Brookhaven National Laboratory

U.S. DEPARTMENT OF ENERGY

Nuclear and Particle Physics Directorate

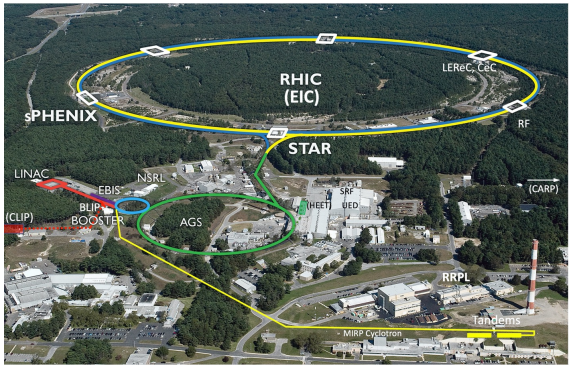
Haiyan Gao

September 9, 2022

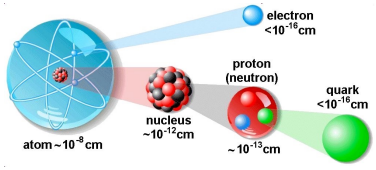
Early Career Scientist Retreat

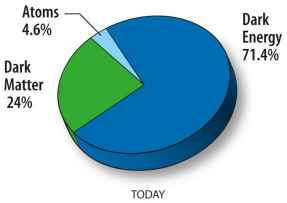
@BrookhavenLab

Nuclear & Particle Physics at BNL

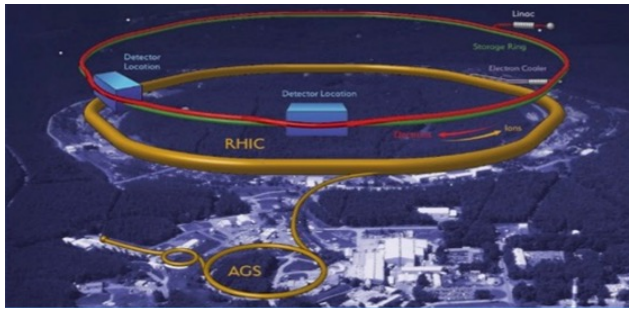


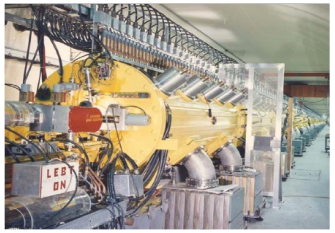
To understand sub-atomic world deeper and deeper





Electron-Ion Collider

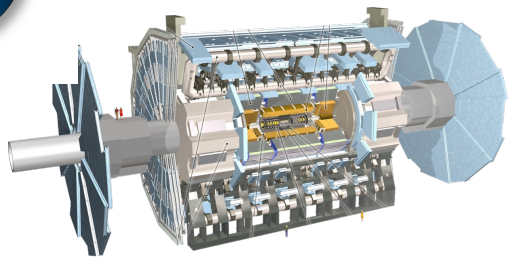




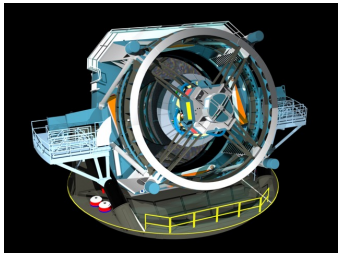
BLIP: Medical Isotopes

NASA Space Radiation Lab

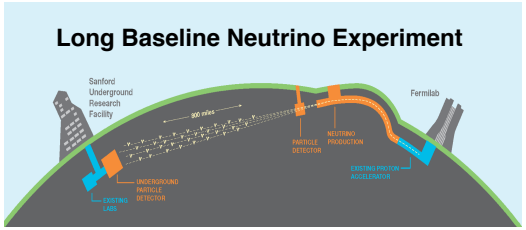
Develop unique technologies to answer fundamental questions in nature and applications of societal benefits

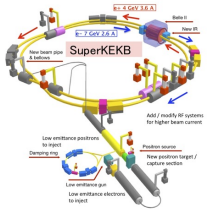


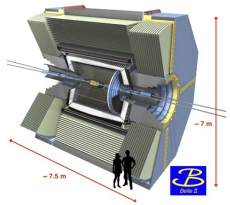
ATLAS @ LHC



Rubin Observatory





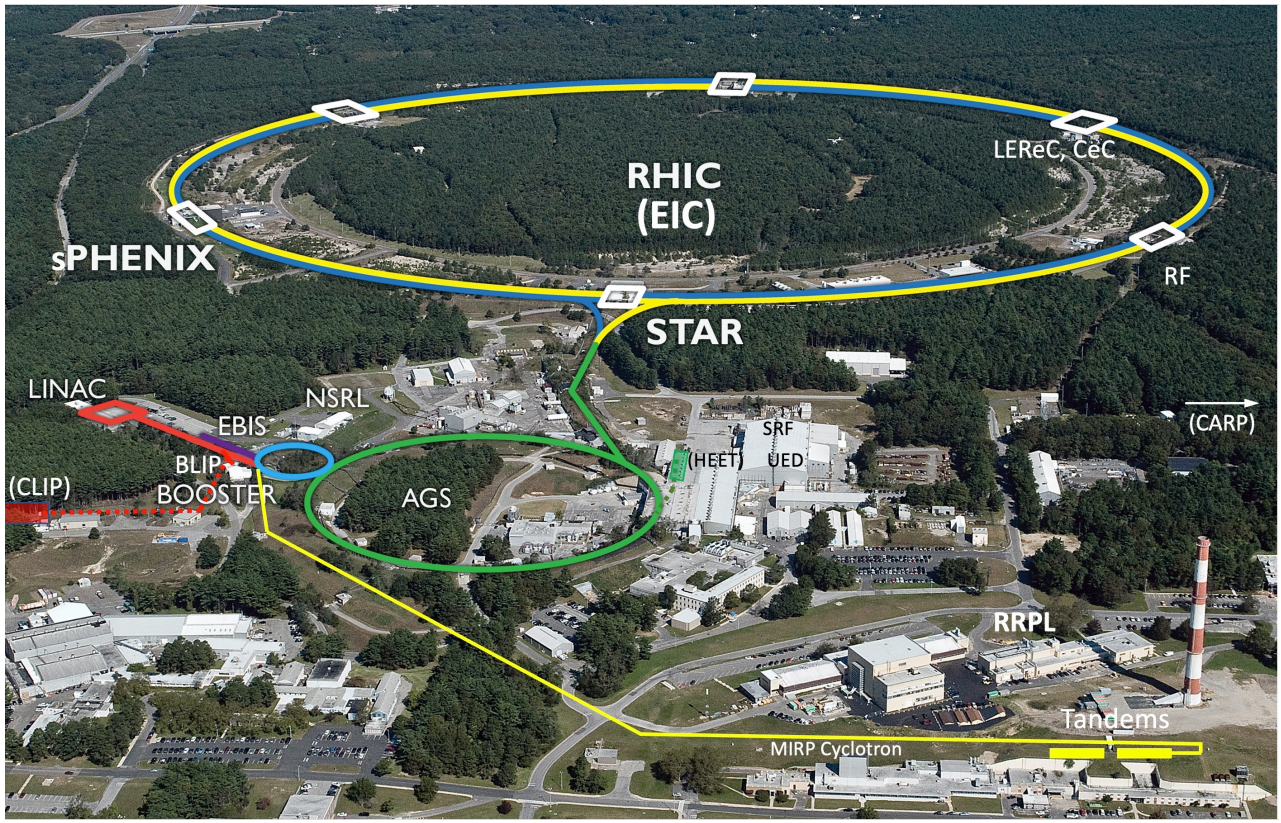


Belle II at SuperKEKB

High-Energy Theory, Nuclear Physics Theory
Center for Fundamental Nuclear Science
RIKEN-BNL Research Center

Brookhaven National Laboratory

Relativistic Heavy Ion Collider (RHIC) Complex

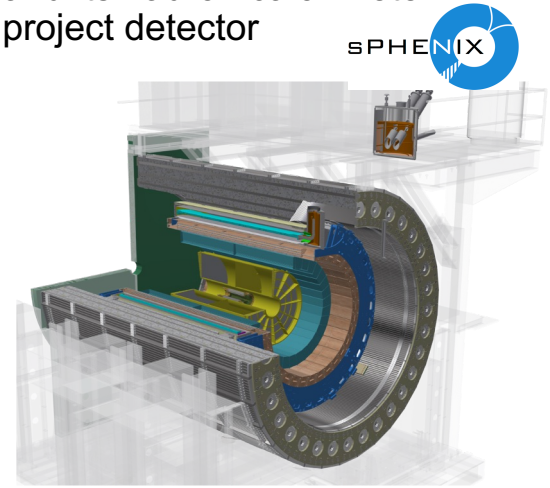


- Uniquely flexible and only hadron collider in the United States for exploration of QCD phase diagram and proton spin
- Injectors also used for application programs
  - Linac/BLIP for isotope production
  - Booster/NSRL for space radiation studies
  - Tandem for industrial/academic users
- R&D for future facilities and application (sources, cooling, pol. beams, …)

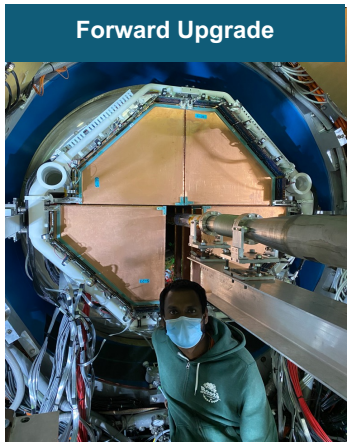
Completing the RHIC Mission with sPHENIX and STAR

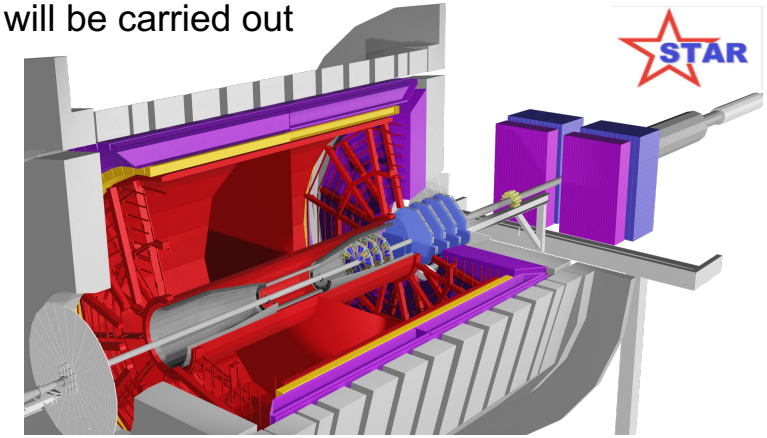
- sPHENIX will use energetic probes (jets, heavy quarks) to study quark-gluon plasma on different length scales with unprecedented precision
  - How the structureless "perfect" fluid emerges from the underlying interactions of quarks and gluons at high temperature
- State-of-the-art collider detector using technology developed for LHC by ONP and OHEP
- sPHENIX magnet and its hadron calorimeter will be part of the EIC project detector

Magnet & Calorimeter



- STAR with forward upgraded detectors ran successfully in Run 2022
  - 3-D tomography (like Magnetic Resonance Imaging) of the nucleon uncovers new information
  - STAR exploits such 3-D parton dynamics in ways complementary to the EIC, where precision tomography of the nucleon and nuclei will be carried out





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

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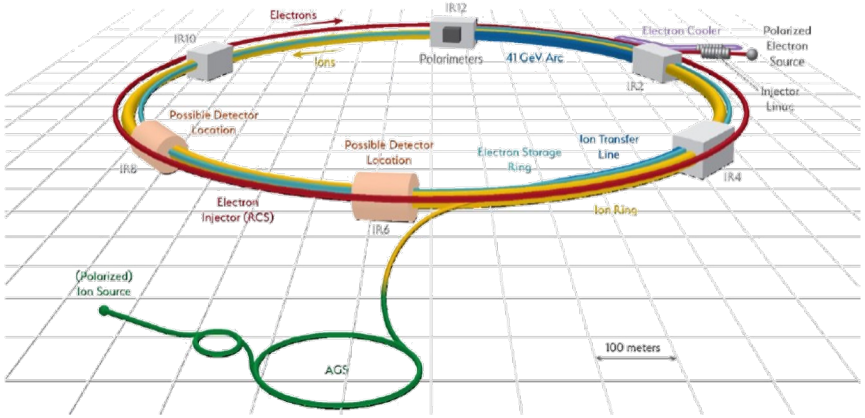
The Electron-Ion Collider

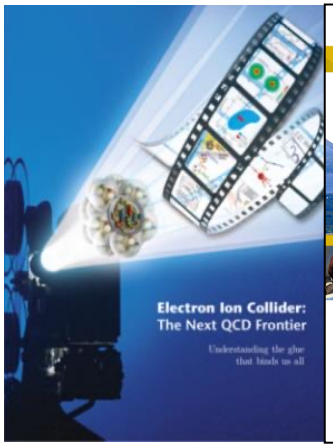
Project Design Goals

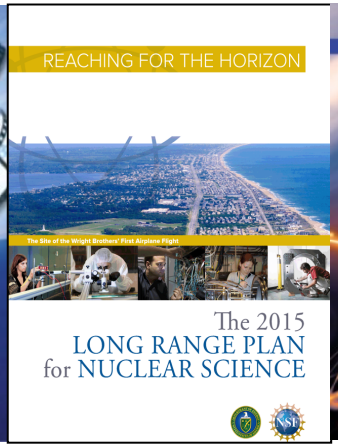
- High Luminosity: L= 10^{33}–10^{34}cm^{-2}sec^{-1}, 10–100 fb^{-1}/year
- Highly Polarized Beams: ~70%
- Large Center of Mass Energy Range: E_{cm} = 20–140 GeV
- Large Ion Species Range: protons – Uranium
- Large Detector Acceptance and Good Background Conditions
- Accommodate a Second Interaction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

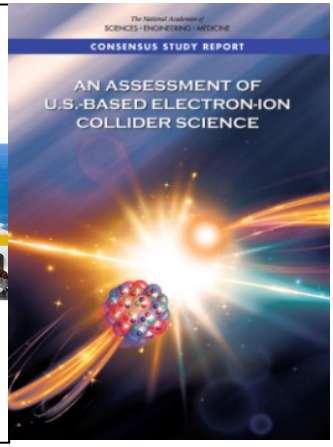
Conceptual design scope and expected performance meet or exceed NSAC Long Range Plan (2015) and the EIC White Paper requirements endorsed by NAS (2018)



Double Ring Design Based on Existing RHIC Facility







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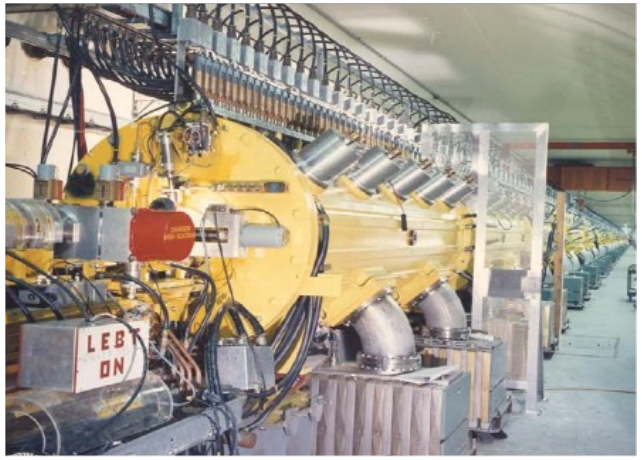
Major milestones: CD-0 December 2019; DOE EIC site (BNL) selection on Jan 9, 2020; CD-1 June 2021; EIC project detector reference design selected in March 2022; ePIC collaboration is being formed

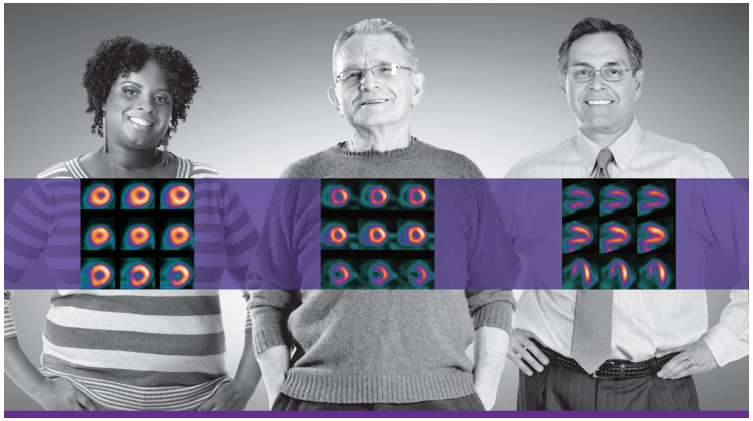
Brookhaven Linac Isotope Producer (BLIP)

50th anniversary

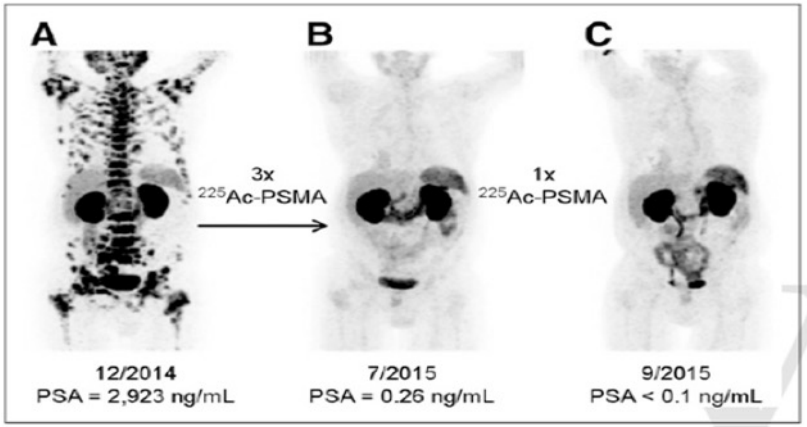
Official Use Only

- Target irradiation with 116 – 200 MeV, 160 mA proton beam
- Production of medical radio-isotopes for U.S.:
  - Mainly Sr-82, shared between LANL and BNL
  - R&D of new radio-isotopes for diagnosis and therapy (Ac-225, needs ~ 200 MeV protons)
- Significant expansion is underway:
  - BLIP target and proton beam intensity upgrades
  - Refurbishment of additional hot cells for Ac-225 processing
  - Bringing up a low-energy Cyclotron for supplying radionuclides currently available only from foreign suppliers, and an alternative Ac-225 production route with radium targets (Ac-225 without Ac-227 contamination)





Sr-82: coronary artery disease diagnosis, used under rest and stress conditions



Ac-225: Alpha emitter for treatment of metastatic prostate cancer

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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”)

High Energy Physics: Understanding the Origin of Space and Time

ATLAS experiment

- Lead Lab for U.S. ATLAS collaboration of 800 U.S. scientists
- Leading US ATLAS Operations program and hosting ATLAS computing center

Neutrino Program

- Studying properties of neutrinos with MicroBooNE experiment
- Operating Proto-DUNE detector with BNL-developed cold electronics

Belle II experiment

- Lead Lab for U.S. Belle II experiment in Japan

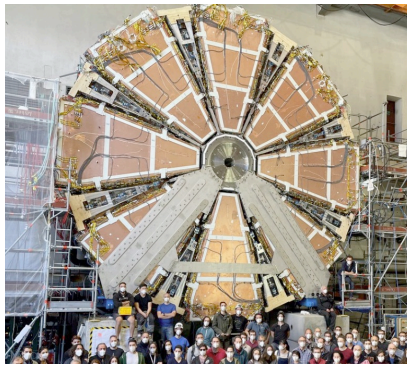
Rubin Observatory

- Commissioning the experiment in Chile
- Developing computing and software for data analysis

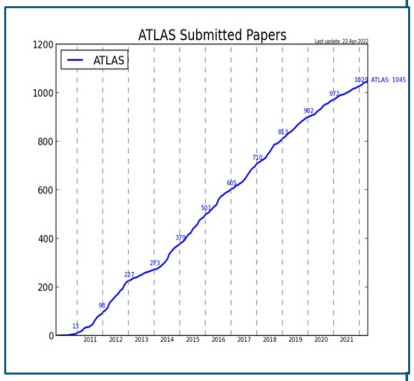
Theory

- Developing new ideas and models in neutrino, collider, and precision particle physics

Assembly of muon system at CERN



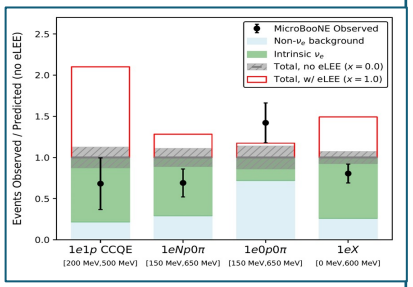
ATLAS published over 1000 papers



New ATLAS/Belle II computing center

2010 2022

Exclusion of sterile neutrinos



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High Energy Physics: Driving and Enabling the Future of the Field

Energy Frontier

- Hosting project office for $250M ATLAS upgrade
- Building magnets for the HL-LHC upgrade
- Developing computing and software for effective ATLAS data management

Intensity Frontier

- Key contributions to DUNE experiment
  - Leading DUNE Module 2 activities
- Planning studies of charge-parity violation with Belle II experiment

Cosmic Frontier

- Soon to analyze unique Rubin Observatory camera data
- Lead lab for LuSEE-Night mission to the far side of the moon
  - Detect “Dark Ages” signal from early Universe

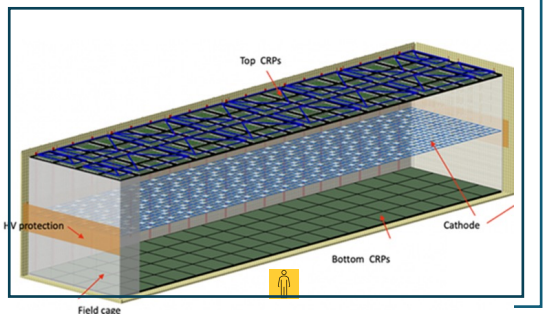
Leading Technology Developments for Particle Physics

- Computing, software, detectors, and electronics
- Accelerator R&D, including superconducting magnets

LHC magnet testing at BNL

ATLAS silicon assembly at BNL

DUNE Module #2 design



Participating in long term planning at Snowmass

- Over 130 white papers with proposals submitted by BNL scientists

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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.*

New NPP web page https://www.bnl.gov/npp