Eco-Gas Studies for the CMS iRPC for the High Luminosity LHC

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Abstract

We will present a summary of the performance of the improved RPC (iRPC) using several RPC gas mixtures with a low Global Warming Potential (GWP). We have replaced the Freon (R134a) from the official CMS gas mixture with HFO and CO2. The results show promising mixtures for the iRPC for the High Luminosity LHC.

Global Warming Potential

The mixture of gases used for RPC CMS detectors is composed of SF6 0.3%, isobutane 4.5% and freon in 95.2% (CMS Mixture), these compounds make the mixture have a high GWP index equal to 1433, being the freon the compound that contributes the most to this index. An alternative with a lower GWP index is looked for and, at the same time, it is required to have the same performance as the aforementioned mixture, besides being friendly to the environment.

RPC Detector

In this work we have analyzed 5 possible candidate mixtures to replace the CMS mixture, in which the freon has been replaced by a mixture of carbon dioxide and HFO in different proportions (see table 1). The 5 mixtures were used in an RPC in 2017, whose dimensions are 97x54 cm^2, 2 gaps of 1.4 mm and consists of 32 strips of 2.5 cm in width. We analyzed 8 analog channels of the detector corresponding to the area covered by scintillation plastics that were used as a trigger (figure 1).

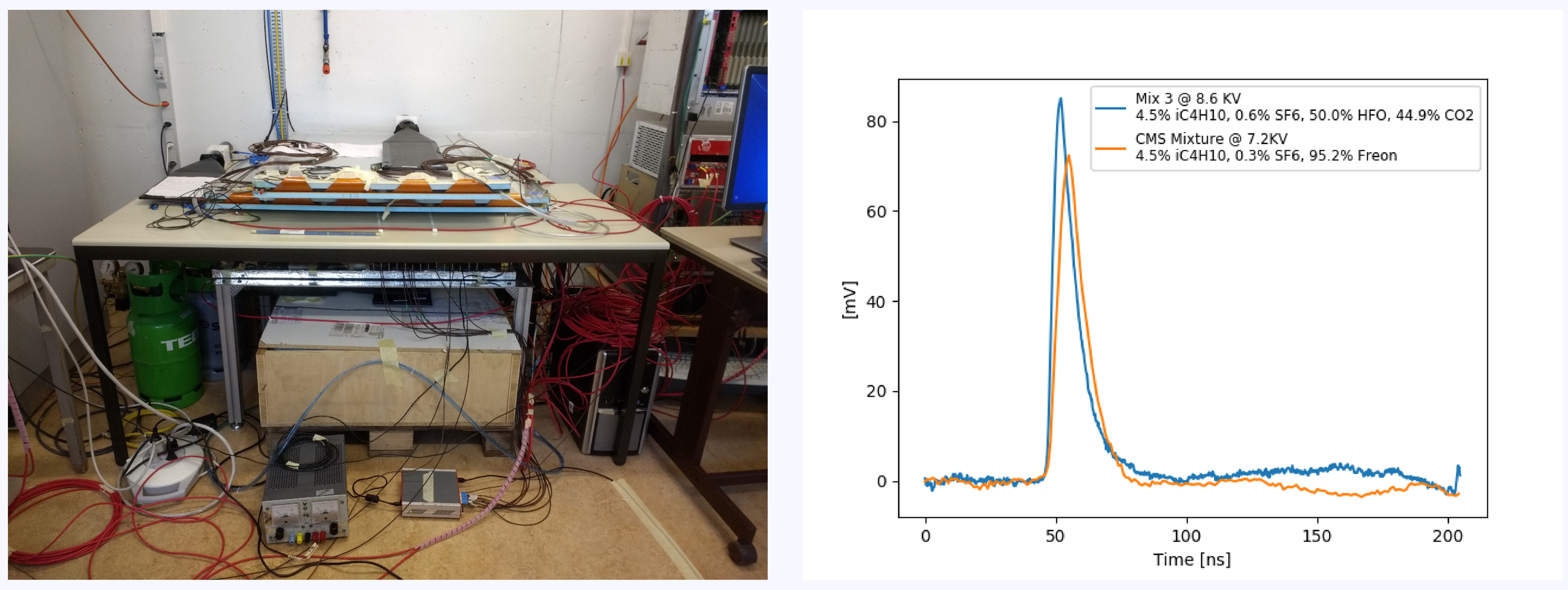

Figure: 1: Experimental setup to study the RPC response to different gas mixtures. A 3-scintillators array is used as a trigger for cosmic rays, analog signals from 1.4 mm gap RPC are digitized using the CAEN Module DT5742 and the RPC is operated in double-gap and single-gap mode. Only one gap was studied in single-gap mode (Left). Example of a typical analog signal obtained with an RPC using a gas mixture of 50% HFO, 44.9% CO2, 0.6% SF6 and 4.5% iC4H10 at 8.6 KV, compared with an analog signal using the CMS RPC mixture 0.3% SF6, 4.5% iC4H10 and 95.2% Freon (Right).

Table: Gas mixture composition used by CMS RPCs and five more eco-friendly mixtures (freon is replaced by gases with lower Global Warming Potential)

Component	CMS	1	2	3	4	5
SF6	0.3%	0.3%	0.6%	0.6%	0.6%	0.6%
Isobutane	4.5%	4.5%	4.5%	4.5%	5%	4.5%
HFO	-	50%	55%	50%	50%	45%
CO_2	-	45.2%	39.9%	44.9%	44.4%	49.9%
Freon	95.2%	-	-	-	-	-

Efficiency

The efficiency was calculated as the number of events with signal in at least one strip, divided by the total number of events. The signal is considered when it is greater than a threshold (defined as 10 times the standard deviation of the first 100 events). Figure 2 shows the efficiency based on the effective high voltage for double-gap and single-gap modes.

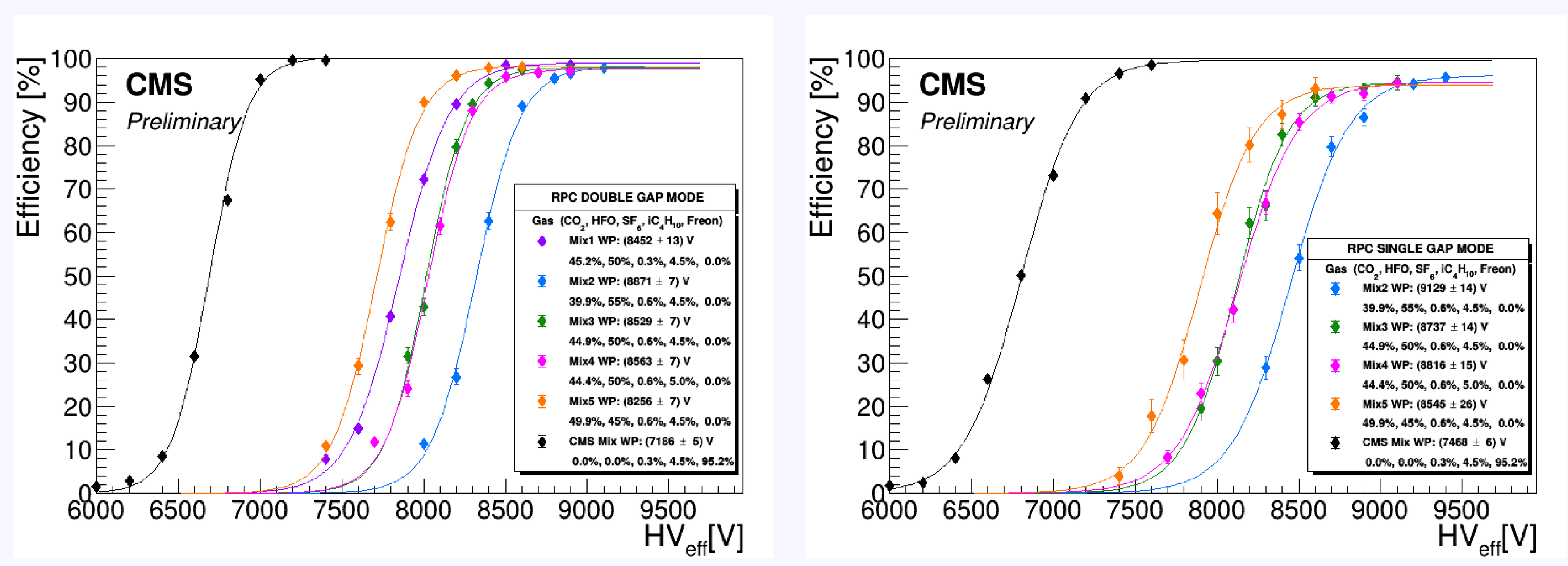

Figure: 2: Efficiency curves and HV Working Point for several gas mixtures obtained with the RPC operating in double-gap mode (left), and operated in single-gap mode (right). Working Point is defined as $HV_{95\%Eff}$+150 V.

Table: Working Point values for the mixtures used, both in double-gap and single-gap modes.

	1	2	3	4	5	CMS
WP±error [V]	8451.9±13.4	8870.5±7.4	8529.3±6.8	8563.5±7.4	8255.6±7.4	7185.8±4.5
	-	9129.3±14	8736.6±13.9	8815.6±14.5	8545±25.7	7467.2±6.02

With these efficiency curves we can compare some of the mixtures like those shown in figure 3, where we see mixtures 3 and 4 for both double and single gaps. In both cases, a similar behavior is observed for both mixtures. The isobutane 0.5% of the mixture 3 to 4 was increased and a decrease of CO2 of 0.5% of the mixture 3 to 4.

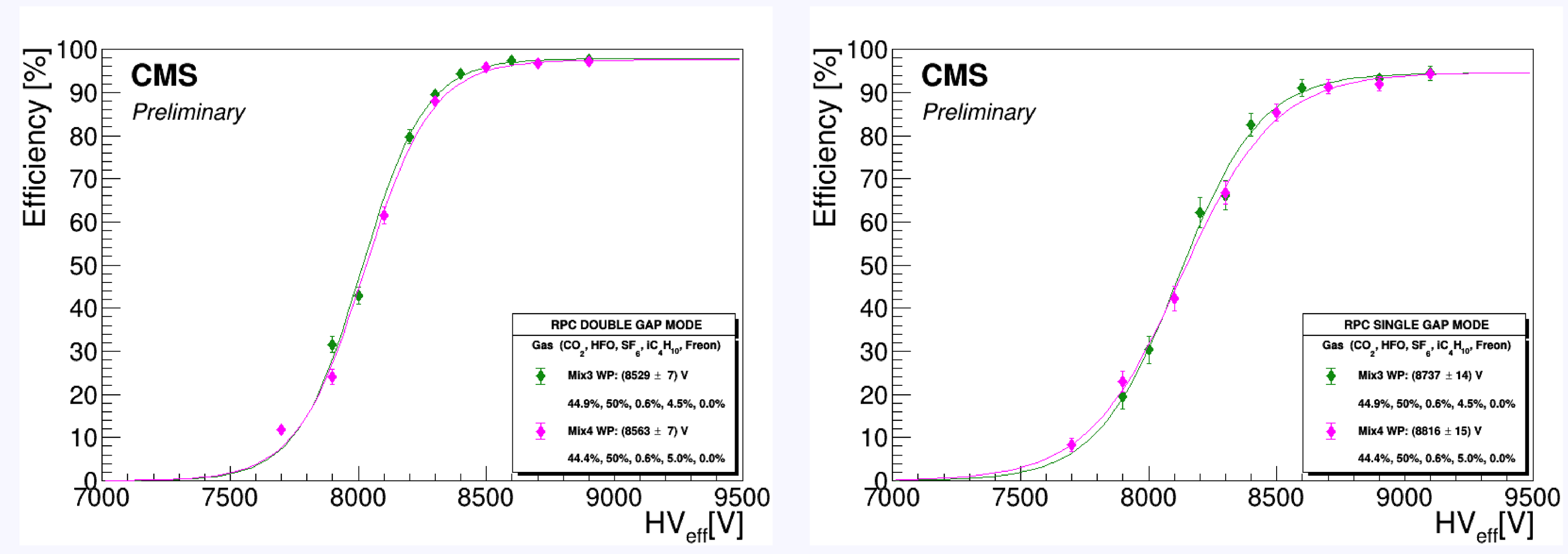

Figure: 3: Efficiency curves and HV Working Point for mixtures 3 and 4 obtained with the RPC operating in double-gap mode (left), and RPC operating in single-gap mode (right). From 3 to 4 mixtures, isobutane is increased 0.5% decreasing CO_2. A similar behavior is observed.

On the other hand, in Figure 4 the mixes 2, 3 and 5 are shown, from which we can conclude that if the HFO is increased by 5% (from mixture 5 to 3 and from 3 to 2) we will obtain an increase in the HV WP (High Voltage Working Point defined as $WP = HV_{95\%\ Efficiency} + 150V$) of around 300 V.

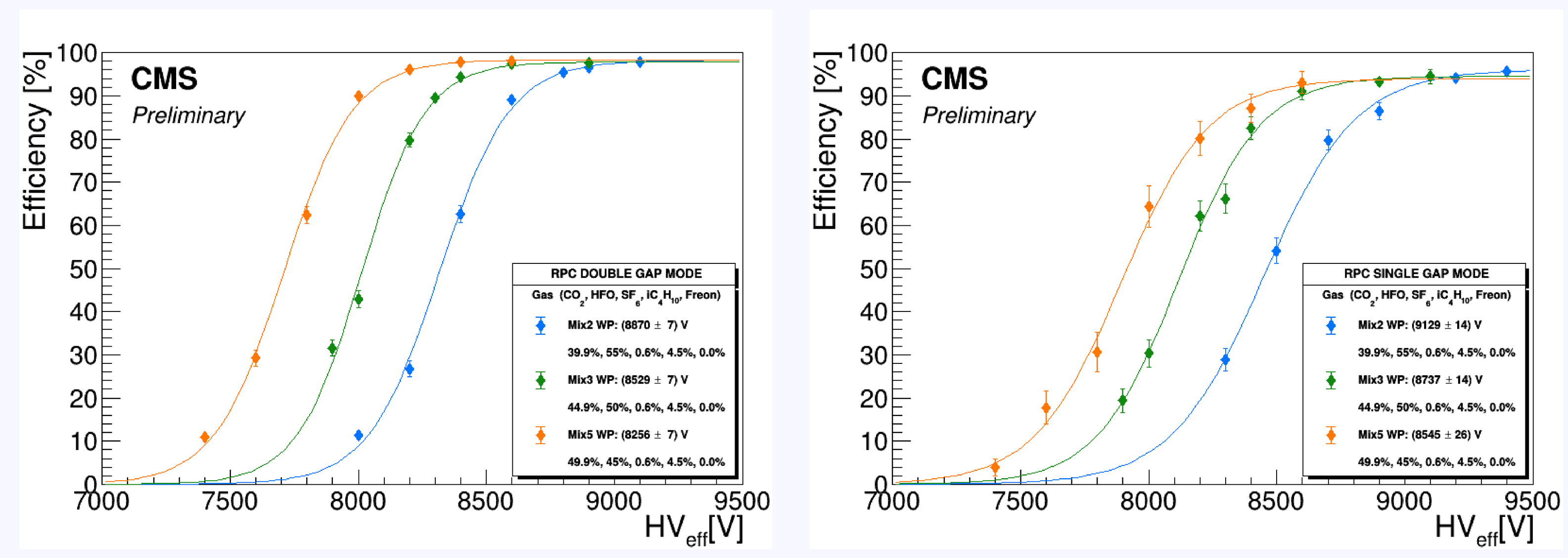

Figure: 4: Efficiency curves and HV Working Point for mixtures 2, 3 and 5 obtained with the RPC operating in double-gap mode (left), and operating in single-gap mode (right). From left to right efficiency curves, HFO is increased 5% decreasing CO_2. The Working Point increased ~ 300 V.

Cluster Size

Cluster size was defined as the number of consecutive strips with signal above the threshold. Figure 6 shows the cluster size versus the Working Point for double-gap and single-gap modes, the latter considering both the top and the bottom for the CMS mixture.

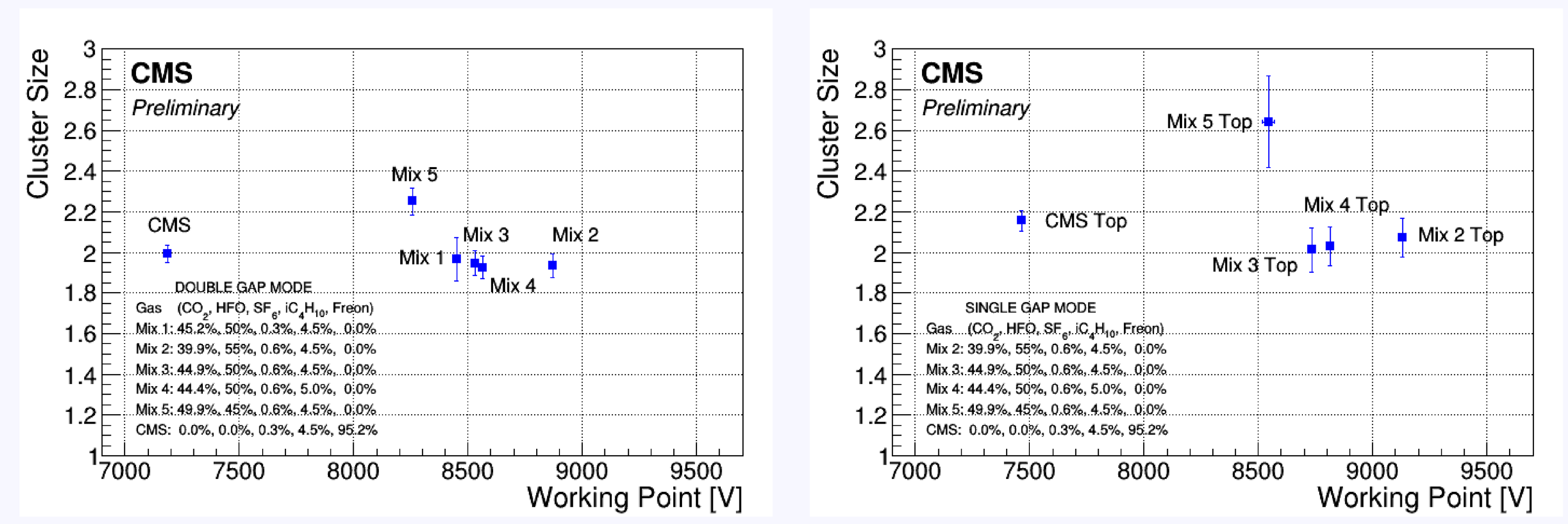

Figure: 6: Cluster Size versus the Working Point with the RPC operating in double-gap mode (left) shows an almost constant behavior for mixtures 1 to 4 and compatible with the CMS mixture value, mixture 5 is considered far away, and operating in single-gap mode (right) , shows an almost constant behavior for all mixtures. In single-gap mode shows and almost constant behavior for all mixtures.

Probability of cluster greater than 6

Here we consider the probability of cluster size with more than 6 consecutive strips.

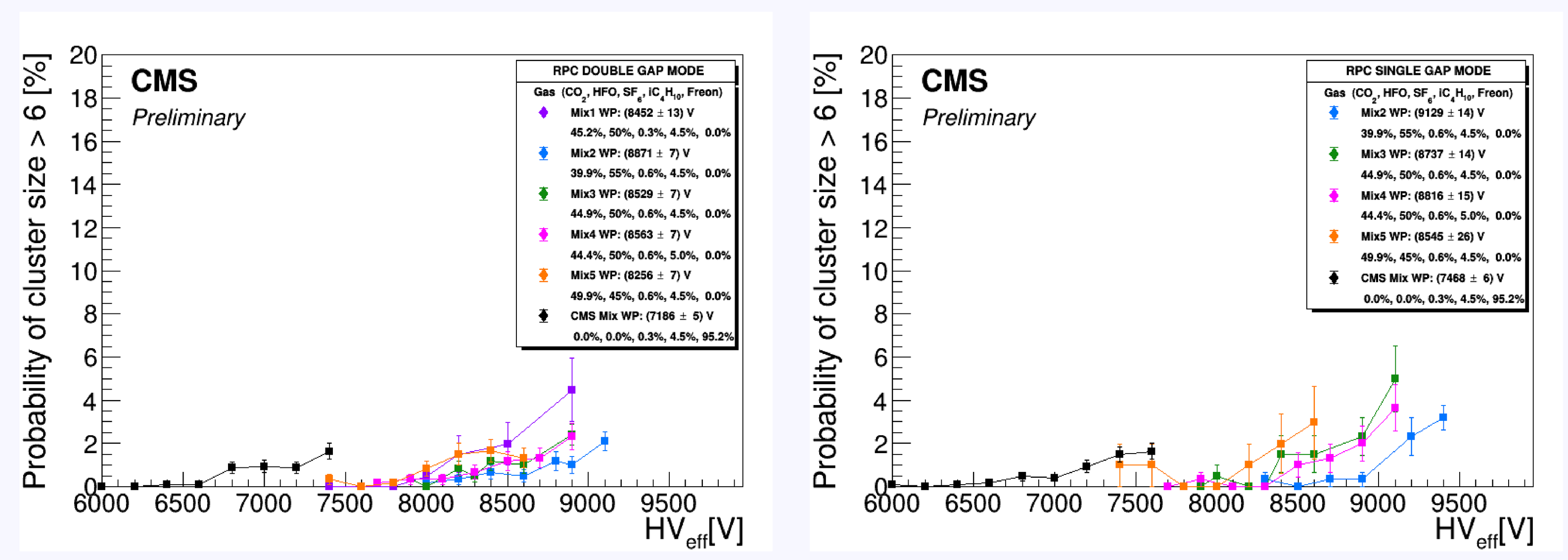

Figure: 7: Probability of event with cluster size greater than 6 for different gas mixtures obtained with the RPC operating in double-gap mode (left), and operating in single-gap mode (right). Shows a good RPC response at the Working Point and close to the CMS mixture value.

Conclusions

With this first study results were obtained on some promising mixtures to replace the current mix of these detectors, the most promising mixtures are 3 and 4 due to its behavior showed in this work. However it is necessary to study them in depth in order to conclude if any of them could truly replace the CMS mixture for the High Luminosity LHC .

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