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 existence of the dark matter (DM), naturalness of the electroweak (EW) scale, structure of the gauge symmetries, and origin of the quark and lepton families. To answer one or several of them, numbers of models are proposed such as the minimally supersymmetric standard model (MSSM), grand unification, 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

Since we now live in the EW vacuum, the requirement of the (meta-)stablity of the vacuum can be used to test and constrain models in a top-down approach. This approach is powerful because it can probe new particles that are too heaby to be accessed using any ongoing or planned experiment. Also, this approach is applicable to many models which contain some additional scalar fields and/or couplings to the SM Higgs boson. During the last few years, I have been developing the next-to-leading order calculation of the decay rate of the EW vacuum ([1,8,9] of my publication list). My treatment filled a gap of existing calculations and enabled us to precisely evaluate the decay rate with error estimations.

It is also important to use the collider experiments as an example of the bottom-up approach. In particular, recent hadron colliders provide a huge amount of data, under which a hint of the new physics may be buried. To fully use the data, it is necesarry to develop a proper physics quantity or a wise way to extract the signal of a new particle. So far, I focused on the search for massive particles with EW charges (EWIMPs) [3–5] that are DM candidates appearing in many famous models such as MSSM. I developed a way to use the signal shape to reduce the systematic uncertainties and obtained the best limit so far for Higgsino, an EWIMP DM candidate in MSSM, which are generally difficut to search for.

Model building is an another approach to the new physics candidates.

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.

(♣ machine learning? ♣)