Monte Carlo Study of CO_2-Based, TFE- and SF_6-Free Gas Mixtures for Resistive Plate Chambers

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Introduction

- The RPC standard gas mixture is based on R134a (Tetrafluoroethane – TFE) and SF_6 (Sulfur Hexafluoride), both high-GWP greenhouse gases facing growing regulatory and supply restrictions.
- The scientific community is searching for suitable alternatives for these gases, such as **HFO1234ze** (Tetrafluoropropene – F-HFO) replacing TFE as the main avalanche gas, and **HFO1233zd** (Chlorotrifluoropropene – Cl-HFO) replacing SF_6 as a streamer suppressor [1].
- This work presents a preliminary study exploring new proportions for the mixture proposed by Proto et al. [1], and a novel Ar-based mixture inspired by Datta et al. [2].

Composition of the studied gas mixtures: STD (standard mixture); HFO1 and HFO2 (new proportions based on Proto et al. [1]); Ar/SF_6 (proposed in Datta et al. [2]); and Ar/HFO (novel variant replacing SF_6 with Cl-HFO). Data from Saviano et al. [3].

Gas mixture	R134a GWP = 1430	i-C_4H_{10} GWP = 3	SF_6 GWP = 23000	CO_2 GWP = 1	Ar GWP = 0	N_2 GWP = 0	HFO1234ze GWP = 6	HFO1233zd GWP = 5	GWP	CO_2e (g/L)
STD	95.2%	4.5%	0.3%						1392	6308
HFO1		3.7%		59.3%			35%	2%	4.2	13
HFO2		4.7%		68.3%			25%	2%	3.6	10
Ar/SF_6			0.5%	60%	5%	34.5%			498	710
Ar/HFO				60%	5%	33%		2%	1.0	1.5

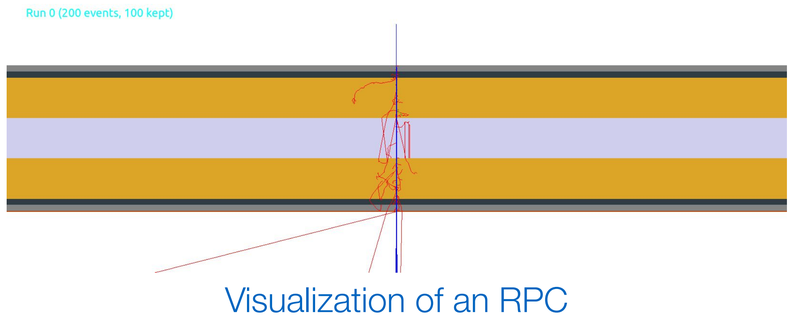
Early-stage research

Geant4 simulation [4-6]

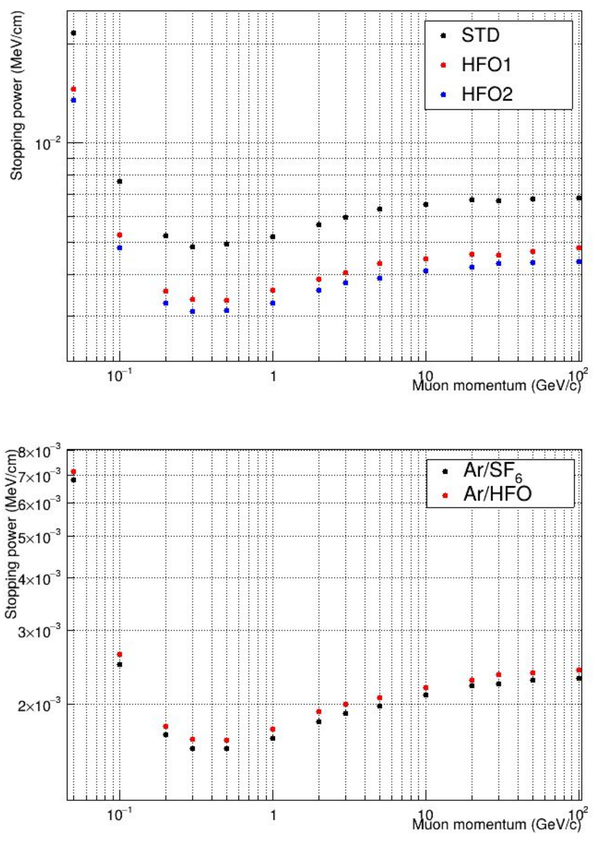
- 2 mm single-gap RPC.
- 10,000 perpendicular muons traversing the gap with varying momentum.
- Electric field of -10 kV applied in the gap.

Garfield++ simulation [7]

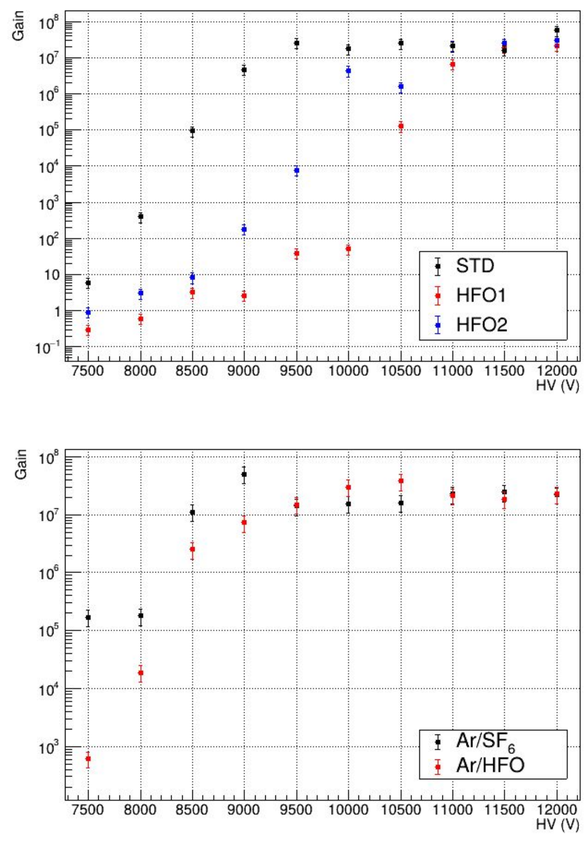
- Same geometry as Geant4.
- A chlorinated HFO is estimated.
- Electrons are placed randomly in the gap.
- Ratio between final and initial avalanche electrons is measured, varying the electric field.



Visualization of an RPC simulation in Geant4.



Stopping power calculated from energy deposition in Geant4.



Electron gain in a Townsend avalanche measured by Garfield++.

Next steps

Missing data

- The W-value of gases is not taken into account.
- Cross-sections of HFO1233zd are not measured for Magboltz simulations.
- Experimental validation of simulated results is still needed.

Further investigation

- Simulate primary ionization of gas mixtures.
- Simulate efficiency, drift velocity, charge induction and streamer probability.
- Explore more F-HFO/CO_2 ratios and Cl-HFO fractions for optimization.

Acknowledgment

CNPq

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References

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[7] I. Alsamak et al., *Garfield*++. https://garfieldpp.docs-.cern.ch/.

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