論文の内容の要旨

Search for direct Chargino production based on a disappearing-track signature at $\sqrt{s} = 13$ TeV with the ATLAS detector

(ATLAS検出器での13TeV衝突エネルギー実験データを用いた消失飛跡を特徴としたチャージーノ探索)

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The discovery of the Higgs boson in 2012 was a milestone on the elementary particle physics, resulting in the reconfirmation of the validity of the Standard Model. The Standard Model is, however, not a perfect nor an ultimate theory because it contains an artificial tuning like the anthropic principle and cannot explain 95% of the energy in our universe. Importance of the searches for new physics beyond the Standard Model is increasing since there is still no clear hint indicating new theories close to the ultimate theory.

One of the most well-motivated theories is a supersymmetric theory, which solves many problems in the Standard Model. Although the supersymmetric theory has a huge number of model parameters, the properties of the supersymmetric theory are expected according to the precise agreements between nature and the Standard Model and a few unexpected deviations, including the existence of dark matter. One of the well-motivated scenarios in the supersymmetric theories is the case where superpartners of the W boson or the Higgs boson is the lightest supersymmetric particle. Such scenarios can be satisfied with constraints from the Higgs boson mass, dark-matter relic density and the flavour physics.

Despite the motivation, it is known to be hard to search for such a scenario in hadron collider experiments within the traditional searches based on only energetic jets, leptons and the missing transverse momentum due to the lack of energetic particles from a cascade decay from the supersymmetric particles. On the other hand, instead of the energetic signatures, such a model predicts a charged meta-stable supersymmetric particle with a lifetime of O(0.01–0.1) ns. Since such a lifetime corresponds to the decay radius of O(1–10) cm, which is smaller than the size of a track detector (tracker) in the ATLAS detector, the charged supersymmetric particles can be observed as suddenly disappearing in the tracker after running some macroscopic distances. Such a signature is called a disappearing track. Since the Standard Model particles do not produce a disappearing track, a requirement for the disappearing track has strong rejection power for the Standard Model particles.

The past experiments using disappearing track signature did not have adequate signal acceptance because it was difficult to reconstruct the short tracks comparable with the typical decay radius (O(1–10) cm) due to the tracker layout. The ATLAS experiment upgraded the tracker in the long-shutdown in 2013–2014, making it possible to reconstruct shorter tracks with the track length of 12 cm, called "pixel tracklet", as shown in Fig. 1. The shorter tracks and the improvements in various parts in the analysis including the track reconstruction, measurements of the tracking performance and the background estimation technique, significantly improve the sensitivity for the supersymmetric particles.

This thesis presents the latest results which are most sensitive to the wino/higgsino LSP scenario, focusing on the direct chargino and neutralino pair production, using 80 fb^{-1} of pp collision data collected by the LHC/ATLAS experiments at $\sqrt{s} = 13$ TeV. Signal extraction is performed based on a tracklet p_{T} shape fitting; most of the p_{T} templates are directly derived from observed data. No significant excess from the Standard Model prediction is found in the signal enhanced region. This result gives a new constraint for the pure wino/higgsino LSP scenarios; the chargino mass up to 490 GeV is excluded in the pure wino LSP scenario, and the chargino mass up to 170 GeV is excluded in the pure higgsino LSP scenario as shown in Fig. 2.

The current LHC does not have a sensitivity to explore the entire chargino-mass parameter space which is viable from the cosmology; the chargino mass up to 3 TeV for the pure wino scenario and 1 TeV for the pure higgsino scenario are motivated. This thesis discusses the discovery sensitivity for such charginos with next-generation colliders: the High-Luminosity LHC and the Future Circular Collider. The Future Circular Collider has the sufficient potential to discover the charginos motivated from the dark-matter relic density.

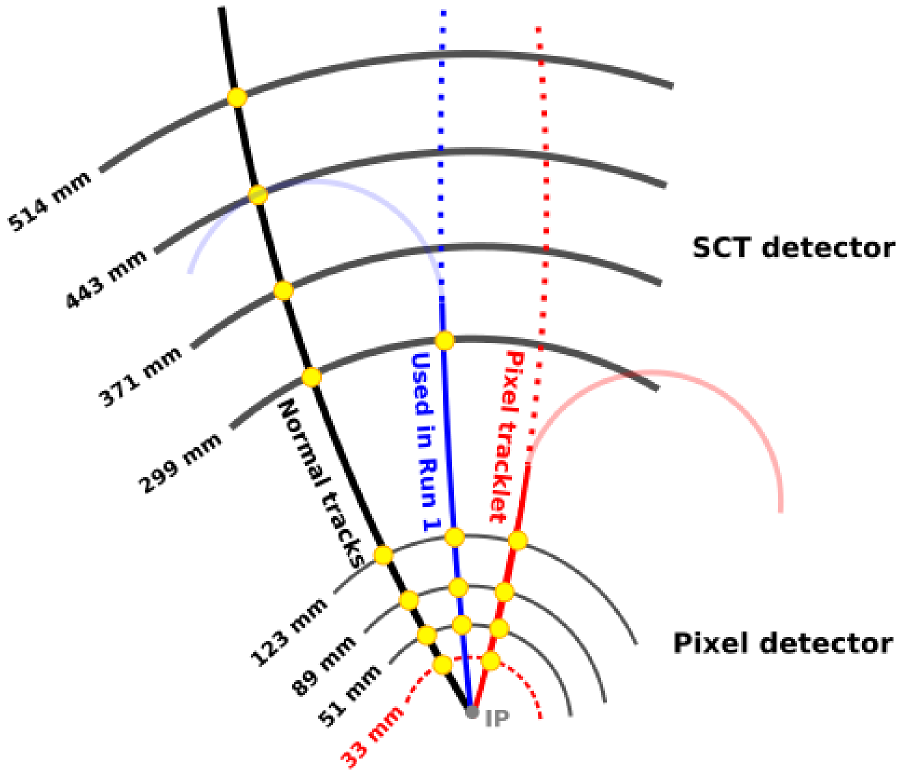
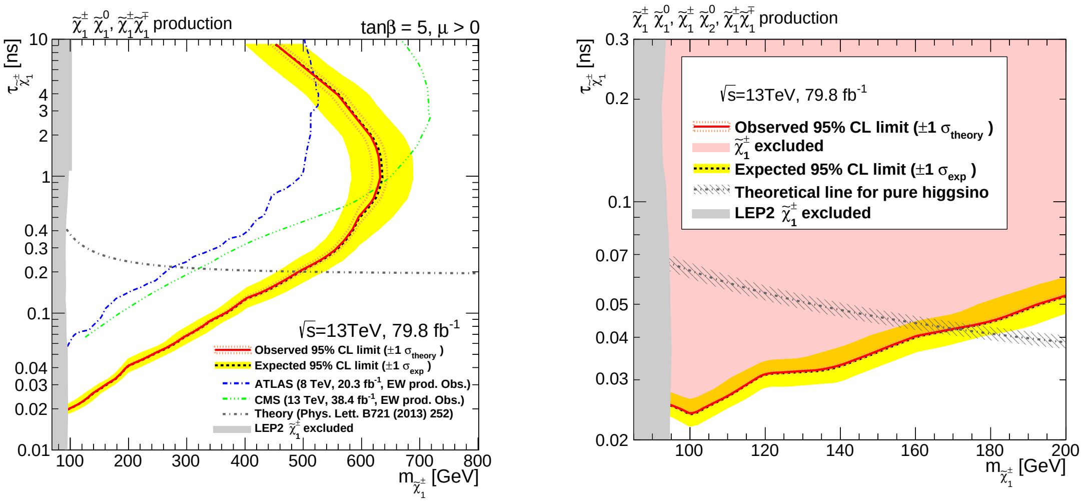
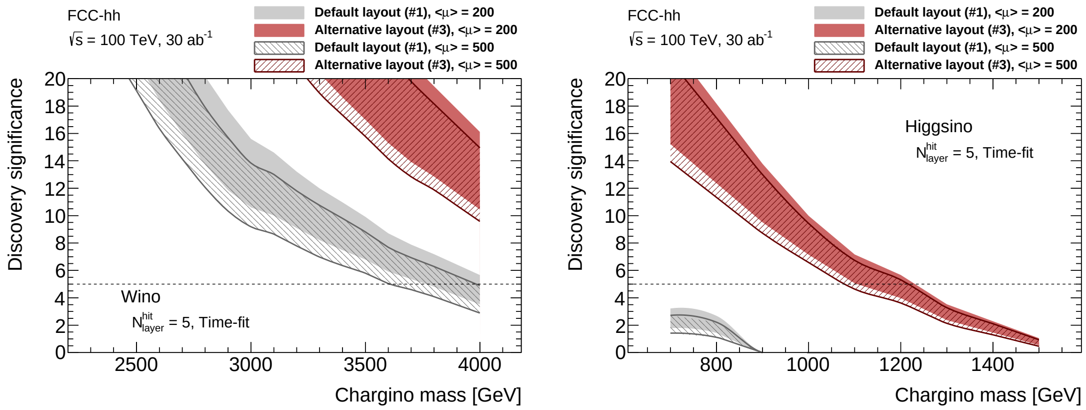


Figure 1: Illustration of tracks in the ATLAS detector. Inner three (four) layers are the Pixel detector, and the outer four layers are the SCT detectors. The yellow points represent hits in each layer. A black line shows the normal length track which consists of full hits in the tracker. A blue line shows a short track used in Run 1 analysis, where a track is made by three Pixel hits and two SCT hits. A red line shows a new short track (pixel tracklet), which consists of four Pixel hits. The pixel tracklet reconstruction became possible thanks to new Pixel-layer shown as red dashed line.



(a) (b)

Figure 2: Exclusion limit on the chargino mass and the chargino lifetime (a) for the pure wino LSP scenario, (b) for the pure higgsino LSP scenario. Observed exclusion limit is shown as a red curve. The dotted orange line around observed limits shows the cross-section uncertainties. The expected sensitivity is shown as a black dotted line, and the 1 sigma fluctuation is represented as a yellow band. Grey chained line shows a relation between chargino mass and chargino lifetime. LEP, ATLAS and CMS results are shown as a grey band, a blue line and a green line, respectively.



(a) (b)

Figure 3: Discovery sensitivities (a) for the pure wino scenario (b) for the pure higgsino scenario. Red graphs show the discovery sensitivities using an optimised tracker layout. Solid graphs are sensitivity with $\mu = 200$ and hatched graphs are sensitivity with $\mu = 500$.