Search for beyond standard model physics at LHC

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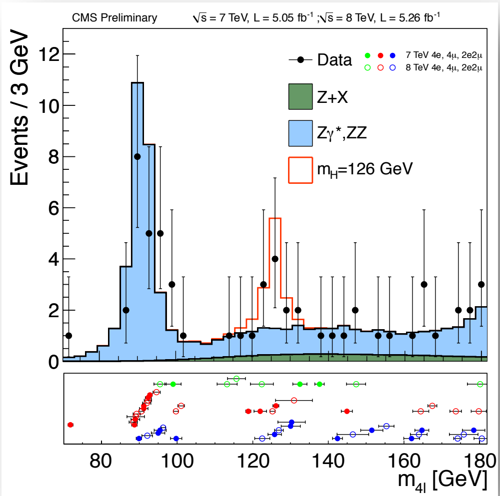
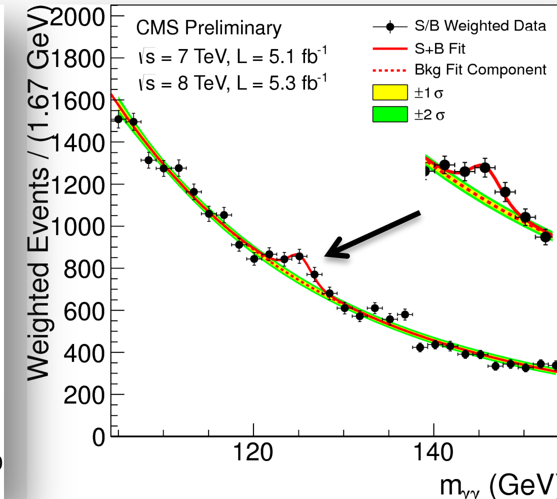
Introduction

- Discovery of a BEH scalar @ ~125 GeV completes SM

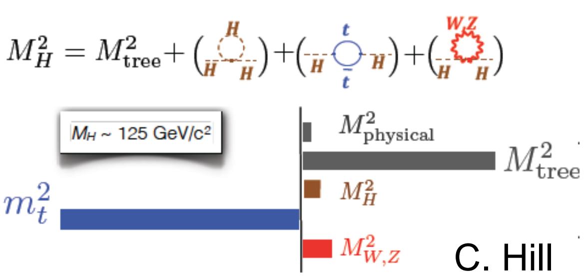




July 4th, 2012

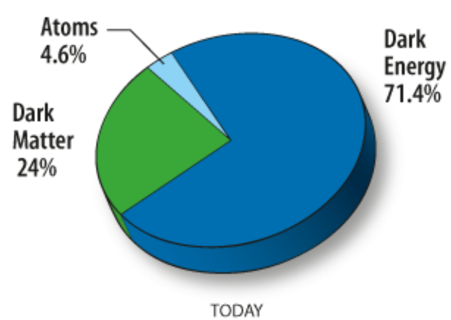
- Still many open questions: motivate searches for physics beyond the SM

Hierarchy

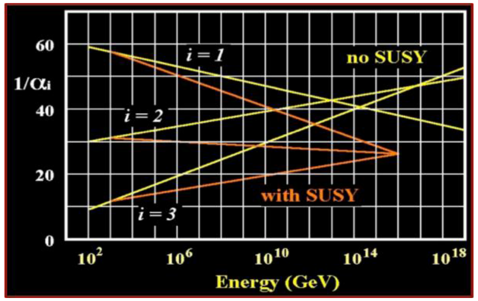


C. Hill

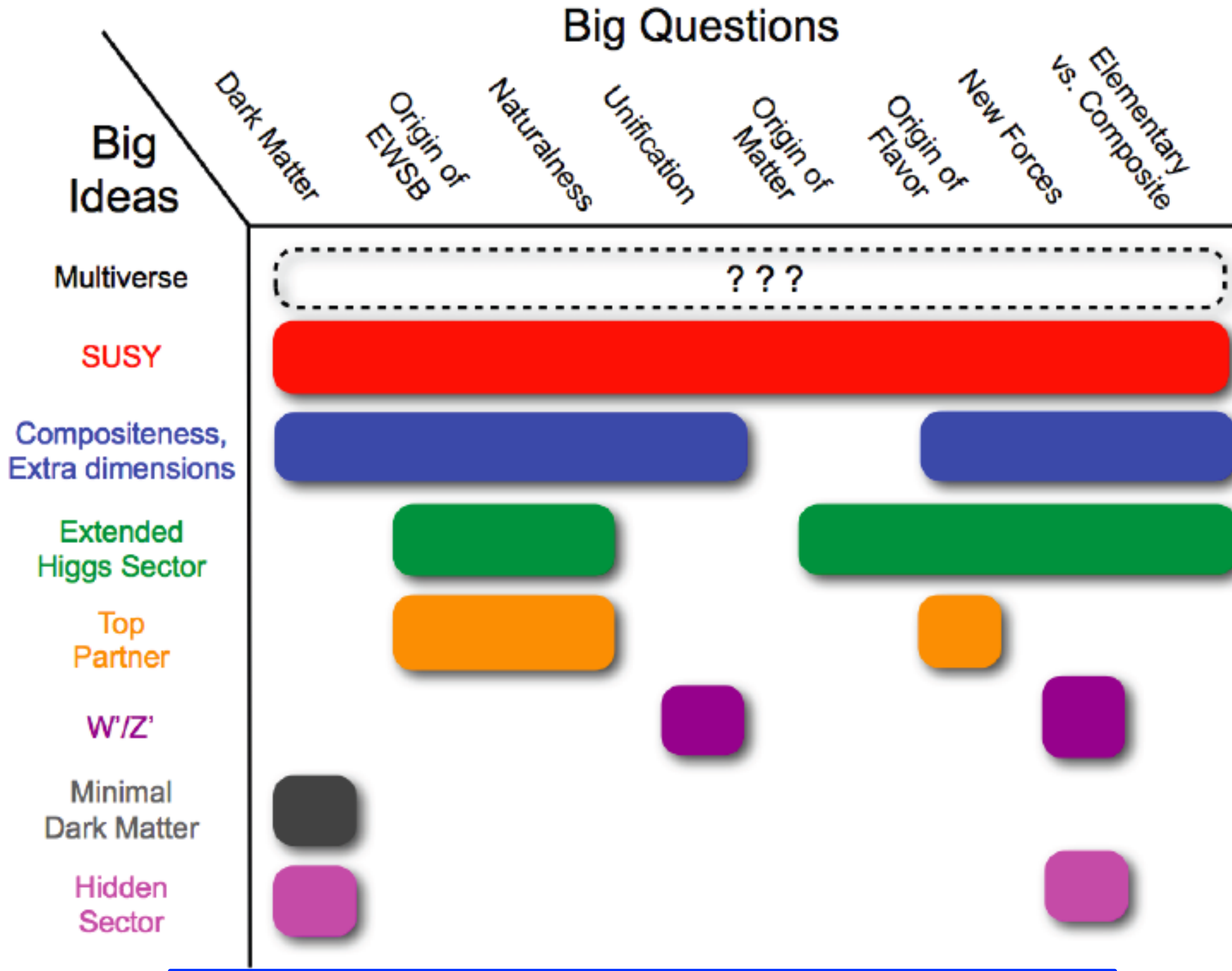
Dark Matter



Unification



Some Guiding Questions & Ideas



Snowmass '13 Energy Frontier Report
arXiv:1401.6081v1 [hep-ex]

We also need to watch out for "unexpected"

A Large # of Results w/ 2012 Data

CMS and ATLAS searched for new physics in a variety of final states

CMS

- Exotica
  - 14 pub + 14 PAS

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsEXO

- Beyond 2 Generations
  - 6 pub + 17 PAS

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsB2G

- SUSY
  - 12 pub + 23 PAS

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS

- BSM Higgs
  - 4 pub + 6 PAS

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsHIG

See also David Rousseau's talk on Monday

ATLAS

- Exotica
  - 14 pub + 29 conf note

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ExoticsPublicResults

- SUSY
  - 18 pub + 38 conf note

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults

- BSM Higgs
  - 4 pub + 6 conf note

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HiggsPublicResults

Obviously cannot cover all these results. I will present only some highlights of these results in this talk. And, …

16 Parallel Talks for Details

Monday:

- Searches for direct pair production of third generation squarks with the ATLAS detector: USAI, Giulio
- 3rd generation SUSY searches at CMS: LACROIX, Florent Sylvain
- Inclusive searches for squarks and gluinos with the ATLAS detector: MARTIN DIT LATOUR, Bertrand
- Inclusive SUSY searches at CMS: VANELDEREN, Lukas
- Search for electroweak SUSY production at CMS: MASCIOVECCHIO, Mario

Tuesday:

- Searches for production of two Higgs bosons using the CMS detector: DAS, Souvik
- Beyond-the-Standard Model Higgs physics using the ATLAS experiment: ERNIS, Gunar
- Search for Higgs Bosons Beyond the Standard Model with the CMS Detector: SCHRöDER, Matthias
- Searches for invisible decay modes of the Higgs boson with the CMS detector: DUNNE, Patrick James
- Constraints on new phenomena through Higgs coupling measurements with the ATLAS detector: MAIANI, Camilla

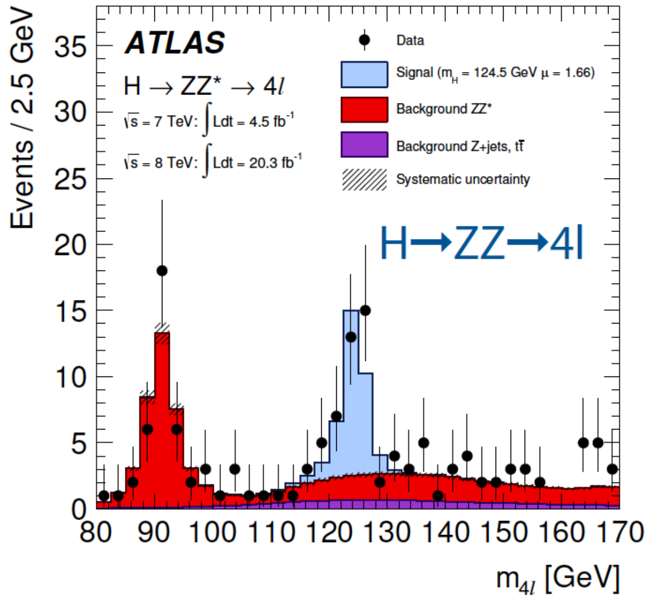
Thursday:

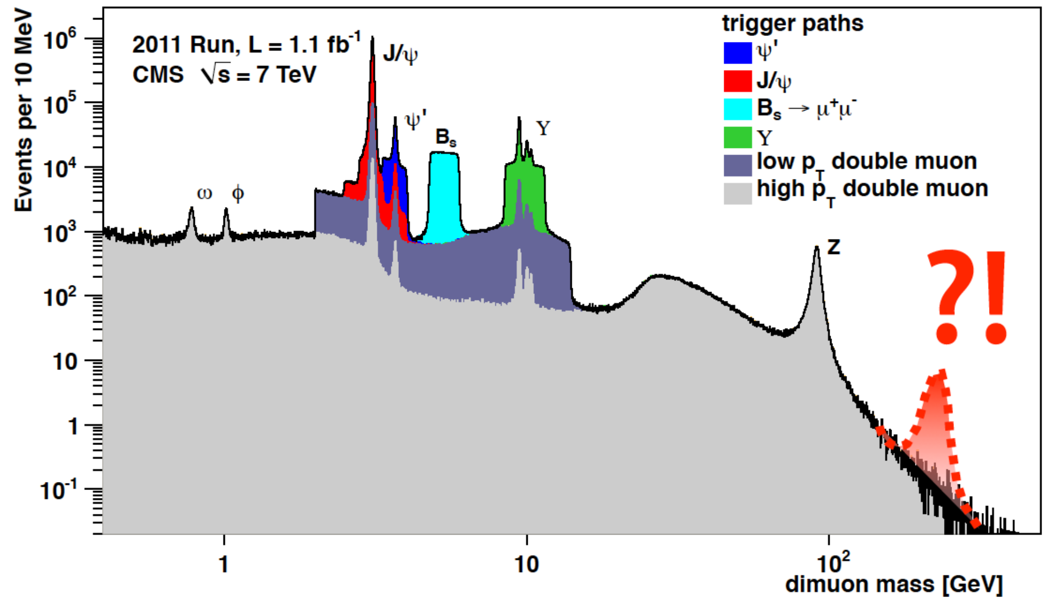
- Search for heavy resonances in two-particle final states with leptons, jets and photons at CMS: GUTH, Andreas
- Searches for heavy resonances and anomalous production of multi-leptons with the ATLAS detector: DAYA, Rozmin
- Searches for vector-like quarks, tt and tb resonances with the ATLAS detector: CALVET, David
- Searches for supersymmetry in resonance production, R-parity violating signatures and events with long-lived particles with the ATLAS detector: GOBLIRSCH-KOLB, Maximilian
- Search for Dark Matter at CMS: HOEPFNER, kerstin
- Searches for dark matter and extra dimensions with the ATLAS detector: Mr. CLEMENT, Christophe

Much more complete stories will be presented in the parallel-session talks

Resonances

Resonance Searches

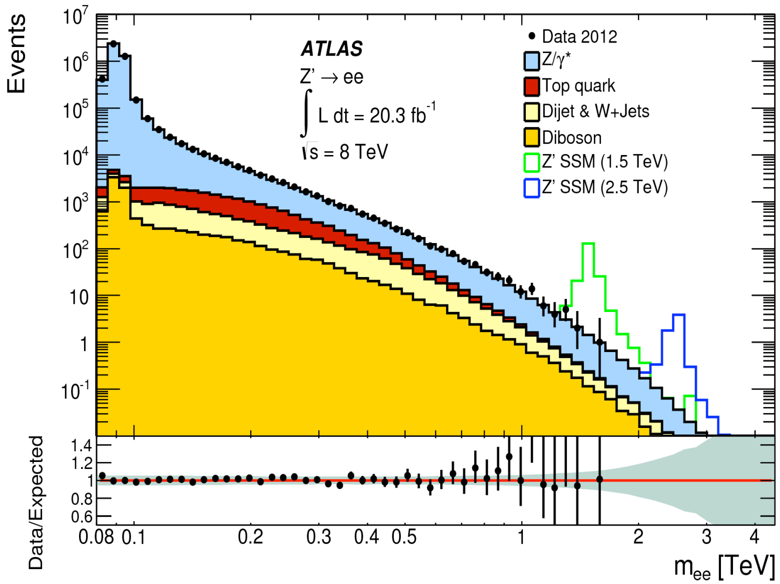




- ☐ Mass resonances are simple yet powerful probe to discover new particles
- ☐ Predicted in many BSM scenarios:
  - Single resonances: Extended gauge theories [W'/Z'], compositeness [excited fermions], Randall-Sundrum (RS) model [KK-graviton/gluon] etc.
  - Paired resonances: Supersymmetry [gluinos/squarks], leptoquarks, vector-like quarks, colorons, etc.
- ☐ Additional information comes from e.g. angular distributions

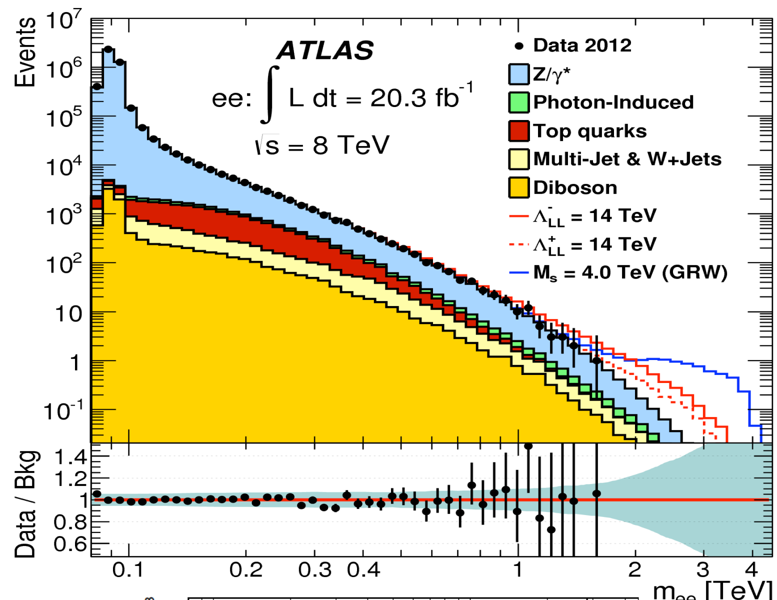
Dileptons

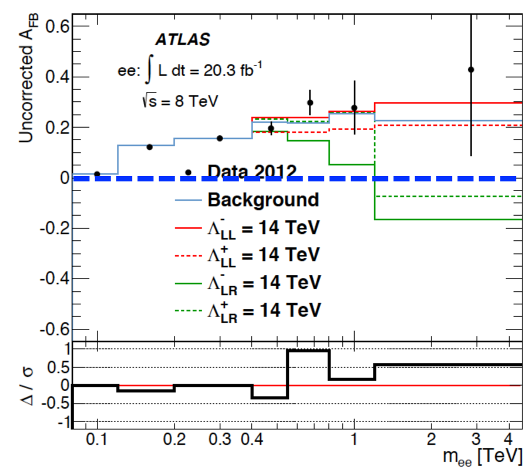
arXiv:1405.4123



Z' excluded up to ~2.9 TeV

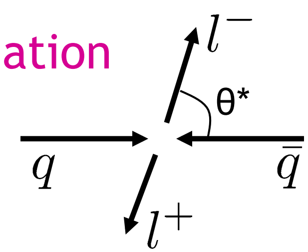
arXiv:1407.2410





Use also the angular information

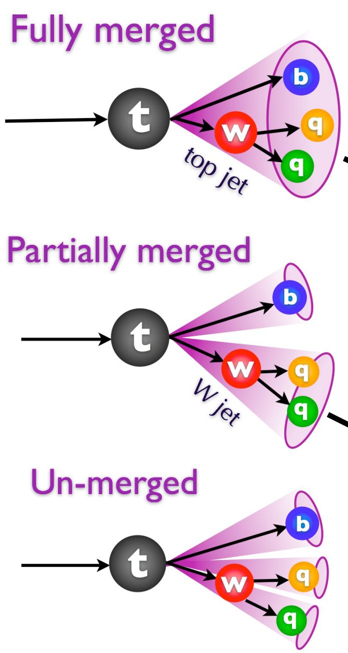
$$A_{\mathrm{FB}} = \frac{N_{\mathrm{F}}(\cos\theta^* > 0) - N_{\mathrm{B}}(\cos\theta^* < 0)}{N_{\mathrm{F}}(\cos\theta^* > 0) + N_{\mathrm{B}}(\cos\theta^* < 0)}$$



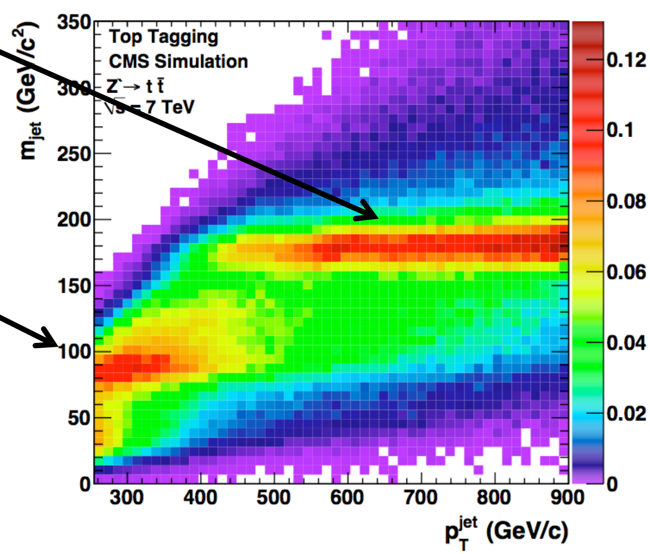
Contact interaction excluded up to Λ ~ 26 TeV

Jet Substructure: Top/W Tagging

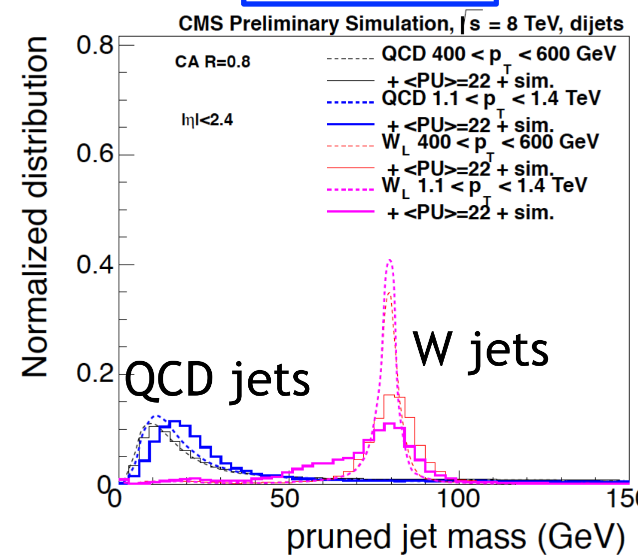
- New physics searches often involve high p_T boosted top/W
  - Boosted decay products → merged jets. E.g. $\Delta R_{qq}^{\min} \approx \Delta\theta_{qq}^{\min} \approx 2\frac{M_V}{p_{T,V}}$



Top tagging



W tagging



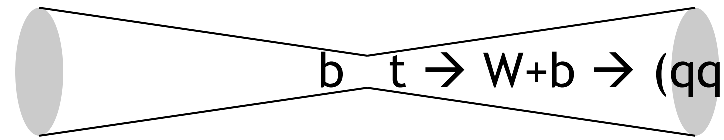
  - Standard jet reconstruction w/ anti-k_T algorithm, size parameter R=0.5
  - Use fat jets tagging algorithm based on Cambridge/Aachen clustering algorithm, with size parameter R=0.8 (CA8) or 1.5 (HEP top tagger)

CMS-JME-13-006/007, ATL-PHYS-PUB-2014-004

W' → t+b

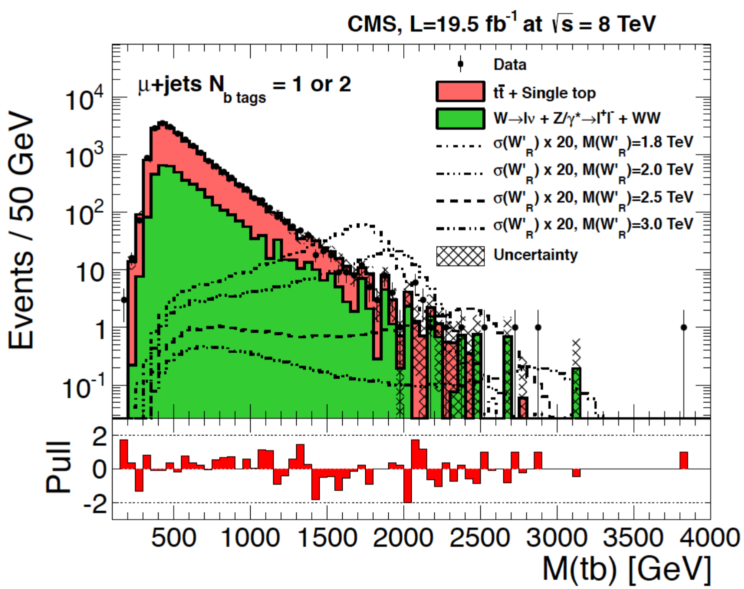
- Semi-leptonic search:
  t → W+b -> (lν)+b
  - One isolated lepton (e,mu)
  - $p_T^{jet1,2}$>120(40) GeV, ≥1 btag(s)
  - p_T^{top}>85 GeV
  - 130 < m_{top} < 210 GeV

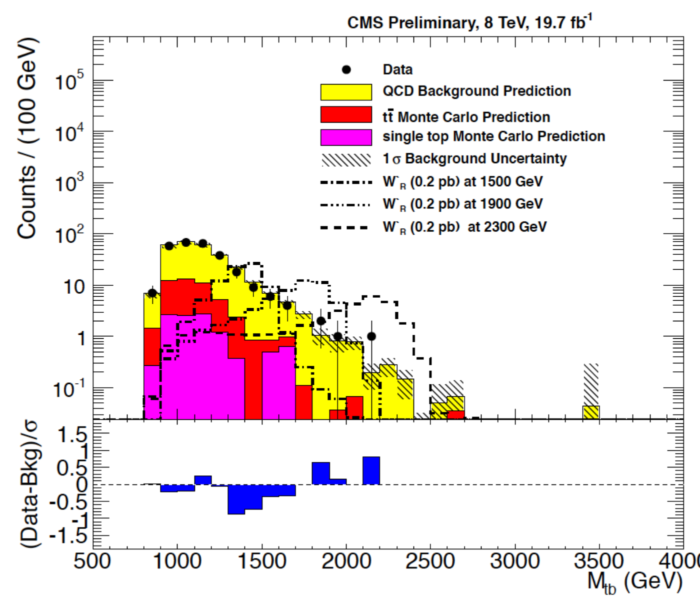
- All hadronic search



  - p_T^{top}>450 GeV: CMS top tagging algo
  - Subjet b-tagging
  - p_T^{b}> 370 GeV

jet substructure technique!





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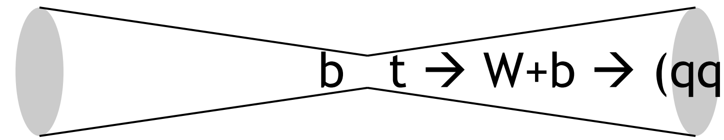

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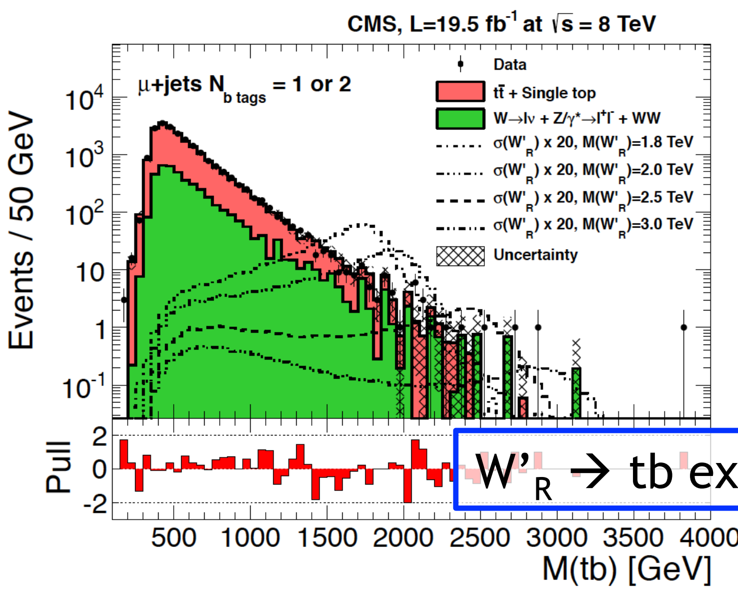
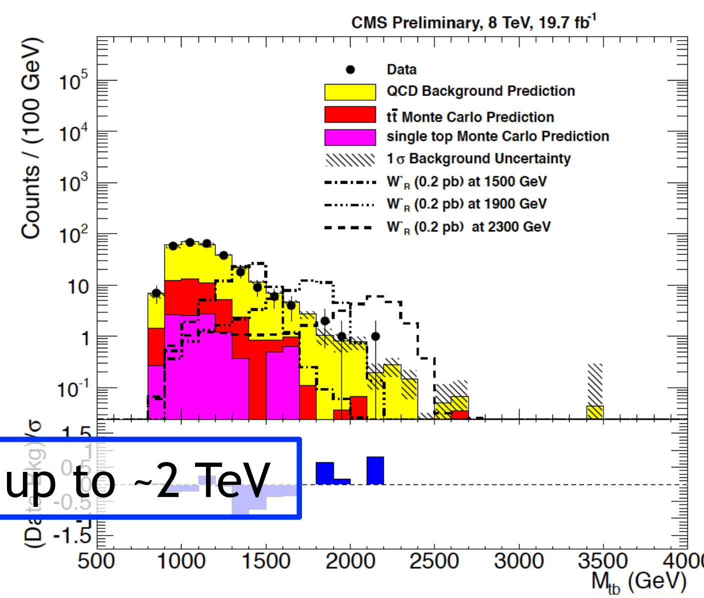


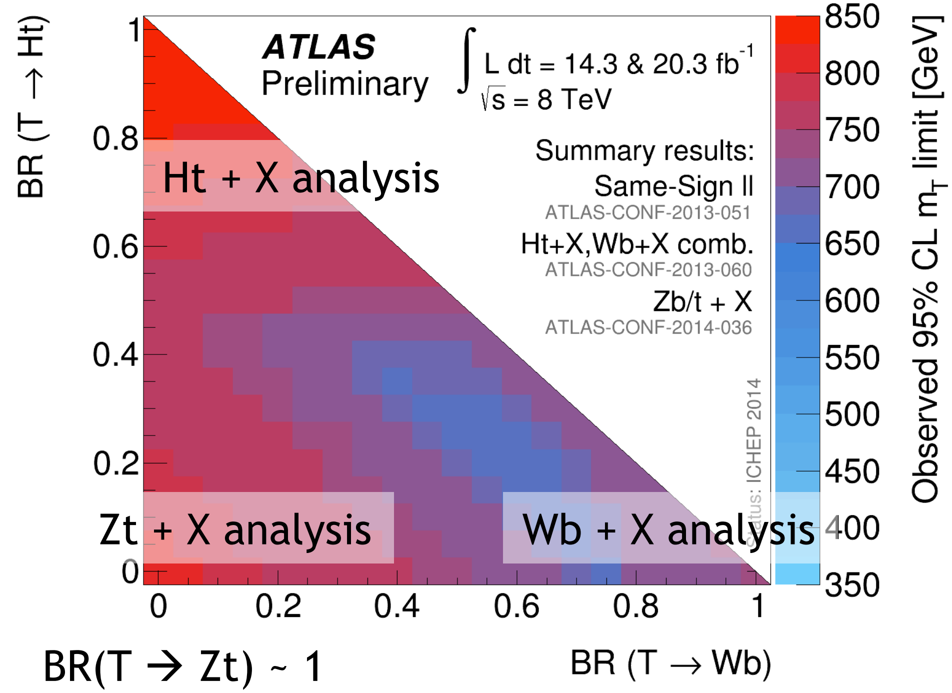


W'$_R$ → tb excluded up to ~2 TeV

arXiv:1402.2176, CMS-PAS-B2G-12-009

Vector-like Top Quark (T') Pair

- T' → Wb, Zt, Ht:
  T' crucial for naturalness
  - Zt + X analysis (ATLAS-CONF-2013-051):
    - Opposite-sign (OS) dileptons or ≥3 leptons + b-tags
  - Wb + X analysis (ATLAS-CONF-2013-060):
    - Boosted-W + b-tags
  - Ht + X analysis (ATLAS-CONF-2014-036):
    - Same-sign (SS) dileptons + b-tags



BR(T → Zt) ~ 1

Different analyses/optimizations complementarily cover a wide phase space

Single Resonances

Final State	Highest mass event	Highest mass limit
Dijet	~5.1 TeV	5.82 TeV
ee	~1.8 TeV	2.79 TeV
μμ	~1.8 TeV	2.53 TeV
ττ	~0.7 TeV	1.90 TeV
lν	~2.3 TeV	3.28 TeV
bb	~4.1 TeV	1.68 TeV
top b*	~3.8 TeV	2.03 TeV
ttbar*	~3.3 TeV	2.5 TeV

Resonances to fermion Pairs

*Analysis is using jet-substructure techniques

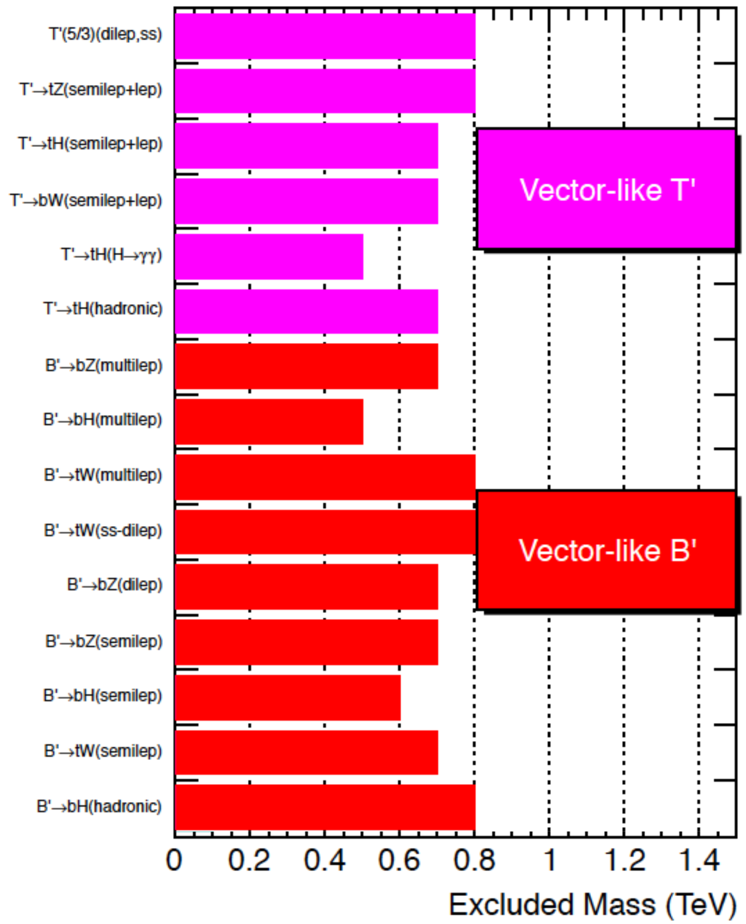
Final State	Highest mass event	Highest mass limit
WZ(3lν)	~1.1 TeV	1.52 TeV
VV(jjlν)*	~3.3 TeV	2.5 TeV
ZZ(lljj)*	~2.2 TeV	1.59 TeV
VV(jj)*	~2.7 TeV	1.7 TeV
Vq(jj)*	~3.7 TeV	3.2 TeV
hh(bbbb)	~1.3 TeV	0.59-0.71TeV
W(lν)γ	~1.3 TeV	0.96 TeV
Z(ll)γ	~1.6 TeV	0.89 TeV
γjet	~3 TeV	3.5 TeV
llγ	~1.3 TeV	2.2 TeV

Resonance decays involving bosons

Probing ~1 - 5 TeV scale masses in a wide range of final states

Paired Resonances

pair-produced



Final State	Highest mass event	Highest mass limit
2x(top jet)	~1.2 TeV	0.8 TeV
2x(jj)	~1.2 TeV	0.74 TeV
2x(jjj)	~1.9 TeV	0.65 TeV
2x(jjb)	~1.7 TeV	0.835 TeV
2x(jjjj)	~1.7 TeV	1.2 TeV
2x(top tau)	S_T ~0.9 TeV	0.63 TeV
2x(tau b)	~0.85 TeV	0.74 TeV

Probing ~0.5-1 TeV scale masses in a wide range of final states

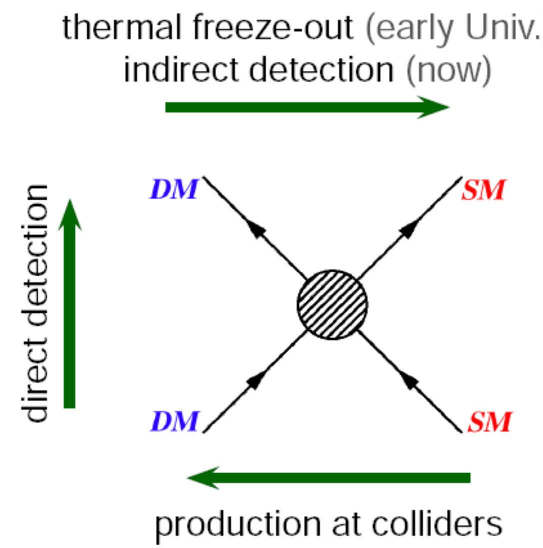
Dark Matter

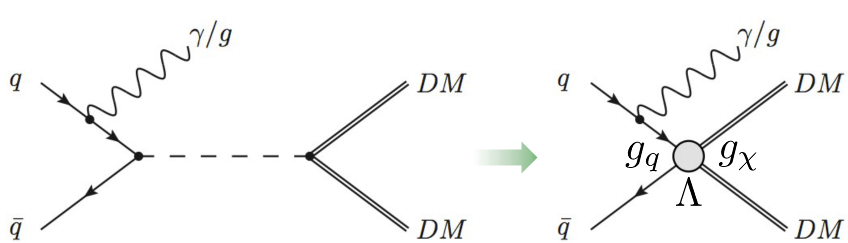
Dark Matter (DM) Searches

Experimental approaches:

- Direct search
  - DM-nucleon scattering: CDMS, SIMPLE, XENON, LUX
- Indirect search
  - DM annihilation or decay: Fermi, PAMELA, AMS, IceCube
- Collider search: LHC
  - DM production in cascade decays from heavier particles: Supersymmetry, Higgs portal
  - Direct DM pair production: Effective field theory (EFT)

    EMF collapses SM-DM interaction in effective 4-point operator





- Parameters: m_{DM}, EFT scale

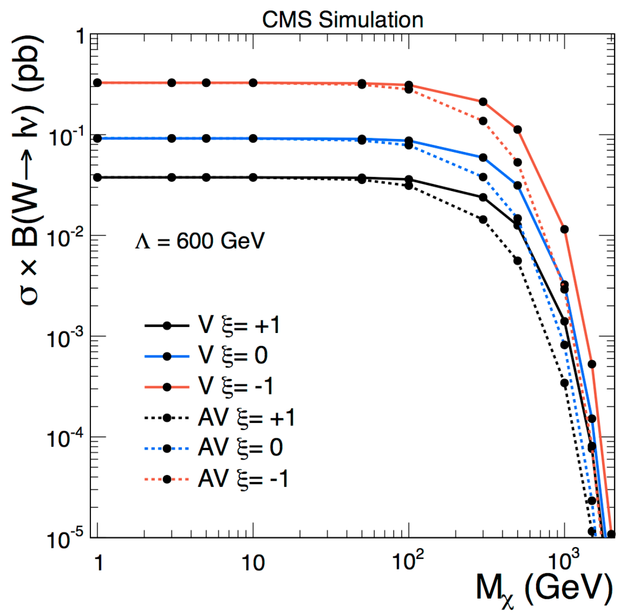
$$\Lambda = M/\sqrt{g_\chi g_q}$$

- Translate to DM-nucleon cross section

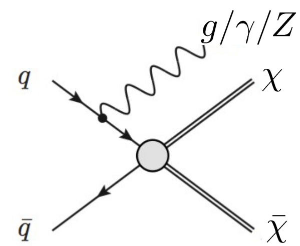
$$\sigma(\chi N \rightarrow \chi N) \sim \frac{1}{\Lambda^4}\mu^2_{\chi,N}$$

Mono-X Searches

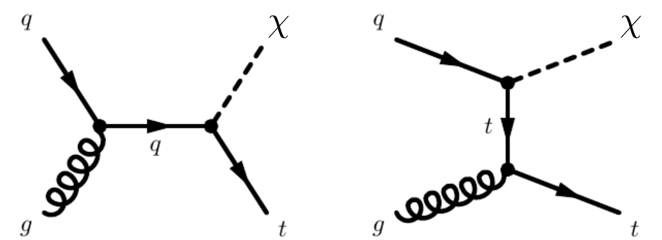
- Use ISR jet to give a boost to DM-pair system & induce MET:
  - Monojet + MET
  - Monophoton + MET
  - Mono-W/Z + MET
  - Monotop + MET



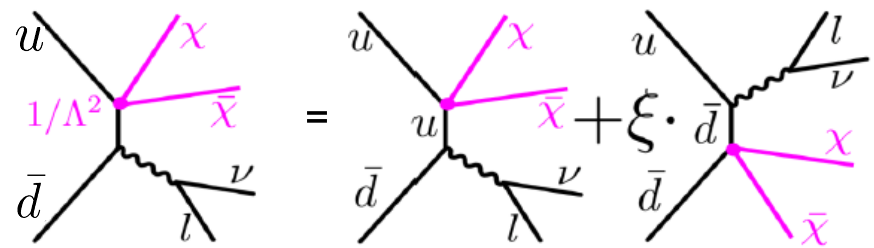
Mono-jet/γ/Z



Mono-top



Mono-W

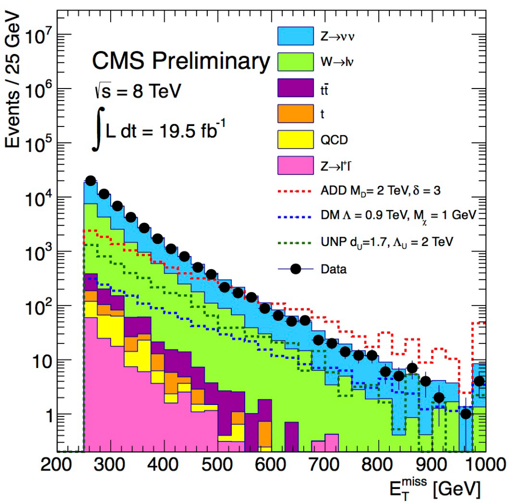


For mono-W, two diagrams with same initial & final state interfere destructively → Mono-W is most sensitive to models where ratio of couplings = -1

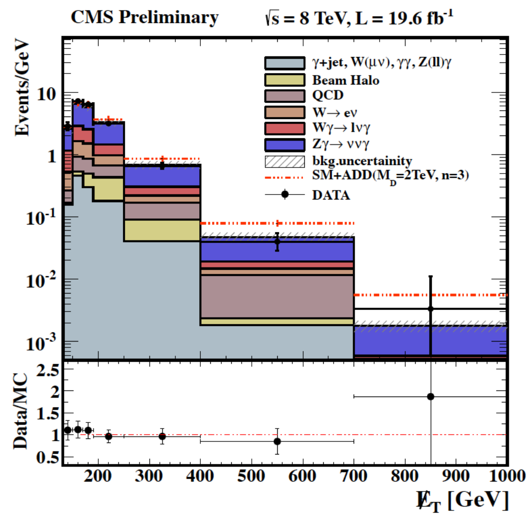
Observations in different channels would give us information about the couplings of the mediator particle to different quarks and to gluons

Mono-X Searches

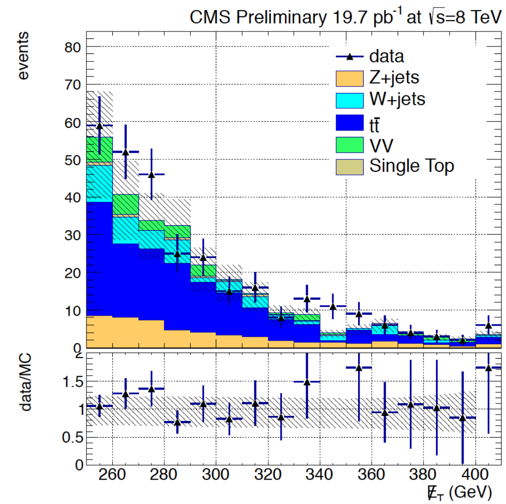
Monojet:
CMS: EXO-12-048



Monophoton:
CMS: EXO-12-047



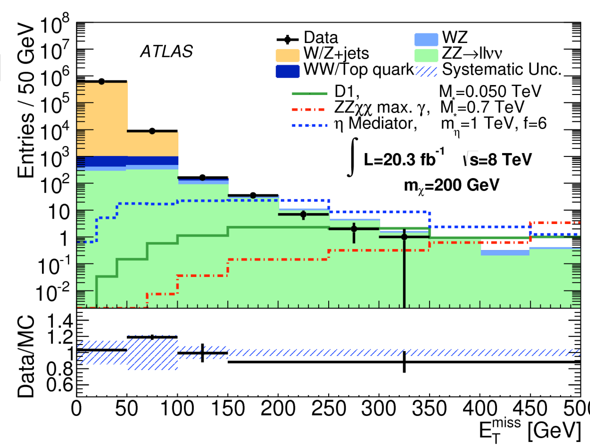
Mono-top:
CMS: B2G-12-022



Mono-W/Z (hadronic):
ATLAS: 1309.4017

Process	$E_T^{\rm miss} > 350$ GeV	$E_T^{\rm miss} > 500$ GeV
$Z \to \nu\bar{\nu}$	402^{+39}_{-34}	54^{+8}_{-10}
$W \to \ell^{\pm}\nu$, $Z \to \ell^{\pm}\ell^{\mp}$	210^{+20}_{-18}	22^{+4}_{-5}
WW, WZ, ZZ	57^{+11}_{-8}	$9.1^{+1.3}_{-1.1}$
$t\bar{t}$, single t	39^{+10}_{-4}	$3.7^{+1.7}_{-1.3}$
Total	707^{+48}_{-38}	89^{+9}_{-12}
Data	705	89

Mono-Z:
ATLAS: 1404.0051

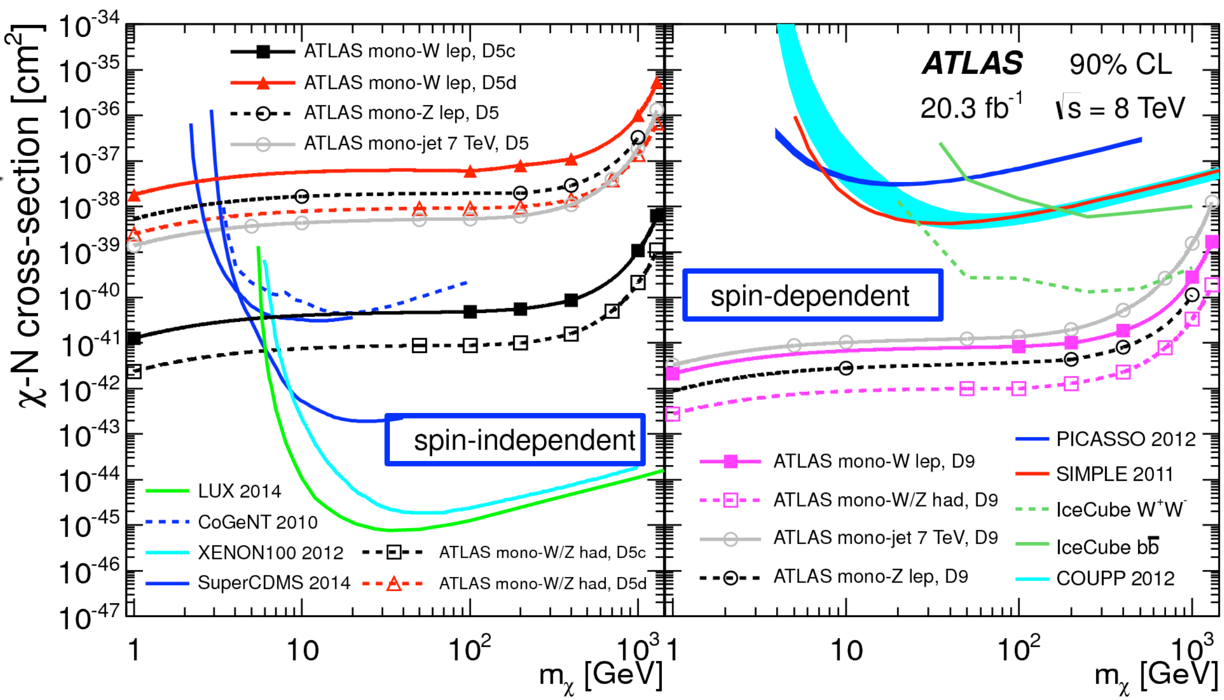


Mono-X Interpretations

- Limits are set on effective field theory scale Λ using effective operators at 90% CL ⇒ limits on elastic DM-nucleon cross section versus DM mass
- Complementary unique coverage at low mass and strong sensitivity for spin-dependent interactions

Vector:

$$\frac{(\bar{\chi}\gamma^{\mu}\chi)(\bar{q}\gamma_{\mu}q)}{\Lambda^2}$$



Axial-vector:

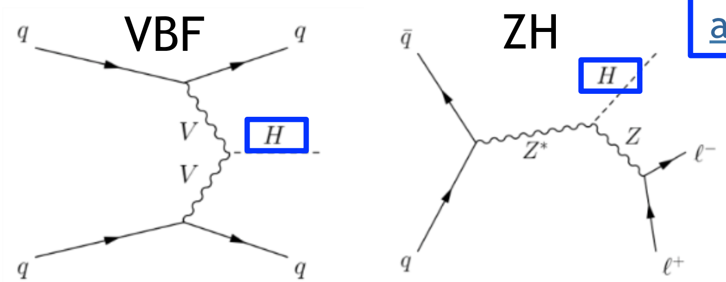
$$\frac{(\bar{\chi}\sigma^{\mu\nu}\chi)(\bar{q}\gamma_{\mu\nu}q)}{\Lambda^2}$$

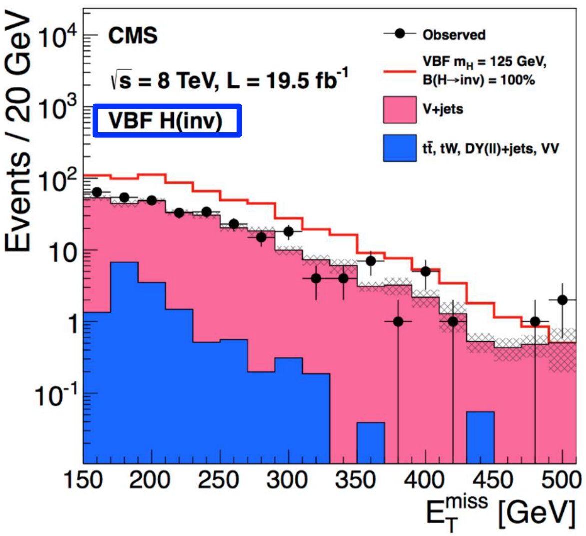
Spin-dependent (SD) scattering is not coherent over the whole nucleus, thus SD scattering is suppressed relative to spin-independent (SI) scattering

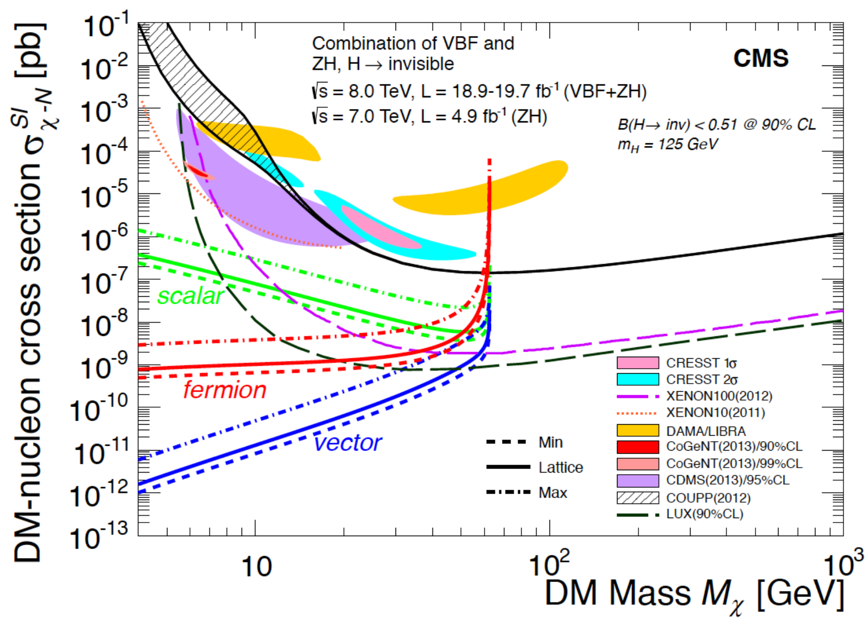
Higgs Portal to Dark Matter

[arXiv:1404.1344]

- DM particles directly couple to the Higgs sector, H → $\chi\chi$
  - Look for H → invisible in VBF+H and Z(ll,bb)+H modes



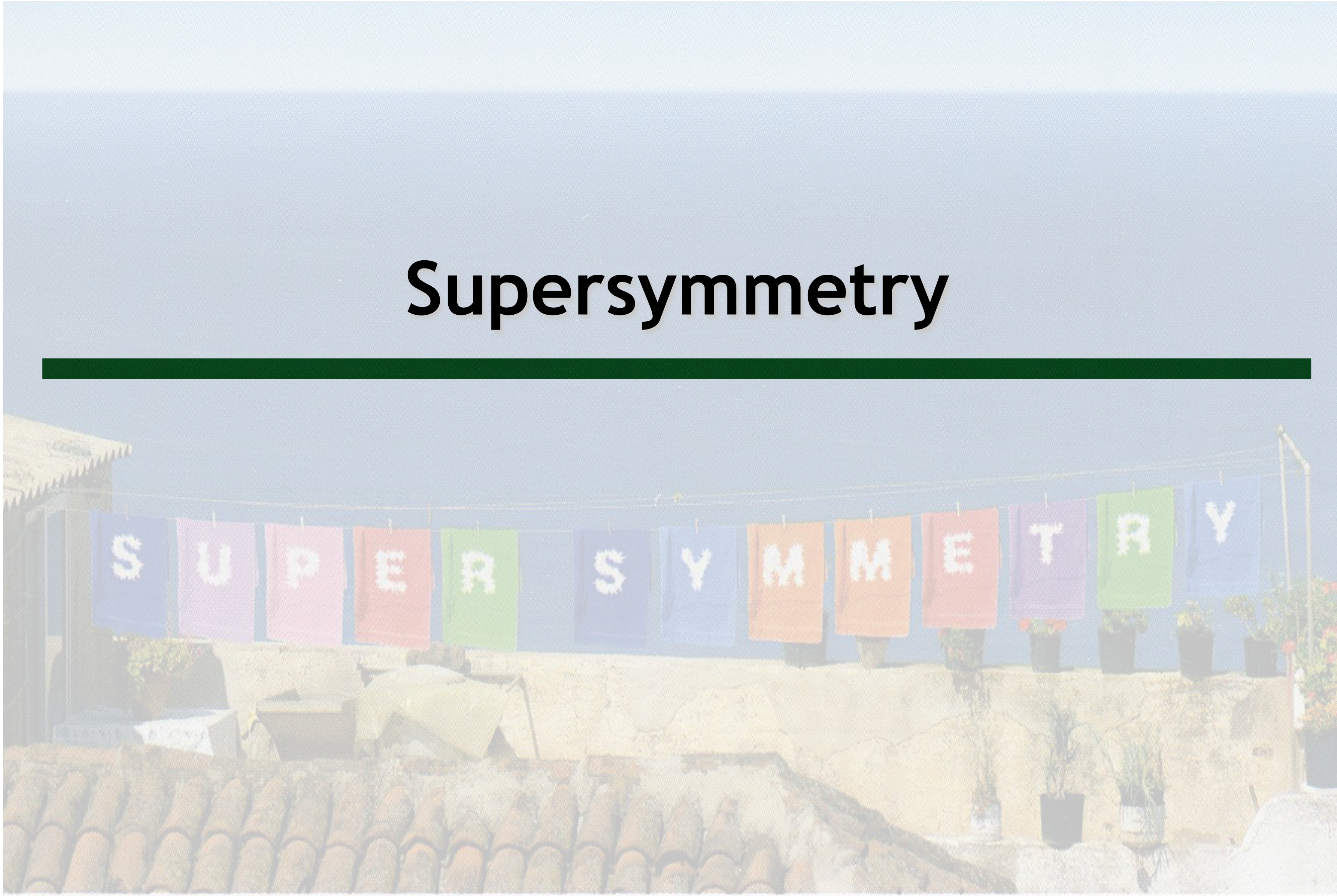




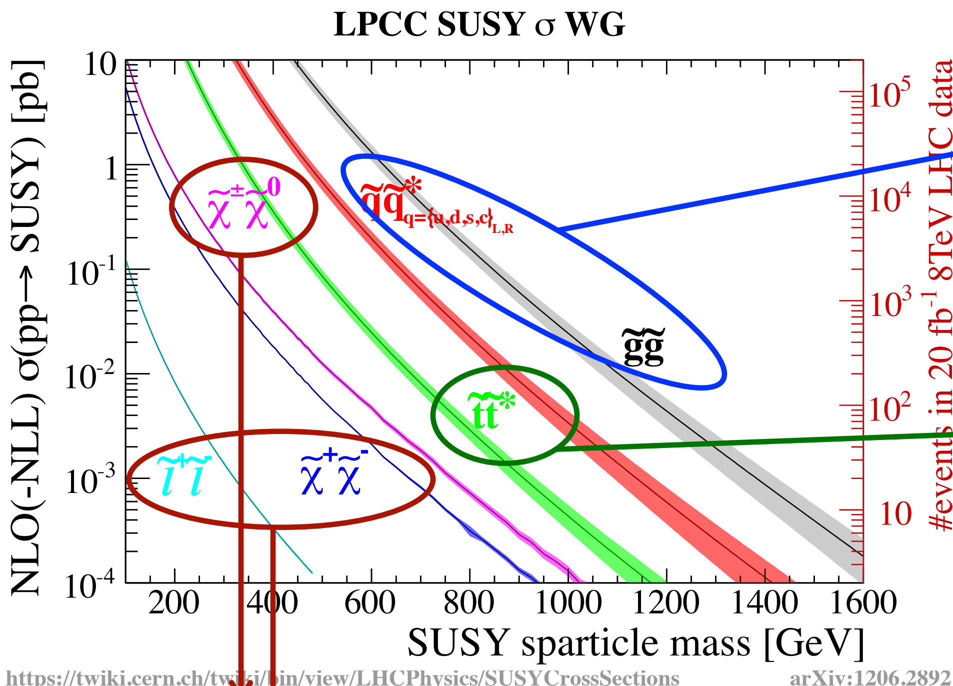
Br(H_{125} → invisible) < 0.68 (0.81) for VBF (Z(ll))

The limits on the DM-nucleon cross section vary for scalar, fermion, & vector, but the most stringent limits at low DM masses

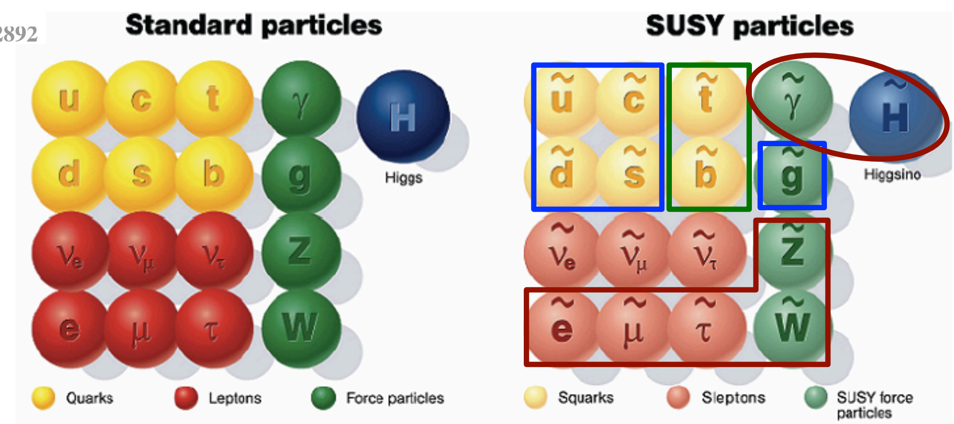
Supersymmetry



SUSY "Framework" for LHC Searches



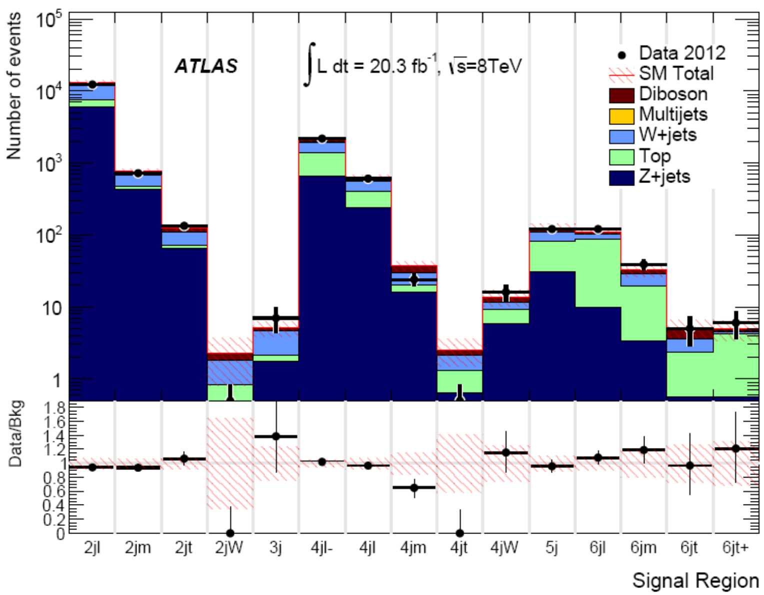
- gluinos and 1st & 2nd generation squarks: high cross section
  - Multiple jets + MET w/w.o. leptons, b-tags, photons
- Stop & sbottom: medium cross section
  - Multiple jets + MET + b-tags w/ w.o. leptons
- Charginos, neutralinos, sleptons: small cross sections
  - 0-4 leptons + MET w/w.o. b-tags, jets, W's, Z's, h's



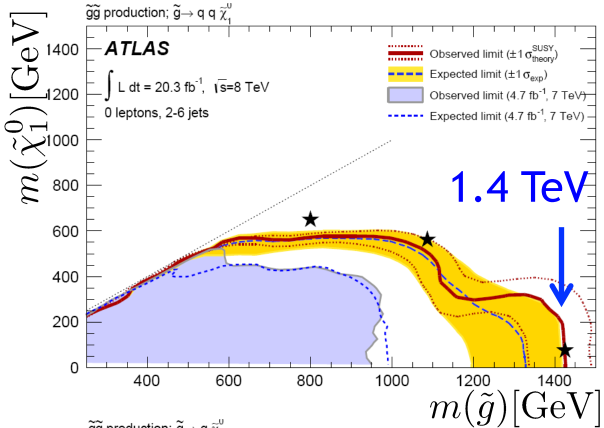
All-hadronic Inclusive SUSY Search

All hadronic inclusive search:

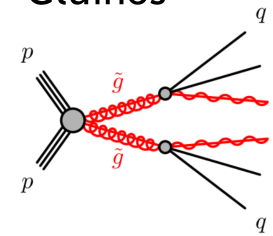
- Minimum jet multiplicity (2 to 6 jets)
- M_{eff} = MET + Σp_T(jets) > 0.8-2.2 TeV
- 15 signal regions targeting different decay chains
  - 2 of which require hadronic W decays (W→jj)

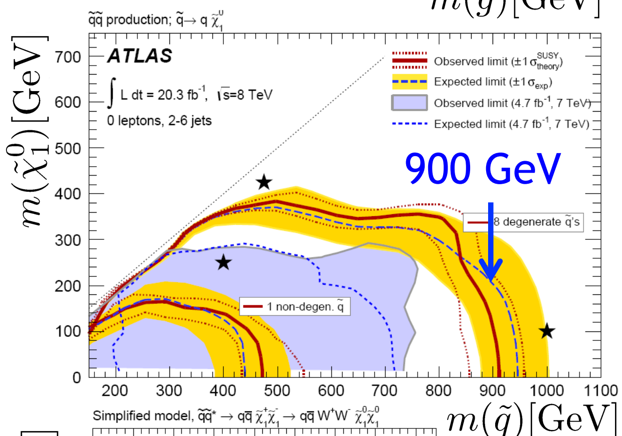


arXiv:1405.7875

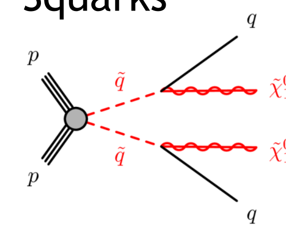


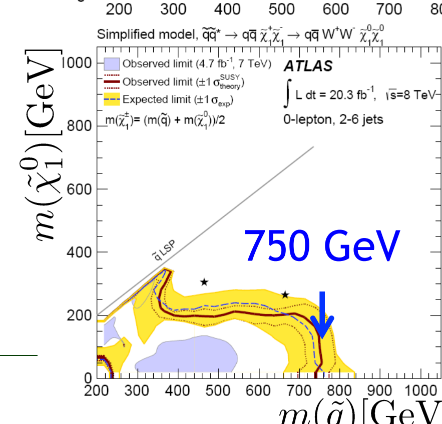
Gluinos

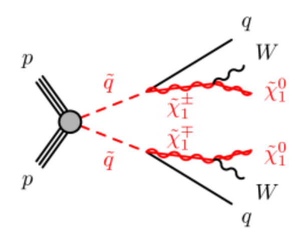




Squarks







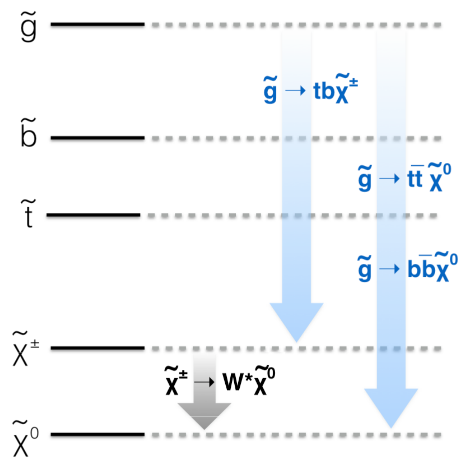
Increased complexity, exploiting boosted W

Stop/Sbottom from Gluino

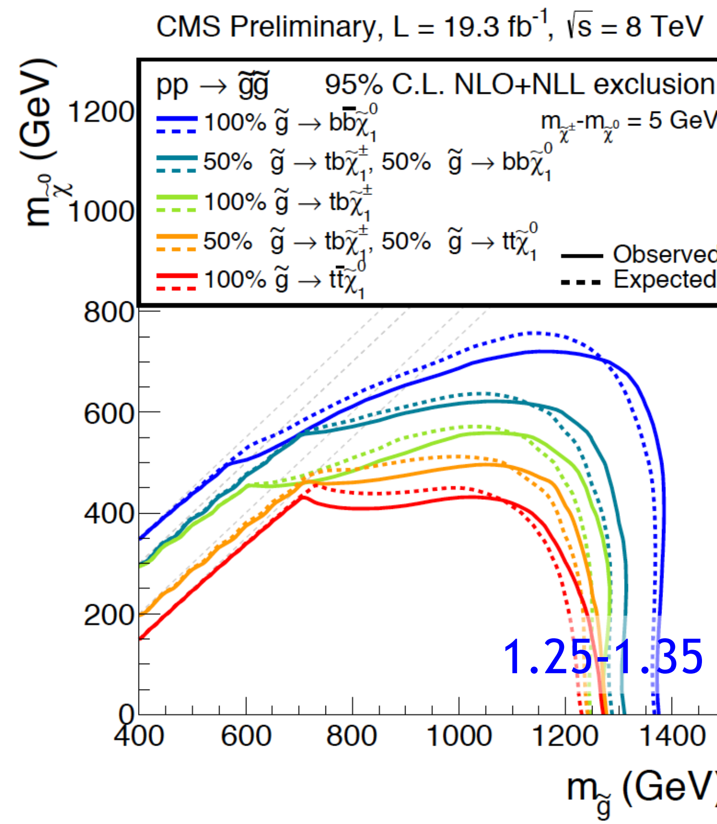
CMS-PAS-SUS-14-011

Inclusive search with b-tags:

- Testing natural SUSY scenario with ~TeV gluino, possible lighter stops and sbottoms, and a nearly degenerate chargino/neutralino triplet.



- Covering all possible combinations of partial widths into: 4b, 3b1t, 2b2t, 1b3t, 4t



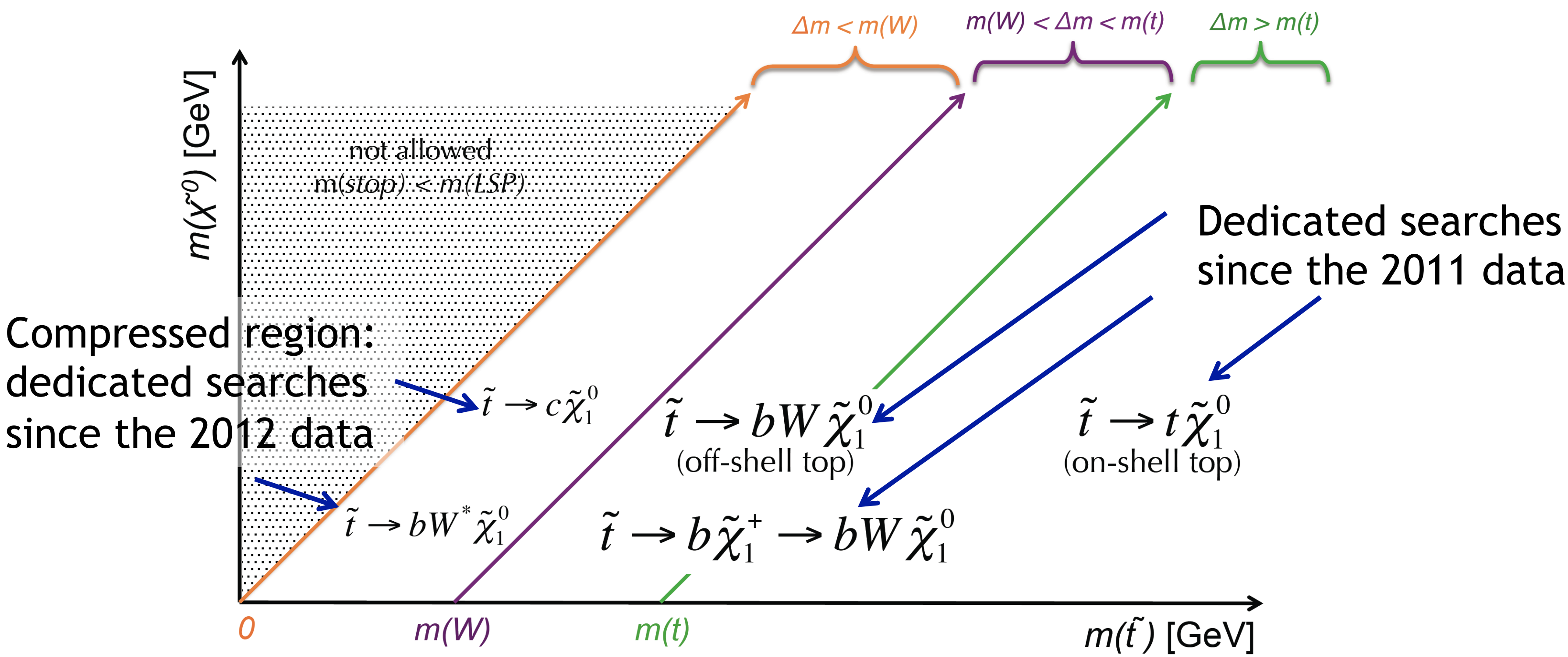
Complex top quark decays lead to the sensitivity degradation vs # of top quarks in the final state

Similar ATLAS analysis: arXiv:1407.0600

Direct Stop Production

- Dominant stop decay channel largely depends on available phase space

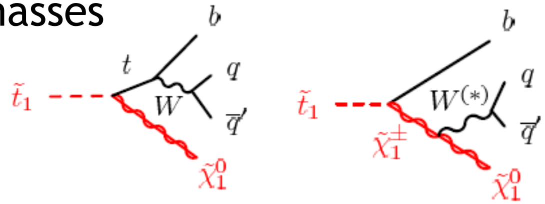
Decay modes in the m(stop) vs. m(LSP) plane
(can be more complex in reality depending on other ewkino, sleptons etc masses)



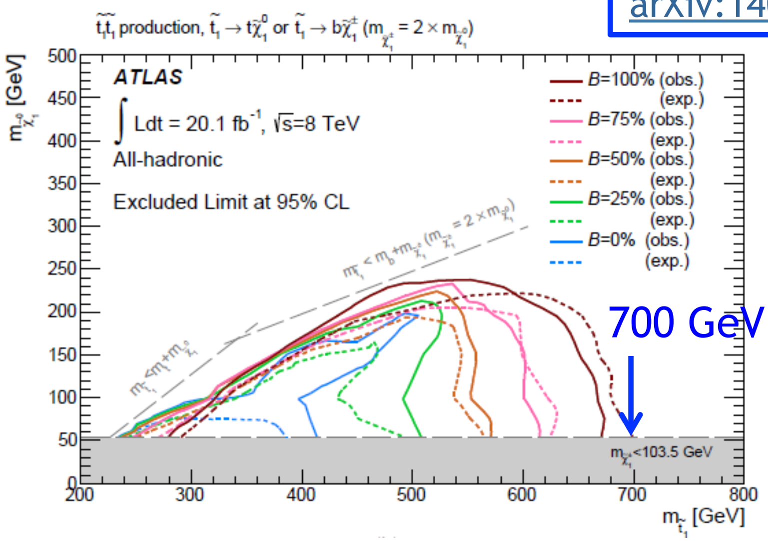
Stop Search with 0/1-leptons

0 lepton + ≥4-6 jets + ≥2 b-tags:

- 3 sets of signal selections targetting different decay modes and stop, χ_1^0 and $\chi_1^{\pm}$ masses

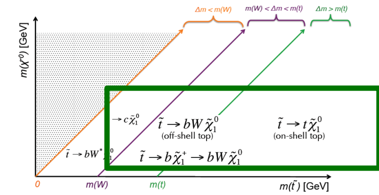


arXiv:1406.1122



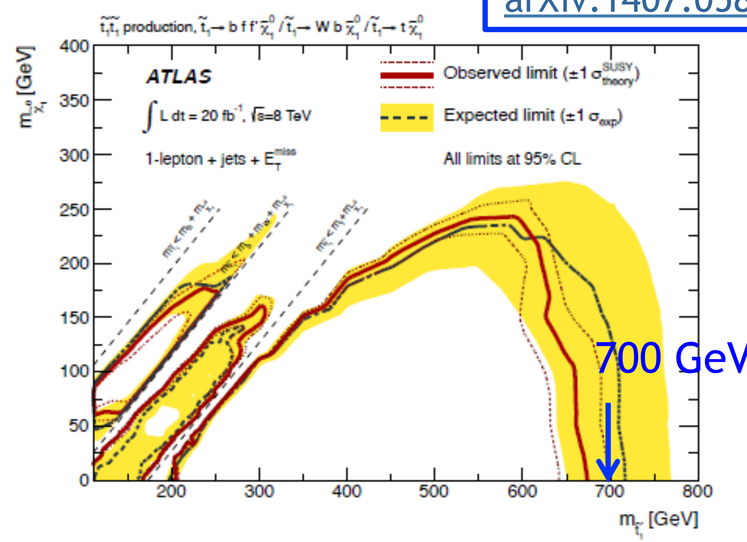
Exclusion as function of BR in $t+\chi_1^0$

1 lepton + ≥4 jets + ≥1-2 b-tags:



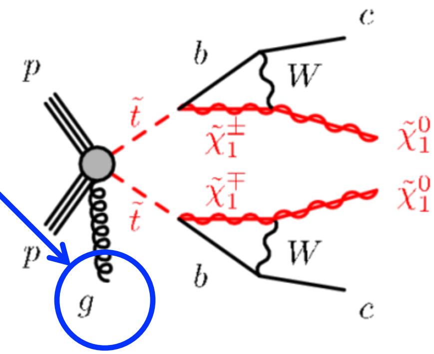
- Hard(>25 GeV) & soft(7-50 GeV) leptons
- 15 search regions sensitive to stop in various scenarios:
  - Large R jets → for high stop mass
  - Soft-lepton based analyses → for compressed scenarios

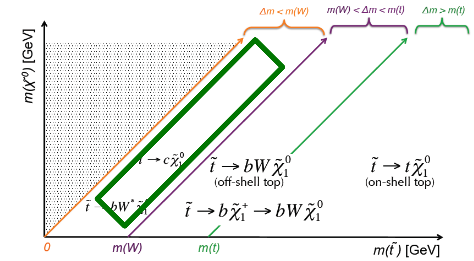
arXiv:1407.0583



Stop with Compressed Spectra

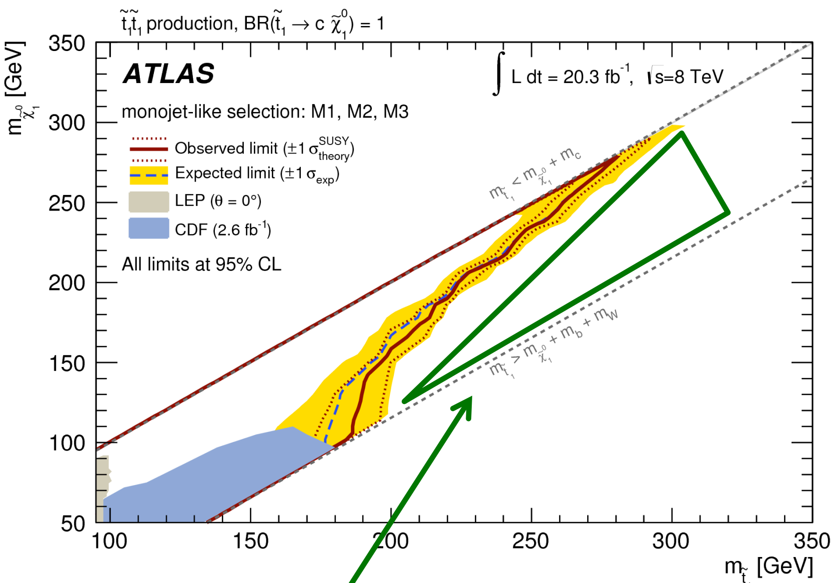
- Use ISR jet to give a boost to stop-pair system & induce MET





[arXiv:1407.0608]

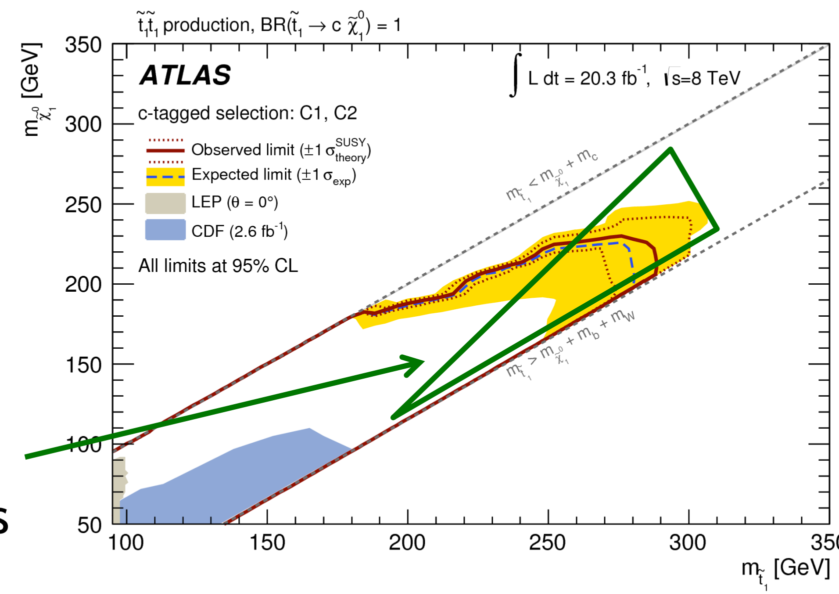
Monojet analysis



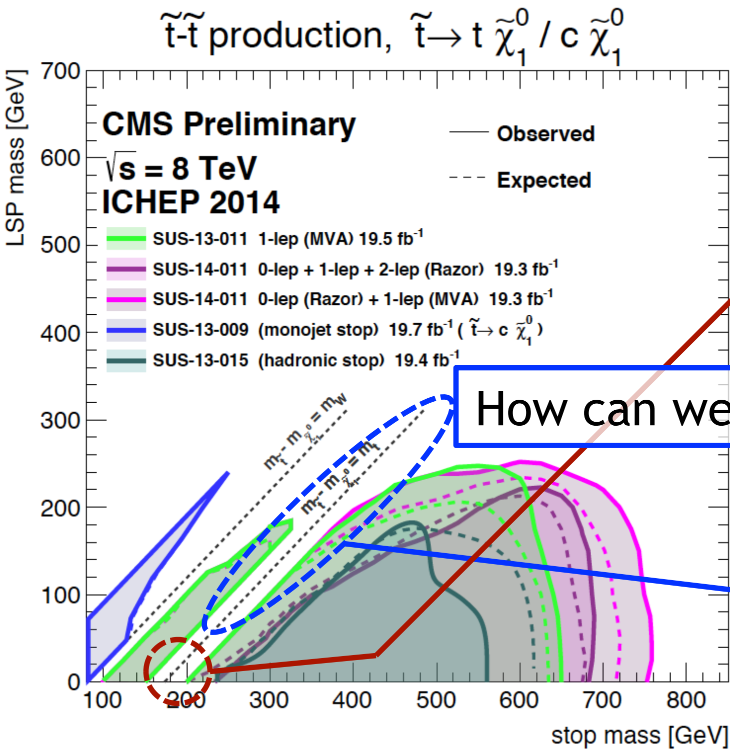
As the m(stop,LSP) increases, monojet search loses its sensitivity

A dedicated search with charm-tag fills this gap

Charm-tag analysis

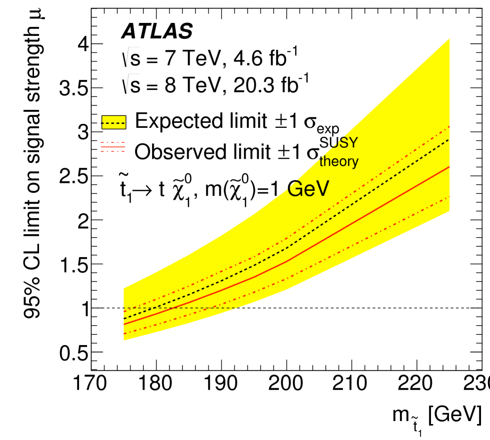


More Stop Searches

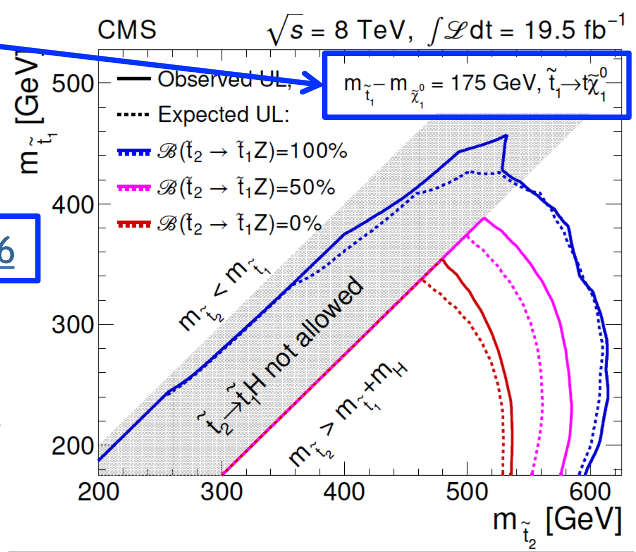


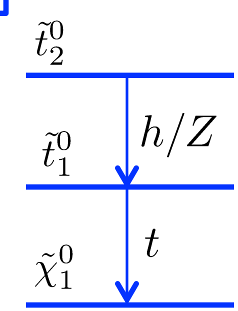
How can we close this gap?

- M(stop) ~ m(top): arXiv:1406.5375
  - New constraints from ttbar cross section measurement



- M(stop) ~ m(top)+m(LSP): arXiv:1405.3886
  - Compressed regions indirectly accessed via stop2 searches:
  - stop2 → stop1 + Z/H, stop1 → top +LSP



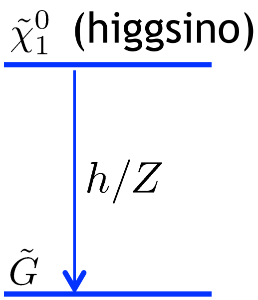


Chargino/Neutralino (EWKino)

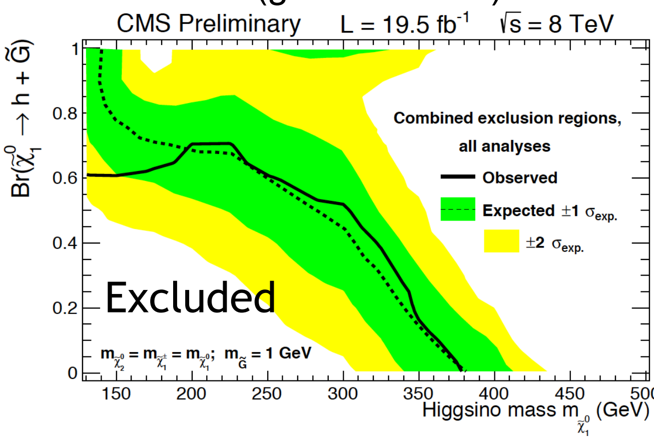
EWKino search in the diboson/multileptons + MET final state

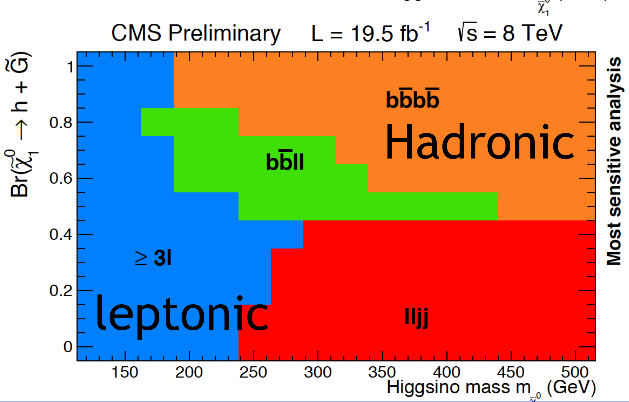
CMS-PAS-SUS-14-002

arXiv:1405.7570

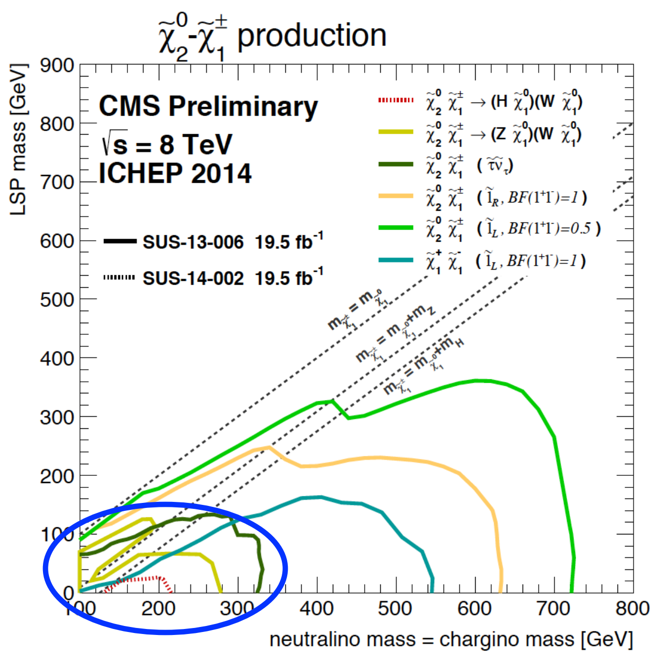


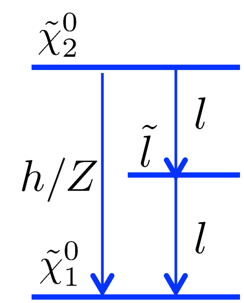
Gauge-mediated SUSY
(gravitino LSP)





Gravity-mediated SUSY
(neutralino LSP)





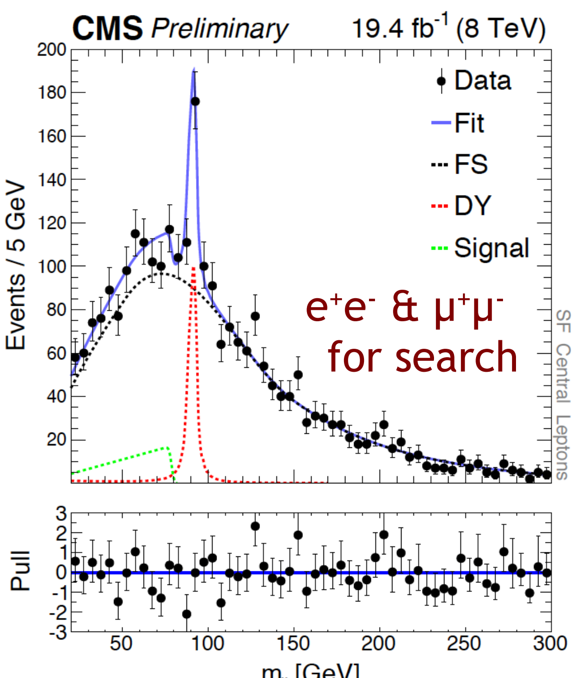
Covered final states:
Multileptons
h(bb)Z(ll)
hh(bbbb)
hh,hZ,hZ
w/ h→γγ
ZZ(lljj)

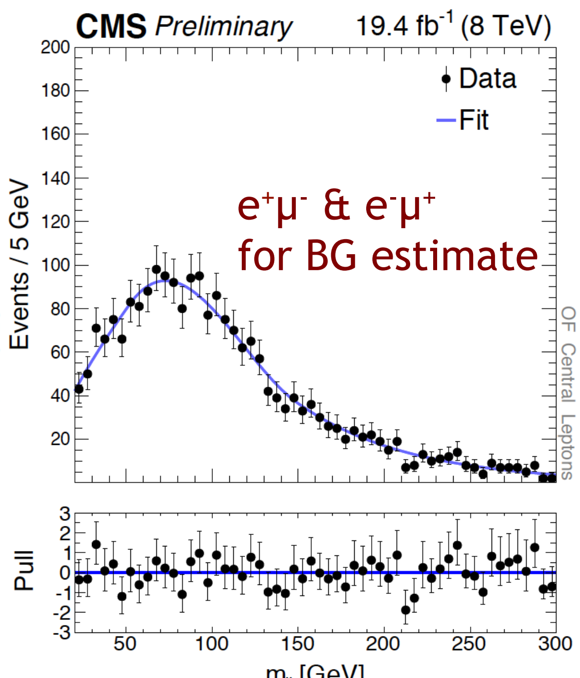
Covered final states:
WZ w. 3l
ZZ w. 4l
$W^{(*)}Z^{(*)}$
w. SS ll
WZ/ZZ
w. Z(ll)+jj
W(lv)h(bb)
Wh
w. SS ll
w. 3-4 l
WW
w. OS ll

The hadronic decays of ewkino is more difficult than leptonic decays.
The sensitivity strongly depends on the branching fraction of ewkino.

M(l^+l^-) Kinematic Edge Search

- Generic search for kinematic endpoint in dilepton (e^+e^- & $\mu^+\mu^-$) mass spectrum
  - e.g. $\tilde{\chi}_2^0 \to l\tilde{l} \to \tilde{\chi}_1^0 l^+ l^-$ with $m_{\mathrm{edge}} = \sqrt{(m^2_{\tilde{\chi}_2^0} - m^2_{\tilde{l}})(m^2_{\tilde{l}} - m^2_{\tilde{\chi}_1^0})}/m_{\tilde{l}}$
- BG estimation with opposite sign, opposite flavor ($e^+\mu^-$ & $e^-\mu^+$) leptons
  - Two search regions: central $|\eta| < 1.4$, forward $1.6 < |\eta| < 2.4$
- Signal and BG contributions determined from kinematic fit
  - In addition, cut & count analysis of events with $20 < M(l^+l^-) < 70$ GeV





CMS-PAS-SUS-12-019

cut & count analysis

	Central	Forward
Observed [SF]	860	163
Flav. Sym. [OF]	$722 \pm 27 \pm 29$	$155 \pm 13 \pm 10$
Drell–Yan	8.2 ± 2.6	1.7 ± 1.4
Total estimates	730 ± 40	157 ± 16
Observed – Estimated	130^{+48}_{-49}	6^{+20}_{-21}
Significance [σ]	2.6	0.3

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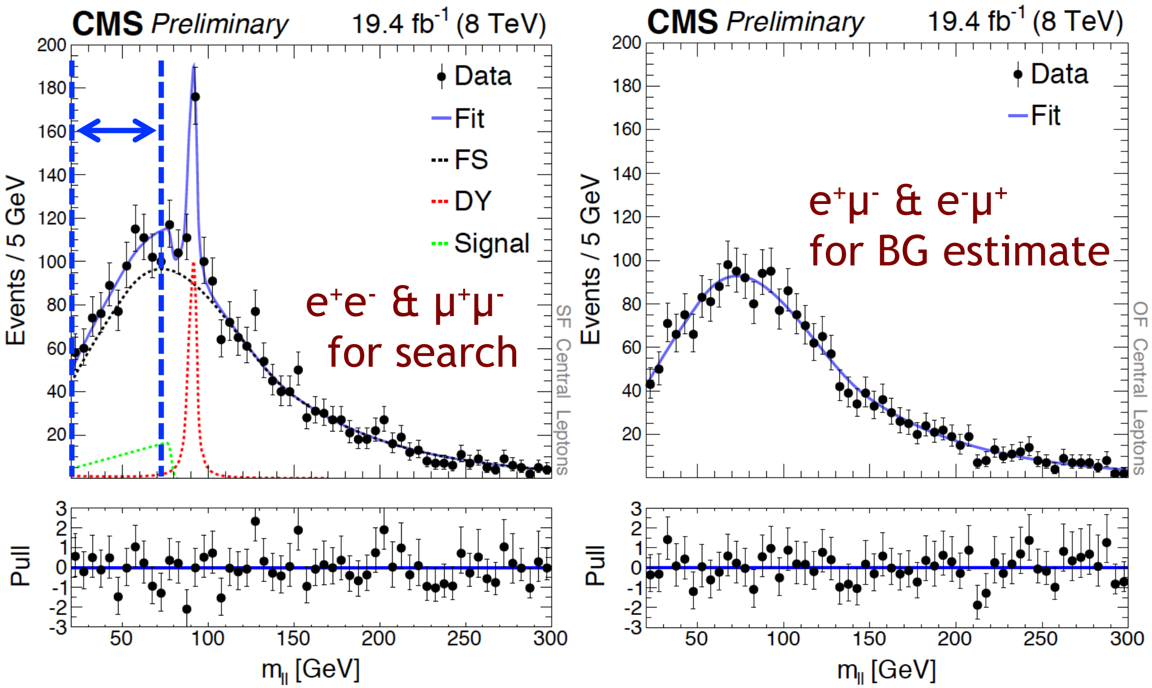

CMS-PAS-SUS-12-019

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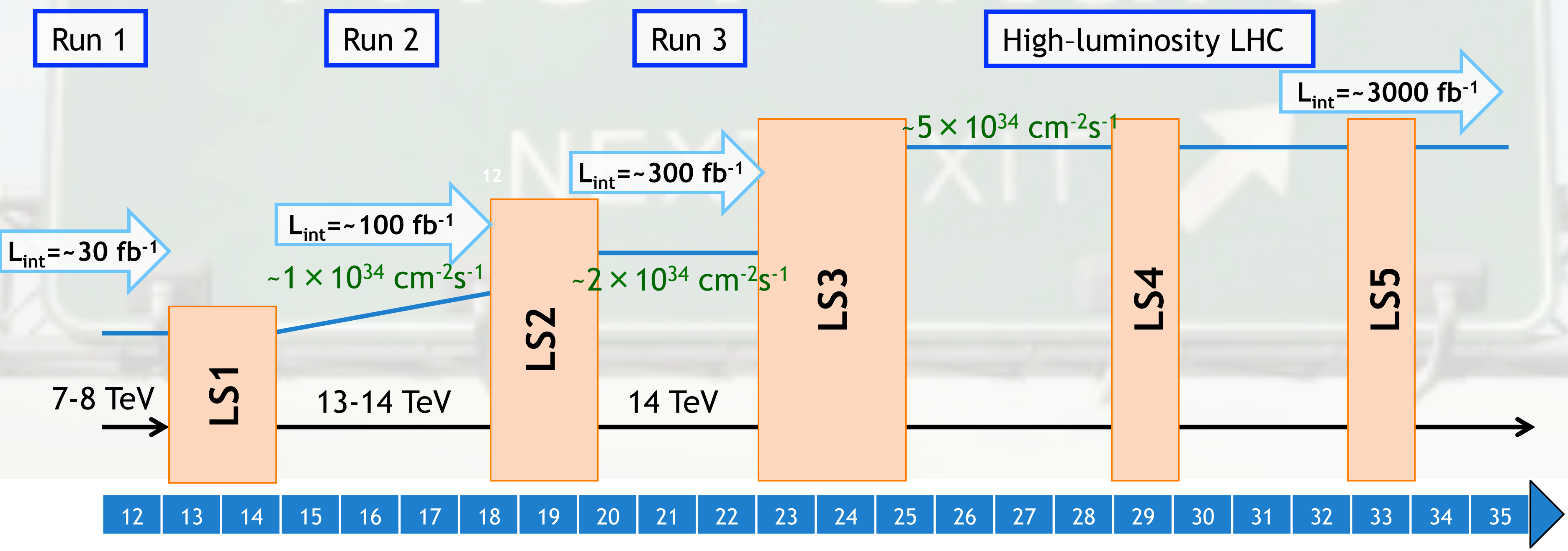
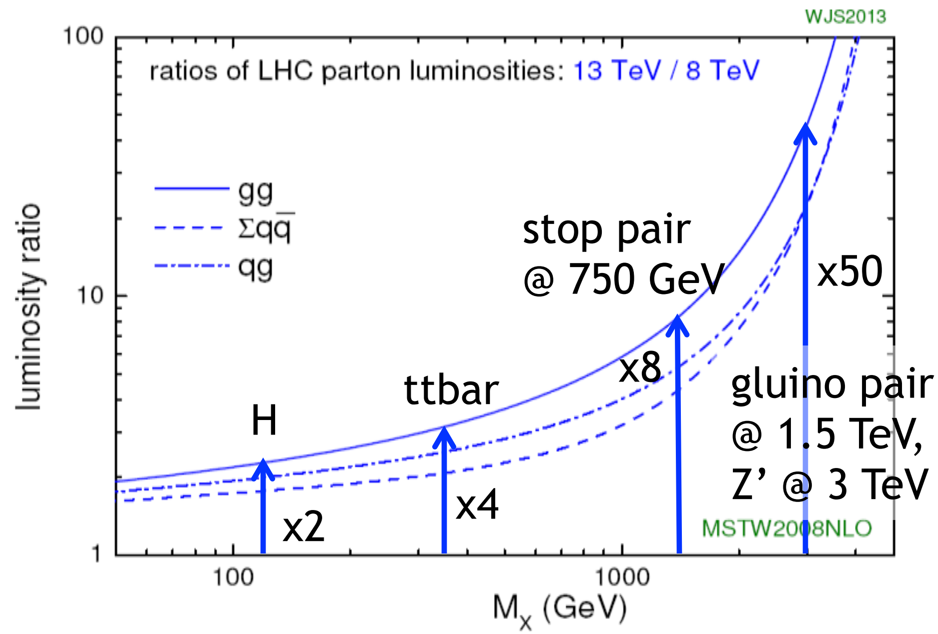
Future Prospects

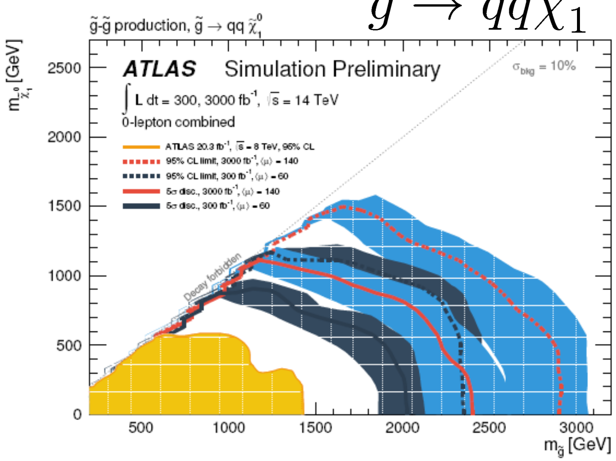


Future Prospects

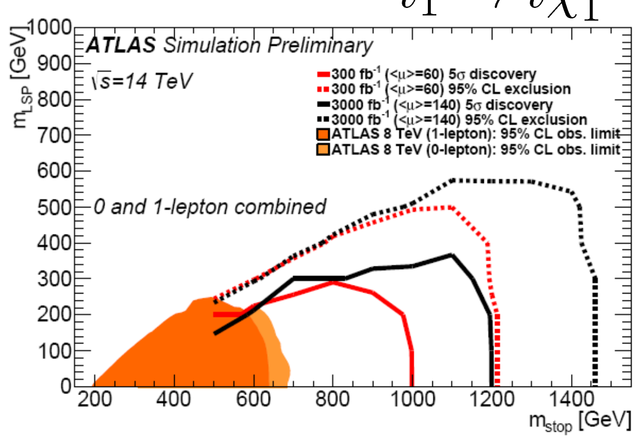
- Good prospects for gluinos, squarks, & high mass resonances from energy increase from 8 → 13/14 TeV
- For weakly interacting particles, high-luminosity helps a lot



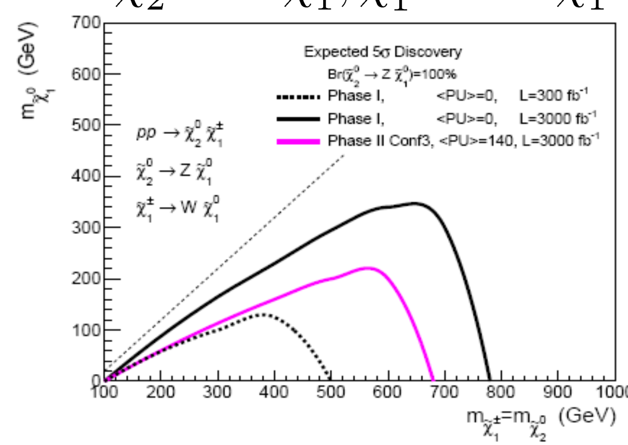
$\tilde{g} \rightarrow qq\tilde{\chi}_1^0$



$\tilde{t}_1 \rightarrow t\tilde{\chi}_1^0$



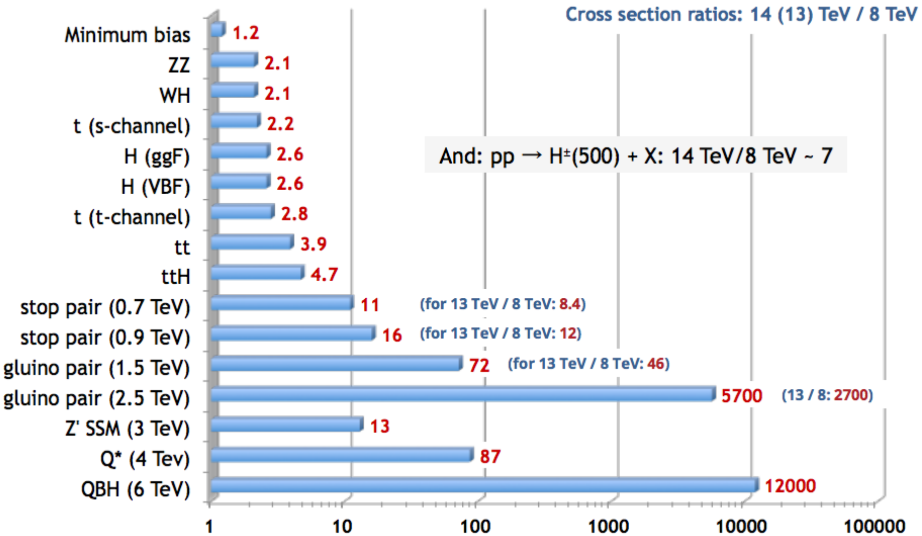
$\tilde{\chi}_2^0 \rightarrow Z\tilde{\chi}_1^0, \tilde{\chi}_1^\pm \rightarrow W\tilde{\chi}_1^0$



ATL-PHY-PUB-2014-010, CMS-PAS-FTR-13-0014

Summary

- CMS & ATLAS have performed a wide variety of searches for physics beyond the Standard Model in the LHC Run 1 (2009-2012) data
- No new physics was observed so far: only exclusions are provided
  - Singly (pair) produced resonances up to 5 (1) TeV
  - Unique complementary dark matter searches
  - Gluinos up to 1.4 TeV, 3rd gen. squarks up to 0.7 TeV, gauginos up to ~0.3-0.7 TeV
- Our journey of new physics searches at the ~ TeV scale have just begun



Stayed tuned when the LHC comes back again

Backup

ATLAS Exotics Summary

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

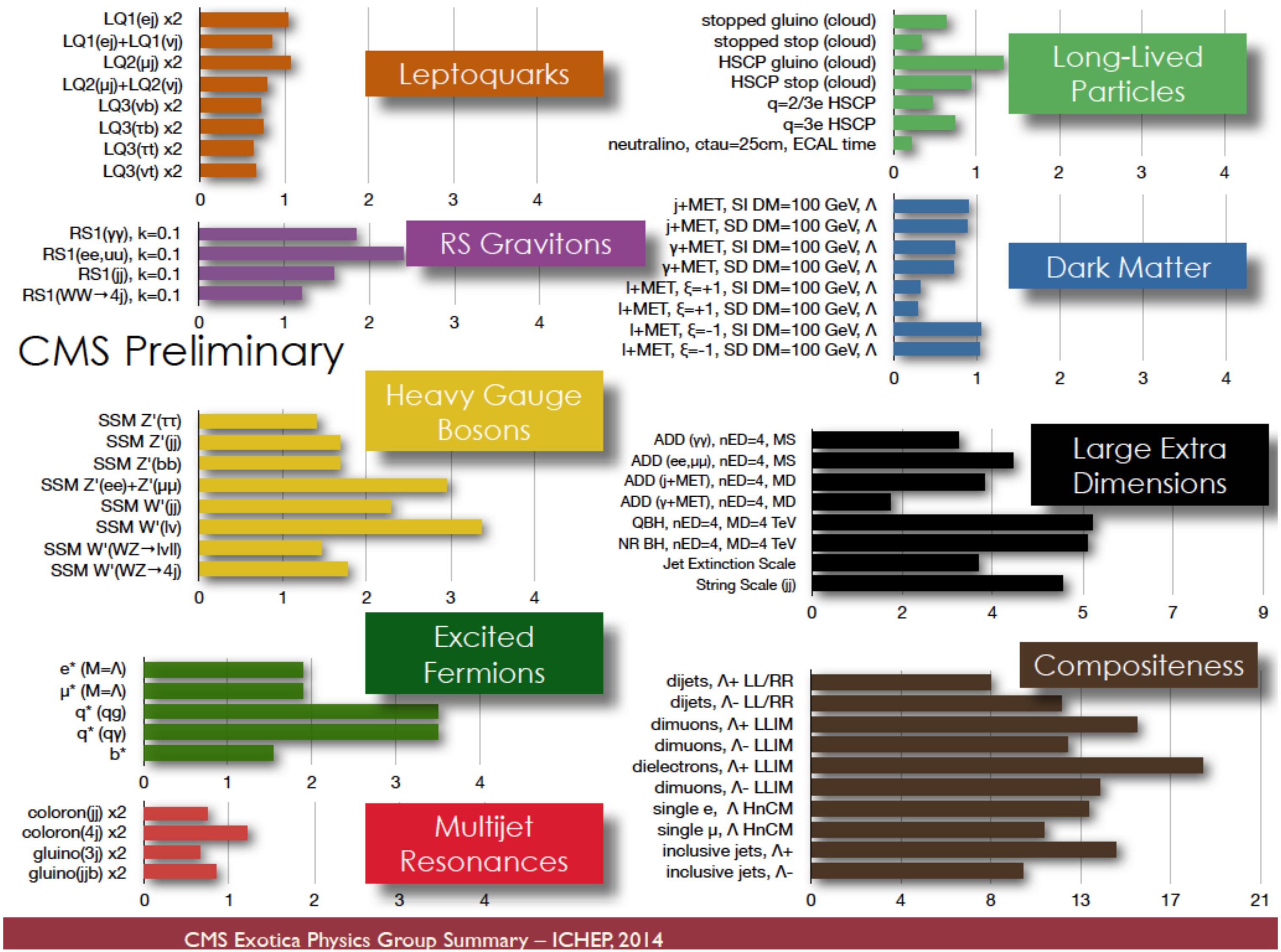
	Model	ℓ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\, dt[\mathrm{fb}^{-1}]$	Mass limit		Reference
Extra dimensions	ADD $G_{KK} + g/q$	–	1-2 j	Yes	4.7	M_D 4.37 TeV	$n = 2$	1210.4491
	ADD non-resonant $\ell\ell$	$2e, \mu$	–	–	20.3	M_S 5.2 TeV	$n = 3$ HLZ	ATLAS-CONF-2014-030
	ADD QBH $\to \ell q$	$1\ e, \mu$	1 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/≥3 e, μ	≥2/≥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/≥3 e, μ	≥2/≥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

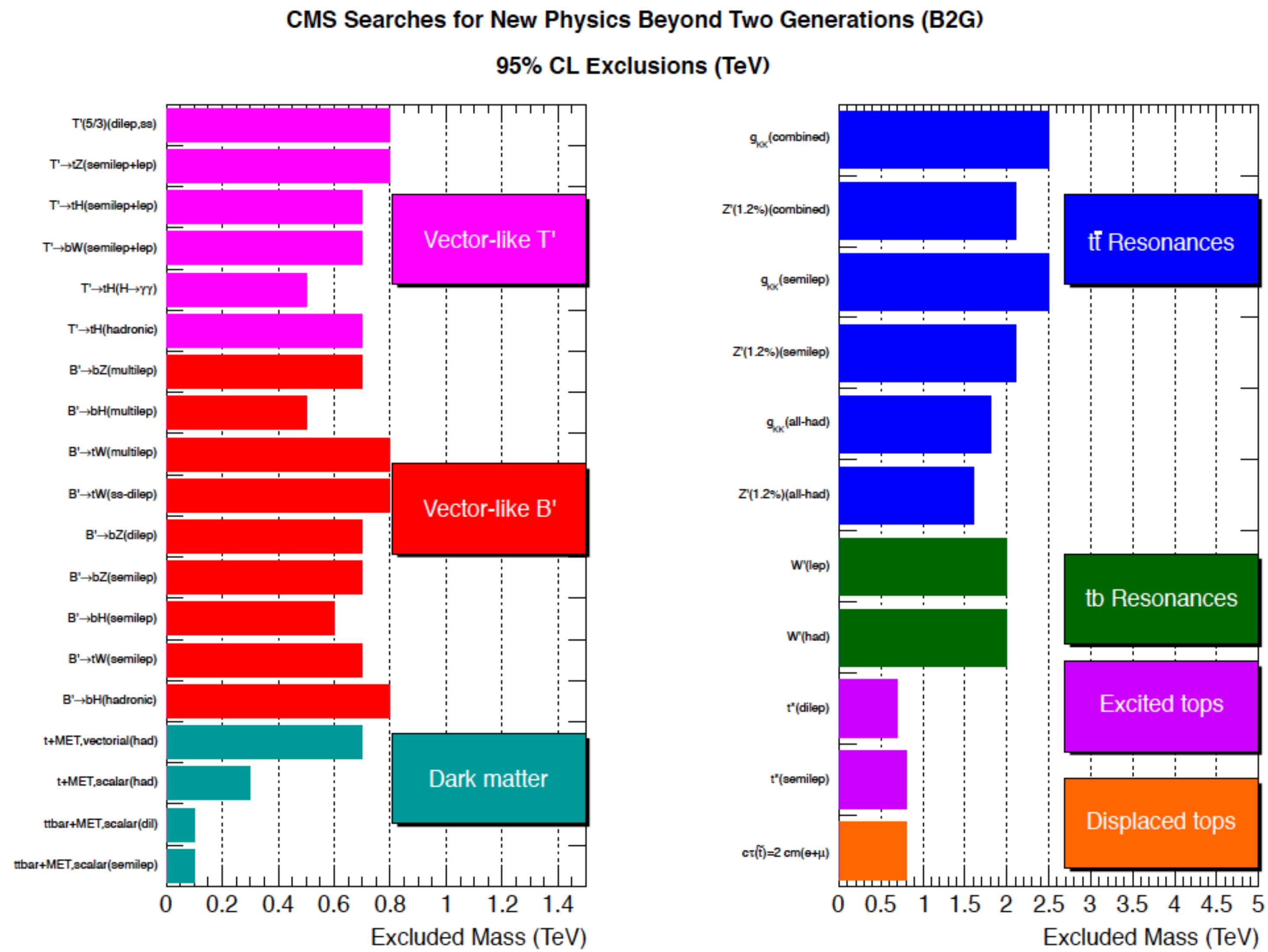
10^{-1} 1 10 Mass scale [TeV]

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

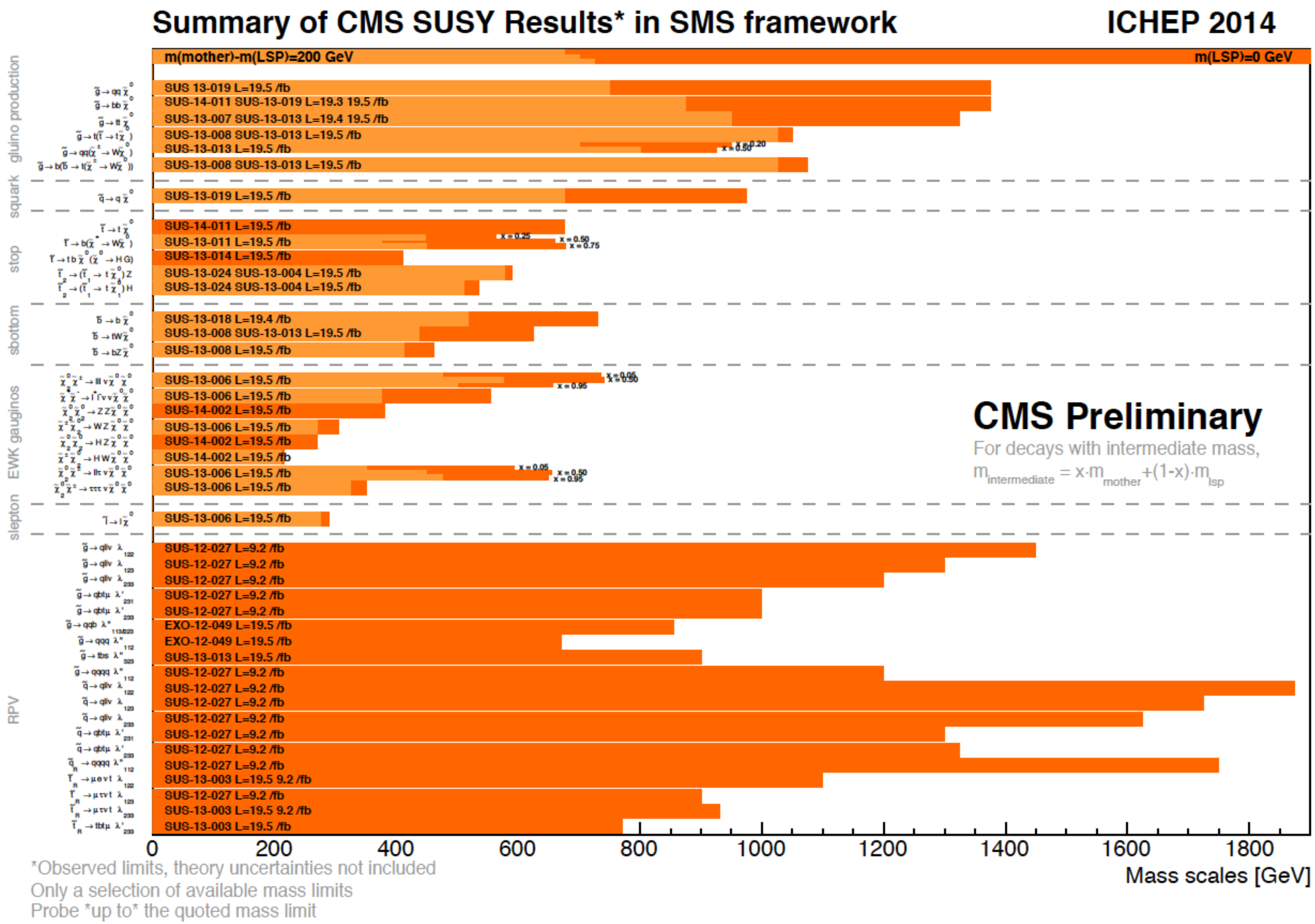
CMS Exotica Summary



CMS B2G Summary



CMS SUSY Summary



ATLAS SUSY Summary

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
	$\tilde{q}\tilde{q}, \tilde{q}\to q\tilde{\chi}^0_1$	0	2-6 jets	Yes	20.3	$\tilde{q}$	850 GeV	$m(\tilde{\chi}^0_1)$=0 GeV, m(1^{st} gen. $\tilde{q}$)=m(2^{nd} gen. $\tilde{q}$)	1405.7875
	$\tilde{g}\tilde{g}, \tilde{g}\to q\bar{q}\tilde{\chi}^0_1$	0	2-6 jets	Yes	20.3	$\tilde{g}$	1.33 TeV	$m(\tilde{\chi}^0_1)$=0 GeV	1405.7875
	$\tilde{g}\tilde{g}, \tilde{g}\to qq\tilde{\chi}^\pm_1\to qqW^\pm\tilde{\chi}^0_1$	1 e, μ	3-6 jets	Yes	20.3	$\tilde{g}$	1.18 TeV	$m(\tilde{\chi}^0_1)$<200 GeV, $m(\tilde{\chi}^\pm)=0.5(m(\tilde{\chi}^0_1)+m(\tilde{g}))$	ATLAS-CONF-2013-062
	$\tilde{g}\tilde{g}, \tilde{g}\to qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}^0_1$	2 e, μ	0-3 jets	-	20.3	$\tilde{g}$	1.12 TeV	$m(\tilde{\chi}^0_1)$=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	$m(\tilde{\chi}^0_1)$>50 GeV	ATLAS-CONF-2014-001
	GGM (wino NLSP)	1 $e, \mu + \gamma$	-	Yes	4.8	$\tilde{g}$	619 GeV	$m(\tilde{\chi}^0_1)$>50 GeV	ATLAS-CONF-2012-144
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	4.8	$\tilde{g}$	900 GeV	$m(\tilde{\chi}^0_1)$>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
3^{rd} gen. $\tilde{g}$ med.	$\tilde{g}\to b\bar{b}\tilde{\chi}^0_1$	0	3 b	Yes	20.1	$\tilde{g}$	1.25 TeV	$m(\tilde{\chi}^0_1)$<400 GeV	1407.0600
	$\tilde{g}\to t\bar{t}\tilde{\chi}^0_1$	0	7-10 jets	Yes	20.3	$\tilde{g}$	1.1 TeV	$m(\tilde{\chi}^0_1)$ <350 GeV	1308.1841
	$\tilde{g}\to t\bar{t}\tilde{\chi}^0_1$	0-1 e, μ	3 b	Yes	20.1	$\tilde{g}$	1.34 TeV	$m(\tilde{\chi}^0_1)$<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	$m(\tilde{\chi}^0_1)$<300 GeV	1407.0600
3^{rd} gen. squarks direct production	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to b\tilde{\chi}^0_1$	0	2 b	Yes	20.1	$\tilde{b}_1$	100-620 GeV	$m(\tilde{\chi}^0_1)$<90 GeV	1308.2631
	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to t\tilde{\chi}^\pm_1$	2 e, μ (SS)	0-3 b	Yes	20.3	$\tilde{b}_1$	275-440 GeV	$m(\tilde{\chi}^\pm_1)=2\,m(\tilde{\chi}^0_1)$	1404.2500
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to b\tilde{\chi}^\pm_1$	1-2 e, μ	1-2 b	Yes	4.7	$\tilde{t}_1$	110-167 GeV	$m(\tilde{\chi}^0_1)$=55 GeV	1208.4305, 1209.2102
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to Wb\tilde{\chi}^0_1$	2 e, μ	0-2 jets	Yes	20.3	$\tilde{t}_1$	130-210 GeV	$m(\tilde{\chi}^0_1)$ =$m(\tilde{t}_1)$-$m(W)$-50 GeV, $m(\tilde{t}_1)$<<$m(\tilde{\chi}^\pm_1)$	1403.4853
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to t\tilde{\chi}^0_1$	2 e, μ	2 jets	Yes	20.3	$\tilde{t}_1$	215-530 GeV	$m(\tilde{\chi}^0_1)$=1 GeV	1403.4853
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to b\tilde{\chi}^\pm_1$	0	2 b	Yes	20.1	$\tilde{t}_1$	150-580 GeV	$m(\tilde{\chi}^0_1)$<200 GeV, $m(\tilde{\chi}^\pm_1)$-$m(\tilde{\chi}^0_1)$=5 GeV	1308.2631
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}^0_1$	1 e, μ	1 b	Yes	20	$\tilde{t}_1$	210-640 GeV	$m(\tilde{\chi}^0_1)$=0 GeV	1407.0583
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}^0_1$	0	2 b	Yes	20.1	$\tilde{t}_1$	260-640 GeV	$m(\tilde{\chi}^0_1)$=0 GeV	1406.1122
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to c\tilde{\chi}^0_1$	0	mono-jet/c-tag	Yes	20.3	$\tilde{t}_1$	90-240 GeV	$m(\tilde{t}_1)$-$m(\tilde{\chi}^0_1)$<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	$m(\tilde{\chi}^0_1)$>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	$m(\tilde{\chi}^0_1)$<200 GeV	1403.5222
EW direct	$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R}, \tilde{\ell}\to\ell\tilde{\chi}^0_1$	2 e, μ	0	Yes	20.3	$\tilde{\ell}$	90-325 GeV	$m(\tilde{\chi}^0_1)$=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	$\tilde{\chi}^\pm_1$	140-465 GeV	$m(\tilde{\chi}^0_1)$=0 GeV, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}^\pm_1)+m(\tilde{\chi}^0_1))$	1403.5294
	$\tilde{\chi}^+_1\tilde{\chi}^-_1, \tilde{\chi}^+_1\to\tilde{\tau}\nu(\tau\tilde{\nu})$	2 τ	-	Yes	20.3	$\tilde{\chi}^\pm_1$	100-350 GeV	$m(\tilde{\chi}^0_1)$=0 GeV, $m(\tilde{\tau},\tilde{\nu})=0.5(m(\tilde{\chi}^\pm_1)+m(\tilde{\chi}^0_1))$	1407.0350
	$\tilde{\chi}^\pm_1\tilde{\chi}^0_2\to\tilde{\ell}_L\nu\tilde{\ell}_L\ell(\tilde{\nu}\nu), \ell\tilde{\nu}\tilde{\ell}_L\ell(\tilde{\nu}\nu)$	3 e, μ	0	Yes	20.3	$\tilde{\chi}^\pm_1, \tilde{\chi}^0_2$	700 GeV	$m(\tilde{\chi}^\pm_1)=m(\tilde{\chi}^0_2)$, $m(\tilde{\chi}^0_1)$=0, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}^\pm_1)+m(\tilde{\chi}^0_1))$	1402.7029
	$\tilde{\chi}^\pm_1\tilde{\chi}^0_2\to W\tilde{\chi}^0_1 Z\tilde{\chi}^0_1$	2-3 e, μ	0	Yes	20.3	$\tilde{\chi}^\pm_1, \tilde{\chi}^0_2$	420 GeV	$m(\tilde{\chi}^\pm_1)=m(\tilde{\chi}^0_2)$, $m(\tilde{\chi}^0_1)$=0, sleptons decoupled	1403.5294, 1402.7029
	$\tilde{\chi}^\pm_1\tilde{\chi}^0_2\to W\tilde{\chi}^0_1 h\tilde{\chi}^0_1$	1 e, μ	2 b	Yes	20.3	$\tilde{\chi}^\pm_1, \tilde{\chi}^0_2$	285 GeV	$m(\tilde{\chi}^\pm_1)=m(\tilde{\chi}^0_2)$, $m(\tilde{\chi}^0_1)$=0, sleptons decoupled	ATLAS-CONF-2013-093
	$\tilde{\chi}^0_2\tilde{\chi}^0_3, \tilde{\chi}^0_{2,3}\to\tilde{\ell}_R\ell$	4 e, μ	0	Yes	20.3	$\tilde{\chi}^0_{2,3}$	620 GeV	$m(\tilde{\chi}^0_2)=m(\tilde{\chi}^0_3)$, $m(\tilde{\chi}^0_1)$=0, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}^0_2)+m(\tilde{\chi}^0_1))$	1405.5086
Long-lived particles	Direct $\tilde{\chi}^+_1\tilde{\chi}^-_1$ prod., long-lived $\tilde{\chi}^\pm_1$	Disapp. trk	1 jet	Yes	20.3	$\tilde{\chi}^\pm_1$	270 GeV	$m(\tilde{\chi}^\pm_1)$-$m(\tilde{\chi}^0_1)$=160 MeV, $\tau(\tilde{\chi}^\pm_1)$=0.2 ns	ATLAS-CONF-2013-069
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	27.9	$\tilde{g}$	832 GeV	$m(\tilde{\chi}^0_1)$=100 GeV, 10 μs<$\tau(\tilde{g})$<1000 s	1310.6584
	GMSB, stable $\tilde{\tau}, \tilde{\chi}^0_1\to\tilde{\tau}(\tilde{e},\tilde{\mu})+\tau(e,\mu)$	1-2 μ	-	-	15.9	$\tilde{\chi}^0_1$	475 GeV	10<$\tan\beta$<50	ATLAS-CONF-2013-058
	GMSB, $\tilde{\chi}^0_1\to\gamma\tilde{G}$, long-lived $\tilde{\chi}^0_1$	2 γ	-	Yes	4.7	$\tilde{\chi}^0_1$	230 GeV	0.4<$\tau(\tilde{\chi}^0_1)$<2 ns	1304.6310
	$\tilde{q}\tilde{q}, \tilde{\chi}^0_1\to qq\mu$ (RPV)	1 μ, displ. vtx	-	-	20.3	$\tilde{q}$	1.0 TeV	1.5 <$c\tau$<156 mm, BR(μ)=1, $m(\tilde{\chi}^0_1)$=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
	$\tilde{\chi}^+_1\tilde{\chi}^-_1, \tilde{\chi}^+_1\to W\tilde{\chi}^0_1, \tilde{\chi}^0_1\to ee\tilde{\nu}_\mu, e\mu\tilde{\nu}_e$	4 e, μ	-	Yes	20.3	$\tilde{\chi}^\pm_1$	750 GeV	$m(\tilde{\chi}^0_1)$>0.2×$m(\tilde{\chi}^\pm_1)$, $\lambda_{121}\neq0$	1405.5086
	$\tilde{\chi}^+_1\tilde{\chi}^-_1, \tilde{\chi}^+_1\to W\tilde{\chi}^0_1, \tilde{\chi}^0_1\to\tau\tau\tilde{\nu}_e, e\tau\tilde{\nu}_\tau$	3 $e, \mu + \tau$	-	Yes	20.3	$\tilde{\chi}^\pm_1$	450 GeV	$m(\tilde{\chi}^0_1)$>0.2×$m(\tilde{\chi}^\pm_1)$, $\lambda_{133}\neq0$	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

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

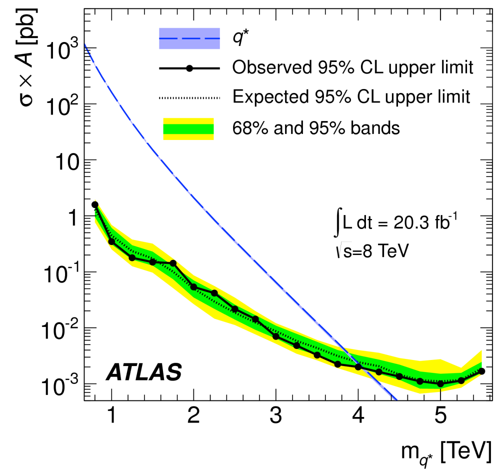
10^{-1} 1   Mass scale [TeV]

*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.

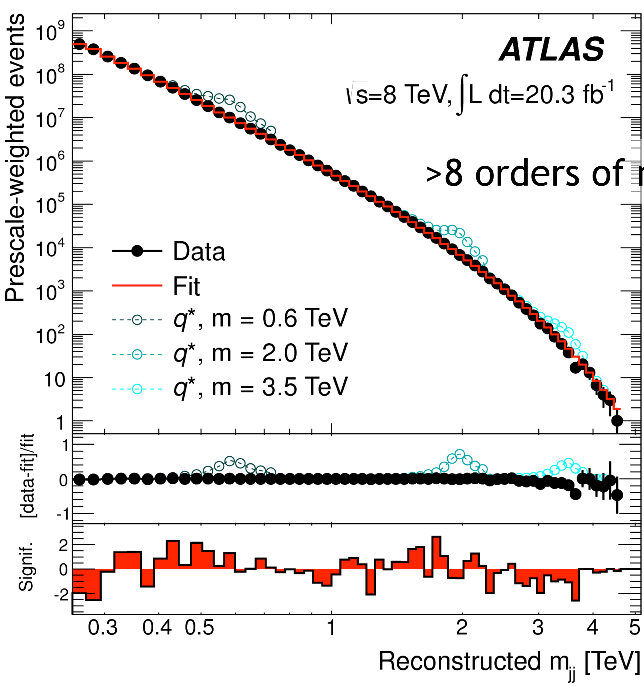
Dijets

- Two-jets with R=0.6, p_T>50 GeV
- M_{jj}: 0.25–4.5 TeV. Cross section spans over >8 orders of magnitude, fitted with

$$f(x) = p_1(1-x)^{p_2} x^{p_3+p_4 \ln x} \qquad x \equiv \frac{M_{jj}}{\sqrt{s}}$$



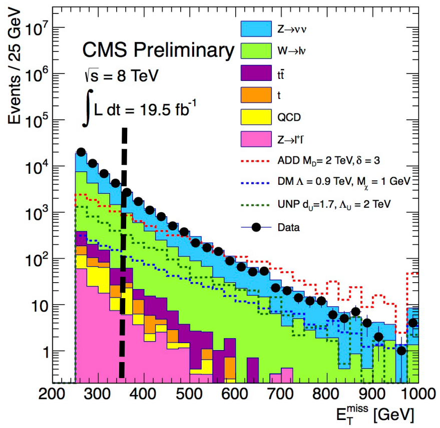
arXiv:1407.1376



>8 orders of magnitude

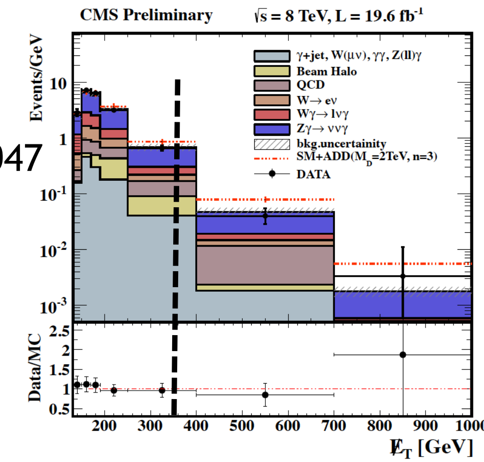
- Exclusions on various models
  - Excited quark (→qg): < 4.1 TeV
  - Color-octet scalar (→gg): < 2.7 TeV
  - W' (→qq'bar): < 2.5 TeV
  - Quantum black hole (→q,g): < 5.8 TeV
- Model-independent interpretations
  - Gaussian signal shape
  - Breit-Wigner shape
    - Γ/M =0.5 – 5%
    - qq, qg, gg, qqbar initial states

Mono-X Searches

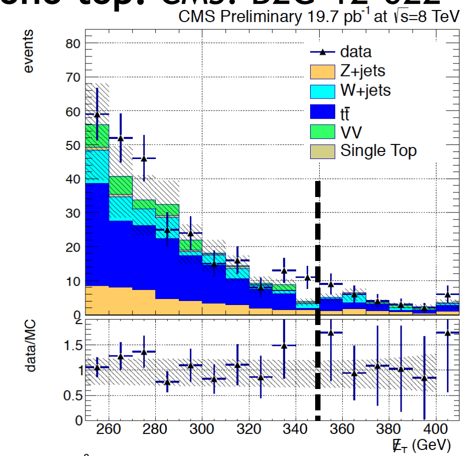


Monojet:
CMS: EXO-12-048

Monophoton:
CMS: EXO-12-047



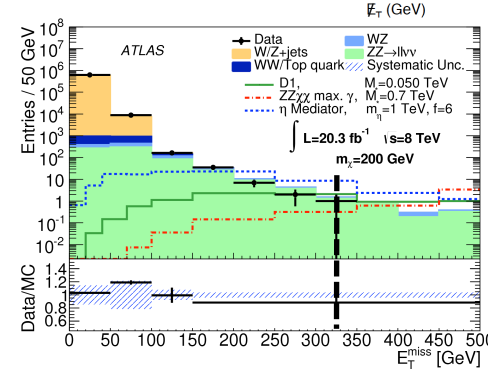
Mono-top: CMS: B2G-12-022



Mono-W/Z (hadronic):
ATLAS: 1309.4017

Process	$E_T^{miss} > 350$ GeV	$E_T^{miss} > 500$ GeV
$Z \to \nu\bar{\nu}$	402^{+39}_{-34}	54^{+8}_{-10}
$W \to \ell^{\pm}\nu$, $Z \to \ell^{\pm}\ell^{\mp}$	210^{+20}_{-18}	22^{+4}_{-5}
WW, WZ, ZZ	57^{+11}_{-8}	$9.1^{+1.3}_{-1.1}$
$t\bar{t}$, single t	39^{+10}_{-4}	$3.7^{+1.7}_{-1.3}$
Total	707^{+48}_{-38}	89^{+9}_{-12}
Data	705	89

Mono-Z:
ATLAS: 1404.0051



SM background for MET > ~350 GeV

Monojet: Mono-W/Z(hadr): Mono-γ: Mono-top(blν): Mono-Z(ll)

# of BG events: ~10,000: ~1,000: ~100: ~10: ~1

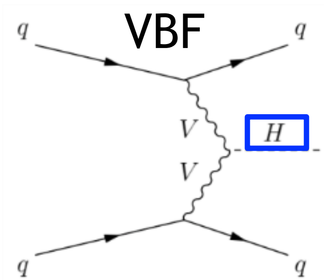
Main BG: Z(νν)+jets/W(lν)+jets Z(νν)γ ttbar Z(ll)Z(νν)

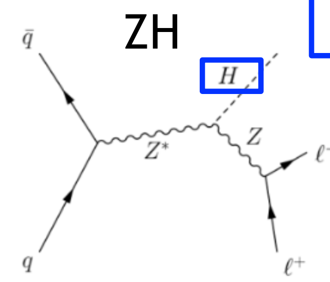
Different mono-X searches deal with different BGs at different level

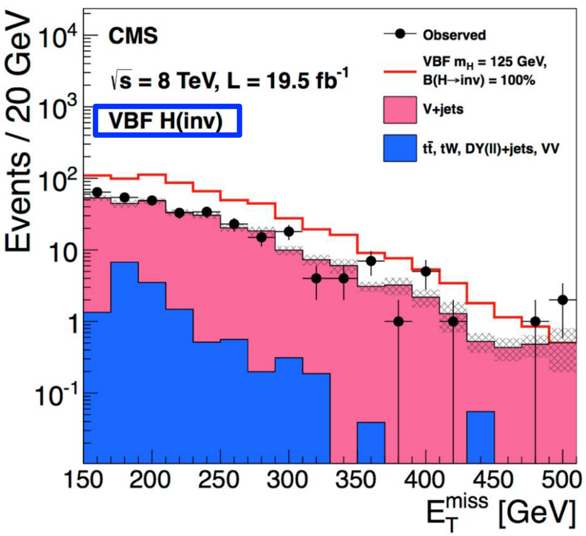
Higgs Portal to Dark Matter

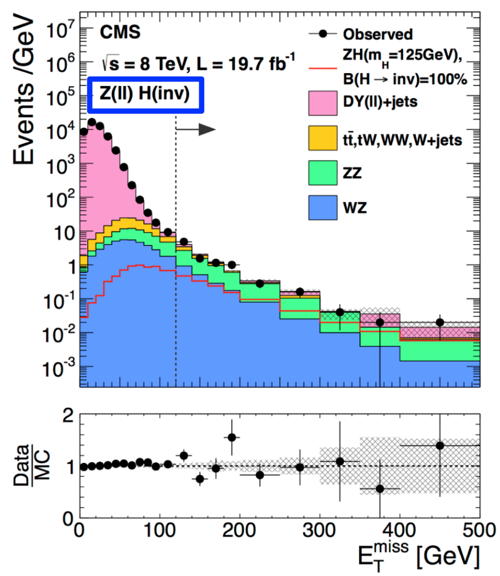
arXiv:1404.1344

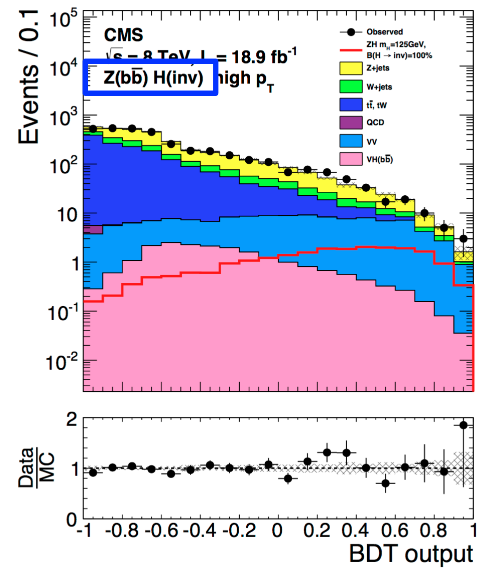
- DM particles directly couple to the Higgs sector, H → χχ
  - Look for H → invisible in VBF+H and Z(ll,bb)+H modes











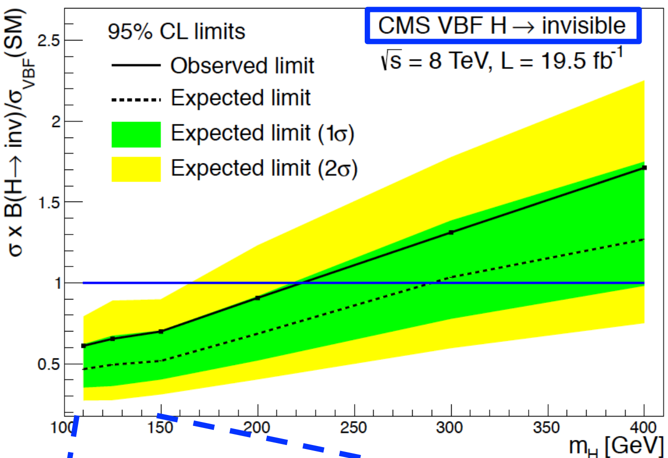
- Lepton vetos
- VBF jets: pT(j1,2)> 50 GeV, |Δη|>4.2 Mjj > 1.1 TeV
- MET > 130 GeV
- Δφ(j1,j2) < 1.0
- Central jet veto

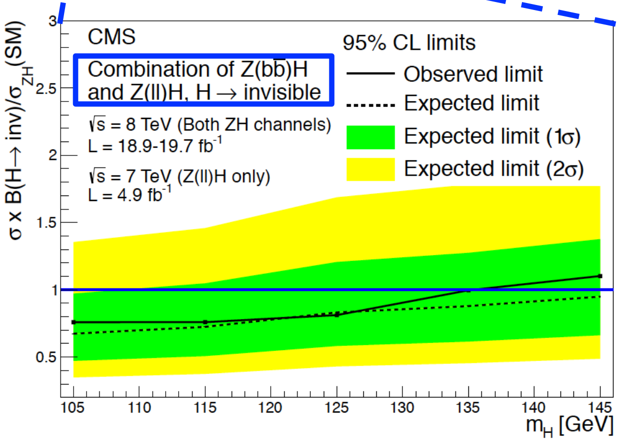
- Dileptons, M(ll)=M(Z)±15 GeV
- Extra (b-)jet vetos
- MET > 120 GeV
- |MET – p_T(ll)| / p_T(ll) < 0.25
- Δφ(ll,MET) > 2.7

- MET: 100-130, 130-170, >170 GeV
- p_T(j1,2)>60,30 GeV, Mjj<250 GeV
- CSV b-tag, additional jet vetos
- lepton vetos, Δφ(Z,H) > 2.0, etc
- BDT > 0.8, 0.7, 0.3

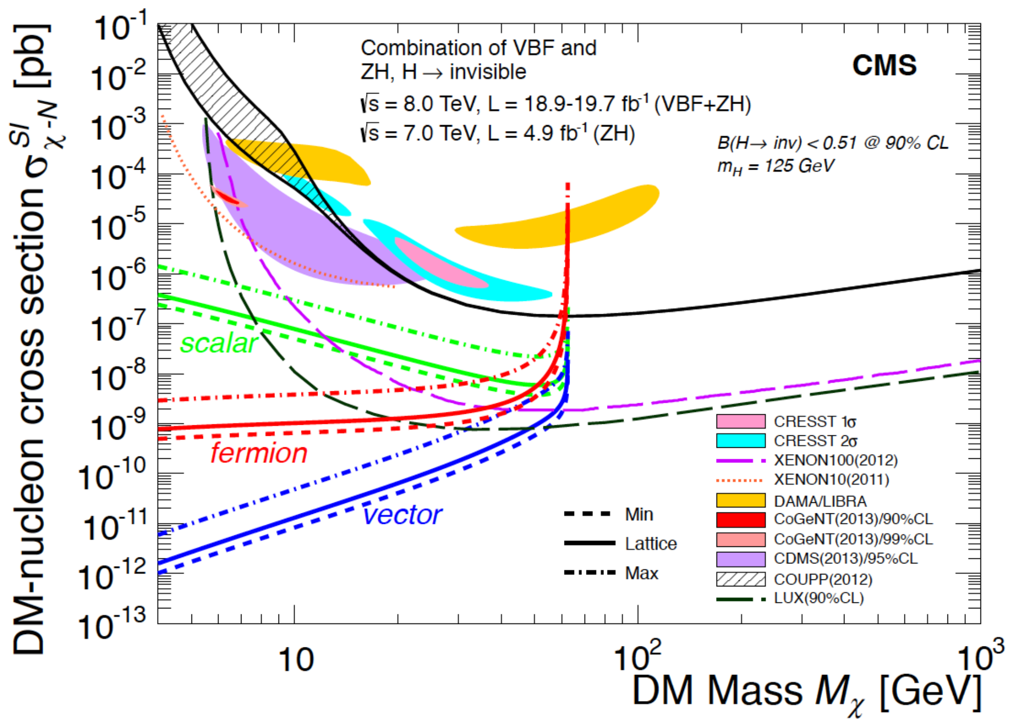
Higgs Portal to Dark Matter

arXiv:1404.1344





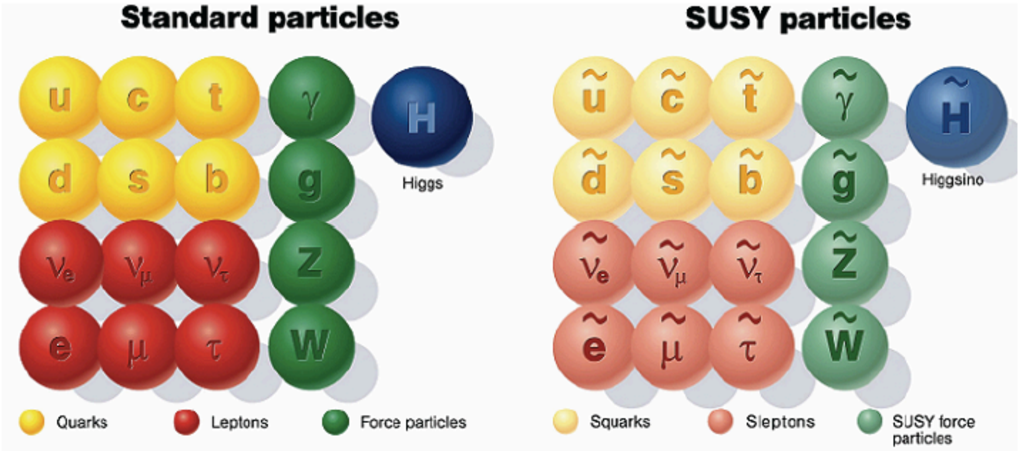
The VBF channel sensitivity far exceeds the ZH one



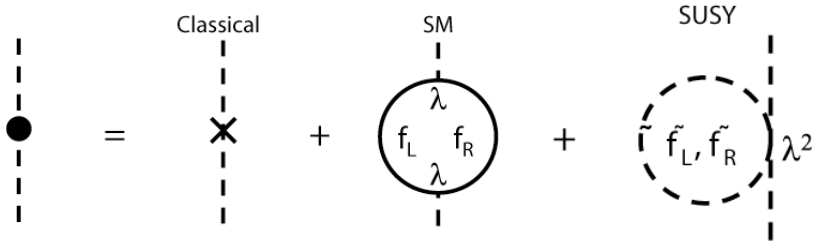
The limits on the DM-nucleon cross section vary for scalar, fermion, & vector, but the most stringent limits at low DM masses

Supersymmetry (SUSY)

- SUSY is a fundamental global symmetry between fermions and bosons
  - Each fermion has a boson superpartner, and vice versa
  - Broken symmetry:
    - Gravity-mediated SUSY breaking, Gauge-mediated SUSY breaking (GMSB), etc



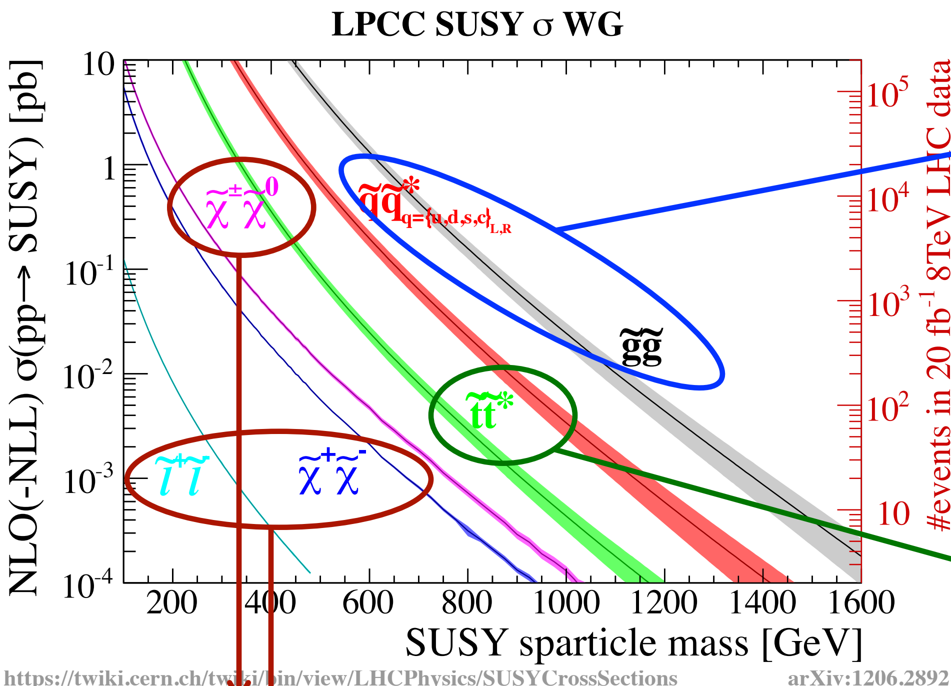
- Why attractive?
  - The Lightest Supersymmetric Particle (LSP, often neutralino or gravitino) is stable & neutral (if R-parity is conserved) → good Dark Matter candidate
  - Supersymmetry provides a beautiful solution to the hierarchy problem



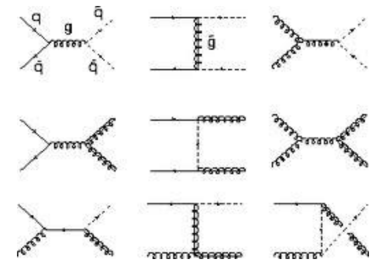
$$m_h^2 = (m_h^2)_0 - \frac{1}{16\pi^2}\lambda^2\Lambda^2 + \frac{1}{16\pi^2}\lambda^2\Lambda^2 + \ldots$$

$$\approx (m_h^2)_0 + \frac{1}{16\pi^2}(m_{\tilde{f}}^2 - m_f^2)\ln(\Lambda/m_{\tilde{f}}) \,,$$

Supersymmetry Searches at the LHC

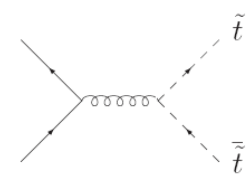


- gluinos and 1st & 2nd generation squarks: high cross section



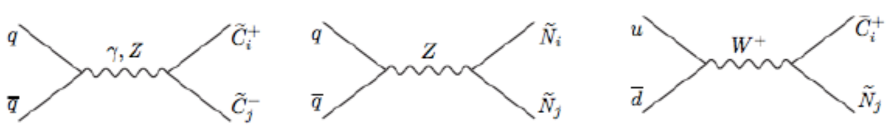
  - Multiple jets + MET w/w.o. leptons, b-tags, photons

- Stop & sbottom: medium cross section



  - Multiple jets + MET + b-tags w/ w.o. leptons

- Charginos, neutralinos, sleptons: small cross sections

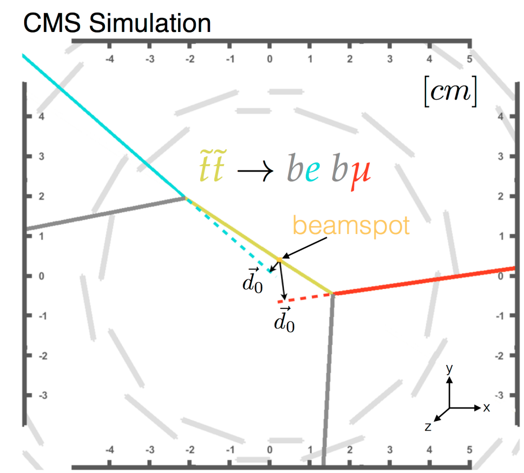


  - selecting 0-4 leptons w/w.o. b-tags, jets, W's, Z's, h's

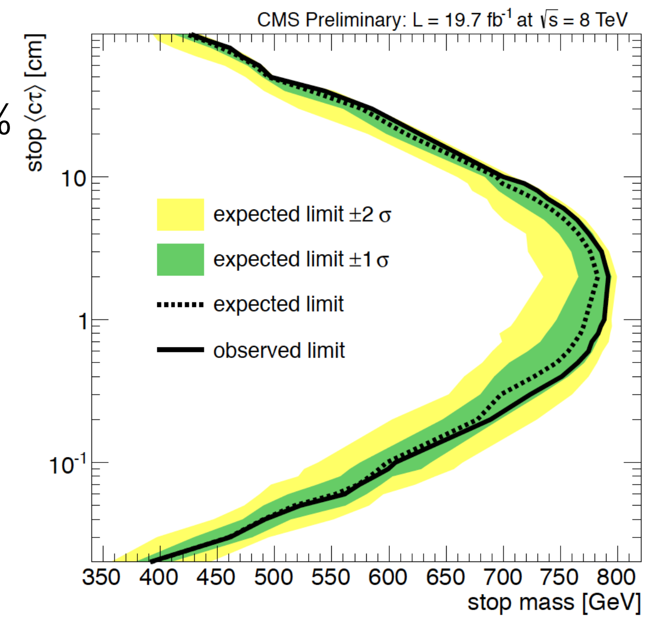
Displaced Dilepton: e, μ

CMS-PAS-B2G-12-024

- Model:
  - stop-stop → bl bl with lifetimes (cτ ~ 100μm - 2 cm)
- Selection:
  - OS and isolated e/μ with no common vertex
  - Control regions: SS & non-isolated regions to derive QCD background estimate
  - Validation regions: control regions with smaller d_0
  - Interpret as colored pair production with 100% BR into lepton + X. No selection on X.

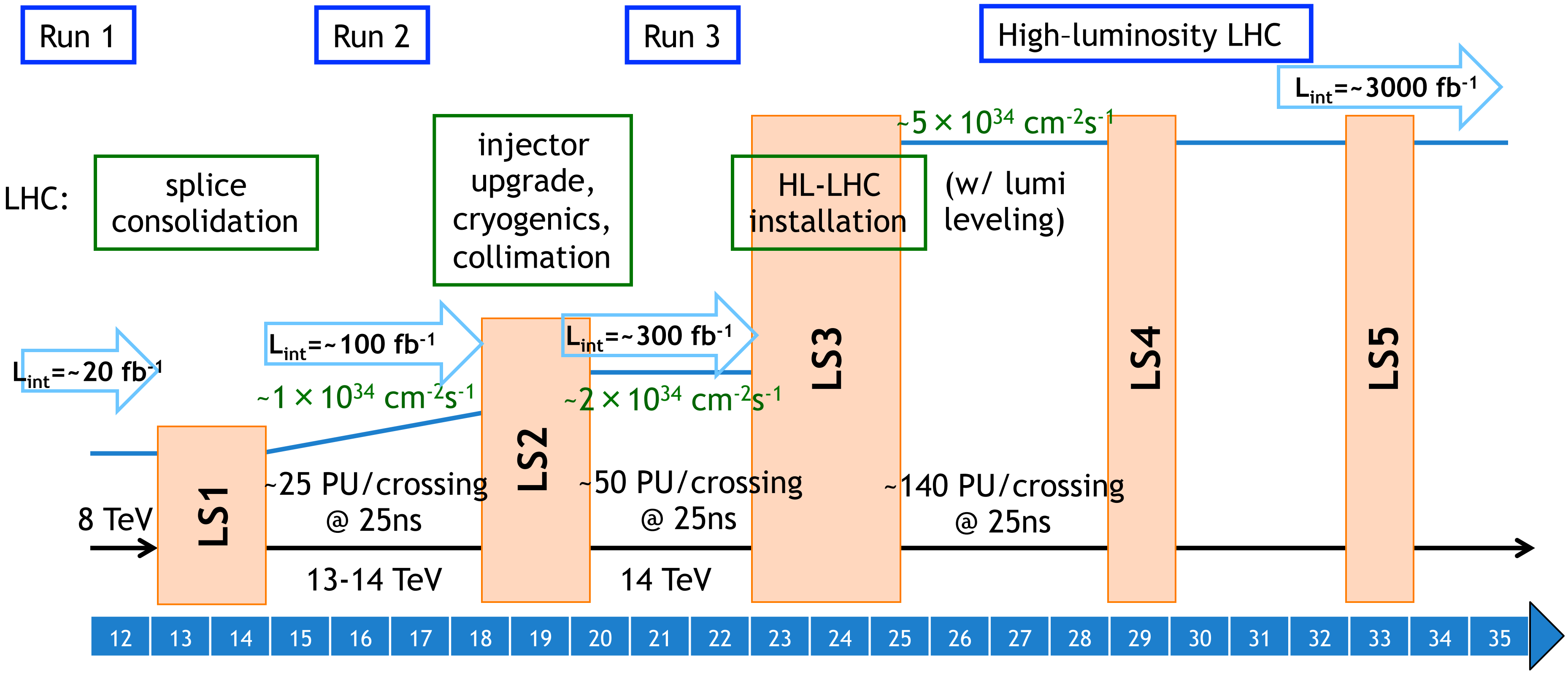


Event Source	0.02 cm < $\lvert d_0 \rvert$ < 0.05 cm	0.05 cm < $\lvert d_0 \rvert$ < 0.1 cm	$\lvert d_0 \rvert$ > 0.1 cm
Total expected background	$18.0 \pm 0.5 \pm 3.8$	$1.01 \pm 0.06 \pm 0.30$	$0.051 \pm 0.015 \pm 0.010$
Observation	19	0	0
$pp \to \tilde{t}_1 \tilde{t}_1^*$			
M = 500 GeV, $\langle c\tau \rangle$ = 1 mm	$30.1 \pm 0.7 \pm 1.1$	$6.54 \pm 0.34 \pm 0.24$	$1.34 \pm 0.15 \pm 0.05$
M = 500 GeV, $\langle c\tau \rangle$ = 1 cm	$35.3 \pm 0.8 \pm 1.3$	$30.3 \pm 0.7 \pm 1.1$	$51.3 \pm 1.0 \pm 1.9$
M = 500 GeV, $\langle c\tau \rangle$ = 10 cm	$4.73 \pm 0.30 \pm 0.17$	$5.57 \pm 0.32 \pm 0.20$	$26.27 \pm 0.70 \pm 0.93$



- Best results at cτ ~ 2 cm with exclusion of m(stop) < 790 GeV at 95% CL

LHC Evolution



Based on LHC schedule approved by CERN management, LHC experiment spokespersons and technical coordinators on Dec 2, 2013 Also, Bordry at ECFA HL-LHC workshop & Gregor.