RWTH

ICNFP2016
Kolymbari

SEARCHES FOR SUPERSYMMETRY AT THE LHC

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on behalf of the ATLAS and CMS collaborations

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Overview

➔ Motivation and Introduction of
New Physics beyond the Standard Model

Direct Inclusive Searches for strong-production of New Physics
- 0 leptons
- ≥1 lepton

"Natural-SUSY"
- stop, sbottom searches

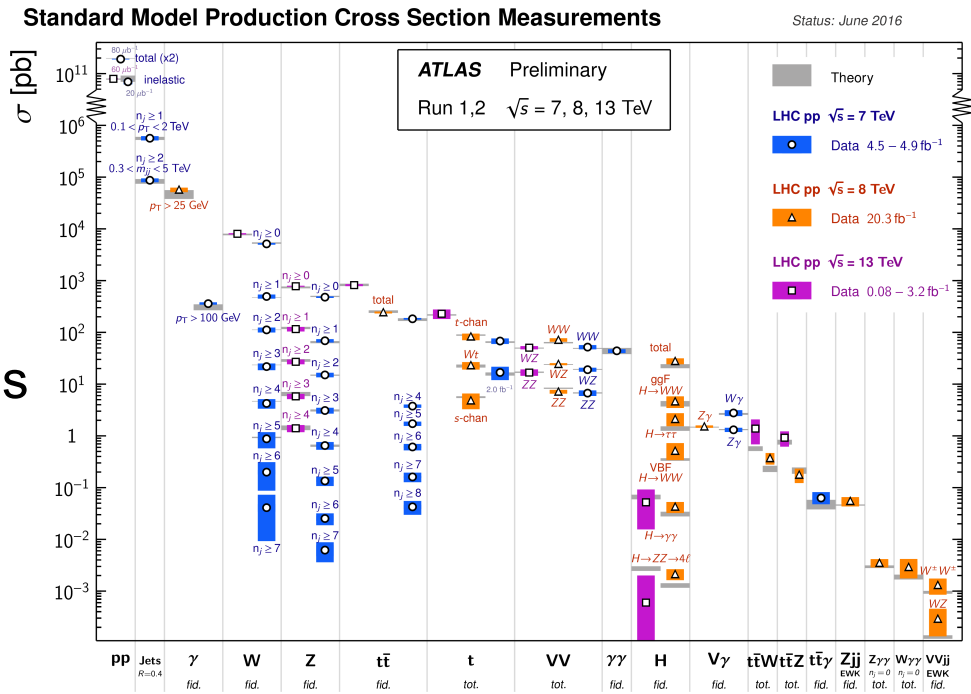
Gauge-mediated SUSY breaking
- photons or tau final states

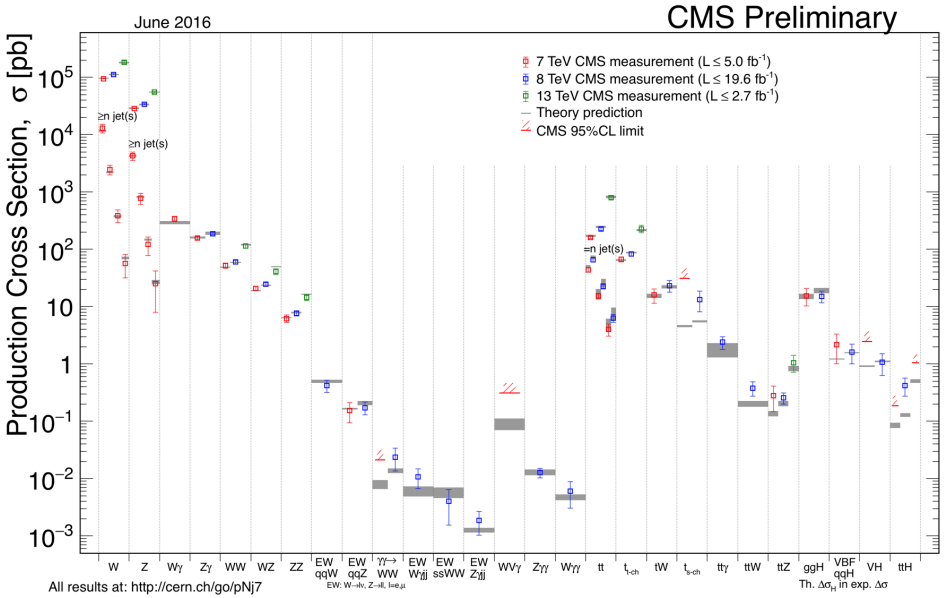
More Specialized Searches
- Di-lepton mass-edge, Z-resonance: A glimpse of signal?

Conclusion

Standard Model

- Remarkably well understood
  - background processes for searches for new physics
- New physics often expected at higher scales (high pT, MET)
  - in the tails of SM backgrounds
- Data-driven background estimation techniques
  - normalized control samples, control regions, jet smearing, …



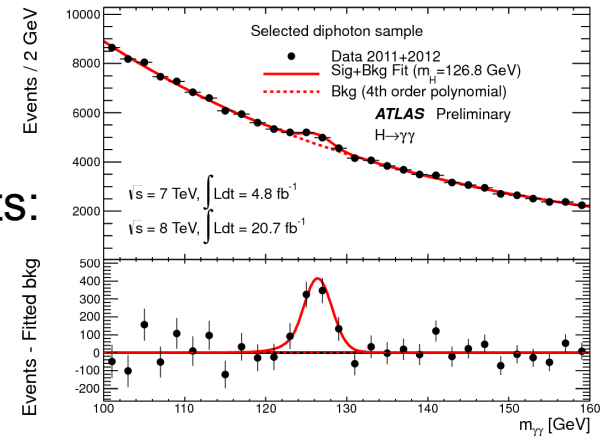


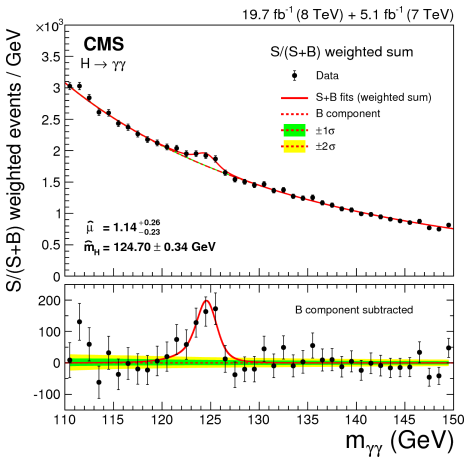
New physics beyond the Standard Model

- Viable dark matter candidates ?
  - Implies new, stable, neutral, (lightest) particle (the “LSP”) leading to missing transverse energy (MET) in the detectors
  - Corollary, limits from MET searches do not apply if the new theory has no LSP
- Unification of Gauge couplings at the GUT scale
- After the discovery of a Higgs Boson:
  - Hierarchy problem has become a real problem!
  - What mechanism is responsible for the Higgs mass?

Different ways to avoid massive fine-tuning

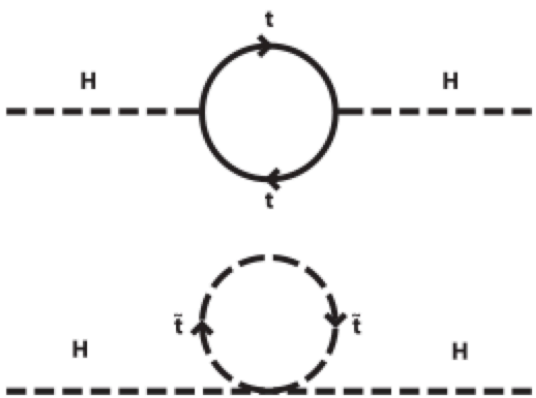
Higgs-mass measurements:





$$(m_{Higgs} = 125 \text{ GeV})^2 \ll \Lambda_{Planck}^2$$

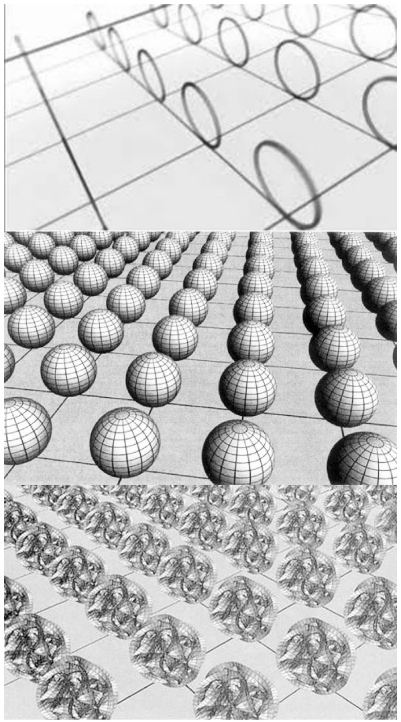
Supersymmetry



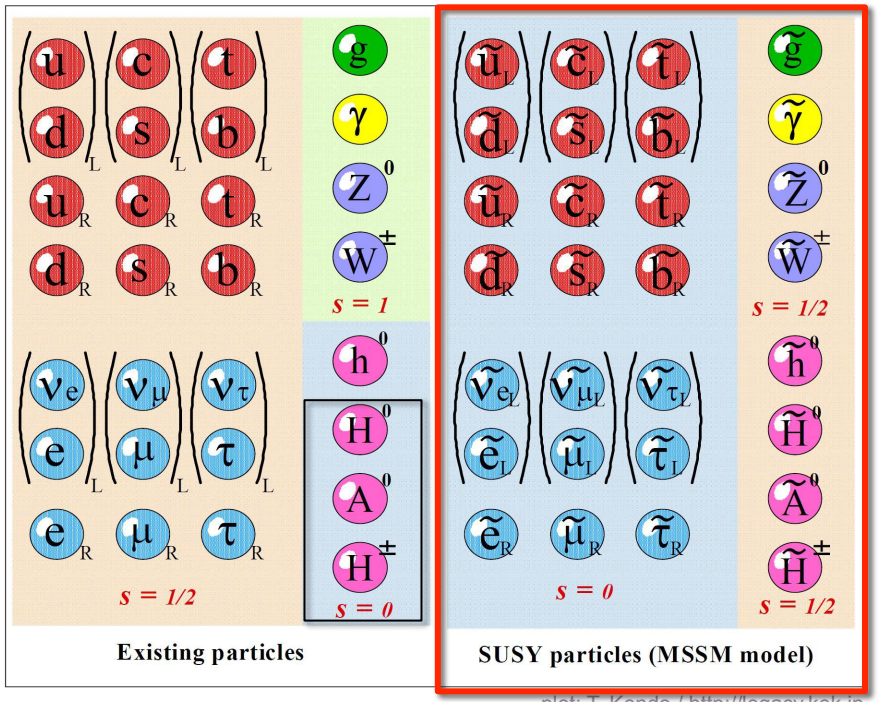
naturally protect Higgs-mass by symmetry

Extra-dimensions, composite Higgs

lowered fundamental scale Λ



Minimal supersymmetric standard model (MSSM)



plot: T. Kondo / http://legacy.kek.jp

- SUSY links Standard-Model particles with new *supersymmetric partners* with different spin
- Partners have same charges and couplings
  - solving the hierarchy problem
- Partners have different mass
  - Broken supersymmetry
  - reintroduce 'little hierarchy' problem, if masses are very different
- 120 new parameters
  - reduced to ~few by particular breaking mechanism

Generalization of lepton- & baryon number conservation: R–parity conservation

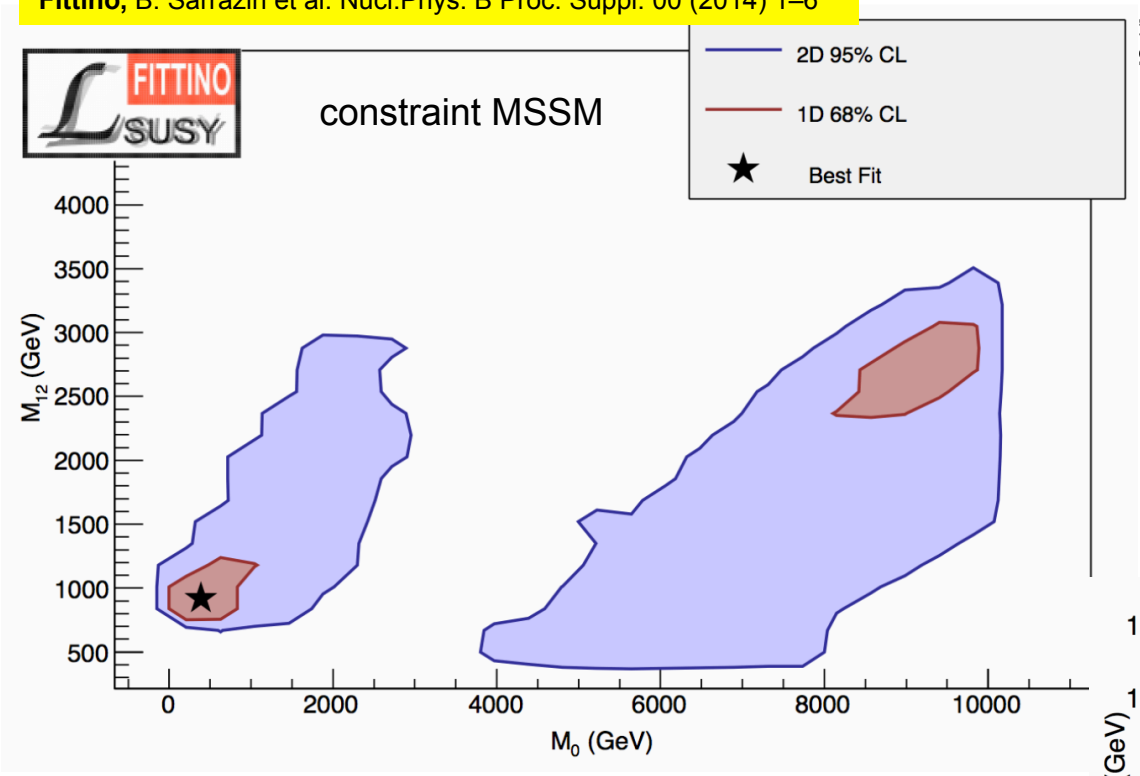
$$(-1)^{3B+L+2S}$$

if conserved

- SUSY particles are only produced in pairs
- the lightest SUSY particle (LSP) is stable

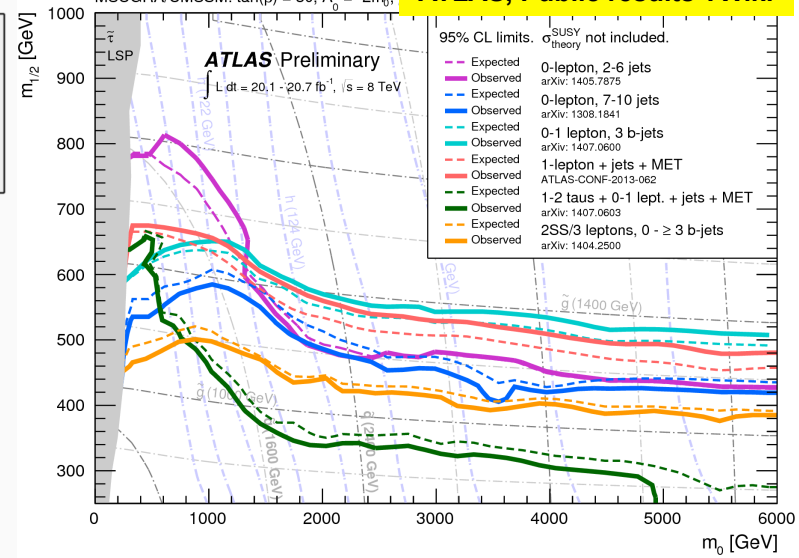
What is the status of the search for Supersymmetry?

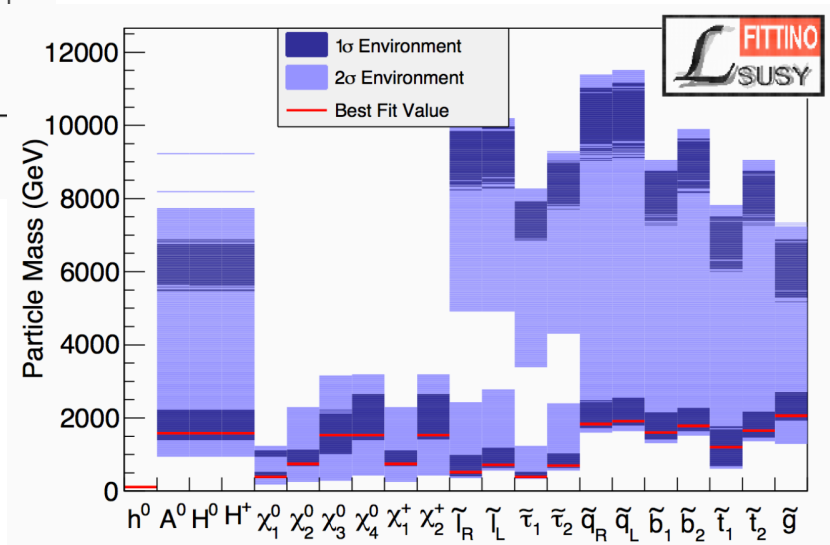
Fittino, B. Sarrazin et al. Nucl.Phys. B Proc. Suppl. 00 (2014) 1–6



cMSSM

ATLAS, Public results TWiki





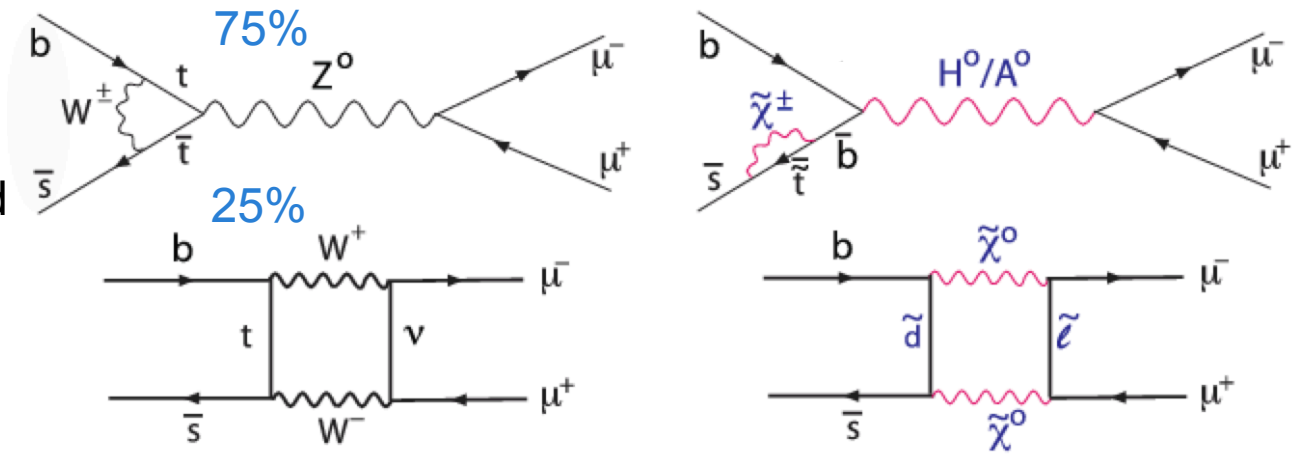
- cMSSM basically out of the game (observed best fit p-value = 2.5±0.5 %)
- “Natural SUSY” has to have decoupled spectra

B^0, B^0_s → μμ: Indirect searches

LHCb,CMS: arXiv:1411.5729
Nature (2015) 14474

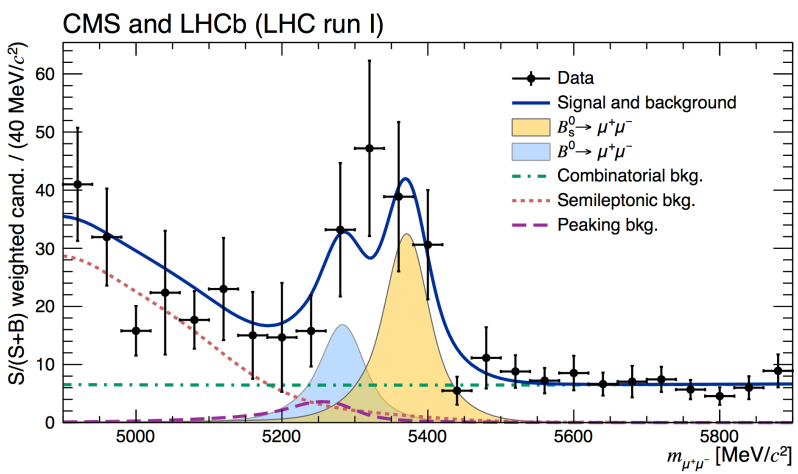
branching fraction to μμ has sensitivity to "new physics" like Supersymmetry

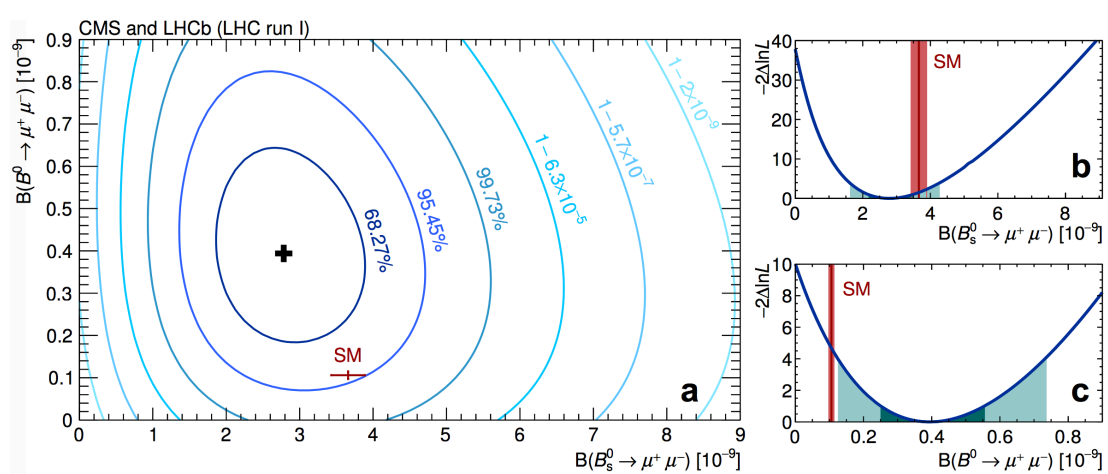
Standard Model

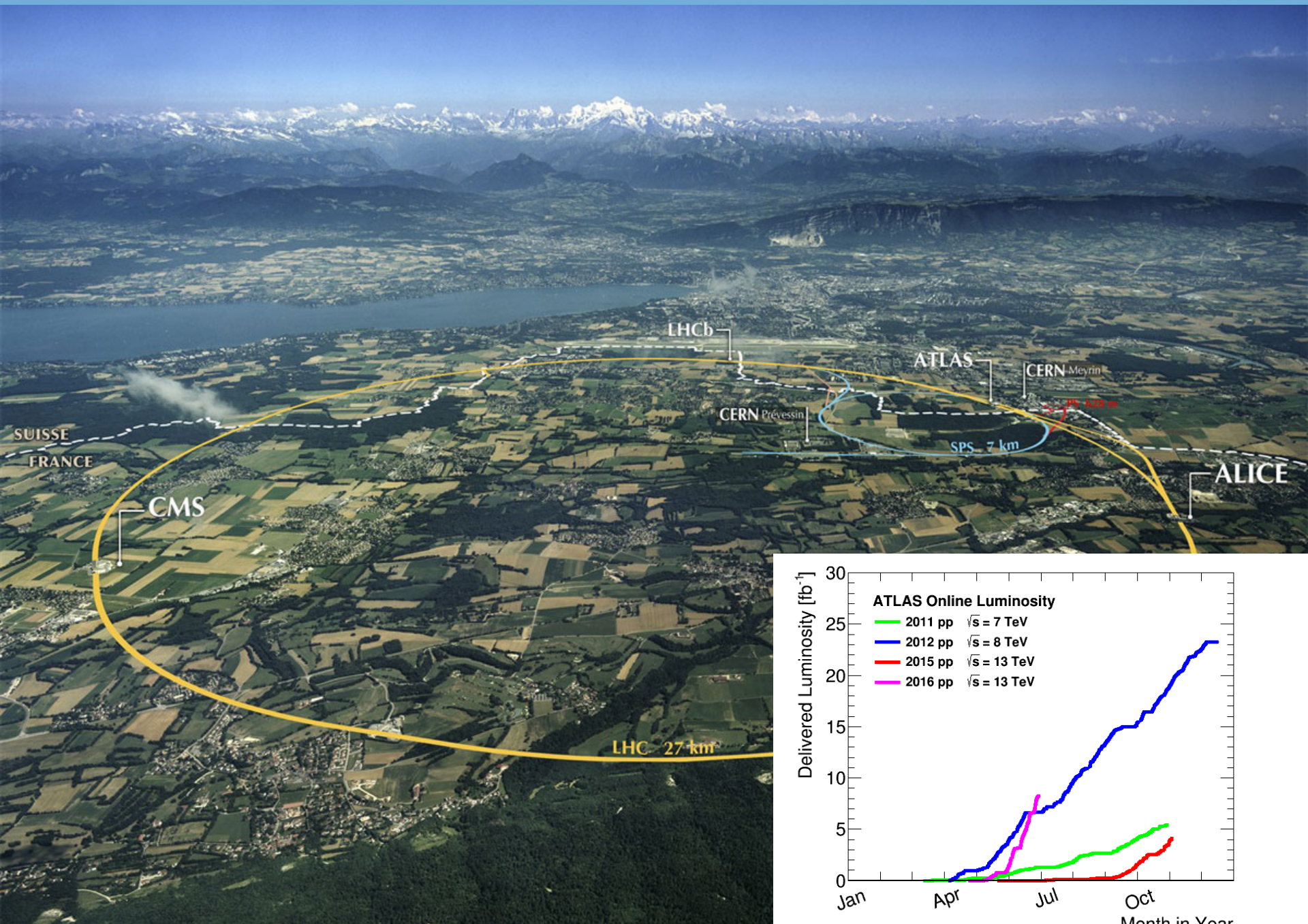


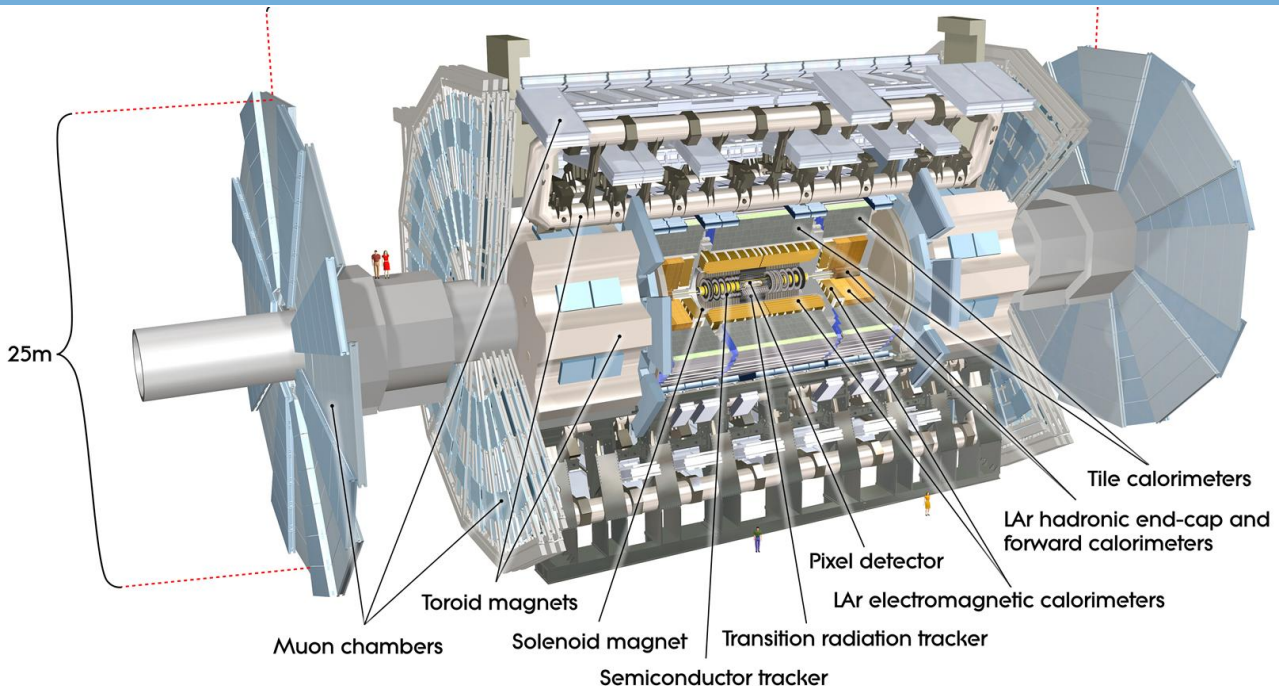
New Physics

Results: Consistent with Standard Model → constraints allowed "New Physics"



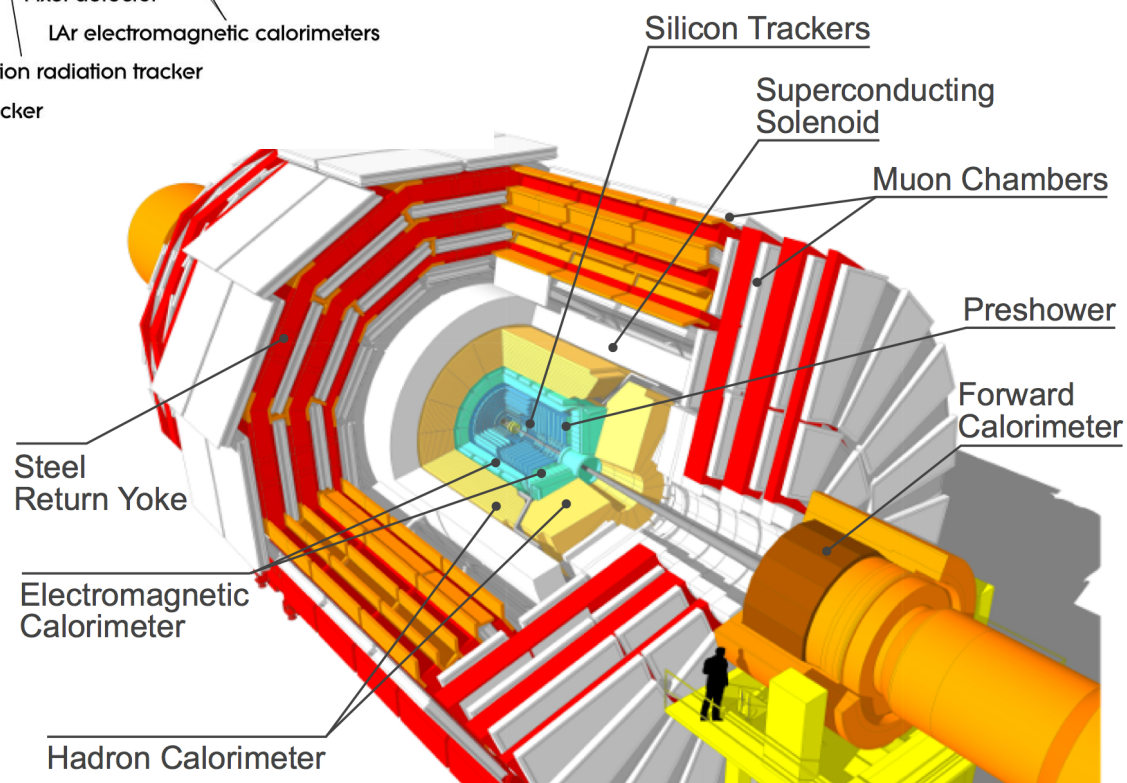



LHCb
ATLAS
CERN Meyrin
CERN Prévessin
SPS 7 km
SUISSE
FRANCE
ALICE
CMS
LHC 27 km
ATLAS Online Luminosity
2011 pp √s = 7 TeV
2012 pp √s = 8 TeV
2015 pp √s = 13 TeV
2016 pp √s = 13 TeV
Delivered Luminosity [fb⁻¹]
0
5
10
15
20
25
30
Jan
Apr
Jul
Oct
Month in Year


25m
Tile calorimeters
LAr hadronic end-cap and forward calorimeters
Pixel detector
LAr electromagnetic calorimeters
Toroid magnets
Muon chambers
Solenoid magnet
Transition radiation tracker
Semiconductor tracker

Atlas

CMS


Silicon Trackers
Superconducting Solenoid
Muon Chambers
Preshower
Forward Calorimeter
Steel Return Yoke
Electromagnetic Calorimeter
Hadron Calorimeter

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Gauge-mediated SUSY breaking
- photons or tau final states

More Specialized Searches
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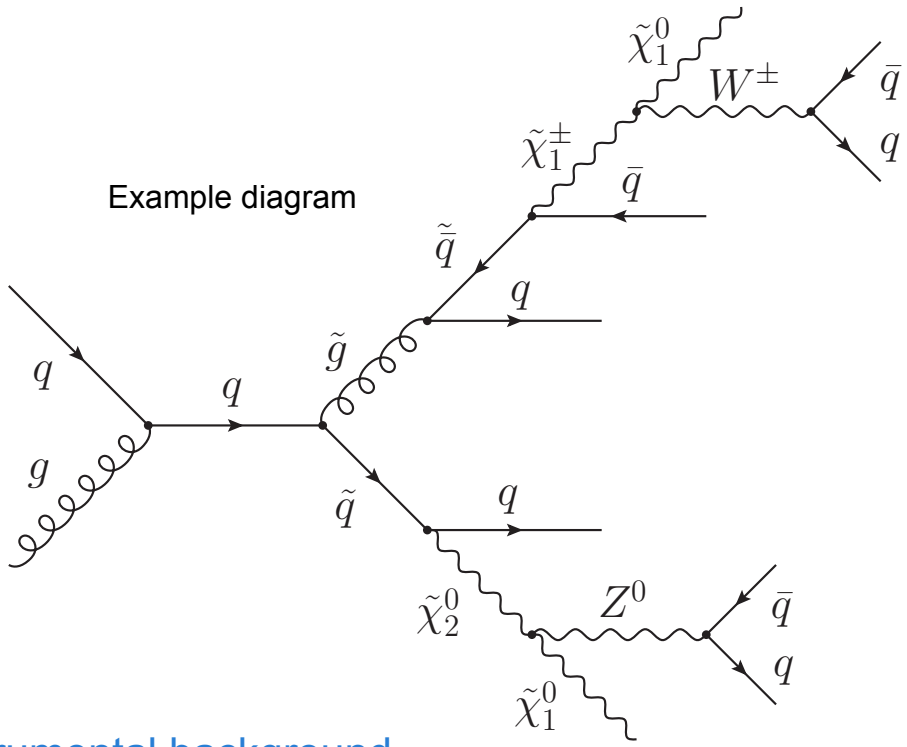
Conclusion

Strong production, 0-lepton final state

Example diagram



- Instrumental background
  - QCD multi-jet production
  - W/tt➔(e/μ)+jets
- Irreducible backgrounds
  - Z➔νν
  - W+jets➔τ+jets

➔ Typically estimated using data-driven methods

Final state

- Stable neutral New-Physics particle (the LSP)
  - missing transverse Energy (MET / MHT) :

$$\not{H}_T = \left| -\sum_i^{jets} \vec{p}_{T,i} \right|$$

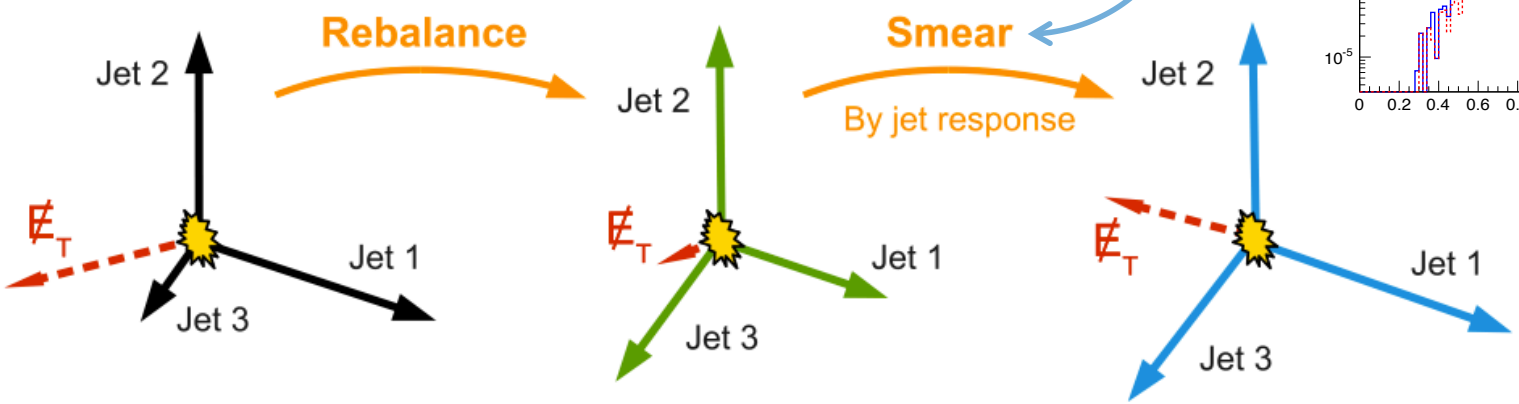
- Jets
  - High multiplicity or
  - High H_T (scalar sum jet p_T)

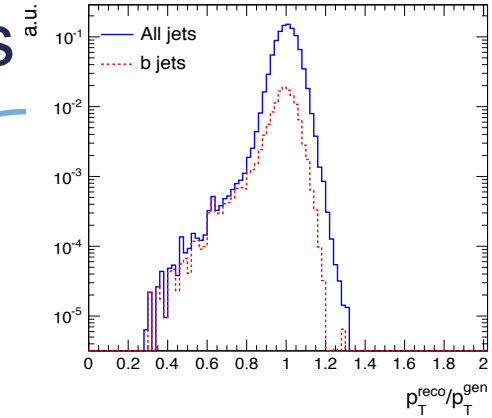
$$H_T = \sum_i^{jets} \left| \vec{p}_{T,i} \right|$$

  - S_T, $m_{eff} = H_T + MET$
- Kinematic variables
  - MT2, “Razor”, α_T using hemisphere algorithms

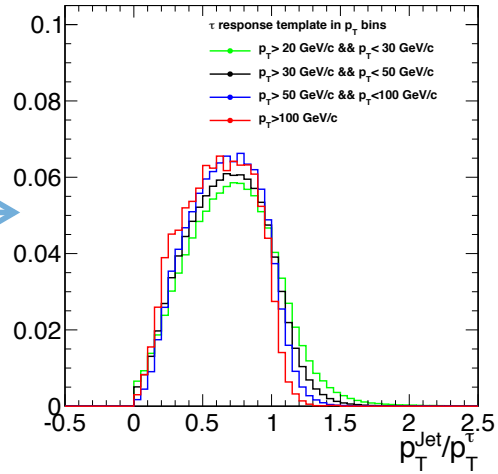
Data-driven background estimation strategies

- QCD multijet estimation





- tt/W ➔ τ(→hadrons) + jets
  - Isolated μ control sample
  - μ replaced by tau response according to template (each μ sampled 100 times)
  - correct for μ efficiencies



- Matrix / “ABCD”-method: normalization to control region
- …

Strong production, ≥ 0 leptons

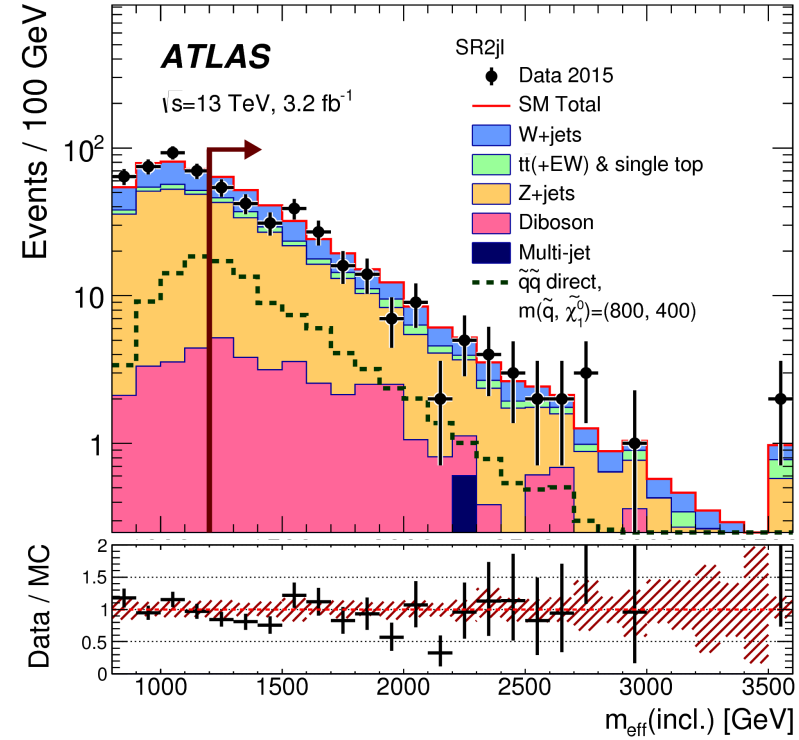
- "Inclusive searches", fully hadronic final state
- "Bread & Butter" workhorse searches
- data-driven background estimation, or estimation scaled in data-control regions

latest 13 TeV results using up to 3.2 fb^{-1} int. luminosity of 2015 data:

ATLAS-15-06	subm. to EPJC	0 – 6 jets
ATLAS-15-07	PLB 757 (2016) 334	7 – 10 jets
ATLAS-15-08	subm. to EPJC	0 – 6 jets, 1 lepton
CMS-15-02	PLB 758 (2016) 152	Jets + MHT
CMS-15-03	subm. to JHEP	M_{T2}
CMS-15-04	PAS	Razor
CMS-15-06	PAS	Inclusive, 1 lepton

$\rightarrow$ updates with the 2016 dataset planned for ICHEP

- **ATLAS-15-06: 2 – 6 jets**

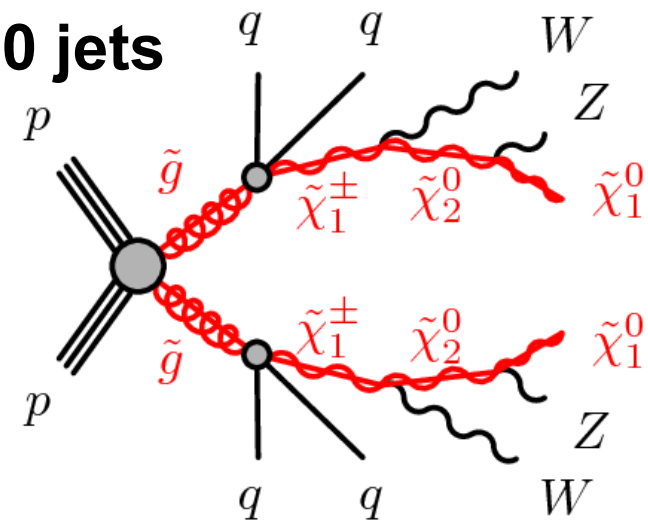


Requirement	Signal Region						
	2jl	**2jm**	**2jt**	**4jt**	**5j**	**6**	
$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV] >	200						
$p_{\mathrm{T}}(j_1)$ [GeV] >	200	300	200				
$p_{\mathrm{T}}(j_2)$ [GeV] >	200	50	200	100			
$p_{\mathrm{T}}(j_3)$ [GeV] >	–			100			
$p_{\mathrm{T}}(j_4)$ [GeV] >	–			100			
$p_{\mathrm{T}}(j_5)$ [GeV] >	–				50		
$p_{\mathrm{T}}(j_6)$ [GeV] >	–					50	
$\Delta\phi(\mathrm{jet}_{1,2,(3)}, \boldsymbol{E}_{\mathrm{T}}^{\mathrm{miss}})_{\mathrm{min}}$ >	0.8	0.4	0.8	0.4			
$\Delta\phi(\mathrm{jet}_{i>3}, \boldsymbol{E}_{\mathrm{T}}^{\mathrm{miss}})_{\mathrm{min}}$ >	–			0.2			
$E_{\mathrm{T}}^{\mathrm{miss}}/\sqrt{H_{\mathrm{T}}}$ [GeV$^{1/2}$] >	15		20	–			
Aplanarity >	–			0.04			
$E_{\mathrm{T}}^{\mathrm{miss}}/m_{\mathrm{eff}}(N_{\mathrm{j}})$ >	–			0.2	0.25		0.2
m_{eff}(incl.) [GeV] >	1200	1600	2000	2200	1600	1600	2000

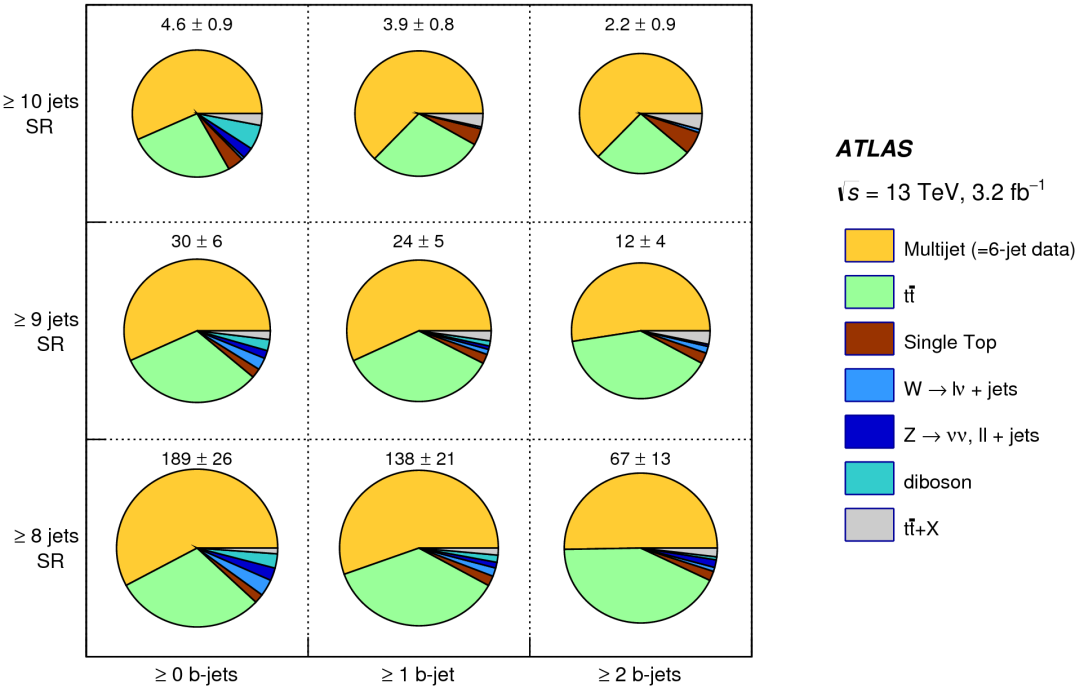
$$m_{\mathrm{eff}} = \sum_{\mathrm{jets}} p_T^i + E_T^{\mathrm{miss}}$$

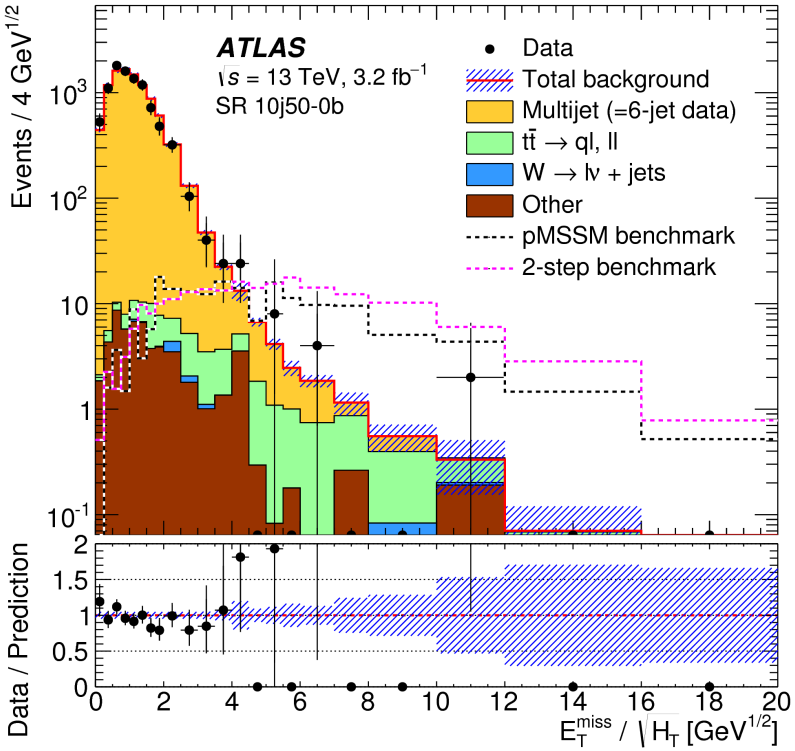
a.k.a S_T

- **ATLAS-15-07**, PLB 757 (2016) 334, **7 – 10 jets**

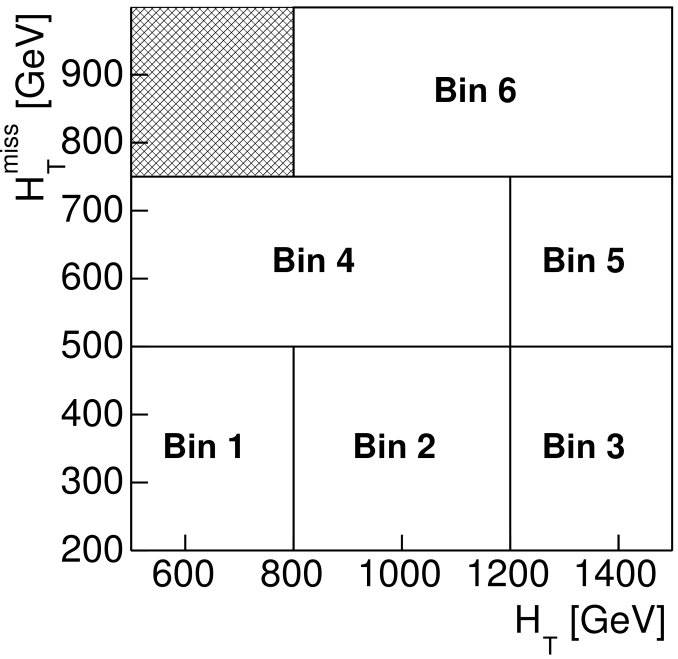


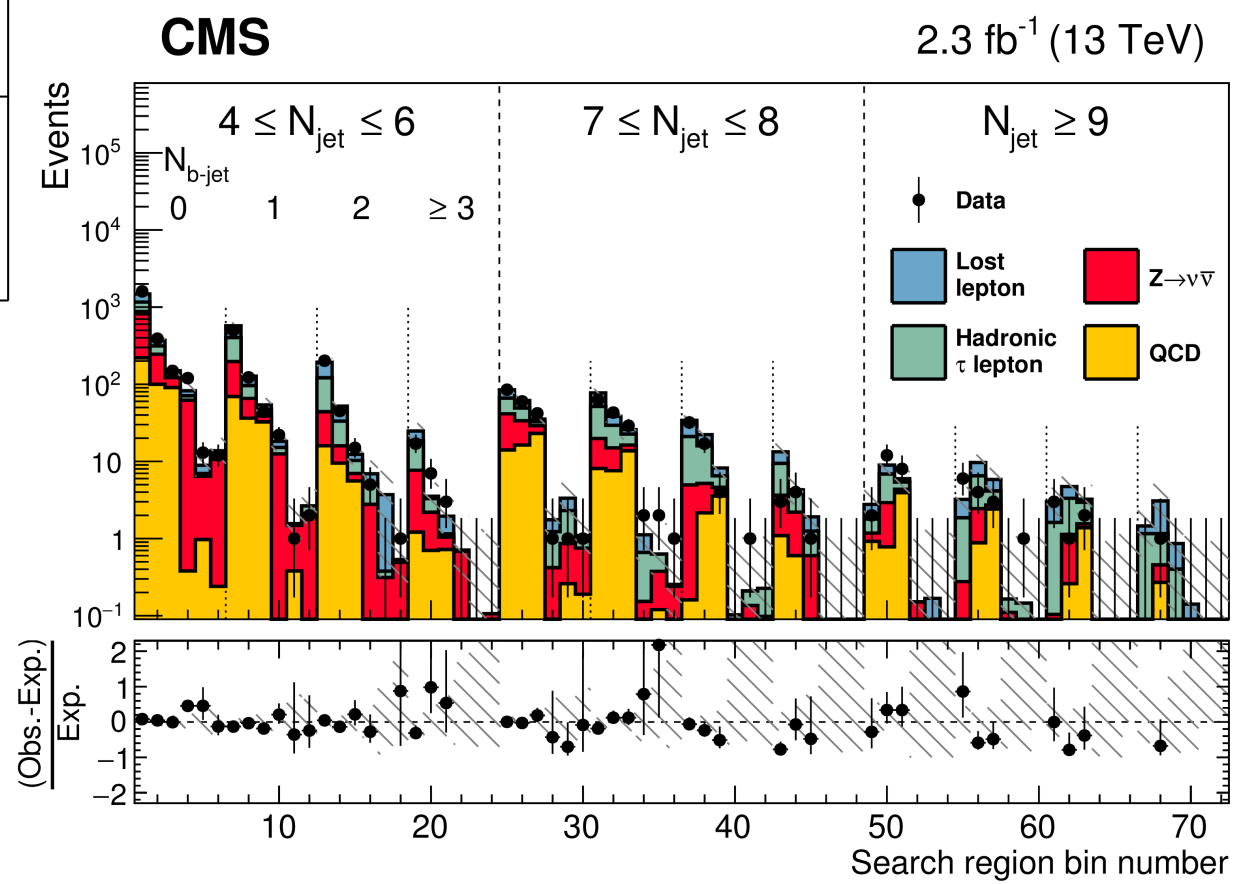
- many jets & b-tag multiplicities
- targeted at long decay chains
- complementary to 2-6 jets searches





- **CMS-15-02**, PLB 758 (2016) 152, **Jets + MET**





further binning:

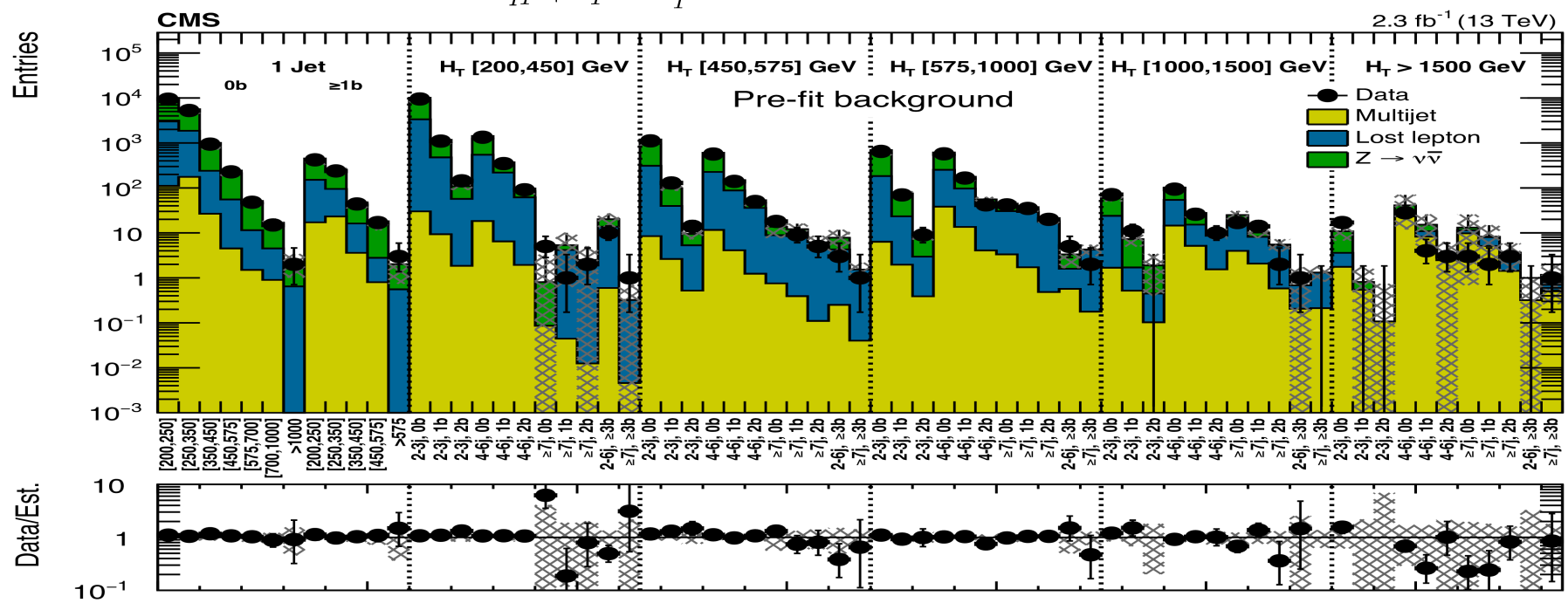
- n_{jet}: 4-6, 7-8, ≥ 9
- $n_{b\text{-tag}}$: 0, 1, 2, ≥ 3

72 signal regions

• CMS-15-03, subm to JHEP, M_{T2}

- Transverse mass $m_T(\vec{p}_T, \vec{q}_T) = \sqrt{2p_T q_T - \vec{p}_T \vec{q}_T}$ (e.g. W→ lν with $q_T \equiv E_t^{miss}$)

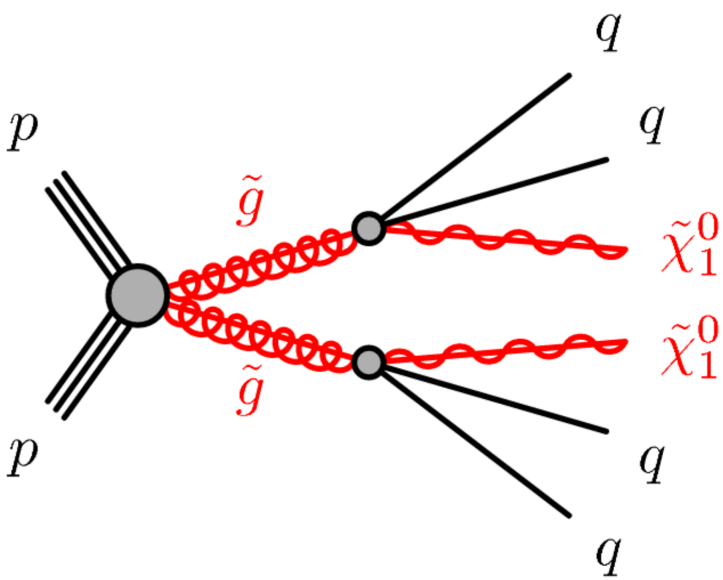
- sTransverse mas $M_{T2} = \min_{\vec{q}_T + \vec{r}_T = \vec{E}_T^{miss}} \left[\max \left(m(p_T^{jet_1}, q_T), m(p_T^{jet_2}, r_T) \right) \right]$

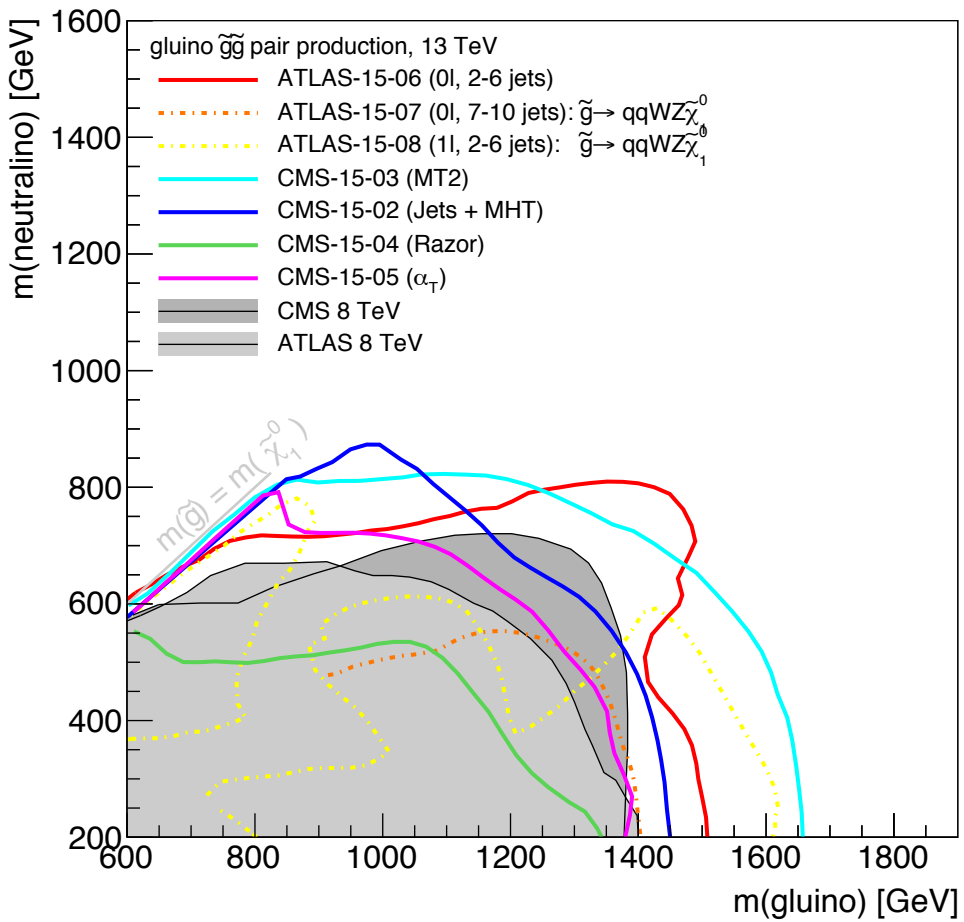


Binning in M_{T2}, H_T, N_j, N_b; 172 exclusive signal regions in total

Results: Inclusive searches

Summary
ATLAS & CMS





Results for simplified scenarios with longer decay chains shown as dashed lines

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Conclusion

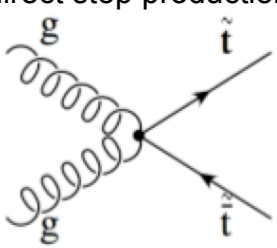
Guidance from naturalness

- To avoid fine-tuning and maintain naturalness at least
  - m(**gluino**) ~< few TeV
  - m(**stop**), m(**sbottom**) ~< 1 TeV
  - **Higgsino** ~ 200 – 300 GeV

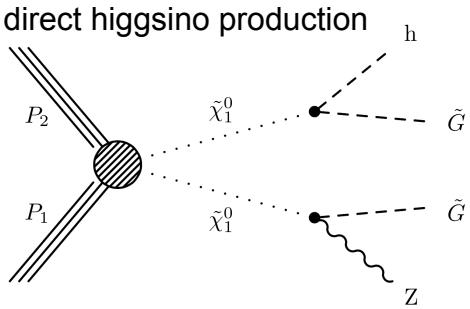
while the other sparticles can be inaccessible at higher scales.

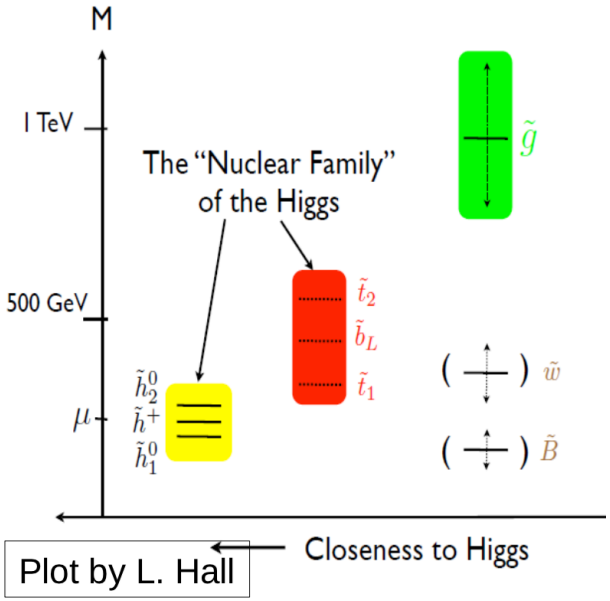
- Searches for "Natural SUSY" guided by dedicated simplified model spectra:

direct stop production



direct higgsino production

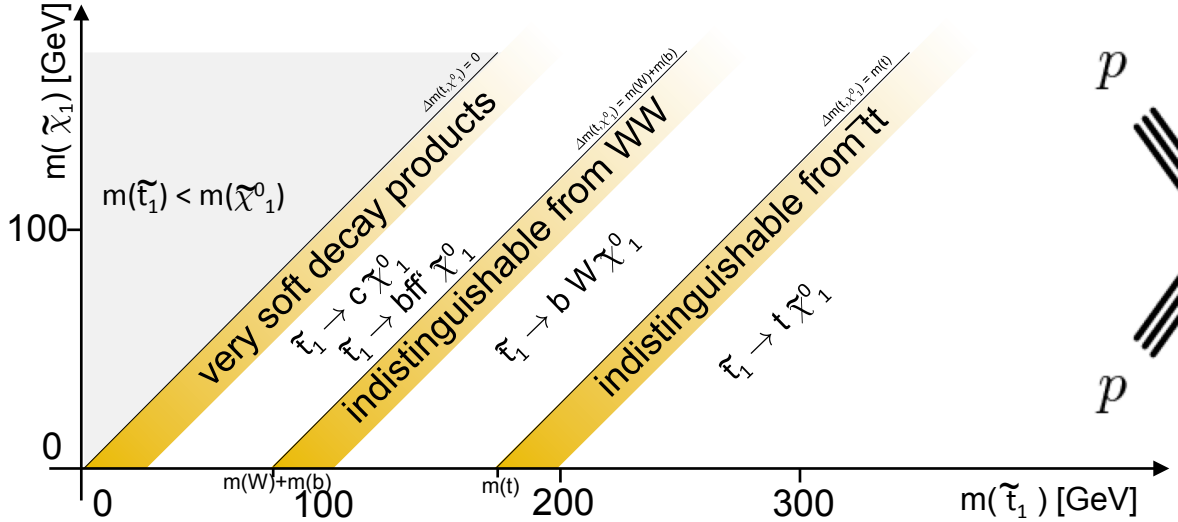


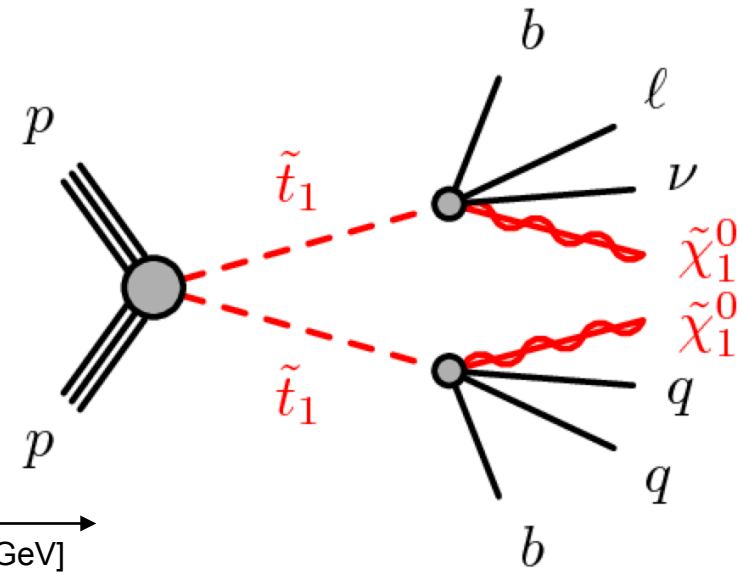


Plot by L. Hall

Direct stop production

- Natural SUSY requires the 3rd generation squarks to be light

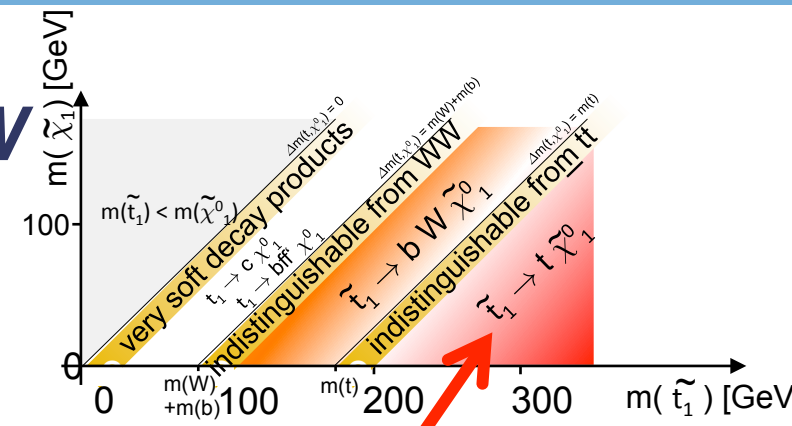




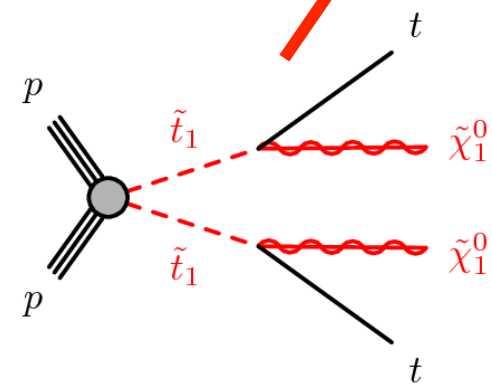
- Several different kinematic regions & blind spots

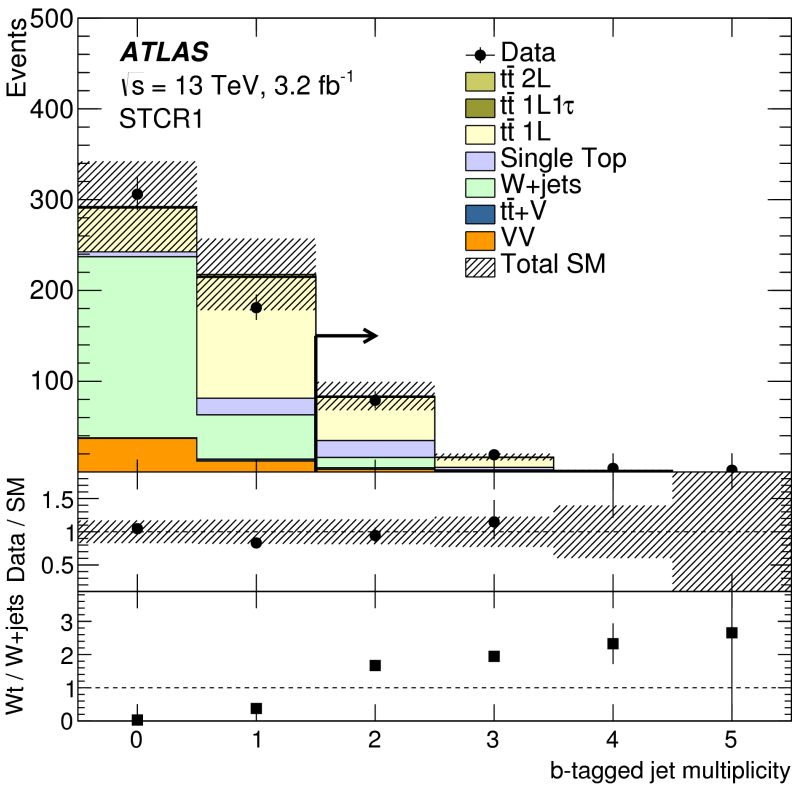
ATLAS-15-02, subm. to PRD	single lepton
ATLAS-EXO-15-03, subm to PRD	monojet
ATLAS-CONF-16-09	dilepton
CMS-PAS-16-01	monojet
CMS-PAS-15-02	single lepton
CMS-PAS-16-07	Jet + MET
CMS-PAS-16-11	soft lepton

Decays of stop to on-shell *t* or *W*



- Highly energetic leptons from W (top) decays
- Experimental challenge to distinguish from Standard Model ttbar and WW



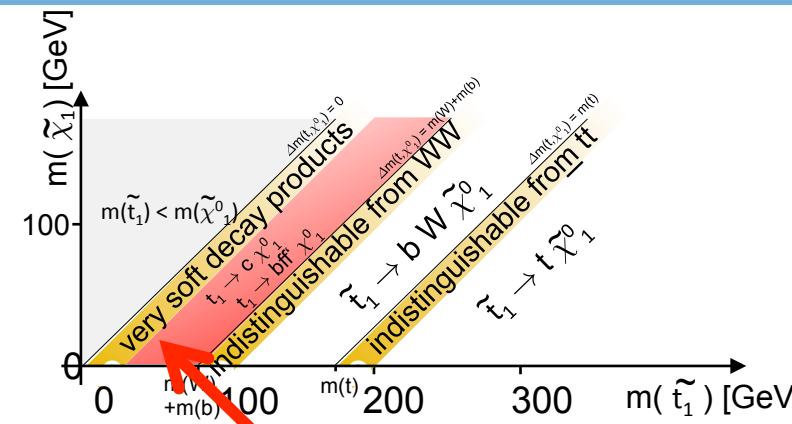


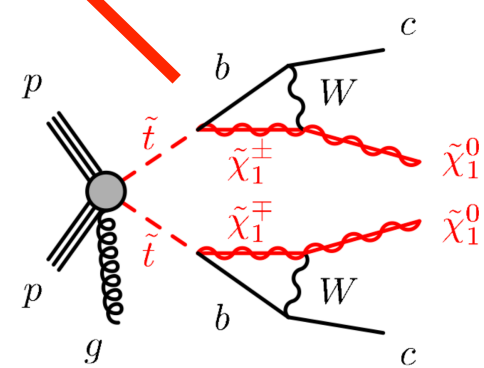
ATLAS-15-02, subm. to PRD (**1 lepton**)

- one isolated electron or muon
- MET > 200 GeV, m_T(l,MET)>30 GeV
- Three overlapping signal regions optimized for direct / gluino-mediated production
- Background estimates from data

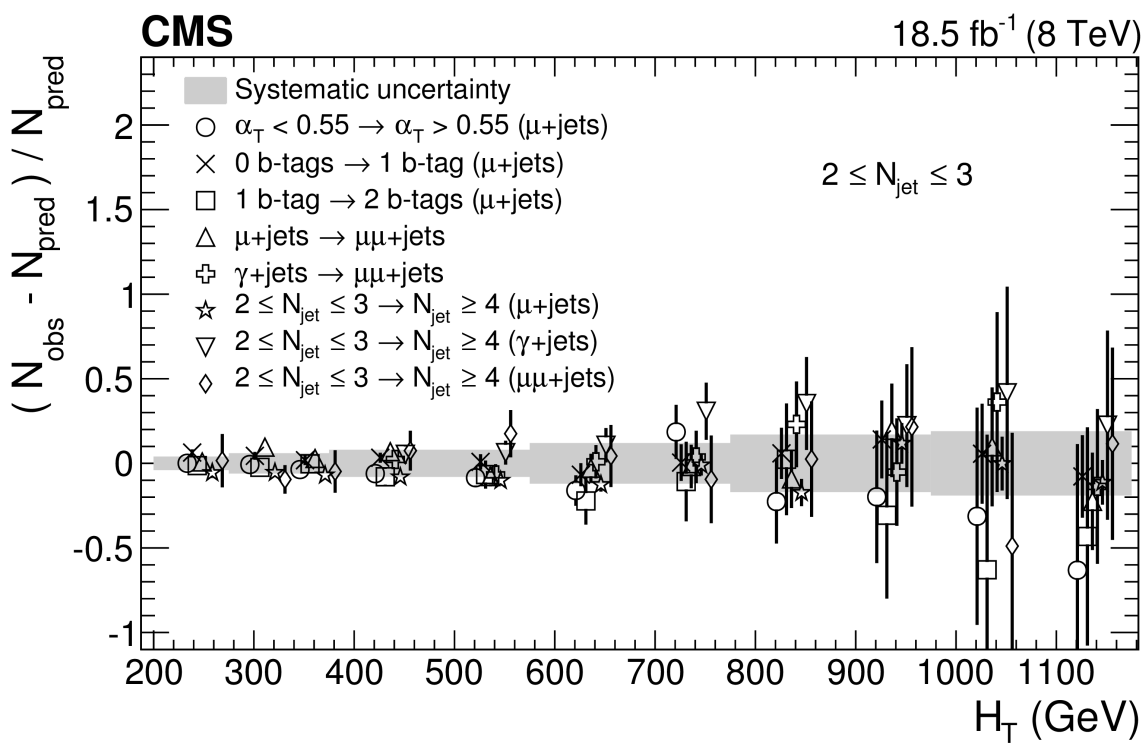
Direct 3rd generation squark production: compresses spectra

- c-tagged selection
- mono-jet selection





CMS-14-06, subm. to PLB, (α_T)



- 75 exclusive signal bins in H_T, N_j, N_b
- α_T > 0.55 to suppress QCD multijet
- Data driven background estimation techniques

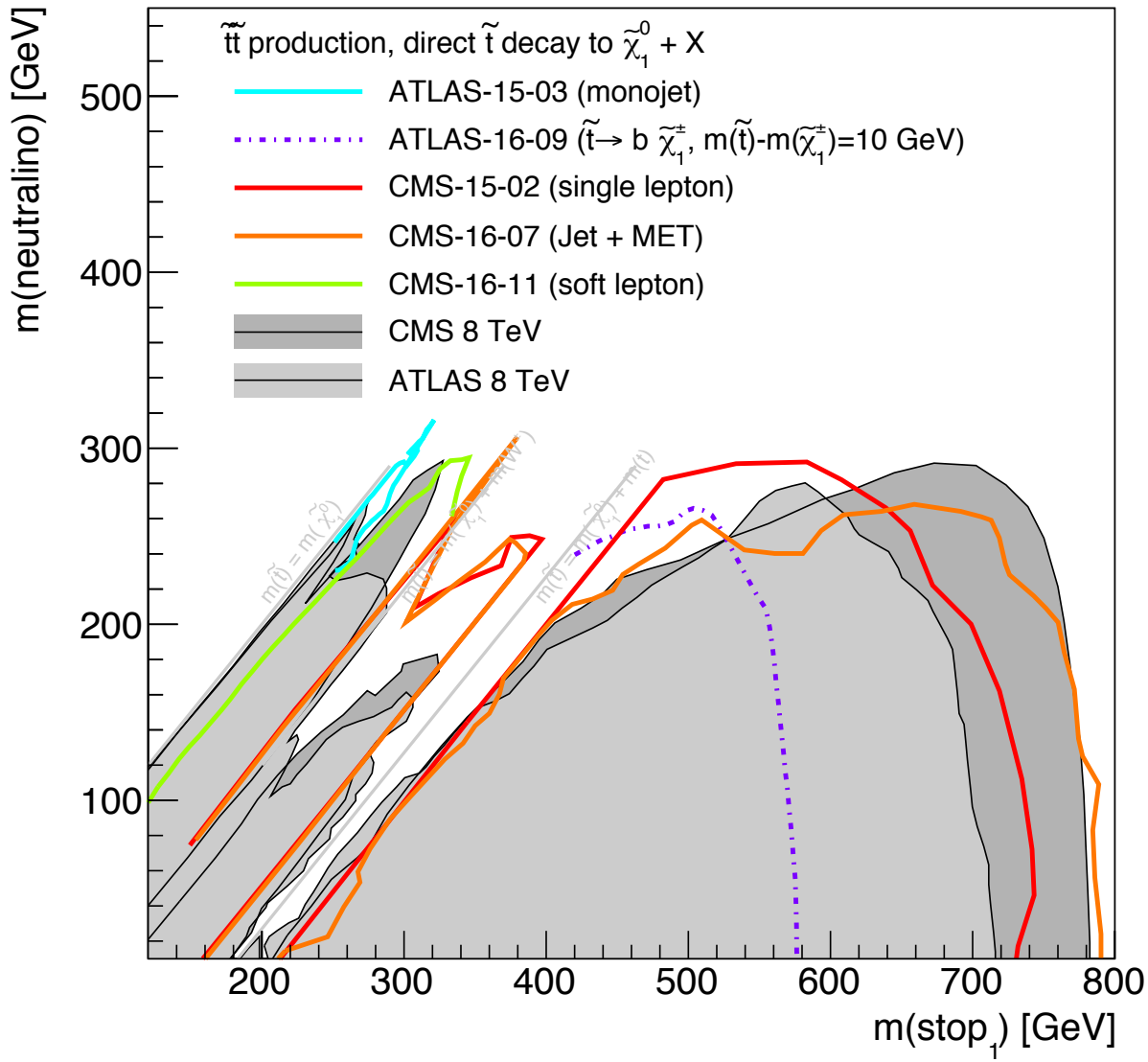
Summary: Direct stop pair production

For clarity, only the most sensitive results wrt the contour envelope are shown

To improve in the difficult gap regions:

- clever new analyses techniques
- theory improvements on ttbar cross-section and angular distributions

crucial to distinguish SM ttbar from signal



Overview

Motivation and Introduction of
New Physics beyond the Standard Model

Direct Inclusive Searches for strong-production of New Physics
- 0 leptons
- ≥1 lepton

"Natural-SUSY"
- stop, sbottom searches

➔ Gauge-mediated SUSY breaking
- photons or tau final states

More Specialized Searches
- Di-lepton mass-edge, Z-resonance: A glimpse of signal?

Conclusion

Gauge mediated supersymmetry breaking

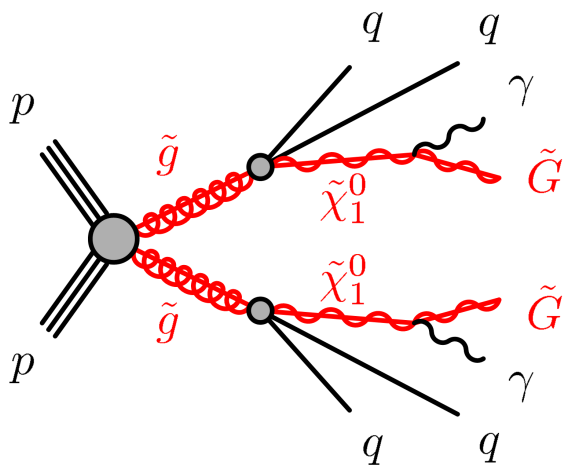
- Gravitino is the lightest SUSY particle (LSP)
  - negligible mass $\leftrightarrow$ prompt NLSP decay
- Next-to-lightest SUSY particle (NLSP) determines final state
  - Neutralino $\rightarrow$ photons, Z-boson, H-boson in final state
  - sTau $\rightarrow$ final states with τ - leptons

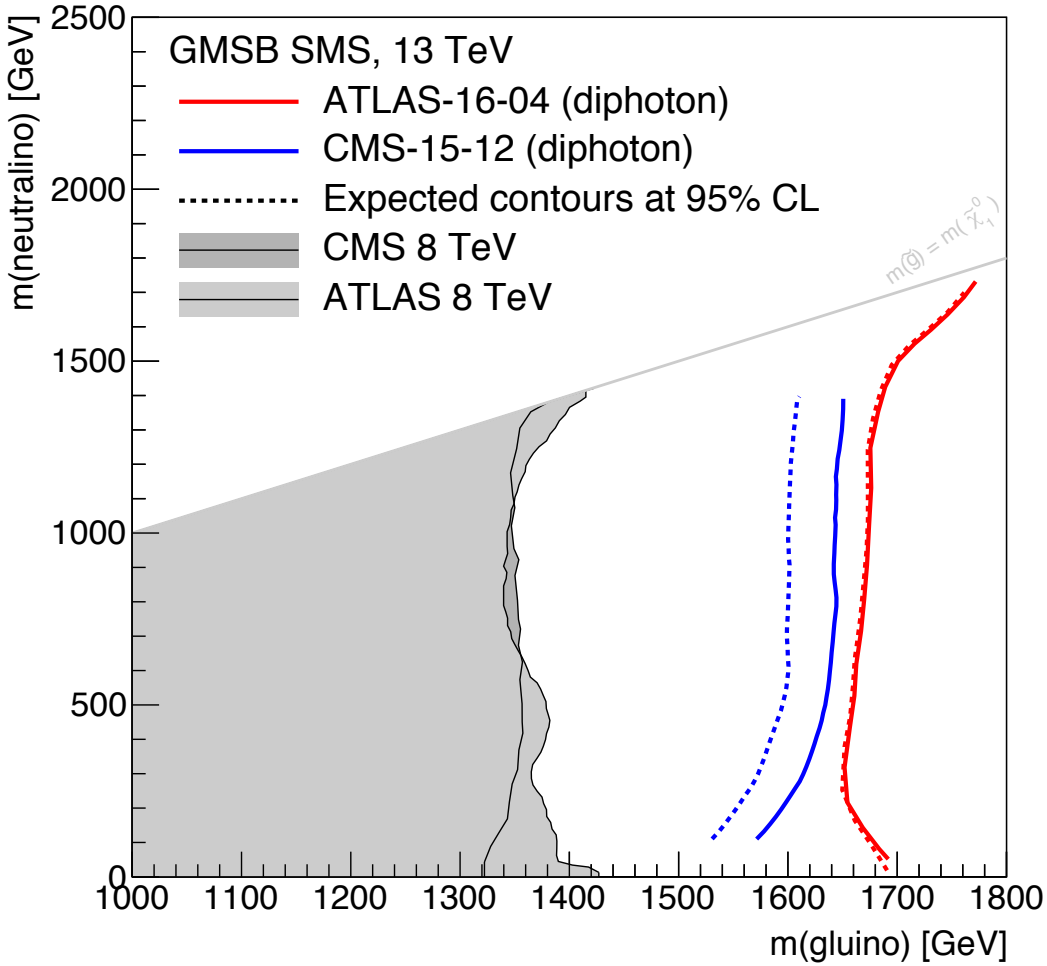
ATLAS-14-01, PRD 92(2015)72001	8 TeV, 20.3 fb^{-1}	single-, diphoton
ATLAS-16-04, subm. to EPJC	13 TeV, 3.2 fb^{-1}	diphoton
ATLAS-14-04, EPJC (2016) 76	8 TeV, 20 fb^{-1}	ditau, 3rd generation
ATLAS-14-05, PRD 93(2016)52002	8 TeV, 20 fb^{-1}	ditau, EWK prod.
CMS-PAS-15-12	13 TeV, 2.3 fb^{-1}	diphoton
CMS-14-16, PLB759 (2016) 479	8 TeV, 7.4 fb^{-1} *	EWK single-photon
CMS-14-04, PRD 92 (2015)072006	8 TeV, 19.7 fb^{-1}	single-, diphoton
CMS-PAS-14-22	8 TeV, 20 fb^{-1}	EWK ditau

(*) parked dataset

Strong production

- Gauge mediated supersymmetry breaking (GMSB)
- Simplified scenario:
  - strong production
  - bino-like neutralino NLSP





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- photons or tau final states

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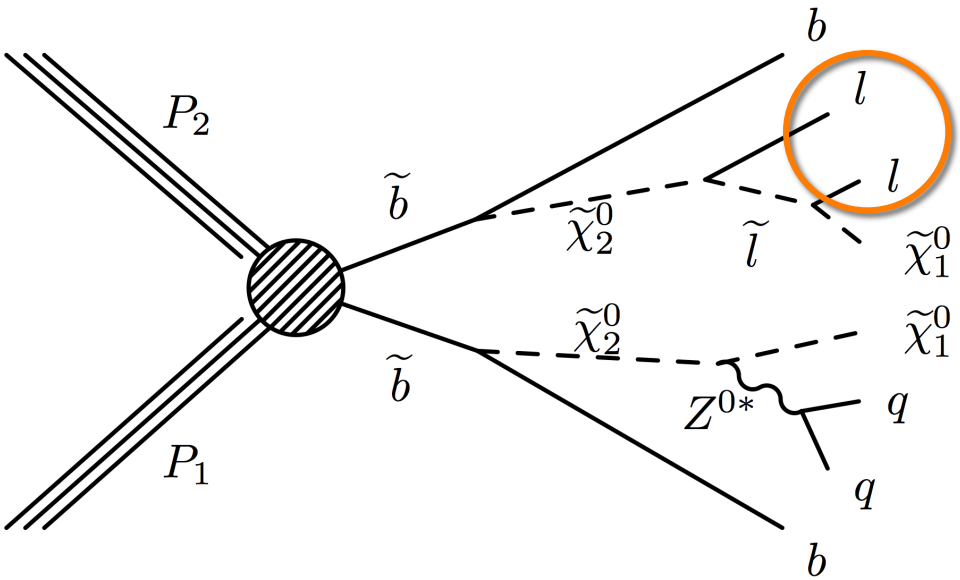
- Di-lepton mass-edge, Z-resonance: A glimpse of signal?

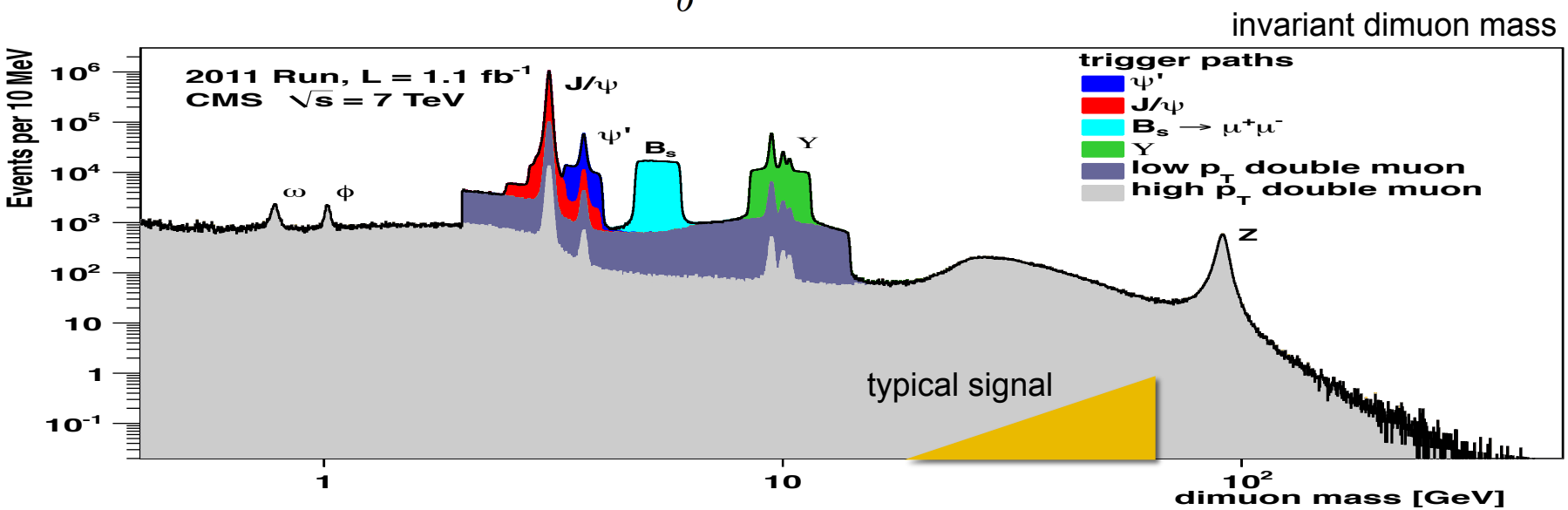
Conclusion

Search for a dilepton mass edge

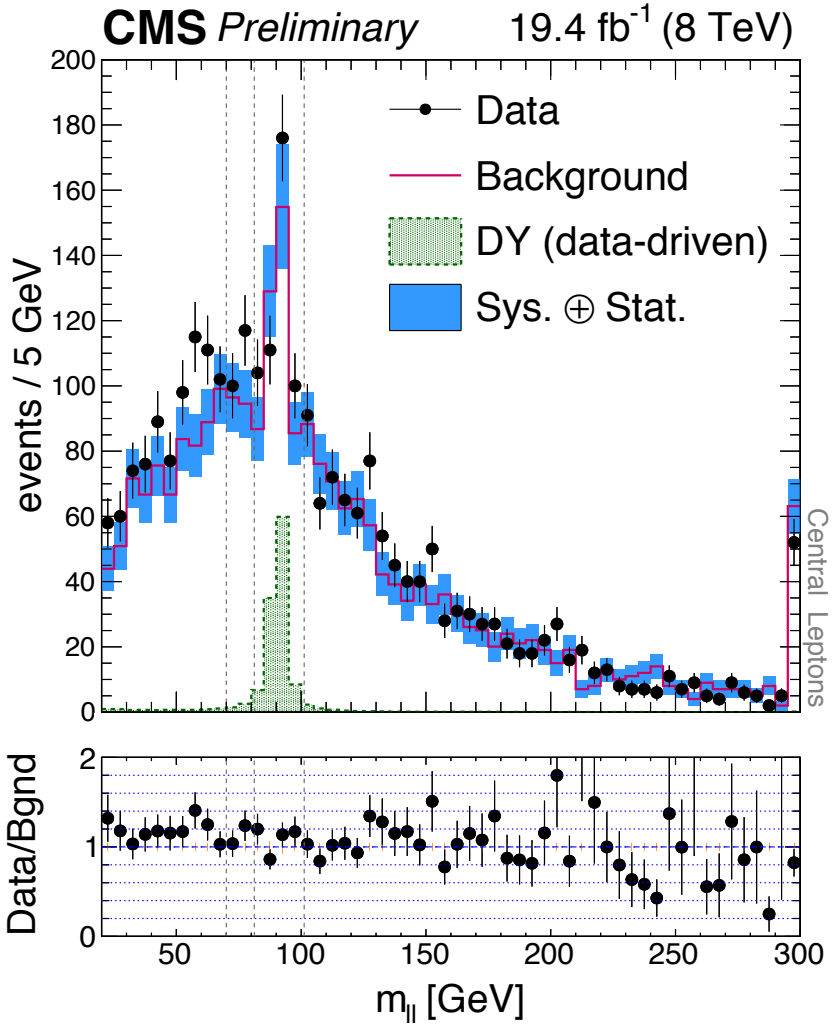


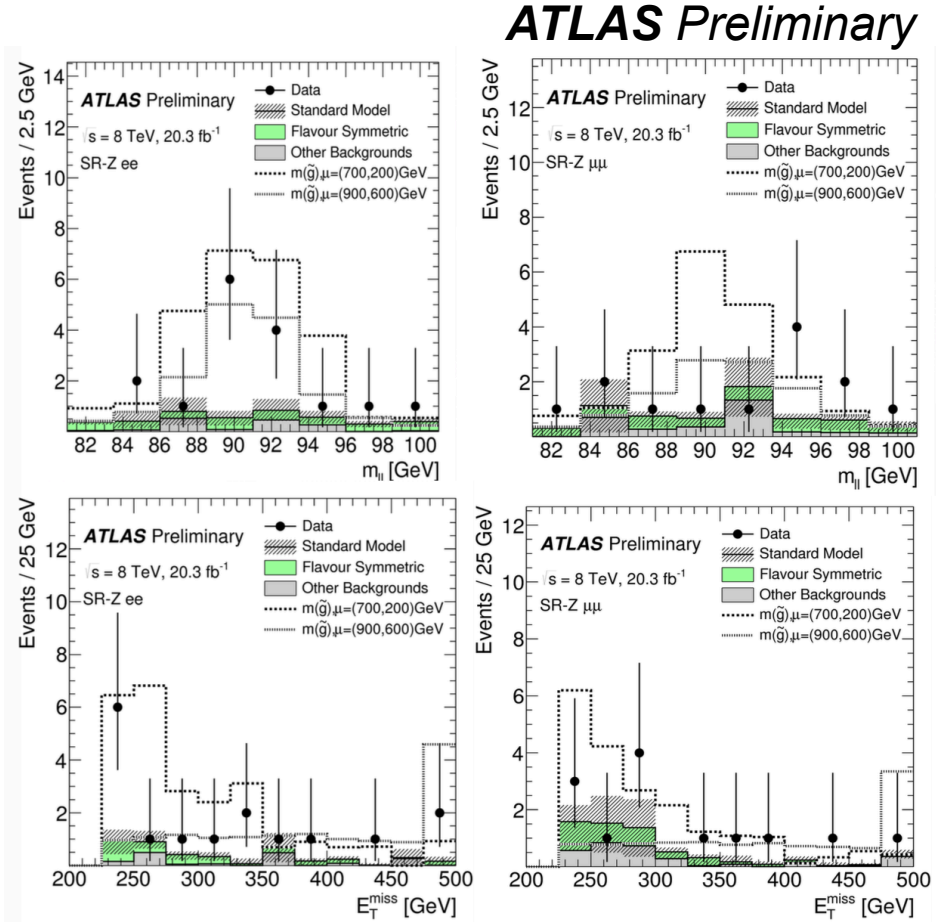
Upper mass edge:
$M_{max} = M(\chi^0_2) - M(\chi^0_1)$

Signal: e^+e^- or $\mu^+\mu^-$
Background: from $e\mu$



Exiting excesses at 2.5σ – 3.0σ in 8 TeV data at CMS & ATLAS, respectively:





Dominant background: **tt**

- use lepton-flavor symmetry

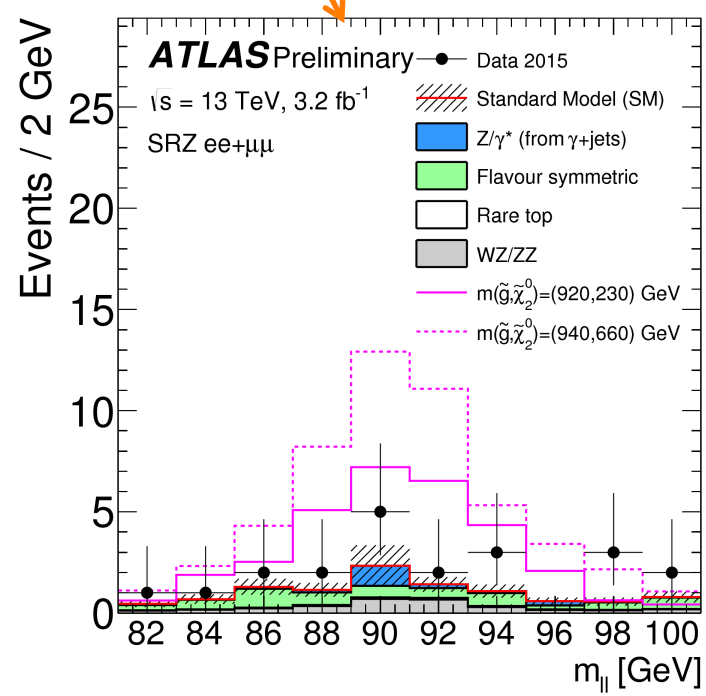
Alternative analysis: Unbinned Fit

on-Z selection:
dominant background: **Z/DY**
H_T > 600 GeV, MET > 225 GeV

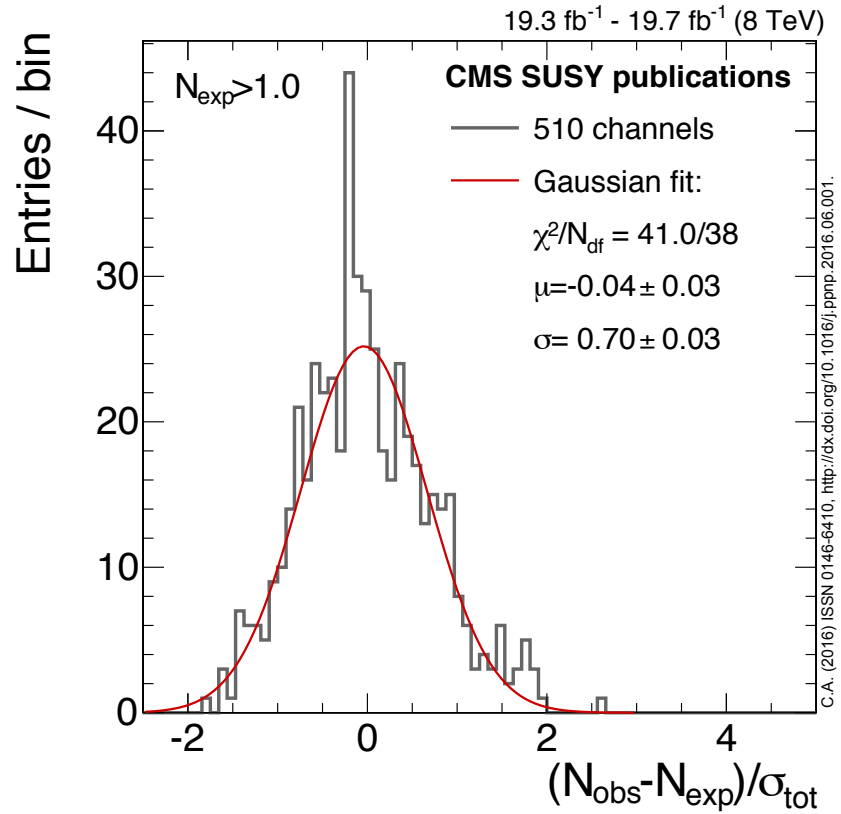
Dileptons: latest results

CMS-14-14, JHEP 04 (2015) 124	8 TeV, 19.4 fb^{-1}	2.5 – 2.6 σ excess at low m(ll)
ATLAS-14-10, EPJ C75(2015) 318	8 TeV, 20.3 fb^{-1}	3.0 σ excess on-Z
CMS-PAS-15-11	13 TeV, 2.2 fb^{-1}	*no excesses*
ATLAS-CONF-15-82	13 TeV, 3.2 fb^{-1}	2.2 σ excess on-Z

- CMS 8 TeV off-Z excess not confirmed by 13 TeV data
- ATLAS non-Z excess not confirmed by CMS data
- 2016 dataset at 13 TeV for ICHEP will clarify situation



Conclusion



- Atlas & CMS have searched for New Physics using the 2012 data
- As more 13 TeV data becomes available, sensitivity on the SUSY phase space evolves fast
- Excellent performance of detectors Standard Model measurements and more complicated & specialized search analyses possible and worthwhile!
- Naturalness arguments promises New Physics at the TeV scale, the TeV scale is now in reach!

References

Atlas public results: https://twiki.cern.ch/twiki/bin/view/AtlasPublic/
CMS public results: https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResults

Additional Material

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: March 2016

ATLAS Preliminary

$\sqrt{s}$ = 7, 8, 13 TeV

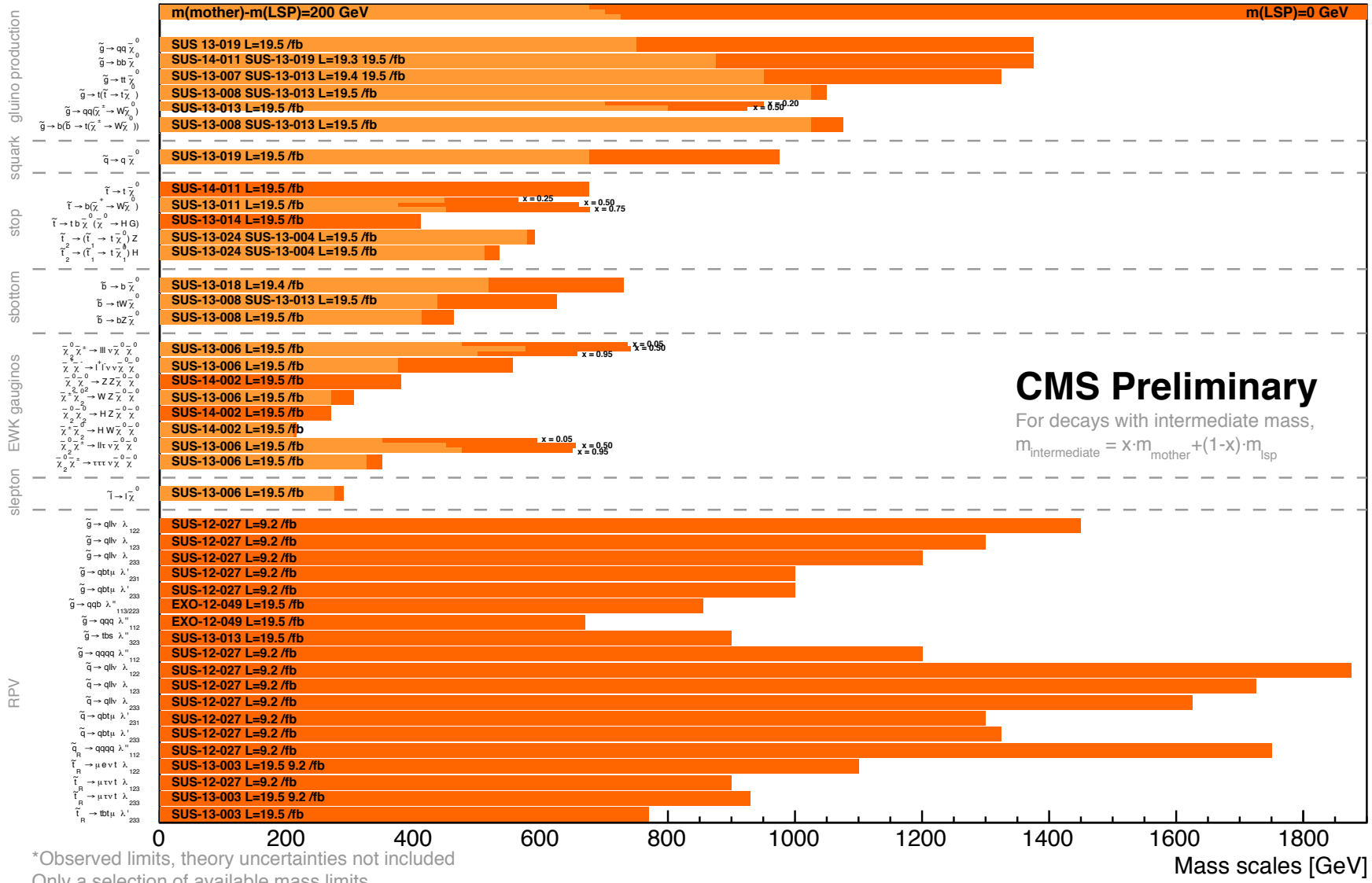
	Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\, dt [fb^{-1}]$	Mass limit ($\sqrt{s}$ = 7, 8 TeV / $\sqrt{s}$ = 13 TeV)		Reference
Inclusive Searches	MSUGRA/CMSSM	0-3 e,μ/1-2 τ	2-10 jets/3 b	Yes	20.3	$\tilde{q}, \tilde{g}$ 1.85 TeV	$m(\tilde{q})=m(\tilde{g})$	1507.05525
	$\tilde{q}\tilde{q}, \tilde{q}\to q\tilde{\chi}_1^0$	0	2-6 jets	Yes	3.2	$\tilde{q}$ 980 GeV	$m(\tilde{\chi}_1^0)$=0 GeV, m(1st gen. $\tilde{q}$)=m(2nd gen. $\tilde{q}$)	ATLAS-CONF-2015-062
	$\tilde{q}\tilde{q}, \tilde{q}\to q\tilde{\chi}_1^0$ (compressed)	mono-jet	1-3 jets	Yes	3.2	$\tilde{q}$ 610 GeV	$m(\tilde{q})-m(\tilde{\chi}_1^0)$<5 GeV	*To appear*
	$\tilde{q}\tilde{q}, \tilde{q}\to q(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$	2 e,μ (off-Z)	2 jets	Yes	20.3	$\tilde{q}$ 820 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	1503.03290
	$\tilde{g}\tilde{g}, \tilde{g}\to q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	3.2	$\tilde{g}$ 1.52 TeV	$m(\tilde{\chi}_1^0)$=0 GeV	ATLAS-CONF-2015-062
	$\tilde{g}\tilde{g}, \tilde{g}\to qq\tilde{\chi}_1^{\pm}\to qqW^{\pm}\tilde{\chi}_1^0$	1 e,μ	2-6 jets	Yes	3.3	$\tilde{g}$ 1.6 TeV	$m(\tilde{\chi}_1^0)$<350 GeV, $m(\tilde{\chi}^{\pm})=0.5(m(\tilde{\chi}_1^0)+m(\tilde{g}))$	ATLAS-CONF-2015-076
	$\tilde{g}\tilde{g}, \tilde{g}\to qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$	2 e,μ	0-3 jets	-	20	$\tilde{g}$ 1.38 TeV	$m(\tilde{\chi}_1^0)$=0 GeV	1501.03555
	$\tilde{g}\tilde{g}, \tilde{g}\to qqWZ\tilde{\chi}_1^0$	0	7-10 jets	Yes	3.2	$\tilde{g}$ 1.4 TeV	$m(\tilde{\chi}_1^0)$ =100 GeV	1602.06194
	GMSB ($\tilde{\ell}$ NLSP)	1-2 τ + 0-1 ℓ	0-2 jets	Yes	20.3	$\tilde{g}$ 1.63 TeV	$\tan\beta$ >20	1407.0603
	GGM (bino NLSP)	2 γ	-	Yes	20.3	$\tilde{g}$ 1.34 TeV	$c\tau$(NLSP)<0.1 mm	1507.05493
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	20.3	$\tilde{g}$ 1.37 TeV	$m(\tilde{\chi}_1^0)$<950 GeV, $c\tau$(NLSP)<0.1 mm, μ<0	1507.05493
	GGM (higgsino-bino NLSP)	γ	2 jets	Yes	20.3	$\tilde{g}$ 1.3 TeV	$m(\tilde{\chi}_1^0)$<850 GeV, $c\tau$(NLSP)<0.1 mm, μ>0	1507.05493
	GGM (higgsino NLSP)	2 e,μ (Z)	2 jets	Yes	20.3	$\tilde{g}$ 900 GeV	m(NLSP)>430 GeV	1503.03290
	Gravitino LSP	0	mono-jet	Yes	20.3	$F^{1/2}$ scale 865 GeV	$m(\tilde{G})>1.8\times10^{-4}$ eV, $m(\tilde{g})=m(\tilde{q})$=1.5 TeV	1502.01518
3rd gen. $\tilde{g}$ med.	$\tilde{g}\tilde{g}, \tilde{g}\to b\bar{b}\tilde{\chi}_1^0$	0	3 b	Yes	3.3	$\tilde{g}$ 1.78 TeV	$m(\tilde{\chi}_1^0)$<800 GeV	ATLAS-CONF-2015-067
	$\tilde{g}\tilde{g}, \tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0-1 e,μ	3 b	Yes	3.3	$\tilde{g}$ 1.76 TeV	$m(\tilde{\chi}_1^0)$=0 GeV	*To appear*
	$\tilde{g}\tilde{g}, \tilde{g}\to b\bar{t}\tilde{\chi}_1^+$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$ 1.37 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	3.2	$\tilde{b}_1$ 840 GeV	$m(\tilde{\chi}_1^0)$<100 GeV	ATLAS-CONF-2015-066
	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to t\tilde{\chi}_1^{\pm}$	2 e,μ (SS)	0-3 b	Yes	3.2	$\tilde{b}_1$ 325-540 GeV	$m(\tilde{\chi}_1^0)$=50 GeV, $m(\tilde{\chi}_1^{\pm})=m(\tilde{\chi}_1^0)$+100 GeV	1602.09058
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to b\tilde{\chi}_1^{\pm}$	1-2 e,μ	1-2 b	Yes	4.7/20.3	$\tilde{t}_1$ 117-170 GeV; 200-500 GeV	$m(\tilde{\chi}_1^{\pm})=2m(\tilde{\chi}_1^0)$, $m(\tilde{\chi}_1^0)$=55 GeV	1209.2102, 1407.0583
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to Wb\tilde{\chi}_1^0$ or $t\tilde{\chi}_1^0$	0-2 e,μ	0-2 jets/1-2 b	Yes	20.3	$\tilde{t}_1$ 90-198 GeV; 205-715 GeV; 745-785 GeV	$m(\tilde{\chi}_1^0)$=1 GeV	1506.08616, ATLAS-CONF-2016-007
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to c\tilde{\chi}_1^0$	0	mono-jet/c-tag	Yes	20.3	$\tilde{t}_1$ 90-245 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	$\tilde{t}_1$ 150-600 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	$\tilde{t}_2$ 290-610 GeV	$m(\tilde{\chi}_1^0)$<200 GeV	1403.5222
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2\to\tilde{t}_1 + h$	1 e,μ	6 jets + 2 b	Yes	20.3	$\tilde{t}_2$ 320-620 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	1506.08616
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	$\tilde{\ell}$ 90-335 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	$\tilde{\chi}_1^{\pm}$ 140-475 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	$\tilde{\chi}_1^{\pm}$ 355 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	$\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$ 715 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	0-2 jets	Yes	20.3	$\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$ 425 GeV	$m(\tilde{\chi}_1^{\pm})=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, sleptons decoupled	1403.5294, 1402.7029
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\to W\tilde{\chi}_1^0h\tilde{\chi}_1^0, h\to b\bar{b}/WW/\tau\tau/\gamma\gamma$	e,μ,γ	0-2 b	Yes	20.3	$\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$ 270 GeV	$m(\tilde{\chi}_1^{\pm})=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, sleptons decoupled	1501.07110
	$\tilde{\chi}_2^0\tilde{\chi}_3^0, \tilde{\chi}_{2,3}^0\to\tilde{\ell}_R\ell$	4 e,μ	0	Yes	20.3	$\tilde{\chi}_{2,3}^0$ 635 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
	GGM (wino NLSP) weak prod.	1 e,μ + γ	-	Yes	20.3	$\tilde{W}$ 115-370 GeV	$c\tau$<1 mm	1507.05493
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	1310.3675
	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^{\pm}$	dE/dx trk	-	Yes	18.4	$\tilde{\chi}_1^{\pm}$ 495 GeV	$m(\tilde{\chi}_1^{\pm})-m(\tilde{\chi}_1^0)$~160 MeV, $\tau(\tilde{\chi}_1^{\pm})$<15 ns	1506.05332
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	27.9	$\tilde{g}$ 850 GeV	$m(\tilde{\chi}_1^0)$=100 GeV, 10 μs<$\tau(\tilde{g})$<1000 s	1310.6584
	Metastable $\tilde{g}$ R-hadron	dE/dx trk	-	-	3.2	$\tilde{g}$ 1.54 TeV	$m(\tilde{\chi}_1^0)$=100 GeV, τ>10 ns	*To appear*
	GMSB, stable $\tilde{\tau}, \tilde{\chi}_1^0\to\tilde{\tau}(\tilde{e},\tilde{\mu})+\tau(e,\mu)$	1-2 μ	-	-	19.1	$\tilde{\chi}_1^0$ 537 GeV	10<$\tan\beta$<50	1411.6795
	GMSB, $\tilde{\chi}_1^0\to\gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$	2 γ	-	Yes	20.3	$\tilde{\chi}_1^0$ 440 GeV	1<$\tau(\tilde{\chi}_1^0)$<3 ns, SPS8 model	1409.5542
	$\tilde{g}\tilde{g}, \tilde{\chi}_1^0\to eey/e\mu\nu/\mu\mu\nu$	displ. $ee/e\mu/\mu\mu$	-	-	20.3	$\tilde{\chi}_1^0$ 1.0 TeV	7 <$c\tau(\tilde{\chi}_1^0)$< 740 mm, $m(\tilde{g})$=1.3 TeV	1504.05162
	GGM $\tilde{g}\tilde{g}, \tilde{\chi}_1^0\to Z\tilde{G}$	displ. vtx + jets	-	-	20.3	$\tilde{\chi}_1^0$ 1.0 TeV	6 <$c\tau(\tilde{\chi}_1^0)$< 480 mm, $m(\tilde{g})$=1.1 TeV	1504.05162
RPV	LFV $pp\to\tilde{\nu}_\tau + X, \tilde{\nu}_\tau\to e\mu/e\tau/\mu\tau$	$e\mu,e\tau,\mu\tau$	-	-	20.3	$\tilde{\nu}_\tau$ 1.7 TeV	λ'_{311}=0.11, $\lambda_{132/133/233}$=0.07	1503.04430
	Bilinear RPV CMSSM	2 e,μ (SS)	0-3 b	Yes	20.3	$\tilde{q}, \tilde{g}$ 1.45 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	$\tilde{\chi}_1^{\pm}$ 760 GeV	$m(\tilde{\chi}_1^0)$>0.2×$m(\tilde{\chi}_1^{\pm})$, $\lambda_{121}\neq0$	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,μ + τ	-	Yes	20.3	$\tilde{\chi}_1^{\pm}$ 450 GeV	$m(\tilde{\chi}_1^0)$>0.2×$m(\tilde{\chi}_1^{\pm})$, $\lambda_{133}\neq0$	1405.5086
	$\tilde{g}\tilde{g}, \tilde{g}\to qqq$	0	6-7 jets	-	20.3	$\tilde{g}$ 917 GeV	BR(t)=BR(b)=BR(c)=0%	1502.05686
	$\tilde{g}\tilde{g}, \tilde{g}\to qq\tilde{\chi}_1^0, \tilde{\chi}_1^0\to qqq$	0	6-7 jets	-	20.3	$\tilde{g}$ 980 GeV	$m(\tilde{\chi}_1^0)$=600 GeV	1502.05686
	$\tilde{g}\tilde{g}, \tilde{g}\to\tilde{t}_1 t, \tilde{t}_1\to bs$	2 e,μ (SS)	0-3 b	Yes	20.3	$\tilde{g}$ 880 GeV		1404.2500
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to bs$	0	2 jets + 2 b	-	20.3	$\tilde{t}_1$ 320 GeV		1601.07453
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to b\ell$	2 e,μ	2 b	-	20.3	$\tilde{t}_1$ 0.4-1.0 TeV	BR($\tilde{t}_1\to be/\mu$)>20%	ATLAS-CONF-2015-015
Other	Scalar charm, $\tilde{c}\to c\tilde{\chi}_1^0$	0	2 c	Yes	20.3	$\tilde{c}$ 510 GeV	$m(\tilde{\chi}_1^0)$<200 GeV	1501.01325

10^{-1} — 1 — Mass scale [TeV]

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

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