Testimony of

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A Review of the P5: The U.S. Vision for Particle Physics after Discovery of the Higgs Boson

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Chairman Lummis, Ranking Member Swalwell and Members of the Subcommittee, I am pleased to be here today to provide my perspective on the future of particle physics in the United States, particularly in light of the new report from the P5 subpanel of the High Energy Physics Advisory Panel, also known as HEPAP.

It is a particular pleasure for me to participate in these hearings. Twelve years ago, I was part of the subpanel that recommended the creation of P5, the Particle Physics Project Prioritization Panel, which is charged with advising HEPAP and the agencies on priorities for scientific projects within our field. We believed that prioritization would be essential in ensuring that we judiciously use the available resources in our field – both human capital and financial – to pursue a diverse and exciting program in particle physics. A balanced program is necessary for the vitality of our field, and only can be achieved if we manage our resources well. It is not possible to pursue all of the scientific opportunities we see before us. We must choose wisely.

In my opinion, this most recent P5 report does an outstanding job of setting a path forward for the U.S. particle physics program and making those difficult choices. Fully recognizing that resources are constrained, the report sets forth a staged plan that focuses on the most compelling science, builds on U.S. strengths across the field, and ensures that the United States retains a leadership role in this important area of research.

Before discussing the P5 report, it helps to remember why having a healthy particle physics program is important for our nation. There are many interrelated factors that make a compelling argument for a strong particle physics program in the U.S.

I will start with the science. Particle physics asks very basic and fundamental questions about the world in which we live. What is the nature of the universe? What are we made of? It is incumbent on us to pursue the answers to these questions, as has every great society that has preceded us for millennia.

In addition, the fundamental nature of the questions related to particle physics draws interest to science generally. Two recent examples are the excitement over the discovery of the Higgs boson at the Large Hadron Collider at CERN, and the tremendous interest in the recent announcement that we may have observed evidence of gravitational waves in the cosmic microwave background. This latest result, which was quite unexpected, may provide a long-sought smoking gun for the theory of cosmic inflation, and a window into the first epochs of our universe.

People of any age and background can understand and relate to these ideas in some way. And while many factors go into an individual's decision to pursue a career in science, the idea of big, fundamental questions out there just waiting to be answered is certainly one enticement.

Finally, particle physics is an essential part of the fabric of the physical sciences in the United States, contributing broadly to other disciplines such as accelerator science and large-scale computing, and benefiting enormously from research in other fields.

A vivid illustration of the interplay between different scientific fields comes from SLAC National Accelerator Laboratory, where I was director from 2007 to 2012. SLAC was born as a particle physics laboratory. We turned off our last accelerator for particle physics in 2008, and our particle physics program is now primarily focused on mid-scale experiments probing the mysteries of dark matter and dark energy.

In 2009 we turned on the world's first X-ray free-electron laser, the Linac Coherent Light Source, whose ultra-short, ultra-bright X-ray pulses are revolutionizing our ability to look at matter on the atomic scale. The LCLS is a tool for chemistry, biology, materials science and condensed matter physics. It is not a tool for particle physics. However, the spectacular early success of this wonderful new scientific tool relied on years of R&D aimed at making precision-controlled beams of electrons for future linear colliders for high energy physics. Moreover, the volumes of data produced by the LCLS are far beyond what most scientists who use X-rays were used to. We were able to use the tools and expertise developed for particle physics at the lab to deliver dramatic early science with these large data sets.

And the benefits cut across fields in both directions. For instance, superconductivity was discovered by and is studied by condensed matter physicists. Every accelerator being built for particle physics – from the LHC to the Long Baseline Neutrino Facility and perhaps, someday, an International Linear Collider – relies on superconducting technology, and advances in understanding superconductivity will benefit particle physics directly.

The challenge we have been facing is how to craft a healthy particle physics program in an increasingly international environment where, in fact, the premier accelerator operating at the highest energy is in Europe. For the first time, we are operating a truly global machine with the LHC, and that has led to great changes in our field.

What is the path forward for a healthy particle physics program in the United States <u>for the future</u>? The P5 subpanel has done an outstanding job of charting our course. They started with the science. To be successful, we will need to focus on and prioritize the opportunities that will give us the most transformational scientific advances and will attract the best talent.

Following a year-long process of engaging the community, P5 articulated five intertwined science drivers for the field, as you have heard from Dr. Steve Ritz:

• Use the Higgs boson as a new tool for discovery

• Pursue the physics associated with neutrino mass

• Identify the new physics of dark matter

• Understand cosmic acceleration: dark energy and inflation

• Explore the unknown: new particles, interactions and physical principles.

These drivers highlight some of the most exciting areas of research within particle physics: They recognize that with the discovery of the Higgs boson, we now have a new tool we can use to examine our understanding of matter at its most fundamental level. They highlight the mysterious neutrinos as particles so bizarre in their properties and behaviors that they defy a clear understanding. They emphasize our continuing struggle to understand the 95 percent of the universe that is made of what we call dark matter and dark energy, things we fundamentally don't know or understand. Finally, the drivers acknowledge that we ***know*** we don't have a complete understanding of the world around us at its most basic and fundamental level, and we ***know*** there are surprises ahead for us.

Having articulated the science goals, P5 then developed two sets of criteria for their prioritization process: one for the optimization of the program, and another for the evaluation of individual projects against those criteria in order to craft a program for the future of the field.

The transparency of the process and the clarity of the P5 arguments are essential for the community. The integrity of the process was incredibly important in order to get the community to support the outcome of the prioritization process. In addition, the P5 process engaged the entire community. There were several components to this engagement to ensure everyone's voice was heard:

- A website was maintained that contained information, frequent news, meetings, and a submissions portal with a public archive.
- There were three large public meetings.
- There were three physical town hall meetings and three virtual town hall meetings. The virtual town halls were particularly effective for hearing from younger members of our scientific community.
- More than 500 physicists convened in a nine-day "Snowmass" community study meeting to work through and digest the P5 input.
- A special effort was made to reach out to younger colleagues; this included a Twitter feed and emails to Snowmass Young Physicist mailing lists and to principal investigators urging them to inform their students and postdocs about the process.

Literally thousands of physicists across the U.S. participated in these events, and the committee received hundreds of written inputs. The transparency and inclusivity of this process were phenomenal and exceptionally well done. The process reflects the voices, priorities and thoughts of many in our community, and conveys the excitement so many of us feel about the scientific frontiers that should be pursued. It is the reason that the community can stand united behind this plan.

Let me end on a somewhat philosophical note. The field of particle physics in the United States and in the world is changing dramatically. We used to define ourselves solely in terms of our primary tools – the big atom smashers or accelerators that let us collide particles at the highest possible energies to uncover the basic building blocks of matter. But, to quote the former White House Science Advisor, Jack Marburger, "Opportunities have emerged for discovery about the fundamental nature of the universe that we never expected, and technology places these discoveries within our reach." We must have a program that allows us to focus efforts across widely separated disciplines to realize the new scientific opportunities. That includes a broad variety of observatories in space, telescopes on mountaintops and sensitive detectors in deep caves under the earth, in addition to our traditional accelerator tools.

The plan outlined by P5, and supported by the particle physics community, is a new beginning for particle physics. It is a realistic and executable roadmap for a new era and it will enable a future of discovery just as exciting as our past, with a balanced program exploiting a wide range of tools. This was hard, but the results are worth the effort. This roadmap will allow the field to move forward and to deliver success.

Thank you for the opportunity to share my views with you today.