論文の内容の要旨

Search for gluinos in final states with jets and missing transverse momentum in pp collisions at $\sqrt{s}$=13 TeV

(重心系エネルギー 13 TeV の陽子・陽子衝突における
終状態にジェットと横方向消失運動量をもつ超対称性粒子グルイーノ探索)

宇野 健太

Standard Model (SM) provides a successful description in the current particle physics and it is consistent with almost all experiment results. However, the SM is not a perfect theory because there are unknown problems, which the SM cannot explain: the hierarchy problem and the existence of the dark matter. In order to explain these problems, the extension of the SM is needed.

One of the promising solution of these problems is SUSY, which is a symmetry between fermions and bosons. When SUSY is considered, partners of all the SM particles (super-partners) are introduced. These undiscovered particles have been searched at several experiments. This thesis presents a search for gluino, which is the super-partner of gluon, using pp collision at $\sqrt{s}$ =13 TeV with the LHC ATLAS detector. The data is collected in 2015-2018 corresponding to the integrated luminosity of 139 fb^{-1}. Since the LHC is proton-proton collider, the cross section of gluino production is relatively large due to strong interaction. Therefore, the gluino search is one of most important physics programmes at the LHC. In order to search for gluinos, two processes are considered as the target signals. One is the process, which decays to the lightest neutralino $\tilde{\chi}_1^0$ through $\tilde{g} \to qq\tilde{\chi}_1^0$ decay (gluino direct decay). This is the most simplest process in all the gluino processes and the broad search for gluinos can be performed. The other is the process, which decays to $\tilde{\chi}_1^0$ through $\tilde{g} \to qq'\tilde{\chi}_1^{\pm}$ or $\tilde{g} \to qq\tilde{\chi}_2^0$ decay (gluino one-step decay). For this process, the final states without leptons have the highest sensitivity in a region where the gluino is heavy.

The search for higher gluino mass becomes more difficult because the cross section

of gluino pair production is smaller as the gluino mass is higher. In order to improve the sensitivities of the target signals with higher gluino mass, a machine learning approach is introduced. It can improve the separation between signals and SM backgrounds using correlations of variables. Since the correlations are not considered explicitly in the previous result, which uses data collected in 2015-2016 corresponding to the integrated luminosity of 36 fb^{-1}, it allows the sensitivities to be improved well.

The analysis using the machine learning has mainly two difficulties. This research solves them as follows.

(i) The kinematics of signal processes depends on SUSY masses, so the determination of training samples considering kinematics is very crucial. In this analysis, eight training categories are prepared such that they can cover the signals with the mass difference between gluino and neutralino. By using these categories, the sensitivities of all signal mass points are improved.

(ii) The estimation of background is more complicated than the conventional approach because the machine learning utilizes correlations. The background estimation considering the correlations is developed to apply the machine learning to data. By this research, it has been proved that the outputs from the machine learning are the well-understood variables.

No significant excess over the background prediction is observed as shown in Figure 1. The exclusion limits for the signal models at 95% confidence level are set. The gluino mass with the direct decay is excluded up to 2.15 TeV for massless neutralino as shown in Figure 2. Compared to the previous results, it is extended by 100 (200-300) GeV in heavier gluino (neutralino) mass. The gluino mass with the one-step decay is excluded up to 2.2 TeV for massless neutralino 3. For gluino one-step with W boson process, it is extended by 200 (300-400) GeV in heavier gluino (neutralino) mass compared to the previous results. For gluino one-step with Z boson process, there is only exclusion limit in final states with two leptons ($Z \to \ell\ell$). Compared to the result, it is extended by 500 (300-400) GeV in heavier gluino (neutralino) mass compared to the previous results. Using the machine learning in this analysis allows the heavier gluino which has not been looked into before to access.

In this research, the framework using the machine learning has been established in gluino search. Based on the framework, the first preliminary result of the gluino search using the machine learning was published from ATLAS. The constraints of gluino mass are the best in the world. It has been proved that the machine learning technique is applicable to SUSY search.

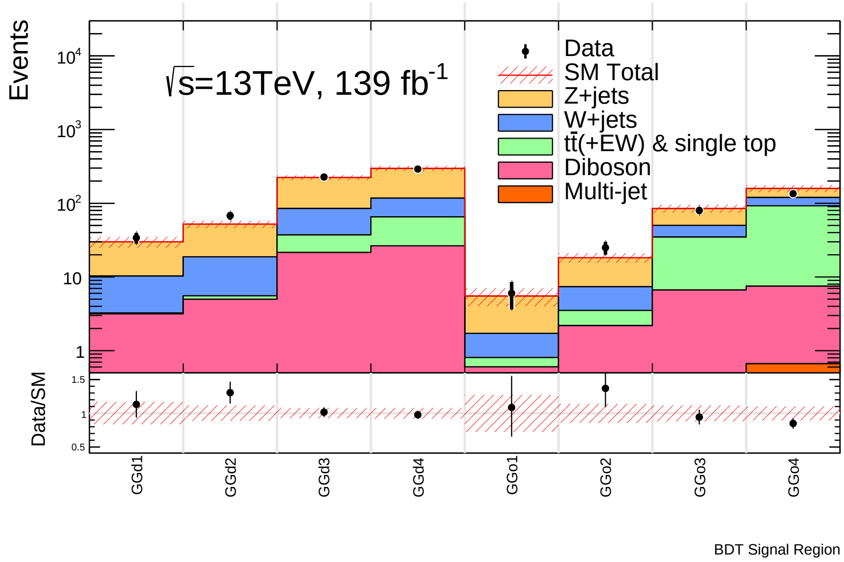

Figure 1: Comparison of the background prediction and observed data for all the signal regions. x-axis corresponds to each SR and y-axis corresponds to the number of events.

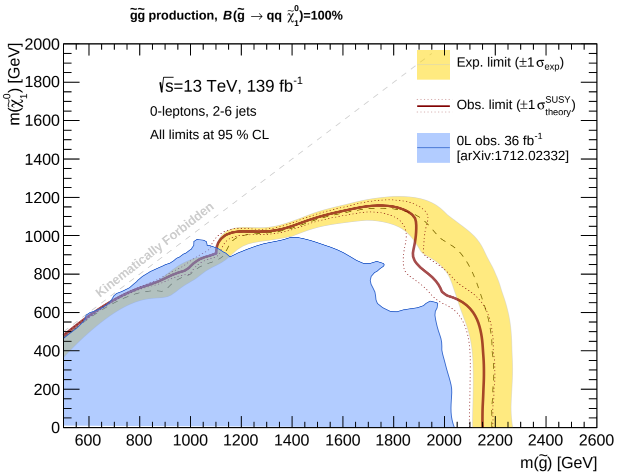

Figure 2: . Expected and observed limits at the 95% confidence level in the neutralino mass versus gluino mass for the gluino-pair production with direct decay. The expected (observed) exclusion limit is denoted by the dash (solid) red line. The blue shaded area is the observed exclusion limits from the previous result corresponding to the integrated luminosity of 36 fb^{-1}.

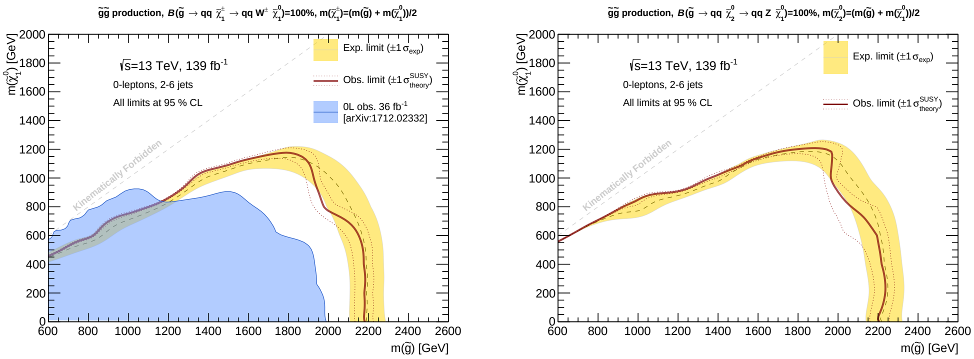

Figure 3: . Expected and observed limits at the 95% confidence level in the neutralino mass versus gluino mass for the gluino-pair production with one-step decay with W boson (left) or Z boson (right) on a simplified model. The expected (observed) exclusion limit is denoted by the dash (solid) red line. For gluino one-step with W boson, the blue shaded area is the observed exclusion limits from the previous publication corresponding to the integrated luminosity of 36 fb^{-1}.