Determining π^0 A_{LL} from STAR 2012 Endcap Calorimeter Data

Anand Agrawal, William Bakke, Michael Bukowski, Claire Kovarik and JD Snaidauf

on behalf of the STAR Collaboration

Mentors: Profs. Shirvel Stanislaus, Adam Gibson, David Grosnick, Donald Koetke

STAR

VALPARAISO UNIVERSITY

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

Background

The STAR Experiment, located at the Relativistic Heavy Ion Collider (RHIC) at the Brookhaven National Laboratory, uses longitudinally polarized proton-proton collisions to produce neutral pions (π^0) whose production is assumed to exhibit a spin asymmetry (A_{LL}). By measuring A_{LL} the gluon spin contribution to the spin of the proton can be studied. The STAR detector (Fig. 1) is located along the 2.3 mile RHIC circumference (Fig. 2). As seen in Fig. 3, a neutral pion decays into two photons immediately (~10^{-16} s). The analysis reported here is based on data taken in 2012 for 510 GeV center of mass energy of the colliding protons.

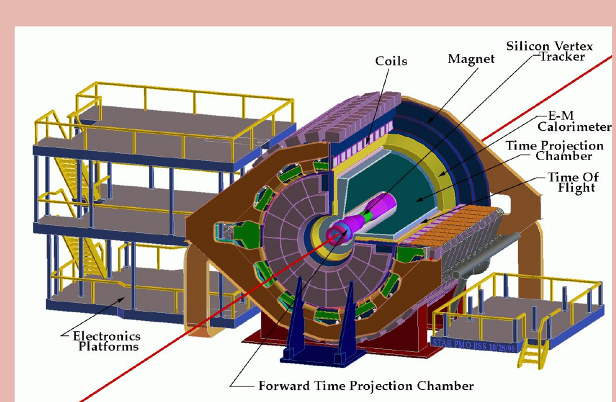


Fig. 1 STAR Detector at Brookhaven National Laboratory
Photo Credit: *The STAR Experiment*

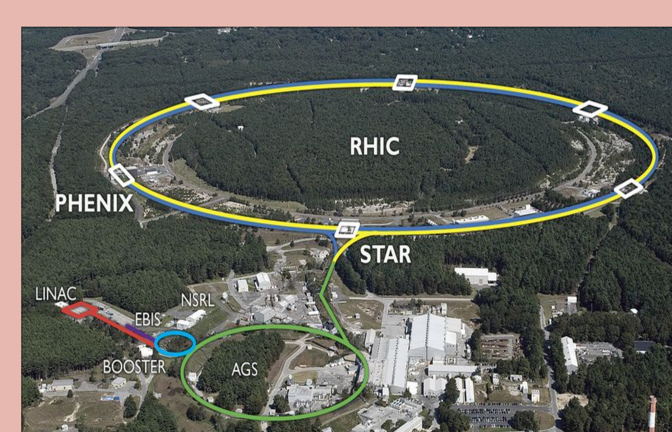


Fig. 2 Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory
Photo Credit: *Brookhaven National Laboratory*

Invariant Mass Spectra

The Endcap Electromagnetic Calorimeter (EEMC) of the STAR detector (Fig. 1) is able to measure the energy (E) and position of incident photon's electromagnetic shower. By using the energy and the opening angle (θ) between the two photons (Fig. 3), the two photon invariant mass plot can be calculated using the following equation:

$$\text{Invariant mass} = (E_1+E_2)\sqrt{1-\left(\frac{E_1-E_2}{E_1+E_2}\right)^2}\sin\frac{\theta}{2}$$

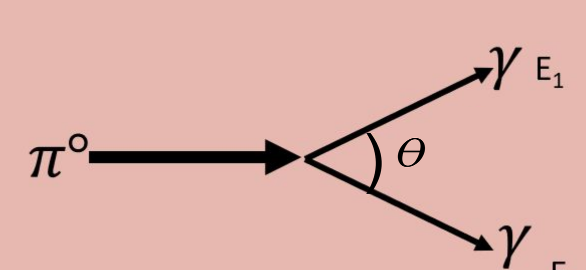
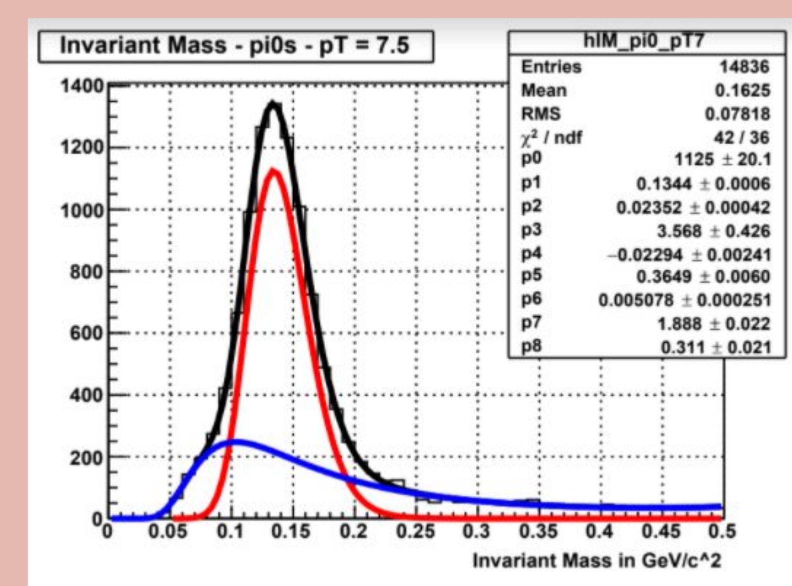


Fig. 3 The neutral pion decays into two photons

The two photon invariant mass histograms for each spin state were fitted with a skewed gaussian for the π^0 peak and a background function. Two different background functions were compared; a Chebyshev function and a modified Planck function. The number of π^0s present is found by integrating the fitted Gaussian function above the background. This number is then used to find the number of π^0s produced in each spin state. This information can then be used to find the π^0 asymmetry (A_{LL}).

$$\text{Skewed Gaussian} = \quad ae^{-0.5\left(\frac{x-b}{c(1+d(x-b))}\right)^2}$$

b= mean
c= sigma
d= 'skewking' parameter

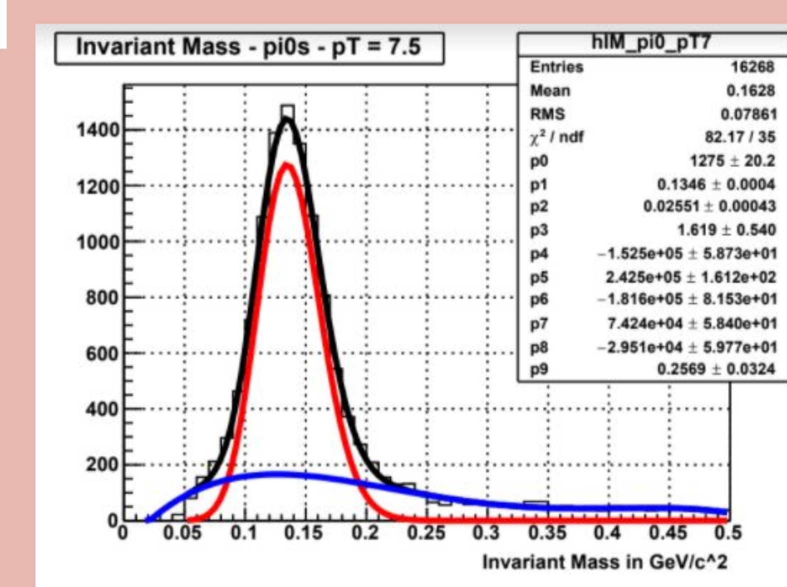


Modified Planck Function

$$= \frac{1}{(x-c_1)^5 e^{\frac{c_2}{x-c_3}} - c_4}$$

Fig. 4 (left) Invariant mass plot at a p_T (transverse momentum of the π^0) range of $7 < p_T < 8$ GeV/c fitted with a modified Planck background function (blue) and a skewed Gaussian for the π^0 peak (red).

Fig. 5 (right). Invariant mass plot at a p_T (transverse momentum of the π^0) range of $7 < p_T < 8$ GeV/c fitted with a Chebyshev background function (blue) and a skewed Gaussian for the π^0 peak (red).



Chebyshev Function=
$c_0+c_1(x)+c_2(2x^2-1)+c_3(4x^3-3x)+c_4(8x^4-8x^2+1)$

False Asymmetry

False Asymmetries are a good measure to cross-check the relative luminosity determinations, and are expected to be zero. The analysis to determine the false asymmetries was done on a fill-by-fill basis. The polarizations and relative luminosity parameters in the calculations are weighted averages for fills – weighted using the number of triggers in a run. There are 4 different false asymmetries: Single Spin Symmetries associated with each of the two beams, Like-spin Double Spin Symmetry, and Unlike-spin Double Spin Symmetry. For Figs. 6 and 7 the number of π^0s, N, used to calculate the false asymmetries was the integral of the skewed Gaussian function. The error was taken as $\sqrt{N}$.

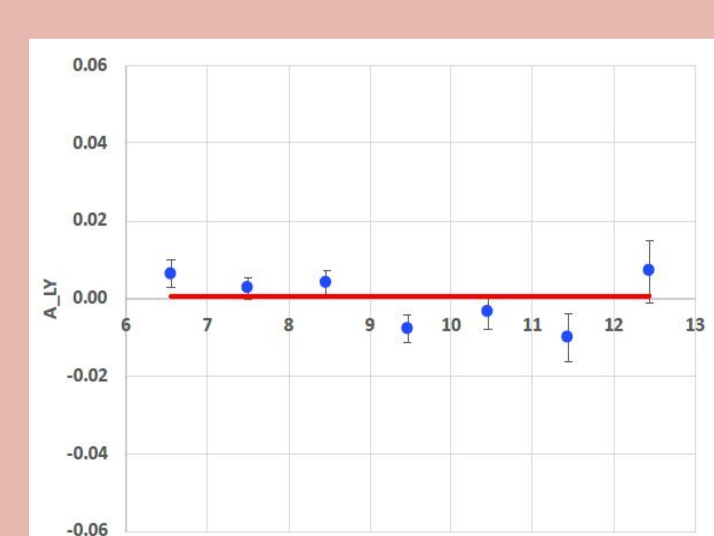


Fig. 6 The single spin asymmetry associated with one of the two beams (A_{LY}) plotted as a function of p_T. The red line shows a fit to the false asymmetries to have the value of p0 = -0.0006 ±0.0015 which is consistent with zero. However, the reduced chi-square (χ^2) value is (11.8/6) which is higher than expected indicating a possible underestimation of the errors.

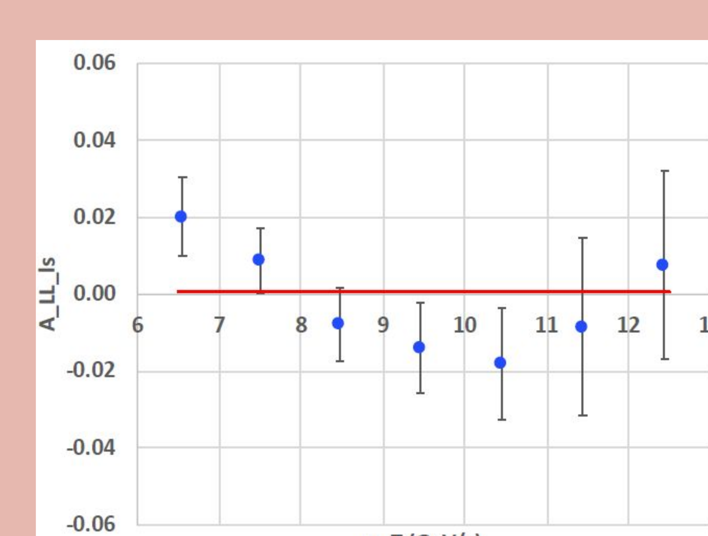


Fig. 7 The Like-sign double spin asymmetry (A_{LL_ls}) plotted as a function of p_T. The red line shows a fit to the false asymmetries to have the value of p0 = -0.0007±0.0045 which is consistent with zero. However, the reduced chi-square (χ^2) value is (8.8/6) which is higher than expected indicating a possible underestimation of the errors.

Quality Assurance

The analysis of the data is in the final stages so quality assurance of the data was necessary to assure good runs were used. QA was executed for collider fills (groups of runs) as well as individual runs. A C++ script was used to look at key parameters such as number of towers, π^0 mass, and signal fraction. Runs were flagged if they exceeded 2σ to be reviewed individually. A fill-by-fill QA was done in a similar fashion.

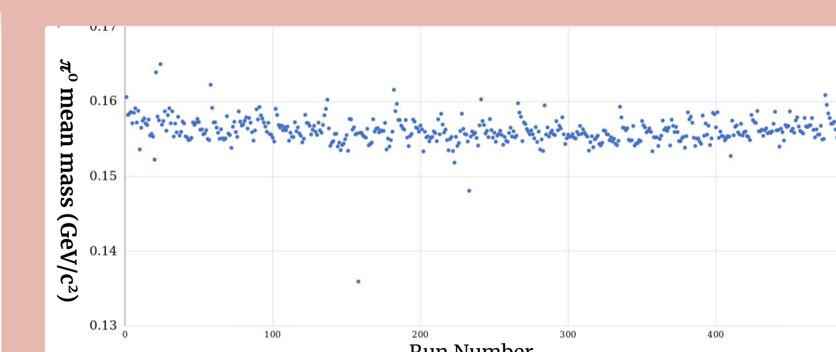


Fig. 8 (left) The π^0 mean mass plotted as a function of run number. The mean mass is higher than the nominal mass of a π^0 because of background.

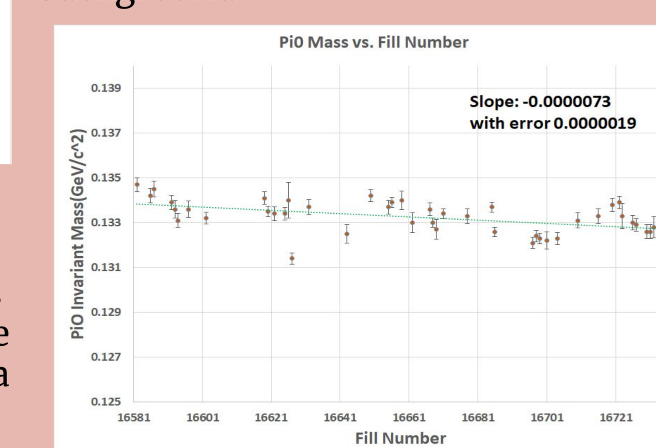


Fig. 9 (right). The fill average π^0 mass plotted as a function of fill number.The green line is a fit to data points, and shows a declining trend of π^0 mass.

Determining A_{LL}

The π^0 A_{LL} is an imbalance in the π^0 production in the different spin states of the colliding protons. Each proton can have positive or negative helicity (spin aligned or anti-aligned with its momentum). There are four different spin combinations for collisions, but they can be grouped into like-helicity or unlike-helicity cases. Using the following formulas, the A_{LL} can be calculated.

N^{++} = number of π^0s from like-helicity collisions
N^{+-} = number of π^0s from unlike-helicity collisions
L = luminosities at different spin states
P_1 & P_2= polarization of the two beams
R_3= relative luminosity

$$R_3 = \frac{L^{++}+L^{--}}{L^{+-}+L^{-+}}$$

$$A_{LL} = \frac{\sum_{runs} P_1P_2\,(N^{++}-R_3N^{+-})}{\sum_{runs} P_1^2P_2^2\,(N^{++}+R_3N^{+-})}$$

Future Work

The analysis of the 2012 dataset is in its final stages so work has begun with preparing the larger, 2013 data set for analysis. Work is underway to retrieve the 2013 data from tape, reconstruct the π^0s and store it in a ROOT tree format for further analysis. As for the 2012 dataset, a quality assurance (QA) proceeds in parallel to ensure the processing is successful and the data quality is high.