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Constraints on the pMSSM from searches for squarks and gluinos by ATLAS

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ABSTRACT: We study the impact of the jets and missing transverse momentum SUSY analyses of the ATLAS experiment on the phenomenological MSSM (pMSSM). We investigate sets of SUSY models with a flat and logarithmic prior in the SUSY mass scale and a mass range up to 1 and 3 TeV, respectively. These models were found previously in the study 'Supersymmetry without Prejudice'. Removing models with long-lived SUSY particles, we show that 99% of 20000 randomly generated pMSSM model points with a flat prior and 85% for a logarithmic prior are excluded by the ATLAS results. For models with squarks and gluinos below 600 GeV all models of the pMSSM grid are excluded. We identify SUSY spectra where the current ATLAS search strategy is less sensitive and propose extensions to the inclusive jets search channel.

KEYWORDS: Supersymmetry Phenomenology

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Contents

1	Introduction	1
2	Event generation, fast simulation and analysis	2
3	pMSSM random points	6
4	Results and discussion	8
4.1	Models from a linear prior in the SUSY mass scale	8
4.2	Models from a logarithmic prior in the SUSY mass scale	13
5	Summary	14
A	Additional tables	15

1 Introduction

Supersymmetry [1–14] is one of the conceivable extensions of the Standard Model (SM). It could provide a natural candidate for cold dark matter [15, 16] and stabilize the electroweak scale by reducing the fine tuning of higher order corrections to the Higgs mass [14, 17–21]. Supersymmetry (SUSY) proposes superpartners for the existing particles. Squarks and gluinos, superpartners of the quarks and the gluon are heavy coloured particles, which can decay to jets and the Lightest Supersymmetric Particle (LSP), i.e. the neutralino. The neutralino is only weakly interacting and stable since we assume the conservation of R-parity. The LSP escapes detection which results in missing transverse momentum in the detector. Channels with jets and missing transverse momentum have a large discovery potential at the LHC [22], since the coupling strength of the strong force would cause an abundance of squarks and gluinos if these particles are not too heavy.

In the present study we investigate the reach of the ATLAS search with jets and missing transverse energy in the phenomenological MSSM (pMSSM) [23]. A primary objective of our study is to identify possible parameter regions of pMSSM scenarios where the ATLAS analysis is insensitive. This has not been studied before. There are other similar searches from CMS and ATLAS which look into the same signature (see for example [24–26]). The reach of the CMS searches in a pMSSM model has been studied recently in ref. [27].

The ATLAS collaboration has analyzed their data to search for squarks and gluinos in events with 2-4 jets and missing transverse momentum corresponding to an integrated luminosity L_{int} of 35 pb^{-1} in ref. [28] and 1.04 fb^{-1} in ref. [29]. No excess above the SM background expectation was observed in the analyzed data. Although these searches are designed to be quite independent of SUSY model assumptions, mass limits are presented

only for a constrained Minimal Supersymmetry Standard Model (cMSSM) model and for simplified models with only squarks, gluinos and the lightest neutralino.

In the pMSSM the more than 120 free parameters of the MSSM are reduced to 19 by demanding CP-conservation, minimal flavor violation and degenerate mass spectra for the 1st and 2nd generations of sfermions. In addition it is required that the LSP is the neutralino $\tilde{\chi}_1^0$. The 19 remaining parameters are 10 sfermion masses,¹ 3 gaugino masses $M_{1,2,3}$, the ratio of the Higgs vacuum expectation values $\tan \beta$, the Higgsino mixing parameter μ , the pseudoscalar Higgs boson mass m_A and 3 A-terms $A_{b,t,\tau}$. This work is based on “Supersymmetry Without Prejudice” [30]. The model points presented in [30] are used for our purpose. Each model point was constructed by a quasi-random sampling of the pMSSM parameters space. The points were required to be consistent with the experimental constraints prior to the LHC [30].

2 Event generation, fast simulation and analysis

We study the reach of the ATLAS search by emulating the ATLAS analysis chain. First we generate events from LHC collisions for each pMSSM SUSY model with a Monte Carlo generator for SUSY processes. These events are then simulated by a fast detector simulation and the acceptance and efficiency is determined by applying the most important ATLAS analysis cuts on the simulated events. Finally these numbers are used to calculate the expected number of signal events for each signal region and analysis. These numbers are compared to the model-independent 95% C.L. limits provided by ATLAS.

PYTHIA 6.4 [31] is used for the event simulation of proton-proton collisions at a 7 TeV centre-of-mass energy. All squark and gluino production processes are enabled as they are of most importance for the inclusive jets search channel. For every model point 10000 events are generated which we found to be enough even for the models with the smallest selection efficiencies. To get as close as possible to the ATLAS analysis we use DELPHES 1.9 [32] as a fast detector simulation with the default ATLAS detector card, modified by setting the jet cone radius to 0.4. The PYTHIA output is read in by DELPHES in HepMC format, which is produced by HepMC 2.04.02 [33]. The object reconstruction is done by DELPHES, which uses the same anti- k_T jet algorithm [34] as ATLAS. Also included in the reconstruction are isolation criteria for electrons and muons. We do not emulate pile-up events.

Reconstructed events are analyzed with the same event selections as used by the ATLAS analysis with 35 pb^{-1} (shown in table 1) and also with the event selections used in the 1.04 fb^{-1} analysis (see table 2). In these tables $\Delta\phi(\text{jet}_i, \vec{E}_T^{\text{miss}})_{\min}$ is the minimum of the azimuthal angles between the jets and the 2-vector of the missing transverse momentum $\vec{E}_T^{\text{miss}}$. The invariant mass m_{eff} is calculated as the scalar sum of E_T^{miss} and the magnitudes of the p_T of the leading jets required in the selection (i.e. 2 jets for the 2-jet selection in region A), except for signal region E, where m_{eff} is the sum of E_T^{miss} and all reconstructed jets with $p_T > 40 \text{ GeV}$.

¹The sfermion parameters are $\tilde{Q}_L, \tilde{Q}_3, \tilde{L}_1, \tilde{L}_3, \tilde{u}_1, \tilde{d}_1, \tilde{u}_3, \tilde{d}_3, \tilde{e}_1$ and $\tilde{e}_3$.

Signal region:	A	C	D
E_T^{miss} [GeV]	for all regions >100		
leading jet p_T [GeV]	for all regions >120		
2nd jet p_T [GeV]	>40	>40	>40
3rd jet p_T [GeV]	-	>40	>40
$\Delta\phi(\text{jet}_i, E_T^{\text{miss}})_{\text{min}}$	for all regions >0.4		
m_{eff} [GeV]	>500	>500	>1000
$f=E_T^{\text{miss}}/m_{\text{eff}}$	>0.3	>0.25	>0.25
95% C.L. limit on σ [pb]	1.3	1.1	0.11

Table 1. Requirements for the signal regions A,C and D for the ATLAS analysis with an integrated luminosity of 35 pb^{-1} . In addition the number of reconstructed leptons has to be zero; also shown are the 95% C.L. upper limits on the cross section for new physics processes σ .

For both analyses there are several signal regions differing mainly by the number of required jets. For all signal regions E_T^{miss} has to be larger than 100 GeV for $L_{\text{int}} = 35 \text{ pb}^{-1}$ (130 GeV for $L_{\text{int}} = 1.04 \text{ fb}^{-1}$). The selection for the leading jet p_T is identical for all signal regions, it has to be larger than 120 GeV (130 GeV). The analysis for $L_{\text{int}} = 35 \text{ pb}^{-1}$ includes signal regions for two and three jets, this is expanded to four and five jet signal regions in the $L_{\text{int}} = 1.04 \text{ fb}^{-1}$ analysis. The required jets have to exceed a p_T of at least 40 GeV. The specifications for m_{eff} and $E_T^{\text{miss}}/m_{\text{eff}}$ vary for each signal region, in general the threshold for m_{eff} is higher for the $L_{\text{int}} = 1.04 \text{ fb}^{-1}$ analysis. In addition to these cuts a veto on electrons and muons with $p_T > 20 \text{ GeV}$ was required.

After this selection the event counts are scaled to the luminosities considered in the analyses, i.e. 35 pb^{-1} and 1.04 fb^{-1} , respectively. The NLO cross section used for this is calculated by LHC-Faser light [35, 36] from PROSPINO2.1 [37, 38] cross section grids.

The limits on the effective cross sections given by the ATLAS analyses are used to calculate a limit on the number of signal events passing the cuts, also given in table 1 and 2. No attempt was made to include theoretical uncertainties. In the studied SUSY mass range these uncertainties are small compared to the differences of the ATLAS and DELPHES setups and would not change drastically any conclusion of this work.

In order to compare our setup to ATLAS we determined the relative efficiency difference

$$\frac{\Delta C}{C} = \frac{(A * E)_{\text{ATLAS}} - (A * E)_{\text{DELPHES}}}{(A * E)_{\text{ATLAS}}}$$

for each SUSY point studied by ATLAS in the m_0 - $m_{1/2}$ plane for the cMSSM grid with $\tan\beta = 10$, $A_0 = 0$ and $\mu > 0$. Here $A * E$ is the acceptance times efficiency of the ATLAS and DELPHES analysis setups.

Figure 1 shows $\frac{\Delta C}{C}$ for the cMSSM. Numerical examples for the ATLAS and DELPHES efficiencies are shown in table 3. The efficiency of our setup is found to be in agreement with the ATLAS efficiency [39] on the level of 10 – 30% for the 2- and 3-jet signal regions $A - B$ and SUSY masses around the present ATLAS limits. These limits are ranging for $m_{1/2}$ from 200 – 500 GeV and go up to intermediate m_0 of 1000 GeV.

Signal region:	A	B	C	D	E
E_T^{miss} [GeV]	for all regions >130				
leading jet p_T [GeV]	for all regions >130				
2nd jet p_T [GeV]	>40	>40	>40	>40	>80
3rd jet p_T [GeV]	-	>40	>40	>40	>80
4th jet p_T [GeV]	-	-	>40	>40	>80
$\Delta\phi(\text{jet}_i, E_T^{\text{miss}})_{\text{min}}$	for all regions >0.4				
m_{eff} [GeV]	>1000	>1000	>500	>1000	>1100
$f=E_T^{\text{miss}}/m_{\text{eff}}$	>0.3	>0.25	>0.25	>0.25	>0.3
95% C.L. limit on σ [fb]	22	25	429	27	17

Table 2. Requirements for the signal regions A-E for the ATLAS analysis with an integrated luminosity of 1.04 pb^{-1} . In addition the number of reconstructed leptons has to be zero; also shown are the 95% C.L. upper limits on the cross section for new physics processes σ .

m_0	$m_{1/2}$		Accepted fraction of signal events per signal region				
			A	B	C	D	E
340	120	ATLAS	0.001	0.002	0.08	0.002	0.003
		DELPHES	0.002 ± 0.0004	0.003 ± 0.0005	0.06 ± 0.003	0.003 ± 0.0005	0.004 ± 0.0006
	300	ATLAS	0.1	0.13	0.19	0.11	0.09
		DELPHES	0.15 ± 0.004	0.14 ± 0.004	0.16 ± 0.004	0.1 ± 0.003	0.06 ± 0.003
	450	ATLAS	0.27	0.26	0.23	0.2	0.15
		DELPHES	0.33 ± 0.006	0.27 ± 0.005	0.18 ± 0.004	0.17 ± 0.004	0.11 ± 0.003
1140	120	ATLAS	0.002	0.003	0.08	0.004	0.004
		DELPHES	0.003 ± 0.0006	0.004 ± 0.0006	0.06 ± 0.002	0.004 ± 0.0006	0.003 ± 0.0005
	300	ATLAS	0.05	0.07	0.13	0.08	0.14
		DELPHES	0.05 ± 0.002	0.07 ± 0.003	0.1 ± 0.003	0.07 ± 0.003	0.09 ± 0.003
	450	ATLAS	0.12	0.16	0.18	0.16	0.2
		DELPHES	0.09 ± 0.003	0.09 ± 0.003	0.08 ± 0.003	0.08 ± 0.003	0.1 ± 0.003
2500	120	ATLAS	0.0001	0.002	0.07	0.002	0.003
		DELPHES	0.001 ± 0.0003	0.002 ± 0.0004	0.07 ± 0.003	0.002 ± 0.0004	0.003 ± 0.0005
	300	ATLAS	0.02	0.05	0.12	0.07	0.11
		DELPHES	0.02 ± 0.001	0.04 ± 0.002	0.08 ± 0.003	0.04 ± 0.002	0.07 ± 0.003
	360	ATLAS	0.03	0.07	0.13	0.08	0.15
		DELPHES	0.03 ± 0.002	0.04 ± 0.002	0.07 ± 0.003	0.05 ± 0.002	0.08 ± 0.003

Table 3. Accepted signal fraction ($E * A$) for the ATLAS and DELPHES setup and shown for the analysis with $L_{\text{int}} = 1.04 \text{ fb}^{-1}$.

At $m_{1/2} < 200 \text{ GeV}$ larger deviations occur. Here both the statistical uncertainty of the ATLAS and DELPHES efficiencies are larger and the selection efficiencies are tiny. The largest deviations occur if in addition m_0 is large. The signal regions are not intended for SUSY signals at $m_{1/2} < 200 \text{ GeV}$ and large m_0 and do therefore not contribute to the search for such SUSY signals. Note that the ATLAS analysis selects always the signal region with the largest exclusion potential for each SUSY model.

For the 4 and more jet channels C-E we observe quite good agreement for $100 \text{ GeV} < m_{1/2} < 400 \text{ GeV}$, for $m_{1/2} < 100 \text{ GeV}$ the same problem as for signal regions A and B occurs. At $m_0 > 1000 \text{ GeV}$ and $m_{1/2} > 400 \text{ GeV}$ there is slightly worse agreement. Here our DELPHES setup underestimates the efficiency by up to 50–70%. The increased differences

Figure 1. Relative efficiency times acceptance difference $\frac{\Delta C}{C}$ of the ATLAS and DELPHES analysis setups for signal region $A - E$ (top left to bottom right) in the m_0 - $m_{1/2}$ plane of the cMSSM model studied by ATLAS. The difference exceeds the indicated range in the white areas. ATLAS has not provided numbers for the upper right box, here the differences was set to 0.

at larger jet multiplicities are probably caused by the slightly different jet reconstruction. DELPHES assumes a perfect clustering algorithm and does not apply corrections for jet energy underestimation as ATLAS does.

In view of the mostly smaller efficiencies of DELPHES compared to ATLAS, our study can be regarded as conservative.

In addition we compared the limit curve in the m_0 - $m_{1/2}$ plane of the cMSSM model as set by ATLAS [39] with the the limit curve produced with our DELPHES setup. In this cMSSM grid m_0 and $m_{1/2}$ are varied while the other three parameters are set to the following values: $\tan \beta = 10$, $A_0 = 0$ and $\text{sign}(\mu) = +1$. The result is shown in figure 2. Both limits are in good agreement except for small variations in the order of 30 GeV in $m_{1/2}$, which is the bin-width used in the figure.

Figure 2. The exclusion limits in the m_0 - $m_{1/2}$ plane for the cMSSM grid with $\tan \beta = 10$, $A_0 = 0$ and $\text{sign}(\mu) = +1$ for $L_{\text{int}} = 1.04 \text{ fb}^{-1}$ as derived with our DELPHES setup (shown in blue) and as determined by ATLAS (shown in red). The region inside the coloured line is excluded. The ATLAS limits are taken from its tabularised form provided by the HEPDATA webpage.

3 pMSSM random points

The pMSSM points are taken from “Supersymmetry Without Prejudice” [30] (related work [40, 41]). All details can be found in these references.

The Monte Carlo method evolved with the availability of computer generated pseudo random samples. The method was already reviewed in 1949 by Metropolis and Ulam [42].

Any probabilistic sampling on a set of parameters does depend on the boundaries on the parameters as well as the underlying probability density functions, which are assigned to each parameter. The outcome of the sampling does depend on the choice of these probability density functions, here called “priors”. The correct choice of the prior is connected to the a priori information available, e.g. in a perfect situation one would know that underlying probability density function of a parameter has a Gaussian shape. However the information about the behaviour of the parameter is often only known partially or might be even totally unknown. Then assumptions have to be made. If this is the case any result obtained by such a sampling is dependent on these assumptions, i.e. on the choice of the prior(s).

If there is no or not much information available on a parameter the first choice/guess is usually a flat prior, that is the parameter is equally distributed in the allowed range. Each element has the same probability to be chosen in the sampling. If the prior shape is unknown it is common to present results in light of several different choices of priors to show the impact of these.

In this study parameters are sampled using a flat and a logarithmic prior. The a priori information is here only used to constrain the parameter ranges, but not the underlying probability distributions. Thus any result presented in this paper can only be interpreted in the context of the underlying prior and the allowed ranges of the parameters. Please note that we do not intend to study “best fit parameters”, but are interested in investigating a broad range of various parameter sets with viable SUSY spectra.

19 free parameters were randomly sampled, one set with a flat prior with masses up to 1 TeV and another one with a logarithmic prior and masses up to 3 TeV, each parameter was varied in the range given in table 4. Where flat prior means that the value for each

Parameter	Flat prior set	Log prior set
$m_{\tilde{f}}$	100 GeV - 1 TeV	100 GeV - 3 TeV
$ M_{1,2}, \mu $	50 GeV - 1 TeV	10 GeV - 3 TeV
M_3	100 GeV - 1 TeV	100 GeV - 3 TeV
$ A_{b,t,\tau} $	0 - 1 TeV	10 GeV - 3 TeV
$\tan\beta$	1 - 50	1 - 60
m_A	43.5 GeV - 1 TeV	43.5 GeV - 3 TeV

Table 4. Parameter range for flat and log prior model sets

parameter was chosen under the assumption of a uniform distribution in its parameter range. In the same way the logarithmic prior assumes a logarithmic distribution in each parameter range. The objective of choosing two different priors is to detect any bias introduced by how one chooses the parameter space points.

The parameters are: 10 sfermion masses $m_{\tilde{f}}$; 3 gaugino masses $M_{1,2,3}$; the ratio of the Higgs vacuum expectation values $\tan\beta$; the Higgsino mixing parameter μ ; the pseudoscalar Higgs boson mass m_A and 3 A-terms $A_{b,t,\tau}$, the A-terms for the first and second generations can be neglected due to the small Yukawa couplings.

It was assumed that the neutralino is the LSP and that the first two squark generations are degenerate. For the flat prior 10^7 model points are generated, for the logarithmic prior two sets of 10^6 model points. The values of the SM parameters which are used as input for the generation are given in [30]. Afterwards several experimental and theoretical constraints are applied on the generated points. Thus the number of model points which can be analyzed in the end is greatly reduced. The implemented constraints are the following (all can be found in more detail in [30]):

- already during generation the sparticle spectrum is demanded to be tachyon free and to not lead to color or charge breaking minima; also the electroweak symmetry breaking has to be consistent and the Higgs potential has to be bounded from below;
- the neutralino as Weak Interacting Massive Particle (WIMP) is assumed to be a conventional thermal relic, so that the LSP is the lightest neutralino;
- precision electroweak constraints by the use of the 95% CL allowed experimental range for $\Delta\rho$: $-0.0007 \leq \Delta\rho \leq 0.0026$ [43];
- the branching ratios for two rare decays $B_{b \rightarrow s\gamma}$ (combined experimental result by HFAG [44] and current theoretical predictions [45, 46]) and $B_{B_s \rightarrow \mu\mu}$ (combined limit by CDF and D0 [47]);
- the difference of the measured anomalous magnetic moment of the muon $(g-2)_\mu$ to the prediction of the SM is allowed to be: $(-10 \leq \Delta(g-2)_\mu \leq 40) \cdot 10^{-10}$
- constraints from heavy flavor measurements: $B_{B \rightarrow \tau\nu}$ (combined experimental result by HFAG [44] and theoretical analyses [48, 49]); meson-antimeson constraints on the squark mass spectra and similar constraints on the slepton spectra;

- the WMAP measurement [50] of the relic density by the use of an upper limit on the LSP contribution: $\Omega h^2|_{LSP} \leq 0.1210$
- cross section limits from direct detection dark matter searches by XENON10 [51], CDMS [52], CRESST I [53] and DAMA [54]
- constraints from LEP and LEP II data [55], here especially that there cannot be any new charged sparticles or Higgs boson below the $M_Z/2$ mass and also no new stable particles with masses below 100 GeV, also the lower limit for light squark masses when the gluino is heavier than the squarks by ALEPH [56]
- and finally constraints from Tevatron data, where the limits for squark and gluino masses [57, 58] are generalized to model independent constraints, also applied are the limits on $\tan\beta$ by both CDF and D0 [59] and the lower limits for heavy stable charged particles, here the stronger limit by D0 [60] was applied.

In addition to [30] we have required that the mass splitting between the chargino and the lightest neutralino is $\Delta m > 0.05$ GeV with $\Delta m = m_{\text{Chargino}} - m_{\tilde{\chi}_0}$, to avoid mishandling by PYTHIA. Small mass splittings make charginos stable and PYTHIA yields error messages in the hadronization routines and drops these events. The problem is avoided by a decay of the chargino before the hadronization routine, i.e. by a sufficiently large mass splitting between the chargino and the neutralino. About 1% of the remaining model points could not be generated with PYTHIA due to other compressed mass spectra, i.e. due to very small mass differences between SUSY particles. Here mostly the mass difference of the sbottom or stop to the neutralino was small. These compressed mass spectra lead to long lived squarks which can not be handled by PYTHIA nor by the detector simulation and causes PYTHIA to stop. These model points are dropped. The following studies are therefore not valid if the SUSY model leads to long-lived particles in the spectrum besides the lightest neutralino.

4 Results and discussion

4.1 Models from a linear prior in the SUSY mass scale

For each SUSY model signal events were generated. Each event was analyzed after a detector simulation with DELPHES and the number of signal events was determined for each SUSY model and each of the 8 studied signal regions. In the following we call “excluded models” SUSY models which produced a larger number of signal events than excluded by the ATLAS model-independent limits in at least one of the signal regions studied. The model-independent limits are listed in table 1 and table 2. Only the SUSY models which yield less signal events in all regions are not excluded by these ATLAS searches. These models are called “not excluded models”.

Figure 3 shows the 20000 pMSSM model points from a flat mass prior as a function of the lightest mass of the first and second generation squarks M_{squark} and the mass of the gluino M_{gluino} . The SUSY points which are excluded by ATLAS are indicated by the colour

Model	$m_{\tilde{q}}$	$m_{\tilde{g}}$	$m_{\tilde{\chi}_0}$	σ_{NLO}	$E_{\text{T}}^{\text{miss}}$	m_{eff}	N_{Jets}	$1^{\text{st}} p_{\text{T}}^{\text{jet}}$	$2^{\text{nd}} p_{\text{T}}^{\text{jet}}$	N_{Lep}	$\Delta\phi$
1956	683.7	820.9	127.4	0.4	261.6	999.4	6.5	379.6	235.9	2.2	1.0
2083	672.8	979.8	504.5	0.2	245.4	740.6	4.8	249.7	155.9	0.4	1.2
3226	826.5	645.7	404.3	0.7	179.8	602.3	6.9	212.4	126.3	0.7	1.0

Table 5. Important properties of some not excluded pMSSM models out of 20000 with flat prior. Shown are the mass of the lightest squark in the 1. and 2. generation $m_{\tilde{q}}$; the gluino mass, $m_{\tilde{g}}$; the mass of the lightest neutralino $m_{\tilde{\chi}_0}$; the NLO cross section σ_{NLO} ; the average values of $E_{\text{T}}^{\text{miss}}$; m_{eff} ; the average number of jets N_{Jets} and the average number of leptons N_{Lep} ; $1^{\text{st}} p_{\text{T}}^{\text{jet}}$ and $2^{\text{nd}} p_{\text{T}}^{\text{jet}}$ are the average of the leading and second highest jet p_{T} and $\Delta\phi$ is the average of the $\Delta\phi(\text{jet}_i, E_{\text{T}}^{\text{miss}})_{\text{min}}$ variable.

Figure 3. Exclusion range of the ATLAS SUSY analysis for $L_{\text{int}} = 35 \text{ pb}^{-1}$ and $L_{\text{int}} = 1.04 \text{ fb}^{-1}$ for 20000 randomly generated pMSSM points with flat prior as a function of the lightest mass of the first and second generation squarks and the mass of the gluino. The number of excluded model points for each bin is indicated by the colour scale, not excluded model points are shown as black dots (small triangles).

Figure 4. The fraction of the not excluded SUSY models to the total number of studied SUSY models as a function of the NLO cross section for squark and gluino production processes.

scale, models not excluded as black triangles. We show that 99% of the points are excluded with the current ATLAS analyses in the jets and missing transverse momentum channels. All studied points with a mass of the squarks and the mass of the gluino $< 600 \text{ GeV}$ are

Figure 5. Exclusion range of the ATLAS SUSY analysis for $L_{\text{int}} = 35 \text{ pb}^{-1}$ and $L_{\text{int}} = 1.04 \text{ fb}^{-1}$ for 20000 randomly generated pMSSM points with flat prior as a function of M_{SUSY} and the mass difference of M_{SUSY} and the mass of the lightest neutralino; the number of excluded model points for each bin is indicated by the colour scale (bottom figure), not excluded model points are shown in black. The top figure shows the same, but the excluded model points are shown in green.

excluded. This means that there is not much room anymore in the pMSSM for having both light squarks of the first generations and at the same time a light gluino.

Remarkably, also points with small mass splittings between the squarks or gluino and the neutralino are excluded in this mass range. The reason is quite simple. It is very unlikely that a “random” sampling yields cases where the mass splittings of *all* squarks and the gluino to the neutralino are small. If one of the squarks or only the gluino is a bit heavier than the neutralino such processes yield detectable rates in the ATLAS signal regions. Note that in these models the left and right handed squarks can have quite different masses.

In table 5 a subset of the not excluded model points are presented together with some of their properties. A complete list of all not excluded model points can be found in appendix A.

We found some features why model points are not excluded. We determined average values for some properties for each SUSY model point, neglecting the fact that these values are coming from different SUSY decay chains. The investigated properties of the

non-excluded SUSY models are shown in table 5. The following features have been found to be significant.

Low cross section. A large fraction of model points at high squark and gluino masses cannot be excluded because the cross section is simply too low to be observed for the integrated luminosity. Figure 4 shows the fraction of not-excluded points as a function of the total SUSY squark and gluino cross section. Below 0.1 pb less than 50% of the SUSY models can be excluded with the analysis setup. These are mainly points with a large average effective mass value. At large cross sections of greater 5 pb all studied pMSSM models can be excluded by the ATLAS analyses.

Lepton and multi-jet events (long decay chains). Around 25% of the not excluded model points have a large average number of leptons. In addition we find that these SUSY models do often have a large average number of jets. It is trivial to note that, because of the lepton veto, there is not much sensitivity to these models with the inclusive jets analysis. These points can most likely be excluded with the single or multi-lepton analyses. These searches do have signal regions investigating events with up to 4 jets [61, 62]. Some SUSY models with long decay chains would yield lepton(s) together with multiple jets.

Compressed spectra together with high squark and gluino masses. Figure 5 shows the excluded and non-excluded SUSY models from the grid with the flat prior as a function of M_{SUSY} and the mass difference of M_{SUSY} and the mass of the lightest neutralino. In this note, the SUSY mass scale M_{SUSY} is defined as the minimal mass of all first and second generation squarks and the gluino. The figure shows the interesting feature that the non-excluded points are mostly located at small mass differences (relative to M_{SUSY}) and high M_{SUSY} .

Small mass differences between the colored particles and the neutralino yield events with small transverse momentum jets. Figure 6 shows the average effective mass (calculated with the leading 3 jets) as a function of M_{SUSY} . More than half of the not-excluded SUSY models at high M_{SUSY} have an effective mass that is significantly below the value found for the excluded SUSY models. We conclude that the cut on the effective mass is too harsh for these models. For those compressed models the effective mass is differently correlated with the SUSY mass scale.

A lower cut on the effective mass, however, would cause a significant increase in the number of background events. We therefore studied additional features of these non-excluded models. A comprehensive study yields as the most significant feature a large average value of missing transverse momentum. Figure 7 shows the ratio f of the missing transverse momentum over the effective mass as a function of the effective mass. The not-excluded models at $m_{\text{eff}} < 600$ GeV do have average f -values above 0.3–0.35. It is interesting to note that for higher m_{eff} values smaller cuts on f seem to be appropriate. Increasing the cuts on f for the high m_{eff} regions seems not to yield to an improved performance.

In addition these points do show a typical average jet multiplicity as can be seen in figure 8, also at $m_{\text{eff}} < 600$ GeV. The non-excluded points have jet multiplicities between 2 – 7.

Figure 6. The distribution of M_{SUSY} to the average value of m_{eff} for excluded points (colour scale) and not excluded points (black dots).

Figure 7. The distribution of the average value $E_{\text{T}}^{\text{miss}}/m_{\text{eff}}$ to the average value of m_{eff} for excluded points (colour scale) and not excluded points (black dots).

Figure 8. The distribution of the average value of m_{eff} to the average number of jets for excluded points (colour scale) and not excluded points (black dots).

Figure 9. Exclusion range of the ATLAS analyses corresponding to $L_{\text{int}} = 35 \text{ pb}^{-1}$ and $L_{\text{int}} = 1.04 \text{ fb}^{-1}$ for 1000 randomly generated pMSSM points from a logarithmic prior; excluded model points are shown as green dots, not excluded models as black triangles.

Model	$m_{\tilde{q}}$	$m_{\tilde{g}}$	$m_{\tilde{\chi}_0}$	σ_{NLO}	$E_{\text{T}}^{\text{miss}}$	m_{eff}	N_{Jets}	$1^{\text{st}} p_{\text{T}}^{\text{jet}}$	$2^{\text{nd}} p_{\text{T}}^{\text{jet}}$	N_{Lep}	$\Delta\phi$
70012	881	700	131	0.31	246.2	788.5	8.6	264.5	167.2	1.6	1.1
70334	487	2042	155	0.29	215.5	709.6	5.4	255.2	151.8	0.5	1.1
70560	908	1765	95	0.02	334.6	1269.4	6.2	494.9	319.0	0.6	0.9

Table 6. Important properties of some not excluded pMSSM models out of 1000 with logarithmic prior. Shown are the mass of the lightest squark in the 1. and 2. generation $m_{\tilde{q}}$; the gluino mass, $m_{\tilde{g}}$; the mass of the lightest neutralino $m_{\tilde{\chi}_0}$; the NLO cross section σ_{NLO} ; the average values of $E_{\text{T}}^{\text{miss}}$, m_{eff} , the average number of jets N_{Jets} and the average number of leptons N_{Lep} ; $1^{\text{st}} p_{\text{T}}^{\text{jet}}$ and $2^{\text{nd}} p_{\text{T}}^{\text{jet}}$ are the average of the leading and second highest jet p_{T} and $\Delta\phi$ is the average of the $\Delta\phi(\text{jet}_i, E_{\text{T}}^{\text{miss}})_{\text{min}}$ variable.

In conclusion we propose that ATLAS adds to future analyses signal regions with $f > 0.3 - 0.35$ and a reduced effective mass cut of $m_{\text{eff}} > 500 \text{ GeV}$ for high and low jet multiplicities. A similar conclusion has been found for lower jet multiplicities in an independent study dedicated to compressed spectra [63]. Some of the non-excluded points found in our study could be used as benchmark sets to further optimise the cut values with a detailed ATLAS simulation including background events.

4.2 Models from a logarithmic prior in the SUSY mass scale

Figure 9 shows the result of our analysis of 1000 points made with the logarithmic prior up to 3 TeV in the mass scale of SUSY. Excluded points are shown as green points, not excluded ones as black triangles. Due to possible larger masses of the squarks and gluinos more points survive at higher masses. In total we find that 85% of the model points are excluded.

In table 6 a subset of the not excluded model points are presented together with some of their investigated properties. A complete list of all not excluded model points can be found in appendix A.

Lepton and multi-jet events Again around one quarter of the not excluded model points have an average lepton number exceeding one. These points cannot be excluded

Figure 10. The total NLO squarks and gluino production cross section as a function of the minimal mass of the first and second generation squarks and the gluino m_{SUSY} for excluded model points (green dots) and not excluded models (black triangles). For some high mass model points the cross section is significantly enhanced by sbottom and stop production processes.

because of the lepton veto. As observed for the flat prior grid these model points do also lead to multi-jet events.

Low M_{SUSY} combined with low cross section A new feature is found in the logarithmic grid. Some SUSY models with gluino masses above 1000 GeV and squark masses between 300 – 600 GeV are not excluded. Figure 10 shows the total cross section for squark and gluino production processes as a function of the SUSY mass scale M_{SUSY} . All not-excluded SUSY models with $M_{\text{SUSY}} < 600$ GeV are close to the *minimal* SUSY cross section at a given value of M_{SUSY} . The cross section is minimal since here only the $\tilde{d}_R$ and $\tilde{s}_R$ or the $\tilde{u}_R$ and $\tilde{c}_R$ are light. All other squarks and the gluino have much larger mass values.

These SUSY scenarios might also be missed in future searches, if the cuts on mass scale related variables (as m_{eff}) are raised further. Limits on squark masses derived at a minimum SUSY cross section might be helpful.

Compressed spectra In contrast to the flat-prior model points compressed mass spectra do not seem to be an important issue for the log-prior grid as far as we could infer from only 1000 model points.

5 Summary

We show that the “Search for squarks and gluinos using final states with jets and missing transverse momentum” of the ATLAS experiment excludes up to 99% of the model points of the randomly generated pMSSM grid of “Supersymmetry without Prejudice” assuming a flat prior for a SUSY mass scale below 1 TeV. For the model points assuming a logarithmic prior up to 85% are excluded.

Besides the models with a high average number of leptons, the most frequent reasons for the model points not to be excluded are a too low cross section below the discovery potential, a too low mass splitting between the lightest coloured sparticle and the neutralino

resulting in a low effective mass m_{eff} . We propose to add selections with an increased missing transverse momentum cut and a decreased m_{eff} cut, both with low and high jet multiplicities. In addition we find that the search is quite insensitive if only one type right handed squarks is light, i.e. if the SUSY cross section is smaller than usually assumed. These scenarios might also profit from low mass signal regions with minimal statistical and systematic uncertainties.

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We also thank Ben O’Leary for providing the cross section calculating program.

A Additional tables

Model	$m_{\tilde{q}}$	$m_{\tilde{g}}$	$m_{\tilde{\chi}_0}$	σ_{NLO}	$E_{\text{T}}^{\text{miss}}$	m_{eff}	N_{Jets}	1 st $p_{\text{T}}^{\text{jet}}$	2 nd $p_{\text{T}}^{\text{jet}}$	N_{Lep}	$\Delta\phi$
81	741	913	442	0.31	232.7	692.0	5.8	241.2	139.1	0.5	1.2
155	676	963	232	0.39	262.1	847.6	5.1	296.1	187.2	1.0	1.2
175	629	841	502	0.46	230.4	667.8	4.7	239.4	132.4	0.3	1.2
247	805	890	310	0.23	262.4	861.0	6.4	297.8	188.3	1.6	1.1
638	930	999	145	0.1	351.9	1083.1	6.1	377.4	231.5	1.5	1.1
949	652	991	472	0.4	234.6	678.1	4.0	246.5	139.2	0.2	1.3
965	740	829	232	0.3	281.6	941.7	6.4	336.9	210.2	1.6	1.1
1294	880	782	416	0.29	222.0	719.1	7.0	234.6	153.6	1.0	1.1
1446	601	775	583	1.51	112.1	269.9	2.4	102.7	39.2	0.0	1.6
1956	684	821	127	0.44	261.6	999.4	6.5	379.6	235.9	2.2	1.0
2001	824	910	402	0.2	305.5	891.5	5.2	322.1	180.5	1.2	1.2
2041	566	908	469	1.09	159.5	449.5	3.5	164.0	88.5	0.4	1.4
2083	673	980	504	0.2	245.4	740.6	4.8	249.7	155.9	0.4	1.2
2157	809	872	473	0.19	247.3	733.2	6.6	251.1	143.8	1.0	1.1
2324	566	707	452	1.38	165.0	493.6	4.9	165.0	101.4	0.3	1.3
2409	553	866	485	1.51	132.7	366.2	3.3	132.5	68.7	0.2	1.4
2519	655	911	101	0.4	266.6	860.1	5.9	299.1	182.8	2.3	1.0
2577	839	944	434	0.2	283.1	882.4	6.1	312.3	188.4	0.7	1.1
2953	760	772	456	0.39	236.0	711.5	5.4	245.5	145.1	0.7	1.2
3226	827	646	404	0.73	179.8	602.3	6.9	212.4	126.3	0.7	1.0
3469	714	895	429	0.31	232.2	667.4	5.5	228.6	129.1	0.5	1.2
3666	782	787	520	0.38	183.3	565.1	6.4	192.3	114.7	0.7	1.1
3806	692	860	402	0.37	237.1	700.4	5.4	246.0	139.3	0.8	1.2
3809	724	811	604	0.39	173.9	503.3	4.7	171.6	100.8	0.6	1.3
4072	665	1026	483	0.29	206.6	583.6	4.8	209.8	109.0	2.1	1.2
4125	831	923	334	0.15	302.7	854.7	6.4	284.7	165.6	1.2	1.2
4293	741	968	167	0.23	298.9	961.9	5.7	336.2	210.2	2.1	1.1
4383	584	760	497	1.13	158.6	473.4	4.8	163.3	95.2	0.2	1.2
4570	800	703	509	0.61	194.1	593.6	5.6	201.7	120.9	0.3	1.1
5052	759	842	238	0.39	315.6	993.8	5.6	370.9	216.8	2.1	1.2
5312	558	765	514	1.02	163.5	433.5	3.7	156.7	75.1	0.6	1.3
5325	740	809	542	0.3	238.8	702.8	5.0	242.4	145.5	0.3	1.2
5360	737	938	262	0.39	263.5	835.3	5.3	285.5	181.4	1.4	1.2
5497	855	1005	207	0.11	349.6	1016.7	5.6	368.2	210.6	0.8	1.2
5700	623	899	555	0.71	148.0	405.4	3.5	146.9	74.9	0.1	1.4
5707	618	698	534	0.91	157.6	468.1	5.1	156.6	92.7	0.0	1.2

Model	$m_{\tilde{q}}$	$m_{\tilde{g}}$	$m_{\tilde{\chi}_0}$	σ_{NLO}	$E_{\text{T}}^{\text{miss}}$	m_{eff}	N_{Jets}	1 st $p_{\text{T}}^{\text{jet}}$	2 nd $p_{\text{T}}^{\text{jet}}$	N_{Lep}	$\Delta\phi$
5805	699	916	164	0.45	275.5	860.8	5.8	307.1	180.6	1.6	1.1
6232	786	729	536	0.6	178.3	543.6	5.6	180.2	112.3	0.2	1.2
6333	825	730	456	0.49	177.8	568.0	7.3	203.6	112.7	0.9	1.0
6880	638	993	281	0.46	255.9	741.3	4.6	260.7	148.6	0.8	1.2
7105	632	900	616	0.53	160.4	408.0	2.8	150.5	69.0	0.1	1.5
7426	746	692	523	0.75	169.0	512.6	5.6	174.1	103.3	0.2	1.1
7514	661	871	493	0.52	205.0	596.3	4.4	212.0	120.8	0.3	1.3
7727	534	767	139	1.16	210.9	809.2	6.0	293.1	188.7	2.5	1.0
7736	846	895	227	0.19	303.9	921.0	6.5	309.8	190.1	1.4	1.1
7751	782	903	144	0.23	311.2	1041.0	6.0	381.1	231.4	1.7	1.1
7782	586	860	544	0.87	167.8	443.1	3.2	164.6	79.2	0.1	1.4
7888	631	688	574	1.68	114.1	308.4	3.5	106.5	57.7	0.1	1.4
7944	821	1023	356	0.16	308.3	980.4	5.6	357.0	217.7	1.2	1.1
8034	714	808	520	0.61	198.6	582.7	4.6	202.2	120.6	0.2	1.3
8396	831	977	499	0.17	279.5	819.1	5.0	296.3	170.3	0.4	1.2
8589	767	938	218	0.25	288.3	918.2	6.3	327.4	199.8	1.5	1.1
8686	572	770	554	0.87	164.4	421.8	3.1	153.4	71.5	0.1	1.5
8915	686	878	353	0.31	278.0	795.4	5.0	280.7	157.4	1.5	1.2
8916	784	895	343	0.19	270.7	852.8	6.0	280.0	183.8	1.3	1.1
9396	707	978	538	0.24	235.9	658.1	4.1	238.2	128.0	1.0	1.3
9497	583	960	435	1.18	167.2	482.9	3.9	174.6	96.5	0.5	1.3
9759	669	672	472	1.23	151.3	475.2	5.6	169.8	95.6	0.4	1.0
9781	563	856	507	1.3	134.9	368.5	3.4	132.7	67.1	0.4	1.4
10019	735	694	552	0.82	158.6	461.0	5.2	159.6	88.0	0.4	1.2
10149	768	789	530	0.41	216.7	639.1	4.9	221.3	129.9	0.4	1.2
10312	594	867	525	0.85	157.6	435.1	3.7	157.1	81.0	0.2	1.3
10531	624	892	610	1.01	107.9	253.5	2.2	97.4	35.4	0.0	1.6
10698	832	866	318	0.21	299.9	939.5	5.9	332.3	201.9	1.4	1.1
10923	841	659	542	0.74	173.9	512.1	5.3	180.3	98.8	0.3	1.1
11017	673	843	114	0.45	291.4	942.7	5.9	328.9	205.3	2.1	1.1
11050	662	1006	304	0.26	271.7	785.6	4.9	278.8	154.1	1.1	1.2
12020	583	830	495	1.09	180.3	503.7	3.4	182.4	100.5	0.0	1.4
12077	670	987	107	0.3	305.0	935.7	5.6	340.2	195.3	2.0	1.0
12942	763	986	424	0.2	250.5	789.8	6.1	281.0	167.6	0.5	1.1
13170	811	763	634	0.32	180.6	514.9	4.4	177.5	99.8	0.3	1.3
13187	622	822	437	0.68	192.0	593.8	5.5	208.8	122.5	0.4	1.1
13484	626	758	459	0.75	184.1	573.9	5.3	192.8	121.9	0.3	1.2
13616	647	970	445	0.48	229.2	667.4	3.9	236.7	140.7	0.1	1.4
13634	949	1006	395	0.09	336.8	1024.6	5.8	358.3	220.3	0.5	1.2
13698	721	971	246	0.4	276.3	925.8	5.5	326.4	205.7	1.7	1.1
13900	795	814	491	0.37	234.1	699.3	5.2	247.8	144.4	0.6	1.2
13938	566	800	508	0.64	190.5	546.7	4.5	194.1	104.3	0.7	1.2
14537	825	1026	273	0.14	311.8	918.1	5.4	327.5	184.0	1.0	1.2
14962	796	1016	125	0.18	320.8	1063.5	5.5	383.2	240.5	1.3	1.1
15788	786	894	240	0.34	257.1	807.2	6.0	286.5	171.9	1.2	1.1
15922	882	799	432	0.21	242.3	755.4	7.2	247.5	158.2	0.9	1.1
15940	859	1015	319	0.13	326.6	1030.4	5.8	372.8	226.7	0.7	1.1
15963	739	967	211	0.28	284.8	832.0	5.3	289.1	163.9	1.0	1.2
16092	682	760	454	0.59	212.8	654.0	5.7	224.3	136.0	0.5	1.2
16179	702	899	393	0.29	280.8	848.2	5.2	303.4	177.4	1.7	1.2
16379	812	988	109	0.14	333.3	1137.5	5.7	412.5	263.7	1.9	1.0
16411	754	632	498	0.97	182.7	539.7	5.2	190.6	103.8	0.4	1.1
16467	699	922	466	0.47	235.3	686.3	4.4	243.7	142.3	0.3	1.3
16539	733	1017	138	0.33	281.6	1022.6	5.8	382.3	241.5	2.0	1.0
16699	670	699	520	1.24	145.6	424.0	5.0	147.1	83.7	0.1	1.2
16722	590	945	505	0.59	172.2	474.5	3.9	174.2	86.9	0.2	1.3
17158	825	1003	741	0.19	131.5	365.5	3.6	126.6	72.0	0.2	1.4

Model	$m_{\tilde{q}}$	$m_{\tilde{g}}$	$m_{\tilde{\chi}_0}$	σ_{NLO}	$E_{\text{T}}^{\text{miss}}$	m_{eff}	N_{Jets}	1 st $p_{\text{T}}^{\text{jet}}$	2 nd $p_{\text{T}}^{\text{jet}}$	N_{Lep}	$\Delta\phi$
17174	882	919	98	0.17	331.6	1117.8	6.4	410.0	253.1	1.1	1.1
17262	863	807	397	0.23	246.0	752.8	7.6	239.3	156.2	1.0	1.1
17559	820	712	548	0.53	173.7	531.0	5.7	178.3	107.6	0.4	1.1
17632	971	927	249	0.14	328.7	975.1	6.6	344.3	204.3	0.8	1.2
17767	659	844	492	0.4	182.6	556.8	6.1	197.5	108.9	0.5	1.1
18551	737	1010	190	0.19	316.5	1113.0	6.2	417.2	260.9	1.4	1.0
18564	1009	1018	234	0.07	413.2	1130.7	5.4	412.4	229.6	1.0	1.2
18884	802	1003	70	0.13	350.4	1076.5	6.1	400.0	233.0	1.0	1.1
18895	569	947	225	0.4	282.4	929.8	5.4	347.8	203.9	2.7	1.1
19016	776	706	538	0.61	171.4	523.7	5.8	174.9	106.4	0.3	1.1
19229	613	679	316	0.84	212.9	631.6	6.1	221.2	122.1	2.0	1.0
19367	696	1006	403	0.33	251.2	772.1	5.1	278.8	162.1	0.4	1.2
19707	789	845	340	0.26	251.8	779.2	6.6	264.2	160.6	0.8	1.1
19740	578	1011	480	0.96	163.1	457.4	3.2	169.6	91.3	0.0	1.4
19750	731	785	475	0.5	223.0	669.5	5.0	233.2	139.8	0.4	1.2

Table 7: Important properties of all not excluded pMSSM models with *flat prior*. Masses and energies are given in GeV, the cross section is given in *pb*, except masses and cross sections all values are average values.

Model	$m_{\tilde{q}}$	$m_{\tilde{g}}$	$m_{\tilde{\chi}_0}$	σ_{NLO}	$E_{\text{T}}^{\text{miss}}$	m_{eff}	N_{Jets}	1 st $p_{\text{T}}^{\text{jet}}$	2 nd $p_{\text{T}}^{\text{jet}}$	N_{Lep}	$\Delta\phi$
70002	1119	1189	217	0.01	391.8	1196.1	7.4	440.1	271.8	1.2	1.2
70007	1319	1805	136	0	390.6	1476.5	6.6	610.7	409.3	2.6	1.0
70012	881	700	131	0.31	246.2	788.5	8.6	264.5	167.2	1.6	1.1
70014	1148	887	46	0.05	264.2	1059.0	10.7	381.4	252.8	1.6	0.9
70017	924	1344	210	0.04	499.2	1301.7	3.9	509.0	300.6	0.2	1.5
70018	2079	1004	354	0.01	302.4	907.6	8.4	300.4	189.3	1.3	1.2
70020	835	2348	128	0.02	386.5	1277.2	5.7	522.7	313.9	0.5	0.9
70024	1164	1079	38	0.04	161.0	711.4	7.6	264.3	173.1	1.1	0.9
70043	799	2322	110	0.03	386.4	1328.5	5.6	522.0	328.9	0.5	1.0
70045	647	1163	122	0.18	286.1	987.3	5.5	366.0	229.8	0.5	1.1
70062	889	707	382	0.3	219.2	734.7	6.1	250.8	161.4	0.8	1.1
70076	405	1367	362	1.19	94.6	244.7	2.6	92.7	42.5	0.0	1.5
70084	546	2800	156	0.32	235.9	795.1	5.1	294.4	180.4	1.4	1.1
70103	858	2748	76	0.08	195.9	556.3	5.7	179.1	109.6	0.7	1.3
70112	849	845	130	0.11	301.3	982.2	7.7	338.2	212.8	1.2	1.1
70128	1023	1005	91	0.09	415.4	1354.2	6.1	510.3	323.6	0.8	1.0
70132	910	2102	98	0.03	443.3	1304.8	4.4	503.9	304.0	0.3	1.1
70143	480	1324	187	0.67	172.8	607.3	5.3	225.3	135.7	0.5	1.1
70148	1182	1945	102	0.01	528.3	1505.7	5.2	638.2	403.5	0.6	1.0
70158	1283	847	211	0.04	305.1	935.3	8.4	317.1	196.4	1.2	1.2
70164	471	2636	345	0.33	123.7	338.6	2.9	131.5	65.7	0.3	1.4
70165	834	791	86	0.19	286.5	967.2	8.0	356.5	207.2	1.2	1.0
70168	808	1585	153	0.05	270.7	800.2	5.1	286.0	170.9	0.6	1.3
70169	862	1243	183	0.04	421.3	1290.6	5.4	504.6	307.4	0.4	1.1
70173	1282	1252	141	0.01	430.2	1503.7	6.9	587.3	392.2	1.0	1.0
70177	611	1283	133	0.16	288.8	952.3	5.5	357.3	210.9	0.5	1.1
70179	1571	1683	43	0.01	224.8	779.1	7.4	264.7	174.7	1.1	1.1
70183	648	1428	114	0.12	284.0	1017.2	5.3	396.8	239.8	0.5	0.9
70185	1313	737	244	0.12	228.1	749.2	8.3	253.9	159.4	1.2	1.1
70196	1001	996	148	0.02	364.6	1130.8	8.3	394.0	238.1	1.7	1.2
70199	387	1803	150	1.12	150.9	463.3	4.2	169.9	94.6	0.9	1.2
70201	463	1492	182	0.47	207.5	602.7	4.3	232.6	114.6	1.9	1.1
70202	946	1154	253	0.04	475.9	1285.4	4.1	479.5	282.7	0.2	1.5

Model	$m_{\tilde{q}}$	$m_{\tilde{g}}$	$m_{\tilde{\chi}_0}$	σ_{NLO}	$E_{\text{T}}^{\text{miss}}$	m_{eff}	N_{Jets}	1 st $p_{\text{T}}^{\text{jet}}$	2 nd $p_{\text{T}}^{\text{jet}}$	N_{Lep}	$\Delta\phi$
70205	1071	1271	237	0.01	553.3	1441.7	5.5	548.0	340.1	0.3	1.3
70206	840	1225	131	0.07	316.1	1153.7	6.3	444.0	278.6	0.7	0.9
70219	934	2407	142	0.02	333.6	1237.3	5.5	485.3	304.0	1.8	1.0
70237	1066	1039	471	0.02	302.9	943.1	7.7	307.2	200.5	1.0	1.2
70239	668	1921	148	0.06	300.0	1075.1	6.0	424.3	255.4	0.6	0.9
70248	608	2602	108	0.11	225.0	786.7	6.6	274.7	180.2	0.7	1.0
70276	873	1473	167	0.03	406.2	1371.0	6.2	545.6	339.3	0.6	0.9
70277	1375	2183	121	0	498.6	1592.5	5.8	741.7	493.4	2.0	0.9
70279	330	2107	155	2.35	158.6	471.4	3.3	177.4	101.7	0.1	1.4
70281	1417	659	37	0.28	187.0	721.5	8.9	252.9	165.7	1.5	1.0
70301	734	2135	142	0.04	402.7	1186.3	5.3	470.7	250.2	2.2	1.1
70302	1272	919	138	0.19	178.6	633.8	7.5	225.0	141.0	1.1	1.1
70303	518	1257	387	0.44	176.9	511.8	3.4	191.0	105.1	0.1	1.4
70306	863	913	66	0.12	369.3	1193.8	6.9	433.4	267.3	1.0	1.1
70313	968	2166	105	0.01	532.5	1369.2	3.5	546.3	323.1	0.1	1.5
70315	369	2010	127	1.44	162.9	540.3	4.6	197.6	116.5	0.7	1.1
70317	869	940	56	0.08	391.8	1162.0	6.0	427.6	251.8	1.0	1.2
70318	705	1244	143	1.33	140.9	415.7	3.6	148.5	87.4	0.4	1.4
70326	1269	886	136	0.07	317.9	1187.9	7.8	404.5	284.4	1.2	1.0
70334	487	2042	155	0.29	215.5	709.6	5.4	255.2	151.8	0.5	1.1
70335	803	2553	173	0.04	307.4	1093.2	6.2	432.9	263.0	0.6	0.9
70351	1256	2541	329	0	515.1	1452.9	5.6	591.2	364.0	0.5	1.0
70353	311	2884	121	3.19	132.1	413.4	4.0	151.9	87.5	0.3	1.2
70360	1504	743	178	0.1	264.1	885.6	7.0	303.4	194.6	1.1	1.1
70367	1312	948	175	0.11	306.0	1239.3	7.5	432.7	305.9	1.2	1.0
70391	1515	1469	180	0	526.6	1438.8	8.5	582.2	346.1	1.3	1.1
70393	1275	1844	294	0	521.6	1379.2	5.9	595.4	376.8	1.0	1.1
70403	972	1694	108	0.38	174.3	508.9	4.3	183.7	106.9	0.5	1.3
70418	309	2062	121	3.03	116.7	417.1	4.5	157.0	96.8	0.4	1.0
70452	1906	1496	271	0	220.6	693.9	6.9	239.1	149.0	0.9	1.1
70454	1146	1971	150	0.01	597.1	1454.6	3.9	604.5	368.0	0.2	1.4
70455	474	1769	103	0.36	200.9	734.7	5.2	292.3	177.2	0.4	0.9
70467	1242	710	126	0.16	188.8	708.2	9.9	245.8	160.3	1.5	1.0
70489	714	1894	269	0.09	290.5	911.1	4.8	343.8	201.5	0.3	1.2
70494	609	1526	361	0.16	268.6	791.3	4.9	305.6	160.7	0.4	1.1
70497	702	1470	250	0.12	311.5	964.2	5.8	334.6	205.6	0.6	1.2
70505	1543	1697	162	0.04	229.9	642.7	4.7	225.3	131.5	0.6	1.4
70506	663	1317	316	0.14	313.5	919.4	4.0	337.8	201.1	0.2	1.4
70511	1157	2643	112	0	384.7	1443.0	5.5	596.0	390.0	2.3	1.0
70513	1499	1879	147	0.05	528.1	1590.3	6.3	757.3	515.7	2.1	0.9
70522	2019	1651	77	0	550.3	1629.3	8.0	657.7	468.8	1.5	1.1
70524	1180	726	331	0.15	222.1	732.1	8.0	252.7	153.4	1.1	1.1
70530	1540	2683	45	0	679.1	1520.6	3.7	726.4	456.1	0.2	1.6
70531	875	1078	33	0.04	468.7	1345.1	4.6	503.6	309.0	0.2	1.3
70533	1053	1294	78	0.02	580.0	1421.7	3.8	577.4	342.3	0.1	1.5
70553	912	2456	306	0.02	454.5	1229.3	3.5	470.3	275.3	0.1	1.5
70560	908	1765	95	0.02	334.6	1269.4	6.2	494.9	319.0	0.6	0.9
70574	2086	2107	131	0	684.0	1654.9	6.0	879.4	609.8	0.8	0.9
70576	1125	970	55	0.04	210.9	919.0	10.4	329.7	222.3	1.6	0.9
70584	635	1928	197	0.09	326.8	1078.1	5.7	426.9	248.1	0.6	0.9
70596	1112	993	52	0.03	287.6	1061.9	9.5	378.9	246.2	1.7	1.0
70598	444	1747	200	0.64	196.0	608.4	4.0	234.4	133.7	0.3	1.2
70606	313	2280	182	2.86	130.8	383.7	2.7	154.0	82.7	0.0	1.5
70607	819	2817	136	0.06	347.7	1172.9	5.4	455.8	278.3	0.5	1.0
70610	429	1789	155	0.6	190.6	606.6	3.9	234.2	135.1	0.2	1.2
70613	826	742	295	0.2	243.0	805.7	8.0	276.2	172.4	1.1	1.1
70624	652	2037	238	0.32	162.1	478.2	4.3	167.4	97.9	0.5	1.4

Model	$m_{\tilde{q}}$	$m_{\tilde{g}}$	$m_{\tilde{\chi}_0}$	σ_{NLO}	$E_{\text{T}}^{\text{miss}}$	m_{eff}	N_{Jets}	1 st $p_{\text{T}}^{\text{jet}}$	2 nd $p_{\text{T}}^{\text{jet}}$	N_{Lep}	$\Delta\phi$
70656	745	1226	108	0.1	321.4	1118.4	6.0	426.8	271.8	0.6	1.0
70667	794	830	209	0.21	272.4	990.8	6.6	360.1	231.3	0.9	1.0
70684	987	2284	134	0.1	212.6	594.7	5.6	194.2	115.7	0.7	1.4
70685	817	1669	105	0.05	287.7	1101.8	6.2	417.6	271.6	0.6	0.9
70688	1023	748	43	0.13	217.0	756.7	9.5	252.9	166.2	1.7	1.0
70695	1250	822	322	0.31	127.2	337.6	3.5	119.2	59.6	0.3	1.4
70707	608	2579	130	0.12	259.0	853.7	5.1	311.5	189.6	1.4	1.1
70717	1085	2139	230	0	531.3	1341.6	4.5	533.2	295.7	0.4	1.3
70727	1001	785	45	0.11	269.8	912.3	9.3	311.5	197.9	1.2	1.0
70735	839	965	173	0.15	315.7	1132.6	6.4	425.2	270.3	0.8	1.0
70737	699	1147	128	0.14	247.8	972.3	6.3	363.7	234.1	2.4	1.0
70739	319	2299	217	2.79	115.1	327.0	3.1	122.2	64.8	0.2	1.4
70741	363	2088	338	1.5	99.1	240.5	2.4	88.4	37.4	0.1	1.6
70744	842	1903	57	0.02	464.4	1267.4	4.4	514.0	304.1	0.3	1.2
70752	1786	2581	105	0.01	568.9	1479.9	6.3	638.8	407.7	1.1	1.1
70762	824	1520	399	0.08	340.9	945.7	3.5	353.5	203.2	0.1	1.5
70765	959	1350	185	0.05	341.2	1214.5	5.9	451.8	289.2	2.0	1.1
70770	2053	885	266	0.02	262.5	854.1	8.4	288.4	182.8	1.2	1.1
70778	995	1140	67	0.02	357.8	1378.5	6.4	535.5	349.7	0.6	0.9
70794	577	2811	48	0.16	284.4	981.7	5.1	376.8	232.1	0.5	1.1
70799	738	1571	115	0.04	411.2	1150.6	3.8	440.5	262.2	0.2	1.4
70811	1000	1103	139	0.07	405.2	1065.9	5.5	406.6	237.6	0.6	1.3
70817	1454	1860	117	0	448.8	1282.9	6.3	486.5	318.8	1.2	1.2
70831	1629	1459	265	0.09	215.8	662.6	6.8	237.1	145.9	0.9	1.1
70832	1530	797	113	0.06	279.7	897.9	8.6	313.2	189.7	1.3	1.1
70842	387	1636	236	2.19	143.1	419.3	3.3	157.8	86.8	0.2	1.4
70845	1345	1996	159	0	567.3	1496.8	5.4	626.2	419.6	0.6	1.2
70852	1018	1454	112	0.03	284.8	805.7	6.1	302.2	187.6	0.8	1.3
70862	986	1946	137	0.15	193.1	539.1	5.4	190.6	115.6	0.6	1.2
70863	652	1618	115	0.08	311.2	1009.4	5.2	391.1	231.4	0.6	1.0
70868	2030	2352	185	0	645.6	1484.8	6.0	696.5	445.7	0.9	1.3
70869	1120	748	119	0.59	165.8	626.5	7.4	221.0	144.2	1.0	1.0
70883	777	2806	129	0.04	303.6	1078.5	5.9	391.7	253.6	0.6	1.1
70887	1016	2594	37	0	583.7	1457.8	3.8	647.4	407.5	0.1	1.4
70890	1172	2078	125	0.01	474.9	1487.5	5.3	620.1	393.7	1.3	1.0
70923	499	1601	122	0.37	205.4	676.8	5.2	252.4	150.0	0.5	1.1
70926	1400	1951	157	0	400.6	1194.9	6.9	447.0	263.5	1.5	1.1
70928	1020	772	117	0.13	302.7	947.2	8.7	322.0	198.5	1.3	1.1
70929	1056	1530	228	0.01	381.5	1116.9	5.2	432.9	268.3	1.1	1.2
70936	943	2532	173	0.01	380.1	1269.1	6.1	503.5	318.8	0.6	1.0
70939	1107	1789	39	0	586.7	1462.7	4.0	612.8	376.5	0.2	1.4
70942	1115	1041	36	0.01	268.5	1065.7	9.5	380.9	251.8	1.6	0.9
70969	1788	1430	215	0	410.4	1088.0	6.9	370.2	232.9	1.0	1.4
70970	379	1975	121	1.08	140.6	480.8	5.1	170.2	106.0	0.5	1.1
70978	779	1935	227	0.02	323.7	906.0	5.5	323.5	184.8	0.5	1.2
70979	1855	1805	75	0	430.5	1112.2	5.5	414.3	246.6	1.0	1.4
70989	1674	1156	209	0.01	265.0	811.4	6.7	288.1	173.4	1.1	1.2
70993	1047	1267	189	0.01	533.6	1459.8	5.3	564.8	355.5	0.2	1.3

Table 8: Important properties of all not excluded pMSSM models with *log prior*. Masses and energies are given in GeV, the cross section is given in *pb*, except masses and cross sections all values are average values. A cross section of 0 indicates a value smaller than 0.001 pb.

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