U.S. DEPARTMENT OF ENERGY | Office of Science

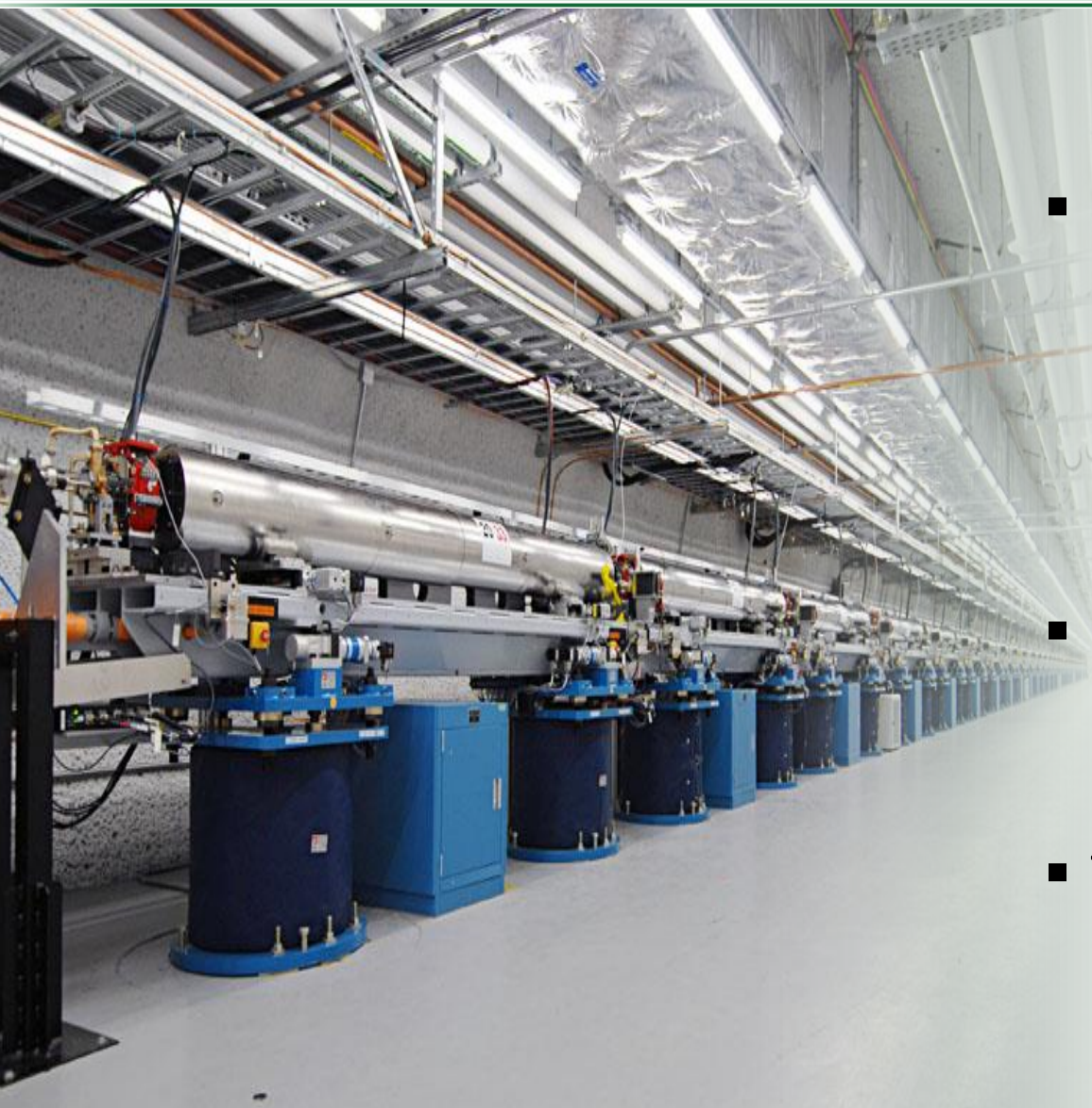
International Science Collaborations: Accelerating Scientific Discovery

J. Stephen Binkley, Deputy Director
Office of Science
U.S. Department of Energy

March 7, 2019

DOE Office of Science

A research funding agency and a steward of national research infrastructure.



The undulator hall at the Linac Coherent Light Source, SLAC National Accelerator Laboratory

- 25,000 Ph.D. scientists, graduate students, undergraduates, engineers, and technical staff supported through competitive awards
- 27 scientific user facilities serving more than 36,000 users each year
- The U.S. largest federal supporter of basic research in the physical sciences

The DOE National Laboratories

Office of Science Laboratories

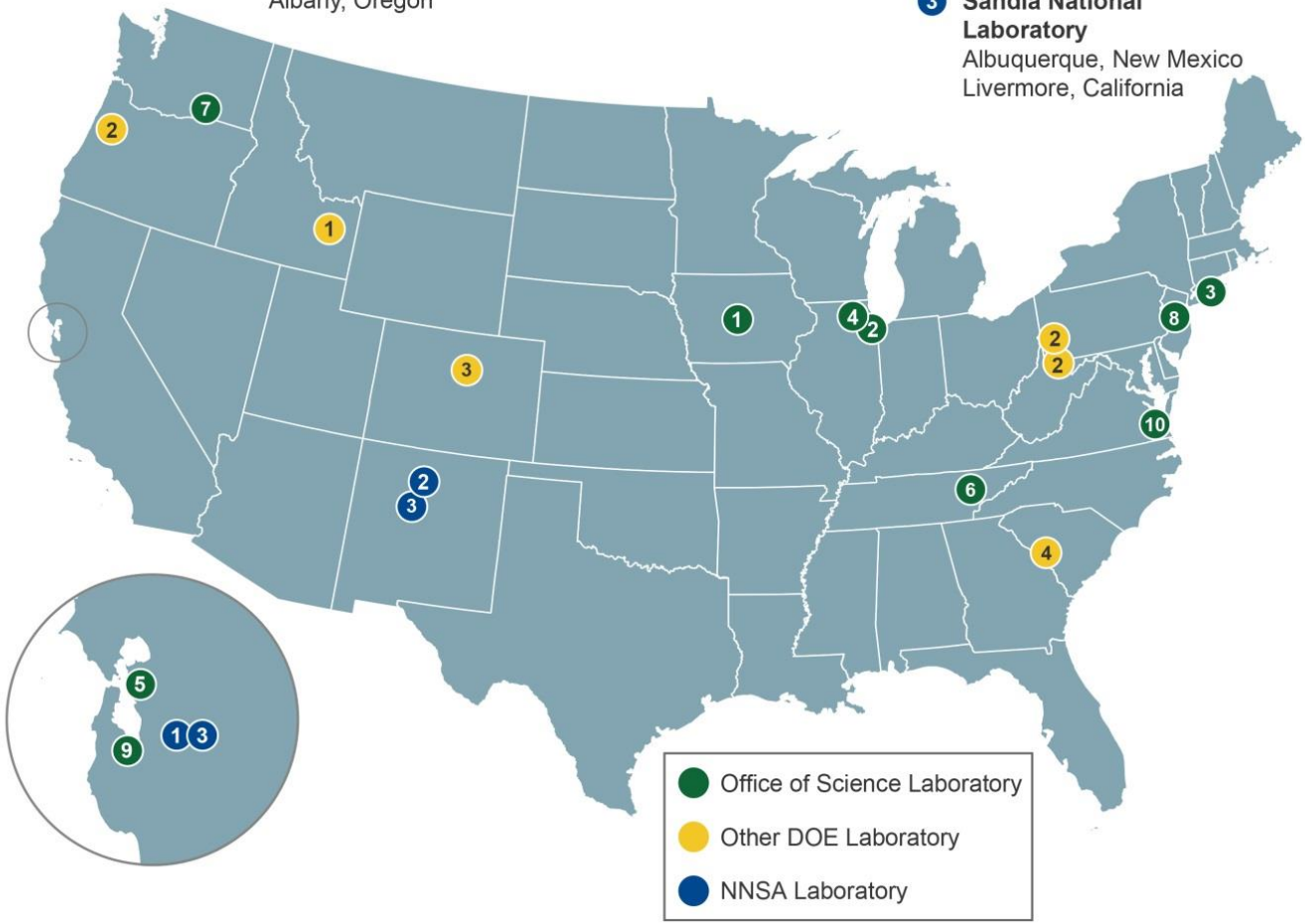
1. **Ames Laboratory**
   Ames, Iowa
2. **Argonne National Laboratory**
   Argonne, Illinois
3. **Brookhaven National Laboratory**
   Upton, New York
4. **Fermi National Accelerator Laboratory**
   Batavia, Illinois
5. **Lawrence Berkeley National Laboratory**
   Berkeley, California
6. **Oak Ridge National Laboratory**
   Oak Ridge, Tennessee
7. **Pacific Northwest National Laboratory**
   Richland, Washington
8. **Princeton Plasma Physics Laboratory**
   Princeton, New Jersey
9. **SLAC National Accelerator Laboratory**
   Menlo Park, California
10. **Thomas Jefferson National Accelerator Facility**
    Newport News, Virginia

Other DOE Laboratories

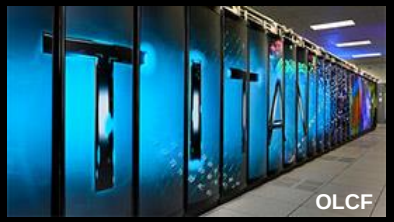
1. **Idaho National Laboratory**
   Idaho Falls, Idaho
2. **National Energy Technology Laboratory**
   Morgantown, West Virginia
   Pittsburgh, Pennsylvania
   Albany, Oregon
3. **National Renewable Energy Laboratory**
   Golden, Colorado
4. **Savannah River National Laboratory**
   Aiken, South Carolina

NNSA Laboratories

1. **Lawrence Livermore National Laboratory**
   Livermore, California
2. **Los Alamos National Laboratory**
   Los Alamos, New Mexico
3. **Sandia National Laboratory**
   Albuquerque, New Mexico
   Livermore, California



27 scientific user facilities



OLCF

ALCF

NERSC

ESnet

EMSL

ARM

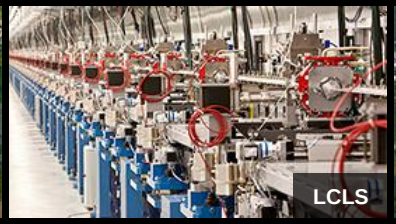
JGI

SNS

HFIR

ALS

APS


LCLS

NSLS-II

SSRL

CFN

CINT

CNM

CNMS

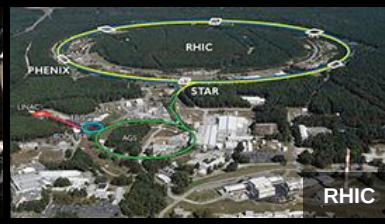
TMF

DIII-D

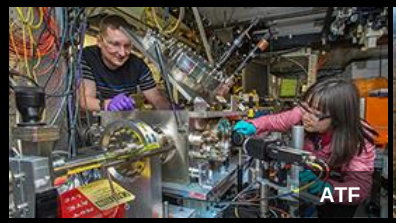
NSTX-U

FACET

ATLAS



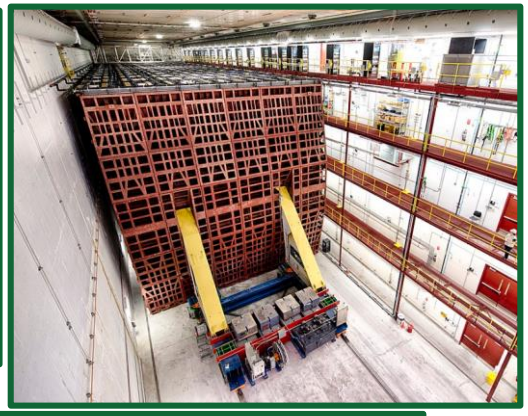
RHIC


ATF

Fermilab AC

CEBAF

Office of Science User Facilities



27 world-leading facilities serving over 36,000 researchers annually

- **supercomputers,**
- **high intensity x-ray, neutron, and electron sources,**
- **nanoscience facilities,**
- **genomic sequencing facilities,**
- **particle accelerators,**
- **fusion/plasma physics facilities, and**
- **atmospheric monitoring capabilities.**

- **Open access; allocation determined through peer review of proposals**

- **Free for non-proprietary work published in the open literature**

- **Full cost recovery for proprietary work**

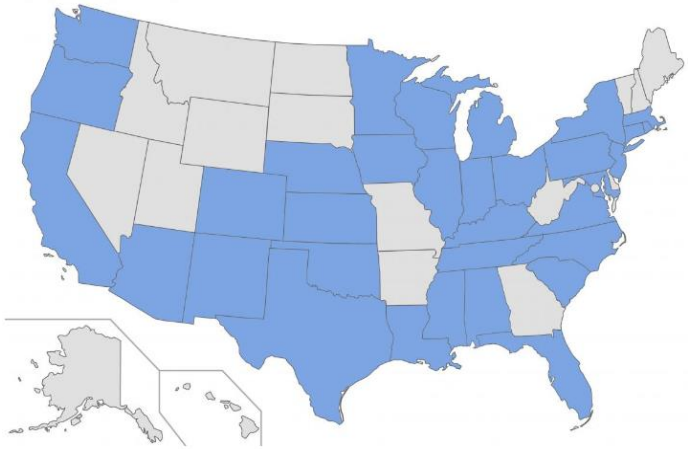
U.S. DOE International Agreements

- **SC Programs' international cooperation currently operates under 62 Office of Science International Agreements**
  - Spanning 16 foreign countries and partner entities (Brazil, Canada, CERN, China, EURATOM, France, Germany, India, IEA, Israel, Italy, ITER, Japan, Russia, South Korea, Sweden)
  - Includes Implementing Arrangements, Protocols, Cooperative agreements, project annexes, and statements of intent
- **13 of the SC International Agreements involve BES facilities, research, and program activities**
- ***Under development:* 17 international agreements between DOE Programs and foreign partner entities**
  - Presently extending to Czech Republic, Poland, United Kingdom
- **Many international collaborations through the DOE/SC National Labs**
  - Agreements, CRADAs, SPPs
  - All are approved through DOE/SC

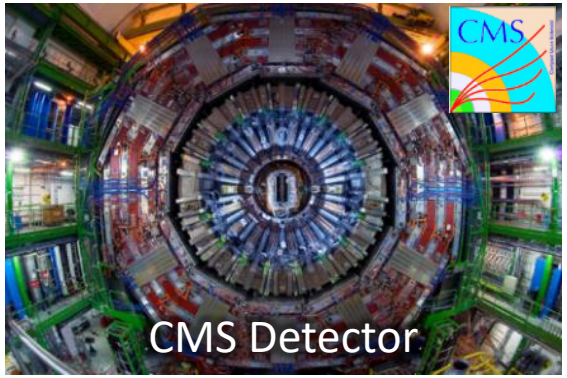
U.S. DOE at the Large Hadron Collider

The U.S. continues strong collaboration in the Large Hadron Collider as part of our bilateral partnership with CERN

- **U.S. ATLAS represents ~19% of the international ATLAS Collaboration**
  - 41 universities, 4 national labs (Argonne, Brookhaven, Lawrence Berkeley, SLAC)
  - Brookhaven is host lab for U.S. ATLAS
- **U.S. CMS represents ~29% of the international CMS Collaboration**
  - 53 universities, 1 national lab
  - Fermilab is host lab for U.S. CMS
- **Participation in LHC proton program at ATLAS and CMS and heavy ion program at ALICE, ATLAS, and CMS**



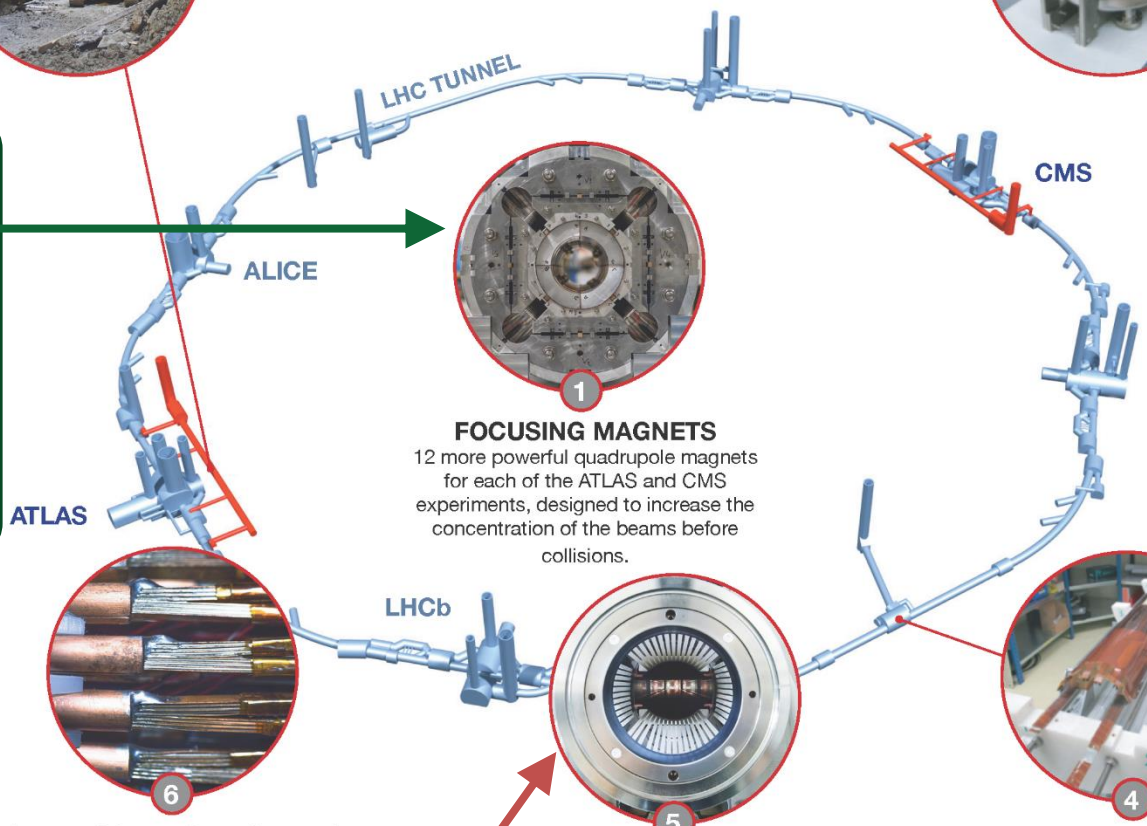
States hosting members of the U.S. LHC experimental program



HL-LHC Accelerator Upgrades

CIVIL ENGINEERING
2 new 300-metre service tunnels and 2 shafts near to ATLAS and CMS.

"CRAB" CAVITIES
16 superconducting "crab" cavities for each of the ATLAS and CMS experiments to tilt the beams before collisions.



DOE contribution:
10 (Nb_3Sn) Cold Mass Assemblies
- **4 each for ATLAS/CMS IRs**
- **2 spares**

DOE contribution:
20 Crab Cavities
- **16 + 4 spares**

OR:
10 Crab cavities & Hollow e-Lens Components

FOCUSING MAGNETS
12 more powerful quadrupole magnets for each of the ATLAS and CMS experiments, designed to increase the concentration of the beams before collisions.

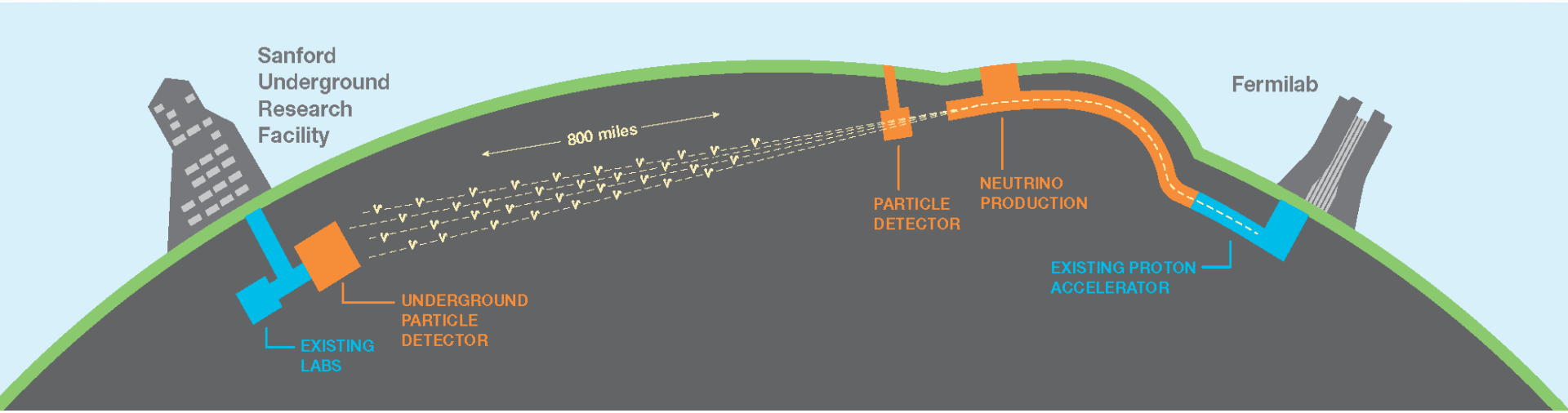
SUPERCONDUCTING LINKS
Electrical transmission lines based on a high-temperature superconductor to carry current to the magnets from the new service tunnels near ATLAS and CMS.

COLLIMATORS
15 to 20 new collimators and 60 replacement collimators to reinforce machine protection.

BENDING MAGNETS
4 pairs of shorter and more powerful dipole bending magnets to free up space for the new collimators.

DOE contribution:
Hollow e-Lens Components (under discussion)

Long Baseline Neutrino Facility & Deep Underground Neutrino Experiment

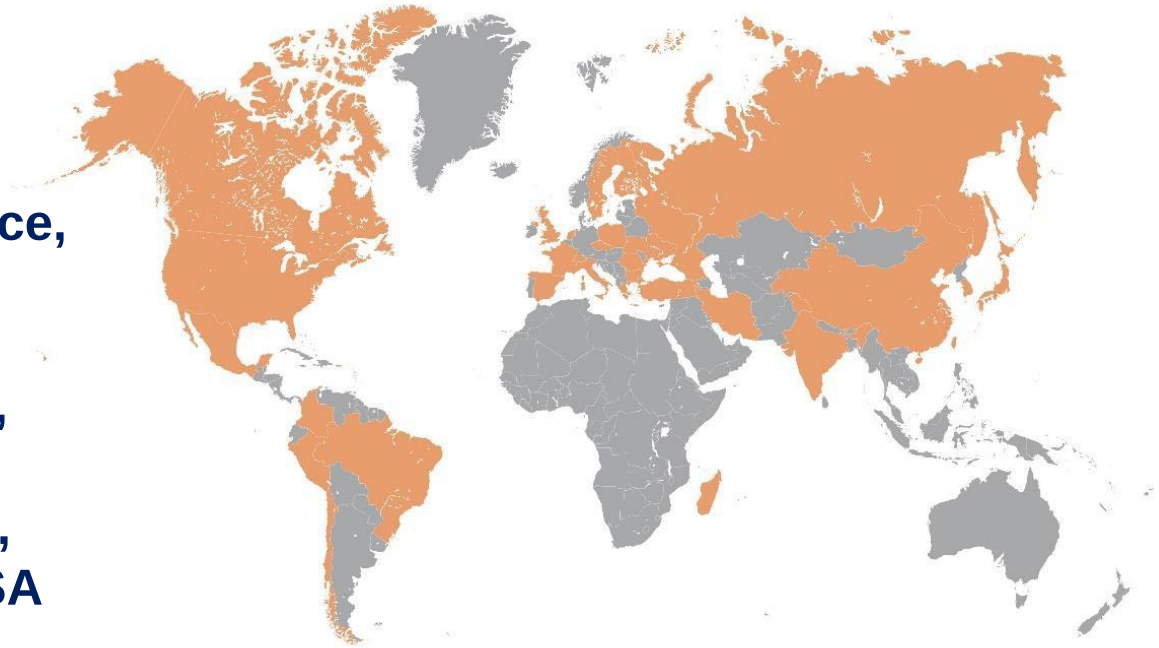


The LBNF/DUNE project will be the first internationally conceived, constructed and operated mega-science project hosted by the Department of Energy in the United States

- **Combination of world's most intense neutrino beam, a deep underground site, and massive liquid argon detectors enables broad science program addressing some of the most fundamental questions in particle physics**
  - **Origin of matter.** Investigate matter-antimatter asymmetry. Are neutrinos the reason the universe is made of matter?
  - **Neutron star and black hole formation.** Ability to observe neutrinos from supernovae events and perhaps watch formation of black holes in real time.
  - **Unification of forces.** Investigate nucleon decay.

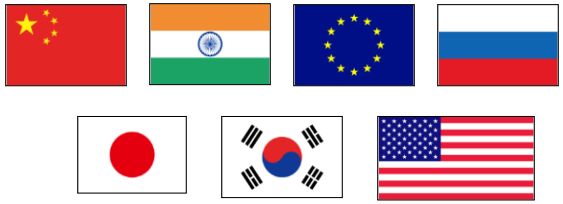
Now 1180 collaborators from 184 institutions in 32 nations

Armenia, Brazil, Bulgaria, Canada, CERN, Chile, China, Colombia, Czech Republic, Spain, Finland, France, Greece, India, Iran, Italy, Japan, Madagascar, Mexico, Netherlands, Paraguay, Peru, Poland, Romania, Russia, South Korea, Spain, Sweden, Switzerland, UK, Ukraine, USA



The US is a partner in ITER, the world's major step forward in fusion research

ITER's mission is to demonstrate scientific and technical feasibility of a "burning plasma", a necessary major step leading to fusion energy



ITER - an essential next step in the development of fusion energy

- With current devices: 10 MW, 100 sec, gain < 1
- With ITER: 500 MW, > 400 sec, gain ≥ 10; (ITER-Phase II to achieve 3000 seconds, gain = 5)
- First-ever access to burning plasma science frontier, leveraging U.S. intellectual investments
- Major contributions from U.S. industry

An international collaboration

- Seven Members, over 50% of the world's population
- U.S. manages its in-kind hardware and financial contributions through "U.S. Contributions to ITER" project line-item (U.S. ITER)
- U.S. involvement and leadership in a "big-science" international physics collaboration
- EU the host Member, site in France

ITER Project is 60% complete to First Plasma

- First Plasma: 2025
- DT Operations: 2035

International Collaborations – Guiding Principles

Goal: to pursue mutually beneficial collaborations that advance and accelerate scientific discovery

- Quid pro quo – mutual benefit
  - Parity in intellectual and financial contributions
  - Scientific credit
- Mutual respect of intellectual property rights
- Openness, transparency, respect for individuals
  - Institutions, funding, people
- For peaceful purposes
- Community engagement and buy in – validated via peer review
- Use of rigorous project management, where appropriate
- Governed by formal, Government-to-Government Agreements when appropriate
  - Intellectual property, access, funding, national security

U.S. DEPARTMENT OF ENERGY | Office of Science