Center for Frontiers in Nuclear Science

sPHENIX

TPC Distortion Software

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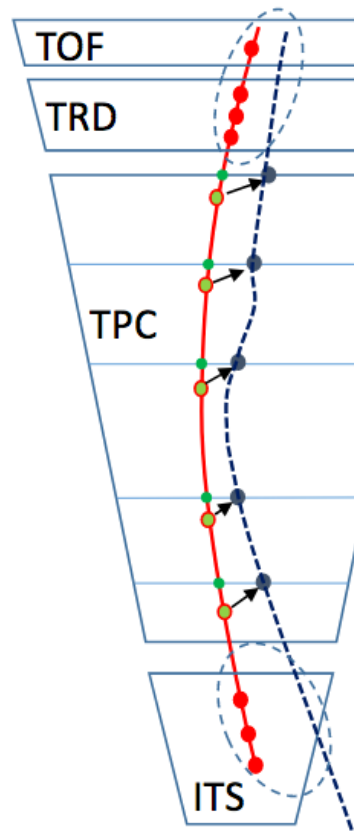
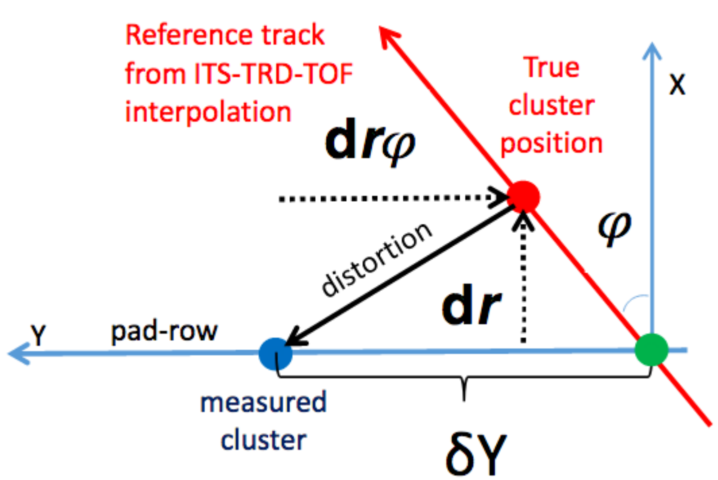
Need to Correct Distortions

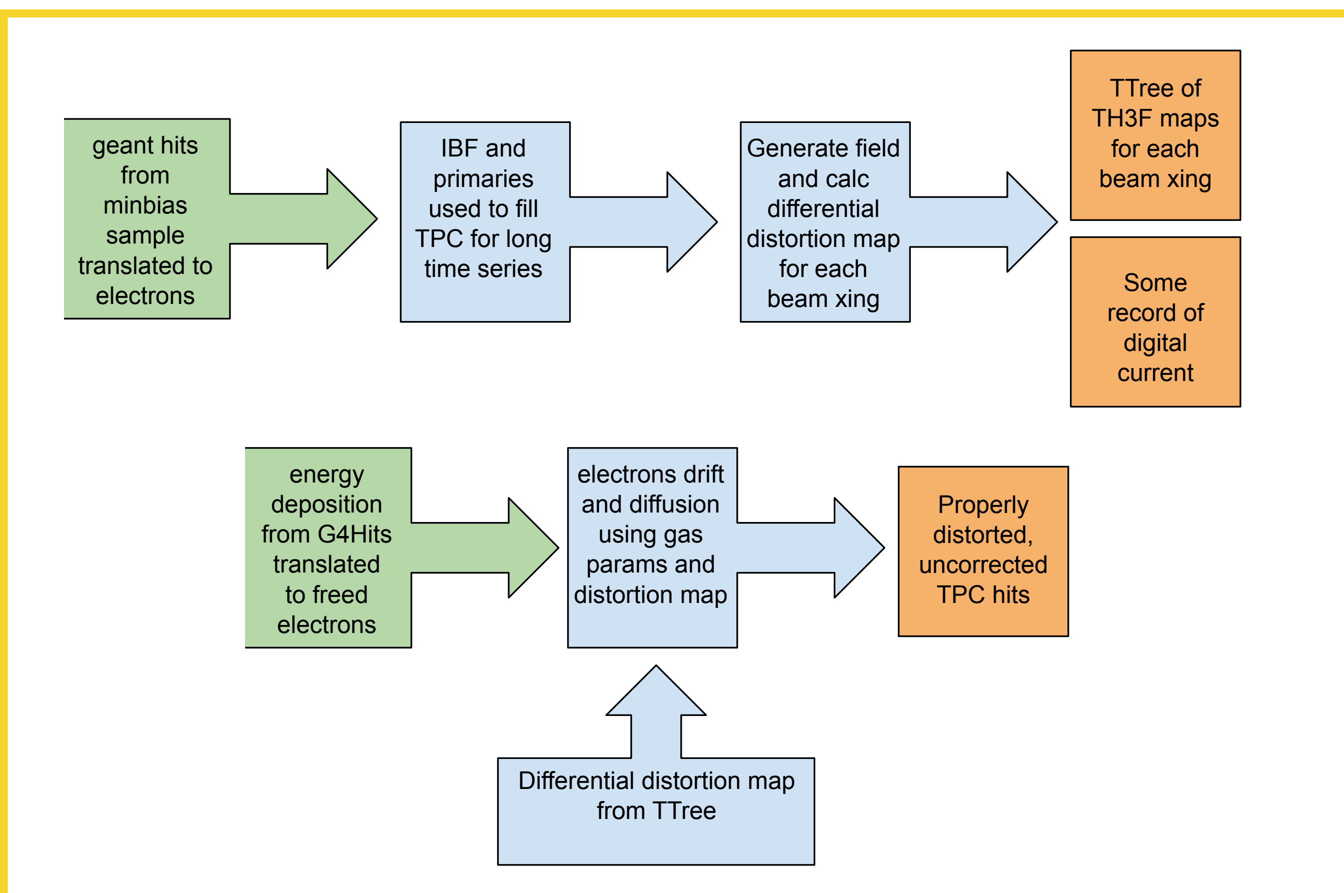




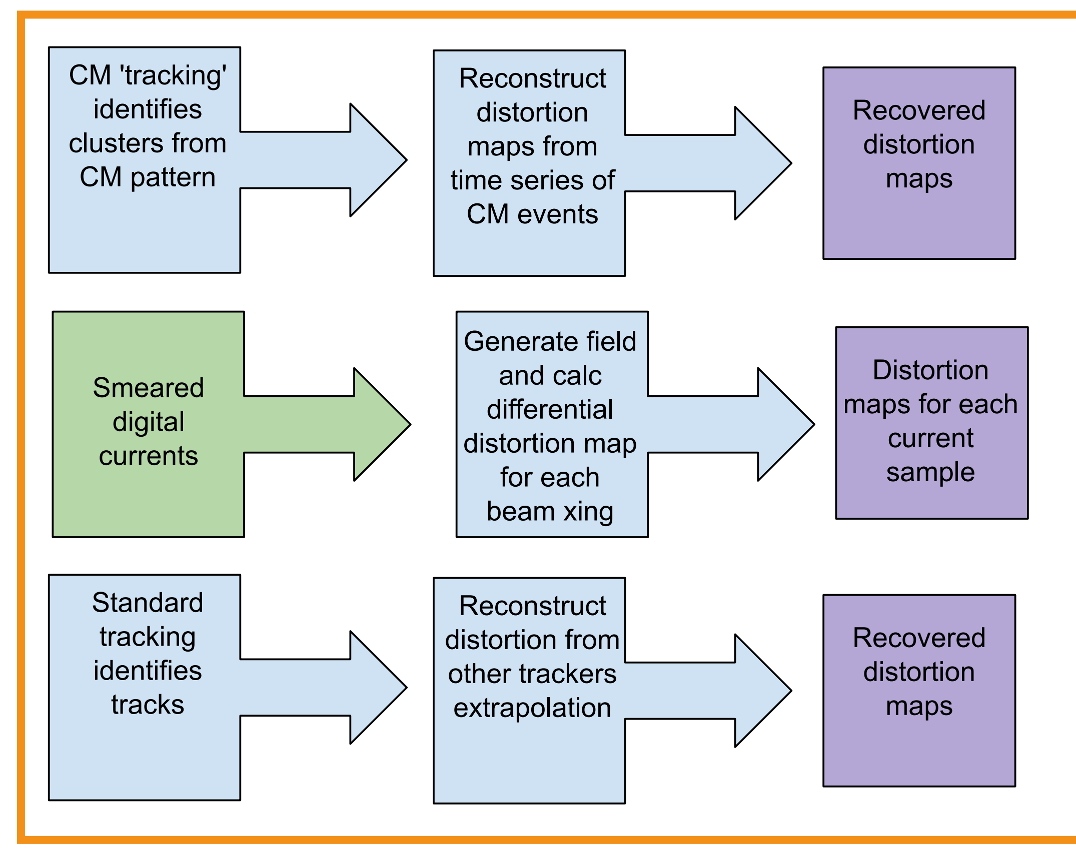
Overview

- Integrate and expand spacecharge modeling in Fun4All
- Implement and study calibration of spacecharge distortions through tracking, lasers, and digital current measurements.

Model and Generation



Reco and Calibration

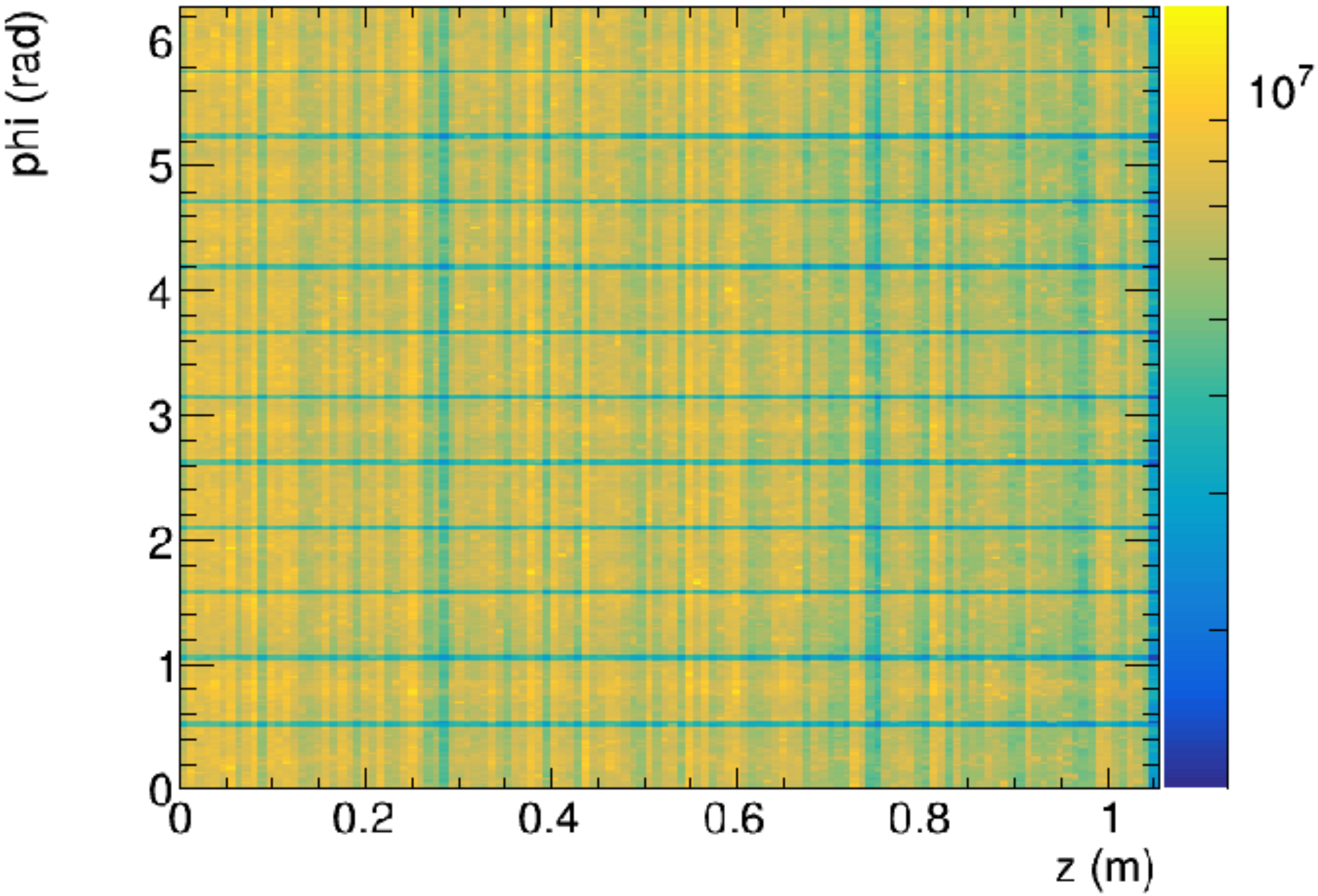


Projects and Milestones

Brainpower	Task	*Early July*	*Mid July*	*Late July*	*Early August*	*Mid August*	*Late August*
Chris P	generate HIJING events	***improved HIJING with backsplash from Cal?***					
Ananya P, Evgeny S	current / SC maps from HIJING	***low-res SC maps for early distortion studies***		***tool to gen. SC time series for desired luminosity and IBF factors***			
Jordan S, Ross	generate distortions from SC maps	***compare and select tiling scheme for field***		*study and select MC truth resolution*		*validate with analytic model*	
Henry K	implement MC truth distortions	***static dist. map in sim.***	***time series distortion maps in simulation.***				
Jordan S, Evgeny S	distortions from currents				*Reconstruct SC from dig.current*	*Reconstruct distortion map from digital current, study*	
Sara K	Simulate laser events	***generate CM stripe G4Hits in event***					
Sara K	Reconstruct laser events			***reconstruct CM hits***			
Sara K, Ross	distortions from laser events				*implement CM calibration loop; extract distortion maps*		
in collab. with other Subcom	Distortions from tracks	*repeat Hugo's analysis with static distortion map*		*study with time-varying map, look at correlations*			
TBD	Cross-validate methods					*study fast distortion maps with slow already subtracted*	
Ross, Chris P, Others	Define MC-truth and correction formats	***revise format for slow+fluctuations***					
Joe	Corrections in reco	*implement movable hits in ACTS...*			*distortion maps in reco.*		
Tony, Hugo, Others	Tracking w/wo correction	*prepare diagnostic tools.*			*check tracking eff. w/ and wo/ distortions and corrections.*		
TBD	Studies of Physics Impact		*develop analysis modules to track physics observables w/wo corrections*				

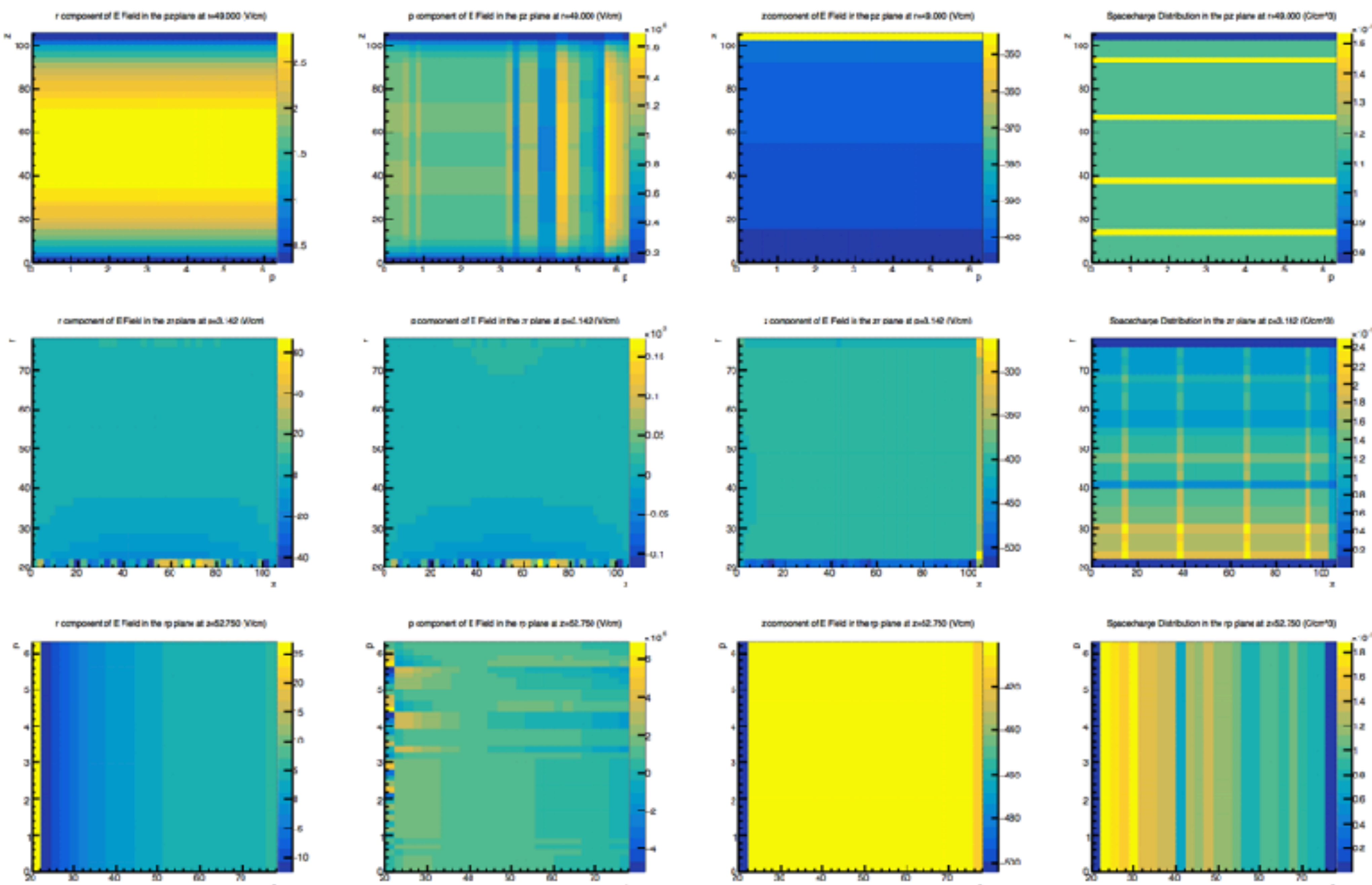
Time Series of Spacecharge Maps

- Evgeny Shulga has produced (and is producing) time series of TPC slices



Average Spacecharge Maps

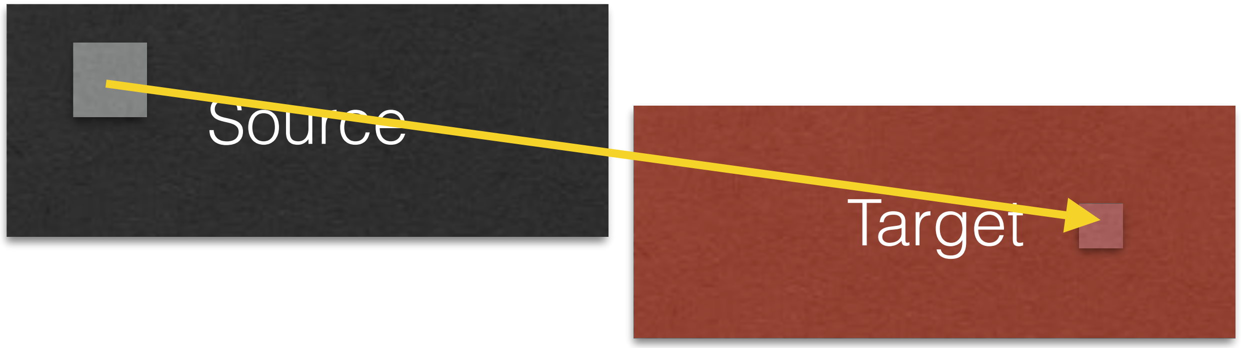
- Use well-spaced (~150cm) tpc frames to build smooth average SC/fieldmap



Generating Distortions Maps

- Jordan Sprague (MIT) and RC implementing more efficient calculation and storage of distortion model from SC
- 3D lookup table structure nearly ready -- high-granularity near 'target' cell, low granularity away, just needs efficient way to calc the center of large cells
- Swim test grid of particles through fields generate by ~matrix multiplication of 6D lookup and 3D charge map to produce distortion map

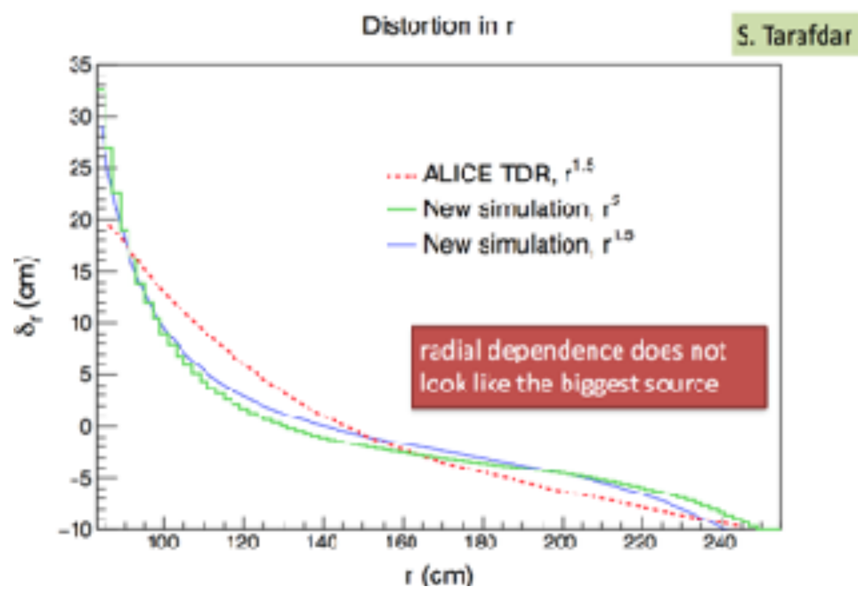
~6D Lookup Table



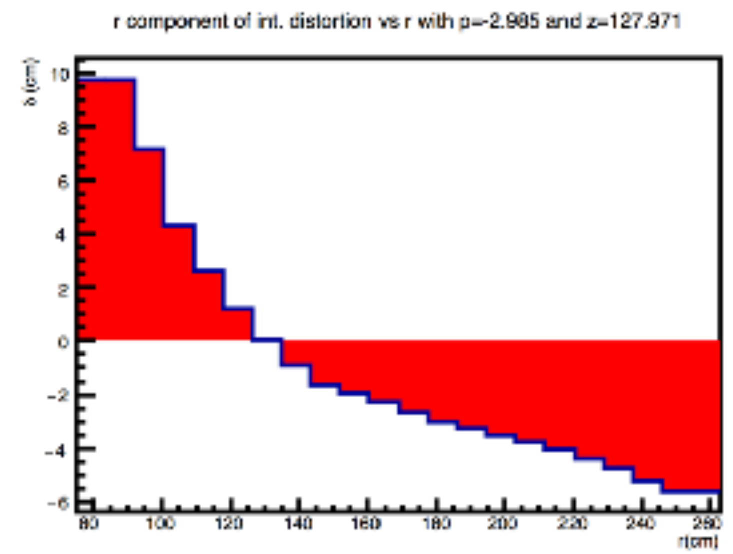
Lookup Table	memory scale
Full 3D	$(n_r \times n_\Phi \times n_z)^2$
Phi Symmetry	$(n_r \times n_z)$x$(n_r \times n_\Phi \times n_z)$: ~1GB at 26x40x40
Multipole 3D	$(n_r \times n_\Phi \times n_z) \times$ ($(m_r \times m_\Phi \times m_z)$+ $(n_r/m_r \times n_\Phi/m_\Phi \times n_z/m_z)$)
Multipole Phi	$(n_r \times n_z) \times$ ($(m_r \times m_\Phi \times m_z)$+ $(n_r/m_r \times n_\Phi/m_\Phi \times n_z/m_z)$)

Distortion Maps Matching

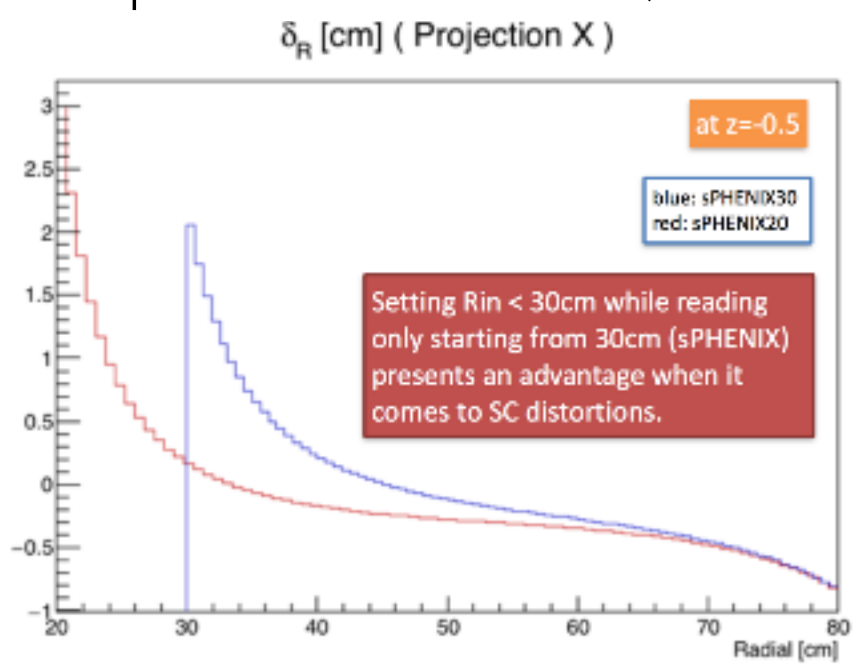
- Matches well to ALICE curve (we measure at z/2, they measure at z=0, so expect ~2x factor):



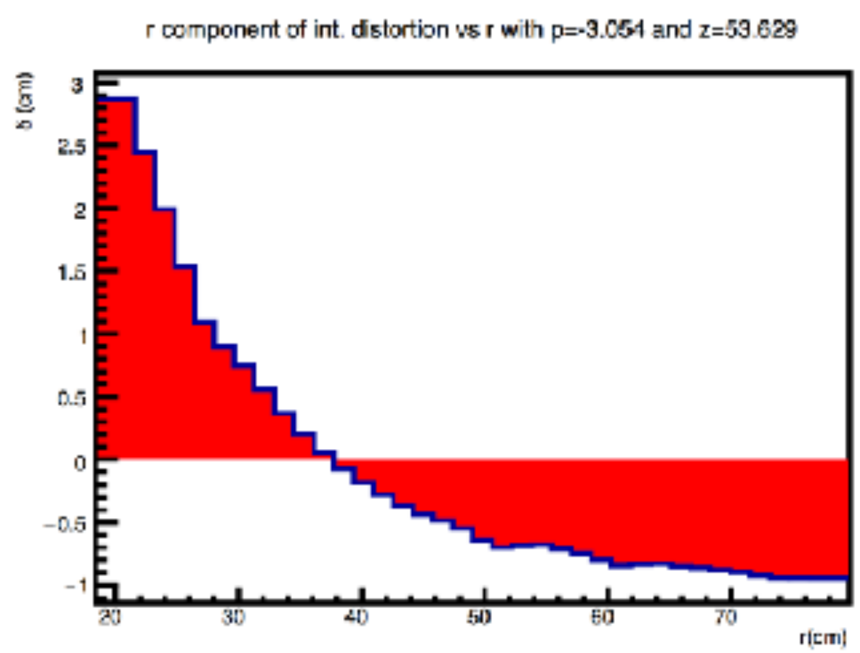
ca. 2016



- Matches our old sPHENIX simulations (once we rebuild the charge model used from Carlos's 2016 presentation: total Q=135nC) (curvature different at high radius?):

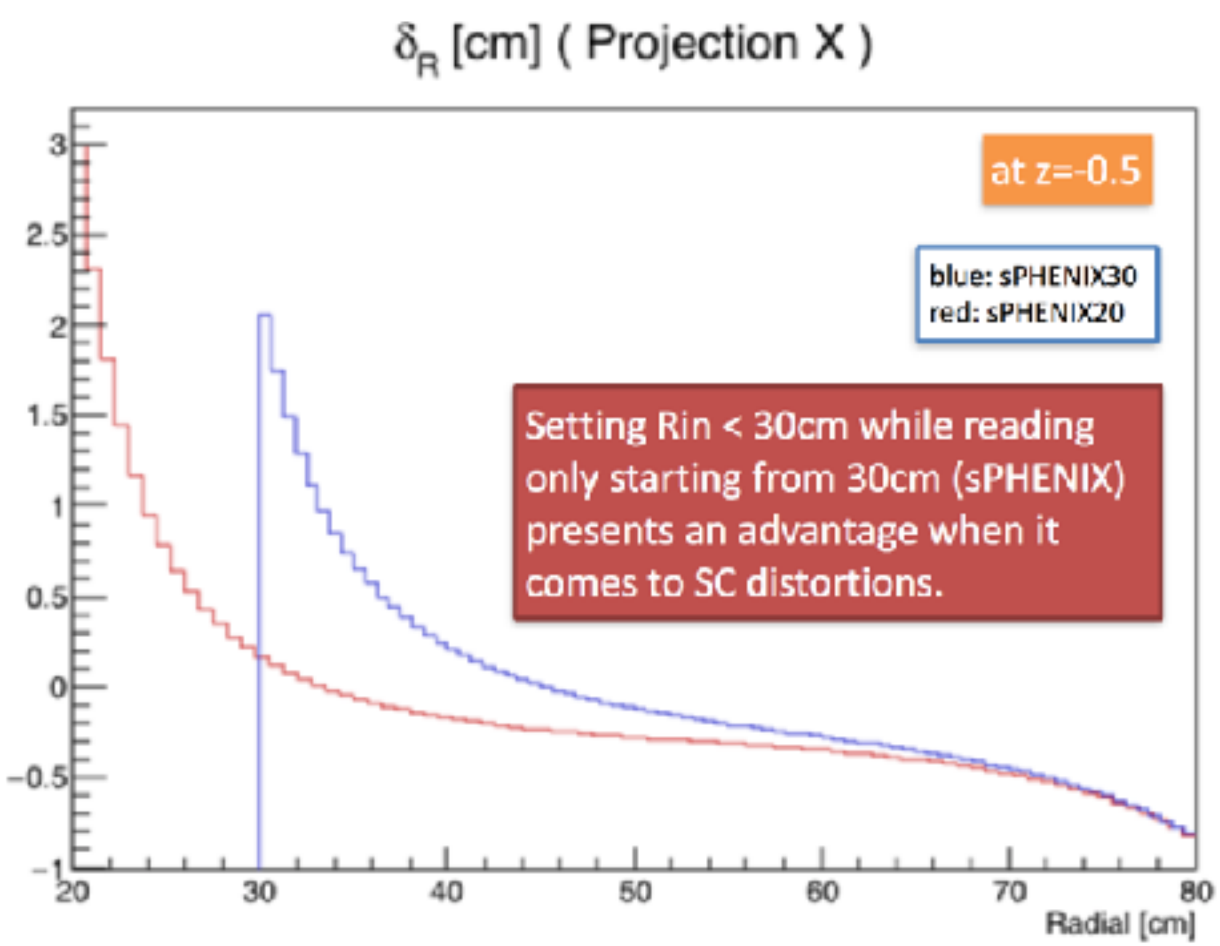


ca. 2016

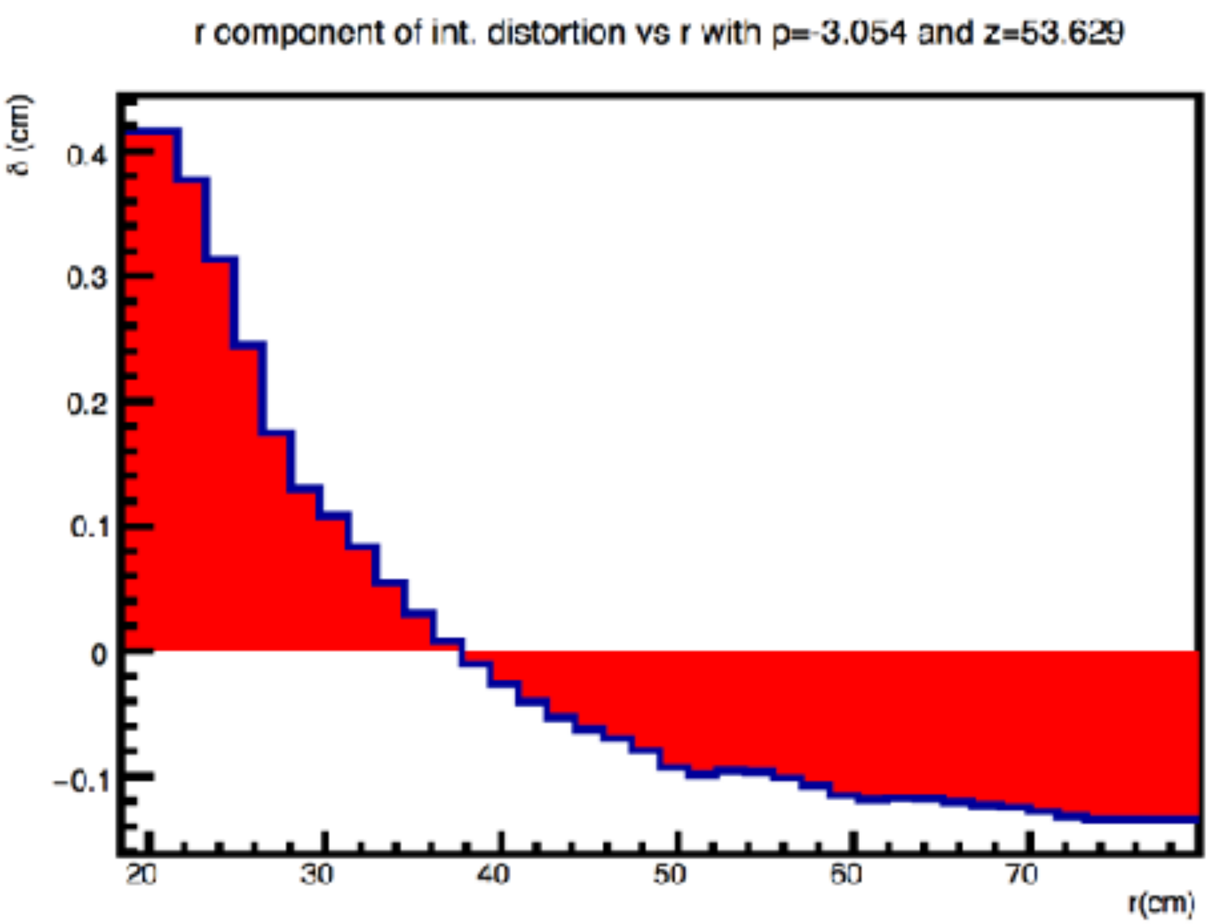


Distortion Maps

- 2016 sPHENIX simulations: drift velocity =4cm/us, B=0.5T ==> omtau=0.5
- New assumptions: velocity = 8cm/us, B=1.4T ==> omtau=2.8
- Ion drift speed will also change from old assumption, but if we use the same heuristic charge:

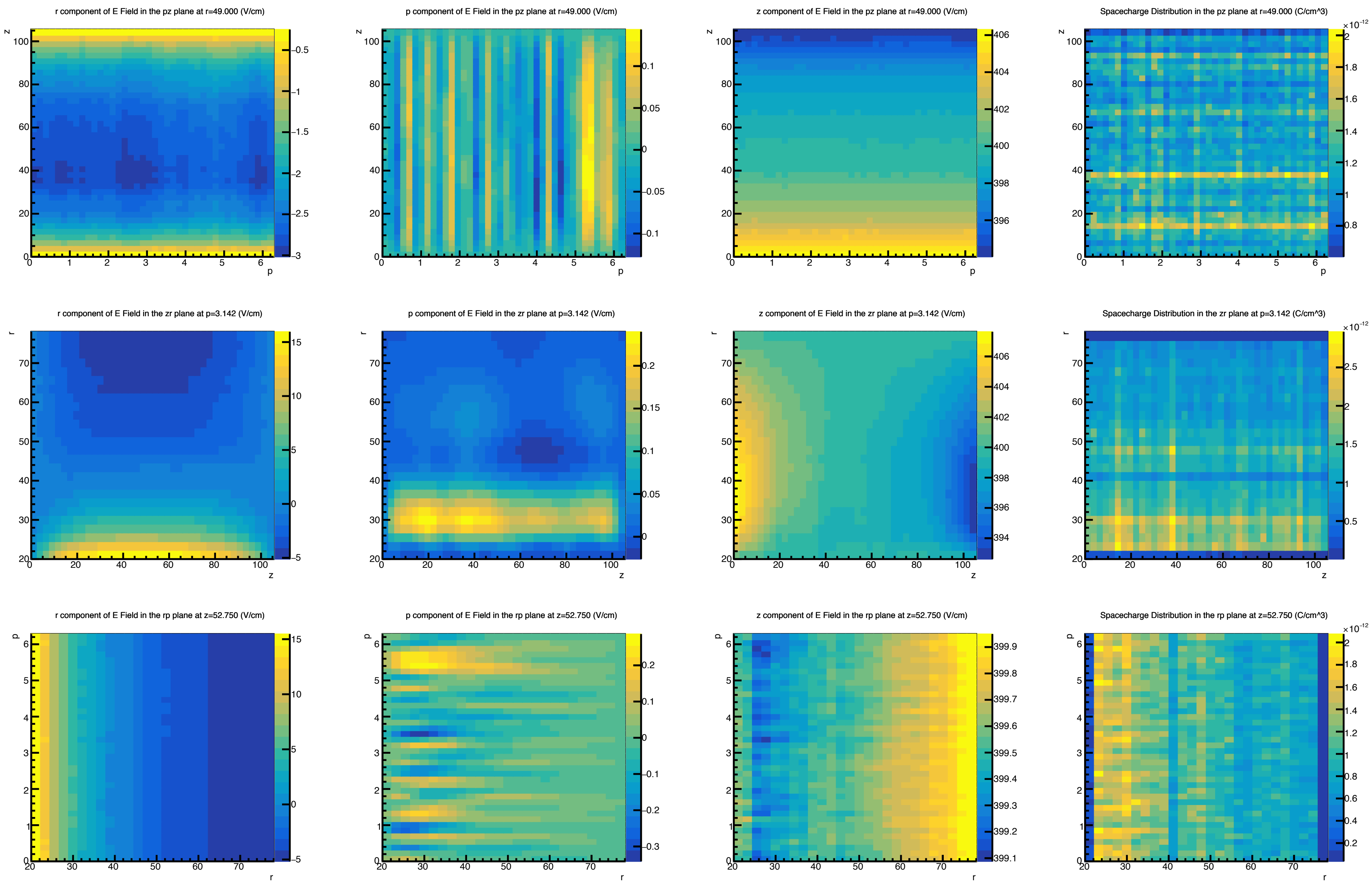


ca. 2016



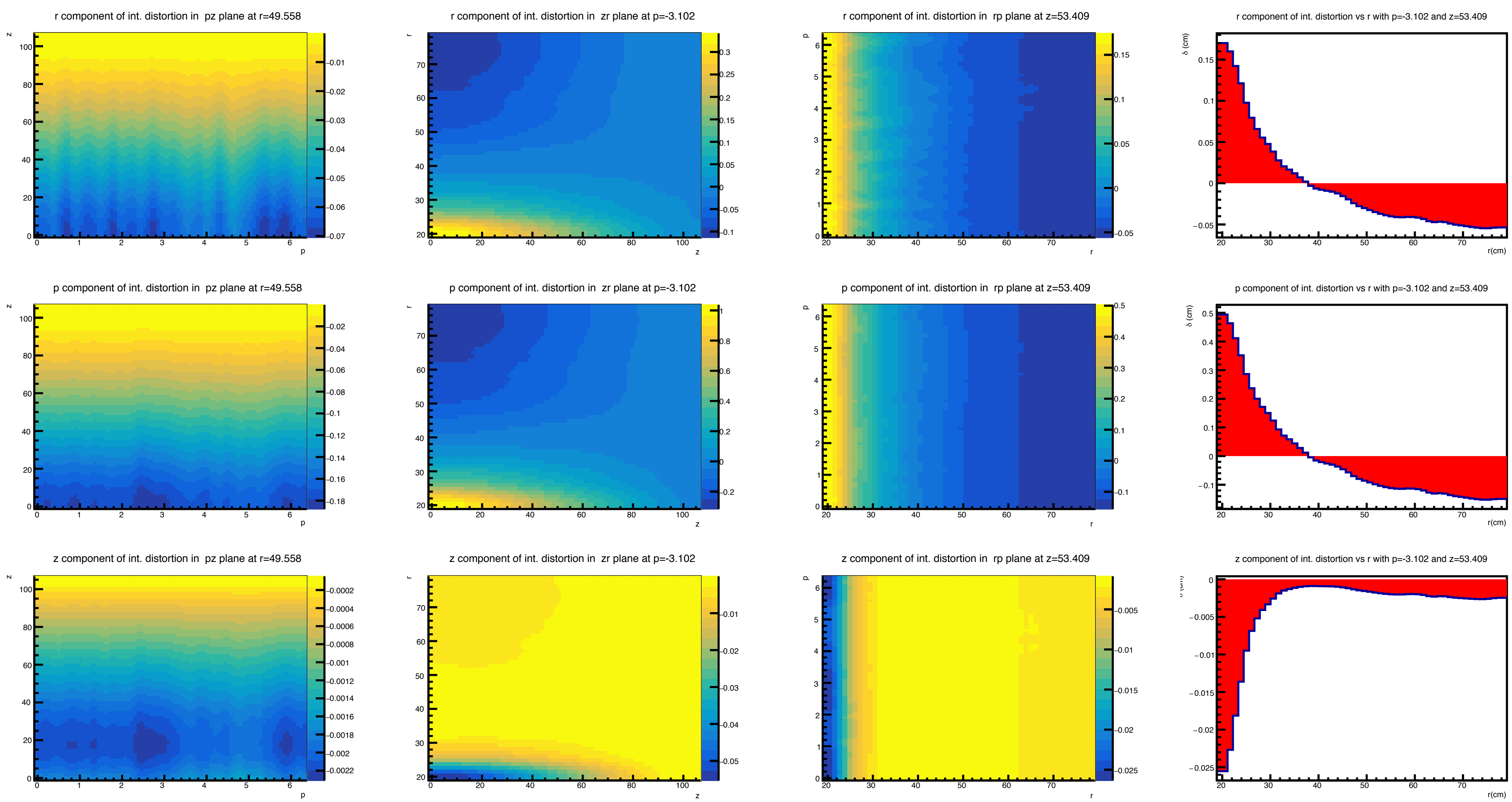
Updated Gas

- Also running 'real' MC events from Evgeny, using new gas mixture (ion drift 0.5x previous ==> charge doubles compared to 90:10)
- Total charge ==> ~40nC (compared to 2016 model's 135nC)



Distortions in Updated Gas

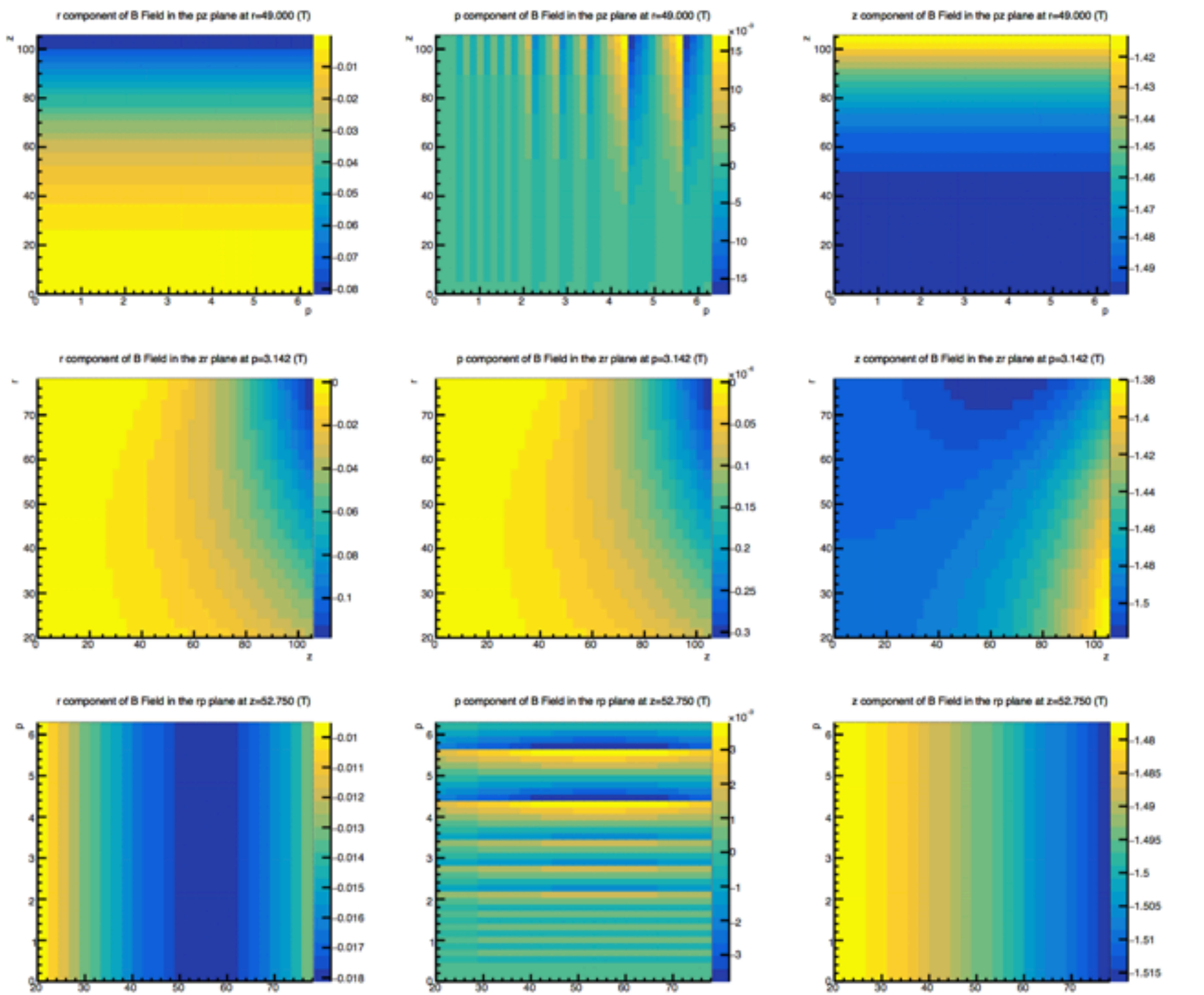
- Distortions drop to ~manageable levels? 3x less charge, 3x higher B field, doubled drift velocity.



E:Flat:400.000000, B:Flat:1.400000
SC from file: evgeny_sept/Summary_bX1508071_0_10_events.root:h_Charge_evt_0. Qtot=4.700590E-08 Coulombs. native dims: (159,360,124)(20.0cm,0.0,0.0cm)-(78.0cm,6.
Drifting grid of (rp)=(54 x 82) electrons with 500 steps
PhiSlice (26 x 40 x 40) with (26 x 1 x 40) roi
vdrift=8.00cm/us, Enom=400.00V/cm, Bnom=1.40T, omtau=-2.8000E+00

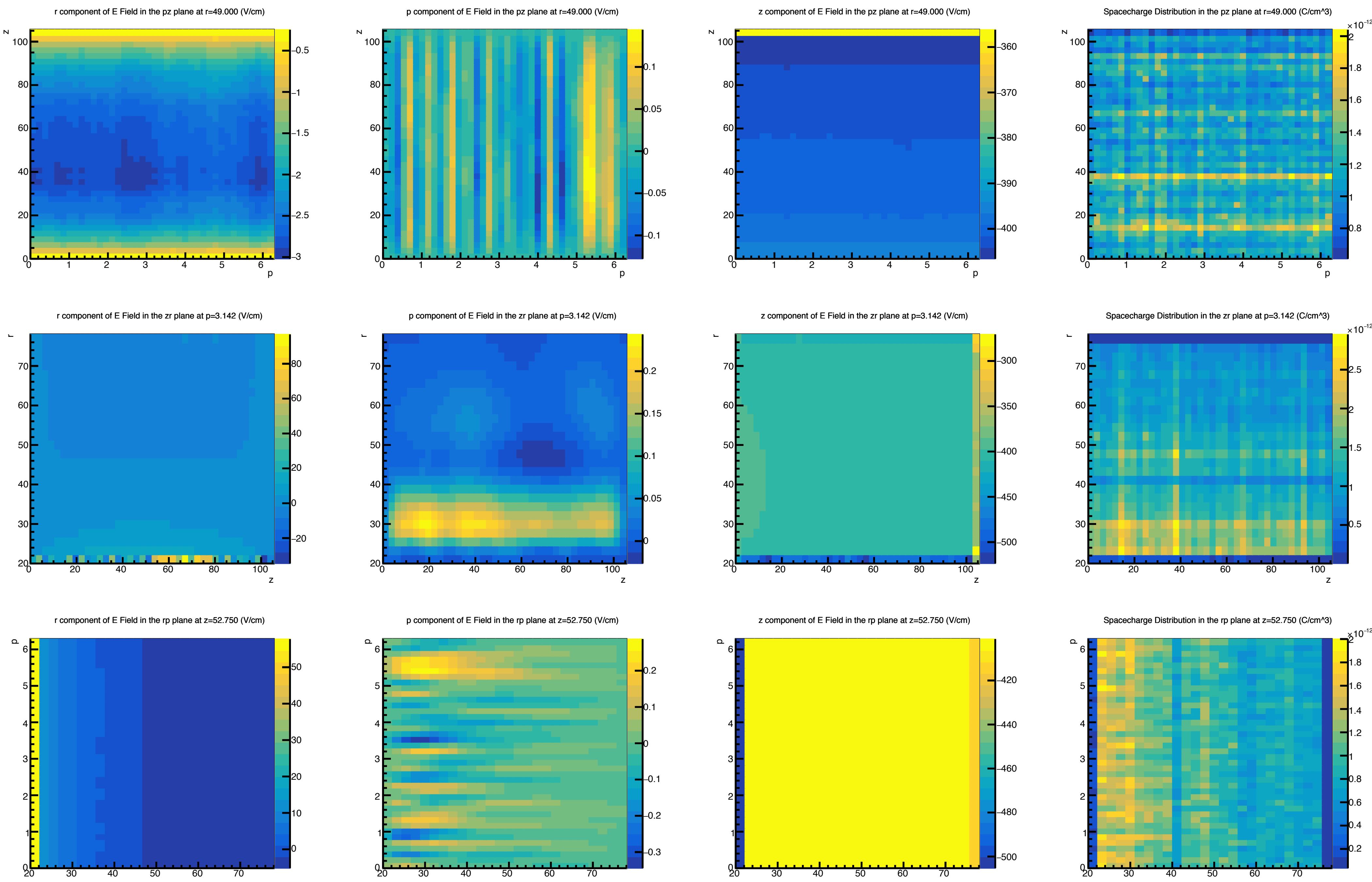
Real Fieldmaps

- Replace ideal z-fields with real (E and) B-field maps:



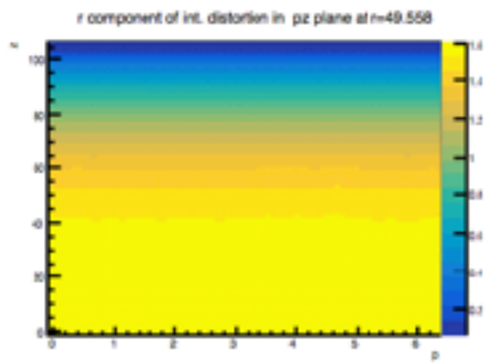
Real Fieldmaps

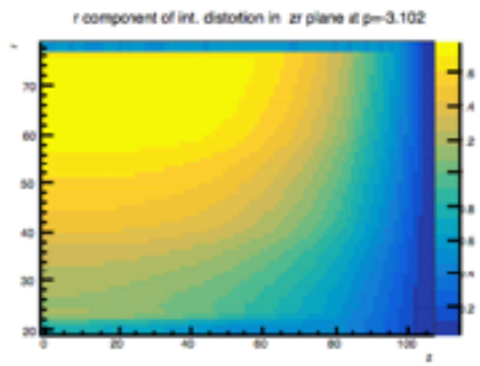
- With charge map on top of it:

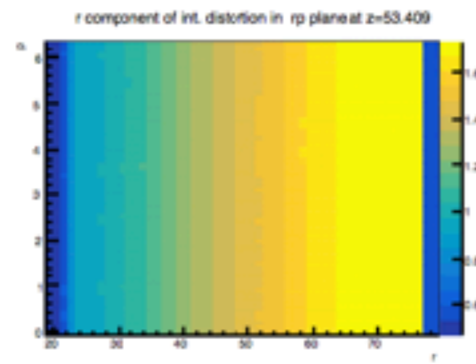


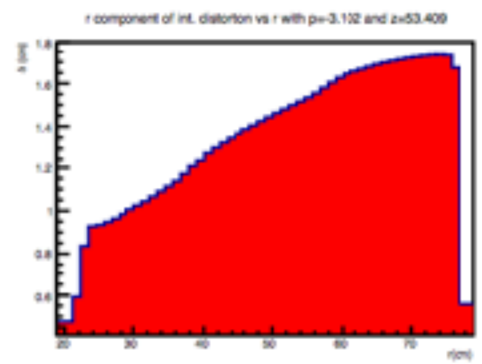
Distortions in Real Fieldmaps

- Transverse components of B field dominate distortion shape









Cartesian Coordinates:

$$\begin{pmatrix}\delta_{xE}\\ \delta_{yE}\end{pmatrix} = \begin{pmatrix}c_0 & c_1\\ -c_1 & c_0\end{pmatrix}\begin{pmatrix}\int \frac{E_x}{E_z}\,dz\\ \int \frac{E_y}{E_z}\,dz\end{pmatrix}$$

$$\begin{pmatrix}\delta_{xB}\\ \delta_{yB}\end{pmatrix} = \begin{pmatrix}c_2 & -c_1\\ c_1 & c_2\end{pmatrix}\begin{pmatrix}\int \frac{B_x}{B_z}\,dz\\ \int \frac{B_y}{B_z}\,dz\end{pmatrix}$$

Cylindrical Coordinates:

$$\begin{pmatrix}\delta_{rE}\\ r\delta_{\phi E}\end{pmatrix} = \begin{pmatrix}c_0 & c_1\\ -c_1 & c_0\end{pmatrix}\begin{pmatrix}\int \frac{E_r}{E_z}\,dz\\ \int \frac{E_\phi}{E_z}\,dz\end{pmatrix}$$

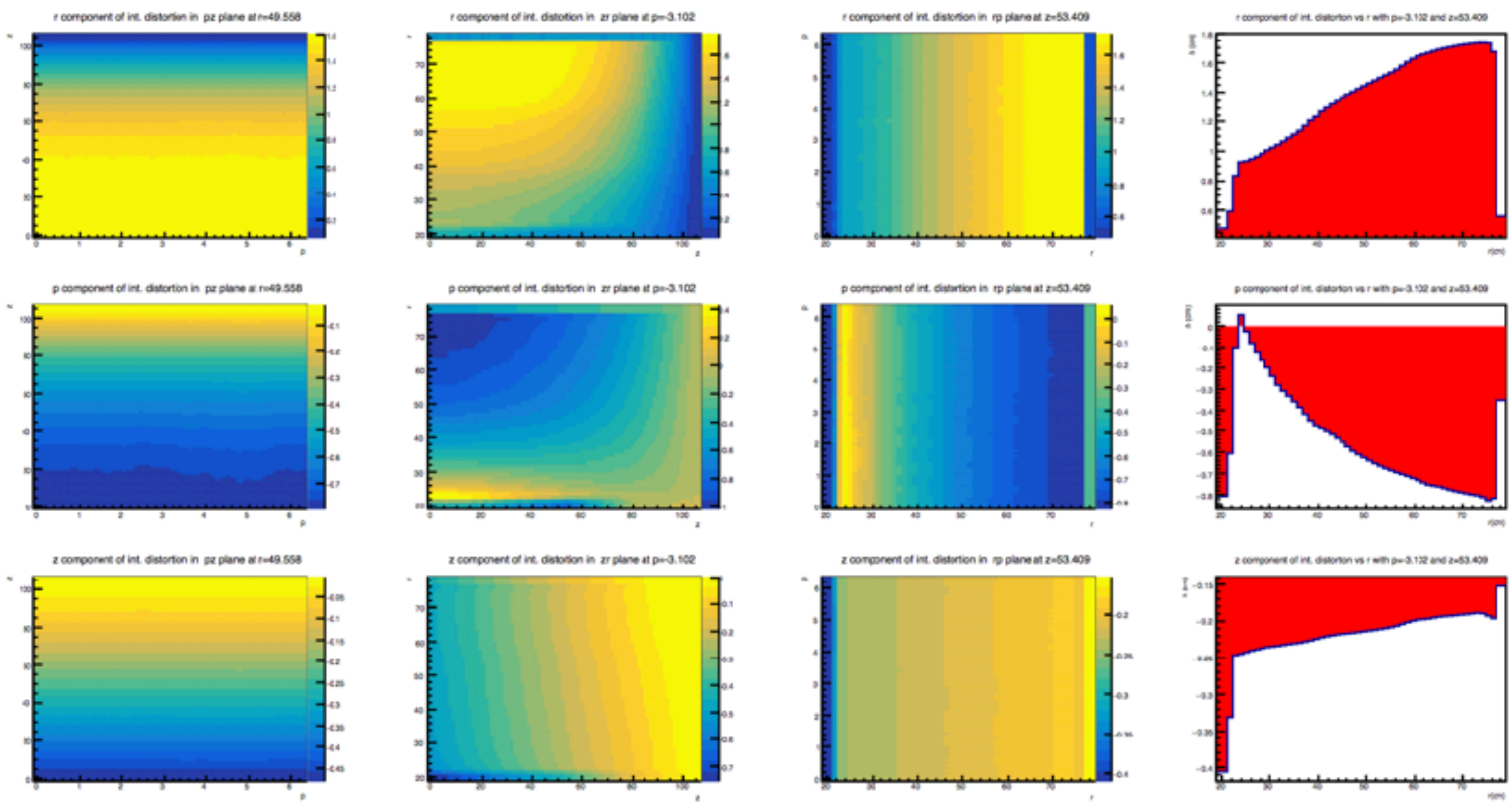
$$\begin{pmatrix}\delta_{rB}\\ r\delta_{\phi B}\end{pmatrix} = \begin{pmatrix}c_2 & -c_1\\ c_1 & c_2\end{pmatrix}\begin{pmatrix}\int \frac{B_r}{B_z}\,dz\\ \int \frac{B_\phi}{B_z}\,dz\end{pmatrix}$$

c2~3 x c1

$$c_0 = \frac{1}{(1+T_2^2\omega^2\tau^2)}, \quad c_1 = \frac{T_1\omega\tau}{(1+T_1^2\omega^2\tau^2)}, \quad \text{and} \quad c_2 = \frac{T_2^2\omega^2\tau^2}{(1+T_2^2\omega^2\tau^2)}$$

Distortions in Real Fieldmaps

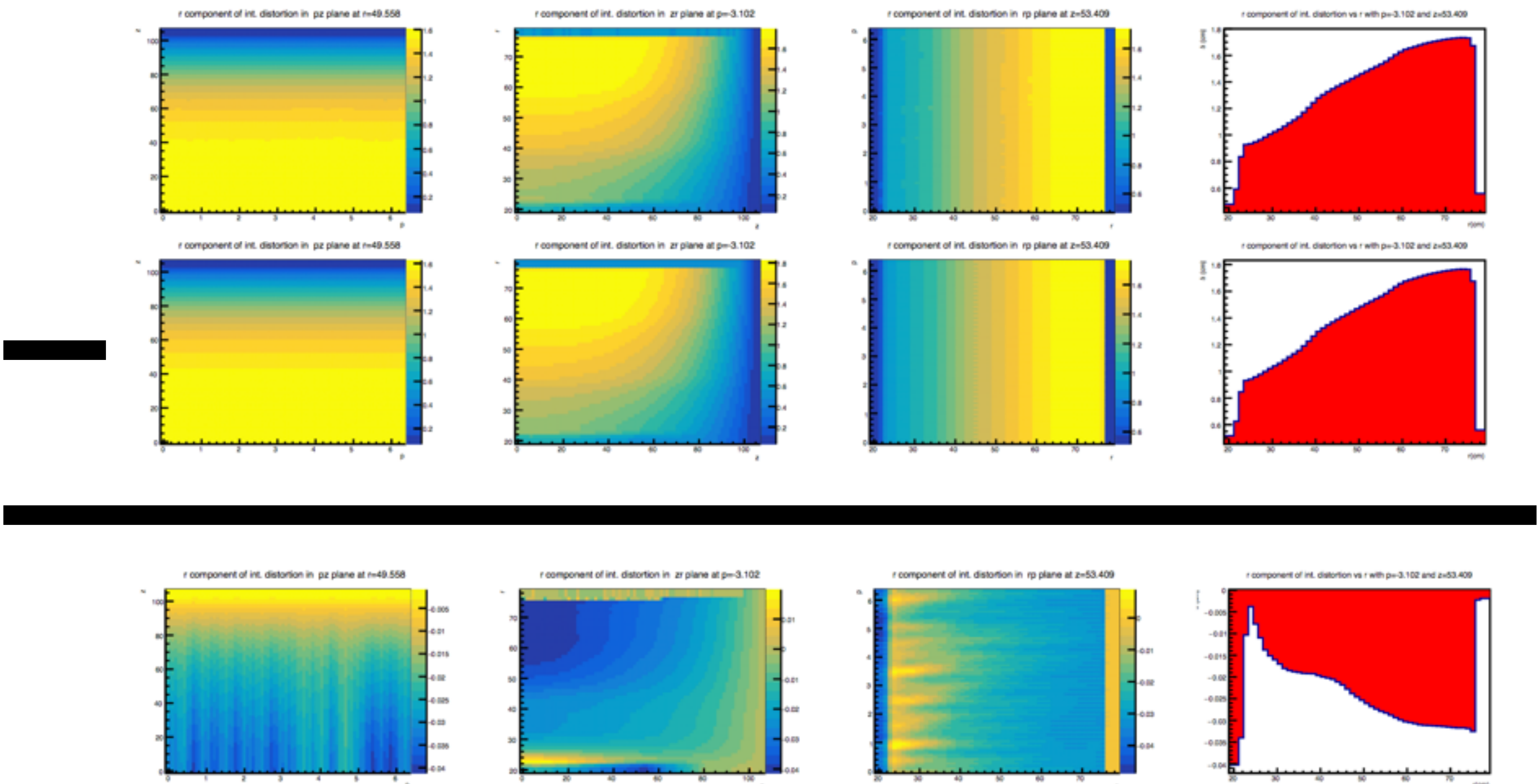
- Transverse components of B field dominate distortion shape



E:externalEfield.ttree.root:fTree, B:sPHENIX.2d.root:fieldmap
SC from file: evgeny_sept/Summary_bX1508071_10_20_events.root:h_Charge_evt_12. Qtot=4.700808E-08 Coulombs. native dims: (159,360,124)(20.0cm,0.0,0.0cm)-(78.0cm
Drifting grid of (rp)=(54 x 82) electrons with 500 steps
PhiSlice (26 x 40 x 40) with (26 x 1 x 40) roi
vdrift=8.00cm/us, Enom=400.00V/cm, Bnom=1.40T, omtau=-2.8000E+00

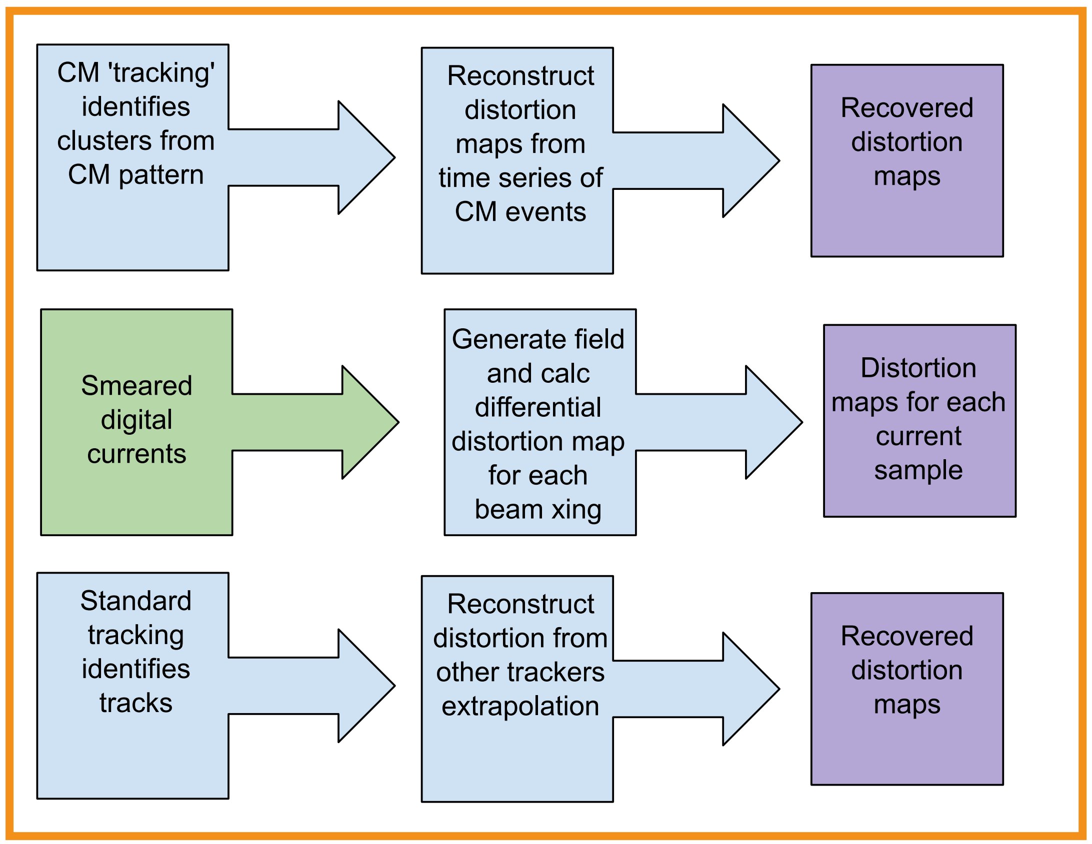
Characterize Fluctuations

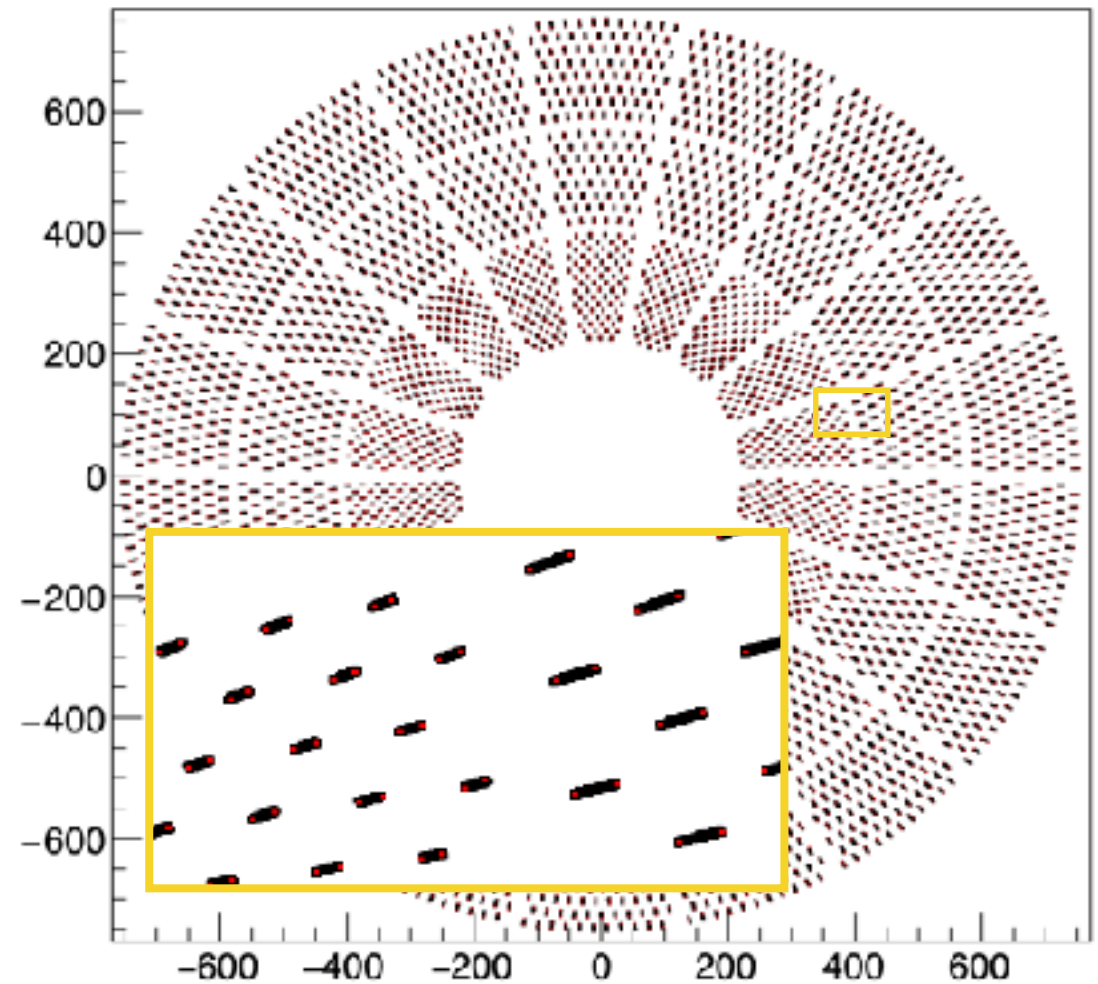
- Subtract off distortion from time-averaged field to see the additional fluctuations due to distortions:



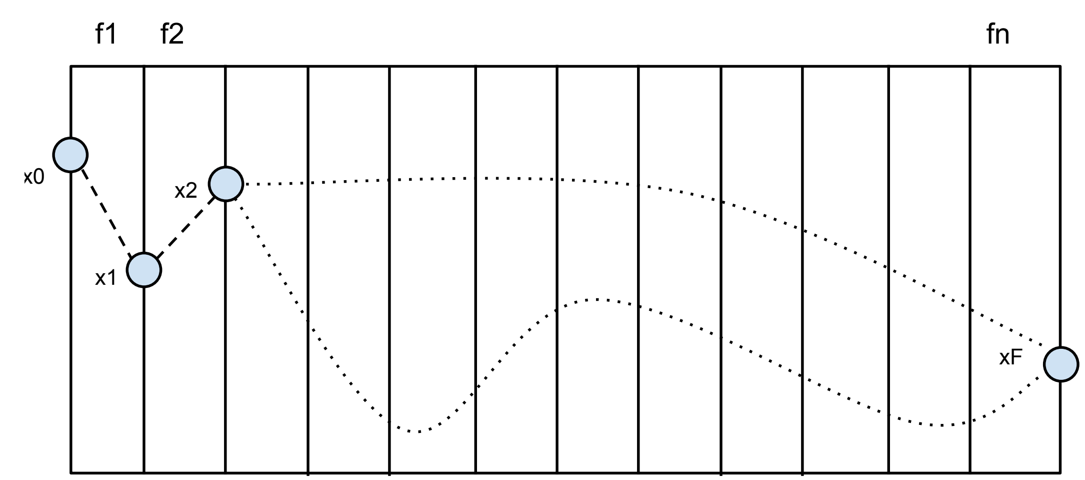
Reconstructing Using Central Membrane

Reco and Calibration



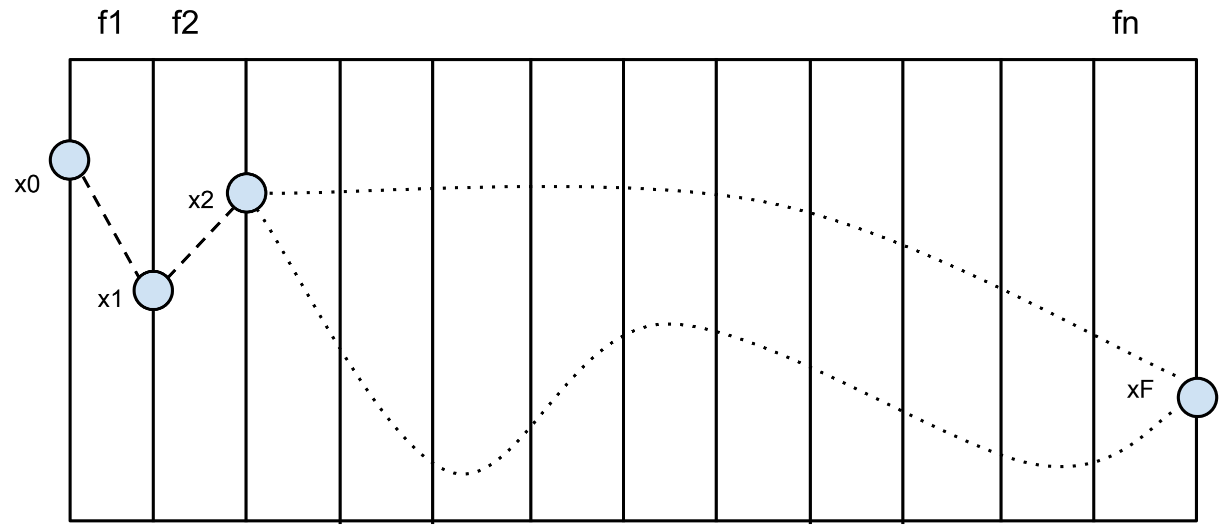


- Henry Klest distorting the CM hits in Fun4All
- Sara Kurdi matching them back to particular stripes
- Building up differential reconstruction for realistic case

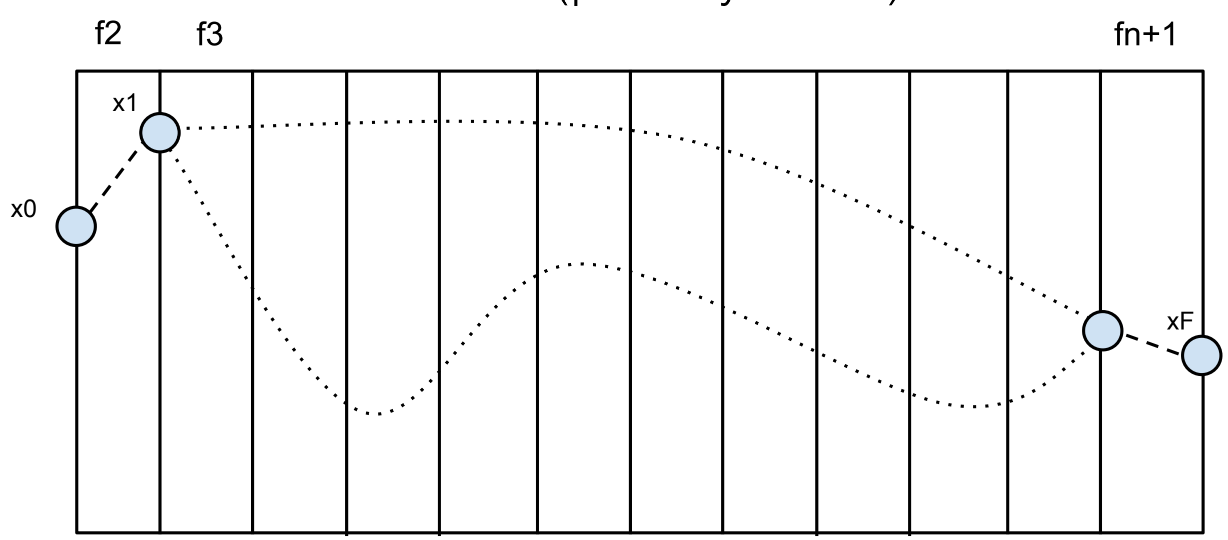


Toy Model of CM Differential Reco

The position of an electron at readout is the sum of the distortion in each z-step along the way. Electrons from the CM stripe pattern integrate over the entire z-column (and tracks over a partial column):



The distortions evolve with the motion of the ions (primary<<IBF):



(improved drawing courtesy Sara Kurdi)

By comparing the reconstructed CM stripe position at two consecutive times, we learn about the portions of the z-column they do not have in common, and can use this to extract differential information about the distortions. The number of iterations where you can link differential information is limited by intrinsic detector resolutions.

Assumptions

- Distortions all move linearly with time (static distortions are okay, but everything in motion has the same velocity)
  - Static B and E distortions can't be measured with this method
- Distortion magnitudes are independent of z-position (distortions do not evolve due to z-position in the tpc, only position relative to spacecharge)
  - Not strictly true. Boundary conditions present

Summary

- Software to generate and implement distortion has been written and consistency-checked,
  - external checks found a few missing terms
  - optimization is ongoing
- Time series sets are in production and in some use
  - still finalizing format
  - 15khz sample allows us to do full-fledged CM-flash study