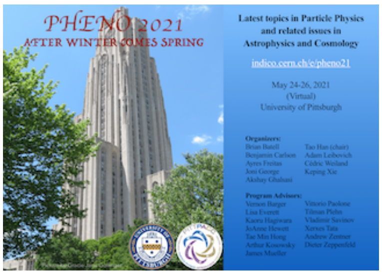

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Vacuum stability and perturbativity with extended Higgs and neutrinos

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The Standard Model (SM) explaining the framework of elementary particles seems to be completed by the discovery of the SM-like Higgs boson with a mass of about 125 GeV at the Large Hadron Collider(LHC) in 2012. Despite this success, there are enough experimental evidences, ranging from observed dark matter (DM) relic density and matter-antimatter asymmetry in the universe to non-zero neutrino mass, which indicates the existence of beyond SM theories. It is also known from the theoretical viewpoint that the SM by itself cannot ensure the electroweak (EW) vacuum stability till the Planck scale. It is observed that an additional scalar sector with bosonic degrees of freedom can ease the stability issue, by compensating for the destabilizing effect of the top-quark Yukawa coupling on the renormalization group (RG) evolution of the SM Higgs quartic coupling. We observed that extension with singlet right-handed neutrinos (RHNs) destabilizes the potential while in extensions with SU(2) triplet fermions, weak gauge coupling g-2 shows contrasting behaviour compared to SM and enhances the stability. Extension with singlet right-handed neutrinos or triplet fermions generated the eV light neutrino mass via seesaw mechanism while scalar sector i.e. Inert Higgs doublet or Higgs triplet provides a dark matter candidate. After the theoretical constraints from Planck scale perturbativity and vacuum stability we focussed on the DM constraints from DM relic density, direct detection and indirect detection of DM. For the freeze-out scenario, the universe started with a large population of DM that was in thermal equilibrium with the bath. As the universe expands, the temperature falls down and the dark matter particles are not able to find each other fast enough to maintain the equilibrium abundance. So when the equilibrium ends and the freeze-out starts, inert particles can contribute to the DM relic density through freeze-out mechanism. Firstly, DM can be detected by the so-called direct detection method via elastic scattering with terrestrial detectors and the quantity that determines the direct detection rate is the dark matter-nucleon (DM-N) scattering cross-section. Secondly, the Indirect detection of dark matter is also an interesting way to probe particle dark matter models. Galactic centre and Dwarf Spheroidal Galaxies (dSphs) are amongst the few targets, where dark matter annihilate or semi-annihilate into electron, positron, neutrinos, etc. and yield excess of gamma rays of different energies which are then observed by various telescopes. We estimated the indirect cross-section constraints for the dominant modes from H.E.S.S. and Fermi-Lat experiments. We also estimated the production cross-sections for various associated Higgs-DM production modes at the LHC for the centre of mass energy of 14, 100 TeV in inert Higgs doublet and inert Higgs triplet (ITM) respectively. It is observed that the compressed spectrum for ITM will easily lead to displaced mono- or di-charged leptonic or displaced jet final states along with missing energy while in case of IDM such displaced case is not so natural. We use an extensive numerical set up, using Calchep, Micromegas 5.0.8, Madgraph, Pythia, Delphes and Machine learning techniques.

Summary

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