TPC Space Charge Calibration
Run 22 (pp508)

STAR Spin PWG
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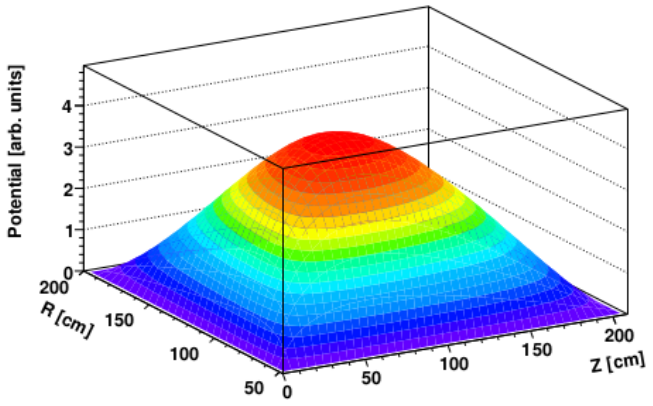
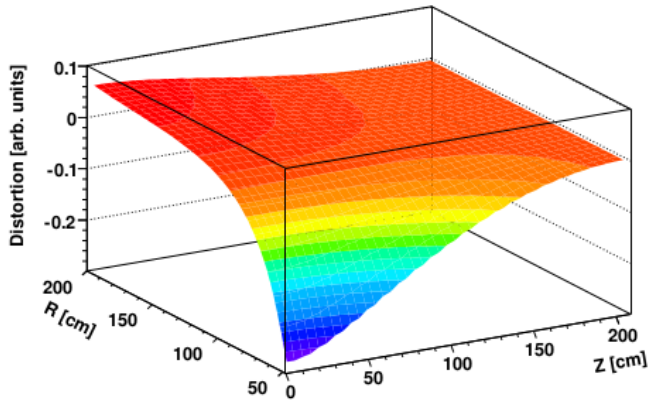
Richard Thrutchley

Space Charge

- Standard operation of the TPC generates a buildup of slow-moving positive ions via ionization of the surrounding gas, which varies with the number of charged particles moving through the chamber.
  - This creates an electromagnetic potential called "Space Charge" (SC), which distorts the measured positions of electron clusters on the readout endcaps.
  - SC is a function of the luminosity of the collider and the number of charged particles emitted by a collision.
- Variations in SC occur on time scales of half a second (the time it takes for the ions to drift through the chamber).
- Previous TPC Calibration efforts also included distortions due to Grid Leak, however that is negligible for Run22.





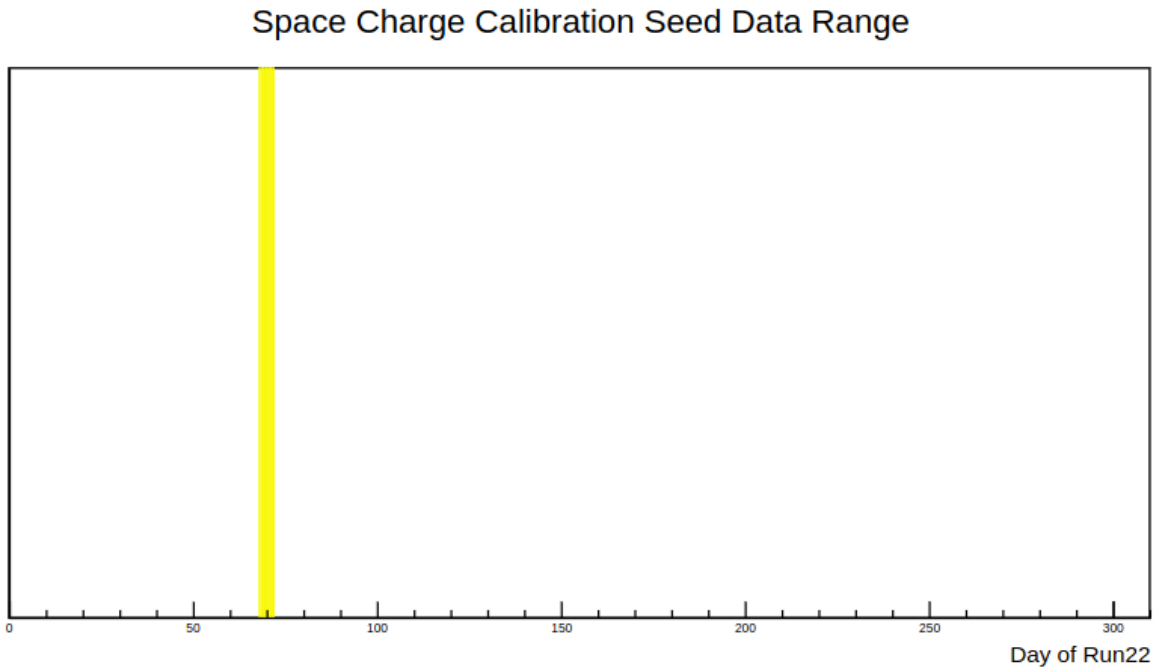
- Left: Simulated SC Potential as a function of R and z.
- Right: Azimuthal distortions of electron clusters caused by drifting through the simulated potential as a function of R and z.
- Nucl.Instrum.Meth. A566 (2006) 22-25
- https://arxiv.org/abs/physics/0512157v1

Method

- The first step is SC measurements event by event for each run.
  - SC is calculated using the signed Distance of Closest Approach for a given track, i.e., how far the closest point on the track is from the primary vertex.
  - For each track geometry, we simulate how far it would be distorted from the primary vertex based on an initial value of Space Charge.
  - This simulated sDCA is compared to the measured sDCA, and a correction to the SC is added based on how much the simulated sDCA must be scaled to match the measured.
  - Contributions from each event are added to the initial SC to get a measurement of SC for a given job.
- The resulting SC from each job are then fitted to a linear combination of RICH scalers, which are dependent on the luminosity of the collider.
- This fit is then used as the initial SC for the next pass, and the process is repeated until the difference in SC calculations between passes is less than $0.001C/\varepsilon_0$, which gives track reconstruction with less than 1mm uncertainty from SpaceCharge.

Data Set

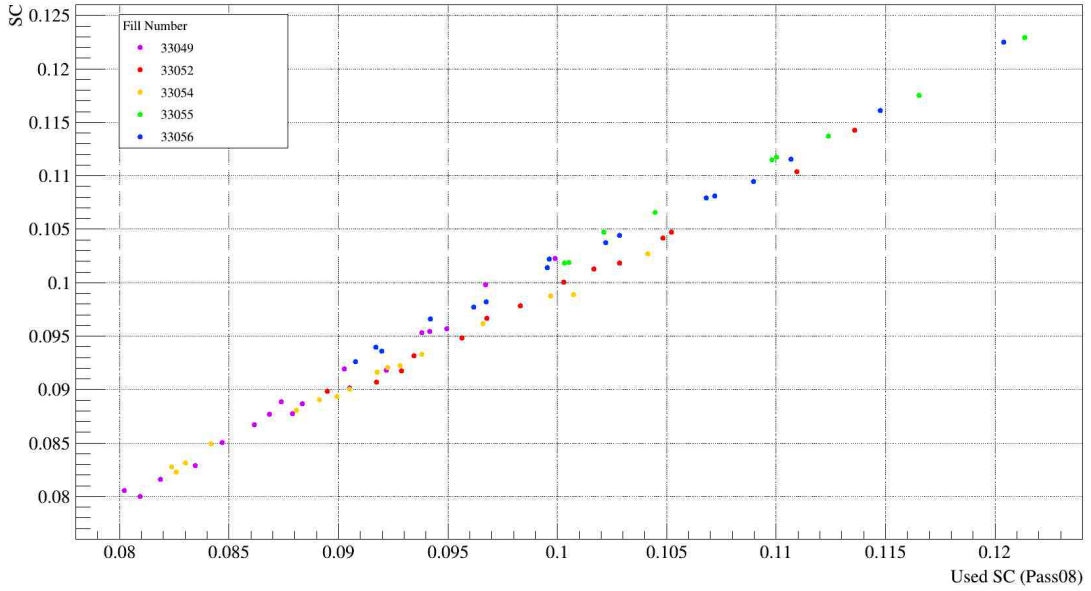
- Fills 33049, 33052, 33054, 33055, 33056; Runs in the range [23034051 - 23037015].
- One file processed per Run, giving 70 DAQ files total as an initial seed sample for Pass01, Pass02, and Pass03.
- Four files processed per run, giving 292 DAQ files total processed for Pass05 and Pass06.
    - An update to the BEMC Pedestal values between Pass03 and Pass04 changed the track reconstruction, resulting in fewer tracks per file which pass the selection cuts, but higher quality tracks overall. Pass04 is excluded, moving directly to Pass05.
- Four to Eight files processed per Run, giving 321 DAQ files total processed for Pass07 and Pass08. More DAQ files were needed to get the minimum number of tracks required for some runs.



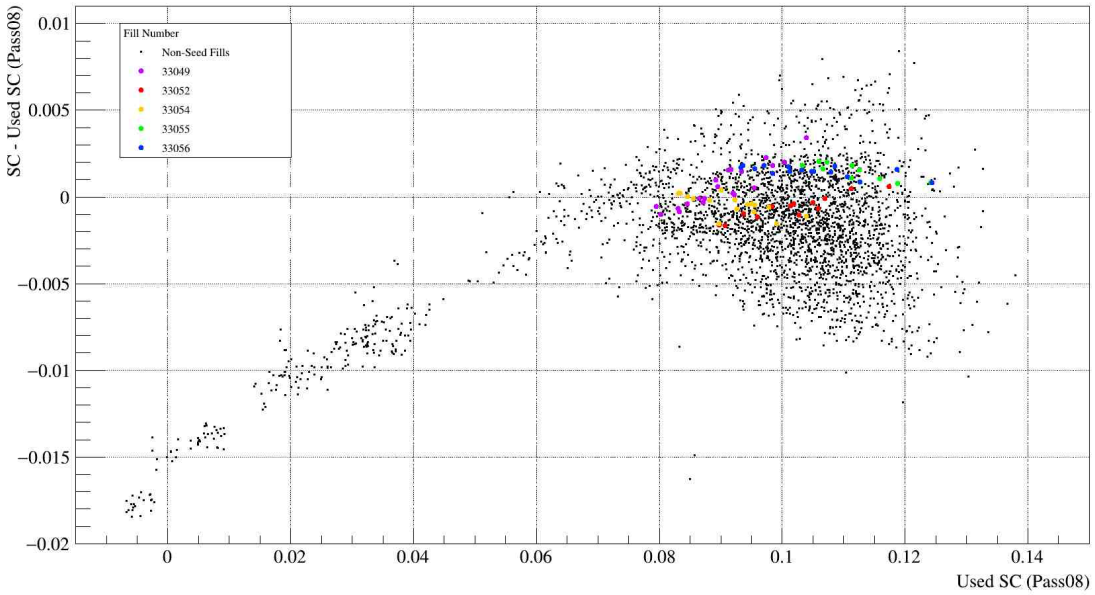
General Calibration Results

- Pass08 Calibration Result:
  - Calibration Fit = (1.793e-07*(zdcwnk-(-7.954e+04))+(-3.989e-08*(bbcx))) in units of C/ε_0

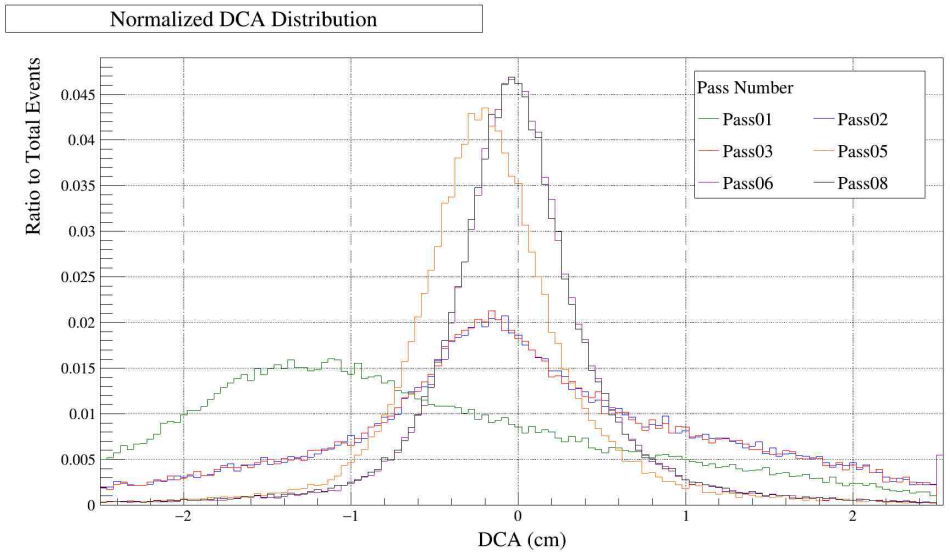
SC vs Used SC (Pass08)

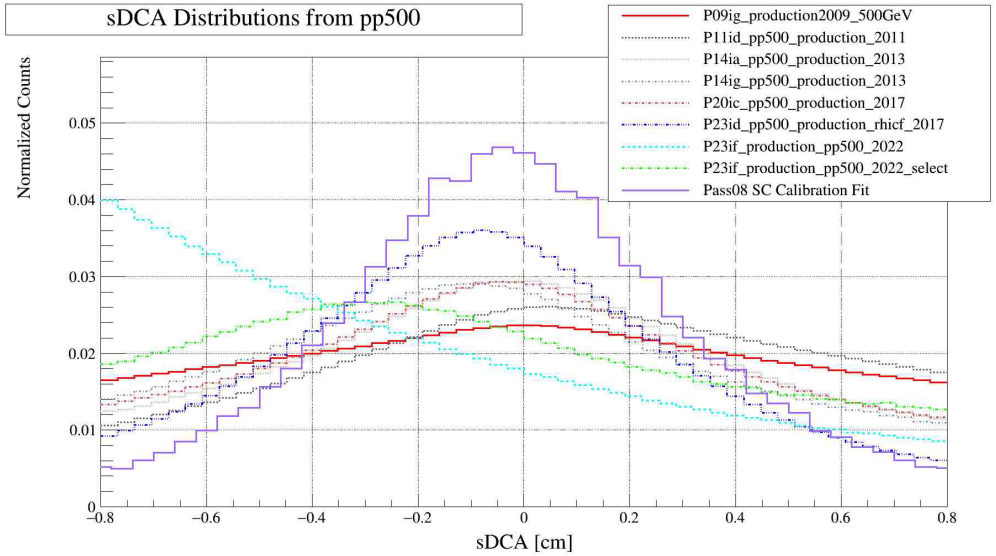


SC - Used SC vs Used SC (Pass08)



Comparisons of DCA Distributions





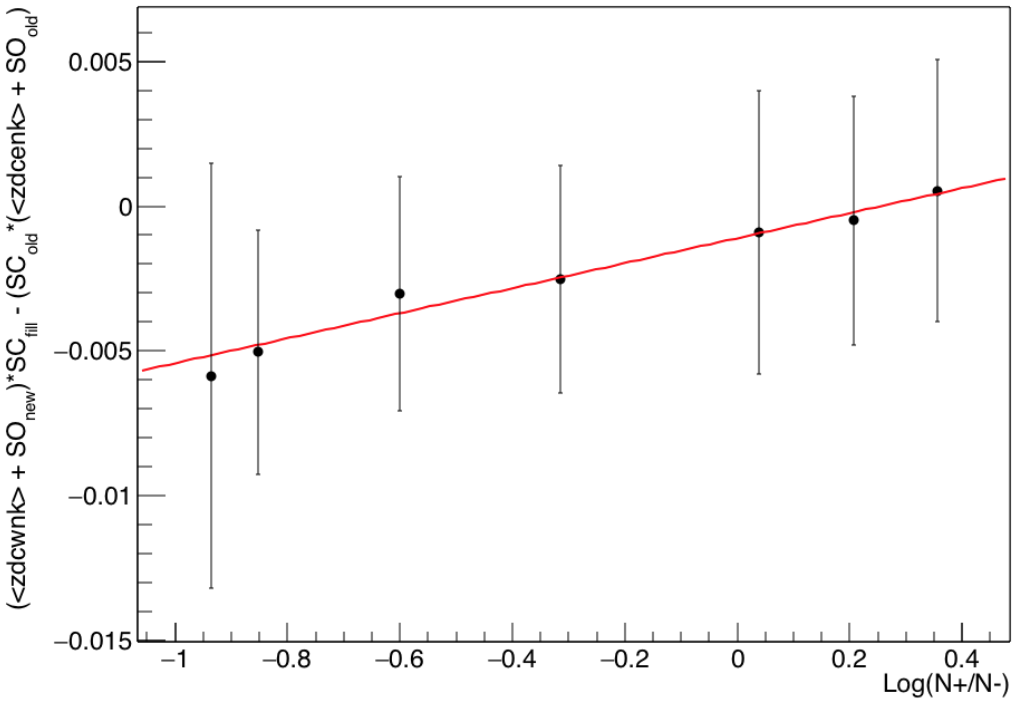
- The preview production shows an okay distribution over the selected fills, but a bad distribution over a general sample of Run22.
- Pass03 Result was used in the Preview Production.
- P23if_production_pp500_2022 uses a random selection of data from all Run22.
- P23if_production_pp500_2022_select uses a selection of data only from the five initial fills used in the calibration.
- The Pass08 Calibration Fit uses the five seed fills and the most recent general calibration result.

So, we're done, right?

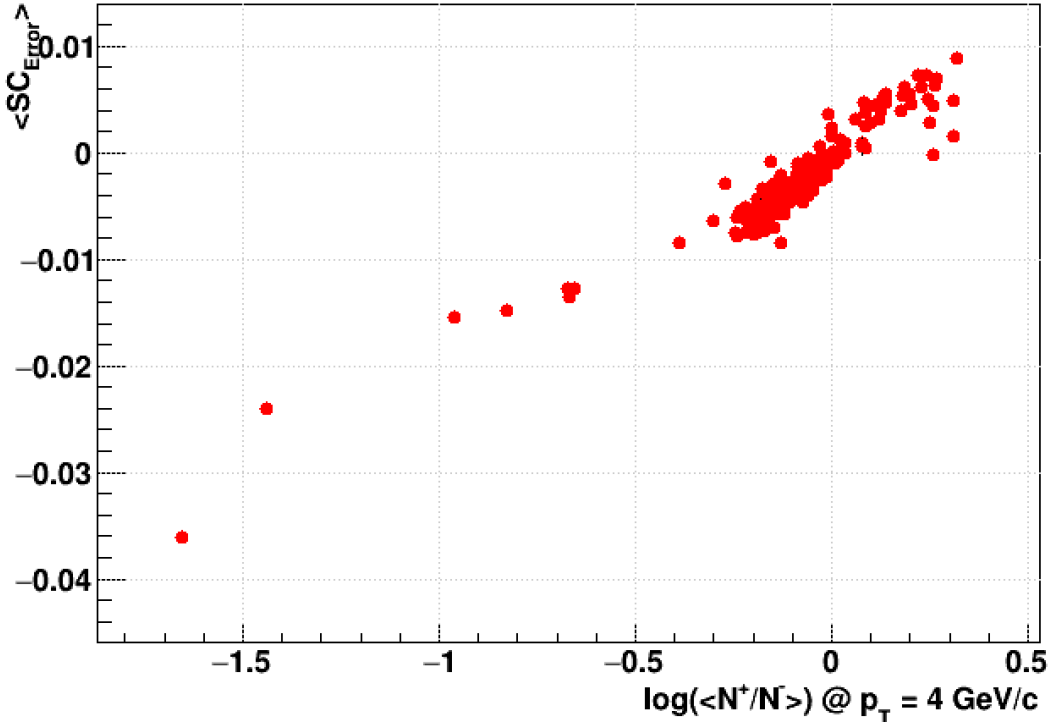
Not quite…

SC Error vs. log N+/N-

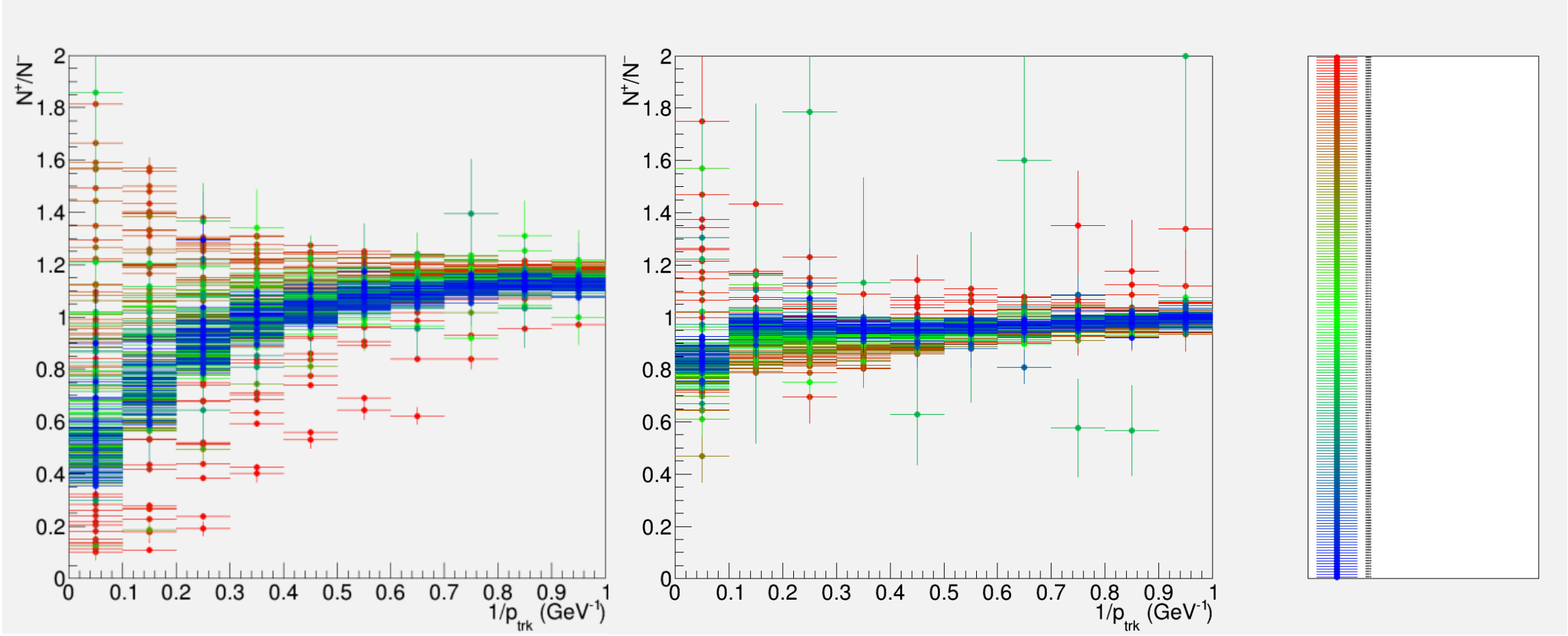
Fill-by-Fill Error in SpaceCharge vs. log of High-p_T Charge Ratio (Run17)



Fill-by-Fill Error in SpaceCharge vs. log of High-p_T Charge Ratio (Run22)



N+/N- vs. $1/p_T$ by Fill



N+/N- Ratio from General Calibration Result

N+/N- Ratio from the First Fill-by-Fill Calibration Results

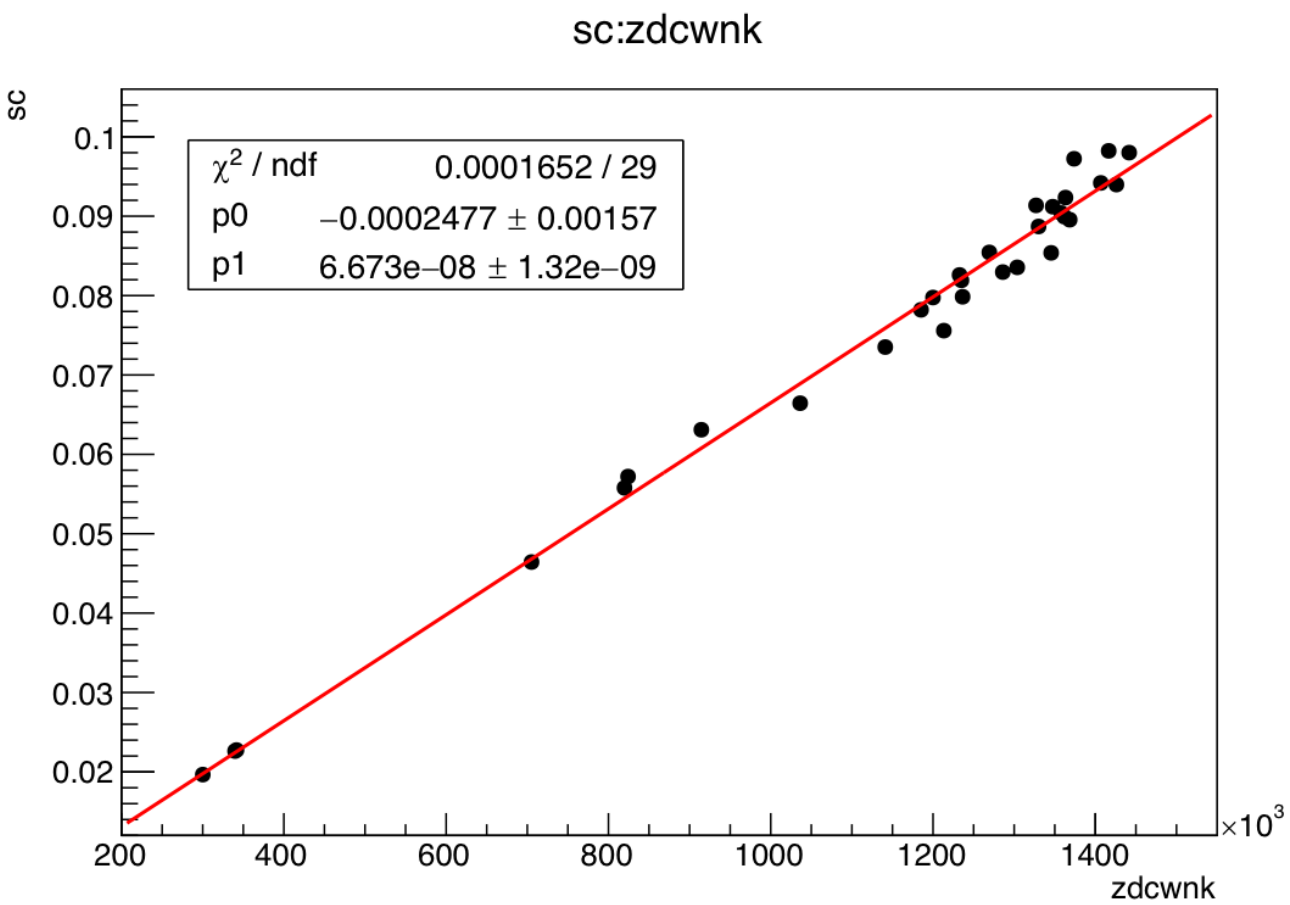
Where is the Variation Coming From?

- In short, we don’t know.
  - These variations have likely been present in the data all along, hiding in the errors that we now have the statistics to investigate.
  - Maybe the TPC Laser Calibration?
- We can perform the Space Charge Calibration anyway.

TPC Space Charge Calibration - Summary

- We have finished a general SC calibration for Run22 and have confirmed the presence of fill dependent variations as previously seen in Run17.
- Larger statistics have allowed us to investigate the variations further.
  - Run17 approach was the best we could do at the time but is not the optimal solution for Run22.
  - Fill-by-Fill Calibration has allowed us to calibrate for these fill-dependent effects without assuming an N+/N- ratio result.
- The current Fill-by-Fill Calibration iteration should be finished in the next few days.
  - We require at least one more iteration to verify convergent solutions, redo the BeamLine calibration with the improved Space Charge, and include dE/dx for the purposes of EMC absolute gain calibration.
  - The finish line is in sight.
- Special thanks to Gene Van Buren for his contributions and continued support, Jae Nam for his investigations into the N+/N- Ratio, and the Spin PWG for their patience and support.

Backup Slide – TPC Space Charge Calibration Run17



Final Calibration Result Run 17

https://drupal.star.bnl.gov/STAR/blog/posik/tpc-run-17-pp500-scgl