Research statement

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My research interests lie in the phenomenology of a broad range of models beyond the standard model (SM) of 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, existence of the dark matter (DM), origin of the quark and lepton families, and naturalness of the electroweak (EW) scale. To answer one or several of them, numbers of models are proposed such as the grand unification, minimally supersymmetric standard model (MSSM), family symmetry, and so on. They 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

Many models contain some additional scalar fields and/or couplings to the SM Higgs boson that affect the stability of the EW vacuum. The requirement of the (meta-)stable EW vacuum can be used to test and constrain models. During the last few years, we have been developing the next-to-leading order calculation of the decay rate of the EW vacuum (please see [1,8,9] of my publication list). We assumed that the SM Higgs is the unique scalar particle in the model and provided a correct treatment of the flat direction of the Euclidean action related to the approximate classical conformal invariance of the potential. This treatment filled a gap of existing calculations and enabled us to precisely evaluate the decay rate with error estimations. We analyzed not only the SM but also models with new particles that couple to Higgs and obtained severe constraints on the couplings and masses of new particles even for the mass region that cannot be accessed using any ongoing or planned experiment.

As for the collider search, massive particles with EW charges (EWIMPs) are interesting targets that often appear in models. This is because TeV-scale EWIMPs naturally explain the relic abundance of the DM if the non-thermal production can be neglected. Recently, we have worked on the EWIMP search and measurement of its properties using future hadron colliders (please see [3–5]). In particular, we focused on EWIMPs with short-lived charged components such as the Higgsino-like state in the MSSM. Since the tracker information cannot be used in this case, instead we considered the vacuum polarization effect from the EWIMP loop on the lepton pair production process. We revealed that the energy dependence of the loop effect possesses a characteristic shape with a sharp peak and used this shape to distinguish the signal from the background and effects of systematic errors. As a result, we obtained the best limit so far for the short lifetime Higgsino and revealed that the signal shape can also 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 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 new particles are beyond the experimental reach. Regarding the collider search, I will apply our method to the pair production process of gauge bosons. This analysis results in the increase in statistics, which may allow us to reach the Higgsino mass preferred 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 topology, I will look for new particles to which our method can be applied.

Now it is an exciting time with many ongoing and future planned experiments that provide a huge number of hints of the new physics. The results of these experiments will guide future theoretical works. At the same time, a great deal of effort is devoted to developing new approaches to the problems of the SM. As a young researcher at this time, I am eager to engage in a new field and to keep seeking a trace of the new physics.