Update on SCE Sim. w/ Liquid Argon Flow

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ProtoDUNE Sim/Reco Meeting

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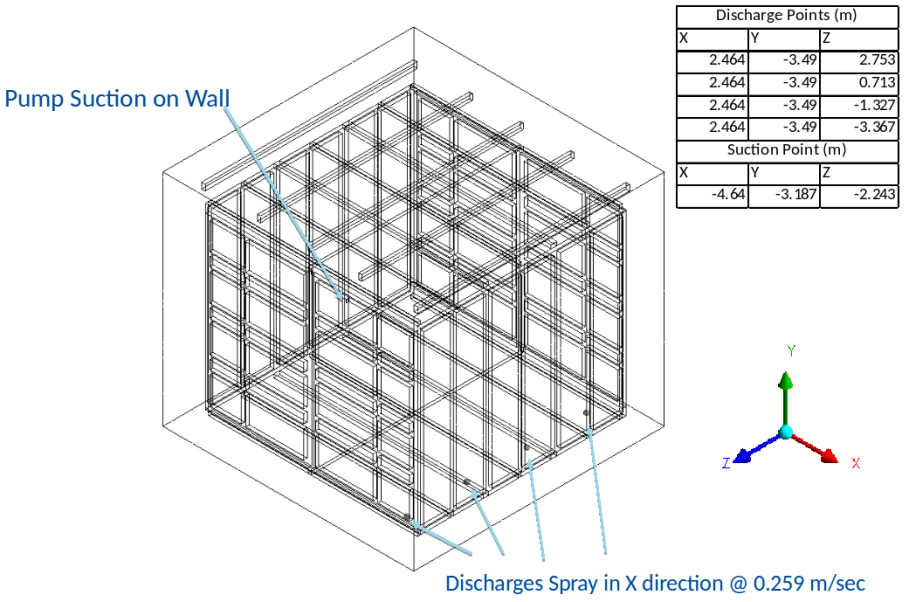
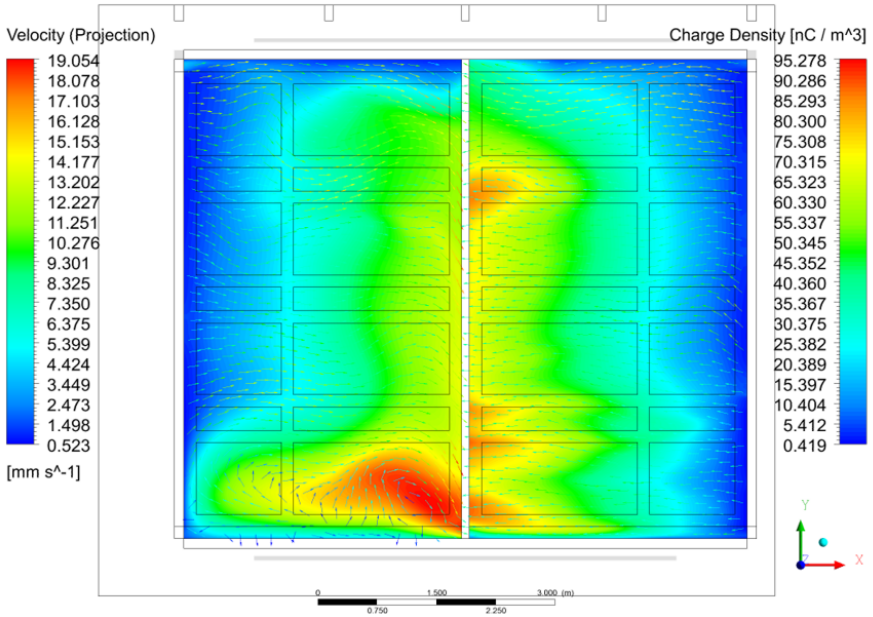
Introduction

- Open question: how much do we expect flow of liquid argon to impact underlying space charge configuration?
  - Ion drift velocity in electric field and expected liquid argon flow velocity are similar in magnitude
  - Could lead to build-up of space charge in certain parts of detector, or at least modify space charge distribution
- Previously showed significant differences in space charge distortions when taking into account fluid flow
  - Erik Voirin (FNAL) produced CFD (computational fluid dynamics) model including space charge migration, for use by Mike M.
  - However some inaccuracies in model, ion deposition rate
- Today: updated study of LAr flow on SCE, using new liquid argon flow simulation from Erik

Fluid Flow Simulation

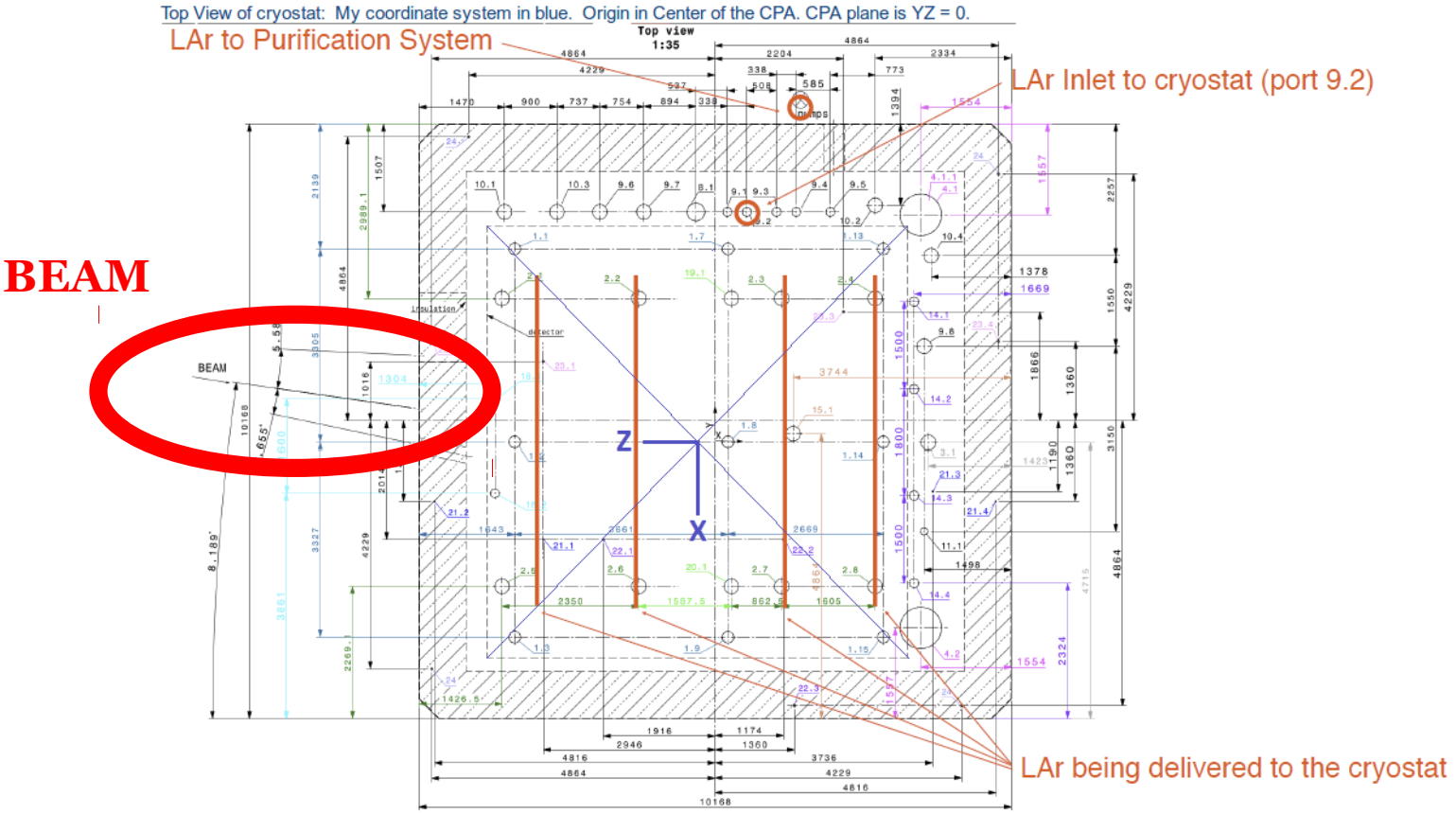


Discharge Points (m)		
X	Y	Z
2.464	-3.49	2.753
2.464	-3.49	0.713
2.464	-3.49	-1.327
2.464	-3.49	-3.367
Suction Point (m)		
X	Y	Z
-4.64	-3.187	-2.243



- Developed by Erik Voirin for ProtoDUNE-SP (previously produced for 35-ton) – see here: **DUNE Doc DB #928**
- 3D simulation of LAr flow, 8 mm/s ion drift @ 500 V/cm, uniform space charge deposition from cosmics (1100 → 1900 ions/cm^3/s)
- **Updated** w/ improved modeling of geometry, more accurate LAr height, more accurate ion deposition rate – see same Doc DB entry

Coordinate Systems

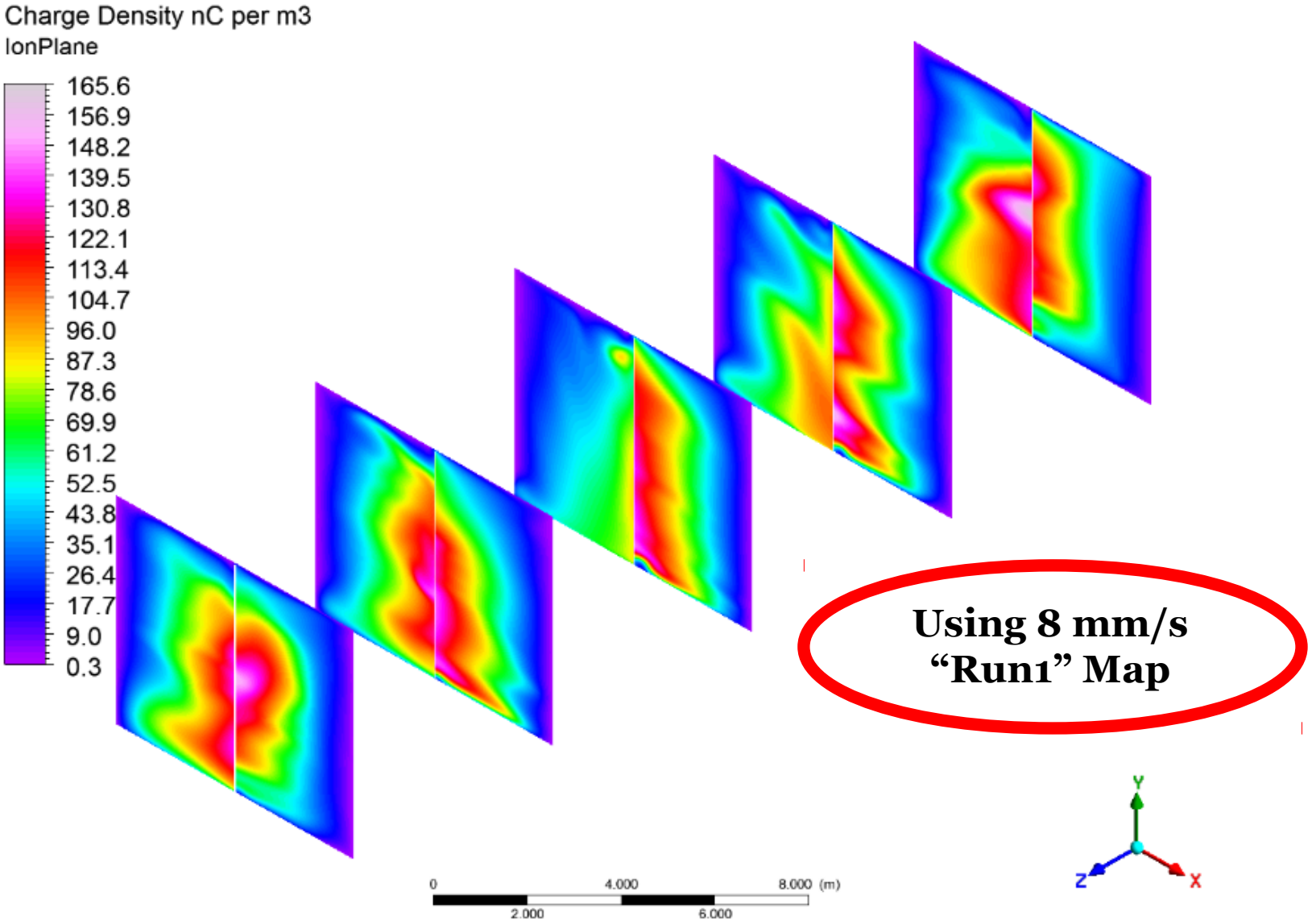


- Moving from Erik's coordinate system to LArSoft, need to flip X and Z coordinates – is this part of previous discrepancy?
  - Previously, X/Z axes were rotated! Definitely part of the data/MC disagreement

SCE Simulation

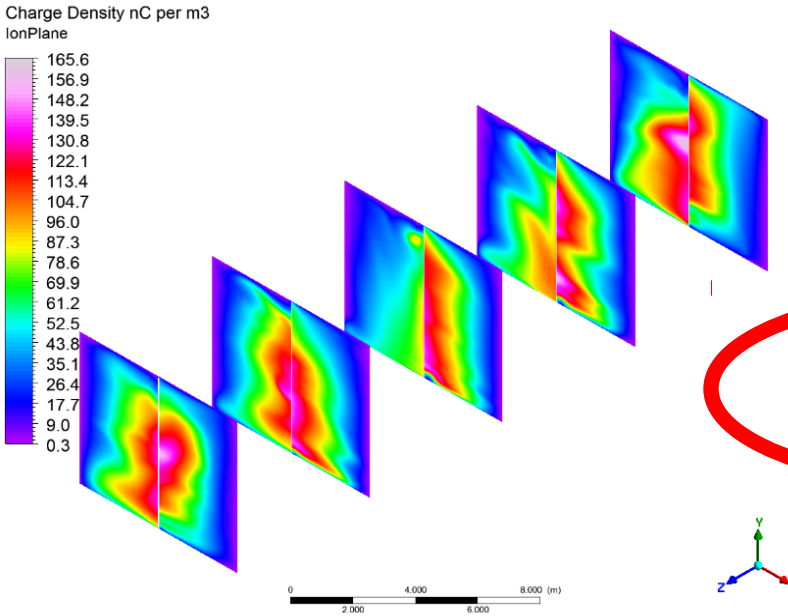
- Make use of code suite developed by M. Mooney for simulation of SCE given space charge density map from Erik's simulation
  - **SpaCE** – Space Charge Estimator
- Fourier series solution for electric field on grid, radial basis functions for interpolation of field between grid points, and ray tracing based on RK45 for determining spatial displacements due to SCE
- Nominally assumes linear space charge distribution (zero at anodes, maximal at cathode), but code suite has capability of using arbitrary space charge distribution as input
  - Compare nominal SCE maps to ones including LAr flow

8 mm/s “Run1” Density Map

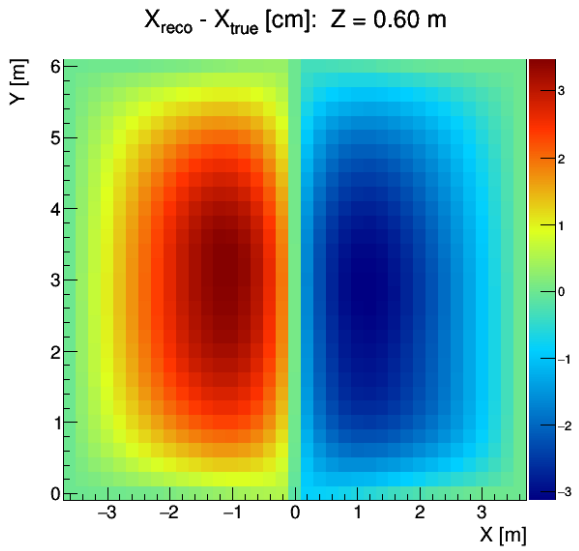


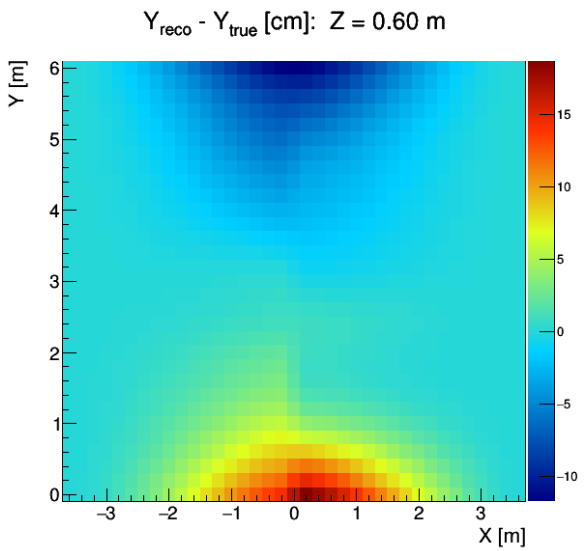
Using 8 mm/s “Run1” Map

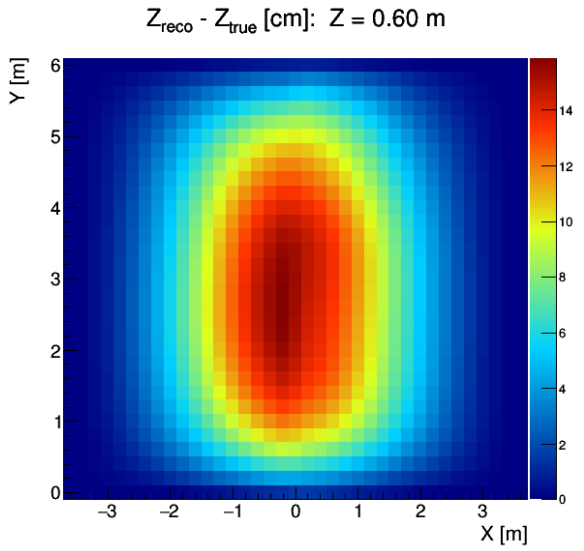
Spatial Offsets: Z = 0.6 m



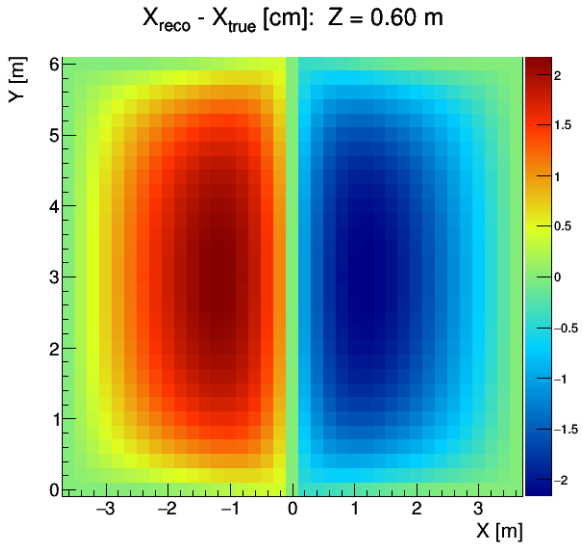
Using 8 mm/s "Run1" Map

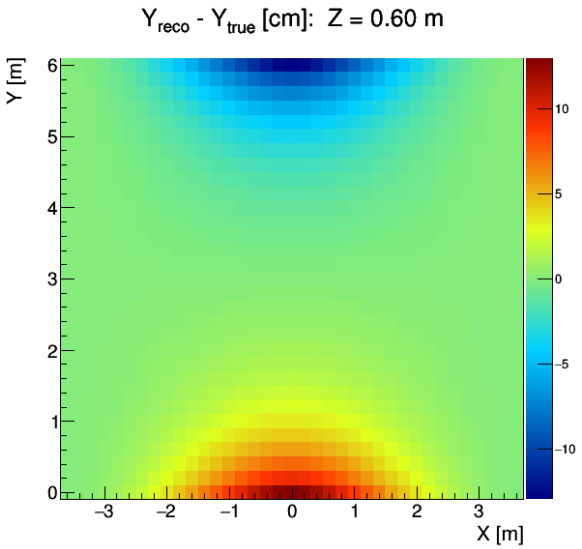


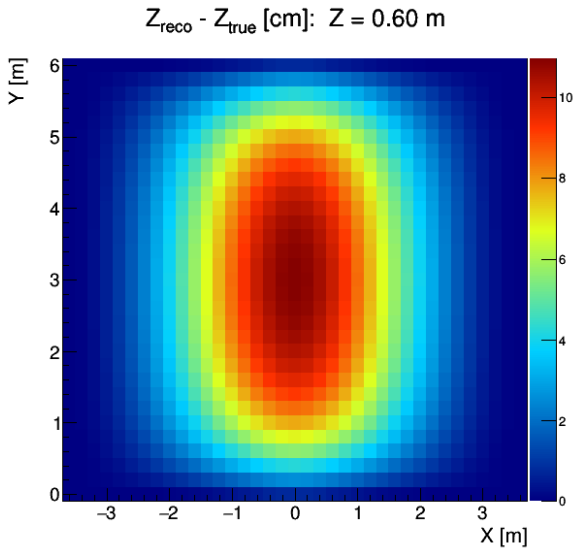


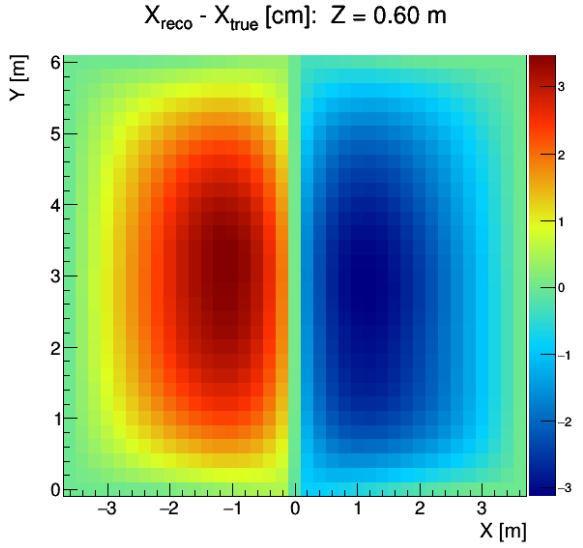


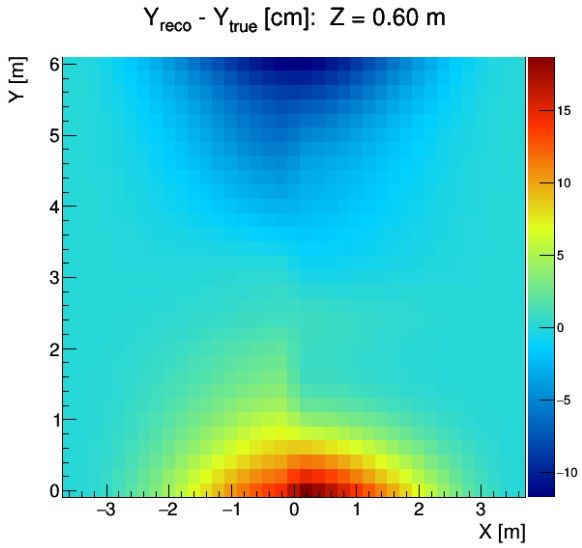
Vs. No Flow: Z = 0.6 m

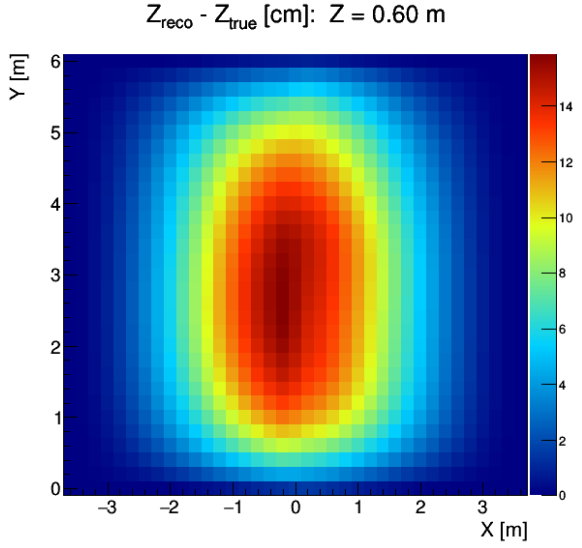




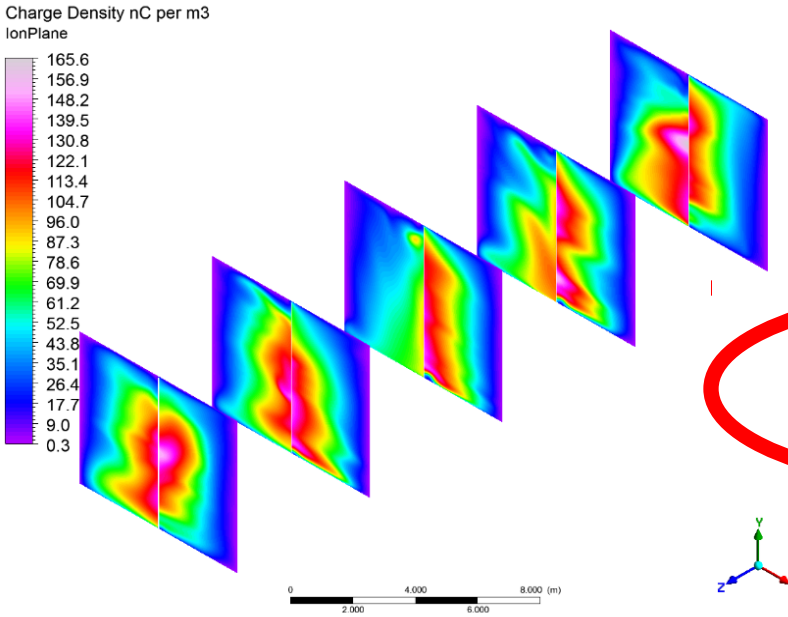




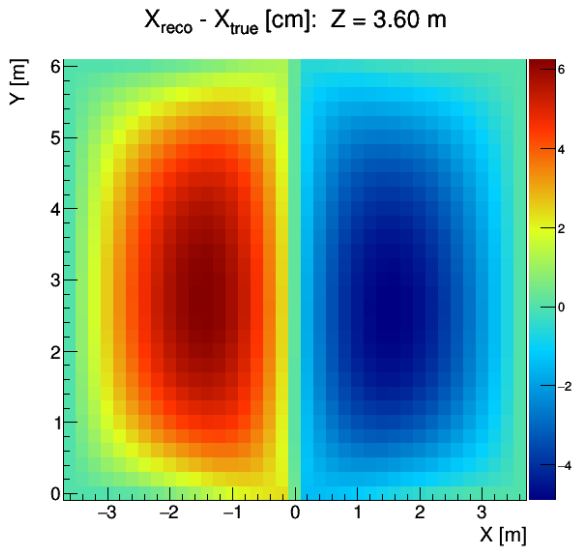


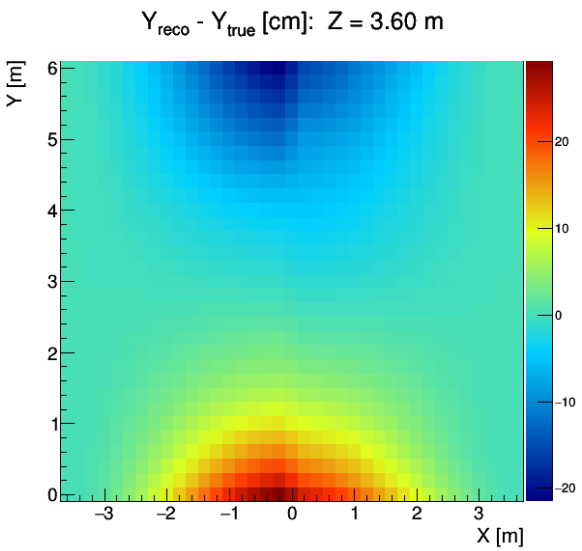


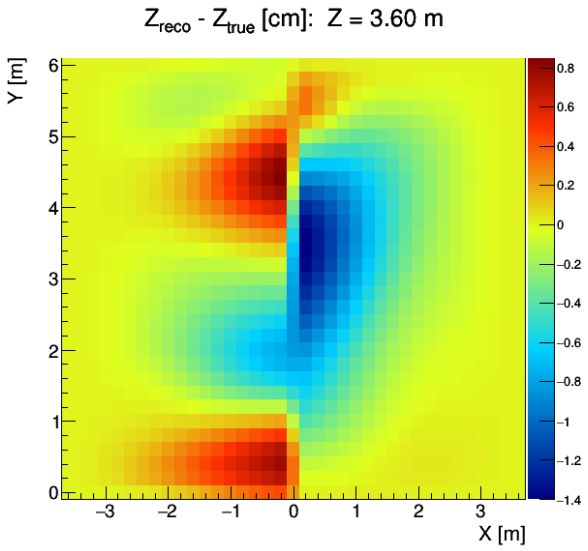
Spatial Offsets: Z = 3.6 m



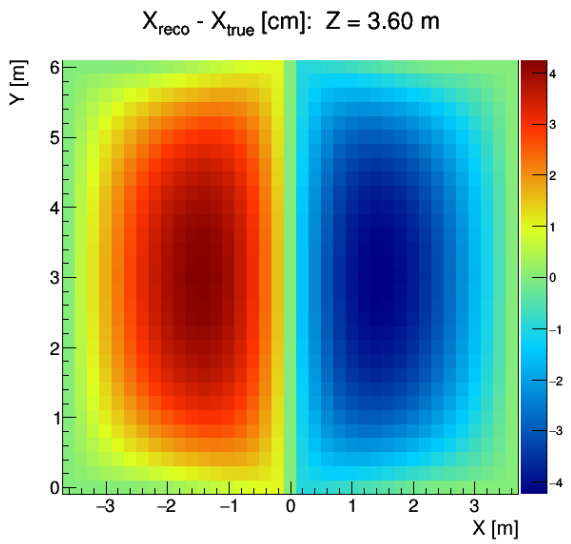
Using 8 mm/s "Run1" Map

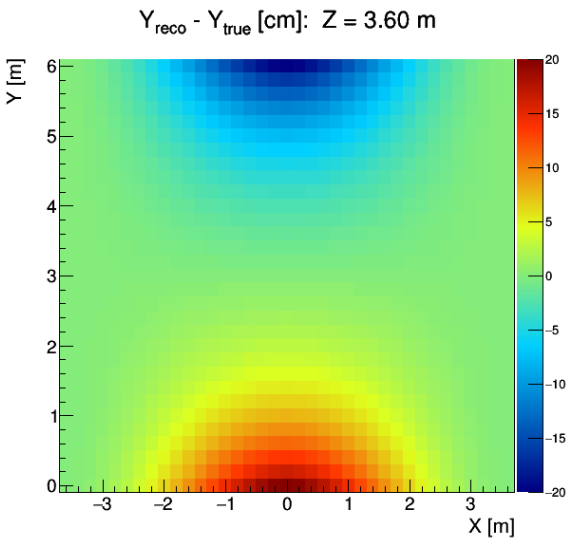


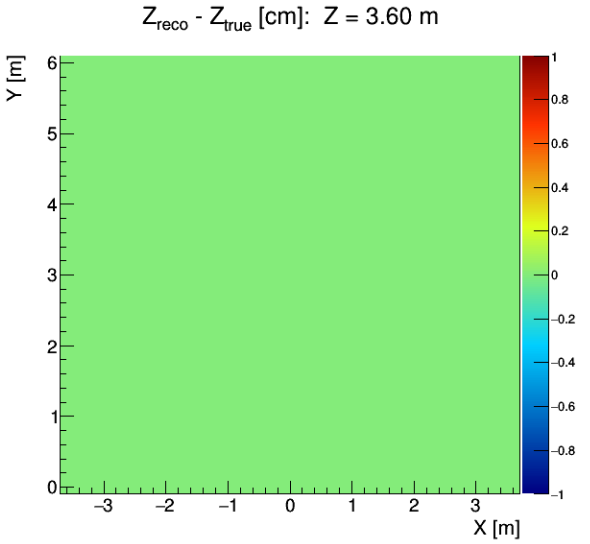


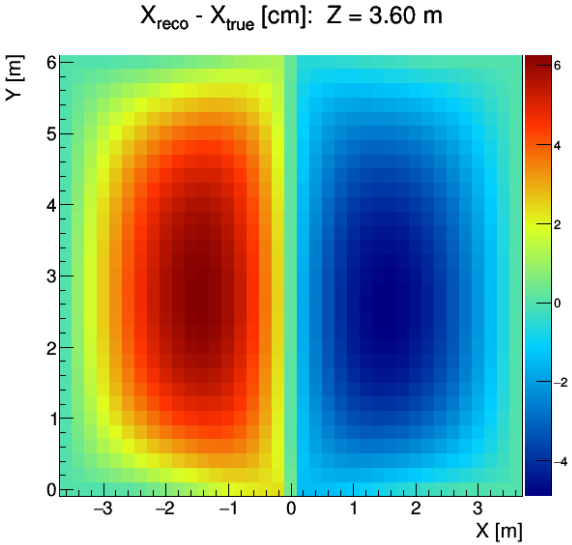


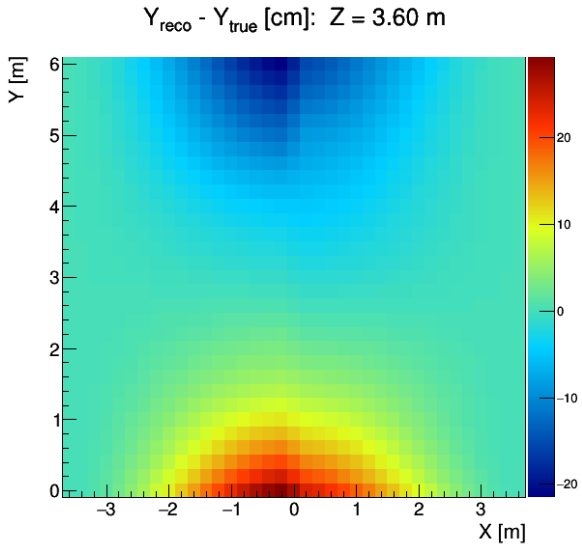
Vs. No Flow: Z = 3.6 m

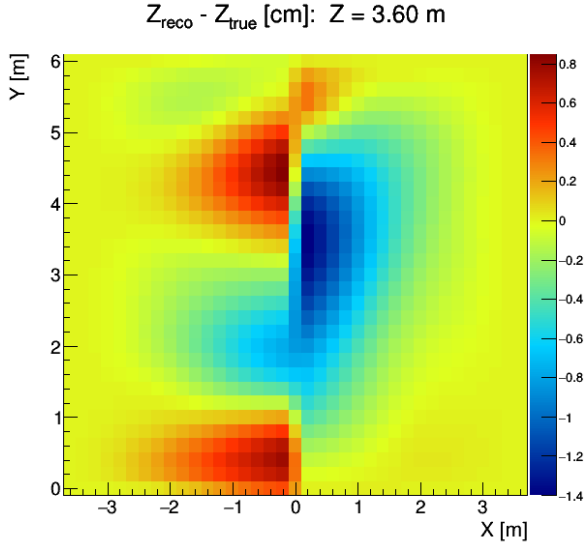




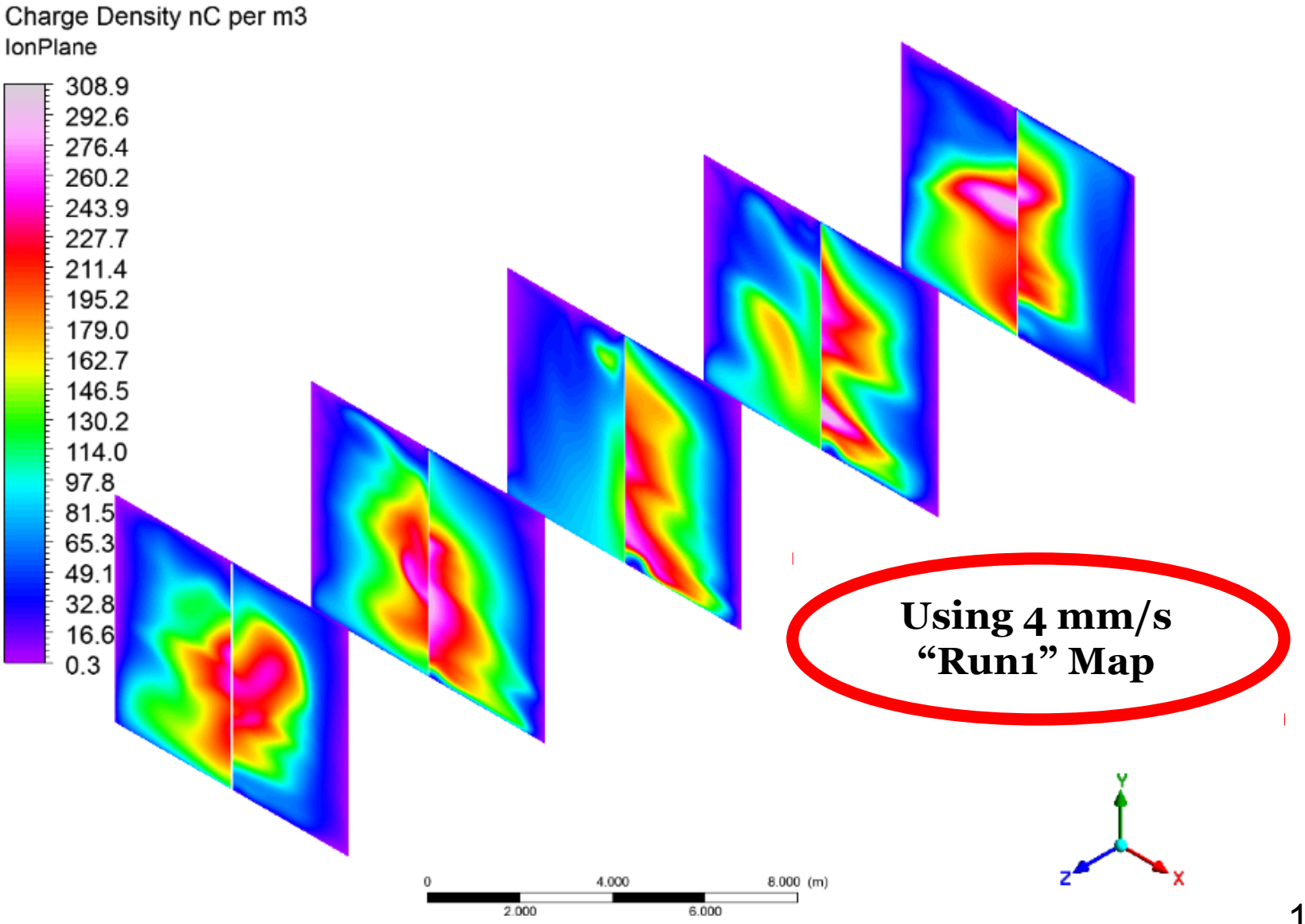






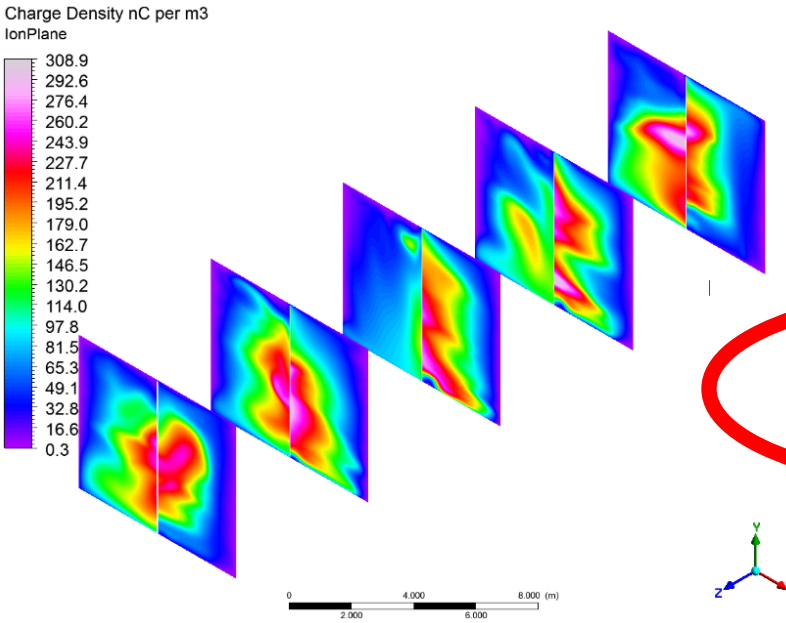


4 mm/s “Run1” Density Map

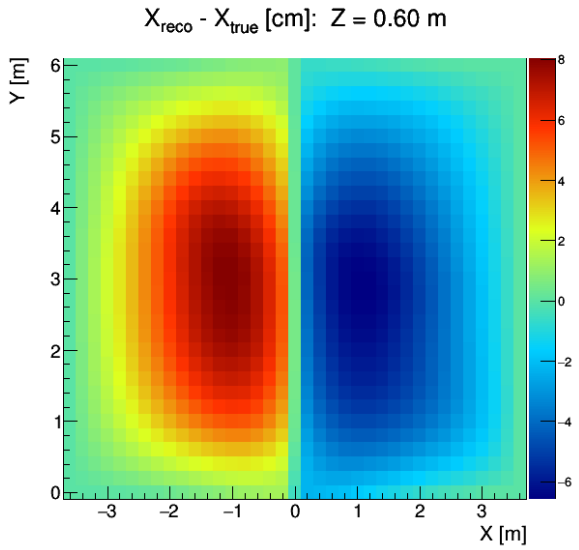


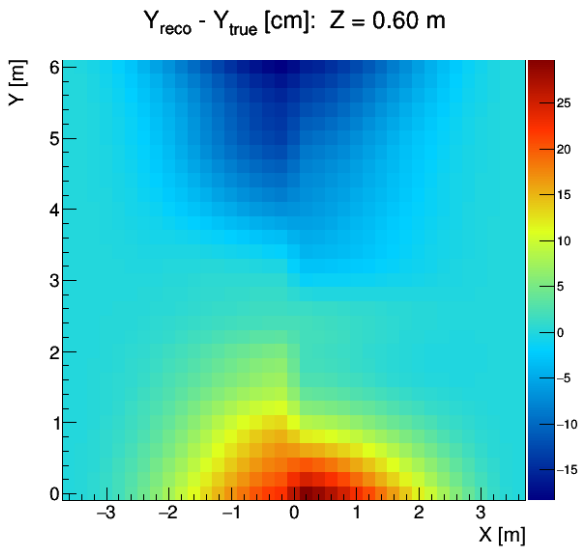
Using 4 mm/s “Run1” Map

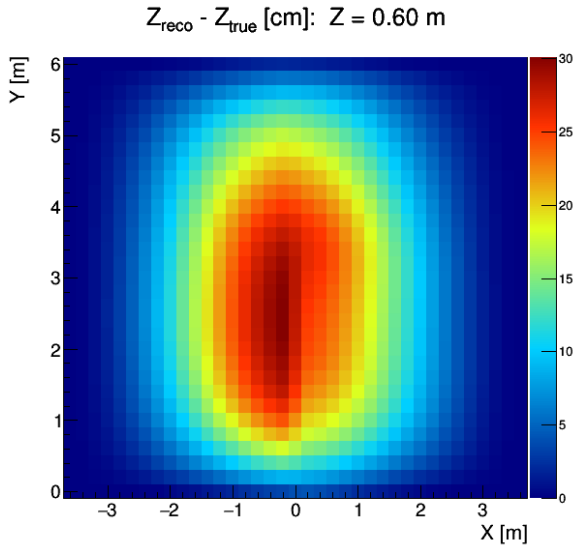
Spatial Offsets: Z = 0.6 m



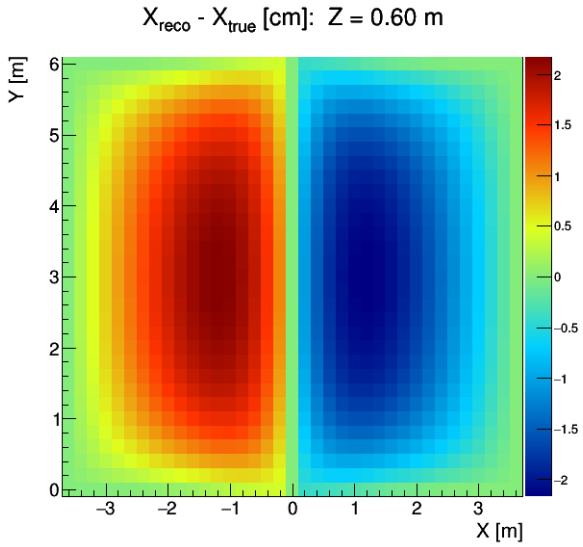
Using 4 mm/s "Run1" Map

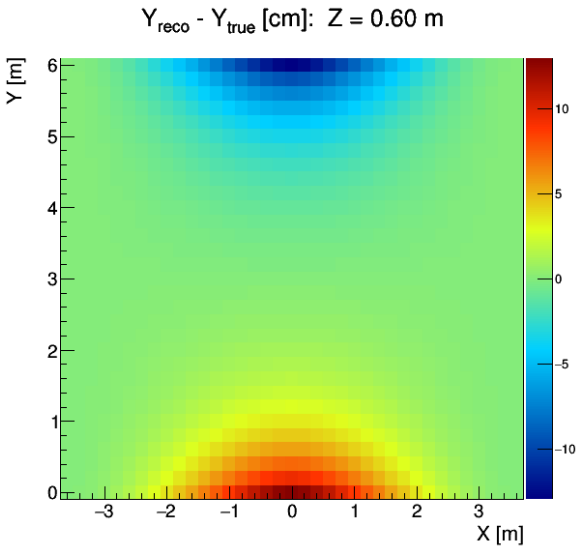


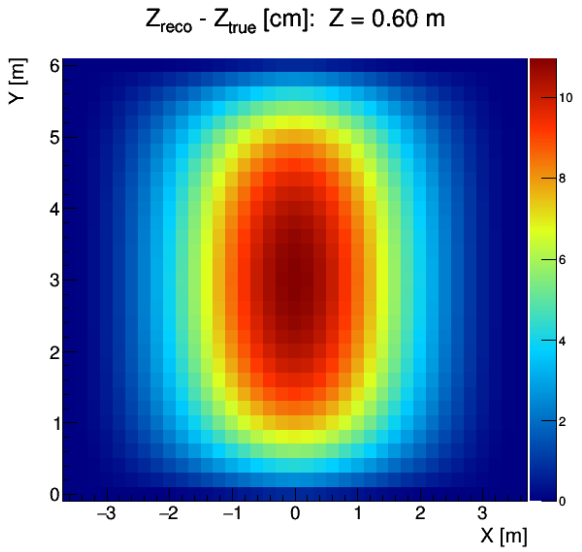


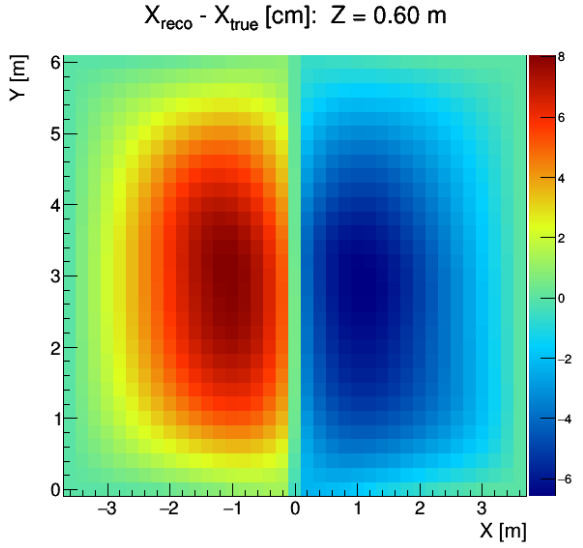


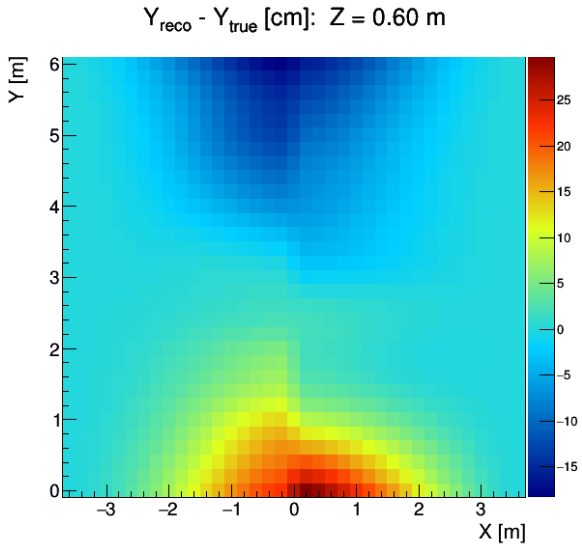
Vs. No Flow: Z = 0.6 m

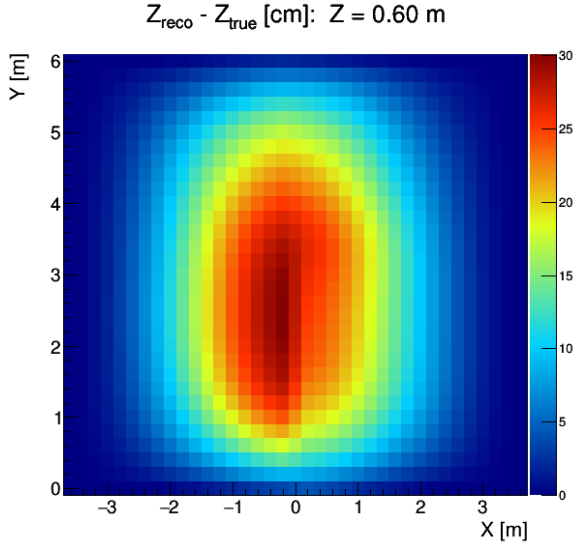




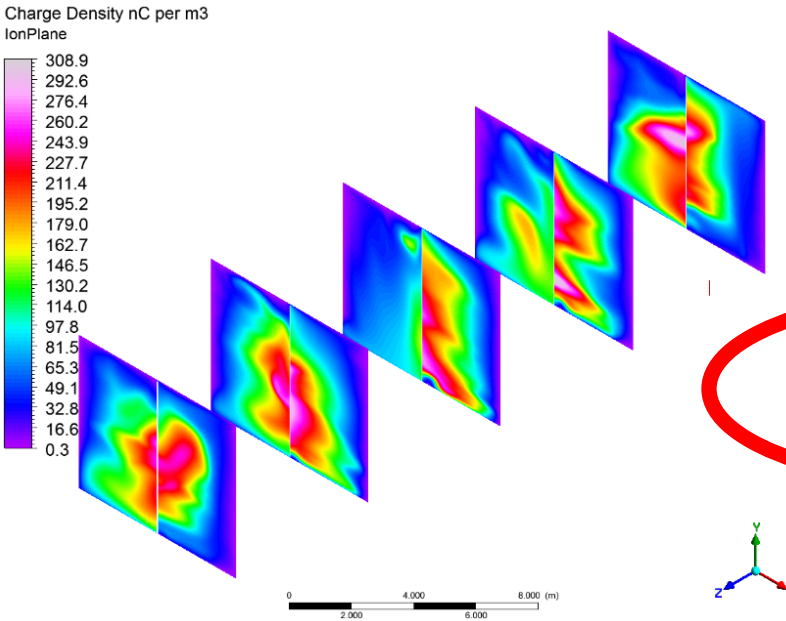




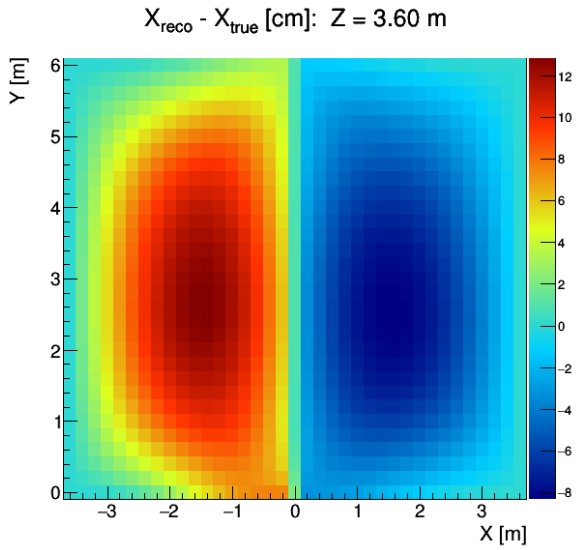


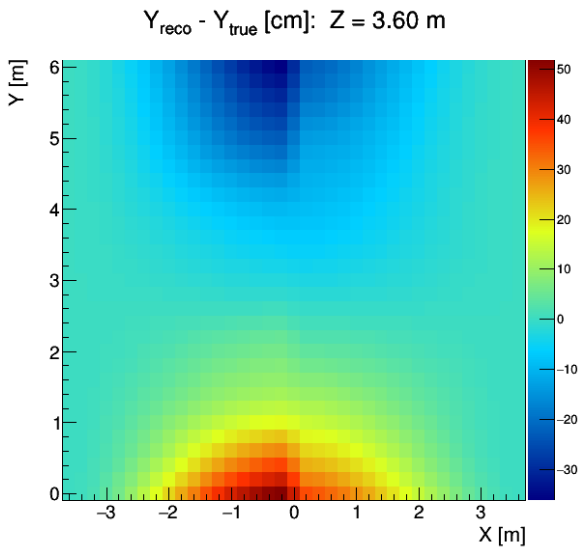


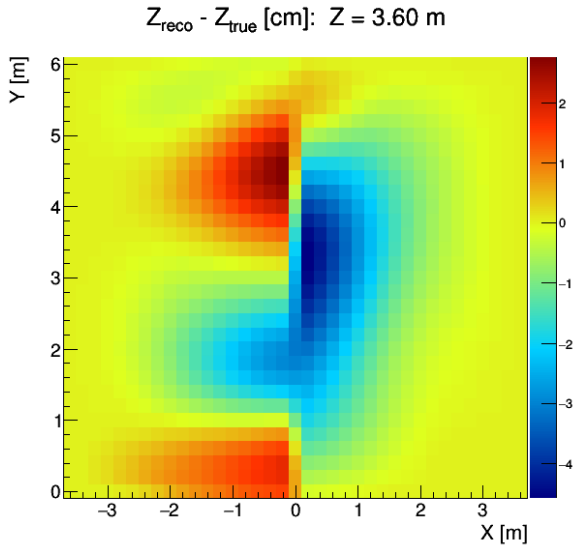
Spatial Offsets: Z = 3.6 m



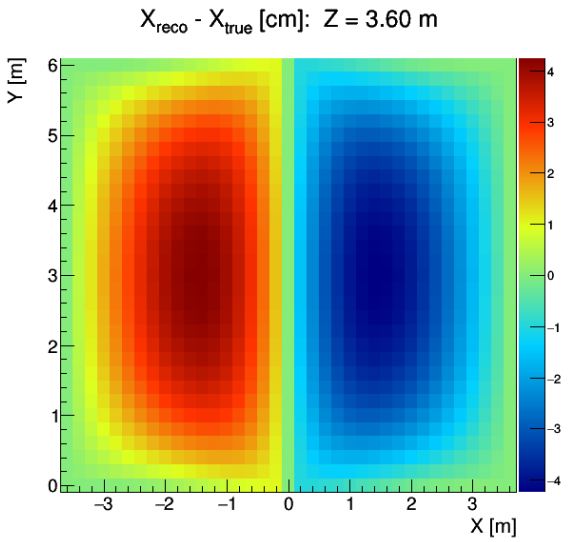
Using 4 mm/s "Run1" Map

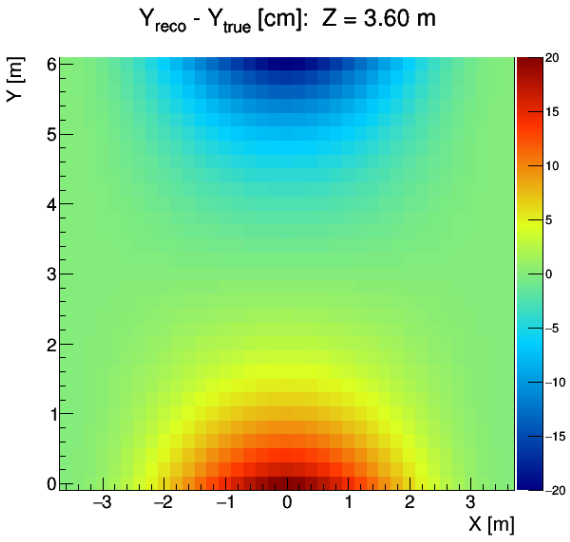


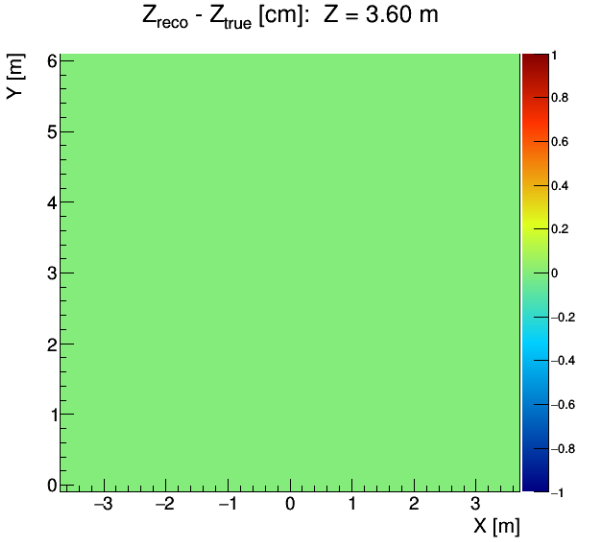


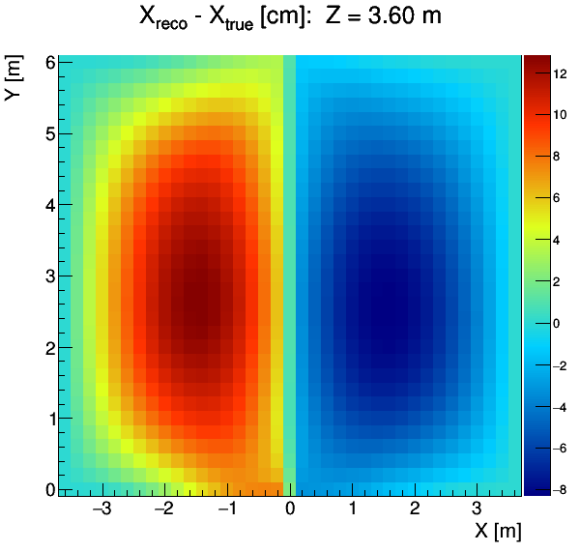


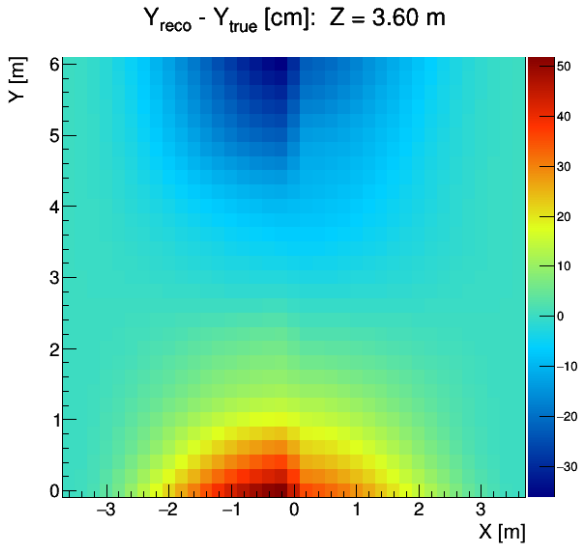
Vs. No Flow: Z = 3.6 m

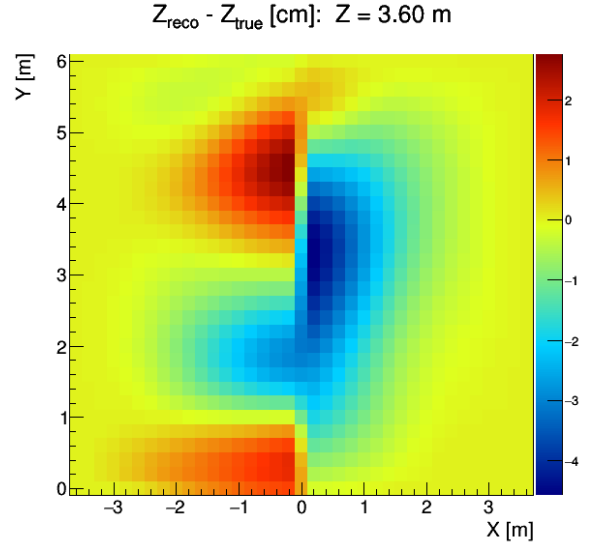




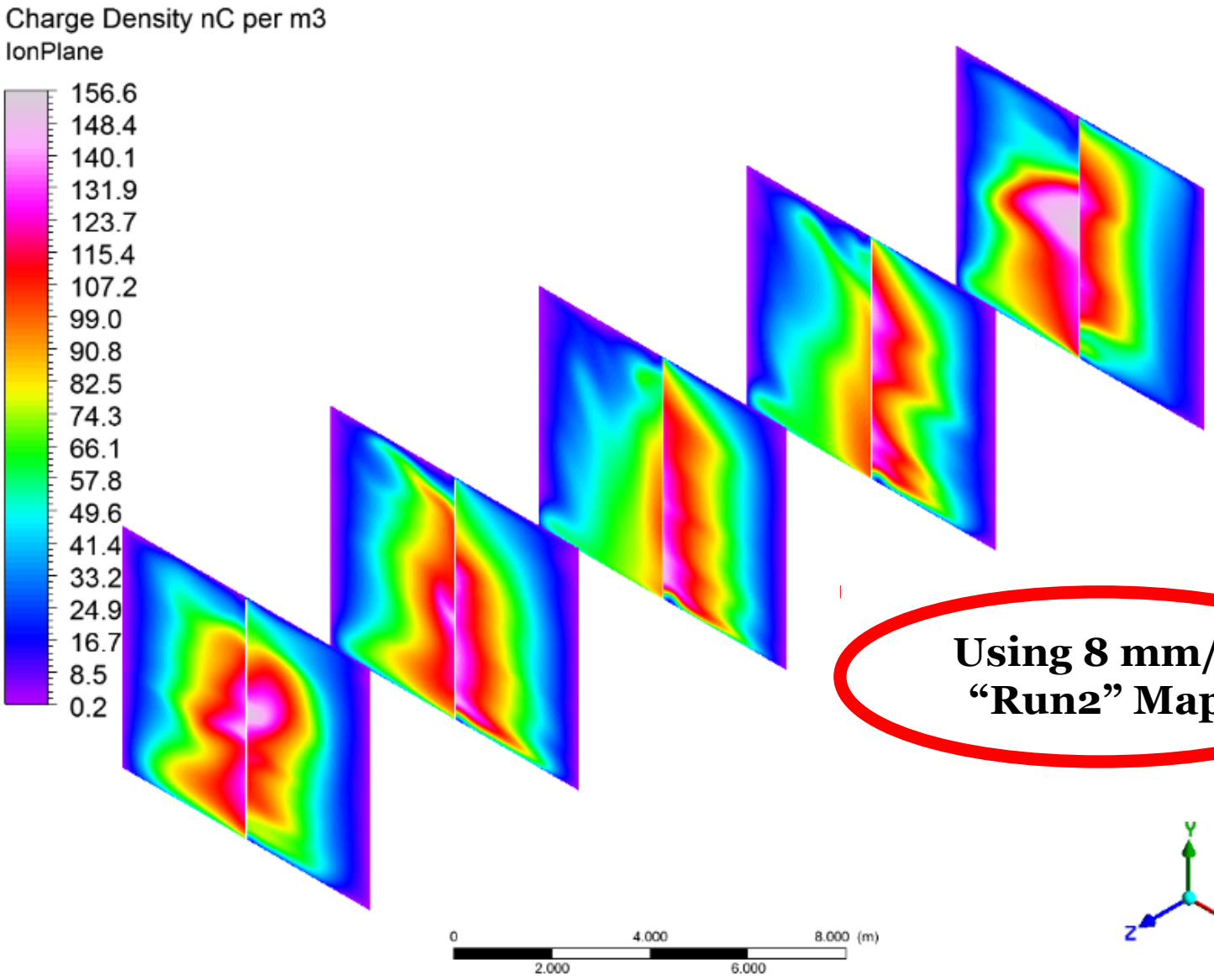






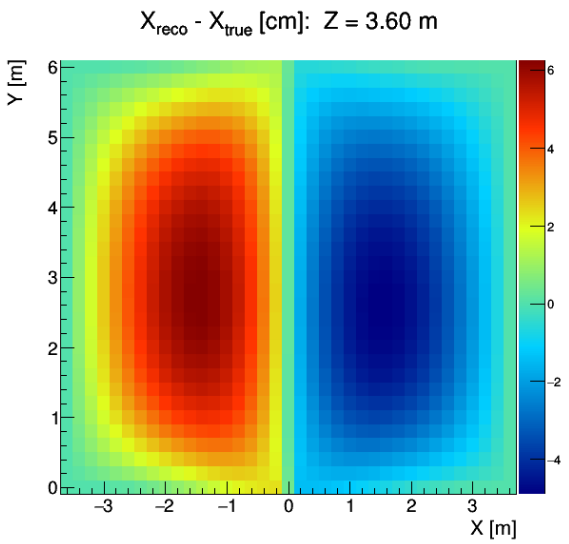


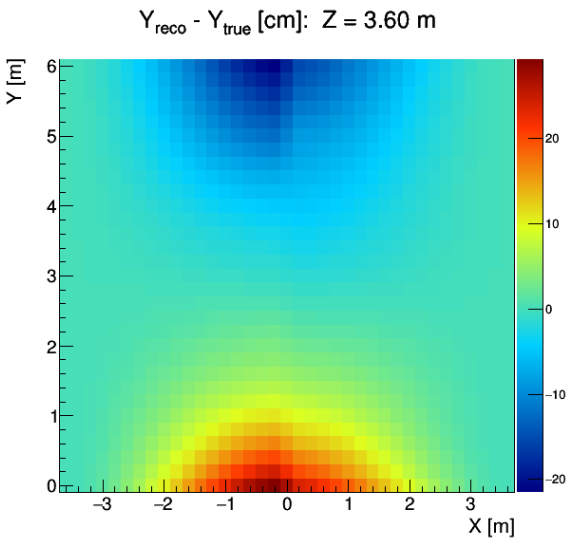
8 mm/s “Run2” Density Map

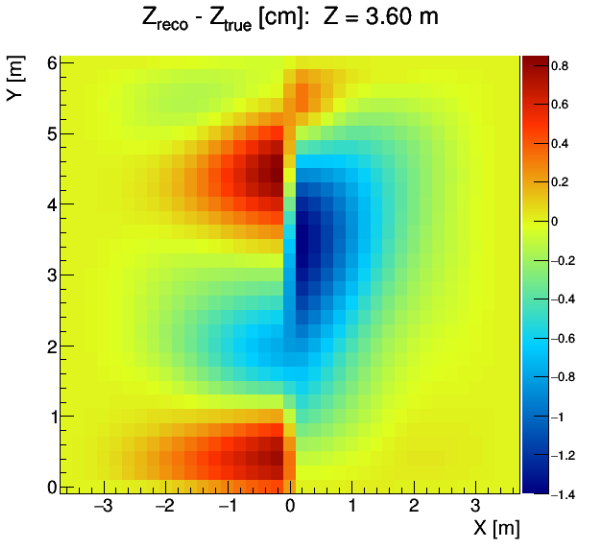


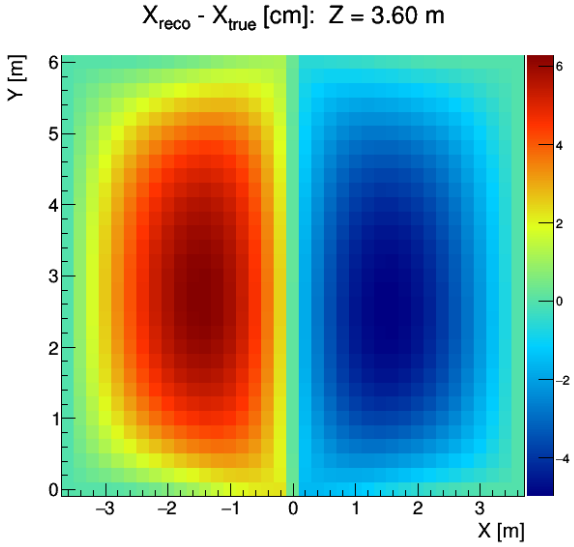
Using 8 mm/s “Run2” Map

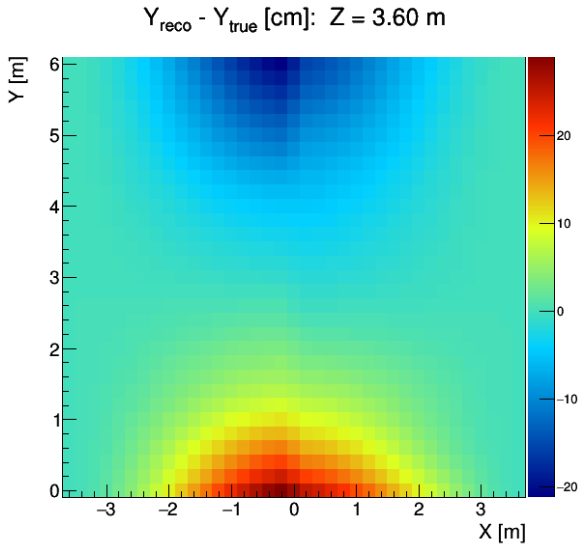
Run1 Vs. Run2: Z = 3.6 m

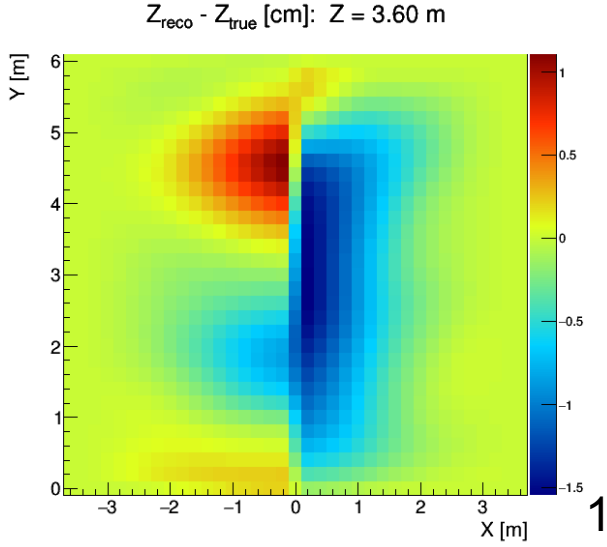




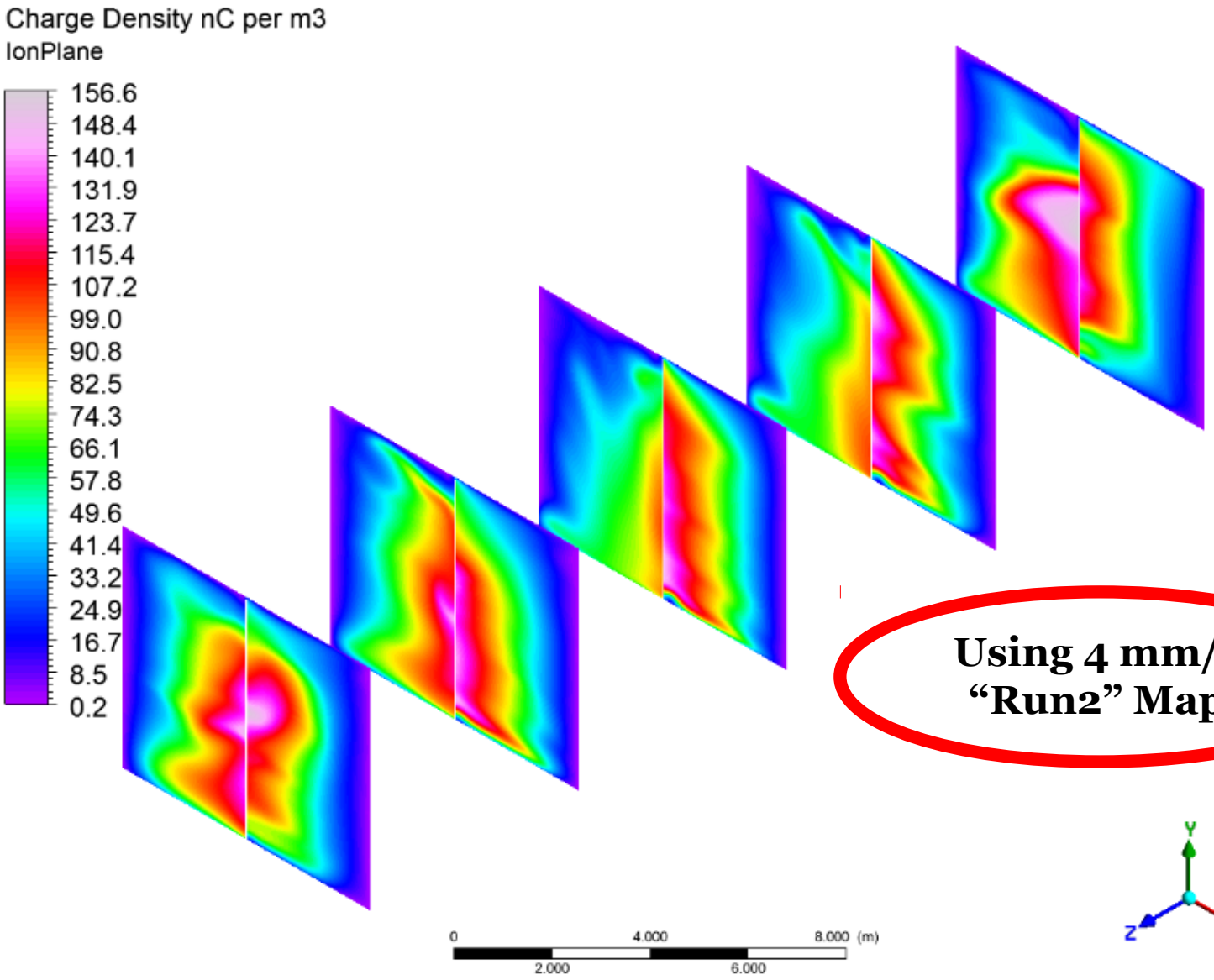






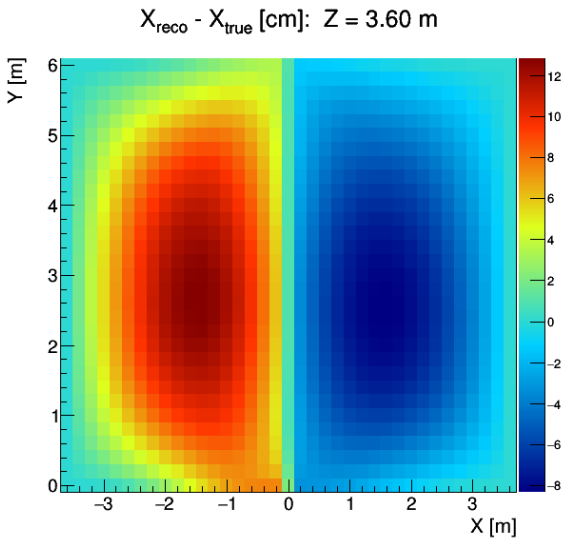


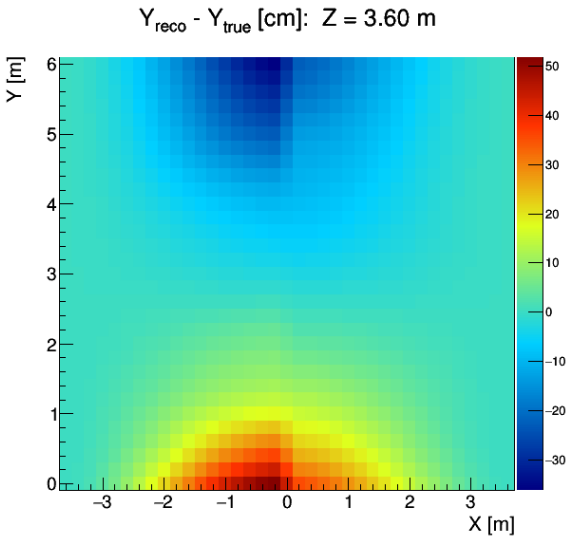
4 mm/s “Run2” Density Map

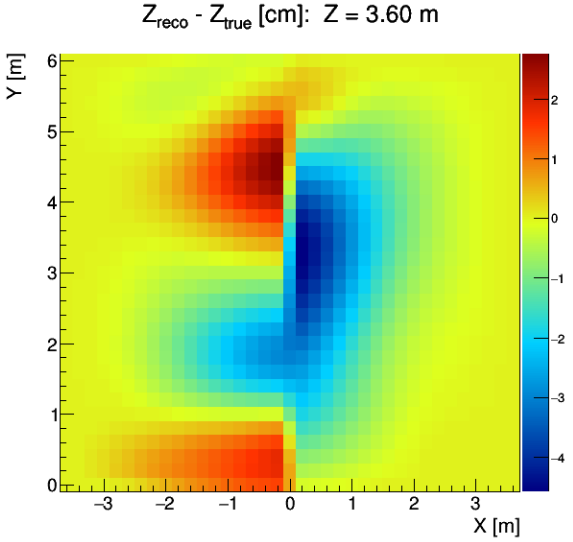


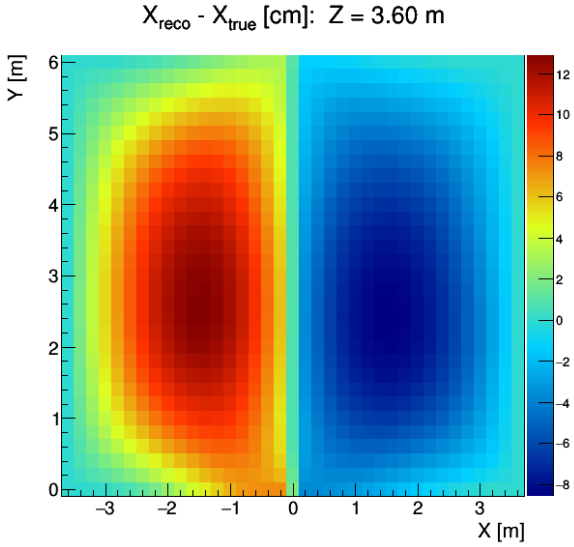
Using 4 mm/s “Run2” Map

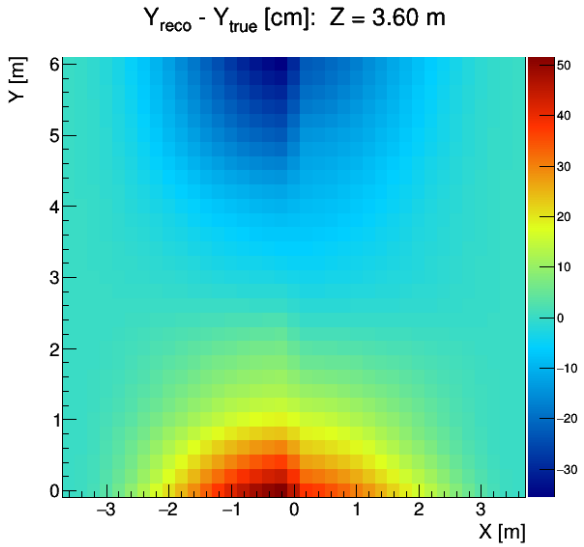
Run1 Vs. Run2: Z = 3.6 m

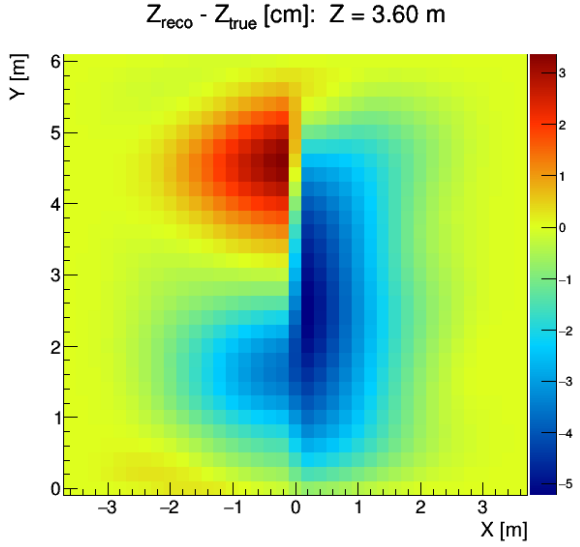




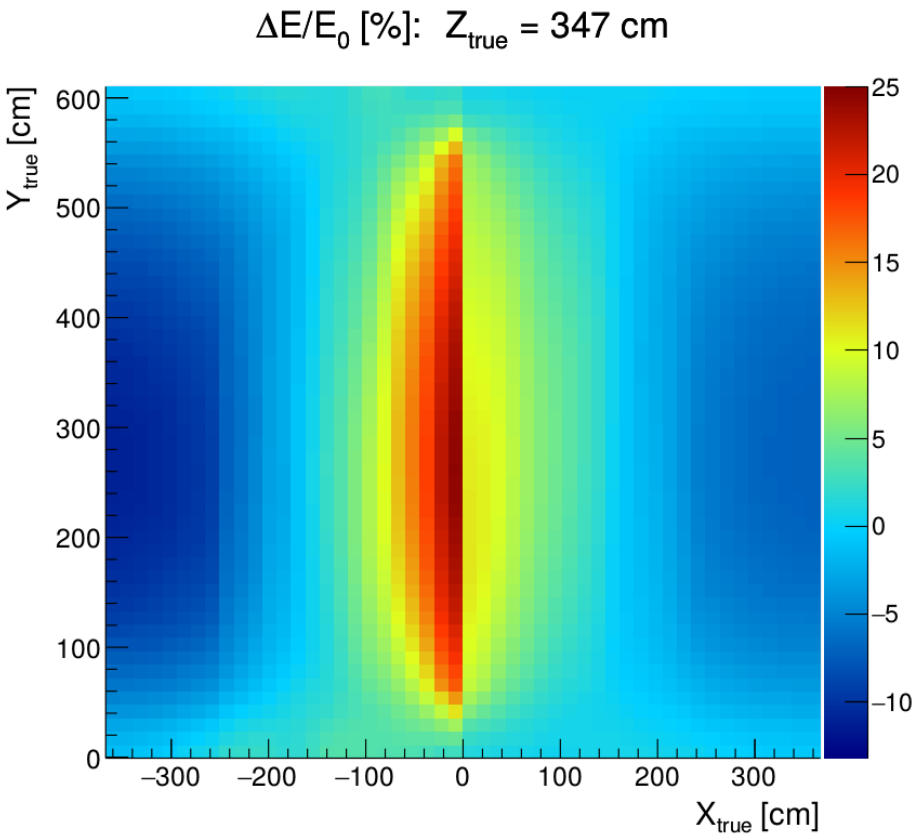


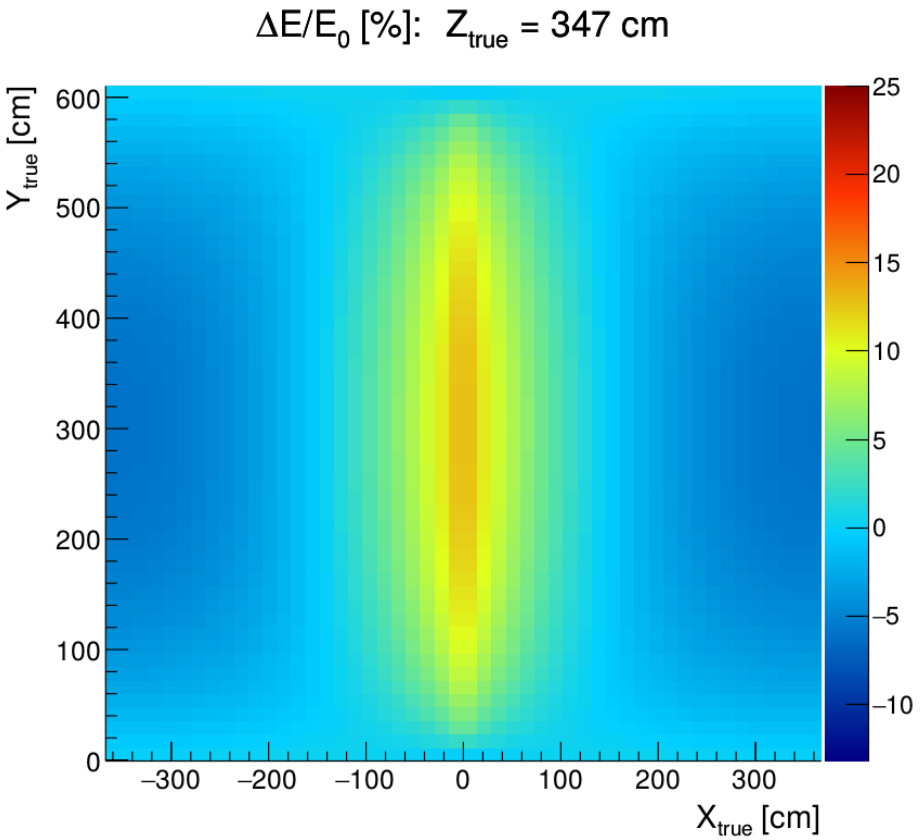






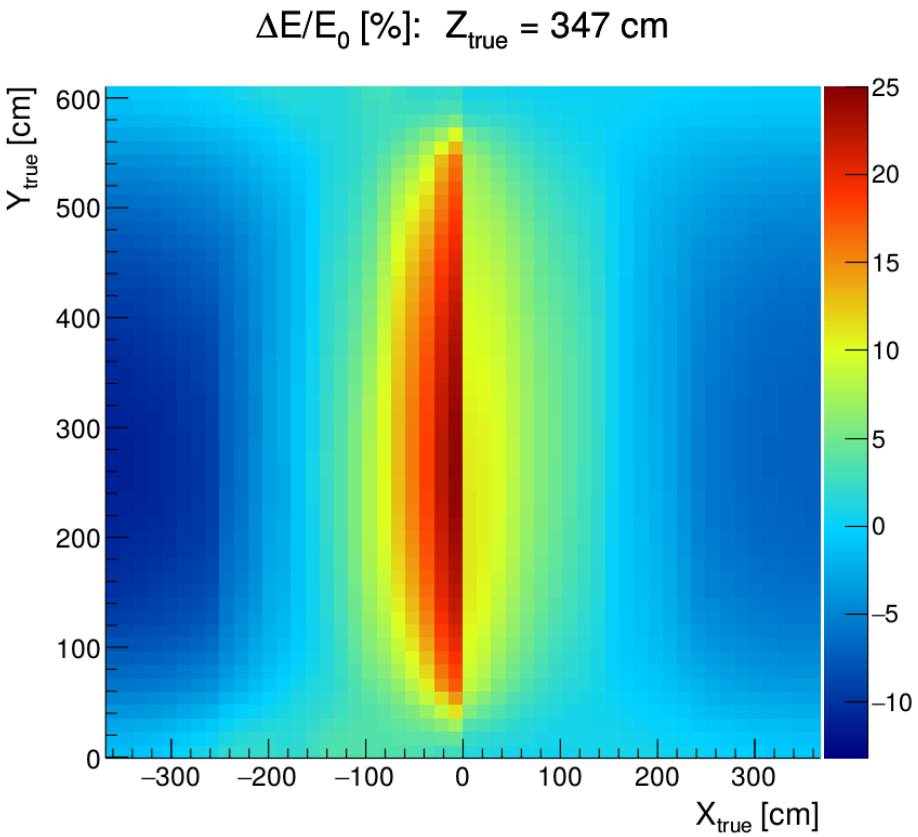
E Field: Data vs. No-Flow MC

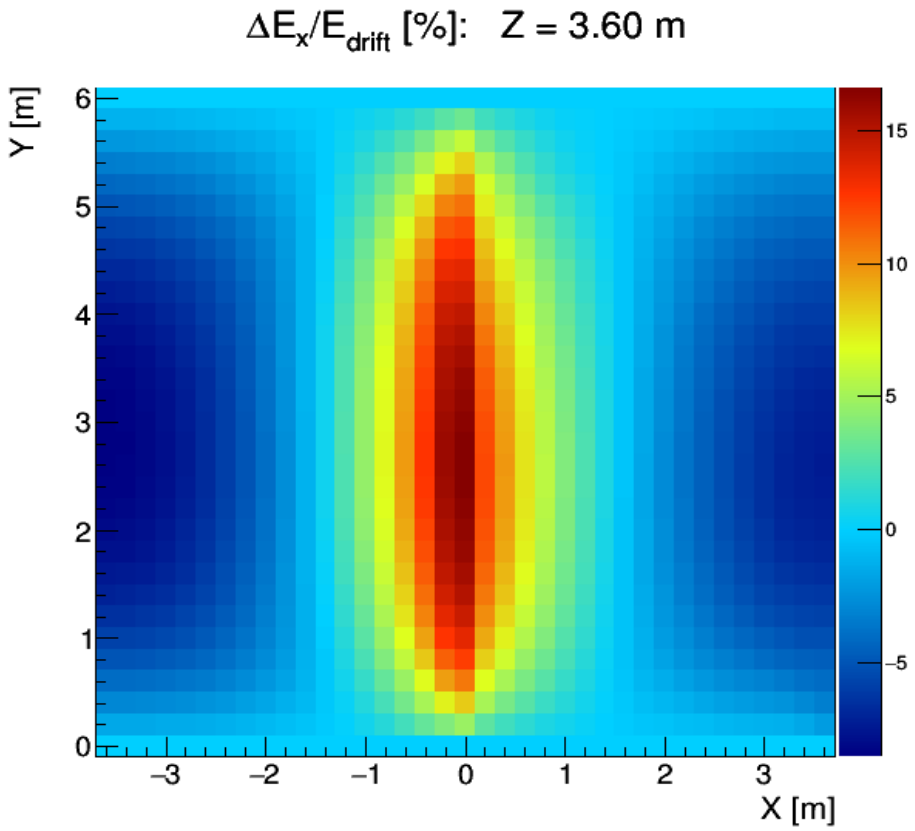




- Better agreement between data and MC for model w/ fluid flow – larger on side where beam comes in ("beam right")

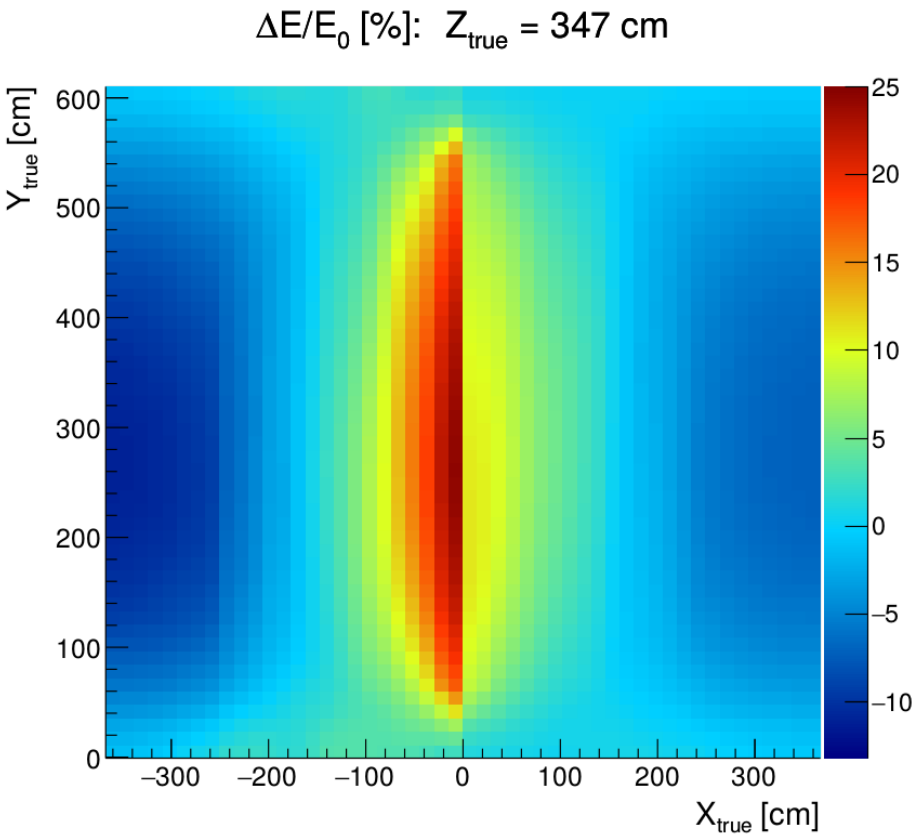
E Field: Data vs. Flow Sim. (8 mm/s)

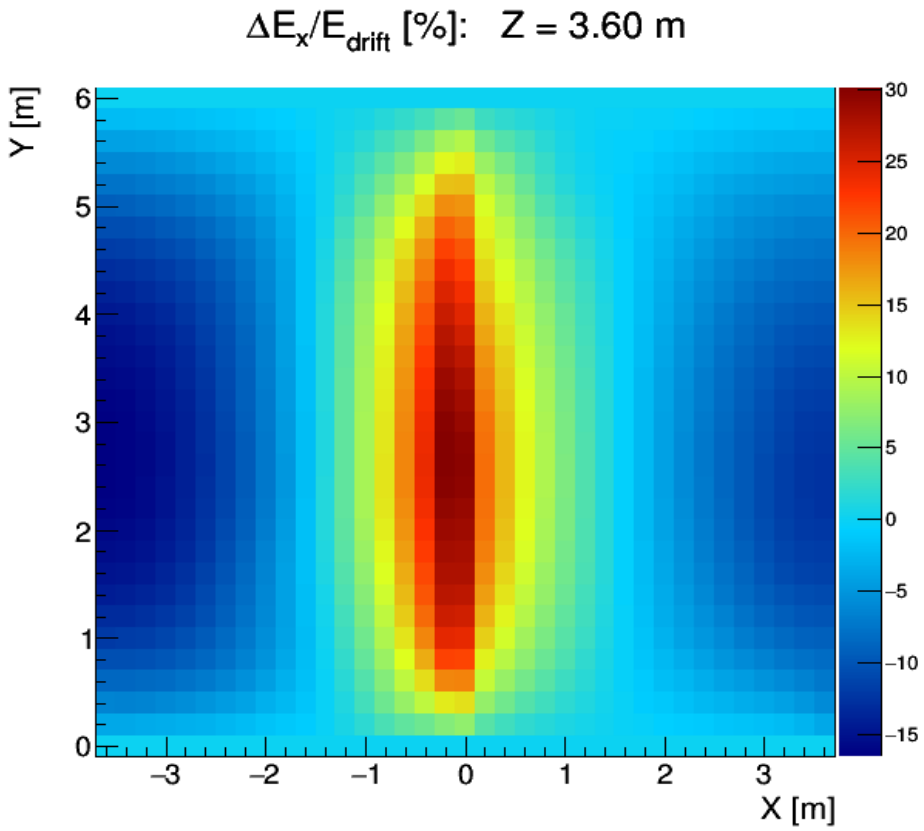




- Better agreement between data and MC for model w/ fluid flow – larger on side where beam comes in (“beam right”)

E Field: Data vs. Flow Sim. (4 mm/s)





- Better agreement between data and MC for model w/ fluid flow – larger on side where beam comes in ("beam right")

Discussion

- Erik Voirin updated fluid simulation, Mike M. produced new SCE simulation (spatial and E field) using new space charge density maps
- Seems to be better agreement between MC and data now
  - Spatial and E field distortions larger on "beam right" side, as in data
  - Spatial offsets larger at TPC bottom, as in data
- Several things changed:
  - Coordinate system fixed
  - Ion deposition rate increased to 1900 ions/cm^3/s (though this may need to drop to **1400** ions/cm^3/s given studies by D. Adams et al.)
  - Multiple ion drift velocities studied – 8 mm/s and 4 mm/s
- Request: generate small cosmics MC samples with new SCE simulation – 100k events for a few variations of SCE maps?

BACKUP SLIDES