論文の内容の要旨

論文題目　　Searches for Supersymmetric Partners of Top and Bottom Quarks　in Proton-Proton Collisions at $\sqrt{s}$=7 TeV
（重心系エネルギー7 TeV の陽子・陽子衝突を用いたトップクォークとボトムクォークの超対称性パートナーの探索）

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Supersymmetry (SUSY) is one of the most promising theories to describe physics beyond the Standard Model (SM) of particle physics. It solves the grand unification, the Higgs mass quadratic divergence, gravity, and predicts the existence of candidate of dark matter. Supersymmetry is a symmetry of exchanging fermions and bosons. It predicts the existence of the corresponding particles to the Standard Model particles. In an unbroken supersymmetry, these supersymmetric partner particles have the same mass and quantum number as the corresponding particles. However, since no such particles have been discovered Therefore if supersymmetry exists, it must be broken.

The minimal extension of the SM by supersymmetry is called the minimal Supersymmetric Standard Model (MSSM). In the MSSM, a new conserved quantity, *R-parity* is introduced, such that the SM particles have 1 and the SUSY particles have -1. As a result of the *R*-parity conservation, SUSY particles are produced in pair and they decay to the lightest supersymmetric particle (LSP) which must be stable. The LSP is a good candidate of dark matter, and in the collier experiment, it behaves like a heavy neutrino and causes the momentum imbalance in evens.

Another feature of SUSY is that it predicts light stops and sbottoms (supersymmetric partners of top and bottom quarks). One reason is that due to the large Yukawa couplings of the top and bottom quarks, the mixing of the mass matrix of left- and right-handed stops and sbottoms is large. The lightest mass in the mass eigenstates is smaller than the masses in helicity eigenstates. The other reason is the "naturalness" of the Higgs mass. In a calculation of the Higgs mass, two terms, one is negative and the other is positive value, contribute. Since the Higgs mass is expected to be an order of 100 GeV, if these two terms are much larger than this energy scale, unnatural tuning of the parameters are required. Thus, the mass of the stop, which gives the largest contribution to the Higgs mass, need to be an order of 100 GeV.

If the stop and the sbottom are lighter than the other SUSY particles, their productions can dominate over the productions of other particles. When the stop or the sbottom are produced in the collider experiments, b-jets are included in the final state. Therefore the expected topology from the SUSY models with the R-parity conservation and the light stop or sbottom is b-jets and the large missing momentum. In this thesis, four searches for the stop and sbottom are presented using the proton-proton collisions at the center-of-mass energy of 7 TeV recorded by the ATLAS detector in 2011. The used data is the integrated luminosity of about 2.05 fb^{-1}.

The ATLAS detector is a general-purpose detector installed at the LHC machine. In the LHC, proton-proton collisions at center-of-mass energy of 7 TeV is performed with the peak luminosity of 3.65×10^{33} $\text{cm}^{-2}\text{s}^{-1}$ at the end of 2011 (it is planned to upgrade the center-of-mass energy of 13 TeV and the peak luminosity of 1.0×10^{34} $\text{cm}^{-2}\text{s}^{-1}$). The ATLAS detector consists of inner tracking detector surrounded by a superconductiong solenoid, electromagnetic and hadronic calorimeters and a muon spectrometer with a toroidal magnetic fileds. These detectors enable the reconstruction of the physics objects (jets, electrons, muons, track particles and the missing transverse momentum) used in the physics analysis.

To detect the signal of the stop/sbottom decays, identification of b-jets is important. Identification of b-jets is performed by using track particles associated to the reconstructed jets. The most powerful algorithm is the one using the combination of the impact parameter-based and secondary vertex-based algorithms, called IP3D+JetFitter. The b-tagging efficiency from this algorithm in ATLAS is about 60 % at the rejection of light-flavor-quark jet of about 400 (estimated by using simulated top pair production events).

The first search is for the stop/sbottom production from the gluino decays. The gluino is the supersymmetic partner of the gluon. If the gluino is not so heavier than the stop/sbottom, its production is much larger than the direct production of the stop/sbottom. If the stop or sbottom is ligher than the other supersymmetic partners of quarks, the branching ratio of gluino decaying to them is larger than the others. The final state has b-jets from the decay of stops and sbottoms and multi-jets from cascade decay of gluinos and the missing momentum from the LSP. By requiring no isolated leptons in an event, the background from the electroweak process like W→lν are reduced. This search is characterized by no-lepton, multi-jet selection. Then at least one *b*-jet is required in an event.

The second search is also for the stop/sbottom production from the gluino decays. The difference to the first search is that one isolated lepton is required in this search. In the SUSY signals, leptons are expected to produce from the decay of the stop or the charginos. Hence this search is characterized by one-lepton multi-jet selection. Also at least one *b*-jet is required in an event.

The third search is for the direct stop/sbottom pair production and decay to the LSP exclusively. The resulting final state is two *b*-jets and the missing momentum only. Since this topology is very different from the above two searches, by optimizing the event selection for this topology, the sensitivity to this kind of SUSY signal is enhanced. This search is characterized by no-lepton two *b*-jet selection.

The last search is for the direct stop pair production in the GMSB model with light higgsino. In this model, very specific topology is possible because of the existence of the gravitino whose mass is order of keV. Since the gravitino is the LSP, the lightest neutralino can decay further to the gravitino.plus the Z or Higgs bosons, if it is heavier than these bosons. The sensitivity to this signal can be enhanced by identifying two leptons produced from the decay of Z boson. This search is characterized by two-lepton multi-jet selection. Then at least one *b*-jet is required in an event.

The observed numbers of events after each signal selection are compared to the SM prediction estimated by the Monte Carlo simulations. However, there are no significant excess can be seen in all searches from the SM prediction. Therefore these results are used to set limits on the SUSY models considered here.

One of the benchmark signals is the mSUGRA model with $\tan\beta=40$, $A_0=-500$ GeV and $\mu>0$, in which relatively large $\tan\beta$ and $|A_0|$ predict the light stops and sbottoms. The result of no-lepton multi-jet and one-lepton multi-jet selections are use to set limits on this model, and a stop mass of 640 GeV is excluded at 95 % CL in all allowed (m_0, $m_{1/2}$) spaces.

The no-lepton two b-jet selection is used to set limits on the stop pair production signals with the degenerated chargino and neutralino. In this case, the lightest chargino can decay to the lightest neutralino producing SM fermion pair but since they are degenerated, these fermions are too soft to be detected. In this signal, a stop mass of 400 GeV with the lighest neuatralino mass of 0 GeV and a stop mass of 350 GeV with the lightest neutaralino mass of 120 GeV are excluded at 95 % CL.

The two-lepton multi-jet selection is used to set limits on the stop pair production signals in the GMSB model with the light higgsino. In this model, a stop mass of 230 GeV is excluded at 95 % CL with the neutralino mass of > 91 GeV.

These limits are the most stringent ones in the collier experiments. Especially for the stop, almost all allowed regions expected from the naturalness of the Higgs mass in the production from gluinos are excluded. In the direct production cases, there are still remaining parameter space but the very tight limits have been set on the naturalness.