Probing Gluon Contribution to Proton Spin with STAR 2015 Endcap Electromagnetic Calorimeter Data

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The STAR Experiment & Its Goals

- A primary goal of the Solenoidal Tracker at RHIC (STAR) Experiment at Brookhaven National Laboratory is understanding the gluon contribution to the proton's spin.
- The Relativistic Heavy Ion Collider (RHIC) collides high energy polarized proton beams to produce many particles such as neutral pions (π^0) and eta (η) mesons.
- These particles decay into two photons whose energies and positions are measured by the Endcap Electromagnetic Calorimeter (EEMC) (Fig. 1).
- Photon pairs are reconstructed to calculate the invariant mass of the particles from which they decayed.

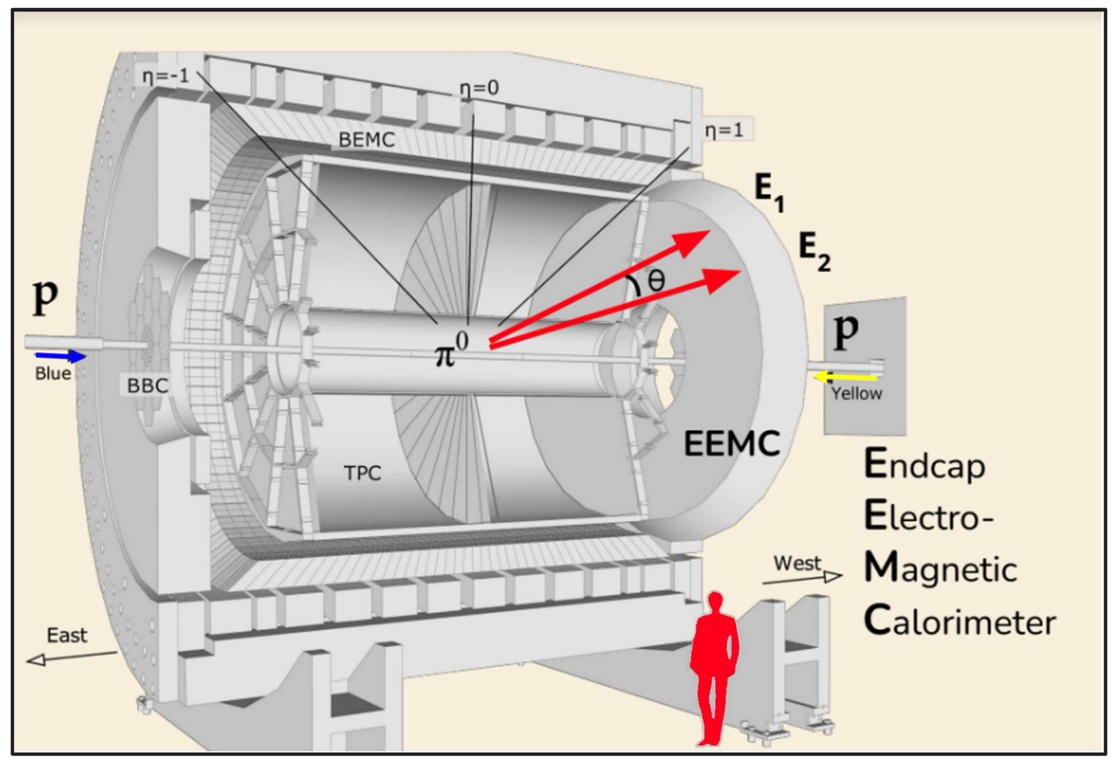

Fig. 1: The STAR detector highlighting the EEMC.

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π^0 Reconstruction & Asymmetry Calculations

- We use the equation below to reconstruct the invariant mass of particle candidates such as the π^0 ($M_{\gamma\gamma}$ = 0.135 GeV) from the energies (E_1 and E_2) and opening angle (θ) of the two photons.

$$M_{\gamma\gamma} = 2\sqrt{E_1 E_2}\sin\left(\frac{\theta}{2}\right)$$

- Investigating the invariant mass of a photon pair is a common method to separate the more likely candidates from background noise. If a particle candidate has a mass close to its nominal value, then we will consider and count it.
- With a good sample of π^0 candidates, we can calculate the asymmetry of their production.
  - The asymmetry of π^0 production is sensitive to the gluon spin contribution to the proton's spin.

$$A_{LL} = \frac{1}{P_B P_Y}\frac{(N^{++} - R_3 N^{+-})}{(N^{++} + R_3 N^{+-})}$$

N - Total number of π^0s measured for different spin alignments (+, -)
P_B - Polarization of the RHIC "blue" beam
P_Y - Polarization of the RHIC "yellow" beam
R_3 - Luminosity ratio of the two spin configurations (N++ and N+-)

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Run-Level QA - Introduction

- The data which we will use to calculate the asymmetry of particles like π^0s are divided into:
  - **Fills** - Batches of protons filled into RHIC, which typically last around 6-8 hours.
  - **Runs -** Segments of data collected within a Fill, which typically last around 30 minutes. They keep the data in manageable chunks.
- I primarily focused on Run-Level Quality Assurance (QA) looking for:
  - Irregularities or inconsistencies that could impact the eventual A_{LL} analysis
  - General trends between Runs
- This is typically done by plotting distributions for various particles given Run-Level datasets.
- For the final A_{LL} analysis, we will make more refined π^0 distributions using larger Fill-Level datasets. They involve:
  - Additional cuts
  - Higher statistics
  - Better fits

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Run-Level QA - "Bug"

- Our old Run-Level QA methods were affected by accidental numerical losses. When we naïvely cut on the data, large amounts of π^0 dropped out.
- Our event data trees are stored as multiple independent vectors, but when we allow ROOT to interpret them as arrays it assumes that they should be indexed together.
- For example, if the trigger of interest (e.g. EHT0) is satisfied at index 2, then *only* the π^0 at index 2 will be considered *even if* there are multiple π^0s in the event.

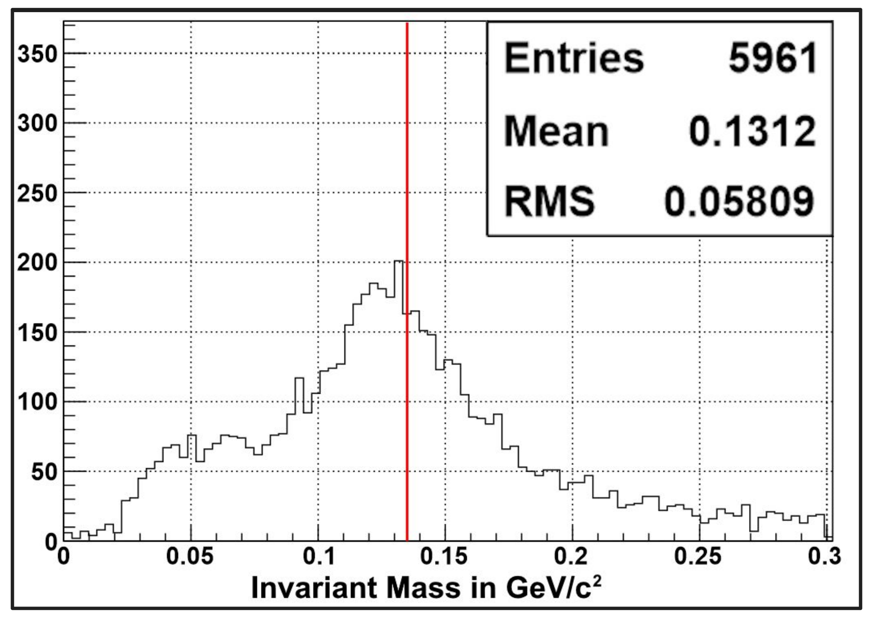

Fig. 2: A Run #16106008 π^0 invariant mass histogram with an EHT0 trigger cut using the old method.

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Run-Level QA - "Bug" Fix

- I fixed these accidental numerical losses by adapting existing analysis code that contained the framework to support more sophisticated cuts.
- Then, I investigated certain events in a run to ensure each π^0 candidate was cut as intended.
  - This gave me confidence my revised method worked as intended.
- Note this "Bug" was restricted to our Run-Level QA studies and didn't affect Fill-Level work in any way.

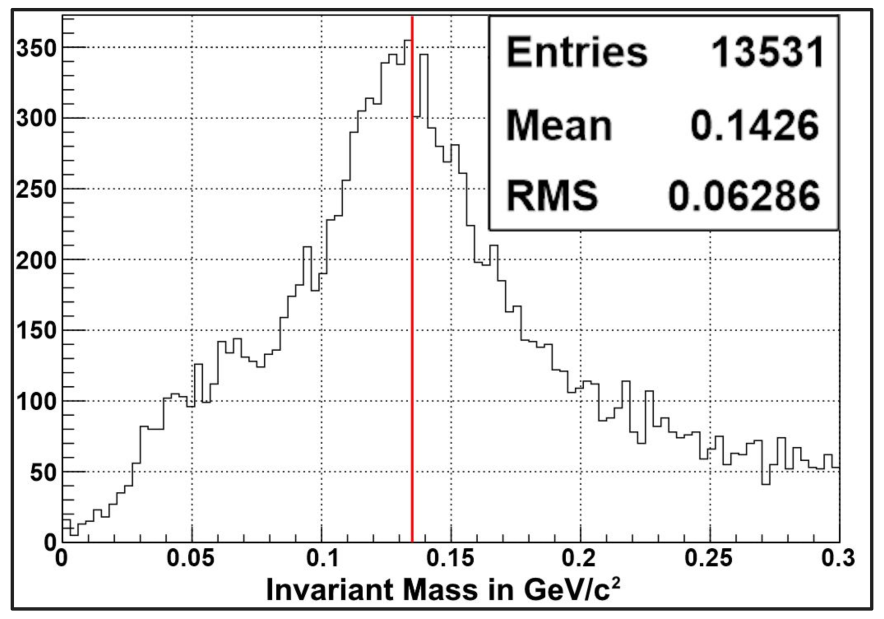

Fig. 3: A Run 16106008 π^0 invariant mass histogram with an EHT0 trigger cut created using the revised method.

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Run-Level QA - Fix Analysis

- The revised method led to a (2.35±0.35)x increase in statistics for these histograms which make it easier to assess data quality.
- Interestingly, previous outliers (runs with a mass parameter >4σ from the mean) moved closer to the mean while some previously good runs became outliers.
- Future work will include investigating and making decisions about the outliers.

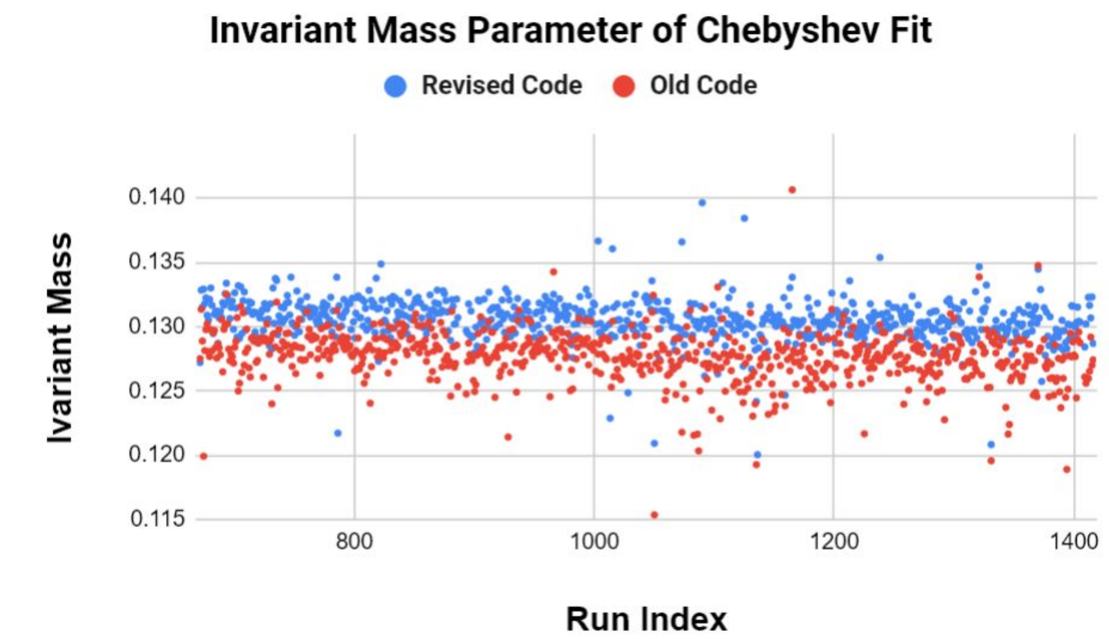

Fig. 4: A π^0 invariant mass parameter comparison of the revised method (blue) and the old method (red).

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Supported in part by the U.S. DEPARTMENT OF ENERGY Office of Science

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