List of Suggested Reviewers or Reviewers Not To Include (optional)

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Pursuant to PAPPG Chapter II.C.1.e., each PI, co-PI, and other senior project personnel identified on a proposal must provide collaborator and other affiliations information to help NSF identify appropriate reviewers.(v.4/21/2017)

Please complete this template (e.g., Excel, Google Sheets, LibreOffice), save as .xlsx or .xls, and upload directly as a Fastlane Collaborators and Other Affiliations single copy doc.
Do not upload .pdf.

There are five tables:
A: Your Name & Affiliation(s);
B: PhD Advisors/Advisees (all);
C: Collaborators;
D: Co-Editors;
E: Relationships

List names as Last Name, First Name, Middle Initial. Additionally, provide email, organization, and department (optional) to disambiguate common names.

Fixed column widths keep this sheet one page wide; if you cut and paste text, set font size at 10pt or smaller, and abbreviate, where necessary, to make the data fit.

To insert *n* blank rows, select *n* row numbers to move down, right click, and choose Insert from the menu.
You may fill-down (crtl-D) to mark a sequence of collaborators, or copy affiliations. Excel has arrows that enable sorting.
"Last active" dates are optional, but will help NSF staff easily determine which information remains relevant for reviewer selection.

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Table B: List names as Last Name, First Name, Middle Initial, and provide organizational affiliations, if known, for the following.

G: Your PhD Advisor(s)
T: All your PhD Thesis Advisees
P: Your Graduate Advisors

to disambiguate common names

B	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)
G:	Gagliardi, Carl A	Texas A&M University	c-gagliardi@tamu.edu
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P:	Tribble, Robert E	Texas A&M University	r-tribble@tamu.edu
P:	Mioduszewski, Saskia	Texas A&M University	mio@comp.tamu.edu
P:	Ko, Che-Ming	Texas A&M University	ko@comp.tamu.edu
P:	Natowitz, Joseph	Texas A&M University	natowitz@comp.tamu.edu

Table C: List names as Last Name, First Name, Middle Initial, and provide organizational affiliations, if known, for the following.

A: Co-authors on any book, article, report, abstract or paper (with collaboration in last 48 months; publication date may be later).

C: Collaborators on projects, such as funded grants, graduate research or others (in last 48 months).

to disambiguate common names

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A:	Ullrich, T.	Brookhaven National Laboratory		10/11/17
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A:	Upsal, I.	Ohio State University		10/11/17
A:	Van Buren, G.	Brookhaven National Laboratory		10/11/17
A:	van Nieuwenhuizen, G.	Brookhaven National Laboratory		10/11/17
A:	Vasiliev, A. N.	Institute of High Energy Physics-Protvino		10/11/17
A:	Videbaek, F.	Brookhaven National Laboratory		10/11/17
A:	Vokal, S.	Joint Institute for Nuclear Research-Dubna		10/11/17
A:	Voloshin, S. A.	Wayne State University		10/11/17
A:	Vossen, A.	Indiana University		10/11/17
A:	Wang, G.	University of California-Los Angeles		10/11/17
A:	Wang, Y.	Tsinghua University		10/11/17
A:	Wang, Y.	Central China Normal University		10/11/17
A:	Wang, F.	Purdue University		10/11/17
A:	Webb, G.	Brookhaven National Laboratory		10/11/17
A:	Webb, J. C.	Brookhaven National Laboratory		10/11/17
A:	Wen, L.	University of California-Los Angeles		10/11/17
A:	Westfall, G. D.	Michigan State University		10/11/17
A:	Wieman, H.	Lawrence Berkeley National Laboratory		10/11/17
A:	Wissink, S. W.	Indiana University		10/11/17
A:	Witt, R.	United States Naval Academy		10/11/17
A:	Wu, Y.	Kent State University		10/11/17
A:	Xiao, Z. G.	Tsinghua University		10/11/17
A:	Xie, G.	University of Science and Technology of China		10/11/17
A:	Xie, W.	Purdue University		10/11/17
A:	Xu, N.	Lawrence Berkeley National Laboratory		10/11/17
A:	Xu, Y. F.	Shanghai Institute of Applied Physics		10/11/17
A:	Xu, Q. H.	Shandong University		10/11/17
A:	Xu, Z.	Brookhaven National Laboratory		10/11/17
A:	Yang, Y.	National Cheng Kung University		10/11/17
A:	Yang, C.	Shandong University		10/11/17

A:	Yang, S.	Brookhaven National Laboratory		10/11/17
A:	Yang, Q.	Shandong University		10/11/17
A:	Ye, Z.	University of Illinois at Chicago		10/11/17
A:	Ye, Z.	University of Illinois at Chicago		10/11/17
A:	Yi, L.	Yale University		10/11/17
A:	Yip, K.	Brookhaven National Laboratory		10/11/17
A:	Yoo, I.-K.	Pusan National University		10/11/17
A:	Zbroszczyk, H.	Warsaw University of Technology		10/11/17
A:	Zha, W.	University of Science and Technology of China		10/11/17
A:	Zhang, J. B.	Central China Normal University		10/11/17
A:	Zhang, J.	Lawrence Berkeley National Laboratory		10/11/17
A:	Zhang, S.	University of Science and Technology of China		10/11/17
A:	Zhang, J.	Institute of Modern Physics-Chinese Academy of Sciences		10/11/17
A:	Zhang, S.	Shanghai Institute of Applied Physics		10/11/17
A:	Zhang, Z.	Shanghai Institute of Applied Physics		10/11/17
A:	Zhang, Y.	University of Science and Technology of China		10/11/17
A:	Zhang, L.	Central China Normal University		10/11/17
A:	Zhang, X. P.	Tsinghua University		10/11/17
A:	Zhao, J.	Purdue University		10/11/17
A:	Zhong, C.	Shanghai Institute of Applied Physics		10/11/17
A:	Zhou, C.	Shanghai Institute of Applied Physics		10/11/17
A:	Zhou, L.	University of Science and Technology of China		10/11/17
A:	Zhu, X.	Tsinghua University		10/11/17
A:	Zhu, Z.	Shandong University		10/11/17
A:	Zyzak, M.	Frankfurt Institute for Advanced Studies FIAS		10/11/17

Table D: List editorial board, editor-in-chief and co-editors with whom you interact. An editor-in-chief should list

B: Editorial board: Name(s) of editor-in-chief and journal (in past 24 months).

E: Other Co-Editors of journals or collections with whom you directly interacted (in past 24 months).

to disambiguate common names

D	Name:	Organizational Affiliation	Journal/Collection	Last Active
B:				
E:				

Table E: List persons for whom a personal, family, or business relationship would otherwise preclude their service

R: Additional names for whom some relationship would otherwise preclude their service as a reviewer.

to disambiguate common names

D	Name:	Organizational Affiliation	Optional (email, Department)	Last Active
R:				

COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./DUE DATE
NSF 14-579

☐ Special Exception to Deadline Date Policy

FOR NSF USE ONLY
NSF PROPOSAL NUMBER
1811138

FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.)
PHY - Nuclear & Hadron Quantum Chrom

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746000298

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☐ AN ACCOMPLISHMENT-BASED RENEWAL

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

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE
Lamar University Beaumont

AWARDEE ORGANIZATION CODE (IF KNOWN)
0035816000

ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE
Lamar University Beaumont
4400 Port Arthur Road
Beaumont, TX. 777055748

NAME OF PRIMARY PLACE OF PERF
Lamar University Beaumont

ADDRESS OF PRIMARY PLACE OF PERF, INCLUDING 9 DIGIT ZIP CODE
Lamar University Beaumont
4400 MLK Parkway
Beaumont ,TX ,777100046 ,US.

IS AWARDEE ORGANIZATION (Check All That Apply) ☐ SMALL BUSINESS ☐ MINORITY BUSINESS ☐ FOR-PROFIT ORGANIZATION ☐ WOMAN-OWNED BUSINESS

☐ IF THIS IS A PRELIMINARY PROPOSAL THEN CHECK HERE

TITLE OF PROPOSED PROJECT **RUI: Exploring the Nature of QCD Through Transverse Spin Physics at RHIC**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ 465,046	36 months	09/01/18	

THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW
☐ BEGINNING INVESTIGATOR
☐ DISCLOSURE OF LOBBYING ACTIVITIES
☐ PROPRIETARY & PRIVILEGED INFORMATION
☐ HISTORIC PLACES
☐ VERTEBRATE ANIMALS IACUC App. Date _____
PHS Animal Welfare Assurance Number _____
☒ TYPE OF PROPOSAL **Research**

☐ HUMAN SUBJECTS Human Subjects Assurance Number _____
Exemption Subsection _____ or IRB App. Date _____
☐ INTERNATIONAL ACTIVITIES: COUNTRY/COUNTRIES INVOLVED
☒ COLLABORATIVE STATUS
Not a collaborative proposal

PI/PD DEPARTMENT
Physics

PI/PD FAX NUMBER
409-880-8245

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NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Email Address
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CO-PI/PD				
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				

CERTIFICATION PAGE

Certification for Authorized Organizational Representative (or Equivalent) or Individual Applicant

By electronically signing and submitting this proposal, the Authorized Organizational Representative (AOR) 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 conflict of interest (when applicable), drug-free workplace, debarment and suspension, lobbying activities (see below), nondiscrimination, flood hazard insurance (when applicable), responsible conduct of research, organizational support, Federal tax obligations, unpaid Federal tax liability, and criminal convictions as set forth in the NSF Proposal & Award Policies & Procedures Guide (PAPPG). 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).

Certification Regarding Conflict of Interest

The AOR is required to complete certifications stating that the organization has implemented and is enforcing a written policy on conflicts of interest (COI), consistent with the provisions of PAPPG Chapter IX.A.; that, to the best of his/her knowledge, all financial disclosures required by the conflict of interest policy were made; and that conflicts of interest, if any, were, or prior to the organization's expenditure of any funds under the award, will be, satisfactorily managed, reduced or eliminated in accordance with the organization's conflict of interest policy. Conflicts that cannot be satisfactorily managed, reduced or eliminated and research that proceeds without the imposition of conditions or restrictions when a conflict of interest exists, must be disclosed to NSF via use of the Notifications and Requests Module in FastLane.

Drug Free Work Place Certification

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent), is providing the Drug Free Work Place Certification contained in Exhibit II-3 of the Proposal & Award Policies & Procedures 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 Certification Pages, the Authorized Organizational Representative (or equivalent) or Individual Applicant is providing the Debarment and Suspension Certification contained in Exhibit II-4 of the Proposal & Award Policies & Procedures Guide.

Certification Regarding Lobbying

This 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.

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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.

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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 Certification Pages, the Authorized Organizational Representative (or equivalent) 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 Certification Pages, the Authorized Organizational Representative is certifying that, in accordance with the NSF Proposal & Award Policies & Procedures Guide, Chapter IX.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 AOR shall require that the language of this certification be included in any award documents for all subawards at all tiers.

CERTIFICATION PAGE - CONTINUED

Certification Regarding Organizational Support

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that there is organizational support for the proposal as required by Section 526 of the America COMPETES Reauthorization Act of 2010. This support extends to the portion of the proposal developed to satisfy the Broader Impacts Review Criterion as well as the Intellectual Merit Review Criterion, and any additional review criteria specified in the solicitation. Organizational support will be made available, as described in the proposal, in order to address the broader impacts and intellectual merit activities to be undertaken.

Certification Regarding Federal Tax Obligations

When the proposal exceeds $5,000,000, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Federal tax obligations. By electronically signing the Certification pages, the Authorized Organizational Representative is certifying that, to the best of their knowledge and belief, the proposing organization:
(1) has filed all Federal tax returns required during the three years preceding this certification;
(2) has not been convicted of a criminal offense under the Internal Revenue Code of 1986; and
(3) has not, more than 90 days prior to this certification, been notified of any unpaid Federal tax assessment for which the liability remains unsatisfied, unless the assessment is the subject of an installment agreement or offer in compromise that has been approved by the Internal Revenue Service and is not in default, or the assessment is the subject of a non-frivolous administrative or judicial proceeding.

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When the proposing organization is a corporation, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Federal Tax Liability:

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that the corporation has no unpaid Federal tax liability that has been assessed, for which all judicial and administrative remedies have been exhausted or lapsed, and that is not being paid in a timely manner pursuant to an agreement with the authority responsible for collecting the tax liability.

Certification Regarding Criminal Convictions

When the proposing organization is a corporation, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Criminal Convictions:

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that the corporation has not been convicted of a felony criminal violation under any Federal law within the 24 months preceding the date on which the certification is signed.

Certification Dual Use Research of Concern

By electronically signing the certification pages, the Authorized Organizational Representative is certifying that the organization will be or is in compliance with all aspects of the United States Government Policy for Institutional Oversight of Life Sciences Dual Use Research of Concern.

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME **Roxanne Smith Parks**	**Electronic Signature**	**Nov 6 2017 11:55AM**

TELEPHONE NUMBER	EMAIL ADDRESS	FAX NUMBER
409-880-8010	**rparks1@lamar.edu**	**409-880-7672**

PROJECT SUMMARY

Overview:

The program detailed in the following proposal illuminates quantum chromodynamics (QCD) through exploration of nucleon transversity and the nature of hadronization. The responding solicitation is NSF 17-561. The PI and his group will analyze data from spin-polarized p+p and p+Au collisions already collected with the detectors of the STAR experiment at RHIC. The Lamar STAR group will study hadronization through the multiplicities of charged pions within jets from p+p collisions at energies of 500 GeV and p+Au collisions at energies of 200 GeV. By analyzing the spin-dependent azimuthal distributions of charged pions within jets, the so-called "Collins effect," from p+p and p+Au collisions, investigators will probe both transversity and hadronization, including the so-called transverse momentum dependent (TMD) fragmentation functions. The analysis will utilize infrastructure developed by the principle investigator (PI) for previous analyses of charged pions within jets at STAR. The program will be carried out by the PI, a postdoctoral associate, and an active group of undergraduate researchers. The PI has carried out an active research program in STAR for several years, including being the principal author for multiple STAR papers, serving as convener for the spin physics working group, and currently serving as a deputy spokesperson for the collaboration.

Intellectual Merit:

Transversity is a distribution function, describing the transverse spin-polarization of quarks within the nucleon. Its effects have been observed extensively in semi-inclusive deep-inelastic scattering (SIDIS) experiments and recently for the first time in p+p collisions at STAR. Investigation with more precise datasets collected at STAR will lead to tighter constraints on global transversity extractions. Moreover, the momentum transfer range of the data collected at STAR is substantially larger than in existing SIDIS data, deepening the understanding of how transversity and TMD functions evolve kinematically. Transversity is also a formidable tool to deepen knowledge of QCD. Comparing Collins asymmetries measured in p+p to those measured in SIDIS tests open questions about the factorization of TMD perturbative QCD cross sections in p+p and the universality of TMD fragmentation functions.

Hadronization is the non-perturbative process by which partons, for instance, when scattered from a hard interaction, convert into colorless hadrons and is a critical component of understanding p+p interactions. Analysis of the multiplicities of pions within jets in p+p collisions at energies of 500 GeV will lend tighter constraints to fragmentation functions, in particular for the gluon, which is difficult to probe directly in SIDIS experiments. Extending multiplicity measurements to p+Au interactions provides insight into the effects of the nuclear system on hadronization and fragmentation. Finally, extending the Collins-effect measurements for the first time to p+Au, one gains a unique tool to probe hadronization and potential modifications due to the nuclear system by comparing to Collins measurements from p+p interactions.

Broader Impacts:

Lamar University is located in Southeast Texas with unique access to students from disadvantaged populations. Quality STEM education is a powerful tool to unlock doors for these students, often first-generation collegians, and simultaneously fulfill critical needs for the region and nation. By actively involving Lamar University undergraduates, this program empowers otherwise disadvantaged students, enhances the quality of STEM education at a unique institution, and serves an urgent need for the local and broader community.

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For font size and page formatting specifications, see PAPPG 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

I. OUTLINE OF OBJECTIVES

In October 2015, the DOE/NSF Nuclear Science Advisory Committee (NSAC) released a long-range plan [1] outlining the framework for advancing United States research programs for the next decade. As part of the first recommendation, the long-range plan states, "The upgraded RHIC facility provides unique capabilities that must be utilized to explore the properties and phases of quark and gluon matter in the high temperatures of the early universe and to explore the spin structure of the proton." The following proposal outlines a program consistent with the priority of the NSAC long-range plan to make use of the RHIC facility as a unique tool to study the spin-structure of the proton and unconstrained aspects of quantum chromodynamics (QCD).

This proposal details a program to increase knowledge of QCD through studies of the transversity parton distribution and hadronization, the process by which quarks and gluons convert into colorless hadrons. To this end, the principal investigator (PI) and his group will analyze data collected from proton-proton ($p+p$) and proton-gold ($p+Au$) collisions by the detectors of the Solenoidal Tracker at RHIC (STAR). This active analysis program will be carried out by the PI, a postdoctoral research associate, and a team of undergraduate researchers from Lamar University. The PI has been a member of STAR for twelve years, serving in leadership roles as co-convener of the Spin Physics Working Group from 2014-2017 and currently as a Deputy Spokesperson. The PI is the principal analyzer and author for STAR's recent paper on asymmetries in the production of jets and hadrons-within-jets at $\sqrt{s} = 500$ GeV (Ref. [2] and discussed in Sec. III D), as well as being a principal analyst and author of STAR's publication of neutral pion cross sections and asymmetries at intermediate pseudorapidity [3]. The PI is also a principal author of the analogous $\sqrt{s} = 200$ GeV paper, soon to be submitted, and has served on the writing committees for four additional STAR papers (Refs. [4–6] and one soon to be submitted). The involvement of undergraduates in physics research is a long and successful tradition at Lamar University and is a unique way to prepare students for graduate school in physics and careers in STEM professions. The PI has served as the research mentor for Suzanne Wheeler, a Lamar undergraduate physics major, who earned a Ronald E. McNair Post-Baccalaureate Achievement Program scholarship in 2017. This work has led her to be the first Lamar undergraduate student to receive a guest appointment at Brookhaven National Laboratory. Suzanne is one example of many Lamar physics majors who have earned scholarships and awards for research work, and the proposed program fits well within the traditions of the Lamar physics department. Additionally, it serves to enhance the quality of STEM education at Lamar University, which has a rich history of reaching students from disadvantaged backgrounds.

The first objective is to analyze the multiplicities of charged pions within jets from $p+p$ collisions at $\sqrt{s} = 500$ GeV, collected at STAR in 2011. Jet events with low transverse momenta, p_T, are particularly sensitive to gluonic subprocesses. These data will therefore offer new insight into hadronization by providing constraints on gluon fragmentation functions, which are critical for understanding hadronic interactions in the factorized pQCD framework. Preliminary investigation has begun, and new analysis infrastructure and sim-

ulations will need to be generated to finalize the results. The effort will be led by the PI with significant involvement of the undergraduate researchers. Specifically undergraduate researchers may focus efforts on evaluating the the production and quality assessment of the simulation sample, critical efforts which require skills in computing but not a sophisticated knowledge of physics above the appropriate undergraduate level. Results should be finalized in Year 2 of the grant.

The second objective is to analyze the Collins effect in the unique 200 GeV transversely polarized $p+Au$ dataset collected at STAR in 2015. This analysis will build extensively upon the infrastructure developed for the 500 GeV Collins analysis, recently submitted for publication by the PI [2]. New analysis techniques are necessary due to the nuclear environment of the 2015 data. These results may be compared with the existing Collins measurements from STAR [2, 7] to glean insight into potential modifications of the hadronization due to the nuclear environment. These are the only data of their kind and present a magnificent opportunity for illuminating some of the longstanding mysteries of QCD. This effort will be led by the postdoctoral associate under the direction of the PI and should be finalized in Year 2 of the grant.

The third and final analysis objective is to analyze the charged pion multiplicities for the same $p + Au$ dataset used for the Collins analysis. Comparison to pion multiplicities at 200 GeV from STAR's 2012 $p + p$ dataset (an independent analysis effort led by STAR collaborators from the University of Kentucky) can reveal insight into hadronization and potential modifications due to the nuclear environment. This effort will proceed in parallel with the Collins analysis, utilizing much of the same infrastructure and resources. The analysis will be led by the postdoctoral associate under the supervision of the PI and significant involvement of the undergraduate researchers. Undergraduates will be able to apply skills and infrastructure developed through the first objective, e.g. simulation productions and evaluation of detector calibrations, to the new data environment, again, without requiring inappropriate amounts of instruction in graduate-level physics concepts. The effort should be finalized in Year 3 of the grant.

II. RELATION TO LONGER-TERM GOALS

By developing a robust analysis program consistent with the priorities of the NSAC long-range plan, the Lamar STAR group will be adequately prepared for longer term efforts beyond the three years of initial funding. At the request of BNL management, in October 2015, STAR has prepared a document detailing the physics opportunities with STAR in the years 2020 and beyond [8]. A related proposal for upgrades to STAR's forward instrumentation has been submitted to BNL management in May 2017. The objectives described above fit seamlessly with the opportunities detailed in the STAR documents. This ensures that the PI and other Lamar STAR group are in position to play a significant role in the long-term future of STAR, RHIC physics, and potentially into the era of the electron-ion collider (EIC). The EIC has been identified by the NSAC long-range plan as the highest priority for new facility construction following the completion of FRIB [1].

The PI has for several years carried out an active research program through STAR, including being the principal author of multiple STAR papers and serving in leadership roles

within the collaboration. The objectives detailed above will ensure that the PI continues to compile a compelling research portfolio in time for the six-year tenure review in 2020. Such a resume is necessary for promotion, which is critical for longer term research efforts at Lamar University. Furthermore, the objectives provide the postdoctoral associate with the opportunity for a robust publication portfolio, suitable for career advancement toward a permanent position within the field. Finally, the objectives are consistent with the PI's goal to extend the effectiveness of Lamar University physics education. By broadening the research opportunities available to Lamar undergraduates, the physics department will be better equipped to provide a broad exposure to the diverse fields of study available within physics. Since arriving at Lamar University, the PI has engaged Lamar Undergraduates, such as Suzanne Wheeler, in STAR research through limited local funding opportunities. The proposed program will firmly establish nuclear physics as a part of the fabric of Lamar University.

III. RELATION TO THE PRESENT STATE OF KNOWLEDGE IN THE FIELD

A. Background: Hadronization and the Nuclear Environment

An essential piece to theoretical pQCD calculations, e.g. for the production of high-p_T hadrons, is the fragmentation function. Since these are non-perturbative elements, their models depend critically upon experimental measurements. Fragmentation functions are usually studied through e^+e^- collisions. One limitation of this technique is that gluon fragmentation functions can only be accessed indirectly. Hadroproduction is an environment directly sensitive to gluon fragmentation functions, and the production of inclusive hadrons is often utilized for this purpose. However, a limitation of this approach is that the information in z, the fraction of parton momentum transferred to the hadron, is smeared due to an involved convolution between the fragmentation function and the hard-scattering functions. Recent theoretical work [9] has shown that this feature can be overcome by studying the production of hadrons within jets. Having information from both the jet and the hadron allows one to measure z_h, the fraction of jet momentum carried by the hadron, which is equivalent to z as calculated relative to the parton, at first order. Additionally, fragmentation function studies in $p + p \rightarrow jet + h + X$ can also serve as an innovative way to test the universality of fragmentation functions, lending deeper insight into the nature of QCD.

Measuring the distribution of hadrons within a jet, one can also investigate the transverse-momentum-dependent, "TMD," structure of the fragmentation function. Factorization of TMD formulations of QCD have been proven for SIDIS as well as Drell-Yan and weak-boson production in polarized-proton collisions [10–15]. However, it is expected that TMD factorization may generally be broken for hadronic interactions [16–18]. The size of any such factorization breaking is not known. A recent paper [19] argues that TMD factorization is robust for hadron-within-jet observables. Significant questions also remain about the kinematic evolution of TMD distributions and fragmentation functions, since TMD evolution equations involve noncalculable factors that depend entirely upon experimental data for constraints. TMD measurements in hadroproduction, therefore, are crucial for expanding insight into the nature of pQCD.

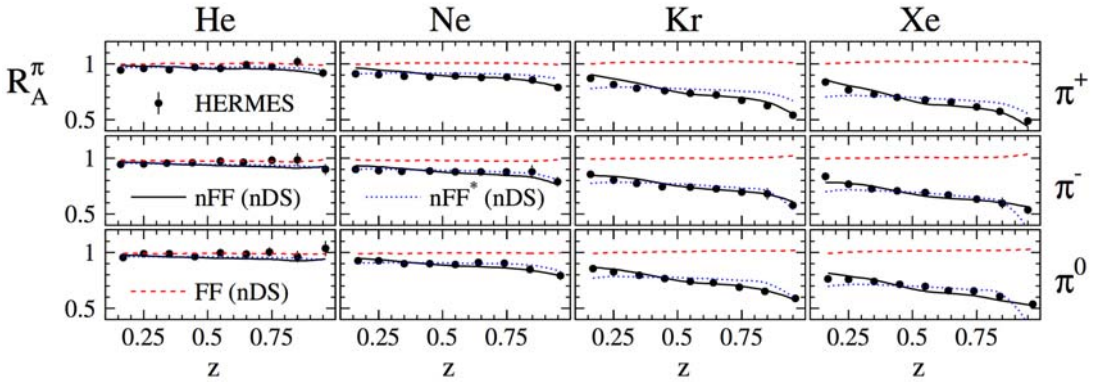

FIG. 1. Data from HERMES in comparison with fragmentation function calculations including nuclear modifications (black solid lines and blue dotted lines) and without nuclear modifications (dashed red lines) [20]. The HERMES data present the ratios of the SIDIS pion production rates from nuclear targets to proton targets. The mode calculations all include the effects of nuclear PDFs. Models which include nuclear modification of the fragmentation are clearly preferred by the data.

Data from the HERMES experiment have shown that pion production rates from $e + A$ collisions are modified relative to those from $e + p$ collisions (see Ref. [20] and references, therein). Figure 1 shows the HERMES data [20] for the ratios of pion production rates for various nuclear targets to those for proton targets. These ratios are compared with theoretical models utilizing nuclear PDFs and three sets of fragmentation functions: one set of vacuum fragmentation functions (red dashed lines) and two sets of nuclear-modified fragmentation functions (solid black lines and dotted blue lines). The data clearly indicate a preference for models including nuclear modification in the hadronization process. A critical test will be to determine if these nuclear modifications to hadronization persist at higher values of the center-of-mass collision energy $\sqrt{s}$ and momentum-transfer Q^2.

B. Multiplicities of Pions within Jets: The First and Third Objectives

The proposed first objective will enhance knowledge of hadronization by probing gluon fragmentation functions through the study of charged-pion multiplicities in jets [9] from $p + p$ collisions at $\sqrt{s} = 500$ GeV. The measurement will utilize data collected by the STAR detectors during the 2011 RHIC run. The PI has recently submitted for publication the measurements of spin-dependent distributions of pions within jets [2] ("Collins" asymmetries, also discussed in Section III D) from these same data. The dataset is therefore thoroughly understood. To enhance sensitivity to gluonic subprocesses, the analysis will focus on jets with relatively low-p_T from the minimum-bias event triggers. This will also significantly simplify the analysis by removing the need to evaluate systematic uncertainties due to bias in the event trigger. Development of the analysis infrastructure has been initiated by the PI and Suzanne Wheeler during the summer of 2017 and is based upon that of the Collins analysis. Two new analysis developments needed specifically for the fragmentation function analysis are a new method for correcting jets for underlying-event contributions and a

multi-dimensional procedure to "unfold" the reconstructed kinematics to the corrected kinematics. A final need before publication of results is a high-statistics Monte Carlo simulation to ensure sufficient precision for the corrections and unfolding. This work will provide significant opportunities for involvement of undergraduate researchers, enabling development of practical computing skills, knowledge of physics detectors, and skills to handle large sets of data. The timeframe for preliminary results, suitable for public dissemination, is the first spring of funding (2019) with publication to follow later that year.

The proposed third objective will utilize multiplicities of charged pions in jets from proton-gold collisions at $\sqrt{s} = 200$ GeV to investigate the effects of the nuclear environment on hadronization. This dataset presents a unique opportunity to extend the hadronization studies, e.g. from HERMES, to much higher $\sqrt{s}$ and Q^2. The analysis will flow naturally out of the first objective, utilizing much of the infrastructure already laid to that point. The methodology developed for correcting underlying event in the second objective will be crucial to evaluating similar corrections for the $p + Au$ analysis. A large Monte Carlo simulation will be necessary and careful optimization of the simulation parameters will be important, again providing prime opportunities for involving undergraduate students. For purposes of evaluating the nuclear modification, a parallel analysis of the 200 GeV $p + p$ dataset is necessary. This work is being carried out independently by STAR colleagues at the University of Kentucky. Consistent with STAR bylaws, the results of the $p + p$ analysis will be available for collaboration-wide utilization, including for the proposed $p+Au$ analysis. To quote from the STAR bylaws, "Data from all parts of the STAR detector shall be available to all members of the STAR Collaboration for analysis. Furthermore, it is the responsibility of all collaborators to see that the necessary correction algorithms and correction parameters be updated and made available to the entire Collaboration in a timely manner. Any member of the Collaboration is free to analyze any part of the data." The timeframe for preliminary results, suitable for dissemination, will be spring in the second year of funding (2020) with publication to follow by the spring of the final year of funding (2021).

C. Background: Transverse Spin Physics and the TMD Formalism

A complete partonic picture of the nucleon requires three parton distribution functions (PDFs): the unpolarized parton distribution, $f(x, Q^2)$; the helicity parton distribution, $\Delta f(x, Q^2)$; and the transversity distribution, $h_1(x, Q^2)$ [21, 22]. Here, x denotes the parton light-cone momentum fraction; while Q^2, again, denotes the momentum transfer. Of the three PDFs, transversity, which describes the transverse polarization of quarks inside a transversely polarized nucleon, has proven the most difficult to probe. This is due to transversity's chiral-odd nature, requiring it to couple to another chiral-odd quantity in order to be observed.

Advances in understanding transversity have been made through the study of transverse single-spin asymmetries, defined as

$$A_{UT} \sin(\phi) = \frac{\sigma^{\uparrow}(\phi) - \sigma^{\downarrow}(\phi)}{\sigma^{\uparrow}(\phi) + \sigma^{\downarrow}(\phi)}. \quad (1)$$

For decades, A_{UT} (also, commonly expressed as "A_N") has been measured to be as large as a few percent at p_T values of several GeV/c for inclusive hadron production at forward

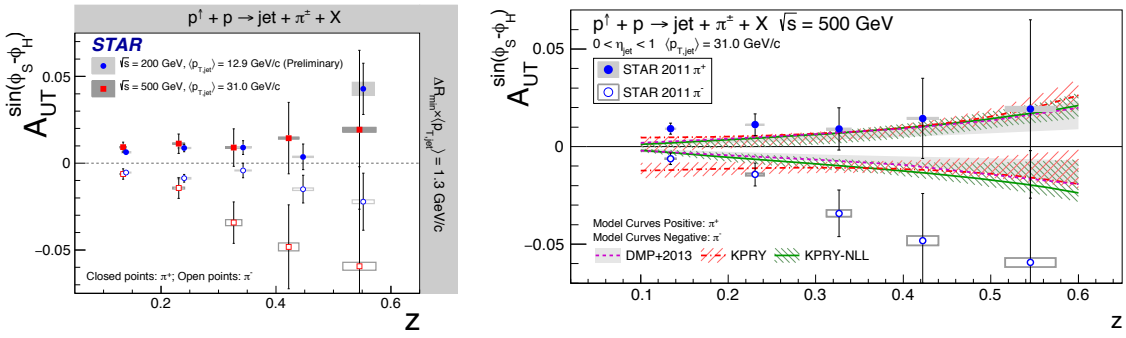

FIG. 2. Collins asymmetries at $\sqrt{s} = 200$ [25] and 500 GeV [2] (left). Asymmetries are consistent when scaling for x_T. Collins [2] asymmetries at $\sqrt{s} = 500$ GeV are shown in comparison to model calculations based on SIDIS [26, 27] (right). Collins asymmetries are consistent with models at the 95% confidence level showing a slight preference for models assuming no TMD evolution.

pseudorapidity ($\eta \sim 3$) from polarized-proton collisions, e.g. Ref. [23]. Moreover, the size of the asymmetries appears to be independent of center of mass energy, across a range of over an order of magnitude. This has presented something of a conundrum, since for over thirty years, it has been known that the partonic hard scattering asymmetry is vanishingly small for modest values of p_T [24]. This mystery has proven a catalyst for theoretical development into how such an asymmetry may arise in the nonperturbative mechanisms and resulted in an opportunity for tremendous deepening in the understanding of QCD.

One of the paths to generate a non-zero A_{UT} in QCD is to utilize TMD parton distributions and fragmentation functions. The TMD formulation [28–30] utilizes correlations between spin polarization and intrinsic transverse momentum. For example, the Collins mechanism [30] requires a correlation between the polarization of a hard-scattered quark and the transverse momentum of a hadron fragment (calculated relative to the scattered quark direction). It is enabled by nonzero transversity coupled to the polarization-dependent "Collins" fragmentation function. SIDIS experiments have provided the first measurements of Collins asymmetries (e.g. Refs. [31–33]). These, combined with independent measurements of the Collins fragmentation function by e^+e^- experiments (e.g. Refs. [34, 35]), have enabled the first extractions of the transversity PDF [36, 37]. The PI has served as the principal analyst and principal author for the STAR paper recently submitted for publication representing the first measurement of the Collins asymmetry from transversely polarized proton-proton, $p^\uparrow + p$ collisions at $\sqrt{s} = 500$ GeV [2]. The results are presented in the left-hand panel of Fig. 2, along with preliminary results at $\sqrt{s} = 200$ GeV [7] from data collected in 2012. The results are selected so that they sample the same range of j_T, the pion momentum transverse to the jet axis, and the same range of $x_T = 2p_T/\sqrt{s}$. The 200 GeV and 500 GeV asymmetries are consistent for common ranges of x_T, which is noteworthy given the open questions about TMD factorization. The 500 GeV asymmetries are compared with model calculations [26, 27] based upon SIDIS and e^+e^- data in the right-hand panel of Fig. 2. The models assume robust TMD factorization and universality, non-trivial assumptions given the general expectation of TMD factorization-breaking in hadroproduction. Furthermore,

the models of Ref. [27] are based on two separate calculations: one assuming no TMD evolution (KPRY) and one assuming TMD evolution up to next-to-leading log (KPRY-NLL). The STAR data agree with all predictions at the 95% confidence level, consonant with the model assumption of universality of the Collins fragmentation function and the assumption of robust TMD factorization for these observables in $p + p$. Between the two KPRY calculations, the 500 GeV data exhibit a slight preference for the model without TMD evolution. Using the data statistical and systematic uncertainties, a χ^2 test yields $\chi^2 = 14.0$ for $\nu = 10$ degrees of freedom without evolution compared with $\chi^2 = 17.6$ with evolution.

The existing STAR results argue the Collins mechanism is a fertile field for probing the nature of QCD and hadronization. While the existing results are suggestive, new results will enable more precise conclusions and probe deeper questions, such as how the polarized hadronization is modified through different collision environments.

D. Collins Measurements from $p + Au$ Collisions: The Second Objective

The proposed second objective will, in the spirit of the NSAC long-range plan, exploit the unique capabilities of RHIC for novel insight into the nature of QCD and especially hadronization through the study of the Collins asymmetry in the production of charged pions within jets from transversely polarized-proton-on-gold, $p^{\uparrow} + Au$, collisions at $\sqrt{s} = 200$ GeV [38, 39]. Specifically, the measurement utilizes Eq. 1 with the azimuthal angle ϕ calculated as $\phi = \phi_S - \phi_H$, where ϕ_S is the azimuthal angle between the proton spin polarization and the jet-scattering plane and ϕ_H is the azimuthal orientation of the pion around the jet axis. The Collins asymmetry has never been measured in an environment where nuclear modification is possible. The proposed objective will therefore provide the first opportunities for observing nuclear modification to polarized hadronization. The 2015 STAR dataset is the only existing dataset where such a study can be done. Projected statistical uncertainties for the 2015 $p + Au$ Collins asymmetries are shown in Fig. 3. The second objective will proceed in parallel with the third objective, and the two efforts will utilize the same analysis framework and simulation sample. Sharing resources between the two objectives will significantly reduce the amount of time to complete the projects. The second objective, also, will be greatly expedited by the groundwork laid by the 500 GeV Collins analysis, which has been submitted for publication by the PI [2]. The timeframe for preliminary results, suitable for dissemination to the public, is spring of the second year of funding (2020) with publication to follow by the spring of the final year of funding (2021). Finally, the second and third objectives serve to position the Lamar STAR group for leadership in the longer-term efforts of STAR beyond 2020 [8].

IV. SUPPORTING WORK FOR THE STAR COLLABORATION

A. STAR Deputy Spokesperson

A critical component of any successful collaborative experiment is broad participation from collaborators in supporting work. The PI has served as a member of STAR for the past twelve years, active in various service roles such as writing committees, institutional

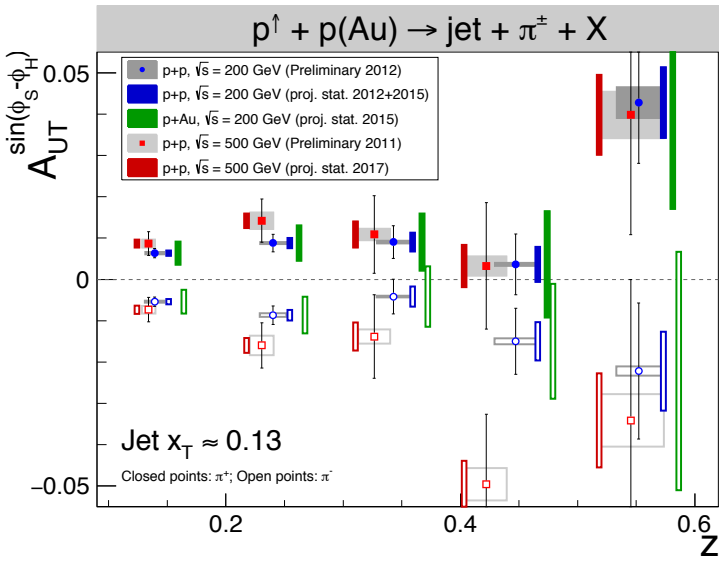

FIG. 3. Projected statistical uncertainties for STAR 2015 and requested 2017 datasets. Projections are placed at the location of the 2011 and 2012 datapoints [7].

review panels, and data simulation productions. As of fall 2017, the PI has concluded a three-year term as co-convener of the STAR Spin Physics Working Group (PWG). As co-convener, the PI was responsible for chairing weekly meetings during this three-year term to discuss analysis progress for the various projects within the PWG, as well as attending additional weekly meetings of the conveners of all STAR PWGs. A second responsibility was to serve on the writing committees for STAR spin physics papers submitted during this term, e.g. STAR papers on transverse spin asymmetries in di-hadron correlations at $\sqrt{s} = 200$ GeV [5], cross section and longitudinal spin asymmetries in dijet production at $\sqrt{s} = 200$ GeV [6], and transverse spin asymmetries in di-hadron correlations at $\sqrt{s} = 500$ GeV (soon to be submitted). During collaboration meetings, the PI was responsible for presenting status reports on the spin PWG to the full collaboration. This fall, the PI has accepted a new leadership role, beginning a three-year term on the STAR management team as Deputy Spokesperson. As described in the STAR bylaws, "The deputy Spokespersons provide support and assistance to the Spokesperson(s) in the management of the experiment and collaboration. They may be authorized by the Spokesperson(s) to act on his/her/their behalf and to represent the Collaboration." This job involves chairing various committees and focus groups pertaining to STAR analyses and activities, attending weekly meetings of the management team, maintaining daily communication with the Spokespersons, participating in weekly analysis discussions with the PWGs, and participating in meetings of the STAR Council. The responsibilities inherent to this position require the PI to travel to Brookhaven National Laboratory for annual STAR Collaboration and Analysis Meetings. One of the PIs first duties has been to chair a committee to identify and document an analysis blinding procedure for the isobar collision data to be collected during the 2018 RHIC run for investigating a possible chiral magnetic effect in heavy-ion collisions. Blind

analyses are commonplace within some fields of physics but to our knowledge have never been attempted in a heavy-ion analysis.

B. STAR Data-taking Shifts

Other required support work for membership in the STAR collaboration is participating in data-taking shifts during RHIC running. The PI has participated in STAR data-taking shifts for twelve years, serving in every capacity up to shift-leader, including training future STAR shift-leaders. Each collaborative institution is required to fulfill a certain number of shifts set each year based upon the number of institutional coauthors requested for STAR publications. The PI and postdoctoral associate will be STAR coauthors, and it is anticipated that each will be required to fulfill two data-taking shifts during each year of RHIC running (years one and three of the funding cycle). These shifts also serve as excellent opportunities for the postdoctoral associate to gain training in the operation of an experiment and to network with the larger collaboration community, which can be valuable for the career goals of the postdoctoral associate.

V. UNDERGRADUATE RESEARCHERS

The Lamar University physics department has a long tradition of engaging undergraduate physics and STEM students in physics research. The proposed program extends this successful tradition for the first time into the field of nuclear physics. The PI has experience both as an undergraduate research student and a supervisor of undergraduate research students. From 2002-2004, the PI was an undergraduate research student at Abilene Christian University and from 2012-2015 supervised undergraduate research students at Valparaiso University. At Lamar University, the PI has mentored undergraduate students through submission of locally funded undergraduate research proposals and through independent study of nuclear physics research in 2016. In 2017, the PI has also served as the research mentor for Suzanne Wheeler, a Lamar physics undergraduate student awarded a scholarship through the Ronald E. McNair Post-Baccalaureate Achievement Program, eligible to first-generation, low-income, and/or underrepresented students. Through her McNair research, Suzanne became the first Lamar undergraduate to receive a guest appointment at Brookhaven National Laboratory. The proposed program builds upon the foundations of these successful experiences.

The role of undergraduate mentor will be performed by the PI. Students will participate in weekly face-to-face meetings with the research group as well as frequent one-on-one meetings with the PI. The PI will work directly with students to identifying analysis projects well-suited to the skills and potential of the individual student, as well as in identifying suitable venues for presentation of their work. The PI will also leverage contacts through the STAR collaboration institutions toward identifying graduate school opportunities. Because of the on-going work of the PI with Lamar students through the McNair program, independent study, and undergraduate research proposals, several Lamar students already possess the background to begin research in this program. To prepare new students, the PI will continue to offer the independent study in nuclear physics research for first-time student

researchers in the program. This mechanism has proven effective not only to prepare new students but also to advertise the research opportunity and engender interest among new Lamar physics students.

The McNair Program is another excellent entryway to the proposed research program for well-qualified students, specifically from underrepresented populations. To qualify, students must be first-generation and low-income and/or from underrepresented populations, maintain at least a 3.0 cumulative GPA, have completed 45 undergraduate semester hours, and express a desire to pursue graduate studies. Scholars are given a stipend and funding for a summer internship period. In fall 2017, funding the Lamar McNair program was renewed for the next four years by the U.S. Department of Education, ensuring stability for the duration of the proposed research proposal. Lamar physics students have a successful history with the McNair program, and the PI has served as a McNair scholar mentor during the summer of 2017. This student has continued to perform research with the PI beyond the duration of the McNair internship, serving as an example for the program moving forward. The PI will actively recruit from among the McNair physics cohort. Scholars will work alongside the other STAR undergraduates and continue working with the research program after the McNair internship has ended. Alongside the other recruiting mechanisms described, the McNair program in particular will help the proposed research program stay equally accessible and open to qualified students from underrepresented populations.

The primary research projects for undergraduate students will involve assisting with data and simulation analyses for the pion multiplicity analyses. Both the $p+p$ and $p+Au$ analyses require large simulation productions for corrections and evaluation of systematic uncertainties. Example projects are the following: assessing the necessary simulation statistics to achieve the desired precision for the corrections, quality assessment of test samples produced prior to full production, and evaluating the level of agreement between the data distributions and the corresponding simulation distributions after production. These examples require a modest level of computing skills but do not require an intimate knowledge of the high-level theoretical underpinnings of the physics and are therefore well-suited for Lamar undergraduate students. For instance, students can begin by studying preexisting examples of macros and code used to generate histograms for previous studies. Once familiar, they can edit the code for the necessary additional histograms required by the present analysis. They will, then, learn the mechanisms for running the code over the simulation or data files to produce the relevant plots. At any point, the students and PI will discuss relevant questions and troubleshoot code, as necessary. Once a successful analysis pass is performed, the students and PI will discuss the resulting plots and subsequent steps of the analysis. This model allows the students to maintain close contact with the mentor while affording a measure of freedom and innovation. It has worked quite well for the PI while mentoring Suzanne Wheeler, as well as during the PI's time as an undergraduate mentor at Valparaiso University.

The PI and postdoctoral associate will travel periodically to STAR collaboration and analysis meetings at Brookhaven to discuss on-going efforts outlined in this proposal. The PI will leverage local funding opportunities, e.g. through the Lamar Office of Undergraduate Research/Creative Activity, to allow the undergraduate researchers to travel to the lab, as well. This will allow the PI to expose the students to the national laboratory atmosphere and the most recent developments in the field, as well as opportunities to form relationships

with potential graduate school advisors.

After completing a project, presenting and discussing the results is a marvelous way to enhance the learning experience for students. The annual Conference Experience for Undergraduates (CEU), held in conjunction with the fall meeting of the APS Division of Nuclear Physics (DNP), is a stellar example. Participation in this conference experience and its associated poster session will be a valuable way for Lamar students to discuss their projects with a diverse group of scientists, including other undergraduate researchers and senior research faculty, alike. The conference experience also includes a graduate school information session, with opportunities to speak face-to-face with representatives from various schools. It will also serve well to develop credibility and enhance the profile of Lamar University within the nuclear physics community. Upon returning, the students will be able to share their experience with the broader Lamar University community, which will enhance the profile of the physics department on-campus. All of these examples are critical to the long-term goals of the PI.

VI. BROADER IMPACTS OF THE PROPOSED WORK

Aside from the powerful intellectual contribution to the field, the proposed program presents a tremendous opportunity to impact the community of Southeast Texas and the Gulf Coast Region. Lamar University is located in the Southeast Texas city of Beaumont, close to the border with Louisiana. The regional economy has historically strong ties to the petroleum industry, and Lamar's large engineering college reflects this history. The Southeast Texas region also has a large population from disadvantaged backgrounds, and Lamar University has a history of reaching these individuals. As has been well documented, Beaumont and all of Southeast Texas have experienced profoundly difficulties associated with Hurricane Harvey. While the people of this region are robust and effectively recovering, complete recovery will take years. Furthermore, the region now looks for ways to improve infrastructure, predictive modeling for storms and the flow of flood water, and information processing on such items as water quality and ecological impact. Technical, analytical, innovative, and problem-solving skills are always at a premium but acutely so in such times of recovery and looking forward. Exposing students to high-quality STEM education, such as physics, is a powerful way to open doors of opportunity. Many of these students have never considered physics research as a possibility. Providing them the opportunity not only to participate in analysis efforts but also to travel to national laboratories and present results of their project at conferences enhances their educational experience, demonstrates the wealth of career possibilities, and encourages yet more students to take advantage of future opportunities. While these students, often first-generation students, need these opportunities, they simultaneously fulfill a critical need for the region and nation. The regional economy critically depends upon an educated and well-trained population; and our nation, as a whole, profoundly benefits by a society with STEM-based skills. The proposed program would empower otherwise disadvantaged students, enhance the quality of STEM education at a strategically located institution, and serve an urgent need for the local and broader community.

The PI will create a vehicle to evaluate the effectiveness of the proposed program on

the retention and matriculation of undergraduates through the physics program. The results of these evaluations will then inform methodologies for future mentoring efforts. Each student participating in research efforts with the proposed program will complete entrance surveys shortly after their selection to the program to gauge their interest in physics and expectations for their participation. Students participating multiple summers will complete a separate survey for each year of participation. Students will follow up with an exit survey at the completion of their activities for the summer. The exit surveys will repeat questions to gauge interest in physics but also separate questions to get feedback on which methodologies were perceived as most effective or made the most impact. At the end of the students time at Lamar, they will complete a final survey to evaluate current interests, future goals, and how their research experiences impacted their path through the program. To the extent possible, surveys will be distributed to students who do withdraw from the physics program or transfer from Lamar to solicit their feedback, as well. The results will be made available to other STEM faculty at Lamar University as well as to collaborators on STAR. This effort is aimed at developing innovative methodologies for mentoring future scientists, contributing constructively to broader mentoring efforts of students, and in particular focused on removing existing barriers to the progress of students from diverse or disadvantaged backgrounds.

VII. RESULTS FROM PRIOR NSF SUPPORT

The PI has not received past NSF support.

VIII. PROPOSED TIMELINE AND MILESTONES

The following list summarizes the milestone targets for completion and dissemination of results for the program objectives. These milestones will aid the Lamar STAR group in evaluating the efficiency of achieving the proposed goals. More importantly they will also serve as an effective program for dissemination of results, facilitating collaboration with theorists and other colleagues in the field, career exposure for the postdoctoral associate, and elevating the profile of Lamar University in the new horizon of nuclear physics.

- Complete preliminary analysis of pion multiplicities at 500 GeV in spring 2019
- Presentation of preliminary 500 GeV pion multiplicity results in fall 2019 at DNP conference
- Complete preliminary analysis of $p + Au$ Collins asymmetries in spring 2020
- Complete preliminary analysis of $p + Au$ pion multiplicities in spring 2020
- Presentation of preliminary $p + Au$ Collins asymmetries and pion multiplicities in fall 2020 at DNP conference
- Publish $p + Au$ Collins asymmetries in spring 2021
- Publish $p + Au$ pion multiplicities in spring 2021

IX. RESPONSIBILITIES FOR PROGRAM COMPONENTS

The following list summarizes the personnel primarily responsible for the various components of the proposed program.

- Pion multiplicities at 500 GeV (PI)
- $p + Au$ Collins asymmetries (postdoctoral associate)
- $p + Au$ pion multiplicities (postdoctoral associate, PI)
- Supervisor for postdoctoral associate (PI)
- Mentor for undergraduate research students (PI)
- Operate STAR detectors during data-taking runs (PI, postdoctoral associate)

X. CONCLUDING REMARKS

The principle investigator believes the scientific program presented

- is a compelling opportunity to enhance the state of knowledge in nuclear physics
- takes full advantage of the existing expertise of the PI and positions the PI for the development of new expertise
- is seamlessly consistent with the priorities outlined in the recent NSAC long-range plan
- is strategically chosen to advance the long-term program of the PI
- will provide a rich experience for early-career scientists, such as postdoctoral associates
- will impact a critical need of the region and nation for a population with strong skills in STEM disciplines
- will impact a critical need of the region and nation for providing historically disadvantaged populations with opportunities for quality STEM education

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lad, R. Gilman, O. Glamazdin, S. Golge, L. Guo, D. Hamilton, O. Hansen, D. Higinbotham, T. Holmstrom, M. Huang, H. Ibrahim, M. Iodice, X. Jiang, G. Jin, M. Jones, A. Kelleher, W. Kim, A. Kolarkar, W. Korsch, J. LeRose, X. Li, Y. Li, R. Lindgren, N. Liyanage, E., H.-J. Lu, D. Margaziotis, P. Markowitz, S. Marrone, D. McNulty, Z.-E. Meziani, R. Michaels, B. Moffit, C. M. Camacho, S. Nanda, A. Narayan, V. Nelyubin, B. Norum, Y. Oh, M. Osipenko, D. Parno, J. Peng, S. Phillips, M. Posik, A. Puckett, Y. Qiang, A. Rakhman, R. Ransome, S. Riordan, A. Saha, B. Sawatzky, E. Schulte, A. Shahinyan, M. Shabestari, S. Sirca, S. Stepanyan, R. Subedi, V. Sulkosky, L.-G. Tang, A. Tobias, G. Urciuoli, I. Vilardi, K. Wang, B. Wojtsekhowski, X. Yan, H. Yao, Y. Ye, Z. Ye, L. Yuan, X. Zhan, Y.-W. Zhang, B. Zhao, X. Zheng, L. Zhu, X. Zhu, and X. Zong (Jefferson Lab Hall A Collaboration), Phys. Rev. Lett. **107**, 072003 (2011).

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S. Akar, E. Ben-Haim, M. Bomben, G. Bonneaud, H. Briand, G. Calderini, J. Chauveau, P. Leruste, G. Marchiori, J. Ocariz, S. Sitt, M. Biasini, E. Manoni, S. Pacetti, A. Rossi, C. Angelini, G. Batignani, S. Bettarini, M. Carpinelli, G. Casarosa, A. Cervelli, F. Forti, M. Giorgi, A. Lusiani, B. Oberhof, E. Paoloni, A. Perez, G. Rizzo, J. Walsh, D. L. Pegna, J. Olsen, A. Smith, R. Faccini, F. Ferrarotto, F. Ferroni, M. Gaspero, L. L. Gioi, G. Piredda, C. Bunger, O. Grunberg, T. Hartmann, T. Leddig, C. Voss, R. Waldi, T. Adye, E. Olaiya, F. Wilson, S. Emery, G. H. de Monchenault, G. Vasseur, C. Yeche, F. Anulli, D. Aston, D. Bard, J. Benitez, C. Cartaro, M. Convery, J. Dorfan, G. Dubois-Felsmann, W. Dunwoodie, M. Ebert, R. Field, B. Fulsom, A. Gabareen, M. Graham, C. Hast, W. Innes, P. Kim, M. Kocian, D. Leith, P. Lewis, D. Lindemann, B. Lindquist, S. Luitz, V. Luth, H. Lynch, D. MacFarlane, D. Muller, H. Neal, S. Nelson, M. Perl, T. Pulliam, B. Ratcliff, A. Roodman, A. Salnikov, R. Schindler, A. Snyder, D. Su, M. Sullivan, J. Va'vra, A. Wagner, W. Wang, W. Wisniewski, M. Wittgen, D. Wright, H. Wulsin, V. Ziegler, W. Park, M. Purohit, R. White, J. Wilson, A. Randle-Conde, S. Sekula, M. Bellis, P. Burchat, T. Miyashita, E. Puccio, M. Alam, J. Ernst, R. Gorodeisky, N. Guttman, D. Peimer, A. Soffer, S. Spanier, J. Ritchie, A. Ruland, R. Schwitters, B. Wray, J. Izen, X. Lou, F. Bianchi, F. D. Mori, A. Filippi, D. Gamba, S. Zambito, L. Lanceri, L. Vitale, F. Martinez-Vidal, A. Oyanguren, P. Villanueva-Perez, H. Ahmed, J. Albert, S. Banerjee, F. Bernlochner, H. Choi, G. King, R. Kowalewski, M. Lewczuk, T. Lueck, I. Nugent, J. Roney, R. Sobie, N. Tasneem, T. Gershon, P. Harrison, T. Latham, H. Band, S. Dasu, Y. Pan, R. Prepost, and S. Wu (BaBar Collaboration), Phys. Rev. D **90**, 052003 (2014).

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Biographical Sketch

Professional Preparation

Abilene Christian University	Abilene, TX	Physics	B.S.	2004
Texas A&M University	College Station, TX	Physics	Ph.D.	2012
Valparaiso University	Valparaiso, IN	Nuclear Physics (Nucleon Spin)		2012-2014

Appointments

Lamar University	Beaumont, TX	Assistant Professor of Physics	2015-present
Valparaiso University	Valparaiso, IN	Visiting Assistant Professor of Physics and Astronomy	2015

Publications

According to collaboration bylaws, STAR publications are co-authored by all collaborators in good standing. For current publications, this is a total of 350 co-authors. The full list of STAR co-authors is included in Supplementary Materials.

Products Most Closely Related to the Proposed Project

- L. Adamczyk et al. (STAR Collaboration), "Azimuthal transverse single-spin asymmetries of inclusive jets and charged pions within jets from polarized-proton collisions at $\sqrt{s} = 500$ GeV," arXiv:1708.07080 [hep-ex] (submitted for publication in Phys. Rev. D).
- J. Adams et al. (STAR Collaboration), "Transverse spin-dependent azimuthal correlations of charged pion pairs measured in $p^{\uparrow} + p$ collisions at $\sqrt{s} = 500$ GeV," arXiv:1710.10215 [hep-ex] (submitted for publication in Phys. Lett. B).
- L. Adamczyk et al. (STAR Collaboration), "Measurement of the Transverse Single-Spin Asymmetry in $p^{\uparrow} + p \rightarrow W^{\pm}/Z^{0}$ at RHIC," Phys. Rev. Lett. 116, 132301 (2016).
- L. Adamczyk et al. (STAR Collaboration), "Observation of Transverse Spin-Dependent Azimuthal Correlations of Charged Pion Pairs in $p^{\uparrow} + p$ at $\sqrt{s} = 200$ GeV," Phys. Rev. Lett. 115, 242501 (2015).
- L. Adamczyk et al. (STAR Collaboration), "Precision Measurement of the Longitudinal Double-Spin Asymmetry for Inclusive Jet Production in Polarized Proton Collisions at $\sqrt{s} = 200$ GeV," Phys. Rev. Lett. 115, 092002 (2015).

Other Significant Products

- L. Adamczyk et al. (STAR Collaboration), "Global Λ hyperon polarization in nuclear collisions: evidence for the most vortical fluid," Nature 548, 62 (2017).
- L. Adamczyk et al. (STAR Collaboration), "Measurement of the cross section and longitudinal double-spin asymmetry for di-jet production in polarized pp collisions at $\sqrt{s} = 200$ GeV," Phys. Rev. D 95, 071103 (2017).
- L. Adamczyk et al. (STAR Collaboration), "Measurement of Interaction between Antiprotons," Nature 527, 345 (2015).

- L. Adamczyk et al. (STAR Collaboration), "Neutral pion cross section and spin asymmetries at intermediate pseudorapidity in polarized proton collisions at $\sqrt{s} = 200$ GeV," Phys. Rev. D 89, 012001 (2014).
- L. Adamczyk et al. (STAR Collaboration), "Longitudinal and transverse spin asymmetries for inclusive jet production at mid-rapidity in polarized $p + p$ collisions at $\sqrt{s} = 200$ GeV," Phys. Rev. D 86, 032006 (2012).

Synergistic Activities

- In 2017, the PI served as the research mentor for Suzanne Wheeler, a Lamar undergraduate physics major and recipient of a scholarship through the Ronald E. McNair Post-Baccalaureate Achievement Program, eligible to first-generation, low-income, and/or underrepresented students. Ms. Wheeler's research focused on analysis of STAR Monte Carlo simulation for jet measurements, and she became the first Lamar undergraduate student to receive a guest appointment at Brookhaven National Lab.
- The PI has developed new curriculum for courses in Data Analysis. Utilizing data and analysis techniques developed for the research described in this proposal, the PI created instructional material for the course taught at Valparaiso University. Building from this foundation, the PI created a new Data Analysis course for the first time at Lamar University in spring 2016. The success of the initial offering, backed by student demand, has led to a subsequent offering for spring 2018.
- The PI is co-author of a letter of intent to the Lamar University administration for developing active-learning methodologies for use in STEM courses. PI is currently implementing and refining methodologies in introductory physics courses for non-physics majors at Lamar University. These methods include creation of original pre-lecture recordings for student viewing, innovative in-class demonstrations, and multiple-choice questions for fostering in-class discussions and peer-to-peer interaction. The active-learning program is especially targeted toward improving the preparation of students from disadvantaged backgrounds or from high schools with sub-standard STEM programs.
- The PI has developed innovative analysis methods for data-driven instrumental-acceptance corrections. Utilizing event-weighting and correlated-event statistical methods, the PI developed a method to analyze in a data-driven way high-order corrections for the effects of competing physics processes coupling to non-uniform detector acceptance.
- The PI is active in the training of early-career scientists on the STAR collaboration. The PI has developed pedagogical presentations detailing methodology for analyzing jet production at STAR. The PI annually trains first-time detector operators and shift leaders during data-taking runs of the STAR detector. This training involves hands-on instruction and evaluation of trainee performance to ensure sufficiently qualified personnel for the continued successful operation of STAR.

SUMMARY PROPOSAL BUDGET

YEAR 1

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

ORGANIZATION
Lamar University Beaumont

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
James Drachenberg

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. **James L Drachenberg - Assistant Professor**	0.00	0.00	1.50	**9,669**	
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	1.50	**9,669**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**1**) POST DOCTORAL SCHOLARS	12.00	0.00	0.00	**48,000**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**3**) UNDERGRADUATE STUDENTS				**27,495**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**85,164**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**18,686**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**103,850**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**11,752**	
2. INTERNATIONAL				**0**	
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				**3,680**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**3,680**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**119,282**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **On-campus indirect cost (Rate: 32.6000, Base: 119282)**					
TOTAL INDIRECT COSTS (F&A)				**38,886**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**158,168**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**158,168**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
James Drachenberg

ORG. REP. NAME*
Roxanne Smith Parks

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
Lamar University Beaumont

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
James Drachenberg

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. **James L Drachenberg - Assistant Professor**	0.00	0.00	1.50	**9,959**	
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	1.50	**9,959**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**1**) POST DOCTORAL SCHOLARS	12.00	0.00	0.00	**49,440**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**3**) UNDERGRADUATE STUDENTS				**27,495**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**86,894**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**7,193**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**94,087**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**20,028**	
2. INTERNATIONAL				**0**	
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)				**114,115**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **On-campus indirect cost (Rate: 32.6000, Base: 114115)**					
TOTAL INDIRECT COSTS (F&A)				**37,201**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**151,316**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**151,316**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
James Drachenberg

ORG. REP. NAME*
Roxanne Smith Parks

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
Lamar University Beaumont

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
James Drachenberg

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. **James L Drachenberg - Assistant Professor**	0.00	0.00	1.50	**10,259**	
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	1.50	**10,259**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**1**) POST DOCTORAL SCHOLARS	12.00	0.00	0.00	**50,923**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**3**) UNDERGRADUATE STUDENTS				**27,495**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**88,677**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**7,407**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**96,084**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**21,233**	
2. INTERNATIONAL				**0**	
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)				**117,317**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **On-campus indirect cost (Rate: 32.6000, Base: 117317)**					
TOTAL INDIRECT COSTS (F&A)				**38,245**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**155,562**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**155,562**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
James Drachenberg

ORG. REP. NAME*
Roxanne Smith Parks

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
Lamar University Beaumont

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
James Drachenberg

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. **James L Drachenberg - Assistant Professor**	0.00	0.00	4.50	**29,887**	
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	4.50	**29,887**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**3**) POST DOCTORAL SCHOLARS	36.00	0.00	0.00	**148,363**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**9**) UNDERGRADUATE STUDENTS				**82,485**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**260,735**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**33,286**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**294,021**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**53,013**	
2. INTERNATIONAL				**0**	
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				**3,680**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**3,680**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**350,714**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**114,332**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**465,046**	
K. SMALL BUSINESS FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**465,046**	

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME
James Drachenberg

ORG. REP. NAME*
Roxanne Smith Parks

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INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

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

Budget Justification

The proposal outlined below requests one postdoctoral associate in addition to the principle investigator (PI). For each year of the proposal, three undergraduate students will be hired for the summer to assist with research efforts and gain hands-on educational experience in physics. The proposal requests salaries and travel funds, as well as, computing resources for the postdoctoral associate. The details of each of these are discussed in the following sections. Indirect costs are set by Lamar University at a rate of 32.60% of the total modified direct costs.

I. SALARIES AND WAGES

The proposal requests a summer research salary for the PI equivalent to 1.5 times the monthly salary of the PI. The requested initial annual salary of $48000 for the postdoctoral associate is consistent with the regular practices toward postdoctoral associates at Lamar University. Commensurate with the practices of Lamar University, an annual salary increase of 3% is budgeted for the PI and postdoctoral associate. The proposal requests salary for three undergraduate summer researchers for each year of the grant. Each undergraduate will work for 19.5 hours each week for 47 weeks during the year. The salary of $10 per hour is commensurate with Lamar University practices toward undergraduate research students. Benefits for the PI and postdoctoral associate are consistent with the practices of Lamar University. Social Security is contributed by the employer at a rate of 7.65% of the salary. For the undergraduate students, the employer contribution includes 7.65% of $234 in summer FICA. Texas teacher retirement benefits for the PI are contributed at a rate of 6.80%. Optional retirement benefits are contributed at a rate of 6.60% of the salary. Health insurance is based upon actual costs in each year for the PI and postdoc.

II. TRAVEL

The proposal requests funds for travel to carry out work necessary to the body of work. All costs are derived utilizing per diem rates in accordance with Uniform Guidelines, University Policy and applicable state and federal laws/guidance.

As members of the STAR collaboration, the PI and postdoctoral associate will be required to participate in data-taking shifts at Brookhaven National Laboratory (BNL). The proposal projects two shifts (ten days and nine nights each) for the PI and one for the postdoctoral associate in the each year of funding.

As PI of the Lamar STAR research group, furthermore as STAR deputy spokesperson, the PI is required to attend annual STAR analysis meetings for face-to-face discussion of analysis efforts and innovations critical to the success and productivity of the research goals outlined in the proposal. The proposal requests funds to support the participation of the PI in the yearly STAR analysis meeting at BNL (five days and four nights). Because of the location and layout of BNL and the lack of adequate food options throughout a given week at the lab, a rental car is a necessity for travel to BNL.

Trip	Year 1	Year 2	Year 3
Brookhaven Shift (PI)	$6,499	$6,499	$6,499
Brookhaven Shift (Postdoc)	$3,250	$3,250	$3,250
Brookhaven Analysis Meeting (PI)	$2,003	$2,003	$2,003
Annual Conference (PI, Postdoc, U.G. Students)		$8,276	$9,481
Total	$11,752	$20,028	$21,233

TABLE I. Travel expenses for years 1-3.

The proposal requests funds for the PI and postdoc to attend one conference in the second and third years of funding. This is critical for the continued maturation of the PI and postdoc, as well as the success of the grant in disseminating results and extending communication and collaboration between members of the experimental and theoretical communities. The projected conferences are the Annual Fall Meetings of the APS Division of Nuclear Physics (DNP), projected for Tuscon, AZ, in October 2019 and Seattle,WA, in October 2020. Funds are also requested to support the attendance of the undergraduates at the Conference Experience for Undergraduates (CEU), held in conjunction with the DNP meetings. For more than a decade, this annual undergraduate experience has been tremendously successful in engaging and encouraging undergraduate research efforts. The meeting also provides prime opportunities for networking for potential graduate schools.

III. MATERIALS AND SUPPLIES AND OTHER RESEARCH SUPPLIES RELATED TO THIS PROJECT

The proposal requests $3680 to purchase a laptop computer for the postdoctoral associate. This computer will be used for the entire requested three years of the grant, exclusively for data and simulation analyses as described in the proposal. Due to the travel needs of the postdoctoral associate, a laptop is required. This will also enable a more flexible schedule to accommodate special needs, should they arise. The computer must support a UNIX-based environment, such as Apple OS X, and be powerful enough to run simulation and data-analysis software.

IV. INDIRECT COSTS

Indirect Costs are calculated at 32.6% of the Total Modified Direct Costs as negotiated with the federal cognizant agency, the U.S. Department of Health and Human Services.

Current and Pending Support

(See PAPPG 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: James Drachenberg

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: RUI: Probing the Nature of QCD Through Transverse Spin Physics at RHIC

Source of Support: National Science Foundation

Total Award Amount: $ 465,046 Total Award Period Covered: 09/01/18 - 08/31/21

Location of Project: Beaumont, TX

Person-Months Per Year Committed to the Project. Cal:1.50 Acad: 0.00 Sumr: 0.00

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: 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, and Other Resources

The objectives of this program primarily involve analysis of data and simulations. Thus, the most critical resources and equipment involve computers and internet connections. All Lamar University students and faculty have access to the high-speed internet necessary for logging onto the RHIC computing facility to access STAR data. Lamar University also provides the PI with an office facility, a laptop computer capable of running the necessary analysis codes, and a salary for the academic year (September through May of the following calendar year). Lamar University will provide the postdoctoral associate with office facilities. The proposal requests a laptop computer for the postdoctoral associate.

STAR datasets are stored on the computers of the RHIC and ATLAS Computing Facility (RACF). This facility is managed by Brookhaven National Laboratory (BNL) and RHIC personnel. The STAR Collaboration and BNL provide all STAR collaboration members with accounts on the RACF. STAR bylaws dictate that all collaborators must have access to all datasets from all portions of the STAR detector. This mandate extends to standard data reconstruction codes and simulation infrastructure. Thus, the internet and office resources provided by Lamar University to the PI and postdoctoral associate are sufficient to carry out the proposed analysis program.

To be a STAR co-author in good standing, the institutional members must commit to contributing to data-taking shifts during RHIC running. STAR, BNL, and the RHIC/AGS Users' Center provide myriad training opportunities necessary to carryout these important tasks. Training courses for general user information are available to all users with many on-line. Specifically, training courses for cybersecurity, collider-accelerator, and low-hazard skill-of-the-craft use are available annually for all collaborators. Instruction manuals for all aspects of STAR operation are available to potential shift-takers and updated by detector experts on a yearly basis. First-time STAR shift takers perform data-acquisition (DAQ) operations, working under direct supervision of the shift-leader. Second-time shift takers are eligible for training as detector operators during a week of shift-taking. The training is provided by the qualified STAR detector operators during the week of shift-taking. Having completed the week of training, the shift taker may serve subsequent shifts as a qualified detector operator. After serving as a DAQ operator and detector operator, the shift-taker is eligible for training to be a shift-leader. This training is provided, again, by qualified STAR shift leaders during the week of data-taking shifts. Sufficient resources for the necessary training are provided by the STAR collaboration, BNL, and the RHIC/AGS Users' center.

This proposal requests funding for undergraduate students to travel and present results at the fall DNP meetings. The funding requested covers flight, luggage fees, public transit, conference registration, and meals. Students will apply for lodging through the NSF-funded Conference Experience for Undergraduates (CEU) program. If the lodging funds through CEU are not available, they will be covered by Lamar University.

The measurements proposed in this program are high-priority measurements for the STAR and feature prominently in STAR long-range program documents. In the spirit of the long-term goals and in keeping with the collaboration bylaws, STAR collaborators and management are committed to the continued and supportive collaboration necessary for bringing the proposed program to completion.

Data Management

The proposed program utilizes data collected by the STAR experiment to complete analyses on behalf of the STAR Collaboration. Therefore, the management of experimental data follows that as outlined in the official STAR publication policies. The relevant policies are as follows:

- Availability of STAR Data: Data from all parts of the STAR detector shall be available to all members of the STAR Collaboration for analysis. Furthermore, it is the responsibility of all collaborators to see that the necessary correction algorithms and correction parameters be updated and made available to the entire Collaboration in a timely manner. Any member of the Collaboration is free to analyze any part of the data.

- Data Analyses in the Context of the Physics Working Group (PWG): It is anticipated that all STAR data will be analyzed in collaboration with the STAR Physics Working Groups (PWG), with the possible exception of technical papers. PWGs shall be designated and PWG convenors appointed by the spokesperson for each major physics analysis topic in STAR. In some instances a physics analysis may have implications for more than one PWG as determined by the spokesperson. In such cases, one of the PWGs shall be the principal PWG for that analysis, as designated by the spokesperson, with the other affected PWGs being secondary. The PWG convenorships are expected to rotate approximately every two years at the discretion of the spokesperson.

- The Common Effort: Given the overriding principle of open communication within the collaboration, collaborators should, upon request of a colleague, provide relevant code and input assumptions that would permit results to be checked and confirmed. Computer code will be kept in a common STAR software archive, and code and Data Summary Tapes (DST's) will be accessible to all collaborators.

The specific datasets proposed for this program were collected in 2011 and 2015. The data are stored on the computers of the RHIC and ATLAS Computing Facility (RACF). This facility has over five thousand processing cores and a distributed and centralized disc storage farm, as well as a robotic tape storage silo. The STAR raw data summary tapes (DSTs) are stored on the RACF, and data reconstruction is performed corporately. The production data files, called μDST files, are produced in a "tree" format, compatible for analysis using the C++-based ROOT software package. The μDSTs are available to all STAR Collaborators. The analyses in this proposal will utilize standard STAR C++ software tools for jet analyses. As a part of this, standard STAR "jet trees" will be produced to distill the data files beyond the large μDST files. The jet trees will be stored on dedicated disc space for large file sets with multiple applications. STAR data are archived on the High Performance Storage System (HPSS), which is accessible through the RACF from anywhere with an internet connection. The jet trees produced specifically for this anlaysis will also be backed up on HPSS and accessible from anywhere with an internet connection. In light of this, backup and archive to local discs, e.g. at Lamar University, are unnecessary.

Postdoctoral Researcher Mentoring Plan

The proposal prioritizes presentation and meeting opportunities for the postdoctoral associate (PD). STAR Analysis Meetings devote entire days to introductory instruction of junior members (graduate students and PDs), including the analysis infrastructure and broader opportunities for participation. The meetings will serve as opportunities to meet other collaborators, network, and gain exposure to the national laboratory. The PD will present in weekly local group meetings and teleconferences for the STAR Spin Physics Working Group and Jet-finding Special Topics group. The private nature of local meetings allows the PI to provide advising and counseling. There will be annual performance reviews in addition to the weekly meetings, and the PD will complete a CITI training course on Responsible Conduct of Research. Presenting regularly outside the local group, the PD will gain broad feedback on their work and experience collaborating with a diverse group of scientists.

The PD will attend two major, high-profile conferences to present their work to the broader physics community, raise their career profile, hone communication skills, and keep abreast of the innovations in the field. The targeted conferences cover a broad range of topics, valuable for the PD's continued education. The PI will attend the conference, allowing mentoring and "debriefing" after the presentation. Furthermore, the annual meetings of the APS Division of Nuclear Physics are among the conferences most frequently attended by representatives of funding agencies such as DOE and NSF, giving the PD invaluable opportunities to communicate directly with those entities and emerge ahead of their peers in terms of being prepared to acquire their own funding after the term of their postdoctoral experience.

The PD will have multiple writing opportunities, such as funding documents and journal publications. The PD will assist the preparation of required documentation for on-going funding and subsequent renewal applications. The PI will provide the PD with appropriate and non-confidential materials related to the current source of funding, enabling experience in writing and compiling successful grant applications. The program targets two peer-reviewed publications directly from the PD's analyses. The PD will be the primary author, compiling both the paper draft and the accompanying STAR technical note, under supervision of the PI, providing the opportunity for an excellent postdoctoral research portfolio.

Central to the proposed program is engaging Lamar University undergraduate students in research. Primary responsibility for mentoring undergraduate students will lie with the PI, giving the PD time to focus on analyzing and publishing data. While not a requirement, if the PD does desire a career as a professor, the PD will have the opportunity to gain experience in mentoring students. The PD may begin by mentoring one student during the summer, selecting a summer research project with the PI providing support and advice. The project will be instructive and engaging for the student, as well as useful to the analysis of the PD. The PD will meet regularly with the student to provide instruction, discuss progress, and organize presentations for the weekly group meetings. Finally, the PD will assist the student in preparing a poster presentation for the CEU meeting in the following autumn. In subsequent years, the PD can mentor additional students, as desired. The program lends itself naturally to local and national scholarship opportunities for student research projects, providing opportunities for the PD to advise and mentor students during the academic year. Pending the needs of the Lamar University physics department and the career goals of the PD, opportunities for classroom instruction may also be available.

Rationale for Performance of All or Part of the Project Off-campus or away from Organizational Headquarters

The proposed program intends to perform the vast majority of work on the campus of Lamar University. Among the exceptions are the data-taking shifts for the PI and postdoc at STAR, on-site at BNL. These shifts are required for STAR members to maintain good standing within the collaboration, including access to STAR data, computing resources, and co-authorship of STAR publications. The PI will also travel to the annual STAR Analysis Meeting to discuss and develop the analyses discussed in detail in this proposal, as well as carry out STAR deputy spokesperson duties, as discussed in this proposal.

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PROGRAMS ADMINISTRATION
LAMAR UNIVERSITY™

Certification of RUI/ROA Eligibility

By submission of this proposal, the institution hereby certifies that the originating and managing institution is an accredited college or university that awards Associate's degrees, Bachelor's degrees, and/or Master's degrees in NSF-supported fields, but has awarded 20 or fewer PhD/DSci degrees in all NSF-supported fields during the combined previous two academic years.

Authorized Organizational Representative

Typed Name and Title Dr. Kumer Das, Interim Authorized Organizational Representative

Signature _____ Date: November 1, 2017

P O Box 10119 Beaumont, Texas 77710 Office 409-880-7670 Fax 409-880-7672

RUI Impact Statement

Lamar University is an institution in the Texas State University System, located in the Southeast Texas city of Beaumont, near the Texas-Louisiana border. The primary source of economy for the area is petroleum, and Lamar largely traces its origins to the need for a population well-trained in engineering and science disciplines. Lamar recruits a diverse population from a wide range of backgrounds, including many first-generation college students and many from disadvantaged backgrounds. Lamar has large student populations in fields of engineering and chemistry, and the physics department has experienced growth in recent years. This growth is reflected in the hiring of a new physics department chair, a tenure-track assistant professor (the PI), and a visiting assistant professor, all within the last three years. This influx of new perspectives and expertise positions Lamar's physics department to build and expand upon a solid existing foundation of engaging engineering and physics students in research as a part of their undergraduate educational experience.

Lamar University physics faculty have built an active program to engage undergraduate students in research. The department currently has five tenured faculty and one tenure-track faculty member, all actively engaged in research. Since arriving at Lamar in fall 2015, the PI has mentored one STAR research student, Suzanne Wheeler, through the Ronald E. McNair program and mentored another student, Alek Hutson, to a successful STAR research grant for 2018 through the Lamar Office of Undergraduate Research. Other examples are as follows: Dr. Cristian Bahrim, Professor of Physics, has advised students in research projects in atomic spectroscopy, light-matter interactions, electron diffraction, and quantum optics. His students have been recipients of the Goldwater Scholarship, participants in the Ronald E. McNair program, and recipients of the Sigma Pi Sigma award. Additionally, his students have also been recipients of Lamar University's Beck Fellowship, which funds summer research projects, e.g at the National Institute of Standards and Technology. Dr. George Irwin, Associate Professor of Physics, has engaged students in investigating radioactivity of fossil specimens to determine possible applications of gamma-ray spectroscopy to geochronology. He has also participated successfully with students groups in national competitions to fly experiments on the NASA reduced-gravity aircraft at Ellington Air Field. This past year, three students from the physics department were awarded grants from the Lamar Office of Undergraduate Research through their annual grant proposal competition.

The proposed program would enhance the student research environment of Lamar University in several ways. The PI brings expertise in hadronic structure nuclear physics, a new field for Lamar. Furthermore, most of Lamar's physics faculty were trained as theorists rather than experimentalists. Thus, the proposed program provides an opportunity for Lamar students to learn hands-on about a new field of physics, and gives them exposure both to theoretical and experimental expertise. Current research projects at Lamar do not require the analysis of large samples of data, such as those obtained during collider operation. The current program will provide the opportunity for students to learn a wide swath of statistical methods for data analysis, a profoundly valuable skill for careers in STEM disciplines or graduate school. Currently, the only way for Lamar students to participate in research affiliated with national laboratories is through programs external to the physics department, such as the REU program or Lamar's Beck fellowship. The current program would enable an internal path for students to participate in national laboratory research, while also affording opportunities to travel to the national laboratory site.

The PI is currently the most junior member of the Lamar physics faculty. For purposes of tenure review, the importance of external funding can hardly be understated. An active research program is critical to the career of the PI, and the proposed program will ensure high-impact

productivity by the seminal six-year review during the 2020-2021 academic year. Beyond peer-review journal publications, the Lamar community places high value on visible productivity with students, e.g. students poster presentations of work conducted with faculty mentors. The proposed project ensures a large supply of engaging and finite projects, suitable for student presentations at poster sessions and conferences. The university administration is supportive and enthusiastic about the proposed program and has provided the PI with temporary start-up funds support, in particular for travel expenses in conjunction with the PI's role as deputy spokesperson of the STAR collaboration. This support has proven valuable for building the infrastructure for the proposed research program, including the successful programs with Suzanne Wheeler and Alek Hutson. As is common at predominantly undergraduate institutions, the teaching load is large compared to predominantly research institutions. This underscores the significant benefit of the postdoctoral associate to the proposed program. The PI has developed the analysis infrastructure necessary for a productive program though the Collins asymmetry analysis. The $p + Au$ Collins analysis will build on the existing infrastructure, and the postdoctoral associate will enable completion of the analyses without the restrictions of teaching. This will not only significantly reduce the publication time of these unique data but also aid the efficiency of other analysis, which will utilize many of the same resources, e.g. simulation production.

Lamar University has a successful history of educating physics and engineering students for STEM careers, graduate, and professional schools. Recent graduates of accepted industry jobs such as

- Electrical engineer at INEOS Olefins and Polymers USA
- Engineer at Syracuse Research Corporation
- Engineer at Shell

Other recent graduates have pursued graduate and professional studies at such institutions as

- University of Texas Southwestern Medical School, Dallas, TX
- University of Alaska, Ph.D. in physics and space sciences
- Louisiana State University, Ph.D. in quantum optics
- Purdue University, graduate school in electrical engineering
- University of Nevada at Las Vegas, M.S. in medical physics
- Rice University, Ph.D. in nano-photonics
- Texas A&M University, Ph.D. in physics
- University of Houston, Ph.D. in physics

Recent Lamar University physics graduates also hold teaching positions at high schools in such areas as Dallas, Baytown, and Beaumont, Texas. In the spring of 2016, the PI successfully implemented a course on data reduction and error analysis for STEM majors, a first for Lamar University. The course was successful enough to generate sufficient interest for a second offering in spring 2018. This course borrows heavily from the analysis techniques developed for the research described in this proposal. Thus, the proposal allows the PI to continue to use and develop innovative teaching methods to enhance the educational and career preparation of Lamar University students.

Students who take the course are also well-prepared for participation as summer researchers in the proposed program or in other research opportunities, such as through the Beck and McNair fellowship programs.

Undergraduate research candidates will be evaluated based upon criteria such as the following: GPA, classification, and written statements of interest. Preference will be given toward students having completed the courses in Modern Physics and data reduction and with interests in graduate school. The proposed program will utilize existing resources at Lamar University to attract qualified students from a broad spectrum of backgrounds. The Ronald E. McNair Post-Baccalaureate Achievement Program is an excellent entryway for well-qualified students, specifically from underrepresented populations. McNair students must be first-generation and low-income and/or from underrepresented populations, maintain at least a 3.0 cumulative GPA, have completed 45 undergraduate semester hours, and express a desire to pursue graduate studies. Lamar physics students have a successful history with the McNair program, and the PI has served as a McNair scholar mentor during the summer of 2017. The PI will continue to recruit actively from the McNair physics cohort, which will help the proposed research program stay accessible and open to qualified students from underrepresented populations.

The PI will maintain a database for tracking students who have participated in the proposed research program. This database will collect information on completed courses, conference presentations, graduation dates, and to the extent possible tracking information beyond undergraduate school. The students will complete entrance and exit surveys to gauge their expectations, intents, and experiences. This information will help the PI evaluate the effectiveness of the mentoring and training aspects of the program. A high priority will be placed upon student retention and matriculation through the physics program, and the various elements of the mentoring program will be modified to optimize their effectiveness in achieving these ends.

Since the proposed program focuses on analysis of data, the most likely innovations will be software-related. However, these software-related research tools are already contributing to the educational opportunities of Lamar students. As discussed earlier, the analysis methodologies are being implemented in the development of a new course on data reduction and error analysis. Additionally, the research program will provide opportunities for Lamar physics students to hone skills in computer programming and software development, which are valuable skills for STEM careers and graduate school. It is anticipated that with the implementation of the proposed program, there will be more consistent student demand for courses in nuclear and particle physics. Currently nuclear physics is a special-topics course, and the PI intends to make this a regular staple of the Lamar physics curriculum. This will enhance both the educational experience and graduate school preparation of Lamar physics students. It will also help to reinforce the PI's position as a contributing and valuable member of the physics faculty, which is essential to the long-term career goals of the PI.