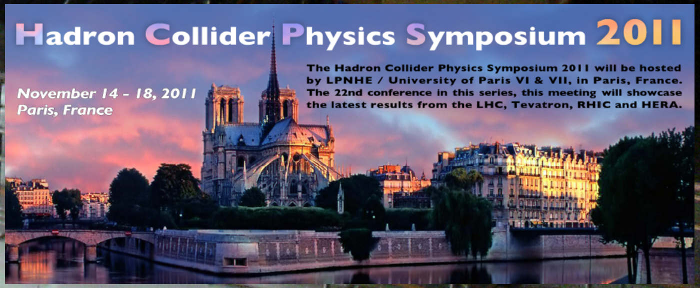
Supersymmetry Searches in ATLAS

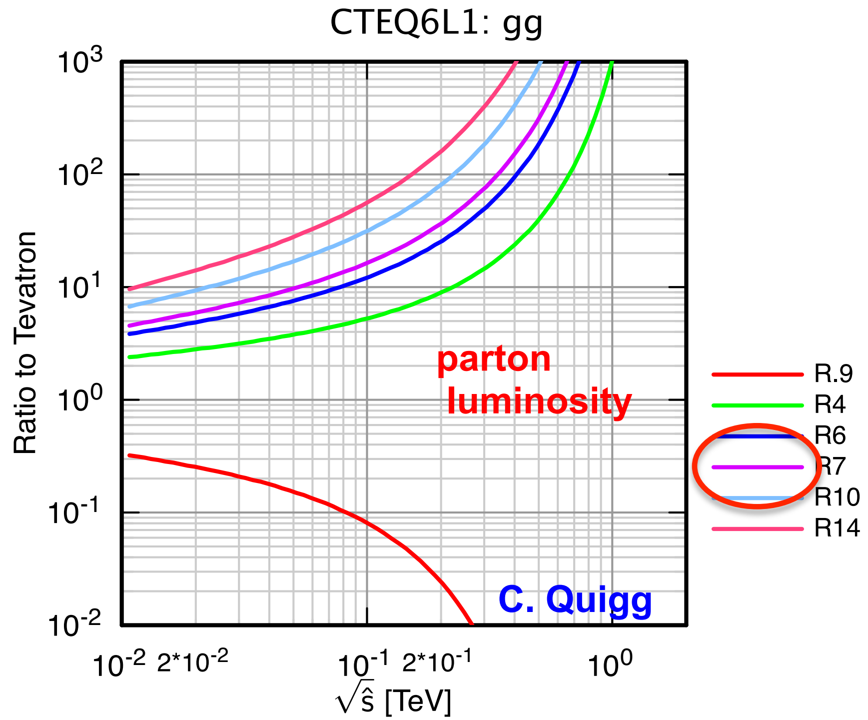
Paul de Jong, Nikhef
On behalf of the ATLAS Collaboration

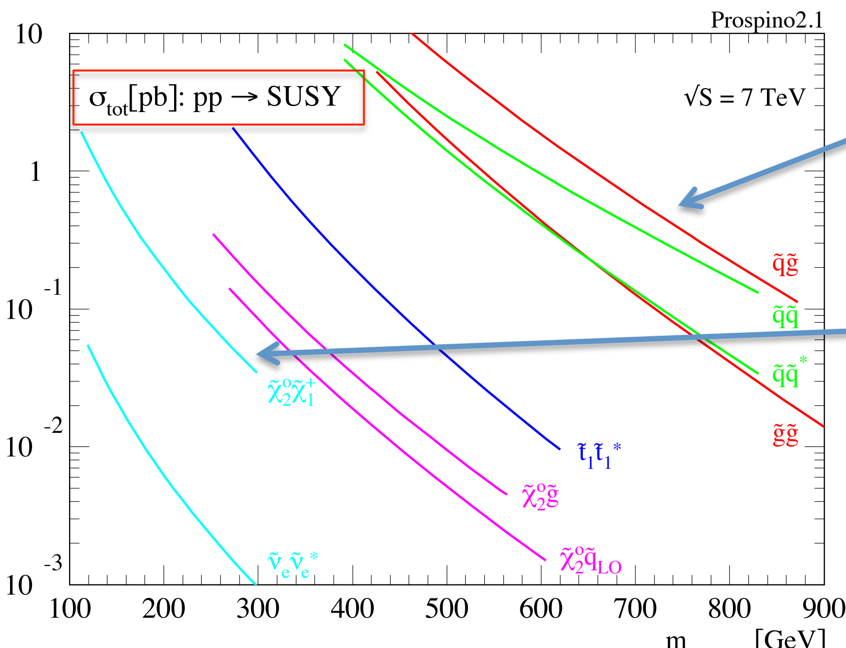


Excellent performance LHC 2011: > 5 fb^{-1} !

Large phase space beyond Tevatron
for high mass particles

Instantaneous lumi > 3.5 x 10^{33} $cm^{-2}s^{-1}$
→ Triggering challenging! Especially on jets.
Workhorse triggers: jet+E_T^{miss}, leptons





LHC: sensitivity first to strong production
of coloured sparticles

But with > 5 fb^{-1}, electroweak production
becomes important too

Results shown in this talk: typically ~1 fb^{-1}
Data taken in the first half of 2011

We do not know how exactly SUSY might show up first.
A good start could be:

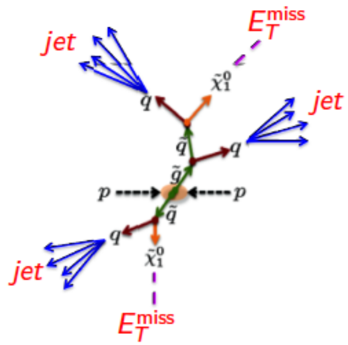
“Canonical” searches with jets and missing momentum

Keep analyses simple, general and robust
Do not overtune on specific models

Jets + E_T^{miss}, no leptons

1.04 fb^{-1}

arXiv.org 1109.6572



R-parity conservation assumed

	Signal Region	≥ 2-jet ($\tilde{q}\tilde{q}$)	≥ 3-jet ($\tilde{q}\tilde{g}$)	≥ 4-jet ($\tilde{g}\tilde{g}$)	High mass ($\tilde{g}\tilde{g}$)
Trigger requirements	E_T^{miss}	> 130	> 130	> 130	> 130
	Leading jet p_T	> 130	> 130	> 130	> 130
Channel definition	Second jet p_T	> 40	> 40	> 40	> 80
	Third jet p_T	–	> 40	> 40	> 80
	Fourth jet p_T	–	–	> 40	> 80
QCD rejection	$\Delta\phi(\text{jet}, \vec{P}_T^{miss})_{min}$	> 0.4	> 0.4	> 0.4	> 0.4
	E_T^{miss}/m_{eff}	> 0.3	> 0.25	> 0.25	> 0.2
Enhance signal	m_{eff}	> 1000	> 1000	> 500/1000	> 1100

arXiv:1109.6572[2]

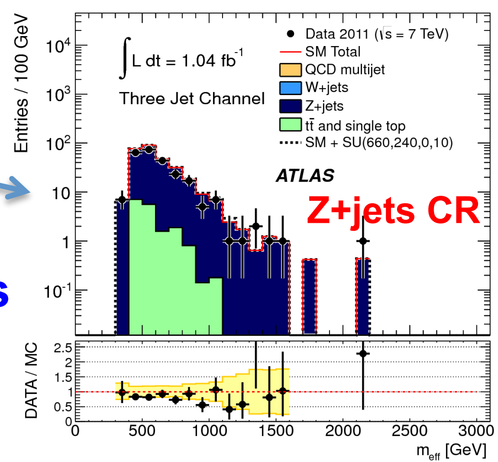
$\Delta\phi$ cut up to 3rd leading jet

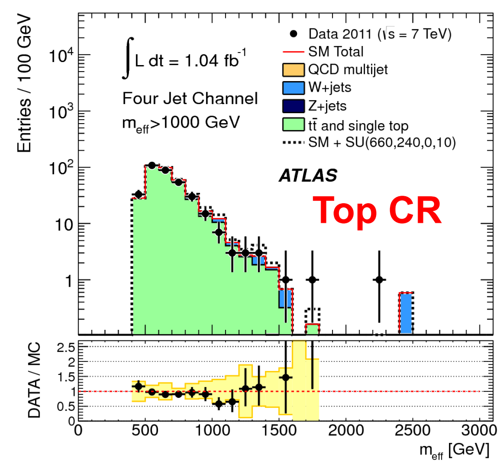
$$m_{eff} = E_T^{miss} + \sum_{\text{SR jets}} p_T \qquad m_{eff}^{incl} = E_T^{miss} + \sum_{\text{jets } p_T>40} p_T$$

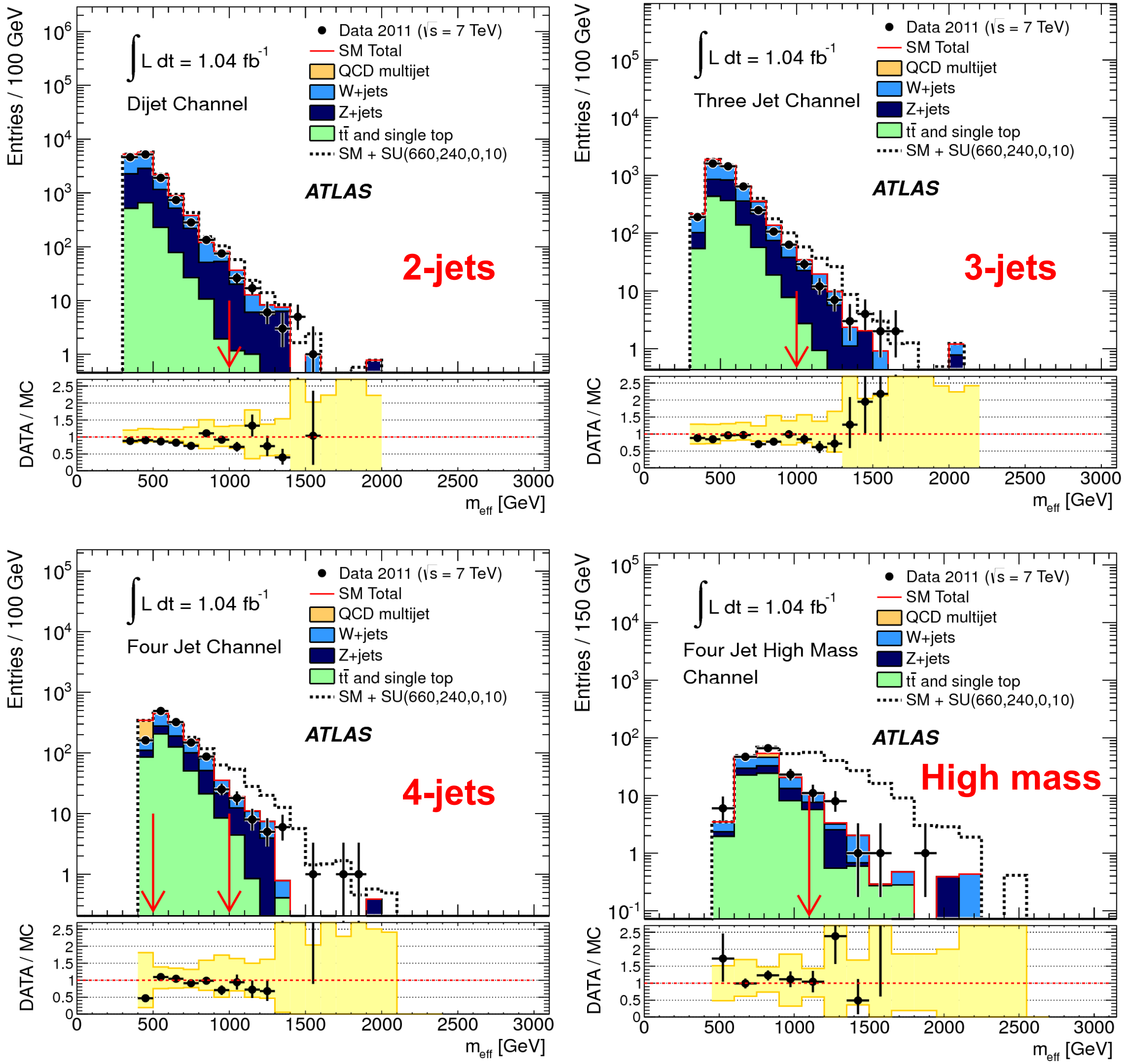
Backgrounds: ttbar, Z+jets, W+jets multijet

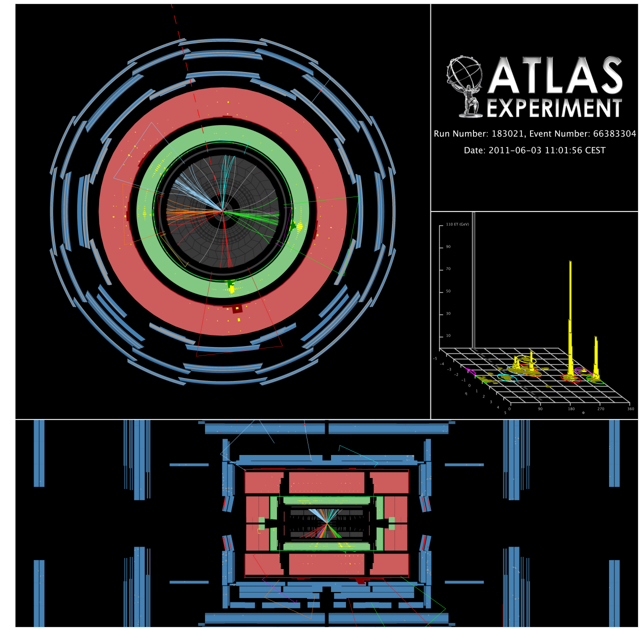
control regions

reverse $\Delta\Phi(\text{jet}, p_T^{miss})$ cut







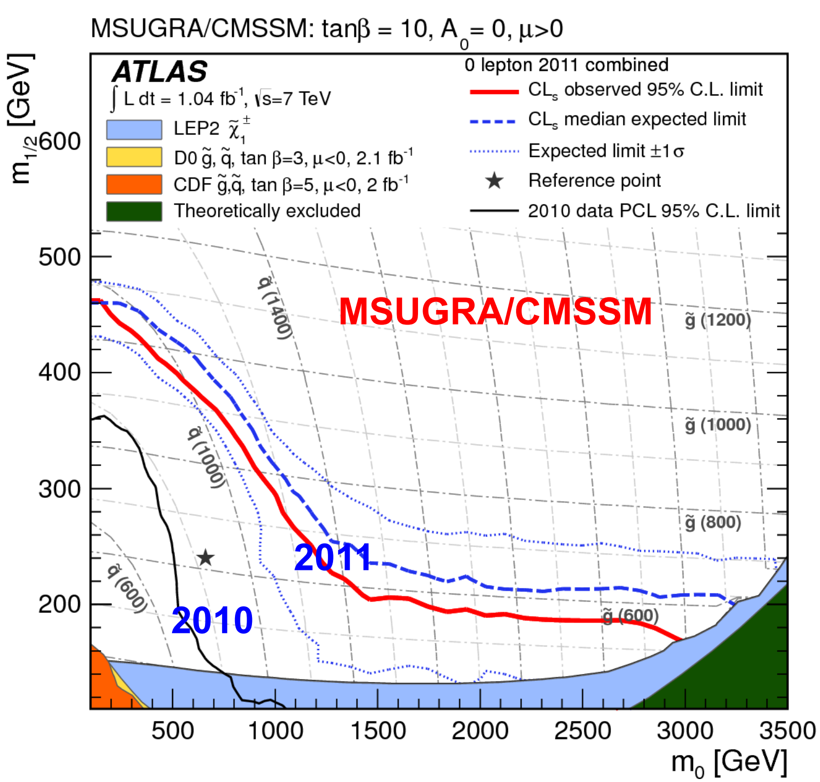


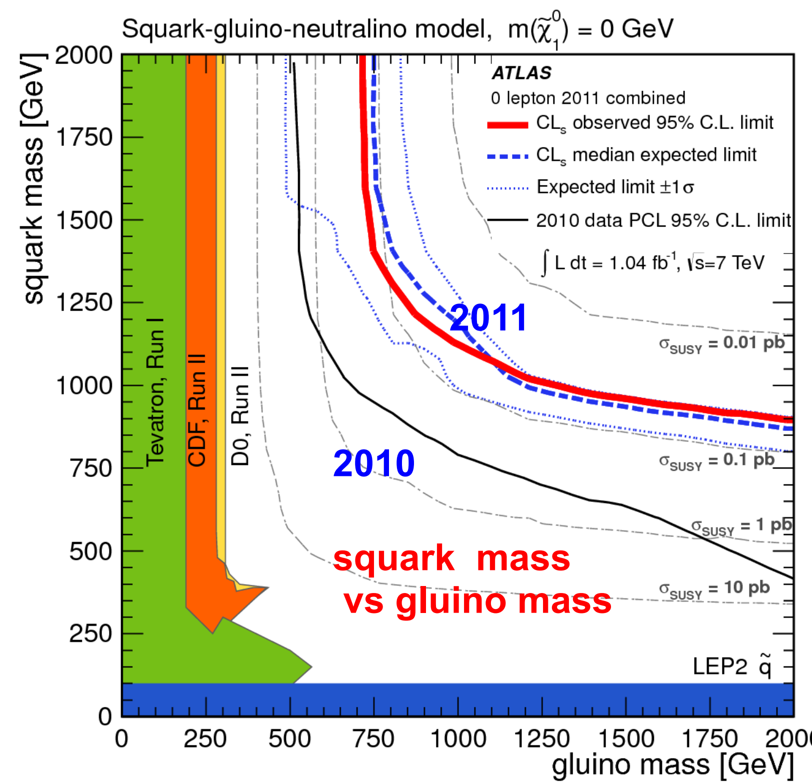
Highest m_{eff} event
m_{eff} = 1.81 TeV
E_T^{miss} = 460 GeV

Effective mass (m_{eff}) distributions in signal regions.

No excess observed: limits set (CL_s method, profile likelihood technique))

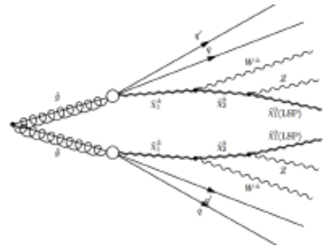
Process	Signal Region				
	$\geq$ 2-jet	$\geq$ 3-jet	$\geq$ 4-jet, $m_{\text{eff}} > 500$ GeV	$\geq$ 4-jet, $m_{\text{eff}} > 1000$ GeV	High mass
Z/γ+jets	$32.3 \pm 2.6 \pm 6.9$	$25.5 \pm 2.6 \pm 4.9$	$209 \pm 9 \pm 38$	$16.2 \pm 2.2 \pm 3.7$	$3.3 \pm 1.0 \pm 1.3$
W+jets	$26.4 \pm 4.0 \pm 6.7$	$22.6 \pm 3.5 \pm 5.6$	$349 \pm 30 \pm 122$	$13.0 \pm 2.2 \pm 4.7$	$2.1 \pm 0.8 \pm 1.1$
$t\bar{t}$+ single top	$3.4 \pm 1.6 \pm 1.6$	$5.9 \pm 2.0 \pm 2.2$	$425 \pm 39 \pm 84$	$4.0 \pm 1.3 \pm 2.0$	$5.7 \pm 1.8 \pm 1.9$
QCD multi-jet	$0.22 \pm 0.06 \pm 0.24$	$0.92 \pm 0.12 \pm 0.46$	$34 \pm 2 \pm 29$	$0.73 \pm 0.14 \pm 0.50$	$2.10 \pm 0.37 \pm 0.82$
Total	$62.4 \pm 4.4 \pm 9.3$	$54.9 \pm 3.9 \pm 7.1$	$1015 \pm 41 \pm 144$	$33.9 \pm 2.9 \pm 6.2$	$13.1 \pm 1.9 \pm 2.5$
Data	58	59	1118	40	18
εσA limit (fb):	22	25	429	27	17





Long decay chains

1.34 fb^{-1}



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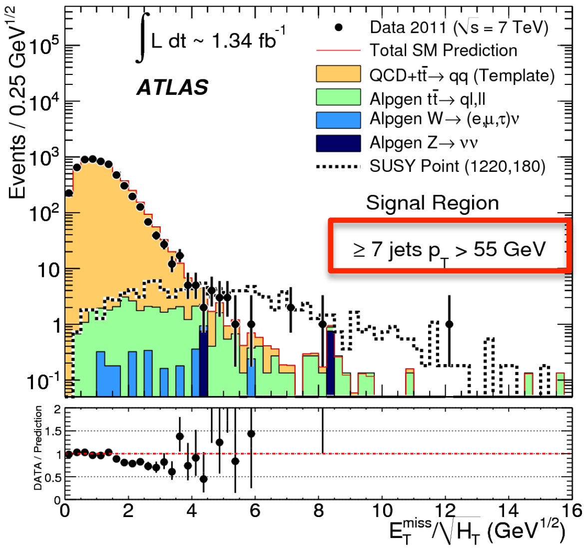
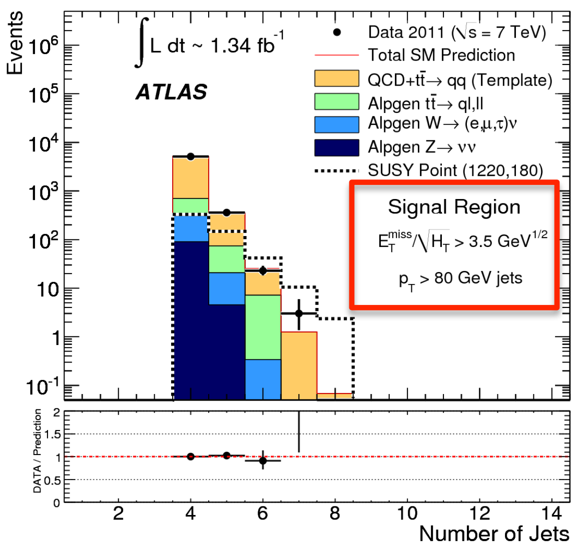
arXiv.org 1110.2299

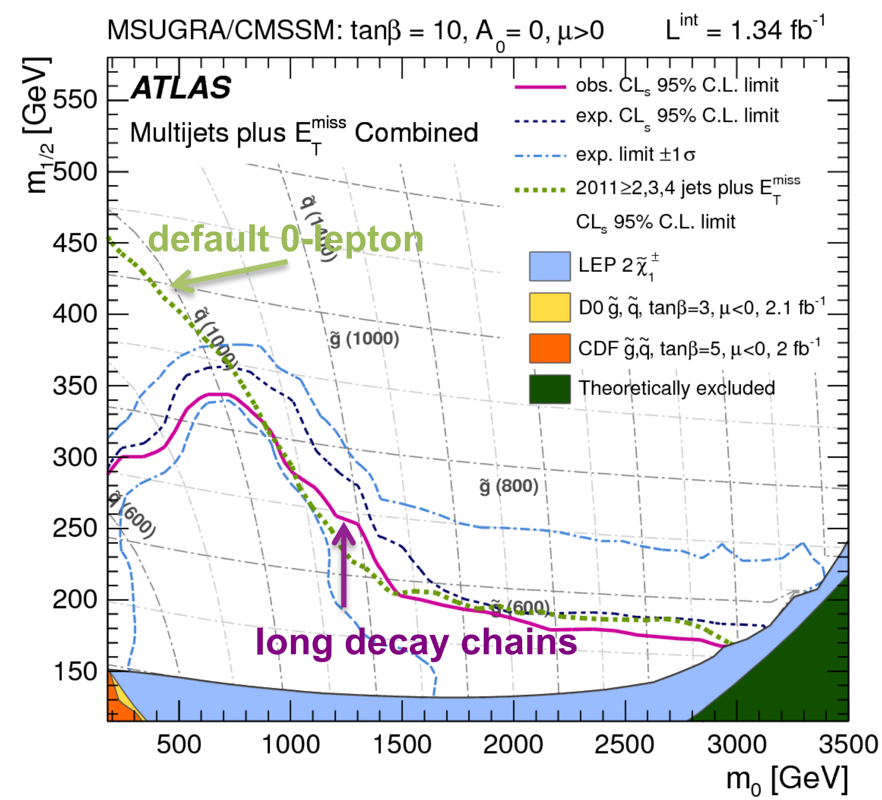
For example multi-step gluino decays
(Or any other scenario with many jets!)





Signal region	7j55	8j55	6j80	7j80
Jet p_T	> 55 GeV		> 80 GeV	
Jet $\lvert\eta\rvert$	< 2.8			
ΔR_{jj}	> 0.6 for any pair of jets			
Number of jets	≥ 7	≥ 8	≥ 6	≥ 7
$E_T^{miss}/\sqrt{H_T}$	> 3.5 $\text{GeV}^{1/2}$			

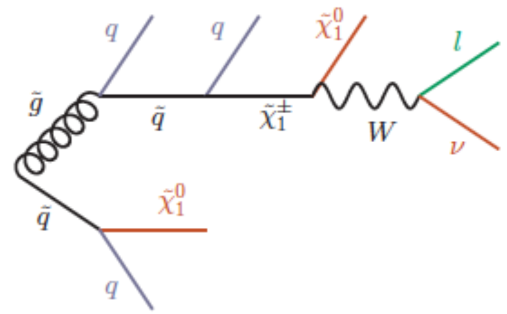
Signal region	7j55	8j55	6j80	7j80
Total Standard Model	39 ± 9	$2.3^{+4.4}_{-0.7}$	26 ± 6	$1.3^{+0.9}_{-0.4}$
Data	45	4	26	3



Jets, E_T^{miss} and 1 isolated lepton (e or μ): **1.04 fb^{-1}**

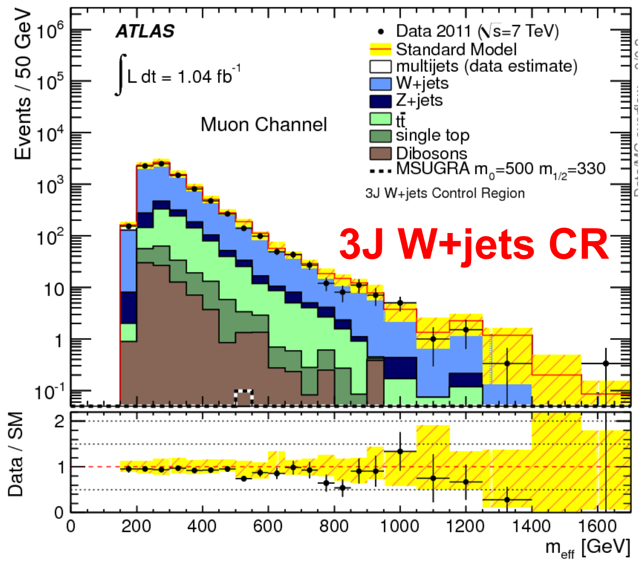
Selection	Signal Regions 3JL	3JT	4JL	4JT	Control Regions 3J	4J
Number of Leptons	= 1					
Lepton p_T (GeV)	> 25(20) for electrons (muons)					
Veto lepton p_T (GeV)	> 20(10) for electrons (muons)					
Number of jets	≥ 3		≥ 4		≥ 3	≥ 4
Leading jet p_T (GeV)	60	80	60	60	60	60
Subsequent jets p_T (GeV)	25	25	25	40	25	25
$\Delta\phi(\vec{\text{jet}}_i, \vec{E}_T^{\text{miss}})$	[> 0.2 (mod.π)] for all 3 (4) jets					
m_T (GeV)	> 100				$40 < m_T < 80$	
E_T^{miss} (GeV)	> 125	> 240	> 140	> 200	$30 < E_T^{\text{miss}} < 80$	
$E_T^{\text{miss}}/m_{\text{eff}}$	> 0.25	> 0.15	> 0.30	> 0.15	–	–
m_{eff} (GeV)	> 500	> 600	> 300	> 500	> 500	> 300

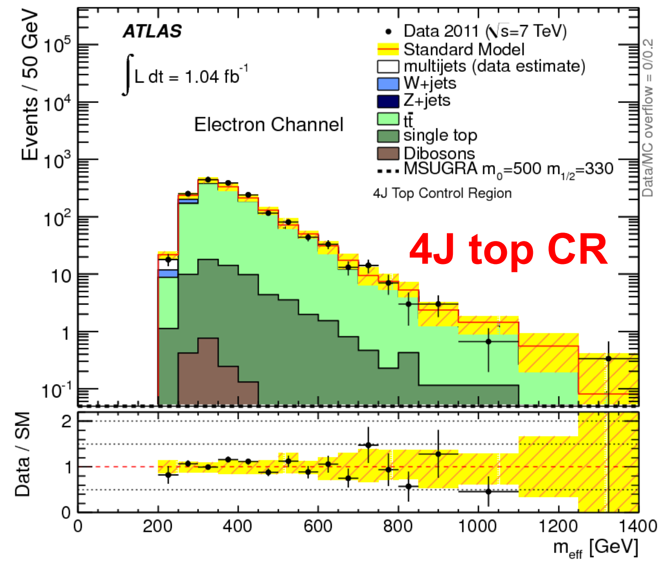
Example 1-lepton signature

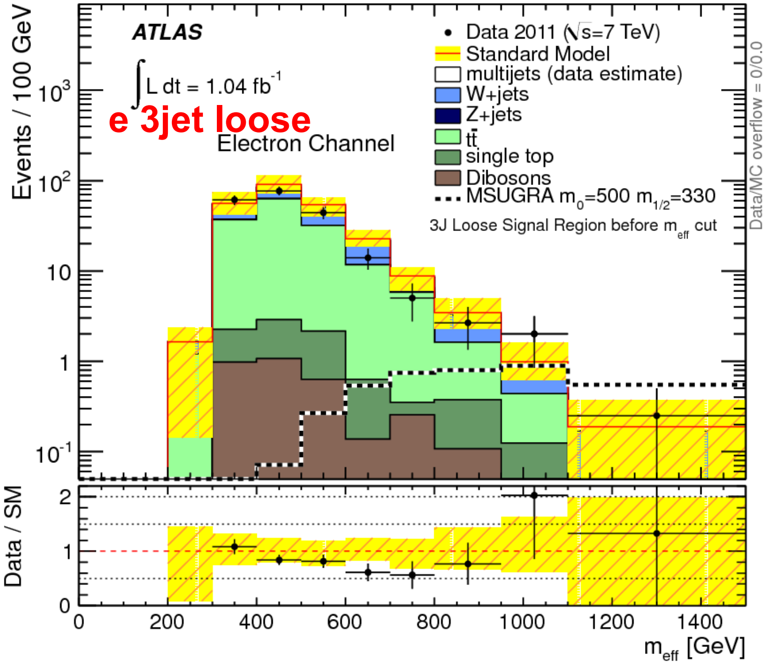


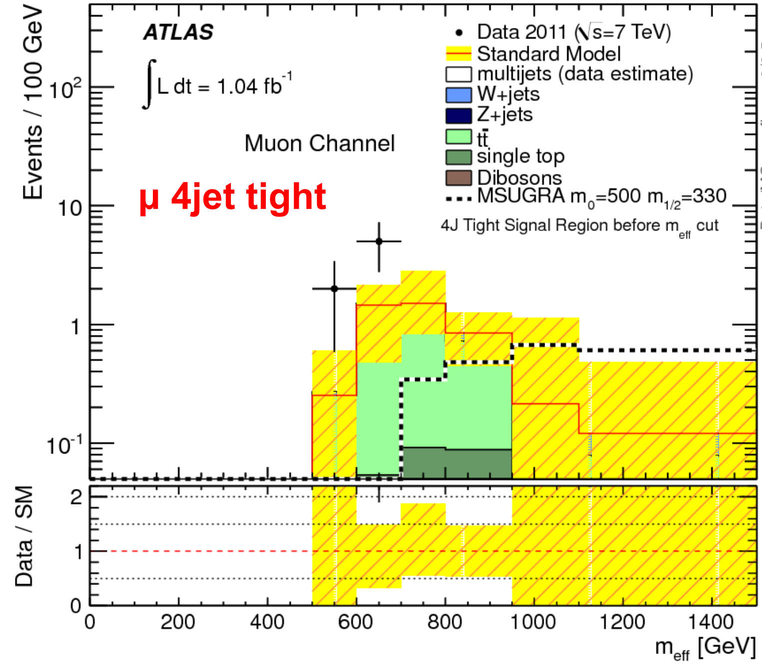
Backgrounds: W+jets, ttbar
(multijet negligible)

BG estimation using
control regions









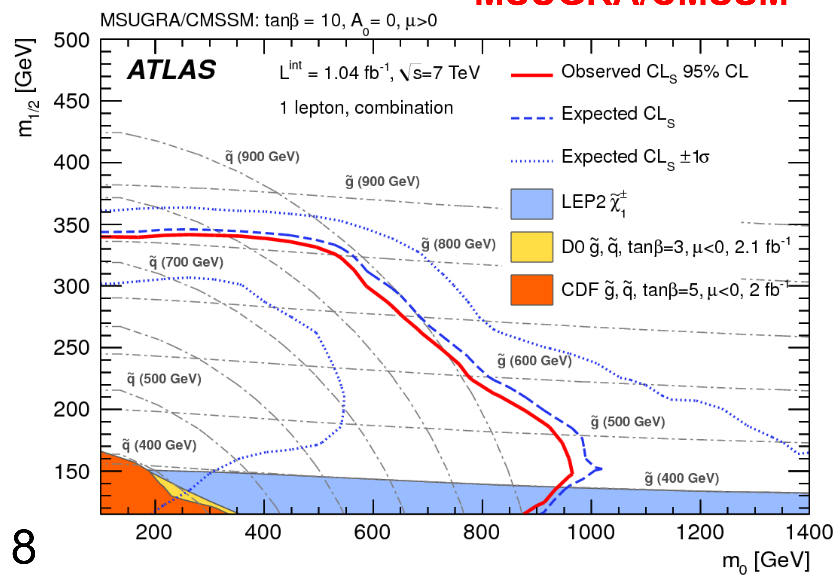
m_{eff} in signal regions: no excess

Electron channel	3JL SR	3JT SR	4JL SR	4JT SR
Observed events	71	14	41	9
Fitted background events	98 ± 28	18.5 ± 7.4	48 ± 18	8.0 ± 3.7

Muon channel	3JL SR	3JT SR	4JL SR	4JT SR
Observed events	58	11	50	7
Fitted background events	64 ± 19	13.9 ± 4.3	53 ± 16	6.0 ± 2.7

εσA limits (fb)	3JL SR	3JT SR	4JL SR	4JT SR
e:	50	14	33	10
μ:	36	10	31	9

MSUGRA/CMSSM

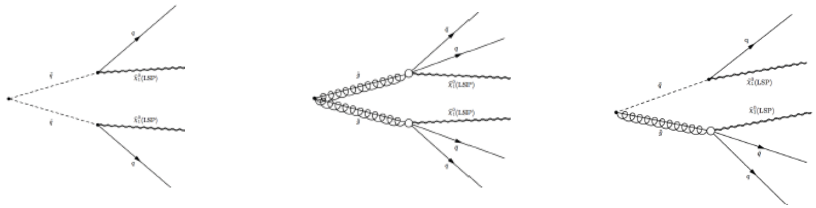


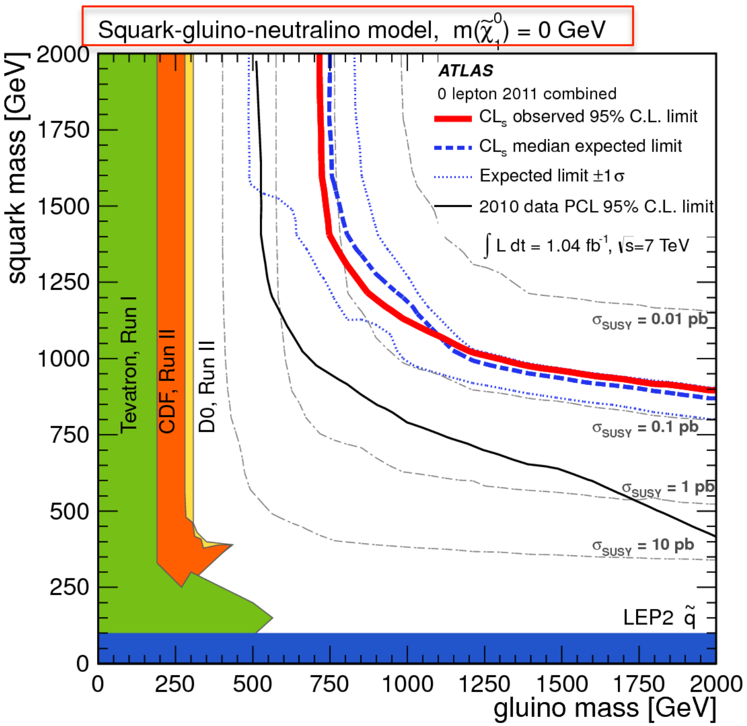
But how about moving beyond constrained models
such as MSUGRA/CMSSM or minimal gauge mediation?

Simplified model interpretation

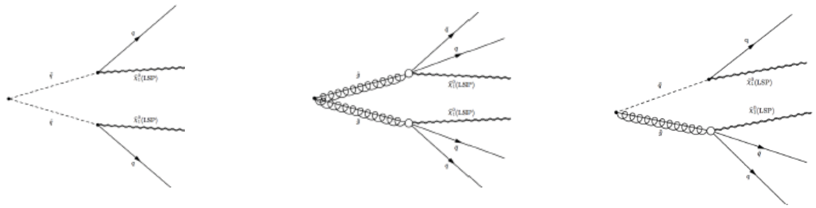
MSSM-inspired models of well-defined production and decay modes
Explore dependence of free parameters
Introduce complexity progressively

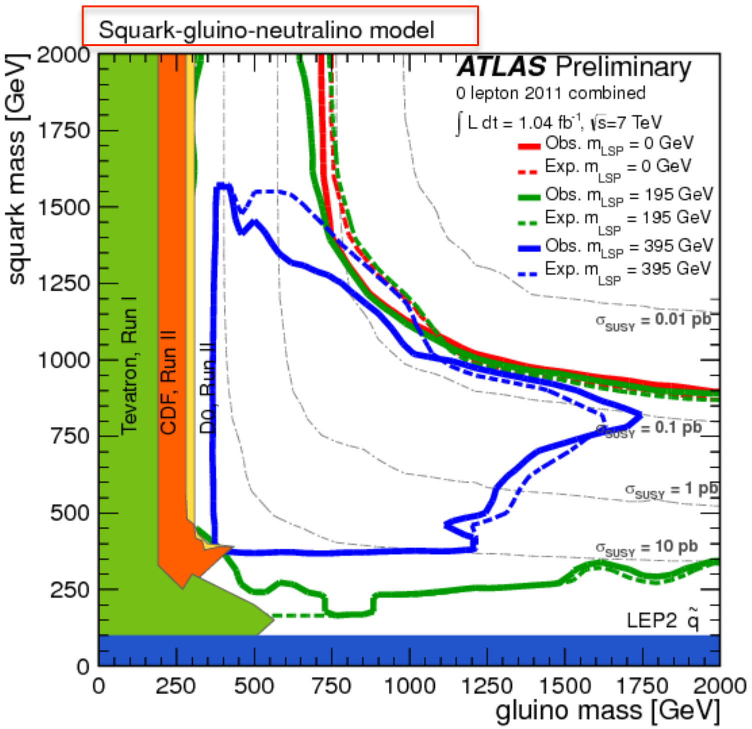
Simplified models for 0-lepton channel





Simplified models for 0-lepton channel





red: massless LSP

green: LSP 195 GeV

blue: LSP 395 GeV

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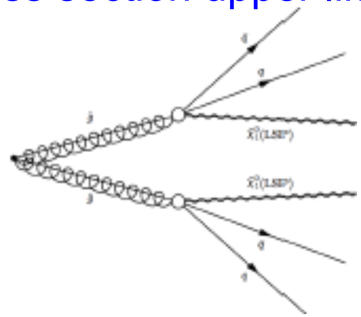
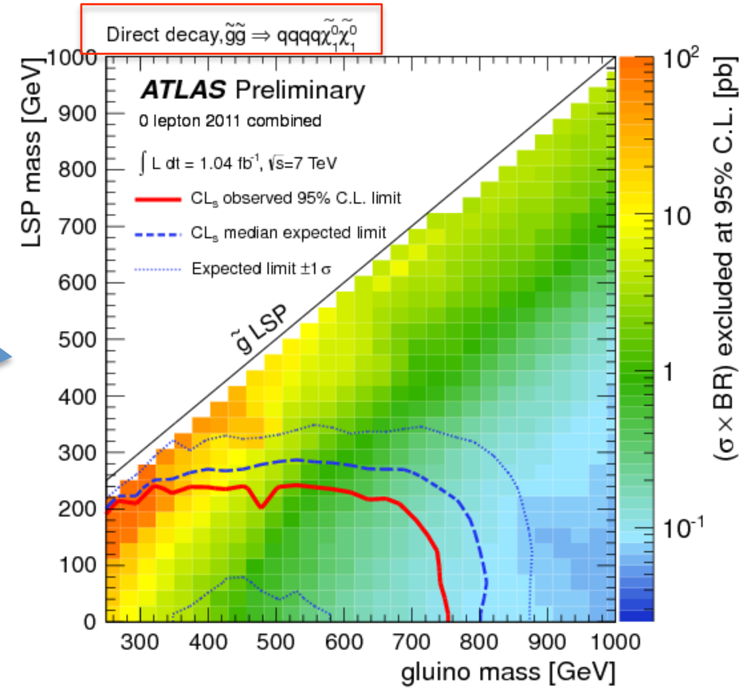
Simplified models for 0-lepton channel

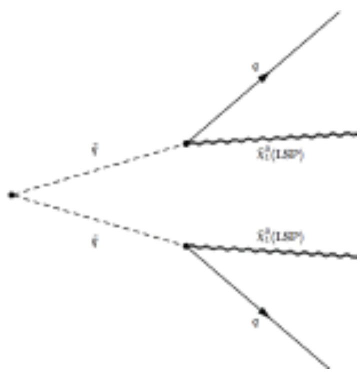
(Colours represent cross section upper limits)

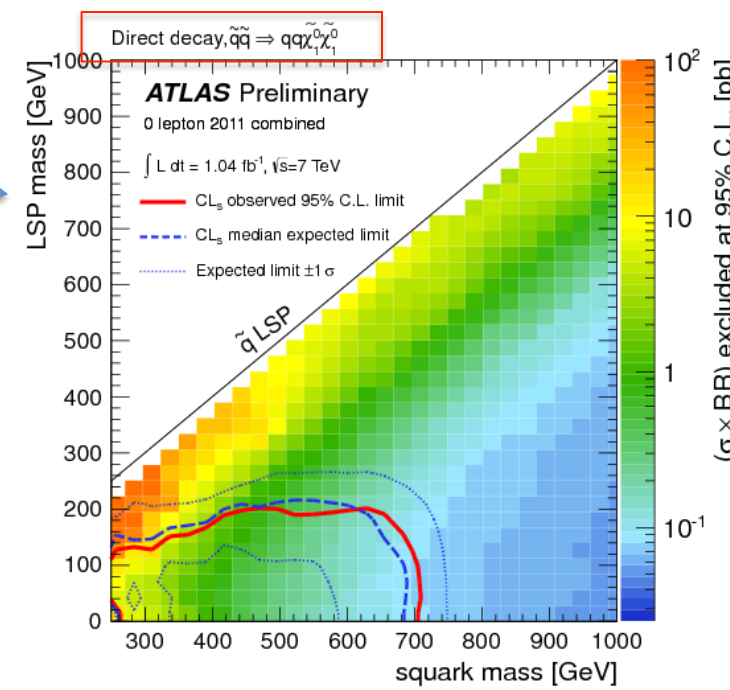
NEW!





Free parameters: gluon and LSP mass





Free parameters: squark and LSP mass

(+ 1-step decays with intermediate chargino not shown here for 0-lepton, but shown for 1-lepton later)

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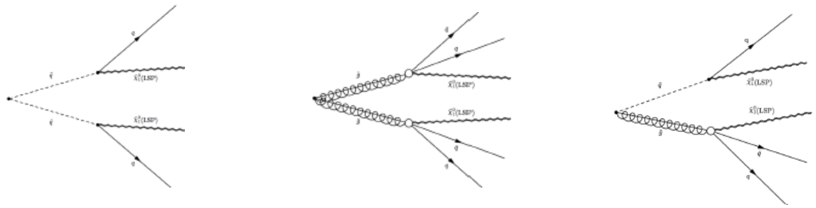
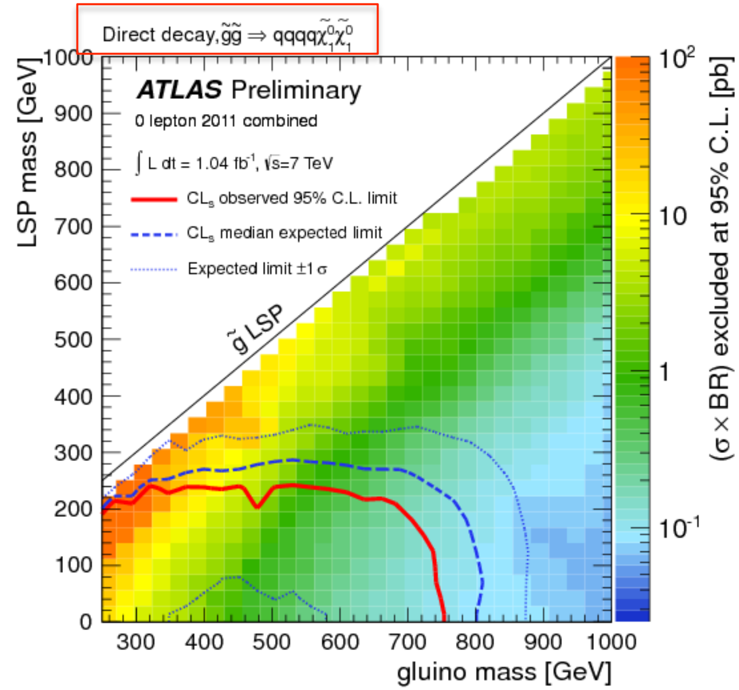
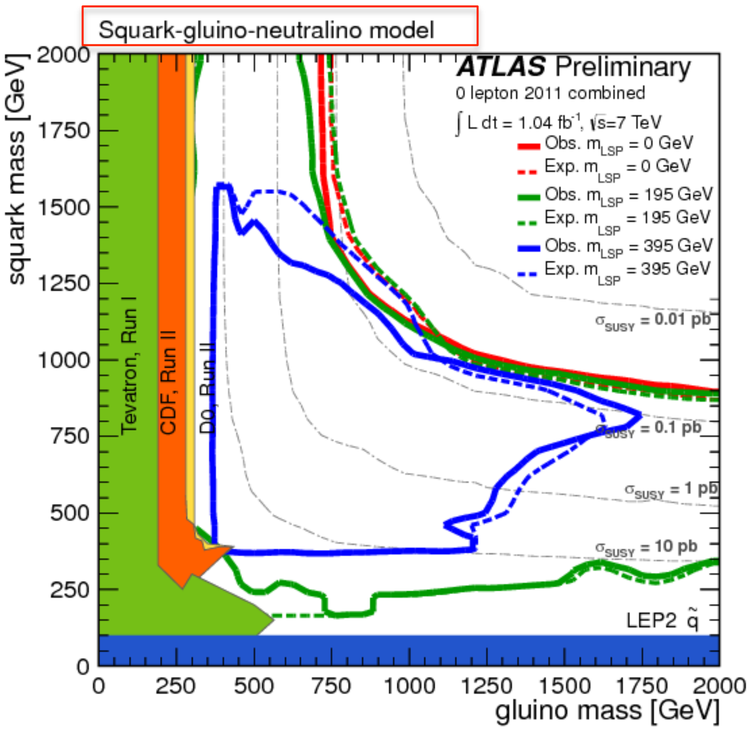
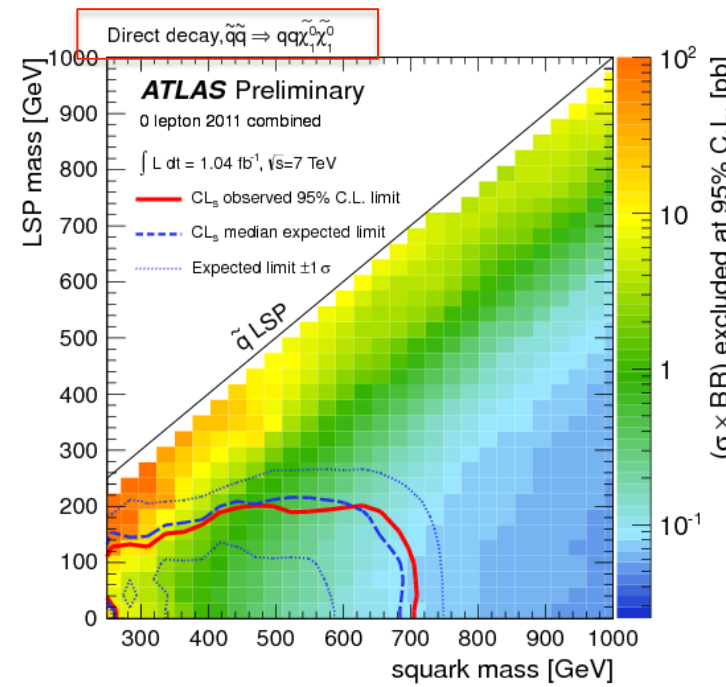
Simplified models for 0-lepton channel



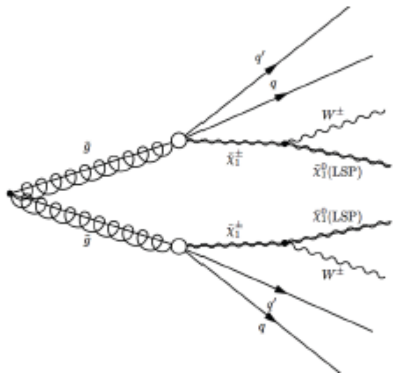






Note: squark/gluino mass limits are less strong for LSP mass > 200 GeV!

1-lepton simplified models



1-step via intermediate chargino

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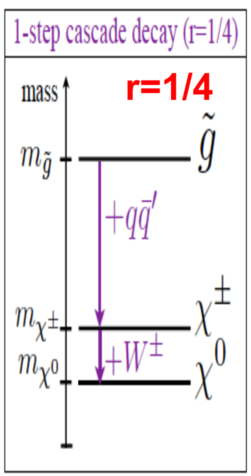
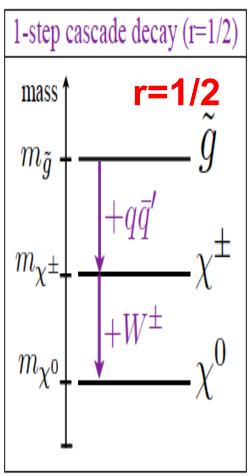
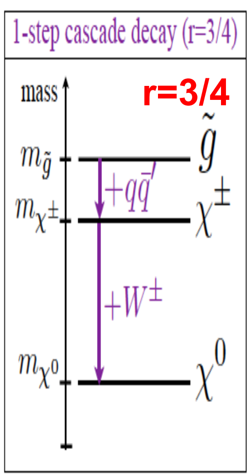
arXiv.org 1109.6606

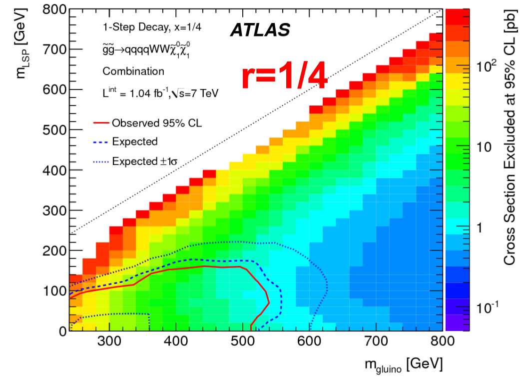


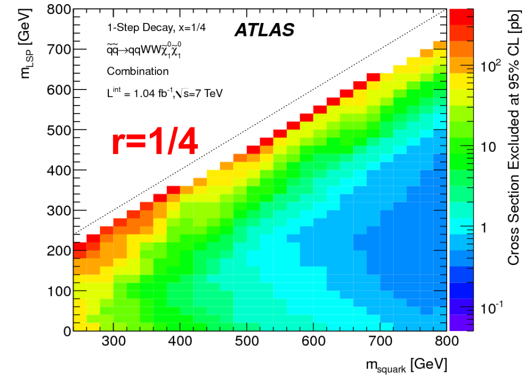


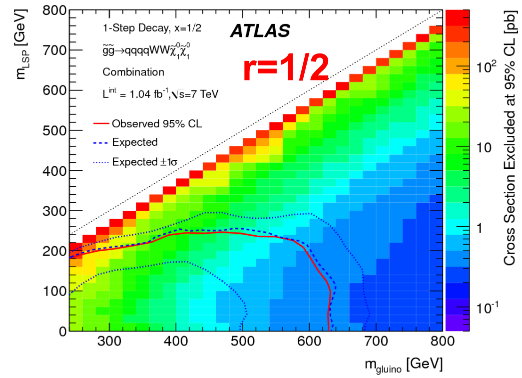


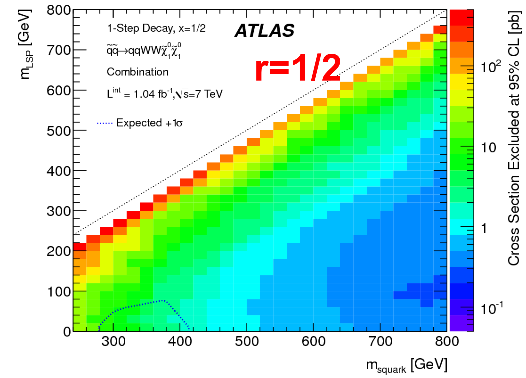
gluino decay

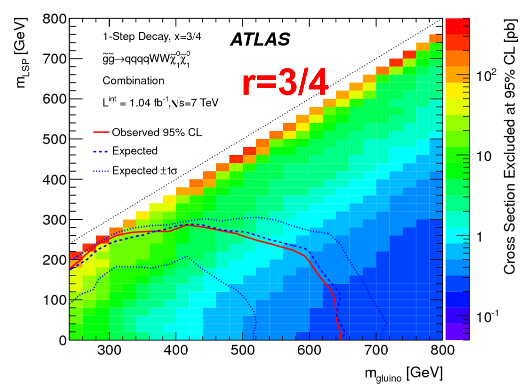
squark decay

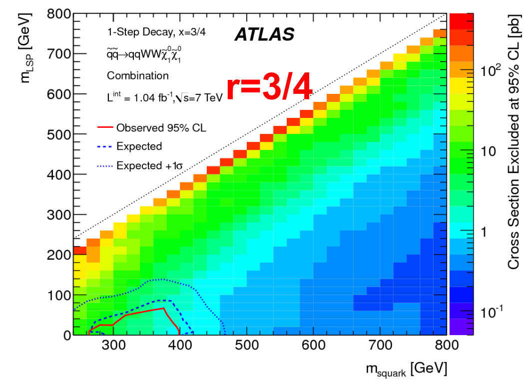












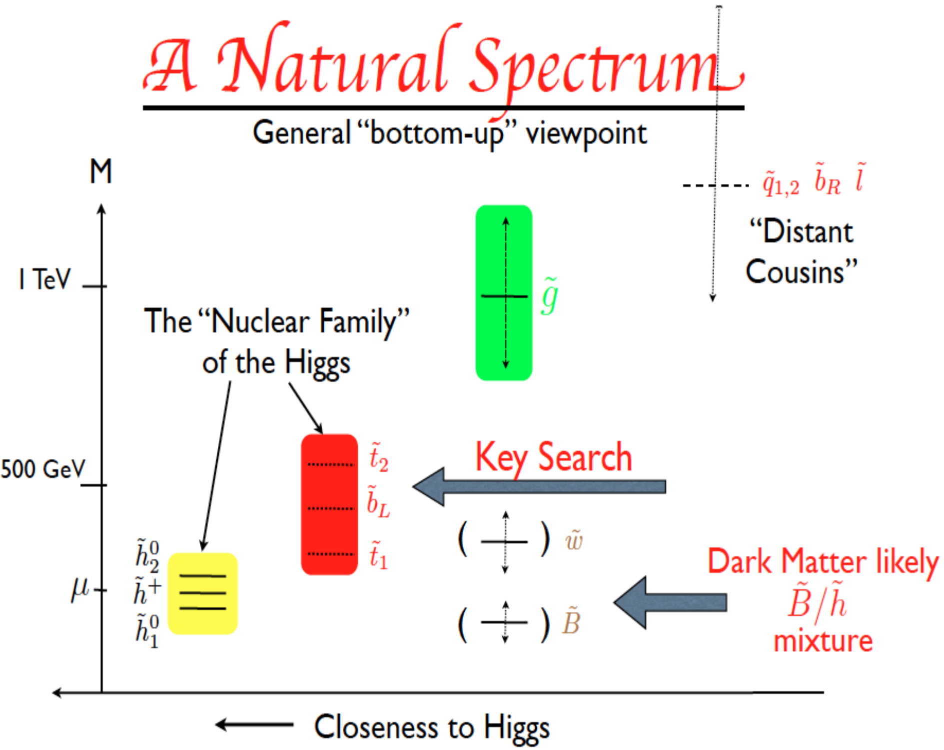
(Colours represent cross section upper limits)

After first 2 years of LHC:

No SUSY so far… Nor any other BSM hints…

Time to take a step back and recap:
SUSY quo vadis?
Have we been too naieve?

(See talk of Giacomo Polesello tomorrow)



(L. Hall, Berkeley)

- Generalize away from (over)constrained scenarios
- Gaugino sector and sleptons: multi-leptons, photons
- Stop (and sbottom and stau) sectors (major motivation for SUSY at low energies)
- Non-``canonical" scenarios: semi-stable SUSY particles, R-parity violation

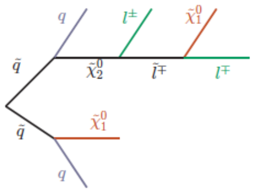
Searches aimed towards electroweak gauginos

Dileptons

NEW!

1.04 fb^{-1}

Example 2-lepton signature (OS)



Common cuts

- Preselection (Data Quality, Trigger, Primary Vertex)
- 2 leptons: electron $p_T > 25/20$ GeV, muon $p_T > 20/10$ GeV, $m_{ll} > 12$ GeV

Opposite Sign

SR1 $\not{E}_T > 250$ GeV

SR2 3 jets $p_T > 80, 40, 40$ GeV, $\not{E}_T > 220$ GeV (gluino 2-body decays)

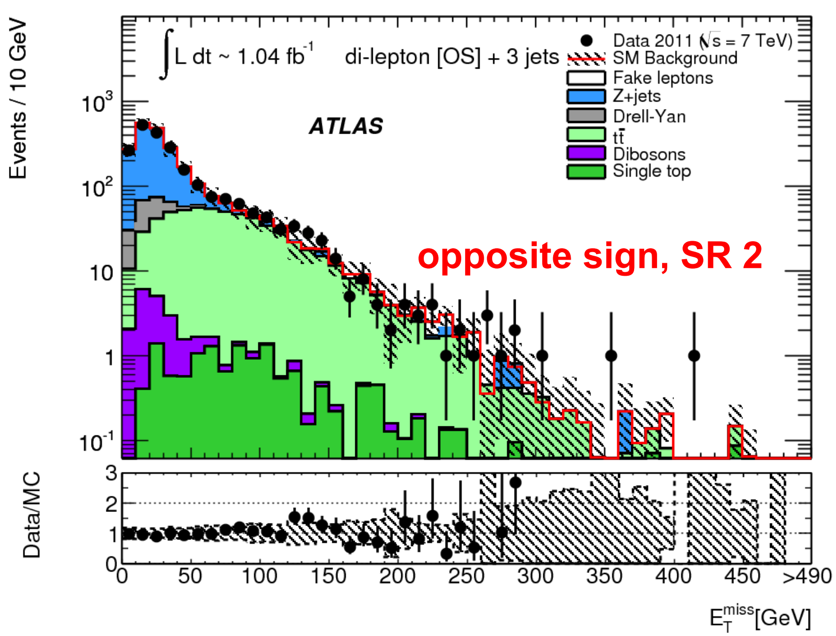
SR3 4 jets $p_T > 100, 70, 70, 70$ GeV, $\not{E}_T > 100$ GeV (gluino 3-body decays)

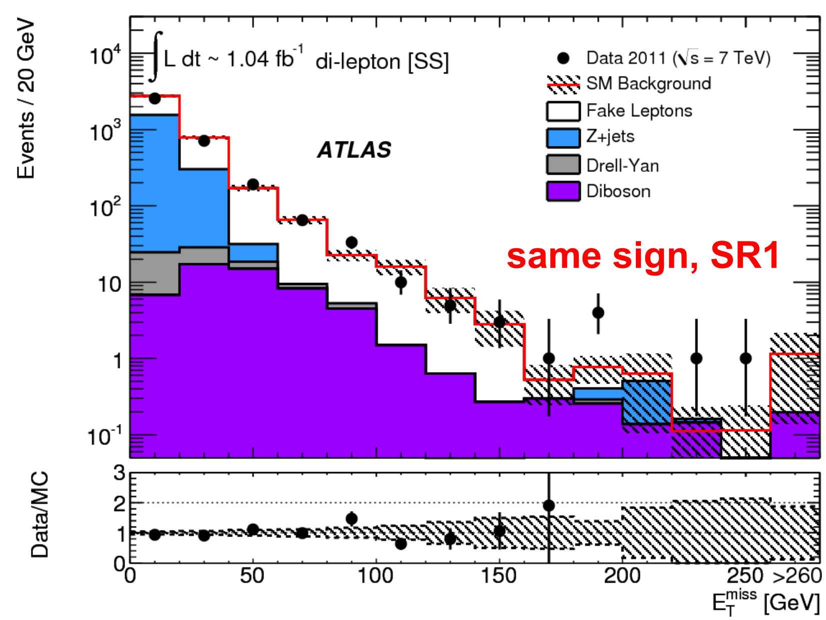
Same Sign

SR1 $\not{E}_T > 100$ GeV (weak gaugino production)

SR2 2 jets $p_T > 50, 50$ GeV, $\not{E}_T > 80$ GeV (mSUGRA/CMSSM)

	Background	Obs.	95% CL
OS-SR1	15.5 ± 4.0	13	9.9 fb
OS-SR2	13.0 ± 4.0	17	14.4 fb
OS-SR3	5.7 ± 3.6	2	6.4 fb
SS-SR1	32.6 ± 7.9	25	14.8 fb
SS-SR2	24.9 ± 5.9	28	17.7 fb





Dileptons: interpretation

Same sign dilepton interpretation in simplified model of weak gaugino production: $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$

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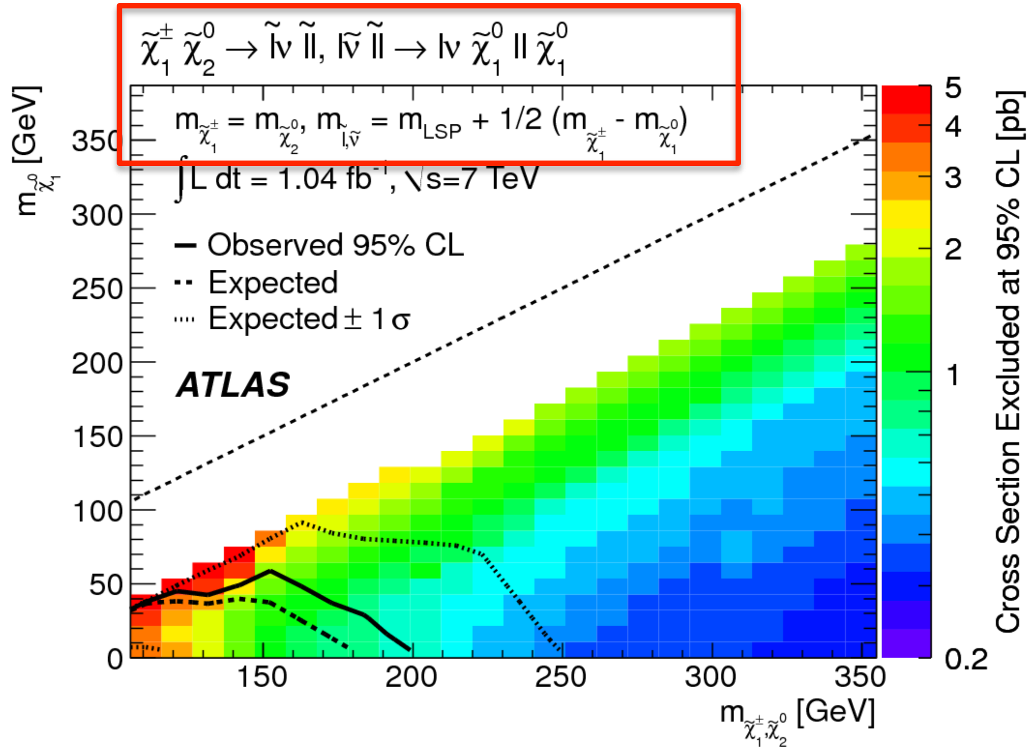
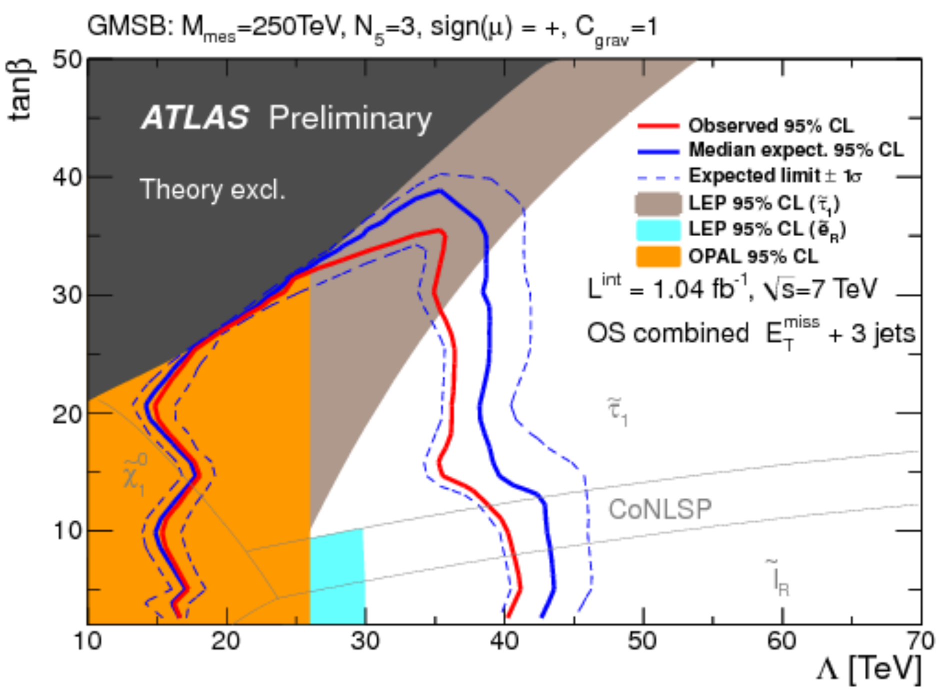
arXiv.org 1110.6189





Interpretation in GMSB

(opposite sign SR2)

NEW!

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paper in preparation

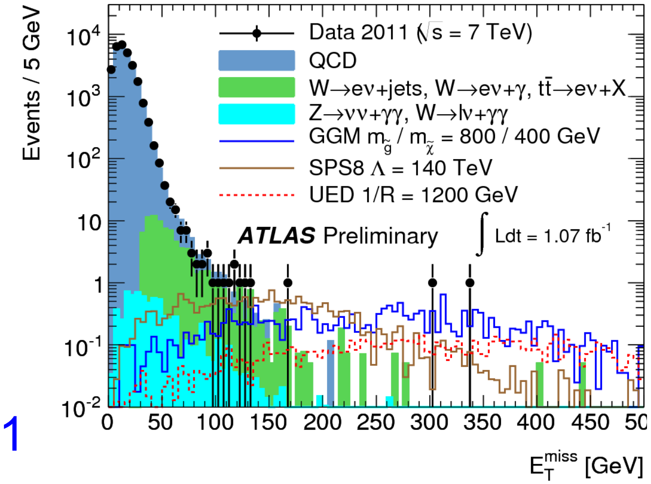
γγ + MET

$1.07\ fb^{-1}$

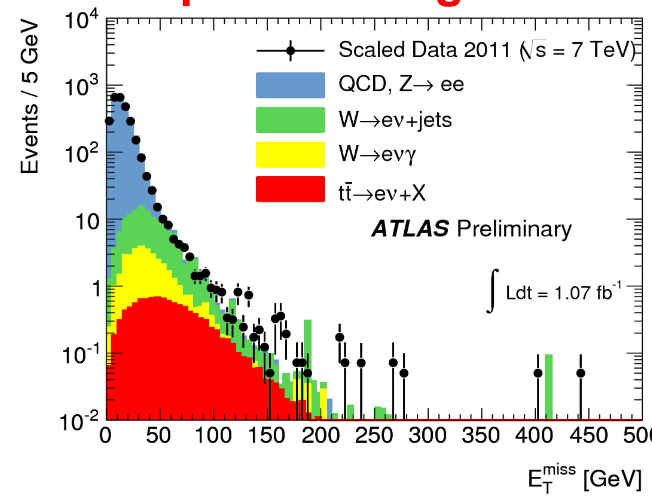
Gauge mediation with bino-like NLSP: $\tilde{\chi}^0 \rightarrow \gamma\ \tilde{G}$

Selection: 2 tight γ $E_T > 25$ GeV, isolated, $|\eta|<1.37$ or $1.52<|\eta|<1.81$

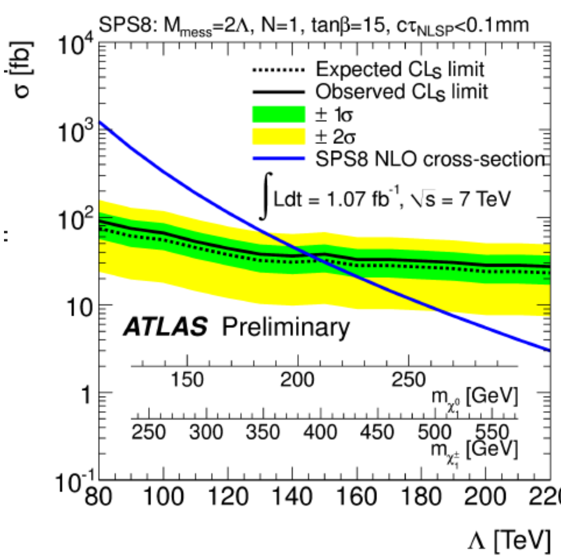
γγ signal region



eγ control region

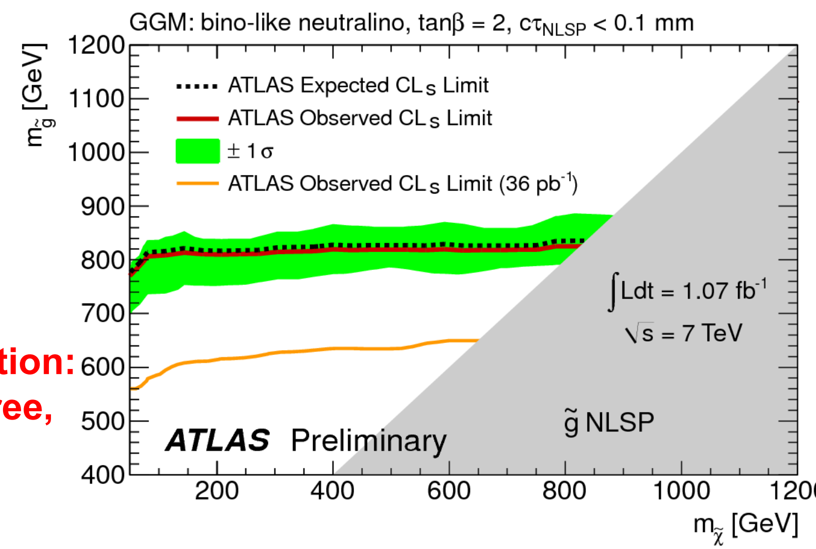


E_T^{miss} range [GeV]	Data events	Predicted background events: Total	QCD	$W/t\bar{t}(\rightarrow e\nu)+X$	Irreducible	Expected signal events: GGM	SPS8	UED
75 - 100	11	14.7 ± 1.2	6.7 ± 0.9	7.4 ± 0.8	0.52 ± 0.10	0.8 ± 0.1	2.1 ± 0.1	0.15 ± 0.01
100 - 125	6	4.9 ± 0.7	1.6 ± 0.4	3.0 ± 0.5	0.23 ± 0.05	1.2 ± 0.1	2.5 ± 0.1	0.29 ± 0.02
> 125	5	4.1 ± 0.6	0.8 ± 0.3	3.1 ± 0.5	0.15 ± 0.01	17.2 ± 0.5	13.0 ± 0.3	9.67 ± 0.11



Interpretation in minimal gauge mediation: SPS 8 benchmark slope

Interpretation in general gauge mediation: gluino and $\tilde{\chi}^0$ mass free, bino-like $\tilde{\chi}^0$



Searches for 3rd generation squarks

stops and sbottoms in gluino decays

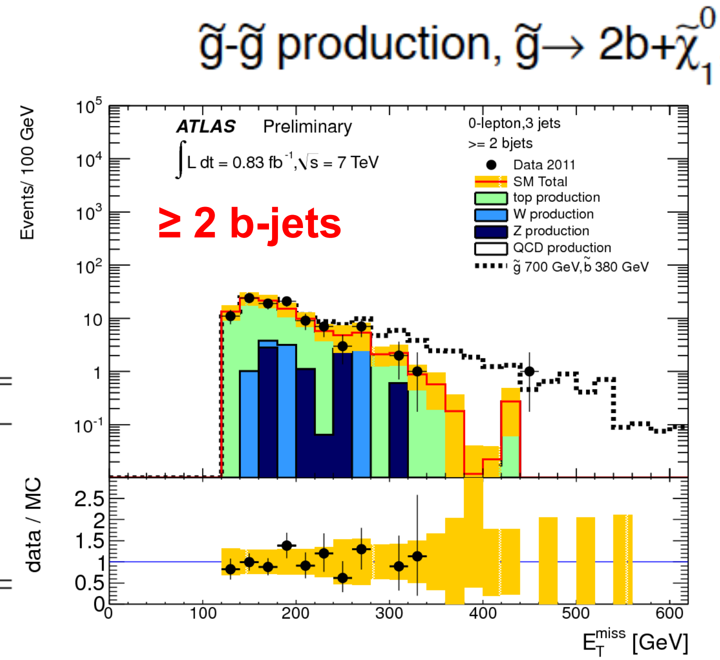
direct stop or sbottom pair production

Sbottom production in gluino decays

0.83 fb^{-1}

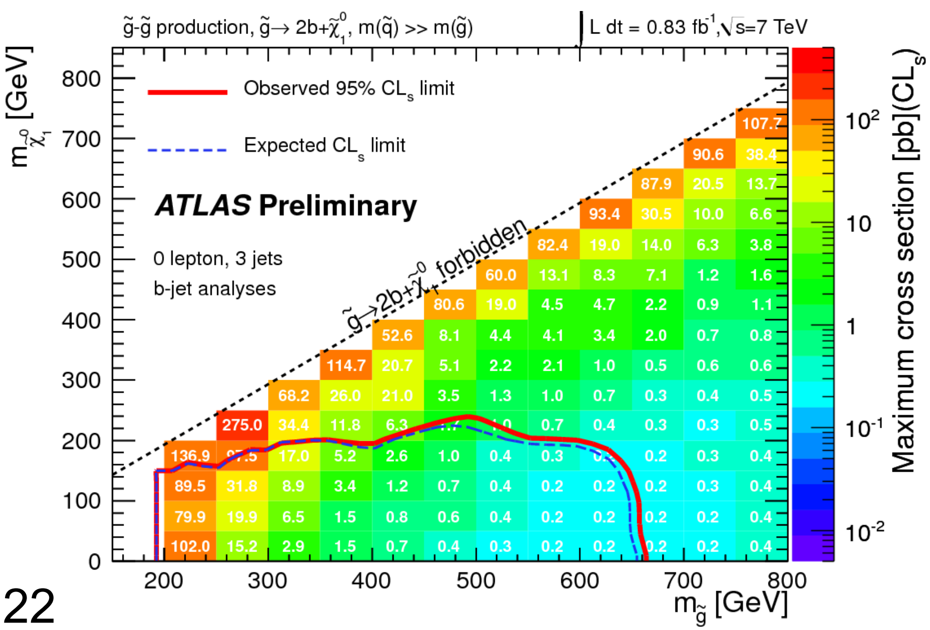
ATLAS-CONF-2011-098

$\geq$3 jets, p_T > 130, 50, 50 GeV, $\geq$1 jet b-tagged
3 jets $\Delta\Phi(jet, E_T^{miss})$ > 0.4
Veto events with isolated e or μ
E_T^{miss} > 130 GeV, E_T^{miss}/m_{eff} > 0.25

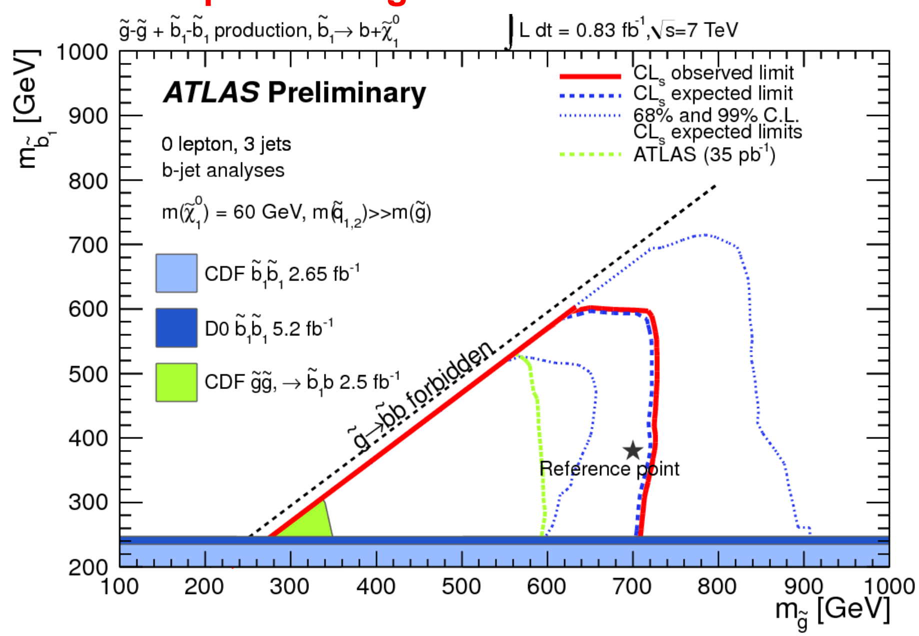


Sig. Reg.	Data (0.83 fb^{-1})	Top	W/Z	QCD	Total
3JA (1 btag m_{eff} >500 GeV)	361	221^{+82}_{-68}	121 ± 61	15 ± 7	356^{+103}_{-92}
3JB (1 btag m_{eff} >700 GeV)	63	37^{+15}_{-12}	31 ± 19	1.9 ± 0.9	70^{+24}_{-22}
3JC (2 btag m_{eff} >500 GeV)	76	55^{+25}_{-22}	20 ± 12	3.6 ± 1.8	79^{+28}_{-25}
3JD (2 btag m_{eff} >700 GeV)	12	$7.8^{+3.5}_{-2.9}$	5 ± 4	0.5 ± 0.3	$13.0^{+5.6}_{-5.2}$

Interpretation: gluino → 2b + LSP



Interpretation: gluino → sbottom + bottom



Stop production in gluino decays

1.03 fb^{-1}

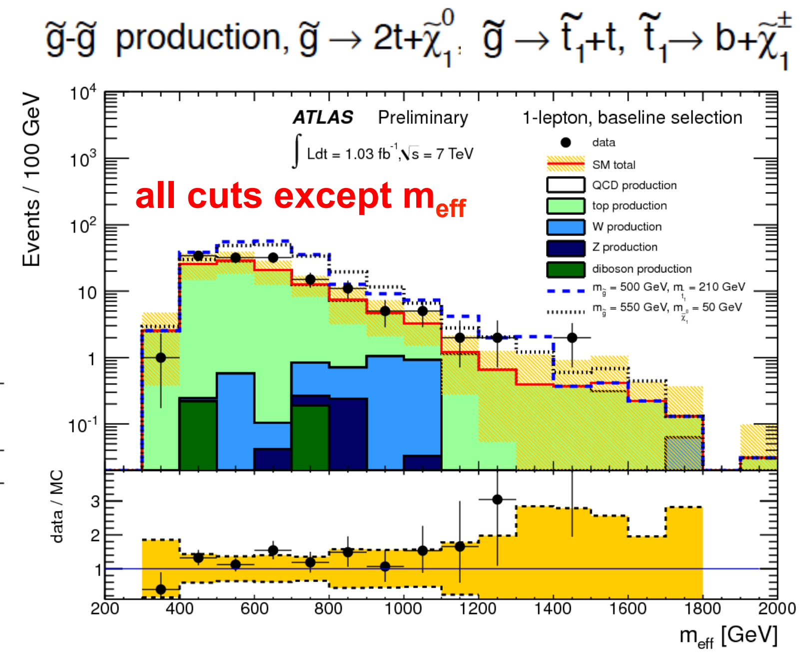
ATLAS-CONF-2011-130

Analysis: b-jets plus isolated lepton signature

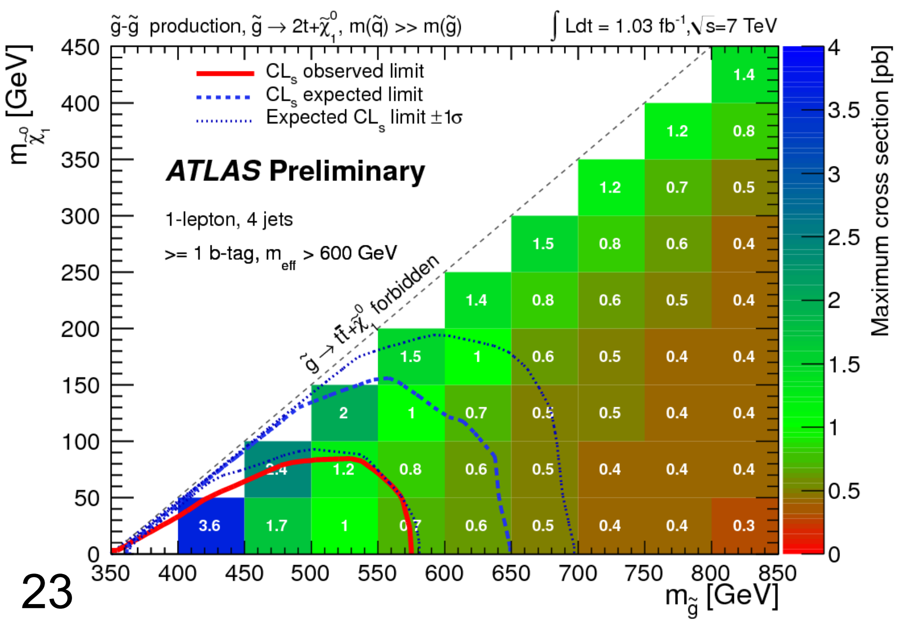
One e or μ with p_T > 20 GeV

At least four jets with p_T > 50 GeV

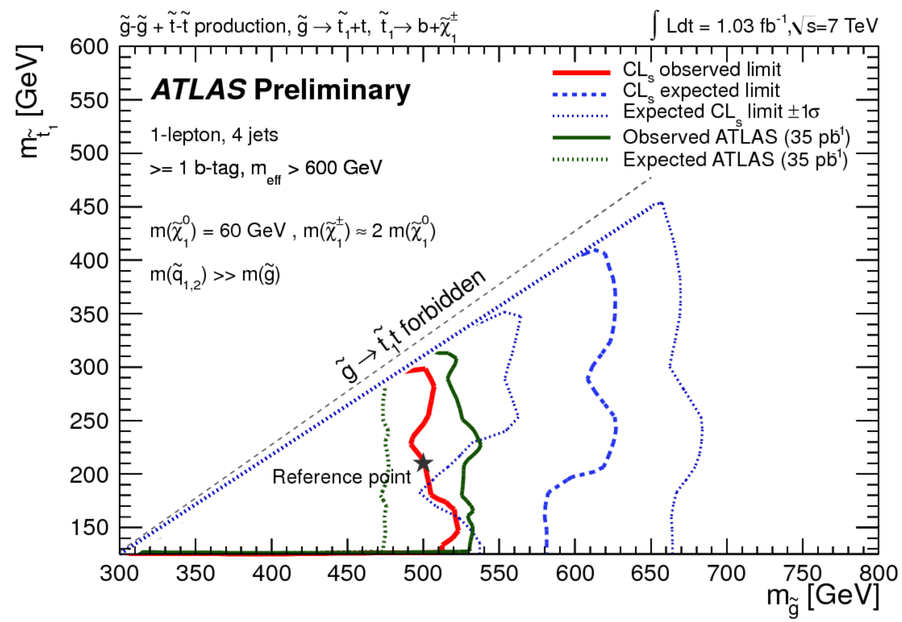
Cuts	≥ 4 jets	≥ 1 b jet	$E_T^{miss} > 80$ GeV	$m_T > 100$ GeV	$m_{eff} > 600$ GeV
SM (MC) SM (d-d)	6574 ± 1870	3096 ± 1042	881 ± 356	109 ± 55	52 ± 28 54.9 ± 13.6
data	6659	3361	989	141	74



Interpretation: gluino → 2t + LSP



Interpretation: gluino → stop (→ b $\tilde{\chi}^\pm$) + top



Direct sbottom pair production

$2.05\ fb^{-1}$

paper in preparation

$\tilde{b}_1$-$\tilde{b}_1$ production, $\tilde{b}_1 \rightarrow b+\tilde{\chi}_1^0$

NEW!

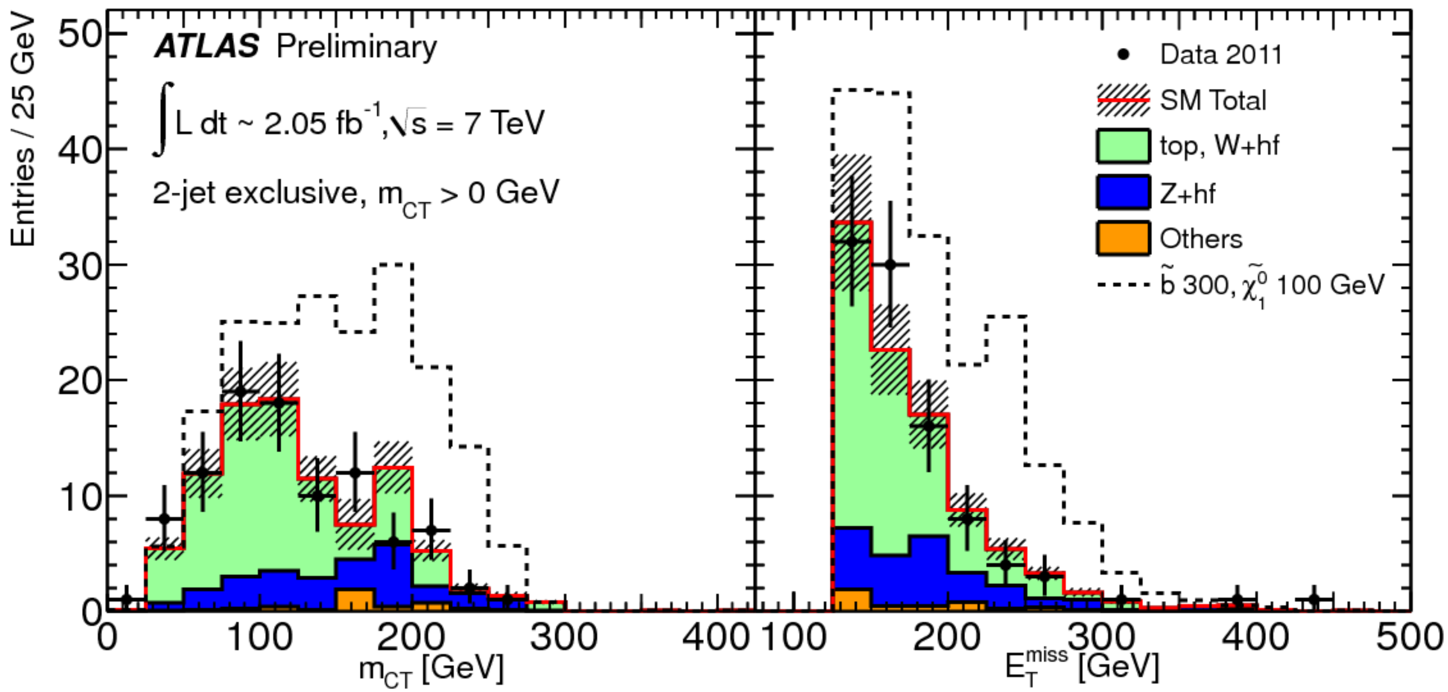
Selection: 2 b-jets, p_T > 130,50 GeV
E_T^{miss} > 130 GeV, E_T^{miss}/m_{eff} > 0.25
$\Delta\Phi(jet, E_T^{miss})$>0.4
Veto leptons and 3rd jet > 50 GeV

Discrimination based on con-transverse mass m_{CT}

$$M_{CT}^2(v_1,v_2) \equiv [E_T(v_1)+E_T(v_2)]^2 - [\mathbf{p_T}(v_1) - \mathbf{p_T}(v_2)]^2$$

has an endpoint at: $(m(\tilde{b}_1)^2 - m(\tilde{\chi}_1^0)^2)/m(\tilde{b}_1)$

(JHEP 0804 (2008) 024,
JHEP 1003 (2010) 030)



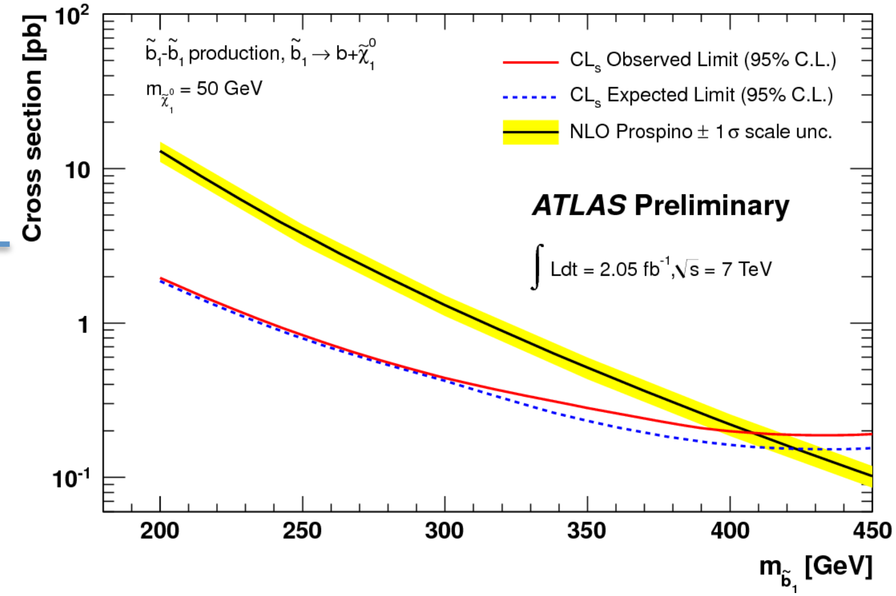
paper in preparation

Direct sbottom pair production

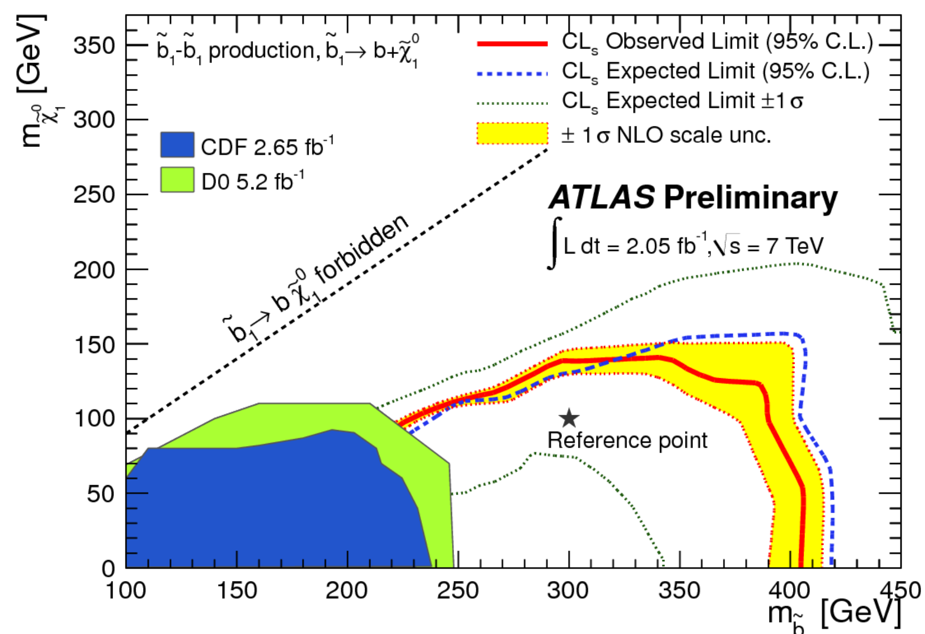
NEW!

$\tilde{b}_1$-$\tilde{b}_1$ production, $\tilde{b}_1 \rightarrow b+\tilde{\chi}_1^0$

M_{CT} cut (GeV)	SM	Data	σ_{eff} limits (fb)
0	94±16	96	
100	62±13	56	13.4
150	27±8	28	9.6
200	8±4	10	5.6

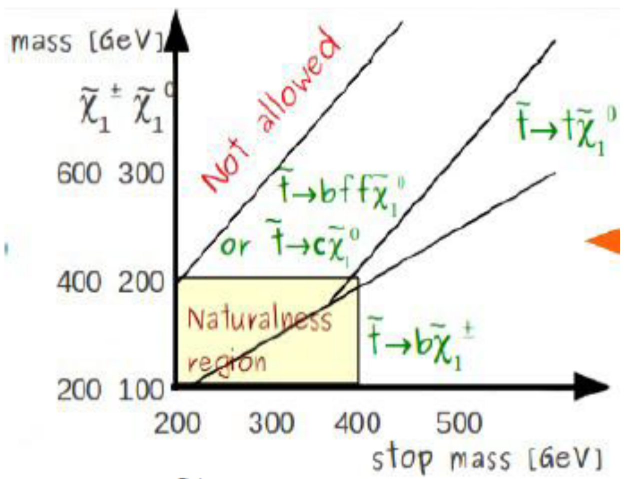


Assuming 100% BR, sbottoms are excluded up to 385 GeV (for LSP < 60 GeV)

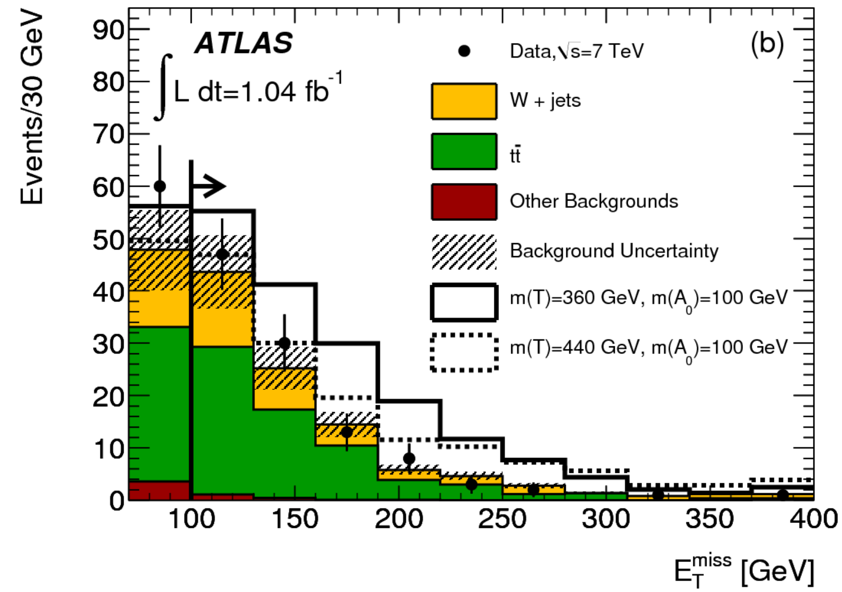


Direct stop pair production 1.04 fb^{-1}

General MSSM



..or $\tilde{t}_1 \to bl\tilde{\nu}$ if sneutrino LSP



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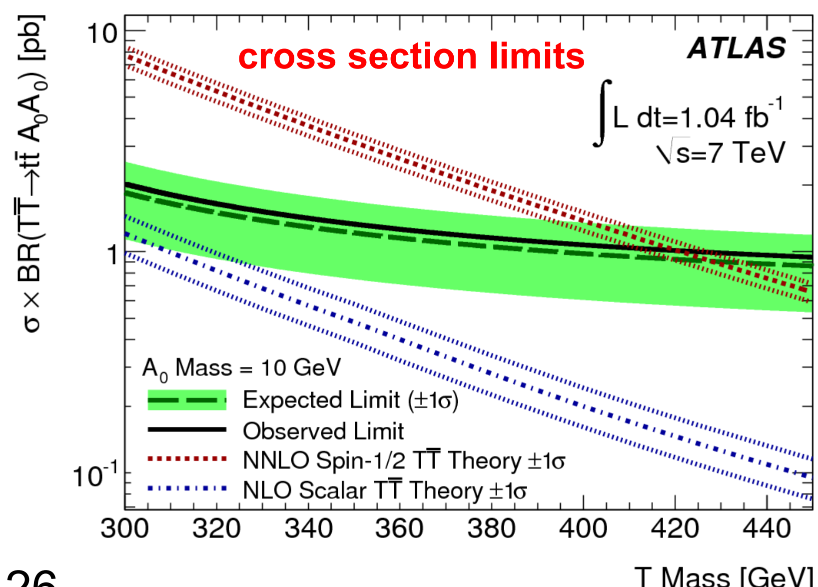
arXiv.org 1109.4725

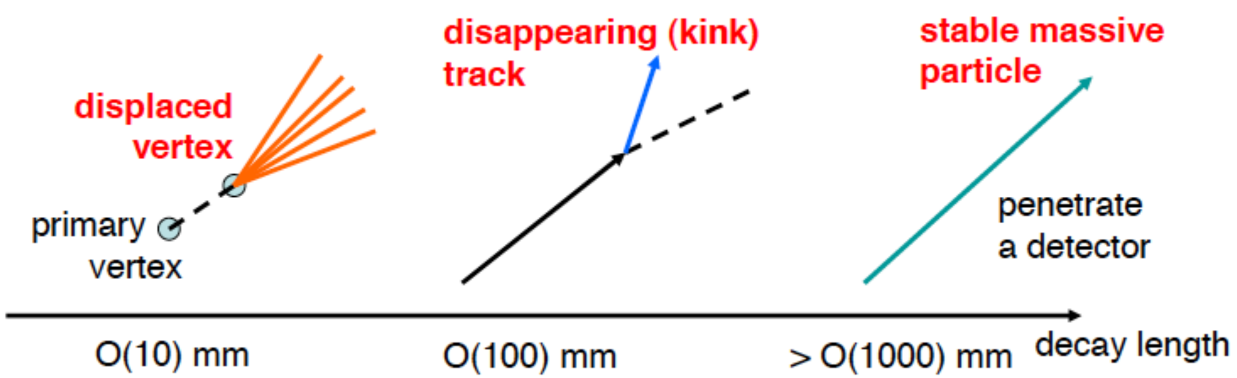
Difficult:
- low stop mass: similar to top
- high stop mass: low cross-section



Shown here: ttbar + E_T^{miss} analysis.
Search for top quark partner T → t + A
Limits set for fermionic T (not yet for scalar)

Special final states

Long-living supersymmetric particles: very well possible in SUSY!



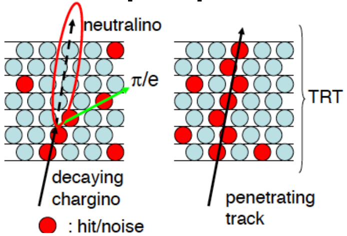
R-hadrons, R-parity violation, compressed spectra (AMSB)

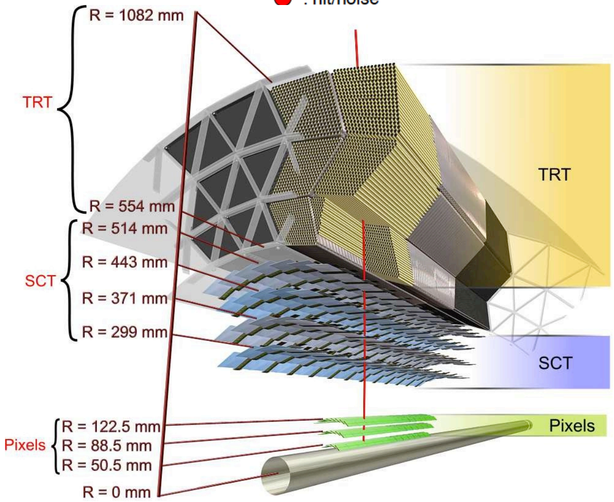
Search for disappearing (kinked) tracks

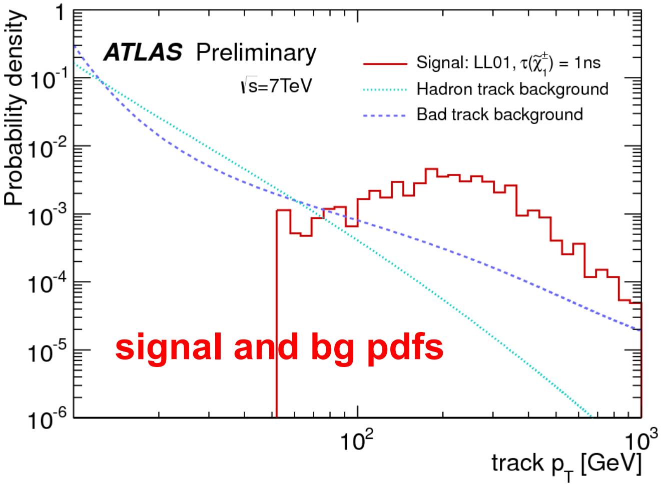
1.02 fb^{-1}

paper in preparation

AMSB: almost degenerate $\tilde{\chi}^{\pm}$ and $\tilde{\chi}^{0}$: long lifetimes
Decay inside tracking volume: disappearing high p_T track
Bg: interactions with TRT, mismeasured low p_T tracks

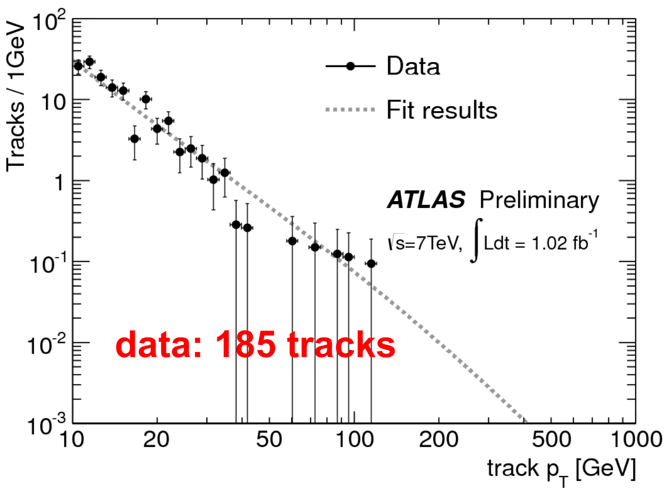


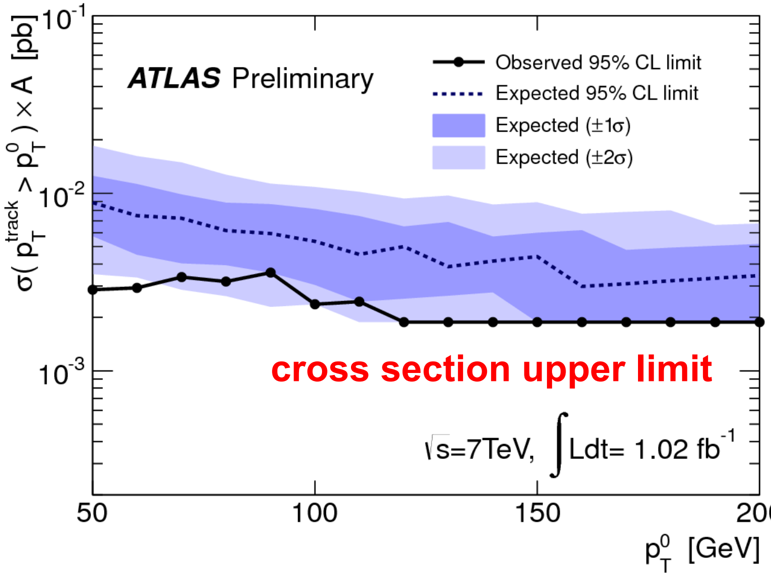




$$\tilde{g}\tilde{g} \to q\bar{q}'\tilde{\chi}_1^- \, q\bar{q}'\tilde{\chi}_1^-$$
$$\hookrightarrow \tilde{\chi}_1^0 \pi^-$$

candidate tracks:
$p_T > 10$ GeV, $N_{TRT3} < 5$

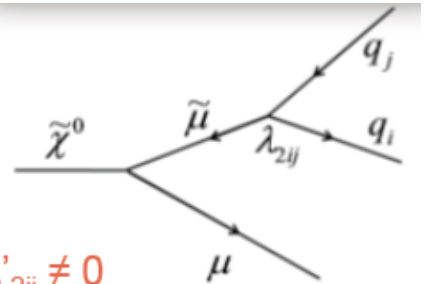




R-parity violation

$$W_{\not R p} = \overbrace{\lambda_{ijk}\hat{L}_i\hat{L}_j\hat{E}^C_k + \lambda'_{ijk}\hat{L}_i\hat{Q}_j\hat{D}^C_k + \epsilon_i\hat{L}_i\hat{H}_u}^{\text{L-number violating terms}} + \underbrace{\lambda''_{ijk}\hat{U}^C_i\hat{D}^C_j\hat{D}^C_k}_{\text{B-number violating terms}}$$

bilinear terms



$\lambda'_{2ij} \neq 0$

Search for high mass secondary vertex

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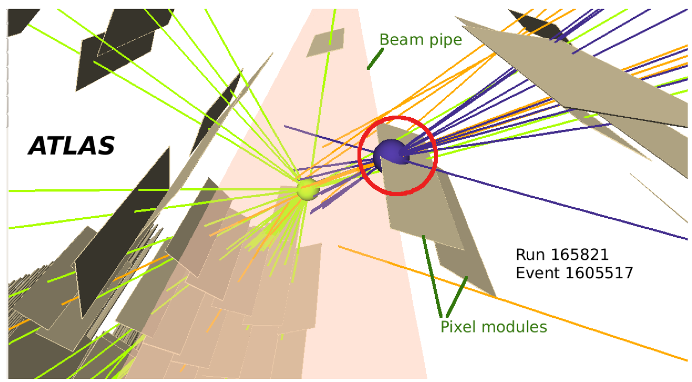
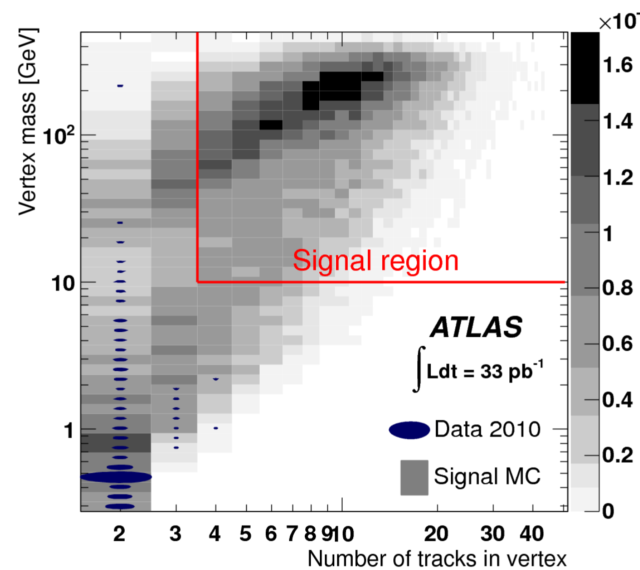
arXiv.org 1109.2242

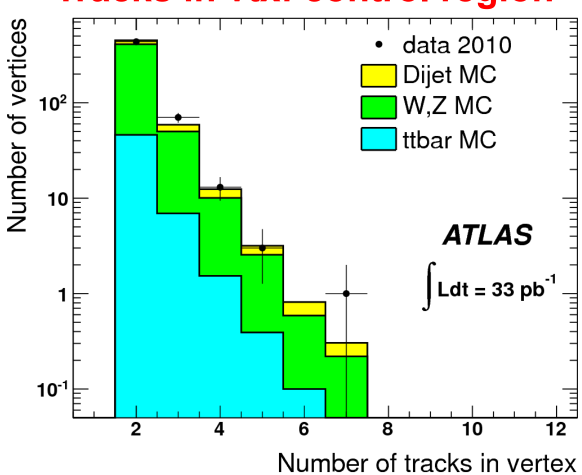
33 pb^{-1}



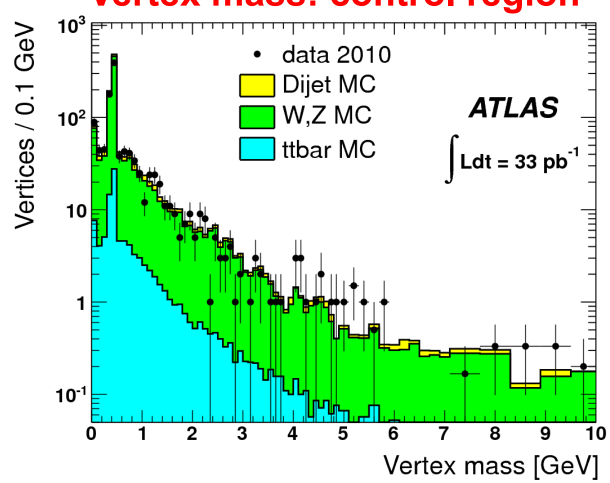
Background: interactions in inner detector material

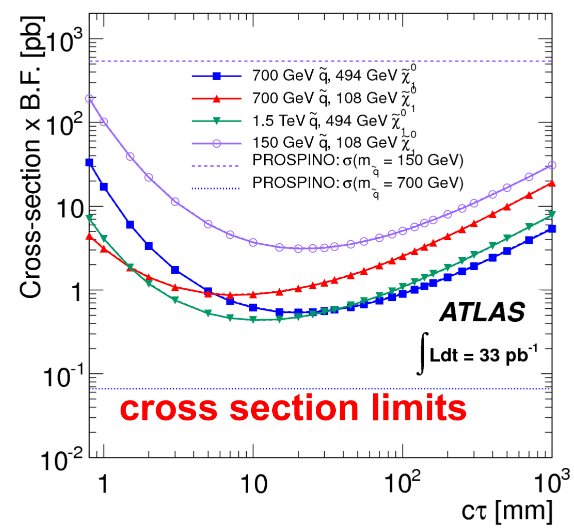


Tracks in vtx: control region



Vertex mass: control region



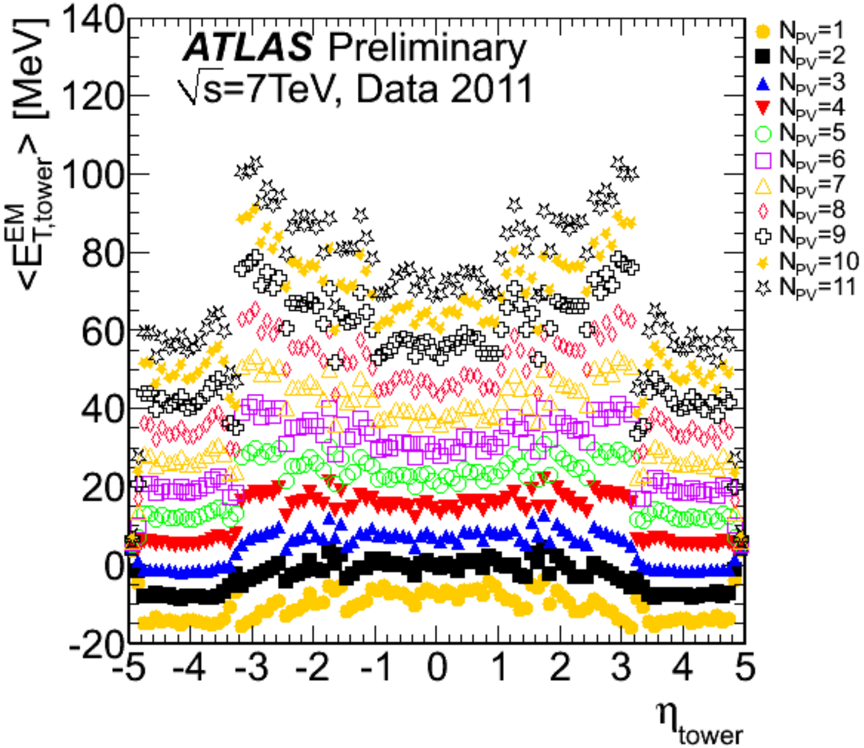


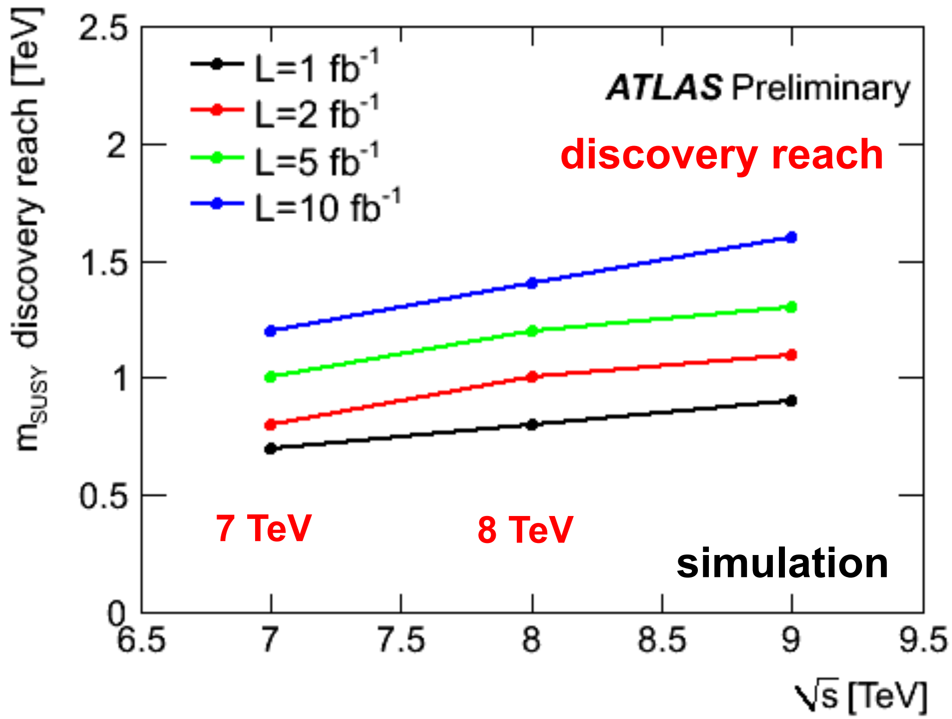
cross section limits

Prospects and challenges for 2012

2012: 10 (?) fb^{-1} L > 5 x 10^{33} $cm^{-2}s^{-1}$
7 or 8 TeV ?
25 ns or 50 ns bunch spacing

E_T in CAL towers vs Number of vtx



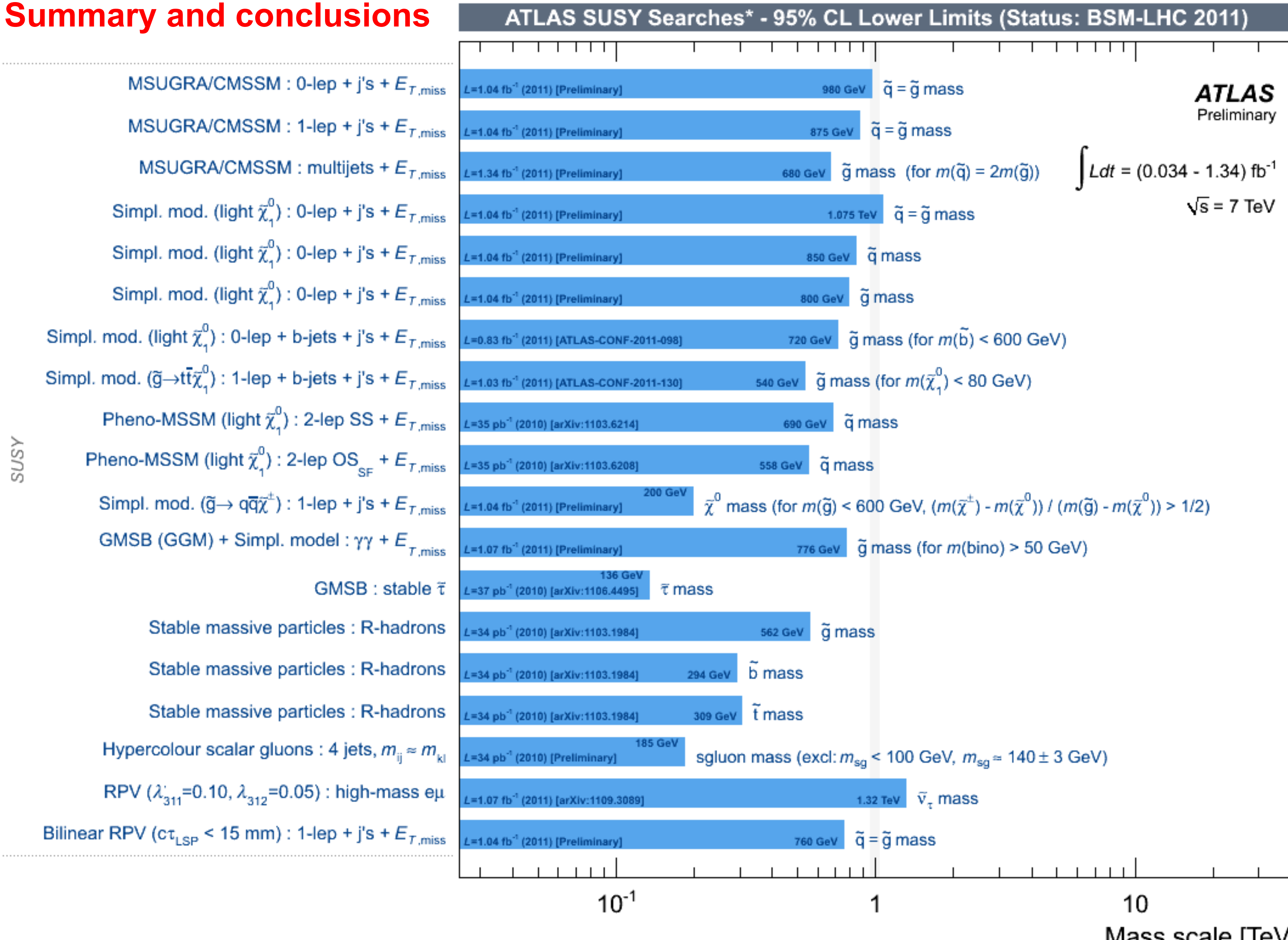


Pile-up: extra ``haze” in calorimeter
→ E_T^{miss} resolution affected

Triggering more and more difficult
→ Higher thresholds?
Physics (compressed spectra) demands lower thresholds!
→ More use of multi-object triggers

Analyses: more coverage of: stop production, electroweak gaugino sector, R-parity violation, and overall better coverage of loopholes

Summary and conclusions



*Only a selection of the available results leading to mass limits shown

Summary and conclusions

ATLAS SUSY Searches* - 95% CL Lower Limits (Status: BSM-LHC 2011)

ATLAS searches: wide variety of analyses, lively and active.
(Note that most analyses have auxiliary information: web or HEPDATA)

Detector operating very well

No excesses seen so far, limits set

NEW! **analyses presented today:**
- **direct sbottom pair production**
- **simplified models 0-lepton analysis**
- **dilepton analysis 2011 data**
- **disappearing high p_T tracks**

Future emphasis: 3rd generation, multileptons, electroweak gauginos, difficult final states, reach to higher masses,…

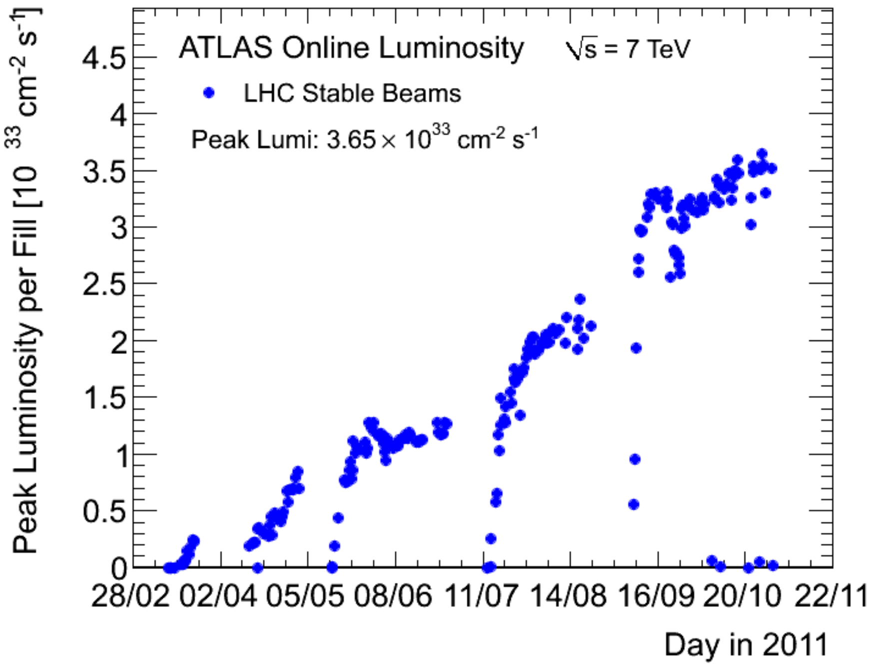
Outlook for 2012: 10 fb^{-1}, perhaps 8 TeV

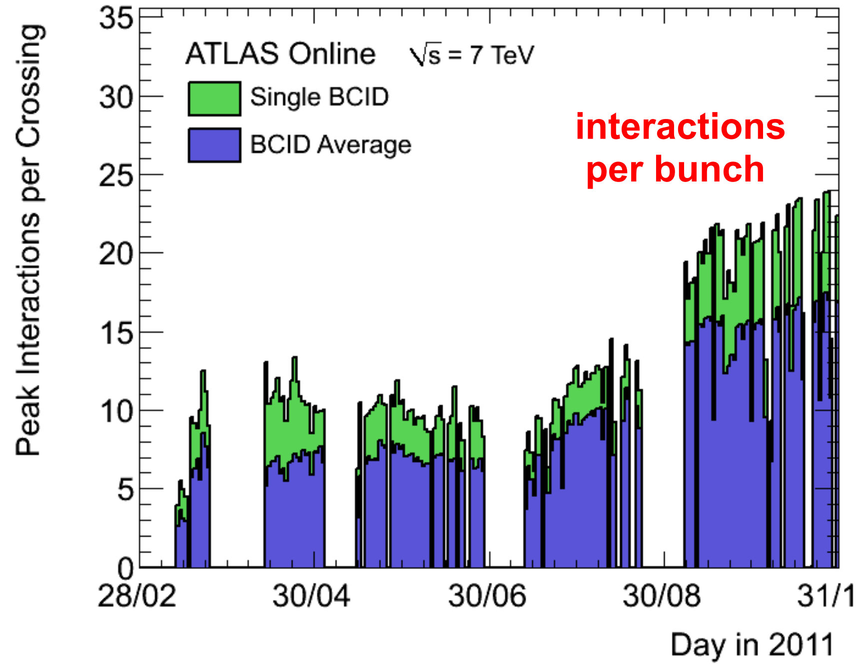
Challenges: triggering, pile-up
covering the enormous variety of SUSY signatures

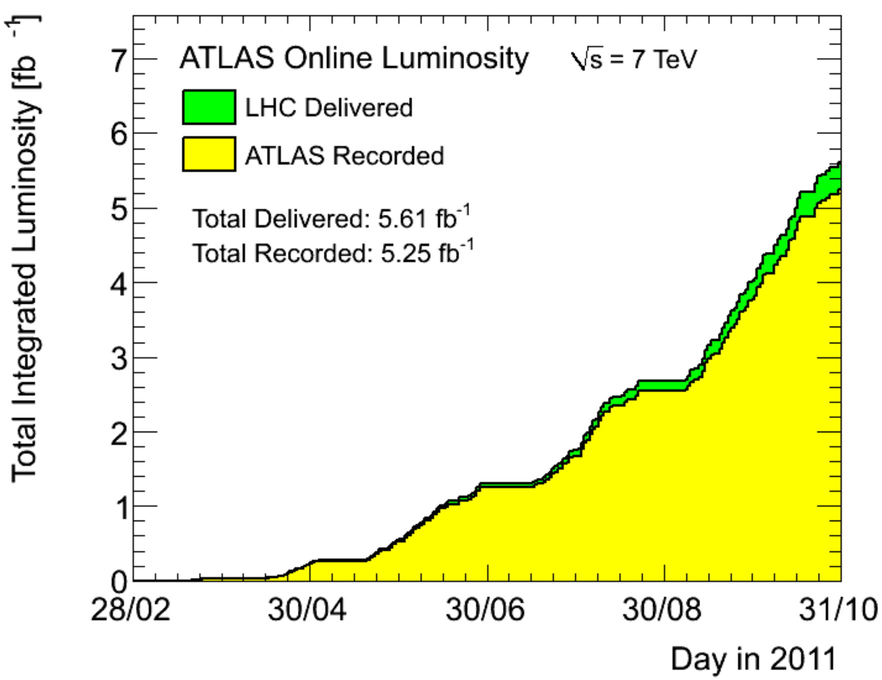
10^{-1} 1 10
Mass scale [TeV]

*Only a selection of the available results leading to mass limits shown


Auxiliary Material


ATLAS Online Luminosity √s = 7 TeV
LHC Stable Beams
Peak Lumi: 3.65 × 10^33 cm^-2 s^-1
Peak Luminosity per Fill [10^33 cm^-2 s^-1]
28/02 02/04 05/05 08/06 11/07 14/08 16/09 20/10 22/11
Day in 2011


ATLAS Online √s = 7 TeV
Single BCID
BCID Average
interactions per bunch
Peak Interactions per Crossing
28/02 30/04 30/06 30/08 31/10
Day in 2011


ATLAS Online Luminosity √s = 7 TeV
LHC Delivered
ATLAS Recorded
Total Delivered: 5.61 fb^-1
Total Recorded: 5.25 fb^-1
Total Integrated Luminosity [fb^-1]
28/02 30/04 30/06 30/08 31/10
Day in 2011

Dileptons

Flavour Subtraction

SR1 $\not\!\!E_T > 80$ GeV
Z veto: $80 > m_{ll} \,||\, m_{ll} > 100$ GeV

SR2 2 jets $p_T > 20, 20$ GeV, $\not\!\!E_T > 80$ GeV

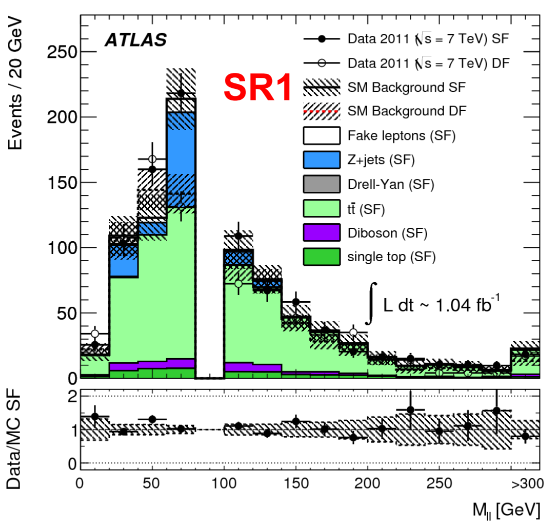
SR3 $\not\!\!E_T > 250$ GeV

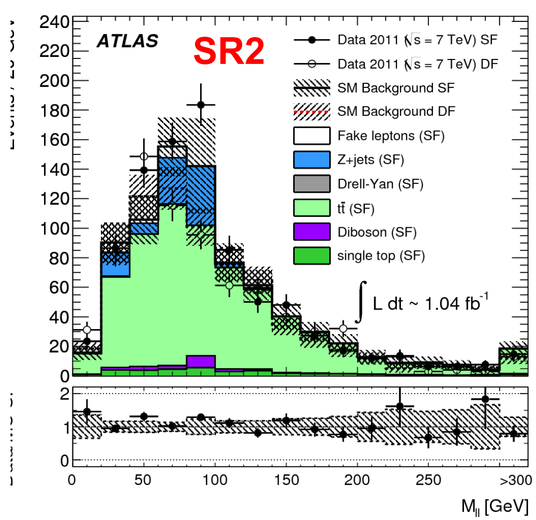
Background rejection by flavour subtraction
(e.g. ttbar reduction)

$$\mathcal{S} = \underbrace{\frac{N(e^{\pm}e^{\mp})}{\beta(1-(1-\tau_e)^2)} + \frac{\beta N(\mu^{\pm}\mu^{\mp})}{(1-(1-\tau_\mu)^2)}}_{\text{same flavour}} - \underbrace{\frac{N(e^{\pm}\mu^{\mp})}{1-(1-\tau_e)(1-\tau_\mu)}}_{\text{different flavour}}$$

OS-FS [FS-SR1]	$e^{\pm}e^{\mp}$	$e^{\pm}\mu^{\mp}$	$\mu^{\pm}\mu^{\mp}$
$t\bar{t}$	198±21	581±50	418±31
Z/γ^*+jets	86±7	41±7	41±11
Fakes	5±3	30±9	22±8
Dibosons	14±3	34±5	32±4
single top	13±1	41±4	37±3
Standard Model	316±21	727±52	549±34
Cosmic rays	$< 10^{-3}$	$< 10^{-3}$	$< 10^{-3}$
Observed	344	750	551

OS-FS [FS-SR2]	$e^{\pm}e^{\mp}$	$e^{\pm}\mu^{\mp}$	$\mu^{\pm}\mu^{\mp}$
$t\bar{t}$	220±25	624±64	437±37
Z/γ^*+jets	46±12	29±7	38±6
Fakes	2±2	32±10	19±8
Dibosons	8±3	11±5	15±5
single top	10±2	32±4	27±3
Standard Model	286±28	728±65	537±38
Cosmic rays	$< 10^{-3}$	$< 10^{-3}$	$< 10^{-3}$
Observed	336	741	567





	$\mathcal{S}_{obs}$	$\bar{\mathcal{S}}_b$	RMS
FS-SR1	131.6±2.5(sys)	118.7±27.0	48.6
FS-SR2	142.2±1.0(sys)	67.1±28.6	49.0
FS-SR3	-3.06±0.04(sys)	0.7±1.6	4.5

	$\mathcal{S} > \mathcal{S}_{obs}$ (%)	Limit $\bar{\mathcal{S}}_s$ (95% CL)
FS-SR1	39	94
FS-SR2	6	158
FS-SR3	79	4.5

2011 data update in pipeline…

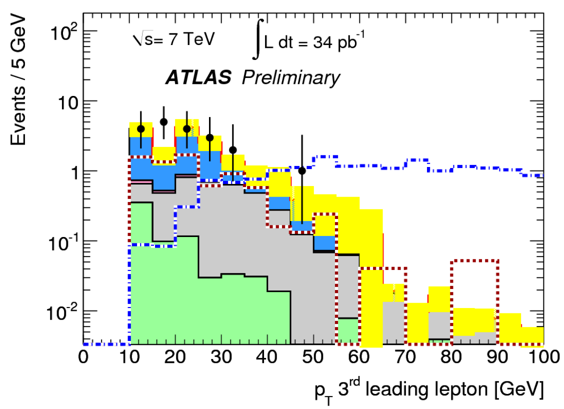
Trileptons

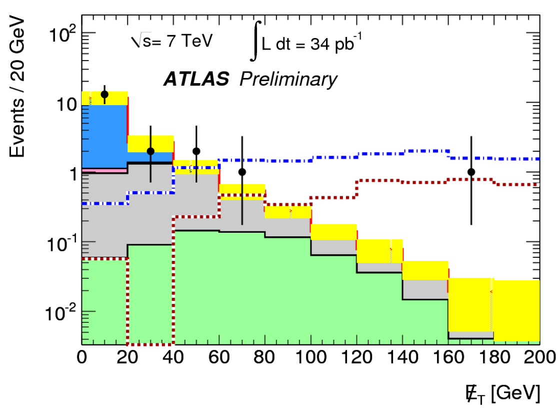
ATLAS-CONF-2011-039 (2010 data)

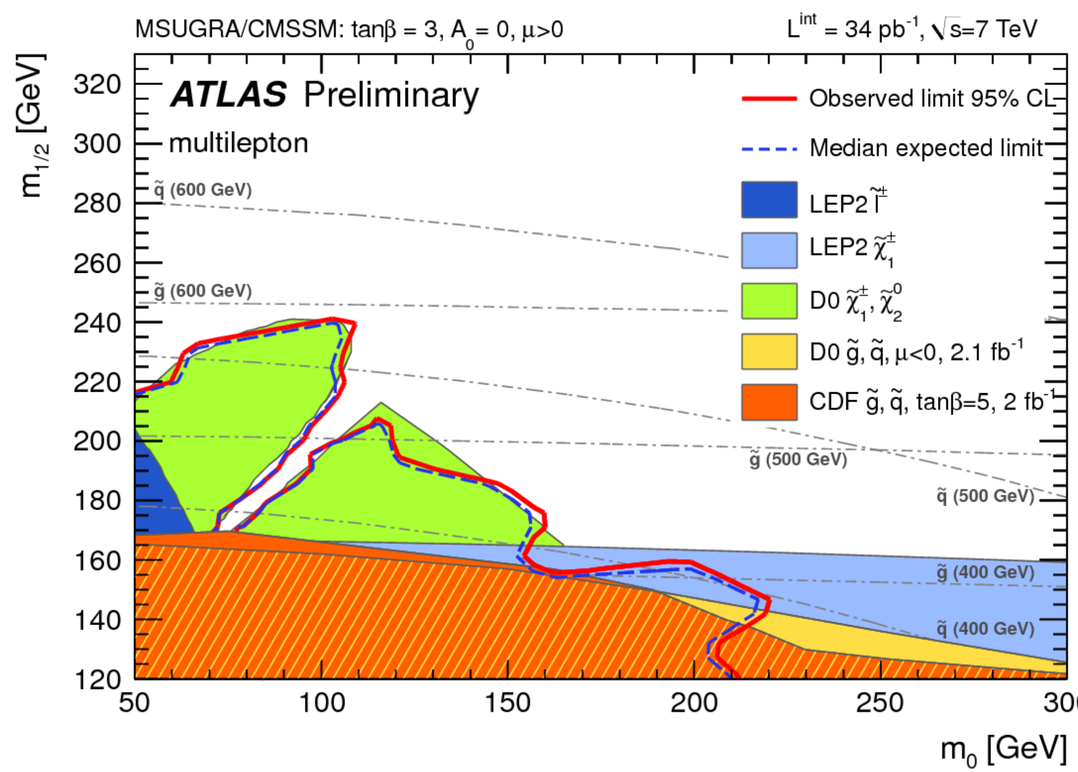
Multilep. events	All	*eee*	*eeμ*	*eμμ*	*μμμ*
$t\bar{t}$	0.68±0.16	0.032±0.016	0.24±0.07	0.31±0.08	0.096±0.030
Z backgrounds	15.6±1.3	3.8±0.8	1.60±0.34	7.9±1.0	2.4±0.4
Other backgrounds	0.28±0.13	0.02±0.14	0.03±0.06	0.21±0.09	0.01±0.11
Total SM	16.6±1.3	3.8±0.8	1.9±0.4	8.4±1.0	2.5±0.4
Data	19	2	1	10	6

p_T lepton 1 & 2 > 20 GeV
p_T lepton 3 > 20 GeV (e)
10 GeV (μ)

Final cuts: 2 jets > 50 GeV
E_T^{miss} > 50 GeV



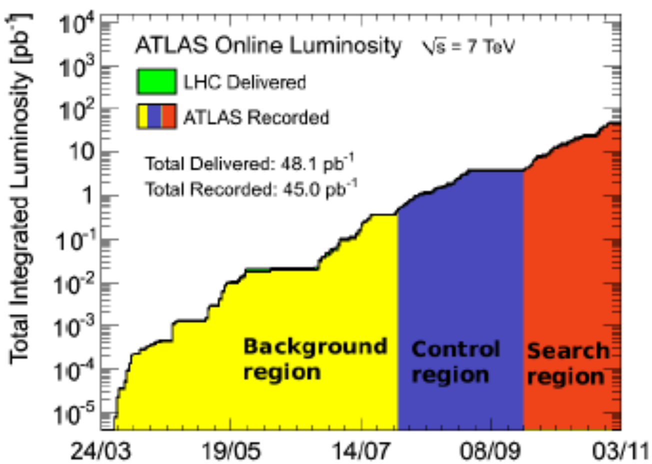


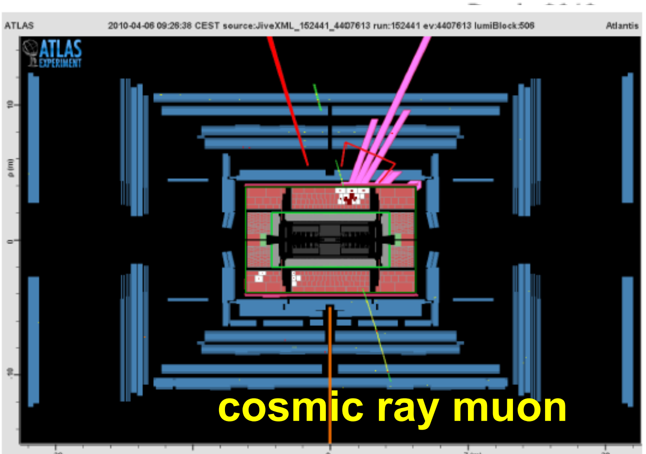


Search for stopped R-hadrons

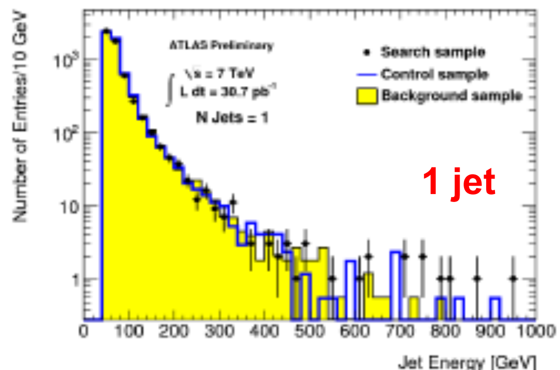
Dense material (calorimeter) could stop R-hadron
Decay at much later time, e.g. uncorrelated with LHC beam

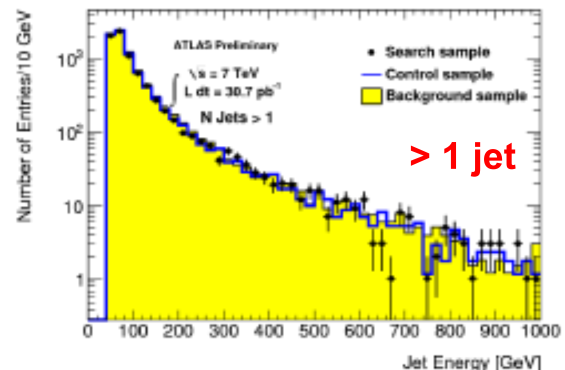
Take data outside LHC bunch crossings
Backgrounds: cosmics, noise, protons in ``empty'' bunch crossings, beam halo



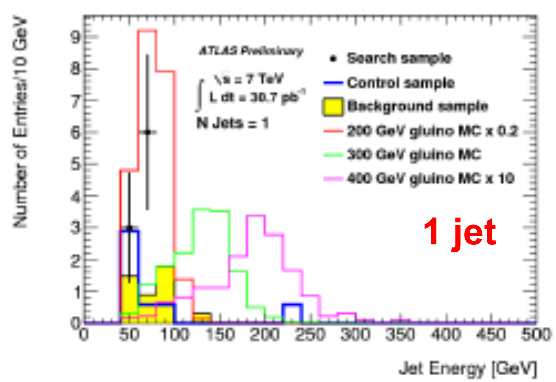


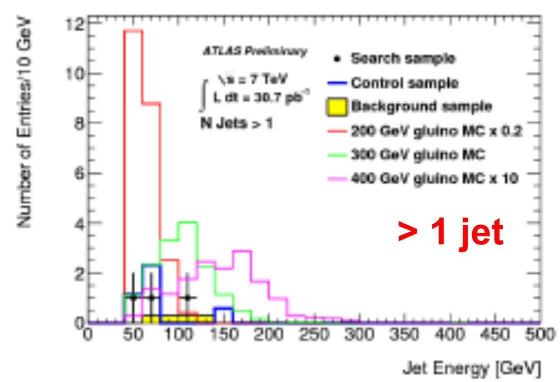
Before muon segment veto





After muon segment veto





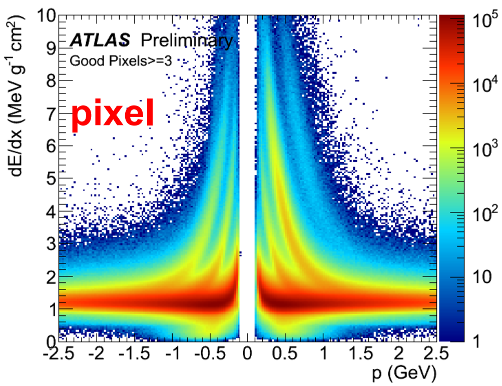
After selection: 1 event observed, 0.6 bg expected

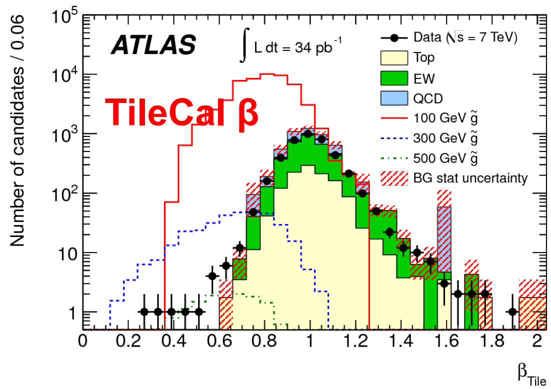
Search for long-lived particles

First approach: inner detector + calorimeter, no muon requirement

Motivation: R-hadrons (stops, gluinos), might be neutral after calorimeter

Analysis uses pixel dE/dx combined with TileCal time (=β) measurement, 2010 data



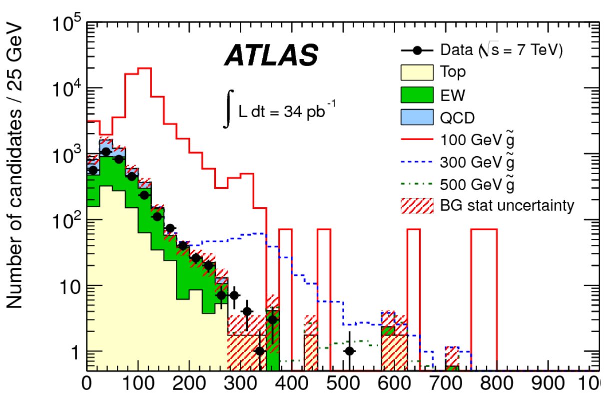


Results:

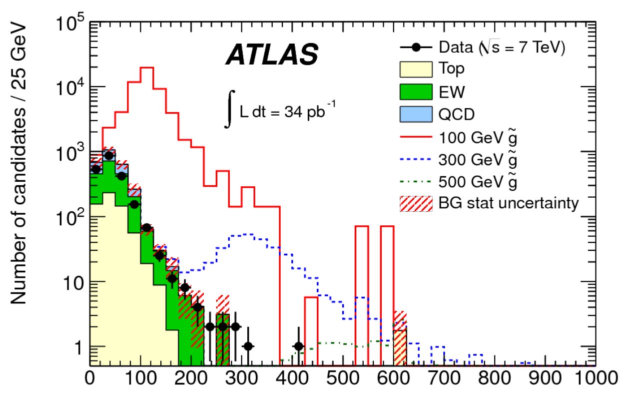
stable sbottoms > 294 GeV

stable stops > 309 GeV

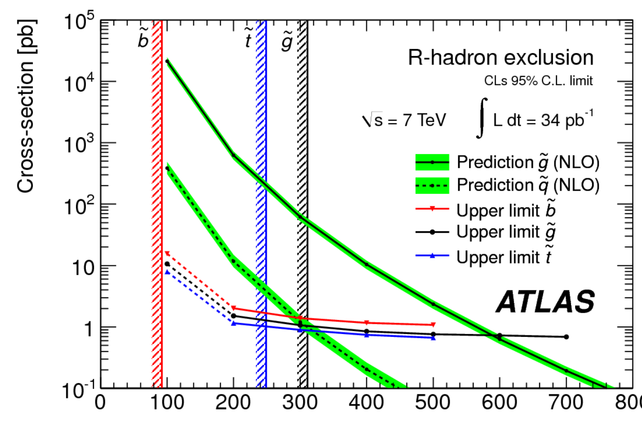
stable gluino > 562-586 GeV



mass of pixel candidates



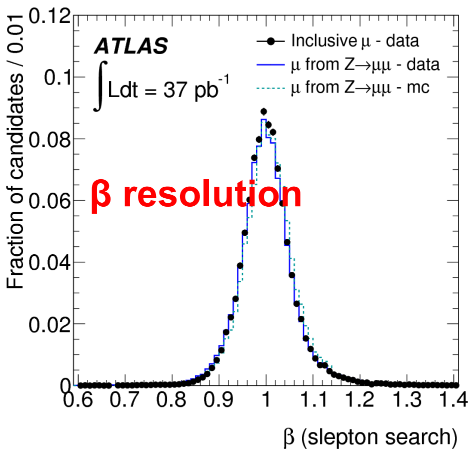
mass of TileCal candidates

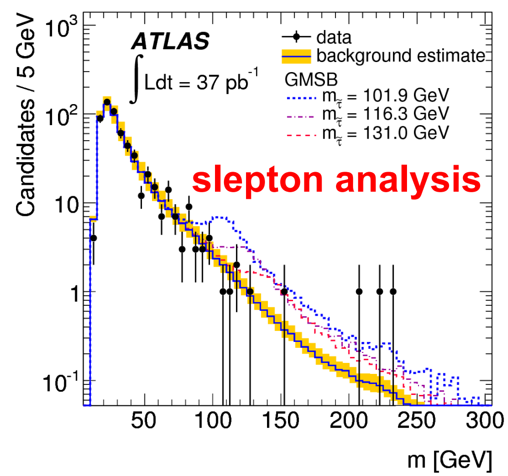


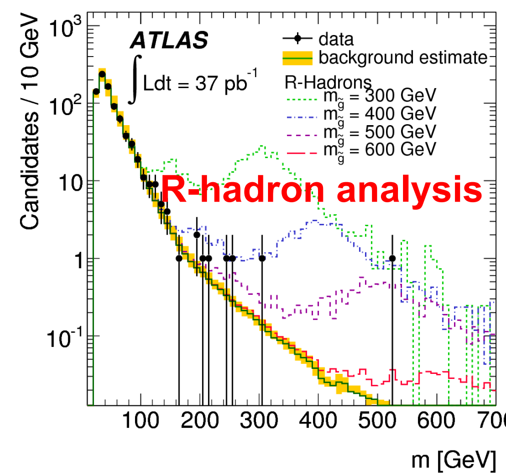
limits

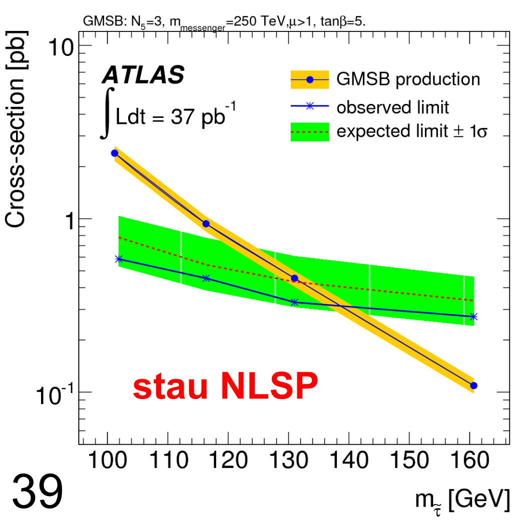
Long-lived particles: search in the muon spectrometer

Large ATLAS muon system with good timing resolution
Refit muon tracks, leaving velocity β as free parameter
Two analyses: sleptons (e.g. semi-stable stau NLSP in GMSB), R-hadrons







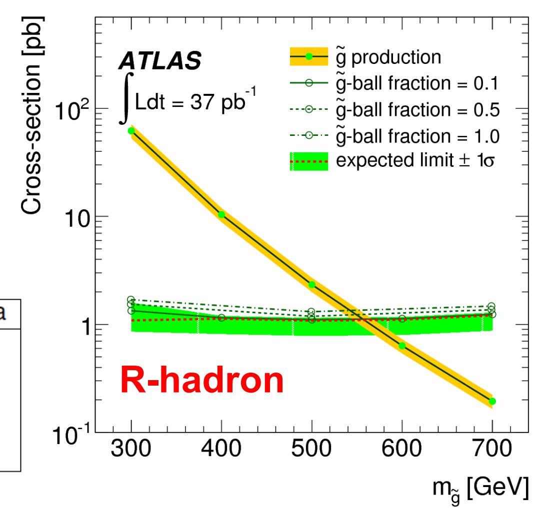


$m(\tilde{\tau})$ (GeV)	Mass cut (GeV)	Exp. signal	Exp. bkg	Data
101.9	90	35.9	19.2	16
116.3	110	13.6	9.8	8
131.0	120	7.3	7.2	5
160.7	130	2.0	5.4	4

Systematic uncertainties on signal and background expectations are 6% and 15% respectively.

$m(\tilde{g})$ (GeV)	Mass cut (GeV)	Exp. signal	Exp. bkg	Data
300	250	254.4	2.3	3
400	350	36.2	0.7	1
500	350	8.7	0.7	1
600	350	2.2	0.7	1
700	350	0.6	0.7	1

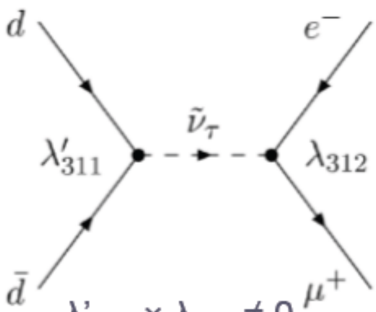
Systematic uncertainties on signal and background expectations are 6% and 20% respectively.



R-parity violation

$$W_{\not{R}p} = \overbrace{\lambda_{ijk}\hat{L}_i\hat{L}_j\hat{E}^C_k + \lambda'_{ijk}\hat{L}_i\hat{Q}_j\hat{D}^C_k + \epsilon_i\hat{L}_i\hat{H}_u}^{\text{L-number violating terms}} + \underbrace{\lambda''_{ijk}\hat{U}^C_i\hat{D}^C_j\hat{D}^C_k}_{\text{B-number violating terms}}$$

bilinear terms



$\lambda'_{131} \times \lambda_{312} \neq 0$

Resonant sneutrino

decaying to eμ

1.07 fb^{-1}

arXiv.org 1109.3089