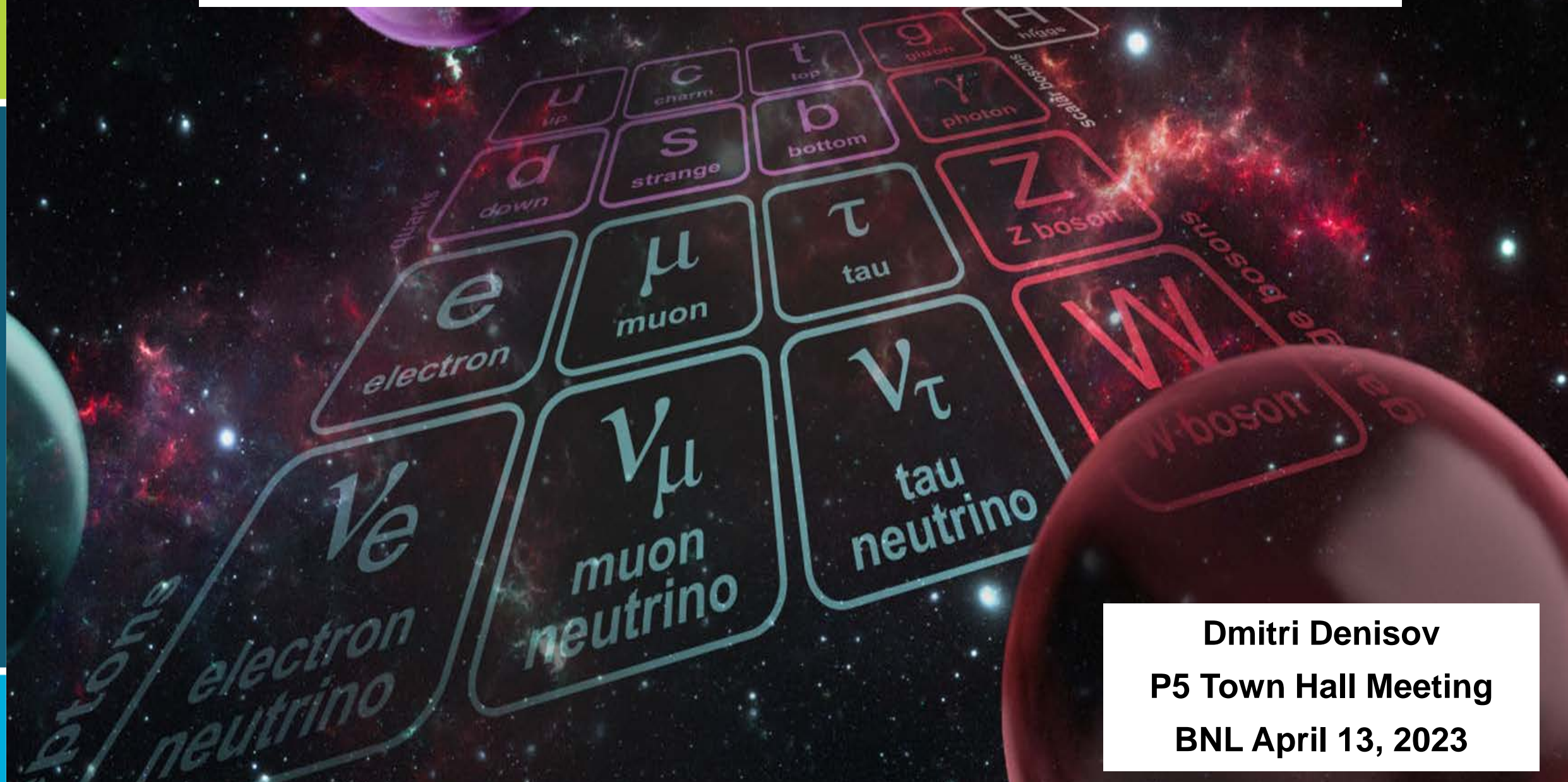


BNL Particle Physics and P5



Dmitri Denisov

P5 Town Hall Meeting

BNL April 13, 2023

Brookhaven National Laboratory



- Assets
 - 5,000 acres, 300 buildings
- People
 - 2,800 staff, 4,400 guests/users
- Annual budget \$700 million
- High energy physics is 3rd largest program
 - \$100 million annual budget
- Nuclear Physics DOE office and Basic Energy Sciences DOE office run largest BNL facilities
 - RHIC/EIC and Light Source

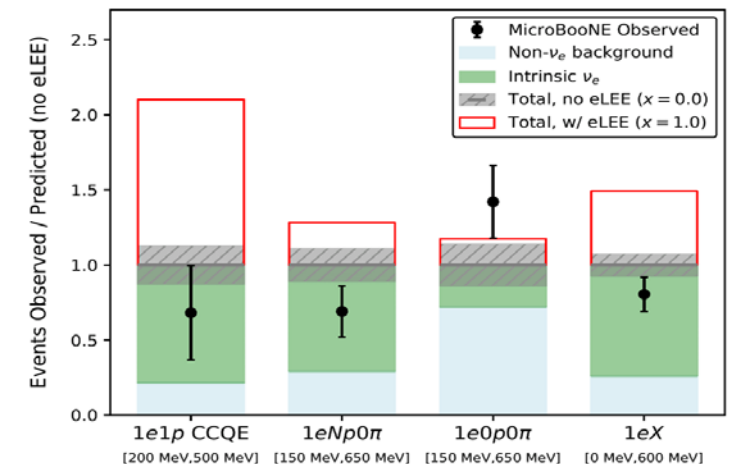
Strong Ongoing BNL Program Enables HEP Science

- **ATLAS experiment at CERN**
 - Lead Lab for U.S. ATLAS collaboration of ~800 US scientists
 - Leading US ATLAS Operations program and hosting Tier 1 computing center
- **Neutrino Program at Fermilab**
 - Proto-DUNE detector with BNL-developed cold electronics
 - Studying properties of neutrinos with short-baseline experiments
- **Belle II experiment at KEK**
 - 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, Detectors and Accelerators R&D**

Assembly of ATLAS muon system at CERN



MicroBooNE sterile neutrinos



Implementing 2013 P5 Program at BNL



- **Energy Frontier**
 - Hosting project for \$275M HL-LHC ATLAS upgrade
 - Building magnets for the HL-LHC
 - Developing HL-LHC computing and software
- **Intensity Frontier**
 - Strongly contributing to DUNE experiment
 - Leading DUNE far detector Module 2 activities
- **Cosmic Frontier**
 - Soon to analyze unique 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
 - Accelerators R&D including superconducting magnets
- **Actively participating in the field long term future planning**
 - BNL scientists submitted over 130 white papers to Snowmass

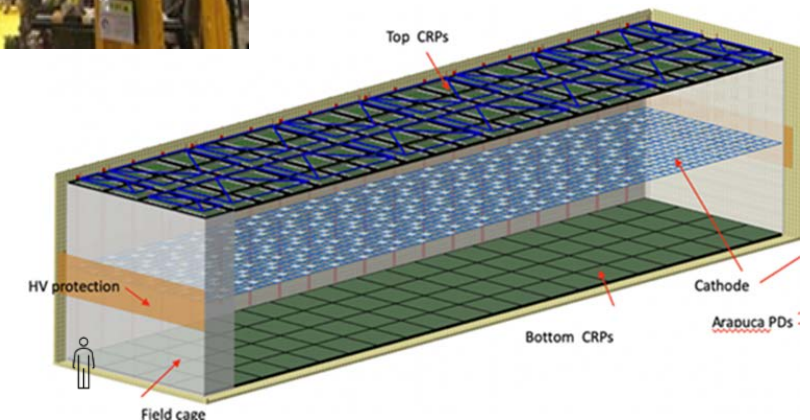
HL-LHC magnet testing at BNL



ATLAS silicon assembly at BNL



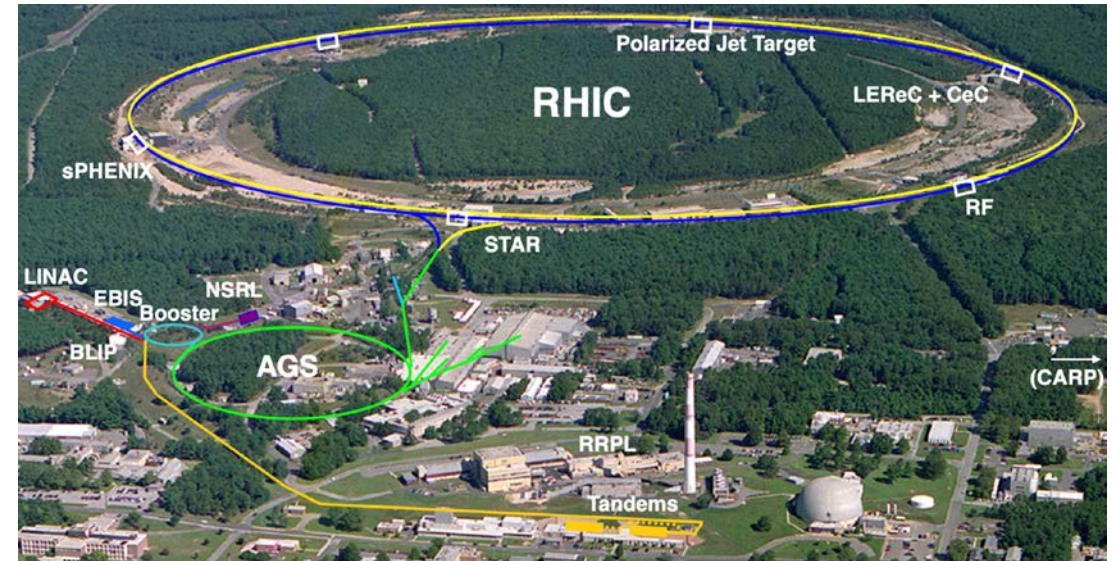
DUNE Module 2 design



Synergies with BNL Programs

- Joint experimental and theoretical efforts
 - Nuclear physics
- Accelerator applications
 - Isotope production (BLIP)
 - Space radiation studies (NSRL)
 - Industrial applications (Tandems)
- Superconducting magnets developments
 - Joint with nuclear physics and fusion
- Instrumentation Division
 - Detectors technologies
- Computing facilities
 - Joint center with nuclear physics and basic energy sciences
- Accelerator Test Facility
- QIS center
 - Quantum computing applications

BNL Hadron Accelerators Complex



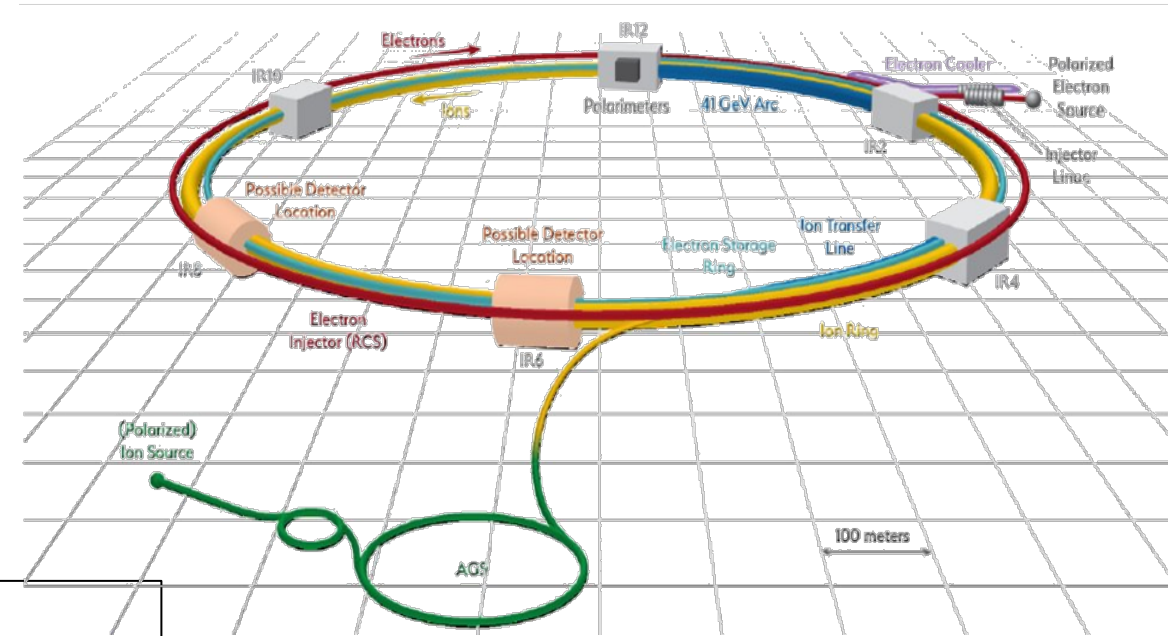
Accelerator Test Facility

NASA Space Radiation Lab



Synergies – Electron Ion Collider

- BNL is hosting Electron Ion Collider
 - The next collider to be built in US
- Synergies with particle physics from accelerators and detectors to physics
- First EIC physics in early 2030s



EIC Design Goals

High Luminosity: $L = 10^{33} - 10^{34} \text{cm}^{-2}\text{sec}^{-1}$, 10 – 100 $\text{fb}^{-1}/\text{year}$

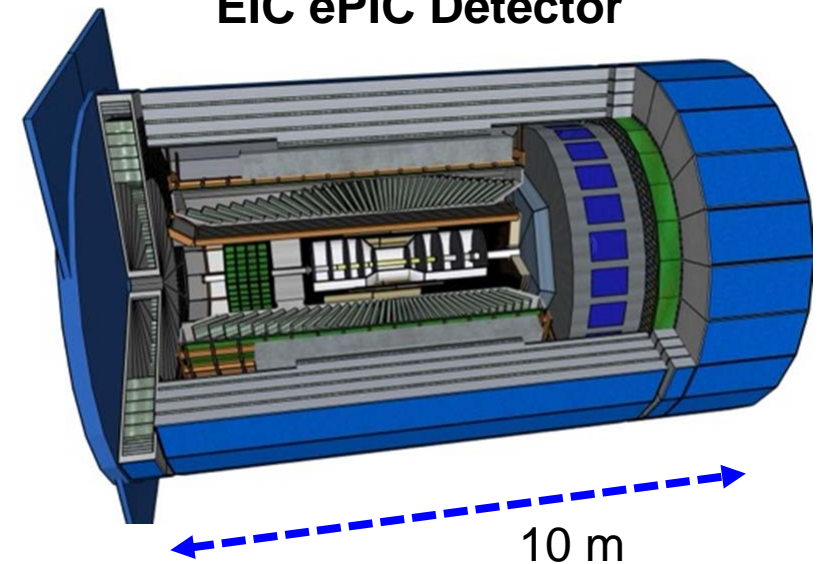
Highly Polarized Beams: 70%

Large Center of Mass Energy Range: $E_{\text{cm}} = 20 - 140 \text{ GeV}$

Large Ion Species Range: protons – Uranium

Large Detector Acceptance

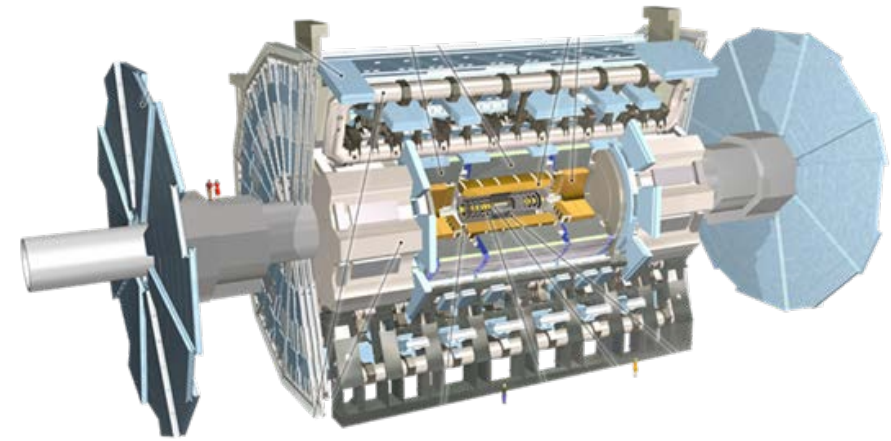
EIC ePIC Detector



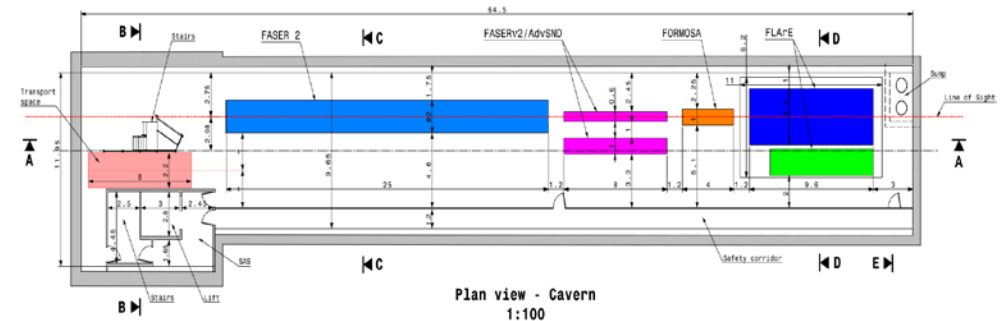
LHC and HL-LHC programs

- Energy frontier collider with 14 TeV center of mass energy
 - The only place to study the Higgs boson and many other elementary particles for 15+ years
 - x10 data set is yet to come
- HL-LHC brings unprecedented challenges
 - Pushing accelerators, detectors and computing technologies
- Excellent training for early career scientists
 - Analysis, detectors, operations
- BNL fully committed to HL-LHC program success
- Exciting options beyond general purpose detectors
 - Forward Physics Facility – unique studies of TeV scale neutrinos and BSM physics
 - LHCb experiment upgrade – studies of heavy flavor with unprecedented data set

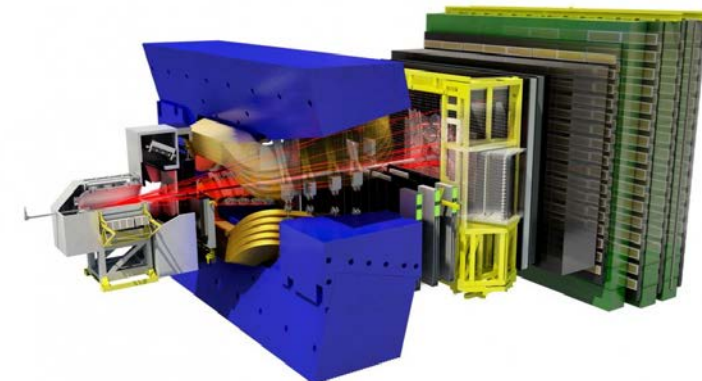
ATLAS



Forward Physics Facility

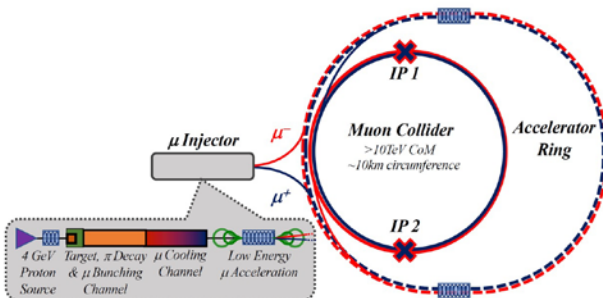
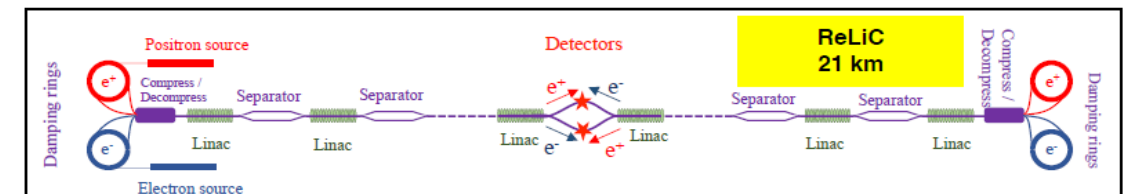
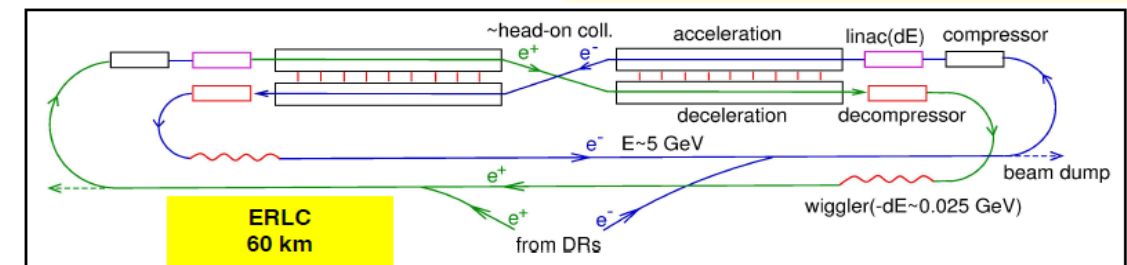
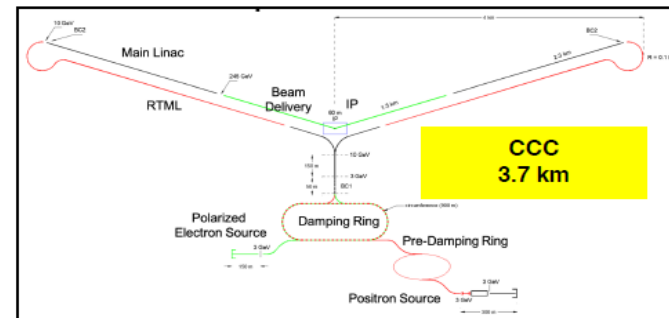
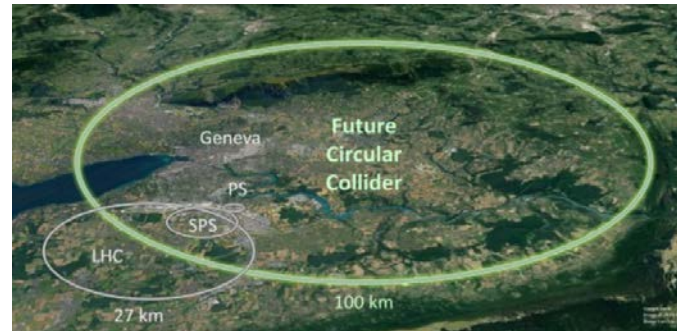
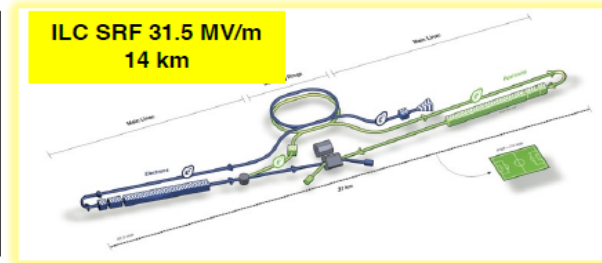
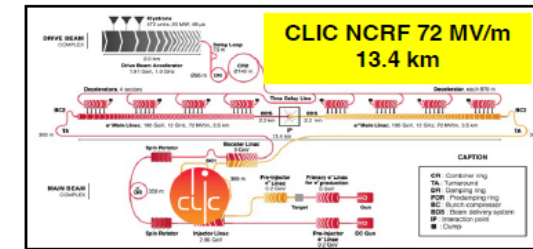
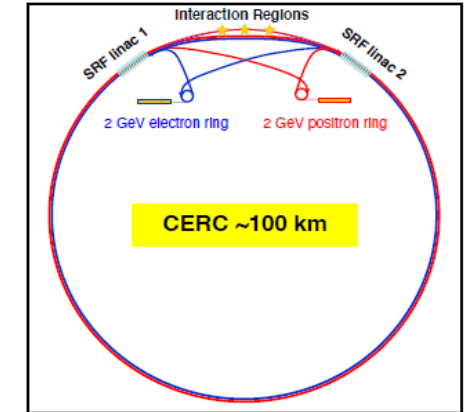
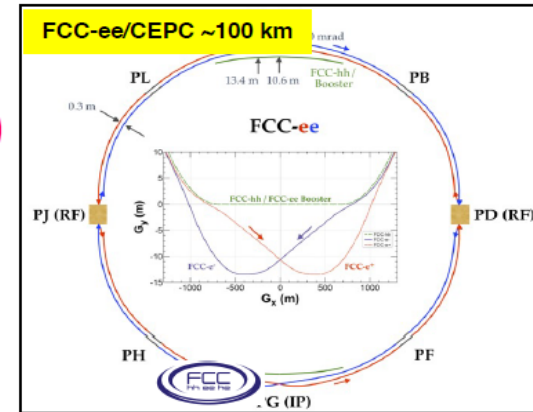


LHCb



Beyond HL-LHC at the Energy Frontier

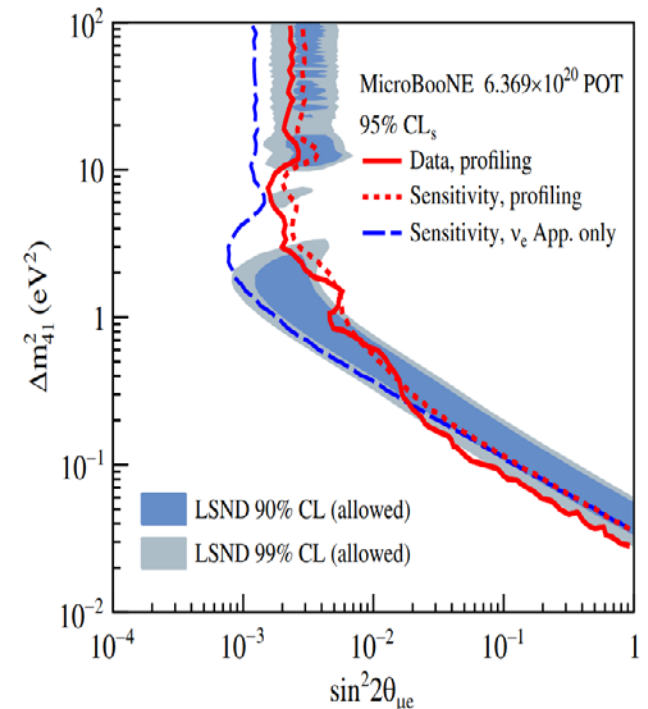
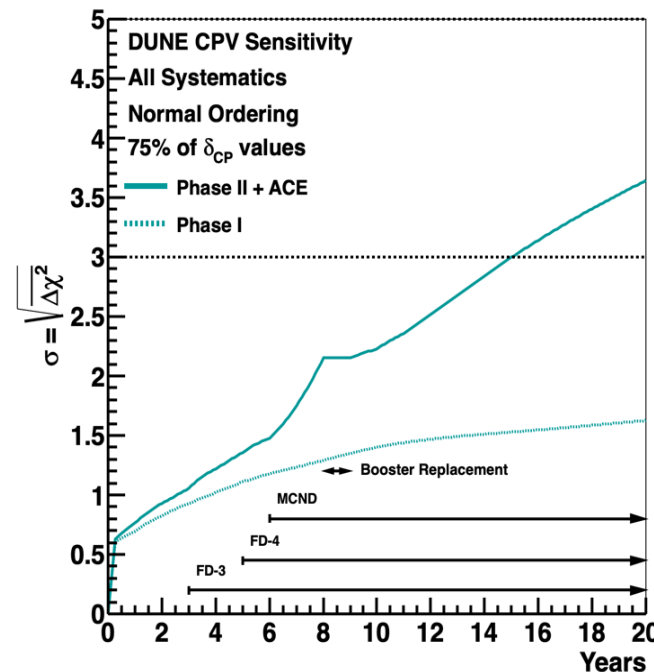
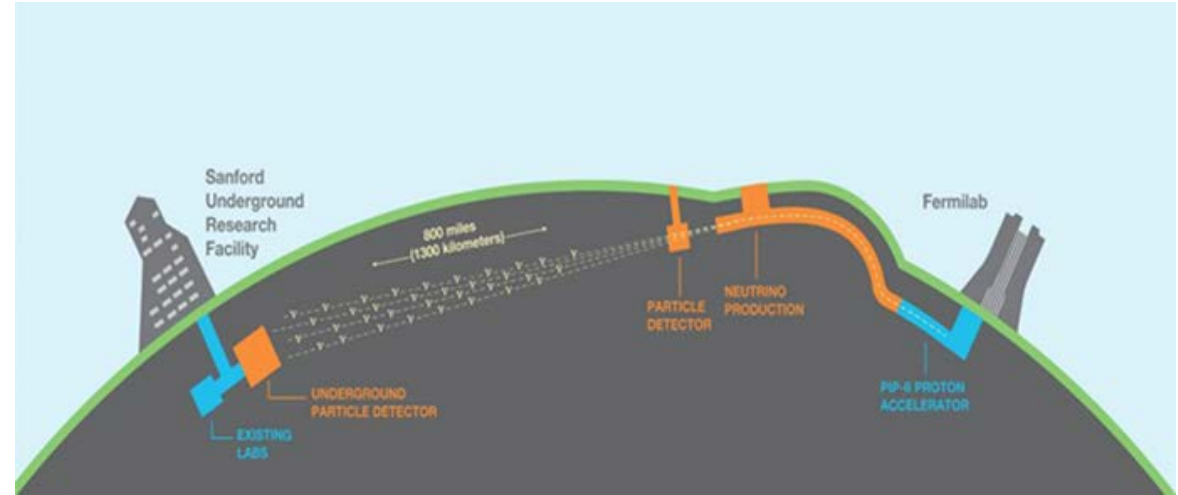
- Consensus is to proceed to e^+e^- Higgs factory
 - Various options are under development - FCCee, ILC, C3, CEPC and others
 - BNL is working with CERN's on FCCee option
- Reduction of cost and power consumption of such machines is critical
- Targeted R&D for both accelerators and detectors in US should be restored
 - BNL is ready to lead and partner
- Options beyond e^+e^- Higgs factory to reach center of mass energies beyond LHC should be pursued
 - Muon collider
 - 100 TeV pp collider



Neutrino Frontier

- Timely construction of the DUNE experiment is the priority
 - Provides unprecedented potential for a wide range of scientific topics
 - BNL is committed to deliver Module 2
- Development of DUNE upgrade program is critical to pursue early implementation
 - BNL is actively engaged in physics and far detectors Modules 3 and 4 developments
- Short baseline neutrino program provides important information about neutrinos and its interactions
- Participation in accelerator and non-accelerator-based neutrino experiments around the globe is vital for strong and balanced program

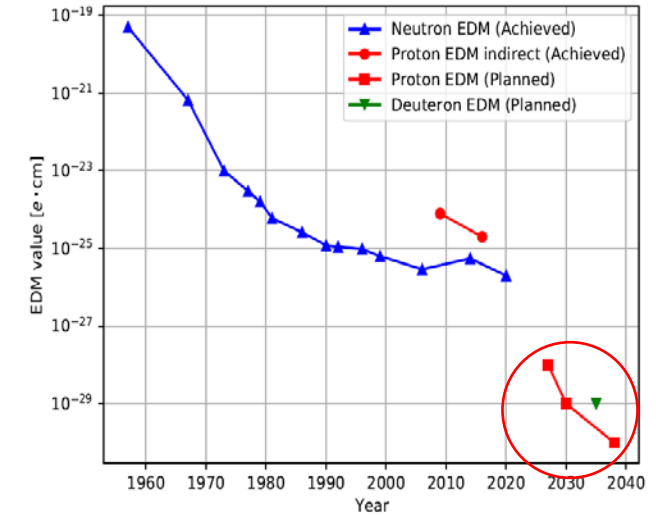
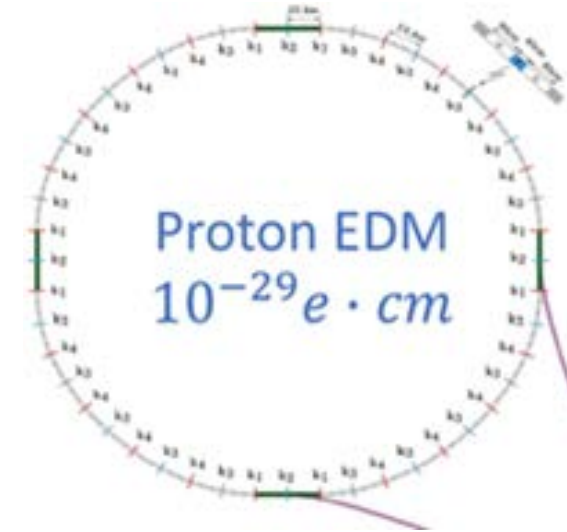
LBNF/DUNE



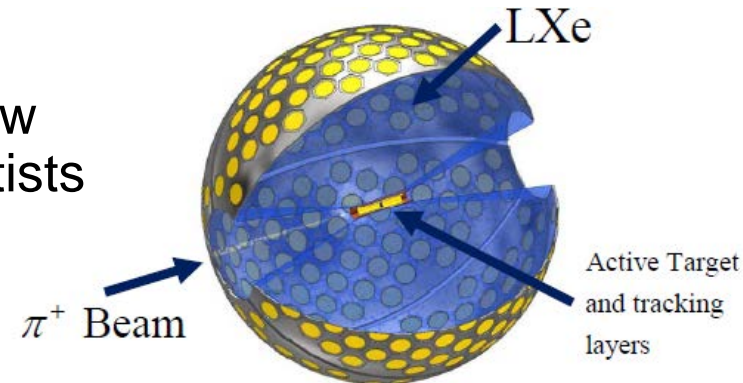
Precision Frontier

- Exciting scientific insights from “small scale” facilities and experiments
- High-sensitivity search of the proton electric dipole moment
 - Electrostatic ring in AGS tunnel at BNL
- Test of lepton flavor universality
 - Via stopped pion’s decay at PSI – PIONEER
- Studies of Heavy quarks
 - Upgrade of Belle II experiment for polarized beams
- Excellent option to develop (and test!) new technologies and train early career scientists

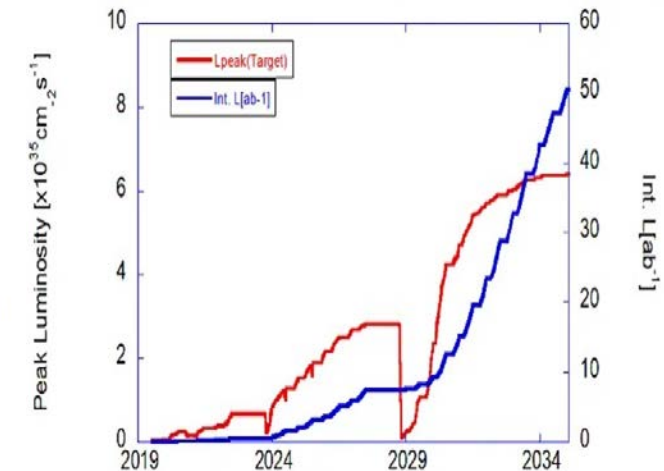
Proton EDM ring in AGS tunnel



PIONEER experiment




Belle II experiment



Cosmic Frontier

- Construct and operate 2013 P5 recommended experiments
 - Commissioning and operations of Vera Rubin telescope in Chile
- Execute exciting opportunities for small scale experiments
 - BNL leads joint DOE/NASA LuSEE-Night program for “Dark Ages” signal studies on the other side of the moon
- Develop plans for the next large scale spectroscopic experiments

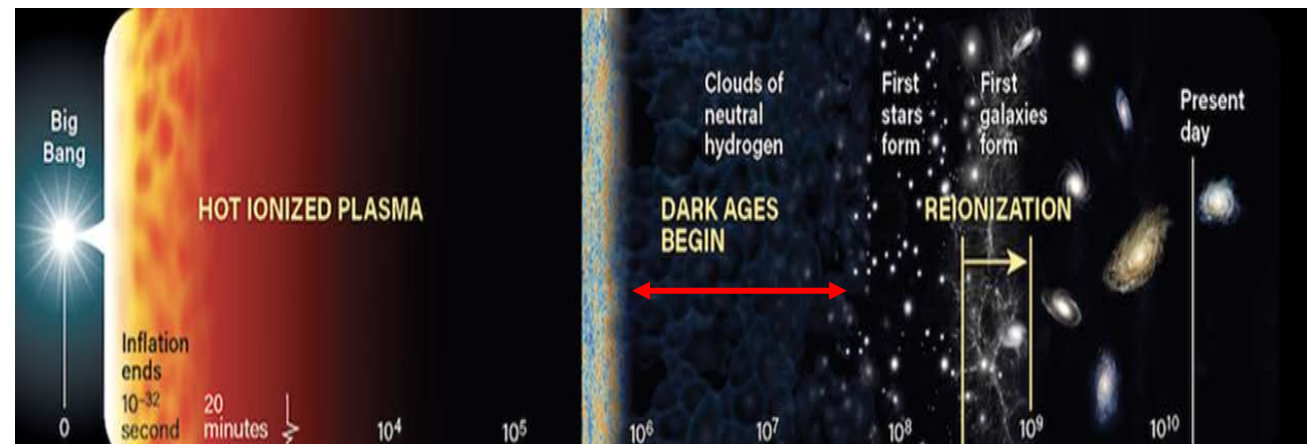
Rubin Commissioning in Chile

 **Katrin Heitmann** 1:06 PM
Most amazing ending of the session! 😊 I was able to capture





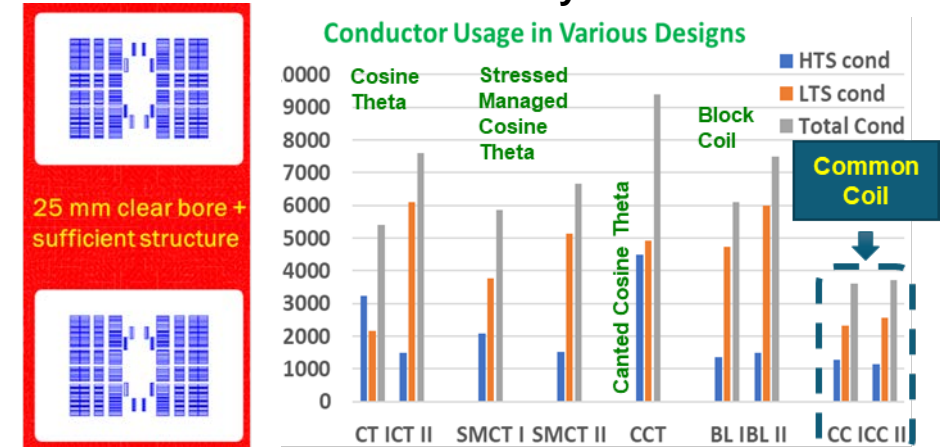
LuSEE-Night on the moon



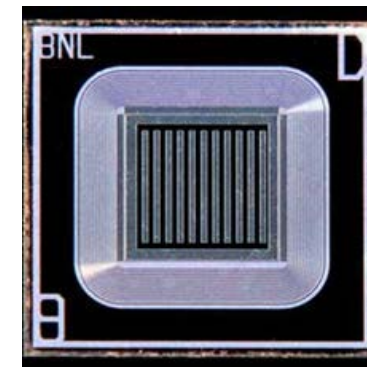
Accelerators and Detectors R&D

- Accelerators R&D is critical to develop next generation of machines
 - Target R&D to design new HEP accelerators and colliders
 - Balanced generic R&D to investigate new ideas
- Cost and energy consumption reduction are important
 - Limits our ability to build and operate particle accelerators
 - Use of new technologies, such as high temperature superconductivity, are critical
 - BNL has unique capabilities and synergies with EIC and beyond
- Particle detectors R&D is critical
 - To enable scientific goals of the field
 - Healthy balance between specific experiments and more generic technologies developments
 - Cost efficient technologies/detectors are of high value
 - BNL leads in multiple areas in cooperation with universities and national labs partners

BNL HTS/Hybrid common coil dipole design study



Students visiting BNL LAr R&D facility

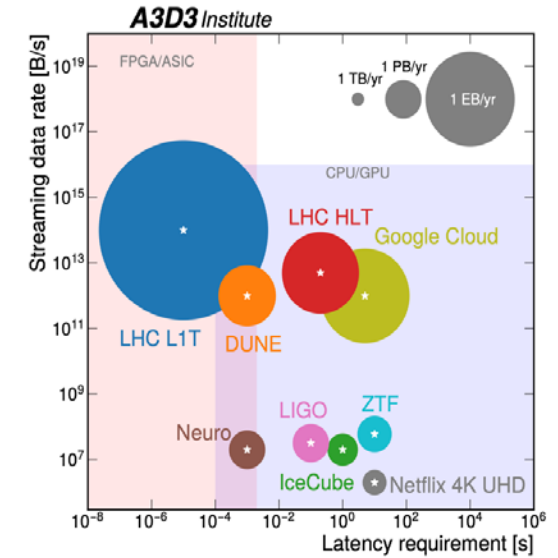
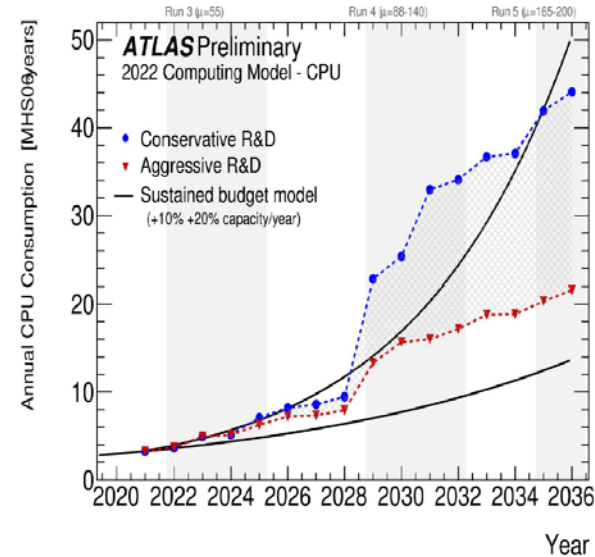


AC-LGAD manufactured at BNL

Computing Frontier

- Particle physics leads in the complexity and amount of the data collected and analyzed
- Computing requirements of HL-LHC and DUNE are substantial
 - Solving them will advance computing frontier
- Synergies with other fields and industry must be explored
 - Joint computing facilities
 - Excellent potential for AI/ML developments
 - BNL Human-AI-Facility Integration (HAI-FI)
- Support for healthy R&D efforts is critical
 - Including to address requirements of the next generation of experiments and theory
- BNL is a leader and strong partner in providing computing support for current experiments and developing future ideas

Computing challenges of LHC and DUNE



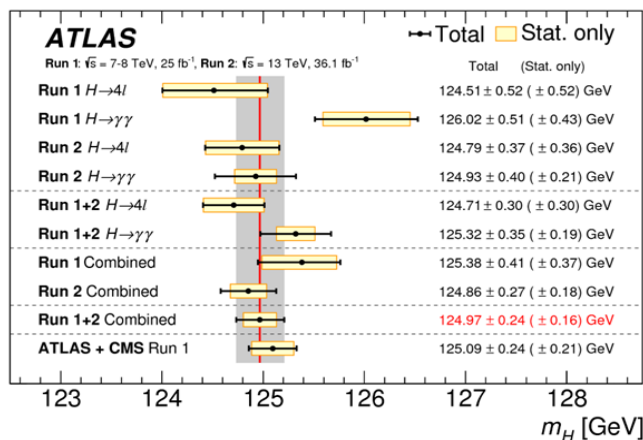
New BNL computing facility for ATLAS, RHIC and Belle II



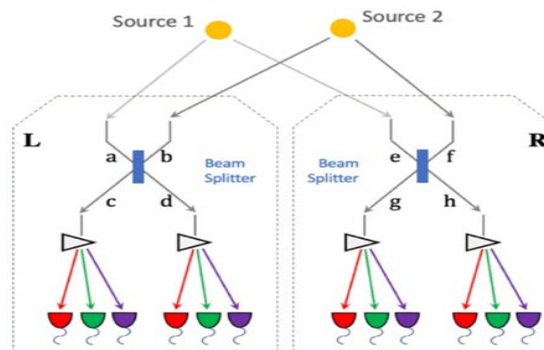
National Initiatives

- HEP is strongly contributing and benefiting from the national initiatives
- AI/ML initiative
 - AI/ML tools are used in HEP for decades, including for discoveries
 - Particle physics is in excellent position to contribute and benefit from industrial scale AI/ML developments
 - Excellent potential in all frontiers: energy, neutrinos, rare processes, cosmic, theory and others
- QIS initiative
 - Quickly developing area with substantial potential
 - Active engagement in various fields, industry, defense
 - HEP has unique expertise, including in detection of quantum states
 - Need to develop coherent program beyond initial QuantISED HEP initiative
- Microelectronics
 - Area where HEP and BNL led, including ASIC operations at cryo temperatures, for decades
 - Developing coherent strategy for the field active engagement in this initiative is critical

AI/ML tools are used in Higgs studies



Quantum astrometry




BNL Microelectronics Laboratory



Diversity, Equity, Inclusion and Accessibility

- Inclusive environment and diverse workforce are crucial for the field and for BNL to successfully pursue our mission
- Deeply committed to DEI improvements
 - Members of DEI committees throughout the laboratory
 - Active involvement in mentoring and workforce development
 - Commitment to STEM outreach and pipeline development, supporting MSIs for RENEW and FAIR
 - Developed hiring practices guidelines
 - Periodically performing surveys to learn and adjust
 - Leading African School of Physics
- Established mentoring programs for post-docs, early career scientists and engineers, and STEM training
- Brookhaven makes the Top 20 Government Employer List for 2023 in the 32nd Annual Equal Opportunity Magazine

Top 20 Government Employers

- | | | |
|---|---|---|
| 1. National Aeronautics and Space Administration (NASA) |  <p>2022 READERS' CHOICE TOP 20 GOVERNMENT EMPLOYERS STEM WORKFORCE DIVERSITY</p> <p>Readers were asked to list the top STEM-focused government agencies for which they'd most like to work or which they believe would provide a positive working environment for members of minority groups and diverse cultures. Here are the results.</p> | 13. The Air Force Research Lab (AFRL) |
| 2. Federal Aviation Administration (FAA) | | 14. U.S. Department of Commerce (DOC) |
| 3. National Security Agency (NSA) | | 15. Oak Ridge National Laboratory (ORNL) |
| 4. U.S. Environmental Protection Agency (EPA) | | 16. Military Sealift Command (MSC) |
| 5. U.S. Nuclear Regulatory Commission (NRC) | | 17. Los Alamos National Laboratory (LANL) |
| 6. Air Force Civilian Service (AFCS) | | 18. U.S. Army Corps of Engineers (USACE) |
| 7. U.S. Naval Research Lab (NRL) | | 19. National Geospatial-Intelligence Agency (NGA) |
| 8. U.S. Department of State (DOS) | | 20. Sandia National Laboratories |
| 9. Central Intelligence Agency (CIA) | | |
| 10. Transportation Security Administration (TSA) | | |
| 11. U.S. Secret Service (USSS) | | |
| 12. Brookhaven National Laboratory | | |



BNL Involvement



- Successfully **complete 2014 P5 program**, including
 - International **HL-LHC program** to provide exciting results on the wide range of the field science drivers
 - Execute **international DUNE program** to study neutrinos, universe and the proton lifetime
 - Uncover the mysteries of the universe with **Rubin observatory**
 - Execute healthy array of **small and medium scale experiments**
- Develop strong **program for the future**
 - Develop strong foundations for an international **Higgs factory**
 - And develop accelerators to reach **next energy frontier beyond the LHC**
 - Re-fill the pipeline of **small and medium scale experiments**
 - **Accelerator, Detector and Computing R&D** efforts and **theory** initiatives
 - **Balanced program of research, operations and construction** with strong participation of **universities, national labs and international partners**