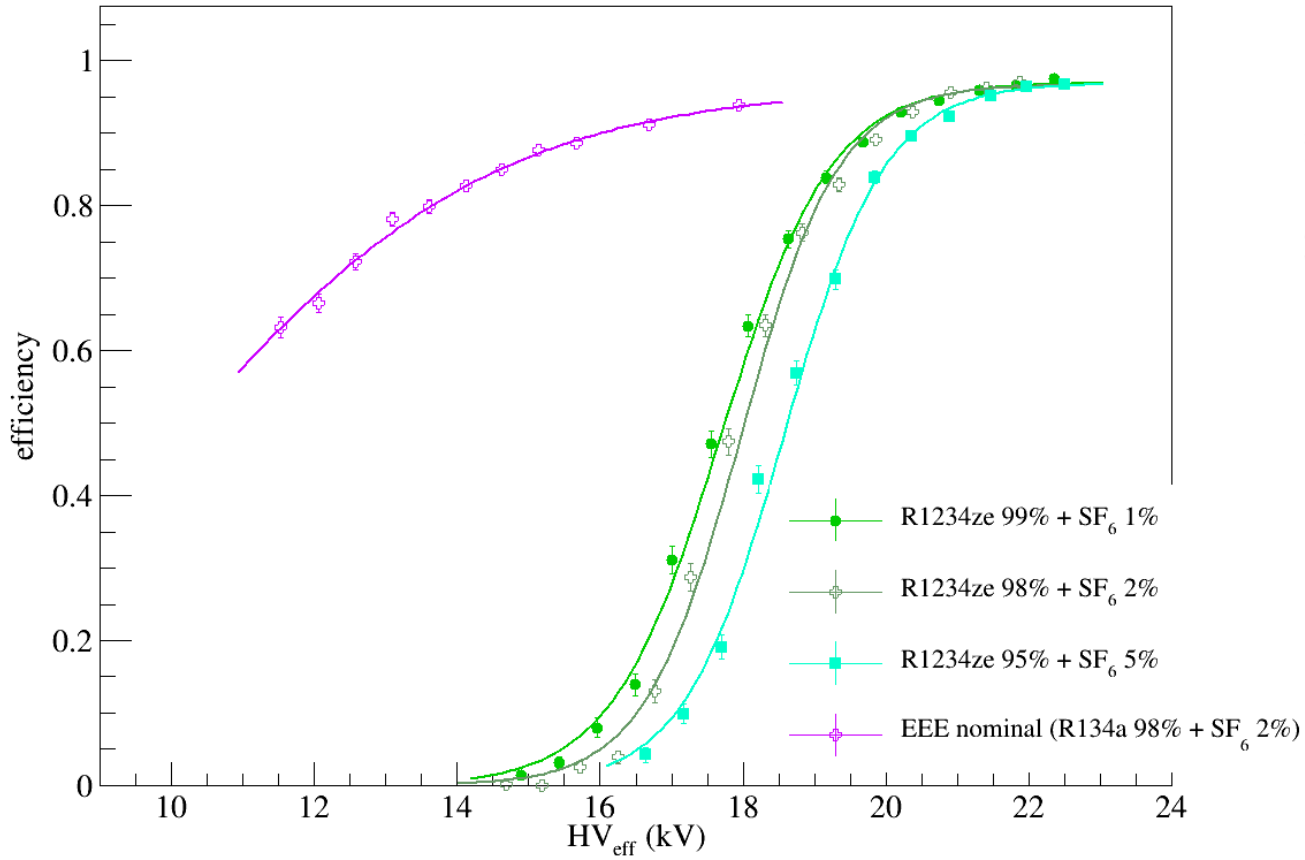
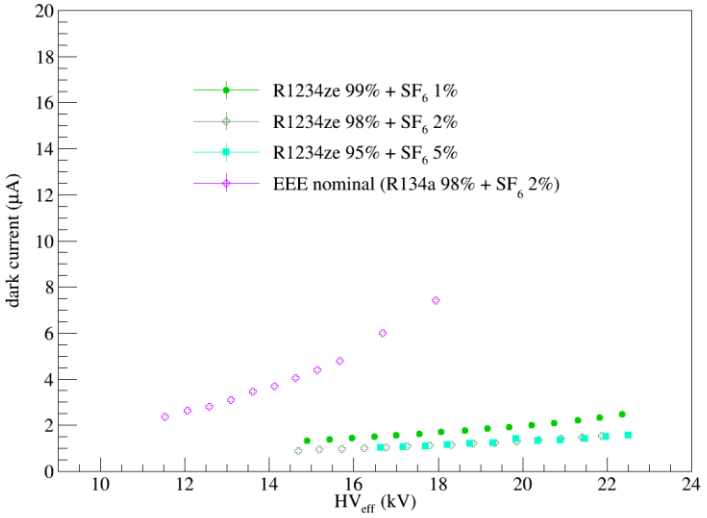
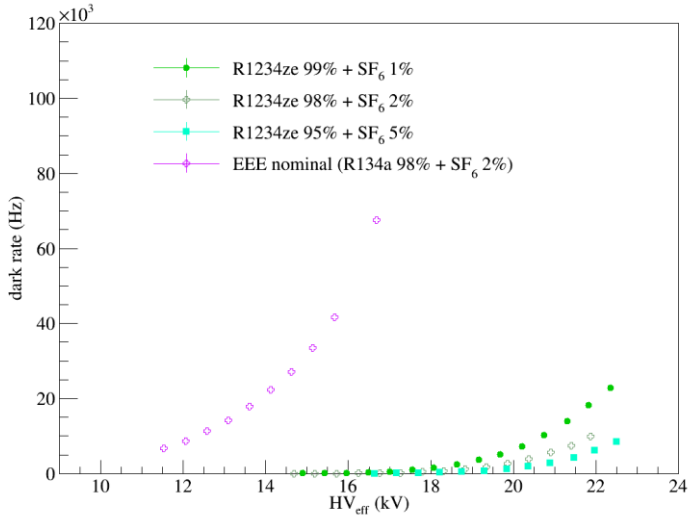
# R1234ze + $SF_6$



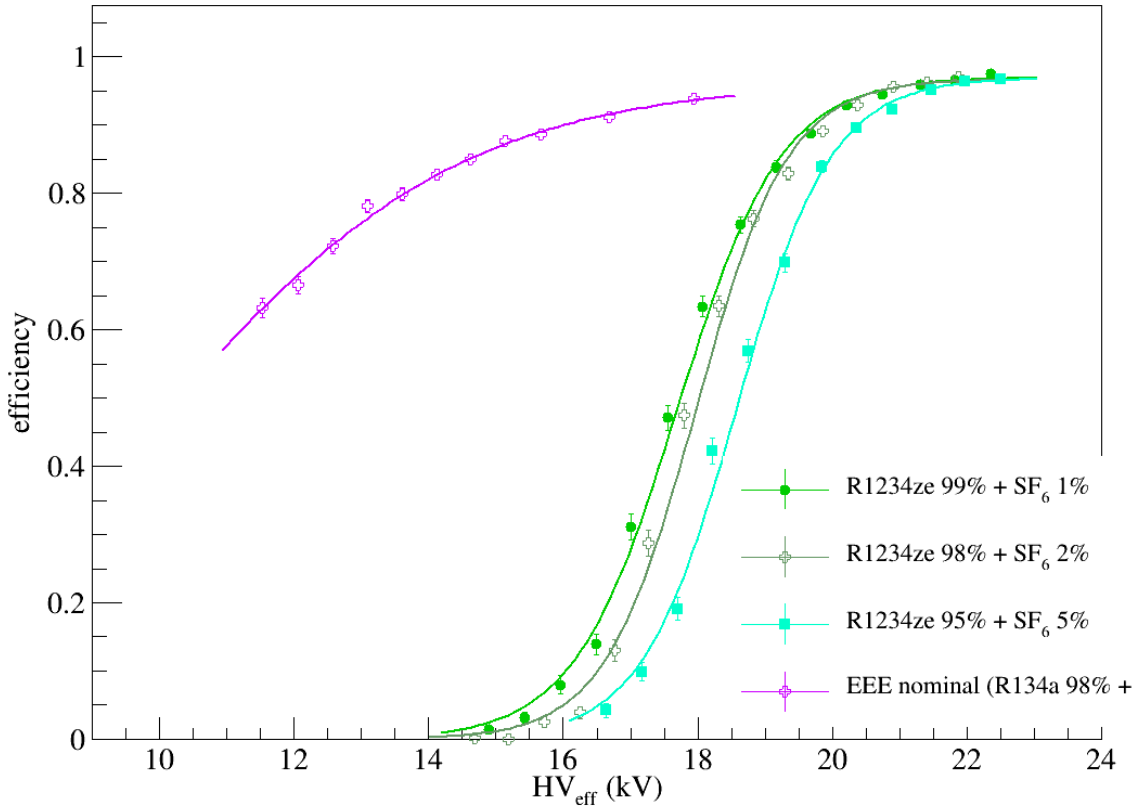
# R1234ze + $SF_6$

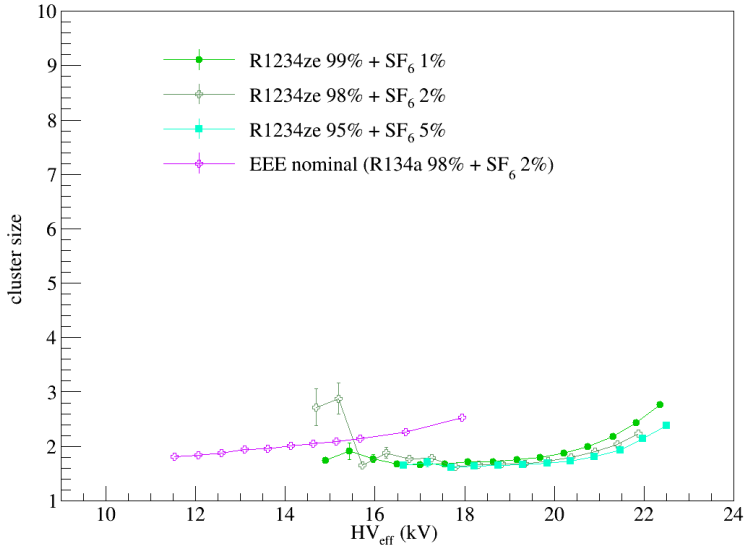

efficiency
HV$_{eff}$ (kV)
R1234ze 99% + SF$_6$ 1%
R1234ze 98% + SF$_6$ 2%
R1234ze 95% + SF$_6$ 5%
EEE nominal (R134a 98% + SF$_6$ 2%)

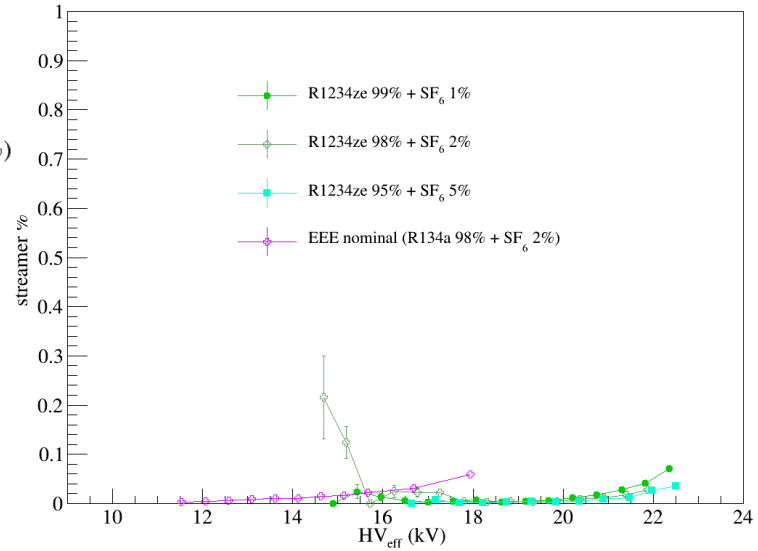

dark current (μA)
HV$_{eff}$ (kV)
R1234ze 99% + SF$_6$ 1%
R1234ze 98% + SF$_6$ 2%
R1234ze 95% + SF$_6$ 5%
EEE nominal (R134a 98% + SF$_6$ 2%)


dark rate (Hz)
×10$^3$
HV$_{eff}$ (kV)
R1234ze 99% + SF$_6$ 1%
R1234ze 98% + SF$_6$ 2%
R1234ze 95% + SF$_6$ 5%
EEE nominal (R134a 98% + SF$_6$ 2%)

# R1234ze + $SF_6$


efficiency
HV$_{eff}$ (kV)
R1234ze 99% + SF$_6$ 1%
R1234ze 98% + SF$_6$ 2%
R1234ze 95% + SF$_6$ 5%
EEE nominal (R134a 98% + SF$_6$ 2%)


cluster size
HV$_{eff}$ (kV)
R1234ze 99% + SF$_6$ 1%
R1234ze 98% + SF$_6$ 2%
R1234ze 95% + SF$_6$ 5%
EEE nominal (R134a 98% + SF$_6$ 2%)


streamer %
HV$_{eff}$ (kV)
R1234ze 99% + SF$_6$ 1%
R1234ze 98% + SF$_6$ 2%
R1234ze 95% + SF$_6$ 5%
EEE nominal (R134a 98% + SF$_6$ 2%)

# R1234ze + $SF_6$

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- **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%**?

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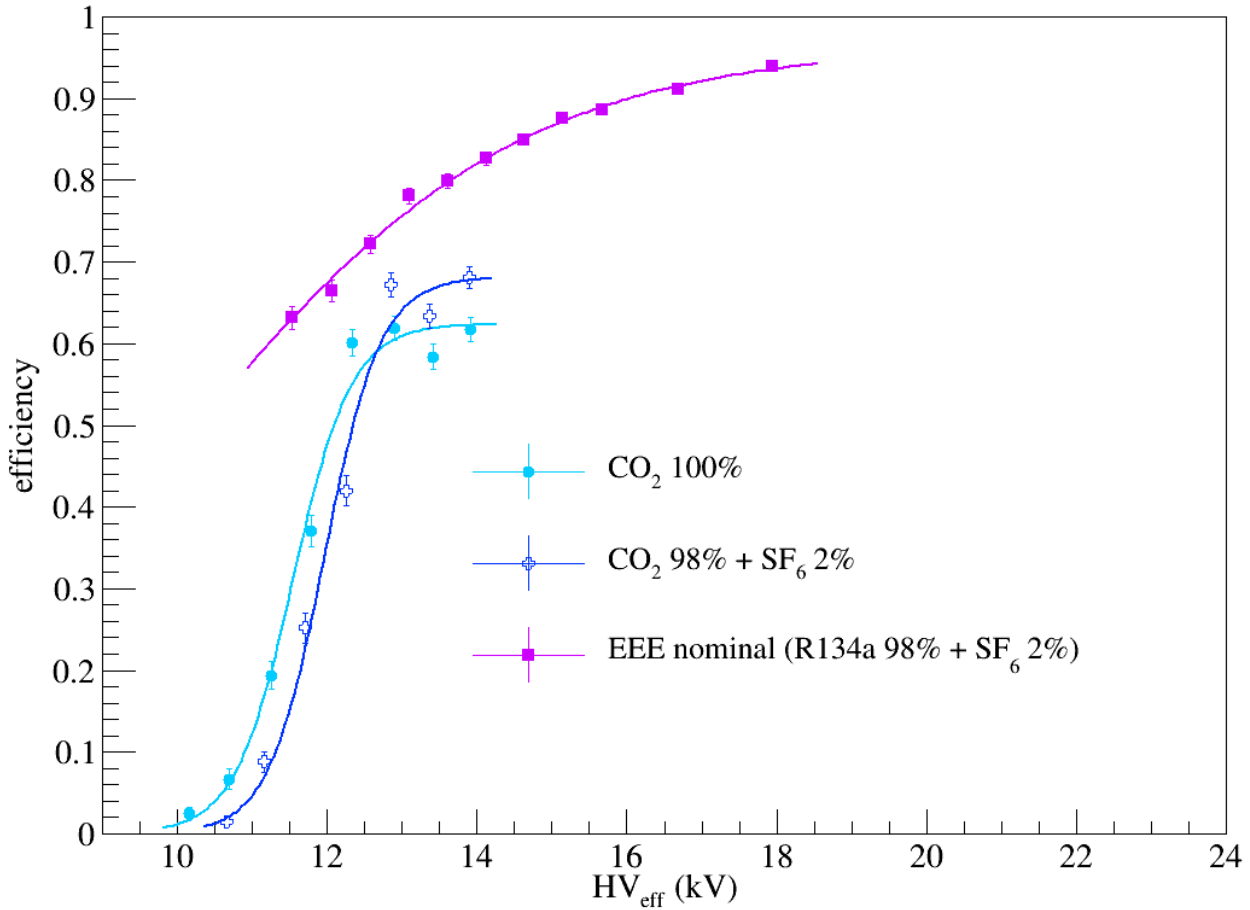
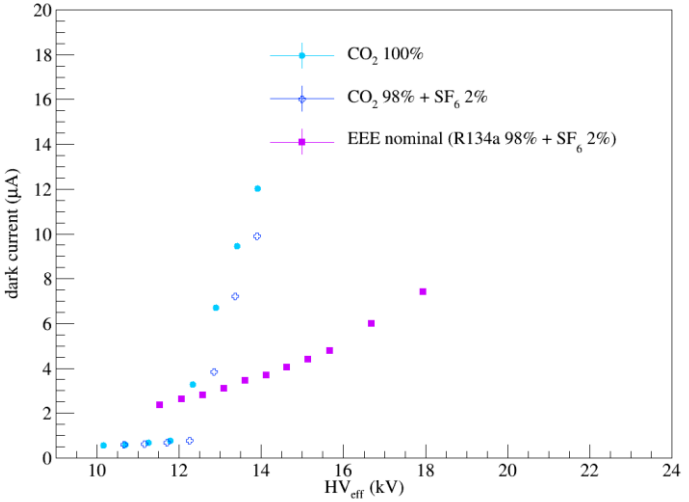
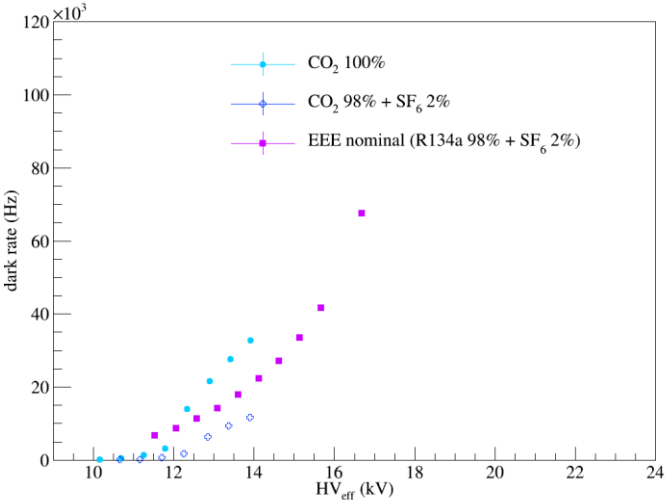
# $CO_2$ based mixtures

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# $CO_2$ based mixtures

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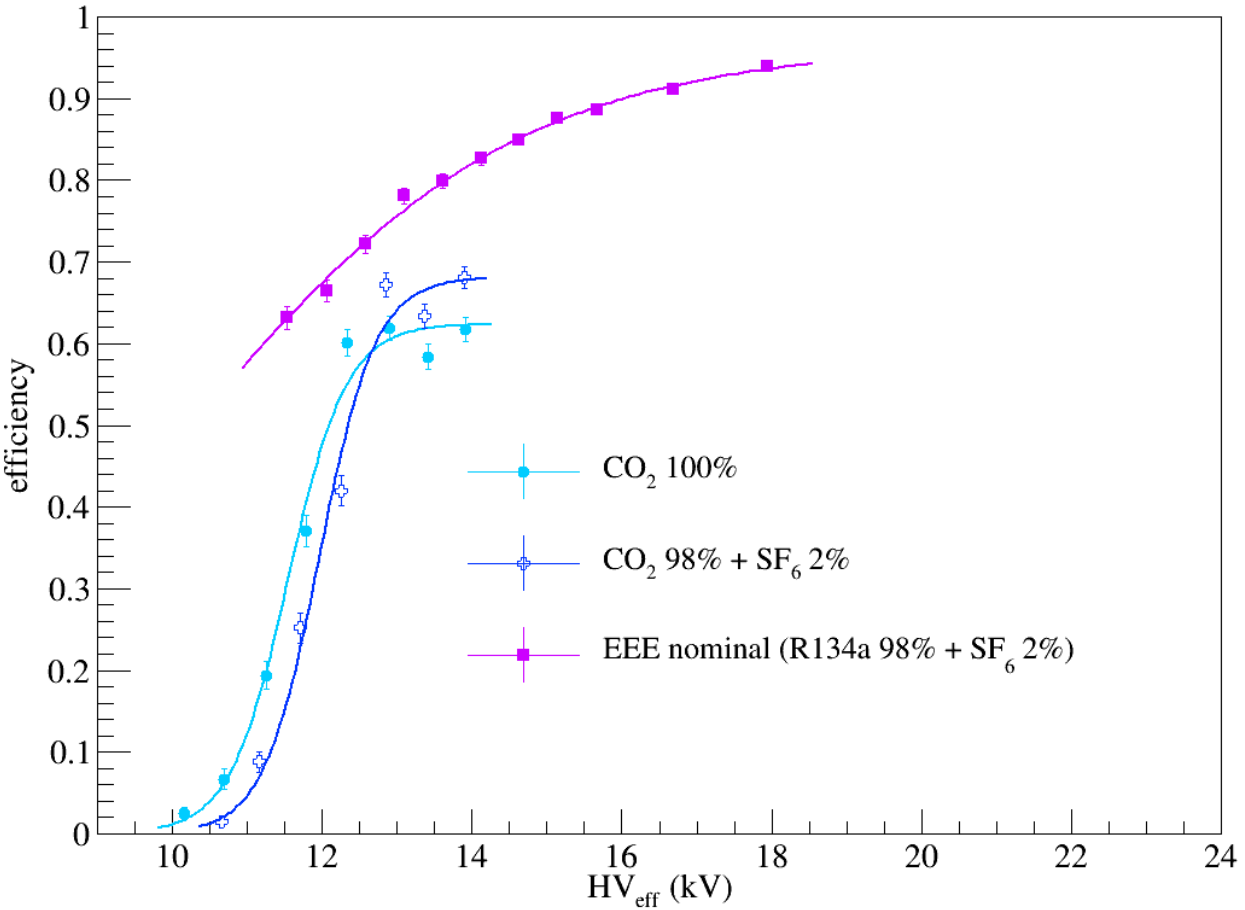


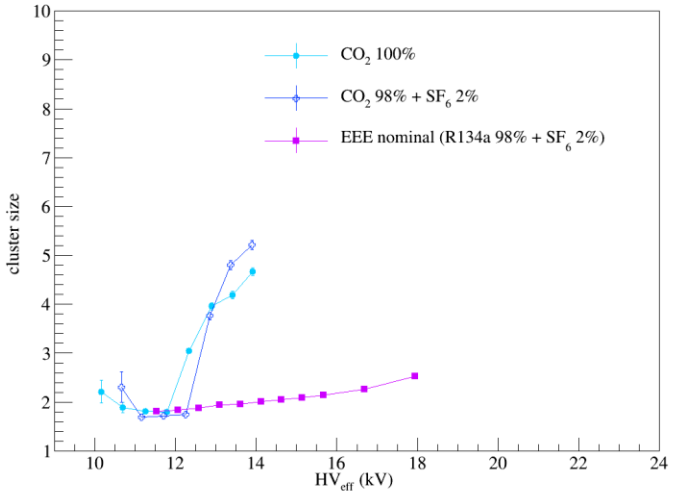


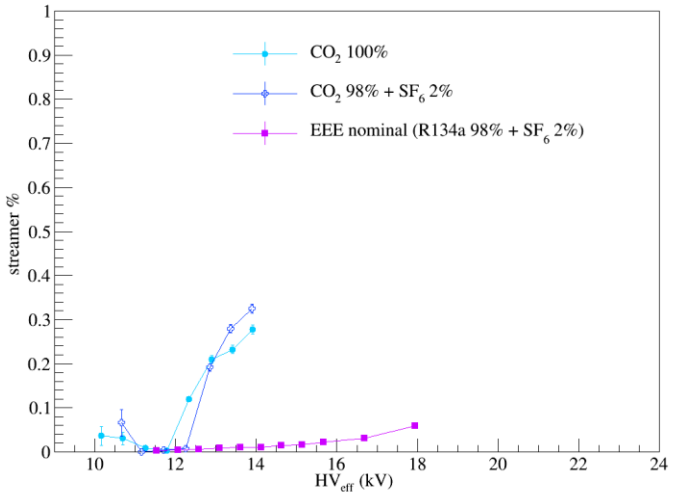


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# $CO_2$ based mixtures

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

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# Conclusions

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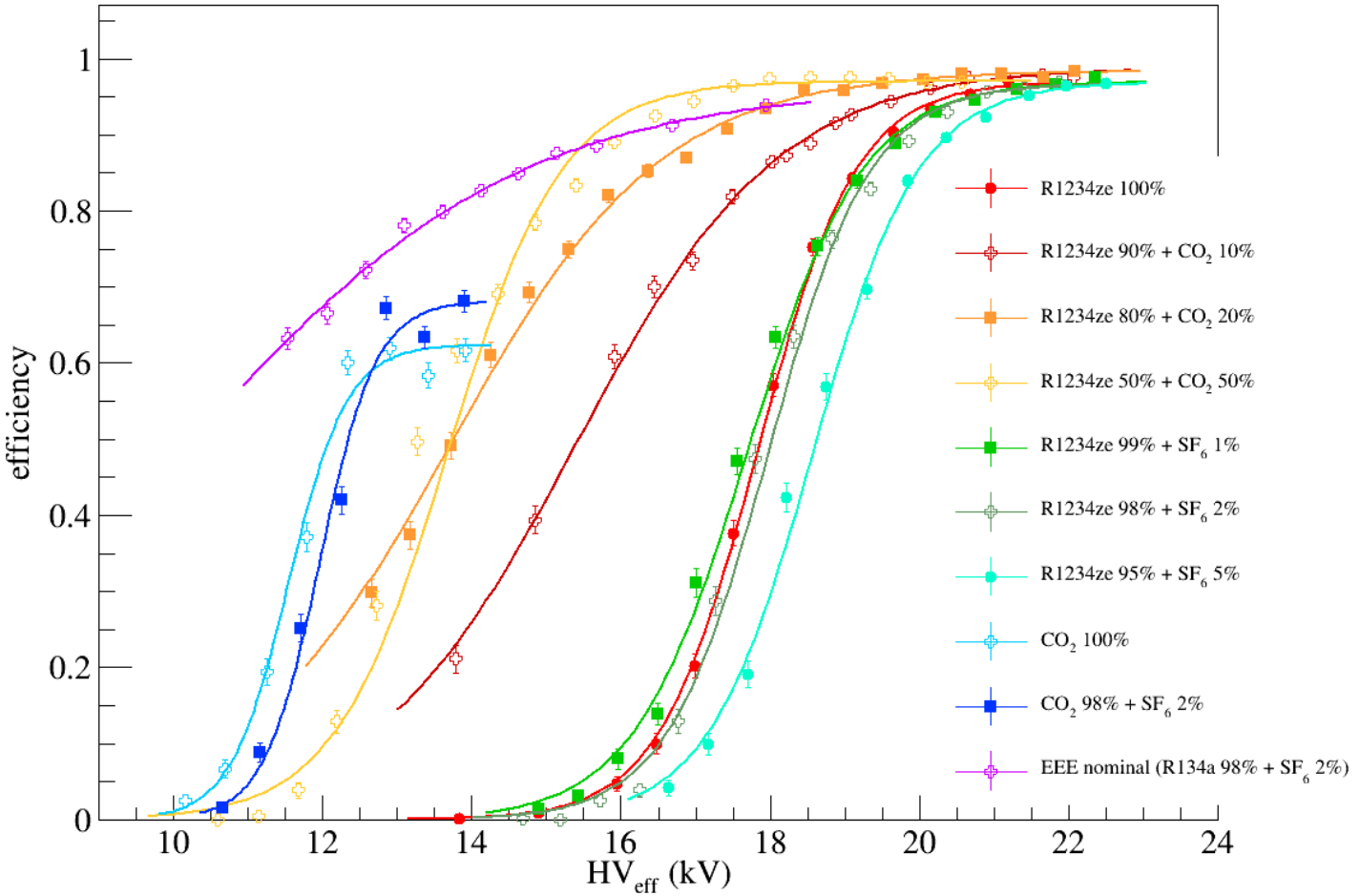
A **stable plateau** can be reached in the low rate configuration

$CO_2$ significantly lowers the working point for HV, but is very noisy

$SF_6$ is the best candidate as a quencher, but only a very small component is allowed by UE requirements (0.5% max)

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# Conclusions

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- First tests on MRPCs at low rate
- Stable plateau observed, differently from the high-rate case
- Possible HV working points can be identified
- **R1234ze 99% + $SF_6$ 1%, R1234ze 50% + $CO_2$ 50%** most promising configurations ⇒ to be properly balanced
- In few months, some stations will be equipped with eco-friendly mixtures **(quale miscela?)**

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# backup

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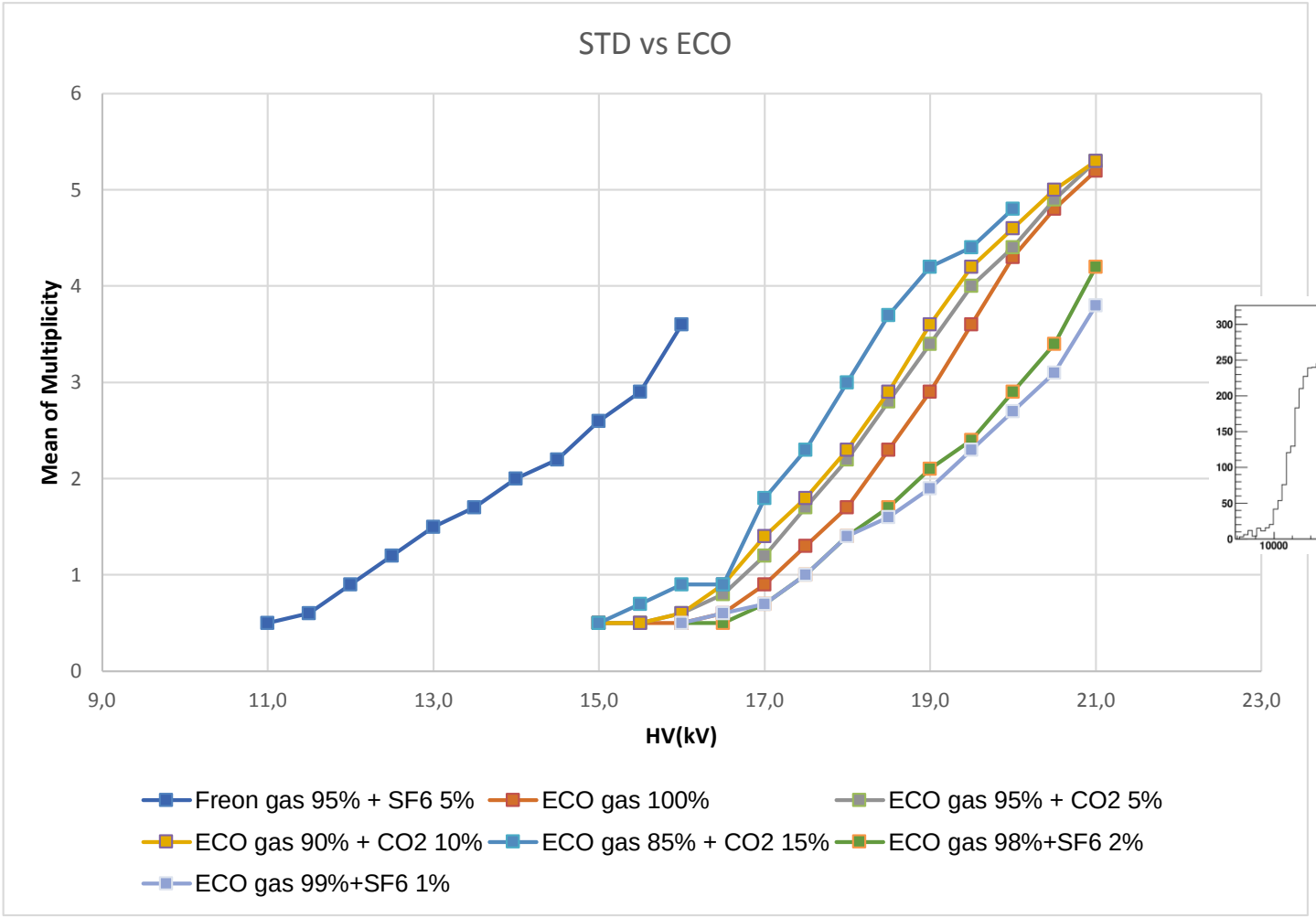
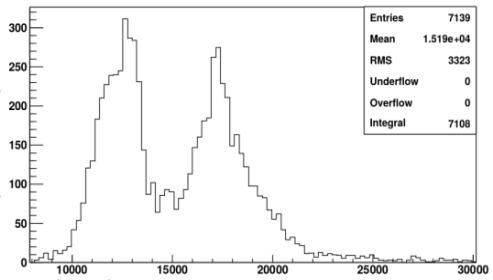
# Mean multiplicity



# Tests with MRPCs at high rate at CERN

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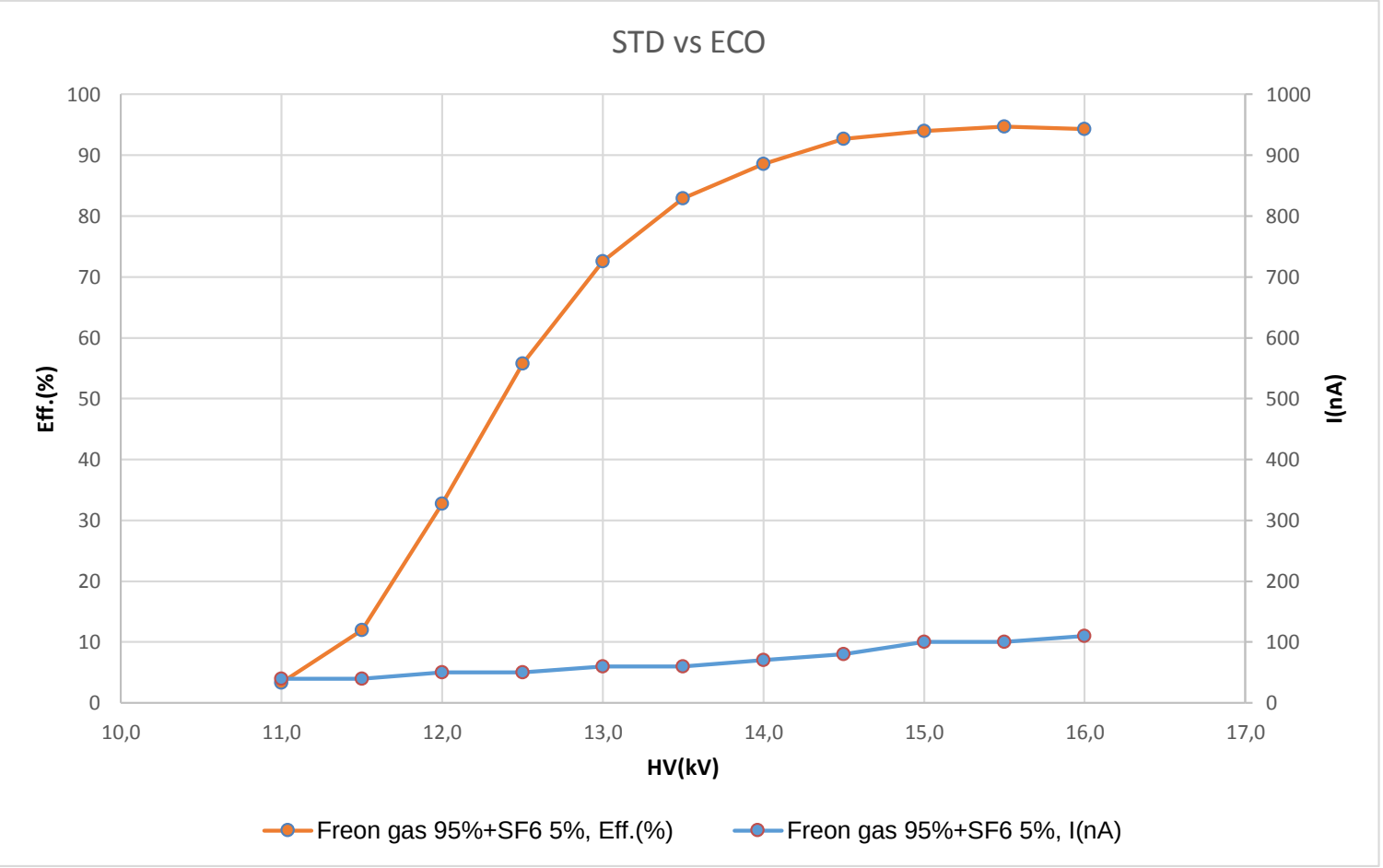
⇒ See Yonwook Baek talk

## 95% R124a + 5% $SF_6$ (EEE nominal)

Good plateau stability

Low dark currents and rates

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# Tests with MRPCs at high rate at CERN: streamer %

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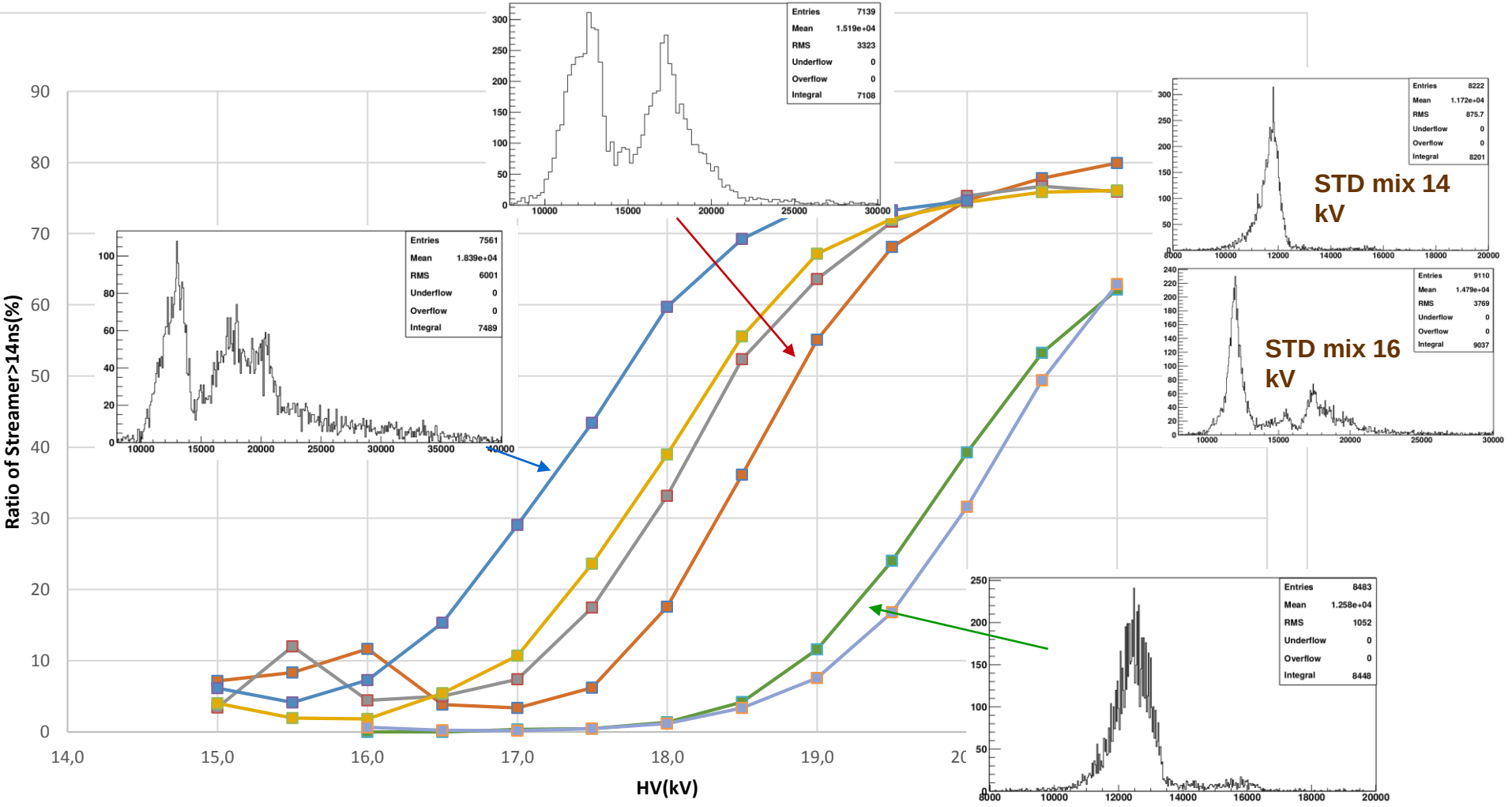


Right peaks are considered as anomalous avalanches (streamers?)