LARGE HADRON COLLIDER (LHC) – ATLAS AND CMS
https://home.cern/science/accelerators/large-hadron-collider

Large Hadron Collider Funding
(Dollars in Millions)

FY 2023 Base Plan	FY 2024 (TBD)	FY 2025 Request	Change over FY 2023 Base Plan Amount	Percent
$20.50	-	$20.50	-	-

Brief Description

LHC, operated by the European Organization for Nuclear Research (CERN) in Geneva, Switzerland, is the world's most powerful particle accelerator. It produces the highest energy particle beams ever created in a laboratory, making it the premier facility in the world for research in elementary particle physics. LHC is a superconducting accelerator ring approximately 16.5 miles in circumference, in which counter-circulating proton beams can collide with a total energy of up to 14 TeV (one TeV=10^{12} electron volts). The collisions occur at four discrete interaction points around the circumference of the accelerator where highly sophisticated detectors measure the characteristics of the debris produced in the proton-proton collisions. LHC can also collide beams of heavy ions, such as lead.

The discovery of the Higgs boson in 2012—one of the original goals of LHC—is one of the most important particle physics discoveries of the last 50 years. Now the scientific focus has shifted to understanding the detailed properties of the Higgs boson and to studying other known processes to elucidate possible deviations from current theory—deviations that might indicate new phenomena.

This search for new phenomena motivates the High Luminosity (HL) upgrades to LHC and its detectors, which will increase the proton collision rate, resulting in a much larger data set. As part of a global effort, NSF is supporting upgrades to two LHC detectors to enable collection and analysis of the HL-LHC data.[1]

Meeting Scientific Community Needs

The FY 2025 Request will support studies using two large general-purpose detectors: A Toroidal LHC ApparatuS (ATLAS) and the Compact Muon Solenoid (CMS), to record and analyze the by-products of proton-proton and heavy ion collisions. Measurements made by the detectors will probe the fundamental structure of matter to elucidate the basic forces that have shaped our Universe since the beginning of time and that will determine its fate. Priority areas of interest to researchers are the search for new physical phenomena (such as new particles or forces) not described by the Standard Model of Particle Physics, extra spatial dimensions, and experimental evidence for Dark Matter.

Currently, more than 1,200 U.S. researchers participate in the ATLAS and CMS collaborations, including more than 100 post-doctoral fellows and more than 400 students, about half of whom are undergraduates. The U.S. researchers comprise about 20 percent of the total membership of the ATLAS and CMS collaborations. NSF supports about 20 percent of the U.S. ATLAS and U.S. CMS

[1] See the HL-LHC narrative in the MREFC chapter for more information.

contingents (plus about 30 of the nearly 1,300 members of the Large Hadron Collider beauty (LHCb) collaboration, which operates the separate, specialized LHCb experiment at LHC). Research at LHC is supported by NSF through the Elementary Particle Physics and Nuclear Physics programs within the Division of Physics (PHY).

In addition, a world-wide cyberinfrastructure effort, the Worldwide LHC Computing Grid (WLCG), is dedicated to LHC data processing, allowing scientists to remotely access and analyze vast data sets. The U.S. ATLAS and U.S. CMS collaborations continue to lead the development and exploitation of distributed computing within their respective international collaborative efforts. The WLCG Tier 1 and Tier 2 computing centers (funded by DOE and NSF, respectively) enable researchers at 98 U.S. universities and five national laboratories to access LHC data and computing resources and thus train students in both state-of-the-art science and computational techniques.

Status of the Facility

LHC is the only experimental particle physics facility operating at the high energy frontier. The facility and the planned HL-LHC upgrades are a high priority of the entire high energy physics community. The 2015 LHC energy upgrade from 8 TeV to 13 TeV pushed the boundaries of our understanding into unknown territory. CERN is carrying out a multi-year program to increase the beam interaction rate that will culminate with HL-LHC operation beginning in 2029. This will produce a very large data set of rare events that could shed light on new physics as researchers look for discrepancies between precision measurements and theoretical predictions.

Installation of smaller-scale detector upgrades, completed in 2021, have prepared the ATLAS and CMS detectors for the current cycle of accelerator operations, which started in April 2022. These upgrades will enable ATLAS and CMS to keep pace with LHC's performance enhancements through 2026. In January 2022, CERN announced a delay to the start of installation of the HL-LHC accelerator and detector components and lengthened this installation period to three years. This three-year shutdown will enable the installation of major upgrades to the accelerator and detectors preparatory to ten years of HL-LHC operation, extending the scientific reach of the facility.

In June 2022, the CERN Council announced its intent to end cooperation with Belarus and Russia (effective in June and December 2024, respectively) in response to Russia's ongoing aggression against Ukraine. Impacts of this announcement are still being evaluated. Also, in light of the European energy supply and cost crisis, CERN will take actions to reduce its energy consumption. For example, CERN closed operations two weeks early in late 2022 and scaled back accelerator operations by 20 percent in 2023 with the same expected in 2024. CERN is working on plans to run the accelerator during 2024 under conditions that may at least partially offset the reduced running time and minimize the impact on science.

Governance Structure and Partnerships

NSF Governance Structure

NSF oversight is led by a program officer in MPS PHY, who works cooperatively with staff from BFA's Research Infrastructure Office and Division of Acquisition and Cooperative Support, the Office of the General Counsel, and the Office of Legislative and Public Affairs. The MPS facilities team and the Chief Officer for Research Facilities also provide high-level guidance, support, and oversight.

External Governance Structure

NSF/PHY staff and their Department of Energy (DOE) Office of Science counterparts meet twice yearly with CERN and funding agencies from other nations at Resource Review Board meetings, where technical and financial issues are discussed and resolved. The ATLAS and CMS experiments are each funded by more than 40 different agencies, including NSF and DOE in the U.S. NSF and DOE coordinate U.S. investments in the LHC program through a Joint Oversight Group (JOG).

Partnerships and Other Funding Sources

U.S. activities at CERN are enabled by a DOE/NSF/CERN agreement signed in 1997 ("Experiments Protocol I") and a Cooperation Agreement signed in May 2015 and renewed every five years. An additional agreement signed in December 2015 ("Experiments Protocol II") further defined the framework for NSF participation in the ATLAS and CMS detector collaborations to include continued participation during the HL-LHC era.

Funding

Total Obligations for LHC

(Dollars in Millions)

	FY 2023 Base Plan	FY 2024 (TBD)	FY 2025 Request	ESTIMATES[1] FY 2026	FY 2027	FY 2028	FY 2029	FY 2030
Operations and Maintenance	$20.50	-	$20.50	$20.50	$21.12	$21.75	$21.75	$21.75

[1] Outyear estimates are for planning purposes only. The current cooperative agreement ends December 2026 (CMS) and January 2027 (ATLAS).

NSF supports detector operation through two awards—one to the University of Nebraska-Lincoln for CMS, and another to Stony Brook University for ATLAS – shown in aggregate above. Annual operations and maintenance funding covers the costs of NSF-provided detector components, software and computing, and contributions to a common fund to maintain shared detector infrastructure. Detector operation and maintenance are projected to require future levels of effort similar to those needed to support the current apparatus. Data handling is an exception, in which extraordinary efforts by CERN, the experiment collaborations, and funding agencies are now underway on a global scale to support HL-LHC operation and the greater volume of data that will be collected beginning in 2029.

Reviews and Reports

NSF and DOE conduct separate and joint external reviews of operations and detector upgrade activities. Each agency is fully cognizant of the activities of the other, and recommendations from reviews are routinely used to inform ATLAS and CMS operations planning and the agencies' oversight thereof. Two JOG review meetings per year assess operational performance, scientific and financial status, management issues, and plans for future activities. DOE and NSF conducted joint external panel reviews of ATLAS and CMS operations at the end of January 2022. The most recent JOG review was held in October 2023 and the next one is planned for March 2024.

Renewal/Recompetition/Disposition

NSF awarded operations funding to CMS and ATLAS through five-year cooperative agreements

beginning in FY 2022, with current awards expiring in December 2026 and January 2027, respectively. The ATLAS award was a renewal of the prior five-year award, while the CMS award was to a new awardee. The awards were implemented after NSF completed a proposal-driven review process that included external review and cost analysis of each collaboration' detector operations proposal. NSF has no ownership of any part of the facility. CERN has taken responsibility for disposal of all irradiated apparatus at the conclusion of experimental activity. No disposition is planned at this time.