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Stability of the Gains of the STAR Endcap Calorimeter from 2009 to 2012

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Abstract

The Solenoidal Tracker at RHIC (STAR) experiment, based at Brookhaven National Laboratory's Relativistic Heavy Ion Collider, uses polarized-proton collisions to investigate sea quark and gluon contributions to the known proton spin. The STAR detector's Endcap Electromagnetic Calorimeter (EEMC) is of particular interest in this experiment because it covers a kinematic region which is sensitive to gluons carrying a low fraction of the proton momentum, where the gluon spin is almost entirely unconstrained. The EEMC is located in the intermediate pseudorapidity range, $1 < \eta < 2$, and measures the electromagnetic energy of particles produced by the collisions using a lead-scintillator sampling calorimeter. The calorimeter consists of several layers that include pre-shower, shower maximum, tower, and post-shower detectors. In these detectors, the energy gains, which convert a measured signal into an energy deposition, have been determined using data taken from the years, 2009, 2011, and 2012. A comparison of the gains from the three years will be presented.

Background

RHIC is the only accelerator in the world capable of colliding high-energy beams of polarized protons. STAR uses these collisions to explore the origin of the intrinsic angular momentum of the proton, known as its "spin". Since a proton is made of two up-quarks and a down-quark, it might seem reasonable to assume that the spin of the proton is equivalent to the sum of the spin components of the individual quarks. Interestingly, previous scattering experiments show that the spin contribution of the quarks inside the proton are only 30% of the total proton spin. In order to explore the remaining fraction of the proton's spin, other factors such as the orbital angular momentum and the spins of the gluons must be taken into consideration. This study using the EEMC concentrates on the spin contributions from the gluons.

$$\text{Total proton spin} = \frac{1}{2} = \frac{1}{2}\Sigma_q + \Sigma_g + L_{q+g}$$

- Angular Momentum Contribution (L_{q+g})
- Gluon Spin Contribution (Σ_g)
- Quark and Anti-quark Spin Contribution ($\frac{1}{2}\Sigma_q$)

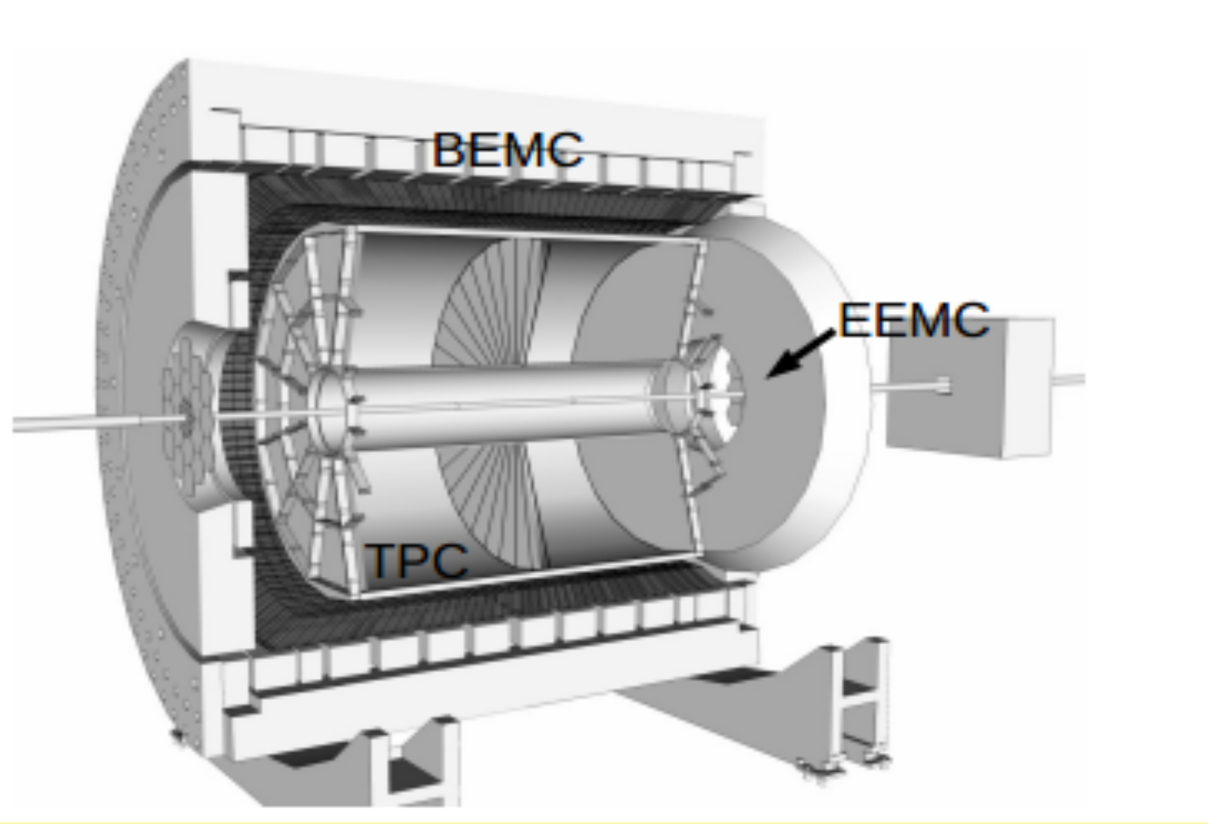

Fig. 1 Model of the STAR detector showing the EEMC

EEMC Calibration

- The EEMC is made up of Pre and Post Shower tiles, Towers, and SMD strips. This project reports the calibration of Pre, Post Shower and Tower tiles, 2880 in total.
- The EEMC is calibrated using minimum ionizing particles (MIPs). These particles pass through the detector and deposit energy in the scintillator detectors. The light in a scintillator produces an electric pulse in the photomultiplier tubes that is then digitized in an ADC.

Pre and Post-Shower Detectors

- For Pre-Shower 1, 2 and Post-Showers, the equation used to calculate the detector tile gains is:

$$Gain = \frac{Mean * \tanh(\eta)}{1layer * 5mm * dE/dx}$$

- The "Mean" is the mean of the distribution of ADC outputs from the scintillator tile. The mean is determined from a Landau function fitted to the ADC spectrum.
- The dE/dx is the reference value for the mean energy per unit length deposited in this specific scintillator.
- Any channels that the program failed to fit automatically were fitted manually.

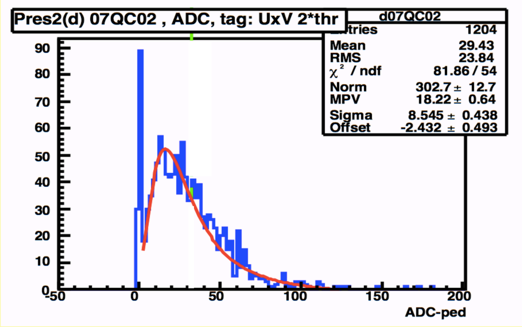

Fig. 2 Example of a fitted histogram. The red line shows the fitted landau curve.

- Gains of different years are compared with each other, to help understand the changes in the EEMC.

	2011/2009 Gain Ratios	2012/2011 Gain Ratio
Pre-Shower 1	1.014 ± 0.003	0.979 ± 0.003
Pre-Shower 2	1.001 ± 0.003	0.981 ± 0.003
Post-Shower	1.025 ± 0.004	0.987 ± 0.003
Towers	1.030 ± 0.002	1.086 ± 0.002

Table. 1 Table showing the preliminary results of the gain ratios of Pre-Showers, Post-Shower and Towers over the years 2009, 2011 and 2012

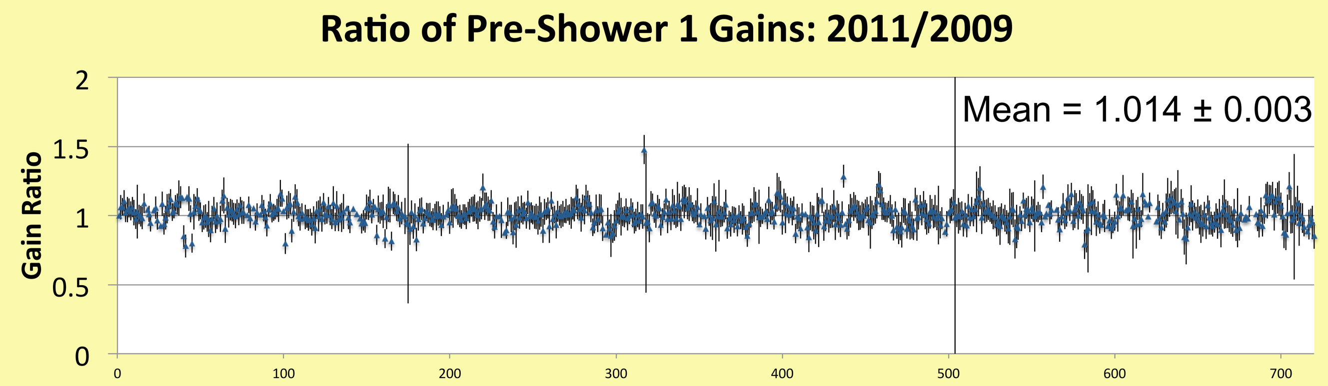

Fig. 3 Plot of the 2011/2009 Pre-Shower 1 gains against tile number.

Tower Detectors

The equation used to calculate the gains of the Towers is:

$$Gain = \frac{Mean * \tanh(\eta)}{24layers * 5mm * dE/dx}$$

- In the case of the towers, the "Mean" in the equation is obtained as the mean of the distribution of ADC values observed for each tower.

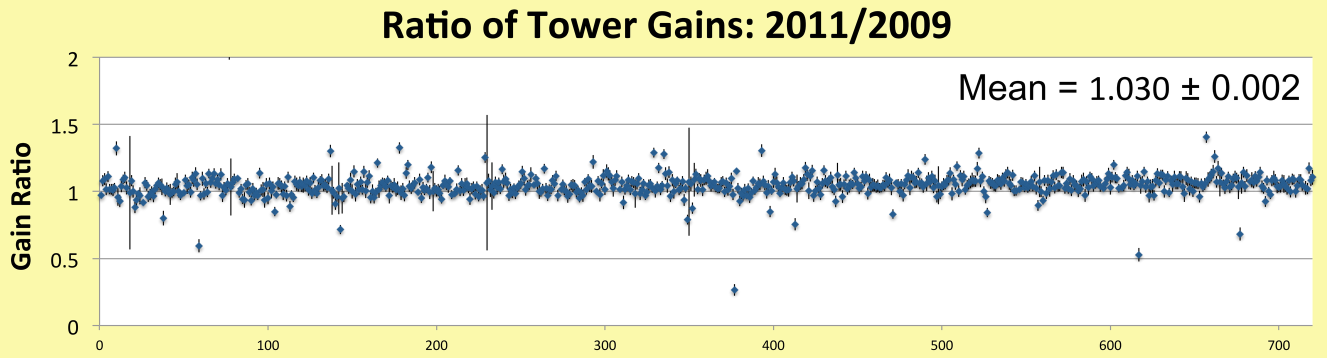

Fig. 4 Plot of the 2011/2009 Tower gains against tile number.

- Since the towers are the detectors that determine the energy of the photons, further tests were carried out to observe the sensitivity of the gains.

1. For a range of 36 sample towers, a study was done to determine the change in *mean* when it is obtained:

- From the mean determined by fitting a Gaussian + Landau function.
- From the mean of the distribution of ADC values.

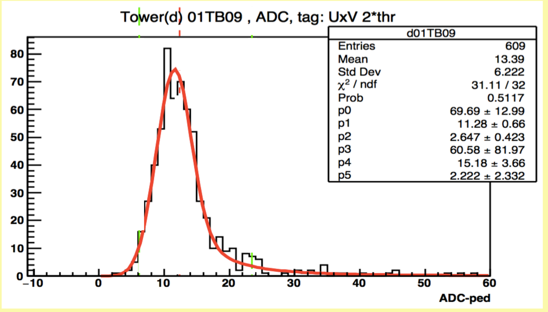

Fig. 5 Example of a fitted tower histogram. The red line shows the fitted Landau + Gaussian curve.

Tower Detectors (continued)

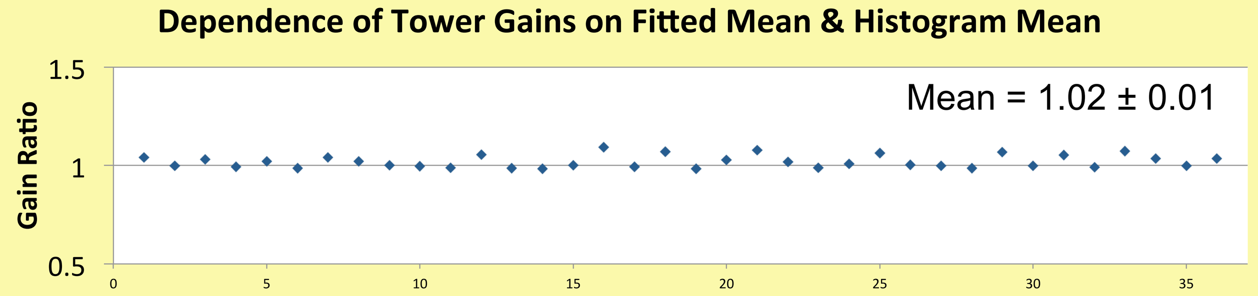

Fig. 6 Ratio of (Fitted Mean/ Histogram Mean) Tower gains for 36 sample histograms.

From Fig. 6, it can be observed that gains obtained by the two different methods agree to within 2%.

2. Studies were carried out to investigate the effect on the gain when MIP selection cuts are varied:

a. The MIP-window range used to identify a MIP was changed from [0.5 – 2.0] to [0.2 – 2.4], the cut is loosened.

b. The minimum ADC threshold for a MIP is changed from 12 to 6

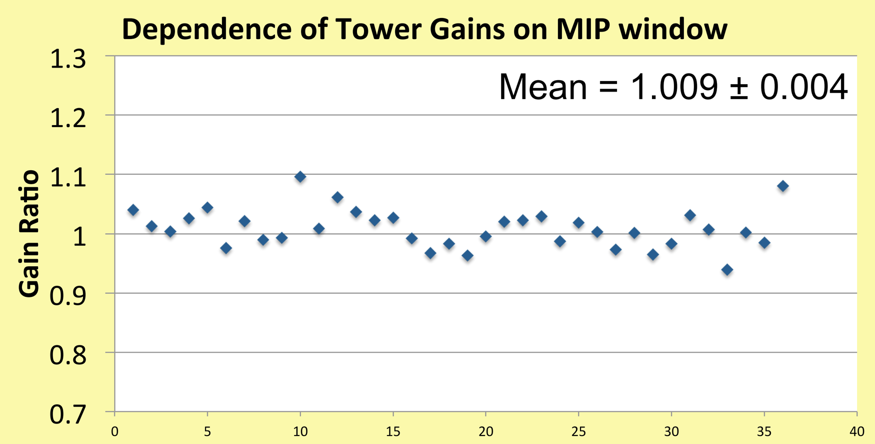

Fig. 7 Ratio of [0.2 – 2.4] MIP window gain to [0.5 – 2.0] MIP window gain.

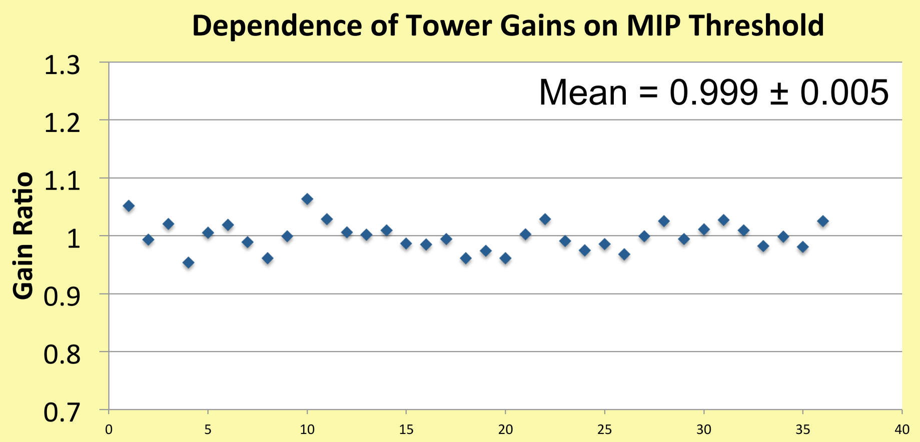

Fig. 8 Ratio of Threshold 12 gain to Threshold 6 gain.

From Figs. 7 and 8, it is evident that the alterations in the various cuts changed the gain very little.

Summary of Results

- Preliminary results show that the ratios of the gains for Pre, Post showers and Towers were relatively stable over the years 2009, 2011 and 2012 except for the 2012/2011 ratio for the Towers, in which case it changed by 8%.
- The gains of the tower detectors changed by an average of 2% when the fitted Landau + Gaussian function was used to extract the mean.
- Changes in the parameters in the identification of a MIP changed only the number of events, and yielded little or no change to the gain of the tower detectors .

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