The “soft SUSY breaking” MSSM R-parity conserving Lagrangian:

$$
\begin{aligned}
-\mathcal{L}_{soft} \; = \; & m_1^2 \mid H_1 \mid^2 + m_2^2 \mid H_2 \mid^2 - B\mu\epsilon_{ij}(H_1^i H_2^j + \mathrm{h.c.}) + \tilde{M}_Q^2(\tilde{u}_L^* \tilde{u}_L + \tilde{d}_L^* \tilde{d}_L) \\
& + \tilde{M}_u^2 \tilde{u}_R^* \tilde{u}_R + \tilde{M}_d^2 \tilde{d}_R^* \tilde{d}_R + \tilde{M}_L^2(\tilde{e}_L^* \tilde{e}_L + \tilde{\nu}_L^* \tilde{\nu}_L) + \tilde{M}_e^2 \tilde{e}_R^* \tilde{e}_R \\
& + \frac{1}{2}\left[M_3 \bar{\tilde{g}} \tilde{g} + M_2 \overline{\tilde{\omega}_i} \tilde{\omega}_i + M_1 \bar{\tilde{b}} \tilde{b}\right] + \frac{g}{\sqrt{2} M_W} \epsilon_{ij} \left[\frac{M_d}{\cos\beta} A_d H_1^i \tilde{Q}^j \tilde{d}_R^* \right. \\
& \left. + \frac{M_u}{\sin\beta} A_u H_2^j \tilde{Q}^i \tilde{u}_R^* + \frac{M_e}{\cos\beta} A_e H_1^i \tilde{L}^j \tilde{e}_R^* + \mathrm{h.c.}\right] \quad .
\end{aligned}
$$

$$
\tilde{Q} = \begin{pmatrix} \tilde{u}_L \\ \tilde{d}_L \end{pmatrix} \qquad \qquad \tilde{L} = \begin{pmatrix} \tilde{\nu}_L \\ \tilde{e}_L \end{pmatrix}
$$

The “soft SUSY breaking” MSSM Lagrangian:

$$
\begin{aligned}
-\mathcal{L}_{soft} \;=\; & m_1^2 \mid H_1 \mid^2 + m_2^2 \mid H_2 \mid^2 - B\mu\epsilon_{ij}(H_1^i H_2^j + \text{h.c.}) + \tilde{M}_Q^2(\tilde{u}_L^* \tilde{u}_L + \tilde{d}_L^* \tilde{d}_L) \\
& + \tilde{M}_u^2 \tilde{u}_R^* \tilde{u}_R + \tilde{M}_d^2 \tilde{d}_R^* \tilde{d}_R + \tilde{M}_L^2(\tilde{e}_L^* \tilde{e}_L + \tilde{\nu}_L^* \tilde{\nu}_L) + \tilde{M}_e^2 \tilde{e}_R^* \tilde{e}_R \\
& + \frac{1}{2}\left[M_3 \bar{\tilde{g}}\tilde{g} + M_2 \overline{\tilde{\omega}_i}\tilde{\omega}_i + M_1 \bar{\tilde{b}}\tilde{b}\right] + \frac{g}{\sqrt{2}M_W}\epsilon_{ij}\Big[\frac{M_d}{\cos\beta} A_d H_1^i \tilde{Q}^j \tilde{d}_R^* \\
& + \frac{M_u}{\sin\beta} A_u H_2^j \tilde{Q}^i \tilde{u}_R^* + \frac{M_e}{\cos\beta} A_e H_1^i \tilde{L}^j \tilde{e}_R^* + \text{h.c.}\Big] \quad .
\end{aligned}
$$

Gaugino’s and their masses M_3, M_2, M_1

The “soft SUSY breaking” MSSM Lagrangian:

$$
\begin{aligned}
-\mathcal{L}_{soft} \;=\;& m_1^2 \mid H_1 \mid^2 + m_2^2 \mid H_2 \mid^2 - B\mu\epsilon_{ij}(H_1^i H_2^j + \mathrm{h.c.}) + \tilde{M}_Q^2(\tilde{u}_L^*\tilde{u}_L + \tilde{d}_L^*\tilde{d}_L) \\
& + M_u^2\tilde{u}_R^*\tilde{u}_R + \tilde{M}_d^2\tilde{d}_R^*\tilde{d}_R + \tilde{M}_L^2(\tilde{e}_L^*\tilde{e}_L + \tilde{\nu}_L^*\tilde{\nu}_L) + \tilde{M}_e^2\tilde{e}_R^*\tilde{e}_R \\
& + \frac{1}{2}\left[M_3\bar{\tilde{g}}\tilde{g} + M_2\overline{\tilde{\omega}_i}\tilde{\omega}_i + M_1\bar{\tilde{b}}\tilde{b}\right] + \frac{g}{\sqrt{2}M_W}\epsilon_{ij}\left[\frac{M_d}{\cos\beta}A_d H_1^i\tilde{Q}^j\tilde{d}_R^*\right. \\
& \left. + \frac{M_u}{\sin\beta}A_u H_2^j\tilde{Q}^i\tilde{u}_R^* + \frac{M_e}{\cos\beta}A_e H_1^i\tilde{L}^j\tilde{e}_R^* + \mathrm{h.c.}\right] \quad .
\end{aligned}
$$

Squarks and sleptons, and their mass terms

The "soft SUSY breaking" MSSM Lagrangian:

$$\begin{aligned}
-\mathcal{L}_{soft} \;=\; & m_1^2 \mid H_1 \mid^2 + m_2^2 \mid H_2 \mid^2 - B\mu\epsilon_{ij}(H_1^i H_2^j + \text{h.c.}) + \tilde{M}_Q^2(\tilde{u}_L^* \tilde{u}_L + \tilde{d}_L^* \tilde{d}_L) \\
& + \tilde{M}_u^2 \tilde{u}_R^* \tilde{u}_R + \tilde{M}_d^2 \tilde{d}_R^* \tilde{d}_R + \tilde{M}_L^2(\tilde{e}_L^* \tilde{e}_L + \tilde{\nu}_L^* \tilde{\nu}_L) + \tilde{M}_e^2 \tilde{e}_R^* \tilde{e}_R \\
& + \frac{1}{2}\left[M_3 \bar{\tilde{g}}\tilde{g} + M_2 \bar{\tilde{\omega}}_i \tilde{\omega}_i + M_1 \bar{\tilde{b}}\tilde{b}\right] + \frac{g}{\sqrt{2}M_W}\epsilon_{ij}\Big[\frac{M_d}{\cos\beta} \boxed{A_d H_1^i \tilde{Q}^j \tilde{d}_R^*} \\
& + \frac{M_u}{\sin\beta} \boxed{A_u H_2^j \tilde{Q}^i \tilde{u}_R^*} + \frac{M_e}{\cos\beta} \boxed{A_e H_1^i \tilde{L}^j \tilde{e}_R^*} + \text{h.c.}\Big] \quad .
\end{aligned}$$

Tri-linear couplings A = Yukawa couplings

Also contribute to squark/slepton masses

The “soft SUSY breaking” MSSM Lagrangian:

$$
\begin{aligned}
-\mathcal{L}_{soft} \; = \; & \boxed{m_1^2 \mid H_1 \mid^2 + m_2^2 \mid H_2 \mid^2 - B\mu\epsilon_{ij}(H_1^i H_2^j + \text{h.c.})} + \tilde{M}_Q^2(\tilde{u}_L^* \tilde{u}_L + \tilde{d}_L^* \tilde{d}_L) \\
& + \tilde{M}_u^2 \tilde{u}_R^* \tilde{u}_R + \tilde{M}_d^2 \tilde{d}_R^* \tilde{d}_R + \tilde{M}_L^2(\tilde{e}_L^* \tilde{e}_L + \tilde{\nu}_L^* \tilde{\nu}_L) + \tilde{M}_e^2 \tilde{e}_R^* \tilde{e}_R \\
& + \frac{1}{2}\left[M_3 \bar{\tilde{g}}\tilde{g} + M_2 \bar{\tilde{\omega}}_i \tilde{\omega}_i + M_1 \bar{\tilde{b}}\tilde{b}\right] + \frac{g}{\sqrt{2}M_W}\epsilon_{ij}\left[\underline{\frac{M_d}{\cos\beta}} A_d H_1^i \tilde{Q}^j \tilde{d}_R^* \right. \\
& \left. + \underline{\frac{M_u}{\sin\beta}} A_u H_2^j \tilde{Q}^i \tilde{u}_R^* + \underline{\frac{M_e}{\cos\beta}} A_e H_1^i \tilde{L}^j \tilde{e}_R^* + \text{h.c.}\right] .
\end{aligned}
$$

Higgs sector: 2 complex doublets (1 for u-type, 1 for d-type)

Both have different expectation values: v_1 and v_2.

$v_1^2 + v_2^2 = 246$ GeV, but ratio is a free parameter: $\tan\beta = v_2/v_1$

Higgs bosons get mass from m_i and from μ

B: bilinear interaction

In SUSY GUTs, parameters unify at 10^{16} GeV:

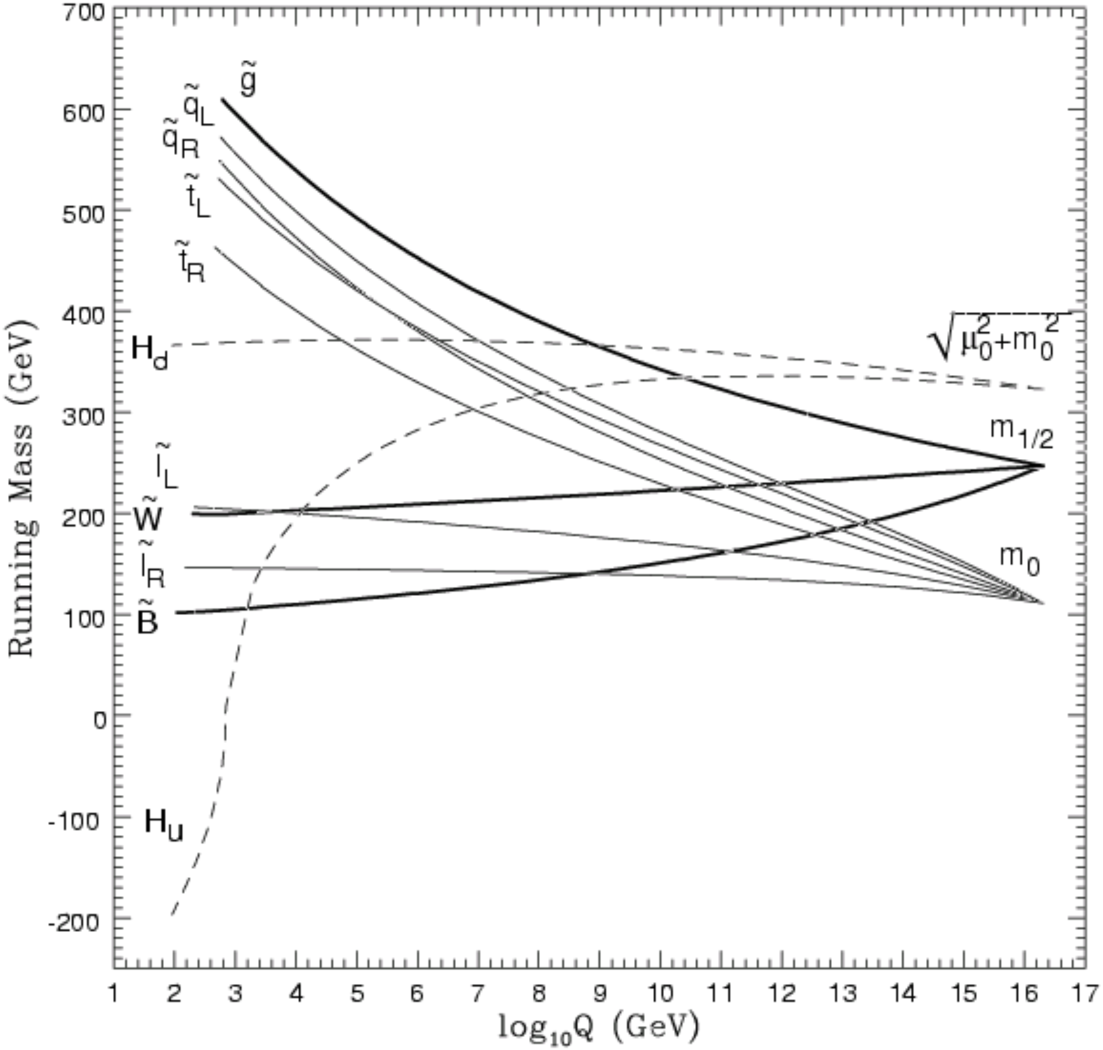
→Common scalar mass m_0 (all squarks and sleptons)
→Common gaugino mass $m_{1/2}$ (all gauginos)
→Common trilinear coupling parameter A_0 (Yukawa)

And then only parameters left: tan β and sign(μ)

→ Constrained MSSM: 4 parameters plus a sign
(CMSSM, or MSUGRA)

(Variations on this theme (since case for m_0 not so strong):
- non-universal Higgs mass models
- $m_0 >> m_{1/2}$: “split supersymmetry”)

Fixing parameters at 10^{16} GeV, the renormalization group equations will tell you exactly all masses at LHC!



Example:

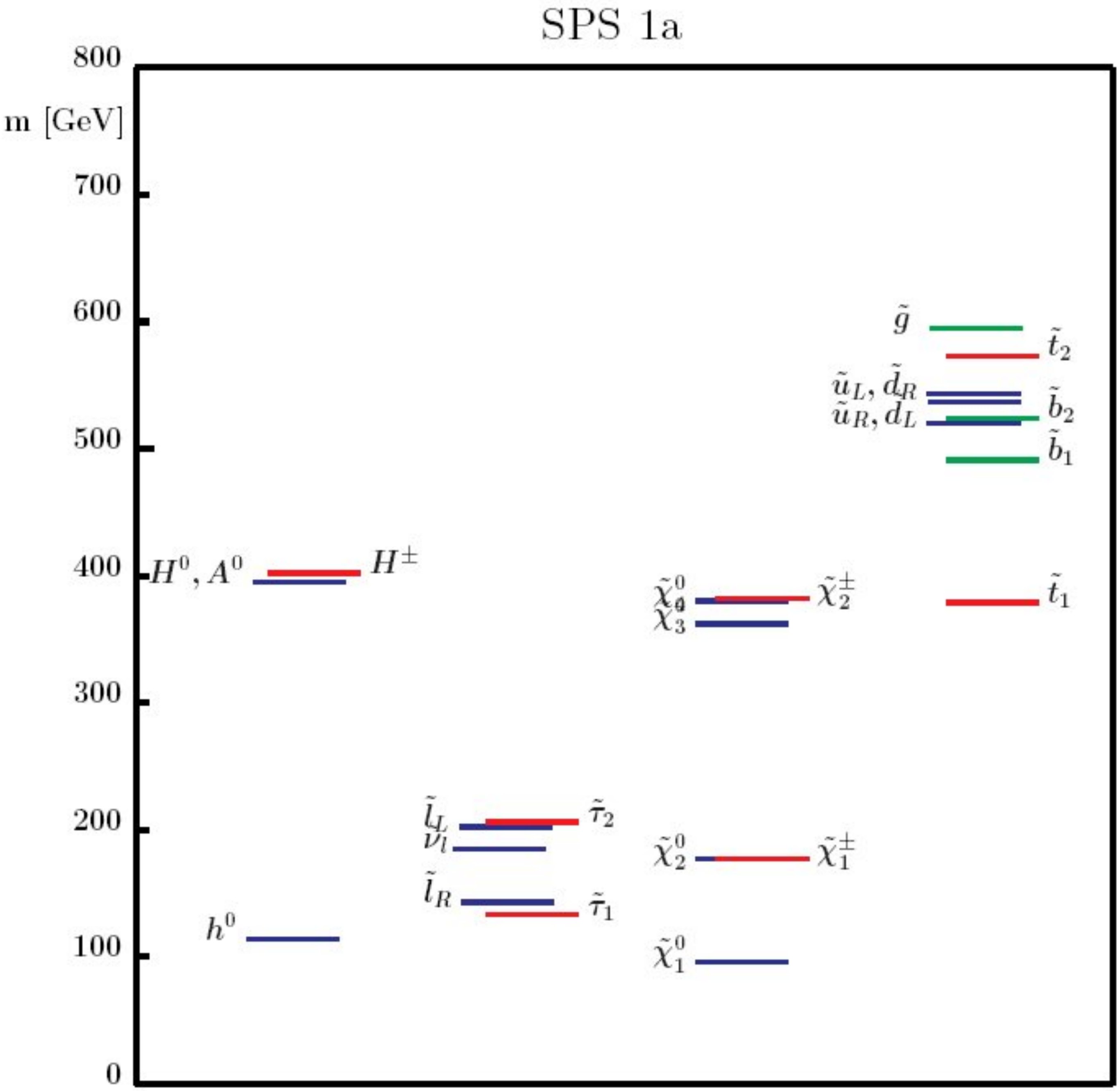
m_0 = 100 GeV

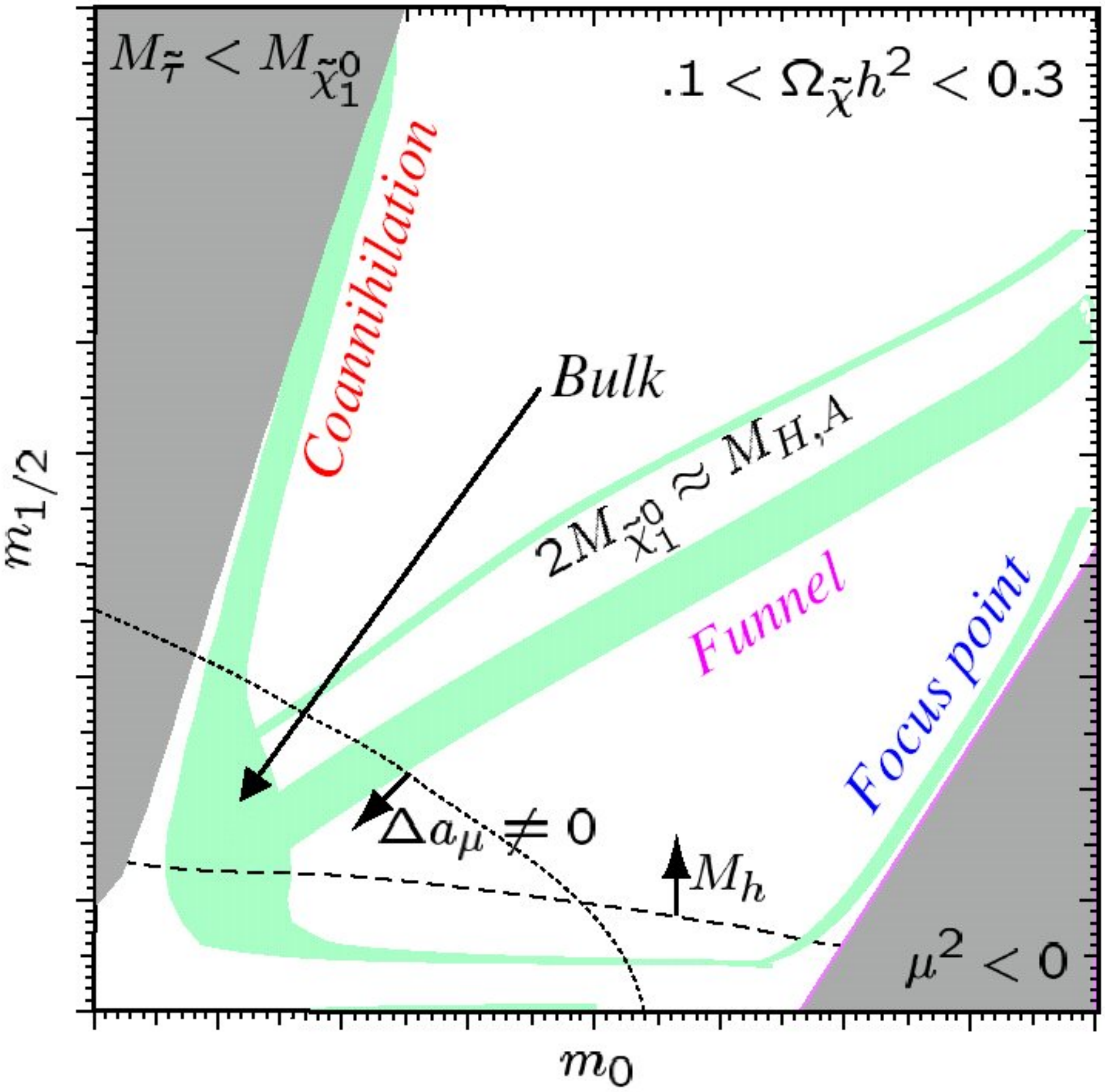
$m_{1/2}$ = 250 GeV

A_0 = -100 GeV

tan β = 10

μ > 0



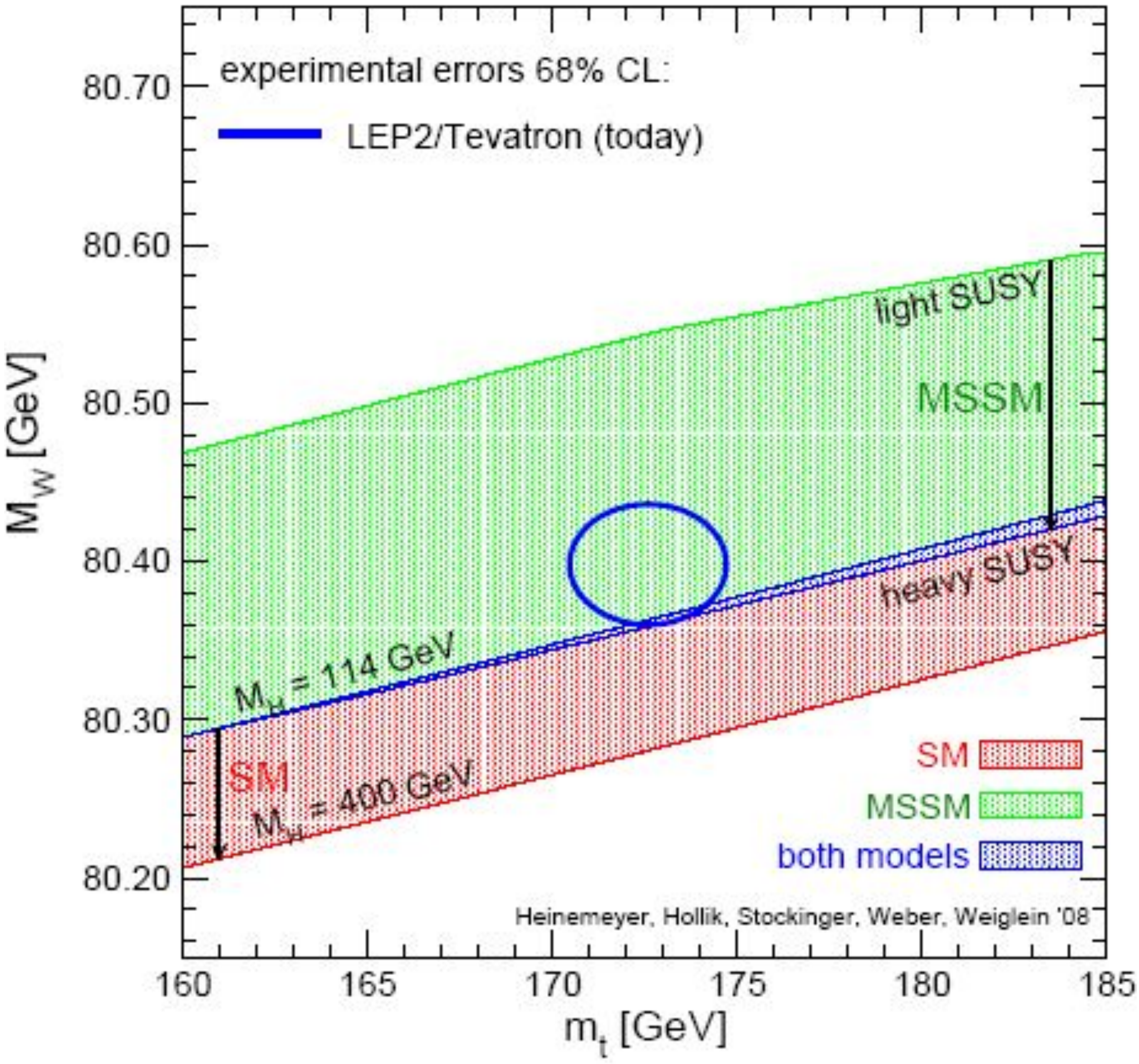


Often shown:
$m_{1/2}$ – m_0 plane

(for given A_0, tan β)

Not every combination is allowed!

Electroweak observables: top vs W mass



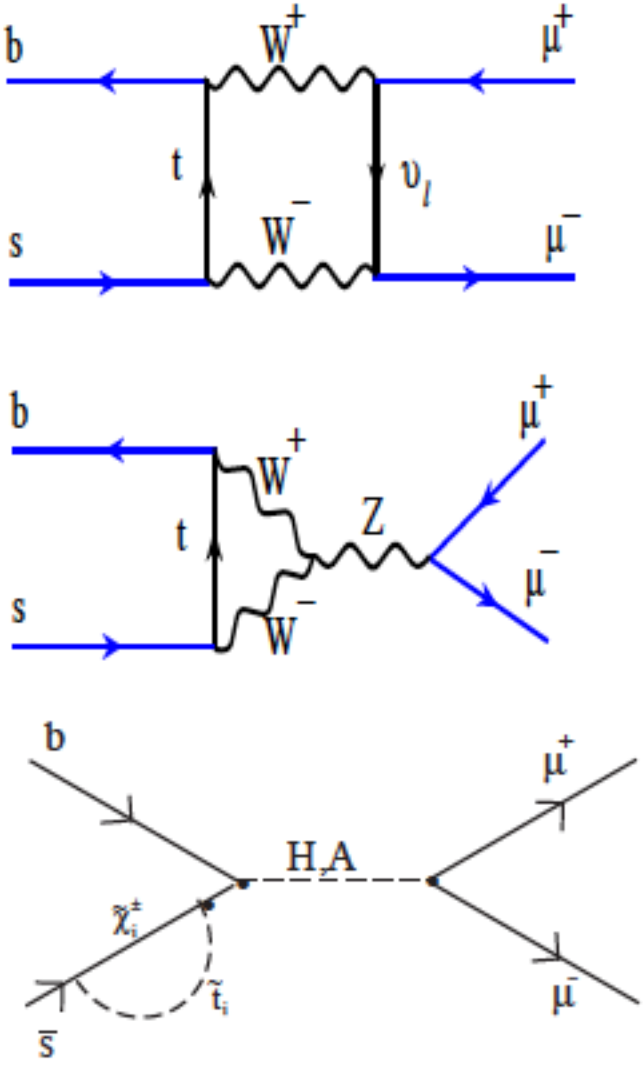
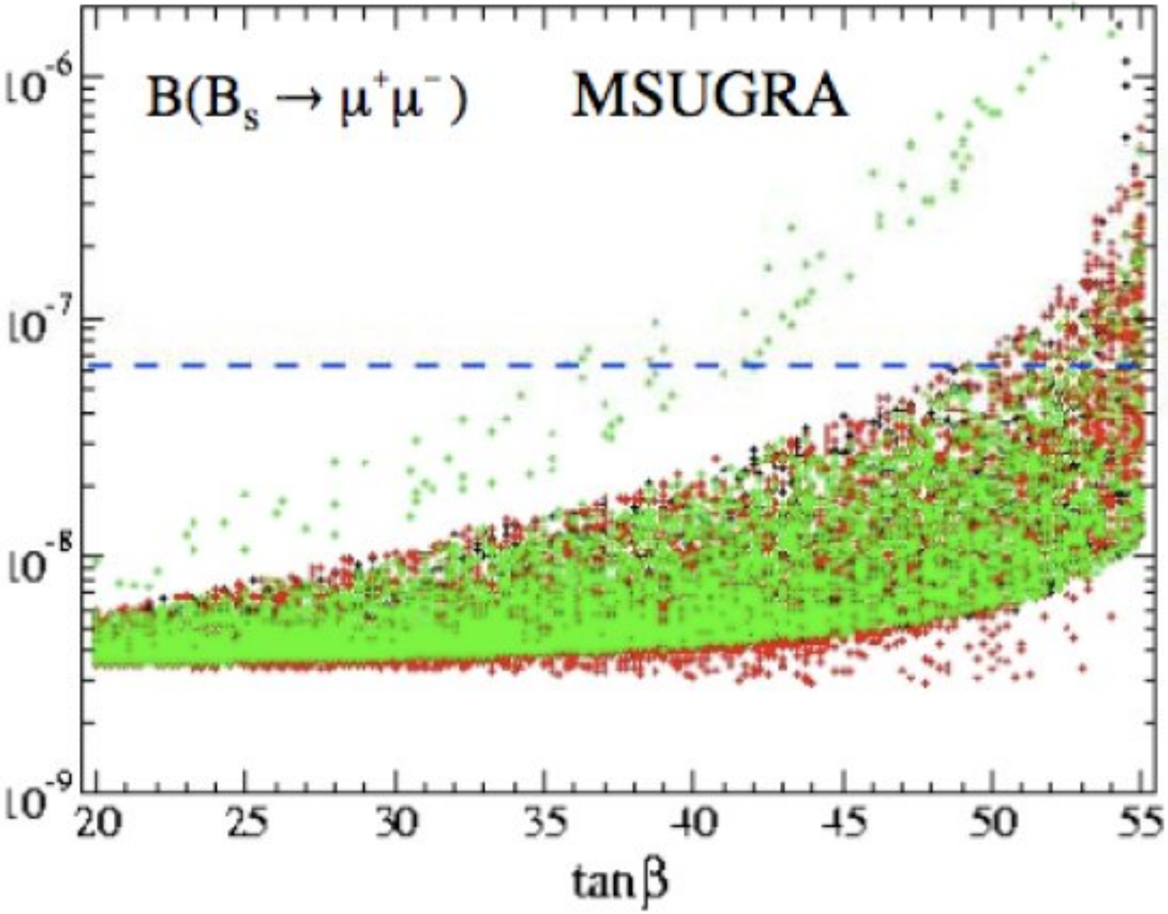


Figure 14. The diagrams contributing to $B_s \to \mu\mu$ decay in the SM and in the MSSM.

SUSY can have effects on low-energy precision observables

Branching of $B_S \rightarrow \mu\mu$



SM prediction: $Br(B_s \rightarrow \mu\mu) = (3.65 \pm 0.23) \times 10^{-9}$

Measurement: $Br(B_s \rightarrow \mu\mu) = (3.0 \pm 0.7) \times 10^{-9}$

ATLAS plots on next slides are taken from JHEP 1510 (2015) 134

Take general SUSY Lagrangian, set all parameters with anomalous CP violation and FCNC to zero ("Miminal Flavour Violation")

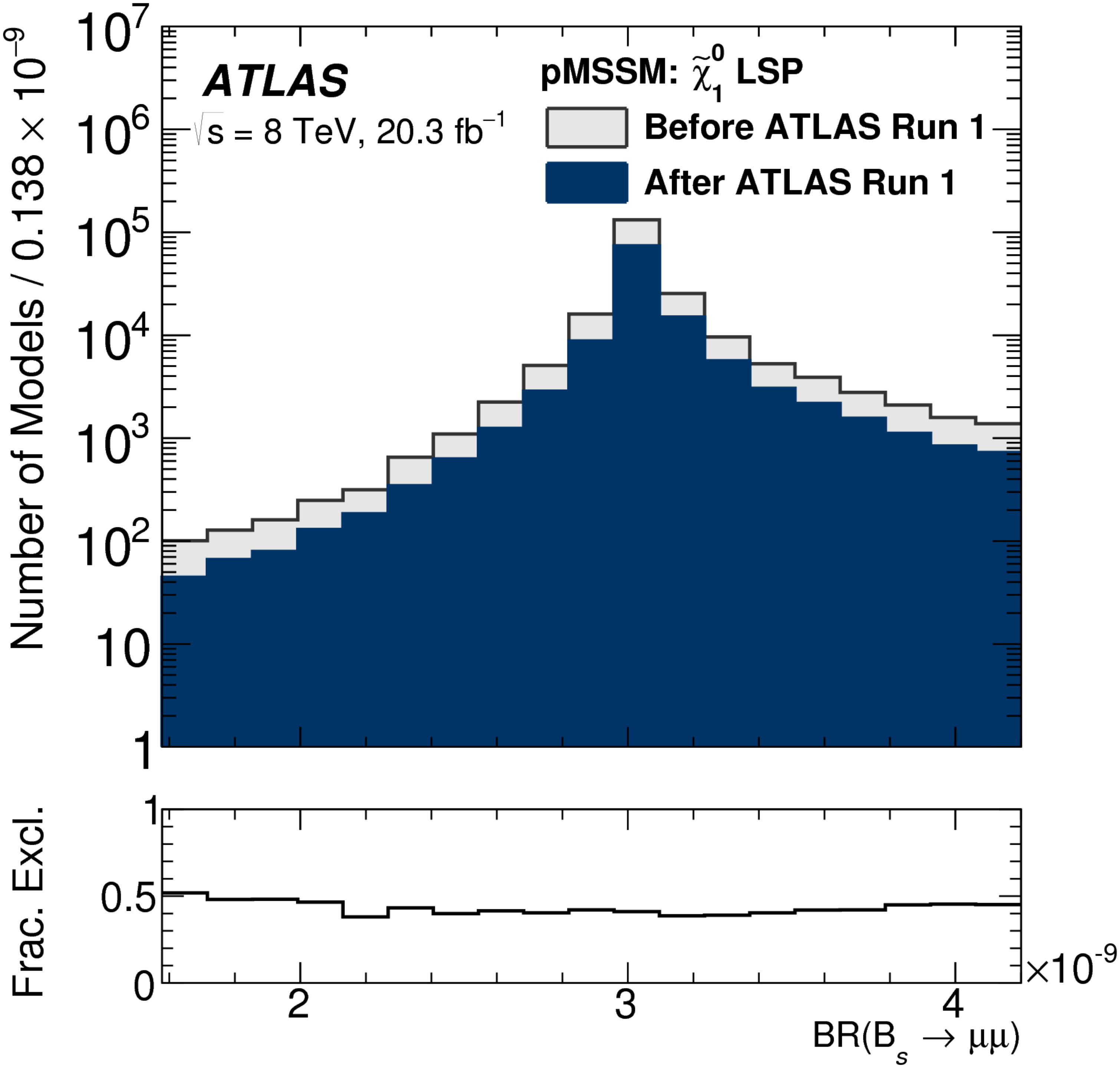
Leaves 19 free parameters (mostly masses squarks, sleptons, gauginos)

Randomly select sets of values for these 19 parameters, calculate mass spectra, branching ratios, cross sections, DM etc.

Only allow models with $\Omega h^2 < 0.12$, no large invisible Z width, no large deviation in ρ parameter, $124 < m_h < 128$ GeV.

300000 models are left, giving impression of what SUSY could look like.

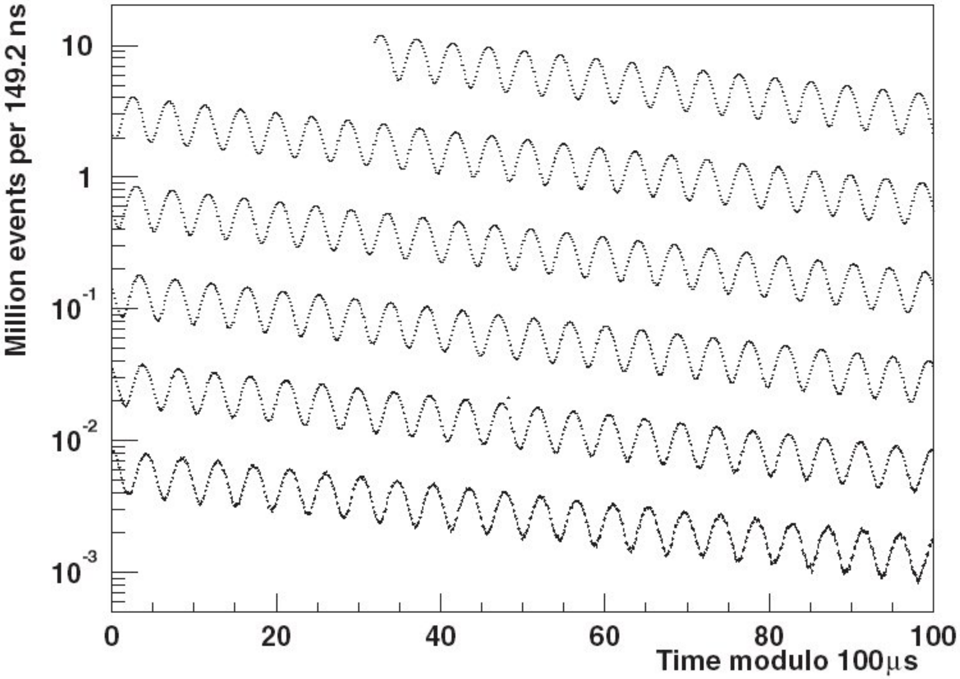
Then we also look at the question: did ATLAS already rule out this model?


ATLAS
$\sqrt{s}$ = 8 TeV, 20.3 fb^{-1}
pMSSM: $\tilde{\chi}_1^0$ LSP
Before ATLAS Run 1
After ATLAS Run 1
Number of Models / 0.138 × 10^{-9}
1
10
10^2
10^3
10^4
10^5
10^6
10^7
Frac. Excl.
0
0.5
1
2
3
4
×10^{-9}
BR($B_s \to \mu\mu$)

Muon magnetic moment: $$\vec{\mu} = g_\mu \frac{e}{2m_\mu} \vec{s}$$

Anomalous part: $$a_\mu = \frac{g_\mu - 2}{2}$$

g-2 experiment at Brookhaven:

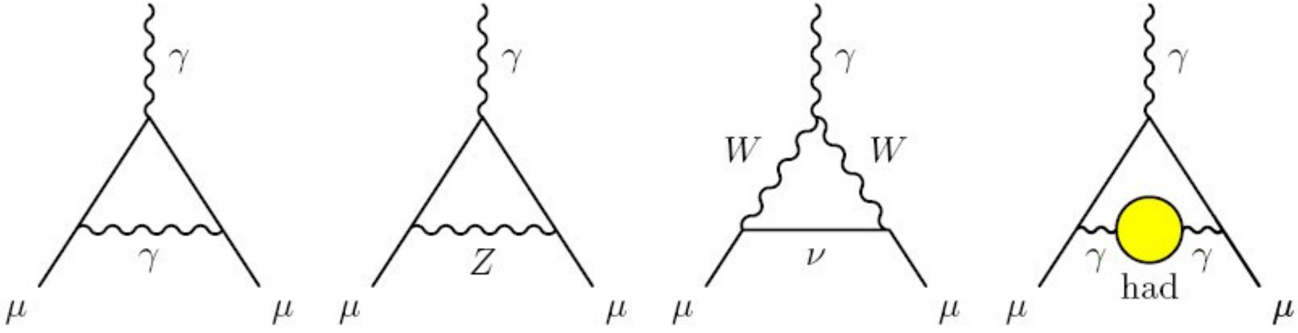


Experiment:
a = 11 659 208.0 (6.3) x 10^{-10}

Standard Model theory:
a = 11 659 178.8 (5.8) x 10^{-10}

Δa = 29.2 (8.6) x 10^{-10} = 3.4 sigma

This is a very difficult calculation: many radiative loops



Options: - mistake in calculation
- experiment wrong
- other particles in loop (SUSY) ?
($\Delta a(\mathrm{susy}) = 13 \times 10^{-10} \times (100\ \mathrm{GeV}/M_{\mathrm{susy}})^2 \times \tan\beta$)

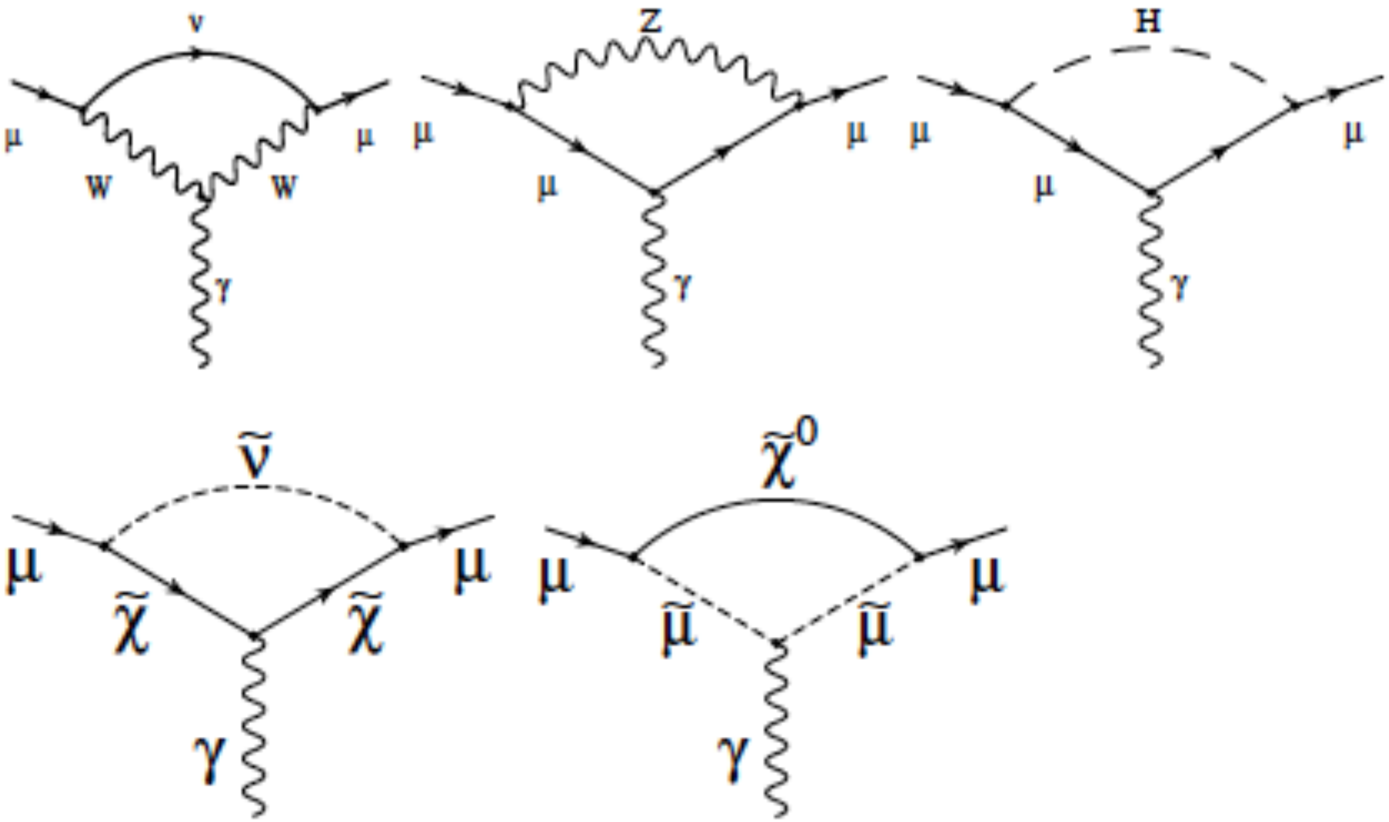
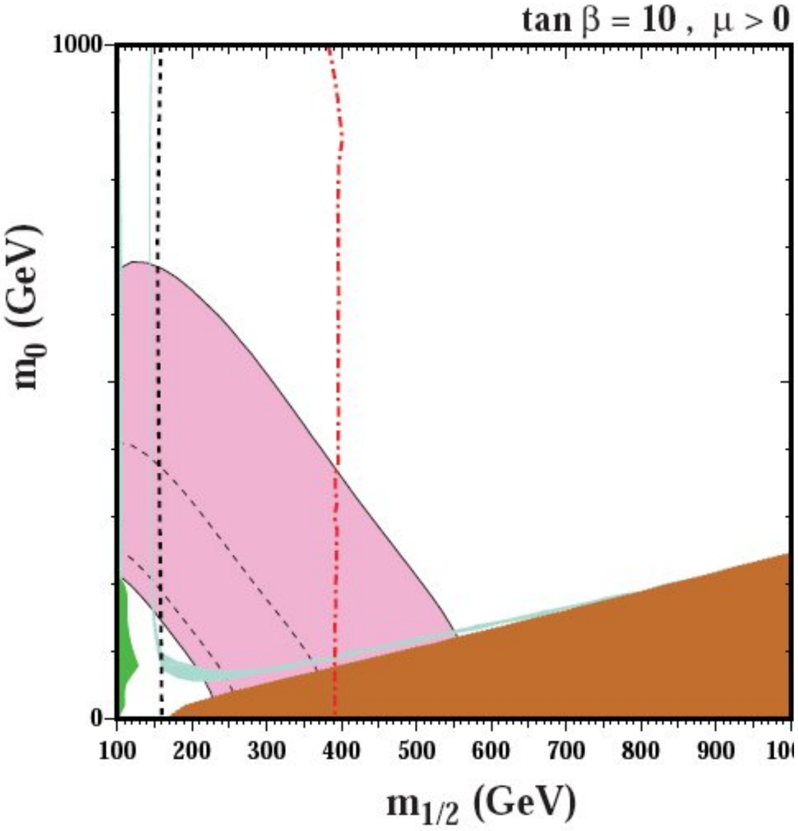
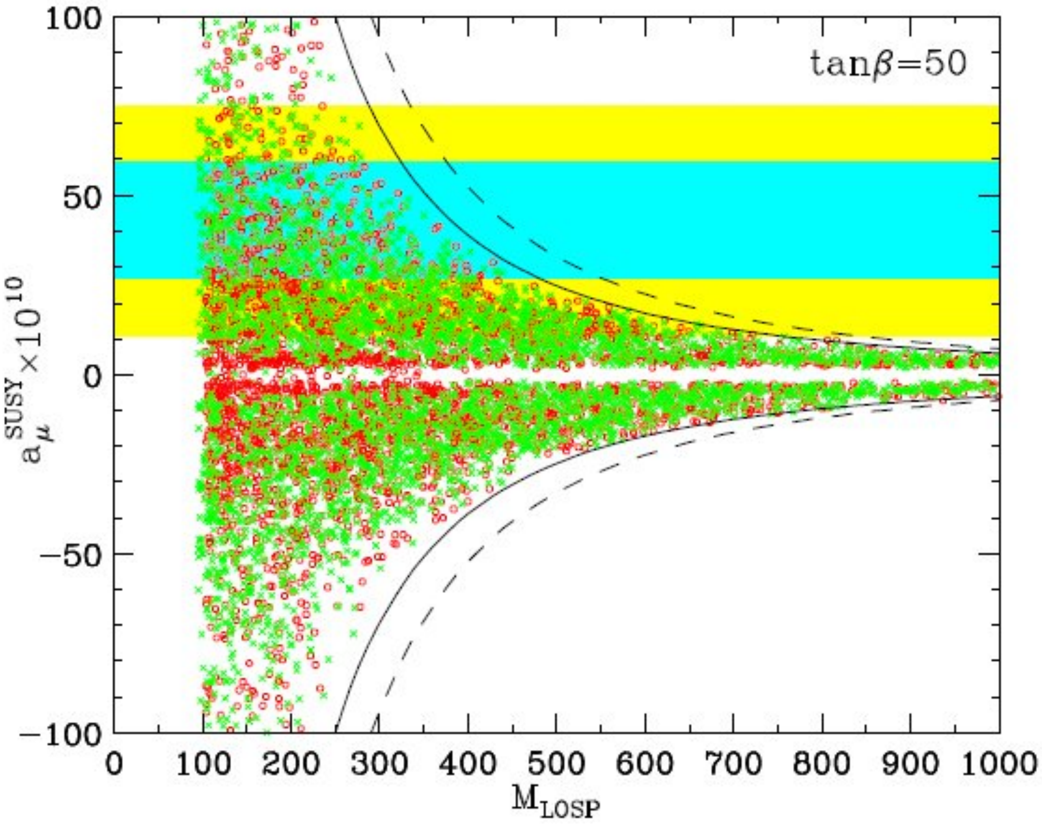
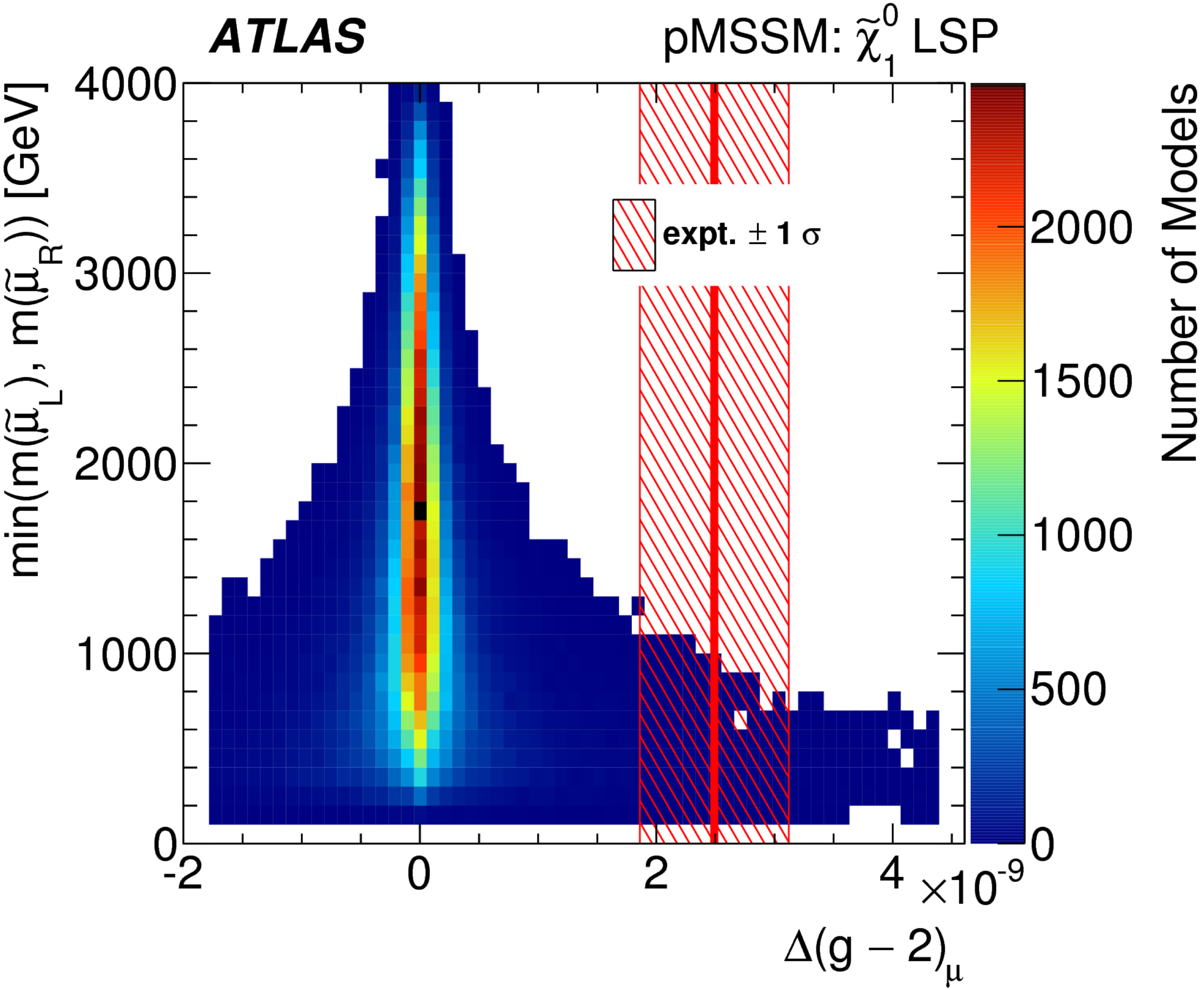


Figure 16. The diagrams contributing to a_μ in the SM and in the MSSM.


tan β = 10 , μ > 0
1000
0
m$_0$ (GeV)
100
200
300
400
500
600
700
800
900
10
m$_{1/2}$ (GeV)


tanβ=50
100
50
0
−50
−100
a$_\mu^{SUSY}$×10^{10}
0
100
200
300
400
500
600
700
800
900
1000
M$_{LOSP}$

g-2 in mSUGRA


ATLAS
pMSSM: $\tilde{\chi}_1^0$ LSP
expt. ± 1 σ
min(m($\tilde{\mu}_L$), m($\tilde{\mu}_R$)) [GeV]
0
1000
2000
3000
4000
-2
0
2
4
$\times 10^{-9}$
$\Delta(g-2)_\mu$
Number of Models
0
500
1000
1500
2000

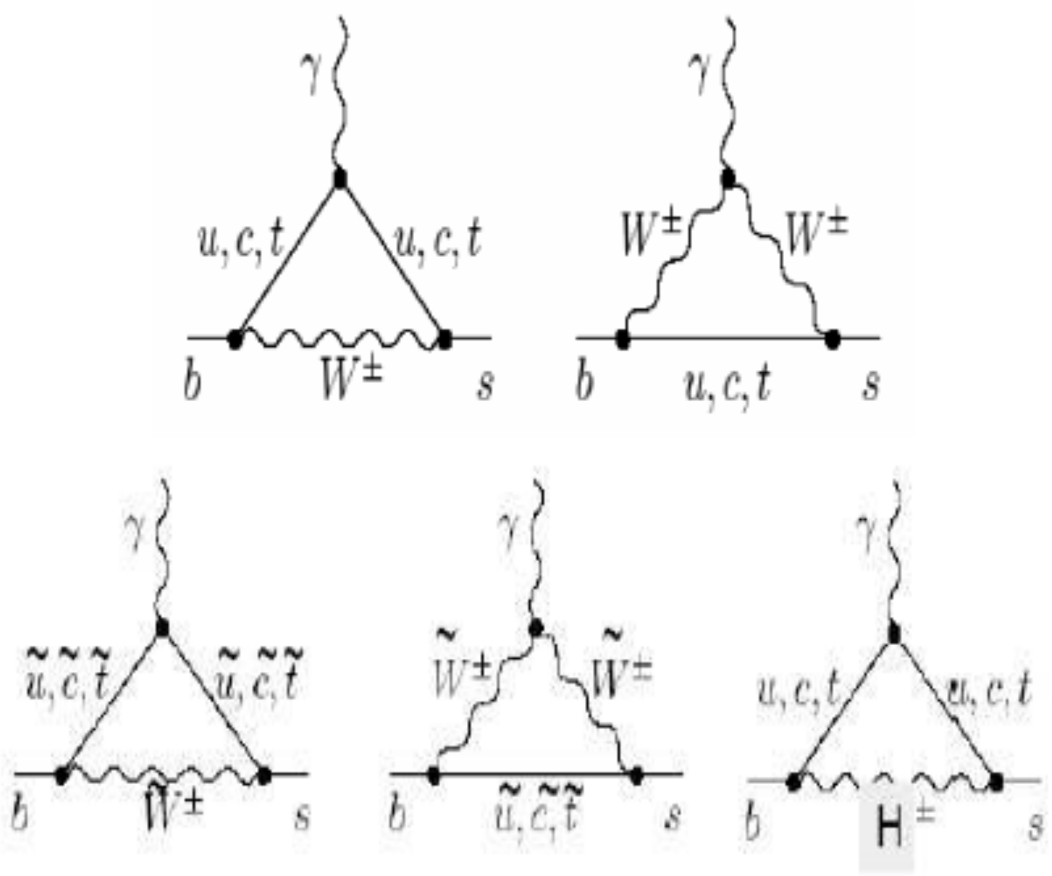
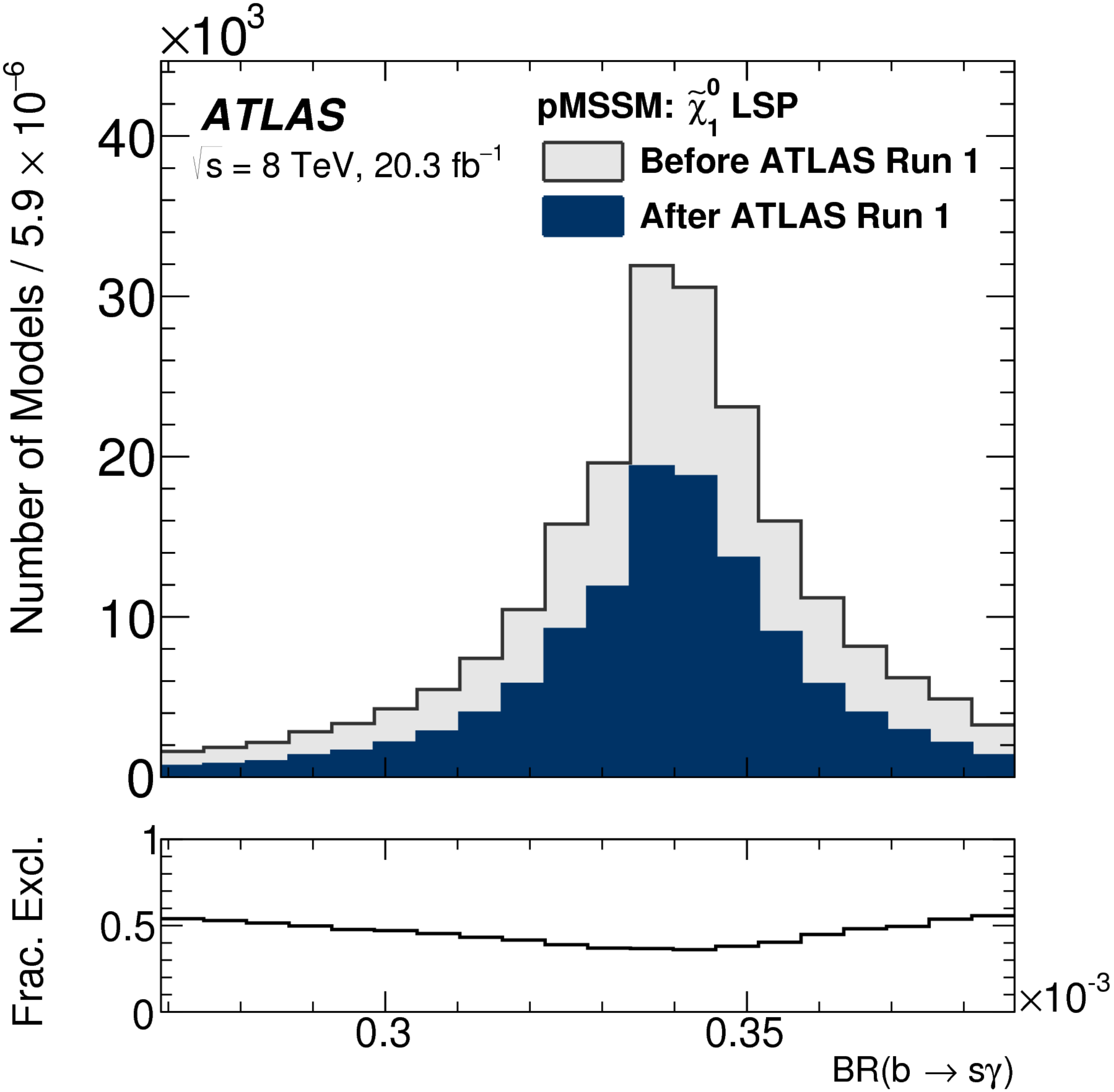
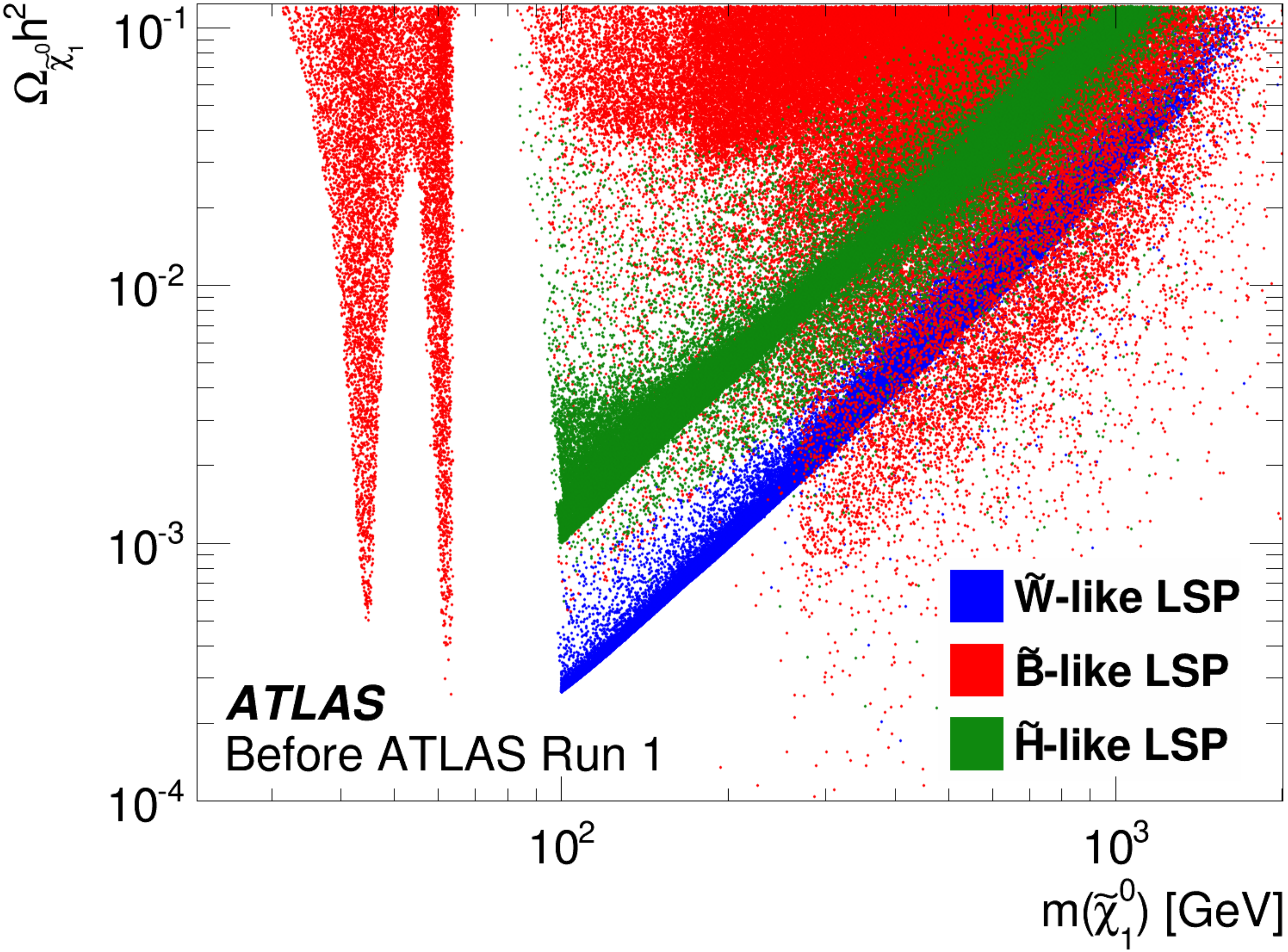


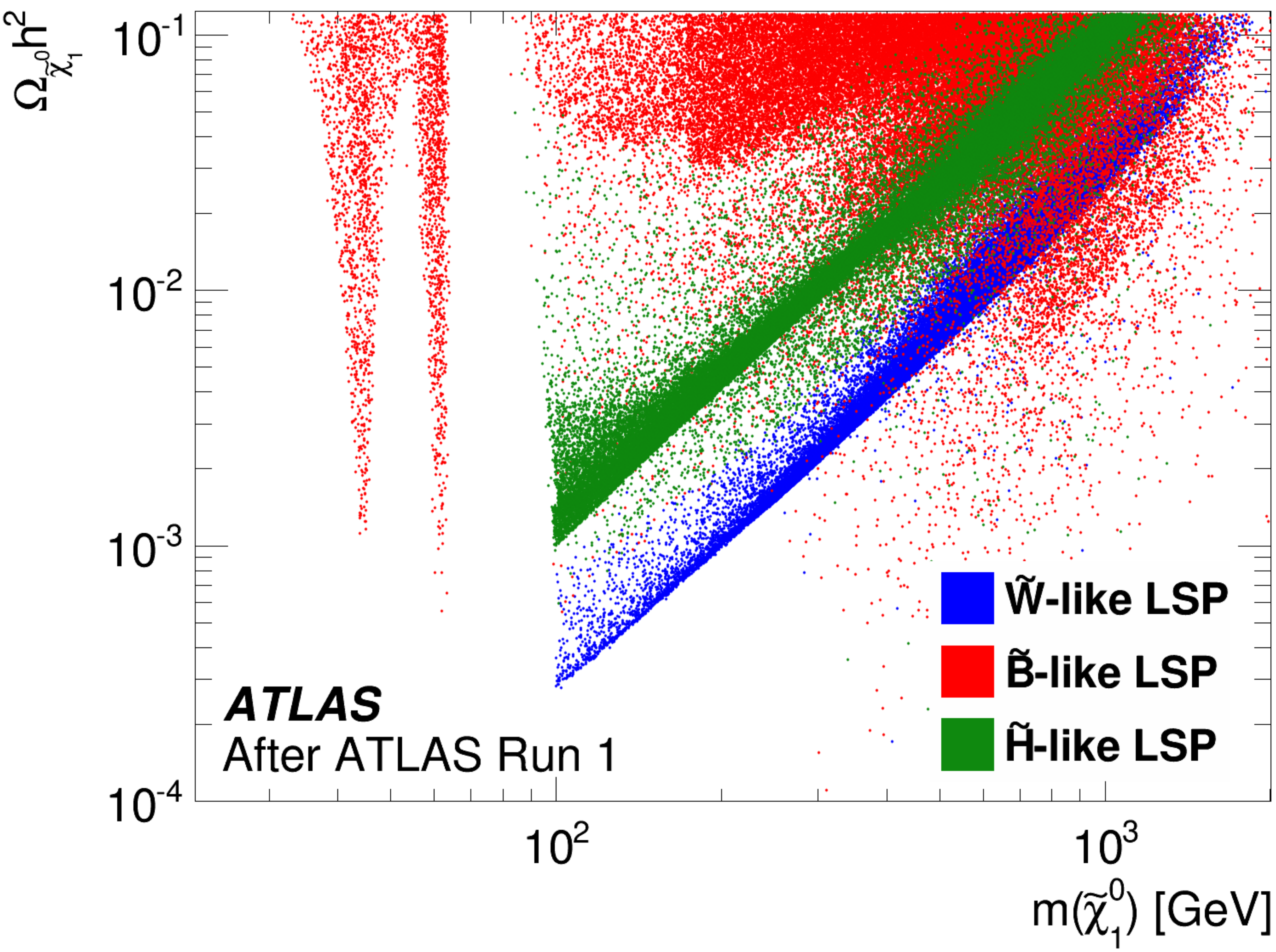
Figure 13. The diagrams contributing to $b \to s\gamma$ decay in the SM and in the MSSM.

SM theory prediction: Br(b→sγ) = (2.98 ± 0.26) x 10^{-4}

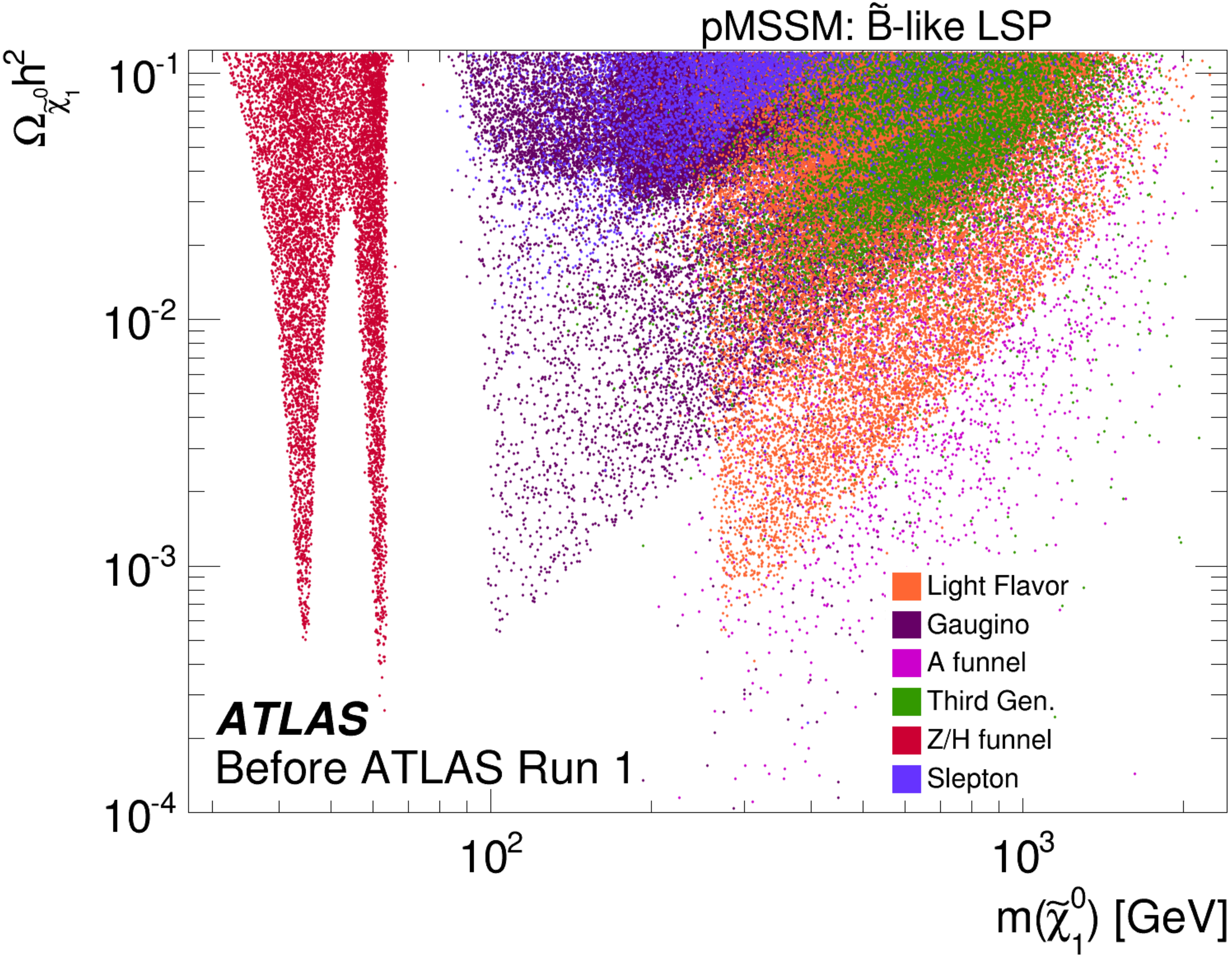
Measurement: (3.43 ± 0.27) x 10^{-4}

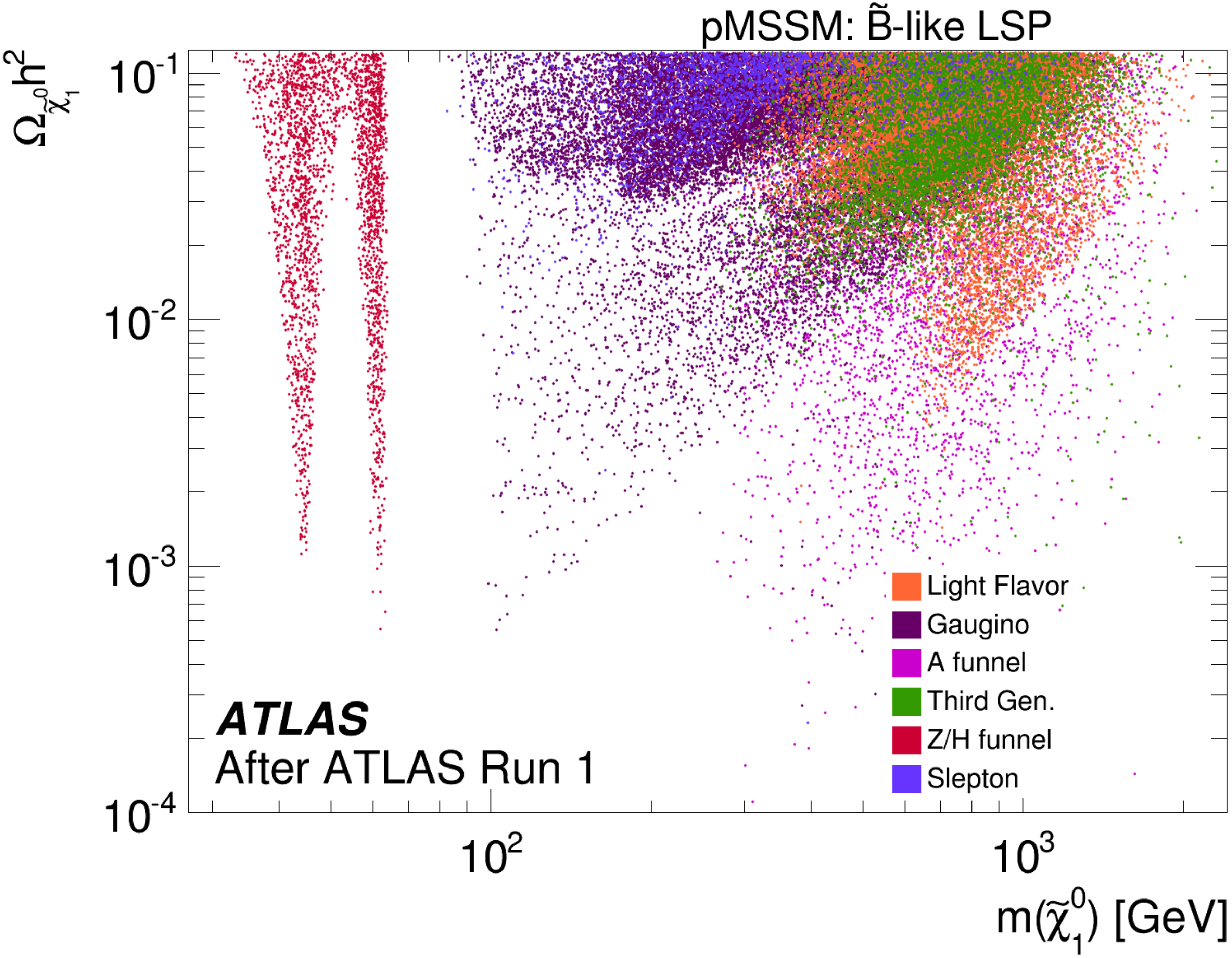

ATLAS
$\sqrt{s}$ = 8 TeV, 20.3 fb^{-1}
pMSSM: $\tilde{\chi}_1^0$ LSP
Before ATLAS Run 1
After ATLAS Run 1
$\times 10^3$
Number of Models / 5.9 $\times 10^{-6}$
0
10
20
30
40
Frac. Excl.
0
0.5
1
0.3
0.35
$\times 10^{-3}$
BR($b \to s\gamma$)


$\Omega_{\tilde{\chi}_1^0} h^2$
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{2}
10^{3}
$m(\tilde{\chi}_1^0)$ [GeV]
$\tilde{W}$-like LSP
$\tilde{B}$-like LSP
$\tilde{H}$-like LSP
ATLAS
Before ATLAS Run 1



$\Omega_{\tilde{\chi}_1^0} h^2$
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^2
10^3
$m(\tilde{\chi}_1^0)$ [GeV]
$\tilde{W}$-like LSP
$\tilde{B}$-like LSP
$\tilde{H}$-like LSP
ATLAS
After ATLAS Run 1


pMSSM: $\tilde{B}$-like LSP
$\Omega_{\tilde{\chi}_1^0} h^2$
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{2}
10^{3}
$m(\tilde{\chi}_1^0)$ [GeV]
Light Flavor
Gaugino
A funnel
Third Gen.
Z/H funnel
Slepton
ATLAS
Before ATLAS Run 1

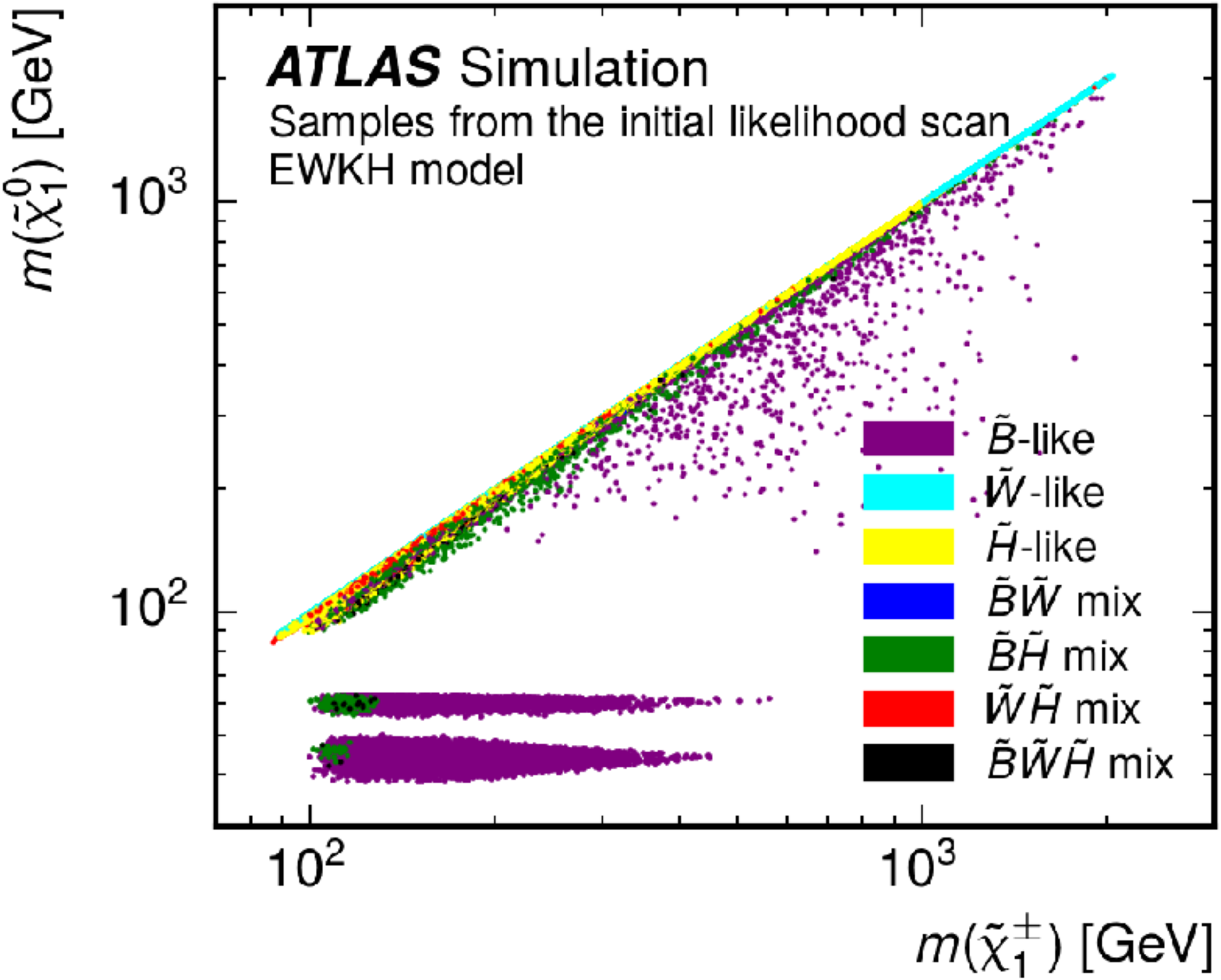

pMSSM: $\tilde{B}$-like LSP
$\Omega_{\tilde{\chi}_1^0}h^2$
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^2
10^3
$m(\tilde{\chi}_1^0)$ [GeV]
Light Flavor
Gaugino
A funnel
Third Gen.
Z/H funnel
Slepton
ATLAS
After ATLAS Run 1

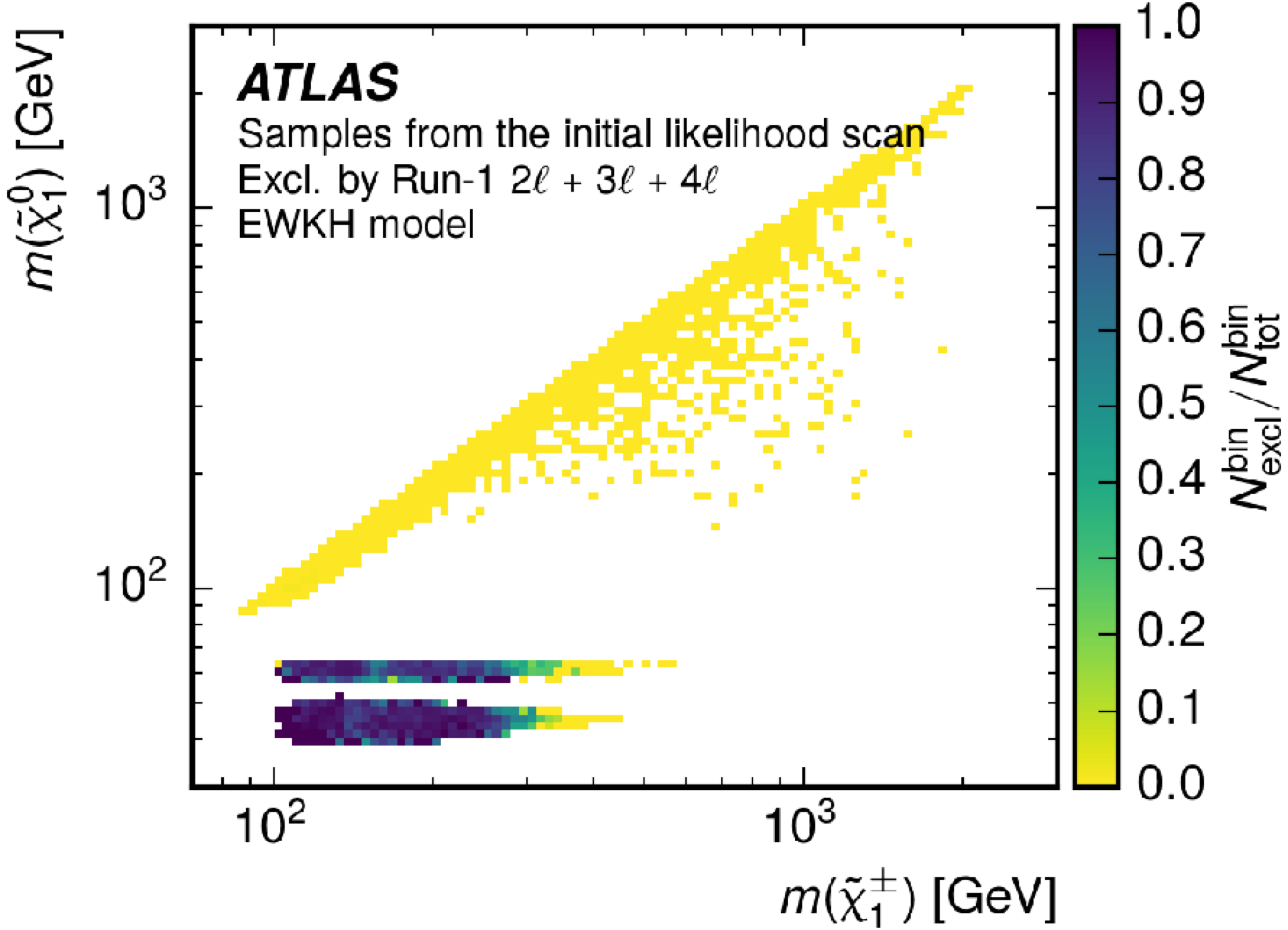
ATLAS plots in next slides taken from JHEP 1609 (2016) 175

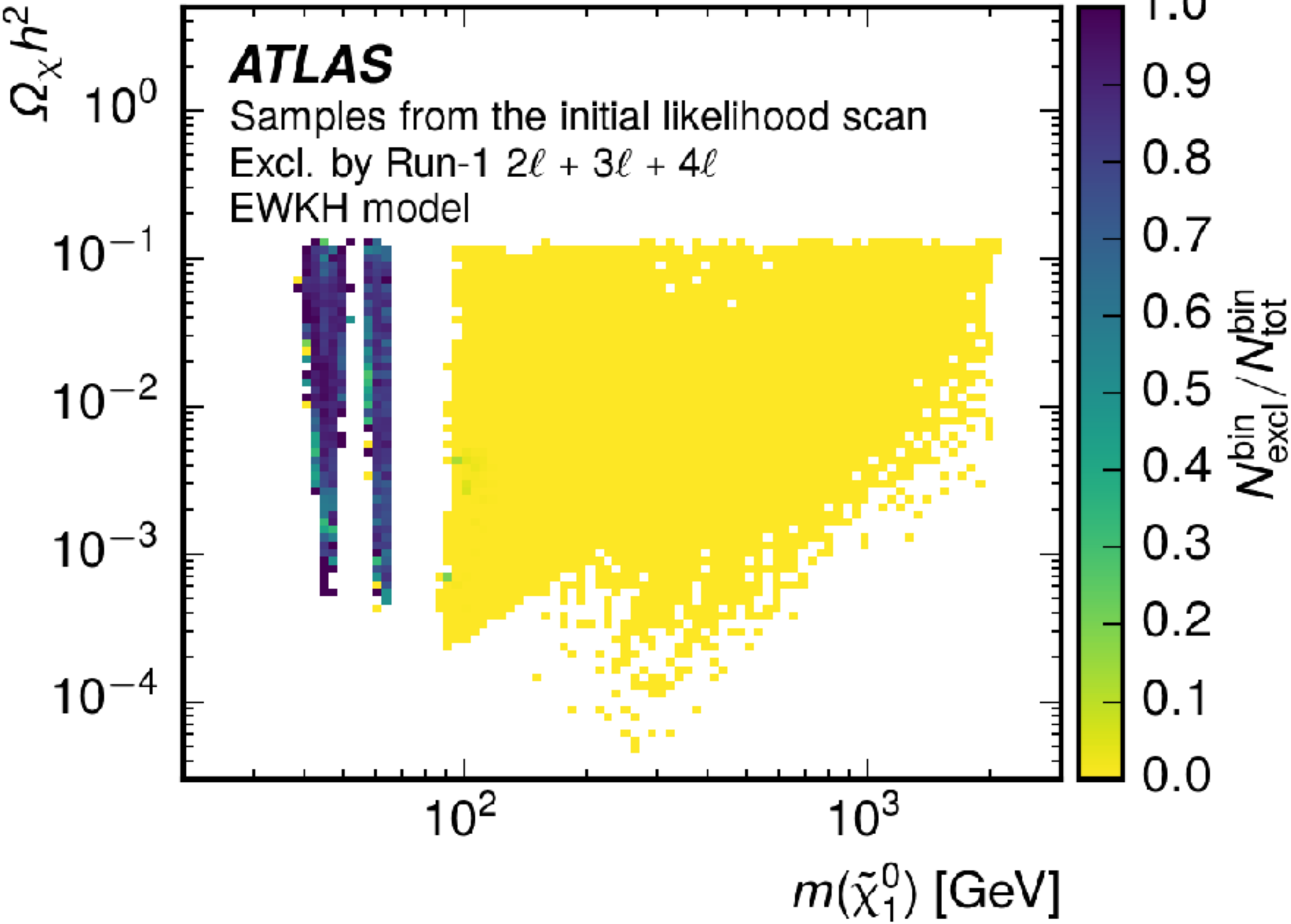
Idea similar to previous paper, but focussed on DM:

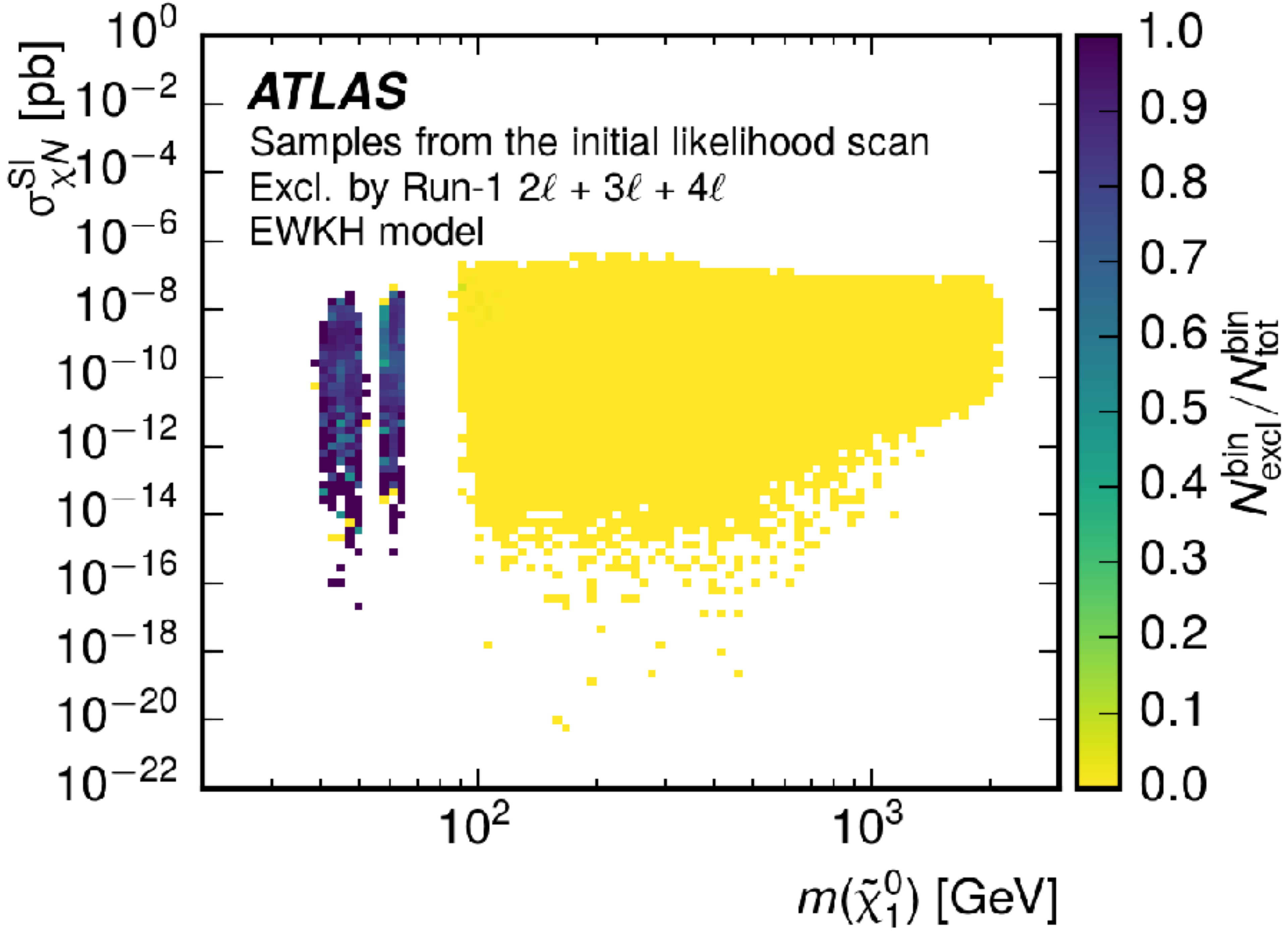
- Only 5 free parameters related to gauginos and Higgs (assume squarks and sleptons very heavy)
- Only consider limited set of ATLAS searches for gauginos
- Not a random scan, but make a proper likelihood fit including electroweak data from LEP, Ωh^2, $b \rightarrow s\gamma$, $B_s \rightarrow \mu\mu$, m_h, XENON limits on direct dark matter detection

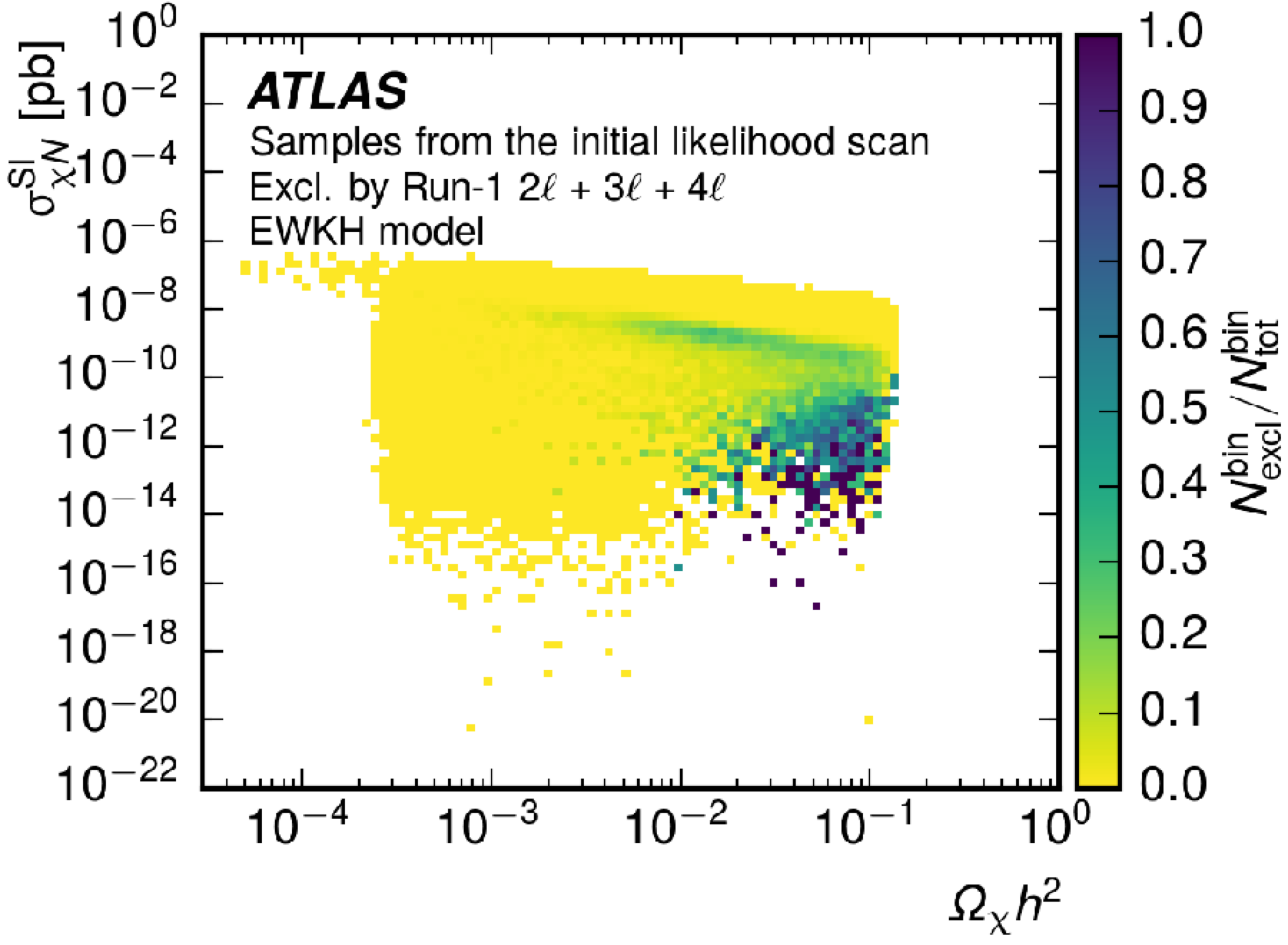
Then we look at feasible DM solutions, and effects of ATLAS searches


ATLAS Simulation
Samples from the initial likelihood scan
EWKH model
$\tilde{B}$-like
$\tilde{W}$-like
$\tilde{H}$-like
$\tilde{B}\tilde{W}$ mix
$\tilde{B}\tilde{H}$ mix
$\tilde{W}\tilde{H}$ mix
$\tilde{B}\tilde{W}\tilde{H}$ mix
$m(\tilde{\chi}_1^0)$ [GeV]
10^3
10^2
$m(\tilde{\chi}_1^{\pm})$ [GeV]


ATLAS
Samples from the initial likelihood scan
Excl. by Run-1 $2\ell + 3\ell + 4\ell$
EWKH model
$m(\tilde{\chi}_1^0)$ [GeV]
10^3
10^2
$m(\tilde{\chi}_1^\pm)$ [GeV]
10^2
10^3
$N^{\mathrm{bin}}_{\mathrm{excl}} / N^{\mathrm{bin}}_{\mathrm{tot}}$
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0

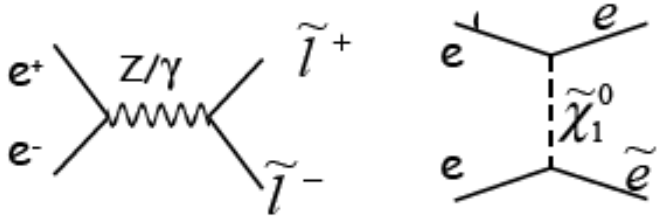

ATLAS
Samples from the initial likelihood scan
Excl. by Run-1 2ℓ + 3ℓ + 4ℓ
EWKH model
$\Omega_\chi h^2$
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^2
10^3
$m(\tilde{\chi}_1^0)$ [GeV]
$N_{\mathrm{excl}}^{\mathrm{bin}} / N_{\mathrm{tot}}^{\mathrm{bin}}$
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0


ATLAS
Samples from the initial likelihood scan
Excl. by Run-1 2ℓ + 3ℓ + 4ℓ
EWKH model
$\sigma^{SI}_{\chi N}$ [pb]
10^{0}
10^{-2}
10^{-4}
10^{-6}
10^{-8}
10^{-10}
10^{-12}
10^{-14}
10^{-16}
10^{-18}
10^{-20}
10^{-22}
10^{2}
10^{3}
$m(\tilde{\chi}^0_1)$ [GeV]
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
$N^{bin}_{excl} / N^{bin}_{tot}$


ATLAS
Samples from the initial likelihood scan
Excl. by Run-1 $2\ell + 3\ell + 4\ell$
EWKH model
$\sigma^{\rm SI}_{\chi N}$ [pb]
10^{0}
10^{-2}
10^{-4}
10^{-6}
10^{-8}
10^{-10}
10^{-12}
10^{-14}
10^{-16}
10^{-18}
10^{-20}
10^{-22}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^{0}
$\Omega_\chi h^2$
$N^{\rm bin}_{\rm excl} / N^{\rm bin}_{\rm tot}$
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0

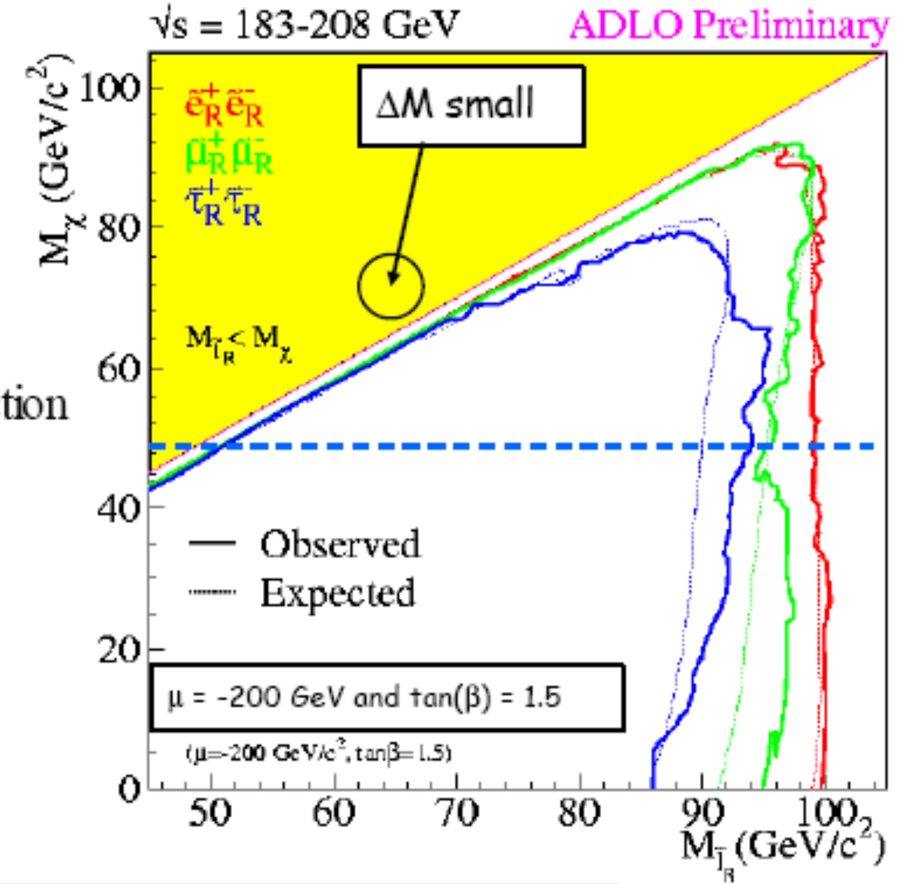
Lep Sleptons

- production



$\oplus$ t – channel $\tilde{e}$ – production

cross sections for l_R smaller than l_L



- decay

if ΔM is small

↓

very soft leptons

- Mass limits:

Lower limits in GeV

	$m_{\tilde{e}}$	$m_{\tilde{\mu}}$	$m_{\tilde{\tau}}$	$m_{\tilde{\tau}}$
$m_{\chi_1^0}$ = 0 GeV	99.9	94.9	86.6	86.6
$m_{\chi_1^0}$ = 40 GeV	99.9	96.6	93.2	92.6

$\tilde{\tau}$ decoupled

from the Z

Charginos: large m_0

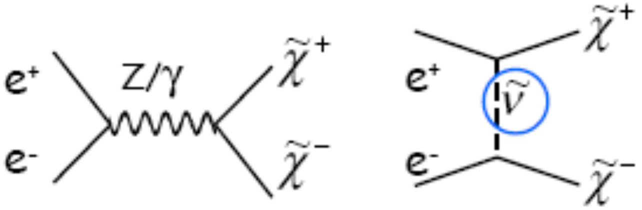
Small m_0: light sfermions

$\sigma(\tilde{\chi}^+\tilde{\chi}^-)$ decreases

$\tilde{\chi}^+ \to \tilde{l}\nu \to l\tilde{\chi}^0\nu$ opens

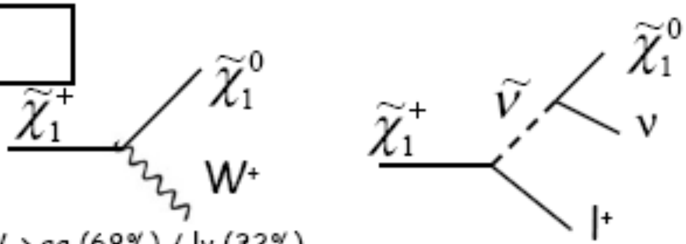
- production

Large cross section in large part of parameter space

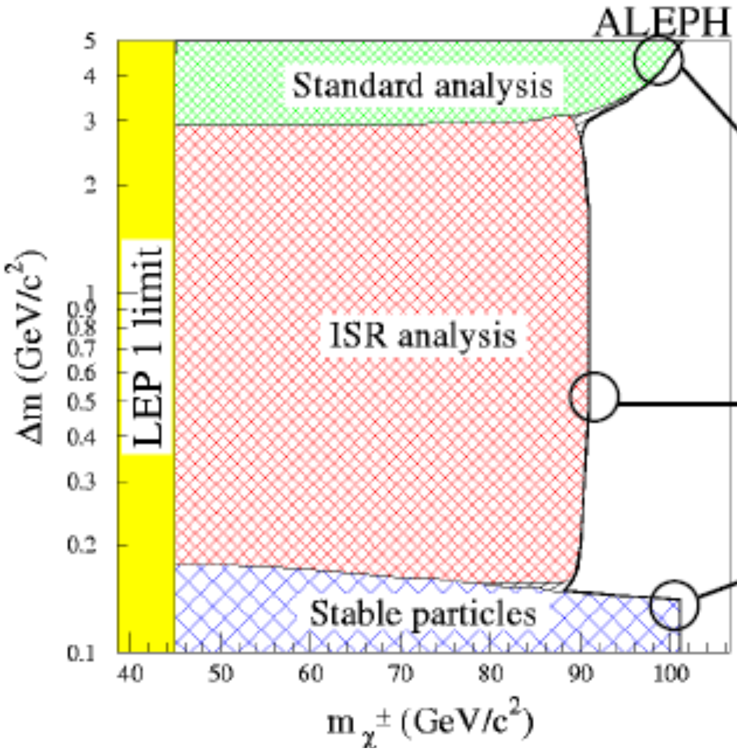


Negative interference if chargino is gaugino

- decay



W-> qq (68%) / lv (32%)



Different ΔM ($m_{\tilde{\chi}_1^+} - m_{\tilde{\chi}_1^0}$) regions

1) ΔM > 3 GeV:

$m_{\tilde{\nu}} > 300$ GeV $m_{\tilde{\chi}^+} > 103.5$ GeV LEP combined

2) 200 MeV < ΔM < 3 GeV:

low momentum particles (use ISR -> high P_T-γ)

3) ΔM < 200 MeV:

'kinky' tracks and displaced vertices

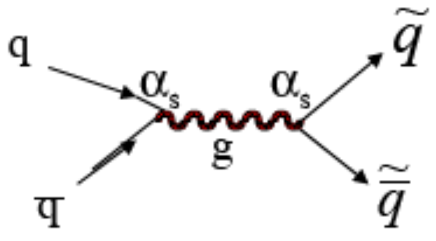
Long lived charged particles (dE/dx information)

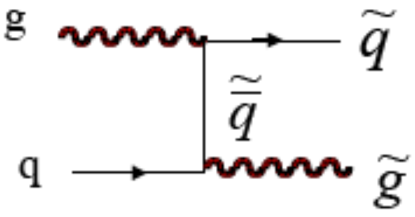
SUSY production

- The SUSY partners have the same coupling constants as the SM particles. QCD production cross sections, if available, are the largest.

	Strong	EM	Weak
Squark	X	X	X
Gluino	X	-	-
Chargino	-	X	X
Neutralino	-	-	X
Slepton	-	X	X
Sneutrino	-	-	X

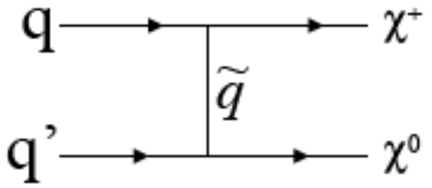
SUSY production - 2

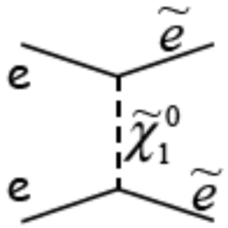




- In a hadron machine Squarks and gluinos produced via strong processes → large cross-section if kinematically allowed

- Charginos, neutralinos, sleptons produced via electroweak processes → much smaller rate





- In e+e- democratic production of everything, but smaller cross section. Good for sleptons and weak gauginos.

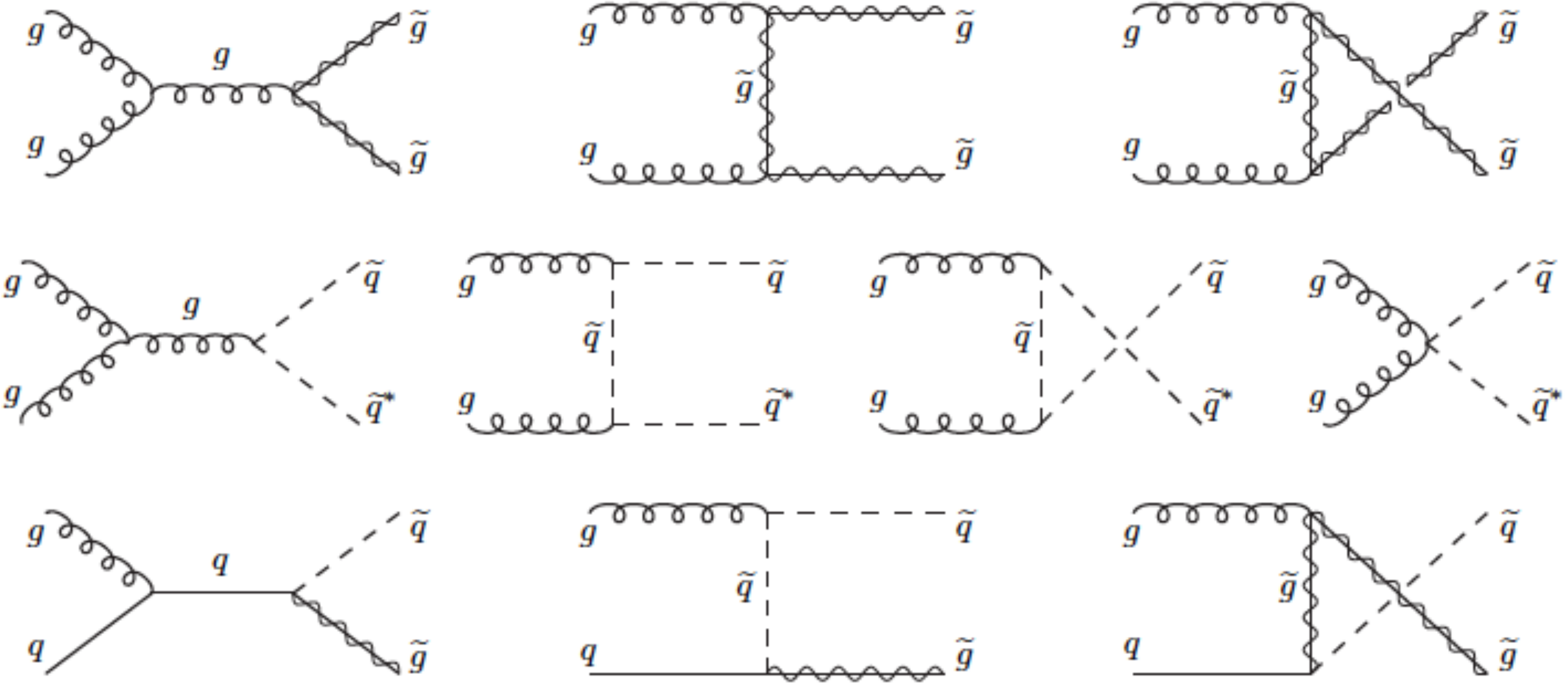


Figure 9.2: Feynman diagrams for gluino and squark production at hadron colliders from gluon-gluon and gluon-quark fusion.

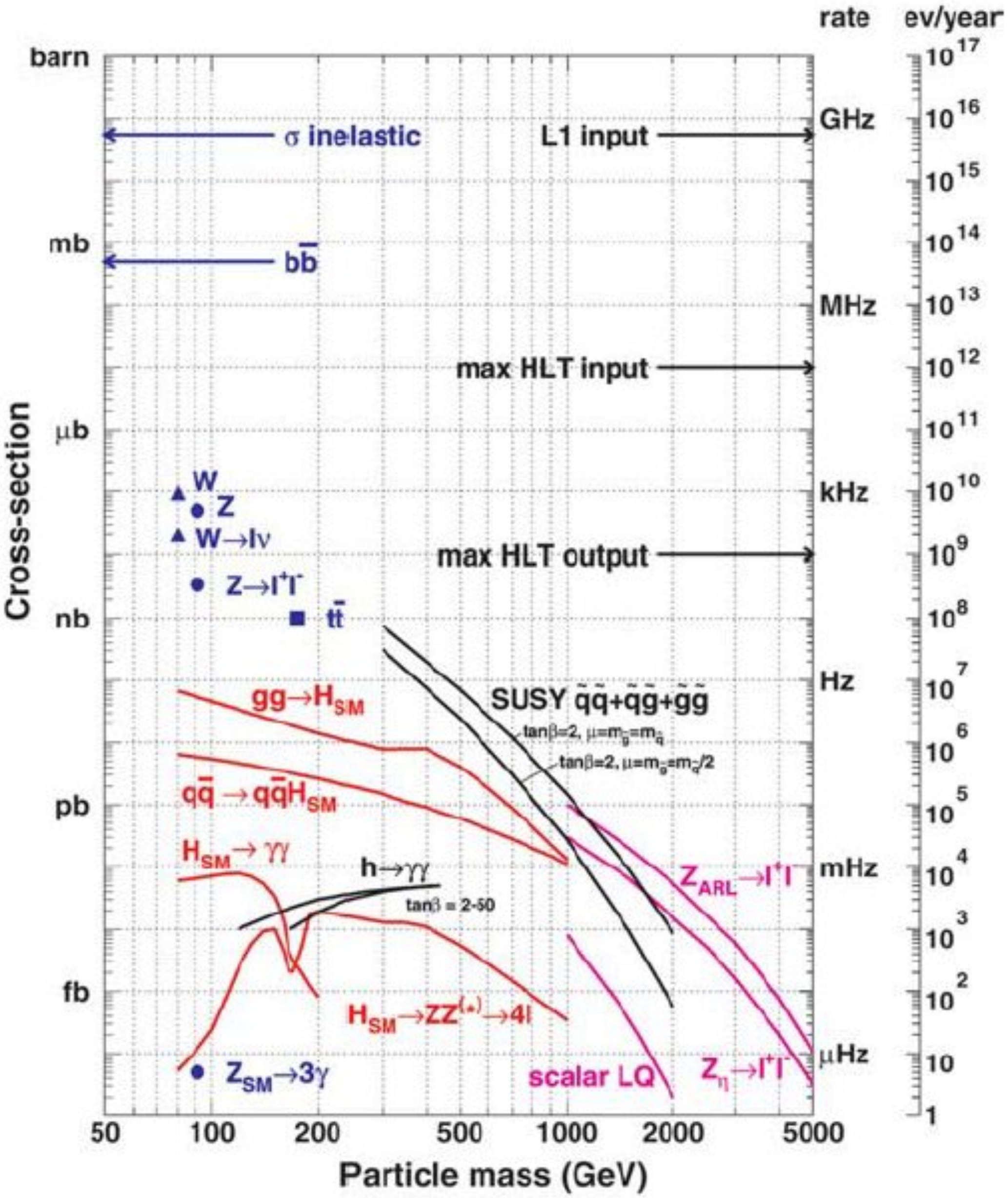
The cross section for
gg → qq at LHC is HUGE

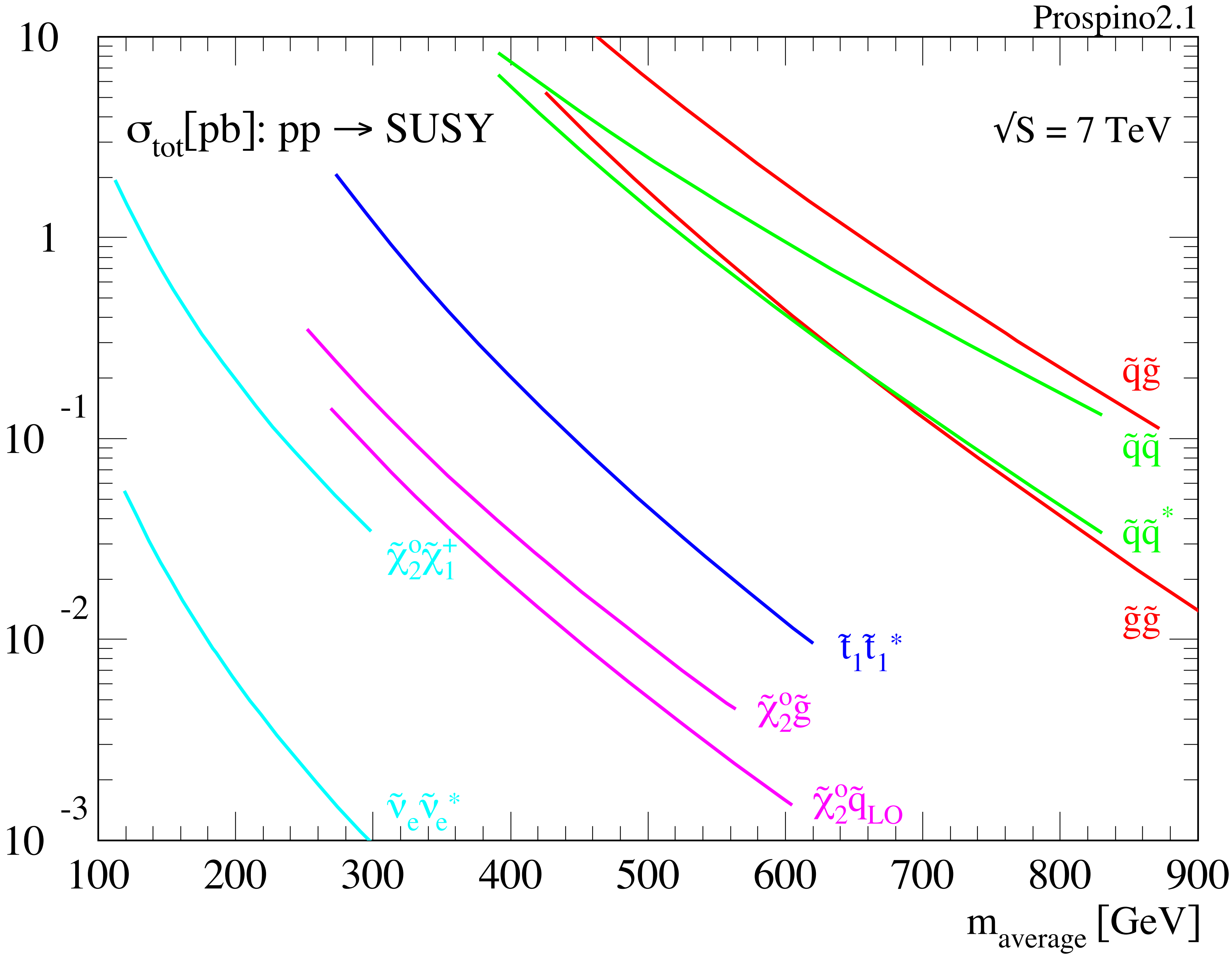
But the cross section for
gg → $\tilde{q}\tilde{q}$ is OF THE SAME
ORDER OF MAGNITUDE

(if $m_q = m_{\tilde{q}}$)

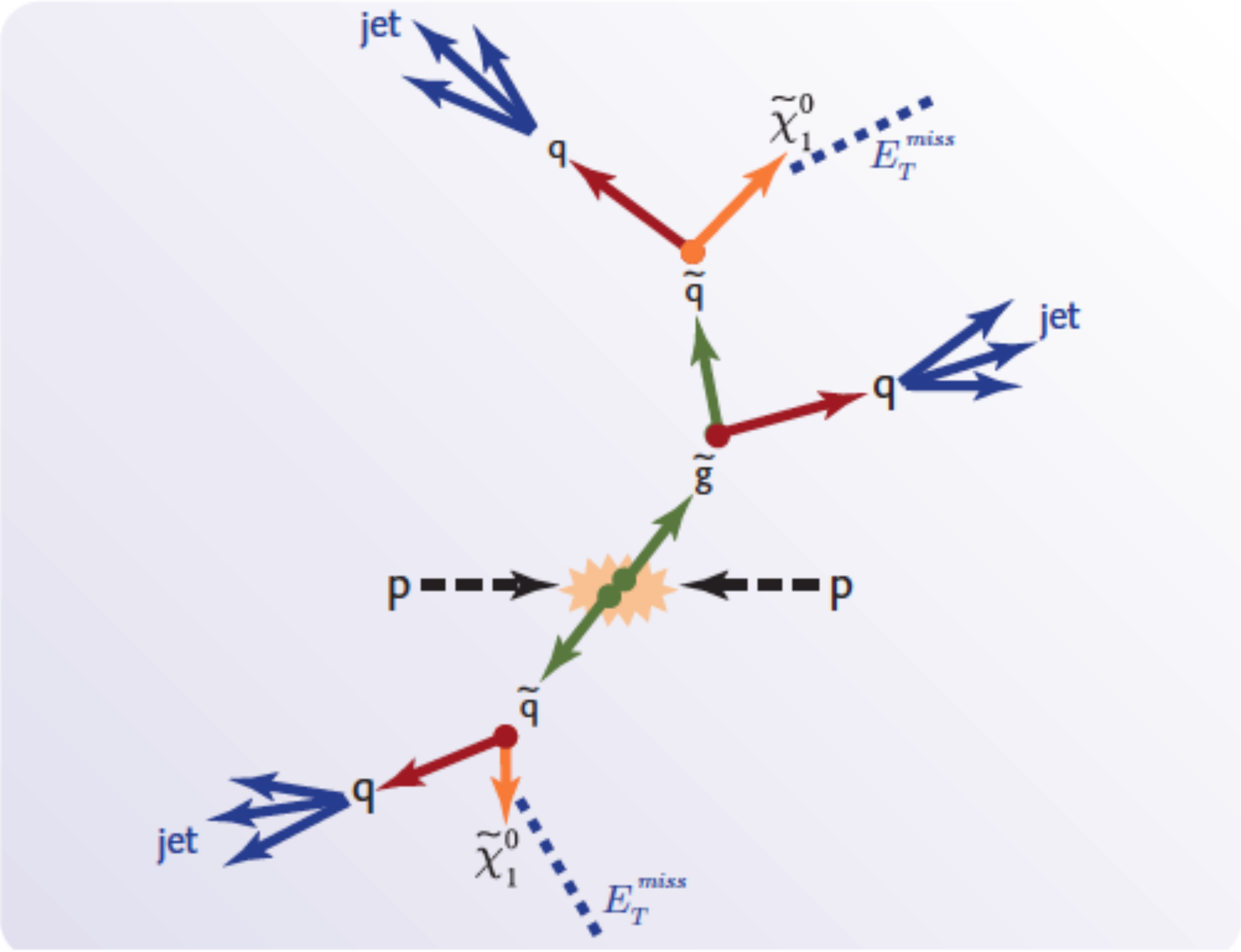
(same order only because
of spin factors, etc)

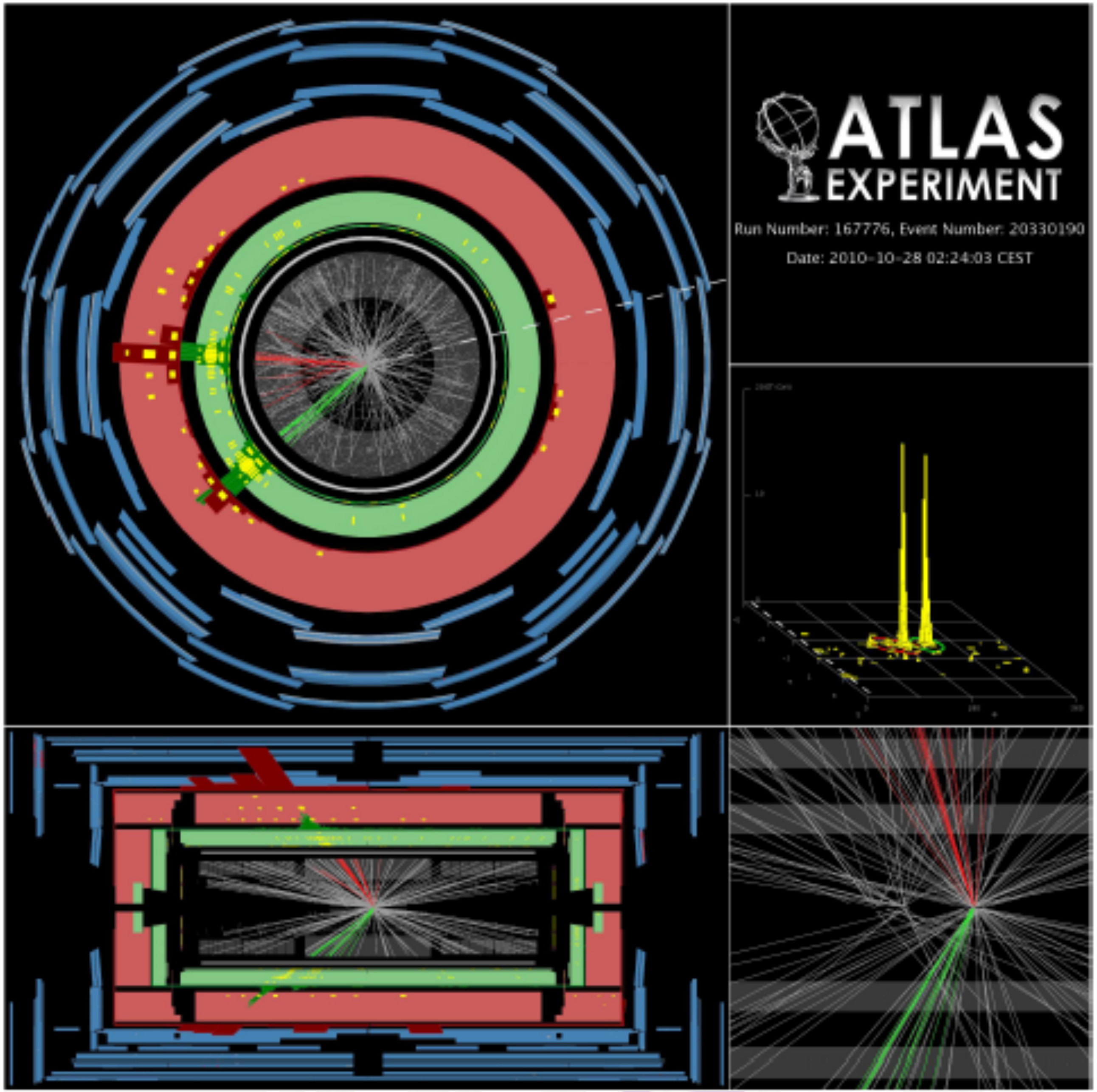
SUSY at LHC dominated by squark and gluino production. Other particles produced in decays.

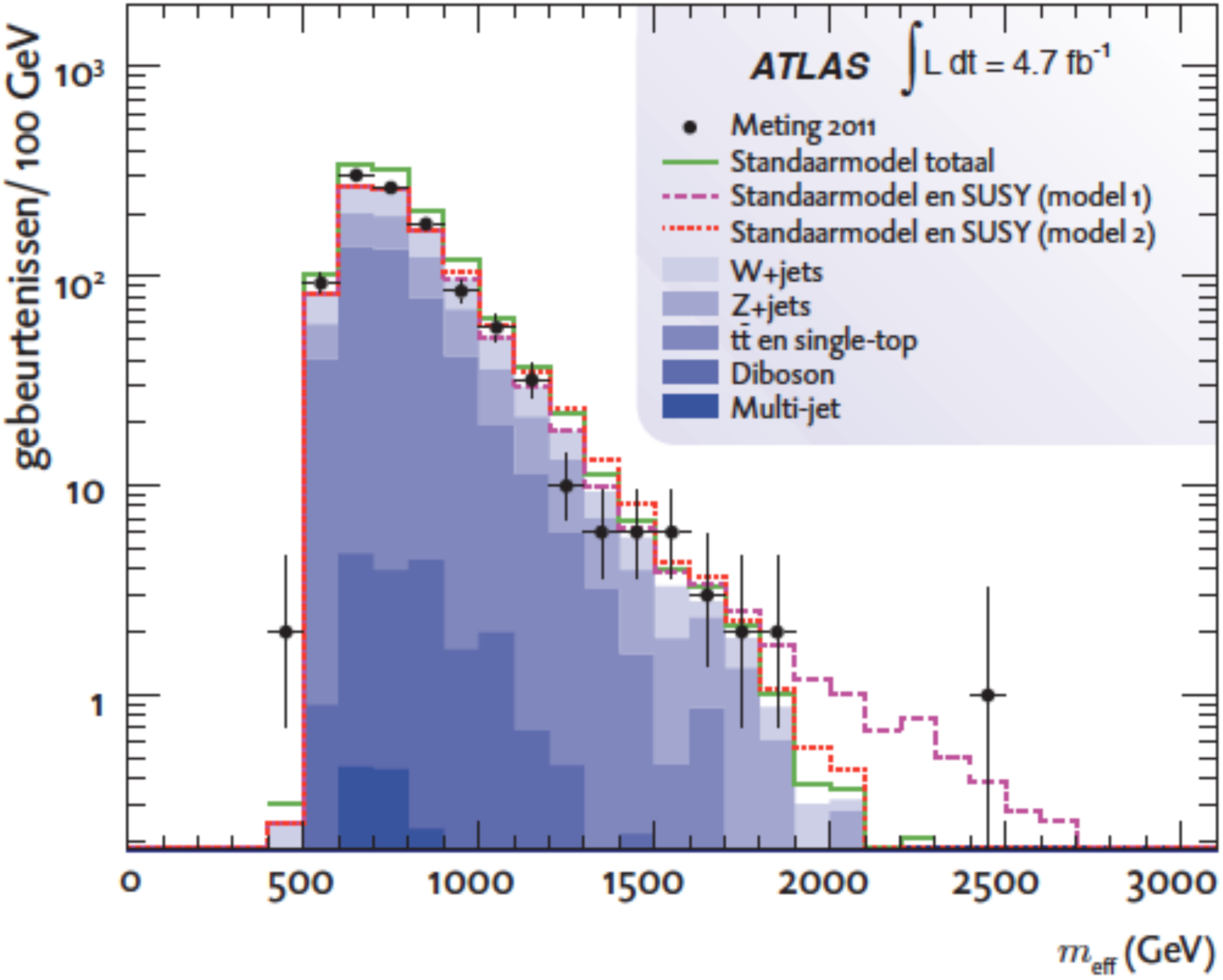



Prospino2.1
σ_tot[pb]: pp → SUSY
√S = 7 TeV
10
1
10^-1
10^-2
10^-3
100
200
300
400
500
600
700
800
900
m_average [GeV]
q̃g̃
q̃q̃
q̃q̃*
g̃g̃
t̃₁t̃₁*
χ̃₂⁰g̃
χ̃₂⁰q̃_LO
χ̃₂⁰χ̃₁⁺
ν̃_eν̃_e*

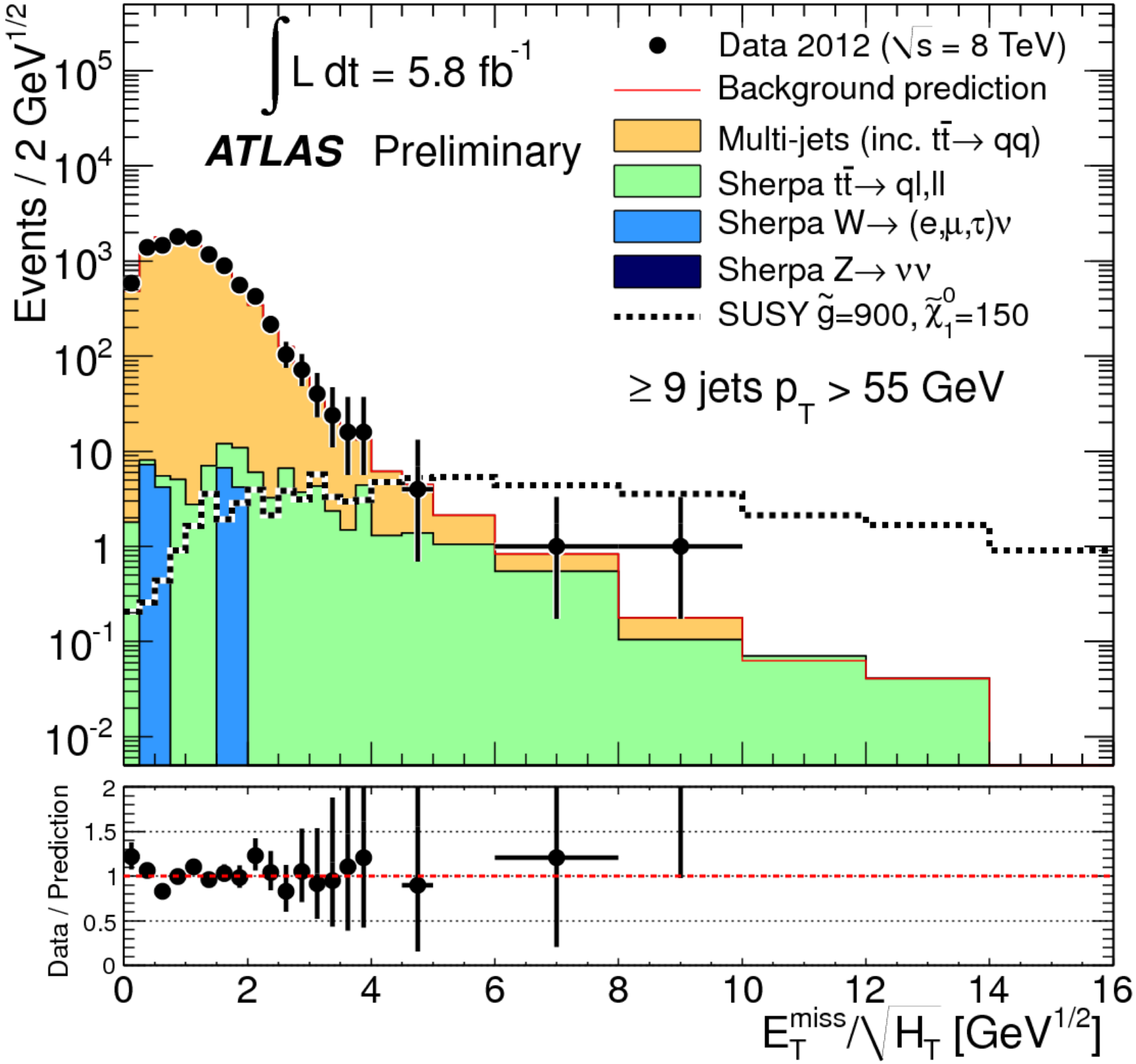
Sparticle decays:



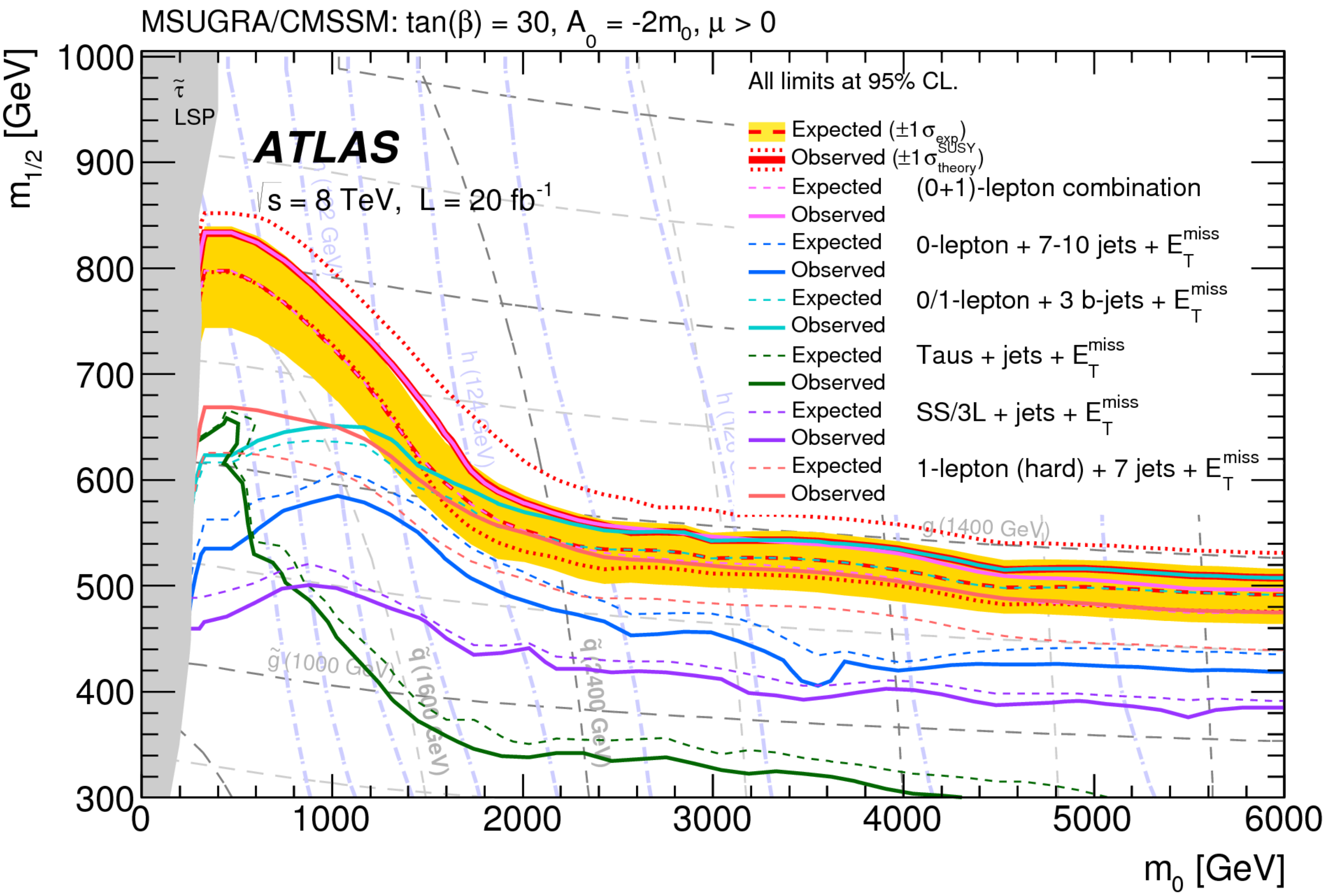

ATLAS EXPERIMENT
Run Number: 167776, Event Number: 20330190
Date: 2010-10-28 02:24:03 CEST



m_{eff} = sum p_T jets + leptons + missing E_T

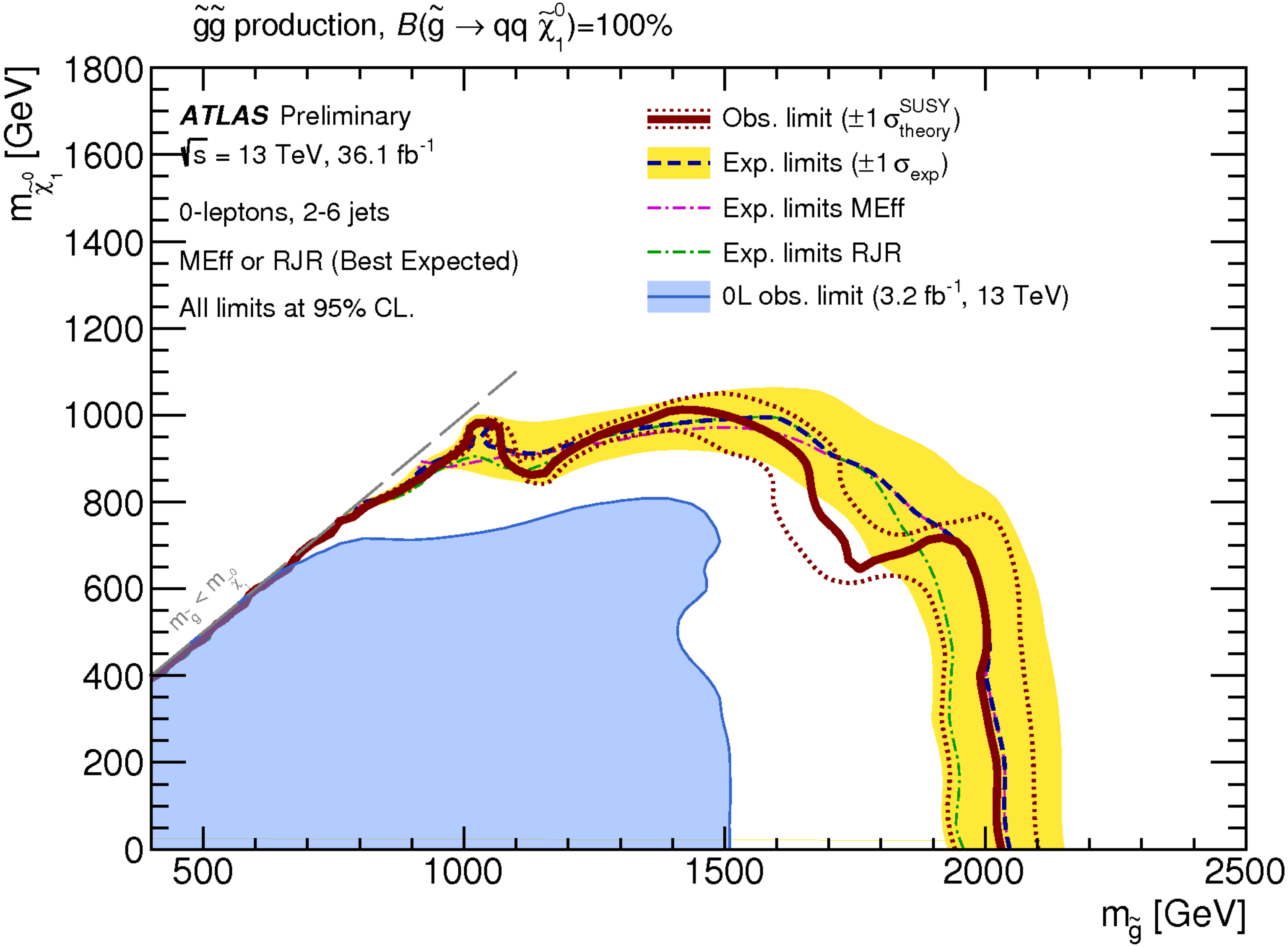


“missing E_T significance”

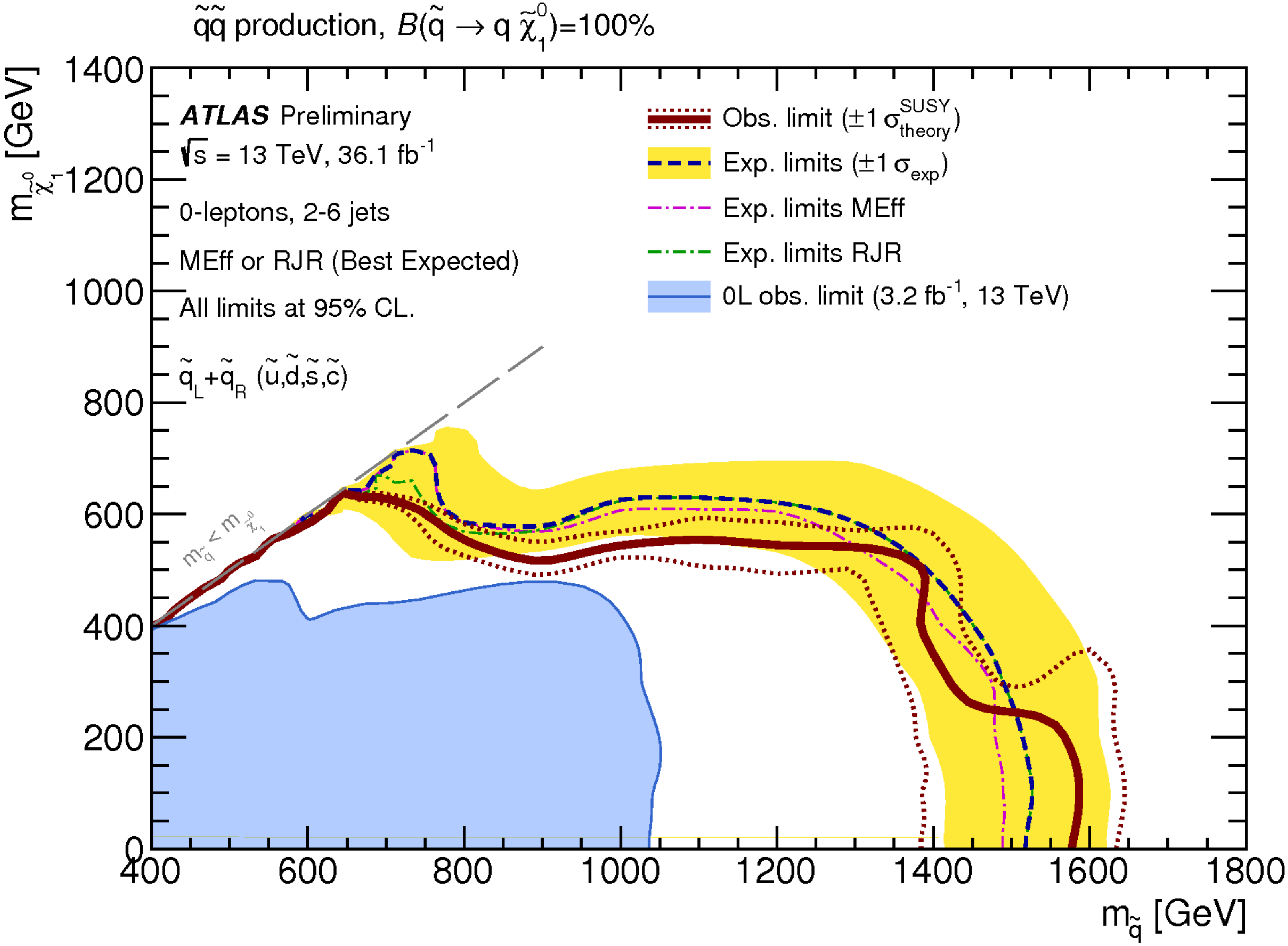


No signal observed → exclusion in mSUGRA plane m_0 vs $m_{1/2}$

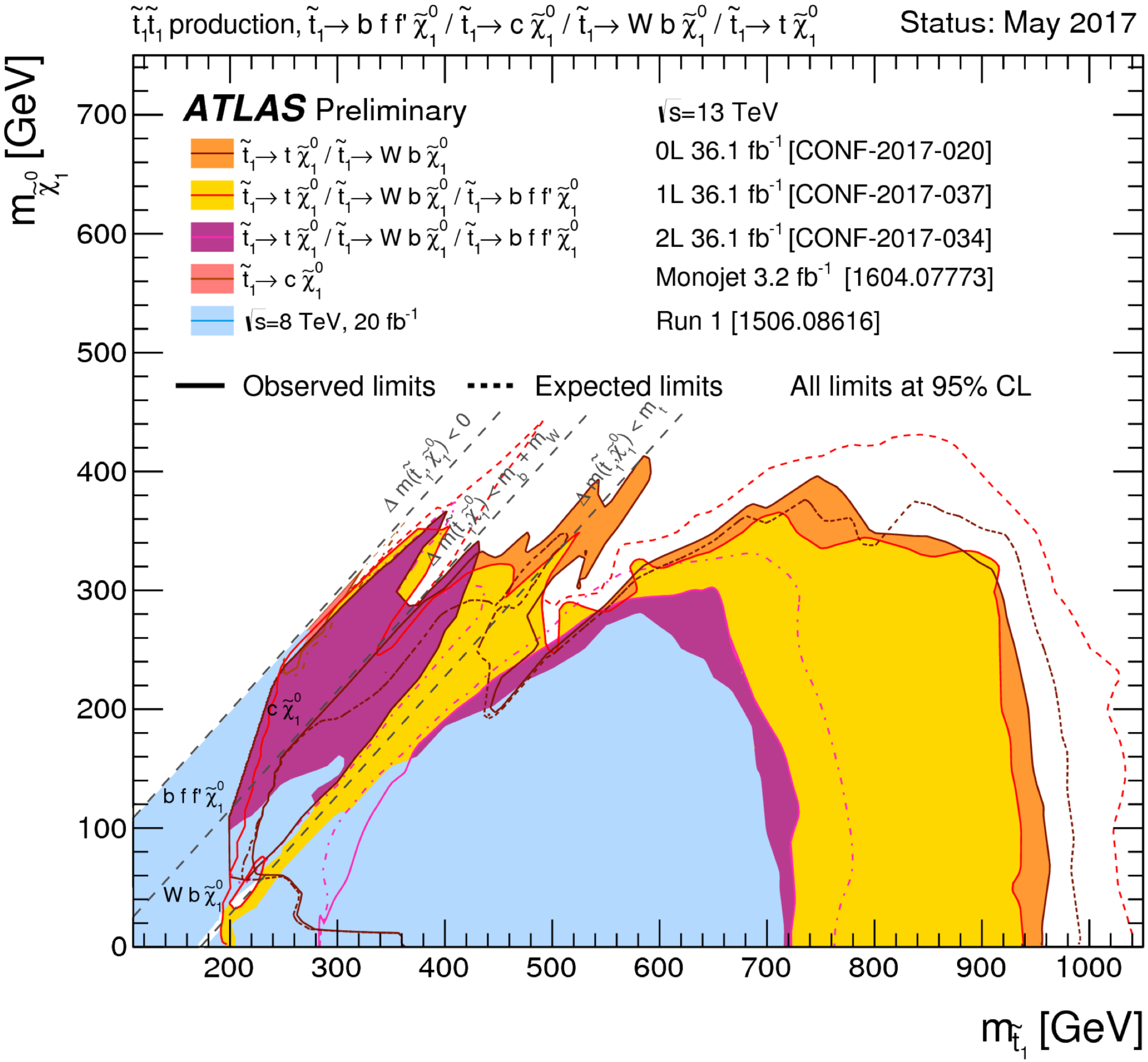
Simplified model for gluino production and decay:



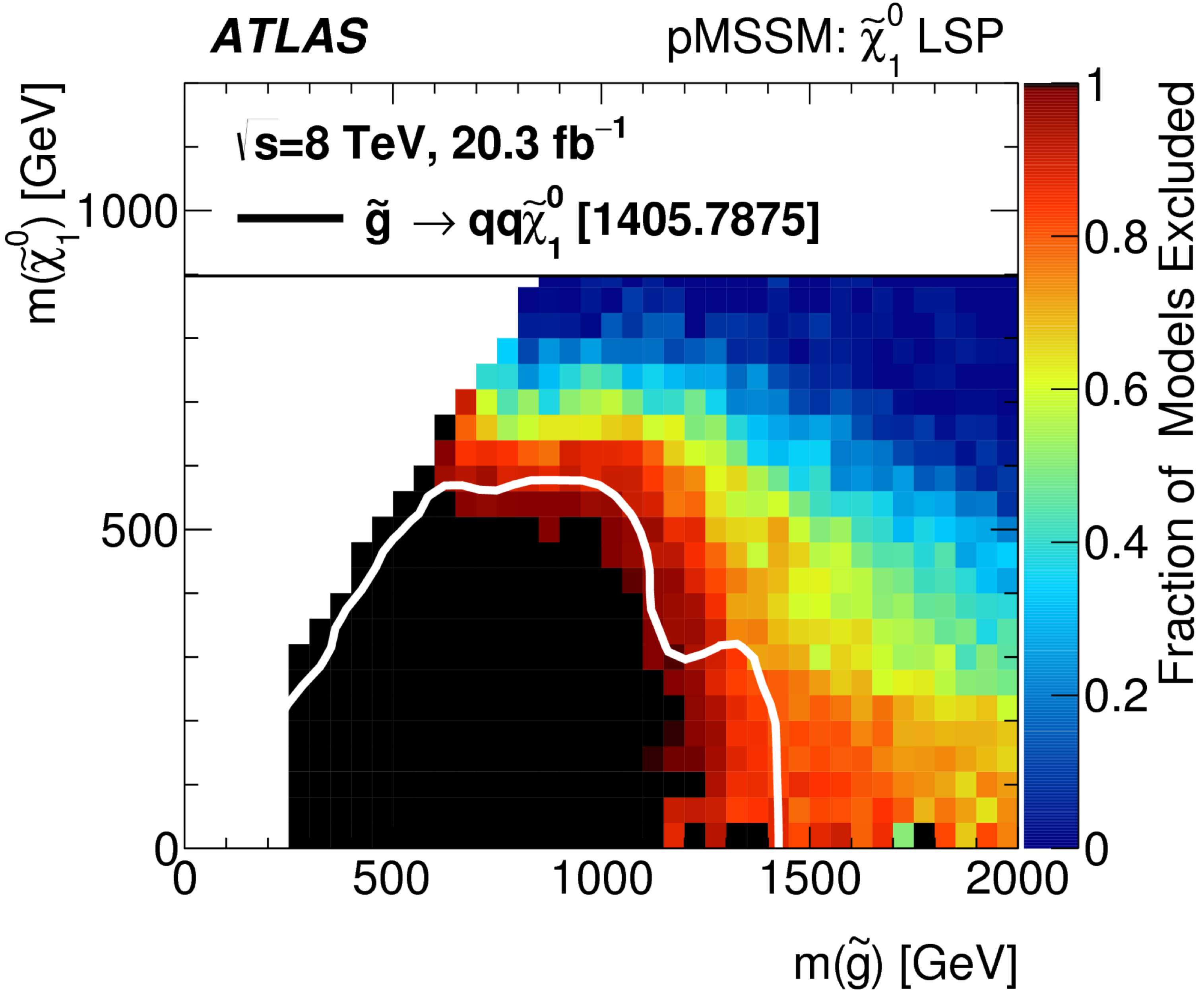
Simplified model for squark production and decay:



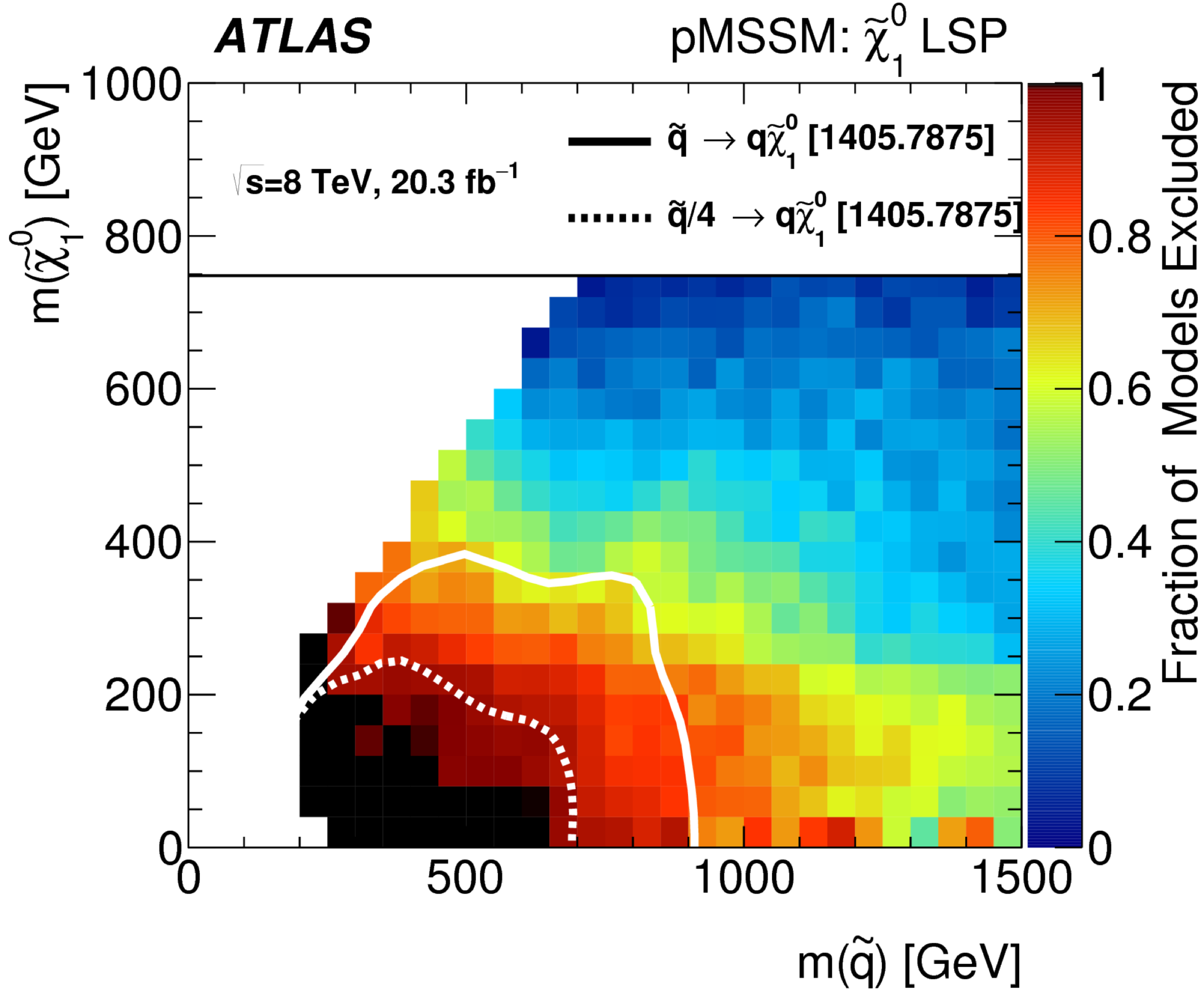
Dedicated analyses for top squarks

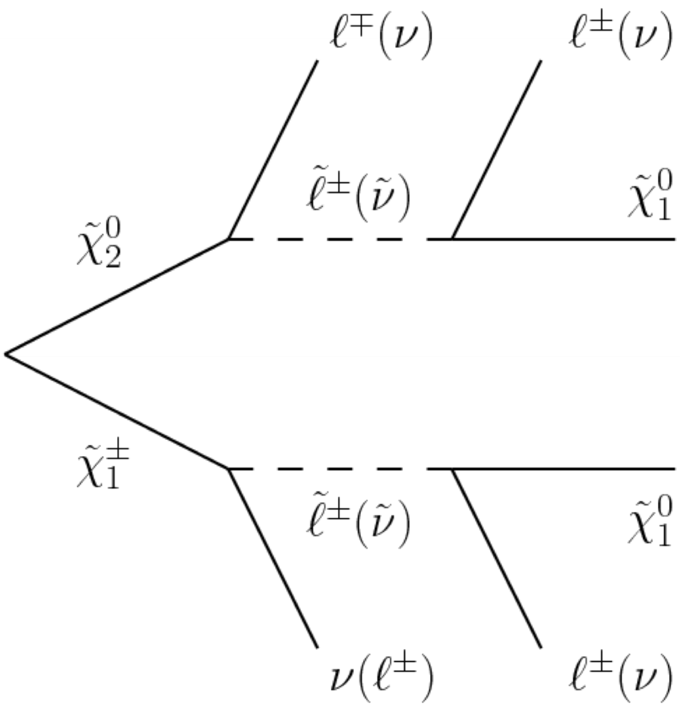


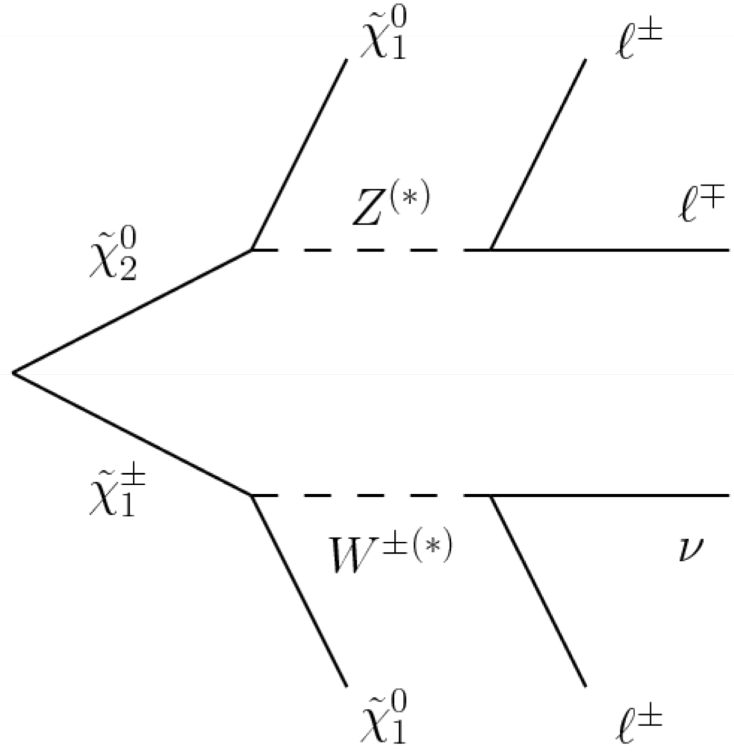
gluino exclusion in the ATLAS pMSSM analysis

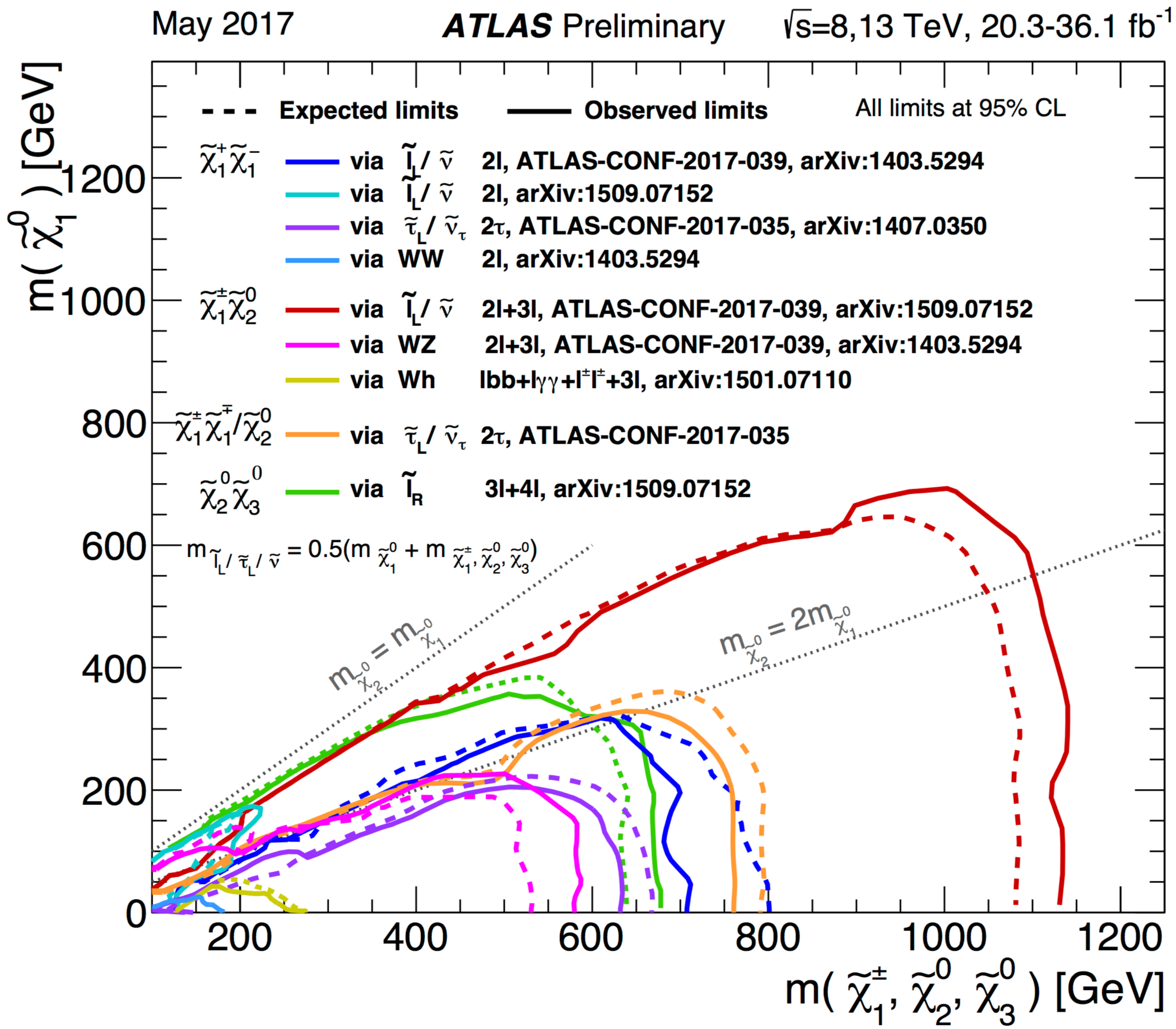


squark exclusion in the ATLAS pMSSM analysis

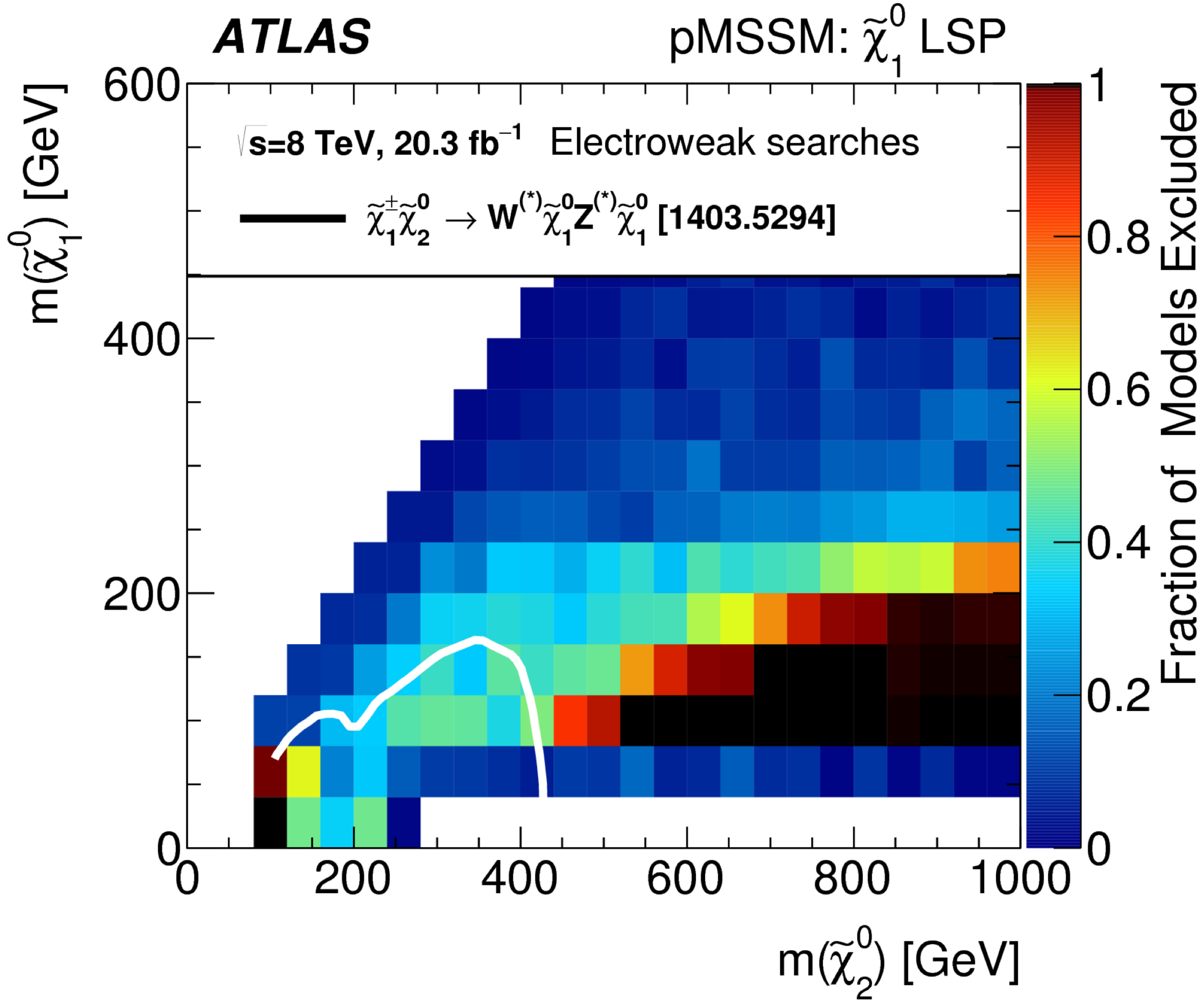



$\ell^{\mp}(\nu)$
$\ell^{\pm}(\nu)$
$\tilde{\ell}^{\pm}(\tilde{\nu})$
$\tilde{\chi}_1^0$
$\tilde{\chi}_2^0$
$\tilde{\chi}_1^{\pm}$
$\tilde{\ell}^{\pm}(\tilde{\nu})$
$\tilde{\chi}_1^0$
$\nu(\ell^{\pm})$
$\ell^{\pm}(\nu)$

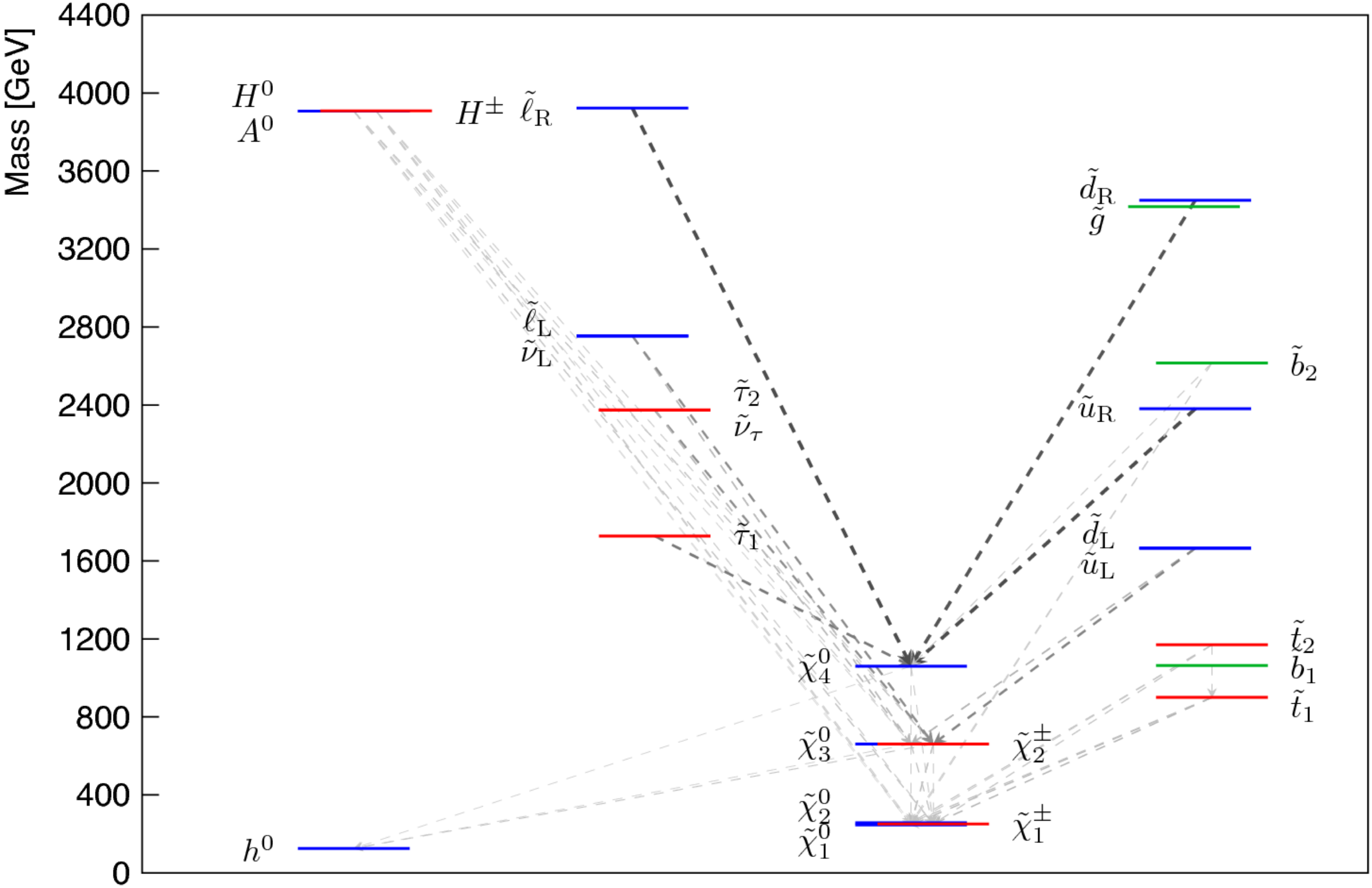

$\tilde{\chi}_1^0$
$\ell^{\pm}$
$Z^{(*)}$
$\ell^{\mp}$
$\tilde{\chi}_2^0$
$\tilde{\chi}_1^{\pm}$
$W^{\pm(*)}$
ν
$\tilde{\chi}_1^0$
$\ell^{\pm}$


May 2017
ATLAS Preliminary
$\sqrt{s}$=8,13 TeV, 20.3-36.1 fb^{-1}
Expected limits
Observed limits
All limits at 95% CL
$\tilde{\chi}_1^+\tilde{\chi}_1^-$
via $\tilde{l}_L / \tilde{\nu}$ 2l, ATLAS-CONF-2017-039, arXiv:1403.5294
via $\tilde{l}_L / \tilde{\nu}$ 2l, arXiv:1509.07152
via $\tilde{\tau}_L / \tilde{\nu}_\tau$ 2τ, ATLAS-CONF-2017-035, arXiv:1407.0350
via WW 2l, arXiv:1403.5294
$\tilde{\chi}_1^\pm\tilde{\chi}_2^0$
via $\tilde{l}_L / \tilde{\nu}$ 2l+3l, ATLAS-CONF-2017-039, arXiv:1509.07152
via WZ 2l+3l, ATLAS-CONF-2017-039, arXiv:1403.5294
via Wh lbb+lγγ+l$^\pm$l$^\pm$+3l, arXiv:1501.07110
$\tilde{\chi}_1^\pm\tilde{\chi}_1^\mp/\tilde{\chi}_2^0$
via $\tilde{\tau}_L / \tilde{\nu}_\tau$ 2τ, ATLAS-CONF-2017-035
$\tilde{\chi}_2^0\tilde{\chi}_3^0$
via $\tilde{l}_R$ 3l+4l, arXiv:1509.07152
$m_{\tilde{l}_L/\tilde{\tau}_L/\tilde{\nu}} = 0.5(m_{\tilde{\chi}_1^0} + m_{\tilde{\chi}_1^\pm,\tilde{\chi}_2^0,\tilde{\chi}_3^0})$
$m_{\tilde{\chi}_2^0} = m_{\tilde{\chi}_1^0}$
$m_{\tilde{\chi}_2^0} = 2m_{\tilde{\chi}_1^0}$
$m(\tilde{\chi}_1^0)$ [GeV]
0
200
400
600
800
1000
1200
200
400
600
800
1000
1200
$m(\tilde{\chi}_1^\pm, \tilde{\chi}_2^0, \tilde{\chi}_3^0)$ [GeV]

neutralino exclusion in the ATLAS pMSSM analysis

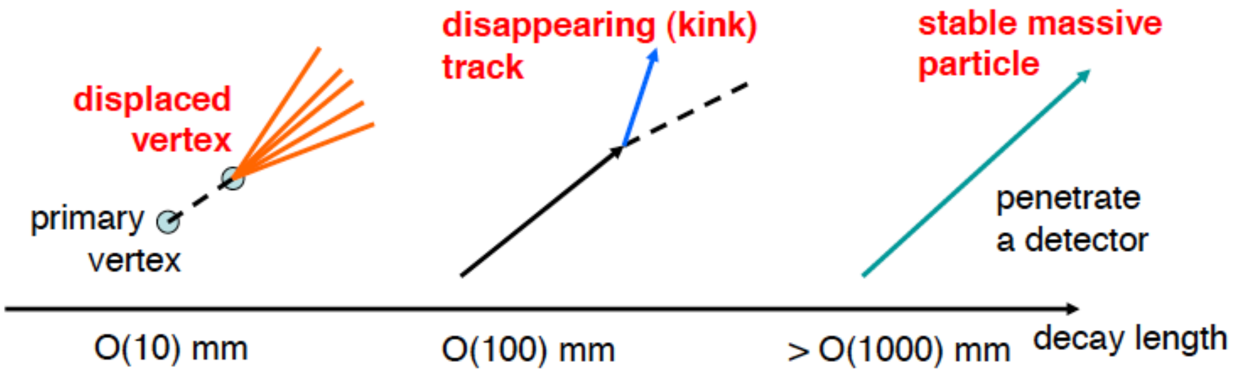


Example of SUSY model not yet ruled out

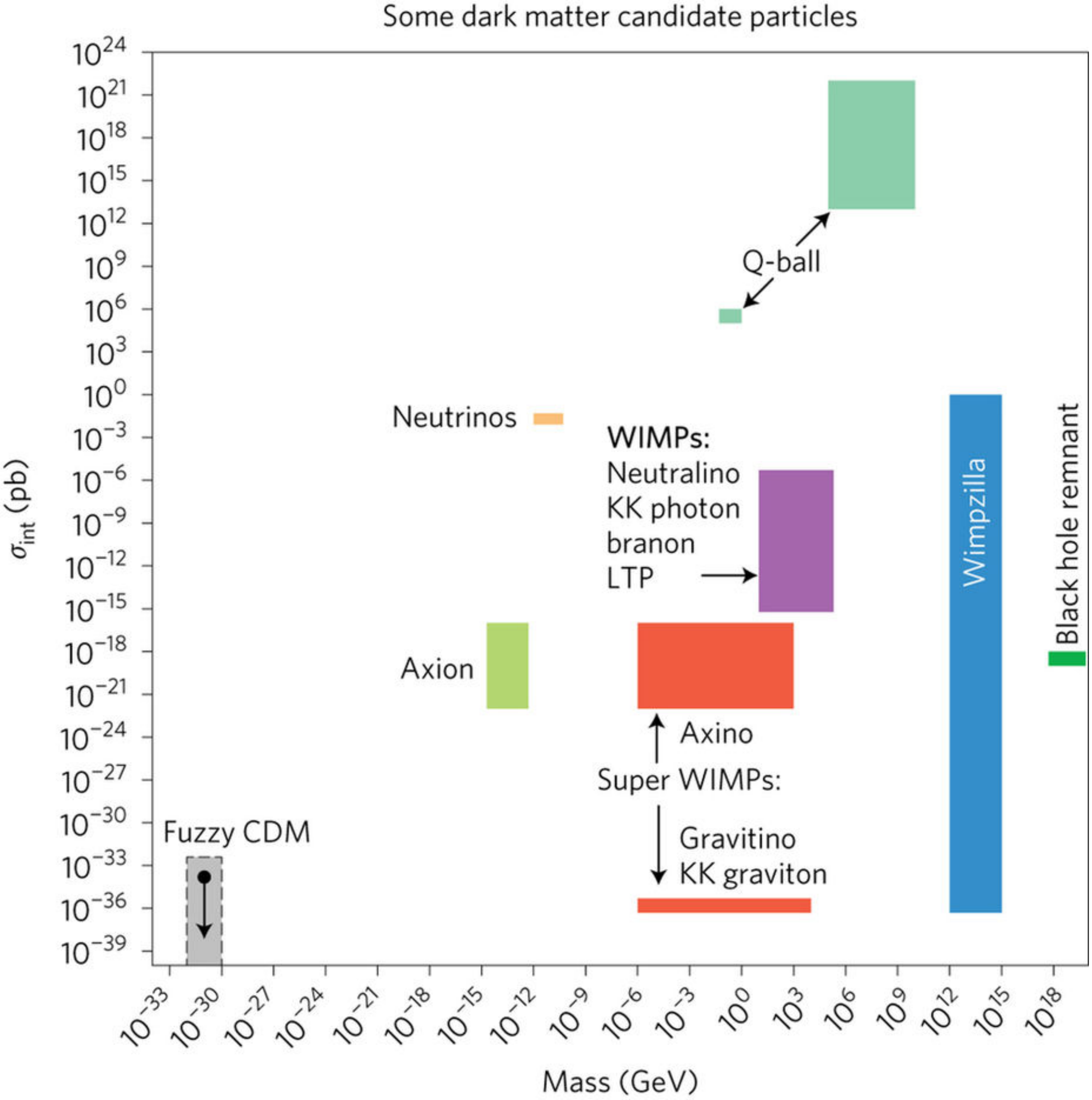


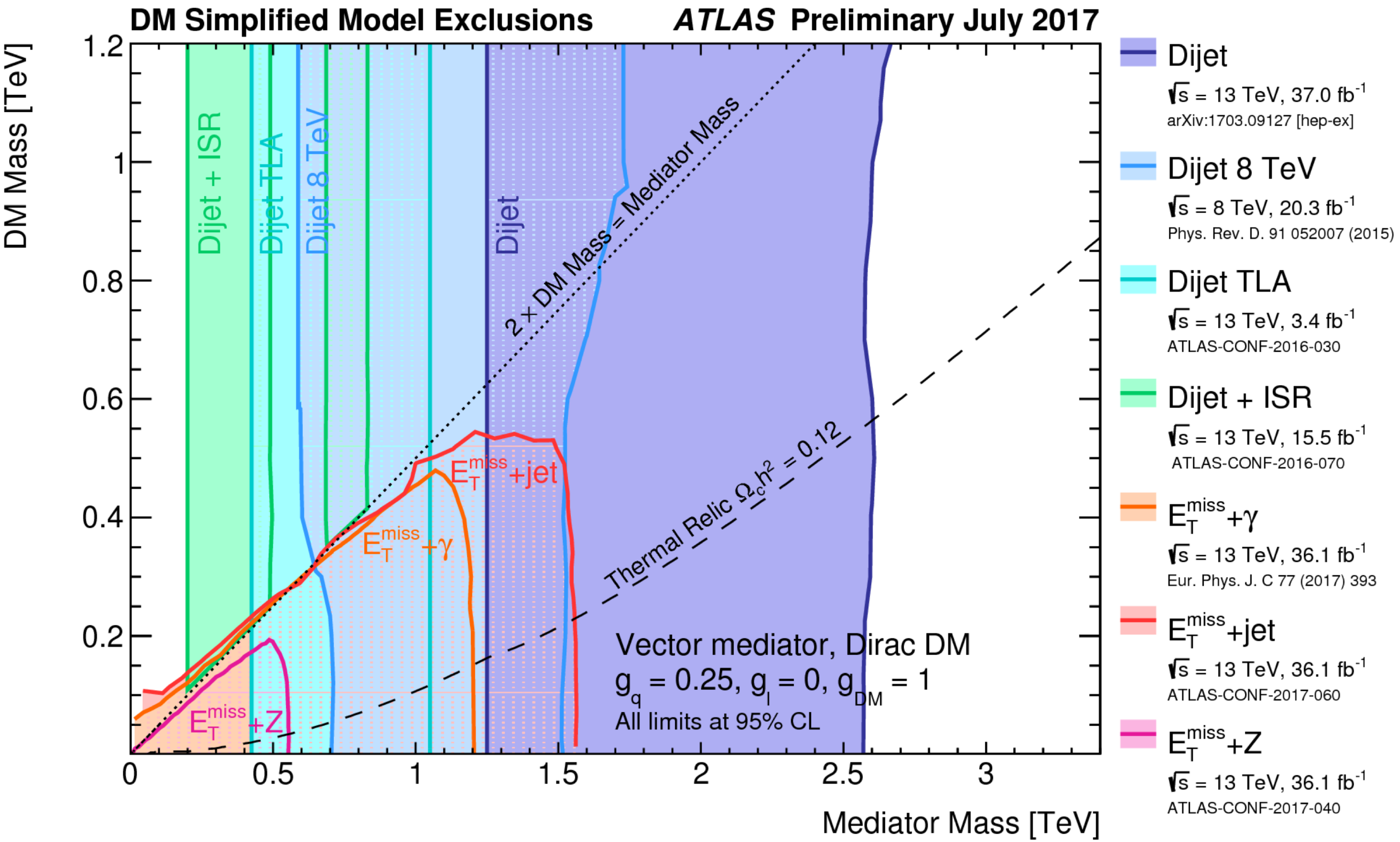
Special final states

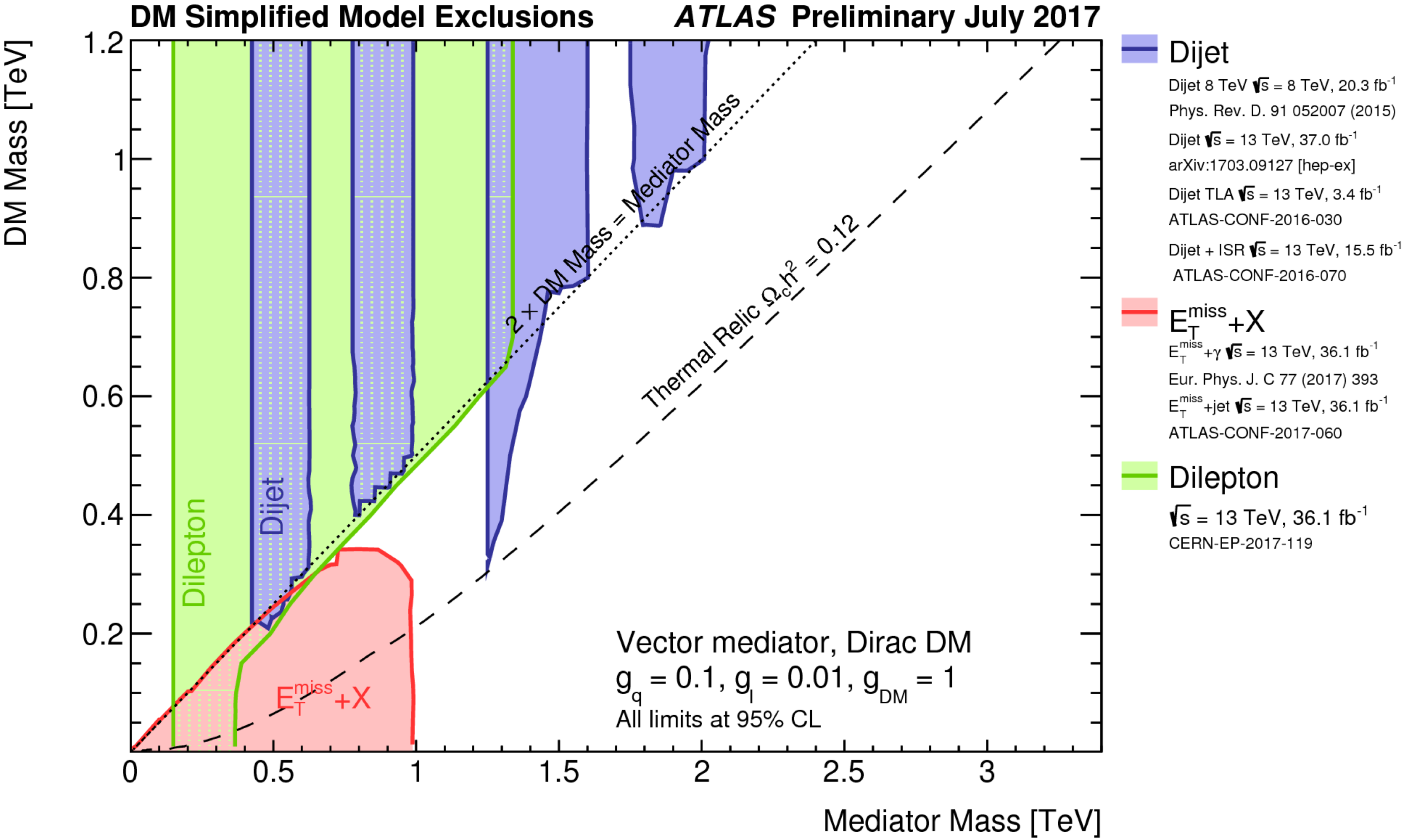
Long-living supersymmetric particles: very well possible in SUSY!



R-hadrons, R-parity violation, compressed spectra


Some dark matter candidate particles
σ_{int} (pb)
10^{24}
10^{21}
10^{18}
10^{15}
10^{12}
10^{9}
10^{6}
10^{3}
10^{0}
10^{-3}
10^{-6}
10^{-9}
10^{-12}
10^{-15}
10^{-18}
10^{-21}
10^{-24}
10^{-27}
10^{-30}
10^{-33}
10^{-36}
10^{-39}
Q-ball
Neutrinos
WIMPs:
Neutralino
KK photon
branon
LTP
Wimpzilla
Black hole remnant
Axion
Axino
Super WIMPs:
Gravitino
KK graviton
Fuzzy CDM
10^{-33}
10^{-30}
10^{-27}
10^{-24}
10^{-21}
10^{-18}
10^{-15}
10^{-12}
10^{-9}
10^{-6}
10^{-3}
10^{0}
10^{3}
10^{6}
10^{9}
10^{12}
10^{15}
10^{18}
Mass (GeV)


DM Simplified Model Exclusions
ATLAS Preliminary July 2017
DM Mass [TeV]
1.2
1
0.8
0.6
0.4
0.2
0
0.5
1
1.5
2
2.5
3
Mediator Mass [TeV]
Dijet + ISR
Dijet TLA
Dijet 8 TeV
Dijet
2 × DM Mass = Mediator Mass
Thermal Relic $\Omega_c h^2 = 0.12$
E_T^{miss}+jet
E_T^{miss}+γ
E_T^{miss}+Z
Vector mediator, Dirac DM
$g_q = 0.25, g_l = 0, g_{DM} = 1$
All limits at 95% CL
Dijet
$\sqrt{s}$ = 13 TeV, 37.0 fb^{-1}
arXiv:1703.09127 [hep-ex]
Dijet 8 TeV
$\sqrt{s}$ = 8 TeV, 20.3 fb^{-1}
Phys. Rev. D. 91 052007 (2015)
Dijet TLA
$\sqrt{s}$ = 13 TeV, 3.4 fb^{-1}
ATLAS-CONF-2016-030
Dijet + ISR
$\sqrt{s}$ = 13 TeV, 15.5 fb^{-1}
ATLAS-CONF-2016-070
E_T^{miss}+γ
$\sqrt{s}$ = 13 TeV, 36.1 fb^{-1}
Eur. Phys. J. C 77 (2017) 393
E_T^{miss}+jet
$\sqrt{s}$ = 13 TeV, 36.1 fb^{-1}
ATLAS-CONF-2017-060
E_T^{miss}+Z
$\sqrt{s}$ = 13 TeV, 36.1 fb^{-1}
ATLAS-CONF-2017-040

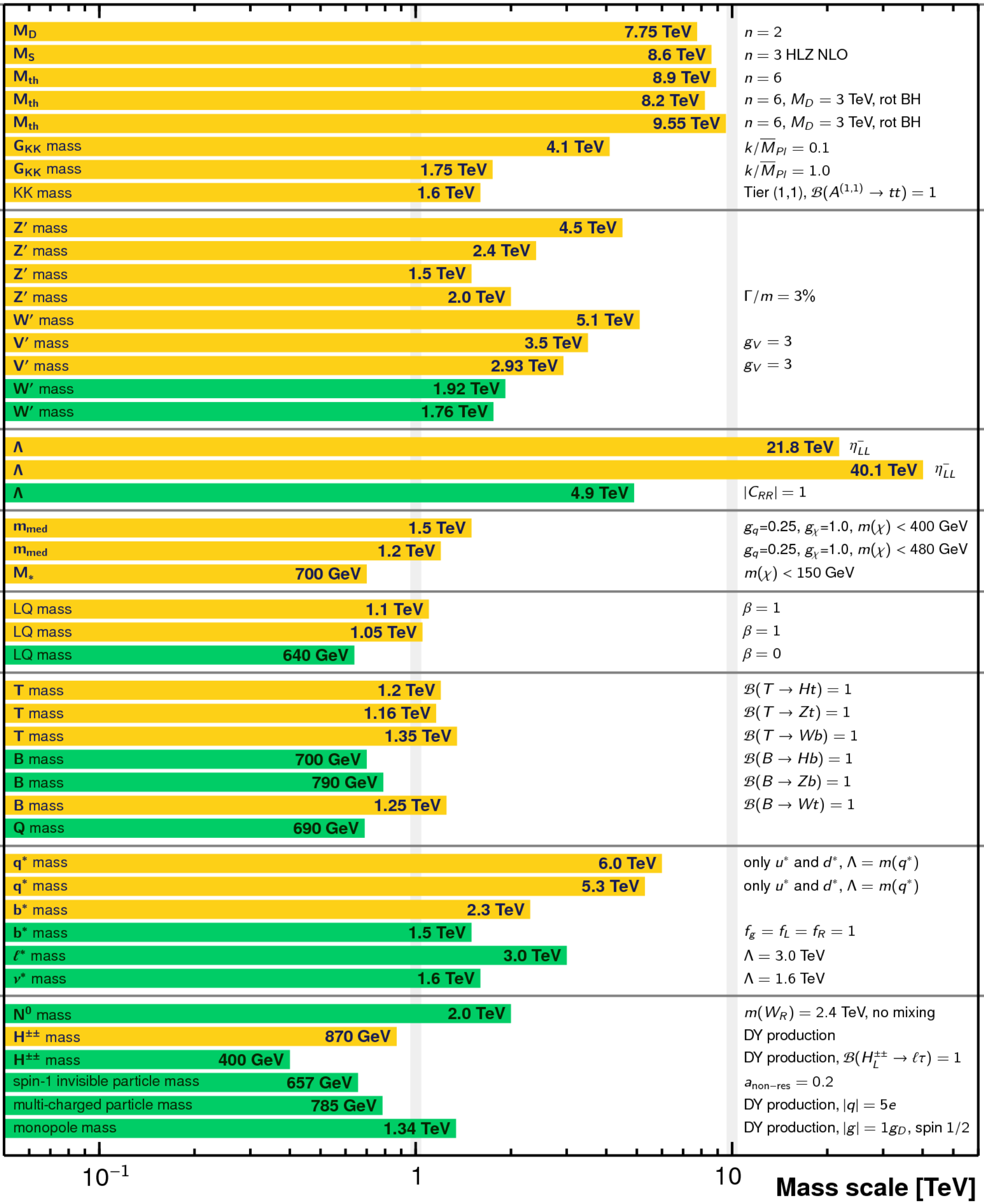

DM Simplified Model Exclusions
ATLAS Preliminary July 2017
DM Mass [TeV]
1.2
1
0.8
0.6
0.4
0.2
Mediator Mass [TeV]
0
0.5
1
1.5
2
2.5
3
Dilepton
Dijet
E_T^{miss}+X
2 × DM Mass = Mediator Mass
Thermal Relic $\Omega_c h^2$ = 0.12
Vector mediator, Dirac DM
g_q = 0.1, g_l = 0.01, g_{DM} = 1
All limits at 95% CL
Dijet
Dijet 8 TeV $\sqrt{s}$ = 8 TeV, 20.3 fb^{-1}
Phys. Rev. D. 91 052007 (2015)
Dijet $\sqrt{s}$ = 13 TeV, 37.0 fb^{-1}
arXiv:1703.09127 [hep-ex]
Dijet TLA $\sqrt{s}$ = 13 TeV, 3.4 fb^{-1}
ATLAS-CONF-2016-030
Dijet + ISR $\sqrt{s}$ = 13 TeV, 15.5 fb^{-1}
ATLAS-CONF-2016-070
E_T^{miss}+X
E_T^{miss}+γ $\sqrt{s}$ = 13 TeV, 36.1 fb^{-1}
Eur. Phys. J. C 77 (2017) 393
E_T^{miss}+jet $\sqrt{s}$ = 13 TeV, 36.1 fb^{-1}
ATLAS-CONF-2017-060
Dilepton
$\sqrt{s}$ = 13 TeV, 36.1 fb^{-1}
CERN-EP-2017-119

ATLAS Exotics Searches* - 95% CL Upper Exclusion Limits

Status: July 2017

ATLAS Preliminary

$\int \mathcal{L}\, dt = (3.2 - 37.0)\ \mathrm{fb}^{-1}$ $\sqrt{s} = 8,\ 13$ TeV



	Model	ℓ, γ	Jets†	E_T^{miss}	$\int\mathcal{L}\, dt[\mathrm{fb}^{-1}]$	Limit		Reference
Extra dimensions	ADD $G_{KK} + g/q$	$0\ e, \mu$	$1-4$ j	Yes	36.1	🟨 M_D 7.75 TeV	$n = 2$	ATLAS-CONF-2017-060
	ADD non-resonant $\gamma\gamma$	$2\ \gamma$	–	–	36.7	🟨 M_S 8.6 TeV	$n = 3$ HLZ NLO	CERN-EP-2017-132
	ADD QBH	–	2 j	–	37.0	🟨 M_{th} 8.9 TeV	$n = 6$	1703.09217
	ADD BH high $\sum p_T$	$\geq 1\ e, \mu$	≥ 2 j	–	3.2	🟨 M_{th} 8.2 TeV	$n = 6$, $M_D = 3$ TeV, rot BH	1606.02265
	ADD BH multijet	–	≥ 3 j	–	3.6	🟨 M_{th} 9.55 TeV	$n = 6$, $M_D = 3$ TeV, rot BH	1512.02586
	RS1 $G_{KK} \to \gamma\gamma$	$2\ \gamma$	–	–	36.7	🟨 G_{KK} mass 4.1 TeV	$k/\overline{M}_{Pl} = 0.1$	CERN-EP-2017-132
	Bulk RS $G_{KK} \to WW \to qq\ell\nu$	$1\ e, \mu$	1 J	Yes	36.1	🟨 G_{KK} mass 1.75 TeV	$k/\overline{M}_{Pl} = 1.0$	ATLAS-CONF-2017-051
	2UED / RPP	$1\ e, \mu$	≥ 2 b, ≥ 3 j	Yes	13.2	🟨 KK mass 1.6 TeV	Tier (1,1), $\mathcal{B}(A^{(1,1)} \to tt) = 1$	ATLAS-CONF-2016-104
Gauge bosons	SSM $Z' \to \ell\ell$	$2\ e, \mu$	–	–	36.1	🟨 Z' mass 4.5 TeV		ATLAS-CONF-2017-027
	SSM $Z' \to \tau\tau$	$2\ \tau$	–	–	36.1	🟨 Z' mass 2.4 TeV		ATLAS-CONF-2017-050
	Leptophobic $Z' \to bb$	–	2 b	–	3.2	🟨 Z' mass 1.5 TeV		1603.08791
	Leptophobic $Z' \to tt$	$1\ e, \mu$	≥ 1 b, ≥ 1J/2j	Yes	3.2	🟨 Z' mass 2.0 TeV	$\Gamma/m = 3\%$	ATLAS-CONF-2016-014
	SSM $W' \to \ell\nu$	$1\ e, \mu$	–	Yes	36.1	🟨 W' mass 5.1 TeV		1706.04786
	HVT $V' \to WV \to qqqq$ model B	$0\ e, \mu$	2 J	–	36.7	🟨 V' mass 3.5 TeV	$g_V = 3$	CERN-EP-2017-147
	HVT $V' \to WH/ZH$ model B	multi-channel			36.1	🟨 V' mass 2.93 TeV	$g_V = 3$	ATLAS-CONF-2017-055
	LRSM $W'_R \to tb$	$1\ e, \mu$	2 b, 0-1 j	Yes	20.3	🟩 W' mass 1.92 TeV		1410.4103
	LRSM $W'_R \to tb$	$0\ e, \mu$	≥ 1 b, 1 J	–	20.3	🟩 W' mass 1.76 TeV		1408.0886
CI	CI $qqqq$	–	2 j	–	37.0	🟨 Λ 21.8 TeV	η_{LL}^{-}	1703.09217
	CI $\ell\ell qq$	$2\ e, \mu$	–	–	36.1	🟨 Λ 40.1 TeV	η_{LL}^{-}	ATLAS-CONF-2017-027
	CI $uutt$	2(SS)/$\geq$3 e,μ	$\geq$1 b, $\geq$1 j	Yes	20.3	🟩 Λ 4.9 TeV	$\lvert C_{RR}\rvert = 1$	1504.04605
DM	Axial-vector mediator (Dirac DM)	$0\ e, \mu$	$1-4$ j	Yes	36.1	🟨 m_{med} 1.5 TeV	g_q=0.25, g_χ=1.0, $m(\chi) < 400$ GeV	ATLAS-CONF-2017-060
	Vector mediator (Dirac DM)	$0\ e, \mu$, $1\ \gamma$	≤ 1 j	Yes	36.1	🟨 m_{med} 1.2 TeV	g_q=0.25, g_χ=1.0, $m(\chi) < 480$ GeV	1704.03848
	$VV\chi\chi$ EFT (Dirac DM)	$0\ e, \mu$	1 J, ≤ 1 j	Yes	3.2	🟨 M_* 700 GeV	$m(\chi) < 150$ GeV	1608.02372
LQ	Scalar LQ 1st gen	$2\ e$	≥ 2 j	–	3.2	🟨 LQ mass 1.1 TeV	$\beta = 1$	1605.06035
	Scalar LQ 2nd gen	$2\ \mu$	≥ 2 j	–	3.2	🟨 LQ mass 1.05 TeV	$\beta = 1$	1605.06035
	Scalar LQ 3rd gen	$1\ e, \mu$	$\geq$1 b, $\geq$3 j	Yes	20.3	🟩 LQ mass 640 GeV	$\beta = 0$	1508.04735
Heavy quarks	VLQ $TT \to Ht + X$	0 or 1 e, μ	≥ 2 b, ≥ 3 j	Yes	13.2	🟨 T mass 1.2 TeV	$\mathcal{B}(T \to Ht) = 1$	ATLAS-CONF-2016-104
	VLQ $TT \to Zt + X$	$1\ e, \mu$	≥ 1 b, ≥ 3 j	Yes	36.1	🟨 T mass 1.16 TeV	$\mathcal{B}(T \to Zt) = 1$	1705.10751
	VLQ $TT \to Wb + X$	$1\ e, \mu$	≥ 1 b, ≥ 1J/2j	Yes	36.1	🟨 T mass 1.35 TeV	$\mathcal{B}(T \to Wb) = 1$	CERN-EP-2017-094
	VLQ $BB \to Hb + X$	$1\ e, \mu$	≥ 2 b, ≥ 3 j	Yes	20.3	🟩 B mass 700 GeV	$\mathcal{B}(B \to Hb) = 1$	1505.04306
	VLQ $BB \to Zb + X$	2/$\geq$3 e, μ	$\geq$2/$\geq$1 b	–	20.3	🟩 B mass 790 GeV	$\mathcal{B}(B \to Zb) = 1$	1409.5500
	VLQ $BB \to Wt + X$	$1\ e, \mu$	≥ 1 b, ≥ 1J/2j	Yes	36.1	🟨 B mass 1.25 TeV	$\mathcal{B}(B \to Wt) = 1$	CERN-EP-2017-094
	VLQ $QQ \to WqWq$	$1\ e, \mu$	≥ 4 j	Yes	20.3	🟩 Q mass 690 GeV		1509.04261
Excited fermions	Excited quark $q^* \to qg$	–	2 j	–	37.0	🟨 q^* mass 6.0 TeV	only u^* and d^*, $\Lambda = m(q^*)$	1703.09127
	Excited quark $q^* \to q\gamma$	$1\ \gamma$	1 j	–	36.7	🟨 q^* mass 5.3 TeV	only u^* and d^*, $\Lambda = m(q^*)$	CERN-EP-2017-148
	Excited quark $b^* \to bg$	–	1 b, 1 j	–	13.3	🟨 b^* mass 2.3 TeV		ATLAS-CONF-2016-060
	Excited quark $b^* \to Wt$	1 or 2 e, μ	1 b, 2-0 j	Yes	20.3	🟩 b^* mass 1.5 TeV	$f_g = f_L = f_R = 1$	1510.02664
	Excited lepton ℓ^*	$3\ e, \mu$	–	–	20.3	🟩 ℓ^* mass 3.0 TeV	$\Lambda = 3.0$ TeV	1411.2921
	Excited lepton ν^*	$3\ e, \mu, \tau$	–	–	20.3	🟩 ν^* mass 1.6 TeV	$\Lambda = 1.6$ TeV	1411.2921
Other	LRSM Majorana ν	$2\ e, \mu$	2 j	–	20.3	🟩 N^0 mass 2.0 TeV	$m(W_R) = 2.4$ TeV, no mixing	1506.06020
	Higgs triplet $H^{\pm\pm} \to \ell\ell$	2,3,4 e, μ (SS)	–	–	36.1	🟨 $H^{\pm\pm}$ mass 870 GeV	DY production	ATLAS-CONF-2017-053
	Higgs triplet $H^{\pm\pm} \to \ell\tau$	$3\ e, \mu, \tau$	–	–	20.3	🟩 $H^{\pm\pm}$ mass 400 GeV	DY production, $\mathcal{B}(H_L^{\pm\pm} \to \ell\tau) = 1$	1411.2921
	Monotop (non-res prod)	$1\ e, \mu$	1 b	Yes	20.3	🟩 spin-1 invisible particle mass 657 GeV	$a_{\mathrm{non-res}} = 0.2$	1410.5404
	Multi-charged particles	–	–	–	20.3	🟩 multi-charged particle mass 785 GeV	DY production, $\lvert q\rvert = 5e$	1504.04188
	Magnetic monopoles	–	–	–	7.0	🟩 monopole mass 1.34 TeV	DY production, $\lvert g\rvert = 1g_D$, spin 1/2	1509.08059

🟩 $\sqrt{s}$ = 8 TeV 🟨 $\sqrt{s}$ = 13 TeV

**Only a selection of the available mass limits on new states or phenomena is shown.*

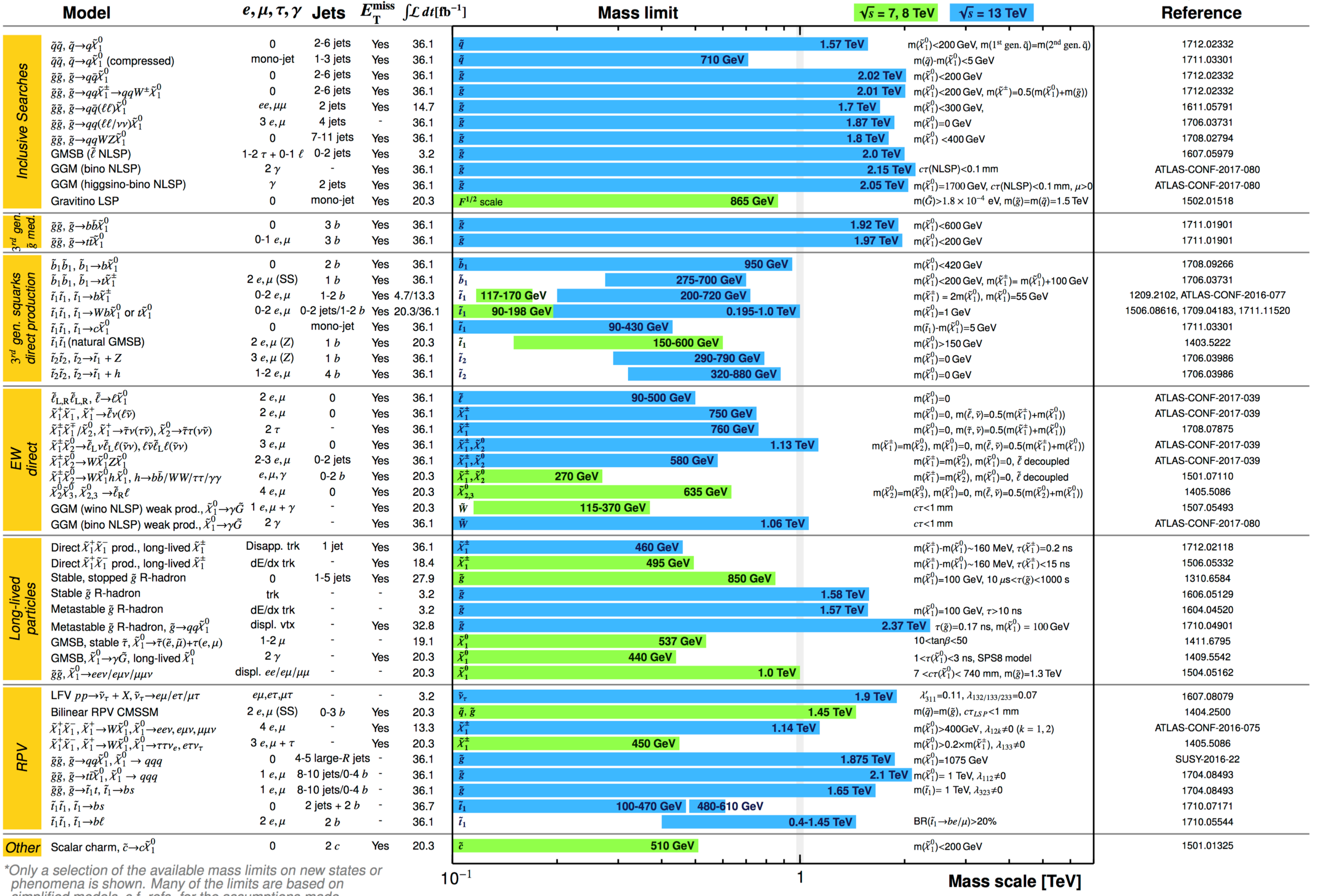
†Small-radius (large-radius) jets are denoted by the letter j (J).

ATLAS SUSY Searches* - 95% CL Lower Limits

December 2017

ATLAS Preliminary

$\sqrt{s}$ = 7, 8, 13 TeV



	Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\, dt[\mathrm{fb}^{-1}]$	Mass limit		Reference
Inclusive Searches	$\tilde{q}\tilde{q}, \tilde{q}\to q\tilde{\chi}_1^0$	0	2-6 jets	Yes	36.1	🟦 $\tilde{q}$ 1.57 TeV	m($\tilde{\chi}_1^0$)<200 GeV, m(1st gen. q̃)=m(2nd gen. q̃)	1712.02332
	$\tilde{q}\tilde{q}, \tilde{q}\to q\tilde{\chi}_1^0$ (compressed)	mono-jet	1-3 jets	Yes	36.1	🟦 $\tilde{q}$ 710 GeV	m($\tilde{q}$)-m($\tilde{\chi}_1^0$)<5 GeV	1711.03301
	$\tilde{g}\tilde{g}, \tilde{g}\to q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	36.1	🟦 $\tilde{g}$ 2.02 TeV	m($\tilde{\chi}_1^0$)<200 GeV	1712.02332
	$\tilde{g}\tilde{g}, \tilde{g}\to qq\tilde{\chi}_1^{\pm}\to qqW^{\pm}\tilde{\chi}_1^0$	0	2-6 jets	Yes	36.1	🟦 $\tilde{g}$ 2.01 TeV	m($\tilde{\chi}_1^0$)<200 GeV, m($\tilde{\chi}^{\pm}$)=0.5(m($\tilde{\chi}_1^0$)+m($\tilde{g}$))	1712.02332
	$\tilde{g}\tilde{g}, \tilde{g}\to q\bar{q}(\ell\ell)\tilde{\chi}_1^0$	$ee, \mu\mu$	2 jets	Yes	14.7	🟦 $\tilde{g}$ 1.7 TeV	m($\tilde{\chi}_1^0$)<300 GeV,	1611.05791
	$\tilde{g}\tilde{g}, \tilde{g}\to qq(\ell\ell/\nu\nu)\tilde{\chi}_1^0$	3 e, μ	4 jets	-	36.1	🟦 $\tilde{g}$ 1.87 TeV	m($\tilde{\chi}_1^0$)=0 GeV	1706.03731
	$\tilde{g}\tilde{g}, \tilde{g}\to qqWZ\tilde{\chi}_1^0$	0	7-11 jets	Yes	36.1	🟦 $\tilde{g}$ 1.8 TeV	m($\tilde{\chi}_1^0$) <400 GeV	1708.02794
	GMSB ($\tilde{\ell}$ NLSP)	1-2 τ + 0-1 ℓ	0-2 jets	Yes	3.2	🟦 $\tilde{g}$ 2.0 TeV		1607.05979
	GGM (bino NLSP)	2 γ	-	Yes	36.1	🟦 $\tilde{g}$ 2.15 TeV	$c\tau$(NLSP)<0.1 mm	ATLAS-CONF-2017-080
	GGM (higgsino-bino NLSP)	γ	2 jets	Yes	36.1	🟦 $\tilde{g}$ 2.05 TeV	m($\tilde{\chi}_1^0$)=1700 GeV, $c\tau$(NLSP)<0.1 mm, μ>0	ATLAS-CONF-2017-080
	Gravitino LSP	0	mono-jet	Yes	20.3	🟩 $F^{1/2}$ scale 865 GeV	m($\tilde{G}$)>1.8 × 10^{-4} eV, m($\tilde{g}$)=m($\tilde{q}$)=1.5 TeV	1502.01518
3rd gen. $\tilde{g}$ med.	$\tilde{g}\tilde{g}, \tilde{g}\to b\bar{b}\tilde{\chi}_1^0$	0	3 b	Yes	36.1	🟦 $\tilde{g}$ 1.92 TeV	m($\tilde{\chi}_1^0$)<600 GeV	1711.01901
	$\tilde{g}\tilde{g}, \tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0-1 e, μ	3 b	Yes	36.1	🟦 $\tilde{g}$ 1.97 TeV	m($\tilde{\chi}_1^0$)<200 GeV	1711.01901
3rd gen. squarks direct production	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to b\tilde{\chi}_1^0$	0	2 b	Yes	36.1	🟦 $\tilde{b}_1$ 950 GeV	m($\tilde{\chi}_1^0$)<420 GeV	1708.09266
	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to t\tilde{\chi}_1^{\pm}$	2 e, μ (SS)	1 b	Yes	36.1	🟦 $\tilde{b}_1$ 275-700 GeV	m($\tilde{\chi}_1^0$)<200 GeV, m($\tilde{\chi}_1^{\pm}$)= m($\tilde{\chi}_1^0$)+100 GeV	1706.03731
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to b\tilde{\chi}_1^{\pm}$	0-2 e, μ	1-2 b	Yes	4.7/13.3	$\tilde{t}_1$ 🟩 117-170 GeV 🟦 200-720 GeV	m($\tilde{\chi}_1^{\pm}$) = 2m($\tilde{\chi}_1^0$), m($\tilde{\chi}_1^0$)=55 GeV	1209.2102, ATLAS-CONF-2016-077
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to Wb\tilde{\chi}_1^0$ or $t\tilde{\chi}_1^0$	0-2 e, μ	0-2 jets/1-2 b	Yes	20.3/36.1	$\tilde{t}_1$ 🟩 90-198 GeV 🟦 0.195-1.0 TeV	m($\tilde{\chi}_1^0$)=1 GeV	1506.08616, 1709.04183, 1711.11520
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to c\tilde{\chi}_1^0$	0	mono-jet	Yes	36.1	🟦 $\tilde{t}_1$ 90-430 GeV	m($\tilde{t}_1$)-m($\tilde{\chi}_1^0$)=5 GeV	1711.03301
	$\tilde{t}_1\tilde{t}_1$ (natural GMSB)	2 e, μ (Z)	1 b	Yes	20.3	🟩 $\tilde{t}_1$ 150-600 GeV	m($\tilde{\chi}_1^0$)>150 GeV	1403.5222
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2\to\tilde{t}_1 + Z$	3 e, μ (Z)	1 b	Yes	36.1	🟦 $\tilde{t}_2$ 290-790 GeV	m($\tilde{\chi}_1^0$)=0 GeV	1706.03986
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2\to\tilde{t}_1 + h$	1-2 e, μ	4 b	Yes	36.1	🟦 $\tilde{t}_2$ 320-880 GeV	m($\tilde{\chi}_1^0$)=0 GeV	1706.03986
EW direct	$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R}, \tilde{\ell}\to\ell\tilde{\chi}_1^0$	2 e, μ	0	Yes	36.1	🟦 $\tilde{\ell}$ 90-500 GeV	m($\tilde{\chi}_1^0$)=0	ATLAS-CONF-2017-039
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to\tilde{\ell}\nu(\ell\tilde{\nu})$	2 e, μ	0	Yes	36.1	🟦 $\tilde{\chi}_1^{\pm}$ 750 GeV	m($\tilde{\chi}_1^0$)=0, m($\tilde{\ell}, \tilde{\nu}$)=0.5(m($\tilde{\chi}_1^{\pm}$)+m($\tilde{\chi}_1^0$))	ATLAS-CONF-2017-039
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}/\tilde{\chi}_2^0, \tilde{\chi}_1^+\to\tilde{\tau}\nu(\tau\tilde{\nu}), \tilde{\chi}_2^0\to\tilde{\tau}\tau(\nu\tilde{\nu})$	2 τ	-	Yes	36.1	🟦 $\tilde{\chi}_1^{\pm}$ 760 GeV	m($\tilde{\chi}_1^0$)=0, m($\tilde{\tau}, \tilde{\nu}$)=0.5(m($\tilde{\chi}_1^{\pm}$)+m($\tilde{\chi}_1^0$))	1708.07875
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\to\tilde{\ell}_L\nu\tilde{\ell}_L\ell(\tilde{\nu}\nu), \ell\tilde{\nu}\tilde{\ell}_L\ell(\tilde{\nu}\nu)$	3 e, μ	0	Yes	36.1	🟦 $\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$ 1.13 TeV	m($\tilde{\chi}_1^{\pm}$)=m($\tilde{\chi}_2^0$), m($\tilde{\chi}_1^0$)=0, m($\tilde{\ell}, \tilde{\nu}$)=0.5(m($\tilde{\chi}_1^{\pm}$)+m($\tilde{\chi}_1^0$))	ATLAS-CONF-2017-039
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\to W\tilde{\chi}_1^0 Z\tilde{\chi}_1^0$	2-3 e, μ	0-2 jets	Yes	36.1	🟦 $\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$ 580 GeV	m($\tilde{\chi}_1^{\pm}$)=m($\tilde{\chi}_2^0$), m($\tilde{\chi}_1^0$)=0, $\tilde{\ell}$ decoupled	ATLAS-CONF-2017-039
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\to W\tilde{\chi}_1^0 h\tilde{\chi}_1^0, h\to b\bar{b}/WW/\tau\tau/\gamma\gamma$	e, μ, γ	0-2 b	Yes	20.3	🟩 $\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$ 270 GeV	m($\tilde{\chi}_1^{\pm}$)=m($\tilde{\chi}_2^0$), m($\tilde{\chi}_1^0$)=0, $\tilde{\ell}$ decoupled	1501.07110
	$\tilde{\chi}_2^0\tilde{\chi}_3^0, \tilde{\chi}_{2,3}^0\to\tilde{\ell}_R\ell$	4 e, μ	0	Yes	20.3	🟩 $\tilde{\chi}_{2,3}^0$ 635 GeV	m($\tilde{\chi}_2^0$)=m($\tilde{\chi}_3^0$), m($\tilde{\chi}_1^0$)=0, m($\tilde{\ell}, \tilde{\nu}$)=0.5(m($\tilde{\chi}_2^0$)+m($\tilde{\chi}_1^0$))	1405.5086
	GGM (wino NLSP) weak prod., $\tilde{\chi}_1^0\to\gamma\tilde{G}$	1 $e, \mu + \gamma$	-	Yes	20.3	🟩 $\tilde{W}$ 115-370 GeV	$c\tau$<1 mm	1507.05493
	GGM (bino NLSP) weak prod., $\tilde{\chi}_1^0\to\gamma\tilde{G}$	2 γ	-	Yes	36.1	🟦 $\tilde{W}$ 1.06 TeV	$c\tau$<1 mm	ATLAS-CONF-2017-080
Long-lived particles	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^{\pm}$	Disapp. trk	1 jet	Yes	36.1	🟦 $\tilde{\chi}_1^{\pm}$ 460 GeV	m($\tilde{\chi}_1^{\pm}$)-m($\tilde{\chi}_1^0$)~160 MeV, τ($\tilde{\chi}_1^{\pm}$)=0.2 ns	1712.02118
	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^{\pm}$	dE/dx trk	-	Yes	18.4	🟩 $\tilde{\chi}_1^{\pm}$ 495 GeV	m($\tilde{\chi}_1^{\pm}$)-m($\tilde{\chi}_1^0$)~160 MeV, τ($\tilde{\chi}_1^{\pm}$)<15 ns	1506.05332
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	27.9	🟩 $\tilde{g}$ 850 GeV	m($\tilde{\chi}_1^0$)=100 GeV, 10 μs<τ($\tilde{g}$)<1000 s	1310.6584
	Stable $\tilde{g}$ R-hadron	trk	-	-	3.2	🟦 $\tilde{g}$ 1.58 TeV		1606.05129
	Metastable $\tilde{g}$ R-hadron	dE/dx trk	-	-	3.2	🟦 $\tilde{g}$ 1.57 TeV	m($\tilde{\chi}_1^0$)=100 GeV, τ>10 ns	1604.04520
	Metastable $\tilde{g}$ R-hadron, $\tilde{g}\to qq\tilde{\chi}_1^0$	displ. vtx	-	Yes	32.8	🟦 $\tilde{g}$ 2.37 TeV	τ($\tilde{g}$)=0.17 ns, m($\tilde{\chi}_1^0$) = 100 GeV	1710.04901
	GMSB, stable $\tilde{\tau}, \tilde{\chi}_1^0\to\tilde{\tau}(\tilde{e}, \tilde{\mu})+\tau(e, \mu)$	1-2 μ	-	-	19.1	🟩 $\tilde{\chi}_1^0$ 537 GeV	10<tanβ<50	1411.6795
	GMSB, $\tilde{\chi}_1^0\to\gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$	2 γ	-	Yes	20.3	🟩 $\tilde{\chi}_1^0$ 440 GeV	1<τ($\tilde{\chi}_1^0$)<3 ns, SPS8 model	1409.5542
	$\tilde{g}\tilde{g}, \tilde{\chi}_1^0\to ee\nu/e\mu\nu/\mu\mu\nu$	displ. $ee/e\mu/\mu\mu$	-	-	20.3	🟩 $\tilde{\chi}_1^0$ 1.0 TeV	7 <$c\tau$($\tilde{\chi}_1^0$)< 740 mm, m($\tilde{g}$)=1.3 TeV	1504.05162
RPV	LFV $pp\to\tilde{\nu}_\tau + X, \tilde{\nu}_\tau\to e\mu/e\tau/\mu\tau$	$e\mu, e\tau, \mu\tau$	-	-	3.2	🟦 $\tilde{\nu}_\tau$ 1.9 TeV	λ'_{311}=0.11, $\lambda_{132/133/233}$=0.07	1607.08079
	Bilinear RPV CMSSM	2 e, μ (SS)	0-3 b	Yes	20.3	🟩 $\tilde{q}, \tilde{g}$ 1.45 TeV	m($\tilde{q}$)=m($\tilde{g}$), $c\tau_{LSP}$<1 mm	1404.2500
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to W\tilde{\chi}_1^0, \tilde{\chi}_1^0\to ee\nu, e\mu\nu, \mu\mu\nu$	4 e, μ	-	Yes	13.3	🟦 $\tilde{\chi}_1^{\pm}$ 1.14 TeV	m($\tilde{\chi}_1^0$)>400GeV, $\lambda_{12k}\neq 0$ ($k = 1, 2$)	ATLAS-CONF-2016-075
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to W\tilde{\chi}_1^0, \tilde{\chi}_1^0\to\tau\tau\nu_e, e\tau\nu_\tau$	3 $e, \mu + \tau$	-	Yes	20.3	🟩 $\tilde{\chi}_1^{\pm}$ 450 GeV	m($\tilde{\chi}_1^0$)>0.2×m($\tilde{\chi}_1^{\pm}$), $\lambda_{133}\neq 0$	1405.5086
	$\tilde{g}\tilde{g}, \tilde{g}\to qq\tilde{\chi}_1^0, \tilde{\chi}_1^0\to qqq$	0	4-5 large-R jets	-	36.1	🟦 $\tilde{g}$ 1.875 TeV	m($\tilde{\chi}_1^0$)=1075 GeV	SUSY-2016-22
	$\tilde{g}\tilde{g}, \tilde{g}\to t\bar{t}\tilde{\chi}_1^0, \tilde{\chi}_1^0\to qqq$	1 e, μ	8-10 jets/0-4 b	-	36.1	🟦 $\tilde{g}$ 2.1 TeV	m($\tilde{\chi}_1^0$)= 1 TeV, $\lambda_{112}\neq 0$	1704.08493
	$\tilde{g}\tilde{g}, \tilde{g}\to\tilde{t}_1 t, \tilde{t}_1\to bs$	1 e, μ	8-10 jets/0-4 b	-	36.1	🟦 $\tilde{g}$ 1.65 TeV	m($\tilde{t}_1$)= 1 TeV, $\lambda_{323}\neq 0$	1704.08493
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to bs$	0	2 jets + 2 b	-	36.7	🟦 $\tilde{t}_1$ 100-470 GeV 480-610 GeV		1710.07171
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to b\ell$	2 e, μ	2 b	-	36.1	🟦 $\tilde{t}_1$ 0.4-1.45 TeV	BR($\tilde{t}_1\to be/\mu$)>20%	1710.05544
Other	Scalar charm, $\tilde{c}\to c\tilde{\chi}_1^0$	0	2 c	Yes	20.3	🟩 $\tilde{c}$ 510 GeV	m($\tilde{\chi}_1^0$)<200 GeV	1501.01325

*Only a selection of the available mass limits on new states or phenomena is shown. Many of the limits are based on simplified models, c.f. refs. for the assumptions made.