



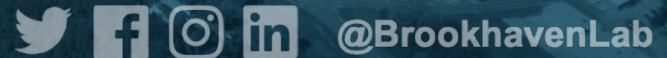
# Nuclear Physics at BNL

Haiyan Gao

ALD, Nuclear and Particle Physics

RHIC & AGS Users' Meeting

August 3, 2023



# ***BNL anti-harassment policy***

At Brookhaven National Laboratory (BNL) or BNL-sponsored events,

“Discriminatory behavior or harassment of conference participants or presenters will not be tolerated.”

Please refer to Participant Information on the webpage for the Annual Users' Meeting

<https://www.bnl.gov/rhicagsaum/logistics.php#webcast>

# BNL Nuclear and Particle Physics (NPP) Code of Conduct (in progress)

## Proposed statement

BNL and NPP stand by a culture of diversity, equity, inclusion, accessibility and professional integrity. It is understood that all members of the NPP community must treat each other with respect regardless of race, color, religion, national origin, disability, sexual orientation, or professional status for NPP to achieve its scientific goals and afford all its members the opportunity to reach their full potential. NPP's mission statement includes a strong belief that work is strengthened by the passion of people from all backgrounds and the diverse, international community they represent, bringing their ideas and unique perspectives to advance the knowledge of humankind.

All participants in BNL's activities: employees, guests, users, students, post-docs, contractors and visitors – including conference attendees, workshop attendees and speakers – are expected to conduct themselves in a professional manner that is welcoming to all, and free from any form of discrimination, harassment, or retaliation. All are expected to treat each other with respect and strive to model behaviors that encourage productive debate and allow for respectful disagreement. NPP strives to encourage innovation, leadership, and teamwork and expects the highest quality of science to be carried out while maintaining scientific ethics and professionalism to the highest standards. Participants of BNL/NPP sponsored activities will achieve their goals with creativity and integrity, commit to constructive dialog and communication, ensuring that all voices can be heard, take initiative to improve the collaborative environment, and are expected to be accountable to a high standard of ethical professional and interpersonal behavior.

Participants *should not* engage in any inappropriate actions or statements that are derogatory or defamatory based on individual characteristics such as age, race, ethnicity, sexual orientation, gender identity, gender expression, marital status, nationality, political affiliation, ability, status, educational background and/or socioeconomic background, neurodiversity, mental or physical health, or any characteristics protected by law. Disruptive, discriminatory, or harassing behavior of any kind will not be tolerated. Harassment includes, but is not limited to, inappropriate or intimidating behavior and language, unwelcoming jokes or comments, offensive images, photography without permission, abuse of authority, bullying, and stalking.

NPP CoC working group report and recommendations version 2 - 2023/04

- Code of Conduct committee was set up by the NPP DEI Council including other NPP members and RHIC/AGS User Group Executive Committee leadership
- The committee has been working on developing CoC for more than a year starting in FY2022
- Received feedback from HR, DEI Office and Legal
- Not finalized yet (reporting paths and processes)
- *Lab Standards of Conduct and Business Ethics*

Participants in BNL/NPP activities are encouraged to report problems that represent a violation of the code of conduct or perceived as a breach of respectful decorum. Reporting a violation would be done either by using our incident reporting interface or discussing it with one of the standing CoC Committee (CoCC) members, who will follow-up on the reported violation. (Please see reporting matrix for additional guidance). Retaliation against the CoCC appointees or the individual(s) reporting inappropriate conduct will not be tolerated.

J. Lauret (co-chair), P. Kankiya\* (co-chair), C. Cutler (co-chair),  
M. Begel, L. Furnari, Y. Hayes, C. Hoffman,  
C. Nattrass, R. Pisarski, M. Wiener, E. Worcester  
\* Left BNL Nov 2022

Presented at the DOE SC User Facility Directors' meeting, June 5, 2023

Training on *Ethical Behavior and Professional Conduct* for BSA staff  
lab plans to incorporate into training for users

# Diversity, Equity, Inclusion and Accessibility

- BNL ranked #7 on the top 20 list of government employers by the STEM Workforce Diversity Magazine in 2023
- BNL launched DEI quarterly theme in FY23 Q3 on “Emotional intelligence” and Q4 on “*Inclusion – Cultivating an Inclusive Workplace*”
- [Workshop on Exploring Collaboration with Minority Serving Institutions \(MSIs\) in Nuclear and Particle Physics](#) was a great success at BNL, July 18-19, 2023, 17 MSIs participated including students, DOE-NP, HEP and IP program managers participated in a panel discussion
- BNL@ North Carolina Agricultural and Technical State Univ. in April was successful
- Proposals submitted responding to DOE-SC FOAs on FAIR and RENEW programs in collaborations with MSIs have been successful
- Workforce development and pipeline: outreach, BNL summer Sundays, SULI, SCGSR and more



# Safety

- **Safety is a core value and a priority**

- Safety events including a few near-misses
- Safety culture, work planning and control, human performance improvement
- Principles of [the Safe Conduct of Research](#):

1. Everyone is personally responsible for ensuring safe operations.
2. Leaders value the safety legacy they create in their discipline.
3. Staff raise safety concerns because trust permeates the organization.
4. Cutting-edge science requires cutting-edge safety.
5. A questioning attitude is cultivated.
6. Learning never stops.
7. Hazards are identified and evaluated for every task, every time.
8. A healthy respect is maintained for what can go wrong.

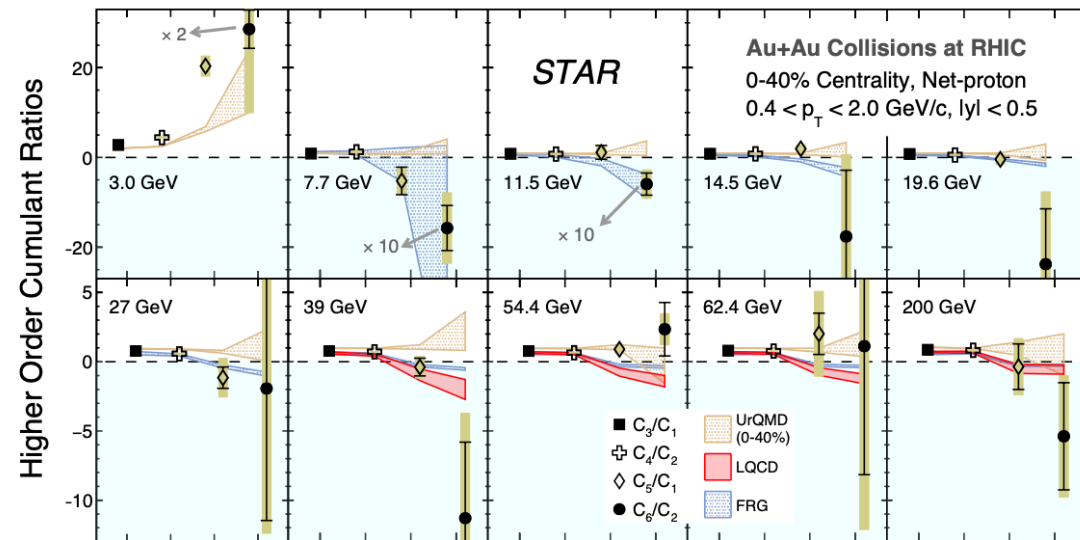
# *Selected Recent Science Highlights*

# Higher order net-proton number fluctuations

2207.09837, PRL 130, 082301 (2023)

Calculations with a cross-over quark-hadron transition (LQCD and FRG) predict a particular ordering of susceptibility ratios:

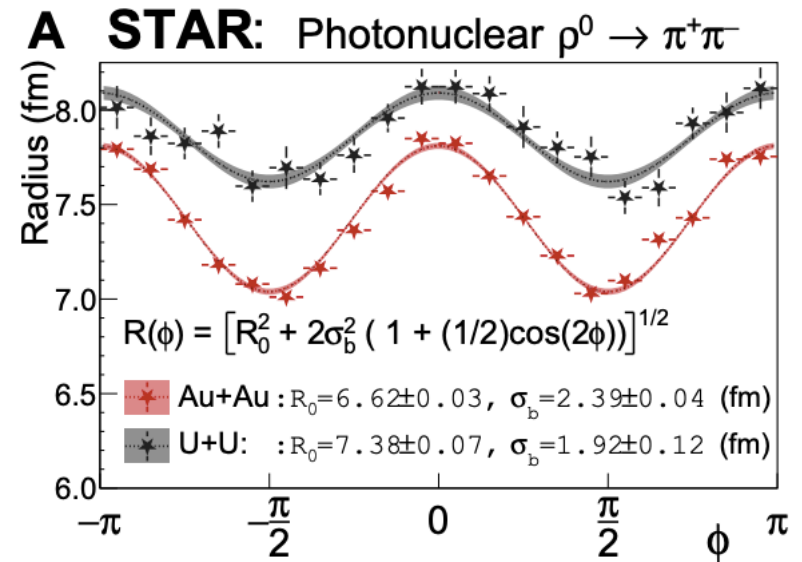
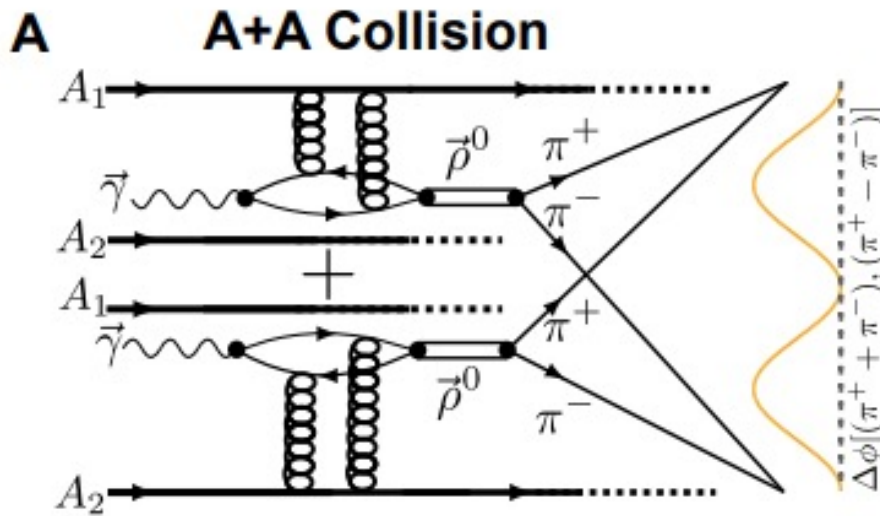
$$\chi_3^B / \chi_1^B > \chi_4^B / \chi_2^B > \chi_5^B / \chi_1^B > \chi_6^B / \chi_2^B$$



- At 7.7-200 GeV, net-proton cumulant ratios consistent with the ordering predicted by LQCD and FRG:  $C_3/C_1 > C_4/C_2 > C_5/C_1 > C_6/C_2$
- The 3 GeV data show a reversing trend

The structure of QCD matter at high baryon density  $\mu_B$   $\sim 750$  MeV starkly different from those at vanishing  $\mu_B$

# Tomography of Ultra-relativistic Nuclei with Gamma + A Collisions



Quantum interference enabled nuclear tomography:

- A novel approach to extract the strong-interaction nuclear radii, which were found to be larger than the nuclear charge radii

2204.01625,  
*Science Advances*  
9 (2023) 3903



# Global spin alignment of vector mesons

$$\rho_{00}(\phi) \approx \frac{1}{3} + c_{\Lambda} + c_{\epsilon} + c_E + c_{\phi};$$

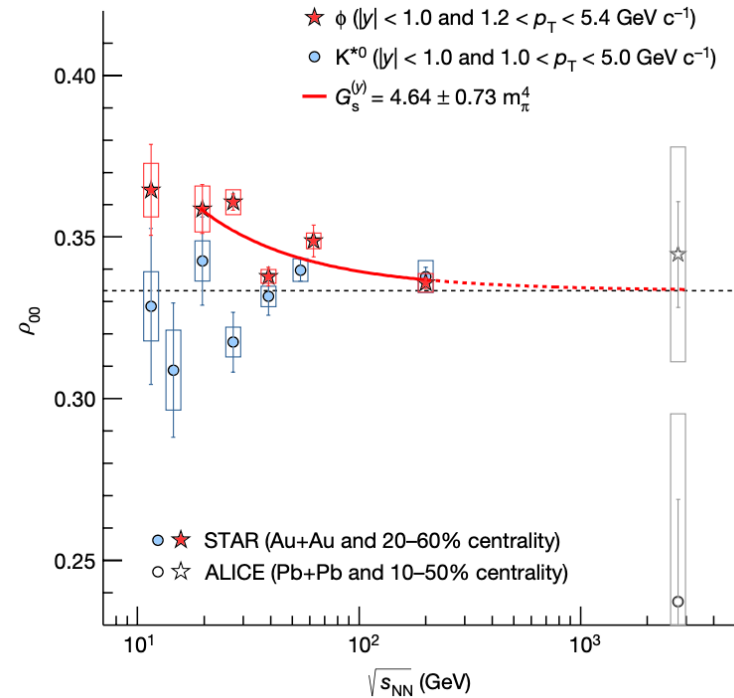
$\Lambda$ -like ( $-10^{-5}$ )  
 Electric field ( $10^{-5}$ )  
 Vorticity tensor ( $-10^{-4}$ )  
 Vector meson field

Surprising pattern observed:

$$\phi\text{-meson } \rho_{00} > 1/3 \text{ by } 7.4\sigma$$

Possible explanation with a strong vector meson field;

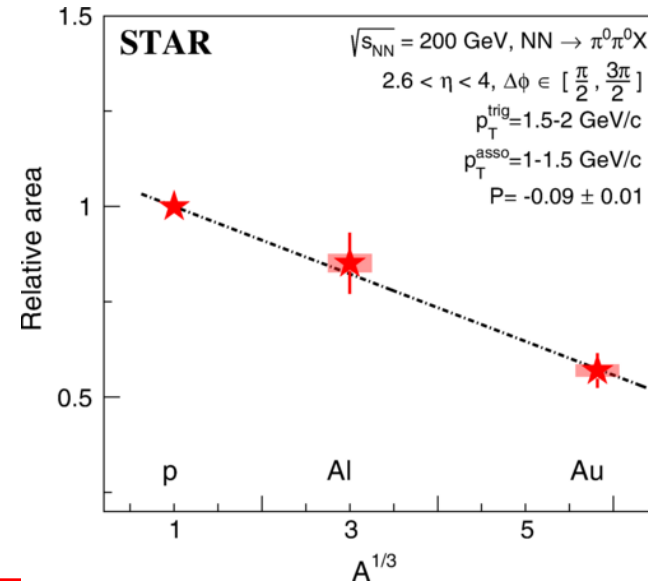
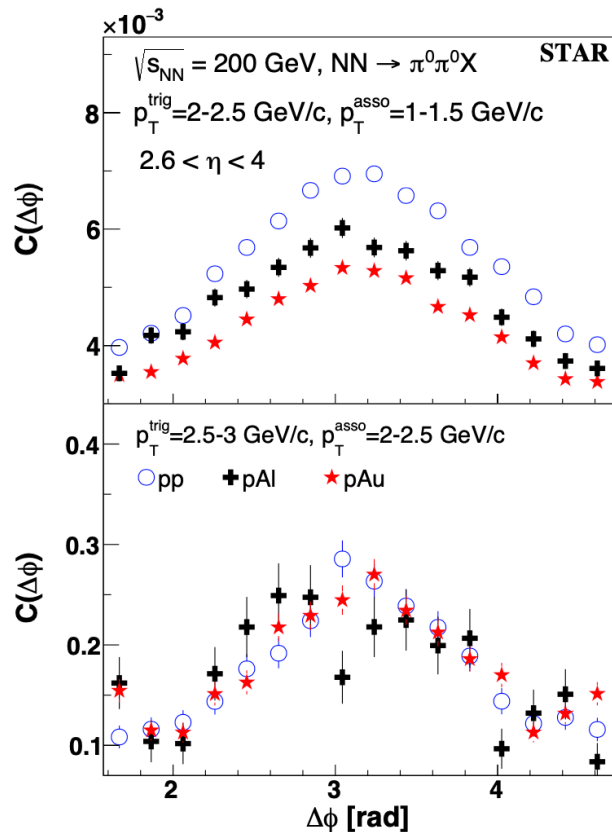
Provides a potential new avenue for understanding the strong interaction at work at the subnucleon level



2204.02302, Nature 614 (2023) 244

# QCD Non-linear Effects

Phys. Rev. Lett. **129**, 092501 (2022)

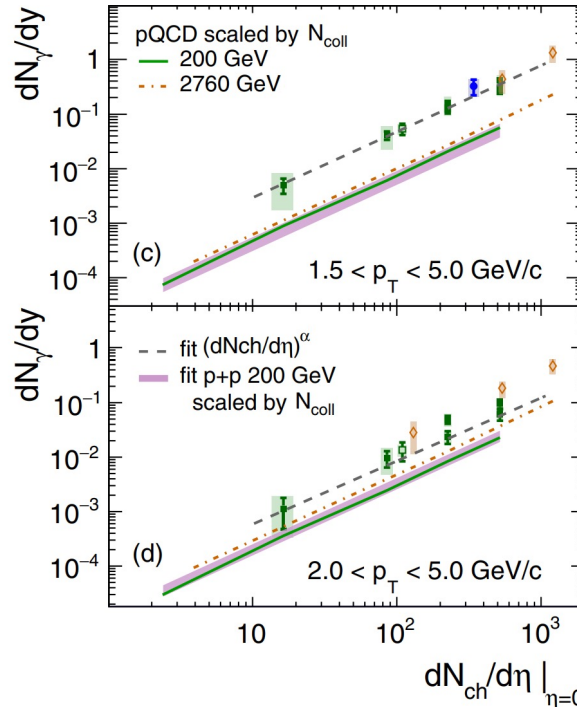
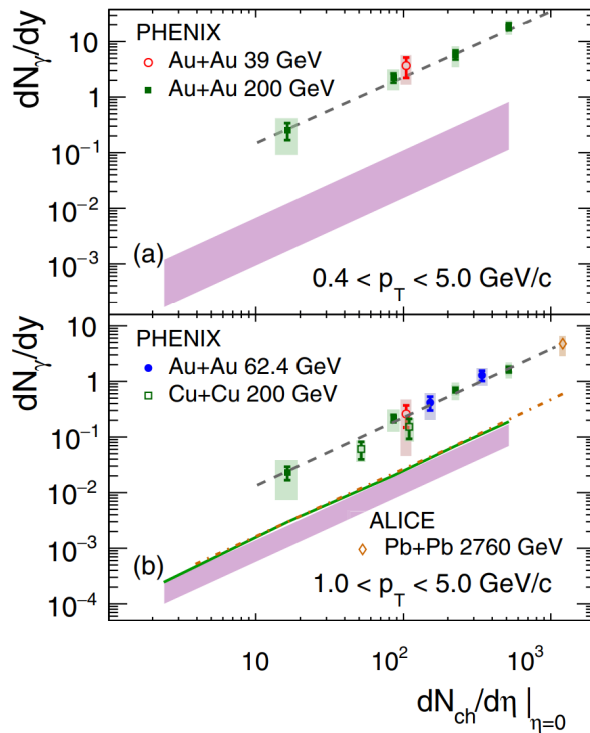


Run-15 di- $\pi^0$  correlation:  
 away side area suppressed significantly, while  
 the pedestal and away side widths change  
 very little.

probe x down to  $10^{-3}$

STAR forward upgrades will characterize non-linear effects  
 with charged di-hadrons,  $\gamma$ -jet, di-jet

# Low $p_T$ direct photon at 39 and 62 GeV

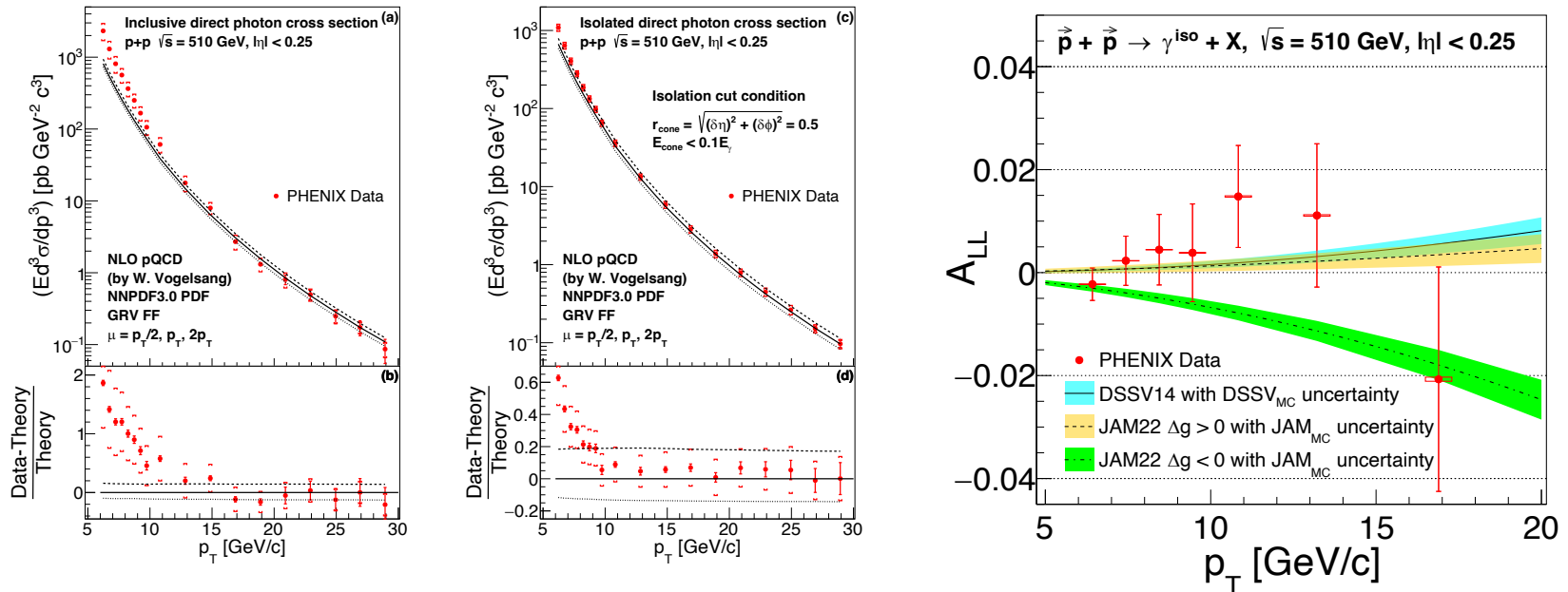


arXiv:2203.12354 (2022),  
PRC 107, 024914 (2023)

- Systematic study of low  $p_T$  direct photon production at 39 and 62 GeV and comparison with higher collisions energy
- Photon yield scaled with  $dN/d\eta$  for all systems
- PRC Editor's suggestion

# PHENIX results on Direct-Photon Cross Section and Double-Helicity Asymmetry

arXiv:2202.08158, PRL 130, 251901 (2023)



- The NLO pQCD calculations are consistent with the results except at lower  $p_T$
- Data consistent with the positive gluon-spin contributions and strongly disfavor the negative gluon-spin scenario

# *Recent Highlights in Nuclear Theory*

The NT group is very productive: many invited talks, papers in refereed journals and conference proceedings; funding successes; active in the 2023 LRP process

## **Visibility on the DOE Office of Science Highlight Site**

[Getting to the Bottom of When the Smallest Meson Melts](#)

[A Simple Solution for Nuclear Matter in Two Dimensions](#)

[Scientists Find a Common Thread Linking Subatomic Color Glass Condensate and Massive Black Holes](#)

[Hitting Nuclei with Light May Create Fluid Primordial Matter](#)

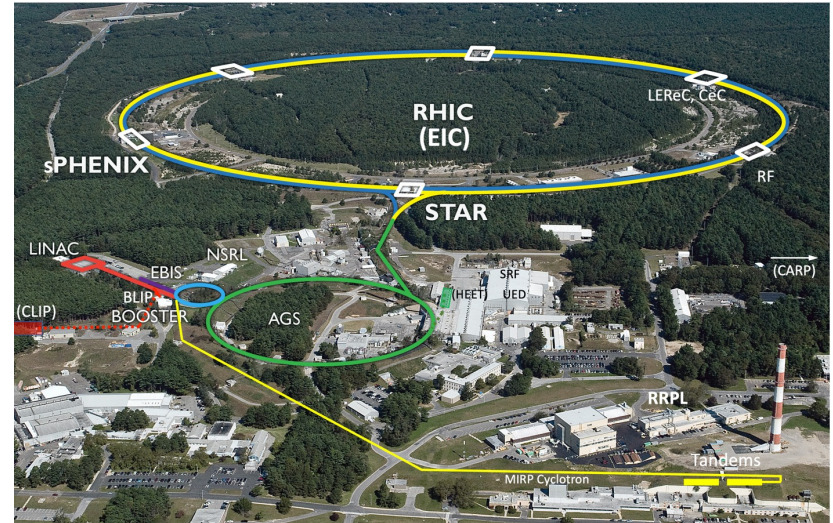
[Theorists Propose a Novel Way to Measure Gluons' Orbital Motion](#)

**Nuclear Theory Group has great synergies with the Riken-BNL Research Center (RBRC) and the Center for Frontiers in Nuclear Science (CFNS) at Stony Brook**

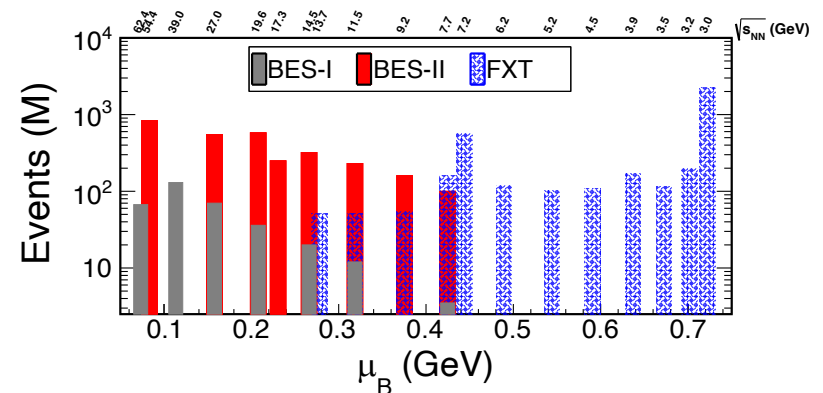
# ***RHIC Run 2023 and plan for 2024 and 2025***

# Complete RHIC Science Mission (2015 NSAC LRP)

“There are two central goals of measurements planned at RHIC, as it completes its scientific mission, and at the LHC: (1) **Probe the inner workings of QGP by resolving its properties at shorter and shorter length scales.** The complementarity of the two facilities is essential to this goal, as is a state-of-the-art jet detector at RHIC, called sPHENIX. (2) **Map the phase diagram of QCD with experiments planned at RHIC.**”  
 (completed data taking in 2021)

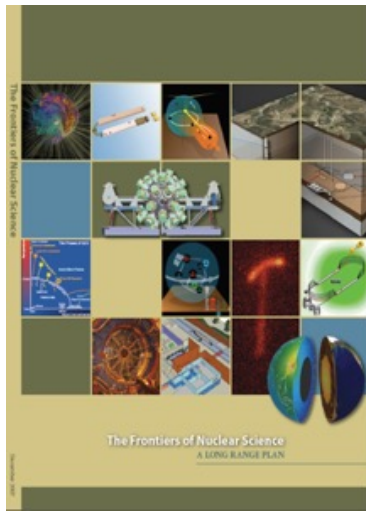


*Exceeded STAR data taking goals*

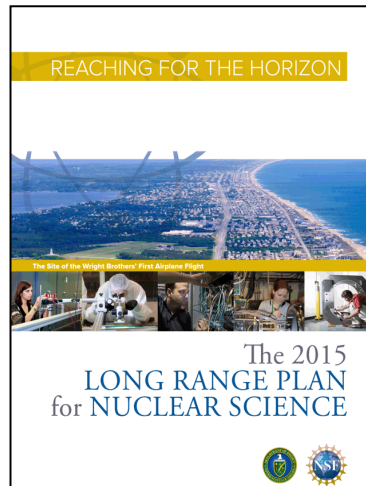


Run 2021: last, lowest (~40% of nominal injection energy), and most difficult colliding Au+Au BES-II energy –second year with low-energy electron cooler (LEReC)

# Ongoing NSAC Long Range Plan



NSAC  
LRP  
2007



NSAC  
LRP  
2015



2023 LRP

NSAC  
LRP 2022-  
2023

- NSAC received the LRP charge from DOE and NSF in July 2022
- Townhall meetings took place September-December 2022
  - Hot and Cold QCD
  - Nuclear Reactions, structure and Astrophysics
  - Fundamental Symmetries, Neutrinos, Neutrons,...(Workforce & DEI, cross cutting areas and applications are integrated)
- Whitepapers received in Feb 2023
- LRP Resolution meeting took place July 10-14, 2023, report is expected this October



# Budget Matters

President Biden signed the Fiscal Responsibility Act of 2023 into law on June 3, which ended the debt ceiling crisis. Discretionary spending is capped during fiscal years 2024 and 2025.

House FY24 Energy and Water Development Appropriations bill released in June

**Office of Science:** \$8.1 B, the same as FY23

**Nuclear Physics:** \$800 M, -\$11.4 M below the FY24 President's Budget Request (PBR); -\$5M below FY23

Senate FY24 Energy and Water Development Appropriations bill released in July

**Office of Science:**

\$8.43 B, an increase of \$330 M over FY23, but \$370.4 M less than the FY24 PBR

**Nuclear Physics:** \$818.4 M, \$13.2 M more than FY23 and \$7 M more than the FY24 PBR

**EIC \$97.85 M (\$95 M for construction, \$2.85 M for OPC),  
the same as the FY24 PBR, both House and Senate versions**

More from Tim Hallman (DOE) and Allena Opper (NSF)

# ***RHIC Run Scenarios 2023-25***

(presented to DOE-NP in FY2024 budget Briefing, Feb 2022)

<b>Year</b>	<b>Scenario 1</b>	<b>Scenario 2</b>
<b>2023</b>	<b>24 cryo-weeks with sPHENIX and STAR Au+Au at 200 GeV</b>	<b>28 cryo-weeks with sPHENIX and STAR Au+Au at 200 GeV</b>
<b>2024</b>	<b>24 cryo-weeks with sPHENIX and STAR p↑+p↑ and p↑+Au at 200 GeV</b>	<b>28 cryo-weeks with sPHENIX and STAR p↑+p↑ and p↑+Au at 200 GeV</b>
<b>2025</b>	<b>24 cryo-weeks with sPHENIX and STAR Au+Au at 200 GeV</b>	<b>28 cryo-weeks with sPHENIX and STAR Au+Au at 200 GeV</b>

# RHIC Run Scenarios 2023-25

(presented to DOE-NP in FY2025 budget Briefing, Feb. 2023)

Year	Scenario 1	Scenario 2
2023	25 cryo-weeks with sPHENIX and STAR Au+Au at 200 GeV	25 cryo-weeks with sPHENIX and STAR Au+Au at 200 GeV
2024	20 cryo-weeks with sPHENIX and STAR p <sup>↑</sup> +p <sup>↑</sup> at 200 GeV	20 cryo-weeks with sPHENIX and STAR p <sup>↑</sup> +p <sup>↑</sup> at 200 GeV
2025	24 cryo-weeks with sPHENIX and STAR Au+Au at 200 GeV	28 cryo-weeks with sPHENIX and STAR Au+Au at 200 GeV

- Run 2023: 20 cryo-weeks for commission and physics, 5 cryo-weeks for sPHENIX magnet testing and mapping
- Budget challenges with Run 2024 and 2025

# sPHENIX commissioning

Commissioning with beam started on May 18

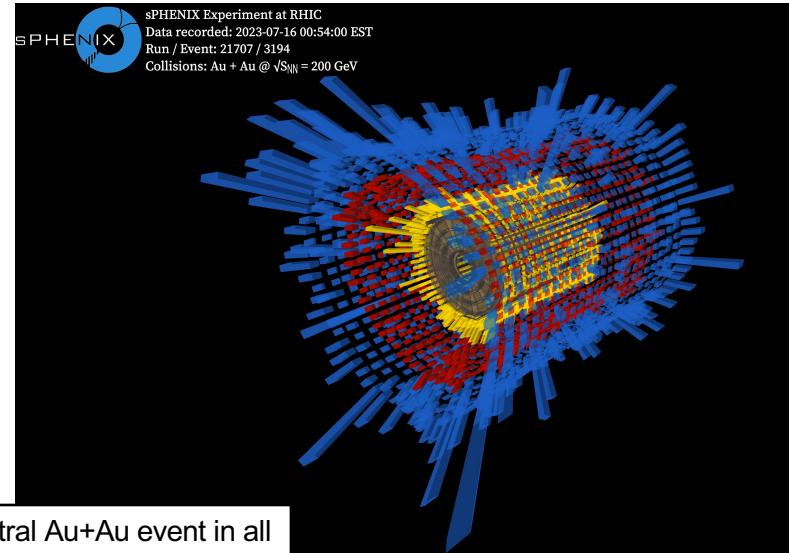
Ten sub-detectors\* and DAQ to commission

SC magnet has operated very stably

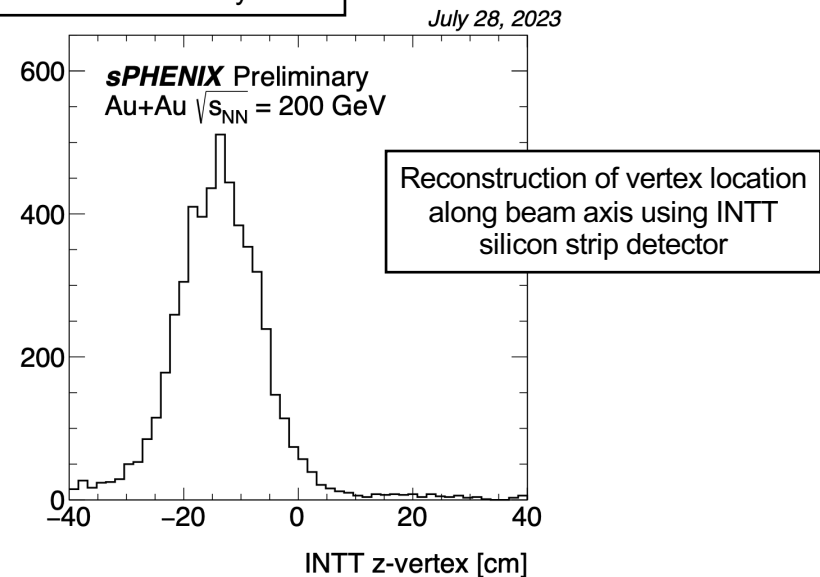
All sPHENIX subsystems, including the MVTX, have taken RHIC data and had the data stored in HPSS

Excellent support from C-AD to provide wide variety of RHIC beam conditions needed

Recent focus has been on operation of TPC at full HV and on MVTX response to apparent beam halo



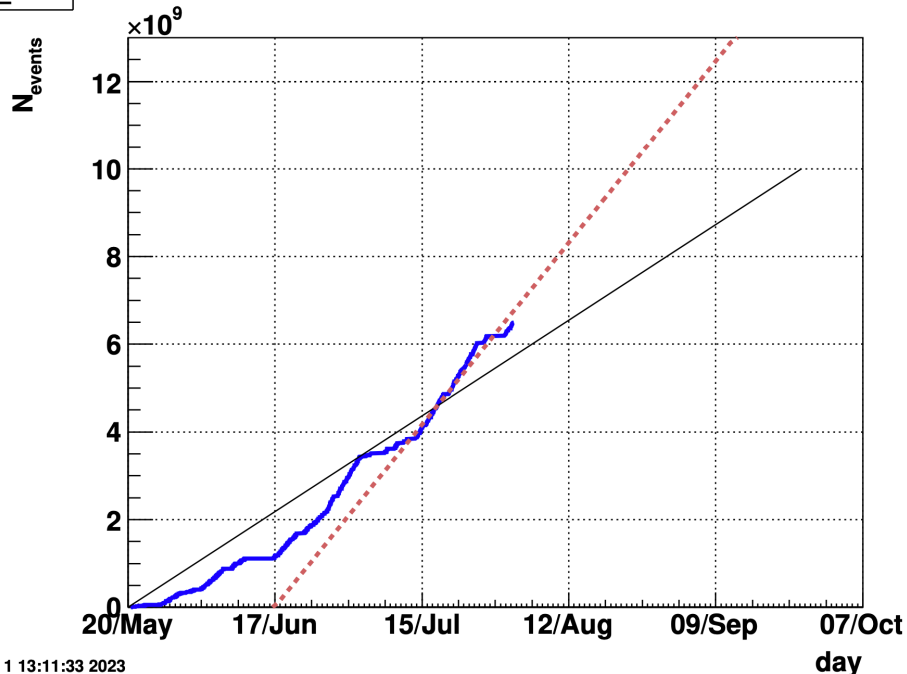
Central Au+Au event in all three calorimeter systems



# Run 23: a very challenging run

From STAR

zdc\_mb



Tue Aug 1 13:11:33 2023

- Run23+25 STAR goals: take **20 B minimum-bias (MB) data** and sample **40 nb<sup>-1</sup> luminosity for hard probes**
- As of Aug. 1, STAR collected **6.5 B MB data**
- STAR takes data smoothly when beams are available
- Focus on MB data taking at low luminosity while sPHENIX is being commissioned

**DAQ5k commissioned and operated successfully during Run 23.  
Thanks for everyone who contributed to this run!**

# Title: Failure of the RHIC Building 1004B Valve Box

SCBNL

Date: 01 August 2023

**Description:** At 12:31PM, August 1, a RHIC magnet quench link interlock occurred in RHIC. As a response to the quench link interlock, 12 DX magnet heaters automatically turned on and the RHIC beam was aborted. The CAD main control room contacted the cryo control room to inform them of the quench link interlock. At 12:39, the cryo control room reported to Main Control that the blue ring valve box in building 1004B was venting helium to the exterior of the building. Cryo control room started to remove helium from the RHIC blue ring. Fire/Rescue and CAD personnel responded to building 1004B. No personnel were in the building at the time of the event. Fire/Rescue swept the building and found no personnel inside the building. Building 1004B entrances were cordoned off and a perimeter established near the vent. At 3:15PM, Fire/Rescue swept the building again, found no oxygen deficiency and turned the building over to C-AD. Helium recovery efforts will continue.



## Potential Cause(s):

- To be determined.

## Immediate/Containment Actions:

- Fire/Rescue swept building for personnel. No personnel found.
- Building entrances secured.
- Perimeter established around vent.
- Helium Recovery commences in blue ring

**POC:** Raymond Filler, Frank Craner, Wolfram Fischer

**The RHIC is down. The valve box will be inspected when it is safe to do so in ~ a week.**

5.0/2008e011.pub

(05/2023)

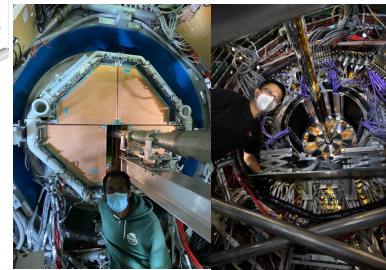
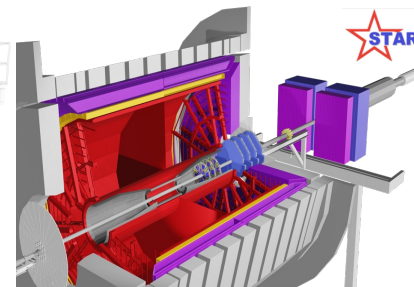
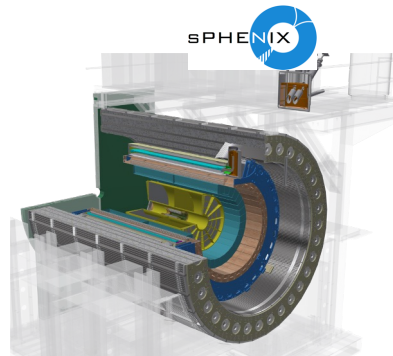
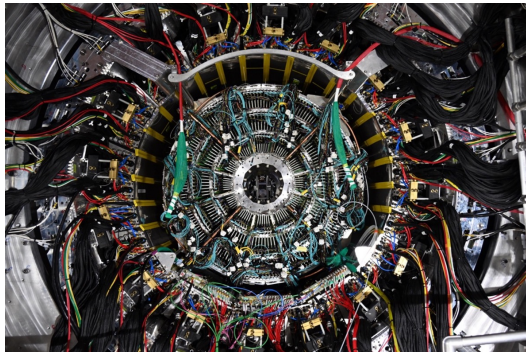
# RHIC/AGS Program Advisory Committee Meeting

- Meeting dates: September 10-11, 2023 (hybrid)
- Charge
  - sPHENIX: Beam Use Requests for Runs 24-25
  - STAR: Beam Use Requests for Runs 24-25
  - Presentations (tentative)
    - PHENIX: Status of data analysis and data preservation
    - STAR: Run 2023 report and Cold QCD Update, Heavy Ion Update on BES-II
    - sPHENIX: update on detector commissioning and integration
- PAC has been highly valuable over the years. This PAC is particularly important to help us optimize the rest of the RHIC running to maximize the science output.

**We are committed to completing the RHIC science mission with strong support of the DOE, Office of Nuclear Physics**

# Completing the RHIC Mission with sPHENIX and STAR

- sPHENIX will use energetic probes (jets, heavy quarks) to study quark-gluon plasma with unprecedented precision
  - How the structureless "perfect" fluid emerges from the underlying interactions of quarks and gluons at high temperature
- sPHENIX outer hadron calorimeter will be part of the EIC project detector
- STAR with forward upgraded detectors will understand the initial state of nucleon and nuclei from high to low x and the inner workings of QGP
- How are gluons and sea quarks distributed in space and momentum inside the nucleon?
- How does a dense nuclear environment affect quarks and gluons, their correlations, and their interactions and giving rise to non-linear effects?



Synergies with the EIC science and contribute to EIC workforce development

RHIC data taking scheduled for 2023–2025  
sPHENIX upgrade and STAR with forward upgrade will fully utilize the enhanced (~50 times Au+Au design) luminosity of RHIC

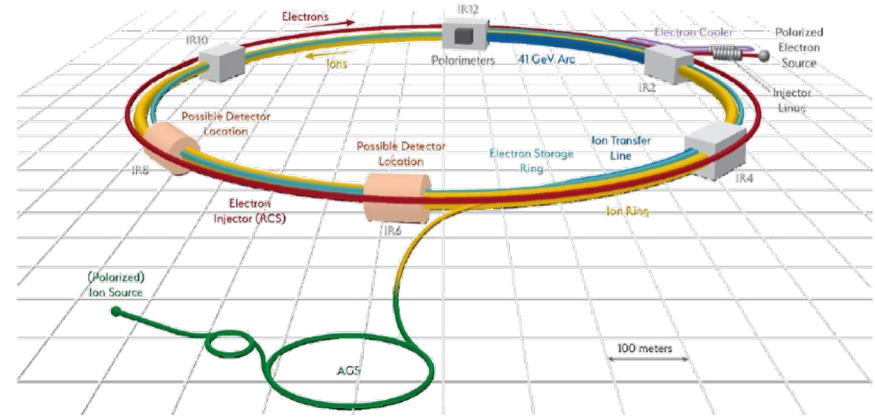


# The Electron-Ion Collider

## Project Design Goals

- High Luminosity:  $L = 10^{33} - 10^{34} \text{ cm}^{-2} \text{ sec}^{-1}$ ,  $10 - 100 \text{ fb}^{-1} / \text{year}$
- Highly Polarized Beams:  $\sim 70\%$
- Large Center of Mass Energy Range:  $E_{\text{cm}} = 20 - 140 \text{ GeV}$
- Large Ion Species Range: protons – Uranium
- Large Detector Acceptance and Good Background Conditions
- Accommodate a Second Interaction Region (IR)

Conceptual design scope and expected performance meet or exceed NSAC Long Range Plan (2015) and the EIC White Paper requirements endorsed by NAS (2018)



Double Ring Design Based on Existing RHIC Facility



Major milestones: CD-0 December 2019; DOE EIC site (BNL) selection Jan 2020; CD-1 June 2021; EIC project detector selected in March 2022; ePIC collaboration formed in July 2022 & spokesperson (John Lajoie) and deputy spokesperson (Silvia Dalla Torre) elected Feb 2023; first EIC Resource Review Board (RRB) meeting April 2023

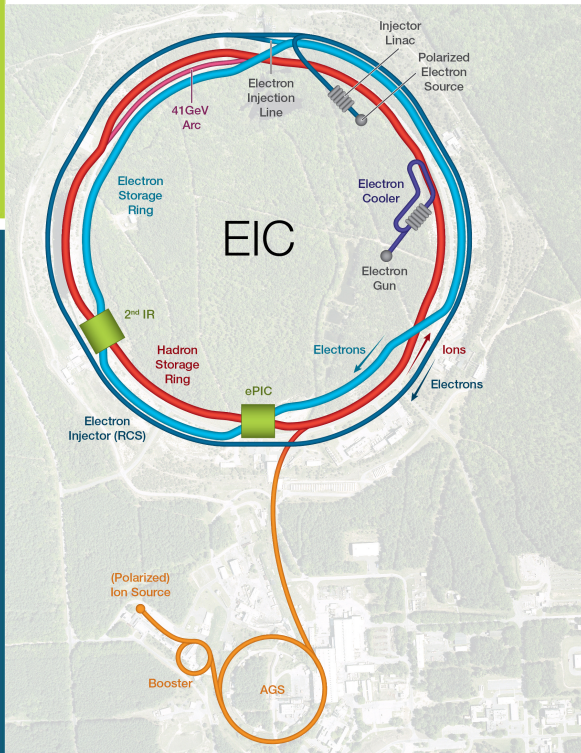
# ***RHIC to EIC Transition***

1. To bring about the successful conclusion of the RHIC mission in FY 2024 and FY 2025 and the change from operations to a more concentrated effort in EIC construction, NPP and EIC have been working on a detailed plan to transition staff.
2. The EIC project plan and timeline match well with our plan for completing the RHIC operations.
3. The Transition Plan is a work in progress to integrate CAD and RHIC related Physics Department staff to meet the requirements of the EIC, EIC Detector effort, Isotope Program, NSRL, TVDG operations, keeping the injector complex in ready state during the EIC construction, and new initiatives.

## ***Organizational Structure Evolution***

We will form a new Department of Isotope Research and Production (IP) in FY 2024 in NPP starting October 1, 2023. Currently, the Medical Isotope Research and Production (MIRP) is part of the Collider Accelerator Department.

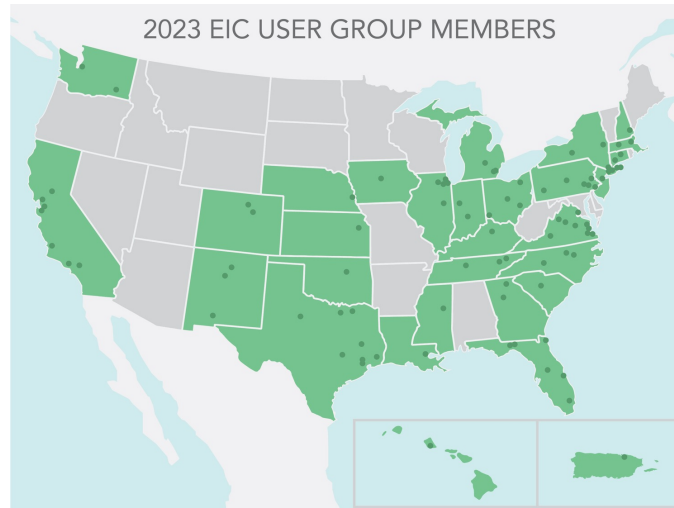
# EIC Network for Discovery Science and Workforce Development



Such a network would empower discovery science at the EIC while strengthening and building nuclear physics research at U.S institutions, especially those with limited research capacities, and supporting training of a diverse STEM workforce for the nation.

The network promotes partnerships between U.S. national labs and universities and supports students and postdoctoral fellows. The network would promote collaborations between experiments and theory, organize traineeships, mentoring and career development programs for students and postdocs.

In addition to discovery science, the nation benefits from a highly skilled STEM workforce for advances in fields such as energy, environment, health, and national security.



# Update on Services

- **Ready to Eat Delivery Service to BNL** provided by [Redefine Meals](https://www.bnl.gov/staffservices/redefine.php)  
<https://www.bnl.gov/staffservices/redefine.php>.
- **Cafeteria:** our near-term goal is to restore Monday through Friday lunch service in Berkner through a single vendor under a pilot program. We will monitor the number of staff that use the cafeteria and use that data to bid out for a permanent vendor.
- **NEW SHUTTLE SERVICE for the summer 2023!**  
No phone call is necessary\* in the morning and afternoon for pickups, as the shuttles will be doing continuous loops as listed here: [BNL | Guest Services | Shuttle Service](#)
- **Gender-neutral dormitory rooms** are now available as an option. Please note current room availability is limited in all dormitories and apartments due to the high volume of summer researchers.
- **The Childcare Development Center** will be re-opening on September 5, 2023, with Skies the Limit as the provider. Email inquiries: [Parents@skiesthelimitllc.com](mailto:Parents@skiesthelimitllc.com)

Thank you for your time and attention!



Thank Yasuyuki Akiba, Dave Morrison, Lijuan Ruan, and STAR, PHENIX, sPHENIX collaborations, many others, and the DOE and NSF