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Improved streamer inception criterion to numerically estimate streamer probabilities of resistive plate chambers for environmentally friendly gas mixture alternatives

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F-gas regulations foresee restrictions and bans of highly potent greenhouse gases such as R134a and SF6 used in RPCs. Current research is dedicated to finding an environmentally friendly gas mixture replacement for RPCs. Simulations of RPCs are crucial in supporting and extending the mostly experimental-based research of identifying suitable eco-friendly alternatives.
To date, there is no comprehensive quantitative description of the avalanche-to-streamer transition in uniform electric fields. Particularly in the context of RPCs, this is essential for estimating the streamer probability of a certain mixture, to accurately predict the avalanche-streamer separation. An improved form of the classical streamer criterion is introduced predicting the transition phase to overcome this problem. The criterion is entirely based on the space-charge field of the many superimposed avalanches due to primary ionization. A rigorous simulation of the single-gap high-pressure laminated RPC (HPL-RPC) is developed to integrate and test the improved streamer criterion along with the capability to estimate other performance parameters, for example, the detector's efficiency. The simulation is based on Garfield++ and is extended for this study to include the axis-symmetric space-charge model originally developed by Christian Lippmann. Additionally, a dedicated electrical signal transmission system is modeled to accurately replicate the experimental setup. Validation of the simulation is achieved through comparison with acquired performance data of the experimental HPL-RPC setup at the GIF++ muon beam experiment for several eco-friendly gas mixtures.
This contribution intends to present the detailed modeling of the RPC simulation and to show that for CO2-based standard mixtures (CO2/R134/i-C4H10/SF6) the experimentally measured avalanche-streamer separation is accurately modeled by the improved streamer criterion.

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