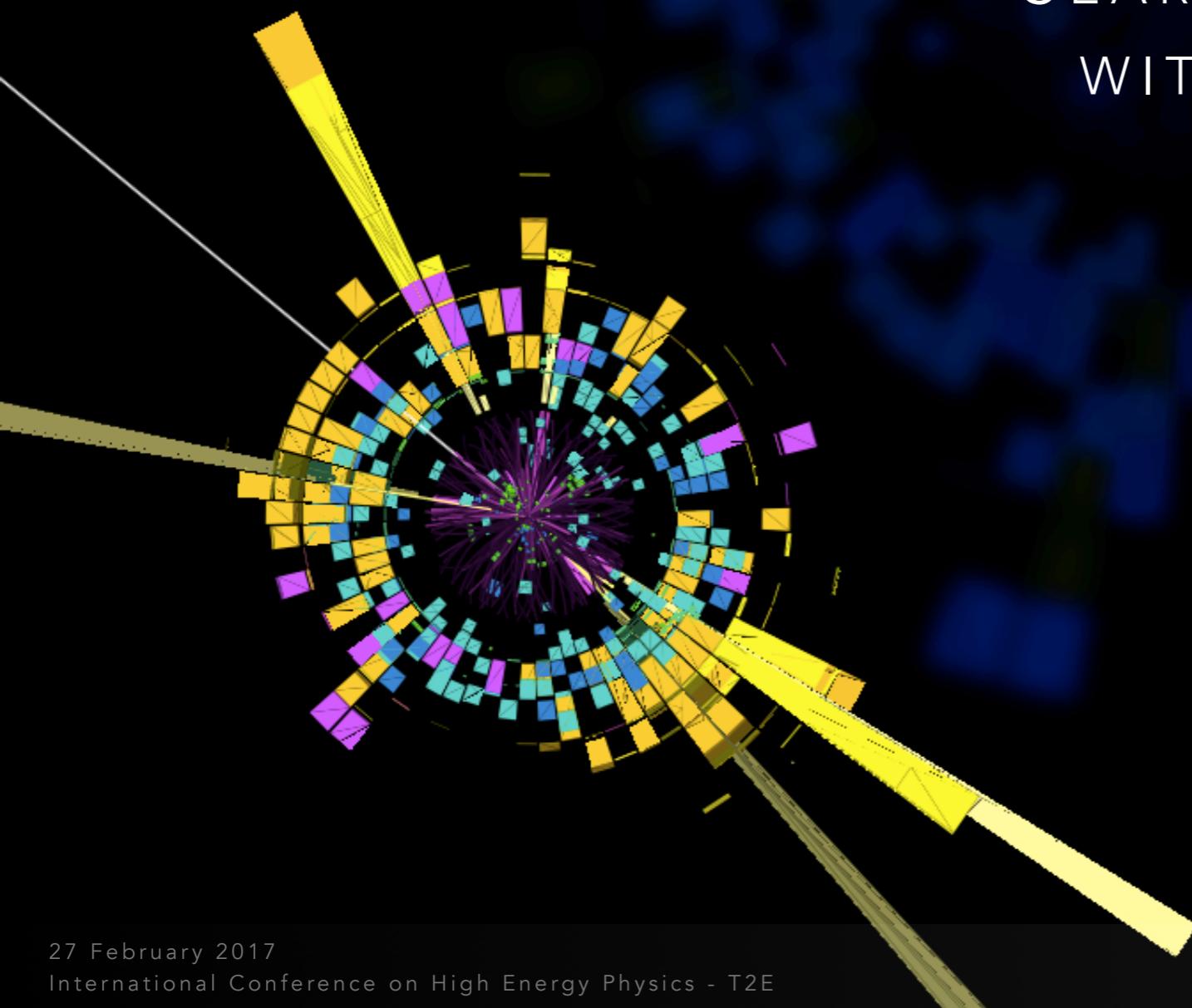


# SEARCHES FOR SUPERSYMMETRY WITH THE ATLAS EXPERIMENT

DR. LAWRENCE LEE

ON BEHALF OF THE ATLAS COLLABORATION

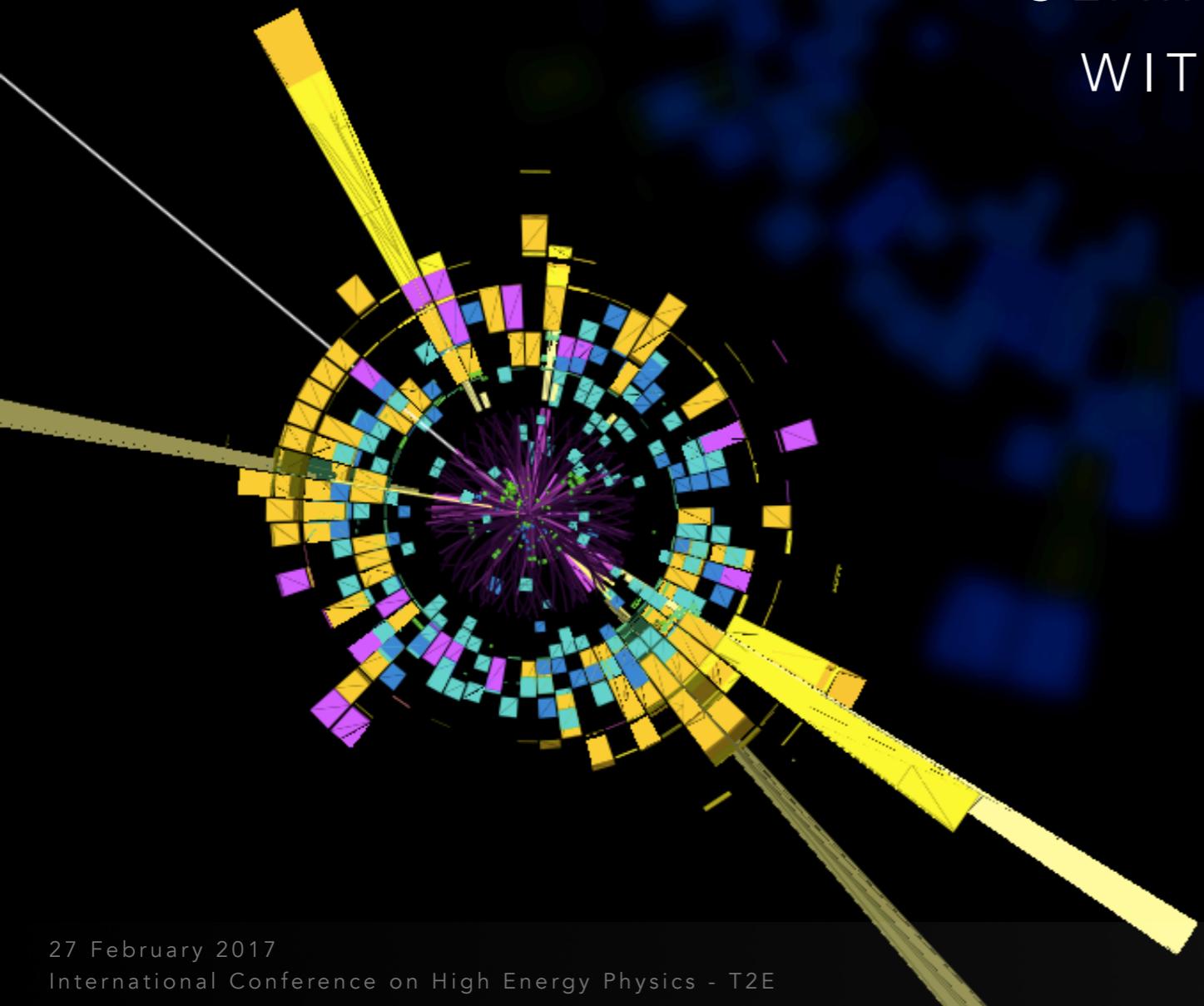


a.k.a. why haven't we found  
SUSY despite all the...

## SEARCHES FOR SUPERSYMMETRY WITH THE ATLAS EXPERIMENT

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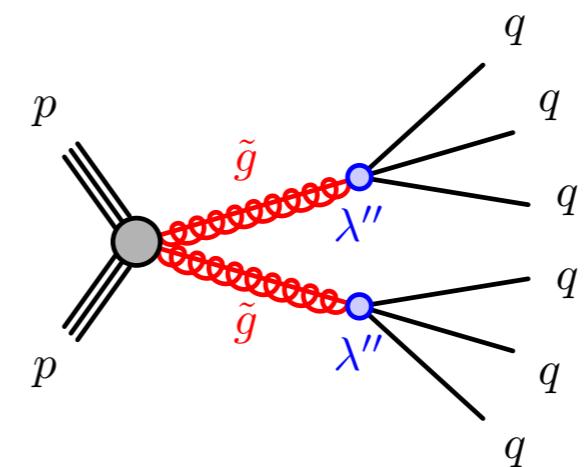
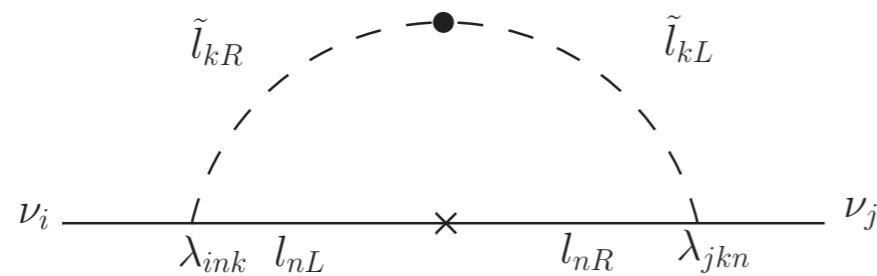
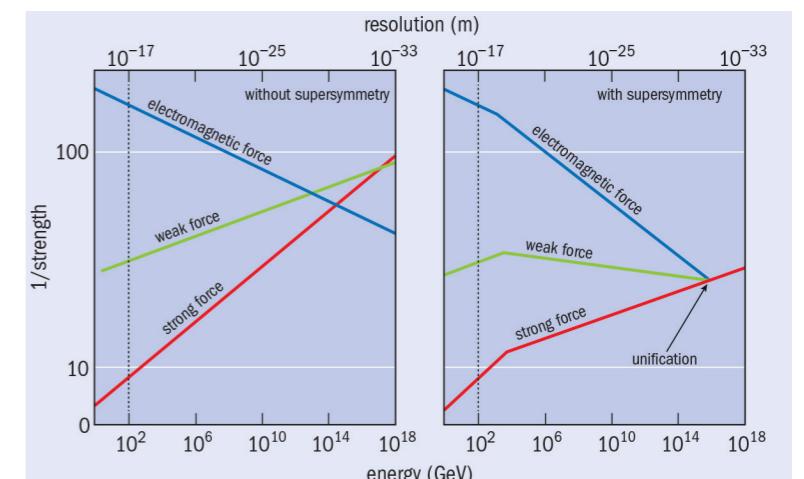
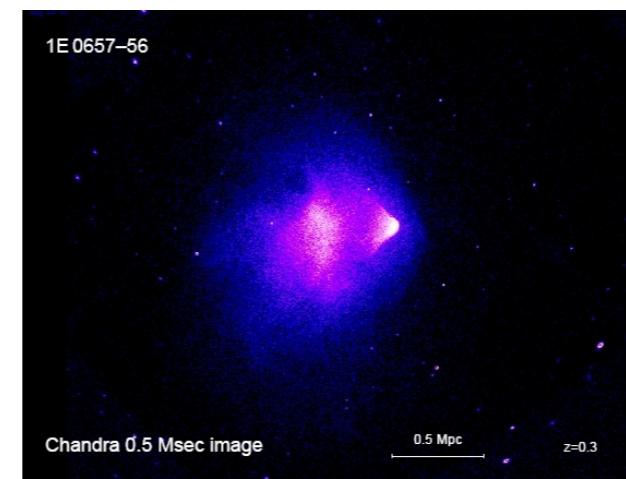
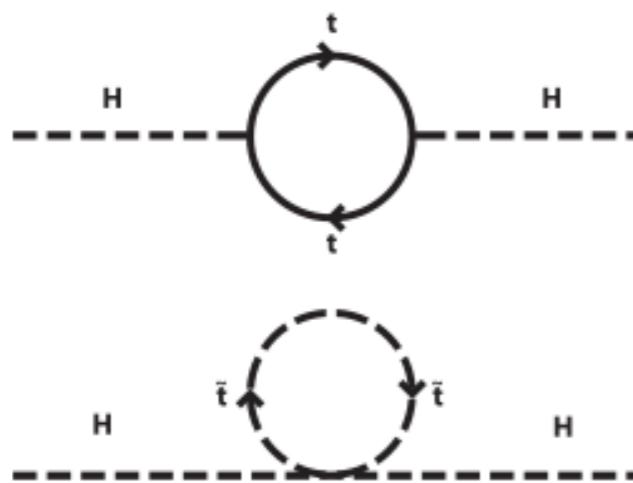


# SUPERSYMMETRY

The simple addition of the **only allowable<sup>(\*)</sup>** kind of symmetry not seen in nature can explain...

# SUPERSYMMETRY

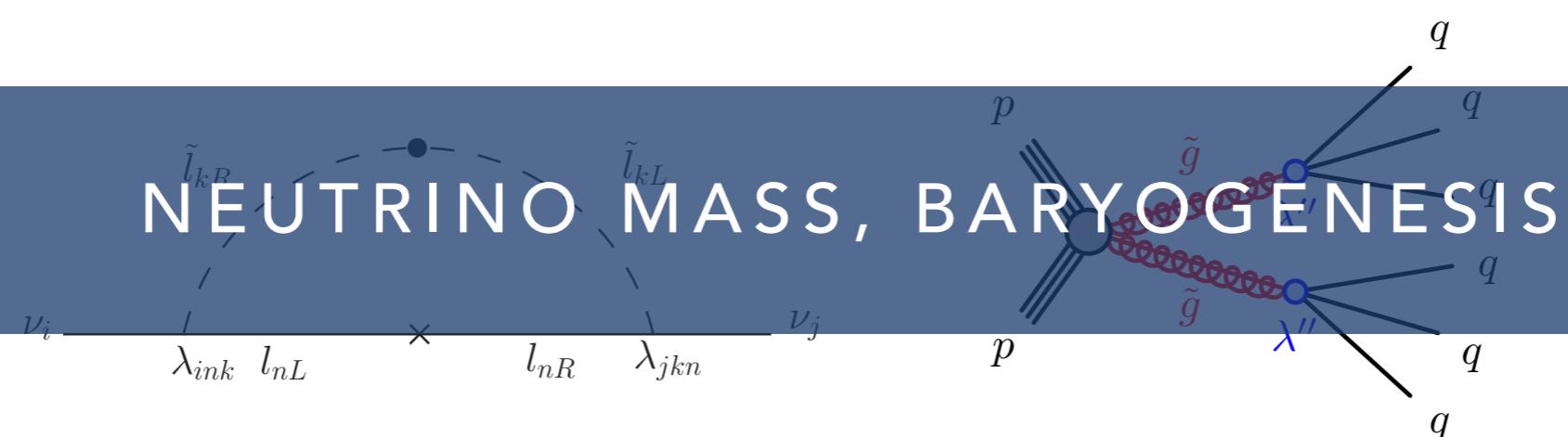
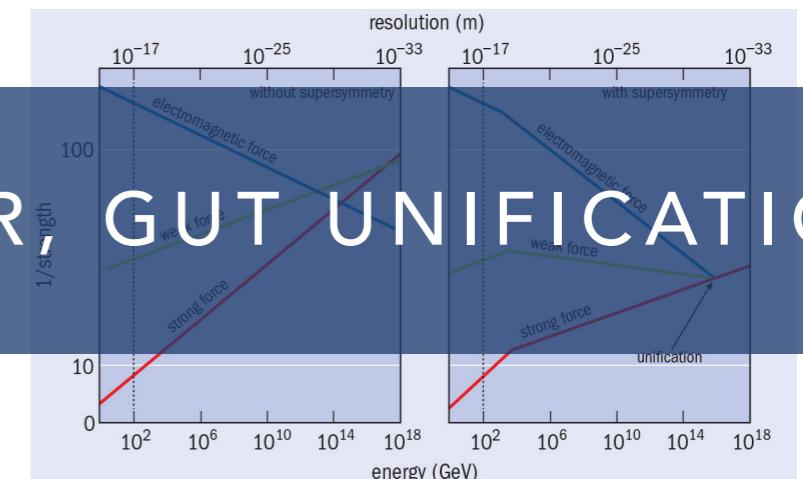
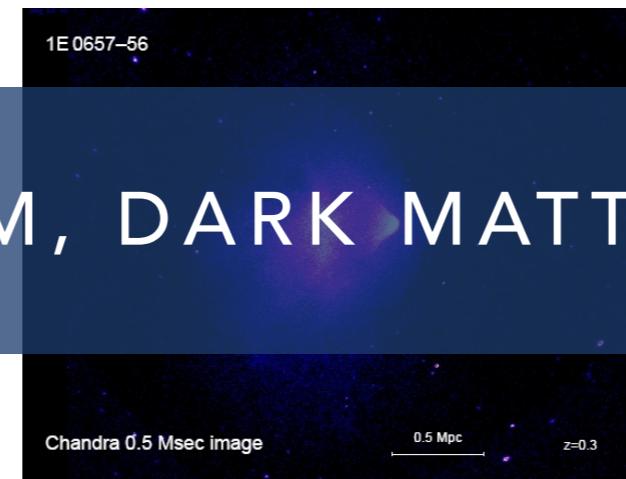
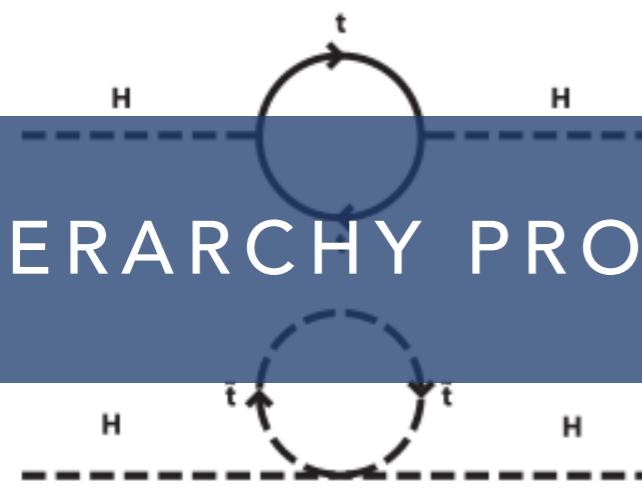
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# SUPERSYMMETRY

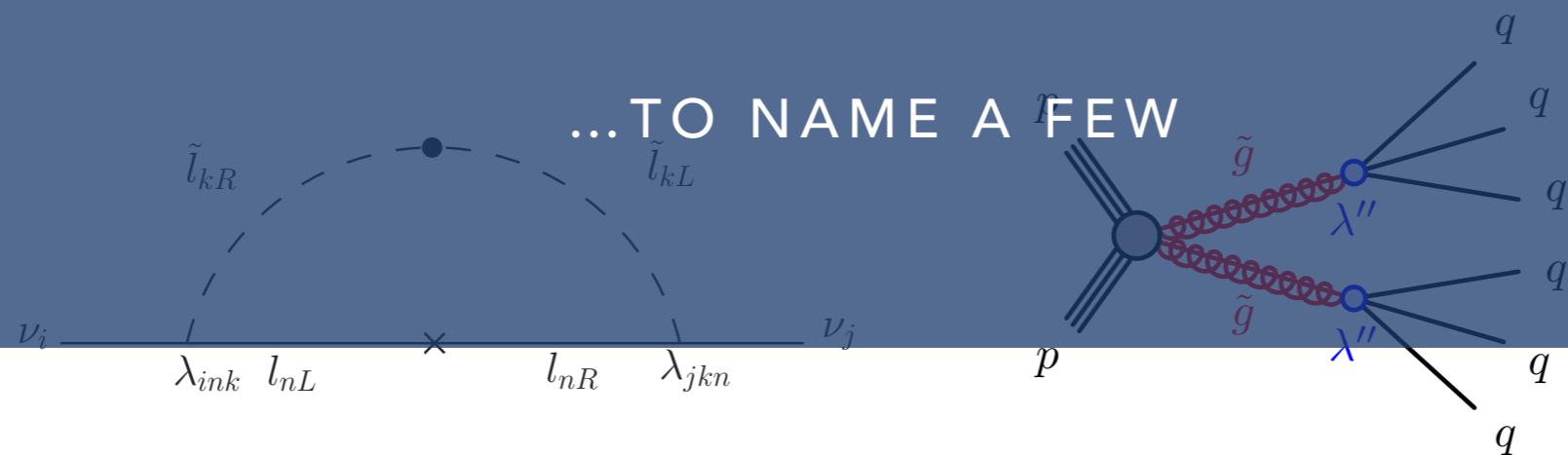
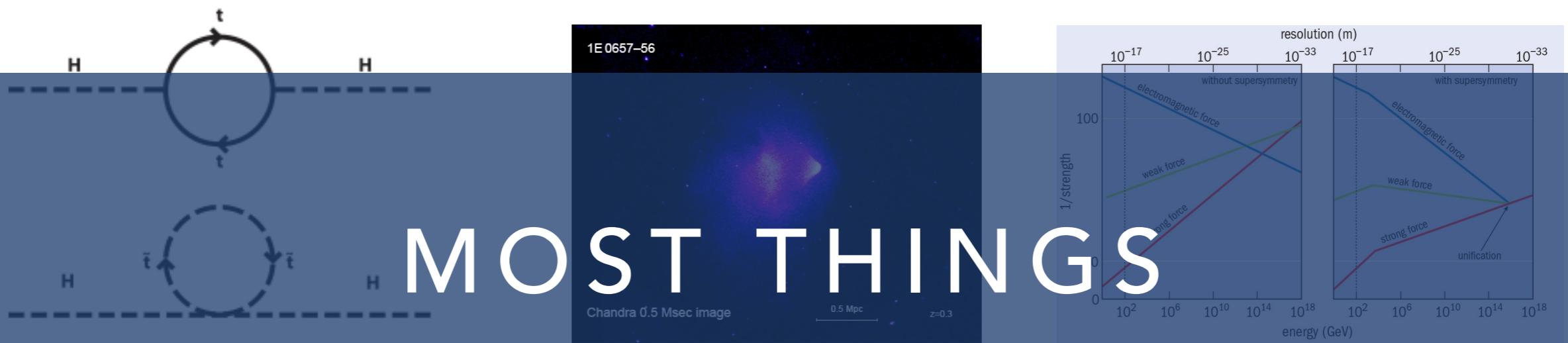
The simple addition of the **only allowable<sup>(\*)</sup>** kind of symmetry not seen in nature can explain...

HIERARCHY PROBLEM, DARK MATTER, GUT UNIFICATION



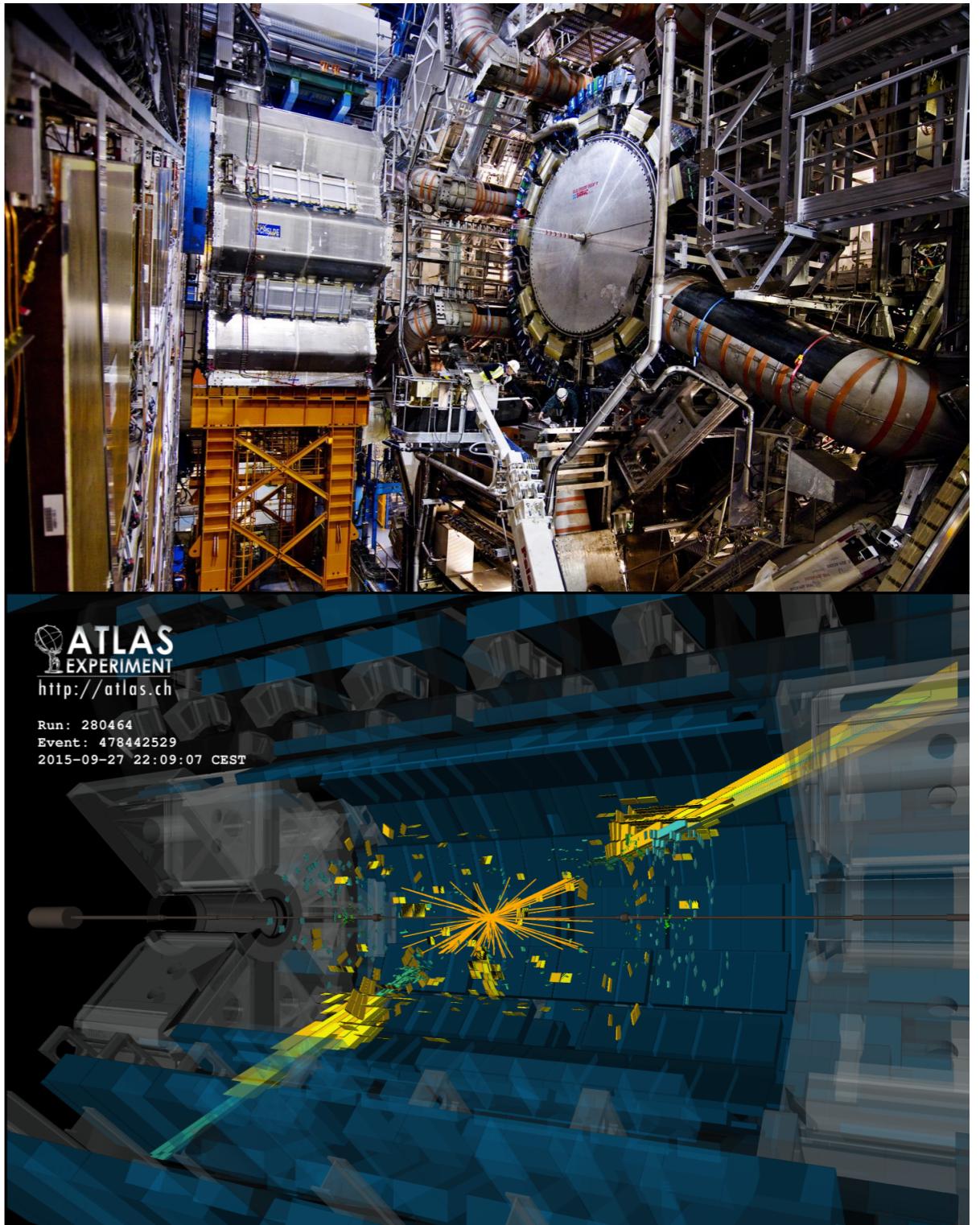
# SUPERSYMMETRY

The simple addition of the **only allowable<sup>(\*)</sup>** kind of symmetry not seen in nature can explain...



# SEARCHES FOR SUPERSYMMETRY

- Despite searching at SPS, LEP, Tevatron, LHC, etc
  - No evidence for SUSY!
- For better or for worst, let's keep looking
- Large effort at ATLAS to find SUSY in many channels
- Today: Rough overview of our program



BUT WHY HAVEN'T WE FOUND IT YET?

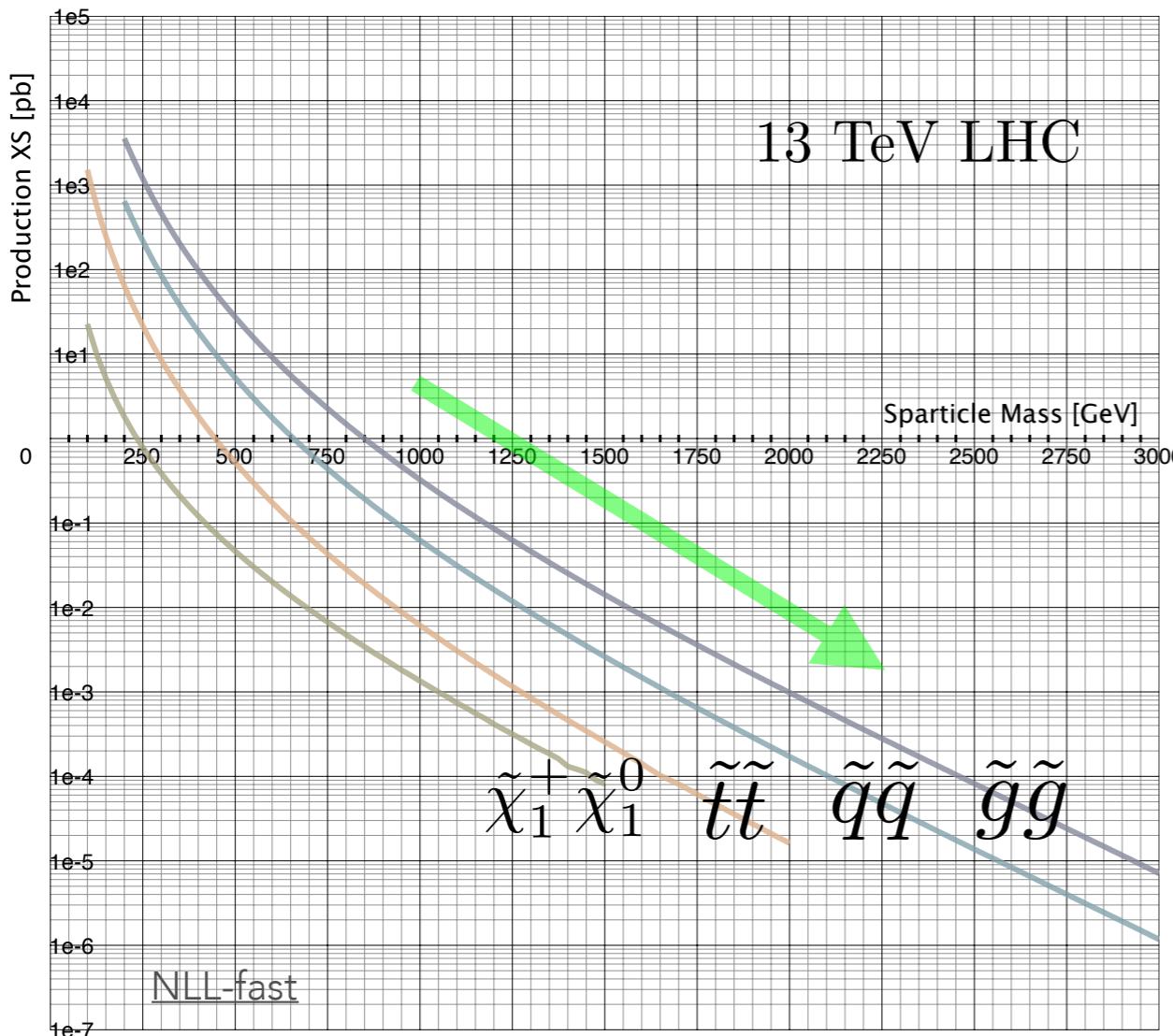
# BUT WHY HAVEN'T WE FOUND IT YET?

1. *It doesn't exist*

## BUT WHY HAVEN'T WE FOUND IT YET?

1. *It doesn't exist*
2. *Masses are too high*

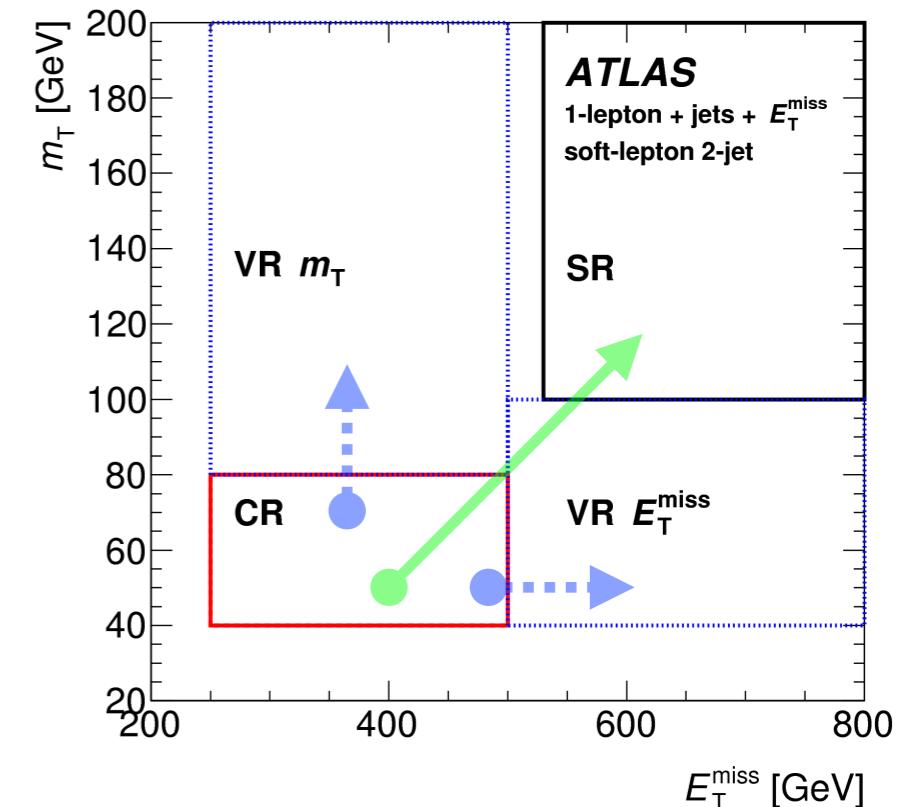
# STRONG SPARTICLE PRODUCTION



- LHC p-p collider → Copious strong production
- Low mass strongly produced sparticles should have been a quick discovery
  - Maybe masses just out of reach!
  - Look for heavier strongly produced sparticles
- Squark and gluino production at higher mass

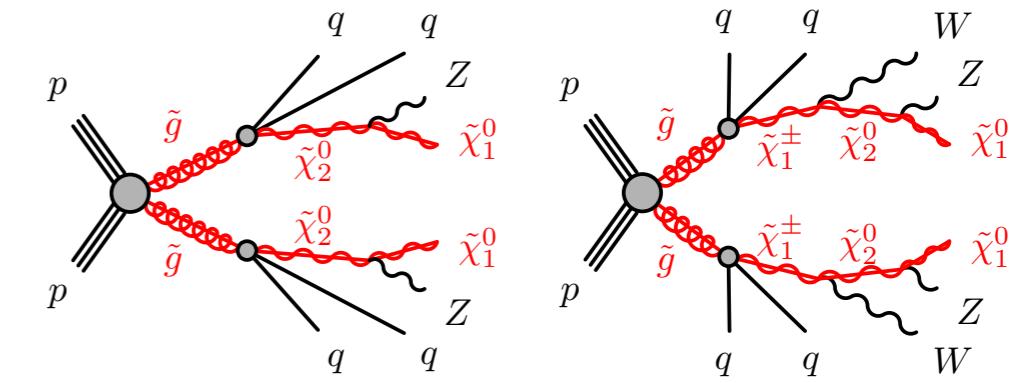
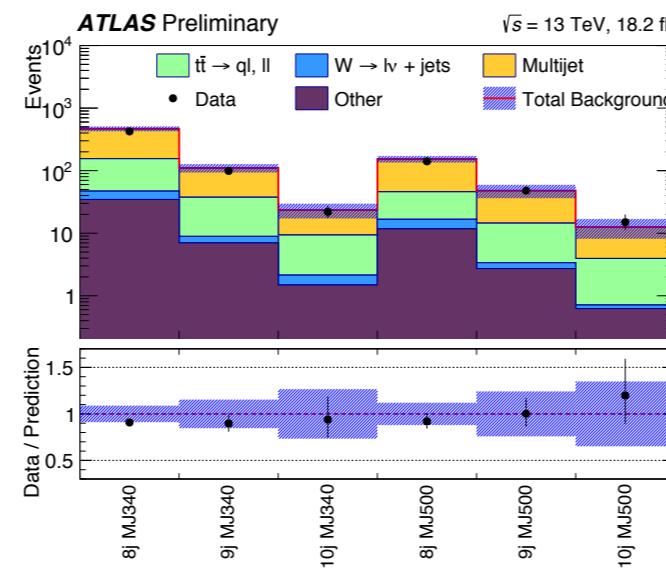
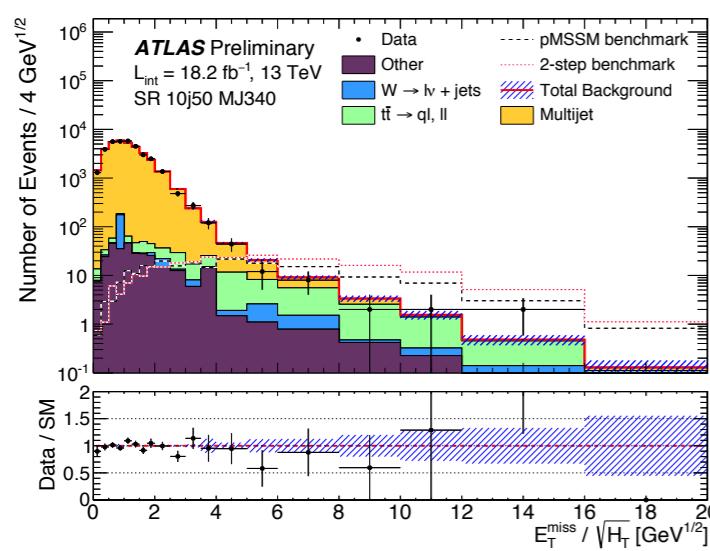
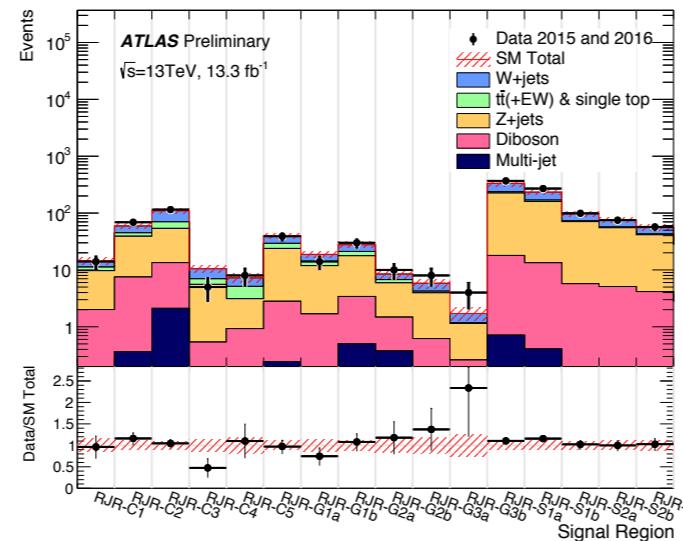
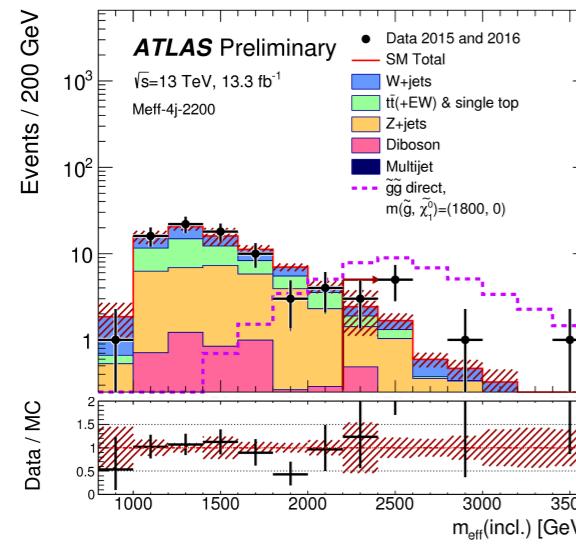
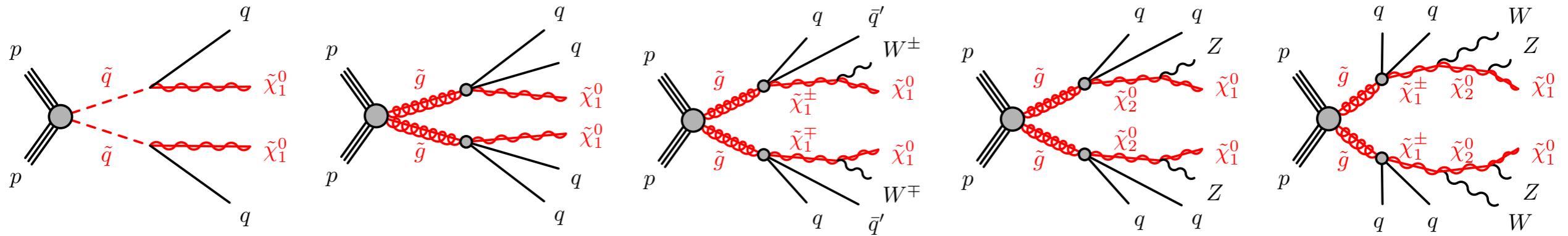
# INCLUSIVE SEARCHES

- Start by searching as inclusively as possible for squarks and gluinos
- General search strategy for most ATLAS SUSY searches:
  - Look for high momentum scale objects and large missing  $E_T$  (MET)
  - Define a **signal region** sensitive to signal
  - Each major BG normalized in dedicated **control regions**
  - Extrapolation to the signal region estimate tested in dedicated **validation regions**
- Inclusive searches categorized by lepton and jet multiplicities



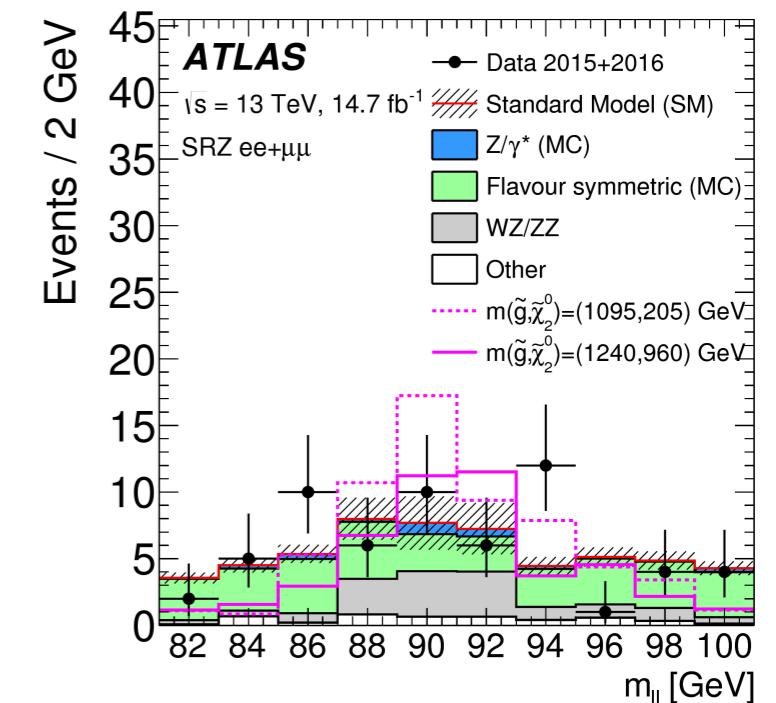
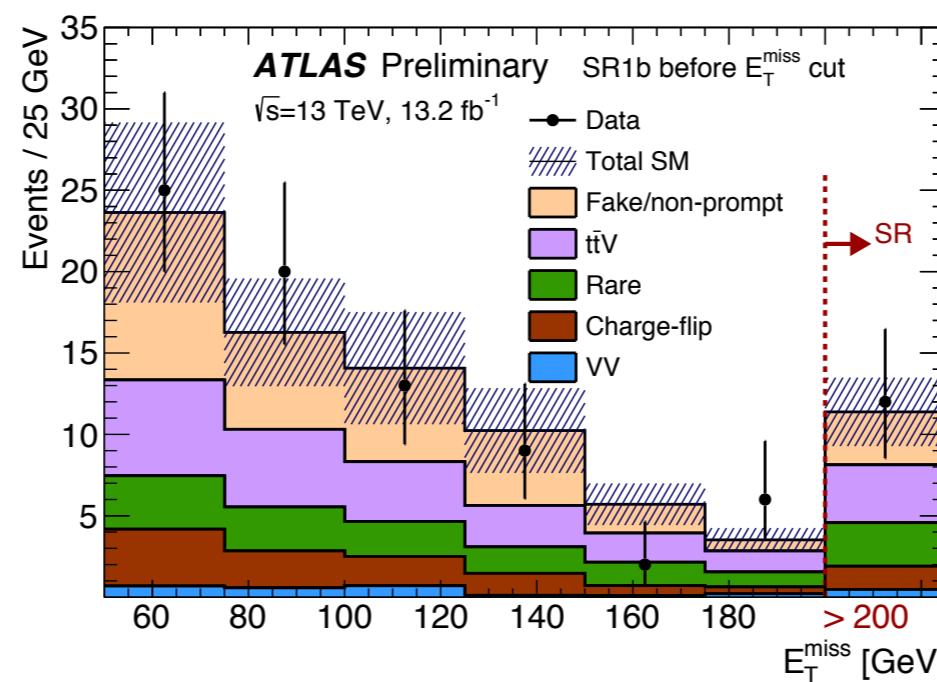
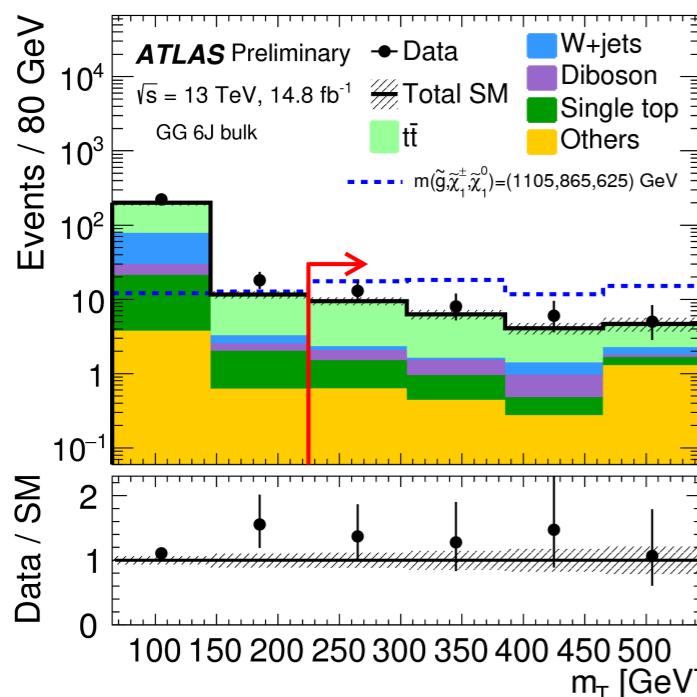
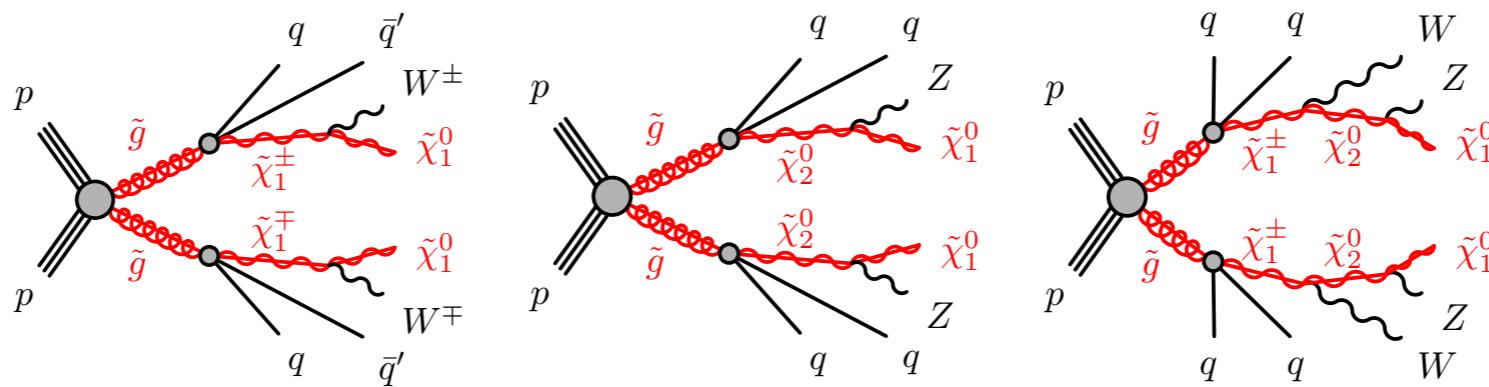
Example BG estimation strategy  
from 1-Lepton+Jets+MET

# OL SEARCHES



- Fully hadronic final states
- OL 2-6 Jets uses two methods
  - **Recursive Jigsaw Reconstruction** and a traditional  $M_{\text{Eff}}$  ( $= \text{MET} + \sum p_T$ ) analysis
  - CRs with leptons (W/T/Z), photons (Z), b-jets (T)
- OL 8-10 Jets
  - Focus on cascades w multiple vector bosons
  - Assumes MET/ $\sqrt{H_T}$  invariance for multijet background
  - Accidental substructure variable  $M_J^\Sigma$
  - Neither sees any significant excess

# 1L, 2L SEARCHES

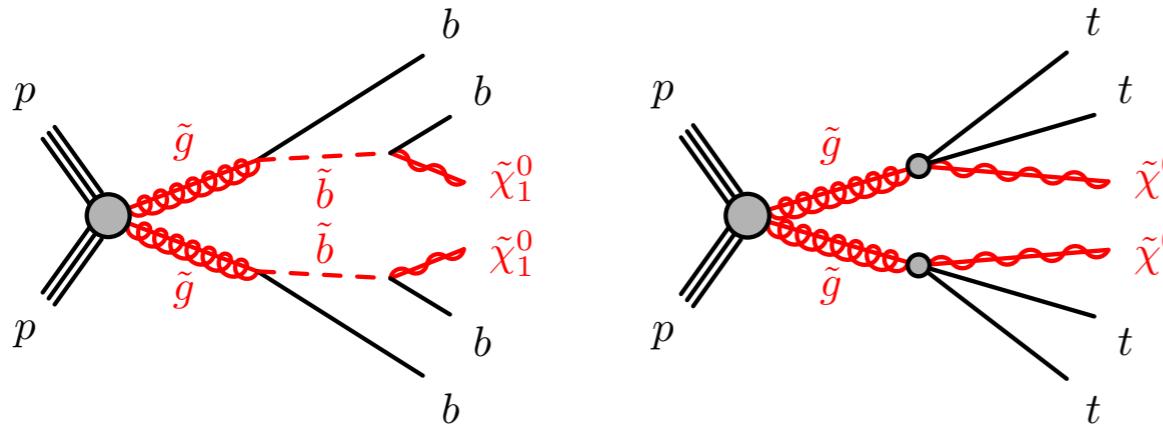


1L+Jets+MET sees nothing unexpected

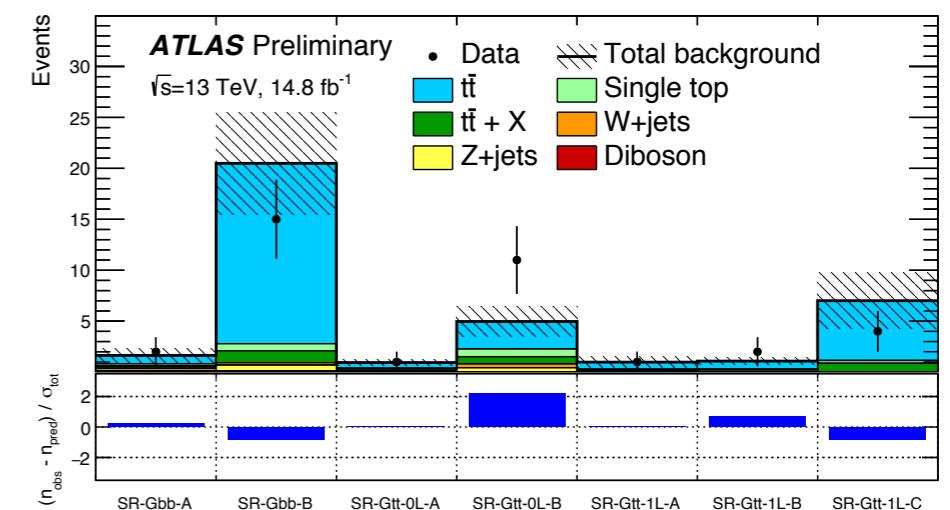
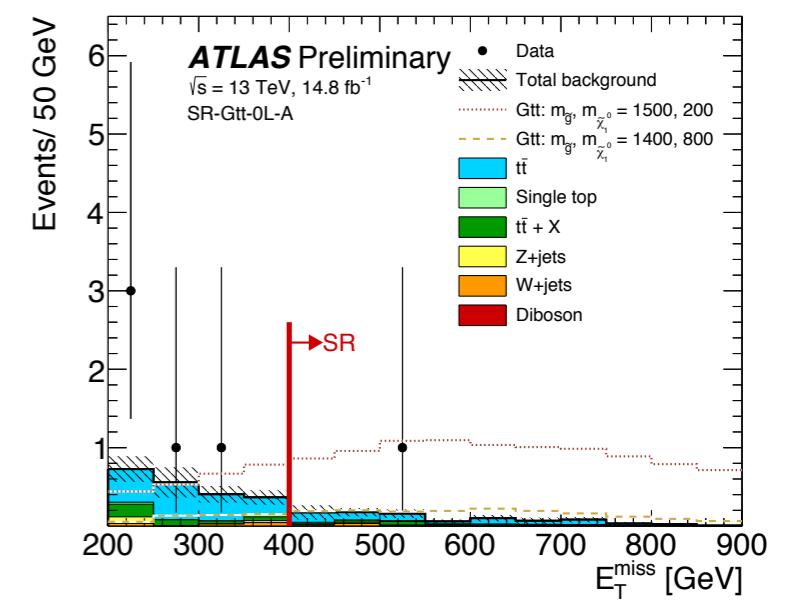
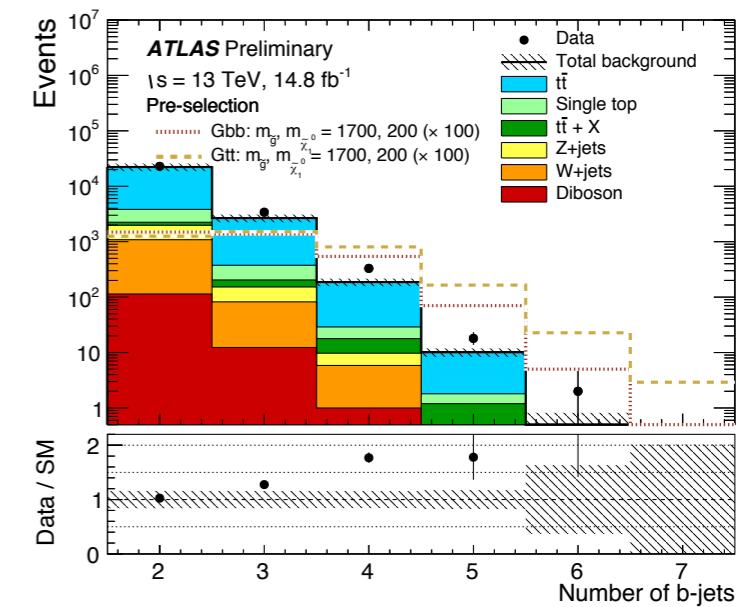
Same-sign 2L / 3L  
+Jets+MET also sees not significant deviation

Unfortunately the 3sigma excess from 2012+2015 of Z+Jets+MET has gone away

# MULTI-B-JET SEARCHES



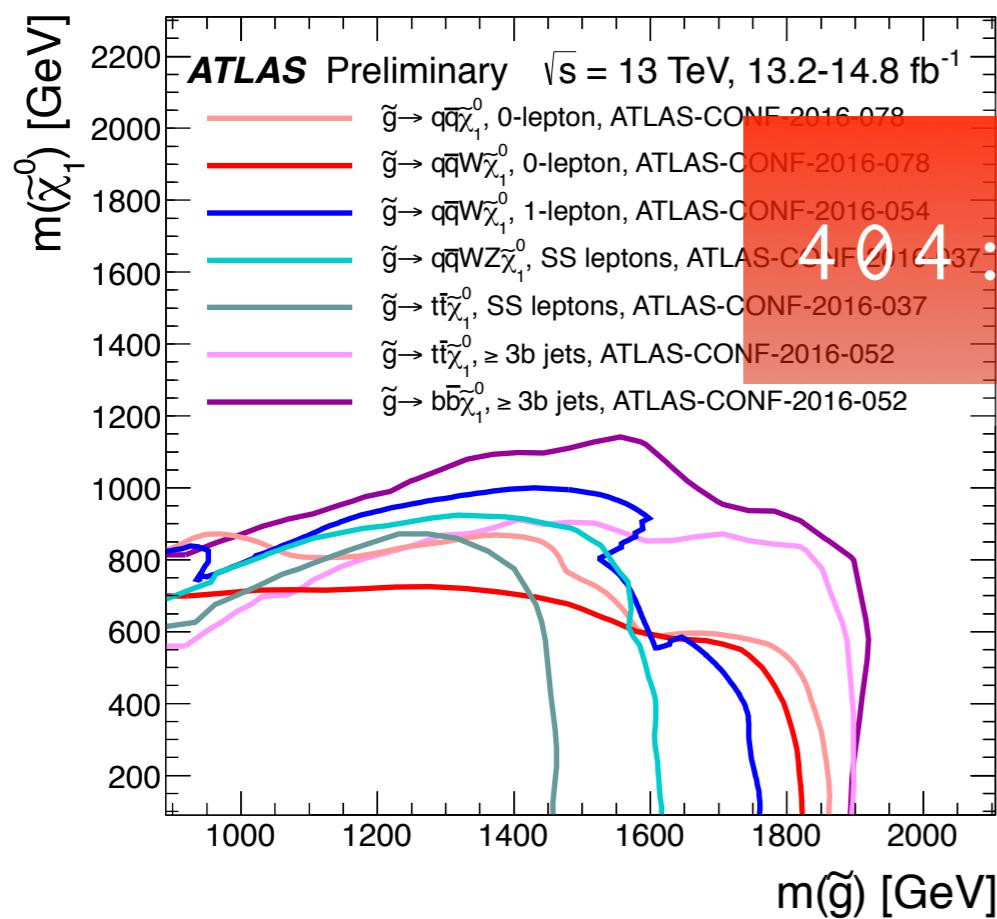
- Gluino-mediated stop/sbottom production
  - Expect many b-jets in final state
  - Probe regions with 0/1L,  $\geq 3/\geq 4$  BJets, MET
    - Kills most SM background, but some ttbar remains
  - 0/1L analyses built to be orthogonal for statistical combination



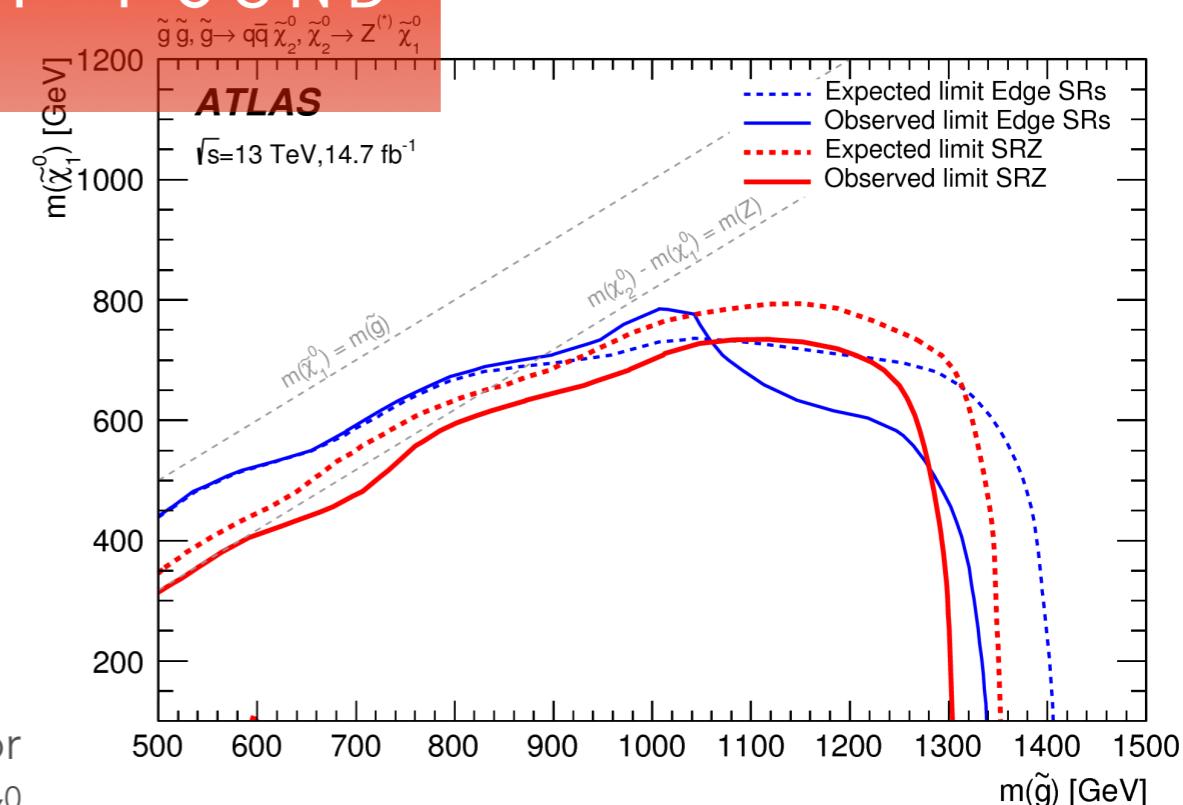
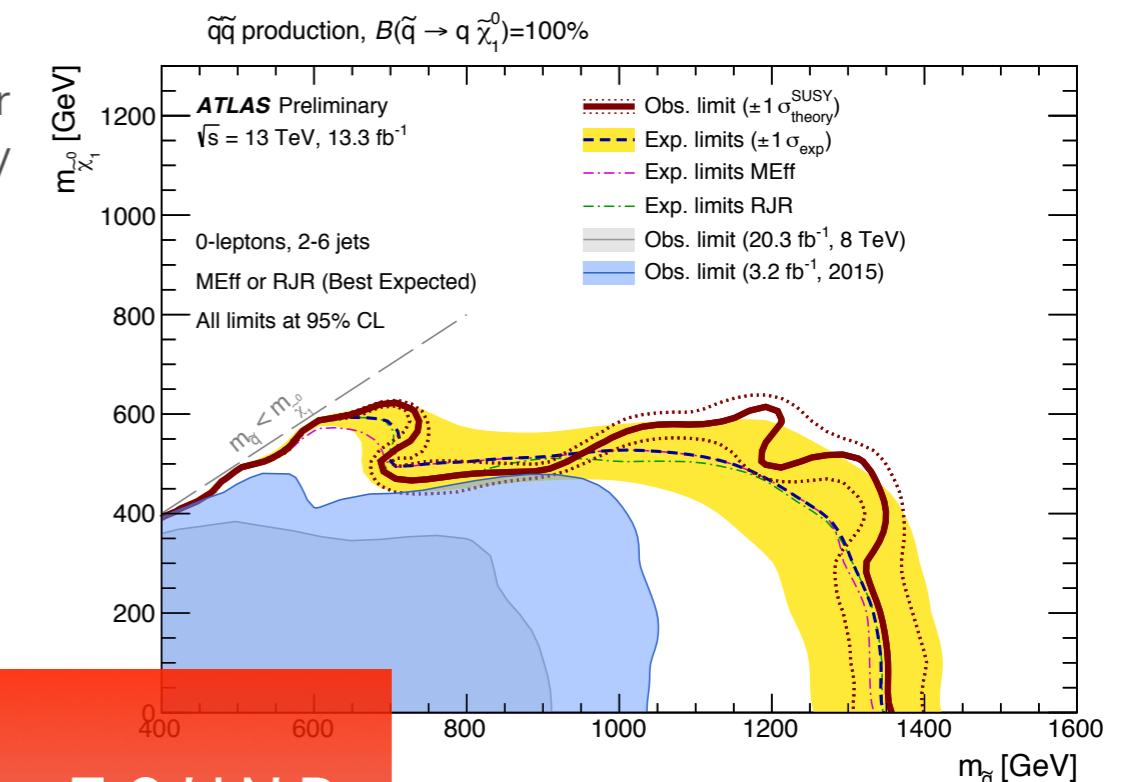
# INCLUSIVE SEARCHES

$\sim q \rightarrow q\tilde{\chi}_1^0$  excluded roughly for  
 $m(\tilde{\chi}_1^0) < 500$  GeV,  $m(\sim q) < 1350$  GeV

$\sim g \rightarrow \tilde{\chi}_1^0 + X$  (for many decay assumptions)  
excluded roughly for  $m(\tilde{\chi}_1^0) < 900$  GeV,  
 $m(\sim g) < [1500-1900]$  GeV



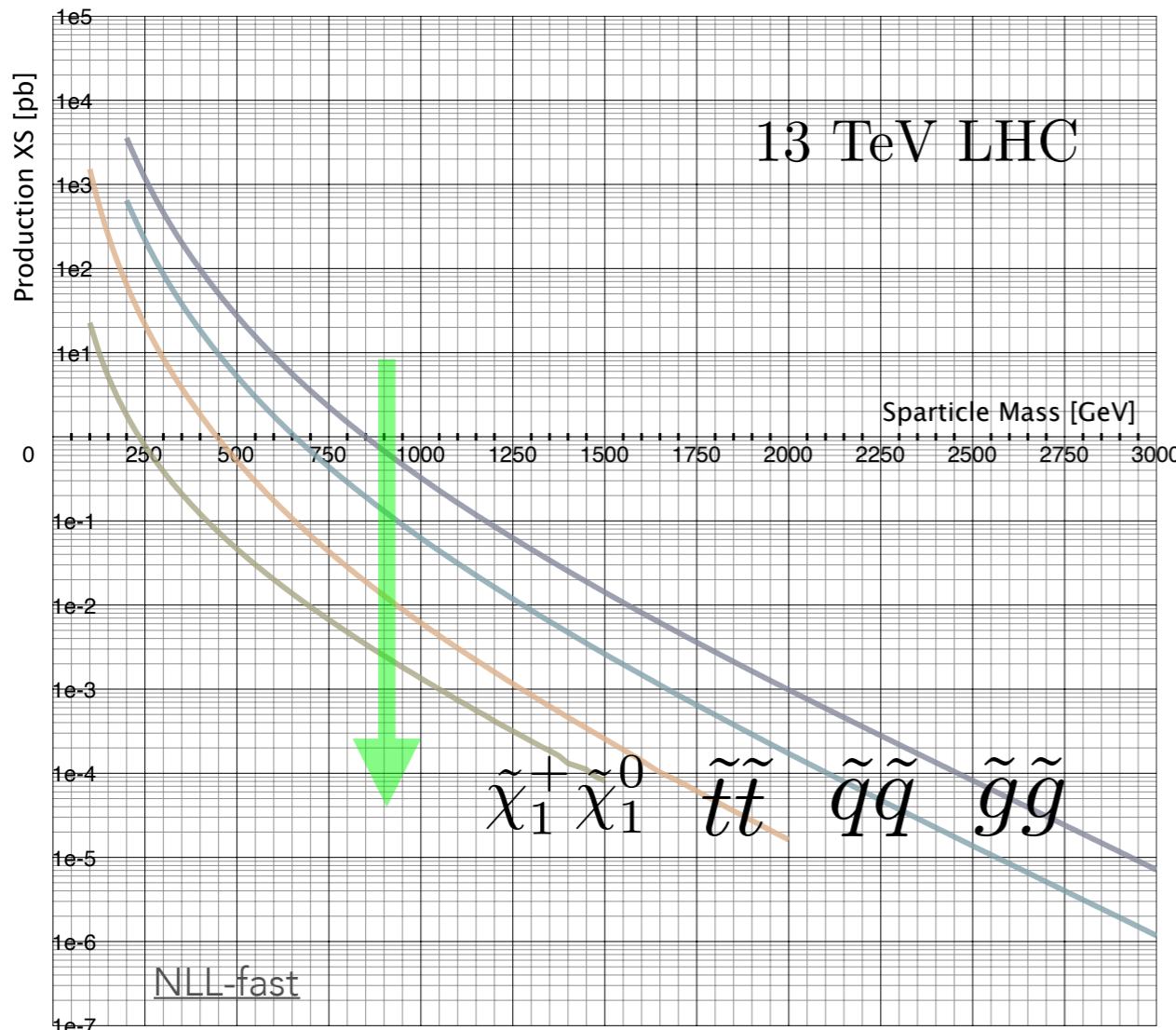
Gluino decays via Z excluded roughly for  
 $m(\sim g) < 1300$  GeV for massless  $\tilde{\chi}_1^0$



## BUT WHY HAVEN'T WE FOUND IT YET?

1. *It doesn't exist*
2. *Masses are too high*
3. *Cross sections are too small*

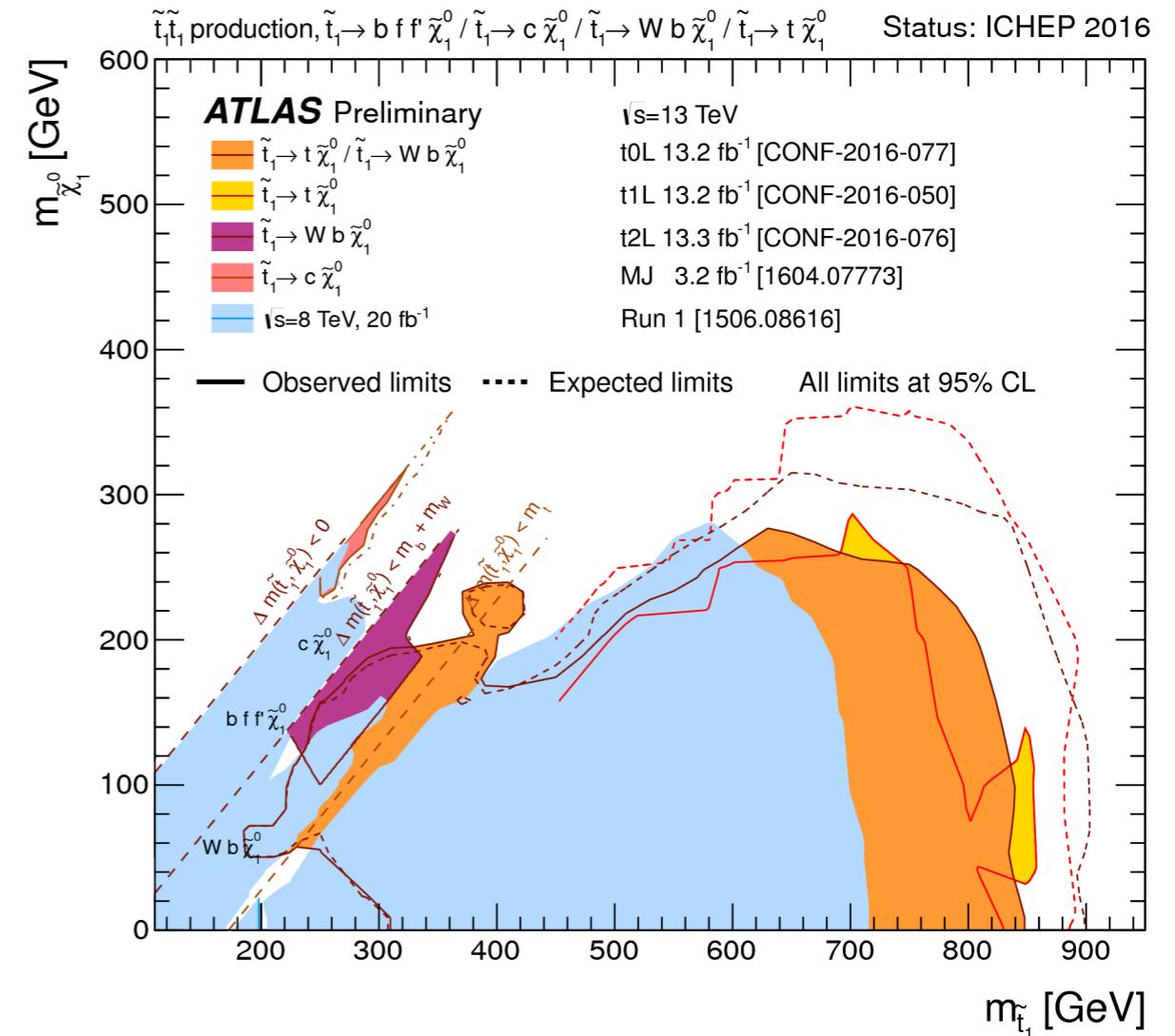
# LOWER XS SPARTICLE PRODUCTION



- Maybe the most collider-accessible sparticles have lower production XS
- Single light squark
  - e.g. stop squark as motivated by naturalness
  - No squark degen  $\rightarrow$  order of mag reduction in squark XS
- Electroweak production
  - EWKino production even further suppressed at pp collider
- More targeted searches to probe these processes

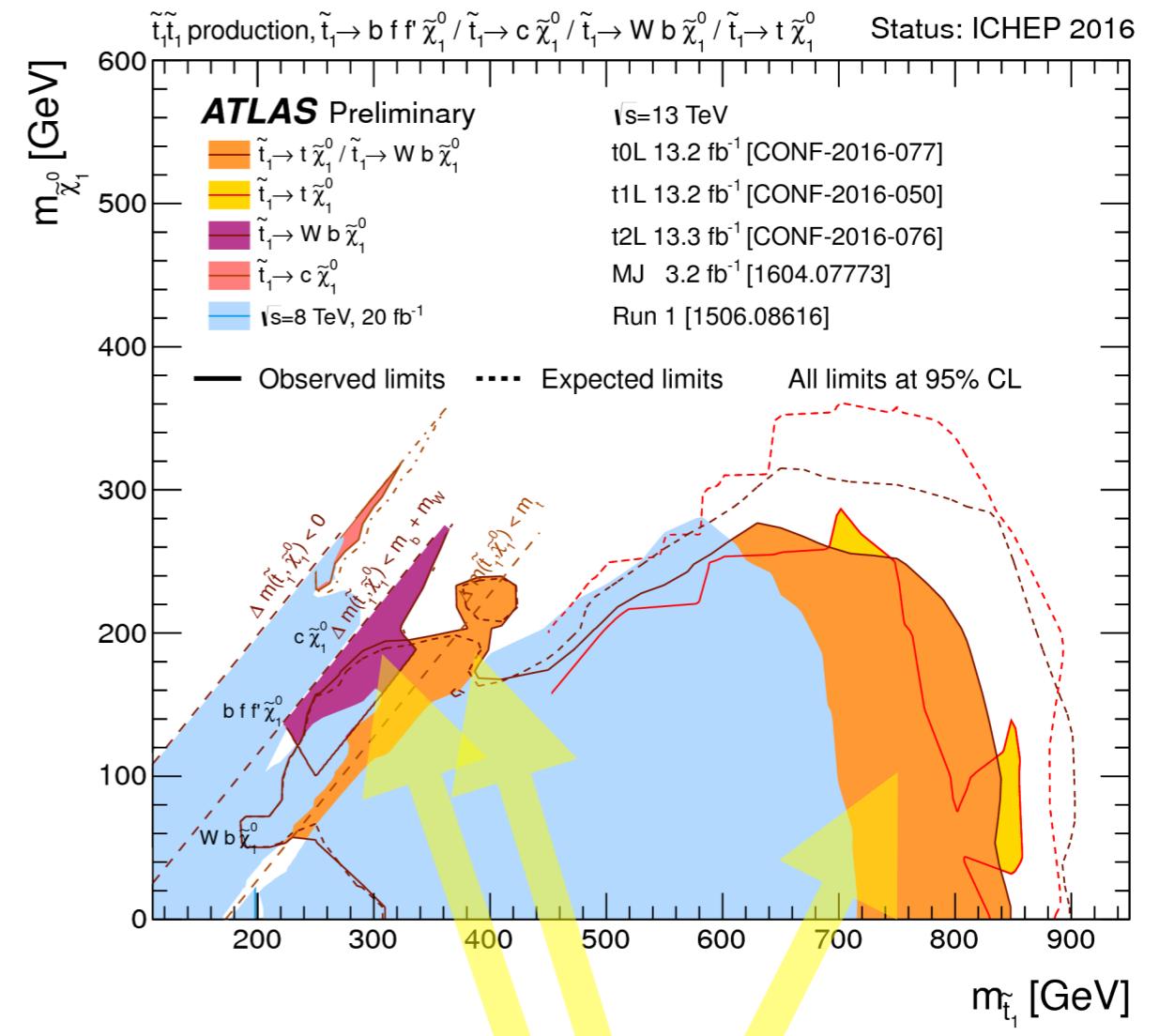
# STOP SQUARK SEARCHES

- To cleanly kill EW fine-tuning, stop squarks shouldn't be too heavy
  - Effectively cancel top-loop contributions to  $m_H$
- Looking for them directly
- Major decay possibilities
  - Stop  $\rightarrow t$  (or c) + neutralino
  - Stop  $\rightarrow b$  + chargino
  - And more!



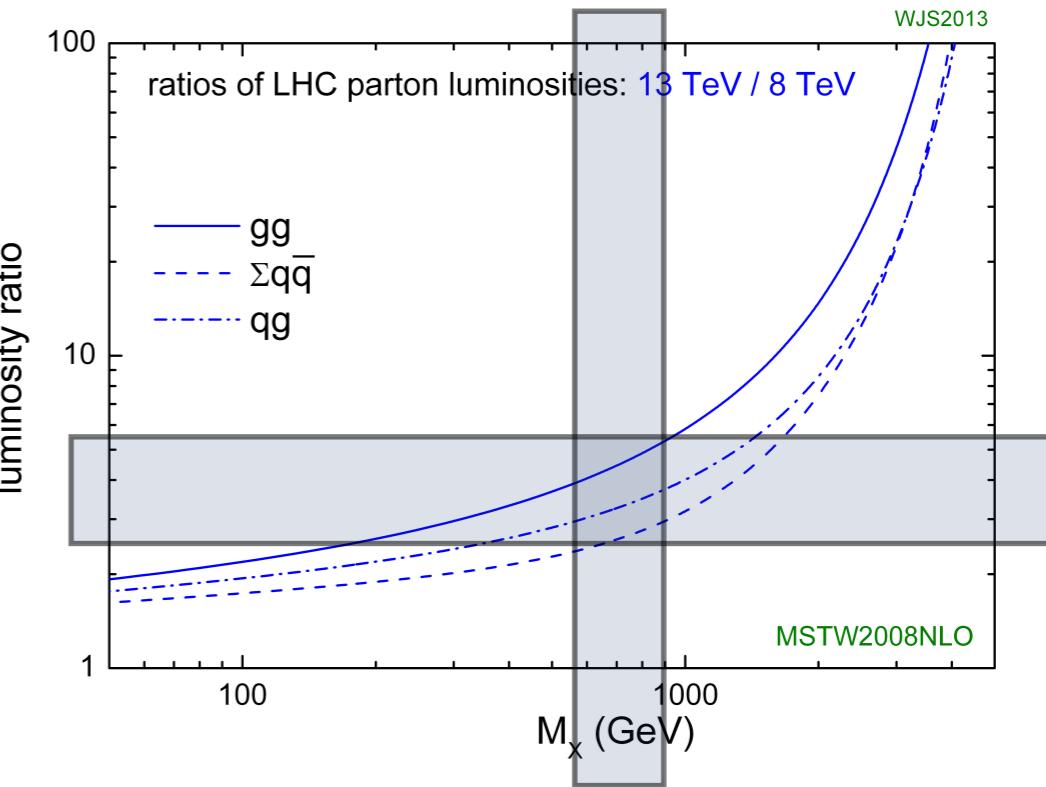
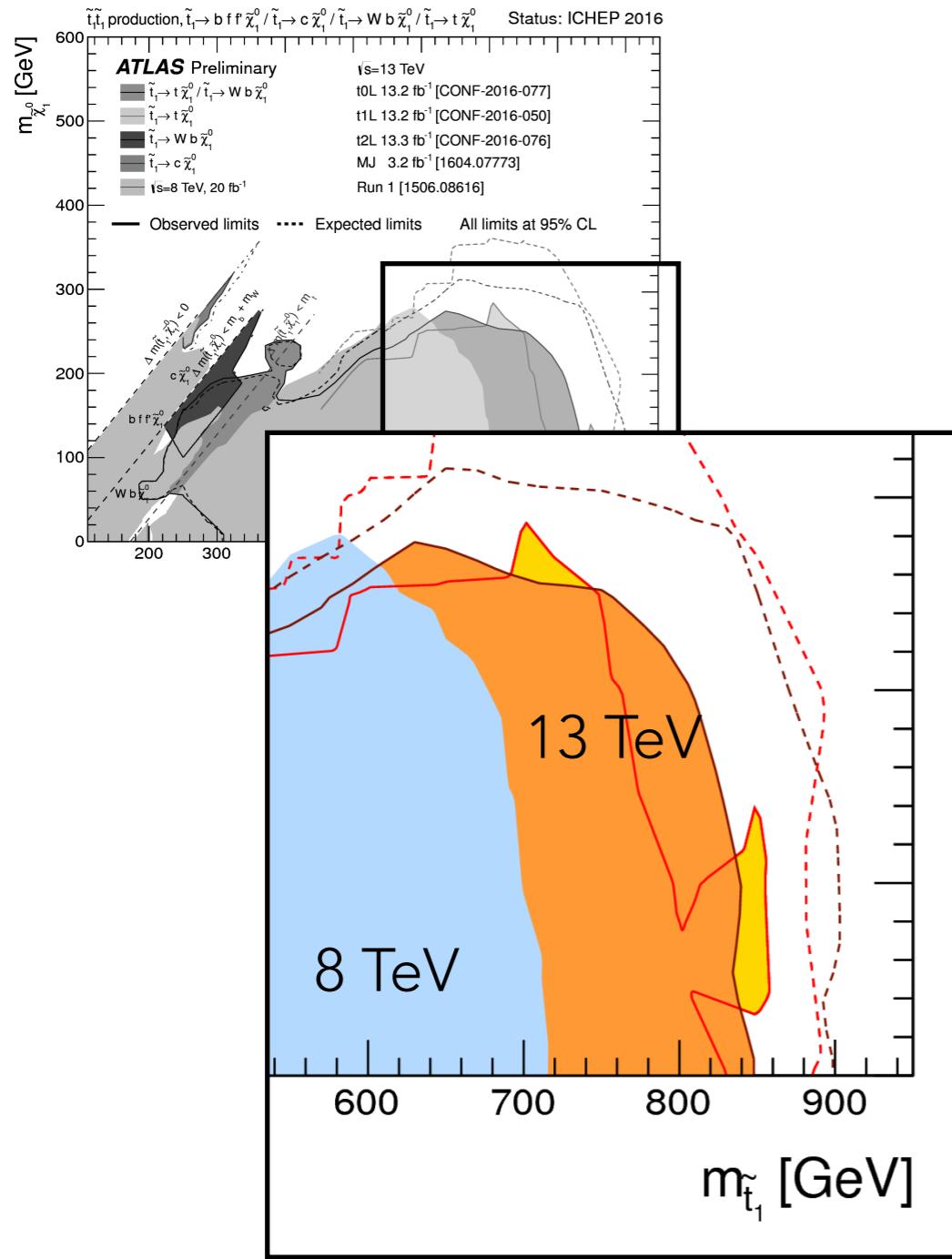
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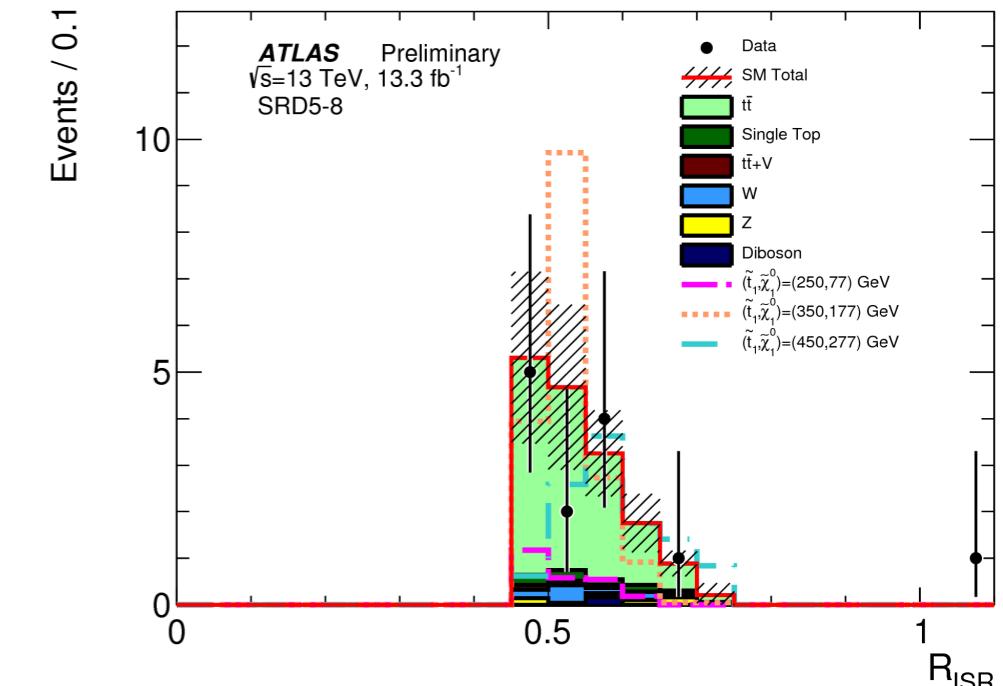
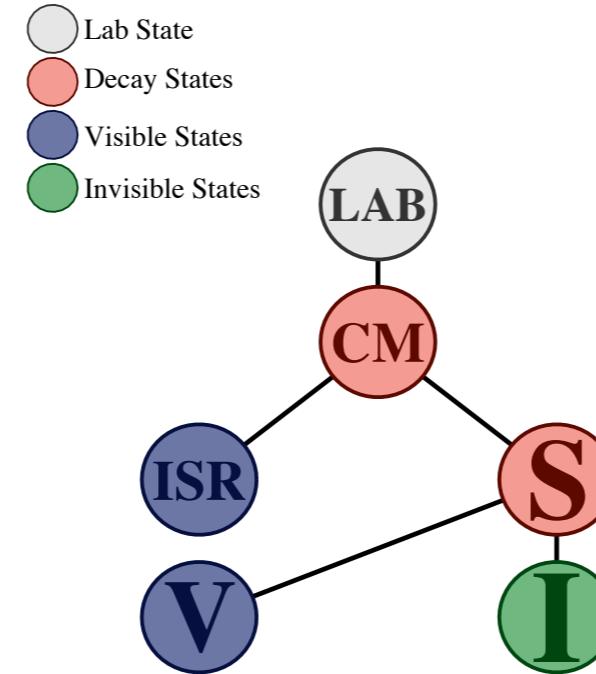
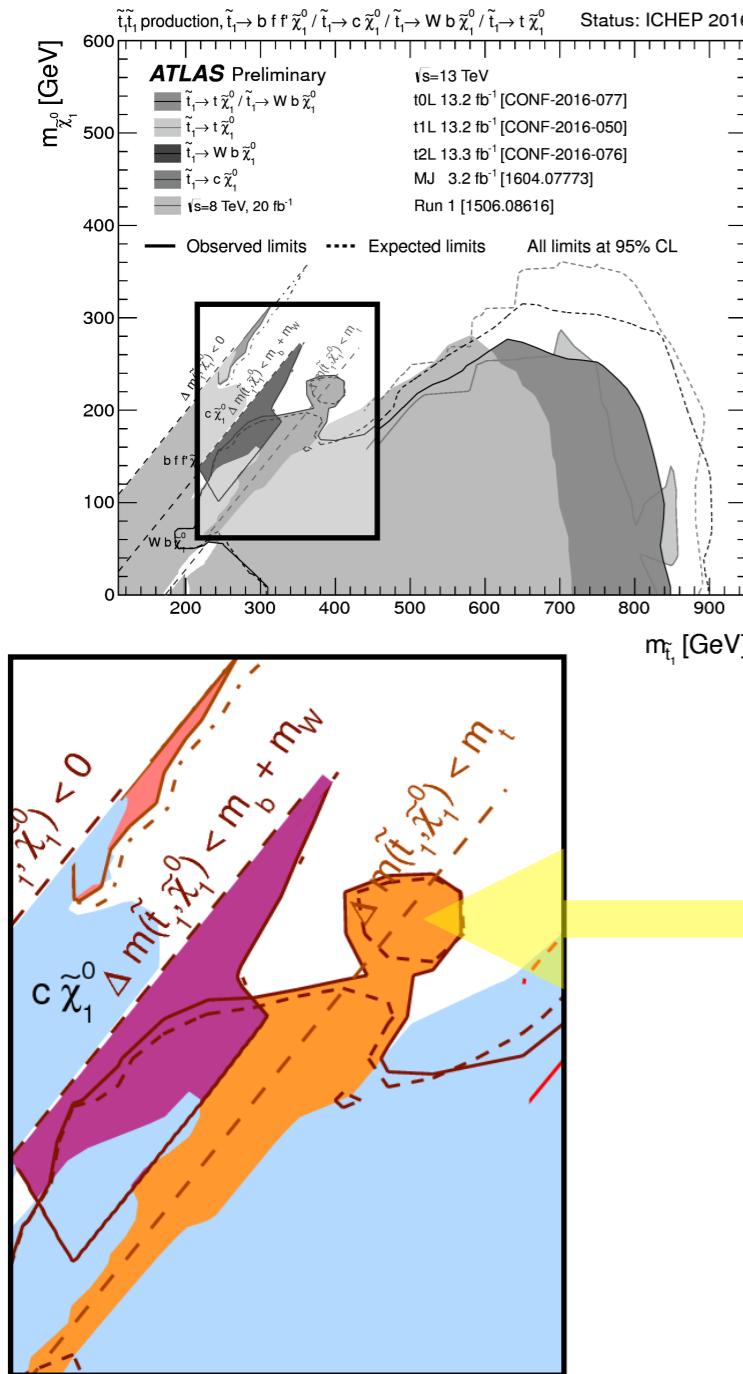
LET'S HIGHLIGHT A  
FEW REGIONS

# HEAVY STOPS



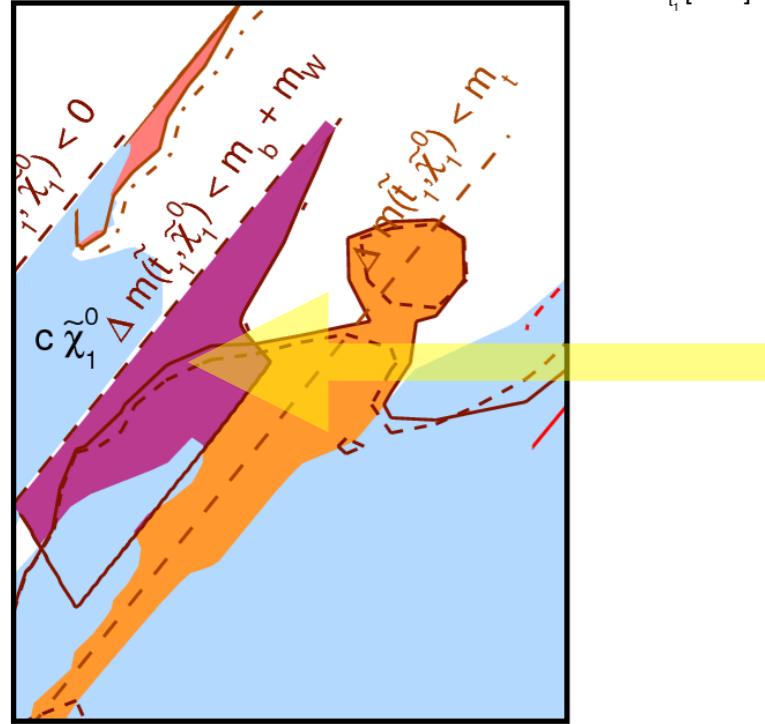
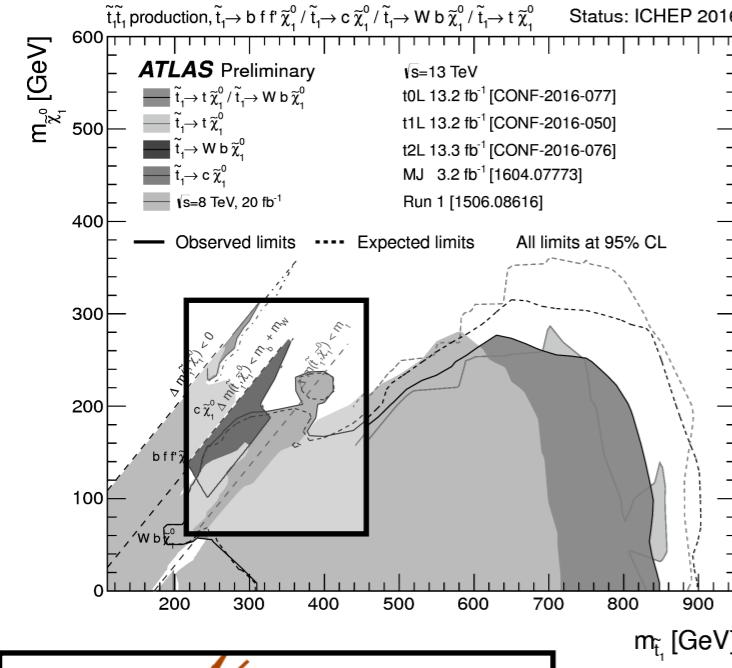
- For heavy stops, few hundred percent increase in production XS!
- No surprise that Run 2 would bring big increases in sensitivity in this region

# COMPRESSED REGIONS

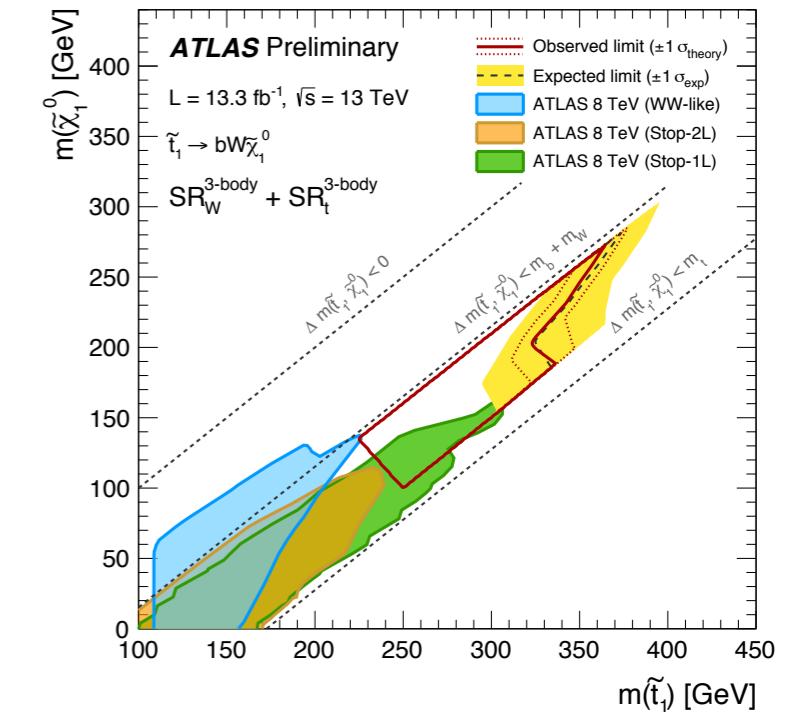
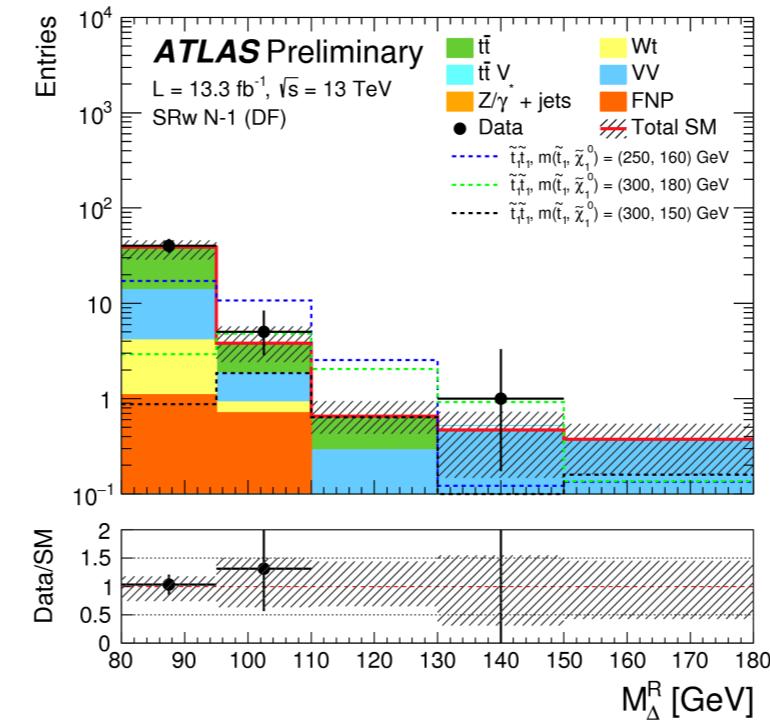


- However these regions can only be probed with new techniques
- $\Delta m \sim m_{\tilde{t}_1}$  region covered with *Recursive Jigsaw Reconstruction (RJR)* looking for ISR-boosted stops
  - 0-Lepton Channel
  - Estimate boost from ISR system ( $p_T^{ISR}$ )
  - Sensitive variable RISR ~ Fraction of the signal system's boost that goes to form the measured MET

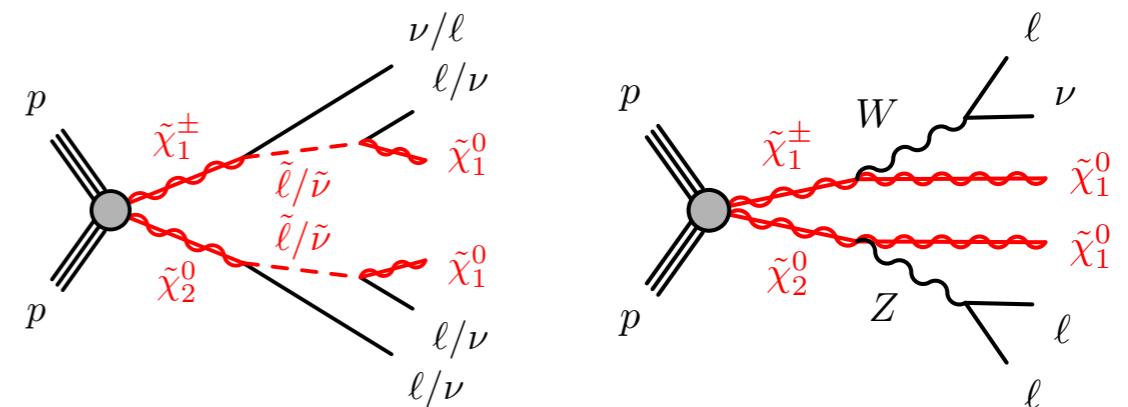
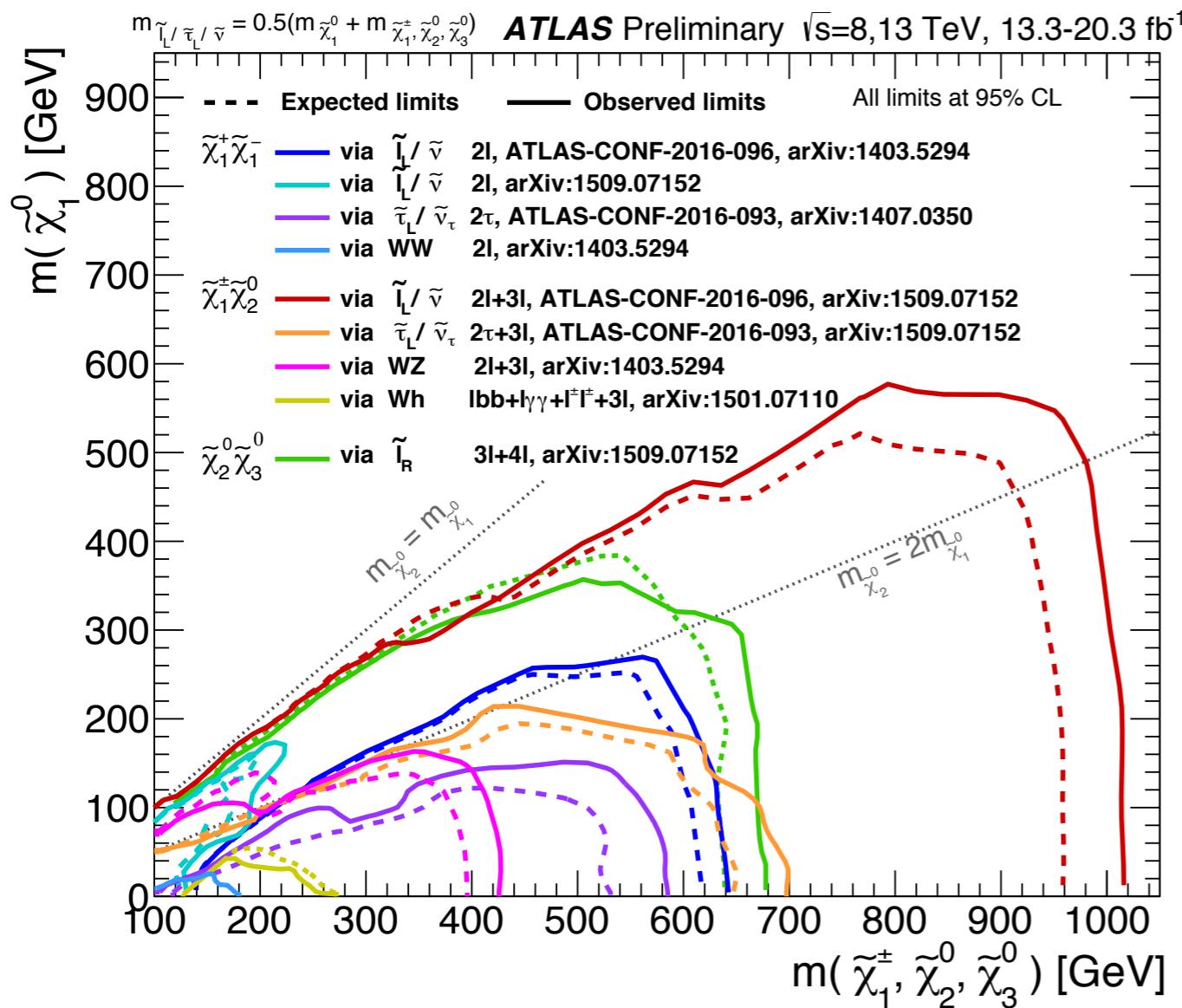
# COMPRESSED REGIONS



- $\Delta m \sim m_b + m_W$  region also with RJR
  - 2-Lepton Channel
  - Here, the *superrazor* subset
  - Look for high mass-scales in  $WW(\rightarrow l\nu l\nu)$ -like topologies
- Carved out two new regions of unique sensitivity!



# EWKINOS



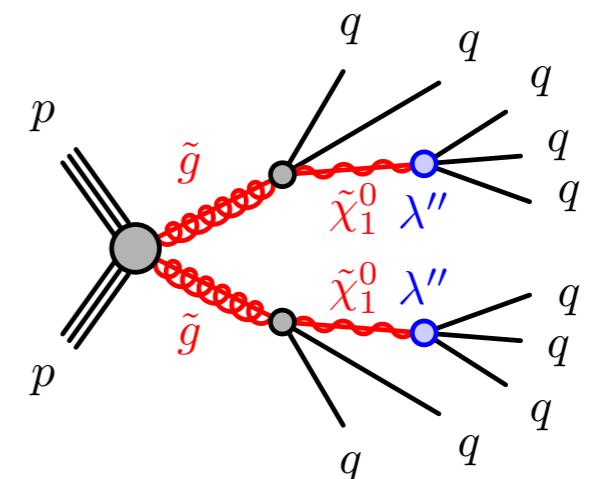
- Even lower cross sections from EWK production modes
- Reasonably strong limits as of Sept 2016
  - Three results from ICHEP+SEARCH
  - But the real fun comes with more data!
- Very impactful statements can start to be made with forthcoming datasets

## BUT WHY HAVEN'T WE FOUND IT YET?

1. *It doesn't exist*
2. *Masses are too high*
3. *Cross sections are too small*
4. *Assumptions are wrong*

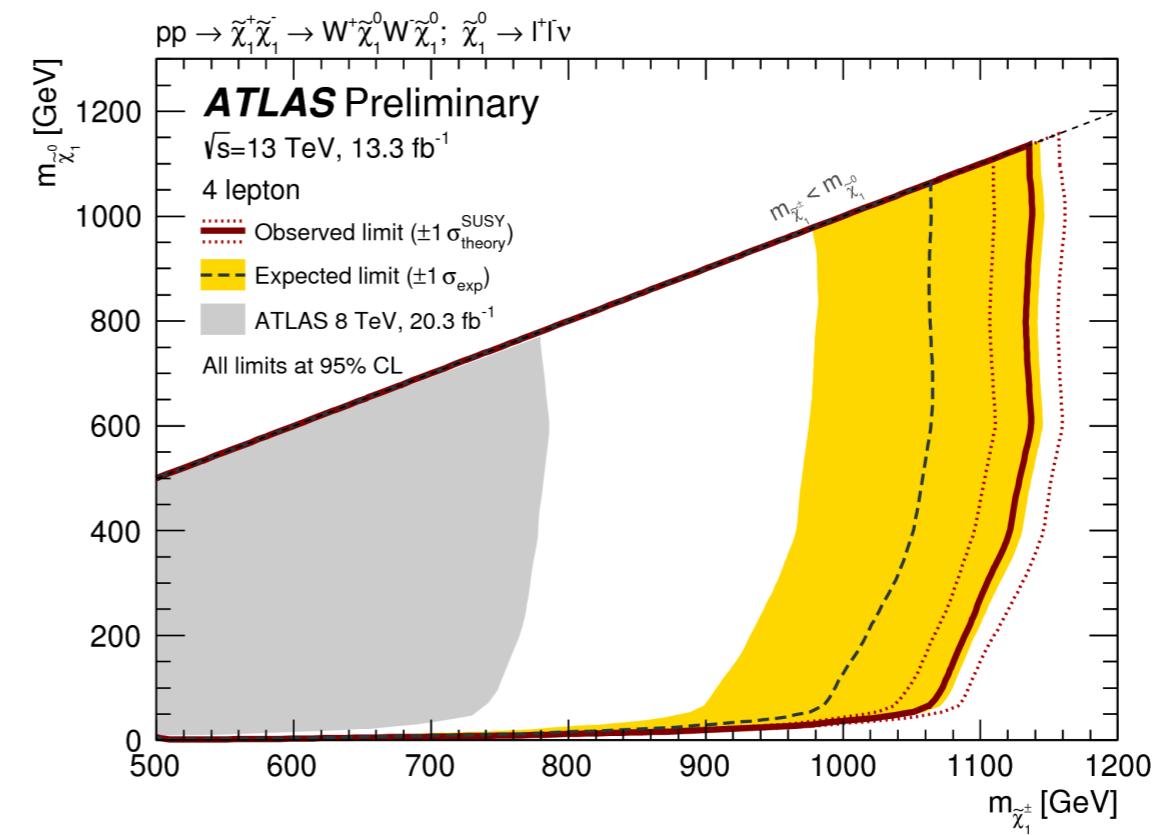
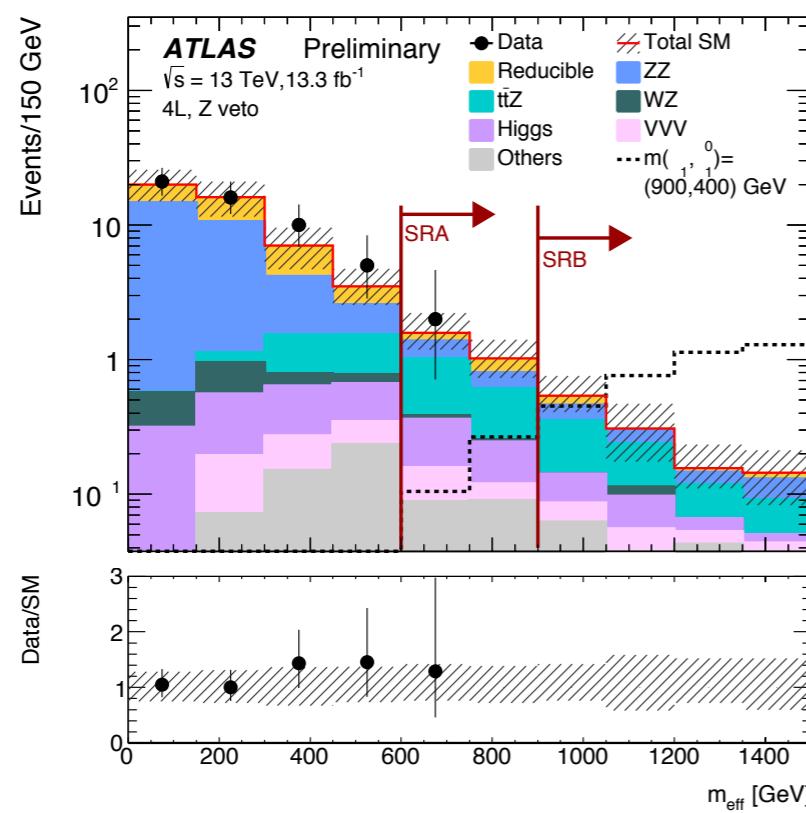
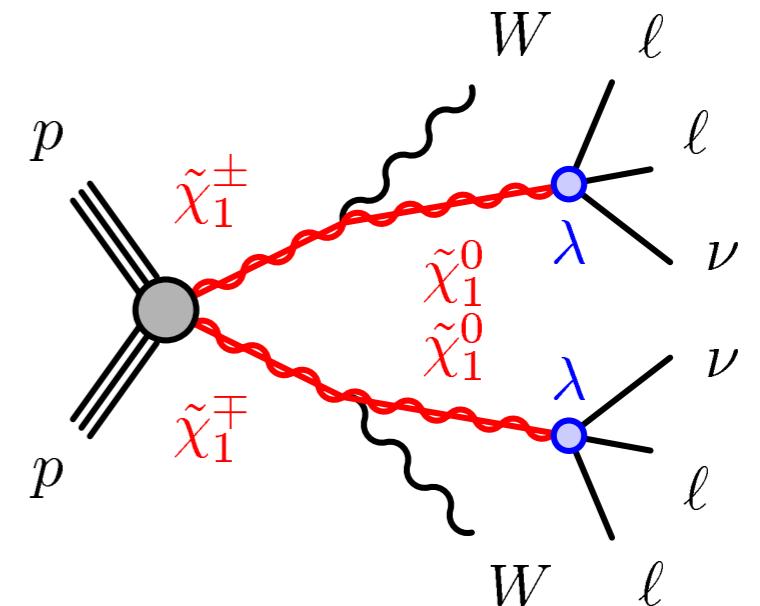
# R-PARITY VIOLATION

- What if R-Parity is violated and the LSP can decay?
    - Assumption of high MET falls apart
      - MET-based searches severely weakened!
    - Lightest neutralino probably not DM, but naturalness can still be restored!

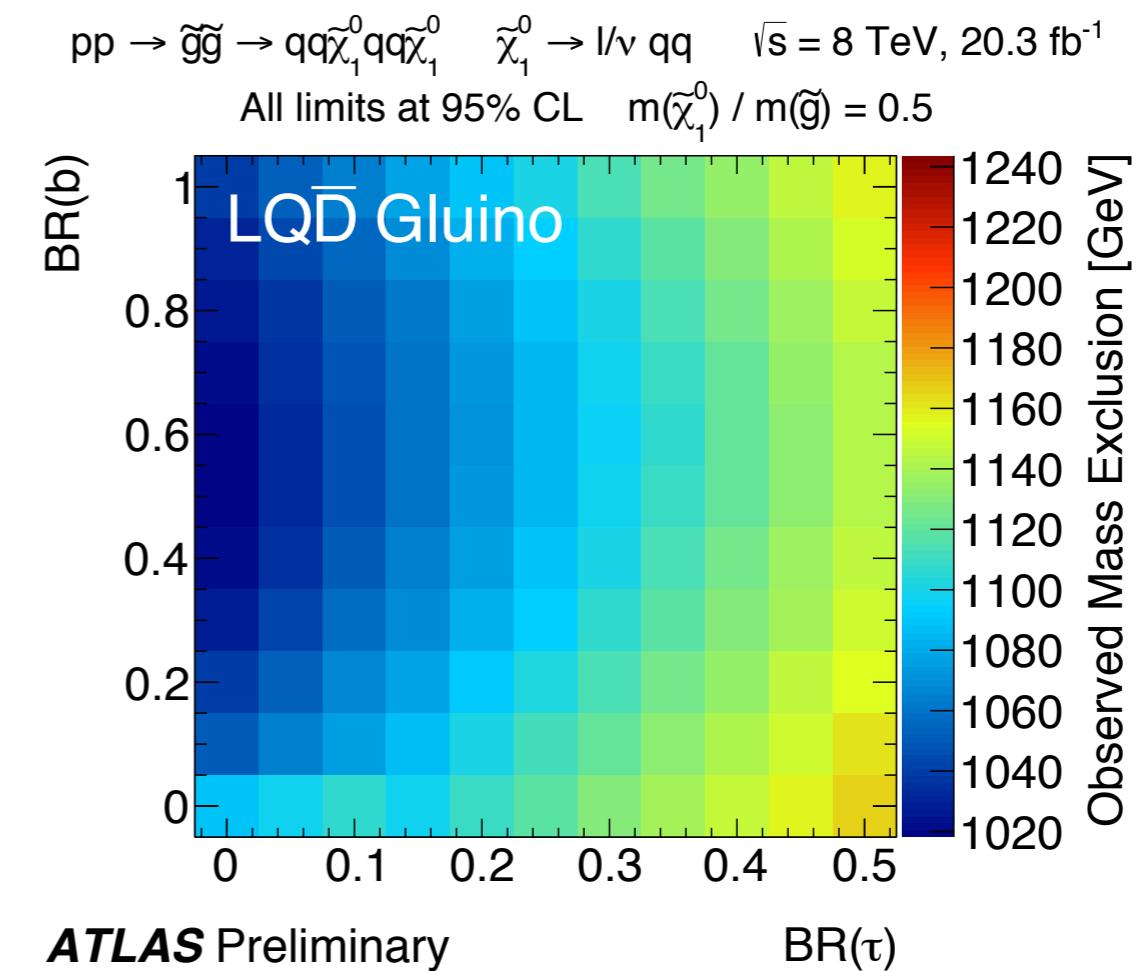
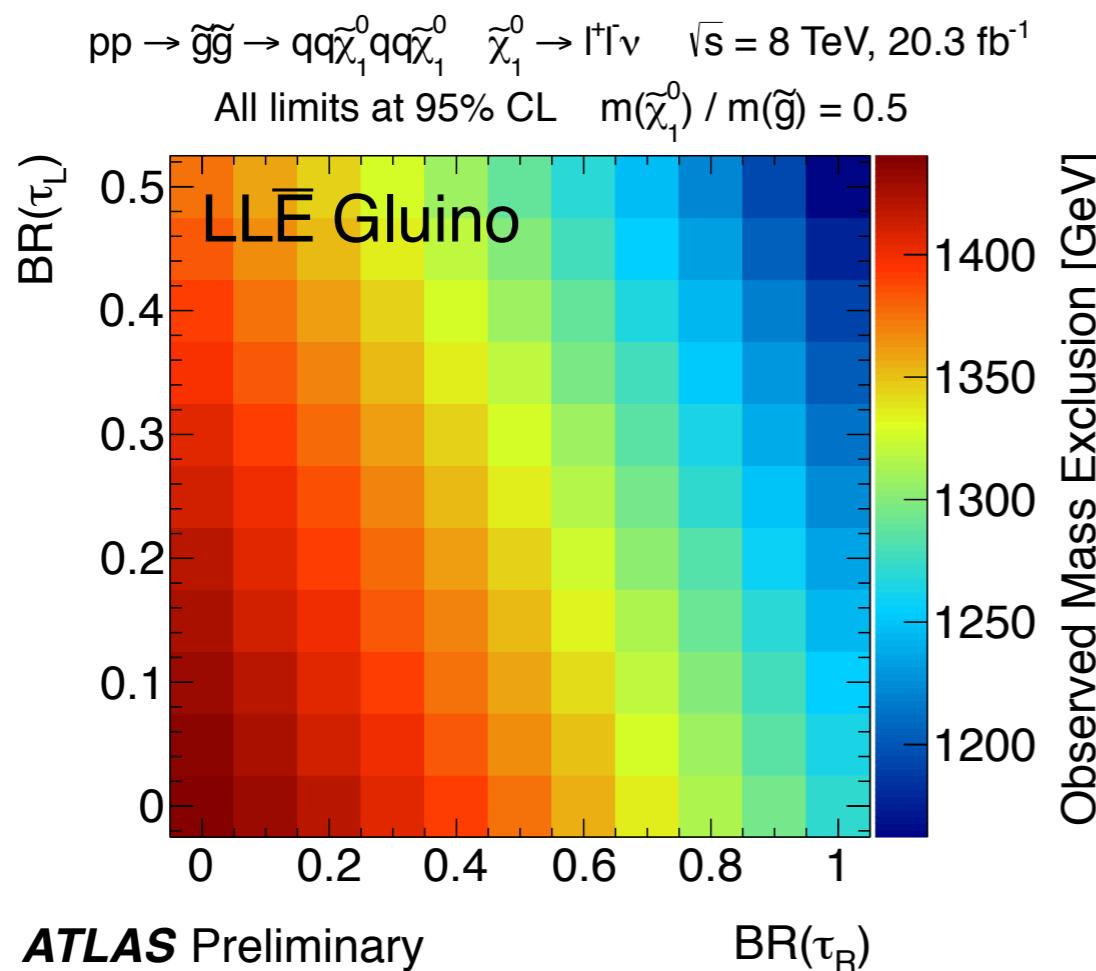


# LEPTON NUMBER VIOLATION

- Dedicated search for EWK production with  $\lambda \neq 0$  (LLE couplings)
- 4 reconstructed light leptons
- Veto any events containing a SF/OS lepton pair consistent with a  $Z$
- No explicit MET requirement
  - Just cuts on  $m_{\text{Eff}} := \text{MET} + \sum_{\text{Leptons, Jets}} p_T$

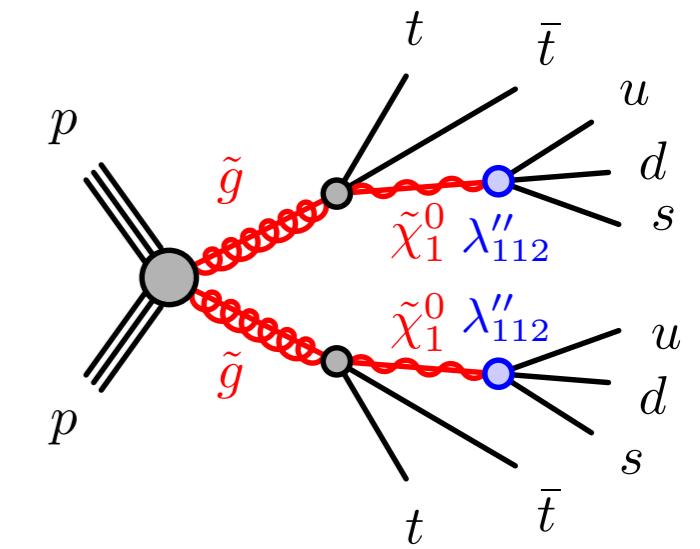
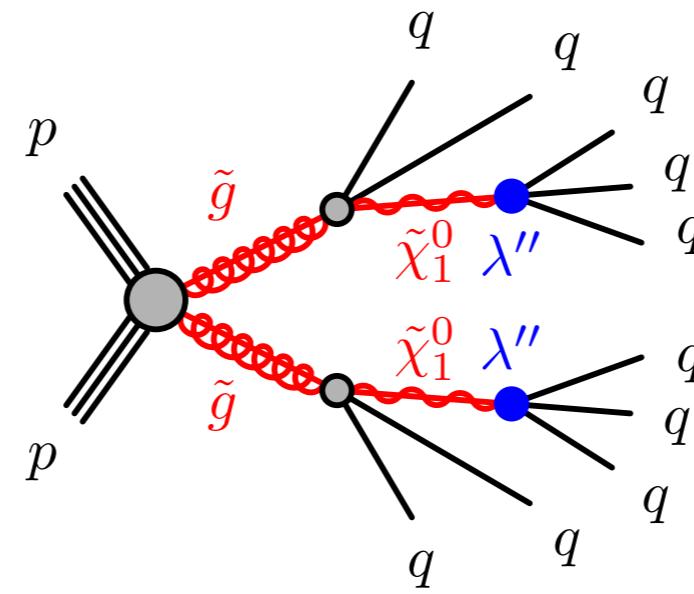
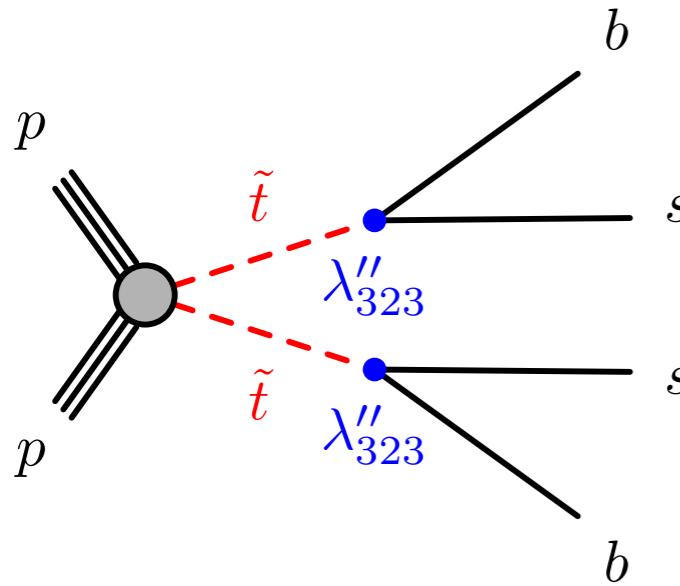
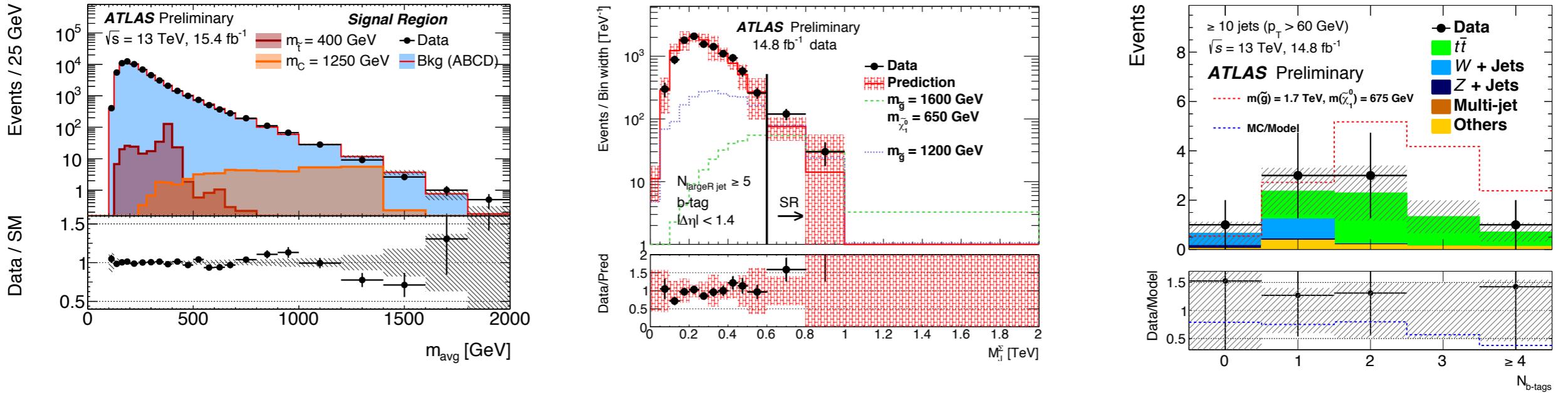


# LEPTON NUMBER VIOLATION



STRONG STATEMENTS FROM RUN-1 SUMMARY ON ALL KINDS OF SUSY L-VIOLATION

# BARYON NUMBER VIOLATION



## BUT WHY HAVEN'T WE FOUND IT YET?

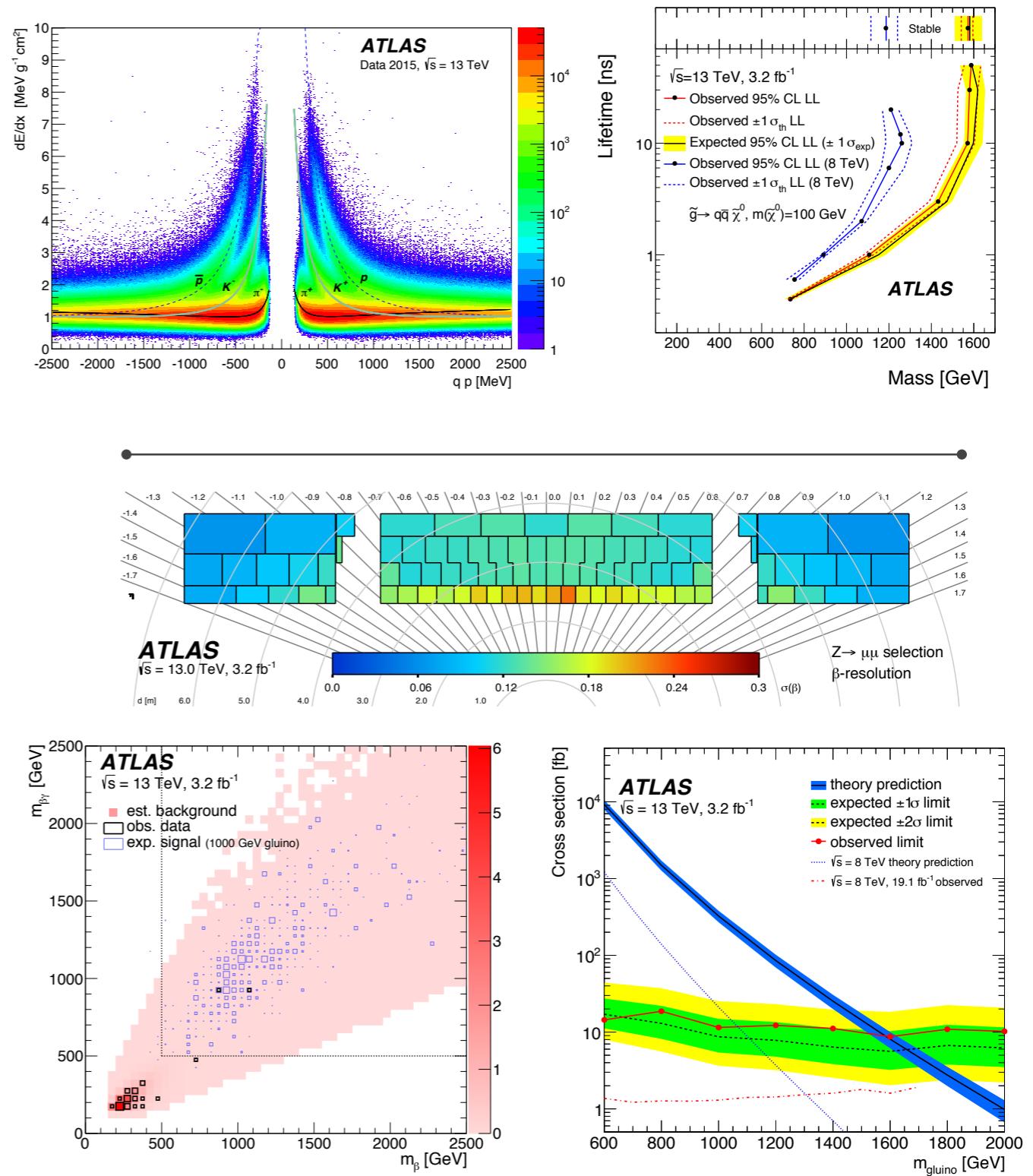
1. *It doesn't exist*
2. *Masses are too high*
3. *Cross sections are too small*
4. *Assumptions are wrong*
5. *Lifetimes are too high*

# LONG-LIVED SPARTICLES

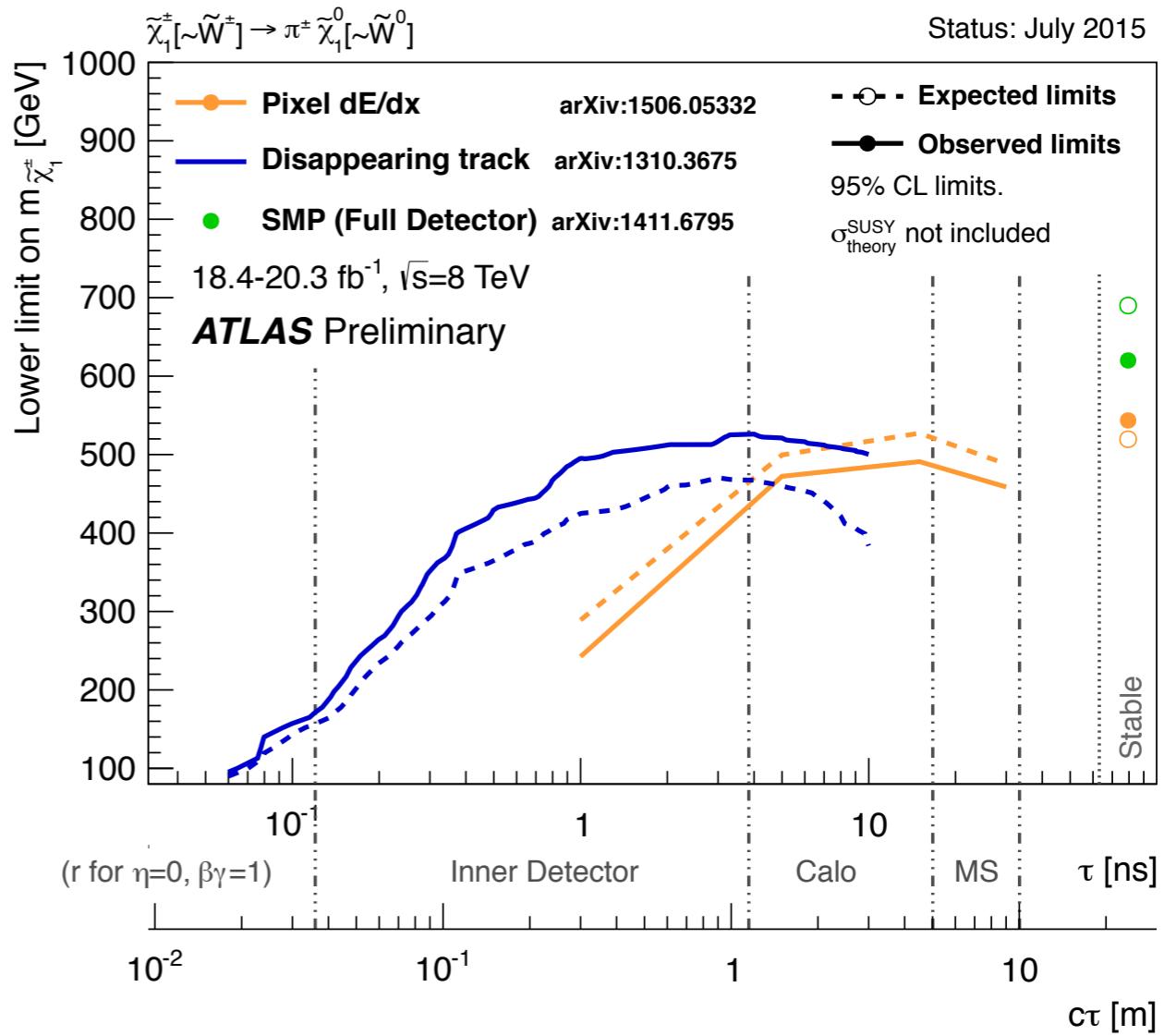
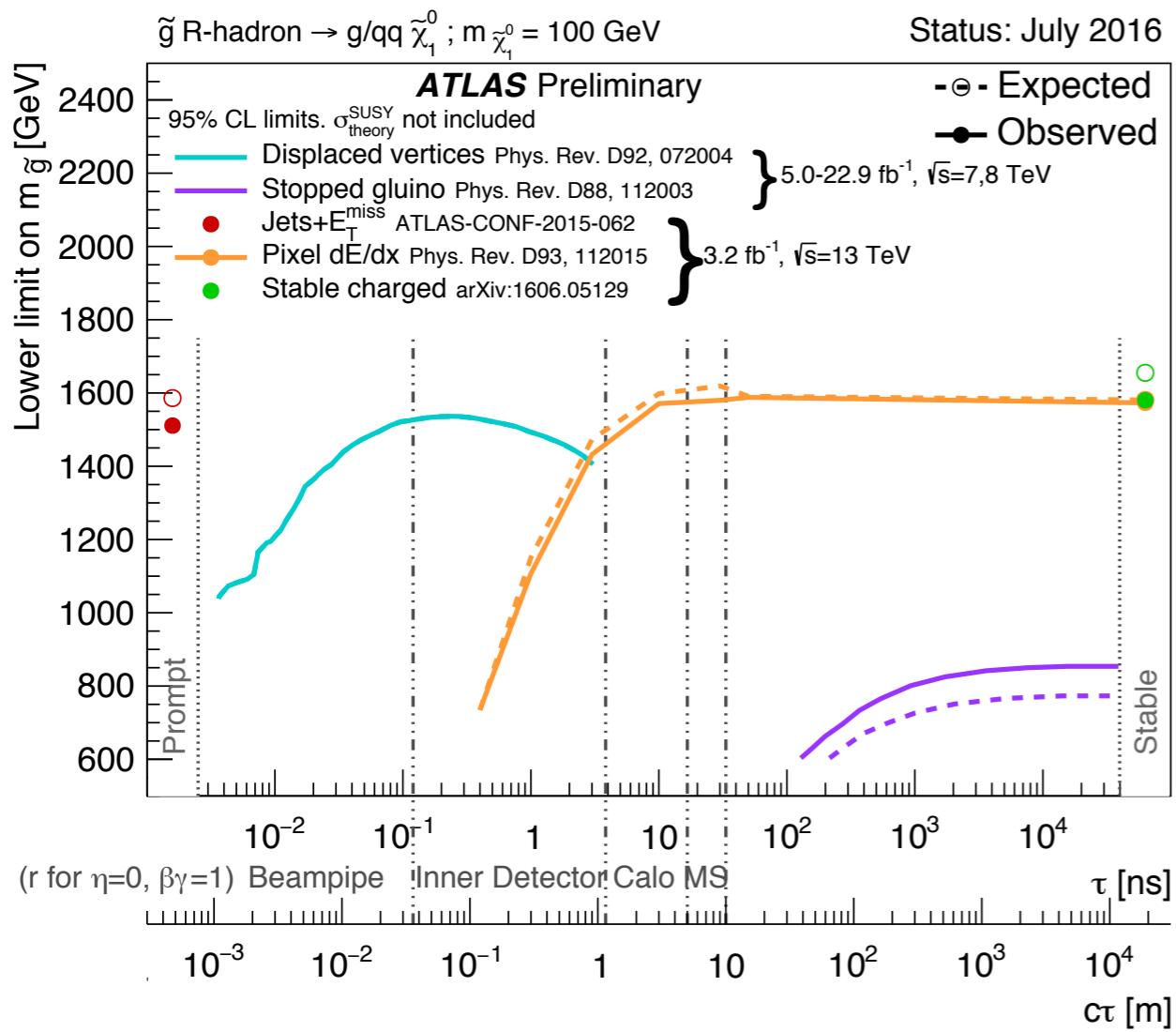
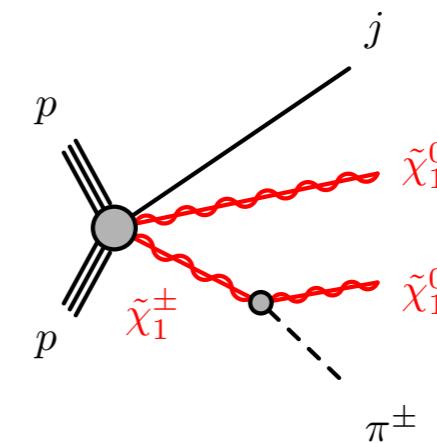
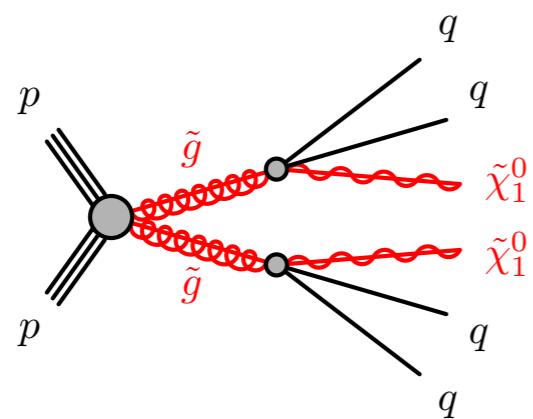
- Lifetimes of sparticles can easily be significantly nonzero
  - Split SUSY, Hidden Valleys, Very small mass splittings, tiny RPV couplings
- Example signatures:
  - Highly ionizing particles passing through tracker
  - Slow-moving heavy sparticles arriving at the detector late
  - Disappearing tracks
  - Displaced vertices in tracker
- If sparticles carry color (squarks/gluinos) and long-lived,
  - Will hadronize with SM particles to form R-Hadrons

# MASSIVE CHARGED R-HADRONS

- Can look for anomalous  $dE/dx$  curves in the pixel detector
  - Benefit from a new pixel layer 3.3 cm from beam line for Run-2
- Measure  $m_{\beta\gamma} \sim \frac{p}{\beta\gamma(dE/dx)}$
- Or combine this with calorimeter timing information
  - Search for (high  $m_\beta$  + high  $m_{\beta\gamma}$ )
  - Since cell-time resolution of 1.3-2.5 ns
  - Calo  $\beta$  resolution < 20-30%



# LONG-LIVED SPARTICLES



# UNFORTUNATELY ...

We have no evidence of SUSY

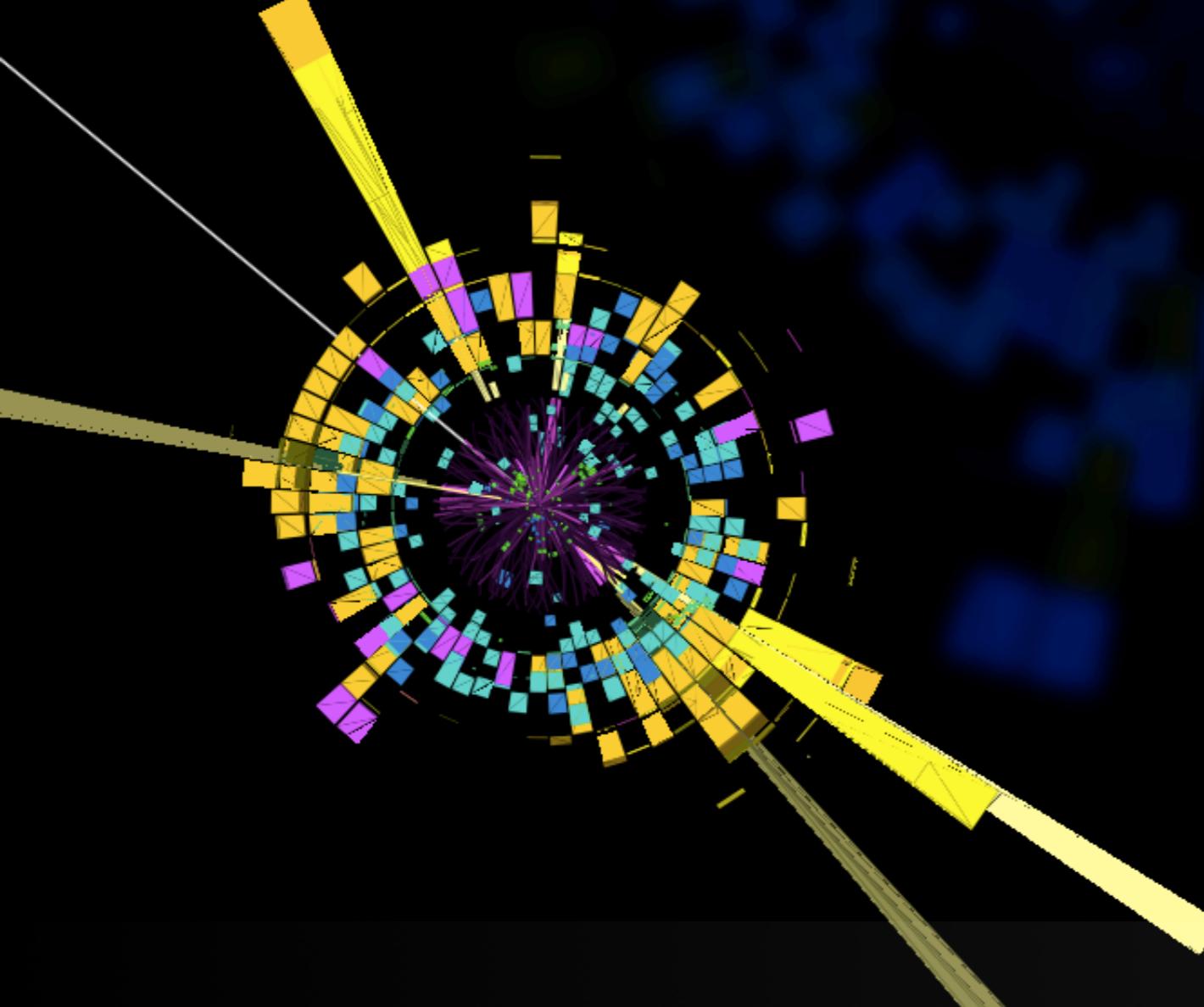
## ATLAS SUSY Searches\* - 95% CL Lower Limits

Status: August 2016

Model	$e, \mu, \tau, \gamma$	Jets	$E_T^{\text{miss}}$	$\int \mathcal{L} dt [\text{fb}^{-1}]$	Mass limit	$\sqrt{s} = 7, 8 \text{ TeV}$	$\sqrt{s} = 13 \text{ TeV}$	Reference
Inclusive Searches	MSUGRA/CMSSM	0-3 $e, \mu/1-2 \tau$	2-10 jets/3 $b$	Yes	20.3	$\tilde{q}, \tilde{g}$	1.85 TeV	$m(\tilde{q})=m(\tilde{g})$
	$\tilde{q}\tilde{q}, \tilde{q}\rightarrow q\tilde{\chi}_1^0$	0	2-6 jets	Yes	13.3	$\tilde{q}$	1.35 TeV	$m(\tilde{q})<200 \text{ GeV}, m(\text{1}^{\text{st}} \text{ gen. } \tilde{q})=m(\text{2}^{\text{nd}} \text{ gen. } \tilde{q})$
	$\tilde{q}\tilde{q}, \tilde{q}\rightarrow q\tilde{\chi}_1^0$ (compressed)	mono-jet	1-3 jets	Yes	3.2	$\tilde{q}$	608 GeV	$m(\tilde{q})<5 \text{ GeV}$
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow q\tilde{\chi}_1^0$	0	2-6 jets	Yes	13.3	$\tilde{g}$	1.86 TeV	$m(\tilde{g})=0 \text{ GeV}$
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow q\tilde{\chi}_1^\pm \rightarrow q q W^\pm \tilde{\chi}_1^0$	0	2-6 jets	Yes	13.3	$\tilde{g}$	1.83 TeV	$m(\tilde{g})<400 \text{ GeV}, m(\tilde{\chi}_1^\pm)=0.5(m(\tilde{\chi}_1^0)+m(\tilde{g}))$
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow q\tilde{q} \ell\ell/\nu\nu \tilde{\chi}_1^0$	3 $e, \mu$	4 jets	-	13.2	$\tilde{g}$	1.7 TeV	$m(\tilde{g})<400 \text{ GeV}$
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow q\tilde{q} W Z \tilde{\chi}_1^0$	2 $e, \mu$ (SS)	0-3 jets	Yes	13.2	$\tilde{g}$	1.6 TeV	$m(\tilde{g})<500 \text{ GeV}$
	GMSB ( $\ell$ NLSP)	1-2 $\tau + 0-1 \ell$	0-2 jets	Yes	3.2	$\tilde{g}$	2.0 TeV	$c\tau(\text{NLSP})<0.1 \text{ mm}$
	GGM (bino NLSP)	2 $\gamma$	-	Yes	3.2	$\tilde{g}$	1.65 TeV	$m(\tilde{g})<950 \text{ GeV}, c\tau(\text{NLSP})<0.1 \text{ mm}, \mu<0$
	GGM (higgsino-bino NLSP)	$\gamma$	1 $b$	Yes	20.3	$\tilde{g}$	1.37 TeV	$m(\tilde{g})<680 \text{ GeV}, c\tau(\text{NLSP})<0.1 \text{ mm}, \mu>0$
3 <sup>rd</sup> gen. squarks	GGM (higgsino NLSP)	$\gamma$	2 jets	Yes	13.3	$\tilde{g}$	1.8 TeV	$m(\text{NLSP})>430 \text{ GeV}$
	GGM (higgsino NLSP)	2 $e, \mu$ (Z)	2 jets	Yes	20.3	$\tilde{g}$	900 GeV	$m(\tilde{g})>1.8 \times 10^{-4} \text{ eV}, m(\tilde{g})=m(\tilde{q})=1.5 \text{ TeV}$
	Gravitino LSP	0	mono-jet	Yes	20.3	$F^{1/2} \text{ scale}$	865 GeV	$m(\tilde{G})>1.5 \text{ TeV}$
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow b\bar{b}\tilde{\chi}_1^0$	0	3 $b$	Yes	14.8	$\tilde{g}$	1.89 TeV	$m(\tilde{\chi}_1^0)=0 \text{ GeV}$
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow t\bar{t}\tilde{\chi}_1^0$	0-1 $e, \mu$	3 $b$	Yes	14.8	$\tilde{g}$	1.89 TeV	$m(\tilde{\chi}_1^0)=0 \text{ GeV}$
3 <sup>rd</sup> gen. direct production	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow b\bar{b}\tilde{\chi}_1^+$	0-1 $e, \mu$	3 $b$	Yes	20.1	$\tilde{g}$	1.37 TeV	$m(\tilde{\chi}_1^0)<300 \text{ GeV}$
	$\tilde{b}_1 \tilde{b}_1, \tilde{b}_1 \rightarrow b\tilde{\chi}_1^0$	0	2 $b$	Yes	3.2	$\tilde{b}_1$	840 GeV	$m(\tilde{\chi}_1^0)=100 \text{ GeV}$
	$\tilde{b}_1 \tilde{b}_1, \tilde{b}_1 \rightarrow \tilde{b}_1 \tilde{\chi}_1^\pm$	2 $e, \mu$ (SS)	1 $b$	Yes	13.2	$\tilde{b}_1$	325-685 GeV	$m(\tilde{\chi}_1^0)<150 \text{ GeV}, m(\tilde{\chi}_1^\pm)=m(\tilde{\chi}_1^0)+100 \text{ GeV}$
	$\tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow b\tilde{\chi}_1^\pm$	0-2 $e, \mu$	1-2 $b$	Yes	4.7/13.3	$\tilde{t}_1$	171-170 GeV	$m(\tilde{\chi}_1^\pm)=2m(\tilde{\chi}_1^0), m(\tilde{\chi}_1^0)=55 \text{ GeV}$
	$\tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow W b\tilde{\chi}_1^0$ or $t\tilde{\chi}_1^0$	0-2 $e, \mu$	0-2 jets/1-2 $b$	Yes	4.7/13.3	$\tilde{t}_1$	200-720 GeV	$m(\tilde{\chi}_1^0)=1 \text{ GeV}$
	$\tilde{t}_1 \tilde{t}_1 \rightarrow c\tilde{\chi}_1^0$	0	mono-jet	Yes	3.2	$\tilde{t}_1$	90-198 GeV	$m(\tilde{t}_1)-m(\tilde{\chi}_1^0)=5 \text{ GeV}$
	$\tilde{t}_1 \tilde{t}_1$ (natural GMSB)	2 $e, \mu$ (Z)	1 $b$	Yes	20.3	$\tilde{t}_1$	90-323 GeV	$m(\tilde{\chi}_1^0)>150 \text{ GeV}$
	$\tilde{t}_2 \tilde{t}_2, \tilde{t}_2 \rightarrow \tilde{t}_1 + Z$	3 $e, \mu$ (Z)	1 $b$	Yes	13.3	$\tilde{t}_2$	150-600 GeV	$m(\tilde{\chi}_1^0)<300 \text{ GeV}$
	$\tilde{t}_2 \tilde{t}_2, \tilde{t}_2 \rightarrow \tilde{t}_1 + h$	1 $e, \mu$	6 jets + 2 $b$	Yes	20.3	$\tilde{t}_2$	290-700 GeV	$m(\tilde{\chi}_1^0)=0 \text{ GeV}$
	$\tilde{t}_2 \tilde{t}_2 \rightarrow W \tilde{\chi}_1^0 Z \tilde{\chi}_1^0$	2-3 $e, \mu$	0-2 jets	Yes	20.3	$\tilde{t}_2 \tilde{t}_2$	320-620 GeV	$m(\tilde{\chi}_1^0)=0 \text{ GeV}$
EW direct	$\tilde{\ell}_{LR} \tilde{\ell}_{LR}, \tilde{\ell} \rightarrow \ell \tilde{\chi}_1^0$	2 $e, \mu$	0	Yes	20.3	$\tilde{\ell}$	90-335 GeV	$m(\tilde{\chi}_1^0)=0 \text{ GeV}$
	$\tilde{\chi}_1^+ \tilde{\chi}_1^-, \tilde{\chi}_1^+ \rightarrow \tilde{\nu} (\ell \tilde{\nu})$	2 $e, \mu$	0	Yes	13.3	$\tilde{\chi}_1^\pm$	640 GeV	$m(\tilde{\chi}_1^0)=0 \text{ GeV}, m(\tilde{\ell}, \tilde{\nu})=0.5(m(\tilde{\chi}_1^+)+m(\tilde{\chi}_1^0))$
	$\tilde{\chi}_1^+ \tilde{\chi}_1^-, \tilde{\chi}_1^+ \rightarrow \tilde{\tau} (\tilde{\tau} \tilde{\nu})$	2 $\tau$	-	Yes	14.8	$\tilde{\chi}_1^\pm$	580 GeV	$m(\tilde{\chi}_1^0)=0 \text{ GeV}, m(\tilde{\ell}, \tilde{\nu})=0.5(m(\tilde{\chi}_1^+)+m(\tilde{\chi}_1^0))$
	$\tilde{\chi}_1^\pm \tilde{\chi}_2^0 \rightarrow \tilde{\ell} \nu \tilde{\ell} \ell (\tilde{\ell} \tilde{\nu})$	3 $e, \mu$	0	Yes	13.3	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$	1.0 TeV	$m(\tilde{\chi}_1^0)=m(\tilde{\chi}_2^0), m(\tilde{\chi}_1^0)=m(\tilde{\chi}_2^0)$
	$\tilde{\chi}_1^\pm \tilde{\chi}_2^0 \rightarrow W \tilde{\chi}_1^0 Z \tilde{\chi}_1^0$	2-3 $e, \mu$	0-2 jets	Yes	20.3	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$	425 GeV	$m(\tilde{\chi}_1^0)=m(\tilde{\chi}_2^0), m(\tilde{\chi}_1^0)=0, \tilde{\ell} \text{ decoupled}$
	$\tilde{\chi}_1^\pm \tilde{\chi}_2^0 \rightarrow W \tilde{\chi}_1^0 h \tilde{\chi}_1^0, h \rightarrow b\bar{b}/WW/\tau\tau/\gamma\gamma$	2 $e, \mu, \gamma$	0-2 $b$	Yes	20.3	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$	270 GeV	$m(\tilde{\chi}_1^0)=m(\tilde{\chi}_2^0), m(\tilde{\chi}_1^0)=0, \tilde{\ell} \text{ decoupled}$
	$\tilde{\chi}_{2,3}^0, \tilde{\chi}_{2,3}^0 \rightarrow \tilde{\ell}_R \ell_L$	4 $e, \mu$	0	Yes	20.3	$\tilde{\chi}_{2,3}^0$	635 GeV	$m(\tilde{\chi}_1^0)=m(\tilde{\chi}_2^0), m(\tilde{\chi}_1^0)=0, m(\tilde{\ell}, \tilde{\nu})=0.5(m(\tilde{\chi}_1^0)+m(\tilde{\chi}_1^0))$
	GGM (wino NLSP) weak prod.	1 $e, \mu + \gamma$	-	Yes	20.3	$\tilde{W}$	115-370 GeV	$c\tau<1 \text{ mm}$
	GGM (bino NLSP) weak prod.	2 $\gamma$	-	Yes	20.3	$\tilde{W}$	590 GeV	$c\tau<1 \text{ mm}$
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	$m(\tilde{\chi}_1^\pm)-m(\tilde{\chi}_1^0)\sim 160 \text{ MeV}, \tau(\tilde{\chi}_1^\pm)=0.2 \text{ ns}$
	Direct $\tilde{\chi}_1^+ \tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^\pm$	dE/dx trk	-	Yes	18.4	$\tilde{\chi}_1^\pm$	495 GeV	$m(\tilde{\chi}_1^\pm)-m(\tilde{\chi}_1^0)\sim 160 \text{ MeV}, \tau(\tilde{\chi}_1^\pm)<15 \text{ ns}$
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	27.9	$\tilde{g}$	850 GeV	$m(\tilde{\chi}_1^0)=100 \text{ GeV}, 10 \mu\text{s}<\tau(\tilde{g})<1000 \text{ s}$
	Stable $\tilde{g}$ R-hadron	trk	-	-	3.2	$\tilde{g}$	1.58 TeV	$m(\tilde{\chi}_1^0)=100 \text{ GeV}, \tau>10 \text{ ns}$
	Metastable $\tilde{g}$ R-hadron	dE/dx trk	-	-	3.2	$\tilde{g}$	1.57 TeV	$10<\tan\beta<50$
	GMSB, stable $\tilde{\tau}, \tilde{\chi}_1^0 \rightarrow \tilde{\tau} (\tilde{e}, \tilde{\mu}) + \tau (e, \mu)$	1-2 $\mu$	-	-	19.1	$\tilde{\tau}$	537 GeV	$10<\tan\beta<50$
	GMSB, $\tilde{\chi}_1^0 \rightarrow \gamma \tilde{G}$ , long-lived $\tilde{\chi}_1^0$	2 $\gamma$	-	Yes	20.3	$\tilde{\chi}_1^0$	440 GeV	$1<\tau(\tilde{\chi}_1^0)<3 \text{ ns}, \text{SPS8 model}$
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow ee/\nu e/\mu\nu$	displ. ee/ep/ep/ep	-	-	20.3	$\tilde{\chi}_1^0$	1.0 TeV	$7 < c\tau(\tilde{\chi}_1^0) < 740 \text{ mm}, m(\tilde{g})=1.3 \text{ TeV}$
	GGM $\tilde{g}\tilde{g}, \tilde{g}\rightarrow Z\tilde{G}$	displ. vtx + jets	-	-	20.3	$\tilde{\chi}_1^0$	1.0 TeV	$6 < c\tau(\tilde{\chi}_1^0) < 480 \text{ mm}, m(\tilde{g})=1.1 \text{ TeV}$
	LFV $pp \rightarrow \tilde{\nu}_\tau + X, \tilde{\nu}_\tau \rightarrow e\mu/\tau\mu/\tau\tau$	$e\mu, e\tau, \mu\tau$	-	-	3.2	$\tilde{\nu}_\tau$	1.9 TeV	$\lambda'_{311}=0.11, \lambda_{132/133/233}=0.07$
RPV	Bilinear RPV CMSSM	2 $e, \mu$ (SS)	0-3 $b$	Yes	20.3	$\tilde{q}, \tilde{g}$	1.45 TeV	$m(\tilde{q})=m(\tilde{g}), c\tau_{LS}<1 \text{ mm}$
	$\tilde{\chi}_1^+ \tilde{\chi}_1^-, \tilde{\chi}_1^+ \rightarrow W \tilde{\chi}_1^0, \tilde{\chi}_1^+ \rightarrow ee/\nu e/\mu\nu/\mu\nu$	4 $e, \mu$	-	Yes	13.3	$\tilde{\chi}_1^\pm$	1.14 TeV	$m(\tilde{\chi}_1^0)>400 \text{ GeV}, \lambda_{12k}\neq 0 \text{ (} k=1, 2 \text{)}$
	$\tilde{\chi}_1^+ \tilde{\chi}_1^-, \tilde{\chi}_1^+ \rightarrow W \tilde{\chi}_1^0, \tilde{\chi}_1^+ \rightarrow \tau\tau\nu_e, \nu\tau\nu_\tau$	3 $e, \mu + \tau$	-	Yes	20.3	$\tilde{\chi}_1^\pm$	450 GeV	$m(\tilde{\chi}_1^0)>0.2 \times m(\tilde{\chi}_1^0), \lambda_{133}\neq 0$
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow q\tilde{q}$	0	4-5 large- $R$ jets	-	14.8	$\tilde{g}$	1.08 TeV	$BR(\tilde{g}\rightarrow BR(b)=BR(c)=0\%)$
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow q\tilde{q} \tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow q\tilde{q}$	0	4-5 large- $R$ jets	-	14.8	$\tilde{g}$	1.55 TeV	$m(\tilde{\chi}_1^0)=800 \text{ GeV}$
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow t\bar{t}\tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow q\tilde{q}$	1 $e, \mu$	8-10 jets/0-4 $b$	-	14.8	$\tilde{g}$	1.75 TeV	$m(\tilde{\chi}_1^0)=700 \text{ GeV}$
	$\tilde{g}\tilde{g}, \tilde{g}\rightarrow \tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow bs$	1 $e, \mu$	8-10 jets/0-4 $b$	-	14.8	$\tilde{g}$	1.4 TeV	$625 \text{ GeV} < m(\tilde{t}_1) < 850 \text{ GeV}$
	$\tilde{t}_1 \tilde$							

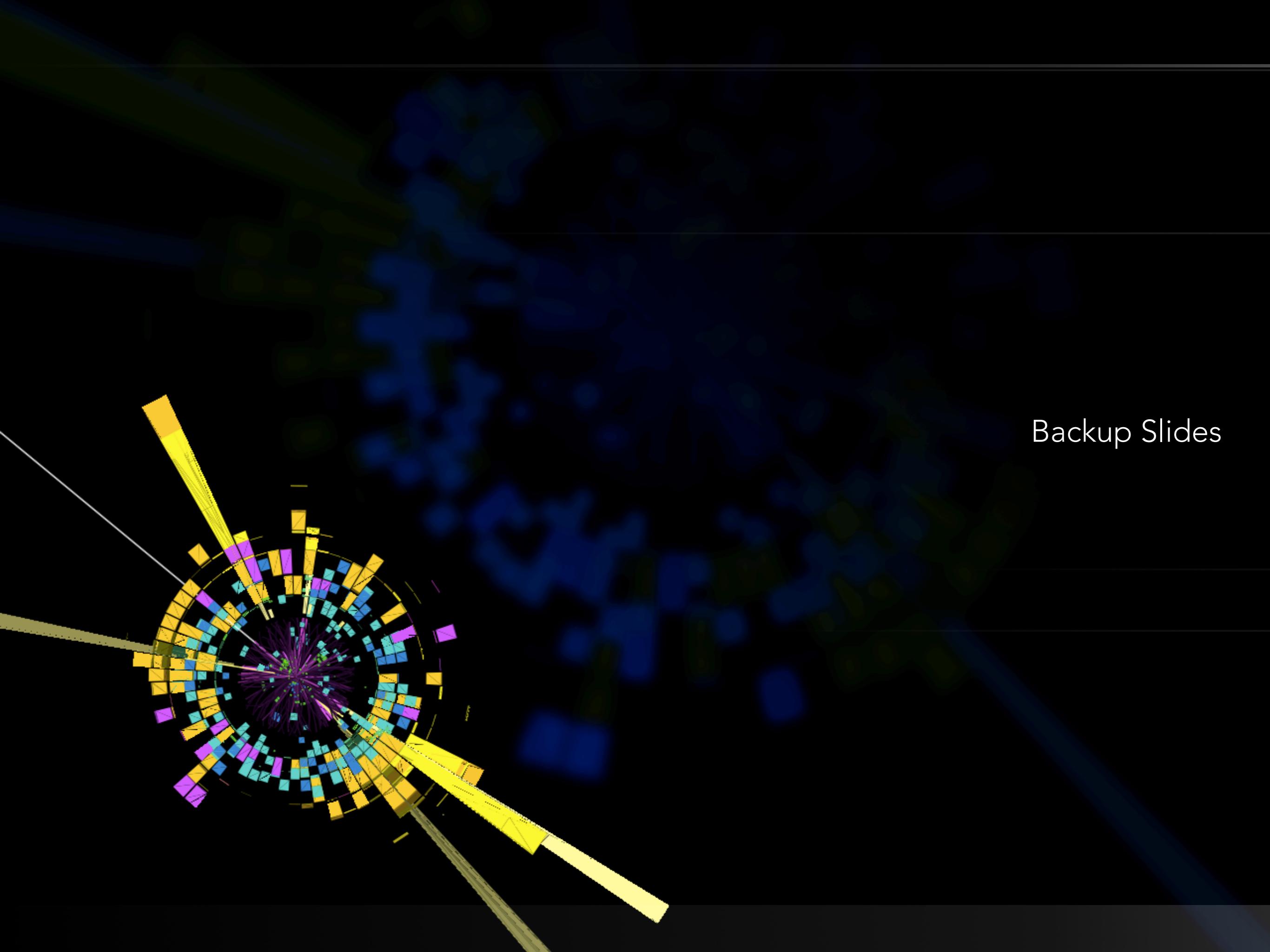
## BUT WHY HAVEN'T WE FOUND IT YET?

1. ~~*It doesn't exist*~~
2. *Masses are too high*
3. *Cross sections are too small*
4. *Assumptions are wrong*
5. *Lifetimes are too high*



...but stay tuned for more results  
at Moriond in a few weeks!

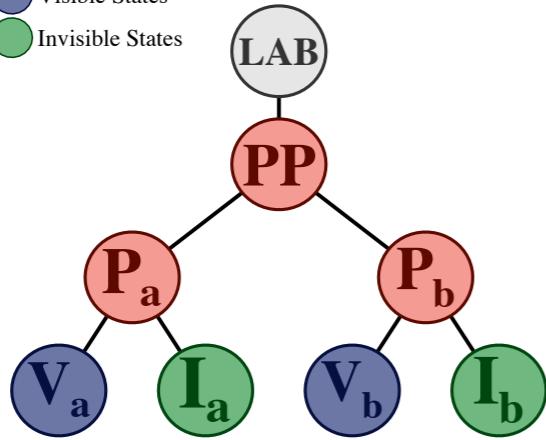
*Thanks for your attention*



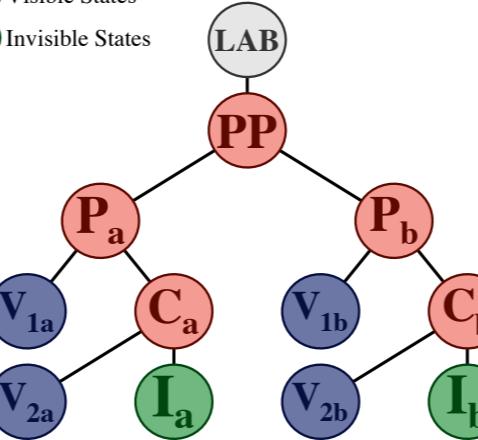
Backup Slides

# OL 2-6 JETS

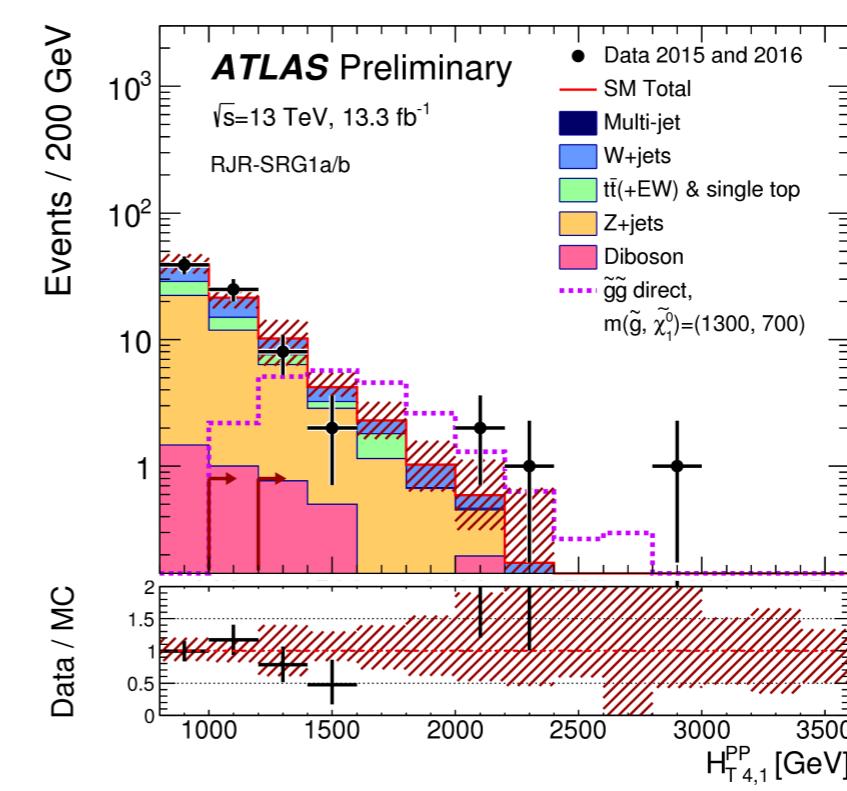
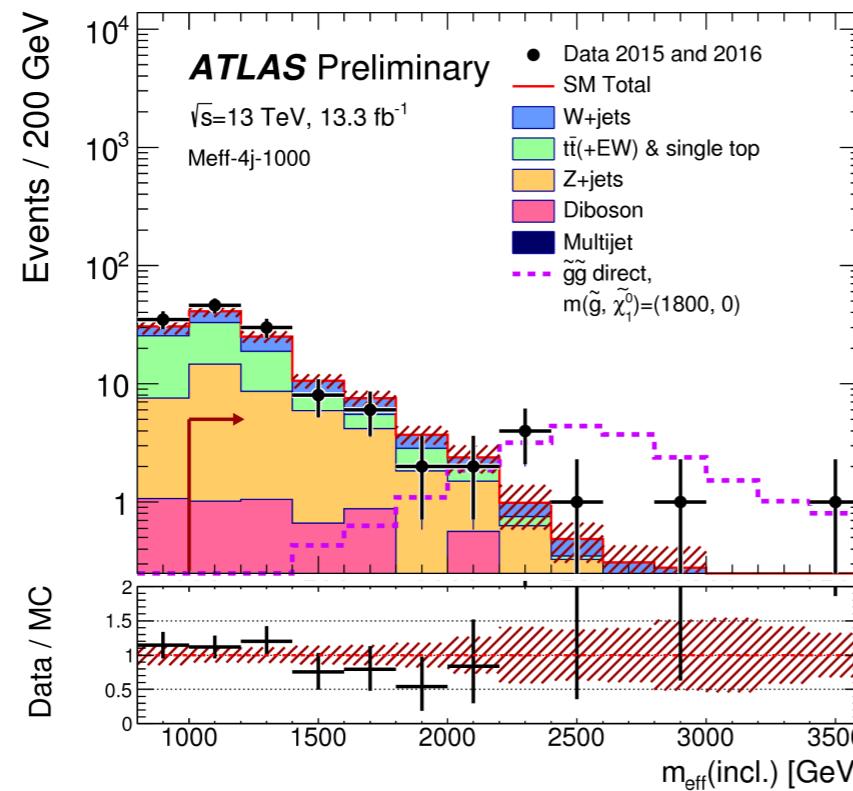
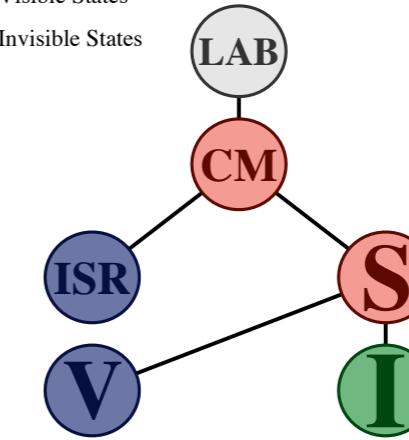
● Lab State  
● Decay States  
● Visible States  
● Invisible States



● Lab State  
● Decay States  
● Visible States  
● Invisible States



● Lab State  
● Decay States  
● Visible States  
● Invisible States



# OL 2-6 JETS

CR	SR background	CR process	CR selection (Meff-based)	CR selection (RJR-based)
Meff/RJR-CR $\gamma$	$Z(\rightarrow \nu\bar{\nu}) + \text{jets}$	$\gamma + \text{jets}$	Isolated photon	Isolated photon
Meff/RJR-CRQ	Multi-jet	Multi-jet	SR with reversed requirements on (i) $\Delta\phi(\text{jet}, \mathbf{E}_T^{\text{miss}})_{\text{min}}$ and (ii) $E_T^{\text{miss}}/m_{\text{eff}}(N_j)$ or $E_T^{\text{miss}}/\sqrt{H_T}$	$\Delta_{\text{QCD}} < 0$ reversed requirement on $H_{1,1}^{\text{PP}}$ (RJR-S/G) or $R_{\text{ISR}} < 0.5$ (RJR-C)
Meff/RJR-CRW	$W(\rightarrow \ell\nu) + \text{jets}$	$W(\rightarrow \ell\nu) + \text{jets}$	$30 \text{ GeV} < m_T(\ell, E_T^{\text{miss}}) < 100 \text{ GeV}$ , b-veto	
Meff/RJR-CRT	$t\bar{t} (+\text{EW})$ and single top	$t\bar{t} \rightarrow b\bar{b}qq'\ell\nu$	$30 \text{ GeV} < m_T(\ell, E_T^{\text{miss}}) < 100 \text{ GeV}$ , b-tag	

Targeted signal	$\tilde{q}\tilde{q}, \tilde{q} \rightarrow q\tilde{\chi}_1^0$				
Requirement	Signal Region				
	Meff-2j-800	Meff-2j-1200	Meff-2j-1600	Meff-2j-2000	Meff-3j-1200
$E_T^{\text{miss}} [\text{GeV}] >$	250				
$p_T(j_1) [\text{GeV}] >$	200	250		600	
$p_T(j_2) [\text{GeV}] >$	200	250		50	
$p_T(j_3) [\text{GeV}] >$		—		50	
$ \eta(j_{1,2})  <$	0.8	1.2		—	
$\Delta\phi(\text{jet}_{1,2,(3)}, \mathbf{E}_T^{\text{miss}})_{\text{min}} >$		0.8		0.4	
$\Delta\phi(\text{jet}_{i>3}, \mathbf{E}_T^{\text{miss}})_{\text{min}} >$		0.4		0.2	
$E_T^{\text{miss}}/\sqrt{H_T} [\text{GeV}^{1/2}] >$	14	16	18	20	16
$m_{\text{eff}} (\text{incl.}) [\text{GeV}] >$	800	1200	1600	2000	1200

Targeted signal	$\tilde{q}\tilde{q}, \tilde{q} \rightarrow q\tilde{\chi}_1^0$		
Requirement	Signal Region		
	RJR-S1	RJR-S2	RJR-S3
$H_{1,1}^{\text{PP}}/H_{2,1}^{\text{PP}} \geq$	0.6	0.55	0.5
$H_{1,1}^{\text{PP}}/H_{2,1}^{\text{PP}} \leq$	0.95	0.96	0.98
$p_{\text{PP}, z}^{\text{lab}} / (p_{\text{PP}, z}^{\text{lab}} + H_{T, 2, 1}^{\text{PP}}) \leq$	0.5	0.55	0.6
$p_{j_2, T}^{\text{PP}}/H_{T, 2, 1}^{\text{PP}} \geq$	0.16	0.15	0.13
$\Delta_{\text{QCD}} >$		0.001	
	RJR-S1a	RJR-S1b	RJR-S2a
$H_{T, 2, 1}^{\text{PP}} [\text{GeV}] >$	1000	1200	1400
	RJR-S2b	RJR-S3a	RJR-S3b
$H_{1,1}^{\text{PP}} [\text{GeV}] >$	1000	1400	1600

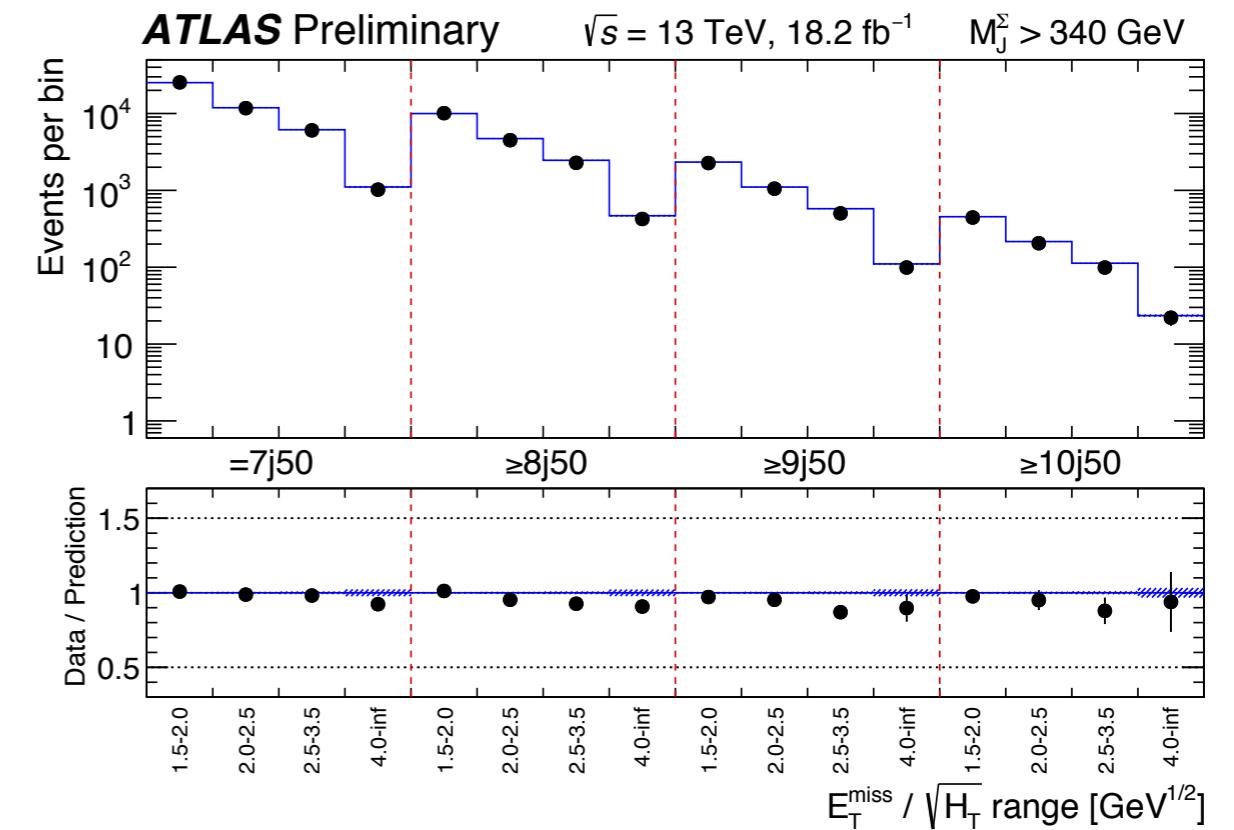
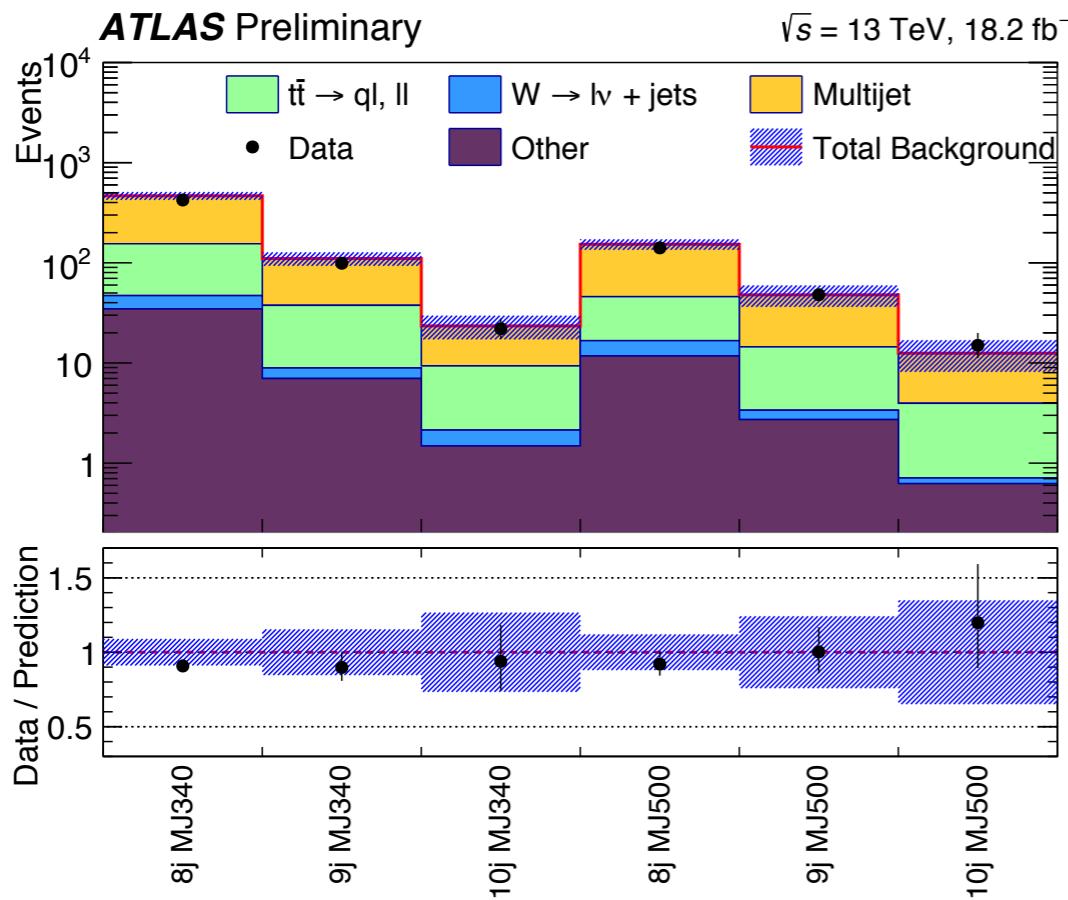
Targeted signal	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{\chi}_1^0$					
Requirement	Signal Region					
	Meff-4j-1000	Meff-4j-1400	Meff-4j-1800	Meff-4j-2200	Meff-4j-2600	Meff-5j-1400
$E_T^{\text{miss}} [\text{GeV}] >$	250					
$p_T(j_1) [\text{GeV}] >$		200			500	
$p_T(j_4) [\text{GeV}] >$	100		150		50	
$p_T(j_5) [\text{GeV}] >$		—			50	
$ \eta(j_{1,2,3,4})  <$	1.2	2.0		—		
$\Delta\phi(\text{jet}_{1,2,(3)}, \mathbf{E}_T^{\text{miss}})_{\text{min}} >$		0.4				
$\Delta\phi(\text{jet}_{i>3}, \mathbf{E}_T^{\text{miss}})_{\text{min}} >$		0.4		0.2		
Aplanarity >		0.04			—	
$E_T^{\text{miss}}/m_{\text{eff}}(N_j) >$	0.25		0.2		0.3	
$m_{\text{eff}} (\text{incl.}) [\text{GeV}] >$	1000	1400	1800	2200	2600	1400

Targeted signal	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{\chi}_1^0$			
Requirement	Signal Region			
	RJR-G1	RJR-G2	RJR-G3	
$H_{1,1}^{\text{PP}}/H_{4,1}^{\text{PP}} \geq$	0.35	0.25	0.2	
$H_{T, 4, 1}^{\text{PP}}/H_{4, 1}^{\text{PP}} \geq$	0.8	0.75	0.65	
$p_{\text{PP}, z}^{\text{lab}} / (p_{\text{PP}, z}^{\text{lab}} + H_{T, 4, 1}^{\text{PP}}) \leq$	0.5	0.55	0.6	
$\min(p_{j_2, T}^{\text{PP}}/H_{T, 2, 1}^{\text{PP}}) \geq$	0.12	0.1	0.08	
$\max(H_{1, 0}^{\text{Pi}}/H_{2, 0}^{\text{Pi}}) \leq$	0.95	0.97	0.98	
$ \frac{2}{3}\Delta\phi_{V,P}^{\text{PP}} - \frac{1}{3}\cos\theta_p  \leq$	0.5	—	—	
$\Delta_{\text{QCD}} >$		0		
	RJR-G1a	RJR-G1b	RJR-G2a	RJR-G2b
$H_{T, 4, 1}^{\text{PP}} [\text{GeV}] >$	1000	1200	1500	1900
	RJR-G3a	RJR-G3b		
$H_{1,1}^{\text{PP}} [\text{GeV}] >$	600	800	2300	2800

Targeted signal	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q}W\tilde{\chi}_1^0$		
Requirement	Signal Region		
	Meff-6j-1800	Meff-6j-2200	
$E_T^{\text{miss}} [\text{GeV}] >$	250		
$p_T(j_1) [\text{GeV}] >$	200		
$p_T(j_6) [\text{GeV}] >$	50	100	
$ \eta(j_{1,...,6})  <$	2.0	—	
$\Delta\phi(\text{jet}_{1,2,(3)}, \mathbf{E}_T^{\text{miss}})_{\text{min}} >$		0.4	
$\Delta\phi(\text{jet}_{i>3}, \mathbf{E}_T^{\text{miss}})_{\text{min}} >$		0.2	
Aplanarity >		0.08	
$E_T^{\text{miss}}/m_{\text{eff}}(N_j) >$	0.2	0.15	
$m_{\text{eff}} (\text{incl.}) [\text{GeV}] >$	1800	2200	

Targeted signal	compressed spectra in $\tilde{q}\tilde{q} (\tilde{q} \rightarrow q\tilde{\chi}_1^0); \tilde{g}\tilde{g} (\tilde{g} \rightarrow q\tilde{\chi}_1^0)$				
Requirement	Signal Region				
	RJR-C1	RJR-C2	RJR-C3	RJR-C4	RJR-C5
$R_{\text{ISR}} \geq$	0.9	0.85	0.8	0.75	0.70
$\Delta\phi_{\text{ISR}, I} \geq$	3.1	3.07	2.95	2.95	2.95
$\Delta\phi(\text{jet}_{1,2}, \mathbf{E}_T^{\text{miss}})_{\text{min}} >$	-	-	-	0.4	0.4
$M_{\text{TS}} [\text{GeV}] \geq$	100	100	200	500	500
$p_{\text{TS}}^{\text{CM}} [\text{GeV}] \geq$	800	800	600	600	600
$N_{\text{jet}}^{\text{V}} \geq$	1	1	2	2	3

# OL 8-10 JETS

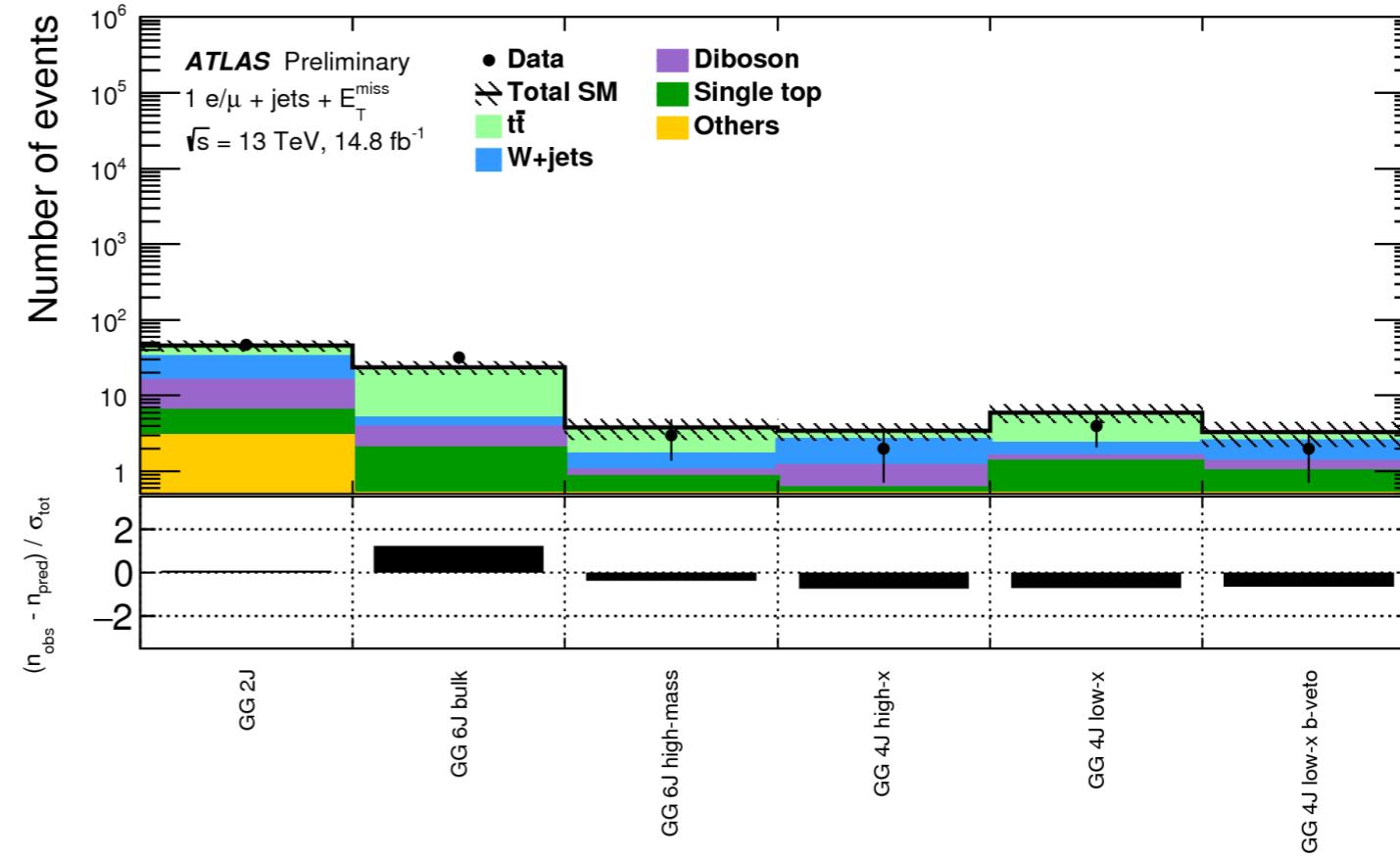
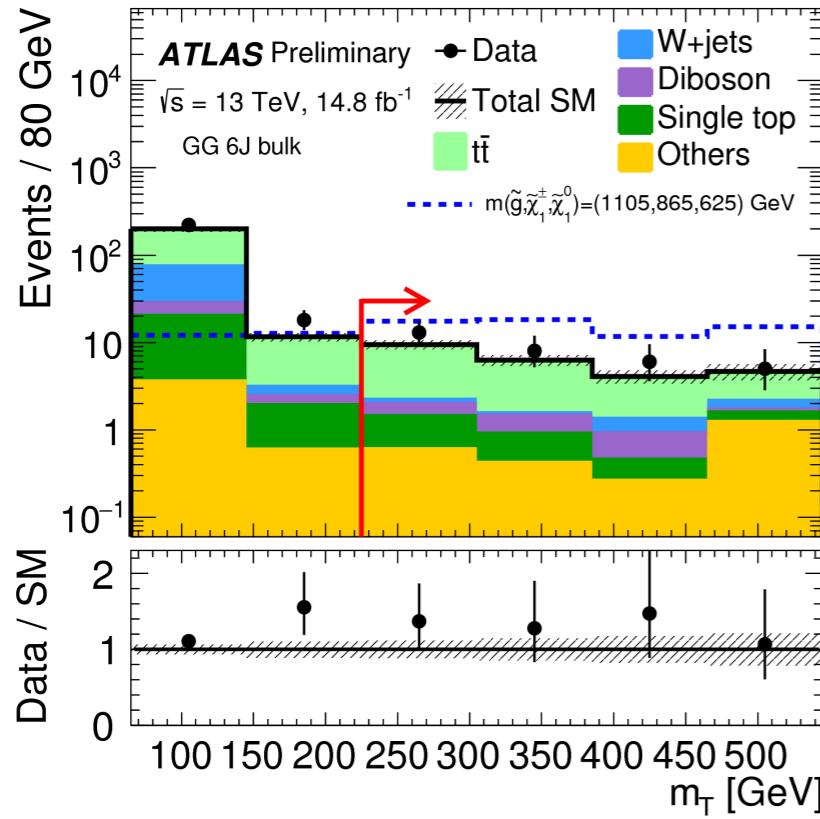



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Signal region	8j50	9j50	10j50
$R = 0.4 \text{ jet }  \eta $		$< 2.0$ for all SRs	
$R = 0.4 \text{ jet } p_T$		$> 50 \text{ GeV}$ for all SRs	
$N_{jet}$	$\geq 8$	$\geq 9$	$\geq 10$
$M_J^\Sigma$		$> 340 \text{ GeV}$ or $> 500 \text{ GeV}$	
$E_T^{\text{miss}} / \sqrt{H_T}$		$> 4 \text{ GeV}^{1/2}$ for all SRs	

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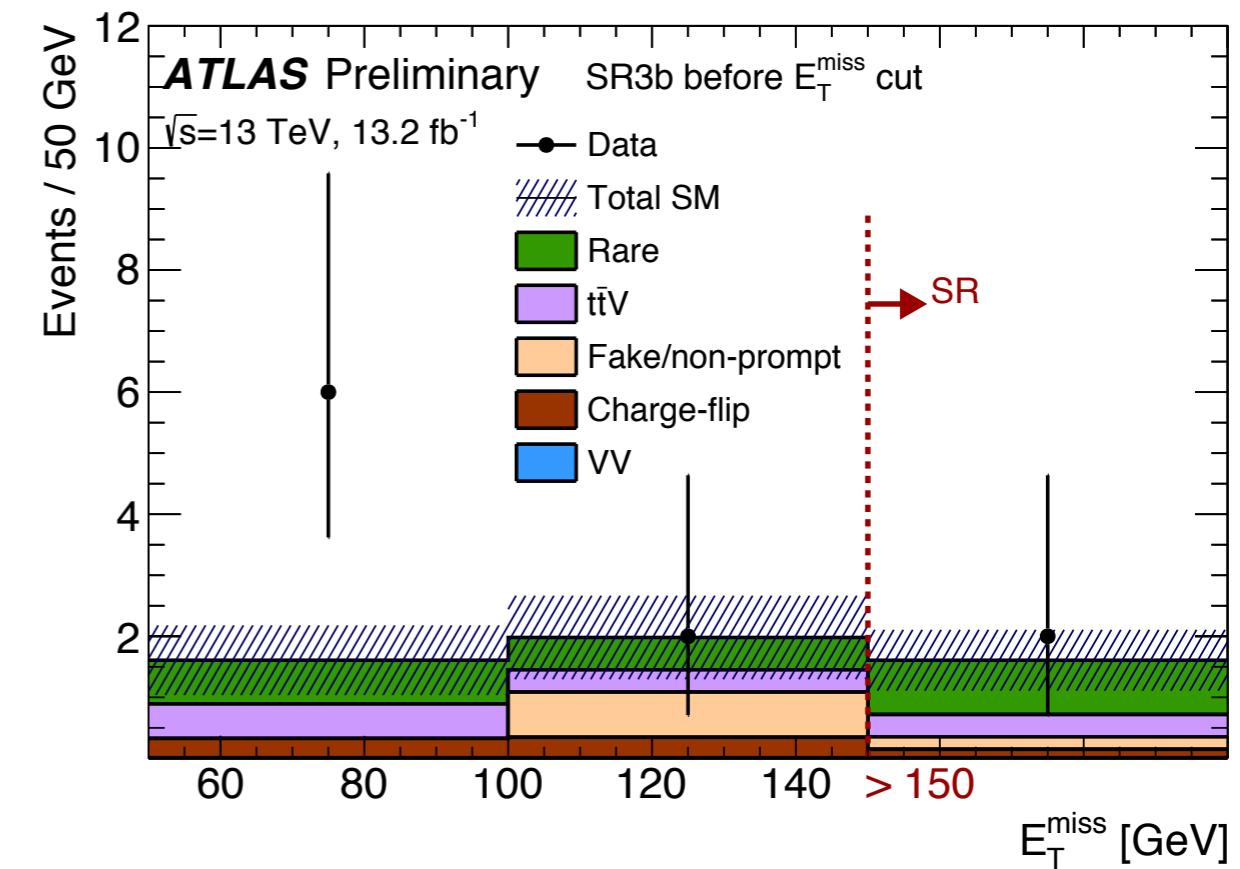
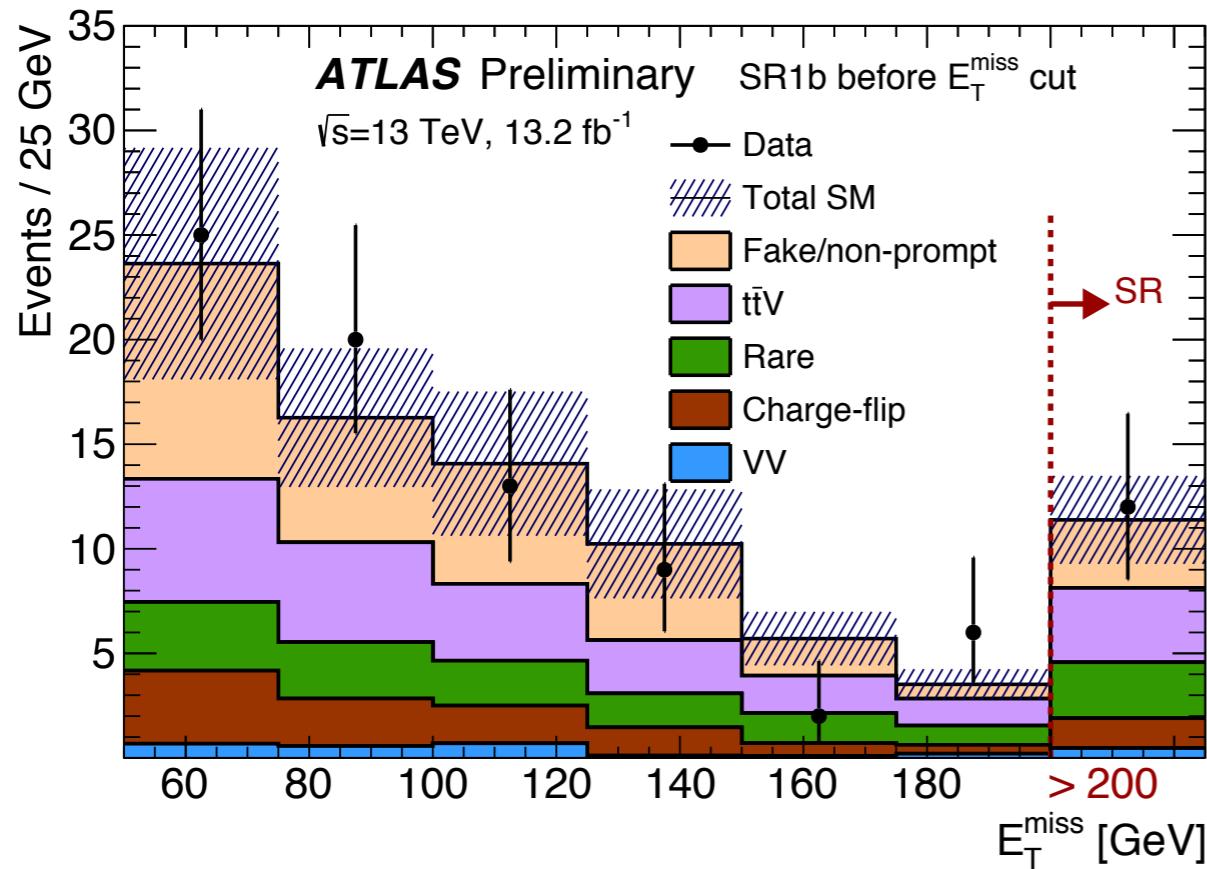
# 1 L + JETS + MET



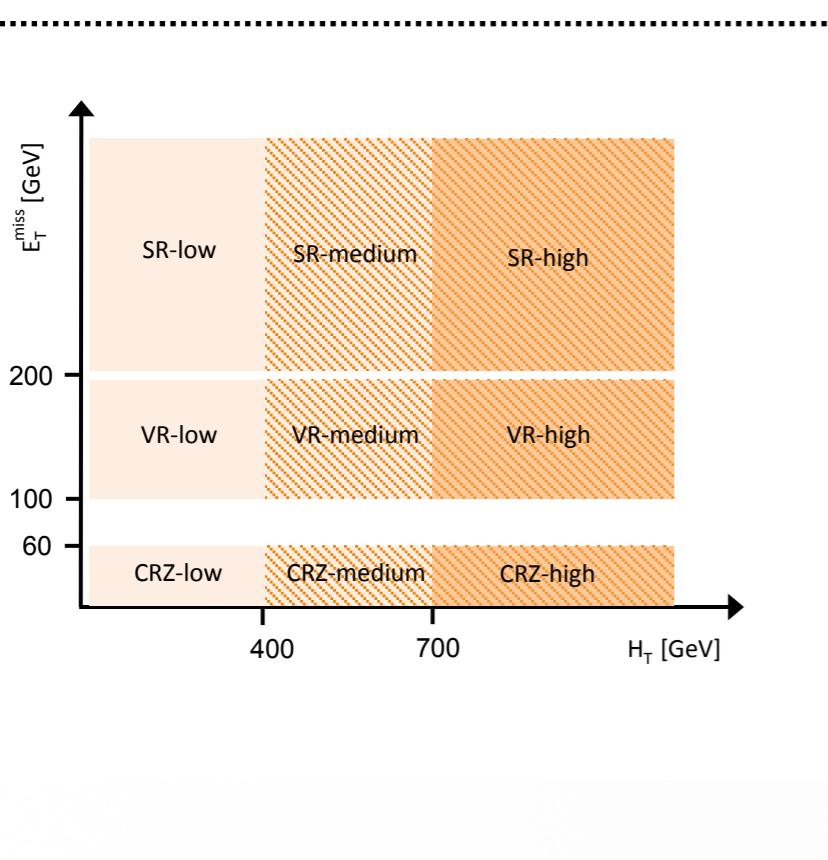
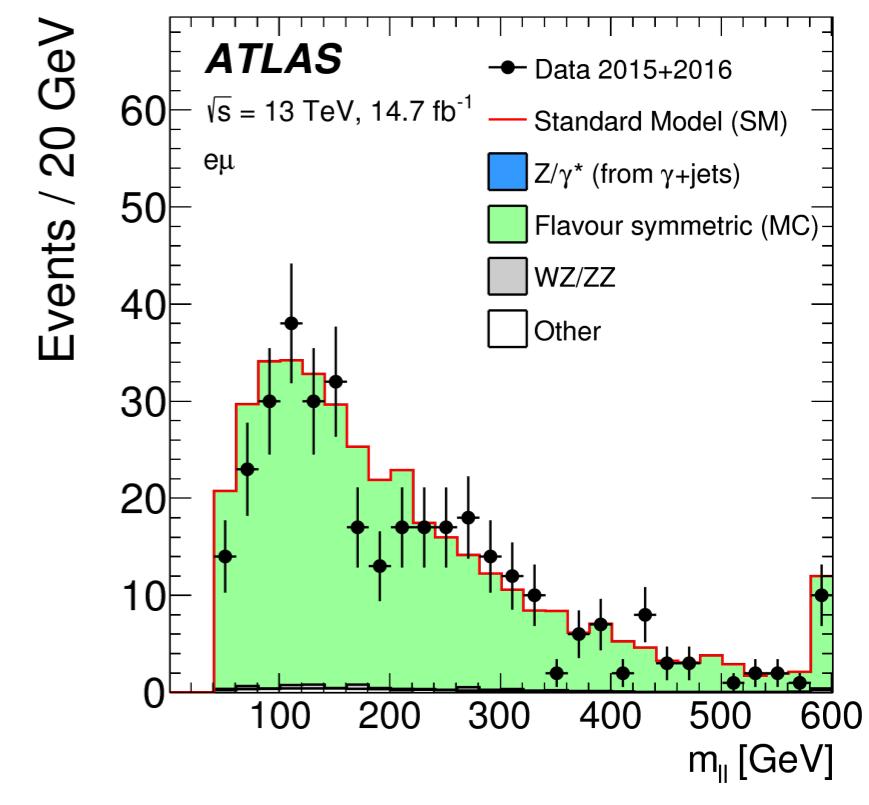
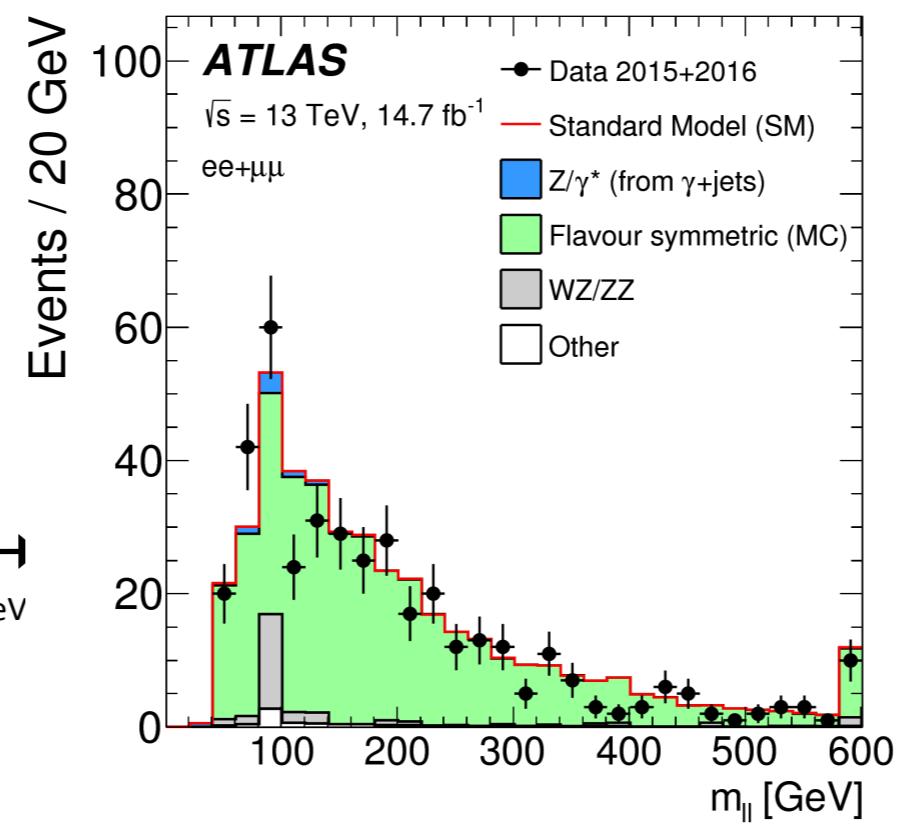
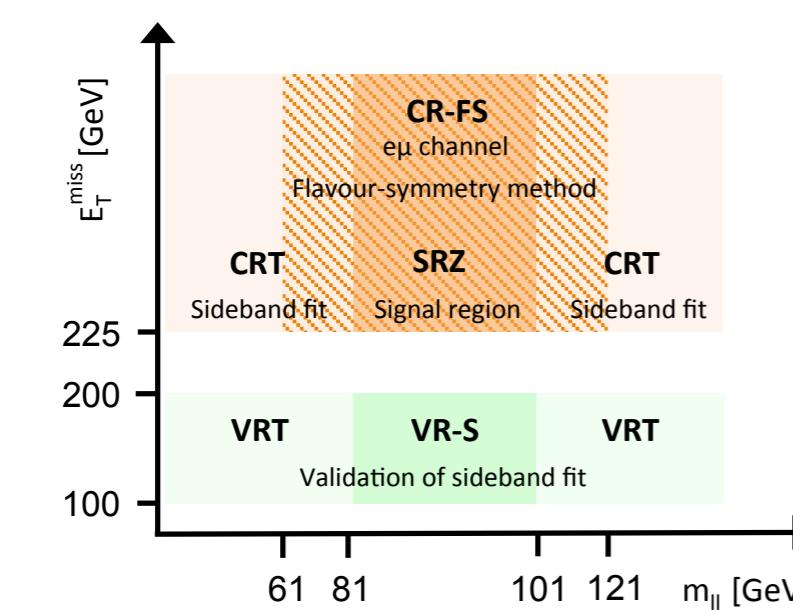
	GG 6J bulk	GG 6J high-mass	GG 4J low-x	GG 4J low-x b-veto	GG 4J high-x
$N_{\text{lep}}$ (preselected)					
$p_T^\ell$ (GeV)	> 35	> 35	= 1 for electron (muon)	> 7(6) for electron (muon)	> 35
$N_{\text{jet}}$	$\geq 6$	$\geq 6$	$\geq 4$	$\geq 4$	$\geq 4$
$p_T^{\text{jet}1}$ (GeV)	> 125	> 125	> 100	> 100	> 400
$p_T^{\text{jet}2,3}$ (GeV)	> 30	> 30	> 100	> 100	> 30
$p_T^{\text{jet}4}$ (GeV)	> 30	> 30	> 100	> 100	[30, 100]
$p_T^{\text{jet}5,6}$ (GeV)	> 30	> 30	-	-	-
$N_{\text{b-jet}}$	-	-	-	= 0	-
$m_T$ (GeV)	> 225	> 225	> 125	> 125	> 475
$E_T^{\text{miss}}$ (GeV)	> 250	> 250	> 250	> 250	> 250
$m_{\text{eff}}^{\text{inc}}$ (GeV)	> 1000	> 2000	> 2000	> 2000	> 1600
$E_T^{\text{miss}}/m_{\text{eff}}^{\text{inc}}$	> 0.2	> 0.1	-	-	> 0.3
Jet aplanarity	> 0.04	> 0.04	> 0.06	> 0.03	-

# SS 2L, 3L + JETS + MET

Signal region	$N_{\text{lept}}^{\text{signal}}$	$N_{b\text{-jets}}^{20}$	$N_{\text{jets}}$	$p_{\text{T,jets}}$ [GeV]	$E_{\text{T}}^{\text{miss}}$ [GeV]	$m_{\text{eff}}$ [GeV]	Other
SR3L1	$\geq 3$	= 0	$\geq 4$	40	$> 150$	-	-
SR3L2	$\geq 3$	= 0	$\geq 4$	40	$> 200$	$> 1500$	-
SR0b1	$\geq 2$	= 0	$\geq 6$	25	$> 150$	$> 500$	-
SR0b2	$\geq 2$	= 0	$\geq 6$	40	$> 150$	$> 900$	-
SR1b	$\geq 2$	$\geq 1$	$\geq 6$	25	$> 200$	$> 650$	-
SR3b	$\geq 2$	$\geq 3$	$\geq 6$	25	$> 150$	$> 600$	-
SR1b-DD	$\geq 2$	$\geq 1$	$\geq 4$	50	-	$> 1200$	$\geq 2$ negatively-charged leptons
SR3b-DD	$\geq 2$	$\geq 3$	$\geq 4$	50	-	$> 1000$	$\geq 2$ negatively-charged leptons
SR1b-GG	$\geq 2$	$\geq 1$	$\geq 6$	50	-	$> 1800$	-

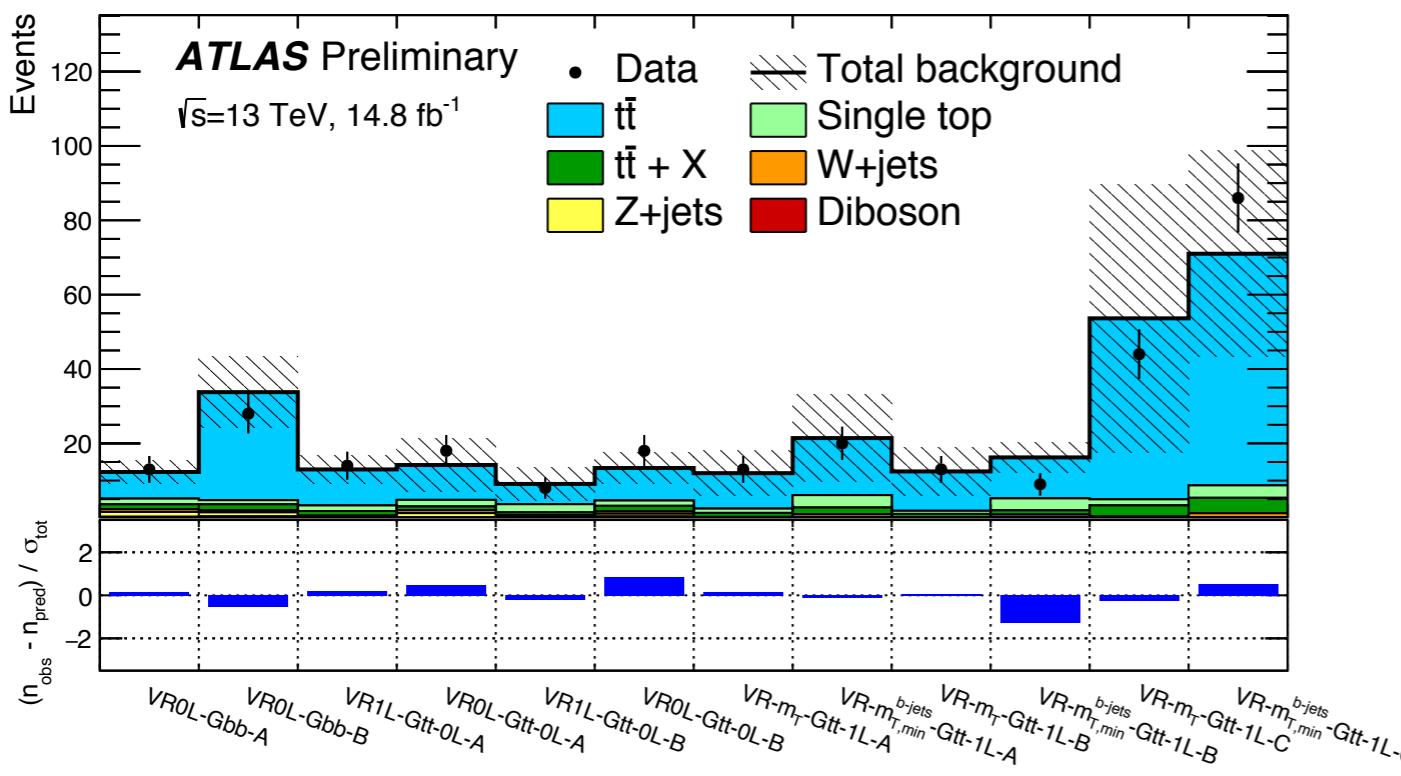
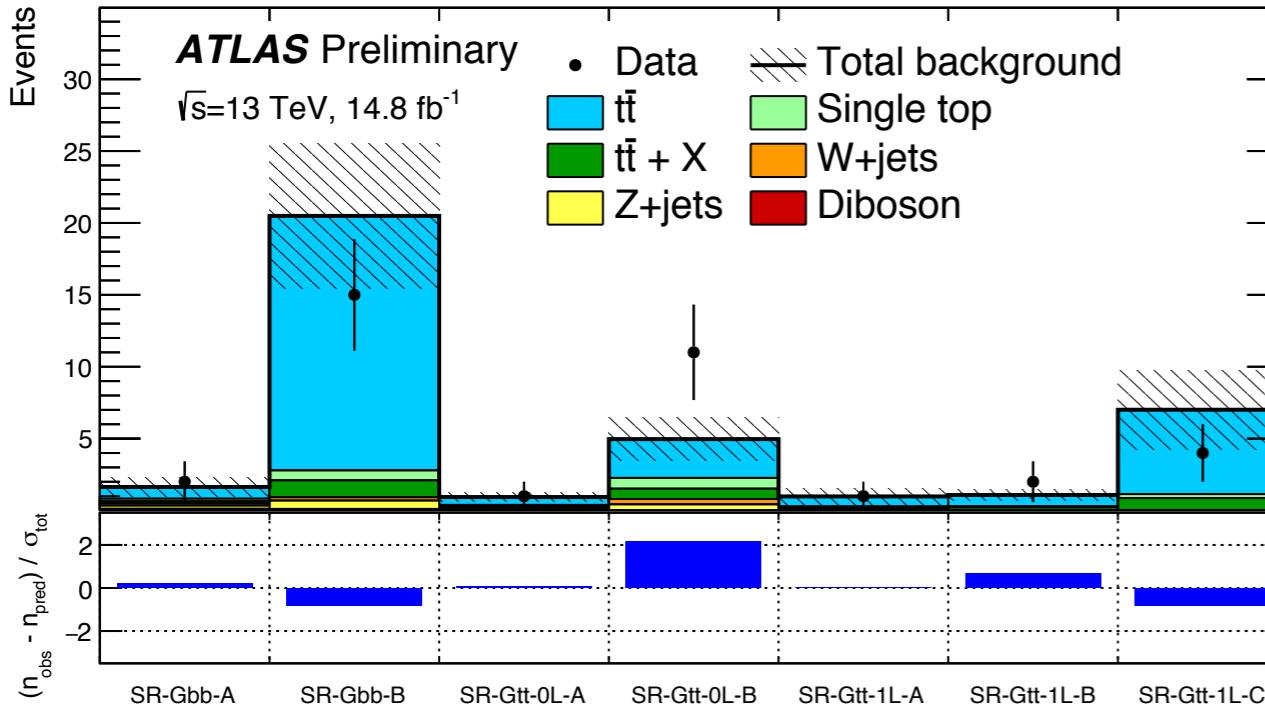


# SF, OS 2L + JETS + MET



On-shell $Z$ regions	$E_T^{\text{miss}}$ [GeV]	$H_T^{\text{incl}}$ [GeV]	$n_{\text{jets}}$	$m_{\ell\ell}$ [GeV]	SF/DF	$\Delta\phi(\text{jet}_{12}, p_T^{\text{miss}})$	$m_T(\ell_3, E_T^{\text{miss}})$ [GeV]	$n_{b\text{-jets}}$
Signal region								
SRZ	> 225	> 600	$\geq 2$	$81 < m_{\ell\ell} < 101$	SF	> 0.4	—	—
Control regions								
CRZ	< 60	> 600	$\geq 2$	$81 < m_{\ell\ell} < 101$	SF	> 0.4	—	—
CR-FS	> 225	> 600	$\geq 2$	$61 < m_{\ell\ell} < 121$	DF	> 0.4	—	—
CRT	> 225	> 600	$\geq 2$	$> 40, m_{\ell\ell} \notin [81, 101]$	SF	> 0.4	—	—
CR $\gamma$	—	> 600	$\geq 2$	—	0 $\ell, 1\gamma$	—	—	—
Validation regions								
VRZ	< 225	> 600	$\geq 2$	$81 < m_{\ell\ell} < 101$	SF	> 0.4	—	—
VRT	100–200	> 600	$\geq 2$	$> 40, m_{\ell\ell} \notin [81, 101]$	SF	> 0.4	—	—
VR-S	100–200	> 600	$\geq 2$	$81 < m_{\ell\ell} < 101$	SF	> 0.4	—	—
VR-FS	100–200	> 600	$\geq 2$	$61 < m_{\ell\ell} < 121$	DF	> 0.4	—	—
VR-WZ	100–200	—	—	—	3 $\ell$	—	< 100	0
VR-ZZ	< 100	—	—	—	4 $\ell$	—	—	0
VR-3L	60–100	> 200	$\geq 2$	$81 < m_{\ell\ell} < 101$	3 $\ell$	> 0.4	—	—

# MULTI-B



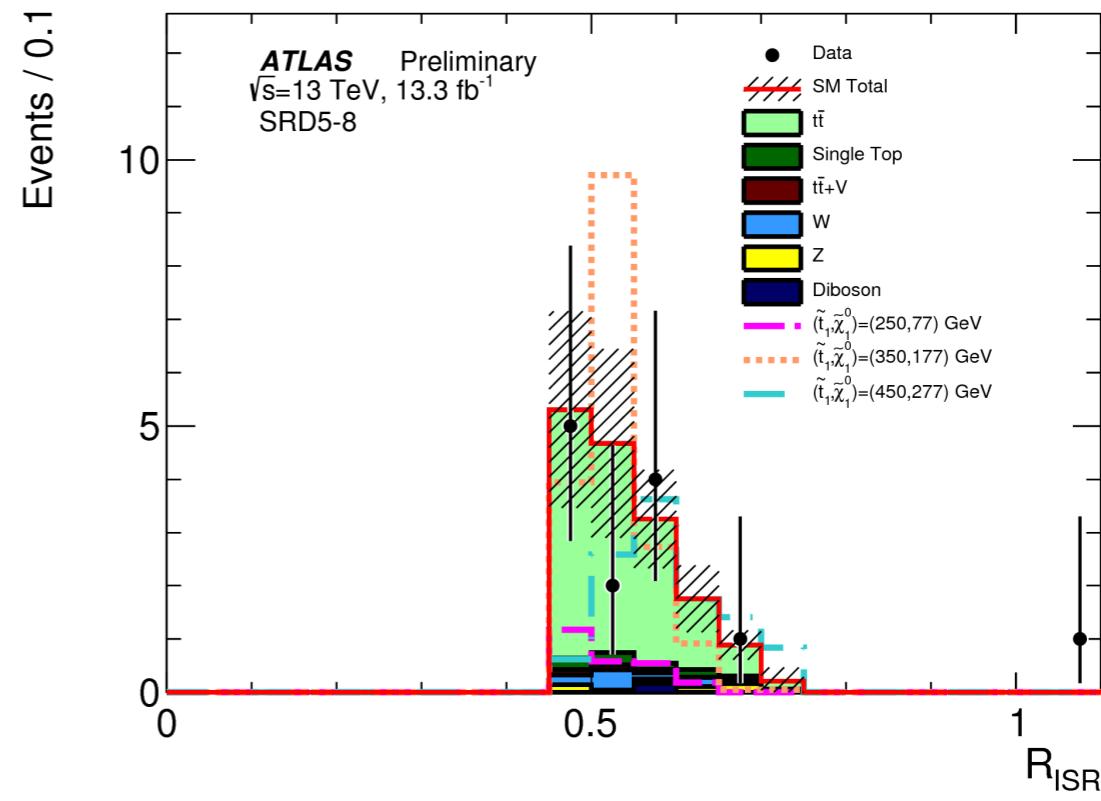
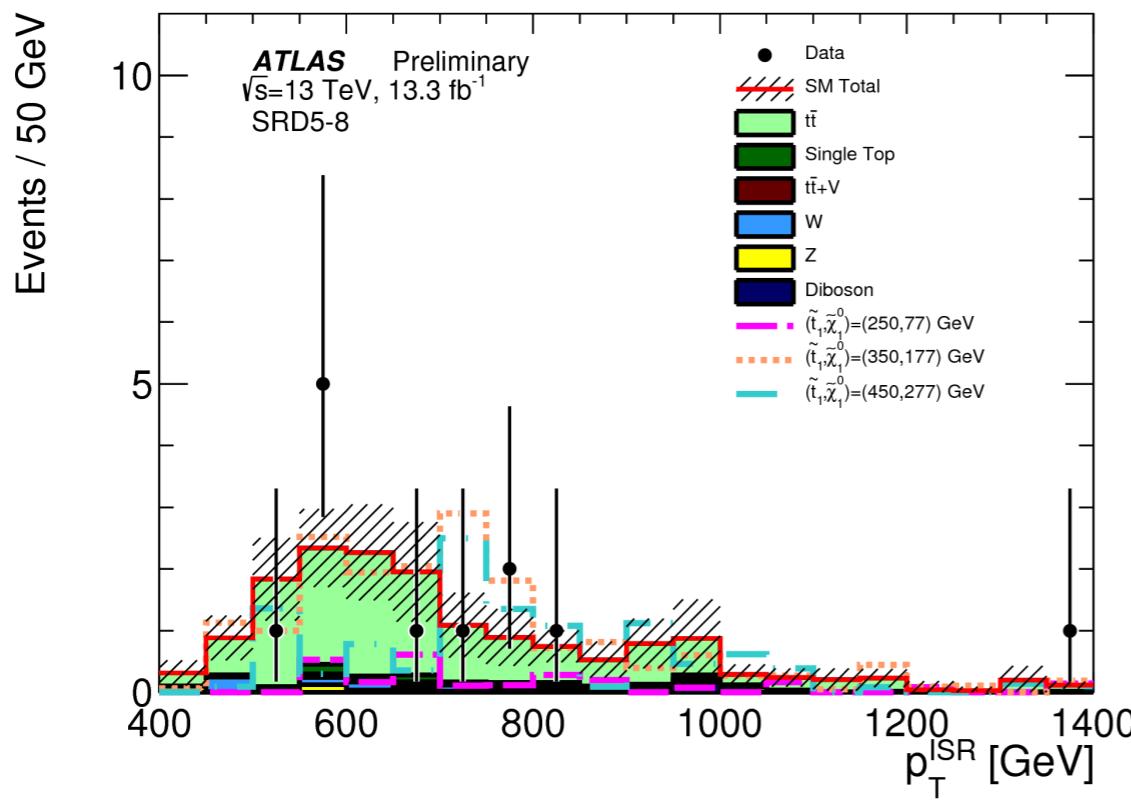
Criterion common to all Gbb regions: $N^{\text{jet}} \geq 4$				
Variable	Signal region	Control region	Validation region	
$N^{\text{Candidate Lepton}}$	= 0	-	-	= 0
Criteria common to all regions of the same type				
$N^{\text{Signal Lepton}}$	-	= 1	-	-
$\Delta\phi_{\min}^{4j}$	> 0.4	-	-	> 0.4
$m_T$	-	< 150	-	-
$p_T^{\text{jet}}$	> 70	> 70	> 70	> 70
Region A (Large mass splitting)				
$N_{b\text{-jets}}$	$\geq 3$	$\geq 3$	$\geq 3$	$\geq 3$
$E_T^{\text{miss}}$	> 450	> 350	> 450	> 450
$m_{\text{eff}}^{4j}$	> 1900	> 1750	< 1900	< 1900
Region B (Small mass splitting)				
$p_T^{\text{jet}}$	> 30	> 30	> 30	> 30
$N_{b\text{-jets}}$	$\geq 4$	$\geq 4$	$\geq 4$	$\geq 4$
$E_T^{\text{miss}}$	> 300	> 300	> 275	> 275
$m_{\text{eff}}^{4j}$	> 1000	> 1000	< 1000	< 1000

Criteria common to all Gtt 1-lepton regions: $\geq 1$ signal lepton, $p_T^{\text{jet}} > 30 \text{ GeV}$				
Variable	Signal region	Control region	VR- $m_T$	VR- $m_T^{b\text{-jets}}$
$N^{\text{jet}}$	$\geq 6$	= 6	$\geq 5$	$\geq 6$
Region A (Large mass splitting)				
$N_{b\text{-jets}}$	$\geq 3$	$\geq 3$	$\geq 3$	$\geq 3$
$m_T$	> 200	< 200	> 200	< 200
$m_{T,\min}^{b\text{-jets}}$	> 120	-	-	> 120
$E_T^{\text{miss}}$	> 200	> 200	> 200	> 200
$m_{\text{eff}}^{\text{incl}}$	> 2000	> 1500	> 1350	> 1500
$M_J^\Sigma$	> 200	> 200	< 200	> 200
Region B (Moderate mass splitting)				
$N^{\text{jet}}$	$\geq 6$	= 6	$\geq 5$	$\geq 6$
$N_{b\text{-jets}}$	$\geq 3$	$\geq 3$	$\geq 3$	$\geq 3$
$m_T$	> 200	< 200	> 200	< 200
$m_{T,\min}^{b\text{-jets}}$	> 120	-	-	> 120
$E_T^{\text{miss}}$	> 350	> 300	> 250	> 300
$m_{\text{eff}}^{\text{incl}}$	> 1500	> 1250	> 1100	> 1500
$M_J^\Sigma$	> 150	> 150	< 150	> 150
Region C (Small mass splitting)				
$N^{\text{jet}}$	$\geq 6$	= 6	$\geq 6$	$\geq 6$
$N_{b\text{-jets}}$	$\geq 4$	$\geq 4$	$\geq 3$	$\geq 4$
$m_T$	> 150	< 150	> 150	< 150
$m_{T,\min}^{b\text{-jets}}$	> 80	-	< 80	> 80
$E_T^{\text{miss}}$	> 200	> 200	> 200	> 200
$m_{\text{eff}}^{\text{incl}}$	> 500	> 500	> 500	> 500

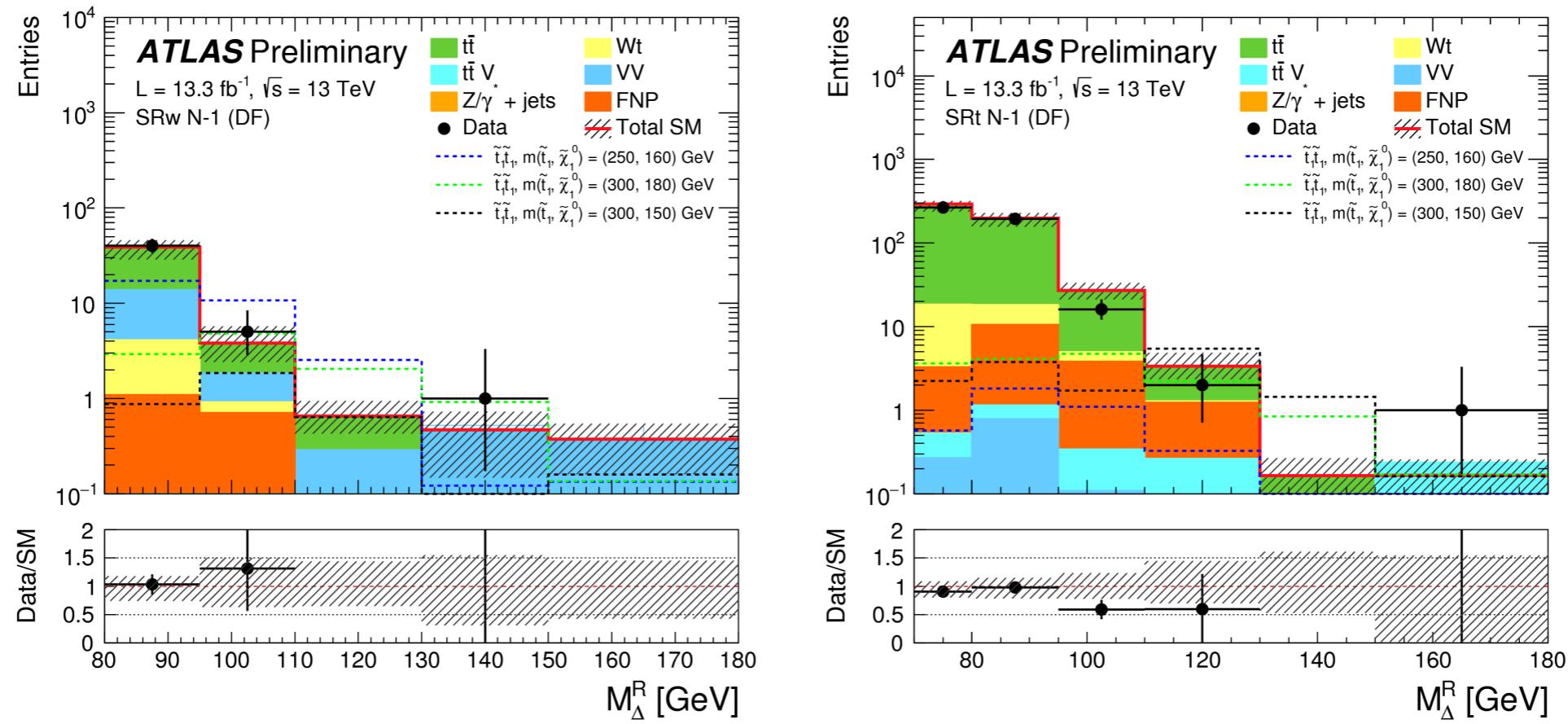
# OL STOP - COMPRESSED

Variable	SRD1	SRD2	SRD3	SRD4	SRD5	SRD6	SRD7	SRD8
min $R_{\text{ISR}}$	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60
max $R_{\text{ISR}}$	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75
$b$ -tagged jets			$\geq 2$			$\geq 1$		
$N_{\text{jet}}^S$				$\geq 5$				
$p_T^{\text{ISR}}$					$> 400 \text{ GeV}$			
$p_T^{b\text{-tag},S}$						$> 40 \text{ GeV}$		
$p_T^{\text{jet } 4,S}$						$> 50 \text{ GeV}$		
$M_T^S$						$> 300 \text{ GeV}$		
$\Delta\phi_{\text{ISR}}$						$> 3.0 \text{ radians}$		

	SRD5	SRD6	SRD7	SRD8
Observed	11	6	5	1
Total SM	$11.6 \pm 3.6$	$8.6 \pm 3.5$	$5.2 \pm 2.1$	$2.56 \pm 0.86$
$t\bar{t}$	$9.7 \pm 3.7$	$6.8 \pm 3.5$	$4.0 \pm 2.0$	$1.77 \pm 0.67$
$W + \text{jets}$	$0.68 \pm 0.40$	$0.68 \pm 0.23$	$0.37 \pm 0.22$	$0.25 \pm 0.18$
$Z + \text{jets}$	$0.27^{+0.52}_{-0.27}$	$0.23^{+0.43}_{-0.23}$	$0.36 \pm 0.13$	$0.30 \pm 0.13$
$t\bar{t}+W/Z$	$0.26 \pm 0.06$	$0.16 \pm 0.11$	$0.08^{+0.09}_{-0.08}$	$0.02^{+0.02}_{-0.02}$
Single top	$0.54^{+0.64}_{-0.54}$	$0.48^{+0.56}_{-0.48}$	$0.31^{+0.35}_{-0.31}$	$0.22^{+0.25}_{-0.22}$
Dibosons	$0.16 \pm 0.13$	$0.16 \pm 0.11$	$0.16 \pm 0.14$	---
Multijets	$0.03^{+0.06}_{-0.03}$	$0.02^{+0.03}_{-0.02}$	$0.01^{+0.01}_{-0.01}$	---



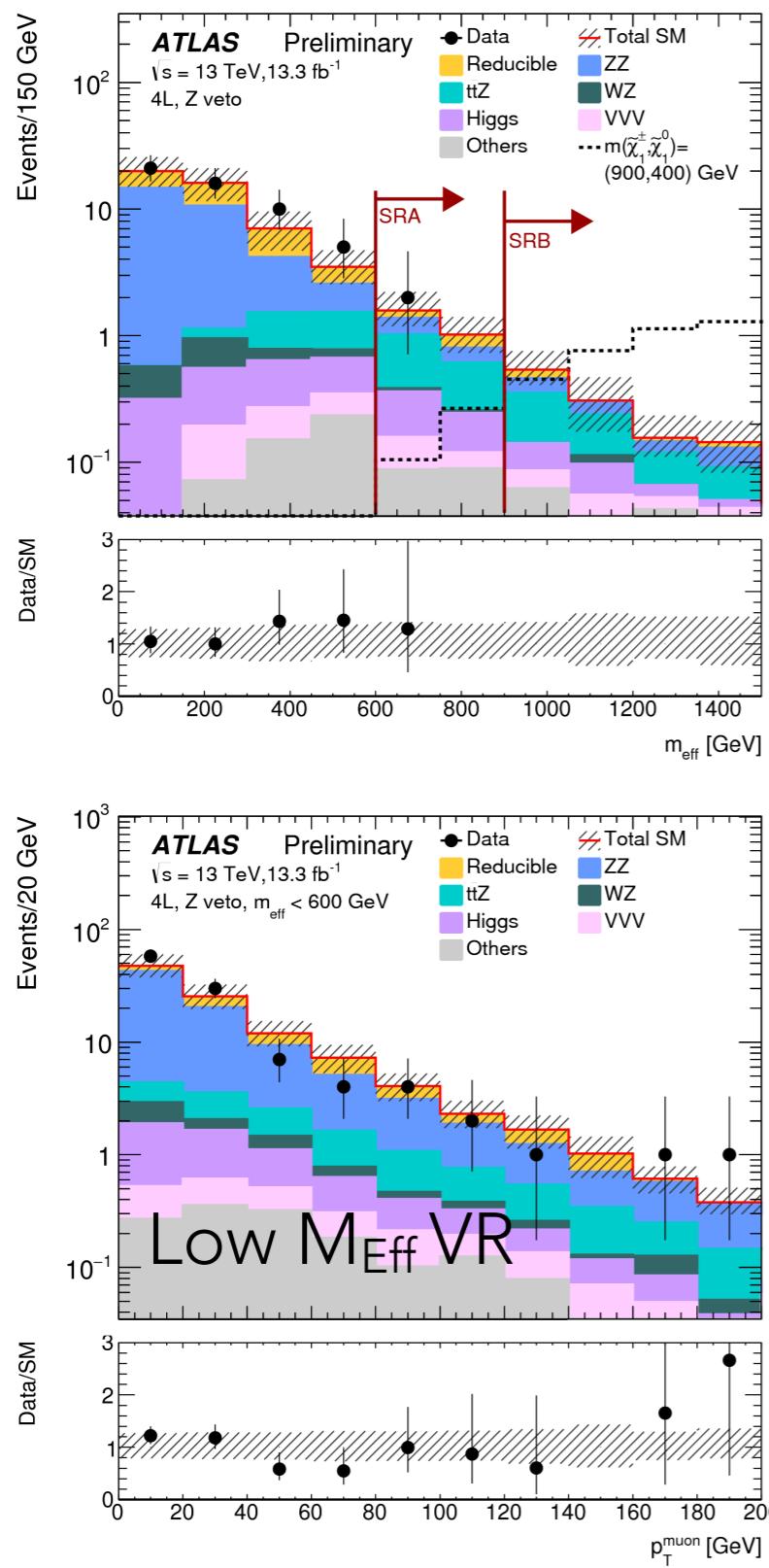
# 2L STOP - COMPRESSED



Selection	CR-Top	CR-VV-DF	CR-VV-SF	VR-Top	VR-VV-DF	VR-VV-SF
Lepton flavour	DF	DF	SF	DF	DF	SF
$b$ -jet multiplicity	$> 0$	$= 0$	$= 0$	$= 0$	$= 0$	$= 0$
$M_{\Delta}^R [\text{GeV}]$	$> 80$	$> 30$	$> 30$	$> 80$	$(30, 80)$	$(30, 80)$
$R_{p_T}$	$> 0.5$	$< 0.5$	$< 0.5$	$< 0.5$	$< 0.5$	$< 0.5$
$1/\gamma_{R+1}$	–	$> 0.8$	$> 0.8$	–	$> 0.8$	$> 0.8$
$E_T^{\text{miss}} [\text{GeV}]$	–	–	$> 70$	–	–	$> 70$
$(\cos \theta_b, \Delta\phi_{\beta}^R)$	$\Delta\phi_{\beta}^R < (0.85 \times  \cos \theta_b  + 1.8)$		$\Delta\phi_{\beta}^R > (0.85 \times  \cos \theta_b  + 1.8)$			

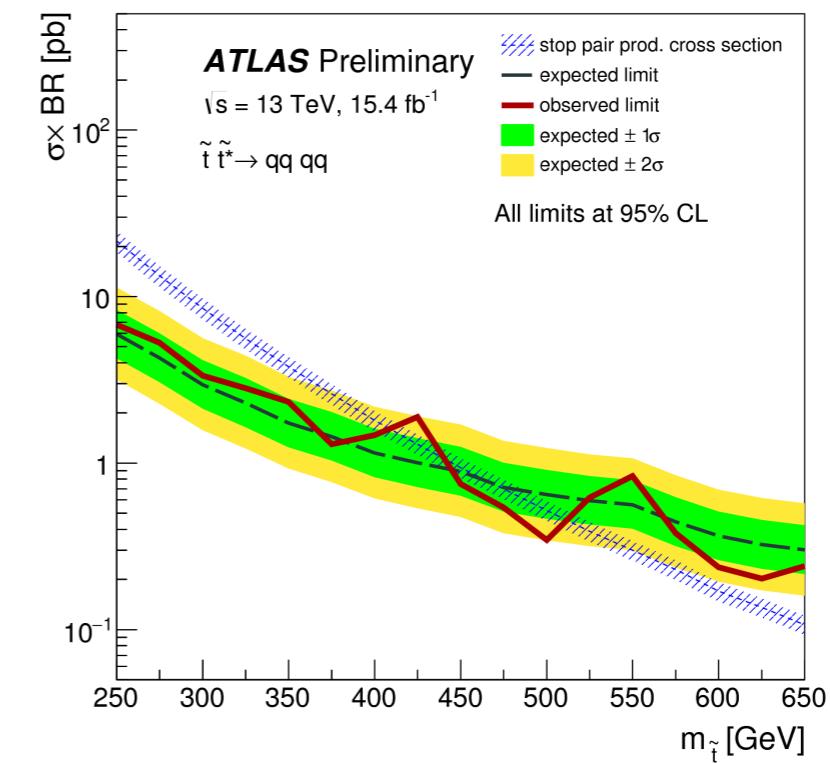
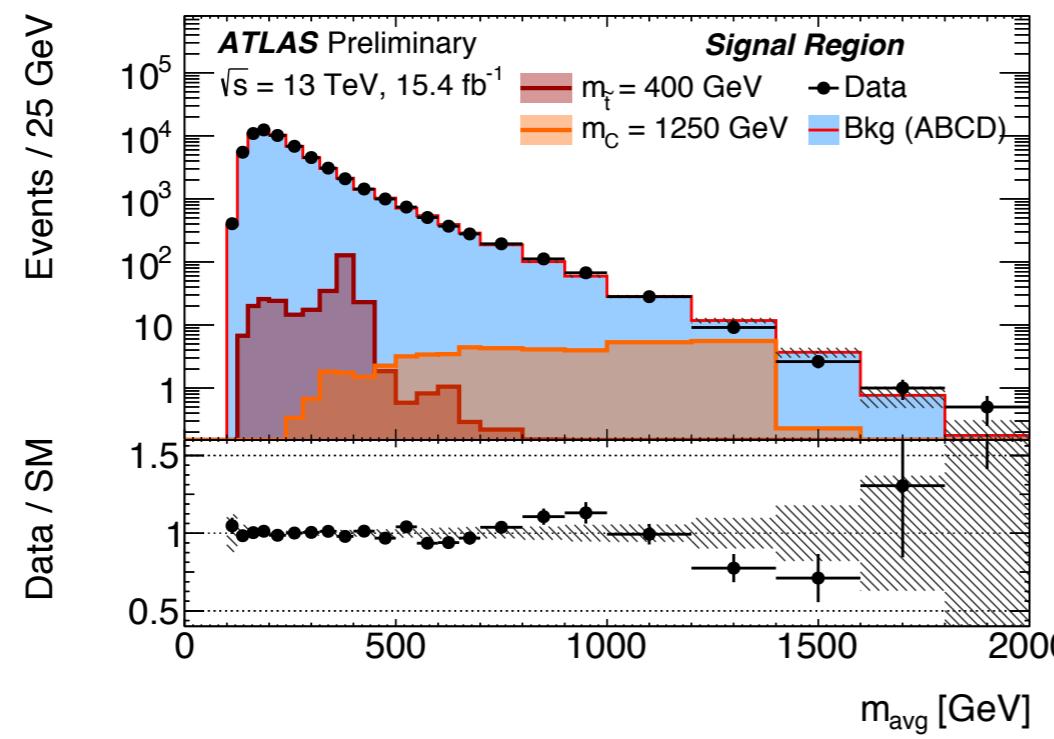
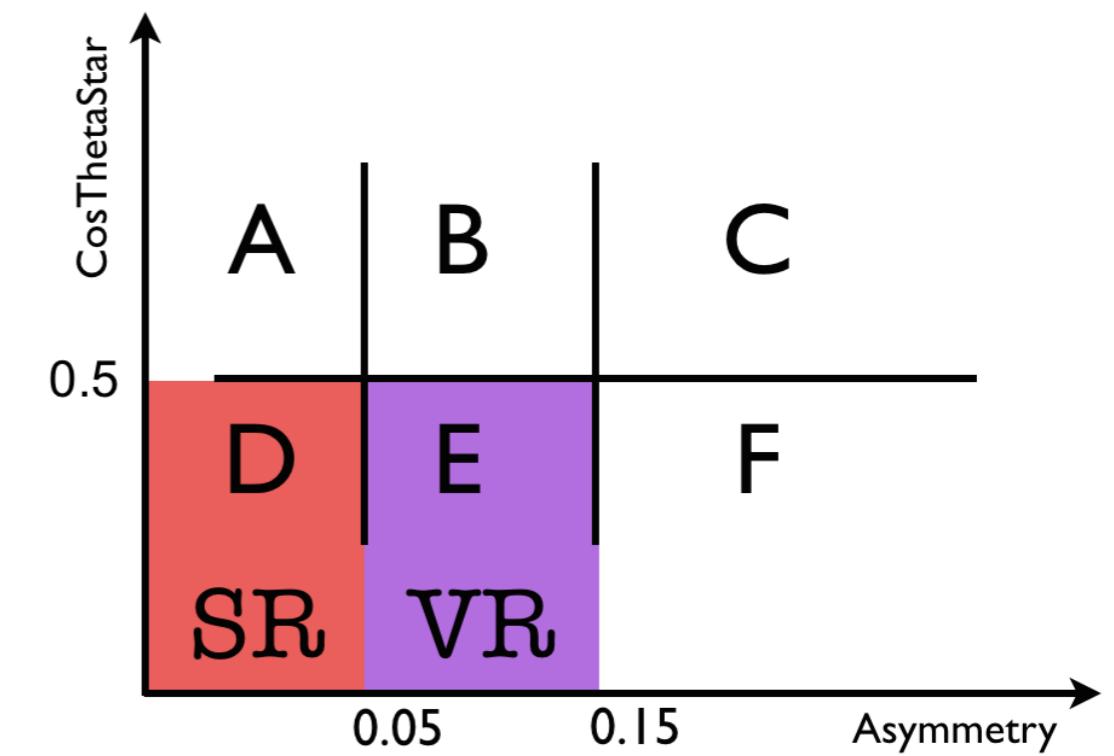
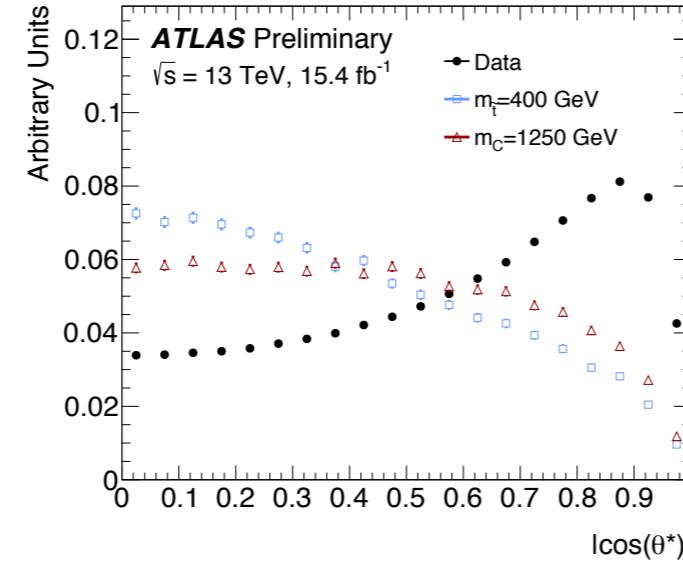
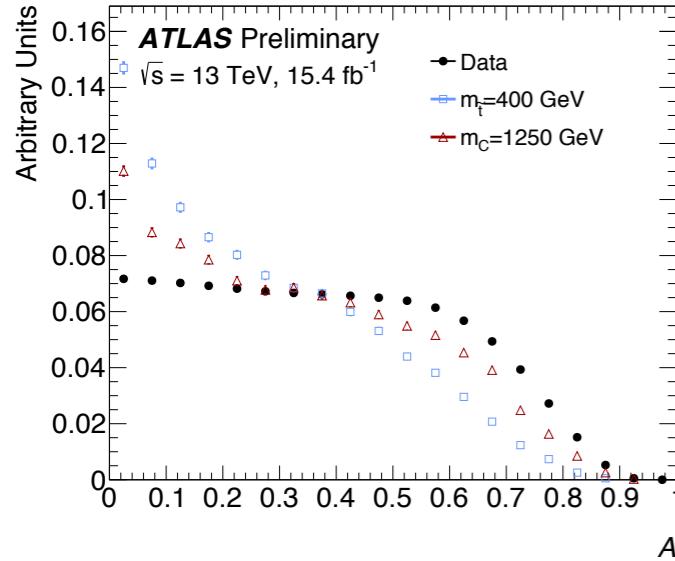
Common selection		
Lepton flavour	SF, DF	
$ m_{\ell\ell} - m_Z  [\text{GeV}]$ (SF only)	$> 10$	
$R_{p_T}$	$> 0.5$	
$1/\gamma_{R+1}$	$> 0.8$	
$\Delta\phi_{\beta}^R$	$> 0.85  \cos \theta_b  + 1.8$	
Region specific	$\text{SR}_W^{3\text{-body}}$	$\text{SR}_t^{3\text{-body}}$
$b$ -jet multiplicity	$= 0$	$> 0$
$M_{\Delta}^R [\text{GeV}]$	$> 95$	$> 110$

# 4L RPV



Trigger	Offline $p_T$ threshold [ GeV ]			
	2015	2016		
Single isolated $e$	25	25		
Single non-isolated $e$	61	61		
Single isolated $\mu$	21	25		
Single non-isolated $\mu$	51	41 or 51		
Double $e$	14,14	16,16		
Double $\mu$	11,11 19,9	11,11 or 15,15 21,9		
Triple $e$	18,10,10	18,10,10		
Triple $\mu$	19,5,5 7,7,7	21,5,5 7,7,7		
Combined $e\mu$	18( $e$ ),15( $\mu$ ) 25( $e$ ),9( $\mu$ ) 8( $e$ ),25( $\mu$ ) 13( $e$ ),13( $e$ ),11( $\mu$ ) 13( $e$ ),11( $\mu$ ),11( $\mu$ )	18( $e$ ),15( $\mu$ ) 25( $e$ ),9( $\mu$ ) 8( $e$ ),25( $\mu$ ) 13( $e$ ),13( $e$ ),11( $\mu$ ) 13( $e$ ),11( $\mu$ ),11( $\mu$ )		
Sample	$N(e,\mu)$ signal	$N(e,\mu)$ loose	Z boson	$m_{\text{eff}}$ [GeV]
SRA	$\geq 4$	$\geq 0$	veto	$> 600$
CR-SRA	$= 2$	$\geq 2$	veto	$> 600$
SRB	$\geq 4$	$\geq 0$	veto	$> 900$
CR-SRB	$= 2$	$\geq 2$	veto	$> 900$
VR	$\geq 4$	$\geq 0$	veto	$< 600$
CR-VR	$= 2$	$\geq 2$	veto	$< 600$

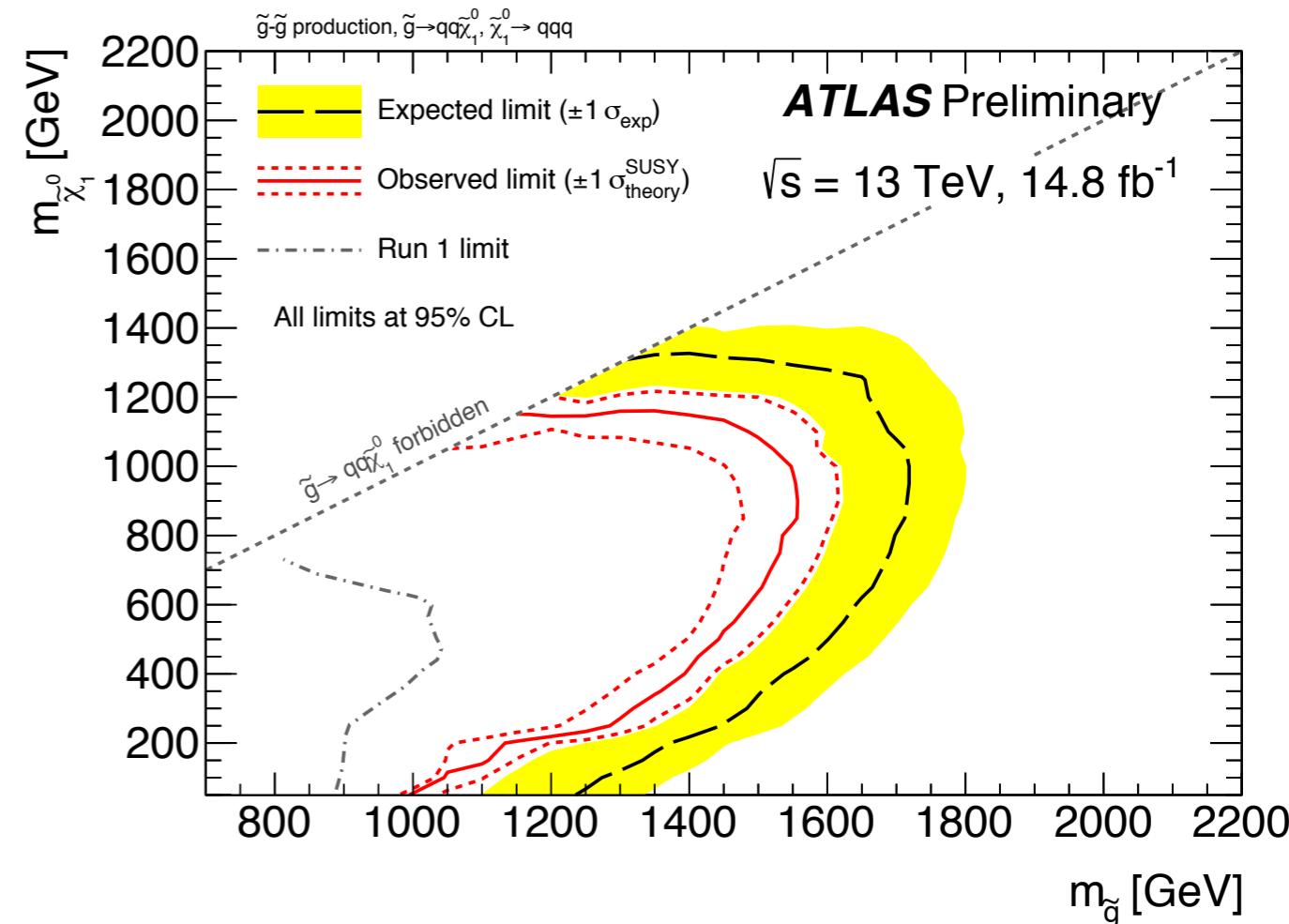
# 2x2 JET UDD RPV STOP



# MULTIJET UDD RPV

n <sub>jet</sub>	b-tag		b-veto		inclusive	
	Δη <sub>12</sub>   > 1.4	Δη <sub>12</sub>   < 1.4	-	Δη <sub>12</sub>   > 1.4	Δη <sub>12</sub>   < 1.4	
= 3	3jCRb1_4j	-	3jCRb0_4j		3jCR_5j	
≥ 4	4jVRb1	4jSRb1	-	4jVR	4jSR	
≥ 5	5jVRb1	5jSRb1	-	5jVR	5jSR	

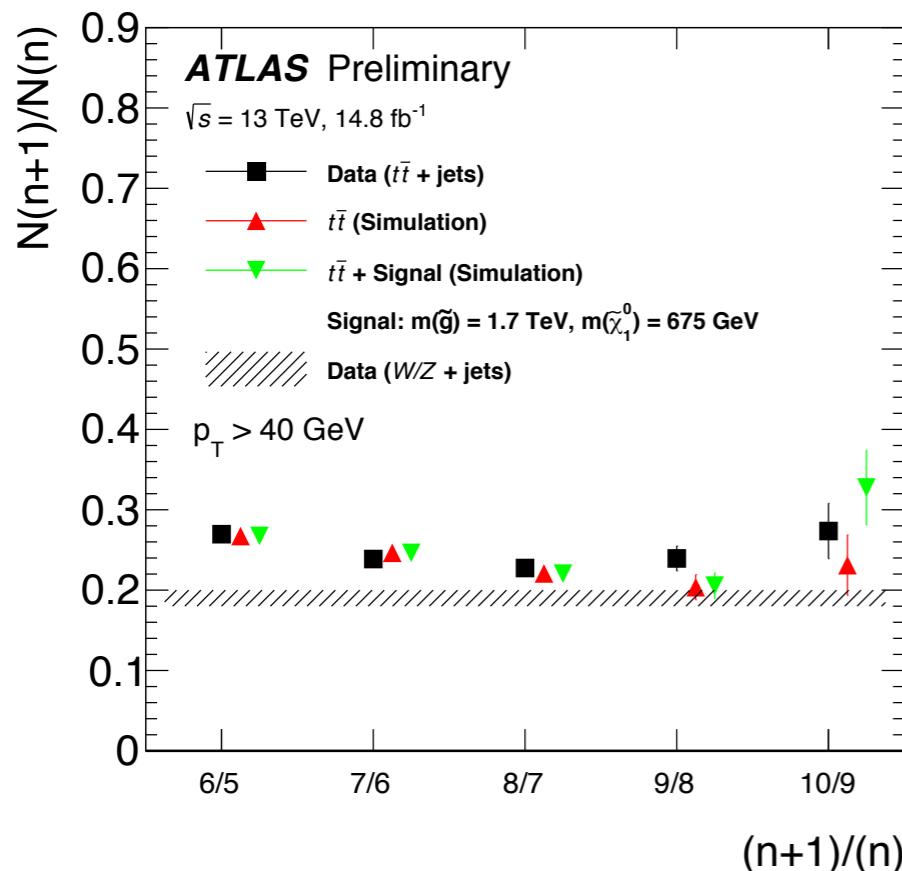
	Gluino cascade (via $\tilde{\chi}_1^0$ ) [ $\tilde{g}, \tilde{\chi}_1^0$ ] : [1600, 650] [GeV]	Gluino direct $\tilde{g}$ : 1100 [GeV]
Trigger $p_T^{lead} > 440 GeV$	120 119	2401 2236
$n_{jet} \geq 4$	97.1	1159
$M_J^\Sigma > 0.8 \text{ TeV}$	35.4	63.3
$ \Delta\eta_{12}  < 1.4$	33.0	56.6
b-tag	25.7	43.3
$n_{jet} \geq 5$	50.2	296
$M_J^\Sigma > 0.6 \text{ TeV}$	28.7	41.6
$ \Delta\eta_{12}  < 1.4$	25.9	35.0
b-tag	20.3	26.7



Region	$M_J^\Sigma$ cut	observed	SM predicted	$m_{\tilde{g}} = 1600 \text{ GeV}$	$m_{\tilde{g}} = 1200 \text{ GeV}$
				$m_{\tilde{\chi}_1^0} = 650 \text{ GeV}$	$m_{\tilde{\chi}_1^0} = 650 \text{ GeV}$
4jSRb1	> 0.8 TeV	46	$61 \pm 10 \pm 6 \pm 12$	$25.6 \pm 2.8$	$32.4 \pm 6.0$
4jSR		122	$151 \pm 15 \pm 17 \pm 20$	$32.9 \pm 3.0$	$43.6 \pm 4.0$
5jSRb1	> 0.6 TeV	30	$18.2 \pm 4.2 \pm 2.5 \pm 3.0$	$20.2 \pm 2.3$	$21.6 \pm 5.0$
5jSR		64	$51.4 \pm 7.7 \pm 7.2 \pm 6.5$	$25.9 \pm 2.8$	$27.6 \pm 5.6$

# 1 L + JETS UDD RPV

Jet requirement	$b$ -tag jet requirement	Bins excluded from fit to avoid signal contamination
$\geq 8$	= 0	$\geq 8$ jet 0 $b$ -tag
$\geq 8$	$\geq 3$	$\geq 8$ jet $\geq 3$ $b$ -tag and $\geq 8$ jet 2 $b$ -tag
$\geq 9$	= 0	$\geq 9$ jet 0 $b$ -tag
$\geq 9$	$\geq 3$	$\geq 9$ jet $\geq 3$ $b$ -tag and $\geq 9$ jet 2 $b$ -tag
$\geq 10$	= 0	$\geq 10$ jet 0 $b$ -tag
$\geq 10$	$\geq 3$	$\geq 10$ jet $\geq 3$ $b$ -tag and $\geq 10$ jet 2 $b$ -tag

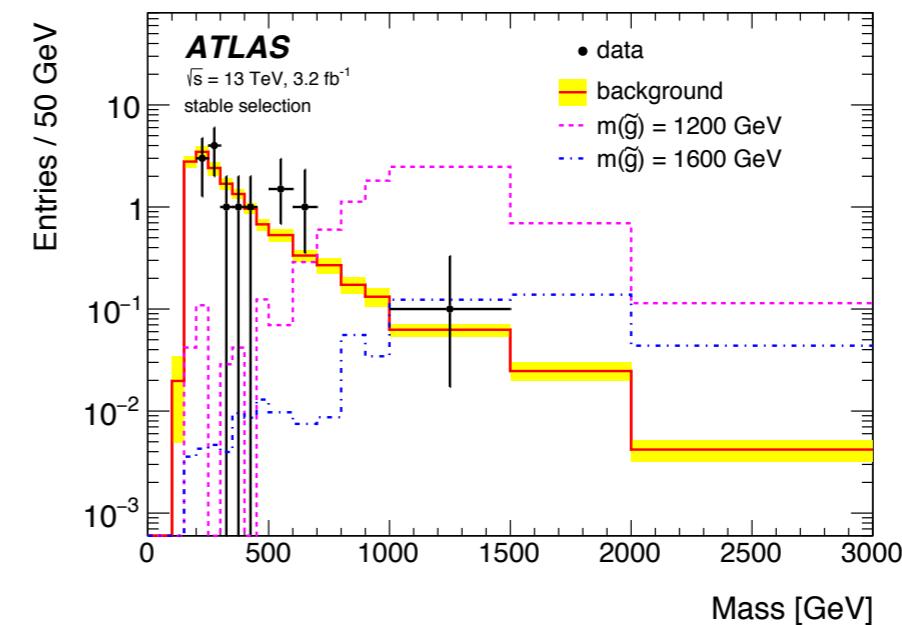
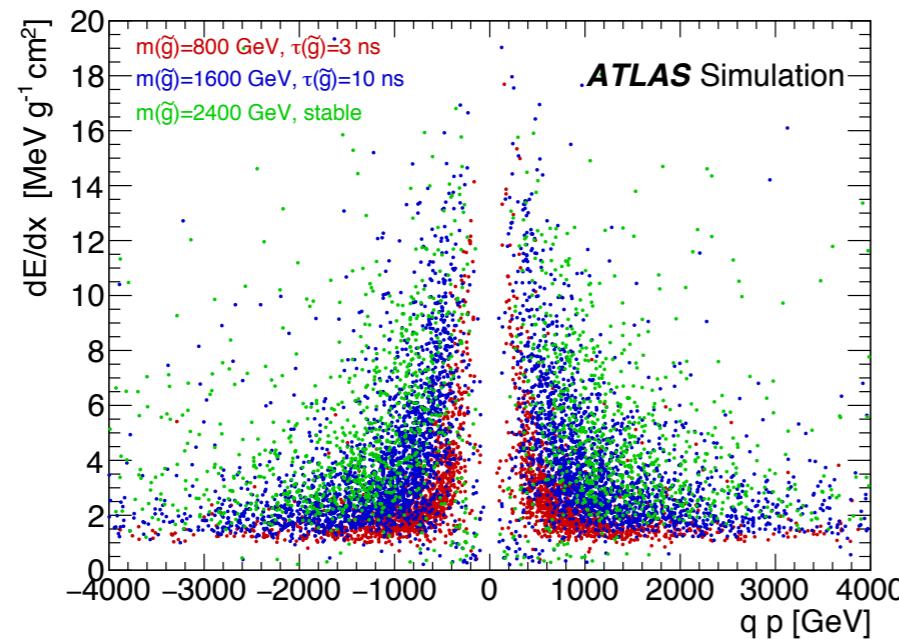


Jet $p_T > 40 \text{ GeV}$	$\geq 8$ Jets		$\geq 9$ Jets		$\geq 10$ Jets	
	0b	$\geq 3$ b	0b	$\geq 3$ b	0b	$\geq 3$ b
$t\bar{t}+\text{jets}$	$69 \pm 35$	$301 \pm 30$	$19 \pm 8$	$90 \pm 12$	$3.4 \pm 1.6$	$23 \pm 6$
$W+\text{jets}$	$150 \pm 50$	$1.5 \pm 1.3$	$20 \pm 7$	$0.7 \pm 0.7$	$3.3 \pm 1.5$	$< 0.1$
Others	$30 \pm 13$	$27 \pm 12$	$7 \pm 4$	$8.1 \pm 2.9$	$1.5 \pm 0.7$	$2.4 \pm 0.8$
$Z+\text{jets}$	$22 \pm 4$	$0.61 \pm 0.10$	$3.0 \pm 0.8$	$0.32 \pm 0.08$	$0.47 \pm 0.16$	$< 0.1$
Multijet	$19 \pm 9$	$3.1 \pm 1.3$	$1.3 \pm 0.7$	$3.3 \pm 1.8$	$0.9 \pm 0.5$	$1.7 \pm 0.9$
Total Bkd.	$286 \pm 20$	$333 \pm 29$	$50 \pm 4$	$102 \pm 12$	$9.6 \pm 1.1$	$27 \pm 6$
Data	252	400	50	115	8	29
$p_0 (\sigma)$	0.5 (0)	0.03 (1.9)	0.5 (0)	0.20 (0.8)	0.5 (0)	0.39 (0.3)
Jet $p_T > 60 \text{ GeV}$	$\geq 8$ Jets		$\geq 9$ Jets		$\geq 10$ Jets	
	0b	$\geq 3$ b	0b	$\geq 3$ b	0b	$\geq 3$ b
$t\bar{t}+\text{jets}$	$4 \pm 4$	$32 \pm 8$	$0.4 \pm 0.6$	$10 \pm 6$	$< 0.1$	$3.1 \pm 3.1$
$W+\text{jets}$	$22 \pm 7$	$0.33 \pm 0.32$	$3.2 \pm 1.6$	$0.11 \pm 0.11$	$0.41 \pm 0.26$	$< 0.1$
Others	$5.0 \pm 2.3$	$4.2 \pm 1.6$	$0.75 \pm 0.30$	$1.1 \pm 0.4$	$< 0.1$	$0.30 \pm 0.09$
$Z+\text{jets}$	$1.7 \pm 0.4$	$< 0.1$	$0.29 \pm 0.08$	$< 0.1$	$0.110 \pm 0.035$	$< 0.1$
Multijet	$2.1 \pm 1.1$	$1.2 \pm 0.6$	$0.15 \pm 0.08$	$0.43 \pm 0.22$	0.0	0.0
Total Bkd.	$34 \pm 5$	$38 \pm 8$	$4.7 \pm 1.3$	$12 \pm 6$	$0.55 \pm 0.28$	$3.4 \pm 3.1$
Data	37	40	12	5	1	1
$p_0 (\sigma)$	0.35 (0.4)	0.41 (0.2)	0.01 (2.3)	0.5 (0)	0.31 (0.5)	0.5 (0)

# PIXEL DE/DX

$$(dE/dx)_{MPV}(\beta\gamma) = \frac{p_1}{\beta^{p_3}} \ln(1 + [p_2\beta\gamma]^{p_5}) - p_4$$

Low momentum pions, kaons, and protons used to calibrate constants  $p_n$



CR1 with inverted  $dE/dx$  req

CR2 with inverted MET req

Background est in SR:

Kinematic sampling from CR1

Ionization sampling from CR2

Selection level	Exp. signal events	Observed events in $3.2 \text{ fb}^{-1}$
Generated	$26.0 \pm 0.3$	
$E_T^{\text{miss}}$ trigger & preselection	$24.8 \pm 0.3$ (95%)	
$E_T^{\text{miss}} > 130 \text{ GeV}$	$23.9 \pm 0.3$ (92%)	
Track $p_T > 50$ and cluster requirements	$10.7 \pm 0.2$ (41%)	368324
Isolation requirement	$9.0 \pm 0.2$ (35%)	108079
Track $p > 150 \text{ GeV}$	$6.6 \pm 0.2$ (25%)	47463
$m_T > 130 \text{ GeV}$	$5.8 \pm 0.2$ (22%)	18746
Electron & hadron veto	$5.5 \pm 0.2$ (21%)	3612
Muon veto	$5.5 \pm 0.2$ (21%)	1668
Ionization requirement	$5.0 \pm 0.1$ (19%)	11

# STABLE MASSIVE PARTICLES

Simulated $R$ -hadron mass [GeV]	600	800	1000	1200	1400	1600	1800	2000
$\beta\gamma^{\max}$	1.35	1.35	1.35	1.35	1.35	1.15	1.15	1.15
$\beta^{\max}$	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
$m_{\beta\gamma}^{\min}$	350	450	500	575	650	675	750	775
$m_{\beta}^{\min}$	350	450	500	575	650	675	750	775

