

# ATLAS SUSY Results with $\geq 3$ $b$ -jets

*SUSY2016@Melbourne*

Maximilian Swiatlowski<sup>1</sup>

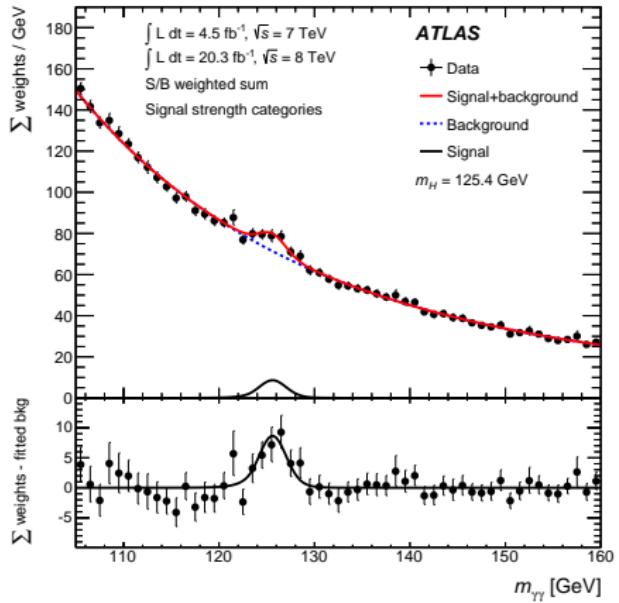
<sup>1</sup>*Enrico Fermi Institute, University of Chicago*

July 5, 2016





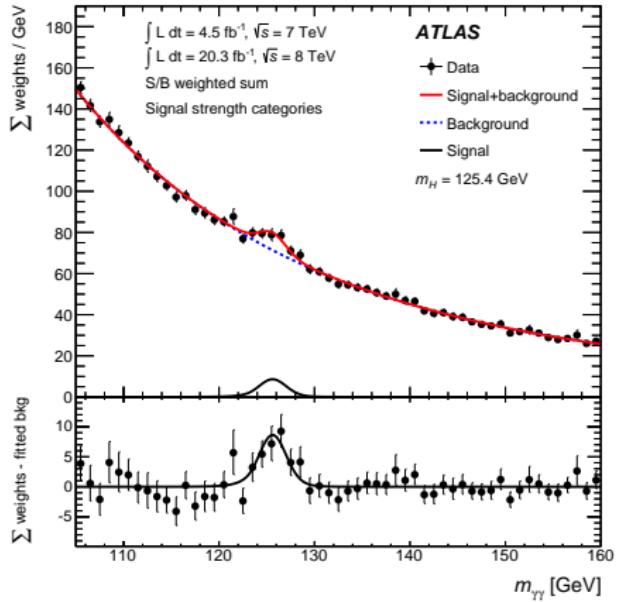
# LHC Run 1 Legacy: The Higgs



What does the Higgs tell us about new physics around the corner?



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# Naturalness with SUSY

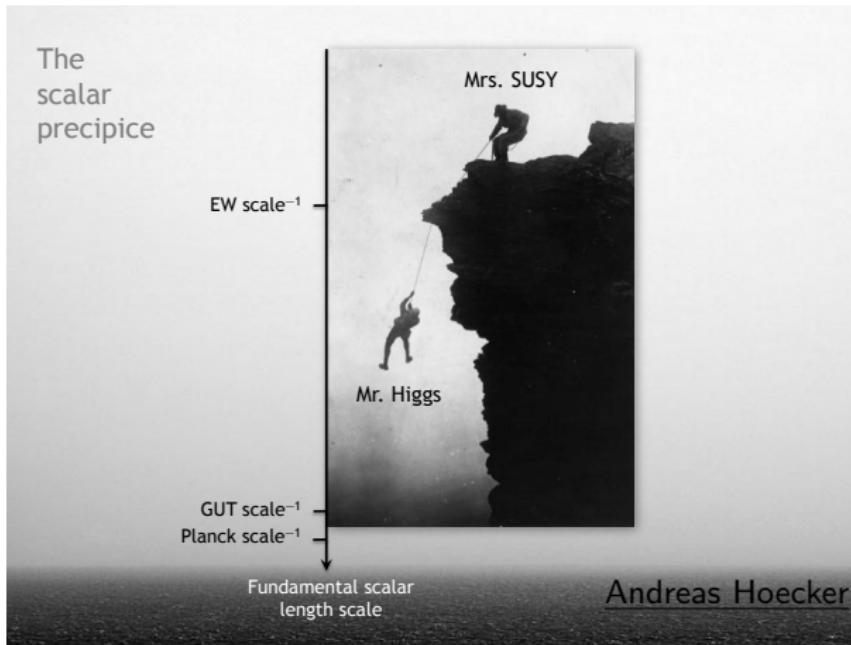
With the discovery of a 125 GeV Higgs, BSM physics is very well motivated!

Searches for (supersymmetric) top-partners are critical!



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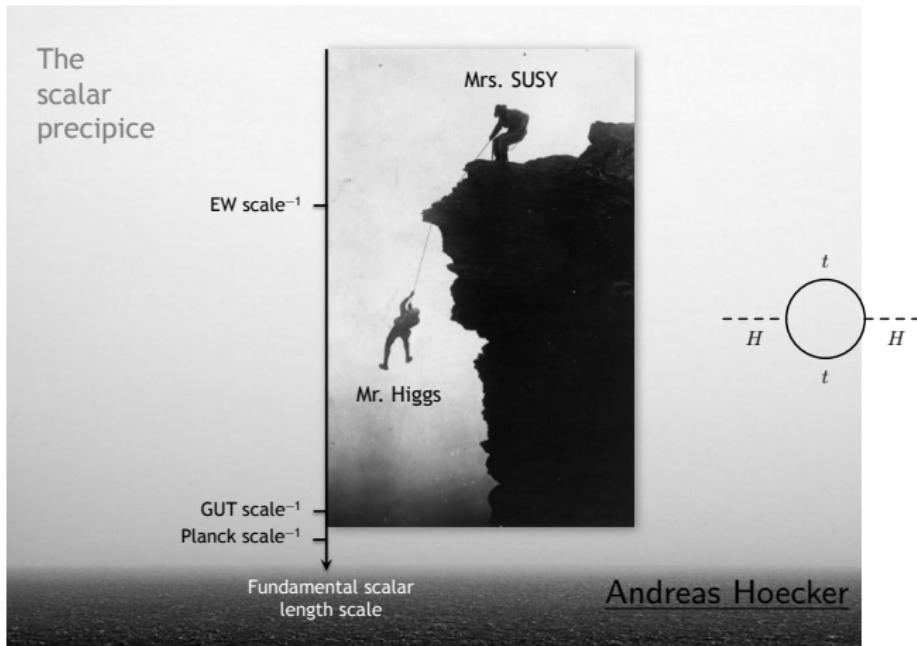


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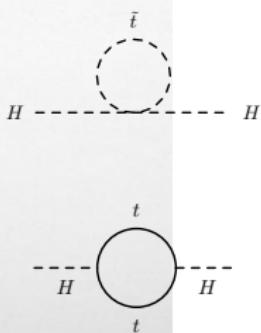
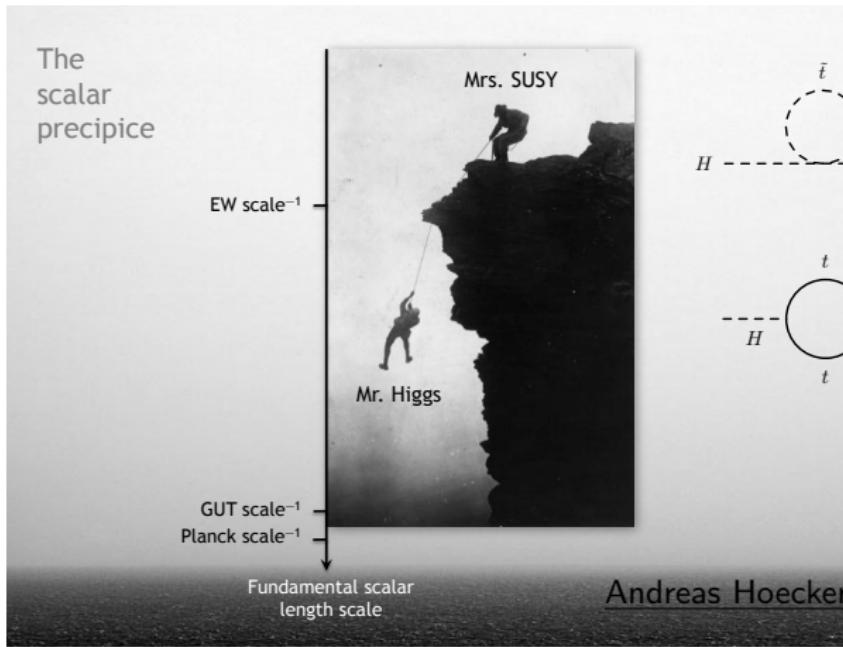


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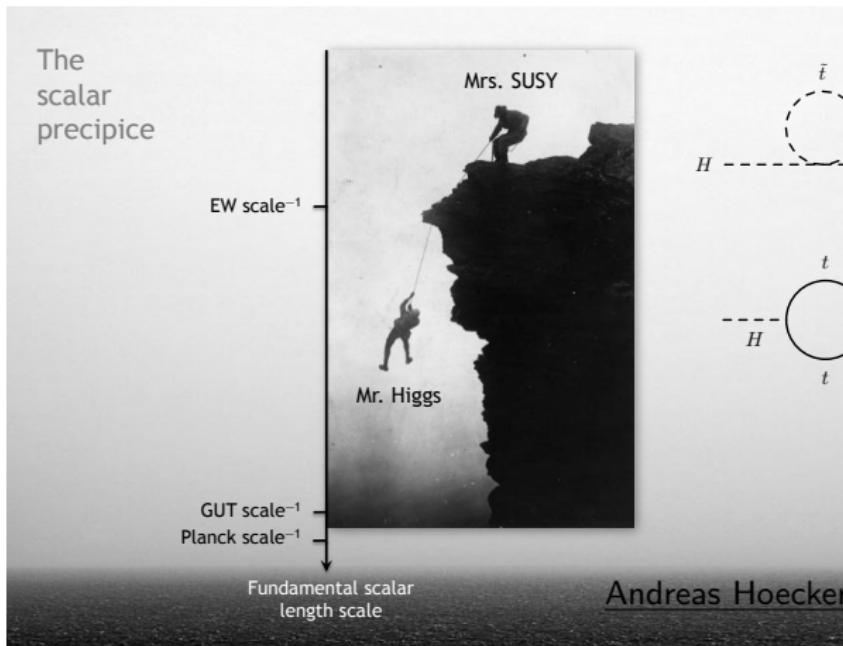


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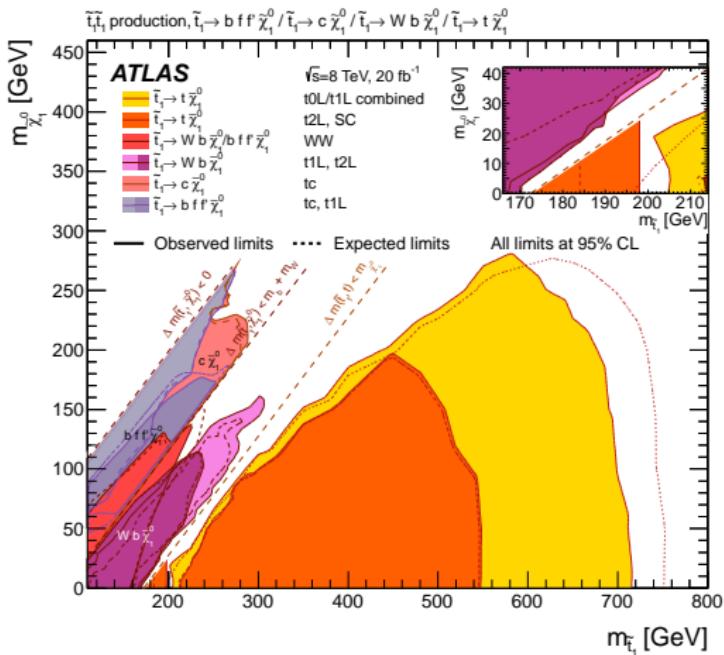
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# Natural SUSY: Direct Production

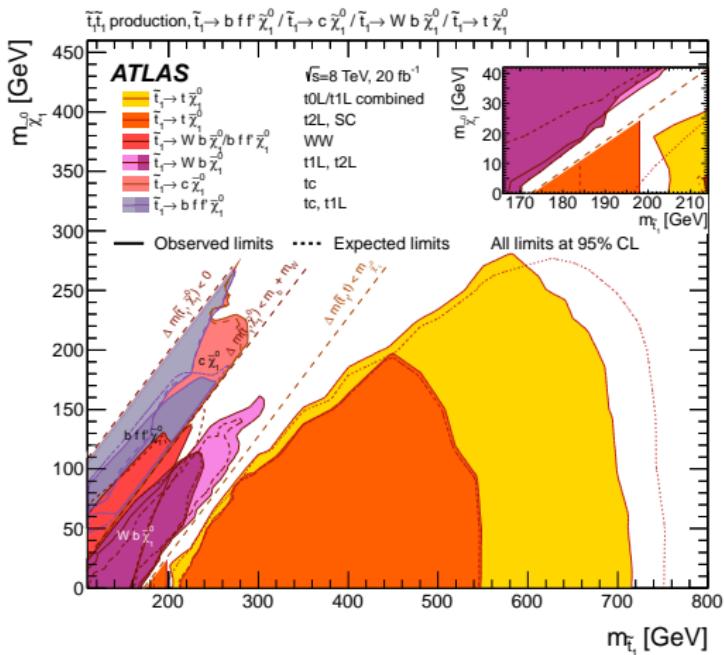


- ▶ Since the stop does the work of canceling top loops, stop production is a good place to look for natural SUSY
- ▶ Strong limits on direct production! But still lots of room for light stops

Where else can we search for signatures of naturalness?  
How stable is Mrs. SUSY's footing?



# Natural SUSY: Direct Production



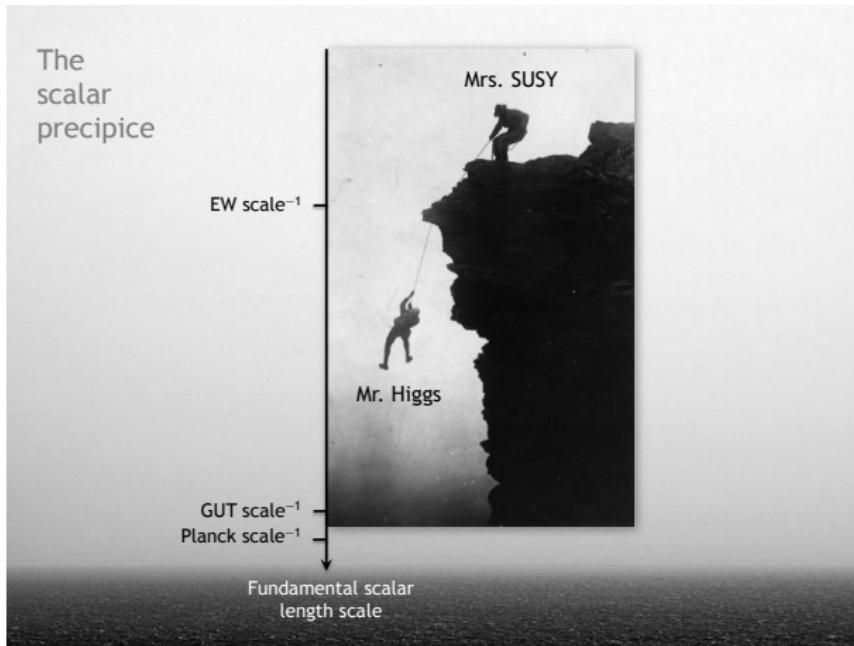
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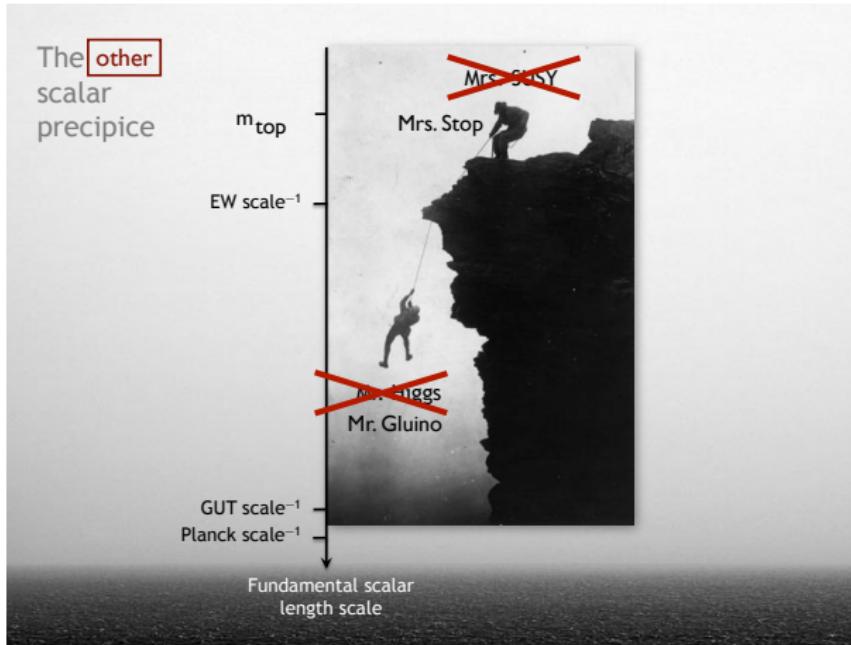
# The Role of Gluinos



- ▶ Stop is a scalar: natural mass value of *stop itself* set by gluino mass
  - ▶ "Gluinos suck" (Savas)
- ▶ Naturalness implies a *light gluino* as well as light stops



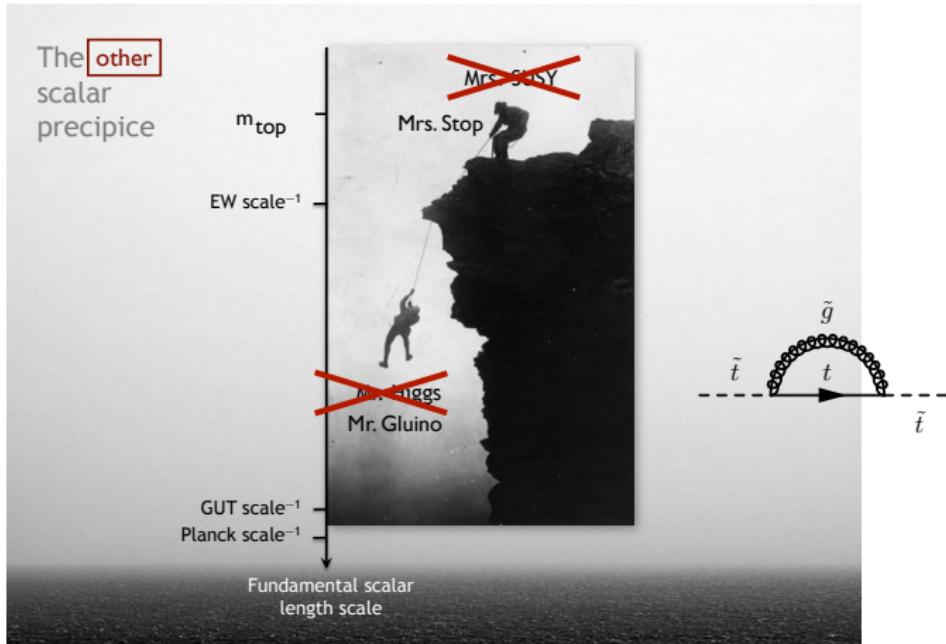
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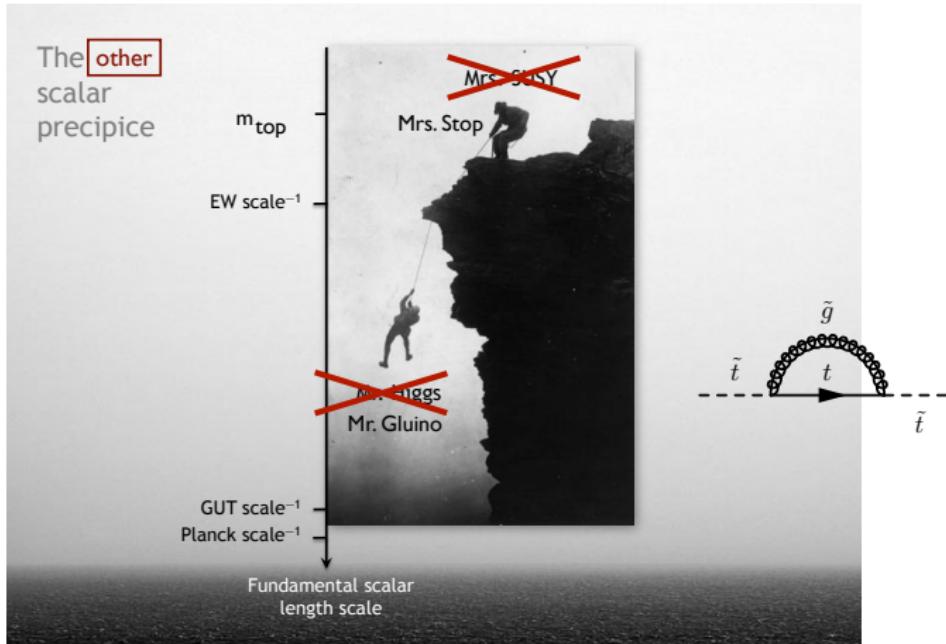
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# The Status of SUSY After $\sqrt{s} = 8$ TeV

ATLAS SUSY Searches\* - 95% CL Lower Limits

Status: July 2015

Model	$e, \mu, \tau, \gamma$ Jets $E_{\text{miss}}$ [ $\int \mathcal{L} dt (\text{fb}^{-1})$ ]			Mass limit	ATLAS Preliminary		
					$\sqrt{s} = 7 \text{ TeV}$	$\sqrt{s} = 8 \text{ TeV}$	
Inclusive Searches							
MSUGRA/CMSM	0-3 $e, \mu, \tau/2, \gamma$ 2-10 jets, 3 $E_{\text{miss}}$	Yes	20.3	$\tilde{\chi}_1^0$	1.3 TeV	1.3 TeV	
	0-3 $e, \mu, \tau/2, \gamma$ 2-4 jets	Yes	20.3		1.25 TeV	1.25 TeV	
	mono-jet	1-3 jets	Yes	20.3	1.25 TeV	1.25 TeV	
	(compressed)	-	-		1.25 TeV	1.25 TeV	
	2 $e, \mu$ (diH)	2 jets	Yes	20.3	1.25 TeV	1.25 TeV	
	2 $e, \mu, \tau/2, \gamma$ (diH)	2 jets	Yes	20.3	1.25 TeV	1.25 TeV	
	2 $e, \mu, \tau/2, \gamma$ (diH)	3 jets	Yes	20.3	1.25 TeV	1.25 TeV	
	2 $e, \mu, \tau/2, \gamma$ (diH)	4 jets	Yes	20.3	1.25 TeV	1.25 TeV	
	0-1 $e, \mu, \tau/2, \gamma$	2-6 jets	Yes	20.3	1.25 TeV	1.25 TeV	
	2-4 $e, \mu, \tau/2, \gamma$	2-6 jets	Yes	20.3	1.25 TeV	1.25 TeV	
	2-4 $e, \mu, \tau/2, \gamma$	0-3 jets	Yes	20.3	1.25 TeV	1.25 TeV	
GMSB (FNLSP)	1-2 $e, \mu, \tau/2, \gamma$ 0-2 jets	Yes	20.3	$\tilde{\chi}_1^0$	1.25 TeV	1.25 TeV	
GGM (Higgsino-blino NLSP)	2 $e, \mu, \tau/2, \gamma$ 2 jets	Yes	20.3	$\tilde{\chi}_1^0$	1.25 TeV	1.25 TeV	
GGM (Higgsino-blino NLSP)	2 $e, \mu, \tau/2, \gamma$ 0 mono-jet	Yes	20.3	$\tilde{\chi}_1^0$	1.25 TeV	1.25 TeV	
Gaugino LSP	-	-	-	$\tilde{\chi}_1^0$ scale	1.25 TeV	1.25 TeV	
				$\tilde{\chi}_1^0$ scale	1.25 TeV	1.25 TeV	
$F^2 \text{ (anti-diH)}$	0	3 jets	Yes	20.3	1.25 TeV	1.25 TeV	
	0	7-10 jets	Yes	20.3	1.25 TeV	1.25 TeV	
	0-1 $e, \mu$	3 jets	Yes	20.3	1.25 TeV	1.25 TeV	
	0-1 $e, \mu$	3 jets	Yes	20.3	1.25 TeV	1.25 TeV	
$F^2 \text{ (anti-diH)}$	0	3 jets	Yes	20.3	1.25 TeV	1.25 TeV	
	2 $e, \mu$ (DS)	3 jets	Yes	20.3	1.25 TeV	1.25 TeV	
	2 $e, \mu, \tau/2, \gamma$ 3 jets	Yes	20.3	1.25 TeV	1.25 TeV		
	2 $e, \mu, \tau/2, \gamma$ 1-2 jets	Yes	4.720.3	150-420 GeV	275-440 GeV	275-440 GeV	
	2 $e, \mu, \tau/2, \gamma$ 1-2 jets	Yes	20.3	150-187 GeV or 200-465 GeV	200-465 GeV	200-465 GeV	
	2 $e, \mu, \tau/2, \gamma$ 1-2 jets	Yes	20.3	90-191 GeV	210-700 GeV	210-700 GeV	
	2 $e, \mu, \tau/2, \gamma$ 0 mono-jet	Yes	20.3	90-240 GeV	210-700 GeV	210-700 GeV	
	2 $e, \mu, \tau/2, \gamma$ 1-2 jets	Yes	20.3	150-345 GeV	290-600 GeV	290-600 GeV	
	3 $e, \mu, \tau/2, \gamma$ 1 jets	Yes	20.3	150-345 GeV	290-600 GeV	290-600 GeV	
	3 $e, \mu, \tau/2, \gamma$ 1 jets	Yes	20.3	150-345 GeV	290-600 GeV	290-600 GeV	
$F^2 \text{ (anti-sparks)}$	0	3 jets	Yes	20.3	1.25 TeV	1.25 TeV	
	2 $e, \mu, \tau/2, \gamma$ 3 jets	Yes	20.3	1.25 TeV	1.25 TeV		
	2 $e, \mu, \tau/2, \gamma$ 1-2 jets	Yes	4.720.3	150-420 GeV	275-440 GeV	275-440 GeV	
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	2 $e, \mu, \tau/2, \gamma$ 1 jets	Yes	20.3	150-345 GeV	290-600 GeV	290-600 GeV	
	2 $e, \mu, \tau/2, \gamma$ 1 jets	Yes	20.3	150-345 GeV	290-600 GeV	290-600 GeV	
EW direct							
	$\tilde{\chi}_1^0$ , $\tilde{\chi}_2^0$ , $\tilde{e}^{\pm}$ , $\tilde{\nu}_e$	0	Yes	20.3	90-325 GeV	90-325 GeV	
	$\tilde{\chi}_1^0$ , $\tilde{\chi}_2^0$ , $\tilde{e}^{\pm}$ , $\tilde{\nu}_e$	2 jets	Yes	20.3	145-415 GeV	145-415 GeV	
	$\tilde{\chi}_1^0$ , $\tilde{\chi}_2^0$ , $\tilde{e}^{\pm}$ , $\tilde{\nu}_e$	2 jets	Yes	20.3	100-320 GeV	100-320 GeV	
	$\tilde{\chi}_1^0$ , $\tilde{\chi}_2^0$ , $\tilde{e}^{\pm}$ , $\tilde{\nu}_e$	3 jets	Yes	20.3	420 GeV	420 GeV	
	$\tilde{\chi}_1^0$ , $\tilde{\chi}_2^0$ , $\tilde{e}^{\pm}$ , $\tilde{\nu}_e$	1-2 jets	Yes	20.3	220 GeV	220 GeV	
	$\tilde{\chi}_1^0$ , $\tilde{\chi}_2^0$ , $\tilde{e}^{\pm}$ , $\tilde{\nu}_e$	0 jets	Yes	20.3	80 GeV	80 GeV	
	$\tilde{\chi}_1^0$ , $\tilde{\chi}_2^0$ , $\tilde{e}^{\pm}$ , $\tilde{\nu}_e$	3 jets	Yes	20.3	124-361 GeV	124-361 GeV	
	$\tilde{\chi}_1^0$ , $\tilde{\chi}_2^0$ , $\tilde{e}^{\pm}$ , $\tilde{\nu}_e$	1 jets	Yes	20.3	1.25 TeV	1.25 TeV	
Long-lived particles							
	Direct $\tilde{\chi}_1^0, \tilde{\chi}_2^0$ , prod. long-lived $\tilde{S}_1^0$	0 jets	Yes	20.3	270 GeV	270 GeV	
	Direct $\tilde{\chi}_1^0, \tilde{\chi}_2^0$ , prod. long-lived $\tilde{S}_1^0$	2 jets	Yes	18.4	482 GeV	482 GeV	
	Stable, stopped $\tilde{B}$ as hadron	0	1-5 jets	27.3	832 GeV	832 GeV	
	Stable, stopped $\tilde{B}$ as hadron	1 jets	Yes	19.1	537 GeV	1.27 TeV	
	GMSB stable $\tilde{S}_1^0$ , $\tilde{S}_2^0$ , $\tilde{B}_1^0$ , $\tilde{B}_2^0$ , $\tilde{D}_1^0$ , $\tilde{D}_2^0$	2 jets	Yes	20.3	435 GeV	1.0 TeV	
	GMSB $\tilde{S}_1^0$ , $\tilde{S}_2^0$ , long-lived $\tilde{S}_1^0$	2 jets	Yes	20.3	435 GeV	1.0 TeV	
	direct $\tilde{\chi}_1^0, \tilde{\chi}_2^0$ , prod. long-lived $\tilde{S}_1^0$	2 jets	Yes	20.3	435 GeV	1.0 TeV	
	direct $\tilde{\chi}_1^0, \tilde{\chi}_2^0$ , prod. long-lived $\tilde{S}_1^0$	3 jets	Yes	20.3	435 GeV	1.0 TeV	
	$\tilde{\chi}_1^0, \tilde{\chi}_2^0$ , $\tilde{B}_1^0$ , $\tilde{B}_2^0$ , $\tilde{D}_1^0$ , $\tilde{D}_2^0$	2 jets	Yes	20.3	435 GeV	1.0 TeV	
RPV							
	LPM $\tilde{\chi}_1^0, \tilde{\chi}_2^0$ , $\tilde{e}^{\pm}$ , $\tilde{\nu}_e$ , $\tilde{\tau}^{\pm}$ , $\tilde{\nu}_{\tau}$	0 jets	Yes	20.3	1.25 TeV	1.25 TeV	
	Bilinear RPV CMSSM	2 $e, \mu$ (DS)	0-3 jets	Yes	20.3	1.25 TeV	1.25 TeV
	4 $e, \mu$	-	Yes	20.3	1.25 TeV	1.25 TeV	
	3 $e, \mu, \tau/2, \gamma$	0 jets	Yes	20.3	1.25 TeV	1.25 TeV	
	2 $e, \mu, \tau/2, \gamma$	6-7 jets	Yes	20.3	1.25 TeV	1.25 TeV	
	2 $e, \mu, \tau/2, \gamma$	0 jets	Yes	20.3	1.25 TeV	1.25 TeV	
	2 $e, \mu, \tau/2, \gamma$	2 jets	Yes	20.3	1.25 TeV	1.25 TeV	
	2 $e, \mu, \tau/2, \gamma$	0 jets	Yes	20.3	1.25 TeV	1.25 TeV	
	2 $e, \mu, \tau/2, \gamma$	2 jets	Yes	20.3	1.25 TeV	1.25 TeV	
	2 $e, \mu, \tau/2, \gamma$	0 jets	Yes	20.3	1.25 TeV	1.25 TeV	
	2 $e, \mu, \tau/2, \gamma$	2 jets	Yes	20.3	1.25 TeV	1.25 TeV	
Other	Scalar charm, $\tilde{t} \rightarrow c \tilde{c}^0$	0	2 c	Yes	20.3	1.25 TeV	
						1.25-1.4 TeV/80%	
						1.25-1.3 TeV	
						1.25-1.3 TeV	

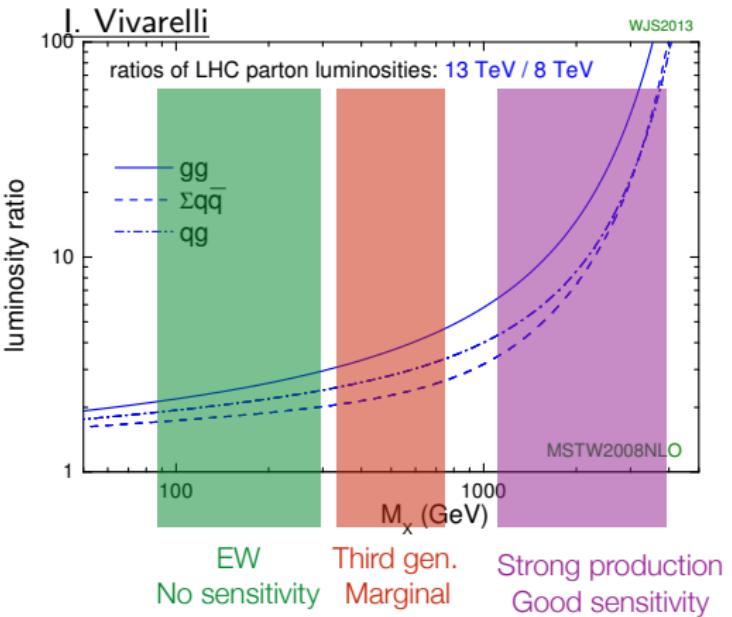
\*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1 $\sigma$  theoretical signal cross section uncertainty.

**Strong limits already exist, but room yet for gluinos and stops!**



# Where to Look First?

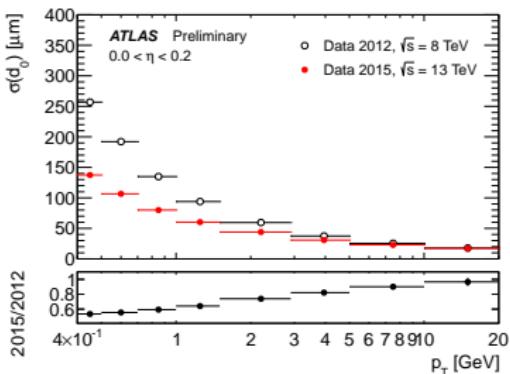
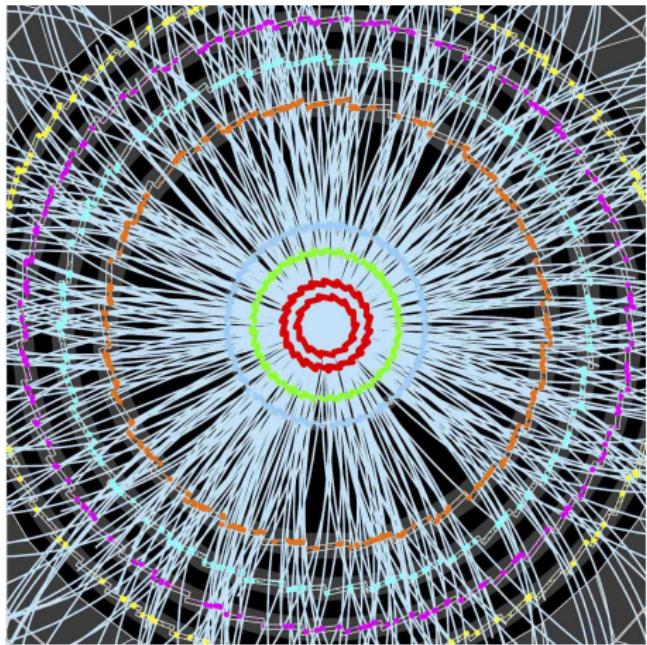
- ▶ New  $\sqrt{s} = 13$  TeV data means exciting new prospects!
- ▶ Cross-section for higher-mass particles grows *dramatically*
  - ▶ Lighter particles, like third-gen squarks and electroweakinos, see a much smaller increase



**Not only are gluinos required for naturalness, their production rate grows enormously during Run 2!**



# New to ATLAS: The Inner-B-Layer

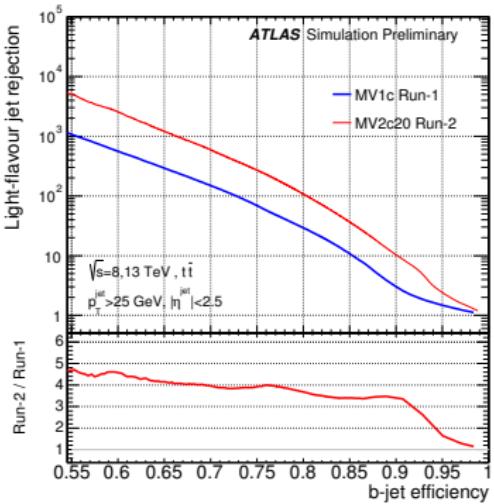
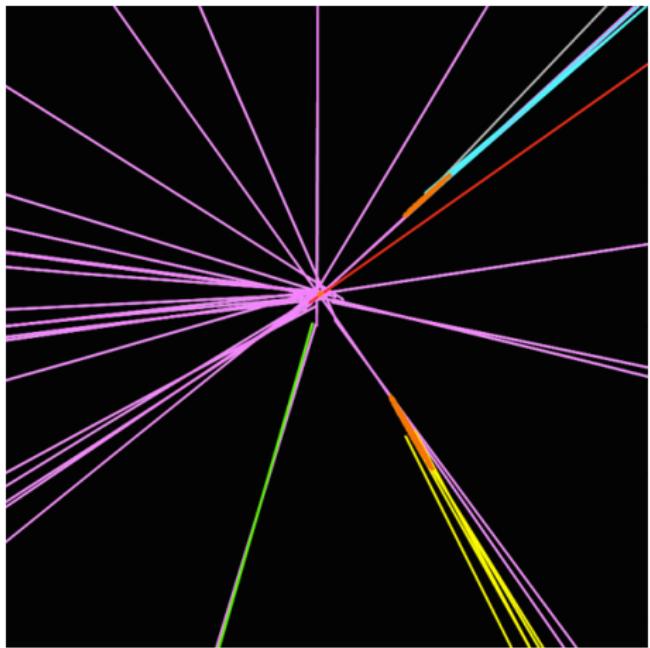


Huge improvement in track  $d_0$  resolution!

- ▶  $b$ -tagging and vertex identification benefit greatly from this upgrade



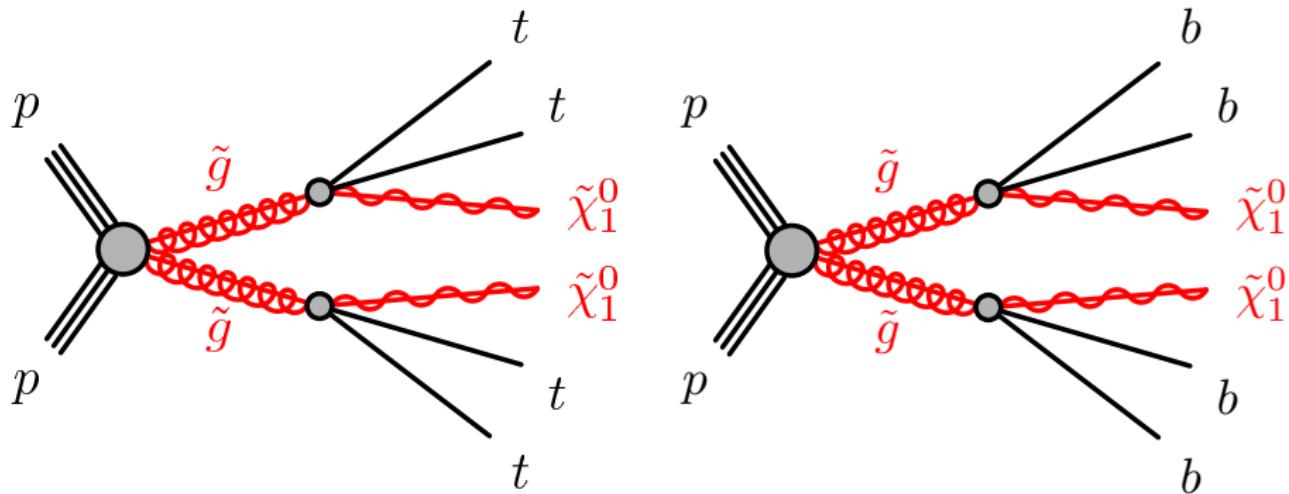
# New to ATLAS: The Inner-B-Layer



Factor of  $\approx 4$  gain in light jet rejection!

- ▶  $b$ -tagging and vertex identification benefit greatly from this upgrade

# Natural SUSY Signatures



- ▶ Look for *pair-production* of gluinos
  - ▶ Highest cross-section particles, pair production guaranteed by  $R$ -parity
- ▶ Gluinos cascade decay to third generation SM particles and LSP
  - ▶ Assume presence of off-shell stop and sbottom
- ▶ Study “Gtt” model with 0 and 1  $\ell$  final state, “Gbb” with 0  $\ell$

# Some Features of Signal Regions



Gbb  $0\ell$

- ▶ 0 leptons
- ▶  $\geq 4$  jets

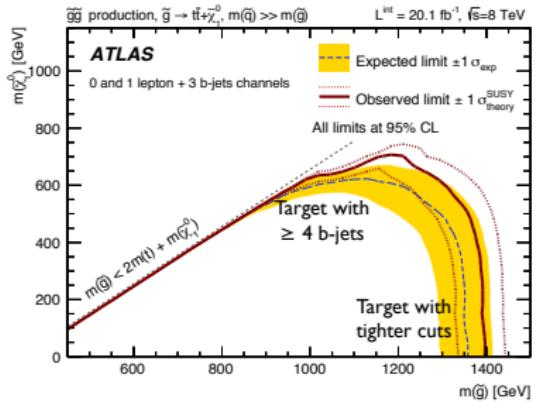
Gtt  $0\ell$

- ▶ 0 leptons
- ▶  $\geq 8$  jets

Gtt  $1\ell$

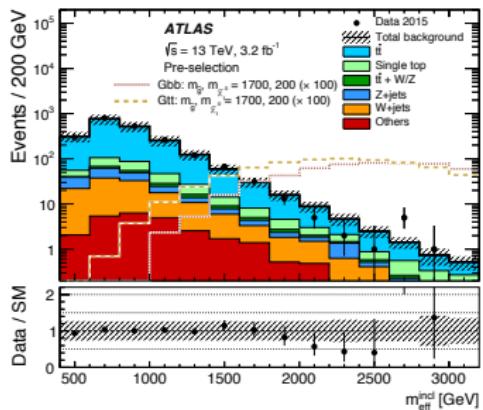
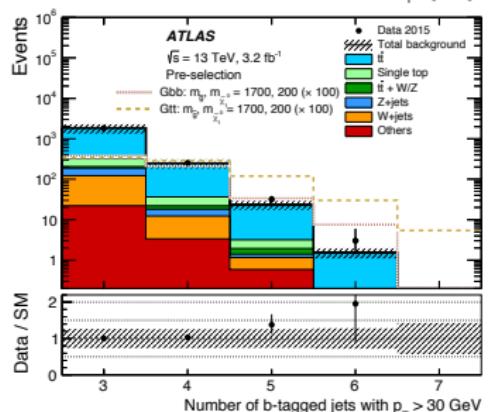
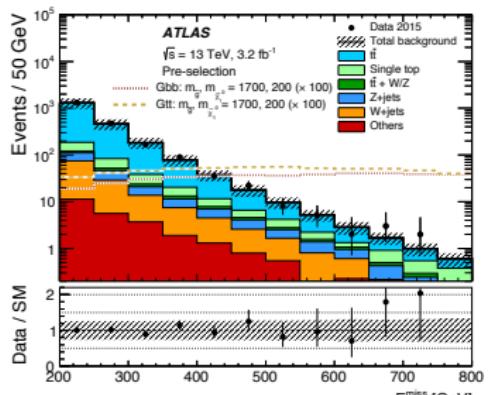
- ▶  $\geq 1$  lepton
- ▶  $\geq 6$  jets

- ▶ Trigger on  $E_T^{miss} > 200$  GeV
- ▶ Look for *spectacular* signatures with high  $E_T^{miss}$  and  $m_{eff} = H_T + E_T^{miss}$ , and  $\geq 3 - 4$  *b*-jets (at 85% efficiency)
- ▶ Define multiple (single-bin) signal regions to better target “compressed” and “boosted” regions





# Signal Discrimination

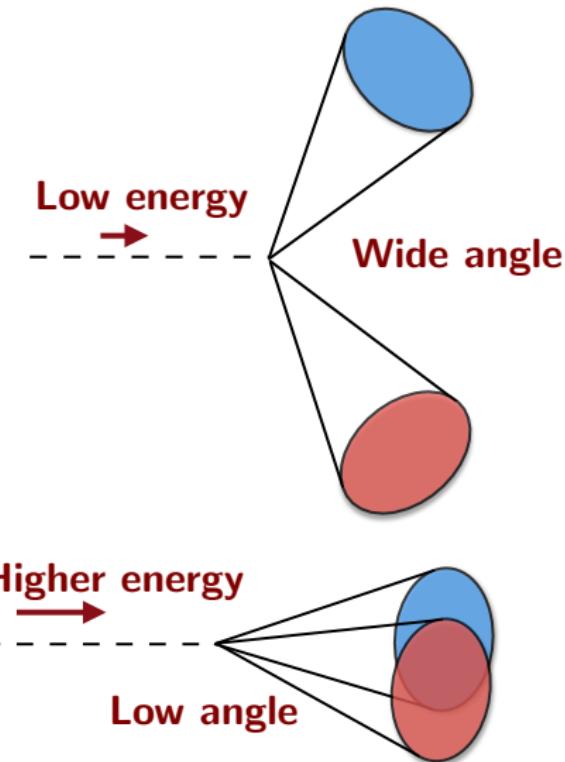


- ▶ Huge amount of power from  $E_T^{\text{miss}}$  and  $m_{\text{eff}}$ 
  - ▶ Especially in “boosted” regions, these provide great signal acceptance and background rejection
- ▶  $b$ -tagging clearly provides significant power as well



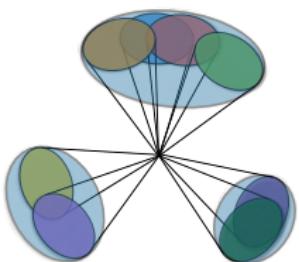
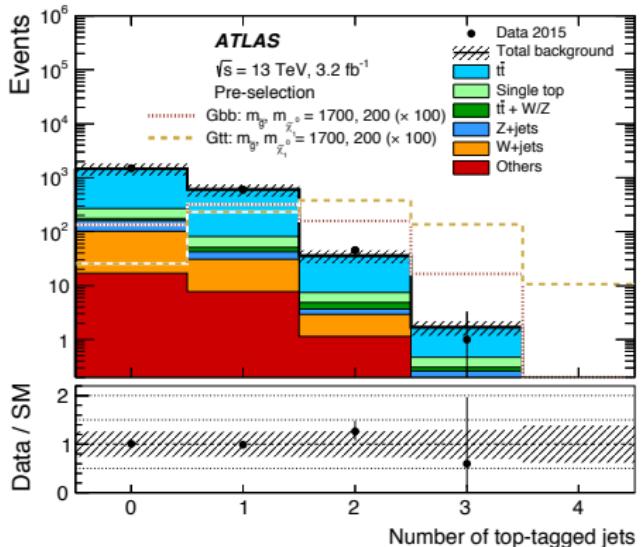
# Boosted Objects

- ▶ Quarks from signal have generally been assumed to be well isolated
- ▶ But with many top decays in one event, can produce particles with **huge boosts**: quarks from decays become **highly collimated**
  - ▶ If we can identify nearby (or overlapping!) jets, can easily reconstruct top candidates
  - ▶ Removes combinatoric challenge from low boost





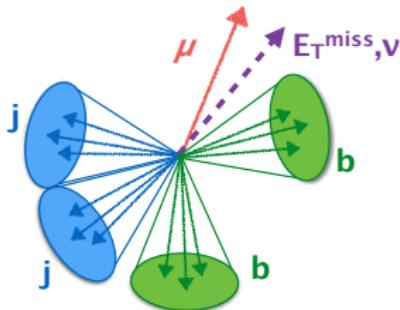
# Multi-*b*: Top Tagging



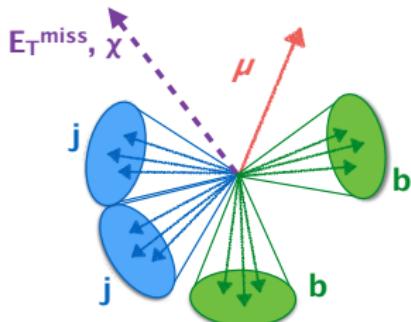
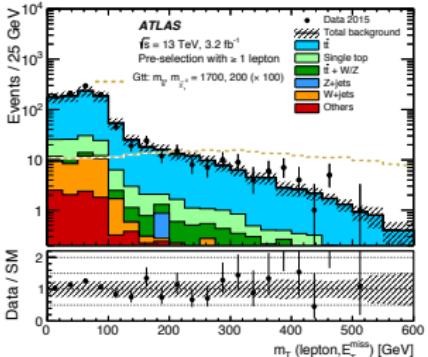
- ▶ Identify top-candidates with *re-clustering* approach
  - ▶ Run a clustering algorithm on already-reconstructed jets, but with large size ( $R = 1.0$ )
  - ▶ Naturally groups jets close to each other
  - ▶ Require mass of grouped jets to be  $> 100 \text{ GeV}$
- ▶ Loose tag sufficient to suppress dominant semi-leptonic  $t\bar{t}$  backgrounds
  - ▶ Both 0L and 1L regions use this very effectively!



# More Variables: Transverse Mass $m_T$



$\ell$  and  $E_T^{\text{miss}}$  aligned:  
background like

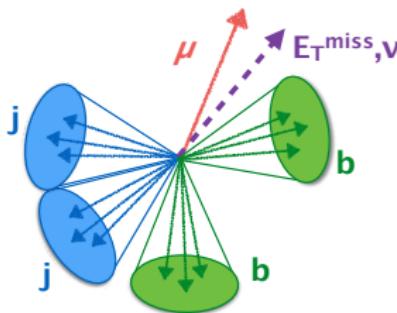


$\ell$  and  $E_T^{\text{miss}}$  unaligned:  
signal like

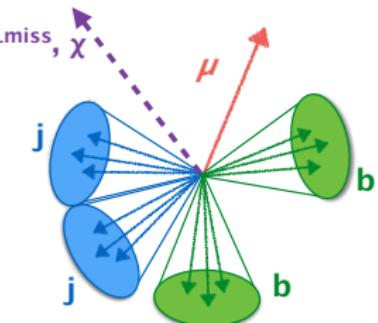
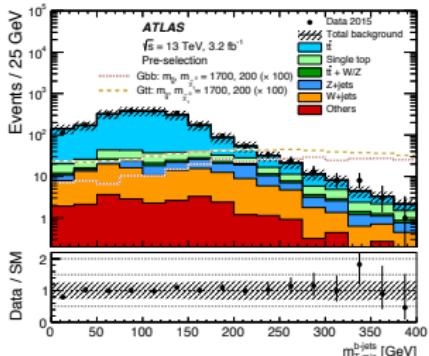
$$m_T = \sqrt{2p_T^\ell(1 - \cos(\Delta\phi(E_T^{\text{miss}}, \ell)))}$$

- ▶ Provides excellent discrimination in  $1\ell$  events

# More Variables: Minimum Transverse $b$ -jet Mass $m_T^{b,min}$



$b$  and  $E_T^{miss}$  aligned:  
background like



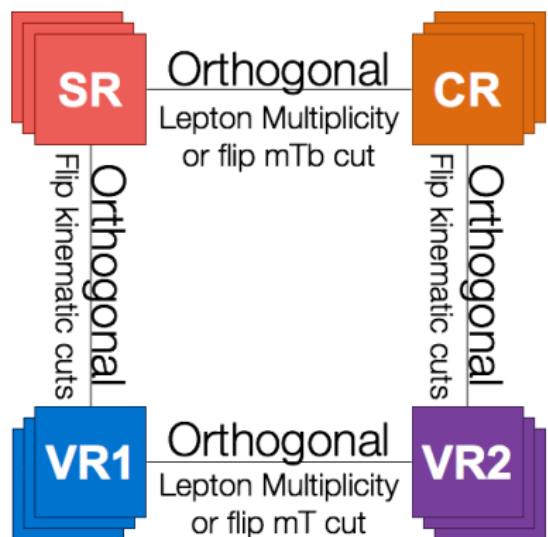
$b$  and  $E_T^{miss}$  unaligned:  
signal like

$$m_T^{b,min} = \min_{i \leq 3} \sqrt{(E_T^{miss} + p_T^{j_i})^2 - (E_x^{miss} + p_x^{j_i})^2 - (E_y^{miss} + p_y^{j_i})^2}$$

- ▶ Provides excellent discrimination in both  $0\ell$  and  $1\ell$  channels



# Background Estimation



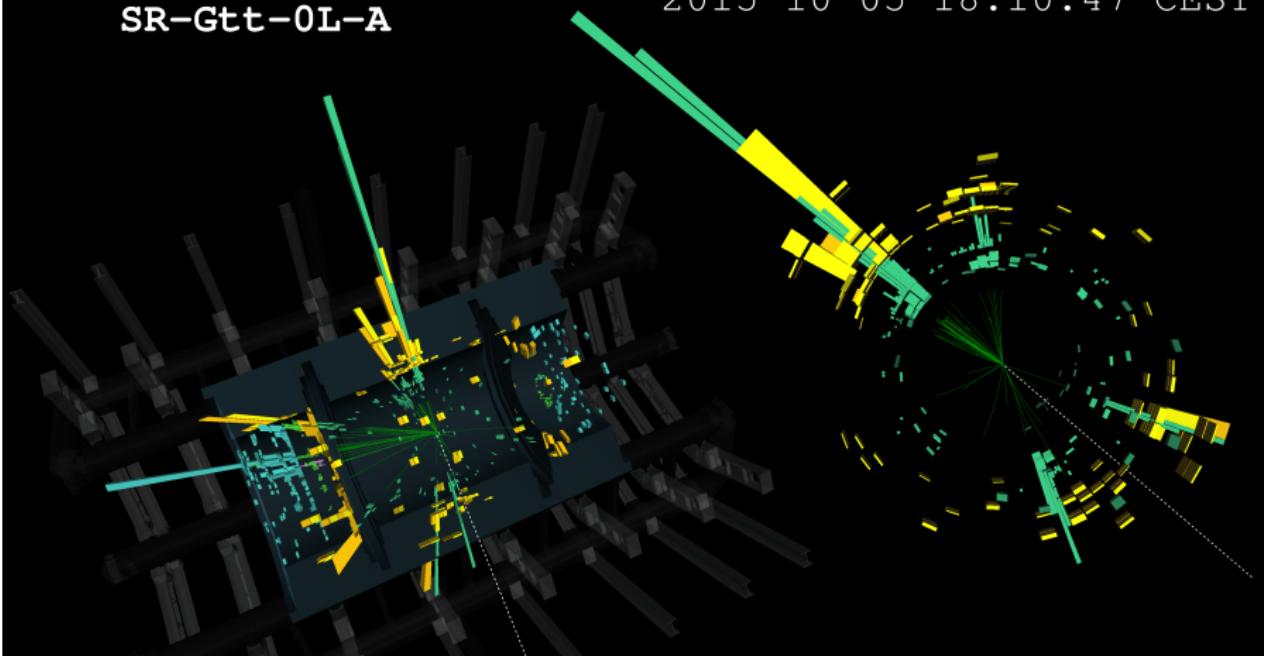
- ▶ After high  $b$ -tagging and  $E_T^{miss}$  requirements,  $t\bar{t}$  is the main background
  - ▶ Even in  $0\ell$  channels, “missed” leptons contribute to  $E_T^{miss}$
- ▶ Use  $1\ell$  control region to model this background ( $flip\ m_T^{b,min}$  cut in  $1\ell$  SR's)
- ▶ Derive scale factor for  $t\bar{t}$  in control region: use to normalize in signal region
- ▶ Use dedicated validation regions to check each CR extrapolation



Run: 281074

Event: 608612341

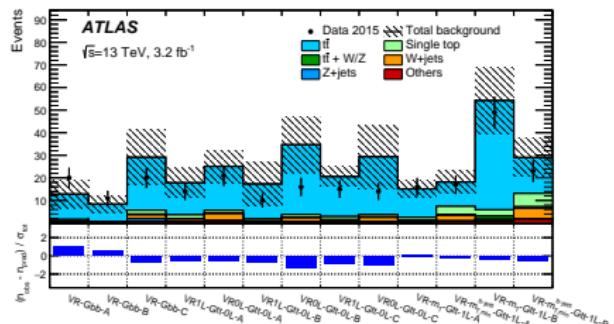
2015-10-05 18:10:47 CEST



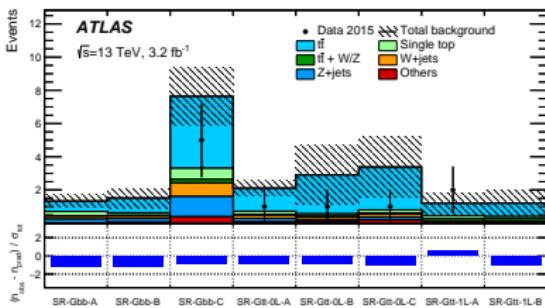


# Multi-*b*: Results

## Validation Region Yields

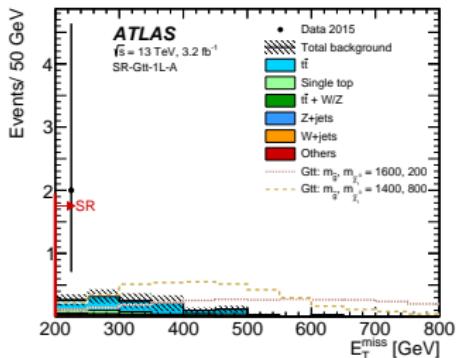
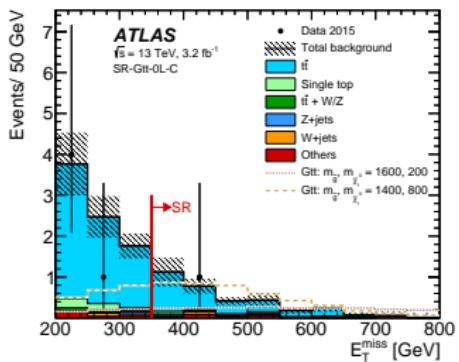
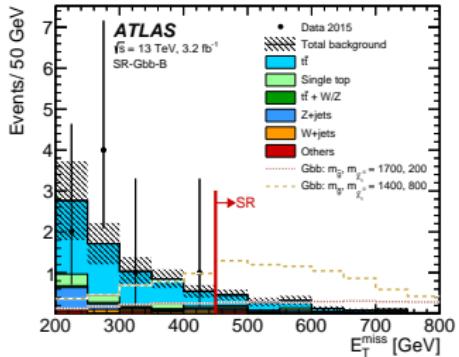


## Signal Region Yields



- ▶ Data compatible with the background estimate, with some tendency as being on the low side
  - ▶ Not as bad as it looks: all regions are strongly overlapping/correlated, so combined significance of underestimate is low
  - ▶ Related to modeling of  $t\bar{t} + b\bar{b}$  backgrounds: exploring improvements here for the future

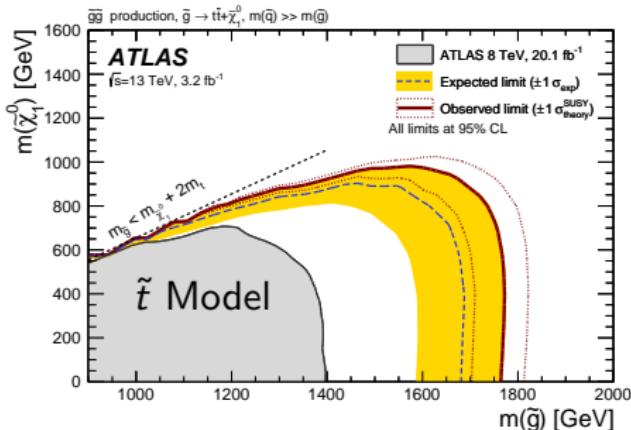
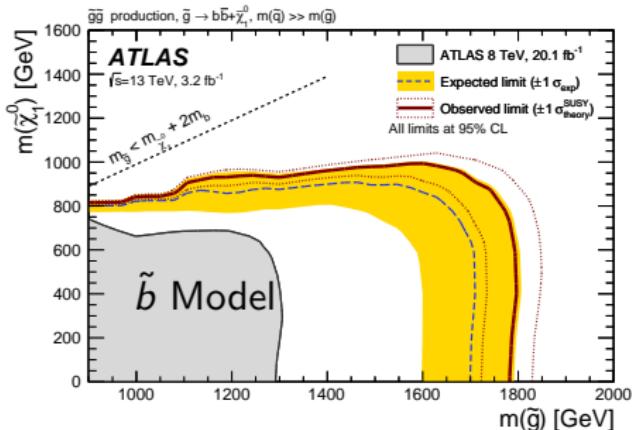
# Multi- $b$ : Results



- ▶ Examples of  $\tilde{b}$  and 0/1L  $\tilde{t}$  regions here
- ▶ No signs of excesses over SM expectation in any signal regions



# Multi-*b*: Limits



- Limits expand significantly Run 1 sensitivity
- Combination of  $0\ell/1\ell$  channels in Gtt regions improves sensitivity by 100 GeV relative to individual channels



# Conclusions

- ▶  $\sqrt{s} = 13$  TeV is here, but SUSY is not (yet!)
- ▶ First searches optimized for discovery have not yet observed any significant deviation from the SM
- ▶ Run 2 has just begun, though: 2016 promises 10x the data, and even more coming in 2017!
  - ▶  $10 \text{ fb}^{-1}$  or more likely available for ICHEP, in just a few weeks
  - ▶  $\tilde{g}$  sensitivity will likely extend to 2 TeV and beyond
- ▶ New techniques and signal models coming in new results: lots of room left to optimize and explore
  - ▶ SUSY could still be right around (one of many) corners!

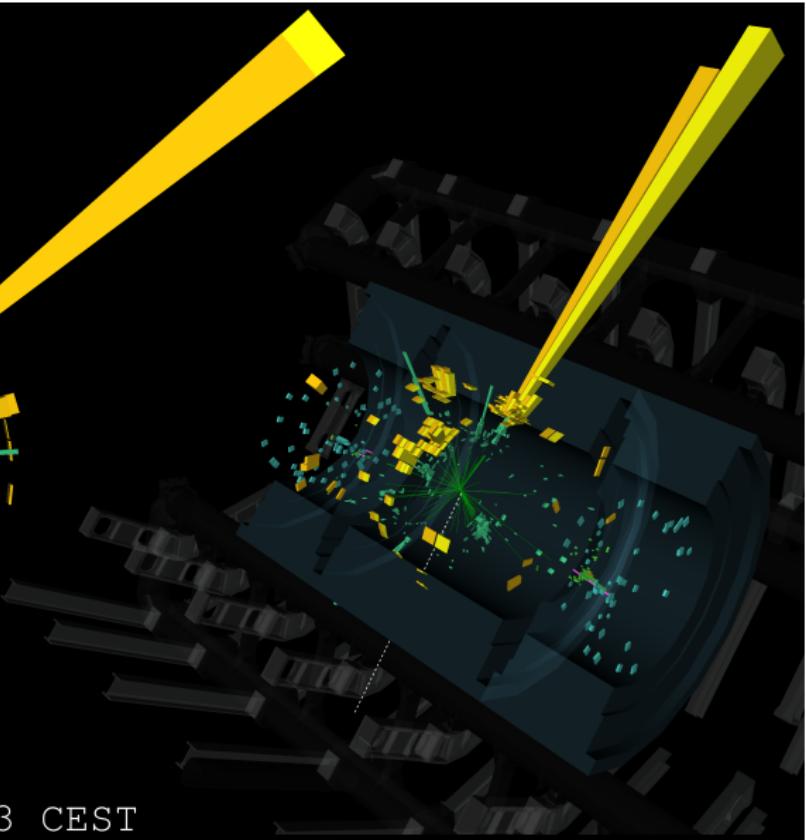
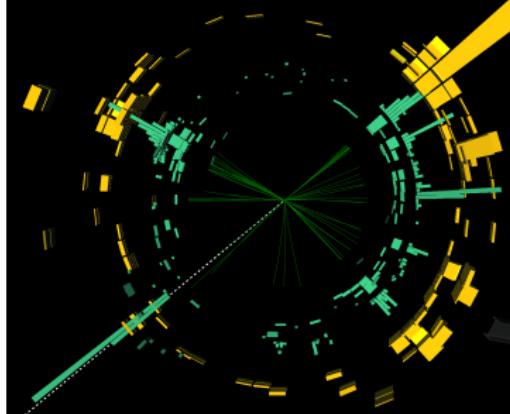
**Thank you for your attention!**

SUSY-2015-10



# ATLAS EXPERIMENT

SR-Gt $t$ -0L-B



Run: 284213

Event: 2364029035

2015-10-31 00:13:13 CEST

# Backup



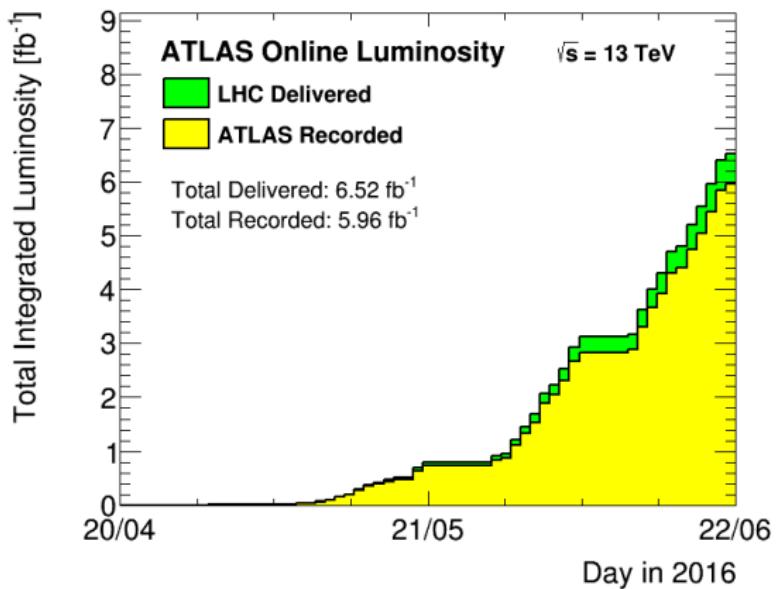
# And Now, $\sqrt{s} = 13$ TeV



Breaking its own energy records!



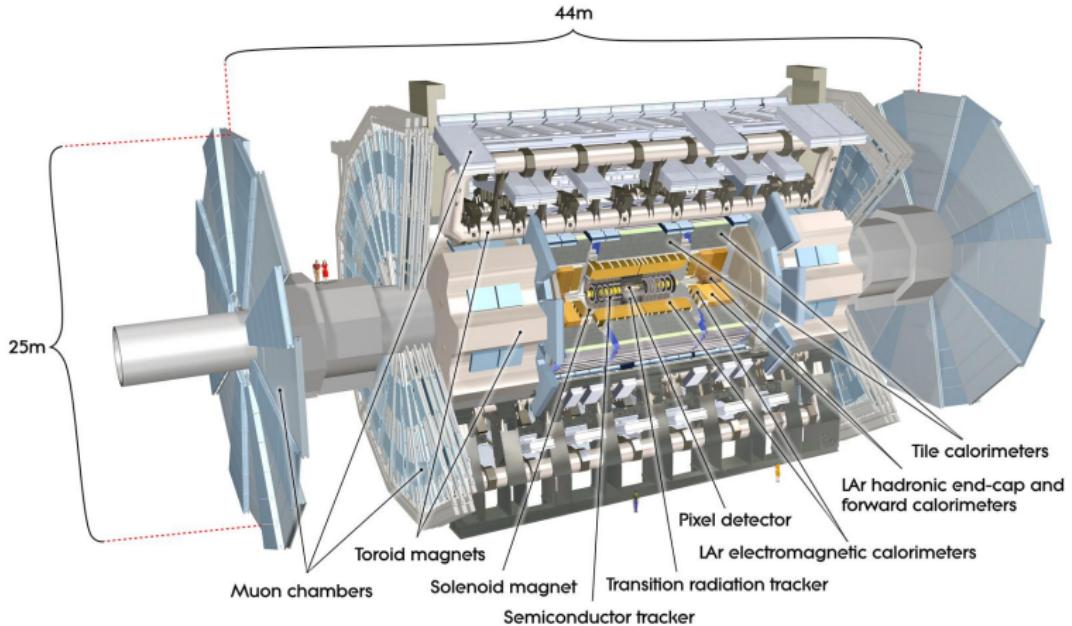
# Luminosity



- ▶ Challenging start to LHC operations: simultaneous transition to higher  $\sqrt{s}$  and smaller bunch spacing ( $50 \rightarrow 25 \text{ ns}$ ) was difficult!
- ▶ Large dataset delivered to experiments:  $3.2 \text{ fb}^{-1}$  usable by ATLAS



# The ATLAS Detector





# Multi- $b$ : $\tilde{t}$ SR Definitions

Criteria common to all Gtt 0-lepton regions: $p_T^{\text{jet}} > 30 \text{ GeV}$					
	Variable	Signal region	Control region	VR1L	VR0L
Criteria common to all regions of the same type	Lepton	0 signal	= 1 signal	= 1 signal	0 signal
	$\Delta\phi_{\min}^{4j}$	$> 0.4$	—	—	$> 0.4$
	N <sub>jet</sub>	$\geq 8$	$\geq 7$	$\geq 7$	$\geq 8$
	$m_{T,\min}^{b\text{-jets}}$	$> 80$	—	$> 80$	$< 80$
	$m_T$	—	$< 150$	$< 150$	—
Region A (Large mass splitting)	$E_T^{\text{miss}}$	$> 400$	$> 250$	$> 250$	$> 200$
	$m_{\text{eff}}^{\text{incl}}$	$> 1700$	$> 1350$	$> 1350$	$> 1400$
	N <sup><math>b</math>-jet</sup>	$\geq 3$	$\geq 3$	$\geq 3$	$\geq 2$
	N <sub>top</sub>	$\geq 1$	$\geq 1$	$\geq 1$	$\geq 1$
Region B (Moderate mass splitting)	$E_T^{\text{miss}}$	$> 350$	$> 200$	$> 200$	$> 200$
	$m_{\text{eff}}^{\text{incl}}$	$> 1250$	$> 1000$	$> 1000$	$> 1100$
	N <sup><math>b</math>-jet</sup>	$\geq 4$	$\geq 4$	$\geq 4$	$\geq 3$
	N <sub>top</sub>	$\geq 1$	$\geq 1$	$\geq 1$	$\geq 1$
Region C (Small mass splitting)	$E_T^{\text{miss}}$	$> 350$	$> 200$	$> 200$	$> 200$
	$m_{\text{eff}}^{\text{incl}}$	$> 1250$	$> 1000$	$> 1000$	$> 1250$
	N <sup><math>b</math>-jet</sup>	$\geq 4$	$\geq 4$	$\geq 4$	$\geq 3$



# Multi- $b$ : $\tilde{t}$ SR Definitions

Criteria common to all Gtt 1-lepton regions:  $\geq 1$  signal lepton,  $p_T^{\text{jet}} > 30 \text{ GeV}$

	Variable	Signal region	Control region	$\text{VR-}m_T$	$\text{VR-m}_{T,\min}^{b\text{-jets}}$
Criteria common to all regions of the same type	$m_T$	$> 150$	$< 150$	$> 150$	$< 150$
	$N^{\text{jet}}$	$\geq 6$	$\geq 6$	$\geq 5$	$\geq 6$
	$N^{b\text{-jet}}$	$\geq 3$	$\geq 3$	$= 3$	$= 3$
Region A (Large mass splitting)	$E_T^{\text{miss}}$	$> 200$	$> 200$	$> 200$	$> 200$
	$m_{\text{eff}}^{\text{incl}}$	$> 1100$	$> 1100$	$> 600$	$> 600$
	$m_{T,\min}^{b\text{-jets}}$	$> 160$	—	$< 160$	$> 140$
	$N^{\text{top}}$	$\geq 1$	$\geq 1$	$\geq 1$	$\geq 1$
Region B (Moderate to small mass splitting)	$E_T^{\text{miss}}$	$> 300$	$> 300$	$> 200$	$> 200$
	$m_{\text{eff}}^{\text{incl}}$	$> 900$	$> 900$	$> 600$	$> 600$
	$m_{T,\min}^{b\text{-jets}}$	$> 160$	—	$< 160$	$> 160$

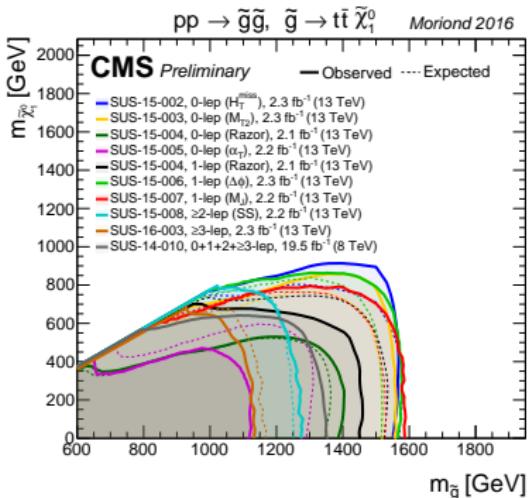
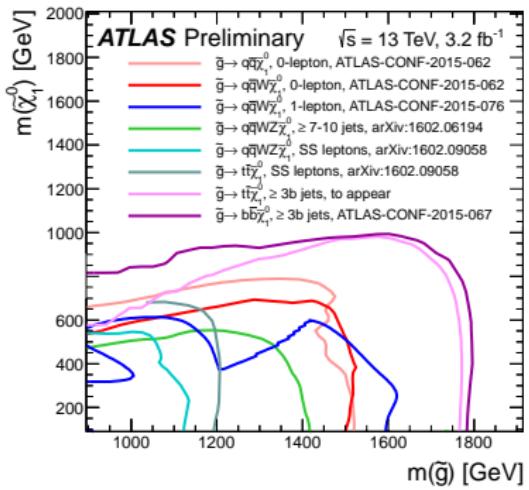


# Multi- $b$ : $\tilde{b}$ SR Definitions

Criteria common to all Gbb regions: $\geq 4$ signal jets, $\geq 3$ $b$ -jets				
	Variable	Signal region	Control region	Validation region
Criteria common to all regions of the same type	Lepton	Candidate veto	= 1 signal	Candidate veto
	$\Delta\phi_{\text{min}}^{\text{4j}}$	$> 0.4$	—	$> 0.4$
	$n_b^{\text{jets}}$	—	—	$< 160$
	$m_{T,\text{min}}$	—	$< 150$	—
Region A (Large mass splitting)	$p_T^{\text{jet}}$	$> 90$	$> 90$	$> 90$
	$E_T^{\text{miss}}$	$> 350$	$> 250$	$> 250$
	$m_{\text{eff}}^{\text{4j}}$	$> 1600$	$> 1200$	$< 1400$
Region B (Moderate mass splitting)	$p_T^{\text{jet}}$	$> 90$	$> 90$	$> 90$
	$E_T^{\text{miss}}$	$> 450$	$> 300$	$> 300$
	$m_{\text{eff}}^{\text{4j}}$	$> 1400$	$> 1000$	$< 1400$
Region C (Small mass splitting)	$p_T^{\text{jet}}$	$> 30$	$> 30$	$> 30$
	$E_T^{\text{miss}}$	$> 500$	$> 400$	$> 400$
	$m_{\text{eff}}^{\text{4j}}$	$> 1400$	$> 1200$	$< 1400$



# Comparisons to Other Results



- ▶ Multi-b limits exceed all other limits from ATLAS on gluinos
  - ▶  $b$ -tagging and top-tagging provide unique and powerful handles: dramatic final states we are very sensitive to!

- ▶ ATLAS also beats CMS by  $\approx 200$  GeV in models with tops
  - ▶ Slightly more data, but  $0/1\ell$  combination and unique-top tagging and kinematic variables