Measurement of attenuation length of drifting electrons in liquid xenon

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1. Introduction

In 1991, a 3 ton liquid argon time projection chamber (TPC) was successfully operated by the ICARUS collaboration and beautiful three-dimensional track patterns were observed [1]. These results are very encouraging for researchers who are working on the development of a liquid xenon TPC for measurement of double beta decay of $^{136}$Xe [2], observation of cosmic gamma ray sources with precise directional resolution [3], and so on. To realize such liquid xenon TPCs, drifting electrons in liquid xenon are required to have a long attenuation length and ii) the anode is required to be a two-dimensional position sensitive detector. The former condition means that the liquid xenon to be used should have a high purity.

In the proposed applications to the double beta decay experiment or the observation of cosmic line gamma rays, the electron drift distance is on the order of 30 cm, which requires an attenuation length of the drifting electrons longer than one meter.

The Columbia group measured an average attenuation length longer than 44 cm at an electric field of 0.5 kV/cm for liquid xenon purified by a combination of Oxisorb, molecular sieves and a Zr-V-Fe alloy getter [4]. They obtained the attenuation length by the waveform analysis of ionization pulses produced by cosmic rays in liquid xenon, but the method was not so precise due to the limited statistics.

Recently, we have constructed a purification system for xenon gas, which is the same as that used by the Columbia group, and a dual type gridded ionization chamber which is suitable for measurement of an attenuation length of electrons longer than 1 m. In this paper, we present the apparatus used in the experiment and the results.

2. Apparatus

2.1. A dual type gridded ionization chamber

Fig. 1 shows a cross-sectional view of the dual type gridded ionization chamber used for measuring the attenuation length of drifting electrons in liquid xenon. The chamber has a common cathode and two grid-collector regions at different distances from the cathode [5]. Radioactive $^{207}$Bi sources of 3.7 kBq are electrochemically deposited on the center of both surfaces of the common cathode plate (K) made of stainless steel. The distance between the cathode and the grid (G1) in the upper chamber is 47 mm and that between the cathode and the grid (G2) in the lower chamber is 17 mm. The gaps between the collectors (C1 or C2) and the grids (G1 or G2) are 3 mm. Field shaping rings are placed between the cathode and the grids at intervals of 10 mm. Each ring is insulated by Macor spacers. The voltages to the field shaping rings are given through an internal resistance divider chain, consisting of resistors of 1 GΩ and 1.6 GΩ, not covered with any coating to avoid contamination. The effective inner diameter is 15 mm. The effective volume of the upper chamber is 8.3 cm³ and that of the lower chamber, 3.0 cm³. The total volume of liquid xenon put into the chamber vessel is 0.6 l. Each grid consists of stainless steel wires of 20 μm in diameter strung on a stainless steel frame.