Electron Drift in Xe Gas

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Abstract

Introduction

The XENON Dark Matter Experiment utilizes ultra-pure xenon (Xe) as a target for particle interaction in the effort to detect dark matter particles. To measure the purity of this Xe, a custom gas purity monitor (GPM) is being developed in which electrons are produced with a photocathode, drifted through gaseous Xe, and detected by measuring photoluminescent scintillation light. As the electrons drift through the Xe, they are attenuated by impurities, so the current can be used to measure the purity. To transport electrons the GPM utilizes electric fields which are broken into a primary drift region shown in Figure 1, and a scintillation region shown in Figure 2. The primary drift region contains an electric field of roughly 0.1 kV /cm that is shaped by a cylindrical resistive film to provide drift space for electrons to be captured by electronegative impurities. The scintillation region provides an electric field of roughly 10 kV /cm that stimulates photoluminescence which is detected by a photodiode.

Utilizing COMSOL Multiphysics:

COMSOL Multiphysics® software is used to calculate the electric fields and determine electron trajectories through these fields. Starting with the electrostatics module, the cylindrically symmetric geometry of a preliminary design introduces physically realistic boundary conditions to simulate the electric fields. With the electric fields in hand, the charged particle tracing module injects electrons at the photocathode surface and propegates these electrons through the GPM. It is necessary to include a drag force to account for the terminal velocity of electrons in Xe. The simulation will take into account linear and quadratic drag forces, as well as particle collision forces to examine which method best matched electron velocities in gaseous Xe. The final shape of the electron trajectories is used to tune the design of the GPM and ensure optimal operation.

Results

Figure 3 shows electron trajectories transitioning from the drift region to the scintillation region where some of these trajectories are not correctly guided through the aperture. Figure 4 shows trajectories inappropriately terminating on the detection plane. Adjusting for these issues is necessary to avoid charge build-up on isolated components of the GPM which could lead to electric discharge and destruction of the GPM all together. The other methods for obtaining

appropriate terminal velocities will be examined in a similar way.

Conclusion

COMSOL provides a fantastic tool in the design of electron drift devices. The simulation provides the ability to optimize detector acceptance and ensure the appropriate transportation of charge. Linking the electric fields with electron trajectories is the first step towards building this GPM, and COMSOL makes it possible.

Figures used in the abstract

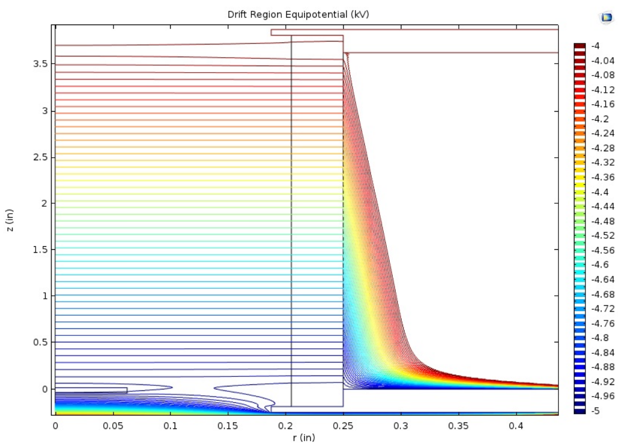

Figure 1: Equipotential lines of electric field in the primary drift region of the GPM.

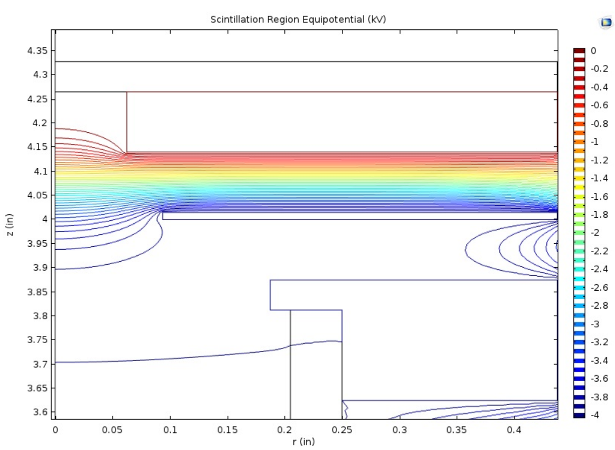

Figure 2: Equipotential lines of electric field in the scintillation region of the GPM.

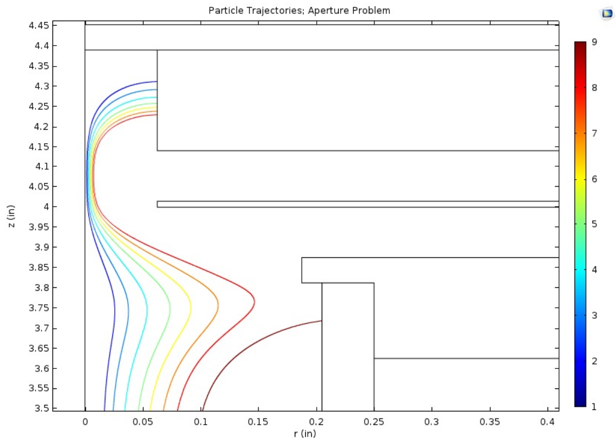

Figure 3: Electron trajectories showing charge build-up on the inside of the field shaping tube.

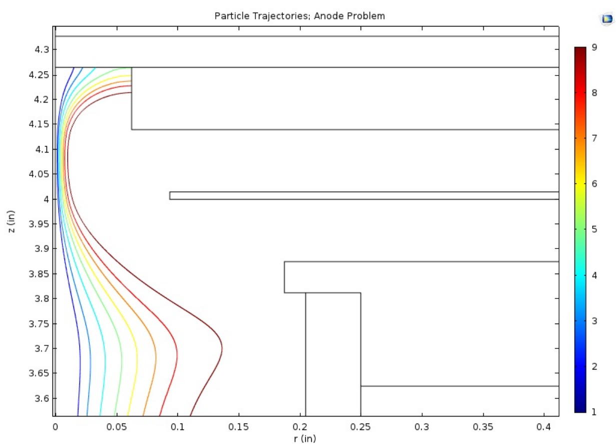

Figure 4: Electron trajectories showing charge build-up on the detection plane.