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Nuclear Instruments and Methods in Physics Research A 548 (2005) 582–589
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
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Technical Note

High-precision measurement of the electron drift velocity in Ne–CO_2

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Received 19 May 2005; accepted 24 May 2005
Available online 22 June 2005

Abstract

The baseline gas mixture which will be used in the ALICE TPC is 90% Ne and 10% CO_2. The change of the drift velocity due to changes of the CO_2 concentration as well as N_2 addition has been studied in high-precision measurements at drift fields between 100 and 900 V/cm. Also a precise absolute measurement of the drift velocity has been made. All measurements are compared with calculations.

PACS: 29.40.Gx

Keywords: ALICE; TPC; Drift velocity; Ne–CO_2 mixture; CO_2 dependence; N_2

1. Introduction

For large TPCs it is very important to understand how the electron drift velocity behaves if the gas parameters such as composition, pressure and temperature change [1]. The ALICE TPC [2–4]—as other TPCs before (NA49, CERES)—is operated with a Ne–CO_2 gas mixture. For the ALICE TPC the gas composition is 90% Ne and 10% CO_2. Ne is chosen mainly because of the high mobility of its ions and its long radiation length. This reduces the accumulation of charge in the drift volume in the high multiplicity heavy-ion collisions at the LHC. CO_2 was chosen as quencher to avoid ageing. Hydrocarbons such as methane would lead to severe ageing of the detector after a few years of operation [5]. The choice of the gas mixture also results in the desired feature of a small diffusion. However, the relatively low drift velocity in CO_2-based mixtures has to be compensated by a large drift field. Nonetheless, the drift velocity is non-saturated within

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0168-9002/$ - see front matter
doi:10.1016/j.nima.2005.05.031

the technically feasible field strengths. This implies a strong dependence of the drift velocity on the temperature. Moreover, the drift velocity strongly depends on the exact amount of CO_2 as well as on N_2 admixtures.[1]

To meet the detectors intrinsic position resolution in drift direction, a stability of the drift velocity of 1‰ is required. Therefore, it is essential to understand how this is reflected in the stability of the gas parameters.

For the ALICE TPC a recirculating gas system is used. Due to small leaks N_2 accumulates in the drift gas with time. A precise knowledge of how this affects the drift velocity is therefore necessary. Since the gas is mixed on site, the effect of a changing CO_2 concentration also has to be understood.

A dedicated measurement for a Ne–CO_2 [90-10] mixture investigating changes in the CO_2 concentration and on N_2 addition with high precision has not been carried out yet.

High-precision measurements also help to understand the quality of simulation programs and to develop them further.

In this paper we present measurements of the electron drift velocity investigating the abovementioned changes in the gas composition. An absolute high-precision measurement has been carried out as well. All results are compared with calculations performed with the simulation program Magboltz [8].

2. Experimental set-up

The measurements were carried out employing a small, specially built TPC. Two ionising laser beams are guided through the gas volume at a distance of 37.5 and 187.5 mm from the readout chamber, respectively. The drift velocity is determined by the relative distance of the two laser beams and the difference of the electron arrival time at the readout chamber.

[1]Recent investigations [5] showed that adding a few percent of N_2 to the Ne–CO_2 gas mixture greatly improves the stability of the readout chamber at high gain. The resulting changes of the drift velocity and gas gain are acceptable.

A sketch of the set-up is shown in Fig. 1. The size of the gas box is about $(43 \times 43 \times 43)\,cm^3$. It includes the HV-plate (a), the field cage which is mounted on the HV-plate (b) and the readout chamber (c). To avoid breakthrough from the HV-plate or the field cage to the grounded gas containment box they are built much smaller than the box itself.

The field cage consists of 16 field strips which are connected by a resistor chain to degrade the potential and provide a homogeneous drift field. Fields up to $\approx 900\,V/cm$ (20 kV on the HV-plate) can be reached. The power dissipation of the resistors at 20 kV is $\approx 1.2\,W$.

To monitor the temperature in the gas, three temperature sensors (d, cf. Section 4.2) are installed in the gas volume, but outside of the field cage. The sensor on the top is placed directly above the resistor chain.

The readout chamber is a small-size prototype of the ALICE TPC inner readout chamber [2]. It consists of a segmented cathode plane with $12 \times 5\,mm^2$ readout pads and three wire planes: a sense wire plane, a cathode plane and a gating grid. Their distances from the pad plane are 2, 4

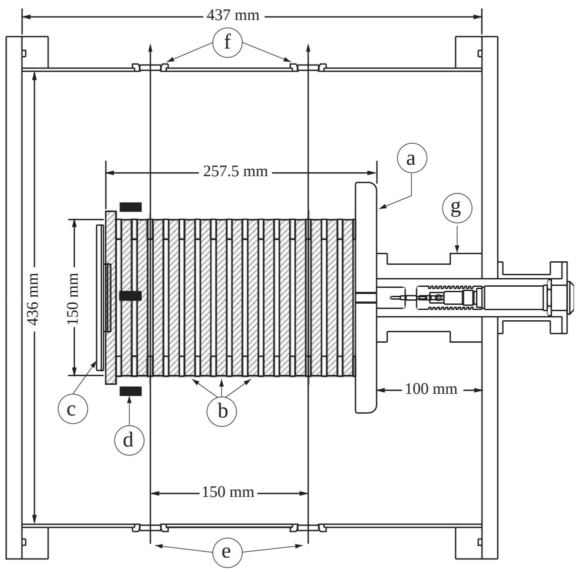

Fig. 1. Sketch of the experimental set-up: a—HV-plate, b—field strips of the field cage, c—readout chamber, d—temperature sensors, e—laser beams, f—quartz windows, g—support for the HV-plate.