LHCP Conference 2013

Searches for supersymmetry in resonance production, R-parity violating signatures and events with long-lived particles with the ATLAS detector

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On behalf of the ATLAS Collaboration

May 17, 2013

Outline

1. **R-Parity Violating (RPV) SUSY**
    - RPV 4 Lepton
    - RPV $e-\mu$, $e-\tau$ or $\mu-\tau$ Resonance
    - Pair of 3 Jet Resonances
2. **Pair of 2 Jet Resonance (sgluon)**
3. **Long-Lived Particles:**
    - Non-pointing Photons
    - Displaced Vertex
    - Disappearing Tracks
    - Stable Massive Particles (SMPs)

R-Parity Violating (RPV) SUSY Searches

- Many SUSY models assume R-parity conservation to forbid lepton- and baryon-number violating decays.
- For example, models with a stable neutralino ($\tilde{\chi}^0$) as the Lightest Supersymmetric Particle (LSP) are common (dark matter candidate).
- This parity is defined as: $P_R = (-1)^{3(B-L)+2S}$, where S, B and L correspond to the spin, baryon and lepton numbers of the particle.
- **Nevertheless, there is no experimental evidence forbidding a RPV super-potential:**

$$W_{RPV} = \underbrace{\lambda_{ijk} L_i L_j \bar{E}_k + \lambda^{'}_{ijk} L_i Q_j \bar{D}_k}_{\text{Lepton Violating}} + k_i L_i H_2 + \underbrace{\lambda^{''}_{ijk} \bar{D}_i \bar{D}_j \bar{D}_k}_{\text{Baryon Violating}}$$

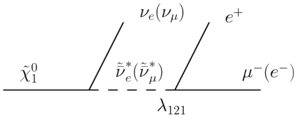
- Stability of proton forbids simultaneous lepton and baryon number violation.
- We conduct RPV searches on both multi-leptonic and multi-jet final states.

RPV 4 Lepton Search (Conference Note) https://cds.cern.ch/record/1532429

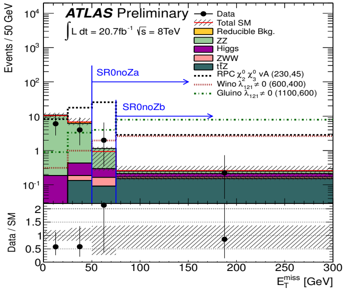
- Non-zero λ coupling can give rise to final states with high lepton multiplicity.
- **Analysis Characteristics**
  1. High signal to background (BG) ratio.
  2. Irreducible BGs contain 4 real leptons.
- **Event Selection Criteria**
  1. Inclusive single and double lepton trigger.
  2. $\geqslant 4$ leptons ($p_T^{min} > 10 GeV$) with $\geqslant 1(2)$ above trigger p_T^{min}.
  3. Z candidate veto
  4. RPV Signal Region (SR) selections:

SR	$N_{(e,\mu)}$	N(τ)	E^T_{miss} or m_{eff} [GeV]
$SR0noZ_b$	$\geqslant 4$	$= 0$	> 75 or > 600
$SR1noZ$	$= 3$	$\geqslant 1$	> 100 or > 400

✓ See Matt Relich's talk for other signal regions on RPC models.



- **Background Estimation**
  1. Irreducible BGs are estimated from MC.
  2. Data-MC agreement checked in control regions.

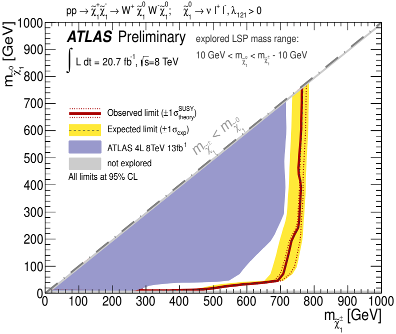


RPV 4 Lepton Search

BG	$SR0noZ_b$	$SR1noZ$
ZZ	0.50 ± 0.26	0.19 ± 0.05
ZZW	0.08 ± 0.08	0.05 ± 0.05
$t\bar{t}Z$	0.75 ± 0.35	0.16 ± 0.12
Higgs	0.22 ± 0.07	0.23 ± 0.06
Irreducible BG	1.6 ± 0.6	0.62 ± 0.21
Reducible BG	$0.05^{+0.14}_{-0.05}$	1.4 ± 1.3
Total BG	1.6 ± 0.6	2.0 ± 1.3
Data	1	4

- ✓ No excess over SM background is observed.
- ✓ The results are interpreted in simplified SUSY models which include several different choices of NLSP (Next to LSP).
  1. LSP : Bino-like neutralino
  2. NLSP: Wino charginos, left-slepton, sneutrinos, gluino.

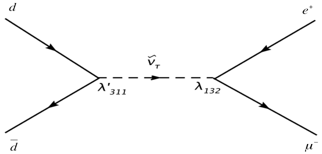
- Wino $\lambda_{121} \neq 0$



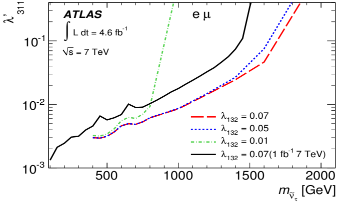
- ✓ Wino excl: $\sim 750\ GeV\ (\lambda_{121})$ and $\sim 400\ GeV\ (\lambda_{133})$
- ✓ Gluino excl: $\sim 1400\ GeV\ (\lambda_{121})$ and $\sim 1000\ GeV\ (\lambda_{133})$

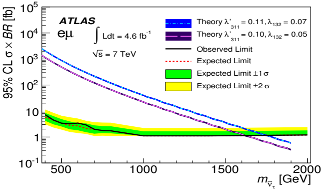
Search For Heavy Resonances Decaying to $e-\mu$ (PLB) http://arxiv.org/abs/1212.1272

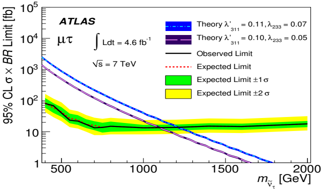
$$L_{(LVF)} = \frac{1}{2}\lambda_{ijk}L_iL_je_k + \lambda'_{ijk}L_iQ_jd_k$$

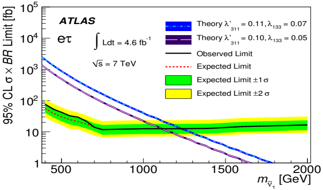


- Event selection (e.g. $e\mu$)
    1. Single lepton trigger
    2. $p_T(e,\mu) > 25 GeV$
    3. $Q(e) * Q(\mu) < 0$
    4. $\Delta\phi > 2.7$
    5. Scan in $Mass(e,\mu)$

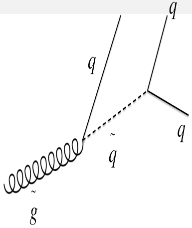






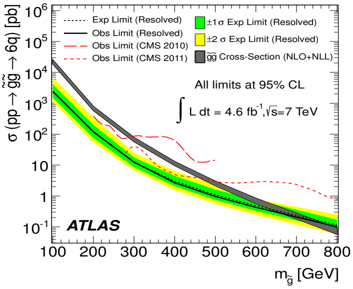


Pair of 3 Jet Resonance Search (JHEP) http://link.springer.com/article/10.1007/JHEP12(2012)086

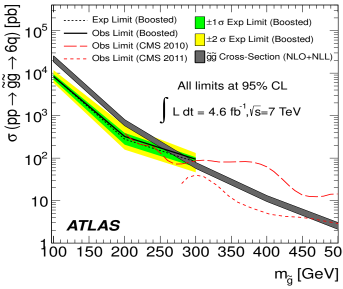


- Search for RPV decays of gluino into three quarks.
- Two complementary methods are used:
  1. Resolved Analysis: Resolve all six jets → optimized for high-mass $\tilde{g}$.
  2. Boosted analysis: Exploit the collimation of the decay products → $\tilde{g}$ produced with large boost: $p_T > 2 \times m_{\tilde{g}}$

Resolved: exclu $m_{\tilde{g}} < 666$ GeV



Boosted: exclu $m_{\tilde{g}} < 255$ GeV



Also: interpretation of SS+jets+MET (ATLAS-CONF-2013-007 → 2012 data) analysis in RPV models with $\tilde{g} \rightarrow t + \tilde{t}, \tilde{t}(RPV) \rightarrow bs$: $m_{\tilde{g}} < 880$ GeV excluded (Analysis details in M. Fehling-Kaschek's talk)

Search for Pair-Produced sgluons Decaying to Four Jets (EPJC)

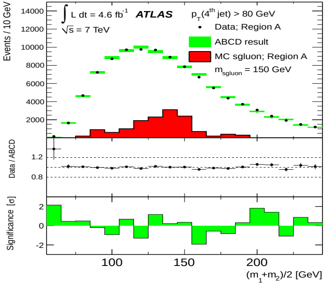
`http://epjc.epj.org/index.php?option=com_article&access=doi&doi=10.1140/epjc/s10052-012-2263-z&Itemid=129`

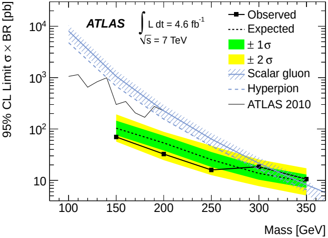
- Event selection criteria:
  1. Multi-jet trigger ($\geqslant$ 4 jets)
  2. $p_T^{jet} > 80\ GeV$ & $|\eta| < 1.4$
  3. $p_T(4^{th}\ jet) > max(0.3 \times m_{sgluon} + 30)$
  4. $(|\Delta R_{pair1} - 1| + |\Delta R_{pair2} - 1|) < 1.6$
  5. Scattering angle $|cos(*\theta)| < 0.5$
  6. $(|m_1 - m_2|/|m_1 + m_2|) < 0.15$
- **BG estimated in a data-driven way.**

Sgluon mass [GeV]	p_T^{min}[GeV]	Data	ABCD
150	80	102162	101100 ± 800 ± 2000
200	90	55194	54500 ± 600 ± 1100
250	105	23404	22500 ± 340 ± 500
300	120	11082	10640 ± 230 ± 210
350	135	5571	5330 ± 180 ± 110

✓ For a mass of 150 GeV (350 GeV), a limit of 70 pb (10 pb) is obtained.

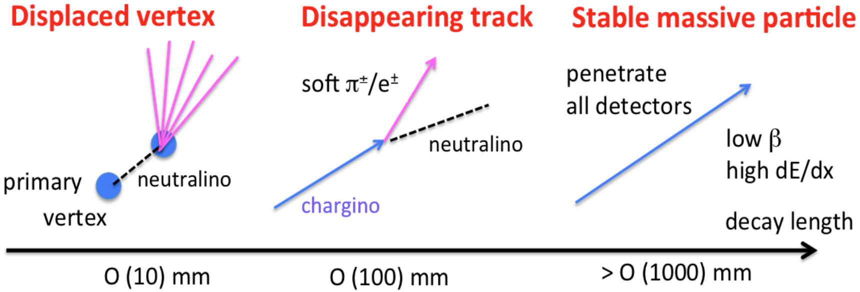
✓ Please see Snezana Nektarijevic's talk for other sgluon searches: `https://cds.cern.ch/record/1545582/files/ATL-COM-PHYS-2013-583.pdf`





Long-Lived Particles

- RPV scenarios: Life time proportional to $\lambda^{-2}, \lambda'^{-2}, \lambda''^{-2}$
  If λ is small, the LSP can be a long lived particle.
- R-parity conserving scenarios (RPC):
  1. Chargino in Anomaly-Mediated SUSY Breaking (AMSB) model.
  2. R-hadron in Split SUSY model.
  3. NLSP stau in Gauge-Mediated SUSY Breaking (GMSB) model.

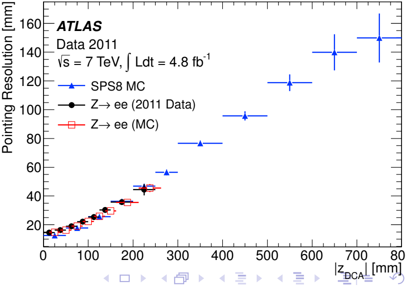


Non-pointing Photons (submitted to PRD) http://arxiv.org/abs/1304.6310 **NEW**

Results are presented in the context of **SPS8** (Snowmass Points and Slopes parameter set 8): describes a set of minimal GMSB models with $\tilde{\chi}_1^0$ (long-lived) as the NLSP. The SUSY breaking scale is denoted by Λ.

1. LSP: Gravitino ($\tilde{G}$)
2. NLSP: $\tilde{\chi}_1^0 \rightarrow \gamma + \tilde{G}$, with γ being produced after a finite delay and with a flight direction that does not point back to the primary vertex.
3. SUSY production dominated by electroweak pair production of gauginos, and in particular of $\tilde{\chi}_2^0 \tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_1^+ \tilde{\chi}_1^-$

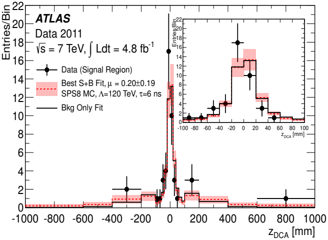
- ✓ γ **flight direction:** measured from centroids of EM showers in the first and second layers of the calorimeter.
- ✓ $z_{DCA} = z_{\gamma} - z_{PV}$ [mm]
  1. Variable used as a measure of the degree of non-pointing of the γ
  2. DCA: Distance of Closest Approach

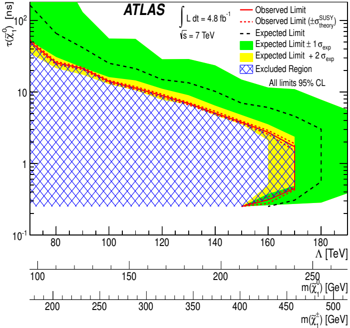


Non-pointing Photons

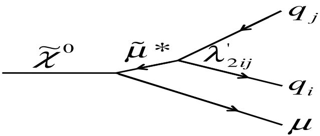
- **Event Selection**
  1. Double γ trigger & PV with $\geqslant 5$ tracks.
  2. $E_T(\gamma) > 50$ GeV & $|\eta| < 2.37$
  3. Isolation < 5 GeV ($\Delta R = 0.2$)
  4. $\geqslant 1$ γ passing tight ID &
     $\geqslant 1$ γ passing loose ID.
     (only loose γ is examined)
  5. $E_T^{miss} > 75$ GeV
- **BG estimated from data**
  1. Prompt γ and electrons: Z_{DCA} obtained from $Z \to ee$ events (tag & probe)
  2. jets: template from SR selections but $E_T^{miss} < 20$ GeV.

✓ For $\Lambda = 70$ TeV (160) TeV, NLSP ($\tilde{\chi}_1^0$) life times between 0.25 and 50.7 ns (2.7 ns) are excluded at 95% CL.

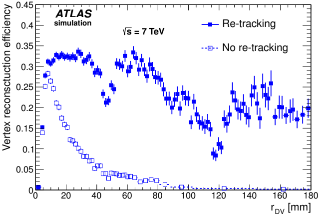




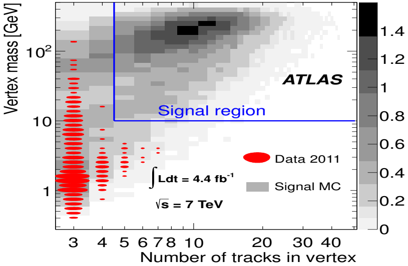
Displaced Vertex (PLB) http://www.sciencedirect.com/science/article/pii/S037026931300083X

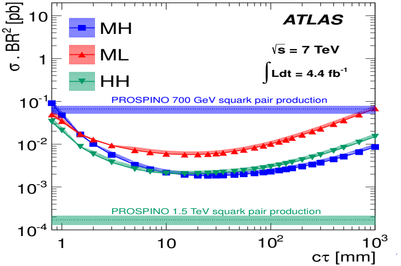


- Search for high mass particles with a displaced vertex with $\geqslant 5$ tracks and a muon.
- A dedicated tracker algorithm was developed to increase the efficiency on the identification of secondary tracks.



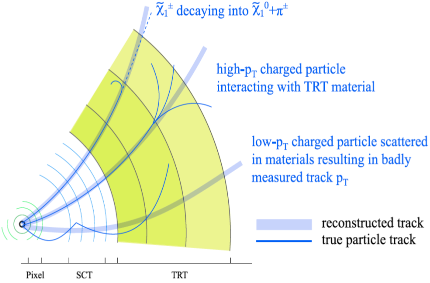
BG: $(4 \pm 60) * 10^{-3}$, Data : 0

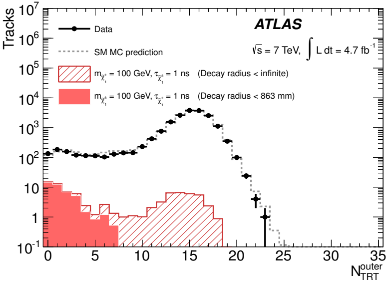




Disappearing Tracks: AMSB (JHEP) `http://link.springer.com/article/10.1007/JHEP01(2013)131`

- LSP = Wino, $\Delta m_{\tilde{\chi}_1}$ can be small ($\approx$ 160 MeV).
- $\tilde{\chi}_1$ could have a measurable lifetime: $c\tau \approx O(0.1ns)$.
- Look for production processes:
  1. $pp \to \tilde{\chi}_1^{\pm}\tilde{\chi}_1^{0} + jet$
  2. $pp \to \tilde{\chi}_1^{-}\tilde{\chi}_1^{+} + jet$
- Analysis Strategy: look for charginos decaying in the inner TRT detector volume, leaving a small number of hits in the outer TRT modules.
- Main BGs:
  1. High p_T charged hadrons (80%)
  2. Low p_T tracks with large bremsstrahlung radiation.



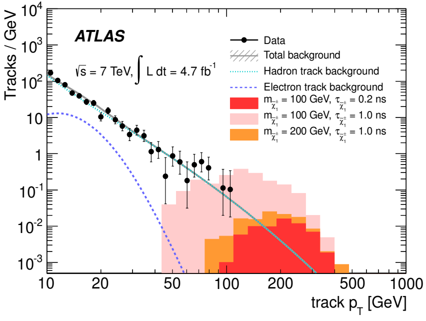


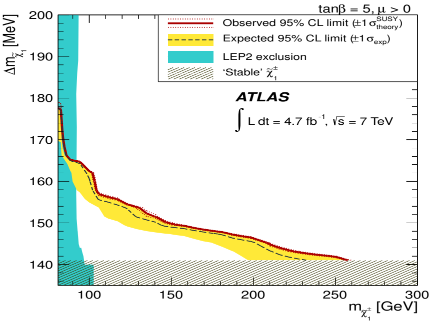
Disappearing Tracks: AMSB

- The BG estimation and the signal extraction is done in two steps:
  1. Derive the BG track p_T shapes from control regions.
  2. Perform a "signal + BG" template fit to candidate tracks.

✓ No excess over the standard model BG is observed.

✓ For $\Delta m \approx 160(170)$ MeV (most probable in AMSB), $m_{\tilde{\chi}_1^\pm}$ up to 103(85) GeV is excluded.



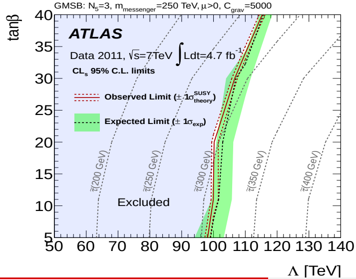


Stable Massive Particles (PLB) http://www.sciencedirect.com/science/article/pii/S0370269313001445

Analysis Characteristics

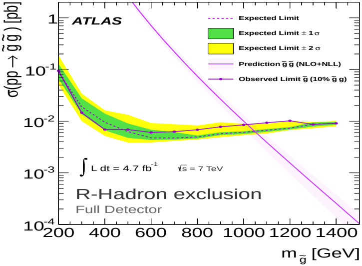
- Search for long lived sleptons, squarks and gluinos ($\beta < 1$).
- The search includes different signatures of sleptons and R-hadrons.
- Mass (m) estimated as $m = \frac{p}{\gamma\beta}$.

Heavy Long-Lived Sleptons



R-hadrons Search

- R-hadrons are composites of a gluino or squark with SM partons.
- R-hadrons can change their electric charge as they traverse the detector!
- Three different analyses: full detector, MS-agnostic, inner detector only.



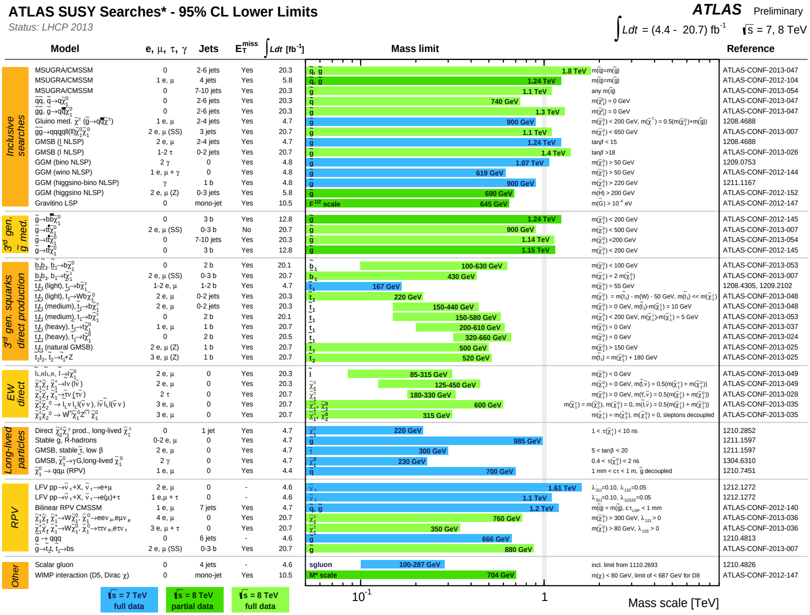
Summary

- ATLAS has covered a broad set of analyses on RPV and long-lived particles searches.
- These analyses require a deep understanding of the detector, which make them interesting, non-conventional and very challenging!
- No excess over the SM background has been observed.
- ATLAS has set competitive limits of exclusion on several models.

- **More results with the 2012 data are coming soon, with several improvements in the analysis techniques, data-driven methods to estimate BGs and inclusion of new models in our studies, so stay tuned!**

Backup

Backup



ATLAS SUSY Searches* - 95% CL Lower Limits

Status: LHCP 2013

ATLAS Preliminary

$\int Ldt = (4.4 -\ 20.7)\ \mathrm{fb}^{-1}$ $\sqrt{s}$ = 7, 8 TeV

	Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int Ldt$ [fb^{-1}]	Mass limit			Reference
Inclusive searches	MSUGRA/CMSSM	0	2-6 jets	Yes	20.3	$\tilde{q}, \tilde{g}$	1.8 TeV	$m(\tilde{q})=m(\tilde{g})$	ATLAS-CONF-2013-047
	MSUGRA/CMSSM	1 e, μ	4 jets	Yes	5.8	$\tilde{q}, \tilde{g}$	1.24 TeV	$m(\tilde{q})=m(\tilde{g})$	ATLAS-CONF-2012-104
	MSUGRA/CMSSM	0	7-10 jets	Yes	20.3	$\tilde{g}$	1.1 TeV	any $m(\tilde{q})$	ATLAS-CONF-2013-054
	$\tilde{q}\tilde{q}$, $\tilde{q}\to q\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{q}$	740 GeV	$m(\tilde{\chi}_1^0)$ = 0 GeV	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g}$, $\tilde{g}\to q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{g}$	1.3 TeV	$m(\tilde{\chi}_1^0)$ = 0 GeV	ATLAS-CONF-2013-047
	Gluino med. $\tilde{\chi}^\pm$ ($\tilde{g}\to q\bar{q}\tilde{\chi}^\pm$)	1 e, μ	2-4 jets	Yes	4.7	$\tilde{g}$	900 GeV	$m(\tilde{\chi}_1^0)$ < 200 GeV, $m(\tilde{\chi}^\pm) = 0.5(m(\tilde{\chi}_1^0)+m(\tilde{g}))$	1208.4688
	$\tilde{g}\tilde{g}\to qqqqll(ll)\tilde{\chi}_1^0\tilde{\chi}_1^0$	2 e, μ (SS)	3 jets	Yes	20.7	$\tilde{g}$	1.1 TeV	$m(\tilde{\chi}_1^0)$ < 650 GeV	ATLAS-CONF-2013-007
	GMSB ($\tilde{l}$ NLSP)	2 e, μ	2-4 jets	Yes	4.7	$\tilde{g}$	1.24 TeV	tanβ < 15	1208.4688
	GMSB (l NLSP)	1-2 τ	0-2 jets	Yes	20.7	$\tilde{g}$	1.4 TeV	tanβ >18	ATLAS-CONF-2013-026
	GGM (bino NLSP)	2 γ	0	Yes	4.8	$\tilde{g}$	1.07 TeV	$m(\tilde{\chi}_1^0)$ > 50 GeV	1209.0753
	GGM (wino NLSP)	1 e, μ + γ	0	Yes	4.8	$\tilde{g}$	619 GeV	$m(\tilde{\chi}_1^0)$ > 50 GeV	ATLAS-CONF-2012-144
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	4.8	$\tilde{g}$	900 GeV	$m(\tilde{\chi}_1^0)$ > 220 GeV	1211.1167
	GGM (higgsino NLSP)	2 e, μ (Z)	0-3 jets	Yes	5.8	$\tilde{g}$	690 GeV	$m(\tilde{H})$ > 200 GeV	ATLAS-CONF-2012-152
	Gravitino LSP	0	mono-jet	Yes	10.5	$F^{1/2}$ scale	645 GeV	$m(\tilde{G}) > 10^{-4}$ eV	ATLAS-CONF-2012-147
3^{rd} gen. $\tilde{g}$ med.	$\tilde{g}\to b\bar{b}\tilde{\chi}_1^0$	0	3 b	Yes	12.8	$\tilde{g}$	1.24 TeV	$m(\tilde{\chi}_1^0)$ < 200 GeV	ATLAS-CONF-2012-145
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	2 e, μ (SS)	0-3 b	No	20.7	$\tilde{g}$	900 GeV	$m(\tilde{\chi}_1^0)$ < 500 GeV	ATLAS-CONF-2013-007
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0	7-10 jets	Yes	20.3	$\tilde{g}$	1.14 TeV	$m(\tilde{\chi}_1^0)$ <200 GeV	ATLAS-CONF-2013-054
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0	3 b	Yes	12.8	$\tilde{g}$	1.15 TeV	$m(\tilde{\chi}_1^0)$ < 200 GeV	ATLAS-CONF-2012-145
3^{rd} gen. squarks direct production	$\tilde{b}_1\tilde{b}_1$, $\tilde{b}_1\to b\tilde{\chi}_1^0$	0	2 b	Yes	20.1	$\tilde{b}_1$	100-630 GeV	$m(\tilde{\chi}_1^0)$ < 100 GeV	ATLAS-CONF-2013-053
	$\tilde{b}_1\tilde{b}_1$, $\tilde{b}_1\to t\tilde{\chi}_1^\pm$	2 e, μ (SS)	0-3 b	Yes	20.7	$\tilde{b}_1$	430 GeV	$m(\tilde{\chi}_1^\pm) = 2\,m(\tilde{\chi}_1^0)$	ATLAS-CONF-2013-007
	$\tilde{t}_1\tilde{t}_1$ (light), $\tilde{t}_1\to b\tilde{\chi}_1^\pm$	1-2 e, μ	1-2 b	Yes	4.7	$\tilde{t}_1$	167 GeV	$m(\tilde{\chi}_1^0)$ = 55 GeV	1208.4305, 1209.2102
	$\tilde{t}_1\tilde{t}_1$ (light), $\tilde{t}_1\to Wb\tilde{\chi}_1^0$	2 e, μ	0-2 jets	Yes	20.3	$\tilde{t}_1$	220 GeV	$m(\tilde{\chi}_1^0) = m(\tilde{t}_1) - m(W) - 50$ GeV, $m(\tilde{t}_1) << m(\tilde{\chi}_1^\pm)$	ATLAS-CONF-2013-048
	$\tilde{t}_1\tilde{t}_1$ (medium), $\tilde{t}_1\to b\tilde{\chi}_1^\pm$	2 e, μ	0-2 jets	Yes	20.3	$\tilde{t}_1$	150-440 GeV	$m(\tilde{\chi}_1^0)$ = 0 GeV, $m(\tilde{t}_1)-m(\tilde{\chi}_1^\pm)$ = 10 GeV	ATLAS-CONF-2013-048
	$\tilde{t}_1\tilde{t}_1$ (medium), $\tilde{t}_1\to b\tilde{\chi}_1^\pm$	0	2 b	Yes	20.1	$\tilde{t}_1$	150-580 GeV	$m(\tilde{\chi}_1^0)$ < 200 GeV, $m(\tilde{\chi}_1^\pm)-m(\tilde{\chi}_1^\pm)$ = 5 GeV	ATLAS-CONF-2013-053
	$\tilde{t}_1\tilde{t}_1$ (heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	1 e, μ	1 b	Yes	20.7	$\tilde{t}_1$	200-610 GeV	$m(\tilde{\chi}_1^0)$ = 0 GeV	ATLAS-CONF-2013-037
	$\tilde{t}_1\tilde{t}_1$ (heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	0	2 b	Yes	20.5	$\tilde{t}_1$	320-660 GeV	$m(\tilde{\chi}_1^0)$ = 0 GeV	ATLAS-CONF-2013-024
	$\tilde{t}_1\tilde{t}_1$ (natural GMSB)	2 e, μ (Z)	1 b	Yes	20.7	$\tilde{t}_1$	500 GeV	$m(\tilde{\chi}_1^0)$ > 150 GeV	ATLAS-CONF-2013-025
	$\tilde{t}_2\tilde{t}_2$, $\tilde{t}_2\to\tilde{t}_1+Z$	3 e, μ (Z)	1 b	Yes	20.7	$\tilde{t}_2$	520 GeV	$m(\tilde{t}_1) = m(\tilde{\chi}_1^0)$ + 180 GeV	ATLAS-CONF-2013-025
EW direct	$\tilde{l}_{L,R}\tilde{l}_{L,R}$, $\tilde{l}\to l\tilde{\chi}_1^0$	2 e, μ	0	Yes	20.3	$\tilde{l}$	85-315 GeV	$m(\tilde{\chi}_1^0)$ = 0 GeV	ATLAS-CONF-2013-049
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to\tilde{l}\nu(l\tilde{\nu})$	2 e, μ	0	Yes	20.3	$\tilde{\chi}_1^\pm$	125-450 GeV	$m(\tilde{\chi}_1^0)$ = 0 GeV, $m(\tilde{l},\tilde{\nu}) = 0.5(m(\tilde{\chi}_1^\pm) + m(\tilde{\chi}_1^0))$	ATLAS-CONF-2013-049
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to\tilde{\tau}\nu(\tau\tilde{\nu})$	2 τ	0	Yes	20.7	$\tilde{\chi}_1^\pm$	180-330 GeV	$m(\tilde{\chi}_1^0)$ = 0 GeV, $m(\tilde{\tau},\tilde{\nu}) = 0.5(m(\tilde{\chi}_1^\pm) + m(\tilde{\chi}_1^0))$	ATLAS-CONF-2013-028
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to\tilde{l}_L\nu\tilde{l}_Ll(\tilde{\nu}\nu)$, $l\tilde{\nu}\tilde{l}_Ll(\tilde{\nu}\nu)$	3 e, μ	0	Yes	20.7	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$	600 GeV	$m(\tilde{\chi}_1^\pm) = m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0) = 0$, $m(\tilde{l},\tilde{\nu}) = 0.5(m(\tilde{\chi}_1^\pm) + m(\tilde{\chi}_1^0))$	ATLAS-CONF-2013-035
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to W^{(*)}\tilde{\chi}_1^0Z^{(*)}\tilde{\chi}_1^0$	3 e, μ	0	Yes	20.7	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$	315 GeV	$m(\tilde{\chi}_1^\pm) = m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0) = 0$, sleptons decoupled	ATLAS-CONF-2013-035
Long-lived particles	Direct $\tilde{\chi}_1^\pm\tilde{\chi}_1^\mp$ prod., long-lived $\tilde{\chi}_1^\pm$	0	1 jet	Yes	4.7	$\tilde{\chi}_1^\pm$	220 GeV	$1 < \tau(\tilde{\chi}_1^\pm) < 10$ ns	1210.2852
	Stable $\tilde{g}$, R-hadrons	0-2 e, μ	0	Yes	4.7	$\tilde{g}$	985 GeV		1211.1597
	GMSB, stable $\tilde{\tau}$, low β	2 e, μ	0	Yes	4.7	$\tilde{\tau}$	300 GeV	5 < tanβ < 20	1211.1597
	GMSB, $\tilde{\chi}_1^0\to\gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$	2 γ	0	Yes	4.7	$\tilde{\chi}_1^0$	230 GeV	$0.4 < \tau(\tilde{\chi}_1^0) < 2$ ns	1304.6310
	$\tilde{\chi}_1^0\to qq\mu$ (RPV)	1 e, μ	0	Yes	4.4	$\tilde{q}$	700 GeV	1 mm < cτ < 1 m, $\tilde{g}$ decoupled	1210.7451
RPV	LFV pp→$\tilde{\nu}_\tau$+X, $\tilde{\nu}_\tau\to e+\mu$	2 e, μ	0	-	4.6	$\tilde{\nu}_\tau$	1.61 TeV	$\lambda'_{311}=0.10$, $\lambda_{132}=0.05$	1212.1272
	LFV pp→$\tilde{\nu}_\tau$+X, $\tilde{\nu}_\tau\to e(\mu)+\tau$	1 e,μ + τ	0	-	4.6	$\tilde{\nu}_\tau$	1.1 TeV	$\lambda'_{311}=0.10$, $\lambda_{1(2)33}=0.05$	1212.1272
	Bilinear RPV CMSSM	1 e, μ	7 jets	Yes	4.7	$\tilde{q}, \tilde{g}$	1.2 TeV	$m(\tilde{q}) = m(\tilde{g})$, $c\tau_{LSP}$ < 1 mm	ATLAS-CONF-2012-140
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to W\tilde{\chi}_1^0$, $\tilde{\chi}_1^0\to ee\nu_\mu, e\mu\nu_e$	4 e, μ	0	Yes	20.7	$\tilde{\chi}_1^\pm$	760 GeV	$m(\tilde{\chi}_1^0)$ > 300 GeV, $\lambda_{121} > 0$	ATLAS-CONF-2013-036
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to W\tilde{\chi}_1^0$, $\tilde{\chi}_1^0\to\tau\tau\nu_e, e\tau\nu_\tau$	3 e, μ + τ	0	Yes	20.7	$\tilde{\chi}_1^\pm$	350 GeV	$m(\tilde{\chi}_1^0)$ > 80 GeV, $\lambda_{133} > 0$	ATLAS-CONF-2013-036
	$\tilde{g}\to qqq$	0	6 jets	-	4.6	$\tilde{g}$	666 GeV		1210.4813
	$\tilde{g}\to\tilde{t}_1t$, $\tilde{t}_1\to bs$	2 e, μ (SS)	0-3 b	Yes	20.7	$\tilde{g}$	880 GeV		ATLAS-CONF-2013-007
Other	Scalar gluon	0	4 jets	-	4.6	sgluon	100-287 GeV	incl. limit from 1110.2693	1210.4826
	WIMP interaction (D5, Dirac χ)	0	mono-jet	Yes	10.5	M* scale	704 GeV	m(χ) < 80 GeV, limit of < 687 GeV for D8	ATLAS-CONF-2012-147

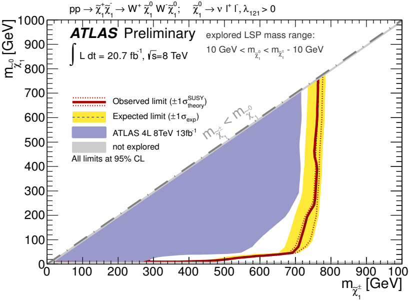
$\sqrt{s}$ = 7 TeV full data

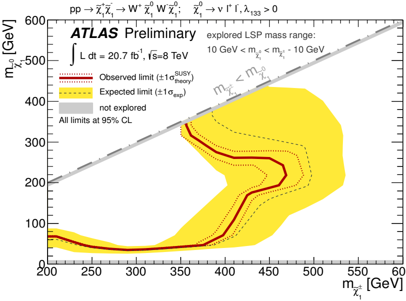
$\sqrt{s}$ = 8 TeV partial data

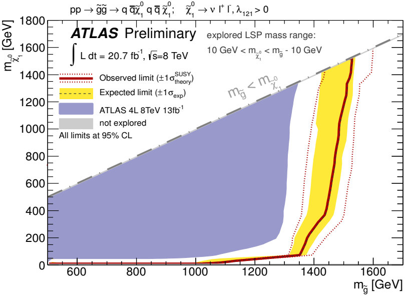
$\sqrt{s}$ = 8 TeV full data

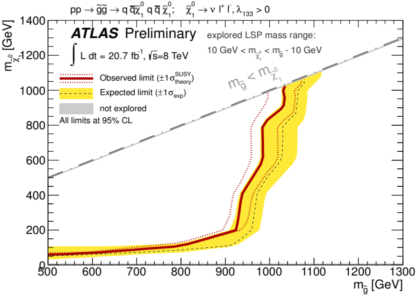
**Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.*

4 Lepton Search





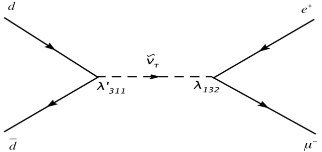


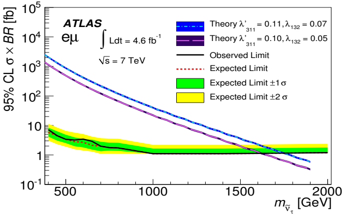


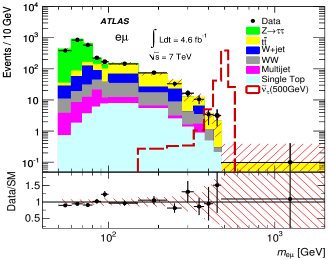
Search For Heavy Resonances Decaying to $e - \mu$ (PLB) http://arxiv.org/abs/1212.1272

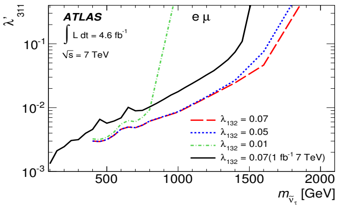
$$L_{(LVF)} = \frac{1}{2}\lambda_{ijk} L_i L_j e_k + \lambda^{'}_{ijk} L_i Q_j d_k$$

- possible resonance $\tilde{\nu}_\tau$
- Event selection
  1. Single lepton trigger
  2. $p_T(e, \mu) > 25 GeV$
  3. $Q(e) * Q(\mu) < 0$
  4. $\Delta\phi > 2.7$
  5. Scan in $Mass(e, \mu)$



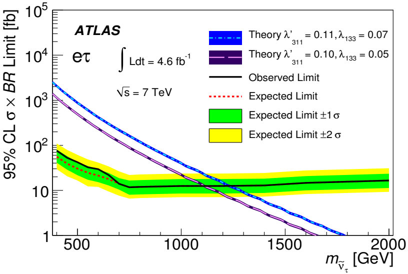


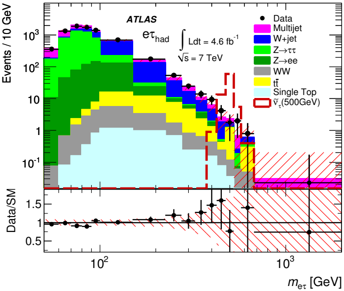


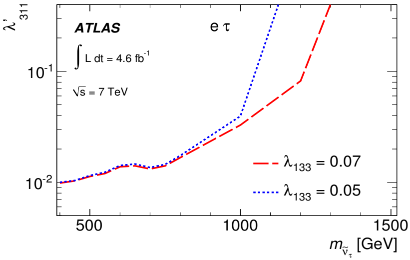


Search for heavy resonances decaying to $e - \tau_{had}$

- Event selection ($e - \tau_{had}$)
  1. Single electron trigger
  2. $p_T(e) > 25 GeV$
  3. $E_T(\tau_{had}) > 20 GeV$
  4. $Q(e) * Q(\tau_{had}) < 0$
  5. $\Delta\phi > 2.7$
  6. $p_T^e > E_T^{\tau_{had}}$
  7. Scan in $Mass(e, \tau_{had})$

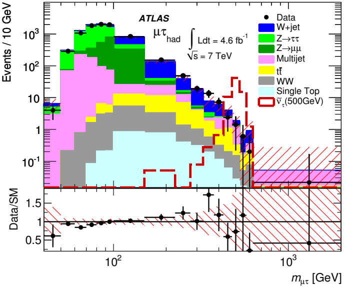


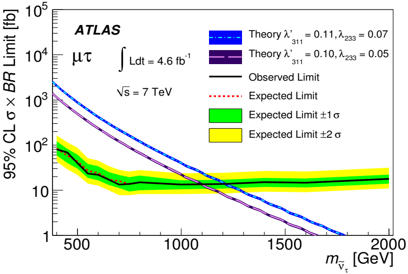


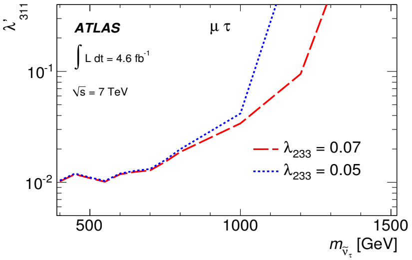


Search for heavy resonances decaying to $\mu - \tau_{had}$

- Event selection ($\mu - \tau_{had}$)
  1. Single muon trigger
  2. $p_T(\mu) > 25 GeV$
  3. $E_T(\tau_{had}) > 20 GeV$
  4. $Q(\mu) * Q(\tau_{had}) < 0$
  5. $\Delta\phi > 2.7$
  6. Scan in $Mass(\mu, \tau_{had})$



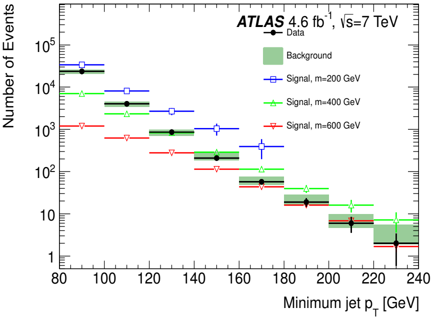


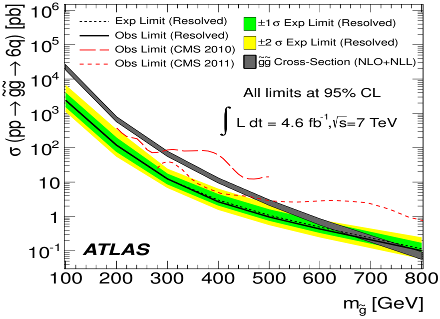


Pair of 3 Jet Resonance Search (JHEP)

- Search for RPV decays of gluino into three quarks.
- Two complementary methods are used:
  1. Resolve all six jets (Resolved Analysis): Optimized for high-mass gluinos.
  2. Exploit the collimation of the decay products (Boosted analysis).

Resolved Analysis

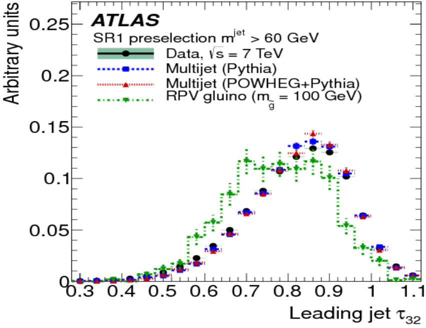


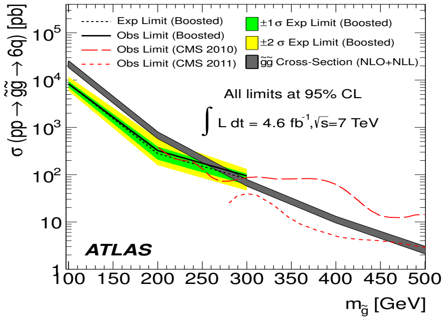


Pair of 3 Jet Resonance Search: Boosted Analysis

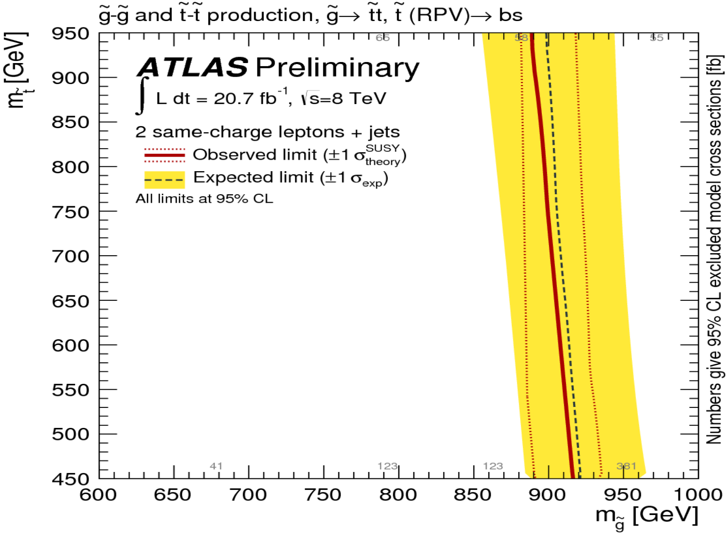
- Search for gluinos are produced with large boost $p_T > 2 \times m_{\tilde{g}}$.
- Highly collimated jets, each containing 3 sub-jets.
- Search for large jets: $R = 1$.
- Use k_T algorithm to fit jet, requiring N sub-jets are found.

$m_{\tilde{g}}$ excluded up to 255 GeV

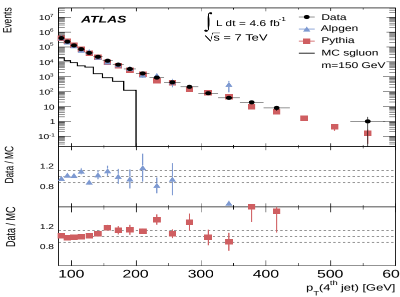


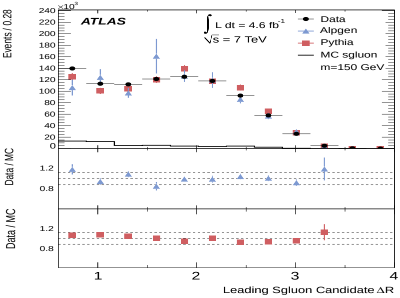


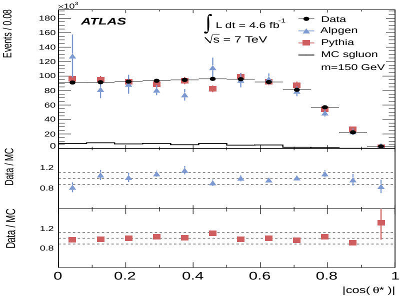
SS+Jets+E_T^{miss} Analysis (RPV)

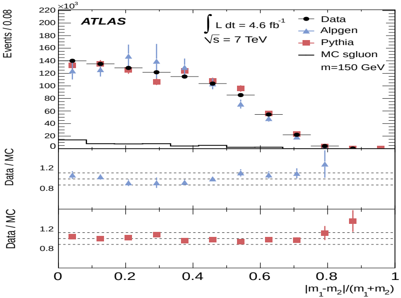


Pair of 2 Jet Resonance (gluon) Search

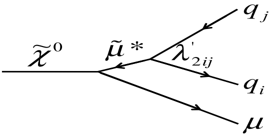




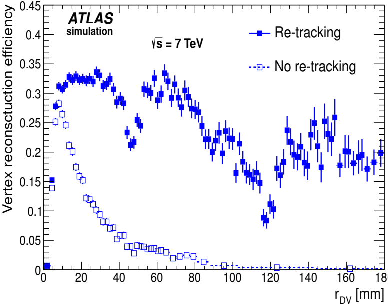




Displaced Vertex (PLB) http://www.sciencedirect.com/science/article/pii/S037026931300083X

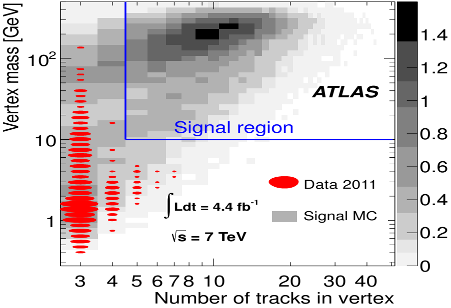


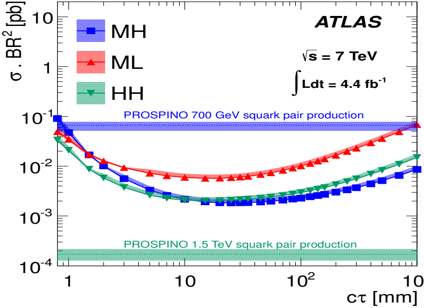
- If a particle has a lifetime of the order of a few nanoseconds, it can decay inside the tracking system producing a displaced-secondary vertex.
- Search for high mass particles with a displaced vertex with $\geqslant 5$ tracks and a muon.
- The standard ATLAS tracking is optimized for tracks coming from the primary interaction point.
- A dedicated tracker algorithm was developed to increase the efficiency on the identification of secondary tracks.



Displaced Vertex

- Potential background sources:
  1. Random combinations of tracks inside the beam pipe.
  2. High-mass tail of distributions of real vertices from hadronic interactions with gas molecules. We veto vertices reconstructed anywhere that there is detector material.
  3. Total background estimated in the signal region is: $(4 \pm 60) * 10^{-3}$ (zero events observed in data).





Displaced Vertex

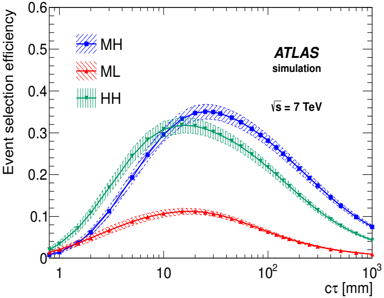
- Muon and Event Selection Criteria:
  1. The PV with the highest sum of p_T^2 of the tracks associated to it is required to have at least five tracks and a z position in the range $|Z_{PV}| < 200$ mm.
  2. Events with two back to back muons are rejected.
  3. Only select muons with $p_T > 50$ GeV and $|\eta|$ <1.05 reconstructed in both MS and ID.
  4. $|d_0| > 1.5$ mm.
  5. ID track associated to reconstructed muon, must have $N_{SCT}^{hits} > 6$ & $N_{TRT}^{hits}(\eta\ dependent) > X$.
- Tracks Selection Criteria to Reconstruct DV
  1. Select only high quality tracks.
  2. $N_{SCT}^{hits} > 2$
  3. $|d_0| > 2.0$ mm

Displaced Vertex

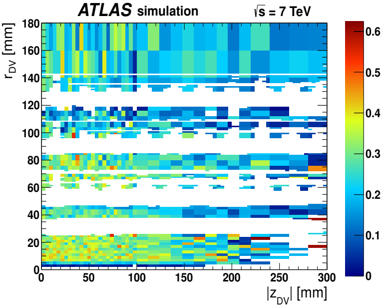
- Modifications to the ATLAS Tracking Algorithm:
  1. Standard algorithms assume that tracks originate from close to the PV.
  2. To counter this problem, the silicon-seeded tracking algorithm is re-run with looser requirements on the radial and z impact parameters, and on the number of detector hits.
  3. p_T of tracks is required to be 1 GeV (400 MeV for standard algorithm).
- DVs are sought with the selected tracks:
  1. Find two-track seed vertices from all pairs of tracks.
  2. Keep the vertices that have that have a vertex fit χ^2 of less than 5.0 per degree of freedom.
  3. Apply strict selection criteria to avoid that tracks associated with more than one vertex.
  4. To minimize BG from PVs, the transverse distance must be $\sqrt{(x_{DV} - x_{PV})^2 + (y_{DV} - y_{PV})^2} > 4$mm.
  5. $N_{DV}^{tracks} > 5$ & $m_{DV} > 10$ GeV (suppresses BGs)

Displaced Vertex

- The event selection efficiency as a function of $c\tau$ for the three signal samples.

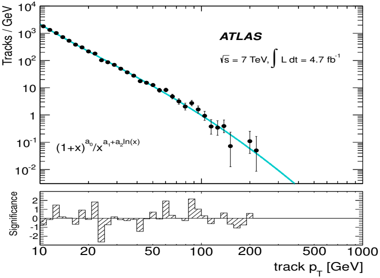


- The efficiency as a function of rDV and zDV for vertices in the signal MC sample MH.

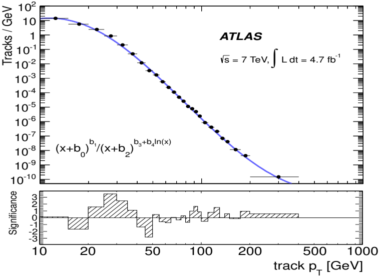


Disappearing Tracks: AMSB

- p_T distribution of the hadron-track control sample.
- The significance of the residuals between the data and the fit is shown at the bottom.

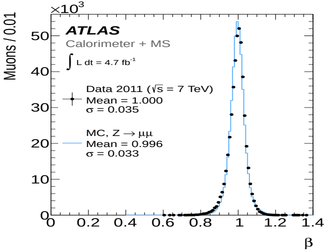


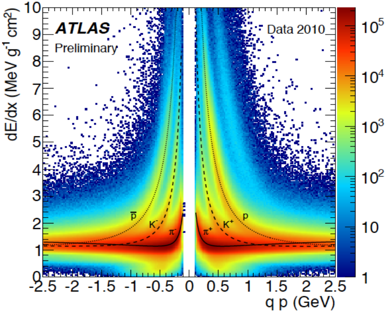
- p_T distribution of the electron-track control sample.
- The significance of the residuals between the data and the fit is shown at the bottom.



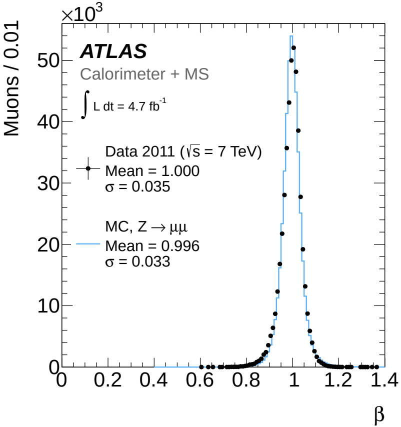
Stable Massive Particles (PLB) http://www.sciencedirect.com/science/article/pii/S0370269313001445

- We search for long lived sleptons, squarks and gluinos ($\beta < 1$).
- Our search includes different signatures of sleptons and R-hadrons.
- The mass (m) of these particles can be estimated as $m = \frac{p}{\gamma\beta}$ where:
  1. p is taken from track
  2. β is measured from ToF (Calo+MDT+RPC)
  3. $\beta\gamma$ is measured from pixels using an empirical Bethe-Bloch-like function: $\mathcal{M}_{\frac{dE}{dX}}(\beta\gamma) = \frac{p_1}{\beta^{p_3}} ln(1 + (p_2\beta\gamma)^{p_5}) - p_4$
- The core of this analysis consists of measuring as accurately as possible the velocity of particles traversing the detector.

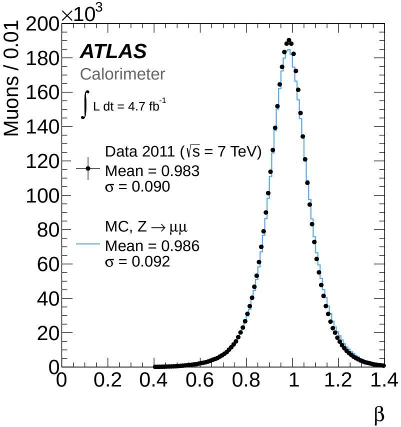




SMP Search



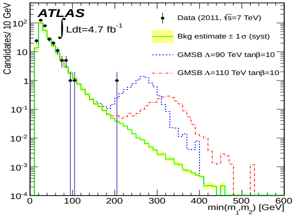
×10^3
Muons / 0.01
0
10
20
30
40
50
ATLAS
Calorimeter + MS
$\int$ L dt = 4.7 fb^{-1}
Data 2011 ($\sqrt{s}$ = 7 TeV)
Mean = 1.000
σ = 0.035
MC, Z → μμ
Mean = 0.996
σ = 0.033
0
0.2
0.4
0.6
0.8
1
1.2
1.4
β



×10^3
Muons / 0.01
0
20
40
60
80
100
120
140
160
180
200
ATLAS
Calorimeter
$\int$ L dt = 4.7 fb^{-1}
Data 2011 ($\sqrt{s}$ = 7 TeV)
Mean = 0.983
σ = 0.090
MC, Z → μμ
Mean = 0.986
σ = 0.092
0
0.2
0.4
0.6
0.8
1
1.2
1.4
β

Stable Massive Particles (PLB) http://www.sciencedirect.com/science/article/pii/S0370269313001445

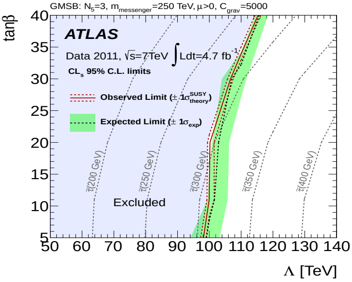
- **Analysis Characteristics**
  1. Search for long lived sleptons, squarks and gluinos ($\beta < 1$).
  2. The search includes different signatures of sleptons and R-hadrons.
  3. Mass (m) estimated as $m = \frac{p}{\gamma\beta}$.
- **Heavy Long-Lived Sleptons**
  1. Expect two sleptons per event.
  2. Main BG source are high p_T muons with mis-measured β.



✓ No excess over the SM background is observed.

✓ Long-lived staus (GMSB) excluded up to 300 GeV for $5 < tan\beta < 20$.

✓ Directly produced sleptons excluded up to 278 GeV.



Heavy Long-Lived R-Hadrons

- R-hadrons are composites of a gluino or squark with SM partons.
- Their energy deposits in the calorimeter may be small.
- R-hadrons can change their electric charge as they traverse the detector!
- Currently we have 3 different analyses to cover the lack of knowledge of the R-hadrons interaction with the detector:
    1. Full detector.
    2. MS-agnostic (ignore muon detectors)
    3. Inner detector only

✓ *$m_{\tilde{g}}$ excluded up to 985 GeV.*