Recent Results on SUSY and Exotica Searches at the LHC

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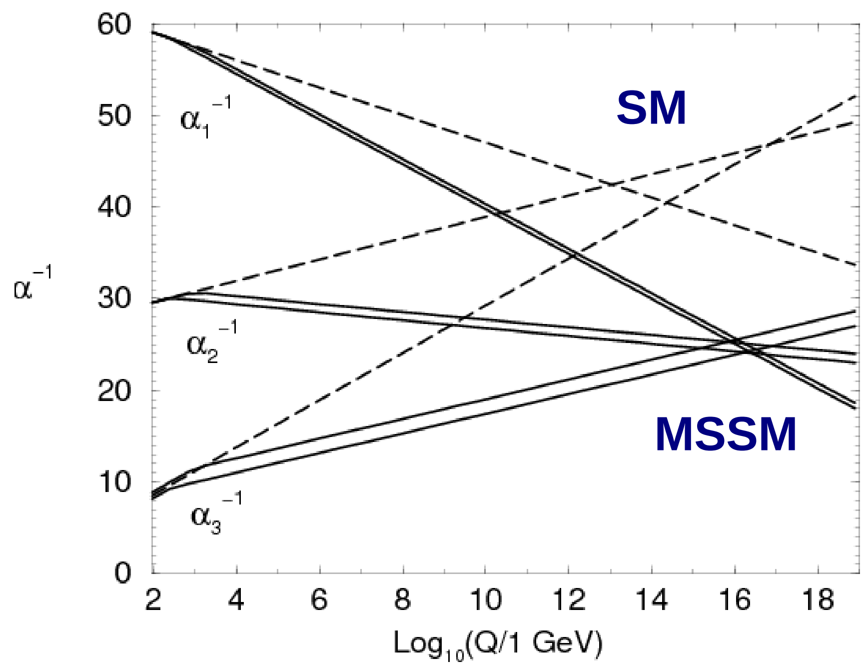
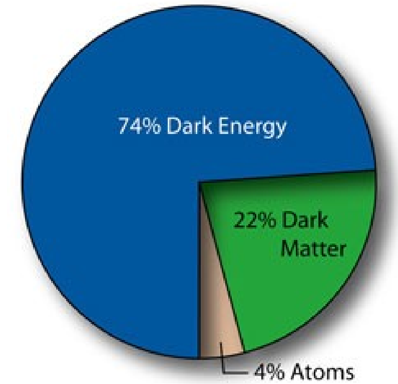
9th September 2014:
ISMD conference, Bologna

Why Beyond the Standard Model?

Gauge Couplings
Unifying theory beyond the Standard Model?



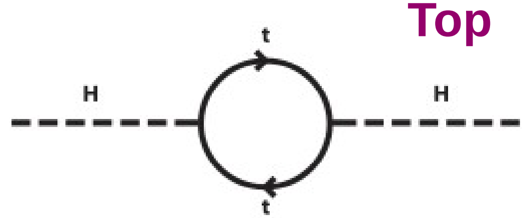
Dark Matter
Effects observed, but what is it?



Gravity
Weak and not easily incorporated into quantum field theory Standard Model

Hierarchy Problem
Divergence in Higgs mass due to divergent terms from couplings to massive particles

Top



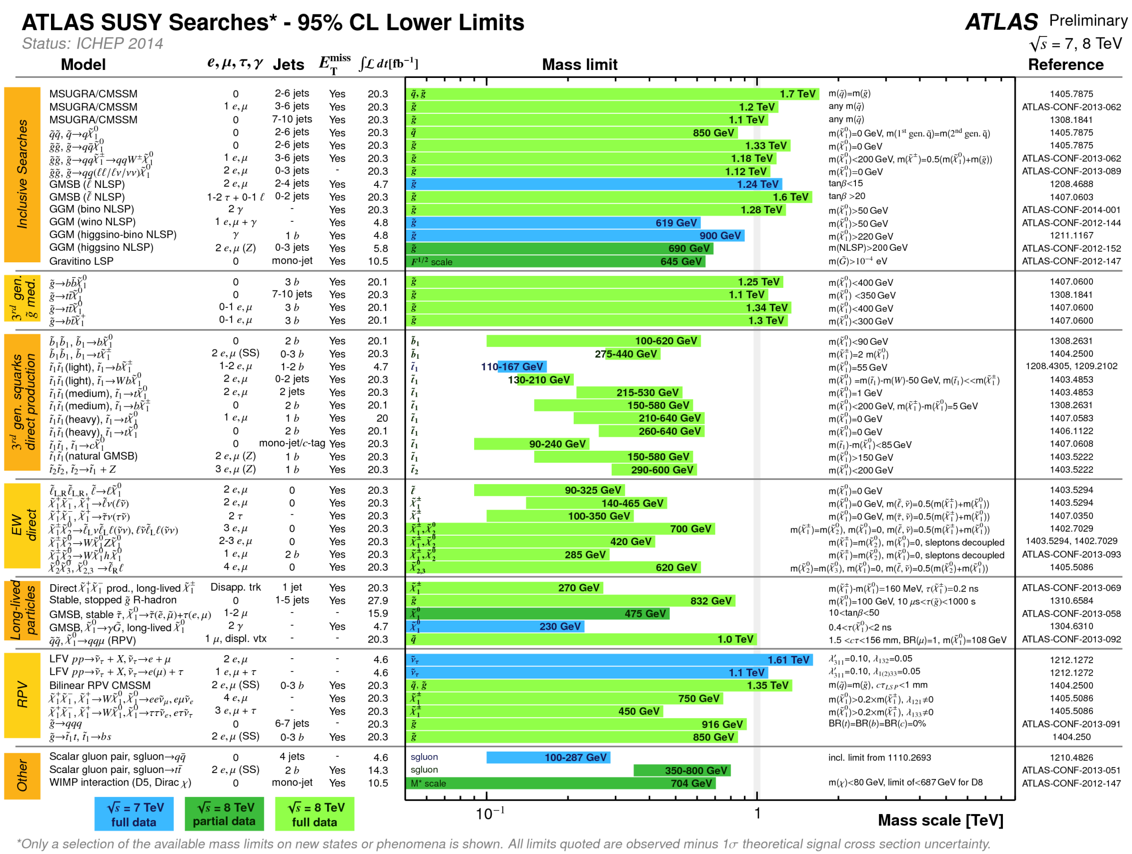
$$\Delta m_H^2 = -\frac{\lambda_f}{8\pi^2}\lambda_V^2 + ...$$

Stop

$$\Delta m_H^2 = \frac{\lambda_s}{16\pi^2}\lambda_V^2 + ...$$

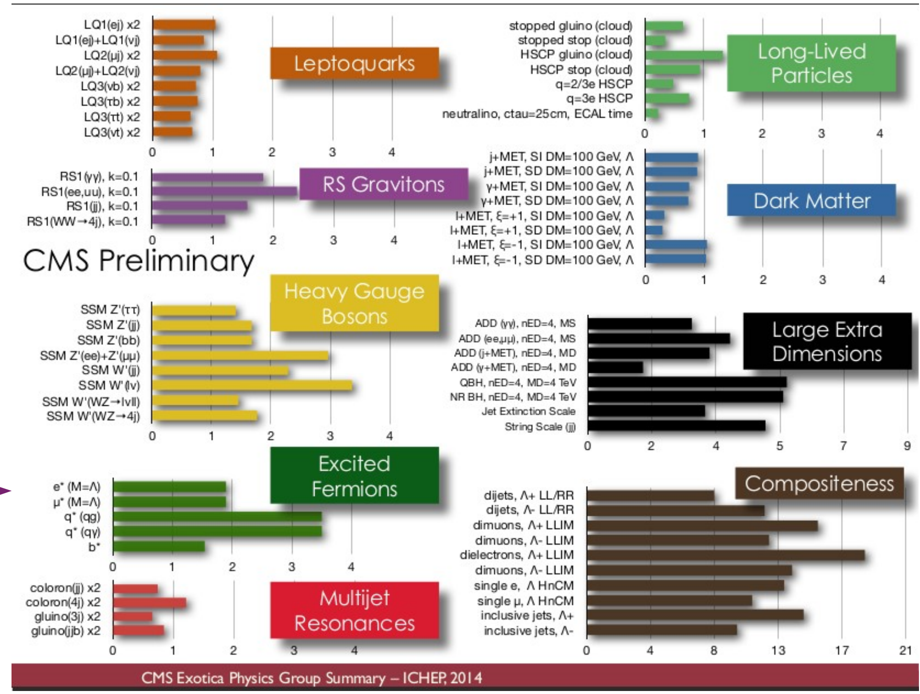
Outline

ATLASSUSYTwikiPublic   ATLASExoticResultsPublic



- BSM searches
  - Motivations and strategy
- Newest SUSY results
  - Strong production
  - Third Generation
  - Electroweak production and R-parity violation

(too many to show everything!)



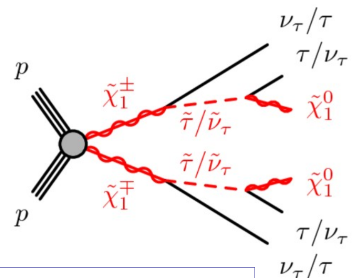
- Newest exotics results
  - Resonances
  - Long-lived particles
  - Other searches
- Conclusions and Outlook

CMSB2GResultsPublic   CMSExoticResultsPublic   CMSSUSYTwikiPublic

Search Strategy

1) Look at interesting signatures possibly based on models of interest e.g. simplified models

e.g. two taus originating from a SUSY model with light staus



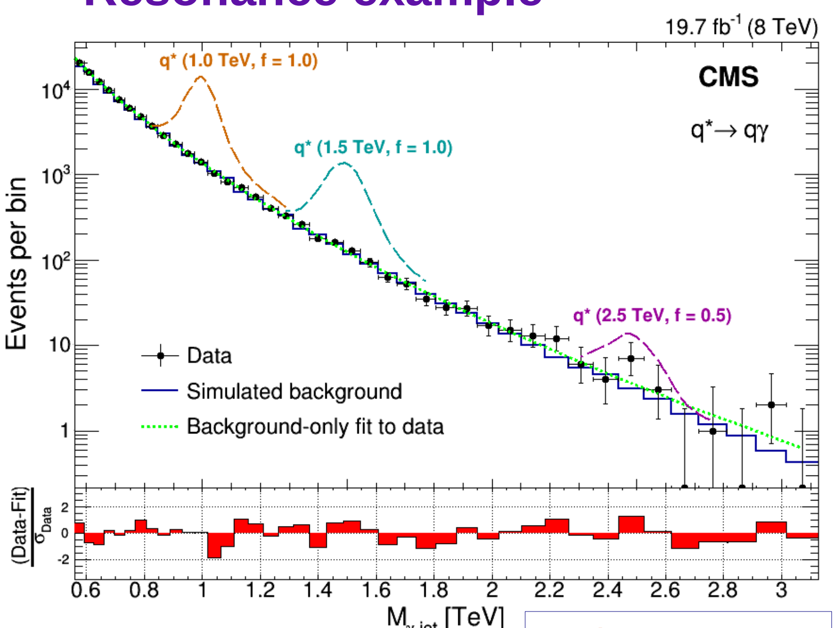
arxiv:1407.0350

2) Find cases where BSM signal is dominant over MC background e.g.

- Events passing object and kinematic requirements
- resonances in object distributions e.g. invariant mass

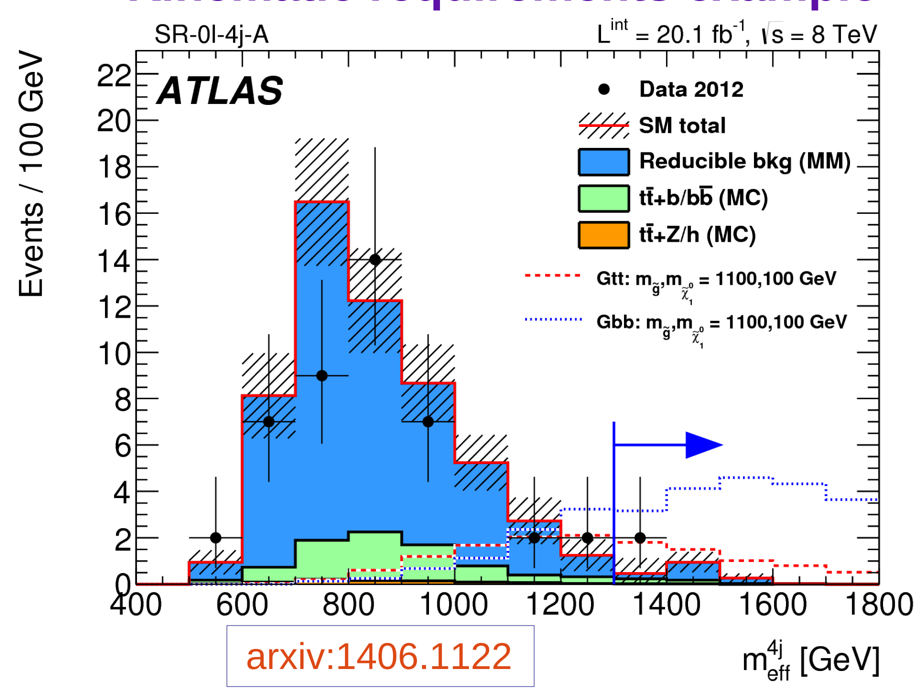
3) Look for discrepancy, or set limit on BSM process at given confidence level, CL

Resonance example



arxiv:1406.5171

Kinematic requirements example



arxiv:1406.1122

Understanding the Background

Important that background is modeled accurately

Irreducible – “real”

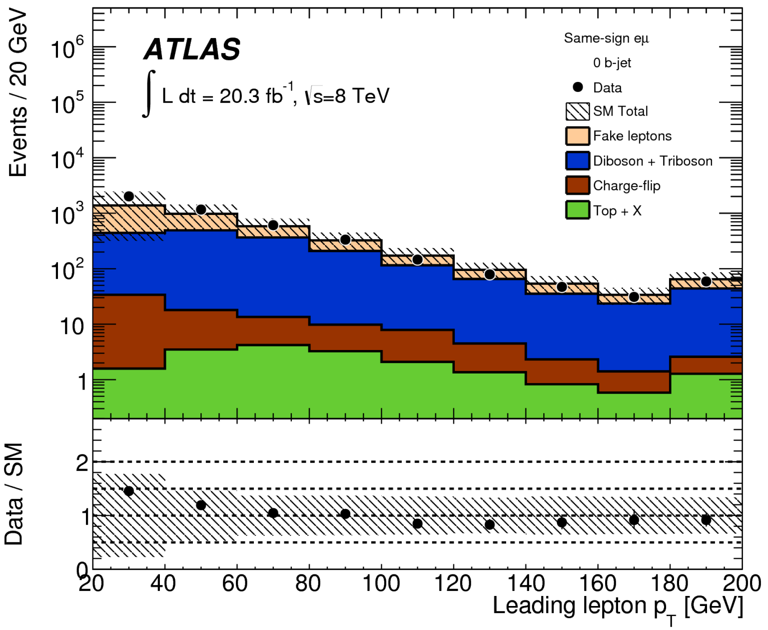
- **Dominant backgrounds** - normalise Monte Carlo to data in process specific **Control Regions** (CR)
- Can't overlap with Signal Region, but needs sufficient statistics and high purity of background process
- **Small backgrounds** – estimated from MC

Test in Validation Regions
- define to target specific background processes or estimation methods, without exposing data in signal regions
e.g. SS leptons and no b-jets VR

JHEP 06(2014)035

Reducible – “fake”

- **Jet smearing** techniques for backgrounds with fake E_T^{miss}
- **Weighting methods** for misidentified leptons e.g. “matrix method”
- Methods are **data-driven** and analysis dependent



Strong Production

1st and 2nd generation squarks and gluinos

ATLAS

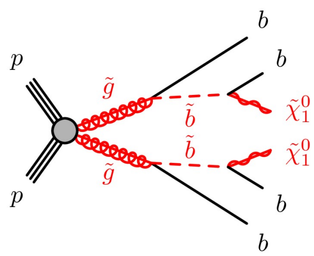
- $0\text{-}1l + \geq 3$ b-jets + E_T^{miss} arxiv:1405.7875
- $0l$ + 2-6 jets + E_T^{miss} arxiv:1405.7875
- Z + b-jet + jets + E_T^{miss} Eur.Phys.J.C(2014) 74:2883
- 2l(SS) / 3l + 0-3 b-jets + E_t^{miss} JHEP 06(2014)035
- $1\text{-}2\tau + 0\text{-}1l$ + jets + E_T^{miss} arxiv:1407.0603

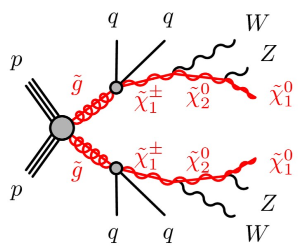
CMS

- $0l$ +3-5, 6-7, ≥8 jets + E_t^{miss} JHEP 06(2014)055
- 1l + jets + b-jets PLB 733 328 (2014)
- Razor 0l + 1l SUS-14-011
- 2l(SS) + jets JHEP 01(2014)163
- ≥3l arxiv:1404.5801

Most recently published or accepted papers and notes (lots more for both experiments!)

Squark Gluino Searches





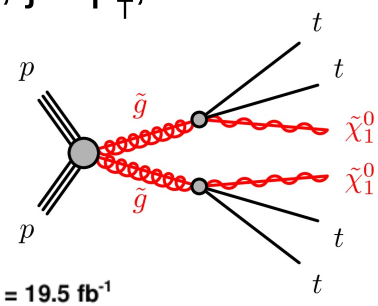
Three or more bjets

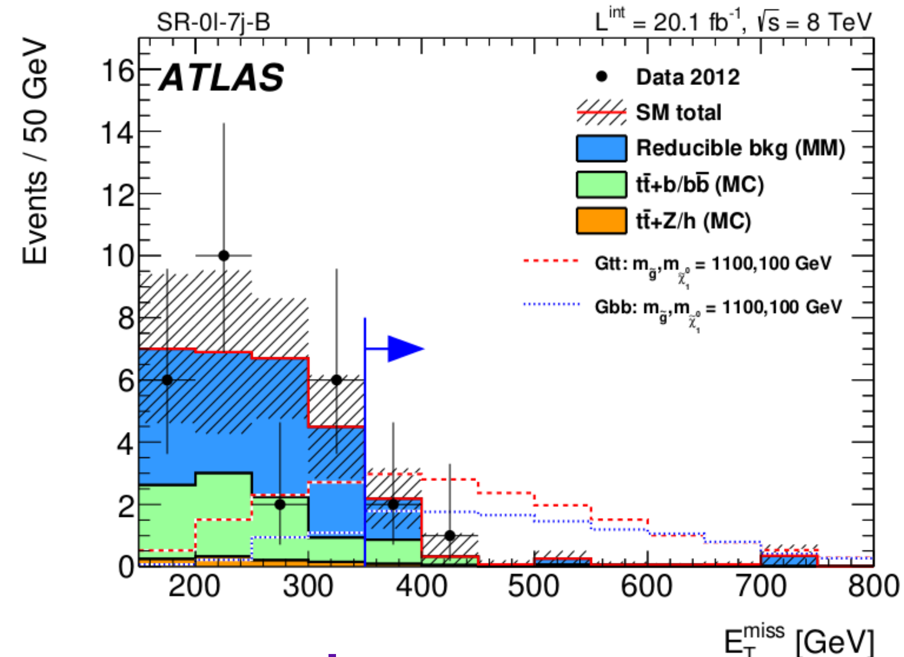
Select events with;

- 0 or 1 lepton,
- ≥4 or ≥7 jets,
- with ≥3 b-jets
- kinematic variables combining E_T^{miss}, jet p_T, lep p_T + more

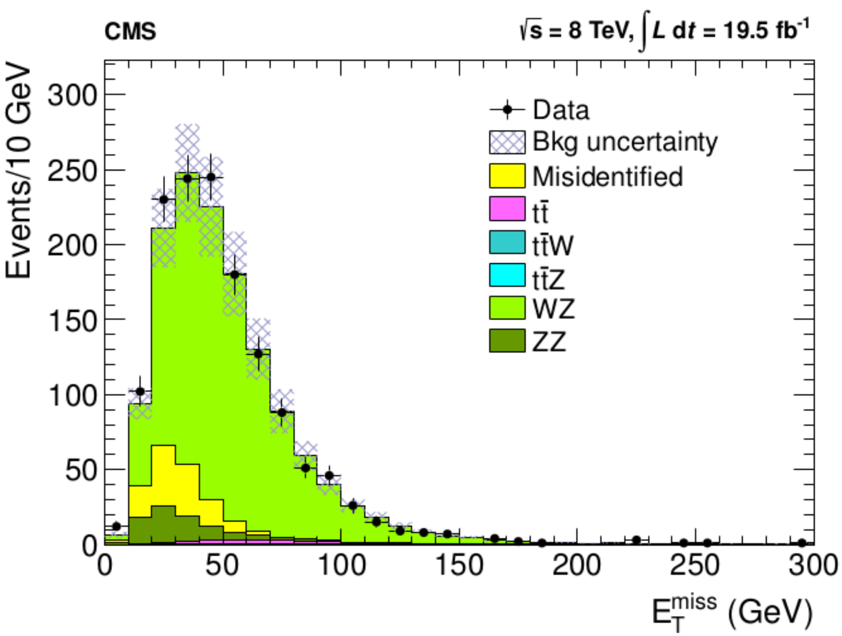
→ **9 SRs**

arxiv:1405.7875



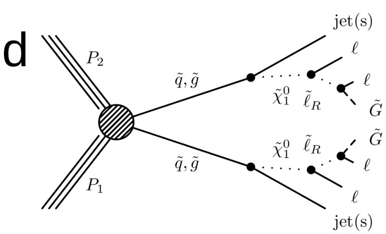


No excesses observed



Three or more leptons

Irreducible contributions from WZ and ZZ – lepton isolation requirements.



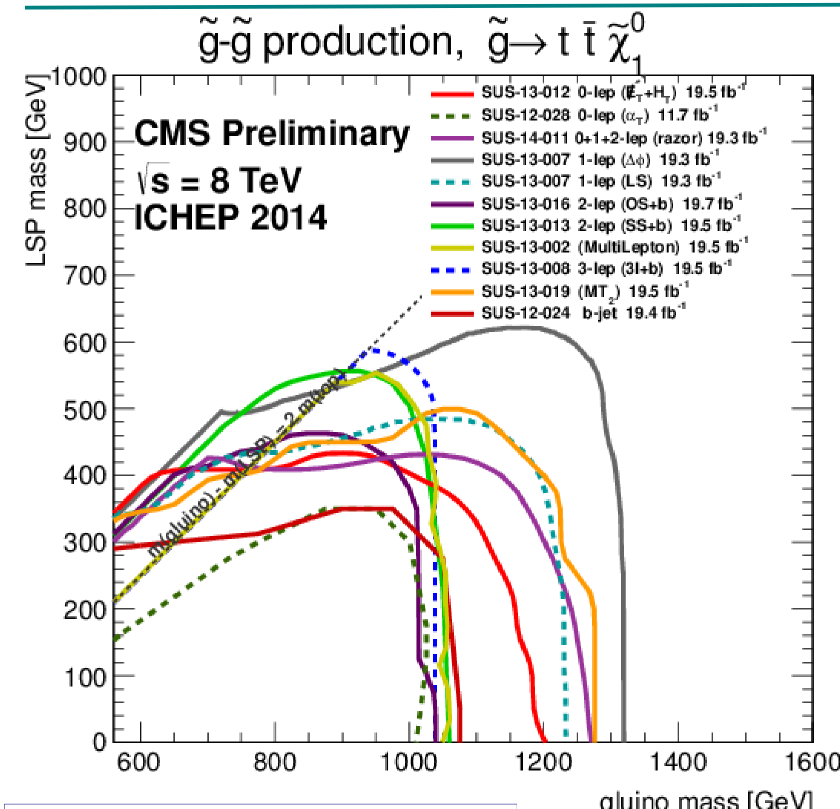
Split into large number of regions -

- 3 or ≥4 leptons
- Sign and flavour of lepton pairs
- Lepton pair invariant mass, m_{ll}
- E_T^{miss} and H_T (jet transverse momentum)

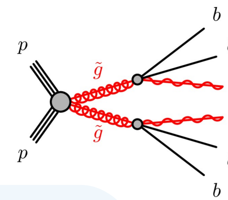
arxiv:1404.5801

Also interpret in 3rd generation SUSY and rare flavour-violating decay t→cH

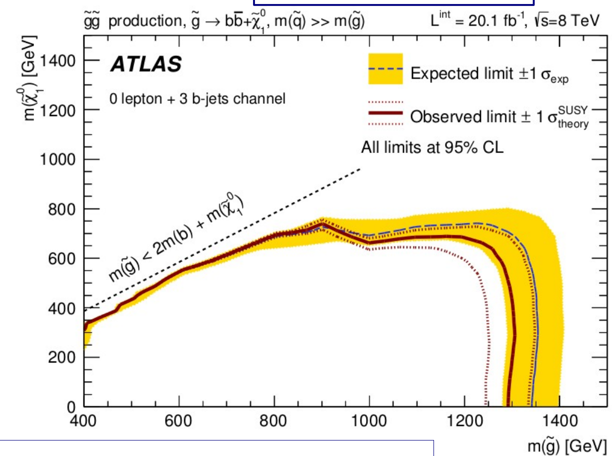
Squark Gluino Summary



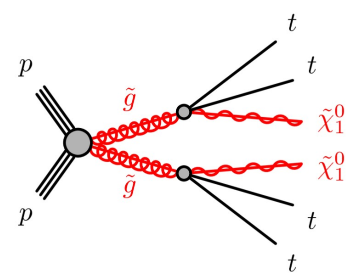
CMSSummaryPlots8TeV



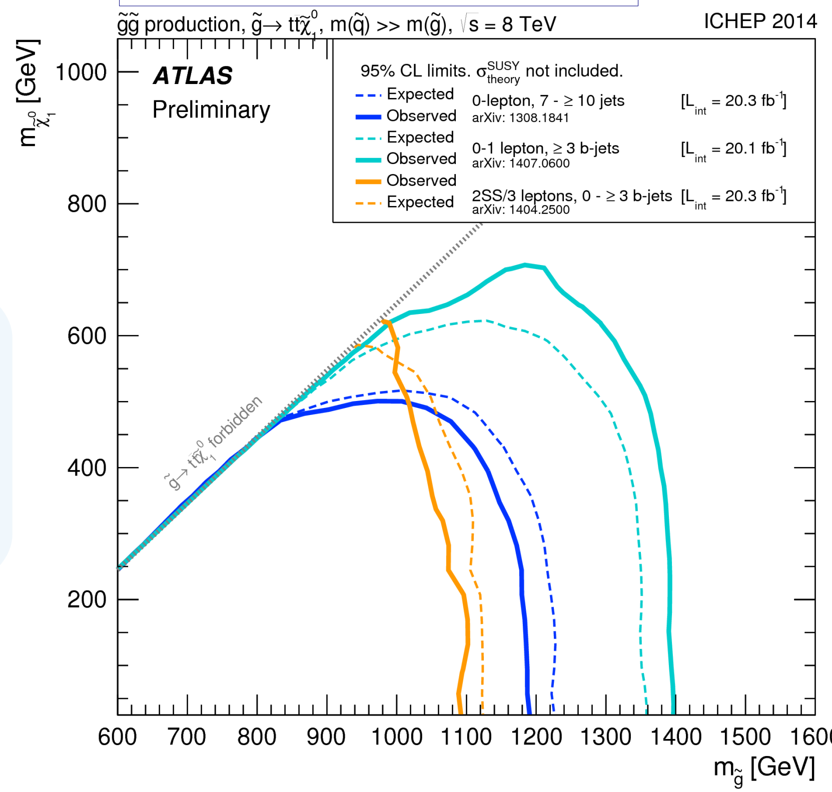
arxiv:1405.7875

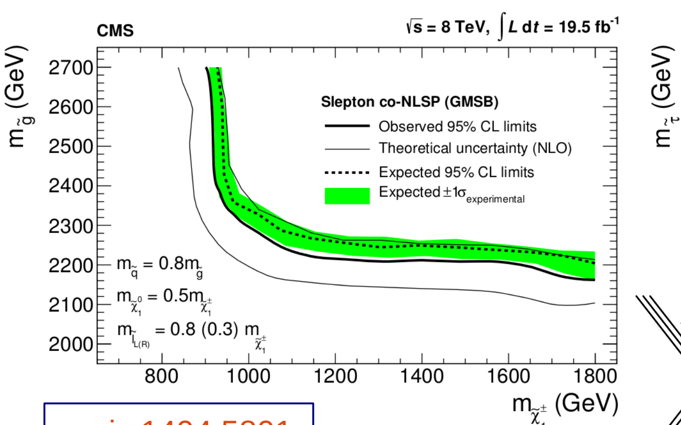


Complementary analyses using different signatures for ATLAS and CMS.



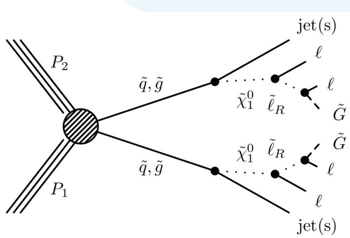
ATLASSummaryPlots8TeV





arxiv:1404.5801

Lots of limits for other strong scenarios – far too many to show!



Third Generation

Direct production of stops and sbottoms

ATLAS

0l +6(2 b-)jets + E_T^{miss} arxiv:1406.1122

0l + monojet/c-jets + E_T^{miss} arxiv:1407.0608

1l + 4(1 b)-jets + E_T^{miss} arxiv:1407.0583

2l + b-jets + E_T^{miss} JHEP 06(2014)124

2l (eμ) ATLAS-CONF-2014-014

$t\bar{t}$ cross-section arxiv:1406.5375

CMS

Diphoton + ≥2 b-jets PRL 112,161802(2014)

0l + 2(≥1 b-)jets + E_T^{miss} PAS-SUS-13-018

0l + monojet + E_T^{miss} PAS-SUS-13-009

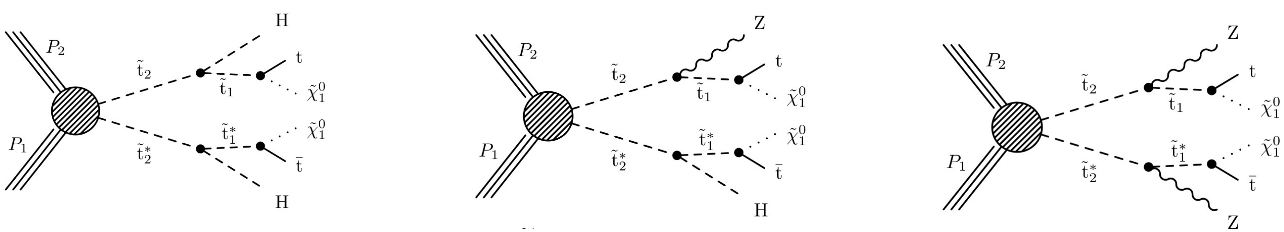
1l (eμ), jets, + E_T^{miss} EPJC 73(2013)2677

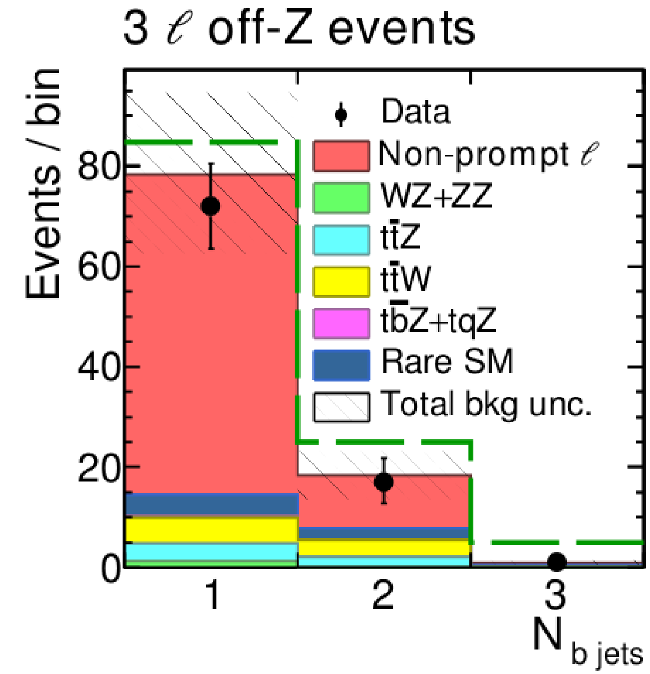
1l, 2l, or ≥3l, and ≥1 or ≥3 b-jets PLB 736371(2014)

Most recently published or accepted papers and notes (lots more for both experiments!)

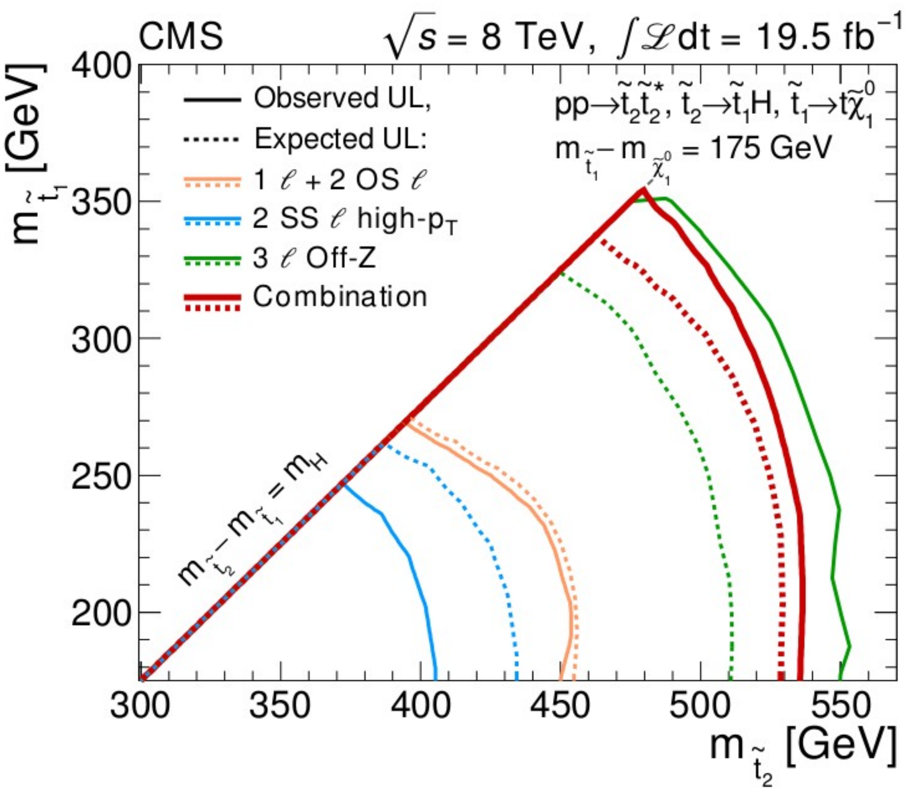
Third Generation Searches

One, two or three+ leptons and one or three b-jets





- Target heavier stop$_2$ decays to target region where $m_{\tilde{t}} - m_{\chi_1^0} \approx m_t$
- Decays produce a Z and/or H with 100% BR



No excesses observed

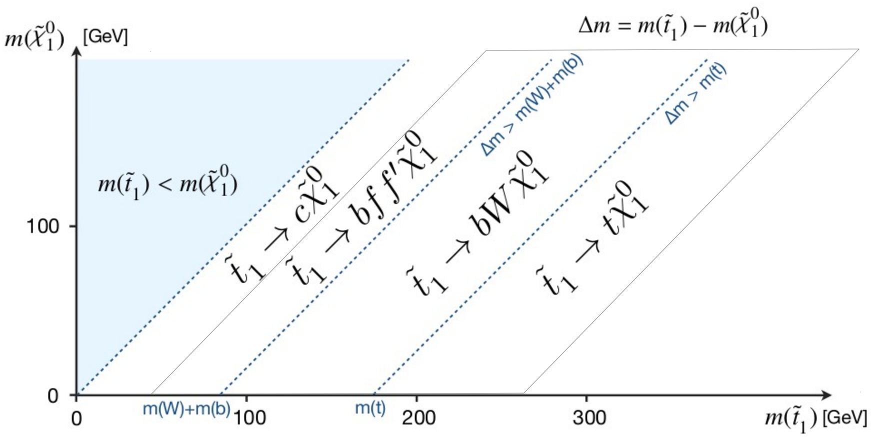
- Split by number of leptons and b-jets
- Use multiple kinematic variables e.g. E_T^{miss}, p_T and m_T
- → **96 SRs** $\quad m_T = \sqrt{2 E_T^{miss} p_T^l (1 - \cos(\Delta\varphi(E_T^{miss}, l)))}$
- Limits in stop$_1$ stop$_2$ mass plane, but indirectly probes difficult region of stop$_1$ χ_1^0 mass plane

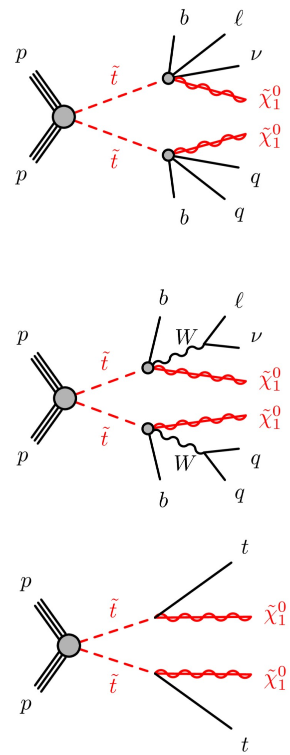
PLB 736371(2014)

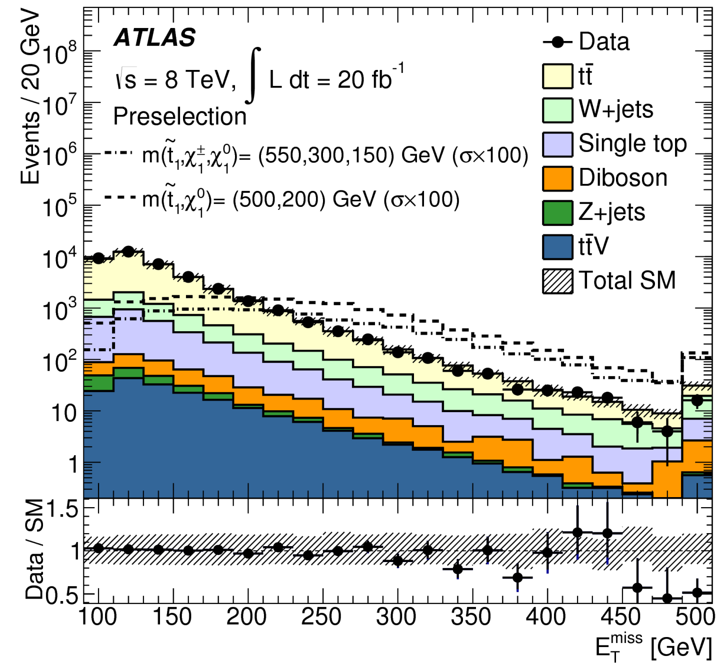
Third Generation Searches

One lepton and four(one b-)jets

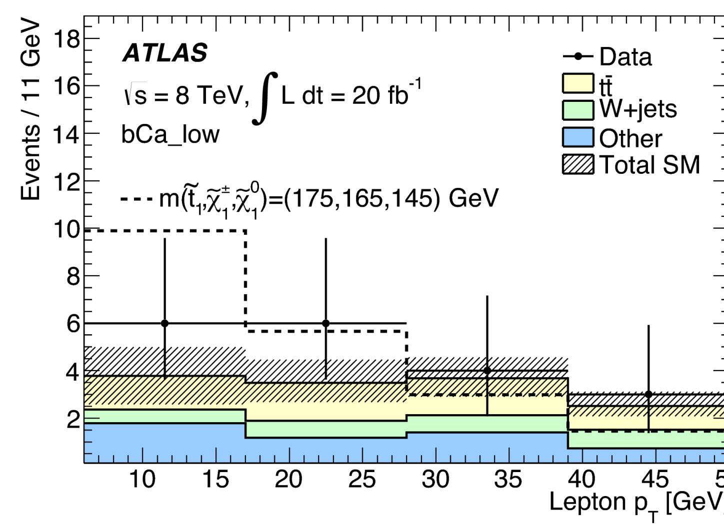
- Target 2, 3, 4 body stop decays in t + χ_1^0 as well as b $\chi_1^\pm$ stop decays with different mass splitting assumptions
- Uses both cut and count and shape fit methods to search for deviations from the Standard Model







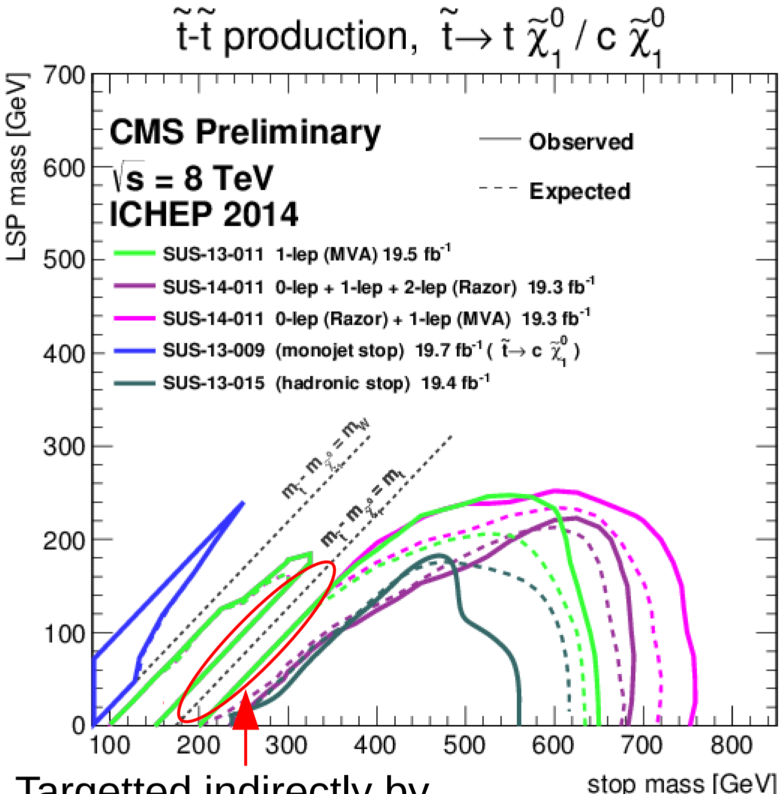
No excesses observed



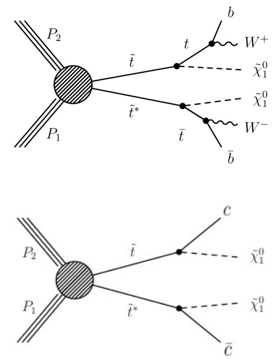
arxiv:1407.0583

- Various variables target different kinematic regions, e.g. **m_T** combinations, **soft leptons** for low mass stop/compressed scenarios and **large- R jets** for heavy stop (boosted)

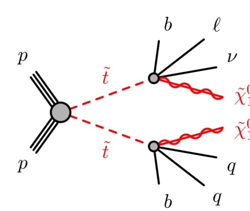
Third Generation Summary

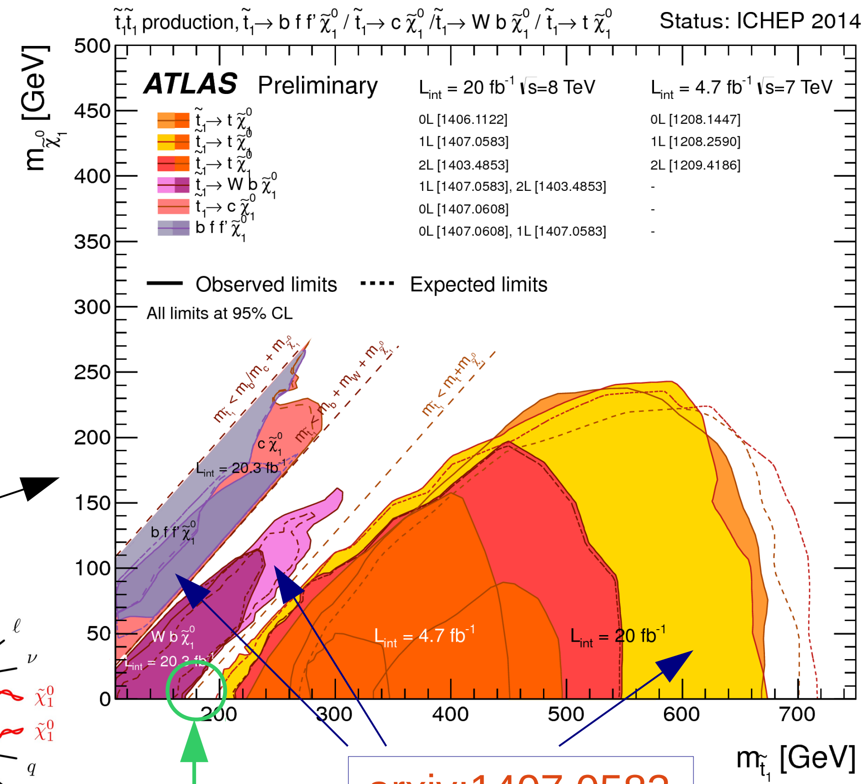


Targetted indirectly by $stop_2 \rightarrow stop_1$ search

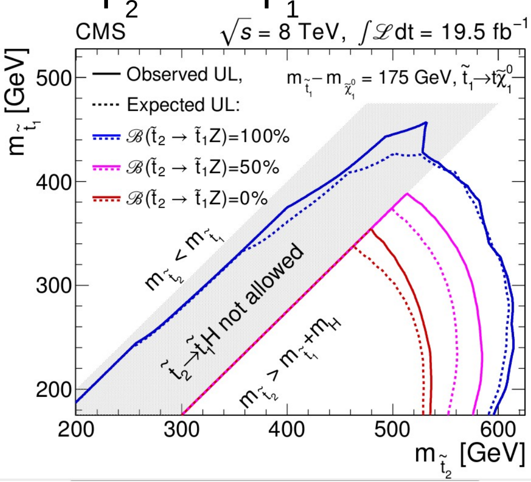


Additional decay included





arxiv:1407.0583

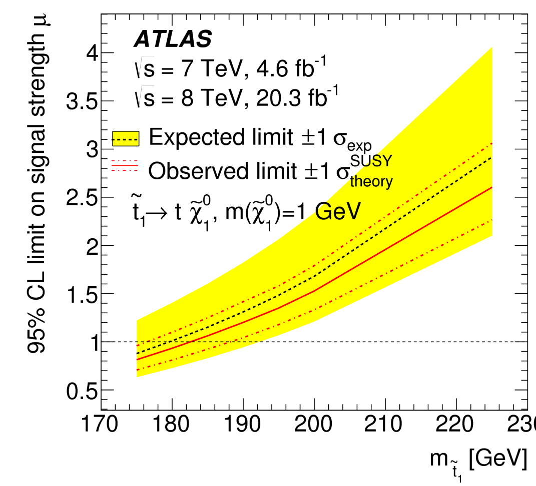


Lots more analyses targeting direct stop and sbottom production

PLB 736371(2014)

Region where stop mass ≈ top mass constrained by recent $t\bar{t}$ cross-section measurement

arxiv:1406.5375



Electroweak Production

Neutralinos, charginos and sleptons

and R-parity violation

ATLAS

1l + bb(H) + E_T^{miss}	ATLAS-CONF-2013-093
2l (eμ) + E_T^{miss}	JHEP 05(2014)071
2τ + E_T^{miss}	arxiv:1407.0350
3l + E_T^{miss}	JHEP 04(2014)169
4l + E_T^{miss}	arxiv:1405.5086

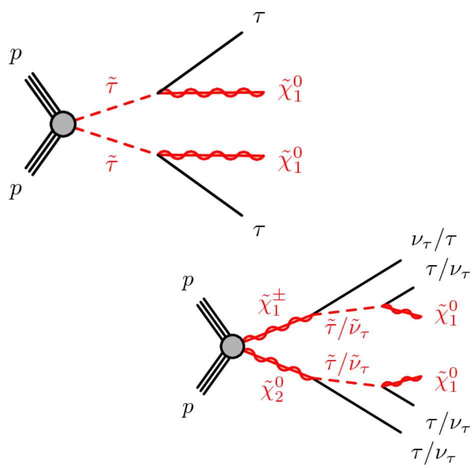
CMS

0l + 4/5 jets	arxiv:1404.5801
1l, 2l, 3l or 4l + E_T^{miss}	arxiv:1405.7570
Chargino neutralino → H,Z,W states (many)	PAS-SUS-14-002
3l (RPV)	PRL 111,221801(2013)

Most recently published or accepted papers and notes (lots more for both experiments!)

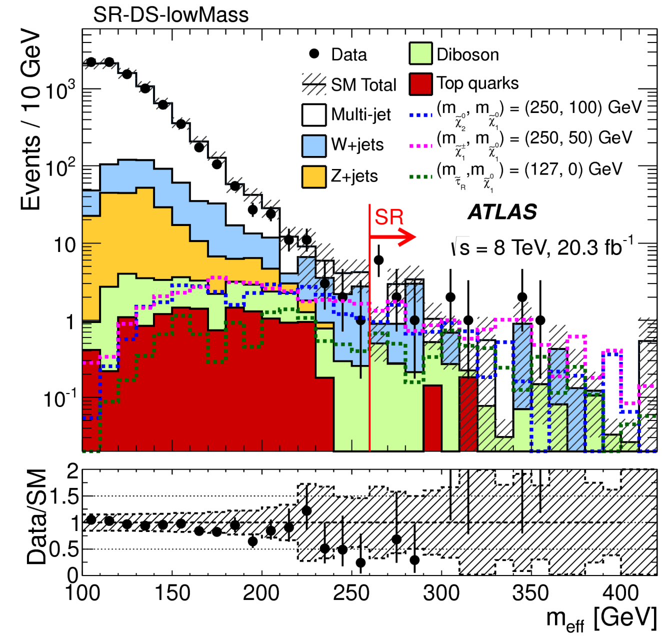
Electroweak Searches

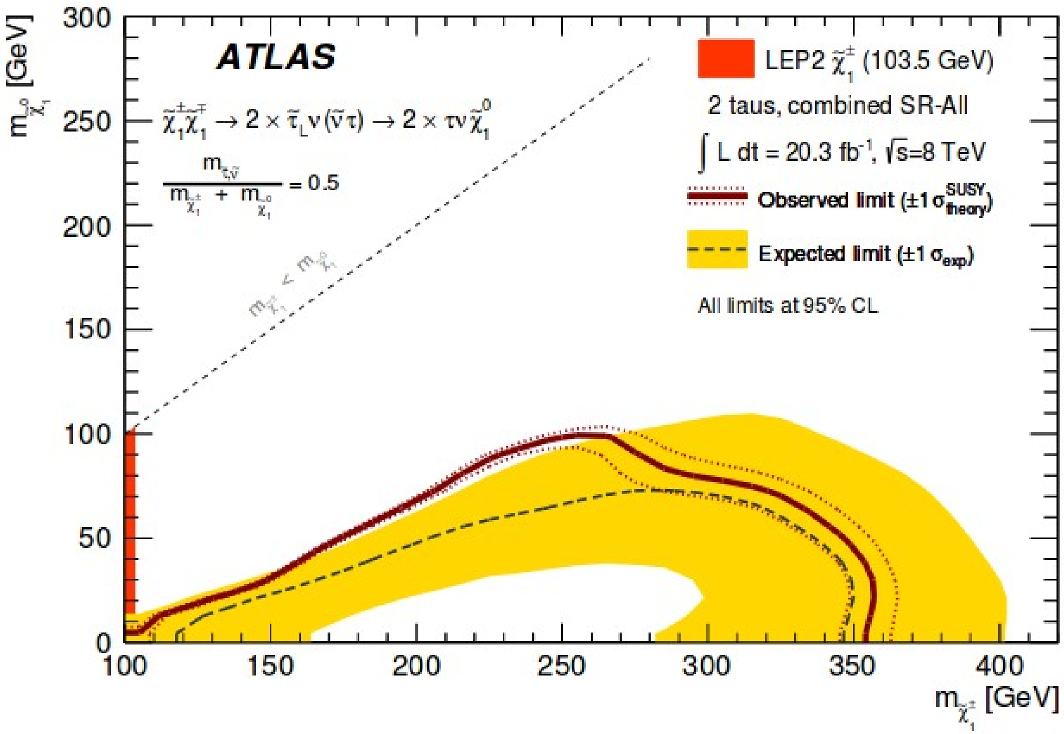
Two taus and missing transverse energy



- Targets direct stau production and chargino neutralino/chargino chargino decays through a stau

arxiv:1407.0350





No excesses observed

- 4 SRs, all with;
  - 2 opposite sign taus,
  - some sort of jet veto
  - cuts on E_T^{miss}, m_T combinations or m_{eff}

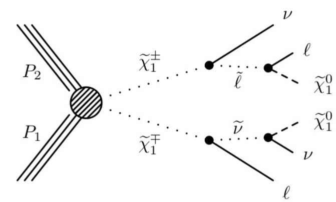
$$m_{eff} = E_T^{miss} + p_T^{\tau_1} + p_T^{\tau_2}$$

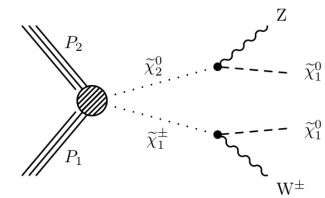
Electroweak Searches

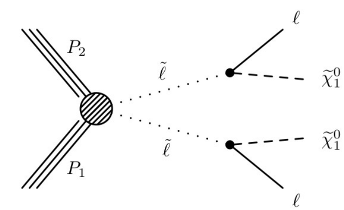
One, two, three or four leptons and missing transverse energy

- Events are split by number of lepton, some use "**binned**" signal regions

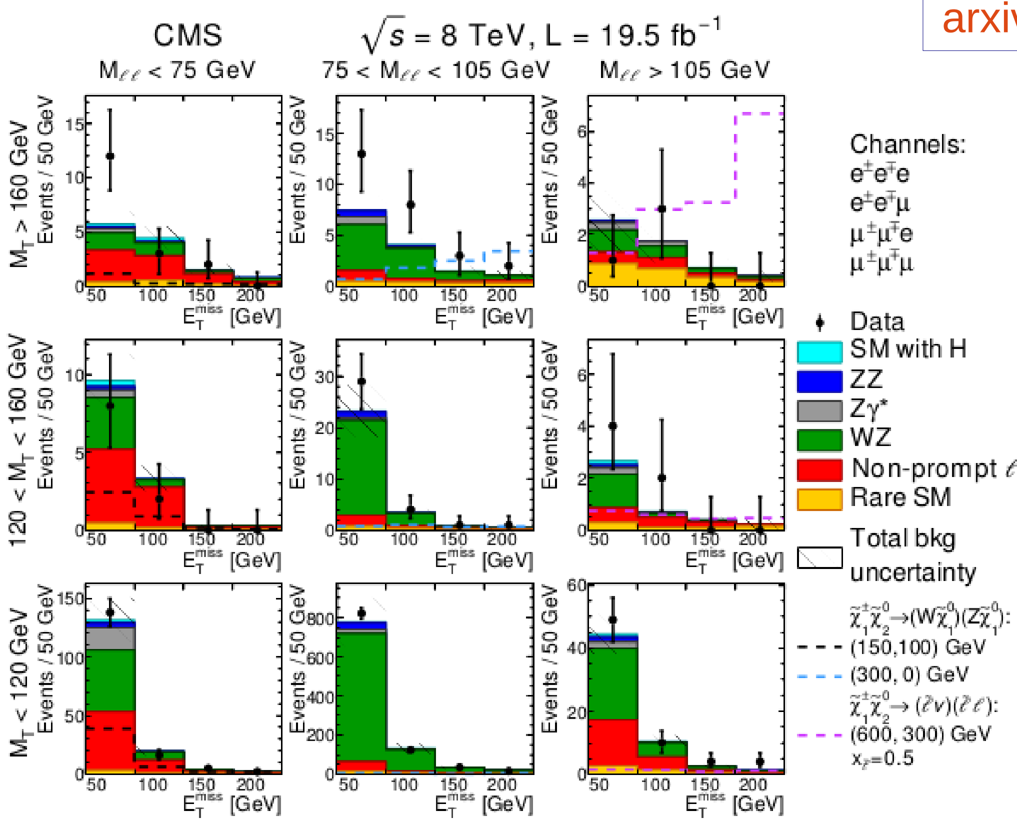
No excesses observed





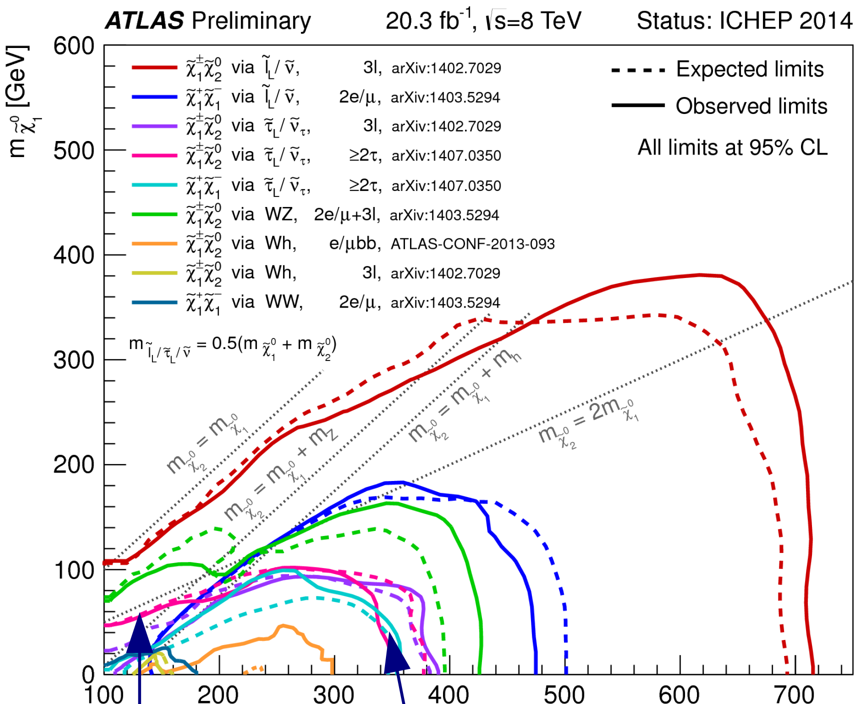


arxiv:1405.7570

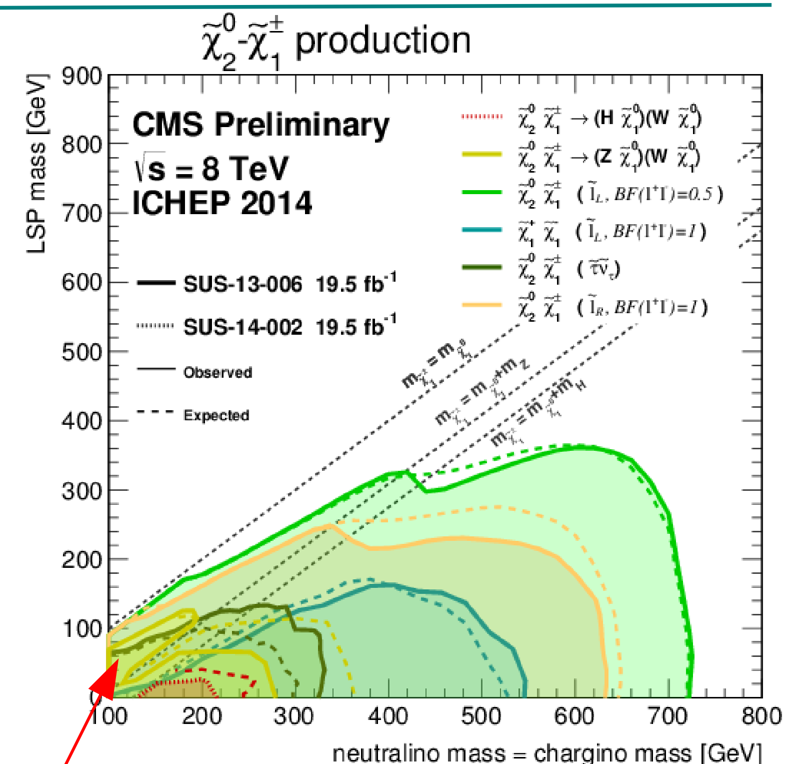


- One lepton targets $\chi_1^{\pm}\chi_2^0 \to$ WH
- Two lepton targets direct slepton production (and three lepton scenarios where one lepton is lost)
- Three leptons target $\chi_1^{\pm}\chi_2^0$ through sleptons or to ZH, ZZ or WH
- Four lepton is interpreted in GMSB

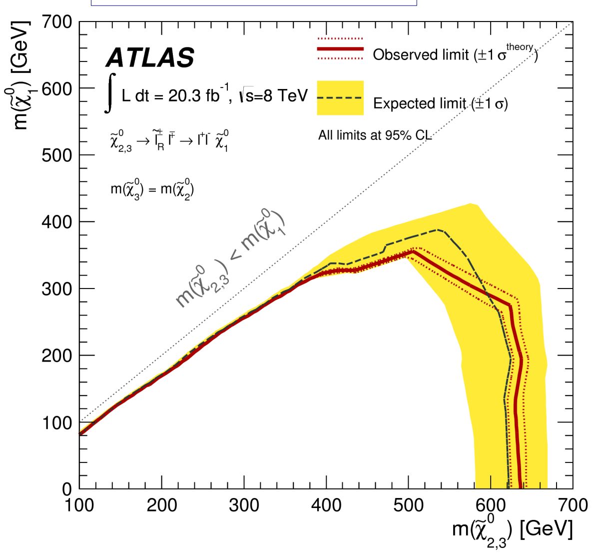
Electroweak Summary



arxiv:1407.0350



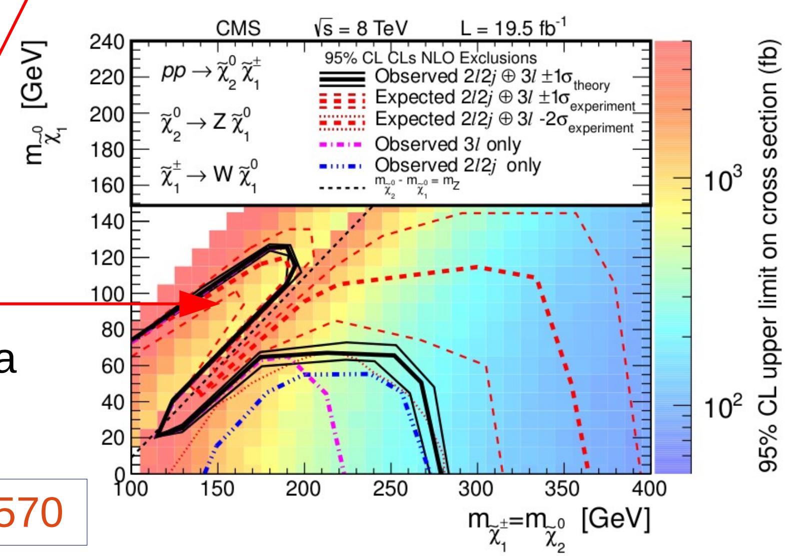
Analyses of both experiments cover wide range of possible decays of neutralino chargino production



Lots of limits in other scenarios e.g. $\chi_2^0\chi_3^0$ via slepton

arxiv:1405.5086

Challenging region of chargino neutralino via WZ grid



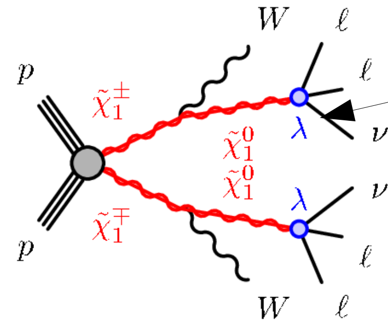
arxiv:1405.7570

R-Parity Violation

R-parity

$$R_P = (-1)^{3(B-L)+2S}$$

+1 for particles, -1 for sparticles
Not conserved → LSP decay



Products of LSP decay depend on λ coupling

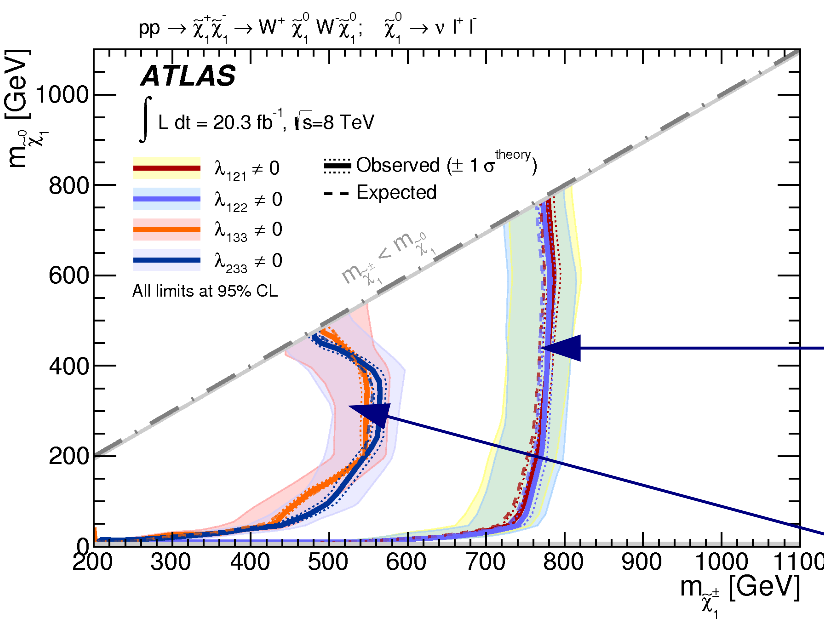
RPV superpotential

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

Four leptons and missing transverse energy

- Versatile analysis – interpreted in EWK, general gauge mediated and R-parity violating (mostly EWK) models
- Very low backgrounds
- 9 SRs containing 0,1 or 2 taus

arxiv:1405.5086

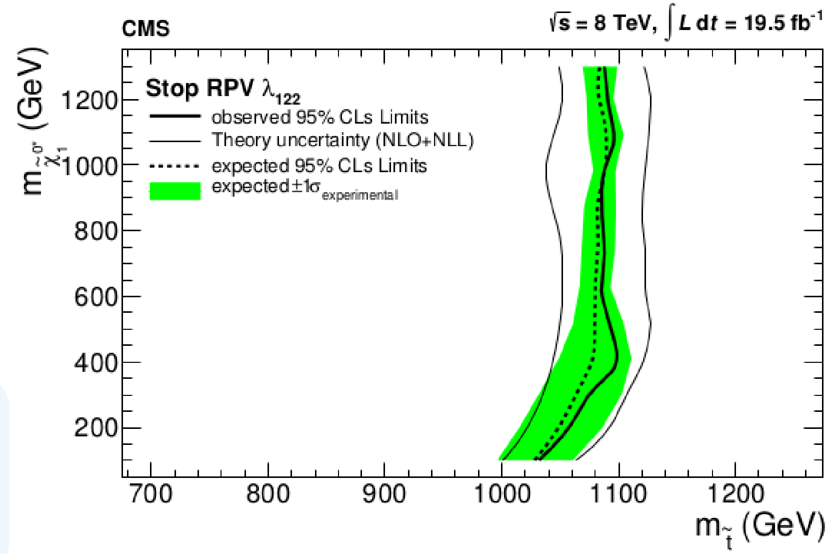


Decay to electrons and muons

Decay to taus

No excesses observed

Three leptons



- Cover non-zero λ and λ' terms
- 8 SRs target R-parity violating stop decays
- Some include b-jets, and are binned in S_T $\quad S_T = E_T^{miss} + E_T^{jets} + E_T^{l}$

PRL 111,221801(2013)

Resonances

ATLAS

Diboson → llqq	ATLAS-CONF-2014-039
Diboson → lllυ (WZ)	arxiv:1406.4456
Wγ + Zγ → ll/lυ (e,μ)	arxiv:1407.8150
Heavy quarks → Z+t/b	ATLAS-CONF-2014-036
W' → $t\bar{b}$ → $b\bar{b}qq'$	arxiv:1408.0886
Di-jet mass spectrum	arxiv:1407.1376
Z → eμ pairs	arxiv: 1408.5774
1l + E_t^{miss}	arxiv:1407.7494

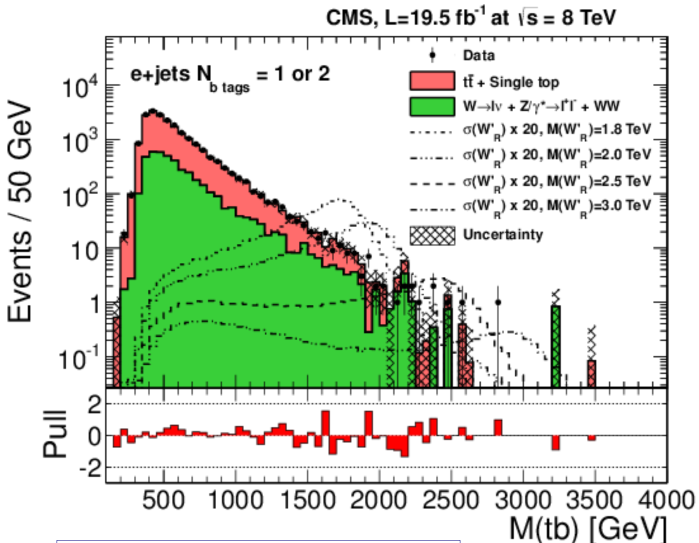
CMS

Diboson → llqq	arxiv:1405.3447
Diboson → jets	arxiv:1405.1994
Contact → 2l	CMS-PAS-EXO-120-20
Q* → γ + jets	arxiv:1406.5171
W/techno-rho → WZ	arxiv:1407.3476
t + b → hadrons	B2G-12-009
t + b → semi-leptonic	JHEP 05(2014)108
Heavy υs and W_R → 2l +2 jets	arxiv:1407.3683
$t\bar{t}$ resonances	Phs Rev Lett 111.211804

Most recently published or accepted papers and notes (lots more for both experiments!)

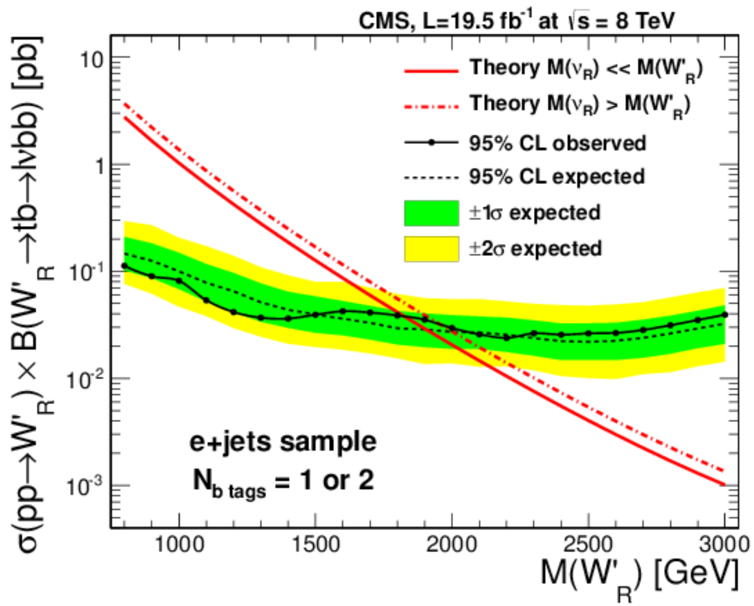
Resonance Searches

W' → t+b semi-leptonic

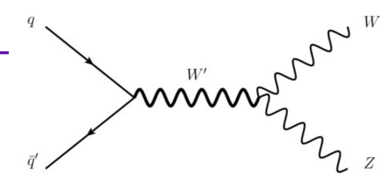


JHEP 05(2014)108

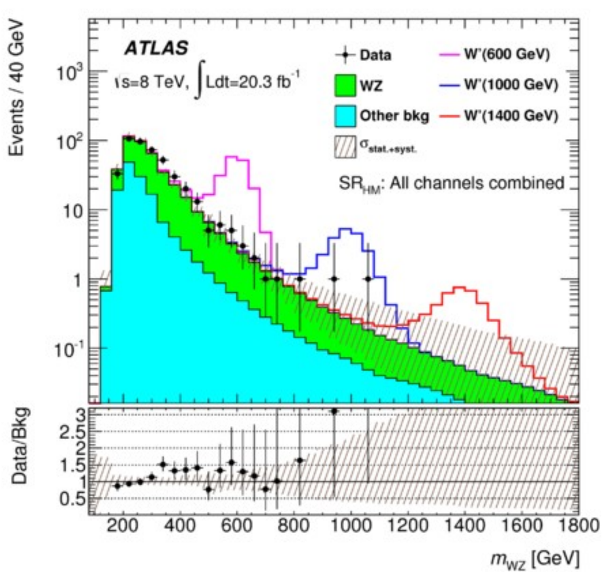
- Select high p_T e/μ,
  - E_T^{miss} > 20,
  - ≥2(1 b-)jets
- Use lepton charge, flavour, mass etc to select **best tb candidate**
- Compare invariant mass to SM background
- Limits on W' cross-section



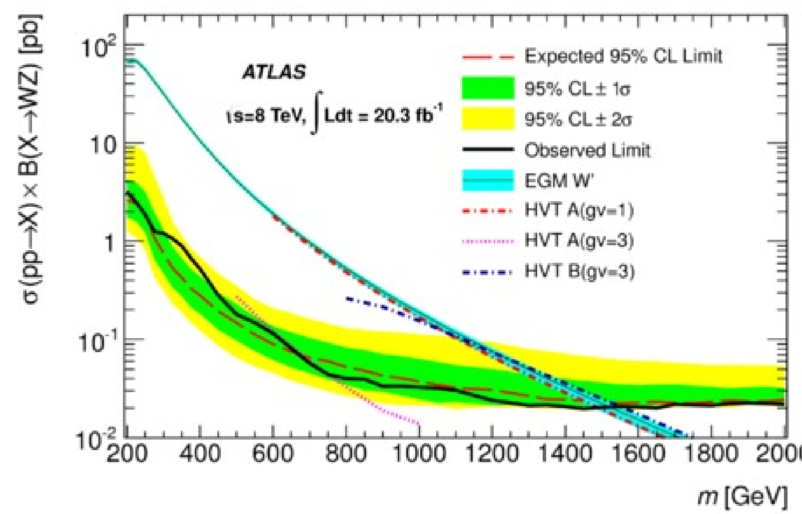
W' → WZ fully leptonic



arxiv:1406.4456



- Select
  - Three leptons
  - E_T^{miss} > 25
- Use m_{ll}, $\Delta\Phi(l,E_T^{miss})$ etc to select **best WZ candidate**
- Compare invariant mass to background
- Limits on W' boson cross-section and HVT couplings



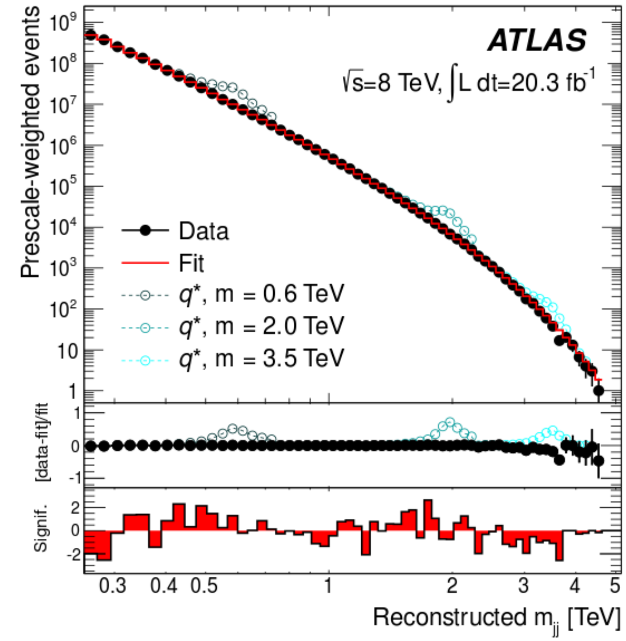
Resonance Searches

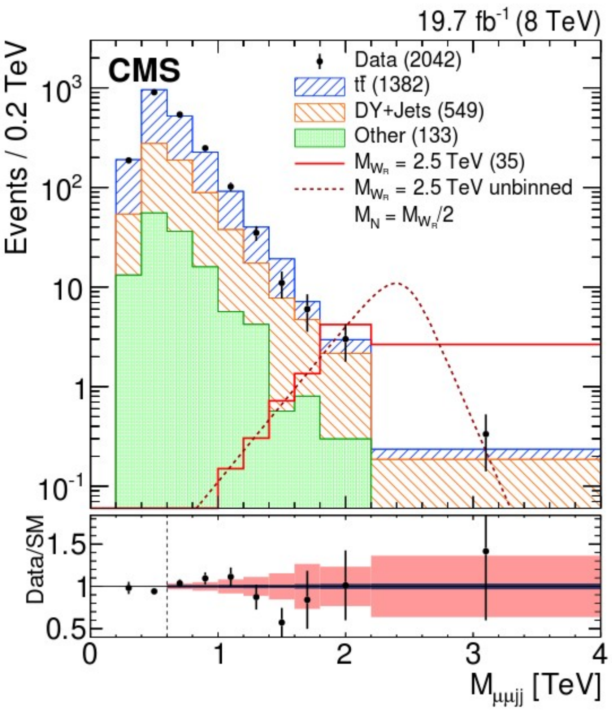
arxiv:1407.1376

Dijet mass

Model and Final State	95% CL Limits [TeV] Expected	Observed
$q^* \to qg$	3.99	4.09
$s8 \to gg$	2.83	2.72
$W' \to q\bar{q}'$	2.51	2.45
Leptophobic $W^* \to q\bar{q}'$	1.93	1.75
Leptophilic $W^* \to q\bar{q}'$	1.67	1.66
QBH black holes (q and g decays only)	5.82	5.82
BlackMax black holes (all decays)	5.75	5.75

- Select ≥2 jets
- Construct mass for two highest p_T jets
- Background fit to function
- Limits on 7 specific theories (see table) but sensitive to anything resulting in jets with these masses

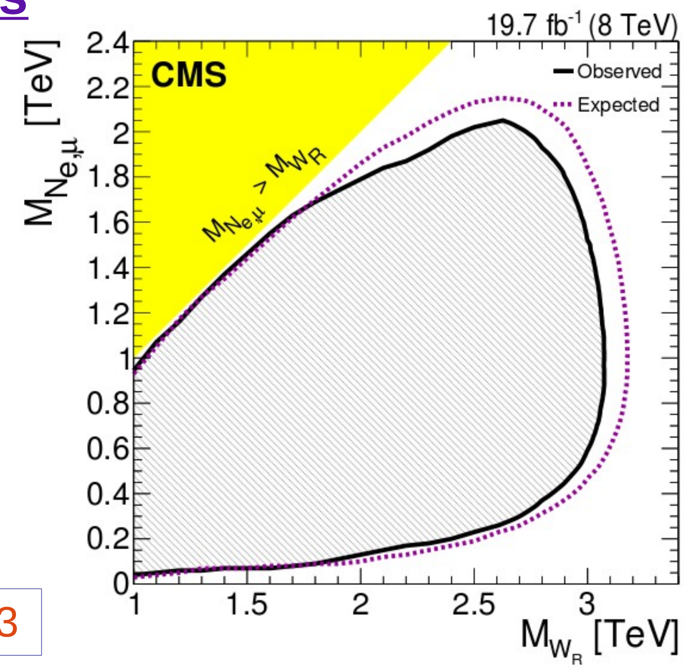




Heavy νs and W_R →2 l + 2 jets

- Select 2 highest p_T leptons and 2 highest p_T jets
- Split into e or μ events
- Left right (LR) symmetric extensions predict heavy neutrinos and right handed W bosons
- Limits on both particles for this scenario

arxiv:1407.1683



Long-lived Particles

ATLAS

Long-lived neutral particles ATLAS-CONF-2014-041

Meta-stable gluinos (SUSY) ATLAS-CONF-2014-037

Long-lived stopped R-hadrons (Split SUSY) Phys Rev D 88,112003(2013)

Disappearing track + jets + E_T^{miss} Phys Rev D 88,112006(2013)

Muon + displaced vertex ATLAS-CONF-2013-092

CMS

Long-lived neutral particles CMS-PAS-EXO-120-38

Displaced dilepton Pairs CMS-PAS-EXO-120-37

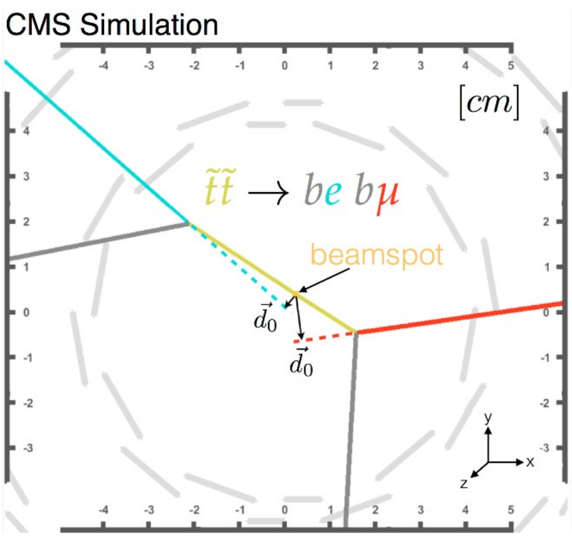
Displaced supersymmetry → 2l B2G-12-024

Most recently published or accepted papers and notes (lots more for both experiments!)

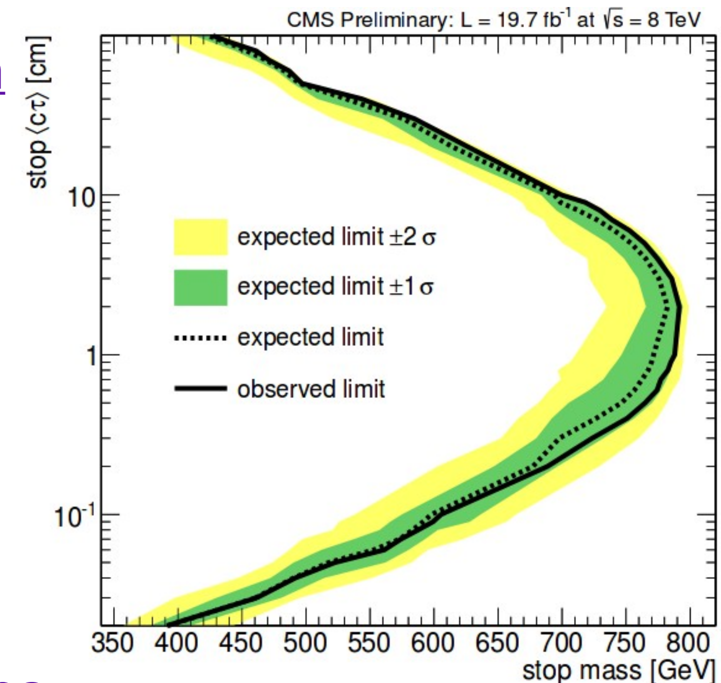
Long-lived Particle Searches

B2G-12-024

Displaced Supersymmetry Dilepton

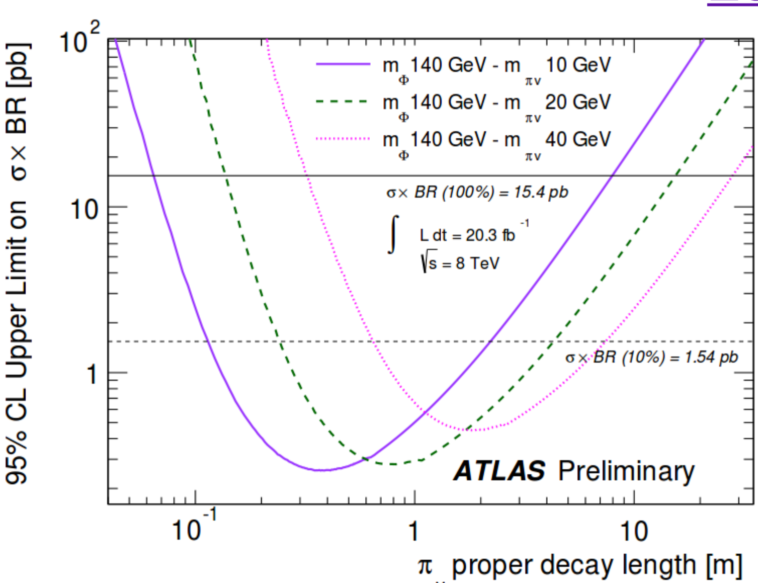


- Select opposite sign eμ pairs > 0.5 apart in θ and φ
- Regions with varying **impact parameter** requirements reduce background and are sensitive to range of scenarios
- Interpret in displaced SUSY model with Stop LSP – weak RPV decay to leptons

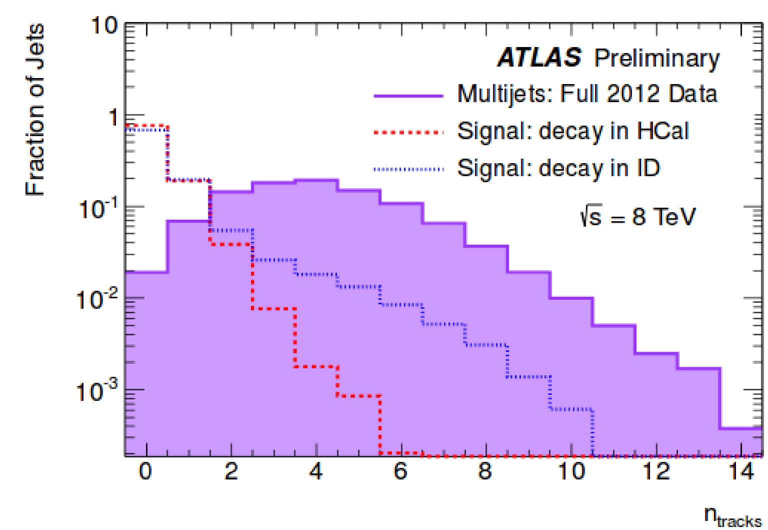


Long lived neutral particles

ATLAS-CONF-2014-041



- Select 2 jets with no "good" tracks in inner detector
- Use **timing** to reject background
- Interpret in "Hidden Valley" model – triplet of heavy "valley pions" decay to SM particles



Other searches

ATLAS

Non-resonant 2l arxiv:1407.2410

1l + jets (black holes) JHEP 08(2014)103

Generic Search ATLAS-CONF-2014-006

Mono + X searches ATL-PHYS-PUB-2014-007 PhysRevLett.112.014802

CMS

Leptoquark searches arxiv.1408.0806 CMS-PAS-EXO-120-41 CMS-PAS-EXO-130-10

DM + t → 1l + jets B2G-14004

Monophoton CMS-PAS-EXO-120-47

Monojet arxiv:1408.3583

Vector-like quark Searches Phys Rev Lett 112.171801 Phys Lett B 729(2014)149 B2G-12-020 B2G-14-003

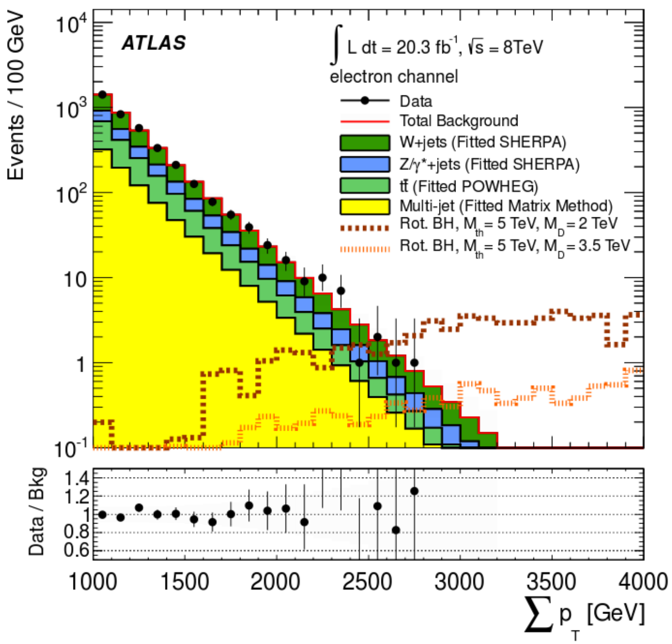
Mono-tops B2G-12-022

Excited tops JHEP 06(2014)125

B number violating tops Phys Lett B 731(2014)173

Most recently published or accepted papers and notes (lots more for both experiments!)

Other Searches

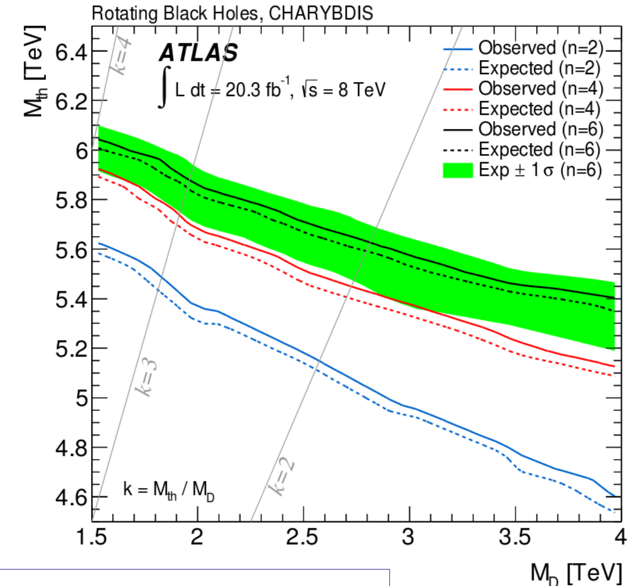


1l + jets (black holes)

- Select ≥3 high p_T leptons/jets (≥1 lepton)
- Bin Σp_T > 2000 GeV

$$\Sigma p_T = \Sigma p_T^{lep>60} + \Sigma p_T^{jet>60}$$

- Limits on 2,4,6 ADD extra dimensions, and black hole production within this framework

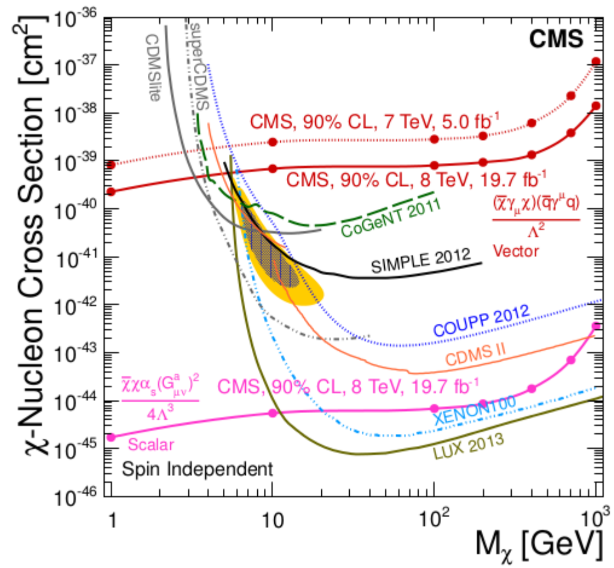


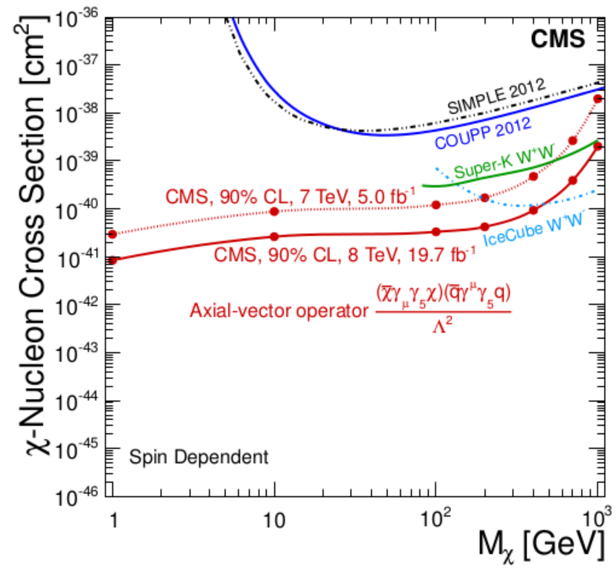
JHEP 08(2014)103

Monojet

- Allow one or two (if well separated) jets
- Veto leptons
- 7 regions with varying E_T^{miss} requirements
- Limits on dark matter produced from contact interactions, extra dimensions (ADD), and unparticle production

arxiv:1408.3583



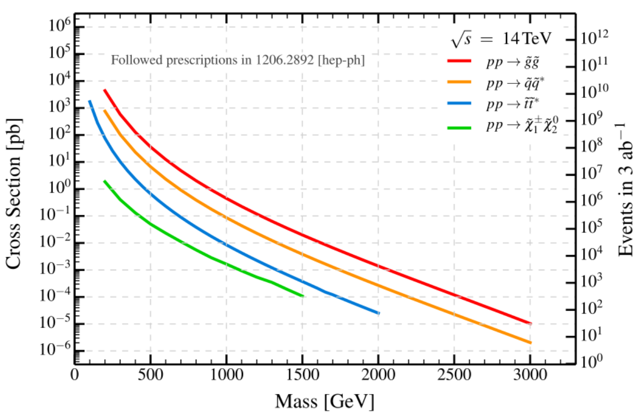


Conclusions and Outlook

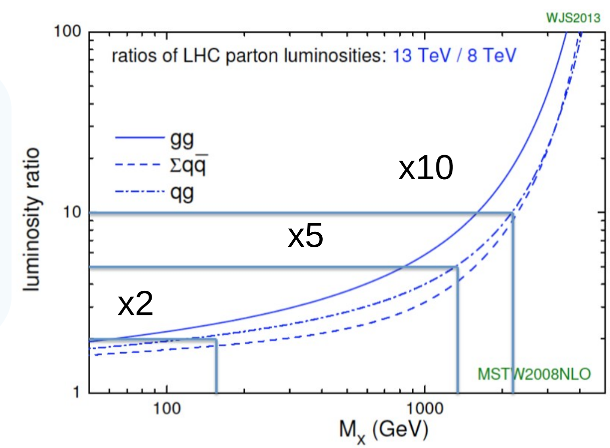
SUSY – Limits set on strong, electroweak and r-parity violating scenarios using a multitude of search regions and analysis techniques

Exotics – Varied range of searches covering many BSM scenarios including large extra dimensions, dark matter, heavy scalar quarks and many many more

No BSM observed – yet....



Run 2 begins early 2015, with great potential for discovery beyond the standard model so stay tuned for more new results!

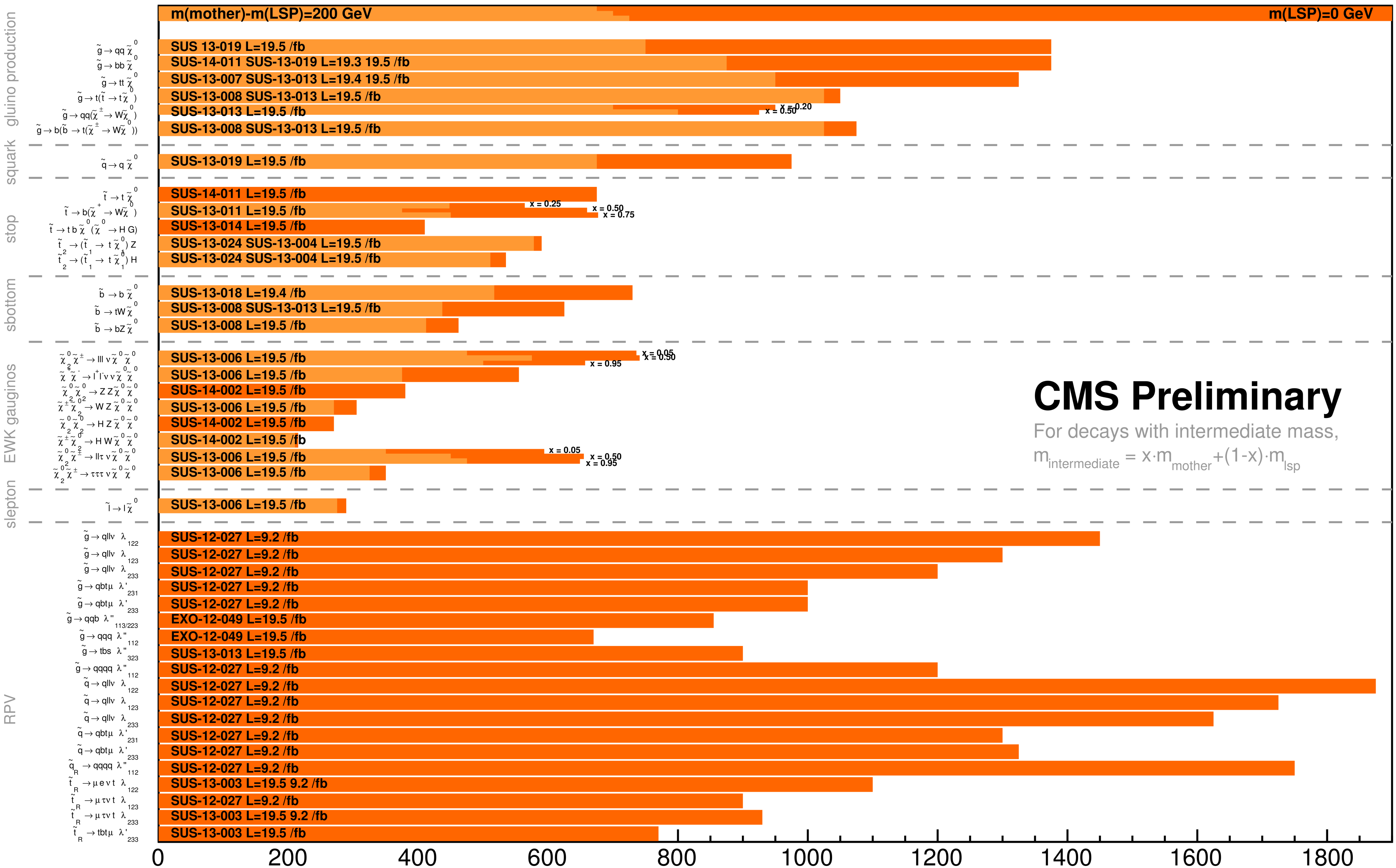


Thank you for your attention

Backup

Summary of CMS SUSY Results* in SMS framework

ICHEP 2014



*Observed limits, theory uncertainties not included
Only a selection of available mass limits
Probe *up to* the quoted mass limit

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: ICHEP 2014

ATLAS Preliminary

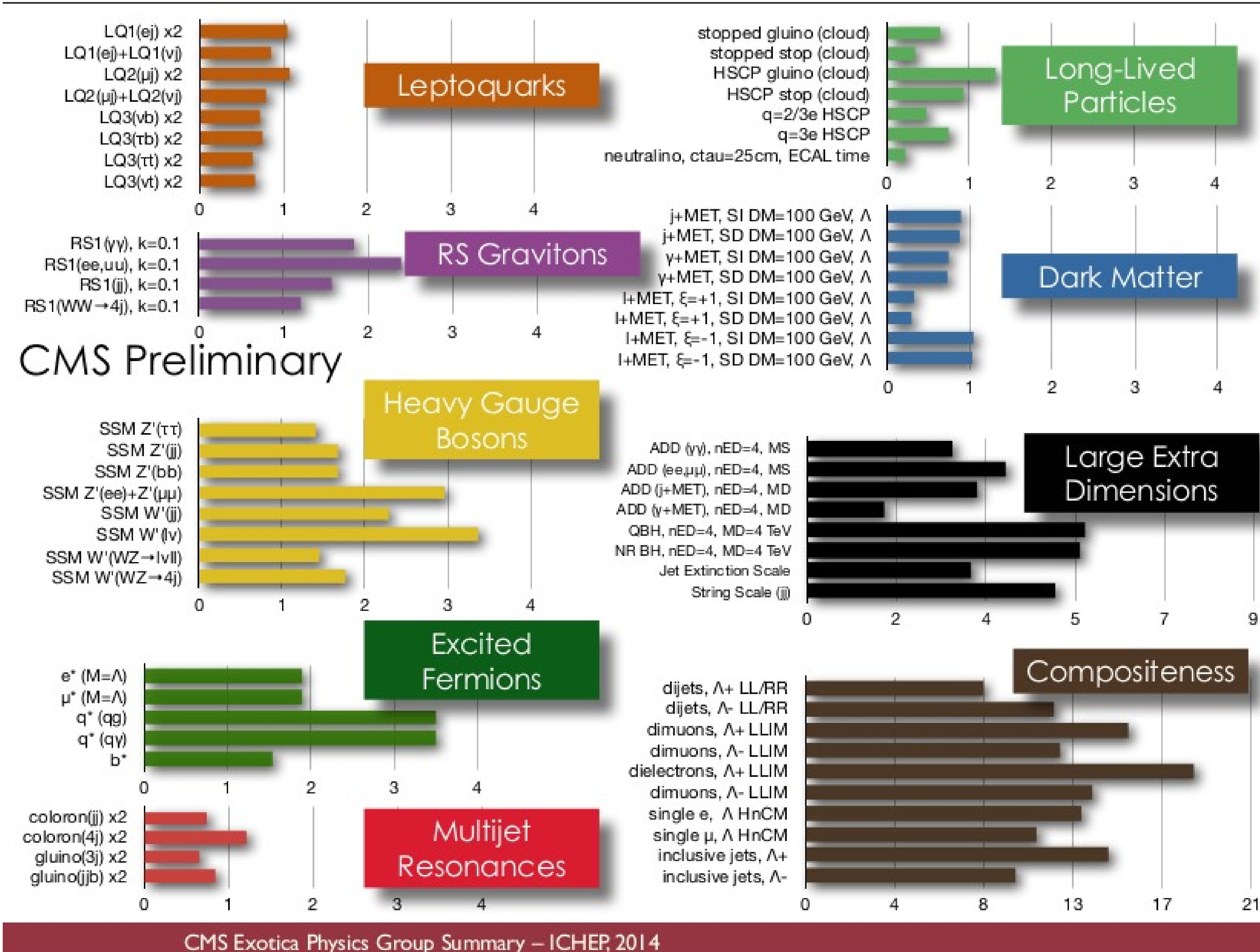
$\sqrt{s}$ = 7, 8 TeV

	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	$m(\tilde{q})=m(\tilde{g})$	1405.7875
	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	$\tilde{q}$	850 GeV	$m(\tilde{\chi}_1^0)$=0 GeV, m(1st gen. $\tilde{q}$)=m(2nd gen. $\tilde{q}$)	1405.7875
	$\tilde{g}\tilde{g}, \tilde{g}\to q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{g}$	1.33 TeV	$m(\tilde{\chi}_1^0)$=0 GeV	1405.7875
	$\tilde{g}\tilde{g}, \tilde{g}\to qq\tilde{\chi}_1^{\pm}\to qqW^{\pm}\tilde{\chi}_1^0$	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	$\tan\beta$<15	1208.4688
	GMSB ($\tilde{\ell}$ NLSP)	1-2 τ + 0-1 ℓ	0-2 jets	Yes	20.3	$\tilde{g}$	1.6 TeV	$\tan\beta$ >20	1407.0603
	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(NLSP)>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
3rd gen. $\tilde{g}$ med.	$\tilde{g}\to b\bar{b}\tilde{\chi}_1^0$	0	3 b	Yes	20.1	$\tilde{g}$	1.25 TeV	$m(\tilde{\chi}_1^0)$<400 GeV	1407.0600
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	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	1407.0600
	$\tilde{g}\to b\bar{t}\tilde{\chi}_1^+$	0-1 e, μ	3 b	Yes	20.1	$\tilde{g}$	1.3 TeV	$m(\tilde{\chi}_1^0)$<300 GeV	1407.0600
3rd 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	20.3	$\tilde{b}_1$	275-440 GeV	$m(\tilde{\chi}_1^{\pm})=2\, m(\tilde{\chi}_1^0)$	1404.2500
	$\tilde{t}_1\tilde{t}_1$(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	$\tilde{t}_1$	210-640 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	1407.0583
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	0	2 b	Yes	20.1	$\tilde{t}_1$	260-640 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	1406.1122
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to c\tilde{\chi}_1^0$	0	mono-jet/c-tag	Yes	20.3	$\tilde{t}_1$	90-240 GeV	$m(\tilde{t}_1)-m(\tilde{\chi}_1^0)$<85 GeV	1407.0608
	$\tilde{t}_1\tilde{t}_1$(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	20.3	$\tilde{\chi}_1^{\pm}$	100-350 GeV	$m(\tilde{\chi}_1^0)$=0 GeV, $m(\tilde{\tau},\tilde{\nu})=0.5(m(\tilde{\chi}_1^{\pm})+m(\tilde{\chi}_1^0))$	1407.0350
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\to\tilde{\ell}_L\nu\tilde{\ell}_L\ell(\tilde{\nu}\nu), \ell\tilde{\nu}\tilde{\ell}_L\ell(\tilde{\nu}\nu)$	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
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\to W\tilde{\chi}_1^0 Z\tilde{\chi}_1^0$	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
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\to W\tilde{\chi}_1^0 h\tilde{\chi}_1^0$	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
	$\tilde{\chi}_2^0\tilde{\chi}_3^0, \tilde{\chi}_{2,3}^0\to\tilde{\ell}_R\ell$	4 e, μ	0	Yes	20.3	$\tilde{\chi}_{2,3}^0$	620 GeV	$m(\tilde{\chi}_2^0)=m(\tilde{\chi}_3^0)$, $m(\tilde{\chi}_1^0)$=0, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}_2^0)+m(\tilde{\chi}_1^0))$	1405.5086
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, $\tau(\tilde{\chi}_1^{\pm})$=0.2 ns	ATLAS-CONF-2013-069
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	27.9	$\tilde{g}$	832 GeV	$m(\tilde{\chi}_1^0)$=100 GeV, 10 μs<$\tau(\tilde{g})$<1000 s	1310.6584
	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<$\tan\beta$<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<$\tau(\tilde{\chi}_1^0)$<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	2 e, μ (SS)	0-3 b	Yes	20.3	$\tilde{q}, \tilde{g}$	1.35 TeV	$m(\tilde{q})=m(\tilde{g})$, $c\tau_{LSP}$<1 mm	1404.2500
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to W\tilde{\chi}_1^0, \tilde{\chi}_1^0\to ee\tilde{\nu}_\mu, e\mu\tilde{\nu}_e$	4 e, μ	-	Yes	20.3	$\tilde{\chi}_1^{\pm}$	750 GeV	$m(\tilde{\chi}_1^0)>0.2\times m(\tilde{\chi}_1^{\pm})$, $\lambda_{121}\neq0$	1405.5086
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to W\tilde{\chi}_1^0, \tilde{\chi}_1^0\to\tau\tau\tilde{\nu}_e, e\tau\tilde{\nu}_\tau$	3 $e, \mu + \tau$	-	Yes	20.3	$\tilde{\chi}_1^{\pm}$	450 GeV	$m(\tilde{\chi}_1^0)>0.2\times m(\tilde{\chi}_1^{\pm})$, $\lambda_{133}\neq0$	1405.5086
	$\tilde{g}\to qqq$	0	6-7 jets	-	20.3	$\tilde{g}$	916 GeV	BR(t)=BR(b)=BR(c)=0%	ATLAS-CONF-2013-091
	$\tilde{g}\to\tilde{t}_1 t, \tilde{t}_1\to bs$	2 e, μ (SS)	0-3 b	Yes	20.3	$\tilde{g}$	850 GeV		1404.250
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	$m(\chi)$<80 GeV, limit of<687 GeV for D8	ATLAS-CONF-2012-147

Mass scale [TeV] (axis: 10^{-1}, 1)

$\sqrt{s}$ = 7 TeV full data | $\sqrt{s}$ = 8 TeV partial data | $\sqrt{s}$ = 8 TeV full data

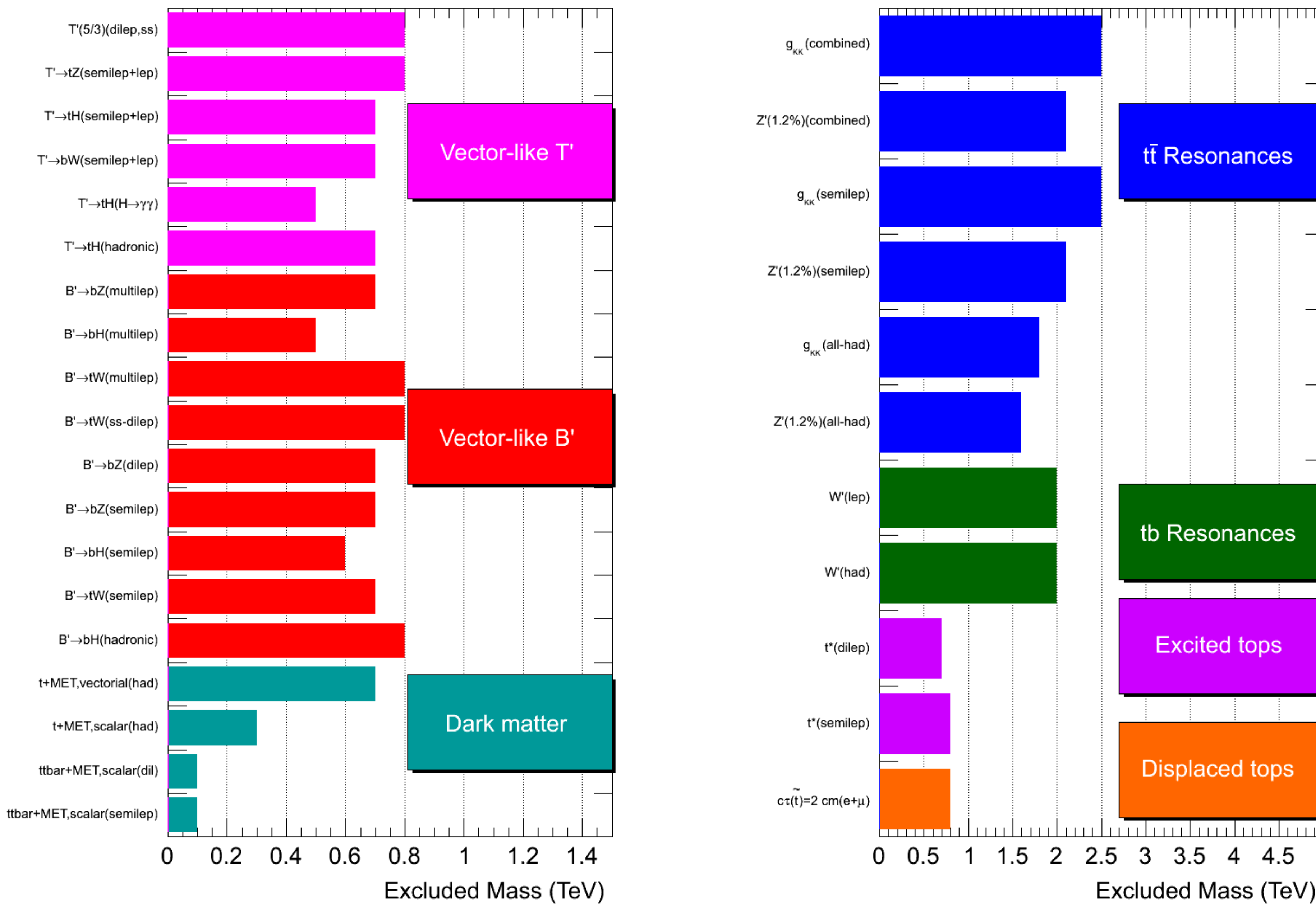
*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.



CMS Preliminary
Leptoquarks
LQ1(ej) x2
LQ1(ej)+LQ1(νj)
LQ2(μj) x2
LQ2(μj)+LQ2(νj)
LQ3(νb) x2
LQ3(τb) x2
LQ3(τt) x2
LQ3(νt) x2
RS Gravitons
RS1(γγ), k=0.1
RS1(ee,μμ), k=0.1
RS1(jj), k=0.1
RS1(WW→4j), k=0.1
Heavy Gauge Bosons
SSM Z'(ττ)
SSM Z'(jj)
SSM Z'(bb)
SSM Z'(ee)+Z'(μμ)
SSM W'(jj)
SSM W'(lν)
SSM W'(WZ→lνll)
SSM W'(WZ→4j)
Excited Fermions
e* (M=Λ)
μ* (M=Λ)
q* (qg)
q* (qγ)
b*
Multijet Resonances
coloron(jj) x2
coloron(4j) x2
gluino(3j) x2
gluino(jjb) x2
Long-Lived Particles
stopped gluino (cloud)
stopped stop (cloud)
HSCP gluino (cloud)
HSCP stop (cloud)
q=2/3e HSCP
q=3e HSCP
neutralino, ctau=25cm, ECAL time
Dark Matter
j+MET, SI DM=100 GeV, Λ
j+MET, SD DM=100 GeV, Λ
γ+MET, SI DM=100 GeV, Λ
γ+MET, SD DM=100 GeV, Λ
l+MET, ξ=+1, SI DM=100 GeV, Λ
l+MET, ξ=+1, SD DM=100 GeV, Λ
l+MET, ξ=-1, SI DM=100 GeV, Λ
l+MET, ξ=-1, SD DM=100 GeV, Λ
Large Extra Dimensions
ADD (γγ), nED=4, MS
ADD (ee,μμ), nED=4, MS
ADD (j+MET), nED=4, MD
ADD (γ+MET), nED=4, MD
QBH, nED=4, MD=4 TeV
NR BH, nED=4, MD=4 TeV
Jet Extinction Scale
String Scale (jj)
Compositeness
dijets, Λ+ LL/RR
dijets, Λ- LL/RR
dimuons, Λ+ LLIM
dimuons, Λ- LLIM
dielectrons, Λ+ LLIM
dimuons, Λ- LLIM
single e, Λ HnCM
single μ, Λ HnCM
inclusive jets, Λ+
inclusive jets, Λ-
0 1 2 3 4
0 2 4 5 7 9
0 4 8 13 17 21
CMS Exotica Physics Group Summary – ICHEP, 2014

CMS Searches for New Physics Beyond Two Generations (B2G)

95% CL Exclusions (TeV)



ATLAS Exotics Searches* - 95% CL Exclusion

Status: ICHEP 2014

ATLAS Preliminary

$\int \mathcal{L}\, dt = (1.0 - 20.3)\ \mathrm{fb}^{-1}$ $\sqrt{s} = 7, 8$ TeV

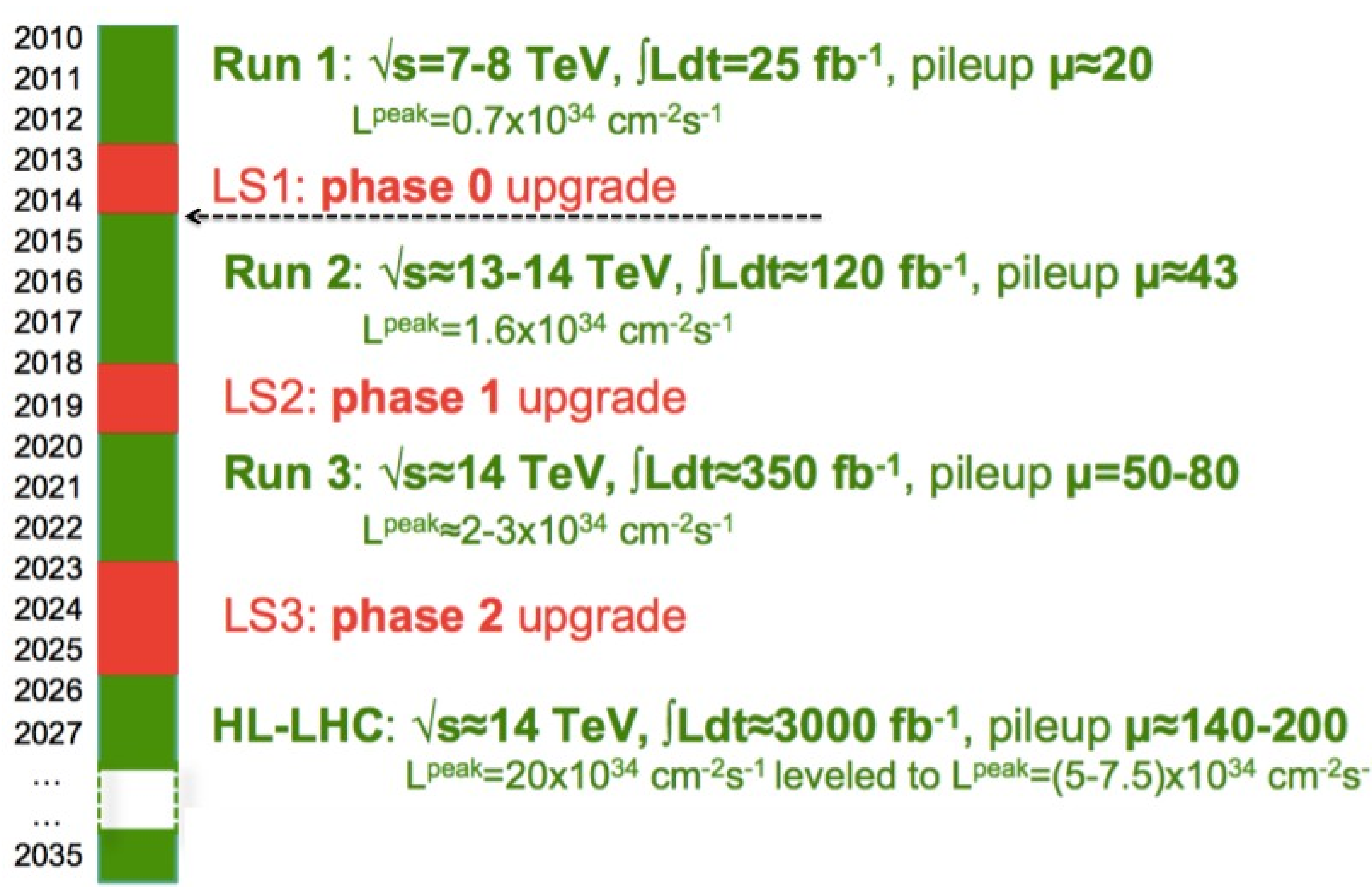
	Model	ℓ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\, dt[\mathrm{fb}^{-1}]$	Mass limit		Reference
Extra dimensions	ADD $G_{KK} + g/q$	–	1-2 j	Yes	4.7	M_D 4.37 TeV	$n = 2$	1210.4491
	ADD non-resonant $\ell\ell$	$2e, \mu$	–	–	20.3	M_S 5.2 TeV	$n = 3$ HLZ	ATLAS-CONF-2014-030
	ADD QBH $\to \ell q$	$1\ e, \mu$	1 j	–	20.3	M_{th} 5.2 TeV	$n = 6$	1311.2006
	ADD QBH	–	2 j	–	20.3	M_{th} 5.82 TeV	$n = 6$	to be submitted to PRD
	ADD BH high N_{trk}	$2\ \mu$ (SS)	–	–	20.3	M_{th} 5.7 TeV	$n = 6$, $M_D = 1.5$ TeV, non-rot BH	1308.4075
	ADD BH high $\sum p_T$	$\geq 1\ e, \mu$	≥ 2 j	–	20.3	M_{th} 6.2 TeV	$n = 6$, $M_D = 1.5$ TeV, non-rot BH	1405.4254
	RS1 $G_{KK} \to \ell\ell$	$2\ e, \mu$	–	–	20.3	G_{KK} mass 2.68 TeV	$k/\overline{M}_{Pl} = 0.1$	1405.4123
	RS1 $G_{KK} \to WW \to \ell\nu\ell\nu$	$2\ e, \mu$	–	Yes	4.7	G_{KK} mass 1.23 TeV	$k/\overline{M}_{Pl} = 0.1$	1208.2880
	Bulk RS $G_{KK} \to ZZ \to \ell\ell qq$	$2\ e, \mu$	2 j / 1 J	–	20.3	G_{KK} mass 730 GeV	$k/\overline{M}_{Pl} = 1.0$	ATLAS-CONF-2014-039
	Bulk RS $G_{KK} \to HH \to b\bar{b}b\bar{b}$	–	4 b	–	19.5	G_{KK} mass 590-710 GeV	$k/\overline{M}_{Pl} = 1.0$	ATLAS-CONF-2014-005
	Bulk RS $g_{KK} \to t\bar{t}$	$1\ e, \mu$	≥ 1 b, ≥ 1J/2j	Yes	14.3	g_{KK} mass 2.0 TeV	BR = 0.925	ATLAS-CONF-2013-052
	S^1/Z_2 ED	$2\ e, \mu$	–	–	5.0	$M_{KK} \approx R^{-1}$ 4.71 TeV		1209.2535
	UED	$2\ \gamma$	–	Yes	4.8	Compact. scale R^{-1} 1.41 TeV		ATLAS-CONF-2012-072
Gauge bosons	SSM $Z' \to \ell\ell$	$2\ e, \mu$	–	–	20.3	Z' mass 2.9 TeV		1405.4123
	SSM $Z' \to \tau\tau$	$2\ \tau$	–	–	19.5	Z' mass 1.9 TeV		ATLAS-CONF-2013-066
	SSM $W' \to \ell\nu$	$1\ e, \mu$	–	Yes	20.3	W' mass 3.28 TeV		ATLAS-CONF-2014-017
	EGM $W' \to WZ \to \ell\nu\, \ell'\ell'$	$3\ e, \mu$	–	Yes	20.3	W' mass 1.52 TeV		1406.4456
	EGM $W' \to WZ \to qq\ell\ell$	$2\ e, \mu$	2 j / 1 J	–	20.3	W' mass 1.59 TeV		ATLAS-CONF-2014-039
	LRSM $W'_R \to t\bar{b}$	$1\ e, \mu$	2 b, 0-1 j	Yes	14.3	W' mass 1.84 TeV		ATLAS-CONF-2013-050
	LRSM $W'_R \to t\bar{b}$	$0\ e, \mu$	≥ 1 b, 1 J	–	20.3	W' mass 1.77 TeV		to be submitted to EPJC
CI	CI $qqqq$	–	2 j	–	4.8	Λ 7.6 TeV	$\eta = +1$	1210.1718
	CI $qq\ell\ell$	$2\ e, \mu$	–	–	20.3	Λ 21.6 TeV	$\eta_{LL} = -1$	ATLAS-CONF-2014-030
	CI $uutt$	$2\ e, \mu$ (SS)	≥ 1 b, ≥ 1 j	Yes	14.3	Λ 3.3 TeV	$\lvert C \rvert = 1$	ATLAS-CONF-2013-051
DM	EFT D5 operator (Dirac)	$0\ e, \mu$	1-2 j	Yes	10.5	M_* 731 GeV	at 90% CL for $m(\chi) < 80$ GeV	ATLAS-CONF-2012-147
	EFT D9 operator (Dirac)	$0\ e, \mu$	1 J, ≤ 1 j	Yes	20.3	M_* 2.4 TeV	at 90% CL for $m(\chi) < 100$ GeV	1309.4017
LQ	Scalar LQ 1st gen	$2\ e$	≥ 2 j	–	1.0	LQ mass 660 GeV	$\beta = 1$	1112.4828
	Scalar LQ 2nd gen	$2\ \mu$	≥ 2 j	–	1.0	LQ mass 685 GeV	$\beta = 1$	1203.3172
	Scalar LQ 3rd gen	$1\ e, \mu, 1\ \tau$	1 b, 1 j	–	4.7	LQ mass 534 GeV	$\beta = 1$	1303.0526
Heavy quarks	Vector-like quark $TT \to Ht + X$	$1\ e, \mu$	≥ 2 b, ≥ 4 j	Yes	14.3	T mass 790 GeV	T in (T,B) doublet	ATLAS-CONF-2013-018
	Vector-like quark $TT \to Wb + X$	$1\ e, \mu$	≥ 1 b, ≥ 3 j	Yes	14.3	T mass 670 GeV	isospin singlet	ATLAS-CONF-2013-060
	Vector-like quark $TT \to Zt + X$	$2/\geq 3\ e, \mu$	$\geq 2/\geq 1$ b	–	20.3	T mass 735 GeV	T in (T,B) doublet	ATLAS-CONF-2014-036
	Vector-like quark $BB \to Zb + X$	$2/\geq 3\ e, \mu$	$\geq 2/\geq 1$ b	–	20.3	B mass 755 GeV	B in (B,Y) doublet	ATLAS-CONF-2014-036
	Vector-like quark $BB \to Wt + X$	$2\ e, \mu$ (SS)	≥ 1 b, ≥ 1 j	Yes	14.3	B mass 720 GeV	B in (T,B) doublet	ATLAS-CONF-2013-051
Excited fermions	Excited quark $q^* \to q\gamma$	$1\ \gamma$	1 j	–	20.3	q^* mass 3.5 TeV	only u^* and d^*, $\Lambda = m(q^*)$	1309.3230
	Excited quark $q^* \to qg$	–	2 j	–	20.3	q^* mass 4.09 TeV	only u^* and d^*, $\Lambda = m(q^*)$	to be submitted to PRD
	Excited quark $b^* \to Wt$	1 or 2 e, μ	1 b, 2 j or 1 j	Yes	4.7	b^* mass 870 GeV	left-handed coupling	1301.1583
	Excited lepton $\ell^* \to \ell\gamma$	$2\ e, \mu, 1\ \gamma$	–	–	13.0	ℓ^* mass 2.2 TeV	$\Lambda = 2.2$ TeV	1308.1364
Other	LSTC $a_T \to W\gamma$	$1\ e, \mu, 1\ \gamma$	–	Yes	20.3	a_T mass 960 GeV		to be submitted to PLB
	LRSM Majorana ν	$2\ e, \mu$	2 j	–	2.1	N^0 mass 1.5 TeV	$m(W_R) = 2$ TeV, no mixing	1203.5420
	Type III Seesaw	$2\ e, \mu$	–	–	5.8	$N^{\pm}$ mass 245 GeV	$\lvert V_e \rvert$=0.055, $\lvert V_\mu \rvert$=0.063, $\lvert V_\tau \rvert$=0	ATLAS-CONF-2013-019
	Higgs triplet $H^{\pm\pm} \to \ell\ell$	$2\ e, \mu$ (SS)	–	–	4.7	$H^{\pm\pm}$ mass 409 GeV	DY production, BR($H^{\pm\pm} \to \ell\ell$)=1	1210.5070
	Multi-charged particles	–	–	–	4.4	multi-charged particle mass 490 GeV	DY production, $\lvert q \rvert = 4e$	1301.5272
	Magnetic monopoles	–	–	–	2.0	monopole mass 862 GeV	DY production, $\lvert g \rvert = 1 g_D$	1207.6411

$\sqrt{s}$ = 7 TeV $\sqrt{s}$ = 8 TeV

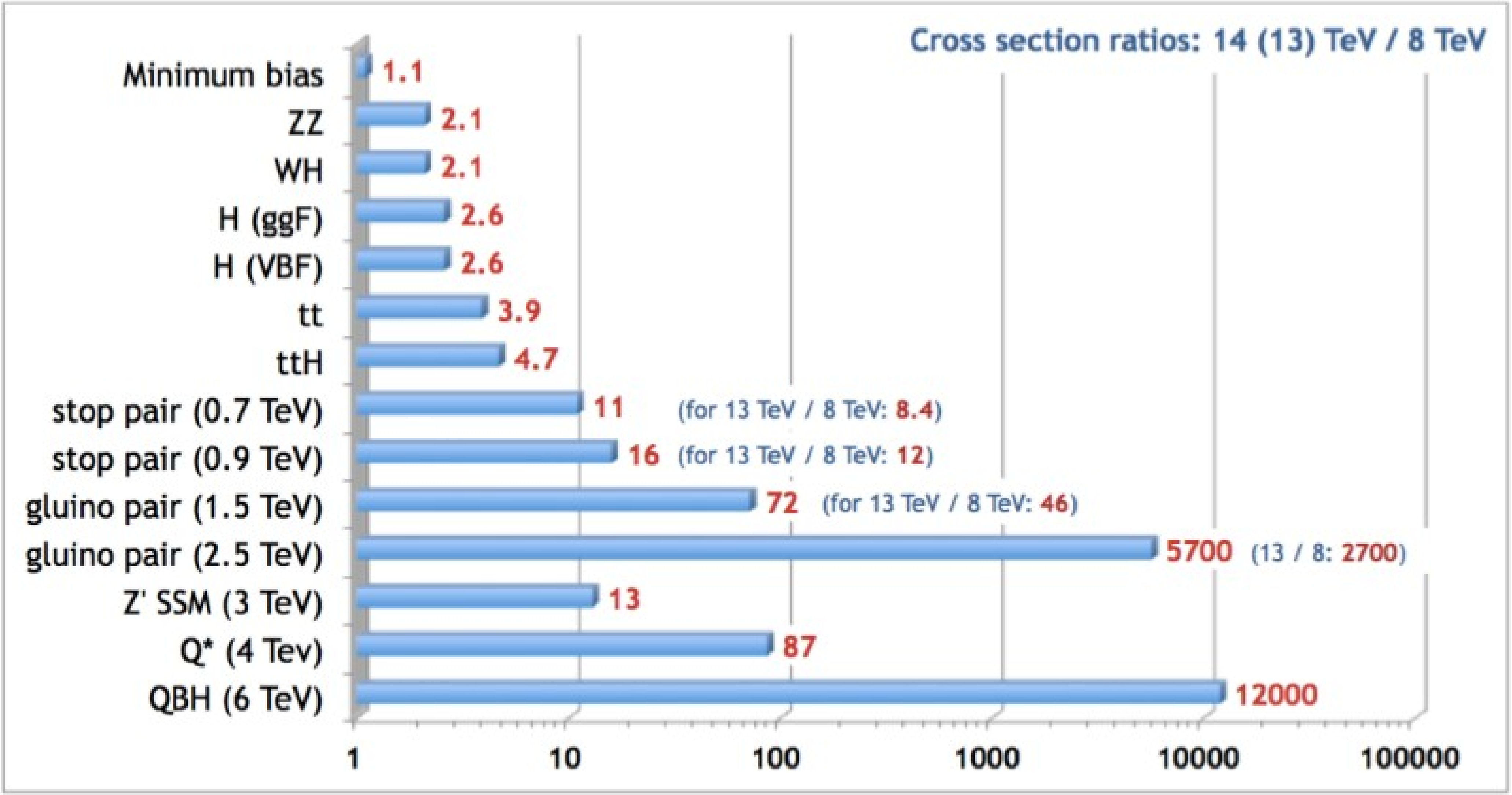
Mass scale [TeV] (10^{-1}, 1, 10)

*Only a selection of the available mass limits on new states or phenomena is shown.

LHC Run and Upgrade Schedule



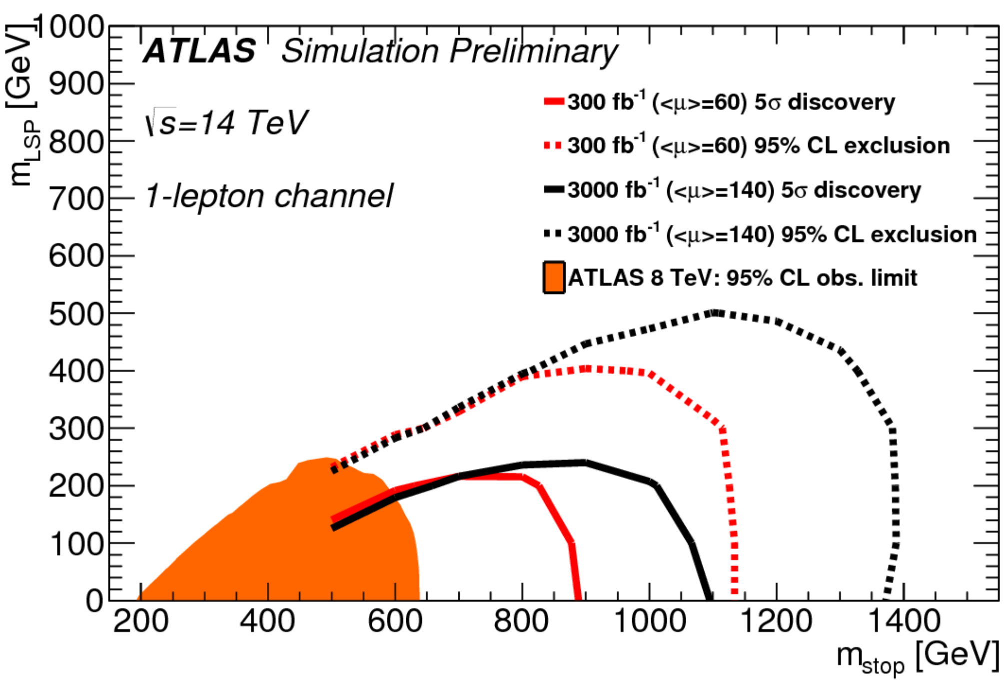
Hugely increased potential for discovery of heavy particles at 13~14 TeV



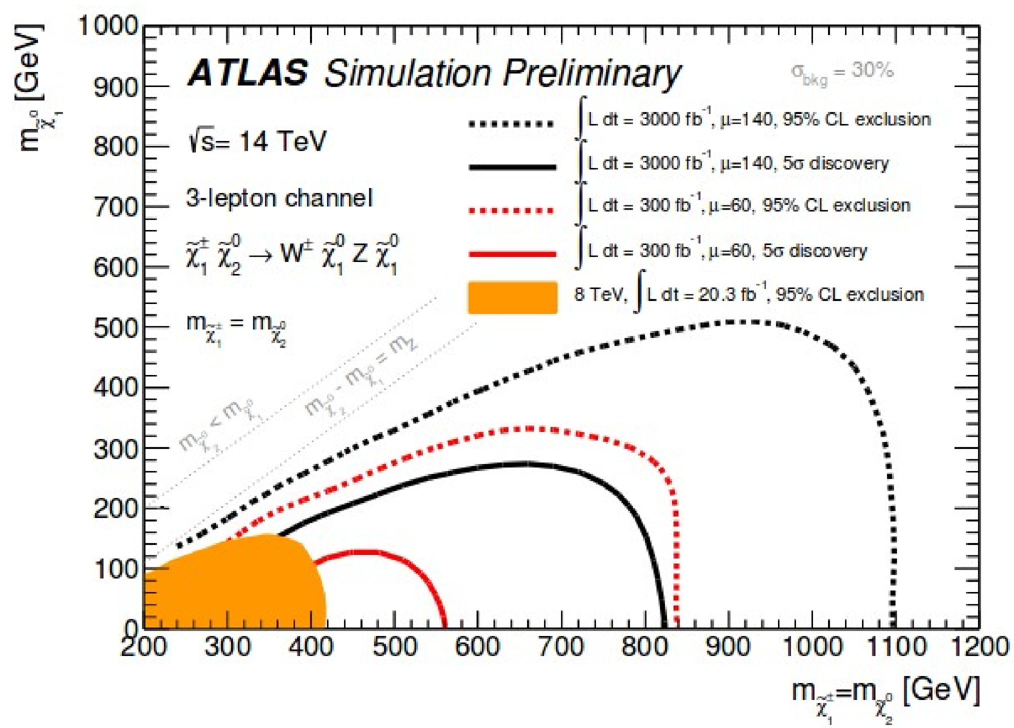
Long term outlook – ATLAS SUSY

- Increase in cross-sections for gluinos and stops once energy and luminosity increase in run 2
- Studies on EWK and strong search prospects for 300fb-1 and 3000fb-1 – striking improvements to limits look possible, work already underway to target SUSY with higher pileup conditions

ATLAS-PHYS-PUB_2013-011



ATLAS-PHYS-PUB-2014-010

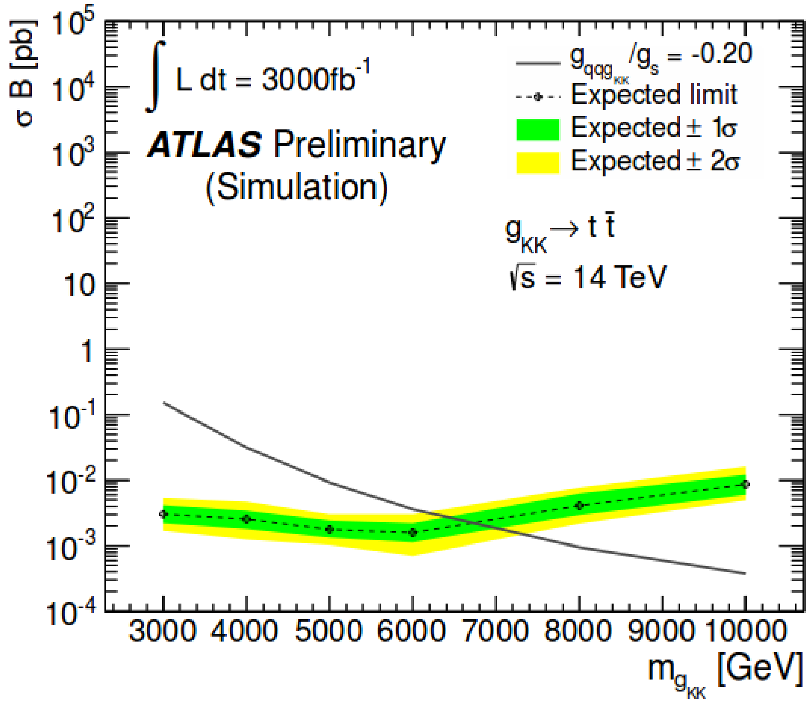


Long term outlook – ATLAS Exotics

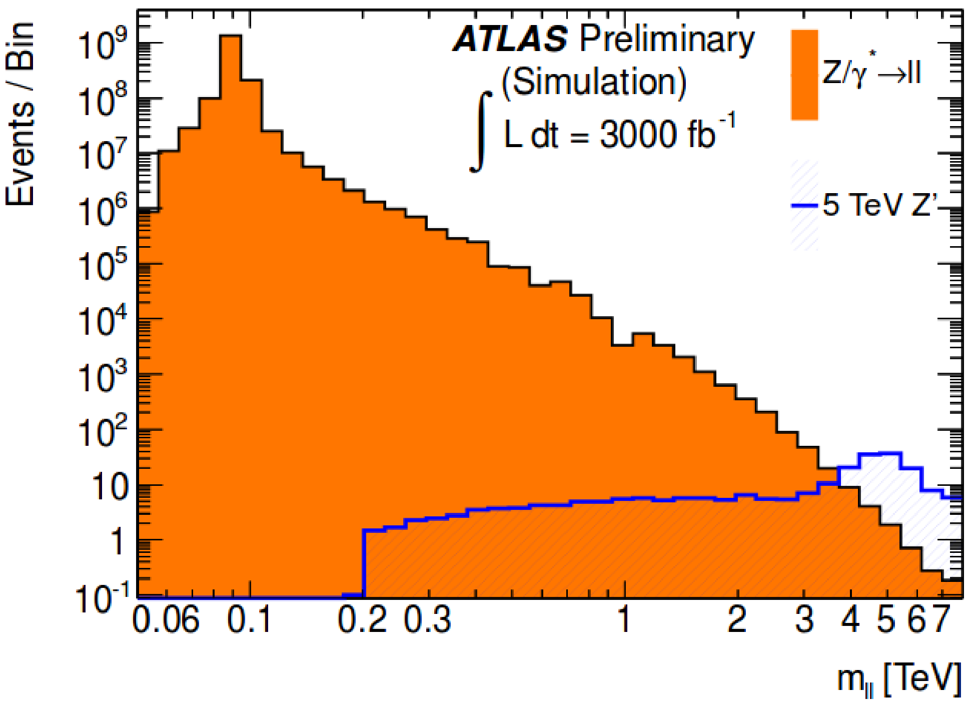
ATLAS-PHYS-PUB-2013-003

Similar study for two exotics searches – ttbar and dilepton resonances can be probed up to 6.7 TeV and 7.8 TeV with 3000fb^{-1}

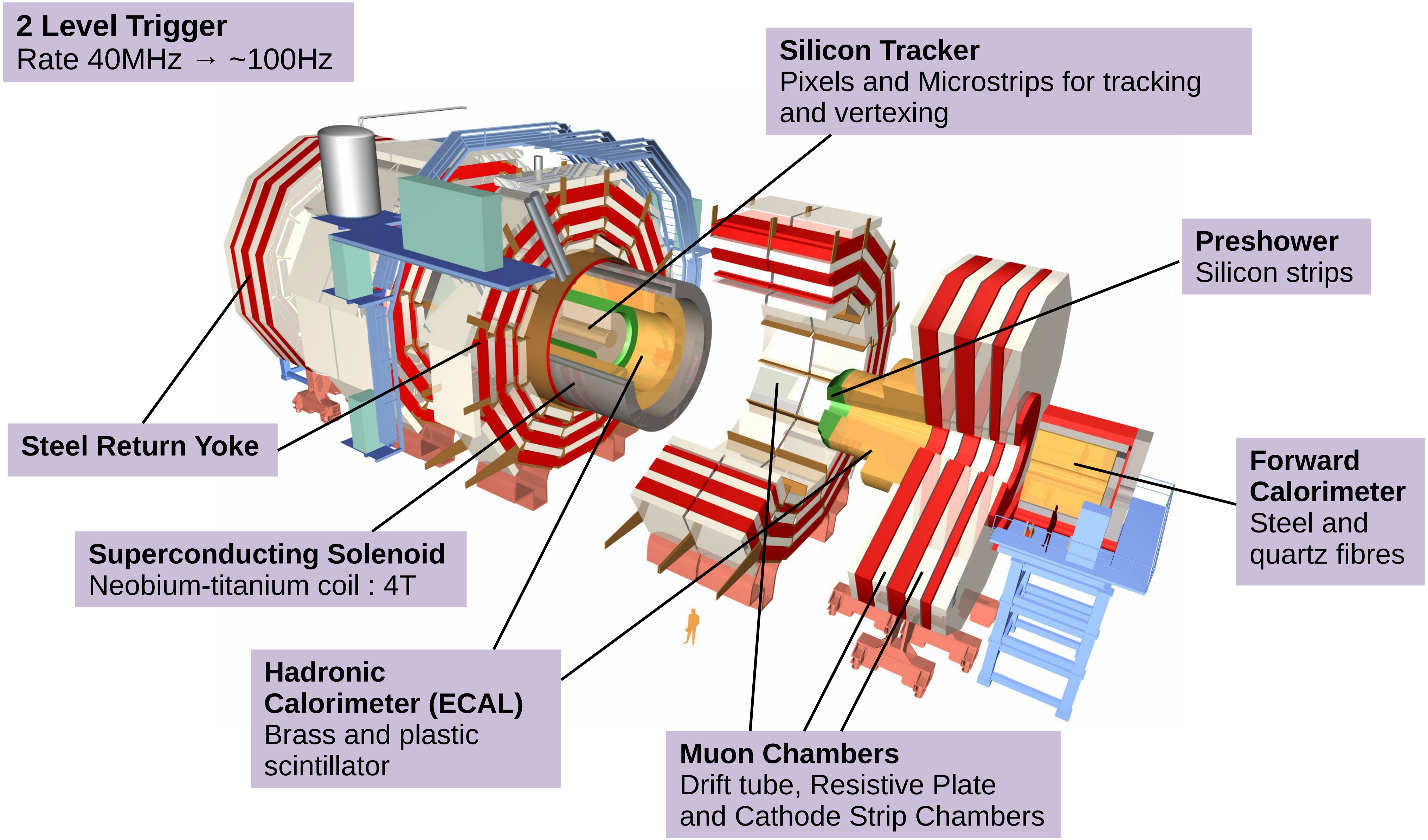
g_{kk-} → ttbar
Lepton + Jets channel



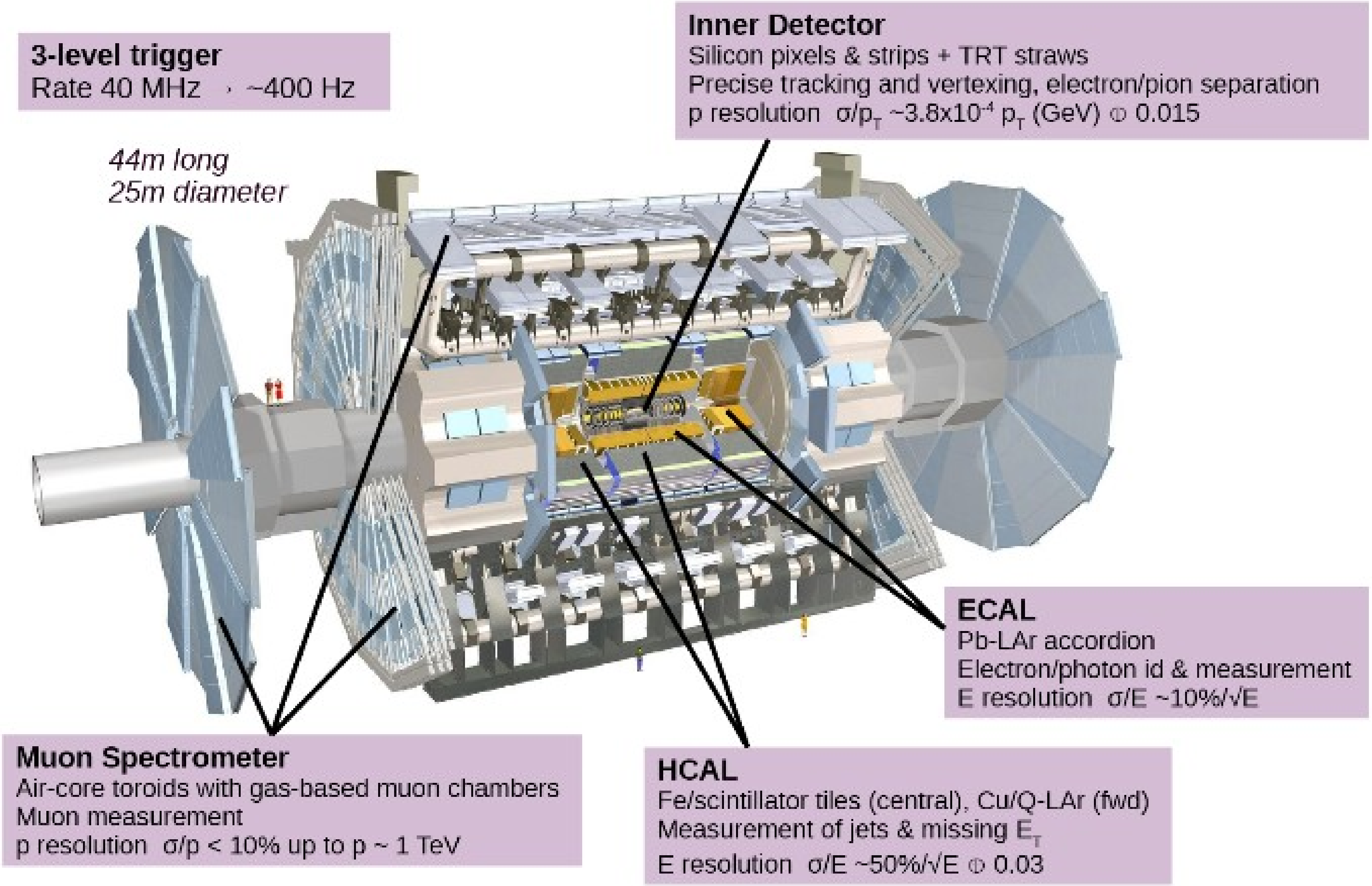
Z' dimuon channel
– dimuon mass resonance



CMS detector



ATLAS detector



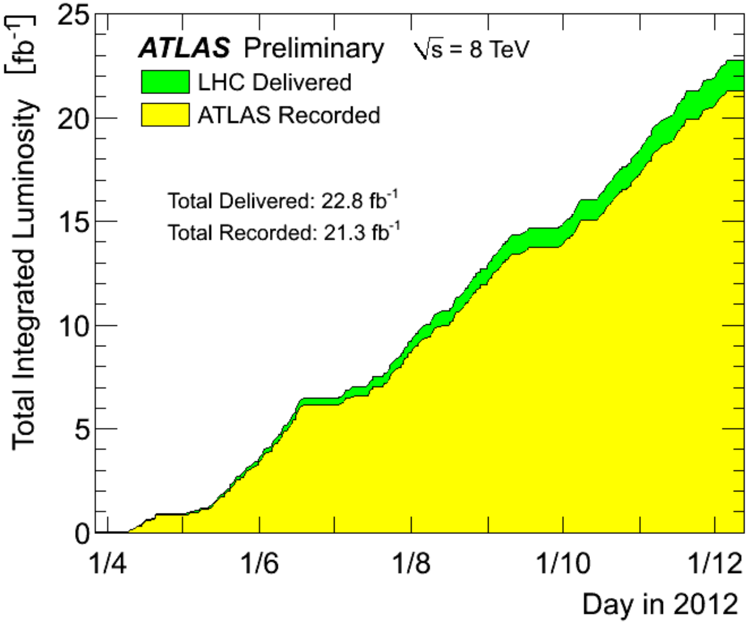
ATLAS vs CMS

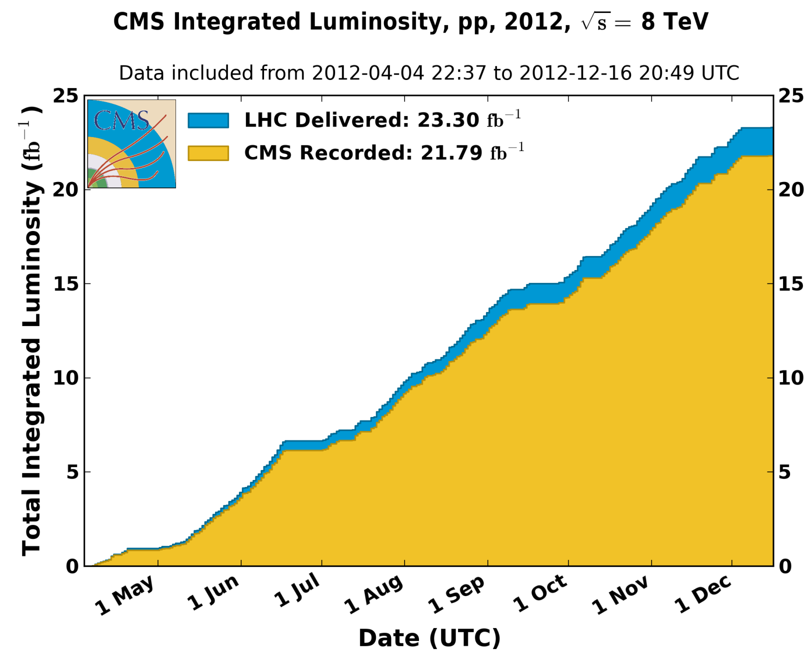
2008 Jinst 3 S08003

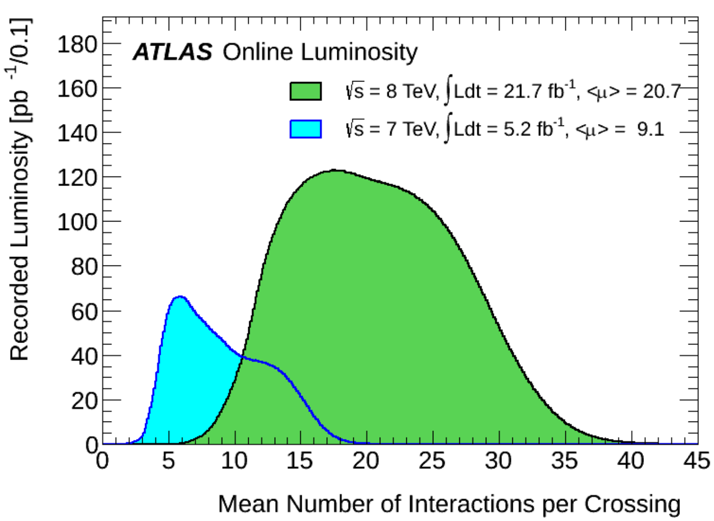
2008 Jinst 3 S08004

	ATLAS	CMS
Magnet	**2 T Solenoid + 0.5 - 1 T Toroid**	**4T Solenoid + yoke**
Tracker	**Si pixels, strips and Transition Radiation Tracker** $\frac{\sigma p_T}{p_T} = 0.05\%$ $\lvert\eta\rvert < 2.5$	**Si Pixels and strips** $\frac{\sigma p_T}{p_T} = 0.015\%$ $\lvert\eta\rvert < 2.5$
ECAL	**LAr + Pb** $\frac{\sigma E}{E} = \frac{10\%}{\sqrt{E}}$ $\lvert\eta\rvert < 3.2$	**$PbWO_4$ crystals** $\frac{\sigma E}{E} = \frac{3\%}{\sqrt{E}}$ $\lvert\eta\rvert < 3.0$
HCAL	**Steel + Scint/Cu + LAr** $\frac{\sigma E}{E} = \frac{50\%}{\sqrt{E}}$ (100% in EC) $\lvert\eta\rvert < 4.9$	**Brass + Scint** $\frac{\sigma E}{E} = \frac{100\%}{\sqrt{E}}$ $\lvert\eta\rvert < 5.0$
Muon Spectrometer	**Combined + Standalone Tracking** $\frac{\sigma p_T}{p_T} = 10\%$ $\lvert\eta\rvert < 2.7$	**Combined Tracking** $\frac{\sigma p_T}{p_T} = 10\%$ $\lvert\eta\rvert < 2.4$

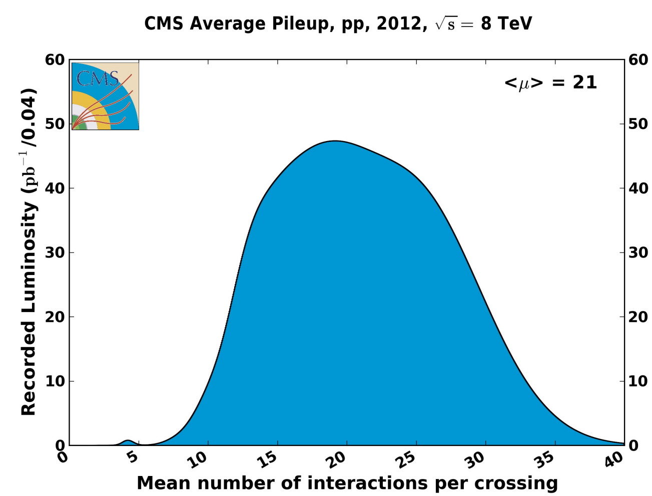
Dataset luminosity and number of interactions







All main analyses shown used 8 TeV dataset taken in 2012



Background Estimation

Matrix Method

Data driven estimation: uses ratios of “real” to “fake” leptons and “tight” to “loose” leptons. Tight leptons are those used as signal leptons, and loose leptons fail some of the criteria for signal leptons.

For a signature with 1 lepton

$$N^{loose} = N^{loose}_{real} + N^{loose}_{fake}$$

$$N^{tight} = \epsilon_{real} N^{loose}_{real} + \epsilon_{fake} N^{loose}_{fake}$$

Measure independently from data

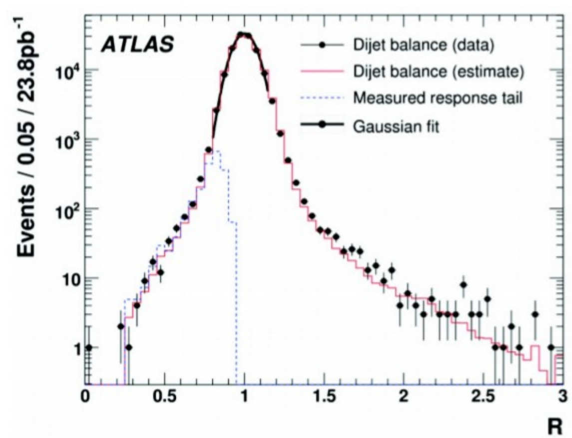
Count in data

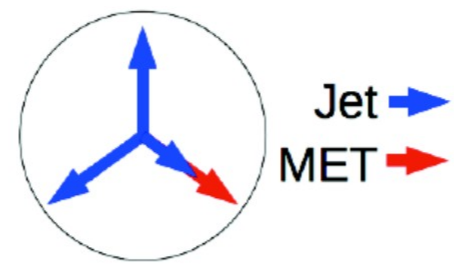
$$N^{tight}_{fake} = \frac{\epsilon_{fake}}{\epsilon_{real} - \epsilon_{fake}} \left(\epsilon_{real} N^{loose} - N^{tight} \right)$$

Jet Smearing

Use MC to derive “jet response function” → adapt to data

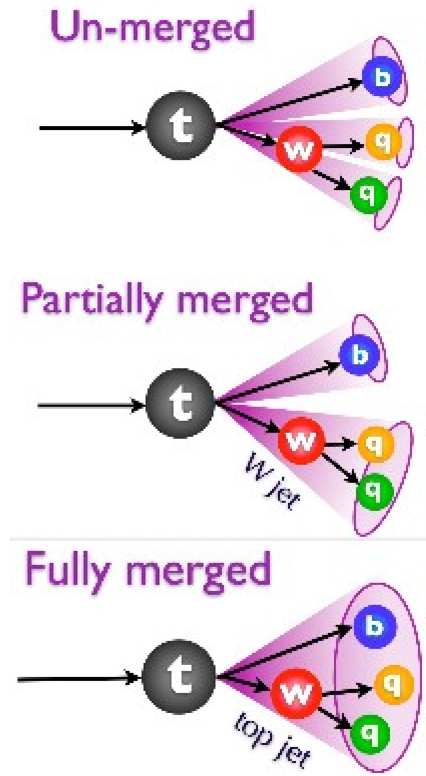
Core modelled from dijet events, tail from 3-jet “mercedes” events





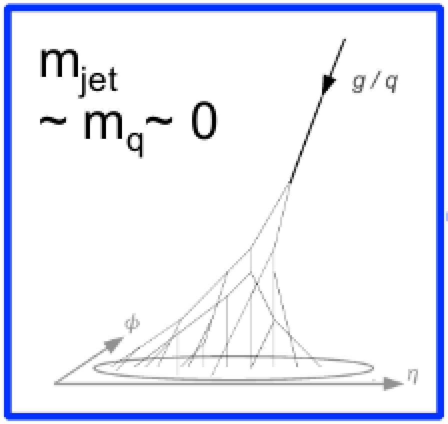
Select data events with low E_T^{miss} and smear using jet response function to get “fake” E_T^{miss} events

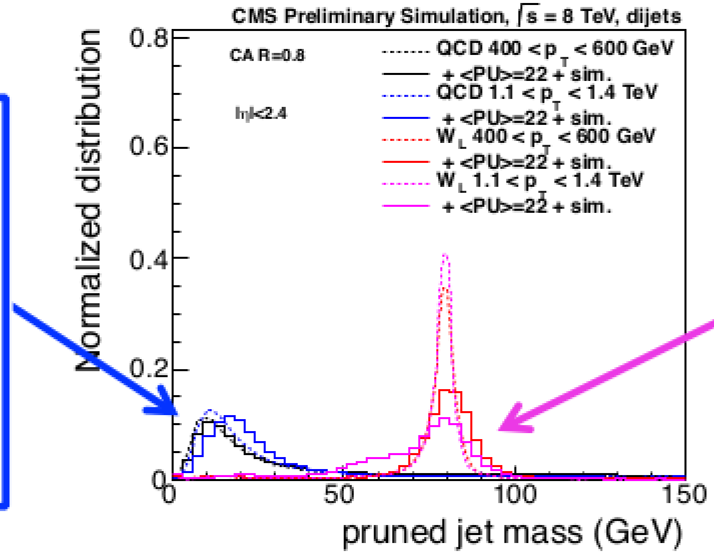
Jet Substructure



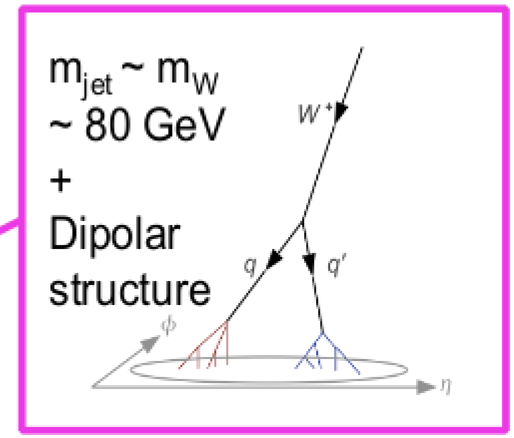
- Standard jet reconstruction with Anti-kt clustering algorithm using distance parameter of 0.5
- Fat jet tagging algorithms using Cambridge/Aachen jet clustering algorithm
- Merged jets result from boosted decay products

Background





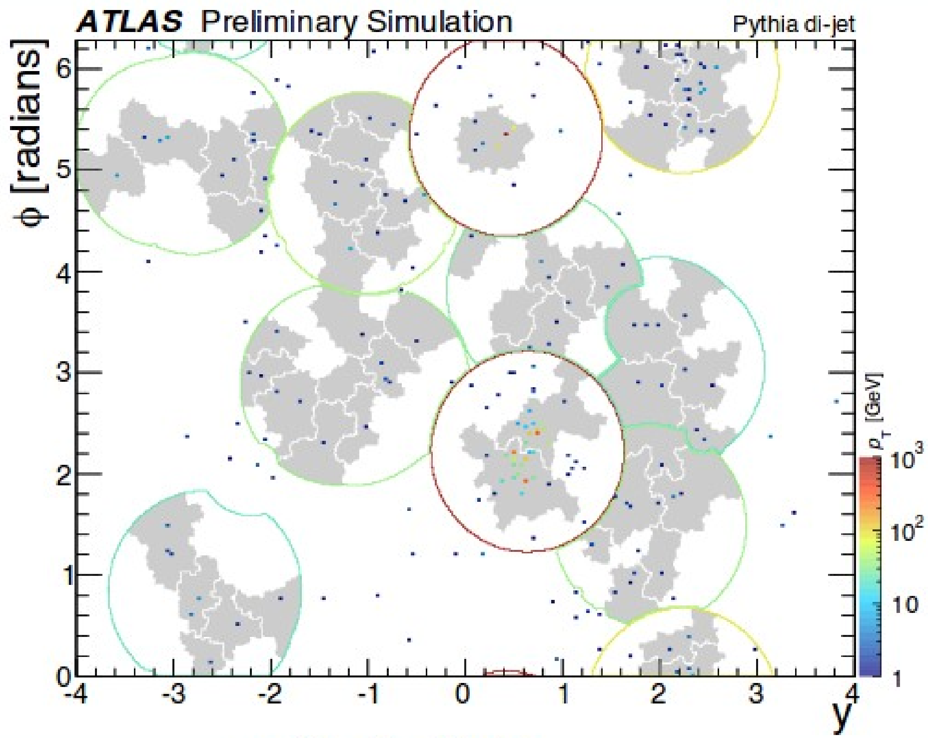
Signal



David Lopez Mateos, Harvard University, BOOST 2014

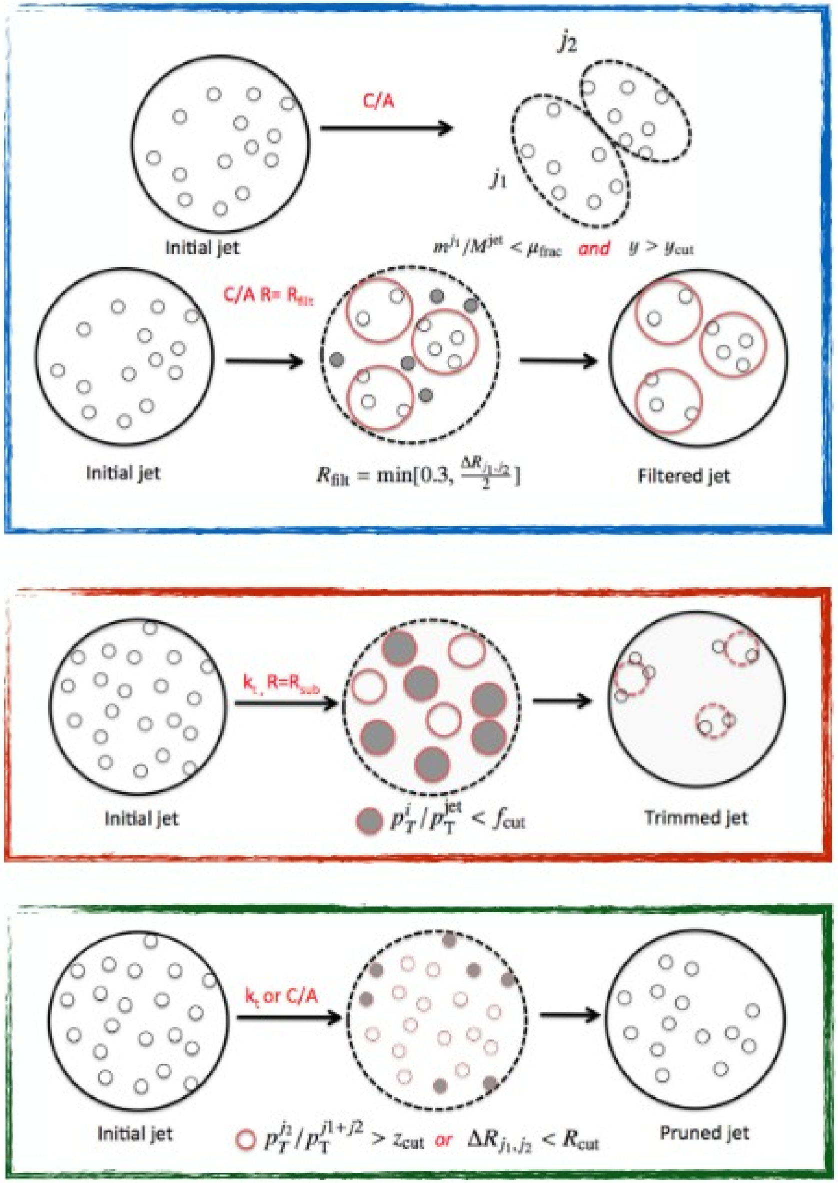
Jet Substructure

- Split-filtering, trimming and pruning studied in detail with 2011 and 2012 data



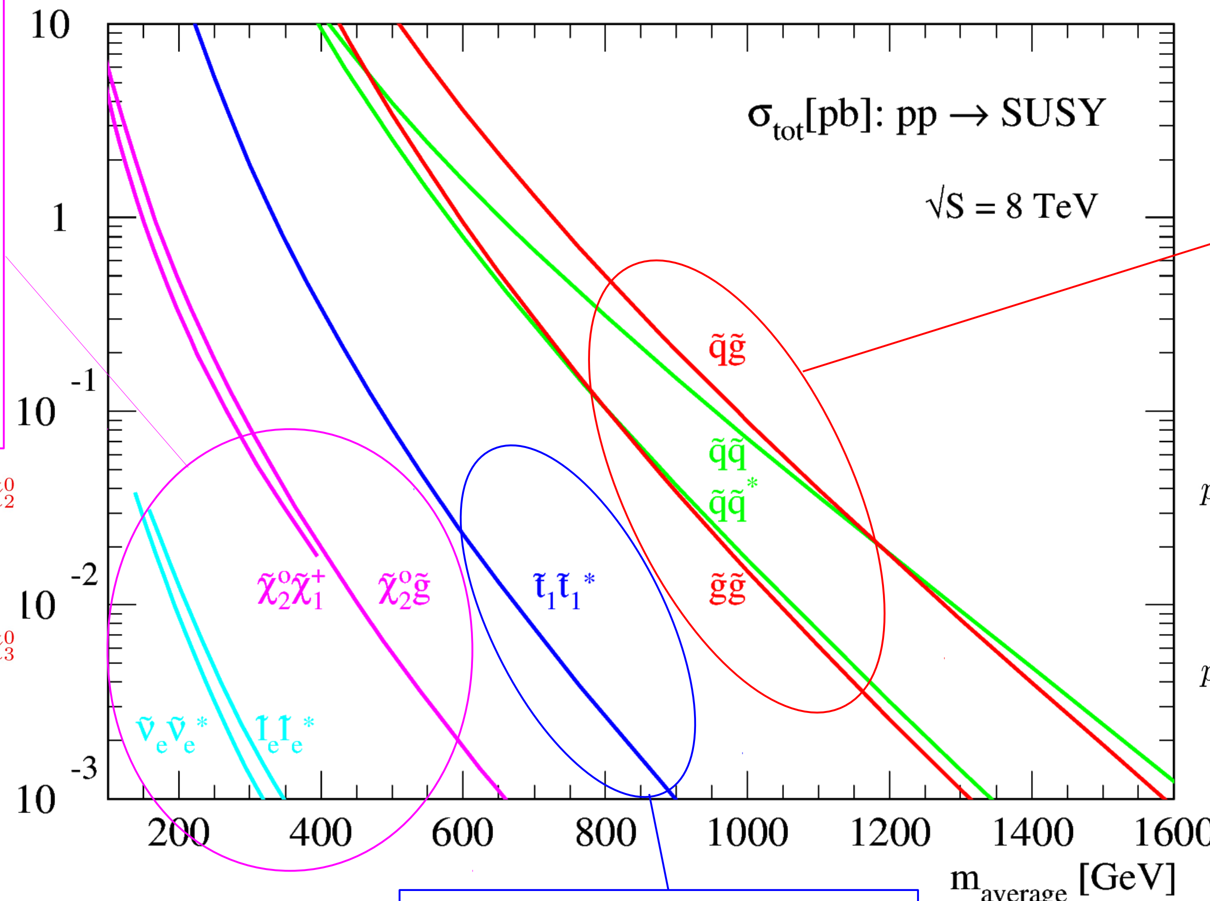
anti-k_t R=1.0 jets
k_t R=0.3 subjets
f_{cut}=0.05

Trimming in action



SUSY at the LHC

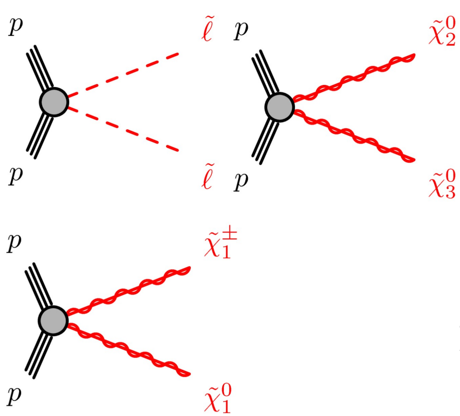
Production cross-sections for SUSY processes in 2012



Electroweak (EWK)

Charginos, neutralinos and sleptons

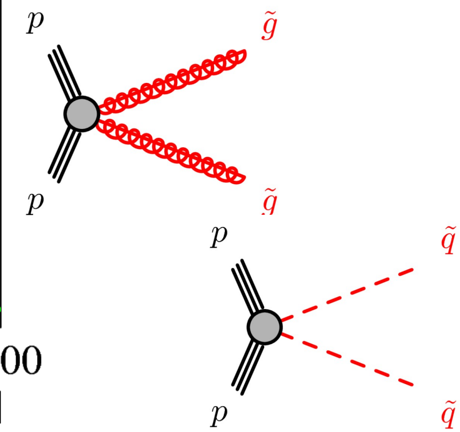
Small cross-section but can dominate if coloured sparticles are heavy



Strong

Gluinos, 1st and 2nd generation squarks

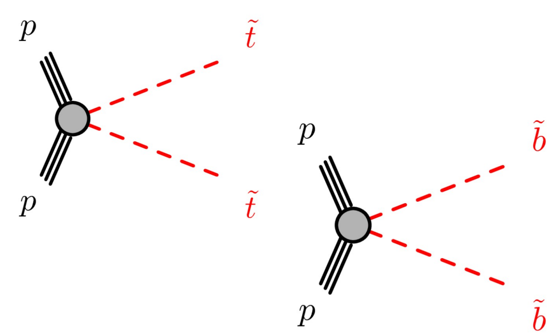
High cross-sections up to 1 TeV



3rd generation

Stops and sbottoms

Moderate cross-section up to 0.5 TeV, motivation from "naturalness"

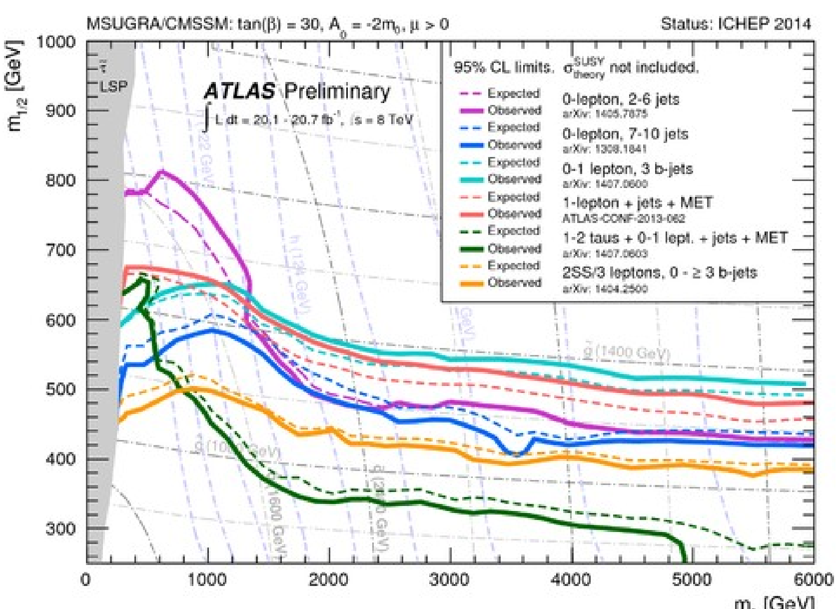


Scenarios have either violated or conserved "R-parity" (usually conserved), and can also have long-lived particles, (LLP) dependent on phenomonology

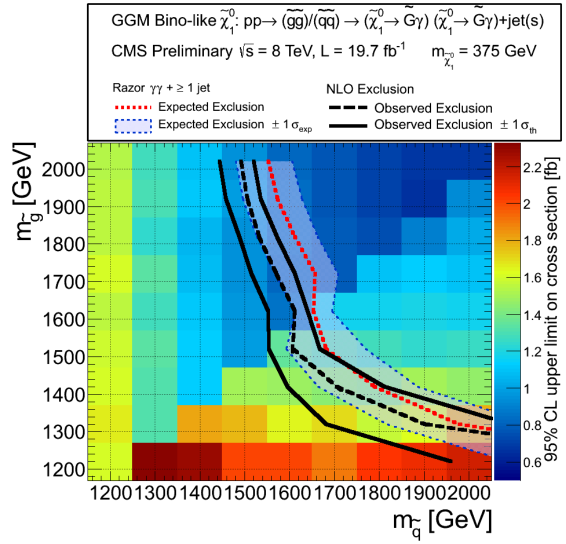
Modelling SUSY

Physics models

- Developed from first principles
- Model specific spectrum at EWK scale and SUSY breaking at high scale
- e.g. mSUGRA, Gauge Mediated SUSY Breaking (GMSB), extended MSSM etc
- Good for comparison of results



ATLAS_MSUGRA_Limit_twiki



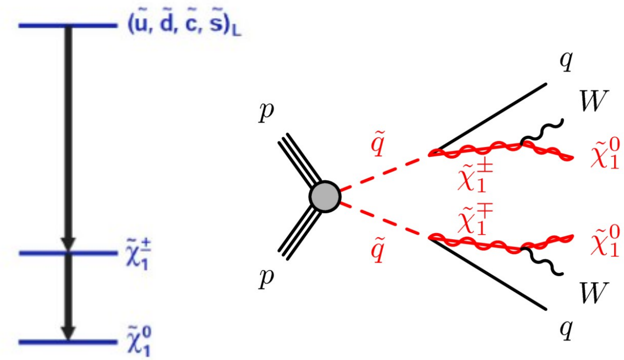
CMS-PAS-SUS-14-008

Generalised models

- Model parameters at EWK scale and specific spectrum at EWK scale
- e.g. General Gauge Mediated (GGM), phenomenological MSSM

Simplified models

- Focus on accessible part of model only
- Simple set of parameters,
- Few low mass sparticles
- Branching ratios set to 100%



W' Origins

A heavy spin-1 boson can result from many BSM theories, including Little Higgs, Technicolor, Grand Unified Theories, Composite Models and models of extra dimensions. Specific benchmark models included in these analyses are;

Heavy Vector Triplets -

- A Heavy triplet of bosons mixes with the SM model gauge bosons
- Couple to fermionic current $g^2 c_F / g_v$
- Couple to Higgs and vector bosons $g_v C_H$
- Can come from;

Extended Gauge Model (EGM) -

- Can originate from GUT group or E_6
- Always results in new gauge bosons
- Couplings same as SM, except from to WZ, which is suppressed by a factor of
- Becomes large when $M_{W'}$ is about $2M_w/M_Z$

Composite Higgs -

- Apply concepts of pseudo-goldstone bosons in QCD to the Higgs sector
- Four Goldstone bosons lead to a Higgs doublet
- In addition, new W,Z,t and b particles
- Interactions of Higgs multiplet at higher dimensions

Extra Dimensions

- Hypothesise new spatial dimensions (kaluza-klein resonances) which can provide a solution to the Hierarchy Problem
- These dimensions are compactified
  - Leads to quantified excitations of the fields
- Excitation modes manifest as new heavy particles

Arkani-Hamed, Dimopoulos, Dvali (ADD)

- SM fields exist in 4D membrane
- Additional large spatial dimensions propagated only by gravity
- Hence weakness of field
- New Plank Scale in 4 + additional dimensions called M_D
- For n extra dimensions with radius R,

$$M_{Pl}^{2} \approx M_{D}^{2+n} R^{n}$$

Left right symmetric extension

- Hypothesise a larger gauge group **$SU_L(2)$ X $SU_R(2)$** containing both chiralities which is then spontaneously broken, leading to the parity violation observed in the SM weak force
- The new $SU_R(2)$ gauge group which is introduced consequently has heavy right-handed gauge bosons **$W^{\pm}_R$ and Z_R**, and heavy right-handed Majorana neutrinos N_l associated
- This explains parity violation in the weak sector, and the relativeness weights of the known neutrinos due to the see-saw mechanism
- The neutrinos can be heavier than the heavy bosons, but in the analysis discussed the decay chain is;

$$W_R \rightarrow \ln_l \rightarrow llW*_R \rightarrow llq\bar{q}$$