Ecogas studies

comparison of efficiency and current density of 2023 vs 2024 Test beam results obtained with the CMS(RE1_1) chamber at GIF++

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Working under guidance of Prof. Marcello Abbrescia and Prof. Davide Piccolo

- To investigate the aging effect of the CMS RPC chamber (RE1_1), the parameters for the 2023 and 2024 data have been compared
- As it is shown in the tables below, the data were analysed with source off and ABS_3.3 condition.
- These comparisons have been conducted for efficiency as a function of HV_eff.

STD : 95.2% R134a, 4.5% i-C_4H_{10} and 0.3% SF_6
ECO2: 60% CO_2, 35% HFO, 4% i-C_4H_{10} and 1% SF_6
ECO3: 69% CO_2, 25% HFO, 5% i-C_4H_{10} and 1% SF_6

2023

ABS	STD	ECO2	ECO3
Off	660	669	650
100	662	672	651
3.3	657	670	648

2024 (April)

ABS	STD	ECO2	ECO3
Off	750	781	813+836
100	764	790	826+844
3.3	762+765	783+807	816+837

2024 (June)

ABS	STD	ECO2	ECO3
Off	881	901	940
100		921	954
3.3	880	905	943+946

Working point voltage

	HV Knee(kV)				
	S_off_23	S_off_24_Apr	Diff(V)	S_off_24_Jun	Diff(V)
STD	9.83	9.71	120	9.87	40
ECO2	11.13	11.02	110	11.18	50
ECO3	10.25	10.25	0	10.23	20

Table 1: Working point voltages (source_off) for all the three gas mixtures

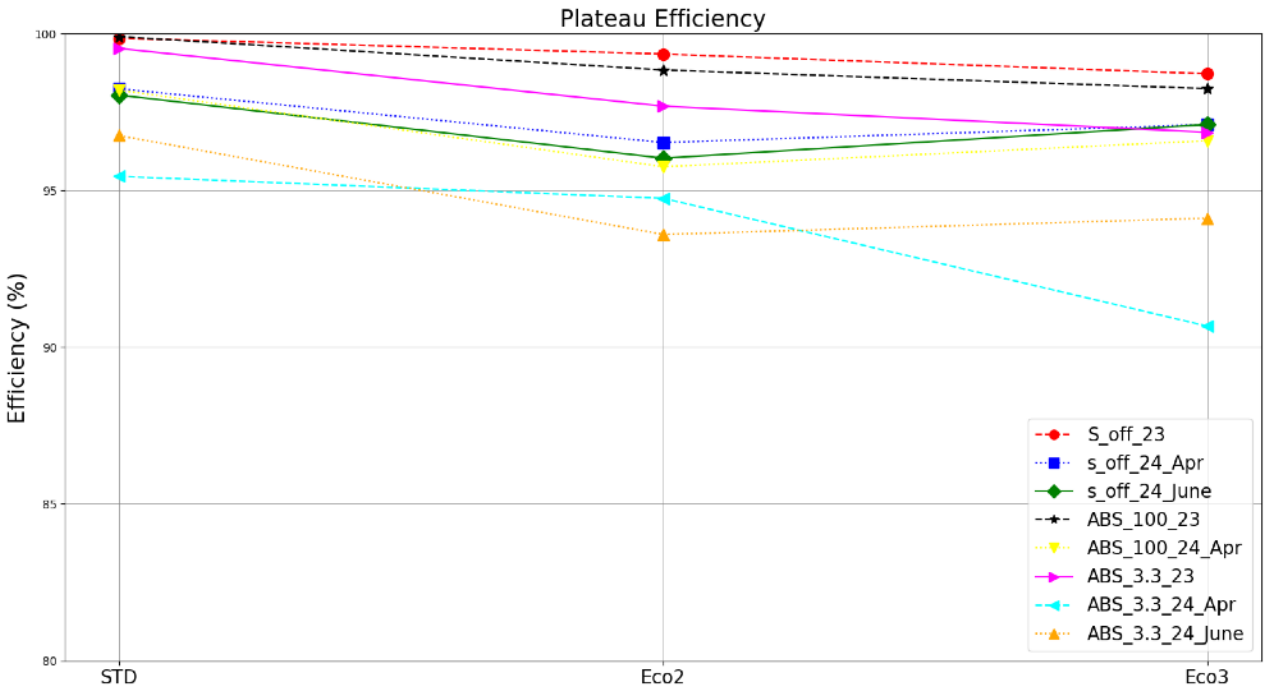
	HV Knee(kV)				
	ABS_100_23	ABS_100_24_Apr	Diff(V)	ABS_100__24_Jun	Diff(V)
STD	9.86	9.77	90		
ECO2	11.14	11.05	90	11.14	0
ECO3	10.28	10.30	20	10.26	20

Table 2: Working point voltages (ABS_100) for all the three gas mixtures

	HV Knee(kV)				
	ABS_3.3_23	ABS_3.3_24_Apr	Diff(V)	ABS_3.3_24_Jun	Diff(V)
STD	10.23	10.78	550	10.53	300
ECO2	11.61	12.17	560	12.18	570
ECO3	10.78	11.12	340	11.42	640

Table 2: Working point voltages (ABS_100) for all the three gas mixtures

Comparison of plateau efficiency of all data



- For 2023 data, plateau efficiency was decreasing from STD mixture to Eco3 for source_off, ABS_100. This trend can be also seen in 2024 april data with ABS_3.3.
- The higher the measured current recorded for 2023 data, the less the plateau efficiency will be.
- However, for 2024 april, when source_off and ABS_100 and for 2024 June data with source_off and ABS_3.3, Plateau efficiency decreases from STD to Eco2 and then experience an increases for Eco3.

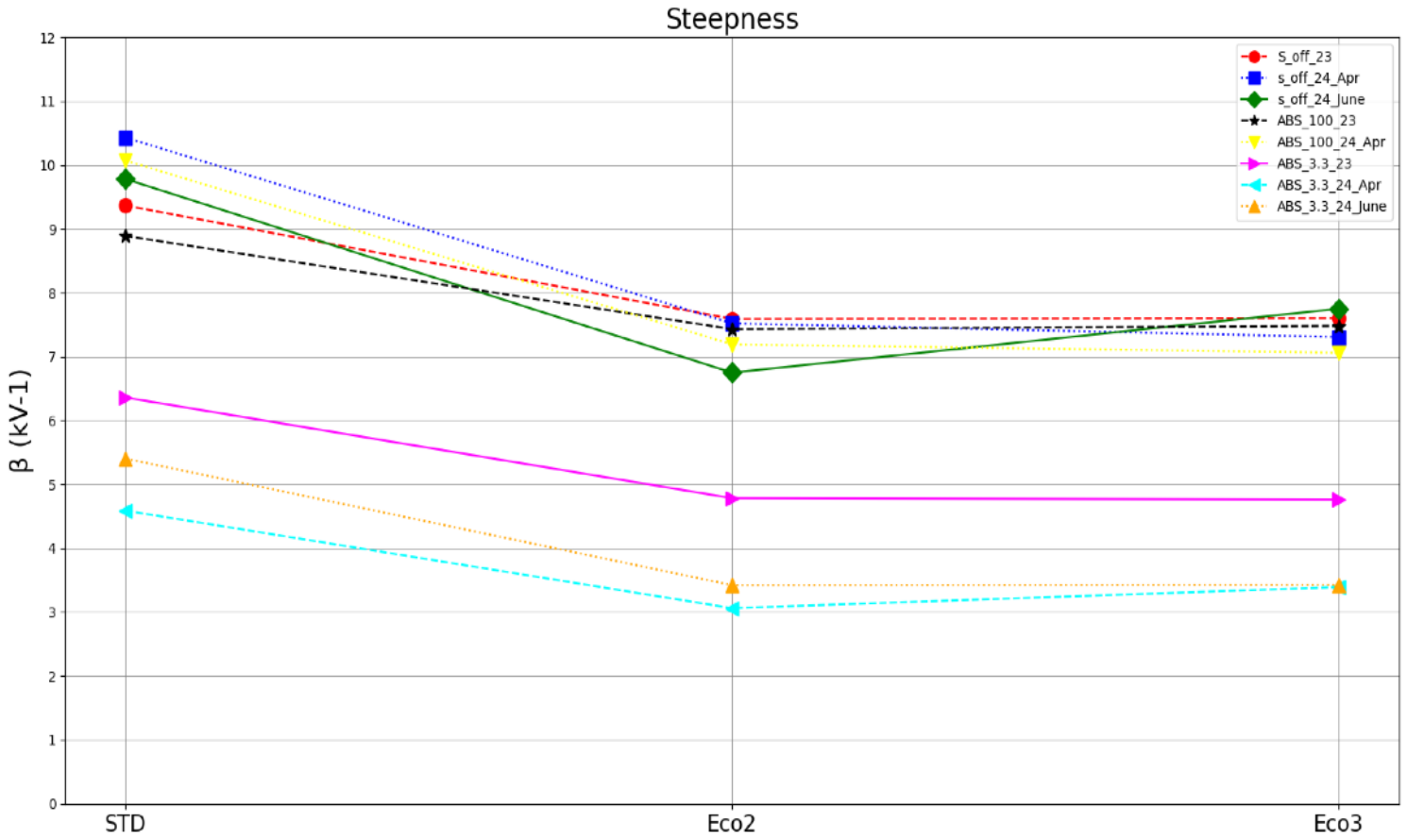
		2023	
ABS	STD	ECO2	ECO3
Off	99.869	99.353	98.723
100	99.907	98.843	98.249
3.3	99.531	97.688	96.855

	2024(April)		
ABS	STD	ECO2	ECO3
Off	98.242	96.53	97.099
100	98.2	95.757	96.586
3.3	95.451	94.75	90.674

	2024(June)	Max_efficiency	
ABS	STD	ECO2	ECO3
Off	98.042	96.03	97.102
3.3	96.75	93.597	94.116

$$\mathcal{E}(HV_{\text{eff}}) = \frac{\mathcal{E}_{\max}}{1 + e^{-\beta(HV_{\text{eff}} - HV_{50})}}$$

Comparison of slop of efficiency curve of all data



		2023	
ABS	STD	ECO2	ECO3
Off	9.365	7.59	7.603
100	8.889	7.43	7.481
3.3	6.359	4.782	4.761

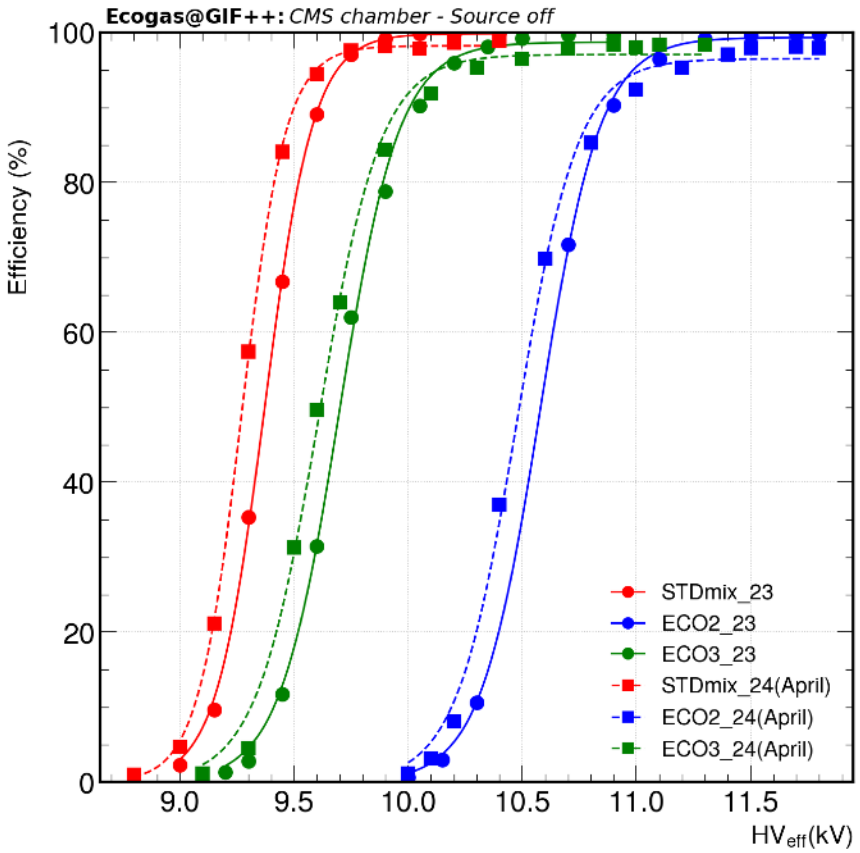
	2024(April)		
ABS	STD	ECO2	ECO3
Off	10.43	7.52	7.306
100	10.07	7.191	7.061
3.3	4.587	3.06	3.39

	2024(June)		
ABS	STD	ECO2	ECO3
Off	9.78	6.748	7.749
100		6.692	7.176
3.3	5.402	3.42	3.424

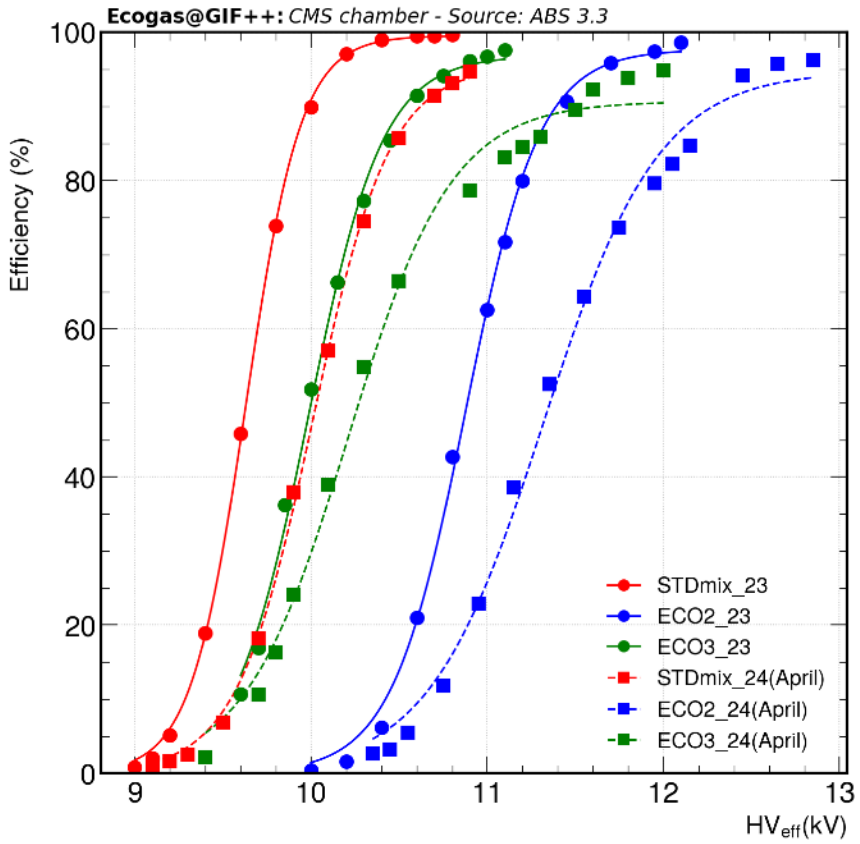
- For all data, the steepness becomes less from STD mixture to Eco2 and Eco3 data An increase is seen from Eco2 to Eco3 for June 24 (source_off) and slightly rise for April 24(ABS_3.3)

Efficiency vs HV_eff for April data

source_off



ABS_3.3

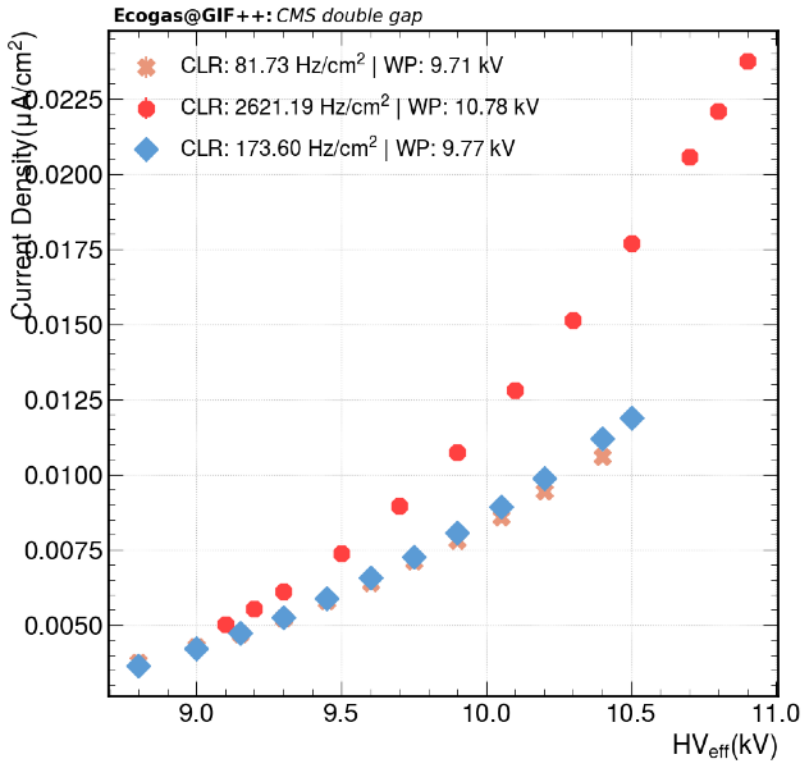


- For all gas mixtures, efficiency measured With source off and ABS_3.3
- A drop in the efficiency curves observed from 2023 to 2024

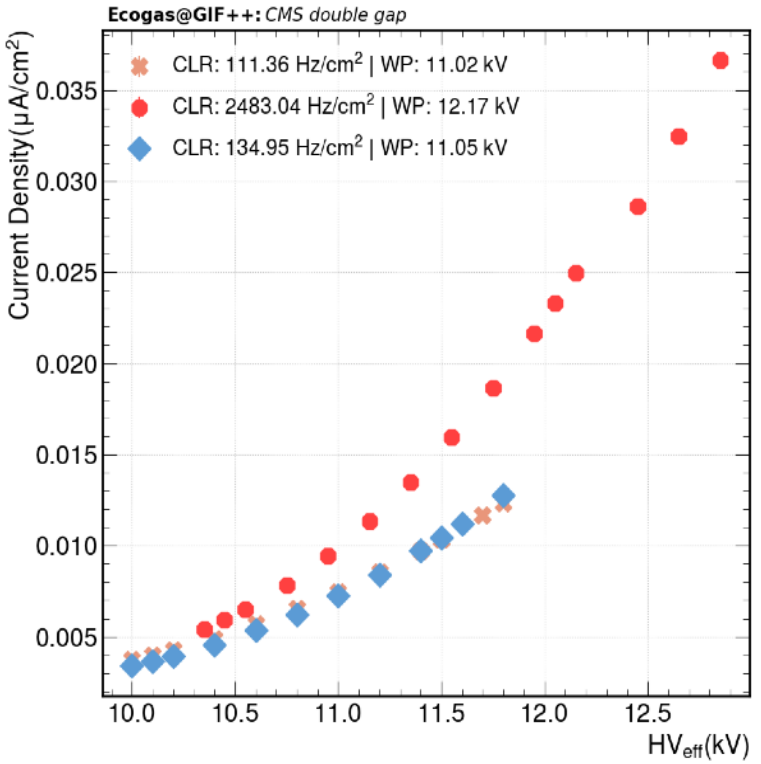
A shift toward negative voltage for data 2024 April.

Current density vs HV_eff for April data

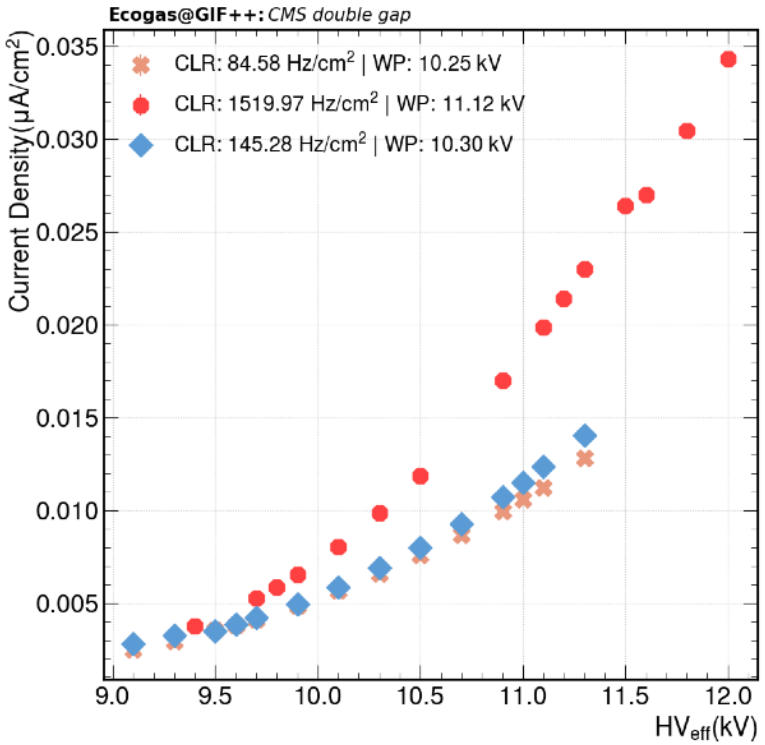
STD mixture



ECO2 mixture

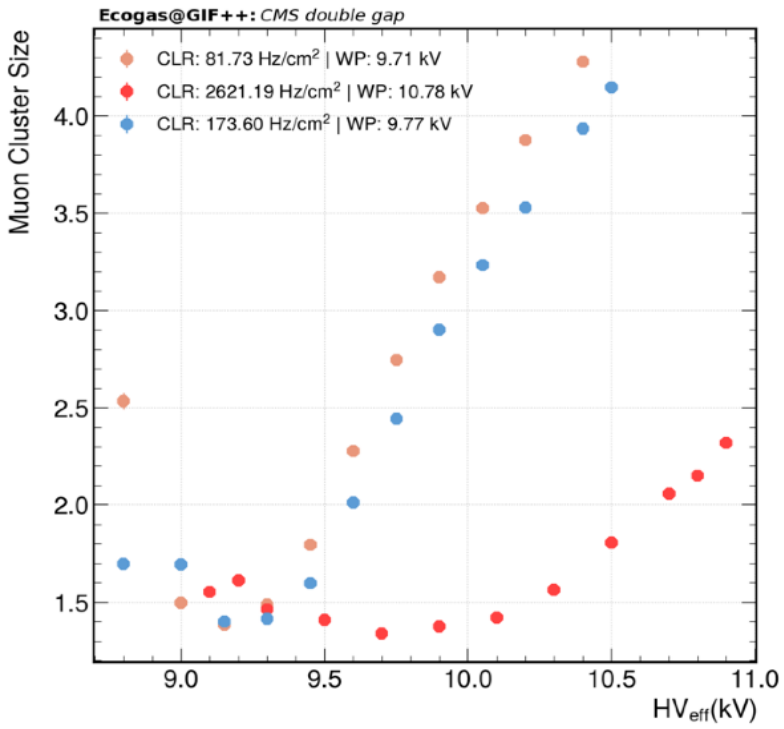


ECO3 mixture

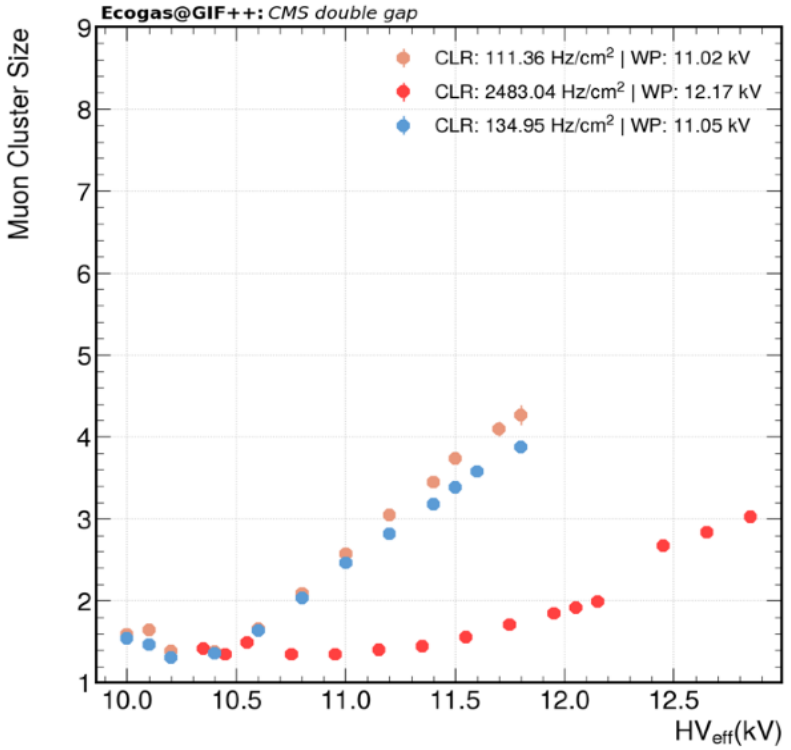


MCS vs HV_eff for April data

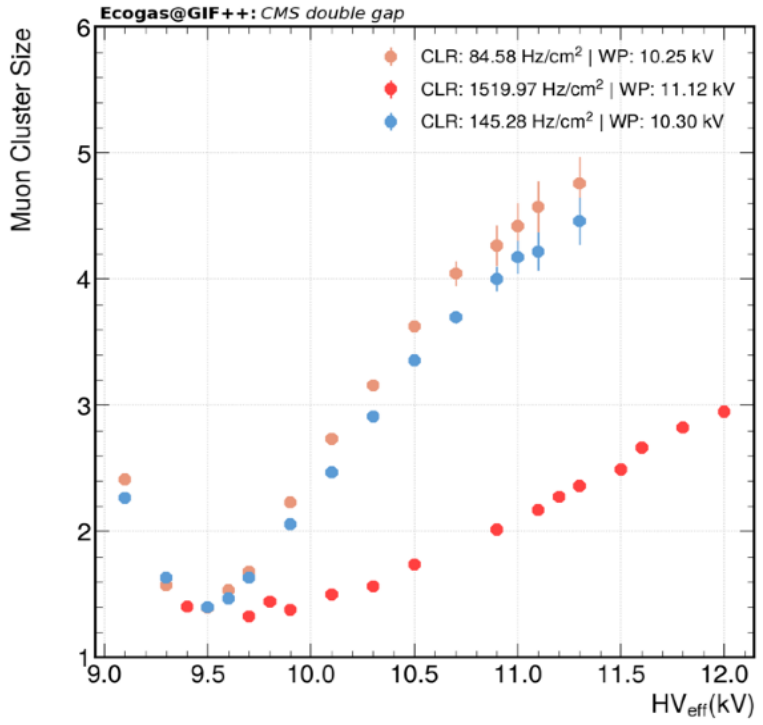
STD mixture



ECO2 mixture

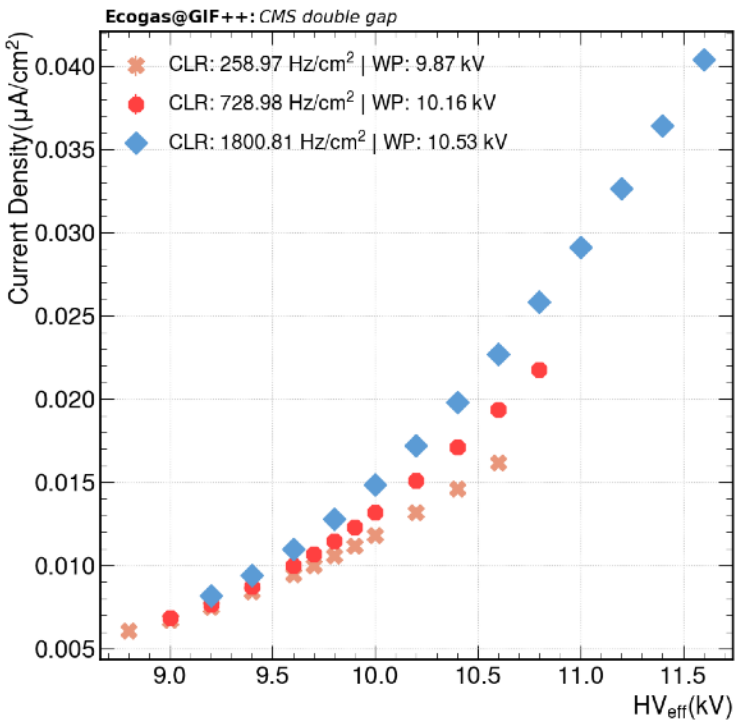


ECO3 mixture

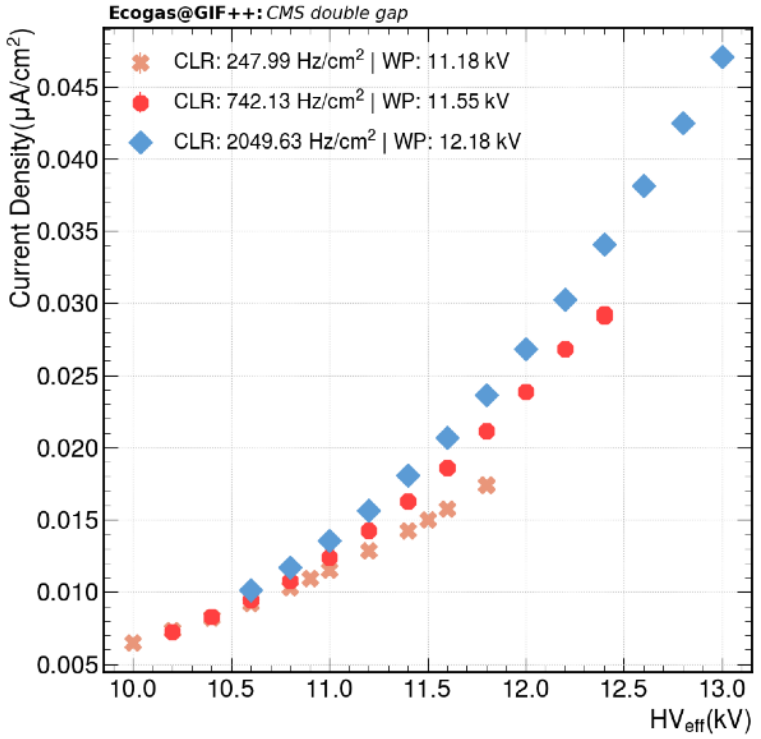


Current density vs HV_eff for June data

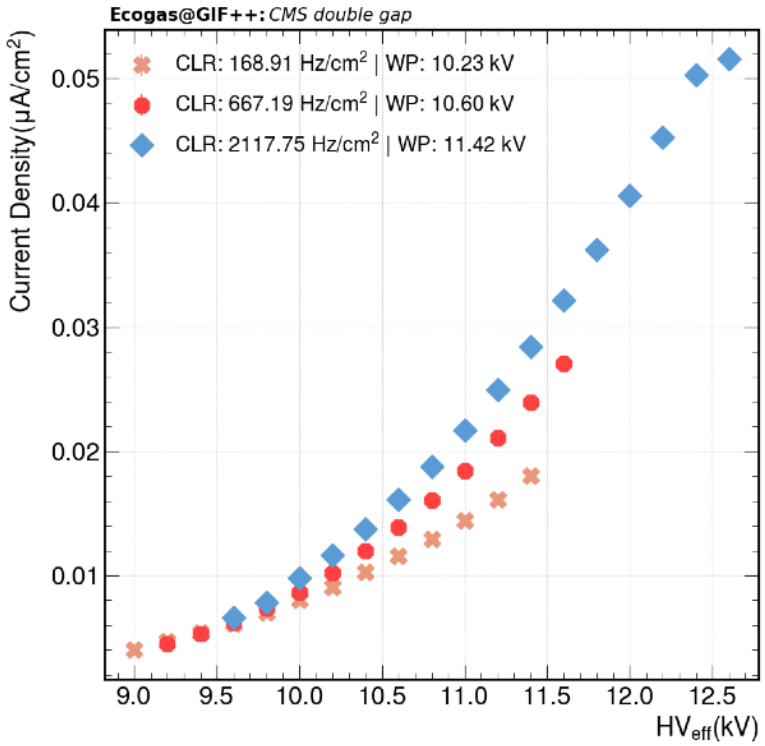
STD mixture



ECO2 mixture

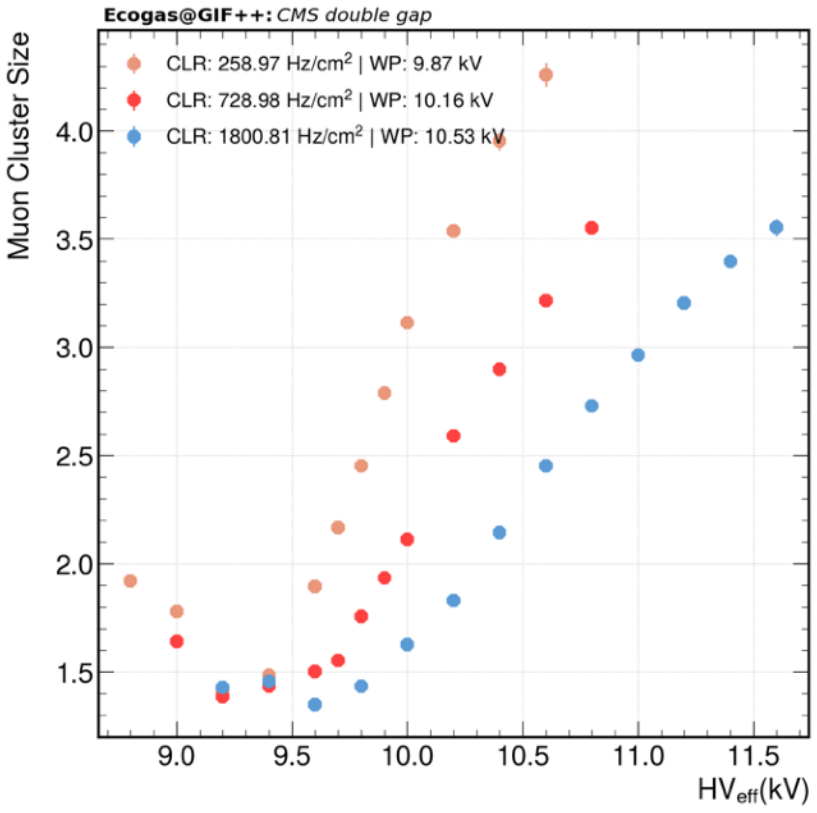


ECO3 mixture

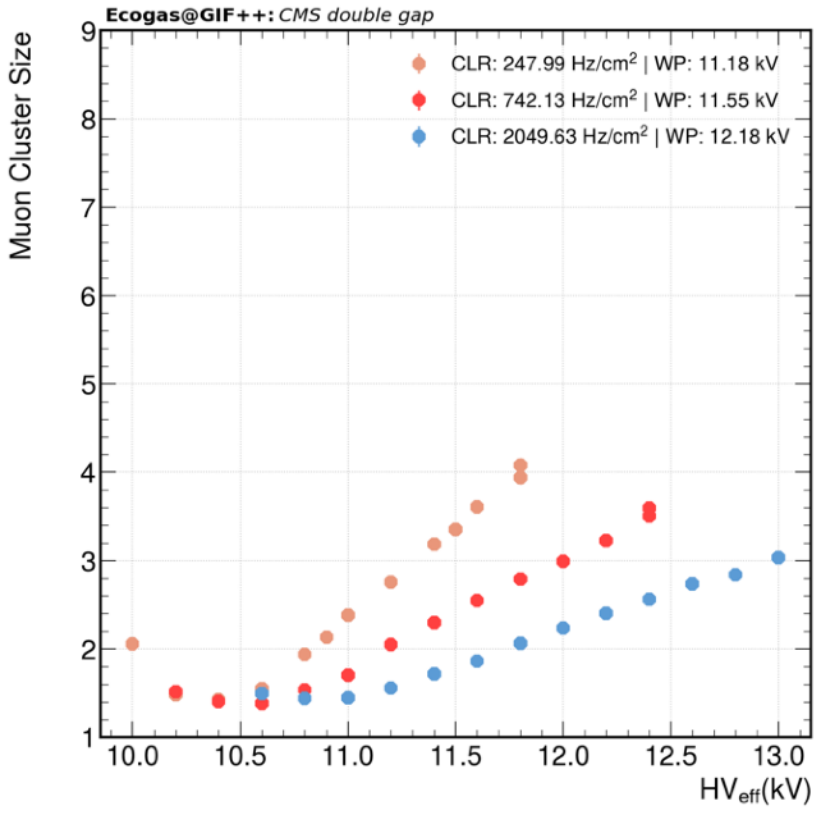


MCS vs HV_eff for June data

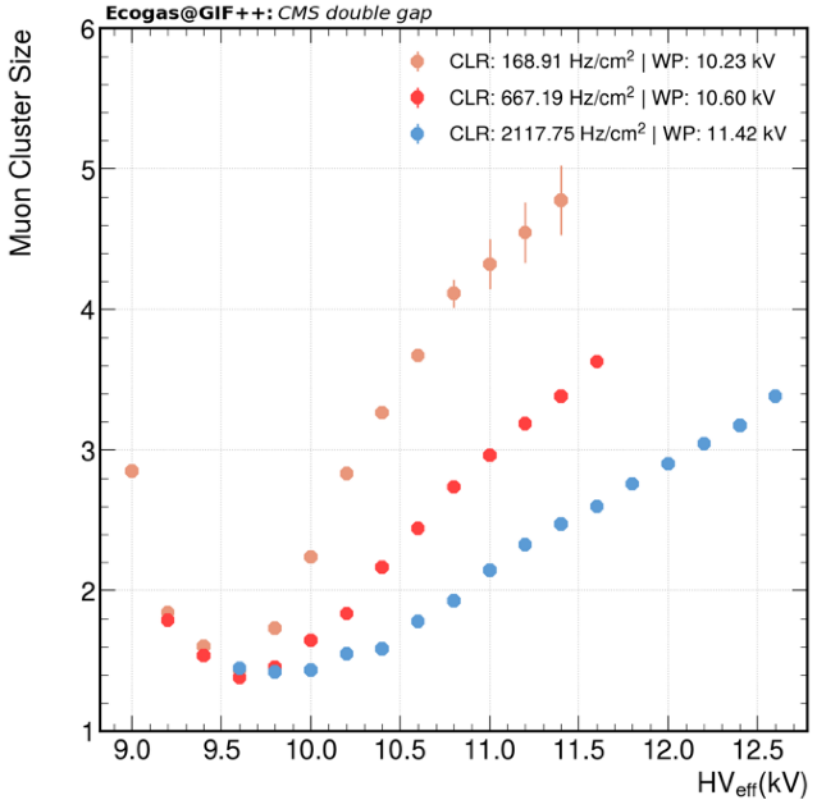
STD mixture



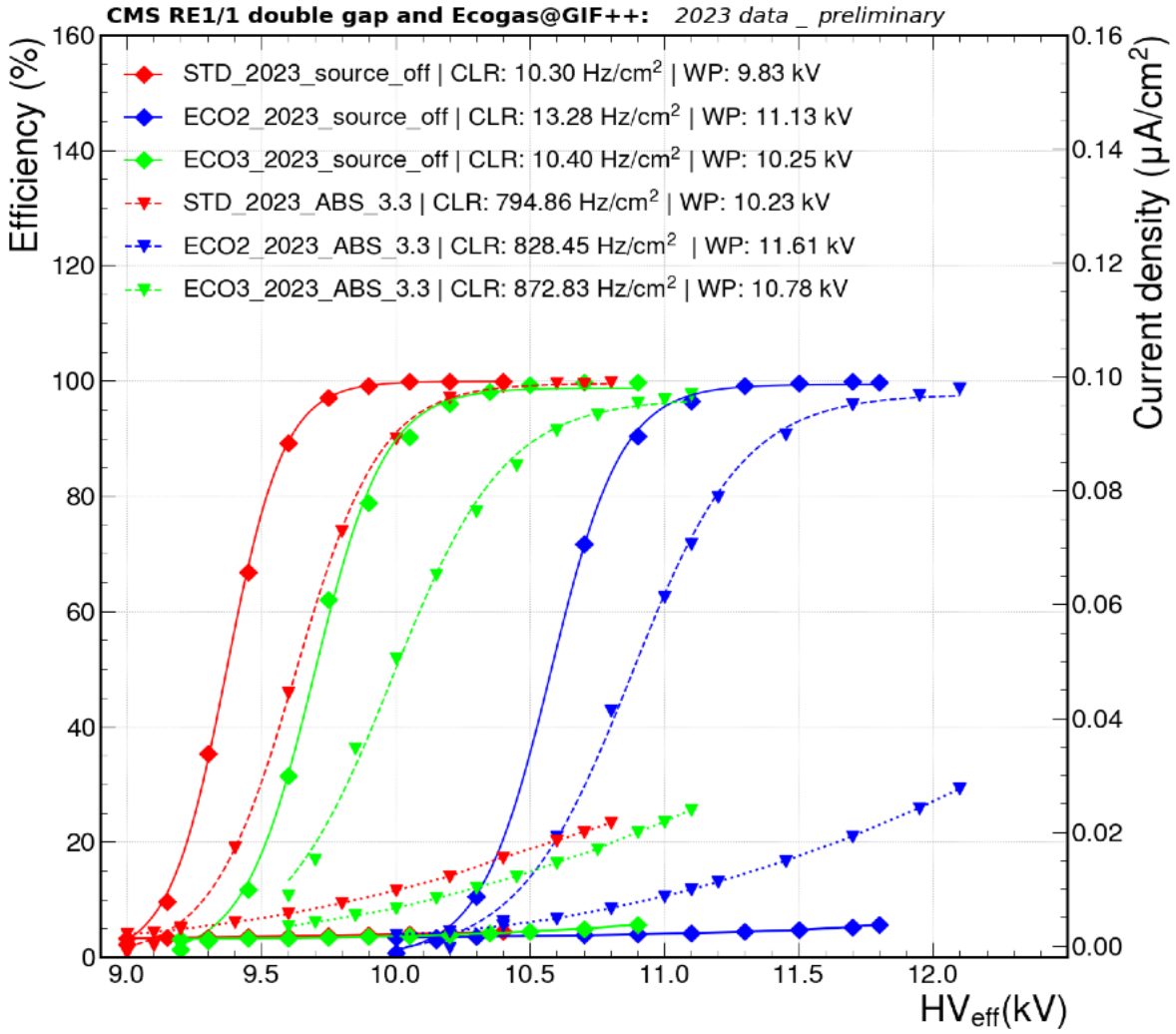
ECO2 mixture

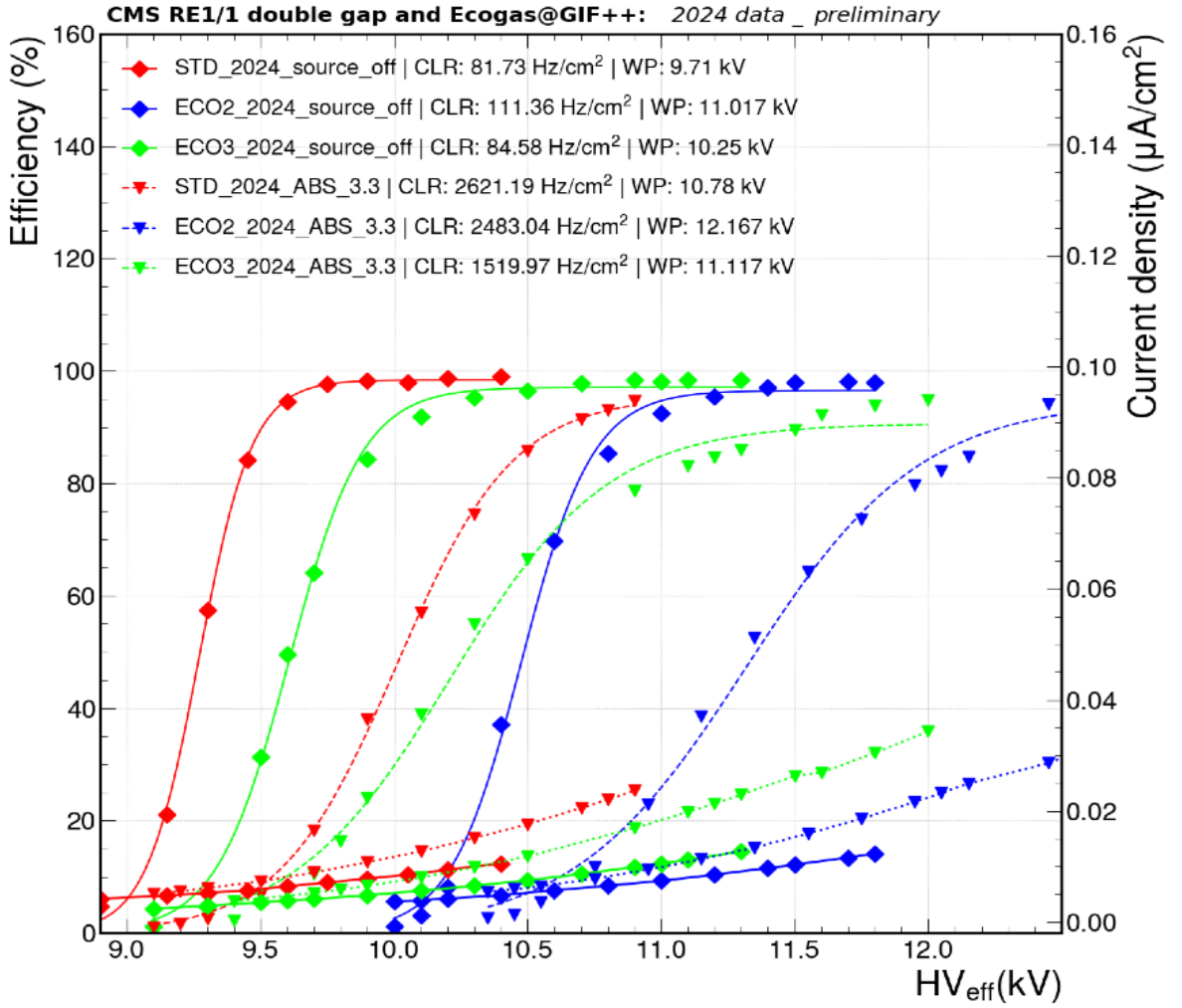


ECO3 mixture



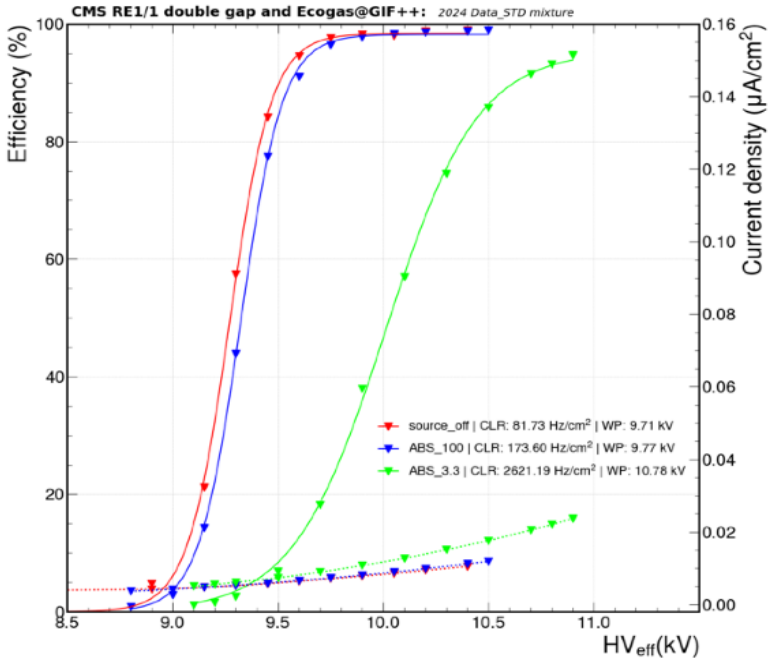
Efficiency and current density vs HV_eff for 2023 and 2024 data_source_off and ABS_3.3



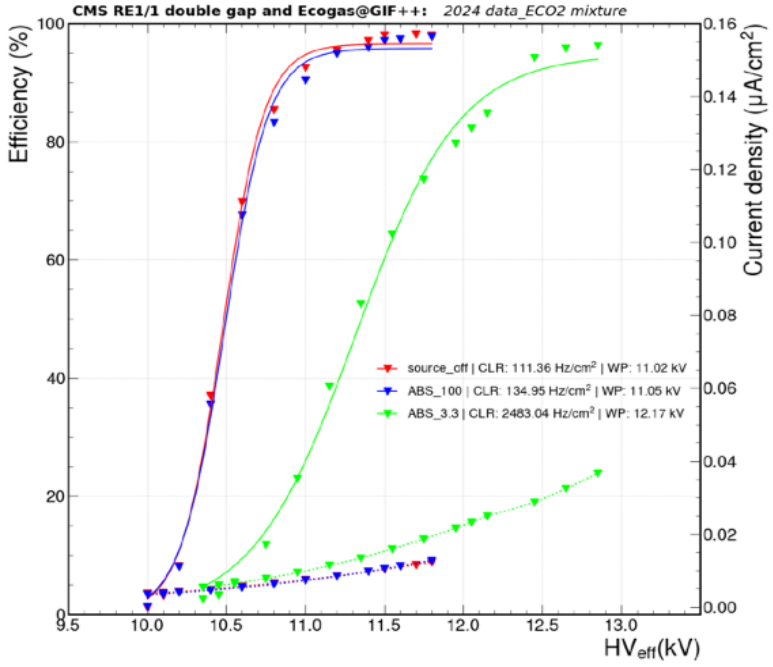


Efficiency and current density vs HV_eff for 2024_STD_Eco2_Eco3

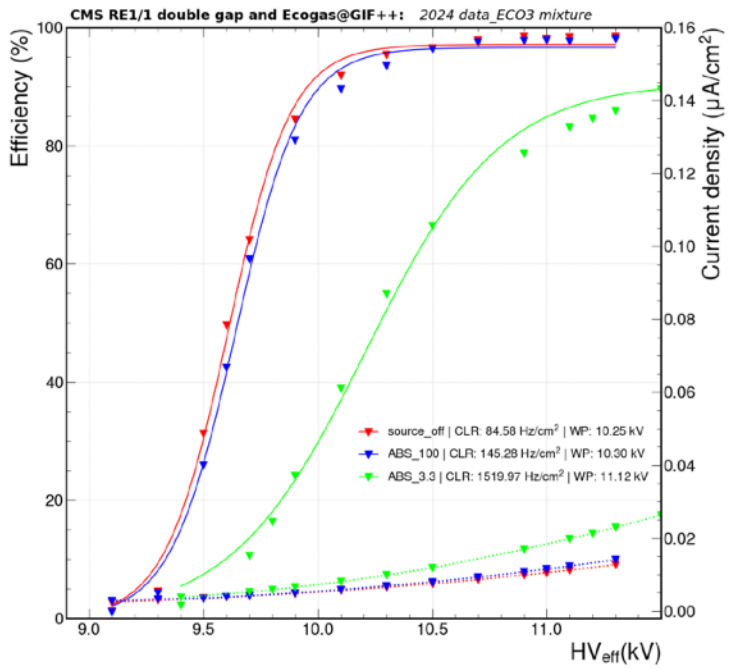
STD mixture



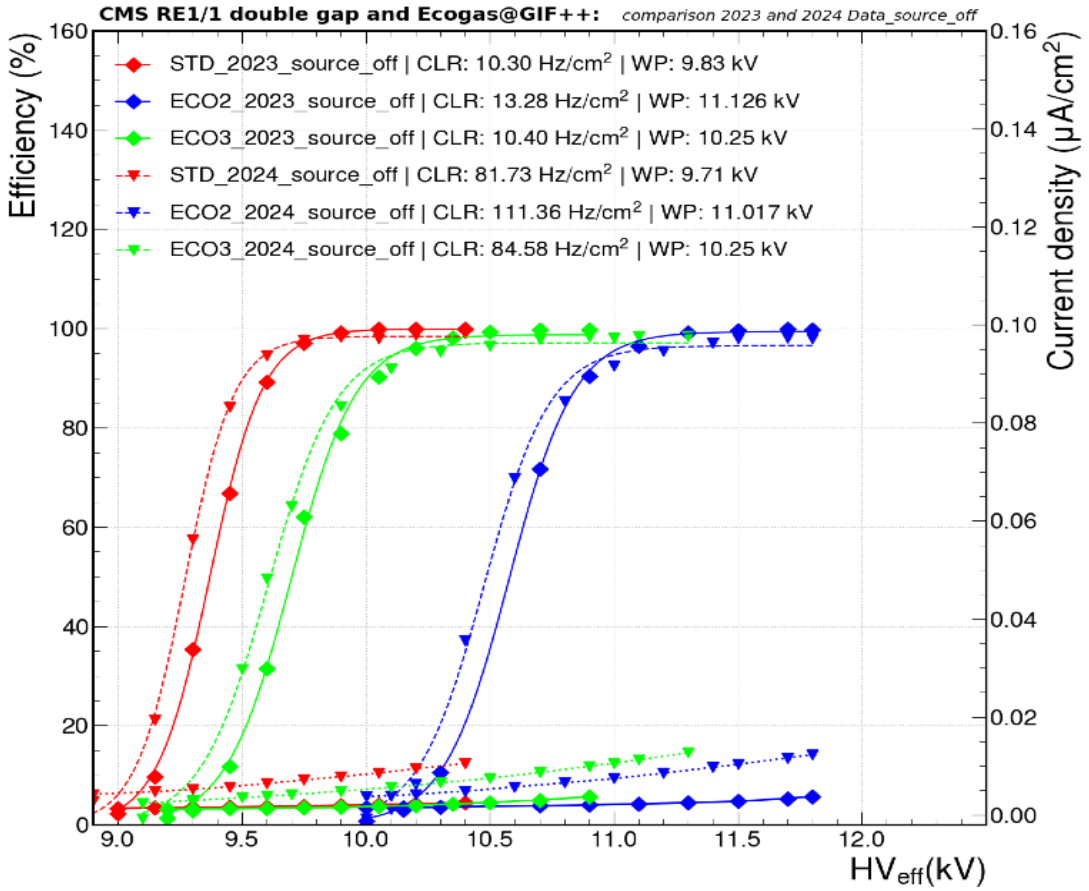
ECO2 mixture

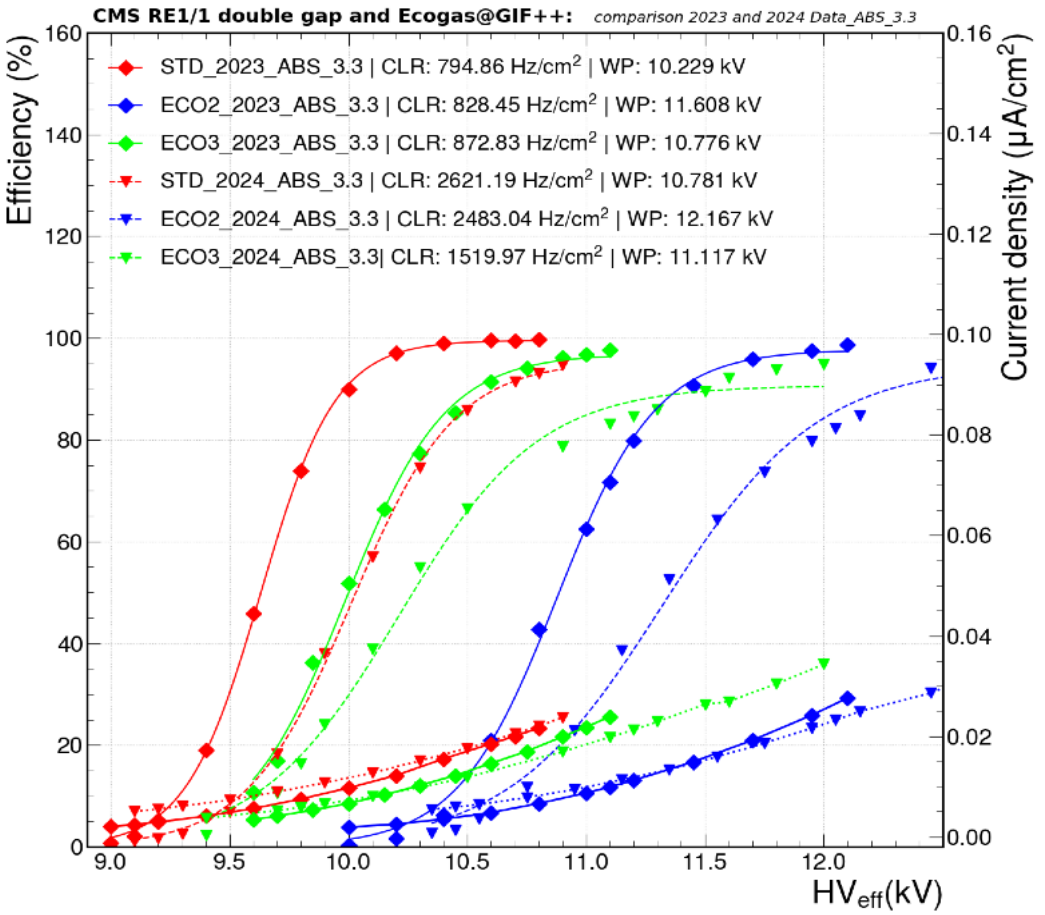


ECO3 mixture



Comparison of efficiency and current density vs HV_eff for 2023 and 2024 data_source_off and ABS_3.3





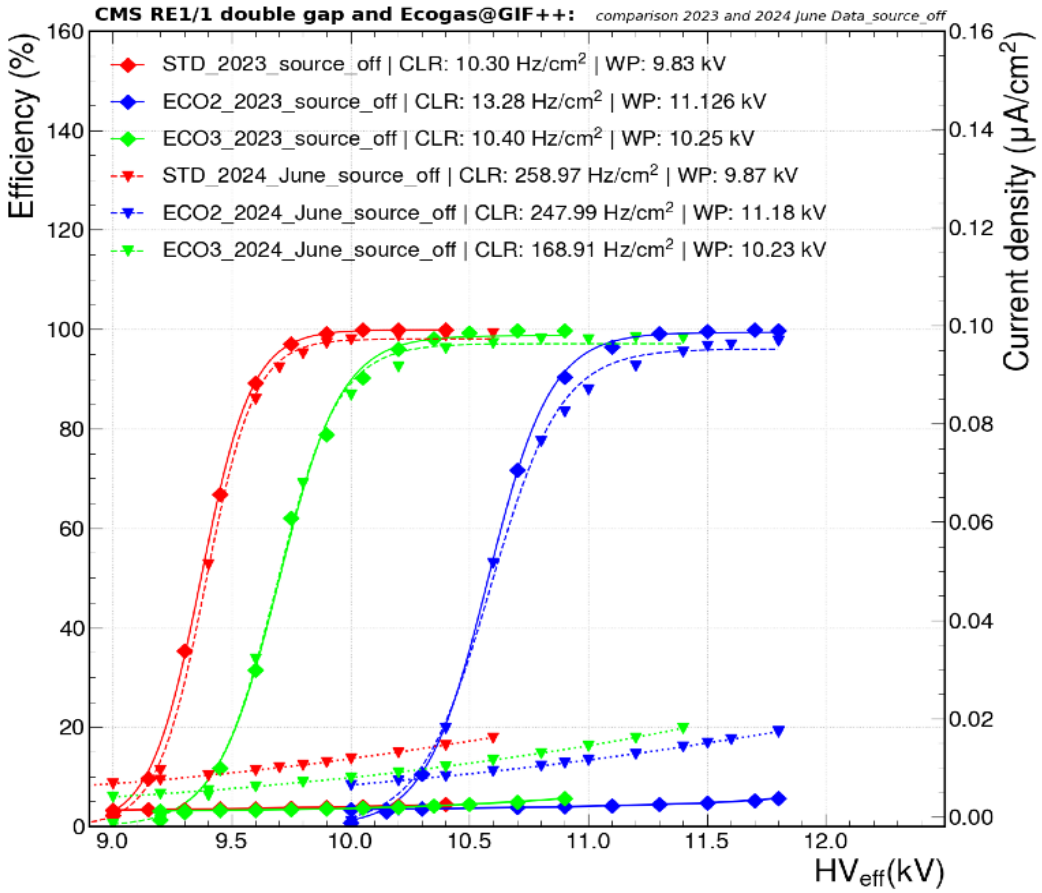
Source off: In the 2023 data, the current density at WP for STD, ECO2, and ECO3 gas mixtures are approximately 2 nA/cm².

In April 2024, the current density rises to 6.4 to 8 nA/cm² for all gas mixtures representing a nearly 4 times increase in current density.

ABS_3.3: 2023 data shows that the current density at WP for STD, ECO2, and ECO3 gas mixtures are around 12.3, 19, and 17 nA/cm².

In April 2024 data, the current densities are 22, 25 and 20 nA/cm², respectively.

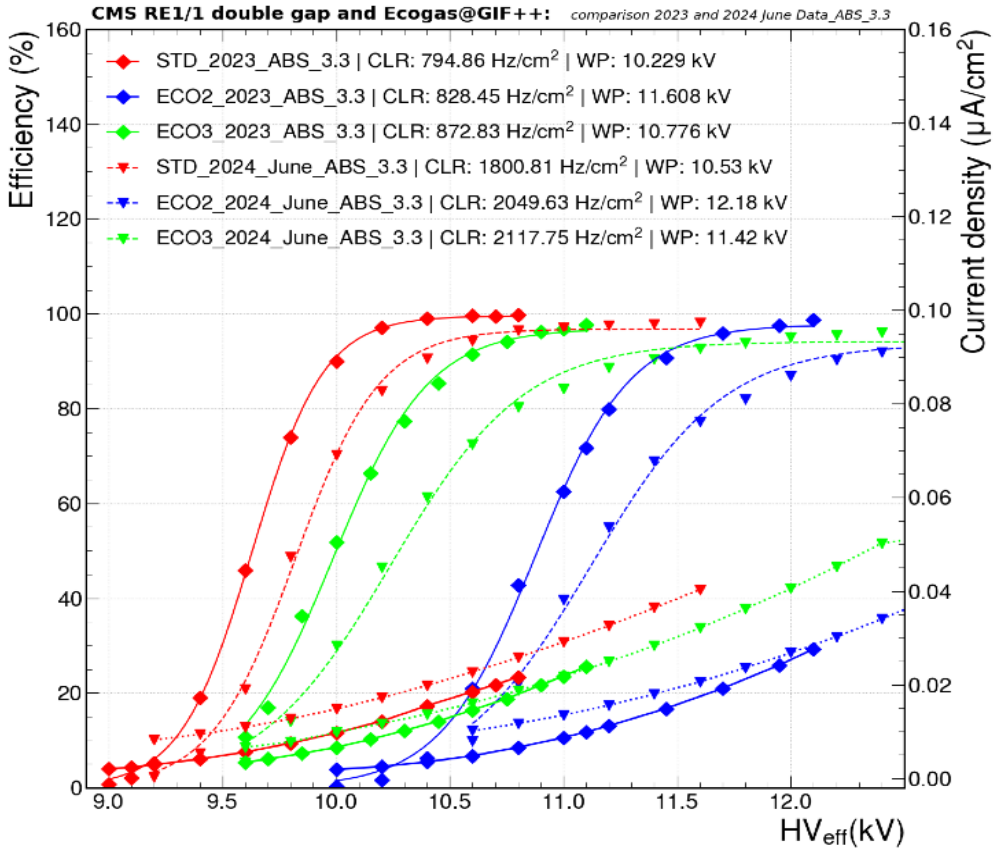
Comparison of efficiency and current density vs HV_eff for 2023 and 2024 June data_source_off and ABS_3.3



Source off: In the 2023 data, the current density at WP for STD, ECO2, and ECO3 gas mixtures are approximately 2 nA/cm².

In June2024, the current density rises from 9.1 to 13 nA/cm² for all gas mixtures representing maximum 6.5 times increase in current density.

Source_off, cluster rate is between 2 and 3 times higher for all mixture than april data when source is off



ABS_3.3: 2023 data shows that the current density at WP for STD, ECO2, and ECO3 gas mixtures are around 12.3, 19, and 17 nA/cm².

In June 2024, the current densities are 22.7, 42 and 28 nA/cm², respectively.

ABS_3.3: for STD and ECO2 mixture, cluster rate for april data is higher. However, cluster rate for ECO3 is less than data June 2024.

Cluster rate for different ABS for April and June data

STD mixture June

ABS	Cluster rate (Hz/ cm^2)	WP(KV)
off	258.97	9.87
10	728.98	10.16
6.9	991.81	10.29
3.3	1800.81	10.53

ECO2 mixture June

ABS	Cluster rate (Hz/cm^2)	WP(KV)
off	247.99	11.18
10	742.13	11.55
6.9	990.56	11.67
3.3	2049.63	12.18

ECO3 mixture June

ABS	Cluster rate (Hz/cm^2)	WP(KV)
off	168.91	10.23
10	667.19	10.60
6.9	1026.57	10.88
3.3	2117.75	11.42

STD mixture April

ABS	Cluster rate (Hz/cm^2)	WP(KV)
off	81.73	9.71
3.3	2621	10.781

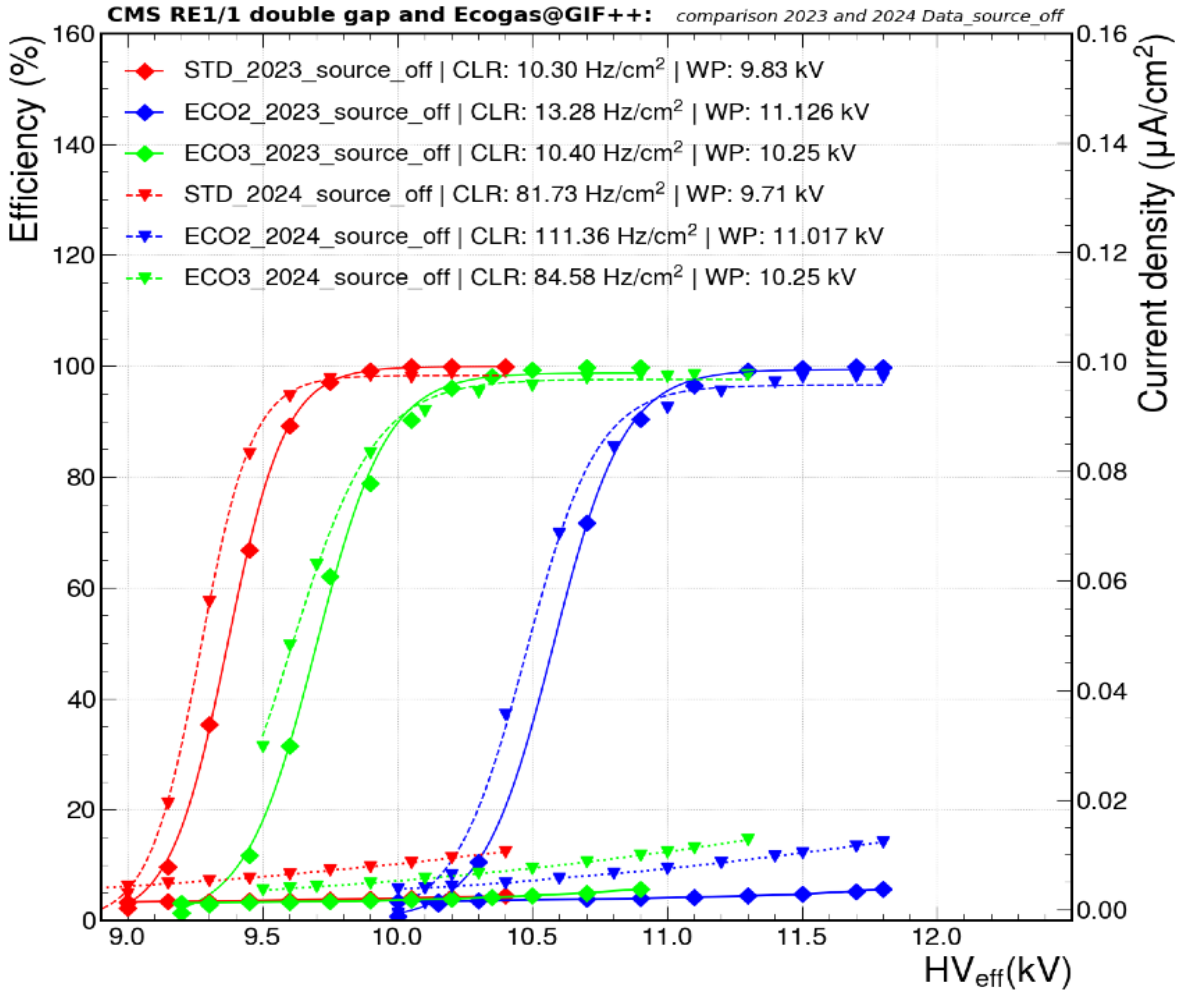
ECO2 mixture April

ABS	Cluster rate (Hz/cm^2)	WP(KV)
off	111.36	11.017
3.3	2483.04	12.167

ECO3 mixture April

ABS	Cluster rate (Hz/cm^2)	WP(KV)
off	84.58	10.25
3.3	1519.97	11.117

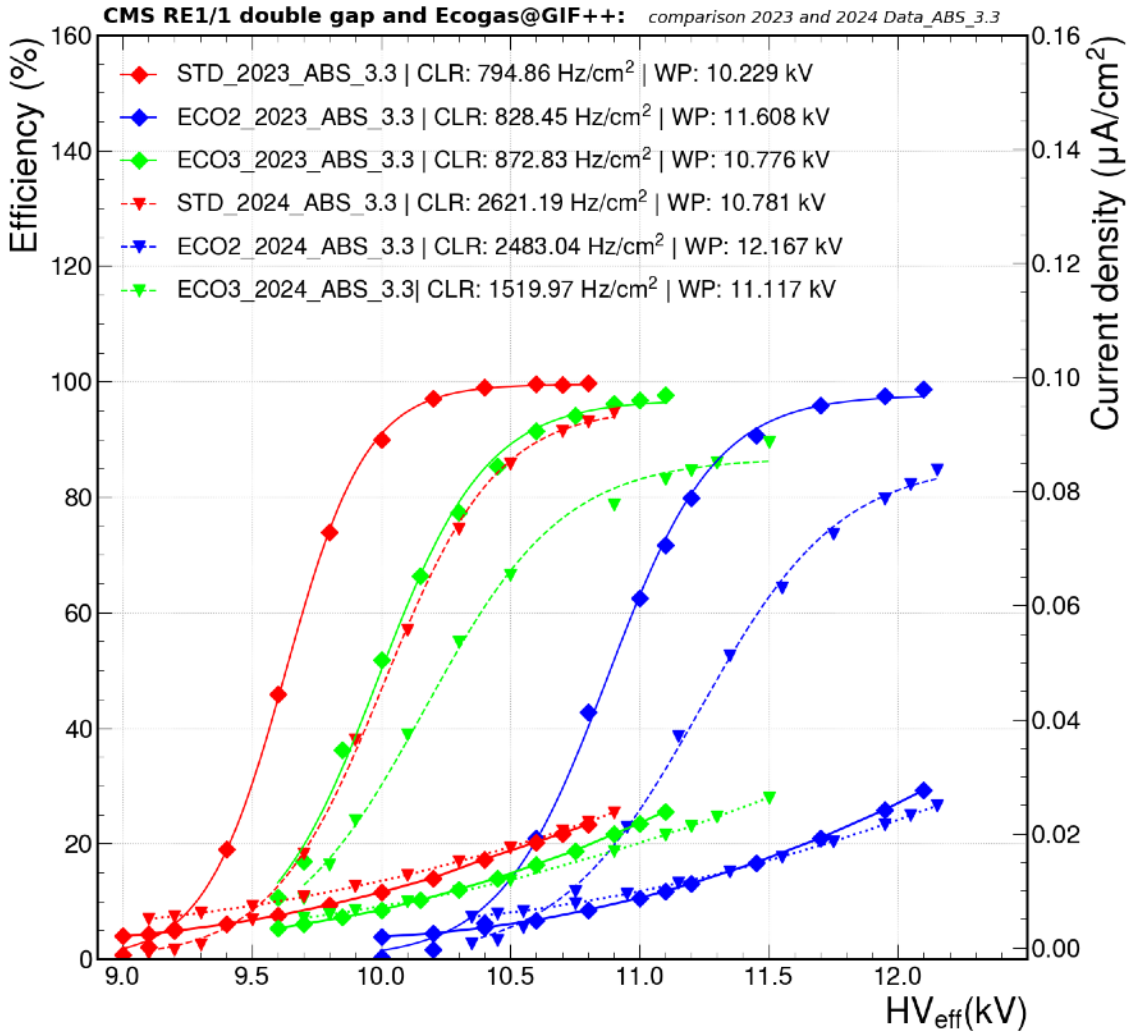
Comparison of efficiency and current density vs HV_eff for 2023 and 2024 data_source_off_for incomplete dataset



Source off: In the 2023 data, the current density at WP for STD, ECO2, and ECO3 gas mixtures are approximately 2 nA/cm^2.

In 2024, the current density rises to 6.4 to 8 nA/cm^2 for all gas mixtures representing a nearly 4 times increase in current density.

Comparison Efficiency and current density vs HV_eff for 2023 and 2024 data_ABS_3.3_for incomplete dataset



ABS_3.3: 2023 data shows that the current density at WP for STD, ECO2, and ECO3 gas mixtures are around 12.3, 19, and 17 nA/cm^2.

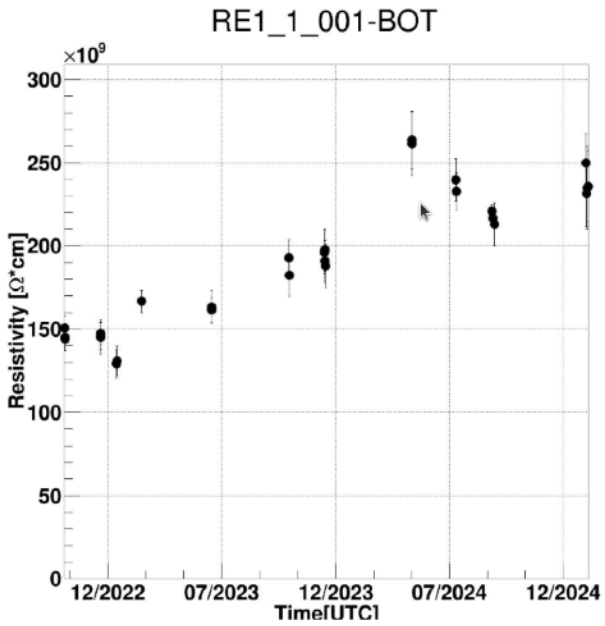
In the 2024 data, the current densities are 22, 25 and 20 nA/cm^2, respectively.

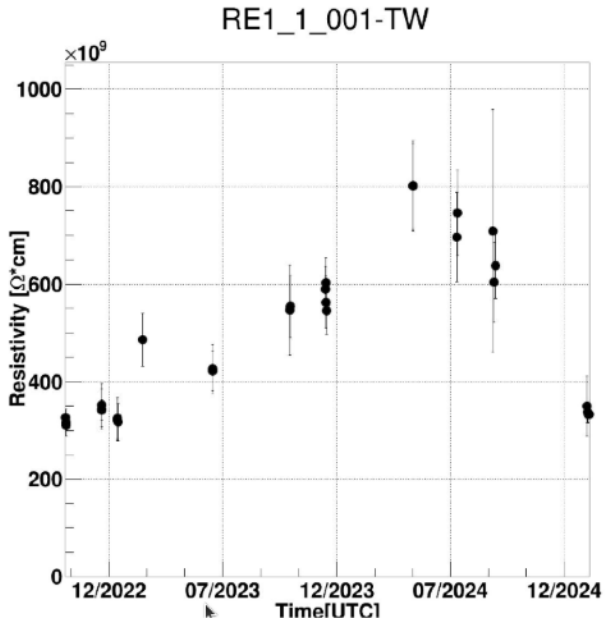
Resistivity

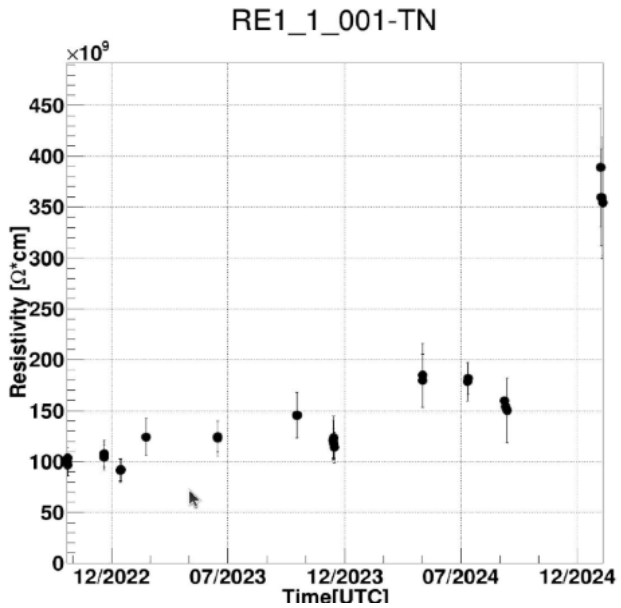
Why Hvgas? First of all, resistivity of the electrode is measured a few times per year and it is an important parameter that affects the RPC performance.

As shown in the resistivity data as a function of time, its value is increasing (due tue the rise in the integraded charge as time passed) through years. As a result, the increase of resistance leads to the rise of voltage drop, shown below:

$$HV_{gas} = HV_{eff} - RI$$





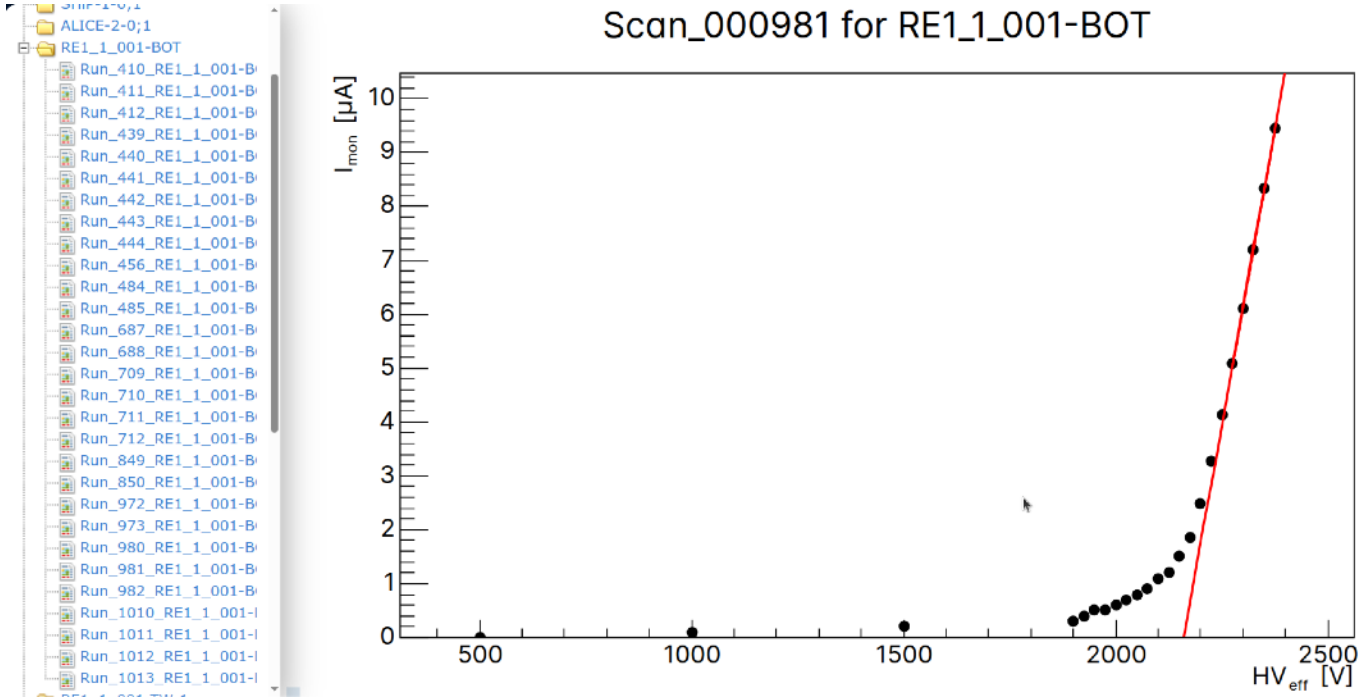


Received Resistivity data from Luca
Data for previous years is from Umesh

Resistivity (ρ) x 10⁹ Ω cm.			
RPC	**2021**	**2023**	2024
BOT	100	150	262.582
TW	150	390	801.40
TN	50	115	182.15

Resistance

From the graph, the resistance at 9 µA and 2400 V will be ~ 266 x 10^6 Ω



Measured Resistance values					
Oct-21		Oct-23 and 24			
RPC	R (Ω)	RPC	R (Ω)	RPC	R (Ω)
BOT	11 x 10^6	BOT	20 x 10^6	BOT	27.46 x 10^6
TW	29 x 10^6	TW	93 x 10^6	TW	139.42 x 10^6
TN	19 x 10^6	TN	48 x 10^6	TN	54.47x 10^6

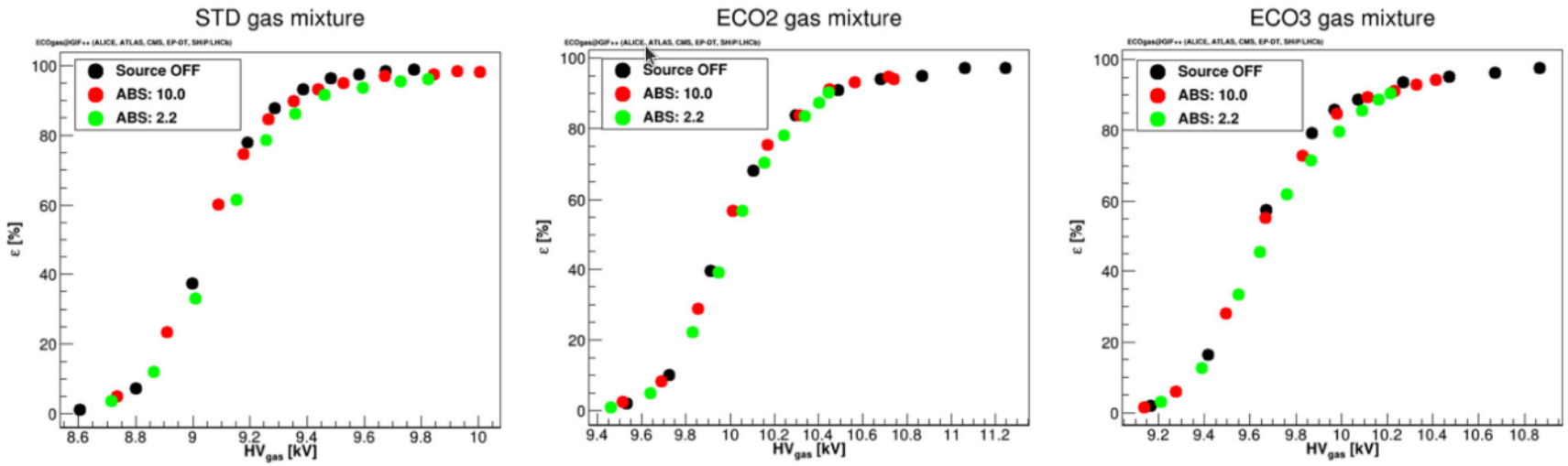
Received Resistance data from Luca
Data for previous years is from Umesh

Why measuring HVgas?

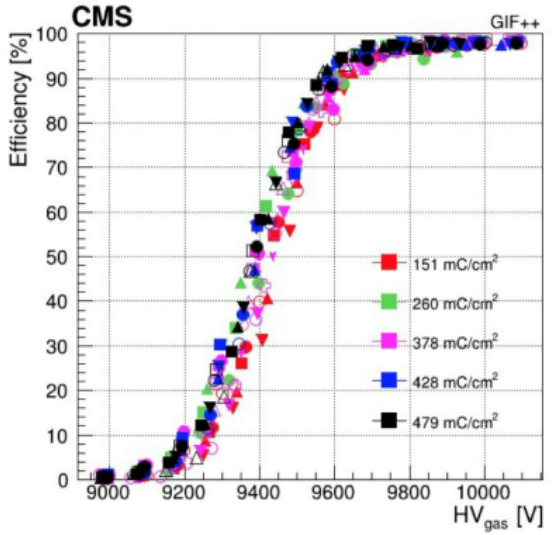
As mentioned before, increase of resistance leads to the rise of voltage drop on the effective voltage (HV) applied to the electrodes, and the effective voltage on the gas (HV gas) is no longer the same:

$HV_{gas} = HV_{eff} - RI$

The detector operation regime will be indifferent with respect to HV gas
The efficiency as a function of HV gas does not depend anymore on the bakelite resistance
On the right, the efficiency at different irradiation periods and different background rates up to 600 Hz/cm2(right)
On the left, efficiency and current density as a function of HVgas for the ALICE chamber



Abbrescia, M., et al. "High-rate tests on resistive plate chambers operated with eco-friendly gas mixtures." The European Physical Journal C 84.3 (2024): 300.

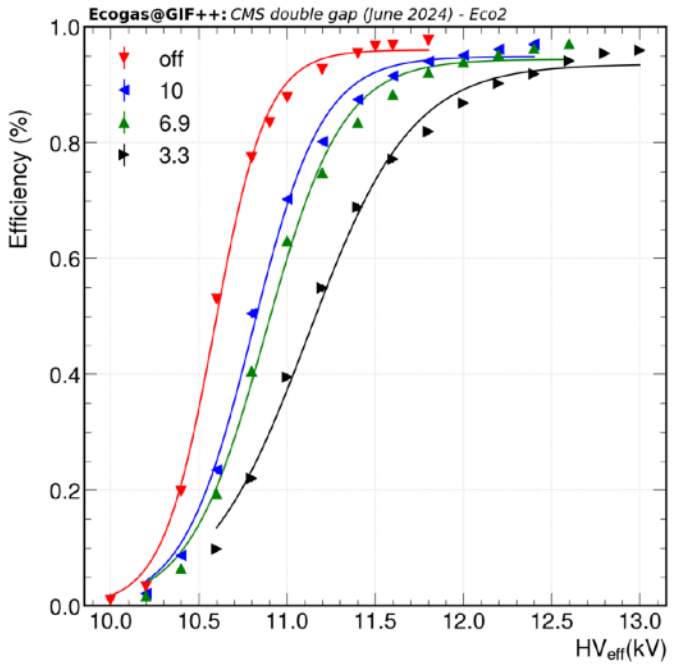


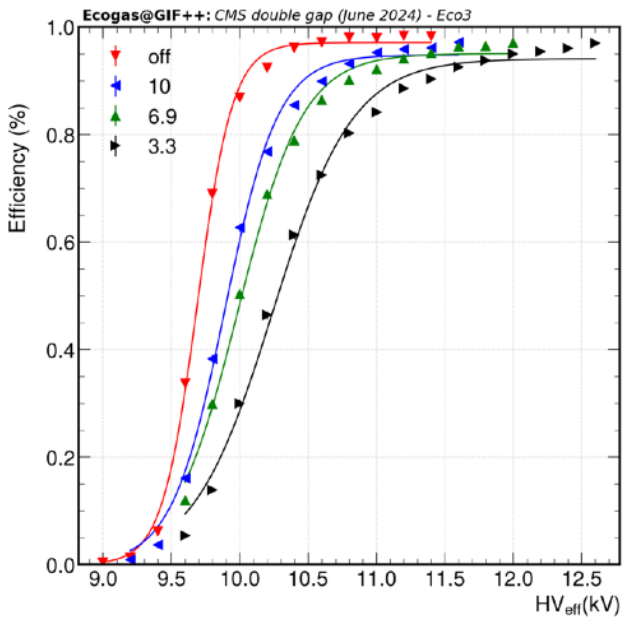
Aly, Reham, et al. "Aging study on Resistive Plate chambers of the CMS muon detector for HL-LHC." Journal of Instrumentation 15.11 (2020): C11002.

Why measuring Hvgas?

To study the shift as measured dose increased, the efficiency as a function of Hvgas should be obtained.

Efficiency as a function of Hveff for different ABS, which the shift is visible



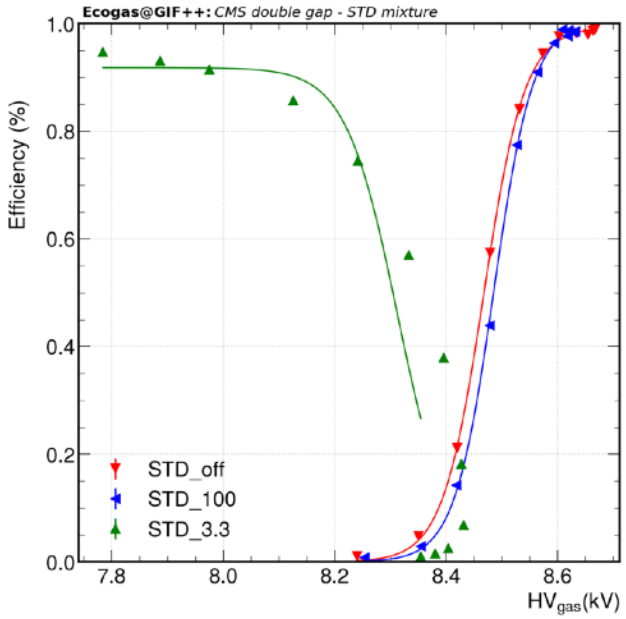


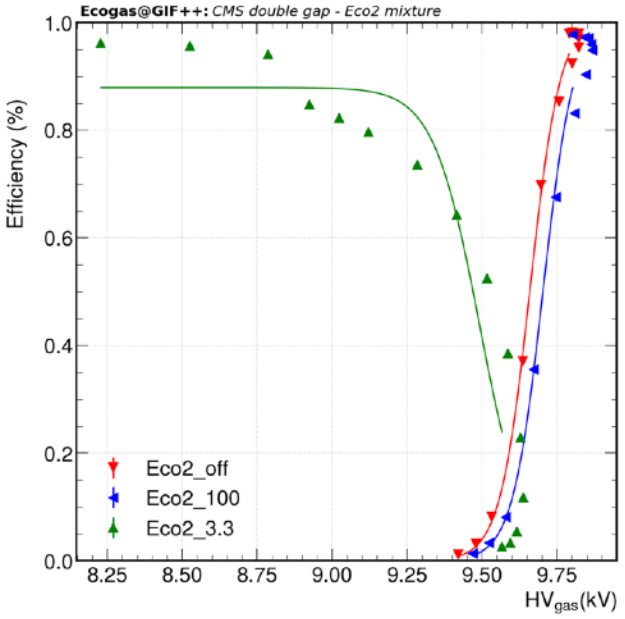
HV_{gas} (BOT) = HV_{eff} – R (BOT) * I (BOT)

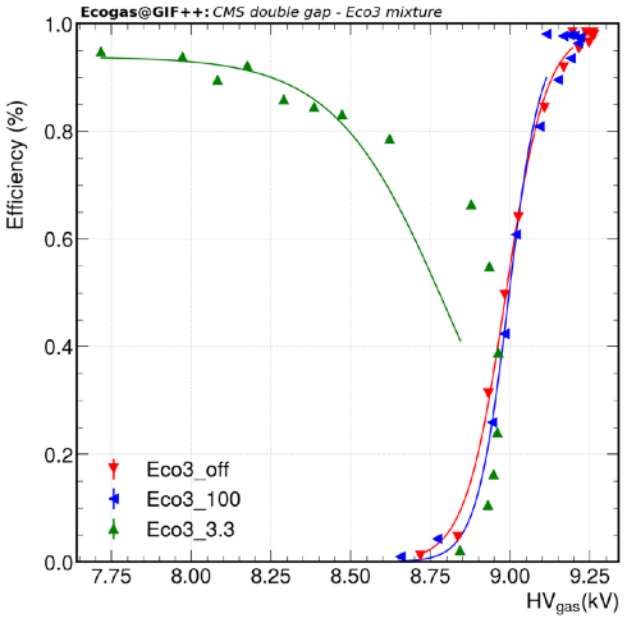
HV_{gas} (TW) = HV_{eff} – R (TW) * I (TW)

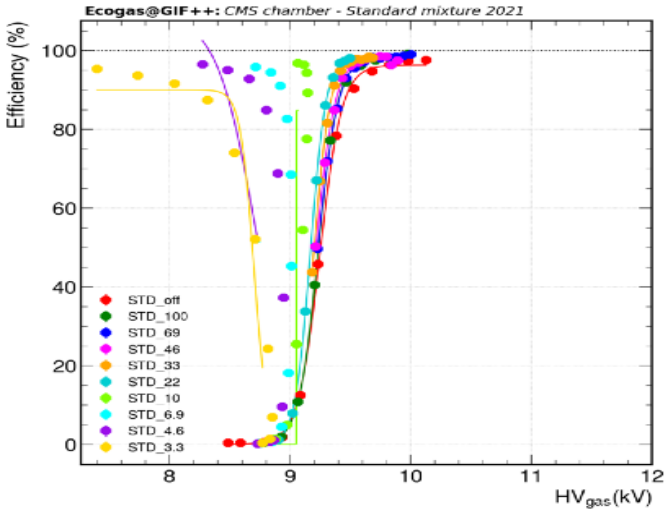
Efficiency as a function of HVgas for 2024 data_source_off and ABS_3.3

This is the same study I did for 2024 data.









From ABS_10 onwards the HV_{gas} observed to be shifting in the opposite direction, meaning Hv_{gas} experienced a reduction.

efficiency will not increase when the HV_{gas} value decreases.

Taken from Umesh presentation.

The problem: what value I need to take into account for resitivity?

Choosing one Bakelite resistivity ρ and iterated to observe the efficiency is increasing for all ABS.

Computed the ΔV as follows:

$\Delta V_{BOT} = R_{BOT} \times I_{BOT} = \rho \times I_{BOT}$ [Area_BOT = 3824.11 cm^2]

$\Delta V_{TW} = R_{TW} \times I_{TW} = \rho \times I_{TW}$ [Area_TW = 2299.08 cm^2]

Estimated ρ value is 65 x 10^9 Ω cm and R_{BOT} = 6.8 MΩ, R_{TW} = 11.3 MΩ for 2021.

Estimated ρ value is 96 x 10^9 Ω cm and R_{BOT} = 10 MΩ, R_{TW} = 16.7 MΩ for 2023.

The smallest value should be selected between ΔV_{BOT} & ΔV_{TW} and called it as ΔV .

HV_{gas} calculated by $HV_{gas} = HV_{eff} - \Delta V$.

Resistivity (ρ) x 10^9 Ω cm.			
RPC	**2021**	**2023**	2024
BOT	100	150	262.582
TW	150	390	801.40
TN	50	115	182.15

Measured Resistance values					
Oct-21		**Oct-23 and 24**			
RPC	**R (Ω)**	**RPC**	**R (Ω)**	**RPC**	**R (Ω)**
BOT	11 x 10^6	BOT	20 x 10^6	BOT	27.46 x 10^6
TW	29 x 10^6	TW	93 x 10^6	TW	139.42 x 10^6
TN	19 x 10^6	TN	48 x 10^6	TN	54.47x 10^6

Comparison of current density vs HV_eff for 2023 and 2024 data_source_off and ABS_3.3