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Editorial: Phenomena Beyond the Standard Model: What Do We Expect for New Physics to Look Like?

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Editorial on the Research Topic

Phenomena Beyond the Standard Model: What Do We Expect for New Physics to Look Like?

Particle physics (PP) is a vast and active research field of contemporary theoretical and experimental physics. Measurements made at microscopic distances have started to confront the most fundamental principles of nature encoded in the structure of the Standard Model (SM) of PP. With recent observations of accelerated expansion of the universe, massive dark halos filled with invisible matter, and persistent flavour physics anomalies, the SM is entering a period of most severe phenomenological tests that could eventually lead to a revision of our current understanding of the fundamental properties of matter, interactions, and even spacetime.

While Large Hadron Collider (LHC) experiments have accessed fundamental interactions at the energy and intensity frontiers without notable discoveries so far, the demand for precision measurements is increasing. Already we are familiar with persistent inconsistencies within the SM framework, such as the absence of a viable dark matter (DM) candidate, the failure to describe the origin of dark energy, the inability to account for sufficient CP violation required for generation of the baryon asymmetry, the yet-to-be resolved hierarchy problem in the Higgs sector, and the lack of a dynamical mechanism for the natural generation of very specific observed patterns in fermion mass and mixing parameters. For instance, there is a substantial lack of first-principles understanding of the Higgs sector properties and origin of the electroweak scale, of the three quark/lepton families, of the unique neutrino features, and of the strong unexplained hierarchies in the lepton and quark sectors of the SM. The non-observation of New Physics (NP) in collider measurements remains puzzling and raises questions as to their discovery potential, methodology, precision, and sensitivity to weak signals. Conversely, with a wealth of new phenomenological information emerging from neutrino oscillation studies, astroparticle physics measurements, low-energy analyses, and, more recently, gravitational waves, can we expect the SM to remain the baseline framework of PP, or should it be replaced eventually by a more accurate and complete theory of the building blocks and symmetries of nature? What kind of NP can we expect to show up and in what particular way?

This Research Topic "Phenomena Beyond the Standard Model: What Do We Expect for New Physics to Look Like?" is devoted to highlighting selected topics in state-of-the-art theoretical

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research at the forefront of PP that explores these most fundamental questions of nature, in the quest for some Beyond the Standard Model (BSM) phenomena. A total of ten papers were submitted, covering exciting developments in the direction of uncovering some NP from both the theoretical and the experimental sides. On the one hand, two paradigms for solving the hierarchy problem of the SM, Supersymmetry and Compositeness, are considered. On the other hand, experiments from low to high energy scales are discussed, in settings ranging from colliders to ground as well as space apparatus. Delle Rose et al. address the case of potential NP signals at energies as low as 17 MeV, while Croon et al. discuss the properties of a prototypical Grand Unified Theory (GUT) at 10^{16} GeV. As two major flaws of the SM are that, therein, neutrinos are massless and there is no viable candidate for DM, it is no surprise that Shindou considers the first case while a number of other authors (Bhattacharya et al.; Belyaev; Corianò et al.; Khlopov) address the second one, including discussing the key phenomenological consequences of the corresponding BSM constructs in the aforementioned experimental settings. Finally, given the importance of the Higgs boson discovery at CERN in 2012 for the whole of PP, it is natural to also see several submissions addressing the possibility of a BSM origin of this crucial particle, within extended Higgs sectors whose motivation (as explained by Miller et al.) builds upon the Multiple Point Principle (MPP), indicating their plausibility, including both the cases of Supersymmetry (Arhrib et al.) and Compositeness (Cacciapaglia et al.). Altogether, this special issue of *Frontiers* serves to inform the reader that even though NP is currently unknown to us, we are well-equipped on both the theoretical and the experimental fronts to extract its possible manifestations, whatever these might look like.

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