



U.S. DEPARTMENT OF  
**ENERGY**

Office of  
Science

# International Science Collaborations: Accelerating Scientific Discovery

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Office of Science  
U.S. Department of Energy

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# DOE Office of Science

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



- 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

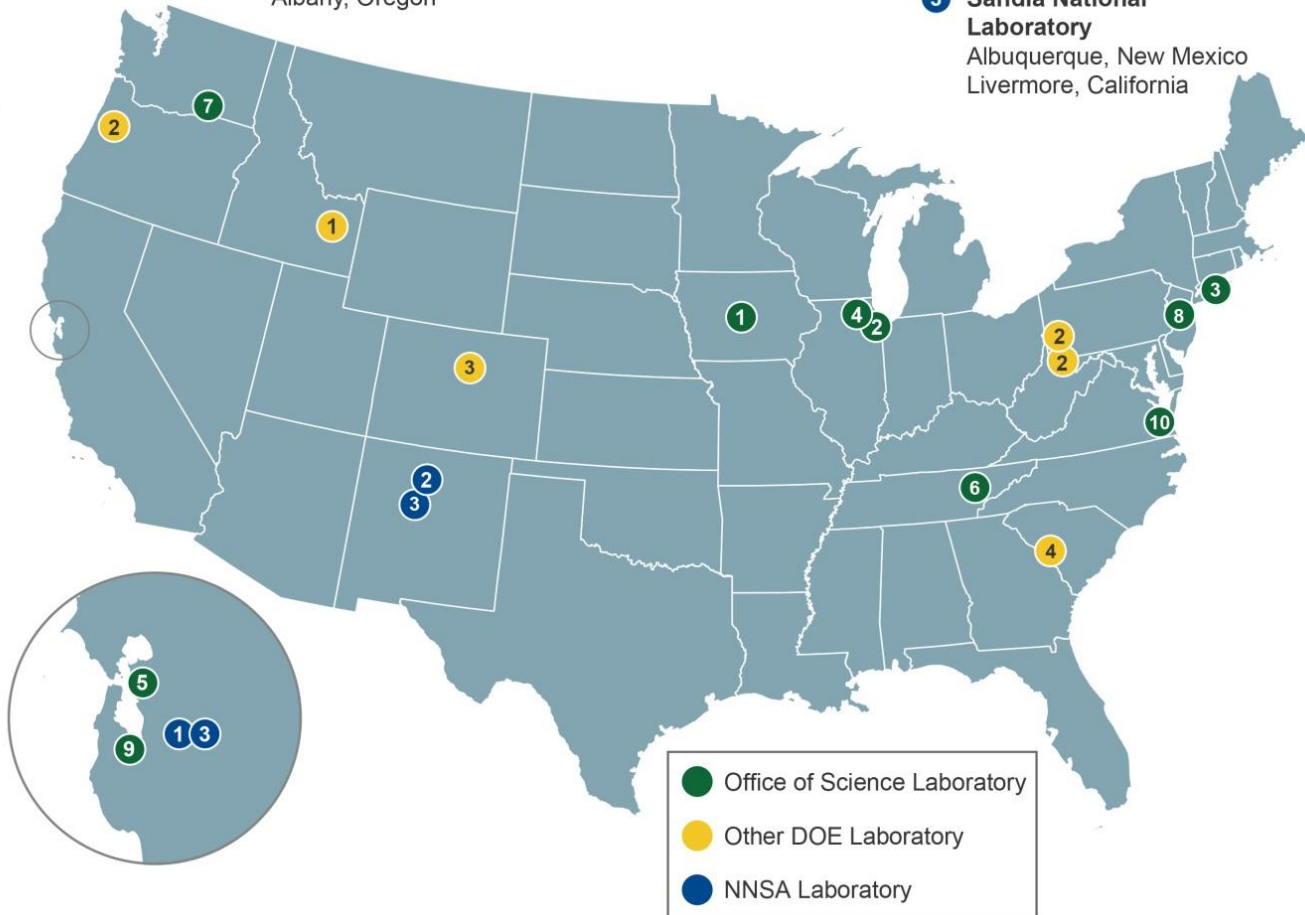
- 1 Ames Laboratory**  
Ames, Iowa
- 2 Argonne National Laboratory**  
Argonne, Illinois
- 3 Brookhaven National Laboratory**  
Upton, New York
- 4 Fermi National Accelerator Laboratory**  
Batavia, Illinois
- 5 Lawrence Berkeley National Laboratory**  
Berkeley, California
- 6 Oak Ridge National Laboratory**  
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

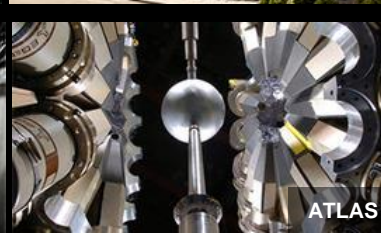
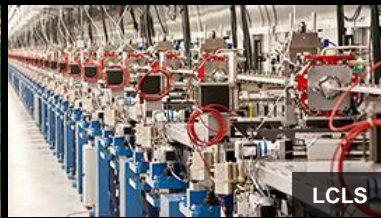
- 1 Idaho National Laboratory**  
Idaho Falls, Idaho
- 2 National Energy Technology Laboratory**  
Morgantown, West Virginia  
Pittsburgh, Pennsylvania  
Albany, Oregon
- 3 National Renewable Energy Laboratory**  
Golden, Colorado
- 4 Savannah River National Laboratory**  
Aiken, South Carolina

## NNSA Laboratories

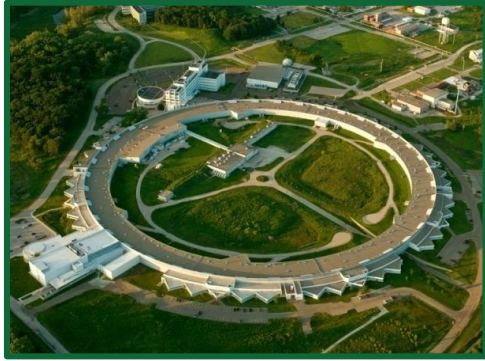
- 1 Lawrence Livermore National Laboratory**  
Livermore, California
- 2 Los Alamos National Laboratory**  
Los Alamos, New Mexico
- 3 Sandia National Laboratory**  
Albuquerque, New Mexico  
Livermore, California



# 27 scientific user facilities



# 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

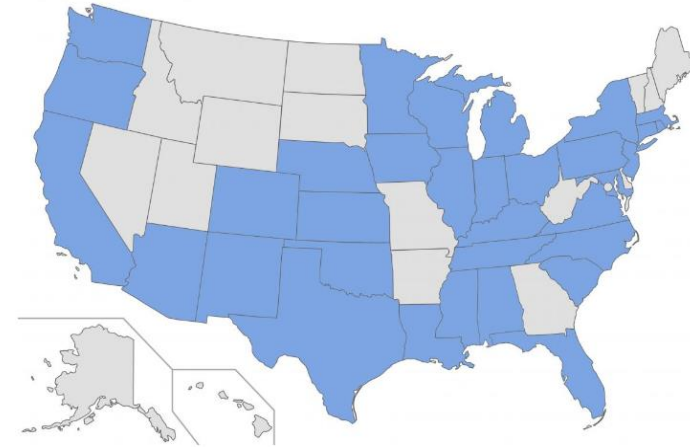
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- **SC Programs' international cooperation currently operates under 62 Office of Science International Agreements**
  - Spanning 16 foreign countries and partner entities (Brazil, Canada, CERN, China, EURATOM, France, Germany, India, IEA, Israel, Italy, 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



Large Hadron Collider Tunnel



ATLAS Detector



CMS Detector

# HL-LHC Accelerator Upgrades



2

## CIVIL ENGINEERING

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



3

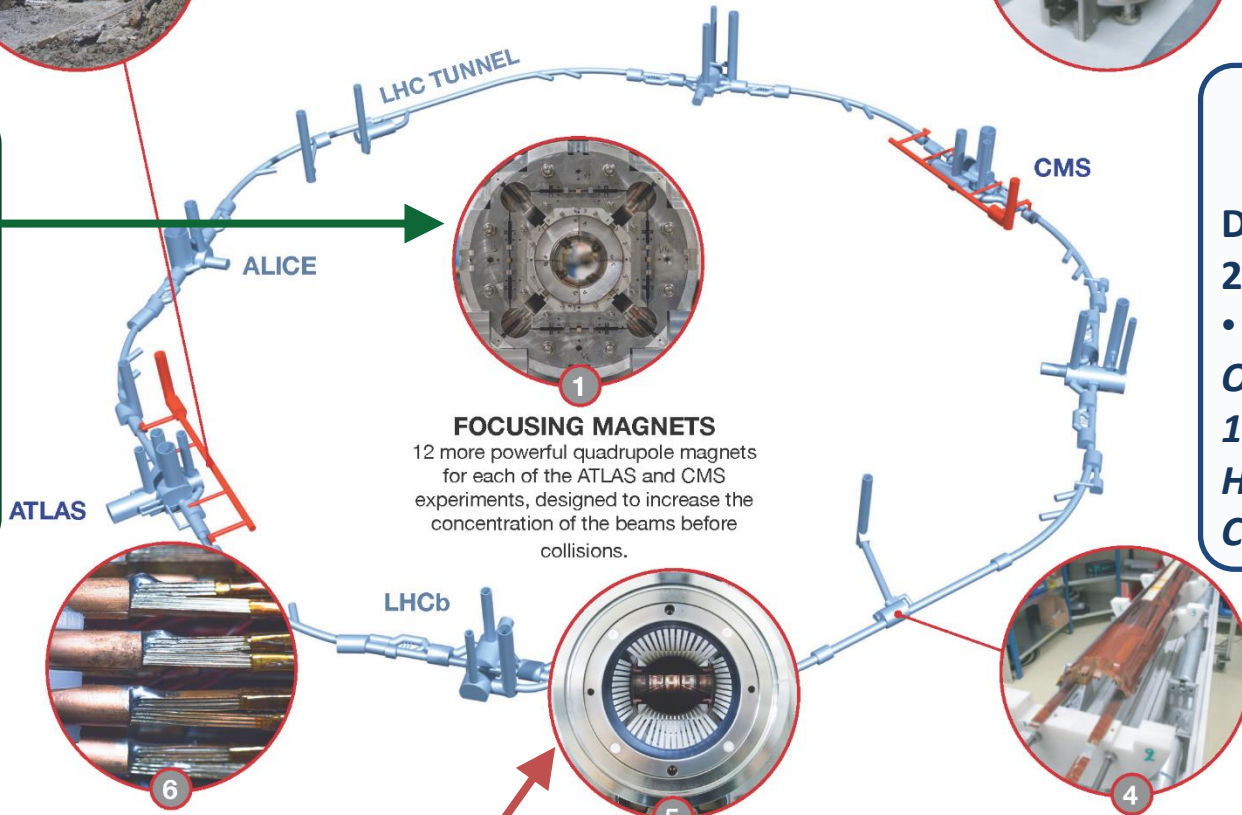
## "CRAB" CAVITIES

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



**DOE contribution:**  
10 (Nb<sub>3</sub>Sn) Cold Mass Assemblies

- 4 each for ATLAS/CMS IRs
- 2 spares



1

## 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.

CMS

ALICE

ATLAS

LHCb

6

## 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.

5

## COLLIMATORS

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

4

## BENDING MAGNETS

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



**DOE contribution:**

20 Crab Cavities

- 16 + 4 spares

**OR:**

10 Crab cavities & Hollow e-Lens Components

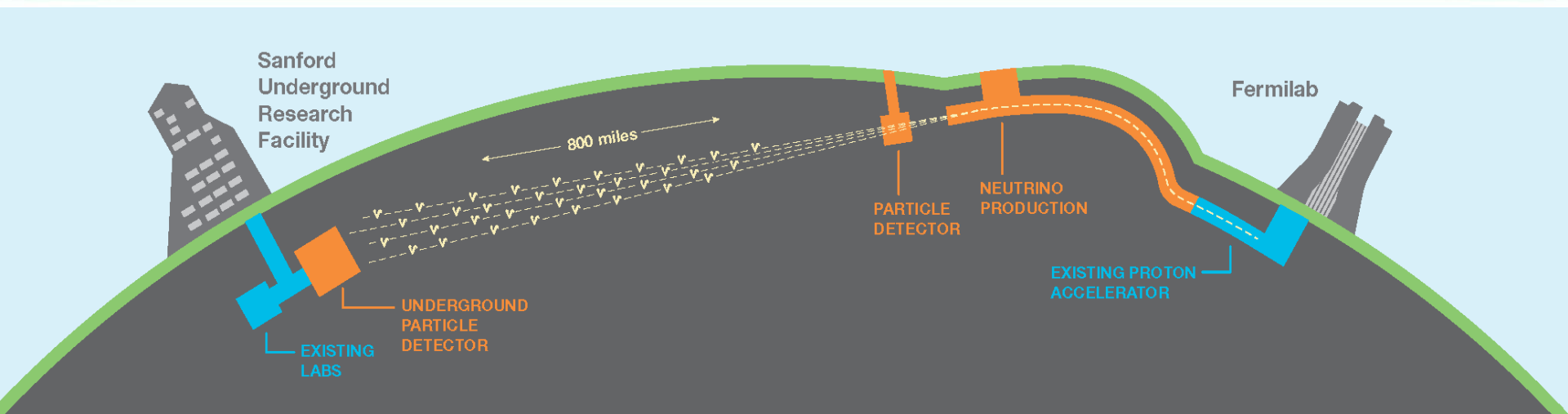


**DOE contribution:**

Hollow e-Lens Components (under discussion)



# Long Baseline Neutrino Facility & Deep Underground Neutrino Experiment

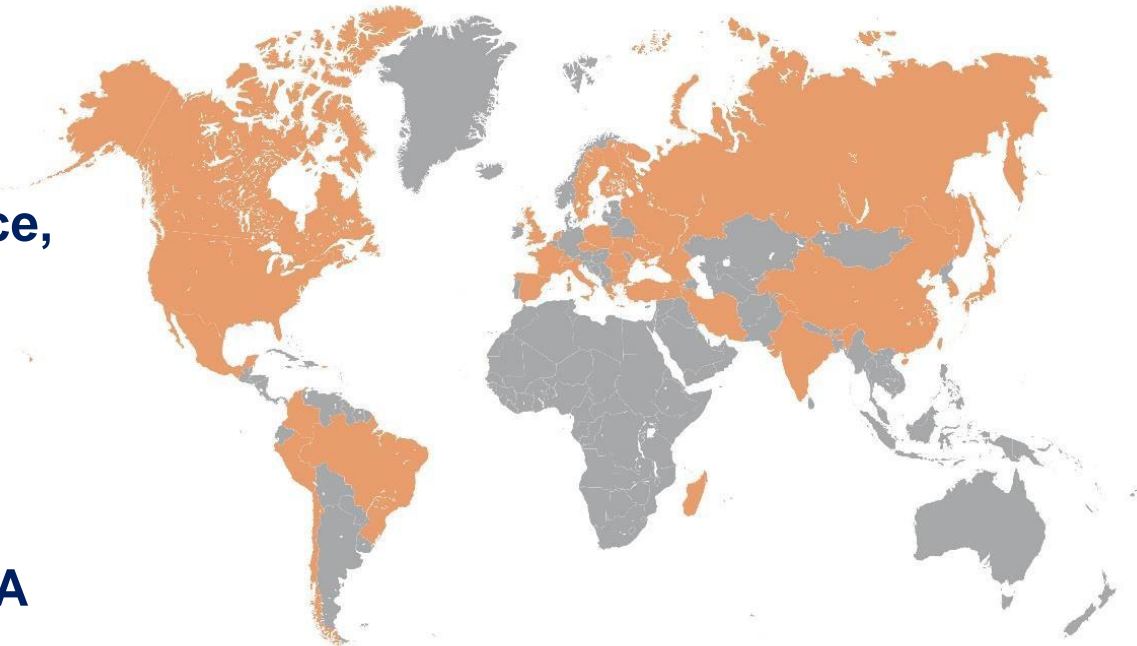


The LBNF/DUNE project will be the first internationally conceived, constructed and operated mega-science project hosted by the Department of Energy in the United States

- **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.

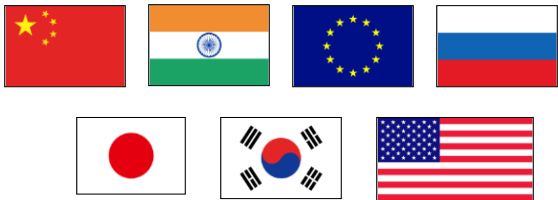
## Now 1180 collaborators from 184 institutions in 32 nations

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  $\geq 10$ ; (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



Courtesy ITER Organization

# International Collaborations – Guiding Principles

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*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



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