Stability of the Gains of the STAR Endcap Calorimeter

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Abstract

The Solenoidal Tracker at RHIC (STAR) experiment, located at Brookhaven National Laboratory's Relativistic Heavy Ion Collider, uses polarized-proton collisions to investigate sea quark and gluon contributions to the 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 poorly constrained. The EEMC is located in the intermediate pseudorapidity range, $1 < \eta < 2$, and as a lead-scintillator sampling calorimeter, measures the electromagnetic energy of particles produced in the polarized-proton collisions. The scintillator elements in the calorimeter consist of segments in which there are the 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 year 2012. The sensitivities of the tower energy gains to beam intensity and running time were studied. The results from these sensitivity studies are reported here.

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 one 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 these valence quarks inside the proton is only approximately 30% of the total proton spin. In order to explore the origins of the remaining fraction of the proton's spin, other factors such as the orbital angular momentum and the spins of the gluons and the sea quarks must be taken into consideration. The project of which this study is a part uses the EEMC to concentrate 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
- Gluon Spin Contribution
- Quark and Anti-quark Spin Contribution

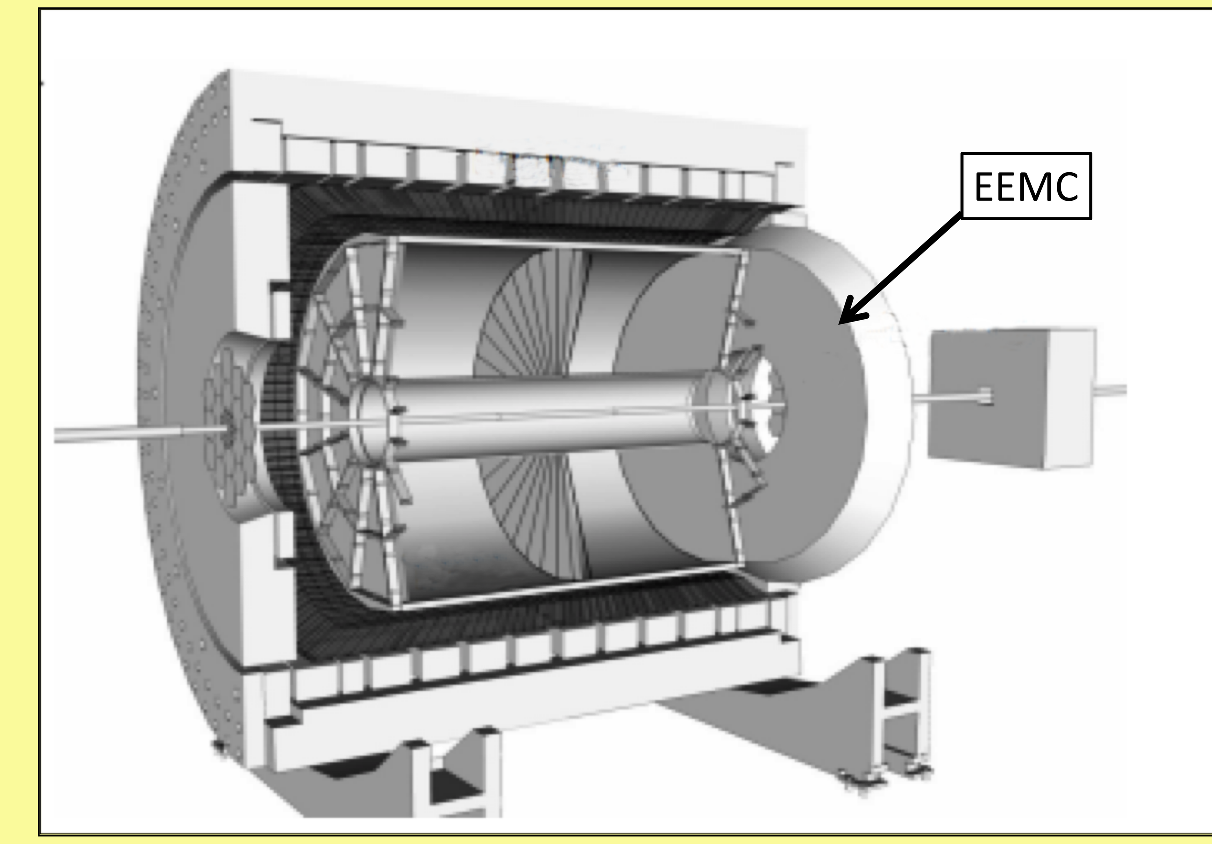

Fig. 1 Model of the STAR detector showing the EEMC

EEMC Calibration

- The EEMC is made up of 6912 Shower Maximum Detectors (SMD) strips and 720 each of Pre-Shower 1, Pre-Shower 2, Post-Shower tiles, and Towers.
- It 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 Analog to Digital Converter (ADC).
- The ADC values are converted to the energy by a conversion factor of each detector called a 'gain'.
- I studied the rate dependence and time dependence of the 2012 tower gains using 500 GeV data.

Tower Detectors

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

$$Gain = \frac{Mean \times \tanh(\eta) \times SamplingFrequency}{24layers \times 4mm \times dE/dx}$$

- 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. 2 shows a typical ADC spectrum for towers.
- Since the towers are the detectors that determine the energy of the photons, tests were carried out to study the sensitivity of the gains to time and rate of protons in the beam.

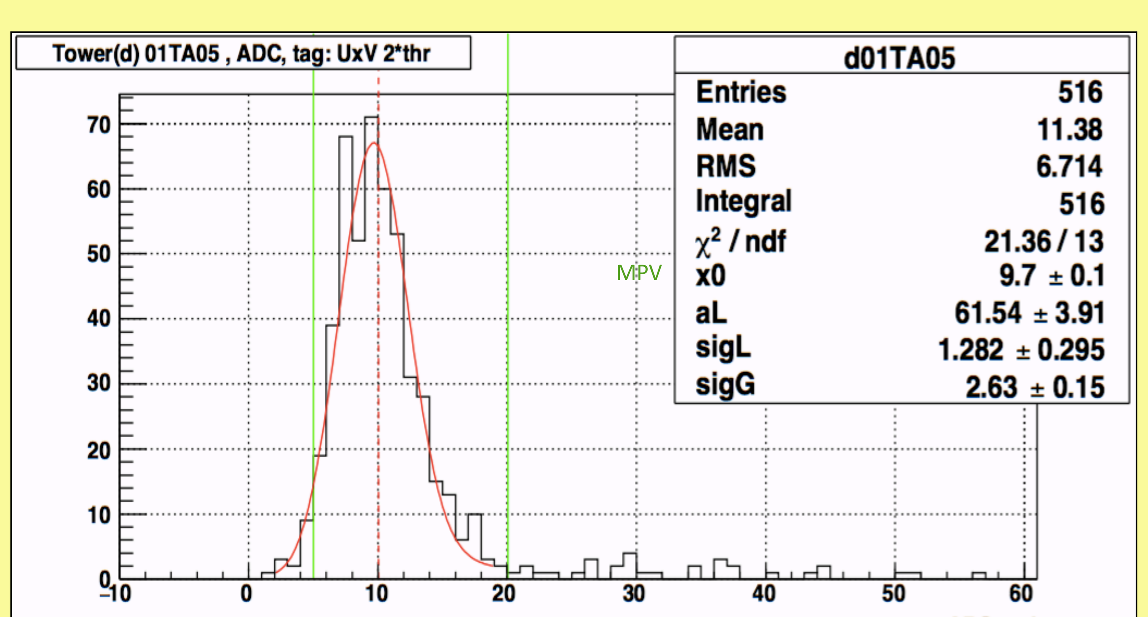

Fig. 2 A typical ADC distribution in a tower. A special function (Gaussian + Landau) was fitted to this. The location of the peak of this fit is called the MPV (Most Probable Value).

Time Dependence

- In this context, time is considered to be the number of days since the start of data taking.
- We have observed a deterioration of tower gains as a function of time (Fig 3). This may be a result of radiation damage to the detector.

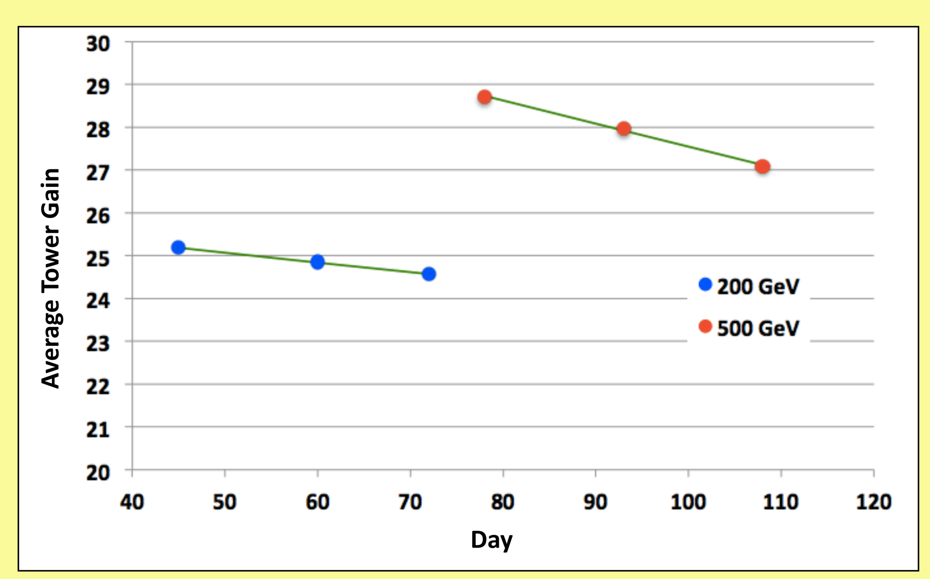

Fig. 3 Plot showing the downward trend of the tower gains as time increases. The jump around day 80 (between 200GeV and 500GeV) is due to the high voltage change of the photomultiplier tubes to account for losses in gain.

Rate Dependence

- We investigated the tower gain dependence as a function of the rate, or beam intensity (Fig.4). The rate is defined as the number of protons in each beam at any given time.

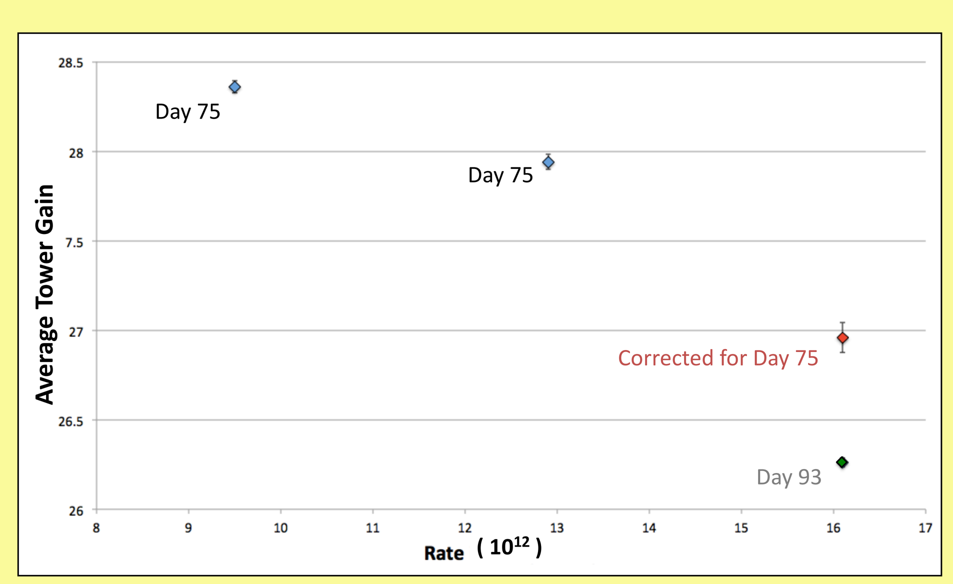

Fig. 4 Plot showing the downward trend of the tower gains as a function of the rate. The rightmost green data point was taken on day 93 whereas the others were taken on day 75. A correction for the time dependence was done on this green point and is shown in red.

- The rightmost point (day 93) was produced using minimum bias triggers while the other two (day 75) were made using a collection of many types of triggers (physics triggers). It is not clear if using the physics triggers introduces a bias on the calibration.

- The decrease in the measured gain that appears correlated with increased collision rate may be due to a decrease in the PMT high voltage that is caused by higher currents in the PMTs at higher rates.
- The MPV (Fig. 2) and the tail (Fig. 6) of tower ADC spectra also show a similar trend to the gain as a function of rate, as shown in Fig. 5 & 7.

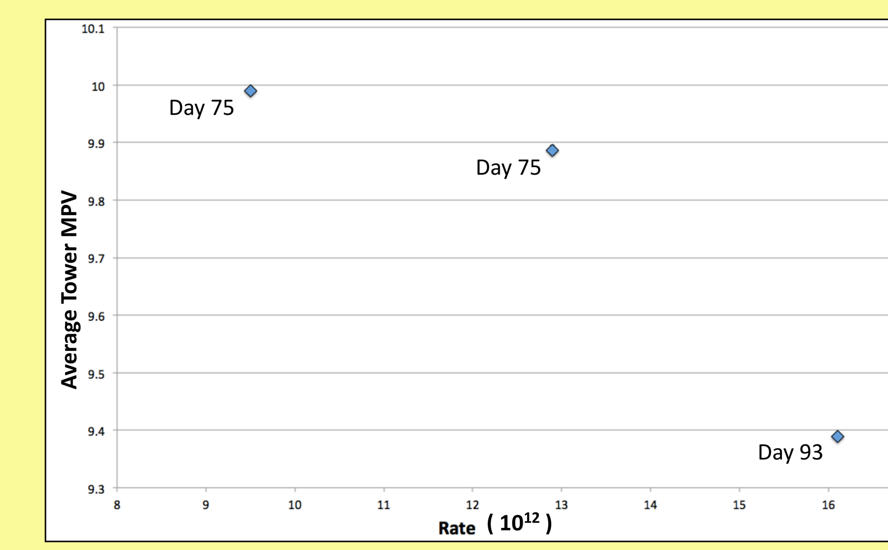

Fig. 5 Plot showing the downward slope of the MPV of the ADC spectrum as a function of rate. The rightmost data point (day 93) is identical to the one in Fig. 3. No time dependence correction was applied to this point.

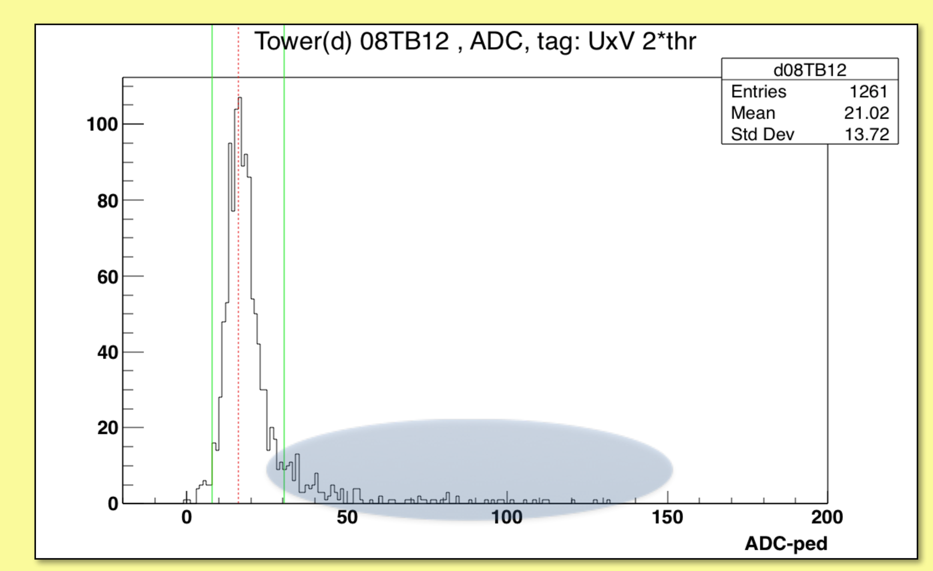

Fig. 6 Plot of a typical tower distribution with the events in the tail highlighted. The presence of these events means that higher energies are deposited in the detector. The number of events in the tail in the histogram was obtained by fitting a Gaussian to the peak and counting all events from 2.5 standard deviations onward from the peak of the fit.

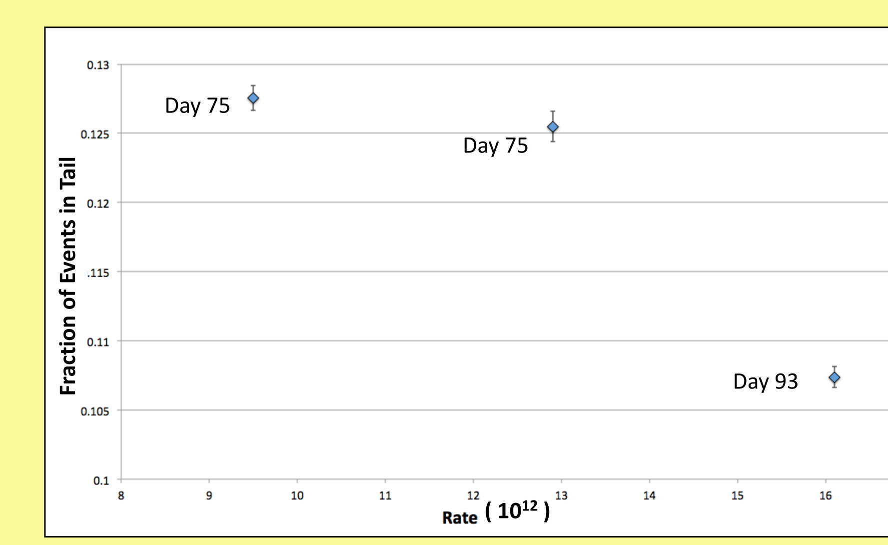

Fig. 7 Plot showing the number of events in the tail of the distribution as a function of the rate. The point for day 93 was not corrected for the time dependence.

Summary of Results

- Preliminary results show that the gain decreases as a function of time.
- The gain, MPV and tail all decrease as a function of the rate.
- How this affects the overall calibration has to be studied and any corrections made.

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