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Fluid modeling of Resistive Plate Chambers

BY DEAN WILLIAMS *on* DECEMBER 1, 2016

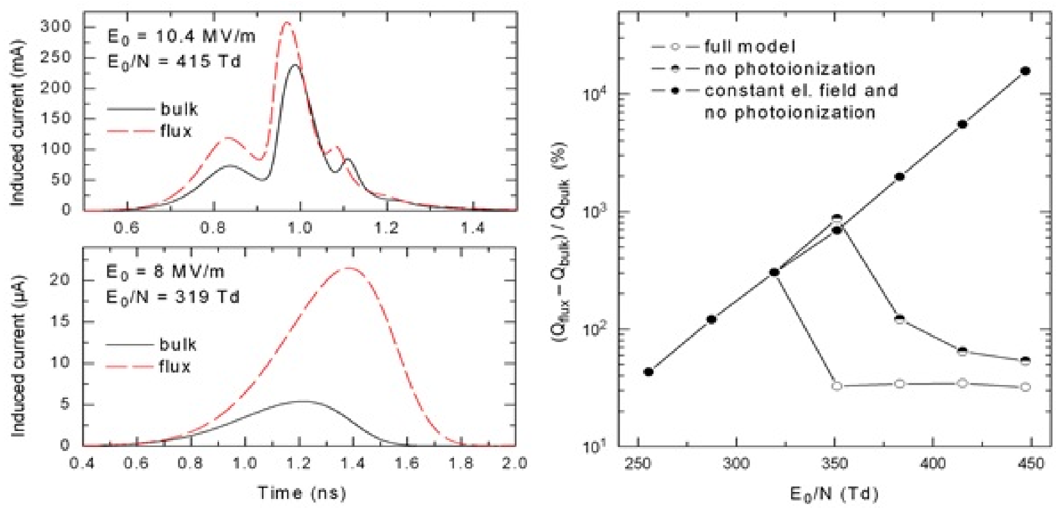
Resistive Plate Chambers (RPCs) are particle detectors mainly used for timing and triggering in high energy physics experiments, such as ATLAS and ALICE at CERN. JPhysD authors Danko Bošnjaković, Saša Dujko and Zoran Petrović are modelling RPCs using a variety of techniques to discover which is best.

Owing to their low cost, good efficiency and outstanding timing resolution, RPCs have found their way into other areas of fundamental physics and technology, including cosmic ray physics, geophysics and medical imaging. They consist of one or many gas filled gaps between the electrodes of high volume resistivity, such as glass or bakelite, which are used for the suppression of destructive higher current discharges.

Despite their simple construction, modeling of RPCs is not a simple task due to several physical processes occurring on different time scales e.g., primary ionization, charge transport and multiplication, electrode relaxation and signal formation. There are many approaches to modeling of RPCs, yet all of them, except the microscopic Monte Carlo model, require accurate electron transport and reaction data in gases as input. These data can be either measured in swarm experiments (such as steady-state Townsend, pulsed Townsend and time of flight experiment) or calculated from cross sections for electron scattering using a Monte Carlo technique or Boltzmann equation analysis. However, there are different types of transport data and their implementation in the modeling of RPCs and also gaseous particle detectors in general, was rarely discussed. In our paper, we try to investigate this issue and answer these questions: which data, and under which conditions, should be used in modeling of RPCs?

First, we discuss the hydrodynamic conditions which can be assumed in RPCs operated in the avalanche mode. Under these conditions, electron transport can be described using flux and bulk transport data. These two data sets may differ considerably when non-conservative collisions such as ionization and attachment are present. For example, flux drift velocity can be defined as mean electron velocity while bulk drift velocity can be defined as the velocity of the center of mass of the electron swarm. The two data sets can be considered as fundamental data for modeling since they are strictly defined as universal quantities and are independent of the particular experimental arrangement. We show that bulk data should be used in modeling of electron transport in the avalanche phase of streamer development in RPCs, while flux data are required for the calculation of induced current.

A fluid model based on drift-diffusion equation and local field approximation is employed to demonstrate the impact of transport data on calculated signals for the ATLAS triggering RPC and ALICE timing RPC used at CERN, and also a timing RPC with high SF_6 content. The same model is also used to study the avalanche to streamer transition in ATLAS triggering RPC under the influence of photoionization and space charge effects.



Results calculated for the timing RPC configuration used in the ALICE experiment at CERN. (Left) induced currents obtained using bulk and flux transport data for two applied electric field strengths. (Right) percentage difference between the induced charges calculated using bulk and flux transport data. The difference is shown for a range of applied electric field strengths and three modeling scenarios. Image taken from D Bošnjaković et al 2016 J. Phys. D: Appl. Phys. 49 405201,

The most striking observation is that the difference between the induced charges calculated using flux and bulk data can reach up to 80% in case of ATLAS triggering RPC, or several hundred percent in case of timing RPCs at lower operating fields. However, at higher electric fields the saturation effect due to space charge and photoionization lowers the difference to about 6% for the ATLAS RPC and 30% for the timing RPCs. This illustrates the importance of correct implementation of data in modeling of RPCs and other types of gaseous particle detectors.

In the future, we shall extend our model to rely solely on the hydrodynamic approximation. Higher-order fluid models will also be used for studying non-local effects in development of streamers in RPCs.

The full article is available now on IOPscience.

About the authors

Danko Bošnjaković is a research assistant at the Institute of Physics, University of Belgrade. He received his PhD from the Faculty of Electrical Engineering, University of Belgrade. His current research interests focus on gaseous particle detectors, gas discharges and electron transport in gases.

Saša Dujko is a research professor at the Institute of Physics, University of Belgrade. He received his PhD from the James Cook University, Townsville, Australia. His research field is in plasma science closely related to low-temperature, non-equilibrium plasmas for material processing, and to the transport theory of charged particles based on the Boltzmann equation. His recent research interests are in the positron physics, planetary atmospheric physics and the physics of particle detectors. He is a Guest Editor of the **special issue on Kinetic Methods in Technological Plasmas in Plasma Sources Science and Technology**.

Zoran Petrović is a research professor at the Institute of Physics, University of Belgrade. He received his PhD from the Australian National University, Canberra, Australia. He is currently the Head of the Centre for Non-equilibrium processes, Institute of Physics, Belgrade. His research interests include atomic and molecular physics of ionized gases, transport of charged particles in gases, physics of swarms, gas discharges and non-equilibrium collisional plasmas, plasma technologies and microwave technologies. He has been a Visiting Professor with Keio University, Yokohama, Japan and a Part-Time Professor with Faculty of Electrical Engineering, University of Belgrade. Professor Petrović is a fellow of the American Physical Society and Serbian Academy of Sciences and Arts.