RPC 2022

XVI Workshop on Resistive Plate Chambers and Related Detectors Sept 26 - 30, 2022, CERN

RPC performance with an alternative eco-friendly gas mixture

Presented by

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Work done with

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Motivation

- The standard gas mixture to operate RPC in avalanche mode consists of R134a (95.2%), iso-butane (4.5%) and SF_6 (0.3%).

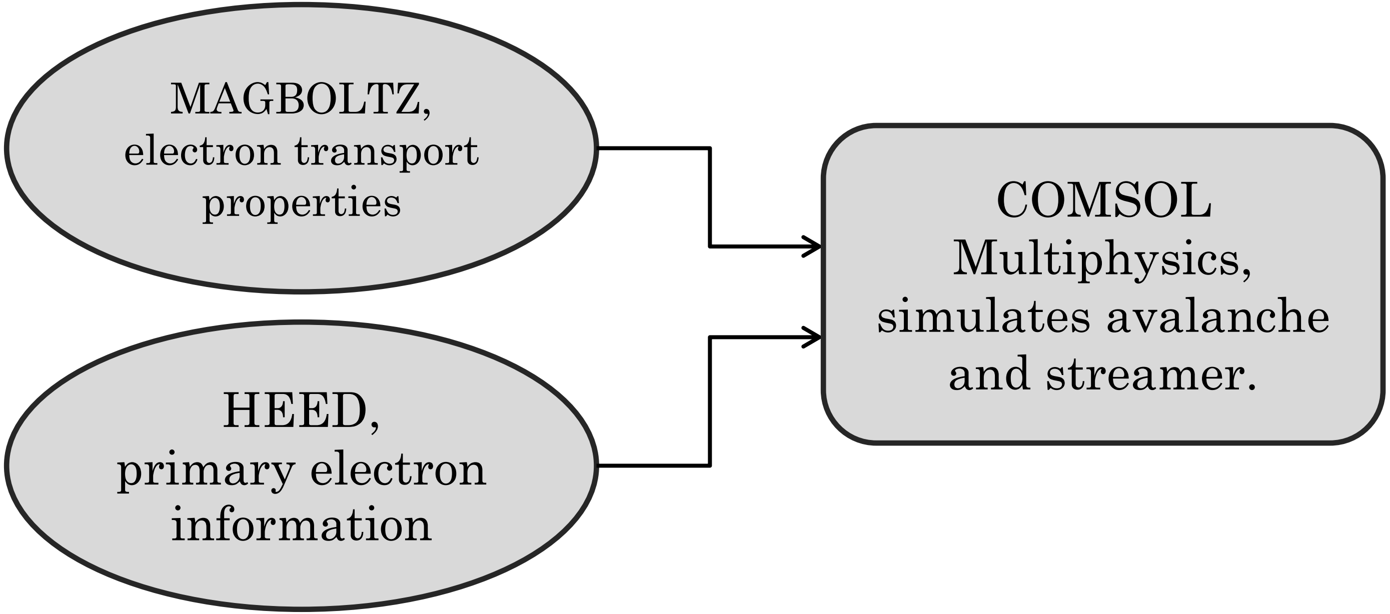
- The Global Warming Potential (GWP), a normalized scale with respect to CO2 (GWP = 1), of these gases are 1300, 3 and 23900, which makes the effective GWP of the mixture nearly 1400.

- GWP beyond the permissible limit of 150, set by the Kyoto protocol, adopted in 1997 by United Nations Framework Convention on Climate Change (UNFCCC) in order to limit and reduce greenhouse gas emission.

- This requires the exploration of eco-friendly gas mixtures that can operate RPCs in avalanche mode.

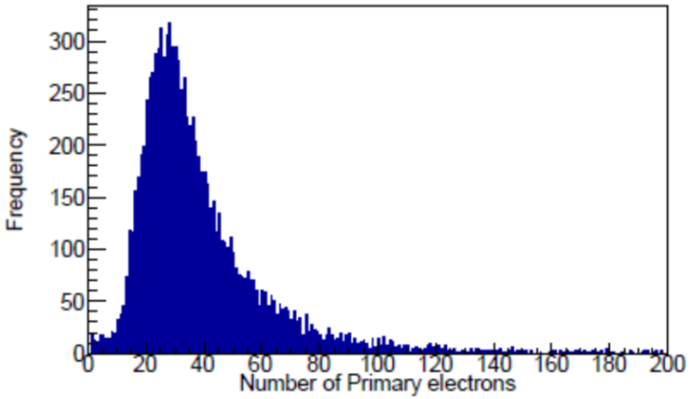
Simulation Framework

- A model has been developed to simulate the charge growth dynamics in RPC using hydrodynamic approach. The gas molecules, ions and electrons are considered as fluids.

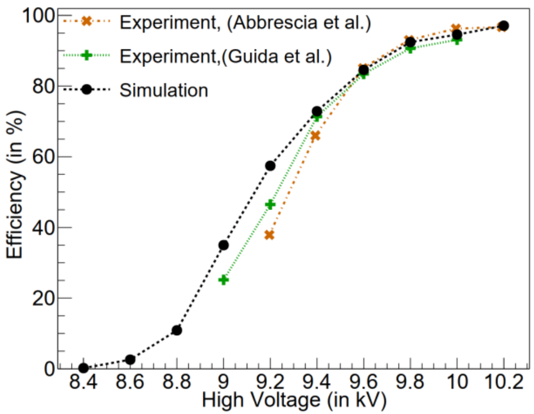


Comparison with Standard Mixture

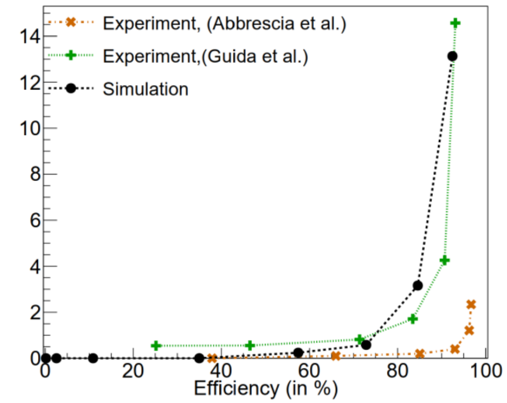
- We have tested the simulation model with a standard mixture (R134a (95.5%) : iC_4H_{10} (4.2%) : SF_6 (0.3%)).
- Number of primary electrons has been varied between 10 to 60.
- Comparison of the simulated and experimental data are shown below .



Number of primary electrons obtained from HEED



Efficiency as function of High Voltage

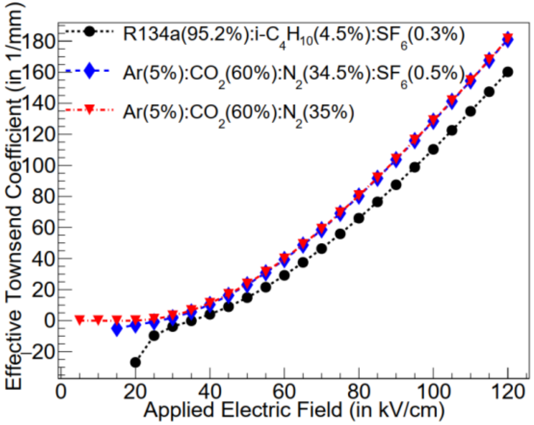


Streamer Probability as function of Efficiency

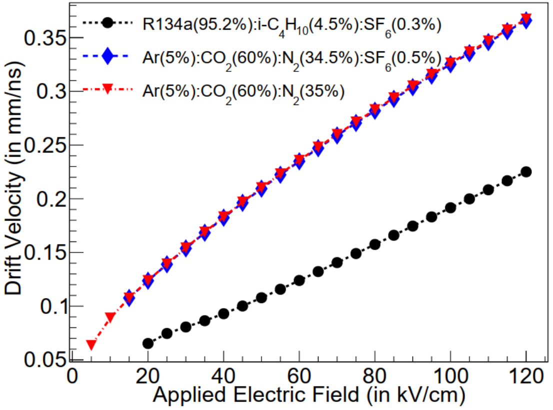
Reference: J. Datta et al., JINST 16 P07012 (2021)

Search for Eco-Friendly Gas

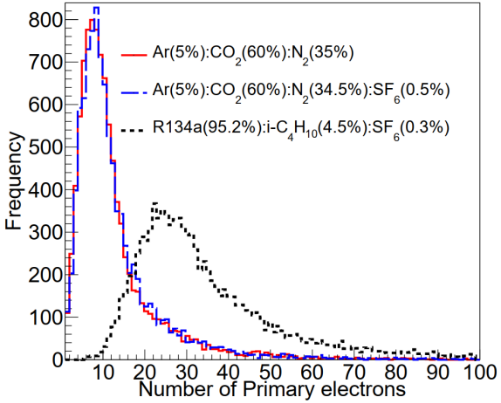
- The effective Townsend coefficient for the mixture of Ar (5%), CO2 (60%) and N2 (35%) and the mixture of Ar (5%), CO2 (60%), N2 (34.5%) and SF6 (0.5%) follows closely that of the standard gas mixture.
- The drift velocity is nearly twice that of the standard mixture, and the primary electron number for this mixture is nearly half of the standard mixture.



Effective Townsend Coefficient



Drift Velocity



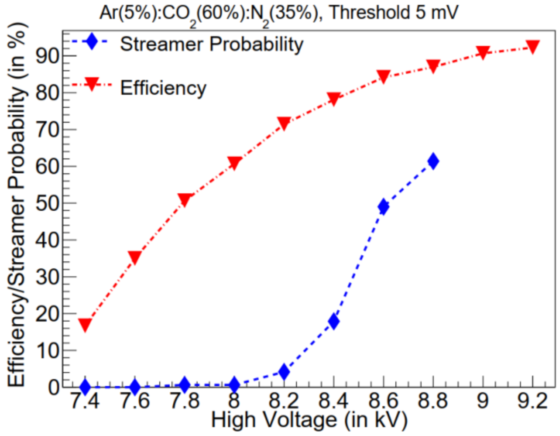
Number of Primary Electron

Reference: J. Datta et al., JINST 16 P07012 (2021)

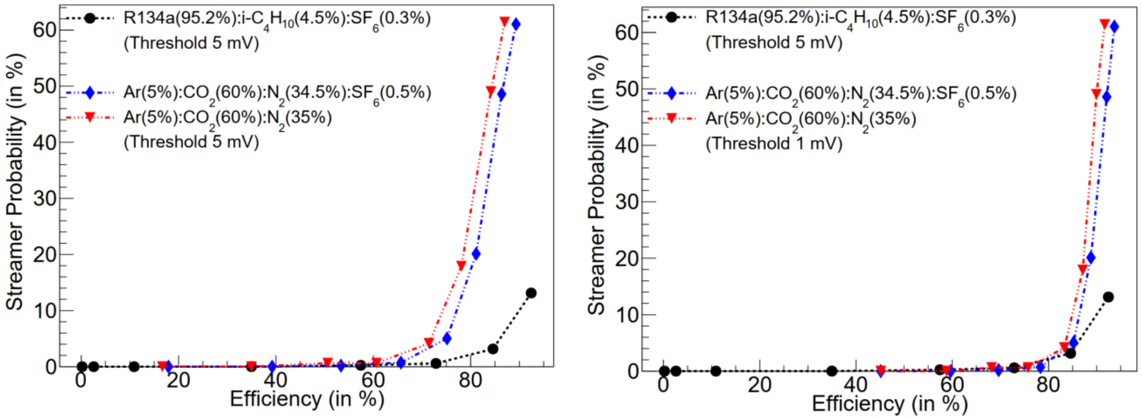
Simulated results for New Gas Mixture

- Simulation has been carried out for the gas mixtures Ar (5%), CO_2 (60%) & N_2 (35%).
- Streamer probability becomes nearly 50% when efficiency is still at 85%.
- Two approaches have been adopted to address the issue :

1. Reducing the threshold for signal and 2. Addition of SF_6.



Efficiency and streamer probability as function of High Voltage

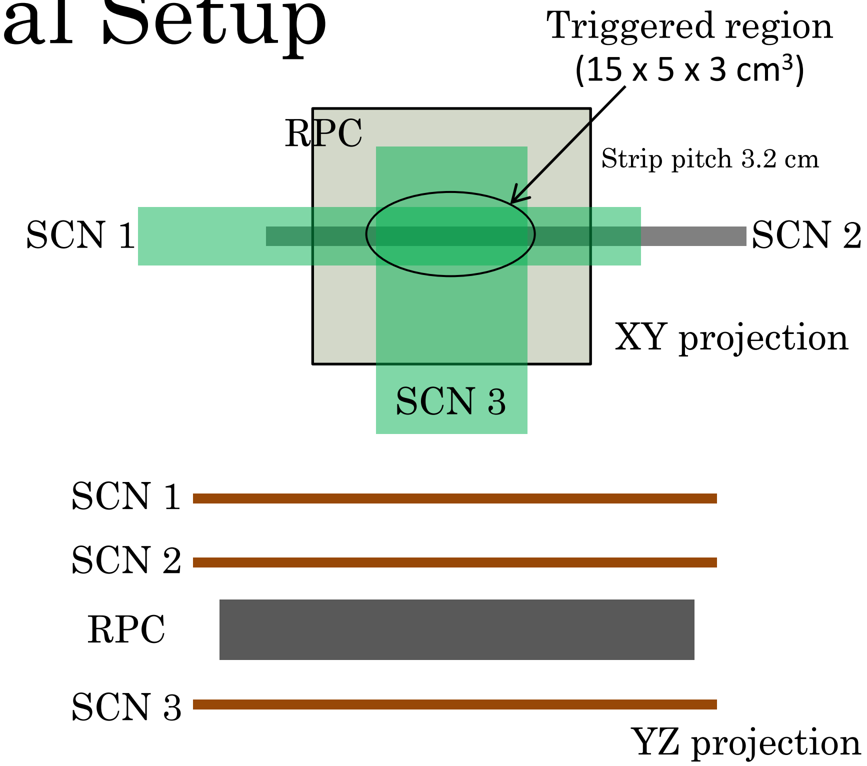


Comparison between the standard and proposed gas mixture With and without SF6 for 5 mV and 1 mV threshold

Reference: J. Datta et al., JINST 16 P07012 (2021)

Experimental Setup

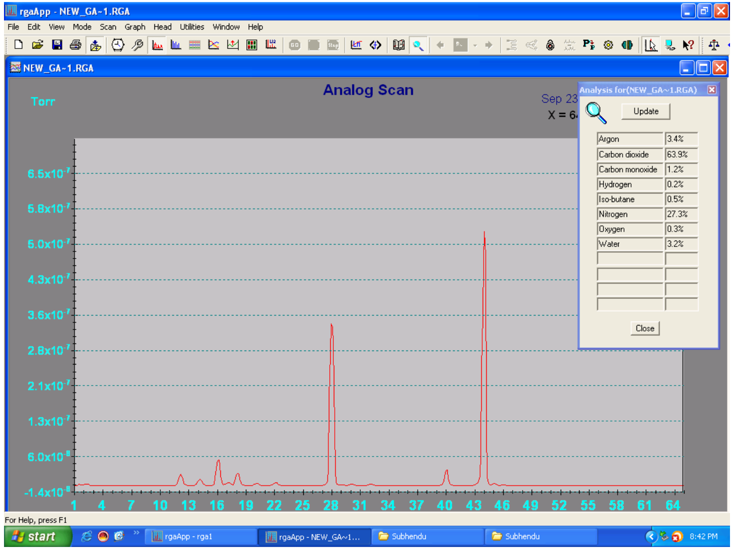
Image of experimental setup

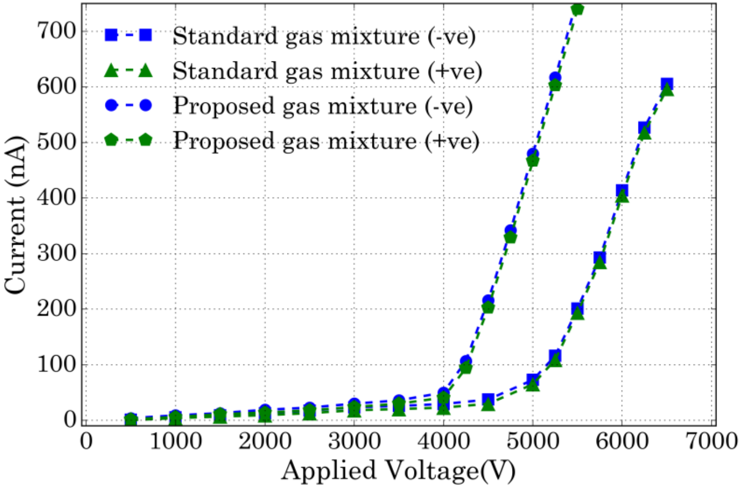


Schematic diagram of setup

I-V Characteristics

- Proposed gas mixture:
  - Ar : CO2 : N2 => 5% : 60% : 35%
- Gas mixture (premixed) for experiment:
  - Ar : CO2 : N2 => 3.6% : 67.5% : 28.9%

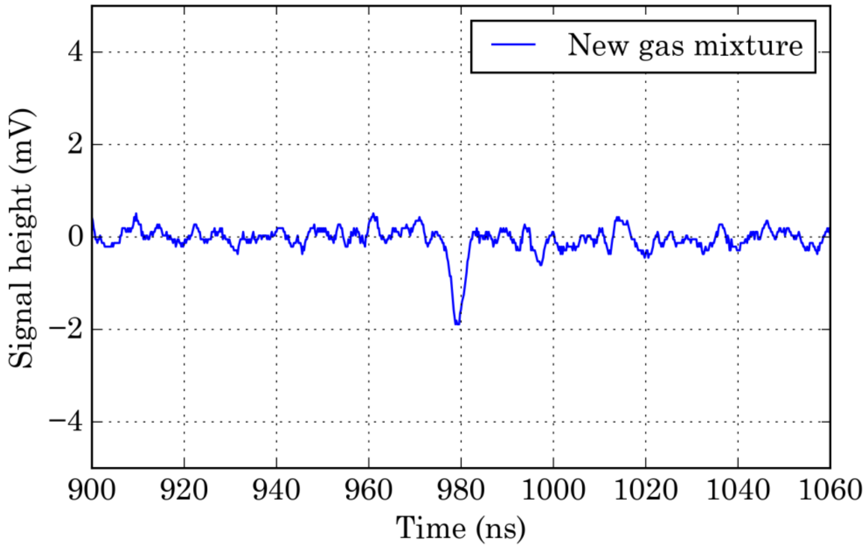




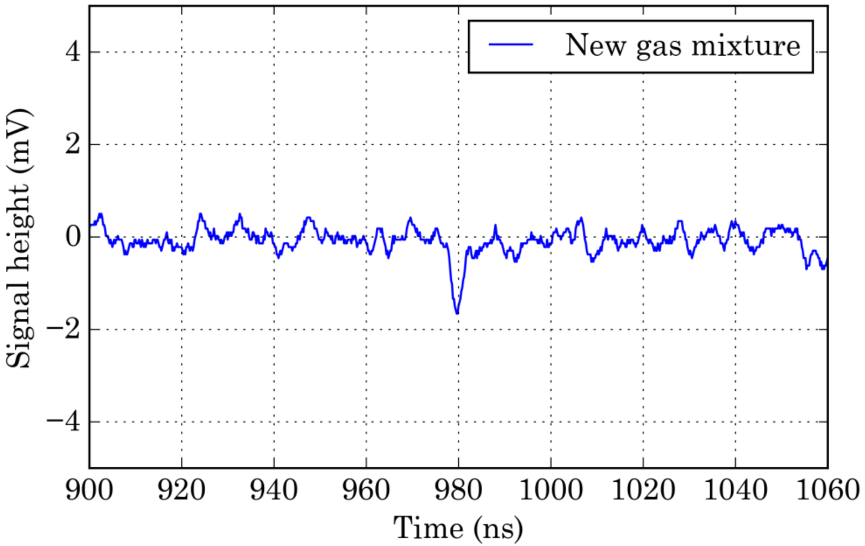
I-V characteristics of RPC

- Expected working region from 8.8kV to 9.6kV

Experimental Results



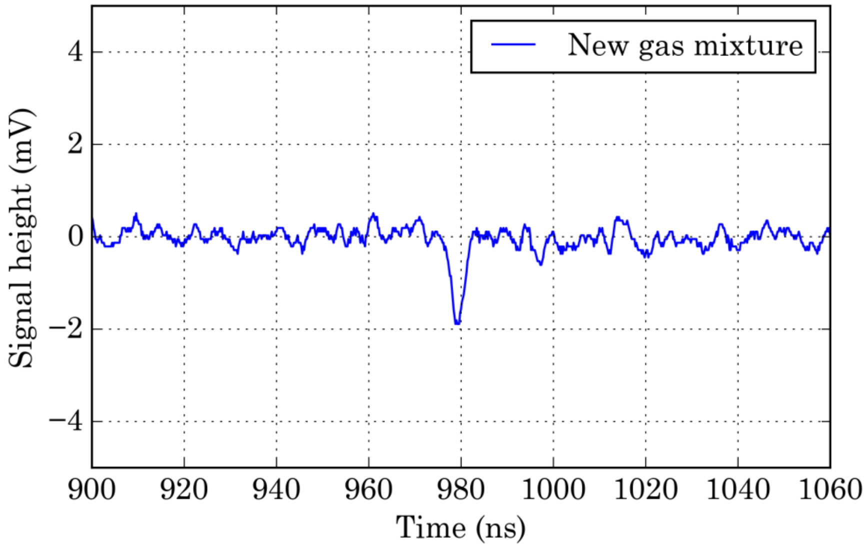
Applied high voltage 9.4kV



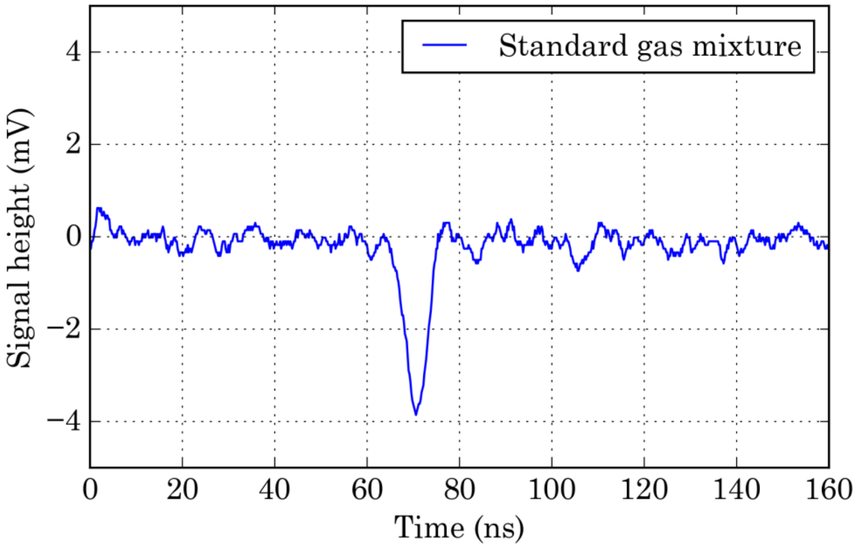
Applied high voltage 9.4kV

- Pulse height : 2 mV – 4 mV
- Pulse width : 2 ns – 5 ns

Experimental Results



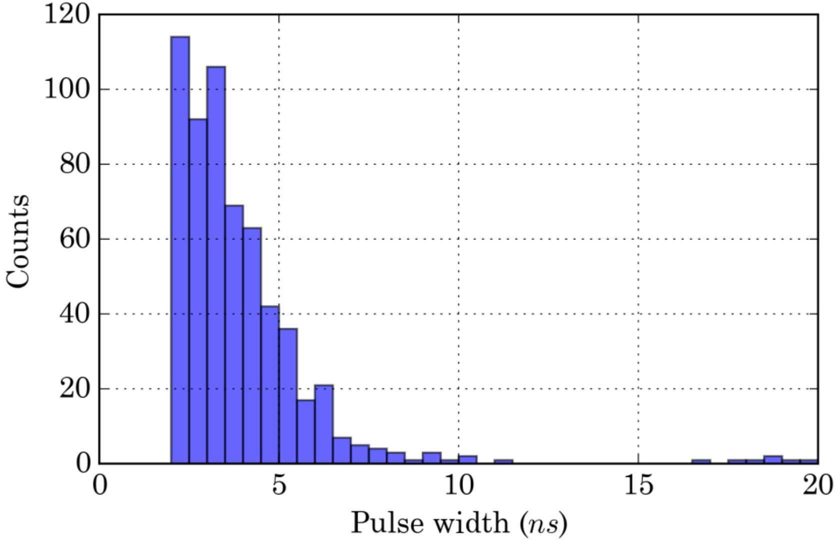
Applied high voltage 9.4kV



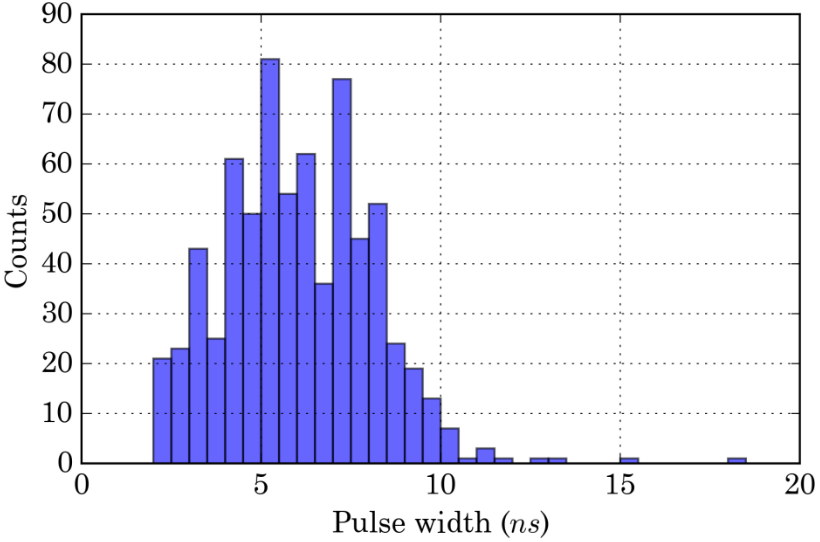
Applied high voltage 10.0kV

- Pulse height and width for proposed gas is small and thin compared with standard gas mixture.

Pulse Width Comparison

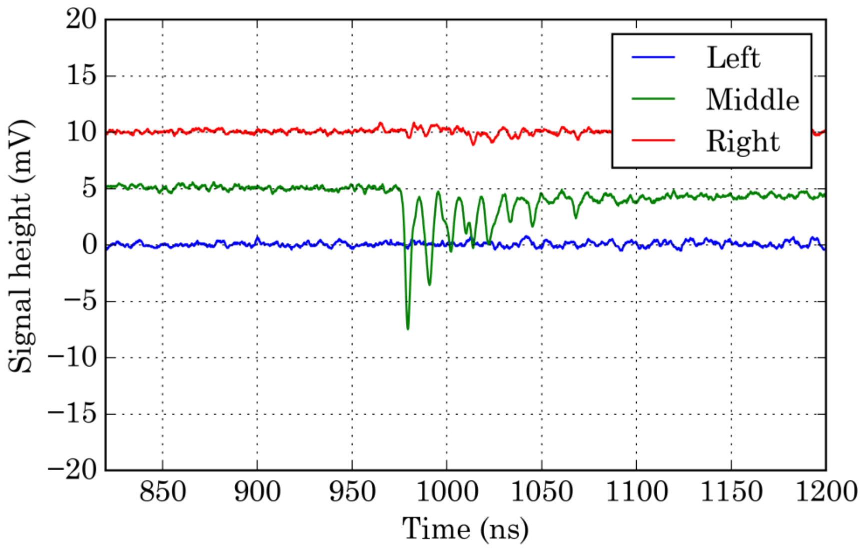


Pulse width distribution for proposed gas mixture (HV=9.4kV)

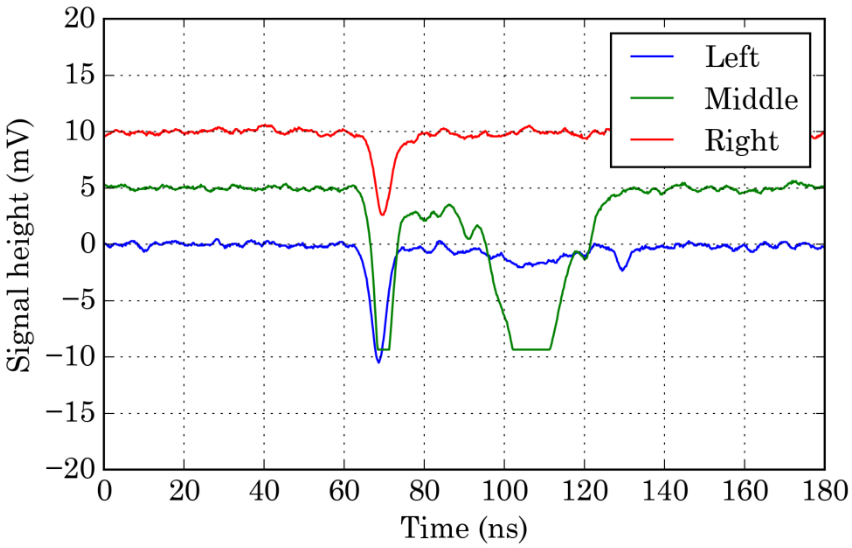


Pulse width distribution for standard gas mixture (HV=10.0kV)

Streamer Pulses



Applied high voltage 10.0kV



Applied high voltage 10.4kV

- Less interferences with side strips with proposed gas mixture.

Possible Reason

- The limited presence of argon limits the possibility that it will interact with muons and form primary electrons.

- For an efficient avalanche-mode operation of RPC with the proposed gas mixture, we need good instrumentation with better noise immunity.

- It is necessary to have a high bandwidth to read such narrow signals with the readout electronics.

Conclusion

- A numerical framework has been developed to simulate avalanche and streamer in RPC from the electron transport properties of the gas mixture.
- Once validated, it has been put to use to identify alternative eco-friendly gas mixture and study the performance of RPC for it.
- The experimental results are in line with those predicted by the simulation like pulse height and width.
- The proposed alternative gas mixture shows its potential for operating the RPCs in avalanche mode.
- We have plan to test different mixture combination to achieve better efficiency and resolution.

Acknowledgements

- I like to thank the organizers for giving me the opportunity to present my work here.

- I would like to thank my lab colleagues Vishal Kumar, Promita Roy, and Pralay Das for there advice and suggestions.

- I like to express my gratitude towards SINP and UGC for helping me financially throughout the work.

Thank You