COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./DUE DATE
NSF 20-580 **12/01/20**

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NSF PROPOSAL NUMBER

2102879

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PHY - HEP-High Energy Physics

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Syracuse University
Office of Sponsored Programs
Syracuse,NY.132441200

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☐ IF THIS IS A PRELIMINARY PROPOSAL THEN CHECK HERE

TITLE OF PROPOSED PROJECT **New physics with precision measurements of b and c quarks at LHCb**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ **4,078,634**	**36** months	**08/01/21**	

THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW
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PHS Animal Welfare Assurance Number _____
☒ TYPE OF PROPOSAL **Research**

☐ HUMAN SUBJECTS Human Subjects Assurance Number _____
Exemption Subsection _____ or IRB App. Date _____
☐ FUNDING OF INT'L BRANCH CAMPUS OF U.S IHE ☐ FUNDING OF FOREIGN ORG
☒ INTERNATIONAL ACTIVITIES: COUNTRY/COUNTRIES INVOLVED
SZ CH PL FR IT
☒ COLLABORATIVE STATUS
Not a collaborative proposal

PI/PD DEPARTMENT
Physics Department

PI/PD FAX NUMBER
315-443-9103

PI/PD POSTAL ADDRESS
Physics Dept., 201 Physics Building
Syracuse University
Syracuse,NY 132441130
United States

NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Email Address
PI/PD NAME **Sheldon Stone**	**PhD**	**1972**	**315-443-5972**	**slstone@syr.edu**
CO-PI/PD **Marina Artuso**	**PhD**	**1986**	**315-443-2356**	**artuso@physics.syr.edu**
CO-PI/PD **Steven Blusk**	**PhD**	**1995**	**315-443-2807**	**sblusk@phy.syr.edu**
CO-PI/PD **Matthew Rudolph**	**PhD**	**2011**		**msrudolp@syr.edu**
CO-PI/PD **Tomasz Skwarnicki**	**PhD**	**1986**	**315-443-5973**	**tomasz@physics.syr.edu**

CERTIFICATION PAGE

Certification for Authorized Organizational Representative (or Equivalent)

By electronically signing and submitting this proposal, the Authorized Organizational Representative (AOR) 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), flood hazard insurance (when applicable), responsible conduct of research and organizational support 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.

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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:

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(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.

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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 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 **Amy Graves**	**Electronic Signature**	**Oct 19 2020 1:35PM**

TELEPHONE NUMBER	EMAIL ADDRESS	FAX NUMBER
315-443-9360	**ajgraves@syr.edu**	**315-443-9361**

Project Summary

Overview: Our group is part of the LHCb experiment that examines pp collisions at CERN's Large Hadron Collider. We lead the Upstream Tracker (UT) detector group being responsible for its construction installation and software and installation in the Upgrade I experiment. Undergraduates are involved with the UT construction. Our continuing efforts include data analysis where we have made seminal discoveries and are involved with and proposing efforts to find the effects of new paradigm changing phenomena. Our graduate students work on UT hardware and software and are also key in data analyses, where they receive training.

Intellectual Merit: Some decays of hadrons containing b and c quarks are sensitive to physics beyond the Standard Model at energy scales several orders of magnitude higher than can be reached in direct production. LHCb has demonstrated the world's best sensitivities in many areas and these will improve markedly with the advent of the Upgrade I detector. The physics program is wide ranging. LHCb is uniquely suited to study B^-, $\overline{B}^0$, $\overline{B}^0_s$, B^-_c and Λ^0_b decays because of their large production cross-sections, the exquisit lifetime resolution of $\sim$40 fs, and excellent particle identification. Studies have shown hints of difference of in b decays with a hadron and $\mu^+\mu^-$ versus e^+e^-. Discoveries of exotic pentaquark and tetraquark states including c quarks have opened new avenues of strong interaction research. Other studies include mixing and CP violation measurements of c quark decays, searches for dark matter, and electroweak measurements using Z and $W^\pm$ decays, fixed target collisions with various gases, and even heavy ion collisions.

Our main goals over the next three year grant cycle is finishing the construction, of the UT silicon tracker, installing it, all collecting data with the full Upgrade I detector. We have been involved in the planning of the overall Upgrade I. Prof. Stone was the LHCb upgrade coordinator during the critical planning stage 2008-2011. Our group is also involved with the planning of Upgrade II.

We also intend to continue doing physics analysis. Decays of hadrons containing b or c quarks are sensitive to the presence of heavy particles than appear virtually in loop diagrams. Search for differences with Standard Model (SM) predictions of branching fractions, angular distributions or CP asymmetries probe the presence of new particles to very large mass scales, higher than those attainable at the LHC for direct production of such new particles, depending on some assumptions regarding their couplings.

Broader impacts: Our group increases the exposure to science and contributes to the education of high school, undergraduate and graduate students. High school teachers are involved via the Quarknet program, that bringing teachers to Syracuse every non-Covid summer. Part of their time is spent viewing UT, or even participating in construction activities. We also conduct LHCb Masterclasses for high school students. Undergraduates from Syracuse and sometimes other institutions are participating in UT construction including quality control, design and gluing of the internal structures. They also have been given lectures by the faculty on physics issues related to the project. Our graduate student participate in all aspects of the project, and indeed, are providing the main source of labor. Our group answers many questions from the public via our "Ask a Particle Physicist" website, where anyone can ask us questions on physics topics. Besides publications, we disseminate our work by giving talks at conferences, communication with local and scientific news organizations and talks at high schools and other Universities and laboratories.

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*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.

1) Intellectual merit

Introduction: We report on research based on two awards, our base grant Award Number:1803004, "New Interactions and New Particles with LHCb", 08/01/2018-07/31/2021, award amount of $3,974,001.00. A separate award supports the hardware acquisition: Award Number:1433122, "Construction of the Upstream Tracker for the LHCb Upgrade: Collaborative Research", 8/1/2014-7/31/2021 for $4,308,458. (Other contributing US groups are Cincinnati, Maryland, and MIT, that have separate funding.) The work described here was done as part of the LHCb experiment at CERN's Large Hadron Collider. We have been members of LHCb since 2005 and contribute to the experiment by participating in the usual activities of running shifts, reviewing papers, writing infrastructure software, and contributing intellectually to the effective pursuit of our scientific goals, as well as performing specific physics analyses, building a new detector for Upgrade I, and contributing to the next upgrade.

The LHCb collaboration uses a general purpose detector covering the forward region [1] shown in Fig. 1. It is arrayed along the beam line because the main production mechanism for b quarks is gluon-gluon fusion that is usually asymmetric in gluon energies causing both the b and anti-b quarks to have large and associated production preferentially close to the beam. The Upgrade I detector, which is currently being installed, consists of a pixel based vertex detector (VELO) that is used to precisely measure the location of charged tracks to accuracies of the order of $10\,\mu$m, and then reconstruct the decay points of mesons or baryons containing heavy quarks. Following downstream is the RICH 1 detector, used to identify low momentum pions, kaons and protons. Then comes the UT, an "Upstream Tracking" device that is combined with the VELO and the Sci-Fi tracker after the magnet to measure the momenta and positions of charged tracks. Other devices after the magnet are RICH 2, the Electromagnetic Calorimeter (ECAL), the hadron calorimeter (HCAL), and the muon identifications stations (M2-M5). In addition, the "trigger" is defined as the set of algorithms used to select events for further processing. It is accomplished only using software [2]. The acquisition of raw data and its real time processing into analysis quality data is called the RTA project. There is a large online computing farm used in the software part for making these decisions.

The main physics goal of the experiment is to find physics beyond the Standard Model (SM),

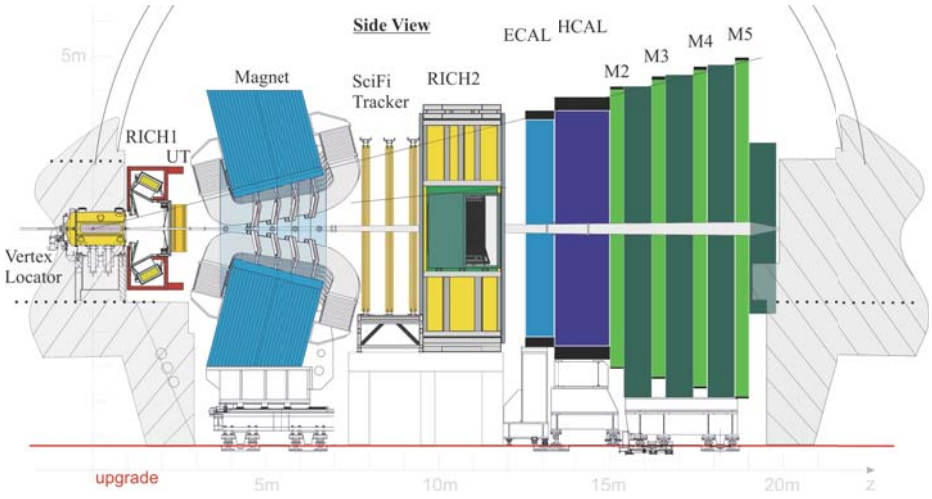

Figure 1: An illustration of the physical components of the Upgrade I LHCb detector.

referred to here as NP, using the quantum interference of as yet unknown new particles with SM particles in b or c quark decay and mixing processes including those that result in *CP* violation. The Lamb shift is a similar effect where known virtual particles caused a small difference in energy between $2S_{1/2}$ and $2P_{1/2}$ energy levels in atomic hydrogen [3]. Pioneering results have already been obtained in the areas of b and c quark decays, and heavy quark spectroscopy; electroweak physics has been explored as well as heavy ion interactions [4].

There have been tantalizing hints that Lepton Flavor Universality (LFU) may be broken from observations by LHCb of the ratios $\mathcal{B}(B \to K^{(*)}\mu^+\mu^-)/\mathcal{B}(B \to K^{(*)}e^+e^-)$ which are $\sim 2.5\ \sigma$ below one for both K [5] and K^* [6] final states. There are also small deviations from the SM seen in the angular distributions of the process $B^0 \to K^{*0}\mu^+\mu^-$ [7], again on the order of 2.5 σ. In addition the combined measurements of $\mathcal{B}(B_s^0 \to \mu^+\mu^-)$ from LHCb, CMS and ATLAS are also 2.1 σ below the SM prediction, as expected in some NP models [8]. Another possible discrepancy is seen in the ratio of $\mathcal{B}(B \to D^{(*)}\tau^+\nu)/\mathcal{B}(B \to D^{(*)}\mu^+\nu)$ when data from several experiments including LHCb are averaged [9].

While these measurements do not yet represent a break down of the SM, they do point out the real possibility of extraordinary discoveries in the flavor sector. This potential was recognized in the P5 report under the main physics driver "Exploring the Unknown" [10]. The presence of new particles can be ascertained by several methods including deviations of branching fractions, angular distributions or *CP* asymmetries, depending on the decay mode under observation. Indeed the European strategy (2013 and 2020 updates) recognizes flavor physics as one of the highest priority paths for the future [11,12]. The mass scales that are probed in this manner are up to 10^4 TeV, depending on the specific model [13], much higher than can be examined directly.

LHCb is well positioned to see the effects of NP, or set limits on its absence, due to the large $b\bar{b}$ cross-section, $\sim$560 μb [14] at 13 TeV, the $4 \times 10^{32}\text{cm}^{-2}\text{s}^{-1}$ instantaneous luminosity in Run II, increased to $2 \times 10^{33}\text{cm}^{-2}\text{s}^{-1}$ for Run III upgrade running, and large trigger efficiencies in Run III approaching 90% in most b-decay modes, reflecting the factor of two increase in purely hadronic decay modes due to the software only trigger. A new high luminosity e^+e^- machine running at or near the $\Upsilon(4S)$ along with a new detector for the Belle II experiment has started running at KEK [15]. Their capabilities are complementary to a large extent with LHCb, with some meaningful overlaps: LHCb has excellent capabilities for detailed studies of B_s^0, B_c^+, Λ_b^0 decays, that Belle II lacks, and LHCb excels at all b decay studies with at most one neutral or missing particle, while Belle II can measure final states with multiple neutral or missing particles and is better at π^0 detection. There is also competition in some selected decay modes involving di-muons from ATLAS and CMS, though being the only dedicated flavor experiment at a hadron collider, LHCb has many distinct advantages including the ability to identify charged hadrons using RICH detectors, and the ability to trigger and reconstruct b-flavored hadrons down to values close to zero transverse momentum ($p_{\rm T}$).

These capabilities have allowed LHCb to make strides in many important measurements of b and c quark decays, including rare decays and *CP* violation that explore high mass scales, and in the discovery and evaluation of states that are candidates for multiquark hadrons, either charmed pentaquarks or tetraquarks. These studies are some of the most interesting in probing our understanding of QCD [16,17]. LHCb also investigates other phenomena where its excellent detection abilities have been shown to be able to produce unique results. These include electroweak measurements [18], searches for dark matter, specifically "dark photons" [19,20], and for hidden-sector bosons, χ, produced in the decay $B^0 \to K^{*0}\chi$, $\chi \to \mu^+\mu^-$ [21], measurement of the $pHe \to \overline{p}X$ cross-section at a center-of-mass energy of 110 GeV [22], useful for interpreting results

from PAMELA and AMS-02, and heavy ion collisions [23].

UT construction: Currently, our primary task in LHCb is to build the upgrade tracker (UT) shown in Fig. 1. This is part of the first LHCb upgrade [24]. We also contribute to the physics analysis, analysis reviewing, data taking, and future planning. (Profs. Artuso, and Stone are involved with the next upgrade's planning group [25], and Stone was the coordinator of the current upgrade for two years, while Skwarnicki coordinated the software.) Details of the UT design are available in the Upgrade Tracking TDR [26]. The sine qua non of the upgrade is to permit data-driven dead-time-less readout at a 40 MHz rate. The Run II hardware trigger that limits the input rate to the online trigger to 1 MHz is eliminated, allowing for a purely software decision that outputs 60 kb events at ≈20 kHz. All sub-detectors have had their electronics modified, and in most cases their hardware modified, making possible a factor of 5 increase in instantaneous luminosity, and a factor of two increase in the efficiency of most triggers on purely hadronic final states. The Covid-19 virus has negatively affected the construction and installation schedules. We believe we are on a path to finish the construction at Syracuse in 2021, but the conditions at CERN remain difficult. For example, the modular clean room needed to safely install the detector was supposed to be set up in April, was moved to August and now is scheduled for Oct. 26. Key personnel have had travel greatly restricted, or even stopped. These delays are making installation in 2021 difficult, but it is still manageable.

The replaced TT silicon strip detector consisted of four stations of planes of silicon planes 500 μm thick, having 183 μm wide strips, one with a stereo angle of 5° in the bend plane. Specifically the sequence is 0° (strips vertical), +5°, −5°, 0°. They covered an area of approximately 1.5×1.3 m^2 divided into top and bottom sections without any other vertical segmentation [1]. The UT will have the same configuration of planes and stereo angles, and be of similar size but uses 320 μm thick silicon sensors, and avoids the vertical gap that the TT had between top and bottom sections. The UT strips are segmented into 10 cm or 5 cm vertical lengths, and special curved sensor segments that fit right around the beam pipe have been added, maximizing the acceptance. All sensors are approximately 10 cm wide. Adjacent staves are staggered along the beam line (z), allowing for a 2 mm overlap in the vertical direction, and the silicon modules are mounted on both sides of the support allowing for a 2 mm overlap in the horizontal direction, both were absent in the TT. A sketch of the geometry is shown in Fig. 2. (The caption describes the different sensor types.) One of the main uses of the UT is to make a quick measurement of the tracks $p_{\rm T}$, possible because of the small magnetic field between the VELO and UT, which allows low $p_{\rm T}$ tracks that are not to be used in the trigger to be rejected, resulting in a speed up of trigger processing by about a factor of three.

The UT detector consists of the several major components. (1) The mechanical design is based loosely on the ATLAS "stave" concept [27]. Each stave runs vertically and supports one of the four layers of 9.75x10.00 cm^2 silicon sensors. The stave is a structure approximately 10 cm wide, 1.4 m long, and 3.9 mm thick that is composed of a carbon fiber sandwich formed from 35 μm thick carbon fiber faces containing a 3.5 mm thick rohacell foam core. It contains a 2.275 mm diameter titanium tube used for the CO_2 cooling fluid, which is embedded in carbon foam for good heat conduction. The cooling tube is bent to go under the SALT ASICs, in order to have the maximum cooling. (2) Kapton flex cables that are glued to both sides of the stave; they provide low voltage and high voltage power to the on detector electronics and data lines for the signals. (3) The front-end electronic chip (SALT). (4) Hybrid flex circuits that house the SALT chips. (5) "Modules" that contain the ∼10 cm wide silicon detectors and the hybrid circuits that hold the

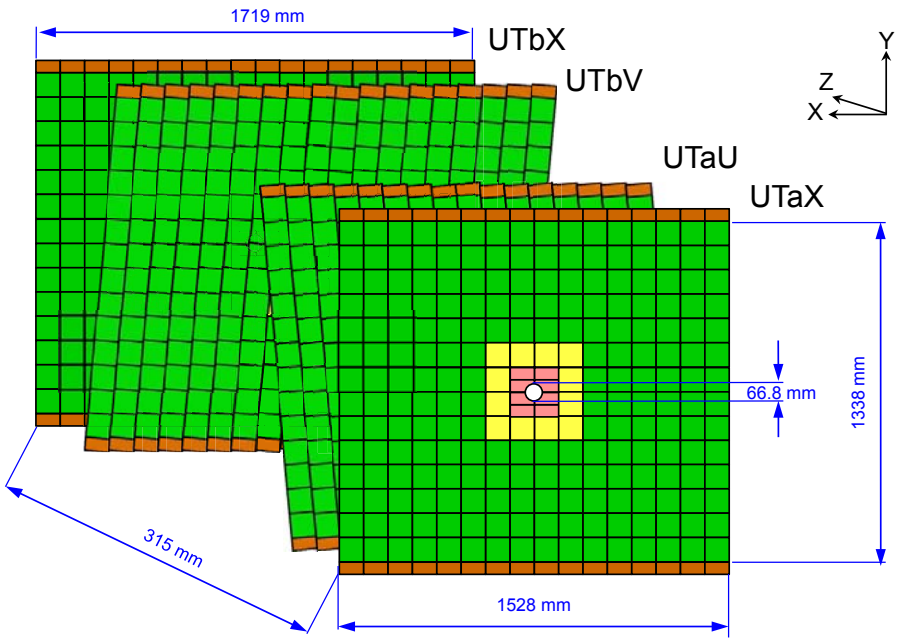

Figure 2: Overview of UT geometry looking downstream. The different sensor geometries are color coded: green for 10 cm length 180 μm wide strips (type A), yellow for 10 cm length 95 μm wide strips (type B), and pink for 5 cm length, 95 μm wide strips (type C) without 1/4 circle cutouts, and with cutouts (type D). The z-coordinate is positive downstream along the beam direction.

SALT chips which are both glued to a thin boron-nitride plate for stiffening; the SALT chip inputs are wire-bonded to the silicon strips, and their power pads and outputs are wire-bonded to the hybrids, which are in turn wire-bonded to the flex cables; the modules are glued to both sides of the staves. (6) An off detector electronics system that converts the signals from the SALT chips into optical signals and drives them along optical cables. (7) A light-tight and air-tight, electrically shielded, detector support box that holds the staves and fits around the beam-pipe. The box is split into two halves horizontally so it can be opened for maintenance or during beam-pipe bakeout. (8) The CO_2 cooling system. (9) The data acquisition system.

The UT project is led by Prof. Artuso and her two deputies: Prof. Stone and Prof. Neri (Universita' degli Studi-Milano). Prof. Rudolph is the project leader for the Silicon sensors and also is involved with the online software. Prof. Blusk led the test beam efforts and is currently supervising the electronics quality assurance of the UT modules. Postdoc Ivan Polyakov is responsible for the data base where all metrology and electrical measurements are recorded, Research Prof. Mountain leads the mechanical effort including construction of the staves that support the modules, and the mounting of the silicon and hybrids on the modules, which are in turn glued on the staves. Postodoc Xuhao Yuan is responsible for the metrology that records the position of the silicon relative to the stave, and postdoc Ivan Polyakov is responsible for the wire bonding of the hybrids to the silicon and also to the flex readout cables. He also performs the silicon detector simulations.

Other institutional involvement is Maryland: design and construction of the off detector electronics. All the boards have been delivered and are being assembled and tested. AGH (Krakow): the front end SALT chip design [28] and software. The chip has been finished. Zürich:

SALT wafer testing, UT specific firmware in the data acquisition boards (TELL40), and high voltage and low voltage distribution systems. Milano: the hybrids that connect the silicon to the front end chips, the flex cables, and the CO_2 cooling distribution system inside the detector volume. The flex cables will be completed in November, and most have been already glued on the bare staves. CERN: detector box and installation. China: installation and testing at CERN. Cincinnati: machining and summer student help. MIT: help manning test beam runs.

Software is a large manpower effort for the UT. It is coordinated by Tomasz Szumlak of AGH and Prof. Skwarnicki. Prof. Skwarnicki has worked with graduate student Andy Beiter to restructure the software used for planning simulations to fit into the Upgrade software scheme, and create a representative distribution of material in the geometry. He worked with postdoc Xuhao Yuan and graduate student Hangyi Wu to define the geometry and transfer it to the new geometry package called DD4HEP. He also worked on the alignment code with Xuhao Yuan. These projects have not finished and will continue in the next grant period. In addition Prof. Rudolph will work with graduate student Joe Shupperd on UT offline monitoring.

Syracuse has designed the silicon sensors with Hamamatsu Co., Japan, based on simulations carried out by postdoc Ivan Polyakov and test beam measurements of prototype detectors. These have all been received and tested. They are then assembled on kapton hybrid circuits containing the SALT chips, and these modules are glued to the the bare staves. At each stage electrical testing is carried out, and any modules with more than 2 dead channels out of a total of 512 are not used on the staves. Most modules have zero bad channels, with a smattering of ones and twos. There are approximately 1000 10x10 cm^2 pieces of silicon that must be glued along with the hybrids to the boron nitride stiffeners, mounted on the staves and wire-bonded. We have as of Oct. 15, 2020 made 45% of the needed modules.

The silicon sensors have two novel features including a "top side biasing" method via a floating cathode to feed the high voltage to the backside of the detector, and an embedded adapter that converts the pitch of the strips to the pitch of the bonding pads on the SALT chips [29]. As far as we are aware, this is the first implementation of both features in actual detectors. In order to ensure that these function properly, we have done nine beam tests of unirradiated and irradiated sensors in a 180 GeV/c proton beam from the SPS at CERN. The UT detector uses mostly n-type substrate, with about 15% of the sensors close to the beam being p-types, since they have better radiation resistance. Most of the sensors are type "A" (see Fig. 2). The maximum radiation level for the A sensors in the detector is 10^{13} 1 MeV neutron equivalent fluence/cm^2, and they were tested at twice this dose. The expected maximum fluence is 20 times higher for the D sensors. Tests on the n-type A sensors showed that they were radiation resistant to needed level. Initial tests are documented in an article written by Prof. Rudolph [30] who organized the software and analyzed the results. The B, C and D sensors must be p-type to withstand the radiation. The p-type D sensors that were tested did not have internal pitch adapters, as they have smaller strip widths that near match the SALT input pads, and showed no efficiency loss. Beam tests of the SALT v3.0 chip with type A and irradiated type B sensors were successful [31]. A more detailed discussion of the design and chip performance is given in Ref. [30].

Test of the silicon detectors and the various iterations of the SALT chip in particle beams have been crucial in having a working system. Prof. Blusk coordinated the LHCb UT testbeam activities. They finished in 2019 with a beam test of unirradiated and irradiated UT sensors using the SALT v3.0 ASIC. Due to the LS2 shutdown at CERN, and the time-critical nature of this work, the beam test was performed at Fermilab (all previous testbeams were conducted at CERN). This was the first beam test of a UT sensor with the 128-channel SALT ASIC. Two sensors were

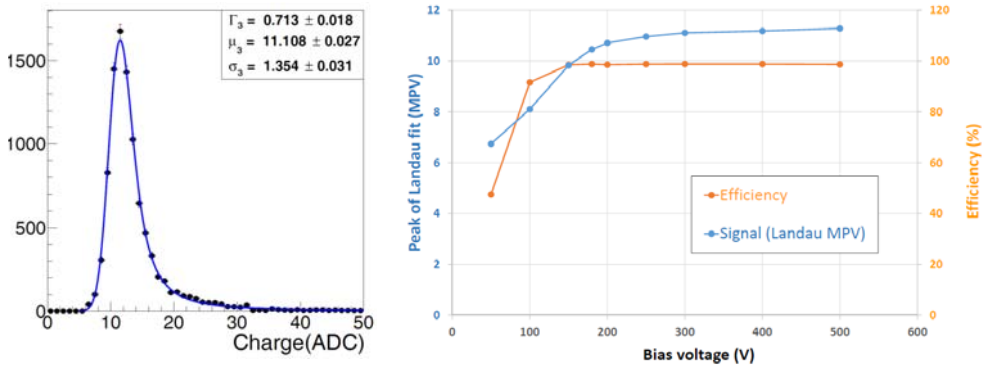

Figure 3: (left) Distributions of collected charge (in ADC counts) for the Type A sensor at 300 V bias fit to a Landau distribution. (right) Most-probable value (MPV) of the Landau fit and efficiency of the Type A unirradiated UT sensor versus the applied bias voltage.

tested, one an unirradiated p-in-n sensor, and the second a n-in-p sensor irradiated to twice the maximum expected fluence. The Fermilab telescope, which tracked the beam particles, and the UT DAQ, which read out the UT sensor, ran asynchronously, and the matching between beam particles in the Fermilab telescope and the associated hits in the UT system was done offline. Fig. 3 shows a typical Landau response for the Type A sensor, The beam test demonstrated that the SALT 3.0 ASIC meets our specifications, and can be used for the production. More details and results are available in Ref. [32].

Transportation boxes have been designed by Prof. Stone, and constructed. They hold five staves each. One instrumented stave has already been shipped to CERN safely, for use in a full "slice" test. The word slice here refers to the fact that the stave was attached to the full electronics readout system appropriate for a single stave. A test CO_2 cooling system was also employed. A photo of the 1.4 m long slice test stave is shown in Fig. 4. In the slice test the individual channels had a noise level of about 2200 electrons, and when coherent noise subtracted reduced to 1000 electrons. This compared with 20,000 produced electrons is great news. Furthermore, the tests have shown that we have a working electronics system.

The staves are first installed into the final holding box at the surface of Point 8. The plan is to

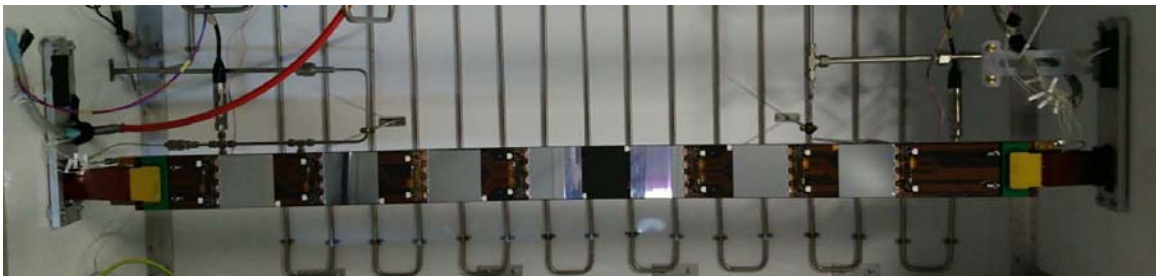

Figure 4: Rotated view of one side of the slice test stave installed in an insulated box with the electronics and cooling connected. The stave is 1.4 m long. The shinny areas are silcon. The brown are the flex cable. Silicon is also placed on the back side to cover the gaps. High voltage is applied via the pins on the top and bottom of the stave.

lower them into the pit using the elevator. Work has already started in installing the cabling and other support structures. Two of our graduate students arrived at CERN in Feb. of 2020 and are helping both on the surface and underground. In particular, senior graduate student Scott Ely is coordinating the assembly work and is expected to lead the detector commissioning effort as a Postodc. Graduate Student Aravindhan Venkateswaran is leading activities related to the UT CO_2 cooling system. In particular, he is engaged in a detailed study of possible contaminants and is now performing important studies to optimize the CO_2 flow rate of the detector.

Future UT activities: At the start of this new grant, summer of 2021, we will still be installing the UT into LHCb due to the delays caused by Covid-19. The most important activity in the next grant period for our faculty is to supervise work on the UT construction, installation, calibration and data quality. During this period the stave production at Syracuse will be slowing down and we plan to move a large fraction $\sim$70% of our postdoc and graduate students to CERN to help with the installation, fully debug the detector, contribute to the software, the calibration, and thoroughly check the initial data. After the beginning phase we will need experienced people to help with data taking and checking. CERN is an excellent environment for young students and postdocs. They learn a lot from being with other physicists and they general take positions of responsibility, which provide them with excellent leadership skills. Hopefully our students will be allowed to travel to CERN at that time even with the burden of a 14 day quarantine period. The software will continue to need work. Prof. Skwarnicki will continue to work with graduate students and postdocs as detailed above.

RD50: Our group is one of the founding members of the RD50 collaboration, whose purpose is to develop silicon sensors for very high-luminosity colliders. Current affiliated members of the group are Artuso, with graduate student Ely. This collaboration has four main lines of investigation: material characterization, detector characterization, new structures, and full detector systems. The work of the Syracuse group spans the detector characterization, and the full detector systems group. In recent years we have focused our attention towards detector systems, with particular emphasis on test beam studies of irradiated sensor-electronics modules. In particular, in 2019 we studied the behavior of sensor-SALT modules, utilizing irradiated sensors, wire-bonded to SALT v3.0 as described above [32]. This collaborative effort gives us access to facilities to test sensors before and after irradiation at CERN, and includes us in a community at the forefront of silicon detector development. In particular, the IRRAD facility at CERN SPS was used to irradiate the sensors used in our test beam program. We are now turning our attention to the sensors, electronics and infrastructure needs for future upgrades. Our work will focus on general R&D on sensors and readout systems needed for a cost-effective optimization of the granularity and timing performance in accordance with the needs of the tracking and calorimeter devices needed for the LHCb II upgrade described below.

R&D towards the LHCb Upgrade II The LHCb collaboration is currently engaged in the preparation of a framework TDR to define the scope of its next upgrade plan. The next major upgrade will happen during the long shut-down 4, and has the ambitious goal of being able to handle a factor of ten higher instantaneous luminosity, in order to achieve a total integrated luminosity of $\sim$300 fb^{-1}. To cope with the increased data rate and being able to preserve the key feature of having a purely software trigger, it is essential to add the fourth dimension of time in most tracking elements, in particular the components employed in the forward tracking

(vertex detector and upstream tracker). In addition, an ambitious goal to add a state of the art electromagnetic calorimeter, featuring the so called 5-dimensional reconstruction, including position, photon energy, and time is being considered. A common requirement to fully exploit the higher luminosity with optimal efficiency is the inclusion of the time information at a hit level in several detector components. The major scope of the proposed R&D is the development of sensors and readout systems that will allow us to achieve this goal in a cost effective manner for several detector components. This research will be implemented in synergy with various detector developers in the US and Europe. The plan is articulated into three years as follows: Year 1: Assembly of the test infrastructure in the laboratory to qualify timing performance of the devices studied and investigation of key technologies. Year 2: Study integration issues in the development of a more realistic module. Year 3: Assembly prototypes and test in particle beam.

The first year is focused on the acquisition of samples of sensors and front-end electronics currently representing the state of the art and the development for the testing infrastructure. The first technology will be investigated are 3D-trench silicon pixel devices [33]. These sensors represent an optimum combination between radiation resilience [34], proven up to $10^{17} n_{eq}/\mathrm{cm}^2$ and time resolution of the order of 20 ps [35]. A concern that has slowed the application of these devices in large scale detectors is the need of 3D MEMS (micro-electro-machining) design, but currently two companies (FBK and SINTEF) are capable of fabricating these devices on 6" wafers with reasonable yields. The second approach considered is based on low-gain avalanche diode (LGAD) detectors, where a large and shallow $n{+}{+}$ layer covers a deep $p+$ layer. Application of a bias across this junction produce a depletion of the $p+$ layer that results in an intense electric field that produces a multiplication in a thin gain layer, which results in large and fast signals. This technology has comparable resolution to the 3D detectors.

Challenges include the radiation tolerance, as their performance is significantly affected at fluences beyond $10^{15} n_{eq}/\mathrm{cm}^2$. In addition, there are some constraints in the cell size posed by the need to have uniform multiplication over the cell [36]. Ideas on how to overcome these limitations are motivated by specifications of the innermost detectors of most tracking devices planned for the future. Our plan is to start with laboratory studies of devices implemented in both technologies, with properties matched to the needs of the intermediate tracking detectors (upgraded UT). In order to assess the timing performance, a first goal is to improve our infrastructure with a digital scope suitable for our needs. We are settling on a a mixed signal oscilloscope from Tektronics, with a bandwidth of 10 GHz, and a sampling rate capability up to 50 GS/s. This instrument can be used in bench test characterizations and future test beam runs [35]. In order to acquire devices to test we are pursuing several avenues. We are in contact with LHCb colleagues who have performed the measurements in Ref. [35]. We are also planning to collaborate with US institutions interested in the development of the next generation of AC-LGAD devices. In particular, we are discussing the terms of a collaborative agreement with A. Tricoli and his team at Brookhaven National Laboratory. This collaborative effort should develop into synergistic submissions of detector designs and novel VLSI electronics through multi-project wafer submissions. In the initial plans of this collaborative effort we are considering also detector elements suitable for 5D calorimetry. We will include these devices in our timing studies as well.

In the second year we will build on the experience developed during these exploratory studies. In particular, we will identify achievable modifications to sensor parameters and front-end electronics specifications that would meet the needs of our planned application in LHCb. A first component of this work is the study of the relationship between different aspects of the sensor design (technology, geometrical and process parameters) and the specifications derived from the LHCb Upgrade II

detector simulation. We will use TCAD, as we have done in the case of the upstream tracker to find an optimal configuration of the embedded pitch adapters [29]. In addition we will study options available for front end building blocks and data flow architecture between front-end electronics and remote data aggregation and processing circuits. We are establishing collaborative efforts with possible synergies with industry in the course of the Snowmass instrumentation frontier work (Artuso is the liaison from the Rare Processes and Precision Measurements frontier). General R&D studies inspired by the grand challenges planned in the BRN report [37] will support this effort. We hope to identify VLSI design partners to develop readout devices adapted to our needs. Currently we are investigating synergies with the AC-LGAD group mentioned above, collaborators for the TIMESPOT group [35] or CERN electronics teams. The support requested this year covers a sensor prototype run and a portion of a joint MPW VLSI submission.

In year three we are planning to assemble a demonstrator module and study its timing properties with a test beam. A preliminary concept of the test beam set-up comprises our module, and at least two timing elements. The reference measurement of the charged hadron arrival time will be provided by two Cherenkov detectors constructed from two quartz radiators attached by means of an optical silicon to micro-channel plate photomultiplier tubes, similar to the test stand use in [35]. The support request for this year is for test beam infrastructure, plus additional electronics needed for the test beam run.

Real Time Analysis: The RTA project serves to coordinate the software trigger with the calibration in order to generate physics quality output containing track parameters, particle identification, and electromagnetic calorimeter information. Thus, raw detector hits are not saved for majority of data. The data will be packaged according to pre-selections geared towards specific physics analyses. The software trigger is somewhat artificially divided into two levels: HLT1 and HLT2. The project is described in Ref. [2] and detailed in Fig. 5(left). A further improvement has been incorporated which uses GPU processors in HLT1. See Fig. 5(right) and Ref. [38] for more details. Our group has joined the RTA project. Prof. Stone is on the organizing board. Prof. Skwarnicki, postdoc Yuan, and graduate students Wu and Beiter are active participants.

Physics analysis: As of this writing there are 530 LHCb physics papers either published or submitted for publication, of these 71 have the primary author from Syracuse. This fraction is lower than in the past, because graduate students, postdocs, and faculty are spending much of their research time on the UT project; in any case, we are 1.5% of the collaboration, but have written 13% of the papers, and we do have significant contributions over the last several years. Our interests vary among group members and with time. All analysis are discussed at weekly group meetings so we learn what each other are doing and everyone in the group asks questions. This is a particularly good educational tool for graduate students and postdocs. We discuss here only papers from the last three years, the period of the current grant, where we were directly involved in performing the analysis, although there are many other LHCb papers worthy of note where we have made contributions by participating in the analysis reviews and the editorial process.

Analyses led by Prof. Artuso: Prof. Artuso was responsible for two major analyses in the past three years. She led the team that measured the ratios of B_s^0 and Λ_b^0 production with respect to the sum of B^0 and B^+ production in the 13 TeV data, called "b-fractions". The team consisted of Prof. Artuso, her graduate students Kelsey and Ely, Prof. Stone, and some help from our former postdoc Liming Zhang who is now a professor at Tsinghua in Beijing. These measurements

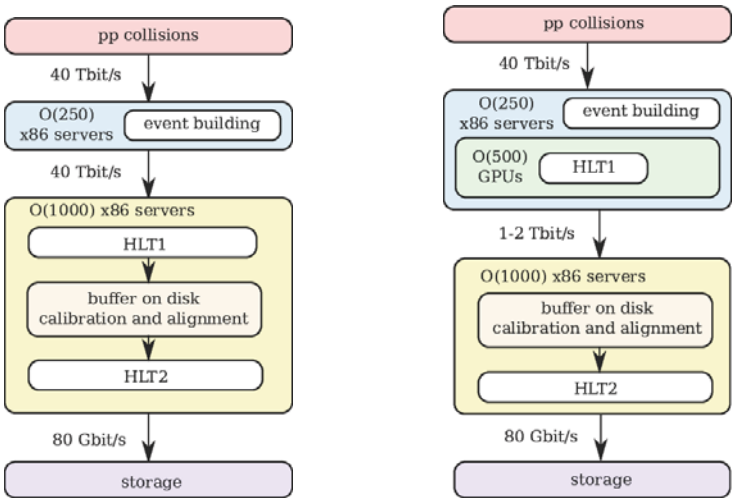

Figure 5: (left) In the baseline proposal for the upgraded LHCb data acquisition system, x86 event building units receive data from the subdetectors and build events by sending and receiving event fragments over a 100G Infiniband (IB) network. The full data stream of built events is sent to x86 event filter servers to process both stages of the high level trigger. (right) In the GPU-enhanced proposal for the upgraded LHCb data acquisition system x86 event building units receive data from the subdetectors and build events by sending and receiving event fragments over a 100G Infiniband (IB) network. The same x86 servers also host GPUs which process HLT1. Built events are sent to x86 event filter servers at a rate reduced by a factor 30 - 60 to process HLT2.

are needed at the LHC in order to be able to measure B_s^0 and Λ_b^0 branching fractions. Inclusive semileptonic decays are used, with the charm hadron tagging the type of b-hadron, H_b, and corrections made for cross-feeds. The results are measured as functions of $p_{\rm T}(H_b)$ and η. In both cases a significant $p_{\rm T}$ dependence is observed as shown in Fig. 6. The results are 0.122 ± 0.006, and 0.259 ± 0.0018, for the B_s^0 and Λ_b^0 fractions, respectively, where the largest uncertainties are due to errors on the charm hadron branching fractions [39]. This result is used to calculate all the B_s^0 and Λ_b^0 branching fractions, in particular $\mathcal{B}(B_s^0 \to \mu^+\mu^-)$ is quite important.

In the b-fractions paper $f_{\Lambda_b^0}$ is determined in large part using $\Lambda_b^0 \to (\Lambda_c^+,$ or $D)X\mu^-\overline{\nu}$ decays. These decays include contributions from excited Λ_c^{+*} decays that decay via dipion emission into the Λ_c^+, and other possible states. The exclusive semileptonic decays $\Lambda_b^0 \to \Lambda_c^+\mu^-\overline{\nu}$ can be used to measure the fundamental parameter $|V_{cb}|$ where there are some advantages over measurements in B meson decays. The decay is described by six form factors corresponding to the vector and axial-vector components of the flavor-changing charged current [40]. In Heavy Quark Effective Theory these decays are particularly simple, as the light ud quark pair has total spin zero, and thus the chromomagnetic corrections, which are of the order of a few percent for B mesons, are not present [41]. Note that the diquark assumption has recently been experimentally verified (see Section "Analyses led by Prof. Stone") [42]. As a first step in making a $|V_{cb}|$ measurement Prof. Artuso working with her students Christos Hadjivasiliou and Scott Ely measured the shape of the four-momentum transfer squared (q^2) distribution between the Λ_b^0 and Λ_c^+ baryons [43] and showed that it is consistent with the Lattice QCD predictions of [44], and the Heavy Quark Effective Theory (HQET). The results were used in Ref. [45] to determine the coefficients of the sub-leading terms at order $\mathcal{O}(\Lambda_{\rm QCD}^2/m_c^2)$ precisely.

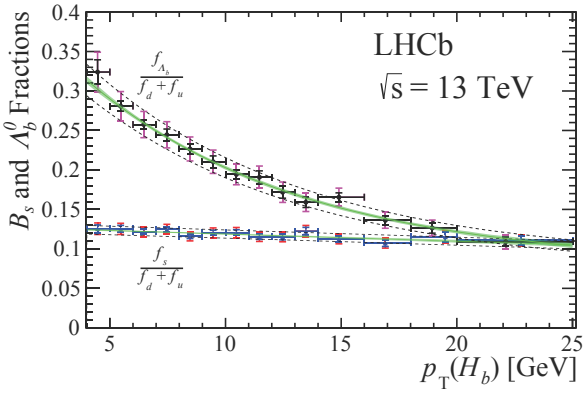

Figure 6: The B_s^0 fraction given by $f_s/(f_u + f_d)$ and the Λ_b^0 fraction given by $f_{\Lambda_b^0}/(f_u + f_d)$ in bins of $p_{\rm T}(H_b)$. The B_s^0 data are indicated by solid circles, while the Λ_b^0 by triangles. The smaller (black) error bars show the combined bin-by-bin statistical and systematic uncertainties, and the larger (purple) ones show the global systematics added in quadrature. The fits to the data are shown as the solid (green) bands, whose widths represents the $\pm 1\sigma$ uncertainty limits on the fit shapes, and the dashed (black) lines give the total uncertainty on the fit results including the global scale uncertainty. In the highest two $p_{\rm T}(H_b)$ bins the points have been displaced from the center of the bin.

Prof. Artuso's future analysis plans: Having checked the measured form-factor shape and showed that it agrees with Lattice QCD, she first plans to measure $|V_{cb}|$ using the differential distribution $\frac{d\Gamma}{dq^2 d\cos\theta_\mu}(\Lambda_b^0 \to \Lambda_c^+ \mu^- \bar{\nu})$. The method follows a procedure similar to the one used in Ref. [43]. What is required in addition is a normalization to the total number of Λ_b^0's produced. A method has been developed and relies on the fact that the inclusive $\Lambda_b^0 \to$ charm hadron $X\mu^-\overline{\nu}$ branching fraction is known from the precise measurement of its lifetime and the near equality of the semileptonic width of all b-flavored hadrons [41]. Thus all the final states in Λ_b^0 semileptonic decay need to be included as was done in Ref. [39]. Use of this method reduces the uncertainty due to the measured value of $\mathcal{B}(\Lambda_b^0 \to pK^-\pi^+)$ because of a partial cancellation in the ratio of exclusive to inclusive decays. Furthermore, the decay angular distribution of the muon can be determined. Thus the analysis can be compared to theory in the two dimensional $q^2 - \cos(\theta)$ plane as suggested in Ref. [46]. Sensitivity comparable to that obtained in B meson decay is foreseen with different theoretical and experimental systematic uncertainties. This is planned to be the Ph.D thesis of Scott Ely. In addition the $\Lambda_c^{+*}(2775)$ state, which was seen previously only by CLEO [47] was also seen in Ref [43]. A future paper will give the first measurement of its width and a better measurement of its mass as well restricting or determining its J^P.

Another $|V_{cb}|$ based planned analysis is $\Lambda_b^0 \to \Lambda_c^+ \mu^- \overline{\nu}$, with $\Lambda_c^+ \to \Lambda\pi^+$. This decay of the Λ adds two additional measurable angular variables. Thus the analysis becomes more sensitive and can be used to search for NP [48]. This is intended to be the Ph.D thesis of Xixin Lang.

Analyses led by Prof. Blusk: Over the last three years, Prof. Blusk's data analysis activities have centered on experimental probes of the strong force, using precision measurements of lifetimes and searches for new baryonic states containing beauty quarks resulting in six publications.

Charmed baryon lifetimes are important to understand the underlying weak decay diagrams and for use in investigating b-baryons that decay into them. Prof. Blusk used the semileptonic

decays of b-baryons into charm baryons because the b-decay lifetimes, all around 1.5 ps, gave clean detached vertices of the charmed hadrons which made the efficiencies of the their detection much more uniform in charm hadron lifetime. The Ω_c^0 baryon lifetime measurement in the PDG was based only on 20-year old fixed target data with just a few dozen events, and yielded a value of 69 ± 12 fs. From a sample of about 1000 semileptonic $\Omega_b^- \to \Omega_c^0(\to pK^-K^-\pi^+)\mu^- X$ decays, the Ω_c^0 lifetime was measured to be 268 ± 25 fs (see Fig. 7), nearly four times larger than the world average [49]. This new value has upended the charm baryonic lifetime hierarchy, and provides information on the higher order corrections in the HQET expansion.

In another paper, precision measurements of the Λ_c^+, Ξ_c^+ and Ξ_c^0 baryon lifetimes [50] was published as a PRD editors suggestion. The measurements led to significantly improved central values and precision on the lifetimes whose values were also based primarily on older fixed target experiments. For example, the existing Ξ_c^0 world-average lifetime was found to be about 3σ below the precise LHCb measurement, and the world average has increased significantly from about 112 fs to 153 fs [51].

Motivated by LHCb's earlier discovery of 5 narrow narrow peaks in the $\Xi_c^+ K^-$ invariant mass spectrum [52], whose structure had some exotic interpretations, Prof. Blusk and his student Kyung Eun Kim carried out a search for similar states in the $\Xi_b^0 K^-$ mass spectrum. Four narrow peaks close to threshold were found, which are consistent with the few theoretical quark-model predictions available for $L = 1$ excited states of the Ω_b^- (see Fig. 8) [53]. This also was a PRL Editor's suggestion.

Prompted by an earlier measurement of evidence of the strangeness-changing weak decay $\Xi_b^- \to \Lambda_b^0 \pi^-$ [54] by Prof. Blusk which yielded the product $(f_{\Xi_b^-}/f_{\Lambda_b^0})\mathcal{B}(\Xi_b^- \to \Lambda_b^0 \pi^-)$, he sought to measure $\mathcal{B}(\Xi_b^- \to \Lambda_b^0 \pi^-)$. This was determined by measurement of the relative decay rates of $\Xi_b^- \to J/\psi \Xi^-$ and $\Lambda_b^0 \to J/\psi \Lambda$ decays, coupled by theory that relates their production ratio to $f_{\Xi_b^-}/f_{\Lambda_b^0}$ at 7, 8 and 13 TeV [55].

A new beauty baryon called the $\Xi_b(6227)^-$ was found by Prof. Blusk, consistent with being an

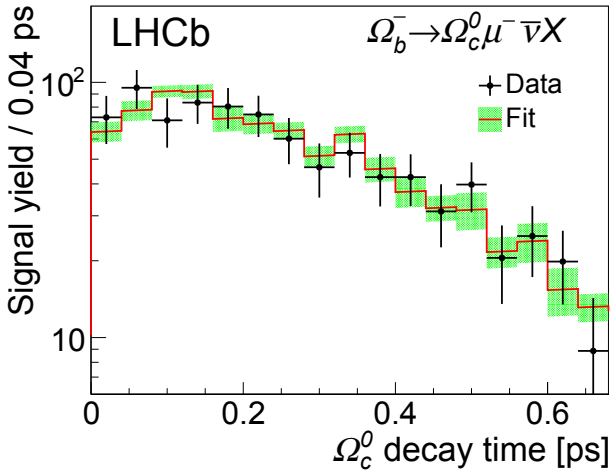

Figure 7: Decay time distribution of Ω_c^0 signal in semileptonic $\Omega_b^- \to \Omega_c^0 \mu^- X$ decays, along with the spectrum obtained using the fitted lifetime of 268 ps.

$L = 1$ orbital excitation of the Ξ_b^- baryon [56]. The aim of a subsequent analysis was to search for the isospin partner of this charged state. It used the full Run I and Run II data sets. A search using the fully hadronic decay $\Xi_b(6227)^- \to \Xi_b^-\pi^+$ was performed, where the Ξ_b^- was reconstructed in both the $\Xi_c^0\pi^-$ and $\Xi_c^0\pi^-\pi^+\pi^-$ final states, with $\Xi_c^0 \to pK^-K^-\pi^+$. The observation and usage of the $\Xi_b^- \to \Xi_c^0\pi^-\pi^+\pi^-$ decay is a first. A $\Xi_b(6227)^0$ signal with about 10σ significance is observed, and its mass and width are consistent with that of the $\Xi_b(6227)^-$. More precise measurements of the $\Xi_b(6227)^-$ mass and width, and the Ξ_b^- mass will also be published in this paper. This paper was submitted to PRD in Oct., 2020.

Prof. Blusk's future analysis plans: There are additional measurements in conventional excited baryon spectroscopy to be pursued. Graduate student theses are planned for these analyses. Some of them will use the existing Run I and II data sets; others would benefit greatly from the much larger samples expected in Run II. These studies are naturally extendable into searches for tetraquarks or pentaquarks produced directly in pp collisions.

Prof. Blusk proposes to look for baryons containing both a beauty and charm quark, such as Ξ_{bc}^+, Ξ_{bc}^0 and Ω_{bc}^0. A golden channel for the discovery of the Ξ_{bc}^+ is $\Xi_{bc}^+ \to J/\psi\Xi_c^+$, with $\Xi_c^+ \to pK^-\pi^+$, and graduate student Zhuoming Li is working on this channel and the topologically similar $\Xi_{bc}^+ \to J/\psi\Lambda_c^+$ and $\Xi_{bc}^0 \to J/\psi\Xi_c^0$ decays using all the current data. This is a whole new sector that is experimentally unexplored, and Prof. Blusk has implemented code into the Run III high level trigger (HLT) that will select a wide range of hadronic decay channels of these bc baryons, in addition to decays selected by the J/ψ triggers.

Prof. Blusk is also interested in pursuing measurements of the CKM phase γ using $B^- \to D^0K^-\pi^+\pi^-$ decays. He and a student performed the analysis using Run I data [57], and he has implemented the code in the Run III HLT to select such decays, along with control modes to enable this future measurement. In the B_s^0 sector, Prof. Blusk was a co-author on the measurement of the CP-violating phase ϕ_s using $B_s^0 \to D_s^+D_s^-$ decays [58], and that would be a measurement that would benefit beyond just luminosity scaling, as the L0 hadron trigger efficiency in Run I and II was less efficient for high multiplicity b-hadron decays (due to the final state particles having, on average, lower $p_{\rm T}$). Finally, his measurement of the $\overline{B}_s^0 \to D_s^+D_s^-$ effective lifetime using Run I

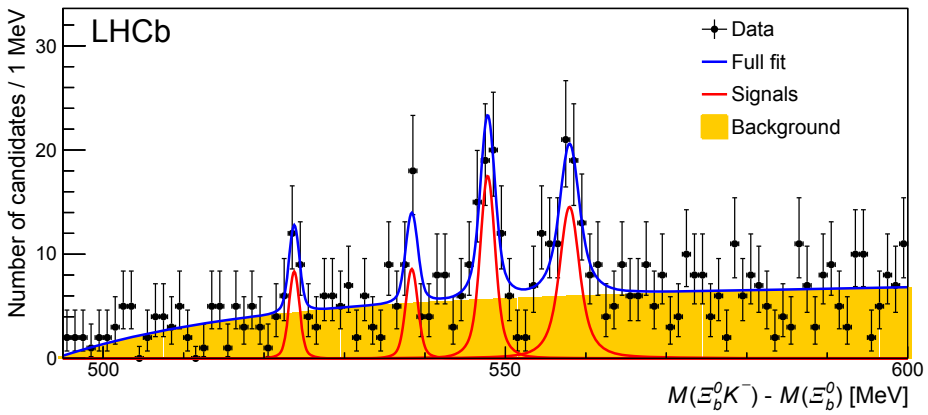

Figure 8: Distribution of the difference in invariant mass, $M(\Xi_b^0K^-) - M(\Xi_b^0)$, between that of the $\Xi_b^0K^-$ combination and the Ξ_b^0 candidate.

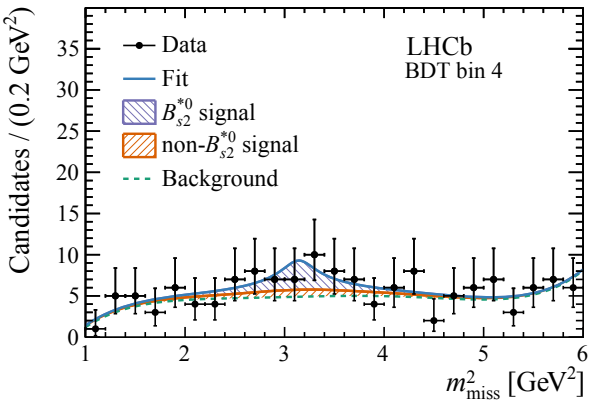

Figure 9: Fit from the search for the lepton flavor violating decay $B^+ \to K^+\mu^-\tau^+$ in the most sensitive BDT bin, using the LHCb Run 1 and Run 2 data. From [64].

data [59] could reach a precision of order 1% in Run III. When combined with the corresponding measurement of the effective lifetime in $\overline{B}{}^0_s \to J/\psi f_0$ [60], a measurement of $\Delta\Gamma_s$ is obtained, which is complementary to that measured in $B^0_s \to J/\psi\phi$ decays [61].

Analyses led by Prof. Rudolph: He has fully developed the analysis technique to study B^+ decays with missing particles by selecting $B^{*0}_{s2} \to B^+K^-$ decays, first suggested by Prof. Stone and Liming Zhang [62]. The additional constraint provided by the B^{*0}_{s2} decay allows the reconstruction of the mass of missing particles in the B^+ decay without further assumptions. B^+ mesons produced in this way total about 1% of all B^+ produced in LHCb. He first used this to study the make-up of semileptonic B^+ decays to D^0 mesons with Run 1 data [63]. Recently, the technique was used to search for the lepton flavor violating decay $B^+ \to K^+\mu^-\tau^+$ [64], which is predicted by many theories seeking to explain anomalies observed in charged and neutral current semileptonic B decays. Because of the extra constraint provided by the B^{*0}_{s2} decay, it is possible to treat the τ lepton as a missing particle, thereby using all of the τ decays, although one charged decay product of the τ is required to reduce backgrounds. The search used the full Run I and Run II data. A fit to the missing mass in the most sensitive signal region is shown in Fig. 9. The resulting limit $\mathcal{B}(B^+ \to K^+\mu^-\tau^+) < 10^{-5}$ at 90% c.l. is comparable, but slightly above the previous BaBar limit [65] which used their fully tagged dataset. This shows that the technique is competitive with existing B-factory datasets, and is promising for the large future data samples that will be available in the LHCb upgrades. It is also complementary with future LHCb measurements exploiting the τ decay to three charged pions.

Prof. Rudolph has also further analyzed the B^+K^- spectrum, leading to the observation of new excited B^0_s states [66], see Fig. 10. These states are likely to belong to mesons with orbital angular momentum $L = 2$.

Prof. Rudolph's future analysis plans: Prof. Rudolph plans to develop further techniques to study partially reconstructed decays in LHCb, and to apply these in searches for new physics and measurements of Standard Model processes. Working with graduate student Maria Polyakova, he will employ the method using B^{*0}_{s2} decays to study the semileptonic decay $B^+ \to \rho\mu^+\nu_\mu$, better knowledge of which is essential to understanding the discrepancy between inclusive and exclusive

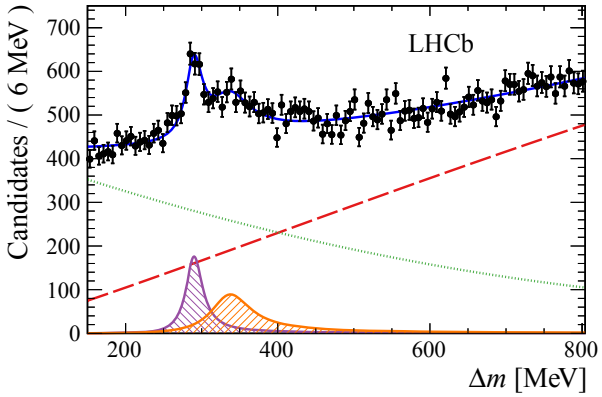

Figure 10: Mass difference spectrum for B^+K^- candidates, where $\Delta m = m(B^+K^-) - m(B_s^0)$, showing the newly observed excited B_s^0 states. [66].

determinations of the CKM matrix element $|V_{ub}|$. The branching fraction of this decay should be measurable with LHCb Run 1 and Run 2 data with an uncertainty similar to that obtained at the b-factories. He plans to continue to apply this technique to charged current semileptonic decays, revisiting the charm sector to investigate the possibility to use it for tauonic decays. The data sample usable for such measurements in Run 3 will be substantial.

He will also develop kinematic fitting techniques for other decay topologies, particularly ones with τ leptons. He plans to work with graduate student Harris Bernstein on $B \to K^{(*)}\tau^+\tau^-$ decays as well as lepton flavor violating decays with hadron $\mu^\pm\tau^\mp$, since these are particularly well motivated by hints of lepton flavor non-universality. Different decay channels using different initial b-hadrons at LHCb expand the effective dataset, and can probe different new physics couplings. Similar fitting techniques will also be used to search for hadron decays with unmeasured axions, as a number of potential axion couplings may be constrained most sensitively in this way [67].

Analyses led by Prof. Skwarnicki: LHCb discovered states consistent with Pentaquarks using $\Lambda_b^0 \to J/\psi K^- p$ decays in 2015 [68]. By adding the data from 13 TeV pp collisions and retuning the analysis, the signal sample grew by a factor of nine. The main results of these improvements was to find a new narrow $P_c(4312)^+$ state just below $\Sigma_c^+\overline{D}^0$ threshold. The previously discovered $P_c(4450)^+$ peak below $\Sigma_c^+\overline{D}^{0*}$ threshold is resolved into two narrower states, called the $P_c(4440)^+$ and $P_c(4457)^+$ baryons [69]. The new $m(J/\psi p)$ mass spectrum is shown in Fig. 11. This is the prelude to a full amplitude analysis.

For help with interpretations and analysis of LHCb and other data three theorists affiliated with the Syracuse group have been admitted to LHCb, in order help with theoretical question involving studies of exotic states. They are Adam Szczepaniak from Indiana University, Alessandro Pilloni from ECT*, Trento, Italy and Cesar Fernandez-Ramirez from UNAM, Mexico City. They helped with analytical parametrization of triangle-diagram peaks, which were ruled out from the fits to the data. This implies that the seen pentaquark states are either molecular in nature or tightly bound. Interestingly, two of them are close to baryon-meson thresholds.

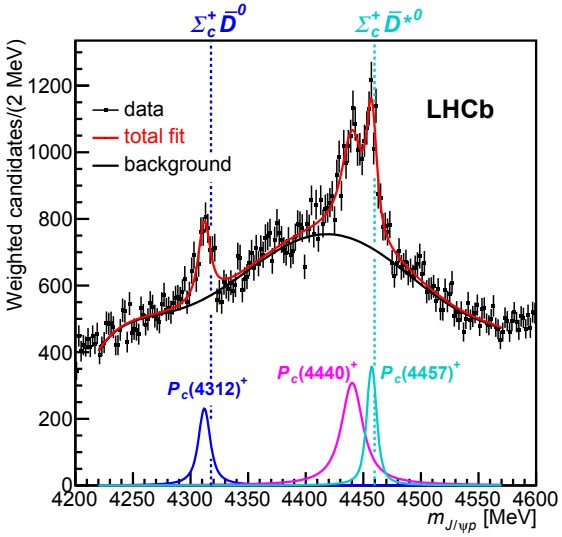

Figure 11: Fit to the $J/\psi p$ decay-angle-weighted m(J/ψ p) distribution with three Breit-Wigner amplitudes and a sixth-order polynomial background. The mass thresholds for the $\Sigma_c\overline{D}^0$ and $\Sigma_c\overline{D}^{0*}$ final states are superimposed.

Prof. Skwarnicki's future analysis plans: He plans to continue on the general topic of exotic hadrons. In the near term future he plans an updated amplitude analysis of $B^+ \to J/\psi\phi K^+$ following on his previous work that showed unexpected structures in the $J/\psi\phi$ mass distribution which are likely compact tetraquarks [70]. Another near term plan is to analyze the $\pi^+\pi^-$ mass spectrum in $B^+ \to X(3872)K^+$, $X(3872) \to \pi^+\pi^- J/\psi$ in order to determine how much of the $\pi^+\pi^-$ is ρ^0 and how much is ω. This is important information useful in determining the internal structure of the $X(3872)$, and is intended to be the Ph.D thesis of B. Baasansuren.

In the longer term Prof. Skwarnicki proposes to update his amplitude analysis of $B^0 \to J/\psi(2S)K^-\pi^+$ that confirmed Belle's observation of the exotic $Z_c(4430)$ state decaying into $J/\psi(2S)K^-$ [71]. With graduate student A. Beiter, he also intends to look at the $B^0 \to J/\psi K^-\pi^+$ decay which has never had an amplitude analysis by LHCb but where resonant structures in $J/\psi\pi^+$ have been report by Belle [72].

In another effort he proposes to do a full amplitude analysis of $\Lambda_b^0 \to J/\psi K^- p$ with combined Run I + II data and and a new formalism which will enable determination of the quantum numbers of the narrow P_c^+ states, and to verify if the wide $P_c(4380)^+$ is needed. Furthermore data from the upgraded detector in Run 3 will allow meaningful studies of suppressed final states, where many opportunities exist.

Analyses led by Prof. Stone: His analysis covered a wide range of physics topics. With graduate student A. Venkateswaran he investigated of the existence of pentaquark states containing a single b quark decaying weakly into four specific final states: $J/\psi K^+\pi^- p$, $J/\psi K^-\pi^- p$, $J/\psi K^-\pi^+ p$, and $J/\psi\phi p$. This search was motivated by discussions with Prof. Igor Klebanov. The data sample came from an integrated luminosity of 3.0 fb^{-1} in 7 and 8 TeV pp collisions. Signals were not observed and upper limits are set on the product of the production cross section times branching fraction with respect to that of the Λ_b^0 [73].

Prof. Stone helped Prof. Artuso with the b-fractions paper [39]. This led to the idea of measuring

the B_c^- fraction. This work was done with postdoc Xuhao Yuan. The decay $B_c^- \to J/\psi\mu^-\overline{\nu}$ was compared with the sum of inclusive semileptonic $\overline{B}^0$ and B^- decays. Theoretical predictions were used for the $B_c^- \to J/\psi\mu^-\overline{\nu}$ branching fraction and dominate the systematic uncertainty. We found that the B_c^- fraction is $\sim$3.7 per mille, with a mild transverse momentum dependence, and no pp energy dependence between 7 and 13 TeV [74]. The fraction is useful to estimate branching ratios and observable yields of other B_c^- decays. The production asymmetry was also determined as being consistent with zero.

After we accumulated 1.9 fb^{-1} of 13 TeV data in Run II, we realized that we had a bit more statistical power than the measurements that were made in Run I. Also, confirming the data quality in Run II was one of our goals. Measurement of the CP violating phase ϕ_s is a corner stone measurement. Prof. Stone and Syracuse postdoc at that time, Liming Zhang, had suggested that $B_s^0 \to J/\psi\pi^+\pi^-$ could be used for this measurement [75], predicted the branching fraction for $B_s^0 \to J/\psi f(980),\ f(980) \to \pi^+\pi^-$ and had shown in a previous LHCb paper that the $J/\psi\pi^+\pi^-$ system is almost purely CP odd [76], obviating the need for an amplitude analysis. While this measurement proved to have a $\sim$35% higher uncertainty than using the $J/\psi\phi$ final state, it is still quite useful in reducing the overall error, provides an important cross-check, and proves a direct measurement of the width difference between the CP odd B_s^0 eigenstate and the B^0 meson. The updated ϕ_s measurement is consistent with the SM prediction [77].

The PDG reports that the isospin of the Λ_b^0 is not measured [51], although a definitive prediction of the quark model is that it is I=0. Besides experimentally determining the isospin there are several other reasons to investigate Λ_b^0 decays into $J/\psi\Lambda$ and $J/\psi\Sigma$. The former is an I=0 final state, while the latter is I=1. Since the Σ decays into a low momentum γ whose detection efficiency in LHCb is low, Prof. Stone and graduate student Aravindhan Venkateswaran decided to eschew its detection and just construct the $J/\psi\Lambda$ mass, where the $J/\psi\Sigma$ would appear as an almost rectangular distribution just below the $J/\psi\Lambda$ mass peak. Complications arise from backgrounds. These include $\Lambda_b^0 \to J/\psi\Sigma^*,\ \Sigma^* \to \pi^0\Lambda$ whose shapes are included in the fit, and $\Xi_b \to J/\psi\Xi,\ \Xi \to \pi\Lambda$ decays. We measure the rate of the latter contribution and simulate its shape in $J/\psi\Lambda$ mass so we can constrain its contribution to the overall fit to the data, which is shown in Fig. 12 [78]. We measure the upper limit on $|A_{I=1}/A_{I=0}| < 0.046\%$ at 95% c.l. This very strong suppression leads to several conclusions. First of all the Λ_b^0 is no doubt an isospin singlet. Secondly, we expect isospin violation of $\sim$10% in amplitude from observations in other decays. Our measurement is considerably smaller and points to the u and d quarks in the Λ_b^0 forming a tightly bound isospin-0 di-quark. This is important knowledge for understanding the charmed-pentaquarks produced in Λ_b^0 decay. Furthermore, some physics analyses in LHCb have assumed dominance of lower isospin changing amplitudes in Λ_b^0 decay. One was the study of $\Lambda_b^0 \to p\mu^-\overline{\nu}$ decays [79] and the other the pentaquark discovery paper [68]. These ideas were based on the $\Delta I = 1/2$ rule in K^0 decays [80]. These are now justified.

In addition, we discovered the $\Xi_b^0 \to J/\psi\Lambda$ decay, which allows us to measure the ratio of the $|A_{I=0}|/A_{I=1/2}|$ amplitudes. We find that they are consistent with the predictions of Dery et. al using SU(3)$_F$ symmetry, and do not favor either amplitude, after the Cabibbo suppression is accounted for [81].

While pursuing studies of double-charmed hadron states with graduate student Michael Wilkinson, we observed an unusual decay of the $\Xi_c^0 \to \pi^-\Lambda_c^+$, where the strange quark in the Ξ_c^0 decay before the charmed quark [82]. This has previously been observed in the $\Xi_b^0 \to \pi^-\Lambda_b^0$ decay and its branching fraction measured in an analysis carried out by Prof. Blusk [54]. Studies of these $\Xi_{b,c}$ baryon decays provide a connection to theories concerning hyperon decays with those

for the heavy b and c quarks. In the Ξ_b^0 case there is only one decay amplitude allowed: $s \to u\overline{u}d$. However, in the Ξ_c^0 case, there is an addition weak scattering amplitude: $cs \to dc$, which allowed Voloshin to determine a lower limit to the decay rate. [83]. Other authors have made predictions assuming positive interference [84], and negative interference between the two amplitudes [85]. Our branching fraction measurement is only consistent with there being positive interference,

Prof. Stone's future analysis plans: Prof. Stone intends to continue his exploration for new physics in the LHCb data as well as investigate interesting aspects of SM physics as the opportunities present themselves. He will work with one or more graduate students on each of these topics. These analyses would start with the current Run I and II samples and then likely progress by adding in Run III data when it becomes available. Prof. Stone has done searches for Majorana neutrinos in LHCb [86] with relatively small data samples and he plans to repeat them.

Other analyses are possible that have not been tried before, but could lead to important results. The plan includes searching for $\overline{B}^0 \to K^{*0}\tau^+\tau^-$ decays, whose branching fraction can be enhanced by several orders of magnitude in models that can explain the lepton flavor universality violations described above [87]. Prof. Rudolph will also be involved.

Theoretical predictions concerning inclusive $b \to s\mu^+\mu^-$ decays are more accurate that those of exclusive decays [88]. All the branching fractions for exclusive $h\mu^+\mu^-$ final states seen so far, where h is a single hadron, are below theoretical predictions at low values of q^2 [89]. However, the calculations have relatively large uncertainties. Thus, we would like to a search for the inclusive

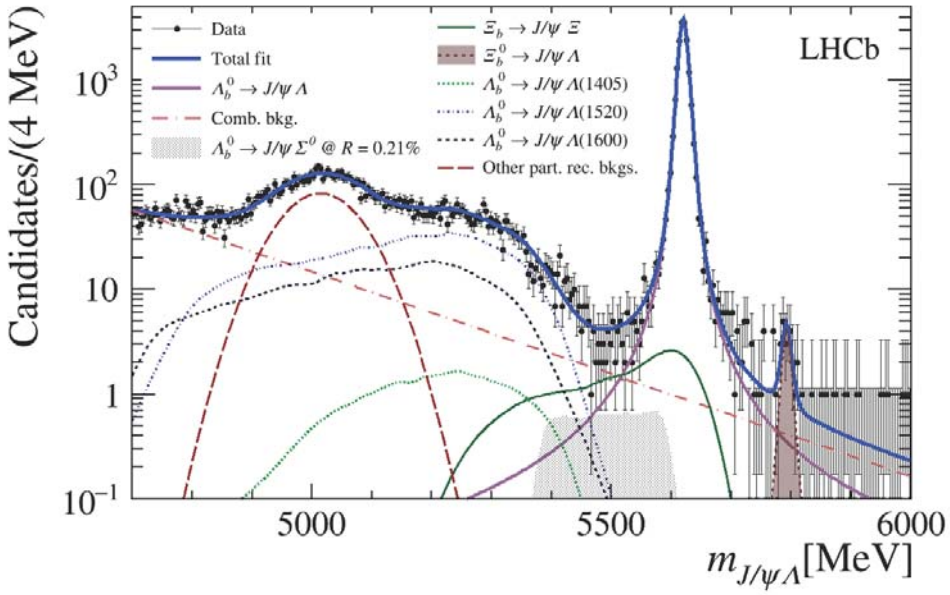

Figure 12: Distribution of the $J/\psi\Lambda$ mass for Run 2 data. Error bars without data points indicate empty bins. The highest peak is due to $\Lambda_b^0 \to J/\psi\Lambda$, while the smaller peak at higher mass is due to $\Xi_b^0 \to J/\psi\Lambda$. Also shown is the projection of the fit to the data. The thick (blue) solid curve shows the total fit. For illustrative purposes, the $\Lambda_b^0 \to J/\psi\Sigma^0$ signal component is artificially scaled to its measured upper limit. The shapes are identified in the legend. Run I data is also used and fit simultaneously.

decays $B^+ \to s^+\mu^+\mu^-$, treating the s^+ related hadrons as missing, using the $B^{*0}_{s2} \to B^+K^-$ decay for a kinematic constraint. The open issue is the size of the backgrounds. These can be reduced by requiring a charged track at the $\mu^+\mu^-$ vertex. It is worth a try, and may work well when a large enough sample of Run III data is accumulated.

Another untried topic is a search for dark matter suggested in a paper by the late Ann Nelson [90]. The idea is that in the early Universe, decays of a long lived particle produce B mesons and $\overline{B}$ out of thermal equilibrium. They then undergo *CP* violating oscillations before decaying into visible and dark sector particles. Dark matter will be charged under baryon number so that the visible sector baryon asymmetry is produced without violating the total baryon number of the Universe. The produced baryon asymmetry will be directly related to the leptonic charge asymmetry in neutral B decays $a^{d \text{ or } s}_{sl}$. Prof. Stone suggested how to perform the original a^s_{sl} measurement at LHCb and did the analysis with Prof. Artuso and others [91]. An upper limit was set and improved upon in Ref. [92], still far from the SM level. Another model prediction is that charged B mesons can decay into a baryon and a dark matter particle that escapes detection. For example, $B^+ \to \Lambda_c^{+*}\Psi$, where the $\Lambda_c^{+*} \to \pi^+\pi^-\Lambda_c^+$ and the Ψ is the invisible dark matter particle. (The $\pi^+\pi^-$ from the Λ_c^{+**} decay are used to define the Λ_b^0 decay point. Without another kinematical constraint this decay would be difficult to see as backgrounds from other decays with Λ_c^{+*}'s from say Λ_b^0 decays would be larger. However, we could use the same $B^{*0}_{s2} \to B^+K^-$ decay [62] that Prof. Rudolph used in two of his analyses not only to add an extra kinematic constraint, but also to ensure that the Λ_c^{+*} came from a B^+ meson and not from a baryon. In addition, Prof. Stone intends to update the a^s_{sl} measurements with Run III data.

2) Broader Impacts

We discuss here first previous results including education, outreach and service the community and then review our proposed activities. An important part of our work is dissemination of knowledge, so we have organized and participated in several widely varying efforts. We maintain a web page for our outreach activities at [93]. This page has a great deal of information about the LHC, the Standard Model etc... It also provides a portal to our "Ask a Particle Physicist" page [94] where people can direct questions to any one of the faculty about particle physics or physics in general. This website was advertised among the local high schoolteachers, and we regularly receive questions not only from them, but from around the world. This page was developed because local science teachers requested this resource. We also link to the LHCb public webpage [95], which is the source of more information and sends news feeds on important articles to many organizations; we contribute written material.

Quark Net and Masterclasses Over the last three years, the group has continued its participation in the Quarknet program. Profs. Blusk and Rudolph co-hosted 2-3 day workshops each summer, with participation of (typically) 8-10 local area high school teachers. The workshops generally have a "knowledge transfer" component, where Profs. Blusk and Rudolph give interactive presentations on various aspects of particle physics. The workshops also include a number of hands-on activities that relate to particle physics. Often these activities draw from those developed by Quarknet. Summaries of the workshops can be found on our Outreach page at: http://hepoutreach.syr.edu/QuarkNet/.

After each of the workshops, we solicited anonymous feedback on the workshops to assess our activities. Five open-ended questions were asked:

1. Please describe which aspects of the workshop were beneficial to you in your role as a teacher, or for greater depth of knowledge.
2. Please describe which aspects of the workshop you felt were not beneficial for you, either for your teaching or your personal knowledge.
3. Are there any topics you wished we spent time on, but did not?
4. Of the topics or activities that we did undertake, which, if any do you wish we had devoted more time to?
5. Is there anything else that you would like the organizers to know, that would be helpful for future Quarknet workshops?

One of the general themes that came across in the 2018 survey responses was a desire to see more of the modern research going on in the laboratories, and see additional ways that physics majors use their degrees beyond fundamental research. To that end, in 2019, in addition to a more extensive set of laboratory tours at Syracuse, Prof. Blusk arranged for a half-day tour of a major defense contractor, Syracuse Research Corporation. The presentation and tour were found to be exceptional, and everyone found their work interesting and enlightening (see Fig. 13).

In 2020, despite the inability to have of an in-person workshop at Syracuse, a two-day workshop was held virtually. Prof. Rudolph gave a presentation on detectors and particle physics, and the teachers engaged in a number of activities. Overall, the teachers were appreciative of the workshop, given the situation with COVID.

With regard to the first question above, some responses included:"It was great seeing how the activities can be accommodated for remote teaching." "I enjoyed learning about the simulations, and benefited greatly from the conversations between the workshop leaders and members. Going through the math behind finding the rest mass of a particles was a wonderful review of the procedure. Dr. Rudolph's presentation was excellent, and clarified several points for me, including hearing how actual teachers incorporate the lessons into their classrooms." Some of the things that teachers found less beneficial about the 2020 workshop include comments as:"I've never tried any of the activities where you analyze traces from the CERN detectors with students. I feel that most of my students wouldn't get much out of it, and I feel like I have limited time to cover topics that will be tested as it is." "My feeling is that conversations frequently get hijacked by a

Figure 13: (Left) Photo of the participants in the 2019 Quarknet tour of the Syracuse Research Corporation, and (right) lab tour of the surface astrophysics laboratory at Syracuse University. (Due to security, no photos could be taken inside the SRC facility.)

few individuals leaving the rest of us out. I think it's important that the things we discuss are relevant to current state guidelines and keep our focus on a level that all participating teachers can understand." "It would have been more beneficial to have activities where we could have interacted with each other more." There were also two comments that indicated that generally everyone found some benefit in everything we did.

On the third and fourth questions, teachers commented: "This year we couldn't tour labs or other facilities, and those always seem to have interesting nuggets of information to share with students." "I'd love to have more lessons on the use of Feynman diagrams, and maybe get an introduction to the link between the equations involved and the diagrams themselves." "How was the Higgs boson detected? How does matter interact with the Higgs field to get mass?" "Quarks and the standard model. Quarks are sometimes really hard to explain to the students. Especially the fact that some of them don't stick around for very long. If I knew a little bit more about them, it may be easier to explain." On the last question, teachers wrote:"It would be nice if materials were available for hands on activities." "Steven Blusk is really great at discussing "modern" physics in a way that relative laymen like ourselves can understand. Hugely appreciate the time of all the people at SU who make this event happen each year." "Keep up the great work!!!" "Thank you so very much!!!", and "in this virtual workshop, I really enjoyed the breakout rooms that were created for us to do the BAMC activity together. It was nice being able to talk to other teachers and work with them on analyzing data." The comments collected will continue to be used to improve what we do and how we do it in future years.

In addition to our summer workshop activities, Profs. Blusk and Rudolph have been hosting the LHCb MasterClass for high school students, typically in March of each year. Due to high demand, we dedicate two full days each year, and we fill our computing room to capacity (about 25 students). Unfortunately, due to COVID, the 2020 MasterClass was cancelled. In the LHCb Masterclass at Syracuse, the morning starts off with a basic presentation on particle physics, detectors, and how we measure physical quantities in particle physics experiments, such as momentum, energy, invariant mass and decay time. We also introduce the idea of seeing a single event versus viewing large samples of data and analyzing them from a statistical perspective, e.g. obtaining the mean and width of the D^0 mass peak in a $K^-\pi^+$ invariant mass plot. We then have an open discussion on what these quantities mean. These presentations and discussions challenge students and create a foundation for the afternoon's hands-on activities using LHCb data.

In these activities students analyze about 30 event displays of $D^0 \to K^-\pi^+$ candidates produced in LHCb, whereby they have to locate the $D^0 \to K^-\pi^+$ decay amongst the many particles in the collision, and then compute the invariant mass based on the K^- and π^+ momenta. Afterwards, the students analyze a larger data set of many thousand D^0 decays to measure the D^0 meson lifetime. They explore systematic biases by varying the requirement on the impact parameter of the D^0 meson to the pp collision vertex. They are lead to learn that the D^0 sample has contamination from secondary b-hadron decays, and this tends to cause a rather larger systematic bias in the D^0 lifetime, if this contribution is not removed. They are guided toward an understanding that the selection on the impact parameter of the tracks relative to the pp collision vertex is an important requirement to apply to the data in order to remove this bias. There are many valuable lessons that are learned from these exercises. The day concludes with a video meeting with colleagues from LHCb, where they have a fun and interactive Q&A session.

Undergraduate Research: An educational priority of our group is to engage students in our research activities. The R&D of the UT detector, and now the construction, provides a great

opportunity for undergraduates and graduate students to actively participate and learn scientific construction techniques and methods of approaching problems. Over the last 3 years, we have had ∼20 undergraduates work in our laboratory on a number of projects, ranging from R&D on mechanical or electrical properties of detector components to analysis of data collected in the lab or in testbeams, as well as analysis of LHCb data. Most importantly, students are playing a major role in construction of the UT, some work on electronics and others on mechanical problems. Some of these students stay in Syracuse over the summer, work full time in our lab, and then continue on through the academic year, typically at the level of about 10 hours/week. Past projects are summarized elsewhere [96]. We also have had great success in attracting undergraduate women to carry out research in our group. Figure 14 shows two students engaged in construction activities. Unfortunately due to Covid-19 restrictions we can only employ one undergraduate currently in our lab.

Other Service: During this grant period, Prof. Artuso continued her work within the group SUWise (Women in Science and Engineering at Syracuse university). In 2018 she worked with Profs. Becklin, Lewis, and Lanzani to develop a special introductory course for undergraduate women in STEM disciplines. The course was highly interactive and well received by the students. She is also active in the "Future professionals program" for women graduate students. A key component of this mentoring program is the development of a portfolio in which the student collects highlights of her achievements in teaching and research, and prepares material for future job searches, including CV, research statement, teaching statement, and other relevant material. Prof. Artuso reviews each year portfolios, providing extensive feedback to the students. Her interest in mentoring is currently focused in developing a mentoring program for underrepresented students in the Physics Department with graduate student Ohana Benevides Rodrigues. She is also participating in the mentoring program of the ECGD outreach group of LHCb and has joined the CERN mentoring program.

Prof. Rudolph is a member of the SU Physics Department's newly formed team in the American Physical Society Inclusion, Diversity, and Equity Alliance (APS-IDEA) program. This program provides a forum to collaborate with peer institutions on the implementation of concrete proposals to improve the inclusivity of the department. Program workshops have begun during 2020, and

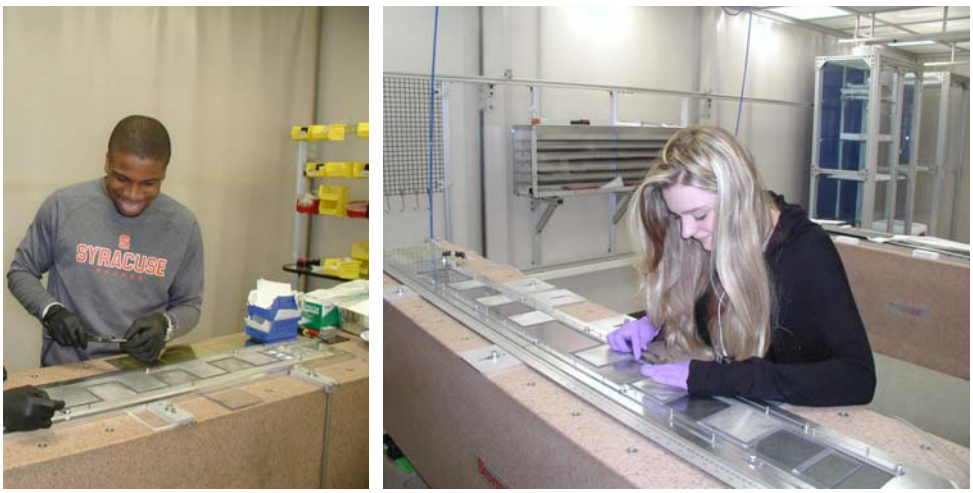

Figure 14: Undergraduates working in our lab.

will continue into the future.

Prof. Skwarnicki was interviewed several times on the topic of exotic hadrons [97–102]. In addition he wrote a commentary on recent discoveries by LHCb of tetraquarks in $J/\psi J/\psi$ and D^+K^- ,which likely are formed from two diquarks, that was published in the CERN courier https://cerncourier.com/a/tetraquarks-back-in-the-spotlight/ [103]. Prof. Skwarnicki also collaborated with theorists resulting in papers concerning formalisms for amplitude analysis. In Ref. [104] they clarified that helicity formalism for hadronic amplitudes is fully relativistic, which had been challenged. In Ref. [105] they applied the method from the earlier paper to baryon decays, including $\Lambda_b^0 \to J/\psi K^- p$. This new approach brought out some additional complications for baryon decays. Prof. Skwarnicki also authored two popular review papers on "Nonstandard heavy mesons and baryons: Experimental evidence," [17] and "Multiquark States," [106]. Prof. Stone wrote a review article: A. Ali, S. Lange, and S. Stone "Exotics: Heavy Pentaquarks and Tetraquarks," [16].

We have performed other service to the high energy physics community. Profs. Skwarnicki and Stone are member of the Particle Data Group (PDG). Prof. Stone with Ruth Van de Water of Fermilab and Jon Rosner of the Univ. of Chicago reviewed pseudoscalar decay constants for the PDG [51]. Prof. Skwarnicki joined with Marek Karliner of Tel Aviv to write the PDG report on pentaquarks [51].

Prof. Artuso is a member of the LHCp conference international advisory committee, the international advisory Committee for Vertex Detector Workshops, and is an executive committee member of the DPF Coordinating Panel for Advanced Detectors (CPAD) [107]. She also served on the DOE panel "DOE Basic Research Needs Study on High Energy Physics Detector Research and Development" [37]. She is co-head of the Snowmass 2021 frontier: "Rare Processes and Precision Measurements." Prof. Skwarnicki is co-head of the "Hadron Spectroscopy" topical sub-group. Prof. Stone serves on several continuing conference and workshop organizing committees including: Flavor Physics & CP Violation, Beauty, and QCD@Work. Prof. Stone also has been elected to the LHCb Management Advisory Board as one of the three representatives from the Collaboration Board, on which he also serves.

Broader Impacts: proposed activities: We intend to continuing carrying out the activities described above. Prof. Rudolph will continue with the APS-IDEA program. We hope to be able to employ more undergraduates in our lab doing work on the UT. We will maintain our public access web efforts. We believe the Quark Net and Masterclass programs bring great benefits to the local area. Profs. Artuso and Stone have signed a book contract with Gino Isidori of Univ. of Zürich entitled "New Physics in B decays."

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NAME: Sheldon Stone

POSITION TITLE & INSTITUTION: Distinguished Professor of Physics, Syracuse University

A. PROFESSIONAL PREPARATION
(see PAPPG Chapter II.C.2.f.(i)(a))

INSTITUTION	LOCATION	MAJOR/AREA OF STUDY	DEGREE (if applicable)	YEAR (YYYY)
Brooklyn College	Brooklyn, NY	Physics	BS in Physics	1967
University of Rochester	Rochester NY	Physics/High Energy Exp.	Ph.D. in Physics	1972
Vanderbilt University	Nashville TN	Physics/High Energy Exp.	Postdoctoral	1971-1973

B. APPOINTMENTS
(see PAPPG Chapter II.C.2.f.(i)(b))

From - To	Position Title, Organization and Location
2012-Present	Distinguished Professor of Physics, Syracuse University, Syracuse, NY
2011-2012	On leave at CERN as Scientific Associate, Geneva, Switzerland
1991-2012	Professor of Physics, Syracuse University, Syracuse, NY
1987-1991	Adjunct Professor of Physics, Physics Department, Cornell University, Ithaca, NY, and
1979-1991	Senior Research Associate Laboratory of Nuclear Studies, Cornell University, Ithaca, NY
1977-1978	On leave at Laboratory of Nuclear Studies, Cornell University, Ithaca, NY
1973-1979	Assistant Professor of Physics, Vanderbilt University, Nashville, Tenn.

C. PRODUCTS

(see PAPPG Chapter II.C.2.f.(i)(c))

Products Most Closely Related to the Proposed Project

1. Observation of J/psi p Resonances Consistent with Pentaquark States in /\b->J/psi K- p Decays, with the LHCb collaboration R. Aaij et al., Phys. Rev. Lett. 115 (2015) 072001, https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.115.072001 .
2. S-waves and the Measurement of CP Violating Phases in Bs Decays, with L. Zhang, Physical Review D79, 074024 (2009).
3. First observation of Bs->J/psi f0(980) decays with the LHCb collaboration R. Aaij et al., Phys. Lett. B698, 115 (2011), https://journals.aps.org/prd/abstract/10.1103/PhysRevD.79.074024.
4. B Meson Decays, with M. Artuso, and E. Barberio, PMC Physics A 2009, 3:3, https://link.springer.com/article/10.1186/1754-0410-3-3 .
5. Measurement of the flavour-specific CP-violating asymmetry asl in Bs decays, with the LHCb collaboration, R. Aaij et al., Phys. Lett. B728 (2014) 607, arXiv:1308.1048, https://www.sciencedirect.com/science/article/pii/S0370269313010058 .

Other Significant Products, Whether or Not Related to the Proposed Project

1. Observation of Exclusive Decay Modes of b-Flavored Mesons, with the CLEO Collaboration, S. Behrends et al., Physical Review Letters 50, 881 (1983), https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.50.881.
2. Evidence for the F Meson at 1970 MeV with the CLEO Collaboration, A. Chen et al., Physical Review Letters 51, 634 (1983), https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.51.634 .
3. Factorization Test Using B0->D*-pi+ and An Estimate of fDs, Using B->DDs with D. Bortoletto, Physical Review Letters 65, 2951 (1990), https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.65.2951.
4. The CLEO RICH detector, with M. Artuso et al., Nucl. Instrum. Meth. A554, 147 (2005).
5. Exotics: Heavy Pentaquarks and Tetraquarks, with A. Ali, and J. S. Lange, published in: Prog. Part. Nucl. Phys. 97 (2017) 123-198, arXiv:1706.00610.

D. SYNERGISTIC ACTIVITIES

(see PAPPG Chapter II.C.2.f.(i)(d))

1. I answer questions asked on the "Ask a Particle Physicist" webpage maintained by Syracuse Univ. HEP, http://hepoutreach.syr.edu/Ask_A_Physicist/index.html .
2. I serve on the DPF program committee that helped in the initial Snowmass organization and plans the program for the DPF and APS meetings.
3. I have developed research tools. In experimental hardware I am contributing to the current UT construction and the design of Upgrade II LHCb detector, in which I introduced the idea of 10's of picosecond timing for the calorimeter and tracking, and had the idea of putting tracking chambers on the inside of the magnet faces to pick up tracks and thus increase the overall detection efficiency. I also have suggested new analysis techniques such as using Bs2* decays to add an extra constraint allowing the reconstruction of decays with a missing particle.

NAME: Marina Artuso

POSITION TITLE & INSTITUTION: Professor of Physics Syracuse University

A. PROFESSIONAL PREPARATION
(see PAPPG Chapter II.C.2.f.(i)(a))

INSTITUTION	LOCATION	MAJOR/AREA OF STUDY	DEGREE (if applicable)	YEAR (YYYY)
Politecnico	Milano, Italy	Electrical Engineering	Laurea	1978
Northwestern University	Evanston, IL	Physics	Ph.D.	1986
Columbia University	New York, NY	Physics	Postdoctoral Work	1986-1988
Cornell University	Ithaca, NY	Physics	Postdoctoral Work	1988-1990

B. APPOINTMENTS
(see PAPPG Chapter II.C.2.f.(i)(b))

From - To	Position Title, Organization and Location
1991-1993	Research Professor, Syracuse University, Syracuse NY
1994-1999	Assistant Professor of Physics, Syracuse University, Syracuse NY
2000-2004	Associate Professor of Physics, Syracuse University, Syracuse NY
2005-present	Professor of Physics, Syracuse University, Syracuse NY

C. PRODUCTS

(see PAPPG Chapter II.C.2.f.(i)(c))

Products Most Closely Related to the Proposed Project

1. Z. Ahmed, A. Apreysan, M. Artuso, P. Barry et al., New technologies for discovery, e-Print: 1908.00194 (2019)
2. R. Aaij et al., Measurement of the shape of the Lambda_b->Lambda_c mu-nu_bar_mu differential decay rate, Phys. Rev. D 96 (2017) 11, 112005
3. I. Bediaga et al., Physics case for an LHCb Upgrade II - Opportunities in flavour physics, and beyond, in the HL-LHC era, e-Print: 1808.08865 [hep-ex], Report number: LHCB-PUB-2018-009, CERN-LHCC-2018-027
4. B. Fleming, I. Shipsey et al., DOE Basic Research Needs Study on High Energy Physics Detector Research and Development, https://science.osti.gov/hep/Community-Resources/Reports (2020)
5. M. Artuso et al., Signal coupling to embedded pitch adapters in silicon sensors, Nucl. Instr. Meth, Phys. Res. A877 (2018) 252

Other Significant Products, Whether or Not Related to the Proposed Project

1. M. Artuso, G. Borissov, and A. Lenz, CP violantion in the Bs system, Rev.Mod.Phys. 88 (2016) 4, 045002, Rev.Mod.Phys. 91 (2019) 4, 049901
2. R. Aaij et al., Measurement of b hadron fractions in 13 TeV pp collisions, Phys. Rev.D 100 (2019) 3, 031102
3. R. Aaij et al., Measurement of the b-quark production cross-section in 7 TeV and 13 TeV collisions, Phys.Rev.Lett. 118 (2017) 5, 052002, Phys.Rev.Lett. 119 (2017) 16, 169901 (erratum)
4. R. Aaij et al., Measurement of the CP asymmetry in Bs-Bsbar system, Phys.Rev. Lett. 117 (2016) 061803
5. R. Aaij et al., Performance of the LHCb Vertex Locator, JINST 9 (2014) P09007

D. SYNERGISTIC ACTIVITIES

(see PAPPG Chapter II.C.2.f.(i)(d))

1. Women in Science and Engineering (Leadership board, Undergraduate development leadership with Loredana Lanzani and Katie Becklin) (2018)
2. Women in Physics at Syracuse University (current): mentorship program
3. Women in Science and Engineering - Wise Future Professional Program Portfolio reviewer
4. Planning the Future of U.S. Particle Physics (Snowmass 2021) Frontier Organizer
5. DPF Coordinating Panel for Advanced Detector - work to promote young scientists interested in instrumentation

NAME: Steven Blusk

POSITION TITLE & INSTITUTION: Professor of Physics

A. PROFESSIONAL PREPARATION
(see PAPPG Chapter II.C.2.f.(i)(a))

INSTITUTION	LOCATION	MAJOR/AREA OF STUDY	DEGREE (if applicable)	YEAR (YYYY)
Potsdam College	Potsdam, NY	Mathematics & Physics	B.A.	1984
University of Pittsburgh	Pittsburgh, PA	Physics	M.S.	1989
University of Pittsburgh	Pittsburgh, PA	Physics	Ph.D.	1995

B. APPOINTMENTS
(see PAPPG Chapter II.C.2.f.(i)(b))

From - To	Position Title, Organization and Location
9/2015 - present	Professor of Physics, Syracuse University, Syracuse, NY 13244
9/2007 - 8/2015	Associate Professor of Physics, Syracuse University, Syracuse, NY 13244
8/2001 - 8/2007	Assistant Professor of Physics, Syracuse University, Syracuse, NY 13244
1996 - 2001	Postdoctoral Researcher, University of Rochester, Rochester, NY 14627
1995 - 1996	Visiting Assistant Professor, University of Pittsburgh, Pittsburgh, PA 15260

C. PRODUCTS

(see PAPPG Chapter II.C.2.f.(i)(c))

Products Most Closely Related to the Proposed Project

[1] LHCb collaboration, R. Aaij et al., "First observation of excited Omega_b- States", Phys. Rev. Lett. 124 (2020) 082002.
[2] LHCb collaboration, R. Aaij et al., "Precision measurement of the Lambda_c+, Xi_c+, and Xi_c0 baryon lifetimes", Phys. Rev. D100 (2019) 032001.
[3] LHCb collaboration, R. Aaij et al., "Observation of a new Xi_b- resonance", Phys. Rev. Lett. 121 (2018) 072002.
[4] LHCb collaboration, R. Aaij et al., "Measurement of the Omega_c0 baryon lifetime", Phys. Rev. Lett. 121 (2018) 092003.
[5] LHCb collaboration, R. Aaij et al., "Measurement of the CP-violating phase ϕs in Bs-->Ds+Ds- decays", Phys. Rev. Lett. 113 (2014) 211801.

Other Significant Products, Whether or Not Related to the Proposed Project

[1] M. Artuso et. al. "First beam test of UT sensors with the SALT 3.0 readout ASIC", LHCb-PUB-2019-009.
[2] LHCb collaboration, R. Aaij et al., "Measurement of the mass and production rate of Xi_b- baryons", Phys. Rev. D99 052006 (2019).
[3] LHCb collaboration, R. Aaij et al., "Study of $B^- \to DK^-\pi^+\pi^-$ and $B^- \to D\pi^-\pi^+\pi^-$ decays and determination of the CKM angle γ", Phys. Rev. D92 (2015) 112005.
[4] LHCb collaboration, R. Aaij et al., "Precision measurement of the mass and lifetime of the Xi_b0 baryon", Phys. Rev. Lett. 113 (2014) 032001.
[5] A. Abba et. al., "Testbeam studies of pre-prototype silicon strip sensors for the LHCb UT upgrade project", Nucl. Instrum. Meth. A806, 244-257 (2015).

D. SYNERGISTIC ACTIVITIES

(see PAPPG Chapter II.C.2.f.(i)(d))

[1] Co-lead of the Syracuse Quarknet outreach program, which "provides science teachers the means to develop their skills and bring research experiences into the high school classroom" (quoted from Quarknet web site).
[2] Co-lead of the LHCb Masterclass program at Syracuse, which brings up to about 50 high school students into the department for a day filled with learning about particle physics and the LHCb experiment. The day includes both presentations, hands-on activities, and a video meeting with LHCb collaborators at CERN.
[3] External reviewer for a number of papers for Physical Review D and Letters.
[4] Have given presentations at local area high schools on topics ranging from particle physics to cosmology.
[5] Member of the LHCb Outreach committee. This is a group of LHCb members who are available to discuss recent exciting LHCb physics results with the public, or news organizations.

NAME: Matthew Rudolph

POSITION TITLE & INSTITUTION: Assistant Professor, Syracuse University

A. PROFESSIONAL PREPARATION
(see PAPPG Chapter II.C.2.f.(i)(a))

INSTITUTION	LOCATION	MAJOR/AREA OF STUDY	DEGREE (if applicable)	YEAR (YYYY)
Johns Hopkins University	Baltimore, MD	Physics	BS	2005
Massachusetts Institute of Technology	Cambridge, MA	Physics	PhD	2011
University of Toronto	Toronto, ON, Canada	Research associate on ATLAS experiment		2011-2015

B. APPOINTMENTS
(see PAPPG Chapter II.C.2.f.(i)(b))

From - To	Position Title, Organization and Location
2015-	Assitant Professor, Syracuse University, Syracuse, NY

C. PRODUCTS

(see PAPPG Chapter II.C.2.f.(i)(c))

Products Most Closely Related to the Proposed Project

LHCb Collaboration. Search for the lepton flavour violating decay B+ to K+ mu- tau+ using Bs2*0 decays. JHEP 06 (2020) 129. doi: 10.1007/JHEP06(2020)129.

Matthew Scott Rudolph. The LHCb Upstream Tracker Upgrade. Proceedings of The 28th International Workshop on Vertex Detectors — PoS(Vertex2019). Vol. 373. 2020, 013. doi:10.22323/1.373.0013

LHCb Collaboration. Measurement of the relative B- to D0/D*0/D**0 mu- nu branching fractions using B- mesons from Bs2*0 decays. Phys. Rev. D 99 (2019) 092009. doi:10.1103/PhysRevD.99.092009.

Matthew Rudolph. An experimentalist's guide to the semileptonic bottom to charm branching fractions. Int. J. Mod. Phys. A 33 (2018) 1850176. doi:10.1142/S0217751X18501762.

M. Artuso, C. Betancourt, I. Bezshyiko, S. Blusk, R. Bruendler, S. Bugiel, R. Dasgupta, A. Dendek, B. Dey, S. Ely, F. Lionetto, M. Petruzzo, I. Polyakov, M. Rudolph, H. Schindler, O. Steinkamp, and S. Stone. Signal coupling to embedded pitch adapters in silicon sensors. Nucl. Instrum. Meth. A 877 (2018) 252–258. doi:10.1016/j.nima.2017.09.039.

Other Significant Products, Whether or Not Related to the Proposed Project

ATLAS Collaboration. Measurements of top quark spin observables in tt events using dilepton final states in s = 8 TeV pp collisions with the ATLAS detector. JHEP 03 (2017) 113. doi:10.1007/JHEP03(2017)113.

ATLAS Collaboration. Reconstruction of primary vertices at the ATLAS experiment in Run 1 proton–proton collisions at the LHC. Eur. Phys. J. C 77.5 (2017) 332. doi:10.1140/epjc/s10052-017-4887-5.

ATLAS Collaboration. Measurement of Top Quark Polarization in Top-Antitop Events from Proton-Proton Collisions at s = 7 TeV Using the ATLAS Detector. Phys. Rev. Lett. 111 (2013) 232002. doi:10.1103/PhysRevLett.111. 232002.

CMS Collaboration. Measurement of the Y(1S), Y(2S) and Y(3S) Polarizations in pp Collisions at s = 7 TeV. Phys. Rev. Lett. 110 (2013) 081802. doi:10.1103/PhysRevLett.110.081802.

D. SYNERGISTIC ACTIVITIES

(see PAPPG Chapter II.C.2.f.(i)(d))

Member of the Syracuse University Physics Department's team in the American Physical Society (APS) Inclusion, Diversity, and Equity Alliance (IDEA) program

Mentor at Quarknet workshops for high school teachers at Syracuse University, 2016-2020

Hosted high school students participating in the LHCb Masterclass program in 2016, 2017, and 2018

Invited to speak on particle physics for high school teachers in the Syracuse University Project Advance program, 2019

Mentor for student in Louise Stokes Alliance for Minority Participation summer REU program at Syracuse University, summer 2016

NAME: Tomasz Skwarnicki

POSITION TITLE & INSTITUTION: Syracuse University

A. PROFESSIONAL PREPARATION

(see PAPPG Chapter II.C.2.f.(i)(a))

INSTITUTION	LOCATION	MAJOR/AREA OF STUDY	DEGREE (if applicable)	YEAR (YYYY)
Jagiellonian University	Krakow, Poland	Physics	M.S.	1982
Instit. of Nuclear Phys	Krakow, Poland	Physics	Ph.D.	1986
DESY	Hamburg, Ger.	High energy experiment	Postdoctoral	1985-1987
Syracuse University	Postdoctoral	High energy experiment	Postodoctoral	1988-1989

B. APPOINTMENTS

(see PAPPG Chapter II.C.2.f.(i)(b))

From - To	Position Title, Organization and Location
2000 - present	Professor, Syracuse University, Syracuse, NY
2007	Guest Scientist, L.A.P.P. Annecy, Annecy, France
1995-2000	Associate Professor, Syracuse University, Syracuse, NY
1992-1995	Assistant Professor, Southern Methodist University, Dallas, TX
1992	Visiting Scientist, Superconducting Super Collider, Dallas, TX
1989-1992	Assistant Professor, Syracuse University, Syracuse, NY

C. PRODUCTS

(see PAPPG Chapter II.C.2.f.(i)(c))

Products Most Closely Related to the Proposed Project

1) "Observation of a Narrow Pentaquark State, Pc(4312)+ , and of the Two-Peak Structure of the Pc(4450)+", with R. Aaij et al (LHCb Collaboration), Phys. Rev. Lett. 122, 222001 (2019).
2) "Observation of J/psi phi structures consistent with exotic states from amplitude analysis of B+ to J/psi phi K + decays", with R. Aaij et al (LHCb Collaboration), Phys. Rev. Lett. 118, 022003 (2017).
3) "Model-independent evidence for J/psi p contributions to Lambda_b to J/psi p K- decays", with R. Aaij et al (LHCb Collaboration), Phys. Rev. Lett. 117, 082002 (2016).
4) "Observation of J/psi p Resonances Consistent with Pentaquark States in Lambda_b to J/psi p K- Decays", with R. Aaij et al (LHCb Collaboration), Phys. Rev. Lett. 115, 072001 (2015).
5) "Observation of the resonant character of the Z(4430)- state", with R. Aaij et al (LHCb Collaboration), Phys. Rev. Lett. 112, 222002 (2014).

Other Significant Products, Whether or Not Related to the Proposed Project

1) "Non-Standard Heavy Mesons and Baryons, an Experimental Review", with S.L. Olsen, D. Zieminska, Rev. Mod. Phys. 90, 015003 (2018).
2) "Multiquark States", with M. Karliner, J.L. Rosner, Ann. Rev. Nucl. Part. Sci. 68, 17 (2018).
3) "Determination of the X(3872) meson quantum numbers", with R. Aaij et al (LHCb Collaboration), Phys. Rev. Lett. 110, 222001 (2013).
4) "First Measurement of the Rate for the Inclusive Radiative Penguin Decay b to s gamma", with M.S. Alam et al (CLEO Collaboration), Phys. Rev. Lett. 74, 2885 (1995).
5) "Pentaquarks" in "Review of Particle Physics", ,with P.A. Zyla et al (PDG), Prog. Theor. Exp. Phys. 2020, 083C01 (2020).

D. SYNERGISTIC ACTIVITIES

(see PAPPG Chapter II.C.2.f.(i)(d))

1)Convener of Topical Group RF7 on Hadron Spectroscopy under Rare Processes and Precision Measurements Frontier of Snowmass2021.
2) Works with journalists on popular science articles related to current research (recent example: "LHCb results add clues to pentaquark mystery", Symmetry Magazine, Apr. 11, 201.)
3) Conference and Workshop organization (e.g. SCGP Workshop on Exotic Hadrons and Flavor Physics, Simons Center, Stony Brook, NY, May 28-June 1, 2018).

SUMMARY PROPOSAL BUDGET

YEAR 1

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

ORGANIZATION: **Syracuse University**

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: **Sheldon Stone**

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. **Sheldon Stone - Distinguished Prof.**	0.00	0.00	2.00	**35,412**	
2. **Marina Artuso - Prof.**	0.00	0.00	2.00	**28,259**	
3. **Steven Blusk - Prof.**	0.00	0.00	2.00	**23,529**	
4. **Matthew Rudolph - Prof.**	0.00	0.00	2.00	**19,412**	
5. **Tomasz Skwarnicki - Prof.**	0.00	0.00	2.00	**32,160**	
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**5**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	10.00	**138,772**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**3**) POST DOCTORAL SCHOLARS	12.00	0.00	0.00	**155,084**	
2. (**1**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	12.00	0.00	0.00	**52,530**	
3. (**10**) GRADUATE STUDENTS				**346,800**	
4. (**6**) UNDERGRADUATE STUDENTS				**9,000**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**702,186**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**123,888**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**826,074**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
Acquisition of sensor samples developed for others $ **20,000**					
Acqusistion of VLSI FE prototypes **20,000**					
Electronic boards, components, and ancillary circuits **15,000**					
Tektronics digital scope 6 Series B MSO **37,900**					
TOTAL EQUIPMENT				**92,900**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**10,000**	
2. INTERNATIONAL				**107,000**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**19,000**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**2,000**	
4. COMPUTER SERVICES				**9,000**	
5. SUBAWARDS				**0**	
6. OTHER				**2,000**	
TOTAL OTHER DIRECT COSTS				**32,000**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**1,067,974**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC Off-campus Research (Rate: 26.0000, Base: 973074)**					
TOTAL INDIRECT COSTS (F&A)				**252,999**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**1,320,973**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**1,320,973**	

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

PI/PD NAME: **Sheldon Stone**

ORG. REP. NAME*: **Amy Graves**

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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: **Syracuse University**

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: **Sheldon Stone**

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. **Sheldon Stone - Distinguished Prof.**	0.00	0.00	2.00	**36,474**	
2. **Marina Artuso - Prof.**	0.00	0.00	2.00	**29,107**	
3. **Steven Blusk - Prof.**	0.00	0.00	2.00	**24,235**	
4. **Matthew Rudolph - Prof.**	0.00	0.00	2.00	**19,994**	
5. **Tomasz Skwarnicki - Prof.**	0.00	0.00	2.00	**33,125**	
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**5**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	10.00	**142,935**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**3**) POST DOCTORAL SCHOLARS	12.00	0.00	0.00	**159,737**	
2. (**1**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	12.00	0.00	0.00	**54,106**	
3. (**10**) GRADUATE STUDENTS				**357,204**	
4. (**6**) UNDERGRADUATE STUDENTS				**9,270**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**723,252**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**127,605**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**850,857**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
electronic components and dedicated pcbs $ **8,000**					
Multiproject wafer contribution **25,000**					
Sensor prototypes **60,000**					
TOTAL EQUIPMENT				**93,000**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**10,300**	
2. INTERNATIONAL				**110,210**	
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				**19,000**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**2,000**	
4. COMPUTER SERVICES				**9,000**	
5. SUBAWARDS				**0**	
6. OTHER				**2,000**	
TOTAL OTHER DIRECT COSTS				**32,000**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**1,096,367**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
MTDC Off-campus Research (Rate: 26.0000, Base: 1001366)					
TOTAL INDIRECT COSTS (F&A)				**260,355**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**1,356,722**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**1,356,722**	

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

PI/PD NAME: **Sheldon Stone**

ORG. REP. NAME*: **Amy Graves**

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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: **Syracuse University**

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: **Sheldon Stone**

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. **Sheldon Stone - Distinguished Prof.**	0.00	0.00	2.00	**37,568**	
2. **Marina Artuso - Prof.**	0.00	0.00	2.00	**29,980**	
3. **Steven Blusk - Prof.**	0.00	0.00	2.00	**24,962**	
4. **Matthew Rudolph - Prof.**	0.00	0.00	2.00	**20,594**	
5. **Tomasz Skwarnicki - Prof.**	0.00	0.00	2.00	**34,119**	
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**5**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	10.00	**147,223**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**3**) POST DOCTORAL SCHOLARS	12.00	0.00	0.00	**164,529**	
2. (**1**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	12.00	0.00	0.00	**55,729**	
3. (**10**) GRADUATE STUDENTS				**367,920**	
4. (**6**) UNDERGRADUATE STUDENTS				**9,548**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**744,949**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**131,433**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**876,382**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
Infrastructure for test beam $ **1,500**					
Multiproject wafer contribution **25,000**					
Planacon MCP from Photonis **72,000**					
Quartz radiators **2,000**					
TOTAL EQUIPMENT				**100,500**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**10,609**	
2. INTERNATIONAL				**113,516**	
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				**19,000**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**2,000**	
4. COMPUTER SERVICES				**9,000**	
5. SUBAWARDS				**0**	
6. OTHER				**2,000**	
TOTAL OTHER DIRECT COSTS				**32,000**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**1,133,007**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
MTDC Off-campus Research (Rate: 26.0000, Base: 1030507)					
TOTAL INDIRECT COSTS (F&A)				**267,932**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**1,400,939**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**1,400,939**	

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

PI/PD NAME: **Sheldon Stone**

ORG. REP. NAME*: **Amy Graves**

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 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

Cumulative

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

ORGANIZATION: **Syracuse University**

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: **Sheldon Stone**

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. **Sheldon Stone - Distinguished Prof.**	0.00	0.00	6.00	**109,454**	
2. **Marina Artuso - Prof.**	0.00	0.00	6.00	**87,346**	
3. **Steven Blusk - Prof.**	0.00	0.00	6.00	**72,726**	
4. **Matthew Rudolph - Prof.**	0.00	0.00	6.00	**60,000**	
5. **Tomasz Skwarnicki - Prof.**	0.00	0.00	6.00	**99,404**	
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**5**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	30.00	**428,930**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**9**) POST DOCTORAL SCHOLARS	36.00	0.00	0.00	**479,350**	
2. (**3**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	36.00	0.00	0.00	**162,365**	
3. (**30**) GRADUATE STUDENTS				**1,071,924**	
4. (**18**) UNDERGRADUATE STUDENTS				**27,818**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**2,170,387**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**382,926**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**2,553,313**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) $ **286,400**					
TOTAL EQUIPMENT				**286,400**	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				**30,909**	
2. INTERNATIONAL				**330,726**	
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				**57,000**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**6,000**	
4. COMPUTER SERVICES				**27,000**	
5. SUBAWARDS				**0**	
6. OTHER				**6,000**	
TOTAL OTHER DIRECT COSTS				**96,000**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**3,297,348**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**781,286**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**4,078,634**	
K. FEE				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**4,078,634**	

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

PI/PD NAME: **Sheldon Stone**

ORG. REP. NAME*: **Amy Graves**

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

BUDGET JUSTIFICATION

Our group consists of five academic faculty members, one research professor, three postdoctoral research associates and ten graduate students. We change the balance between research associates and students depending on the availability of good students, which have the highest priority. Our research professor, Ray Mountain is very good at detector construction, including such items as mechanical design, vacuum systems, scintillation counters and innovative new technologies, such as stage driven optical testing systems. He is essential for UT construction and future R&D activities. The postdocs work on both hardware and physics analysis. They interact with the faculty, undergraduate and graduate students, who also are individually trained in both hardware and physics analysis. The funds requested here are sufficient to maintain our level of personnel. Research Prof. Jianchun Wang recently left the group to take a Professor position at the Institute for High Energy Physics of the Chinese Academy of Sciences in Beijing. We propose to replace him with a postdoc at CERN. During the period of this grant, we plan to have most of our personnel at CERN working on UT detector installation, calibration, and monitoring of data when Run III of the LHC starts. They will also be working on physics analyses with their thesis or postdoc advisors.

A. Salaries and Wages – Senior Personnel: The Principal Investigator, Dr. Sheldon Stone, will devote two summer months per year throughout the three-year project period. Prof. Stone leads the project, is directly involved with physics analysis, works on Upgrade II planning, and is the UT deputy project leader.

The Co-Principal Investigators, Profs. Marina Artuso, Steven Blusk, Mathew Rudolf and Tomasz Skwarnicki, will each devote two summer months per year of the project. Prof. Artuso is the UT project leader. Profs. Blusk and Rudolph work on various aspects of online monitoring. Prof. Skwarnicki heads the simulation development and data base activities. All of the faculty are also involved with physics analysis. Thus, salary support is requested for two summer months of the equivalent academic year salary for the PI and the CoPI's.

Effort spent on the project but not compensated for within the academic year is deemed to be included within the faculty member's regular organizational duties.

Syracuse University faculty appointments are for 8.5 months. Salaries are escalated by 3.0% annually for budget preparation purposes; actual salaries in place during the time of the award are charged.

B. Salaries and Wages – Other Personnel: In each year of the project, we request 12 months support for Research Prof. Raymond Mountain, who is co-leader of the mechanical and cooling subproject of the UT and supervises students in UT construction activities.

Support for three postdoctoral research associates for work on the UT. Dr. Polyakov is responsible for the wire bonding and simulation of the silicon sensor response. Dr. Yuan is responsible for overall stave metrology, the measurements of the silicon sizes, detecting defects in the silicon. They will be moving to CERN to work on UT operations and data analysis. Graduate student Scott Ely is an outstanding candidate for the third postdoc position. He is already at CERN and is the current UT installation coordinator. He is expected to graduate early next year. For all three 12 months calendar effort is requested. The salary of Mountain is listed separately from the two other postdoctoral research associates in the ``Professionals" category, as he is a Research Prof. in the Physics Dept.

Supporting our graduate students is a very high priority for us. Funding for ten graduate research assistants in each year of the project, 4.5 months AY effort and 3 months summer effort, is requested. The GRAs will be helping the faculty and research staff with their many tasks. We have also requested $8,000 for 5 undergraduates each year, who work part-time during the semester and full time in the summer and on long breaks. The graduate students all participate in the UT construction. We believe that not only do they get an unparalleled learning experience; they also are particularly useful in various software, hardware construction and R&D efforts.

C. Fringe Benefits: Fringe Benefits are calculated as direct costs in accordance with Syracuse University's indirect cost rate agreement (Department of Health and Human Services), 17.6% for faculty during the summer, 29.2% for research faculty and postdocs, 11.0% for graduate students during the academic year, and zero for the summer, and 7.7% for undergraduate students and temporary staff). Actual rates in place during the time of the award would be charged.

D. Permanent Equipment: These are for the picosecond level timing studies in the proposal. In order to study precision timing devices, we have to acquire a scope suitable for measurements that we are planning to make. In year 1, we ask for a Tektronics MSO68B Mixed Signal Scope (6 channels – 10GHz- maximum time resolution 20 ps) for $37,900 –. A digital scope with similar specifications was used in the timespot 3d pixel study (both laboratory and embedded in the test beam DAQ). We are planning to acquire samples of 3d devices and AC coupled LGADS through collaborative efforts. We estimate that $20,000 allows us to acquire a few samples of each technology for preliminary studies. Similarly, we need to acquire samples of VLSI front end components, also for $20,000. We also need custom electronic boards, components, and ancillary circuits needed to complete our DAQ infrastructure to perform timing studies that costs $15,000. This estimate is based on previous experience from the Upstream Tracker construction.

In year 2, we need to do sensor prototyping. The $60,000 requested reflects an estimate of the NRE + fabrication cost for 1 prototype submission, based on the cost of previous R&D runs. The multi-project-wafer run cost of $25,000 assumes that we will share the cost of a submission with colleagues from the picosecond-consortium discussed in the text. One of the goals of this collaborative effort is to development of an ASIC with improved timing performance. The new devices will require custom made testing infrastructure, in particular hybrids and ancillary electronics (in the budget sheet this expenditure is identified as "electronics components") which cost $8,000.

In year 3 our central goal is to perform a test beam study of the devices we have developed. A referenced time will be provided by 2 Cherenkov detectors made of quartz bars, cost of $2,000, read out with Planacon MCP-PMT tubes which cost $72,000, that provide picosecond level timing. We also request some small electrical infrastructure support to adapt the laboratory test bench to the test beam environment and some additional funds to contribute to a joint ASIC submission for possible design fixes to be implemented ($1500), and a multi-project wafer run ($25,000).

E1. Domestic Travel: The $10,000 in domestic travel is mostly for trips to domestic conferences and companies for our R&D activities.

E2. Foreign Travel: To work effectively on the LHCb experiment we have found it necessary to either make frequent trips to CERN when possible, especially for teaching faculty, and to position ∼70% of our graduate students and postdocs at CERN for the UT installation and running, with the understanding that they can travel back to the US at least once a year. Our foreign travel request is $107,000 for the first year (then inflated) mainly for trips to CERN that will occur throughout the year as LHCb collaboration meetings are quarterly and last for a full week. There are also ``analysis and software weeks" at CERN, which we participate in, and monthly Upgrade meetings, some of which we must attend. Each trip costs about $3,000, providing the CERN Hostel is available, and we expect a total of 22 trips per year, for a total of $66,000. Another $14,000 per year is for travel of other personnel to CERN for longer stays and yearly trips back to Syracuse. The additional $27,000 per year is for Faculty to spend part of the summer working at CERN, and for conference travel of the whole group.

F. Participant Support Costs: Not Applicable

G. Other Direct Costs

1. **Materials and Supplies:** $57,000 for Personal Computer replacements and

repairs, telephone ethernet connections, printer paper and miscellaneous supplies for three years.

2. **Publication Costs/Documentation/Dissemination:** Not Applicable
3. **Consultant Services:** Wire bonder maintenance is required each year and costs $6,000 over three years.
4. **Computer Services**: $27,000 includes various software and software license purchases, including "Synopsis" for three years.
5. **Subawards:** Not Applicable

   Other: We request yearly membership costs for RD50 ($6,000) for three years

I. Indirect Costs

Indirect Costs are calculated in accordance with Syracuse University's federally negotiated indirect cost rate agreement (Department of Health and Human Services, effective 07/1/2020). The 26% off-campus research rate is applied. Operation and Maintenance costs of LHCb are for equipment, and thus are not subject to F&A. Syracuse University's threshold for equipment is $5,000

*PI/co-PI/Senior Personnel Name: Artuso, Marina

***Required fields**

Note: NSF has provided 15 project/proposal and 10 in-kind contribution entries for users to populate. Please leave any unused entries blank.

Project/Proposal Section:

Current and Pending Support includes all resources made available to an individual in support of and/or related to all of his/her research efforts, regardless of whether or not they have monetary value.[1] Information must be provided about all current and pending support, including this project, for ongoing projects, and for any proposals currently under consideration from whatever source[2], irrespective of whether such support is provided through the proposing organization or is provided directly to the individual. Concurrent submission of a proposal to other organizations will not prejudice its review by NSF, if disclosed.[3]

Please enter your support entries so they are grouped together based on the "Status of Support" and are in the order of Current, Pending, Submission Planned, and Transfer of Support from top to bottom

[1] If the time commitment or dollar value is not readily ascertainable, reasonable estimates should be provided.
[2] For example, Federal, State, local, foreign, public or private foundations, non-profits, industrial or other commercial organizations or internal funds allocated toward specific projects.
[3] The Biological Sciences Directorate exception to this policy is delineated in PAPPG Chapter II.D.2.

Projects/Proposals

1. *Project/Proposal Title : Construction of the Upstream Tracker for the LHCb Upgrade: Collaborative Research

*Status of Support : (•) Current ( ) Pending ( ) Submission Planned ( ) Transfer of Support

Proposal/Award Number (if available):

*Source of Support: NSF

*Primary Place of Performance : Syracuse University

Project/Proposal Start Date (MM/YYYY) (if available) : 08/2014

Project/Proposal End Date (MM/YYYY) (if available) : 07/2021

*Total Award Amount (including Indirect Costs): $ 4,788,744

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1. 2014	0.00	4. 2017	0.00
2. 2015	0.00	5. 2018	0.00
3. 2016	0.00		

2. *Project/Proposal Title : New interactions and new particles with LHCb

*Status of Support : (•) Current ( ) Pending ( ) Submission Planned ( ) Transfer of Support

Proposal/Award Number (if available):

*Source of Support: NSF

*Primary Place of Performance : Syracuse University

Project/Proposal Start Date (MM/YYYY) (if available) : 08/2018

Project/Proposal End Date (MM/YYYY) (if available) : 07/2021

*Total Award Amount (including Indirect Costs): $ 3,969,003

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1. 2018	2.00	4.	
2. 2019	2.00	5.	
3. 2020	2.00		

Projects/Proposals

3. *Project/Proposal Title : New physics with precision measurements of b and c quarks at LHCb

*Status of Support : ○ Current ◉ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support: NSF

*Primary Place of Performance : Switzerland (CERN)

Project/Proposal Start Date (MM/YYYY) (if available) : 08/2021

Project/Proposal End Date (MM/YYYY) (if available) : 07/2024

*Total Award Amount (including Indirect Costs): $ 4,078,634

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)
1. 2021	2.00
2. 2022	2.00
3. 2023	2.00

Year (YYYY)	Person Months (##.##)
4.	
5.	

4. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)
1.	
2.	
3.	

Year (YYYY)	Person Months (##.##)
4.	
5.	

Projects/Proposals

5. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

6. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

Projects/Proposals

7. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

8. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

Projects/Proposals

9. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

10. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

Projects/Proposals

11. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

12. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

Projects/Proposals

13. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

14. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

Projects/Proposals

15. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

In Kind Contributions

*Required fields

In-Kind Contribution Section:

Current and Pending Support also includes in-kind contributions (such as office/laboratory space, equipment, supplies, employees, students). If the in-kind contributions are intended for use on the project being proposed to NSF, the information must be included as part of the Facilities, Equipment and Other Resources section of the proposal and need not be replicated in the individual's Current and Pending Support submission. In-kind contributions not intended for use on the project/proposal being proposed that have associated time obligations must be reported below. If the time commitment or dollar value is not readily ascertainable, reasonable estimates should be provided.

Please enter your support entries so they are grouped together based on the "Status of Support" and are in the order of Current to Pending from top to bottom

1.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)
1.	
2.	
3.	

Year (YYYY)	Person Months (##.##)
4.	
5.	

*Dollar Value of In-Kind Contribution: $

In Kind Contributions

2.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

3.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

In Kind Contributions

4.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

5.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

In Kind Contributions

6.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

7.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

In Kind Contributions

8.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

9.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

In Kind Contributions

10.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

*PI/co-PI/Senior Personnel Name: Blusk, Steven

***Required fields**

Note: NSF has provided 15 project/proposal and 10 in-kind contribution entries for users to populate. Please leave any unused entries blank.

Project/Proposal Section:

Current and Pending Support includes all resources made available to an individual in support of and/or related to all of his/her research efforts, regardless of whether or not they have monetary value.[1] Information must be provided about all current and pending support, including this project, for ongoing projects, and for any proposals currently under consideration from whatever source[2], irrespective of whether such support is provided through the proposing organization or is provided directly to the individual. Concurrent submission of a proposal to other organizations will not prejudice its review by NSF, if disclosed.[3]

Please enter your support entries so they are grouped together based on the "Status of Support" and are in the order of Current, Pending, Submission Planned, and Transfer of Support from top to bottom

[1] If the time commitment or dollar value is not readily ascertainable, reasonable estimates should be provided.
[2] For example, Federal, State, local, foreign, public or private foundations, non-profits, industrial or other commercial organizations or internal funds allocated toward specific projects.
[3] The Biological Sciences Directorate exception to this policy is delineated in PAPPG Chapter II.D.2.

Projects/Proposals

1. *Project/Proposal Title : Construction of the Upstream Tracker for the LHCb Upgrade: Collaborative Research

*Status of Support : (•) Current ( ) Pending ( ) Submission Planned ( ) Transfer of Support

Proposal/Award Number (if available):

*Source of Support: NSF

*Primary Place of Performance : Syracuse University

Project/Proposal Start Date (MM/YYYY) (if available) : 08/2014

Project/Proposal End Date (MM/YYYY) (if available) : 07/2021

*Total Award Amount (including Indirect Costs): $ 4,788,744

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1. 2014	0.00	4. 2017	0.00
2. 2015	0.00	5. 2018	0.00
3. 2016	0.00		

2. *Project/Proposal Title : New interactions and new particles with LHCb

*Status of Support : (•) Current ( ) Pending ( ) Submission Planned ( ) Transfer of Support

Proposal/Award Number (if available):

*Source of Support: NSF

*Primary Place of Performance : Syracuse University

Project/Proposal Start Date (MM/YYYY) (if available) : 08/2018

Project/Proposal End Date (MM/YYYY) (if available) : 07/2021

*Total Award Amount (including Indirect Costs): $ 3,969,003

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1. 2018	2.00	4.	
2. 2019	2.00	5.	
3. 2020	2.00		

Projects/Proposals

3. *Project/Proposal Title : New physics with precision measurements of b and c quarks at LHCb

*Status of Support : ○ Current ◉ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support: NSF

*Primary Place of Performance : Switzerland (CERN)

Project/Proposal Start Date (MM/YYYY) (if available) : 08/2021

Project/Proposal End Date (MM/YYYY) (if available) : 07/2024

*Total Award Amount (including Indirect Costs): $ 4,078,634

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)
1. 2021	2.00
2. 2022	2.00
3. 2023	2.00

Year (YYYY)	Person Months (##.##)
4.	
5.	

4. *Project/Proposal Title : QuarkNet Participation Site 2018-2023

*Status of Support : ◉ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support: NSF

*Primary Place of Performance : Syracuse University

Project/Proposal Start Date (MM/YYYY) (if available) : 09/2018

Project/Proposal End Date (MM/YYYY) (if available) : 08/2023

*Total Award Amount (including Indirect Costs): $ 6,000

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)
1. 2018	0.00
2. 2019	0.00
3. 2020	0.00

Year (YYYY)	Person Months (##.##)
4. 2021	0.00
5. 2022	0.00

Projects/Proposals

5. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

6. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

Projects/Proposals

7. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

8. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

Projects/Proposals

9. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

10. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

Projects/Proposals

11. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

12. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

Projects/Proposals

13. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

14. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

Projects/Proposals

15. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

In Kind Contributions

*Required fields

In-Kind Contribution Section:

Current and Pending Support also includes in-kind contributions (such as office/laboratory space, equipment, supplies, employees, students). If the in-kind contributions are intended for use on the project being proposed to NSF, the information must be included as part of the Facilities, Equipment and Other Resources section of the proposal and need not be replicated in the individual's Current and Pending Support submission. In-kind contributions not intended for use on the project/proposal being proposed that have associated time obligations must be reported below. If the time commitment or dollar value is not readily ascertainable, reasonable estimates should be provided.

Please enter your support entries so they are grouped together based on the "Status of Support" and are in the order of Current to Pending from top to bottom

1.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)
1.	
2.	
3.	

Year (YYYY)	Person Months (##.##)
4.	
5.	

*Dollar Value of In-Kind Contribution: $

In Kind Contributions

2.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

3.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

In Kind Contributions

4.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

5.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

In Kind Contributions

6.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

7.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

In Kind Contributions

8.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

9.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

In Kind Contributions

10.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

*PI/co-PI/Senior Personnel Name: Rudolph, Matthew

***Required fields**

Note: NSF has provided 15 project/proposal and 10 in-kind contribution entries for users to populate. Please leave any unused entries blank.

Project/Proposal Section:

Current and Pending Support includes all resources made available to an individual in support of and/or related to all of his/her research efforts, regardless of whether or not they have monetary value.[1] Information must be provided about all current and pending support, including this project, for ongoing projects, and for any proposals currently under consideration from whatever source[2], irrespective of whether such support is provided through the proposing organization or is provided directly to the individual. Concurrent submission of a proposal to other organizations will not prejudice its review by NSF, if disclosed.[3]

Please enter your support entries so they are grouped together based on the "Status of Support" and are in the order of Current, Pending, Submission Planned, and Transfer of Support from top to bottom

[1] If the time commitment or dollar value is not readily ascertainable, reasonable estimates should be provided.
[2] For example, Federal, State, local, foreign, public or private foundations, non-profits, industrial or other commercial organizations or internal funds allocated toward specific projects.
[3] The Biological Sciences Directorate exception to this policy is delineated in PAPPG Chapter II.D.2.

Projects/Proposals

1. *Project/Proposal Title : New interactions and new particles with LHCb

*Status of Support : (•) Current ( ) Pending ( ) Submission Planned ( ) Transfer of Support

Proposal/Award Number (if available):

*Source of Support: NSF

*Primary Place of Performance : Syracuse University

Project/Proposal Start Date (MM/YYYY) (if available) : 08/2018

Project/Proposal End Date (MM/YYYY) (if available) : 07/2021

*Total Award Amount (including Indirect Costs): $ 3,969,003

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)
1. 2018	2.00
2. 2019	2.00
3. 2020	2.00

Year (YYYY)	Person Months (##.##)
4.	
5.	

2. *Project/Proposal Title : New physics with precision measurements of b and c quarks at LHCb

*Status of Support : ( ) Current (•) Pending ( ) Submission Planned ( ) Transfer of Support

Proposal/Award Number (if available):

*Source of Support: NSF

*Primary Place of Performance : Switzerland (CERN)

Project/Proposal Start Date (MM/YYYY) (if available) : 08/2021

Project/Proposal End Date (MM/YYYY) (if available) : 07/2024

*Total Award Amount (including Indirect Costs): $ 4,078,634

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)
1. 2021	2.00
2. 2022	2.00
3. 2023	2.00

Year (YYYY)	Person Months (##.##)
4.	
5.	

Projects/Proposals

3. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

4. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

Projects/Proposals

5. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

6. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

Projects/Proposals

7. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

8. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

Projects/Proposals

9. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

10. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

Projects/Proposals

11. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

12. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

Projects/Proposals

13. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

14. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

Projects/Proposals

15. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

In Kind Contributions

*Required fields

In-Kind Contribution Section:

Current and Pending Support also includes in-kind contributions (such as office/laboratory space, equipment, supplies, employees, students). If the in-kind contributions are intended for use on the project being proposed to NSF, the information must be included as part of the Facilities, Equipment and Other Resources section of the proposal and need not be replicated in the individual's Current and Pending Support submission. In-kind contributions not intended for use on the project/proposal being proposed that have associated time obligations must be reported below. If the time commitment or dollar value is not readily ascertainable, reasonable estimates should be provided.

Please enter your support entries so they are grouped together based on the "Status of Support" and are in the order of Current to Pending from top to bottom

1.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)
1.	
2.	
3.	

Year (YYYY)	Person Months (##.##)
4.	
5.	

*Dollar Value of In-Kind Contribution: $

In Kind Contributions

2.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

3.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

In Kind Contributions

4.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

5.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

In Kind Contributions

6.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

7.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

In Kind Contributions

8.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

9.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

In Kind Contributions

10.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

*PI/co-PI/Senior Personnel Name: Skwarnicki_Tomasz

***Required fields**

Note: NSF has provided 15 project/proposal and 10 in-kind contribution entries for users to populate. Please leave any unused entries blank.

Project/Proposal Section:

Current and Pending Support includes all resources made available to an individual in support of and/or related to all of his/her research efforts, regardless of whether or not they have monetary value.[1] Information must be provided about all current and pending support, including this project, for ongoing projects, and for any proposals currently under consideration from whatever source[2], irrespective of whether such support is provided through the proposing organization or is provided directly to the individual. Concurrent submission of a proposal to other organizations will not prejudice its review by NSF, if disclosed.[3]

Please enter your support entries so they are grouped together based on the "Status of Support" and are in the order of Current, Pending, Submission Planned, and Transfer of Support from top to bottom

[1] If the time commitment or dollar value is not readily ascertainable, reasonable estimates should be provided.
[2] For example, Federal, State, local, foreign, public or private foundations, non-profits, industrial or other commercial organizations or internal funds allocated toward specific projects.
[3] The Biological Sciences Directorate exception to this policy is delineated in PAPPG Chapter II.D.2.

Projects/Proposals

1. *Project/Proposal Title : Construction of the Upstream Tracker for the LHCb Upgrade: Collaborative Research

*Status of Support : (•) Current ( ) Pending ( ) Submission Planned ( ) Transfer of Support

Proposal/Award Number (if available):

*Source of Support: NSF

*Primary Place of Performance : Syracuse University

Project/Proposal Start Date (MM/YYYY) (if available) : 08/2014

Project/Proposal End Date (MM/YYYY) (if available) : 07/2021

*Total Award Amount (including Indirect Costs): $ 4,788,744

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1. 2014	0.00	4. 2017	0.00
2. 2015	0.00	5. 2018	0.00
3. 2016	0.00		

2. *Project/Proposal Title : New interactions and new particles with LHCb

*Status of Support : (•) Current ( ) Pending ( ) Submission Planned ( ) Transfer of Support

Proposal/Award Number (if available):

*Source of Support: NSF

*Primary Place of Performance : Syracuse University

Project/Proposal Start Date (MM/YYYY) (if available) : 08/2018

Project/Proposal End Date (MM/YYYY) (if available) : 07/2021

*Total Award Amount (including Indirect Costs): $ 3,969,003

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1. 2018	2.00	4.	
2. 2019	2.00	5.	
3. 2020	2.00		

Projects/Proposals

3. *Project/Proposal Title : New physics with precision measurements of b and c quarks at LHCb

*Status of Support : ○ Current ◉ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support: NSF

*Primary Place of Performance : Switzerland (CERN)

Project/Proposal Start Date (MM/YYYY) (if available) : 08/2021

Project/Proposal End Date (MM/YYYY) (if available) : 07/2024

*Total Award Amount (including Indirect Costs): $ 4,078,634

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)
1. 2021	2.00
2. 2022	2.00
3. 2023	2.00

Year (YYYY)	Person Months (##.##)
4.	
5.	

4. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)
1.	
2.	
3.	

Year (YYYY)	Person Months (##.##)
4.	
5.	

Projects/Proposals

5. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

6. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

Projects/Proposals

7. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

8. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

Projects/Proposals

9. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

10. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

Projects/Proposals

11. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

12. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

Projects/Proposals

13. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

14. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

Projects/Proposals

15. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

In Kind Contributions

*Required fields

In-Kind Contribution Section:

Current and Pending Support also includes in-kind contributions (such as office/laboratory space, equipment, supplies, employees, students). If the in-kind contributions are intended for use on the project being proposed to NSF, the information must be included as part of the Facilities, Equipment and Other Resources section of the proposal and need not be replicated in the individual's Current and Pending Support submission. In-kind contributions not intended for use on the project/proposal being proposed that have associated time obligations must be reported below. If the time commitment or dollar value is not readily ascertainable, reasonable estimates should be provided.

Please enter your support entries so they are grouped together based on the "Status of Support" and are in the order of Current to Pending from top to bottom

1.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)
1.	
2.	
3.	

Year (YYYY)	Person Months (##.##)
4.	
5.	

*Dollar Value of In-Kind Contribution: $

In Kind Contributions

2.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

3.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

In Kind Contributions

4.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

5.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

In Kind Contributions

6.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

7.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

In Kind Contributions

8.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

9.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

In Kind Contributions

10.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

*PI/co-PI/Senior Personnel Name: Stone, Sheldon

***Required fields**

Note: NSF has provided 15 project/proposal and 10 in-kind contribution entries for users to populate. Please leave any unused entries blank.

Project/Proposal Section:

Current and Pending Support includes all resources made available to an individual in support of and/or related to all of his/her research efforts, regardless of whether or not they have monetary value.[1] Information must be provided about all current and pending support, including this project, for ongoing projects, and for any proposals currently under consideration from whatever source[2], irrespective of whether such support is provided through the proposing organization or is provided directly to the individual. Concurrent submission of a proposal to other organizations will not prejudice its review by NSF, if disclosed.[3]

Please enter your support entries so they are grouped together based on the "Status of Support" and are in the order of Current, Pending, Submission Planned, and Transfer of Support from top to bottom

[1] If the time commitment or dollar value is not readily ascertainable, reasonable estimates should be provided.
[2] For example, Federal, State, local, foreign, public or private foundations, non-profits, industrial or other commercial organizations or internal funds allocated toward specific projects.
[3] The Biological Sciences Directorate exception to this policy is delineated in PAPPG Chapter II.D.2.

Projects/Proposals

1. *Project/Proposal Title : Construction of the Upstream Tracker for the LHCb Upgrade: Collaborative Research

*Status of Support : (•) Current ( ) Pending ( ) Submission Planned ( ) Transfer of Support

Proposal/Award Number (if available):

*Source of Support: NSF

*Primary Place of Performance : Syracuse University

Project/Proposal Start Date (MM/YYYY) (if available) : 08/2014

Project/Proposal End Date (MM/YYYY) (if available) : 07/2021

*Total Award Amount (including Indirect Costs): $ 4,788,744

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1. 2014	0.00	4. 2017	0.00
2. 2015	0.00	5. 2018	0.00
3. 2016	0.00		

2. *Project/Proposal Title : New interactions and new particles with LHCb

*Status of Support : (•) Current ( ) Pending ( ) Submission Planned ( ) Transfer of Support

Proposal/Award Number (if available):

*Source of Support: NSF

*Primary Place of Performance : Syracuse University

Project/Proposal Start Date (MM/YYYY) (if available) : 08/2018

Project/Proposal End Date (MM/YYYY) (if available) : 07/2021

*Total Award Amount (including Indirect Costs): $ 3,969,003

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1. 2018	2.00	4.	
2. 2019	2.00	5.	
3. 2020	2.00		

Projects/Proposals

3. *Project/Proposal Title : New physics with precision measurements of b and c quarks at LHCb

*Status of Support : ○ Current ◉ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support: NSF

*Primary Place of Performance : Switzerland (CERN)

Project/Proposal Start Date (MM/YYYY) (if available) : 08/2021

Project/Proposal End Date (MM/YYYY) (if available) : 07/2024

*Total Award Amount (including Indirect Costs): $ 4,078,634

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)
1. 2021	2.00
2. 2022	2.00
3. 2023	2.00

Year (YYYY)	Person Months (##.##)
4.	
5.	

4. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)
1.	
2.	
3.	

Year (YYYY)	Person Months (##.##)
4.	
5.	

Projects/Proposals

5. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

6. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

Projects/Proposals

7. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

8. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

Projects/Proposals

9. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

10. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

Projects/Proposals

11. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

12. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

Projects/Proposals

13. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

14. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

Projects/Proposals

15. *Project/Proposal Title :

*Status of Support : ○ Current ○ Pending ○ Submission Planned ○ Transfer of Support

Proposal/Award Number (if available):

*Source of Support:

*Primary Place of Performance :

Project/Proposal Start Date (MM/YYYY) (if available) :

Project/Proposal End Date (MM/YYYY) (if available) :

*Total Award Amount (including Indirect Costs): $

*Person-Month(s) (or Partial Person-Months) Per Year Committed to the Project

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

In Kind Contributions

*Required fields

In-Kind Contribution Section:

Current and Pending Support also includes in-kind contributions (such as office/laboratory space, equipment, supplies, employees, students). If the in-kind contributions are intended for use on the project being proposed to NSF, the information must be included as part of the Facilities, Equipment and Other Resources section of the proposal and need not be replicated in the individual's Current and Pending Support submission. In-kind contributions not intended for use on the project/proposal being proposed that have associated time obligations must be reported below. If the time commitment or dollar value is not readily ascertainable, reasonable estimates should be provided.

Please enter your support entries so they are grouped together based on the "Status of Support" and are in the order of Current to Pending from top to bottom

1.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)
1.	
2.	
3.	

Year (YYYY)	Person Months (##.##)
4.	
5.	

*Dollar Value of In-Kind Contribution: $

In Kind Contributions

2.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

3.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

In Kind Contributions

4.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

5.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

In Kind Contributions

6.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

7.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

In Kind Contributions

8.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

9.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

In Kind Contributions

10.*Status of Support : ○ Current ○ Pending

*Source of Support :

*Primary Place of Performance :

*Summary of In-Kind Contributions :

Time Commitment - Month(s) (or Partial Person-Months) Committed Per Year

If the time commitment is not readily ascertainable, reasonable estimates should be provided.

*Year (YYYY)	*Person Months (##.##)	Year (YYYY)	Person Months (##.##)
1.		4.	
2.		5.	
3.			

*Dollar Value of In-Kind Contribution: $

FACILITIES EQUIPMENT & OTHER RESOURCES

Laboratory: Two rooms 700 sq. ft for construction and testing. One class 100 clean room, 90 sq. ft., two class 1000 clean rooms one 25x25 ft^2 and the other 10x20 ft^2, and another room 200 sq. ft. for testing assemblies and associated electronics.

Computer: We have a farm configured with 21 Intel Xeon CPU at 2.66 GHz, 2.7 TB of normal disk on individual nodes, and 3.2 TB RAID disk on an disk server, all on a local network with GBPS a switch. Nine Dec. ALPHA compatible machines (3 OSF) (6 LINUX) 500 MHz with 1000 gigabites of storage. Faculty, postdocs and graduate students all have PC's. We also have access to Syracuse Universities "Green data center."

MAJOR EQUIPMENT:
One FTK 64/6400 fully automatic wire bonder. One Nordson Dage 4000 bond tester. Two Flash 200 SmartScope semiautomatic measuring machines that also digitize shapes. One Keyence VHX950 digital microscope, with camera, and zoom lens. A Tektronix DSA70404C 4 GHz Digital Serial Analyzer with four analog channels, along with Tetronix P7504 4 GHz trim mode differential probe. Cascade Microtek REK3200 Probe Station equipped with a variety of microprobes and two active probes. Kulicke and Soffa semi-automatic wire bonding station model 4523. Quad Tech 7600 precision LCR meter, Keithely 237 HV Power Source measuring unit., Keithley 2002 multimeter, and Keithely 619 electrometer/mulitmeter. One SmartScope Flash 200 precision optical measuring system. A 1060 CERN Laser system; homemade transmission spectrophotometer with x-y state capable of measuring in the range 120-450 nm. Capability for PCB design.

OTHER RESOURCES Use of Physics department machine shop including CNC milling machine with 5 ft. x 5 ft. bed., and two CNC milling machines.

OTHER RESOURCES SUPPLIED BY THE LHCb COLLABORATION The LHCb collaboration is providing data acquisition crates and technical infrastructure at Point 8 of the LHC where the LHCb detector is being installed.

Data Management Plan

The LHCb experiment acquires data from the detector at a rate of approximately 30 kHz with the Upgrade II detector. This data sample is not stored but examined in the higher level trigger software for interesting events and then reconstructed. This data is saved. The next step is to further select the interesting events some of which are sent to "turbo' lines fully reconstructed in separate categories and selected via a processes called "sprucing", with most of the uninteresting tracks or photon candidates are not kept. There are also some spruced selections that keep all the tracks and photon candidates. The resulting data sample is archived by the experiment at CERN. Everyone in the collaboration is welcome to add selections to the sprucing. However it is closely monitored as there are constraints on the overall CPU usage and available disk space. The turbo or spruced data is available to everyone in the collaboration to use for further physics analysis. The use of the data soon after it is collected is restricted to collaboration members.

The current plan is that turbo and spruced selected data, associated simulations, and analysis software will be made available at minimally the 50% level five years after collection and 100% after 10 years following application by persons outside of LHCb to the Collaboration Board. This plan could be modified by CERN after further discussions.

The Syracuse group does not need a detailed plan for data management as we do not store any raw data ourselves. We adhere to the general LHCb plan described briefly above.

Postdoctoral Researcher Mentoring Plan

Three postdoctoral researchers will be supported by this project and their professional development will be enhanced by a structured program of mentoring activities. The goal of this program is to ensure that the postdocs gain the scientific, technical, and professional skills necessary to excel in their careers. To accomplish this goal, the plan will generally follow the mentoring guidance informed by Enhancing the Postdoctoral Experience for Scientists and Engineers: A Guide for Postdoctoral Scholars, Advisers, Institutions, Funding Organizations, and Disciplinary Societies (National Academies of Science & Engineering and Institute of Medicine, 2000) enhancing the postdoctoral experience. A structured mentoring plan will be pursued that includes career planning assistance, and opportunities to learn a number of critical skills such as writing grant proposals, teaching students, writing articles for publication, communication skills and supervising employees and mentoring students.

Specific elements of the mentoring plan will include:

- Development of an individual development plan to define the expectations and goals of postdoctoral researcher. Through a combination of self assessment and formal evaluations (at least annually) the postdoc will ensure that their goals are appropriate and are being achieved.

- Advice on preparation of the teaching statement required for a faculty application, and voluntary participation in seminars and workshops on teaching and learning.

- Attendance at the weekly Physics Department colloquia for those at Syracuse, or talks at CERN for those postdocs at CERN.

- Participation in our bi-weekly research group meetings. All group members will be expected to present their research regularly, and feedback and coaching will be given to help all members to develop their communication and presentation skills. These meetings are often used as preparation for the next item.

- Postdocs also present results of their efforts at LHCb collaboration working groups. (Even those postdocs who are at Syracuse participate via video conferencing). These presentations are crucial to their development in expressing complicated ideas and are ideal vehicles for learning how to teach.

- Presentation of research results at one or more conferences each year.

Success of this mentoring plan will be assessed by tracking the progress of the postdoctoral researchers through their individual development plan, with interviews to assess the postdocs satisfaction with the mentoring program, and tracking of the postdoctoral fellows progress toward their career goals after finishing the postdoc.