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BEMC (Barrel Electromagnetic Calorimeter) Calibration for STAR Run 2022

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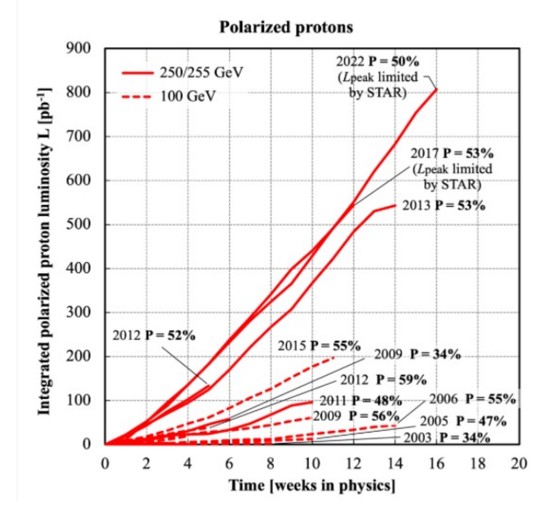
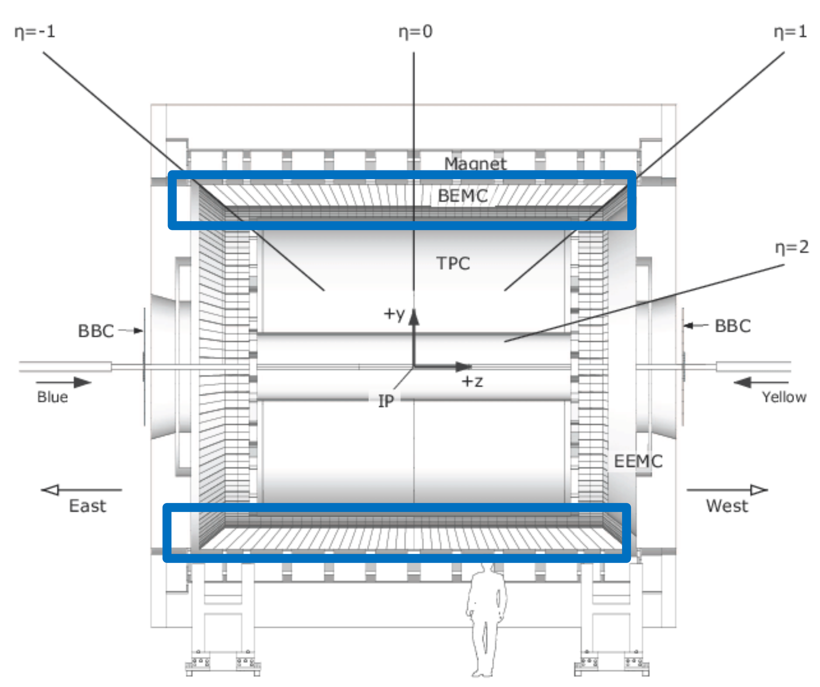
Run22 BEMC Calibration

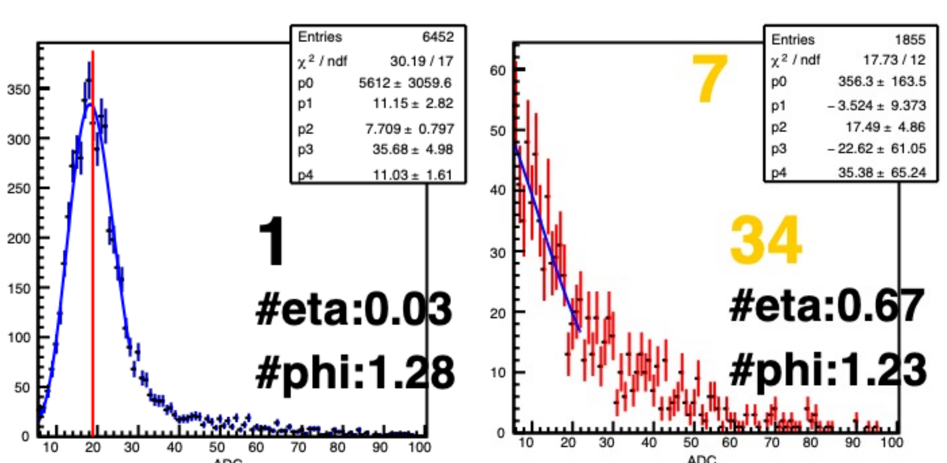
- During STAR Run 2022, proton beams were collided at a center-of-mass energy, $\sqrt{s} = 508\ GeV$.
- Data set: Run22 pp508 physics preview production that contains 20% of st_physics stream from all runs.
- This sample contains a suboptimal (Pass03) Space Charge calibration (see TPC Calibration poster).





- 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 these analyses.

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



- The ideal candidates for this calibration are $e^{\pm}$ tracks. However, STAR's kinematics doesn't give us enough $e^{\pm}$ tracks to cover all towers in the BEMC.
- Because of this reason, the BEMC calibration is split into two parts:
  1. Relative variations of tower gain are studied based on minimum-ionizing particles (MIPs). They are abundant in STAR kinematics. The tower gain can be extracted from the expected energy deposit in each tower via the following expression:

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

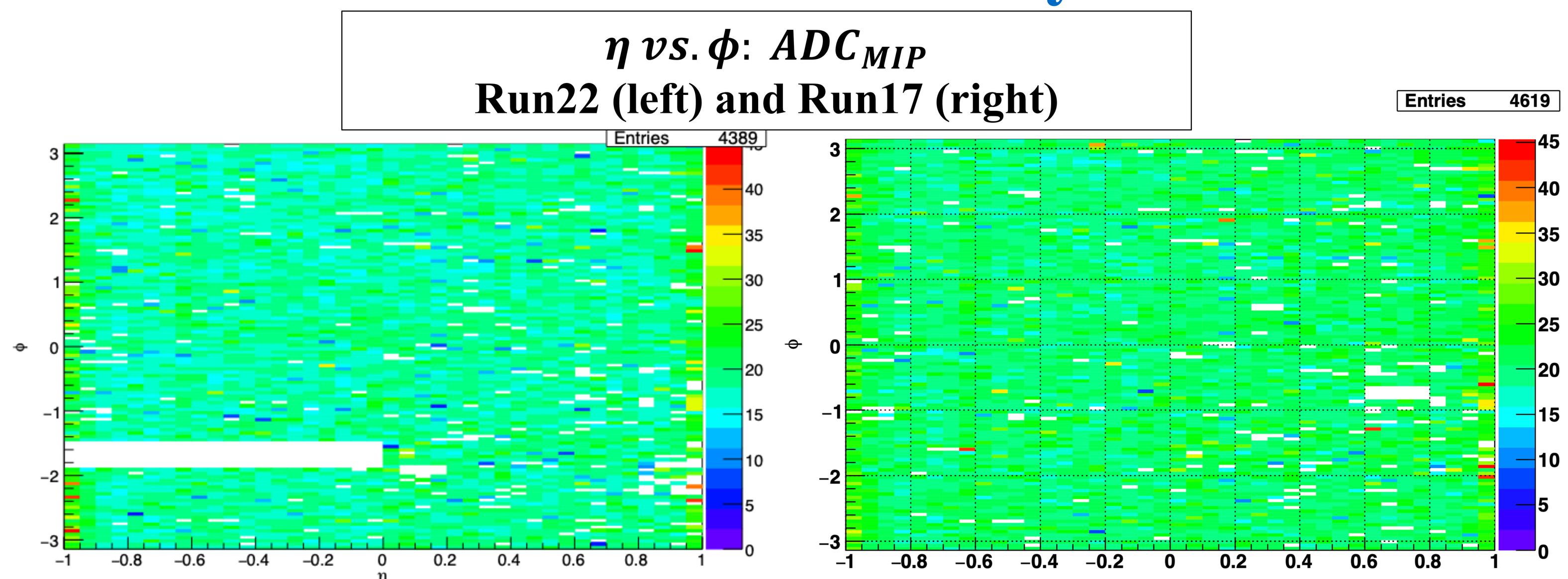
     where $C_{rel} * ADC_{MIP}$ (ADC: Analog-to Digital Conversion signal) is the expected energy deposit in a tower at η due to MIPs. ($\theta =$ polar angel, $\eta =$ pseudorapidity)
  2. Electron candidates in the towers at the same η-ring are used to obtain ring-wise absolute gain:

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

- During the MIP analysis, MIP spectra is analyzed by plotting the ADC signal for each tower. Each distribution is fitted with a Gaussian*Landau fit and the mean from the fit is used as the ADC_{MIP} value for the relative gain equation.
- Each tower is given a status of good, bad, and empty based on the quality of the distribution and how well the fit quality is to that distribution.
- Triggering: Barrel High Tower (BHT) and Jet-Path (JP) triggers.
- Selection Cuts:
  - Vertex: Vertex Rank > 10^6, $|z_{vtx}| < 30$ cm
  - Track: Only one track per tower per event, tracks must enter and exit the same tower, $p_{trk} > 1$ GeV
  - Tower: $x_{ADC} - x_{ped} > 1.5\sigma(x_{ped})$, $x_{ADC} - x_{ped} < 2\sigma(x_{ped})$ for surrounding towers.

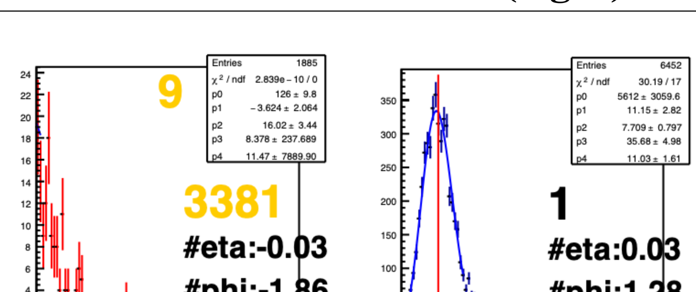
Initial MIP Study

η vs. ϕ: ADC_{MIP}
Run22 (left) and Run17 (right)

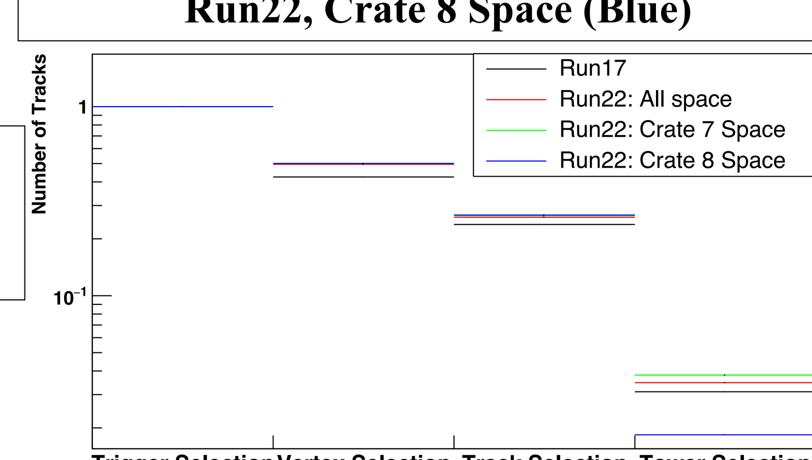


- Initial MIP study for Run22 was performed on the preview sample based on parameters optimized for Run17.
- Run22's plot shows low track counts and no sign of MIPs for towers in $\eta < 0$ and $-1.91 < \phi < -1.44$ that region that passes all selection criteria.
- The cause of the low MIP yield in this region is currently under investigation.

Tower from Crate 8 that shows low track count and no MIP peak (left) compared to tower outside of Crate 8 (right)



Comparing 4 regions/samples for Selection Cut Efficiency in MIP Selection Criteria :
Run17, All Space (Black)
Run22, All Space (Red)
Run22, Crate 7 Space (Green)
Run22, Crate 8 Space (Blue)

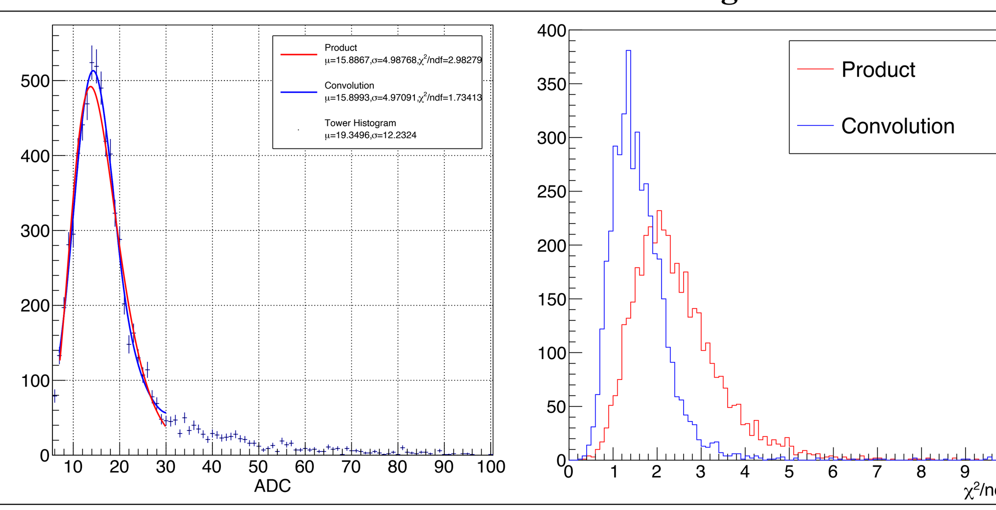


- In the plot above, the efficiency in the MIP analysis selection cuts shows that the track output from Crate 8 is significantly less at the tower selection compared to the 3 other samples.

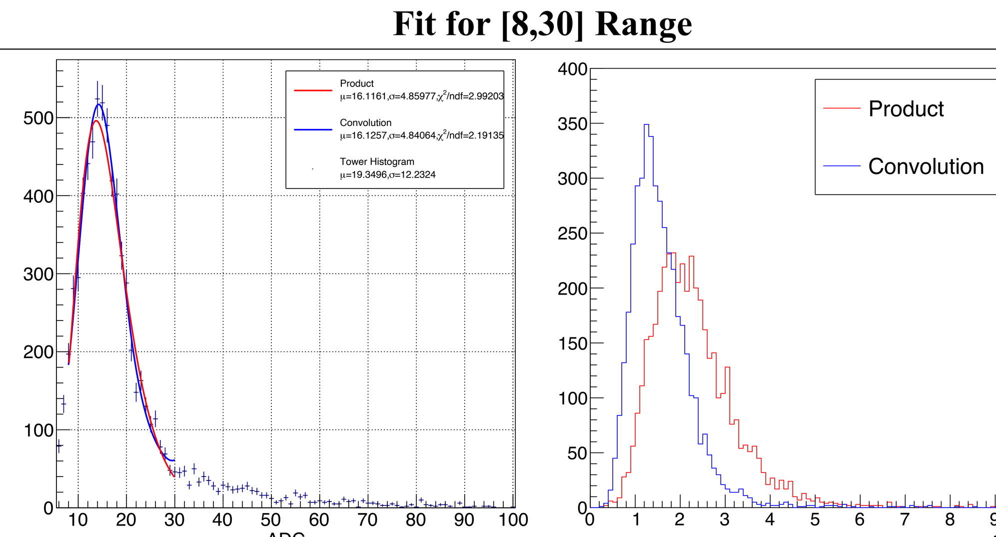
MIP Peak Fit Study

- Gaussian* Landau distribution was used to fit each MIP peak in all good towers. However, there is no physical motivation to use the product fit. Gaussian⊗Landau (Gaussian convoluted by a Landau) distribution can be used alternatively to check the stability of resolution to the fit and relative gains.
- In this study, good towers were fitted with the two types of distributions mentioned above. This study used 5 fixed fitting ranges to analyze the fit-range dependence on the resulting MIP peak mean ADC, starting with the nominal range [7,30]. The upper bound stayed fixed for two ranges, [8,30] and [6,30]. The lower stayed fixed for the last two ranges, [7,25] and [7,40].
- As the upper bound increase, the convolution fit showed significant improvement based on the

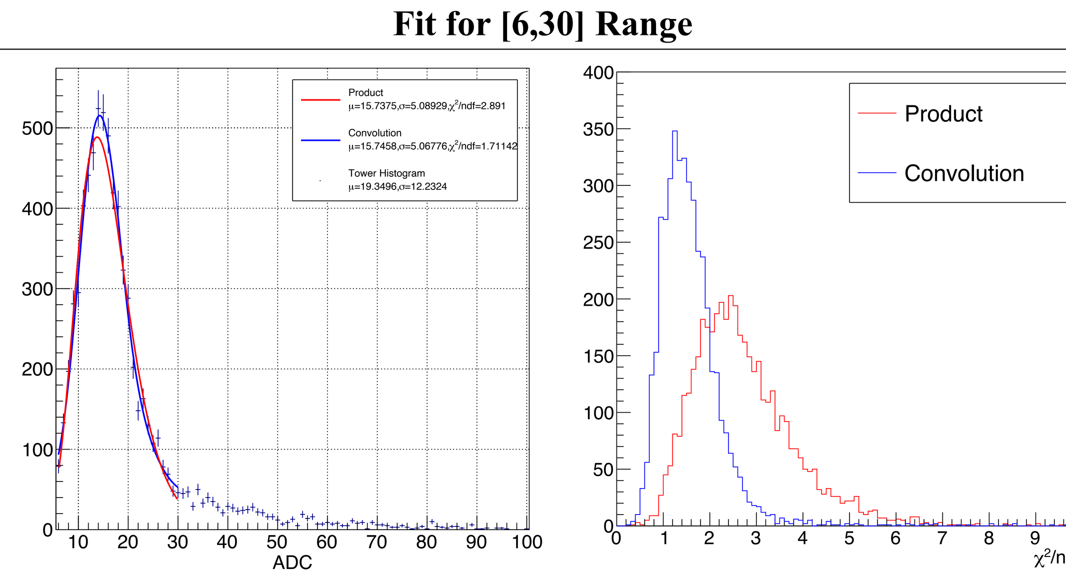
Fit Distributions (Product [Red], Convolution [Blue]) in Tower Histogram (left) and Reduced χ^2 Distribution for each Fit for Nominal Range



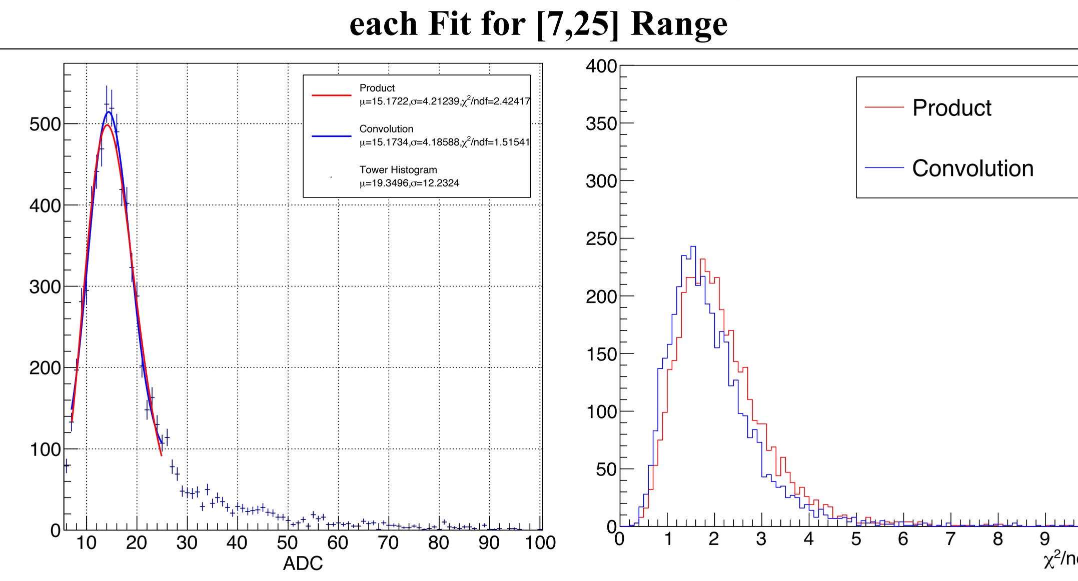
Fit Distributions (Product [Red], Convolution [Blue]) in Tower Histogram(left) and Reduced χ^2 Distribution for each Fit for [8,30] Range



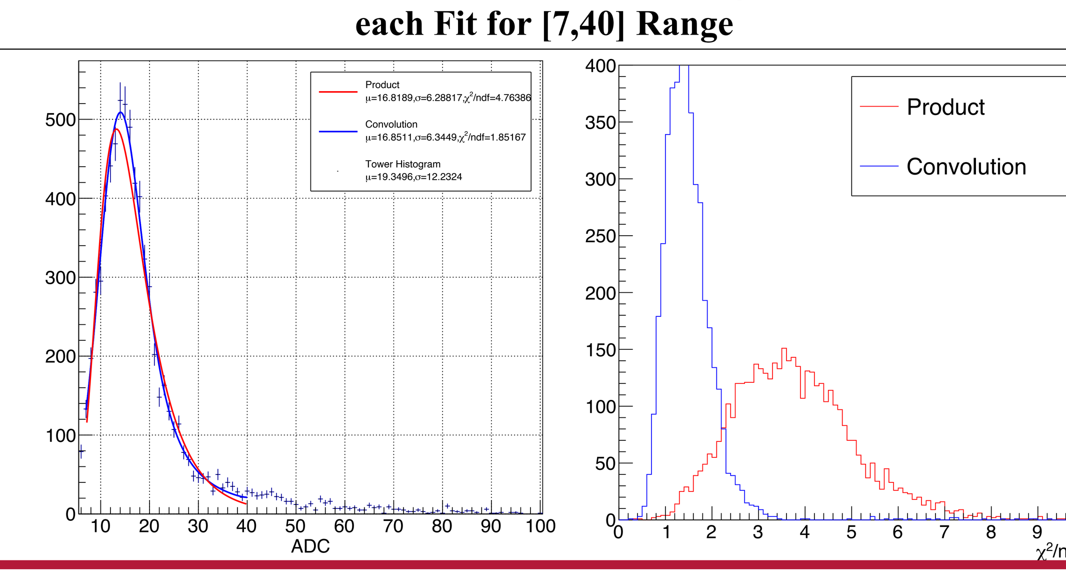
Fit Distributions (Product [Red], Convolution [Blue]) in Tower Histogram(left) and Reduced χ^2 Distribution for each Fit for [6,30] Range



Fit Distributions (Product [Red], Convolution [Blue]) in Tower Histogram(left) and Reduced χ^2 Distribution for each Fit for [7,25] Range



Fit Distributions (Product [Red], Convolution [Blue]) in Tower Histogram (left) and Reduced χ^2 Distribution for each Fit for [7,40] Range



Summary and Next Steps

- This calibration aims to find the relative and absolute gains for each tower in the calorimeter through analyzing MIPs and electron tracks, respectively.
- The MIP analysis was done using a suboptimal value of space charge provided from the TPC calibration. The behavior of the Crate 8 towers could be related to the pedestal values and pedestal width values from the database, or some selection cut in the source code.
- The fit study showed no significant lower-limit dependence from both convolution and product fits. However, a significant improvement was observed with the convolution fit when increasing the upper limit up to 40 ADC.
- Further study will be performed with ADC_{MIP} obtained from the convolution fits.
- Next steps include:
  1. Repeat the MIP study on a small sample using the latest space charge correction to investigate improvements with better tracking.
  2. Study the corrected space charge from the TPC calibration by plotting N+/N- vs. p_T for any charged particles (pions, electrons, and tracks without any PID selection, for example, were used for the Run17 analysis). This is done as a cross-check to see if the TPC calibration corrected the fill-by-fill dependence.
  3. Perform electron analysis and analyze the systematic uncertainties.