Determining Gluon Contribution to the Spin of a Proton using η Production at STAR

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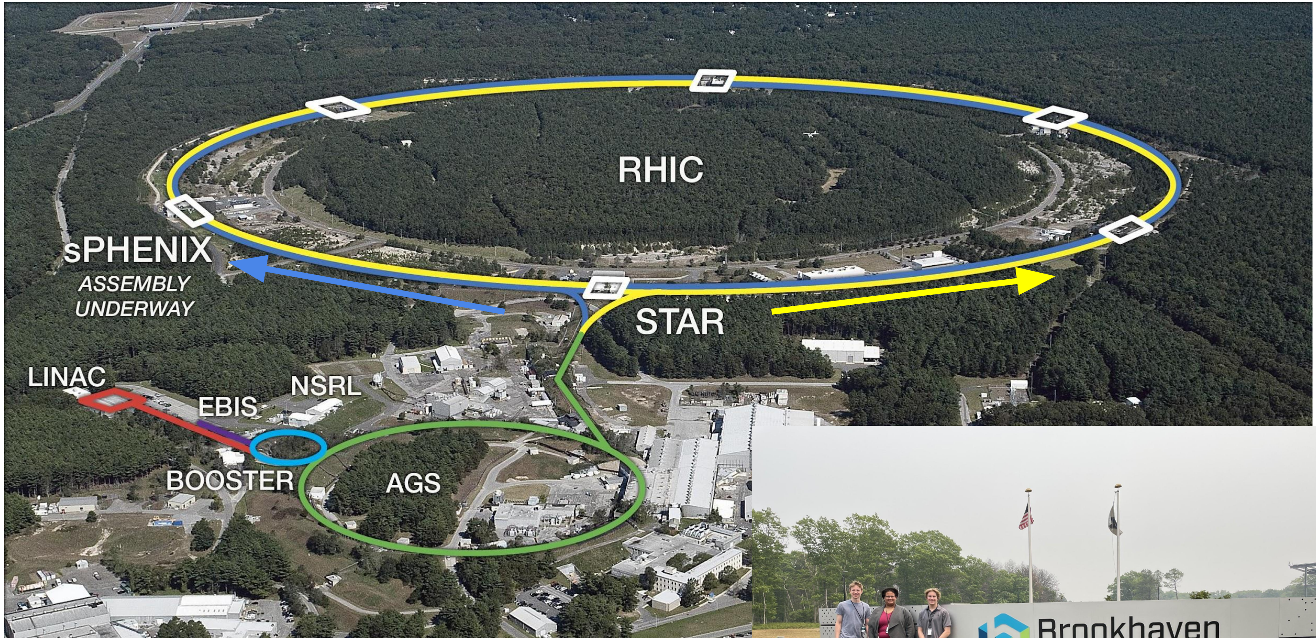
RHIC and STAR`

Relativistic
Heavy
Ion
Collider

Solenoidal
Tracker
At
RHIC



~2 mile circumference
Longitudinally Polarized at ~500 GeV

Background - Proton Spin

- Spin is the intrinsic angular momentum of a particle
- The proton has spin ½ ħ
- Quarks are elementary particles which make up composite particles called hadrons (e.g. protons, neutrons, pions, etas)

Gluon spin

Gluon orbital angular momentum

$$\frac{1}{2}\hbar = \underbrace{\frac{1}{2}\Delta\Sigma}_{\text{Quark spin} \sim 30\%} + \overbrace{\Delta G}^{\text{Gluon spin}} + \underbrace{L_q}_{\text{Quark orbital angular momentum}} + \overbrace{L_g}^{\text{Gluon orbital angular momentum}}$$

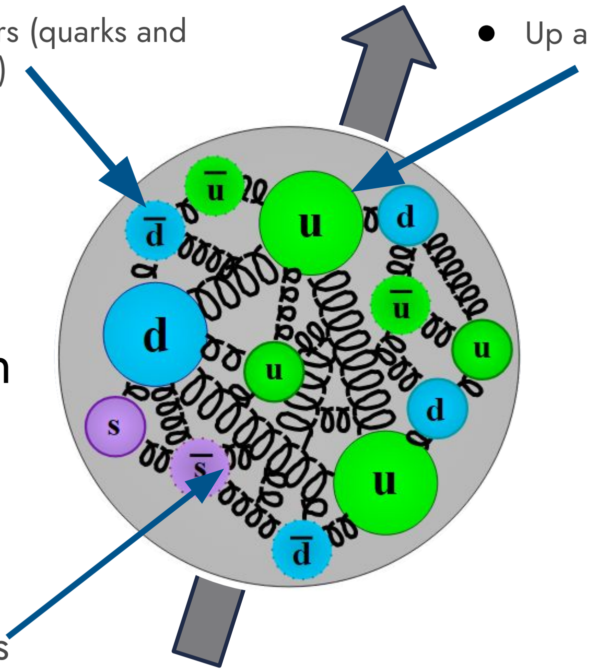
Quark spin ~30%

Quark orbital angular momentum

Sea Quarks
- Quark pairs (quarks and antiquarks)

Valence Quarks
- Up and Down

Proton (uud)

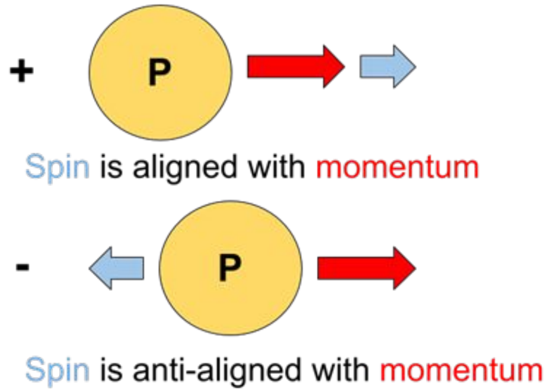


Gluons
- Mediates the strong nuclear force

Asymmetry (A_{LL})

- Using the number of the π^0 or η particles and the known polarization of the beams, we can calculate the asymmetry of π^0 and η production from different spin states of the protons
- The asymmetry formula:
  - Pb and Py are the polarization of the blue and yellow beams
  - N^{++} and N^{+-} are the number of π^0 or η in the respective spin state
  - R is the relative luminosity ratio
- If A_{LL} is nonzero, then there is a sensitivity to π^0 or η production from spin of the proton

$$A_{LL} = \frac{N^{++} - RN^{+-}}{P_b P_y (N^{++} + RN^{+-})}$$



Asymmetry is related to the gluon contribution to the spin of the proton

Invariant Mass

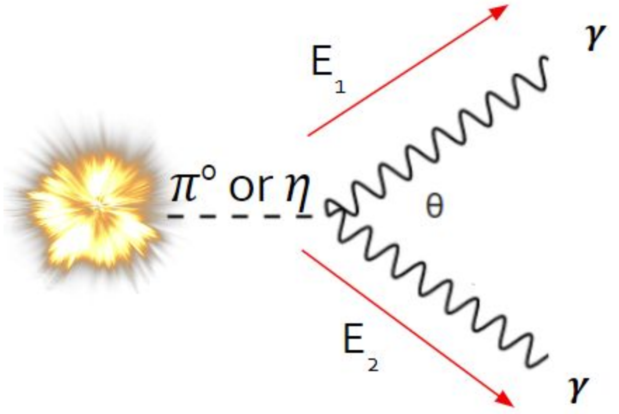
- The invariant mass of two photons ($M_{\gamma\gamma}$) can be calculated from the energy and position of the photons

Invariant Mass

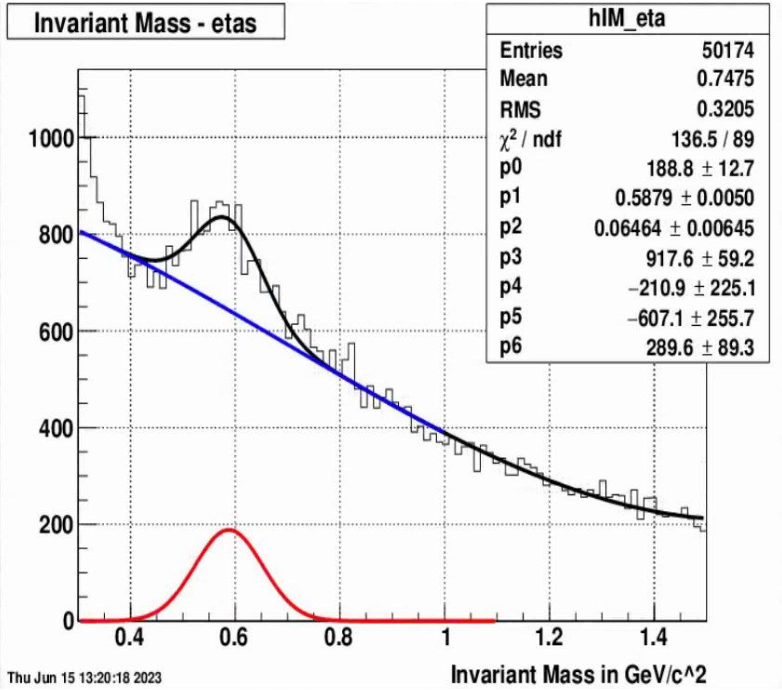
$$M_{\gamma\gamma} = (E_1 + E_2)\sqrt{1 - \left(\frac{E_1 - E_2}{E_1 + E_2}\right)^2} \, sin\left(\frac{\theta}{2}\right)$$

- The software package ROOT will take all of the invariant mass results and make a histogram

- The invariant mass plots help us identify particles and how many there are



Fitting the η Histogram



- η particles are massive (0.548 GeV/c^2)
- They also produced less often than π^0s
- A histogram is fit using:
  - a Gaussian function to represent the eta particles and,

    $$f(x) = p_0 \cdot exp\left(-0.5\left(\frac{x-p_1}{p_2}\right)^2\right)$$

  - a third order polynomial function to represent the background photon pairs

    $$B=p_3+p_4x+p_5x^2+p_6x^3$$

- Integrating the signal function gives the total number of η
- We look for three main things in this graph:
  - Mean mass value
  - Width of the invariant mass peak
  - Signal fraction

My Research

I studied η production from proton-proton collisions conducted at Brookhaven National Lab from the 2013 data set

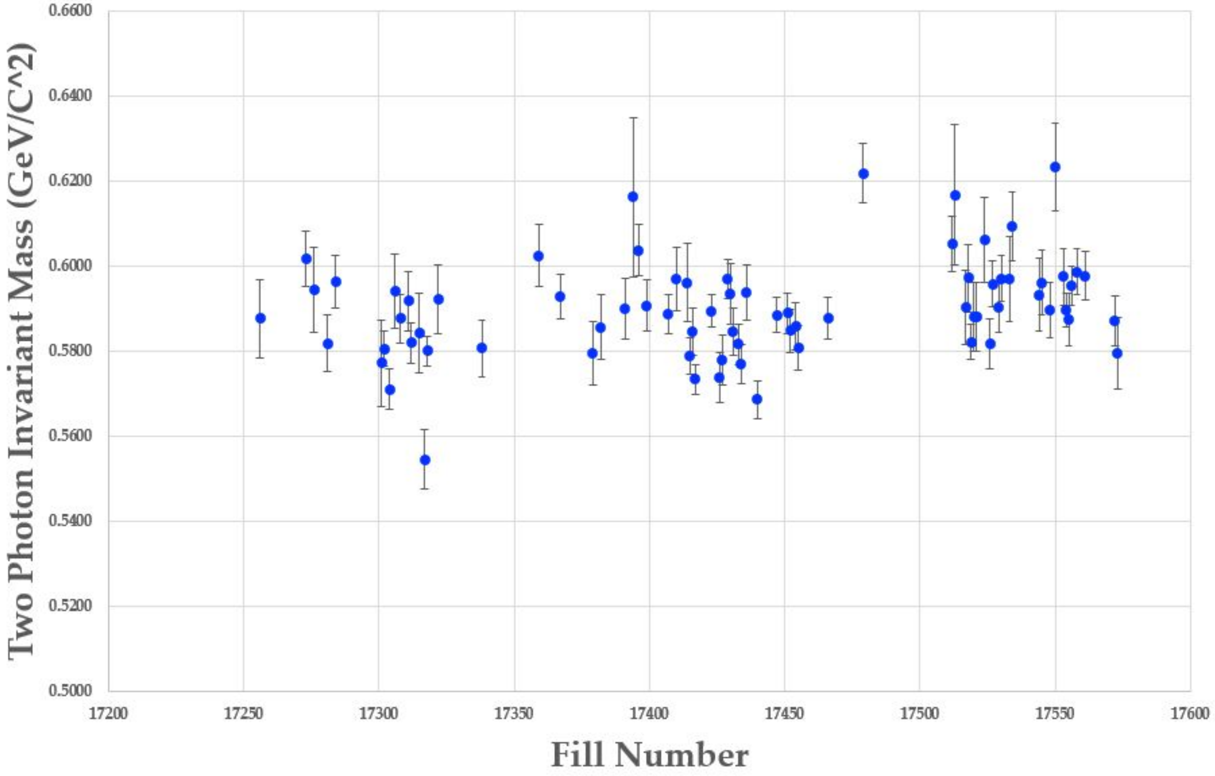
Run vs. Fill:

- The data-collection window between a beam injection (into the ring for collision) and the subsequent beam dump is referred to as a "fill"
- A run is a period when STAR is taking data
- Breaks up data in manageable pieces

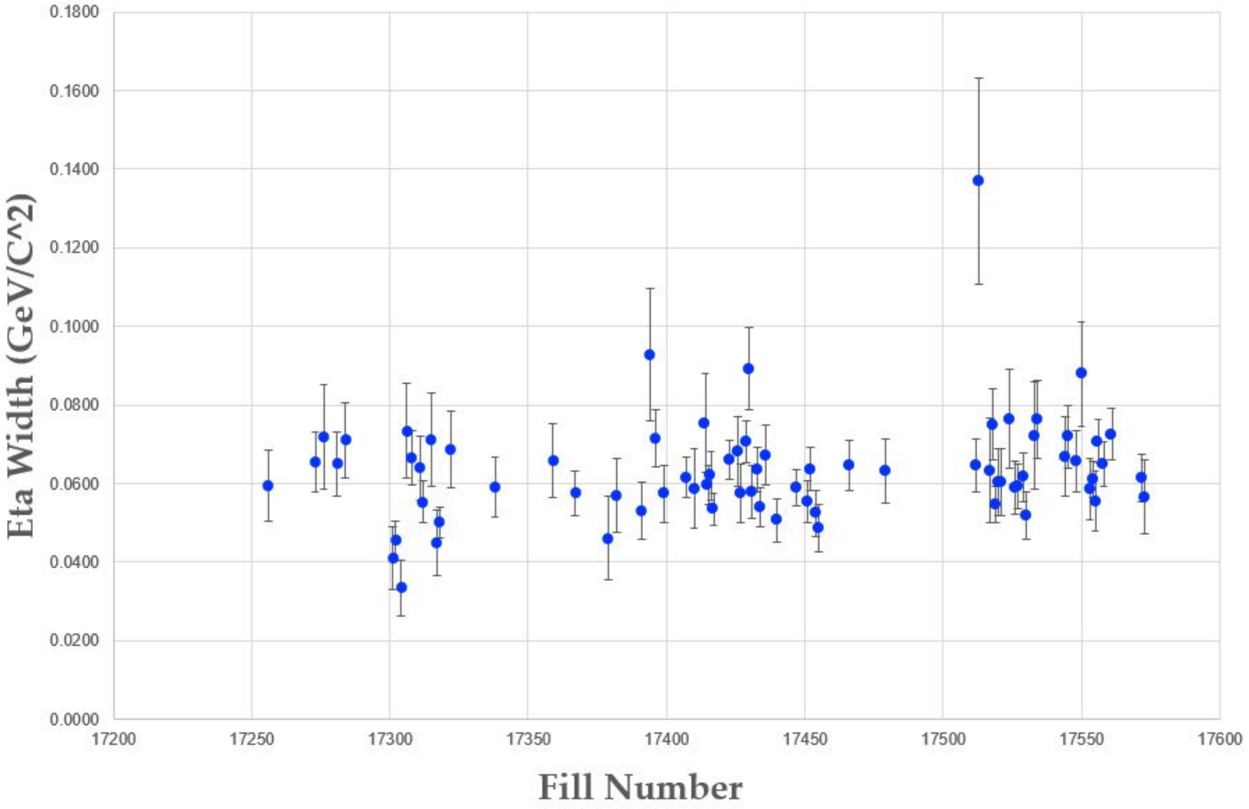
My Research

- I worked on the 2013 data set, which was longitudinally polarized at $\sqrt{s} = 510\ GeV$
- I studied the three characteristics of the η mass histogram
  - Mean, Width, and Signal Fraction
- I looked for data that could be deemed as outliers

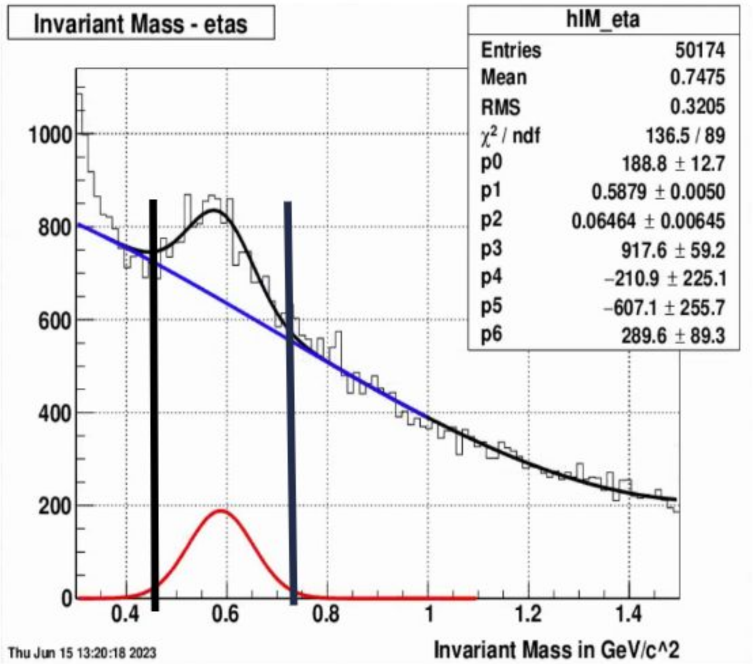
η Invariant Mass vs. Fill Number

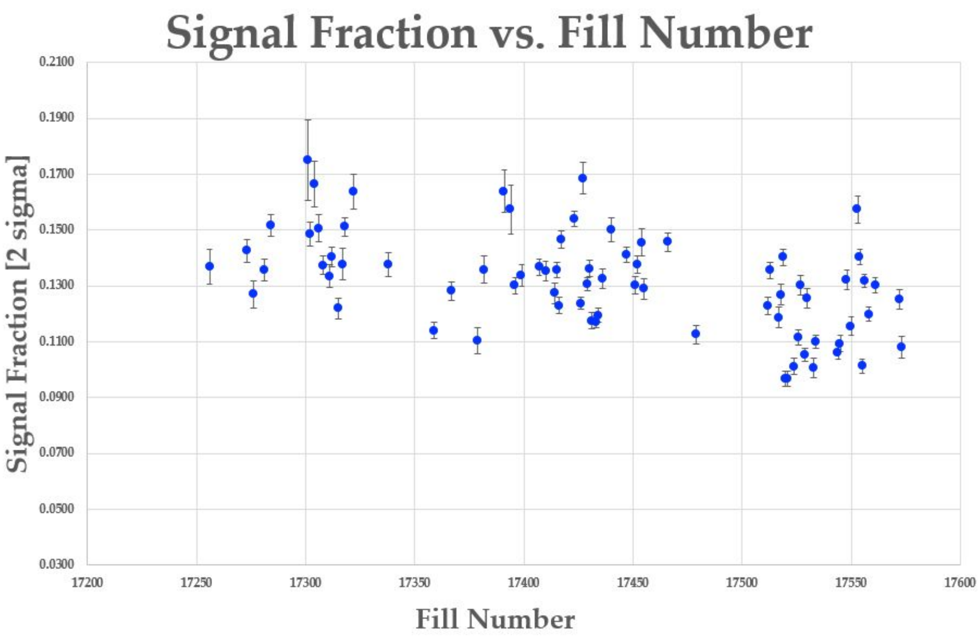


η Peak Width vs. Fill Number



η Signal Fraction vs. Fill Number





Signal fraction = Number of ηs within 2σ of the η peak (red) ÷ Total number of counts (black)

Summary

- QA was carried out on 2013 data at the fill level for the η particle
- This data will be used to select good fills for the next step in the analysis of the 2013 data set