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TECHNIQUE OF MEASURING THE FIRST IONIZATION COEFFICIENT IN GASES

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ABSTRACT

In this work we present measurements of first ionization coefficient in N_2 as a function of the reduced electric field in the range of 115 – 166Td by means of an RPC-like configuration. Although N_2 is a widely studied gas, the current study will enable us to extend the technique to gases for which the ionization coefficient is unknown. The used method follows from the Townsend equation solution for uniform electric field and is based on electric current measurements in primary ionization and avalanche regimes. The current validation also covers comparisons with tabulated data from literature and determination of molecular parameters by the means of Korff's parameterization.

1. INTRODUCTION

The first ionization coefficient α is a parameter widely studied in avalanche counters which represents the number of electrons produced per unit of length and is related to ionization cross section. Nevertheless, the advances in high energy physics and other nuclear applications led to the development of gaseous detectors operating at high electric field. In this context, the Resistive Plate Chambers (RPCs) were introduced as a planar gaseous detector with excellent timing properties and high counting rate capability [1-2]. Therefore, such progress demands the employment of gas mixtures that fulfill these requirements, thus stimulating the usage of molecular gases with complex structure.

In this work we present measurements of first ionization coefficient in nitrogen (N_2) as a function of the reduced electric field (E/N, where N is the gas density) in the range of 115 – 166Td by means of an RPC-like configuration. Nitrogen is a widely studied gas and there are several well established data on literature [3-5]. Therefore, the current study will enable to extend the technique to gases for which the ionization coefficient is unknown. The present determination method follows from the Townsend equation solution for uniform electric field

$$\alpha = d^{-1} \ln\left(\frac{I}{I_0} \right) \quad , \tag{1}$$

where d is the gas gap, I is the current in avalanche regime and I_0 is the primary ionization current.

The experimental setup and some previous results on ionization coefficient, obtained by pulse shape analysis, are presented elsewhere [6]. The actual results were acquired by means of Pulsed Townsend Technique (PT), for which the first ionization coefficient is not theoretically defined, what occurs only in Steady-State Technique (SST). However, due to the time constant of our system, the current measurements were taken under integral mode. The current validation covers comparisons with tabulated data from literature and also determination of molecular parameters by the means of Korff's parameterization

$$\frac{\alpha}{N} = Ae^{-B\frac{N}{E}} \quad , \tag{2}$$

where A and B are constants which depend on the gas and on the E/N range analyzed. According to the classical theory of ionization of gases, the constants A and B can be expressed in terms of effective molecular parameters, as the effective ionization potential (V_i) [7]. The V_i can be determined by the ratio B/A, and its value should lies between the first ionization potential and the mean energy required for an electron to produce ionization in the gas.

2. MATERIALS AND METHODS

The experimental setup consists of parallel electrodes (Fig. 1a) in a stainless steel enclosure, at gas flow regime and atmospheric pressure. The cathode is made of a 40mm diameter aluminum plate and the anode consists of a 3.5mm thick and 32.5 x 32.5mm² area glass block with high resistivity ($2.10^{10}\Omega$.m). The parallelism procedures are made by the means of three micrometers (189 Mitutoyo®) connected to the anode while the cathode is fixed to a linear positioner (L2241-2 Huntington®), which enables varying the gas gap (Fig. 1b).

In this system, the electrons are released from the cathode by the incidence of a nitrogen laser beam (MNL200-LD LTB®) with 700ps pulse duration, and λ = 337.1nm. The extracted electrons drift toward the anode under the electric field applied through a high voltage power supply (225-30R Bertan®). This charges movement produces an electric current which is measured by an electrometer (610C Keithley®), directly connected to the cathode.

The method employed to measure the parameter α is based on the solution of the Townsend equation for uniform electric fields. Considering the ratio between the current measured in avalanche mode (I) and the primary ionization current (I_0), the α coefficient can be determined by means of Eq. (1).

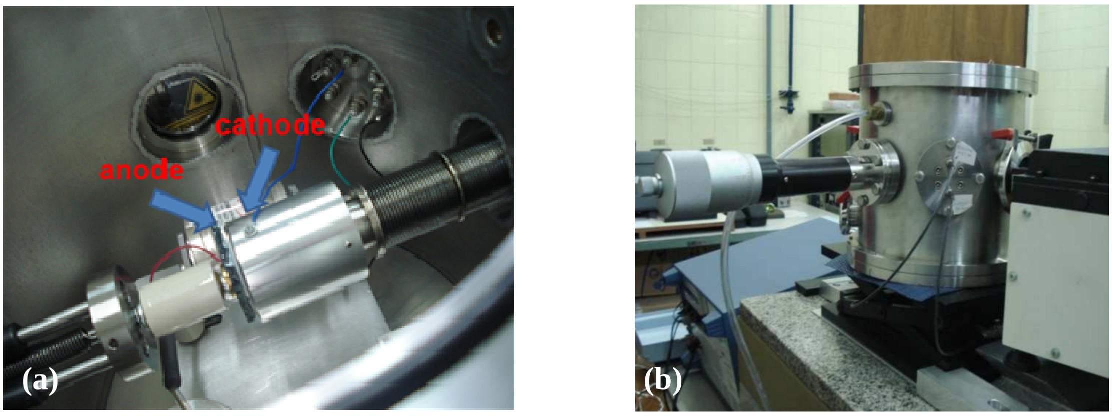

Figure 1. (a) Electrodes inside the chamber and (b) the linear positioner.

3. RESULTS

The first ionization coefficient was measured for nitrogen as a function of the reduced electric field E/N, where N is the gas density. The uncertainties were evaluated considering the electrometer instrumental precision. Our results were compared with data from Magboltz 2.8.6 simulation [8] and with data from literature [5]. Written by S. Biagi, this simulation is based on a Monte-Carlo integration and solves numerically the Boltzmann transport equation. The "N2 2008" corresponds to a cross-section set which includes values from several authors. The program includes different formalisms concerning the anisotropic scattering and the "aniso 2" is the program default.

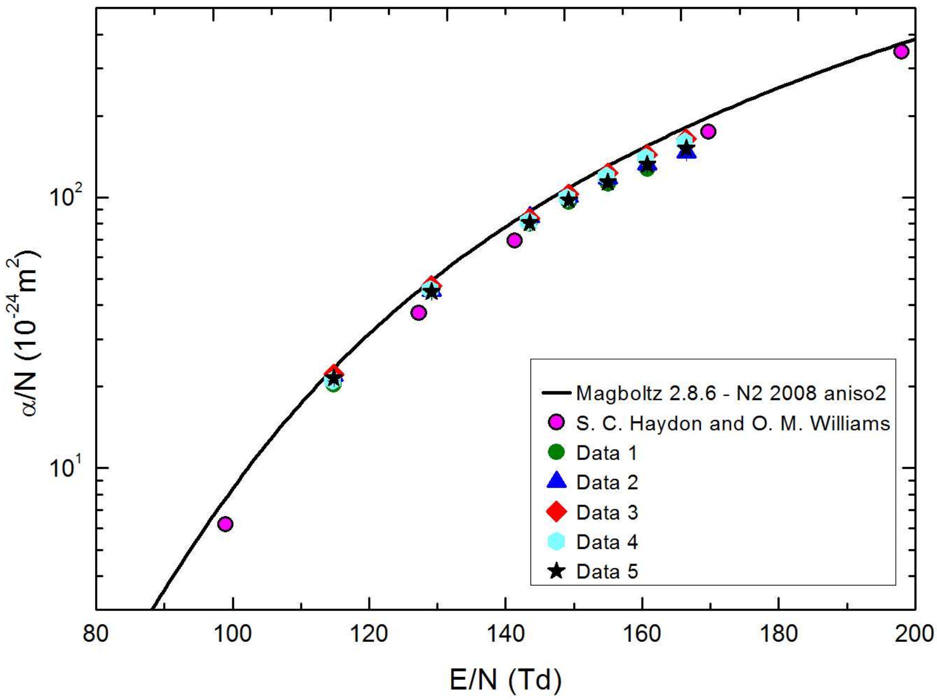

Figure 2. Magboltz result (color online), S. C. Haydon and O. M. Williams values (magenta circles) and data obtained in the present work.

In order to determine the constants A and B for nitrogen, curves of α/N versus N/E were obtained (Fig. 3). The results for each data set are presented in Tab.1 with values from literature. As discussed in the section 1, the effective ionization potential (V_i) can be determined by the ratio B/A and its value should lies between the first ionization potential and the mean energy required for an electron to produce ionization in the gas. For nitrogen the first ionization potential is 15.58eV [9] and the mean energy required to produce ionization varies from 36.68eV to 1030.38eV [10], depending on the incident electron energy.

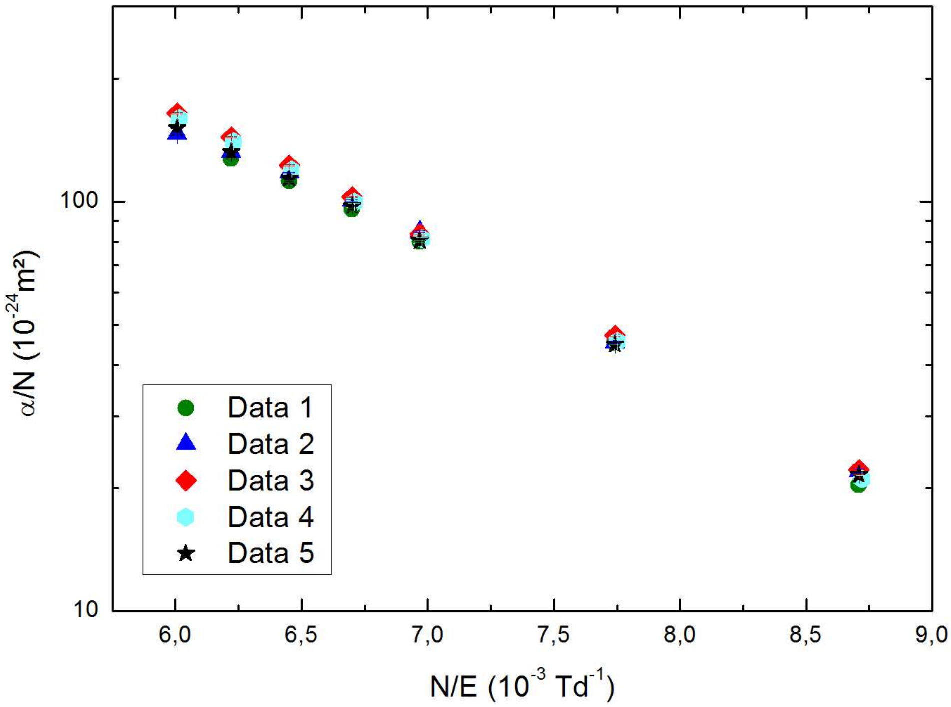

Figure 3. Korff parameterization applied to our data sets.

Table 1. Constants A and B, effective ionization potential (V_i) for nitrogen and the E/N range analyzed.

	A(10^{-20}m²)	B (Td)	V_i (eV)	E/N range (Td)
T. N. Daniel and F. M. Harris [3]	2.33	802	34	85 - 152
A. H. Cookson *et al.*[4]	1.55	770	47	89 – 166
Present work - Data 1	0.906(24)	683(4)	75	115 - 166
Present work - Data 2	0.701(14)	639(3)	91	115 - 166
Present work - Data 3	1.23(3)	716(4)	58	115 - 166
Present work - Data 4	1.27(3)	725(4)	57	115 - 166
Present work - Data 5	0.963(21)	689(3)	72	115 - 166

3. CONCLUSIONS

In the present work the technique for determining the first ionization coefficient was validated by means of measurements with nitrogen. The data were compared with Magboltz 2.8.6 simulation results and literature values, showing a good agreement with both. Moreover, the Korff parameterization was applied to our data sets and lead to the determination of the effective ionization potential. From the values of the first ionization potential and the mean energy required to produce ionization in nitrogen, our results can be considered quite satisfactory.

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