High-Energy Physics Office Hours

Introduction to HEP and Program Mission

Bryan J. Field

March 19, 2024

Office of High-Energy Physics

Program Manager, Cosmic Frontier (Cosmology and Dark Energy)

U.S. DEPARTMENT OF ENERGY | Office of Science

Energy.gov/science

Office of Science Statement of Commitment & other Guidance

- **SC Statement of Commitment** – SC is fully and unconditionally committed to fostering safe, diverse, equitable, inclusive, and accessible work, research, and funding environments that value mutual respect and personal integrity. https://science.osti.gov/SW-DEI/SC-Statement-of-Commitment
- **Expectations for Professional Behaviors** – SC's expectations of all participants to positively contribute to a professional, inclusive meeting that fosters a safe and welcoming environment for conducting scientific business, as well as outlines behaviors that are unacceptable and potential ramifications for unprofessional behavior. https://science.osti.gov/SW-DEI/DOE-Diversity-Equity-and-Inclusion-Policies/Harassment
- **How to Address or Report Behaviors of Concern** – Process on how and who to report issues, including the distinction between reporting on unprofessional, disrespectful, or disruptive behaviors, and behaviors that constitute a violation of Federal civil rights statutes. https://science.osti.gov/SW-DEI/DOE-Diversity-Equity-and-Inclusion-Policies/How-to-Report-a-Complaint
- **Implicit Bias** – Be aware of implicit bias, understand its nature – everyone has them - and implicit bias if not mitigated can negatively impact the quality and inclusiveness of scientific discussions that contribute to a successful meeting. https://kirwaninstitute.osu.edu/article/understanding-implicit-bias

HEP Office Hours

- **Introduction to HEP and Program Mission (today!)**
  - **March 19, 2024**
- **Funding Opportunities for Early Career Researchers**
  - **April 16, 2024**
- **Technology Initiatives and HEP Core Research**
  - **May 21, 2024**

https://science.osti.gov/hep/officehours

Join us on the **third Tuesday of each month**, 2-3 pm Eastern Time, for virtual office hours to learn about our programs and ask questions. Researchers, educators, and research administrators from all institutional types are encouraged to join. A primary goal of the virtual office hours is to broaden awareness of our programs; no prior history of funding from DOE is required to join. Program managers will be available to answer questions. **Registration is required for attendance.** Please use an institutional email address to complete the registration process.

There are also office hours for Advanced Scientific Computing Research (**ASCR**), Basic Energy Sciences (**BES**), Biological and Environmental Research (**BER**), Fusion Energy Science (**FES**), Nuclear Physics (**NP**), Accelerator R&D and Production (**ARDP**), Isotope R&D and Production (**DOE IP**)

U.S. DEPARTMENT OF ENERGY | Office of Science

SC Mission:

Deliver scientific discoveries and major scientific tools to transform our understanding of nature and advance the energy, economic, and national security of the United States.

The nation's largest supporter of basic research in the physical sciences.

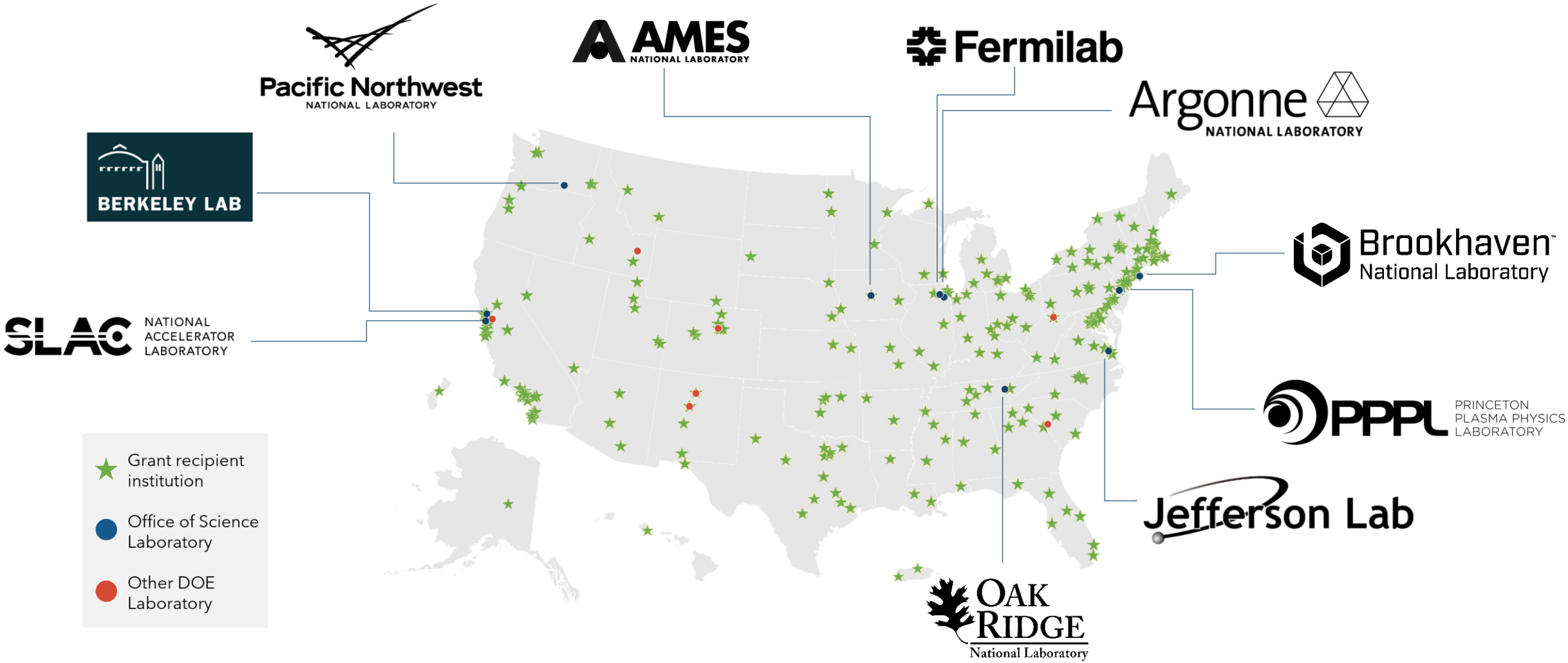
More than **34,000 r**esearchers supported at more than **300** institutions and **17** DOE national laboratories

Steward **10** of the 17 DOE national laboratories

More than **37,000** users of **28** Office of Science scientific user facilities

$8.2B
(FY 24 enacted)

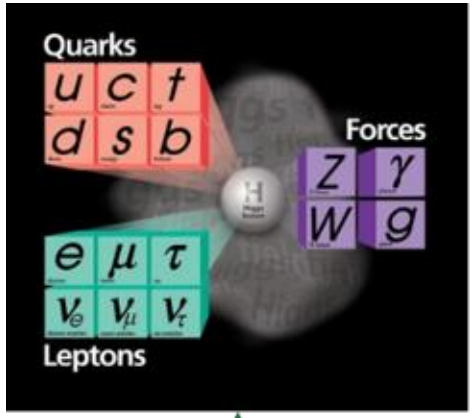
Where we are, who we support

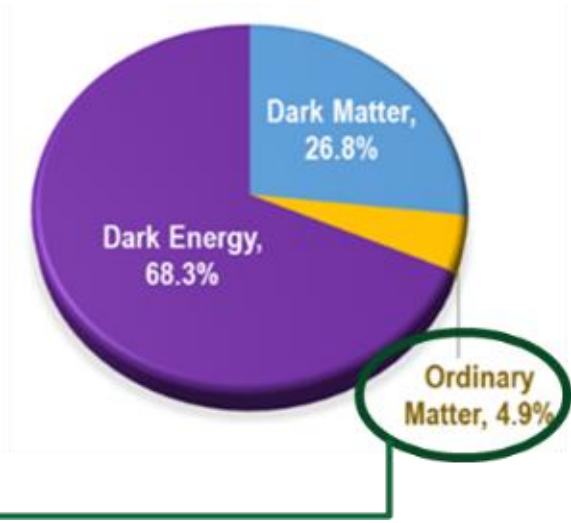


Office of High Energy Physics (HEP) Mission

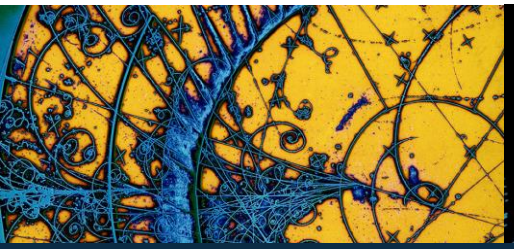
Understanding the how the universe works at its most fundamental level

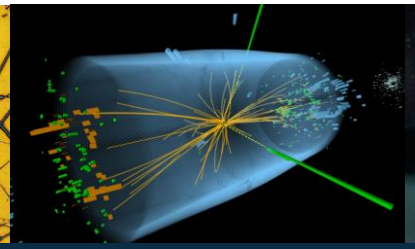
- Discover the elementary constituents of matter and energy
- Probe the interactions between them
- Explore the basic nature of space and time

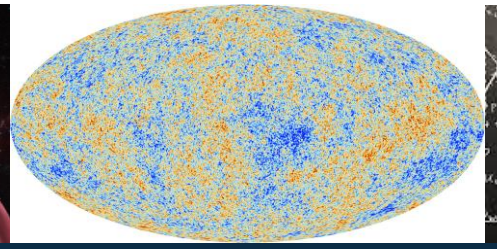


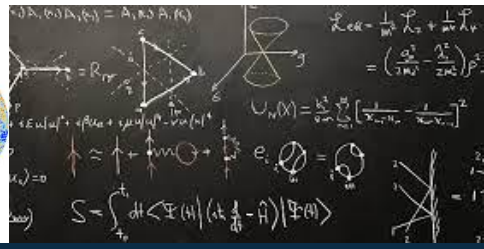


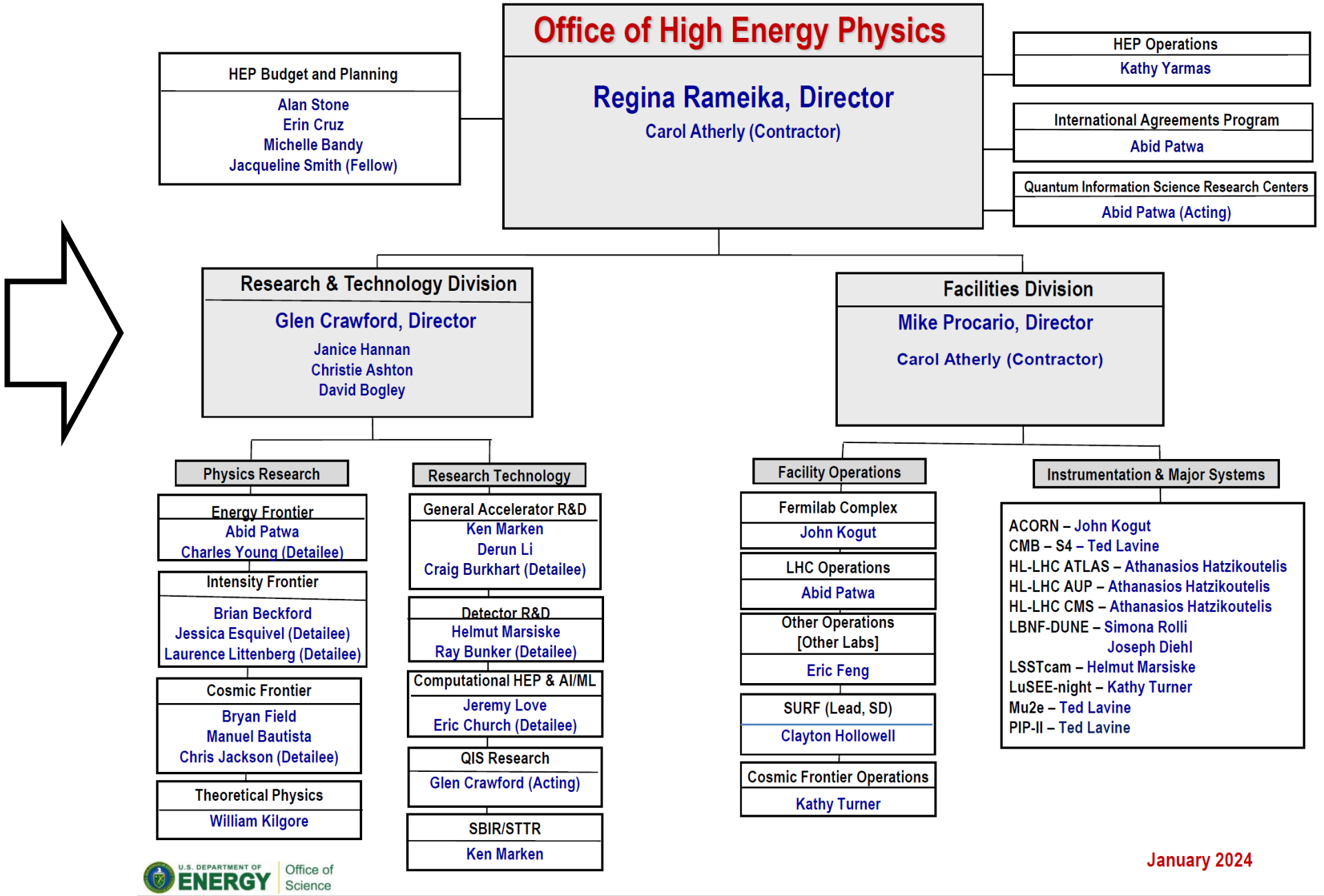
HEP carries out the DOE mission and objectives through a balanced portfolio to work at the cutting edge of science










Office of High Energy Physics
Regina Rameika, Director
Carol Atherly (Contractor)
HEP Budget and Planning
Alan Stone
Erin Cruz
Michelle Bandy
Jacqueline Smith (Fellow)
HEP Operations
Kathy Yarmas
International Agreements Program
Abid Patwa
Quantum Information Science Research Centers
Abid Patwa (Acting)
Research & Technology Division
Glen Crawford, Director
Janice Hannan
Christie Ashton
David Bogley
Facilities Division
Mike Procario, Director
Carol Atherly (Contractor)
Physics Research
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Abid Patwa
Charles Young (Detailee)
Intensity Frontier
Brian Beckford
Jessica Esquivel (Detailee)
Laurence Littenberg (Detailee)
Cosmic Frontier
Bryan Field
Manuel Bautista
Chris Jackson (Detailee)
Theoretical Physics
William Kilgore
Research Technology
General Accelerator R&D
Ken Marken
Derun Li
Craig Burkhart (Detailee)
Detector R&D
Helmut Marsiske
Ray Bunker (Detailee)
Computational HEP & AI/ML
Jeremy Love
Eric Church (Detailee)
QIS Research
Glen Crawford (Acting)
SBIR/STTR
Ken Marken
Facility Operations
Fermilab Complex
John Kogut
LHC Operations
Abid Patwa
Other Operations [Other Labs]
Eric Feng
SURF (Lead, SD)
Clayton Hollowell
Cosmic Frontier Operations
Kathy Turner
Instrumentation & Major Systems
ACORN – John Kogut
CMB – S4 – Ted Lavine
HL-LHC ATLAS – Athanasios Hatzikoutelis
HL-LHC AUP – Athanasios Hatzikoutelis
HL-LHC CMS – Athanasios Hatzikoutelis
LBNF-DUNE – Simona Rolli
Joseph Diehl
LSSTcam – Helmut Marsiske
LuSEE-night – Kathy Turner
Mu2e – Ted Lavine
PIP-II – Ted Lavine
U.S. DEPARTMENT OF ENERGY
Office of Science
January 2024

HEP Research and Technology

Colliders to the Cosmos

Spans the breadth of three "Frontiers":

- Energy Frontier
- Intensity Frontier
- Cosmic Frontier

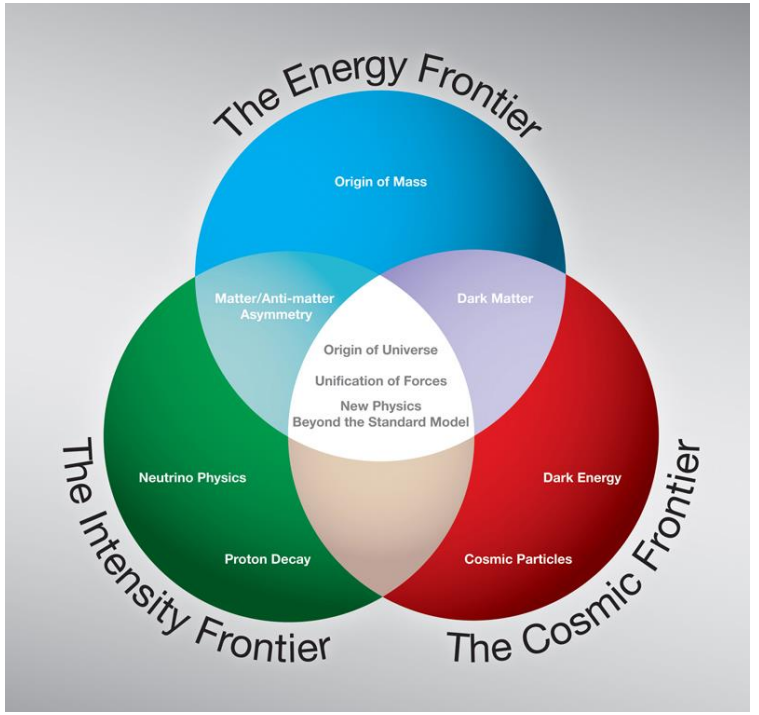
Plus, cross-cutting themes:

- Theoretical physics
- General Accelerator and Detector R&D
- Computational HEP and AI/ML
- QIS Research and Microelectronics

2008 P5 Defined Three Experimental Frontiers

HEP is carried out along 3 Frontiers:

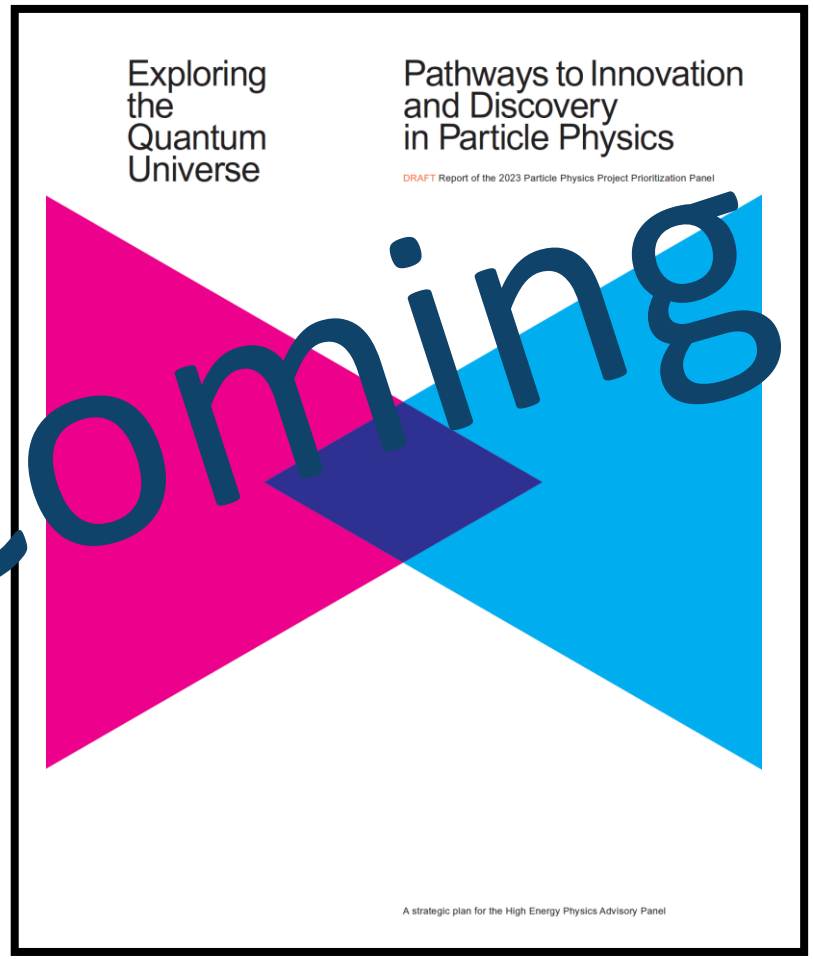
- HEP has historically been primarily a **Particle Accelerator based program**: Energy & Intensity Frontiers
- Cosmic Frontier uses **naturally occurring particles and the cosmos itself** to study the fundamental nature of matter, energy, space and time in areas complementary to accelerator experiments.
- Increasingly important area for discovery
- In the last decade, Cosmic Frontier has grown into an integral and priority part of the HEP program.



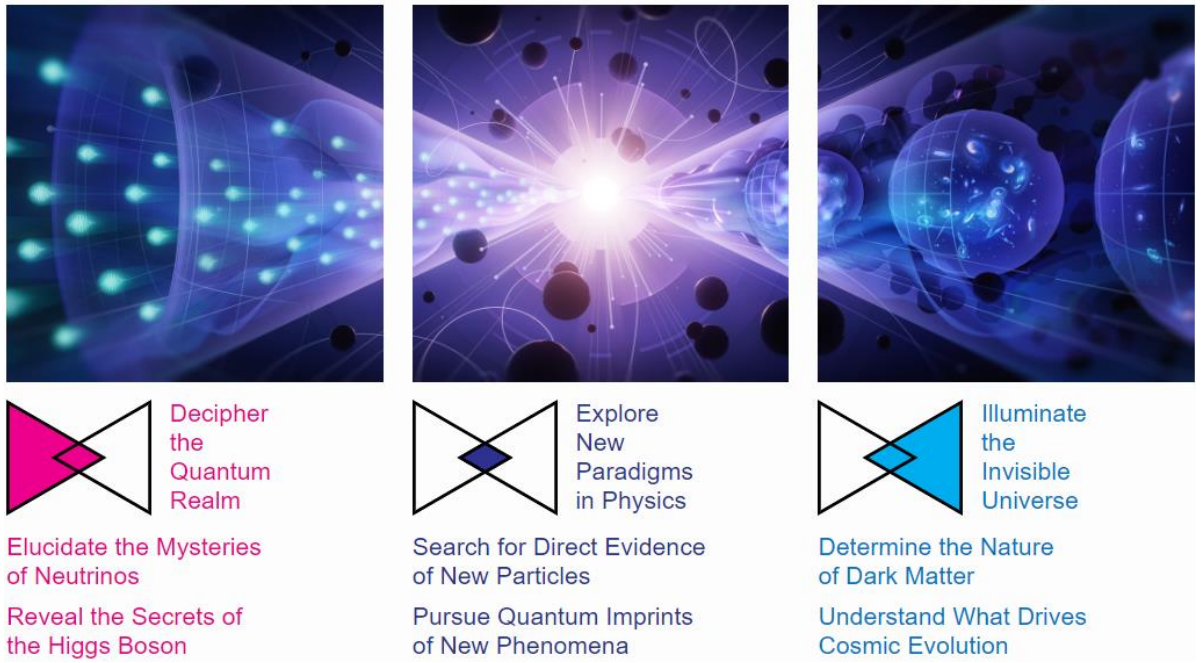
2014 : Frontiers to Science Drivers

	Energy Frontier	Intensity Frontier	Cosmic Frontier
Higgs Boson	●		
Neutrino Mass		●	●
Dark Matter	●	●	●
Cosmic Acceleration			●
Explore the Unknown	●	●	●

2023 : Science Themes and Science Drivers



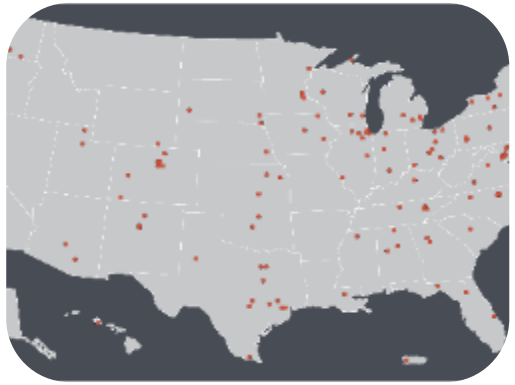
Coming Soon!



Office of High Energy Physics at a Glance

FY 2024 Enacted: $1.196B

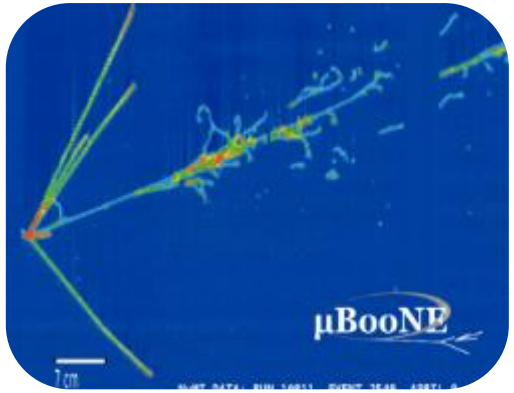
Largest Supporter (**~85%**) of Particle Physics in the U.S.



Funding at **>160** Institutions, including **12** DOE Labs

Over **1,175** Ph.D. Scientists and **525** Grad Students Supported

Over **2,325** Users at **2** SC Scientific Facilities



Research: 40% Budget

~30% of Research to Universities

Projects: 30% Budget

Facility Operations: 30% Budget

HEP Mission and Support at DOE National Laboratories

Fermi National Accelerator Laboratory

- Quantum Information Science
- Superconducting Quantum Materials and Systems Center
- Artificial Intelligence and Machine Learning
- Energy, Intensity, and Cosmic Frontier particle physics research
- Theoretical and Computational Physics
- Advanced Technology R&D and Microelectronics
- Fermilab Accelerator Complex *(SC User Facility)*
- LHC Operations
- Cosmic Frontier Experimental Operations
- Acc. and Det. Infrastructure and Test Facilities
- LBNF/DUNE, PIP-II, Mu2e Construction Projects
- HL-LHC Accelerator, CMS Detector Upgrade, and ACORN MIE

Argonne National Laboratory

- Quantum Information Science
- Artificial Intelligence and Machine Learning
- Energy, Intensity, and Cosmic Frontier particle physics research
- Theoretical and Computational Physics
- Advanced Technology R&D
- LHC Operations
- Cosmic Frontier Experimental Operations

Brookhaven National Laboratory

- Quantum Information Science
- Artificial Intelligence and Machine Learning
- Energy, Intensity, and Cosmic Frontier particle physics research
- Theoretical and Computational Physics
- Advanced Technology R&D and Microelectronics
- LHC Operations
- Intensity Experimental Operations (Belle-II)
- Cosmic Frontier Experimental Operations, including Vera C. Rubin Observatory
- LBNF/DUNE Construction Project
- HL-LHC Accelerator and ATLAS Detector Upgrade MIEs
- Lunar Surface Electromagnetic Experiment (LuSEE)-Night MIE

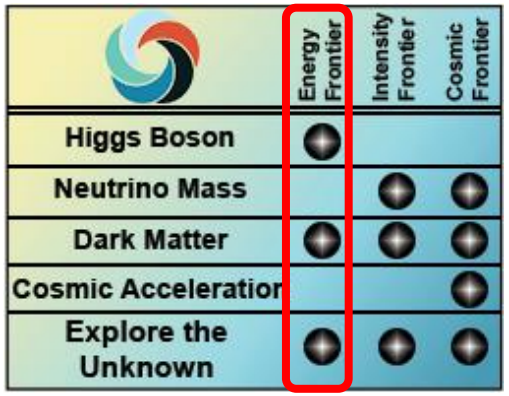
Lawrence Berkeley National Laboratory

- Quantum Information Science
- Artificial Intelligence and Machine Learning
- Energy, Intensity, and Cosmic Frontier particle physics research
- Theoretical and Computational Physics
- Advanced Technology R&D and Microelectronics
- LHC Operations
- Cosmic Frontier Experimental Operations, including DESI and LZ
- Accelerator and Detector Infrastructure and Test Facilities (BELLA)
- CMB-S4 MIE (lead lab)
- HL-LHC Accelerator and ATLAS Detector Upgrade MIEs

SLAC National Accelerator Laboratory

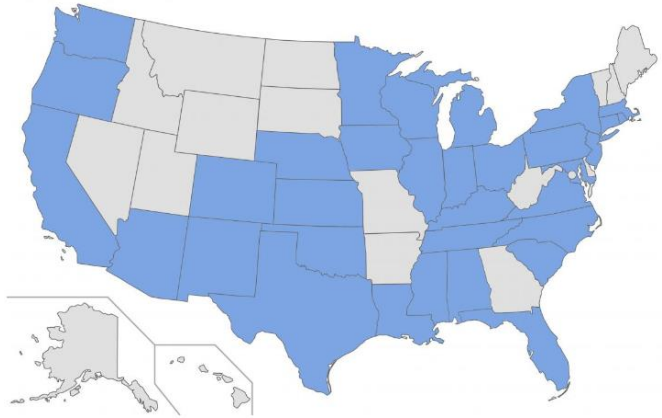
- Quantum Information Science
- Artificial Intelligence and Machine Learning
- Energy, Intensity, and Cosmic Frontier particle physics research
- Theoretical and Computational Physics
- Advanced Technology R&D and Microelectronics
- FACET-II Operations *(Scientific User Facility)*
- Cosmic Frontier Experimental Operations, including Vera C. Rubin Observatory, SuperCDMS-SNOLAB
- Accelerator Infrastructure and Test Facilities

Energy Frontier Program

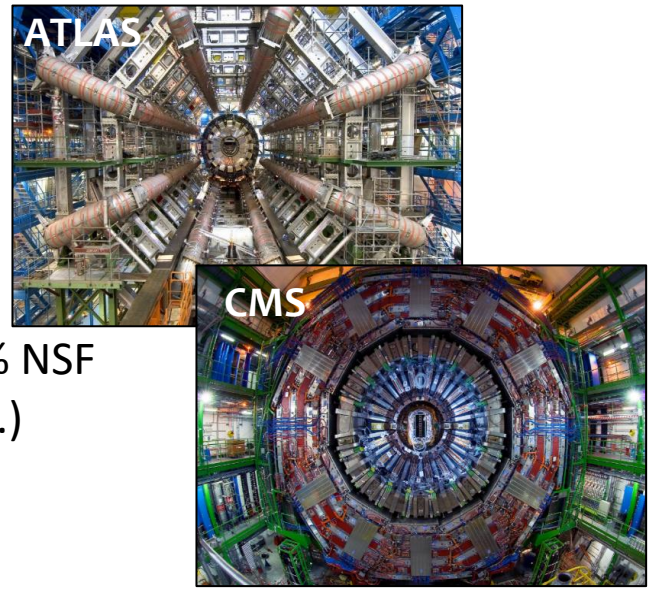


- **Two main focuses:**
  - U.S. participation at the **Large Hadron Collider (LHC) program at CERN**
  - Studies of an off-shore future collider in the intermediate term — i.e., linear or circular configurations

States hosting members of the U.S. LHC experimental program



- LHC: U.S. is the single largest collaborating nation in both the ATLAS and CMS experiments at the LHC
- CMS Collaboration: ~3,250 scientists from 255 institutions in 57 countries
  - U.S. CMS: ~29% of CMS collaboration = ~22% DOE/HEP + ~2.2% DOE/NP + ~5.7% NSF
  - 33 DOE-supported universities; 1 DOE lab: Fermilab (host lab for U.S.)
- ATLAS Collaboration: ~2,900 scientists from 183 institutions in 42 countries
  - U.S. ATLAS: ~19.5% of ATLAS collaboration = ~15.3% DOE/HEP + 0.6% DOE/NP + ~3.6% NSF
  - 30 DOE-supported universities; 4 DOE labs: ANL, LBNL, SLAC, and BNL (host lab for U.S.)



- **Seeding the future: R&D and conceptual physics studies towards next-generation largescale future colliders such as FCC-ee or ILC (Higgs factory); or FCC-hh or Muon Collider (multi-TeV collider)**

Intensity Frontier Experiments

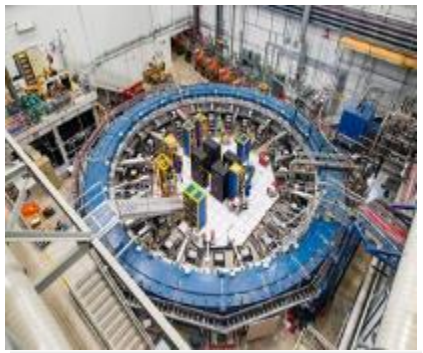
	Energy Frontier	Intensity Frontier	Cosmic Frontier
Higgs Boson	●		
Neutrino Mass		●	●
Dark Matter	●	●	●
Cosmic Acceleration			●
Explore the Unknown	●	●	●

NOvA : Fermilab & Ash River, MN

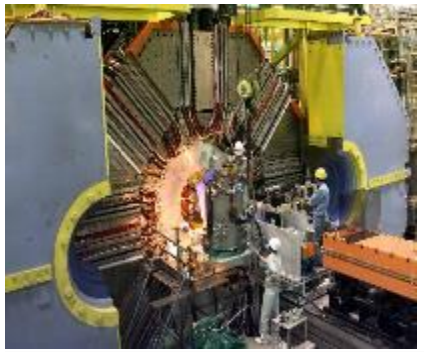
NOvA at Fermilab and Ash River

ICARUS at Fermilab

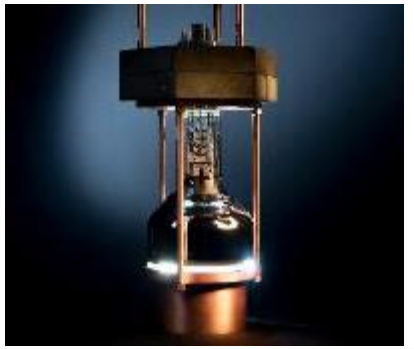
Mu2E at Fermilab



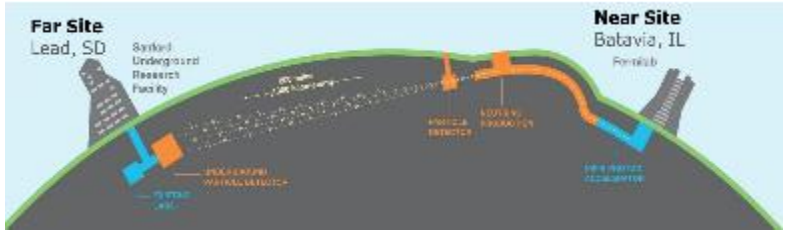
Muon g-2 at Fermilab



Belle II at KEK, Japan



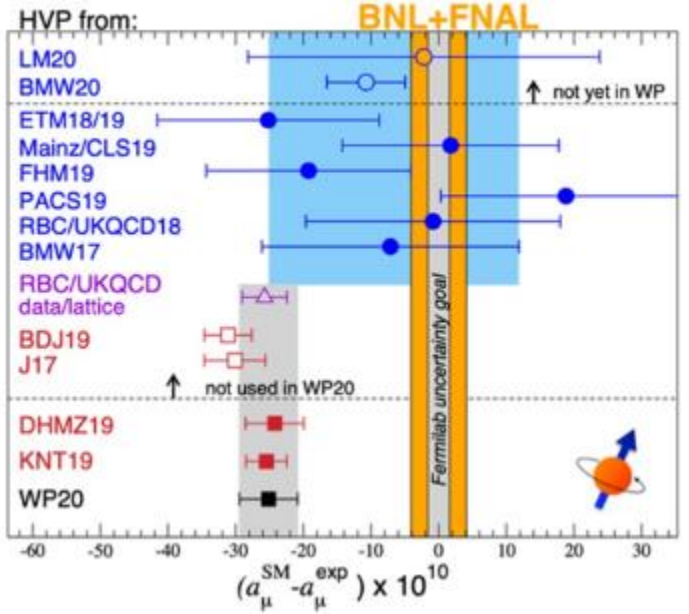
COHERENT at ORNL

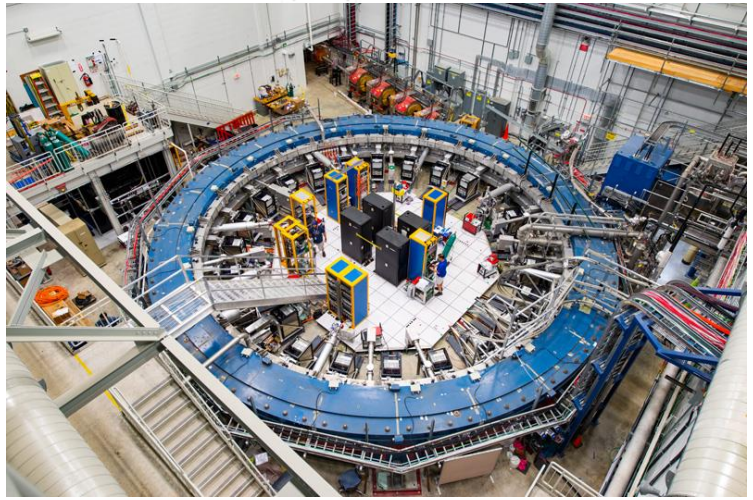


DUNE at Fermilab and Lead, SD

HEP Intensity Frontier Highlights: Muon (g-2)

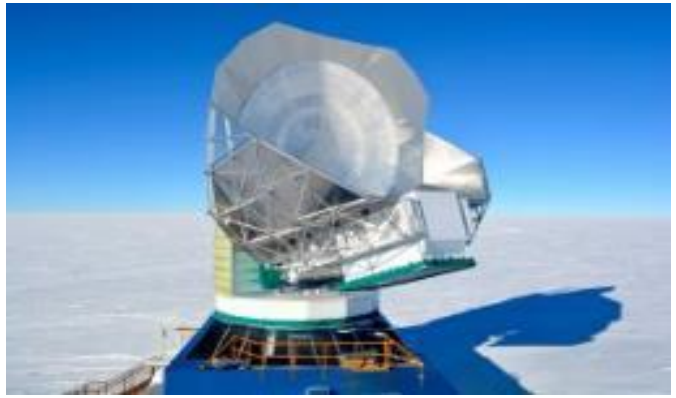
- FNAL's accelerator infrastructure is a key enabler of world-leading Intensity Frontier experiments such as Muon (g-2) and Mu2e
- Muon (g-2) completed TDR goal collecting 21x BNL stats
- Muon (g-2) Run6 has been completed closing out their planned data taking and experimental runs.

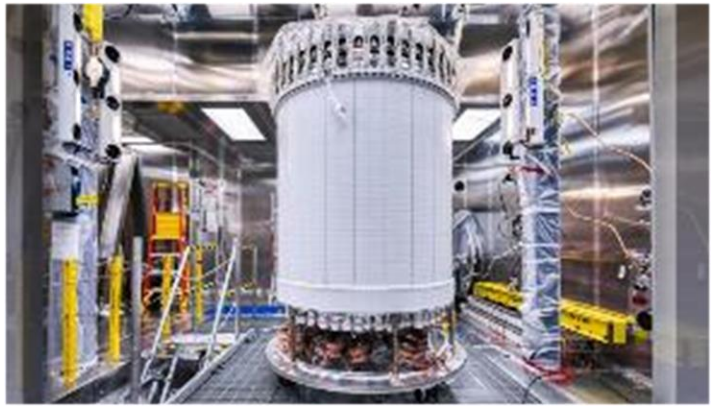




Cosmic Frontier Experiments

	Energy Frontier	Intensity Frontier	Cosmic Frontier
Higgs Boson	●		
Neutrino Mass		●	●
Dark Matter	●	●	●
Cosmic Acceleration			●
Explore the Unknown	●	●	●





- Partnerships w/NSF (PHY, AST, OPP) NASA (AST, ISS, CLPS) are essential

Direct Detection Dark Matter - DM-G2's & DMNI's

- Staged suite of complementary generation 2 direct detection experiments with multiple technologies to search for dark matter axions and WIMPs as recommended by P5
- ADMX-G2 axion search is currently operating at U. Washington
  - 2021 results are 5-orders of magnitude better than previous limits, ruling out axion DM hypothesis in this mass-coupling range
- LZ data-taking started end of 2021; now in Run 2. World-leading results published in PRL July 2023.
- SuperCDMS-SNOLAB MIE project in fabrication phase; CD-4 March 2023; Data-taking with one production tower in 2023; with all 4 towers in 2025.
- Dark Matter New Initiatives (DMNI) for <u>new</u> small projects to address the 2019 Basic Research Needs study; 4 Cosmic Frontier concepts in design and project execution <u>planning phase</u> (ADMX-EFR, DM-Radio, OSCURA, TESSERACT) + 1 Intensity Frontier (LDMX)
- Most could be ready to start fabrication in FY2025

SUPER CDMS
Cryogenic Dark Matter Search

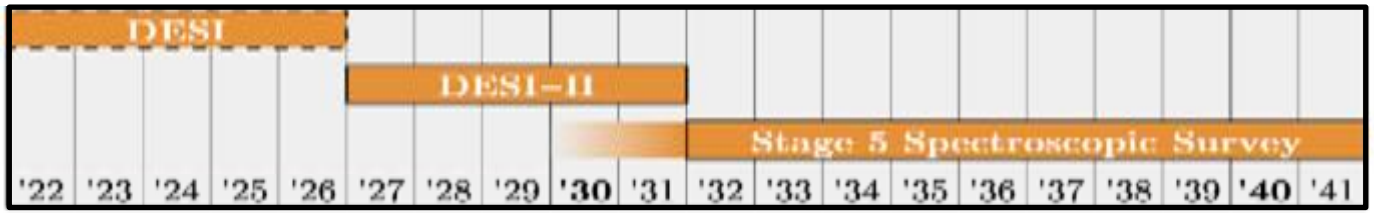
ADMX
AXION DARK MATTER EXPERIMENT

Cosmic Acceleration: Dark Energy (DES, DESI)

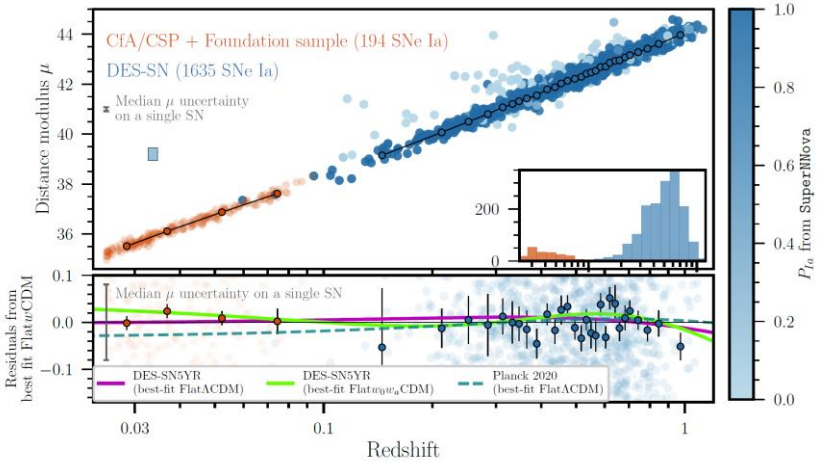
Stage III DES imaging survey in final data processing and analysis in progress. Cosmology with ~ 1700 type 1a supernovae to be published soon (largest and deepest sample from a single telescope). Public data release of SNe1a light curves end of 2023 & full cosmology catalogs by end of 2024.

Stage IV DESI – continues successful spectroscopic survey; down June to Sept. 2022 due to the Contreras Fire; primary mirror just completed re-aluminized due to reflectivity loss from fire-borne particulates. June 2023: Early Data Release was made publicly available and contains all the data from the Commissioning and Survey Validation phases. Collaboration released 2 "Key papers" describing the data, and 14 science and technical papers simultaneously. **New results will be announced at April 2024 APS Meeting!**

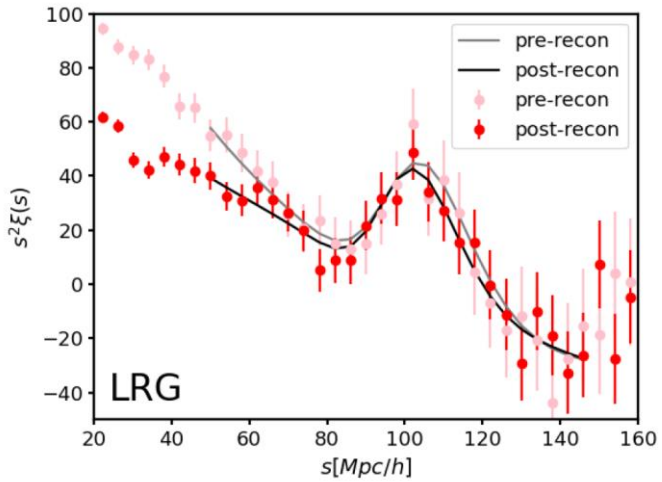
Upgrade to DESI-II and then stage 5 project proposed to P5.



DES SNe1a sample



DESI BAO signal at 5sigma from first 2 months of data!



HEP Theory Mission

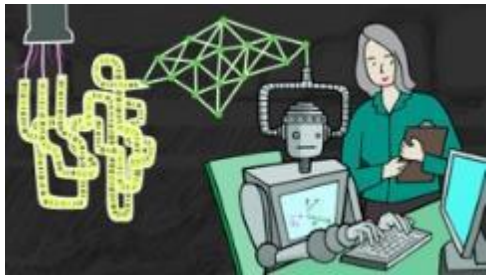
- The HEP Theory program seeks to support theoretical activities that provide the vision and the mathematical framework for understanding and extending our knowledge of particles, forces, space-time, and the universe. Topics studied include but are not limited to:
  - phenomenological studies to interpret experimental data, suggest searches for new physics and develop a research program for future facilities;
  - precision calculations of experimental observables;
  - the development of new models of physical interactions;
  - progress in quantum field theory, quantum gravity and other possible frameworks to develop a deeper understanding of nature;
  - the development of analytical and numerical computational techniques to facilitate studies in these areas.

HEP Theory Portfolio

- Topics studied in theoretical high energy physics research include but are not limited to:
  - Phenomenological studies
  - Precision calculations
  - Development of new models
  - Progress in Quantum Field Theory
  - Development of analytical and numerical computational techniques
- The program is distributed across several research areas:
  - Standard Model Phenomenology
  - Beyond the Standard Model Phenomenology
  - Cosmology and Astroparticle Theory
  - Lattice Field Theory
  - Formal Theory and Mathematical Physics

HEP Research Initiatives (from SC initiatives)

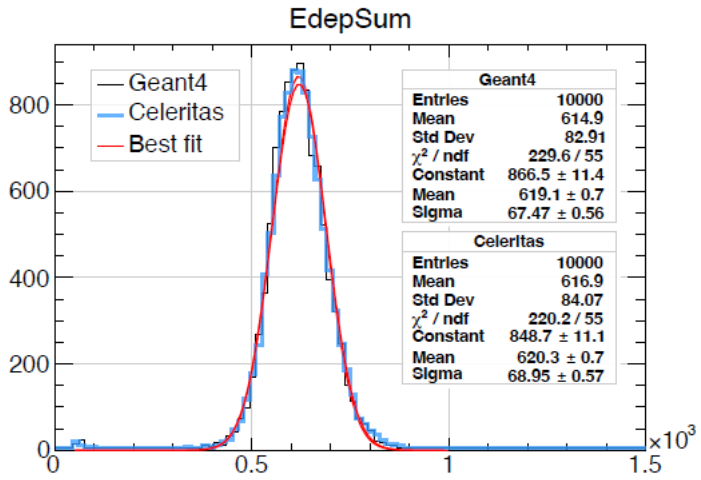
- QIS, AI/ML, Microelectronics, Advanced Computing, Accelerator Science and Technology, and ACCELERATE
- Quantum Information Science co-develops quantum information, theory, and technology with core research activities.
  - to more strongly focus and integrate efforts that align with HEP strengths in quantum sensors and theory
- AI/ML effort is highly embedded in core HEP research and accelerator technology, with a new thrust in proposal-driven, cross-cutting R&D. The balance between leveraging AI/ML tools for HEP science and using HEP data to drive AI/ML development will be reassessed.



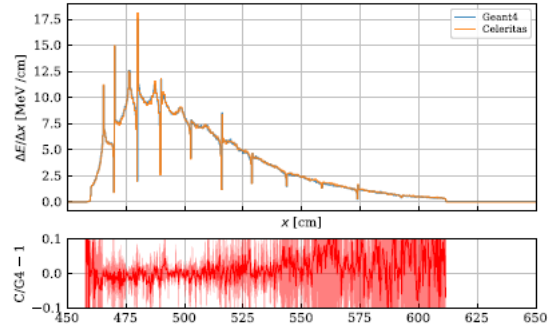
Computational HEP Program

- **Computational HEP** – advanced computing research and development targeting challenges that are or have the capability of being broadly applicable to the increasingly complex HEP computing ecosystem
  - These challenges may include hardware-software co-design, development of collaborative software infrastructure, and research into high performance software and algorithms
  - Aspects of the program are supported by the ASCR Computational User Facilities
- Example project:
  - Celeritas – Collaboration targeting exascale simulation of HEP detector modeling
    - Collaboration of HEP, ASCR, and NE scientists to parallelize and port particle transport codes to GPUs
    - Physics modeling of EM interactions offloaded to GPU shows promising speed-up
      - Integrated with GEANT4 speed-up of 42-256x for GPU:CPU core equivalence

CELERITAS



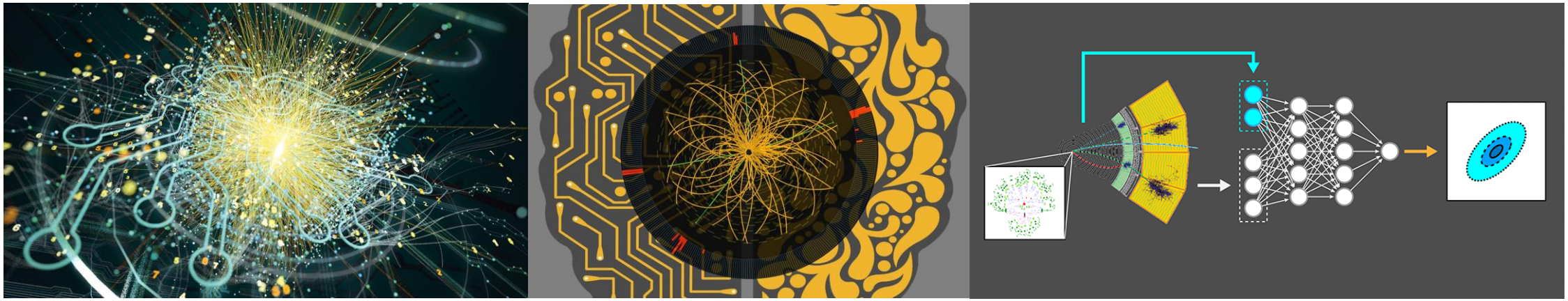
Average energy deposition with pi⁺ test beam



Slab-integrated energy deposition

AI Initiative in HEP

- Development in AI/ML is a national strategic priority
  - Develop cutting edge tools and applications of AI/ML to maintain US expertise
  - Develop a technically capable workforce able to lead the economy of the future
- DOE HEP is pursuing research into AI/ML topics in two broad thrusts
  - **Programmatic AI/ML** – integrated/embedded in the frontier programs. Applications of primarily ML techniques to improve HEP results within a given frontier.
  - **Core AI/ML** – research into AI/ML topics from an HEP perspective and blue-sky R&D necessary to enable future HEP breakthroughs across frontiers



SQMS Research Center

Superconducting Quantum Materials and Systems Center at Fermilab

- **SQMS – the National QIS Research Center – hosted at Fermilab making excellent progress**
  - To-date: 155 publications of which 76 in peer-reviewed journals
  - Trained over 200 students with schools and internships in 2023
  - Today: 33 partner institutions with over 500 collaborators
  - During the last year, four additional partner institutions joined the Center, including new collaborations with University of Michigan, U. Southern California, and UK institutions Royal Holloway and National Physical Laboratory

HEP Detector R&D Program Goals/Portfolio

- Support research leading to fundamental advances in the science of particle detection, and develop the technologies for the next generation of instrumentation for HEP
- Provide (under)graduate and post-doctoral research training in instrumentation to foster the next generation of detector experts
- Support "infrastructure"—technical personnel, equipment, "facilities", and test beams—required for experimental detector R&D and fabrication
- Forward-looking, broad Detector R&D program in support of all research efforts in the Cosmic, Energy, and Intensity Frontiers
  - Support personnel and equipment at nine national labs and more than 20 universities
  - Support large-scale facilities/test-beams and sizable hardware installations at multiple national labs
- Project portfolio aims to improve all technologies in use in current HEP experiments and aims to discover and mature new ones for the future
  - Priority research directions identified in Basic Research Needs Study
- Synergistic with SC-wide initiatives in Microelectronics, Quantum Information Science, and AI/ML

General Accelerator Research and Development (GARD)

- Supports Accelerator Science and Technology R&D for beam-based scientific research needs, including HEP, BES, NP, FES and applications in security, industry, medicine etc.
  - Particle colliders, synchrotron light sources, free electron lasers, linear accelerators etc.
- GARD Research Thrusts:
  - Accelerator and Beam Physics (ABP)
    - includes computation, instrumentation and controls
  - Advanced Accelerator Concepts (AAC)
  - Particle Sources and Targets (PST)
  - RF Acceleration Technology (normal conducting (NC) and superconducting)
    - includes SRF, NCRF, high gradient research and RF sources
  - Superconducting Magnets and Materials (SCM)
- Plus:
  - Test Facilities: beam physics and technology/hardware
  - US Particle Accelerator School (USPAS)
  - DOE Accelerator Traineeship
  - US-Japan Collaboration on HEP (including accelerator R&D)
  - SBIRs


Fermilab booster

LCLS-II SRF module assembly at Fermilab

GARD Highlights – HL-LHC Superconducting Magnets

A successful multi-lab collaboration project:

- Berkeley Lab completed the HL-LHC-AUP cabling, magnet assembly on track to enable the next set of collider experiments;
- Fermilab completed the first AUP quadrupole cryo-assembly reached acceptance current and stable operation at 1.9K in Fermilab's IB1 test facility;
- Culmination of years of effort to realize high field Nb3Sn magnets in colliders;
- The cryo-assembly (13 meter long and weights 25 tons) arrived safely at CERN in Nov. 2023.

The SCM arrival celebration at CERN in December 2023


THANK YOU!