

Handling distortions in the STAR TPC at high luminosity



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Brookhaven National Laboratory

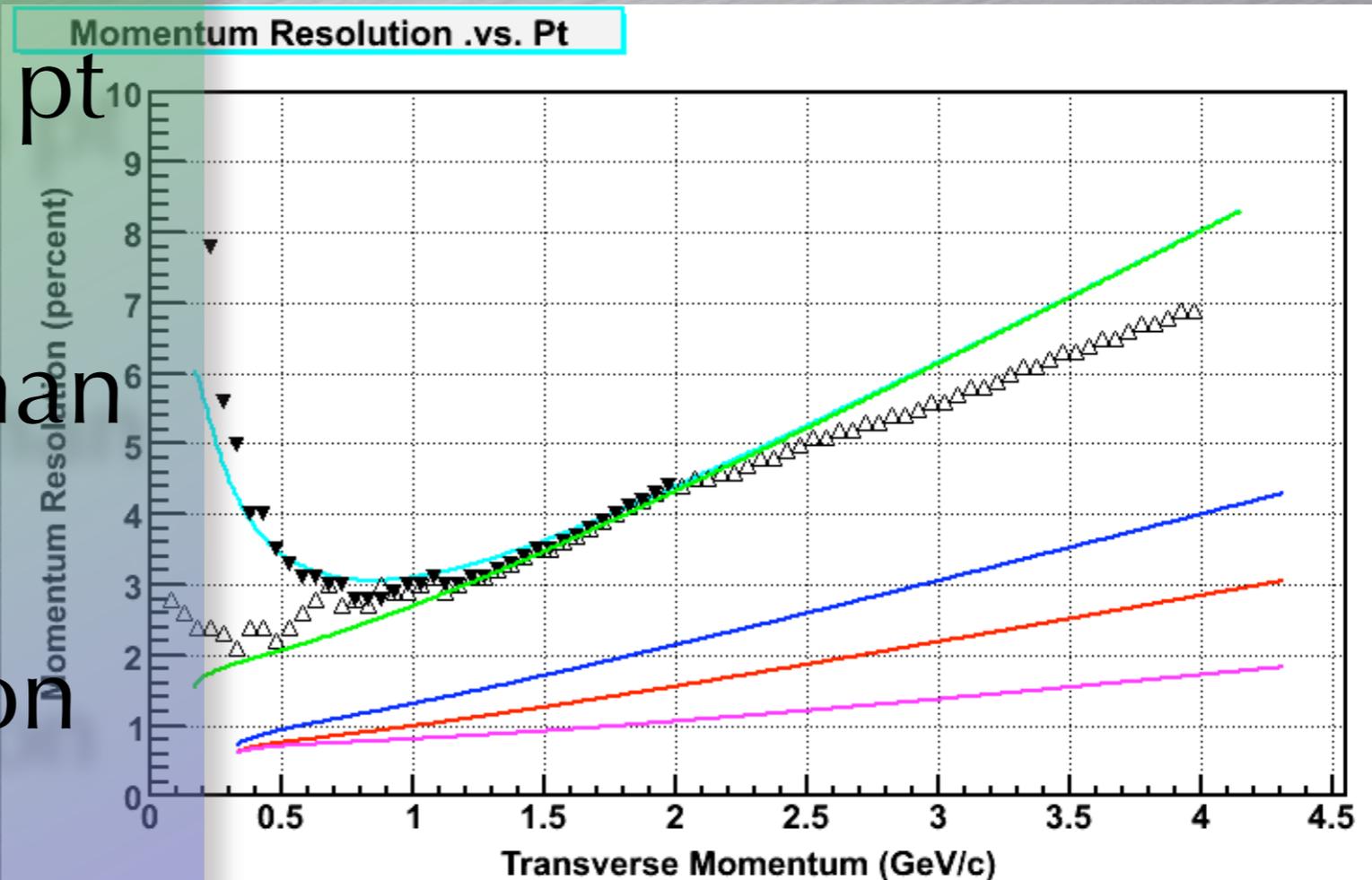
STAR TPC Review
BNL, June 4-5, 2009

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
- Some are highly dynamic (volatile)

Momentum resolution

- Important for physics at high p_t
- Biases can be more serious than smearing
- More Discussion



Distortion Corrections

| Distortion | Approximate Scale [microns] | Correction Scale [microns] |
|----------------------------|-----------------------------|----------------------------|
| Twist (E-B alignment) | 800 | 50 |
| IFC Shift | 100 | 50 |
| Clock (East-West rotation) | 800 | 50 |
| Padrow 13 | 400 | 50 |
| B field shape | 800 | 50 |
| Shorted Ring | 2000 ^A | 100 ^B |
| Space Charge | up to 5000 ^C | 100-200 ^D |
| Grid Leak | up to 2500 ^C | 100-200 ^D |
| Unknown | 100??? 300??? | 100??? 300??? |

• Overall contribution to $\delta p_t/p_t \sim 1/4 - 3/4\% * p_t$ for TPC-only tracks (primary vtx, silicon help)

A. Larger (up to 5000) without compensating resistor.

B. Known to be ~400 microns in a region of the TPC not used for physics.

C. Luminosity dependent

D. Dataset dependent

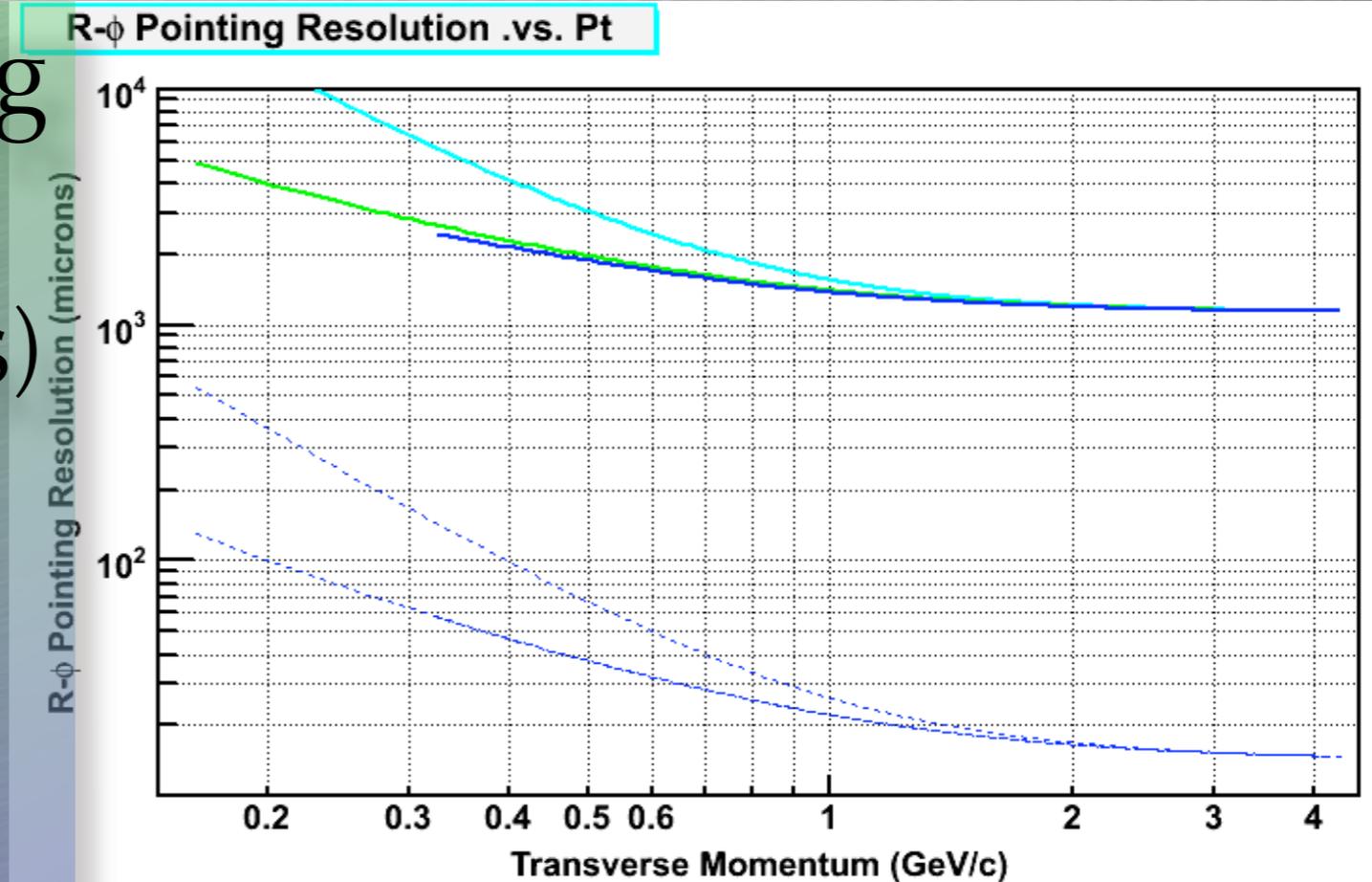
CDR design was ~1%*pt

Distortion Corrections

- The BIG THREE:
 - Shorted Field Cage Rings
 - Particularly problematic when dynamic (fluctuating)
 - Space Charge
 - Fluctuations on the sub-one-second scale
 - Gated Grid Ion Leakage
 - Strongly tied to Space Charge, but there exist some mysteries

Pointing resolution

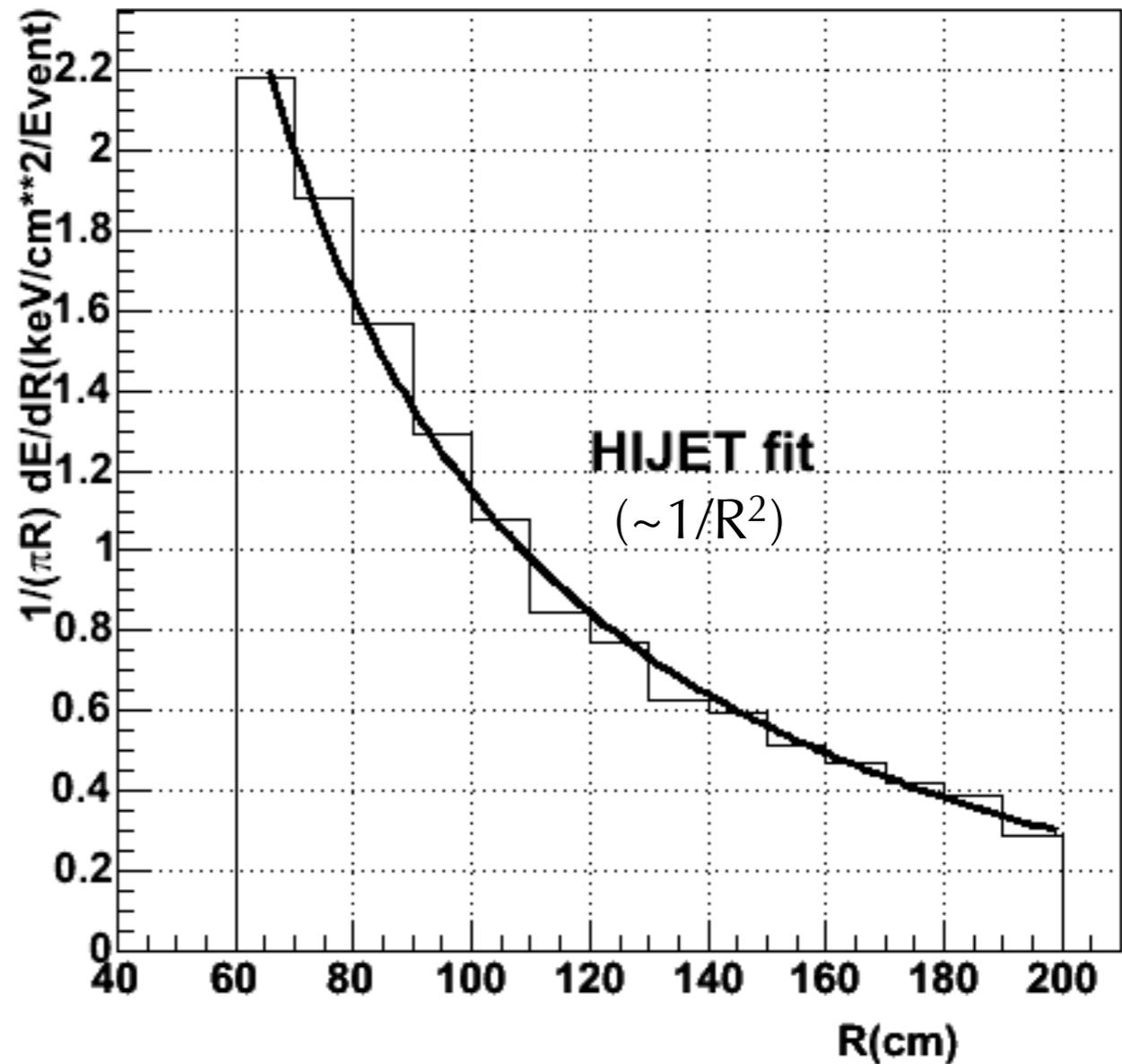
- Important for using inner (silicon tracking, upgrades)
- More Discussion



SpaceCharge: model of charge

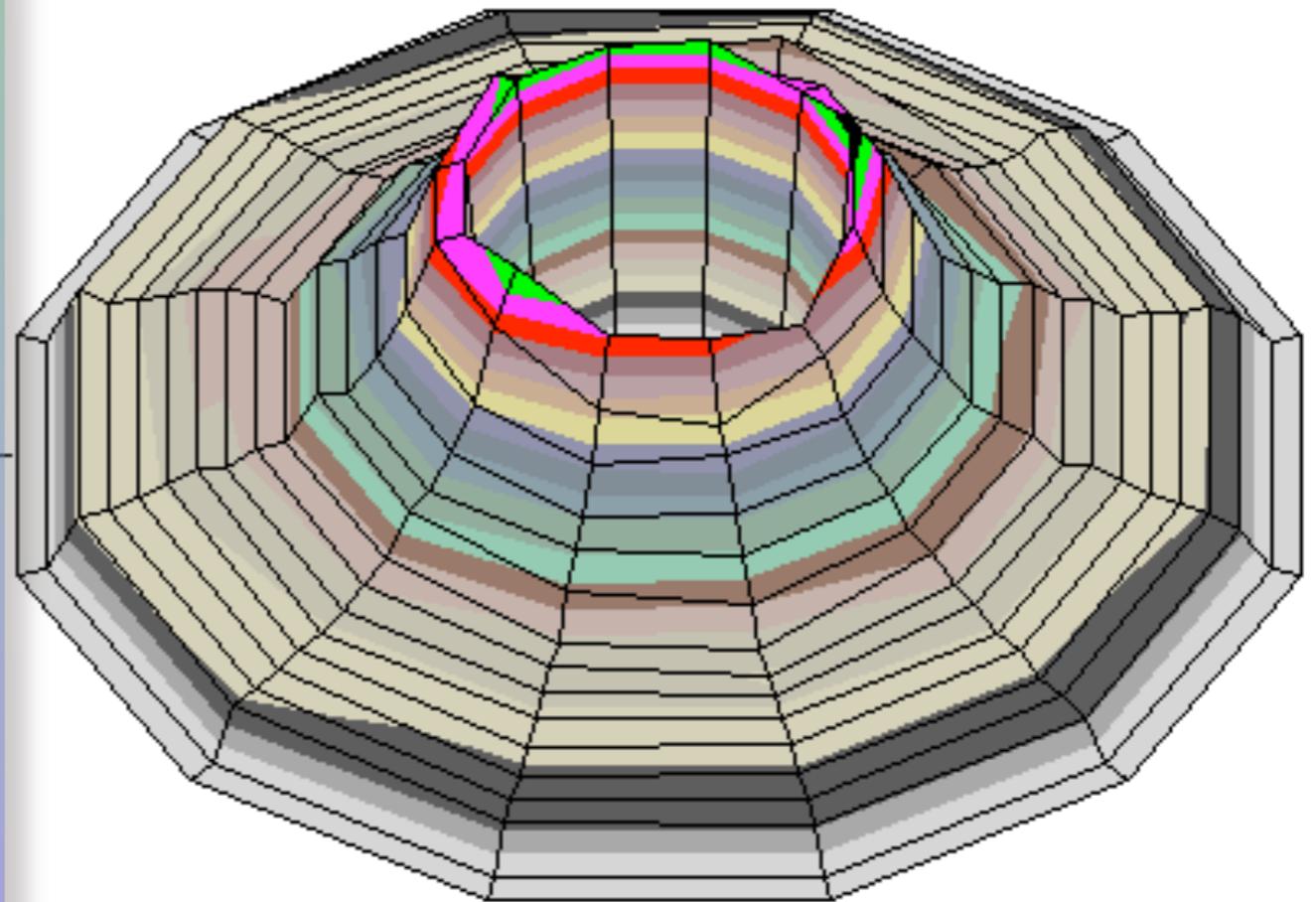
- HIJET model of “event shape” for 200 GeV AuAu collisions matches radial distribution of zerobias data well for much of the runs.

Radial distribution of TPC SpaceCharge



SpaceCharge: model of charge

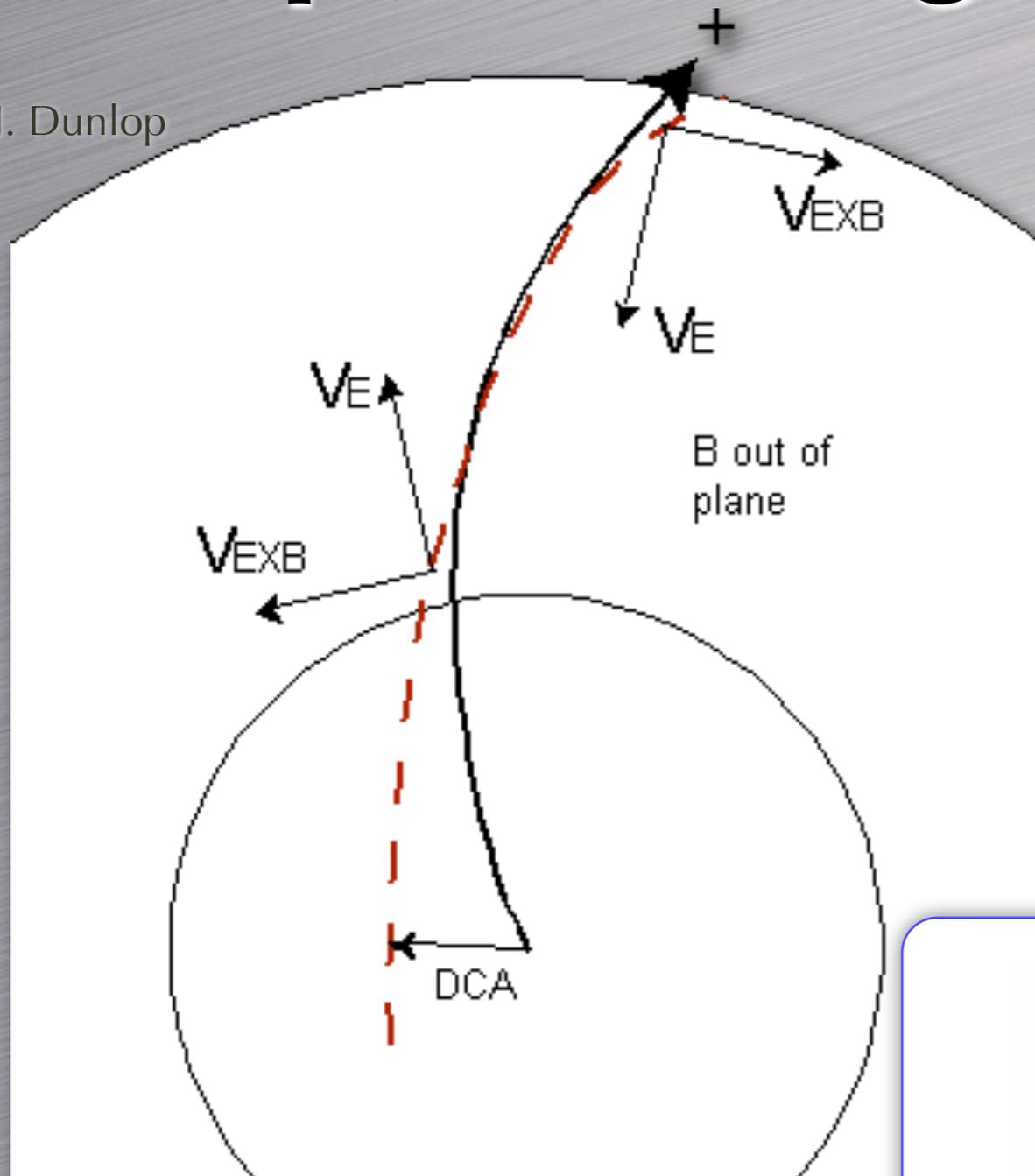
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March 1, 2004 data

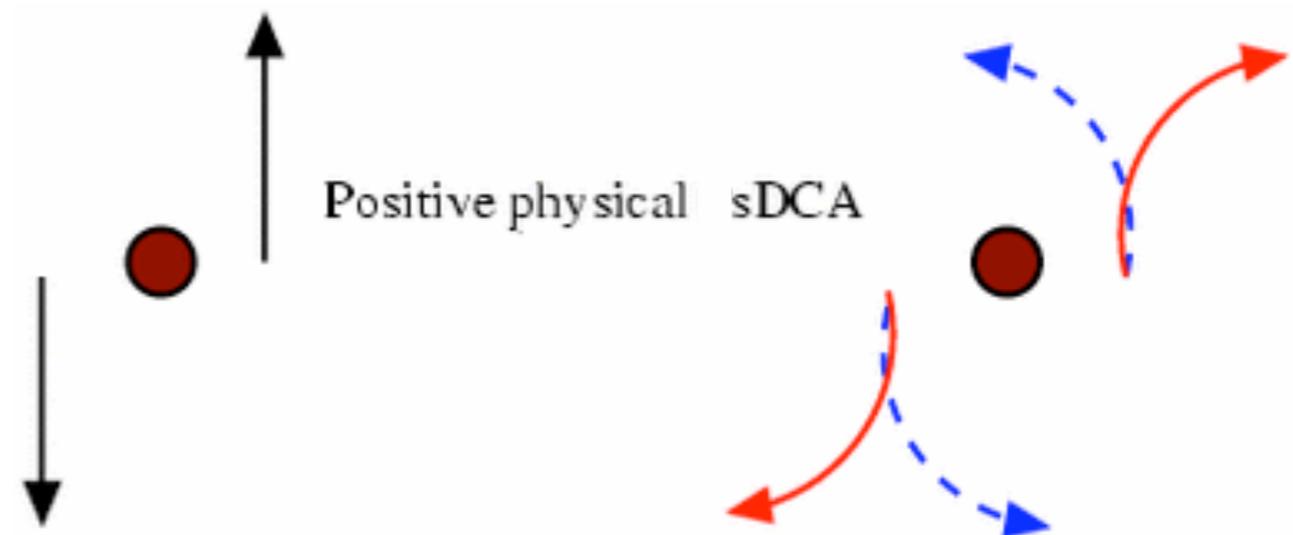
SpaceCharge effect on sDCA

J. Dunlop



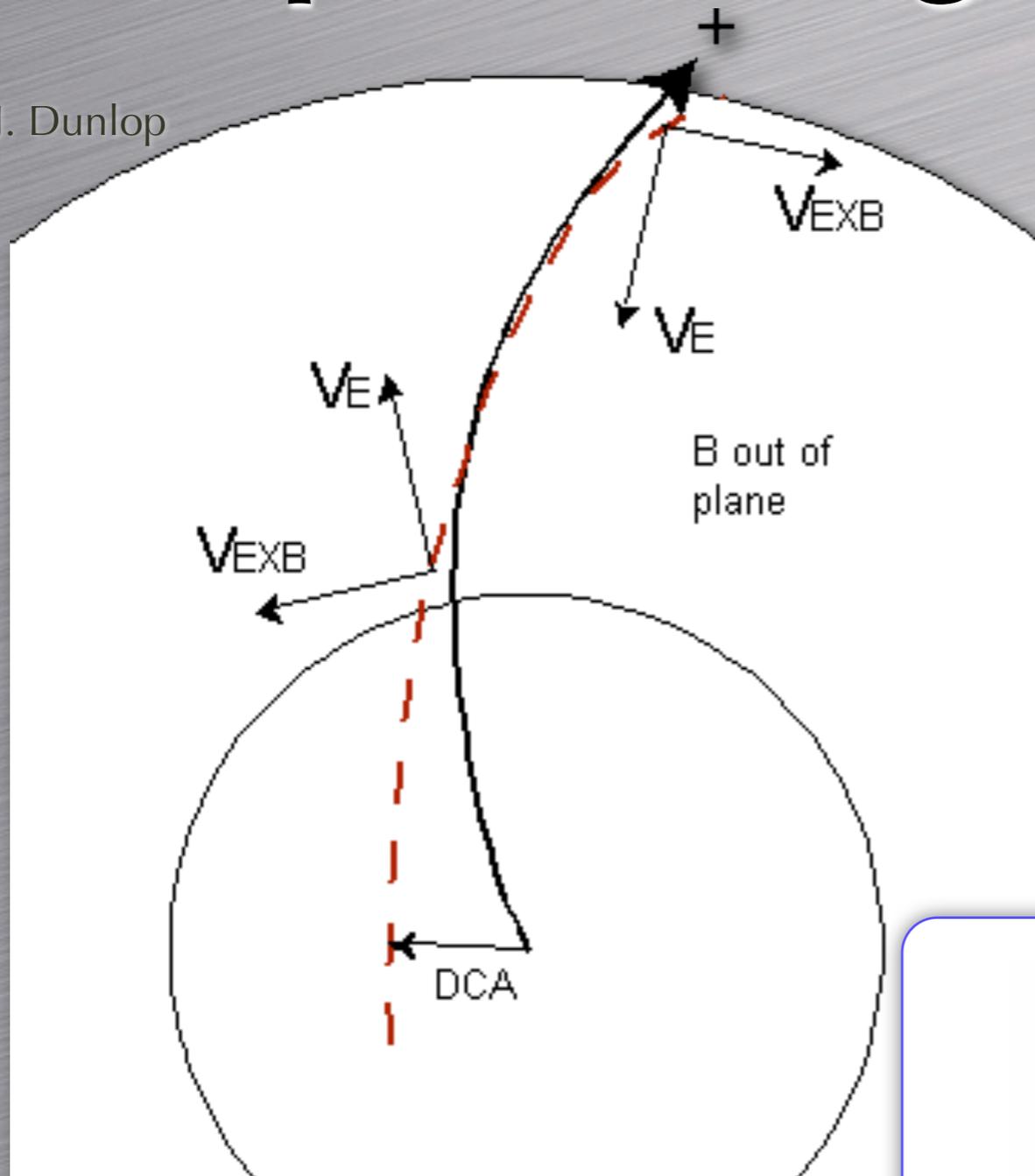
- All tracks go the same direction (pos. or neg.)
- Track charge independence
- Field dependence

sDCA = signed distance of closest approach



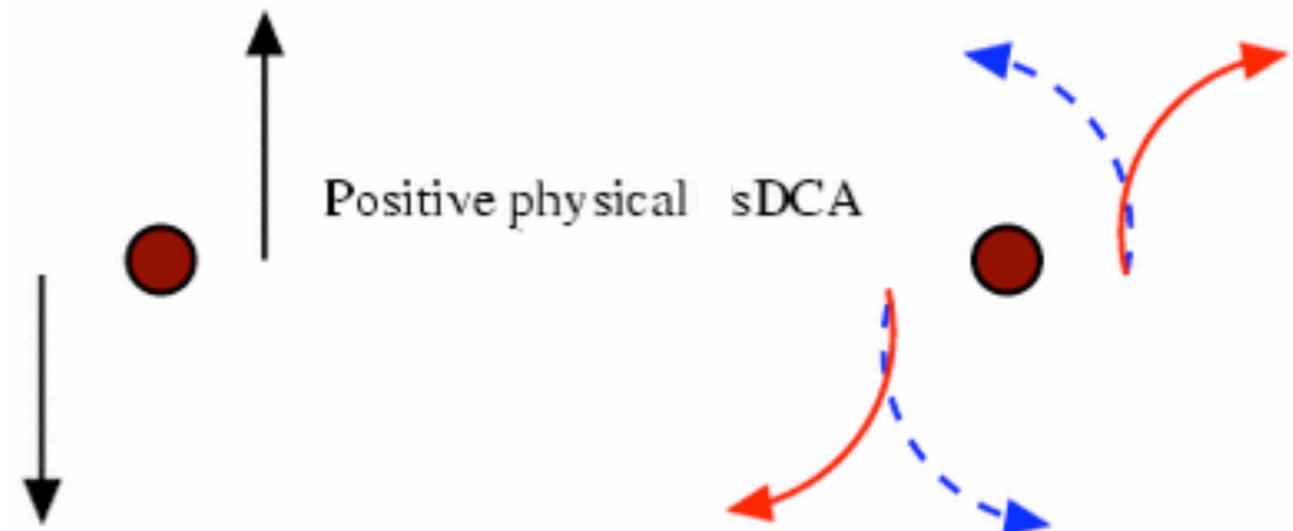
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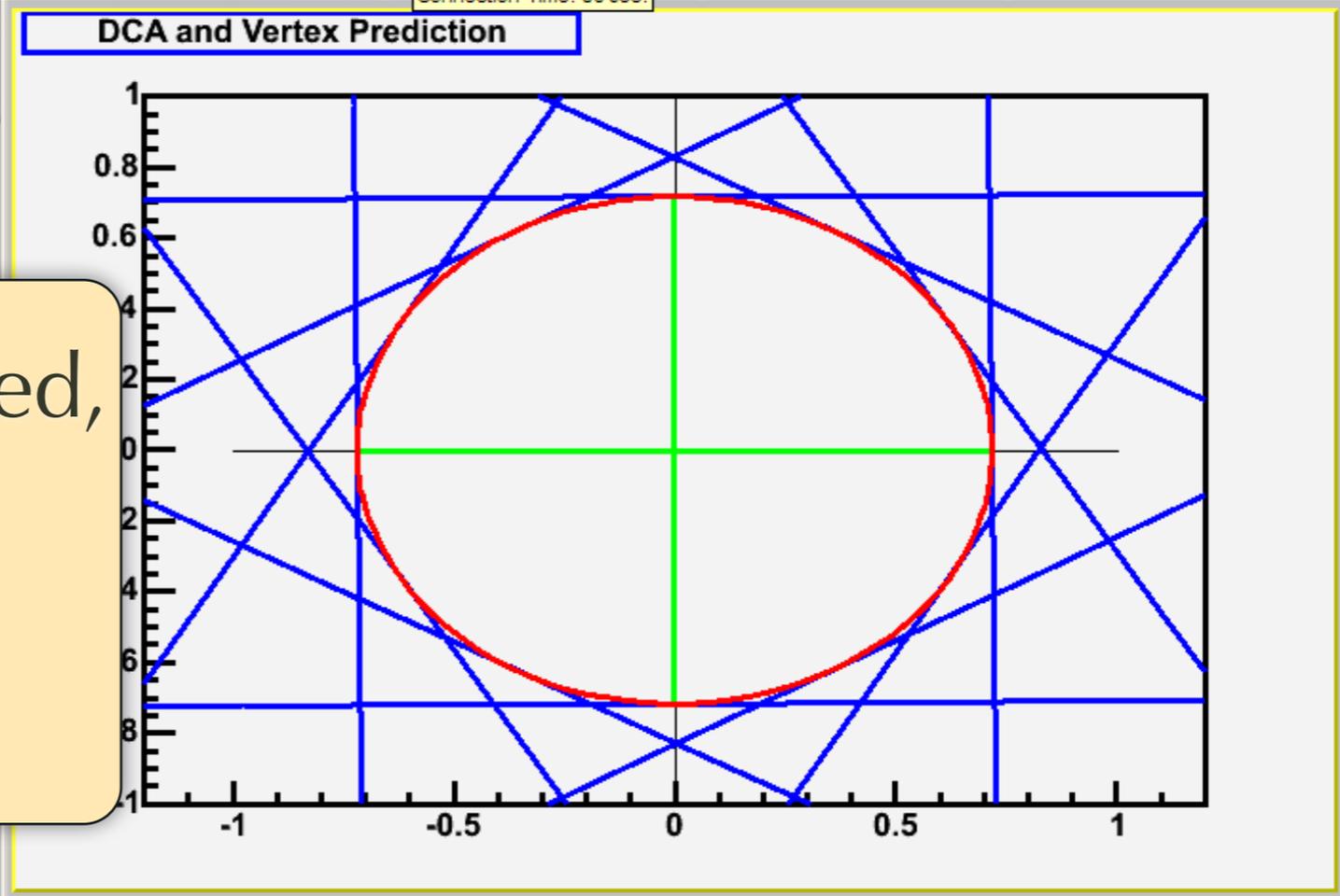
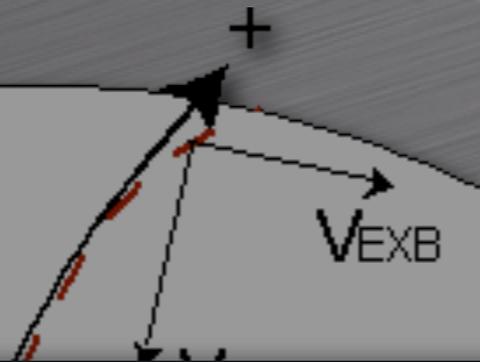
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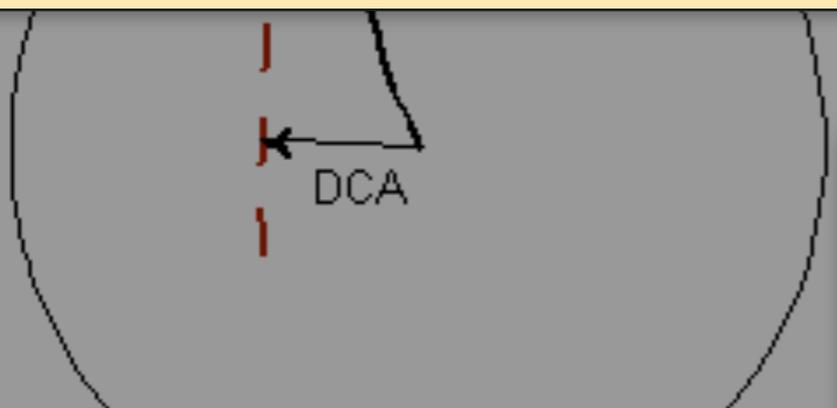


SpaceCharge effect on sDCA

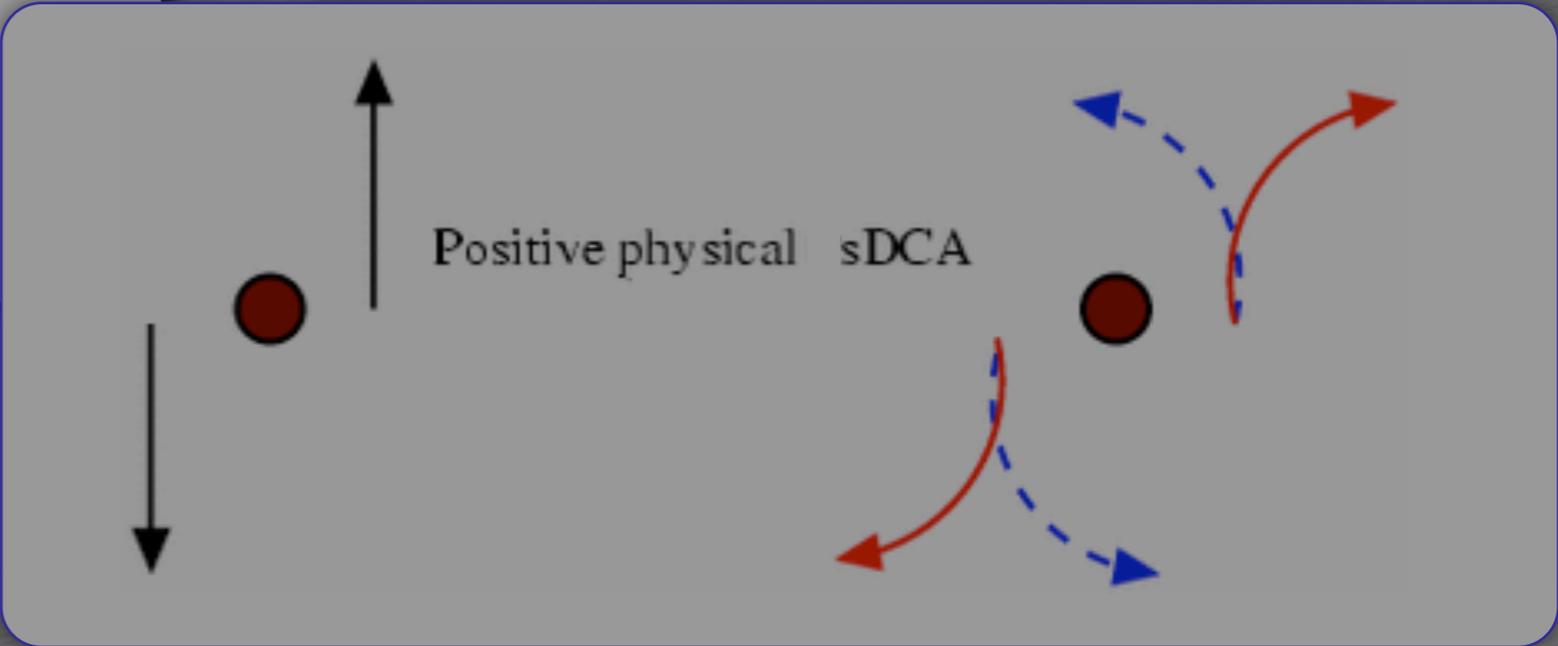
J. Dunlop



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

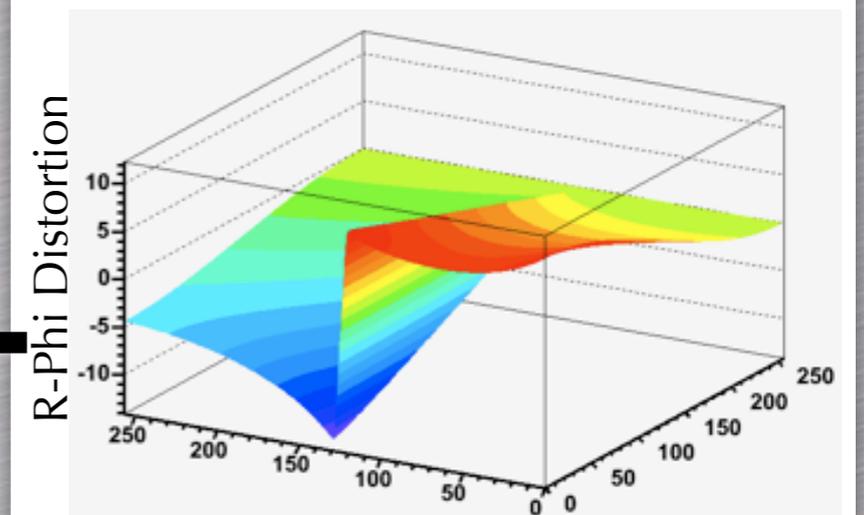
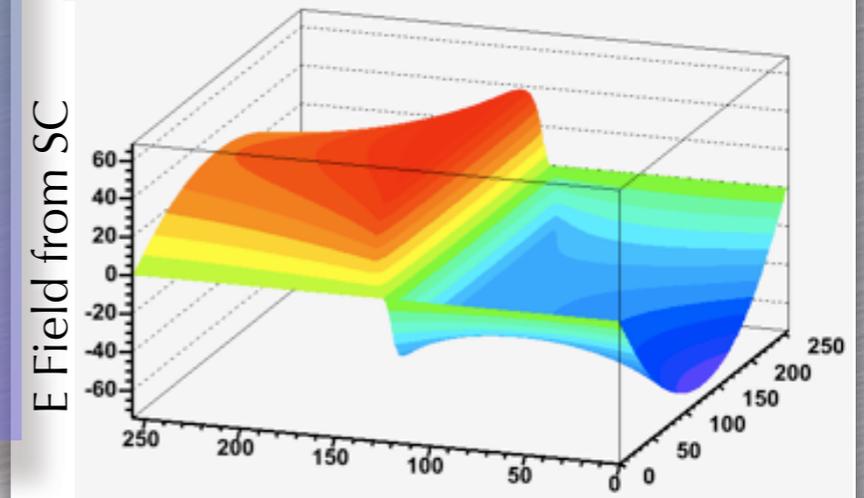
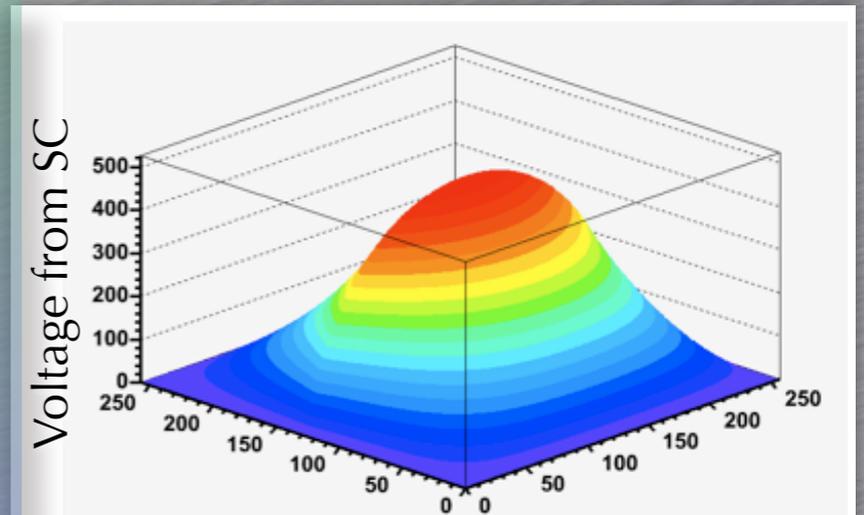


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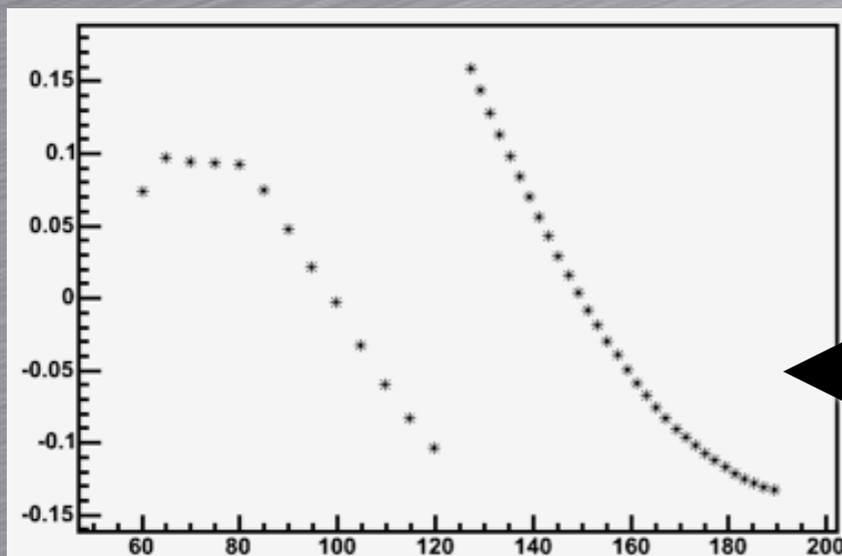


GridLeak Field Effects

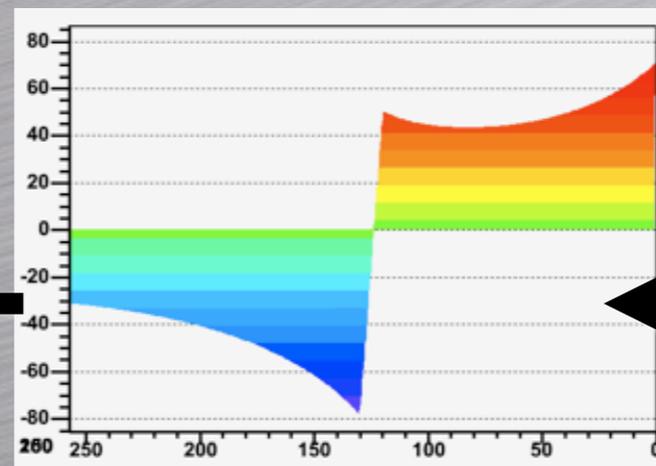
- Modeled sheets of charge
 - Relaxation done on custom 3D grid (plots assume Φ symmetry, but leak is 12-fold symmetry from grid shape)
 - E-field and distortion discontinuity at grid gap
- GridLeak scales as SpaceCharge!*



Simulated residuals on a track

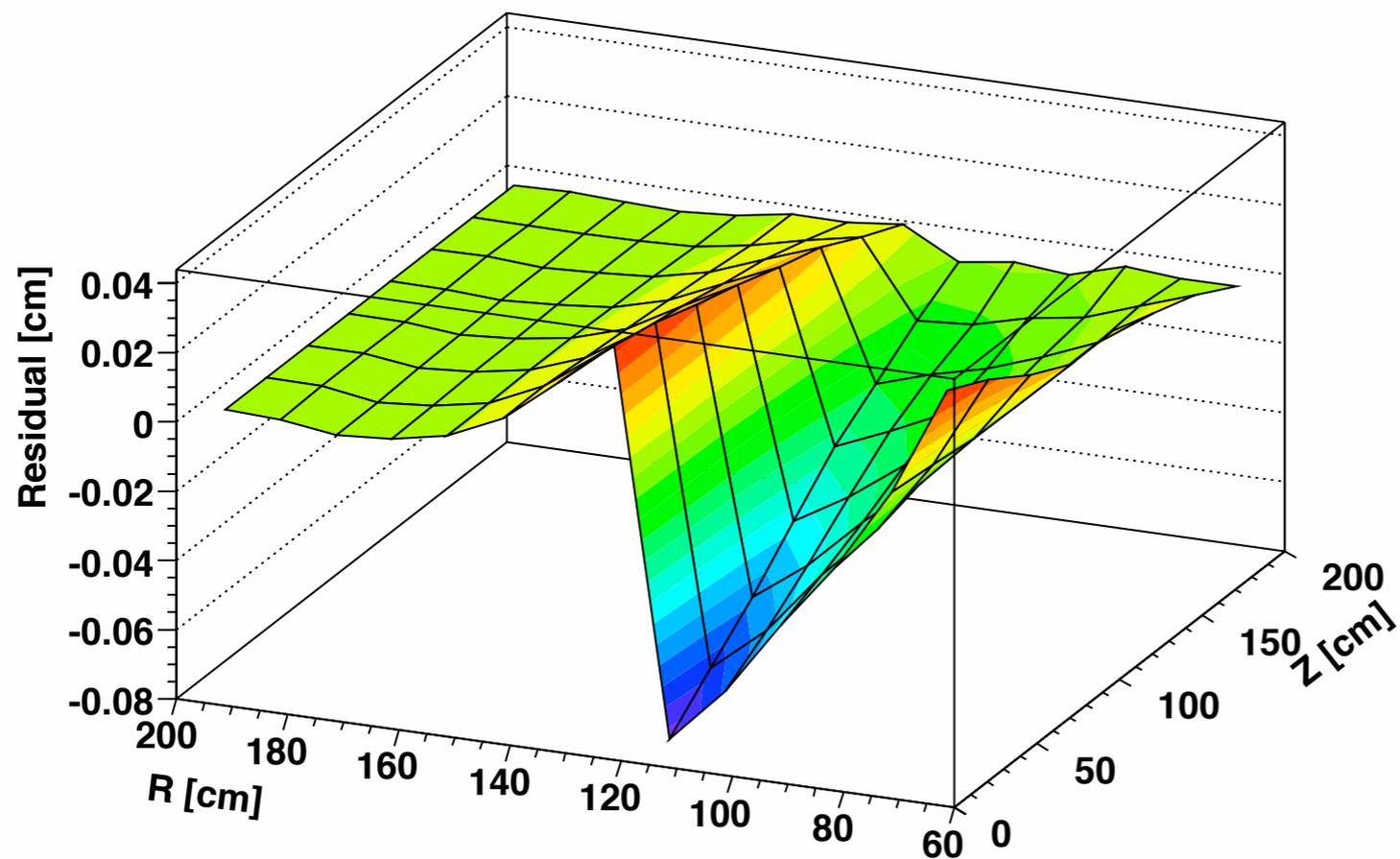


Distortion near CM



Applied GridLeak Correction

- Not perfect, but as good as design spec!

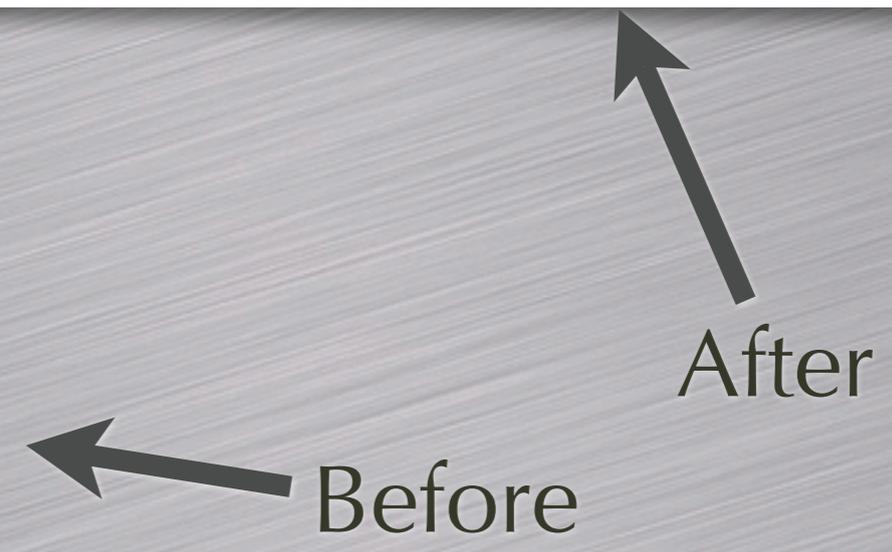
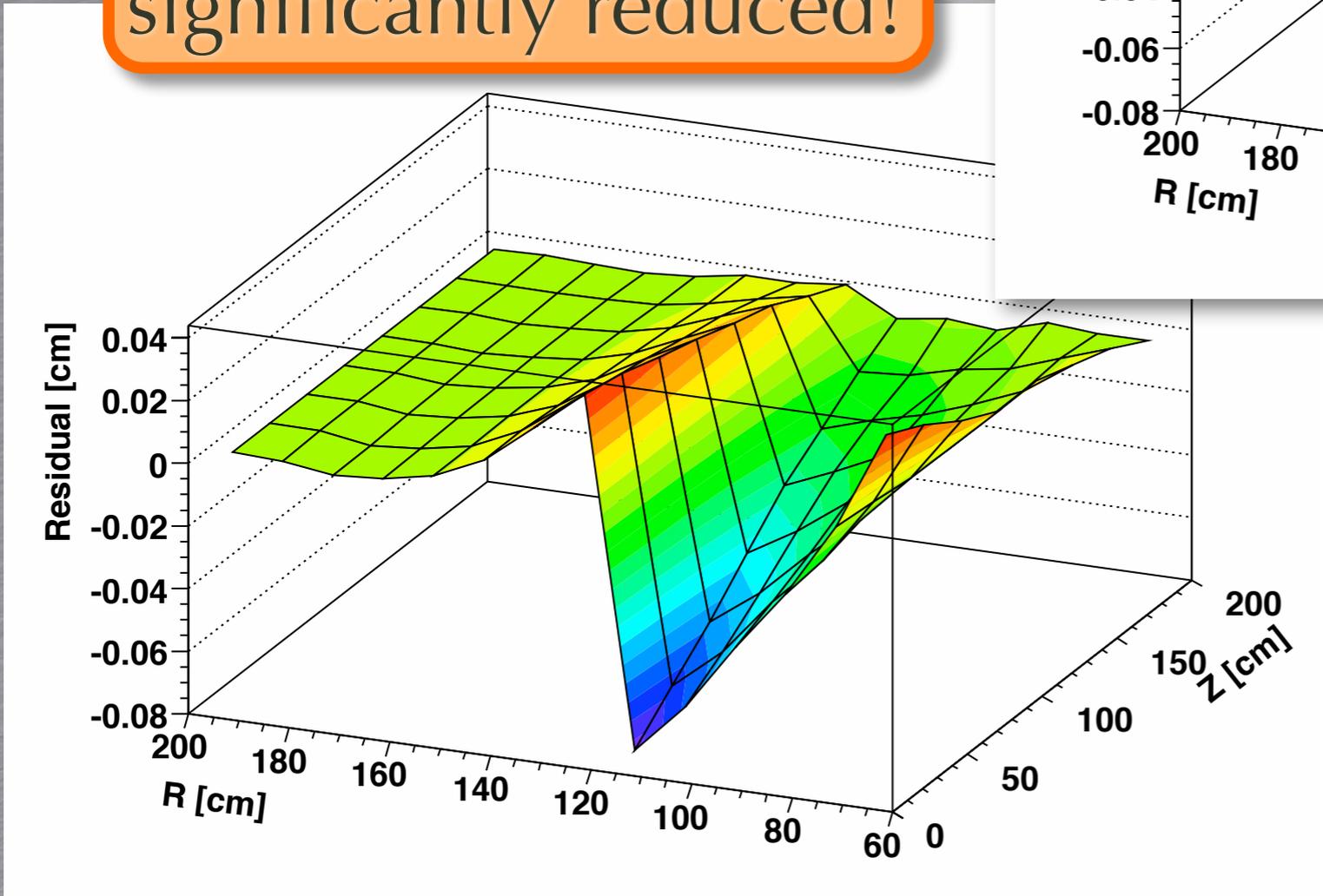
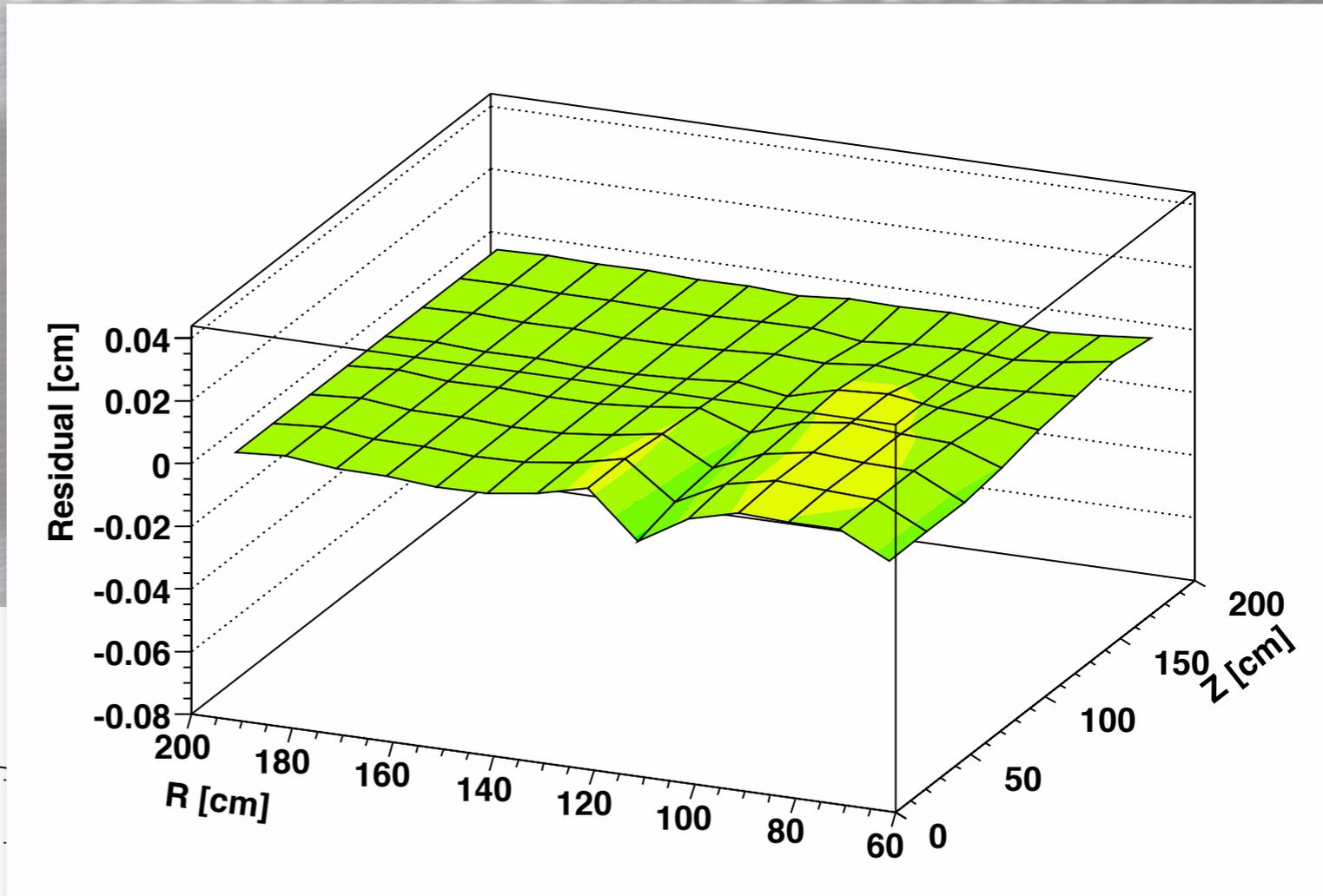


← Before

Applied GridLeak Correction

• Not perfect, but as good as design spec!

Distortions scale significantly reduced!



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!

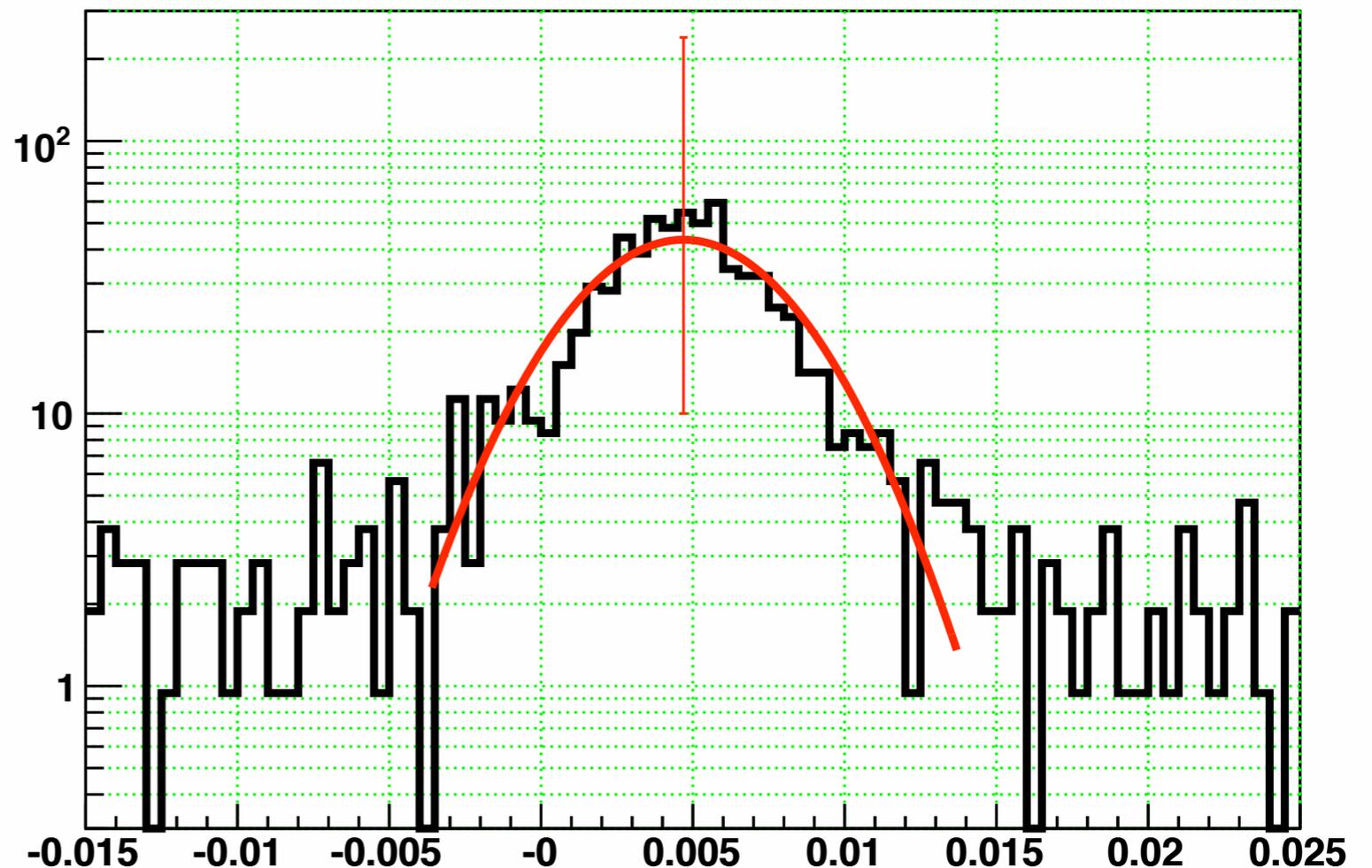
First steps to corrections

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First steps to corrections

- Observables (s distortion quar SpaceCharge b
- Easy with “idea
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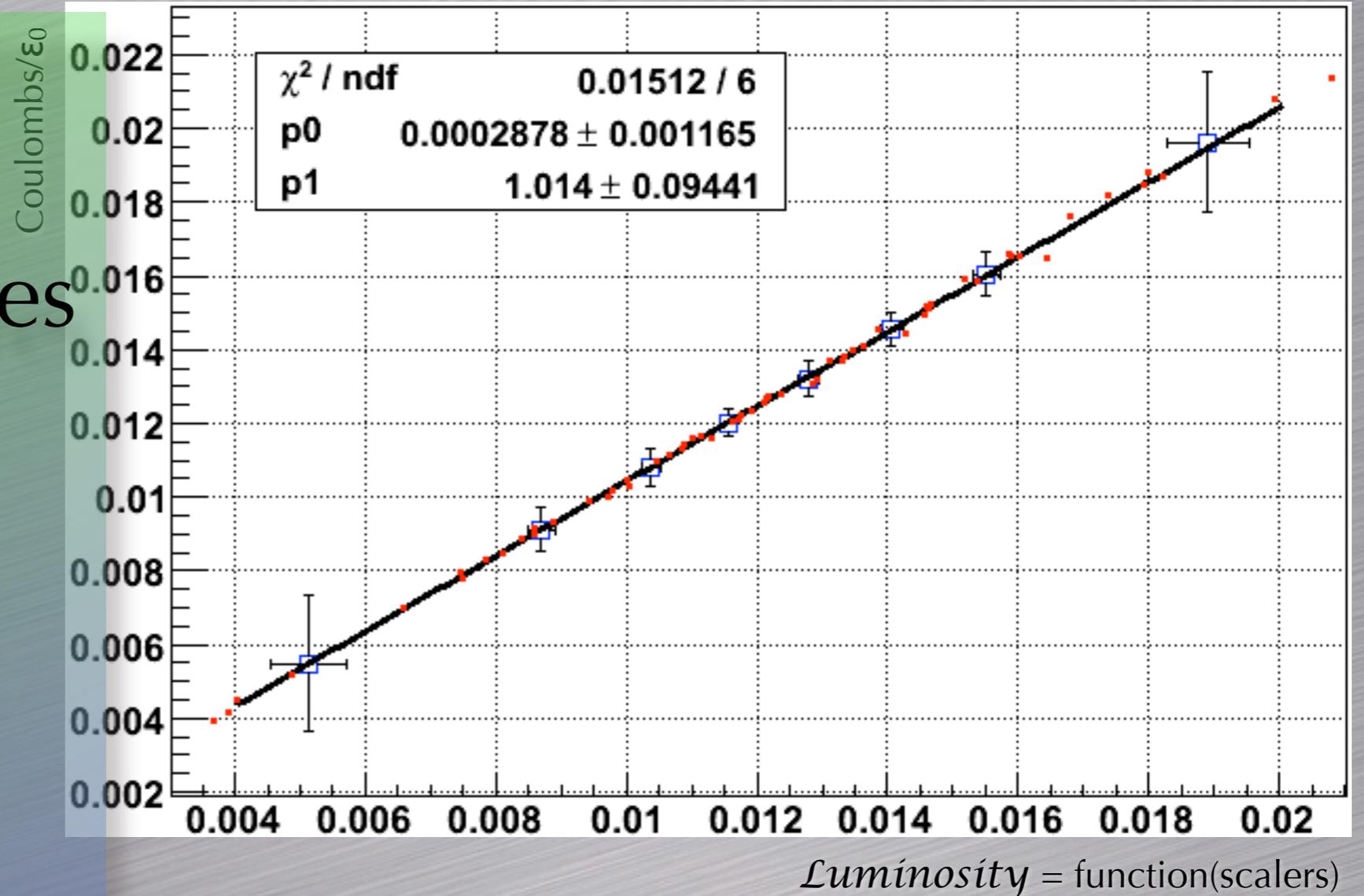
Space Charge



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- Generally need many events for stats
 - Could be many runs for pp collisions!

Ionization: Scalers

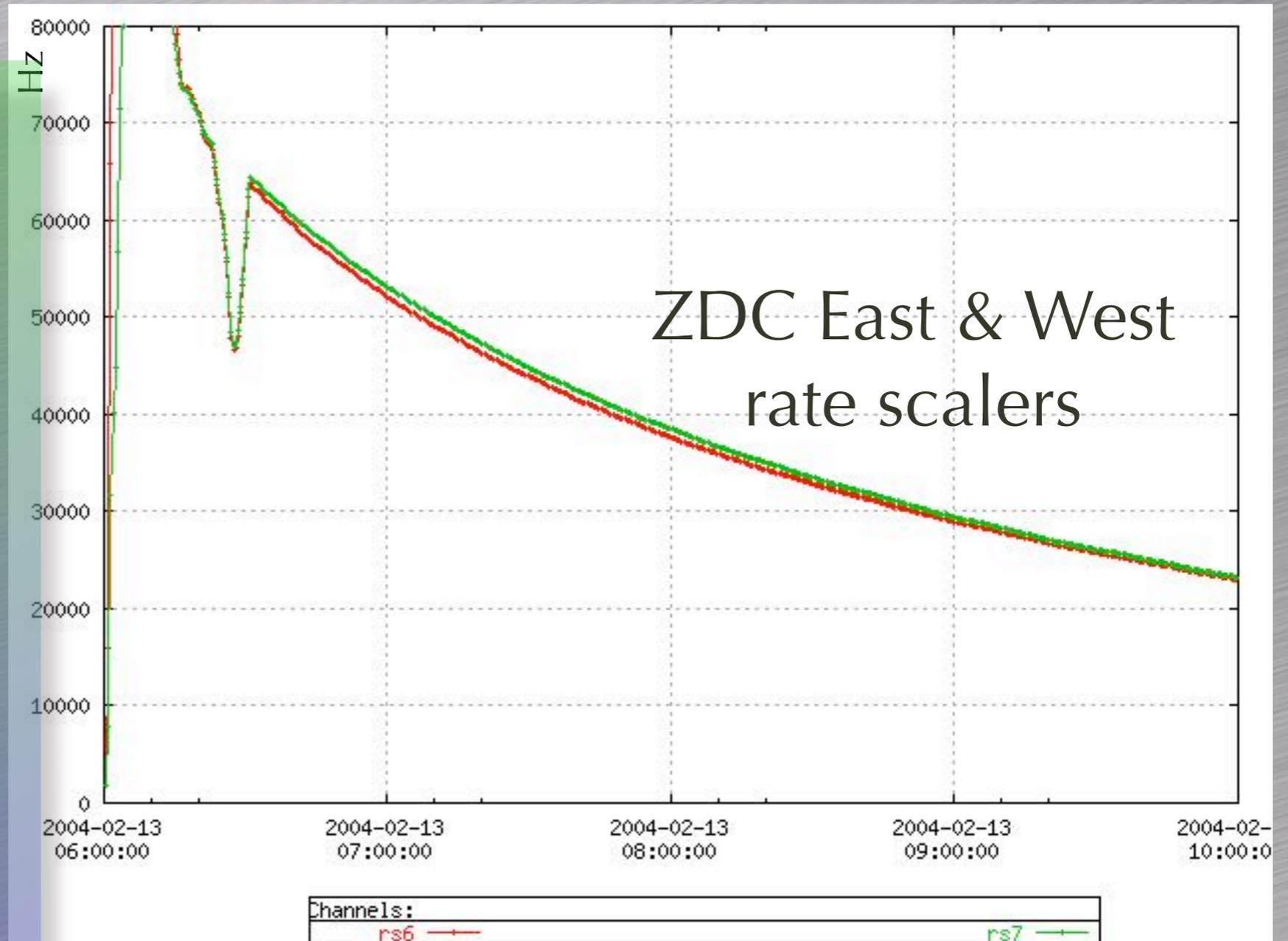
- Ionization is linear with scaler measures of luminosity
- Points out problem runs
- Now using 1 second averages



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

Ionization: Fluctuations

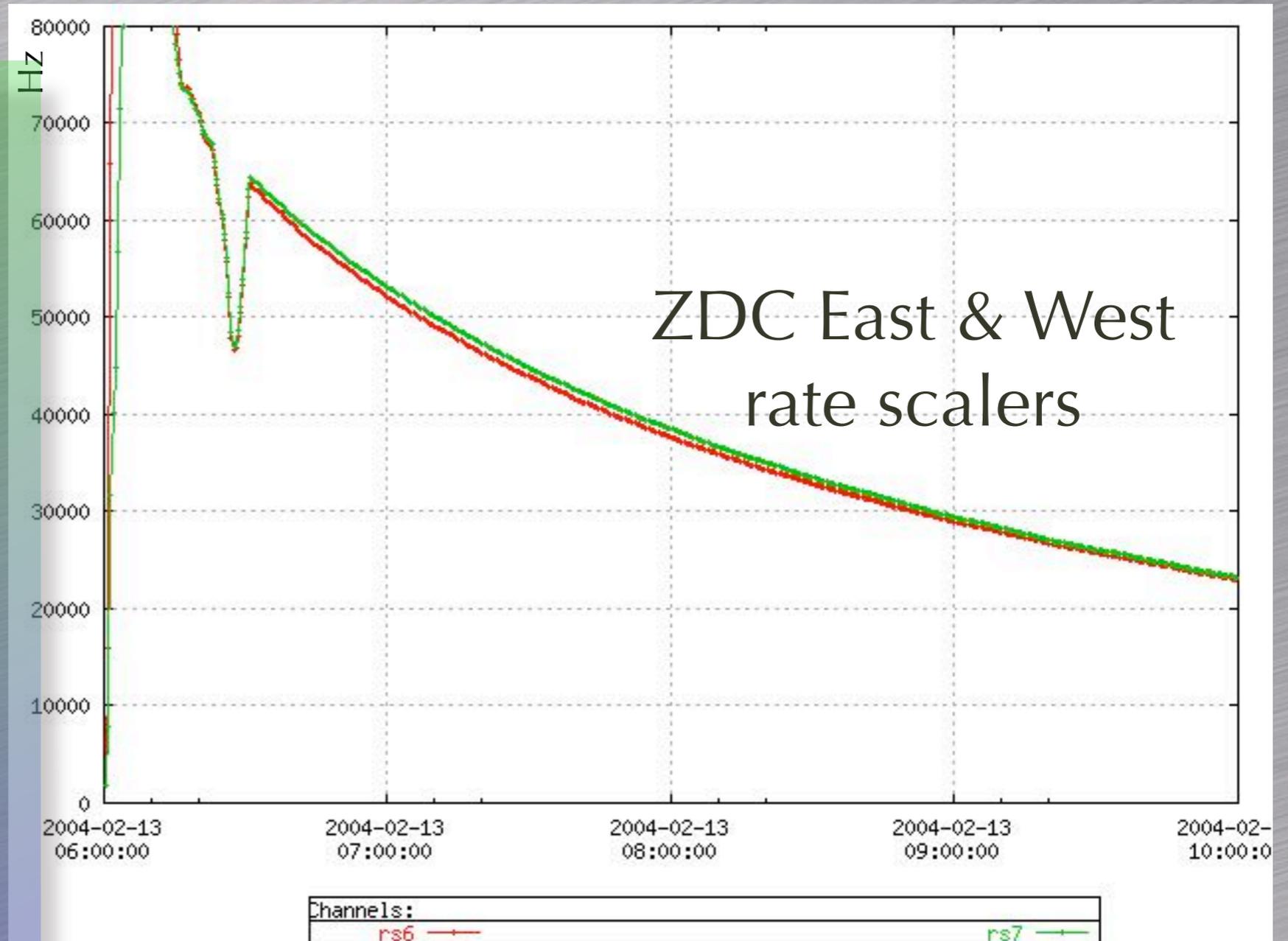
- Collision rates look smooth in ZDC rates...
- ...but background rates show something going on...



Fill 4529, February 13, 2004

Ionization: Fluctuations

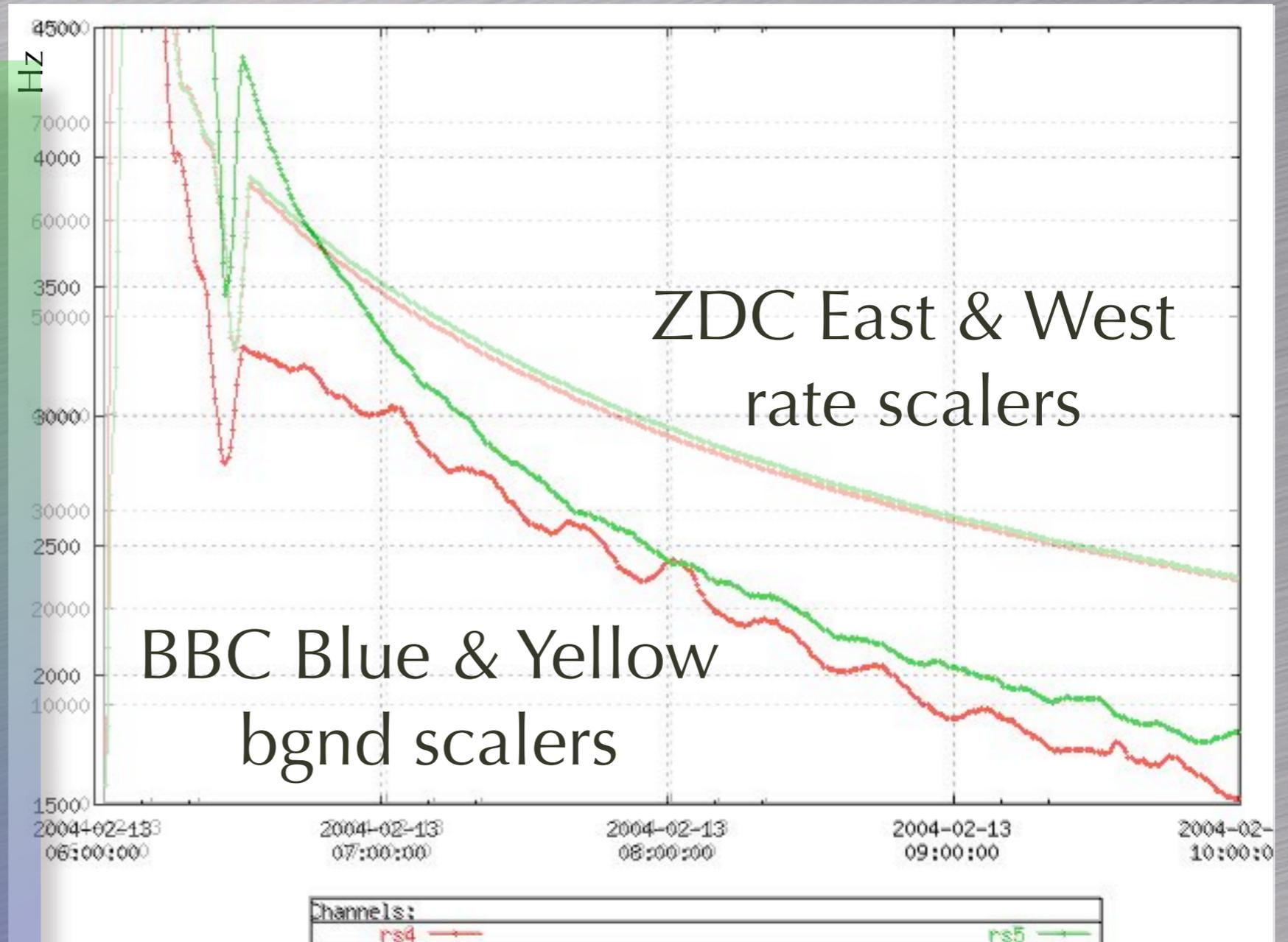
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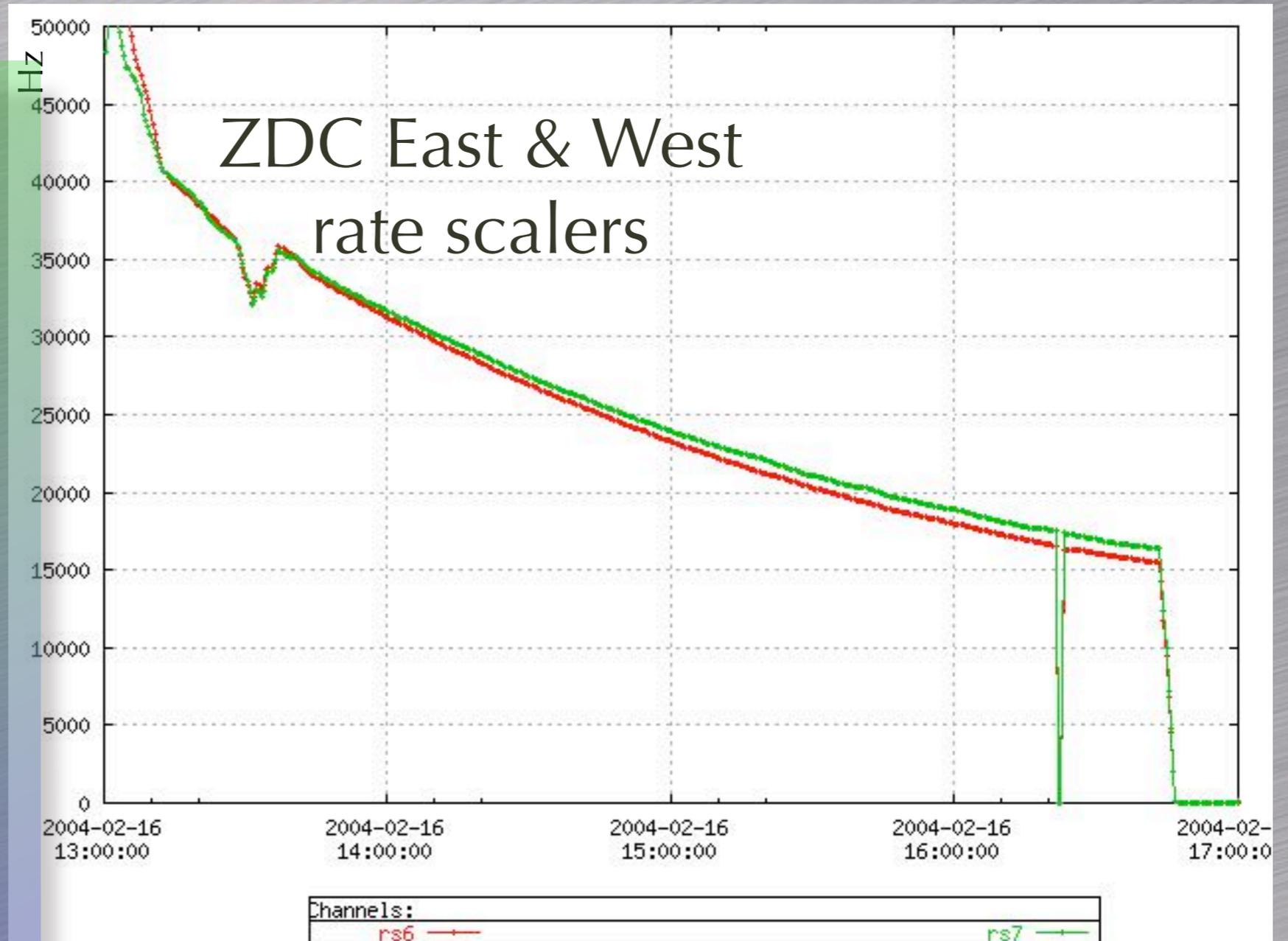
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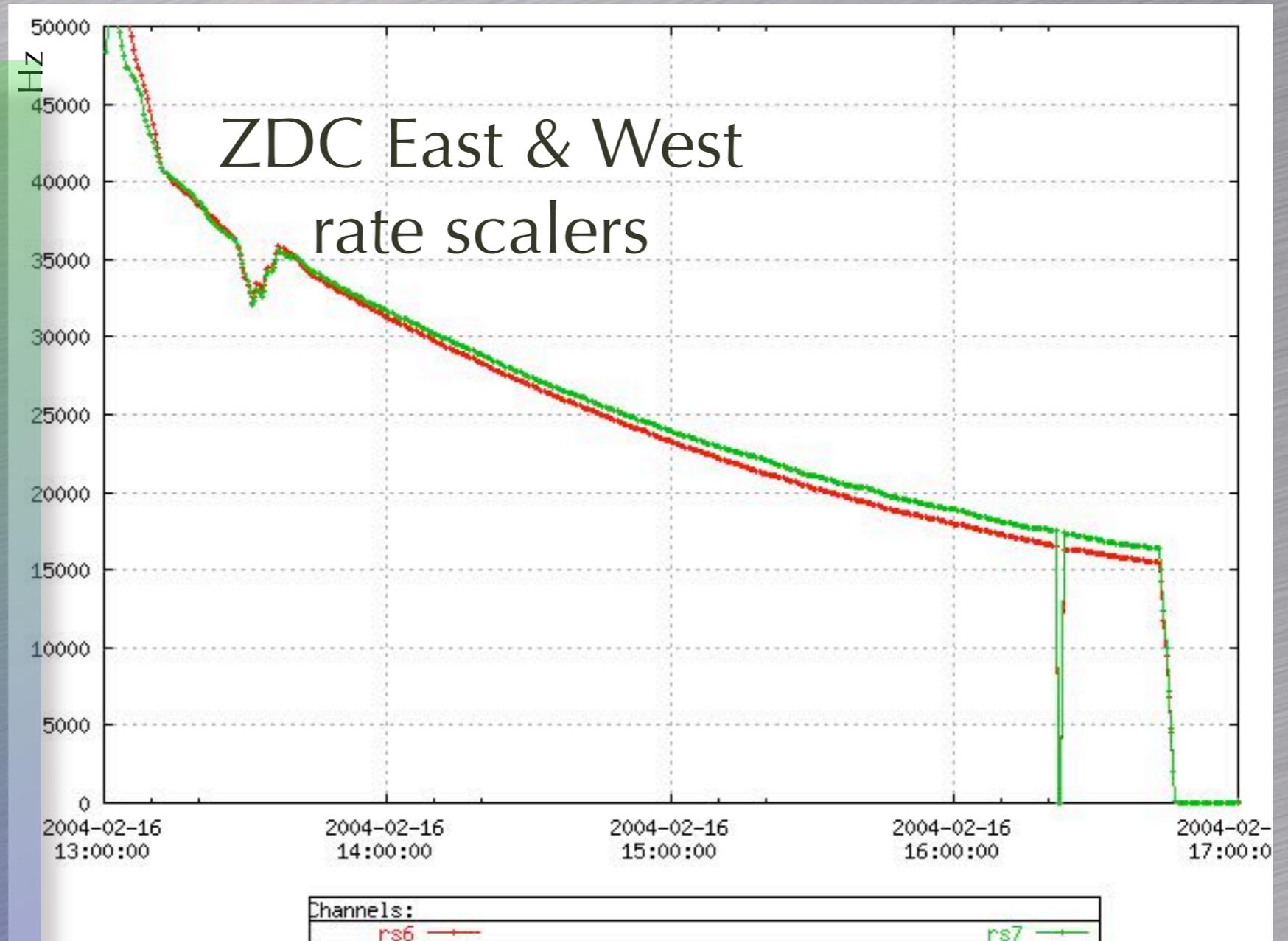
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Fill 4547, February 16, 2004

Ionization: Fluctuations

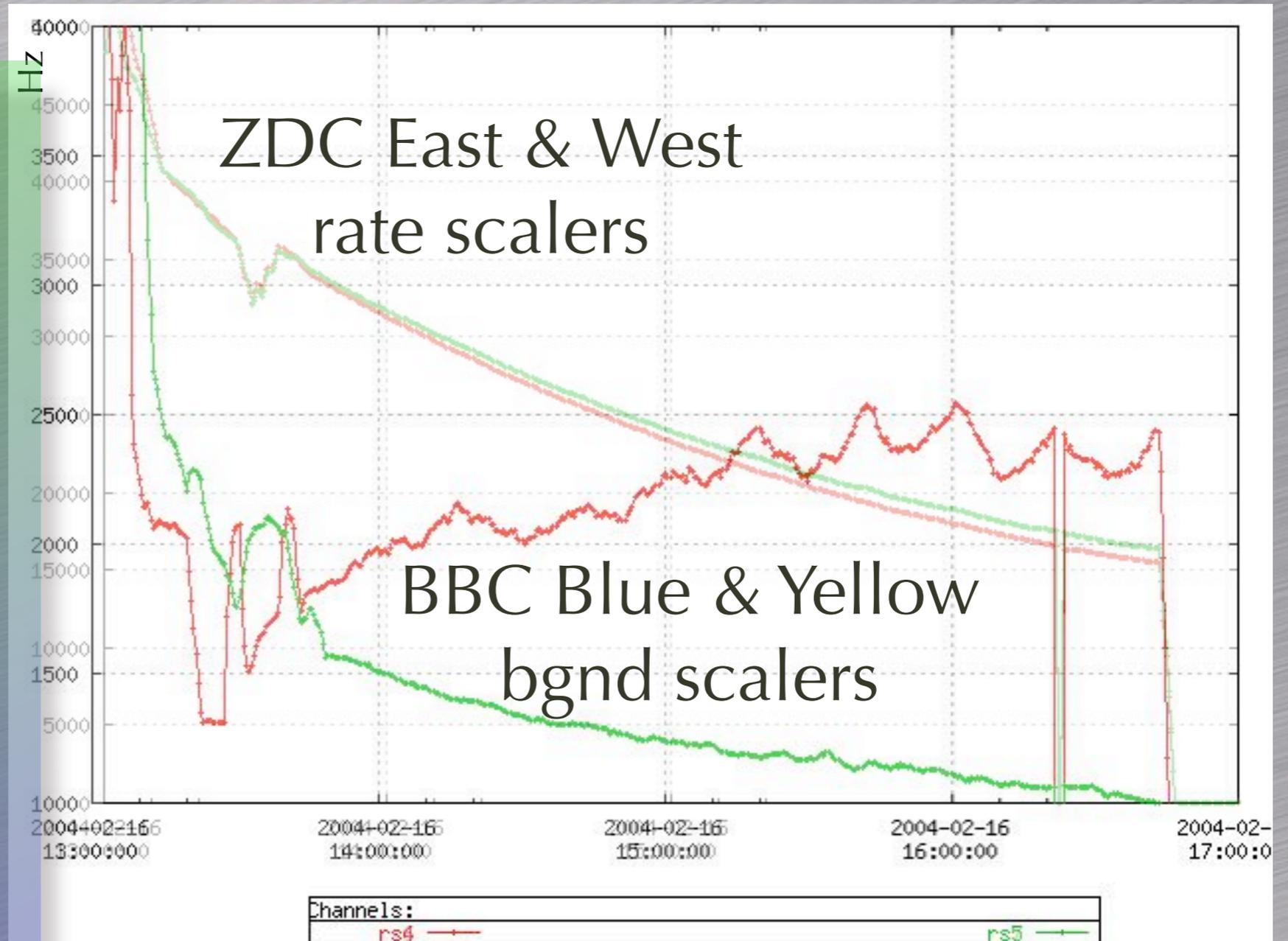
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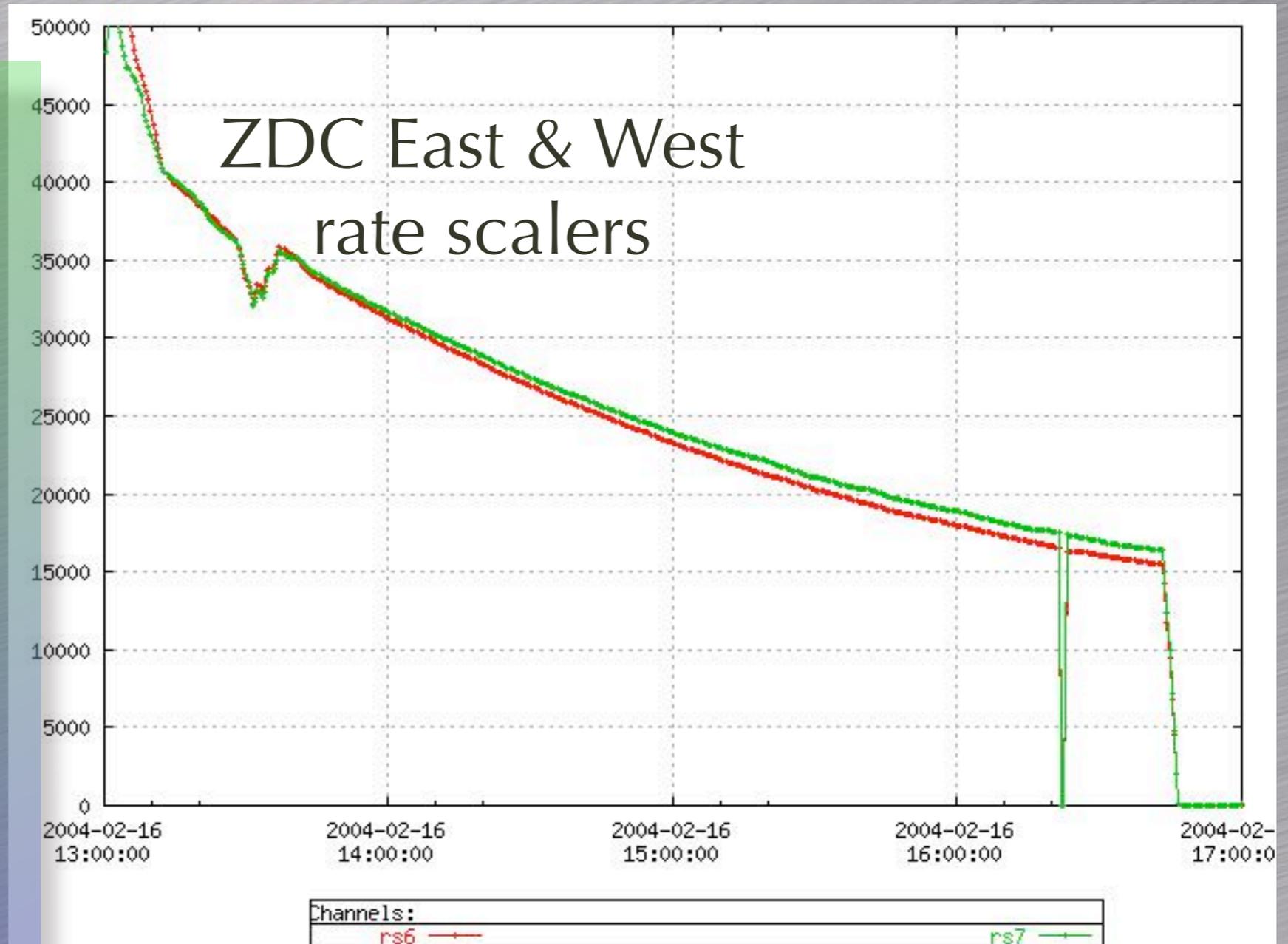
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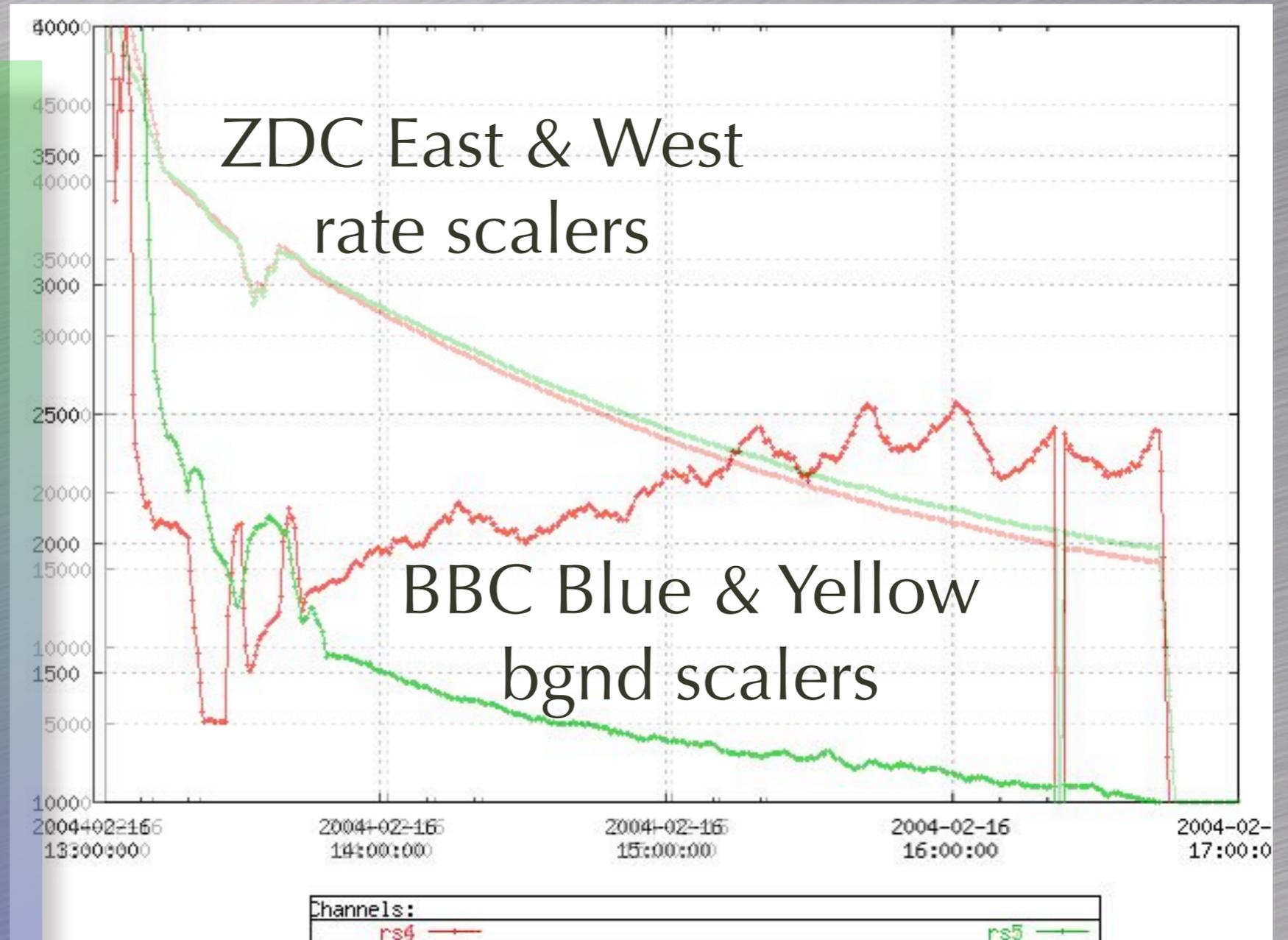
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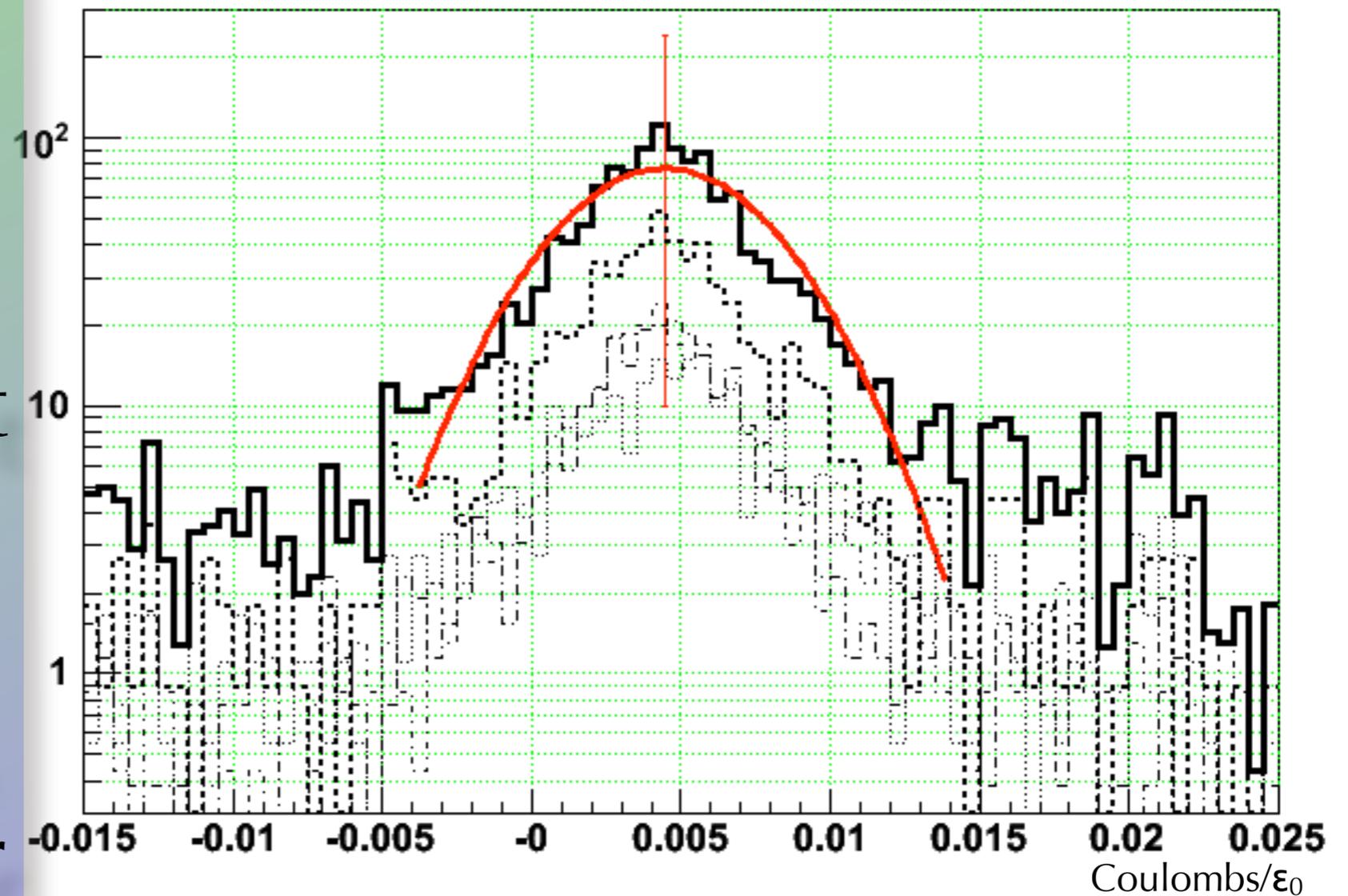


Fill 4547, February 16, 2004

Event-by-Event: use history

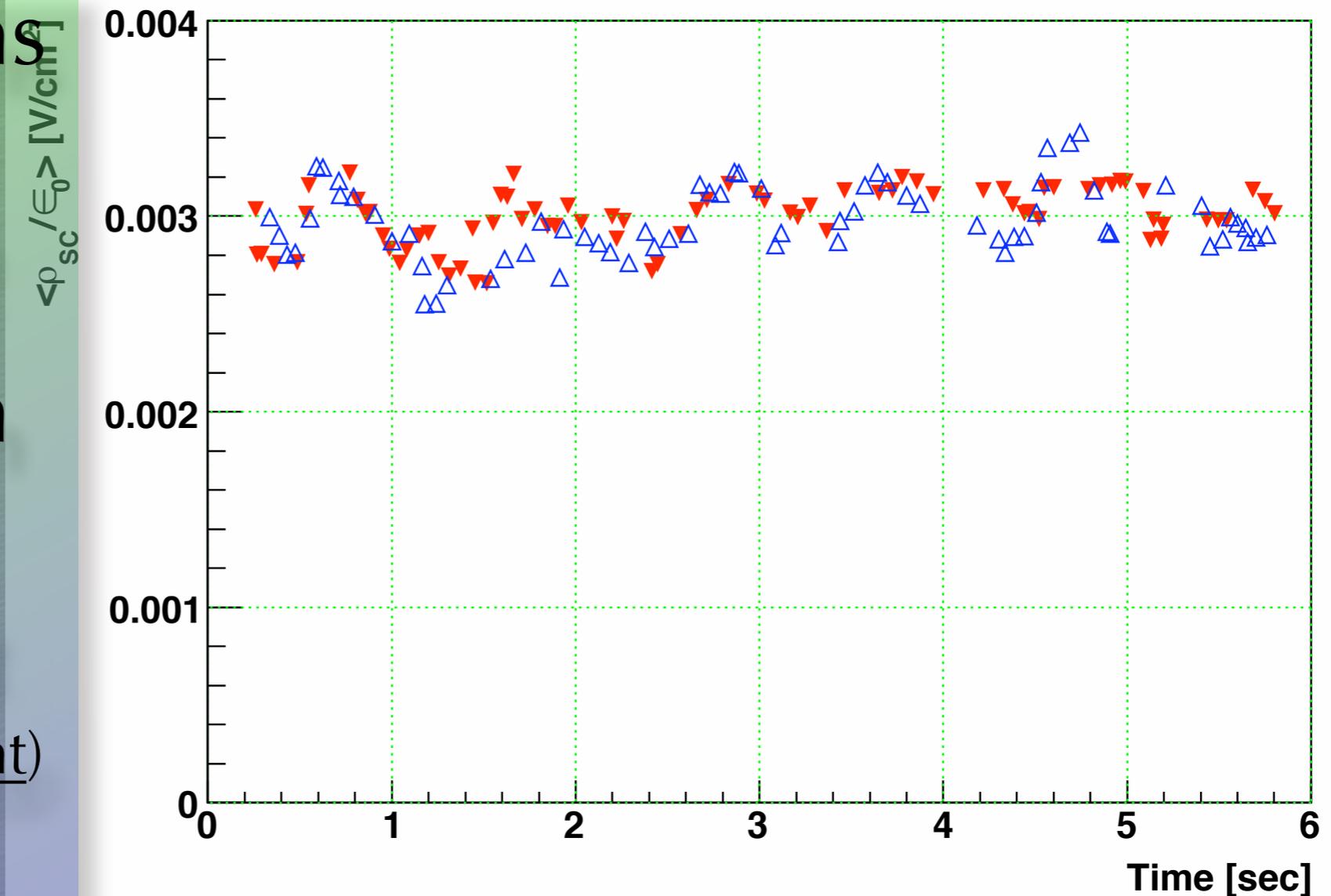
- Use several recent events with age weighting
- Throw and refit tracks with simple (quick) model to allow for larger selection

Space Charge



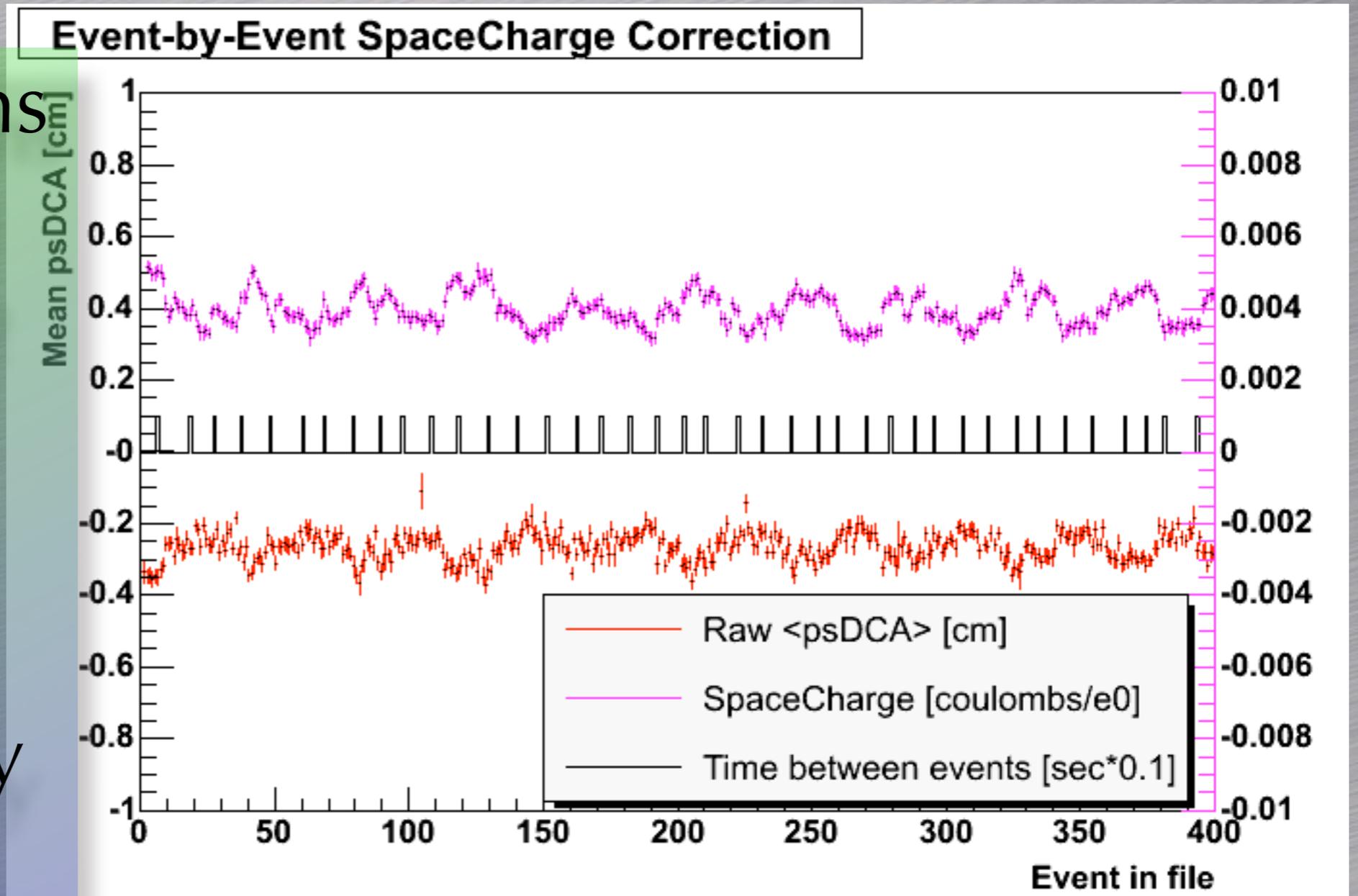
E-by-E Successes

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



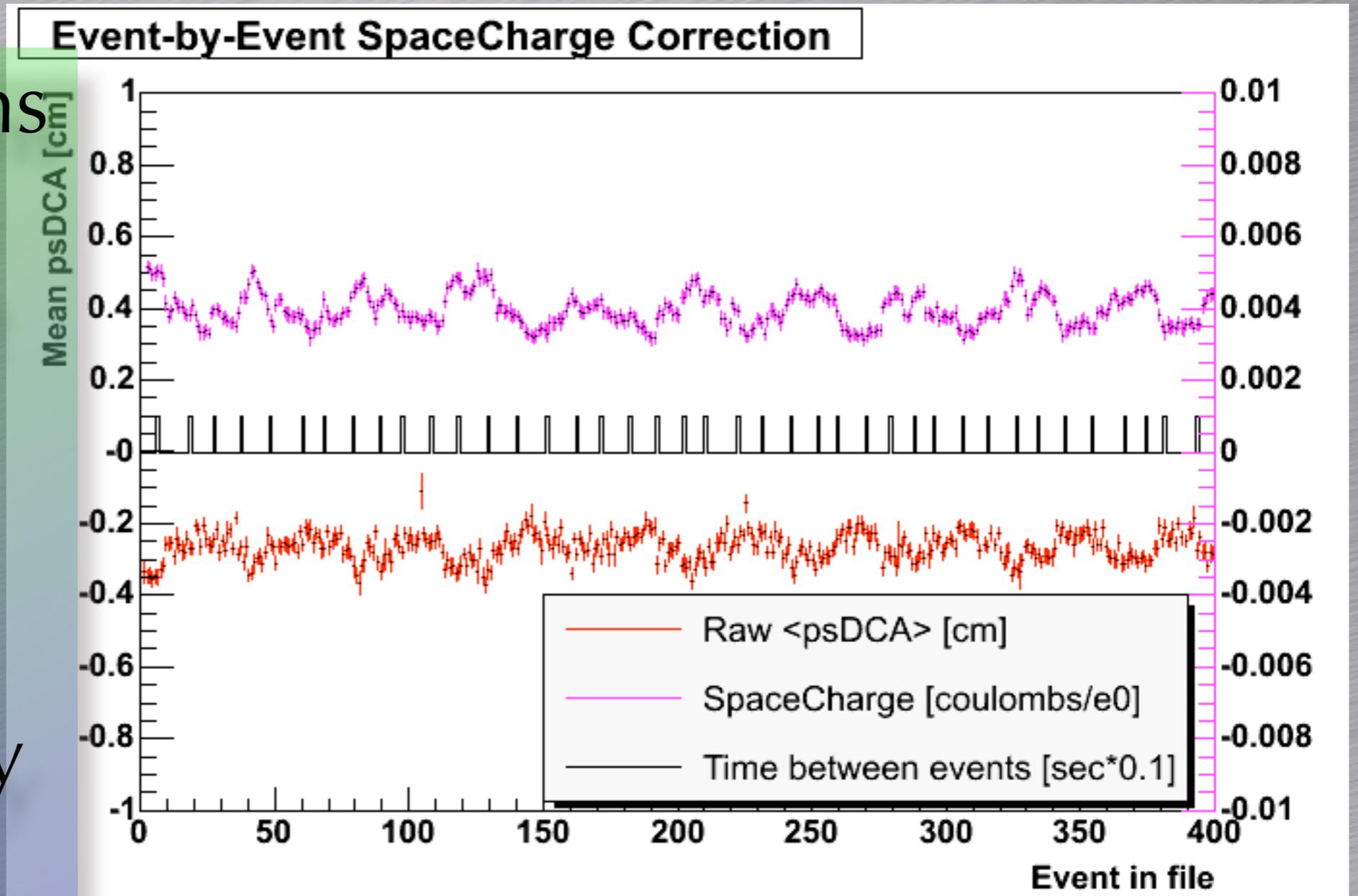
E-by-E Successes

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



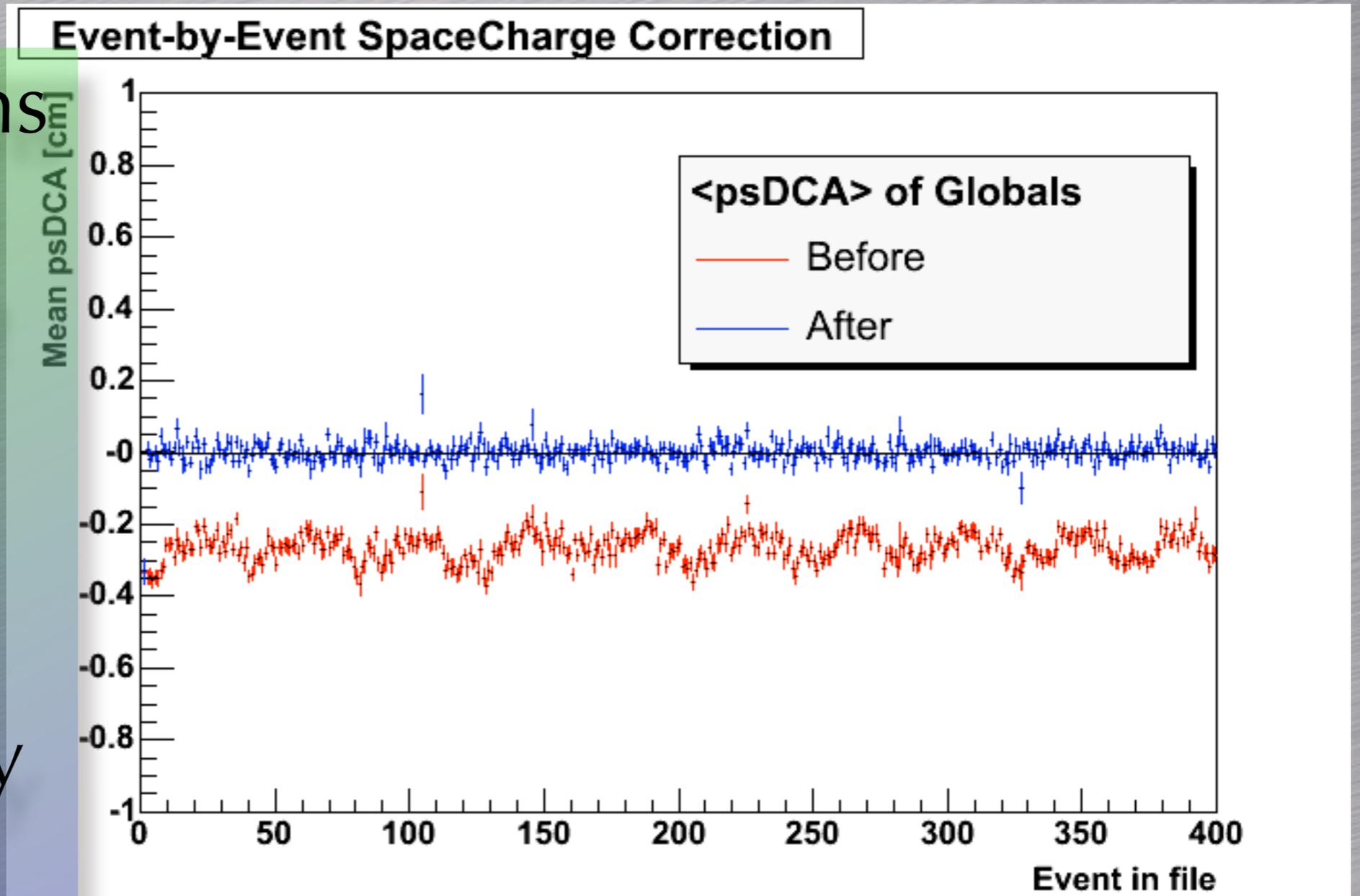
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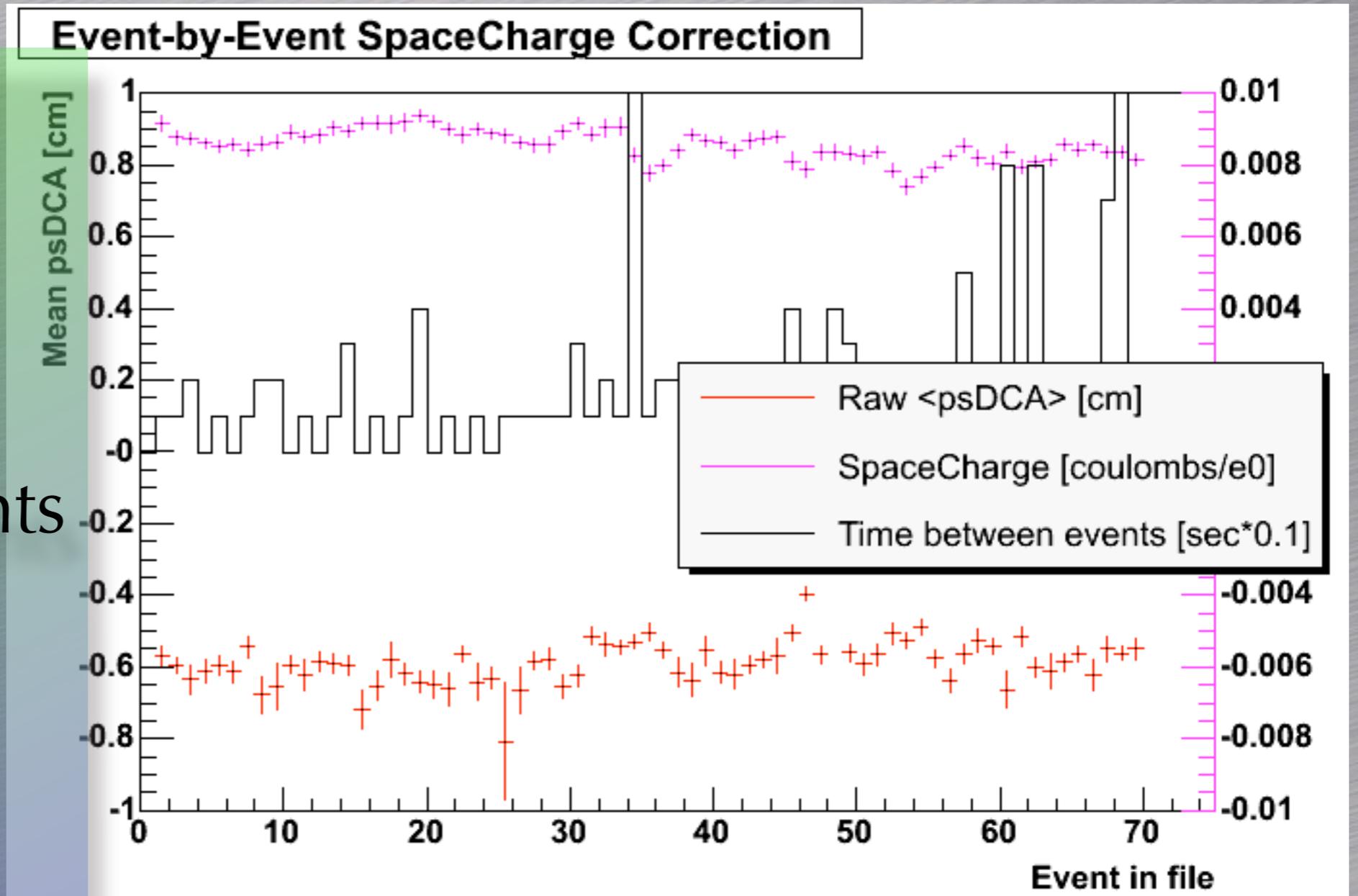
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E-by-E Issues

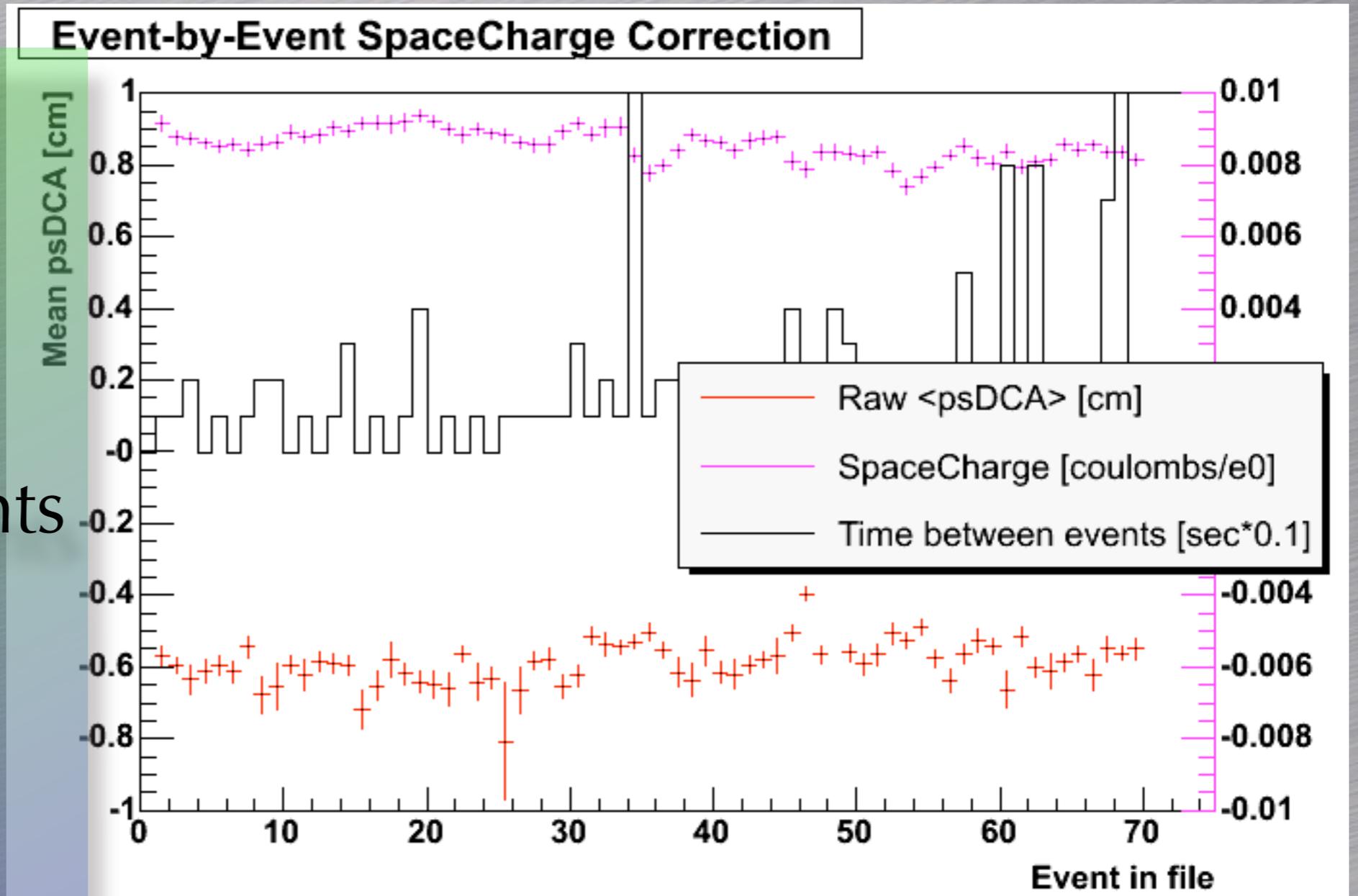
- Beginning of files
- ☑ Prepass
- Time gaps between events
- Frequent low multiplicity events
- ☑ Fall back to prepass value (or scalers)



Run 5044026: productionHigh

E-by-E Issues

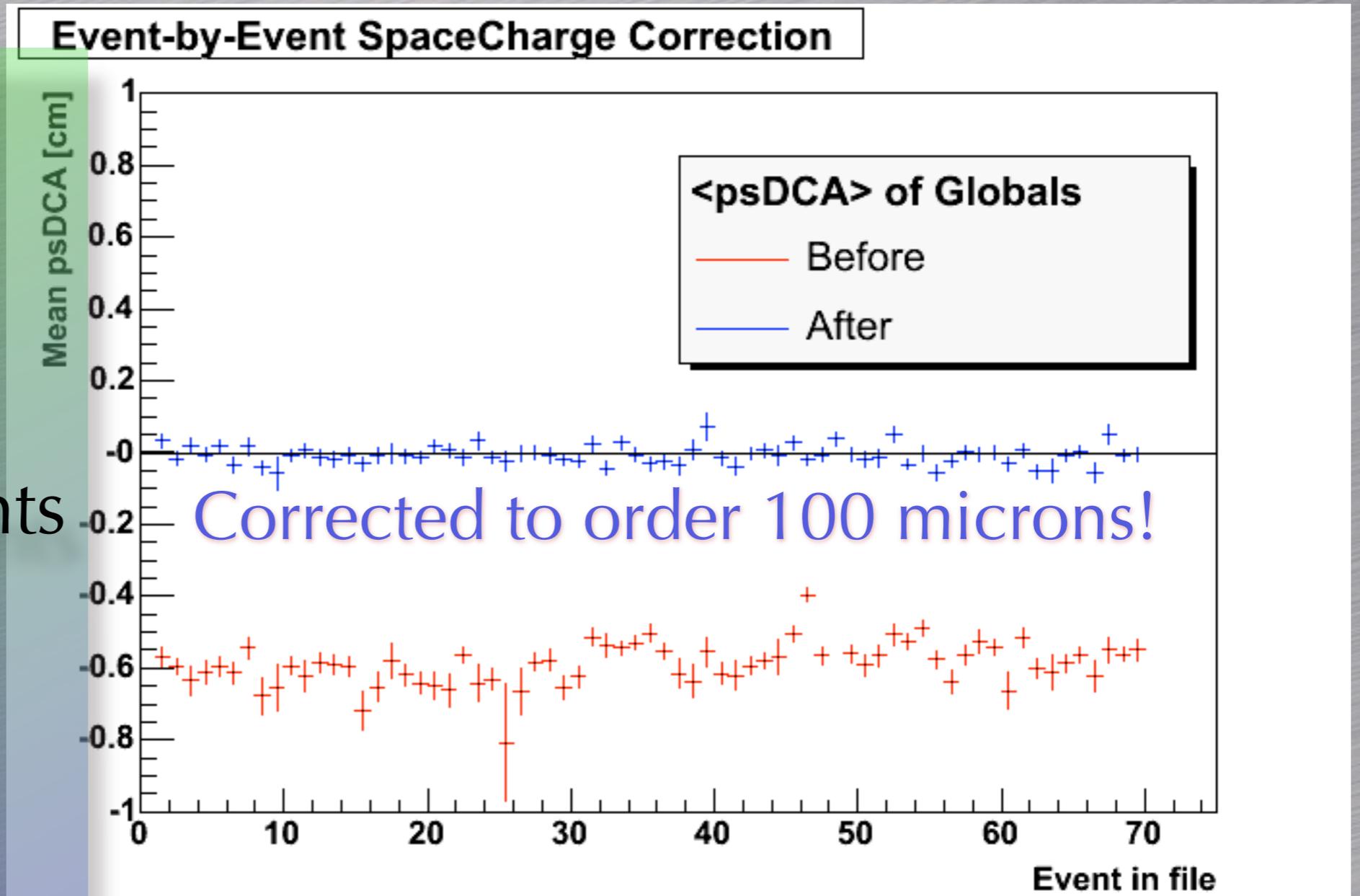
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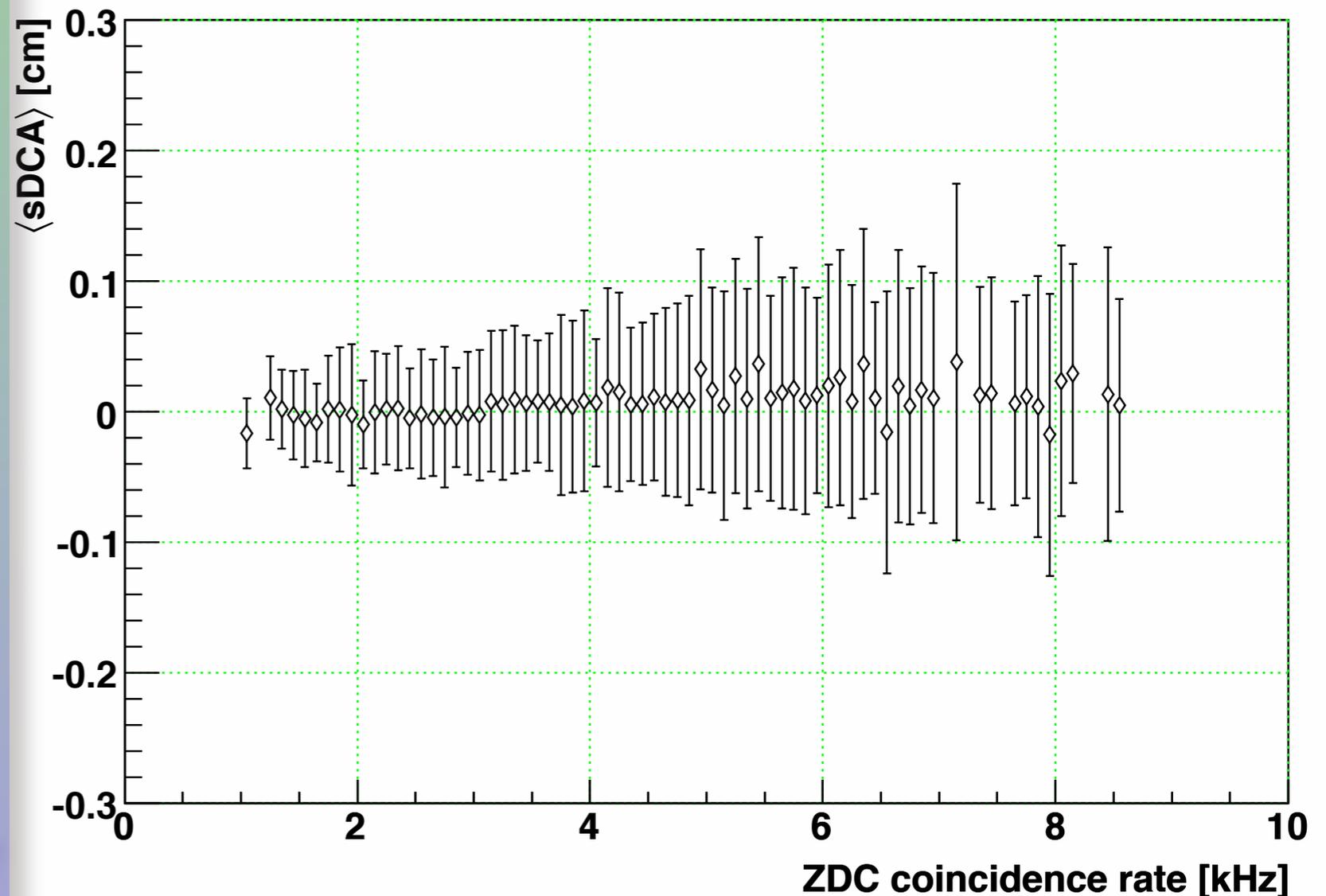


Run 5044026: productionHigh

Performance Measures: sDCA

2004 AuAu at 200 GeV, all B fields

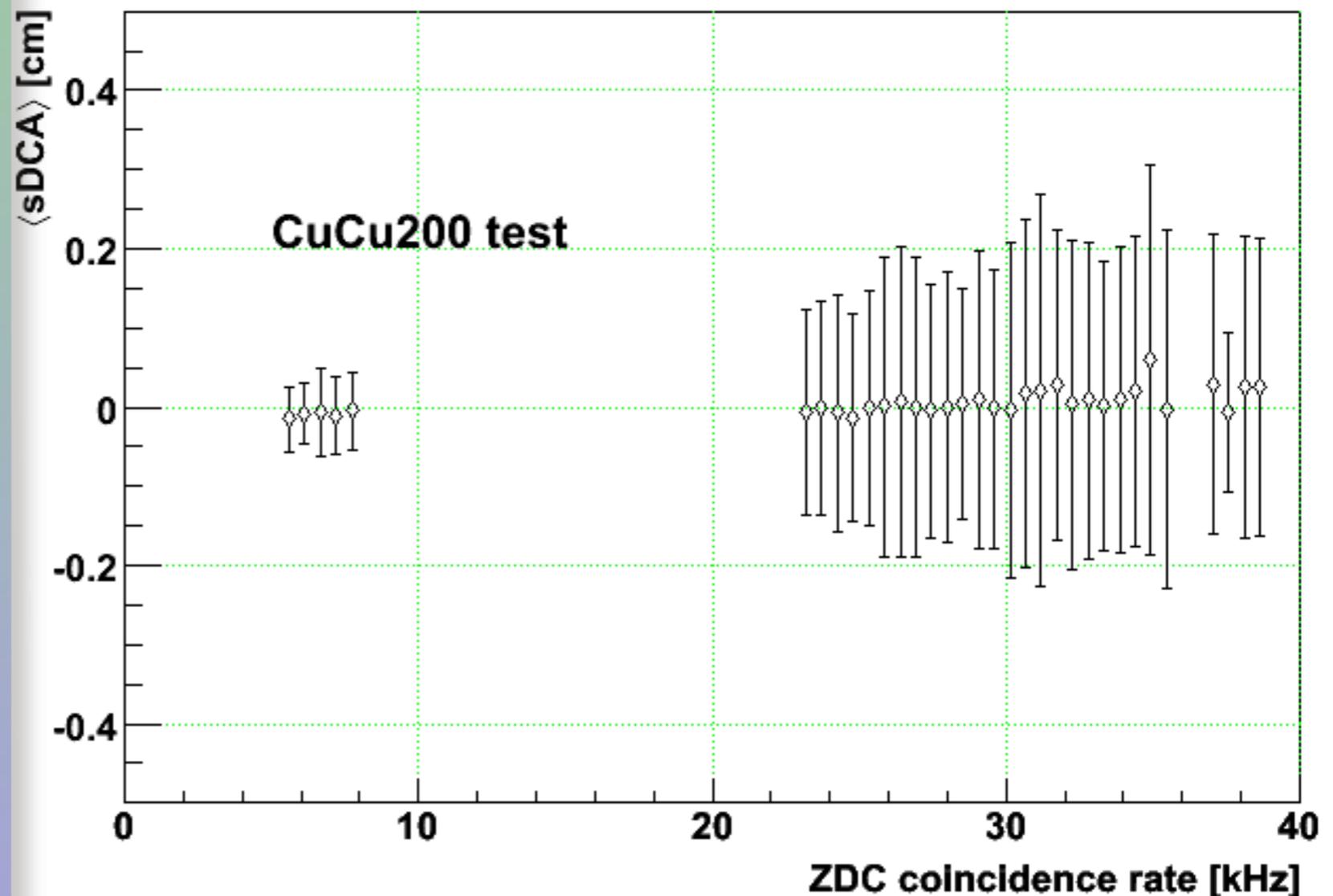
- Can't beat low luminosity, but holding steady at high luminosity:
- Spread from 5-9kHz appears roughly uniform
- No indication we can't go higher!



Performance Measures: sDCA

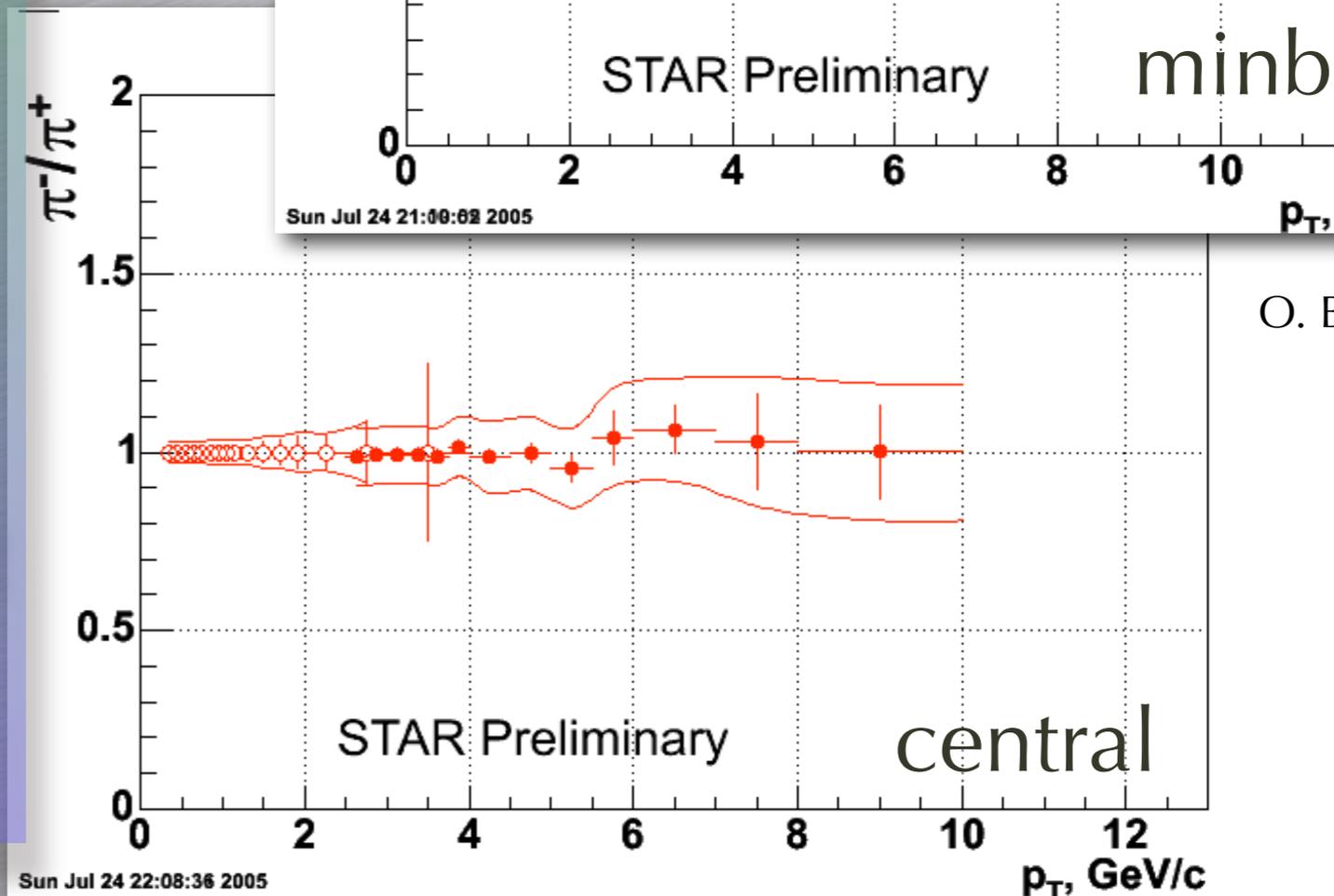
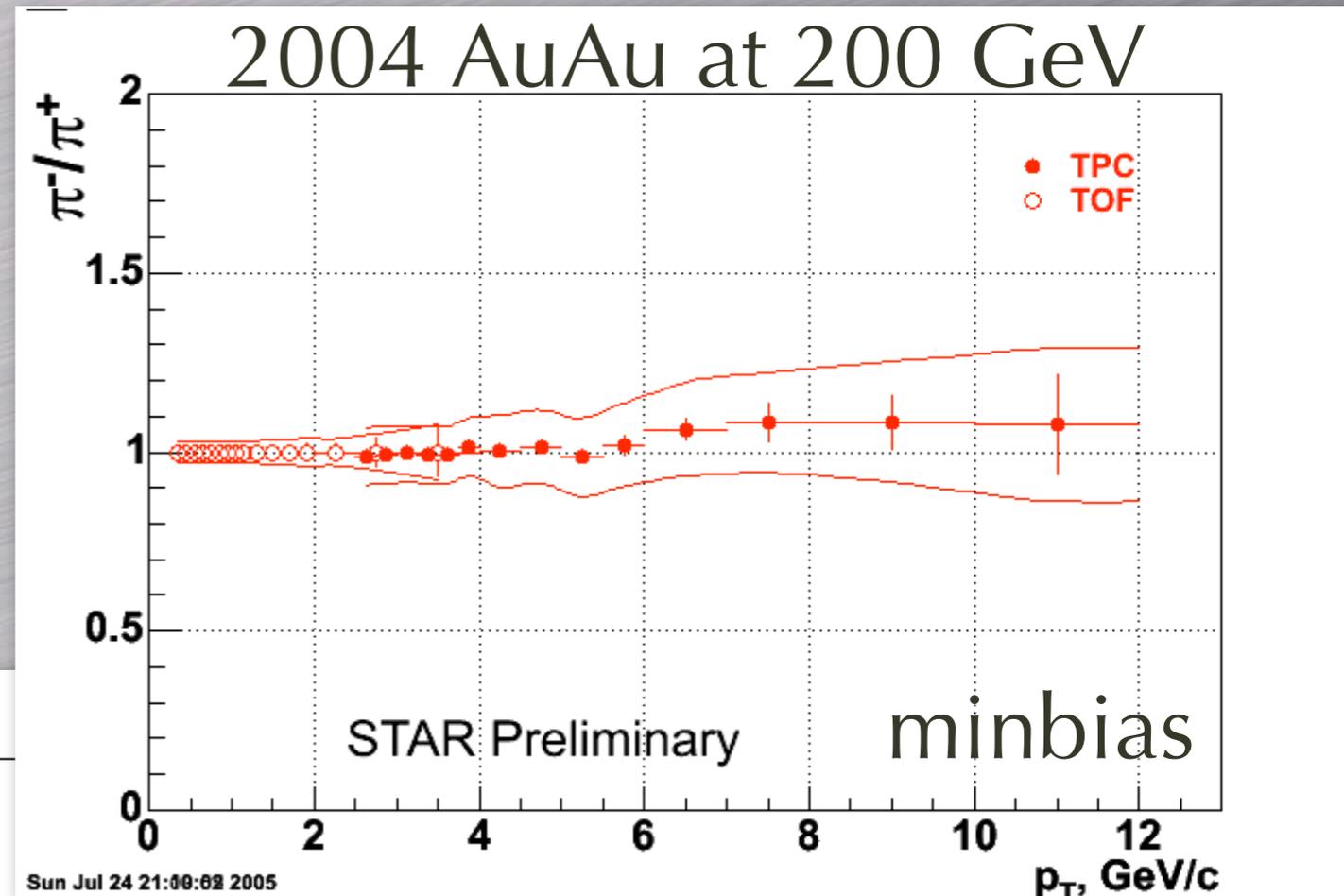
2005 CuCu at 200 GeV, full field

- Can't beat low luminosity, but holding steady at high luminosity:
- E-by-E method performs worse due to statistics per unit time



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

The Future: Up and Up

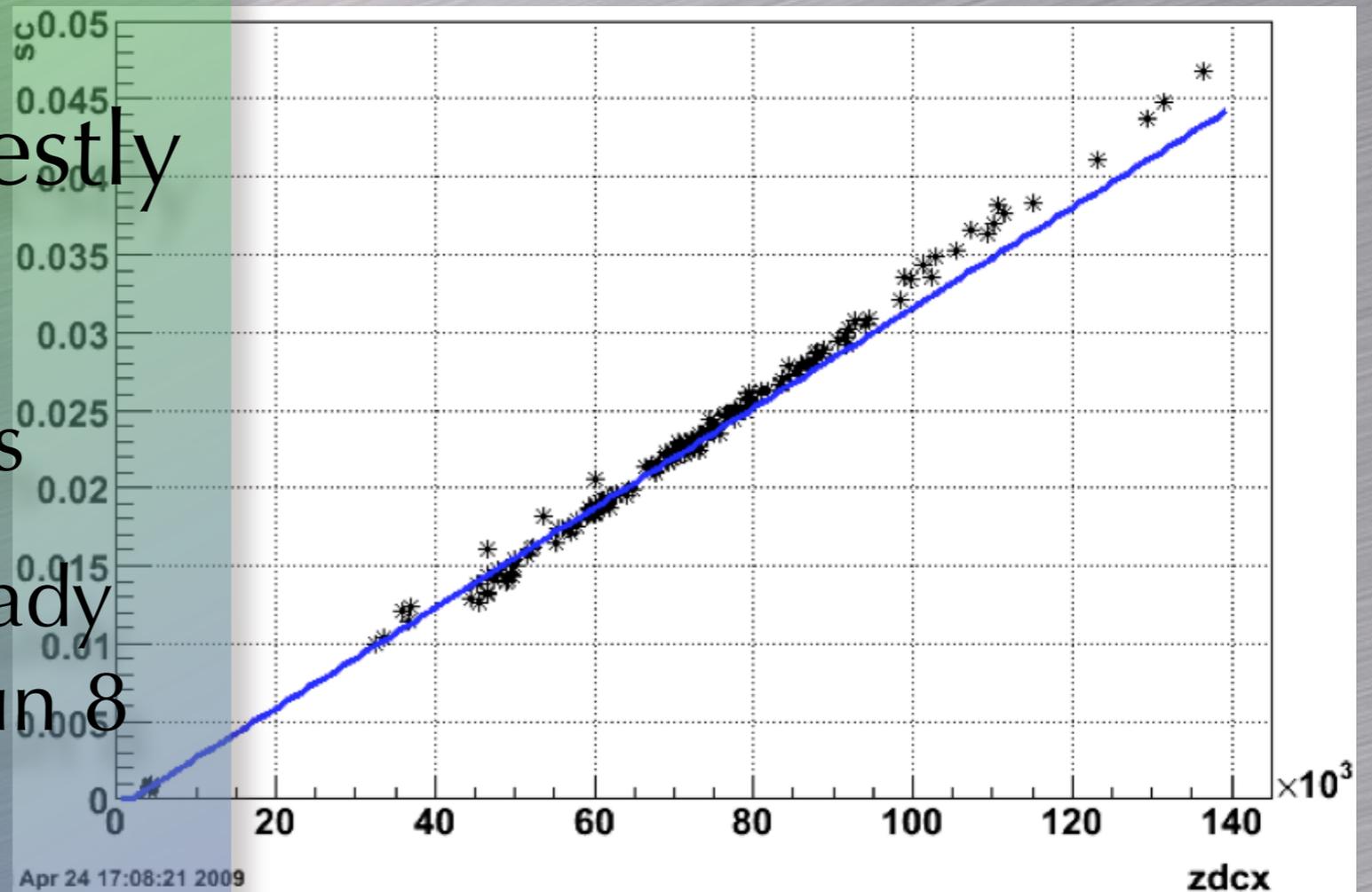
- Higher luminosities
 - Upon us now!
 - Can't even do tracking across TPC without some GridLeak correction
 - How close is our model to reality?
 - Differences will amplify with increasing luminosity.
 - How will the backgrounds change/grow/quell?
 - Not clear that the shielding has removed non-collision contributions

The Future: Up and Up (part 2)

- Higher DAQ rates
 - Increasing gating grid rates allows more return ion flux
 - We performed a test of near 1 kHz GG rate and saw no notable change in SpaceCharge-like distortions(!)
 - Higher event rate *might* benefit the E-by-E approach
- Other techniques for SpaceCharge measures
 - Fixed detectors (GMT upgrade proposal)
 - Use identified pileup hits in the data (work in progress)

pp500: getting pretty high

- Preliminary calibration modestly successful
- No major surprises
- Non-linearity already encountered in Run 8 dAu 200 GeV.
- More Discussion



Back to the table...

- Analyses requirement: don't gain another $\sqrt{2}$
- What can we afford?
 - It is NOT the increasing distortions which hurt most, it is the increasing error of our understanding!
- Room to increase the error on our luminosity-dependent corrections
 - Hard to say what will happen...

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“Overall contribution to $\delta p_t/p_t \sim 1/4\text{-}3/4\%$ * p_t for TPC-only tracks (primary vtx, silicon help)”

- A. Larger (up to 5000) without compensating resistor.
- B. Known to be ~ 400 microns in a region of the TPC not used for physics.
- C. Luminosity dependent
- D. Dataset dependent

Our efforts are worthwhile!

- STAR TPC has major distortions with which we have been coping for years now (Physics produced!)
- Preliminary efforts appear successful with pp500, but we expect even higher luminosities and things could get worse for us
- ...but we have some margin for further error; we can live with somewhat worse than we have

