Brookhaven National Laboratory

U.S. DEPARTMENT OF ENERGY

Introduction to Nuclear and Particle Physics Directorate

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Associate Laboratory Director

Postdoc Retreat

August 25, 2023

@BrookhavenLab

Brookhaven Lab: A Multi-purpose DOE Office of Science Lab

Managed by Brookhaven Science Associates

- Partnership between Stony Brook University and Battelle Memorial Institute
- Core universities: Columbia, Cornell, Harvard, MIT, Princeton, Yale

People

- 2,800 staff, 130 joint faculty, 500 students (FY22)
- 166 summer interns remotely; 189 in person (FY22)
- ~4,400 guests/users, including remote (FY22)
- >30,000 (K-12) students and educators annually (pre-COVID)
- 7 Nobel Prizes; 21 Laureates

Budget

- FY22 costs: $704 million
- Strongly aligned to SC (86%) and to DOE (91%)

Regional Economic Impact

- Supports over 4,700 New York jobs
- ~$400M NYS investment since 2013
- Long Island RailRoad Station near Discovery Park

A Few of BNL's Employee Resource Groups

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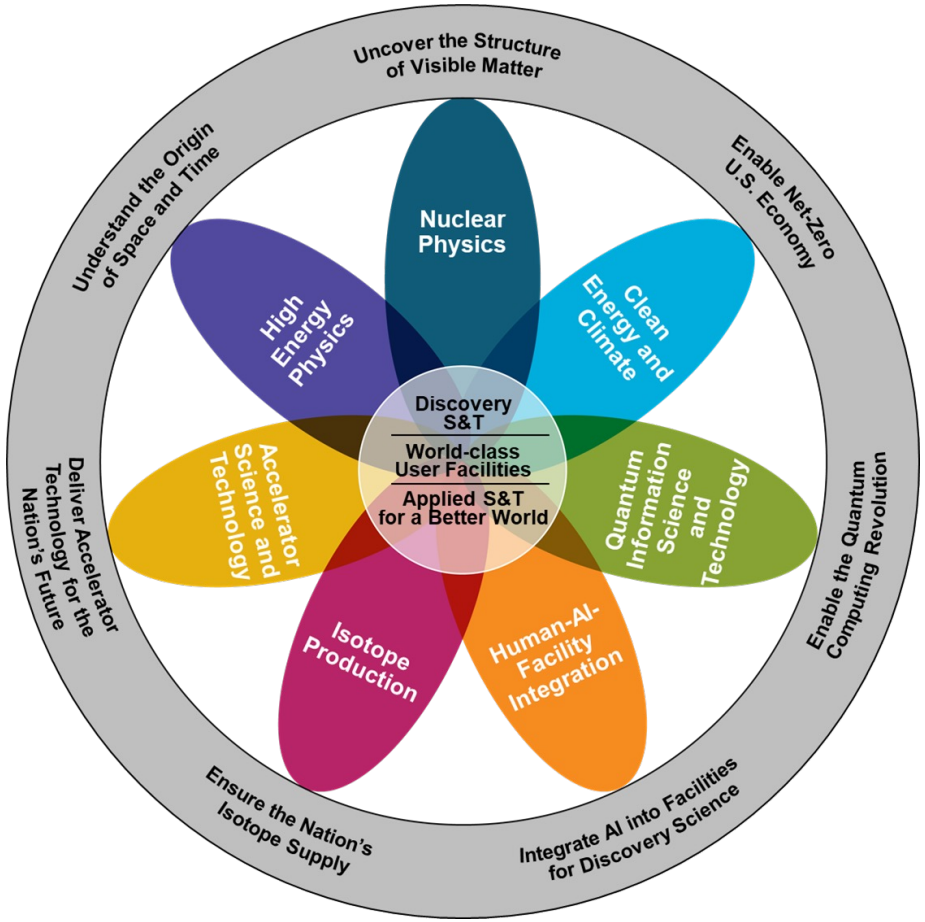
Science Organizations at BNL



- Nuclear and Particle Physics
- Electron-Ion Collider
- Energy & Photon Sciences
- Environment, Biology, Nuclear Science & Nonproliferation
- Advanced Technology Research Office
- Computational Sciences Initiative

Nuclear and Particle Physics

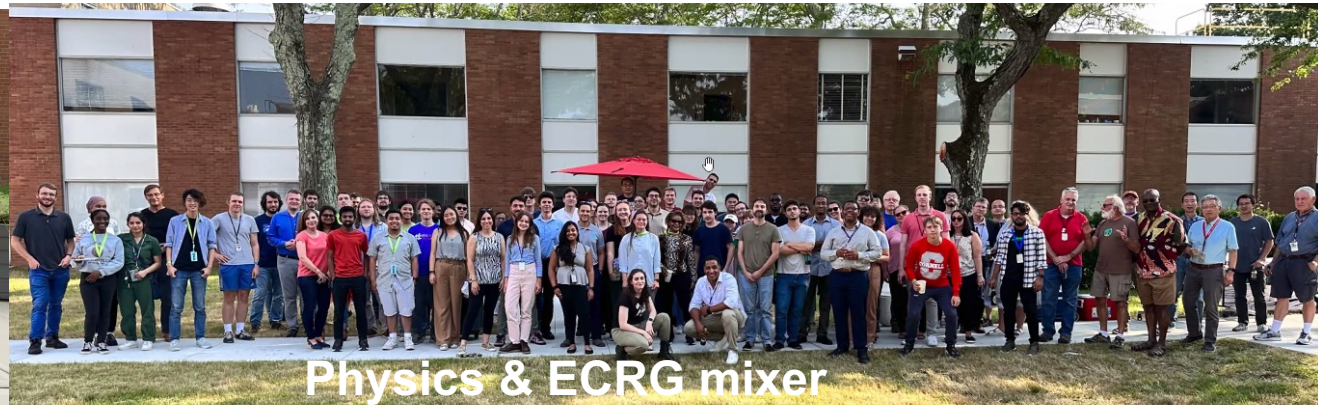
Our mission is to lead and support discovery-based, innovation-driven research at the frontiers of the subatomic world. We are world-leading in nuclear physics research, building and operating accelerator-based user facilities that serve international scientific communities. We also play a leading role in global particle physics programs that push the limits of precision and expand our understanding of the cosmos. Our pursuit of this fundamental and discovery research yields scientific and technological breakthroughs, and applications that benefit society—such as radioisotopes used to support industrial, medical and national security needs.

Our work draws on an international community filled with unique voices and perspectives, all contributing their ideas and experiences. We are passionate about welcoming people from all backgrounds and helping them succeed. Collectively, we will expand the boundaries of science and technology, advance the knowledge of humankind, bring new applications to society, and further our understanding of the natural world.

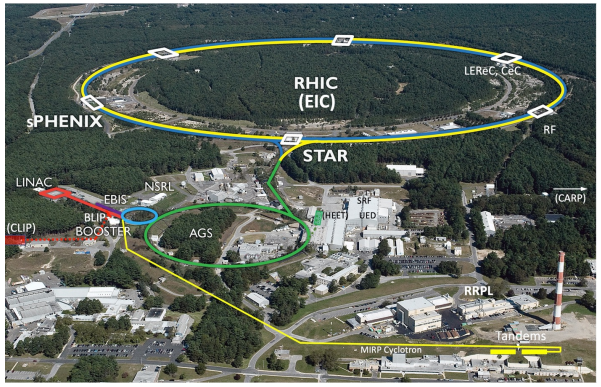
Diversity, Equity, Inclusion and Accessibility

- 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*" –NPP actively participating and part of the pilot program with the launch
- NPP DEI council has been active with many initiatives (e.g., Code of Conduct committee report)
- 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
- Led BNL@ North Carolina Agricultural and Technical State Univ. in April was successful & strong NPP participation
- Working on improving physical spaces and activities to make the working environment more welcoming and inclusive, collaborating with DEI council and ERGs
- Responding to DOE-SC FOAs on FAIR and RENEW programs in collaborations with MSIs
- Workforce development and pipeline: outreach, BNL summer Sundays, SULI, SCGSR, Nuclear Chemistry Summer School, African School of Physics, and more

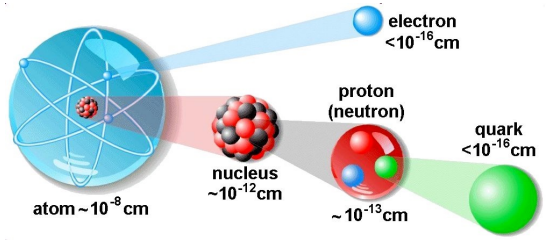
MSI workshop


Physics & ECRG mixer

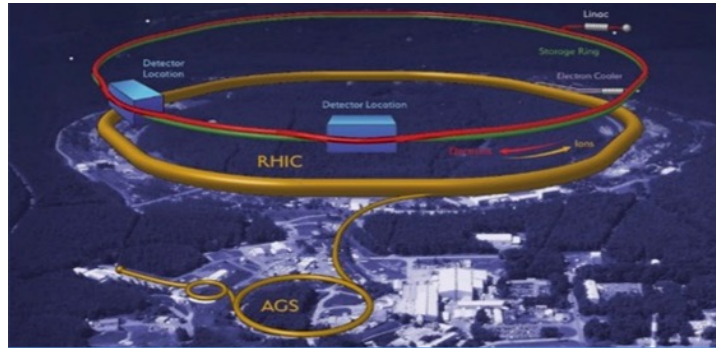
Nuclear & Particle Physics at BNL

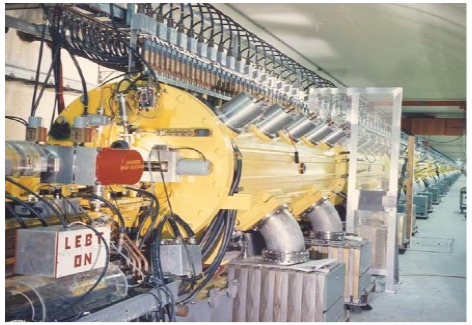


To understand sub-atomic world deeper and deeper



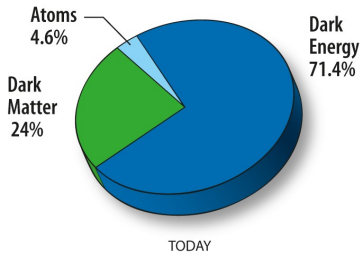
Electron-Ion Collider

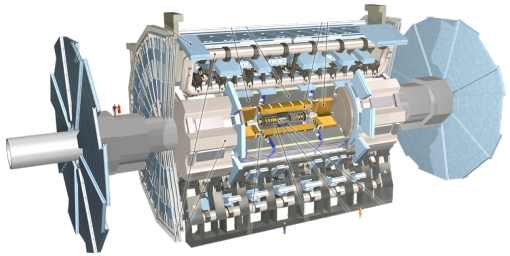




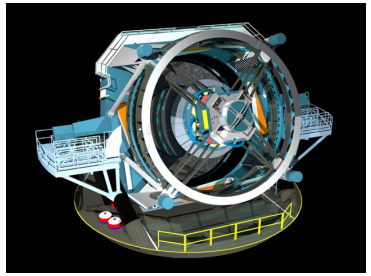
BLIP: Medical Isotopes

Develop unique technologies to answer fundamental questions in nature and for applications

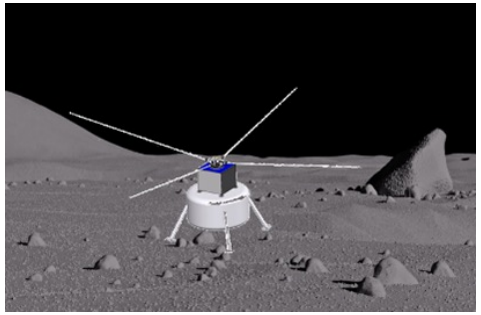




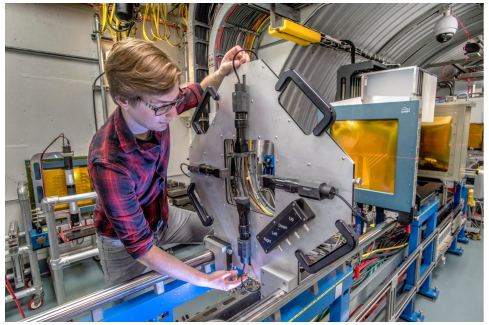
ATLAS @ LHC



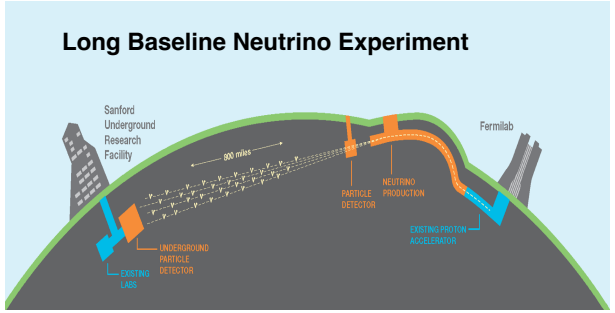
Rubin Observatory

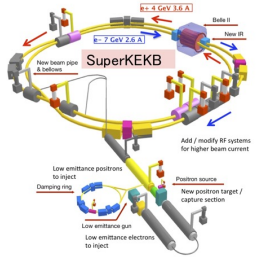


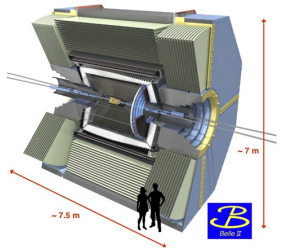
LuSEE-Night mission



NASA Space Radiation Lab







Belle II at SuperKEKB

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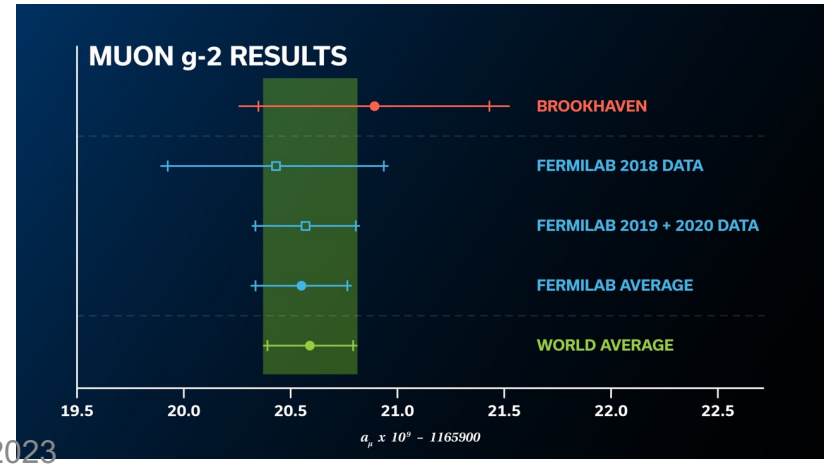
Active high-energy and nuclear theory groups; RIKEN-BNL Research Center (RBRC) and Center for Frontiers in Nuclear Science at Stony Brook

Strong Ongoing BNL Program Enables HEP Science

- **ATLAS experiment at CERN**
  - Lead laboratory for US ATLAS
- **Neutrino Program at Fermilab**
  - Proto-DUNE detector with BNL-developed components
  - Studying properties of neutrinos at short-baseline
- **Belle II experiment at KEK**
  - Lead laboratory for US Belle II
- **Rubin Observatory**
  - Commissioning the experiment in Chile
- **Theory, Detectors and Accelerators R&D**
  - Major contributions to the field

ATLAS muon system at CERN

New g-2 Result



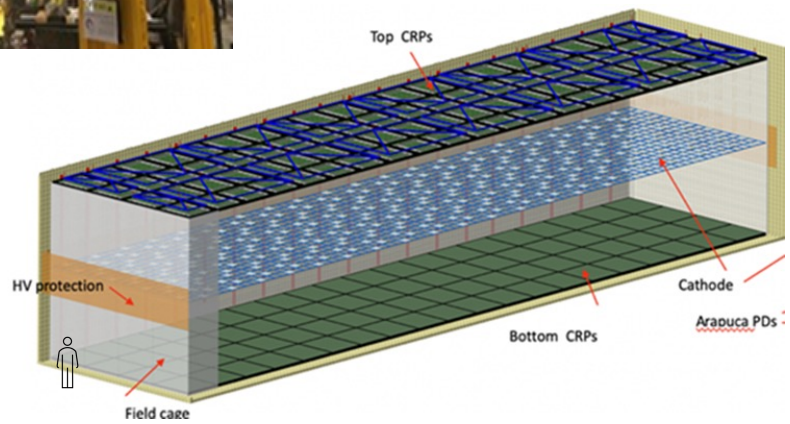
Implementing 2013 P5 Vision

- **Energy Frontier**
  - Hosting project for $300M HL-LHC ATLAS upgrade
  - Building magnets for the HL-LHC
  - Developing HL-LHC computing and software
- **Intensity Frontier**
  - Contributing to DUNE experiment
    - Leading DUNE far detector Module 2 activities
  - Preparing Belle II detector for Run II
- **Cosmic Frontier**
  - Getting ready to analyze Rubin Observatory data
  - Building LuSEE-Night mission to the far side of the moon
- **Leading Technologies Developments for Particle Physics**
  - Computing and software
  - Detectors and electronics
  - Accelerator R&D including superconducting magnets
- **Actively participating in developing long term future**
  - Snowmass and P5

HL-LHC magnet testing at BNL

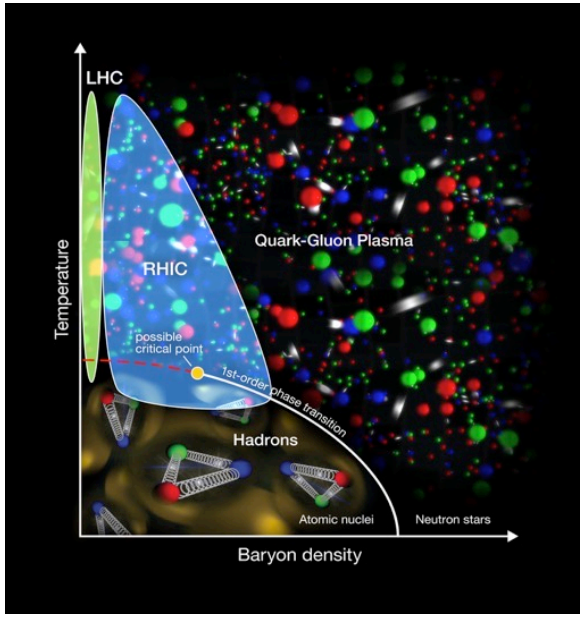
ATLAS silicon assembly at BNL

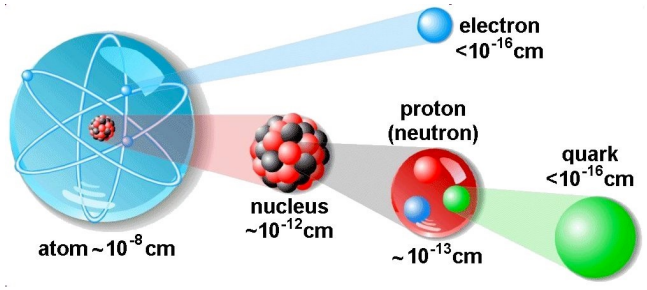
DUNE Module 2 design

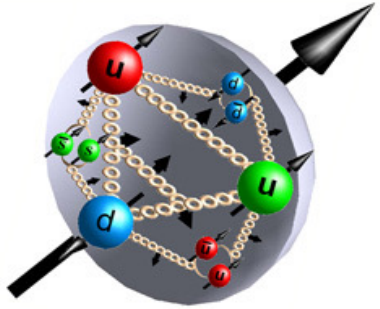


RHIC – a Unique Research Tool

- Heavy ion collisions
  - Explore new state of matter: Quark Gluon Plasma
  - Highest collision rates and collide many different ion species
- Polarized proton collisions
  - Only collider of spin polarized protons to explore the internal spin structure of protons.
  - Gluons carry part of proton spin







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Relativistic Heavy Ion Collider (RHIC) Complex

Uniquely flexible and only hadron collider in US for exploration of QCD phase diagram and proton spin

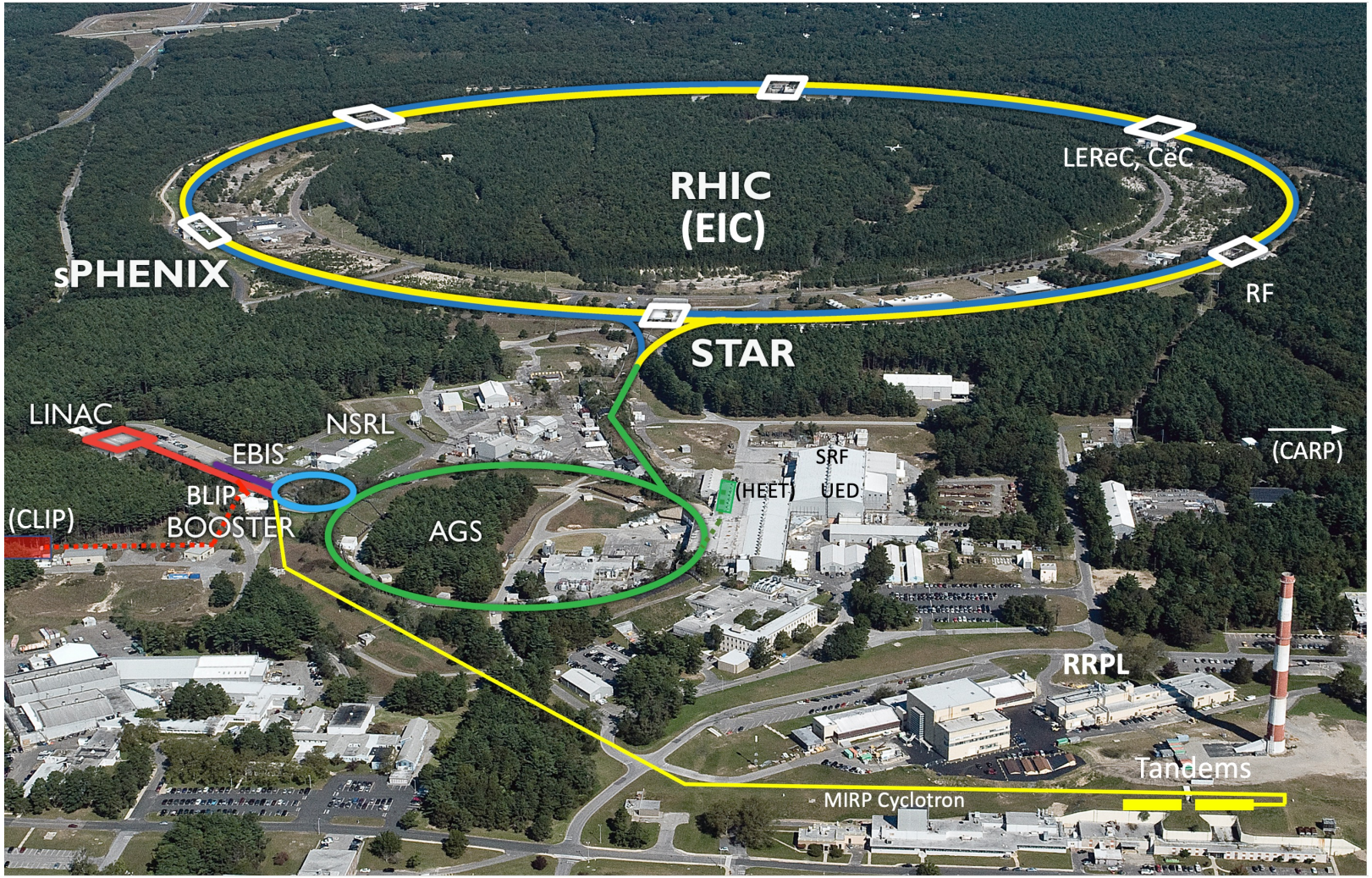
Injectors also used for application programs:

- Linac/BLIP for isotope production

- Booster/NSRL for space radiation studies

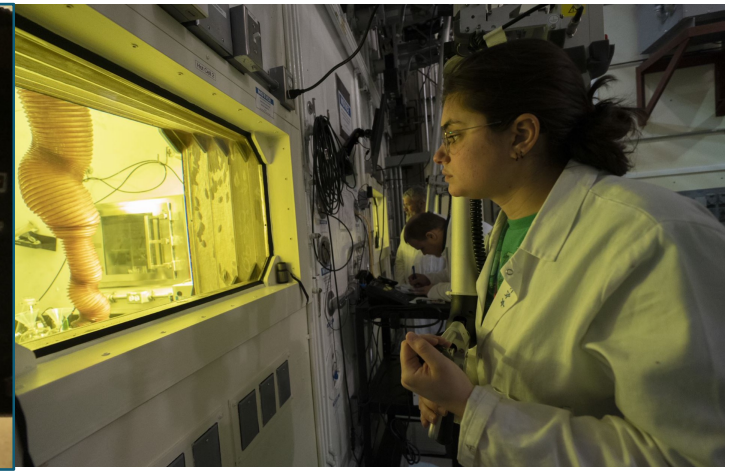
- Tandem for industrial/academic users

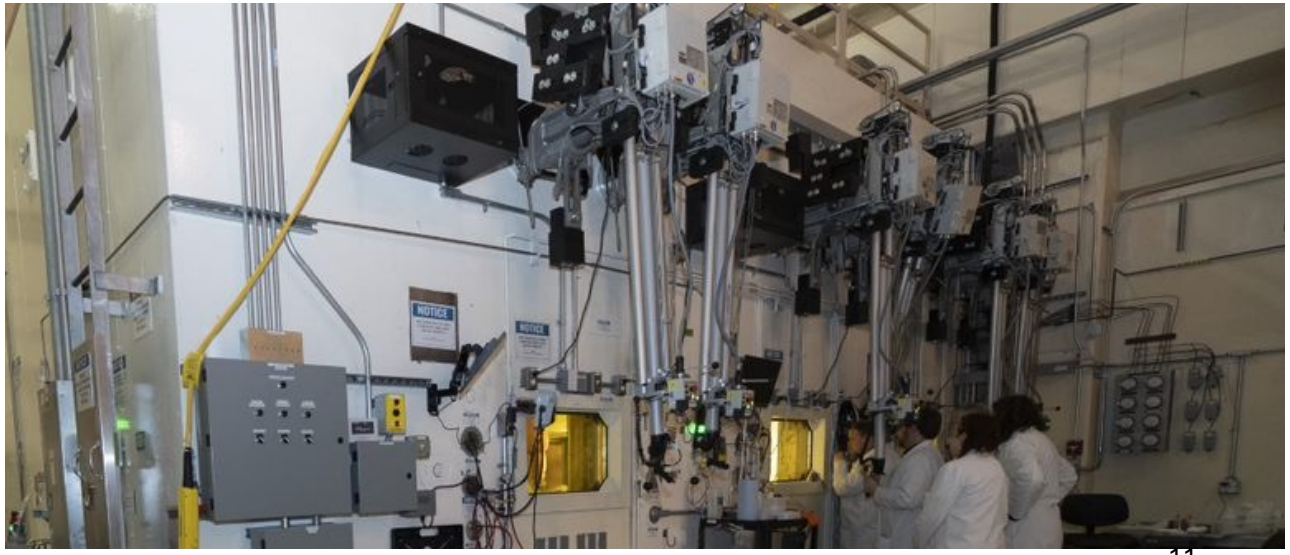
R&D for future facilities and application sources, cooling, pol. beams, …



Accelerating Isotope Production: Securing the Nation's Supply

- Producing isotopes with protons beam of up to 200 MeV and 165 μA
  - Extended accelerator operation period to provide Ac-225 for clinical trials
  - Produced a record batch of over 500 mCi of Ac-225
- Commissioned new hot cells for processing of Ac-225 to meet growing demand
- Bringing up a low energy cyclotron for supplying radionuclides currently available from foreign suppliers, and initiate production of Ac-225 from Ra-226 targets
- Engaging minority serving institutions to attract diverse talent
- Executing a BNL isotope program strategic vision

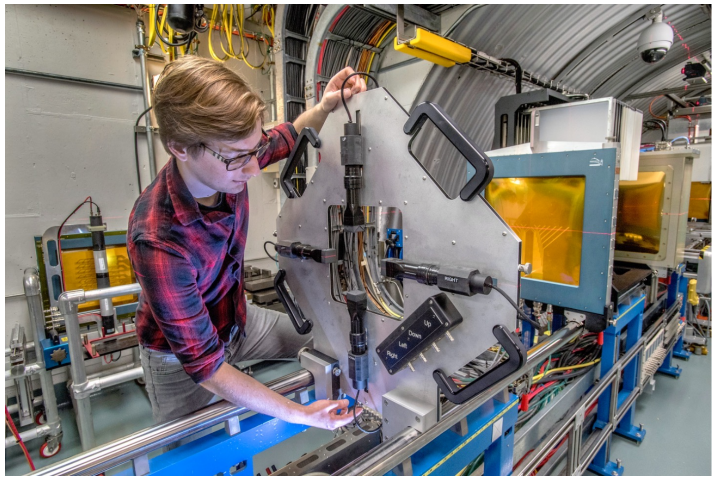


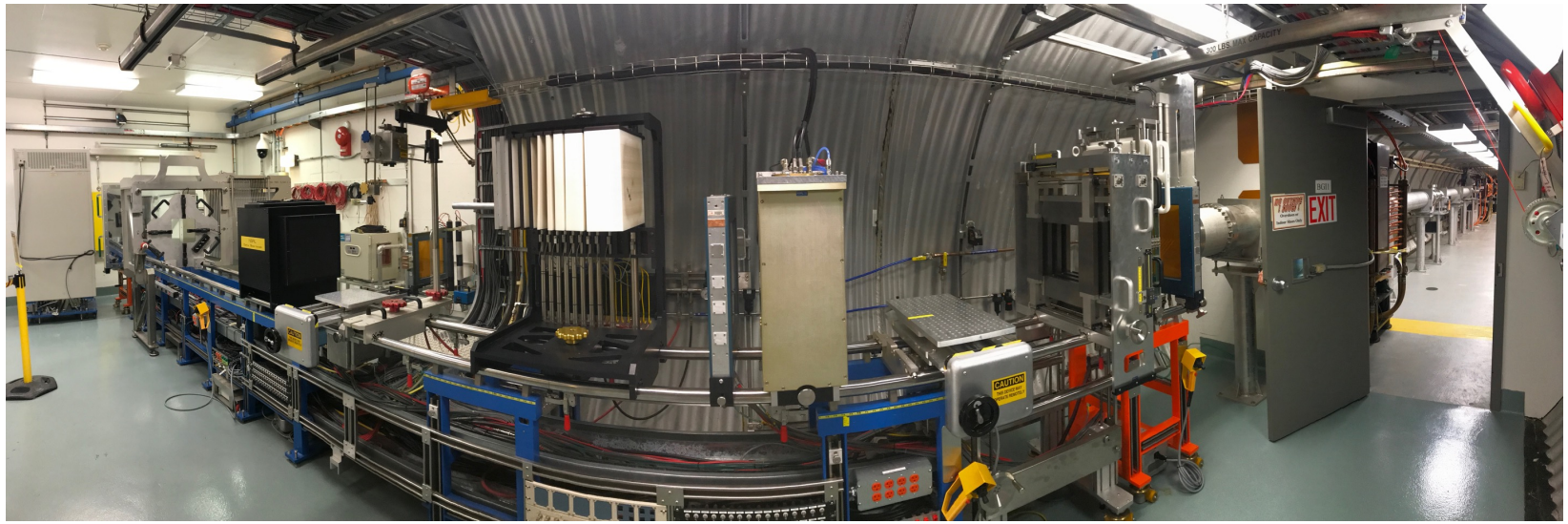


NASA Space Radiation Laboratory (NSRL)

- Started in 2003, simulates galactic radiation for human space flight
  - Heavy ion beams from AGS Booster
  - Electron Beam Ion Source (EBIS) provides all necessary ion beams
  - New laser ion source for EBIS allows for rapid species switching to simulate energy and species spectrum of deep space radiation field

- Additional uses of NSRL
  - Radiation effects studies (rapidly growing demand for satellite electronics testing
  - R&D of ion beam cancer treatment
  - Agreement with NASA in place for non-NASA users (“non-designated user facility”)





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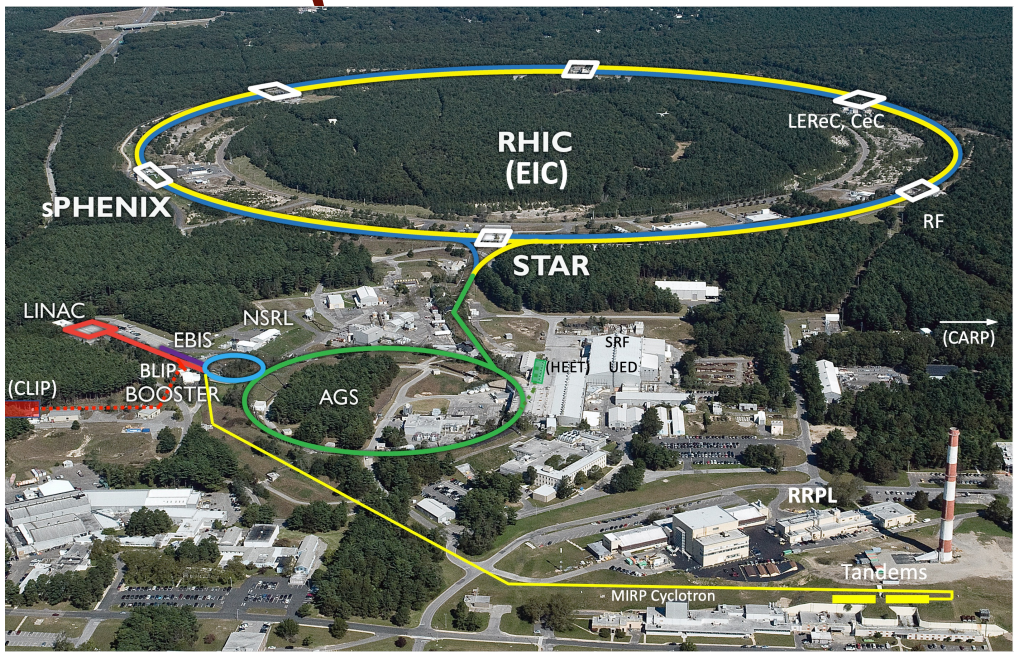
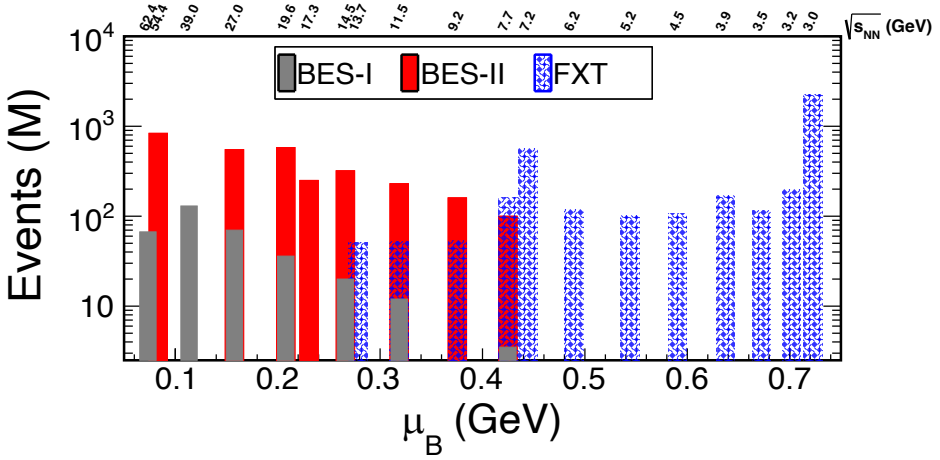
Complete RHIC Science Mission (2015 NSAC LRP)

"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)**



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)

Exceeded STAR data taking goals



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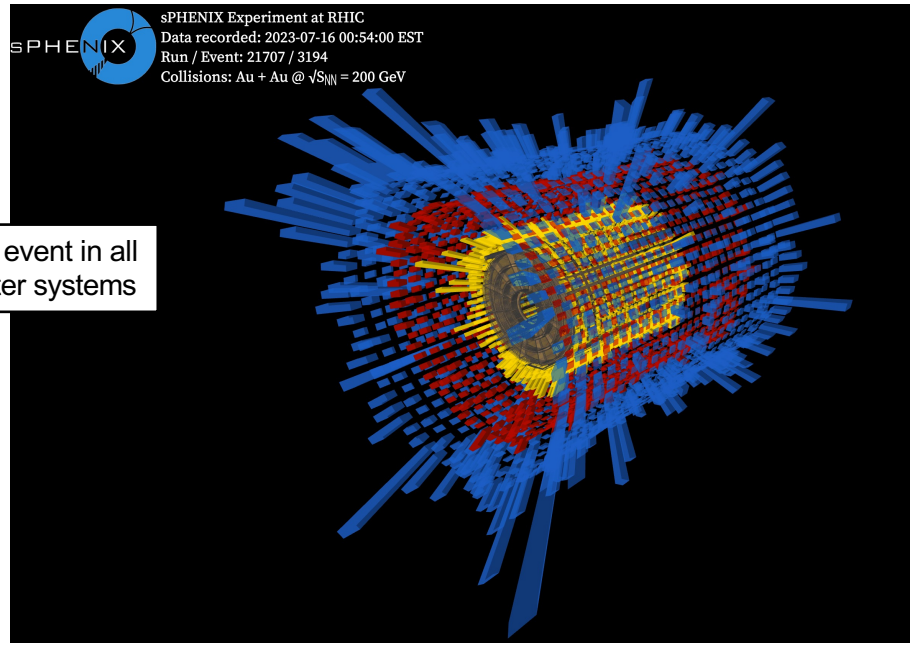
sPHENIX commissioning

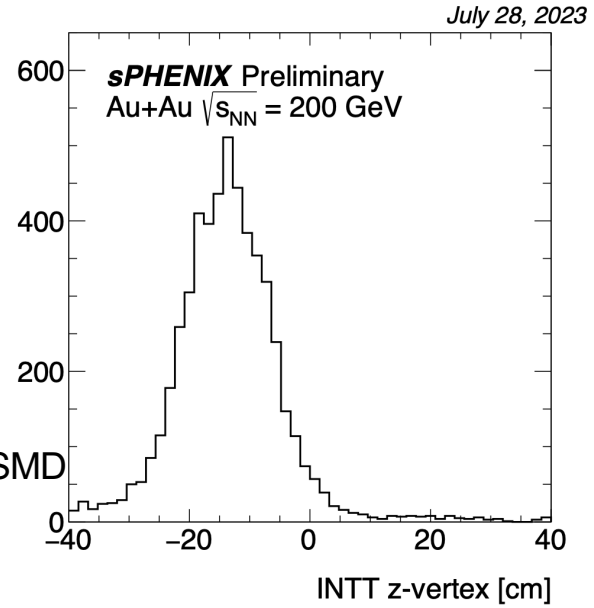
- Commissioning with beam started on May 18
- Ten sub-detectors* and DAQ to commission
- SC magnet operated very stably
- All sPHENIX subsystems, including the MVTX, had taken RHIC data and had the data stored in HPSS
- Excellent support from C-AD to provide wide variety of RHIC beam conditions
- Recent focus had been on operation of TPC at full HV and on MVTX response to apparent beam halo prior to August 1, 2023

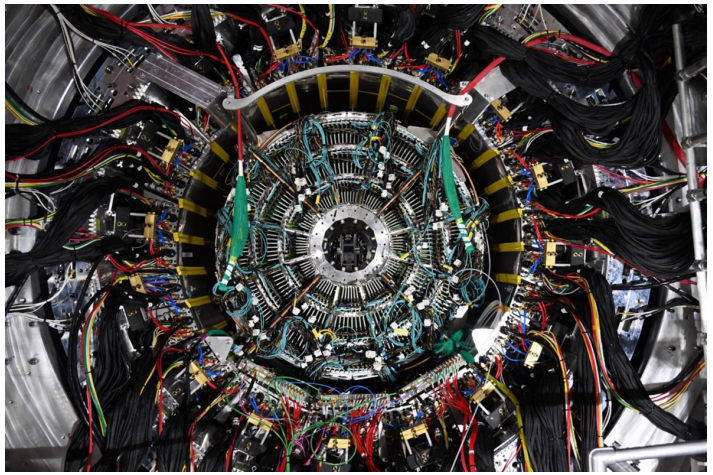
*MVTX, INTT, TPC, TPOT, EMCal, iHCal, oHCal, MBD, sEPD, ZDC/SMD



Central Au+Au event in all three calorimeter systems

Reconstruction of vertex location along beam axis using INTT silicon strip detector





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 Fliller, Frank Craner, Wolfram Fischer

We decided to end Run 2023 Friday August 4th and started controlled warm-up as repair is estimated to take several weeks.

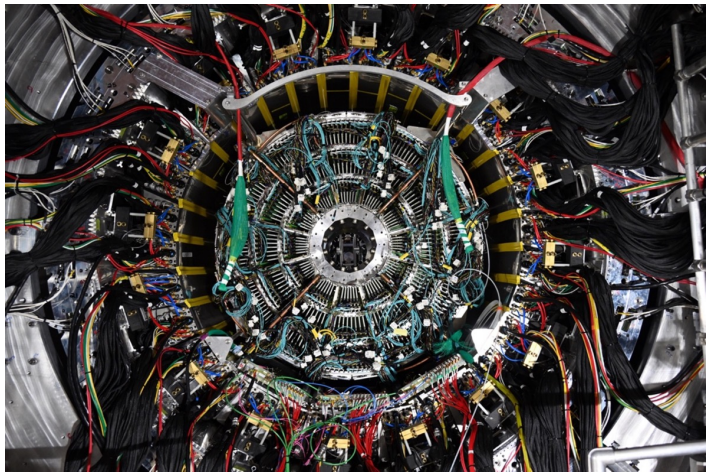
We start the planned shutdown activities

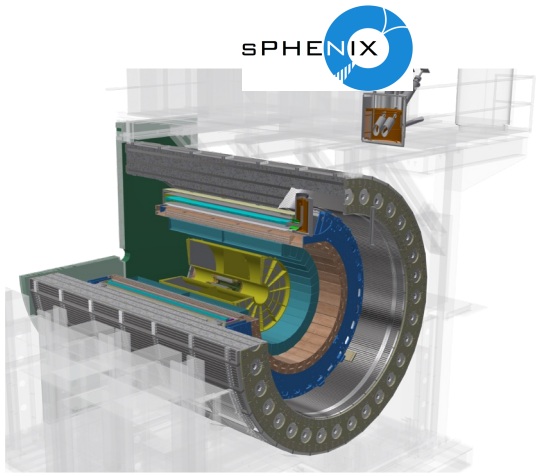
Run 2024 will start earlier than previously planned

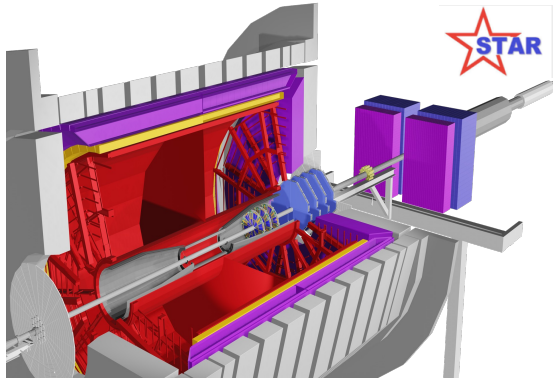
Completing the RHIC Mission with sPHENIX and STAR

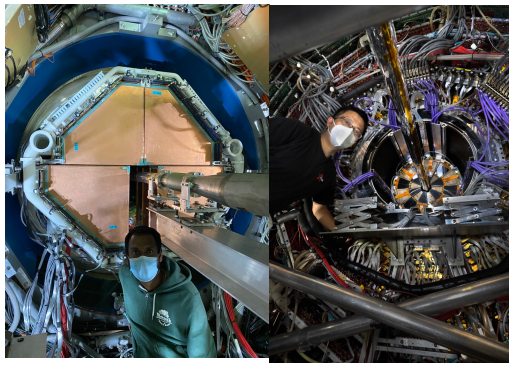
- sPHENIX will use energetic probes (jets, heavy quarks) to study quark-gluon plasma with unprecedented precision
  - How the structureless "perfect" fluid emerges from the underlying interactions of quarks and gluons at high temperature
- sPHENIX outer hadron calorimeter will be part of the EIC project detector
- Detector (sPHENIX and STAR) removal and repurpose for EIC

- 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 2024–2025
sPHENIX upgrade and STAR with forward upgrade will fully utilize the enhanced (~50 times Au+Au design) luminosity of RHIC

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The Electron-Ion Collider

2015 NSAC LRP

"We recommend a high-energy high-luminosity polarized EIC as the highest priority for new facility construction following the completion of FRIB."

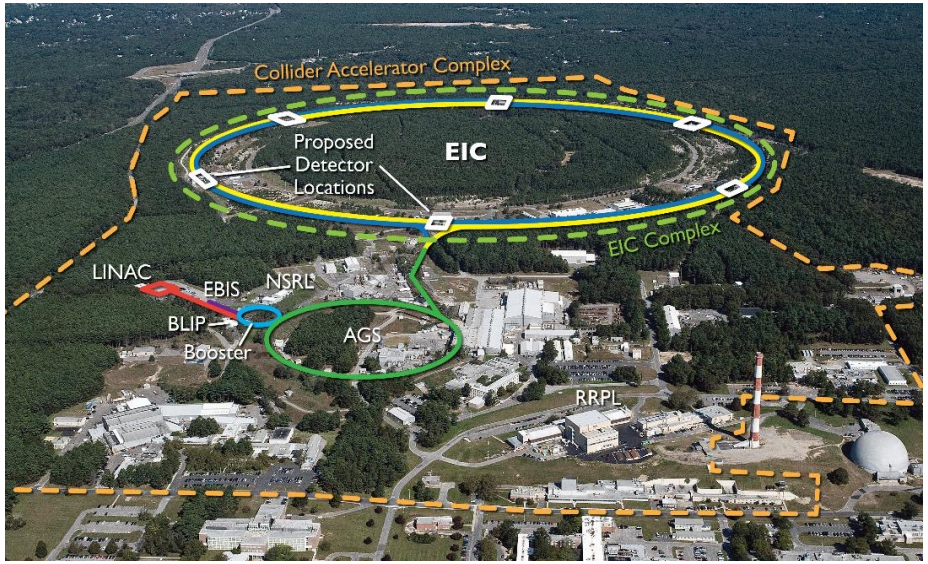
Project Design Goals

- High Luminosity: L= 10^{33}–10^{34}cm^{-2}sec^{-1}, 10–100 fb^{-1}/year
- Highly Polarized Beams: ~70%
- Large Center of Mass Energy Range: E_{cm} = 20–140 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)

An EIC can uniquely address three profound questions about nucleons—neutrons and protons—and how they are assembled to form the nuclei of atoms:

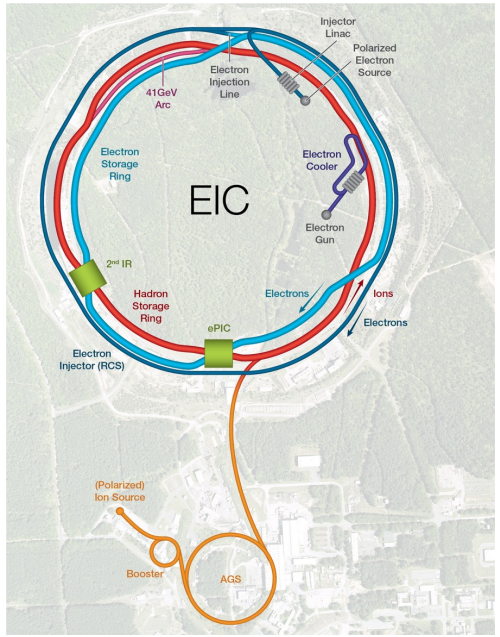
- How does the **mass** of the nucleon arise?
- How does the **spin** of the nucleon arise?
- What are the emergent properties of dense systems of gluons?



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; EIC Resource Review Board (RRB) meeting April 2023

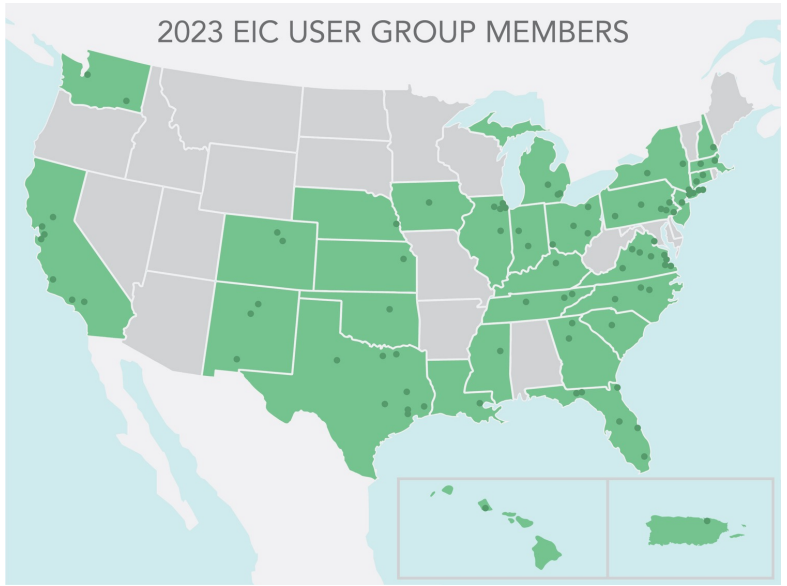
EIC Network for Discovery Science and Workforce Development



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 STEM workforce for the nation from a broad pool of talent.

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.



Thank you for your time and attention!