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STAR TPC and BEMC Calibration: Methods and Strategy

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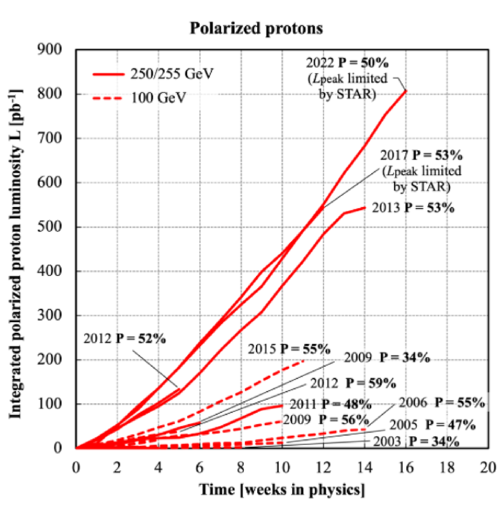
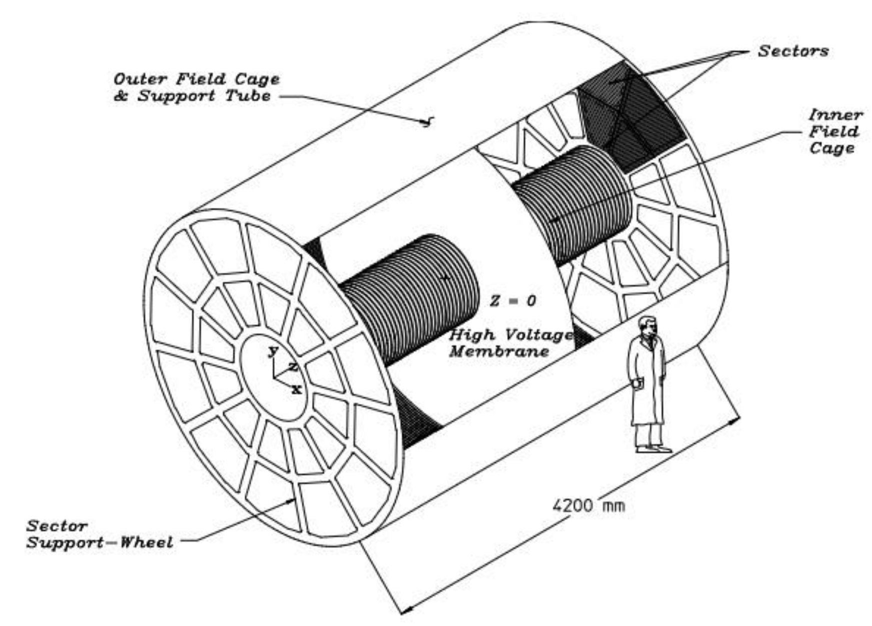
RHIC Run 2022 pp 508 GeV



- During STAR Run 2022, proton beams were collided at a center-of-mass energy, $\sqrt{s} = \mathbf{508\ GeV}$.
- The size of $p^{\uparrow}p$ data sample collected during this period is larger than Run 2017 ($\mathbf{\sim 400 pb^{-1}}$), which will greatly improve the statistics of precision measurements at STAR such as W/Z cross section and IFF analyses.

Time Projection Chamber (TPC)

- The Time Projection Chamber (TPC) records event tracks, particle momenta, and provides particle identification (PID) for charged particles via measurement of ionization energy loss *dE/dx*.
- The TPC covers ±1 units of pseudorapidity and the full azimuthal range.
- Particles collide very close to the TPC center. Paths of primary ionizing particles are reconstructed by the read out of secondary electrons released by ionization of the surrounding gas.
- Electrons drift to the readout caps at either end of the chamber driven by a uniform electric field of ~135V/cm generated by a thin conductive central membrane.
- Precise calibration of the TPC is necessary to ensure accurate data and analysis.

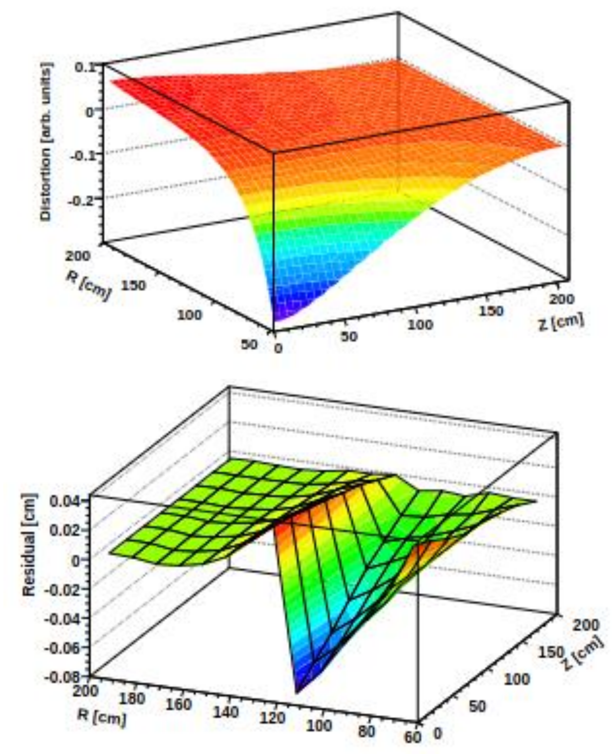


Time Projection Chamber Diagram

TPC Space Charge and Grid Leak Calibration

Distortions to TPC Hit Points

- Gas ions in the chamber create a positive charge density called the Space Charge (SC).
- Ions from around the anode wires leak through gaps in the gated grid. This leakage is called Grid Leak (GL)
- Distortions of tracking from SC and GL are reduced by subtracting calculated charge contributions from measured electron positions to estimate the undistorted track.
- The figures on the right show the simulation of azimuthal distortions of the position of electron clusters as well as track residuals over R and Z for high luminosity events before correcting for SC and GL distortions.



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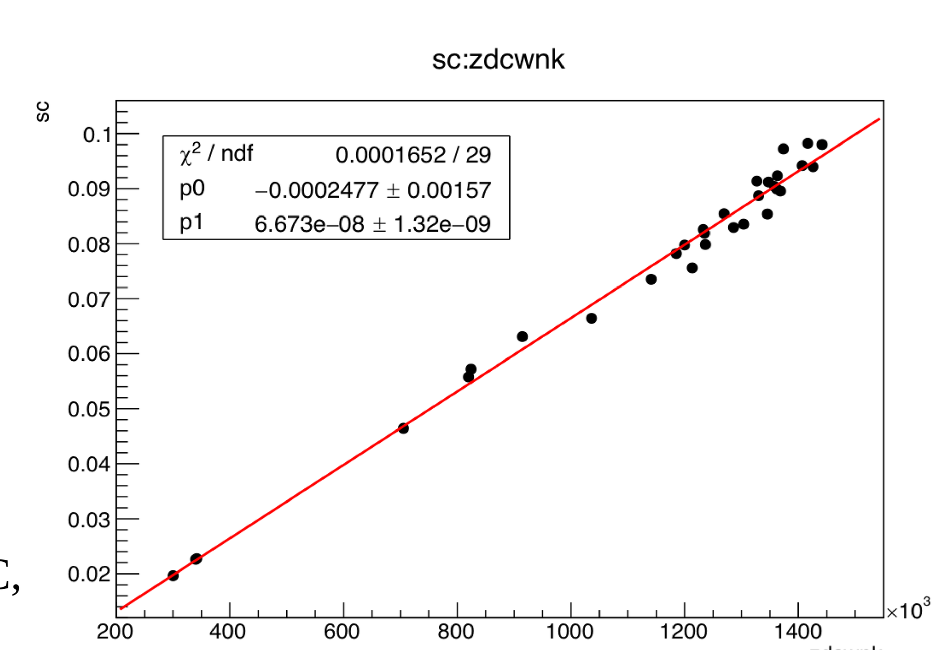
Calibration Methodology

- Calibration for Run 22 will be done following well established calibration procedures.
- Corrections are linearly proportional to SC and GL. Scaler coefficients and offsets will be found according to the equation below.

$$SC = SC_{obs} \cdot (\text{scaler} + SC_{offset})$$

- If SC_{obs} is directly linearly proportional to SC, then that scaler can be used to subtract out distortions from the tracks. In the graph on the right from the Run 17 TPC Calibration, SC is seen to be linearly proportional to the scaler 'zdcwnk', an event trigger of the detector.
- A fit will be produced for each scaler available, the fit with the smallest χ^2 will then be used.



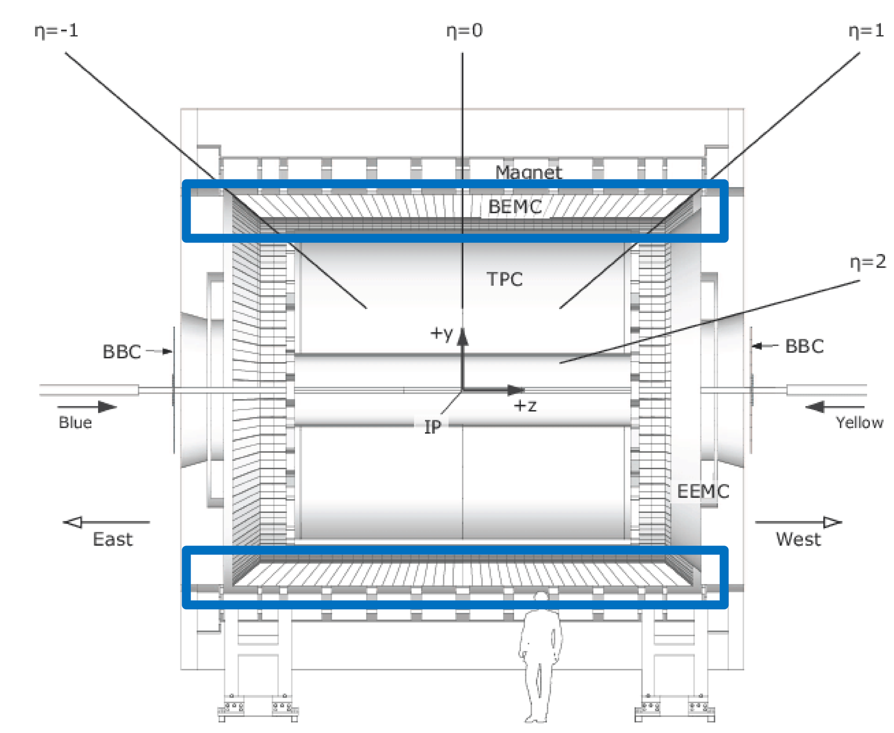
Run 17 Official TPC Calibration

- If the best fitting scaler does not produce a fit with a low χ^2, the calibration will be iterated treating the first SC as an SC_{obs}.
- This iteration process can be repeated until the fit shows a direct linear relationship with a low χ^2 value.

Seed Data and Status for Calibration

- A total of 69 runs across 5 fills will be used as the initial seed for TPC calibration.
  - Fills: 33049, 33052, 33054, 33055, 33056
  - Run Range: [23034051 - 23037015]
- Runs with around 1000 events and no reported issues in the Shift Log were picked at random from this range.
- Calibration has begun.
- All framework for the calibration is ready, and calibration efforts are moving forward.
- After the initial seed is finished calibration efforts will be expanded across the whole of Run 22.

Barrel Electromagnetic Calorimeter (BEMC)



- The BEMC comprises 4800 towers, each approximately covering an $\eta \times \phi$ region of 0.05×0.05.

$$(-1 < \eta_{BEMC} < 1 \ \& \ 0 < \phi_{BEMC} < 2\pi)$$

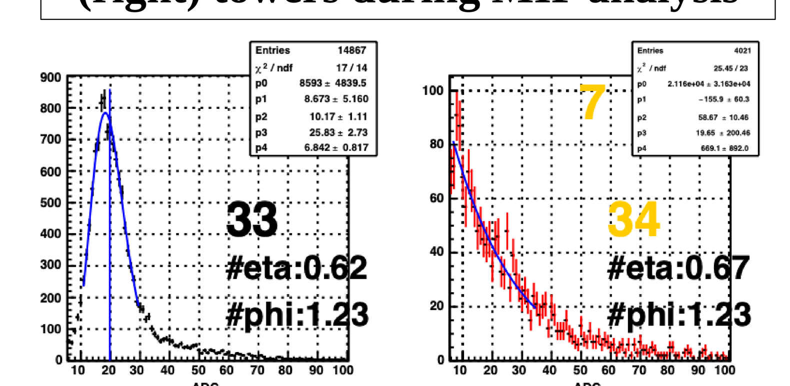
- The BEMC is used for measurements of electrons and photons and to trigger on high p_T processes such as jet/di-jets and W/Z events.
- Precise understanding of the performance of BEMC is critical to reduce systematic uncertainties in the analyses.

BEMC Calibration Method

- In this calibration, we compare the measured signal in the calorimeter by $e^{\pm}$ tracks that are measured in the TPC.
- Because there are not enough $e^{\pm}$ tracks to cover all towers in the BEMC, minimum-ionizing particles (MIPs) are used to find the tower-by-tower relative gain. The MIP spectra is analyzed by plotting the analog-to-digital converter (ADC) signal for each tower. The mean ADC is extracted from the Gaussian ⊗ Landau fit.

$$C_{rel} = \frac{0.264(1 + 0.056\eta^2)}{ADC_{MIP}\sin(\theta)}$$

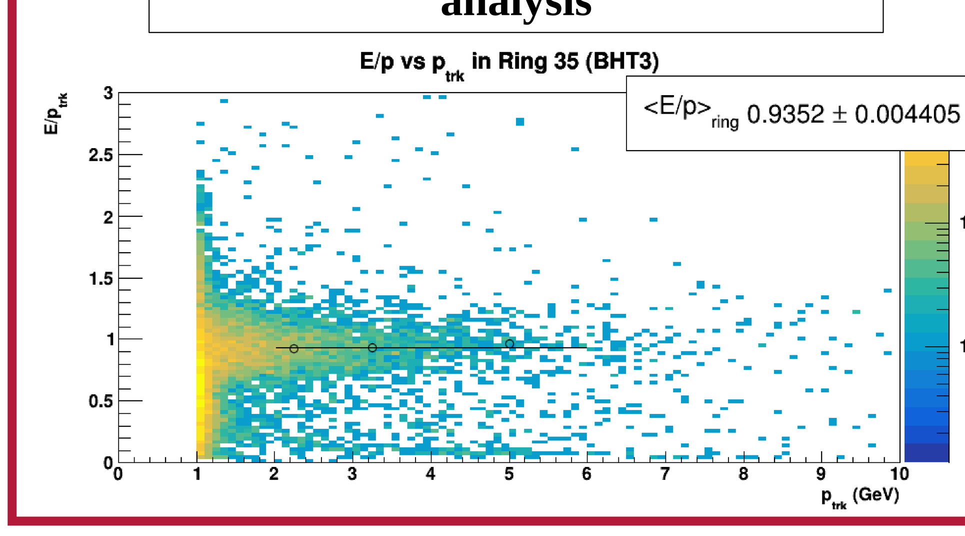
Example of good (left) and bad (right) towers during MIP analysis



- The MIP analysis probes the variation in the gain among individual towers.
- All towers are grouped into 40 η- rings (120 towers per ring) each covering 0.05 in η for the electron analysis.
- The averaged energy deposited into all towers in one ring is compared with the momentum measurement from the TPC in order to determine the absolute scale of the calibration.
- The $\langle E/p \rangle_{ring}$ value is measured from the mean value of the fitted Gaussian + Exponential distribution and is used to calculate the absolute gain.
- The systematic uncertainties for various parameter dependences are analyzed during the electron analysis.

$$C_{abs} = \frac{C_{rel}}{\langle E/p \rangle_{ring}}$$

Example of $< E/p >_{ring}$ measurement during Electron analysis



BEMC Calibration Status and Beyond

- The procedure for Run 2022 calibration will include methods that were used during Runs 2015 and 2017:
  - Similar selection criteria for MIPs (i.e., vertex based, tracking based, and pedestal) and for Electron tracks (i.e., vertex based, tracking based, pedestal, trigger based, electron PID, and tower clustering).
  - Vetoing both towers and jet patches that fired the corresponding trigger, to remove trigger threshold effects.
  - In Run 2017, a fill-dependent space charge anomaly was observed, resulting in an asymmetric N_{charge} distribution and high charge dependence in BEMC calibration. In order to investigate this behavior for Run 2022, the TPC and BEMC calibration will be done simultaneously.
- This calibration will work into the thesis topic: Measurement of W^+/W^- Cross-Section Ratios in pp Collisions at 508 GeV at RHIC.

Example of Tower and Jet Patch Veto Scheme from Run 2017