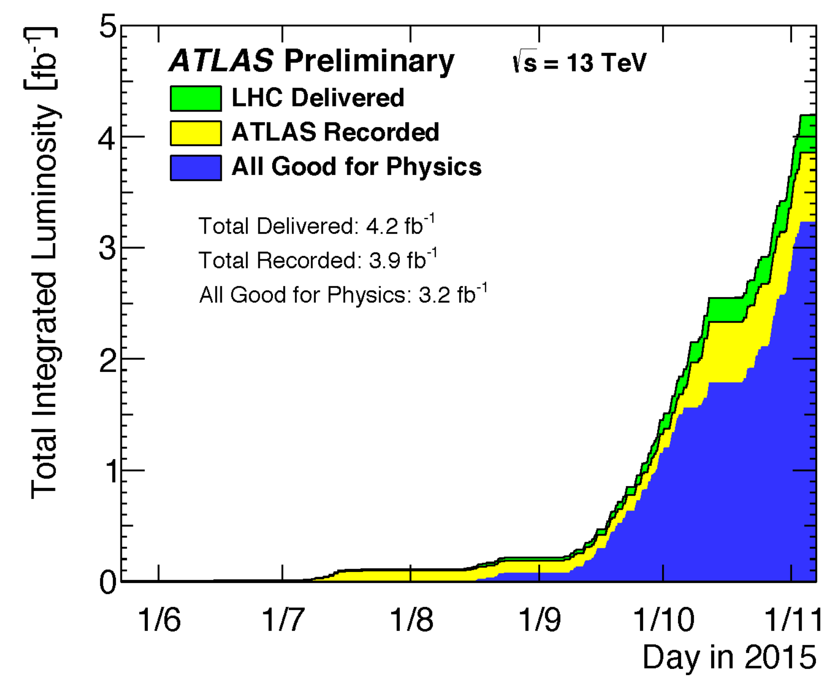
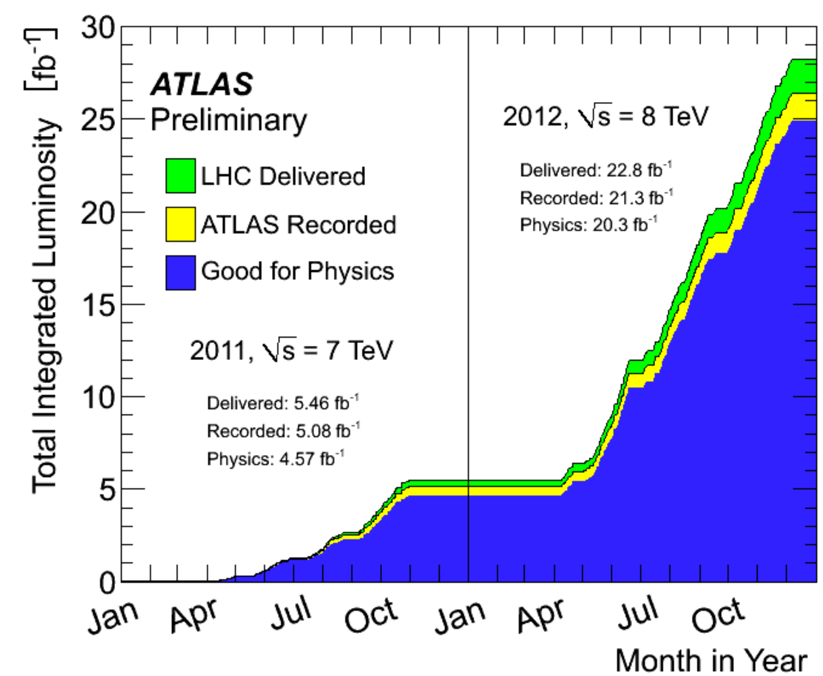
SUSY Searches at 13 TeV at ATLAS

Isabel TRIGGER
TRIUMF
Blois 2016/5/30-2016/6/3

Run-2 Data in 2015

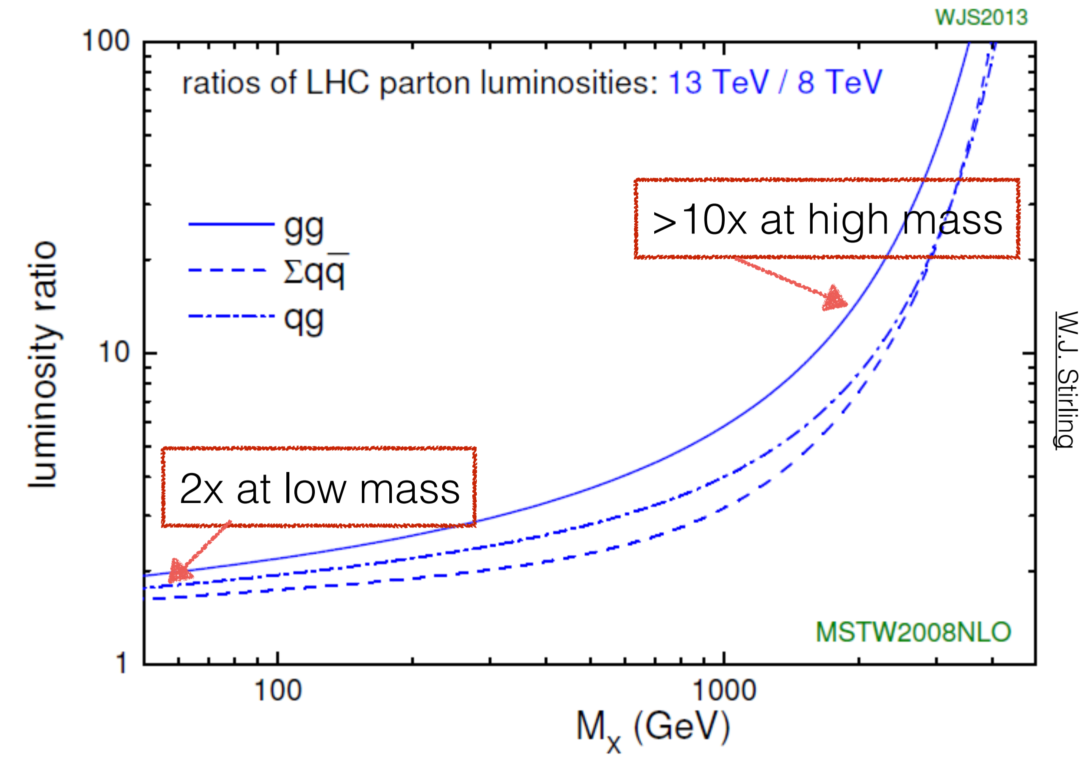
- Generally smooth operation: 3.2 fb^{-1} good for analysis
- New "insertable B-layer" in pixel detector
- More complete coverage with additional muon detectors
- Fraction of live channels even better than Run-1
- And, of course, **substantially higher energy (8 $\rightarrow$ 13 TeV)!**

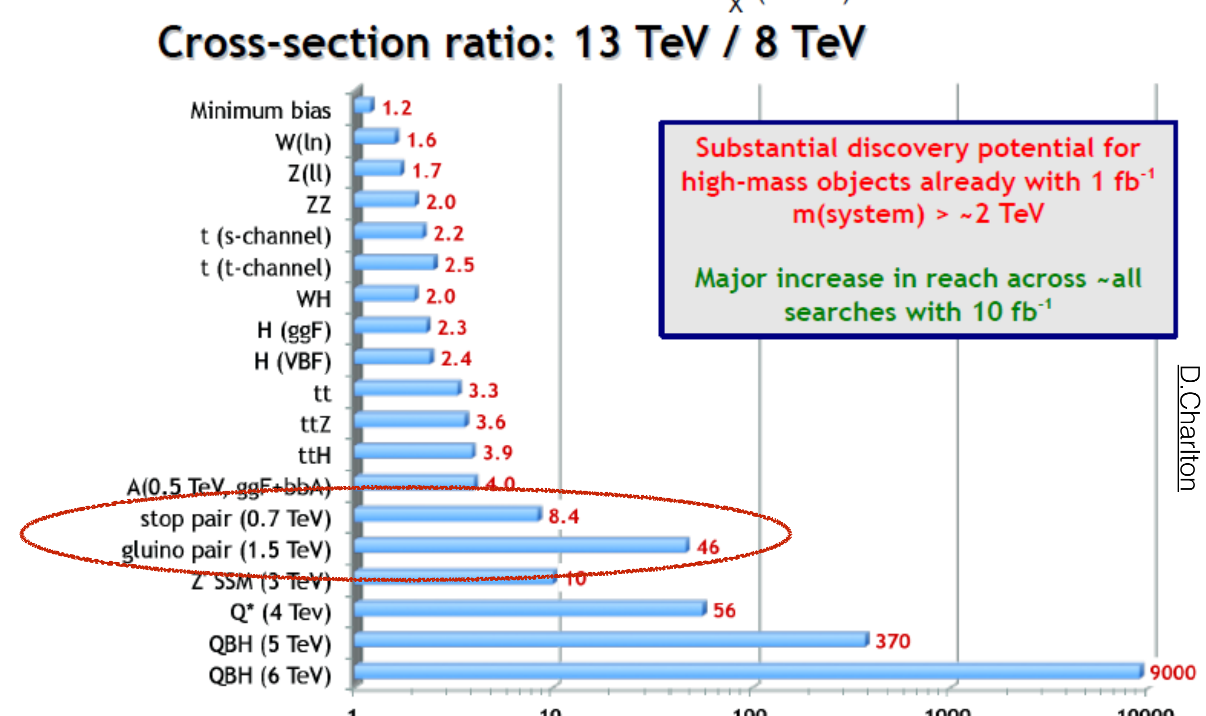




Outline: what to do with a *relatively* small data sample at a brand new energy

- **Strong interaction:** squark / gluino pairs
  - Steep cross-section increase from 8 to 13 TeV
  - Consider possibility of compressed scenarios with long-lived sparticles
  - 3rd generation squark searches very important (theoretically motivated)
    - But stop searches covered in talk by Bertrand Martin d.L. so explicitly not included here; will touch on sbottom
  - Talk arranged approximately in increasing order of complexity
  - Goal is NOT to show all results, but to illustrate analysis strategy, reach





Jets

Strong production:

squarks or gluinos have large cross section if they are “light”;

if cross section large enough, 2015 data surpasses Run 1 limits;

simplest decays contain only jets and missing E_T

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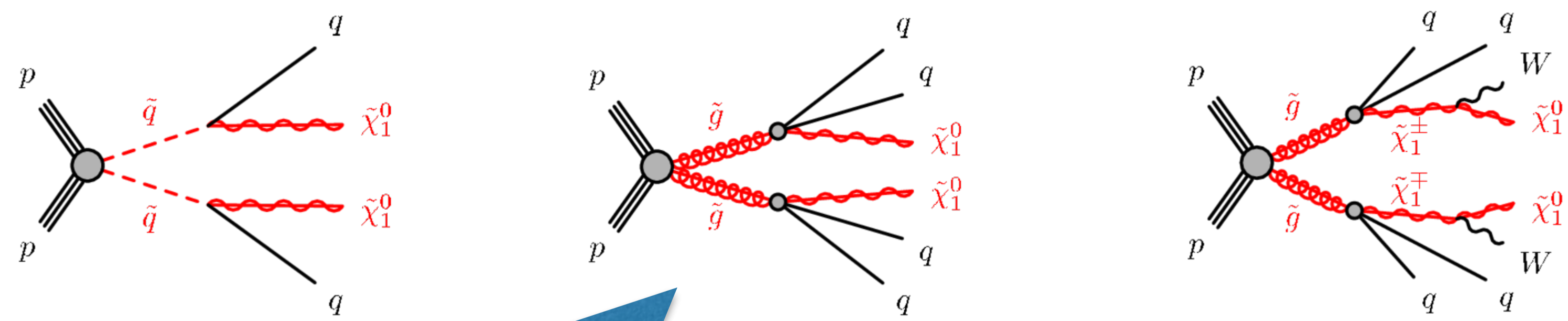
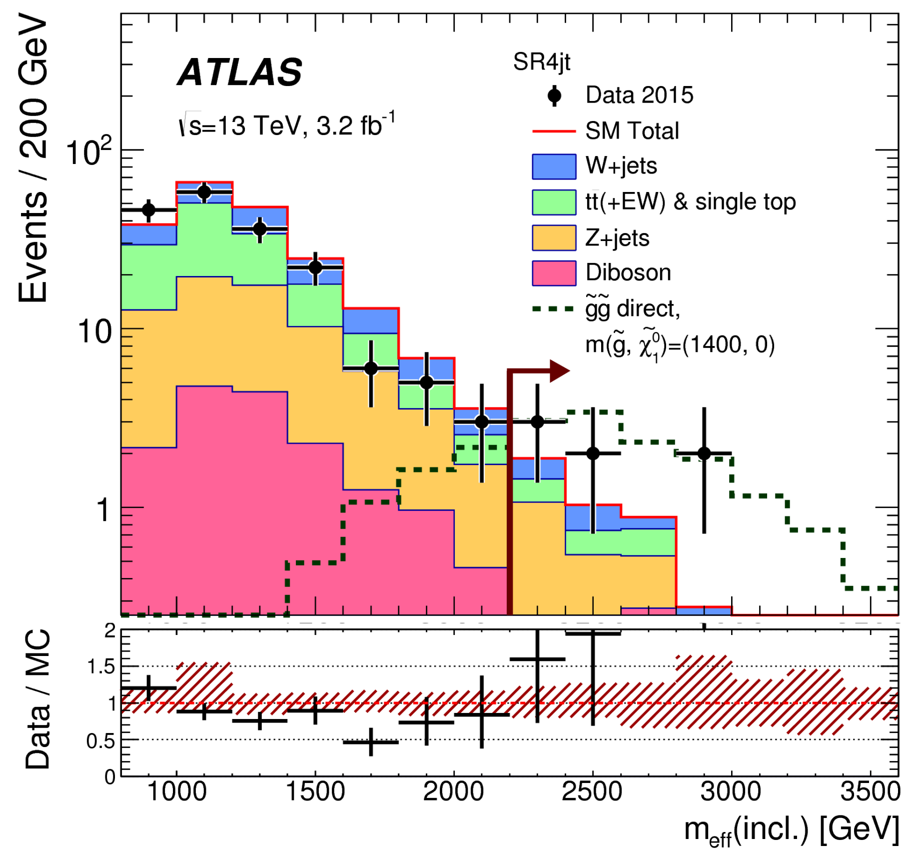
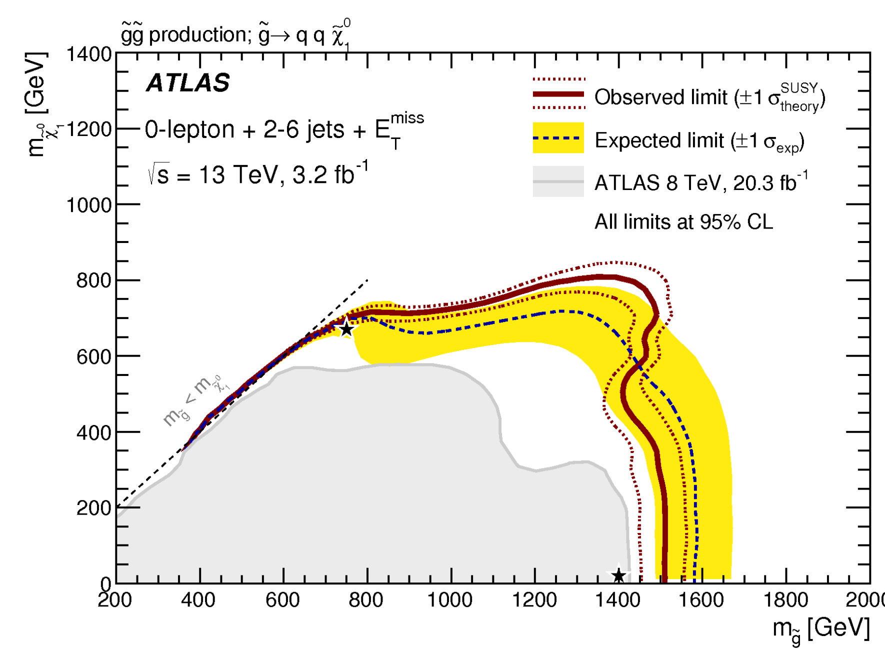
2-6 jets & E_T^{miss} (no leptons)



- Start simple:
    - assume only **gluinos** (or only **squarks**) and **LSP** light
    - 2- or 3-body decays to quark jets and LSP
    - also consider intermediate light chargino
    - 7 signal regions depend on number of jets (2, 4, 5, 6), compression of mass spectrum (loose, medium or tight background rejection)
- Analyses all based on cut on m_{eff}, (scalar sum of p_T of N leading jets and E_T^{miss})
- Exclusions to 1-1.5 TeV, generally exceed Run-1 limits





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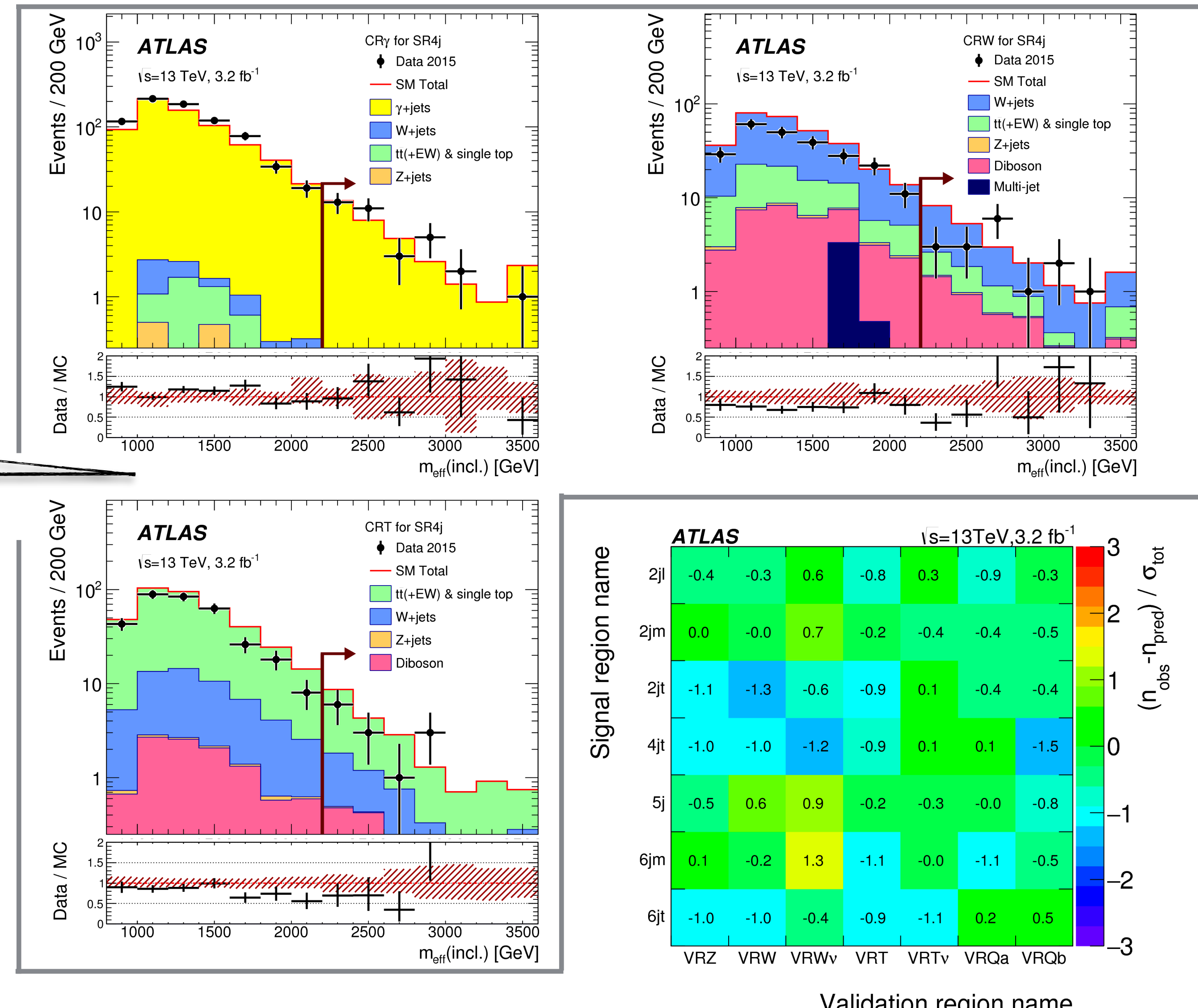
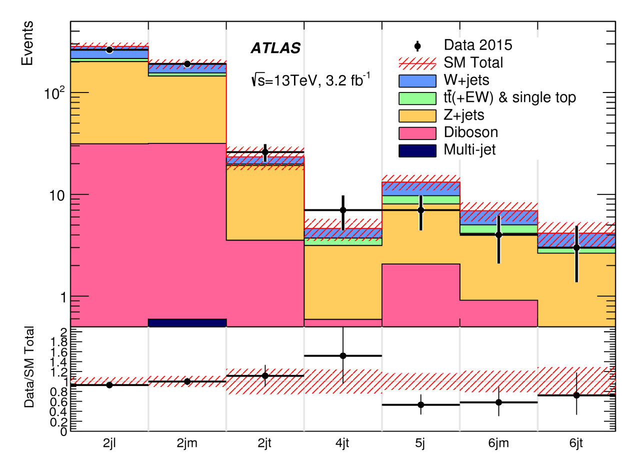
Generic Analysis Strategy

- Signal Regions (SR) optimized e.g. for higher or lower masses or larger or smaller mass differences between strongly produced SUSY particle and LSP
- Control Regions defined for each SR and each major background (top, W/Z+jets, multijets… in this case, 4 CR for each SR)
  - orthogonal to SR
  - minimal Signal contamination and maximum statistics
  - similar systematics & kinematics to SR
  - fit for major backgrounds and extract **scale factors** from fits to apply in SR and Validation Regions
- Validation Regions (VR, orthogonal to both SR and CR, and with little signal contamination) used to cross-check background estimations from CR fits
- Then compare number of events predicted in SR from all fitted backgrounds (plus smaller ones taken from MC) and with number in SR in data
- Limits then set on new physics: background-only, model-independent and model-dependent

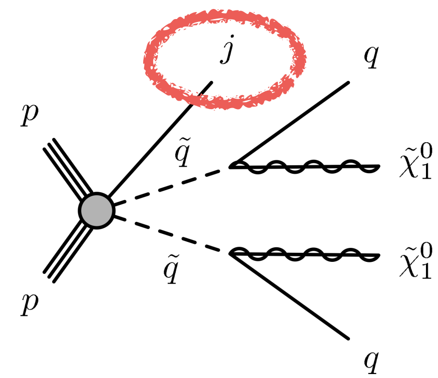
pre-fit!

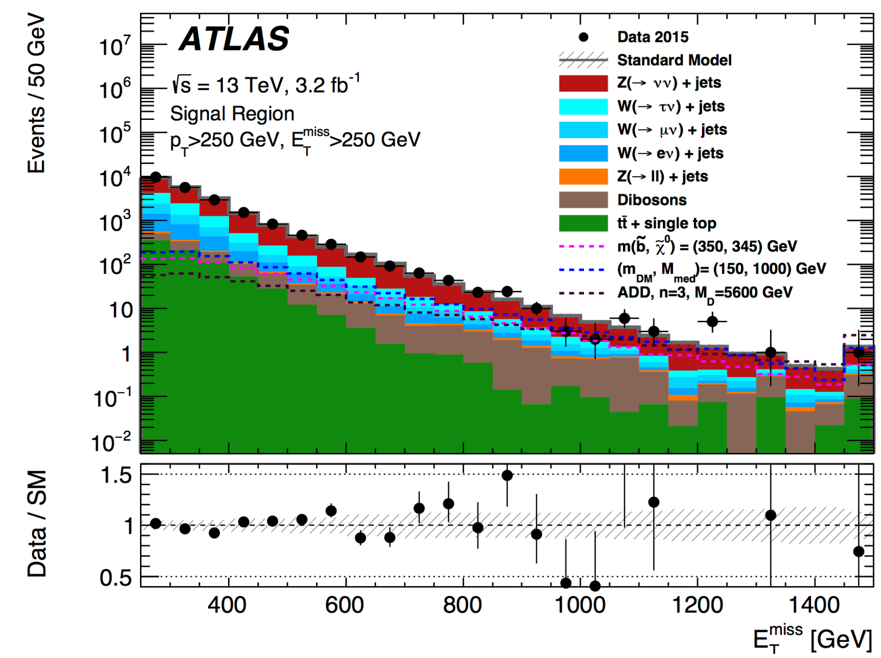


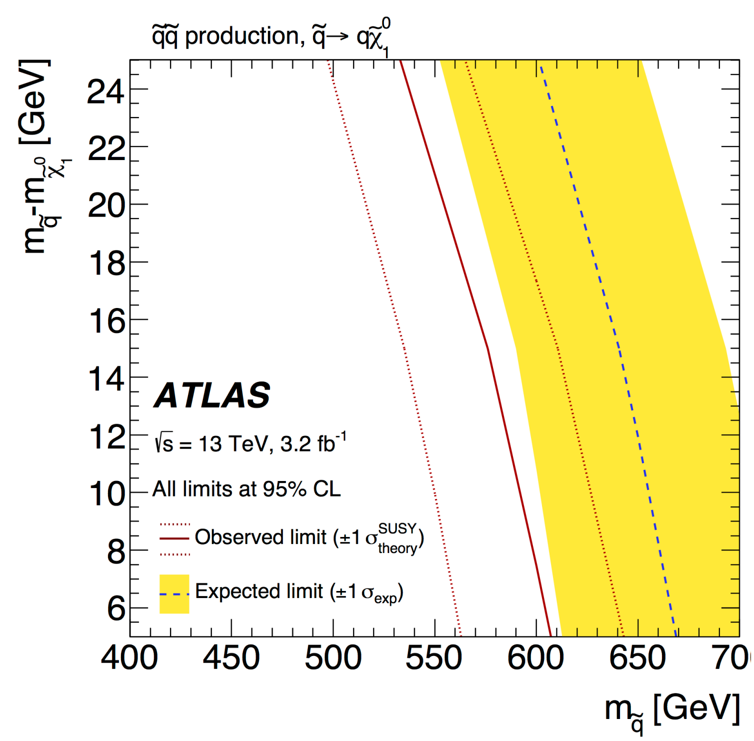


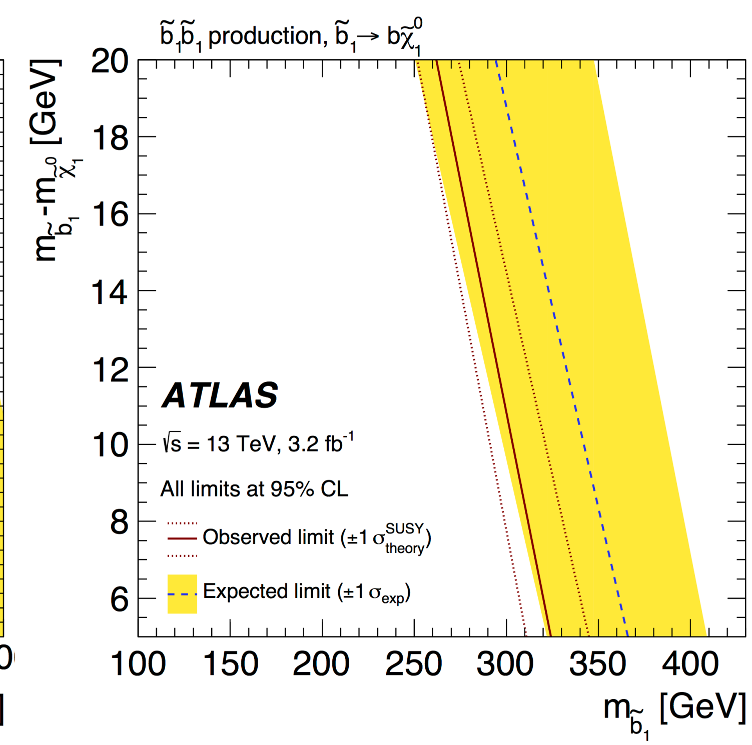
Monojet & large E_T^{miss}

- Very compressed mass spectrum scenarios: small squark-LSP mass difference
- Consider light squark and sbottom pair production (also stop to charm), with ISR jet
- Fit 3 main backgrounds: W(eν)/ W(μν)/Z(νν)+jets
    - (Z⟶μμ is proxy for Z⟶νν)
- 13 signal regions defined by E_T^{miss} thresholds/ranges from 250 - 700 GeV









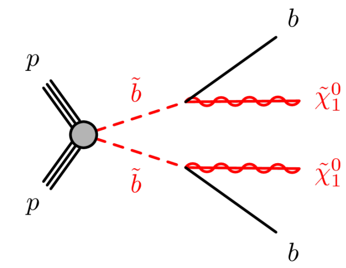
2 b-jets and E_T^{miss}

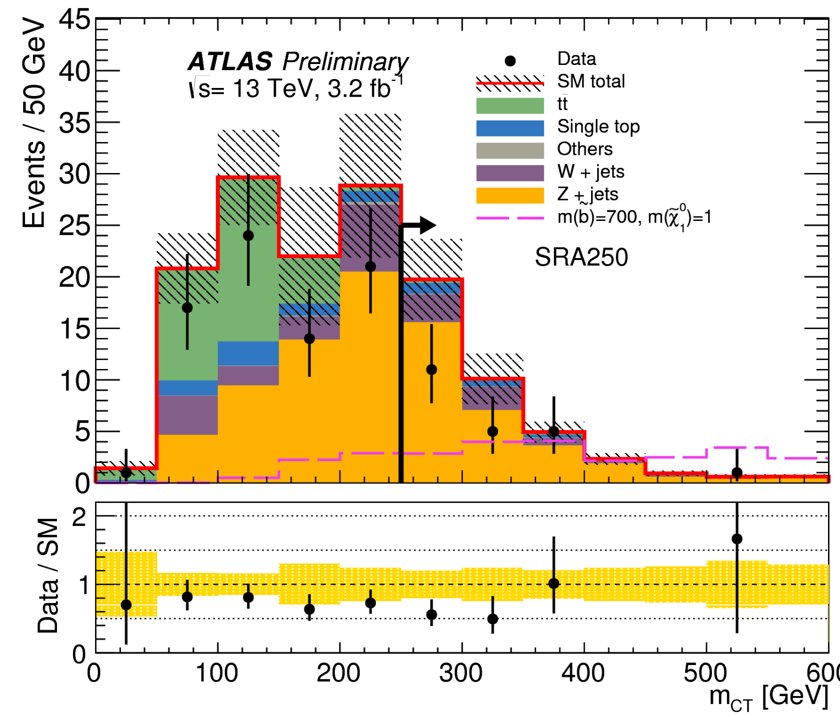
ATLAS-CONF-2015-066

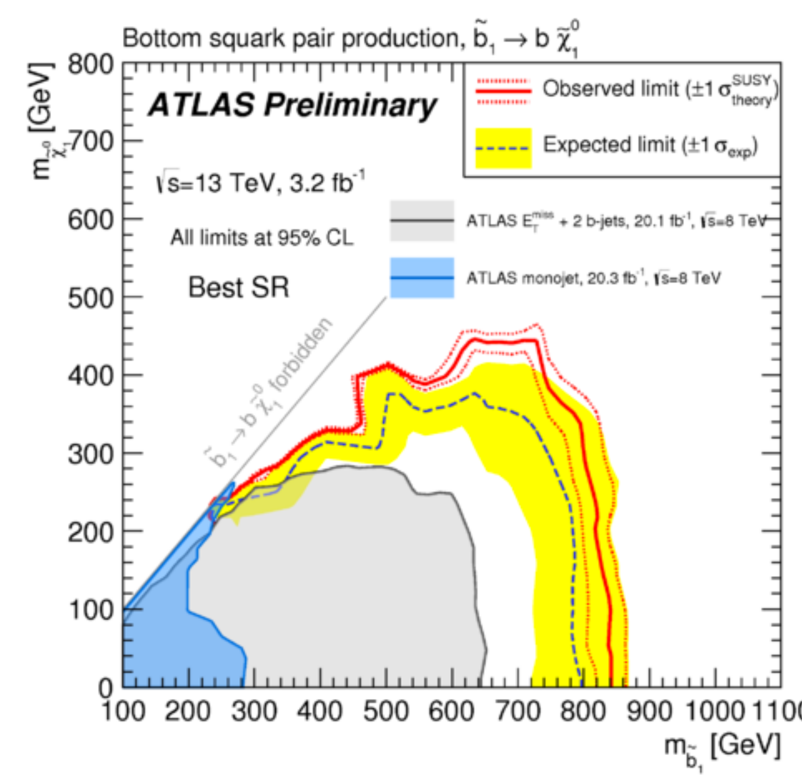
- Light 3rd gen sparticles favoured - cancel heavy quark terms in Higgs mass self-energy corrections
  - Stop searches covered in plenary talk by B.Martin.d.L.
  - Focus here on simple sbottom pair production. Cut-based SR requires 2 b-jets in events passing E_T^{miss} trigger:
    - E_T^{miss} >250 GeV, m_{bb}>200 GeV
      - "Contransverse mass">250 GeV

$$m_{CT}^2(v_1, v_2) = [E_T(v_1) + E_T(v_2)]^2 - [\mathbf{p}_T(v_1) - \mathbf{p}_T(v_2)]^2$$

    - 2nd signal region focuses on small Δm region, requires ISR jet (pT>300 GeV) to boost sbottom pair, E_T^{miss} >400 GeV
  - Slight deficit seen in all SR; stringent limits







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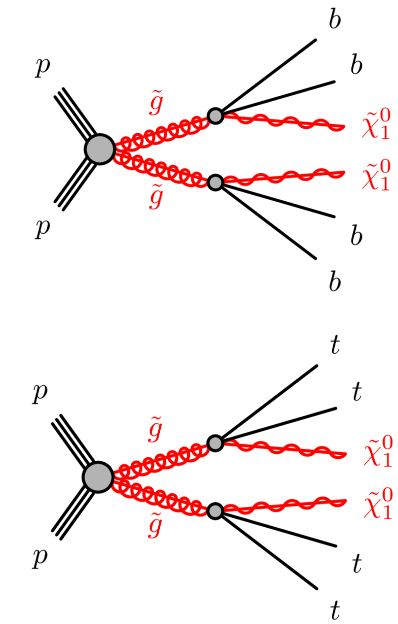
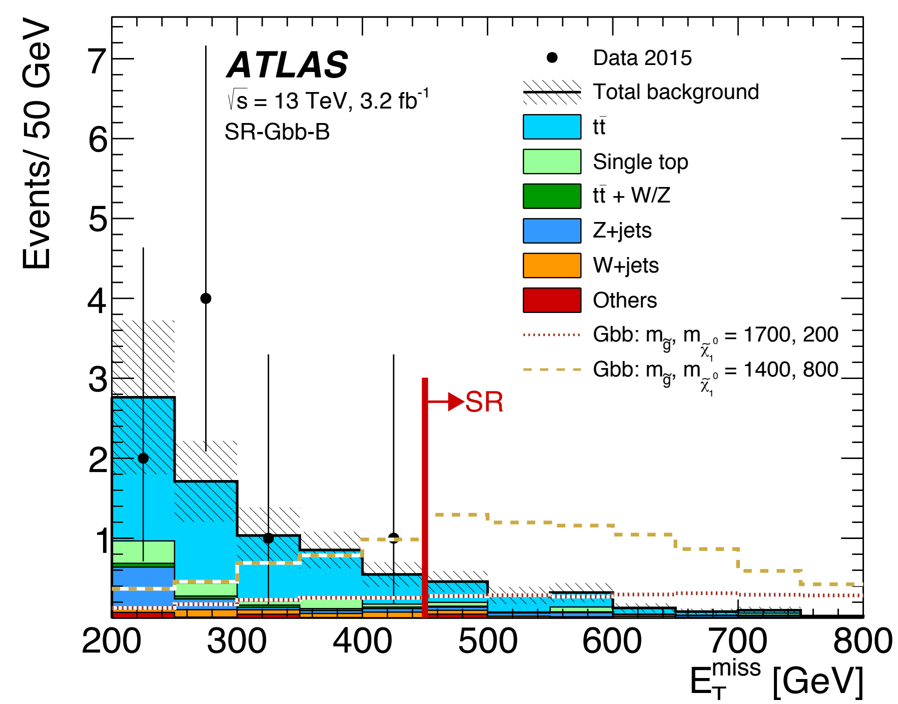
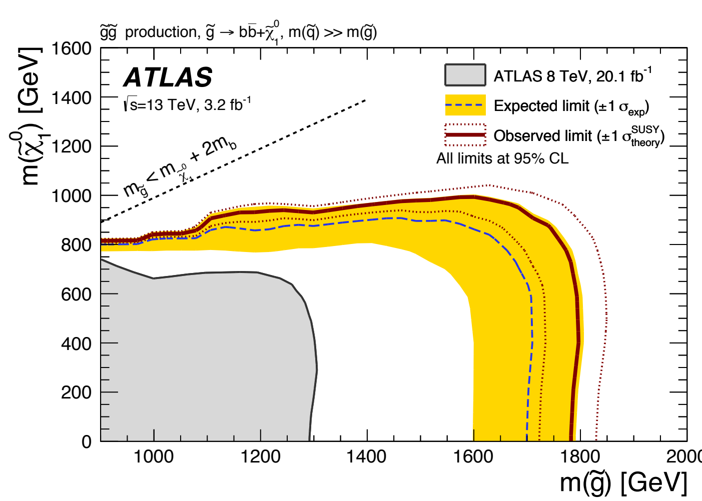
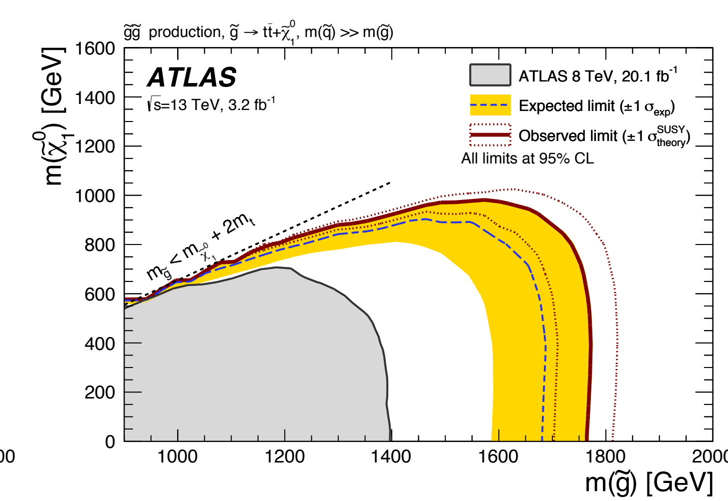
3 (or more) b-jets and E_T^{miss}

- Pair-produced gluinos decaying via virtual sbottom or stop
    - 4 b-jets (≥3 tagged) and E_T^{miss}
    - 4 b-jets (≥3 tagged), E_T^{miss} and additional decay products of W-bosons from the 4 tops (0 or ≥1 lepton and many jets)
- Several signal regions for each final state, targeting increasingly compressed scenarios
- Observe slightly fewer events than expected (also in validation regions) so limits somewhat better than expected, 1.78 TeV for sbottom and 1.76 TeV for stop, for M(neutralino)≲700 GeV

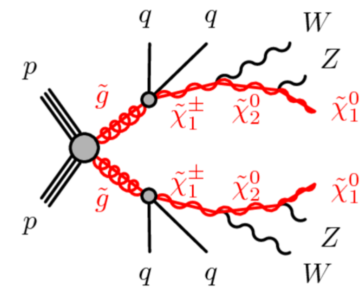
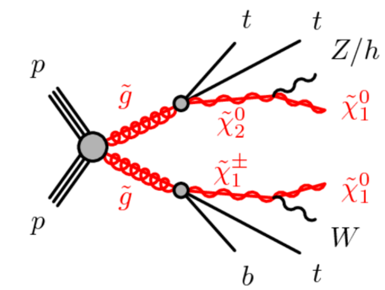




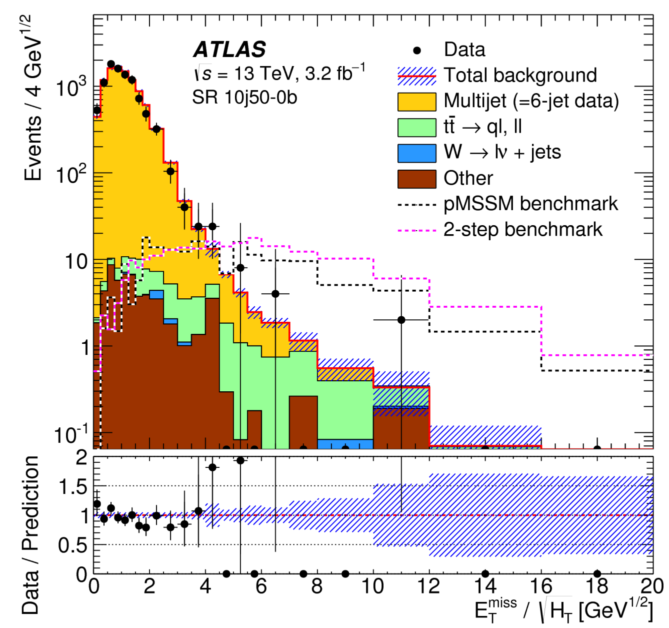


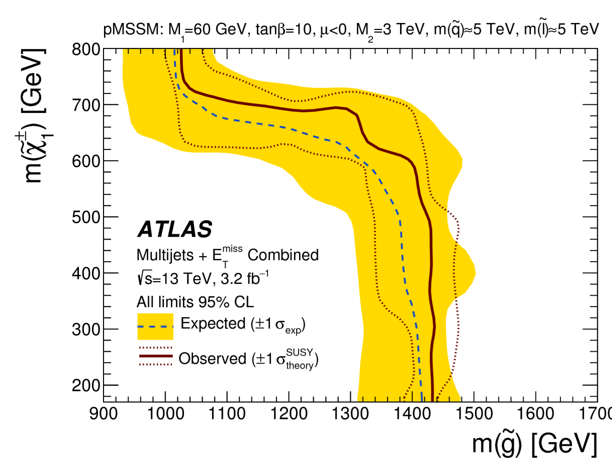


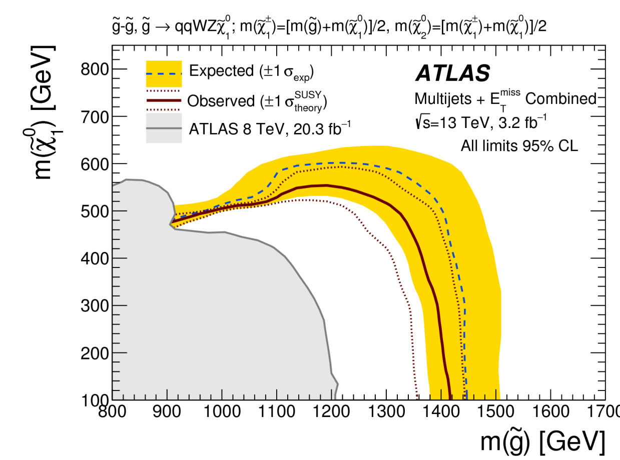
7-10 jets & E_T^{miss} (no leptons)

- If more complex cascade decays of gluinos allowed, produce more jets (possibly including b-jets), but potentially less E_T^{miss}
- Use high-multiplicity jet triggers:
    - 6 jets of pT>45 GeV
        - 9 SR: 8, 9 or 10 jets of which 0, 1 or 2 b-tagged
    - or 5 of pT>70 GeV
        - 6 SR with 7 or 8 jets of which 0, 1 or 2 b-tagged
- Cut-based analyses, discriminant $E_T^{miss}/\sqrt{H_T}$
    - H_T = scalar sum of jet p_T
- Gluino masses up to 1.4 TeV excluded in large regions in these simplified models







Jets with Leptons

Strong production, with electroweak particles in the cascade decays leading to final-state electrons or muons, greatly increasing trigger efficiency

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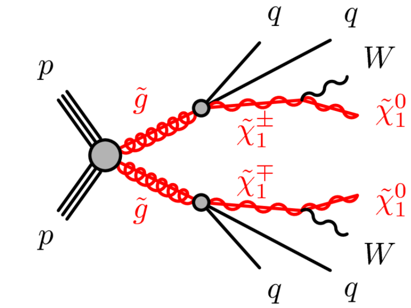
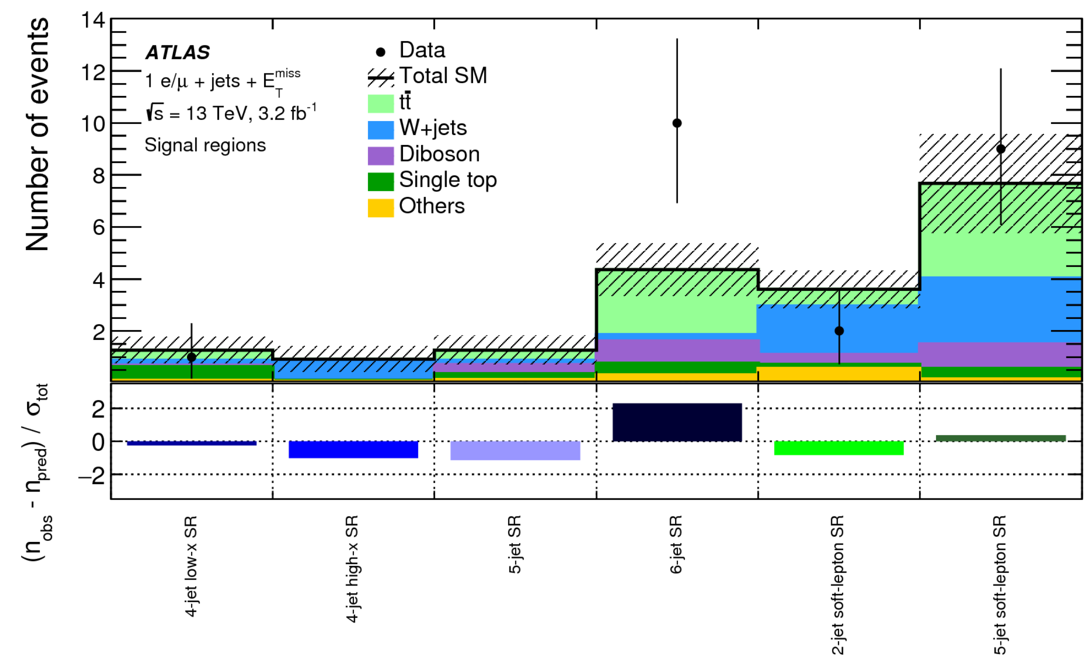
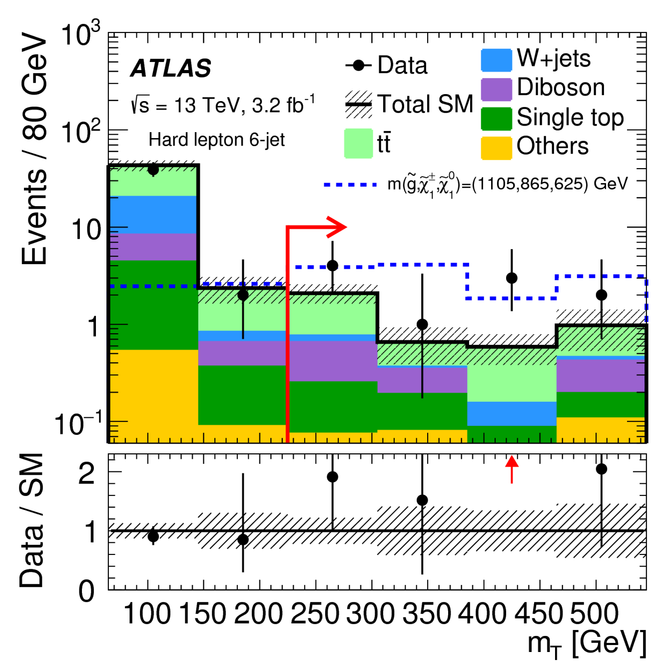
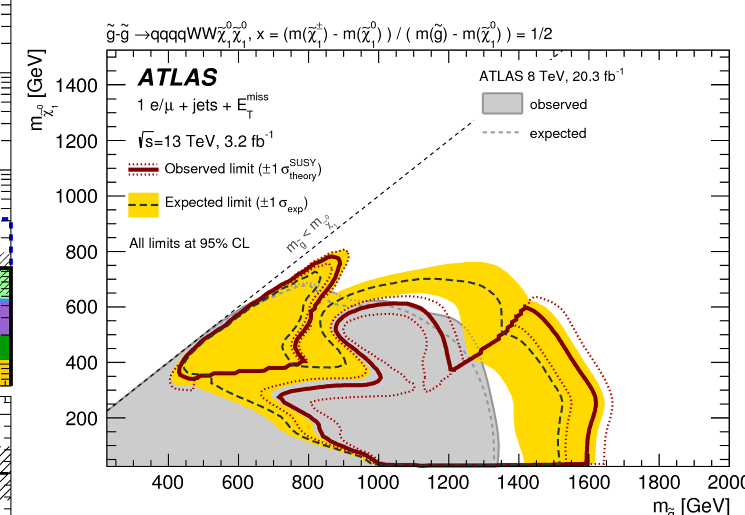
1 lepton, jets & E_T^{miss}



- Pair-produced gluinos decaying via light charginos
    - 3-body decay via virtual squarks; one final-state W(*) decays leptonically, along with up to 6 jets and E_T^{miss}
- E_T^{miss} trigger (70 GeV in trigger, 200 GeV offline) lets very soft leptons be included
- Several E_T^{miss}-dependent variables (m_T, H_T, m_{eff}, E_T^{miss}) used to define 6 SR:
    - soft lepton & ≥2 or ≥5 jets; hard lepton & ≥4 (2 variants), 5 or 6 jets
- Interpretation in several simplified models with assumptions about relations between sparticle masses







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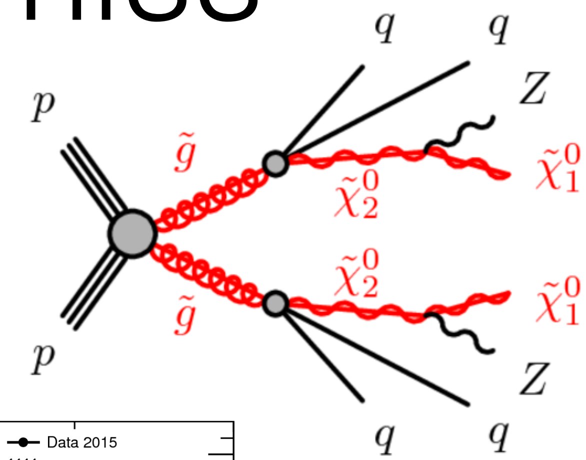
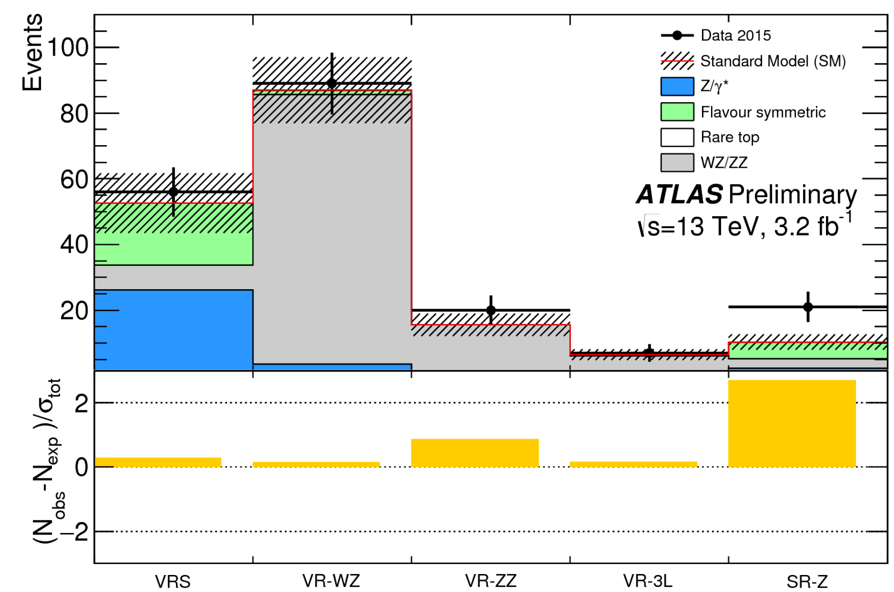
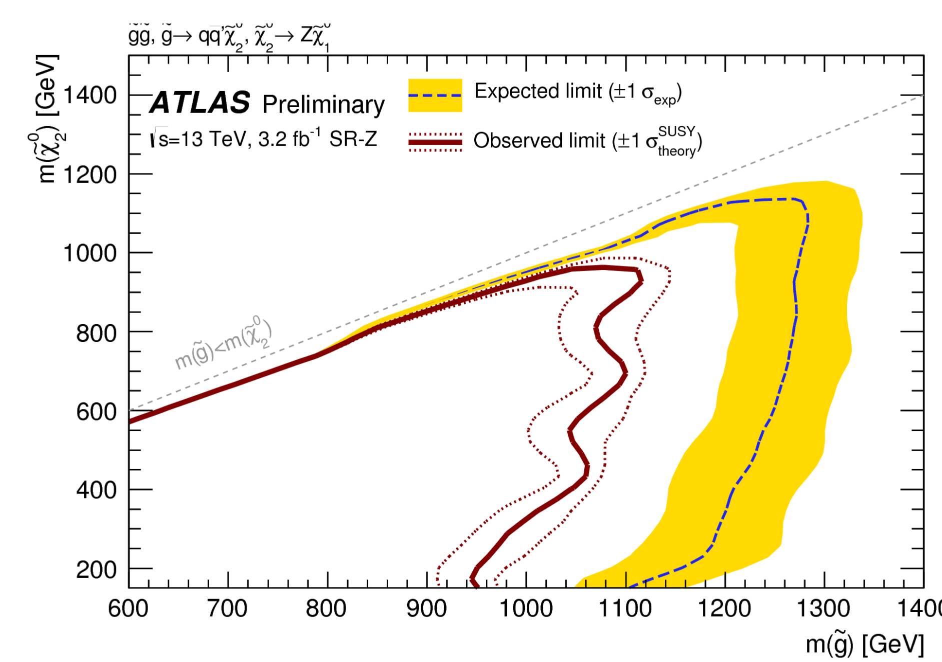
Z(→ll) & Jets, E_T^{miss}



- Similar to previous, with both neutralinos light, and Z replacing W in final state
- One Z decays leptonically, along with E_T^{miss} and several jets
- In signal, both leptons come from Z-decay, so same-flavour. Control sample with different-flavour leptons used to estimate e.g. top-pair background.
- Cuts: E_T^{miss} >225 GeV, H_T>600 GeV, n_{jets}≥2, 81<m_{ll}<101 GeV define signal region

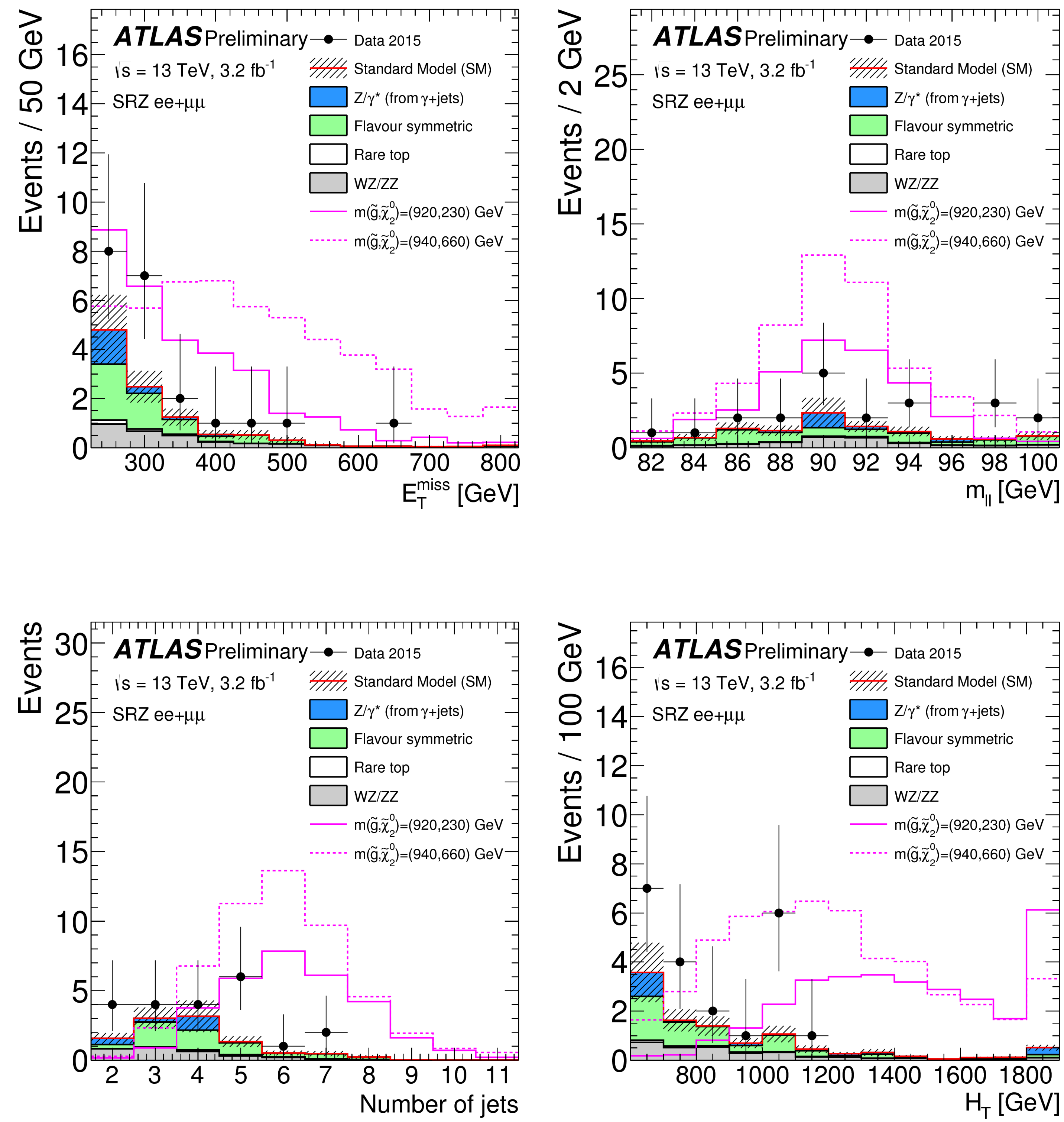




ATLAS-CONF-2015-082

Z(→ll)+ Jets, E_T^{miss} *(cont'd)*

- 21 events observed in SR (10 ee, 11 μμ)
- 10.3 ± 2.3 expected
  - p-value: 0.013
  - 13 TeV signif.: 2.2σ
  - Observed (Expected) S^{95}: 20.0 ($10.2^{+4.4}_{-3.0}$)



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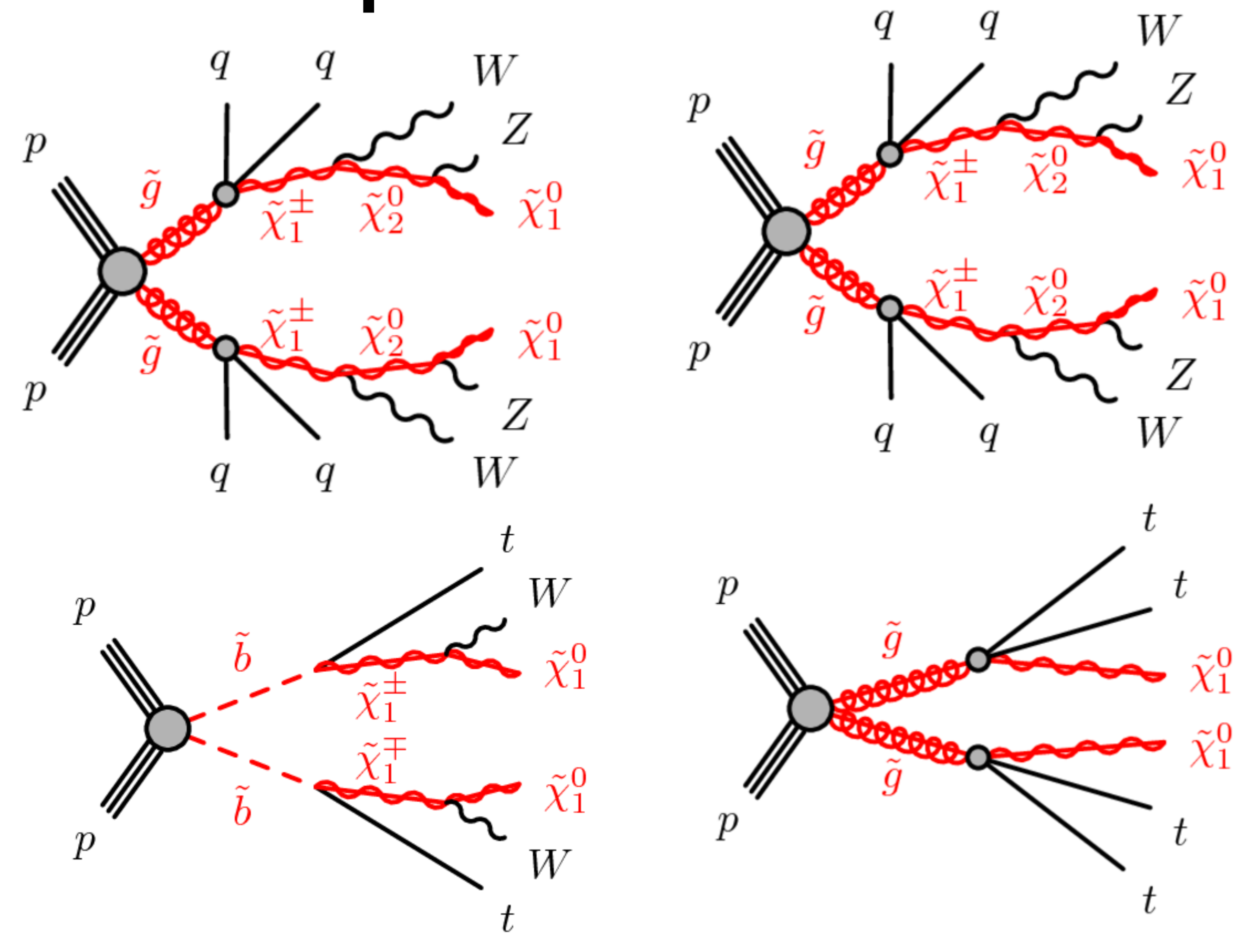
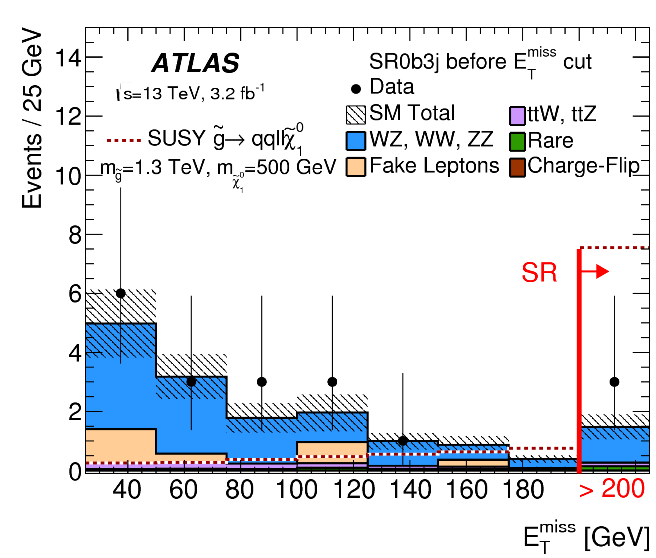
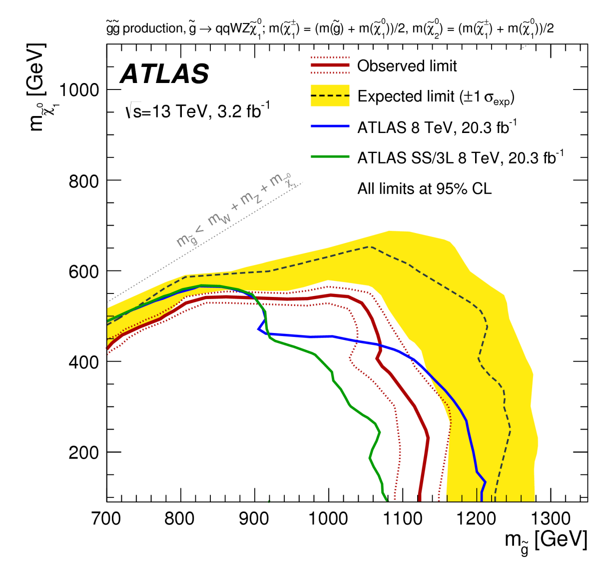
EPJ C, 76(5),1-26

2 same-sign or 3 leptons

- Gluinos are neutral - charged electroweak particles in both decay branches may have same charge
- Can also have 3 leptons (or 2 SS leptons) arising from final states with multiple Z, W or t decaying leptonically
  - Both signatures extremely rare in SM
- 4 signal regions according to number of b-jets and/or light jets
- Final discriminant is high E_T^{miss}
- Exceeds Run-1 limits in certain models







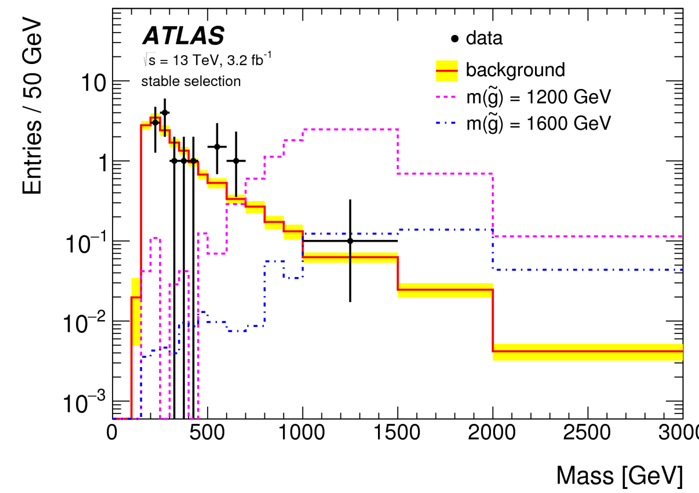
Lifetime

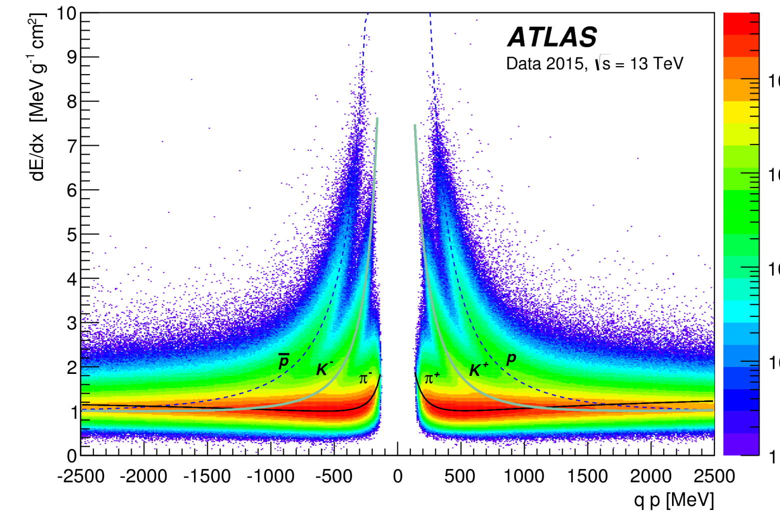
In (for example) compressed mass-spectrum scenarios or situations like "split" SUSY where 3-body decays can by highly suppressed by large sparticle masses, there may be very little phase space for decays to the LSP, resulting in a long-lived NLSP. This could elude standard missing-energy searches, and requires special attention.

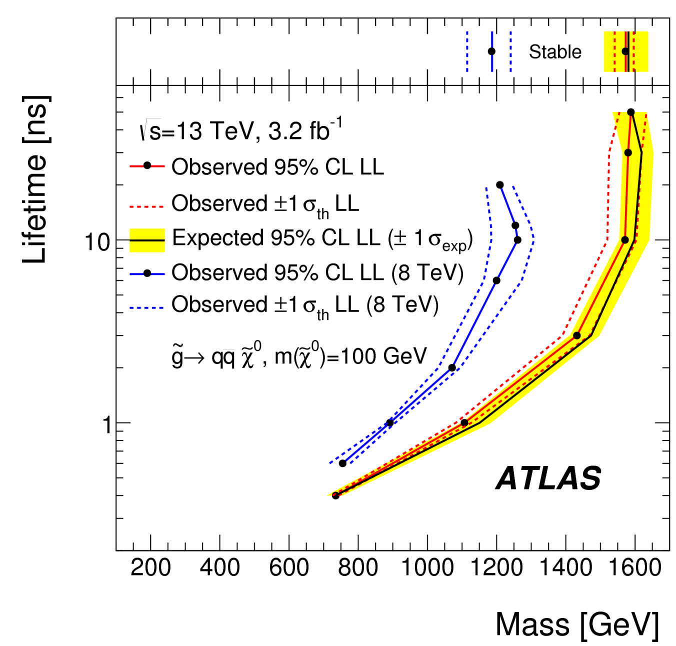
long-lived highly ionizing particles

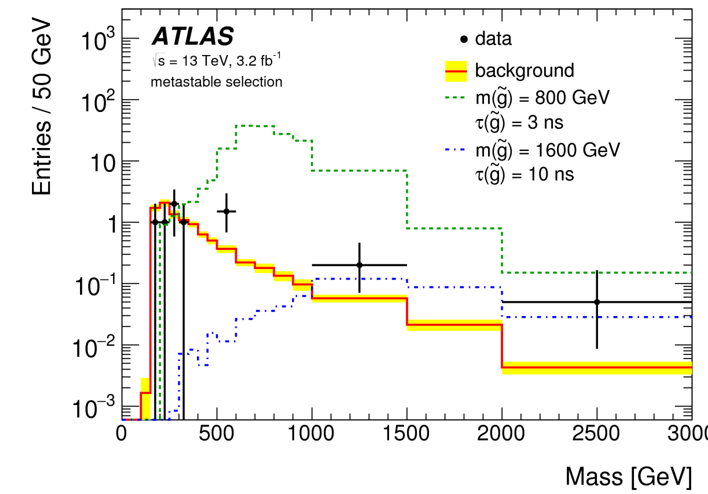
1604.04520

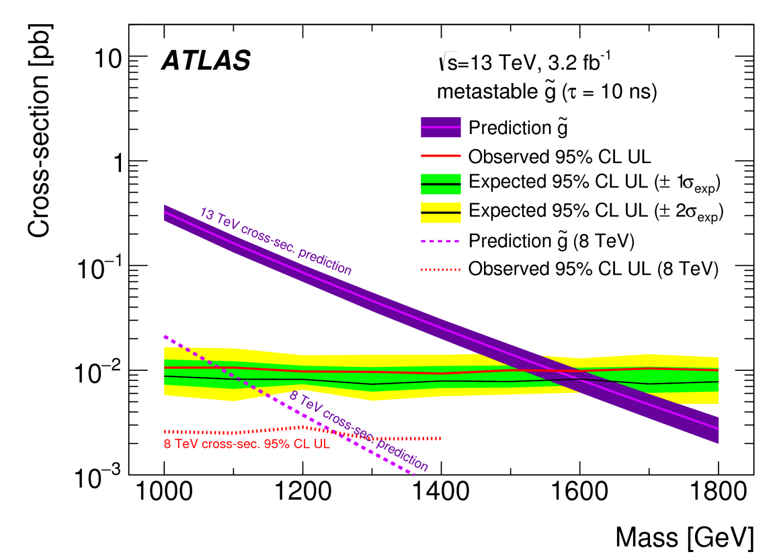
- Gluino (charged) R-hadrons:
  - stable (lifetime>50 ns)
  - or metastable (decay to qq +LSP)
- Look for tracks with large dE/dx from Si-pixels and high pT
- stable gluino R-hadrons excluded below 1570 GeV
- Gluino R-hadrons with lifetime > 0.4 ns exclusions given for 100 GeV LSP, lower mass limits 740-1590 GeV



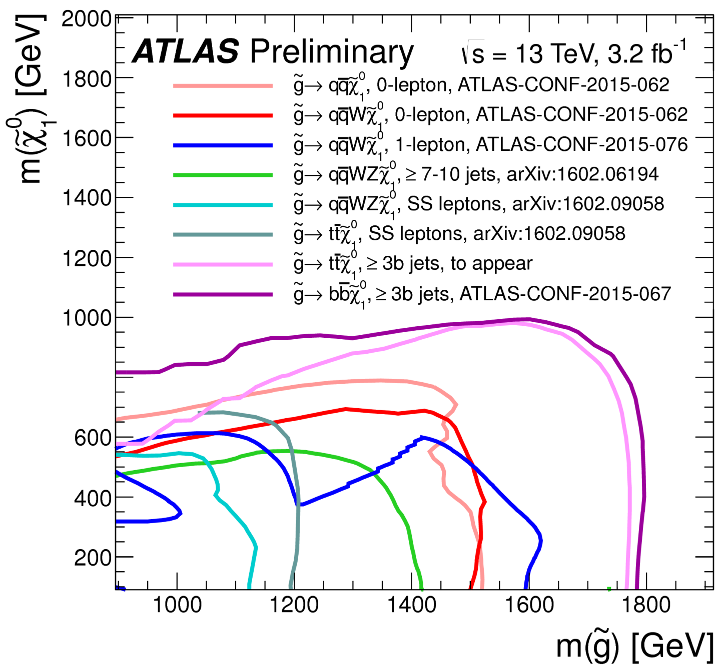


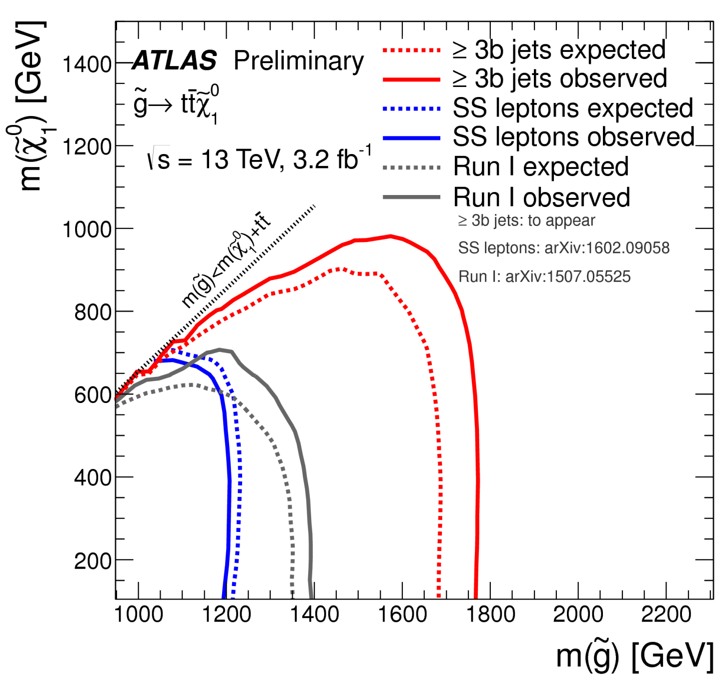




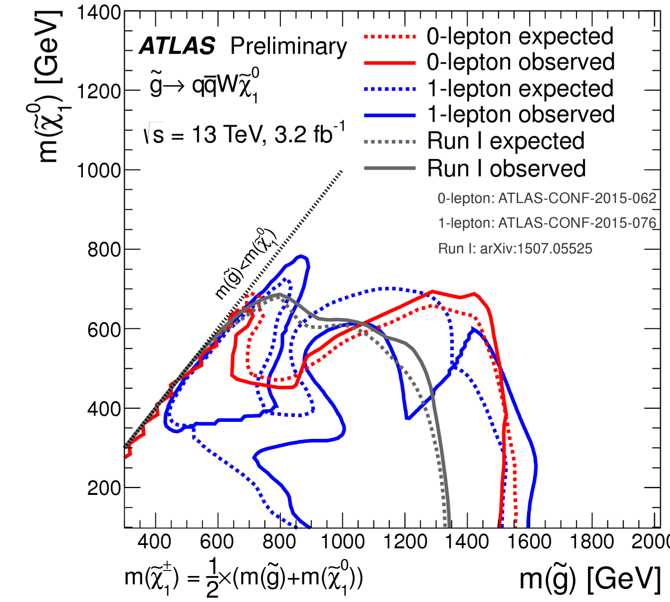


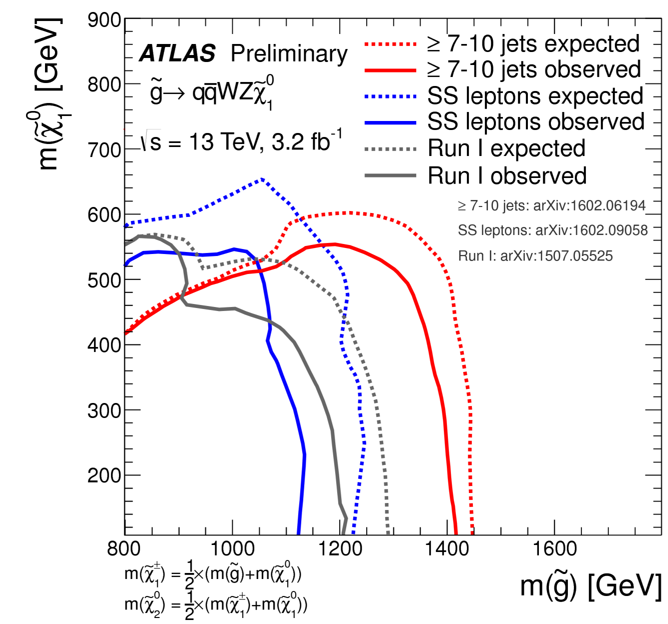
Summary

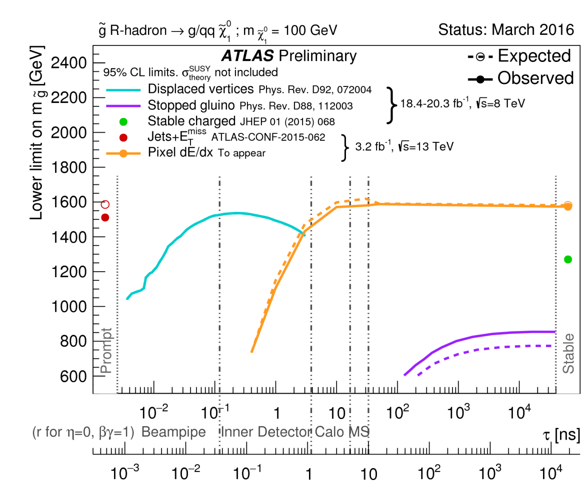




- With 3.2 fb^{-1} at 13 TeV, ATLAS already extends reach of many strong-production SUSY scenarios over 8 TeV limits
- Limits ~1.5 TeV for gluinos in simplest models
- Interesting - but not (yet?) significant - excess in Z(to ll)+ETmiss analysis first seen at 8 TeV persists
- Expect ~25 fb^{-1} in 2016:
    - Confirm or demolish the excess
    - Extend limits in strong production toward kinematic limits
    - Look for weakly produced SUSY with sensitivity beyond Run-1
- An interesting year for SUSY. The year?







ATLAS SUSY Searches* - 95% CL Lower Limits

Status: March 2016

ATLAS Preliminary

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

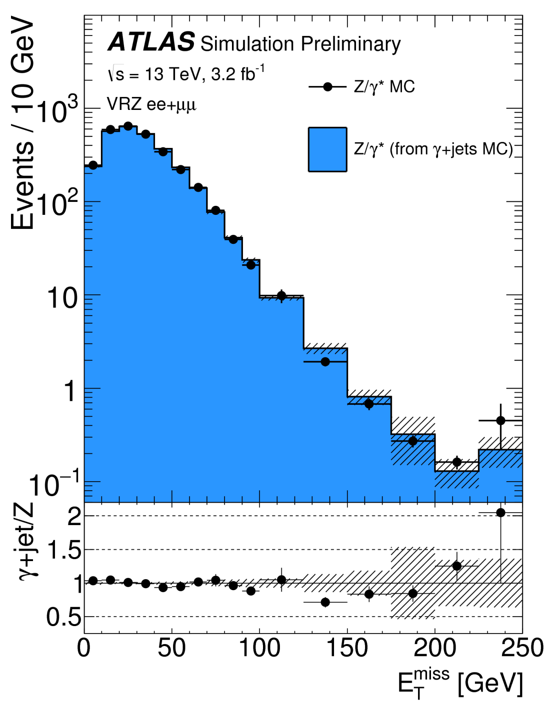
	Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\, dt [fb^{-1}]$	Mass limit	$\sqrt{s}$ [TeV]		Reference
Inclusive Searches	MSUGRA/CMSSM	0-3 e,μ/1-2 τ	2-10 jets/3 b	Yes	20.3	$\tilde{q}, \tilde{g}$ 1.85 TeV	7, 8	$m(\tilde{q})=m(\tilde{g})$	1507.05525
	$\tilde{q}\tilde{q}, \tilde{q}\rightarrow q\tilde{\chi}_1^0$	0	2-6 jets	Yes	3.2	$\tilde{q}$ 980 GeV	13	$m(\tilde{\chi}_1^0)$=0 GeV, m(1st gen. $\tilde{q}$)=m(2nd gen. $\tilde{q}$)	ATLAS-CONF-2015-062
	$\tilde{q}\tilde{q}, \tilde{q}\rightarrow q\tilde{\chi}_1^0$ (compressed)	mono-jet	1-3 jets	Yes	3.2	$\tilde{q}$ 610 GeV	13	$m(\tilde{q})-m(\tilde{\chi}_1^0)$<5 GeV	To appear
	$\tilde{q}\tilde{q}, \tilde{q}\rightarrow q(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$	2 e,μ (off-Z)	2 jets	Yes	20.3	$\tilde{q}$ 820 GeV	7, 8	$m(\tilde{\chi}_1^0)$=0 GeV	1503.03290
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	3.2	$\tilde{g}$ 1.52 TeV	13	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2015-062
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow qq\tilde{\chi}_1^{\pm}\rightarrow qqW^{\pm}\tilde{\chi}_1^0$	1 e,μ	2-6 jets	Yes	3.3	$\tilde{g}$ 1.6 TeV	13	$m(\tilde{\chi}_1^0)$<350 GeV, $m(\tilde{\chi}^{\pm})=0.5(m(\tilde{\chi}_1^0)+m(\tilde{g}))$	ATLAS-CONF-2015-076
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$	2 e,μ	0-3 jets	-	20	$\tilde{g}$ 1.38 TeV	7, 8	$m(\tilde{\chi}_1^0)$=0 GeV	1501.03555
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow qqWZ\tilde{\chi}_1^0$	0	7-10 jets	Yes	3.2	$\tilde{g}$ 1.4 TeV	13	$m(\tilde{\chi}_1^0)$ =100 GeV	1602.06194
	GMSB ($\tilde{\ell}$ NLSP)	1-2 τ + 0-1 ℓ	0-2 jets	Yes	20.3	$\tilde{g}$ 1.63 TeV	7, 8	$\tan\beta$ >20	1407.0603
	GGM (bino NLSP)	2 γ	-	Yes	20.3	$\tilde{g}$ 1.34 TeV	7, 8	$c\tau$(NLSP)<0.1 mm	1507.05493
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	20.3	$\tilde{g}$ 1.37 TeV	7, 8	$m(\tilde{\chi}_1^0)$<950 GeV, $c\tau$(NLSP)<0.1 mm, μ<0	1507.05493
	GGM (higgsino-bino NLSP)	γ	2 jets	Yes	20.3	$\tilde{g}$ 1.3 TeV	7, 8	$m(\tilde{\chi}_1^0)$<850 GeV, $c\tau$(NLSP)<0.1 mm, μ>0	1507.05493
	GGM (higgsino NLSP)	2 e,μ (Z)	2 jets	Yes	20.3	$\tilde{g}$ 900 GeV	7, 8	m(NLSP)>430 GeV	1503.03290
	Gravitino LSP	0	mono-jet	Yes	20.3	$F^{1/2}$ scale 865 GeV	7, 8	$m(\tilde{G})>1.8\times10^{-4}$ eV, $m(\tilde{g})=m(\tilde{q})$=1.5 TeV	1502.01518
3rd gen. $\tilde{g}$ med.	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow b\bar{b}\tilde{\chi}_1^0$	0	3 b	Yes	3.3	$\tilde{g}$ 1.78 TeV	13	$m(\tilde{\chi}_1^0)$<800 GeV	ATLAS-CONF-2015-067
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow t\bar{t}\tilde{\chi}_1^0$	0-1 e,μ	3 b	Yes	3.3	$\tilde{g}$ 1.76 TeV	13	$m(\tilde{\chi}_1^0)$=0 GeV	To appear
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow b\bar{t}\tilde{\chi}_1^+$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$ 1.37 TeV	7, 8	$m(\tilde{\chi}_1^0)$<300 GeV	1407.0600
3rd gen. squarks direct production	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\rightarrow b\tilde{\chi}_1^0$	0	2 b	Yes	3.2	$\tilde{b}_1$ 840 GeV	13	$m(\tilde{\chi}_1^0)$<100 GeV	ATLAS-CONF-2015-066
	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\rightarrow t\tilde{\chi}_1^{\pm}$	2 e,μ (SS)	0-3 b	Yes	3.2	$\tilde{b}_1$ 325-540 GeV	13	$m(\tilde{\chi}_1^0)$=50 GeV, $m(\tilde{\chi}_1^{\pm})$= $m(\tilde{\chi}_1^0)$+100 GeV	1602.09058
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\rightarrow b\tilde{\chi}_1^{\pm}$	1-2 e,μ	1-2 b	Yes	4.7/20.3	$\tilde{t}_1$ 117-170 GeV; 200-500 GeV	7, 8	$m(\tilde{\chi}_1^{\pm})$ = 2$m(\tilde{\chi}_1^0)$, $m(\tilde{\chi}_1^0)$=55 GeV	1209.2102, 1407.0583
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\rightarrow Wb\tilde{\chi}_1^0$ or $t\tilde{\chi}_1^0$	0-2 e,μ	0-2 jets/1-2 b	Yes	20.3	$\tilde{t}_1$ 90-198 GeV; 205-715 GeV; 745-785 GeV	7, 8; 745-785 GeV: 13	$m(\tilde{\chi}_1^0)$=1 GeV	1506.08616, ATLAS-CONF-2016-007
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\rightarrow c\tilde{\chi}_1^0$	0	mono-jet/c-tag	Yes	20.3	$\tilde{t}_1$ 90-245 GeV	7, 8	$m(\tilde{t}_1)-m(\tilde{\chi}_1^0)$<85 GeV	1407.0608
	$\tilde{t}_1\tilde{t}_1$ (natural GMSB)	2 e,μ (Z)	1 b	Yes	20.3	$\tilde{t}_1$ 150-600 GeV	7, 8	$m(\tilde{\chi}_1^0)$>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	20.3	$\tilde{t}_2$ 290-610 GeV	7, 8	$m(\tilde{\chi}_1^0)$<200 GeV	1403.5222
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2\rightarrow\tilde{t}_1 + h$	1 e,μ	6 jets + 2 b	Yes	20.3	$\tilde{t}_2$ 320-620 GeV	7, 8	$m(\tilde{\chi}_1^0)$=0 GeV	1506.08616
EW direct	$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R}, \tilde{\ell}\rightarrow\ell\tilde{\chi}_1^0$	2 e,μ	0	Yes	20.3	$\tilde{\ell}$ 90-335 GeV	7, 8	$m(\tilde{\chi}_1^0)$=0 GeV	1403.5294
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\rightarrow\tilde{\ell}\nu(\ell\tilde{\nu})$	2 e,μ	0	Yes	20.3	$\tilde{\chi}_1^{\pm}$ 140-475 GeV	7, 8	$m(\tilde{\chi}_1^0)$=0 GeV, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}_1^{\pm})+m(\tilde{\chi}_1^0))$	1403.5294
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\rightarrow\tilde{\tau}\nu(\tau\tilde{\nu})$	2 τ	-	Yes	20.3	$\tilde{\chi}_1^{\pm}$ 355 GeV	7, 8	$m(\tilde{\chi}_1^0)$=0 GeV, $m(\tilde{\tau},\tilde{\nu})=0.5(m(\tilde{\chi}_1^{\pm})+m(\tilde{\chi}_1^0))$	1407.0350
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\rightarrow\tilde{\ell}_L\nu\tilde{\ell}_L\ell(\tilde{\nu}\nu), \ell\tilde{\nu}\tilde{\ell}_L\ell(\tilde{\nu}\nu)$	3 e,μ	0	Yes	20.3	$\tilde{\chi}_1^{\pm},\tilde{\chi}_2^0$ 715 GeV	7, 8	$m(\tilde{\chi}_1^{\pm})=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}_1^{\pm})+m(\tilde{\chi}_1^0))$	1402.7029
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\rightarrow W\tilde{\chi}_1^0 Z\tilde{\chi}_1^0$	2-3 e,μ	0-2 jets	Yes	20.3	$\tilde{\chi}_1^{\pm},\tilde{\chi}_2^0$ 425 GeV	7, 8	$m(\tilde{\chi}_1^{\pm})=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, sleptons decoupled	1403.5294, 1402.7029
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\rightarrow W\tilde{\chi}_1^0 h\tilde{\chi}_1^0, h\rightarrow b\bar{b}/WW/\tau\tau/\gamma\gamma$	e,μ,γ	0-2 b	Yes	20.3	$\tilde{\chi}_1^{\pm},\tilde{\chi}_2^0$ 270 GeV	7, 8	$m(\tilde{\chi}_1^{\pm})=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, sleptons decoupled	1501.07110
	$\tilde{\chi}_2^0\tilde{\chi}_3^0, \tilde{\chi}_{2,3}^0\rightarrow\tilde{\ell}_R\ell$	4 e,μ	0	Yes	20.3	$\tilde{\chi}_{2,3}^0$ 635 GeV	7, 8	$m(\tilde{\chi}_2^0)=m(\tilde{\chi}_3^0)$, $m(\tilde{\chi}_1^0)$=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.	1 e,μ + γ	-	Yes	20.3	$\tilde{W}$ 115-370 GeV	7, 8	$c\tau$<1 mm	1507.05493
Long-lived particles	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^{\pm}$	Disapp. trk	1 jet	Yes	20.3	$\tilde{\chi}_1^{\pm}$ 270 GeV	7, 8	$m(\tilde{\chi}_1^{\pm})-m(\tilde{\chi}_1^0)$~160 MeV, $\tau(\tilde{\chi}_1^{\pm})$=0.2 ns	1310.3675
	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	7, 8	$m(\tilde{\chi}_1^{\pm})-m(\tilde{\chi}_1^0)$~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	7, 8	$m(\tilde{\chi}_1^0)$=100 GeV, 10 $\mu s<\tau(\tilde{g})$<1000 s	1310.6584
	Metastable $\tilde{g}$ R-hadron	dE/dx trk	-	-	3.2	$\tilde{g}$ 1.54 TeV	13	$m(\tilde{\chi}_1^0)$=100 GeV, τ>10 ns	To appear
	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	7, 8	10<$\tan\beta$<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	7, 8	1<$\tau(\tilde{\chi}_1^0)$<3 ns, SPS8 model	1409.5542
	$\tilde{g}\tilde{g}, \tilde{\chi}_1^0\rightarrow ee\nu/e\mu\nu/\mu\mu\nu$	displ. $ee/e\mu/\mu\mu$	-	-	20.3	$\tilde{\chi}_1^0$ 1.0 TeV	7, 8	7 <$c\tau(\tilde{\chi}_1^0)$< 740 mm, $m(\tilde{g})$=1.3 TeV	1504.05162
	GGM $\tilde{g}\tilde{g}, \tilde{\chi}_1^0\rightarrow Z\tilde{G}$	displ. vtx + jets	-	-	20.3	$\tilde{\chi}_1^0$ 1.0 TeV	7, 8	6 <$c\tau(\tilde{\chi}_1^0)$< 480 mm, $m(\tilde{g})$=1.1 TeV	1504.05162
RPV	LFV $pp\rightarrow\tilde{\nu}_\tau + X, \tilde{\nu}_\tau\rightarrow e\mu/e\tau/\mu\tau$	$e\mu,e\tau,\mu\tau$	-	-	20.3	$\tilde{\nu}_\tau$ 1.7 TeV	7, 8	λ'_{311}=0.11, $\lambda_{132/133/233}$=0.07	1503.04430
	Bilinear RPV CMSSM	2 e,μ (SS)	0-3 b	Yes	20.3	$\tilde{q}, \tilde{g}$ 1.45 TeV	7, 8	$m(\tilde{q})=m(\tilde{g})$, $c\tau_{LSP}$<1 mm	1404.2500
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\rightarrow W\tilde{\chi}_1^0, \tilde{\chi}_1^0\rightarrow ee\tilde{\nu}_\mu, e\mu\tilde{\nu}_e$	4 e,μ	-	Yes	20.3	$\tilde{\chi}_1^{\pm}$ 760 GeV	7, 8	$m(\tilde{\chi}_1^0)>0.2\times m(\tilde{\chi}_1^{\pm})$, $\lambda_{121}\neq0$	1405.5086
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\rightarrow W\tilde{\chi}_1^0, \tilde{\chi}_1^0\rightarrow\tau\tau\tilde{\nu}_e, e\tau\tilde{\nu}_\tau$	3 e,μ + τ	-	Yes	20.3	$\tilde{\chi}_1^{\pm}$ 450 GeV	7, 8	$m(\tilde{\chi}_1^0)>0.2\times m(\tilde{\chi}_1^{\pm})$, $\lambda_{133}\neq0$	1405.5086
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow qqq$	0	6-7 jets	-	20.3	$\tilde{g}$ 917 GeV	7, 8	BR(t)=BR(b)=BR(c)=0%	1502.05686
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow qq\tilde{\chi}_1^0, \tilde{\chi}_1^0\rightarrow qqq$	0	6-7 jets	-	20.3	$\tilde{g}$ 980 GeV	7, 8	$m(\tilde{\chi}_1^0)$=600 GeV	1502.05686
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow\tilde{t}_1 t, \tilde{t}_1\rightarrow bs$	2 e,μ (SS)	0-3 b	Yes	20.3	$\tilde{g}$ 880 GeV	7, 8		1404.2500
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\rightarrow bs$	0	2 jets + 2 b	-	20.3	$\tilde{t}_1$ 320 GeV	7, 8		1601.07453
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\rightarrow b\ell$	2 e,μ	2 b	-	20.3	$\tilde{t}_1$ 0.4-1.0 TeV	7, 8	BR($\tilde{t}_1\rightarrow be/\mu$)>20%	ATLAS-CONF-2015-015
Other	Scalar charm, $\tilde{c}\rightarrow c\tilde{\chi}_1^0$	0	2 c	Yes	20.3	$\tilde{c}$ 510 GeV	7, 8	$m(\tilde{\chi}_1^0)$<200 GeV	1501.01325

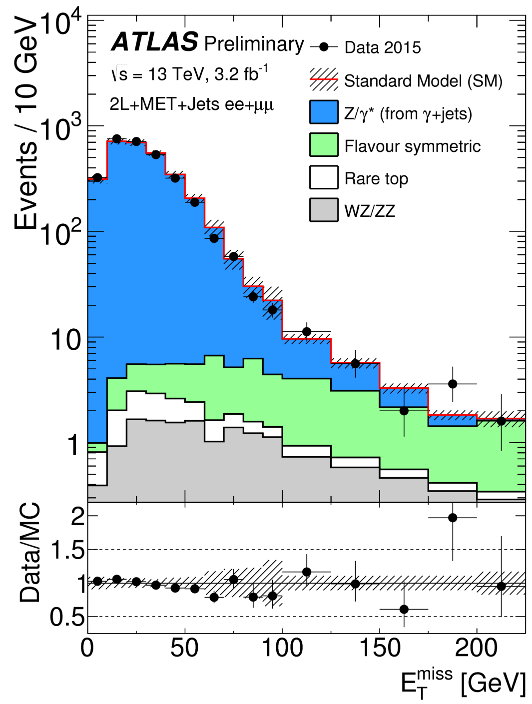
Mass scale [TeV] (axis from 10^{-1} to beyond 1)

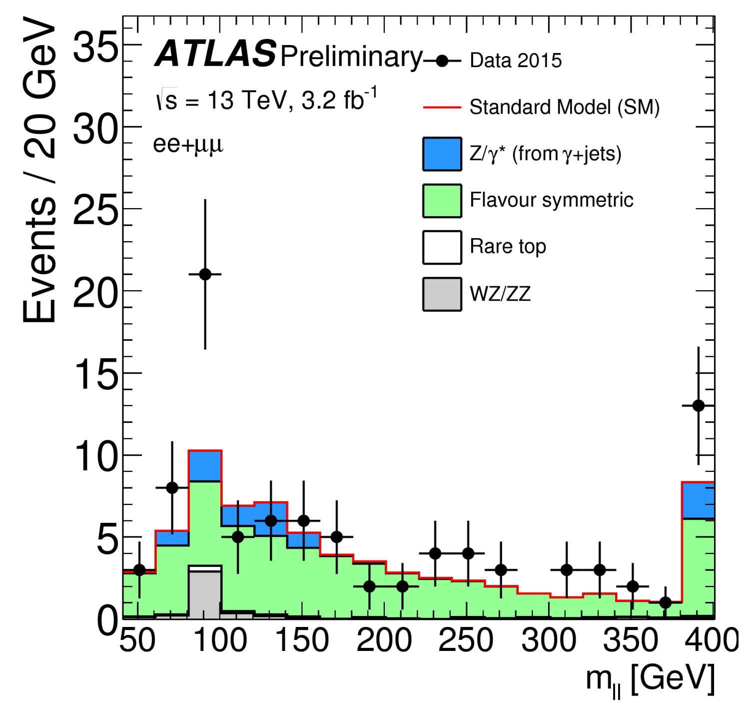
*Only a selection of the available mass limits on new states or phenomena is shown.

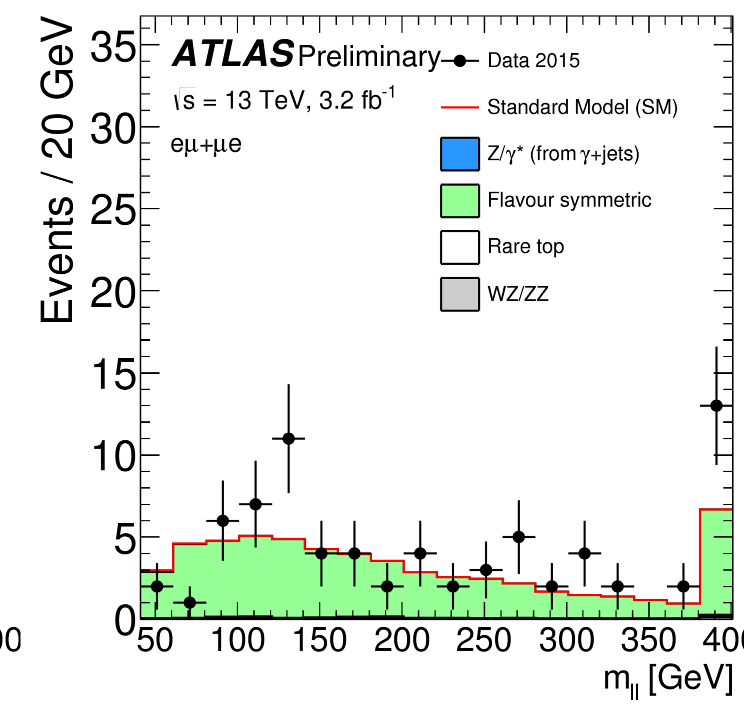
Backups

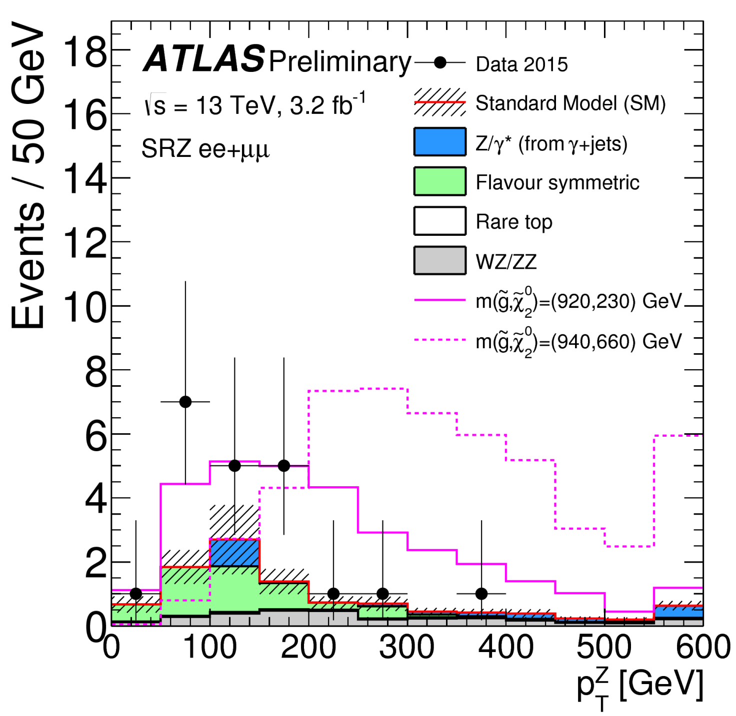
Z(⟶ll)+ Jets, E_T^{miss} *(more)*











Region	E_T^{miss} [GeV]	H_T [GeV]	n_{jets}	$m_{\ell\ell}$ [GeV]	SF/DF	$\Delta\phi(\mathbf{jet}_{12}, \boldsymbol{p}_T^{miss})$	$m_T(\ell_3, E_T^{miss})$ [GeV]	$n_{b\text{-jets}}$
Signal regions								
SRZ	> 225	> 600	≥ 2	$81 < m_{\ell\ell} < 101$	SF	> 0.4	-	-
Control regions								
Z normalisation	< 60	> 600	≥ 2	$81 < m_{\ell\ell} < 101$	SF	> 0.4	-	-
CR-FS	> 225	> 600	≥ 2	$61 < m_{\ell\ell} < 121$	DF	> 0.4	-	-
CRT	> 225	> 600	≥ 2	$m_{\ell\ell} \notin [81, 101]$	SF	> 0.4	-	-
Validation regions								
VRZ	< 225	> 600	≥ 2	$81 < m_{\ell\ell} < 101$	SF	> 0.4	-	-
VRT	100–200	> 600	≥ 2	$m_{\ell\ell} \notin [81, 101]$	SF	> 0.4	-	-
VRS	100–200	> 600	≥ 2	$81 < m_{\ell\ell} < 101$	SF	> 0.4	-	-
VR-FS	100–200	> 600	≥ 2	$61 < m_{\ell\ell} < 121$	DF	> 0.4	-	-
VR-WZ	100–200	-	-	-	3ℓ	-	< 100	0
VR-ZZ	< 100	-	-	-	4ℓ	-	-	0
VR-3L	60–100	> 200	≥ 2	$81 < m_{\ell\ell} < 101$	3ℓ	> 0.4	-	-

$Z(\rightarrow ll)$+ Jets, E_T^{miss} *(more)*

Physics process	Generator	Parton Shower	Cross section	Tune	PDF set
$Z/\gamma^*(\rightarrow \ell\ell)$ + jets	SHERPA 2.1.1	SHERPA 2.1.1	NNLO [23,24]	SHERPA default	NLO CT10
$t\bar{t}$	POWHEG Box v2 r3026	PYTHIA 6.428	NNLO+NNLL [26,27]	PERUGIA2012	NLO CT10
Single-top (Wt)	POWHEG Box v2 r2856	PYTHIA 6.428	Approx. NNLO [28,29]	PERUGIA2012	NLO CT10
$t\bar{t}+W$ and $t\bar{t}+Z$	MADGRAPH5 2.2.2	PYTHIA 8.186	NLO [31,32]	A14 NNPDF23LO	CTEQ6L1
$t\bar{t}+WW$	MADGRAPH5 2.2.2	PYTHIA 8.186	LO	A14 NNPDF23LO	CTEQ6L1
WW, WZ and ZZ	SHERPA 2.1.1	SHERPA 2.1.1	NNLO [33,34]	SHERPA default	NLO CT10

Region	Flavour-symmetry	Sideband fit
SRZ	5.1 ± 2.0	6.1 ± 1.7
VRS	18.9 ± 4.8	20.5 ± 5.6

	VRS	VR-WZ	VR-ZZ	VR-3L
Observed events	56	89	20	7
Total expected background events	52.6 ± 9.1	87 ± 10	15.5 ± 3.4	6.5 ± 1.6
Flavour symmetric ($t\bar{t}$, Wt, WW and $Z \rightarrow \tau\tau$) events	18.9 ± 4.8	1.3 ± 0.4	0	0.3 ± 0.2
WZ/ZZ events	7.5 ± 1.7	82 ± 10	15.5 ± 3.4	4.9 ± 1.6
$Z/\gamma^* +$ jets events	24.8 ± 7.6	2.7 ± 2.8	0	0.2 ± 0.2
Rare top events	1.4 ± 0.2	0.9 ± 0.4	0.04 ± 0.02	1.0 ± 0.1

Source	Relative systematic uncertainty [%]
	SRZ
Total systematic uncertainty	22
Flavour symmetry (statistical)	14
Flavour symmetry (systematic)	12
$Z/\gamma^* +$ jets (systematic)	7.8
WZ generator uncertainty	7.6
$Z/\gamma^* +$ jets (statistical)	2.2

	SRZ
Observed events	21
Total expected background events	10.3 ± 2.3
Flavour symmetric ($t\bar{t}$, Wt, WW and $Z \rightarrow \tau\tau$) events	5.1 ± 2.0
WZ/ZZ events	2.9 ± 0.8
$Z/\gamma^* +$ jets events	1.9 ± 0.8
Rare top events	0.4 ± 0.1
p-value	0.013
Significance	2.2
Observed (Expected) S^{95}	$20.0\ (10.2^{+4.4}_{-3.0})$