Target Single Spin Asymmetry Measurements in the Inclusive Deep-Inelastic $\vec{N}(e, e')$ Reaction on Transversely Polarized Proton and Neutron (^{3}He) Targets using the SoLID Spectrometer

Hall A Collaboration Meeting

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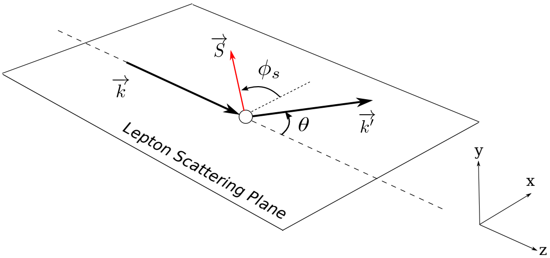
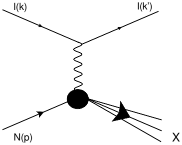
Outline

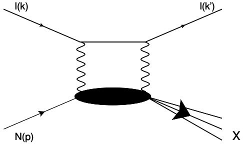
Overview



- Deep Inclusive elastic Scattering, unpolarized beam, transversely polarized NH_3 and ^3He.
- Measure single-spin asymmetry (SSA) $A_{UT} = \frac{\sigma^{\uparrow} - \sigma^{\downarrow}}{\sigma^{\uparrow} + \sigma^{\downarrow}} = A_y \sin\phi_S$, $A_y = \frac{d\sigma_{UT}}{d\sigma_{UU}}$ from target spin flip.

Physical Motivation





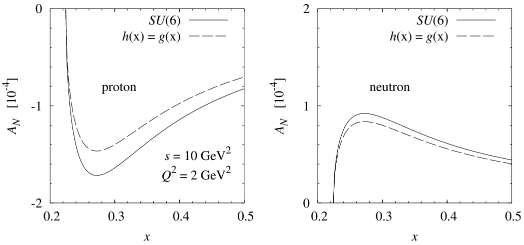
- Motivated by discrepancy between Rosenbluth/Polarization Transfer measurement of G_E/G_M, many calculations now exist for the two-photon exchange reaction.
- $A_y = \frac{\sigma^{\uparrow}-\sigma^{\downarrow}}{\sigma^{\uparrow}+\sigma^{\downarrow}} \frac{1}{\sin\phi_S} = \frac{d\sigma_{UT}}{d\sigma_{UU}}$
- $d\sigma_{UU} \propto \mathcal{R}e(\mathcal{M}_{1\gamma}\mathcal{M}^*_{1\gamma})$ and $d\sigma_{UT} \propto \mathcal{I}m(\mathcal{M}_{1\gamma}\mathcal{M}^*_{1\gamma}) = 0$ at Born level
- $d\sigma_{UT} \propto \mathcal{I}m(\mathcal{M}_{1\gamma}\mathcal{M}^*_{2\gamma}) \neq 0$ with one- and two-photon interference

Physical Motivation (con't)

- Evaluation of 2γ box diagram involves *full* nucleon response to doubly virtual Compton scattering. Elastic intermediate contribution well-known. Calculate inelastic response using e.g. GPD's, nucleon resonances, DIS form factors.
- A_y provides a unique new tool to study nucleon structure.
- This experiment will test parton-models for protons and neutrons in DIS.

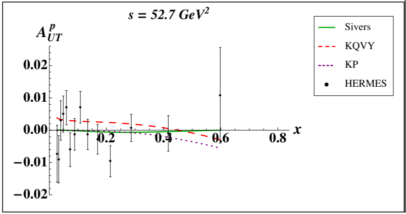
Theoretical Predictions

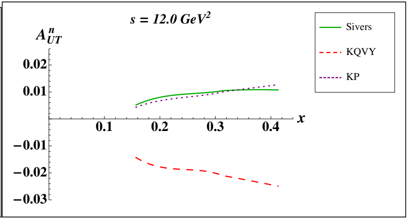
- A. Afanasev *et al.* assumes the scattering is dominated by two-photon exchange with a single quark. They predict $A_y^n \sim 10^{-4}$ and $A_y^p \sim -2 \times 10^{-4}$ at $x \sim 0.3$ and $Q^2 = 2.0$ GeV^2.



Theoretical Predictions (con't)

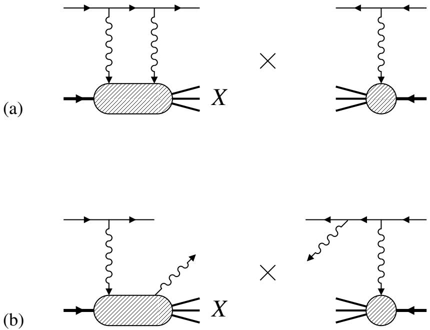
- A. Metz *et al.* argue that the DIS asymmetry is dominated by the process in which one of the photons couples to an active quark and the other couples to one of the quarks in the spectator di-quark system. They predict an asymmetry with magnitude $A_y^p < 10^{-2}$ that crosses zero in the mid-x range. The magnitude of A_y^n is predicted to be $\sim \pm 10^{-2}$ depending on the quark-gluon-quark correlators T_F^f for quarks of flavor f.





Theoretical Predictions (con't)

- An additional contribution to $d\sigma_{UT}$ at $\mathcal{O}(\alpha_{em}^3)$ may arise from interference between real photon emission (bremsstrahlung) by the electron and the hadronic system.



Existing Proton Data

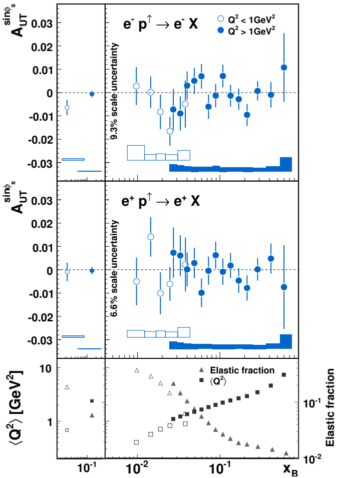


Figure: $A_{UT}^{\sin\phi_S}$ $(= A_y^p)$ measured with an electron beam (top) and a positron beam (center). The open (closed) circles identify the data with $Q^2 < 1$ GeV^2 ($Q^2 > 1$ GeV^2). The error bars show the statistical uncertainties, while the error boxes show the systematic uncertainties. The asymmetries integrated over x are shown on the left. Bottom panel: average Q^2 vs. x from data (squares), and the fraction of elastic background events to the total event sample from a Monte Carlo simulation (triangles).

Existing Neutron Data

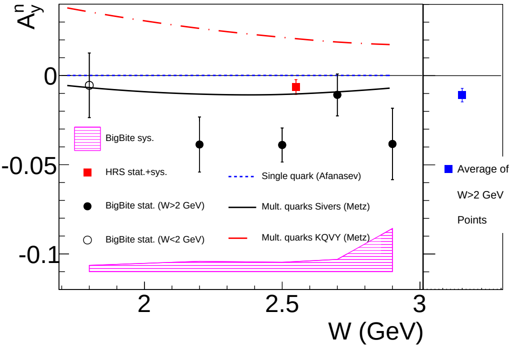
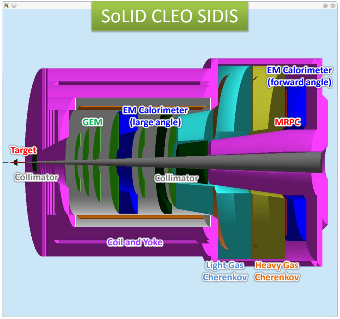


Figure: Neutron asymmetry results (color online). **Left panel:** Solid black data points are DIS data ($W > 2$ GeV) from the BigBite spectrometer; open circle has $W = 1.72$ GeV. BigBite data points show statistical uncertainties with systematic uncertainties indicated by the lower solid band. The square point is the LHRS data with combined statistical and systematic uncertainties. The dotted curve near zero (positive) is the calculation by A. Afanasev *et al.*, The solid and dot-dashed curves are calculations by A. Metz *et al.* [**?**] (multiplied by -1). **Right panel:** The average measured asymmetry for the DIS data with combined systematic and statistical uncertainties.

Overview

- The goal is to determine A_y for both proton and neutron with a statistical precision of $10^{-4} - 10^{-3}$ (kinematic dependent) over a broad range of x and $1.5 < Q^2 < 7.5$ GeV^2 $(0.05 < x < 0.65,\ W > 2$ GeV$)$ by measuring the ϕ_S-dependence of A_{UT}.
- Systematic uncertainties will be kept to the $\sim 10^{-4} - 10^{-3}$-level.
- The polarized NH_3 (100 nA, 3 cm) and ^{3}He targets (15 μA, 40 cm) with 8.8 and 11 GeV beam.
- SoLID will be used as the detector for this experiment.
- Run concurrent with neutron and proton SIDIS. No more equipments and beam time are required.
- The singles trigger rate in the detector will be as large as 80-100 kHz (DAQ limited).



NH_3 Kinematics

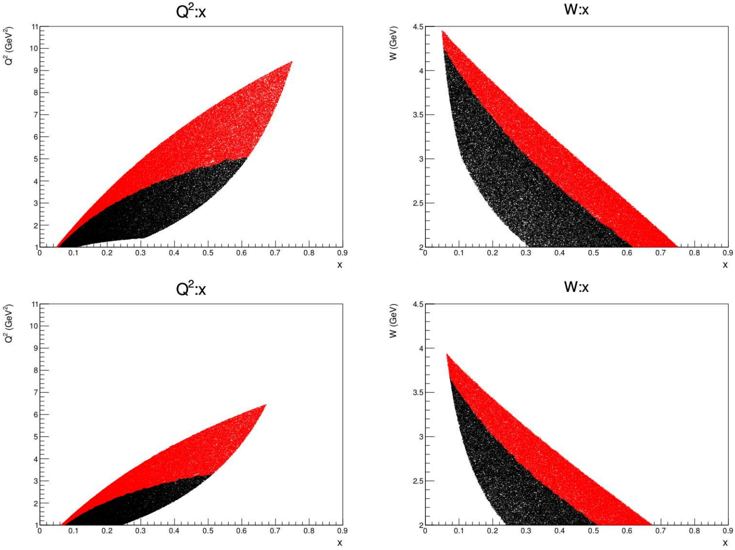


Figure: Kinematic coverage with polarized NH_3 target. The upper plots are for 11 GeV. The lower plots are for 8.8 GeV. Black (red) is for forward (large) angle.

^{3}He Kinematics

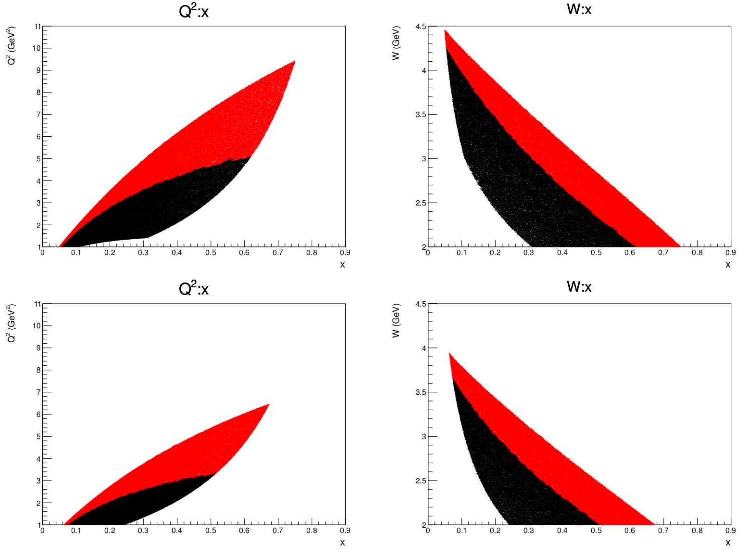


Figure: Kinematic coverage with polarized ^{3}He target. The upper plots are for 11 GeV. The lower plots are for 8.8 GeV. Black (red) is for forward (large) angle.

Rate Estimation

- Most recent acceptance.
- “line of flame" cut on NH_3 target.
- FAEC trigger (conservative about 90% of the one from the transversity).
- LAEC trigger ($>$ 3 GeV).
- GC trigger.
- Impose a maximum rate of 80 kHz on the singles trigger.

Rate Estimation (NH_3)

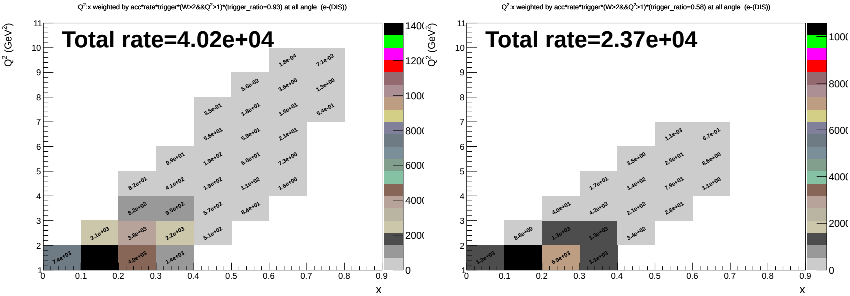


Figure: Good electron rates (after PID and DIS cuts) in each Q^2 vs x bin for the NH_3 target. Units for rates are Hz. Left one is for 11 GeV. Right one is for 8.8 GeV.

Rate Estimation (^{3}He)

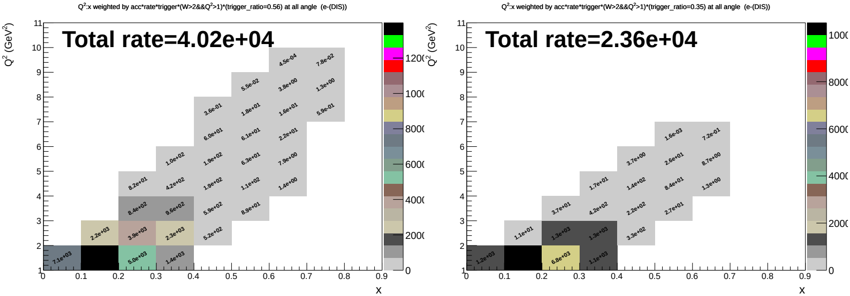


Figure: Good electron rates (after PID and DIS cuts) in each Q^2 vs x bin for the ^{3}He target. Units for rates are Hz. Left one is for 11 GeV. Right one is for 8.8 GeV.

Project Results

Corrections used to determine the A_{UT}^{phys} from A_{UT}^{raw}.

- Dilution factor 13% for NH_3, 85% for ^{3}He.
- Target polarization 70% for NH_3, 60% for ^{3}He.
- Nuclear effect 80% for ^{3}He.
- Detector efficiency 70%.

Project Results (NH_3)

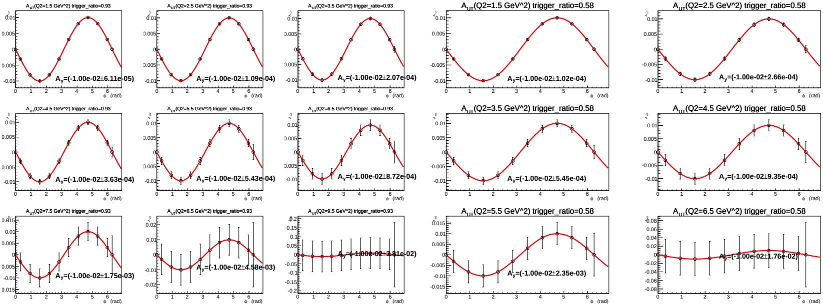


Figure: Expected uncertainties in A_{UT} vs. ϕ_S at different Q^2 for the NH_3 target. Left 9 figures are for 11 GeV from $1.5 \leq Q^2 \leq 9.5$ (GeV^2). Right 6 figures are for 8.8 GeV from $1.5 \leq Q^2 \leq 6.5$ (GeV^2).

Project Results (NH_3) (con't)

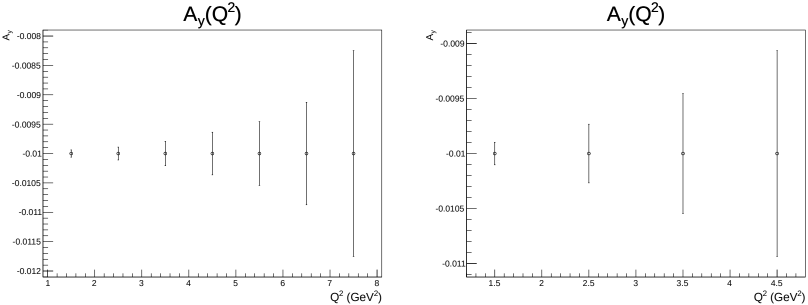
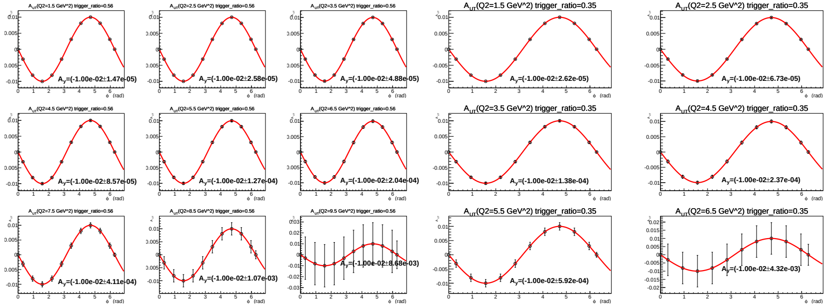


Figure: Expected uncertainties in A_y vs. Q^2 for the NH_3 target. Left one is for 11 GeV. Right one is for 8.8 GeV.

Project Results (^{3}He)



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Project Results (^{3}He) (con't)

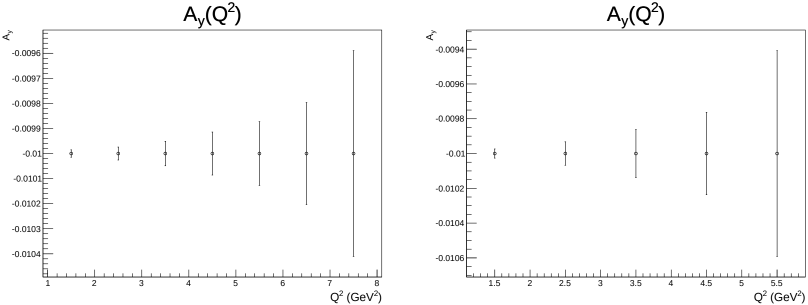


Figure: Expected uncertainties in A_y vs. Q^2 for the ^{3}He target. Left one is for 11 GeV. Right one is for 8.8 GeV.

Systematic Uncertainties (NH_3)

Sources	Type	δA_y^{raw}	δA_y^{phys}
False Asymmetries	absolute	3×10^{-4}	3×10^{-3}
Background Subtraction	absolute	4×10^{-4}	4×10^{-3}
Target Polarization	relative	3%	3%
Dilution Factor	relative	5%	5%
Radiative Correction	relative	2%	2%

Table: Systematic uncertainties on the proton asymmetries for the proposed NH_3 experiment.

Systematic Uncertainties (^{3}He)

Sources	Type	δA_y^{raw}	δA_y^{phys}
False Asymmetries	absolute	3×10^{-4}	1×10^{-4}
Background Subtraction	absolute	4×10^{-4}	1×10^{-3}
Target Polarization	relative	3%	3%
Dilution Factor	relative	2%	2%
Radiative Correction	relative	2%	2%
Neutron Extraction	relative	5%	5%

Table: Systematic uncertainties on the neutron asymmetries for the proposed ^{3}He experiment.

Summary

- Measurements of $A_{UT}(\phi_S)$ and A_y in a large number of x and Q^2 bins ($1.5 < Q^2 < 7.5$ GeV^2, $0.05 < x < 0.65$, $W > 2$ GeV) for both proton and neutron.
- The statistical uncertainties of $10^{-4} - 10^{-3}$ (kinematic dependent) with similar expected systematic uncertainties will provide information on the transverse target single spin asymmetry at a level never before achieved.
- The precision will discriminate between various parton model predictions.
- Provide an answer to the important sign mis-match in the neutron predictions using either the Sivers or KQVY input for quark-gluon correlations.
- A new opportunity to access the dynamics of the nucleon beyond the non-interacting parton level without the significant contribution from Born scattering.

Extra Slides

π/e^- ratio

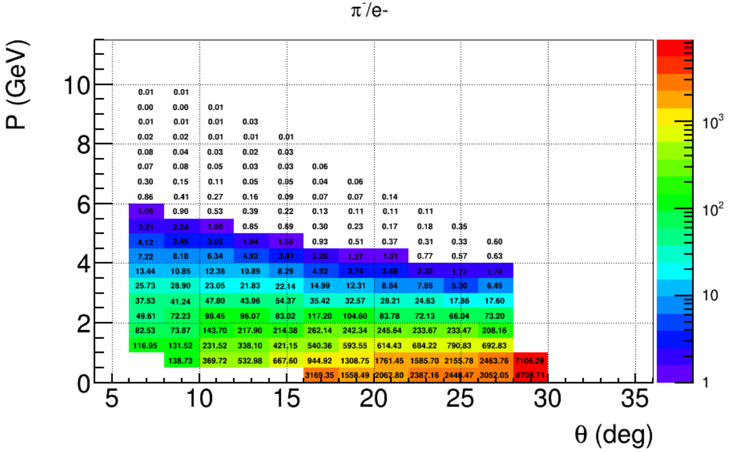


Figure: The π^-/e^- ratio for the SIDIS experiment with a 15 μA beam on a 40 cm ^{3}He target. The momentum and polar angles are at the vertices in the target where particles are created.

π/e^- ratio (con't)

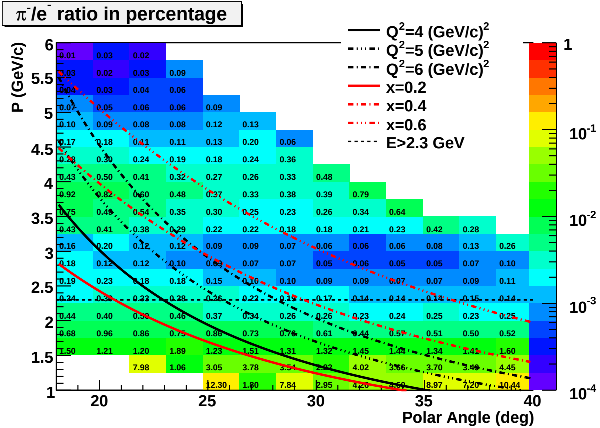


Figure: The π/e^- ratio from combined Cherenkov and Calorimeter detector performance as a function of the scattered momentum P and polar angle θ. The numerical values are the ratios corresponding to that cell in (P,θ). The curves indicate various regions of Q^2, x or scattered energy E.

Singles trigger

	e^-	$e^-(\pi^0)$	$\gamma(\pi^0)$	hadron	Total
FA rate (kHz)	90	16.75	1.32	18.7	127
LA rate (kHz)	4.7	0.16	0.8	12.4	18

Table: Contributions to the singles electron trigger rates in the forward (FA) and large (LA) detectors. From left to right they are: good electrons, electrons from pair production in π^0 decay, photons from π^0 decay, and hadrons.

Line of flame

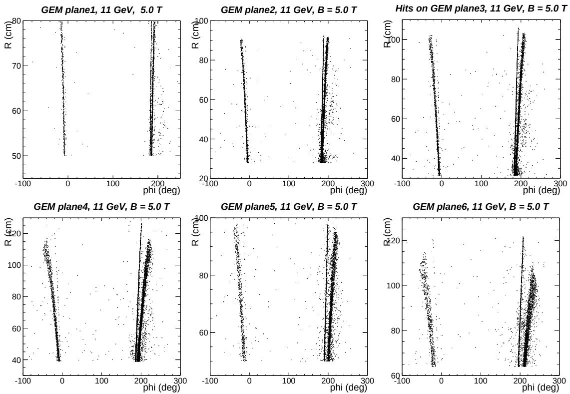
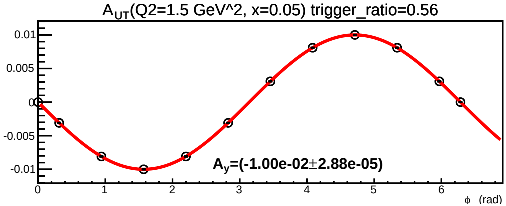
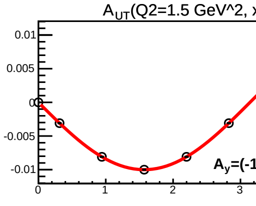
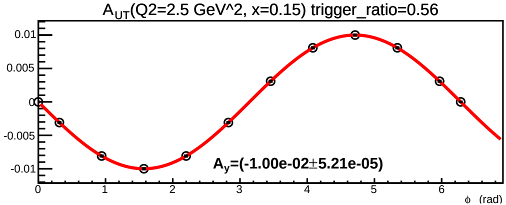


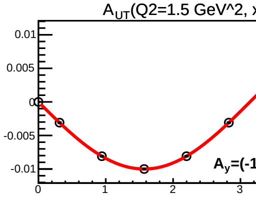
Figure: GEANT3 simulation results of background with NH_3 target field ON. The x-axis is the azimuthal angle in lab frame. The y-axis is the radius of GEM chambers (1-6). Narrow regions of high rate (compared to rest of the acceptance) are clearly seen as a function of azimuthal angle ϕ.

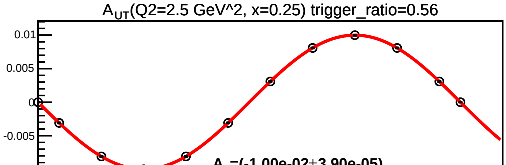
More results

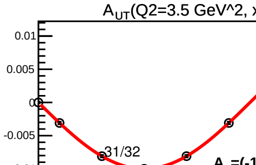












More results (con't)

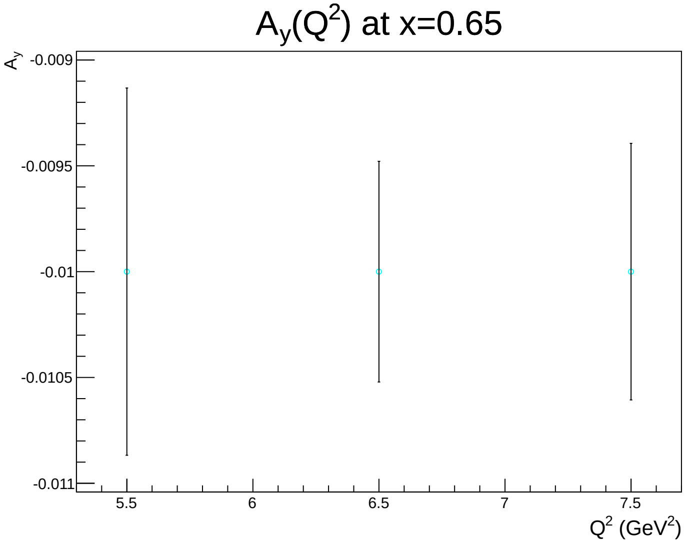


Figure: A_y vs Q^2 for $x = 0.65$ for the ^{3}He target at 11 GeV.