TPC Distortions and Calibrations: Preparing for d-Au Analysis

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Soft Hadron Group Meeting
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Outline:

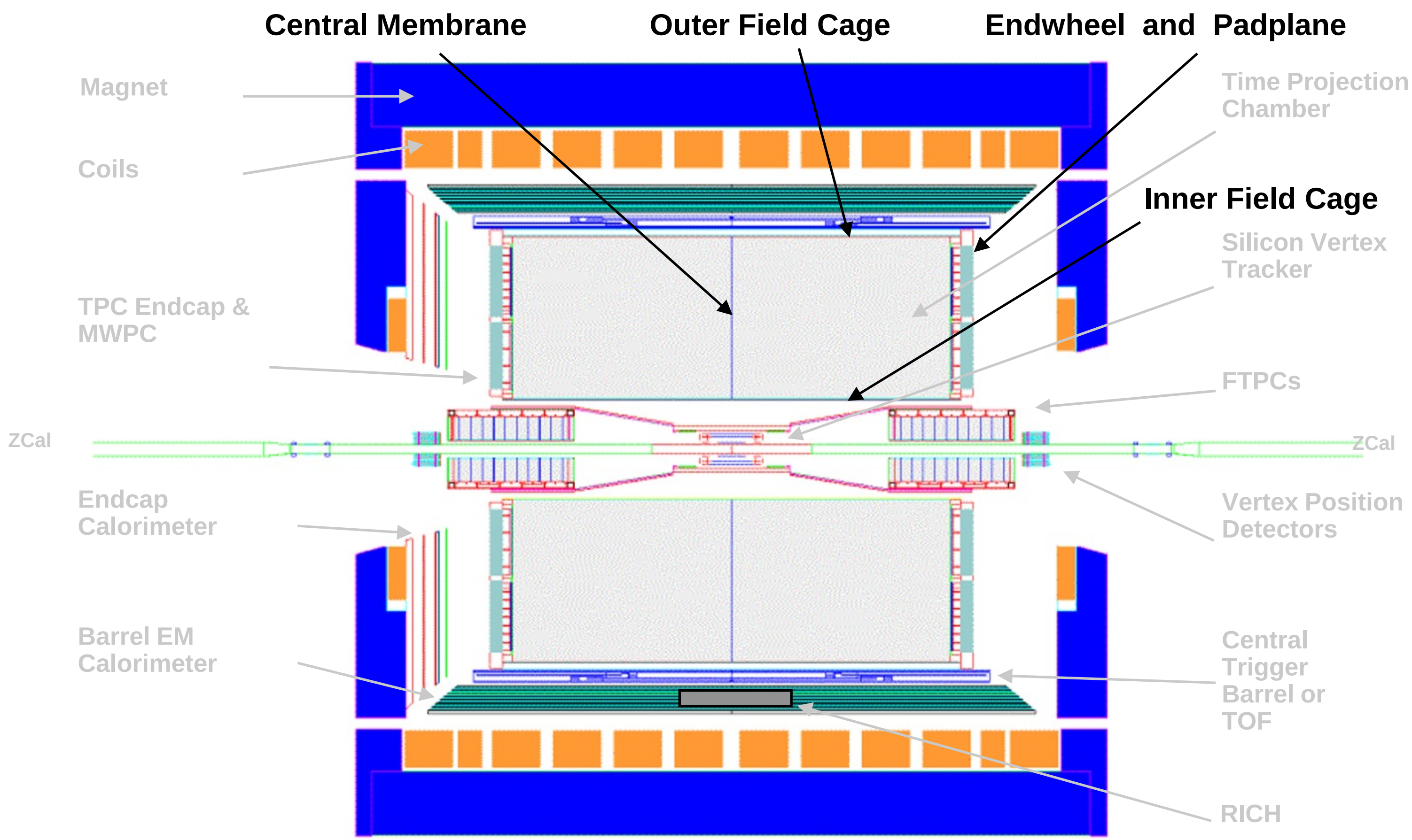
1.) Introduction – long but lite

2.) Two case studies for d-Au … which perhaps only an expert can love

New Insights

- **At the close of a run, each year, we have an intense 'couple' of months exercise where we calibrate the TPC and decipher whatever new mysteries have appeared that year**
  - **Many people are involved – including Gene van Buren, Richard Witt, Patricia, Andrew, Yuri, Alexei Lebedev, Hao Qiu, …**
- **Luminosity increase is the driving force behind most of the riddles**
  - $\mathscr{L}$ **is up by a factor of 100x since the earliest days of running at 1 Hz**
  - $\mathscr{L}$ **is a factor of 15x above 'design luminosity'**
- **We also experience shorted 'rings' and other hardware issues**
  - **Including shorted rings whose effect wanders with the humidity and weather …**

Distortions and Calibrations enumerated



Enumerate by surface and in the volume of the TPC

The List of Distortions in the Transverse Plane

STAR

- **The list can be enumerated by surfaces:**
- Outer field cage corrections
- Inner field cage corrections
- Central membrane corrections
- End-wheel and pad-plane corrections – especially grid leak
- Pad Row 13 corrections and other local electrostatic defects
- Rotation and miss-alignment of sectors with respect to their ideal locations
- Rotation of either TPC end-wheel with respect to its ideal location

- **and by volume:**
- Space Charge corrections due to charge in the volume of the TPC
- Magnetic field corrections due to B fields in the volume of the TPC
- Twist of the TPC with respect to the magnetic field axis and/or the measured map
- General coordinate transformations

- **A few additional items are listed for completeness.** (These items affect the drift of the electrons in the Z direction but do not strongly affect the distortions in the transverse plane.)
- Gas composition and variations in the drift velocity
- Barometric pressure changes and variations in the drift velocity
- Pressure variations as a function of height in the TPC
- Temperature gradients in the TPC

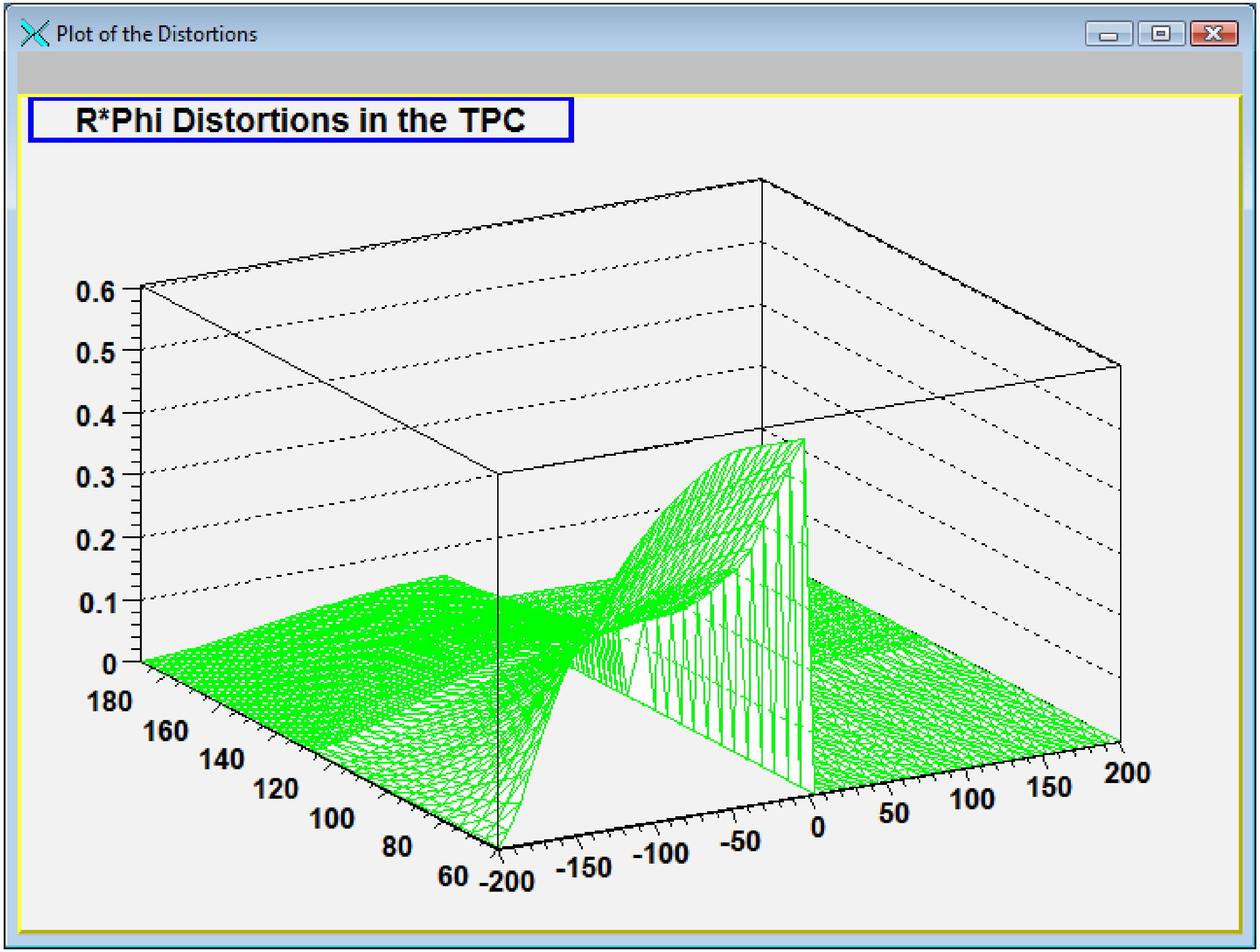
We check the list each year, and always find a surprise

Resistor Chain

- **There are 182 resistors that form a chain from the CM down to the pad plane of the TPC**
  - **Each is 2 M Ohm**

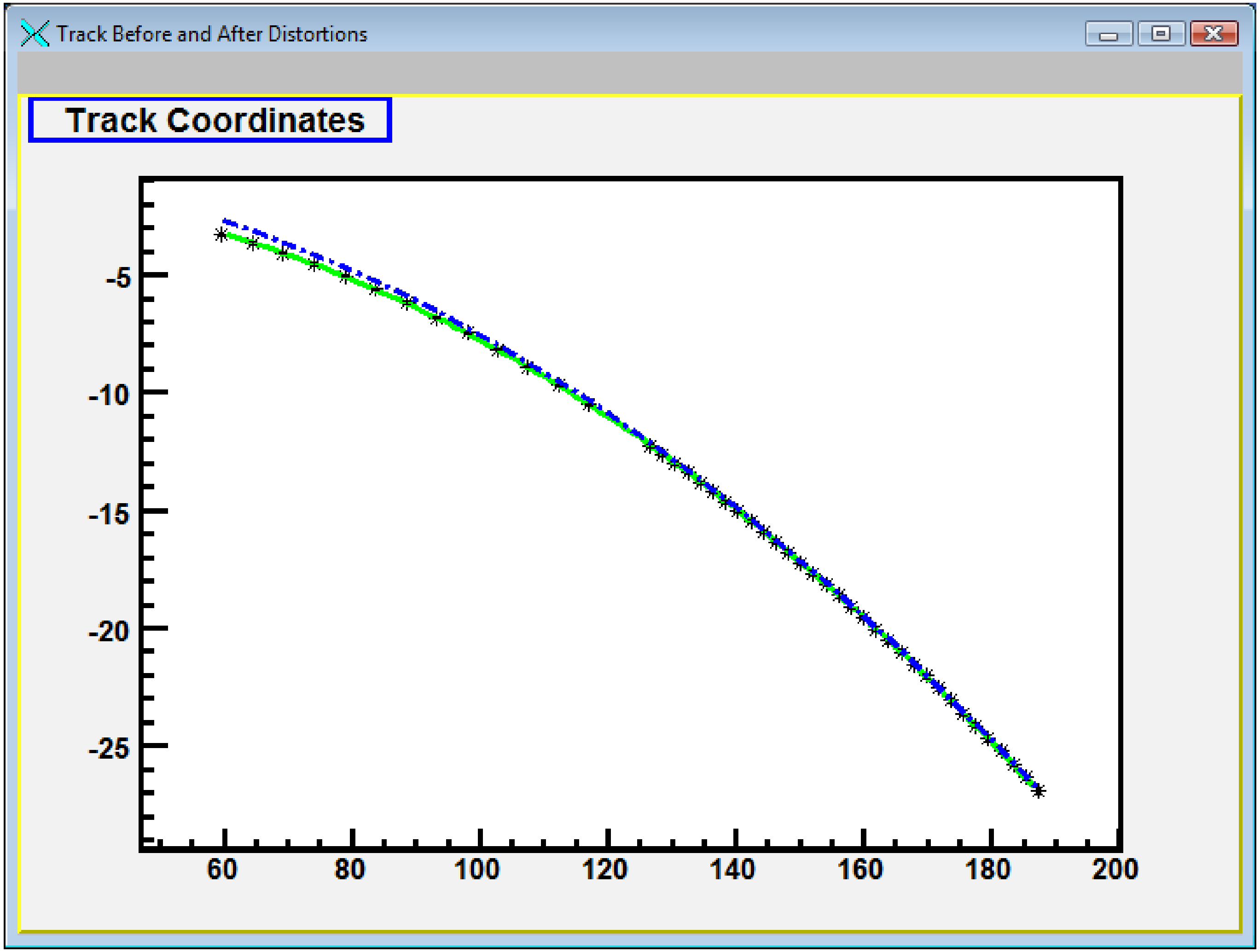
- **Occasionally dirt falls between two rings causing a short**
  - **An annual exercise whenever the inner detectors are removed or installed**

Shorted Ring Distortion



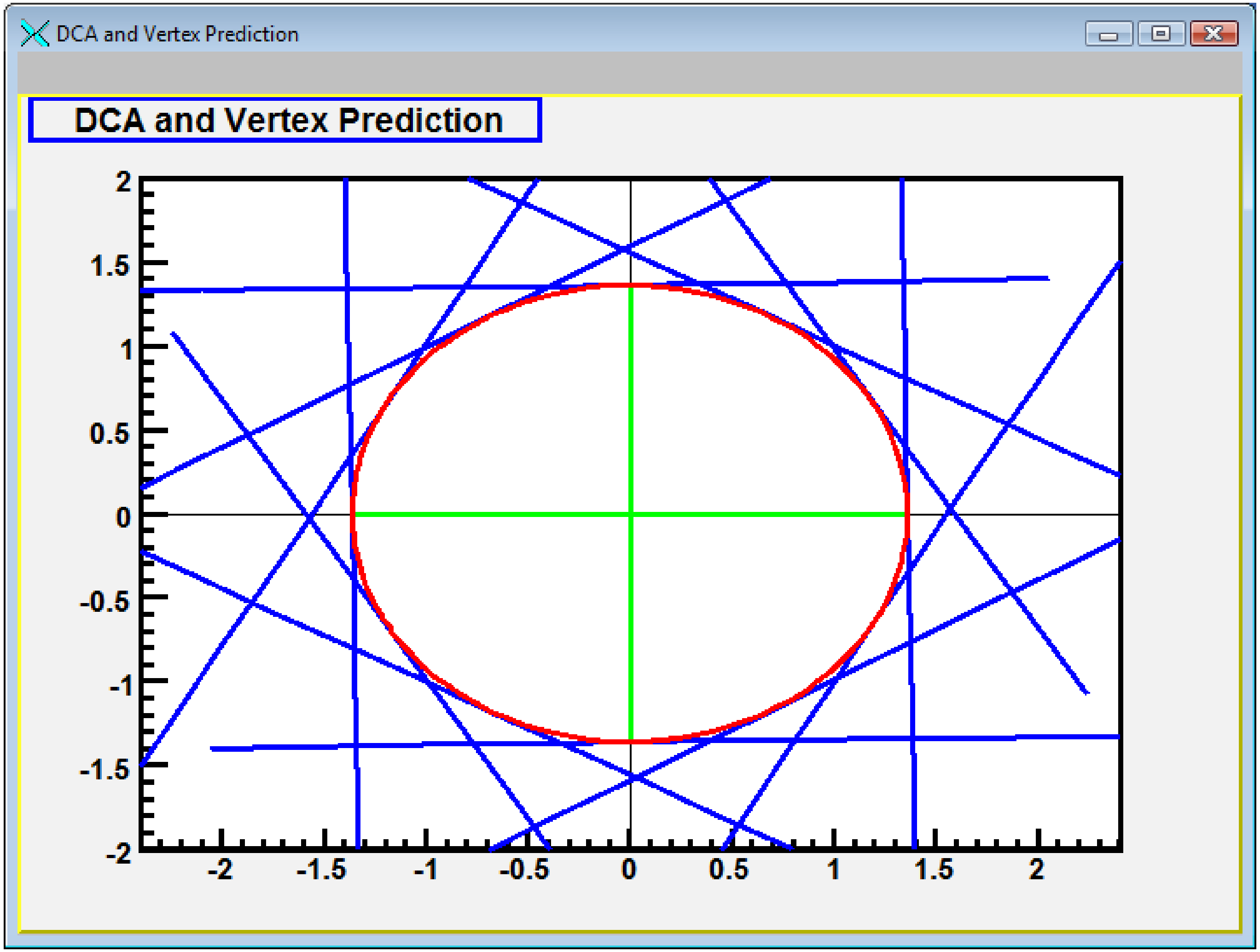
- Rings 169 and 170 shorted together
- This is a real distortion
- Two years ago, it wandered around hour by hour … depending on the humidity and temp
- It also depends on eta, pt, and zed

Shorted Ring Distortion



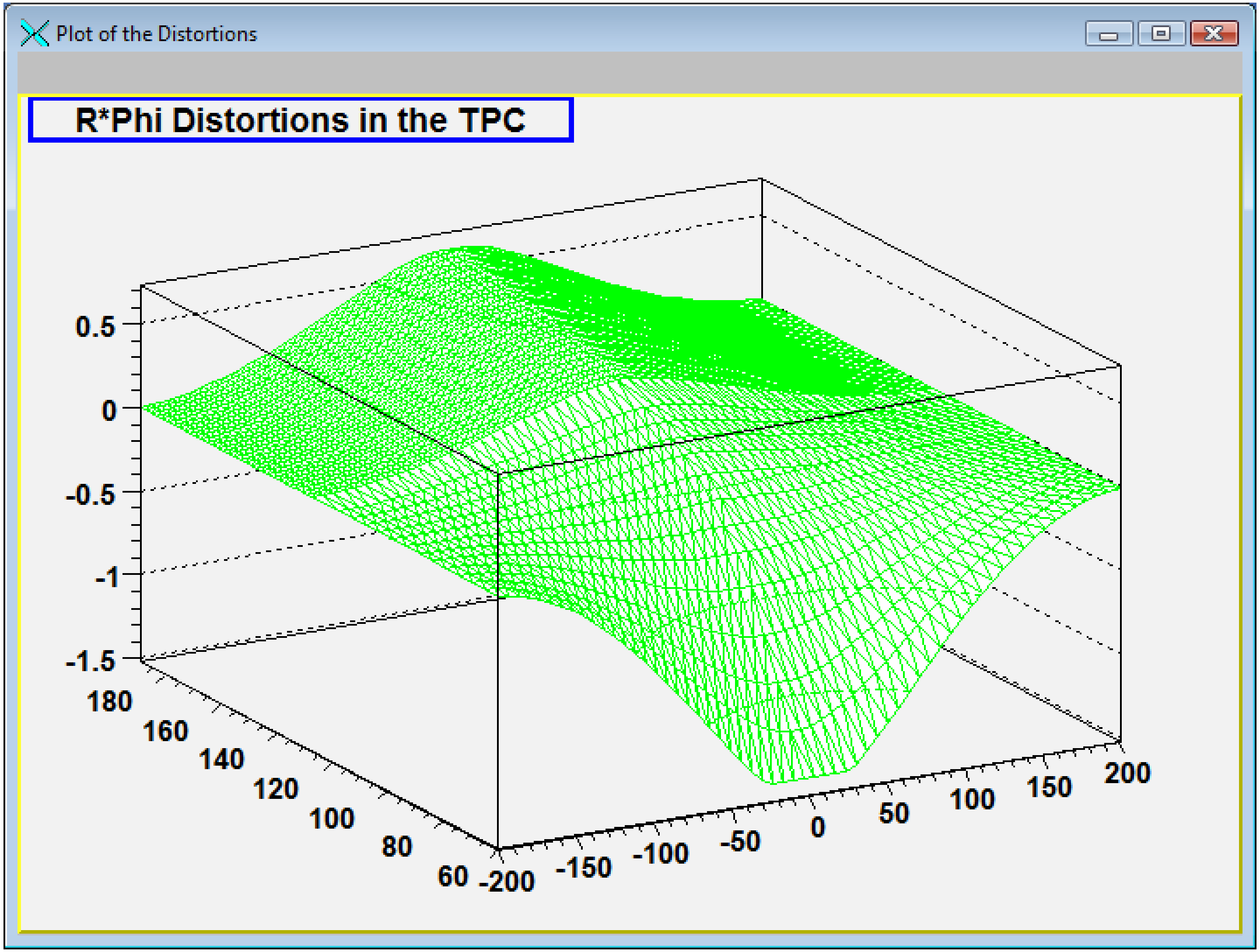
- Track in blue
- Distorted hits in black
- Refit in green
- Scale in cm
- Note the projected DCA error at zero is going to be large
- Distortion on first few pad rows is few mm

DCA error due to shorted ring ~1.4 cm



- **Once again, this is a real distortion**
  - **we have dealt with it for 2 or 3 years**
- **This is currently our biggest systematic distortion in Cu-Cu data**
  - **and it wanders around hour by hour**
- **Problem solved in time for d-Au running**

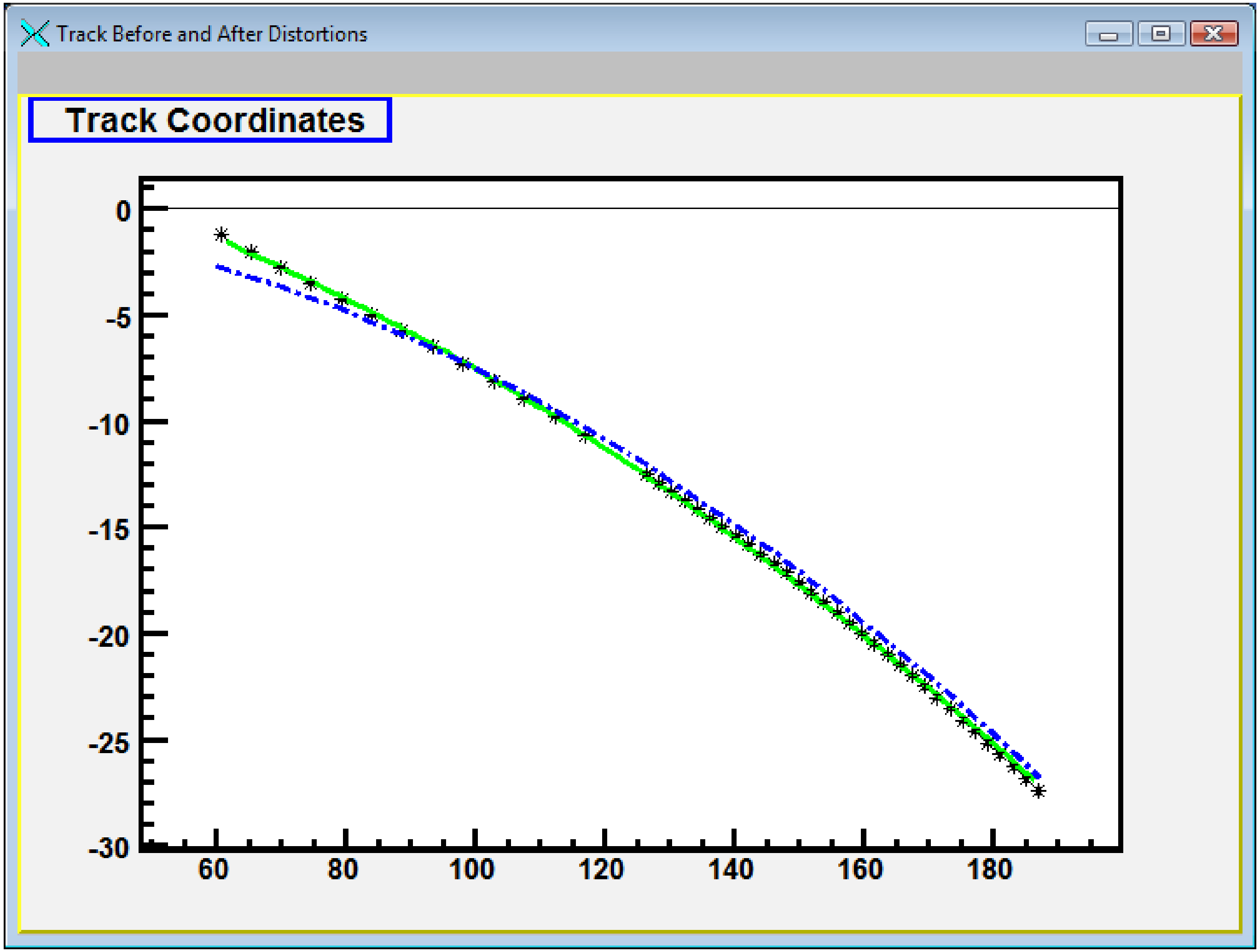
Space Charge under RHIC II Conditions



ZDC rate = 80 kHz

for Au-Au collisions

Space Charge at RHIC II Luminosities



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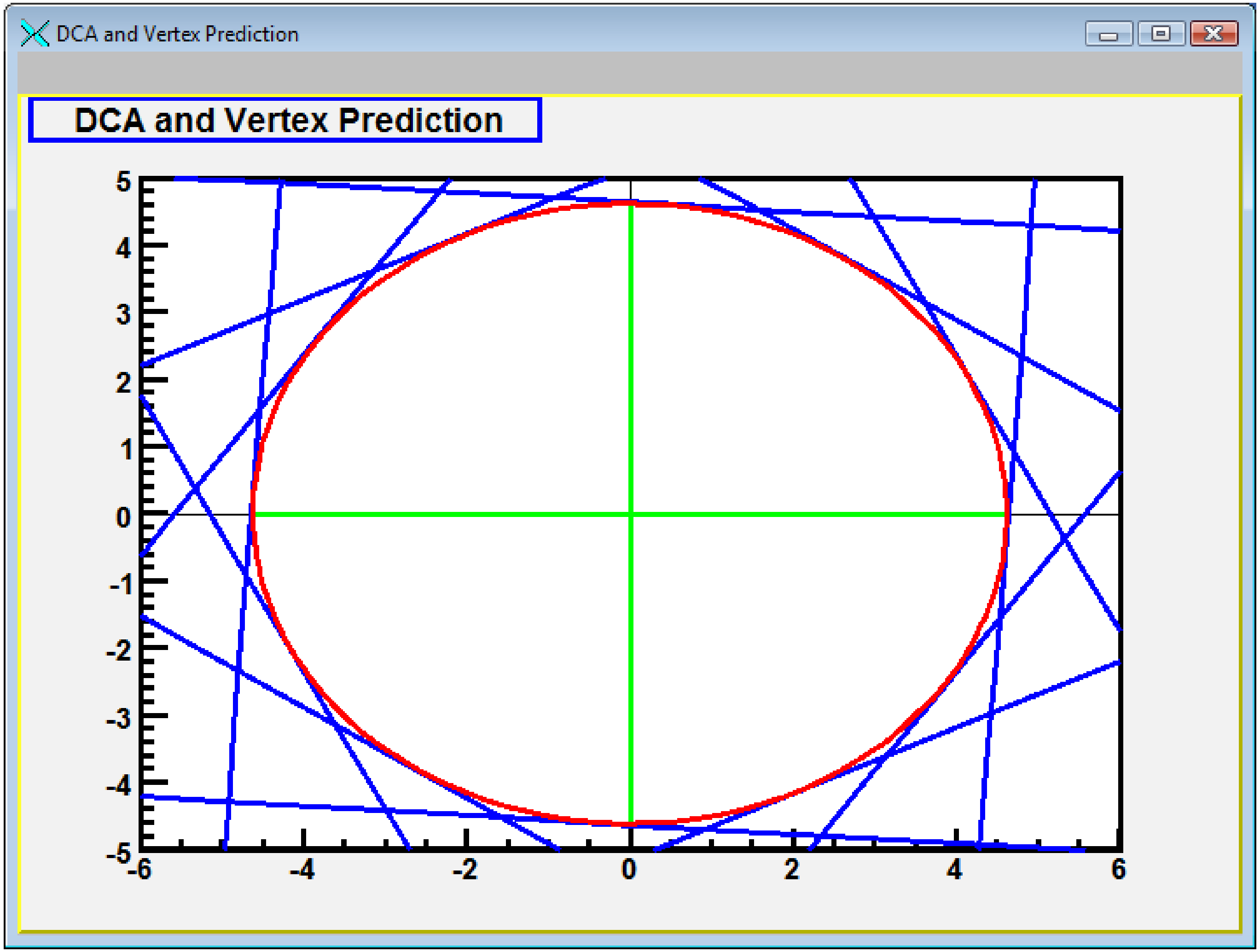
Space charge at RHIC II Luminosities

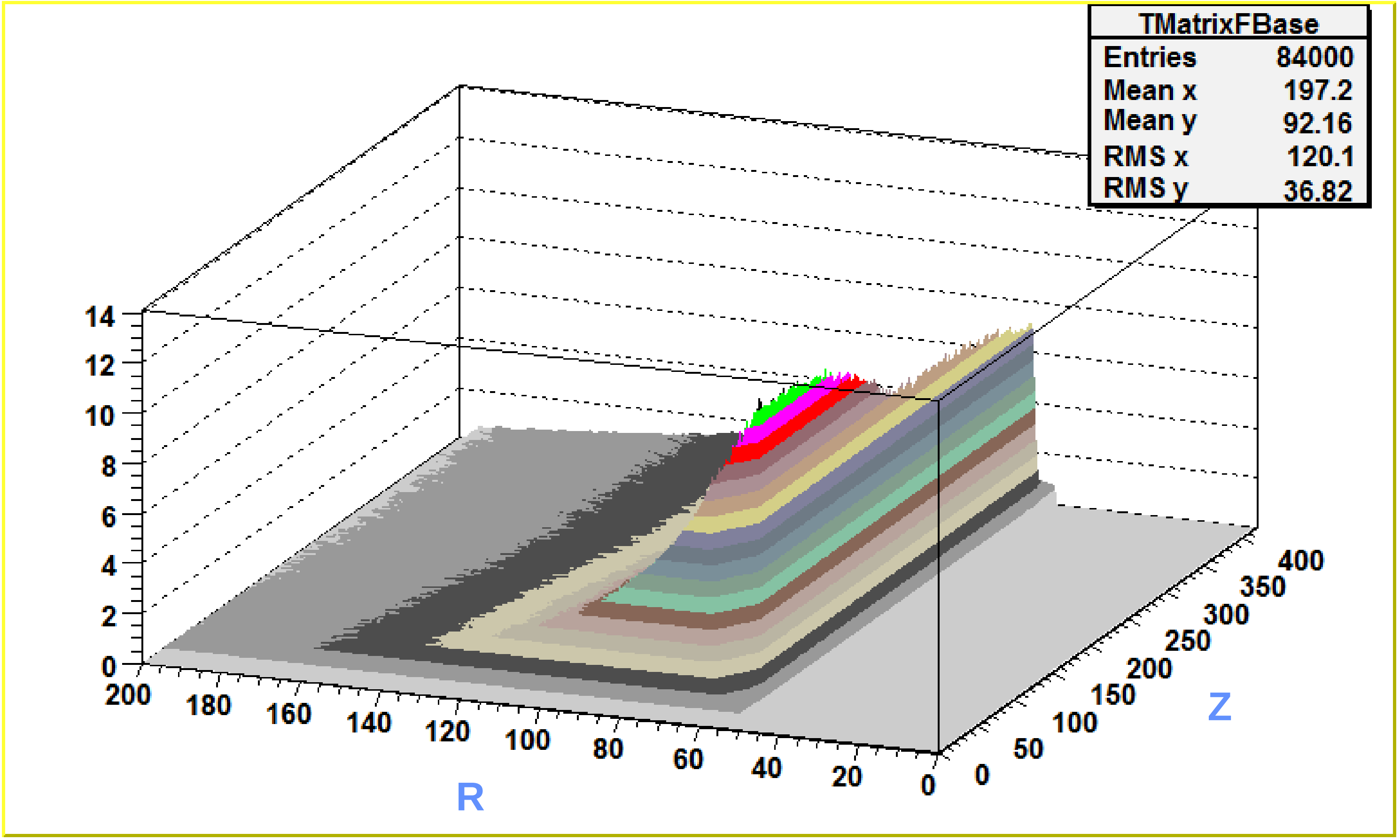


- **Note CM scale on the Horizontal axis.**
- **Radius of this circle is 4.6 cm**
- **Inside TPC the shift is ~1 cm on first pad rows**

Work for another year

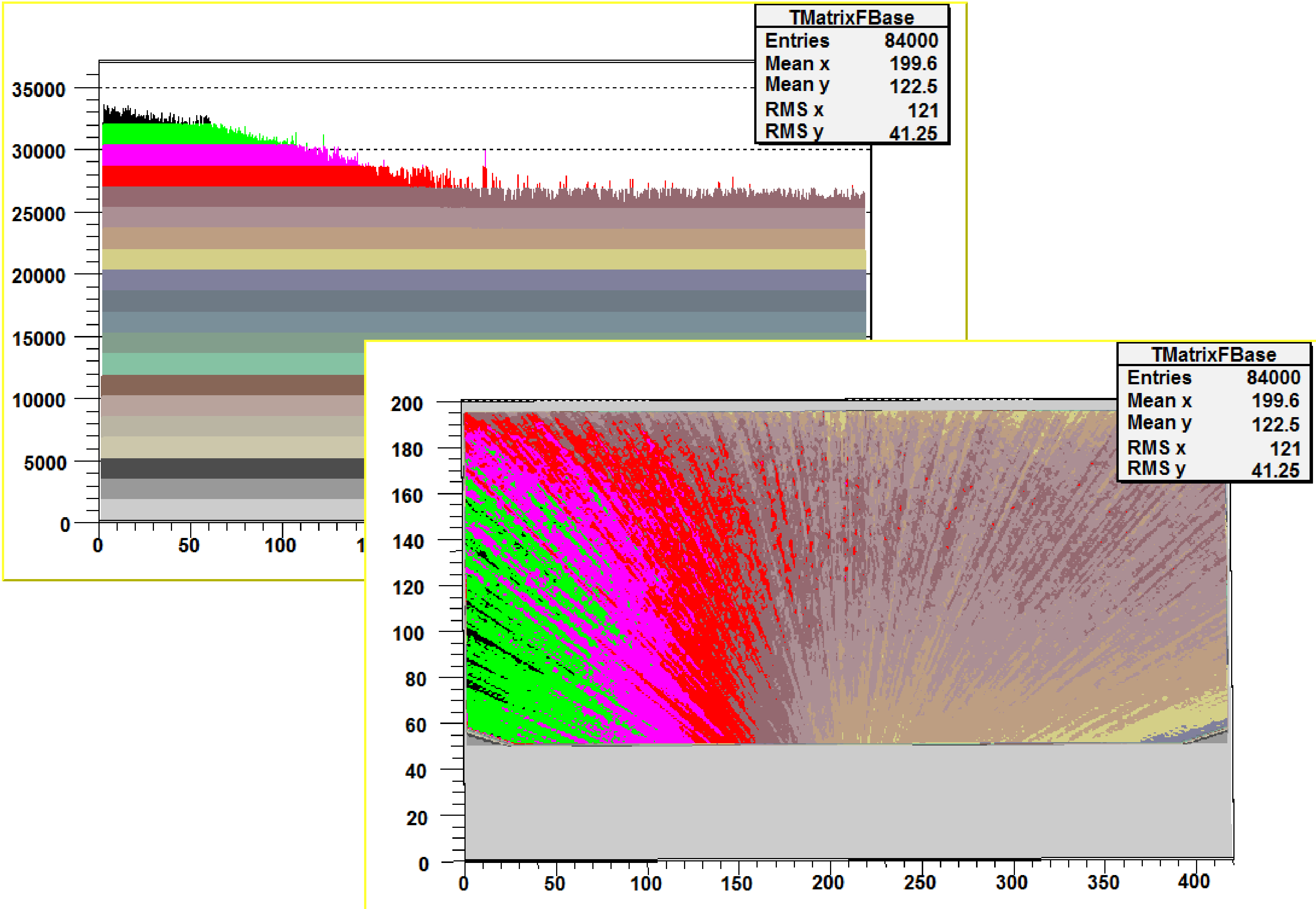
Two Case Studies from the most recent d-Au run

The Most Recent d-Au run



d-Au charge distribution is dominated by 1/R**2 distribution but is not symmetric in Z

d-Au Charge Distribution after Scaling 1/R**2

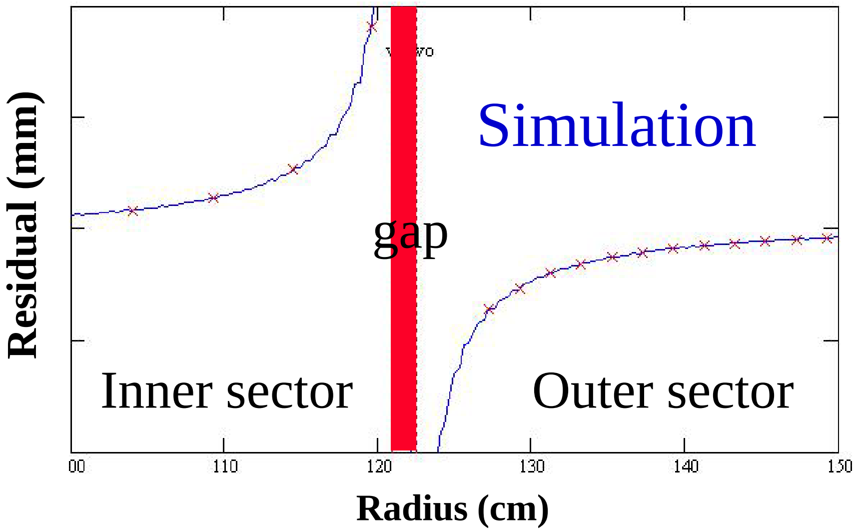


d-Au Distortion Corrections

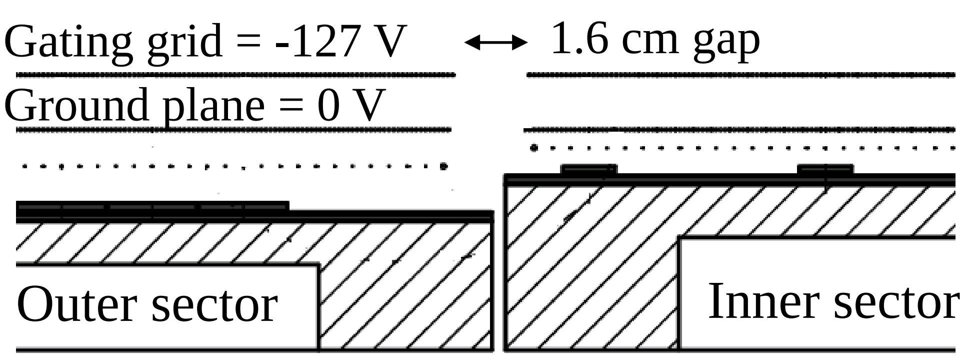
- The previous slides showed HiJing charge distributions for the primary tracks
- Several things happen before a track becomes “spacecharge”
  - Electrons drift to the padplane in ~ 40 μsec (and disappear)
  - Ions drift to the CM in ~ 0.5 sec … jogging speed for a human
  - The ions take so long to drift that hundreds of events “pile-up” leaving more positive charge near the endcap and less at the CM
    - We assume a linear integral in Z
- A full solution of Poisson’s equation is required before the impact of the drifting ions can be calculated upon the transverse drift of the electrons
- Magic
  - The net effect of the HiJing track distribution, the integral in Z, and Poisson’s equation … is that distortion becomes independent of R and Z (in one end of the TPC) and only depends on East and West
- A ‘flat’ ratio of 6/5 agrees very well with the data

6/5 Correction assumed to be mathematically perfect

Now, finally, something only an expert can love



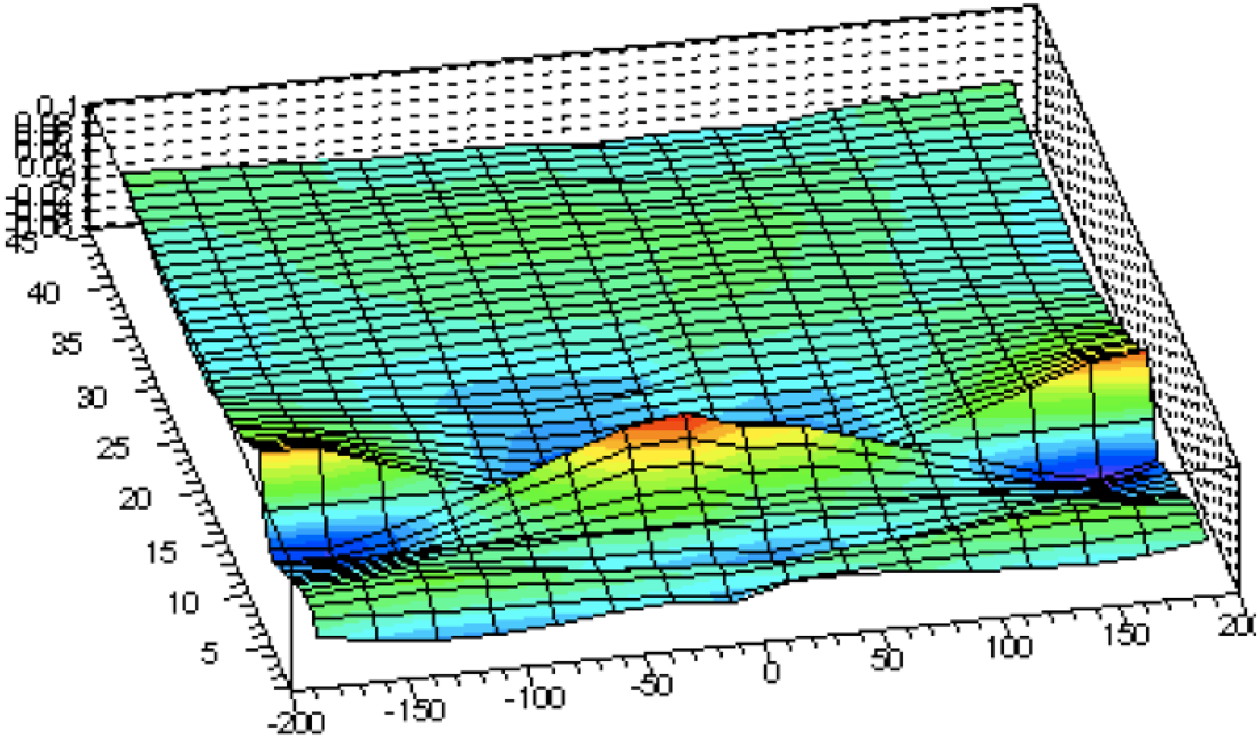
- **No wires at the boundary between the inner and outer sectors**
  - **E field leak ⇨ ExB effect in R and ϕ**



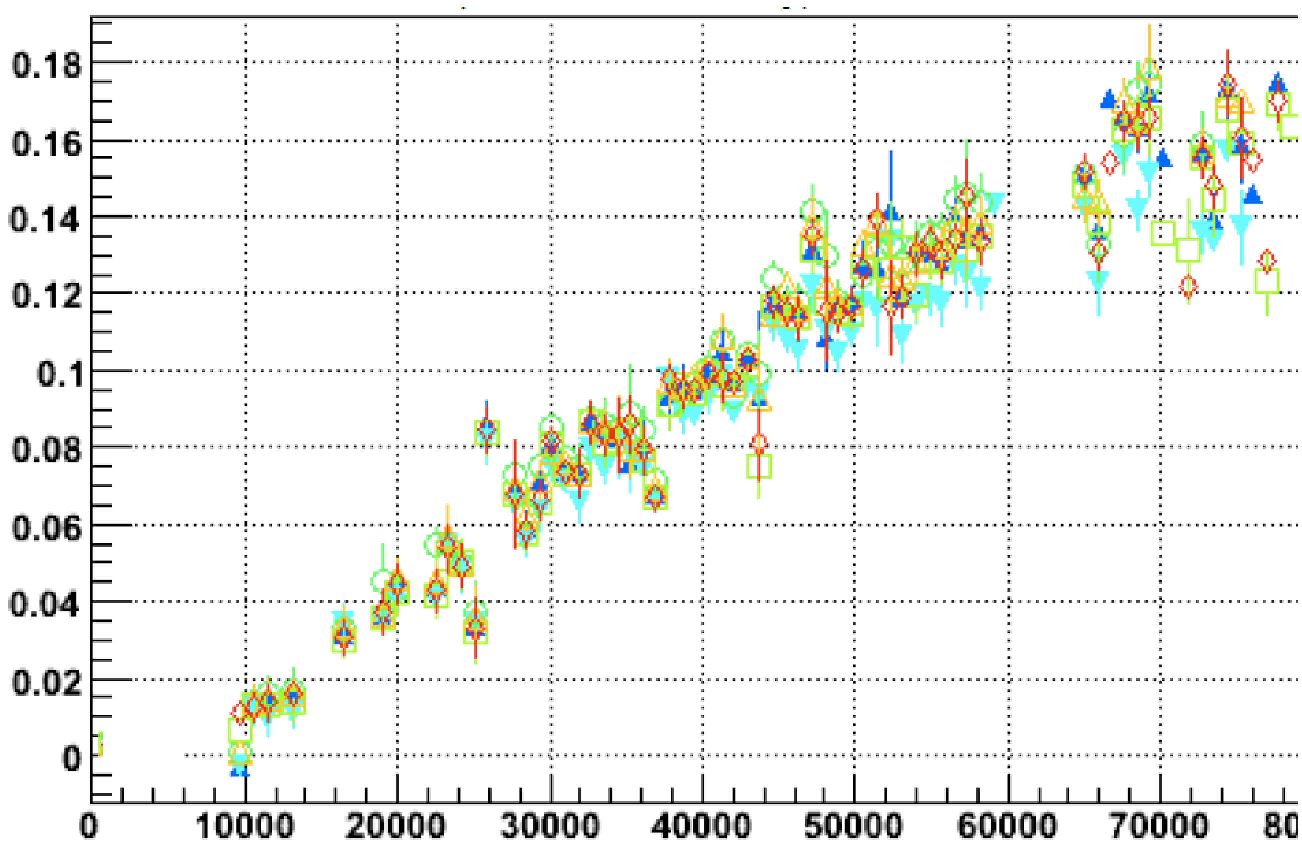
- **Using our standard tools: Grid leak appears to have gone hay-wire in the d-Au run**
  - **The inner and outer sector grid wires don’t cover the full sector.**
  - **There is an ~1.5 cm gap in the grids between the inner and outer sectors.**
  - **Positive ions leak out of the gap and drift to the cm without loss (> 2 meters!).**
  - **The sheet of charge distorts the tracks seen on the pad plane.**
  - **Effects are as big as for all-spacecharge in the volume of the TPC**

Grid leakage in the d-Au run

- **This year the effective luminosity went so high that we can see effects that we have never seen before**
  - **The immediate problem was that the grid leak developed an offset and did not go to zero when Z went to zero (at the endcaps)**
- **Previous years' work assumed that the 'Grid Leak' was strictly dependent on Luminosity and Z (should go to zero at the endcaps)**



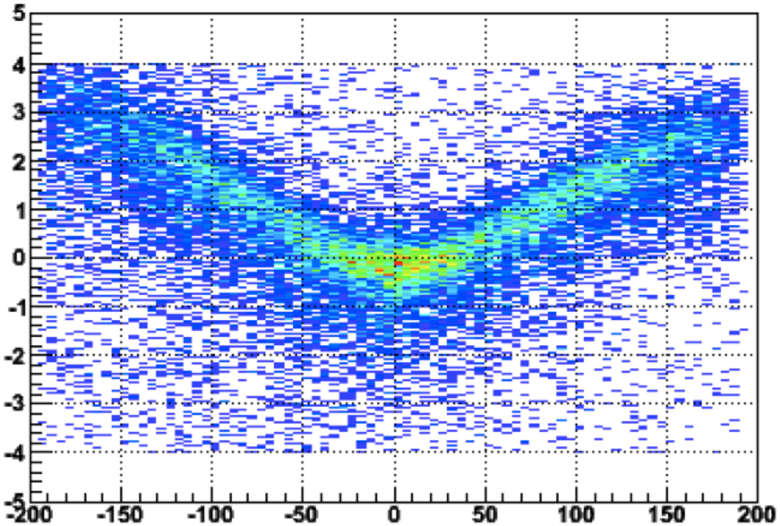
Residuals at Pad Row 13 > 1 mm



- Analysis for global tracks after normal grid leak correction
- Does not go to zero at Z=0 and residual grows with L
- We re-examined the list on page 4 and proved that it is not one of many things
- For example, it is not a Luminosity dependent Pad Row 13 correction (radial dependence is wrong)

To make a long story short …

- To make a long story short … the mysterious behavior in the grid-leak distortion is due to pileup
- The d-Au intensity is so high that we have multiple events in each frame of the TPC imaging system
- Only one event per frame has a proper vertex. The other events occurred earlier, or later, than the triggered event and so their vertex is split (appears at the wrong location)



- Because the pileup events are reported at the wrong location, they also receive the wrong set of distortion corrections. This gives a very odd Z dependence to the fully corrected DCA distribution

Bottom line for experts

- The Pileup rate has risen so high that we can only calibrate upon tracks with a vertex that is in the correct position
  - Pileup was so low in previous years that this was not an issue
- Track used for calibration must be as carefully chosen as tracks used for a physics analysis
  - This is possible … but also a bit of a tautology
    - you can't select high quality tracks until they are distortion corrected
  - Only the highest ranked vertex, and its associated tracks can be used to calibrate the TPC. ALL OTHER TRACKS MUST BE IGNORED even though they are the primary source of distortion and spacecharge.
- It's a brave new world as we go forward to higher luminosities

I am delighted to report that everything appears to be working with mathematical precision, and no unknowns.
At least for this year.

Other stories to tell

But those are issues and problems to be attacked another day