COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE/if not in response to a program announcement/solicitation enter NSF 10-1

PD 08-1232 **09/29/10**

FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.)

PHY - HADRONS AND LIGHT NUCLEI

FOR NSF USE ONLY

NSF PROPOSAL NUMBER

1068766

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION
09/29/2010	1	03010000 PHY	1232	837322494	09/29/2010 8:11pm

EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN)

581845423

SHOW PREVIOUS AWARD NO. IF THIS IS
☐ A RENEWAL
☐ AN ACCOMPLISHMENT-BASED RENEWAL

IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY? YES ☒ NO ☐ IF YES, LIST ACRONYM(S)

DOE

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE

Georgia State University Research Foundation, Inc.

AWARDEE ORGANIZATION CODE (IF KNOWN)

5300001194

ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE

Georgia State University Research Foundation, Inc.
G-76 Alumni Hall 30 Courtland Street
Atlanta, GA. 303033999

NAME OF PERFORMING ORGANIZATION, IF DIFFERENT FROM ABOVE

Georgia State University

PERFORMING ORGANIZATION CODE (IF KNOWN)

0015743000

ADDRESS OF PERFORMING ORGANIZATION, IF DIFFERENT, INCLUDING 9 DIGIT ZIP CODE

Georgia State University
University Plaza
Atlanta, GA 30303-3044

IS AWARDEE ORGANIZATION (Check All That Apply) (See GPG II.C For Definitions)
☐ SMALL BUSINESS ☐ MINORITY BUSINESS ☐ FOR-PROFIT ORGANIZATION ☐ WOMAN-OWNED BUSINESS

☐ IF THIS IS A PRELIMINARY PROPOSAL THEN CHECK HERE

TITLE OF PROPOSED PROJECT **Accessing the Proton Spin Structure**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ **279,909**	**36** months	**07/01/11**	

CHECK APPROPRIATE BOX(ES) IF THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW

☒ BEGINNING INVESTIGATOR (GPG I.G.2)
☐ DISCLOSURE OF LOBBYING ACTIVITIES (GPG II.C.1.e)
☐ PROPRIETARY & PRIVILEGED INFORMATION (GPG I.D, II.C.1.d)
☐ HISTORIC PLACES (GPG II.C.2.j)
☐ EAGER* (GPG II.D.2) ☐ RAPID** (GPG II.D.1)
☐ VERTEBRATE ANIMALS (GPG II.D.6) IACUC App. Date _____
PHS Animal Welfare Assurance Number _____
☐ HUMAN SUBJECTS (GPG II.D.7) Human Subjects Assurance Number _____
Exemption Subsection _____ or IRB App. Date _____
☐ INTERNATIONAL COOPERATIVE ACTIVITIES: COUNTRY/COUNTRIES INVOLVED (GPG II.C.2.j)
_____
☐ HIGH RESOLUTION GRAPHICS/OTHER GRAPHICS WHERE EXACT COLOR REPRESENTATION IS REQUIRED FOR PROPER INTERPRETATION (GPG I.G.1)

PI/PD DEPARTMENT
Physics & Astronomy

PI/PD FAX NUMBER
404-413-6025

PI/PD POSTAL ADDRESS
G-76 ALUMNI HALL 30 COURTLAND ST
P. O. Box 3999
ATLANTA, GA 303033999
United States

NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Electronic Mail Address
PI/PD NAME **Murad G Sarsour**	**DPhil**	**2002**	**404-413-3500**	**msar@gsu.edu**
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				

Electronic Signature

CERTIFICATION PAGE

Certification for Authorized Organizational Representative or Individual Applicant:

By signing and submitting this proposal, the Authorized Organizational Representative or Individual Applicant is: (1) certifying that statements made herein are true and complete to the best of his/her knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and conditions if an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding debarment and suspension, drug-free workplace, lobbying activities (see below), responsible conduct of research, nondiscrimination, and flood hazard insurance (when applicable) as set forth in the NSF Proposal & Award Policies & Procedures Guide, Part I: the Grant Proposal Guide (GPG) (NSF 10-1). Willful provision of false information in this application and its supporting documents or in reports required under an ensuing award is a criminal offense (U. S. Code, Title 18, Section 1001).

Conflict of Interest Certification

In addition, if the applicant institution employs more than fifty persons, by electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative of the applicant institution is certifying that the institution has implemented a written and enforced conflict of interest policy that is consistent with the provisions of the NSF Proposal & Award Policies & Procedures Guide, Part II, Award & Administration Guide (AAG) Chapter IV.A; that to the best of his/her knowledge, all financial disclosures required by that conflict of interest policy have been made; and that all identified conflicts of interest will have been satisfactorily managed, reduced or eliminated prior to the institution's expenditure of any funds under the award, in accordance with the institution's conflict of interest policy. Conflicts which cannot be satisfactorily managed, reduced or eliminated must be disclosed to NSF.

Drug Free Work Place Certification

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant is providing the Drug Free Work Place Certification contained in Exhibit II-3 of the Grant Proposal Guide.

Debarment and Suspension Certification

(If answer "yes", please provide explanation.)

Is the organization or its principals presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency? Yes ☐ No ☒

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant is providing the Debarment and Suspension Certification contained in Exhibit II-4 of the Grant Proposal Guide.

Certification Regarding Lobbying

The following certification is required for an award of a Federal contract, grant, or cooperative agreement exceeding $100,000 and for an award of a Federal loan or a commitment providing for the United States to insure or guarantee a loan exceeding $150,000.

Certification for Contracts, Grants, Loans and Cooperative Agreements

The undersigned certifies, to the best of his or her knowledge and belief, that:
(1) No federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.
(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, ''Disclosure of Lobbying Activities,'' in accordance with its instructions.
(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, Title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

Certification Regarding Nondiscrimination

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative is providing the Certification Regarding Nondiscrimination contained in Exhibit II-6 of the Grant Proposal Guide.

Certification Regarding Flood Hazard Insurance

Two sections of the National Flood Insurance Act of 1968 (42 USC §4012a and §4106) bar Federal agencies from giving financial assistance for acquisition or construction purposes in any area identified by the Federal Emergency Management Agency (FEMA) as having special flood hazards unless the:
(1) community in which that area is located participates in the national flood insurance program; and
(2) building (and any related equipment) is covered by adequate flood insurance.

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant located in FEMA-designated special flood hazard areas is certifying that adequate flood insurance has been or will be obtained in the following situations:
(1) for NSF grants for the construction of a building or facility, regardless of the dollar amount of the grant; and
(2) for other NSF Grants when more than $25,000 has been budgeted in the proposal for repair, alteration or improvement (construction) of a building or facility.

Certification Regarding Responsible Conduct of Research (RCR)
(This certification is not applicable to proposals for conferences, symposia, and workshops.)

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative of the applicant institution is certifying that, in accordance with the NSF Proposal & Award Policies & Procedures Guide, Part II, Award & Administration Guide (AAG) Chapter IV.B., the institution has a plan in place to provide appropriate training and oversight in the responsible and ethical conduct of research to undergraduates, graduate students and postdoctoral researchers who will be supported by NSF to conduct research.
The undersigned shall require that the language of this certification be included in any award documents for all subawards at all tiers.

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME **Marca Gurule**	**Electronic Signature**	**Sep 29 2010 5:12PM**

TELEPHONE NUMBER	ELECTRONIC MAIL ADDRESS	FAX NUMBER
404-413-3550	**reomg@langate.gsu.edu**	**404-413-3545**

* EAGER - EArly-concept Grants for Exploratory Research
** RAPID - Grants for Rapid Response Research

Project Summary: Accessing the Proton Spin Structure

Principal Investigator: Murad Sarsour

The origin of nucleon spin has been the focus of experimental and theoretical efforts ever since polarized deep-inelastic scattering experiments found that the total quark spin contribution to the nucleon spin is much smaller than expected. This was termed as the "proton spin crisis." An outstanding puzzle for more than three decades that revolves around the questions: How is the proton's spin built up from its quark and gluon constituents? Why is the total quark spin contribution so small? Figuring out the spin puzzle would require measurements of the gluon spin, ΔG, and orbital angular momentum of both quarks and gluons as well as individual quark and antiquark contributions.

In this proposal the Principal Investigator, Murad Sarsour, requests support to pursue investigations into the origin of the proton spin within the PHENIX Collaboration at Brookhaven National Lab's Relativistic Heavy Ion Collider (RHIC). These investigations include the gluon helicity and the quark and antiquark polarizations. The PI proposes to measure the double longitudinal spin asymmetry of the inclusive η meson at $\sqrt{s} = 500$ GeV. The objective of this measurement is to constrain ΔG over wide x-region, in addition, provide constraints on Δs in the accessible kinematic range. The PI is also a member of the forward upgrade group which is carrying out the PHENIX muon trigger upgrades with an objective of getting PHENIX ready for the quark and antiquark polarization measurements via single spin asymmetry of the W-decay muons.

Intellectual Merit

The results of the proposed measurements are long awaited, as much is still unknown of the internal constituent contributions to the proton's spin. Current world spin data have accessed gluon probes in a very limited kinematic region and significant uncertainty remains regarding the magnitude of the gluon helicity distribution. In addition, there is still much to be learned about the separate spin contributions carried by the sea quarks. Clear knowledge of the proton spin can emerge, by a global effort on the analysis of the world data where many channels are studied across a wide kinematic region, and the proposed measurements will be very valuable addition to the world data.

Broader Impacts

The proposed projects provide undergraduate and graduate students a unique opportunity in a large collider experiment. They will have hands on hardware and software experiences. To develop better understanding of the major component of the forward upgrade project, the RPCs, the students will build small RPC sets. Each of these sets will include a detector and computer-based data acquisition system, and the students will use them for cosmic ray studies, analyze and interpret the data, and write a project summary. To promote advanced science projects in high schools completed monitoring sets will be installed at participating local public schools where teachers and students maintain the operation of the detectors and participate in these data analysis.

TABLE OF CONTENTS

For font size and page formatting specifications, see GPG section II.B.2.

*Proposers may select any numbering mechanism for the proposal. The entire proposal however, must be paginated. Complete both columns only if the proposal is numbered consecutively.

Project Description

1 Introduction

More than 99.9% of the visible universe is made of nucleons - protons and neutrons, which are created by very complex interactions between elementary particles called partons - quarks and gluons. These interactions are described by the quantum field theory of the strong force: Quantum Chromo Dynamics (QCD). The partons cannot be studied directly due to what is known as the confinement, but rather within the confines of other particles like nucleons. Unlike partons, nucleons are stable and readily accessible and can serve as a laboratory to study the quarks and gluons. In 1968, electron-proton deep inelastic scattering (DIS) experiments at the Stanford Linear Accelerator Center (SLAC) showed that the proton was not an elementary particle, but instead contained much smaller, point-like objects [1, 2]. Since then significant progress in understanding the nucleon structure has been made. However, many important questions remain open; in particular we are still left with only poor understanding of the origin of the nucleon spin. The spin is especially important since it is responsible for many fundamental properties of the matter, including the magnetic moment, the different phases of matter in low temperature physics, and the stability of the universe in general.

The origin of nucleon spin has been the focus of experimental and theoretical efforts ever since polarized DIS experiments found that the total quark spin contribution to the nucleon spin is surprisingly small [3, 4]. This was termed as the "proton spin crisis." An outstanding puzzle for more than three decades that revolves around the questions: How is the proton's spin built up from its quark and gluon constituents? Why is the total quark spin contribution so small?

Obvious candidates for the rest of the proton's spin are the gluon and/or orbital angular momentum of the constituent quarks and gluons. The spin sum rule that relates the spin of the proton to its constituents is written as [4],

$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma(\mu) + \Delta G(\mu) + L_q(\mu) + L_g(\mu), \tag{1}$$

where $\Delta\Sigma$ and ΔG are the total quark and gluon helicity contributions to the proton spin, respectively, $L_q(\mu)$ and $L_g(\mu)$ are quark and gluon orbital angular momentum, respectively. The scale μ indicates the momentum scale at which these quantities are measured. Figuring out the spin puzzle would require measurements of ΔG, L_q and L_g.

The Principal Investigator (PI), Murad Sarsour, requests support to pursue investigations into the origin of the proton spin within the PHENIX Collaboration at RHIC. These investigations include ΔG and the quark and antiquark helicity distributions. Measurements of the double longitudinal spin asymmetry of the inclusive η meson at $\sqrt{s}$= 500 GeV will provide a valuable tool to constrain ΔG in the accessible kinematic range. The PI is also a member of the forward upgrade group which is carrying out the PHENIX muon trigger upgrades with an objective of getting PHENIX ready for the quark and antiquark helicity distributions via single spin asymmetry of the W-decay muons.

2 Review of Spin Structure Measurements

Three decades ago, the EMC (European Muon Collaboration) experiment [3] at CERN found, using deep-inelastic scattering of polarized muon beam off polarized protons, that the total quark spin contribution, $\Delta\Sigma$, to the spin of the proton is surprisingly small [3, 4]. The findings triggered several other polarized DIS experiments, with electron beams at SLAC [5, 6, 7], DESY [8] and JLAB [9], and a muon beam at CERN [10]. These experiments confirmed the EMC findings with much increased precision and also expanded the covered range of x and Q^2. The results stimulated a number of theoretical and experimental groups to try to extract the polarized parton distribution functions from fits of these data [11, 12, 13, 14]. $\Delta\Sigma$ was quite consistent in all fits, indicating that the polarized DIS data offer a reasonable constraint.

The gluons contribute to the polarized DIS cross section at the next-to-leading-order (NLO) level, so ΔG was extracted from NLO perturbative QCD (NLO pQCD) analyses of the scale dependence of the inclusive deep-inelastic spin structure function from the DIS data. However, due to the limited x and Q^2 coverage the resulting ΔG have rather large uncertainties [7, 10, 12, 14, 15, 16]. In addition, these inclusive DIS measurements provide only sensitivity to the combined contribu-

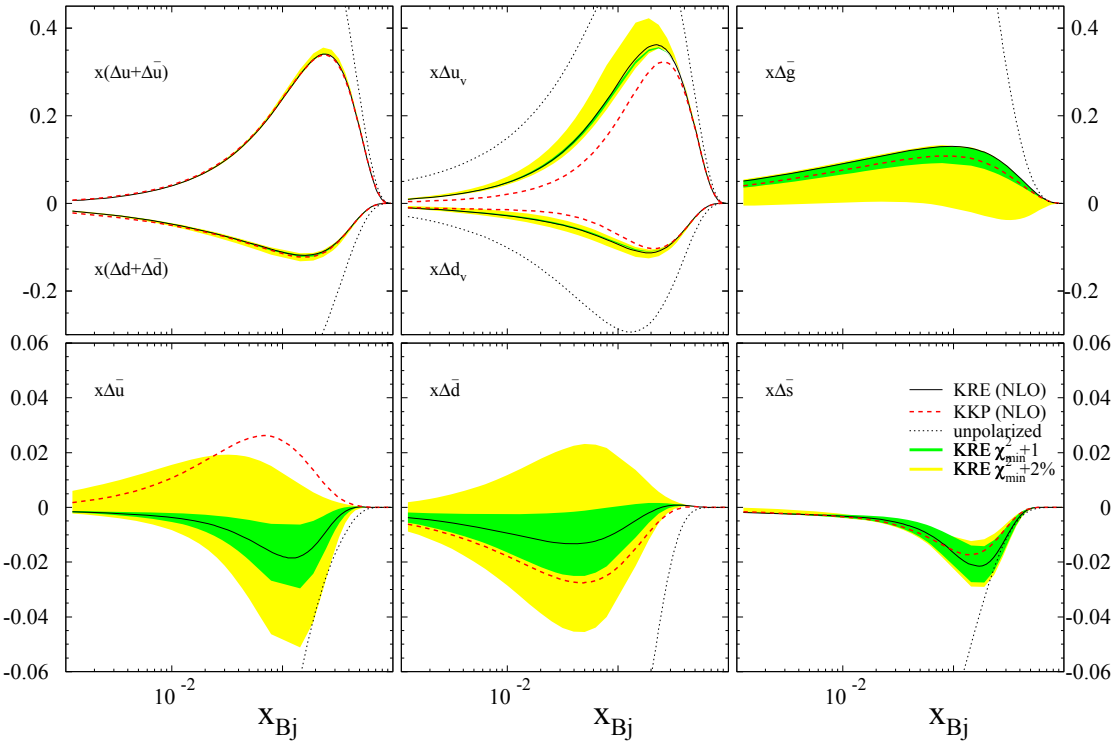

Figure 1: Polarized parton densities [15] extracted from polarized inclusive DIS and polarized semi-inclusive DIS data at Q^2=10 GeV^2. The green (yellow) bands correspond to $\Delta\chi^2$= 1 ($\Delta\chi^2/\chi^2 = 2\%$).

tions of quarks and anti-quarks summed over all flavors. In order to disentangle the individual

spin contributions carried by the quarks, several semi-inclusive DIS measurements have been also made [17, 18, 19]. Figure 1 shows the polarized parton densities from a recent NLO QCD global analysis [15] that included polarized inclusive DIS and polarized semi-inclusive DIS (pSIDIS) data. The SIDIS data combined with fragmentation function measurements allowed for the flavor separation of quark helicity densities. However, it is clear from Figure 1 that significant uncertainty remains regarding the magnitude of the gluon and sea quark helicity distributions. Another outstanding issue is the strange quark helicity distribution. The inclusive DIS data prefer a large negative value for $\Delta\bar{s}$ while when including the SIDIS data a small positive value is preferred [20, 21].

COMPASS Collaboration utilized the photon-gluon fusion, with a leading order sensitivity to gluons, to access ΔG. This was done by looking at charmed mesons [22] or high p_T particles [17]. Figure 2 shows the latest COMPASS data [23] along with earlier measurements by HERMES [19] and SMC [18] collaborations which used the high p_T charged particles production to access ΔG. These measurements reflect real progress, however, the limited precision, Q^2 reach, and uncertainties due to assumptions in the extraction of ΔG from leading order Monte Carlo simulations suggest that these measurements cannot provide definitive answer for ΔG.

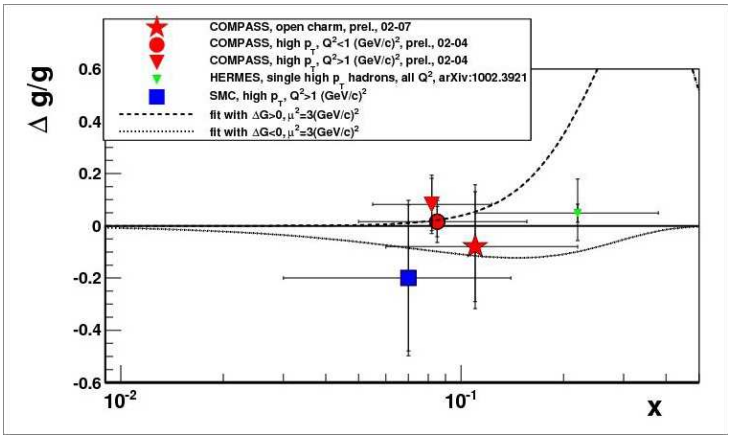

Figure 2: Compilation of leading order ΔG extractions from various gluon-photon fusion measurements [23].

Currently, there are several DIS facilities that study the nucleon spin structure. COMPASS is expected to run for the next couple of years to improve on their measurements of the quark and gluon polarizations in the proton. JLab, with the 12 GeV program, will focus on the longitudinal quark structure of protons and neutrons at high x. E906 at Fermilab will exploit the Drell-Yan process to probe selectively the antiquark distributions of target protons, deuterons, and nuclei.

The Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL) unites several features that make it unique to explore the gluon polarization. The high center of mass energy and high p_T make NLO pQCD analysis more reliable. Indeed, both PHENIX and STAR, the two major experiments at RHIC, have measured the unpolarized proton-proton cross sections for reactions sensitive to gluons and they are very well described by pQCD predictions over several orders of magnitude [24, 25, 26, 27]. At collider energies, a range of kinematics opens up which allows probing the gluon helicity distribution, $\Delta g(x)$, over a wide range of x, thus helping to significantly constrain its x-integral, ΔG ($= \int_0^1 dx \Delta g(x)$). In addition, quark polarization measurements at RHIC will be compared to those from DIS and SIDIS. A crucial feature of RHIC is providing two different energies, $\sqrt{s} = 200$ and 500 GeV. It is conceivable that gluons are still rather strongly polarized towards low momentum fractions, x, so that a significant contribution to ΔG could come from that region.

In the past several years, as RHIC was still developing higher luminosity and polarization, mea-

surements exploited the abundant channels of inclusive pions and jets. The PHENIX collaboration with its highly segmented calorimeter focused on the inclusive π^0 A_{LL} [26, 27, 28, 29] and inclusive photon reconstruction [30], while the STAR collaboration with its large acceptance detector focused on the inclusive jets A_{LL} [25, 31, 32]. RHIC data from inclusive probes (jets and π^0) were included in a recent NLO global analysis [20, 21], DSSV, which is the first to include inclusive DIS, SIDIS, and RHIC pp collision data. The results of this analysis, shown in Figure 3, indicate that $\Delta g(x, Q^2)$

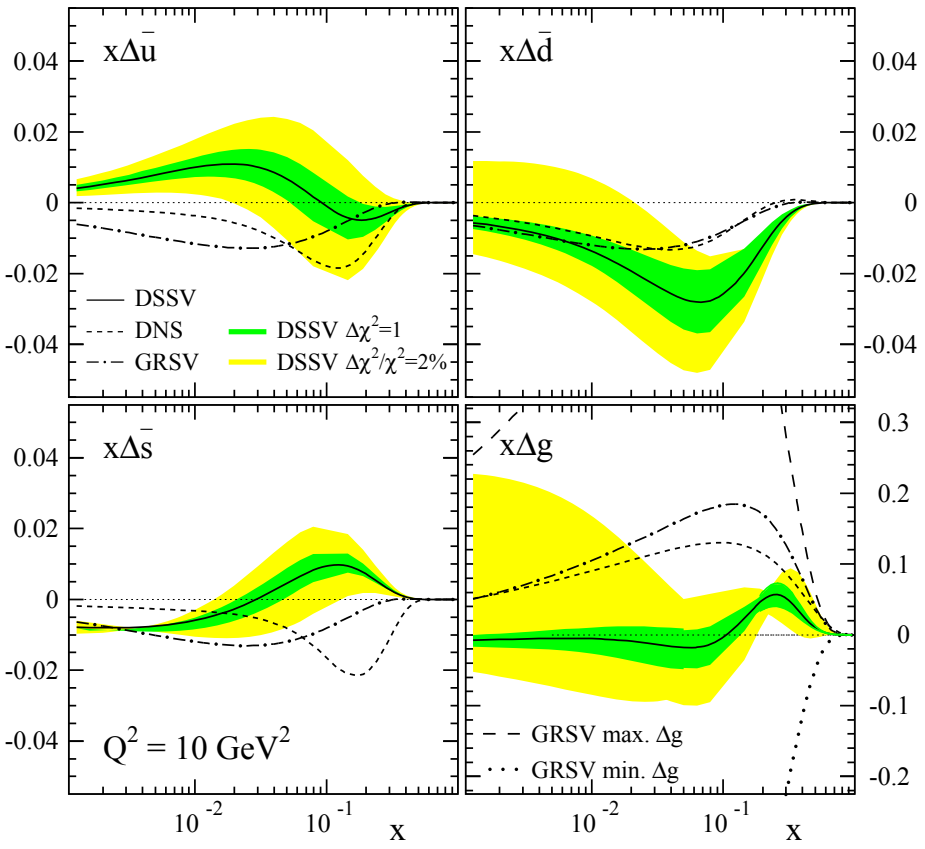

Figure 3: DSSV polarized sea and gluon densities [20] compared to previous fits [12, 15]. The green (yellow) bands correspond to $\Delta\chi^2 = 1$ ($\Delta\chi^2/\chi^2 = 2\%$).

is small in the accessible range of momentum fraction, x, with a possible node in the distribution near $x \sim 0.1$, basically evolving away at higher scales with an opposite phase from GS-C [11]. A study of the DSSV χ^2 distribution shows that RHIC data set substantial new constraints on the polarized gluon distribution in the proton over the kinematic range $0.05 < x < 0.2$ [20]. However, in spite of these improvements there are still significant uncertainties regarding ΔG. This is clear in Figure 4 which shows the GS-C in the left panel and DSSV in the lower right panel, two independent global fits, both fit the inclusive jet data very well even though they assume two different

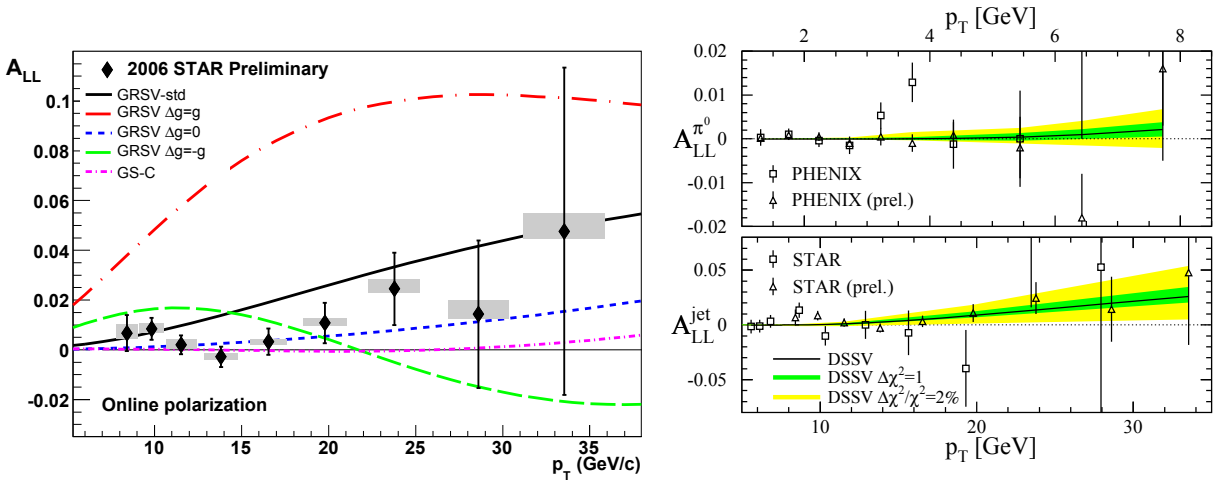

Figure 4: Left panel: preliminary 2006 A_{LL} for inclusive jet production at $\sqrt{s} = 200$ GeV versus jet p_T , where the error bars are statistical and the gray bands indicate the systematic uncertainties. Right panel: comparison of PHENIX (top) and STAR (bottom) data to the DSSV fit. The shaded bands correspond to $\Delta\chi^2 = 1$ and $\Delta\chi^2/\chi^2 = 2\%$ [20].

functional forms. RHIC provided lengthy $\sqrt{s} = 200$ GeV run in 2009 that will decrease the uncertainties associated with the inclusive π^0 and jets, allow for studying other inclusive probes like prompt photons and η mesons, and give the opportunity to collect enough statistics to do di-jets and di-hadron measurements that will provide x-dependence of $\Delta g(x, Q^2)$. RHIC also provided the first exploratory run at $\sqrt{s} = 500$ GeV for luminosity and polarization development. The $\sqrt{s} = 500$ GeV data allows probing lower x-region for ΔG measurement and will also put RHIC in a unique position to shed light on the quark and antiquark polarizations, sorted by quark flavor, through parity-violating production of W bosons [33, 34, 35].

3 Proposed Project

This proposal requests support for the Georgia State University spin group to carry out measurements that shed light on the proton spin structure. The project will have the following components:

3.1 Inclusive η Double Longitudinal Spin Asymmetry

The PI proposes to measure the double longitudinal spin asymmetry in η meson production ($\vec{p}+\vec{p} \rightarrow \eta+X$), A_{LL}^{η}, which provides a valuable tool to constrain ΔG in the accessible kinematic range. η meson is produced copiously in the proton-proton collisions, and it is reconstructed through its primary decay channel, $\eta \rightarrow \gamma\gamma$, with $\sim 39\%$ branching ratio, in the highly segmented PHENIX electromagnetic calorimeter (EMCal) [36]. The reconstruction procedure is very similar to π^0 meson which has been done successfully over the past years [24, 27, 37]. Figure 5 shows reconstructed invariant mass distributions in the vicinity of the η peak from run 2009 data at $\sqrt{s} = 200$ GeV. The primary inclusive channel to study ΔG at the PHENIX experiment is π^0, however, η is the second most abundant probe [38] and gives reasonable statistical uncertainties and thus sizable weights in global fits.

In addition, the measurement of the A_{LL}^{η} adds independent data with different systematics to the present set of polarized data available to PDF fits. Even when compared to the π^0 data on double helicity asymmetries, the difference in the fragmentation functions can lead to a different sensitivity to certain PDFs.

A_{LL} is defined as,

$$A_{LL} = \frac{\sigma^{++} - \sigma^{+-}}{\sigma^{++} + \sigma^{+-}} = \frac{\Delta\sigma}{\sigma} \quad (2)$$

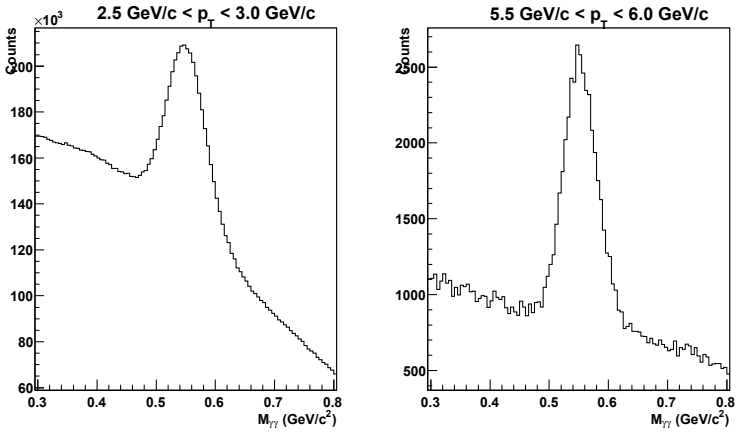

Figure 5: Invariant mass distributions in the vicinity of the η peak for the high p_T triggered data set and for two different bins of p_T.

where σ^{++} (σ^{+-}) is the differential cross section when the beam protons have equal (opposite) helicities. Assuming the hadron (i.e. η) produced at high transverse momentum, p_T, the cross section reads up to corrections suppressed by inverse powers of p_T:

$$d\Delta\sigma = \sum_{abc} \Delta f_a \otimes \Delta f_b \otimes \Delta\hat{\sigma}^{ab\to cX'} \otimes D_c^h, \quad (3)$$

where Δf_a and Δf_b are the polarized parton distributions for quarks (u,d,s) and gluons, and $\Delta\hat{\sigma}$ is the spin dependent hard scattering cross section which is calculable in pQCD. D_c^h is the fragmentation function (FF) which represents the probability for a parton c to fragment into a hadron h. It is apparent in Equation 3 that gaining information on the spin-dependent PDFs depends on how well we know the FF of the inclusive hadron being measured. Initially, η cross section measurements from $e^+ + e^-$ scattering have been used to extract FFs for η production, but the η FF is constrained further by including precise η to π^0 cross section ratios [39]. Figure 6 shows the contributions of the various scattering subprocesses gluon-gluon (gg), quark-gluon (qg), and quark-quark (qq) to the η production as a function of p_T. For comparison, they are also shown in the case of π^0 production [40]. In addition to the dominant gluon to η fragmentation, a strong strange quark to η fragmentation is expected especially at higher z, and A_{LL}^{η} measurement would provide constraint on the strange quark contribution to the spin of the proton [41]. This is particularly important given the disagreement between the global fits when including or excluding the SIDIS data to the DIS data as mentioned earlier. The size of $\Delta s + \Delta\bar{s}$ is not only a topic of interest for nucleon spin structure but also for dark matter enthusiasts, the uncertainty in $\Delta s + \Delta\bar{s}$ provides the single largest uncertainty in predictions of the spin-dependent elastic scattering cross sections of super-symmetric dark matter particle on protons and neutrons [21].

Experimentally, A_{LL} is determined by counting the luminosity normalized observable yields when the colliding protons have aligned (N^{++}) and anti-aligned (N^{+-}) helicities and polarizations

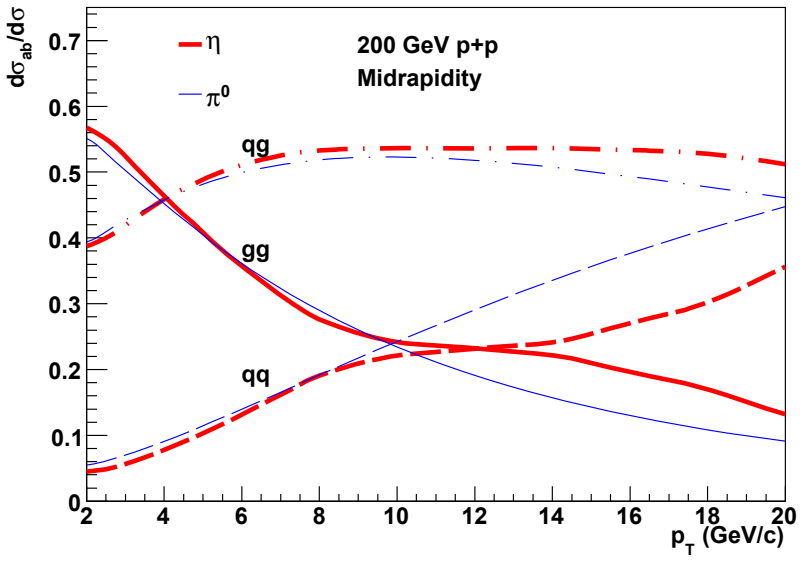

Figure 6: Fractional contribution of gluon-gluon (gg), quark-gluon (qg), and quark-quark (qq) scattering to the η and π^0 production as a function of p_T .

of P_1 and P_2, according to the following equation,

$$A_{LL} = \frac{1}{|P_1||P_2|}\frac{N^{++} - N^{+-}}{N^{++} + N^{+-}} \tag{4}$$

In 2009, PHENIX collected $\sim$ 13 pb^{-1} at $\sim$ 55% polarization at $\sqrt{s}$ = 200 GeV. The PI carried out the data analysis to extract A_{LL}^{η} from the 200 GeV data set and preliminary results were released in June 2010 and soon to be published with $A_{LL}^{\pi^0}$. Figure 7 shows the preliminary A_{LL} for mid-rapidity inclusive η production from the combined 2005, 2006, and 2009 data at 200 GeV as a function of p_T . Figure 7 also shows NLO pQCD calculations which incorporate two different scenarios for $\Delta g(x)$, including the best global fit to the inclusive DIS data (std) and the zero gluon polarization ($\Delta g(x) = 0$) [12, 20]. It also shows the DSSV global fit prediction that includes data from DIS, SIDIS, and RHIC [20]. A_{LL}^{η} is consistent with zero over the measured range as expected based on the apparent similarity of the η and π^0 fragmentation functions and since $A_{LL}^{\pi^0}$ is consistent with zero as well [27]. The PI gave a public presentation of the preliminary 2009 A_{LL}^{η} results along with other recent PHENIX results from the longitudinal and transverse spin programs at Diffraction 2010 [42].

In 2009, RHIC also had its first exploratory run at $\sqrt{s} = 500$ GeV and the PHENIX experiment collected $\sim$ 8 pb^{-1} at $\sim$ 39% polarization which provides a good data sample for η cross section and first look A_{LL} measurements. At 500 GeV, A_{LL}^{η} measurement is especially important since η is less effected by the cluster merging of the reconstructed di-photons than π^0. This not only brings η statistically closer to π^0 but also makes A_{LL}^{η} a vital independent cross check for $A_{LL}^{\pi^0}$. The plan for the PI is to work with Mr. Behnam Aryafar, a graduate student, to extract A_{LL}^{η} from the 500 GeV runs in 2011 and 2012. The projected uncertainties on A_{LL}^{η} from the 500 GeV run in

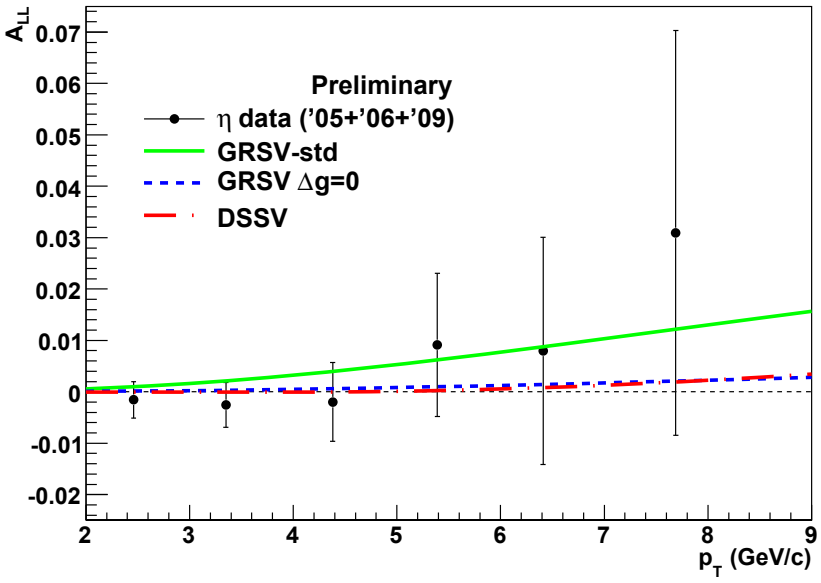

Figure 7: preliminary A_{LL} for mid-rapidity inclusive η production from the combined 2005, 2006, and 2009 data at 200 GeV as a function of p_T. The results are compared to NLO pQCD calculations using two different sets of polarized PDFs [20, 12], and DSSV fit [20].

2011, assuming 50 pb^{-1} recorded luminosity at 60% polarization and compared to 300 pb^{-1} at 60% polarization, are shown in Figure 8. This project is expected to be Mr. Aryafar's thesis project.

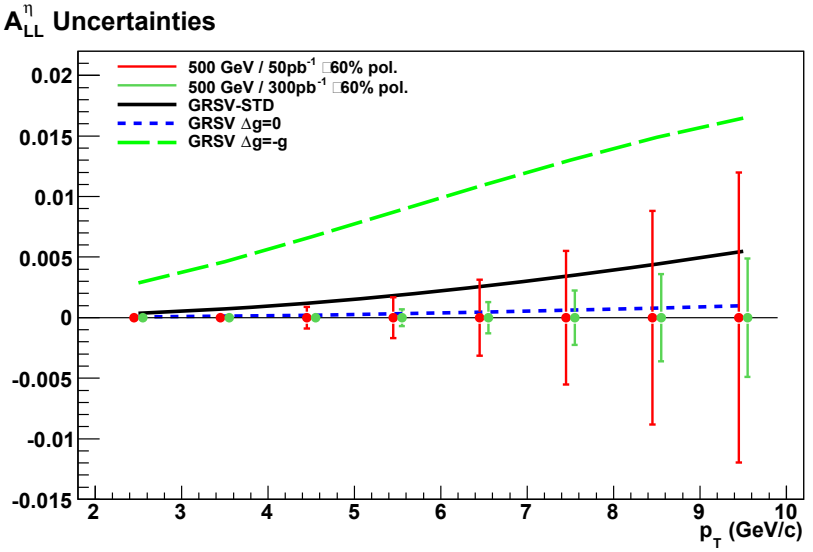

Figure 8: Statistical projections of A_{LL} for inclusive η production at $\sqrt{s} = 500$ GeV expected in run 2011.

The PI is currently finishing up the analysis of the 500 GeV data set to produce η cross section

and A_{LL}. The cross section measurement is be to added to η cross section measurements from $e^+ + e^-$ scattering and PHENIX's previous η cross section measurements to reduce uncertainties associated with the extracted fragmentation functions for η production. The cross section and A_{LL} from inclusive η production are expected to be published soon along with those of π^0 production at 500 GeV.

3.2 Sea Quark and Antiquark Polarization

A major emphasis of the PHENIX spin program is to cleanly and accurately measure the sea quark and antiquark polarizations, sorted by quark flavor. This will clarify the overall picture of small total quark and antiquark contribution to the spin of the proton. The single spin asymmetry, A_L, of maximally parity violating W production in the longitudinal polarized proton scattering provide a very clean way to study quark and antiquark polarizations. These asymmetries are expected to be large in polarized proton-proton collisions at RHIC [33, 43]. In addition, independence of fragmentation functions and associated uncertainties and the high energy scale set by the W mass will make it possible to extract quark and antiquark polarizations from the single spin asymmetries in W production with minimal theoretical uncertainties. All the mentioned above makes RHIC an ideal place and powerful tool to study quark and antiquark polarizations.

The single spin asymmetry in W production, A_L^W, is defined as the difference over the sum of the cross-sections for one longitudinally polarized proton to scatter off another unpolarized proton:

$$A_L^W = \frac{\sigma^{\uparrow}(pp^{\uparrow} \to WX) - \sigma^{\downarrow}(pp^{\downarrow} \to WX)}{\sigma^{\uparrow}(pp^{\uparrow} \to WX) + \sigma^{\downarrow}(pp^{\downarrow} \to WX)} \tag{5}$$

At RHIC, the W boson is observed through its leptonic decay, $W \to l\nu$, and since RHIC detectors are not hermetic only the high p_T charged lepton can be measured and not the associated neutrino. However, it was shown in [44] that by applying certain experimental cuts on the observed leptons the measurable asymmetries as a function of rapidity are a viable alternative to those of the W boson. The full impact of such measurement is realized through a global analysis that also includes the SIDIS data [43].

At the lowest order (LO) the W^- production, for example, involves primarily $d\bar{u} \to W^-$ and $A_L^{W^-}$ can be written as a superposition of two cases,

$$A_L^{W^-} \approx \frac{-\Delta d(x_1)\bar{u}(x_2) + \Delta\bar{u}(x_1)d(x_2)}{d(x_1)\bar{u}(x_2) + \bar{u}(x_1)d(x_2)} \tag{6}$$

where Δd and $\Delta\bar{u}$ are the helicity distributions and $x_{1,2} = \frac{M_W}{\sqrt{s}} e^{\pm y_W}$. y_W is the rapidity of the W boson and $\sqrt{s}$ is the hadronic center of mass. PHENIX's forward muon detectors present a unique opportunity to carry out this measurement since they sample quite asymmetric parton collisions where at these large rapidities: $x_1 \sim 1$ and $x_2 \ll 1$. This allows the separation between the quark and antiquark contributions where the W^- production at $x_1 >> x_2$ gives: $A_L(forward\ W^- \to \mu^-) \approx -\Delta d(x_1)/d(x_1)$ and $A_L(backward\ W^- \to \mu^-) \approx \Delta\bar{u}(x_1)/\bar{u}(x_1)$. Similarly, the W^+ production will allow access to $\Delta u/u$ and $\Delta\bar{d}/\bar{d}$ but due to the fixed neutrino helicity the relative flavor contributions in forward and backward rapidity regions are not as easily separable. In addition, midrapidity A_L measurements of $W^{\pm}$ production combine contributions from both u and $\bar{d}$ polarizations, and from d and $\bar{u}$ polarizations in W production [35].

The rate for W production in proton-proton collisions at 500 GeV is very small and the measurement requires high luminosity running which results in high backgrounds. These backgrounds are dominated by decay muons from low momentum hadrons (i.e. pions and kaons) that punch through the front absorber and decay in the tracking volume of the muon tracking detector (MuTr). MC simulations of these background muons along with W-decay muons versus p_T are shown in Figure 9. Cosmic rays and beam backgrounds are another expected source of backgrounds.

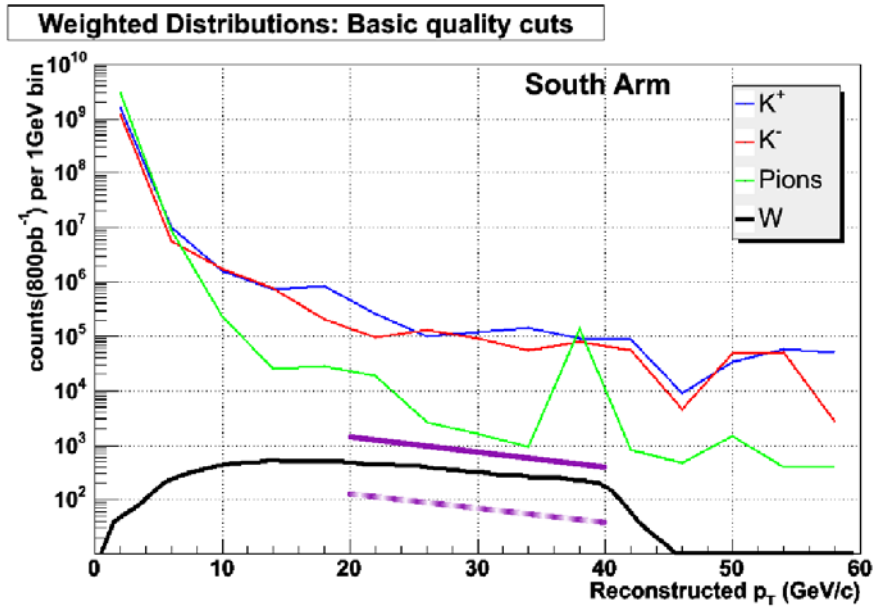

Figure 9: False high p_T muon background from kaon and pion decays. The thick black curve shows the W-decay muons.

The existing detector and muon trigger setup provide a rejection factor $R \sim 100$ or even less under higher rate conditions that we expect to see at 500 GeV running. Consequently, the forward trigger upgrade was started several years ago, where tracking and timing information are provided to a new set of muon trigger processors to complement the current trigger and to improve the overall rejection power. The forward trigger upgrades include: (1) New front-end electronics for the muon tracking chambers to send tracking information to new dedicated muon trigger processors. This system has been developed, constructed, and fully installed and integrated. (2) Two resistive plate chamber (RPC) trigger detector stations, RPC-1 upstream and RPC-3 downstream, added to each muon spectrometer (north and south muon arms). RPC-3 is completely installed in both south and north arms. RPC1 in both arms will be completed before the start of run 2012. The RPC stations will be used for both tracking and timing. The timing information will add background rejection power in offline analysis. Additionally, new 35 cm thick steel absorbers will be installed upstream of each of the muon spectrometers before run 2011. MC simulations as well as analysis of the data taken in 2009 at 500 GeV with a prototype absorber show that an absorber with a thickness of two nuclear interaction lengths will provide full suppression of these backgrounds.

Cosmic ray muons are another source of background that was not well understood. The PI, X. He, and J. Ying from Georgia State University analyzed recent cosmic ray data taken before and

after run 2009 and near the end run 2010 by the PHENIX collaboration to study this background. Detailed analysis of these data showed that using the current system with all possible cuts suppresses the cosmic muon survival rate to 0.0017 ± 0.006 mHz from run 2009 data and 0.0013 ± 0.004 mHz from run 2010. These rates are at least 30 times less than the expected W-decay muon rate, ~ 0.5 mHz. Additional suppression power of the cosmic backgrounds comes from the RPCs timing information. The cosmic muons enter the muon arms from back and can be easily distinguished from W-decay muons which emerge from the collision region since they register hits in RPC 3 before RPC1. This means that with the help of the RPCs the cosmic backgrounds will be suppressed to a very negligible level even at high rates were using all possible cuts may not be as efficient.

Currently, the PI is working with a smaller group within the forward upgrade group on new full detector simulation to understand the backgrounds more thoroughly and confirm them in the data to simulate the various QCD background in preparation for run 2011. Full PYTHIA 6.4 simulation has been started using the tune A which reproduces most of the 200 GeV cross sections measured at RHIC. No direct comparisons of this tune to 500 GeV RHIC data were performed and some differences are possible. The events are generated separately for different sub-processes: light and diffractive physics, open charm, open bottom, onium production, direct photon processes, Drell Yan and Z boson processes, W boson processes as well as Z+jet and W+jet processes. Those events are then processed by the PHENIX detector simulation (based on GEANT) and reconstructed by the muon arm reconstruction software.This MC production will allow us to test all previously considered cuts to reduce the backgrounds in the high p_T region for the W-decay muon signals. In comparison to the previous work, mostly single particle simulations, it will be possible to test these cuts under realistic conditions and also be able to investigate further isolation criteria.

With the ongoing upgrade efforts of the forward muon trigger and extended data collection at $\sqrt{s} = 500$ GeV decay lepton measurements in the forward rapidity regions can be made with sufficient accuracy to discriminate between different flavor scenarios for the polarized quark distributions in the nucleon. PHENIX is projected to collect 150 pb^{-1} from runs 2011 and 2012 combined. Assuming that background rejection capability with offline cuts and the absorber doesn't live up to the expectation, the forward silicon vertex detector (fvtx) can be used for further rejection beginning in run 2012. In this case a tighter cut on the vertex is required which will result in collecting only 50 pb^{-1} in run 2012, and having signal-to-background ratio of 3.0. Figure 10 shows the expected uncertainties for this scenario. The curves in the figure are the results of various pQCD fits including different inclusive and smei-inclusive DIS data along with previous RHIC data. It is quite clear that even if things don't live up expectations the 500 GeV data from PHENIX will have a substantial impact. The top two panels in Figure 11 show the current uncertainties obtained by a pQCD fit [20, 21] to the world data from inclusive and semi-inclusive deep inelastic scattering, while the lower two panels show the impact of the $W^{\pm}$ A_L for 300 pb^{-1} with a mean polarization of 60%. The W data reduce the uncertainties on the sea-quark polarizations for $0.05 < x < 0.6$ significantly, furthermore, serve as a set of complementary measurements to the ones in semi-inclusive DIS.

The plan for PI is to continue contributing to the simulations efforts and with Mr. Guragain work on data from runs 2011 and 2012 to extract A_L for W-decay muons. These asymmetry measurements are expected to be Mr. Guragain Ph.D. project. In addition, the PI and the GSU heavy ion group are making substantial contributions to several aspects of the Forward Muon Trigger Upgrade hardware and devoted significant resources to the RPC factory work. The Forward Muon Trigger Upgrade project will serve the interests of both W physics (spin program) and heavy flavor physics (heavy ion program). A major part of GSU involvement is RPC research and

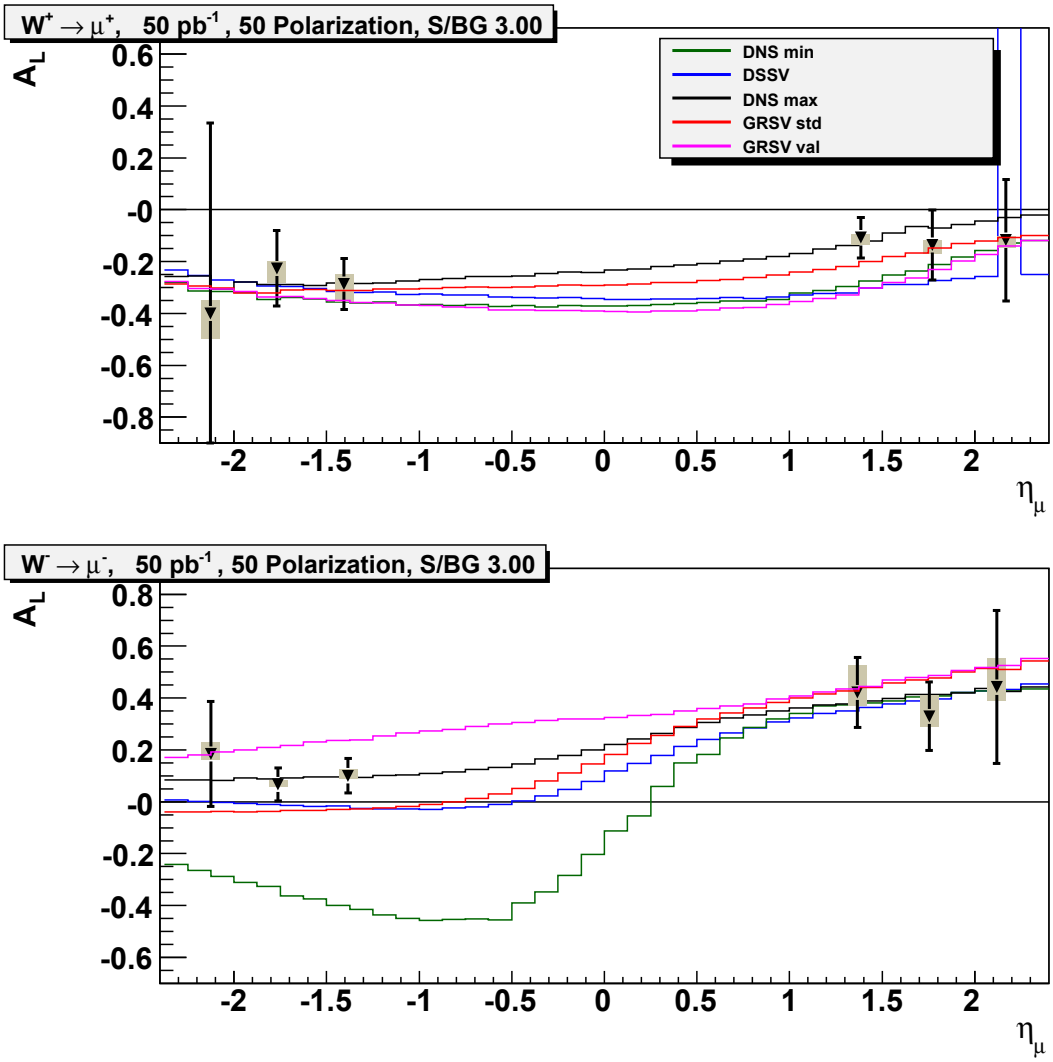

Figure 10: Expectation for uncertainties in W asymmetry measurements with 50 pb^{-1} recorded with 50% polarization and S/B=3.0.

development (R&D) to gain a working knowledge of RPC detectors in PHENIX and to develop detector assembly and quality assurance procedures for the RPC factory at BNL. The PI recently obtained a large laboratory space at GSU to house the RPC prototype that was used for testing and cosmic studies during run 2009. This prototype will extend our R&D studies from much smaller RPC modules to real size and similar design to the actual PHENIX RPCs which would provide more realistic model for our R&D efforts of PHENIXs RPCs and thus most beneficial. The PI gave a public presentation at the April APS meeting where he presented the results from run 2009 prototype RPC tests at 500 GeV and other RPC performance tests, as well as results for local RPC monitoring and studies at GSU [45].

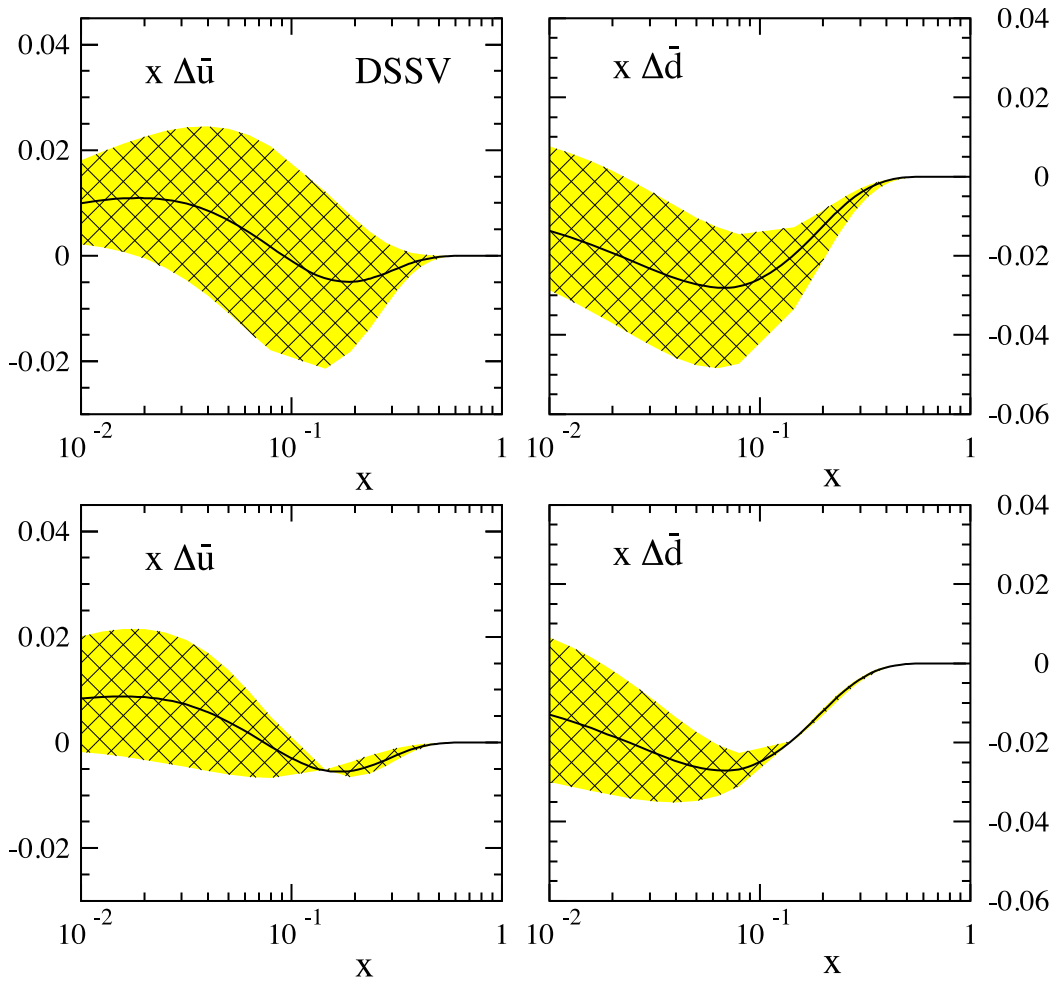

Figure 11: Upper plots: Uncertainty band on $x\Delta u$ and $x\Delta d$ resulting from the current fit to the world data from inclusive and semi-inclusive DIS by DSSV [20, 21]. Lower plots: Improvement in the uncertainties adding constraint from W A_L measured with 300 pb^{-1} of 500 GeV p + p collisions with 60% polarization.

3.3 Personnel

The PI became an Assistant Professor at GSU in Fall, 2008, and joined the PHENIX Collaboration at that time. Prior to that, the PI was a member of the STAR Collaboration for five years, during which he developed very extensive experience with A_{LL} measurements and the various systematic uncertainties associated with them and the collider at large. He assisted in runs 2003 and 2004 inclusive jet A_{LL} analysis which resulted into Physical Review Letters publication [25]. Then the PI together with Dr. C.A. Gagliardi and Dr. R. Fatemi, developed new analysis procedures that account for most of the distortions that were introduced in the inclusive jet A_{LL} measurement by the STAR detector in run 2005. This allowed performing a quantitative comparison of the results to global fits of polarized DIS data within the GRSV framework for various fixed values of ΔG [12]. The final results are published in Physical Review Letters [31]. The PI is one of the principal authors of that paper. These results imply that the gluon polarization in the nucleon cannot be

much larger than the GRSV-std polarized parton distribution fit. In parallel, the PI analyzed the inclusive jet data that were recorded during 2006 to determine A_{LL} with higher precision at higher transverse momentum. The analysis procedures were similar to those developed for the 2005 analysis. However, the increased calorimeter coverage during run 2006 allowed increasing the jet cone radius from 0.4 to 0.7. The PI also improved the treatment of several of the systematic uncertainties, especially those due to beam-gas and pile-up backgrounds. The PI gave the first public presentation of the preliminary 2006 results in a talk at the DNP meeting in Newport News [32]. The same talk also included the first public presentation of the final 2005 results described above. The STAR publication on the 2006 inclusive jet A_{LL} measurement is in collaboration review and to be released soon. The 2007 NSAC Long-Range Plan for Nuclear Science identified these preliminary 2006 inclusive jet A_{LL} results, in conjunction with preliminary 2006 inclusive π^0 measurements from PHENIX experiment, as one of the highlights of the past five years in the field of nuclear physics.

As a member of the PHENIX collaboration, the PI assisted in collecting data in run 2009, and he has been working on run 2009 data to extract asymmetries and cross section for η meson at both energies: 200 and 500 GeV. The PI is one of the principal authors on two of PHENIX's papers that will be soon be submitted for publications; $A_{LL}^{\pi^0}$ and A_{LL}^{η} at 200 GeV and π^0 and η cross sections and A_{LL} at 500 GeV. The PI is also a member of internal review committee on A_{LL}^{η} measurement from runs 2005 and 2006 as well as η to π^0 cross section ratio paper. Two graduate students, Hari Guragain and Behnam R. Arayafar, joined the PI in August 2010. Both are expected to finish their basic courses and qualifier exams by the end of Spring 2011, and will be able to play a major role in the data analysis starting in Summer 2011. Currently, they are being transitioned into research with small duties to get them ready for larger projects in the summer. Mr. Guragain is expected to work on W-decay muon A_L from runs 2011 and 2012 data, while Mr. Arayafar is expected to work on A_{LL} for inclusive η production from run 2011 at 500 GeV. Currently, start-up funds are being used to pay for travel expenses for the PI and to pay salary for Mr. Guragain, however, Mr. Arayafar is enrolled as a part time student to be able to support himself. The PI requests support for the graduate students for the next three years to work on their projects toward Ph.D. in addition to the PI's summer salary and travel expenses for the PI and students.

4 Project Objectives:

The polarized p+p collisions at the Relativistic Heavy Ion Collider (RHIC) provide a very suitable environment, rich with strongly interacting probes, to constrain ΔG over wide x-region. In addition, RHIC is in a unique position to cleanly measure the sea quark and antiquark polarizations, sorted by quark flavor, through parity-violating production of W bosons. This proposal outlines plans to benefit from these great aspects and use the support and available resources to achieve the following objectives:

- Constrain ΔG and possibly Δs over wide x-region via inclusive η asymmetry (A_{LL}^{η}) measurements at beam energies of 200 and 500 GeV.
- Disentangle the separate spin contributions carried by the sea quarks and antiquarks by measuring A_L of the W-decay muons at $\sqrt{s} = 500$ GeV. The GSU spin group will specifically contribute in the following tasks:
  - Contribute to the ongoing simulations efforts.

  - Gain a working knowledge of RPC detectors in PHENIX including environmental effects and gas mixing on various RPC chamber properties such as: dark current, efficiency, time resolution, and electronic readout characteristics.
  - Assist in the RPC installation, testing, and software development.
  - Contribute to the data analysis and generating A_L of the W-decay muon.

- Explore future physics projects that will further improve our knowledge of the nucleon spin structure, especially the orbital angular momentum.

5 Education and Outreach

R&D work for PHENIX RPCs is an important part of the PI's contribution to PHENIX and used as an educational tool as well. At GSU, we have several small RPC prototypes, some built locally and others in Korea, and complete monitoring units. Their installation, maintenance and associated R&D work present excellent opportunities for undergraduate and graduate students at GSU to have hands on hardware and software experience. The PI and students work with the rest of GSU nuclear physics group to build complete RPC sets and test them at GSU. Each of these sets will include a detector and computer-based data acquisition system. The students are trained on labview and encoureged to write the read out software for the built units which are then used for cosmic studies and students have to analyze and interpret the data and write a project summary. Basically a complete small physics experiment that can be an excellent graduation project for undergraduate students or prepares graduate students for their thesis projects. In addition, the PI obtained a laboratory space at GSU to house some of the RPC protype chambers that were used in 2009 for RPC performance testing in PHENIX at 500 GeV. The main objective of having the prototype at GSU is to study the performance of RPC detectors, including leakage current, efficiency, timing resolution, and electronic readout characteristics, under different conditions (gas mixing and various weather parameters). These are ongoing studies at GSU with the current RPCs, however, the prototypes being studied have much smaller size than the real detectors at BNL which could affect the conclusions that can be drawn from these studies. The PHENIX RPC prototypes will provide the most realistic information about PHENIXs RPCs and thus most beneficial. This project will also provide valauble experience opportinties to students.

The PI also intends to extend these efforts by joining Dr. X. He outreach program to promote advanced science in high schools in the state of Georgia. Completed cosmic ray monitoring sets, built up by GSU students, are installed at the local public schools that are interested in participating in this program and have the ability to provide the appropriate environment. Teachers and students in these schools will have to maintain the operation of the detectors and participate in the data analysis. These monitoring stations will be connected through the internet for time-correlated muon flux measurements which will be recorded at GSU. Some local highschools are already involved and some teachers joined our team for training and cosmic studies.

References Cited

[1] E. D. Bloom *et al.*, Phys. Rev. Lett. **23**, 930 (1969).

[2] B. Breidenbach *et al.*, Phys. Rev. Lett. **23**, 935 (1969).

[3] J. Ashman *et al.*, Nucl. Phys. B **328**, 1 (1989).

[4] B. W. Filippone and X. D. Ji, Adv. Nucl. Phys. **26**, 1 (2001).

[5] P. L. Anthony *et al.*, Phys. Rev. D **54**, 6620 (1996).

[6] K. Abe *et al.*, Phys. Lett. B **452**, 194 (1999).

[7] P. L. Anthony *et al.*, Phys. Lett. B **493**, 19 (2000).

[8] A. Airapetian *et al.*, Phys. Lett. B **442**, 484 (1998).

[9] K. V. Dharmawardane *et al.*, Phys. Lett. B **641**, 11 (2006).

[10] B. Adeva *et al.*, Phys. Rev. D **58**, 112002 (1998).

[11] T. Gehrmann and W.J. Stirling, Phys. Rev. D **53**, 6100 (1996).

[12] M. Glück, E. Reya, M. Stratmann and W. Vogelsang, Phys. Rev. D **63**, 094005 (2001).

[13] J. Bluemlein and H. Bottcher, Nucl. Phys. B **636**, 225 (2003).

[14] E. Leader, A. V. Sidorov and D. B. Stamenov, Phys. Rev. D **73**, 034023 (2006).

[15] D. de Florian, G. A. Navarro and R. Sassot, Phys. Rev. D **71**, 094018 (2005).

[16] A. Airapetian *et al.*, Phys. Rev. D **75**, 012007 (2007).

[17] E. S. Ageev *et al.*, Phys. Lett. B **633**, 25 (2006).

[18] B. Adeva *et al.*, Phys. Rev. D **70**, 012002 (2004).

[19] A. Airapetian *et al.*, Phys. Rev. Lett. **84**, 2584 (2000).

[20] D. de Florian, R. Sassot, M. Stratmann, and W. Vogelsang, Phys. Rev. Lett. **101**, 072001 (2008).

[21] D. de Florian, R. Sassot, M. Stratmann, and W. Vogelsang, Phys. Rev. D **80**, 034030 (2009).

[22] M. Alekseev *et al.*, arXiv:0904.3209 [hep-ex].

[23] H. Fischer, *Review of COMPASS spin physics*, talk at the "International Workshop on Diffraction in High-Energy Physics", Sept. 10-15, 2010; Otranto (Lecce), Italy.

[24] S. S. Adler *et al.*, Phys. Rev. Lett. **91**, 241803 (2003).

[25] B. I. Abelev *et al.*, Phys. Rev. Lett. **97**, 252001 (2006).

[26] S. S. Adler *et al.*, Phys. Rev. D **76**, 051106 (2007).

[27] A. Adare *et al.*, Phys. Rev. D **79**, 012003 (2009).

[28] S. S. Adler *et al.*, Phys. Rev. D **73**, 091102(R) (2006).

[29] A. Adare *et al.*, Phys. Rev. Lett. **103**, 012003 (2009).

[30] S. S. Adler *et al.*, Phys. Rev. Lett. **98**, 012002 (2007).

[31] B. I. Abelev *et al.*, Phys. Rev. Lett. **100**, 232003 (2008).

[32] M. Sarsour for the STAR Collaboration, Talk at the APS-DNP07 meeting, Oct. 2007.

[33] A. Tkabladze and O. Teryaev, Phys. Rev. D 56, 7331 (1997).

[34] M. M. Aggarwal *et al.*, arXiv:1009.0326 [hep-ex].

[35] A. Adare *et al.*, arXiv:1009.0505 [hep-ex].

[36] L. Aphecetche *et al.*, Nucl. Instrum. Meth. A **499**, 521 (2003).

[37] S. S. Adler *et al.*, Phys. Rev. Lett. **93**, 202002 (2004).

[38] S. S. Adler *et al.*, Phys. Rev. C **75**, 024909 (2007).

[39] A. Adare et al. (PHENIX), to be published.

[40] D. de Florian et al., Phys. Rev. D **75**, 114010 (2007).

[41] C. Aidila and J. Seele (June 2009), private communications.

[42] M. Sarsour, for the PHENIX collaboration, *Overview of the PHENIX transverse and longitudinal spin physics program*, talk at the "International Workshop on Diffraction in High-Energy Physics", Sept. 10-15, 2010; Otranto (Lecce), Italy.

[43] D. de Florian and W. Vogelsang, Phys. Rev. D 81, 094020 (2010).

[44] P.M. Nadolsky and C.P. Yuan, Nucl. Phys. B **666**, 31 (2003).

[45] M. Sarsour, for the PHENIX collaboration, *Performance of PHENIX Resistive Plate Chambers*, talk at APS April Meeting 2010, February 1316, 2010; Washington, DC

Biographical Sketch: Murad Sarsour

(a) Professional Preparation (education):

Applied Science University	Physics	B.S. (1996)
University of Houston	Nuclear Physics	Ph.D. (2002)
Indiana University & Texas A&M University	Nuclear Physics	2002 - 2008

(b) Appointments:

- Assistant Professor, Georgia State University, 2008 - present.
- Postdoctoral Research Associate, Texas A&M University, 2005 - 2008.
- Visiting Assistant Professor, Texas A&M University, Fall 2007.
- Postdoctoral Research Associate, Indiana University Cyclotron Facility, 2002 - 2005.
- Research Assistant, University of Houston, 1999 - 2002.

(c) Publications

- Publications most closely to the proposed project
  1. A. Adare *et al.*, "*Cross Section and Parity Violating Spin Asymmetries of $W^{\pm}$ Boson Production in Polarized p+p Collisions at $\sqrt{s} = 500$ GeV*", arXiv:1009.0505 [hep-ex]. (submitted to PRL on Sept. 3, 2010)
  2. B.I. Abelev *et al.*, "*Longitudinal double-spin asymmetry for inclusive jet production in p+p collisions at $\sqrt{s} = 200$ GeV*", Phys. Rev. Lett. **100**, 232003 (2008).
  3. M. Sarsour for the STAR collaboration, "*Recent results from the STAR spin program at RHIC*", J.Phys. Conf. Ser. **69**, 012033 (2007).
  4. B.I. Abelev *et al.*, "*Measurement of Transverse Single-Spin Asymmetries for Dijet Production in Proton-Proton Collisions at $\sqrt{s} = 200$ GeV*", Phys. Rev. Lett. **99**, 142003 (2007).
  5. B.I. Abelev *et al.*, "*Longitudinal Double-Spin Asymmetry and Cross Section for Inclusive Jet Production in Polarized Proton Collisions at $\sqrt{s} = 200$ GeV*", Phys. Rev. Lett. **97**, 252001 (2006).
- Other significant publications
  1. M. Sarsour *et al.*, "*Measurement of the absolute differential cross section for np elastic scattering at 194 MeV*", Phys. Rev. C **74**, 044003 (2006).
  2. L. Yuan and M. Sarsour *et al.*, "*Hypernuclear spectroscopy using the $(e, e'K^+)$ reaction*", Phys. Rev. C **73**, 044607 (2006).
  3. M. Sarsour *et al.*, "*Measurement of the Absolute np Scattering Differential Cross Section at 194 MeV*", Phys. Rev. Lett. **94**, 082303 (2005).
  4. T. Miyoshi, M. Sarsour, L. Yuan and X. Zhu *et al.*, "*High Resolution Spectroscopy of the ${}^{12}_{\Lambda}B$ Hypernucleus Produced by the $(e, e'K^+)$ Reaction*", Phys. Rev. Lett. **90**, 232502 (2003).
  5. T. Miyoshi, K. A. Lan, Y. Fujii, O. Hashimoto, E. V. Hungerford, Y. Sato, c, M. Sarsour, T. Takahashi, L. Tang, M. Ukai and H. Yamaguchi, "*A Silicon strip detector used as a high rate focal plane sensor for electrons in a magnetic spectrometer*", Nucl. Instrum. Meth. A **496**, 362 (2003).

(d) Synergistic Activities:

- Invited speaker at the SpinFest of the PHENIX Collaboration, BNL, July 2008.
- Member of the spin physics group of the PHENIX Collaboration, 2008 - present.
- Member of the forward upgrade group of the PHENIX Collaboration, 2008 - present.

(e) Collaborations & Other Affiliations

- Collaborations and Co-Editors: The PI is currently a member of the PHENIX and the Neutron Spin Rotation Collaboration. He was also a memeber of the STAR Collaboration until 2009. Both PHENIX and STAR collaborations have many particpants and won't be able to fit due to page limitation, thus the PI only list those individuals in the core group with whom he interacted on a regular basis while working:
  1. C. Aidala, *Los Alamos National Laboratory, Los Alamos, NM 87545, USA*
  2. J. Balewski, *MIT, Cambridge, MA 02139-4307, USA*
  3. A. Bazilevsky, *Brookhaven National Laboratory, Upton, NY 11973-5000, USA*
  4. A. Deshpande, *Stony Brook University, SUNY, Stony Brook, NY 11794, USA*
  5. R. Fatemi, *University of Kentucky, Lexington, Kentucky, 40506-0055, USA*
  6. Y. Goto, *RIKEN BNL Research Center, BNL, Upton, NY 11973-5000, USA*
  7. M. Grosse Perdekamp, *UIUC, Urbana, IL 61801, USA*
  8. X. He, *Georgia State University, Atlanta, GA 30303, USA*
  9. D. Kawall, *University of Massachusetts, Amherst, MA 01003-9337, USA*
  10. K. Okada, *RIKEN BNL Research Center, BNL, Upton, NY 11973-5000, USA*
  11. R. Seidl, *RIKEN BNL Research Center, BNL, Upton, NY 11973-5000, USA*
  12. E. P. Sichtermann, *LBNL, Berkeley, California 94720, USA*
  13. B. Surrow, *MIT, Cambridge, MA 02139-4307, USA*
  14. S. Trentalange, *University of California, Los Angeles, California 90095, USA*
  15. J. Ying, *Georgia State University, Atlanta, GA 30303, USA*
- There are no co-editors to report.
- Graduate Advisers and Postdoctoral Sponsors:
  1. Professor Ed Hungerford, University of Houston, Houston, TX 77004, USA (Graduate Adviser)
  2. Professor Carl A. Gagliardi, Texas A&M University Cyclotron Institute, College Station, Texas 77843, USA
  3. Professor William Michael Snow, Indiana University Cyclotron Facility, Bloomington, IN 47408, USA
  4. Dr. James Sowinski, Indiana University Cyclotron Facility, Bloomington, IN 47408, USA
  5. Professor Robert Tribble, Texas A&M University Cyclotron Institute, College Station, Texas 77843, USA
  6. Dr. Steven Vigdor, Brookhaven National Laboratory, Upton, New York 11973, USA

SUMMARY PROPOSAL BUDGET

YEAR 1

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
Georgia State University Research Foundation, Inc.

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Murad G Sarsour

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Murad G Sarsour - Assistant Professor**	0.00	0.00	2.00	$ **13,556**	$
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	2.00	**13,556**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**2**) GRADUATE STUDENTS				**30,000**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**43,556**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**2,342**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**45,898**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**15,280**	
2. FOREIGN				**2,000**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**0**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**0**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**63,178**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 44.5000, Base: 63178)**					
TOTAL INDIRECT COSTS (F&A)				**28,114**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**91,292**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ **91,292**	$

M. COST SHARING PROPOSED LEVEL $ **Not Shown** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Murad G Sarsour

ORG. REP. NAME*
Marca gurule

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 2

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
Georgia State University Research Foundation, Inc.

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Murad G Sarsour

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Murad G Sarsour - Assistant Professor**	0.00	0.00	2.00	$ **13,963**	$
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	2.00	**13,963**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**2**) GRADUATE STUDENTS				**30,900**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**44,863**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**2,413**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**47,276**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**15,280**	
2. FOREIGN				**2,000**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**0**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**0**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**64,556**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 44.5000, Base: 64556)**					
TOTAL INDIRECT COSTS (F&A)				**28,727**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**93,283**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ **93,283**	$

M. COST SHARING PROPOSED LEVEL $ **Not Shown** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Murad G Sarsour

ORG. REP. NAME*
Marca gurule

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 3

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
Georgia State University Research Foundation, Inc.

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Murad G Sarsour

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Murad G Sarsour - Assistant Professor**	0.00	0.00	2.00	$ **14,382**	$
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	2.00	**14,382**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**2**) GRADUATE STUDENTS				**31,828**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**46,210**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**2,485**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**48,695**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**15,280**	
2. FOREIGN				**2,000**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**0**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**0**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**65,975**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 44.5000, Base: 65975)**					
TOTAL INDIRECT COSTS (F&A)				**29,359**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**95,334**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ **95,334**	$

M. COST SHARING PROPOSED LEVEL $ **Not Shown** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Murad G Sarsour

ORG. REP. NAME*
Marca gurule

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

Cumulative

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION
Georgia State University Research Foundation, Inc.

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Murad G Sarsour

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Murad G Sarsour - Assistant Professor**	0.00	0.00	6.00	$ **41,901**	$
2.					
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	6.00	**41,901**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**6**) GRADUATE STUDENTS				**92,728**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**134,629**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**7,240**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**141,869**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**45,840**	
2. FOREIGN				**6,000**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**0**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**0**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**193,709**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**86,200**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**279,909**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ **279,909**	$

M. COST SHARING PROPOSED LEVEL $ **Not Shown** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Murad G Sarsour

ORG. REP. NAME*
Marca gurule

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

C ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

Budget Request and Justification

The budget request is based on the average costs and expenses that the principal investigator (PI), Murad Sarsour, and colleagues in the Physics and Astronomy Department at Georgia State University have incurred in the past and the expected cost for the projected research activities. The annual increase after the first year is the expected 3% annual salary increase. The fringe rate is 27.78% for faculty academic and staff and 17.28% for faculty summer. There are no fringe benefits for students at GSU at the present time. Detailed description of each category is given in the following subsections.

1 Personnel Costs

- Senior Personnel (PI)
  The PI is a tenure track assistant professor at GSU and is paid on nine month basis for a total amount of \$61k for the current academic year. A two-month summer salary is requested to be paid from this research grant per budget year.

- Two Graduate Students
  Mr. Hari Guragain will work on the W measurement as his Ph.D. project. He started in August 2010 and being paid from the startup funds until 2011. Mr. Behnam Aryafar, another graduate student, will wok on the η meson channel as his Ph.D. project. He also started August 2010. The students are supported mostly by GSU for their tuition and partial salary (they teach labs through the duration of their graduate school) and just request a contribution of \$15k per student.

The total personnel costs are summarized in the tables below:

Year 07/01/2011 - 06/30/2012	PI (Murad Sarsour, 2 months salary)	\$13,556
	Two PHENIX Ph.D students	\$30,000
	Subtotal	\$43,556

Year 07/01/2012 - 06/30/2013	PI (Murad Sarsour, 2 months salary)	\$13,963
	Two PHENIX Ph.D students	\$30,900
	Subtotal	\$44,863

	PI (Murad Sarsour, 2 months salary)	$14,382
	Two PHENIX Ph.D students	$31,828
Year 07/01/2013 - 06/30/2014	Subtotal	$46,210

2 Travel Costs

The detailed travel budget justification is given below:

- Murad Sarsour (PI)
  On yearly basis, Murad Sarsour is expected to travel to Brookhaven National Lab four times at minimum: one trip for data-taking shift, two trips for the yearly two semi-annual collaboration meetings, and one trip to BNL to help with detector installations and maintenance. On average, each trip will take about 10 days. The daily cost is about $181 which includes $36 for dorm room, $50 for per diem, $60 for rental car and $35 for airline ticket. Murad Sarsour also plans to attend the yearly DIS conference or the biyearly spin conference. The estimated cost for this trip is about $2,000. The total travel budget for Murad Sarsour is $9,240.

- Graduate Students
  The two Ph.D students will make at minimum two trips each to BNL for working on their required service tasks which include regular data-taking shifts and data analysis work. On average, 10 days per trip per student, a daily cost is about $121 which includes $36 for dorm room, $50 for per diem, $30 for rental car (they are expected to share rental car) and $35 for airline ticket. In addition, each is expected to give a presentation at one of the national conferences. The estimated cost for both students is $2000. The total student travel budget is $8,040.

The total travel costs are summarized in the tables below:

	Murad Sarsour	$9,240
	Two PHENIX Ph.D students	$8,040
Year 07/01/2011 - 06/30/2012	Subtotal	$17,280
	Murad Sarsour	$9,240
	Two PHENIX Ph.D students	$8,040
Year 07/01/2012 - 06/30/2013	Subtotal	$17,280
	Murad Sarsour	$9,240
	Two PHENIX Ph.D students	$8,040
Year 07/01/2013 - 06/30/2014	Subtotal	$17,280

Current and Pending Support

(See GPG Section II.C.2.h for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Murad Sarsour	Other agencies (including NSF) to which this proposal has been/will be submitted. DOE

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: Accessing the Proton Spin Structure

Source of Support: NSF
Total Award Amount: $ 279,909 Total Award Period Covered: 07/01/11 - 06/30/14
Location of Project: Georgia State University
Person-Months Per Year Committed to the Project. Cal: 0.00 Acad: 0.00 Sumr: 2.00

Support: ☐ Current ☐ Pending ☒ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: Accessing the Proton Spin Structure

Source of Support: DOE
Total Award Amount: $ 279,909 Total Award Period Covered: 07/01/11 - 06/30/14
Location of Project: Georgia State University
Person-Months Per Year Committed to the Project. Cal: 0.00 Acad: 0.00 Sumr: 2.00

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Summ:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

FACILITIES, EQUIPMENT & OTHER RESOURCES

FACILITIES: Identify the facilities to be used at each performance site listed and, as appropriate, indicate their capacities, pertinent capabilities, relative proximity, and extent of availability to the project. Use "Other" to describe the facilities at any other performance sites listed and at sites for field studies. USE additional pages as necessary.

Laboratory: The data are collected by the PHENIX detector which is located at BNL. At Georgia State University there is detector laboratory that is equipped with various data acquisition electrons which has been mainly used for our RPC R&D study since 2005 for the PHENIX Forward Muon Trigger Upgrade.

Clinical:

Animal:

Computer: The major data analysis that include calibrations and event reconstruction are carried out either at BNL or at the PHENIX Computing Center in Japan (CCJ). Smaller analysis tasks like extracting final physics probes and publication works are carried out locally.

Office:

Other:

MAJOR EQUIPMENT: List the most important items available for this project and, as appropriate identifying the location and pertinent capabilities of each.

OTHER RESOURCES: Provide any information describing the other resources available for the project. Identify support services such as consultant, secretarial, machine shop, and electronics shop, and the extent to which they will be available for the project. Include an explanation of any consortium/contractual arrangements with other organizations.

COLLEGE OF SCIENCE

CYCLOTRON INSTITUTE

Carl A. Gagliardi
Professor of Physics

September 28, 2010

To Whom It May Concern:

Dr. Murad Sarsour has asked me to write a letter of support for his proposal, "Accessing the Proton Spin Structure." I'm very happy to do so.

Dr. Sarsour joined my group as a post-doctoral research associate in 2005. While at Texas A&M, Dr. Sarsour analyzed STAR Collaboration data that were recorded at RHIC during 2005 and 2006 to determine the longitudinal double-spin asymmetry A_{LL} for inclusive jet production in p+p collisions at a center-of-mass energy of 200 GeV. This asymmetry provides the most precise information currently available regarding the polarization of the gluons within the proton. Dr. Sarsour did an excellent job! He developed new analysis techniques that led to considerably smaller systematic uncertainties than had been achievable with the procedures that had previously been in use within STAR. In the process, he became one of the recognized experts on jet reconstruction in STAR. The results that Dr. Sarsour obtained with the 2006 data were identified, together with related measurements for inclusive π^0 production performed by the PHENIX Collaboration, as a highlight in the 2007 NSAC Long-Range Plan for Nuclear Physics.

In August, 2008, Dr. Sarsour left Texas A&M to become an Assistant Professor at Georgia State University. Georgia State already had an established group studying relativistic heavy-ion collisions in the PHENIX Collaboration at RHIC, so Dr. Sarsour also moved from STAR to PHENIX at that time. Switching from one ~500-person collaboration to another is not easy; it takes considerable time and effort to become fully integrated in the new collaboration. Some people never achieve their former level of productivity. Since moving to PHENIX, Dr. Sarsour has been investigating A_{LL} for inclusive η-meson production. This analysis has required him to address a completely different set of leading backgrounds and systematics than he dealt with when measuring jets. It pleases – but doesn't surprise – me to see that Dr. Sarsour has navigated the change to PHENIX so well that he is already one of the principal authors of a new PHENIX publication describing his η results. In parallel, he has also begun a simulation effort that promises to play a significant role in upcoming PHENIX measurements of longitudinal single-spin asymmetries for $W^{\pm}$ production. The W measurements will provide important, new information regarding the polarization of anti-quarks within the proton, and represent the flagship PHENIX spin physics measurement for the next several years.

Dr. Sarsour's new proposal describes forefront physics measurements that he is eminently qualified to perform. I recommend it to you very strongly for your consideration.

Sincerely,

Carl A. Gagliardi
Professor, Department of Physics and Astronomy
Former Deputy Spokesperson, STAR Collaboration (2005-08)

Cyclotron Institute
3366 TAMU
College Station, TX 77843-3366

Telephone 979-845-1411
Fax 979-845-1899
cggroup@comp.tamu.edu