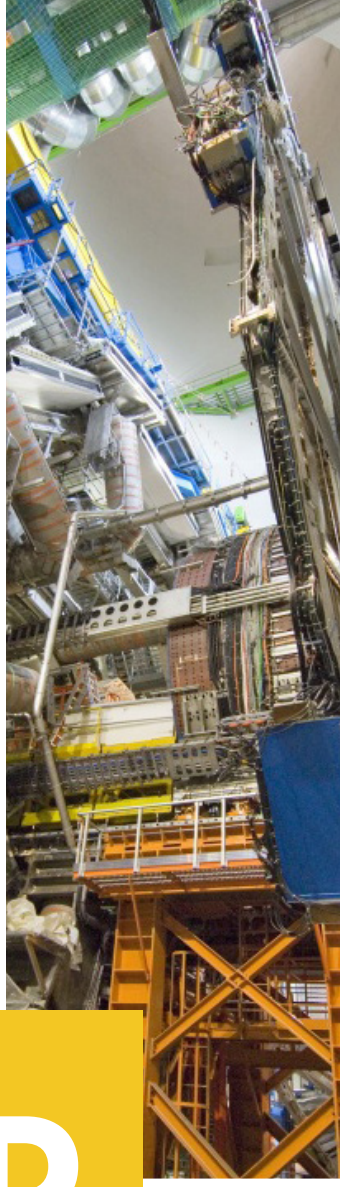
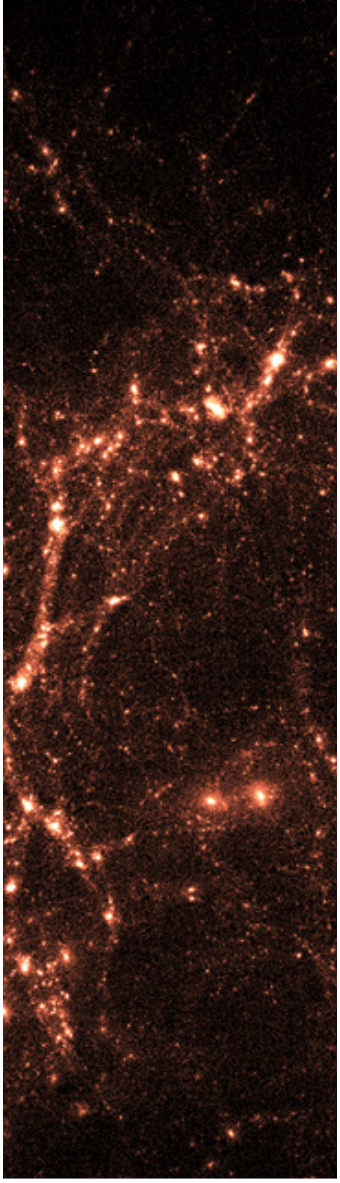
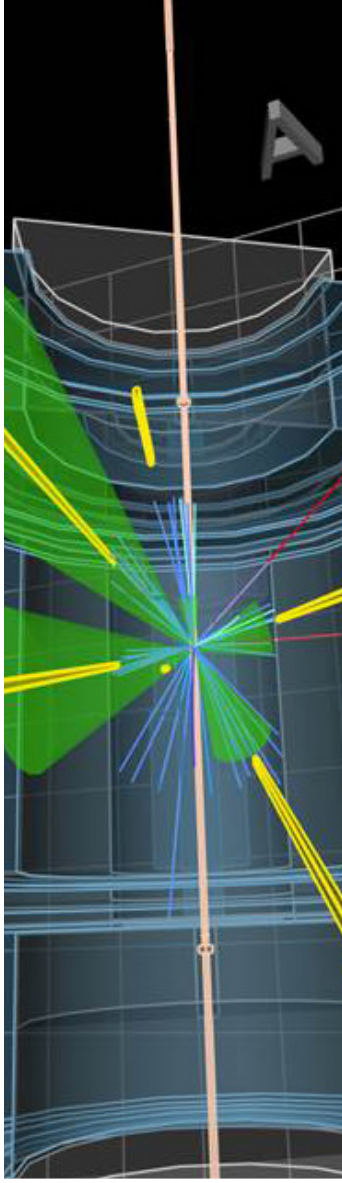





HEP

HIGH ENERGY PHYSICS

EXASCALE REQUIREMENTS REVIEW

An Office of Science review sponsored jointly by
Advanced Scientific Computing Research
and High Energy Physics

June 10–12, 2015
Bethesda, Maryland

U.S. DEPARTMENT OF ENERGY

HIGH ENERGY PHYSICS

1
YEAR OF **PLANNING**

3
DAYS OF **DISCUSSION**

18
WHITE PAPERS AND **CASE STUDIES** PREPARED IN ADVANCE OF THE REVIEW

70
PARTICIPANTS FROM MORE THAN TWO DOZEN **INSTITUTIONS**

Exascale Requirements Reviews: Overview

During 2015 and 2016, the U.S. Department of Energy (DOE) conducted Exascale Requirements Reviews for each of its six Office of Science (SC) program offices. The goal of the reviews was to help ensure the ability of DOE's Advanced Scientific Computing Research (ASCR) facilities to support SC mission science in the exascale age. The reviews brought together scientists, planners, and experts to identify:

1. **Grand Challenges:** forefront scientific challenges and opportunities that could benefit from exascale computing over the next decade.
2. **Priority Research Directions:** how new high-performance computing (HPC) capabilities will be used to advance boundaries at the various scientific frontiers.
3. **Computing Requirements:** how to maximize the potential for exascale computing to advance scientific discovery.

DOE program managers are using the review reports to guide strategic planning and investments for the 2020–2025 time frame.

HEP Grand Challenges

The high energy physics (HEP) community developed an updated strategic plan for U.S. HEP that will be executed over the next 10 years to fulfill a 20-year global vision for the field. The plan identified the following five science drivers:

1. Use the Higgs boson as a new tool for discovery;
2. Pursue the physics associated with neutrino mass;
3. Identify the new physics of dark matter;
4. Understand cosmic acceleration: dark energy; and
5. Explore the unknown: new particles, interactions, and physical principles.

Results from new projects in the coming decade (e.g., Large Synoptic Survey Telescope, Cosmic Microwave Background-Stage 4, Dark Energy Spectroscopic Instrument, Deep Underground Neutrino Experiment, Muon-to-Electron Conversion Experiment, High-Luminosity Large Hadron Collider [LHC]) could profoundly alter our understanding of the world we live in.

Answering HEP Challenges in the Exascale Age

The results of the HEP review are as follows.

- Larger, more capable computing and data facilities are needed to support HEP science goals in all three frontiers: Energy, Intensity, and Cosmic. The expected scale of the demand in 2025 is at least two orders of magnitude greater than that available currently.

- The growth rate of datasets produced by simulations and HEP experimental facilities is overwhelming the current ability of both facilities and researchers to store and analyze them. Additional resources and new techniques for data analysis are urgently needed; appropriately configured leadership-class facilities can play a transformational role in enabling scientific discovery from these datasets.
- A close integration of high-performance computing (HPC) simulation and data analysis is needed to interpret the results of HEP experiments. Such integration will minimize data movement and facilitate interdependent workflows.

- Long-range planning between HEP and ASCR is required to meet HEP's research needs. To best use ASCR HPC resources, the experimental HEP program needs the following:
  - A long-term plan for access to ASCR computational and data resources,
  - Ability to map workflows to HPC resources,
  - Ability to accommodate workflows run by collaborations potentially comprising thousands of individuals,
  - Transition of codes to the next-generation HPC platforms, and
  - A workforce capable of developing and using simulations and analysis to support HEP scientific research on next-generation systems.

One of seven tape libraries at the Feynman Computing Center at Fermilab. Tape libraries house data from Energy, Intensity, and Cosmic Frontier experiments; each library can hold 10,000 tapes (total storage capacity exceeds 1000 PB).

HIGH ENERGY PHYSICS

Priority Research Directions

The HEP Exascale Requirements Review focused on three frontiers in which an exascale ecosystem can be transformative.

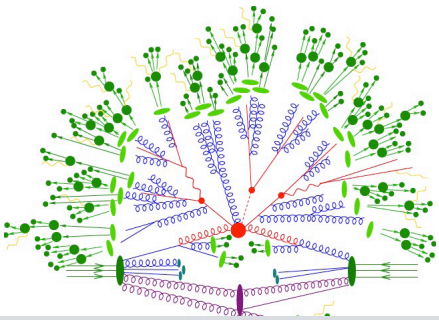
Energy Frontier

Two general-purpose detectors at the LHC in Geneva, Switzerland, are designed to investigate a broad program of physics opportunities at the Energy Frontier. The Compact Muon Solenoid (CMS) and ATLAS record the "interesting" high-energy proton-proton collisions and keep track of the position, momentum, energy, and charge of each of the resulting particles from the collision event. Scientists will use this information to gain a deeper insight into the fundamental laws of nature at high energies and improve their understanding of the physics of the early universe. LHC scientists will also characterize the newly found Higgs boson to see whether it behaves as expected.

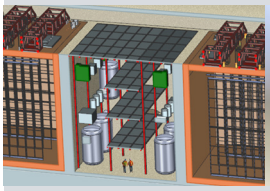
Intensity Frontier

A certain set of HEP experiments requires intense particle beams and/or highly sensitive detectors to study rare processes with ever-greater precision and sensitivity. The neutrino sector is a primary area of interest in the Intensity Frontier. The experimental picture in this area is incomplete. Powerful new facilities are needed to move forward, addressing the following questions: What is the origin of neutrino mass? What are the neutrino masses and how are they ordered? Do neutrinos and antineutrinos oscillate differently? Are there additional neutrino types or interactions? Are neutrinos their own antiparticles? The answers to these questions can have profound consequences for understanding the current makeup of the universe and its evolution.

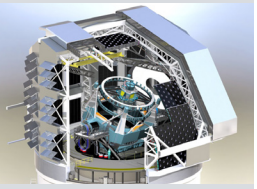
FRONTIERS



Energy



Intensity



Cosmic

Cosmic Frontier

The Cosmic Frontier program focuses on the detection and mapping of galactic and extra-galactic sources of radiation using a variety of well-instrumented telescopes to better understand the fundamental nature of the dynamics and constituents of the Universe. Dark matter detection experiments also fall under this frontier. The primary science thrusts within this frontier are (1) understanding the nature of cosmic acceleration (investigating dark energy); (2) discovering the origin and physics of dark matter, the dominant matter component in the universe; and (3) investigating the nature of primordial fluctuations, which is also a test of the theory of inflation.

The Exascale Requirements Review reports and supporting materials can be found at http://exascaleage.org

DOE's HPC centers are based at Argonne National Laboratory (ALCF), Lawrence Berkeley National Laboratory (NERSC), and Oak Ridge National Laboratory (OLCF), with networking services provided by ESNet; all of these facilities operate under the direction of ASCR.

Argonne NATIONAL LABORATORY · ESnet ENERGY SCIENCES NETWORK · NERSC · OAK RIDGE National Laboratory