Recommendations of the Nuclear and Particle Physics Program Advisory Committee, Brookhaven National Laboratory

June 10 – 11, 2019

1. Executive Summary

The Program Advisory Committee (PAC) convened on June 10 – 11, 2019, to evaluate the STAR Beam Use Request for completion of the Beam Energy Scan II (BES-II) in Runs 20 and 21, and plans for possible Run 22 running. The PAC was also presented a request for the use of the RHIC beam for further investigation of Coherent electron Cooling. The progress in ongoing analysis efforts and publications from the STAR, PHENIX and RHICf research programs was presented.

The PAC heard a status report on the STAR upgrades for the BES-II, as well as forward physics and physics beyond the beam energy scans. In addition, presentations were made on the performance of RHIC during Run-19, a status report on progress in sPHENIX, a report on the status of the Low Energy RHIC electron Cooling (LEReC), and a report on progress with Coherent electron Cooling (CeC) for possible use in an Electron Ion Collider.

The PAC thanks the collaborations for their work and presentations, and the collaborations and C-AD for their input and cooperation in responding to questions. We commend C-AD and STAR for the successful completion of the runs at the two highest energies in the BES-II program. The performance of RHIC was outstanding. STAR is congratulated for the successful installation, operation and the performance of the iTPC, which positions STAR to be able to complete successfully the BES-II Run Program.

The PAC places highest priority on accomplishing the BES-II program. We commend the C-AD for its success with LEReC, having just accomplished electron cooling using a bunched electron beam. Once commissioned in the collider, it should enable RHIC to accomplish the BES-II Program. This is the highest priority for C-AD at RHIC. In the coming two years, in Run 20 and 21, RHIC is poised to execute the lower energy BES-II runs, that rely upon cooling of the low energy beams, and that are needed in order to realize the significant discovery potential of this program. We look forward with anticipation to the results of the BES-II with the 2019, 2020 and 2021 runs.

The PAC commends both the PHENIX and the STAR collaborations for their outstanding scientific productivity and for delivering stimulating discoveries and high-impact publications, and continued production of PhDs. The PAC is pleased to see that bottlenecks in data production have been addressed in both STAR and PHENIX and that plans are in place for timely production of all data sets taken. The PAC appreciates BNL management efforts to consolidate HEP and NP computing resources and provide expert support serving the RHIC experiment needs.

The investigation of small systems to determine the extent to which the QGP persists as the system size is decreased is a topic of intensive study at both RHIC and the LHC. A highlight of the heavy-ion program this year is the PHENIX publication indicating formation of small QGP droplets by changing projectile nuclei (H, ^{2}H and ^{3}He) to produce three different initial collision geometries.

PHENIX has also reported that in A+A collisions the yield of direct photons scales as a power law as a function of overall multiplicity and is independent of beam energy or system size, suggesting that direct photons at a transverse momentum around 1 GeV/c are also mainly produced from the hadronization region.

STAR has published a number of important results, which include a comprehensive paper on strange hadron production over the BES I energies, first measurement of the directed flow (v_1) of D-mesons, the mass of the Hypertriton, and papers on their investigation of quarkonium production as a function of centrality and transverse momentum in Au+Au and U+U, as well as p+p measurements. The PAC is pleased to see that STAR is finalizing papers from BES I on the beam energy dependence of net-proton cumulants, intended for Nature Physics, and a longer more detailed journal publication.

Furthermore, STAR has extended previous system comparisons of the azimuthal anisotropy with a comprehensive study of large and small systems. Although the azimuthal anisotropy (v_2) is system-dependent, they have found that when it is divided by the eccentricity (e_2), it (v_2/e_2) scales for all system sizes from U+U down to p+Au.

A highlight of the RHIC spin program is the STAR measurement of longitudinal spin asymmetries for weak boson production in polarized proton-proton collisions elucidating the role of the sea quarks in the proton spin. PHENIX also found that the transverse single-spin asymmetry of forward hadrons, A_N, decreases with target mass, which represents progress towards understanding the contributions to A_N of the Sivers and Collins effects.

The PAC congratulates BNL and the sPHENIX collaboration on the successful PD-2/3 review, and recognizes the progress in the technical development towards commencement of the detector construction phase. The PAC commends the sPHENIX Collaboration on the progress made on detailed studies of the sPHENIX capabilities on key physics topics of Upsilon production, jet structure and tagged parton energy loss, and heavy flavor measurements.

2. The Beam Use Request

2.1 Discussion and Recommendations for RHIC Run 20

The successful completion of the runs at the two highest energies in the BES-II program during Run 19 and the substantial progress made by the C-AD on commissioning LEReC positions the RHIC program for successful completion of the BES-II research program. In Run 20 and 21, RHIC is poised to execute the lower energy BES-II runs, runs that rely on cooling of the low energy beams and that are needed in order to realize the significant discovery potential of this physics program. The PAC described the motivations and the discovery potential for this program in its reports from each of the past several years and is pleased to see it underway. The PAC looks forward to seeing results next year from the Run 19 data taking, as these data may influence our recommendations for Run 21.

Our recommendation for Run 20 is contingent on advice from C-AD that is anticipated before the end of this Summer. Because the C-AD has been commissioning LEReC this year for operation with $\sqrt{s_{NN}}$ = 7.7 GeV, their preference at the time of this meeting is to run at $\sqrt{s_{NN}}$ = 7.7 GeV in Run 20. This is also the preference of the PAC and, we understand, of STAR. From the PAC perspective, this is the highest priority running for Run 20 because it is at this energy that the error bars from BES-I measurements are the largest and so is the discovery potential. Running at $\sqrt{s_{NN}}$ = 7.7 GeV in Run 20 will then result in running at $\sqrt{s_{NN}}$ = 9.1 GeV in Run 21. Assuming that this remains the preference of the C-AD at the end of this Summer, our recommendations for Run 20 are:

First priority: *The PAC recommends a run with Au+Au collisions at $\sqrt{s_{NN}}$ = 7.7 GeV that employs LEReC cooling and yields at least 100M min bias collisions. We reiterate the assessment of the PAC from its previous two meetings that this run is the highest priority among the planned BES-II runs.* This should be second in the RHIC run sequence.

Second priority: *The PAC recommends a run with AuAu collisions at $\sqrt{s_{NN}}$ = 11.5GeV (with no LEReC cooling at this energy) that yields at least 230 M min bias events.* This should be placed first in the RHIC run sequence with LEReC commissioning interspersed during this run.

Third priority: *The PAC recommends 2-day runs of fixed target collisions at each of the five energies that complete the fixed target component of the BES-II program, namely $\sqrt{s_{NN}}$ = 3.5, 4.5, 5.2, 6.2 and 7.7 GeV.* The specific RHIC run sequencing will need to be determined based on logistical considerations. *Of these energies, the top priority is $\sqrt{s_{NN}}$ = 7.7 GeV, as this will allow benchmarking comparisons between measurements of the same observables made in fixed-target and collider mode.* The comparison between measurements made with this fixed-target data and with collider data taken at the same $\sqrt{s_{NN}}$will be very important. Making the same measurements with very different systematics offers the opportunity to gain confidence in these results, and in measurements made at lower fixed-target energies, and hence the opportunity to enhance the lasting scientific impact of the BES II program. STAR and BNL should assess the potential value of a few extra days of fixed-target running at $\sqrt{s_{NN}}$ = 7.7 GeV, in particular to acquire a larger data set allowing for more differential comparisons with data from the future collider run and measurement of the full rapidity dependence of various observables using data from the fixed-target and collider runs in concert.

Fourth priority: *8 days of running for the Coherent Electron Cooling experiments, for the purpose of demonstrating the amplification of the imprint that the ion beam leaves on the electron beam.* However, this recommendation is contingent on the Laboratory finalizing a decision to proceed with these experiments. This decision should be made only after the results from this year's experiments become available and after review of the Coherent Electron Cooling program by a committee with appropriate expertise. The experiments were underway at the time of our meeting and not completed, and have the goal of the reducing noise.

If by the end of this summer the preference of the C-AD has changed such that they prefer to run $\sqrt{s_{NN}}$ = 9.1 GeV collisions with LEReC cooling in Run 20, this run -- yielding at least 160M min bias collisions, would be the first priority recommendation of the PAC, but second in the sequence, for Run 20.

2.2 Discussion and Recommendations for RHIC Run 21

On the assumption that the $\sqrt{s_{NN}}$ = 7.7 GeV run has been completed during Run 20, the PAC recommends as top priority for Run 21 a run with $\sqrt{s_{NN}}$ = 9.1 GeV and LEReC cooling that yields at least 160M min bias collisions. If it turns out that this run has been accomplished in Run 20, then the PAC recommends as top priority for Run 21 a run with $\sqrt{s_{NN}}$ = 7.7 GeV and LEReC cooling that yields at least 100M min bias collisions.

If the CeC experiment that we list as 4th priority for Run 20 has gone ahead, and has been successful in demonstrating the imprint that the ion beam leaves on the electron beam, our second priority recommendation for Run-21 is the continuation of CeC experimentation, with 14 days of running devoted to the CeC experiment for the purpose of demonstrating coherent electron cooling. If this can be demonstrated it would be of considerable significance for the planning of an EIC program, and hence for the Laboratory. We hope to frame this recommendation with fewer caveats at our meeting next year, after hearing the outcome of this year's experiments, the review of the CeC program that we recommend, and after hearing at least an initial report on the Run 20 experiments if they have gone ahead.

Our two remaining requests for Run 21 are at present not ordered in priority. In both cases, we will finalize our recommendations only at our meeting next year as we anticipate hearing more fully articulated science cases for these possible runs at that time. *One of these is an additional BES-II run with AuAu collisions with $\sqrt{s_{NN}}$ = 17.1 GeV (and no LEReC cooling) that yields 250M min bias collisions. The other is a 1 week run of O+O collisions at an energy of $\sqrt{s_{NN}}$ = 200 GeV, anticipating 400 M min bias collisions.*

To make the case for a $\sqrt{s_{NN}}$ = 17.1 GeV run, the key input will be results from measurements of fluctuation observables from Run-19 data taken at $\sqrt{s_{NN}}$ = 19.6 and 14.6 GeV. If these measurements, with the smaller error bars that are anticipated, show evidence for a possible two-peaked structure in the plot of net proton kurtosis or other fluctuation observables as a function of $\sqrt{s_{NN}}$, this could at that time become a strong argument for a run at $\sqrt{s_{NN}}$ = 17.1 GeV.

With regards to an O+O run, the case for this could become persuasive if, between now and next year, theorists with expertise in hydrodynamics can provide some simulations that demonstrate what hydrodynamics predicts for v_2 and v_3 behavior in O+O collisions, and how this compares to results from p+A, Cu+Cu, and Au+Au collisions. We also suggest that these calculations should be undertaken for α+α, Be+Be, Al+Al and Ar+Ar collisions also, as well as for O+Au and other asymmetric small+large nuclear collision options, so as to be able to make the case that O+O is the optimal physics choice, most likely to yield new or substantially improved understanding of questions relating to how small droplets of QGP equilibrate and what is the smallest droplet of QGP that is possible to be formed in collisions at $\sqrt{s_{NN}}$ = 200 GeV.

2.3 Looking Ahead to RHIC Run 22

The PAC heard the status and plan for the STAR Forward Upgrade, to be discussed in a later section of this report. Anticipating the completion of this upgrade by September 2021, the STAR collaboration is considering a dedicated polarized pp run at 500 GeV in Run 22 to explore spin physics opportunities provided by the forward upgrade as well as the new subsystem, iTPC. With 16 weeks of pp running, either with longitudinally or transversely polarized beams, new kinematic regions in large and small *x*, yet unexplored in the RHIC-spin program, can be investigated.

The primary physics goal presented by the STAR collaboration for a possible transverse pp run is to extract the quark transversity distribution in the large *x* valence region. Recent results from STAR, based on the analysis of the 2011 transverse pp run, indicate that the quark transversity distribution can be measured through the Collins asymmetry in the hadron-jet azimuthal angular correlation. While the observation of a non-zero Collins effect for π^+-jet and π^--jet events at the largest value of jet p_T and the hadron fractional momentum is very interesting, it should be cautioned that there remain many theoretical challenges, such as the applicability of factorization in this particular process and the large uncertainty of the Collins gluon fragmentation functions, before a reliable determination of the quark transversity distributions can be obtained. As the overall uncertainty of the 2011 result is dominated by statistics, a timely analysis of the much higher statistics 2017 data would be crucial for evaluating the merit of obtaining additional 500 GeV transverse pp data. New results from the 2017 data on the hadron-in-jet Collins asymmetry are likely to motivate further theoretical work on this subject.

To further strengthen the case for a 2022 run to improve the current knowledge on the transversity distribution and the comparison of measured tensor charges with lattice QCD calculations, it would be very helpful for STAR to evaluate the impact of the proposed measurement on the expected improvement of the precision of u and d quark tensor charges.

The main scientific program for a possible longitudinal polarized 500 GeV pp run in 2022 would center on the measurement of gluon polarization at small *x* using dijet production. The proposed STAR forward calorimeter system will cover the region $2.8 < \eta < 3.7$, allowing the dijet measurement to probe the gluon helicity distribution down to $x \sim 10^{-3}$, which is currently poorly constrained from existing data. This is clearly an important measurement to further pin down the origin of proton's spin.

The PAC considers the physics case for a pp run at 500 GeV to be very strong, and stresses again the importance of a timely analysis of the 2017 data with transverse polarization, which should be given high priority. These results will be very important for deciding the beam polarization to be proposed for a fSTAR run in 2022, and for further sharpening of the physics case that we expect to hear at the PAC next year.

3. RHIC Data and Physics Analysis

The STAR and PHENIX collaborations continue to deliver breakthrough discoveries, high-impact publications, and a large number of PhDs. Both collaborations have exhibited outstanding scientific productivity.

The PAC commends the STAR collaboration for maintaining a successful multi-faceted program with detector upgrades, data analysis, and publications, and for attracting new collaborating institutions. The PAC appreciates the PHENIX continued efforts to keep the vitality of the collaboration by organizing PHENIX data analysis schools, and the efforts to improve documentation and to develop a framework for long-term data preservation. The PAC is pleased to see that both STAR and PHENIX have overcome previous bottlenecks for timely data production of data sets that were taken, especially for the large Au+Au data sets from 2014 and 2016. In the case of STAR, this has been possible due to the successful utilization of NERSC/Cori resources. Maintaining access to adequate data production and analysis resources (CPU and disk space) both at BNL and elsewhere is crucial for the success of the program. The PAC appreciates BNL management efforts to consolidate HEP and NP computing resources and to provide expert support serving the RHIC experiment needs.

Recommendations:

- The PAC recommends that sufficient resources be identified and deployed for data preservation efforts both for the data sets taken and the corresponding simulations, initially in PHENIX and subsequently in STAR.

3.1 PHENIX

The PAC commends the PHENIX collaboration for continuing to produce high profile scientific results despite the fact that the PHENIX data-taking operation ended three years ago. This includes over 20 papers since January 2018. A notable highlight of the heavy-ion program this year is the PHENIX publication (*Nature Physics,* **vol. 15**, p. 214–220 (2019)) of compelling evidence for formation of small QGP droplets with three distinct geometries that were successfully engineered through the selection of the projectile nuclei, which is a unique RHIC capability. The yield of direct photons was inferred for momenta down to 400 MeV/c for $\sqrt{s_{NN}}$ = 39 and 62.4 GeV using the PHENIX Hadron Blind Detector. The yield of direct photons was observed to scale with the overall multiplicity via a power law, independent of beam energy or system size. This suggests that direct photons at a transverse momentum around 1 GeV/c are mainly produced in the hadronization region, consistent with a previous PHENIX analysis of flow in direct photons. Using the VTX, PHENIX was able to separate electrons from bottom quarks versus those from charm in pp collisions, representing crucial progress in understanding the properties of open charm or bottom mesons, including R_AA out to nearly 10 GeV/c. The transverse single-spin asymmetry of forward hadrons, A_N, was found to decrease with the mass of the target. This represents significant progress towards clarifying whether A_N is driven by the Sivers and/or Collins effects.

Analysis of 2016 PHENIX data was hampered by an alignment issue. The PAC was pleased to hear that PHENIX has now completed a long and difficult recalibration process. An impressive list of analyses for heavy ions is now underway, which should elucidate issues related to small systems, jets, EM probes and heavy flavor. An equally ambitious set of observables is being analyzed for pp and spin analysis, including the measurement asymmetries in very forward neutrons.

Current PHENIX analyses involve over 30 graduate students and approximately a half dozen postdocs. PHENIX analysis schools continue to be effective, and another is planned for the coming year. Nonetheless, PHENIX has reported that the current available effort, especially for postdocs, may be insufficient to cover the rich set of analyses enabled by PHENIX measurements. This includes some of the potentially highest profile results. More disturbing, the PAC was told that PHENIX is without a simulation coordinator, and is having difficulty in funding and hiring for the position. This is critical for practically all current and future analyses of PHENIX data.

Recommendations:

- The PAC encourages PHENIX to continue to work with BNL and DOE to fill the Simulation Coordinator position as quickly as possible. The PAC supports the PHENIX request of resources to ensure that the most important analyses will be completed in a timely manner.
- The PAC was pleased to hear that PHENIX is taking the initiative in data preservation. A work force is scheduled to convene this fall. The PAC believes this should be assigned highest priority at BNL, and that BNL should aim for a uniform approach for archiving all heavy ion and spin data from RHIC.

3.2 STAR

The STAR collaboration has maintained high productivity, publishing 20 papers since the last PAC meeting, submitting 17 other papers for publication, and graduating 17 Ph.D.s. STAR has obtained many interesting results, such as measurement of the directed flow (v_1) of D-mesons, the mass of the Hypertriton, a comprehensive paper on strange hadron production over the BES I energies, and new results on quarkonium production as a function of centrality and transverse momentum in Au+Au and U+U, and in p+p for reference measurements. A recent highlight of the RHIC spin program is the STAR measurement of longitudinal spin asymmetries for weak boson production in polarized proton-proton collisions (Phys. Rev. D 99, 051102(R)) elucidating the role of the sea quarks in the proton spin.

Concerning the results obtained from BES I, the PAC is pleased to see that STAR is in the process of finalizing two papers on the beam energy dependence of net proton cumulants, a short one intended for Nature Physics together with a comprehensive write-up containing all the details. To address the crucial question of efficiency corrections STAR proposes to model the detector response in terms of a beta-binomial distribution where the parameter characterizing the deviation from a binomial distribution is fitted to a limited set of results obtained via embedding. While this procedure will save considerable computing resources, it seems wise to validate this procedure for at least one centrality and energy point, preferably the most central events at 7.7 GeV center-of-mass energy.

The STAR FXT data is important for the success of BES II. The PAC looks forward to seeing at its next meeting results from the physics analyses of the FXT data already collected in Run 19.

The PAC is pleased to hear that STAR is developing plans for unblinding the data acquired in the isobar run (Run 18) that was dedicated to establishing or ruling out the chiral magnetic effect. The PAC is concerned, however, about the possibility that STAR may need to apply corrections AFTER unblinding in order to address possible inconsistencies between various CME observables. Even if the inconsistencies are shown to come from clear errors, such post-processing of the unblinded data may well undermine the entire purpose of the blinding procedure, and as a result may limit the credibility of the results from the isobar run. Thus, if any post-unblinding corrections are applied to the data, it is especially important that STAR publicly explain how and why any of the blind analyses were altered after the unblinding, including via publication of a paper containing both the unblinded and post-unblinded results for reference in any papers reporting the isobar data. Therefore, the PAC encourages the STAR collaboration to vet the analysis procedures as thoroughly as possible prior to the unblinding.

The data-taking in Run 19 is going well with STAR having already met and slightly exceeded the goal for the two collider energies of the beam energy scan at $\sqrt{s_{NN}}$ =19.6 GeV and 14.7 GeV.

The PAC congratulates the STAR collaboration for the successful iTPC upgrade.

Unfortunately, the readout electronics for the STAR eTOF detector were damaged during Run 19. The PAC is pleased to see that the STAR collaboration has a clear plan on how to repair the damaged readout electronics of the eTOF detector and we encourage STAR to make this a high priority to ensure timely completion for Run 20, where its availability is essential for a successful completion of the FXT program.

Recommendations:

- The PAC recommends that STAR validate the time-efficient model based on the beta-binomial distribution for the efficiency correction of net-proton cumulants for at least one centrality bin using full embedding with sufficient statistics.
- The PAC strongly recommends that any STAR publication regarding CME observables should contain the result after unblinding and without any additional corrections applied after unblinding that are deemed necessary by STAR. If such additional corrections are needed, then a paper containing both the unblinded and post-unblinded results should be published for reference in papers reporting the isobar data.

3.3 RHICf with STAR

The PAC heard the presentation on the data-taking of RHICf in Run 17 and the status of data-analysis. Using two compact position-sensitive calorimeters placed in front of the STAR ZDC detector, ~110M events were collected during three days with 510 GeV transversely polarized pp collisions. Neutral particles (γ, π^0, neutron) produced at $p_T < 1$ GeV/c and $\eta > 6$ were detected. Most of these data were collected in coincidence with the STAR detector.

The data analysis of RHICf is progressing well. A clear π^0 peak with a mass resolution of ~10 MeV is observed in the $\gamma\gamma$ invariant mass distribution. First results of the π^0 single-spin asymmetry, A_N, have been obtained, showing intriguing p_T scaling behavior for data taken at different Feynman-x (x_F) values. In contrast, the A_N data show no x_F-scaling behavior. The origins of the large A_N for forward hadron production in pp collisions remain a mystery. The new data from RHICf covering a new kinematic region of low p_T and very large rapidity are highly significant. In particular, the combined analysis of the RHICf and STAR data could potentially provide valuable insights into the physics of A_N.

The PAC is pleased to see good progress in the analysis of the RHICf data. Close interaction between the RHICf collaboration and theorists to understand the salient features of A_N over a broad range of kinematics, such as the identification of the underlying mechanisms for the p_T scaling behavior, is strongly encouraged. The PAC looks forward to the qualitatively new results from the ongoing analysis combining RHICf and STAR data. The prospects for taking additional RHICf data in future pp, pA, and AA runs should also be explored.

4. Forward Physics at STAR

The PAC commends the timely action by the BNL management to conduct a technical review of the proposed forward upgrades to the STAR detector in November 2018. The favorable assessment of the review panel has generated much enthusiasm and activities in recent months for this upgrade project.

Impressive progress has been made by the STAR collaboration on the forward upgrade, with the goal of completing the upgrade before Run 22. An organizational structure for the STAR forward upgrade has been formed. New groups have been recruited, and new funding resources have been identified and actively pursued.

The PAC heard the status of the R&D and prototype testing of the four major hardware components of the forward upgrade: forward silicon tracker, small-strip Thin Gap Chamber (sTGC), forward electromagnetic calorimeter (ECal), and forward hadronic calorimeter (HCal). Prototypes of both the ECal and HCal subsystems have been tested using the test beam at Fermilab, and are currently installed at STAR and being tested during Run 19. Similarly, a prototype sTGC module is also being tested at RHIC. The PAC anticipates no major issues for these three subsystems as good progress has been made. On the other hand, the silicon tracker subsystem remains on the critical path.

The PAC congratulates the STAR forward upgrade team for their excellent effort and impressive progress within a relatively short time. To fully assess the prospect for the STAR forward upgrade to be completed in time for a productive 500 GeV pp run in FY22, it would be very helpful if BNL management would conduct a review shortly prior to the 2020 PAC meeting to evaluate the status of the STAR forward upgrade.

Recommendations:

- The PAC recommends that BNL management conduct a review to evaluate the status of the STAR forward upgrade, and the results presented at the next PAC meeting.

5. sPHENIX

The PAC congratulates BNL and the sPHENIX Collaboration for the successful PD-2/3 review. The detector subsystems including Outer HCAL, SC Magnet, Inner HCAL, EMCAL, TPC, INTT and MVTX are in sound technical shape and ready for commencement of the formal construction phase of the project.

The sPHENIX scientific program centers on the measurement of the emergent properties of the Quark-Gluon Plasma (QGP) created at RHIC. The PAC commends the sPHENIX Collaboration on the progress made on detailed studies of the sPHENIX capabilities on key physics topics of Upsilon production, jet structure and tagged-parton energy loss, and heavy flavor measurements.

The PAC recognizes the importance of a possible cold QCD physics at sPHENIX and the consequent scientific potential for a sPHENIX forward upgrade. The PAC encourages the sPHENIX Collaboration to continue to seek potential additional resources necessary for a viable path towards a sPHENIX forward upgrade, whereas the existing resources are understandably devoted to the detector construction of the sPHENIX baseline.

The PAC recognizes the importance of an instrumented Inner HCAL to the sPHENIX jet physics program. The PAC strongly encourages BNL management, the sPHENIX Collaboration and the Project Team to identify funding sources to allow for a timely instrumentation of the Inner HCAL compatible with the construction schedule of the other detector subsystems.

Recommendations:

- The PAC recommends that the sPHENIX Collaboration and the newly established BNL Physics Department HEP/NP Software Group work closely together to develop a plan that will meet the sPHENIX computing needs on a time scale appropriate for sPHENIX data-taking. The PAC expects a report on this topic at the PAC meeting next year.

6. LEReC

The PAC congratulates the Low Energy RHIC electron Cooling (LEReC) group for accomplishing electron beam cooling using a bunched electron beam and state-of-the-art technology. It is the first radio-frequency linear-accelerator based electron cooler providing bunched beam cooling. Successful commissioning and operation of LEReC is the highest priority in 2020 for C-AD and RHIC. This is the last step of the LEReC project goals and will be essential for RHIC to operate in the collider mode at $\sqrt{s_{NN}}$ = 7.7 GeV and for completing the BES-II program. C-AD presented results of successful electron cooling simultaneously of six bunches of the ion beam in both the yellow and blue rings of RHIC. Given that all hardware has been installed and commissioned, and that the electron cooling is now proven, the attention turns to the final stage of optimization of the operational aspects of electron cooling of the ion beams in RHIC. The intention is to use electron cooling at the two lowest RHIC BES II energies, namely 7.7 and 9.1 GeV, once developed. This will require interleaving RHIC operation for physics and the commissioning of electron cooling in the first part of Run 20 so that physics running with electron cooling can begin in the second part of Run 20. See the beam use section of this report for discussion of Run 20 scheduling.

7. CeC Proof of Principle & BUR

Cooling of the hadron beam is necessary to achieve high luminosity for the Electron-Ion Collider (EIC). The proposed Coherent electron Cooling (CeC) is a novel cooling technology for hadron beams. Proof-of-Principle demonstration of the CeC is technically very challenging and has been considered a high priority technical task for the development of eRHIC. The FEL Amplifier approach failed to achieve the desired cooling in Run 18. Subsequent studies led to the discovery of new plasma instabilities in the electron beam at high frequency (~ 10 THz). The CeC Collaboration designed a plasma-cascade amplifier approach for cooling of hadron beams, which is fully compatible with low energy RHIC operation. The Collaboration requested RHIC beam time in Run 20 and Run 21 to test the new approach.

The PAC concurs that the demonstration of the CeC principle is a high priority task for eRHIC development. The proposed new CeC scheme should be evaluated by appropriate experts. If experts deem the approach technically promising and feasible, the PAC recommends the allocation of beam time to investigate the viability of the proposed CeC scheme. See the beam use section of this report for discussion of Run 20 and 21 scheduling.

Recommendations:

- The PAC strongly recommends that, prior to allocating time for further CeC use of RHIC beam, the Laboratory decide on whether to proceed with the CeC experiment, once results from this year's experiment are known and a review is convened of the Coherent Electron Cooling program by a committee with appropriate expertise.

8. PAC Recommendations

STAR Analysis:

- The PAC strongly recommends that any STAR publication regarding CME observables should contain the result after unblinding and without any additional corrections applied after unblinding that are deemed necessary by STAR. If such additional corrections are needed, then a paper containing both the unblinded and post-unblinded results should be published for reference in papers reporting the isobar data.
- The PAC recommends that STAR validate the time-efficient model based on the beta-binomial distribution for the efficiency correction of net-proton cumulants for at least one centrality bin using full embedding with sufficient statistics.

PHENIX Analysis:

- The PAC encourages PHENIX to continue to work with BNL and DOE to fill the Simulation Coordinator position as quickly as possible. The PAC supports the PHENIX request of resources to ensure that the most important analyses will be completed in a timely manner.

Forward Physics at STAR and BNL Laboratory Management:

- The PAC recommends that BNL management conduct a review to evaluate the status of the STAR forward upgrade, and the results presented at the next PAC meeting.

CeC Developments:

- The PAC strongly recommends that, prior to allocating time for further CeC use of RHIC beam, the Laboratory decide on whether to proceed with the CeC experiment, once results from this year's experiment are known and a review is convened of the Coherent Electron Cooling program by a committee with appropriate expertise.

sPHENIX and BNL Laboratory Management

- The PAC recommends that the sPHENIX Collaboration and the newly established BNL Physics Department HEP/NP Software Group work closely together to develop a plan that will meet the sPHENIX computing needs on a time scale appropriate for sPHENIX data-taking operation. The PAC expects a report on this topic at the PAC meeting next year.

BNL Laboratory Management

- The PAC recommends that sufficient resources are identified and deployed for data preservation efforts both for the data sets taken and the corresponding simulations, initially in PHENIX and subsequently in STAR.

9. 2019 BNL Nuclear and Particle Physics Program Advisory Committee:

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