Final Report for James Wells "Precision Higgs boson …."

Award Information

DOE Award Number: DE-SC0011719
Recipient: Regents of the University of Michigan
Project Title: Precision Higgs Boson Physics and Implications for Beyond the Standard Model Physics Theories
Principal Investigator: James Wells
Consortium/teaming members: N/A.

Executive summary of proposed research efforts and benefits

The Higgs boson discovery at the CERN Large Hadron Collider (LHC) in summer 2012 was one of the most momentous occasions in science in the last half century. The grant received by Prof. James Wells springs largely from this discovery. The Higgs boson is the field that gives mass to all other known elementary particles. Its discovery relied on limited data showing its decay into photons and into Z bosons, followed by subsequent decay into leptons. Prof. Wells's research investigated how precisely we can know the Higgs boson's decay into a variety of final states, including bottom quarks, charm quarks, gluons, W bosons, tau leptons, etc. This is required in order to fully test if the boson that was found at the LHC is really precisely the Higgs boson that has been expected for so many years. The implications of the Higgs boson go further, and its mass value and properties imply many possibilities for new physics, including supersymmetric theories, and generic non-renormalization operators (i.e., model-independent corrections). The research project proposed investigating these implications as well.

Comparison and summary of accomplishments of goals and objectives

Regarding the goal of establishing the precision Higgs boson final state branching fractions, this effort is ongoing. However, an important first step was achieved when Wells and collaborators produced the first expansion of the Higgs boson partial width and branching fractions in terms of a minimal set of precision electroweak observables [1]. This was then followed up on a study of the role of low-energy observables in precision Higgs boson analysis [2]. One of the co-authors, Zhang, was supported on the grant when carrying out the research.

Regarding the goal of combining electroweak and precision Higgs in global fits and its implications for non-standard Higgs corrections, Wells and collaborators produced one paper directly on the idea of combining low-energy and high-energy observables self-consistently in a global analysis [2], and also outlined a comprehensive scheme for global precision electroweak analysis in the post Higgs boson discovery era [3].

Regarding identify and developing other new physics theories compatible with the data, Wells and collaborators have built on Wells's earlier work on PeV scale supersymmetry, to not that PeV scale superpartner spectrum works very well to explain the Higgs boson mass. There are many implications to that, and one is in the neutrino sector. Wells and collaborators investigated [4] a scenario by which the Higgs boson mass is matched in supersymmetry and active neutrino masses are compatible with data. This then implies the existence of light sterile neutrinos. The implications for dark matter and experiment were assessed.

Regarding the determination of how new physics theories that are compatible with the Higgs boson mass can affect Higgs couplings to photons and also deviations of its couplings to the top quark, Wells and collaborators investigated [5] the role of vector-like top quarks added to the supersymmetric spectrum. In some sense this is an alternative explanation to the PeV scale supersymmetry idea of above, and allows for rather light superpartners in the spectrum. We were able to show that the scenario is very tightly constrained by Higgs couplings to top quarks, etc. compared to other constraints (such as direct detection constraints) under a wide region of parameters space. This has been helpful for experiment to see the value of increasing the precision on Higgs coupling determinations.

Regarding the investigation of new physics motivations for future colliders, Wells and collaborators showed that a 100 TeV collider, currently under consideration by the Chinese government, as well as other governments, has powerful search capacity for some forms of supersymmetry. In particular, Wells and collaborators [6] showed that the electroweak charged (as opposed to strongly charged) gauginos of the the minimal supersymmetric standard model are very well probed at a high energy hadron collider. This is sometimes not appreciated by the community, how well a hadron collider can do searching for electroweak states, and so this study has received a fair amount of attention, despite it being applicable only for motivation of a new collider years down that line. However, approval and continued efforts on these next-generation colliders requires theory work today, which we provided.

Publications

[1] L.G. Almeida, S.J. Lee, S. Pokorski, J.D. Wells. "Study of the standard model Higgs boson partial widths and branching fractions." Phys. Rev. D89 (2014) 3, 033006.

[2] A.A. Petrov, S. Pokorski, J.D. Wells, Z. Zhang. "Role of low-energy observables in precision Higgs boson analyses." Phys. Rev. D91 (2015) 7, 073001.

[3] J.D. Wells, Z. Zhang. "Precision electroweak analysis after the Higgs boson discovery." Phys Rev D90 (2014) 3, 033006.

[4] S.B. Roland, B. Shakya, J.D. Wells. "Neutrino masses and sterile neutrino dark matter from PeV scale". To be published in PRD.

[5] Z. Lalak, M. Lewicki, J.D. Wells. "Higgs boson mass and high-luminosity LHC probes of supersymmetry with vectorlike top quark." Phys. Rev. D91 (2015) 9, 095022.

[6] S. Gori, S. Jung, L.-T. Wang, J.D. Wells. "Prospects for electroweak discovery at a 100 TeV Hadron collider." JHEP 1412 (2014) 108.