2009 International Nuclear Atlantic Conference - INAC 2009
Rio de Janeiro,RJ, Brazil, September27 to October 2, 2009
ASSOCIAÇÃO BRASILEIRA DE ENERGIA NUCLEAR - ABEN
ISBN: **978-85-99141-03-8**

MEASUREMENTS OF ELECTRON DRIFT VELOCITY IN PURE ISOBUTANE

Túlio C. Vivaldini[1], Iara B. Lima[1], Josemary A. C. Gonçalves[1,2], Suzana Botelho[1,2], Marco A. Ridenti[3], Paulo Fonte[4], Alessio Mangiarotti[4], Paulo R. Pascholati[3] and Carmen C. B. Tobias[1,2]

[1] Instituto de Pesquisas Energéticas e Nucleares (IPEN / CNEN - SP)
Av. Professor Lineu Prestes 2242
05508-000 São Paulo, SP - Brazil
ccbueno@ipen.br

[2] Pontifícia Universidade Católica de São Paulo (PUC - SP)
Rua Marquês de Paranaguá 111
01303-050 São Paulo, SP- Brazil

[3] Laboratório do Acelerador Linear – Instituto de Física da Universidade de São Paulo
Rua do Matão, Travessa R, 187
01303-050 São Paulo, SP- Brazil

[4] Laboratório de Instrumentação e Física Experimental de Partículas – Depto. de Física
Universidade de Coimbra
3004-516 Coimbra - Portugal

ABSTRACT

In this work we report on preliminary results related to the dependence of the electron drift velocity for pure isobutane as a function of reduced electric field (*E/N*) in the range from 100 Td up to 216 Td. The measurements of electron drift velocity were based on the Pulsed Townsend technique. In order to validate the technique and analyzing non-uniformity effects, results for nitrogen are also presented and compared with a numerical simulation of the Bolsig+ code.

1. INTRODUCTION

The electron drift velocity is one of the most important transport parameters used to describe the physical behaviour of gas discharges and the development of avalanches in gaseous detectors where the temporal information is crucial, as occurs in drift chambers and Resistive Plate Chambers (RPCs) used as muon detectors in accelerators [1], and has been extensively studied for many gases of practical interest [2].

There are different methods to determine electron drift velocity in a gas: Steady-State Townsend technique [3], Pulsed Townsend technique [4] and the Time of flight experiments [5]. Our measurements were based on the Pulsed Townsend technique, which consists of extracting electrons from a metallic cathode and accelerates them toward the anode by a uniform electric field. Once the drift distance and the transit time are known, the drift velocities could be determined.

Although pure isobutane is frequently used as filling gas of RPCs due to its excellent timing properties [2], there is insufficient data available for this gas at high electric fields. In this work we report on preliminary results related to the dependence of the electron drift velocity for pure isobutane as a function of reduced electric field (*E/N*), where *N* is the gas density, in the range from 100 Td until 216 Td (1Td = 10^{-17} V.cm^2). The values obtained were compared with a numerical simulation of the Bolsig+ code. In order to validate the technique and analyzing non-uniformity effects, results for nitrogen are also presented.

2. EXPERIMENTAL SETUP

The experimental setup consists of two parallel electrodes (Fig. 1) in a stainless steel enclosure, at gas flow regime and atmospheric pressure. The cathode is made of a 40 mm diameter aluminium plate and the anode consists of a 3 mm thick and 5x5 mm² area glass block with high resistivity (2.10^{12} Ω.cm). This configuration allows high reduced electric fields to be achieved, without self-sustaining discharges.

In this system, the electrons are released from the cathode by the incidence of a nitrogen laser beam (MNL200-LD LTB® laser) with 700 ps pulse duration (FWHM), λ = 337 nm and 100 μJ pulse mean energy. In order to accelerate these electrons toward the anode, an electric field was applied by using a 225-30 BERTAN® high voltage supply.

As the timing information presented in the fast electric signal originated in the anode is significant in our application, the amplifier circuit had to hold special features in order to preserve the signal shape. The linear amplifier used, based on the BGM1013 integrated circuit (Philips®), reaches up to 2.1 GHz bandwidth with 35.5 dB gain and was developed and built at Laboratory of Instrumentation and Experimental Particles Physics/Portugal [6].

After being amplified, the signals are digitalized by a oscilloscope (WavePro 7000, LeCroy®) with 1 GHz bandwidth and 10 GS/s sampling rate, which allows signal storage and analysis. Since the cathode is coupled to a micrometer linear positioner, different gas gaps can be achieved. Once the drift distance and the transit time are known, the drift velocities could be determined from the relationship between the gap (*d*) and the transit time (*t*) for a particular value of *E/N*.

Figure 1. The stainless steel chamber with the electrodes.

3. RESULTS

As previously outlined, the initial measurements were carried out for nitrogen. The voltage pulses obtained after amplification stage for different E/N values are presented in Figure 2. They result from an arithmetic mean of thirty waveforms performed by mathematical functions from the oscilloscope.

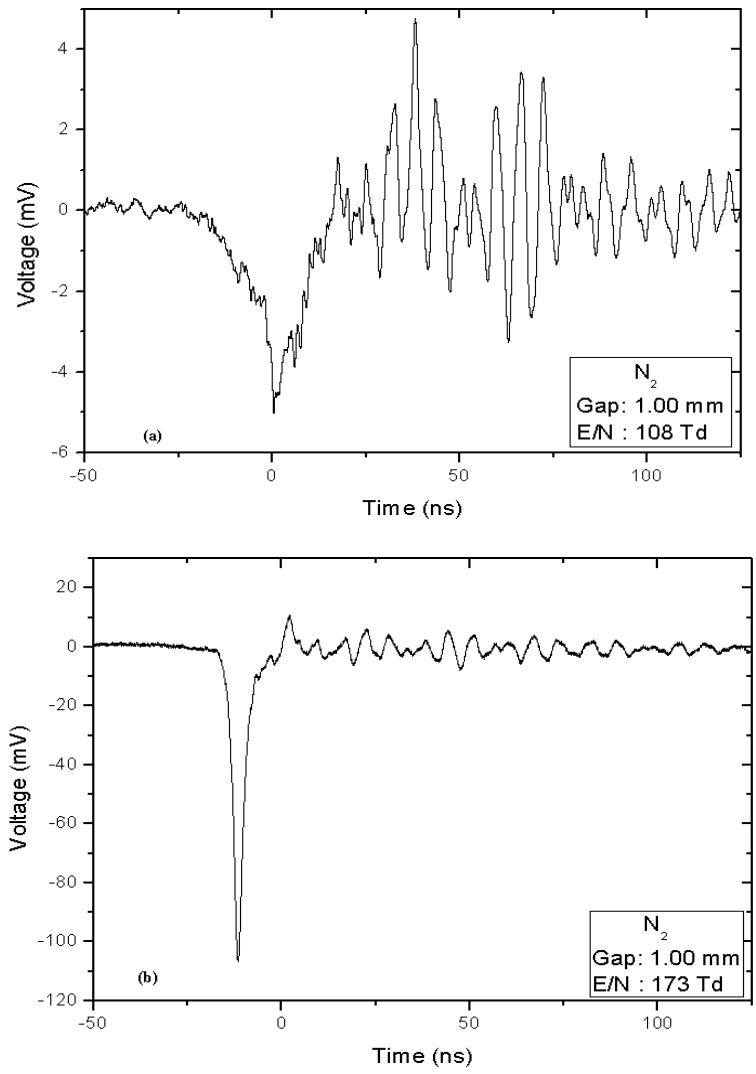

Figure 2. Voltage signal for nitrogen for different reduced electric fields: (a) 108 Td and (b) 173 Td.

Taking into account the predominant physical process involved in the measurements, as for example the contribution of diffusion losses [8], initial studies concerning the determination of the transit time of electrons from the cathode to the anode and drift velocity were performed. In Table 1 the preliminary results are summarized for nitrogen.

Table 1. Preliminary data on electron drift velocity. (1 Td =10^{-17} V.cm^2)

Gap (mm)	Voltage (V)	E/N (Td)	Time (ns)	v (cm/μs)
1.00	2500	108	9.5 (3)	10.5 (3)
1.00	2750	119	8.64 (22)	11.57 (29)
1.00	3000	130	8.30 (19)	12.05 (28)
1.00	3250	140	7.51 (17)	13.3 (3)
1.00	3500	151	6.81 (15)	14.7 (3)
1.00	3750	162	6.31 (10)	15.85 (25)
1.00	4000	173	5.50 (10)	18.2 (3)
0.50	2250	194	2.80 (10)	17.9 (6)
0.50	2500	216	2.63 (10)	19.0 (7)

A comparative analysis of results with that ones from Nakamura [5], Raju [8] and Roznerski [9] using different experimental methods is depicted in Figure 3, where the values determined with Bolsig+ simulation were also presented. It is important to point out that in the simulation, the ionization was the only collisional process considered.

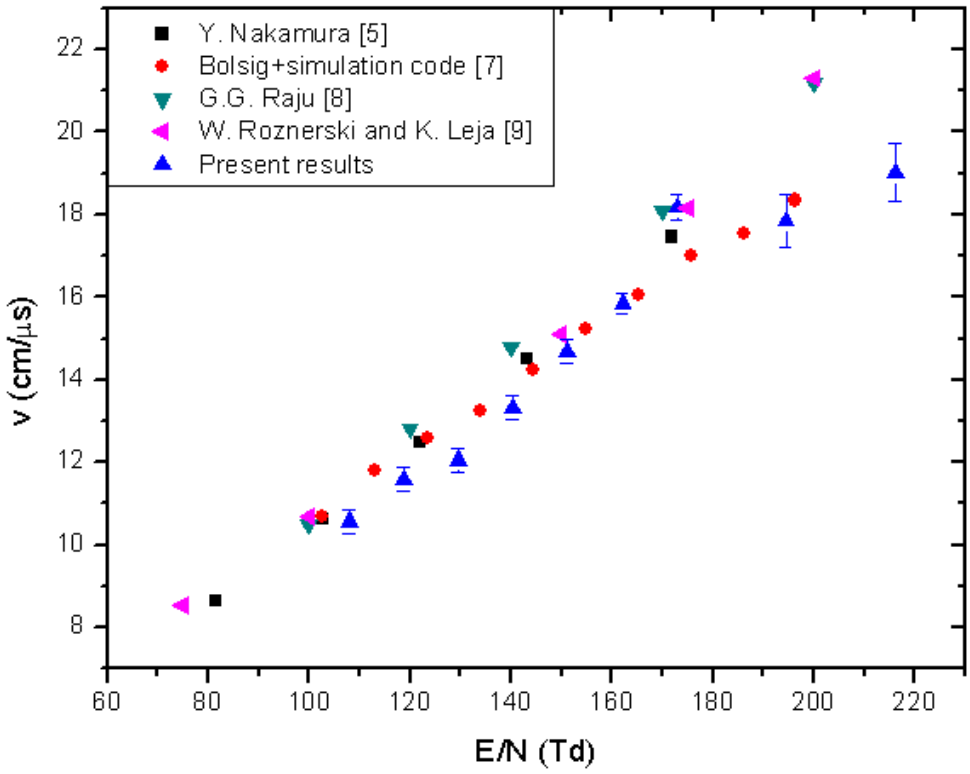

Figure 3.Curve of the electron drift velocity in the nitrogen gas.

As the initial measurements showed a good agreement for nitrogen, the same procedure has been carried out for isobutane. A voltage signal obtained with isobutane is displayed in Figure 4 for a gas gap of 1.00 mm. The results of drift velocity, concerning a qualitative analysis, are presented in Figure 5, where the recent results of Fonte et al. [10] for *E/N* up to 200 Td are also plotted. The discrepancies observed between these results are probably due to alignment and non-linearity effects that become more evident in the higher electric field region. The corresponding Bolsig+ simulation is in progress.

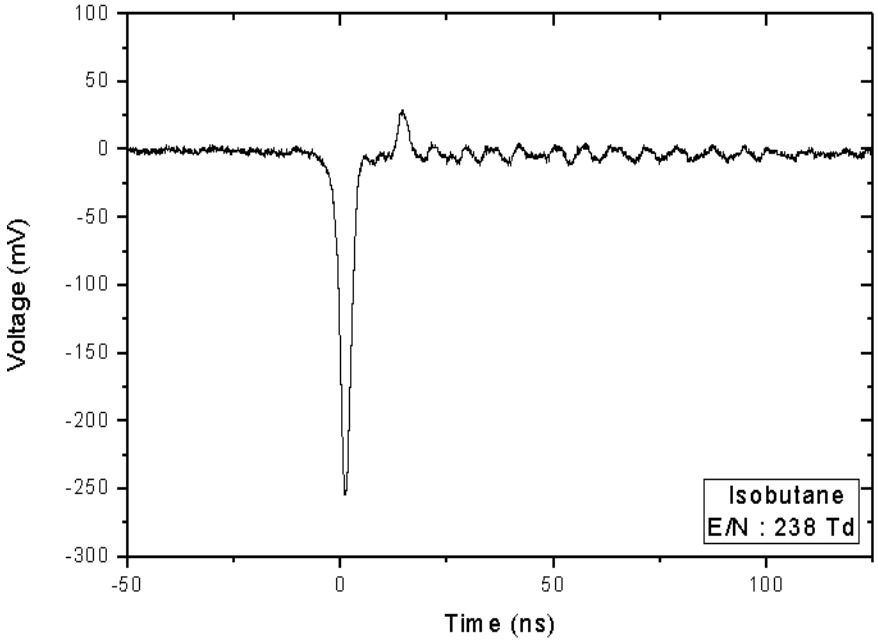

Figure 4. Voltage signal for isobutane.

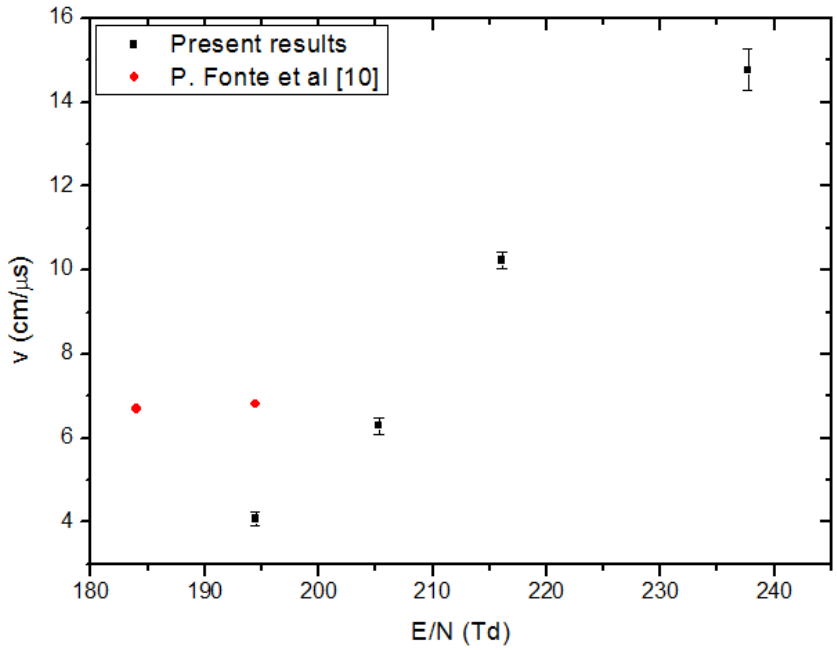

Figure 5. Drift velocity as function of the reduced electric field for isobutane.

4. CONCLUSIONS

For the *E/N* range under study, the results for nitrogen demonstrated good agreement with the literature data and with Bolsig+ values, which allowed employing the technique for isobutane safely. The obtained results of electron drift velocity in isobutane, despite of being preliminary, constitute a significant contribution to the data available in the literature at this reduced electric field region. The Bolsig+ simulation for isobutane is underway. Nevertheless, in the higher electric field region, alignment and non-linearity effects will also be further investigated.

ACKNOWLEDGMENTS

Túlio C. Vivaldini and Iara B. Lima are grateful to FAPESP for the award of scholarships (process nº.: 2007/06773-0 and 2007/06771-8). One of us, M. A. Ridenti, thanks CNPq for the award of a scholarship. This work was financed by FAPESP under contract 02/04697-1.

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