論文の内容の要旨

Search for the neutral heavy Higgs bosons decaying to hadronic ditau in proton-proton collisions at $\sqrt{s}$ = 13 TeV

(重心系エネルギー13 TeV の陽子衝突におけるタウ粒子のハドロニック崩壊を用いた重い中性ヒッグス粒子の探索)

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The Standard Model of the particle physics (SM) is turned out to be well-consistent with most of the experimental results. After the discovery of the scalar Higgs boson with the mass of 125 GeV at the Large Hadron Collider (LHC) at CERN, there are still a lot of questions remaining to be answered, such as unknown nature of the astrophysical dark matter, the hierarchy problem of the Higgs mass, unification of the fundamental interactions, and quantification of the gravitational interaction. An extension of the Standard Model of the particle physics is expected to address the problems. Extensive studies to search the beyond-the-SM (BSM) physics have been actively conducted in both theoretical and experimental methodologies.

The LHC is the energy frontier proton-proton collider running at the center-of-mass energy of 13 TeV. Many questions of the incomplete SM may be addressed by an observation of a new symmetry between bosons and fermions, which is known as a ``supersymmetry'' or SUSY. The supersymmetry is one of the most motivated extensions of the SM as it may address the missing of dark matter candidates, the hierarchy problem of Higgs boson mass, and realization of the grand unification simultaneously. The supersymmetry requires the Higgs sector of the SM to be extended with at least one additional Higgs doublet, resulting in five physical Higgs states; two neutral CP-even Higgs states (h, H), one CP-odd Higgs state (A), and two charged Higgs states ($H^{\mp}$). One of the two neutral CP-even Higgs states is considered to be the discovered 125 GeV boson (h), and the other will be an additional heavy Higgs boson (H). An observation of the new neutral heavy Higgs boson (H and A) can provide important insight into the nature of the supersymmetry. The coupling constants of the new neutral heavy Higgs bosons are expected to depend on the ratio of the vacuum expectation values of the two Higgs doublet (tanβ), and the coupling constants to down-type fermions are enhanced for a large tanβ scenario. Among the decay channels of the new neutral heavy Higgs boson, tautau and bb channels are dominant modes with the typical branching ratios of ~10% and ~90%, respectively, for the high tanβ region.

This thesis presents a search for the neutral heavy Higgs boson (H or A) decaying into a pair of tau leptons (H/A→tautau), which can provide the best search sensitivity for a large tanβ scenario of the Higgs sector extension. This thesis work uses 139 fb^{-1} of proton-proton collisions recorded by the energy frontier ATLAS experiment at the Large Hadron Collider at a center-of-mass energy of 13 TeV during the 2015 and 2018 data-taking period, which is denoted as the LHC Run2. The tau leptons will further decay in either of a hadronic decay mode and a leptonic decay mode. As tau leptons decay hadronically approximately 65% of the time, the hadronic decay mode of tau leptons is considered in the identification of the tau leptons in this analysis. The channel where the both tau leptons decay hadronically is found to provide the best sensitivity in the $m_{H/A}$ > 600 GeV region of all the search channels. The hadronically decaying tau leptons are selected with respect to the combination of the information of the calorimeter clusters and charged particle tracks. This thesis work has introduced the two major improvements in order to pursue the search sensitivity in a wide-range; the improvement of the tau reconstruction with use of 2-prong signature and the categorization. The categorization technique introduces a major improvement in a low mass region (<1~TeV). The additional 2-prong signature introduces a major improvement of the sensitivities for high mass (>1.5~TeV) heavy neutral Higgs scenarios.

Since no indication of an excess over the expected SM background is found, this thesis sets the upper limits on the cross-section times branching fraction to di-tau for the production of heavy neutral Higgs bosons H/A at 95% confidence level for bottom-annihilation and gluon-gluon fusion processes. In the single production hypothesis of the gluon-gluon fusion and bottom-annihilation, the exclusion limits are around 236 (2) fb and 145 (1) fb at m_A = 300 (1500) GeV, respectively. The limits are also interpreted in the context of the MSSM scenarios, in particular, in the hMSSM scenario as the benchmark of this analysis. The constraint presented here is applicable more generally to type-Ⅱ 2HDM. Figure1 shows the exclusion limit on m_A- tanβ plane in terms of the hMSSM benchmark scenario. The observed upper limit of signal production rate excludes tanβ>2 hypothesis for mass of 300 GeV and tanβ>23 region for mass of 1500 GeV. This is the most stringent observed (expected) constraints for the hMSSM scenarios with addition high mass heavy neutral Higgs bosons and high tanβ.

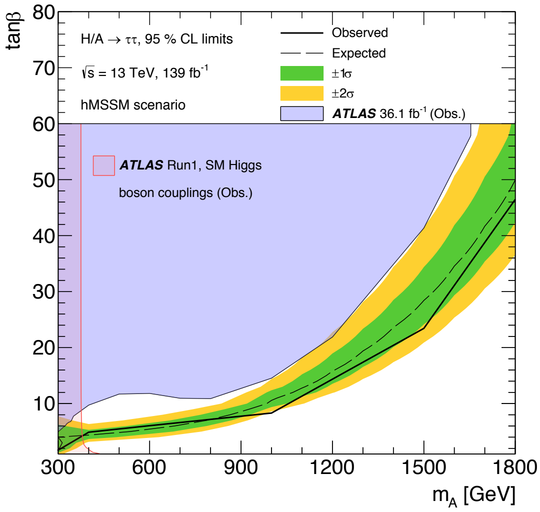

Figure 1.:
The plot shows the exclusion limits (black solid line) in the two dimensions $m_A - \tan\beta$ parameter space at 95% confidence level, along with 1σ and 2σ error bands for the expected limit (black dot line). The previous published result with 36 fb^{-1} (light purple block) is shown. The MSSM interpretation for the SM 125 GeV Higgs is illustrated as red line.