U.S. DEPARTMENT OF ENERGY | Office of Science

International Science Collaborations and Science Infrastructure: Accelerating Scientific Discovery

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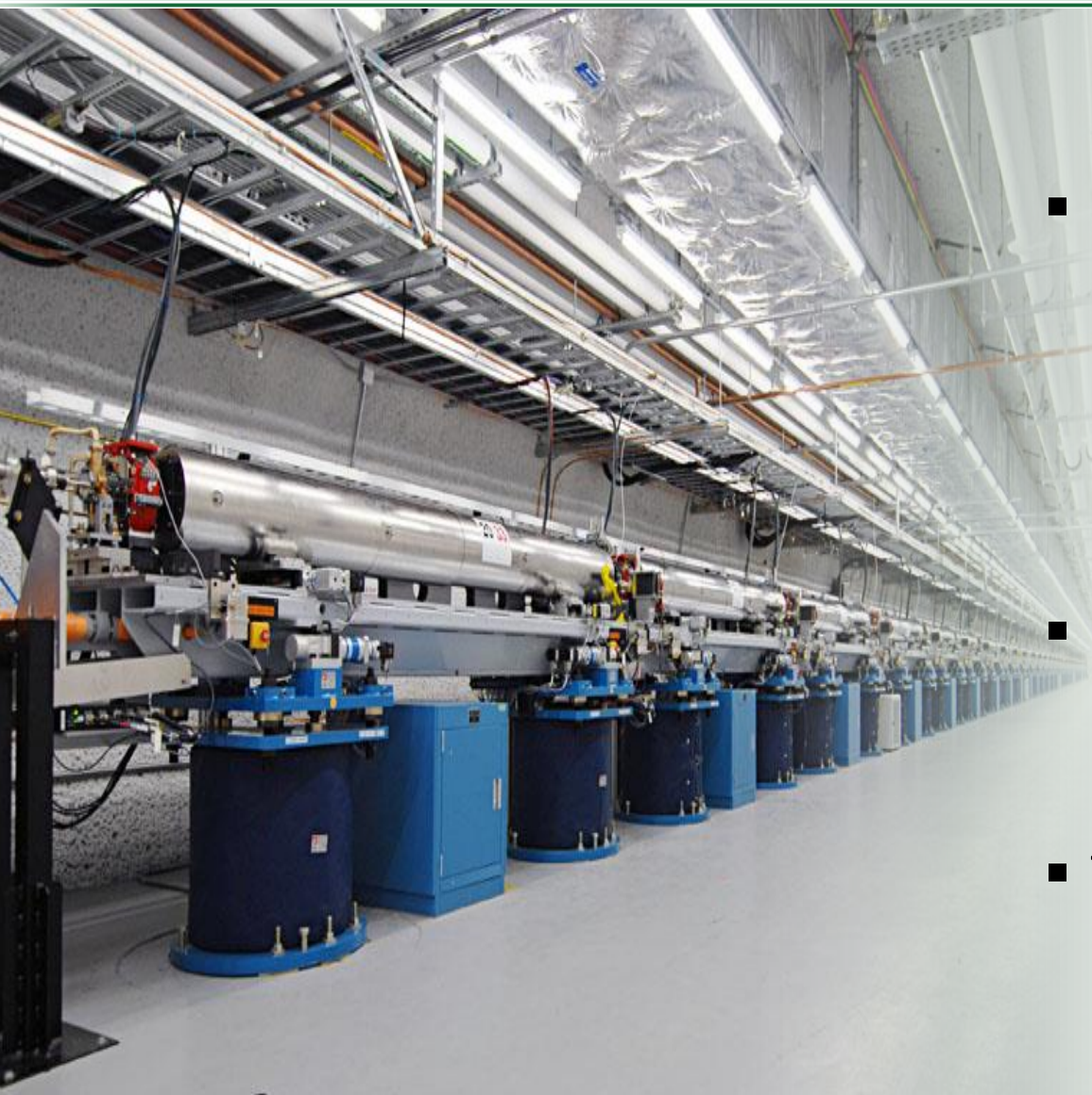
FY 2020 President's Budget Request

Supports Cutting-Edge Basic Research and Leading Scientific User Facilities. The Budget provides $5.5 billion for the Office of Science to continue its mission to focus on early-stage research, operate the national laboratories, and continue high priority construction projects. Within this amount, $500 million is budgeted for Exascale computing to help secure a global leadership role in supercomputing, $169 million for Quantum Information Science, $71 million for artificial intelligence and machine learning, and $25 million to enhance materials and chemistry foundational research to support U.S.-based leadership in microelectronics.

- Within the Office of Science, Science Laboratory Infrastructure focuses on strengthening the backbone of the labs with $118 million to modernize aging critical infrastructure and laboratory space.
- The Budget continues to ensure access to the scientific user facilities of the future, including $104 million for the Long Baseline Neutrino Facility/Deep Underground Neutrino Experiment and $40 million to complete the Facility for Rare Isotope Beams.
- The Budget prioritizes select infrastructure and testbeds to maintain the world-class nature of national laboratory facilities and better enable private sector demonstration and deployment of energy technologies.

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

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**

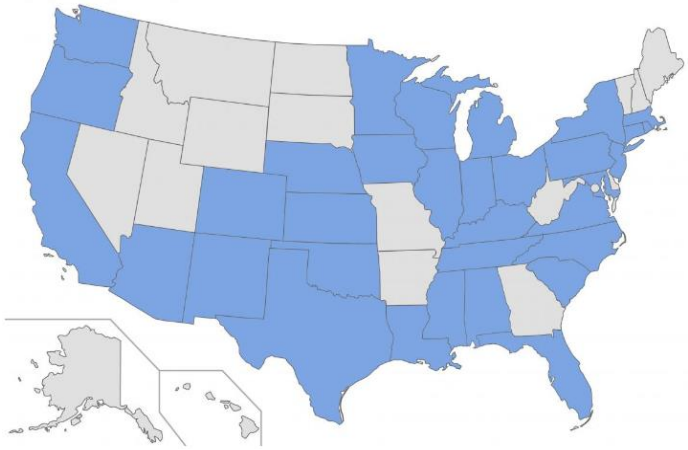
U.S. DOE International Agreements

- **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
- **Several of the SC International Agreements involve FES 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

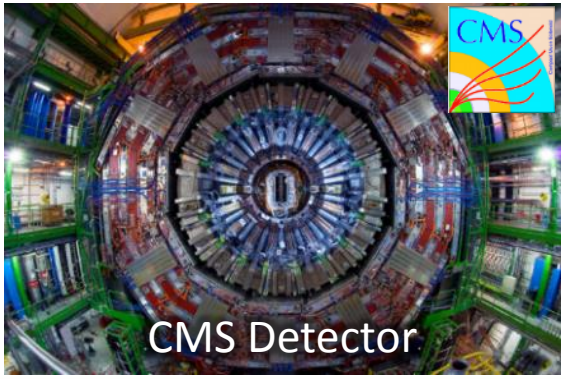
U.S. DOE at the Large Hadron Collider

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

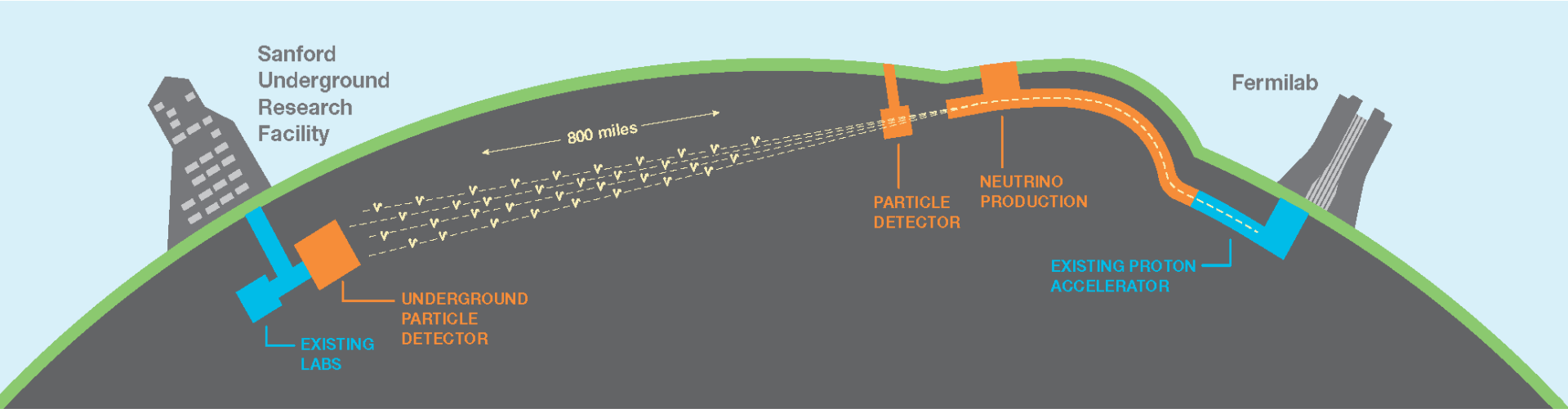
- **U.S. ATLAS represents ~19% of the international ATLAS Collaboration**
  - 41 universities, 4 national labs (Argonne, Brookhaven, Lawrence Berkeley, SLAC)
  - Brookhaven is host lab for U.S. ATLAS
- **U.S. CMS represents ~29% of the international CMS Collaboration**
  - 53 universities, 1 national 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



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

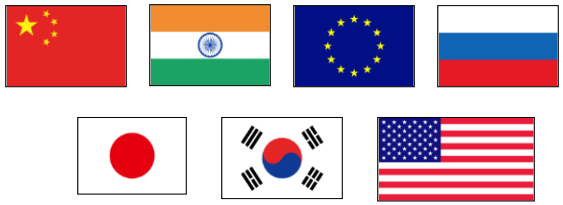
- **Combination of world's most intense neutrino beam, a deep underground site, and massive liquid argon detectors enables broad science program addressing some of the most fundamental questions in particle physics**
  - **Origin of matter.** Investigate matter-antimatter asymmetry. Are neutrinos the 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

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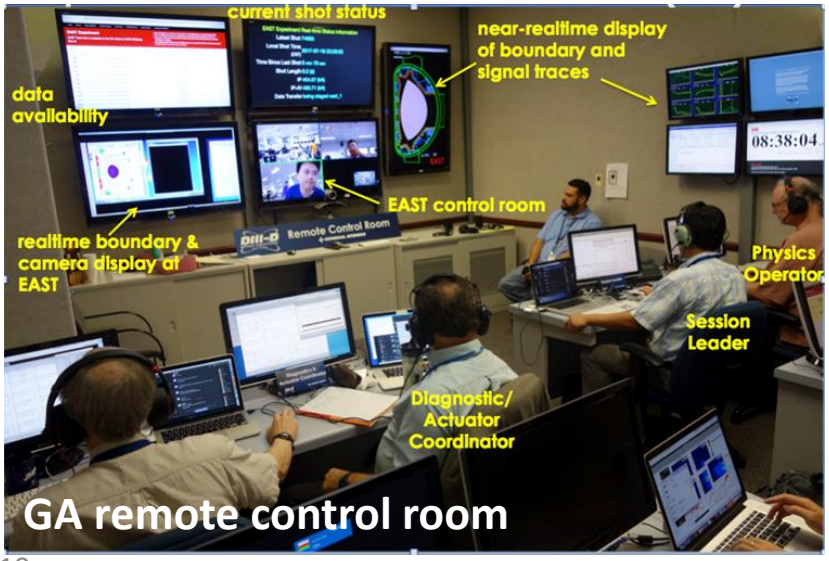
Fusion research at EAST tokamak
CAS Institute of Plasma Physics, China

Experimental Advanced Superconducting Tokamak (EAST) is a first-generation superconducting tokamak capable of steady-state operation:

- $1 billion-class, 1.85-m major radius (similar to DIII-D in the U.S.), 3.5 T magnetic field
- Extensive heating and current drive systems to enable long pulse: capable of 1000-second operation (present best = 100 seconds)



Two U.S. multi-institutional teams perform research at EAST, both on-site and remotely

- Develop advanced control algorithms for long-pulse tokamak scenarios
- Develop strategies to manage plasma-material interactions, thus enabling long-pulse plasmas

State-of-the art remote control room at General Atomics allows "3rd shift" off-site operation of EAST by U.S. scientists

- 2-3 weeks of 3rd shift ops in 2018
- 4-6 weeks of 3rd shift ops planned in 2019

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Fusion research at W7-X stellarator
Max-Planck Institute of Plasma Physics, Germany

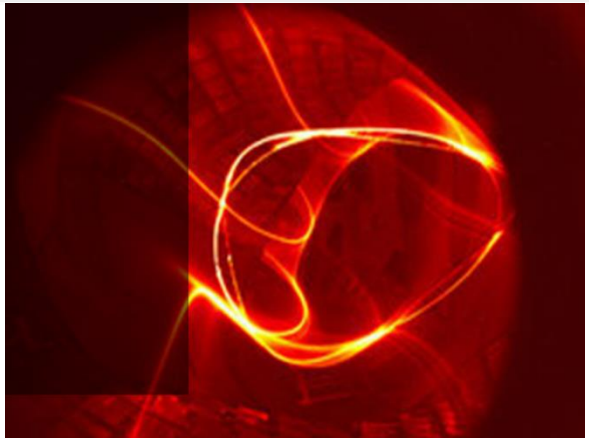
Wendelstein 7-X is a superconducting stellarator capable of steady-state operation:

- $1 billion-class, 5.5-m major radius, 3 T magnetic field, no internal current
- Extensive heating and current drive systems to enable long pulse: present best = 30 minutes

- **A U.S. team of national lab and university scientists and students performs research at W7-X**
- **The U.S. team has fabricated, installed, and operated two hardware systems and several plasma diagnostics**
- **The U.S. is a member of the W7-X Governing Board, and U.S. scientists are task group leaders**

U.S. infra-red camera & visible imaging systems

U.S. scientists helped measure magnetic field flux surfaces



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

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