Positive Ion Field Distortions Study for Long Bo

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1 Assumptions

We use a finite analysis program (FreeFem++) to study the effect of an assumed positive ion distribution on Long Bo's potential and electric field within the TPC. A number of assumptions are made to carry out this calculation. We assume:

- A minimally ionizing cosmic muon produces 50,000 electrons/cm in LAr.
- The cosmic rate is $1/(\text{min cm}^2)$.
- Positive ions move at a rate of 0.5 cm/s.
- The relative permittivity of LAr is 1.6.
- The radius of Long Bo is 12.5 cm and length is 200 cm.

To compute the charge distribution, we assume a steady state is reached after 400 seconds, so

$$\begin{aligned}\langle\rho(z)\rangle &= \frac{1}{60 \text{ sec cm}^2} \cdot 400 \text{ sec} \cdot \frac{50,000 \text{ e}}{\text{cm}} \cdot \frac{1.6 \times 10^{-19} \text{ C}}{1 \text{ e}} \\ &= 5.33 \times 10^{-14} \text{ C/cm}^3\end{aligned}$$

Then, if we assume a linear charge distribution in z, we have

$$\rho(z) = 2\langle\rho(z)\rangle \left(1 - \frac{z}{L}\right)$$

Then

$$\begin{aligned}\nabla^2\phi &= \frac{\rho}{\epsilon} \\ &= \frac{2\langle\rho(z)\rangle \left(1 - \frac{z}{L}\right)}{\epsilon}\end{aligned}$$

and

$$\begin{aligned}\langle\rho(z)\rangle &= 5.33 \times 10^{-14} \frac{\text{C}}{\text{cm}^3} \\ \epsilon &= 1.42 \times 10^{-13} \frac{\text{C}}{\text{V cm}}\end{aligned}$$

so

$$\nabla^2\phi = 0.75 \cdot (1 - \frac{z}{L}) \cdot \frac{\text{V}}{\text{cm}^2}$$

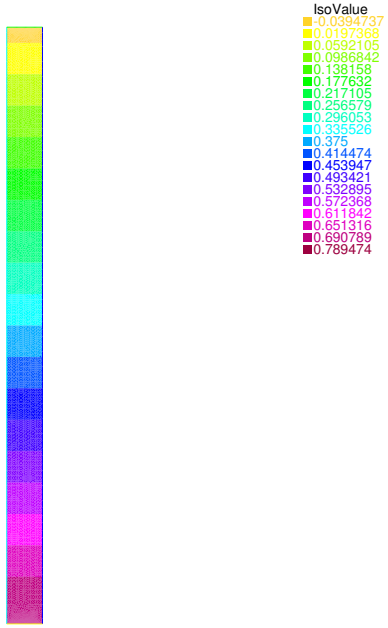
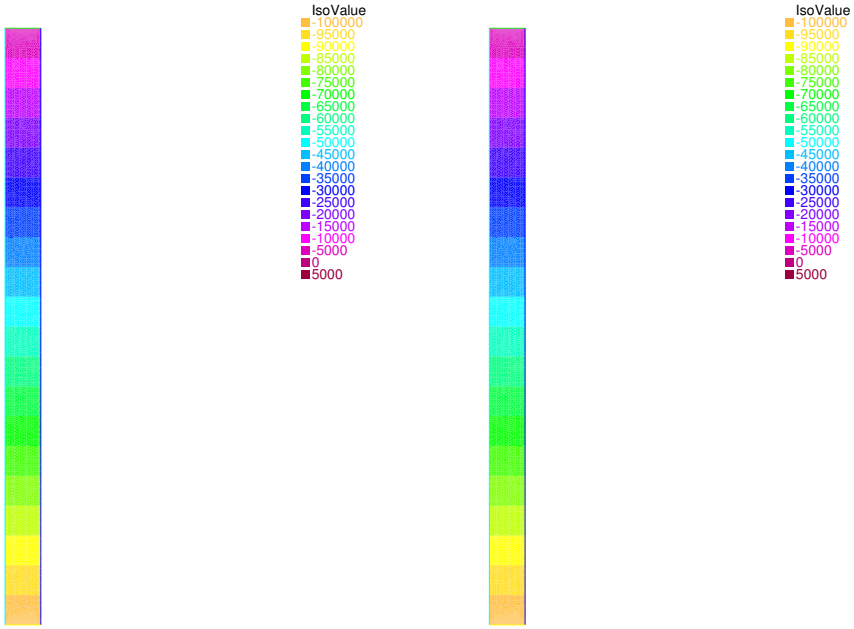
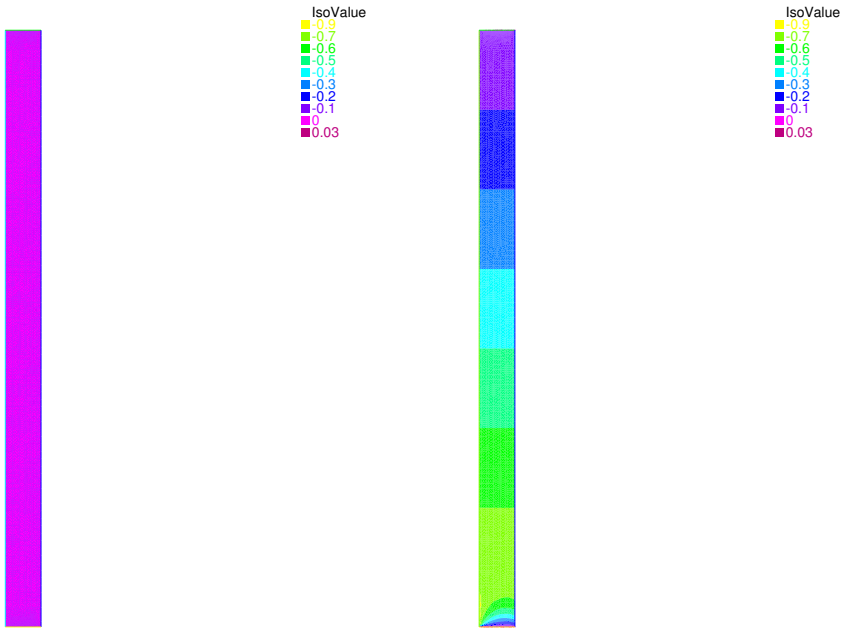


Figure 1: Assumed charge distribution over the permitivity (V/cm^2).



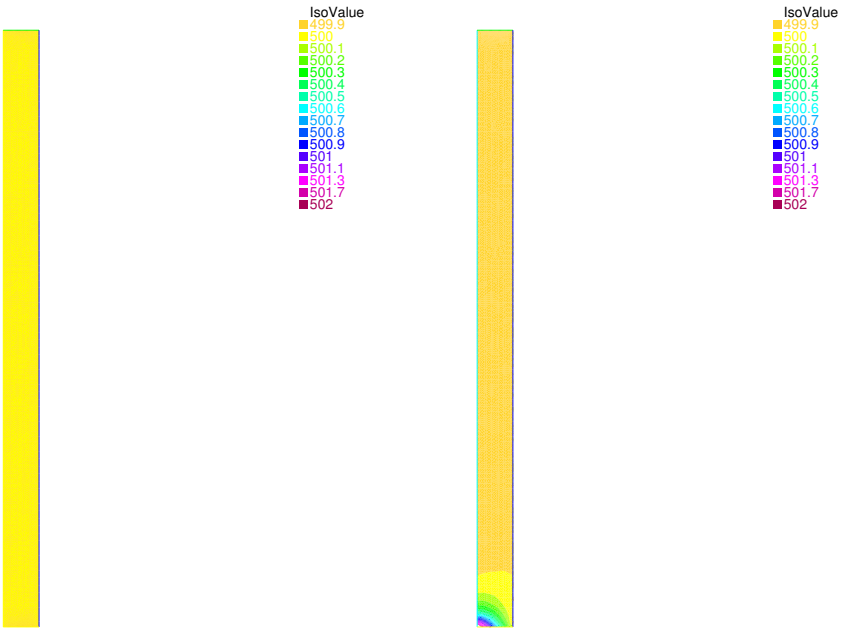
(a) No positive charge density (b) Including posititve charge density

Figure 2: Potential (V).



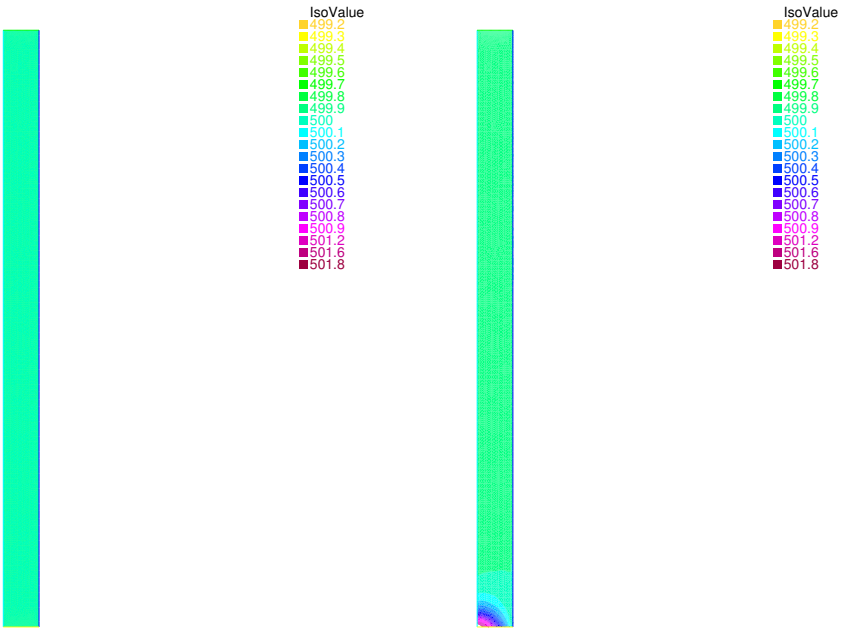
(a) No positive charge density (b) Including posititve charge density

Figure 3: Electric field in the r direction (V/cm).



(a) No positive charge density (b) Including posititve charge density

Figure 4: Electric field in the z direction (V/cm).



(a) No positive charge density (b) Including posititve charge density

Figure 5: Electric field (V/cm).