Search for new physics in events with 2 same sign leptons, jets and $\not{E}_T$ with ATLAS and CMS detectors

Otilia Ducu (IFIN-HH Bucharest, CPPM)

Supervisors : Calin Alexa (IFIN-HH), Pascal Pralavorio (CPPM)

Thanks to: JF Arguin (U. Montreal), David Cote (U. Arlington) and Julien Maurer

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ATLAS

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université

IFIN-HH

CENTRE DE PHYSIQUE DES
PARTICULES DE MARSEILLE
CPPM

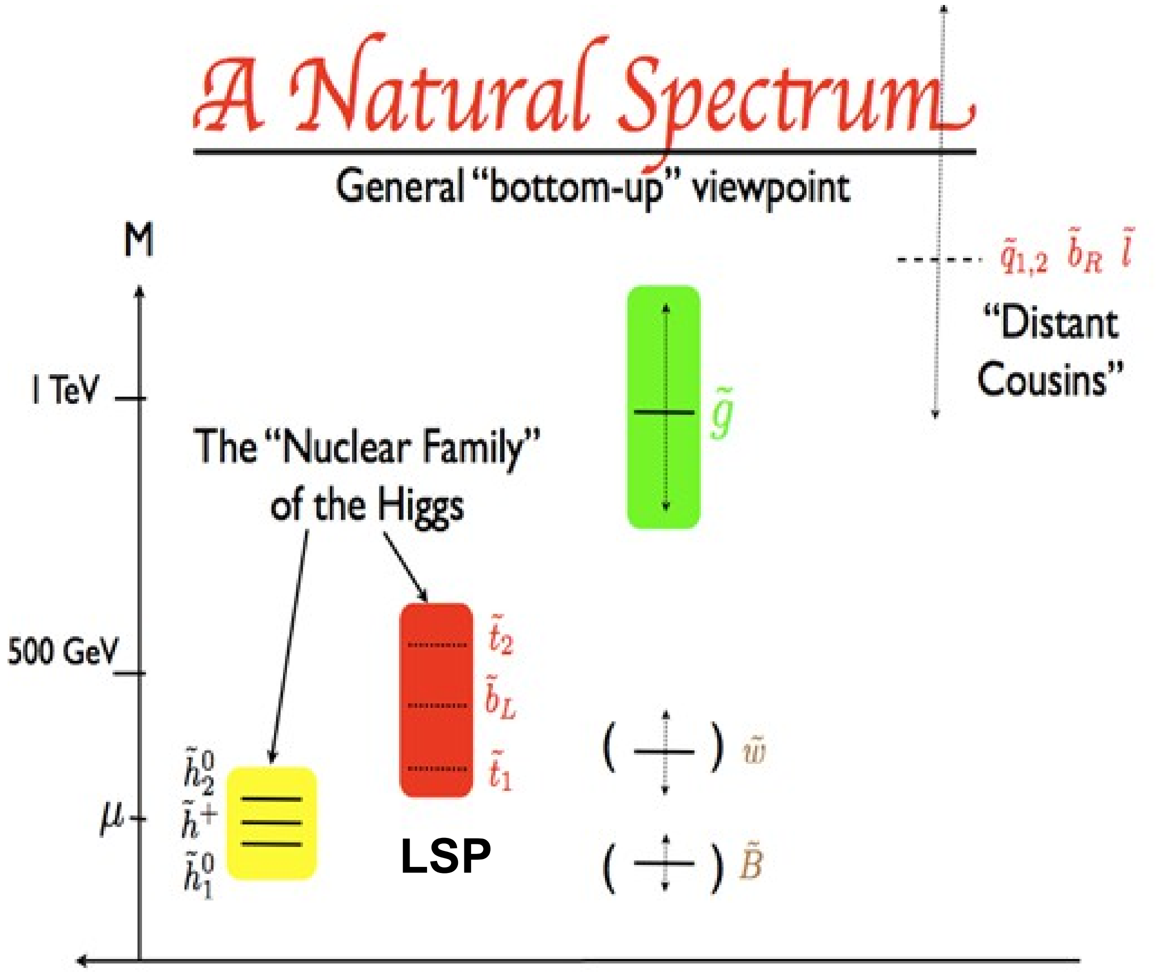
Overview

- Search for new physics in events with 2 same sign leptons (e or μ) , jets and $\not{E}_T$
  - With **ATLAS** detector: arXiv:1404.2500
  - With **CMS** detector: arXiv:1311.6736

8 TeV, ~ 20 fb^{-1}

- Contents of this talk:
  - A natural SUSY spectrum
  - Searches with same sign leptons → motivation
  - Target SUSY models
  - Signal regions definitions
  - Background estimation: techniques and validation
  - Results and interpretation

A natural SUSY spectrum



Closeness to Higgs

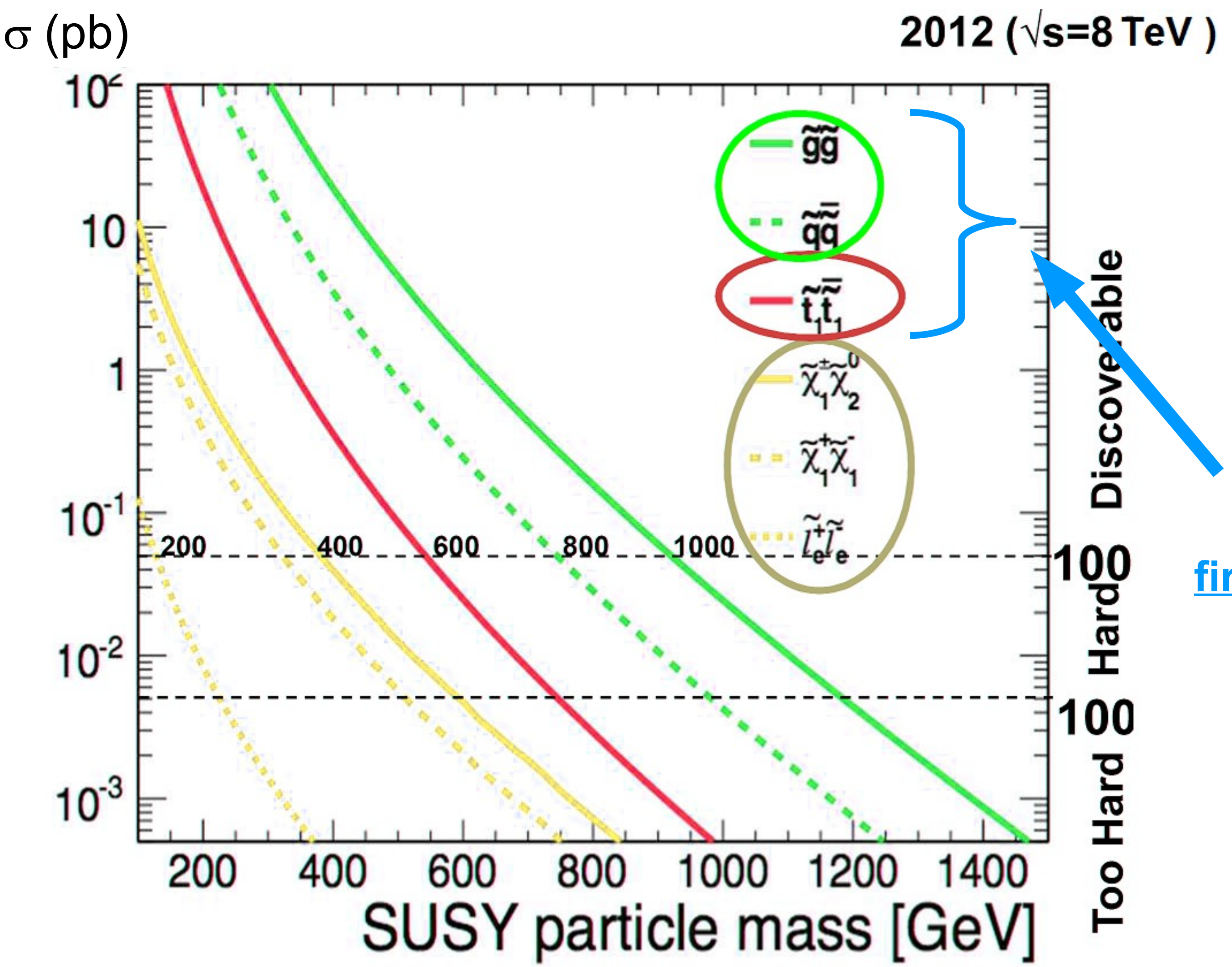
Open spectra

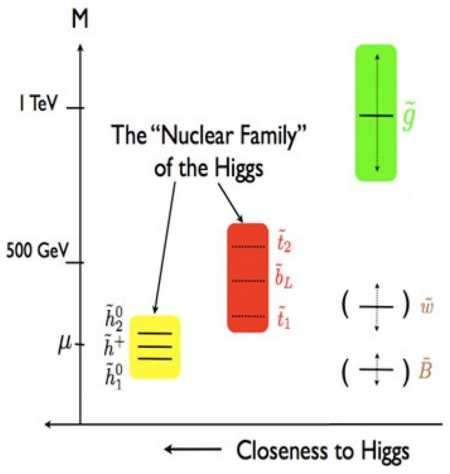
Hard kinematics in the final state

Compressed spectra

Soft kinematics in the final state

A natural SUSY spectrum





If natural SUSY,
first discoverable at LHC
(high production σ)

arXiv:hep-ph/9610490

Searches with SS leptons, motivations

- Rare signature in Standard Model – very low SM background

- Gluinos are Majorana particles → $\tilde{g} \rightarrow q\tilde{q}^* / \bar{q}\tilde{q}$ with same probability → if there are leptons → same probability to have SS or OS signature

- 3rd generation searches, motivated by natural SUSY → top quarks in the chain → SS leptons, (b–) jets and $\not{E}_T$

- Searches with leptons → smaller BR but
  - – can consider looser cuts on jet / lep p_T, m_T, m_{eff}, $\not{E}_T$
  - – can reach uncovered regions of the phase space or compressed spectra

- Highly sensitive to new physics beyond Standard Model (not only SUSY)

SUSY models

- To help building signal regions several topologies were considered:

$\tilde{g} \longrightarrow t\ \tilde{t}_1$

$\quad \hookrightarrow t\ \tilde{\chi}_1^0$ - - - - - - - - - - - - - - - gluino-mediated top squark $\to t\,\tilde{\chi}_1^0$

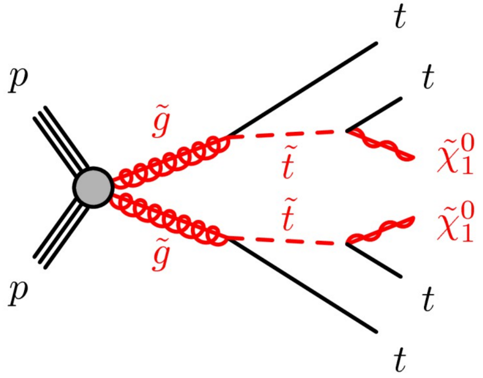
$\quad \hookrightarrow b\ s$ - - - - - - - - - - - - - - - - gluino-mediated top squark $\to b\,s$ (RPV)

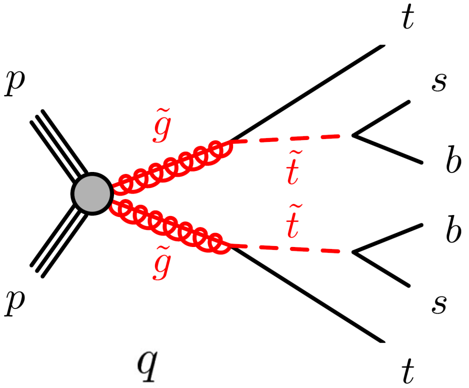
$\tilde{g} \longrightarrow q\ \tilde{q}^{(*)}$

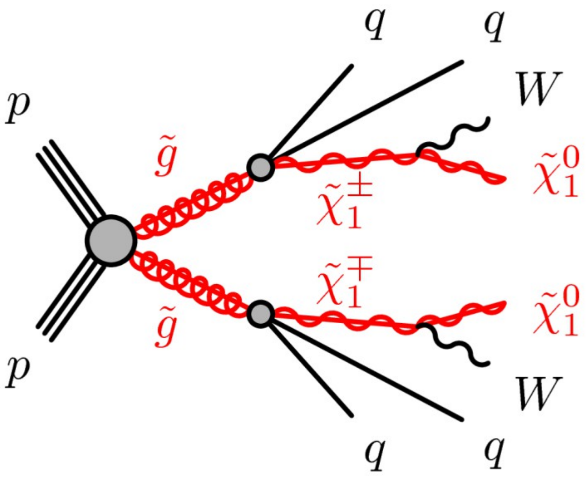
$\quad \hookrightarrow q'\ \tilde{\chi}_1^\pm \longrightarrow W^{\pm(*)}\tilde{\chi}_1^0$ - - gluino-mediated squark $\to q'\,W\,\tilde{\chi}_1^0$

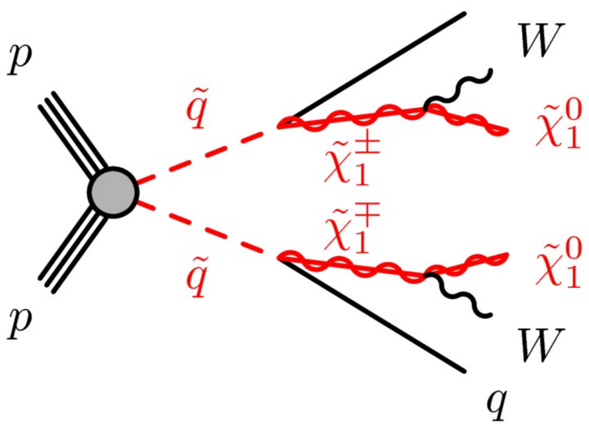
$\tilde{b}_1 \longrightarrow t\ \tilde{\chi}_1^\pm$

$\quad \hookrightarrow W^{\pm(*)}\tilde{\chi}_1^0$ - - - - - - - - - - - direct bottom squark $\to t\,\tilde{\chi}_1^\pm$









ATLAS: Signal regions definitions

SR	Leptons	$N_{b-\text{jets}}$	Other variables	Additional requirement on m_{eff}
SR3b	SS or 3L	$\geq$3	$N_{\text{jets}} \geq 5$	m_{eff}>350 GeV
SR0b	SS	$= 0$	$N_{\text{jets}} \geq 3$, $E_{\text{T}}^{\text{miss}}$> 150 GeV, m_{T}> 100 GeV	m_{eff}>400 GeV
SR1b	SS	$\geq$1	$N_{\text{jets}} \geq 3$, $E_{\text{T}}^{\text{miss}}$> 150 GeV, m_{T}>100 GeV, SR3b veto	m_{eff}>700 GeV
SR3Llow	3L	-	$N_{\text{jets}} \geq 4$, $50 < E_{\text{T}}^{\text{miss}} < 150$ GeV, Z boson veto, SR3b veto	m_{eff}>400 GeV
SR3Lhigh	3L	-	$N_{\text{jets}} \geq 4$, $E_{\text{T}}^{\text{miss}}$> 150 GeV, SR3b veto	m_{eff}>400 GeV

- 5 statistically independent SRs depending on leptons and b–jet multiplicities
- **Leptons with p_T > 15 GeV** (20 for leading lepton)
- Jets with p_T > 40 GeV ; **b–jets with p_T > 20 GeV**
- **$\not{E}_T$, m_{eff} and m_T main discriminant variables**

CMS: Signal regions definitions

$N_{\text{b-jets}}$	$E_{\text{T}}^{\text{miss}}$ (GeV)	N_{jets}	$H_{\text{T}} \in [200, 400]$ (GeV)	$H_{\text{T}} > 400$ (GeV)
= 0	50–120	2–3	SR01	SR02
		≥4	SR03	SR04
	>120	2–3	SR05	SR06
		≥4	SR07	SR08
= 1	50–120	2–3	SR11	SR12
		≥4	SR13	SR14
	>120	2–3	SR15	SR16
		≥4	SR17	SR18
≥ 2	50–120	2–3	SR21	SR22
		≥4	SR23	SR24
	>120	2–3	SR25	SR26
		≥4	SR27	SR28

- (**b–**) **jets with pT > 40 GeV**
- H_T and $\not\!\!E_T$ main discriminant variables

- **p_T > 20 GeV for leptons in the hard analysis**
- For soft analysis leptons p_T is lowered to **10** GeV
  - **Same 24 SRs** with H_T threshold increased to 250 GeV (compressed spectra)
- 2 additional signal regions for RPV model:
  - Here leptons with p_T > 20 GeV

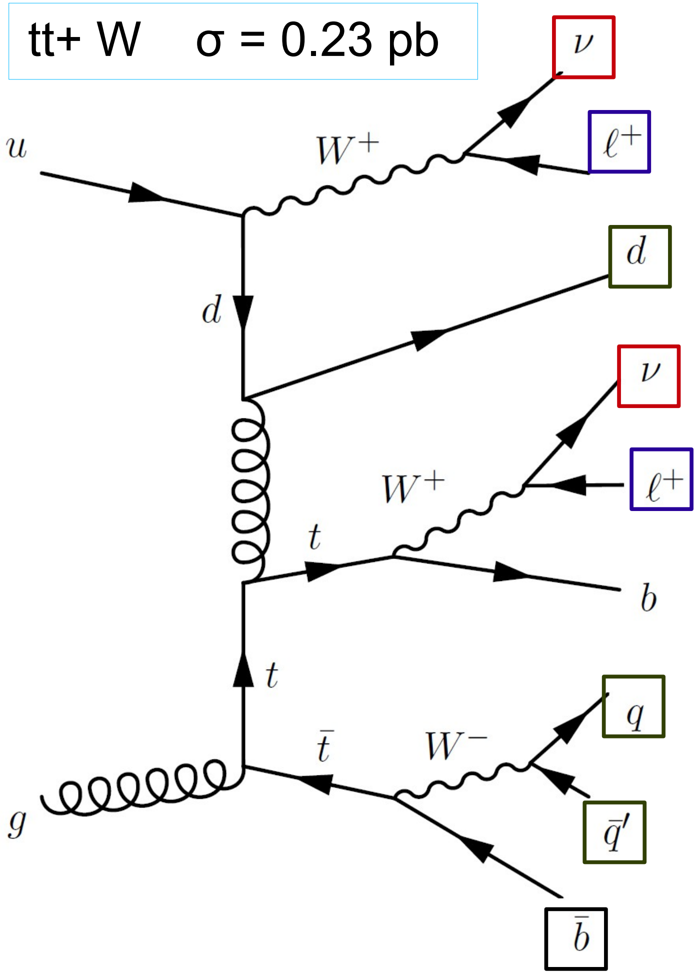
N_{jets}	$N_{\text{b-jets}}$	$E_{\text{T}}^{\text{miss}}$ (GeV)	H_{T} (GeV)	Lepton charge	SR name
≥2	≥0	>0	>500	++/−−	RPV0
≥2	≥2	>0	>500	++/−−	RPV2

50 signal regions

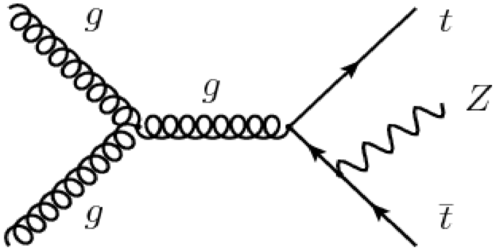
Background classification

- **Three main categories**:
  - **Prompt leptons background**: tt + W, t + Z, ZZ, WZ, W±W±
    - Estimated from Monte Carlo

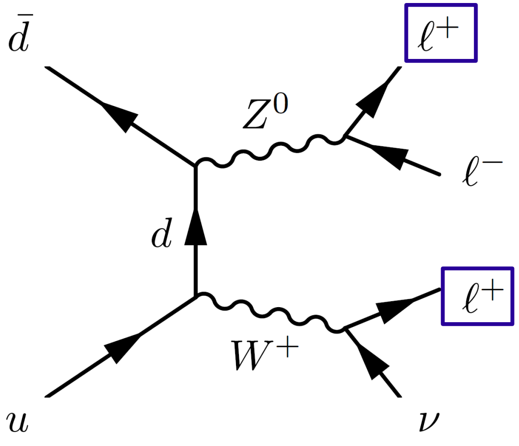
tt+ W σ = 0.23 pb



tt + Z σ = 0.21 pb



☐ SS leptons
☐ b-jets
☐ jets
☐ $\not{E}_T$



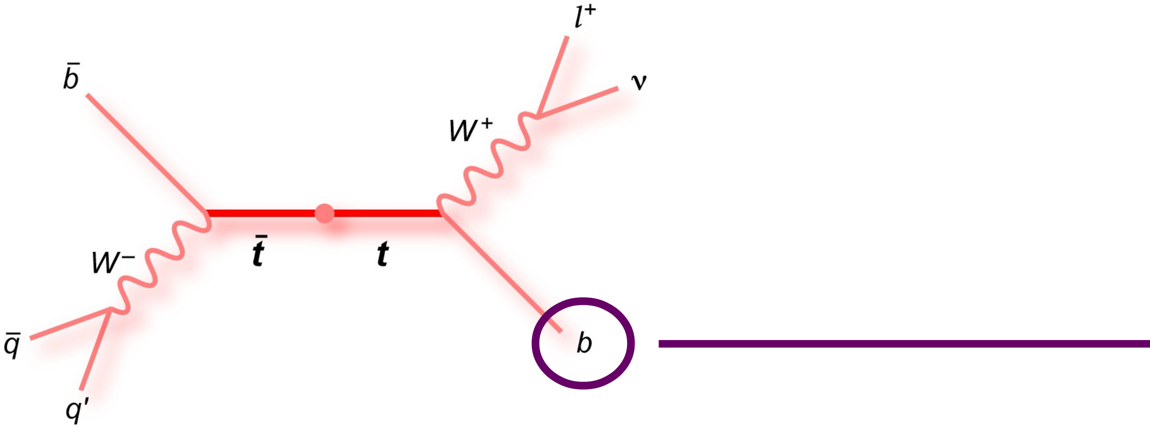
WZ → 3l + ν σ = 10.2 pb

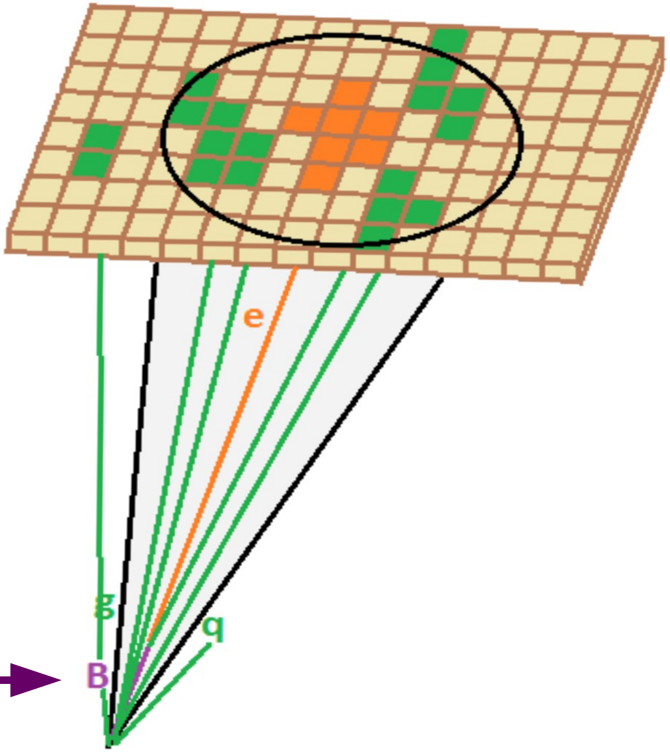
Background classification

- **Three main categories**:
  - **Prompt leptons background**: tt + V, t + Z, WZ, WW, ZZ
  - **Fake lepton background**: hadrons misidentified as leptons, **leptons from heavy flavor decays**, electrons from photon conversions
    - Data driven estimation using : (ATLAS & CMS) a **Tight to Loose** method
      - Fake efficiency – input parameter

1 lepton + 1 away jet sample
CMS
smaller syst uncert. – 50 %

2 SS leptons sample
ATLAS
higher syst uncert.





Background classification

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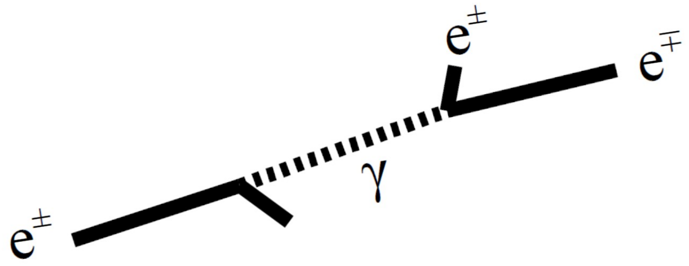
  - **Prompt leptons background**: tt + V, t + Z, WZ, WW, ZZ
  - **Fake lepton background**: hadrons misidentified as leptons, **leptons from heavy flavor decays**, electrons from photon conversions
  - **Charge flip background**: reconstructed electron charge flipped with respect to original electron (not important for muons)
    - **CMS**: charge flip rate obtained from simulation and validated in data (30% syst)
    - **ATLAS**: fully data – driven

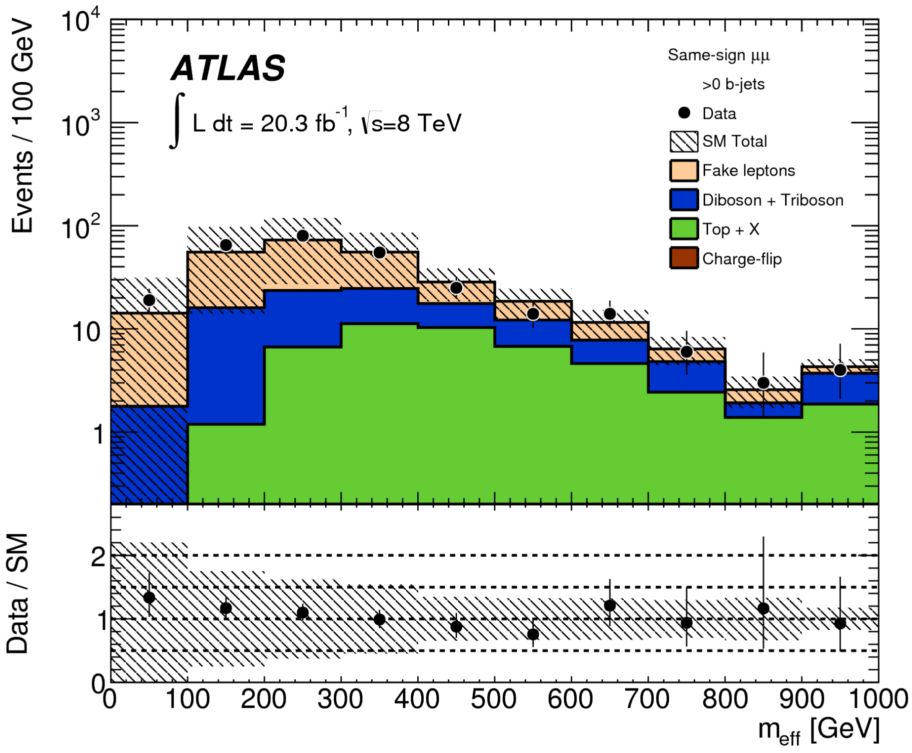
Estimation done with OS data events weighted by

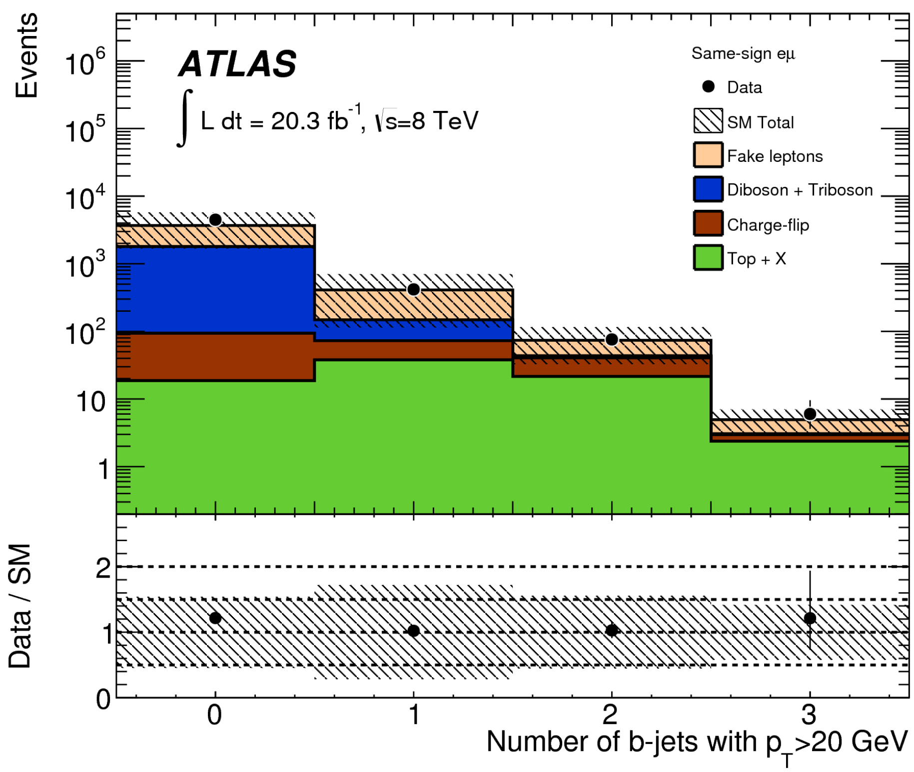
η and p_T dependent charge flip probability



Background validation
ATLAS

- Fair agreement between data and Standard Model background in the bkg validation regions for all three channels

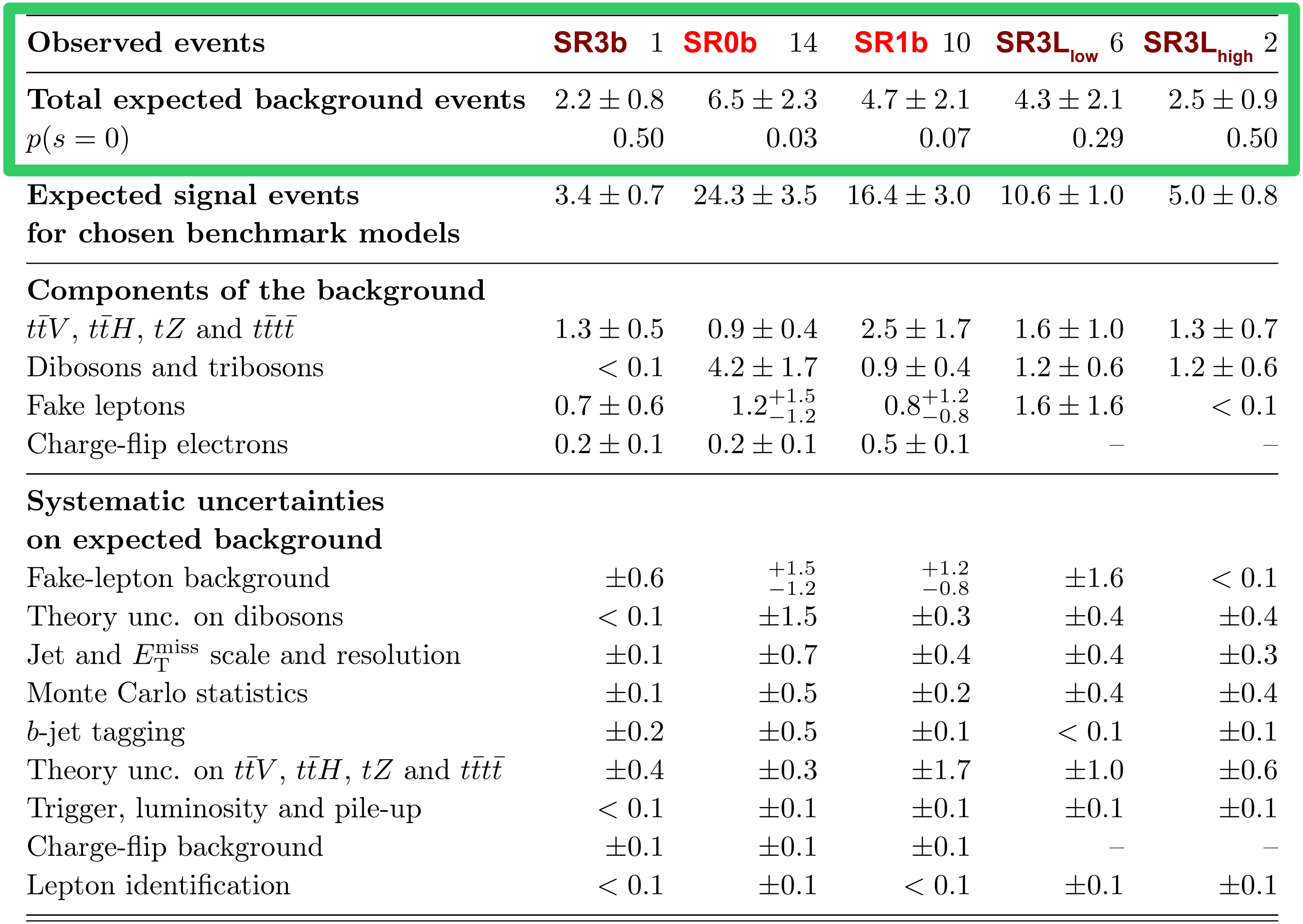




Results in the signal regions

- Good agreement between observation and expectation in SR3b, SR3Lep

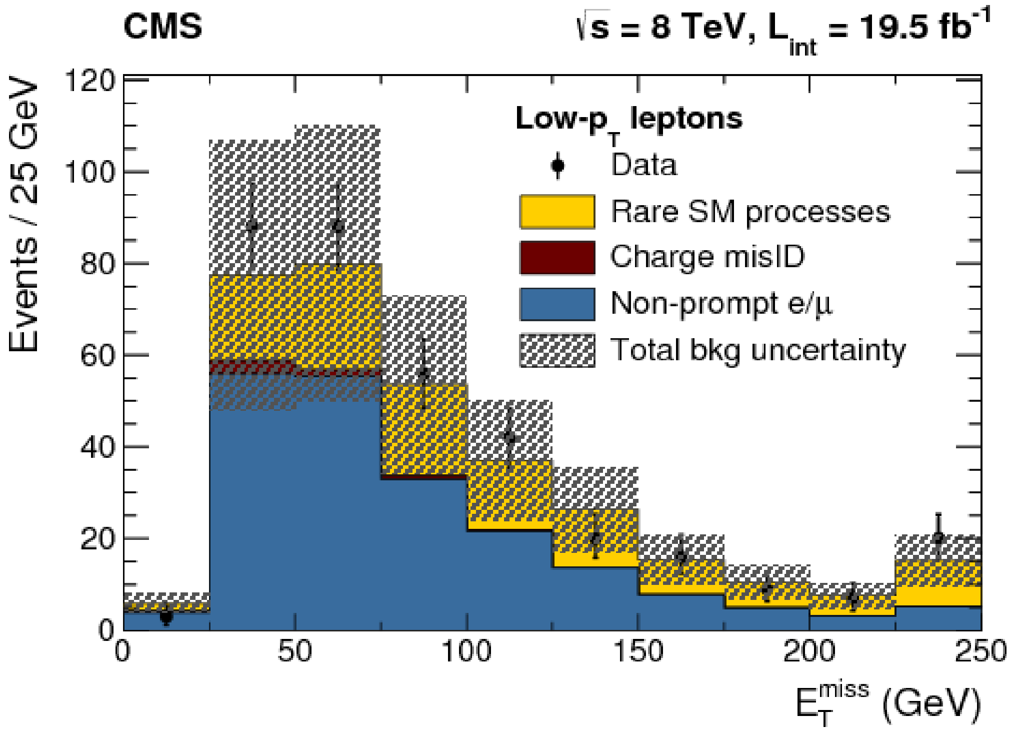
→ Small excess in SR0b (1.8 σ) and SR1b (1.5 σ) with a combined significance of 2.1

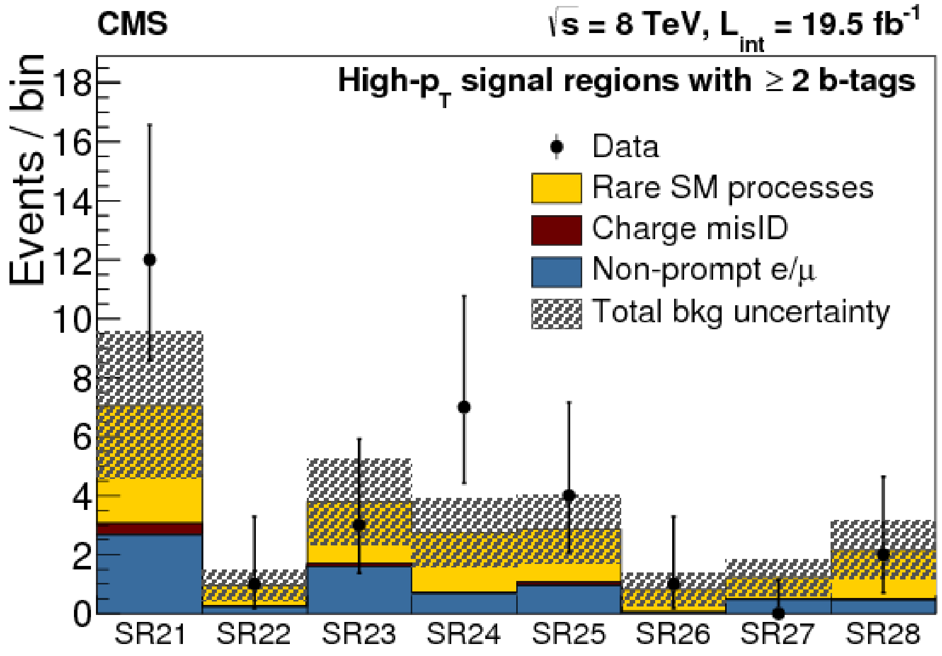


Observed events	**SR3b** 1	**SR0b** 14	**SR1b** 10	**SR3L$_{\text{low}}$** 6	**SR3L$_{\text{high}}$** 2
Total expected background events	2.2 ± 0.8	6.5 ± 2.3	4.7 ± 2.1	4.3 ± 2.1	2.5 ± 0.9
$p(s = 0)$	0.50	0.03	0.07	0.29	0.50
Expected signal events for chosen benchmark models	3.4 ± 0.7	24.3 ± 3.5	16.4 ± 3.0	10.6 ± 1.0	5.0 ± 0.8
Components of the background					
$t\bar{t}V$, $t\bar{t}H$, tZ and $t\bar{t}t\bar{t}$	1.3 ± 0.5	0.9 ± 0.4	2.5 ± 1.7	1.6 ± 1.0	1.3 ± 0.7
Dibosons and tribosons	< 0.1	4.2 ± 1.7	0.9 ± 0.4	1.2 ± 0.6	1.2 ± 0.6
Fake leptons	0.7 ± 0.6	$1.2^{+1.5}_{-1.2}$	$0.8^{+1.2}_{-0.8}$	1.6 ± 1.6	< 0.1
Charge-flip electrons	0.2 ± 0.1	0.2 ± 0.1	0.5 ± 0.1	–	–
Systematic uncertainties on expected background					
Fake-lepton background	± 0.6	$^{+1.5}_{-1.2}$	$^{+1.2}_{-0.8}$	± 1.6	< 0.1
Theory unc. on dibosons	< 0.1	± 1.5	± 0.3	± 0.4	± 0.4
Jet and $E_{\mathrm{T}}^{\mathrm{miss}}$ scale and resolution	± 0.1	± 0.7	± 0.4	± 0.4	± 0.3
Monte Carlo statistics	± 0.1	± 0.5	± 0.2	± 0.4	± 0.4
b-jet tagging	± 0.2	± 0.5	± 0.1	< 0.1	± 0.1
Theory unc. on $t\bar{t}V$, $t\bar{t}H$, tZ and $t\bar{t}t\bar{t}$	± 0.4	± 0.3	± 1.7	± 1.0	± 0.6
Trigger, luminosity and pile-up	< 0.1	± 0.1	± 0.1	± 0.1	± 0.1
Charge-flip background	± 0.1	± 0.1	± 0.1	–	–
Lepton identification	< 0.1	± 0.1	< 0.1	± 0.1	± 0.1

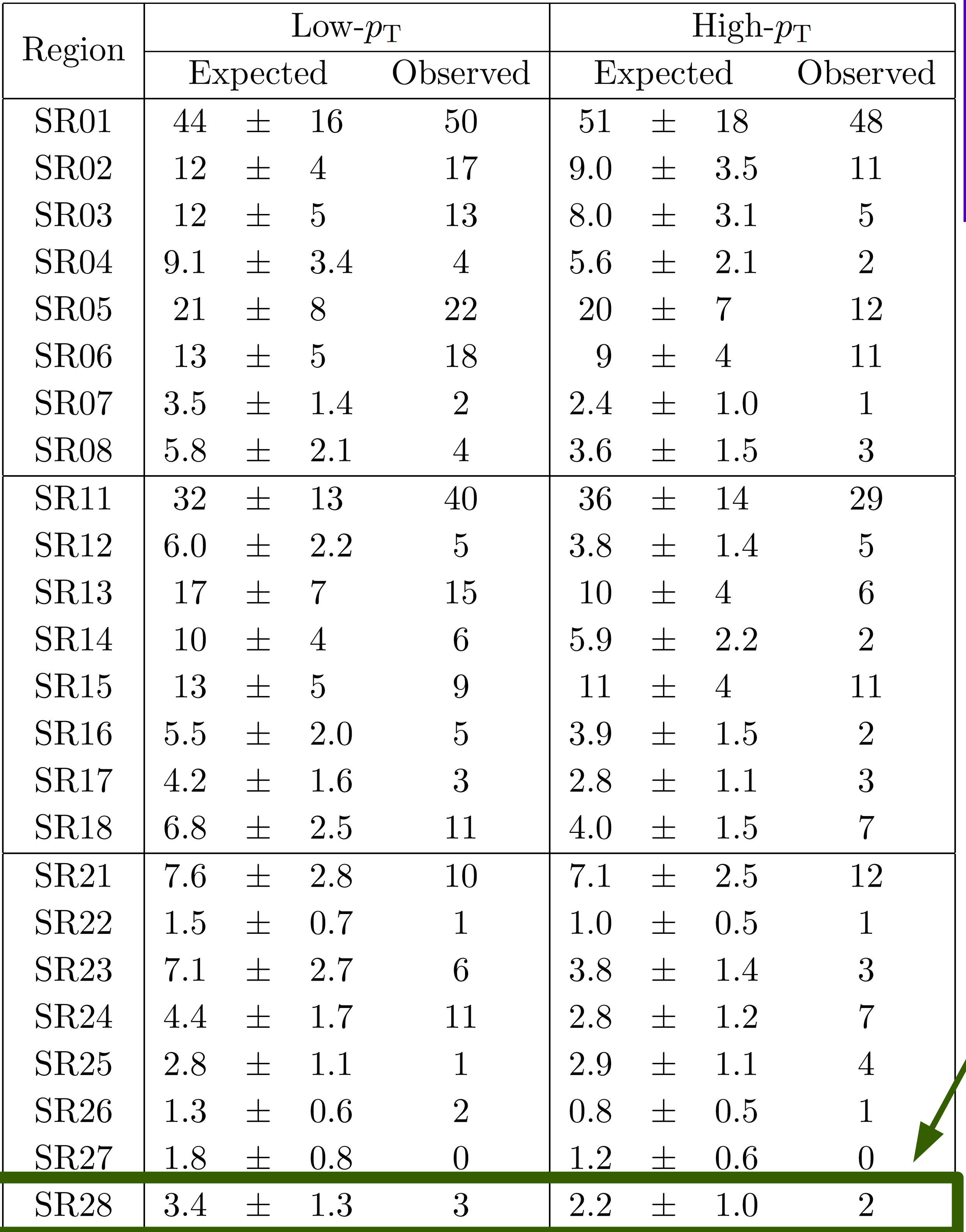
What about CMS ?

- Fair agreement between data and Standard Model background in all baseline and signal reg.





What about CMS ?



Region	Low-p_T		High-p_T	
	Expected	Observed	Expected	Observed
SR01	44 ± 16	50	51 ± 18	48
SR02	12 ± 4	17	9.0 ± 3.5	11
SR03	12 ± 5	13	8.0 ± 3.1	5
SR04	9.1 ± 3.4	4	5.6 ± 2.1	2
SR05	21 ± 8	22	20 ± 7	12
SR06	13 ± 5	18	9 ± 4	11
SR07	3.5 ± 1.4	2	2.4 ± 1.0	1
SR08	5.8 ± 2.1	4	3.6 ± 1.5	3
SR11	32 ± 13	40	36 ± 14	29
SR12	6.0 ± 2.2	5	3.8 ± 1.4	5
SR13	17 ± 7	15	10 ± 4	6
SR14	10 ± 4	6	5.9 ± 2.2	2
SR15	13 ± 5	9	11 ± 4	11
SR16	5.5 ± 2.0	5	3.9 ± 1.5	2
SR17	4.2 ± 1.6	3	2.8 ± 1.1	3
SR18	6.8 ± 2.5	11	4.0 ± 1.5	7
SR21	7.6 ± 2.8	10	7.1 ± 2.5	12
SR22	1.5 ± 0.7	1	1.0 ± 0.5	1
SR23	7.1 ± 2.7	6	3.8 ± 1.4	3
SR24	4.4 ± 1.7	11	2.8 ± 1.2	7
SR25	2.8 ± 1.1	1	2.9 ± 1.1	4
SR26	1.3 ± 0.6	2	0.8 ± 0.5	1
SR27	1.8 ± 0.8	0	1.2 ± 0.6	0
SR28	3.4 ± 1.3	3	2.2 ± 1.0	2

No excess in data

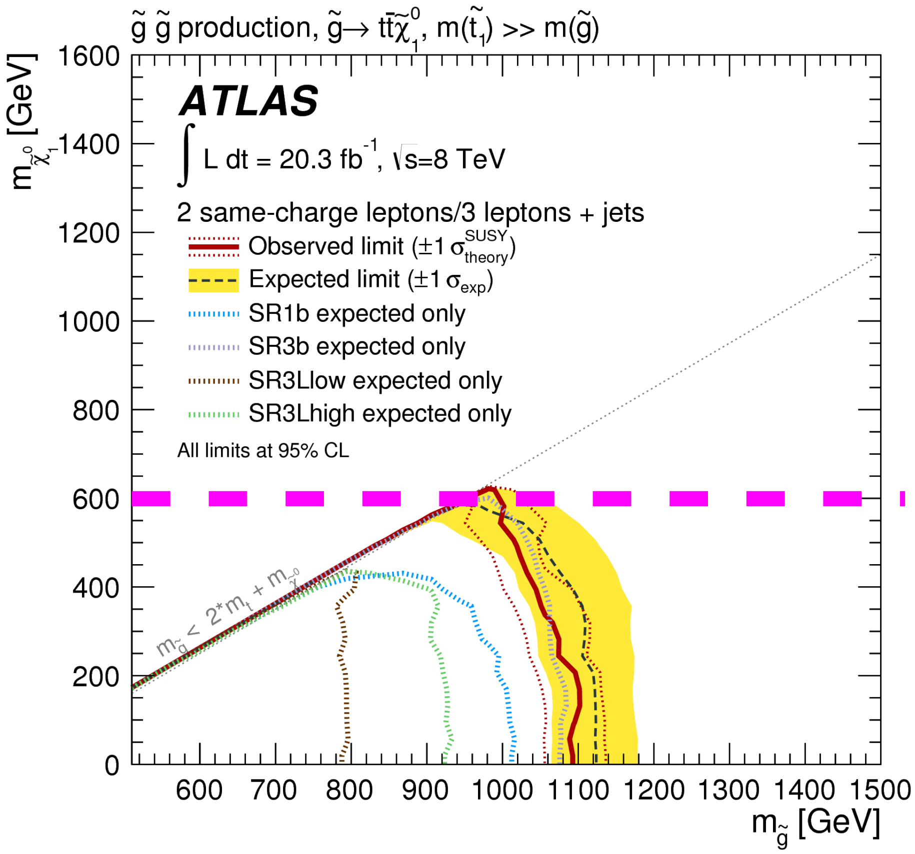
above SM expectation

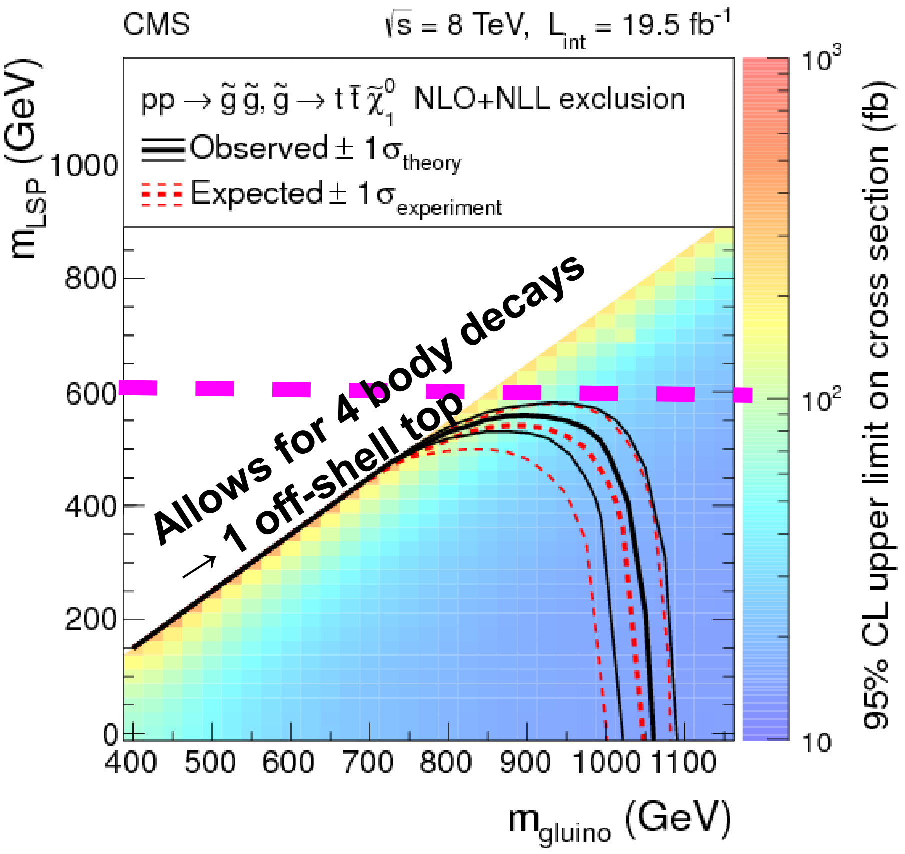
In any of the 50 SRs

Highest sensitivity in models with b-jets

Interpretation: model dependent limits

- Gluino stop model (t χ^0_1) off – shell





- **SR3b → best sensitivity**

SR3b → SS / 3Lep; Njets > 4

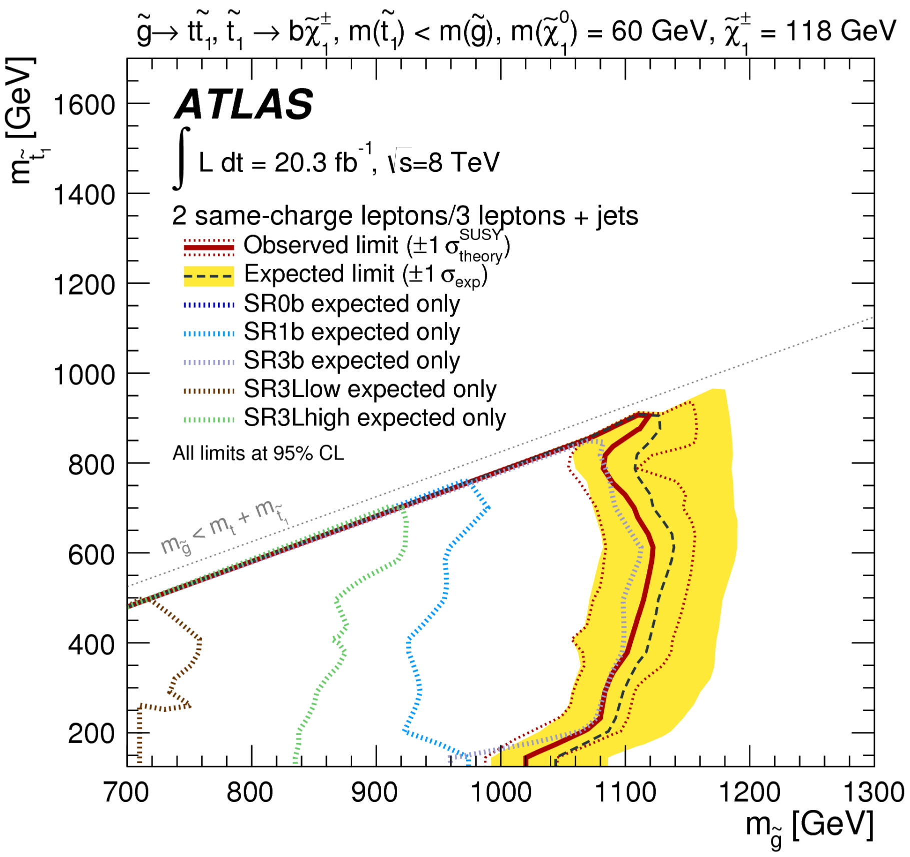
- **SR28 → best sensitivity**

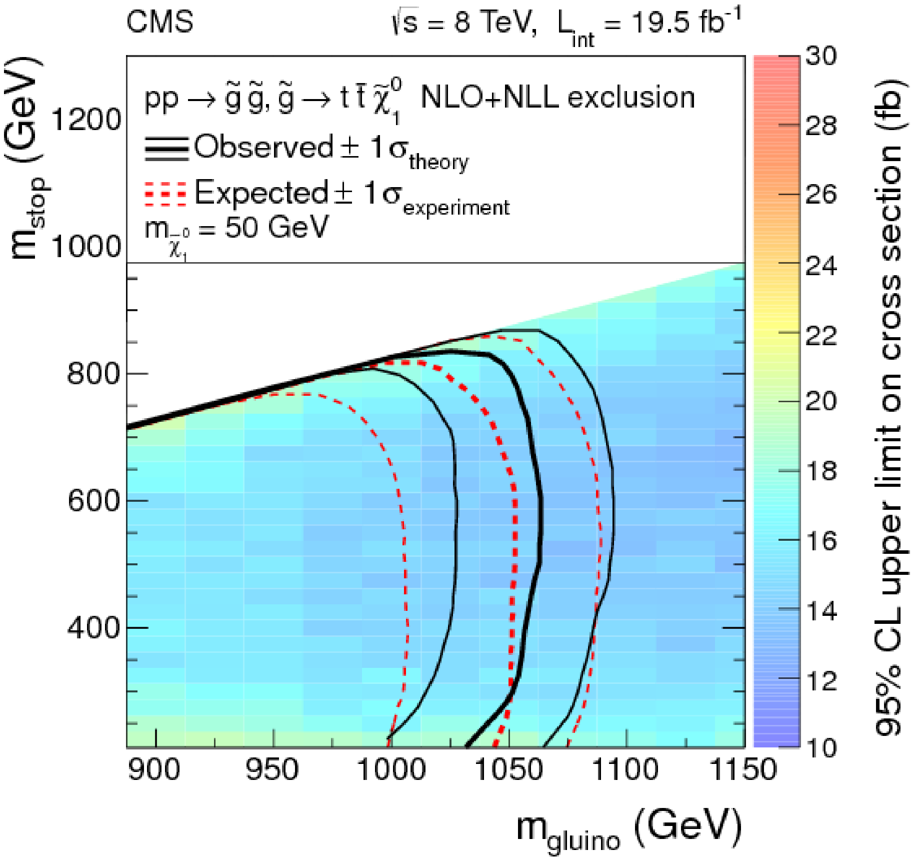
SR21 – Sr28 : 2 b–tagged jets and high pT leptons

SR28 → $\not{E}_T$ > 120, H_T > 400 GeV

Interpretation: model dependent limits

- Gluino stop model (t χ^0_1) on – shell





- **SR3b → best sensitivity**

  Higher sensitivity

  – requiring 3 b–jets is helping (higher reduction of tt + V bkg.)

SR3b → SS / 3Lep; Njets > 4

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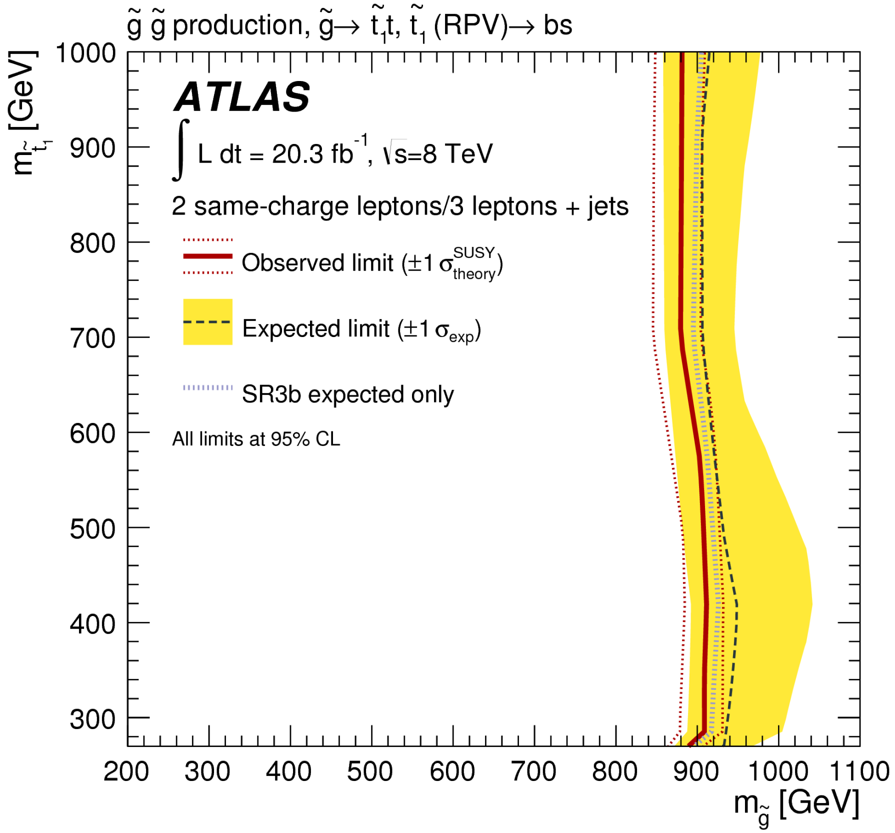
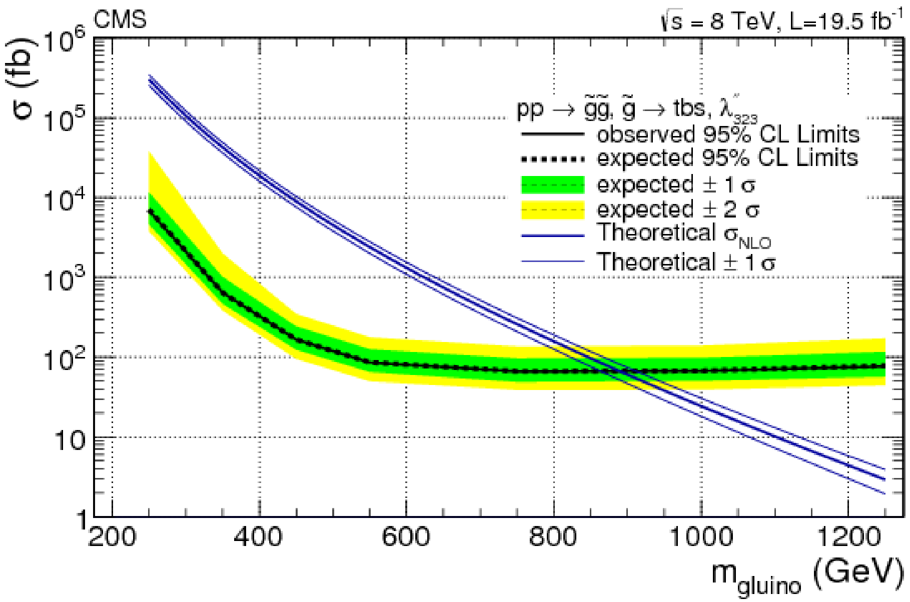
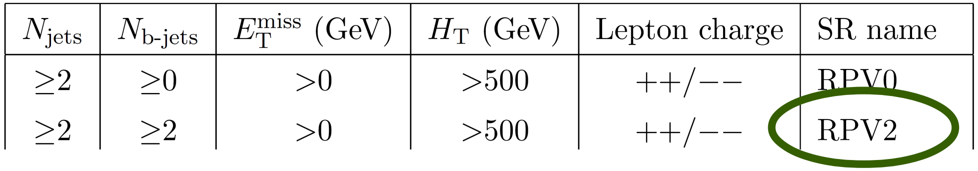
Interpretation: model dependent limits

- Gluino stop RPV model (stop → b s)







N_{jets}	$N_{\text{b-jets}}$	E_T^{miss} (GeV)	H_T (GeV)	Lepton charge	SR name
≥ 2	≥ 0	>0	>500	$++/--$	RPV0
≥ 2	≥ 2	>0	>500	$++/--$	RPV2

SR3b → SS / 3Lep; Njets > 4

- **SR3b → best sensitivity – no $\not{E}_T$ cut**

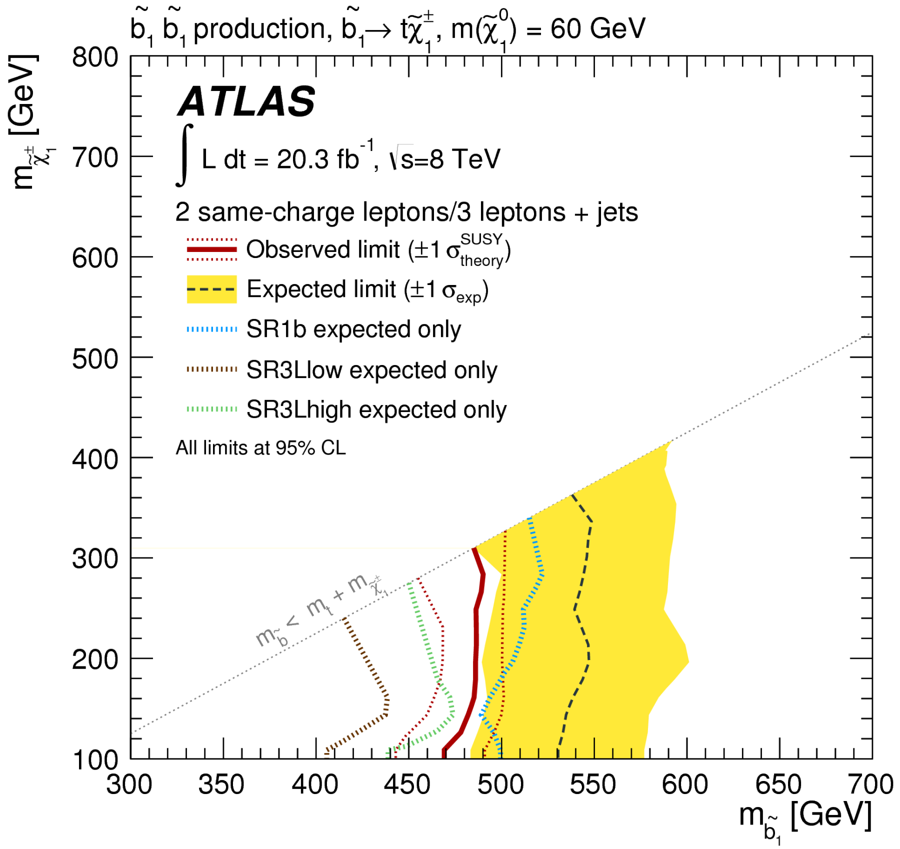
  Similar sensitivity for ATLAS and CMS

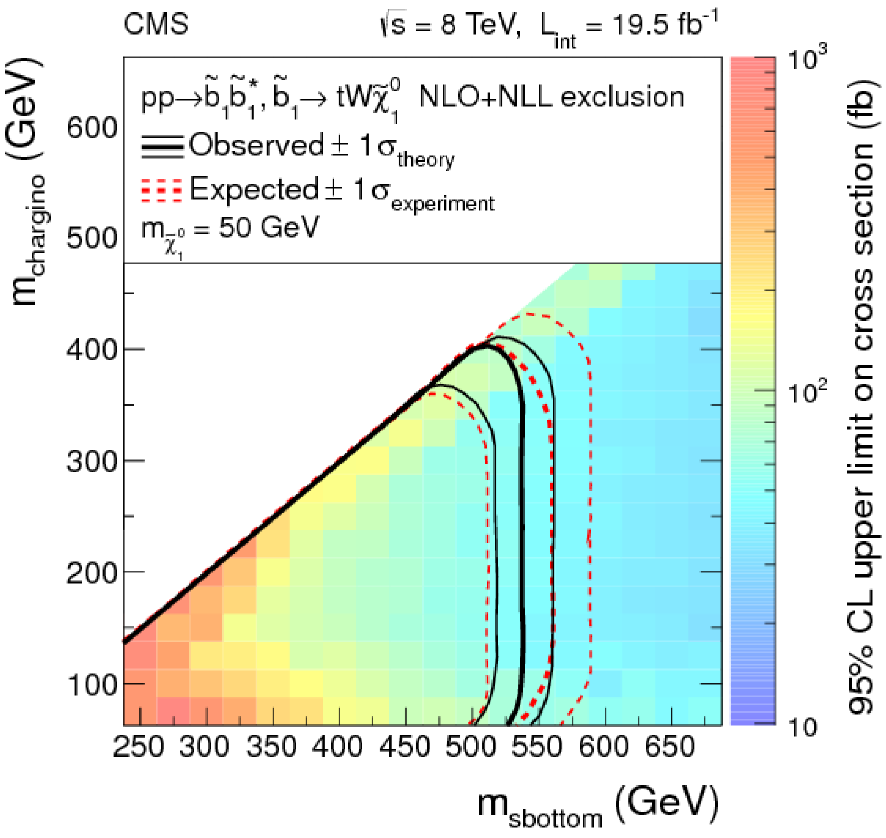
- **RPV2 (high p_T lep) used to place UL on the production σ**

Interpretation: model dependent limits

- Direct sbottom model

  – m χ^0_1 = 60 / 50 GeV, $\chi^\pm_1$ mass is varied → m_b – m $\chi^\pm_1$ plane





- **SR1b (at leat 3 jets) → best sensitivity**

  Worse obs. limits due to the excess in SR1b

  – slightly better exclusion limits for CMS

  → due to (b–) jets multiplicity

- **SR28 → best sensitivity**

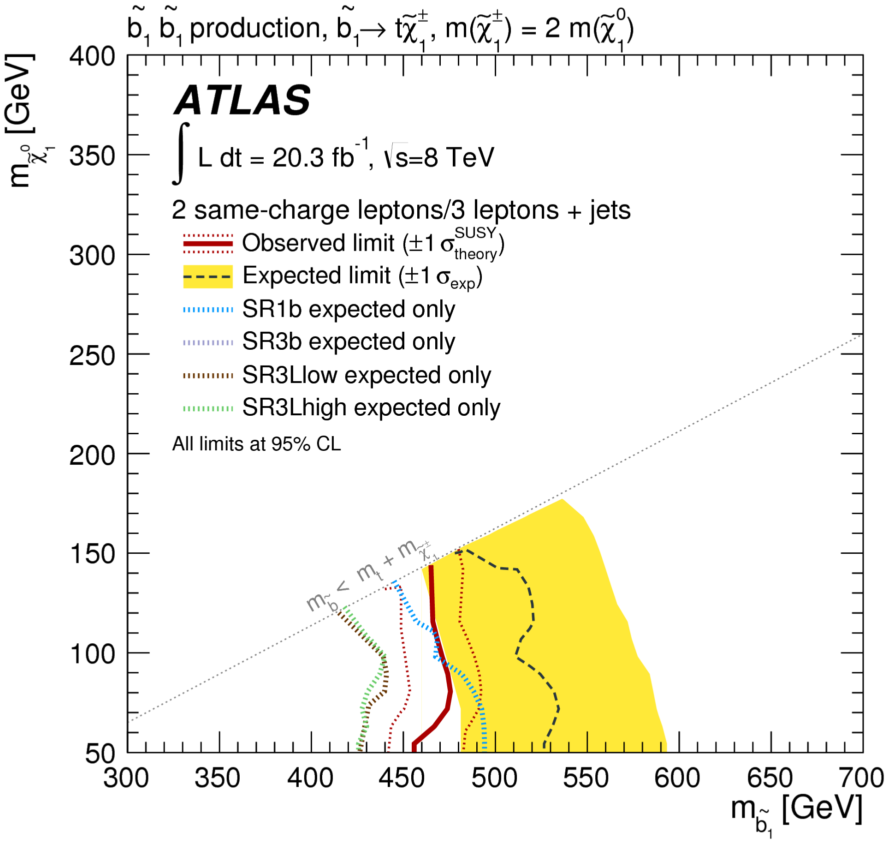
  SR18, SR15 and SR13with 1 b–tagged jet and high pT leptons

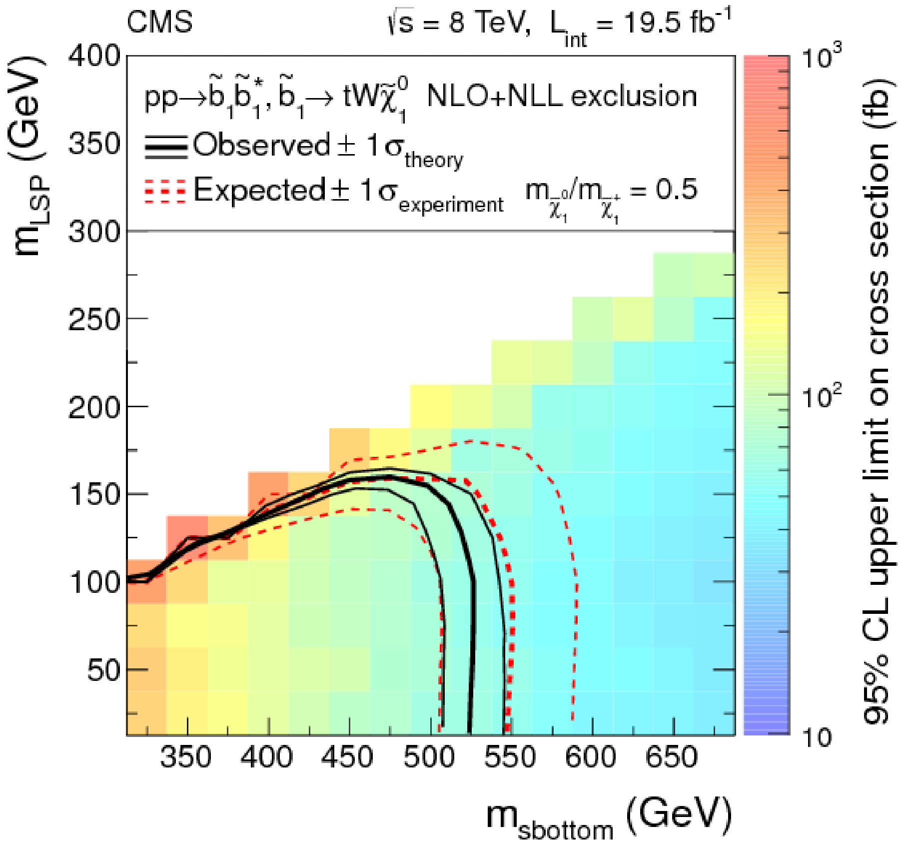
  – at least 4 jets in the event

Interpretation: model dependent limits

- Direct sbottom model

  – $m\ \chi^{\pm}_1 = 2 * m\ \chi^0_1 \rightarrow m_b - m\ \chi^0_1$ plane





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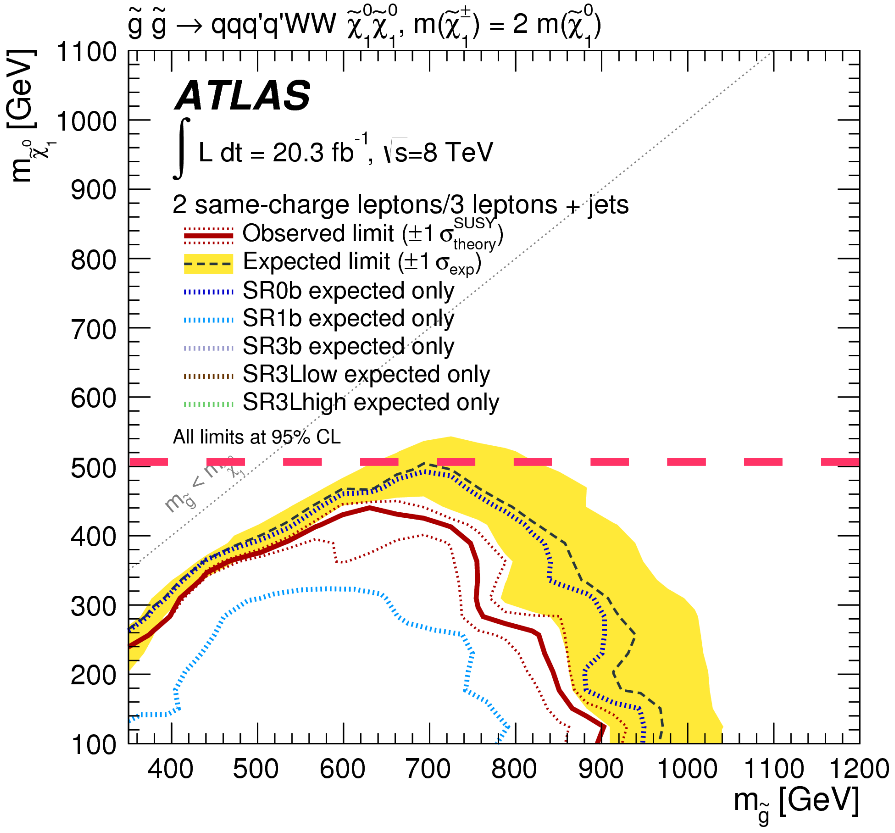
  SR18, SR15 and SR13with 1 b–tagged jet and high pT leptons

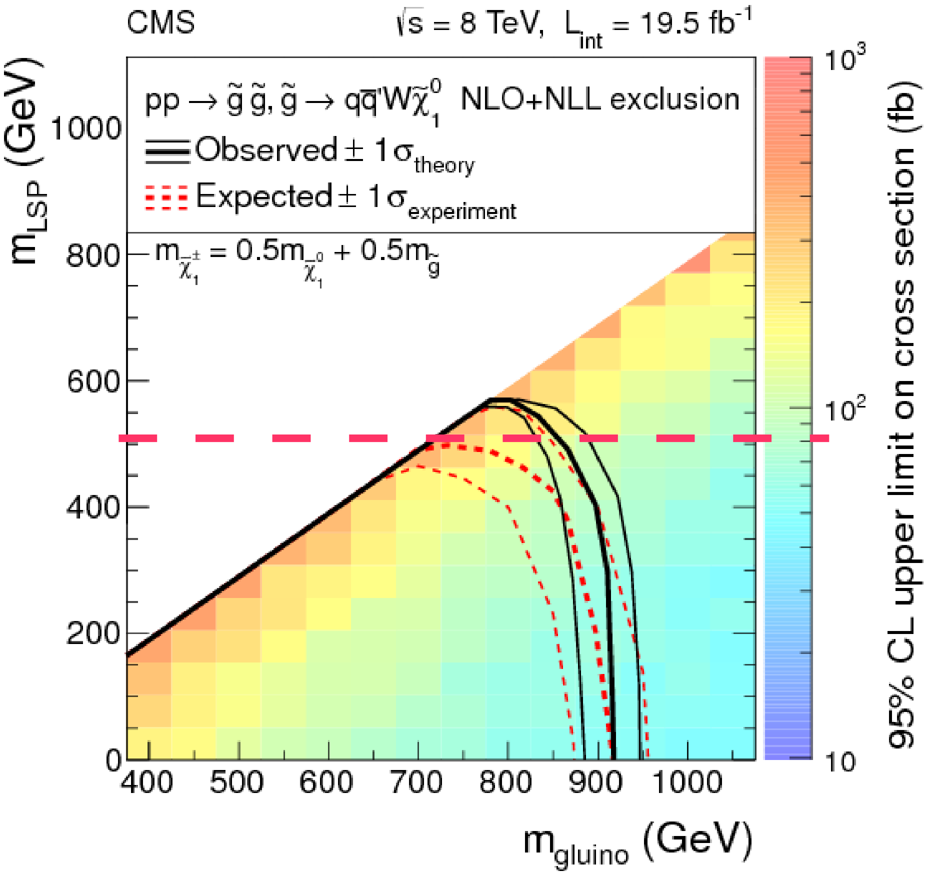
  – at least 4 jets in the event

Interpretation: model dependent limits

- Gluino mediated first and second generation squarks

  – $m\,\chi^{\pm}_{1} = 2 * m\,\chi^{0}_{1}$ in ATLAS and $m\,\chi^{\pm}_{1} = 0.5 * m\,\chi^{0}_{1} + 0.5 * m_{g} \rightarrow m_{g} - m\,\chi^{0}_{1}$ plane





- **SR0b (at leat 3 jets) → best sensitivity**

  Worse obs. limits due to the excess in SR0b

  – slightly better expected exclusion limits at high gluino mass

- **SR08 → best sensitivity**

  SR01 – SR08 with 0 b–tagged jets and high / low pT leptons

  2 –3 or at least 4 jets in the event

Conclusions

- **Search for new physics in final states with 2 same – sign leptons in ATLAS and CMS experiments**
  - **Low Standard Model background → high sensitivity to BSM physics**
  - **Charge flip and fake leptons backgrounds** are important sources (almost half of the total bkg)

- **ATLAS – CMS comparison: complementary approaches**
  - **CMS: full scan of the phase space using 50 SRs (soft & hard analyses)**
  - **ATLAS: few general–purpose SRs, low look–elsewhere effect**

Comparing performances on several signal models: generally similar sensitivities

Conclusions

- **Search for new physics in final states with 2 same – sign leptons in ATLAS**
  - **Paper accepted by JHEP : arXiv:1404.2500**, link to figures

- **Changes wrt. previous version of the analysis in ATLAS:**
  – Merge 2 same sign pair with 3 leptons signatures – signal region re-optimization
  – Isolation variables optimization for signal leptons
  – Add cross-check methods to validate the charge flip and fake leptons / b-jets bkg.
  – Interpretation: add new models (in total **14 SUSY models and 1 mUED model**)

- **Other ATLAS public results** are here

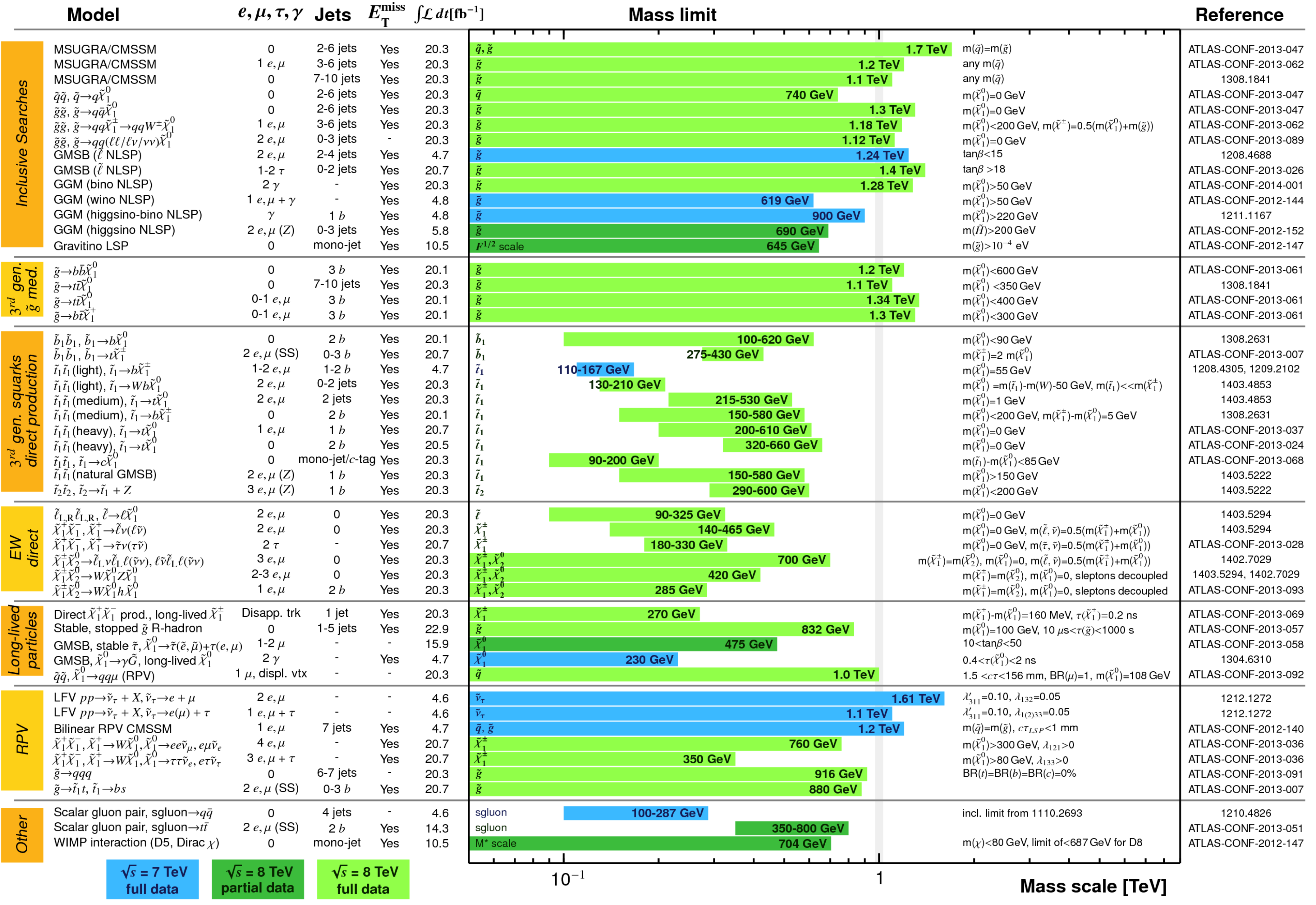
- **Run 2 preparation studies:**
  - **– Improve the background estimation techniques**
  - **– Add control regions to decrease the tt + V / diboson systematic uncertainty**
  - **– Add new models to interpret the results**

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: Moriond 2014

ATLAS Preliminary

$\int\mathcal{L}\,dt$ = (4.6 - 22.9) fb^{-1} $\sqrt{s}$ = 7, 8 TeV



	Model	e,μ,τ,γ	Jets	E_T^{miss}	$\int\mathcal{L}\,dt[fb^{-1}]$	Mass limit			Reference
Inclusive Searches	MSUGRA/CMSSM	0	2-6 jets	Yes	20.3	$\tilde{q},\tilde{g}$	1.7 TeV	m($\tilde{q}$)=m($\tilde{g}$)	ATLAS-CONF-2013-047
	MSUGRA/CMSSM	1 e,μ	3-6 jets	Yes	20.3	$\tilde{g}$	1.2 TeV	any m($\tilde{q}$)	ATLAS-CONF-2013-062
	MSUGRA/CMSSM	0	7-10 jets	Yes	20.3	$\tilde{g}$	1.1 TeV	any m($\tilde{q}$)	1308.1841
	$\tilde{q}\tilde{q}$, $\tilde{q}\to q\tilde{\chi}_1^0$	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
	$\tilde{g}\tilde{g}$, $\tilde{g}\to qq\tilde{\chi}_1^{\pm}\to qqW^{\pm}\tilde{\chi}_1^0$	1 e,μ	3-6 jets	Yes	20.3	$\tilde{g}$	1.18 TeV	m($\tilde{\chi}_1^0$)<200 GeV, m($\tilde{\chi}^{\pm}$)=0.5(m($\tilde{\chi}_1^0$)+m($\tilde{g}$))	ATLAS-CONF-2013-062
	$\tilde{g}\tilde{g}$, $\tilde{g}\to qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$	2 e,μ	0-3 jets	-	20.3	$\tilde{g}$	1.12 TeV	m($\tilde{\chi}_1^0$)=0 GeV	ATLAS-CONF-2013-089
	GMSB ($\tilde{\ell}$ NLSP)	2 e,μ	2-4 jets	Yes	4.7	$\tilde{g}$	1.24 TeV	tanβ<15	1208.4688
	GMSB ($\tilde{\ell}$ 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	-	Yes	20.3	$\tilde{g}$	1.28 TeV	m($\tilde{\chi}_1^0$)>50 GeV	ATLAS-CONF-2014-001
	GGM (wino NLSP)	1 $e,\mu+\gamma$	-	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	20.1	$\tilde{g}$	1.2 TeV	m($\tilde{\chi}_1^0$)<600 GeV	ATLAS-CONF-2013-061
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0	7-10 jets	Yes	20.3	$\tilde{g}$	1.1 TeV	m($\tilde{\chi}_1^0$) <350 GeV	1308.1841
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$	1.34 TeV	m($\tilde{\chi}_1^0$)<400 GeV	ATLAS-CONF-2013-061
	$\tilde{g}\to b\bar{t}\tilde{\chi}_1^+$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$	1.3 TeV	m($\tilde{\chi}_1^0$)<300 GeV	ATLAS-CONF-2013-061
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	$\tilde{b}_1$	100-620 GeV	m($\tilde{\chi}_1^0$)<90 GeV	1308.2631
	$\tilde{b}_1\tilde{b}_1$, $\tilde{b}_1\to t\tilde{\chi}_1^{\pm}$	2 e,μ (SS)	0-3 b	Yes	20.7	$\tilde{b}_1$	275-430 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	$\tilde{t}_1$	110-167 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	$\tilde{t}_1$	130-210 GeV	m($\tilde{\chi}_1^0$) =m($\tilde{t}_1$)-m(W)-50 GeV, m($\tilde{t}_1$)<<m($\tilde{\chi}_1^{\pm}$)	1403.4853
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to t\tilde{\chi}_1^0$	2 e,μ	2 jets	Yes	20.3	$\tilde{t}_1$	215-530 GeV	m($\tilde{\chi}_1^0$)=1 GeV	1403.4853
	$\tilde{t}_1\tilde{t}_1$(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($\tilde{\chi}_1^0$)=5 GeV	1308.2631
	$\tilde{t}_1\tilde{t}_1$(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
	$\tilde{t}_1\tilde{t}_1$, $\tilde{t}_1\to c\tilde{\chi}_1^0$	0	mono-jet/c-tag	Yes	20.3	$\tilde{t}_1$	90-200 GeV	m($\tilde{t}_1$)-m($\tilde{\chi}_1^0$)<85 GeV	ATLAS-CONF-2013-068
	$\tilde{t}_1\tilde{t}_1$(natural GMSB)	2 e,μ (Z)	1 b	Yes	20.3	$\tilde{t}_1$	150-580 GeV	m($\tilde{\chi}_1^0$)>150 GeV	1403.5222
	$\tilde{t}_2\tilde{t}_2$, $\tilde{t}_2\to\tilde{t}_1+Z$	3 e,μ (Z)	1 b	Yes	20.3	$\tilde{t}_2$	290-600 GeV	m($\tilde{\chi}_1^0$)<200 GeV	1403.5222
EW direct	$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R}$, $\tilde{\ell}\to\ell\tilde{\chi}_1^0$	2 e,μ	0	Yes	20.3	$\tilde{\ell}$	90-325 GeV	m($\tilde{\chi}_1^0$)=0 GeV	1403.5294
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to\tilde{\ell}\nu(\ell\tilde{\nu})$	2 e,μ	0	Yes	20.3	$\tilde{\chi}_1^{\pm}$	140-465 GeV	m($\tilde{\chi}_1^0$)=0 GeV, m($\tilde{\ell},\tilde{\nu}$)=0.5(m($\tilde{\chi}_1^{\pm}$)+m($\tilde{\chi}_1^0$))	1403.5294
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to\tilde{\tau}\nu(\tau\tilde{\nu})$	2 τ	-	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
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\to\tilde{\ell}_L\nu\tilde{\ell}_L\ell(\tilde{\nu}\nu)$, $\ell\tilde{\nu}\tilde{\ell}_L\ell(\tilde{\nu}\nu)$	3 e,μ	0	Yes	20.3	$\tilde{\chi}_1^{\pm},\tilde{\chi}_2^0$	700 GeV	m($\tilde{\chi}_1^{\pm}$)=m($\tilde{\chi}_2^0$), m($\tilde{\chi}_1^0$)=0, m($\tilde{\ell},\tilde{\nu}$)=0.5(m($\tilde{\chi}_1^{\pm}$)+m($\tilde{\chi}_1^0$))	1402.7029
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\to W\tilde{\chi}_1^0Z\tilde{\chi}_1^0$	2-3 e,μ	0	Yes	20.3	$\tilde{\chi}_1^{\pm},\tilde{\chi}_2^0$	420 GeV	m($\tilde{\chi}_1^{\pm}$)=m($\tilde{\chi}_2^0$), m($\tilde{\chi}_1^0$)=0, sleptons decoupled	1403.5294, 1402.7029
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\to W\tilde{\chi}_1^0h\tilde{\chi}_1^0$	1 e,μ	2 b	Yes	20.3	$\tilde{\chi}_1^{\pm},\tilde{\chi}_2^0$	285 GeV	m($\tilde{\chi}_1^{\pm}$)=m($\tilde{\chi}_2^0$), m($\tilde{\chi}_1^0$)=0, sleptons decoupled	ATLAS-CONF-2013-093
Long-lived particles	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^{\pm}$	Disapp. trk	1 jet	Yes	20.3	$\tilde{\chi}_1^{\pm}$	270 GeV	m($\tilde{\chi}_1^{\pm}$)-m($\tilde{\chi}_1^0$)=160 MeV, τ($\tilde{\chi}_1^{\pm}$)=0.2 ns	ATLAS-CONF-2013-069
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	22.9	$\tilde{g}$	832 GeV	m($\tilde{\chi}_1^0$)=100 GeV, 10 μs<τ($\tilde{g}$)<1000 s	ATLAS-CONF-2013-057
	GMSB, stable $\tilde{\tau}$, $\tilde{\chi}_1^0\to\tilde{\tau}(\tilde{e},\tilde{\mu})+\tau(e,\mu)$	1-2 μ	-	-	15.9	$\tilde{\chi}_1^0$	475 GeV	10<tanβ<50	ATLAS-CONF-2013-058
	GMSB, $\tilde{\chi}_1^0\to\gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$	2 γ	-	Yes	4.7	$\tilde{\chi}_1^0$	230 GeV	0.4<τ($\tilde{\chi}_1^0$)<2 ns	1304.6310
	$\tilde{q}\tilde{q}$, $\tilde{\chi}_1^0\to qq\mu$ (RPV)	1 μ, displ. vtx	-	-	20.3	$\tilde{q}$	1.0 TeV	1.5 <$c\tau$<156 mm, BR(μ)=1, m($\tilde{\chi}_1^0$)=108 GeV	ATLAS-CONF-2013-092
RPV	LFV $pp\to\tilde{\nu}_\tau+X$, $\tilde{\nu}_\tau\to e+\mu$	2 e,μ	-	-	4.6	$\tilde{\nu}_\tau$	1.61 TeV	λ'_{311}=0.10, λ_{132}=0.05	1212.1272
	LFV $pp\to\tilde{\nu}_\tau+X$, $\tilde{\nu}_\tau\to e(\mu)+\tau$	1 $e,\mu+\tau$	-	-	4.6	$\tilde{\nu}_\tau$	1.1 TeV	λ'_{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
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to W\tilde{\chi}_1^0$, $\tilde{\chi}_1^0\to ee\tilde{\nu}_\mu$, $e\mu\tilde{\nu}_e$	4 e,μ	-	Yes	20.7	$\tilde{\chi}_1^{\pm}$	760 GeV	m($\tilde{\chi}_1^0$)>300 GeV, λ_{121}>0	ATLAS-CONF-2013-036
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to W\tilde{\chi}_1^0$, $\tilde{\chi}_1^0\to\tau\tau\tilde{\nu}_e$, $e\tau\tilde{\nu}_\tau$	3 $e,\mu+\tau$	-	Yes	20.7	$\tilde{\chi}_1^{\pm}$	350 GeV	m($\tilde{\chi}_1^0$)>80 GeV, λ_{133}>0	ATLAS-CONF-2013-036
	$\tilde{g}\to qqq$	0	6-7 jets	-	20.3	$\tilde{g}$	916 GeV	BR(t)=BR(b)=BR(c)=0%	ATLAS-CONF-2013-091
	$\tilde{g}\to\tilde{t}_1t$, $\tilde{t}_1\to bs$	2 e,μ (SS)	0-3 b	Yes	20.7	$\tilde{g}$	880 GeV		ATLAS-CONF-2013-007
Other	Scalar gluon pair, sgluon$\to q\bar{q}$	0	4 jets	-	4.6	sgluon	100-287 GeV	incl. limit from 1110.2693	1210.4826
	Scalar gluon pair, sgluon$\to t\bar{t}$	2 e,μ (SS)	2 b	Yes	14.3	sgluon	350-800 GeV		ATLAS-CONF-2013-051
	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

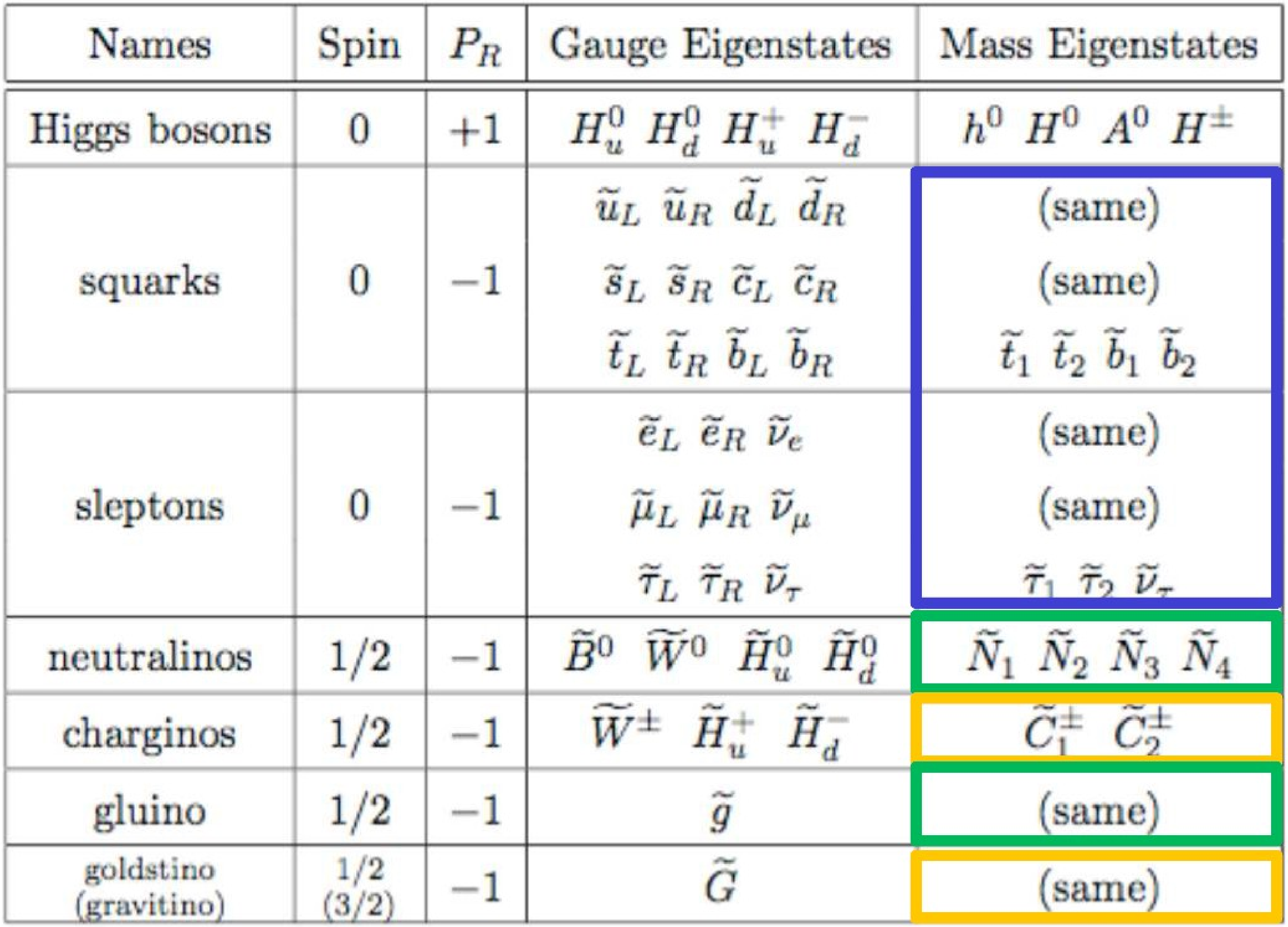
🟩 $\sqrt{s}$ = 8 TeV partial data

🟩 $\sqrt{s}$ = 8 TeV full data

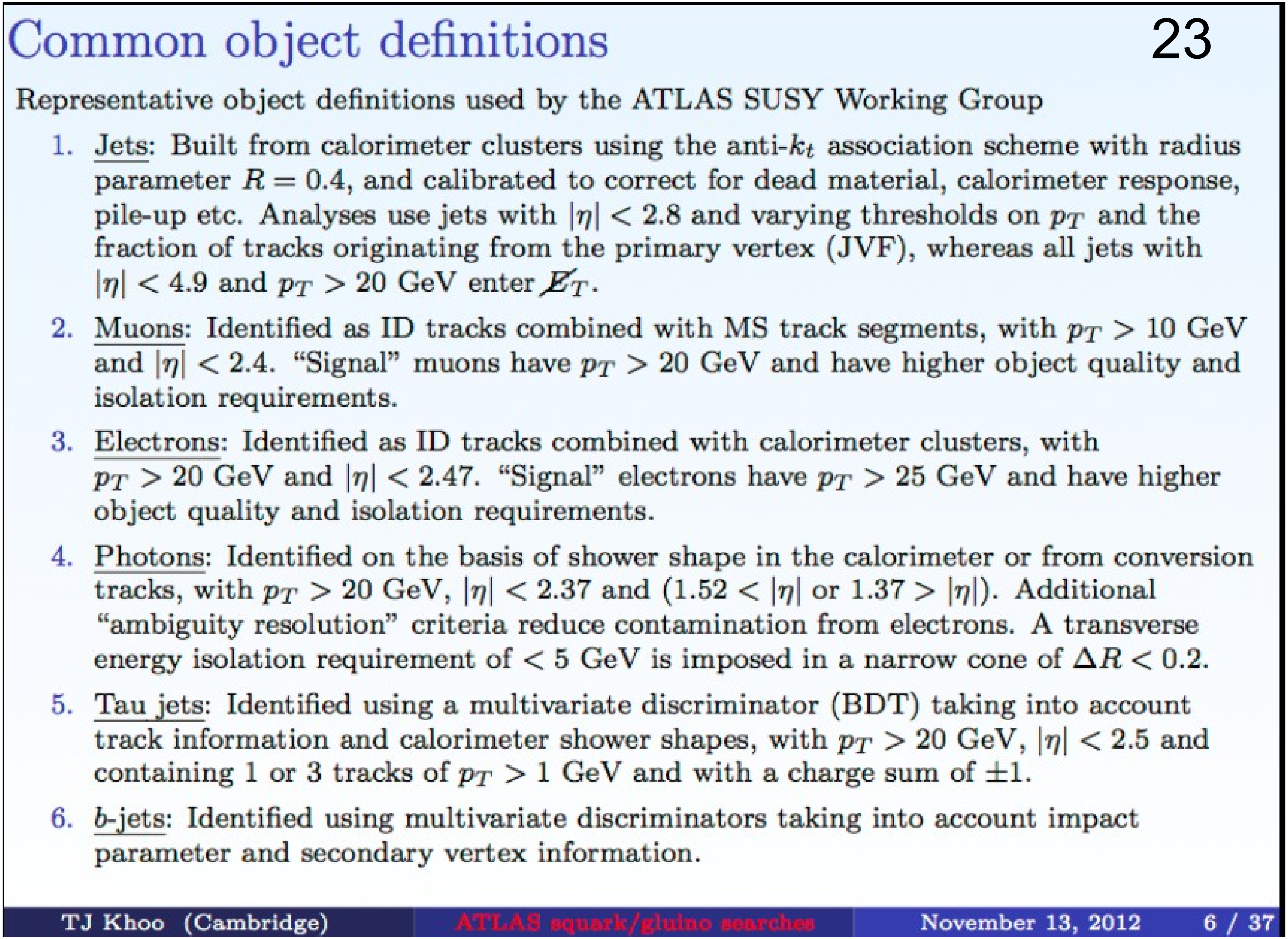
Back-up

MSSM a.k.a Weak Scale SUSY :
29 sparticles + 4 Higgs undiscovered

21 **scalars** + 5 **Majorana** + 3 **others fermions**



Names	Spin	P_R	Gauge Eigenstates	Mass Eigenstates
Higgs bosons	0	$+1$	$H_u^0\ H_d^0\ H_u^+\ H_d^-$	$h^0\ H^0\ A^0\ H^\pm$
squarks	0	-1	$\widetilde{u}_L\ \widetilde{u}_R\ \widetilde{d}_L\ \widetilde{d}_R$	(same)
			$\widetilde{s}_L\ \widetilde{s}_R\ \widetilde{c}_L\ \widetilde{c}_R$	(same)
			$\widetilde{t}_L\ \widetilde{t}_R\ \widetilde{b}_L\ \widetilde{b}_R$	$\widetilde{t}_1\ \widetilde{t}_2\ \widetilde{b}_1\ \widetilde{b}_2$
sleptons	0	-1	$\widetilde{e}_L\ \widetilde{e}_R\ \widetilde{\nu}_e$	(same)
			$\widetilde{\mu}_L\ \widetilde{\mu}_R\ \widetilde{\nu}_\mu$	(same)
			$\widetilde{\tau}_L\ \widetilde{\tau}_R\ \widetilde{\nu}_\tau$	$\widetilde{\tau}_1\ \widetilde{\tau}_2\ \widetilde{\nu}_\tau$
neutralinos	1/2	-1	$\widetilde{B}^0\ \widetilde{W}^0\ \widetilde{H}_u^0\ \widetilde{H}_d^0$	$\widetilde{N}_1\ \widetilde{N}_2\ \widetilde{N}_3\ \widetilde{N}_4$
charginos	1/2	-1	$\widetilde{W}^\pm\ \widetilde{H}_u^+\ \widetilde{H}_d^-$	$\widetilde{C}_1^\pm\ \widetilde{C}_2^\pm$
gluino	1/2	-1	$\widetilde{g}$	(same)
goldstino (gravitino)	1/2 (3/2)	-1	$\widetilde{G}$	(same)



Common object definitions

Representative object definitions used by the ATLAS SUSY Working Group

1. Jets: Built from calorimeter clusters using the anti-k_t association scheme with radius parameter $R = 0.4$, and calibrated to correct for dead material, calorimeter response, pile-up etc. Analyses use jets with $|\eta| < 2.8$ and varying thresholds on p_T and the fraction of tracks originating from the primary vertex (JVF), whereas all jets with $|\eta| < 4.9$ and $p_T > 20$ GeV enter $\not{E}_T$.
2. Muons: Identified as ID tracks combined with MS track segments, with $p_T > 10$ GeV and $|\eta| < 2.4$. "Signal" muons have $p_T > 20$ GeV and have higher object quality and isolation requirements.
3. Electrons: Identified as ID tracks combined with calorimeter clusters, with $p_T > 20$ GeV and $|\eta| < 2.47$. "Signal" electrons have $p_T > 25$ GeV and have higher object quality and isolation requirements.
4. Photons: Identified on the basis of shower shape in the calorimeter or from conversion tracks, with $p_T > 20$ GeV, $|\eta| < 2.37$ and $(1.52 < |\eta|$ or $1.37 > |\eta|)$. Additional "ambiguity resolution" criteria reduce contamination from electrons. A transverse energy isolation requirement of < 5 GeV is imposed in a narrow cone of $\Delta R < 0.2$.
5. Tau jets: Identified using a multivariate discriminator (BDT) taking into account track information and calorimeter shower shapes, with $p_T > 20$ GeV, $|\eta| < 2.5$ and containing 1 or 3 tracks of $p_T > 1$ GeV and with a charge sum of ± 1.
6. b-jets: Identified using multivariate discriminators taking into account impact parameter and secondary vertex information.

Kinematic variables definitions

- **Exclusive effective mass =** scalar sum of the transverse momenta of the N leading jets, X leptons and missing transverse energy
- **Inclusive effective mass** = scalar sum of the transverse momenta of all jets, leptons and missing transverse energy
- **HT =** scalar sum of the transverse momenta of all jets
- $M_J^{\Sigma} = \Sigma\, m_j^{R=1.0}$ (mass of the composite jet), where $p_T^{R=1.0} > 100$ GeV and $|\eta^{R=1.0}| < 1.5$ The four momenta of the R = 0.4 jets satisfying pT > 20 GeV and $|\eta| < 2.8$ are used as input to a second iteration of anti-k_T jet algorithm with R = 1.0. The resulting larger objects are denoted as composite jets.
- $\Delta R_{\min} = \min\left(\Delta R(j_1, \ell), \Delta R(j_2, \ell), ..., \Delta R(j_n, \ell)\right)$
- $m_T = \sqrt{2 p_T^{\ell} E_T^{\text{miss}} (1 - \cos(\Delta\phi(\vec{\ell}, \boldsymbol{p}_T^{\text{miss}})))}.$
- $m_{CT}^2\,(b\text{-jet}_1, b\text{-jet}_2) = [E_T\,(b\text{-jet}_1) + E_T\,(b\text{-jet}_2)]^2 - [\boldsymbol{p}_T\,(b\text{-jet}_1) - \boldsymbol{p}_T\,(b\text{-jet}_2)]^2$
-

SUSY Models

mSUGRA/CMSSM Parameters

- → gravity-mediated SUSY breaking
- m_0: mass of scalar particles
- $m_{1/2}$: gaugino masses
- A_0: trilinear Higgs-sfermion-sfermion coupling parameter
- $\tan\beta = \nu_u/\nu_d$: ratio of the vacuum expectation values of the two Higgs doublets
- sign of the Higgsino mass parameter μ

GMSB Parameters

- → gauge-mediated SUSY breaking
- Λ: SUSY breaking mass scale felt by the low-energy sector
- M_{mes}: mass scale of the messenger fields
- N_5: number of SU(5) messenger fields
- C_{grav}: scale factor of the gravitino coupling
- $\tan\beta = \nu_u/\nu_d$: ratio of the vacuum expectation values of the two Higgs doublets
- sign of the Higgsino mass parameter μ

NGM

- starts from General Gauge Mediation
- GGM: no specific SUSY mass hierarchy is predicted for colored and uncolored states
  ⇒ gluinos and squarks can be below the TeV scale = within reach of LHC
- NGM: decouple all sparticles not related to fine-tuning of Higgs sector
  ⇒ light stop and light gluino as only light (relevant) coloured sparticle
- some additional mechanism needed (as in GMSB) to produce “correct” Higgs mass