NATIONAL SCIENCE FOUNDATION
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Dear Colleague Letter: Searching for New Physics Beyond the Standard Model of Particle Physics Using Precision Atomic, Molecular, and Optical Techniques

September 24, 2020

Dear Colleagues:

With this Dear Colleague Letter (DCL), the NSF Division of Physics (PHY) encourages the community to explore the scientific opportunities at the intersection between Atomic, Molecular, and Optical (AMO) physics and Elementary Particle Physics (EPP). The discovery of the Higgs boson in 2012 at the Large Hadron Collider (LHC), the world's highest-energy accelerator facility, provided remarkable confirmation of the Standard Model of particle physics, which forms the bedrock for our understanding of the elementary particles. Yet we know that the Standard Model is not a complete description of Nature: it does not account for dark matter, dark energy, gravity, or neutrino masses and mixings. There also remain many features of the Standard Model itself which are not understood, and which may find their answers in speculative ideas beyond the Standard Model such as supersymmetry, large extra dimensions, and/or extended Higgs sectors.

While direct detection of new particles at facilities such as the LHC would provide clear evidence of new physics, joint experimental and theoretical studies involving precision measurements (PM) at atomic-scale energies can in some cases also provide evidence for new phenomena beyond the Standard Model. For example, quantum field theoretic methods can be used to calculate at great precision how virtual particles at all mass scales populate the quantum vacuum and manifest themselves in potentially measurable quantities such as an electron or neutron electric dipole moment. Likewise, advances in AMO-based techniques, including those involving emerging quantum sensors and high-accuracy clocks, open the door to a variety of measurements that may indicate the presence of new physics beyond the reach of present-day particle colliders. These measurements may involve looking for signals of new physics in an important "next digit" of a precisely known quantity, or by looking for the first non-zero amplitude of a previously unobserved quantity.

This DCL encourages interdisciplinary research across the domains of AMO and EPP physics aimed at developing new small-scale experiments and techniques that could complement large EPP facilities. Towards this end, the NSF Division of Physics encourages the submission of proposals that explore this overlap regime. Proposals can be submitted to one of the following programs for review and funding consideration, as described in Solicitation NSF 20-580:

- Atomic, Molecular, and Optical Physics - Experiment
- Atomic, Molecular, and Optical Physics - Theory
- Elementary Particle Physics - Experiment
- Elementary Particle Physics - Theory

Titles of proposals addressing the goals of this DCL should begin with "PM: . . . " Proposals for theoretical and/or experimental research, conceptual development, conferences, or development of new instruments are welcome. Plans for data analysis should include a detailed assessment of systematic errors and use appropriate statistical methods. Experimental designs that incorporate empirical exploration of unknown systematics are desirable. Potential proposers are encouraged to contact the cognizant program directors of the programs listed above.

Sincerely,

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Directorate for Mathematical and Physical Sciences