Testimony of

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U.S. House of Representatives
Committee on Appropriations,
Subcommittee on Energy and Water Development, and Related Agencies

On
The Department of Energy's High Energy Physics Program Funding for FY 2018

Introduction

Chairman Simpson, Ranking Member Kaptur and Distinguished Members of the Subcommittee, thank you for the opportunity to testify today. The views and words that I present here today are my own, on behalf of the HEP community. Sustained and robust funding of High Energy Physics (HEP) within the Department of Energy's (DOE) Office of Science is crucial to maintain U.S. leadership in science and technology and $868 million will be needed in Fiscal Year (FY) 2018 to advance critical research and infrastructure projects. FY 2018 comes at a pivotal point for the U.S. HEP community, falling nearly midway through the 10-year strategic vision laid out in the Report of the Particle Physics Project Prioritization Panel (P5), ***Building for Discovery***. This report serves as a framework for research in the three Frontiers of Particle Physics: Energy, Intensity, and Cosmic. The P5 plan has enabled a world class physics research program funded by the Office of Science by strategically investing our Nation's resources. Of note, P5 called for the construction of the Long-Baseline Neutrino Facility/Deep Underground Neutrino Experiment (LBNF/DUNE), to be operated by the Fermi National Accelerator Laboratory (Fermilab) in Illinois, the continued pursuit of second generation dark matter and dark energy experiments**,** and the ongoing upgrades to the Large Hadron Collider (LHC) at CERN. I want to underline that over 2,000 scientists, engineers, and technicians work in the U.S. in tandem with American industries to advance our contributions at the LHC.

Within the HEP program, we are conducting some of the most advanced research ever attempted, in pursuit of a deeper understanding of the universe and our place in it. The work of high energy physicists is to answer big questions. Therefore, the program's greatest asset is the breadth and depth of talent among the researchers, physicists, engineers, and technologists at all levels of their career and training: from talented undergraduate students to the most senior expert faculty and staff. HEP is successful because it attracts the most creative researchers and scholars in a large array of science and technology domains dedicated to the full and open exchange of ideas and to collaborating across many disciplines in the service of discovery. Like all other scientists, we are fearless and ambitious, but also cognizant of the demand to improve and make the case for the future: that discovery and invention are essential aspects of our Nation's ability to compete.

Particle Physics Project Prioritization Panel (P5)

In the past 25 years, since I arrived in the US as a graduate student at Harvard, I have witnessed first-hand two momentous discoveries that changed and framed in a fundamental way how we think about the Universe. As a graduate student, I moved to Fermilab at a time of great excitement for the field of high energy physics: the announcement of the top quark. The significance of this discovery in the field has only been surpassed by the discovery of the Higgs Boson in 2012. This latter discovery captured the imagination of the public, and demonstrates the importance of long-term and robust funding of HEP. These two fundamental particles have much to say about the fate of the Universe, and still today we are researching what they are telling us.

Discoveries like these are not a given. It is only with deliberate planning, federal support, and the continued growth in the field that these transformational discoveries can continue. It took two years for the HEP community, through the High Energy Physics Advisory Panel (HEPAP), of which I am a member, to reach consensus and formulate the P5 plan to position U.S. for world-leading science. P5 brings clear priorities and resource requirements. Sacrifices were made and the HEP community has been successful in executing the plan. I am happy to report that, so far, all projects are on time and on budget! This makes our community a model for other science disciplines on how to successfully prioritize competing interests in a constrained budget environment. As a result, we keep learning and pushing the frontiers of knowledge at an accelerated rate.

Neutrino Physics and the Long Baseline Neutrino Facility

Crucially, the P5 report recognizes the importance of U.S. based efforts with a specific recommendation that Fermilab host and lead the world's accelerator-based neutrino research program through LBNF. This is the largest and most complex research program on neutrinos ever undertaken worldwide. Enormous progress has been made in preparing for the neutrino beams and the associated detectors at Fermilab and the Sanford Underground Research Facility (SURF) at the Homestake mine is South Dakota. Federal funding for the facilities at SURF are creating a modern state-of-the-art underground laboratory. The ongoing R&D phase is now moving into the detailed design stage.

LBNF/DUNE will answer big questions that connect the physics of the neutrinos to the dynamics of the large-scale structure in the universe, the nature and the age of the universe, and their crucial role in the collapse and explosion of massive stars. Neutrino research is important for the understanding of the universe at the intersection of particle physics, astrophysics, and cosmology! My testimony comes at a vital time for the U.S. particle physics program. LBNF/DUNE is set to begin constructing detectors and large structures to house these complex instruments. Cessation or a delay in funding could cause increased costs, and would signal to our international partners that the United States is not prepared to lead this internationally renowned project. I note that as is the case with most curiosity-driven research, the federal government is the sole supporter. Its backing is crucial and must be sustained.

Dark Universe Experimental program

The quest to understand the "Dark Universe," especially the dark matter that modifies the motion of stars in galaxies and the dark energy that appears to be driving the expansion of the universe, is also undertaken by our field. Important experiments in the P5 portfolio include the Dark Energy Survey, using the Dark Energy Camera built at Fermilab; the Large Synoptic Survey Telescope whose camera is being built at SLAC; the Large Area Telescope on the Fermi Gamma Ray Space Telescope spacecraft, which was funded by the DOE, NASA, and foreign partners and DESI, the Dark Energy Spectroscopic Instrument, designed to improve our understanding of the role dark energy plays in the expanding universe. High energy physicists are also directly searching for evidence of dark matter particles in underground laboratories, most notably in the LZ experiment at SURF but also other small to medium size experiments. The US is already a leader in this area, and a strong particle physics program will ensure that we stay there.

CERN and Large Hadron Collider

CERN, a Fermilab sibling laboratory in Geneva, Switzerland, is home of the LHC. As a member of the global community of high energy physicists, the United States must meet its commitments to the LHC and the American scientists working there by funding upgrades to the detectors. Through such acts, the U.S. will be able to ensure that our scientists are part of global innovation. Given our history of cooperation and partnership, CERN is now our most important partner in the construction and development of LBNF/DUNE. Two years ago, the National Science Foundation (NSF) and DOE signed a cooperative agreement with CERN to ensure that thousands of physicists from hundreds of American institutions could invest and participate in this program. U.S. researchers will have leading roles in this challenging science for more than another decade to come, pressing on how the Higgs boson is connected to the dark universe and even the fate of the universe. We will continue our research over the next decade to better understand these connections.

Additionally, the data from the LHC constitutes the largest collection of scientific data ever produced. The rate and size of the LHC data have forced the invention and development of Grid Computing (the precursor of Cloud Computing) pioneered in the United States. Particle physics has been and continues to be the source of the most complex "big data" architectures, and the field is used as a prototype for all sciences that are now producing huge volumes of data.

HEP Trains A Scientific Workforce

HEP is a vital engine of the American workforce. Most of the particle physics students and young researchers today, and in all research domains detailed in the P5 plan, are expertly versed in the artificial intelligence (AI) methods and tools that are commonly written about in the media. When the motivation to generate new technology lies with deeper scientific questions we make unprecedented leaps in both areas: the domain sciences and the technology. As technicians, students, and researchers develop and use these technologies, they expand into the workforce and generate innovation. Additionally, physics research provides the base from which technology develops. As such, not only are high-energy physicists a vital part of the workforce, we are also vital to the creation of technologies that are driven to the market with unexpected consequences of the original federal investment.

To quote Neal Lane, former NSF Director, "One thing I have learned over the four decades

I have been working with particle physicists is that the men and women who emerge as leaders in this demanding field of science are extraordinary by any measure." Indeed, over 90% of the young scientists we train in our HEP experiments now work in the tech industry, medicine, government, and finance, to name a few, and are taking leadership positions and making a huge impact. I would like to highlight one recent young graduate from my group. Alex Mott received his PhD in 2015. He was hand-picked by Elon Musk's team at Tesla Motors auto-pilot group, and in the past 20 months he has been responsible in large part for astonishing self-driving car developments based on machine learning and AI. His next endeavor is with DeepMind, a company with the culture of research and academia and the drive and rigor of the top tech startups. Alex and others trained as high energy physicists like him are making leaps in the areas of neuroscience applications in AI.

HEP as a Driver of Innovation

Fundamental research is crucially dependent on advanced technology. Superconductivity researched and studied by condensed matter physicists is the source of the advanced accelerators we have today. Indeed, superconducting materials were scaled up by HEP for advanced accelerators which are now used also by other scientists to discover even more advanced materials. A current and striking example of the convergence of fundamental research and technology can be identified in the search for dark matter. New ideas to search for dark matter particles call for novel superconducting, semiconducting, graphene, superfluid helium and other exotic and novel quantum materials. Remarkably, technologies developed for quantum computers are being adapted in HEP as sensors for dark matter, pushing further the advancement of those technologies. Further important applications of particle physics technologies span areas of manufacturing, computing, medicine and national security. For example, particle physics detectors improve homeland security using advanced screening and provide new techniques for monitoring the contents of nuclear reactor cores.

Conclusion

I want to thank all Members of the House Appropriations Subcommittee on Energy and Water Development for their valuable time and continued support for the DOE Office of Science's High Energy Physics research program, and for considering a funding level of $868 million in FY 2018 to sustaining U.S. leadership in this critical fundamental research area.

Maria Spiropulu

Biography

MARIA SPIROPULU, a professor of physics at Caltech's Division of Physics Mathematics and Astronomy, is a world renowned experimental particle physics researcher and a notable mentor of many graduate and undergraduate students. She worked for ten years at the Tevatron's collider experiments at Fermilab in Chicago and thirteen years at the CERN's Large Hadron Collider, with leading roles on detector R&D and operations and in the searches for dark matter and other new physics, including the discovery of the Higgs boson. She is known for developing the "double blind" data analysis method for the first time in searches for supersymmetry at the Tevatron and inventing the novel "razor" framework for discovery and characterization of new physics in colliders.

Spiropulu received her PhD from Harvard in 2000 and was an Enrico Fermi Fellow at the University of Chicago until 2003. She moved to CERN in 2004 as a research staff physicist at the Physics Division and was promoted to a senior physicist position at CERN in 2008. She was appointed a professor of physics at Caltech in 2008. Spiropulu has been an AAAS fellow since 2010 "For her leadership in experimental high-energy physics, in particular for her pioneering efforts in the experimental search for supersymmetry and extra dimensions," and an APS fellow since 2014 "For pioneering searches for supersymmetry and extra dimensions at the Tevatron, innovative searches for new physics and the study of the Higgs boson at the LHC, and key contributions to triggering and data flow for CDF and CMS."

Since 2014 she has been working on advanced data technologies with an eye on using AI methods to enable and accelerate scientific discovery. She initiated a collaboration with leading quantum computation researchers targeting the embedding of physics problems onto the D-Wave quantum annealer.

Spiropulu is the chair of the Fermilab Physics Advisory Committee and a member of the High Energy Physics Advisory Panel (HEPAP) to the U.S. Department of Energy and the National Science Foundation. She is the chair of the Forum of International Physics of the American Physical Society, serves on the Advisory Panel of the HEP Forum for Computational Excellence and is a member of the Aspen Center for Physics.

Spiropulu has been contributing to intellectual exchange forums such as *Edge* (edge.org) and has participated in many public outreach science events and documentaries (NASA TV,*NOVA*, *Through the Wormhole*, the History Channel, among others). She is the author of "Where is Einstein?", the final chapter in *My Einstein: Essays by Twenty-Four of the World's Leading Thinkers on the Man, His Work, and His Legacy*.

She is the founder of the Physics of the Universe Summit (potus.caltech.edu), a meeting held under Chatham House Rules at SpaceX and Caltech since 2010 that explores challenges in emerging and cross-cutting areas of science and technology.