# ATLAS NOTE

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# Combined exclusion reach of searches for squarks and gluinos using final states with jets, missing transverse momentum, and zero or one lepton, with the ATLAS detector in $\sqrt{s} = 7$ TeV proton-proton collisions

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**Abstract**

The combination of searches for squarks and gluinos in final states containing jets, missing transverse momentum and zero or one electron or muon is presented. In the MSUGRA/CMSSM framework with $\tan\beta = 3$, $A_0 = 0$ and $\mu > 0$, squarks and gluinos of equal mass are excluded below 815 GeV at 95% confidence level.

# 1 Introduction

This document describes the combination of the searches for supersymmetry in the 0-lepton channel [1] and the 1-lepton channel [2] performed by ATLAS using the 2010 dataset. Both analyses are counting experiments. The signal and control regions of each channel are statistically exclusive. The combination is done per grid point in the $m_0$, $m_{1/2}$ plane of the MSUGRA/CMSSM framework [3, 4]. The total likelihood is the product of contributions from the 0-lepton and 1-lepton channels. At each grid point, the 0-lepton channel provides the likelihood that corresponds to the one of the four signal regions considered in the analysis giving the best expected exclusion sensitivity. The 1-lepton channel provides the combined likelihood of the electron and muon channels.

The signal strength parameter $\mu$ is treated as a common parameter between the 0-lepton channel, the electron channel and the muon channel. Systematic uncertainties in common between all channels are: the jet energy scale, signal cross section uncertainty, and the luminosity uncertainty. These uncertainties are treated as 100% correlated. The correlated systematic uncertainties are accounted for when building the combined likelihood through the use of common nuisance parameters, and a single common Gaussian constraint per nuisance parameter. The jet energy resolution uncertainties are small and treated as uncorrelated between the channels, with no observable impact on the final result. All other uncertainties are taken as uncorrelated. The dominant uncorrelated uncertainties are the statistical uncertainties from control regions, limited Monte Carlo statistics, and the theoretical uncertainties from background extrapolation into the signal regions.

The combined exclusion limits are obtained performing pseudo-experiments; they are derived at 95% confidence level (C.L.) using as test statistic a one-sided profile likelihood ratio. The statistical procedure is identical to the one already described in both Refs. [1] and [2]. This profile likelihood method is explained in detail in Ref. [5].

The combined exclusion contour is shown in Fig. 1. In the MSUGRA/CMSSM framework with $\tan\beta = 3$, $A_0 = 0$ and $\mu > 0$, squarks and gluinos of equal mass are excluded below 815 GeV at 95% C.L. The corresponding expected exclusion at 95% C.L. lies at 745 GeV. These are the most stringent limits to date.

The combination yields a slightly better exclusion reach than the stand-alone 0-lepton result, especially in the low $m_{1/2}$ and high $m_0$ region. In this region with low gluino masses, the production is gluino-gluino dominated, with long decay chains having low jet, lepton, and missing transverse momenta. For the 1-lepton channels this results in reduced signal selection efficiencies at the level of O(0.1)% [2]. In this area the sensitivity of the 1-lepton analysis does not reach the 95% C.L. exclusion threshold, but it is not negligible: the 95% observed exclusion lies just below $m_{1/2}$ values of 100 GeV, and extends along the gluino mass isocontour. When combining the 0-lepton and 1-lepton channels, the 95% C.L. exclusion limit is pushed up to $m_{1/2} > 130$ GeV.

Compared with the stand-alone 0-lepton result, the combined observed limit improves more than the combined expected limit. The reason is that the stand-alone 1-lepton analysis is affected more significantly by a downward fluctuation in the observed number of events, leading to a better observed exclusion limit. The combined expected limit is dominated by the 0-lepton result.

The limits obtained with the above method are referred to as Power Constrained Limits (PCLs), and are taken as the default result. In addition, as described below, the observed and expected limit curves have been calculated with the $CL_s$ method [6].

The two methods deal differently with the case of excluding signal hypotheses in regions with small sensitivities. The PCL method sets limits based on $CL_{s+b}$. To protect against excluding the (signal) null hypothesis in cases of downward fluctuations of the background, the observed limit is not allowed to fluctuate below the -1$\sigma$ expected limit. This is equivalent to restricting the interval to cases in which the statistical power of the test of $\mu$ against the alternative $\mu = 0$ is at least 16 %. This is referred to

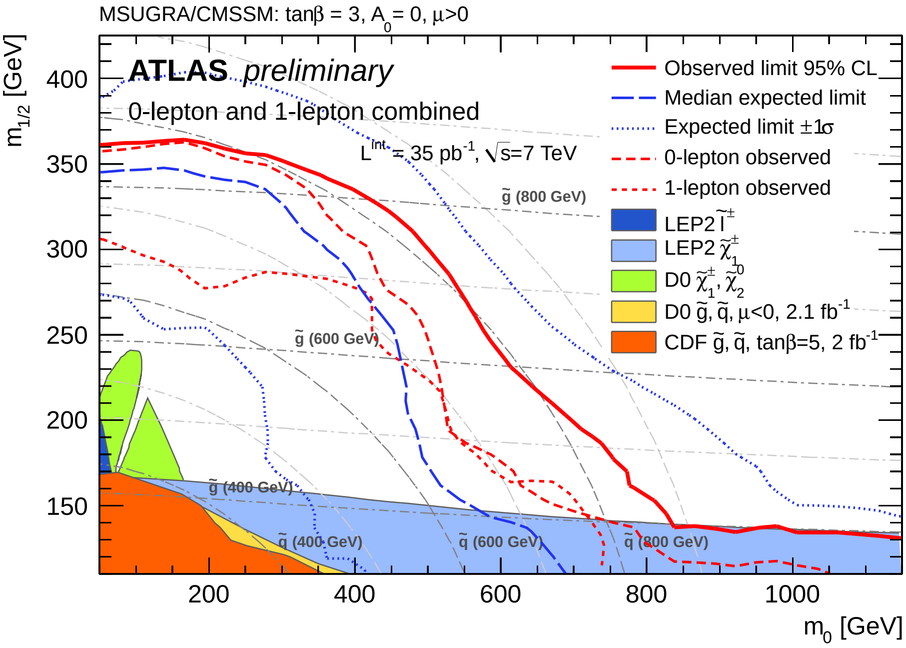


Figure 1: Expected and observed limits for the combined 0- and 1-lepton channels. The blue dashed line corresponds to the expected median 95% C.L. exclusion limit, the dashed-solid blue lines to $\pm 1\sigma$ 95% C.L. limits respectively. The red line represents the combined observed limit. The observed limits for the individual 0-lepton and 1-lepton channels are indicated with red dashed lines. Tevatron and LEP limits on $m_{\tilde{q}}$ and $m_{\tilde{g}}$ are marked for searches in the specific context of MSUGRA/CMSSM, with $\tan\beta = 3$, $A_0 = 0$ and $\mu > 0$, and are also shown for illustration.

as a power constrained limit. If the observed limit fluctuates below the 16% power, the quoted limit is the -1$\sigma$ expected limit. $CL_s$ is defined as $CL_s = CL_{s+b}/CL_b$, and corrects for downward fluctuations continuously. The $CL_s$ approach over-covers compared with PCL, and – in case of downward fluctuations in data – results in smaller observed exclusion limits, which are closer to the expected exclusion limits.

Limits obtained with both methods are shown in Fig. 2. As expected, the observed and expected $CL_s$ exclusion contours lie closer to each other, and are less restrictive than the power-constrained limit over the entire $m_0$, $m_{1/2}$ plane. For the observed dataset, no correction for downward fluctuations is applied by the PCL method, as the combined observed limit is consistent with the expectation within 1$\sigma$. In the $CL_s$ approach squarks and gluinos of equal mass are excluded below 730 GeV at 95% C.L. At this threshold $CL_b$ has a value of 0.33.

# References


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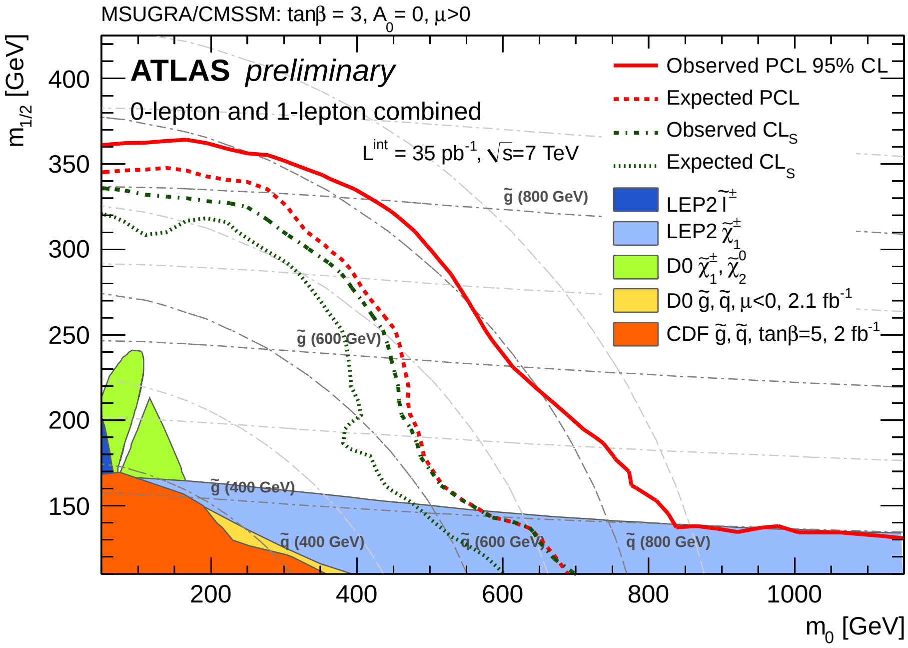


Figure 2: Expected and observed limits of the combined 0-and 1-lepton channels derived with the power constrained limit (PCL) and the $CL_s$ method. The red dashed line corresponds to the expected median PCL at 95% C.L., and the red solid line to the observed PCL at 95% C.L. The green dotted line corresponds to the expected median exclusion contour at 95% C.L. derived with the $CL_s$ method, and the green dashed-dotted line corresponds to the observed exclusion contour at 95% C.L. derived with the $CL_s$ method. Tevatron and LEP limits on $m_{\tilde{q}}$ and $m_{\tilde{g}}$ are marked for searches in the specific context of MSUGRA/CMSSM, with $\tan\beta = 3$, $A_0 = 0$ and $\mu > 0$, and are also shown for illustration.

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