HIGH-RESOLUTION LIQUID-FILLED MULTI-WIRE CHAMBERS FOR USE IN HIGH-ENERGY BEAMS

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ABSTRACT

We describe experiments with liquid-xenon-filled wire chambers operating in the proportional mode and the difficulty of achieving useful gain when the anode wires have a spacing < 1 mm. As a result, we have largely turned our attention to chambers with closely spaced wires operated in the ionization mode. We have previously demonstrated a spatial resolution of 15 μ rms in this mode, using a 5-wire chamber and a collimated alpha source.

We describe the construction of two small high-resolution test chambers to be filled with liquid argon, krypton, or xenon. The chambers consist of two flat cathodes 1 to 2.5 mm apart with a wire plane between them. The wire plane is an array of 24 wires, 5 μ in diameter, spaced on 20-μ centers, and a charge amplifier is attached to each wire. The space resolution (expected rms < 20 μ), time resolution (expected rms < 50 ns), and efficiency will be measured in an accelerator beam. Chambers of this type with only a few hundred wires have sufficient area to cover nearly every beam at NAL.

1.-INTRODUCTION

For several years, following a suggestion by Luis Alvarez[1], we have been studying the use of liquified noble gases for particle detection. Two types of wire chambers are emerging: one type having high spatial resolution for high-energy physics[2-3] and the other type having a unique combination of size, spatial resolution, energy resolution, and gamma-ray detection efficiency for nuclear medicine[4-5].

In Section 2 we discuss what we have learned about the avalanche of electrons in liquid xenon, both in single-wire and multi-wire proportional chambers. In Section 3 we discuss the construction of high-resolution liquid-filled multi-wire ionization chambers for use in high-energy beams.

2.-ELECTRON AVALANCHE IN LIQUID XENON

2.1.-Single-Wire Proportional Chambers

We have learned much from these simple chambers (see Fig. 1, Ref. 3): (i) the electron avalanche in liquid argon has low reliability, low detection efficiency, and the pulses are in general not proportional to the initial ionization[6], (ii) the electron avalanche in liquid xenon is highly reliable, has ~100% detection efficiency, and the pulses are proportional to the initial ionization, (iii) liquid xenon can be prepared free from nearly all electronegative contaminants by use of a specially designed noble gas purifier[7] and by the use of field emission electrons from the fine central electrode to ionize impurities and sweep them to the outer electrode[4].

In addition, we have taken data of pulse height vs applied voltage for 2.9-, 3.5-, and 5.0-μ diameter anode wires (see Fig. 2, Ref. 3) and these data vary by < 10% from one chamber filling to another. The electron avalanche has an exponential growth and the characteristic distance for that growth is $1/\alpha$, where α is the first Townsend coefficient. By comparing pulse heights between chambers having somewhat different anode diameters, it is possible to derive α as a function of electric field E. In fact, we performed a χ^2 fitting of a single function $\alpha(E)$ to the data for all three wires[8]. The result is plotted in Fig. 1 as $\eta = \alpha/E$ vs E/ρ (ρ = density) and compared with corresponding values measured in xenon gas[9-10]. We conclude that electrons avalanche in liquid xenon as they would in xenon gas at a density of 120 g/liter rather than the liquid density of 3057 g/liter.

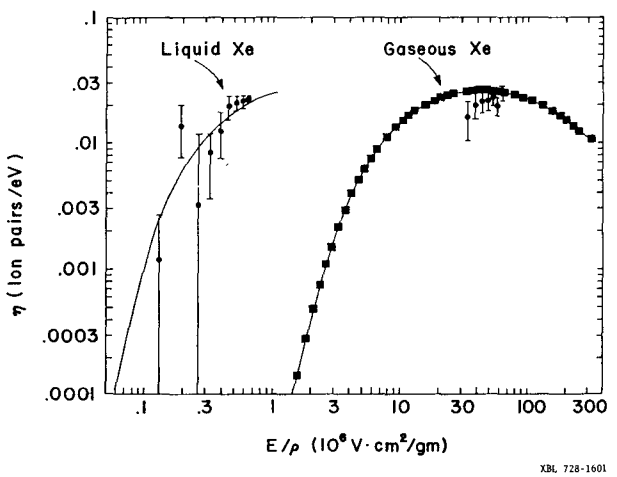

Fig. 1. Avalanche ionization coefficient $\eta = \alpha/E$ vs E/ρ for gaseous and liquid xenon, where α is the first Townsend coefficient (the inverse of the ionization mean free path), E is the electric field, and ρ is the density. (See Ref. 8 for details)

We have used the function $\alpha(E)$ measured in liquid xenon to predict the pulse-height-vs-voltage curve measured in solid xenon by Pisarev et al.[11]. The agreement is very good, indicating that $\alpha(E)$ is nearly identical in both liquid and solid xenon.

These same authors also measured pulse height vs voltage in the same chamber, using a gaseous xenon filling at pressures ranging from 1 to 50 atm[12]. Their solid-xenon curve agrees best with