TPC Distortions & Calibrations

estimated magnitudes and our ability to correct

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Outline

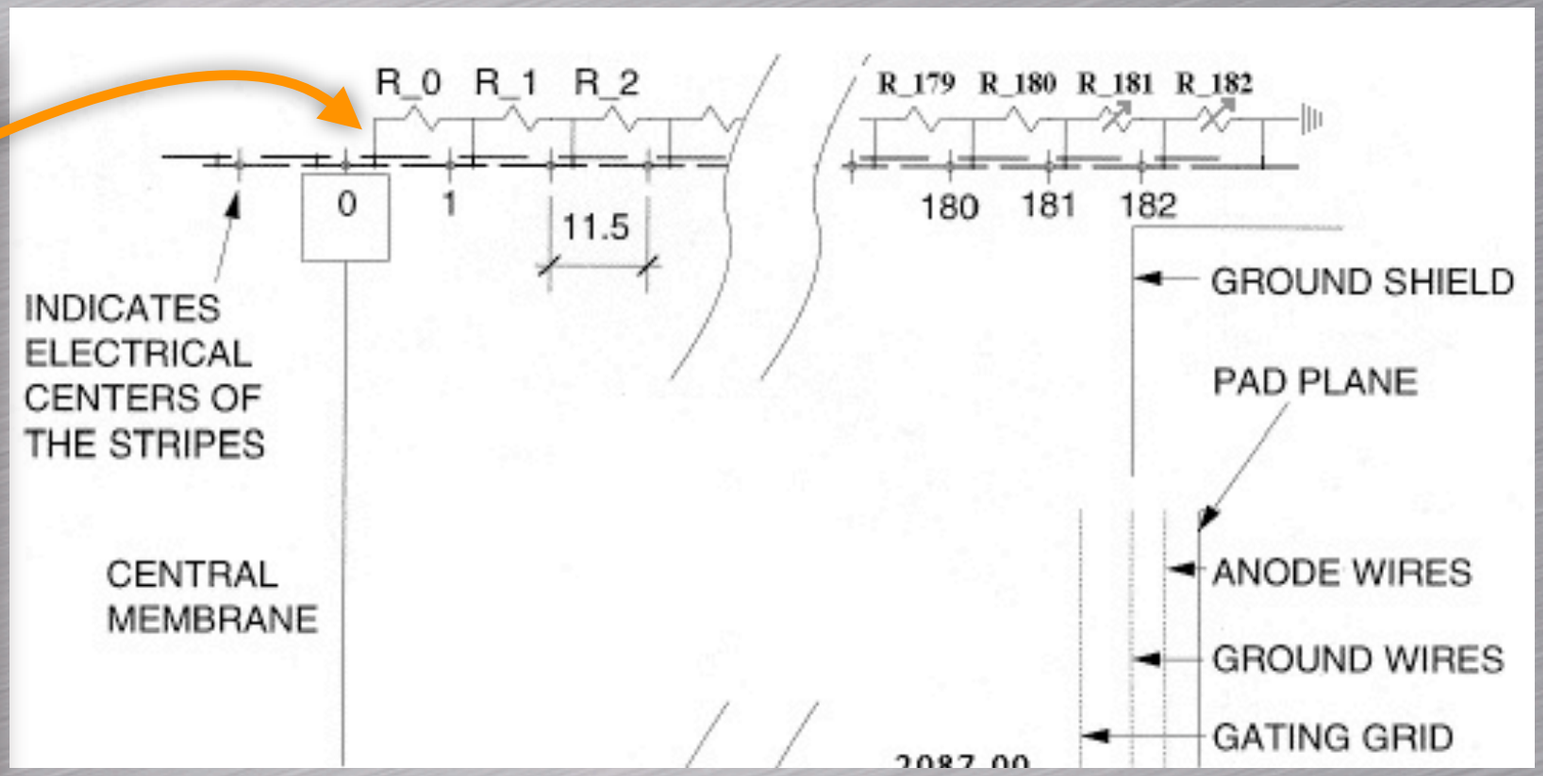
- Overview of the distortions
- Goals / physics requirements
- Corrections (calibrations)
  - Techniques
  - High luminosity challenges
- Past results
- Future prospects
- Summary

Distortions

- EM fields: non-uniformities are a reality
  - B field: very small static deviations, mapped, done
  - E field: surface & volume issues, static & volatile
    - The big three: (1) shorted field cage rings, (2) primary space charge, (3) gated grid ion leakage
- Electrostatics is known physics
  - Requirements: (1) model of the distortion, (2) measures/rulers (e.g. surveys, residuals) which keep pace with volatility

Field Cage Electrical Shorts

- Potential stepped from cathode to anode
- "Stripes" express potential inside the chamber
- Contaminants (dirt) can short the stripes

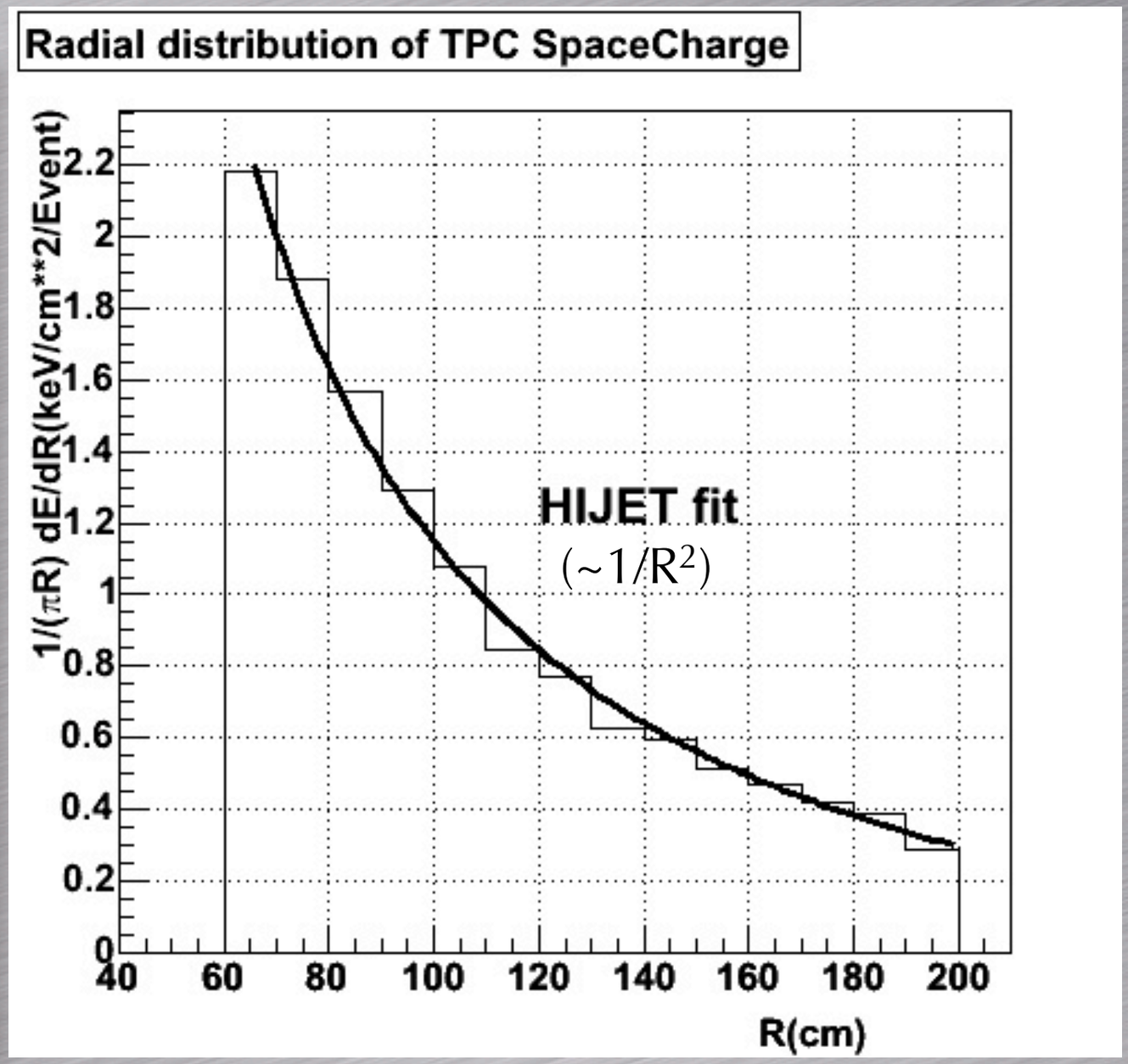


Field Cage Electrical Shorts

- Shorts have been a problem for several years
  - Some fixed
  - Some not understood (e.g. partial resistor)
- Worst threat comes from volatile shorting
  - Not a problem presently
- Very unlikely a high luminosity issue
  - Unknown whether its an aging issue

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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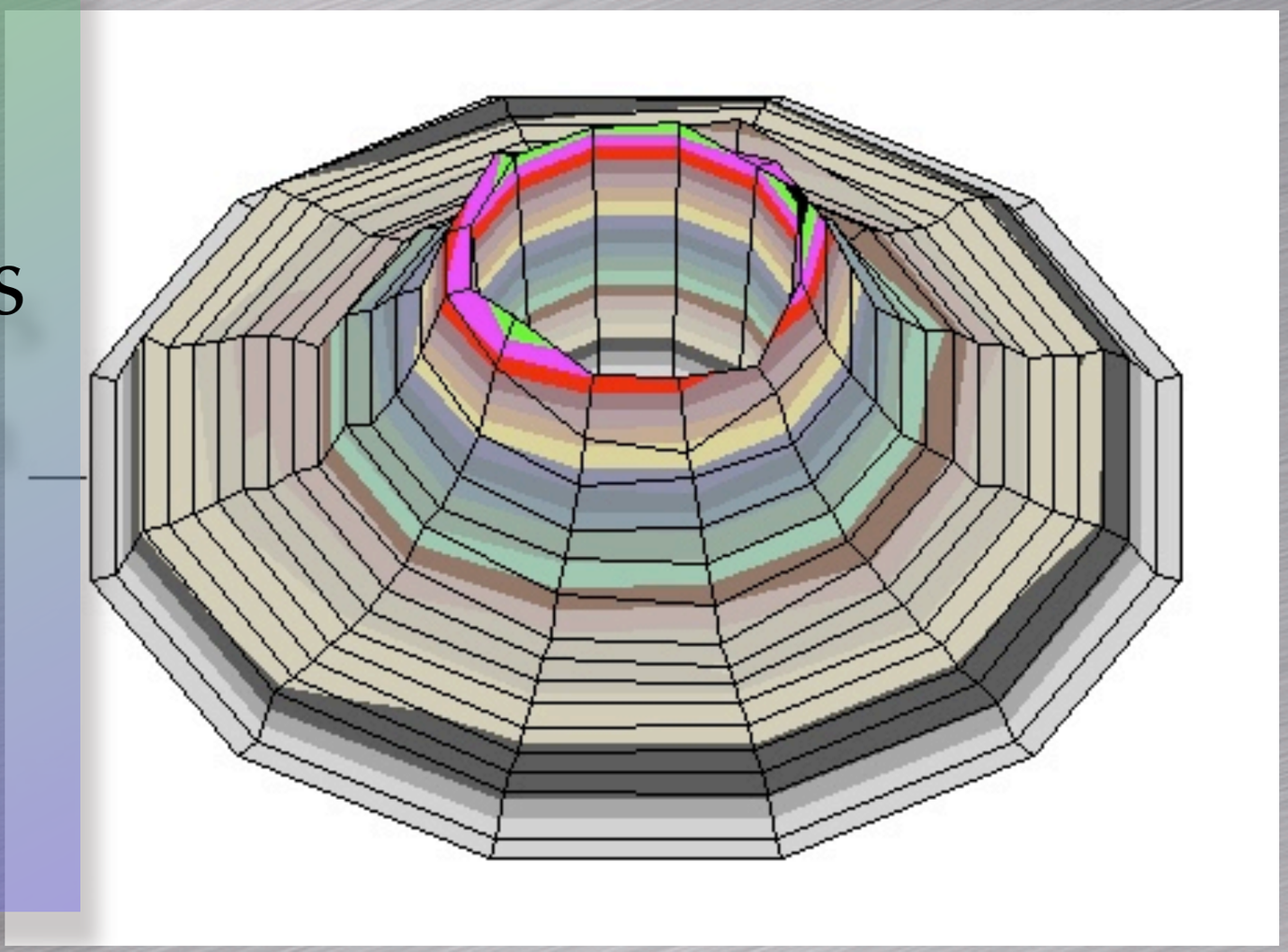
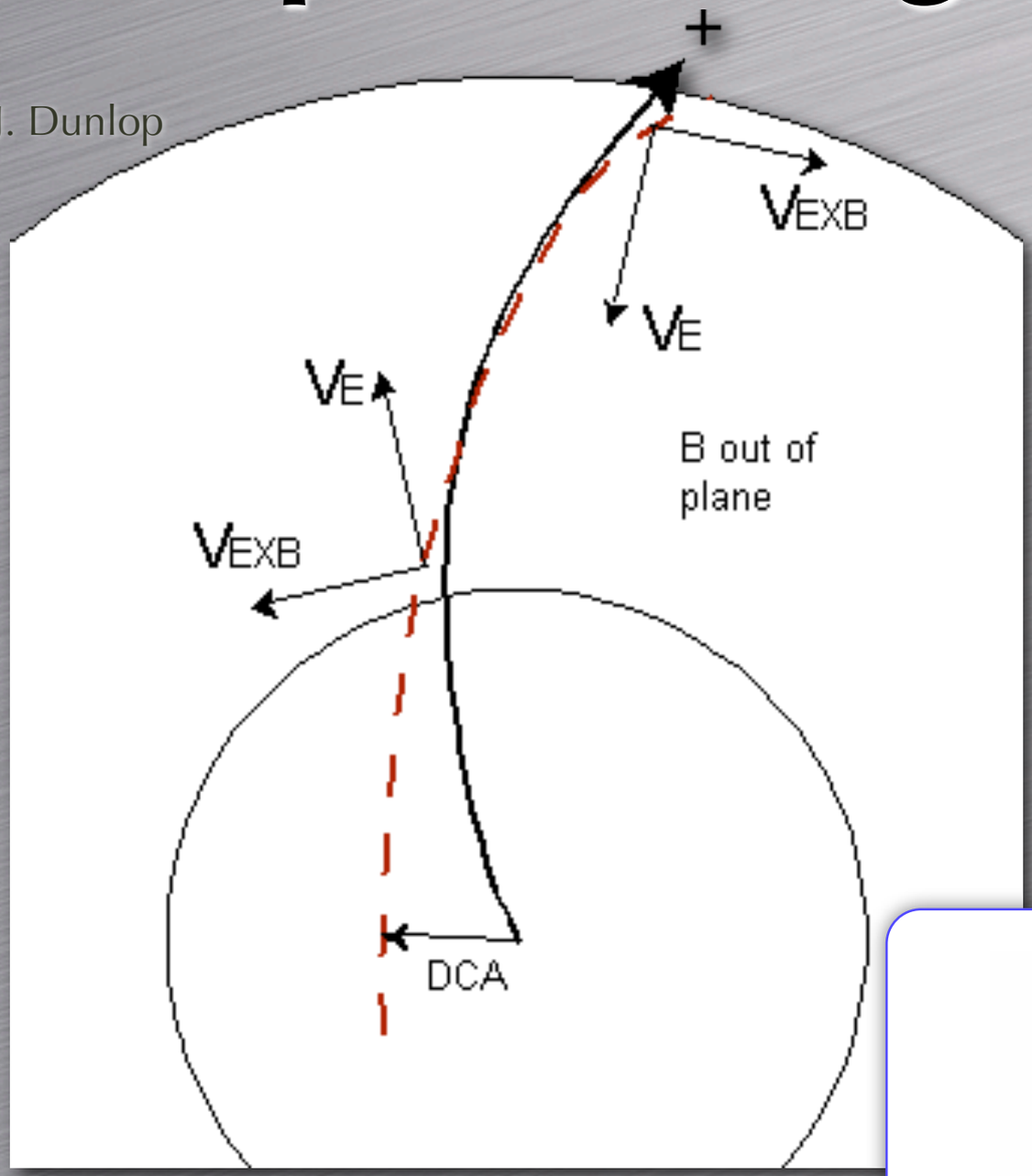


March 1, 2004 data

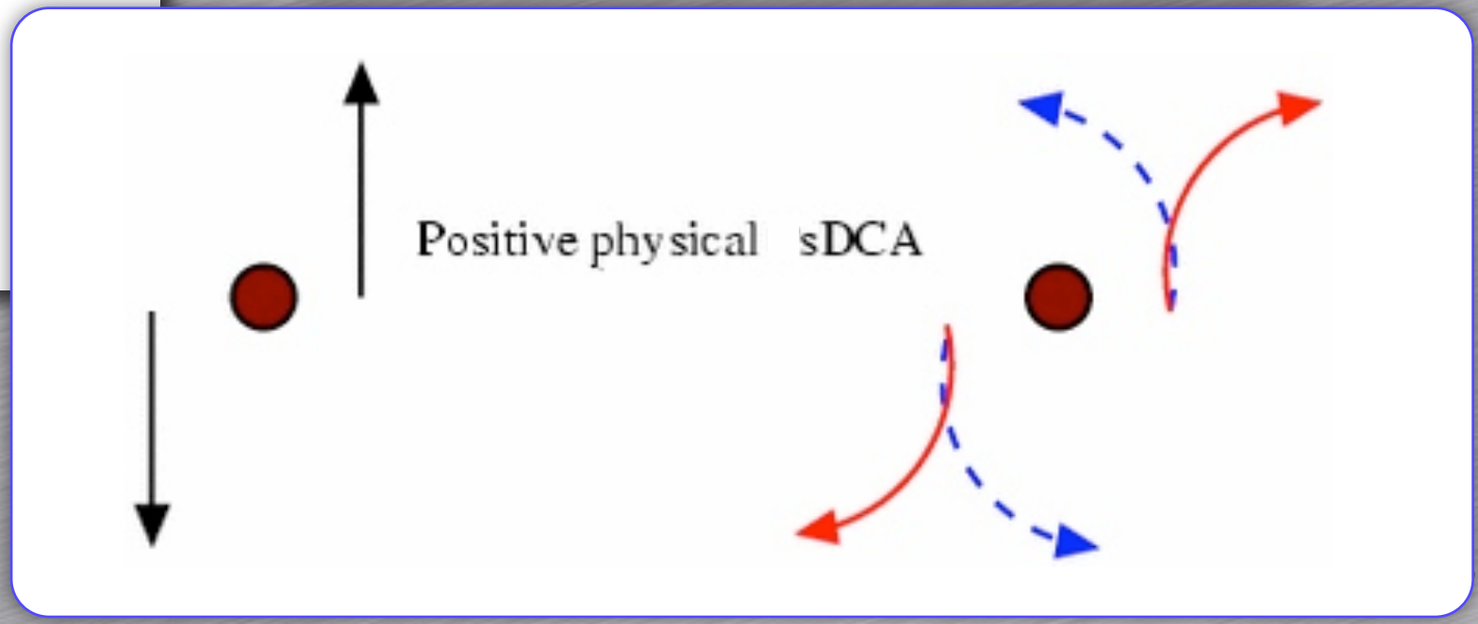
SpaceCharge effect on sDCA



J. Dunlop

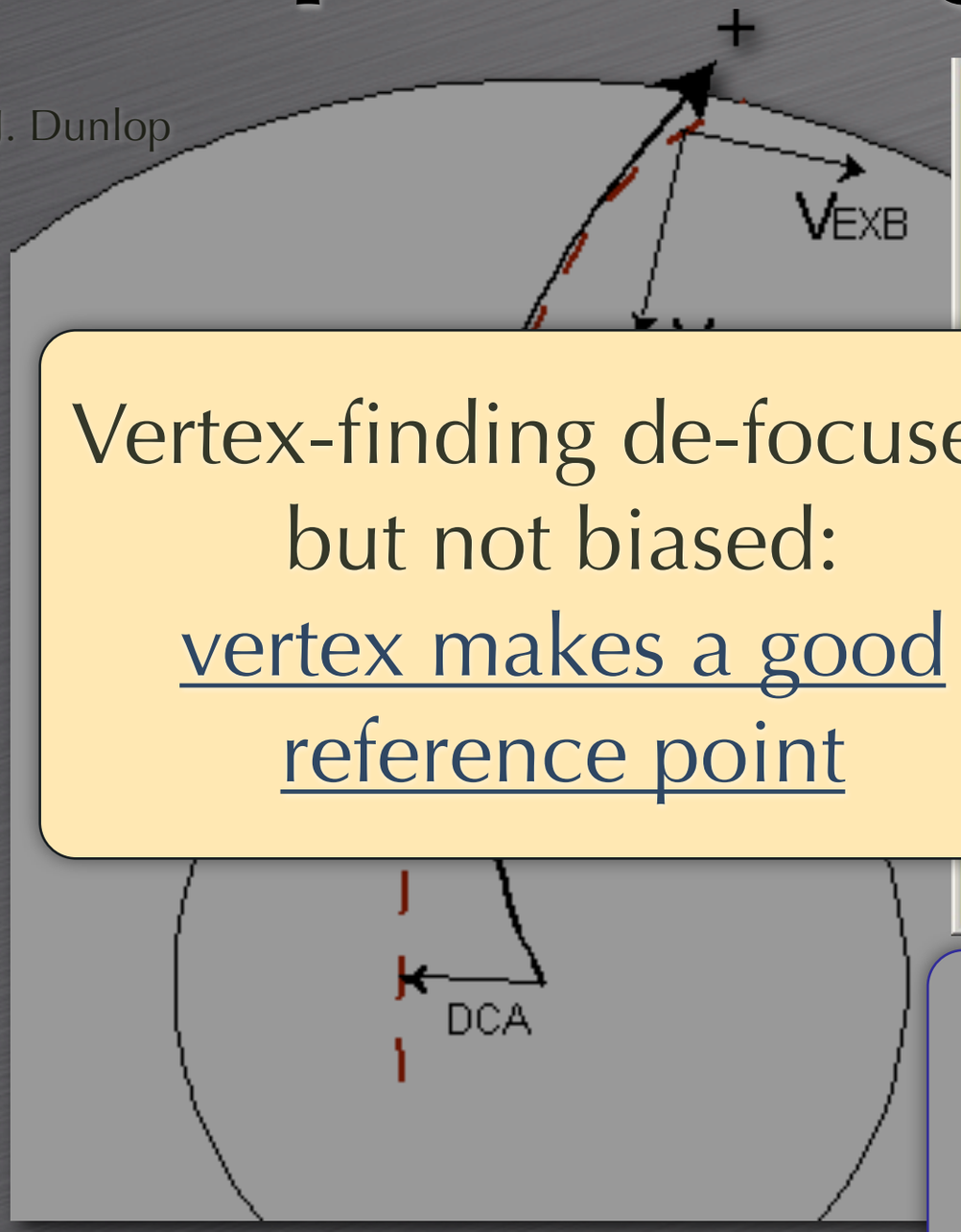
- All tracks go the same direction (pos. or neg.)
- Track charge independence
- Field dependence

sDCA = signed distance of closest approach

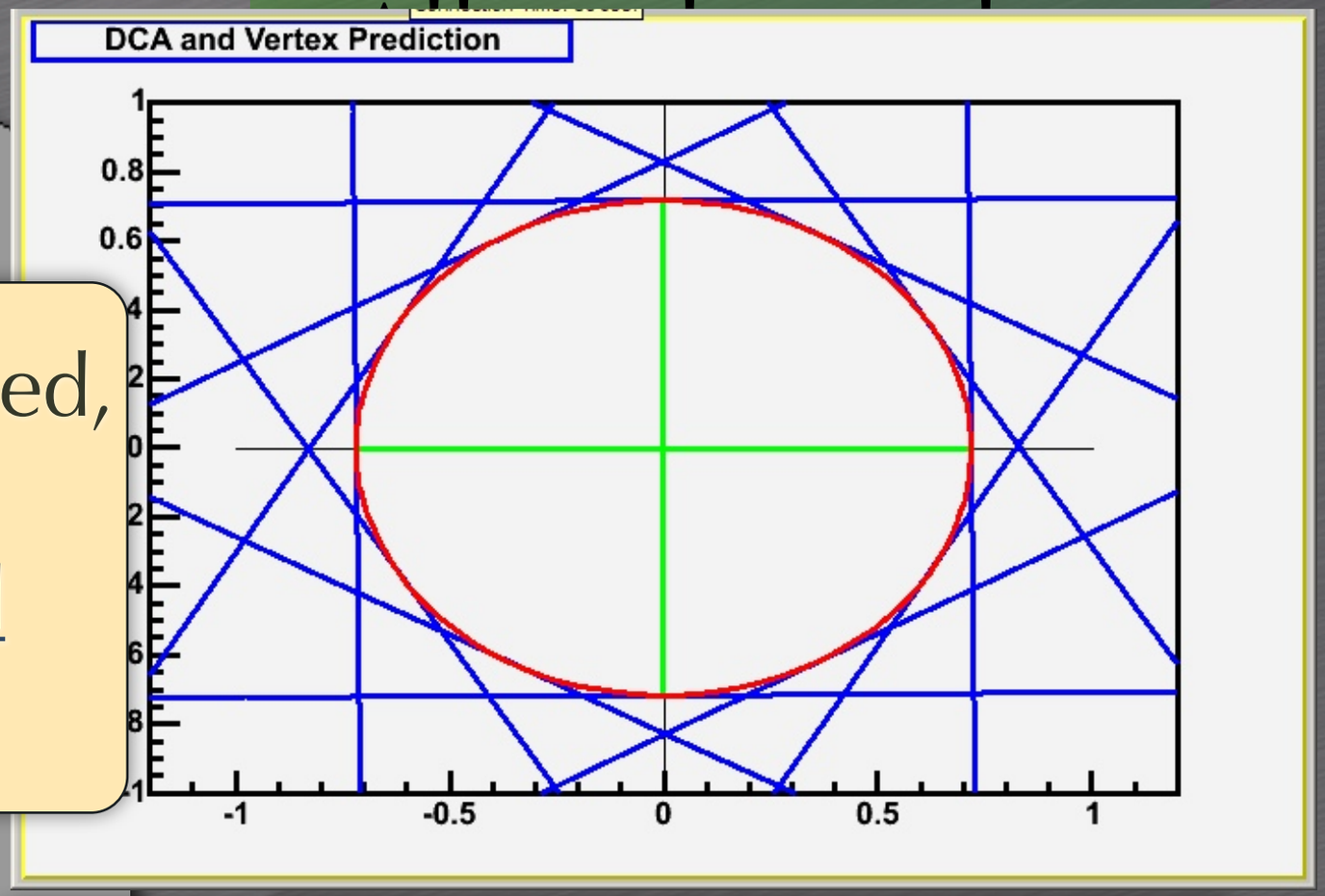


SpaceCharge effect on sDCA

J. Dunlop



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



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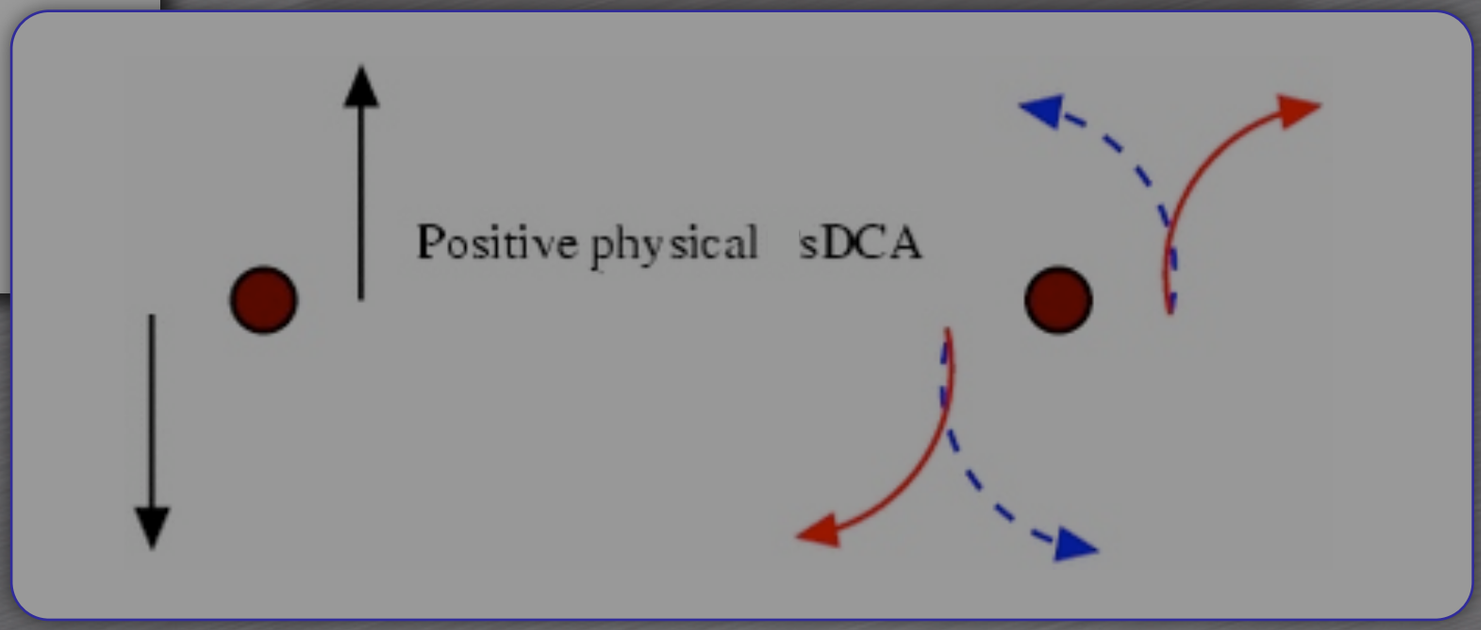
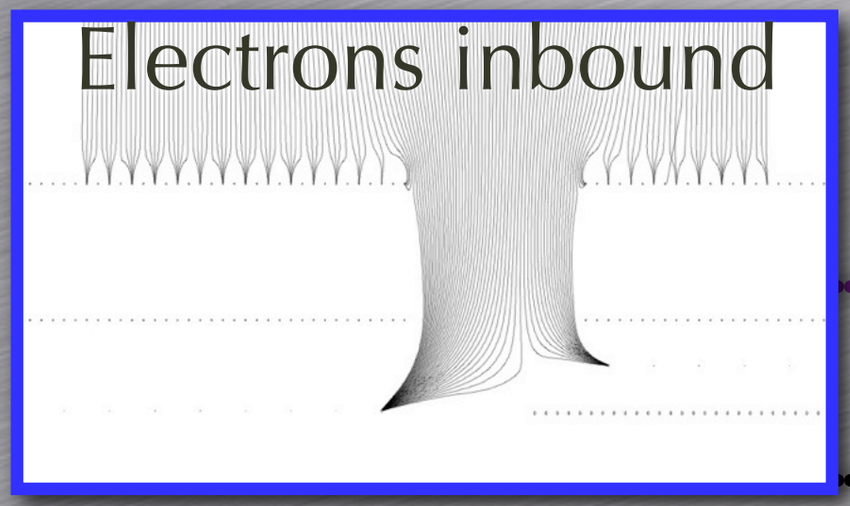
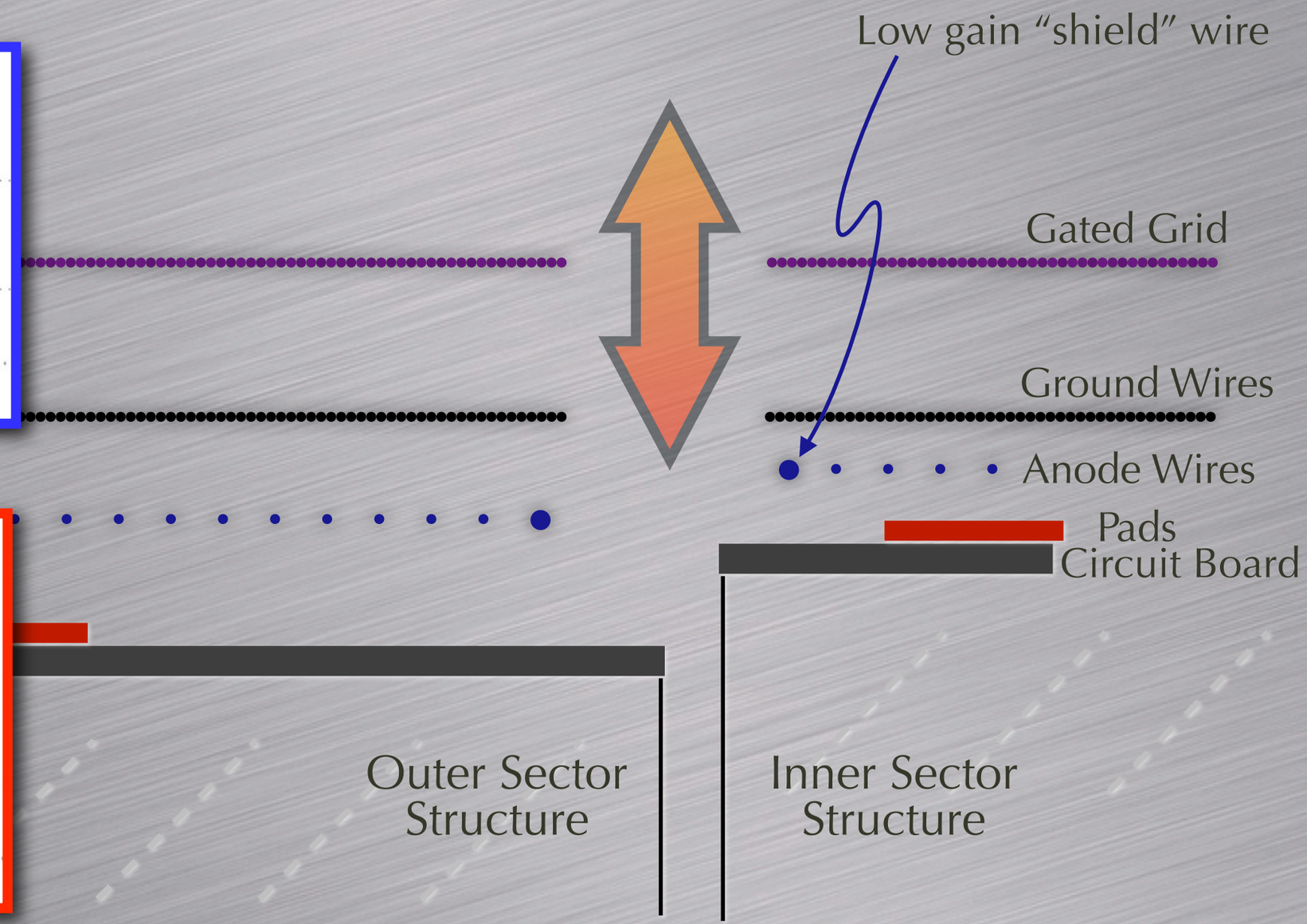


TPC GridLeak distortions

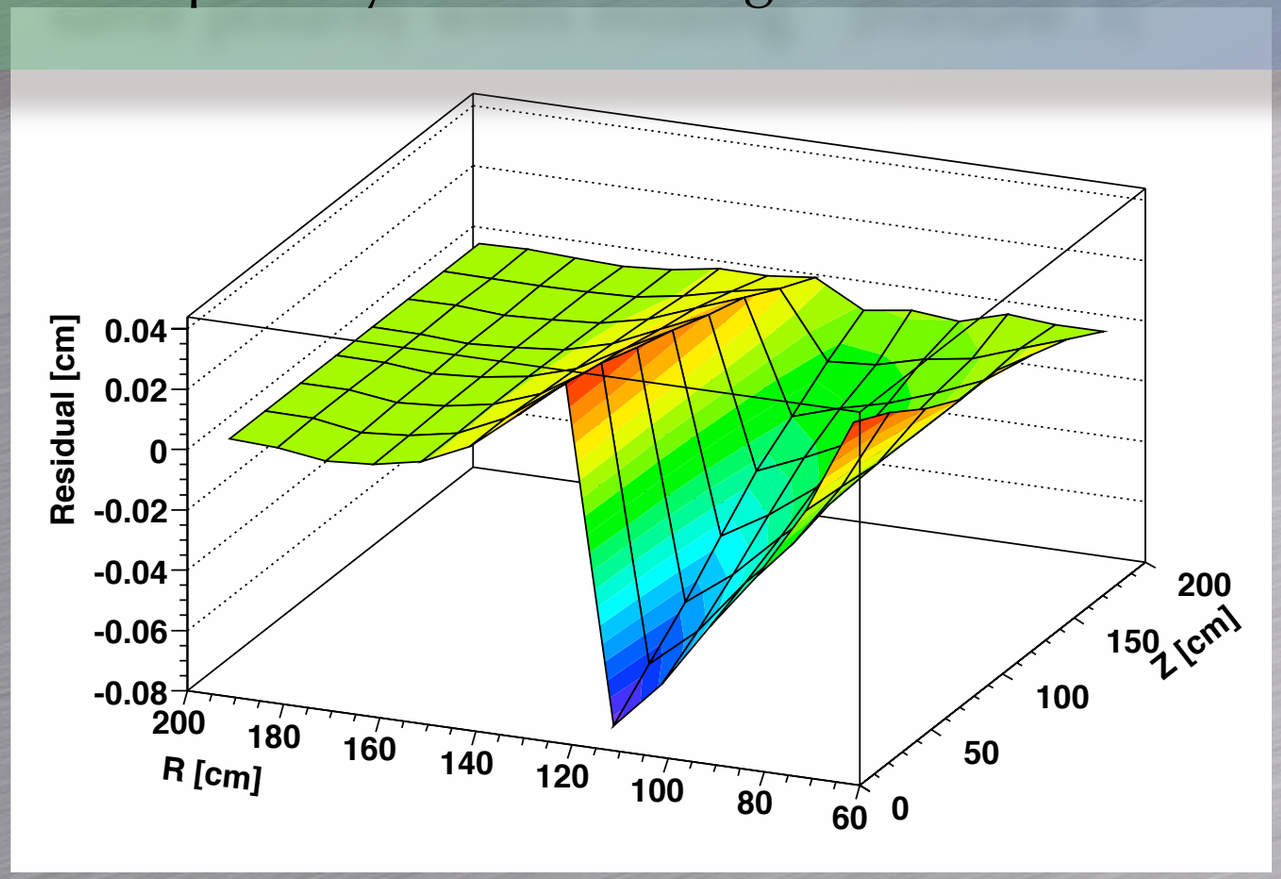
- Electrons leak in, ions leak out.

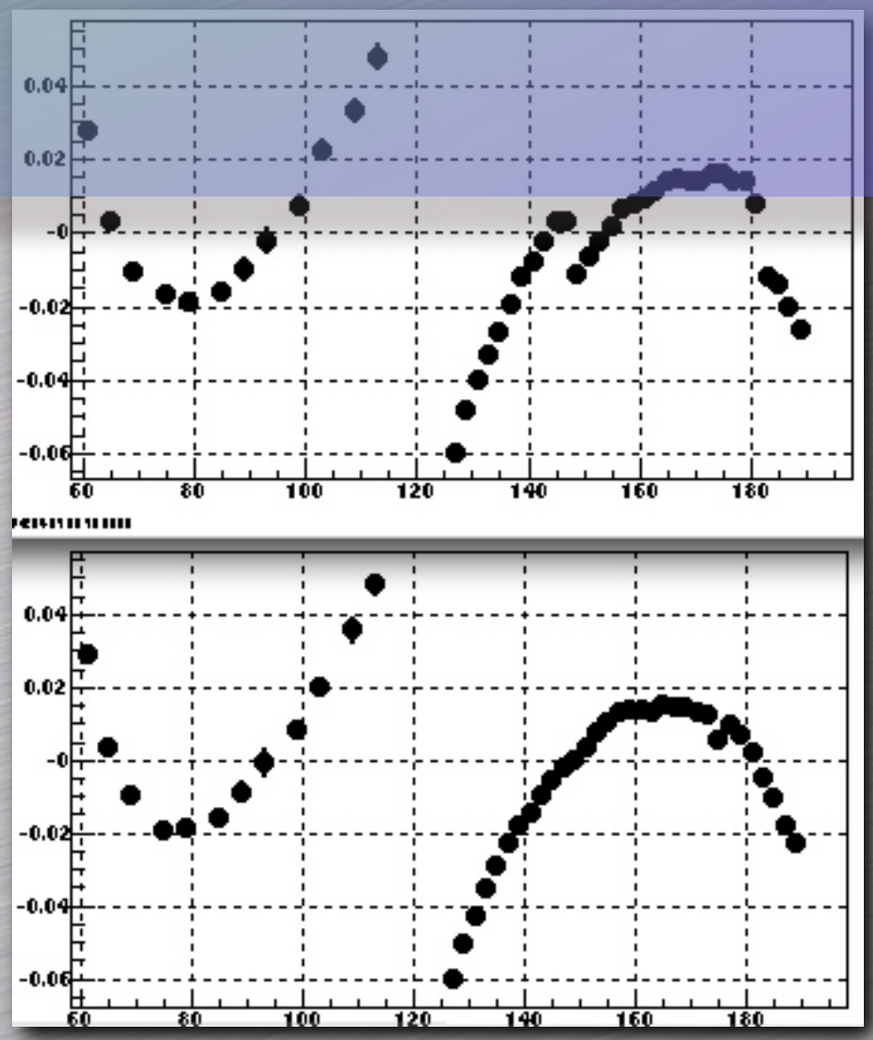




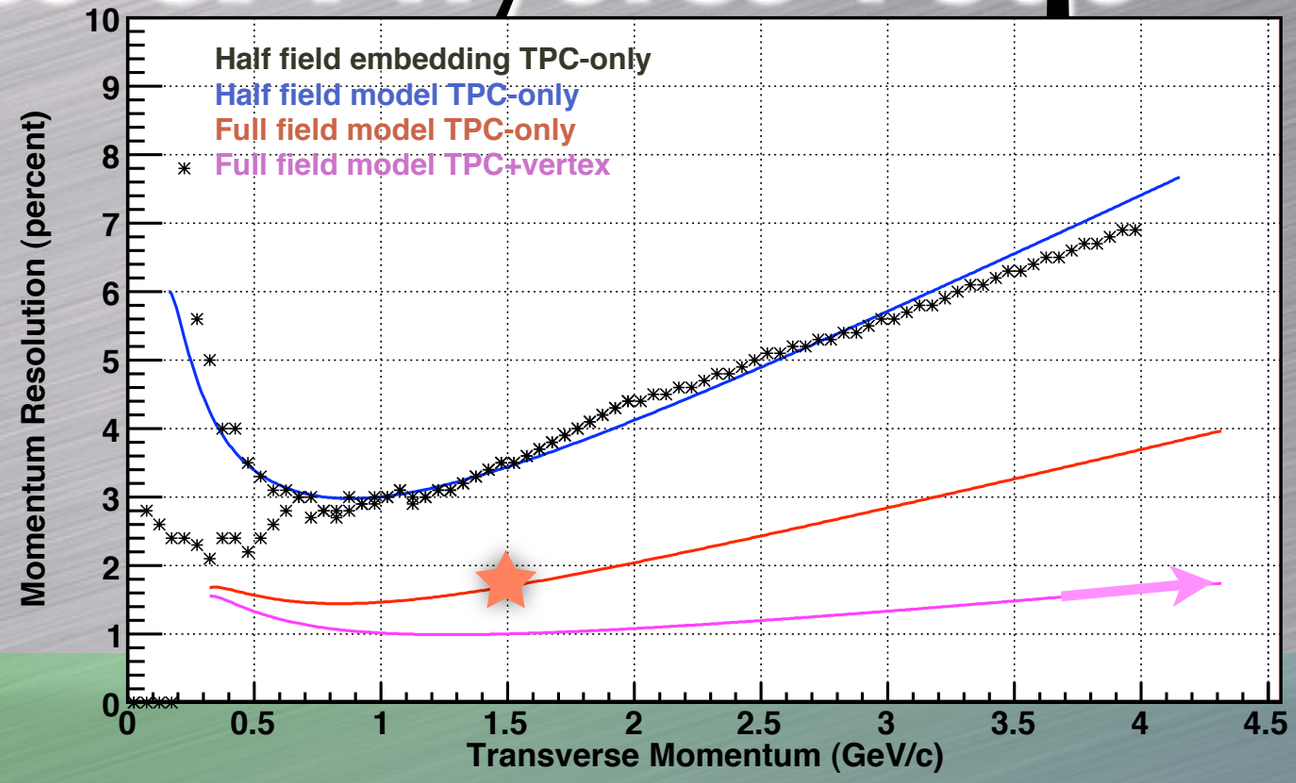
TPC GridLeak distortions

- Ratio of leakage charge to space charge approximately constant (over several years & collision species!) [Fortune 1]
- Smaller leaks have been spotted (more with age?)
  - Consistent with single Gating Grid wires at *floating* voltage
  - Reversing polarity of GG wires closes the leak [Fortune 2]
  - Sectors with more than one have had the same polarity wires missing [Fortune 3]





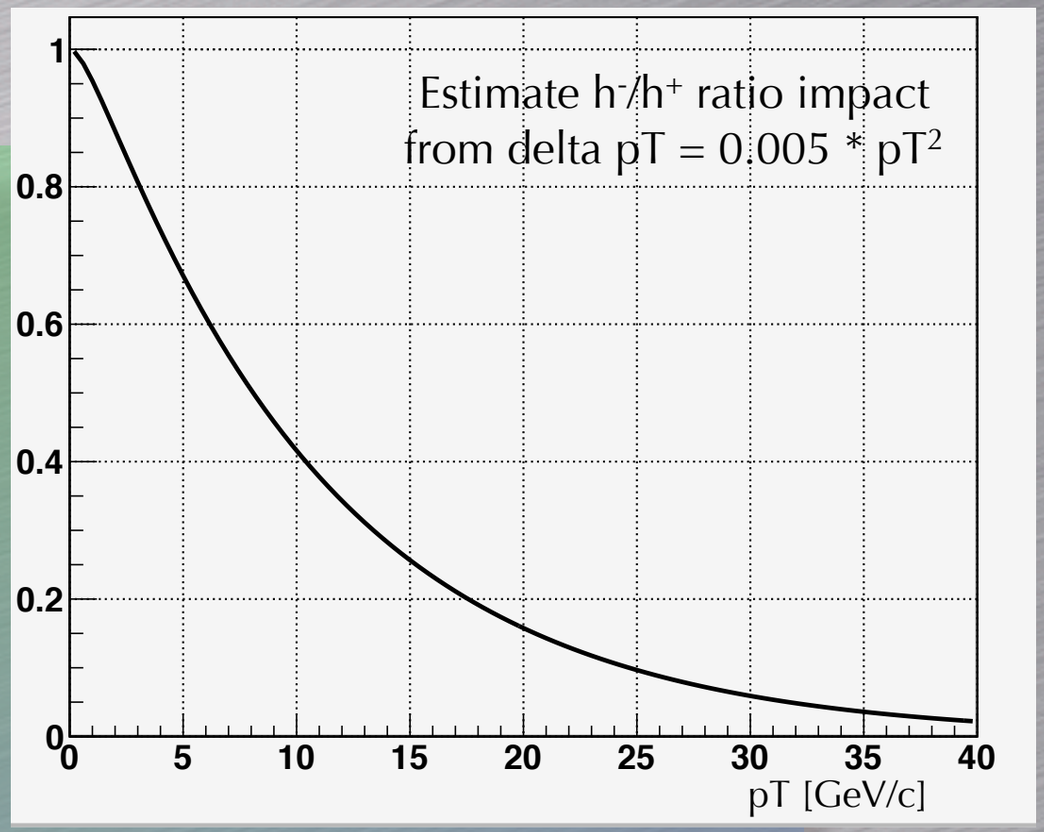
Design specs & Physics reqs



- Momentum Resolution:
  - Soft physics (TPC-only): $\Delta P/P$ @ 1.5 GeV/c $\leq$ 2%
  - Hard physics (TPC+vertex): $\Delta P/P$ @ 10 GeV/c $\leq$ 5%
- Implied sagitta & hit resolutions:
  - CDR (Not-final design): Δ(sagitta) $\leq$ 250 μm, $\Delta(\text{hit})_{r\phi} \leq$ 570 μm
  - Physics needs
    - Δ(sagitta) $\leq$ 400 [300] μm (soft [hard]), $\Delta(\text{hit})_{r\phi} \leq$ 700 μm

Design specs & Physics reqs

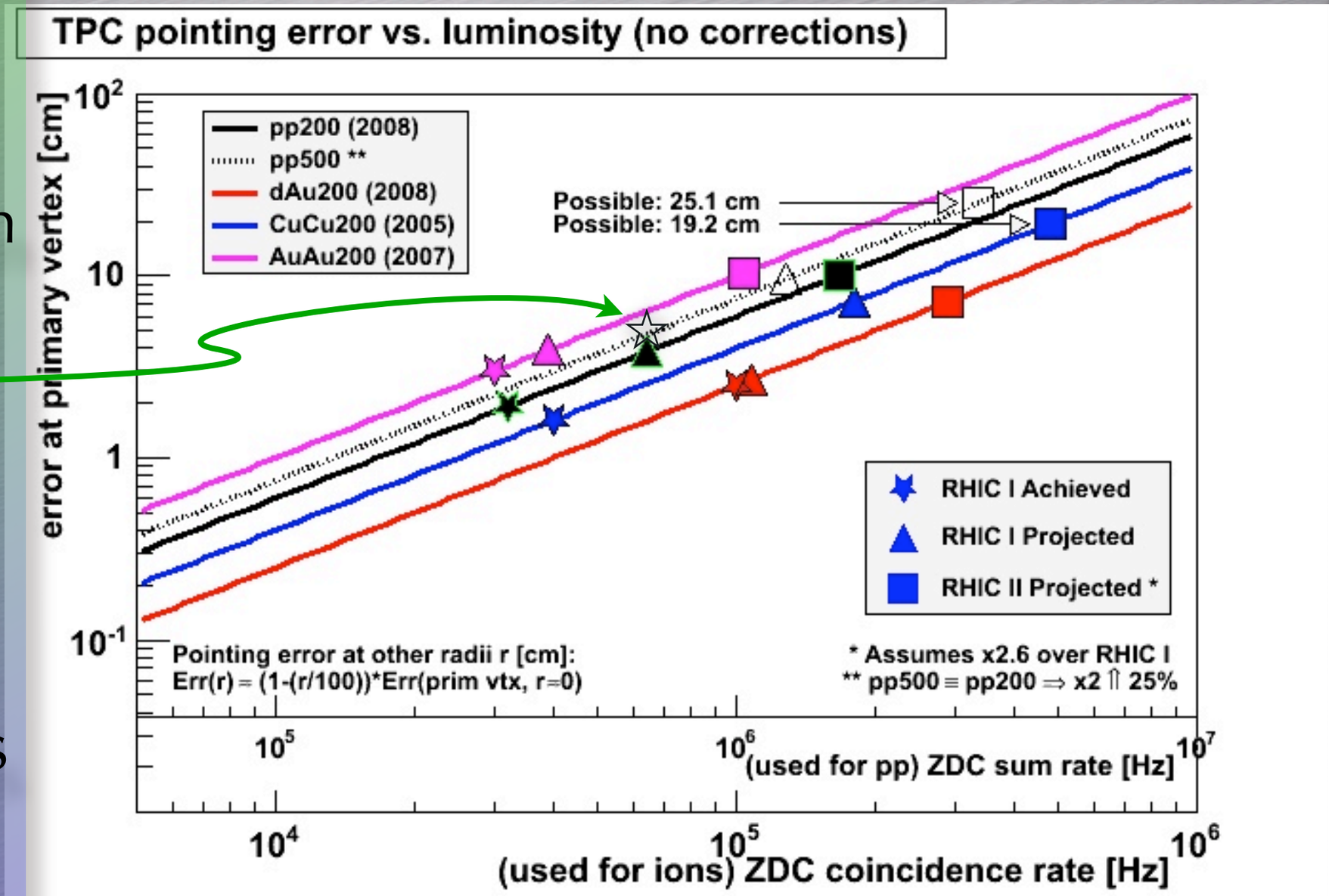
- Momentum Biases:
  - A big concern for hard physics
    - Biases tend to grow as pT^2
    - Biases tend to be opposite for -/+



- Pointing Resolution & Bias:
  - CDR: topological strange decays w/ Si inner tracking
  - Physics needs:
    - ~5 mm pointing at vertex for strangeness w/o Si
    - ~1 mm pointing at Si to enable heavy flavor topology
    - Biases directly degrade resolution

Projected pointing errors

- pp500 is worst!
  - Run 9 has been a valuable test (over 4cm!)
- Intermediate ions (CuCu) perhaps worse than heavy ions (AuAu, UU?)



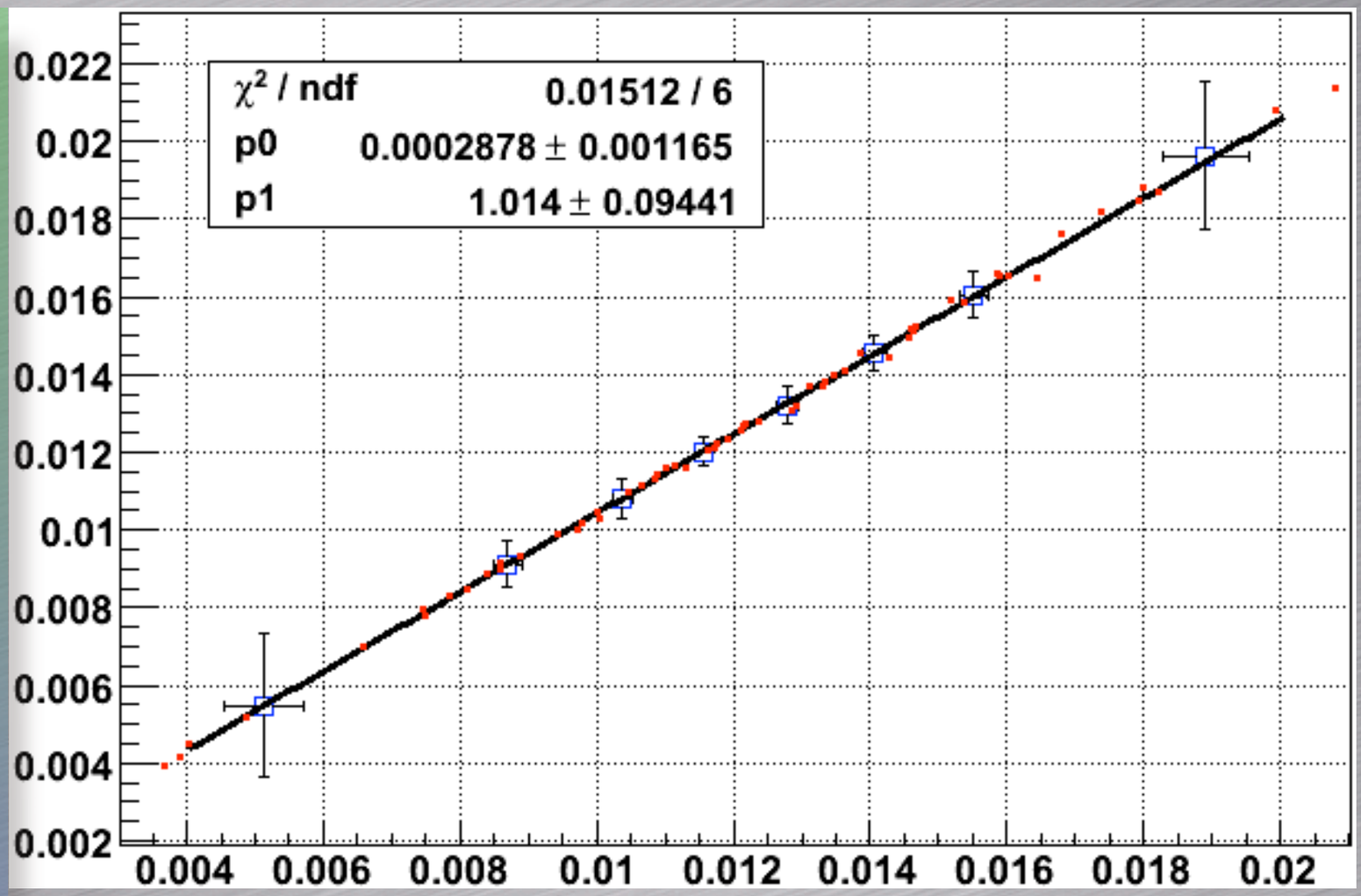
More info at: http://drupal.star.bnl.gov/STAR/subsys/tpc/spacecharge-studies/luminosityProjections

Calibration first steps

- Non-volatile calibrations must be completed first (e.g. internal alignment, and w.r.t. B field)
  - Necessitates low luminosity data
    - RHIC did not deliver this during pp500 this year.....the future?
- Field cage currents measure electrical shorts
- sDCA and residuals tell us about the SpaceCharge and GridLeak ionization (via model)
  - Systematics must be understood (e.g. pile-up)

Ionization: scalers

- Ionization is linear with scaler measures of luminosity
- Occasional outliers
- Now using 1-second scaler averages, and multiple scalers

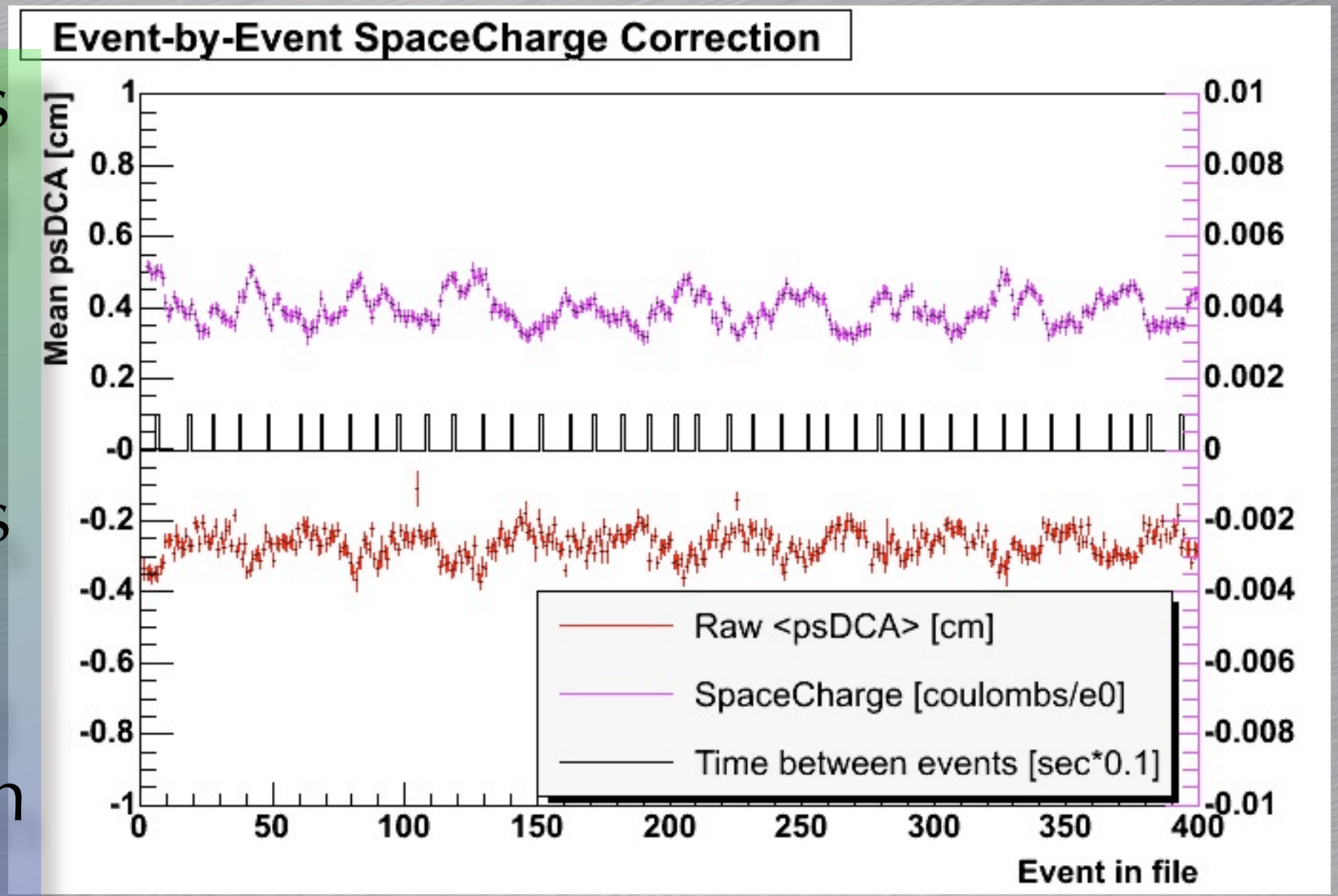


Luminosity = function(scalers)

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

On-the-fly calibration successes

- Fluctuations on ~second time scale
- High-rate DAQ allows calibration on ~second time scale in A+A data



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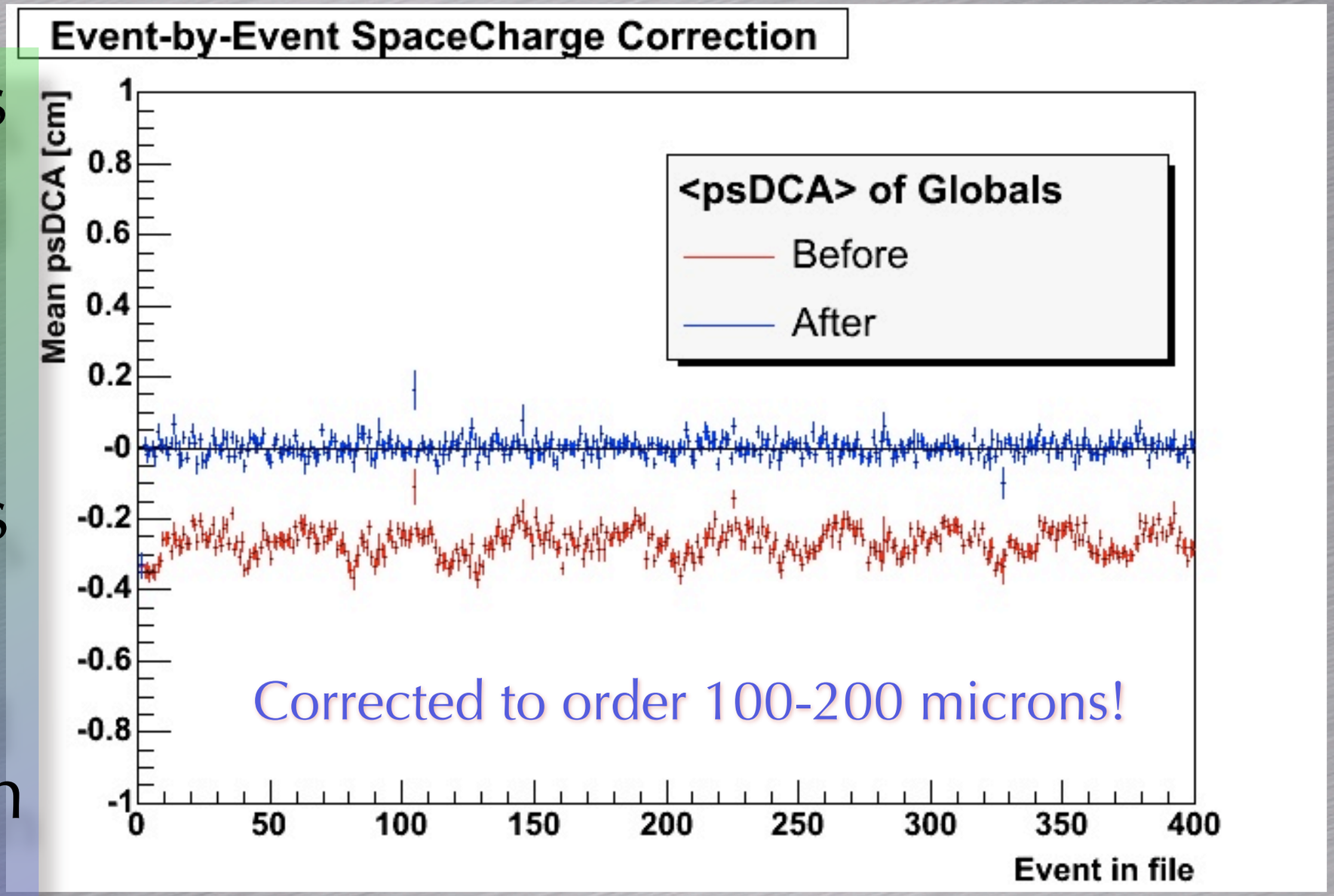


Distortion Corrections (pre-Run9)

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 $\delta p_t/p_t \sim {}^1/_4\text{-}{}^3/_4\% * p_t$ for TPC-only tracks (primary vtx, silicon help)

A. Larger (up to 5000) without compensating resistor.
B. Worse for continuously varying short.
C. Luminosity dependent
D. Dataset dependent

CDR design was ~1%*pt

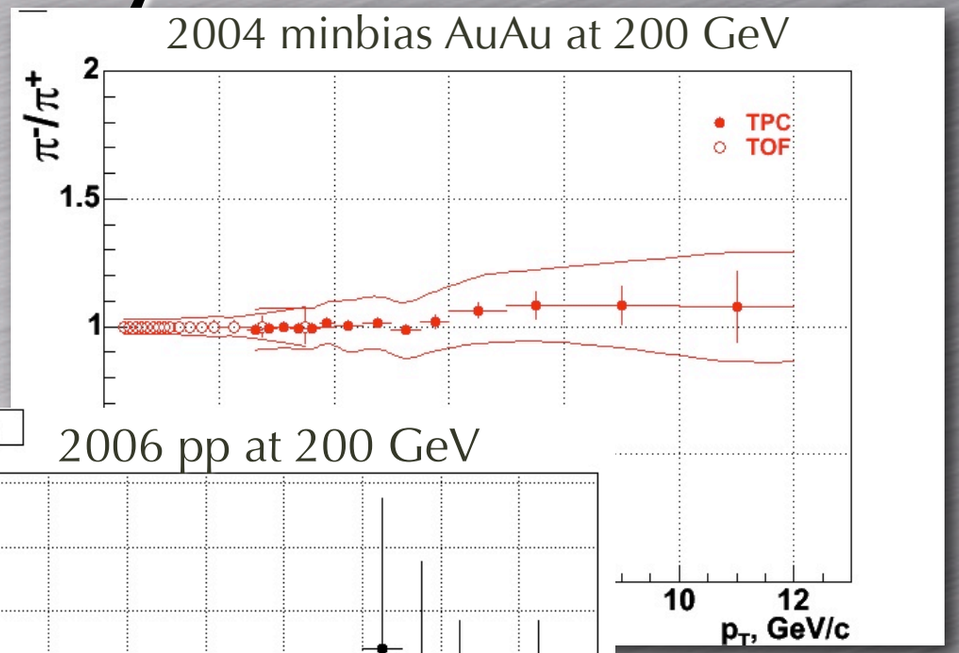
Performance: specs

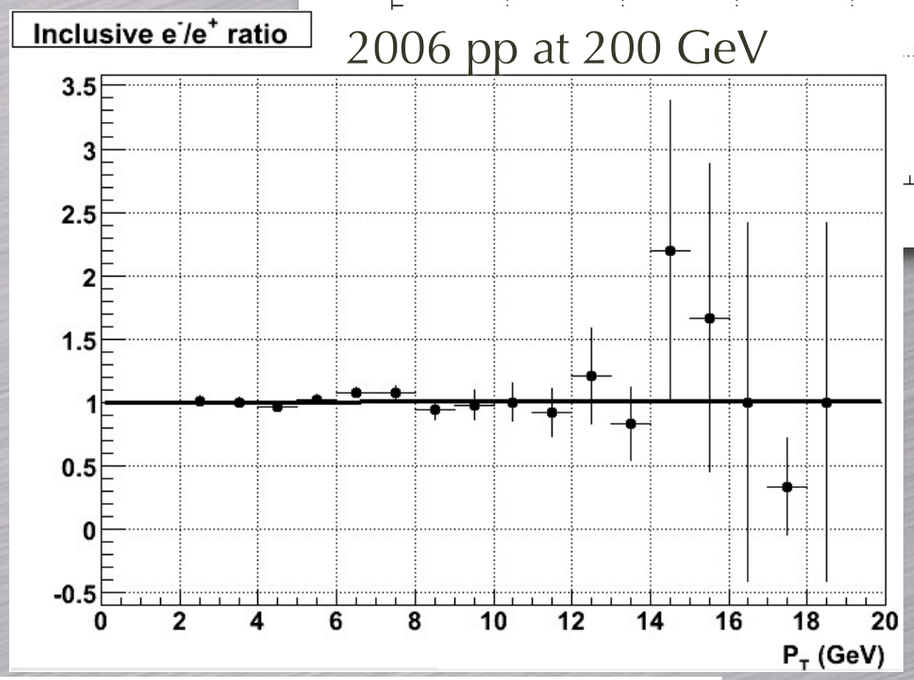
	Design	Results
Momentum Resolution: Soft physics: ΔP/P @ 1.5 GeV/c	2%	~2%
Hard physics: ΔP/P @ 10 GeV/c	5%	5-6%
Sagitta Resolution: Soft physics: **Δ**(sagitta)	400	600*
Hard physics: **Δ**(sagitta)	300	400*
Hit Resolution: Δ$(hit)_{r\varphi}$	700	300-550**
Topological reconstruction of weak decays: strange decays	via silicon	TPC alone ~2-3 mm resolution near vertex
heavy quark decays	-	Possibly via silicon ~1 mm hit-matching resolution

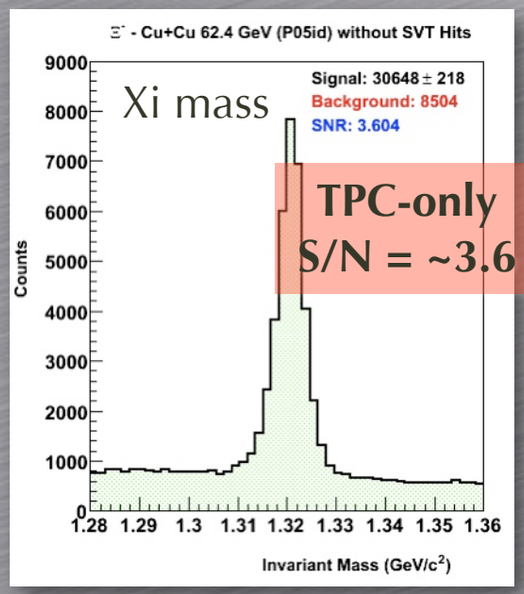
* averaged over whole TPC
** for 0° crossing angle (up to 1.5mm for 30°), drift length [diffusion] dependent, slightly better/worse for inner/outer pads

Performance: physics

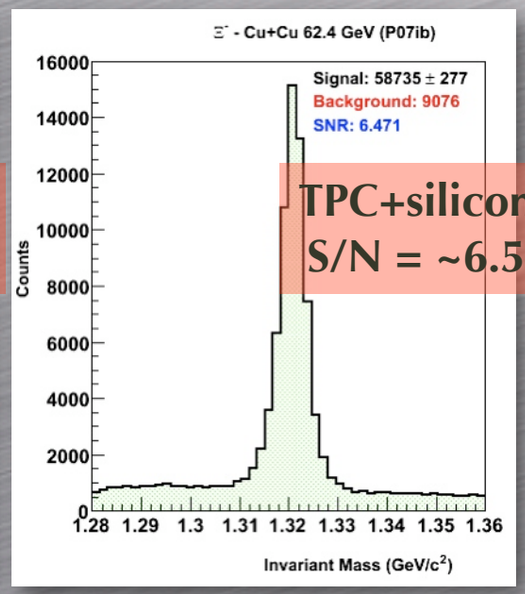
- Flat (as expected) anti-X / X ratios at high pT (e.g. π^-/π^+, e^-/e^+)
- Topological strange decays even w/o Si (e.g. Xi mass)
- Efficient matching to Si detectors enabling heavy flavor decays (e.g. D0 mass)



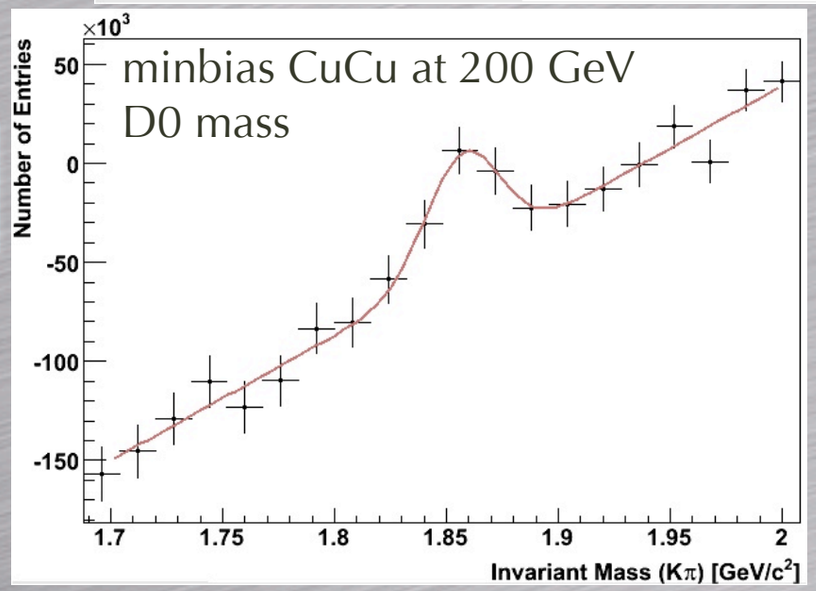




TPC-only S/N = ~3.6

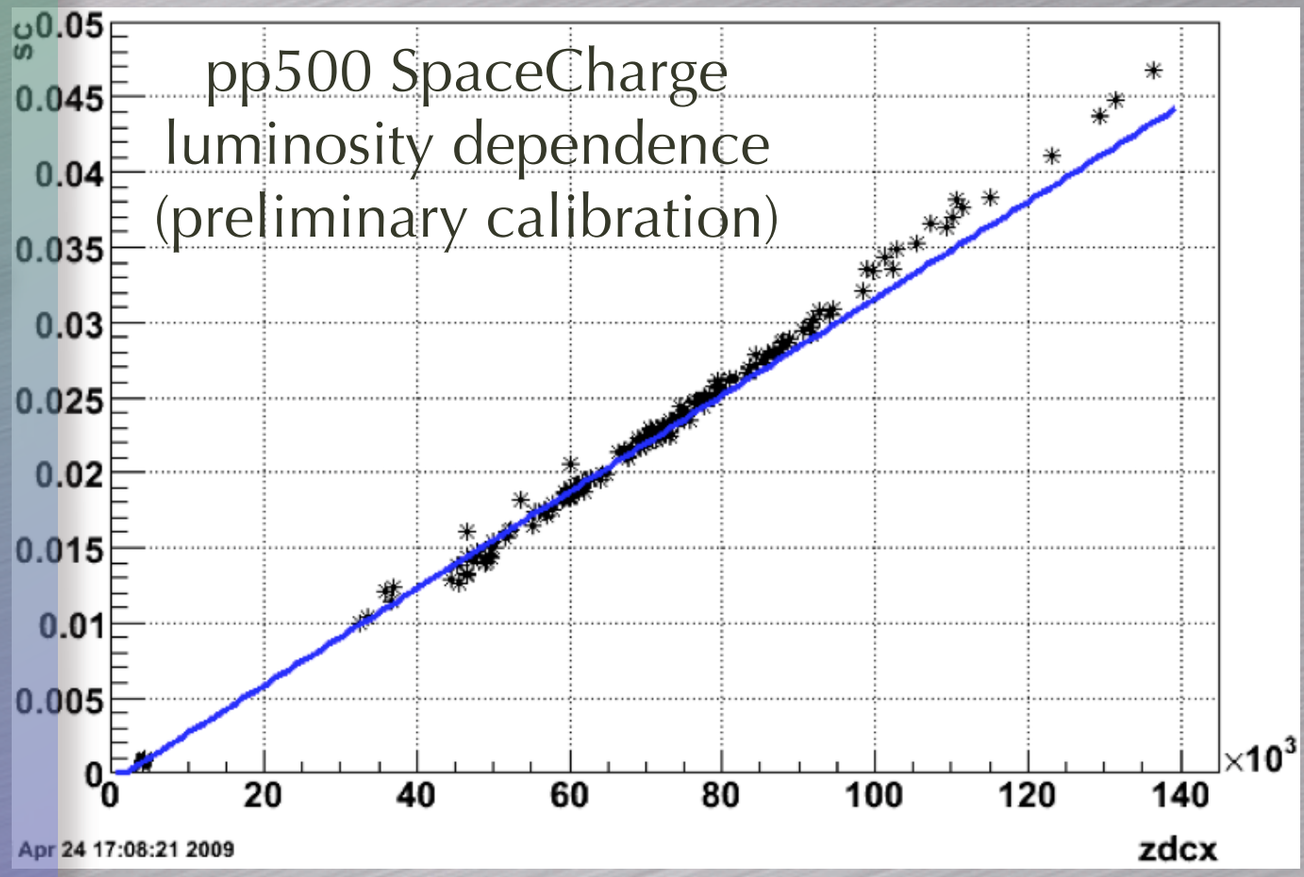


TPC+silicon S/N = ~6.5



The Future: higher luminosities

- Tracking across TPC now fails w/o some GridLeak correction
- How close is model to reality?
  - Differences will amplify with increasing luminosity
    - *Biases hurt physics most!*
  - How will the backgrounds change/grow/quell?
    - Shielding has helped
- Run 9 pp500 has twice the SpaceCharge as ever before
  - ...no major surprises...yet...



The Future: calibrations

- Higher DAQ rates
  - Increasing gating grid rates produced no notable change in SpaceCharge-like distortions(!)
  - Higher event rates benefit on-the-fly calibration approach
- Other techniques for SpaceCharge measures
  - Fixed detectors (GMT upgrade proposal)
  - Use identified pileup hits in the data (see Joe's talk)
- Feedback from users on margins
  - Margin for degraded pT resolution (less than $\sqrt{2}$)
  - No margin for pT biases
  - Little-to-no margin on pointing resolution/biases w/SSD

Reasons for faith

- *The past and present:*
  - So far, we have built the tools we need and have delivered physics beyond design goals
- *The future:*
  - Preliminary efforts for pp500 appear successful, but we expect even higher luminosities and things could get worse for us
  - We have some margin for further resolution errors, but even small biases are dangerous