SEARCHES FOR SUPERSYMMETRY IN RESONANCE PRODUCTION, R-PARITY VIOLATING SIGNATURES AND EVENTS WITH LONG-LIVED PARTICLES WITH THE ATLAS DETECTOR

DIS 2013 Matthew King Kobe University

Overview

Most Recent

1. SUSY search in events with 4 or more leptons, [RPV]
   8TeV, 21fb^{-1}, ATLAS-CONF-2013-036
2. SUSY search in events with 2 same-sign leptons and jets [RPV]
   8TeV, 21fb^{-1}, ATLAS-CONF-2013-007

Resonance

3. Heavy narrow resonance decaying to $e\mu$, $e\tau$, $\mu\tau$ [RPV]
   7TeV, 4.6fb^{-1}, arxiv:1212.1272v2
4. Pair of 2-jet resonances [scalar gluon]
   7TeV, 4.6fb^{-1}, arxiv:1210.4826v2
5. Pair of 3-jet resonances [RPV]
   7TeV, 4.6fb^{-1}, arxiv:1210.4813v2

Long-lived

6. Displaced vertex with multi-tracks and muon [RPV, LLP]
   7TeV, 4.4fb^{-1}, arxiv:1210.7451v2
7. Non-pointing photons [LLP]
   7TeV, 4.8fb-1, ATLAS-CONF-2013-016
8. Direct chargino production based on disappearing track signature [AMSB, LLP]
   7TeV, 4.7fb^{-1}, arxiv:1210.2852v2
9. Heavy long lived slepton/R-hadron [LLP]
   7TeV, 4.7fb^{-1}, arxiv:1211.1597v2

R-parity violating supersymmetry

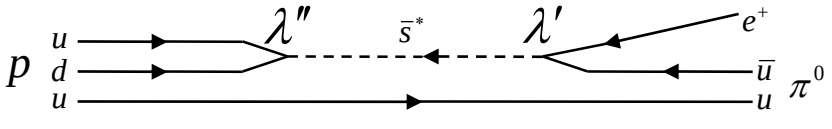
- R-parity ($\equiv (-1)^{3(B-L)+2S}$) need not be exactly conserved.
  - No experimental evidence against R-parity violation (RPV)
  - R-parity violating terms are allowed in the superpotential

$$W_{RPV} = \lambda_{ijk} L_i L_j \overline{E}_k + \lambda'_{ijk} L_i Q_j \overline{D}_k + \kappa_i L_i H_2 + \lambda''_{ijk} \overline{U}_i \overline{D}_j \overline{D}_k$$

lepton number violating — baryon number violating

- However, if all terms exist then the proton becomes unstable

$$\tau_p \propto \frac{|\lambda'||\lambda''|}{M_{SUSY}^2}$$

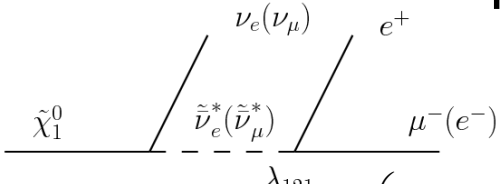


  - Partial inclusion of RPV terms allows stable proton and leads to:
    - Unstable Lightest SUSY Particle (LSP) → Missing E_T/p_T signature reduced or absent
      - Cannot rely heavily on missing E_T/p_T
    - Lepton or Baryon number violating resonances
      - Low missing E_T/p_T allows for clear resonance detection

ATLAS-CONF-2013-036

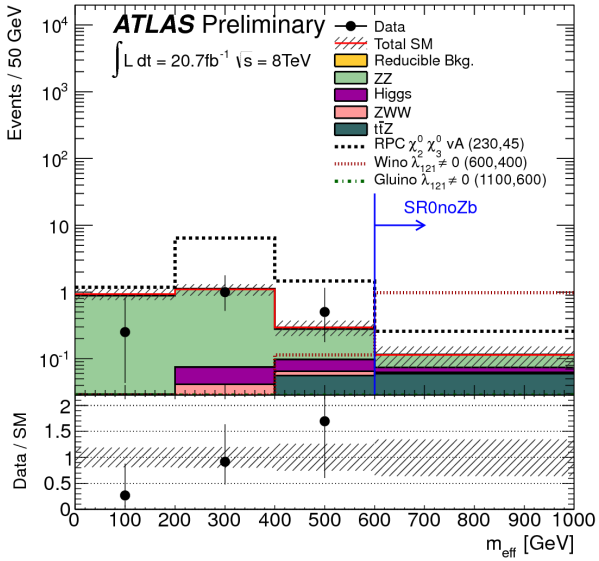
SUSY search in events with 4 or more leptons

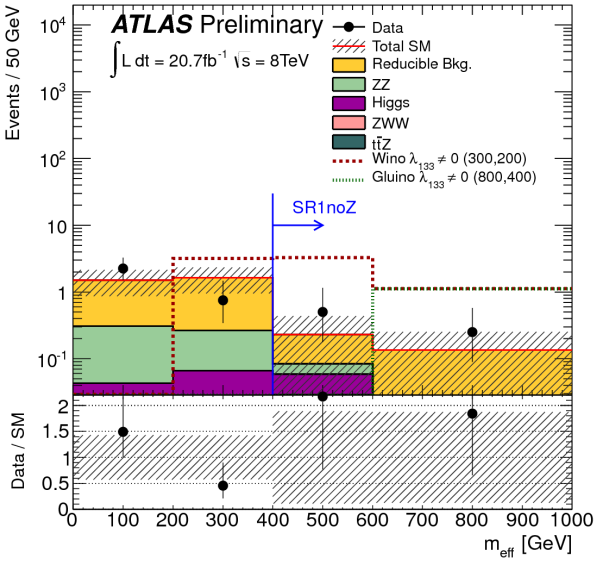
- High lepton multiplicities can be indicative of lepton number violating SUSY
  - Very low SM background
  - Search for such events with high E_T^{miss} or high m_{eff} $\left(= E_T^{miss} + \sum_l p_T^l + \sum_j p_T^j \right)$



- Two signal region types defined:
  - additional Z candidate veto/request option in each SR
    - veto removes Z tagged events
    - request requires Z tagged events

SR	N(e)+ N(μ)	N(τ)	E_T^{miss}[GeV]	m_{eff}[GeV]
SR0	≥ 4	≥ 0	> 75 or	> 600
SR1	= 3	≥ 1	> 100 or	> 400





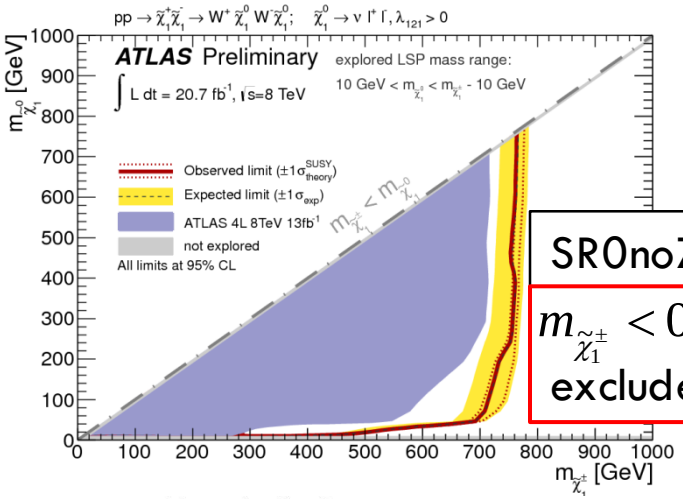
ATLAS-CONF-2013-036

SUSY search in events with 4 or more leptons

Wino model

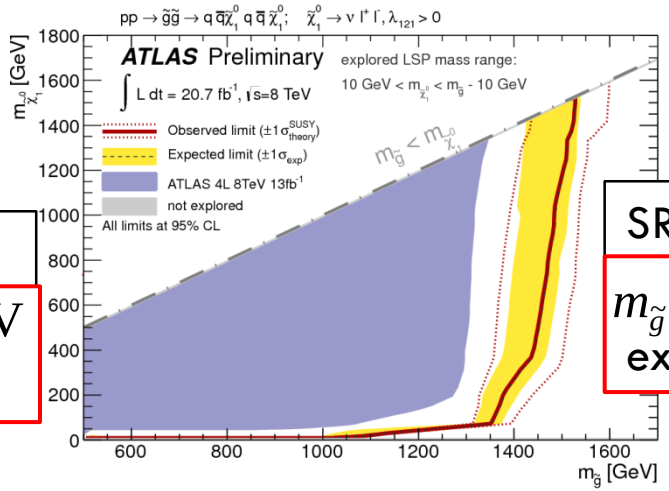
Gluino model

$\lambda_{121} \neq 0$



SR0noZ

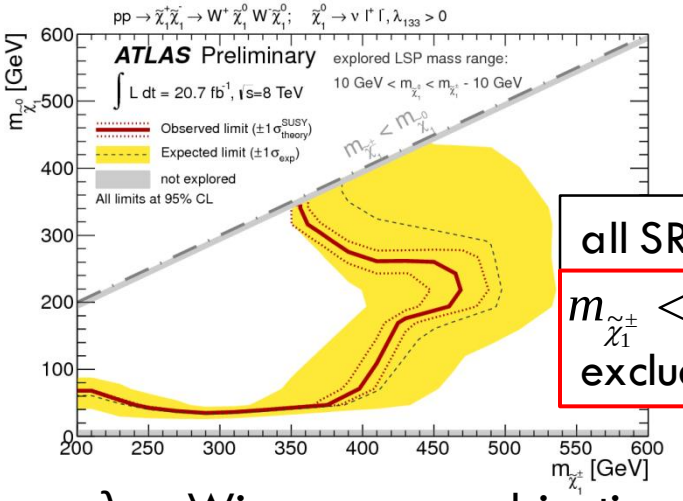
$m_{\tilde{\chi}_1^\pm} < 0.75\text{TeV}$ excluded



SR0noZ

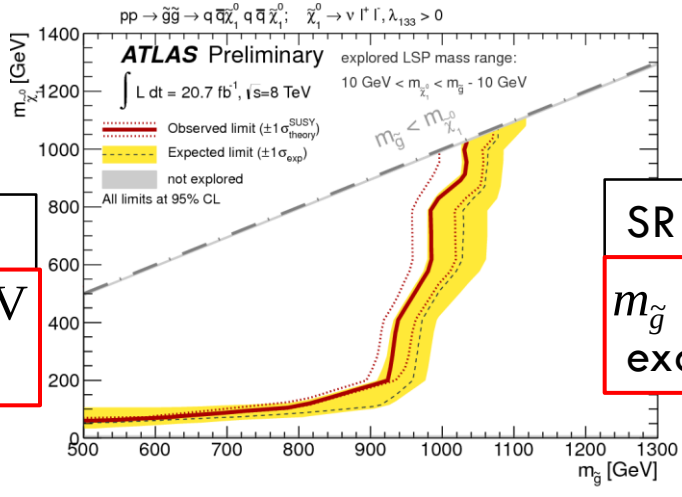
$m_{\tilde{g}} < 1.4\text{TeV}$ excluded

$\lambda_{133} \neq 0$



all SR

$m_{\tilde{\chi}_1^\pm} < 0.3\text{TeV}$ excluded



SR1noZ

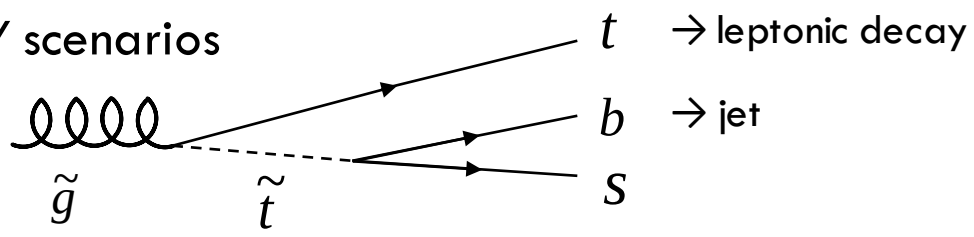
$m_{\tilde{g}} < 1.0\text{TeV}$ excluded

λ_{133} Wino uses a combination of all 4 SR variants

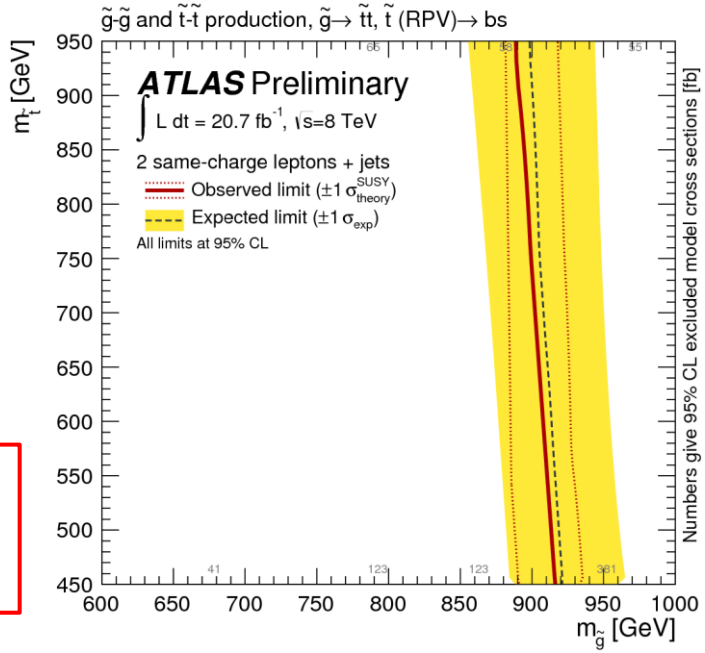
ATLAS-CONF-2013-007

SUSY search in events with 2 same-sign leptons and jets

- Same-sign lepton pairs are rare in SM
  - Low background
  - Applicable to many SUSY scenarios
- RPV scenario
  - gluino pair production
  - characterised by relatively low p_T^{miss} and several b-jets



- RPV signal region:
  - $N_{jets} \geq 5$
  - $E_T^{miss} < 150$GeV or $m_T < 100$GeV



- $N_{obs}=1, N_{exp}=1.8\pm1.3$

$m_{\tilde{g}} < 860\text{GeV}$ can be excluded over the whole stop mass range

3.

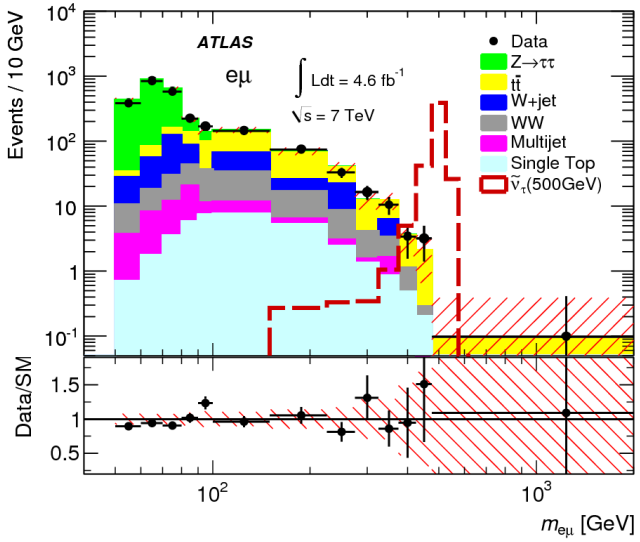
arxiv:1212.1272v2

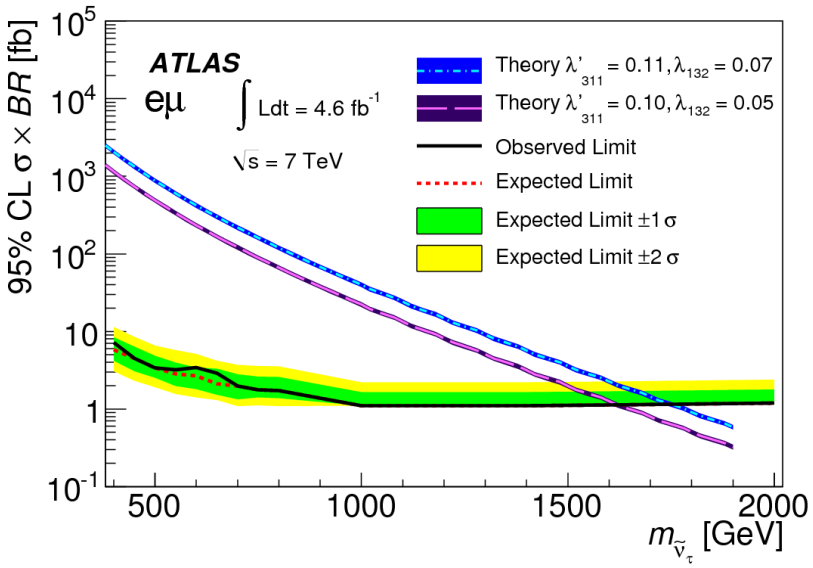
Heavy narrow resonance decaying to $e\mu$, $e\tau$, $\mu\tau$

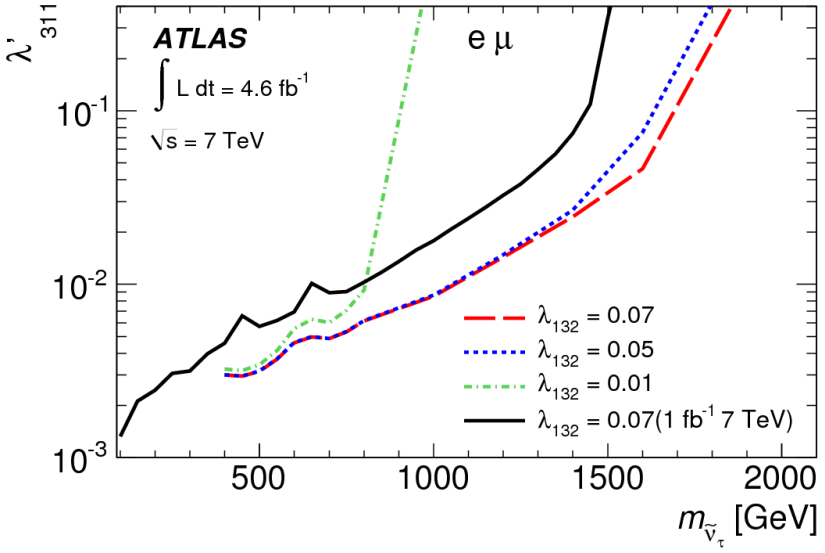
- Lepton number violation can lead to decays of heavy particles into pairs of different generation leptons
  - → Resonance in lepton pairs
  - Search performed for $\tilde{\upsilon}_\tau$ decays

exclusions at $m_{\tilde{\upsilon}_\tau} = 500\text{GeV}$, $\lambda_{i3k} = 0.07$

$e\mu$	channel:	$\lambda'_{311} > 0.003$
$e\tau$	channel:	$\lambda'_{311} > 0.01$
$\mu\tau$	channel:	$\lambda'_{311} > 0.01$





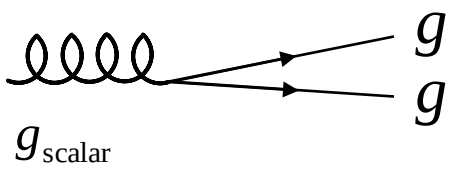


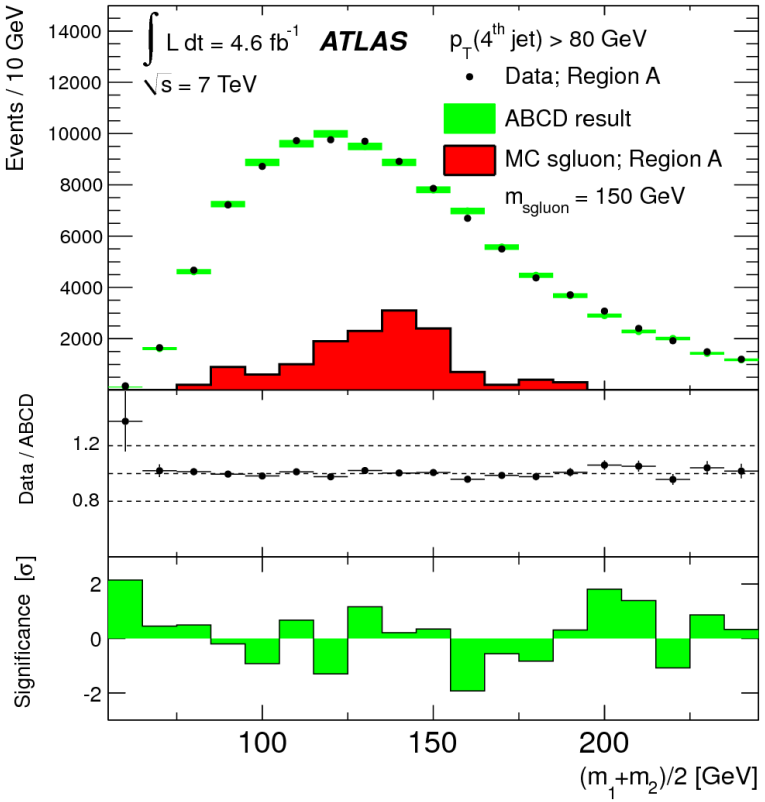
arxiv:1210.4826v2

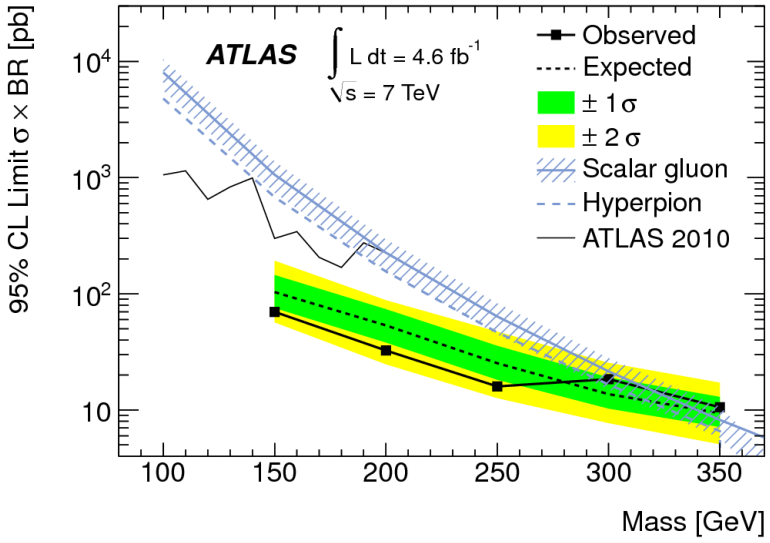
Pair of 2-jet resonances

- Search performed in framework of pair produced scalar gluons (sgluon)
  - Decays other than $g_{scalar} \rightarrow gg$ are suppressed
  - → pair of 2-jet resonances with similar mass
  - in Signal Region (Region A): $\frac{|m_1 - m_2|}{(m_1 + m_2)} < 0.15$, $|\cos(\theta^*)| < 0.15$

(Massive, colored, present in extended SUSY models)





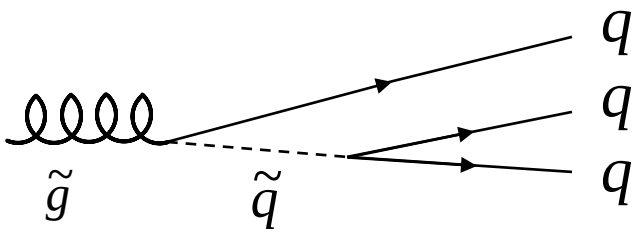


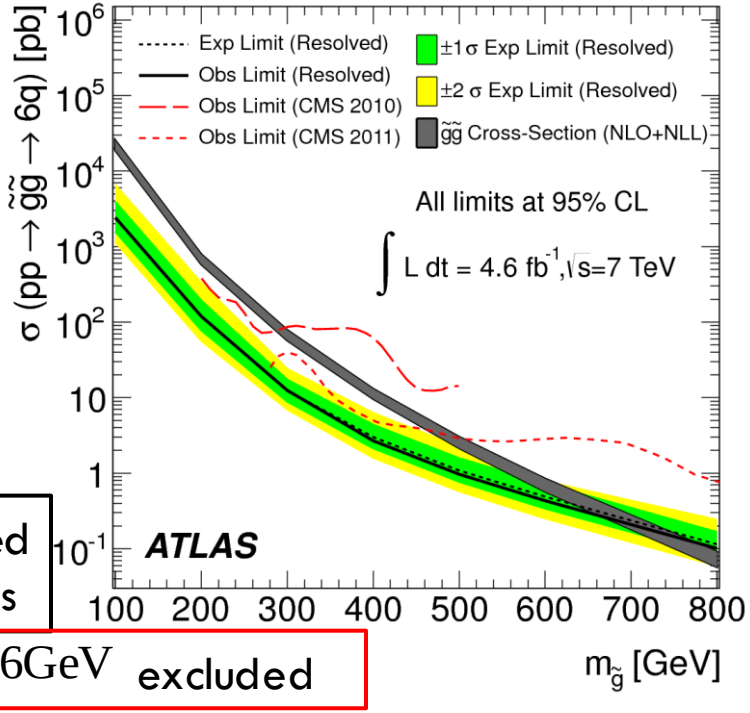
$150\text{GeV} < m_{\text{sgluon}} < 287\text{GeV}$ excluded

arxiv:1210.4813v2

Pair of 3-jet resonances

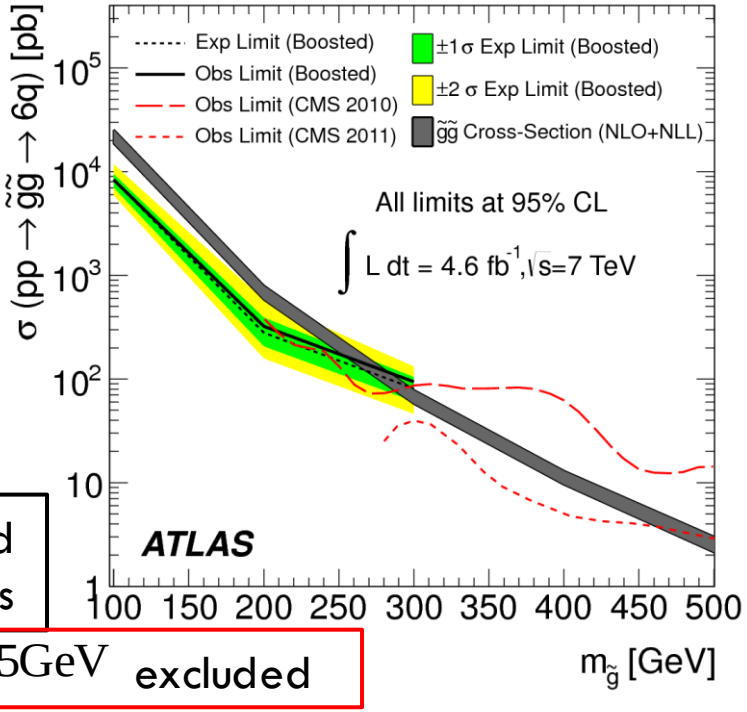
- In RPV, gluino may decay into 3 quarks
- Two orthogonal search channels:
  - High $\tilde{g}$ mass → resolve all 6 jets
  - Low $\tilde{g}$ mass → jets are heavily boosted and difficult to resolve
    → analyse jets for structure indicative of 3 sub-jets





Resolved Analysis

$m_{\tilde{g}} < 666\text{GeV}$ excluded



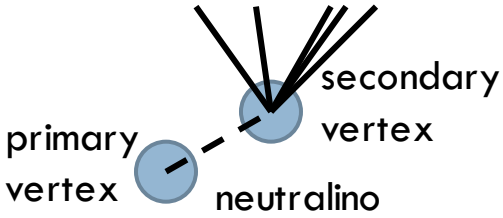
Boosted Analysis

$m_{\tilde{g}} < 255\text{GeV}$ excluded

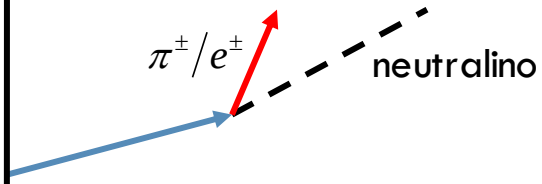
Long-lived particles (LLPs)

- R-parity violating (RPV) scenarios:
  - Lifetimes proportional to λ^{-2}; λ'^{-2}; λ''^{-2}
    - → if λ is very small, long-lived $\tilde{\chi}$ LSPs are possible
- R-parity conserving (RPC) scenarios:
  - Slow NLSP decay to LSP due to mass degeneracy or weak coupling
    - $\tilde{\chi}$ in Anomaly-Mediated SUSY Breaking (medium decay length)
    - $\tilde{\tau}$ in Gauge-Mediated SUSY Breaking (long decay length)
    - R-hadron (generic SUSY) (long decay length)

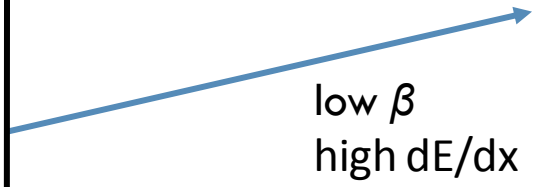
Short decay length (~10mm)
Displaced vertex



Medium decay length (~100mm)
Disappearing/Kinked track



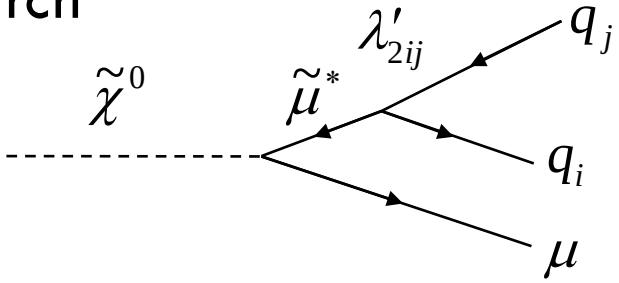
Long decay length (>~1000mm)
Stable massive particle (SMP)

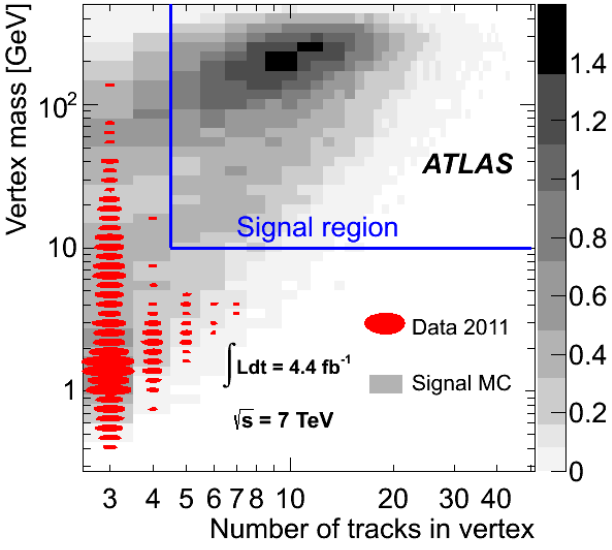


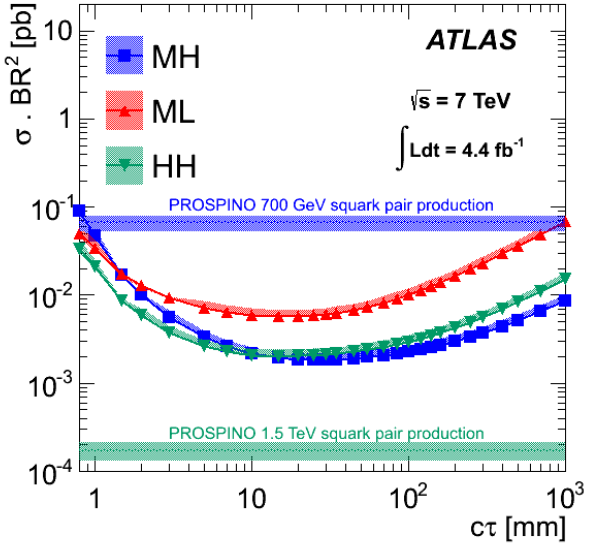
arxiv:1210.7451v2

Displaced vertex with multi-tracks and muon

- Search conducted in the framework of a search for neutralino decay in RPV SUSY
  - Short, but measurable, flight length leads to displaced secondary vertex
    - Require impact parameter (d0) > 1.5mm
    - Require high mass vertex to reduce background
      - Random "fake vertexes" of real and fake tracks, gas interactions
    - Require high number of tracks to increase vertex reconstruction reliability







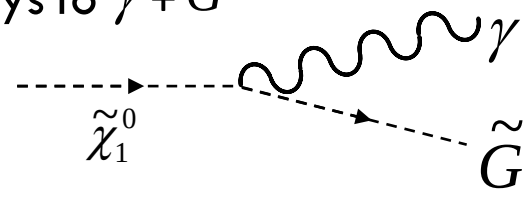
model masses (GeV)	$m_{\tilde{q}}$	$m_{\tilde{\chi}}$
MH:	700	494
ML:	700	108
HH:	1500	494

for 1mm<cτ<1000mm $m_{\tilde{q}} < 700\text{GeV}$ are excluded

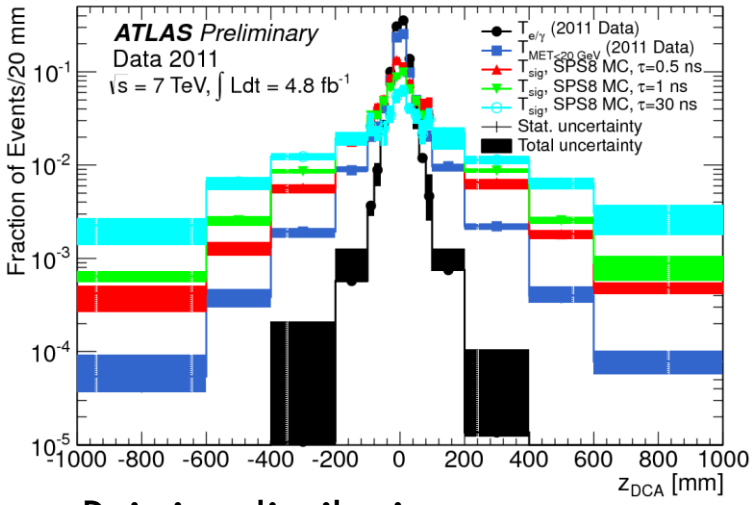
ATLAS-CONF-2013-016

Non-pointing photons

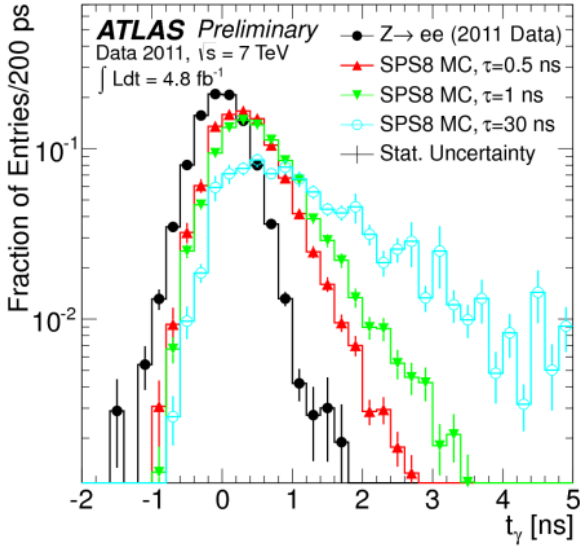
- In SPS8 GMSB, NLSP $\tilde{\chi}_1^0$ is long lived ($c\tau$ =free parameter)
  - Decays to $\gamma + \tilde{G}$



  - Search for signature of E_T^{miss} plus:
    - Pairs of high (>75GeV) E_T photons not pointing back to primary vertex
      (in practice, pointing of only one can be checked)
    - Evidence of late photon detection
      - Only used as a cross-check, not to generate limits
  - Requires specialist use of ATLAS EM calorimeter
  - Pointing distribution templates generated from MC (signal) and Data (background)



Pointing distributions



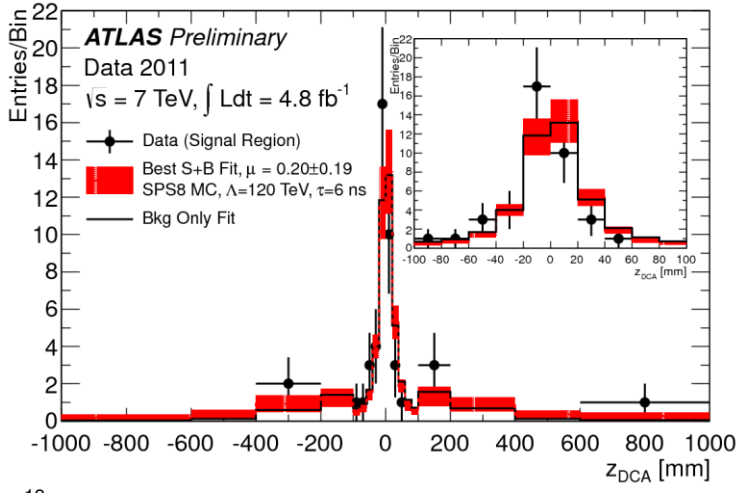
Timing distributions

ATLAS-CONF-2013-016

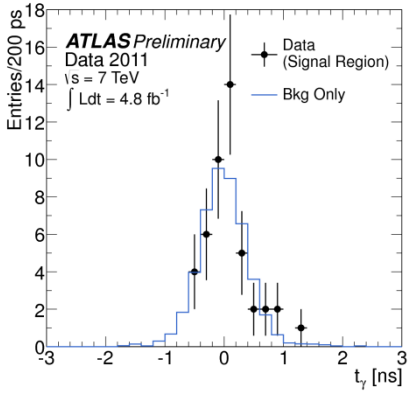
Non-pointing photons

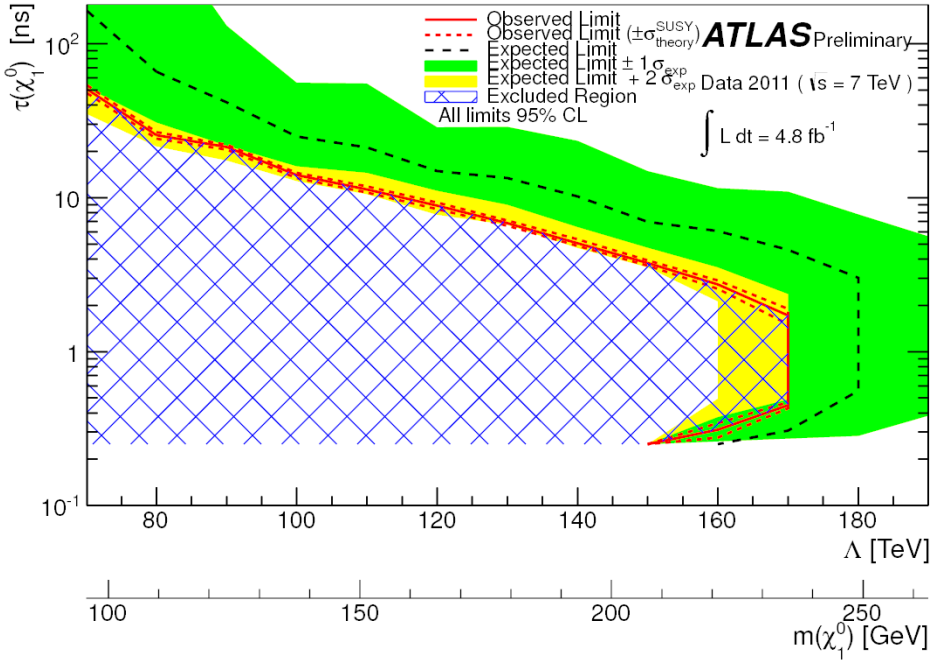
- Limits obtained by fitting templates to SR photon pointing distribution
- Cross check on photon times is consistent with prompt photon production

Pointing distribution



Timing distribution





$m_{\tilde{\chi}_1^0} < 230\text{GeV}$

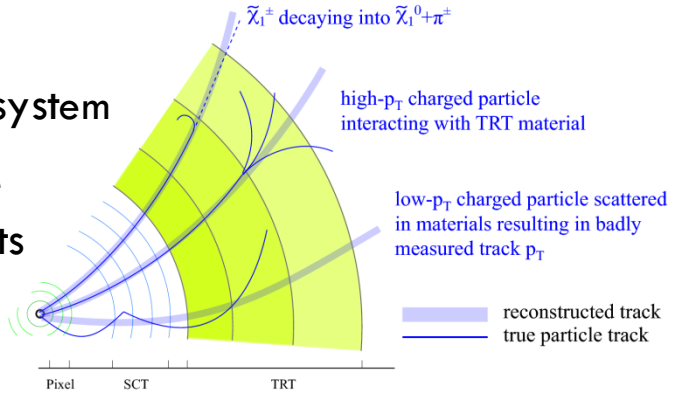
excluded for

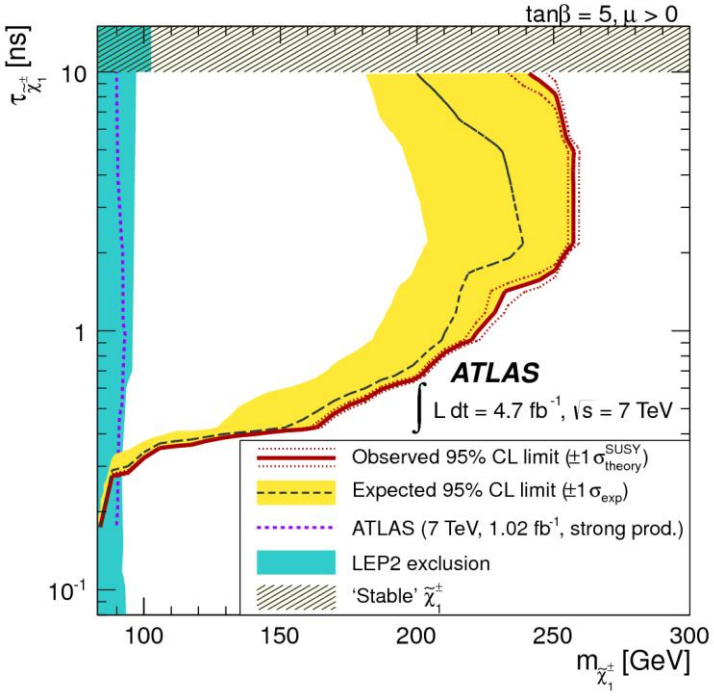
$0.4 < \tau_{\tilde{\chi}_1^0} < 2.0\text{ns}$

Direct chargino production based on disappearing track signature

arxiv:1210.2852v2

- Chargino $\tilde{\chi}_1^{\pm}$ in AMSB may have decay length of order ~10cm
  - Decays into neutralino and low-momentum $\pi^{\pm}$
  - →Tracks disappear inside the inner detector's TRT system
    - Search by finding tracks well reconstructed in the pixel and SCT systems, but with low number of hits in the outer TRT modules

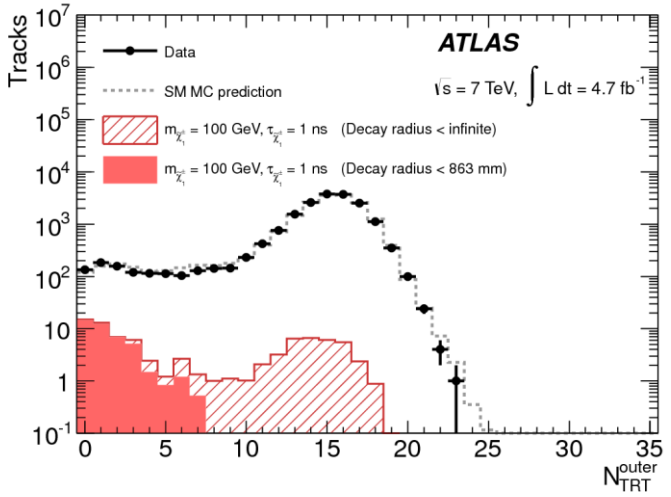




- Excludable mass depends on decay time

$m_{\tilde{\chi}_1^0} <\sim 100\text{GeV}$
for $\tau_{\tilde{\chi}_1^0} \approx 0.3\text{ns}$
(most probable τ)

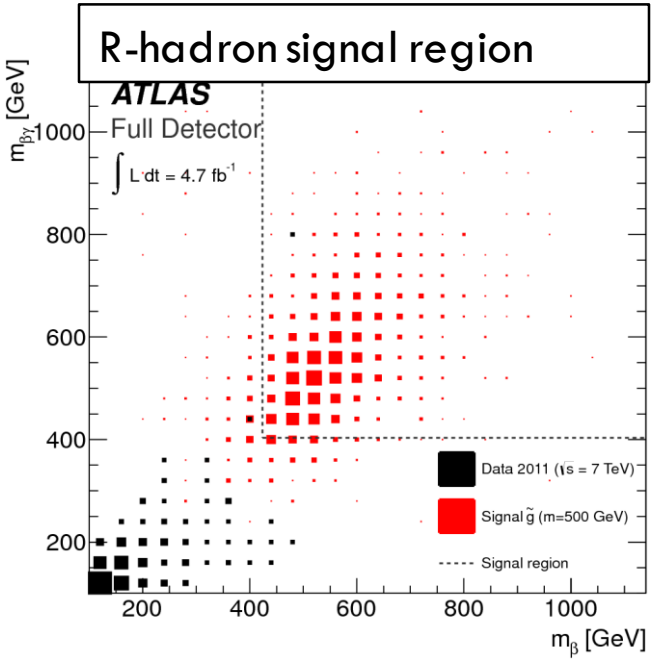
$m_{\tilde{\chi}_1^0} < 260\text{GeV}$
for $\tau_{\tilde{\chi}_1^0} \approx 3\text{ns}$
(most stringent limit)

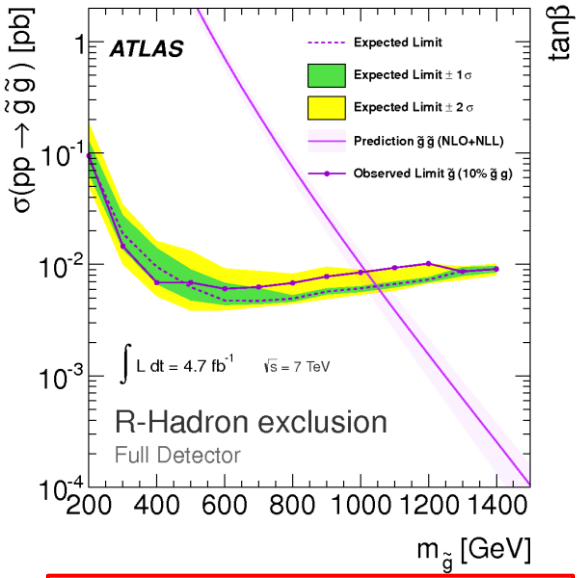


arxiv:1211.1597v2

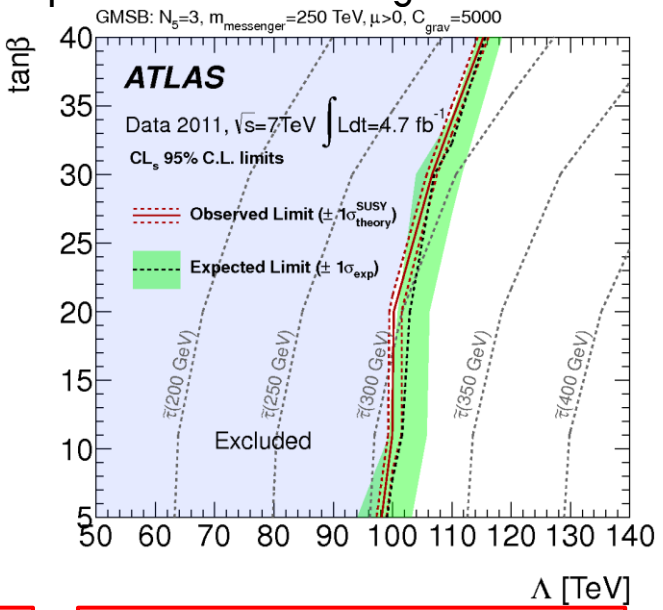
Heavy long lived slepton/R-hadron

- Search performed for LLPs with decay lengths >1000mm
  - Particle passes through all detectors
    - Slepton → constant charge, low energy loss
      - Measure β across whole detector
    - R-hadron → charge may change during flight, high energy loss
      - For full detector search, measure dE/dx as well as β
      - Additional searches over shorter ranges to account for possible loss of charge





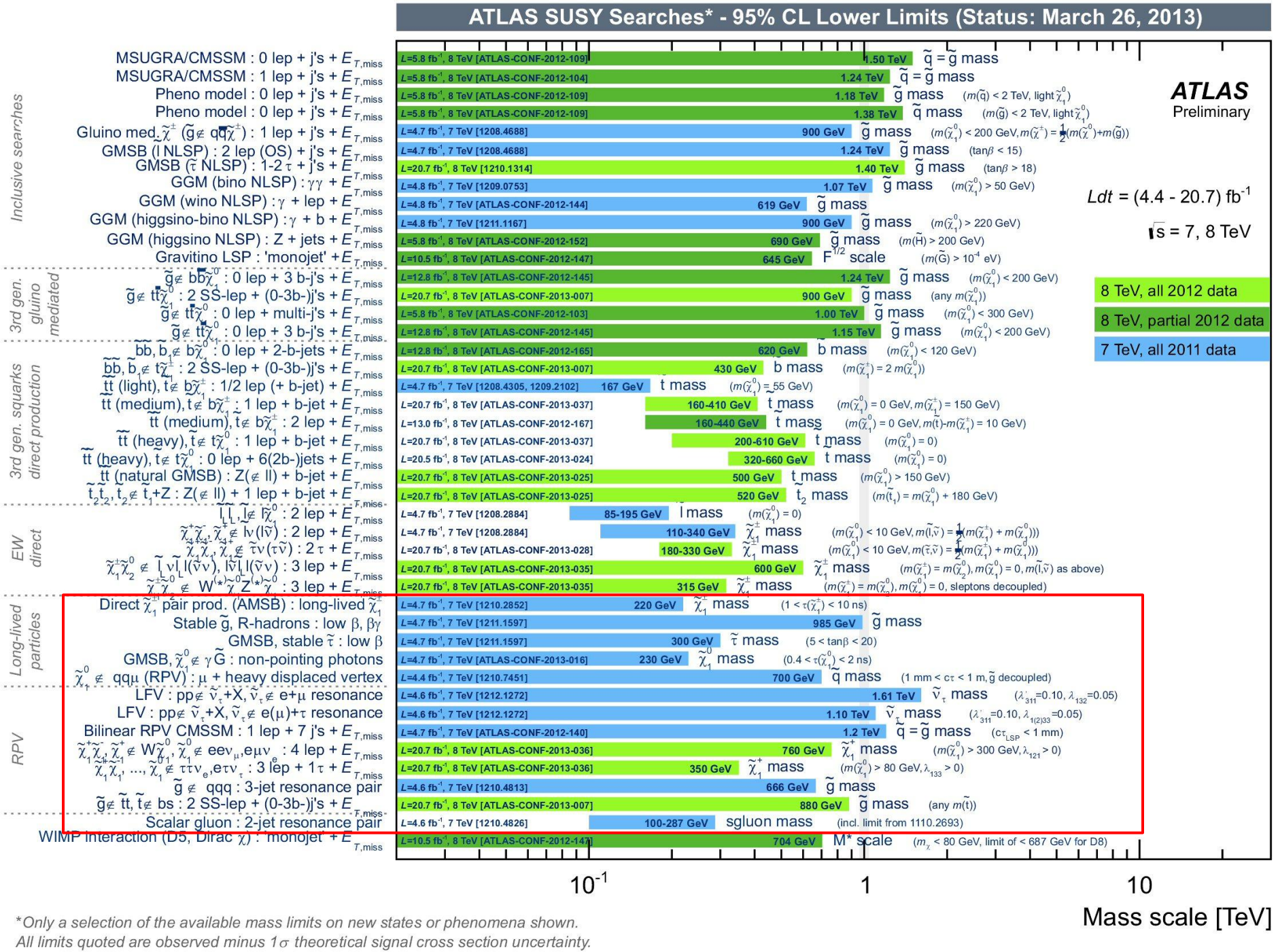
$m_{\tilde{g}} < 985\,\mathrm{GeV}$ (full detector)



$m_{\tilde{\tau}} < 300\,\mathrm{GeV}$ (for tanβ<20)

Summary

- Certain SUSY models predict interesting signatures
  - RPV: resonances, multi-jet, multi-lepton
  - LL: displaced vertex, non-pointing photons, disappearing tracks, SMP
- These analyses can require unusual reconstruction techniques
  - Low E_T, time of flight measurements, non-pointing photon identification…
  - Challenging to perform!
- No evidence of SUSY observed as of yet
- $20fb^{-1}$ of new 8TeV data allows significant increases in exclusion limits over previous searches
  - Most analyses on 8TeV data not yet finished, watch for updates



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

Backup Slides

ATLAS-CONF-2013-036

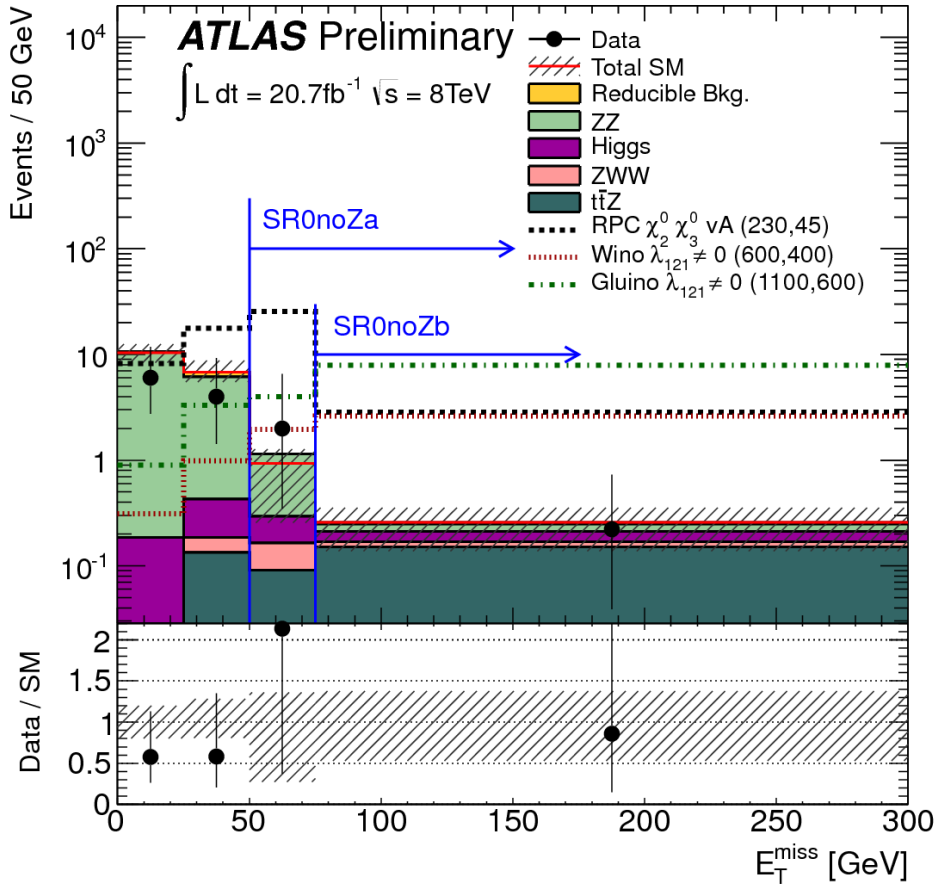
SUSY search in events with 4 or more leptons

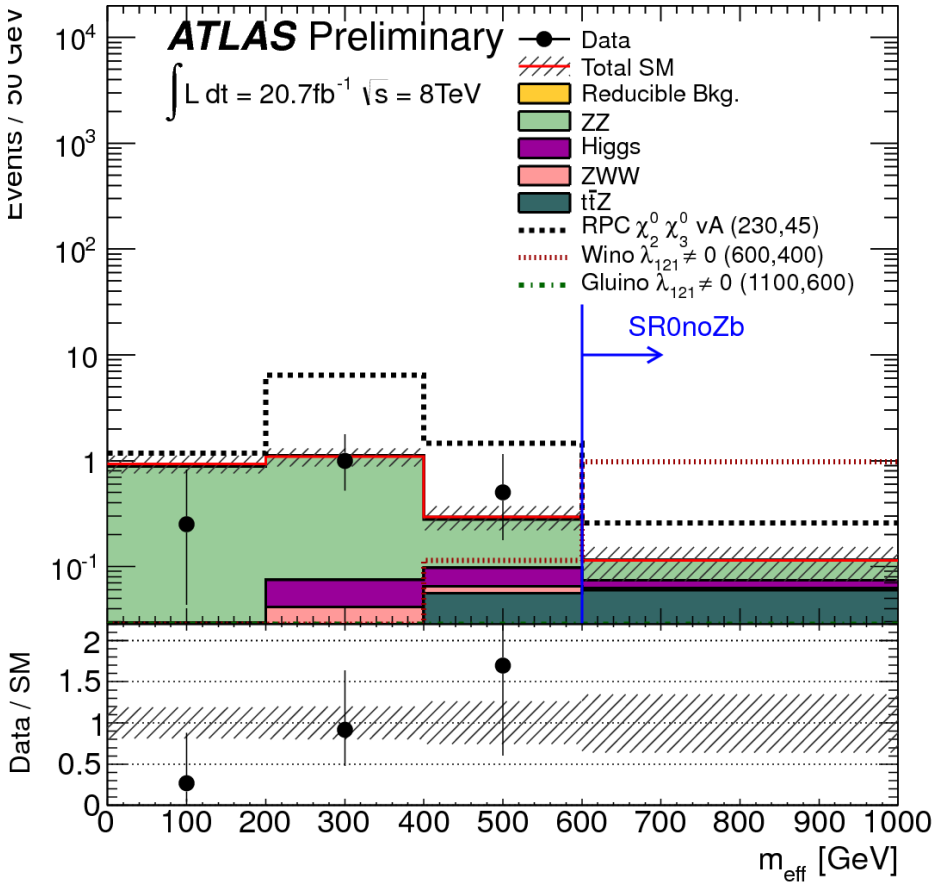
- Main backgrounds processes:

Sample	SR0noZa	SR0noZb	SR1noZ	SR0Z	SR1Z
ZZ	0.6 ± 0.5	0.50 ± 0.26	0.19 ± 0.05	1.2 ± 0.4	0.49 ± 0.10
ZWW	0.12 ± 0.12	0.08 ± 0.08	0.05 ± 0.05	0.6 ± 0.6	0.13 ± 0.13
$t\bar{t}Z$	0.73 ± 0.34	0.75 ± 0.35	0.16 ± 0.12	2.3 ± 0.9	0.29 ± 0.24
Higgs	0.26 ± 0.07	0.22 ± 0.07	0.23 ± 0.06	0.58 ± 0.15	0.14 ± 0.05
Irreducible Bkg.	1.7 ± 0.8	1.6 ± 0.6	0.62 ± 0.21	4.8 ± 1.8	1.1 ± 0.4
Reducible Bkg.	$0^{+0.16}_{-0}$	$0.05^{+0.14}_{-0.05}$	1.4 ± 1.3	$0^{+0.14}_{-0}$	$0.3^{+1.0}_{-0.3}$
Total Bkg.	1.7 ± 0.8	1.6 ± 0.6	2.0 ± 1.3	4.8 ± 1.8	$1.3^{+1.0}_{-0.5}$
Data	2	1	4	8	3
p_0-value	0.29	0.5	0.15	0.08	0.13
N_{signal} Excluded (exp)	3.9	3.6	5.3	6.7	4.5
N_{signal} Excluded (obs)	4.7	3.7	7.5	10.4	6.5
σ_{visible} Excluded (exp) [fb]	0.19	0.17	0.26	0.32	0.22
σ_{visible} Excluded (obs) [fb]	0.23	0.18	0.36	0.50	0.31

ATLAS-CONF-2013-036

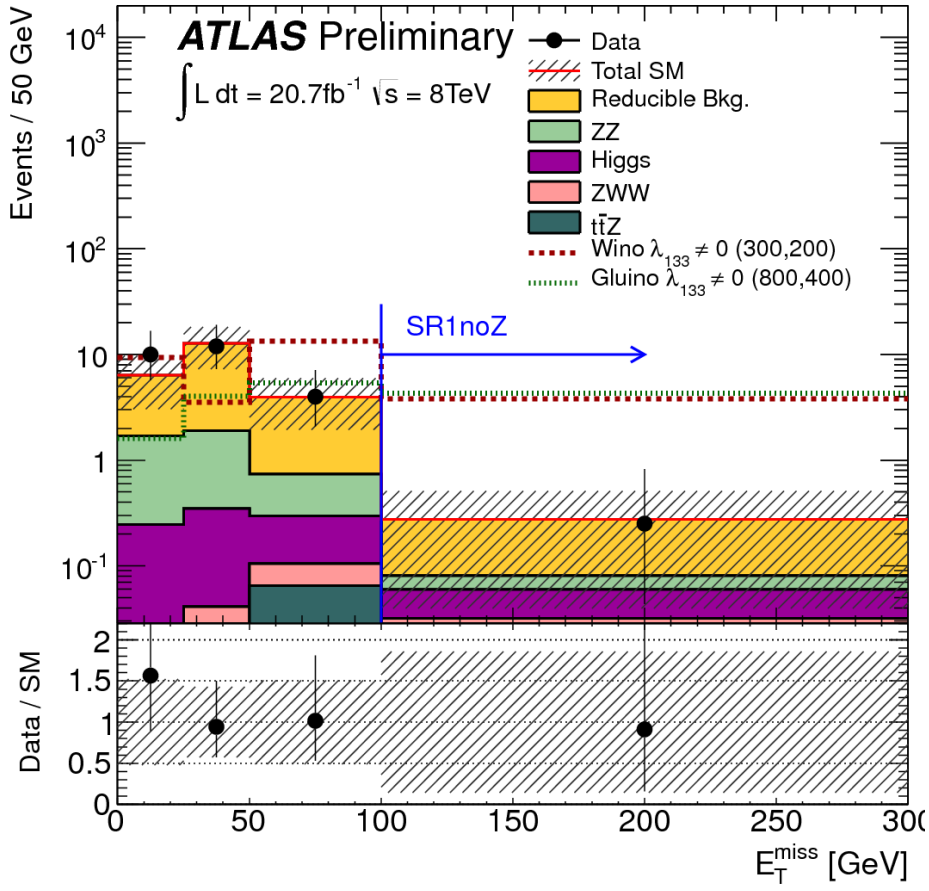
SUSY search in events with 4 or more leptons

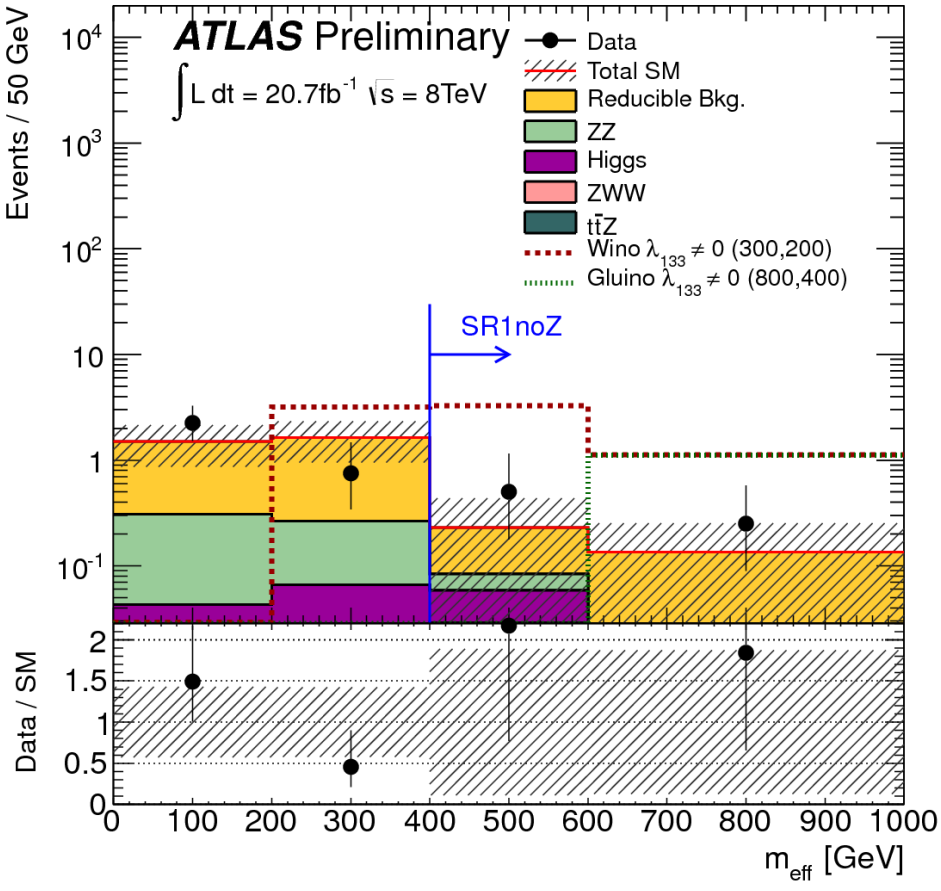




ATLAS-CONF-2013-036

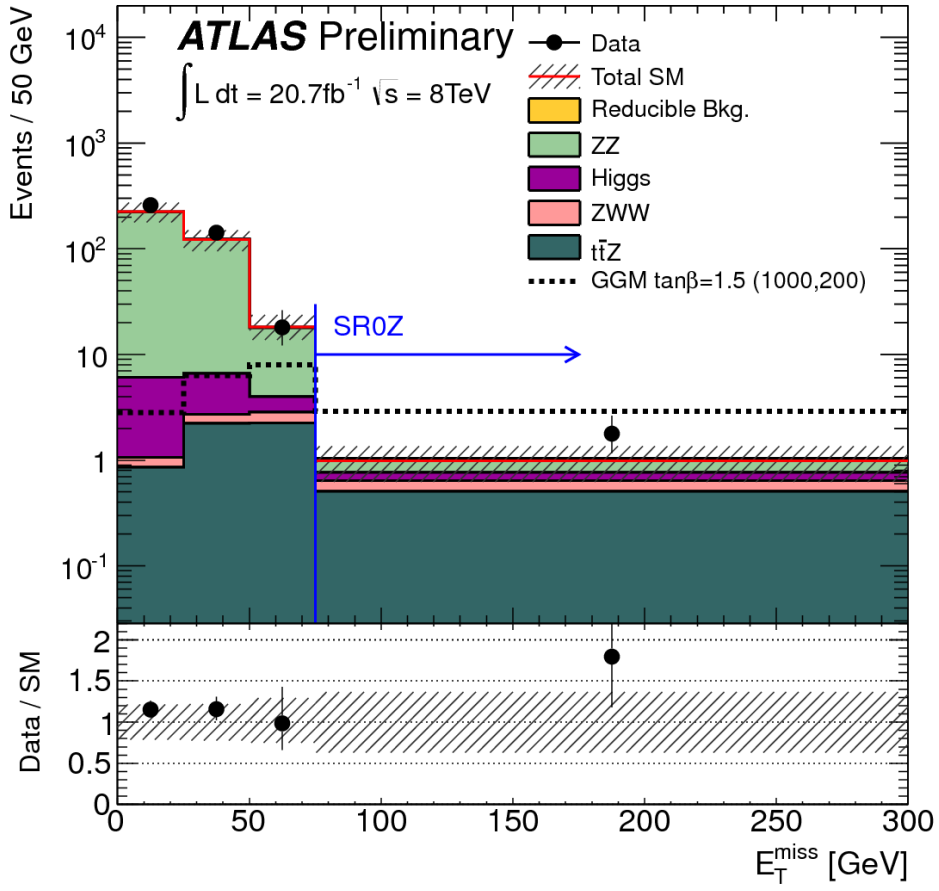
SUSY search in events with 4 or more leptons

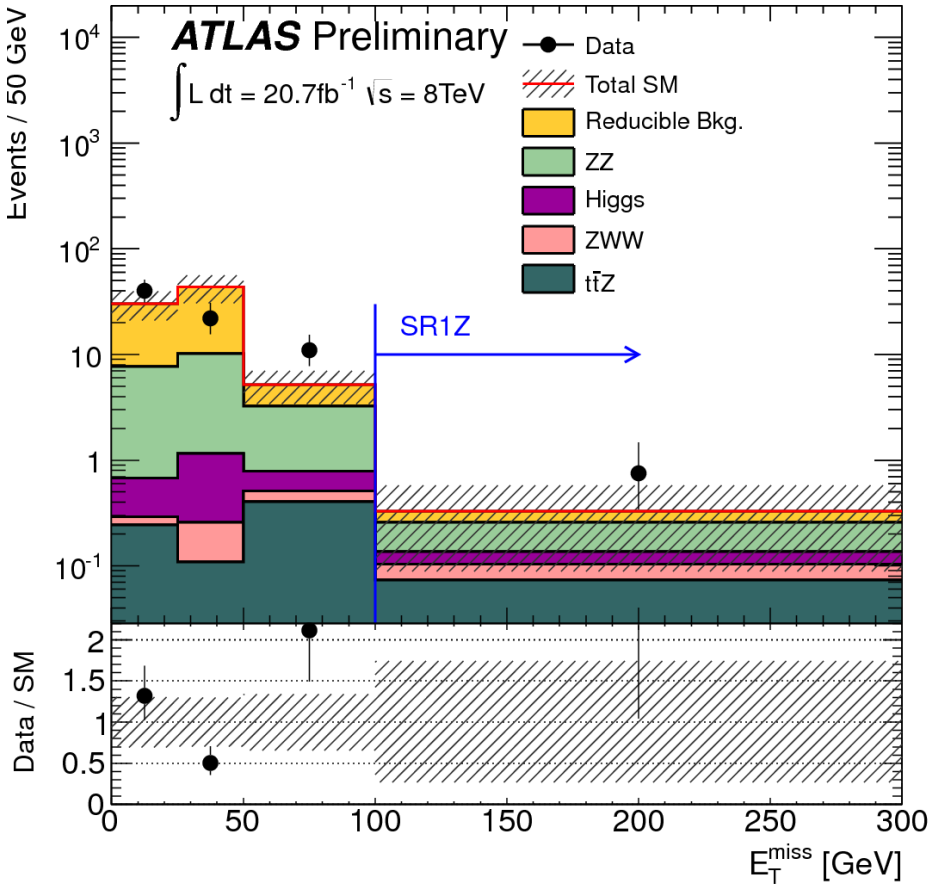




ATLAS-CONF-2013-036

SUSY search in events with 4 or more leptons





arxiv:1212.1272v2

Heavy narrow resonance decaying to $e\mu$, $e\tau$, $\mu\tau$

- Main Background Processes:

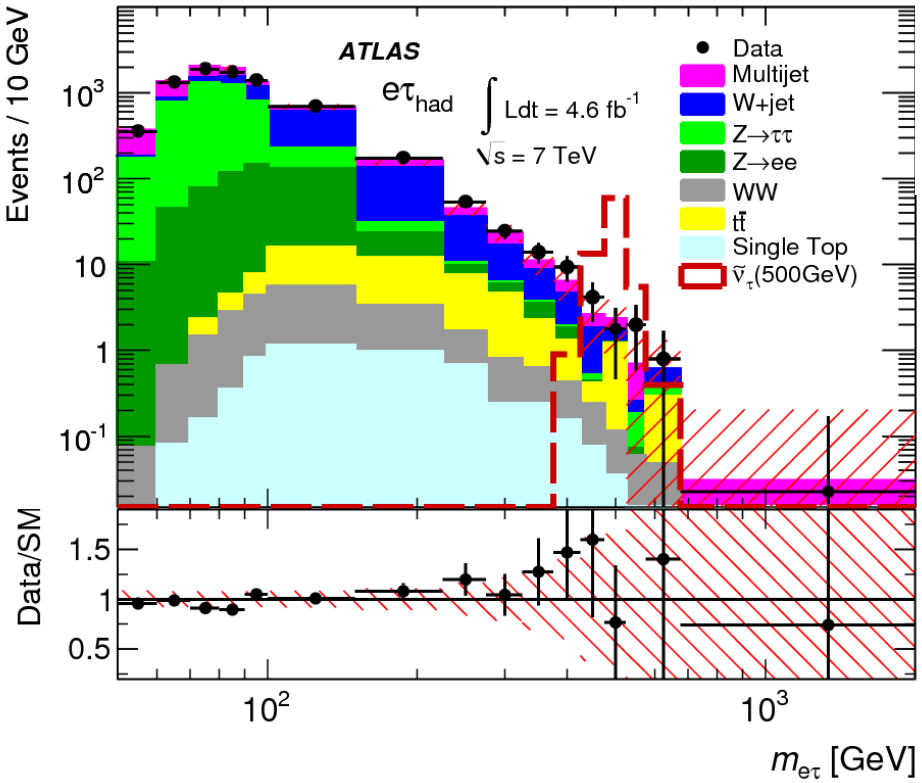
	$m_{\ell\ell'} < 200$ GeV			$m_{\ell\ell'} > 200$ GeV		
Process	$N_{e\mu}$	$N_{e\tau_{\text{had}}}$	$N_{\mu\tau_{\text{had}}}$	$N_{e\mu}$	$N_{e\tau_{\text{had}}}$	$N_{\mu\tau_{\text{had}}}$
$Z/\gamma^* \to \tau\tau$	1880 ± 150	4300 ± 600	5300 ± 600	8 ± 1	24 ± 3	28 ± 4
$Z/\gamma^* \to ee$		1050 ± 80			44 ± 3	
$Z/\gamma^* \to \mu\mu$			3030 ± 290			29 ± 3
$t\bar{t}$	760 ± 110	96 ± 18	94 ± 14	251 ± 30	90 ± 15	70 ± 13
Diboson	260 ± 27	57 ± 8	60 ± 7	71 ± 8	26 ± 3	24 ± 3
Single top quark	87 ± 8	11 ± 2	9 ± 1	39 ± 4	10 ± 2	8 ± 1
W+jets	420 ± 260	3500 ± 700	3200 ± 600	90 ± 40	370 ± 80	470 ± 110
multijet	37 ± 13	2200 ± 700	730 ± 230	6 ± 2	150 ± 50	24 ± 18
Total background	3440 ± 300	11200 ± 900	12400 ± 800	460 ± 60	720 ± 80	650 ± 90
Data	3345	11212	12285	498	795	699

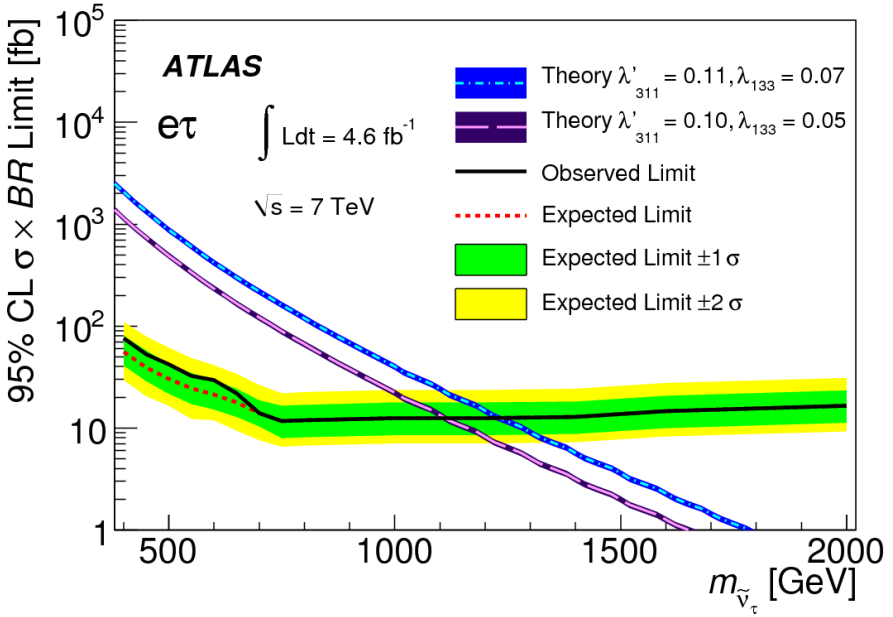
3.

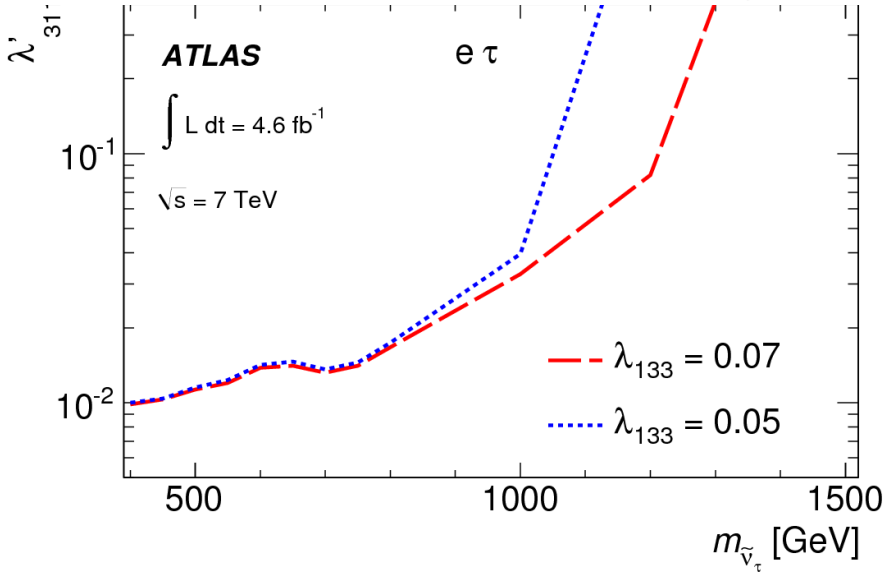
arxiv:1212.1272v2

Heavy narrow resonance decaying to $e\mu$, $e\tau$, $\mu\tau$

- $e\tau$ channel





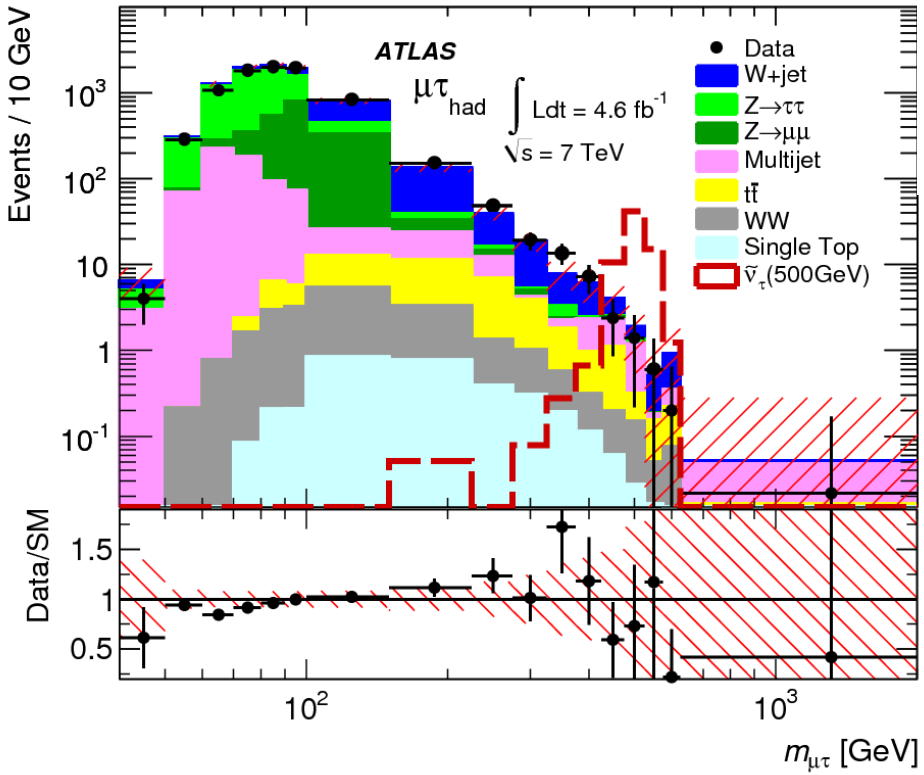


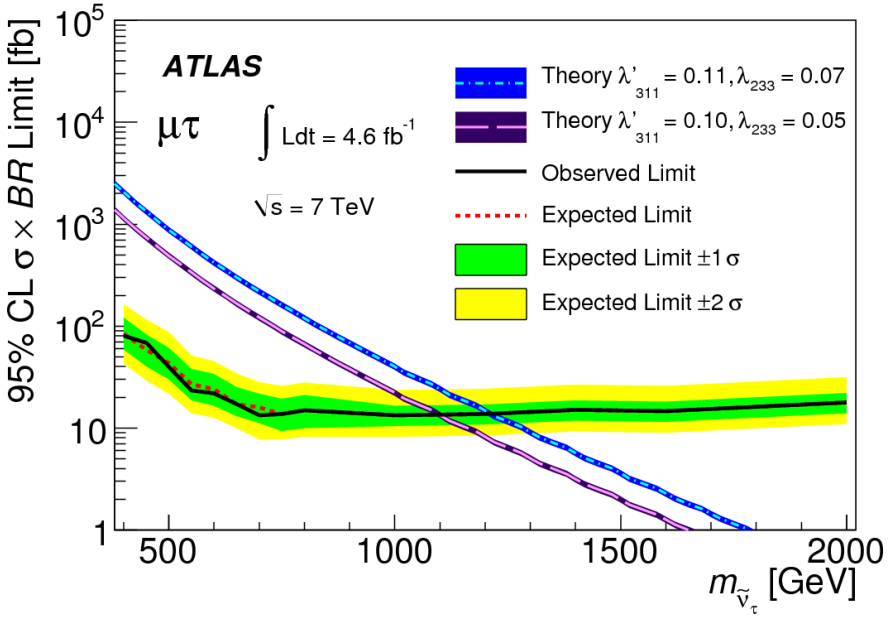
3.

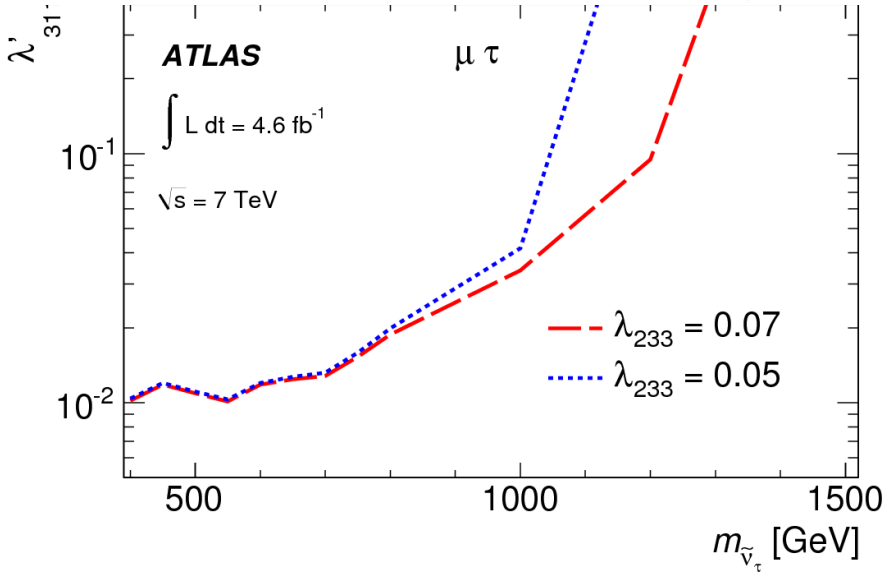
arxiv:1212.1272v2

Heavy narrow resonance decaying to $e\mu$, $e\tau$, $\mu\tau$

- $\mu\tau$ channel



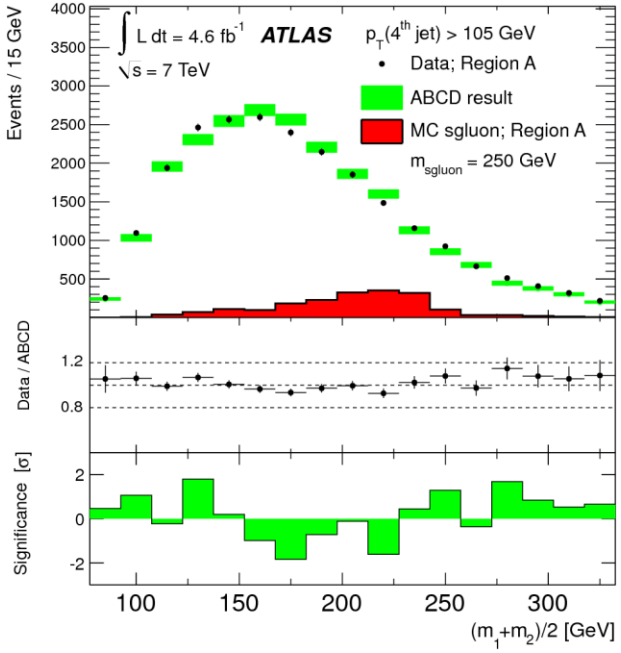


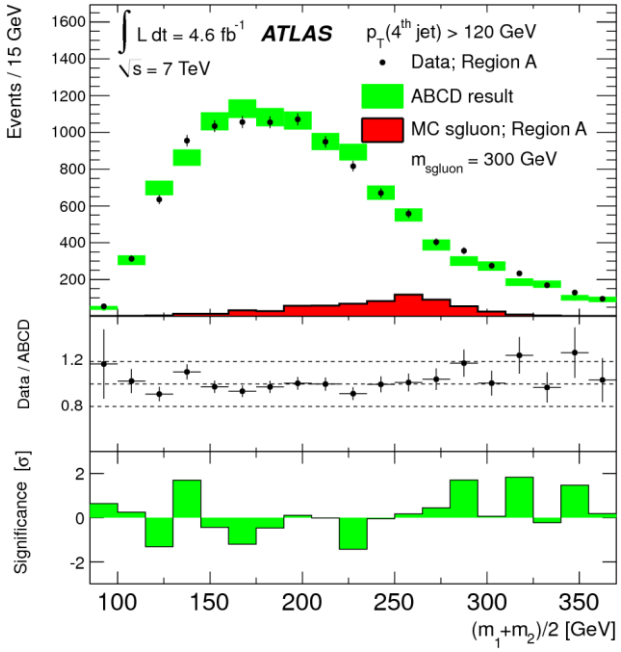


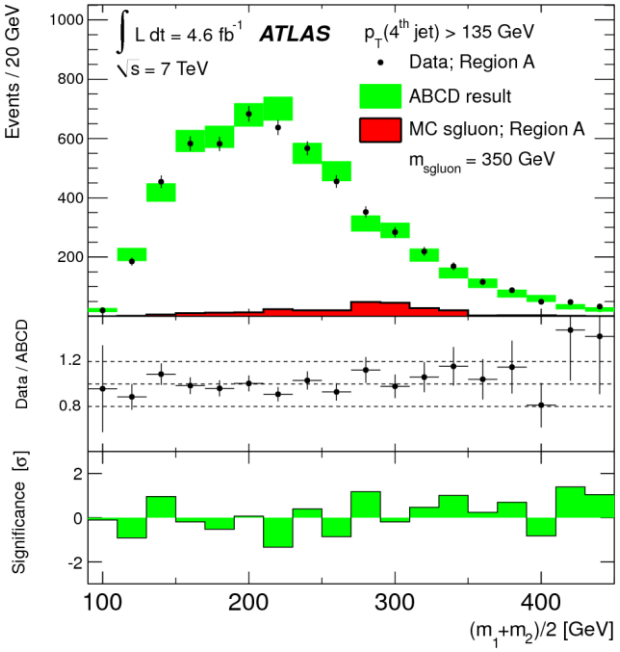
arxiv:1210.4826v2

Pair of 2-jet resonances

Sgluon Mass [GeV]	$p_{\mathrm{T}}^{\mathrm{min}}$ [GeV]	Data	ABCD prediction	Shape p-value(A,B)
150	80	102162	$101100 \pm 800 \pm 2000$	0.22
200	90	55194	$54500 \pm 600 \pm 1100$	0.10
250	105	23404	$22500 \pm 340 \pm 500$	0.28
300	120	11082	$10640 \pm 230 \pm 210$	0.24
350	135	5571	$5330 \pm 180 \pm 110$	0.70



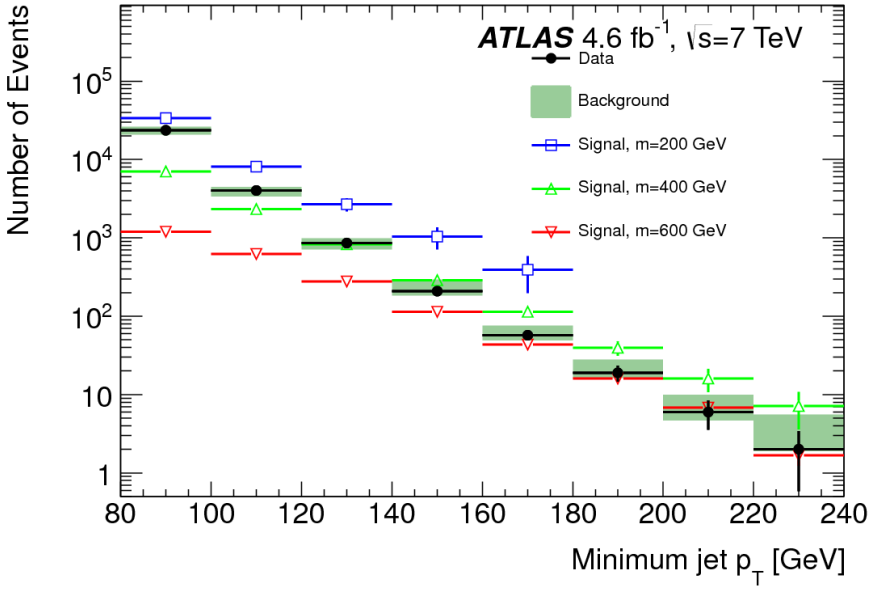




arxiv:1210.4813v2

Pair of 3-jet resonances

- Resolved Analysis



Model ($m_{\tilde{g}}$)	$p_{\mathrm{T,min}}^{\text{6th-jet}}$	Data	Background	Signal bias [%]	Signal
100 GeV	80 GeV	23600	23500 ± 2800	8.5	99200 ± 20000
200 GeV	120 GeV	856	851 ± 140	3.7	2700 ± 500
300 GeV	120 GeV	856	851 ± 140	1.0	1460 ± 240
400 GeV	160 GeV	57	62 ± 13	0.8	110 ± 13
500 GeV	160 GeV	57	62 ± 13	0.3	67 ± 9
600 GeV	160 GeV	57	62 ± 13	0.1	43 ± 7
800 GeV	160 GeV	57	62 ± 13	0.0	20 ± 3

arxiv:1210.4813v2

Pair of 3-jet resonances

- Boosted Analysis:
  - Main decay products form large-R jet, other jets offshoot

Selection	Baseline Selection	SR1	SR2
Small-R ($R = 0.4$) jet $p_{\mathrm{T}}^{\mathrm{jet}}$	$p_{\mathrm{T}}^{\mathrm{jet}} > 30$ GeV	$p_{\mathrm{T}}^{\mathrm{jet}} > 30$ GeV	$p_{\mathrm{T}}^{\mathrm{jet}} > 30$ GeV
Large-R ($R = 1.0$) jet $p_{\mathrm{T}}^{\mathrm{jet}}$	$p_{\mathrm{T}}^{\mathrm{jet}} > 200$ GeV	$p_{\mathrm{T}}^{\mathrm{jet}} > 200$ GeV	$p_{\mathrm{T}}^{\mathrm{jet}} > 350$ GeV
Scalar sum $\sum_{i=1}^{N_{\mathrm{jet}}^{R4}=4} p_{\mathrm{T}}^{\mathrm{jet}}$	(—)	600 GeV	(—)
Small-R jet multiplicity	(—)	$N_{\mathrm{jet}}^{R4} \geq 4$	$N_{\mathrm{jet}}^{R4} \geq 4$
Large-R jet multiplicity	$N_{\mathrm{jet}} \geq 2$	$N_{\mathrm{jet}} \geq 2$	$N_{\mathrm{jet}} \geq 2$
Large-R jet mass	(—)	$m_{J_1,J_2}^{\mathrm{jet}} > 60$ GeV	$m_{J_1,J_2}^{\mathrm{jet}} > 140$ GeV
Large-R jet τ_{32}	(—)	$\tau_{32} < 0.7$	$\tau_{32} < 0.7$

  - ($M_{\mathrm{threshold}}$ used in control region)

Model ($m_{\tilde{g}}$)	$M_{\mathrm{threshold}}$	Data	Background	Signal Bias [%]	Signal
100 GeV	60 GeV	40683	42400 ± 9700	65	77900 ± 16000
200 GeV	140 GeV	1059	860 ± 460	31	2400 ± 670
300 GeV	140 GeV	1059	860 ± 460	9	590 ± 55

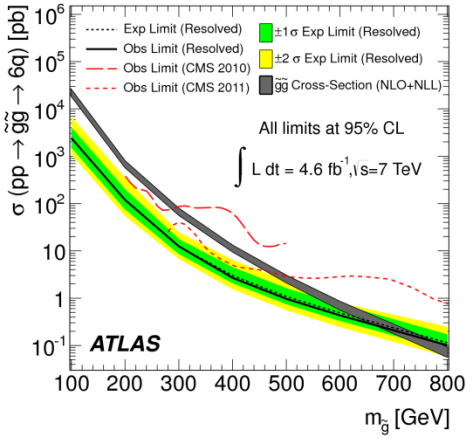
arxiv:1210.4813v2

Pair of 3-jet resonances

- Acceptances and Exclusions:

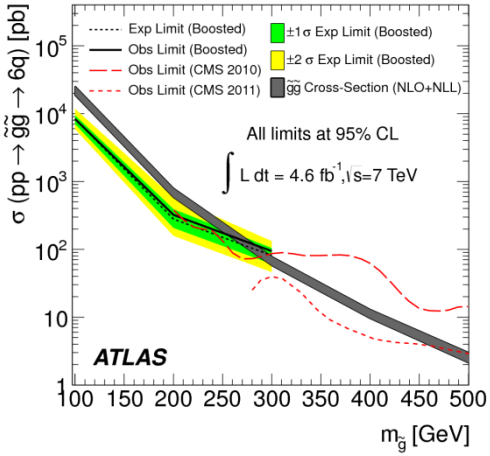
Resolved Analysis

$m_{\tilde{g}} < 666\text{GeV}$ excluded



Boosted Analysis

$m_{\tilde{g}} < 255\text{GeV}$ excluded

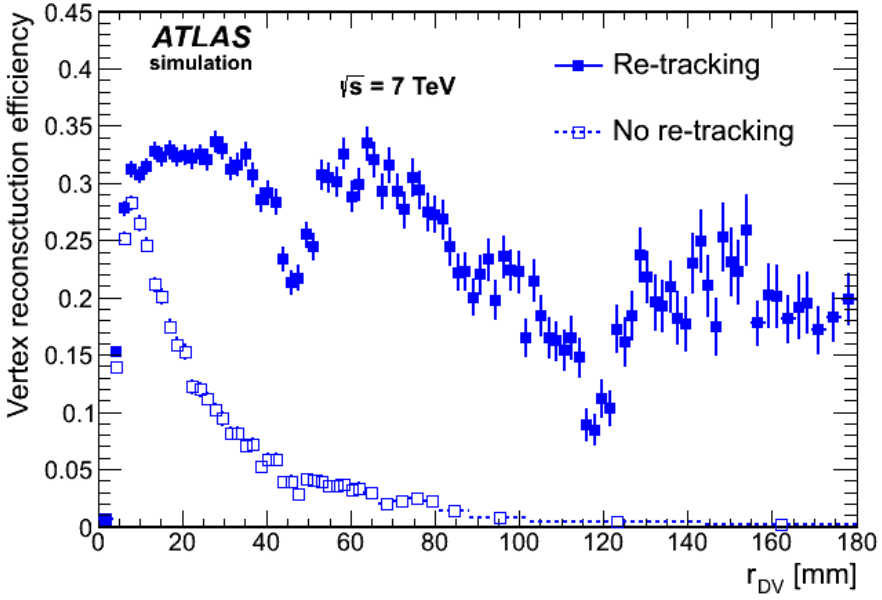


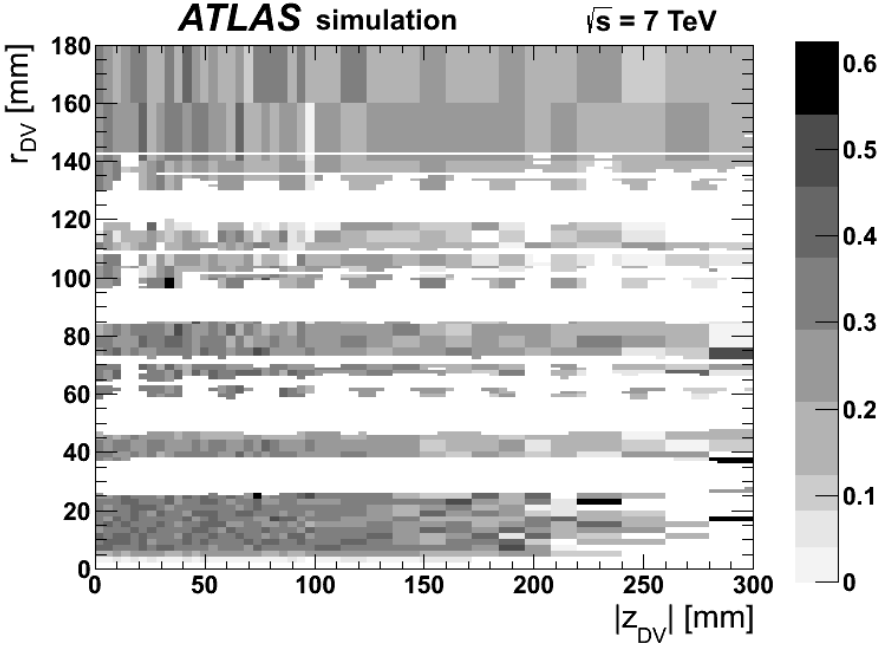
Model ($m_{\tilde{g}}$)	$\sigma^{\text{theory}}_{\text{min}}$ [pb]	$\sigma^{\text{theory}}_{\text{max}}$ [pb]	Acceptance (%)	
			Resolved	Boosted
100 GeV	18700	25400	0.098	0.077
200 GeV	584	790	0.094	0.070
300 GeV	57.6	77.9	0.451	0.182
400 GeV	9.61	13.0	0.210	–
500 GeV	2.13	3.01	0.565	–
600 GeV	0.574	0.843	1.30	–
800 GeV	0.0572	0.0913	5.73	–

arxiv:1210.7451v2

Displaced vertex with multi-tracks and muon

- Re-tracking:
  - Recover tracks lost through standard reconstruction by re-running SCT/Pixel seeded tracking algorithms with looser requirements on r_{DV}, z_{DV} and n hits allowed to be shared between tracks.
  - Reduce false track rate by applying: p_T>1GeV (up from 0.4GeV)





ATLAS-CONF-2013-016

Non-pointing photons

- Acceptance:

τ (ns)	Λ (TeV)		
	80	120	160
0.25	15.3 ± 0.3	29.6 ± 0.3	45.1 ± 0.3
1	11.1 ± 0.1	27.0 ± 0.2	35.9 ± 0.3
6	2.01 ± 0.02	5.38 ± 0.02	8.06 ± 0.06
20	0.39 ± 0.01	1.006 ± 0.005	1.43 ± 0.01
40	0.175 ± 0.005	0.384 ± 0.002	0.510 ± 0.004
80	0.090 ± 0.004	0.164 ± 0.001	0.196 ± 0.002

- Observed events:

Fit Type	Event Type	Range of $\lvert z_{DCA}\rvert$ values [mm]								
		0 – 20	20 – 40	40 – 60	60 – 80	80 – 100	100 – 200	200 – 400	400 – 600	> 600
-	Data	27	7	4	1	1	3	2	0	1
Bkg Only	Bkg	25.0±2.2	9.1±0.8	3.8±0.3	2.1±0.5	1.4±0.4	3.0±1.1	1.3±0.5	0.2±0.1	0.08±0.03
Signal Plus Bkg	Total	25.1±4.2	9.3±1.5	3.3±0.7	1.6±0.6	1.1±0.4	2.6±1.0	1.8±0.8	0.7±0.5	0.5±0.4
	Sig	0.7±0.6	0.5±0.5	0.4±0.3	0.3±0.3	0.3±0.3	1.2±1.1	1.3±1.2	0.6±0.5	0.4±0.4
	Bkg	24.4±4.2	8.8±1.5	2.9±0.8	1.3±0.7	0.8±0.6	1.4±1.5	0.5±0.7	0.1±0.1	0.03±0.04

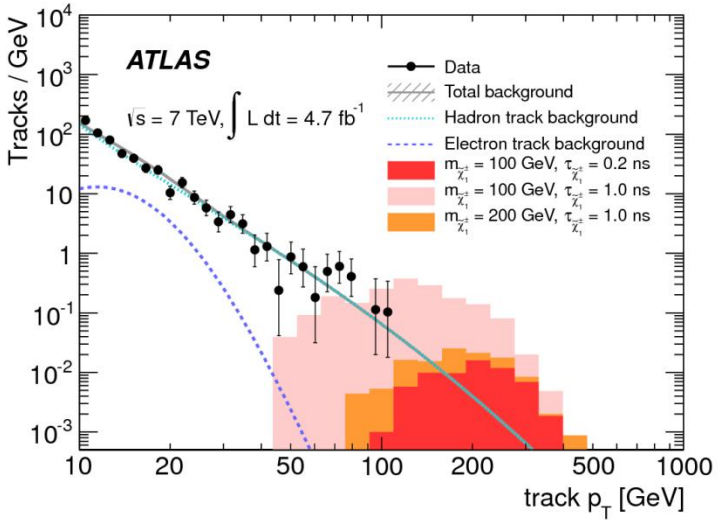
- Signal is for Λ = 120TeV, τ = 6ns

8.

Direct chargino production based on disappearing track signature

arxiv:1210.2852v2

- Candidate track p_T :



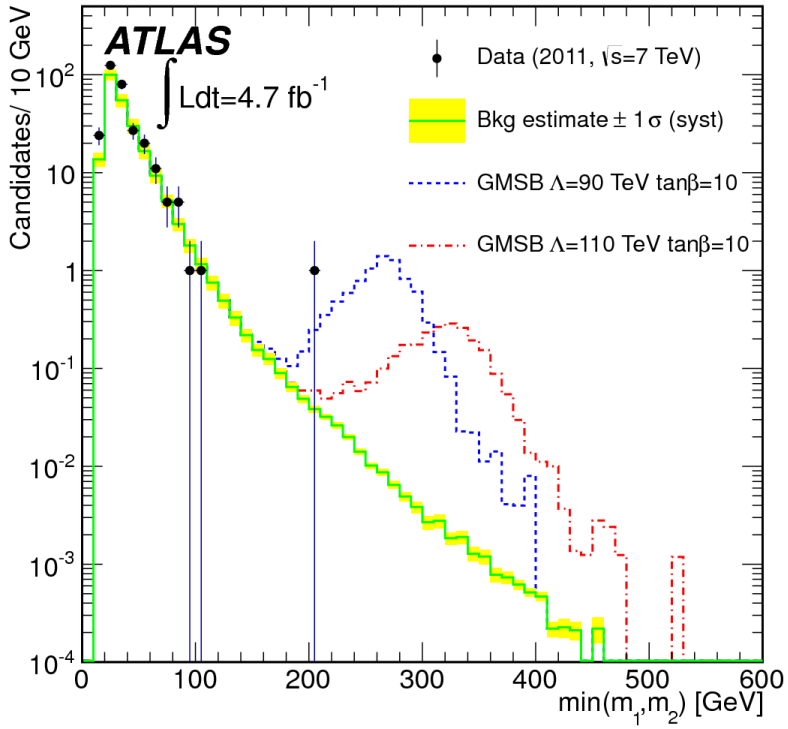
- Observed events:

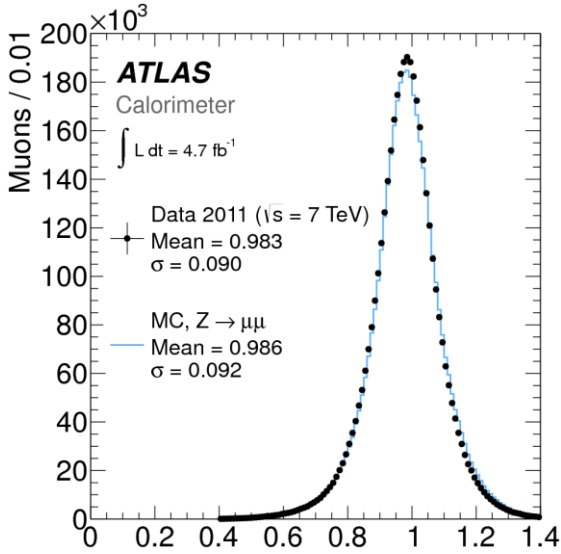
Requirement	Observed	Signal events (efficiency [%])	
		$m_{\tilde{\chi}_1^\pm} = 100$ GeV	$m_{\tilde{\chi}_1^\pm} = 200$ GeV
Quality requirements and trigger	3765627	1983 (3.0)	283.3 (6.7)
Non-collision background rejection	2899498	1958 (3.0)	279.6 (6.6)
Lepton veto	2186581	1906 (2.9)	274.8 (6.5)
Leading jet $p_T > 90$ GeV	2054262	1497 (2.3)	237.7 (5.6)
$E_T^{miss} > 90$ GeV	1233864	1420 (2.2)	230.2 (5.5)
$\Delta\phi_{min}^{jet-E_T^{miss}} > 1.5$ rad	1191298	1402 (2.1)	227.4 (5.4)
High-p_T isolated track selection	18493	90.5 (0.14)	9.1 (0.26)
Disappearing-track selection	710	42.9 (0.066)	4.1 (0.12)

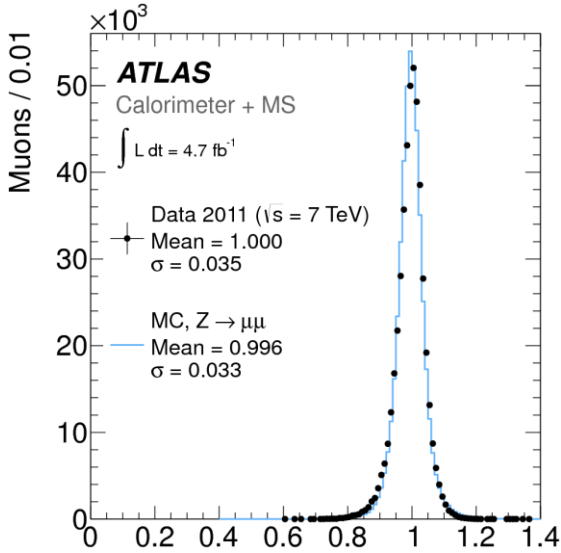
arxiv:1211.1597v2

Heavy long lived slepton/R-hadron

- Slepton:
  - Particle β measurement
  - Require 2 candidates with β <0.95
  - Plot candidate with lower mass:



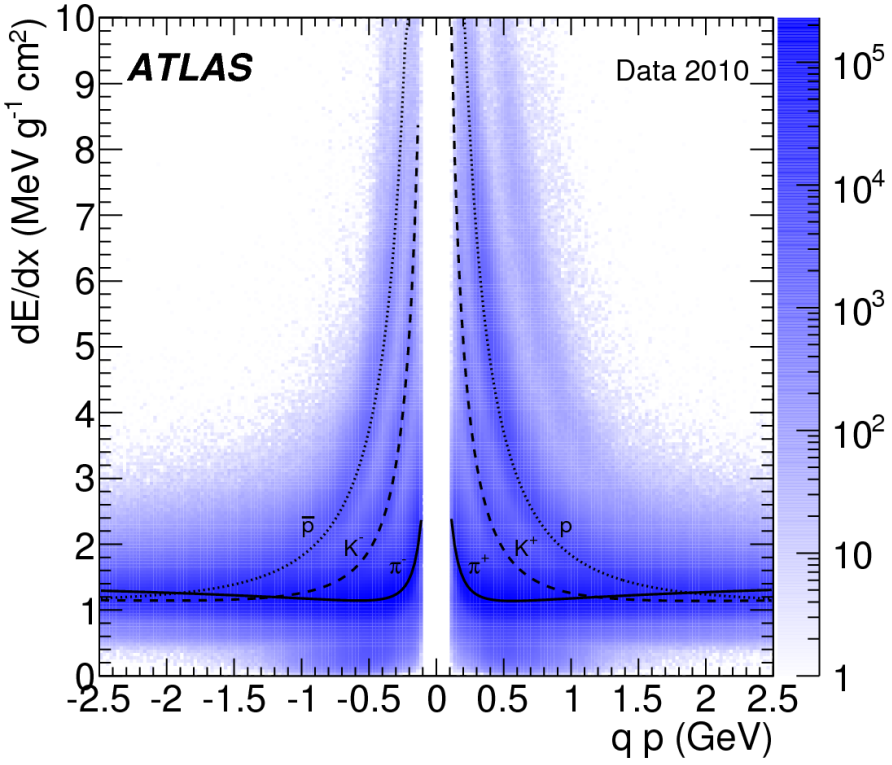


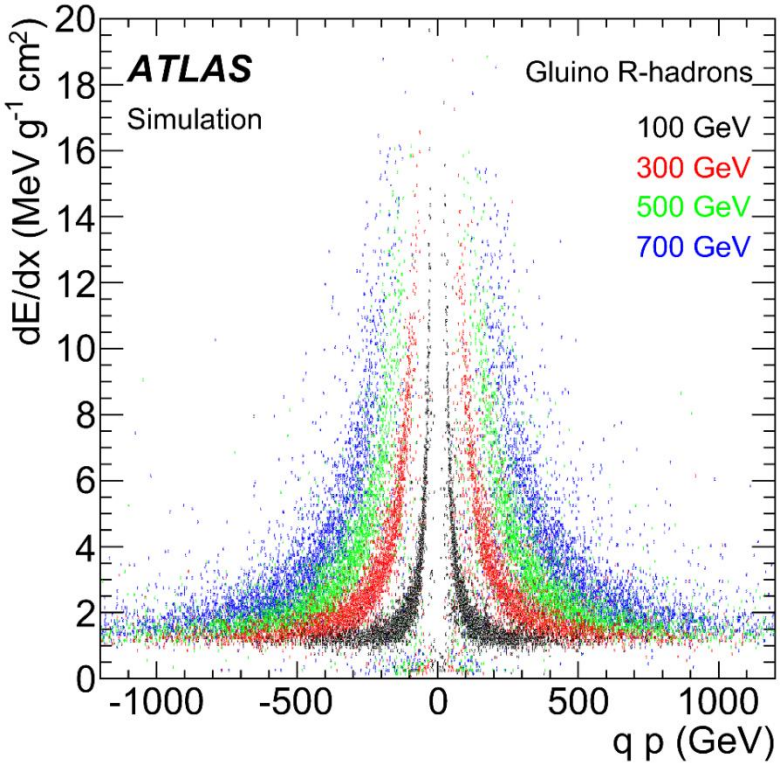


arxiv:1211.1597v2

Heavy long lived slepton/R-hadron

- High d*E*/dx deposition characteristic of LLPs:
- Measure in ID pixel detector and calorimeter

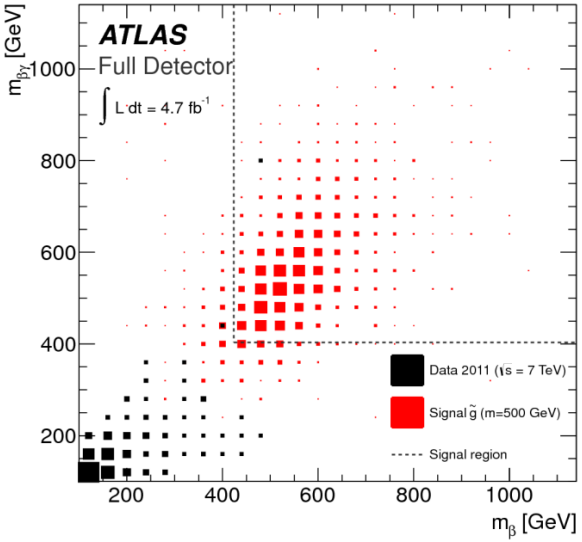




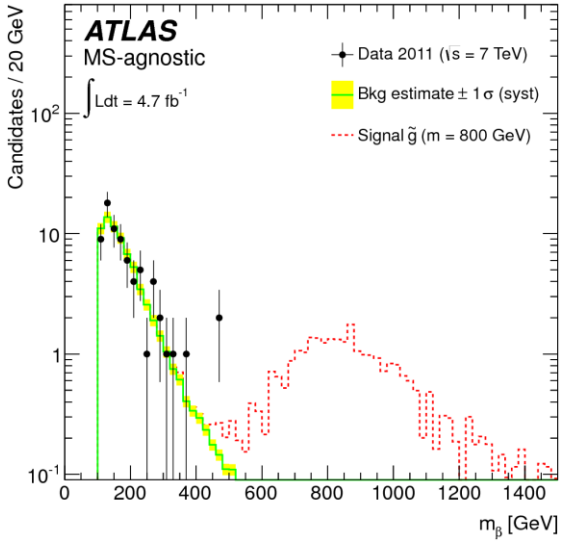
arxiv:1211.1597v2

Heavy long lived slepton/R-hadron

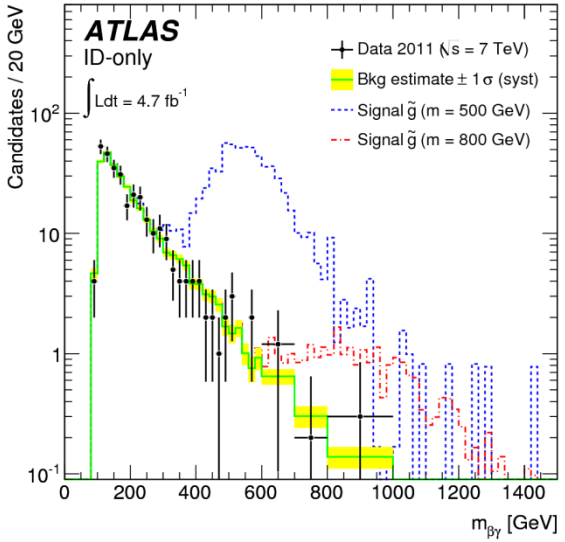
- Rhadron:
  - Particle β and d*E*/dx measurements across detector:



Full detector
MS: β measurements
Calo/ID: d*E*/dx



MS agnostic
Calo/ID: d*E*/dx



ID-only
ID: d*E*/dx