Report from the RHIC PAC

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RHIC PAC Meeting (10 – 11 June 2019)

Data Analysis, Data-taking, Beam Operations & *Beam Use Requests*

- STAR presentation of

Data-taking, analysis progress & key pubs from Runs 18 & 19

Beam Use Request for Runs 20 and 21 (Beam Energy Scan Years 2-3)

Beam Use Request for Run 22 (500 GeV pp run)

- PHENIX presentation of

Data-taking, analysis progress and key pubs through Run 19

Data release plan

- RHICf presentation of

Data-taking, analysis progress & pubs from Runs 18 & 19

- *CeC Beam Use Request*

RHIC PAC Meeting (10 – 11 June 2019)

Reports and Upgrades

- RHIC Run-19 Performance
- LEReC Status
- CeC Status
- sPHENIX Progress
- STAR upgrades
- EIC News

RHIC Run 19 Summary

Effective and efficient operation of detectors and collider:

- RHIC – performance in Run 19 was outstanding.

  Successful completion of runs at two energies ($\sqrt{s_{NN}}$ = 19.6 and 14.6 GeV) in the BES-II program

- STAR – successful installation of the iTPC; successful operation and performance of the iTPC during the above runs (582M and 324M events, respectively)

  Positions STAR to be able to complete the BES-II Run Program.

- C-AD – accomplished electron cooling using a bunched electron (LEReC) beam.

  Once commissioned in the collider, it enables RHIC to accomplish the BES-II program.

PAC Comment → "The highest priority for C-AD at RHIC is LEReC, which allows execution of the lower energy BES-II runs. This is essential to realize the significant discovery potential of the BES-II physics program."

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PAC Comment → "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."

PHENIX Selected Heavy Ion Highlights

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. Nature Physics, Vol. 15 , p. 214–220 (2019)
- PHENIX reports 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. This suggests that direct photons at a transverse momentum below around 2 GeV/c are mainly produced from the hadronization region. Phys. Rev. Lett, vol 123, no 022301, (2019).
- Using their VTX, PHENIX has been able to separate electrons from b quarks versus those from c in pp collisions: crucial progress in understanding the properties of open charm or bottom mesons; baseline for R_{AA} out to nearly 10 GeV/c. Phys. Rev. D99 (2019) 092003

The PHENIX collaboration continues 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.

STAR Selected Heavy Ion Highlights

STAR has published a number of important results, which include:

- A comprehensive paper on strange hadron production over the BES I energies, arXiv: 1906.03732
- First measurement of the directed flow (v_1) of D-mesons, arXiv:1905.02052
- The mass of the Hypertriton, arXiv:1904.10520
- Papers on their investigation of quarkonium production as a function of centrality and transverse momentum in Au+Au and U+U, eg arXiv:1905.13669
- 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 (ε_2), i.e. v_2 / ε_2, scales for all system sizes from U+U down to p+Au. Phys. Rev. Lett. 122 (2019) 172301

The STAR collaboration has maintained high productivity, publishing 20 papers since the last PAC meeting, submitting 17 other papers for publication, and graduating 17 PhDs.

Selected Spin Highlights

- 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. Phys Rev D99 (2019) 051102
- 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. arXiv:1903.07422

PAC Comment → "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."

STAR and PHENIX Science

PAC Comment → "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."

SPHENIX

- The sPHENIX collaboration has successfully completed PD-2/3 review.
- Significant progress in technical development towards the detector construction phase.

PAC Comment → "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."

RHIC Run 20 Beam Use Requests (BUR) Perspective

STATUS: The PAC described the motivations and discovery potential of the BES-II program in its reports from each of the past several years and is pleased to see it underway.

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.

BACKGROUND: Our recommendation for Run 20 is contingent on advice from C-AD on the ability of LEReC to operate effectively at $\sqrt{s_{NN}}$ = 7.7 GeV, which is preferred by all.

PAC PERSPECTIVE: $\sqrt{s_{NN}}$ = 7.7 GeV is the highest priority running for Run 20 because it is at this energy that the error bars from BES-I measurements are largest and so is the discovery potential. Run 21 would then be run at $\sqrt{s_{NN}}$ = 9.1 GeV. Assuming this still holds –

RHIC Run 20 BUR Recommendations

- 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.
- Second priority: The PAC recommends a run with AuAu collisions at $\sqrt{s_{NN}}$ = 11.5 GeV with no LEReC cooling 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 BESII program, namely $\sqrt{s_{NN}}$ = 3.5, 4.5, 5.2, 6.2 and 7.7 GeV. Of these, the top priority is 7.7 GeV, to benchmark vs collider run.
- Fourth priority: 8 days of running for the CeC 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, eg after results from this year‘s experments are available and after a review of the CeC program by a committee with appropriate expertise.

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

RHIC Run 21 BUR Perspective and Recommendations

- On the assumption that the $\sqrt{s_{NN}}$ = 7.7 GeV run is completed during Run 20, the PAC recommends as top priority for Run 21 a $\sqrt{s_{NN}}$ = 9.1 GeV run and LEReC cooling that yields at least 160 M collisions.
- If this run has not been accomplished in Run 20, then the PAC recommends as top priority for Run 21 a $\sqrt{s_{NN}}$ = 7.7 GeV run with LEReC cooling that yields at least 100 M 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 of the ion beam on the electron beam, our second priority for Run 21 is the continuation of CeC experimentation with 14 days of running devoted to the CeC experiment to demonstrate coherent electron cooling, which is of considerable significance for planning of an EIC program and BNL.

PAC Comment → "After hearing the outcome of this year's experiments, the review of the CeC program that we recommend, and at least an initial report on the Run 20 experiments (at next year's PAC), we hope to frame this recommendation with fewer caveats."

RHIC Run 21 BUR Recommendations (Part 2)

The two other BURs for Run 21 are at present not ordered in priority. In both cases, the PAC will finalize 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 Au+Au collisions with $\sqrt{s_{NN}}$ = 17.1 GeV and no LEReC cooling that yields 250M 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.

RHIC Run 21 BUR Recommendations (Part 3)

- The other of these two BURs is a 1 week run of O+O collisions at $\sqrt{s_{NN}}$ = 200 GeV anticipating 400 M min bias collisions.

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 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. These calculations should also be undertaken for α+α, Be+Be, Al+Al and Ar+Ar collisions, for O+Au and other asymmetric small+large nuclear collision options, to justify that O+O is the optimal physics choice to yield new or substantially improved understanding of questions relating to how small droplets of QGP equilibrate and the smallest droplet of QGP possible at 200 GeV.

Looking Ahead to RHIC Run 22

The PAC heard the status and plan for the STAR Forward Upgrade. With planned completion of this upgrade by September 2021, STAR is considering a dedicated polarized pp run at 500 GeV in Run 22 to explore spin physics opportunities provided by the forward upgrade and iTPC.

With 16 weeks of pp running, either with longitudinally or transversely polarized beams, new kinematic regions in large and small x can be investigated.

- The primary physics goal presented by STAR for a possible transverse pp run is to extract the quark transversity distribution in the large x valence region, based on analysis of the 2011 transverse pp run. [As the overall uncertainty of the 2011 result is statistics dominated, timely analysis of the much higher statistics 2017 data would be crucial for evaluating the merit of obtaining additional 500 GeV transverse pp data.]
- The main scientific program for a possible longitudinal polarized 500 GeV pp run in 2022 would be measurement of gluon polarization at small x using dijet production. The 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 $x \sim 10^{-3}$, currently poorly constrained from existing data. This is an important measurement to pin down further the origin of proton spin.

Looking Ahead to RHIC Run 22 (Part 2)

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.

PAC Comments → "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."

PAC Recommendations (Part 1)

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 makes this recommendation because even if the reason for making such corrections were the need to correct clear errors, post-processing of unblinded data may undermine the purpose of blinding, limiting credibility of the results. If any post-unblinding corrections are applied, it is important for STAR to explain how and why, and to publish two versions of the results as above. With this in mind, the PAC encourages the STAR collaboration to vet the analysis procedures as thoroughly as possible prior to the unblinding.

PAC Recommendations (Part 2)

STAR Analysis :

- 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, with the results presented at the next PAC meeting.

PAC Recommendations (Part 3)

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.

2019 BNL Nuclear and Particle Physics Program Advisory Committee

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