

# Studying Track Distortions From the Space Charge Effect With MicroBooNE

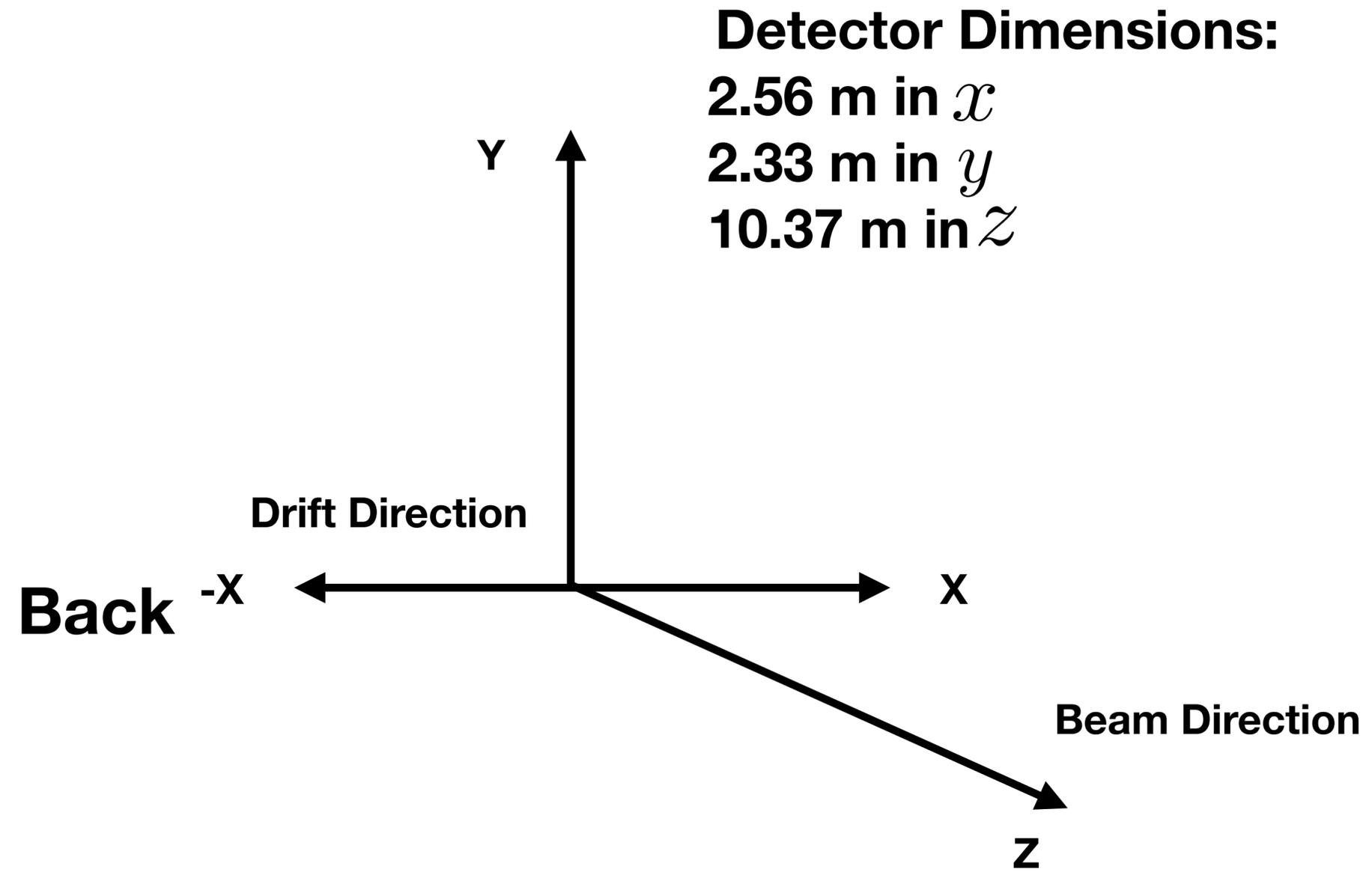
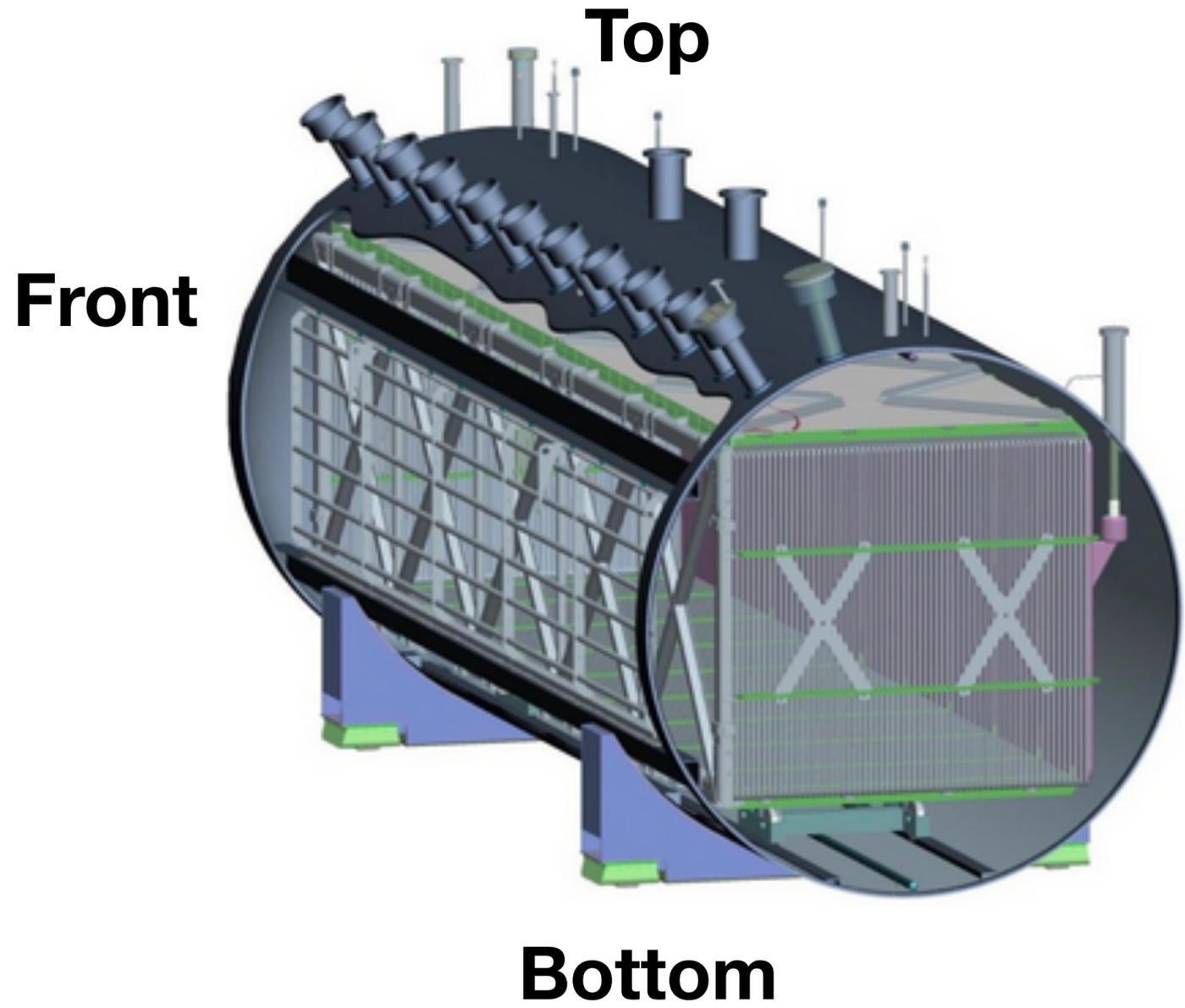
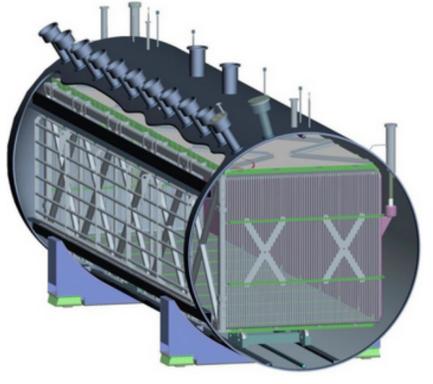
Christopher Barnes  
University of Michigan

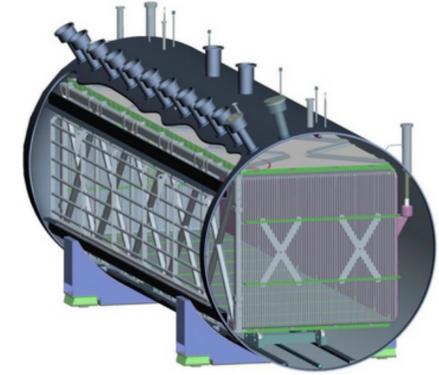
2018 New Perspectives Conference  
Batavia, IL





# Method of Measuring Track Distortions From SCE





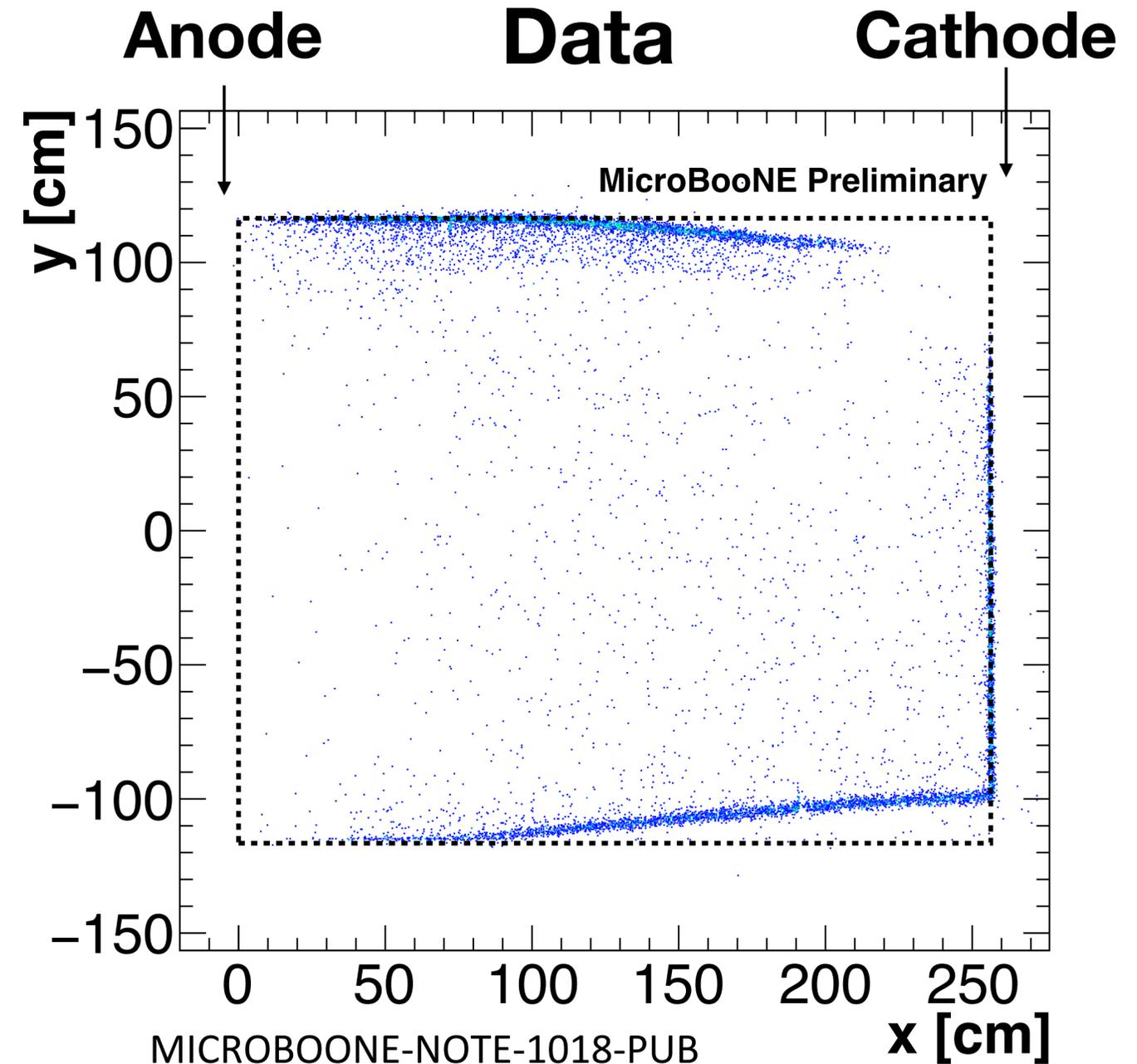
# Space Charge Effect (SCE)

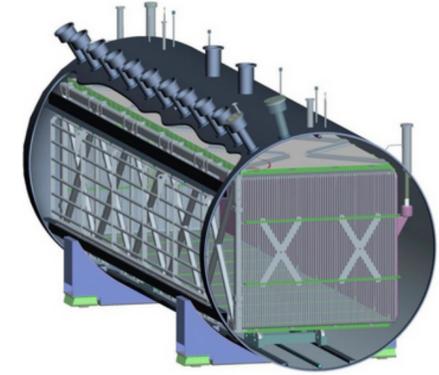


**SCE is caused by positive ions which are flowing towards the cathode.**

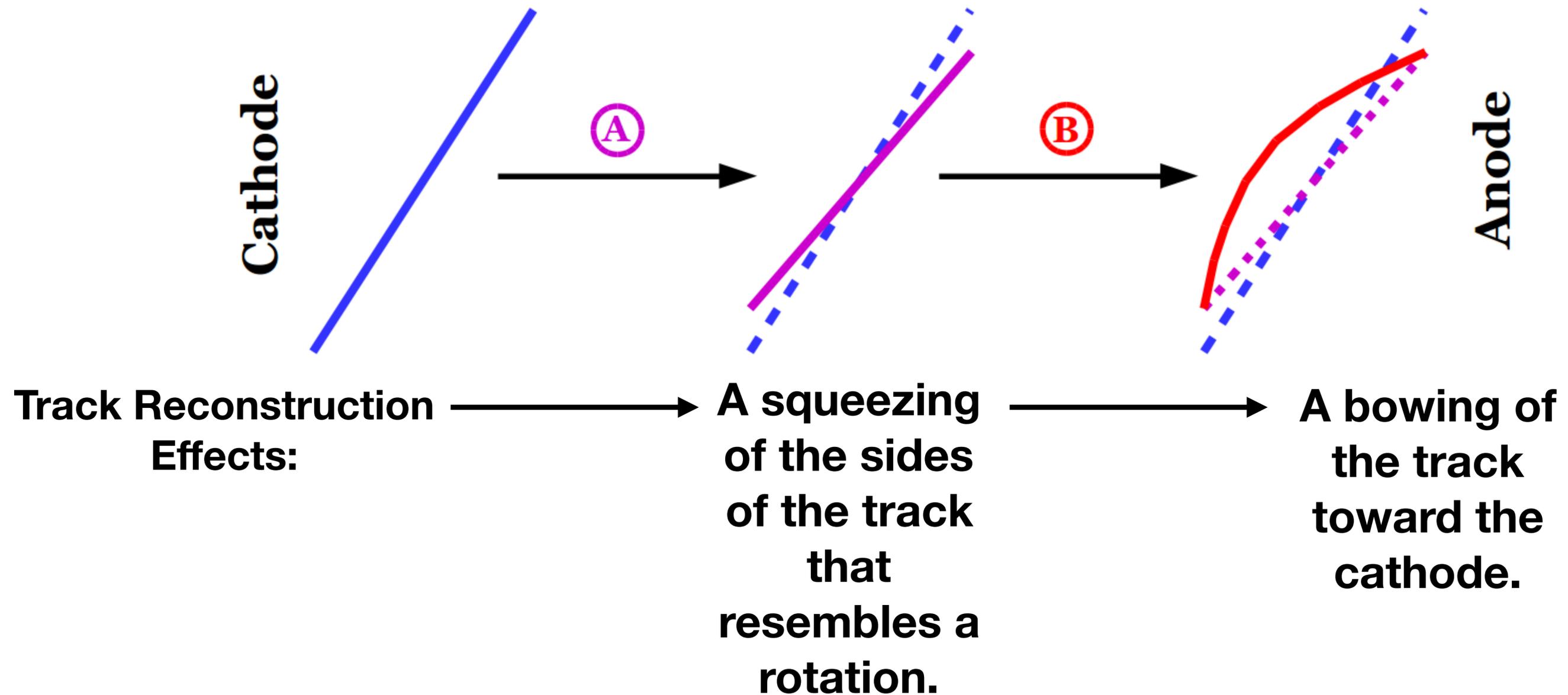
**Electric Field Distortions Of Up To 15%.**

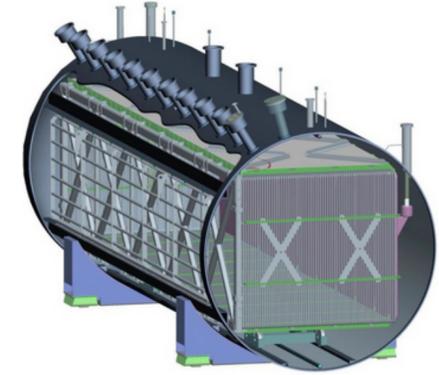
**Maximum Track Distortions of Up To 18 cm.**





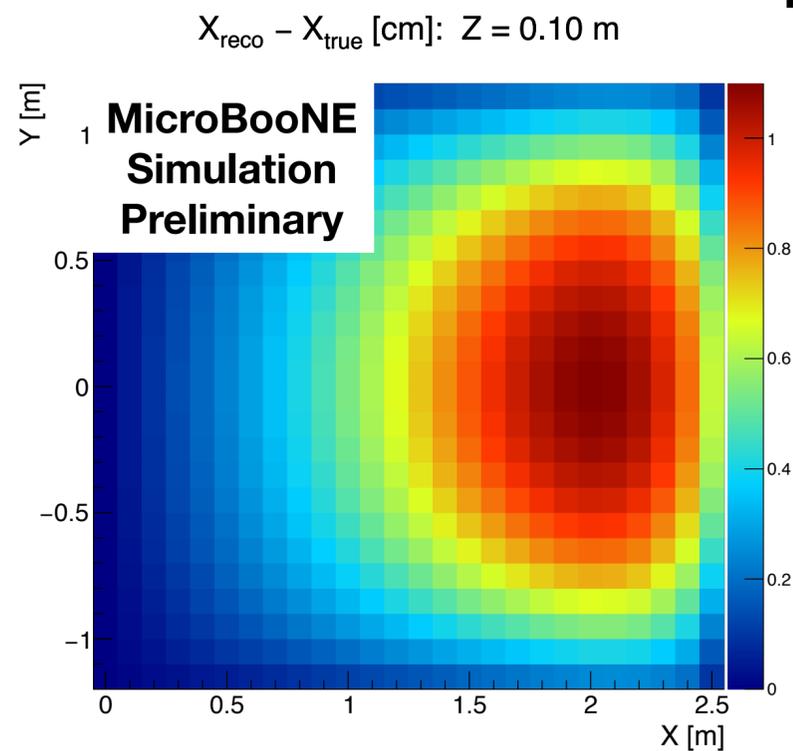
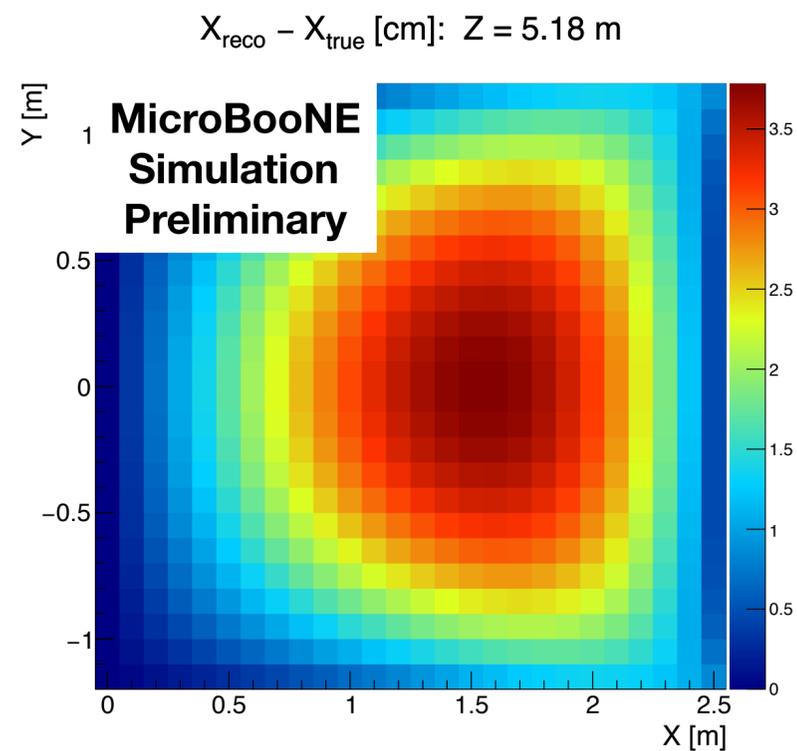
# Effects of SCE on Track Reconstruction



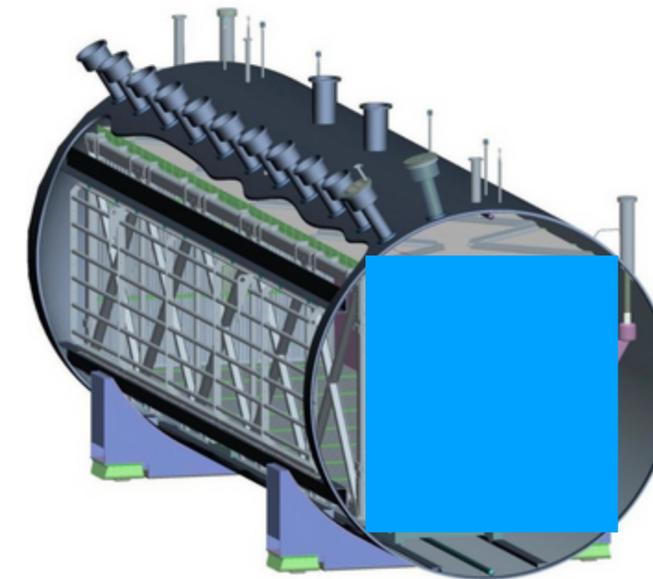


# Simulation of Space Charge Effects

Effects on track reconstruction from space charge effects were integrated into our last simulation campaign (Early 2017).

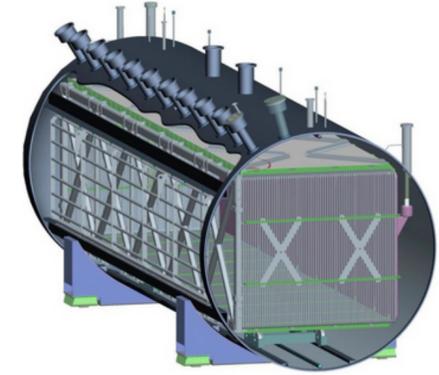


**Note the different color scales of the plots!**

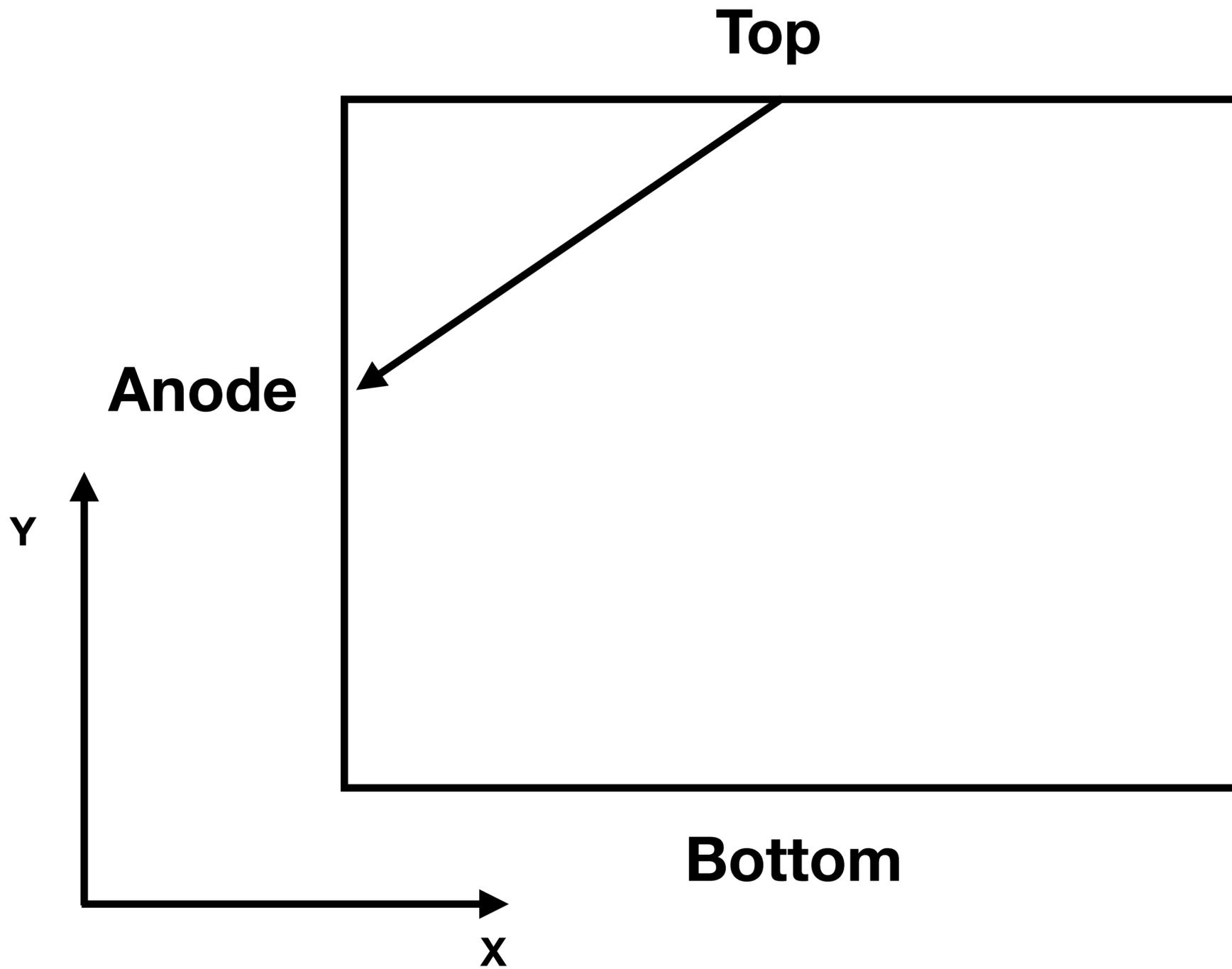


MicroBooNE Public Note: <http://microboone.fnal.gov/wp-content/uploads/MICROBOONE-NOTE-1018-PUB.pdf>

(November 29th, 2016)



# Cosmic Ray Muon Tracks

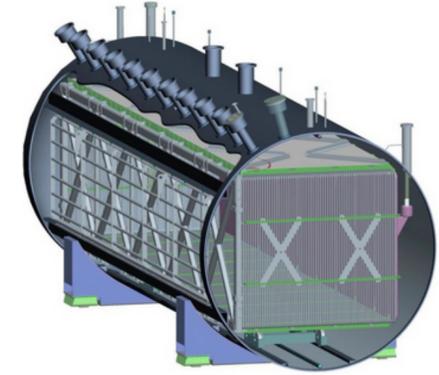


**An example cosmic ray muon track that pierces the top and anode of the TPC.**

**Cathode**

**All four permutations of top/bottom with each side contribute tracks.**

**Permutations of front/back with each side contribute tracks.**



# Cosmic Ray Muon Tracks

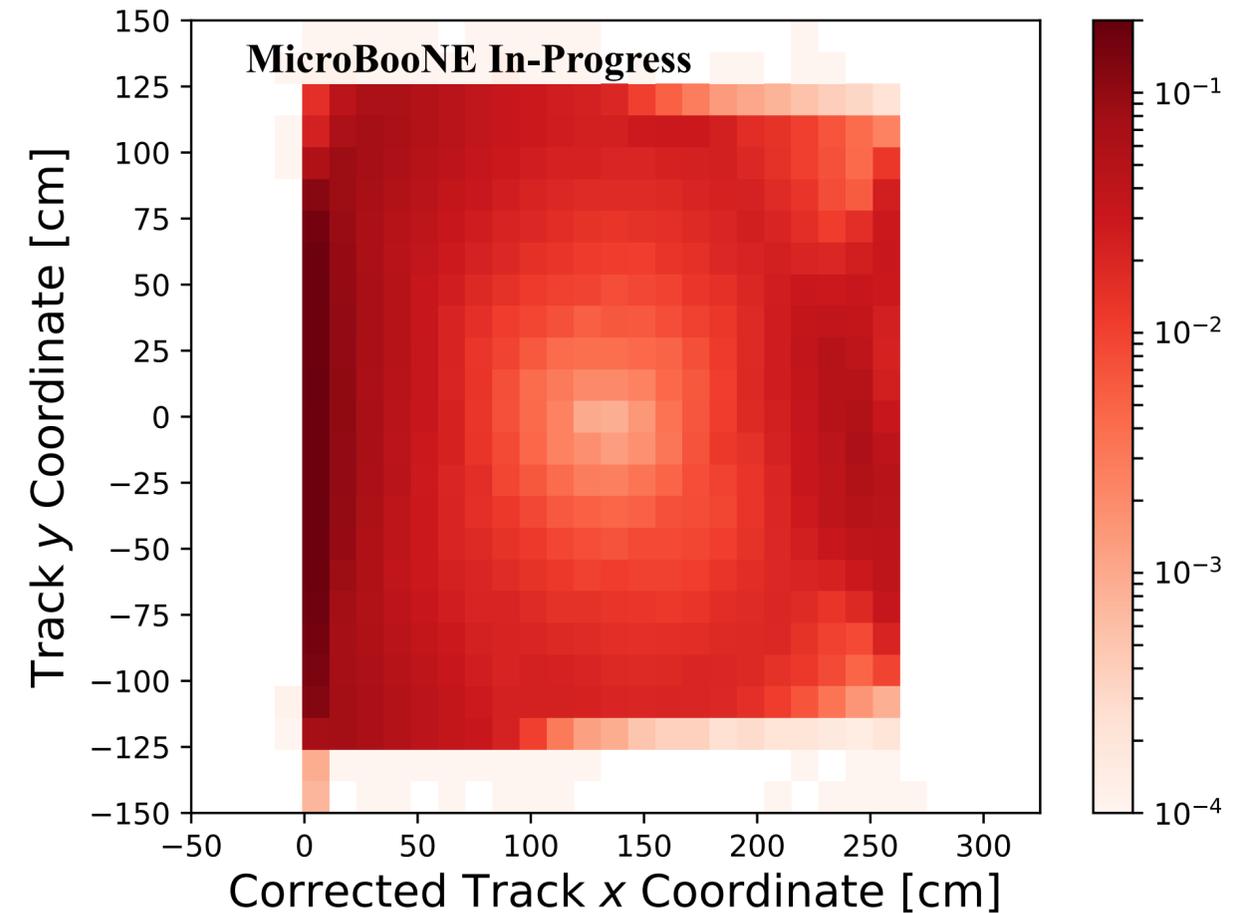
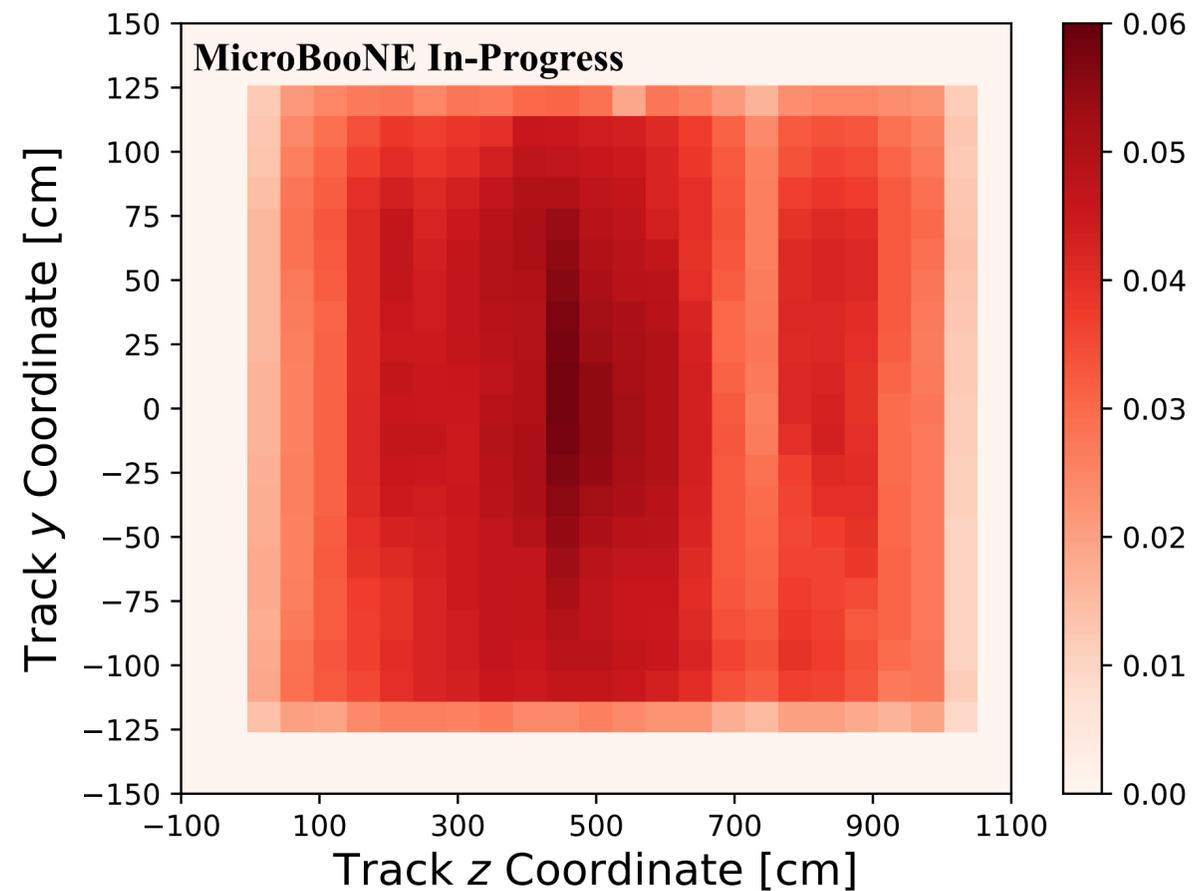


**Y vs. Z**

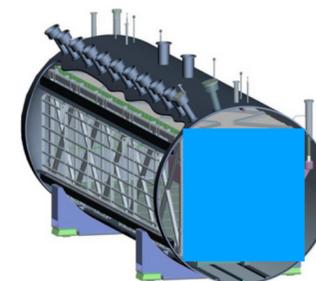
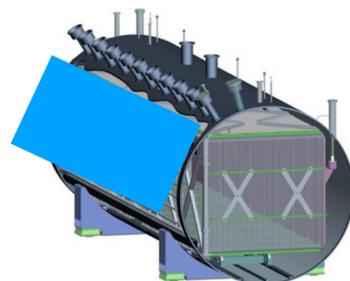
**Efficiency [Tracks/Event]**

**Y vs. X**

**Efficiency [Tracks/Event]**



**Note the different axis/colorbar scales in comparing these plots.**



**A sample of tracks with complete 3D positional information is necessary for an SCE study.**

# Spatial Dependence Study: Top

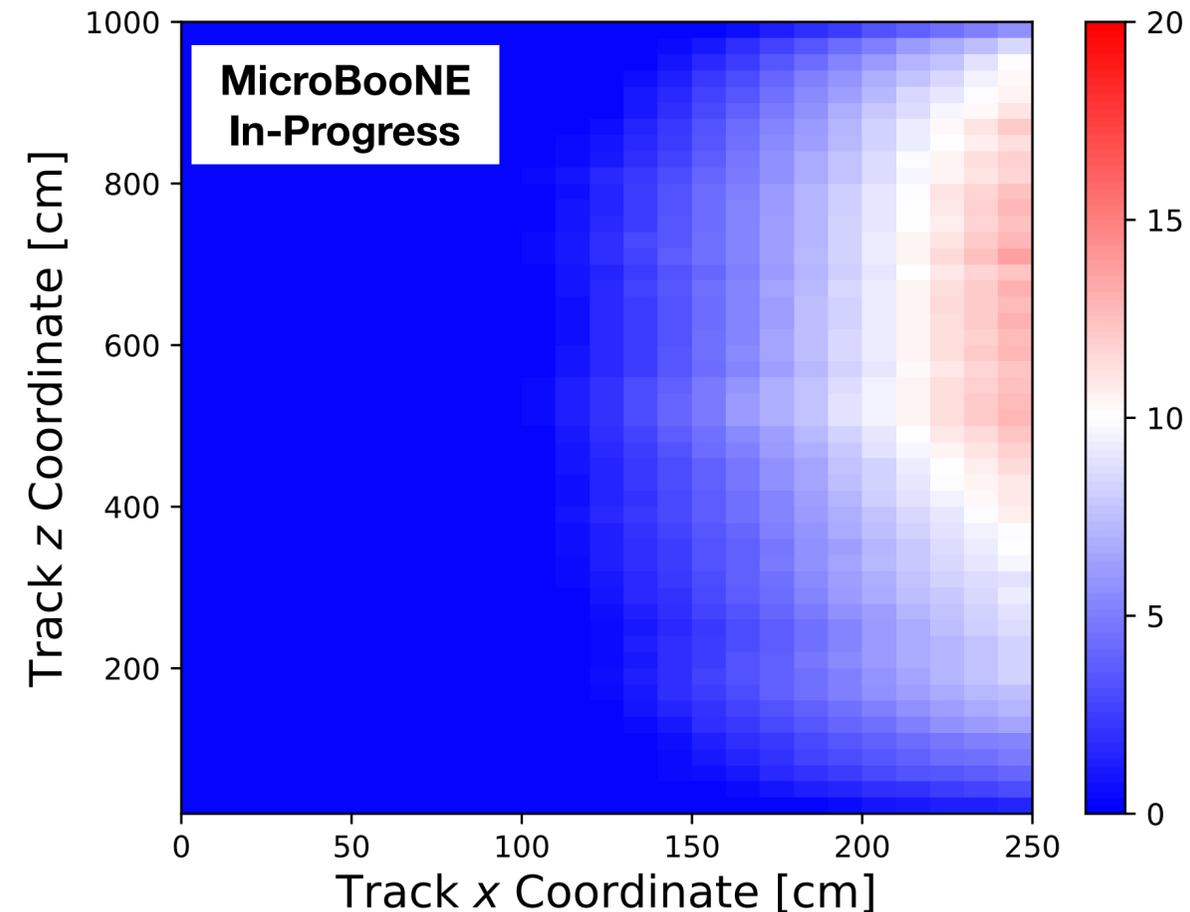
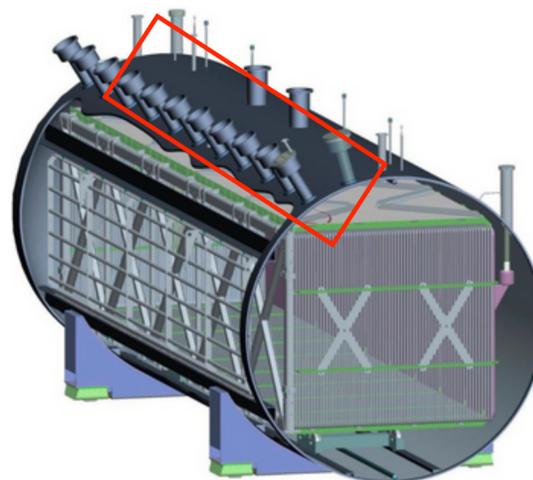
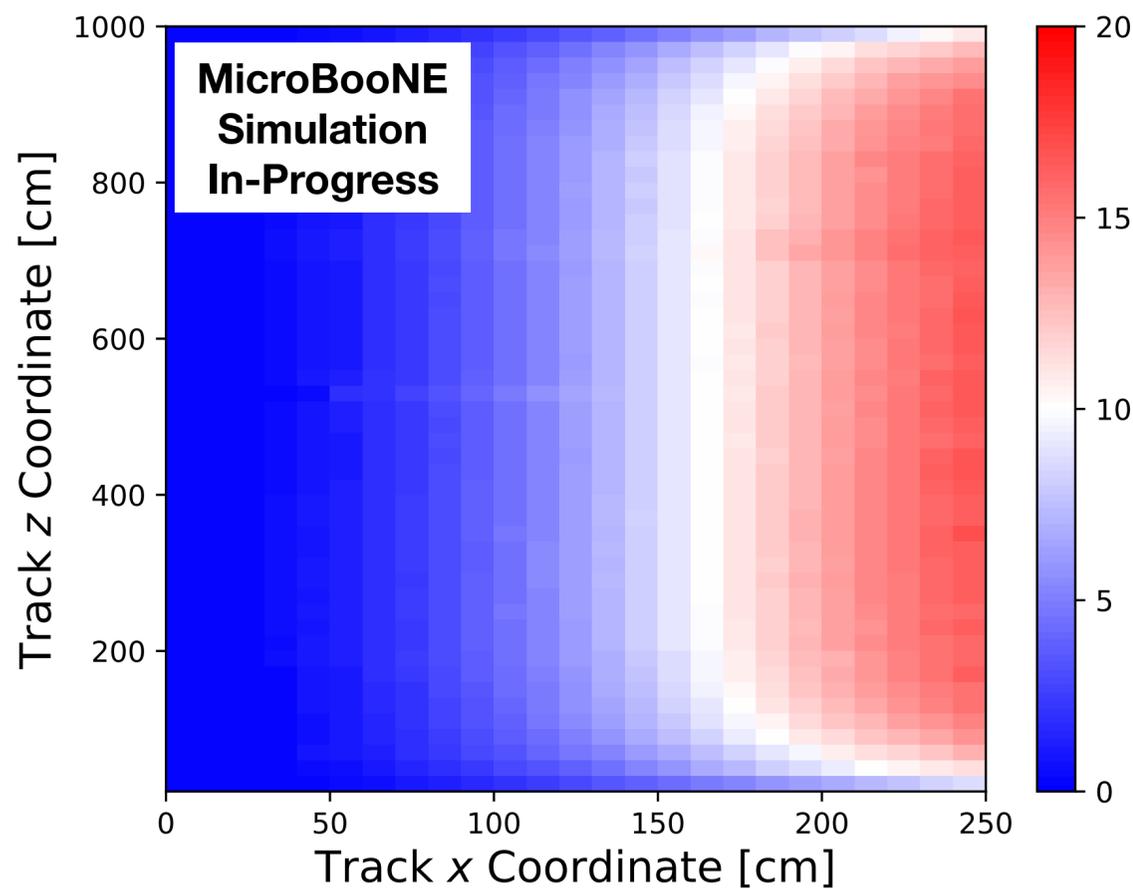


**Simulation**

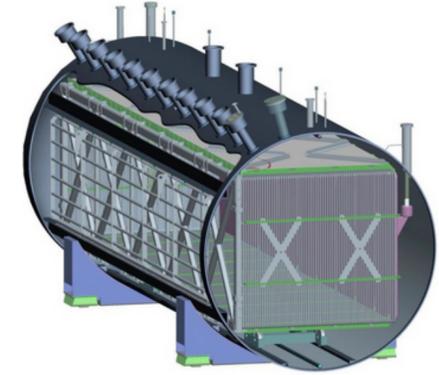
**Data**

**Track Distortion From TPC Face [cm]**

**Track Distortion From TPC Face [cm]**



**The differences between reconstructed data and reconstructed simulation can possibly be attributed to variations in argon flow in certain regions of the detector.**

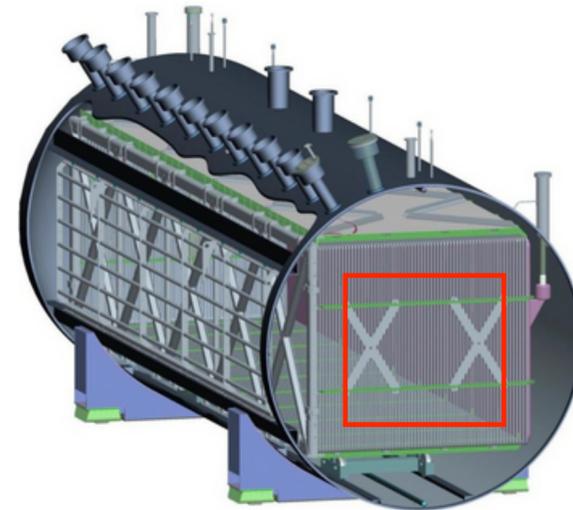
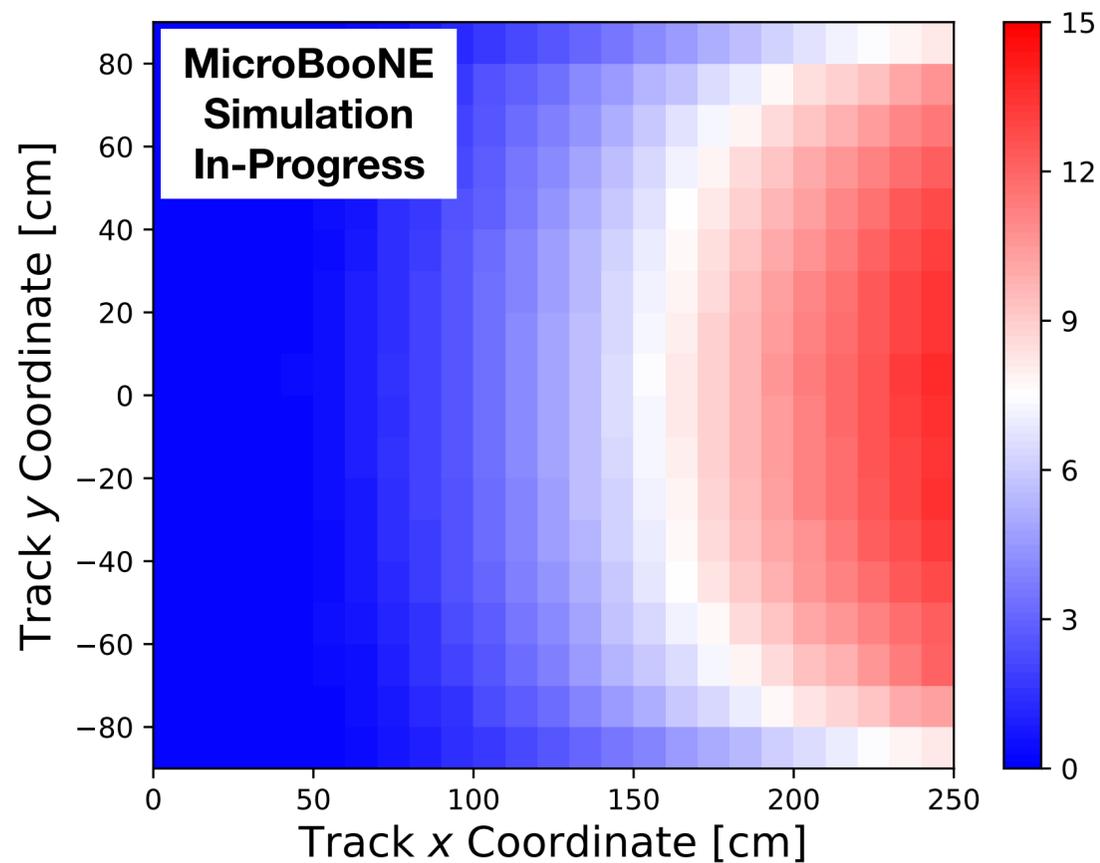


# Spatial Dependence Study: Front



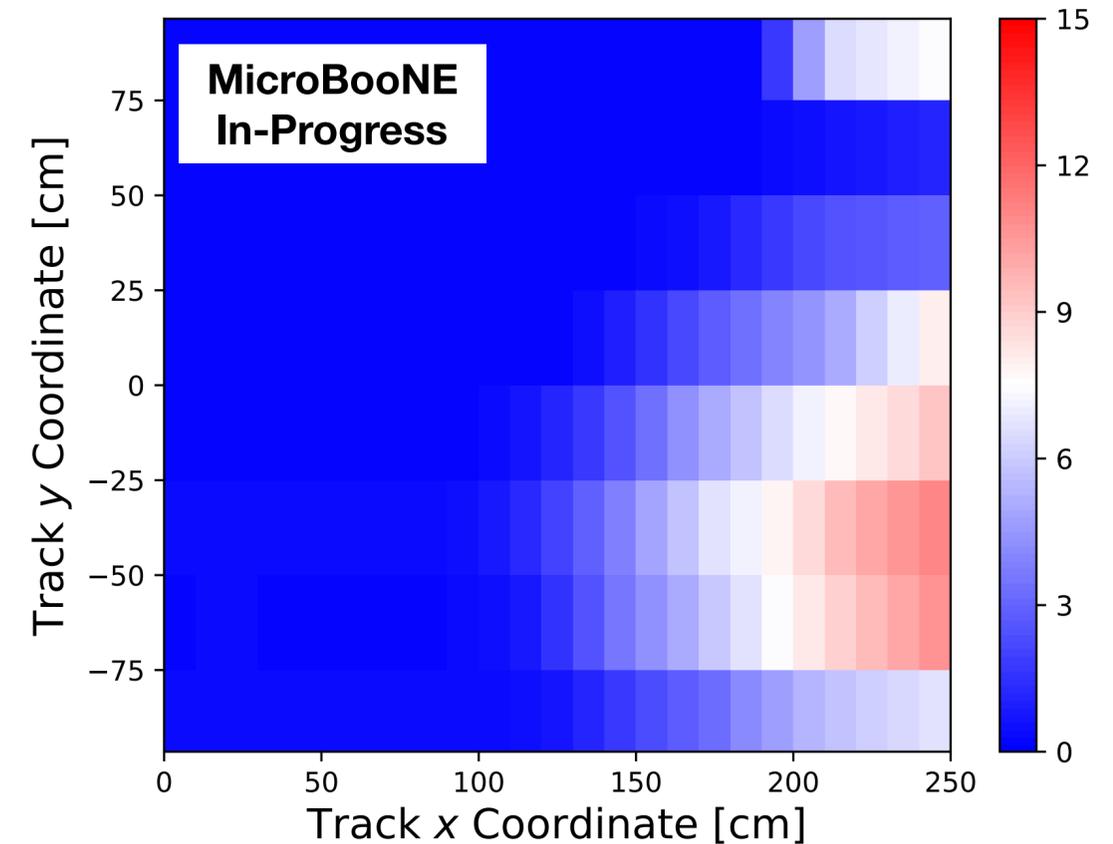
## Simulation

Track Distortion From TPC Face [cm]



## Data

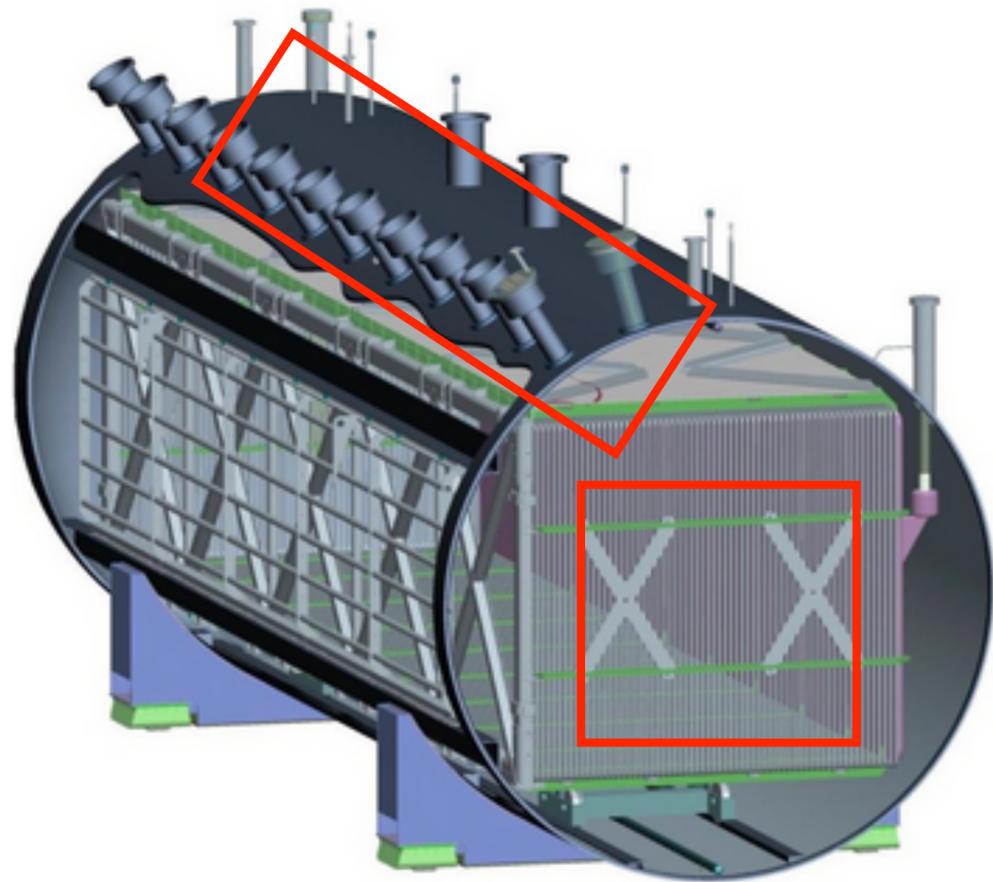
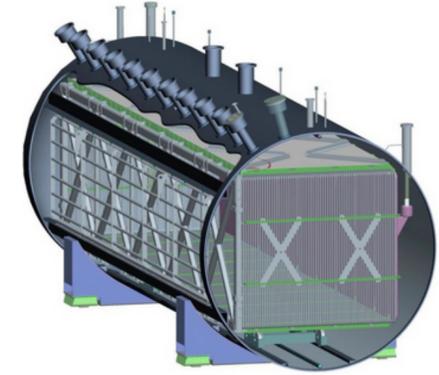
Track Distortion From TPC Face [cm]



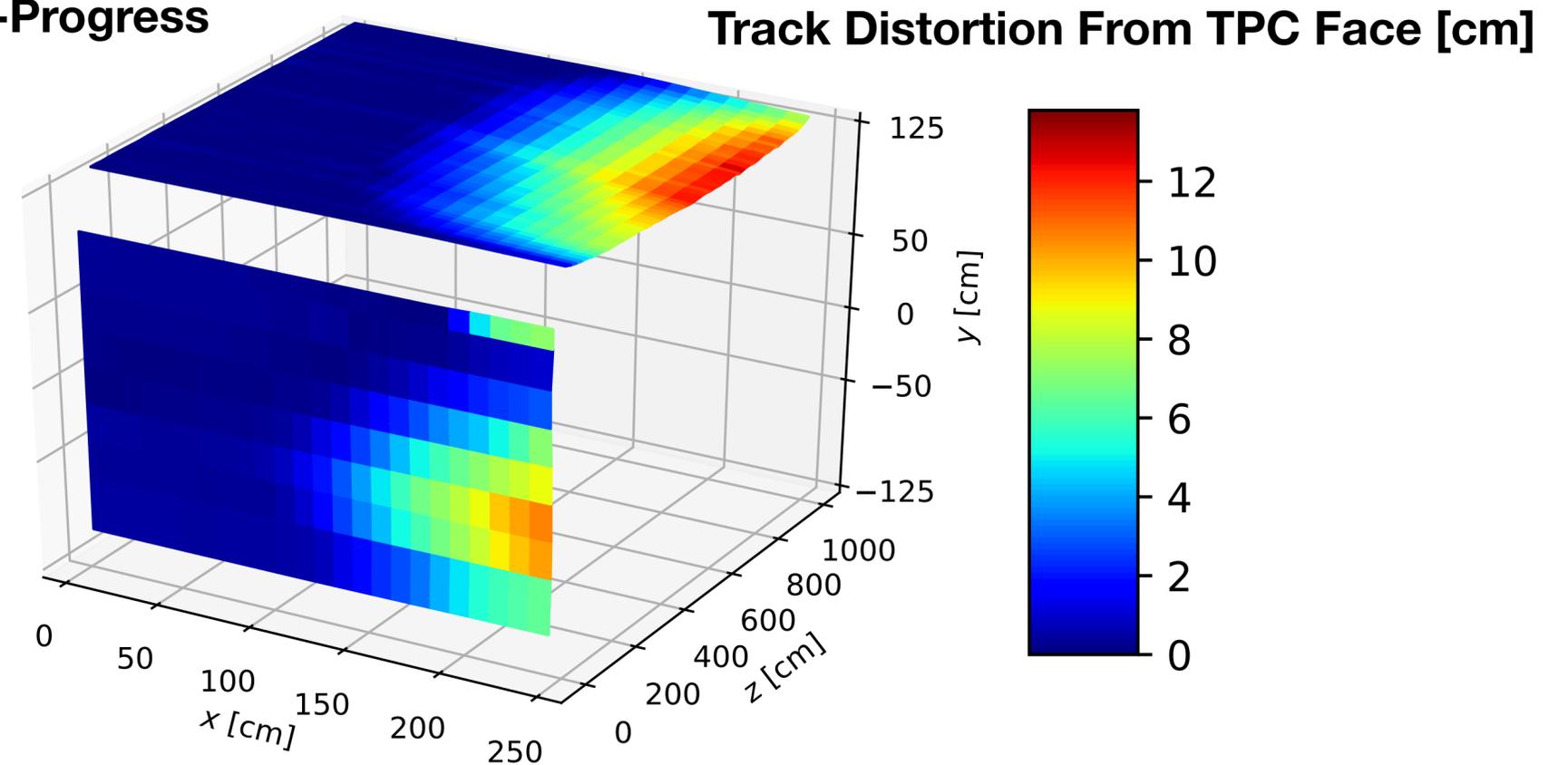
The lesser amount of track distortions due to SCE at the detector front seen in the previous two slides is seen in the righthand plot.



# Spatial Dependence Study: Interface Distortion Comparison

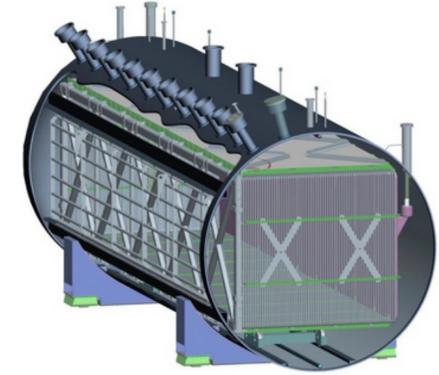


MicroBooNE  
In-Progress



This view of the track distortions due to SCE at the top and front of the detector display:

1. The lack of track distortions due to SCE at the top/front of the detector (not predicted by simulation).
2. The greater magnitude of the track distortions at the top of the detector vs. the front (predicted by simulation).

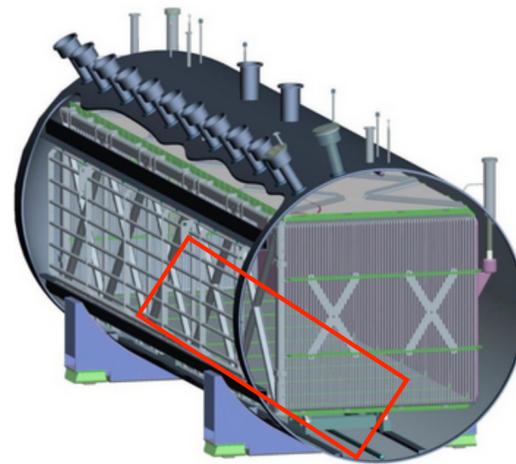
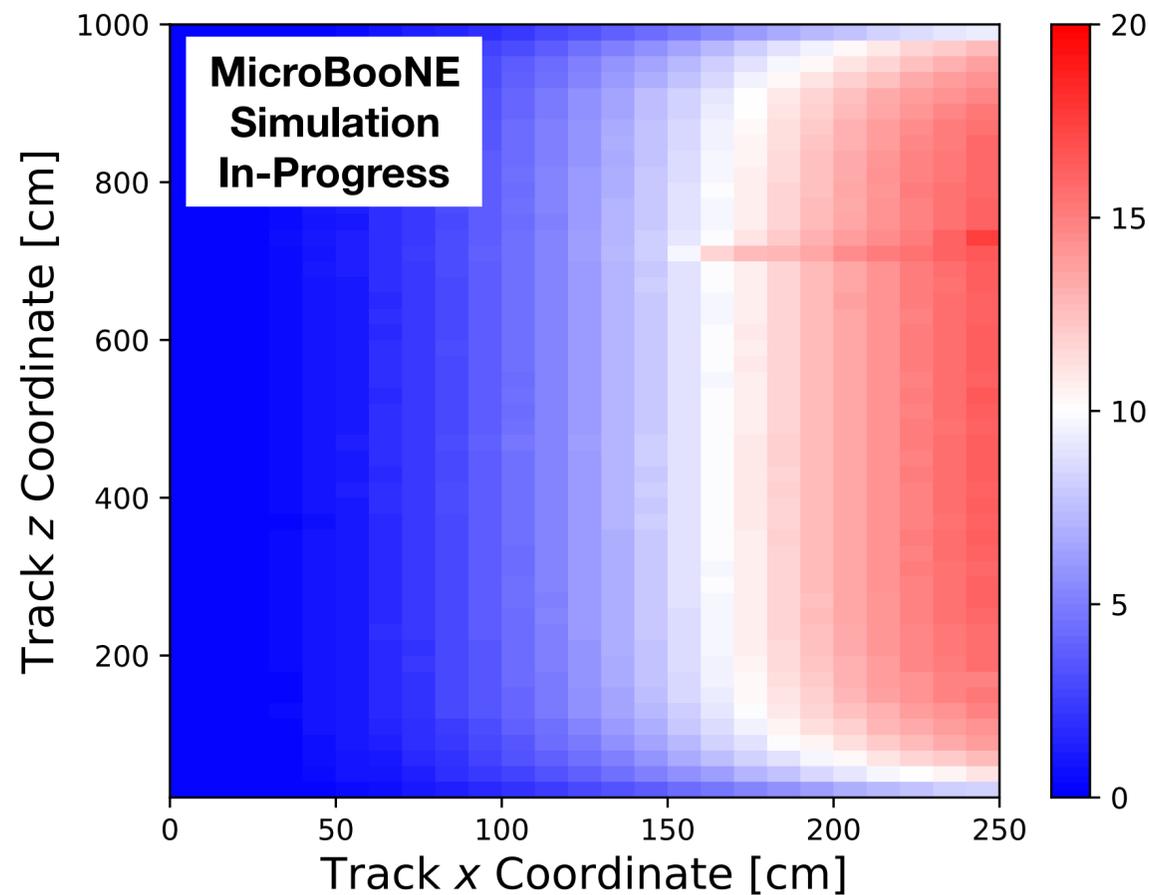


# Spatial Dependence Study: Bottom



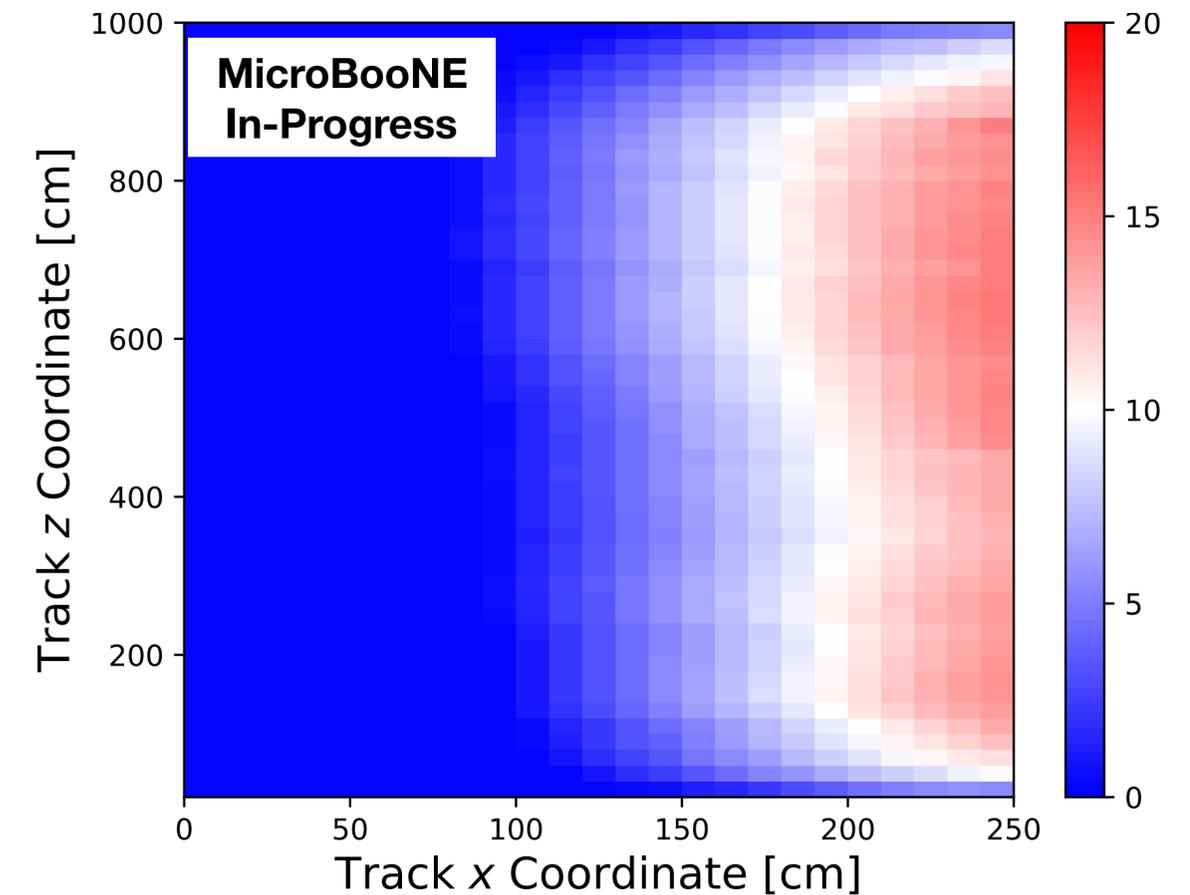
**Simulation**

Track Distortion From TPC Face [cm]

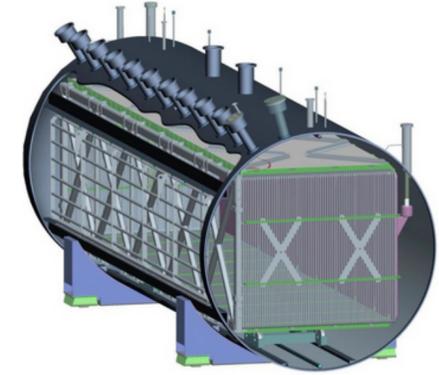


**Data**

Track Distortion From TPC Face [cm]



**The differences between reconstructed data and reconstructed simulation can possibly be attributed to variations in argon flow in certain regions of the detector.**

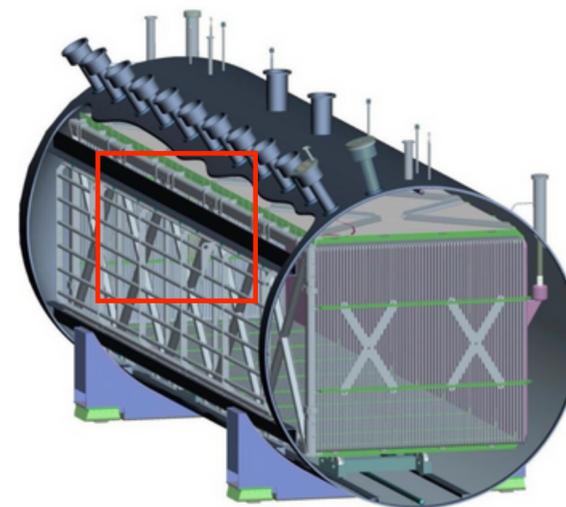
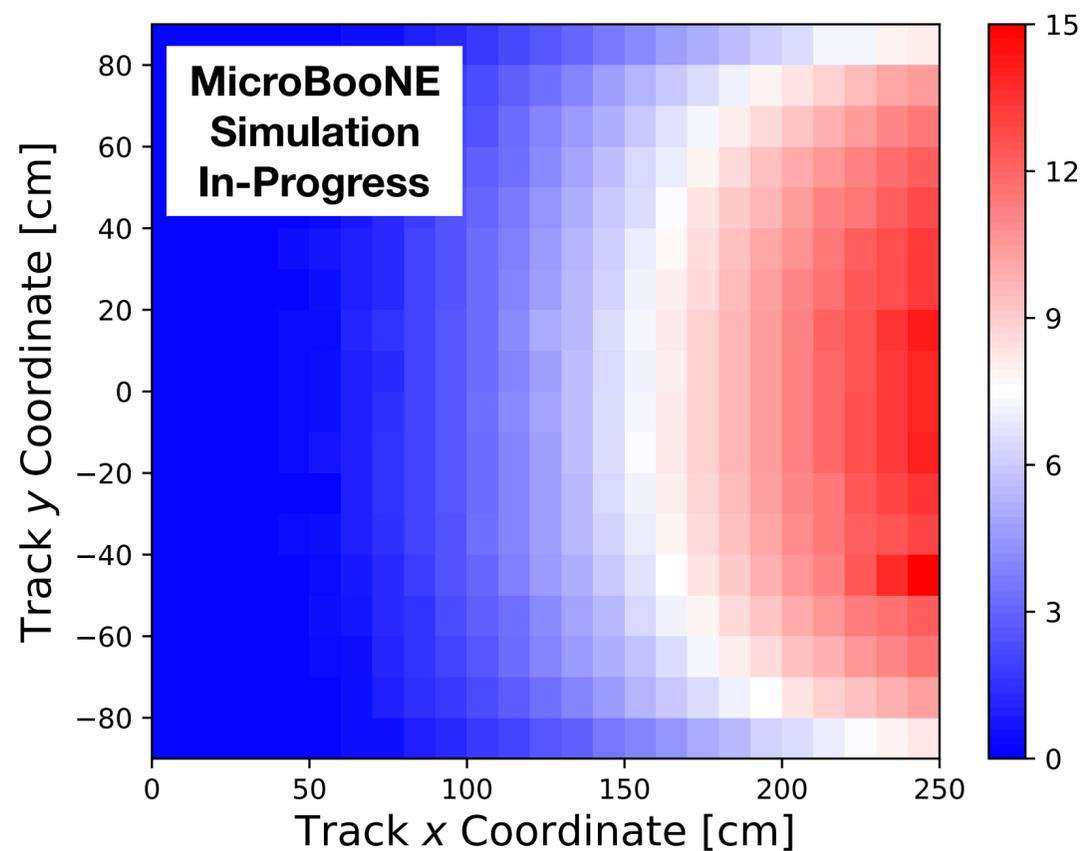


# Spatial Dependence Study: Back



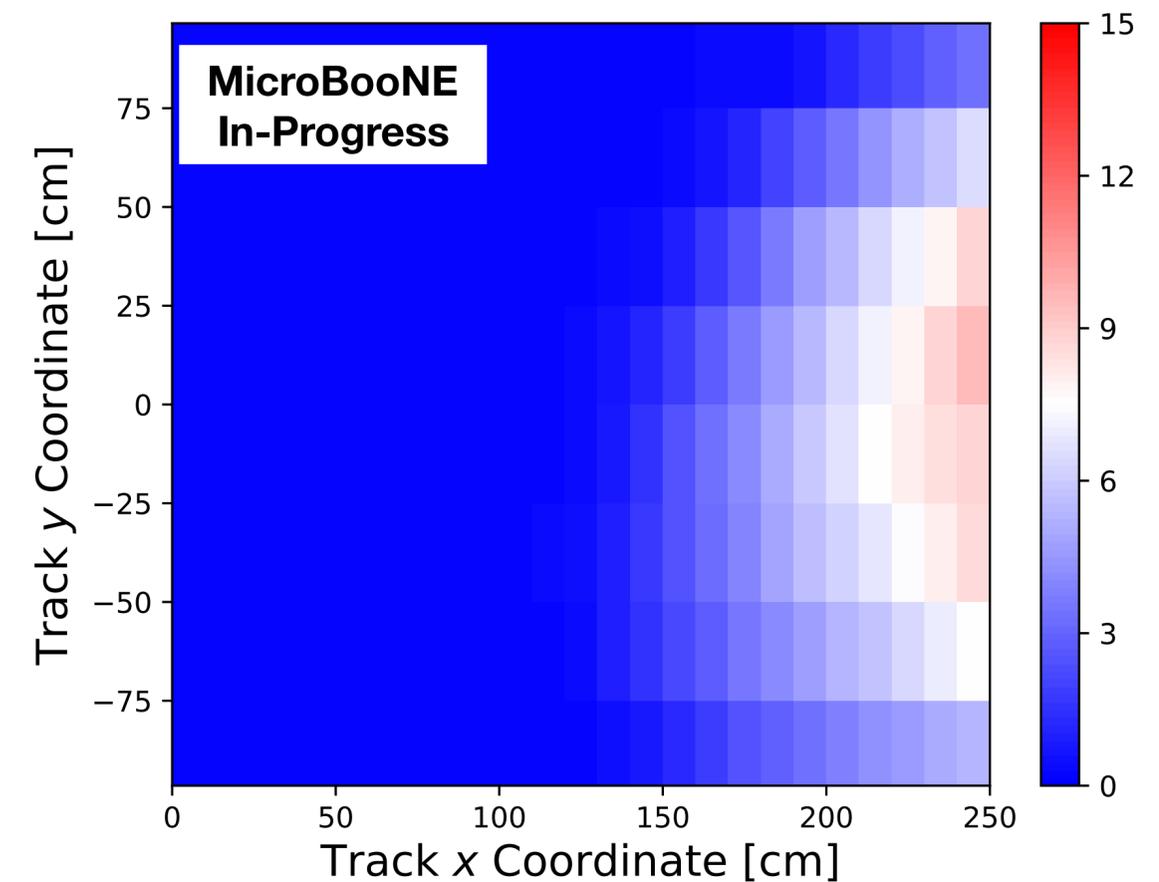
## Simulation

Track Distortion From TPC Face [cm]

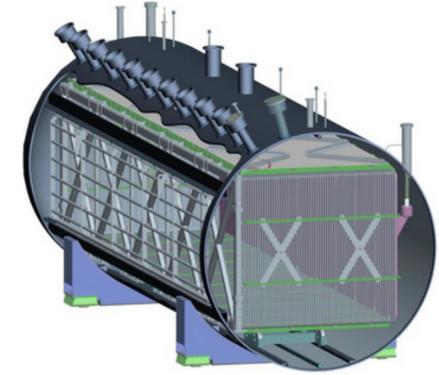


## Data

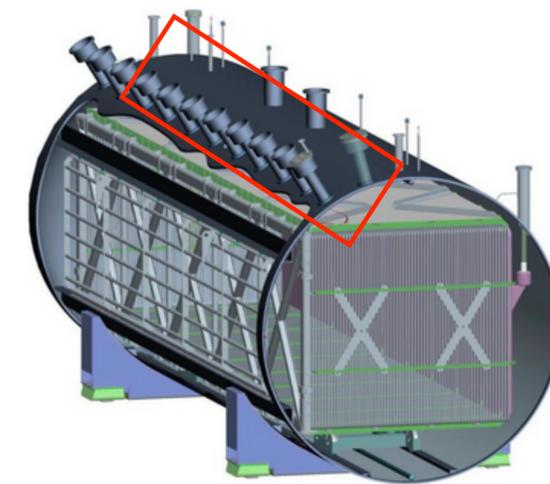
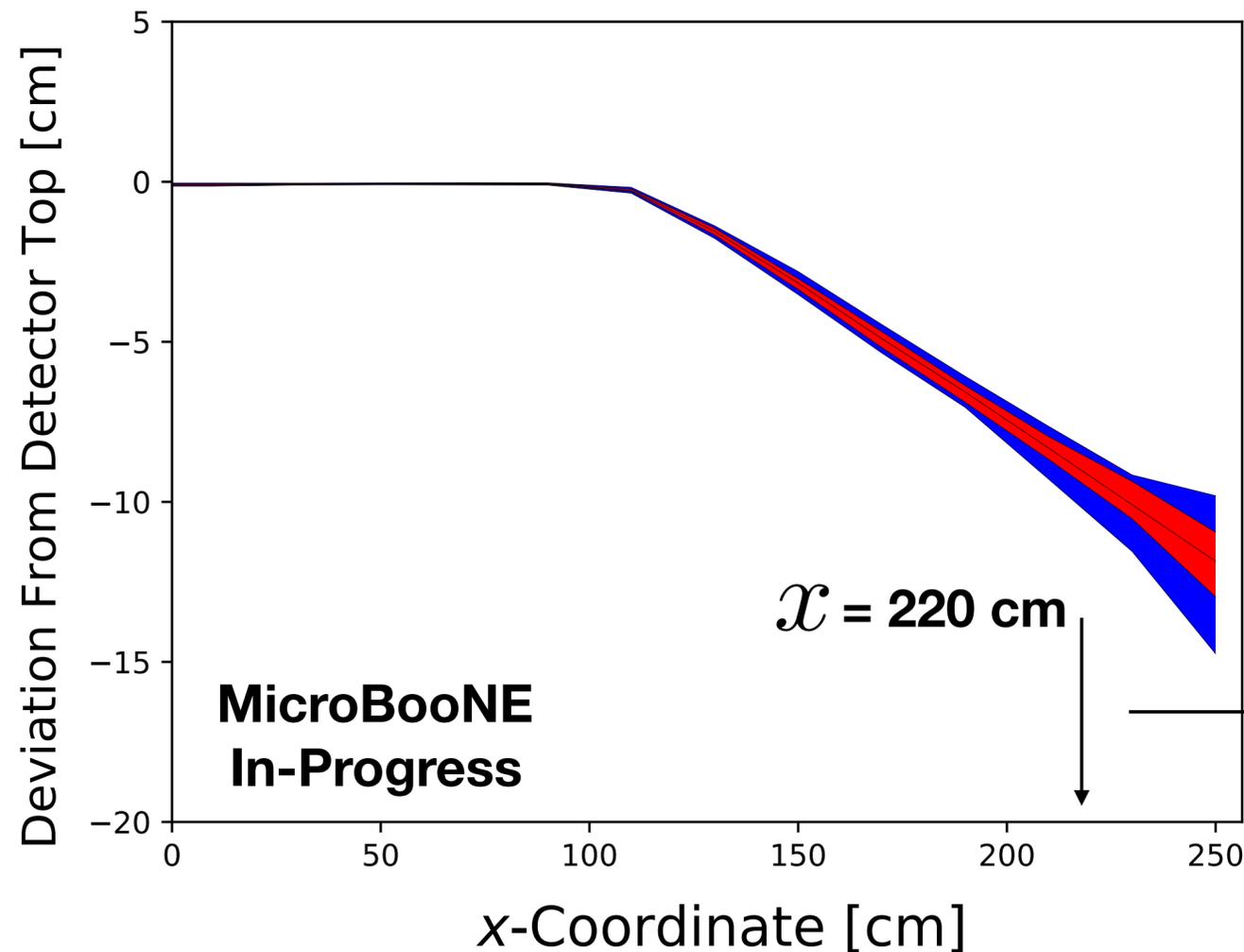
Track Distortion From TPC Face [cm]



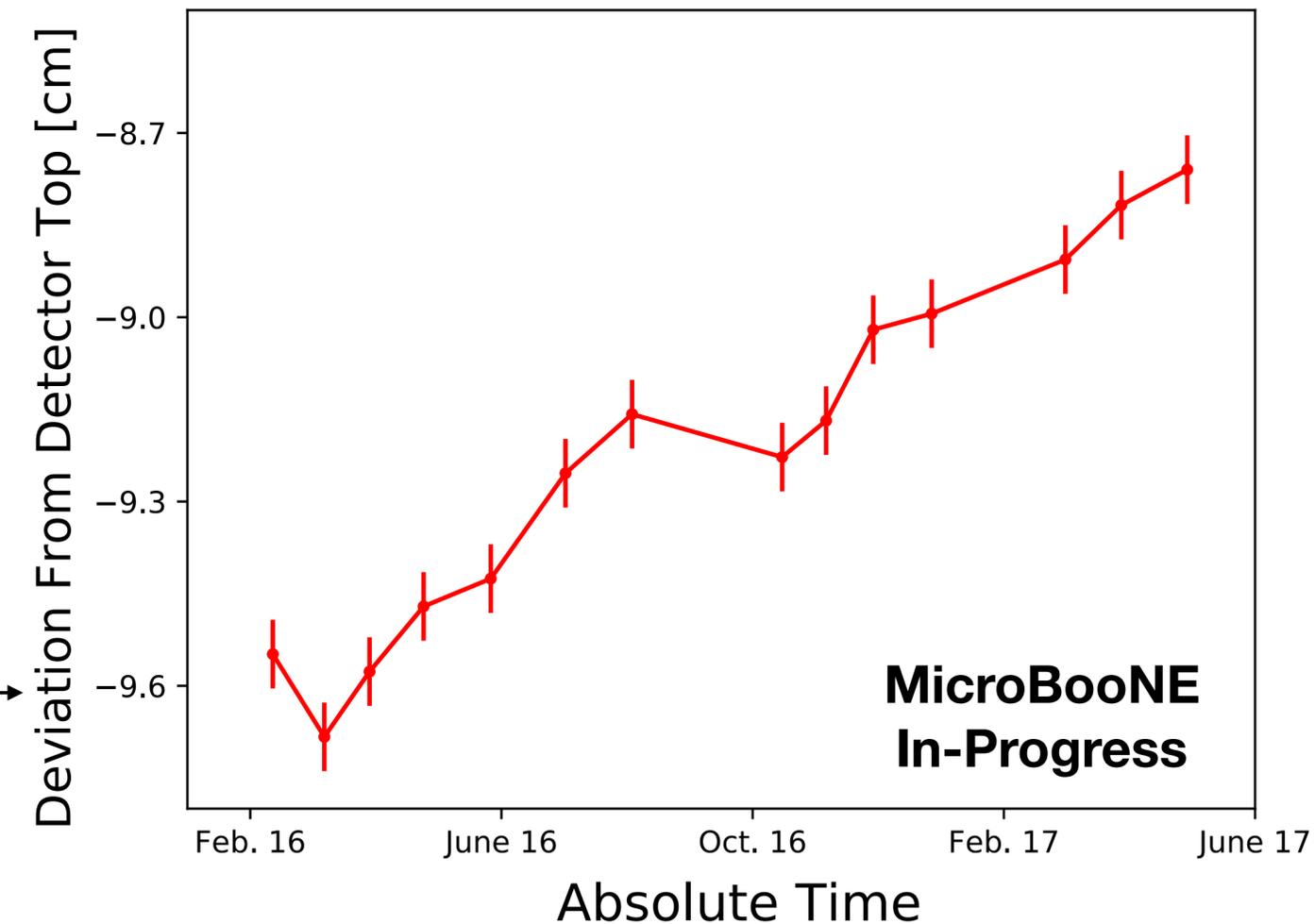
The distortions in data at the back of the TPC are more symmetric than at any of the other three faces in data.



# Time Dependence Study: Data



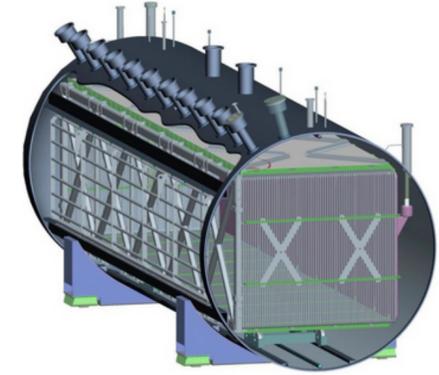
Variation over time  
shown in the next  
plot.



**68% Band**  
**95% Band**

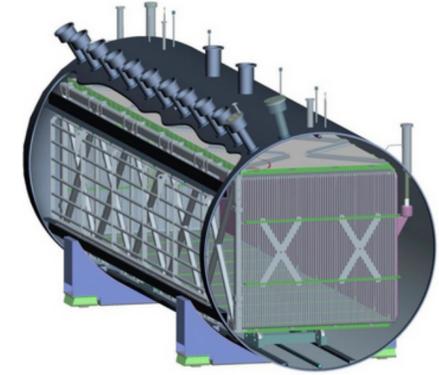
**The track distortions due to SCE are lessening at the detector top as a function of time.**

**We should be able to recognize seasonal variations of the cosmic ray rate in the righthand plot, but that is not observable behind the overall decrease of track distortions at that face.**



# Conclusions

- MicroBooNE has observed space charge effects in data.
- We have quantified differences in the space charge effects in simulation and in data.
- Therefore, a full data-driven calibration of the space charge effect is necessary.
- Liquid argon flow could explain the non-uniformities at the detector boundaries in data.



# Acknowledgments



U.S. DEPARTMENT OF  
**ENERGY**

Office of  
Science



**FNSNF**

SWISS NATIONAL SCIENCE FOUNDATION



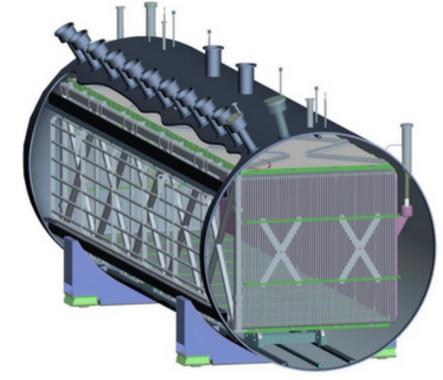
Science & Technology  
Facilities Council



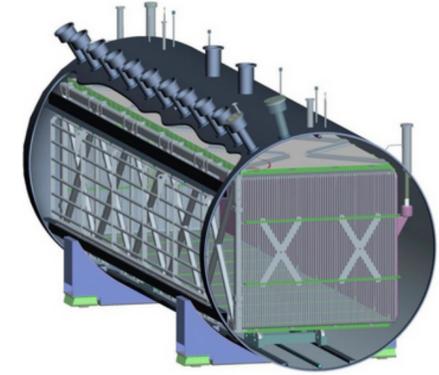
Thank you to Michael Mooney and Joel Mousseau for the help with this analysis.

Thank you to Brandon Eberly, Jyoti Joshi, Matthew Toups, and Michele Weber for the helpful comments.

Thank you to Joshua Spitz for the guidance and support.



**Backup**



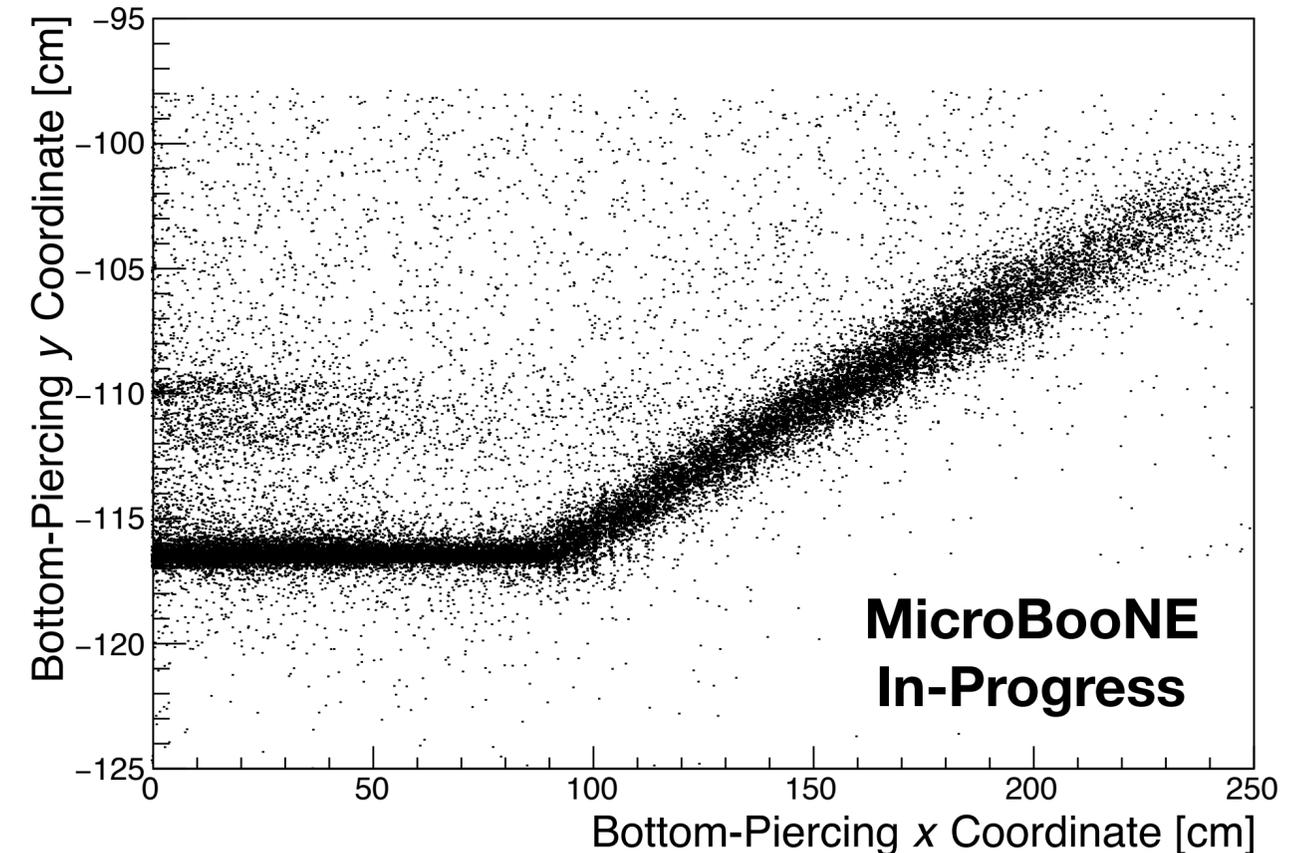
# Method

**This study measures the magnitude of track distortions from SCE at the TPC top, bottom, front, and back.**

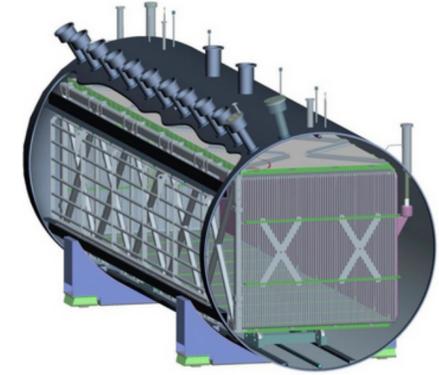
**$t_0$ -tagged tracks are first sorted according to which boundary of the TPC they pierce. Track distortions from SCE are studied for each face as a function of position along the  $x$ -axis.**

**Track distortions from SCE are studied as a function of (1) position and (2) time by:**

- (1) dividing the detector in slices in the transverse  $y/z$  axis.**
- (2) dividing the data up in time.**



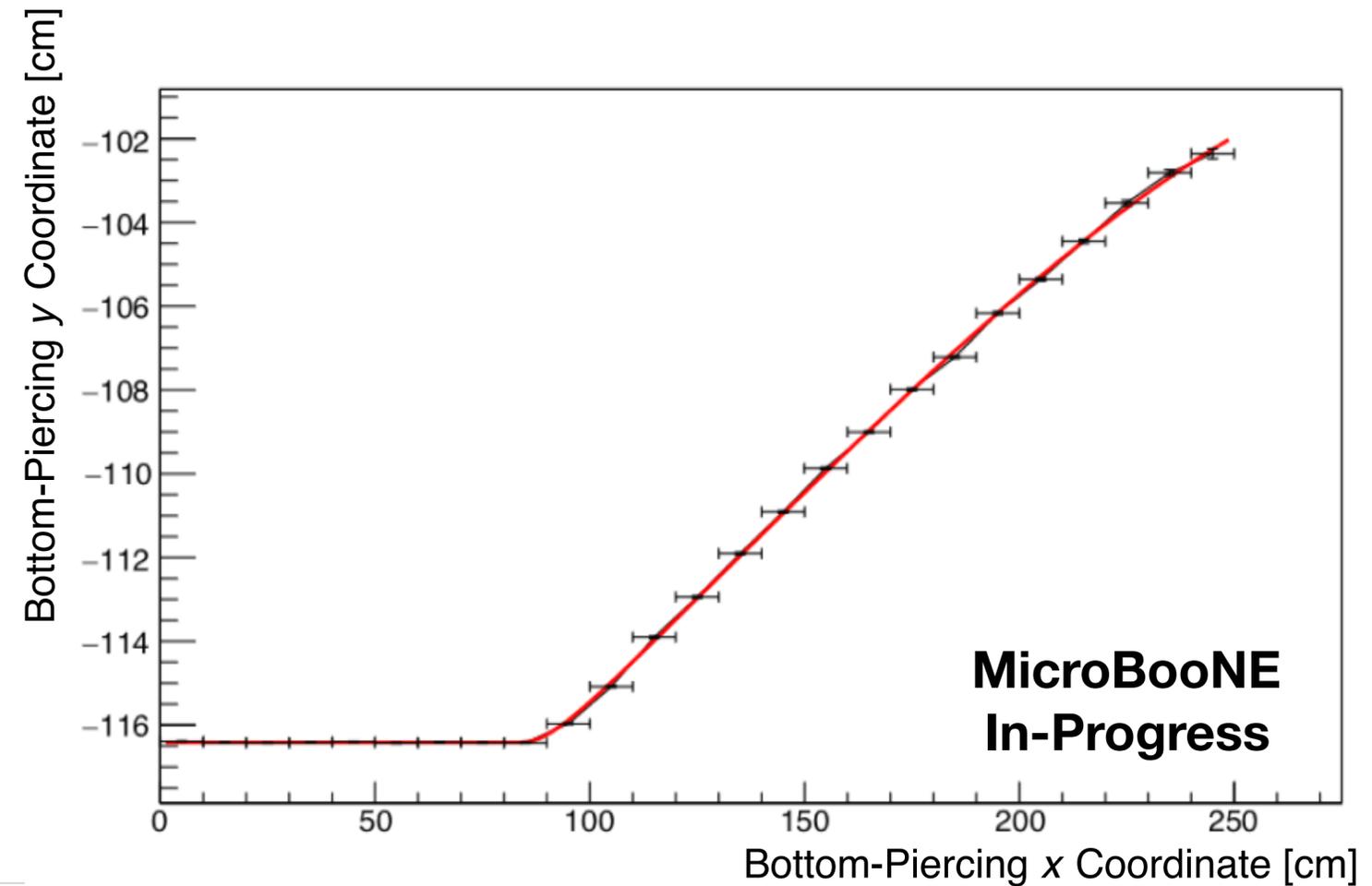
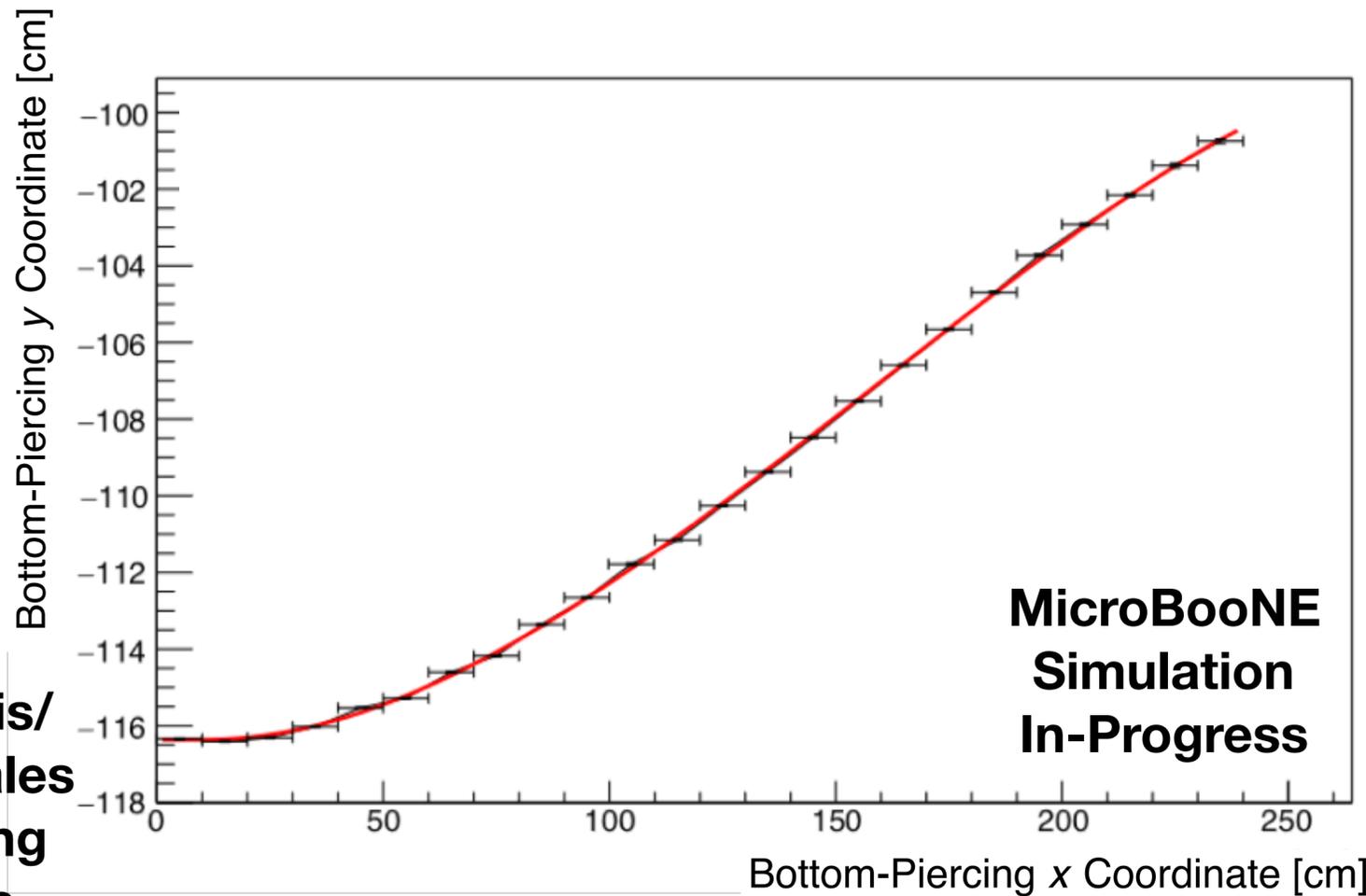
**An example histogram of bottom-piercing track endpoints for a midstream slice of the detector in  $z$  (same as on Slide #15).**



# Method



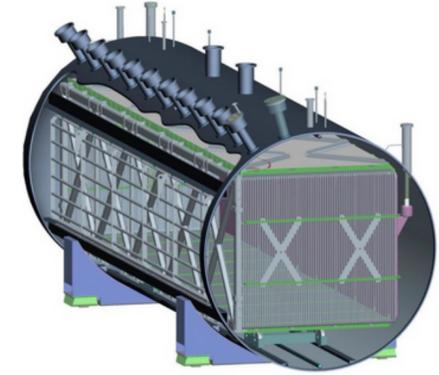
Note the slightly different axis/colorbar scales in comparing these plots.



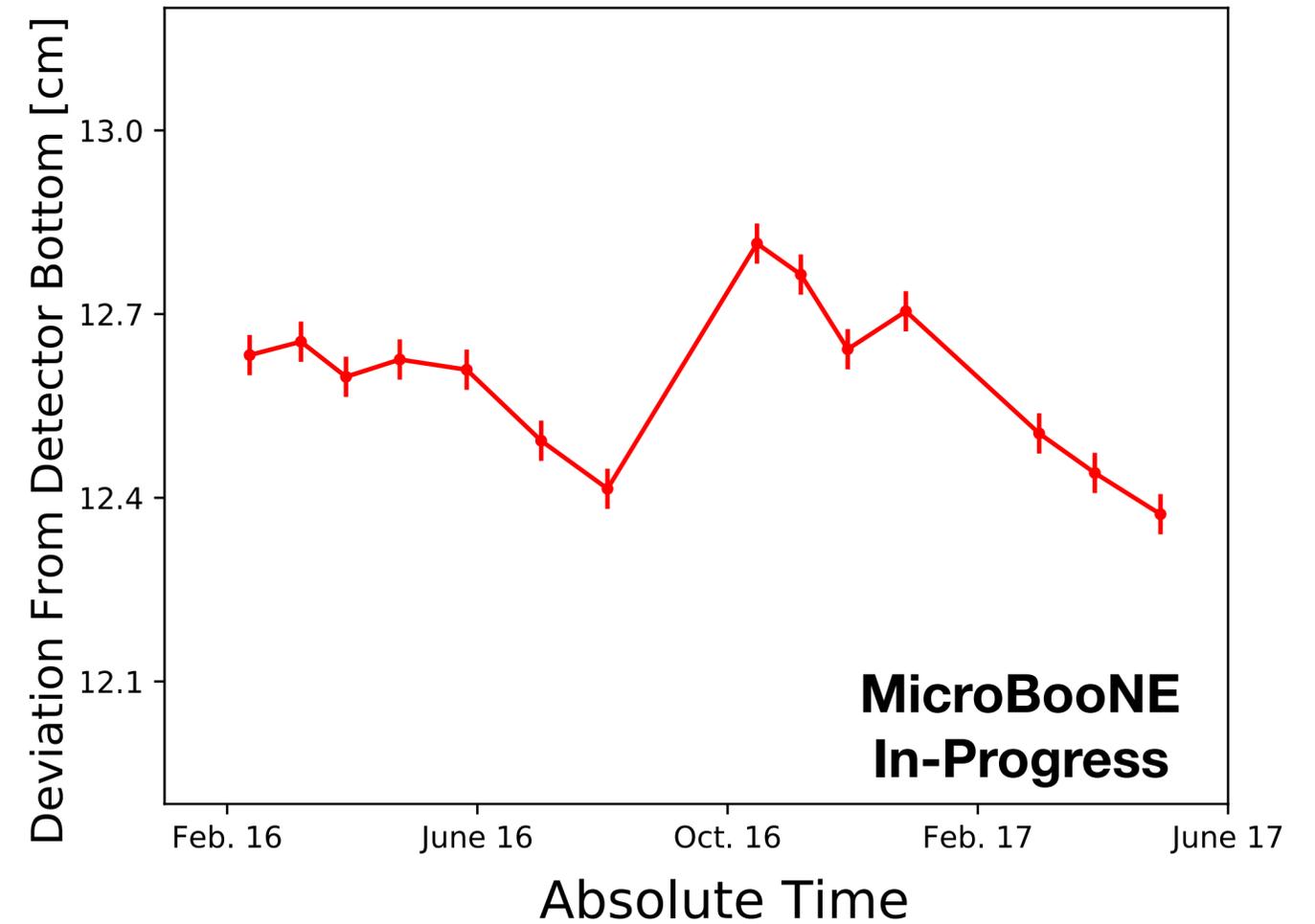
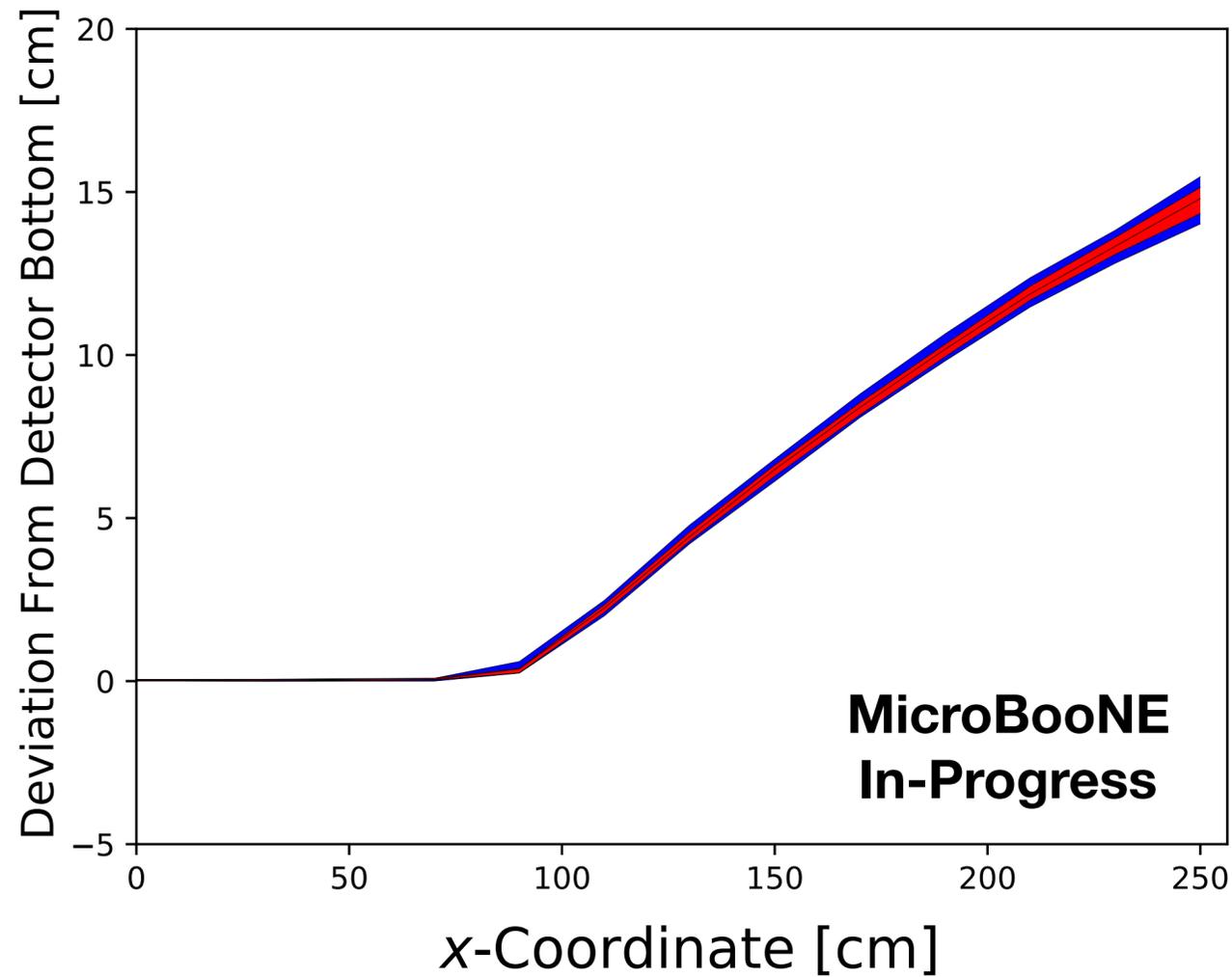
Each  $\mathcal{X}$  bin in the histograms is fit to a Gaussian, with the median and error bars shown in these plots.

For the spatial distortion study, a fit function is used to extrapolate to  $\mathcal{X} = 250$  cm, where statistics are scant.

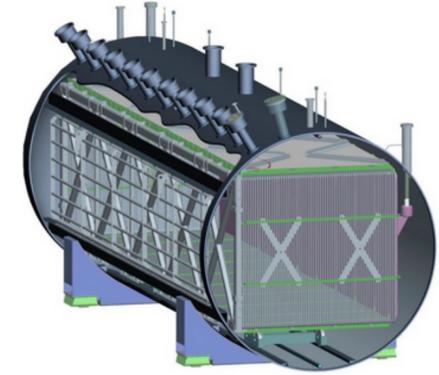
In the time-dependent study, a linear extrapolation of the trendline formed by the  $\mathcal{X}$  bins is used.



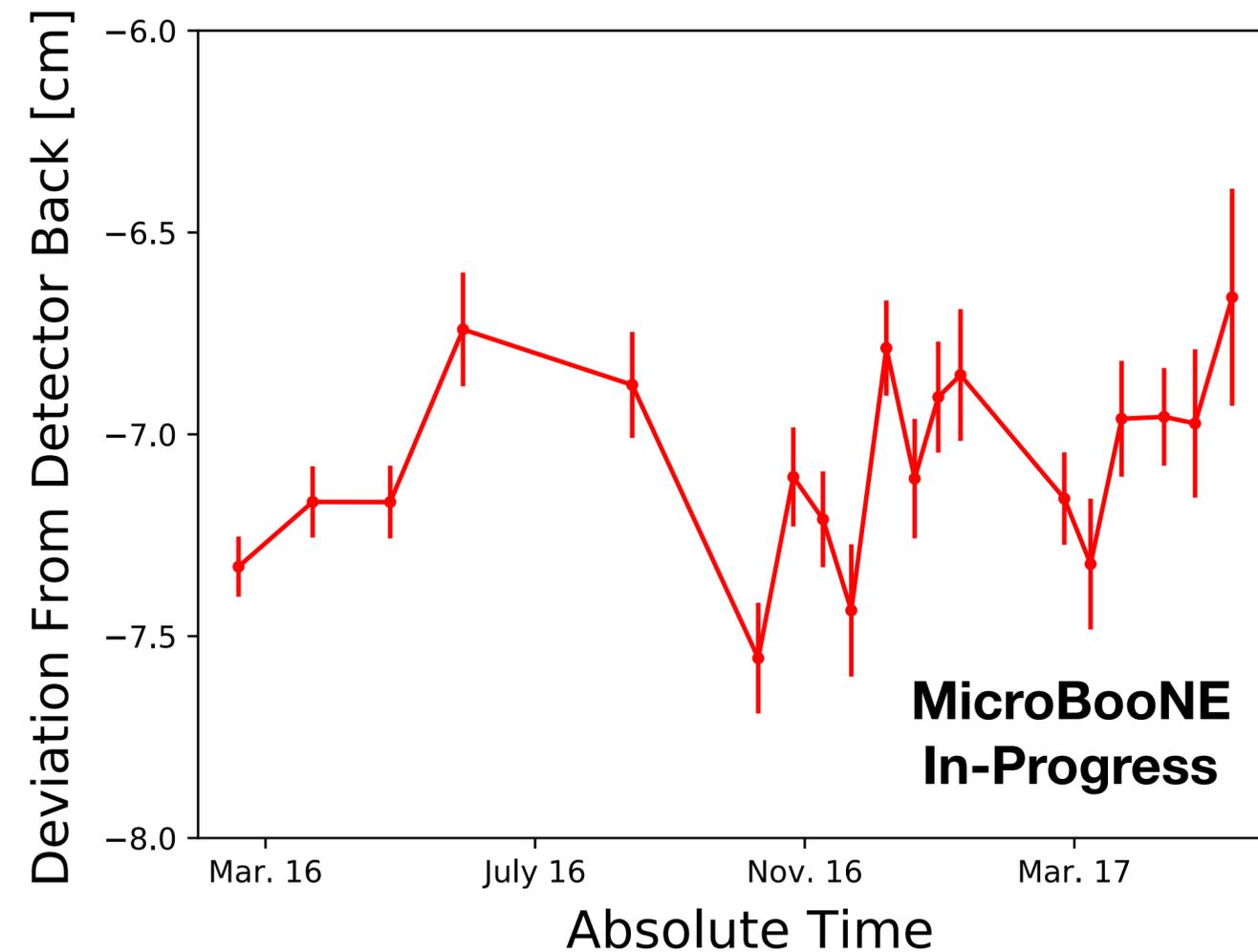
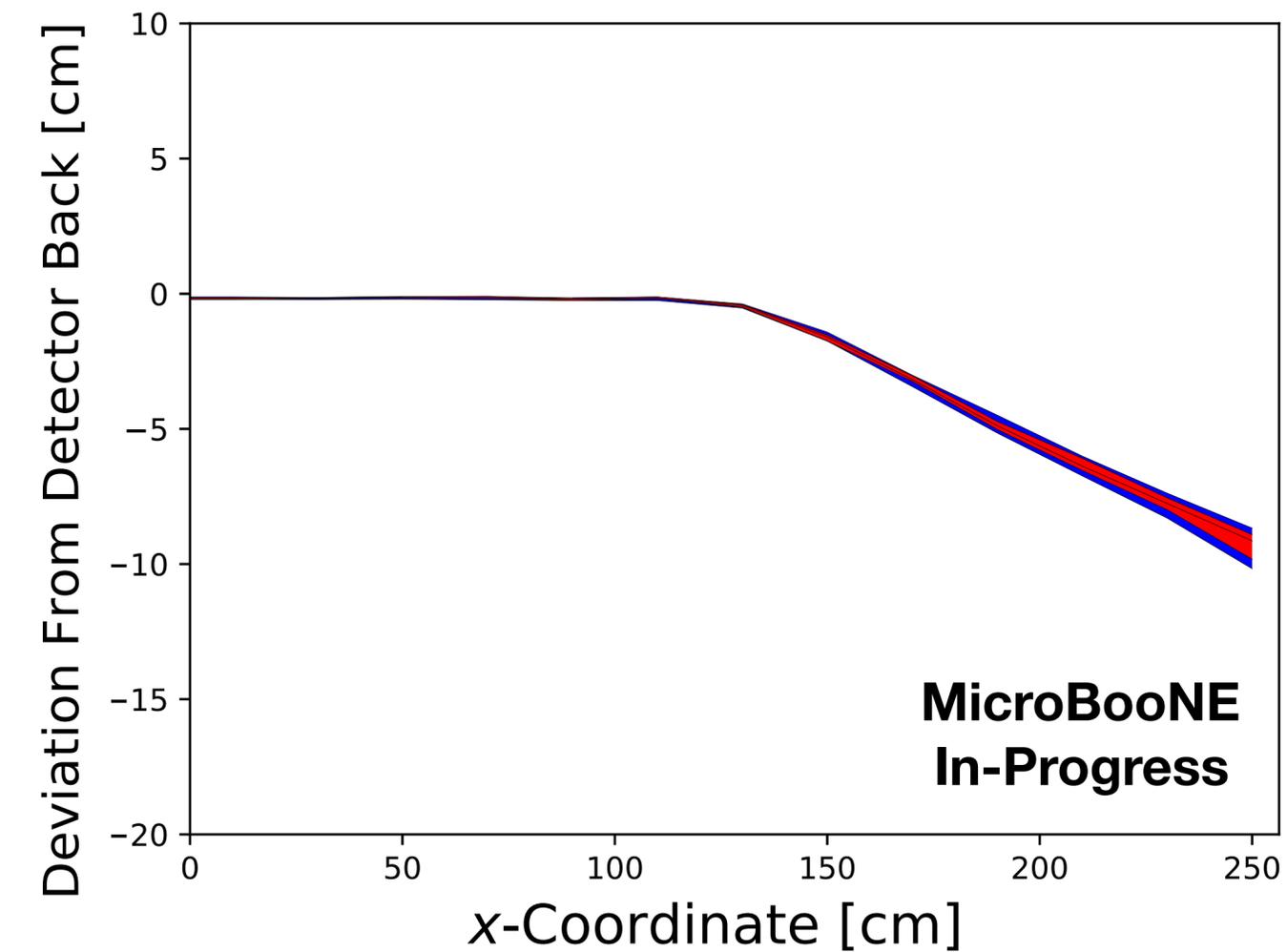
# Time Dependence Study: Data



**68% Band** There is no noticeable trend for the time dependence of the track distortions from SCE at the bottom  
**95% Band** in the righthand plot.



# Time Dependence Study: Data



68% Band  
95% Band

There is no noticeable trend for the time dependence of the track distortions from SCE at the back in the righthand plot.