Research statement

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My research interests lie in the phenomenology of broad range of models beyond the standard model (SM) of the particle physics. In spite of the great success of the SM, there remain many questions that cannot be answered within the SM. These questions include, for example, the structure of the gauge symmetries, the existence of the dark matter, origin of the quark and lepton families, naturalness of the electroweak scale. To give an answer to one or several of these questions, numbers of models are proposed such as the grand unification, supersymmetry, family symmetry, and so on. These models often lead to some interesting phenomenology that can be used to distinguish them from the SM. I seek ways to test them using both a top-down approach where a model or its parameter space is constrained from theoretical consideration, and a bottom-up approach where the experimental search probes a new particle contained in a model.

Achievements so far

There are several theoretical motivations to consider TeV-scale EWIMPs. They appear in various new physics models that explain the energy scale of the EW symmetry breaking. Besides, they can naturally explain the relic abundance of the dark matter (DM). Well-motivated examples of EWIMPs are Higgsino and Wino in the minimally supersymmetric standard model (MSSM), which are the superpartners of the standard model (SM) Higgs and W boson, respectively. Since their existence significantly modifies the fate of the EW vacuum and the phenomenology at the high energy scale, considerable efforts have been devoted, but the results are still unsatisfactory.

During the last few years, we have been developing the next-to-leading order calculation of the decay rate of the EW vacuum. We apply a recently proposed calculation which is manifestly gauge-invariant to the models that contain the SM-like Higgs as a unique scalar field. We assume a purely quartic Higgs potential and provide the correct treatment of the flat direction of the Euclidean action related to the classical conformal invariance of the potential. This treatment fills a gap of the existing calculation and enables us to precisely evaluate the decay rate with error estimations. We analyze not only the SM but also several models with new particles that couple to Higgs and obtain severe constraints on the coupling and mass of new particles even for the mass region much heavier than the TeV-scale.

Recently, we have also worked on the new physics search and measurement using future hadron colliders. Although EWIMPs possess charged components that interact with detector materials, these components may be too short-lived to detect, which is sometimes the case for Higgsino. To probe such short lifetime EWIMPs, we consider the vacuum polarization effect from the EWIMP loop and its effects on the lepton pair production process. The energy dependence of the loop effect possesses a characteristic dip structure around the EWIMP pair production threshold. We use this shape to distinguish the signal from the background and effects of systematic errors and obtain the best limit so far for the short lifetime Higgsino. We also reveal that the signal shape can be used for measurement of the coupling and mass of discovered EWIMPs.

Future plans

In the near future I will extend our calculation of the vacuum decay rate to the models with several scalar fields involved in the bounce configuration. This allows us to evaluate the vacuum decay rate in various complicated models such as the MSSM, and to constrain the parameter space even when the relevant scalar particles are beyond the experimental reach. For the generic models with several mass scales, the multi-scale nature of the bounce makes the numerical calculation difficult. Therefore, another possible future direction is to develop an algorithm to adaptively adjust the lattice spacing for the fast and accurate computation.

Regarding the collider phenomenology, I will apply our method to the pair production process of gauge bosons. This gives us a severer bound on the Higgsino that may reach the mass prefered from the DM relic abundance. Another possibility is to study loop topologies different from the vacuum polarization. Through the classification of the signal shape for each loop topology, it will become possible to find new particles to which our detection method can be applied. Finally, the future planned lepton colliders such as ILC and CLIC also bring us some exciting possibilities. Since they provide more precise measurements in lower energy scale compared with hadron colliders, it will be efficient to analyze the new particles effect using the effective field theory approach. I will provide some model-independent constraints on EWIMPs through the precise measurement at lepton colliders.