The Standard Model (SM) of particle physics has provided a remarkable description of experimental results across a wide energy range, but nevertheless is regarded as a low energy effective theory. Supersymmetry (SUSY) is an extension of the Poincaré symmetry group that predicts partner particles for each of the SM particles. This dissertation focuses on searches for SUSY particles in proton-proton collisions delivered by the Large Hadron Collider and collected by the ATLAS detector.

The lightest chargino ($\tilde{\chi}_1^{\pm}$) and next-to-lightest neutralino ($\tilde{\chi}_2^0$) are searched for in proton collisions using 20.3 fb^{-1} at $\sqrt{s} = 8$ TeV. Building on the discovery of the 125 GeV Higgs boson in 2012, the targeted decay modes of the chargino and neutralino are $\tilde{\chi}_2^0 \to h^0\ \tilde{\chi}_1^0$ and $\tilde{\chi}_1^{\pm} \to W^{\pm}\ \tilde{\chi}_1^0$. A final state of one-lepton (electron or muon), two b-jets from the Higgs boson decay, and missing transverse momentum is explored through a multi-bin likelihood fit to the Higgs invariant mass hypothesis. No excesses above the SM backgrounds are observed, and the results are statistically combined with analyses targeting $\ell\ell\ell$, $\ell\gamma\gamma$, $\ell^{\pm}\ell^{\pm}$ final states. In addition, the direct pair production of squarks or gluinos is searched for in proton-proton collisions using 36.5 fb^{-1} of data collected at $\sqrt{s} = 13$ TeV. A final state of one-lepton (electron or muon), 2-6 jets, and missing transverse momentum is explored. Four statistically orthogonal signal regions are devised to target the wide range of kinematics expected from the decay of the squarks or gluinos. The data is found to be consistent with SM only expectations. The results from both searches are interpreted in a combination of simplified and phenomenological models.

The first layer of the Muon Spectrometer end-cap will be replaced with the New Small Wheels (NSW) in 2019 to improve triggering and muon tracking capabilities in the forward regions of the ATLAS detector. Small-strip Thin Gap Chambers (sTGC) are one of the two detector technologies that will be used in the NSW, and are studied under prolonged radiation in preparation for their installation. A prototype sTGC detector is irradiated with a ^{90}Sr source of intensity 10 mCi. No degradation of the signal characteristics is observed up to 11.8 C/cm of accumulated charge per cm of wire.