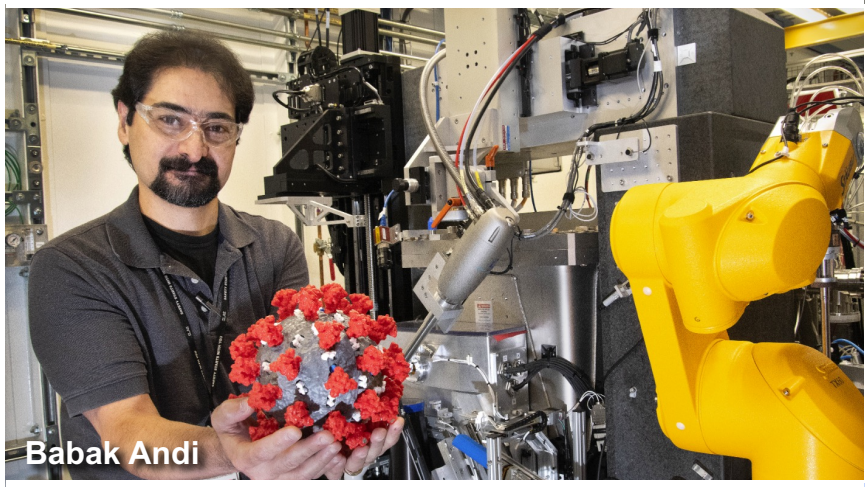

Brookhaven
National Laboratory
U.S. DEPARTMENT OF
ENERGY
Brookhaven’s Physics Program
JoAnne Hewett
@BrookhavenLab

Brookhaven National Laboratory

A Multipurpose DOE Office of Science Lab

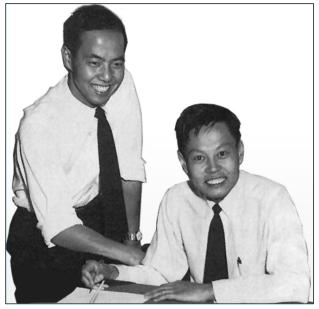
- Managed for the U.S Department of Energy (DOE) by Brookhaven Science Associates. BSA is a partnership between Stony Brook University and Battelle Memorial Institute.
- Vision: To accelerate pathways to scientific discovery and technological innovation that transforms the world.
  - Pull together large teams from labs, industry, universities
  - Builds, operates large facilities
- People
  - 2,900 staff
  - 140 joint faculty
  - 500 students
  - 4,400 facility users and guests
  - Pre-COVID: 30,000+ students and educators (K–12) annually
- Budget: $800 million
- Regional economic impact
  - Supports over 4,700 jobs in New York State
  - Strong relationship with New York State: $400M invested by NYS since 2013
  - New Long Island Railroad station bordering campus
  - Developing strategy for carbon-free operations by 2040


Jasmine Hatcher-Lamarre


Babak Andi

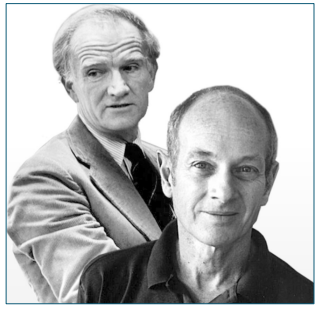

Jantana Keereetaweep

Brookhaven's History of Discovery

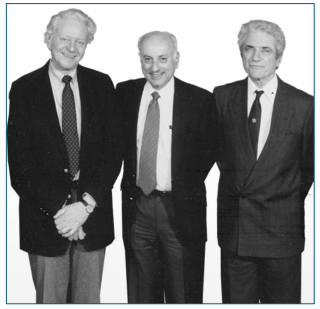


1957 Physics: Lee (Columbia) and Yang (BNL) for parity violation

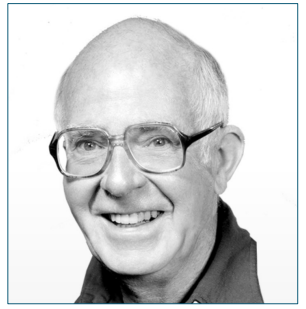
1976 Physics: Ting (MIT) for discovery of the J/Psi particle



1980 Physics: Cronin and Fitch (Princeton) for CP Violation



1988 Physics: Lederman, Schwartz, Steinberger (Columbia) for discovery of the muon-neutrino



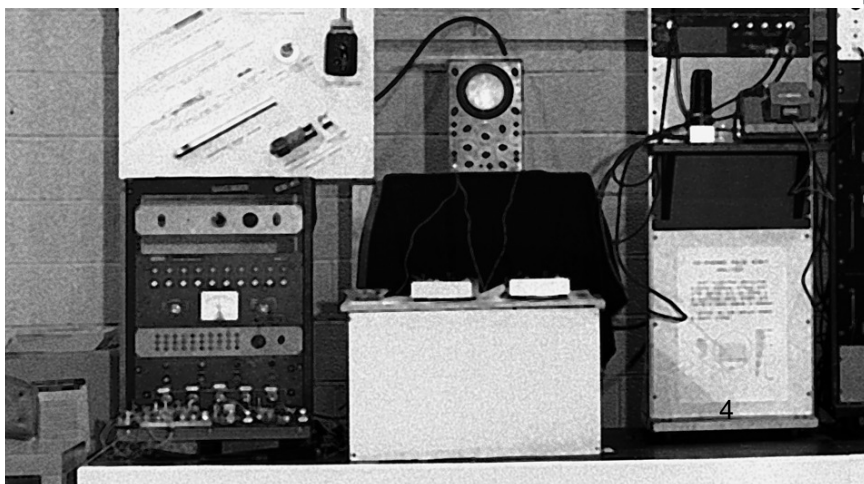
2002 Physics: Davis (BNL) for detection of solar neutrino deficit

2003 Chemistry: MacKinnon (BNL) explained how proteins generate nerve impulses

2009 Chemistry: Ramakrishnan and Steitz (BNL, Cambridge, Yale) for structure and function of the ribosome

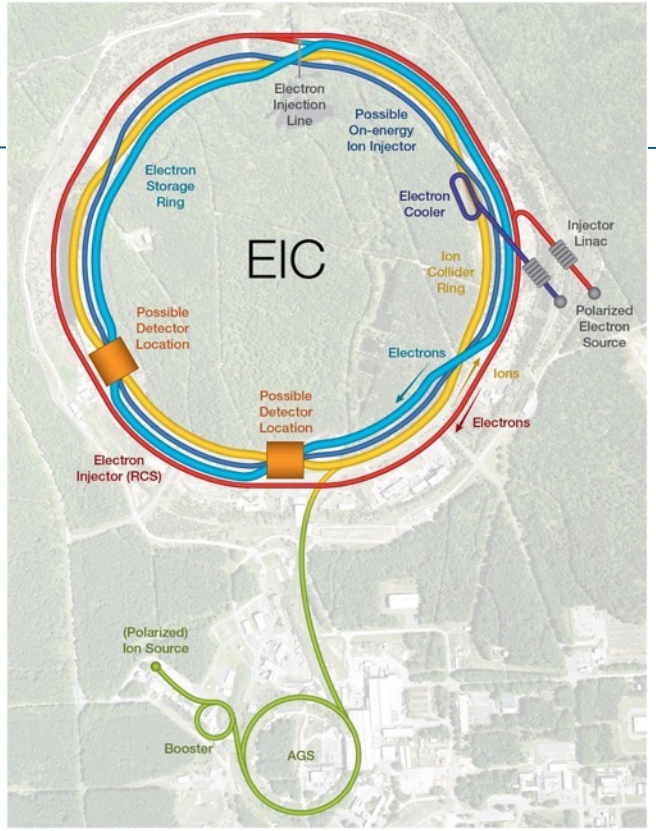
Billion-Dollar Impacts

- T7 virus genome for biomedical research, diagnostics, and treatment. More than 35 years after being patented, was used to scale up production of Pfizer-BioNTech and Moderna's COVID-19 vaccines (2023 Nobel Prize in Medicine)
- Patented Maglev
- Cleaner-combusting oil burners, saving consumers approximately $25 billion in fuel costs and avoiding 160 megatons of carbon dioxide emissions
- Synthesized human insulin to treat diabetes
- Technetium-99m, most widely used radioisotope for imaging diseased organs
- Developed L-dopa, gold standard for treating Parkinson's disease
- "Tennis for Two" in 1958: the world's first video game



Electron-Ion Collider (EIC) Is the Future for BNL

- Discovery machine will allow scientists to look inside protons and neutrons and unlock mysteries of the strong force that binds nature's building blocks: quarks and gluons
- Research and development for the EIC will lead to advanced technology and useful applications
- The EIC is being built through a partnership with DOE, Brookhaven, and Thomas Jefferson National Accelerator Facility with additional support from New York State
- The EIC benefits from participation among international collaborators
  - £58M commitment from the UK
  - Statement of interest from CEA, CRNS
- IRA funding of $138M
- CD-3A received March 2024
- $100M New York State grant for EIC infrastructure



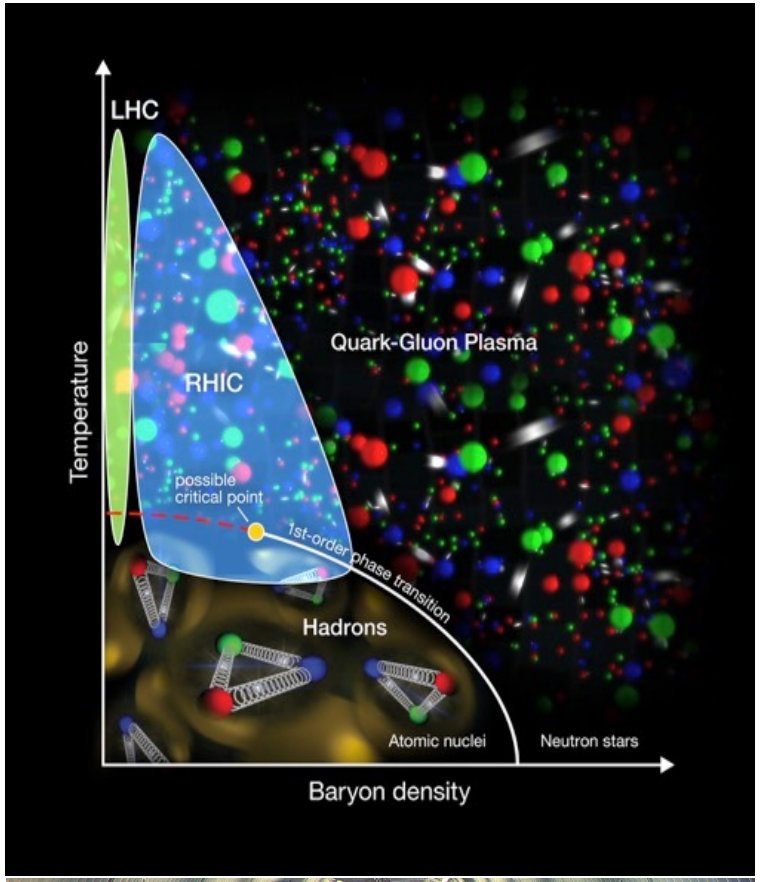
Planning for Brookhaven's Future: Vision and Science Initiatives

Vision: To accelerate pathways to scientific discovery and technological innovation that transforms the world

Brookhaven National Laboratory

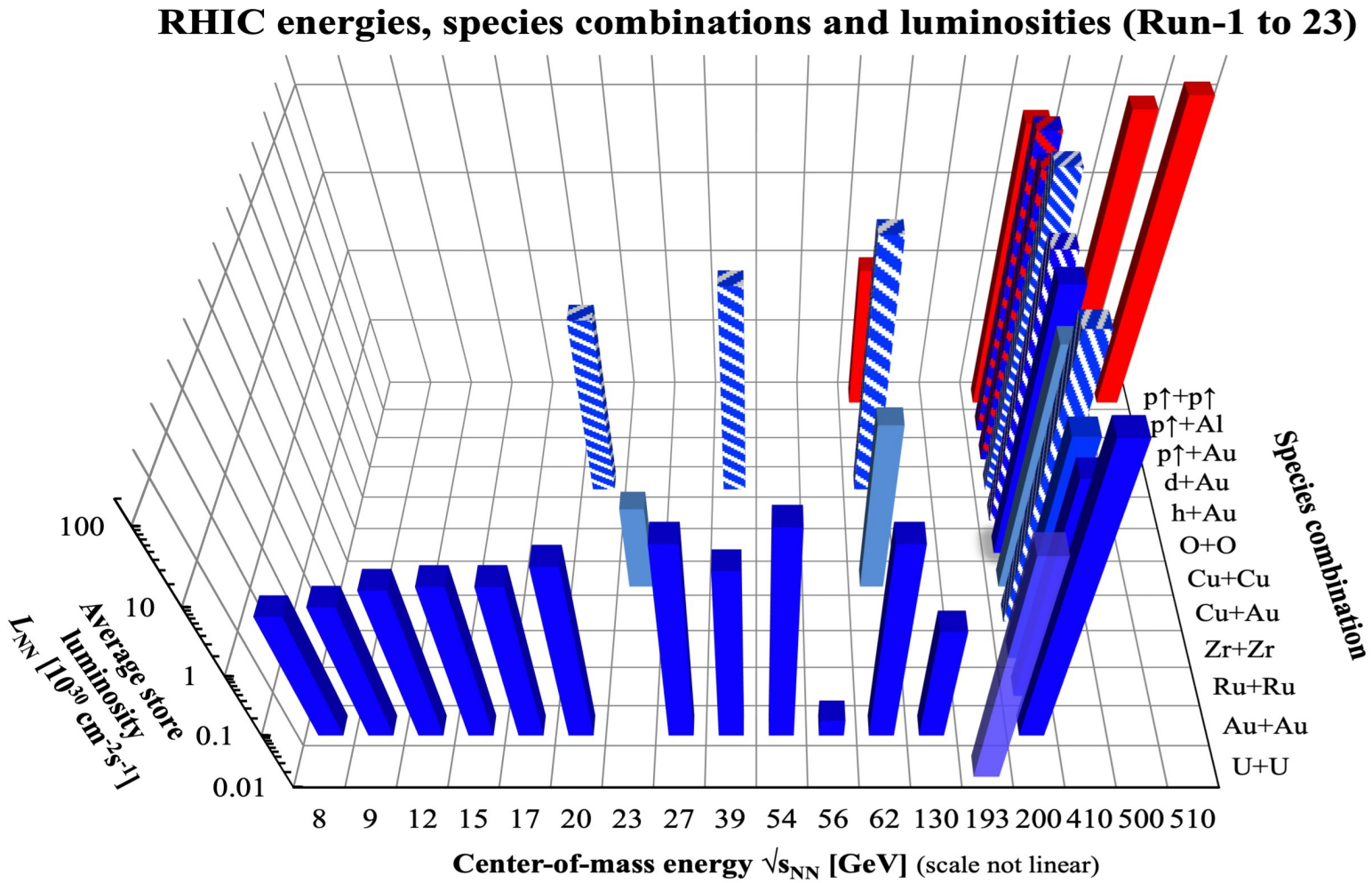
Relativistic Heavy Ion Collider – a Unique Research Tool

- 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 worldwide with spin polarized protons to explore the internal spin structure of protons
- Only operating collider in the U.S.



Brookhaven National Laboratory

23 years of RHIC Performance: A versatile collider!

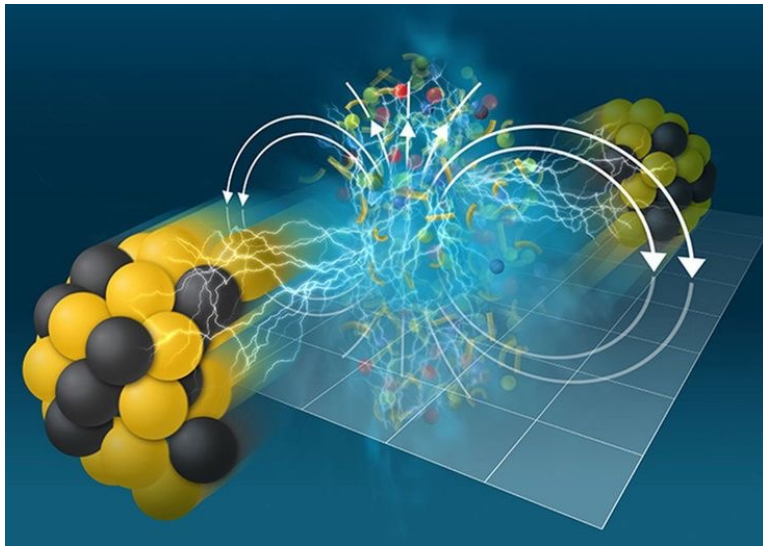


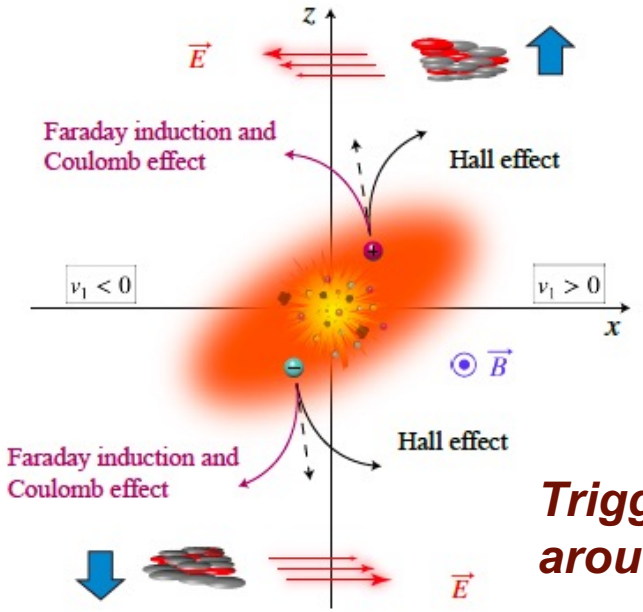
- 2024 Run starts Monday! Plan for 25 cryo-weeks
- 2025 run is expected to be RHIC's last

Brookhaven National Laboratory

Colossal Magnetic Field Detected in Nuclear Matter

STAR, arXiv: 2304.03430, PRX 14, 011028 (2024)

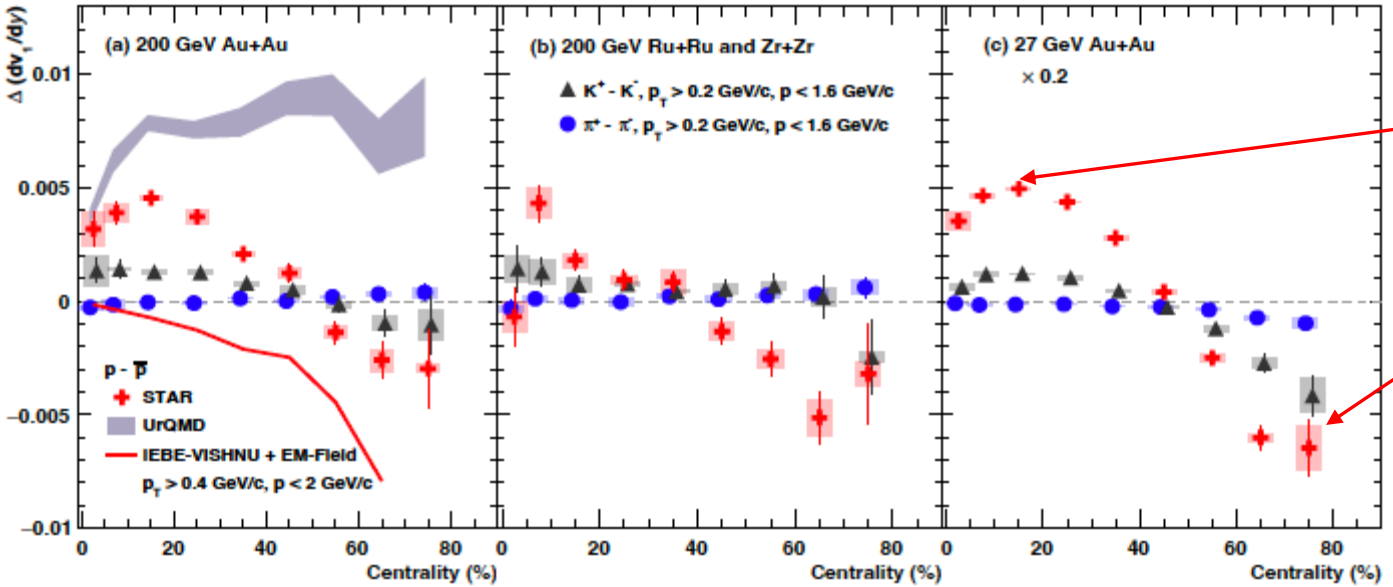




Transported-quark effect:
positive charge-dependent v_1 slope

Faraday + Coulomb:
negative charge-dependent v_1 slope

Triggered international media interest around the world!



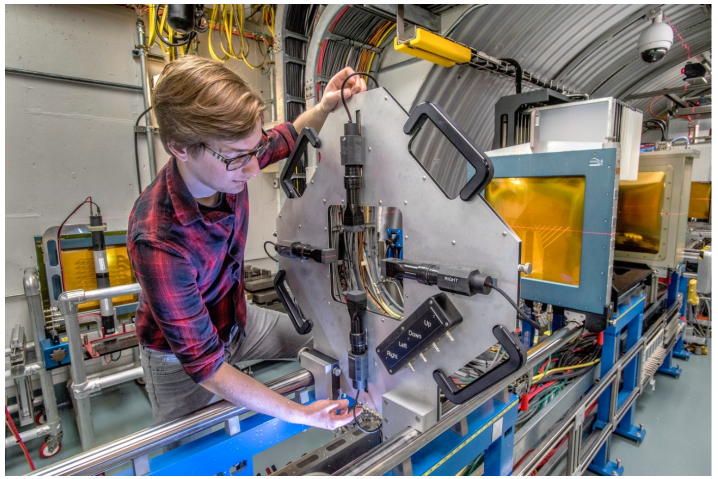
Results in central collisions can be explained by transported quark effect.

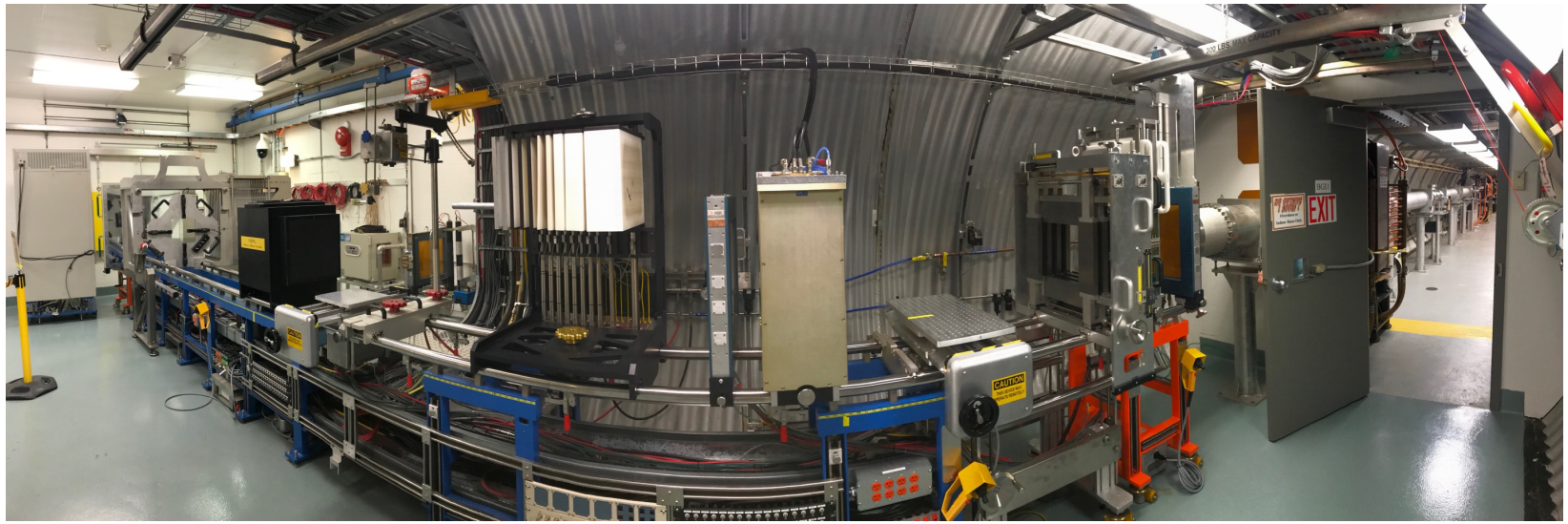
Results in peripheral collisions reveal the contributions from the Faraday induction and Coulomb effect for the first time in heavy-ion collisions.

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

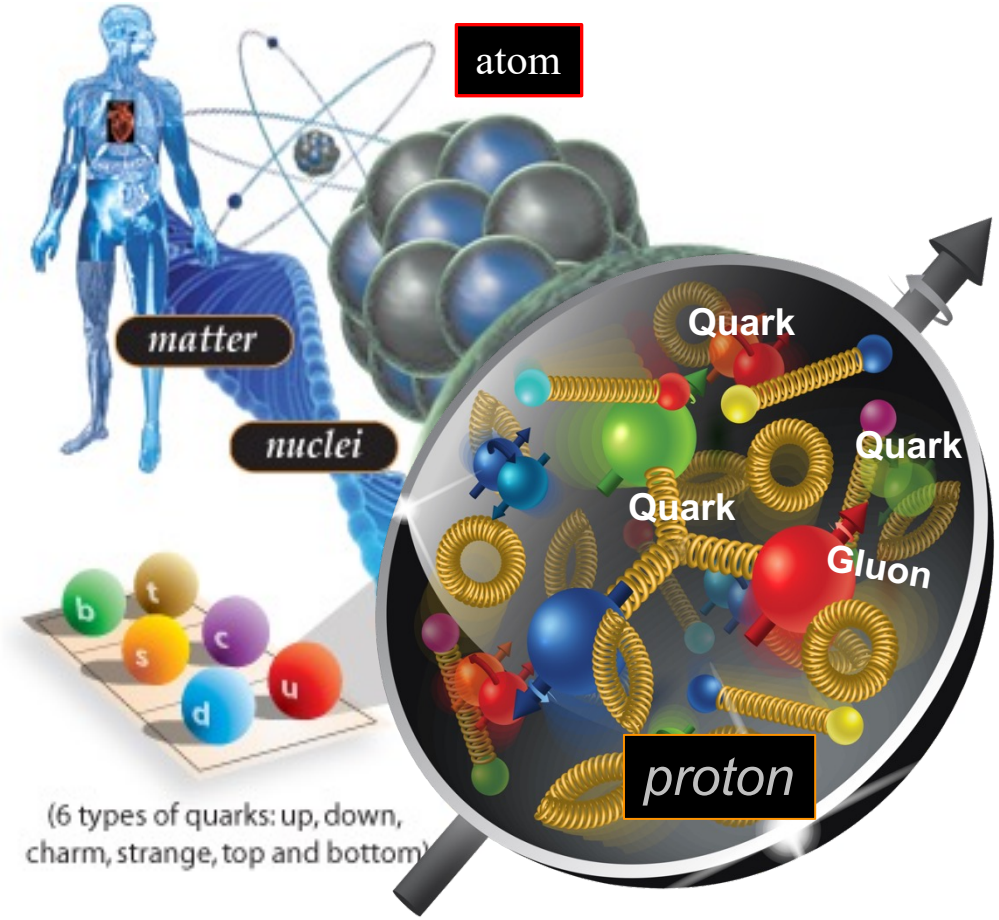
- Additional uses of NSRL
  - Radiation effects studies (rapidly growing demand for satellite electronics testing)
  - R&D of ion beam cancer treatment
  - Agreement with NASA in place for non-NASA users ("non-designated user facility")





Brookhaven National Laboratory

Electron-Ion Collider is the Future for Brookhaven

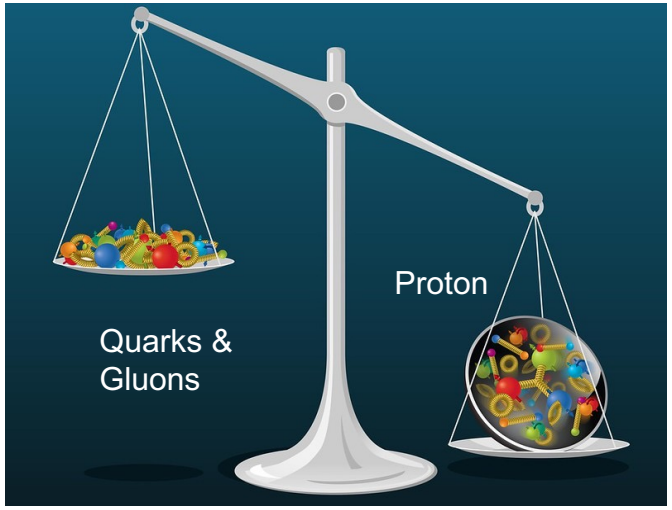


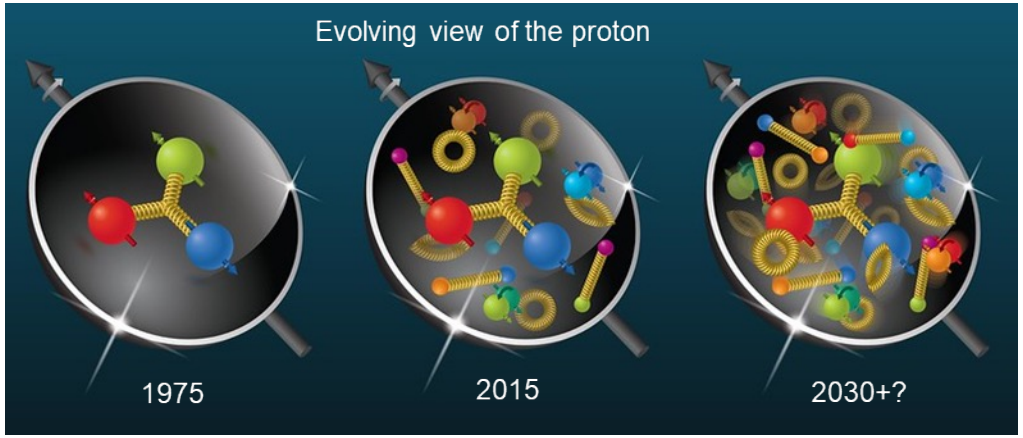
- The electronics revolution and today's technologies were driven by discoveries about electrons in the last century.
- EIC will peer *inside* atomic nuclei and individual protons to study the smallest building blocks of visible matter and the strongest force in nature.
- What we learn at the EIC will inspire the technologies of tomorrow.
- Partnership between DOE, NYS, BNL, and Jefferson Lab

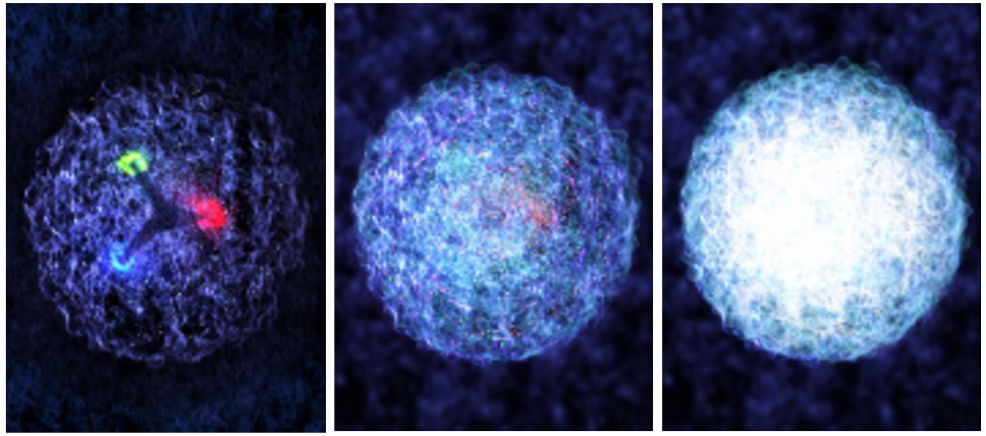
EIC Science Goals

EIC will answer these compelling questions:

- What is the origin of visible mass?
- What holds visible matter together, how?
- How do quarks and gluons contribute to the proton's spin?
- What is the nature of the "glue" that binds visible matter?
- Do gluons saturation the proton?
- What is the nature of pdf's at low-x?



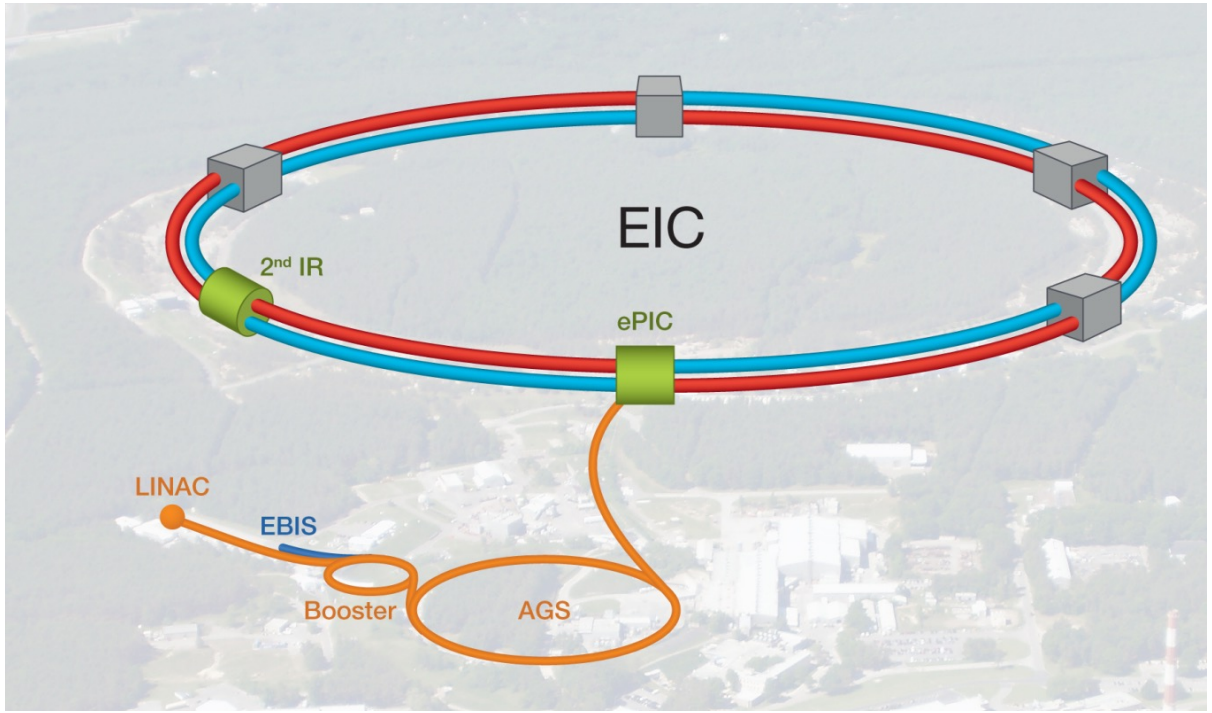




Brookhaven National Laboratory

EIC Machine in the RHIC Tunnel

- Rapid Cycling Synchrotron (RCS) for electrons and Electron Storage Ring (SR) fit easily into the existing RHIC tunnel
- Polarized electron and proton and light-ion beams
- Two existing detector halls available for interaction regions and detectors
- Repurpose RHIC infrastructure and operations funding

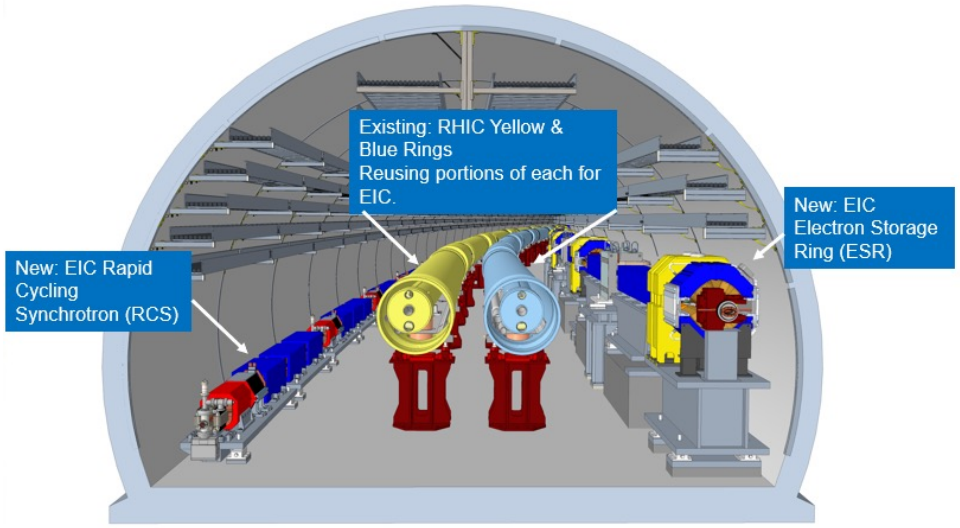


Brookhaven National Laboratory

Electron-Ion Collider Project Snapshot

TPC	Project Leader	Last CD Achieved
$1.7B - $2.8B	Jim Yeck, EIC Project Director	CD-3A

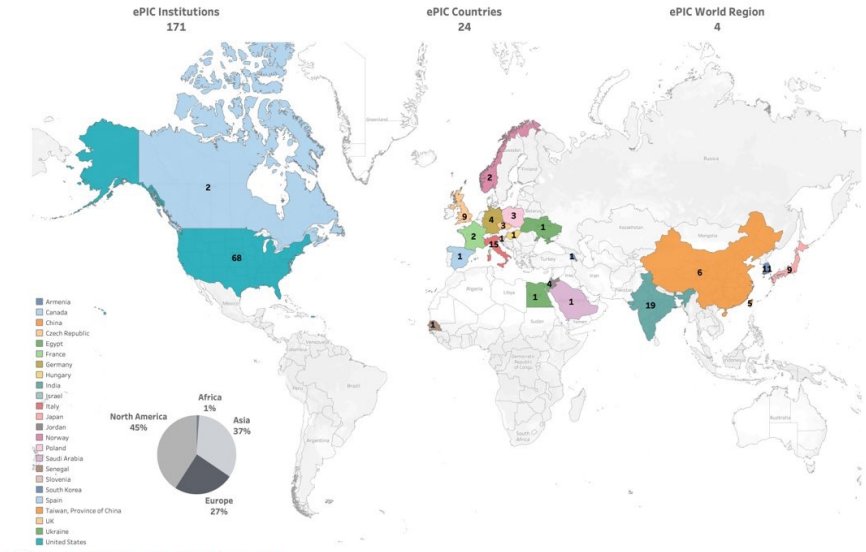
- CD-1 Approved Cost Range = $1.7-2.8B
- Current TPC Point Estimate = $2.78B
- Target Critical Decision Milestones Proposed Approval dates
  - Q2FY2024 CD-3A ($100M long-lead procurements)
  - CD-3B scheduled for Jan 2025
  - FY2025-2026 CD-2/3
  - FY2034-35 CD-4 (early)



EIC Machine in the RHIC Tunnel

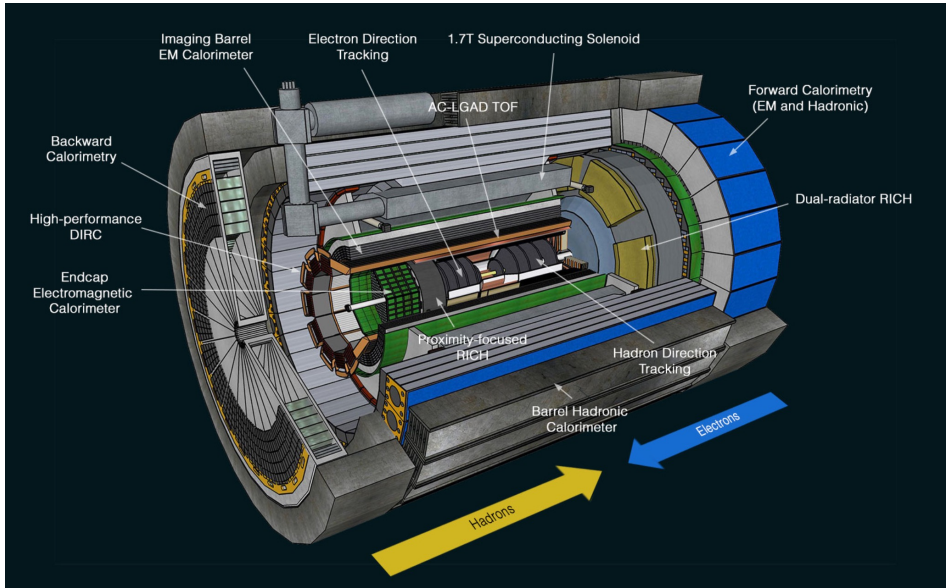
Collaboration formed in 2022

- Current: ~600 members, 24 countries, 171 institutions
- 13 new institutions since July 2023
- Leadership:
  - John Lajoie (ORNL) Spokesperson,
  - Silvia Dalla Torre (INFN Trieste) Deputy-Spokesperson



25 Detector subsystems

- Asymmetric beams and energies requires asymmetric detector with electron and hadron endcaps
- Tracking, PID, EM and hadronic calorimetry in all directions, covering equal rapidity areas (-4<η<4), high-precision polarimetry
- Momentum resolution dictates 2T large bore magnet
- Streaming electronic readout
- AI integrated from the start



ePIC Baseline Technologies

Radius/Distance from IP

Vertex detector → Identify primary and secondary vertices,
Low material budget: 0.05% X/X_0 per layer;
High spatial resolution: 10 mm pitch CMOS Monolithic Active Pixel Sensor

Central tracker → Measure charged track momenta
MAPS – tracking layers in combination with micro pattern gas detectors
MPGD: m-RWell or MicroMegas

world's first

electron and hadron endcap tracker → Measure charged track momenta
MAPS – disks in combination with micro pattern gas detector disks

world's first

Particle Identification → pion, kaon, proton separation on track level
RICH detectors (modular and dual radiator RICH, DIRC) & Time-of-Flight
high resolution timing detectors (LAPPS, LGAD) 10 – 30 ps
novel photon sensors for RICHs: LAPPD & SiPMs

world's first

Electromagnetic calorimeter → Measure photons (E, angle), identify electrons
$PbWO_4$ Crystals (backward) with SiPM readout,
W/SciFi Spacal (forward), Barrel: Pb/SciFi+imaging part using ASTROPIX

world's first

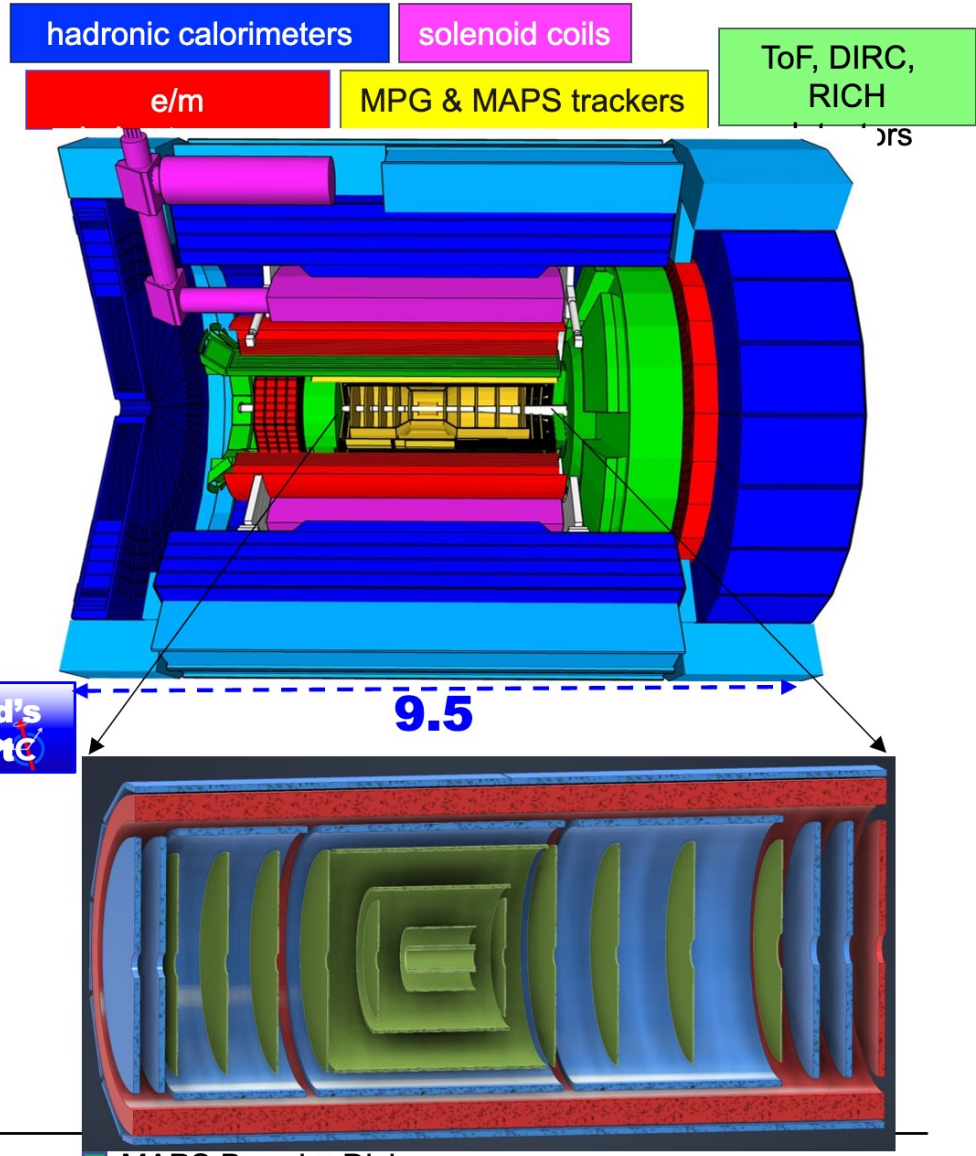
Hadron calorimeter → Measure charged hadrons, neutrons and K_L^0
challenge achieve ~50%/√E + 10% for low E hadrons (<E> ~ 20 GeV)
Steel/Sc sandwich sandwich with longitudinal segmentation & SiPM readout

world's first

DAQ & Readout Electronics: trigger-less / streaming DAQ
Integrate AI into DAQ → cognizant Detector

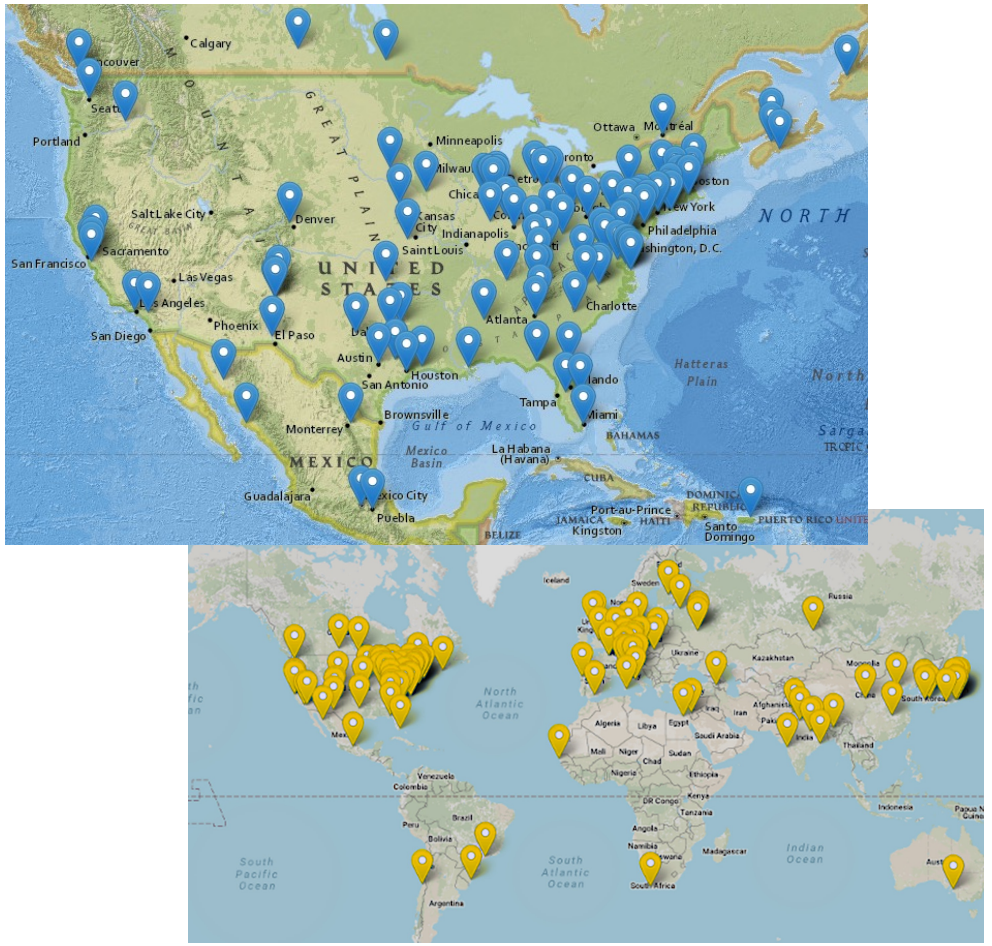
Very forward and backward detectors → scattered particles under very small angles
AC-LGAD tracking layers in lepton and hadron beam direction
Zero – degree high resolution electromagnetic and hadronic calorimeter

Polarimetry
Lepton: integrated transverse and longitudinal Compton polarimeter
Hadron: absolute and relative hadron polarimetry in the CNI region



Vibrant National & International Community

- Nine national labs and 99 U.S. universities and institutions, as well as 139 international partners, will participate in the EIC.
- The EIC scientist community has been growing rapidly—more than 1,400 scientists from more than 290 institutions in 38 countries around the world.
  - Electron-Ion Collider Group
  - EIC Theory Group
  - Center for Frontiers in Nuclear Science
  - EIC2@JLab



Brookhaven National Laboratory

International Commitments & Interest

£ 58M Commitment

J. Hill (BNL), R. Patel (UKRI)

Signed Statements of Interest from CEA and CNRS

CNRS + BNL + DOE

A-I Etienvre (CEA), A. Berhe DOE

Outlook

Mark Thomson
Summary slide

Overall, the STFC is in decent position

- As always, there are many highlights
  - I was delighted that we secured approval of EIC funding
  - More generally, we are on track to deliver our Strategic Delivery Plan objectives

BNL is delighted with the UK EIC funding!

Brookhaven National Laboratory

$100M from New York State ‘Empire State Development’

Record funding from NYS for a scientific project!

- Partnership between NYS and DOE
- Signing ceremony April 9, 2024
- First installment already in hand
- Will support civil construction of EIC support buildings and roads
- Will create local jobs

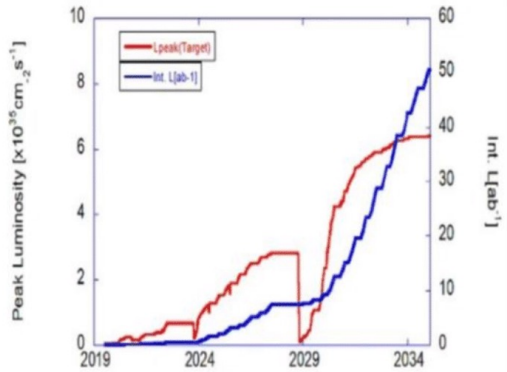
Brookhaven National Laboratory

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
- **Lu-SEE Night**
  - 21-cm cosmology from the dark-side of the moon
- **Theory, Detectors and Accelerators R&D**
  - Major contributions to the field

ATLAS muon system at CERN

SuperKEKB Luminosity



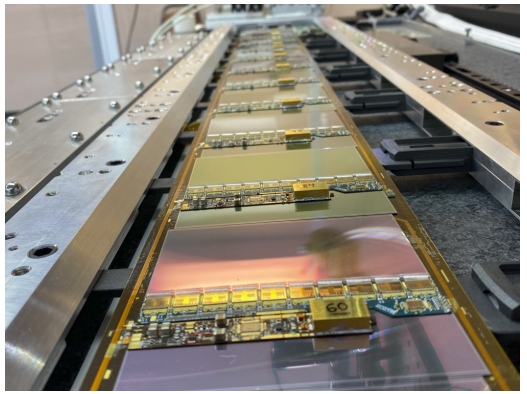
Brookhaven National Laboratory

Developing Future of BNL HEP Program

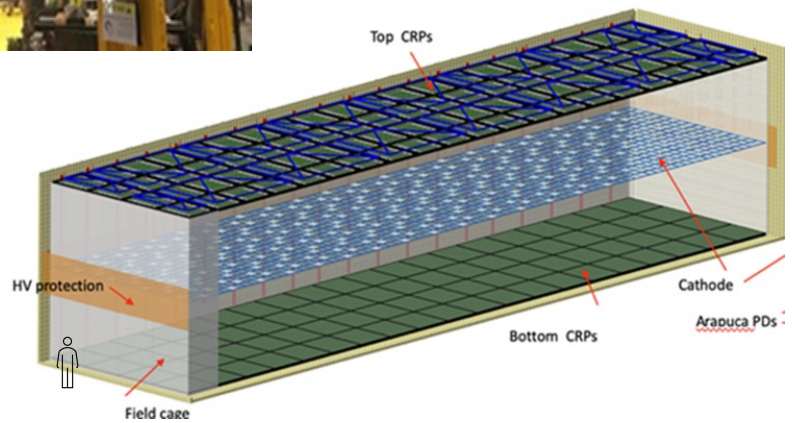
- **Energy Frontier**
  - Hosting project for $300M HL-LHC ATLAS upgrade
  - Building magnets for the HL-LHC
  - Developing HL-LHC computing and software
- **Intensity Frontier**
  - Contributing to DUNE experiment
    - Leading DUNE far detector Module 2 activities
  - Preparing Belle II detector for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

HL-LHC magnet testing at BNL

ATLAS silicon assembly at BNL



DUNE Module 2 design



Brookhaven National Laboratory

Brookhaven is Poised for Progress

The EIC will be a world-leading discovery machine

- The only collider scheduled to be designed and built globally in the next one to two decades
- Crucial project to develop and maintain accelerator science workforce
- RHIC is a science producing machine!
- 23 continuous years of operation with 2 more years planned before shut-down
- Particle physics program is strong with major involvement in each of the Energy, Intensity, and Cosmic frontiers

Brookhaven National Laboratory