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*Title:* RHIC Spin Physics Highlights

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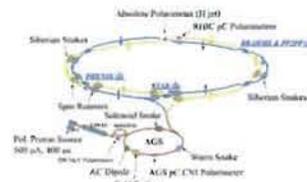
## Introduction

The Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory is the world only machine that has the capability to collide polarized high energy proton beams at the center of mass energy up to 500 GeV/c<sup>2</sup> and beam polarization of 70%. RHIC has been in operation since 2000, and the RHIC-SPIN program has contributed significantly to our understanding of the polarized proton structure and the nucleon spin puzzle.

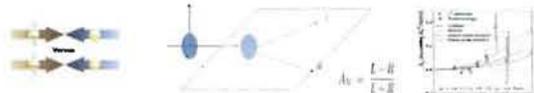
In the past a few years, the novel transverse spin phenomena observed at RHIC have stimulated much activities in theoretical investigation of strong interaction Quantum Chromodynamics (QCD) and provided much deeper understanding of the origin of the transverse spin asymmetry. LANL P-25 Group PHENIX team has played a key role in the RHIC-SPIN program in the PHENIX experiment. With the upcoming Forward Vortex Detector upgrade, we expect to play a critical role for the future spin physics program.



## The RHIC-SPIN Facility @BNL



RHIC-SPIN has the capability to collide protons with various polarization configurations. In order to maintain and monitor the beam polarization over several hours in a store, various methods have been used. Here we showcase the physics with transversely polarized beams:



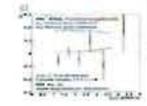
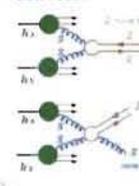
The observed large transverse left-right single spin asymmetry is a novel phenomenon that can provides us with unique information about the polarized proton internal structure and the dynamics of quark and gluon's strong interactions. Significant asymmetry has been observed in the valence quark dominant region. Very little known about the role of gluons, which account for about 50% of the proton's energy.

## LANL Physics Highlights

study the role of gluons in strong interactions



### Gluon Fusion



- Gluon fusion cross-sections fraction reduced in Generalized Parton Functions (GPDs) are well constrained by the helicity sum rule, assuming GPDs are gluons are not already coupled by other quark channels.
- Gluon fusion fraction can be directly access in  $q\bar{q}$  collisions via gluon fusion production of  $h_1$ .
- F-VTX Charge tags enable the measure gluon helicity distribution function.
- The F-VTX upgrade will significantly improve such measurements with reduced systematic errors.

- First measurement of  $A_{1T}$  in heavy vector meson  $J/\psi$  production.
- Motivated new theoretical study.
  - Constraints on gluon twist functions.
  - path to a new development in spin physics: beyond traditional spin topics, study GPD production mechanisms. It new way to study QCD.

## Summary and Outlook

1. LANL has been playing a key role in the PHENIX experiment at RHIC. PHENIX is a major US based high energy nuclear physics experiment with 650 people from 13 countries.
2. LANL has developed a physics program with muon measurements from the beginning and also laid out the ground work for the future program with the FVTX upgrade.
3. LANL is expanding its physics probes by including other important channels and working toward new measurements, such as  $\eta \rightarrow \gamma\gamma$  and Drell-Yan  $q + \bar{q} \rightarrow \gamma^* \rightarrow \mu^+ \mu^-$  that will shed new light on our understanding of the polarized nucleon structure and QCD dynamics in quark and gluon strong interactions.



## Introduction

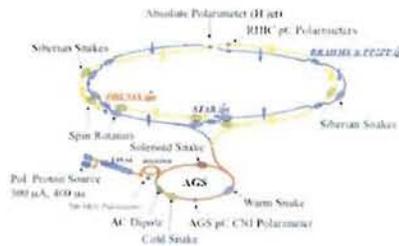
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In the past few years, the novel transverse spin phenomena observed at RHIC have stimulated many activities in theoretical investigation of strong interaction Quantum Chromodynamics (QCD) and provided much deeper understanding of the origin of transverse spin asymmetries. The LANL P-25 Group PHENIX team has played a key role in the RHIC-SPIN program in the PHENIX experiment. With the upcoming Forward Silicon Vertex Detector upgrade, we expect to play a critical role in the future spin physics program.

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## The RHIC-Spin Facility @BNL



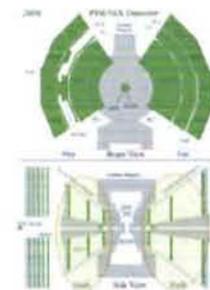
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Observing large transverse left-right single spin asymmetries at energies as high as at RHIC was a surprise that has fueled intense theoretical activity in recent years. Several models have been developed to explain the asymmetries. These asymmetries can provide us with unique information about the dynamics of the quarks and gluons inside the proton. **Significant asymmetry has been observed in the valence quark dominant region, however, very little is known about the role of gluons, which account for about 50% of the proton's energy, in generating such asymmetries.**

## LANL Physics Highlights

probing the role of gluons in strong interactions

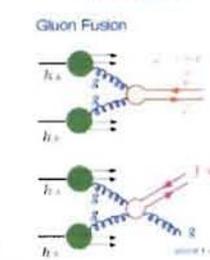


Muon Trackers

**Muon Trackers:** LANL designed, built, installed, commissioned the largest detectors in PHENIX  
**Forward Silicon VTX:** LANL-led PHENIX upgrade, initiated by LANL LDRD funds. **New capability:** Charm & Drell-Yan  
**Muon Physics:** LANL developed most of the physics programs with muon measurements.



Forward Silicon VTX



Gluon Fusion



- Gluon's Sivers distribution function (related to Gluon's Orbital Angular Momentum) is not well constrained by GPD-inclusive scattering v/f data as gluons are not directly probed by electromagnetic scattering.
- Gluon's Sivers function can be directly accessed in ep collisions via gluon-gluon interactions at RHIC.
- PHENIX charm analysis (started out by LANL) includes the necessary gluon Sivers distribution function.
- The FVTX upgrade will significantly expand our measurements in reducing systematic errors.

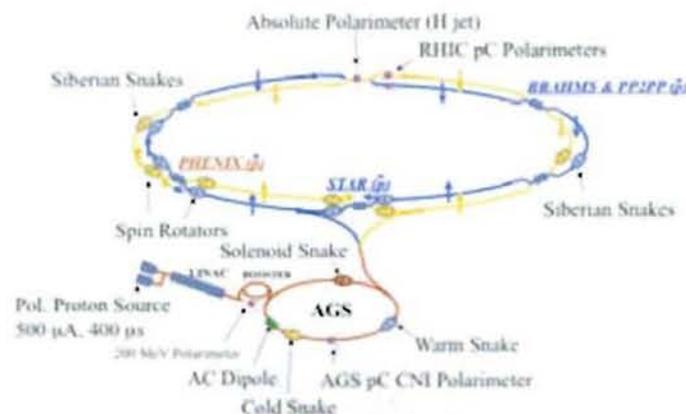


- First measurement of  $A_N^{\Delta}$  in heavy ion collisions (gluon production):**
- Consistent with gluon's Sivers function
- Motivated new theoretical study, which led to a new development in spin physics beyond traditional spin topics, to study the production mechanisms. A new way to test QCD models.

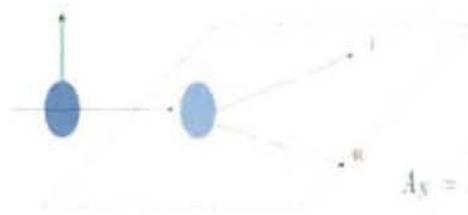
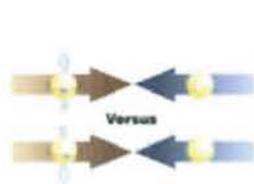
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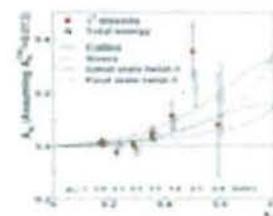
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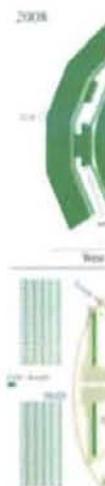
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$$A_N = \frac{L - R}{L + R}$$



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Gluon

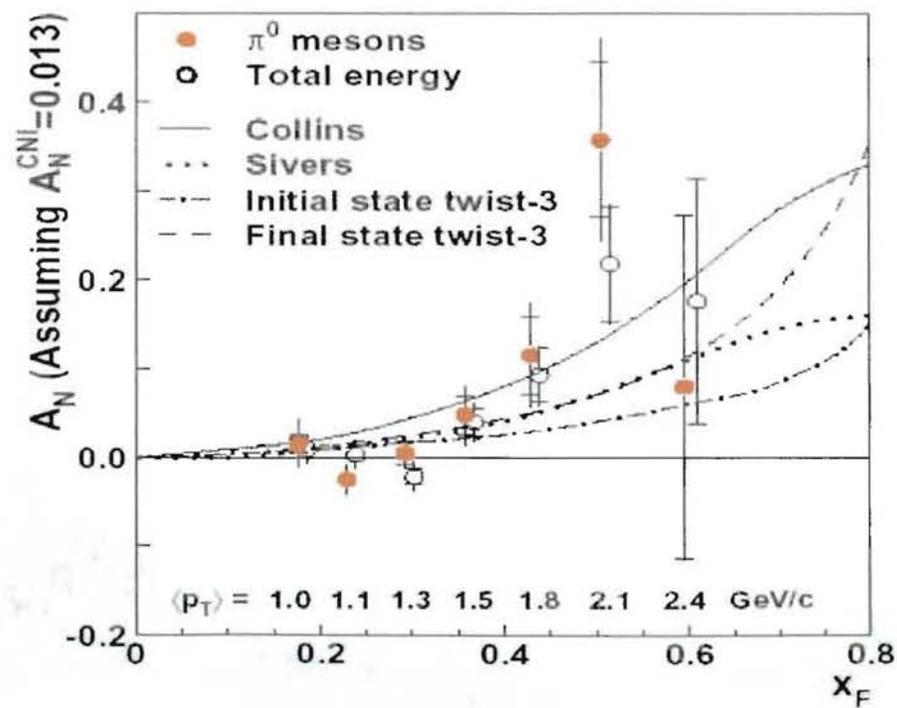
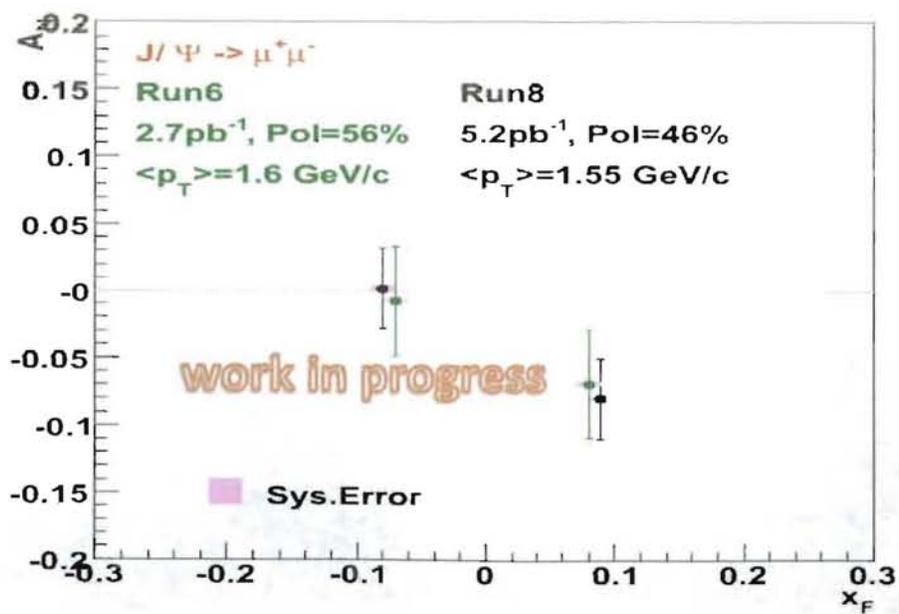
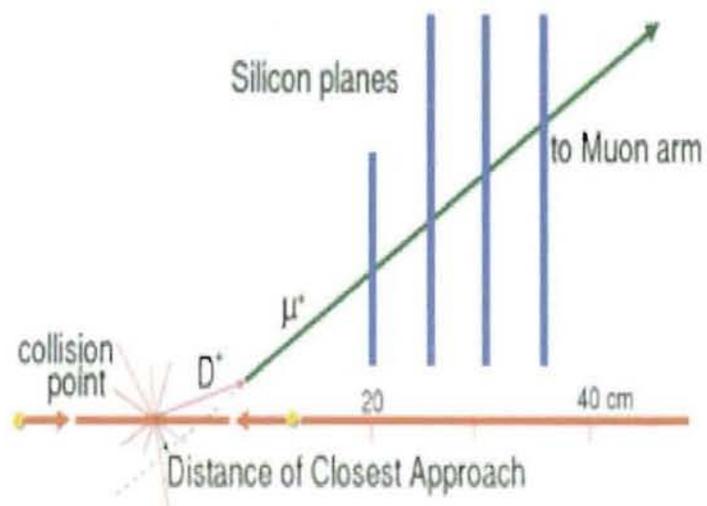
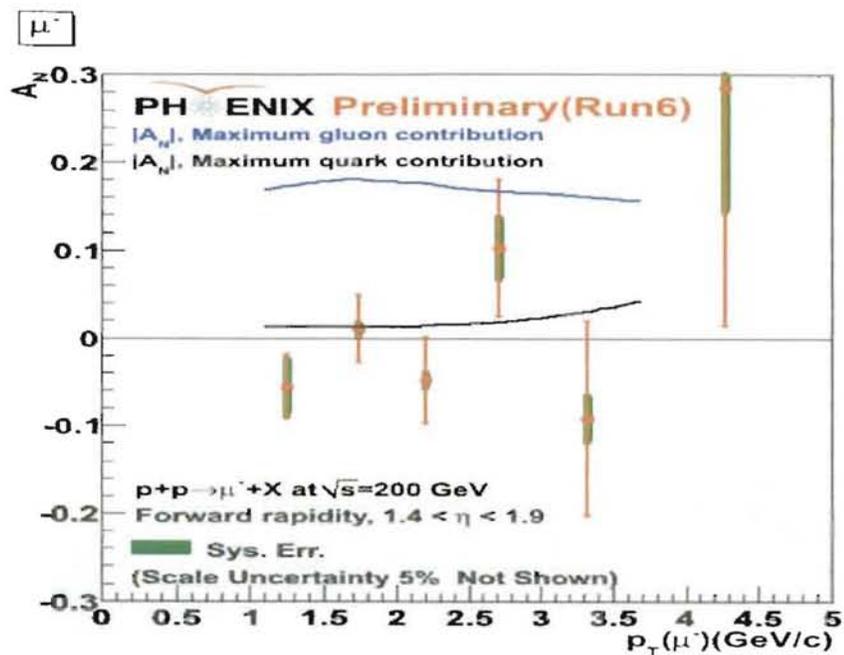
$h_A$

$h_V$

$h_A$

$h_V$





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# PHENIX Detector

