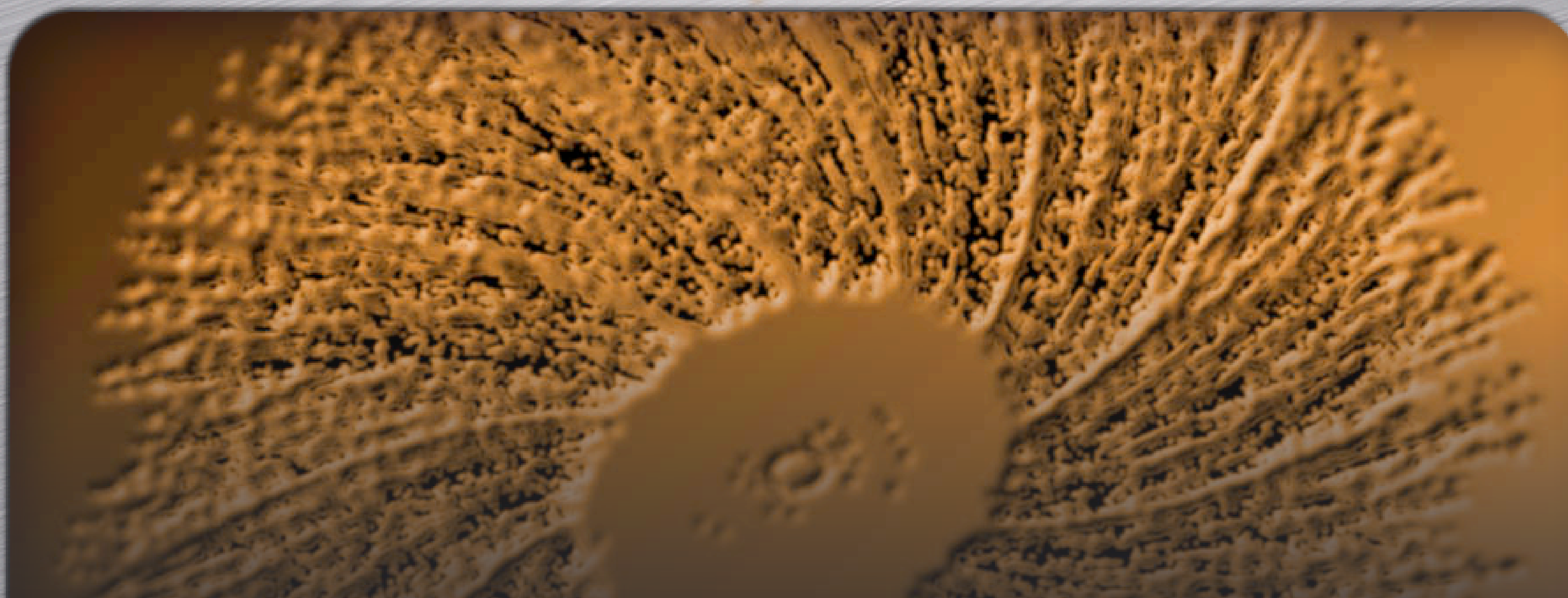
CHEP '06
Mumbai, February 2006

Gene Van Buren
Brookhaven National Lab

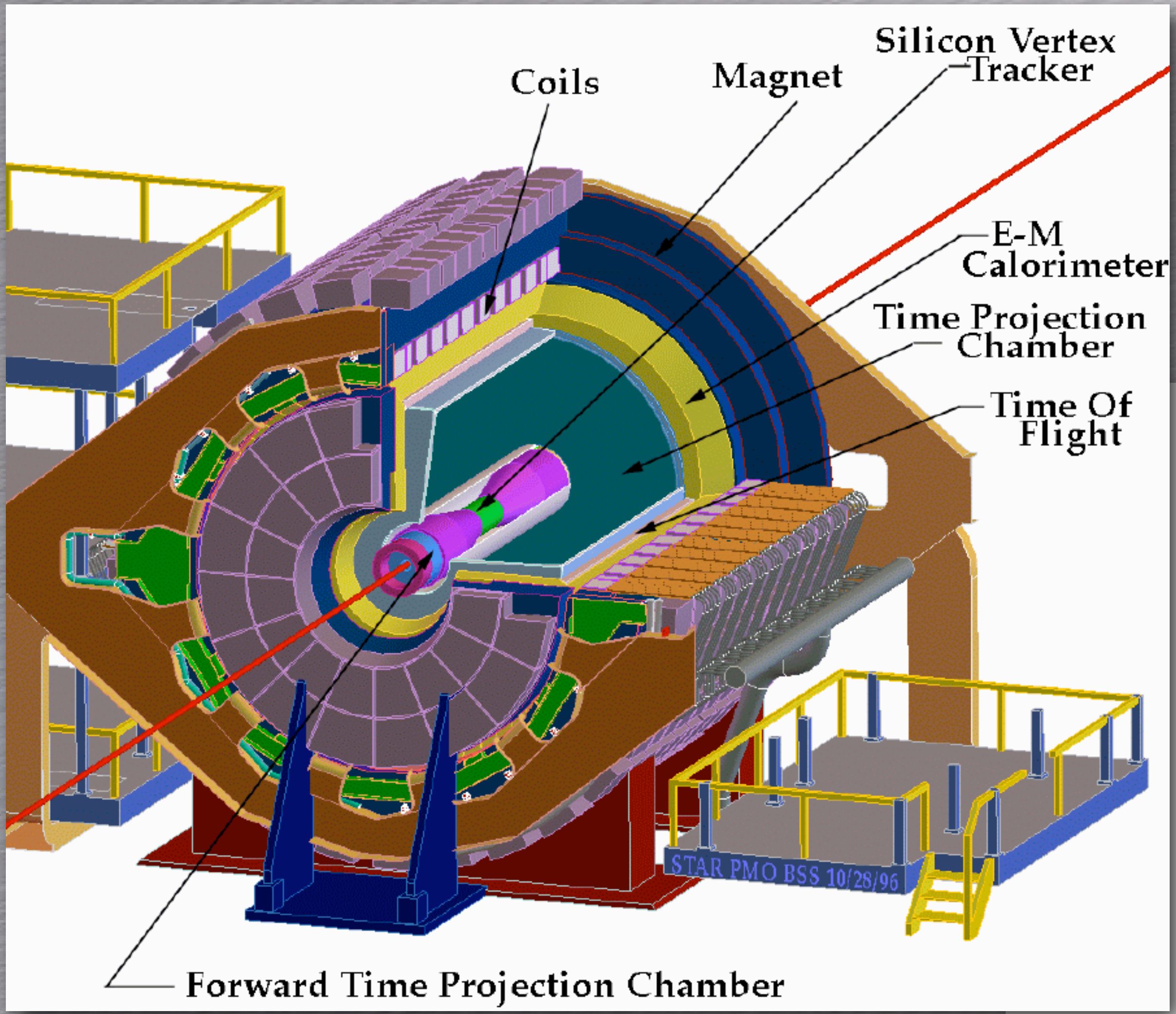
STAR Experiment

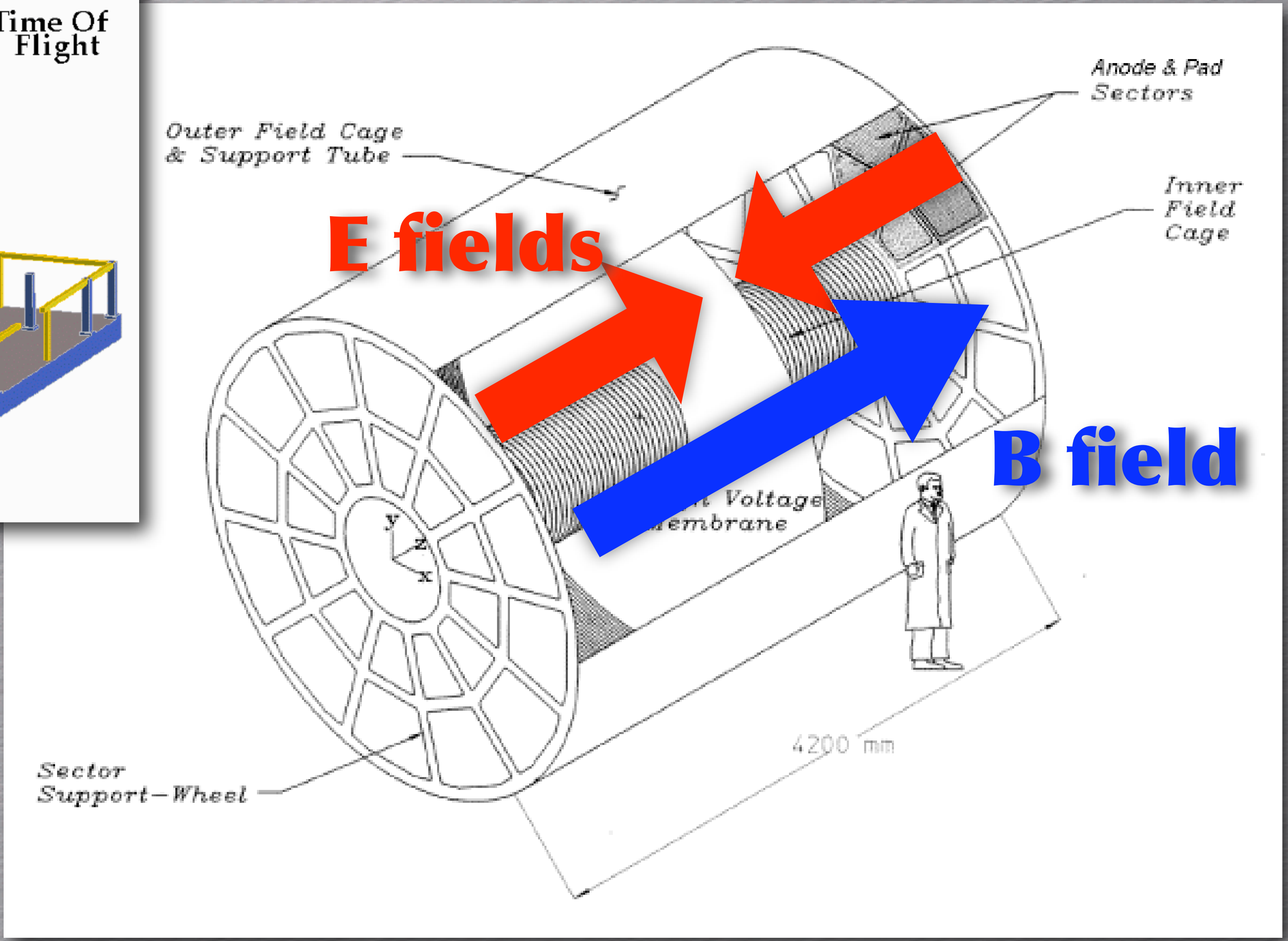


Co-authors: L. Didenko, J. Lauret (BNL),
J.H. Thomas (Lawrence Berkeley National Lab)

Adaptive on-the-fly calibration of TPC distortions

STAR TPC


Coils
Magnet
Silicon Vertex Tracker
E-M Calorimeter
Time Projection Chamber
Time Of Flight
STAR PMO BSS 10/28/96
Forward Time Projection Chamber

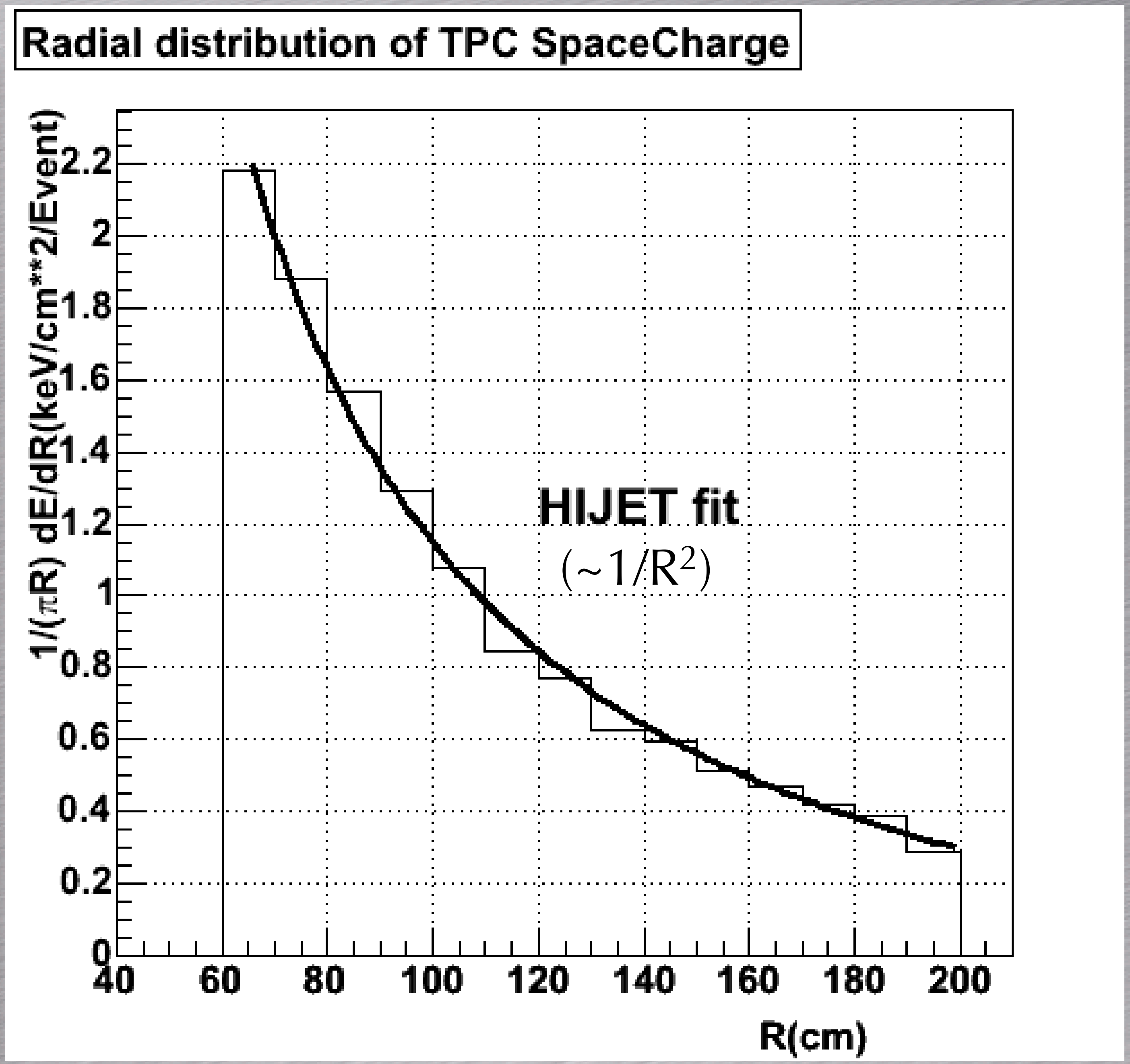

Anode & Pad Sectors
Outer Field Cage & Support Tube
Inner Field Cage
E fields
B field
Sector Support–Wheel
4200 mm

TPC Distortion Corrections

- Each TPC distortion correction requires some "measure" of the problem:
  - Field maps, surveys, reconstructed track observables
  - Observables are most easily determined from some set of "ideal" tracks (e.g. perfectly straight) which may require large statistics (many reconstructed events)
- Most distortions have static causes
- Conflict: what to do when a highly dynamic (volatile) distortion needs large stats? .....

SpaceCharge: model of charge

- HIJET model of "event shape" for 200 GeV AuAu collisions matches radial distribution of zerobias data well for much of the runs.



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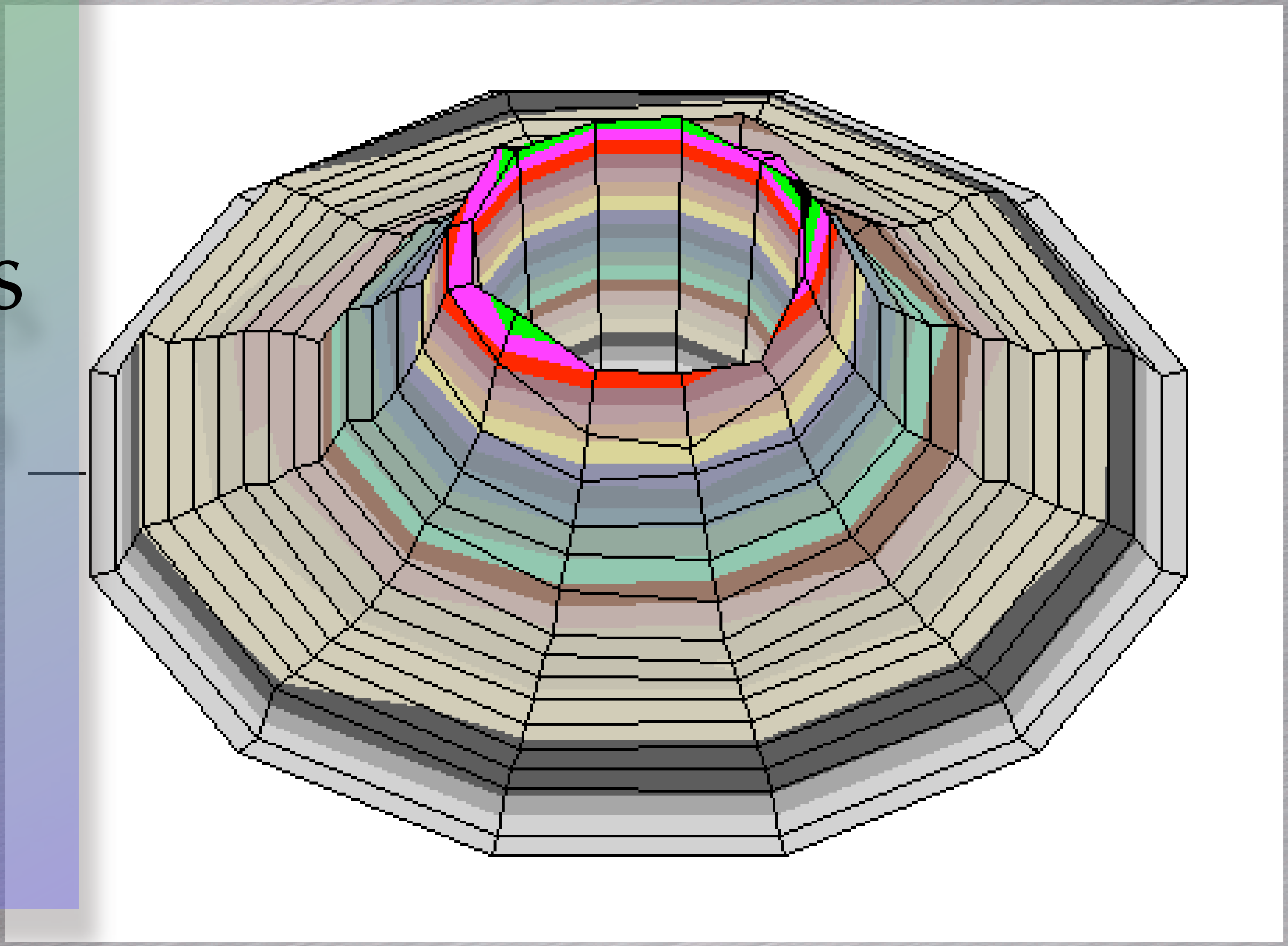


March 1, 2004 data

Distortion equations

(see Blum & Rolandi)

Solve:

$$m\frac{d\bar{u}}{dt} = e\bar{E} + e\left[\bar{u}\times\bar{B}\right] - K\bar{u}$$

Langevin Equation with “Friction”

substituting:

$$\tau = \frac{m}{K}, \quad \omega = \frac{e}{m}|\bar{B}|, \quad \mu = \frac{e}{m}\tau, \quad \text{and} \quad \hat{E} = \frac{\bar{E}}{|\bar{E}|}$$

subject to the steady state condition

$$\frac{d\bar{u}}{dt} = 0$$

yields

$$\bar{u} = \frac{\mu|\bar{E}|}{(1+\omega^2\tau^2)}\left(\hat{E} + \omega\tau\left[\hat{E}\times\hat{B}\right] + \omega^2\tau^2\left(\hat{E}\bullet\hat{B}\right)\hat{B}\right)$$

If you have a well defined model, and good data, then the distortion can be removed with great precision

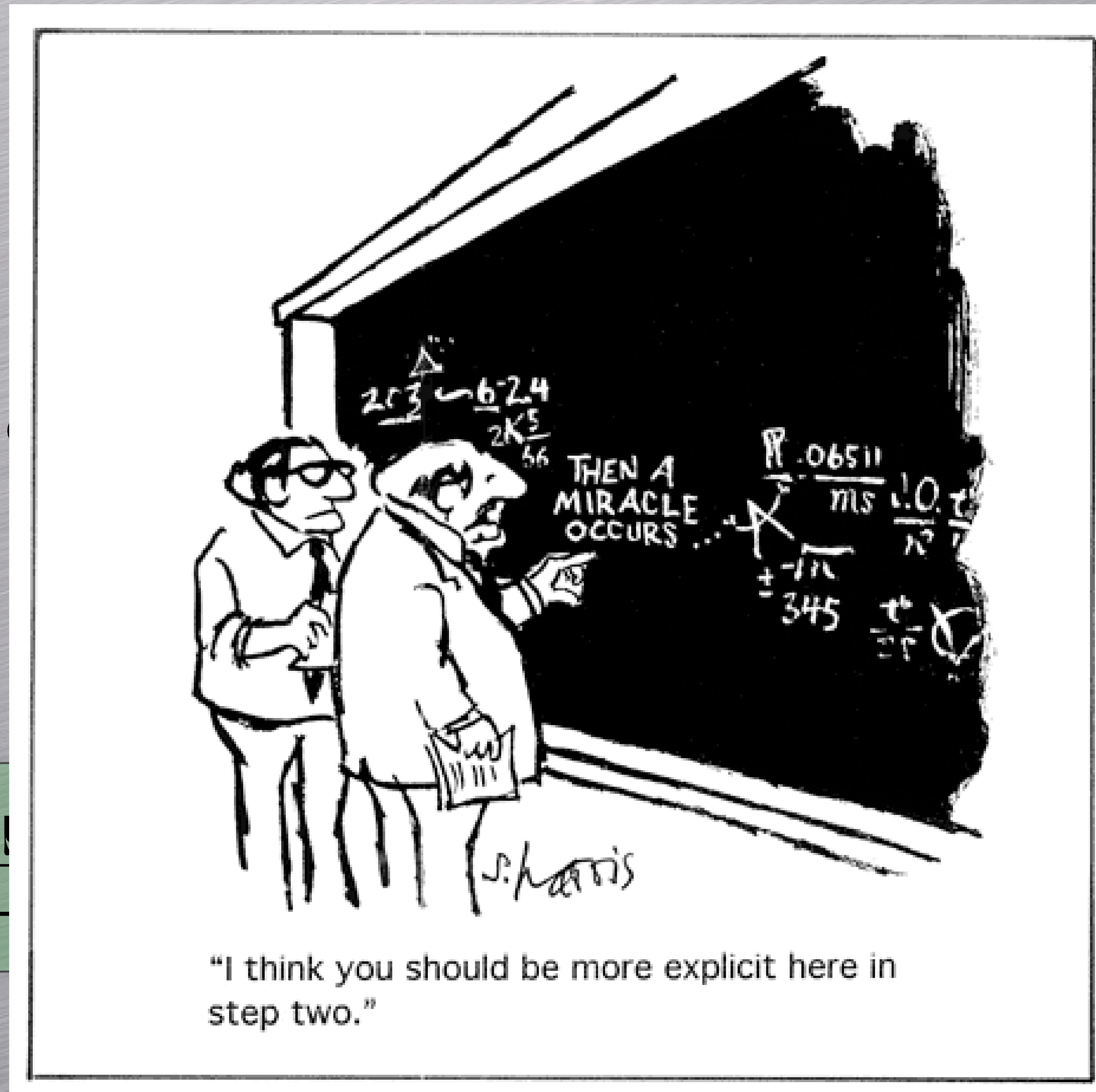
Distortion equations

Solve:

substituting: ... on”

$$\tau = \frac{m}{K}\ , \quad \ldots \quad \frac{\bar{E}}{|\bar{E}|}$$

$$\bar{u} = \frac{\ldots}{(1 \ldots} \ldots \bullet \hat{B})\hat{B} \ \ )$$

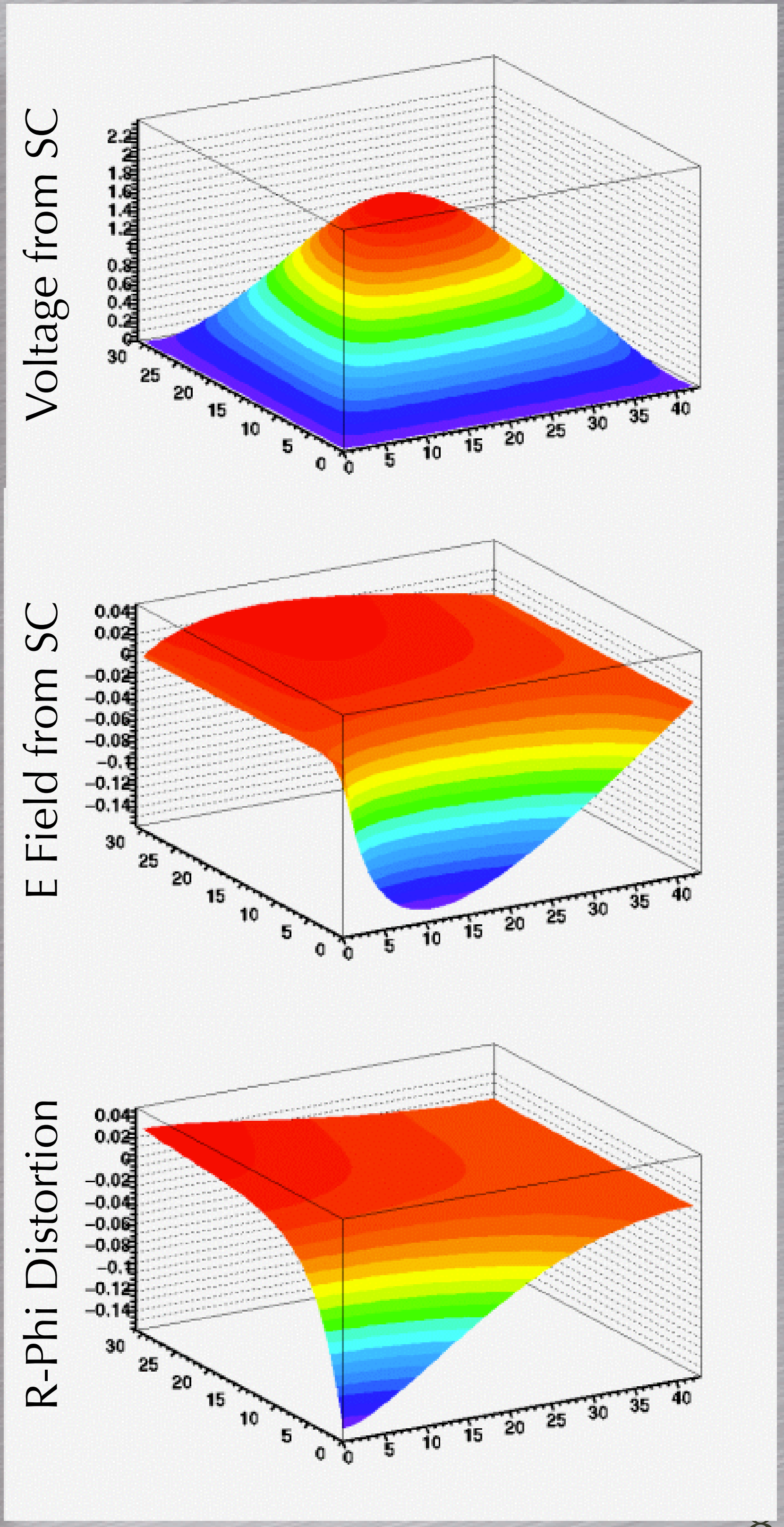


“I think you should be more explicit here in step two.”

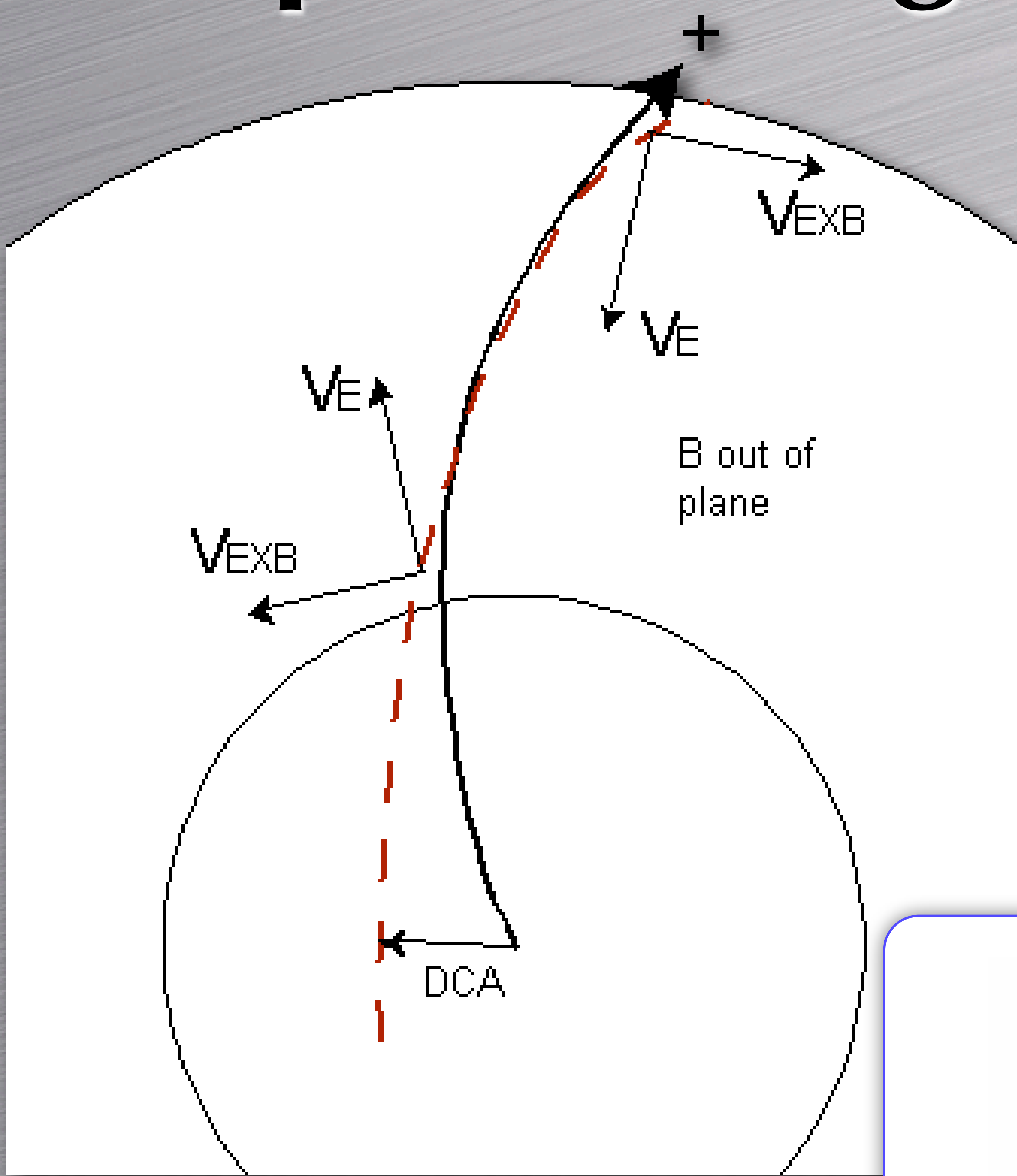
If you have a well defined model, and good data, then the distortion can be removed with great precision

SpaceCharge Field Effects

- Using our "event shape" model
  - Relaxation done on 5cm x 5cm 2D (r-z) grid (assume Φ symmetry)
  - Treat as a perturbation on top of standard TPC E field
  - Distortions are integral of E field in z (drift direction)
  - Not very sensitive to radial component of distortion because tracks are radial-like
  - Lorentz Force Eqn: $\vec{F} \propto q \bullet (\vec{E} \times \vec{B})$

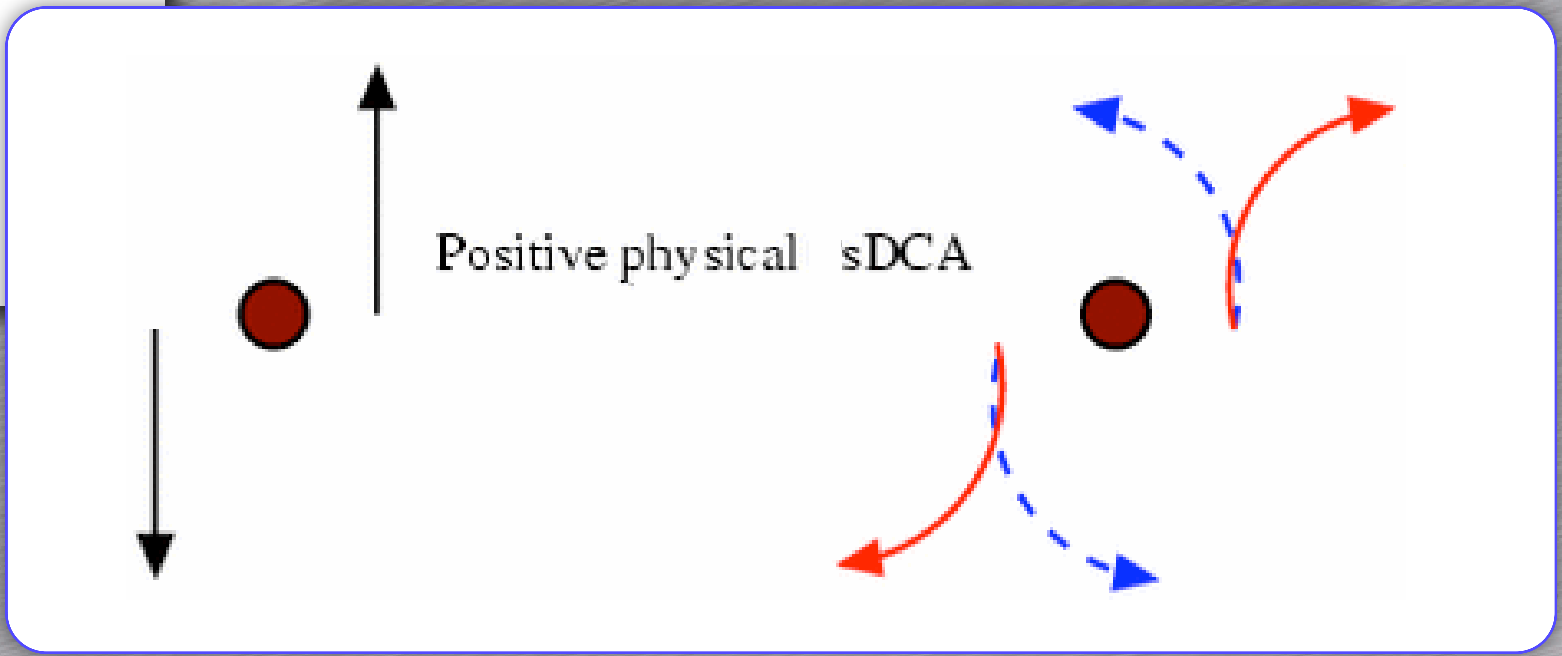


SpaceCharge effect on sDCA

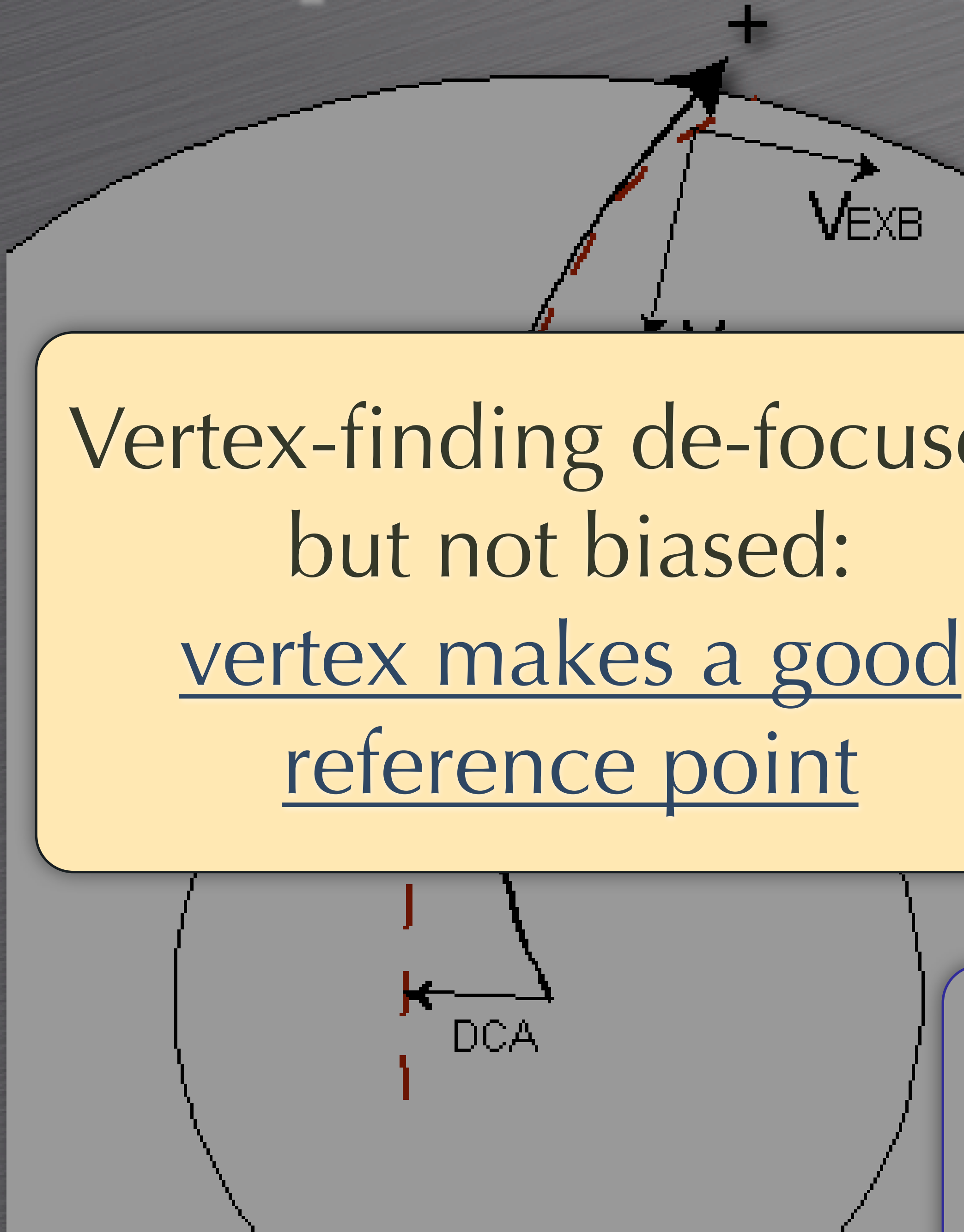


- All tracks go the same direction (pos. or neg.)
- Track charge independence
- Field dependence

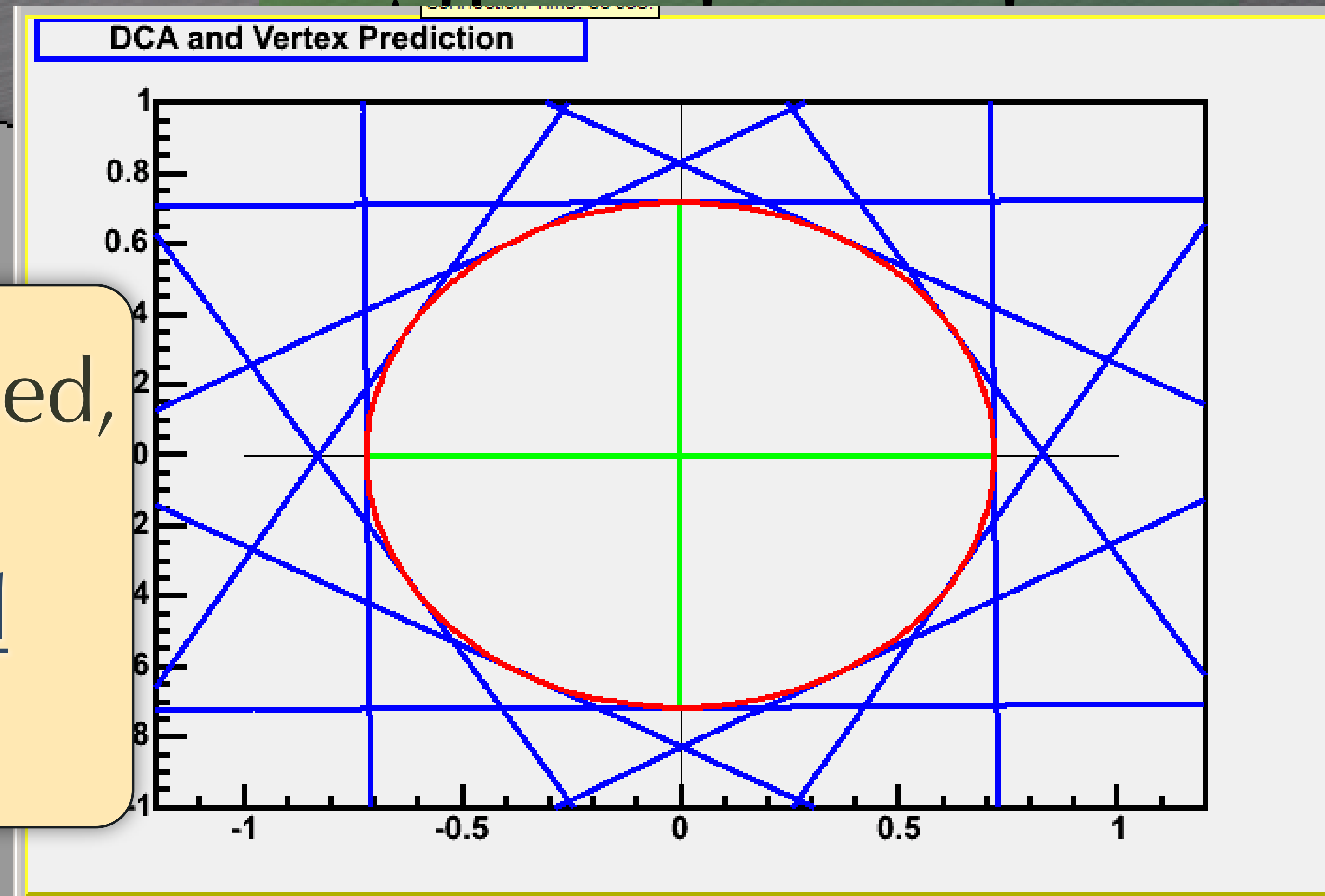
sDCA = signed distance of closest approach



SpaceCharge effect on sDCA



Vertex-finding de-focused, but not biased:
vertex makes a good reference point



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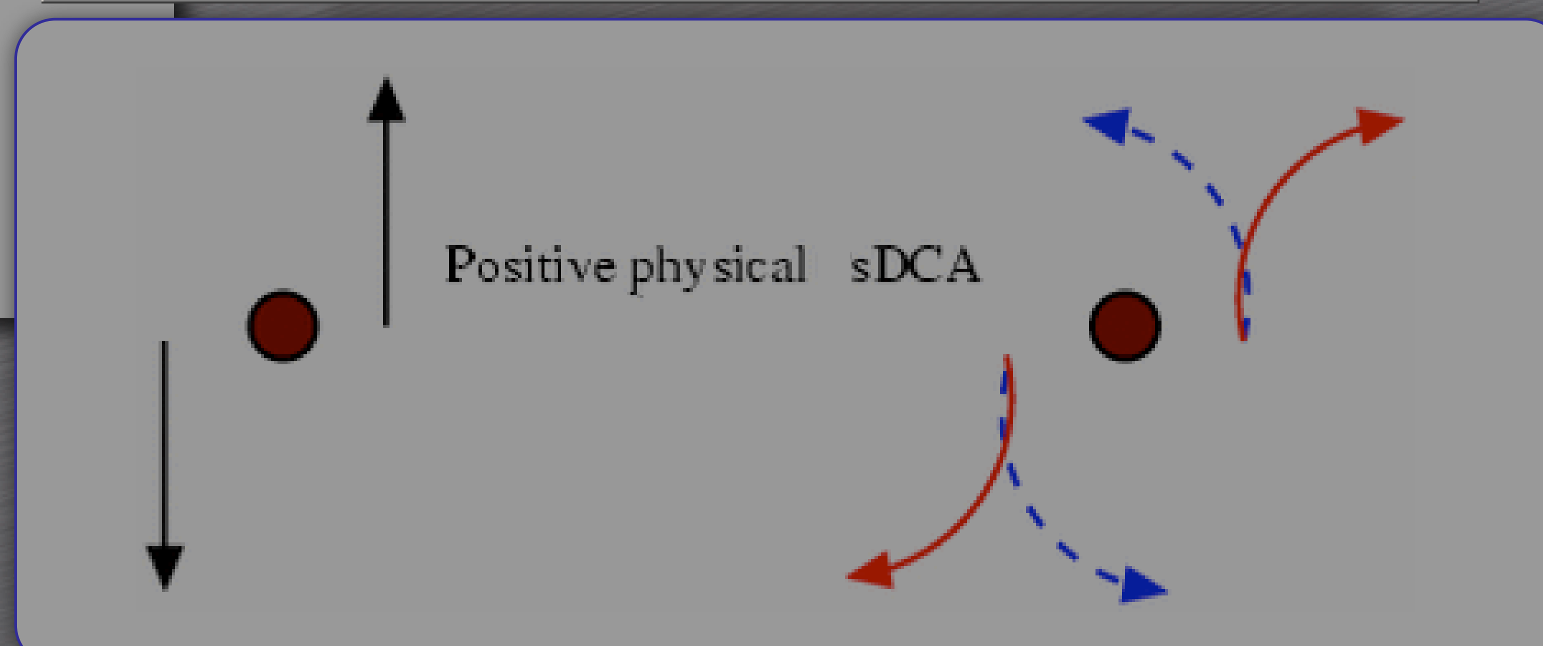
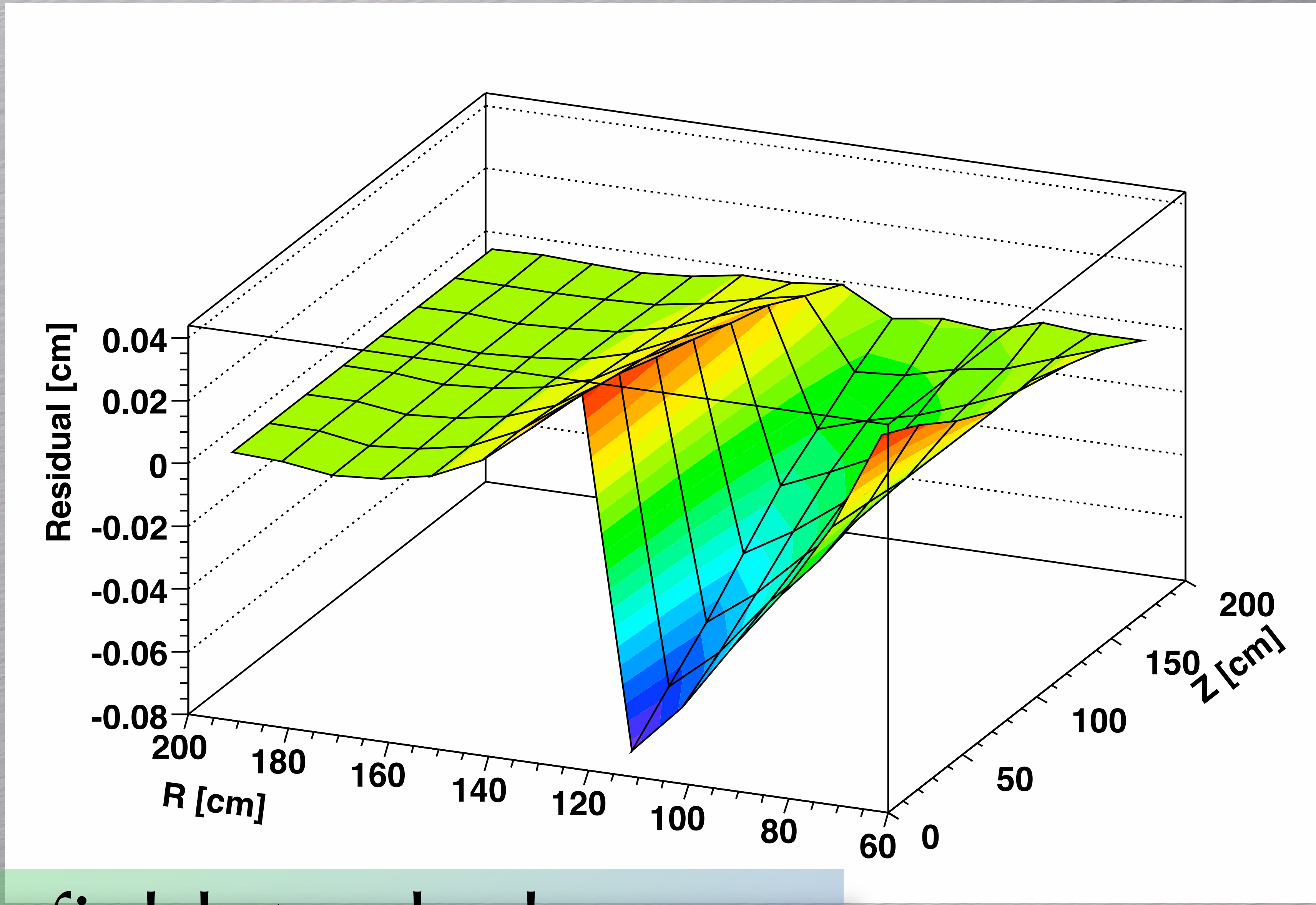
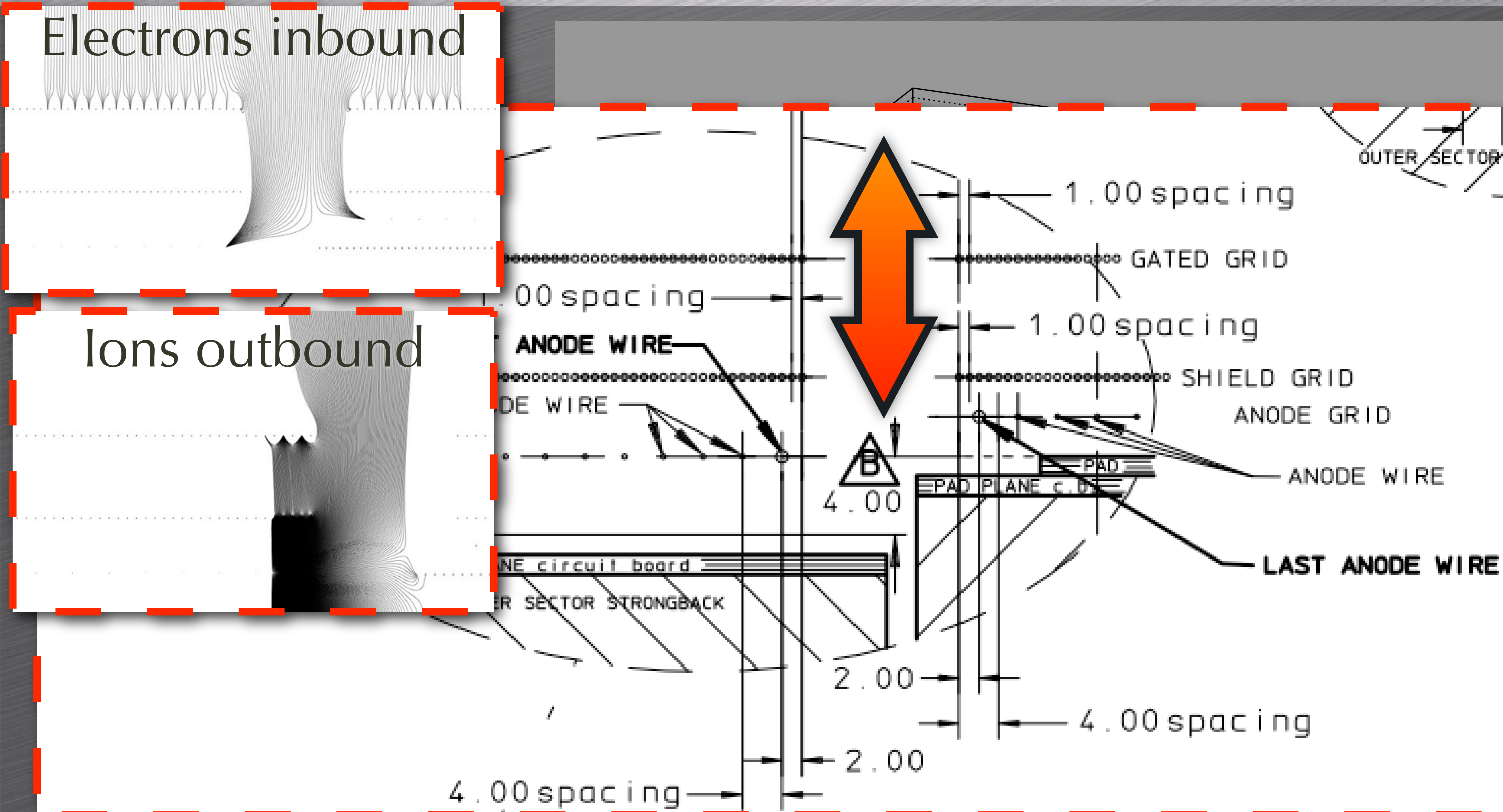


TPC GridLeak distortion



- Dependence on field, track charge, location, luminosity consistent with ion leakage at gating grid gap

TPC GridLeak distortion

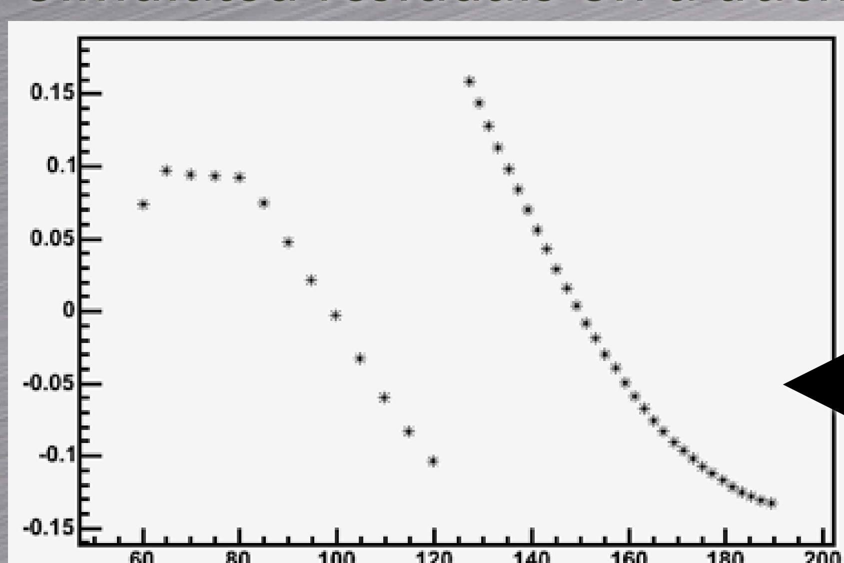


ion leakage at gating grid gap

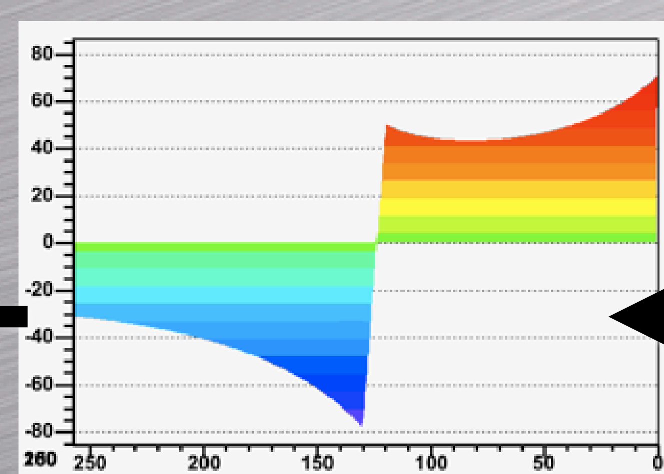
GridLeak Field Effects

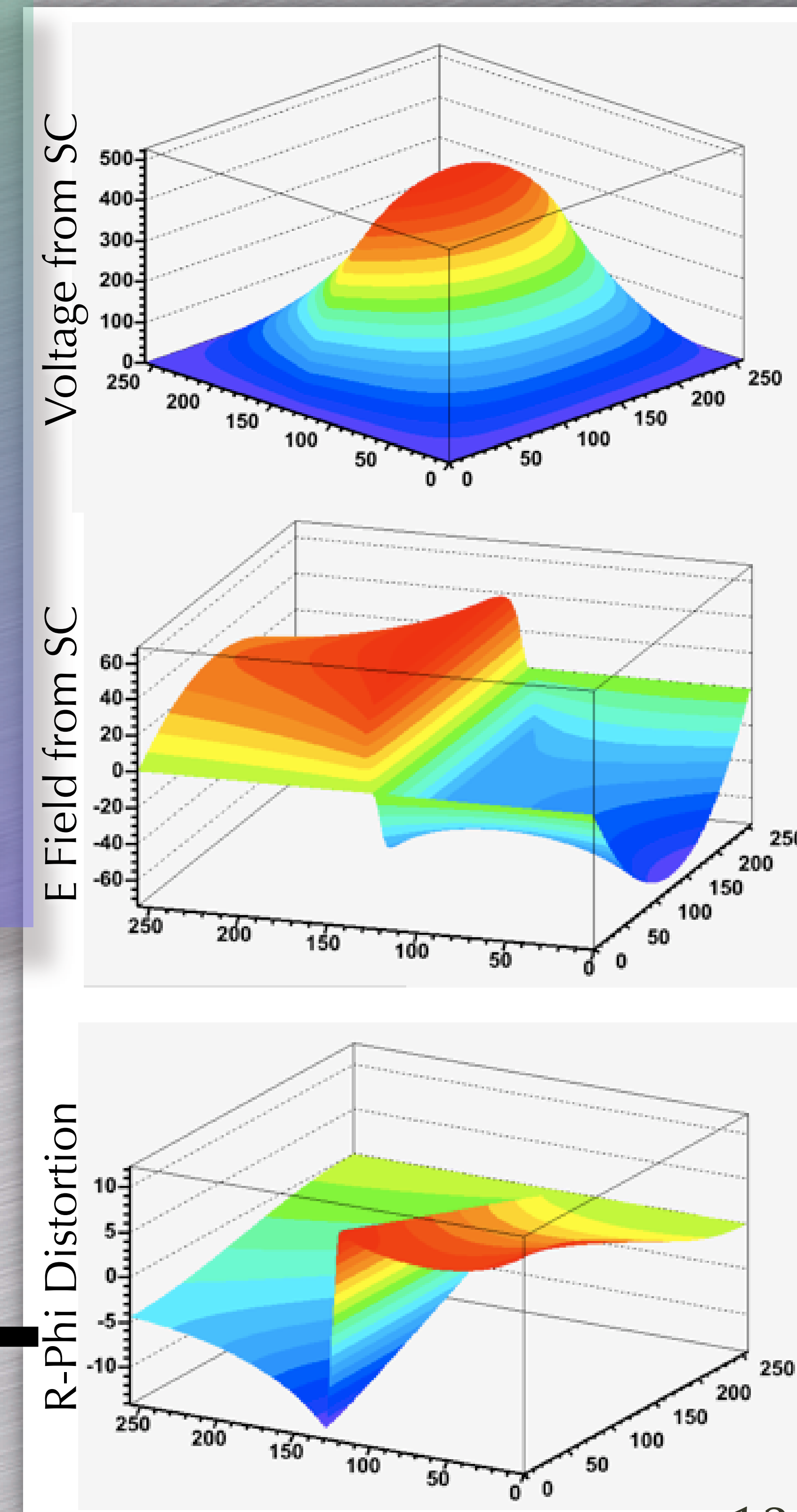
- Modeled sheets of charge
  - Relaxation done on custom 3D grid (plots assume Φ symmetry, but leak is 12-fold symmetry from grid shape)
  - E-field and distortion discontinuity at grid gap
- ***GridLeak scales as SpaceCharge!***

Simulated residuals on a track



Distortion near CM

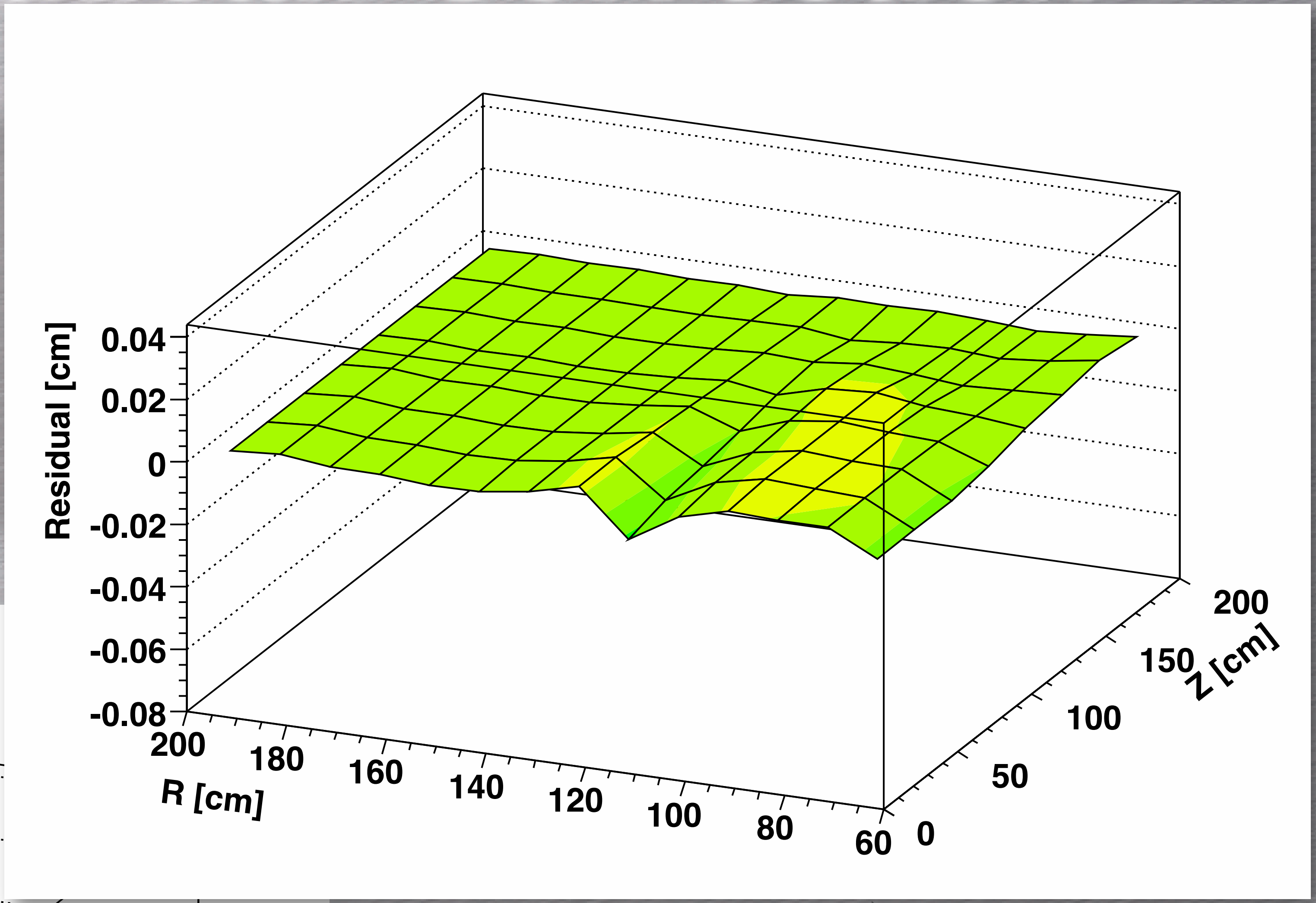




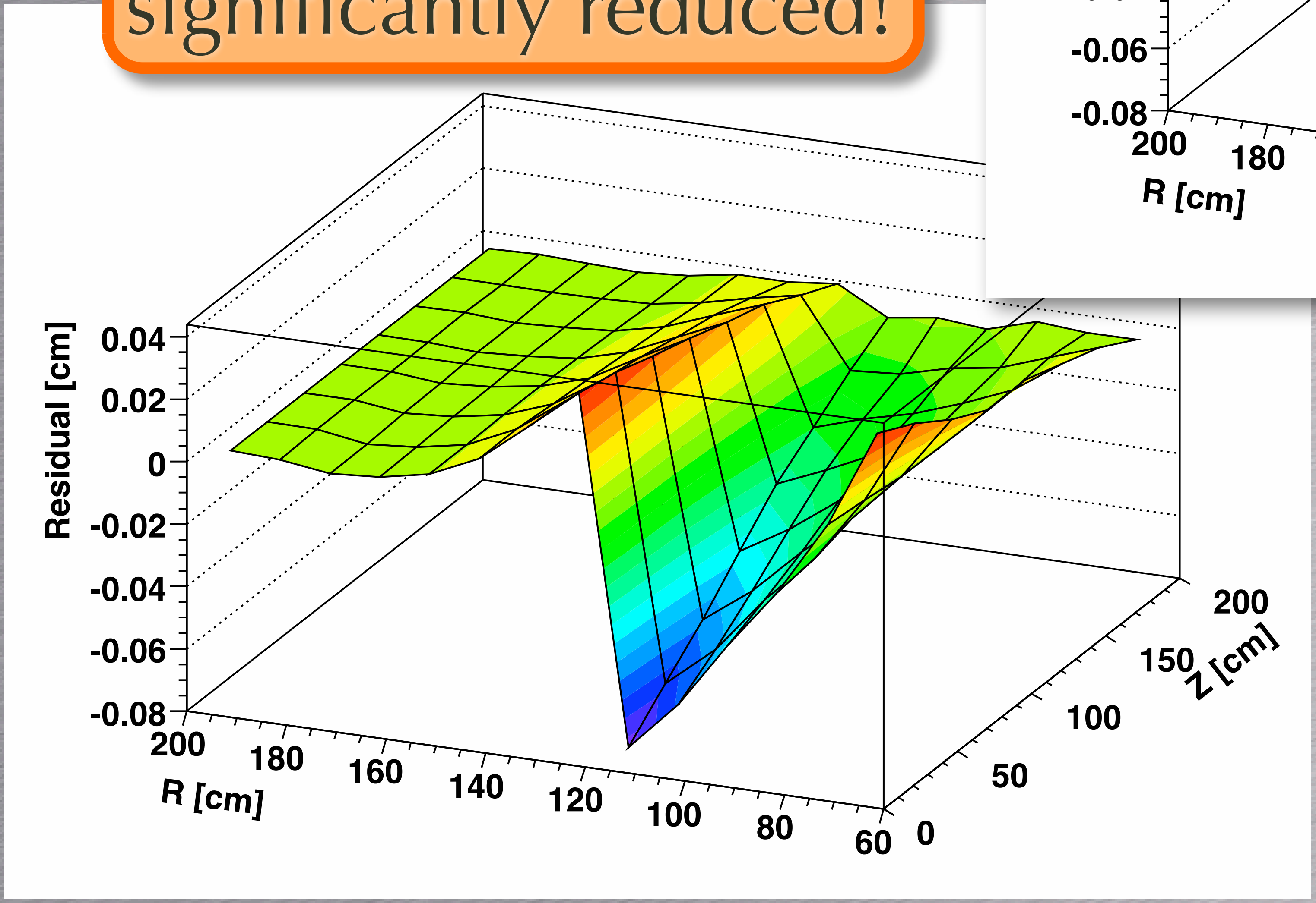
Applied GridLeak Correction

- Not perfect, but as good as design spec!

Distortions scale significantly reduced!



After

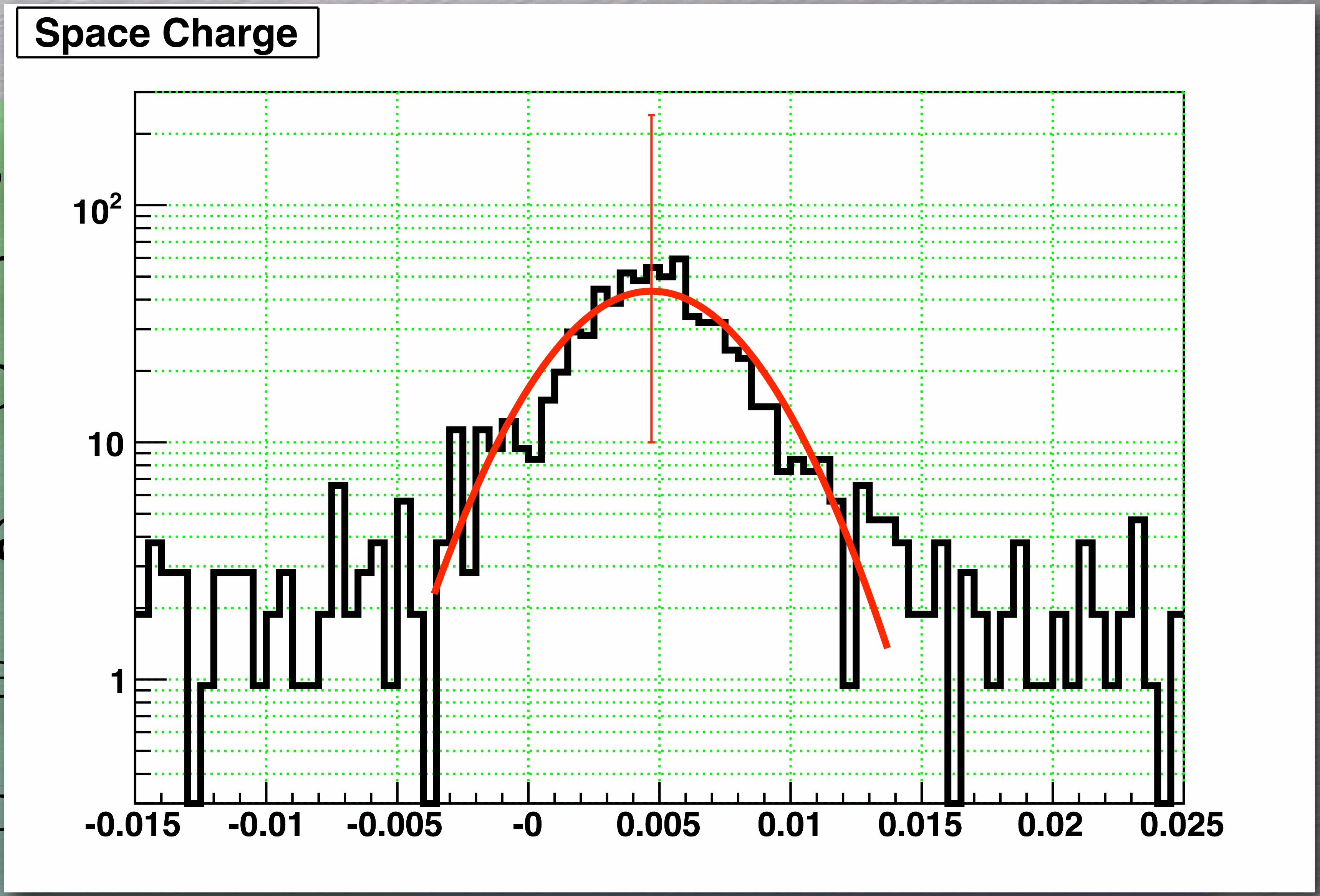


Before

First steps to corrections

- Observables (sDCA) can tell you the distortion quantity (ions in the TPC due to SpaceCharge buildup + GridLeakage)
- Easy with "ideal" tracks
  - Little or no dependencies on reconstruction itself
  - Observable maps easily to distortion quantity
    - sDCA = C * f(Z) * (SpaceCharge + GridLeak)
  - Generally need many events for stats
    - Could be many *runs* for pp collisions!

First steps to corrections



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  distortion quar
  SpaceCharge b
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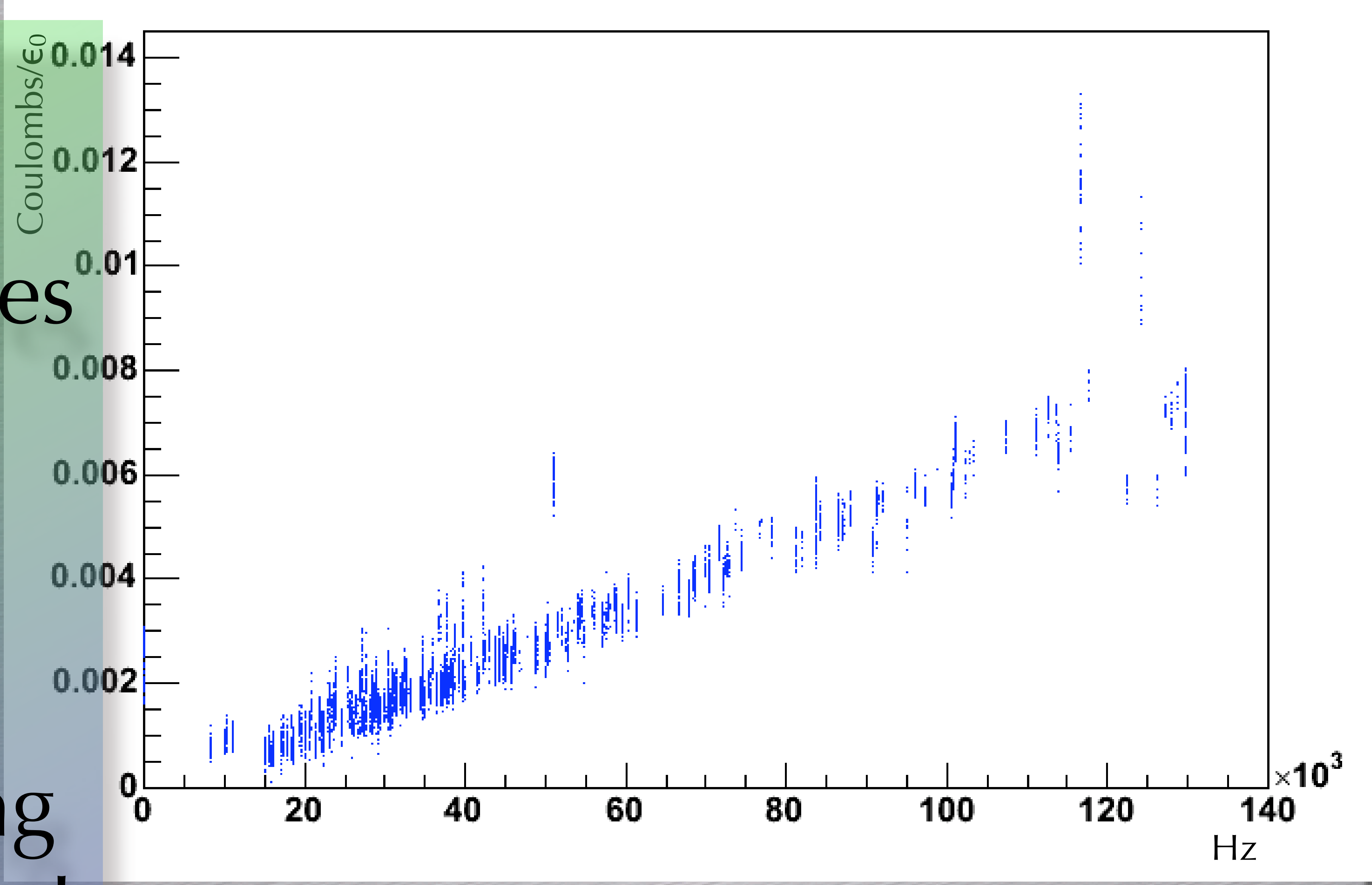
Ionization: Scalers

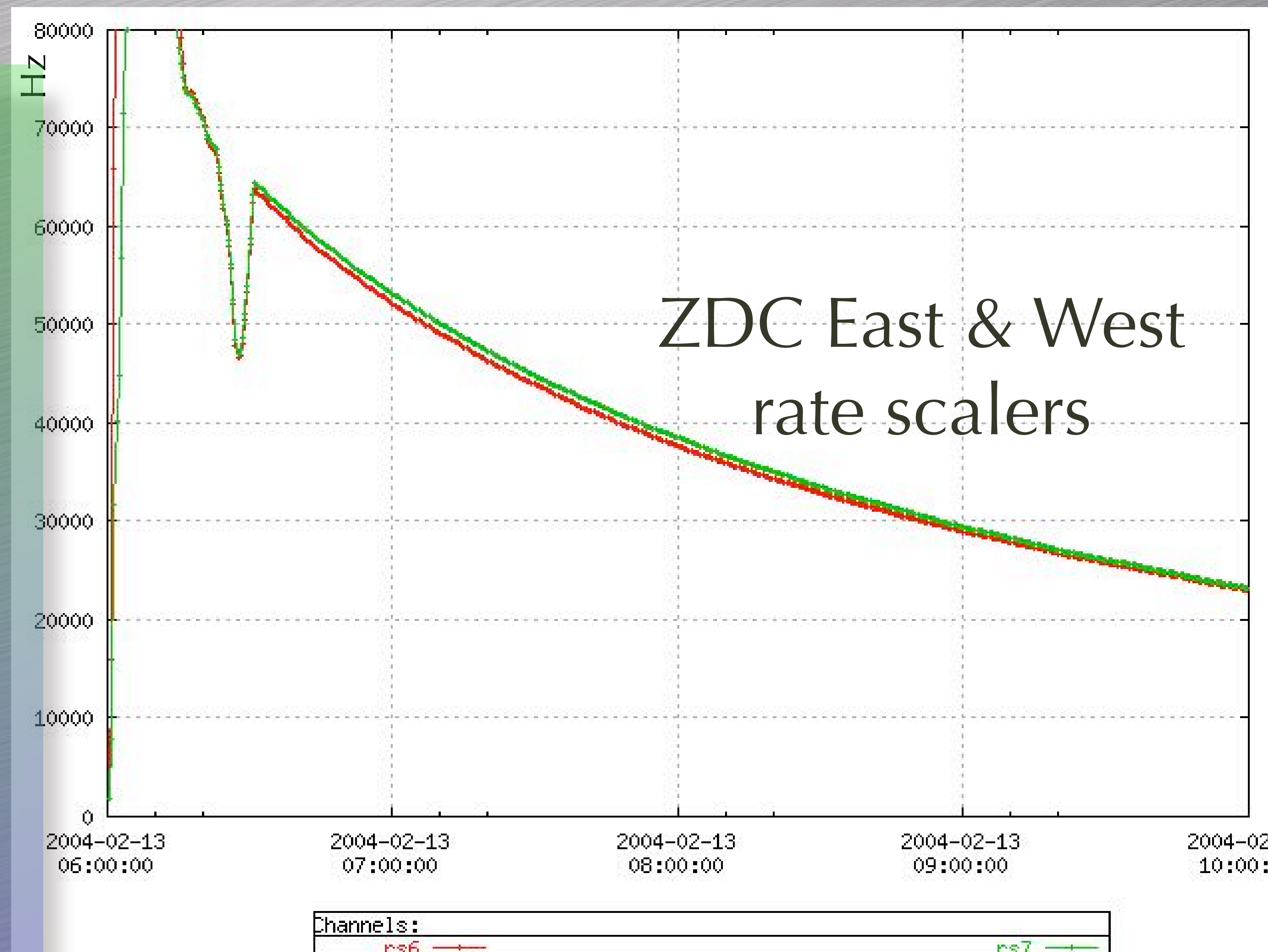
- Ionization is linear with scaler measures of luminosity
- Points out problem runs
- Some smearing from 30 second average



STAR records scaler rates on Zero Degree Calorimeters (ZDCs) and Beam-Beam Counters (BBCs)

Ionization: Fluctuations

- Collision rates look smooth in ZDC rates...
- ...but background rates show something going on...



Fill 4529, February 13, 2004

Ionization: Fluctuations

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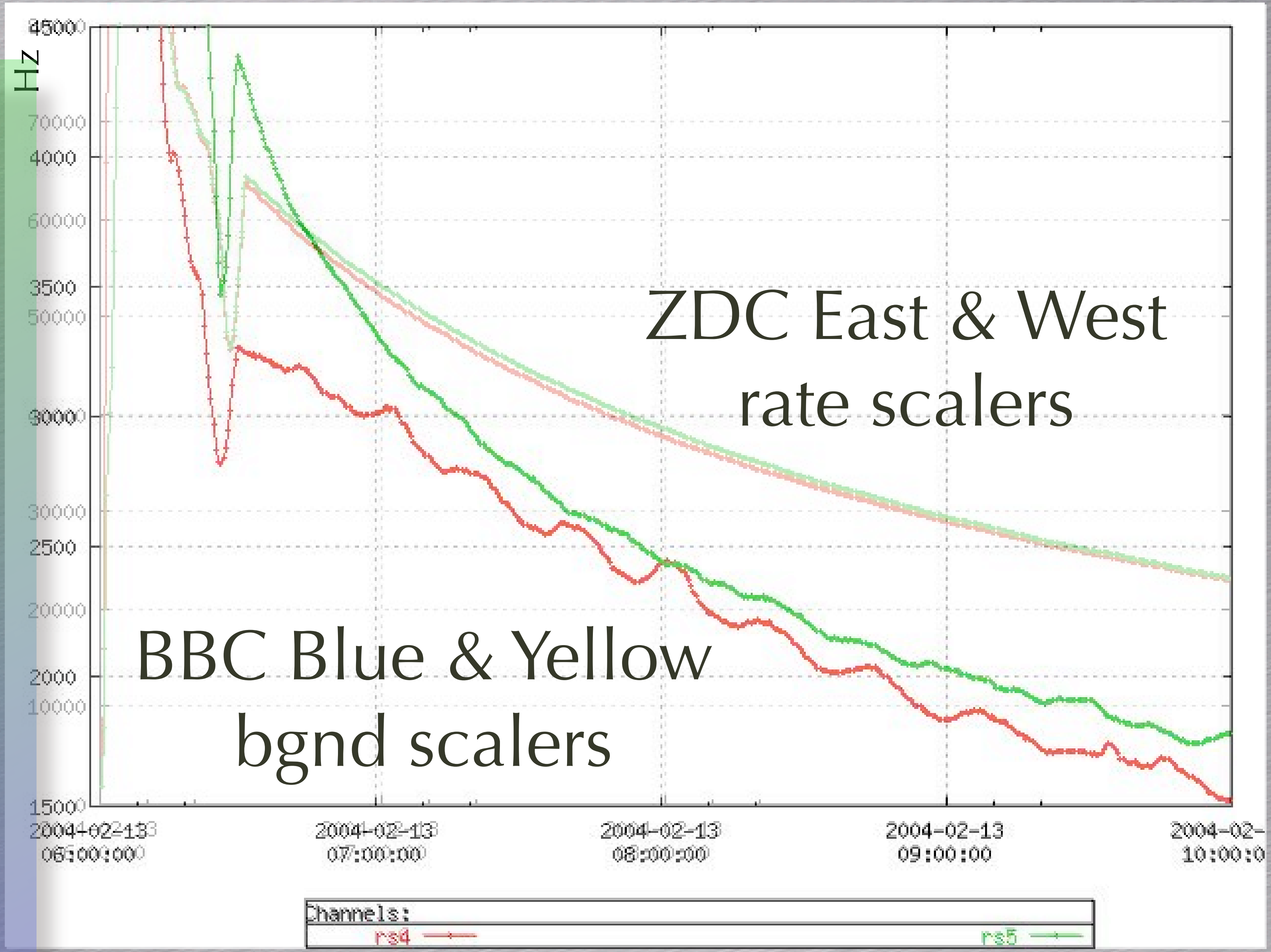

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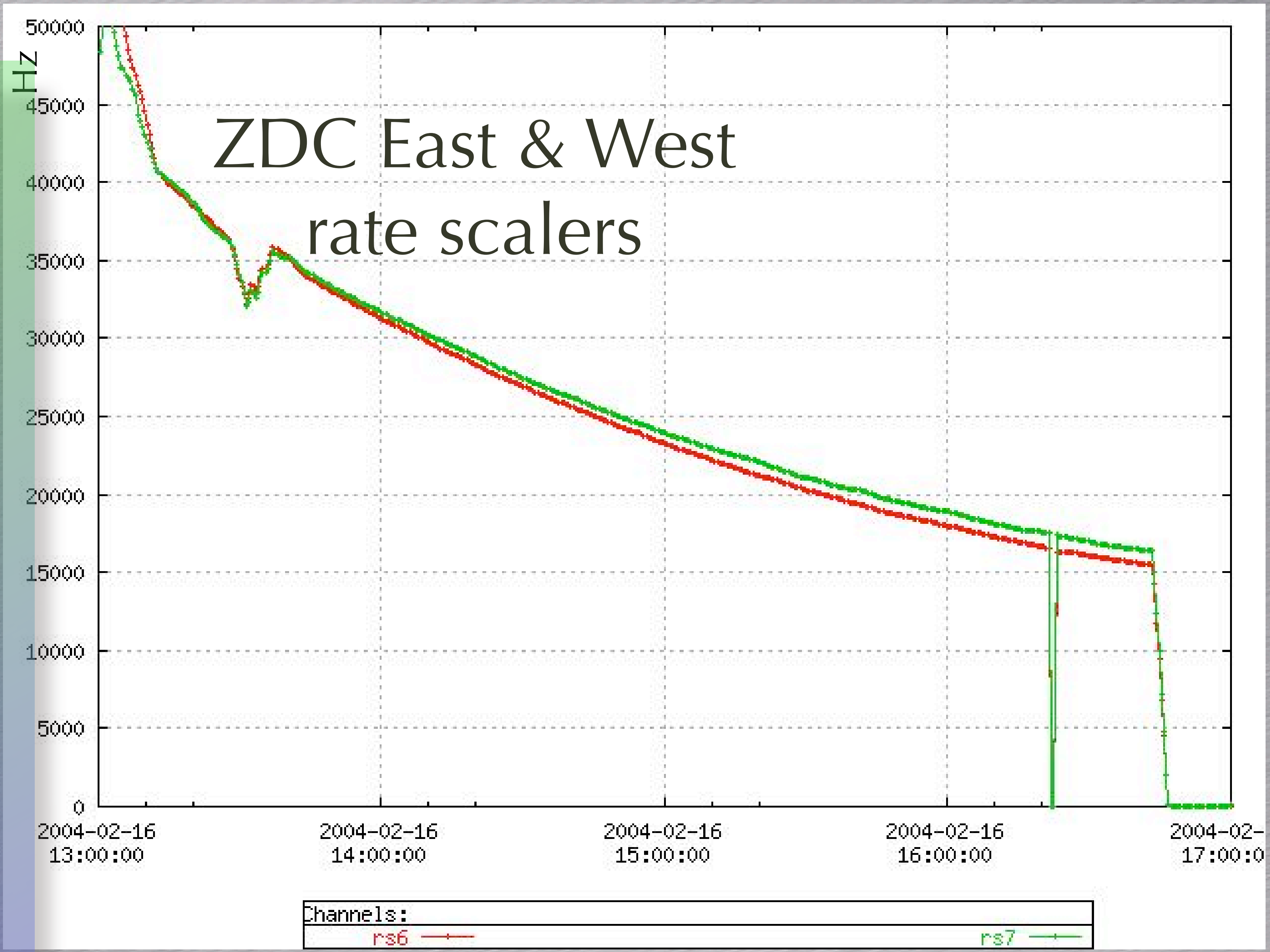

Fill 4547, February 16, 2004

Ionization: Fluctuations

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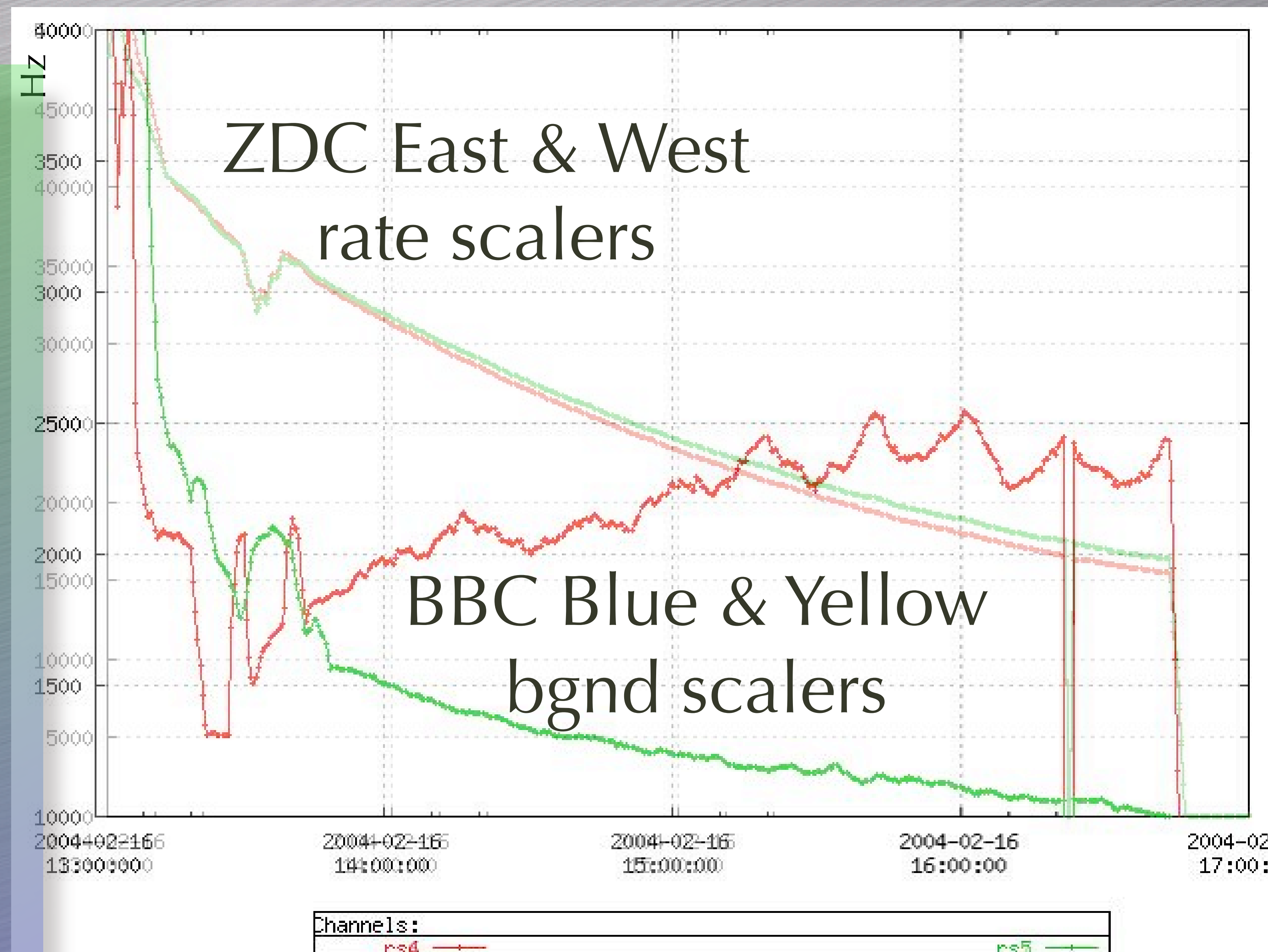

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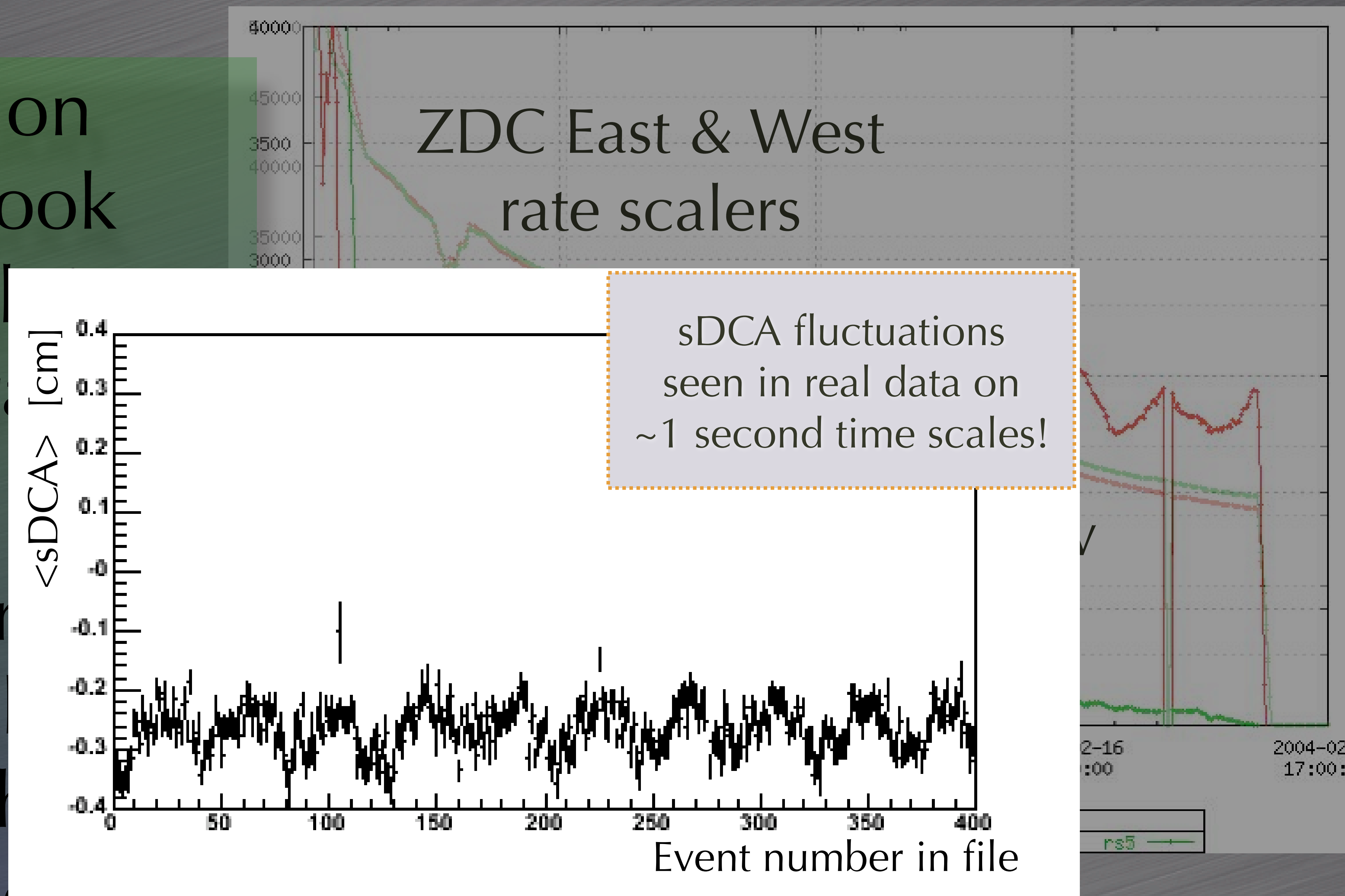
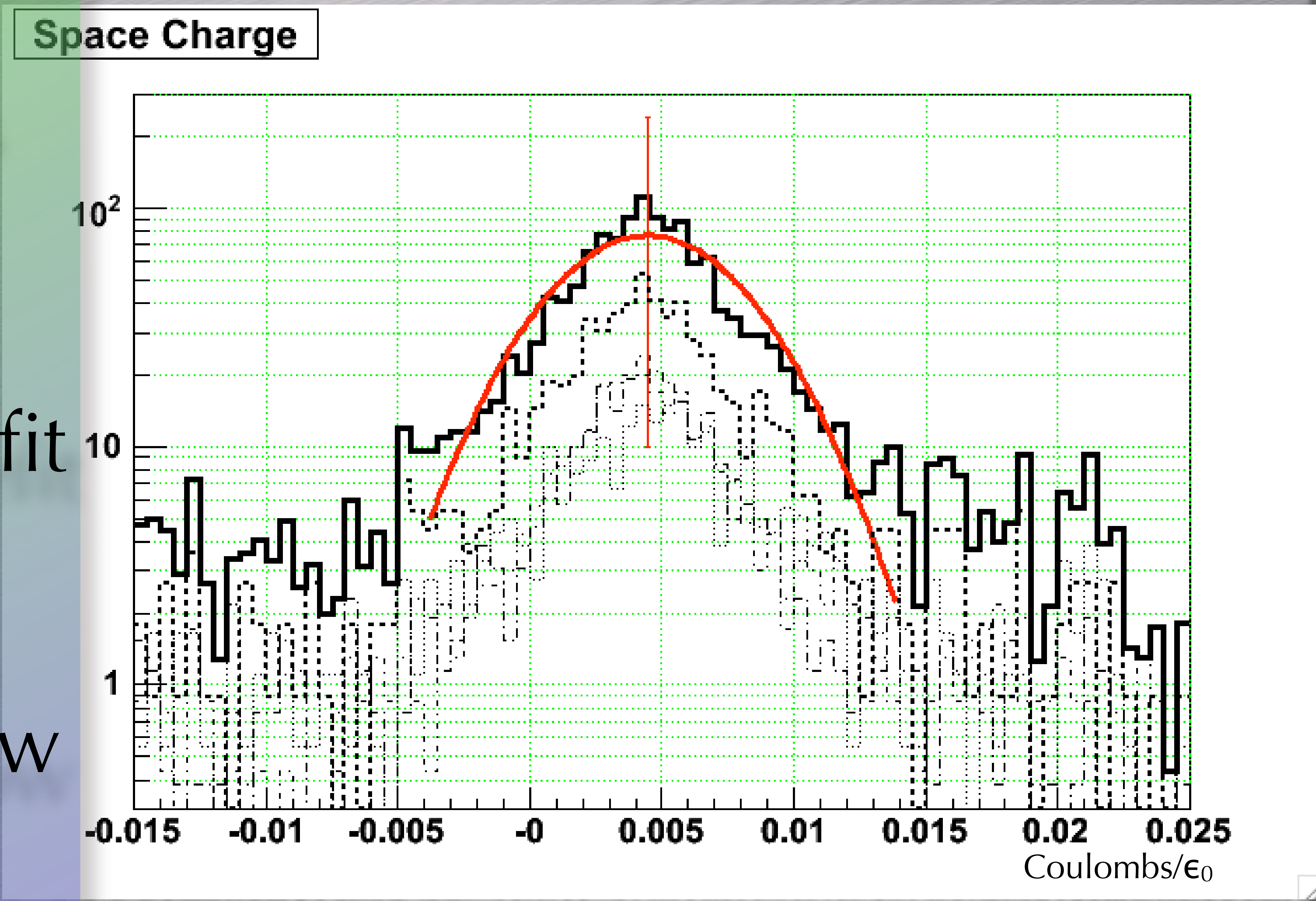


Fill 4547, February 16, 2004

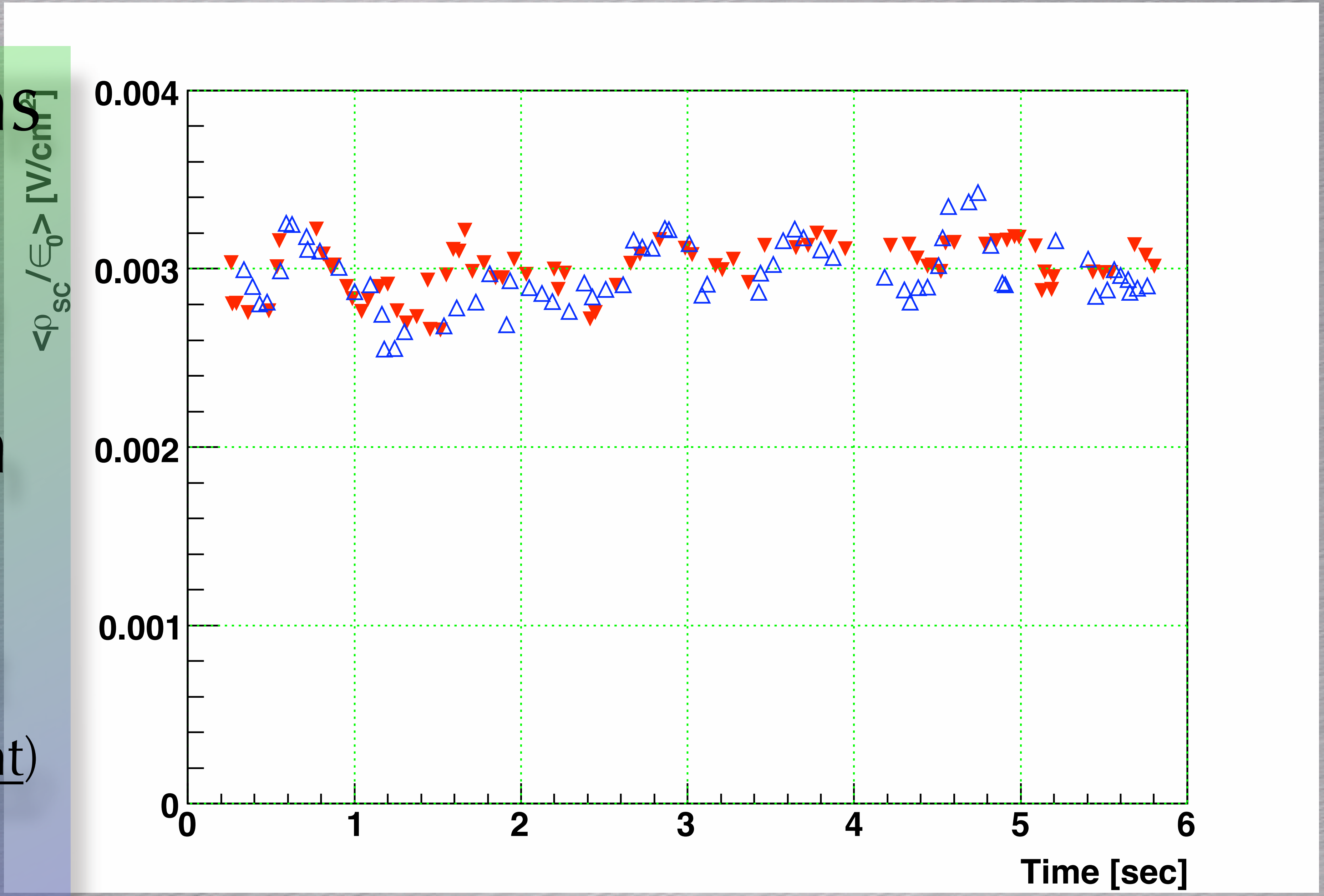
Event-by-Event: use history

- Use several recent events with age weighting
- Throw and refit tracks with simple (quick) model to allow for larger selection



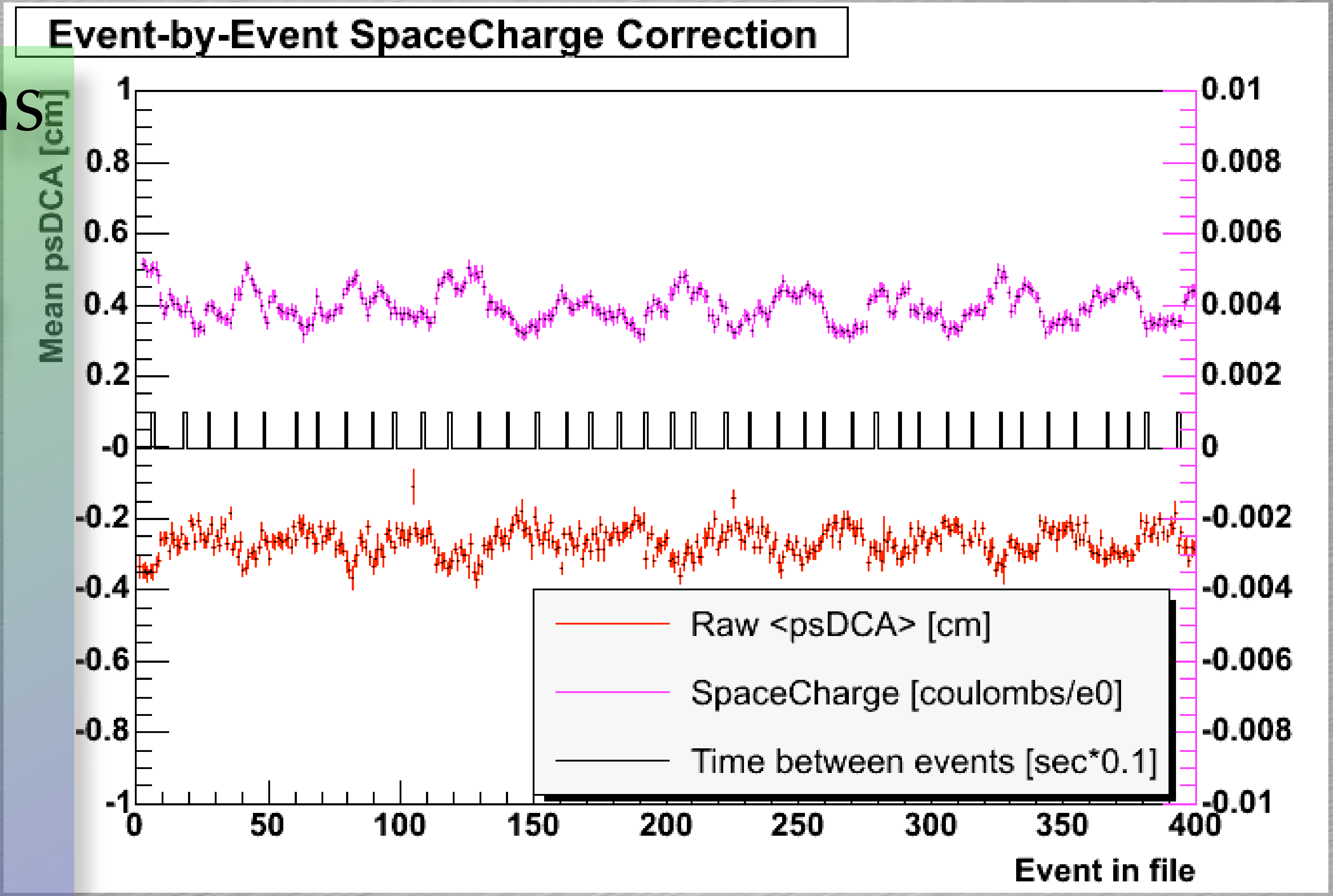
E-by-E Successes

- Fluctuations on second time scale!
- Correlation between concurrent (but <u>independent</u>) event sets
  - Differences show method uncertainty



E-by-E Successes

- Fluctuations on second time scale!
- But high-rate DAQ (~100 Hz) actually helps!



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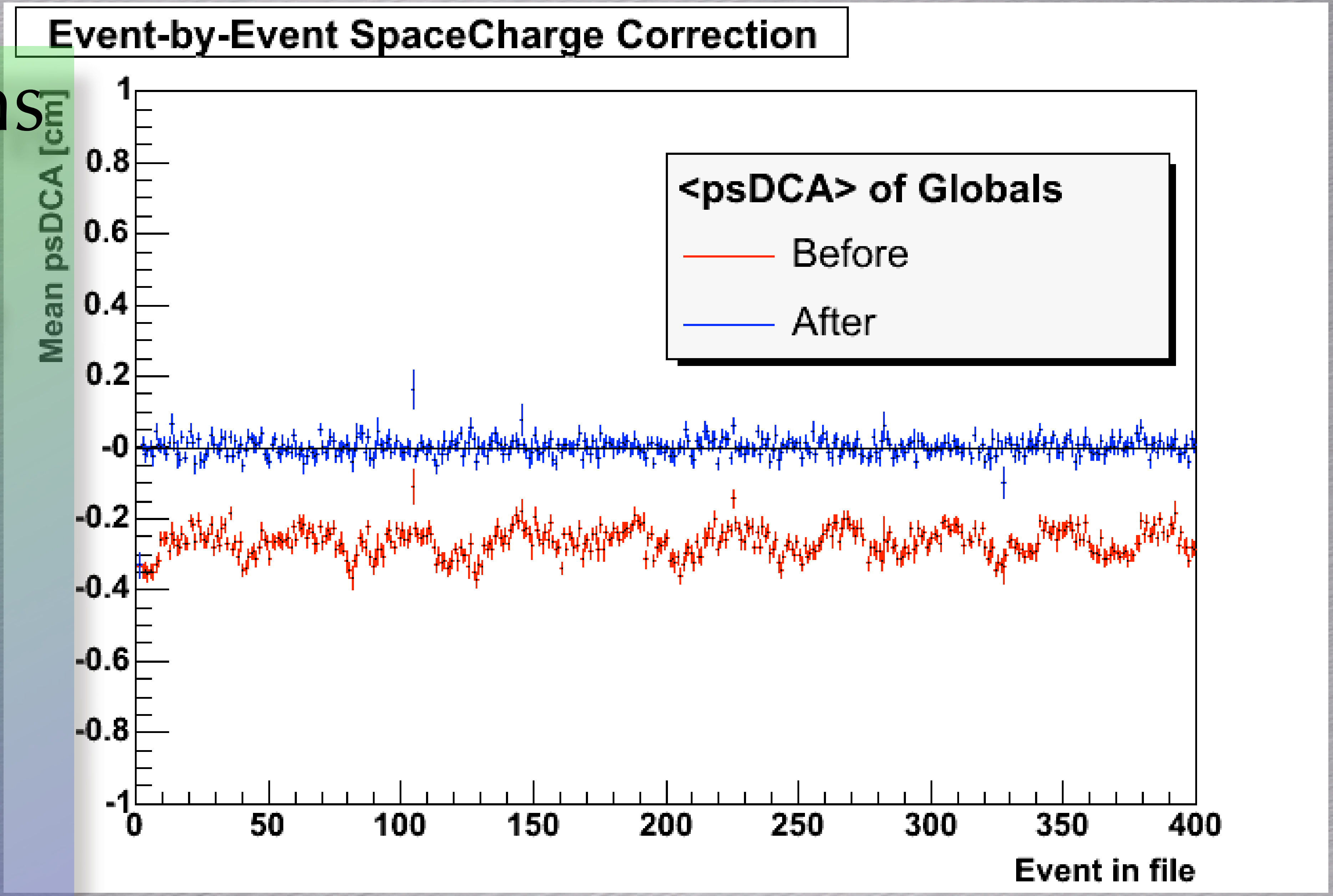
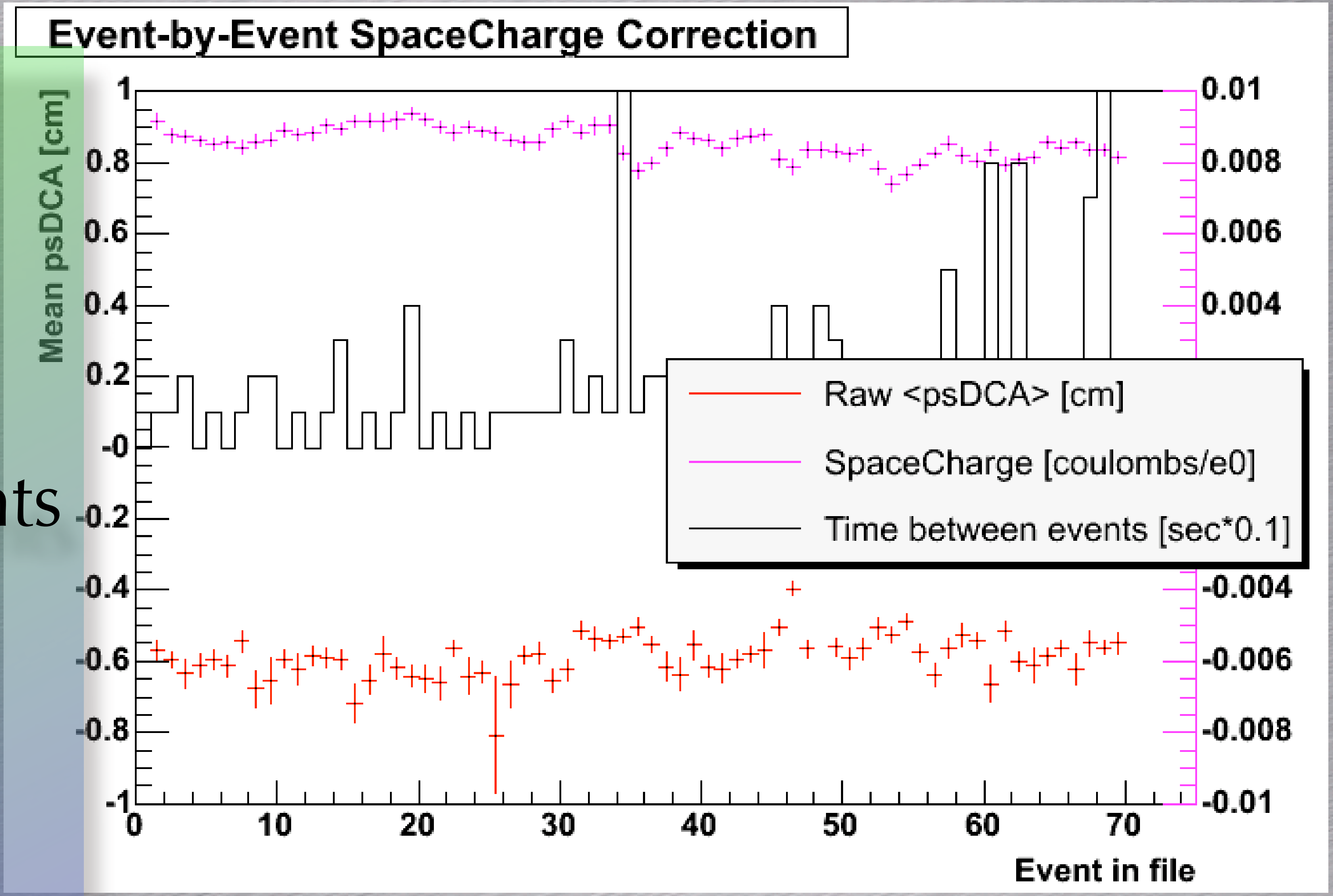


E-by-E Issues

- Beginning of files
  - ☑ Prepass
- Time gaps between events
- Frequent low multiplicity events
  - ☑ Fall back to prepass value (or scalers)



Run 5044026: productionHigh

E-by-E Issues

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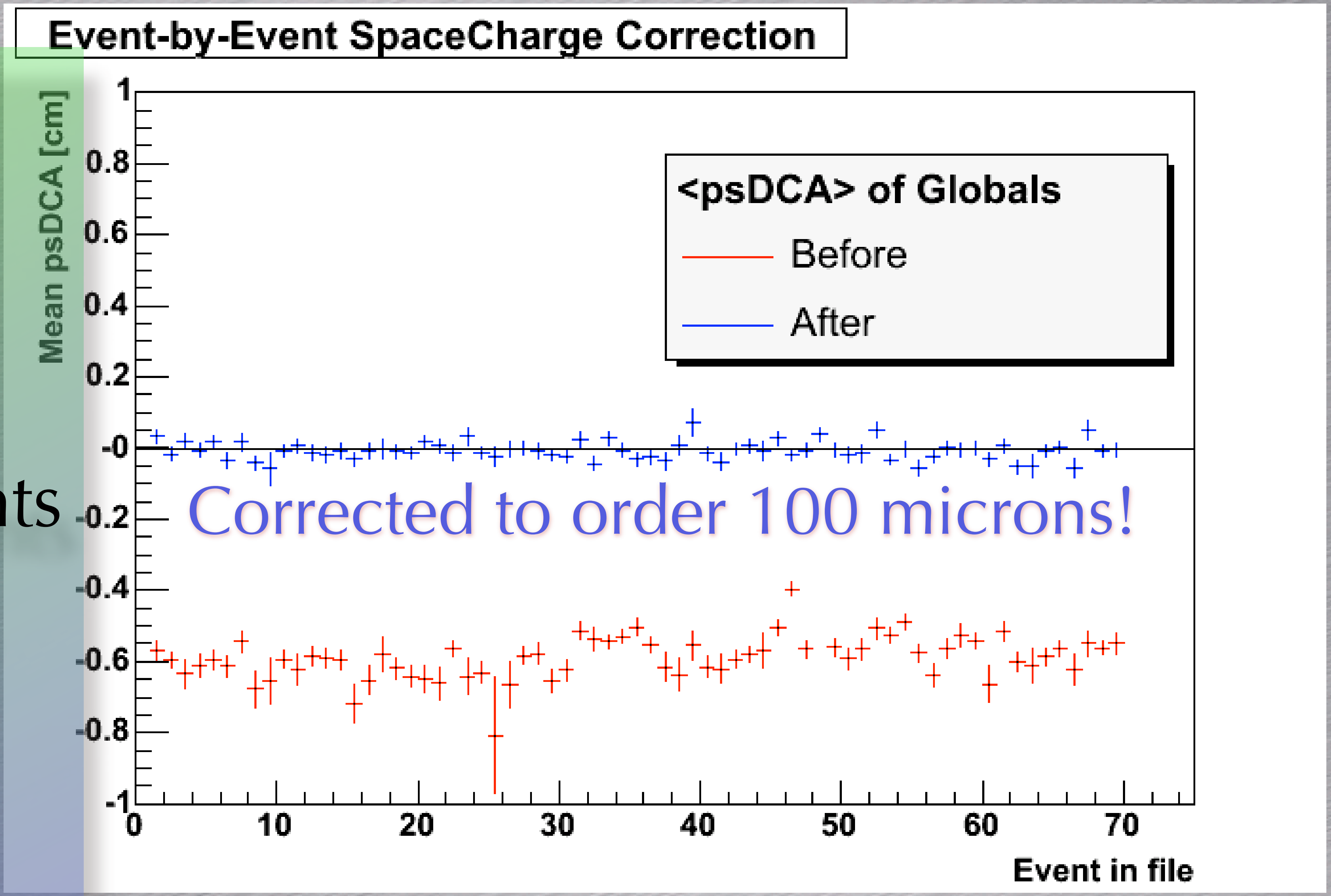
  - ☑ Prepass
- Time gaps between events
- Frequent low multiplicity events
  - ☑ Fall back to prepass value (or scalers)

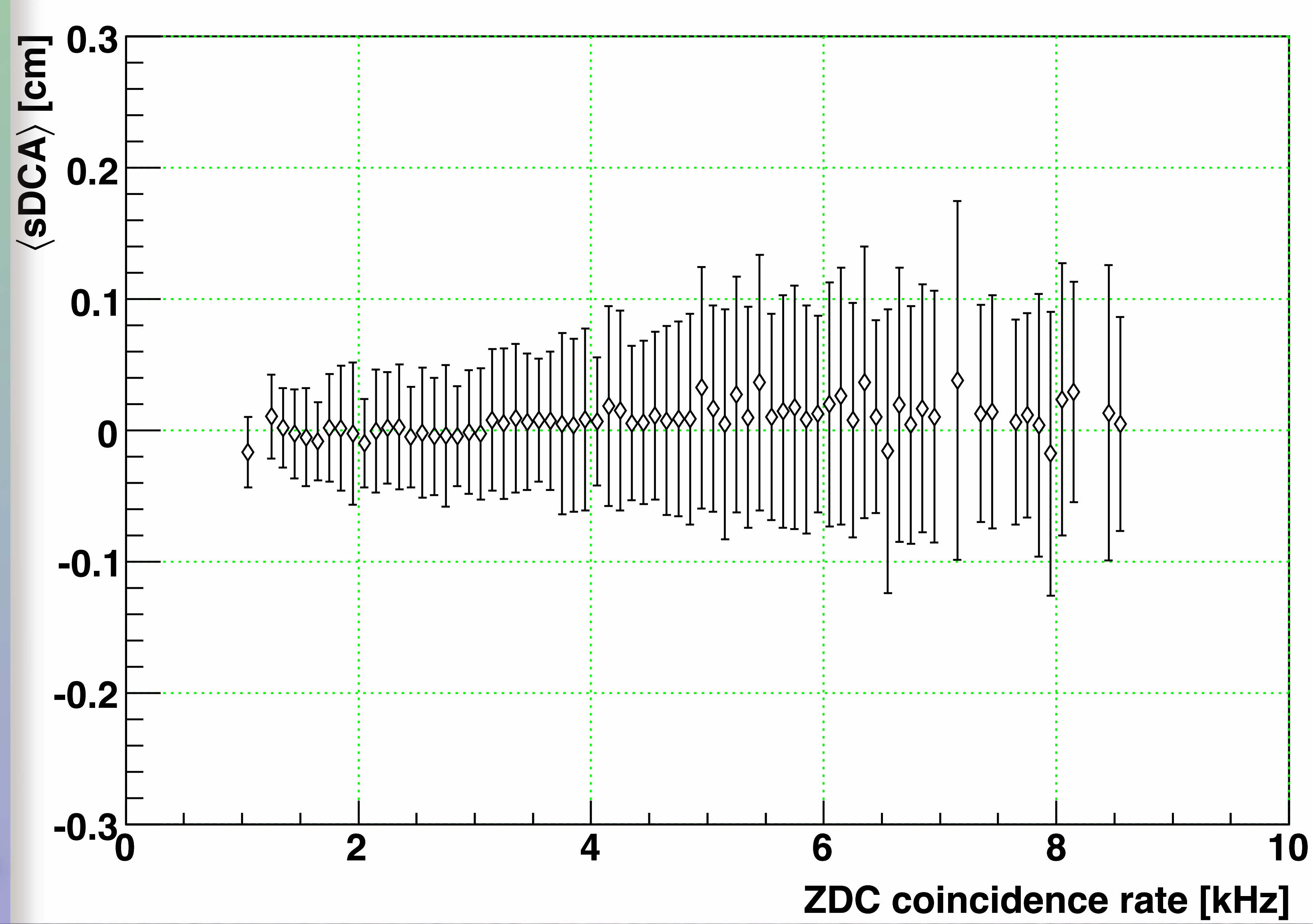


Run 5044026: productionHigh

Performance Measures: sDCA

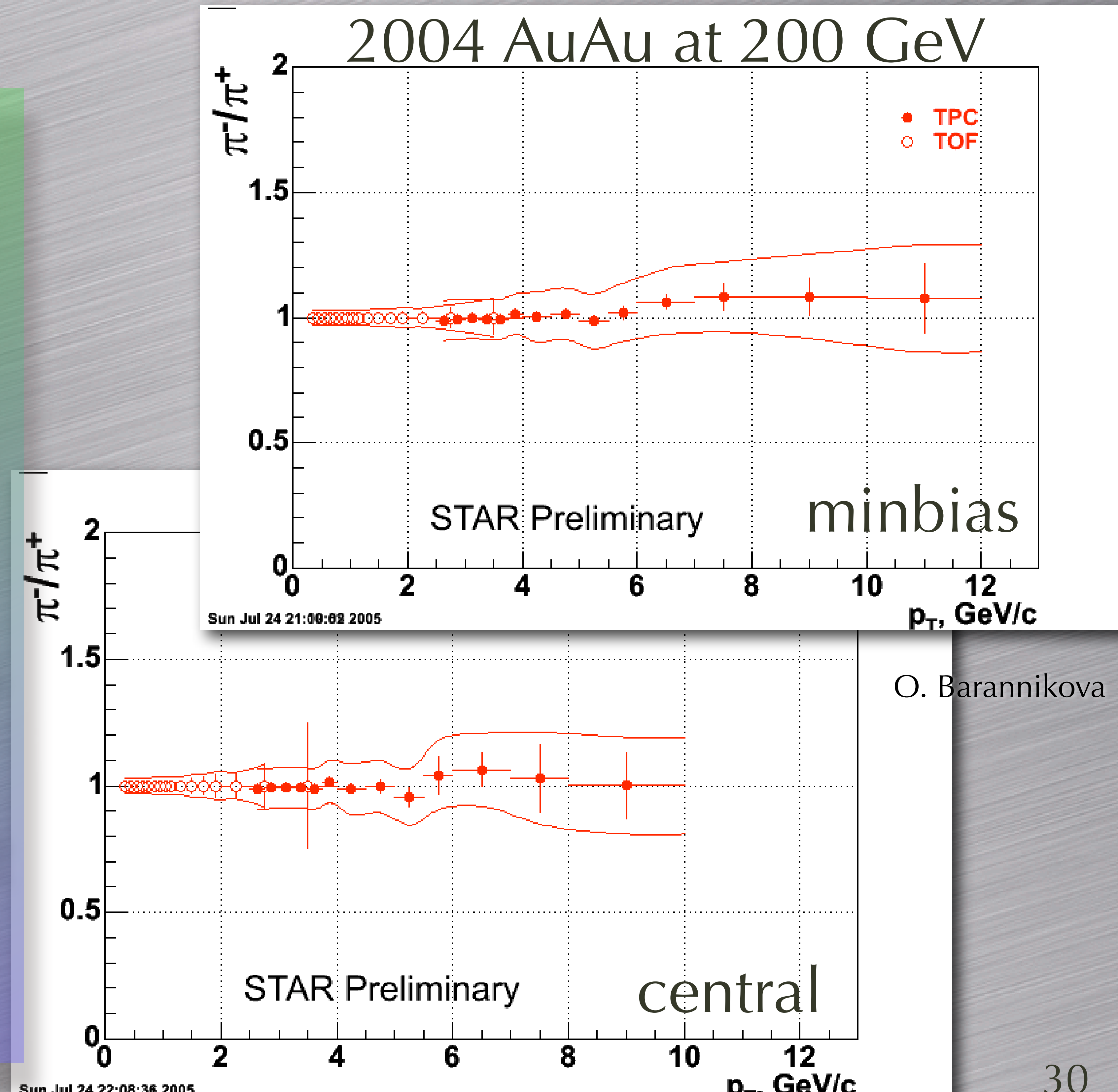
- Can't beat low luminosity, but holding steady at high luminosity:
  - Spread from 5-9kHz appears roughly uniform
  - No indication we can't go higher!

2004 AuAu at 200 GeV, all B fields



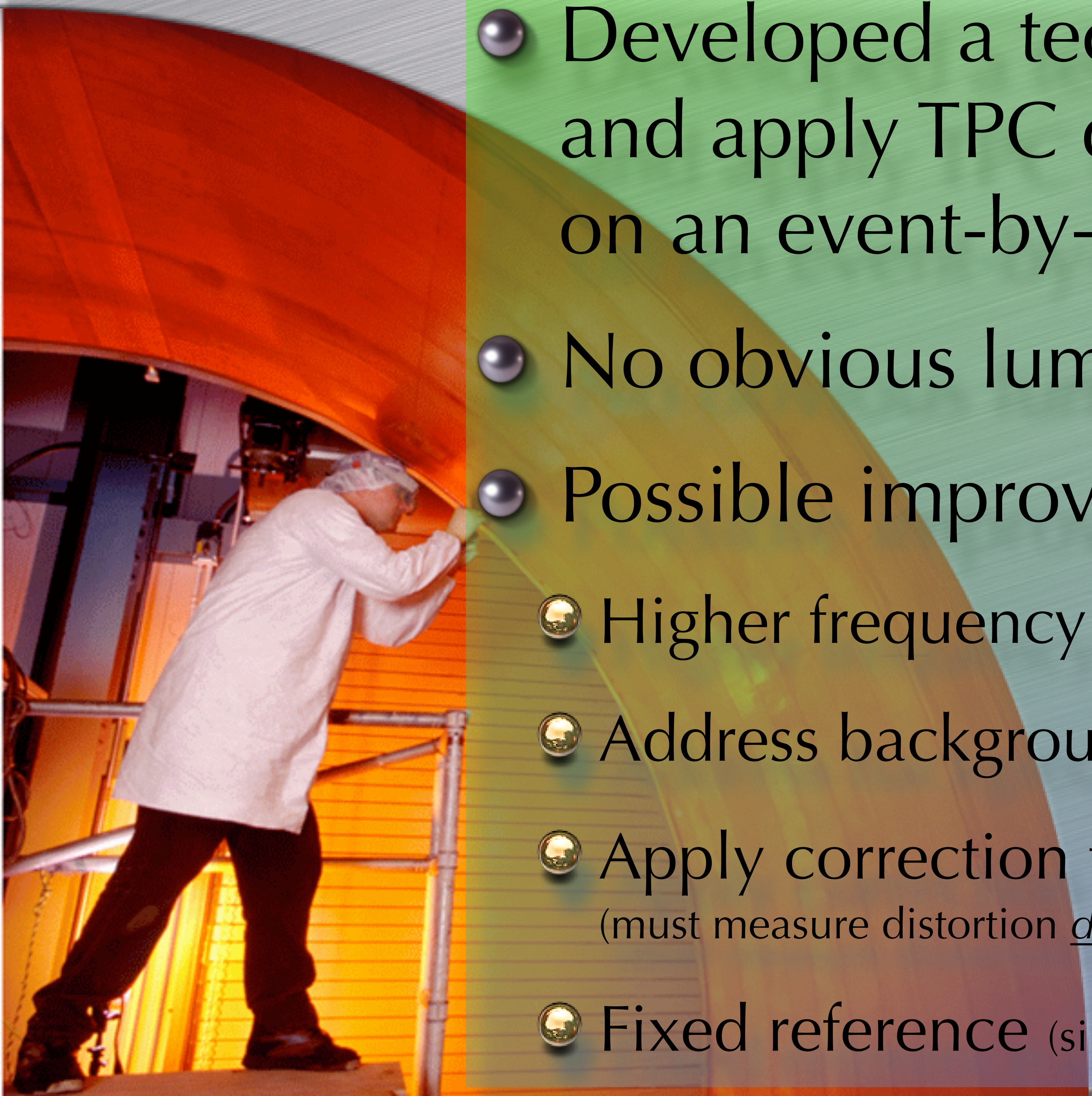
Performance Measures: π^-/π^+

- TPC-measure of the ratio essentially flat all the way to p_T=12 GeV/c !
- Central triggers (taken at high luminosity) just about as good!



O. Barannikova

Summary & Outlook



- Developed a technique to determine and apply TPC distortion corrections on an event-by-event basis
- No obvious luminosity limitations
- Possible improvements:
  - Higher frequency scalers (instead of Prepass)
  - Address backgrounds (shielding, 3D correction)
  - Apply correction to same event (must measure distortion *during* tracking)
  - Fixed reference (silicon tracking)