From the ALD's Desk
RHIC News Bulletin Update

July 2018

As we celebrated this year's Independence Day holiday, there was much in the "world of RHIC" to rejoice in. The 2018 RHIC run turned out to be another spectacular success, exceeding the goal for the number of recorded events for the isobar system (^{96}Zr and ^{96}Ru) by 150%. The FY 2018 operations budget for RHIC turned from expectations of a very painful cut into a healthy increase that sustains 28 cryo-weeks of accelerator/cryo-operations, thanks to the FY2018 Congressional appropriation for Nuclear Physics. The necessary upgrades for the high-statistics beam energy scan are proceeding according to plan, and sPHENIX successfully passed the major hurdle of its Critical Decision 1 review. However, while there is ample reason to celebrate, we cannot take our eyes off the ball: The preparations for Beam Energy Scan II have a tight and challenging schedule, both technically and scientifically, and every year of record breaking performance and results raises the expectations. With this in mind, I hope that the successes reported in this edition of the RHIC Bulleting provide ample motivation to focus on the work ahead.

RHIC Run-18: The 15 cryo-week RHIC Run 18 had three components: The highest priority of the run was the comparison of the two isobar systems (^{96}Zr and ^{96}Ru, with 40 and 44 protons, respectively). The STAR detector collected more than 3 million minimum bias events for each system, 250% of the original goal. The different electric charge of the two systems is results in an approximately 15 percent difference in the short-lived magnetic field that is thought to drive the "chiral magnetic effect". The data will allow to measure observables that can be attributed to this CME with a statistical uncertainty of only about 4 percent of the expected difference and thus will be able to establish the presence of the CME even it is only a tiny contribution to the observable.

This is the first time that RHIC scientists aim at a comparative measurement with this kind of precision the RHIC operators and scientists have taken unprecedented steps: RHIC switched between the two systems fill by fill, and the data have been recorded in such a way that they can be analyzed in a blinded manner.

The second component of the run was a 3-week Au+Au run at 27 GeV. The primary goal of this part of the run was to collect high statistics data for a measurement of the global Lambda hyperon polarization, to confirm the recently published results and to attempt a measurement of the difference between the polarization of hyperons and anti-hyperons that could indicate the presence of a persistent magnetic field at the moment of hadron emission. This goal ties back to the isobar comparison run because a clear manifestation of the chiral magnetic effect requires the presence of long-lived magnetic fields in the quark-gluon plasma. STAR collected more than 500 milion "good" events in this part of the run.

The third component of the run was a prototype fixed target run at the center-of-mass energy of 3.0 GeV per nucleon pair as a test for the internal fixed target component of the beam energy scan. This part of the run also succeeded beyond expectations, recording 300 million events in three days, three times as much as originally planned.

RHIC Operations: RHIC Run 18 posed new challenges for the machine, with six different modes in total - and typically interleaved operation requiring fast switches between modes. For collisions of ^{96}Zr with ^{96}Zr and ^{96}Ru with ^{96}Ru at a center-of mass energy of 200 GeV STAR requested switching between the two species every store and have store conditions as closely matched as possible. This had never been done before in any collider in the world. In addition, the two isotopes, ^{96}Zr and ^{96}Ru, have natural abundances of only 3% and 6% respectively, and making beams is difficult. It took many technologies developed over the lifetime of RHIC to fulfill STAR's demanding request, ranging from the world-class ion sources, injector developments, beam-based feedbacks to stochastic cooling.

The ^{96}Ru beam was a particular challenge since no enriched material is commercially available. With support from DOE, ORNL made a special enrichment run for ^{96}Ru in a newly commissioned stable isotope enrichment facility. For the ^{96}Zr target preparation the RIKEN Laboratory in Japan provided invaluable help. All in all, the meticulous preparation and help from DOE, ORNL, and RIKEN paid off as all goals could be met or exceeded.

Equally successful was the Au+Au portion of the run, with collisions at 27 GeV center-of-mass energy, and in Au+Au fixed target operation with 3.85 GeV beam energy - the lowest energy at which RHIC can operate. The projected luminosity was exceeded by delivering a higher bunch intensity than anticipated.

In addition, the machine ran for more than a week in dedicated mode in support of the Coherent electron Cooling Proof-of-Principle (CeC PoP) experiment and supported the commissioning of the Low-Energy RHIC electron Cooling (LEReC) upgrade project. Until mid-September RHIC is continuing with LEReC electron beam commissioning for a total of 28 weeks of cryo-operations.

PHENIX: The PHENIX collaboration presented many new results at the Quark Matter 2018 Conference that included both, preliminary results and ones summarized in 8 new papers submitted for journal publication before the conference. Some highlights of the results are:

- Elliptic and triangular flow measured in central p+Au, d+Au, and ^{3}He+Au collisions were shown to be simultaneously described by hydrodynamical models assuming formation of a short-lived QGP droplet in these systems. A paper on these results were submitted to Nature Physics.
- A scaling behavior was discovered for the yield dN/deta of direct photons with low transverse momentum over a variety A+A collision systems in all centralities and wide range of collision energies. If direct photon yield in p+p collisions was scaled in the same way, the yield was found to be much smaller than that in A+A collisions, implying the transition from small p+p yield to enhanced A+A yield. A paper on these results was submitted to Physical Review Letters.

- Preliminary results of low p_T direct photon measurement show a hint of enhanced production of low p_T direct photons in central p+Au collisions. This is consistent with formation of small droplet of hot QGP in central p+Au collisions.
- Bottom and charm pair production mechanisms were studied through the novel analysis technique utilizing measurements of muon and electron pairs in p+p collisions, which resulted also in the first measurement of Drell-Yan process at RHIC. One paper on these results was submitted to Physical Review D, and another paper was submitted to Physical Review Letters.
- First RHIC results on bottom quark elliptic flow were also presented.

STAR: STAR far surpassed its goal of 1.5 billion events for both, Ru+Ru and Zr+Zr collisions. The collaboration thanks C-AD for providing incredibly stable luminosity levels, long stores of 20 hours and more, and daily switching between isobars to minimize systematic uncertainties. In addition, excellent data were collected in Au+Au collisions at 27 GeV and 3 GeV. The event plane detector (EPD), the first sector of the iTPC, and an eTOF module were commissioned and operated at, or beyond, specifications. The remaining iTPC and eTOF modules will be installed during a very busy summer/fall shutdown in preparation for the much-anticipated BES-II.

As usual, STAR had a strong presence at QM2018 with 19 invited oral presentations, and 32 poster presentations. In addition, five STAR collaborators gave invited plenary presentations and Daniel Brandenberg presented a flash talk on account of his outstanding poster. In June, the PAC agreed we should place highest priority on accomplishing the BES-II program, and commended STAR for developing and sharpening our forward physics program, which enriches the range of future opportunities for BNL.

Congratulations go to John Campbell, Leszek Kosarzewski, Zhen Liu, Maowu Nie, Isaac Upsal, and Shenghui Zhang, who all defended their Ph.D. theses since January 2018. At the RHIC/AGS Users meeting Jan Rusnak and Ting Lin were awarded the Best Thesis Prize, while Amani Kraishan won the Best Poster Award. Merit awards went to Jim Drachenberg, Xiaofeng Luo, Takafumi Niida and Isaac Upsal. Sevil Salur, Oleg Eyser, Frank Geurts, Sooraj Radhakrishnan, and David Tlusty were newly elected to the Users Executive Committee.

Since January, STAR has published 6 papers and submitted 6 new papers for publication. In heavy ions the topics of these papers range from investigations of the beam energy dependence of jet quenching, rapidity-even dipolar flow, and directed flow of strange hadrons, to the hypertriton's lifetime, low-p_T dilepton pair production, global hyperon polarization at 200 GeV, the elliptic flow of the D^0, correlations between flow harmonics and J/Ψ production in p+p, while the Cold QCD/Spin groups reported on the transverse spin-dependent correlations of charged pions and the azimuthal transverse single-spin asymmetries of inclusive jets at 500 GeV, as well as the longitudinally double-spin asymmetries of di-jets at 200 GeV and forward π^0s at 510 GeV.

sPHENIX: The sPHENIX project successfully passed the DOE Office of Project Assessment (OPA) CD-1/3A review held on May 23-25, 2018 at BNL. This review panel scrutinized the project's cost and schedule plans and the proposed long lead-time procurements. The

review committee recommended that sPHENIX receive CD-1/3A approval pending a few modest revisions, and optimistic that formal DOE approval will come later this summer.

sPHENIX collaborators traveled to Fermilab again this year for the experiment's most sophisticated and extensive beam test so far. The exercise began in February, continued in phases through the end of May, and showcased advanced prototypes of the full calorimeter stack, the silicon trackers, the readout electronics, and even a bucket-sized version of the time projection chamber. The collected data are being used to validate a number of refinements made since last year's beam test. As always, the collaboration enjoyed great support from the staff of the Fermilab test beam facility. A review of the software and computing plans for sPHENIX was held on June 18, 2018. The review concluded that the presented estimates of S&C needs were fundamentally sound but recommended a follow-up review of more detailed plans within a 12-18 months timeframe.

The sPHENIX collaboration has had strong showings at recent conferences, including at Quark Matter 2018 in Venice, Italy, with a talk by Yongsun Kim (ISU) and with ten posters detailing the science and the technology of the experiment. A task force was established to update by the end of September an earlier Letter of Intent describing how sPHENIX could serve as the basis for an EIC detector. The sixth sPHENIX collaboration meeting was held during the second week of June, this time at BNL, with about 70 people participating, in person and by phone. The two-day meeting featured a packed agenda and included presentations by new institutions looking to join the growing collaboration.

RHIC Users' Meeting: Scientists and others with a stake in the research taking place at the Relativistic Heavy Ion Collider (RHIC) and Alternating Gradient Synchrotron (AGS) gathered at the U.S. Department of Energy's (DOE) Brookhaven National Laboratory June 12-15, for their annual users' meeting. In a series of workshops and plenary sessions, attendees from across the nation and around the world had a chance to catch up on the latest research results across all aspects of the RHIC-AGS scientific program and engage in conversations about the exciting plans that lie ahead.
Keynote speakers at this year's users' meeting included Tim Hallman, Associate Director of the DOE Office of Nuclear Physics, Allena Opper, Nuclear Physics Program Director at the National Science Foundation, and Berndt Mueller, BNL Associate Laboratory Director for Nuclear and Particle Physics, and BNL Laboratory Director Doon Gibbs. Hallman and Opper described the plans and opportunities of the nuclear physics programs at DOE and NSF. Hallman highlighted the remarkable operational successes and continued scientific discoveries of RHIC and praised RHIC as "a facility that's unparalleled in the world for heavy ion and spin research."

The bulk of the program focused on new results from the STAR and PHENIX collaborations: The latest data from the beam energy scan; characteristics of tiny droplets of quark-gluon plasma created in collisions of small particles with larger nuclei; details of how different types of particles containing heavy quarks interact with the QGP; new measurements of the vorticity of RHIC's quark-gluon plasma; and new data from collisions of polarized proton beams that are revealing how quarks and gluons contribute to proton spin. The steadily growing effort directed at scientific and technical R&D for a future electron-ion collider also garnered significant attention.

The user's meeting devoted considerable time to the discussion of community values, in particular, respect for others, inclusion and diversity, and career development. Shirley Kendall gave a presentation on the BNL's plan to foster an environment in which everyone at the Laboratory—representing diversity in all its forms—values and respects one another while working together. Major initiatives described by Kendall included the Lab's efforts to recruit, develop, and retain a diverse, talented workforce; prevent discrimination and profiling; and educational outreach and community involvement. This was followed by a session in which attendees heard personal accounts from two individuals who have pursued differing career paths: Dave Winter who made his way from physics to the global bond marketplace, and Megan Connors, who now participates in the sPHENIX collaboration as a professor at Georgia State University and gave a talk titled "How Did I Get Here." They were then joined by a diverse group of attendees for a panel discussion on career tips.

RHIC/AGS PAC: The Program Advisory Committee (PAC) convened on June 7 – 8, 2018, to evaluate the STAR Beam Use Request for Runs 19 and 20 and comment on the overall RHIC program. The PAC was presented with the status of ongoing analysis efforts and publications from the STAR, PHENIX, and RHICf research programs. The PAC heard a status report on the STAR upgrades for the Beam Energy Scan II and STAR Plans for physics beyond the beam energy scans. In addition, presentations were made on the performance of RHIC during Run-18, a status report on the science program and progress in sPHENIX, an update of the proposed science program for an EIC detector based on sPHENIX, the Coherent electron Cooling Proof of Principle Experiment, and a report on the status and the prospects for the Low Energy RHIC electron Cooling (LEReC).

The PAC was impressed by the successful installation of the EPD, fixed-target protptype run, and the iTPC sector test, which positions STAR to be able to pursue the BES-II goals. The PAC placed highest priority for runs 19, 20, and 21 on accomplishing the BES-II program; within this program highest priority running should be placed on the 7.7 GeV collider run. The PAC also commended the CA-D for bringing LEReC to the state of the art that it is today and stated that the highest priority for CAD and RHIC for the coming year is the commissioning and successful operation of LEReC.

In detail, the PAC recommendations for Run 19 are:

- Commissioning of LEReC for beams that yield Au+Au collisions with center-of-mass energy $\sqrt{s_{NN}}$ = 7.7 GeV and, if possible, also for beams that yield Au+Au collisions with $\sqrt{s_{NN}}$ = 9.1 GeV.
- The highest priority for data acquisition in Run 19 is Au+Au collider runs at $\sqrt{s_{NN}}$ = 19.6 and 14.5 GeV accumulating at least 400M and 300M minimum bias events, respectively. This will begin the BES II program by acquiring the full data sets needed for all analyses proposed at these two highest BES energies, where LEReC is not needed.
- The next priority for Run 19 is acquiring at least 100M events in fixed-target Au+Au collisions with $\sqrt{s_{NN}}$ = 3.9, 4.5, 7.7 GeV, beginning the fixed-target component of the BES II program, thus extending its reach to lower energies and higher baryon density.

EIC News: The eagerly awaited release of the report of the National Academies assessment is expected in the first half of July. The Next EIC Users Group Meeting will be held on July 30 – August 31, 2017 at the Catholic University in Washington, DC. The meeting will provide updates from BNL and JLab, reports from the funding agencies, and talks about progress of EIC science and accelerator design efforts.

A draft version of the pre-conceptual design report describing BNL's ring-ring reference design for eRHIC was favorably reviewed by a committee of experts in April 2018 and is now in the final stages of editing. The new $7M national program funding R&D for future accelerators for nuclear physics, aimed at developing critical technologies for an electron-ion collider, received its first round of competitive awards.

The joint SBU/BNL Center for Frontiers of Nuclear Science (CFNS) held its first workshop on June 4-6, 2018 at Stony Brook University on the topic *Next-generation GPD studies with exclusive meson production at an EIC.* Future workshops on *Probing quark-gluon matter with jets*, *Short-range nuclear correlations at an electron-ion collider, Quantum entanglement at collider eneries,* and *Forward Physics and instrumentation from colliders to cosmic rays* are presently being organized. Interested scientists are encouraged to consult the CFNS webpage for details.