

Positive Ion Distortions for MicroBooNE

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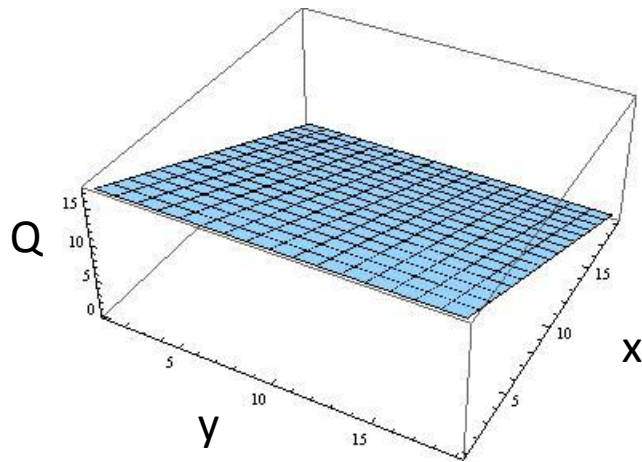
With input from Bo Yu (BNL), Erik Voirin (FNAL), Lincoln Bryant, and
Athula Wickremasinghe



Positive Ion Buildup

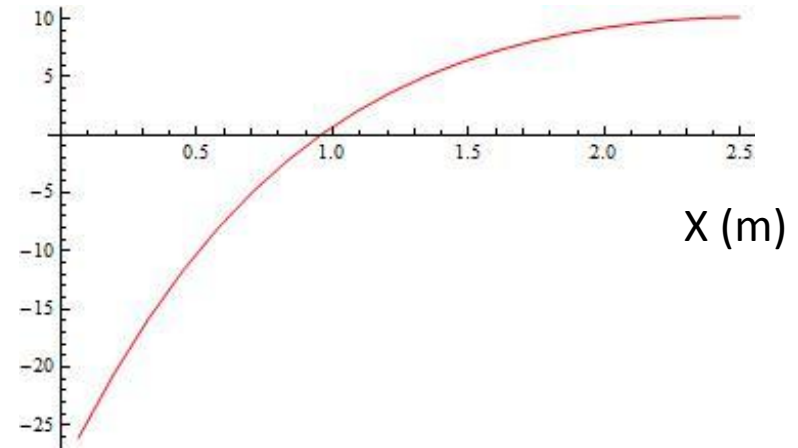


- Cosmic Rays: ~ 3 muons/ms into MicroBooNE (CRY)
- Positive ions take ~ 6 minutes to drift across MicroBooNE (500 V/cm)
- Positive ions build up approximately linearly from anode to cathode.



FE input charge distribution
(arbitrary units)

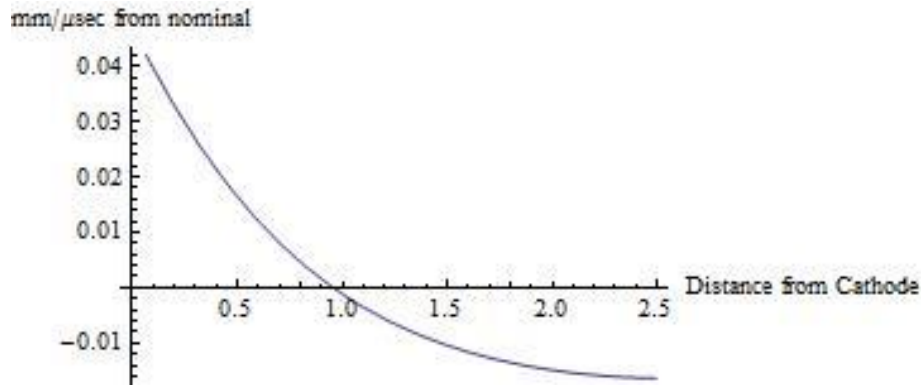
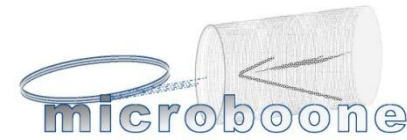
Volts/cm



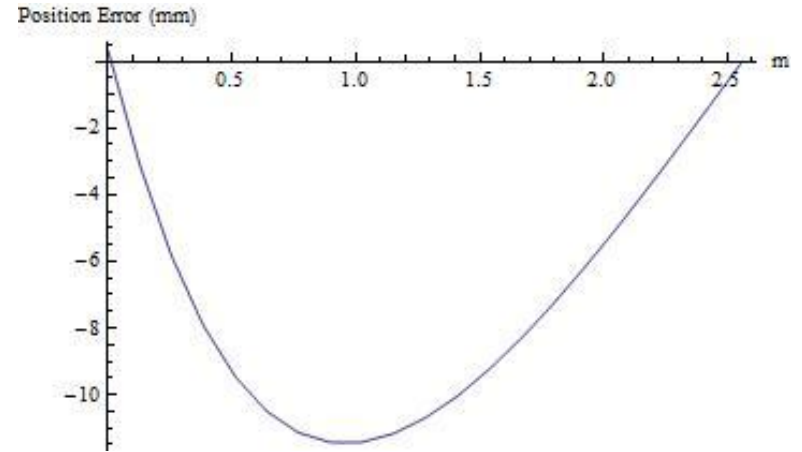
Electric field difference from nominal
on centerline.



Longitudinal Distortions Time Delays



Drift velocity from nominal
(basically linear in this range)



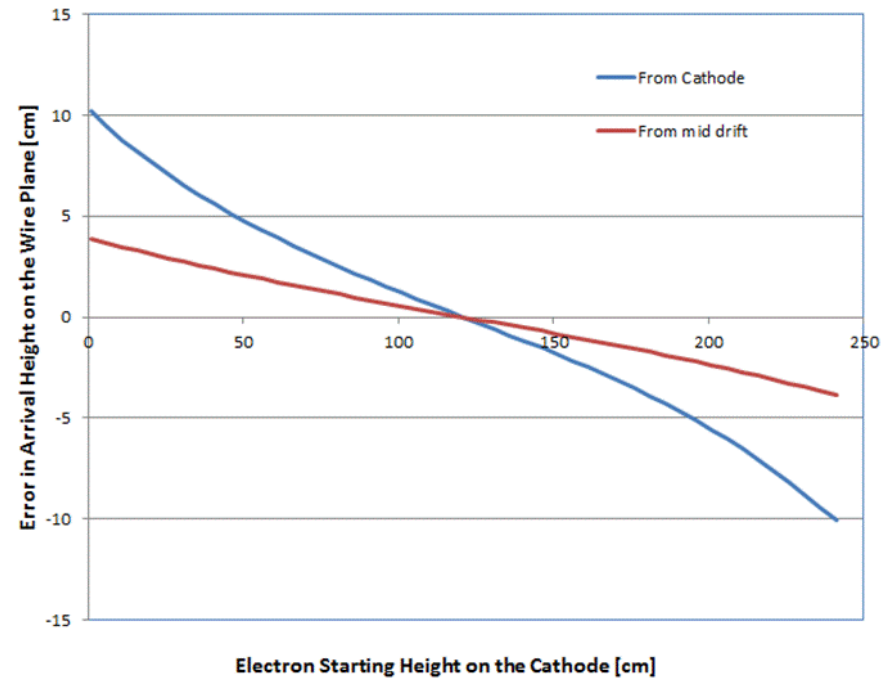
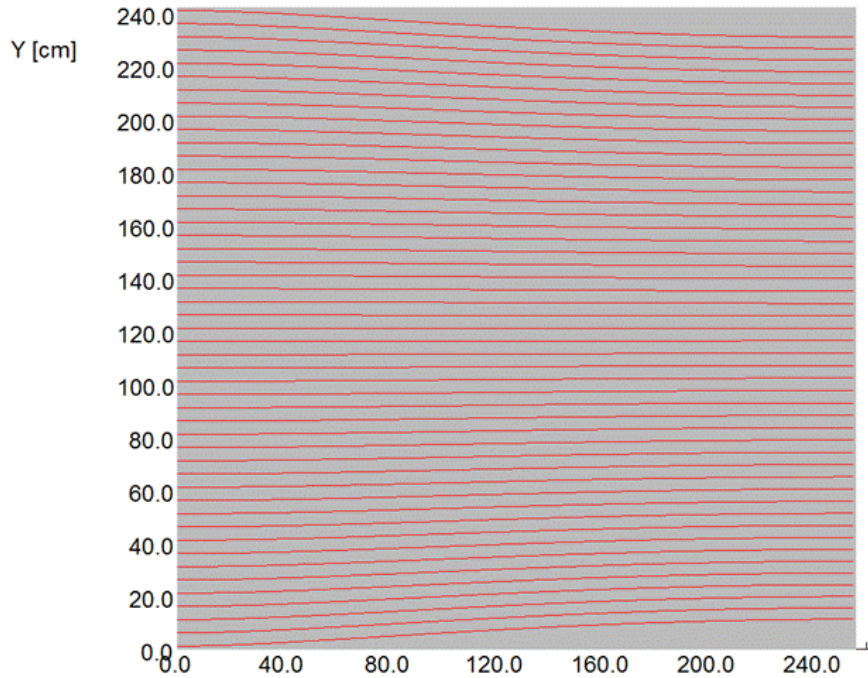
Position error



Lateral Distortions



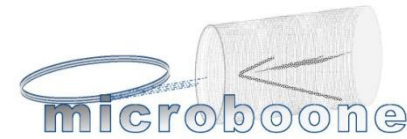
- Cause:
- Bulk positive ions attract electrons
 - Negative image charges repel electrons



Bo Yu's (BNL) calculations



Negative Ion Build-Up

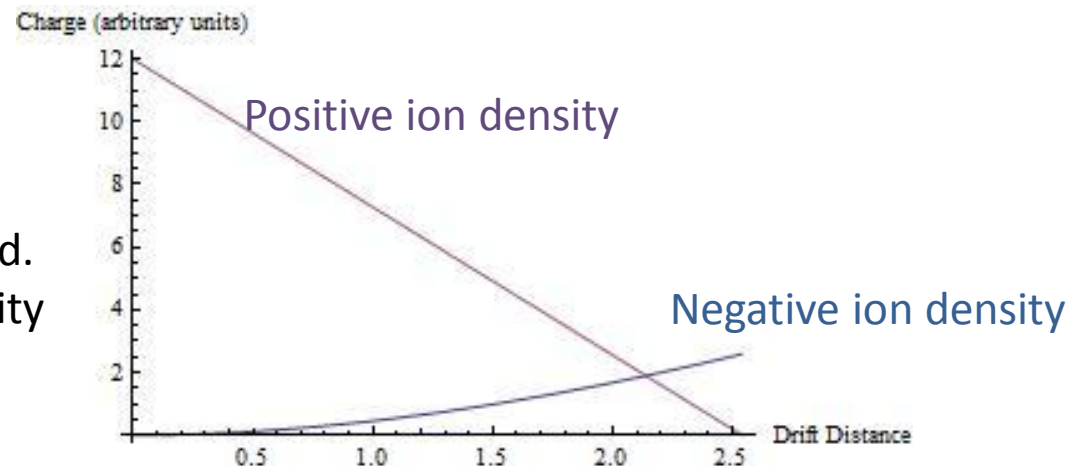


Bill Willis has pointed out:

- We will lose electrons due to electronegative impurities in the argon. These captured electrons form negative ions.
- Those negative ions will cause electric field distortions just like the positive ions.
- The drift velocity of these ions are unknown but probably of the same order of magnitude as the positive ions.
- Whether these ions recombine with the positive ions or drift to the anode is unknown.
- The number of negative ions is smaller than but of the same order of magnitude as the positive ions.

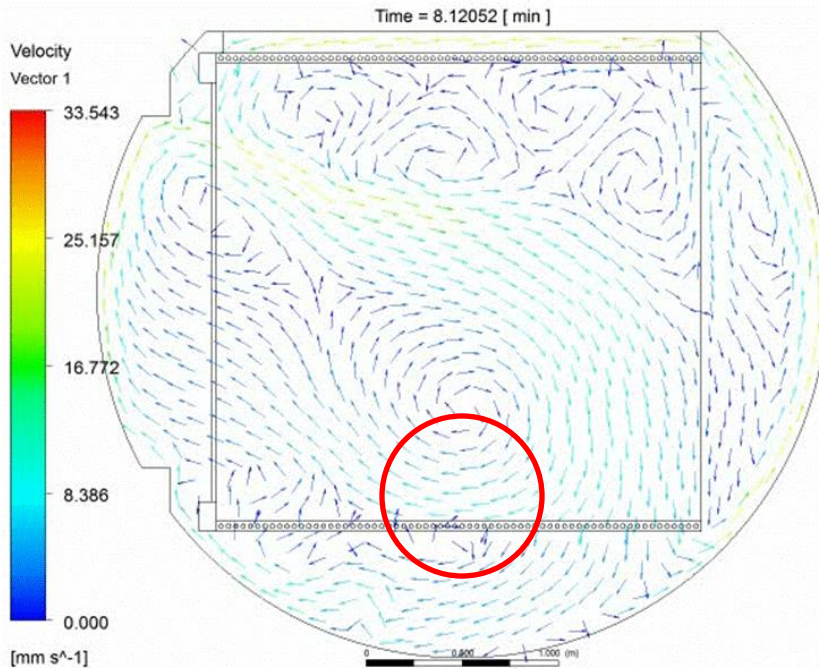
Assume:

- $\frac{1}{2}$ of the electrons from the far side are captured.
- Negative ion drift velocity equals positive ion velocity.





Complication – Liquid Argon Flow



Erik Voirin - Fermilab

MicroBooNe Buoyancy Driven Flow Analysis



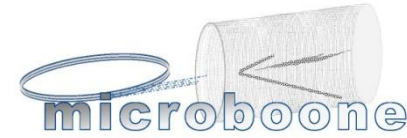
Problem: Liquid argon flow velocity toward anode can equal positive ion drift velocity toward cathode. Implies region where positive ions are stagnant and only diffuse out.

With one day argon exchange times, positive ions are swept from one end to the other. Thus build-up is longitudinal position dependent (and dependent on amount of turbulence in system).

ANSYS calculation by Erik Voirin

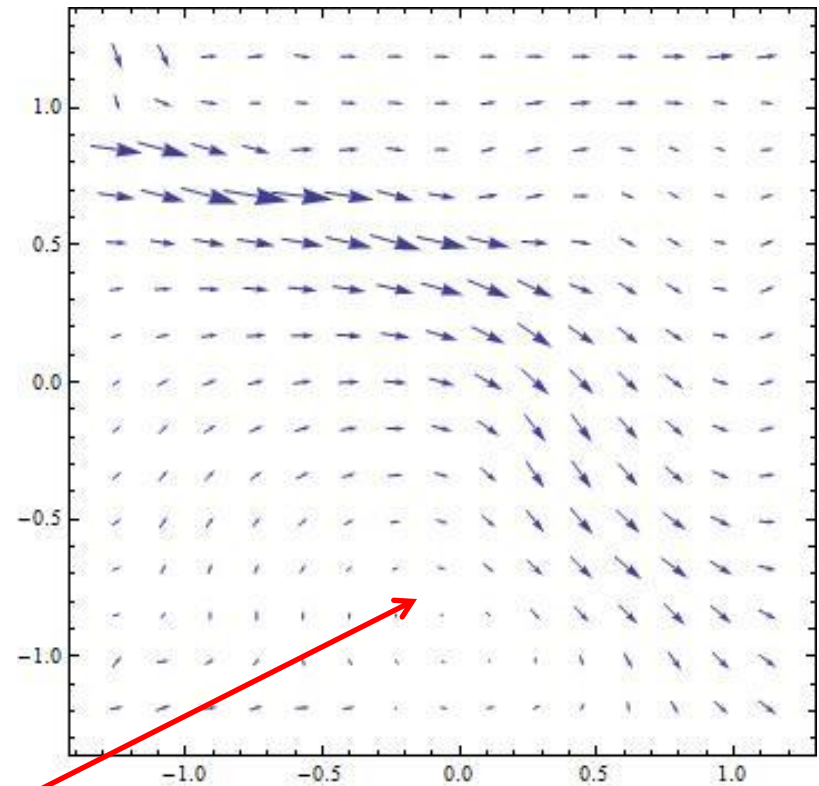
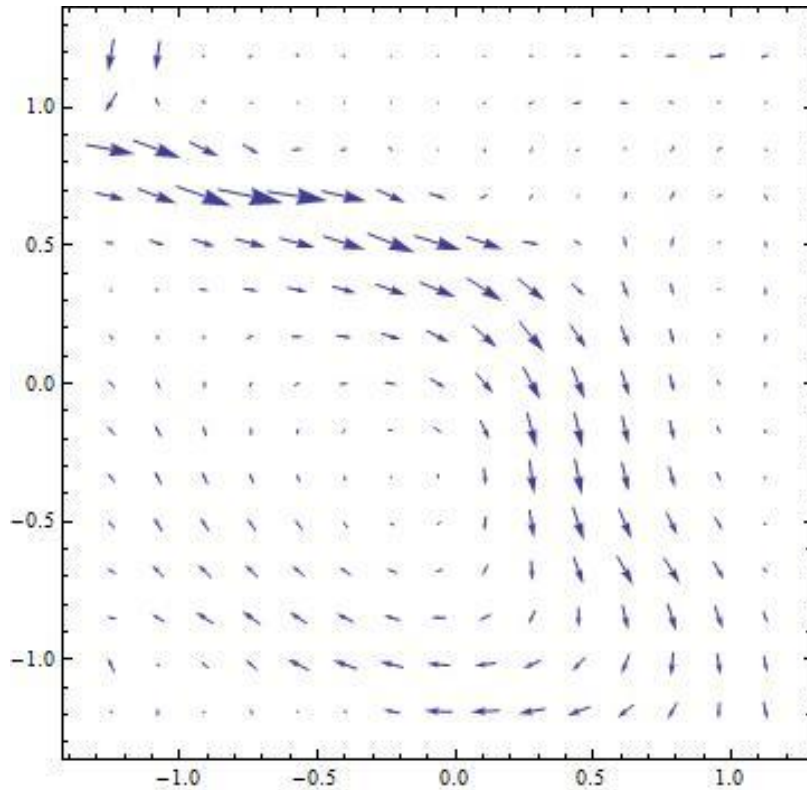


Complication – Liquid Argon Flow



Argon Flow

Positive Ion Drift



Erik's calculation

Stagnant Area

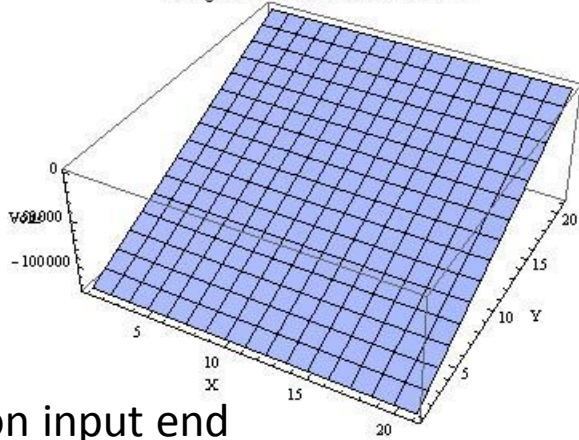
Add in positive ion drift



Drift Voltage Changes

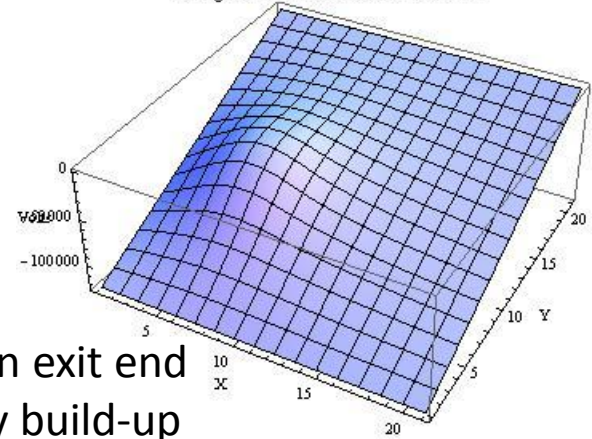


Voltages—Finite Element Matrix Method

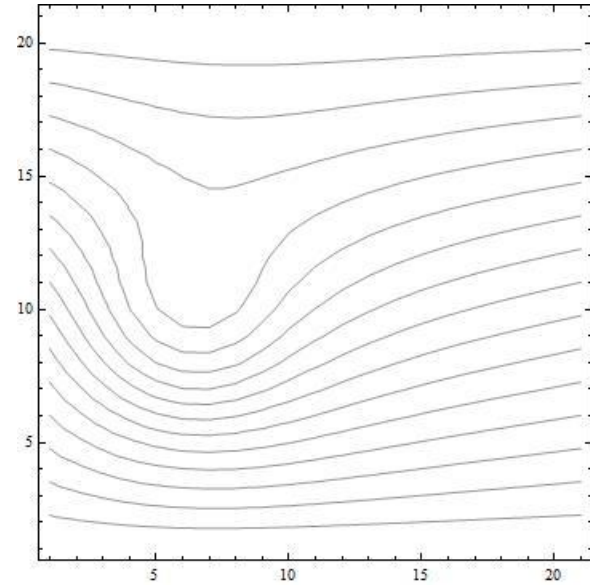
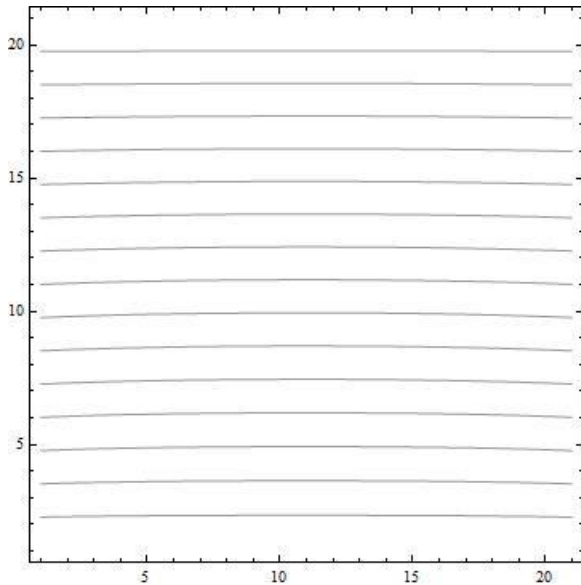


Argon input end

Voltages—Finite Element Matrix Method



Argon exit end
1 day build-up





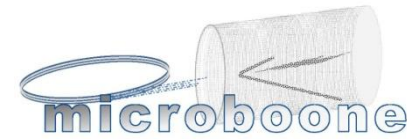
Comments on Eddy Problem



1. Flavio has shown MicroBooNE cosmic ray shower events from ICARUS on the surface which do not seem to show this problem.
 - a. No eddies in ICARUS?
 - b. Something wrong with this calculation?
2. Electrostatic repulsion of positive ions and attraction of them to the walls not taken into account. May (partially) mitigate ion build-up.
3. Attraction of negative ions to positive ions may also mitigate build-up.



Conclusions



- Cosmic Ray rate difficult to predict. (Time dependent?)
- Multiple effects all taking place at the same time:
 - Positive ion build-up
 - Negative ion build-up
 - Liquid argon drift
 - Positive ion vortices which change in ion density along length of detector
 - Turbulent disruption of flow
- Each effect changes the others
 - Image charges change drift patterns of both electrons and positive ions
 - Charge recombination
 - Etc.

My conclusion:

One should put in as many of these effects as possible into the simulations with the knowledge that whatever you put in will probably be wrong. Experiments need to monitor electric field throughout the drift volume continuously with a high precision cosmic ray telescope (?), a laser (?), or something else(?).