Lorentz Angle of Electrons Drifting in Liquid Argon in a Magnetic Field

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Abstract

The "Lorentz angle" of electrons drifting in both electric and magnetic fields is negligible in liquid argon, due to the low drift velocity.

An electron of charge e drifting in liquid argon with velocity $\mathbf{v}$ in an electric field $\mathbf{E}$ and magnetic field $\mathbf{B}$ experiences a Lorentz force,

$$\mathbf{F} = e(\mathbf{E} + \mathbf{v} \times \mathbf{B}), \tag{1}$$

in SI units. As an example, for electric field $E = 500$ V/cm $= 5 \times 10^4$ V/m, the drift velocity is $v = 1.6$ mm/μs $= 1.6 \times 10^3$ m/s [1]. If the drift velocity $\mathbf{v}$ is perpendicular to the magnetic field $\mathbf{B}$, then the ratio of the magnetic to electric forces is,

$$\frac{vB}{E} = \frac{1.6 \times 10^3 \cdot 0.5}{5 \times 10^4} = 0.016, \tag{2}$$

for $B = 0.5$ T, as might be appropriate for a magnetized liquid argon detector [2]. The resulting "Lorentz angle" between the electron trajectory and the electric field lines is at most 1°, as occurs when $\mathbf{E}$ and $\mathbf{B}$ are orthogonal.[1]

In case the liquid argon detector is used to study interactions due to a beam with a known direction, the electric and magnetic fields are favorably chosen to be orthogonal to the beam direction, such that the deflection of particle tracks in the beam direction would be orthogonal to the direction of the magnetic Lorentz force, which further reduces the effect of that force on measurement of the particles' momenta.

References

[1] Q. He and K. McDonald, *Electron Drift Velocity in the μBooNE TPC* (Mar. 20, 2009), http://kirkmcd.princeton.edu/microBooNE/KTM/DriftV.pdf

[2] D.B. Cline, F. Sergiampietri, J.G. Learned and K.T. McDonald, *LANNDD, A Massive Liquid Argon Detector for Proton Decay, Supernova and Solar Neutrino Studies, and a Neutrino Factory Detector* (May 26, 2001), http://kirkmcd.princeton.edu/nufact/Lanndd_NUFact01.pdf

[3] A. Rubbia, *Experiments For CP-Violation: A Giant Liquid Argon Scintillation, Cerenkov And Charge Imaging Experiment*, (Feb. 10, 2004), https://arxiv.org/abs/hep-ph/0402110

[1] The "Lorentz angle" is not necessarily negligible in detectors using argon gas, including liquid argon detectors with electrons extracted into a gas phase [3].