



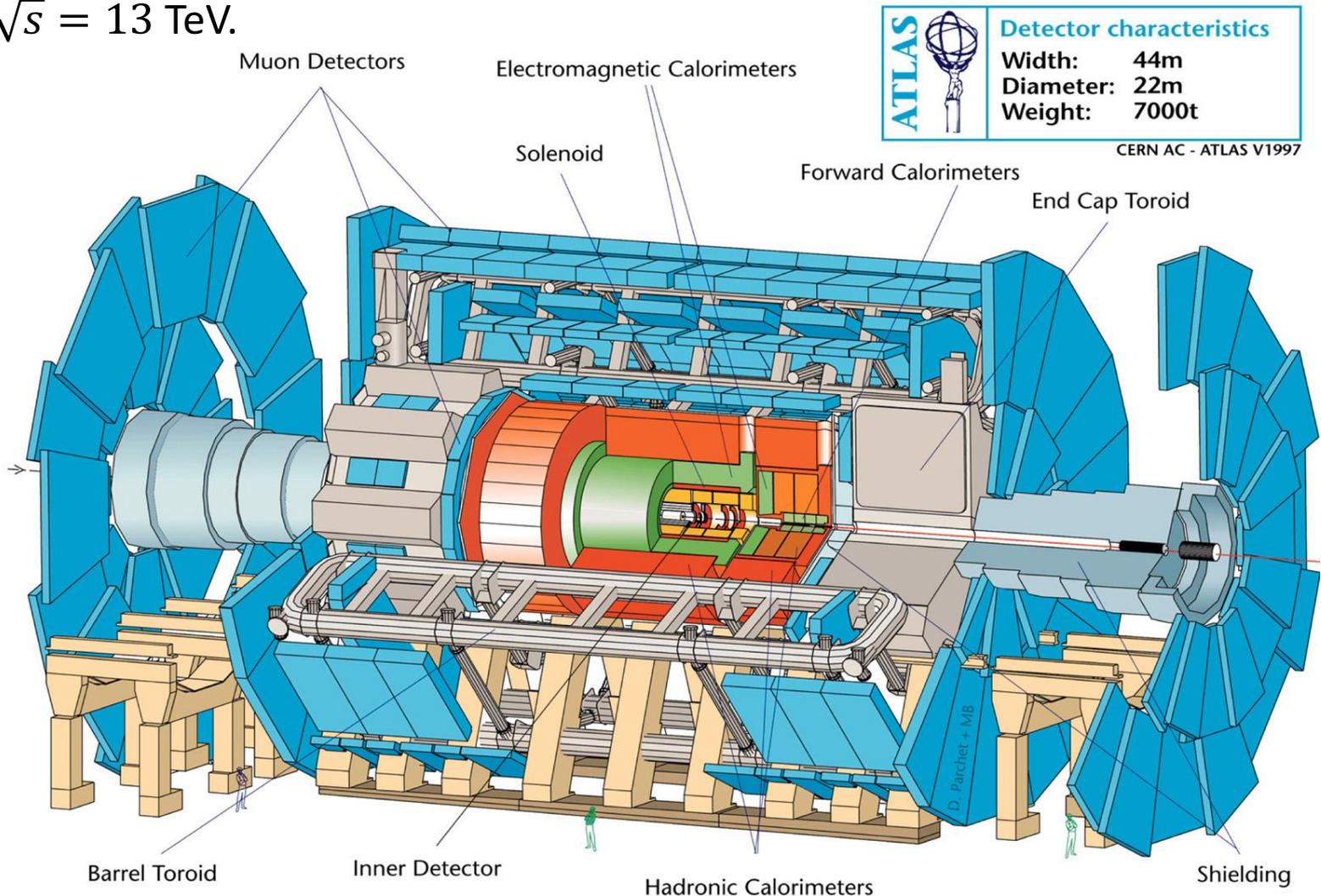
ATLAS results on searches for Supersymmetry

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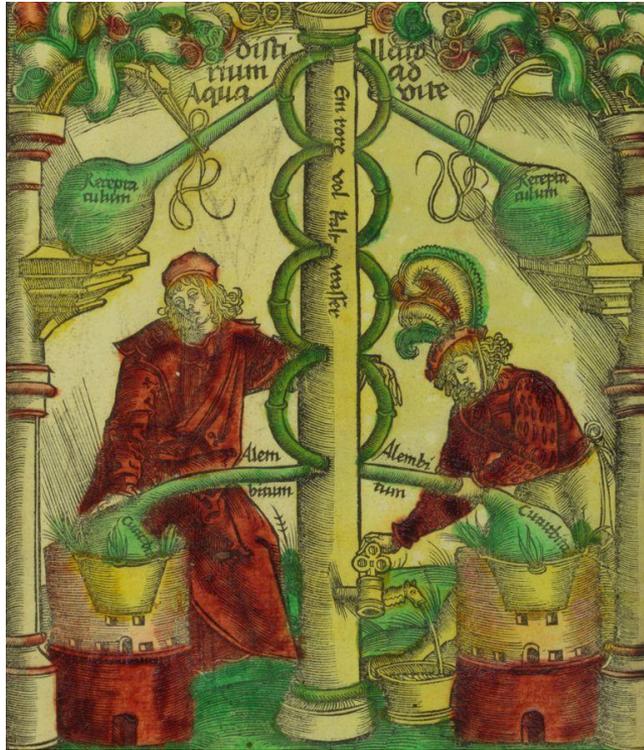
Aspen 2018 – The particle frontier

The ATLAS experiment at the LHC

- Multi-purpose experiment exploring proton-proton (and HI) collisions at $\sqrt{s} = 13$ TeV.



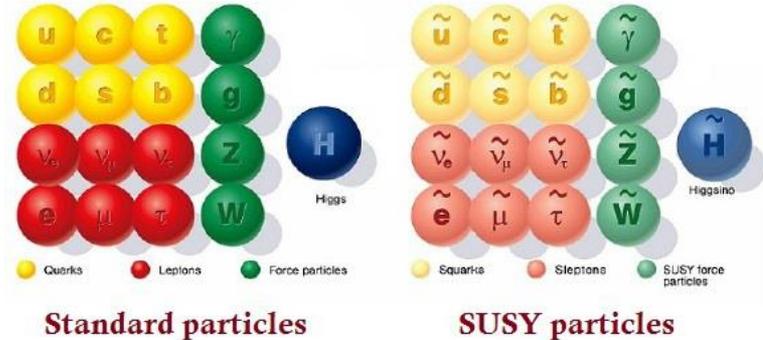
Why SUSY?



"philosopher's stone" enables:

- creation of an elixir of immortality
- transmutation of common substances into gold

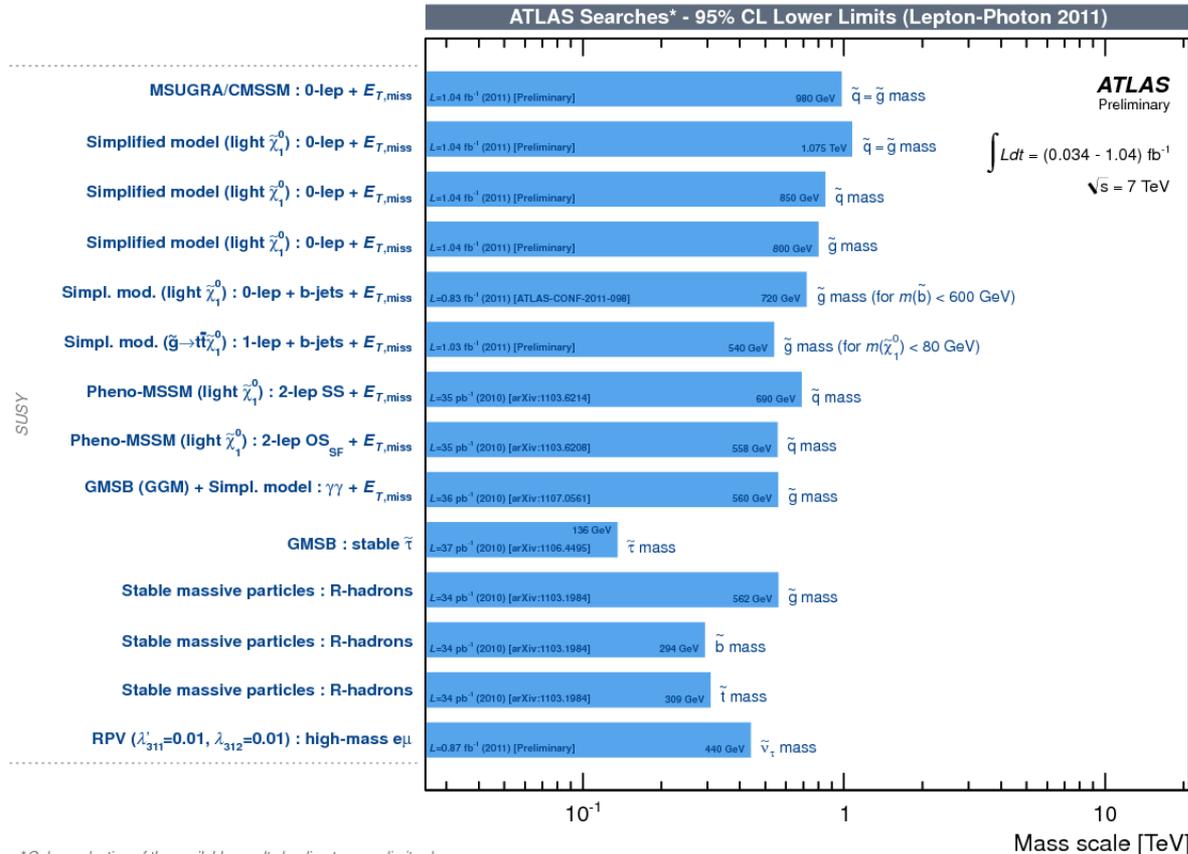
SUPERSYMMETRY



- A supersymmetric extensions of the SM could solve the central issues:
 - Gauge coupling unification
 - Hierarchy problem (e.g. loop corrections to Higgs mass)
 - DM candidate
- Half of SUSY particles have been discovered already:
 - SUSY partners to squarks, gluinos, higgsinos, and sleptons

ATLAS searches pre-Higgs (2011)

- The majority of searches were inclusive. They targeted strongly-produced SUSY particles that cascade decay to WIMPS (DM candidates) and generic models like MSUGRA/MSSM/GMSB.
- Searches for the 3rd generation were emerging (e.g. arXiv:1101.1963)



* Only a selection of the available results leading to mass limits shown

Contemporary search program

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}	$\int L dt [\text{fb}^{-1}]$	Mass limit		Reference	
						$\sqrt{s} = 7, 8$ TeV	$\sqrt{s} = 13$ TeV		
Inclusive Searches	$\tilde{q}\tilde{q}, \tilde{q} \rightarrow q\tilde{\chi}_1^0$	0	2-6 jets	Yes	36.1	\tilde{q}	1.57 TeV	$m(\tilde{\chi}_1^0) < 200$ GeV, $m(1^{\text{st}} \text{ gen. } \tilde{q}) = m(2^{\text{nd}} \text{ gen. } \tilde{q})$	1712.02332
	$\tilde{q}\tilde{q}, \tilde{q} \rightarrow q\tilde{\chi}_1^0$ (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
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	36.1	\tilde{g}	2.02 TeV	$m(\tilde{\chi}_1^0) < 200$ GeV	1712.02332
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q}\tilde{\chi}_1^0 \rightarrow q\tilde{q}W\tilde{\chi}_1^0$	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
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q}(\ell\ell)\tilde{\chi}_1^0$	$ee, \mu\mu$	2 jets	Yes	14.7	\tilde{g}	1.7 TeV	$m(\tilde{\chi}_1^0) < 300$ GeV,	1611.05791
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q}(\ell\ell/\nu\nu)\tilde{\chi}_1^0$	$3e, \mu$	4 jets	-	36.1	\tilde{g}	1.87 TeV	$m(\tilde{\chi}_1^0) = 0$ GeV	1706.03731
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q}WZ\tilde{\chi}_1^0$	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)	$1-2 \tau + 0-1 \ell$	0-2 jets	Yes	3.2	\tilde{g}	2.0 TeV	$m(\tilde{\chi}_1^0) = 1700$ GeV, $c\tau(\text{NLSP}) < 0.1$ mm, $\mu > 0$	1607.05979
	GGM (bino NLSP)	2γ	-	Yes	36.1	\tilde{g}	2.15 TeV	$c\tau(\text{NLSP}) < 0.1$ 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, $c\tau(\text{NLSP}) < 0.1$ mm, $\mu > 0$	ATLAS-CONF-2017-080
Gravitino LSP	0	mono-jet	Yes	20.3	$R^{1/2}$ scale	865 GeV	$m(\tilde{G}) > 1.8 \times 10^{-4}$ eV, $m(\tilde{g}) = m(\tilde{q}) = 1.5$ TeV	1502.01518	
3 rd gen. \tilde{g} med.	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow b\tilde{b}\tilde{\chi}_1^0$	0	3 b	Yes	36.1	\tilde{g}	1.92 TeV	$m(\tilde{\chi}_1^0) < 600$ GeV	1711.01901
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow t\tilde{t}\tilde{\chi}_1^0$	0-1 e, μ	3 b	Yes	36.1	\tilde{g}	1.97 TeV	$m(\tilde{\chi}_1^0) < 200$ GeV	1711.01901
3 rd gen. squarks direct production	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1 \rightarrow b\tilde{\chi}_1^0$	0	2 b	Yes	36.1	\tilde{b}_1	950 GeV	$m(\tilde{\chi}_1^0) < 420$ GeV	1708.09266
	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1 \rightarrow t\tilde{\chi}_1^0$	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
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow b\tilde{\chi}_1^0$	0-2 e, μ	1-2 b	Yes	4.7/13.3	\tilde{t}_1	117-170 GeV	$m(\tilde{\chi}_1^\pm) = 2m(\tilde{\chi}_1^0), m(\tilde{\chi}_1^\pm) = 55$ GeV	1209.2102, ATLAS-CONF-2016-077
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow Wb\tilde{\chi}_1^0$ 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	$m(\tilde{\chi}_1^0) = 1$ GeV	1506.08616, 1709.04183, 1711.11520
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow c\tilde{\chi}_1^0$	0	mono-jet	Yes	36.1	\tilde{t}_1	90-430 GeV	$m(\tilde{\chi}_1^0) = 5$ 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
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2 \rightarrow \tilde{t}_1 + Z$	3 e, μ (Z)	1 b	Yes	36.1	\tilde{t}_2	290-790 GeV	$m(\tilde{\chi}_1^0) = 0$ GeV	1706.03966
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2 \rightarrow \tilde{t}_1 + h$	1-2 e, μ	4 b	Yes	36.1	\tilde{t}_2	320-880 GeV	$m(\tilde{\chi}_1^0) = 0$ GeV	1706.03966
EW direct	$\tilde{\ell}_{L,R}, \tilde{\ell}_{L,R}, \tilde{\ell} \rightarrow \ell\tilde{\chi}_1^0$	2 e, μ	0	Yes	36.1	$\tilde{\ell}$	90-500 GeV	$m(\tilde{\chi}_1^0) = 0$	ATLAS-CONF-2017-039
	$\tilde{\chi}_1^\pm\tilde{\chi}_1^\pm, \tilde{\chi}_1^\pm \rightarrow \tilde{\chi}_1^0(\tilde{\nu})$	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
	$\tilde{\chi}_1^\pm\tilde{\chi}_1^\pm/\tilde{\chi}_2^0, \tilde{\chi}_1^\pm \rightarrow \tilde{\chi}_1^0(\tilde{\nu}), \tilde{\chi}_2^0 \rightarrow \tilde{\tau}(\tilde{\nu})$	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
	$\tilde{\chi}_1^\pm\tilde{\chi}_1^\pm \rightarrow \tilde{\ell}_1\nu\tilde{\ell}_1(\tilde{\nu}\nu), \tilde{\ell}\tilde{\nu}\tilde{\ell}_1(\tilde{\nu}\nu)$	3 e, μ	0	Yes	36.1	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$	1.13 TeV	$m(\tilde{\chi}_1^\pm) = m(\tilde{\chi}_2^0), m(\tilde{\chi}_1^\pm) = 0, m(\tilde{\ell}, \tilde{\nu}) = 0.5(m(\tilde{\chi}_1^\pm) + m(\tilde{\chi}_1^0))$	ATLAS-CONF-2017-039
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0 \rightarrow W\tilde{\chi}_1^0Z\tilde{\chi}_1^0$	2-3 e, μ	0-2 jets	Yes	36.1	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$	580 GeV	$m(\tilde{\chi}_1^\pm) = m(\tilde{\chi}_2^0), m(\tilde{\chi}_1^\pm) = 0, \tilde{\ell}$ decoupled	ATLAS-CONF-2017-039
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0 \rightarrow W\tilde{\chi}_1^0h\tilde{\chi}_1^0$	e, μ, γ	0-2 b	Yes	20.3	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$	270 GeV	$m(\tilde{\chi}_1^\pm) = m(\tilde{\chi}_2^0), m(\tilde{\chi}_1^\pm) = 0, \tilde{\ell}$ decoupled	1501.07110
	$\tilde{\chi}_2^0\tilde{\chi}_3^0, \tilde{\chi}_2^0 \rightarrow \tilde{\ell}_R\ell$	4 e, μ	0	Yes	20.3	$\tilde{\chi}_{2,3}^0$	635 GeV	$m(\tilde{\chi}_2^0) = m(\tilde{\chi}_3^0), m(\tilde{\chi}_1^\pm) = 0, m(\tilde{\ell}, \tilde{\nu}) = 0.5(m(\tilde{\chi}_2^0) + m(\tilde{\chi}_1^0))$	1504.5086
	GGM (wino NLSP) weak prod., $\tilde{\chi}_1^0 \rightarrow \gamma\tilde{G}$	1 $e, \mu + \gamma$	-	Yes	20.3	\tilde{W}	115-370 GeV	$c\tau < 1$ mm	1507.05493
	GGM (bino NLSP) weak prod., $\tilde{\chi}_1^0 \rightarrow \gamma\tilde{G}$	2 γ	-	Yes	36.1	\tilde{W}	1.06 TeV	$c\tau < 1$ mm	ATLAS-CONF-2017-080
	Long-lived particles	Direct $\tilde{\chi}_1^\pm\tilde{\chi}_1^\pm$ 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, $\tau(\tilde{\chi}_1^\pm) = 0.2$ ns	1712.02118
Direct $\tilde{\chi}_1^\pm\tilde{\chi}_1^\pm$ 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, $\tau(\tilde{\chi}_1^\pm) < 15$ 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, $10 \mu\text{s} < \tau(\tilde{g}) < 1000$ 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, $\tau > 10$ ns	1604.04520
Metastable \tilde{g} R-hadron, $\tilde{g} \rightarrow q\tilde{q}\tilde{\chi}_1^0$		displ. vtx	-	Yes	32.8	\tilde{g}	2.37 TeV	$\tau(\tilde{g}) = 0.17$ ns, $m(\tilde{\chi}_1^0) = 100$ GeV	1710.04901
GMSB, stable $\tilde{\tau}, \tilde{\chi}_1^0 \rightarrow \tilde{\tau}(\tilde{e}, \tilde{\mu}) + \tau(e, \mu)$		1-2 μ	-	-	19.1	$\tilde{\chi}_1^0$	537 GeV	$10 < \text{tan}\beta < 50$	1411.6795
GMSB, $\tilde{\chi}_1^0 \rightarrow \gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$		2 γ	-	Yes	20.3	$\tilde{\chi}_1^0$	440 GeV	$1 < \tau(\tilde{\chi}_1^0) < 3$ ns, SPS8 model	1409.5542
$\tilde{g}\tilde{g}, \tilde{\chi}_1^0 \rightarrow ee\nu/\mu\nu/\mu\nu$		displ. $ee/\mu\mu/\mu\mu$	-	-	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 $pp \rightarrow \tilde{\nu}_\tau + X, \tilde{\nu}_\tau \rightarrow e\mu/\tau\mu$	$e\mu, e\tau, \mu\tau$	-	-	3.2	$\tilde{\nu}_\tau$	1.9 TeV	$\lambda'_{311} = 0.11, \lambda_{132/133/233} = 0.07$	1607.08079
	Billinear 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
	$\tilde{\chi}_1^\pm\tilde{\chi}_1^\pm, \tilde{\chi}_1^\pm \rightarrow W\tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow ee\nu, \mu\nu, \mu\nu$	4 e, μ	-	Yes	13.3	$\tilde{\chi}_1^\pm$	1.14 TeV	$m(\tilde{\chi}_1^\pm) > 400$ GeV, $\lambda_{12k} \neq 0$ ($k = 1, 2$)	ATLAS-CONF-2016-075
	$\tilde{\chi}_1^\pm\tilde{\chi}_1^\pm, \tilde{\chi}_1^\pm \rightarrow W\tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow \tau\nu_e, e\nu_\tau$	3 $e, \mu + \tau$	-	Yes	20.3	$\tilde{\chi}_1^\pm$	450 GeV	$m(\tilde{\chi}_1^0) > 0.2 \times m(\tilde{\chi}_1^\pm), \lambda_{133} \neq 0$	1405.5086
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q}\tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow q\tilde{q}$	0	4-5 large-R jets	-	36.1	\tilde{g}	1.875 TeV	$m(\tilde{\chi}_1^0) = 1075$ GeV	SUSY-2016-22
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow t\tilde{t}\tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow q\tilde{q}$	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
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow t\tilde{t}\tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow q\tilde{q}$	1 e, μ	8-10 jets/0-4 b	-	36.1	\tilde{g}	1.65 TeV	$m(\tilde{\chi}_1^0) = 1$ TeV, $\lambda_{323} \neq 0$	1704.08493
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow \tilde{t}_1 t, \tilde{t}_1 \rightarrow bs$	0	2 jets + 2 b	-	36.7	\tilde{t}_1	100-470 GeV	$m(\tilde{t}_1) = 1$ TeV, $\lambda_{323} \neq 0$	1710.07171
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow bs$	0	2 jets + 2 b	-	36.7	\tilde{t}_1	480-610 GeV	-	1710.07171
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow b\ell$	2 e, μ	2 b	-	36.1	\tilde{t}_1	0.4-1.45 TeV	$BR(\tilde{t}_1 \rightarrow b\ell/\mu) > 20\%$	1710.05544
Other	Scalar charm, $\tilde{c} \rightarrow c\tilde{\chi}_1^0$	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.

10⁻¹ 1 Mass scale [TeV]

Contemporary search program

- The 125 GeV Higgs is considered as “SUSY model killer” (tension with high-scale theories). However, the discovery of Higgs inspired a number of searches for $m \sim O(1 \text{ TeV})$ 3rd generation squarks.
- Overall, the search program is more exciting than ever before.
- Goes even beyond the R-parity conserving models and in the corners of phase space where the mass differences are small (compressed and long-lived).
- Caveat: The data are often interpreted for simplified models so the limits need to be translated carefully for your model of choice.
 - The simplified models may give overly high or low exclusion.

Hidetoshi will discuss this later on.

ATLAS SUSY Searches* - 95% CL Lo
December 2017

	Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int \mathcal{L} dL$
Inclusive Searches	$\tilde{q}\tilde{q}, \tilde{q} \rightarrow q\tilde{\chi}_1^0$	0	2-6 jets	Yes	36.1
	$\tilde{q}\tilde{q}, \tilde{q} \rightarrow q\tilde{\chi}_1^0$ (compressed)	mono-jet	1-3 jets	Yes	36.1
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	36.1
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q}\tilde{\chi}_1^{\pm} \rightarrow q\tilde{q}W^{\pm}\tilde{\chi}_1^0$	0	2-6 jets	Yes	36.1
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q}(\ell\ell)\tilde{\chi}_1^0$	$ee, \mu\mu$	2 jets	Yes	14.7
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q}(\ell\ell/\nu\nu)\tilde{\chi}_1^0$	3 e, μ	4 jets	-	36.1
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q}WZ\tilde{\chi}_1^0$	0	7-11 jets	Yes	36.1
	GMSB ($\tilde{\ell}$ NLSP)	1-2 $\tau + 0-1 \ell$	0-2 jets	Yes	3.2
	GGM (bino NLSP)	2 γ	-	Yes	36.1
	GGM (higgsino-bino NLSP)	γ	2 jets	Yes	36.1
Gravitino LSP	0	mono-jet	Yes	20.3	
3 rd gen. \tilde{g}, \tilde{g} med.	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow b\tilde{b}\tilde{\chi}_1^0$	0	3 b	Yes	36.1
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow t\tilde{t}\tilde{\chi}_1^0$	0-1 e, μ	3 b	Yes	36.1
3 rd gen. squarks direct production	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1 \rightarrow b\tilde{\chi}_1^0$	0	2 b	Yes	36.1
	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1 \rightarrow t\tilde{\chi}_1^0$	2 e, μ (SS)	1 b	Yes	36.1
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow b\tilde{\chi}_1^0$	0-2 e, μ	1-2 b	Yes	4.7/13.3
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow Wb\tilde{\chi}_1^0$ or $t\tilde{\chi}_1^0$	0-2 e, μ	0-2 jets/1-2 b	Yes	20.3/36.1
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow c\tilde{\chi}_1^0$	0	mono-jet	Yes	36.1
	$\tilde{t}_1\tilde{t}_1$ (natural GMSB)	2 e, μ (Z)	1 b	Yes	20.3
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2 \rightarrow \tilde{t}_1 + Z$	3 e, μ (Z)	1 b	Yes	36.1
$\tilde{t}_2\tilde{t}_2, \tilde{t}_2 \rightarrow \tilde{t}_1 + h$	1-2 e, μ	4 b	Yes	36.1	
EW direct	$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R}, \tilde{\ell} \rightarrow \ell\tilde{\chi}_1^0$	2 e, μ	0	Yes	36.1
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}, \tilde{\chi}_1^{\pm} \rightarrow \tilde{\ell}\nu(\ell\bar{\nu})$	2 e, μ	0	Yes	36.1
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_1^0/\tilde{\chi}_2^0, \tilde{\chi}_1^{\pm} \rightarrow \tilde{\tau}\nu(\tau\bar{\nu}), \tilde{\chi}_2^0 \rightarrow \tilde{\tau}\tau(\nu\bar{\nu})$	2 τ	-	Yes	36.1
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_1^0 \rightarrow \tilde{\ell}_i\nu\tilde{\ell}_i(\nu\bar{\nu}), \tilde{\ell}\nu\tilde{\ell}_i(\nu\bar{\nu})$	3 e, μ	0	Yes	36.1
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \rightarrow W\tilde{\ell}_i\tilde{\chi}_1^0 Z\tilde{\chi}_1^0$	2-3 e, μ	0-2 jets	Yes	36.1
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \rightarrow W\tilde{\chi}_1^0 h\tilde{\chi}_1^0, h \rightarrow b\bar{b}/W\tilde{\tau}\tau/\gamma\gamma$	e, μ, γ	0-2 b	Yes	20.3
	$\tilde{\chi}_2^0\tilde{\chi}_3^0, \tilde{\chi}_2^0 \rightarrow \tilde{\ell}_R\ell$	4 e, μ	0	Yes	20.3
	GGM (wino NLSP) weak prod., $\tilde{\chi}_1^0 \rightarrow \gamma\tilde{G}$	1 $e, \mu + \gamma$	-	Yes	20.3
GGM (bino NLSP) weak prod., $\tilde{\chi}_1^0 \rightarrow \gamma\tilde{G}$	2 γ	-	Yes	36.1	
Long-lived particles	Direct $\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}$ prod., long-lived $\tilde{\chi}_1^{\pm}$	Disapp. trk	1 jet	Yes	36.1
	Direct $\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}$ prod., long-lived $\tilde{\chi}_1^{\pm}$	dE/dx trk	-	Yes	18.4
	Stable, stopped \tilde{g} R-hadron	0	1-5 jets	Yes	27.9
	Stable \tilde{g} R-hadron	trk	-	-	3.2
	Metastable \tilde{g} R-hadron	dE/dx trk	-	-	3.2
	Metastable \tilde{g} R-hadron, $\tilde{g} \rightarrow q\tilde{q}\tilde{\chi}_1^0$	displ. vtx	-	Yes	32.8
	GMSB, stable $\tilde{\tau}, \tilde{\chi}_1^0 \rightarrow \tilde{\tau}(\tilde{e}, \tilde{\mu}) + \tau(e, \mu)$	1-2 μ	-	-	19.1
	GMSB, $\tilde{\chi}_1^0 \rightarrow \gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$	2 γ	-	Yes	20.3
$\tilde{g}\tilde{g}, \tilde{\lambda}_1^0 \rightarrow ee\nu/\mu\nu/\mu\nu$	displ. $ee/\mu\mu/\mu\mu$	-	-	20.3	
RPV	LFV $pp \rightarrow \tilde{\nu}_e + X, \tilde{\nu}_e \rightarrow e\mu/\tau\mu$	$e\mu, e\tau, \mu\tau$	-	-	3.2
	Bilinear RPV CMSSM	2 e, μ (SS)	0-3 b	Yes	20.3
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}, \tilde{\chi}_1^{\pm} \rightarrow W\tilde{\chi}_1^0, \tilde{\chi}_1^{\pm} \rightarrow ee\nu, e\mu\nu, \mu\nu$	4 e, μ	-	Yes	13.3
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}, \tilde{\chi}_1^{\pm} \rightarrow W\tilde{\chi}_1^0, \tilde{\chi}_1^{\pm} \rightarrow \tau\tau\nu_e, e\tau\nu_e$	3 $e, \mu + \tau$	-	Yes	20.3
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q}\tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow q\tilde{q}\tilde{\chi}_1^0$	0	4-5 large- R jets	-	36.1
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow t\tilde{t}\tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow q\tilde{q}\tilde{\chi}_1^0$	1 e, μ	8-10 jets/0-4 b	-	36.1
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow \tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow b\tilde{s}$	1 e, μ	8-10 jets/0-4 b	-	36.1
$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow b\tilde{s}$	0	2 jets + 2 b	-	36.7	
$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow b\tilde{\ell}$	2 e, μ	2 b	-	36.1	
Other	Scalar charm $\tilde{c} \rightarrow \tilde{c}^0$	0	2 c	Yes	20.3

New results since spring of 2017

1.	RPV multijet 1-lepton	1704.08493 [hep-ex]
2.	long-lived reinterpretation	CONF-SUSY-2018-03
3.	displaced vertices	1710.04901 [hep-ex]
4.	disappearing track	PHYS-PUB-2017-019
5.	multijet (7-11)	1708.02794 [hep-ex]
6.	0L inclusive	1712.02332 [hep-ex]
7.	1-lepton + MET + jet	1708.08232 [hep-ex]
8.	stop in Z/h	1706.03986 [hep-ex]
9.	SS/3L	1706.03731 [hep-ex]
10.	stop 2L	1708.03247 [hep-ex]
11.	2b+MET	1708.09266 [hep-ex]
12.	stop 0L	1709.04183 [hep-ex]
13.	stop b-l	1710.05544 [hep-ex]
14.	multi b-jets	1711.01901 [hep-ex]
15.	stop 2x2	1710.07171 [hep-ex]
16.	stop 1L	1711.11520 [hep-ex]
17.	Stop in stau	ATLAS-CONF-2017-079
18.	electroweak compressed	1712.08119 [hep-ex]
19.	SUSY with photons	1802.03158 [hep-ex]
20.	GMSB Higgsinos in 4b	ATLAS-CONF-2017-081
21.	Electroweak di-tau	1708.07875 [hep-ex]
22.	EW 2/3L	1803.02762 [hep-ex]

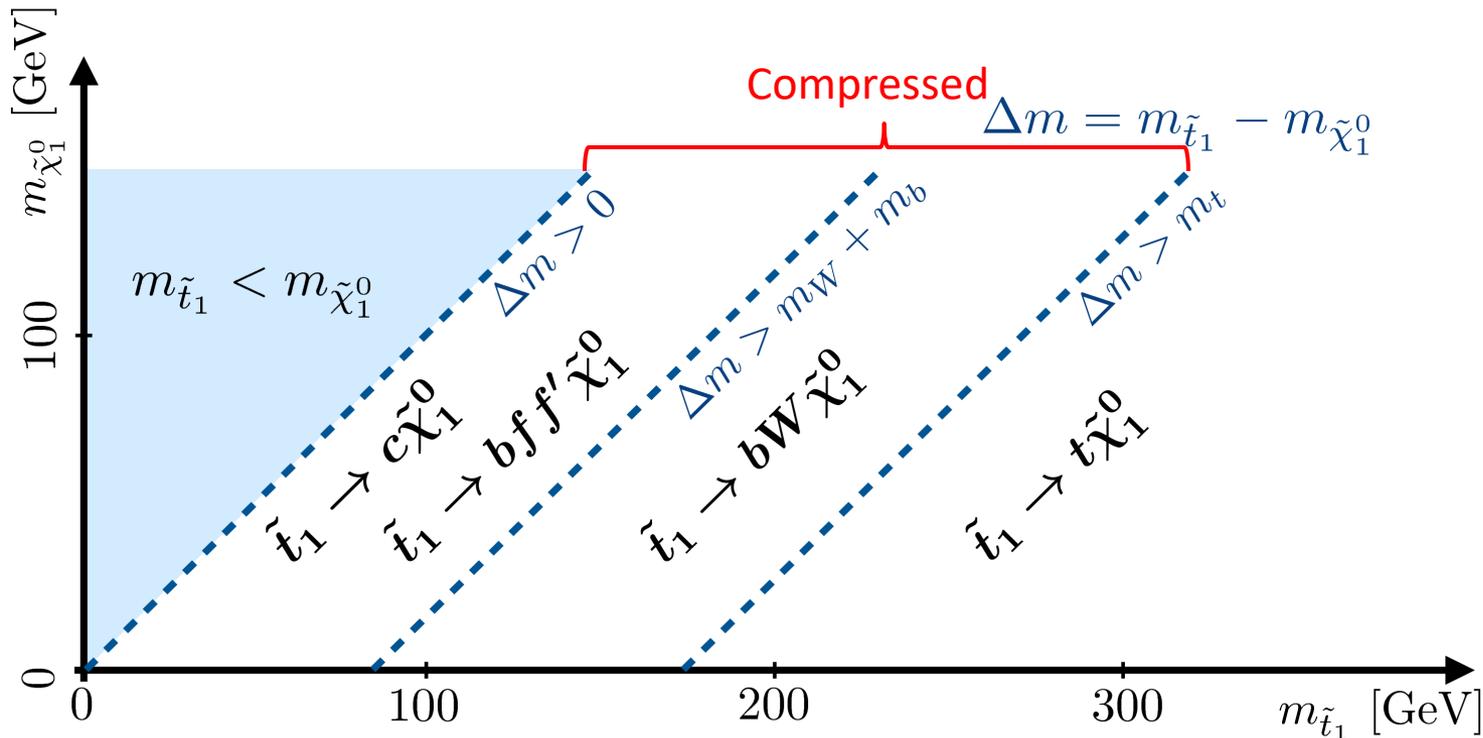
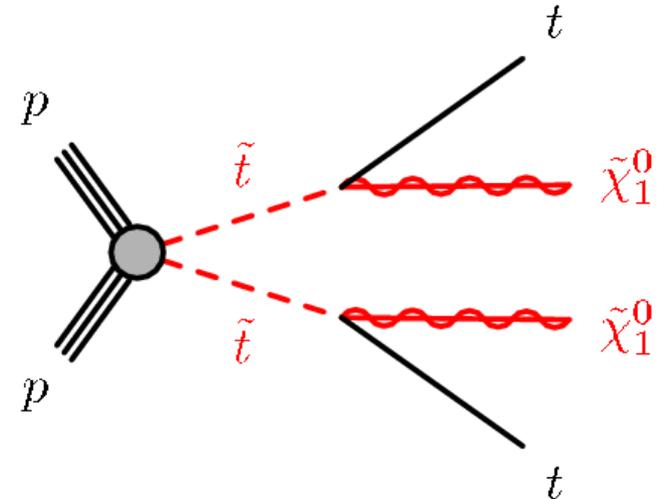
All these use 2015+2016 data:
36 fb⁻¹ at $\sqrt{s} = 13$ TeV

Expect ~ 150 fb⁻¹ in Run2. We
already have about 80 fb⁻¹.

No significant excesses.
Searches in red have slight excess.

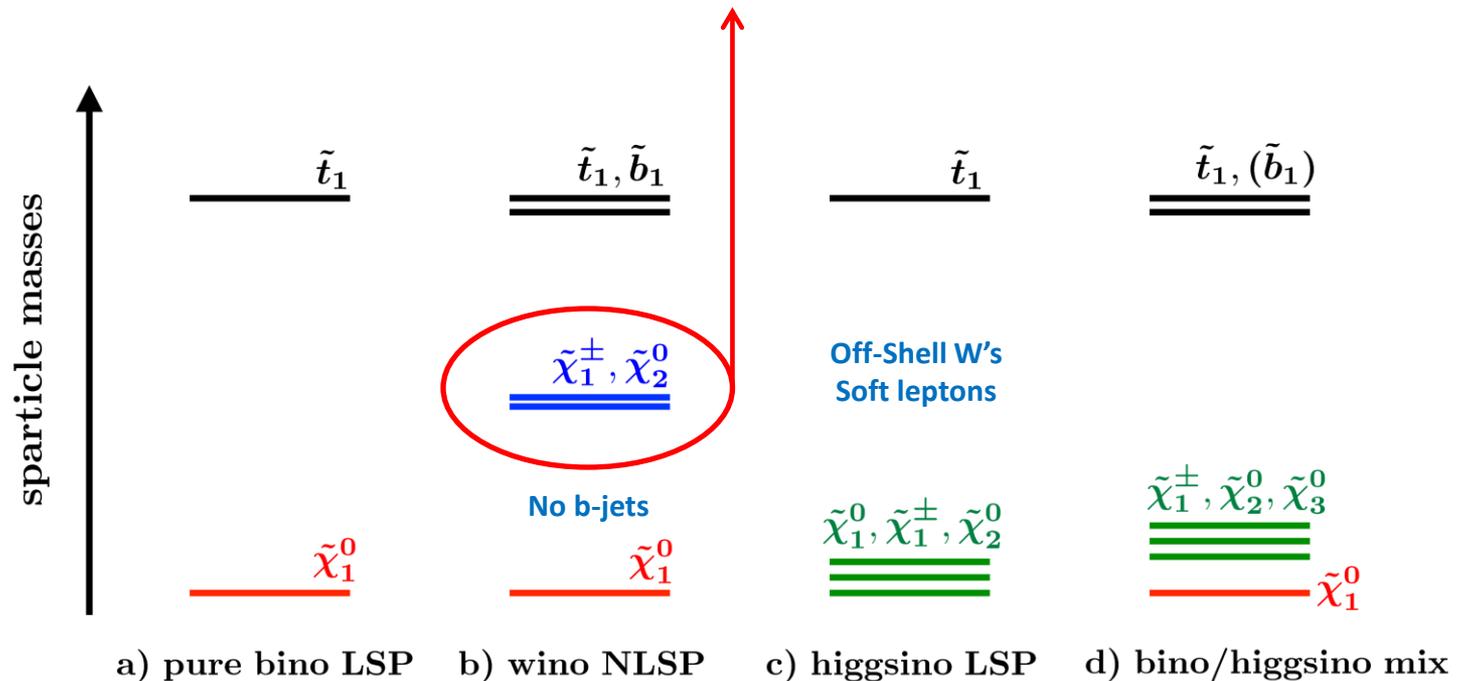
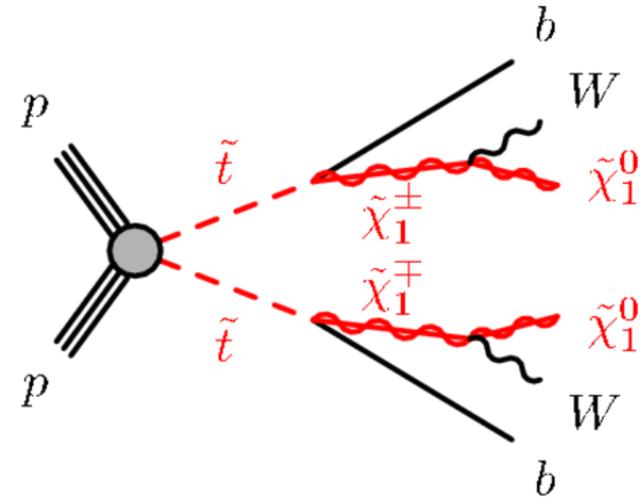
Direct stop pair-production

- The Higgs at 125 GeV inspires $m \sim O(1\text{TeV})$ top squarks. The decay chain depends on model parameters and there are a lot of variations.
- The experimental signatures become difficult when the top quarks are off-shell (compressed)



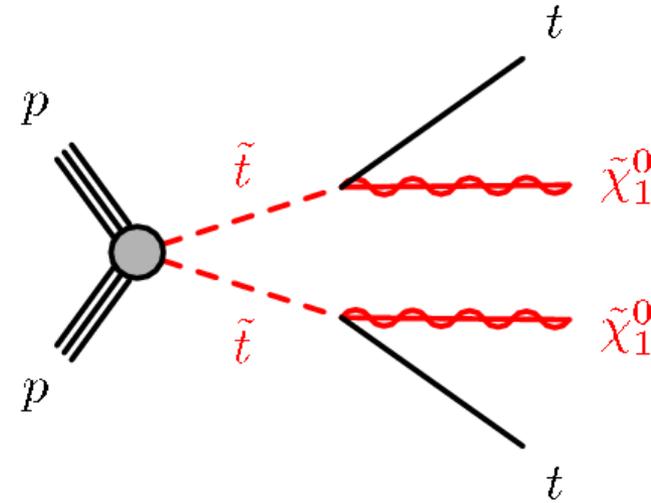
Direct stop pair-production

- Complexity of the decay chain can escalate quickly.
- What will happen if the intermediate state is much heavier than a top squark?
- 16 channels are used to target all the scenarios.

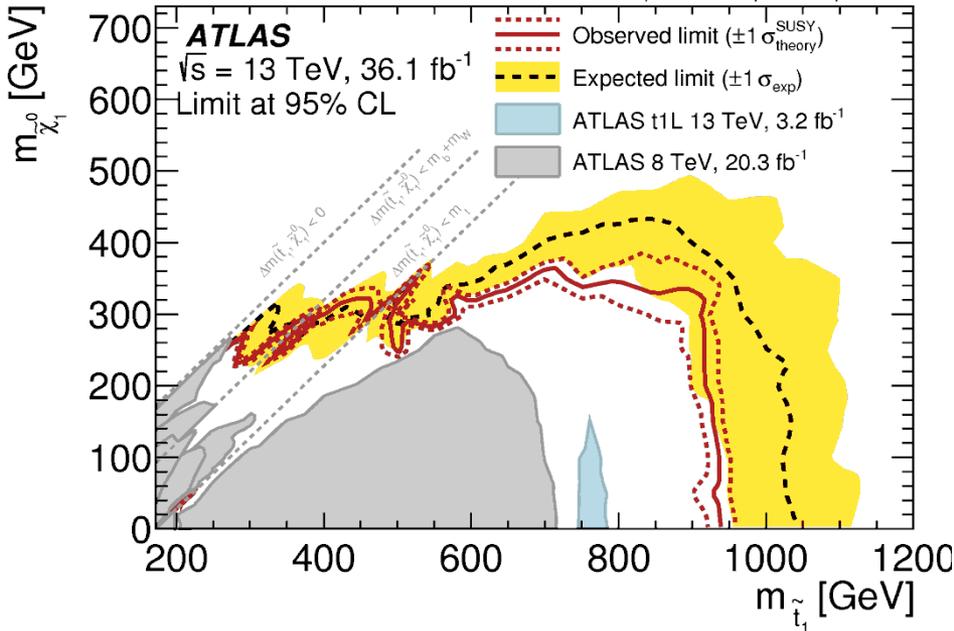


Direct stop pair-production: 1L

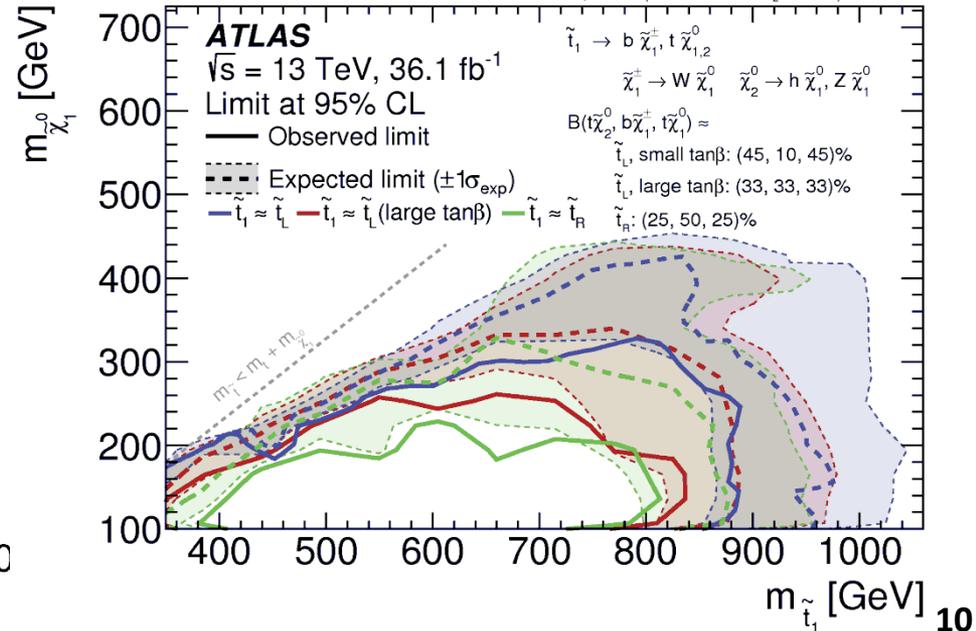
- The 13 TeV searches probe the compressed decays (near the $m(\tilde{t}) = m(t) + m(\tilde{\chi}^0)$ diagonal) better than the 8 TeV searches by using events with jet ISR.
- Data is mostly interpreted with simplified models.
- Multiple simultaneous decay chains degrade sensitivity. → Right-hand plot



Pure Bino LSP model: $\tilde{t}_1\tilde{t}_1$ production, $\tilde{t}_1 \rightarrow b\tilde{\chi}_1^0$, $\tilde{t}_1 \rightarrow Wb\tilde{\chi}_1^0$, $\tilde{t}_1 \rightarrow t\tilde{\chi}_1^0$

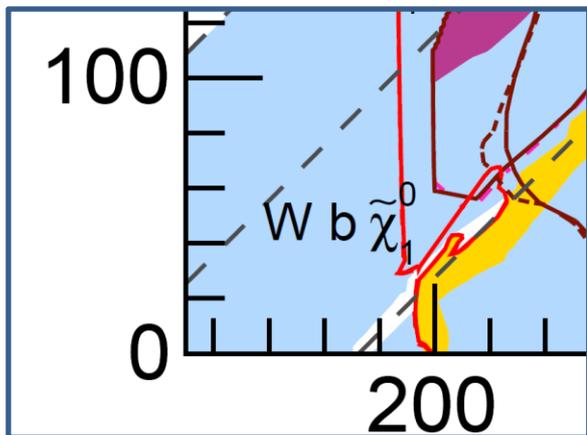
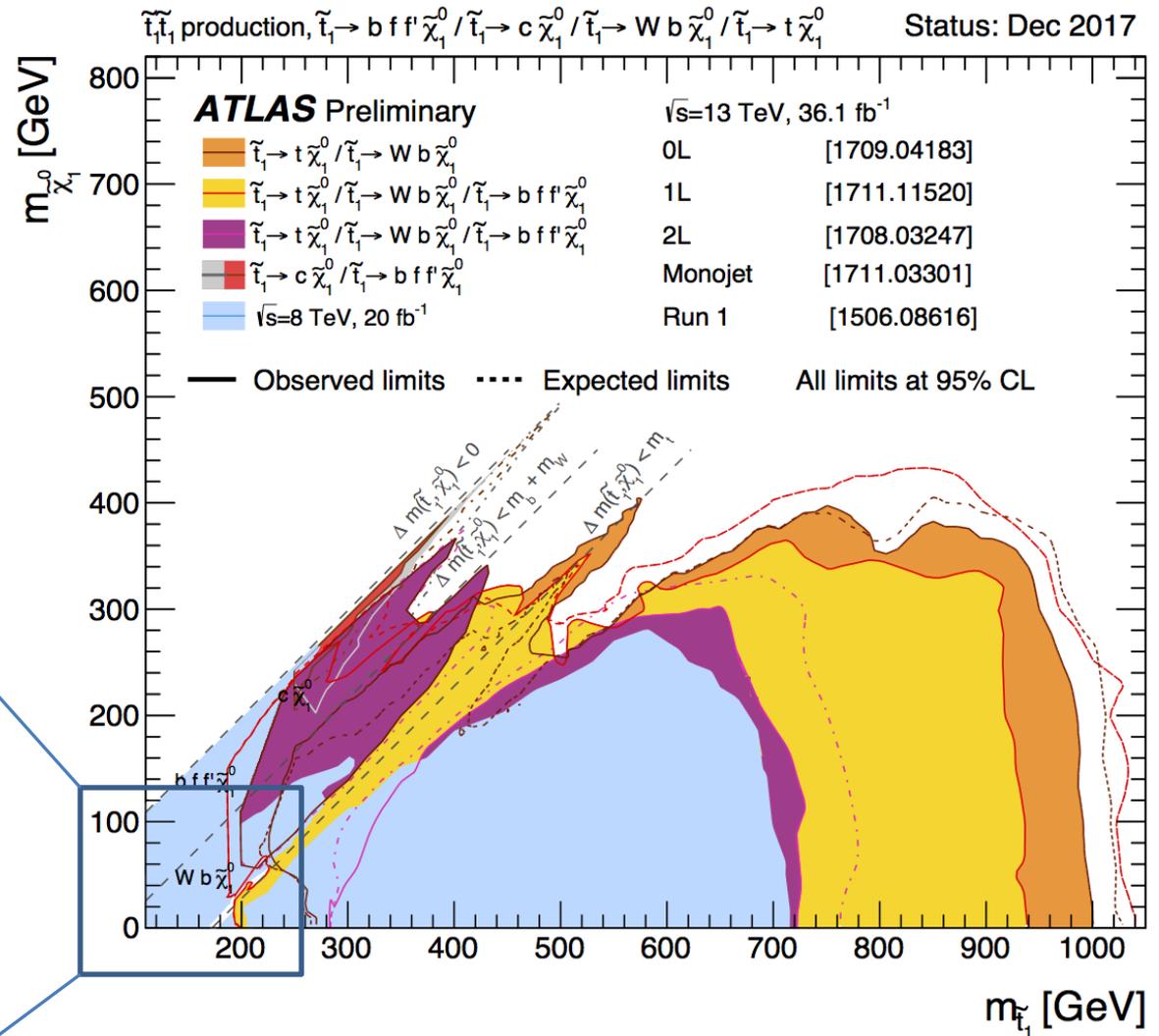


Higgsino LSP model: $\tilde{t}_1\tilde{t}_1$ production, $m_{\tilde{\chi}_1^0} = m_{\tilde{\chi}_1^+} + 5$ GeV, $m_{\tilde{\chi}_2^0} = m_{\tilde{\chi}_1^+} + 10$ GeV



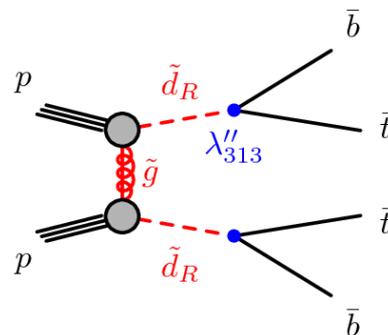
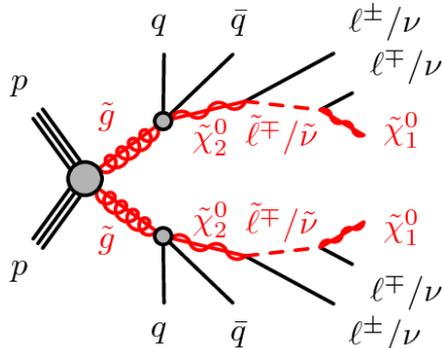
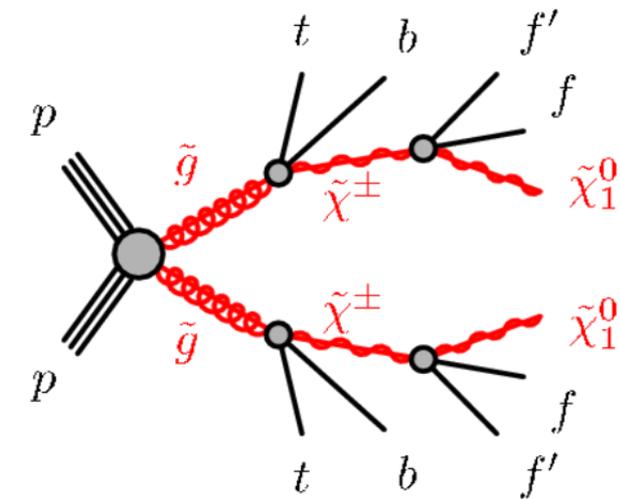
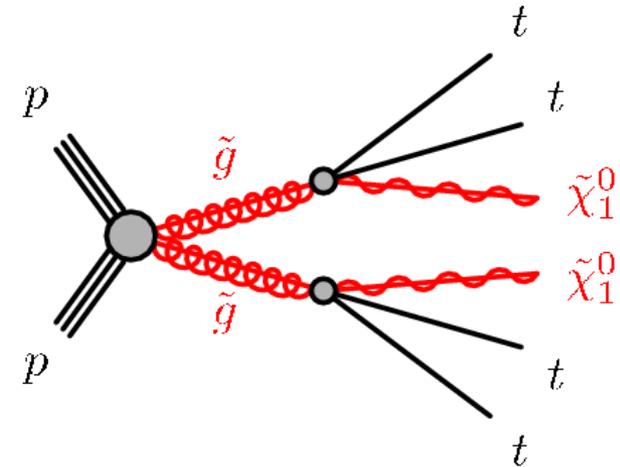
Direct stop pair-production: Overview

- Huge improvement in sensitivity in comparison to Run 1
- Decays with neutralinos heavier than 300-400 GeV are difficult to probe.
- What is happening with $m(\text{stop}) \sim 220$ GeV and $m(\text{LSP}) \sim 50$ GeV?



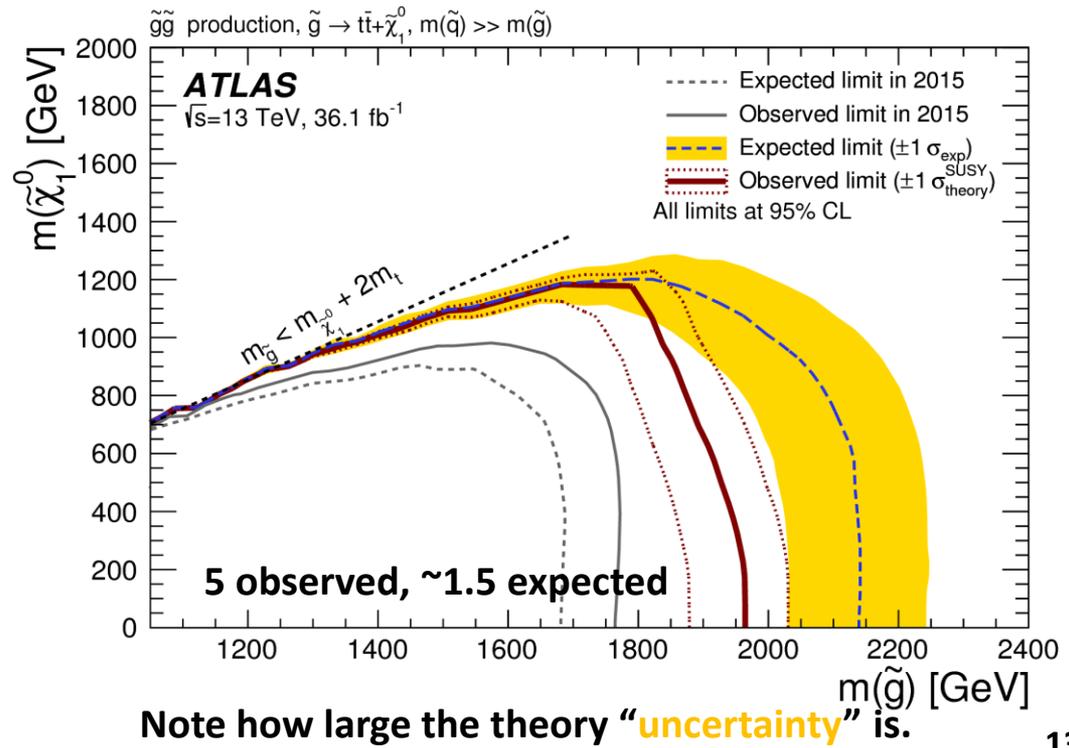
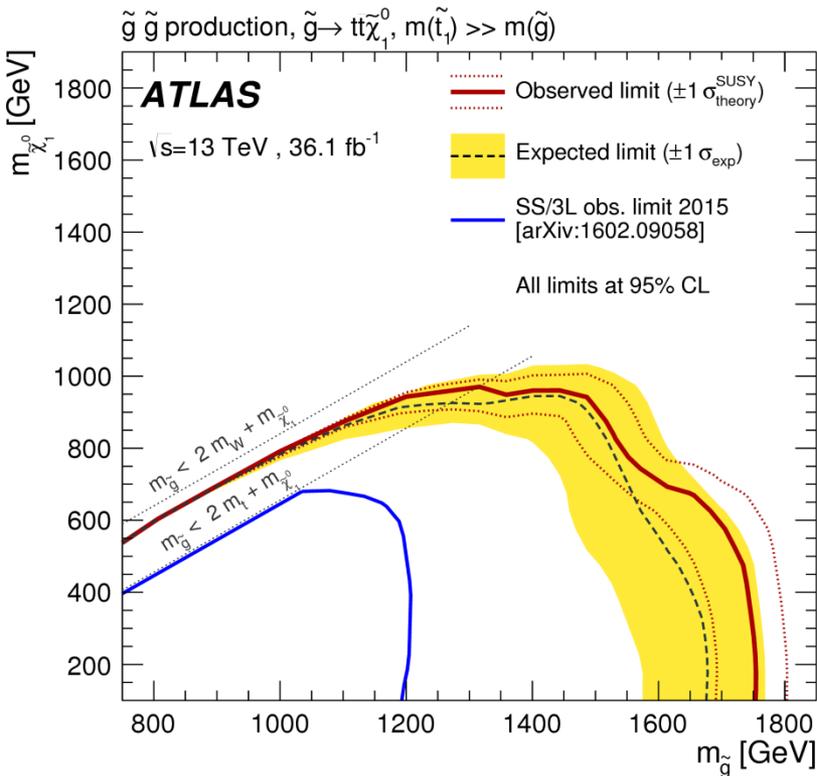
Gluino-mediated stop production

- I learned about this interesting channel in the paper by Gordy Kane, Lian-Tao Wang, and others [1101.1963](#) [hep-ph]
- Complementary to direct stop pair-production.
- Best when $m(\text{glu}) < m(\text{stop})$.
- The stop decays of different complexity are considered.
- There are separate searches with 0 or 1 lepton and b-jets and 2SS or 3 leptons and jets:
 - SS/3L 1706.03731 [hep-ex]
 - multi b-jets 1711.01901 [hep-ex]
- The searches cover a broad range of models. e.g.:



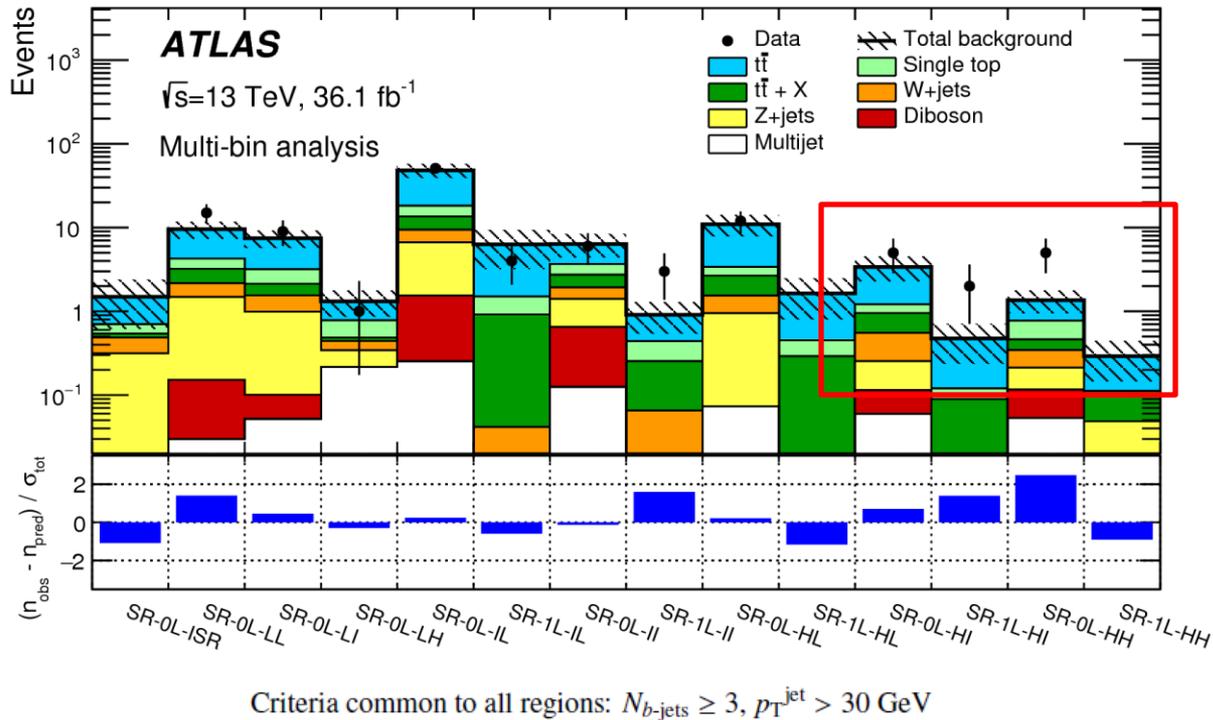
Gluino-mediated stop production

- 0/1L gives better reach for heavy gluinos and 2SS/3L helps in the compressed region.
- Slight excess in the 0/1L multi-b search (right-hand figure).
 - Would a model with $m(\text{gluino})=2.3 \text{ TeV}$; $m(\text{stop})=220 \text{ GeV}$ and $m(\text{LSP})=50 \text{ GeV}$ be excluded by CMS?



Gluino-mediated stop production

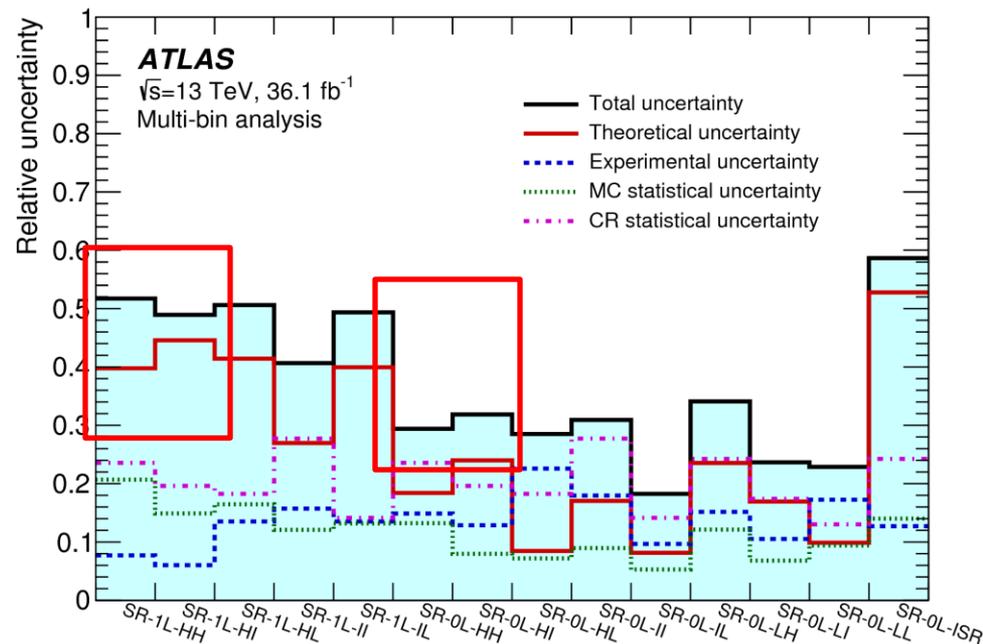
- The excess is driven by a small number of events.



Targeted kinematics	Type	N_{lepton}	$\Delta\phi_{\text{min}}^{4j}$	m_T	N_{jet}	$m_{T,\text{min}}^{b\text{-jets}}$	M_J^Σ	E_T^{miss}	m_{eff}
High- m_{eff} (HH) (Large Δm)	SR-0L	= 0	> 0.4	–	≥ 7	> 100	> 200	> 400	> 2500
	SR-1L	≥ 1	–	> 150	≥ 6	> 120	> 200	> 500	> 2300
Intermediate- m_{eff} (HI) (Intermediate Δm)	SR-0L	= 0	> 0.4	–	≥ 9	> 140	> 150	> 300	[1800, 2500]
	SR-1L	≥ 1	–	> 150	≥ 8	> 140	> 150	> 300	[1800, 2300]

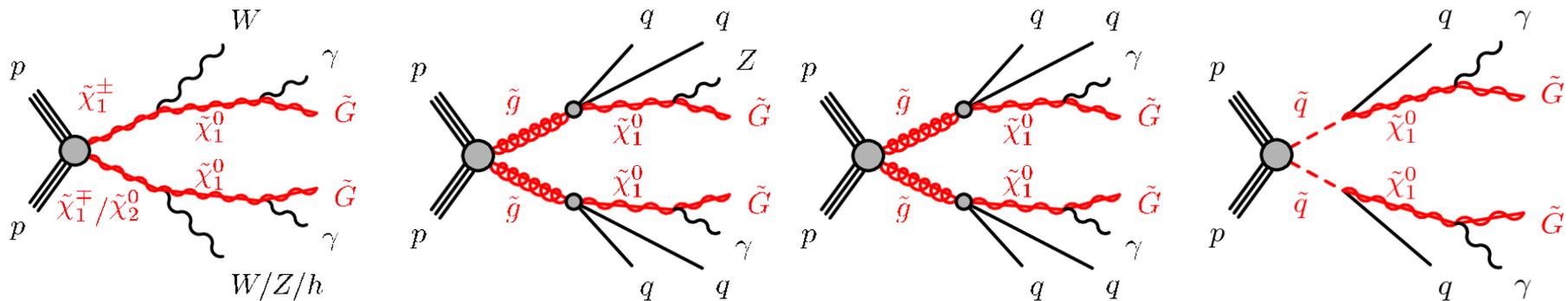
Gluino-mediated stop production

- Background estimation for the multi-jet final states (e.g. $t\bar{t}$ +extra jets) is challenging.
 - Effectively, the backgrounds are extrapolated from control regions to the signal regions using SM predictions.
 - The extrapolation process is verified using the validation regions.
- Often have to rely on parton showering as the ME for $t\bar{t}+1p$, which can give up to 7 jets (both W 's decay hadronically).
 - Control regions are also used to constrain the predictions in situ (background fit).



Photonic signatures

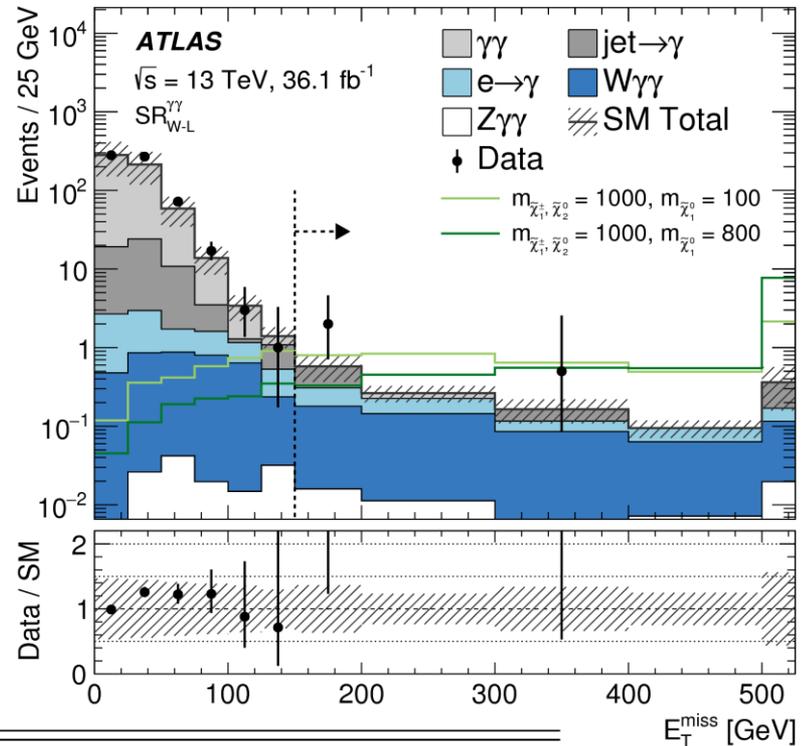
- The search targets models where Gravitino is the LSP and it is produced in association with a photon.



Signal Region	$SR_{S-L}^{\gamma\gamma}$	$SR_{S-H}^{\gamma\gamma}$	$SR_{W-L}^{\gamma\gamma}$	$SR_{W-H}^{\gamma\gamma}$	$SR_L^{\gamma j}$	$SR_{L200}^{\gamma j}$	$SR_H^{\gamma j}$
Number of photons	≥ 2	≥ 2	≥ 2	≥ 2	≥ 1	≥ 1	≥ 1
E_T^γ [GeV]	> 75	> 75	> 75	> 75	> 145	> 145	> 400
Number of jets	≥ 5	≥ 5	≥ 3
Number of leptons	...	...	...	...	0	0	0
E_T^{miss} [GeV]	> 150	> 250	> 150	> 250	> 300	> 200	> 400
H_T [GeV]	> 2750	> 2000	> 1500	> 1000	...	...	...
m_{eff} [GeV]	...	...	...	...	> 2000	> 2000	> 2400
R_T^4	...	...	...	...	< 0.90	< 0.90	...
$\Delta\phi_{\text{min}}(\text{jet}, E_T^{\text{miss}})$	> 0.5	> 0.5	> 0.5	> 0.5	> 0.4	> 0.4	> 0.4
$\Delta\phi_{\text{min}}(\gamma, E_T^{\text{miss}})$ ($\Delta\phi(\gamma, E_T^{\text{miss}})$)	...	> 0.5	...	> 0.5	(> 0.4)	(> 0.4)	(> 0.4)

Photonic signatures

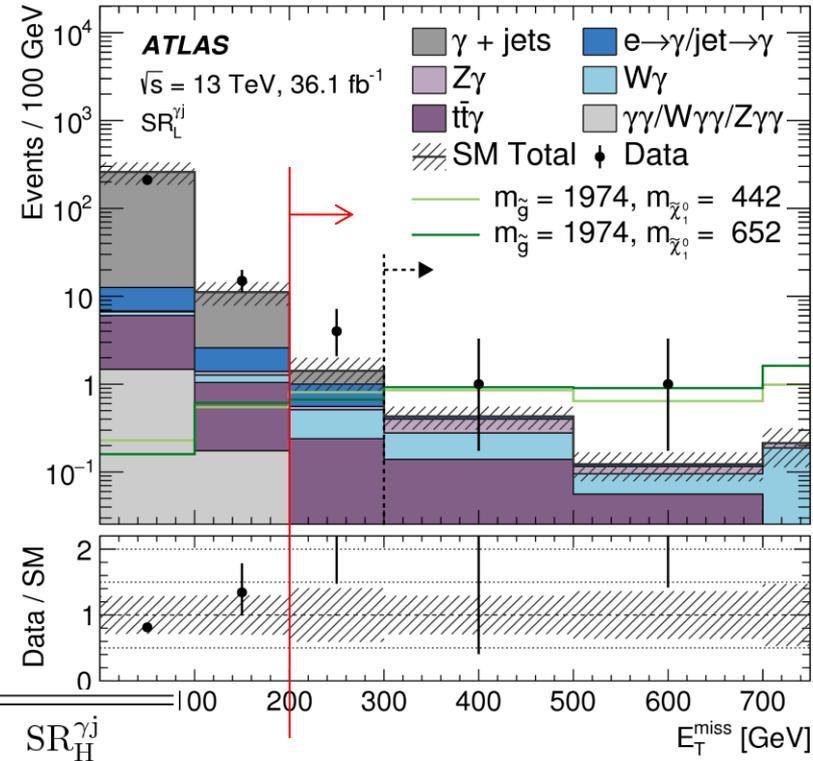
- Deviations between observed events and expected backgrounds are small in the two-photon signal regions.
- The rate of $jet \rightarrow \gamma$ is estimated with data. The rate of $W\gamma\gamma$ is extrapolated from a control region using SM prediction.



Signal Region	$SR_{S-L}^{\gamma\gamma}$	$SR_{S-H}^{\gamma\gamma}$	$SR_{W-L}^{\gamma\gamma}$	$SR_{W-H}^{\gamma\gamma}$
Jet $\rightarrow \gamma$	$0.19^{+0.21}_{-0.19}$	$0.19^{+0.21}_{-0.19}$	0.93 ± 0.67	$0.19^{+0.21}_{-0.19}$
QCD diphoton	$0.00^{+0.17}_{-0.00}$	$0.00^{+0.17}_{-0.00}$	$0.15^{+0.17}_{-0.15}$	$0.00^{+0.17}_{-0.00}$
EW background	0.08 ± 0.04	0.06 ± 0.04	0.88 ± 0.23	0.51 ± 0.15
$(W \rightarrow \ell\nu)\gamma\gamma$	0.22 ± 0.14	0.21 ± 0.13	1.55 ± 0.78	1.08 ± 0.56
$(Z \rightarrow \nu\nu)\gamma\gamma$	0.01 ± 0.01	0.03 ± 0.02	0.15 ± 0.08	0.27 ± 0.13
Expected background events	$0.50^{+0.30}_{-0.26}$	$0.48^{+0.30}_{-0.25}$	3.7 ± 1.1	$2.05^{+0.65}_{-0.63}$
Observed events	0	0	6	1

Photonic signatures

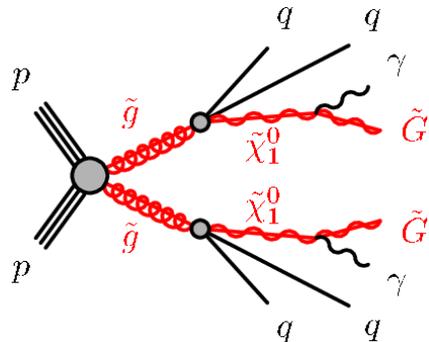
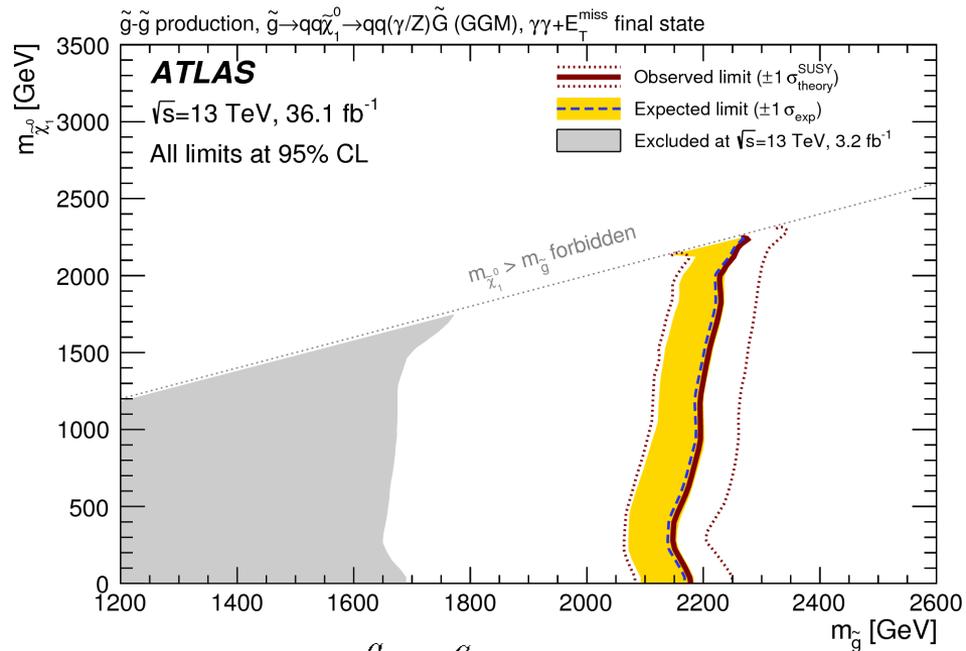
- The deviations are larger in the single-photon signal regions.
- The backgrounds are from various processes.
- It will be interesting to re-visit this channel with 80/150 fb⁻¹.



Signal Region	$SR_L^{\gamma j}$	$SR_{L200}^{\gamma j}$	$SR_H^{\gamma j}$
$\gamma + \text{jets}$ (QCD)	$0.00^{+0.21}_{-0.00}$	$0.42^{+0.43}_{-0.42}$	0.14 ± 0.14
$W\gamma$	0.54 ± 0.24	0.81 ± 0.22	0.40 ± 0.26
$Z\gamma$	0.31 ± 0.16	0.36 ± 0.13	0.42 ± 0.19
$t\bar{t}\gamma$	0.30 ± 0.11	0.54 ± 0.17	0.07 ± 0.03
$e \rightarrow \gamma$	0.07 ± 0.03	0.16 ± 0.06	0.04 ± 0.04
Jet $\rightarrow \gamma$	$0.07^{+0.44}_{-0.07}$	$0.35^{+0.36}_{-0.35}$	$0.01^{+0.50}_{-0.01}$
$\gamma\gamma/W\gamma\gamma/Z\gamma\gamma$	0.03 ± 0.01	0.03 ± 0.01	0.06 ± 0.02
Expected background events	$1.33^{+0.58}_{-0.32}$	$2.68^{+0.64}_{-0.63}$	$1.14^{+0.61}_{-0.36}$
Observed events	4	8	3

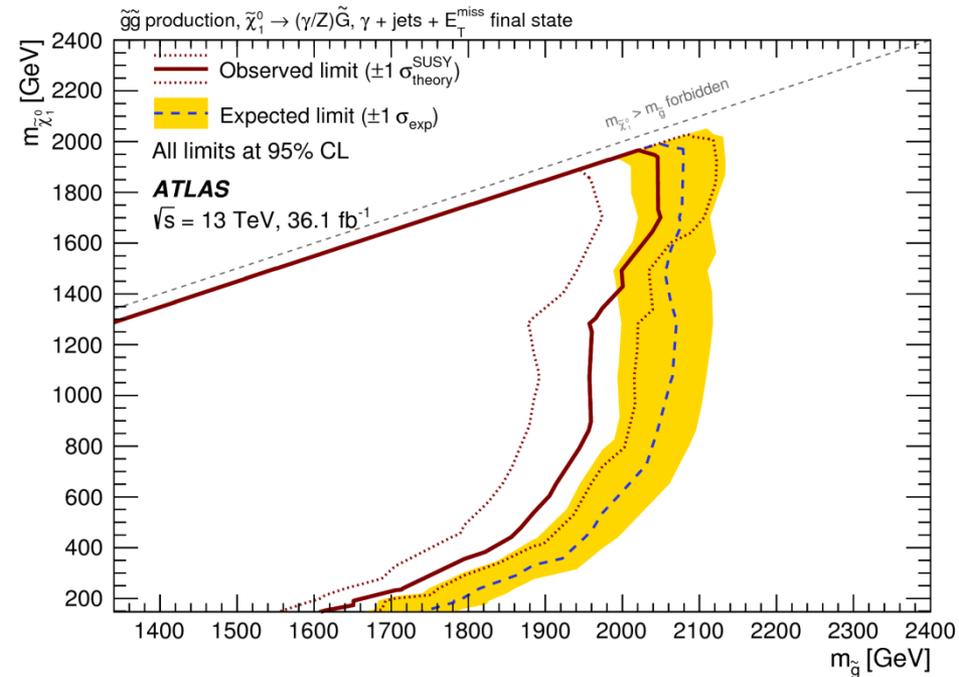
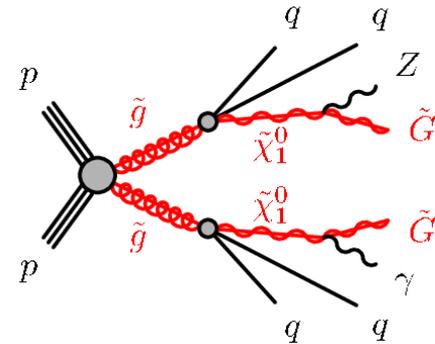
Photonic signatures

- Good improvement in sensitivity.

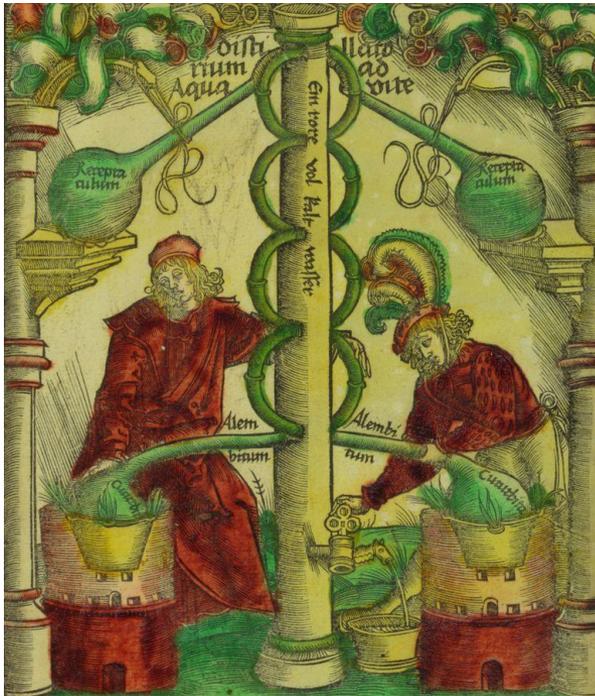


$$Br(\tilde{\chi}_1^0 \rightarrow \gamma\tilde{G}) \sim 50\%$$

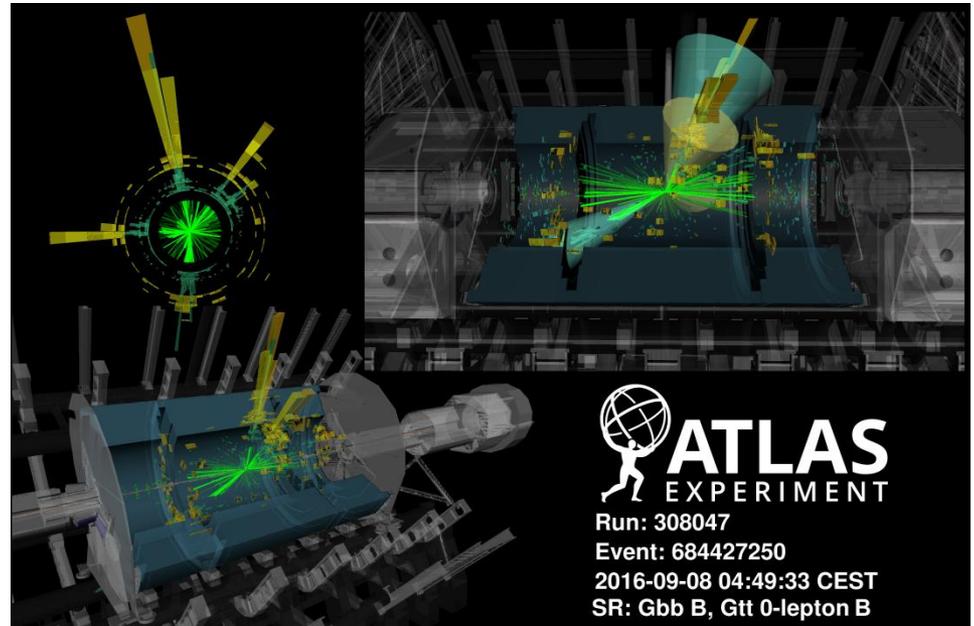
$$Br(\tilde{\chi}_1^0 \rightarrow Z\tilde{G}) \sim 49\%$$



Outlook

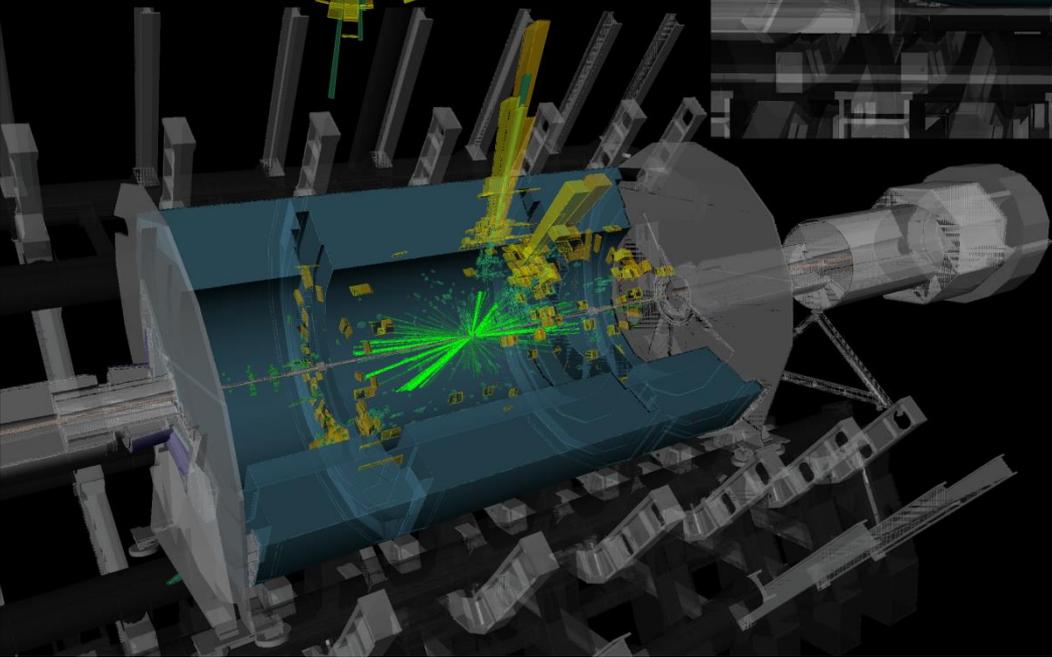
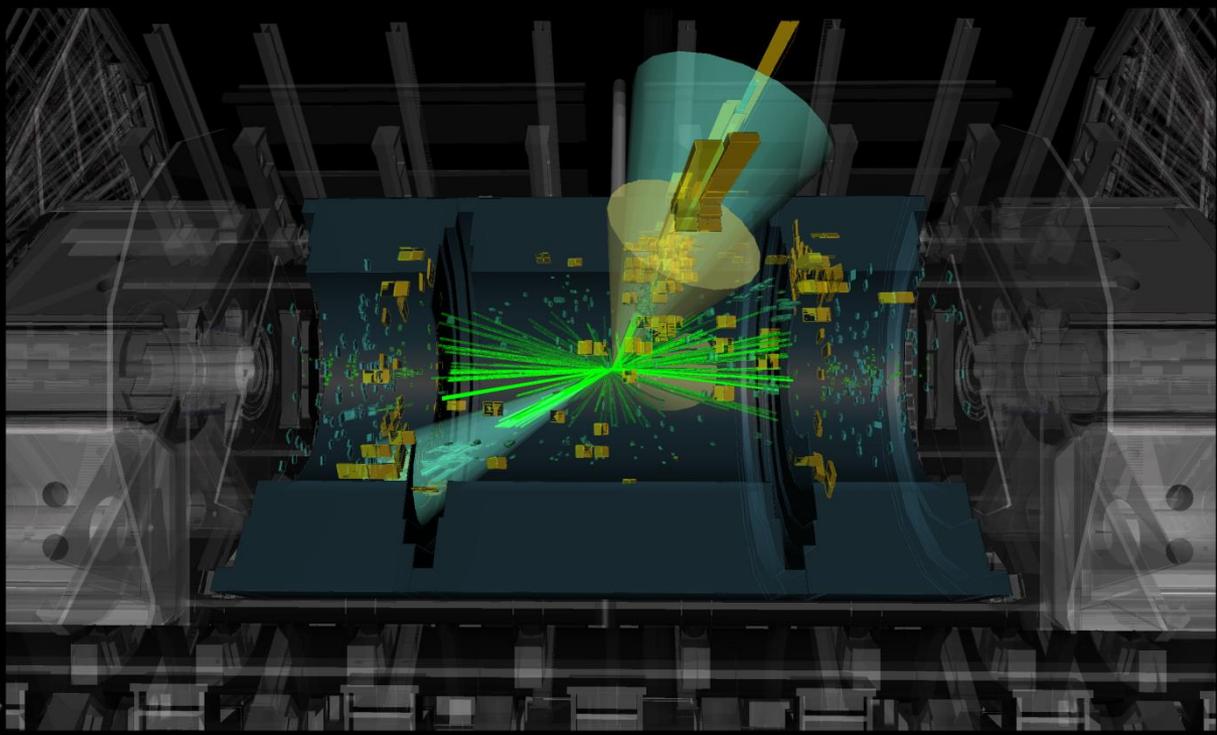
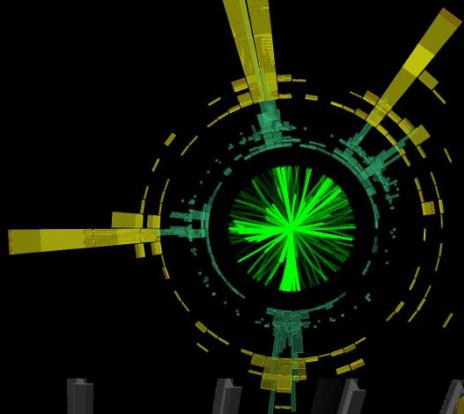


- Now we know that the philosopher's stone does not exist. However, the medieval alchemy laid the foundation for development of modern chemistry.



- ATLAS has tremendous sensitivity to a broad range of models but we are not seeing anything big ... yet.
- Our tools (SM predictions) and experimental techniques (understanding instrumental effects) are evolving. Every generation of searches covers a broader range of signatures.
- The ultimate sensitivity is not reached yet.

$m_{\text{eff}}^{\text{incl}}$ is 2.9 TeV!
 $E_{\text{T}}^{\text{miss}}$ is 500 GeV



ATLAS
EXPERIMENT

Run: 308047

Event: 684427250

2016-09-08 04:49:33 CEST

SR: Gbb B, Gtt 0-lepton B

Thank you!