sPHENIX Spacecharge distortions

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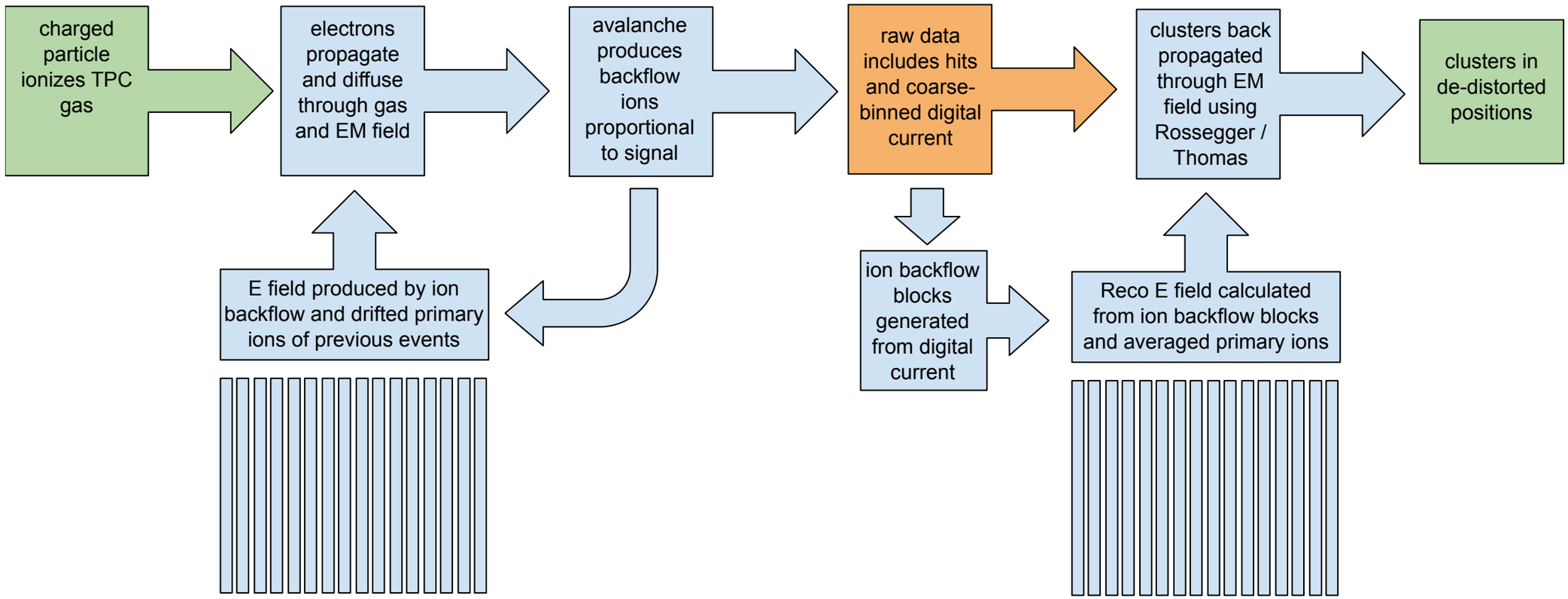
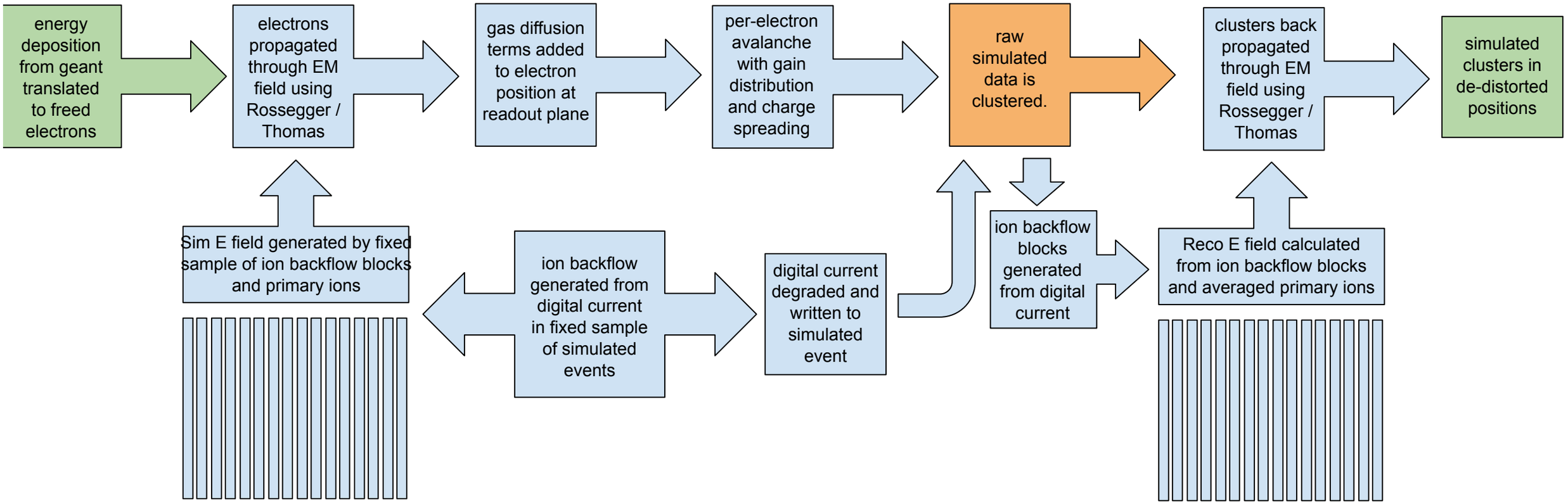
Real Space Charge in sPHENIX TPC



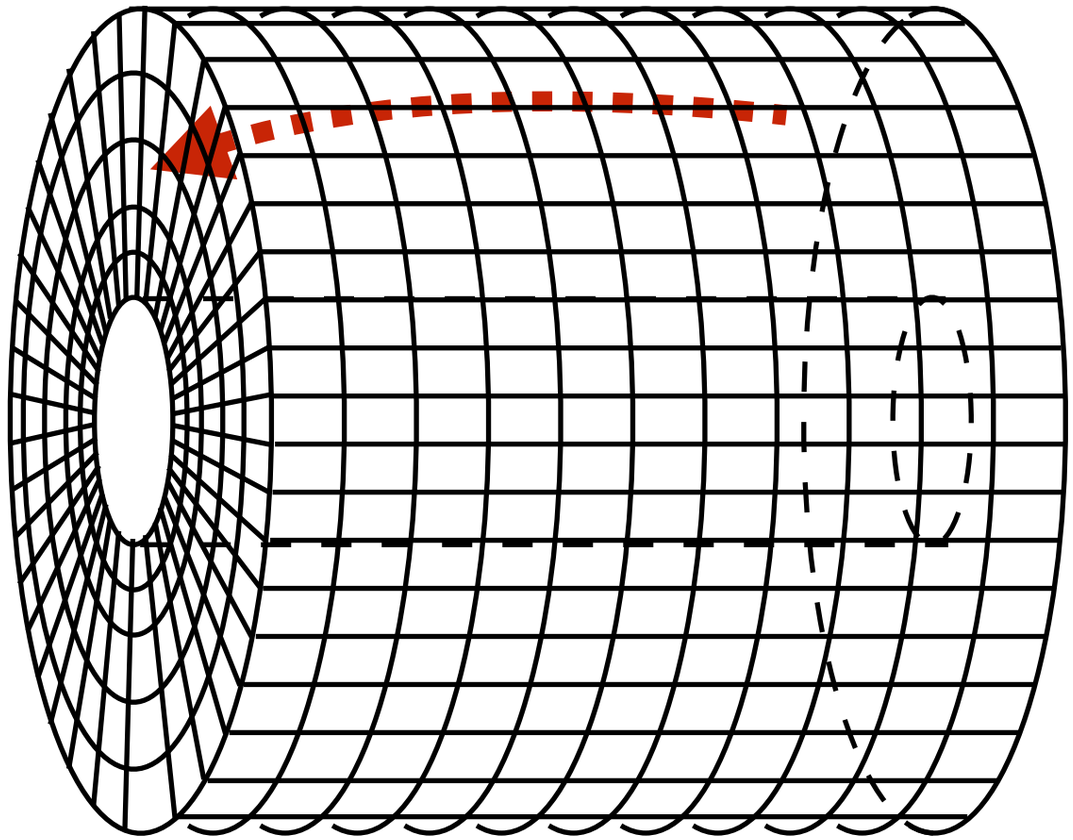
- measure 'digital current' as proxy for ion backflow
- back-propagate electrons through 'same' field
- challenge: Do it quickly enough for timely reconstruction

Simulating Space Charge in sPHENIX TPC



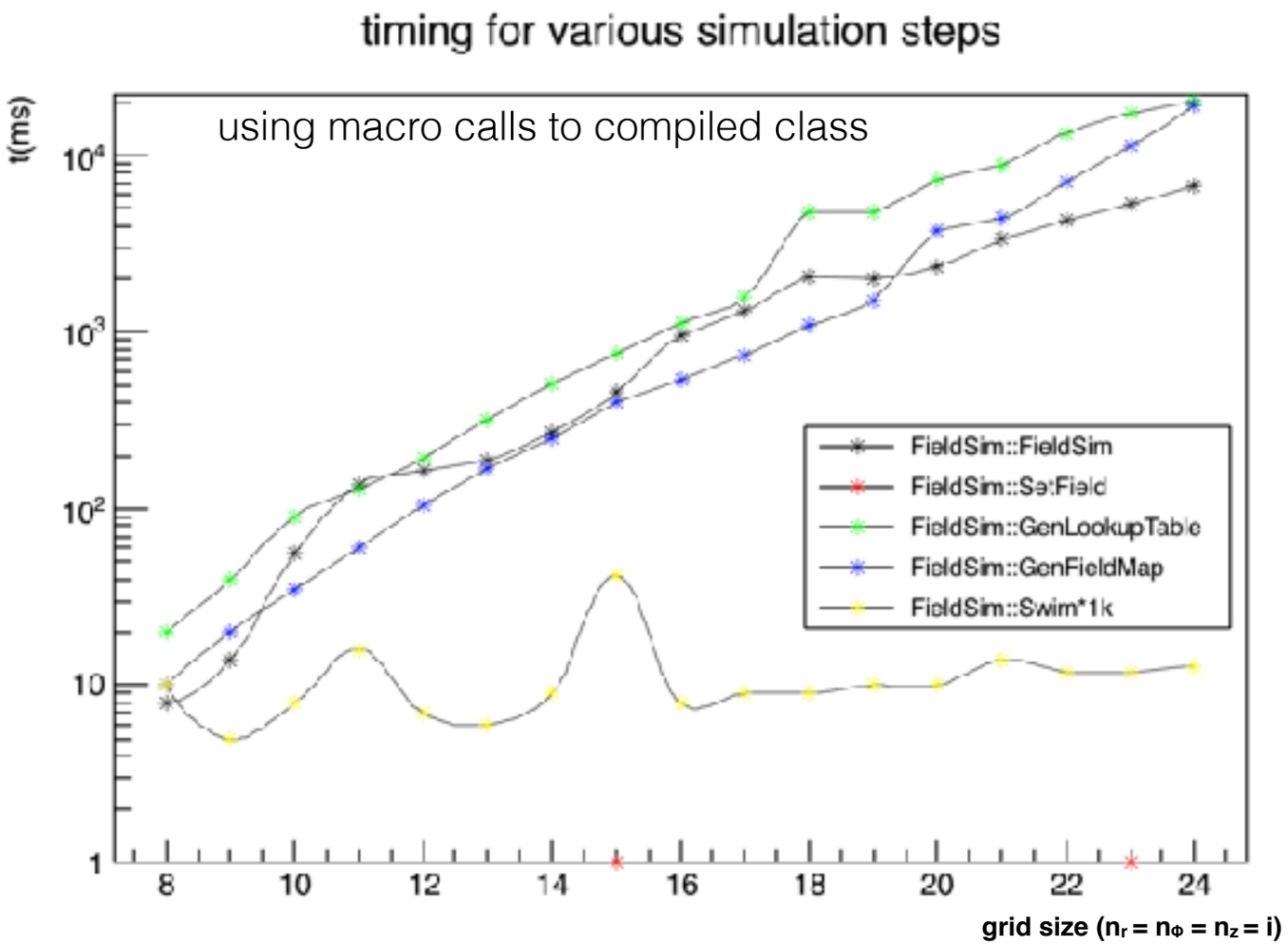
- mock-up same data flow in simulation:
  - fixed sample to generate 'actual' distortions
  - data from fixed sample feed simulated digital current

Propagation Model



- Divide TPC into Pieces of Cake (POC) grid
- Compute (free-space) cell-to-cell Green's functions
- Use SC distribution to sum field vector per cell (in various ways)
- Propagate each electron using 2nd order Langevin
  - interpolate between r,phi adjacent cells
  - take small steps in z to increase accuracy

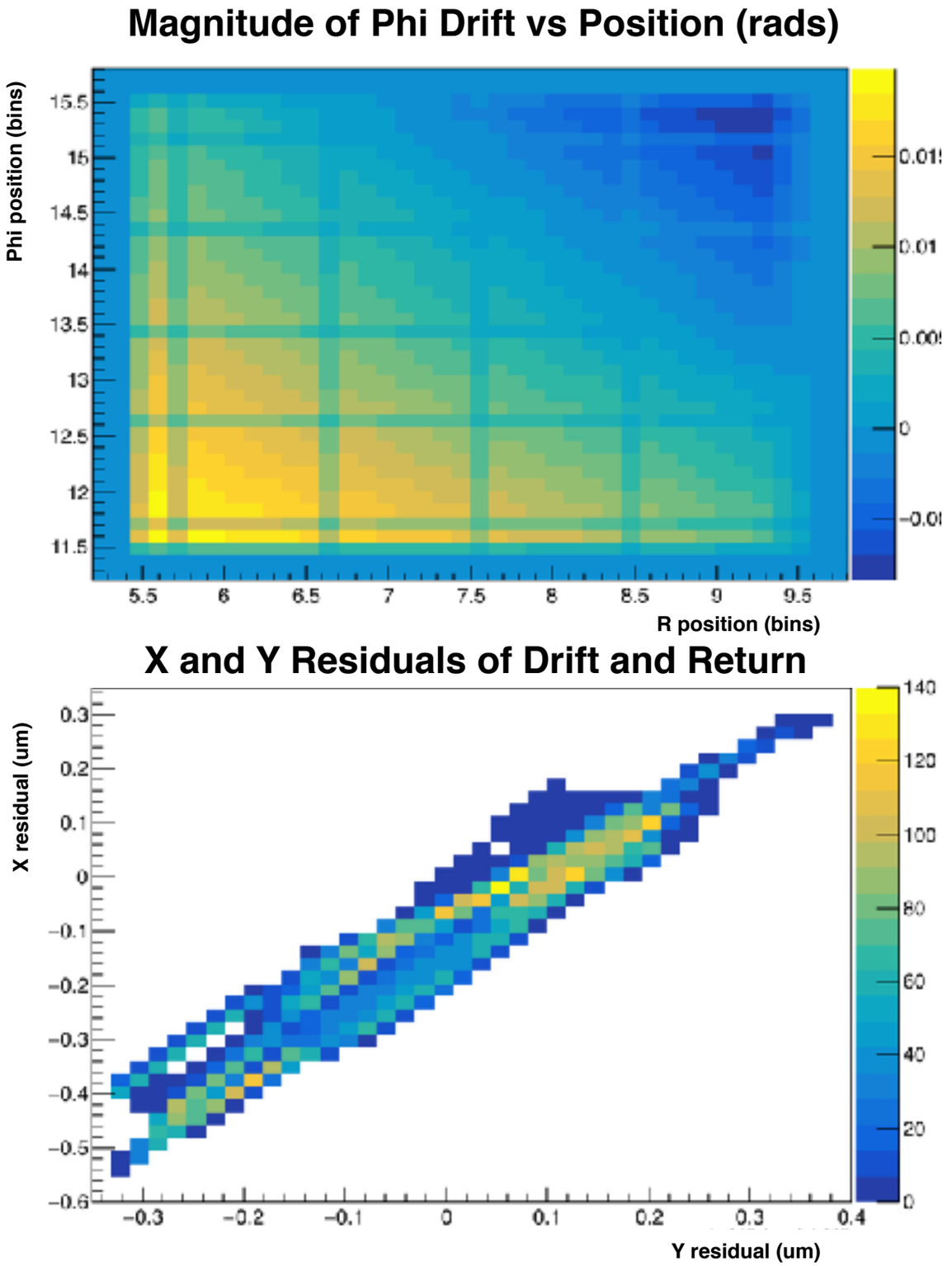
Propagation Model



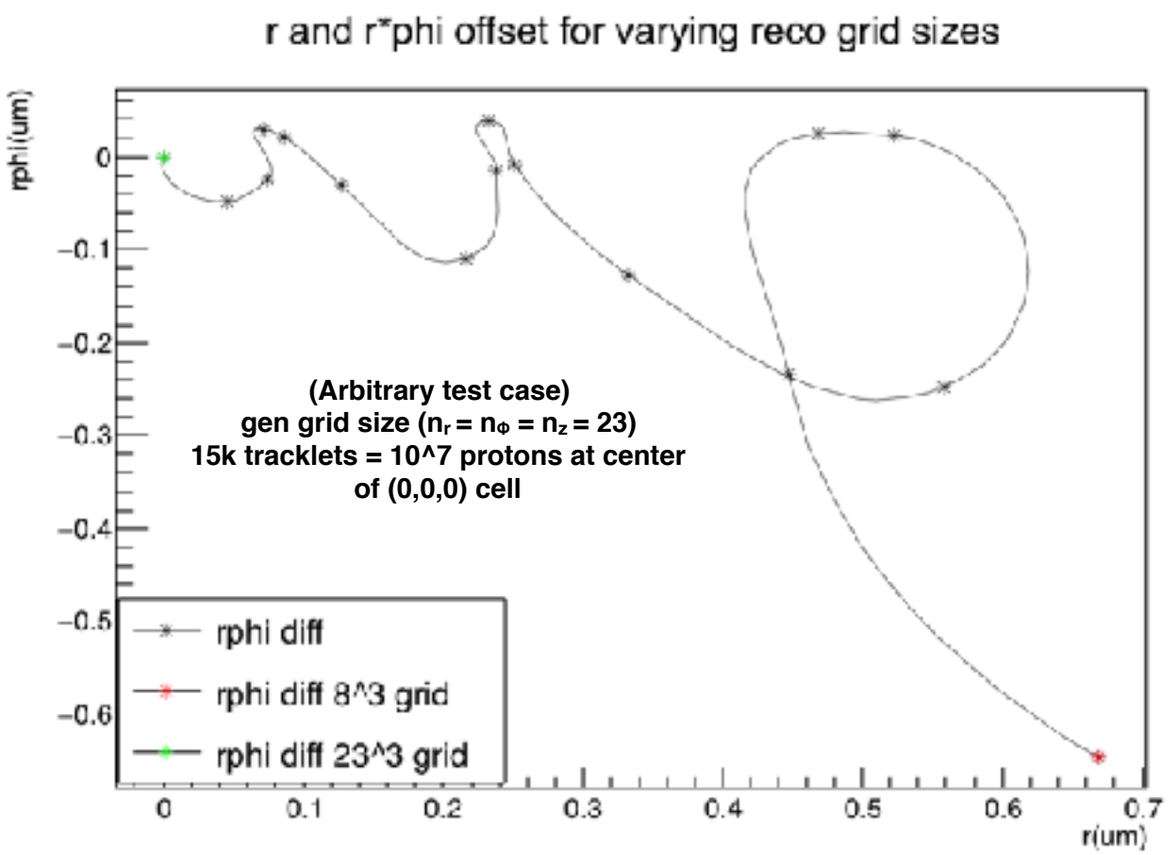
Element	memory scale	compute scale	timing
Lookup Table	$(n_r \times n_\Phi \times n_z)^2$	$(n_r \times n_\Phi \times n_z)^2$	startup
Field from SC	$(n_r \times n_\Phi \times n_z)$	$(n_r \times n_\Phi \times n_z)^2$	per event
Swim	1	n_z	per cluster

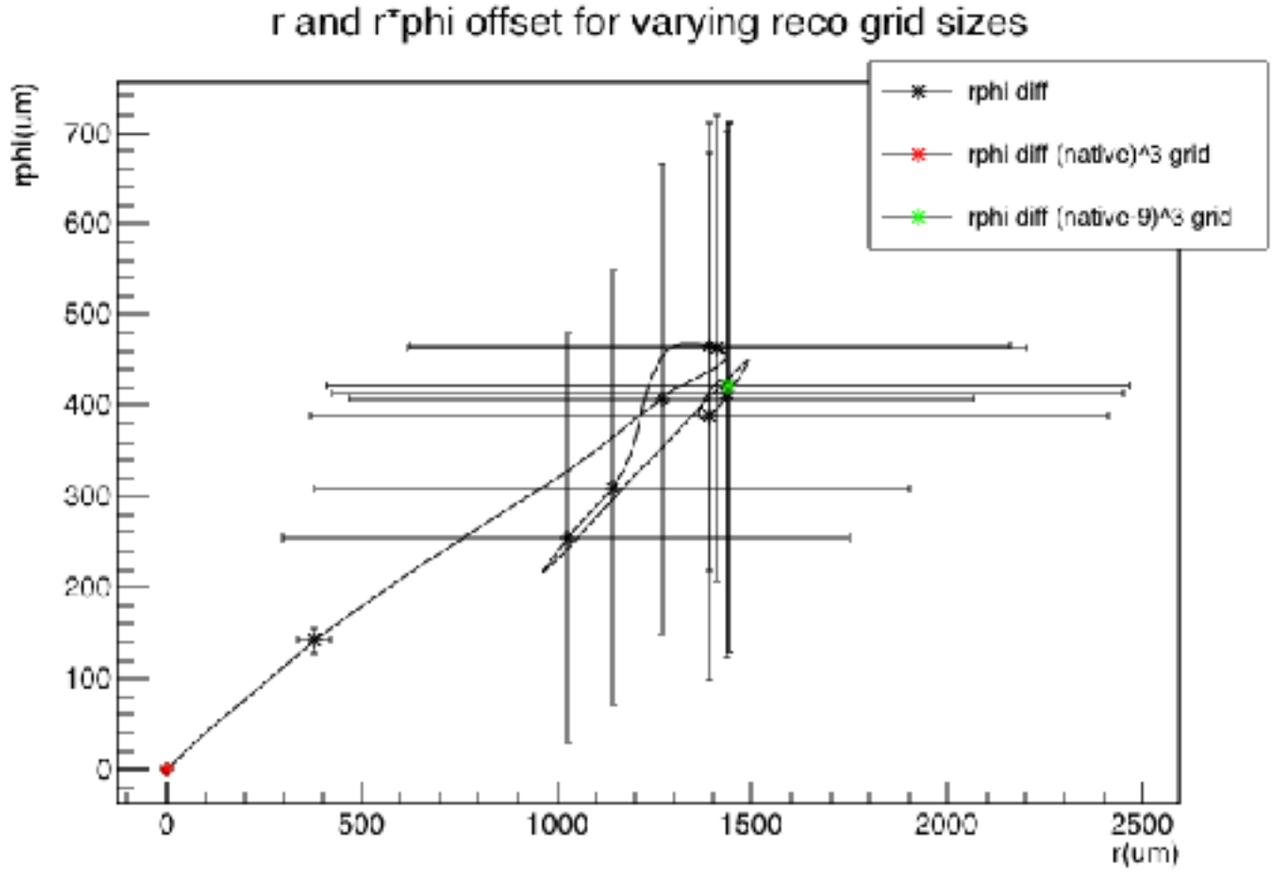
Model Performance

- Back-propagation residual due to field variation at drifted position
- Native resolution can easily reach <um scale
- But what resolution is needed to match reality?



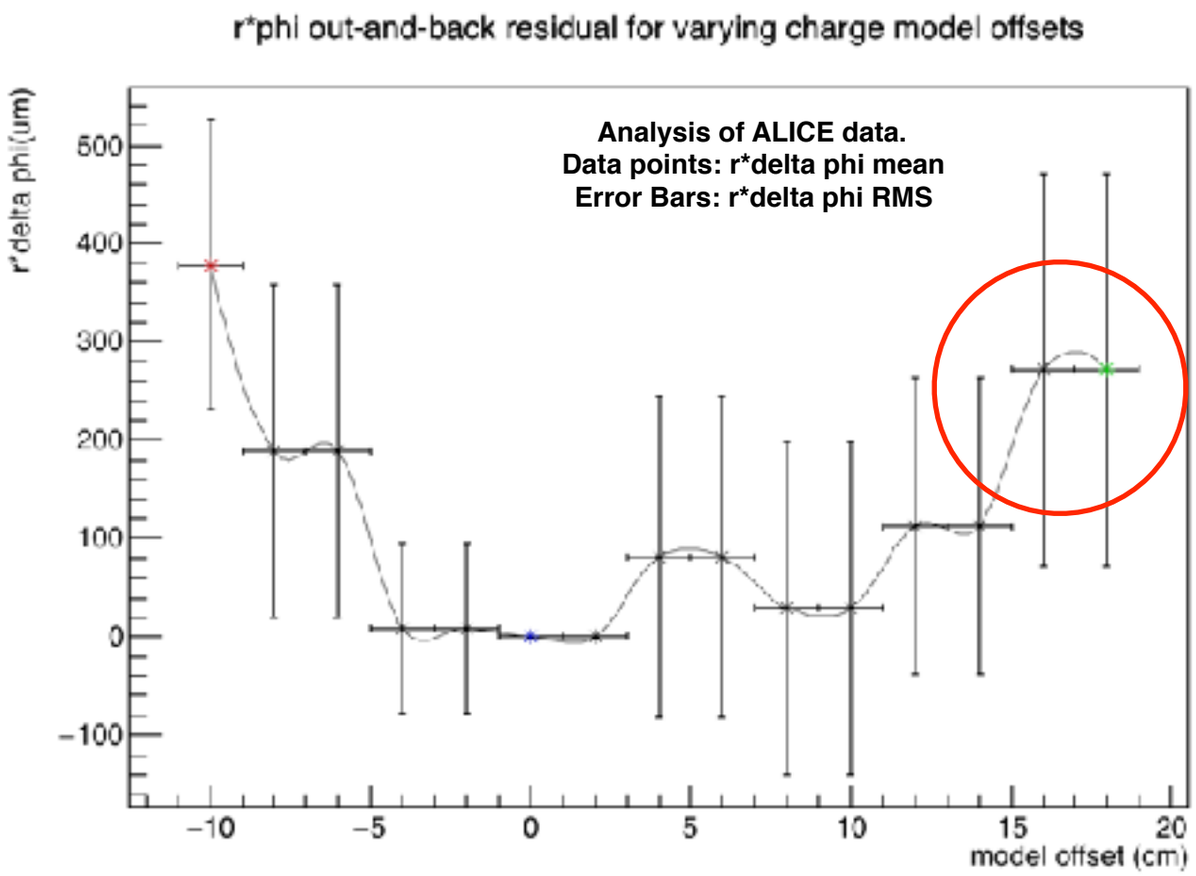
Fidelity vs Scale

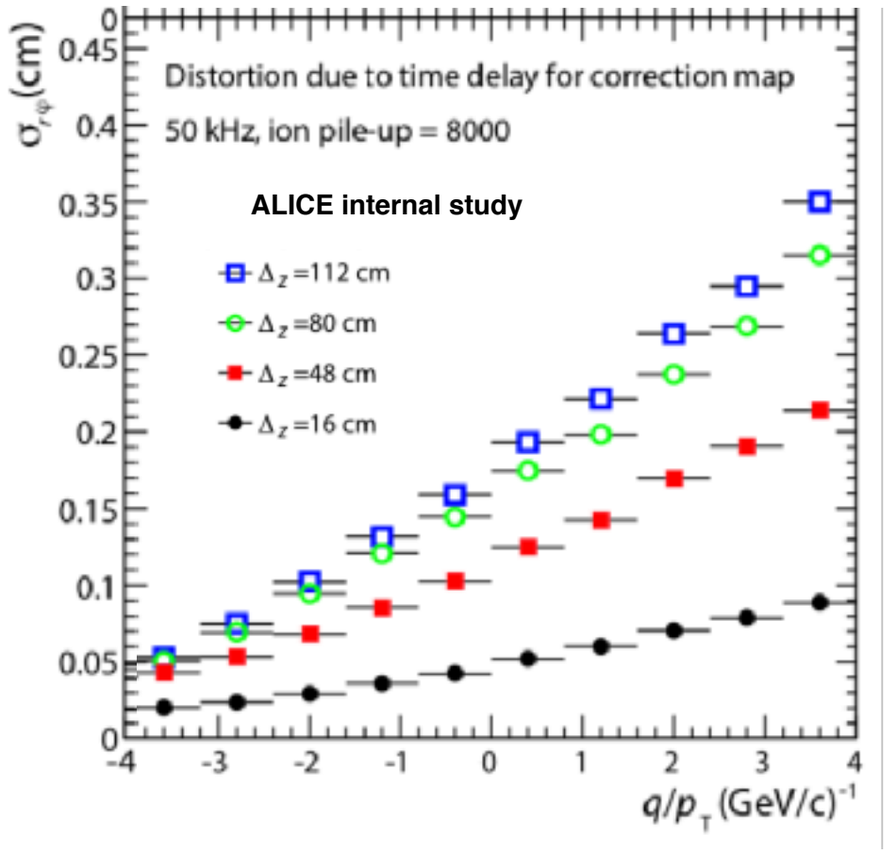




- Using free-space Greens functions -- assuming these are okay far
- Full all-to-all grids (23x23x23) (left), All-to-ROI grids (159x360x62) (right)
- Swim forward using fixed 'gen' grid, backward using reco grid of different sizes
- Arbitrary SC distribution (left), ALICE SC (right)
- Single sample particle (left), 50x50 particles at far end of ROI (right)
- Error bars from RMS -- due to aliasing of charge histogram?

Fidelity vs Offset

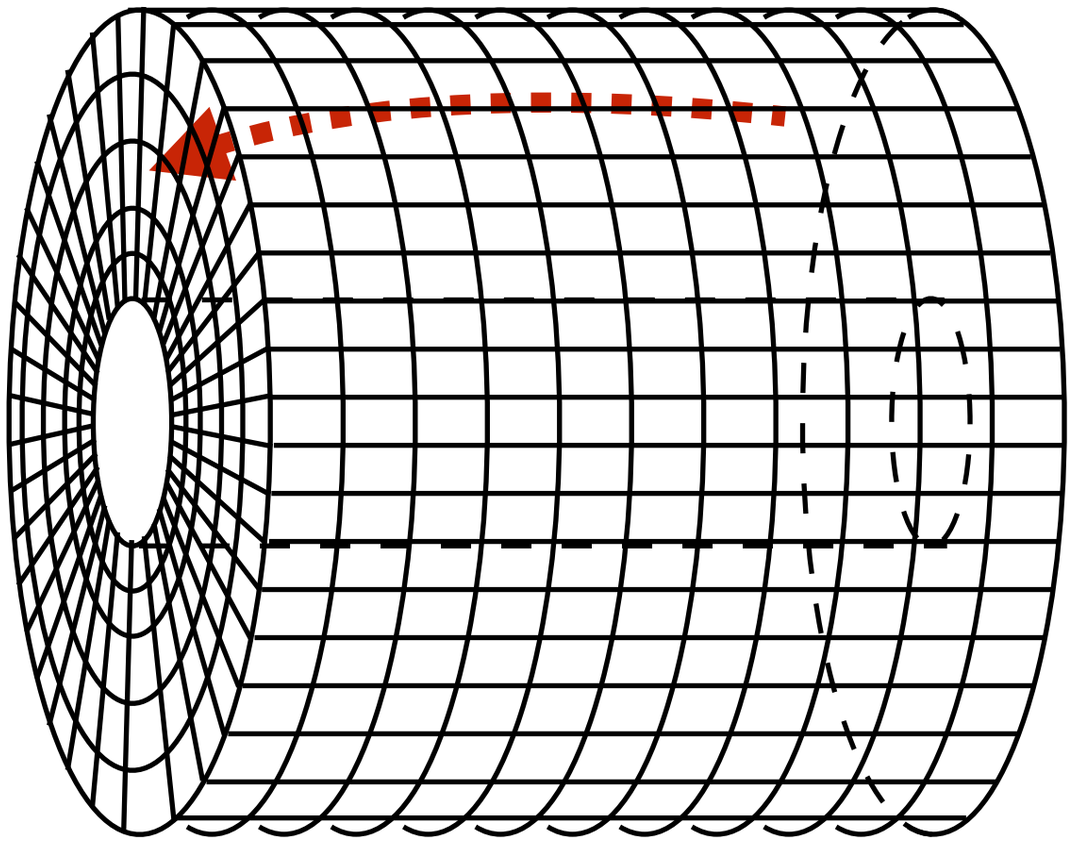




- Using free-space Greens functions
- Swim to readout using 10cm shift of charge histogram
- Cyclicly advance charge histogram*, swim back through shifted field

Other Models

- Full 3D - Every cell from every cell.
  - Very legible. Highest memory footprint
- 2D Phi Slice - Every cell with phi=0 from every cell. Rotates result to match cells in question.
  - Exploits near symmetry in phi. Moderate memory footprint.
- Varying Resolution 3D - Every cell from every cell in that neighborhood, then every lower-resolution group of cells from every lower-resolution group.
  - Preserves high-resolution features where that resolution is important. Smallest footprint



Status

- Currently:
  - Injected actual space charge from ALICE study
  - Studied at full-resolution in small region of interest
  - Framework overhauled to handle large number of space points
  - phi-symmetric Green's functions may be possible from FEA (would include field cage details)
  - working on phi components. Rossegger? Free Space?
- Homework for the Mega-Workfest:
  - Finish developing sPHENIX SC first-pass.
  - Swap parameters with Jens and Ernst so they can replicate sPHENIX