Monte Carlo studies of eco-friendly gas mixtures for RPC detectors using Geant4+Garfield++

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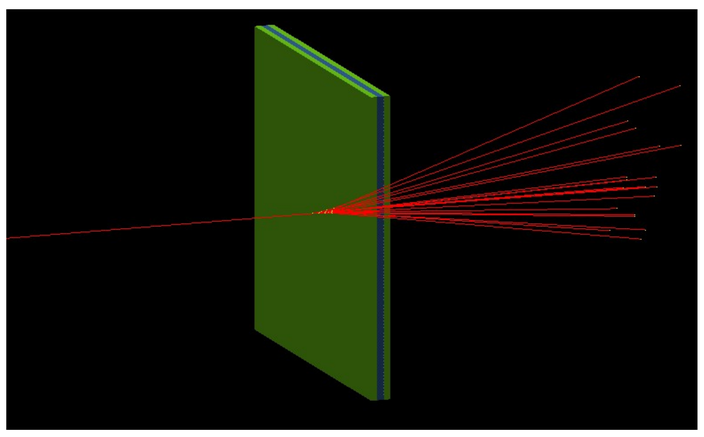
Abstract

In this work, we investigate the performance of Resistive Plate Chambers (RPC) using Geant 4 and Garfield++. RPCs detectors are commonly operated with a freon-based gas mixture containing $C_2H_2F_4$ and SF_6, both with a very high global warming potential. The present work aims at contributing to the search for eco-friendly gas mixtures for RPCs detectors. Based on the studies presented by [1], some alternatives to $C_2H_2F_4$ are tested in simulations, such as CO_2, He and iC_4H_{10}. Moreover, Novec 4710 was studied as a substitution of SF_6. The RPC performance is evaluated by calculating the efficiency of the detector and the cluster size. Finally, in preparation for the implementation of these gas mixtures in the detector's lab of UNAM, the performance of the detector with atmospheric muons using $C_2H_2F_4$ and SF_6 is reported.

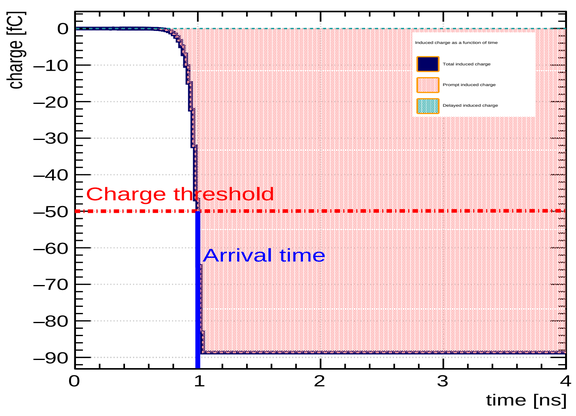
2. Methods

We generate the geometry of a 2mm gap RPC with 2mm thick bakelite plates and a perpendicular beam of muons with 400 MeV/c in Geant4. On the other hand, we calculate numerically the parameters of the gas mixture used in the RPC with the MAGBOLTZ program included in Garfield++. This information is provided to Garfield++ to simulate the charge avalanche per event in the detector, along with a readout plane and electronics effects.



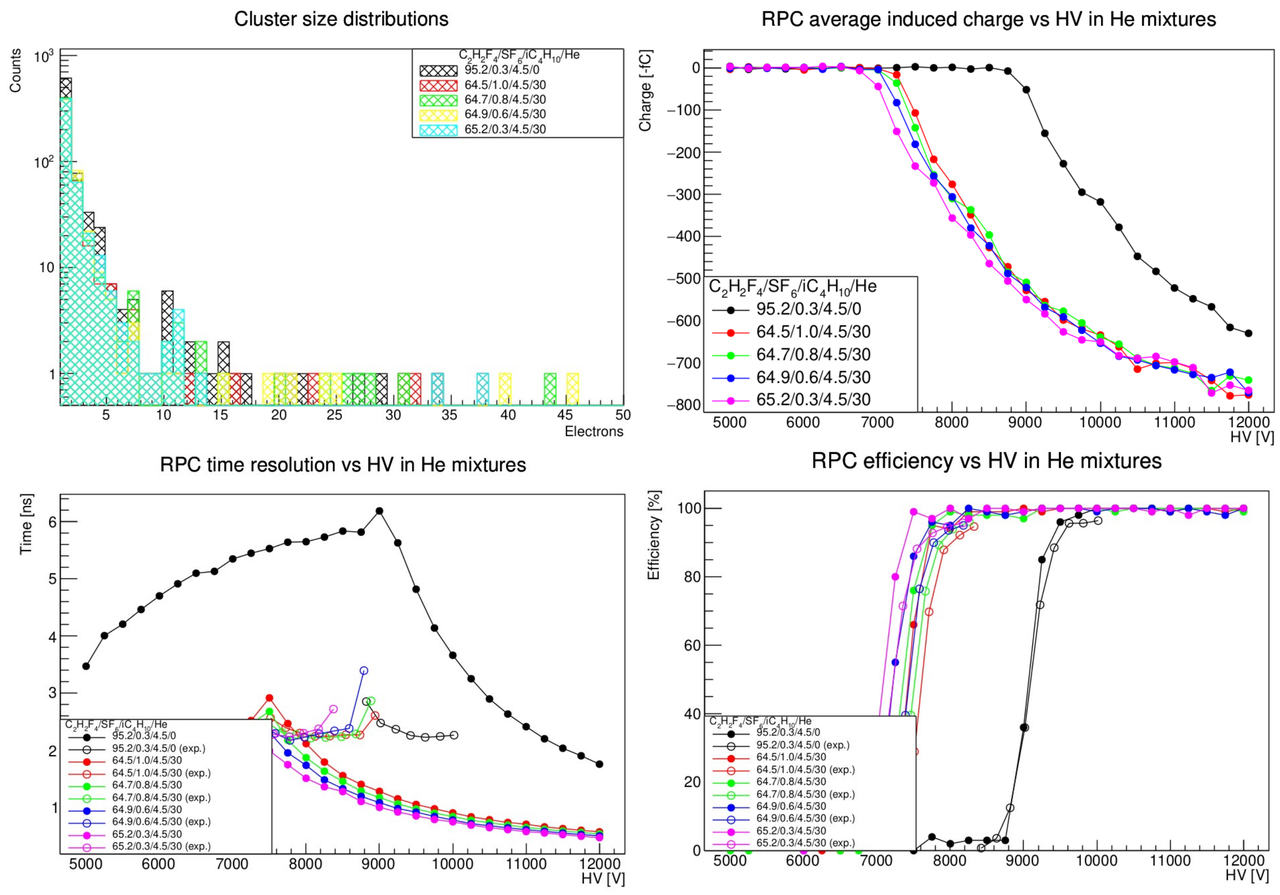
3. Analysis

We compare the primary ionization clusters distribution for each gas mixture. We then integrate the current signal calculated in the readout for each event, the induced charge is registered, the efficiency is calculated as the number of events with a total induced charge greater than a 50 fC threshold. Finally, we calculate the time resolution as the FWHM of the arrival time distribution.



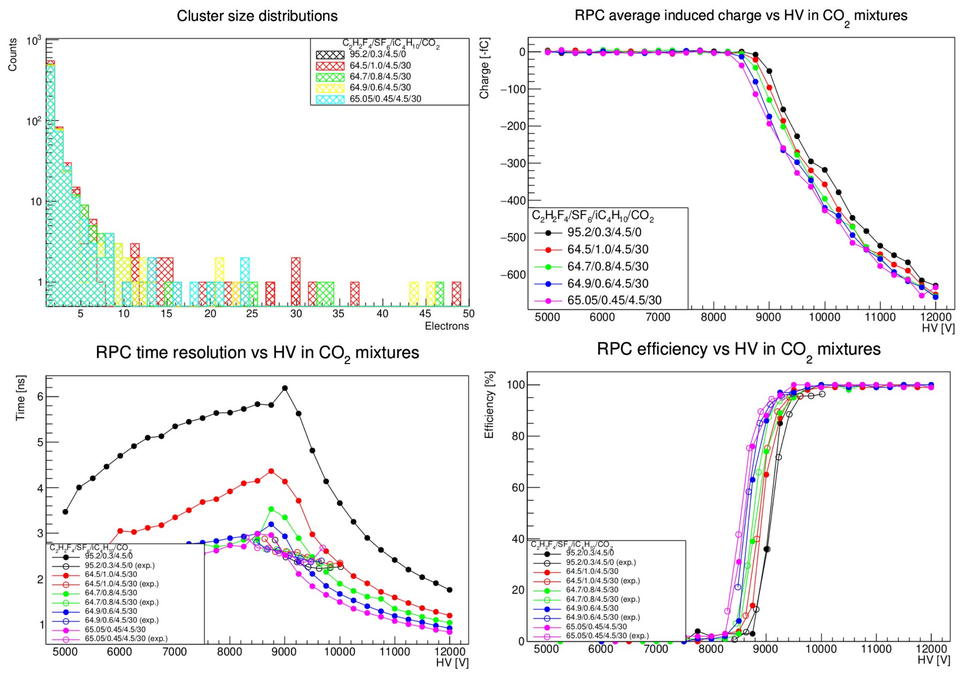
4. Mixtures with He

We investigate gas mixtures including mainly $C_2H_2F_4$ and SF_6 and with additions of CO_2 and He in order to reduce the $C_2H_2F_4$ usage by 30%, which improves the Global Warming Potential (GWP) of the mixture from 3384 down to 2389 [1]. There is good agreement between experimental results [1] marked as (exp.) and those obtained with the simulations for the efficiency and time resolution for He.

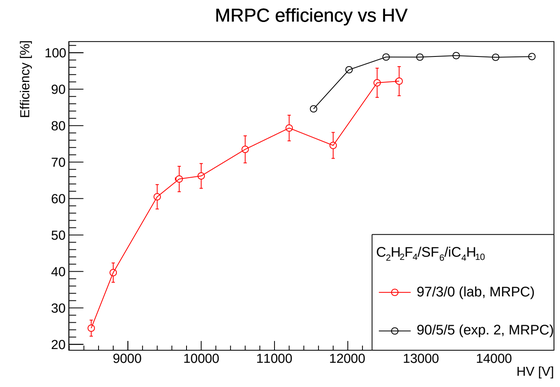


5. Mixtures with CO_2

For CO_2 we obtain good agreement also between experimental and simulation results.



We measured the efficiency of a Multi-gap RPC detector (MRPC) and compared the gas mixture used in the detectors' laboratory at UNAM with the used in [2] without applying pressure and temperature corrections.



6. Conclusions

With our simulations we have been able to reproduce the induced charge, efficiency and time resolution dependance with the applied voltage in the RPC detector. We proved that CO_2 and He can be used to decrease the working voltage of the RPC detector, but needing a higher concentration of SF_6 in the case of CO_2 to avoid discharges. We know that the MRPC detector has an improved time resolution with narrower gas gaps, we would expect a similar behaviour of the MRPC with the gas mixtures tested here.

7. References

[1] M. Verzeroli. Studies of eco-friendly gas mixtures for rpc detectors at cern lhc experiments. *CERN-THESIS-2022-040*, 2022.

[2] A. Akindinov et al. The mrpc detector for the alice time of flight system: Final design and performances. *Nuclear Physics B - Proceedings Supplements*, 158(1):60–65, 2006.