STAR Experiment and Forward Upgrade at RHIC

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A proton is a positively charged particle made of three quarks, two up quarks and one down quark, held together by gluons. One major goal of the STAR Experiment is to understand the gluon contribution to the spin of the proton. The spin of a particle is similar to the angular momentum of a spinning top. A particle has a distinct value for its intrinsic spin depending on what kind of particle it is, for the proton this value is ½. The total spin (½) is a result of the angular momentum of the constituents of the proton: the spin of the quarks and gluons, and their orbital angular momenta as they move through space (Equation 1). In order to get a precise and accurate measurement of the gluon contribution, protons are collided at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Lab in New York to identify an imbalance in the production of particles in the different spin states of the colliding protons (parallel or antiparallel to the momentum). At RHIC the STAR detector (see Fig. 1), and for our group in particular, the Endcap Electromagnetic Calorimeter (EEMC), is used to identify photons from a short lived particle (π^0) produced in the collisions in order to determine the π^0 count as a function of proton spin state.

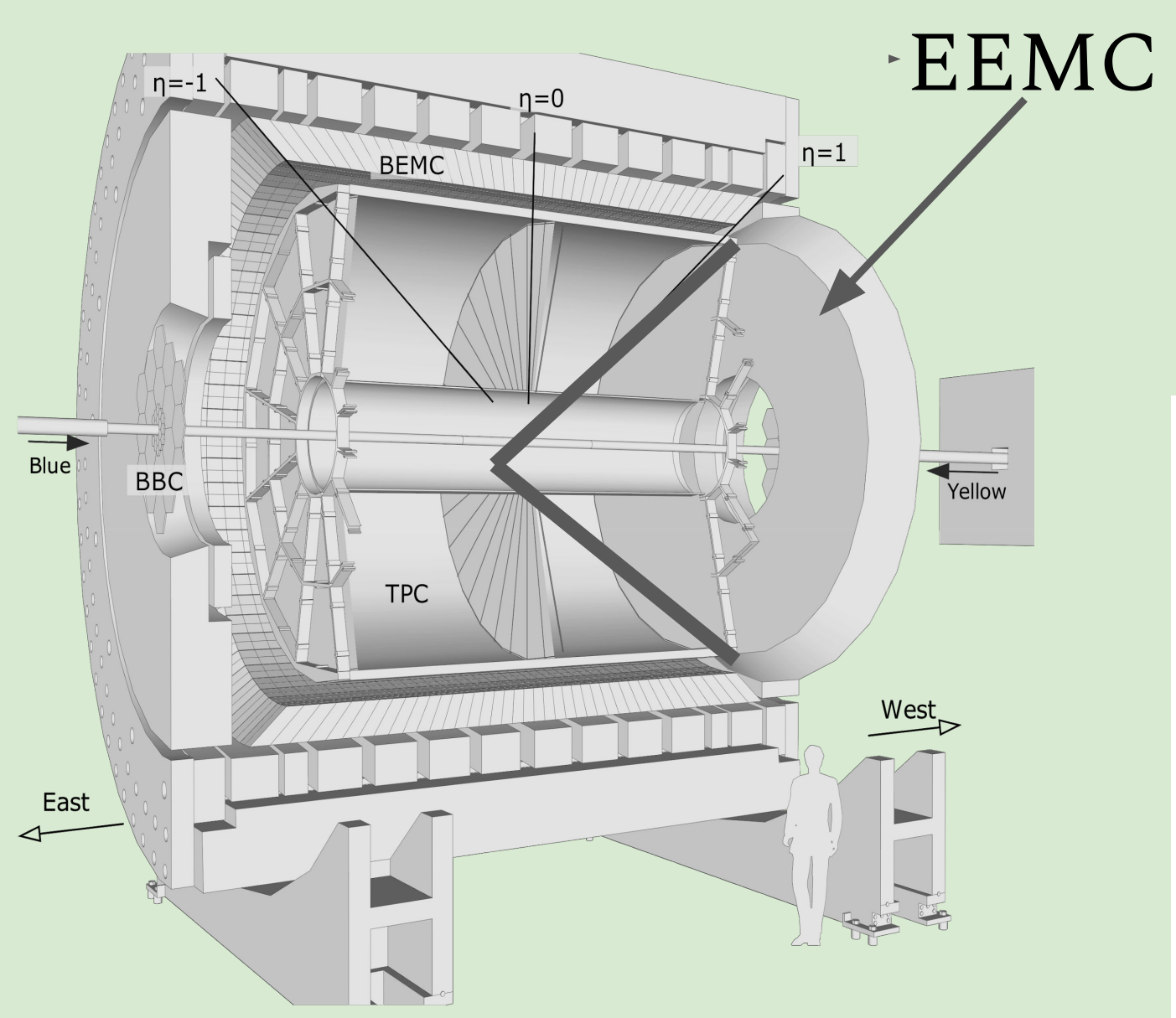

Fig 1 (left): The three story STAR detector. It is capable of measuring particles' energy and momentum in several regions. The EEMC region (enclosed by the black lines) is what we're interested in.

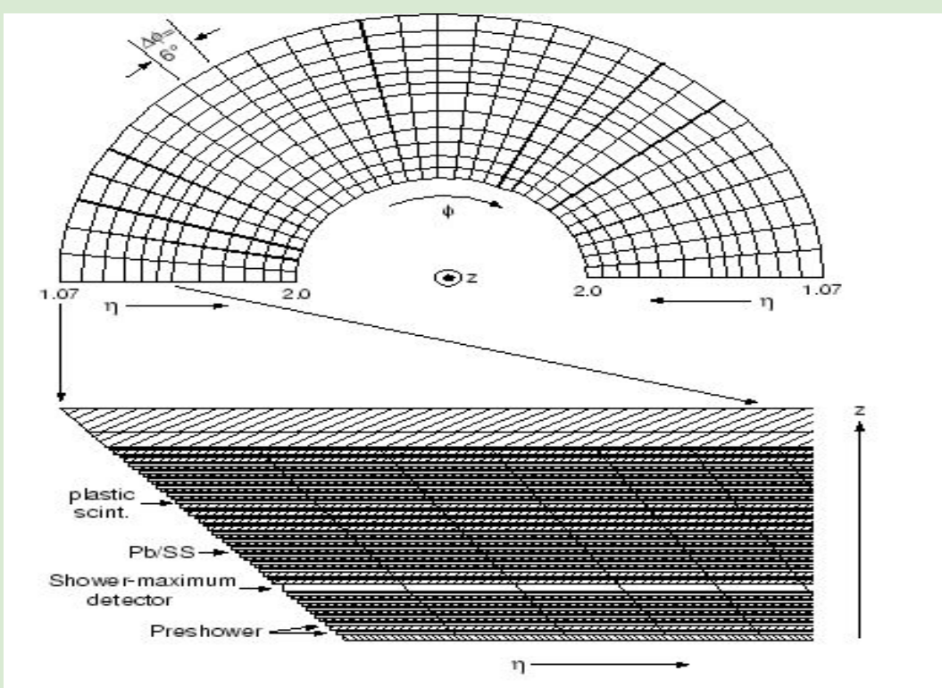

Fig 2 (left): Towers of the EEMC. A tower is a sector of the EEMC that consists of lead+scintillator layers. In total, there are 720 towers in the EEMC. Half are shown here.

Equation 1 (right): The formula for the spin of a proton contains contributions from the spins of the quarks, gluons, and their respective orbital angular momentum.

$$\frac{1}{2}=\frac{1}{2}\Sigma_q+\Sigma_g+L_{q+g}$$

π^0 Reconstruction and A_{LL}

- The π^0 decays into two photons in 10^{-16} seconds (Fig 3).
- The EEMC measures the energy and momentum of the photon.
- Using the photon's energy and the angle between them, the mass (invariant mass) of the particle that produced the photons is calculated using Equation 2.
- Figure 4 shows the histogram of the invariant mass distribution.
- The plots are fitted with a skewed Gaussian (representing the π^0) and a background function that accounts for photons that might not have come from the same π^0
- The π^0 function is then integrated to find the number of π^0s produced which is used to calculate the π^0 asymmetry (A_{LL}) in Equation 3.
- The A_{LL} values are used by theorists to determine the gluon contribution to the spin of the proton..

$$\pi^0 \rightarrow \gamma + \gamma$$

Fig. 3: The π^0 (mass: 135 MeV/c^2) immediately (10^{-16}s) decays into two photons.

$$M_{\gamma\gamma} = (E_1+E_2)\cdot\sqrt{(1-\left(\frac{E_1-E_2}{E_1+E_2}\right)^2}\sin\frac{\theta}{2}$$

Equation 2 (above): Formula for calculating the invariant mass of the decaying particle..

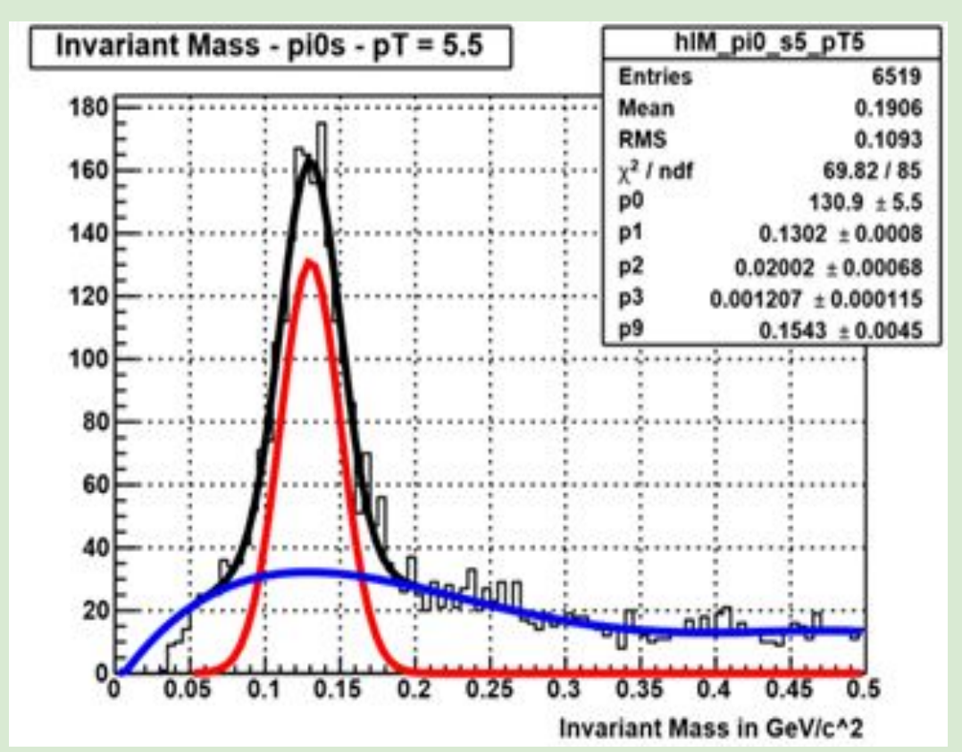

Fig 4 (above): Fitted invariant mass plot. The blue line is a background function which is subtracted from the black function, yielding the π^0 peak (red).

$$A_{LL}=\frac{\Sigma_{runs}P_YP_B(N^{++}-R_3N^{+-})}{\Sigma_{runs}P_Y^2P_B^2\,(N^{++}+R_3N^{+-})}$$

Equation 3 (above): The formula for A_{LL} uses the number of π^0s and the spin and polarization of the beams.

Run 12 Quality Assurance (QA)

- We are just about done analyzing the 2012 p+p data, so quality assurance is needed to make sure we selected good runs.
- A C++ script was used to analyze key-parameters of the π^0 reconstruction, like number of towers hit, π^0 mass, and signal fraction.
- Runs were flagged for exceeding a 2σ significance for each of the three variables and removed on a case by case basis.
- A fill-by-fill QA was executed to get a broader view of the data rather than individual runs in each fill.
- The QA was used to determine any outlying fills that did not follow the trend of the rest of the data.
- The declining trend shown in the graph is due to the change in the gains of the detector over time.
- Individually flagged runs were reanalyzed and compared to the fill-by-fill QA results to determine which runs were to be removed.

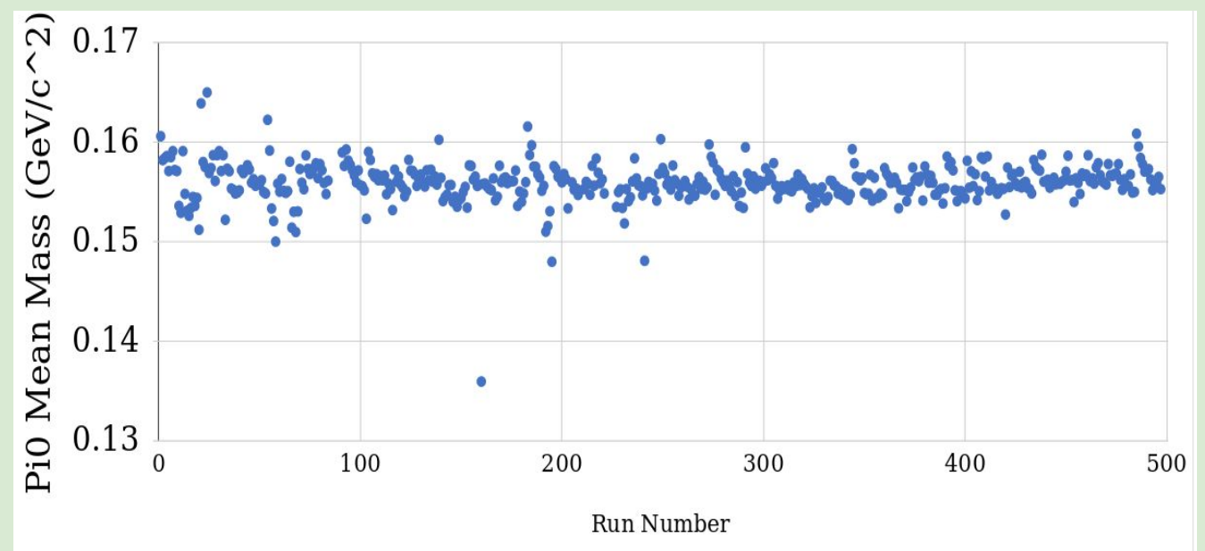

Fig 5: The π^0 mass plotted as a function of run number. The mean mass is higher than the nominal mass of a π^0 because there is background.

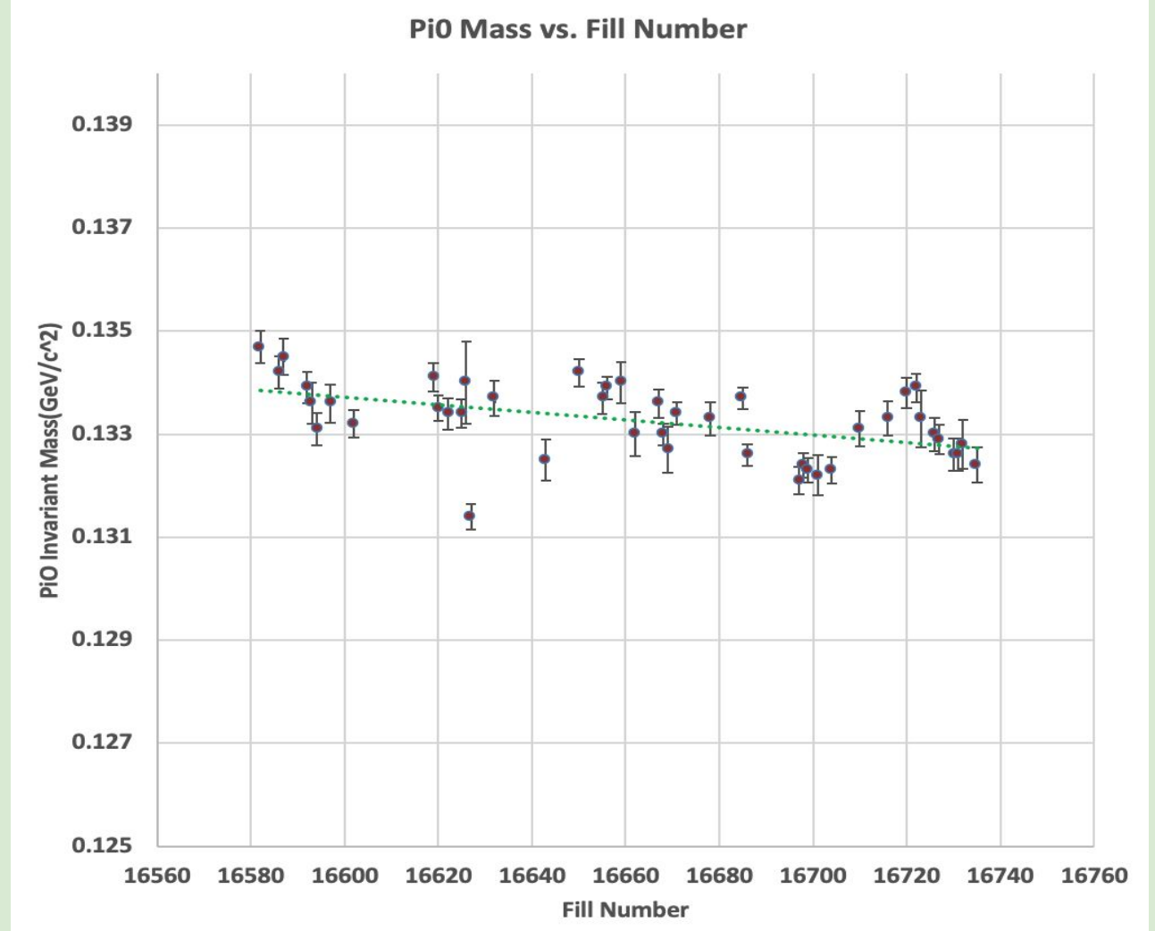

Fig 6: The Fill Average π^0 mass plotted as a function of Fill number. The green line shows the declining trend of π^0 mass.

Run 13 Tree Generation

- In order to work on a larger 2013 dataset, we need to have the data stored into trees. There are 3 parts to each dataset:
  - Part 1 Trees store the "raw energy data" from the detector; Part 2 stores semi-completed data; Part 3 is useful physics data such as π^0 Mass, Energy, and γ counterparts.
    - Cannot have Part 2 & 3 without Part 1 Trees, therefore, Part 1 Trees are created first.
- An XML script tells another program, ROOT, what to do for each of the trees.
- QA of Run 13 Trees
  - Checking file sizes, number of files, the data in single files, "chaining" files together and looking at the output
    - Look at π^0 mass, energy, p_T and γ counterparts of energy and p_T and search for errors, warnings, fatal errors in log files
- Future Work:
  - Get more 'raw' data files onto the local disk
  - Start large scale production of brand new trees via partial automation
  - Running baseline QA on new trees

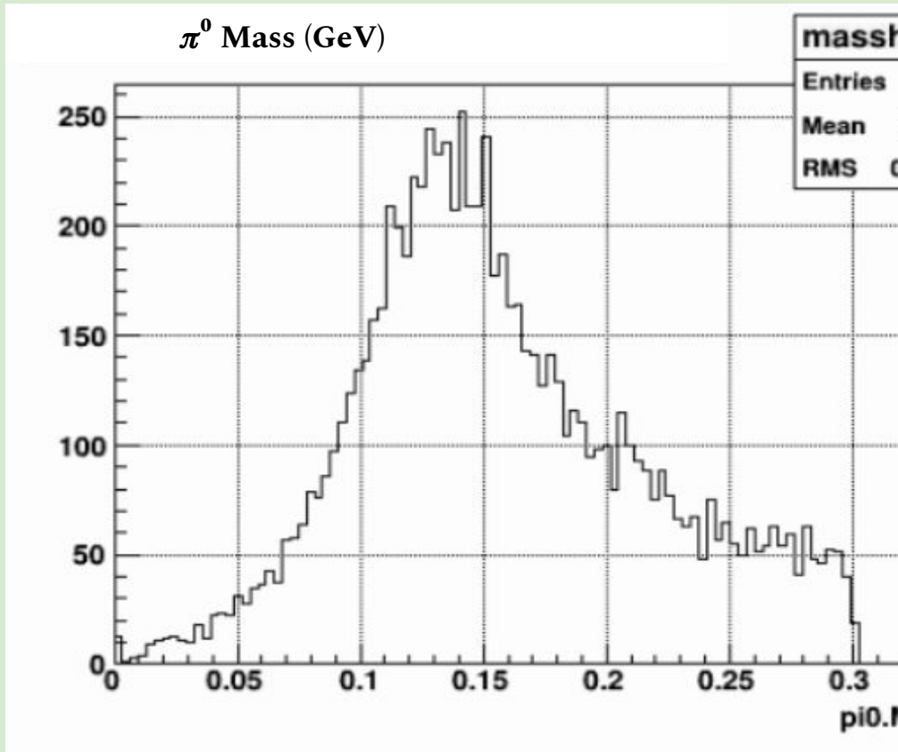

Fig 11: Histogram of the π^0 Mass for one run. Note: expected peak at 0.155 ± 0.06 GeV. Included is background from the detector, which accounts for the additional 0.020 GeV of mass.

FCS Upgrade (Scintillating Tiles)

Overview:

The forward region of the detector (i.e. the region close to the beam) is undergoing an upgrade. The region that was formerly occupied by the Forward Meson Spectrometer (FMS) is being replaced by the Forward Calorimeter System (FCS).

Why Upgrade?:

The FMS was only able to measure the energy of particles that interact electromagnetically (photons, electrons, etc.). The FCS, on the other hand, will be able to measure the energy of electromagnetic particles and hadronic particles (particles that feel the strong force).

Our Task:

Scintillating tiles are a component of the FCS. When charged particles pass through tiles, light is emitted. The amount of light is proportional to the energy deposited by the particle. For better light collection, two opposite edges need to be polished and the other two need reflective paint on them. 9,600 tiles were polished, painted, and individually bagged to be shipped to Brookhaven National Laboratory.

Fig 12: The polishing machine that is used polish the edges of the scintillating tiles.

Fig 13: The protective film on the tiles need to be removed, and excess paint has to be chipped off, before the tiles can be shipped.