Search for new physics at the LHC & prospects for new discoveries

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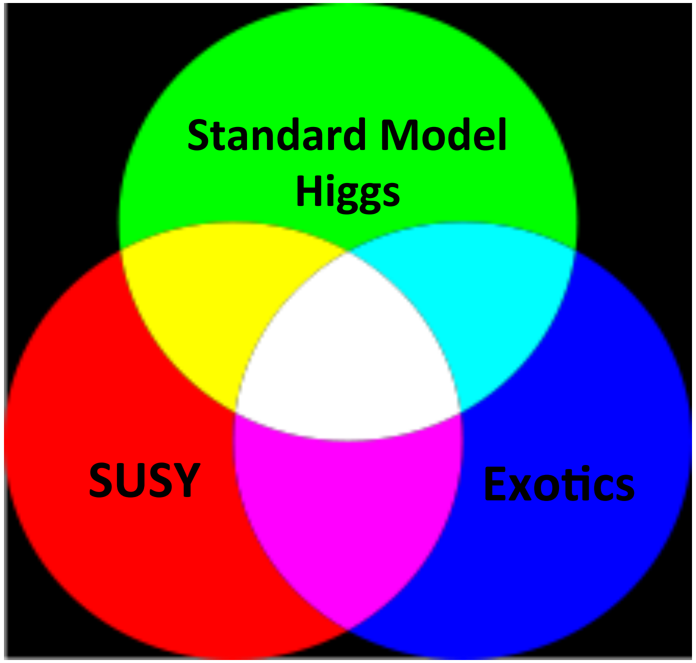
on behalf of the ATLAS and CMS collaborations

May 11th, 2015

Introduction

From LHC up to now (2010 - 2012), collision energies of 7 and 8 TeV (**Run1**) :

- An **impressive amount of searches** have been carried out in various physics areas
  - *Disclaimer : not possible to show them all !*
- **No observation of excesses** "Beyond the Standard Model (**BSM**)" predictions observed
  - A few **legacy 2-3 σ discrepancies** remaining



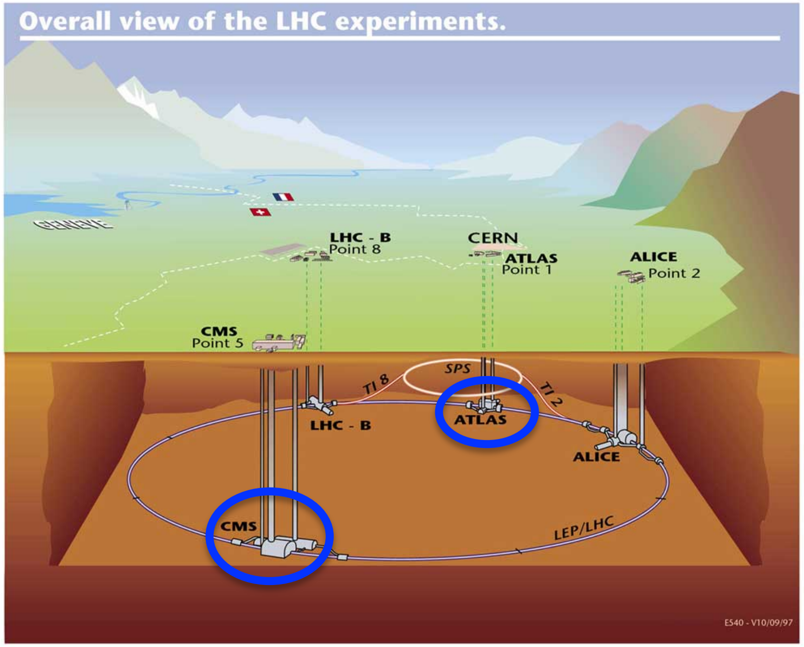
For LHC 2015 - 2018, collision energies of 13 TeV (**Run2**) :

- An **ambitious program** to test further the TeV energy frontier

LHC, ATLAS and CMS

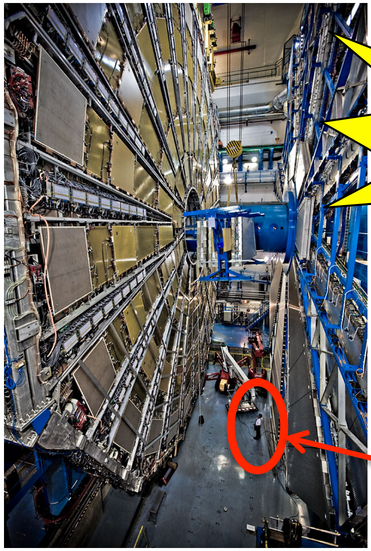
- LHC is a 27km **proton accelerator and colliding ring** at CERN
- The **LHC Run1 dataset** consists of:
  - 2010 : **≈45 pb^{-1}** of $\sqrt{s}$=7 TeV data
  - 2011 : **≈ 5 fb^{-1}** of $\sqrt{s}$=7 TeV data
  - 2012 : **≈ 20 fb^{-1}** of $\sqrt{s}$=8 TeV data

  Tevatron got **8 fb^{-1}** of **$\sqrt{s}$~2 TeV** data

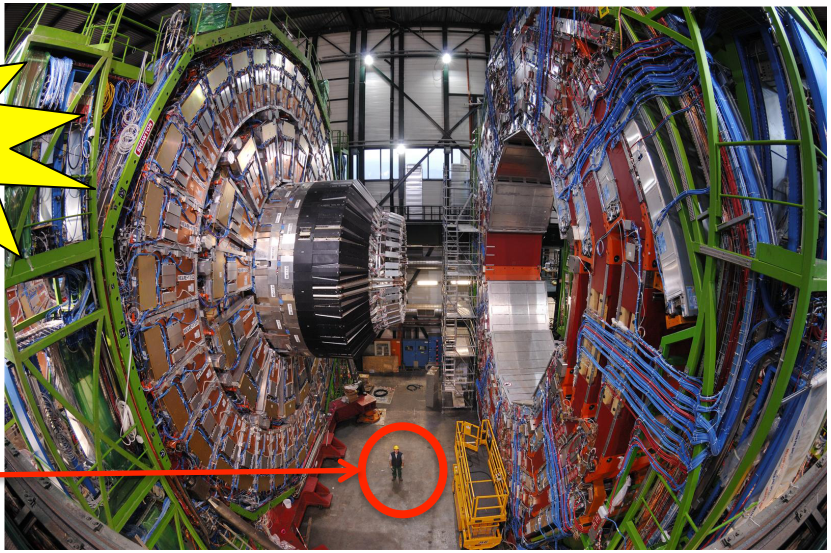


- ATLAS and CMS are **general purpose experiments**

(see C. Biino presentation)


ATLAS muon system

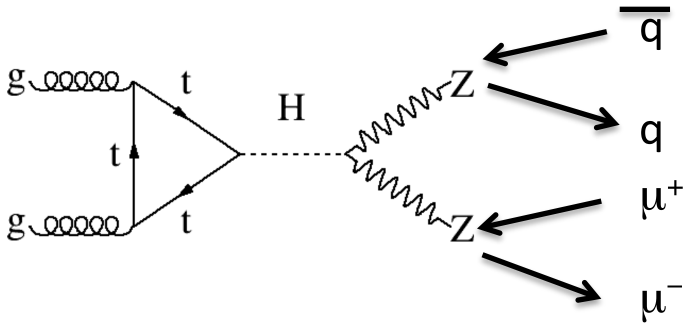
people

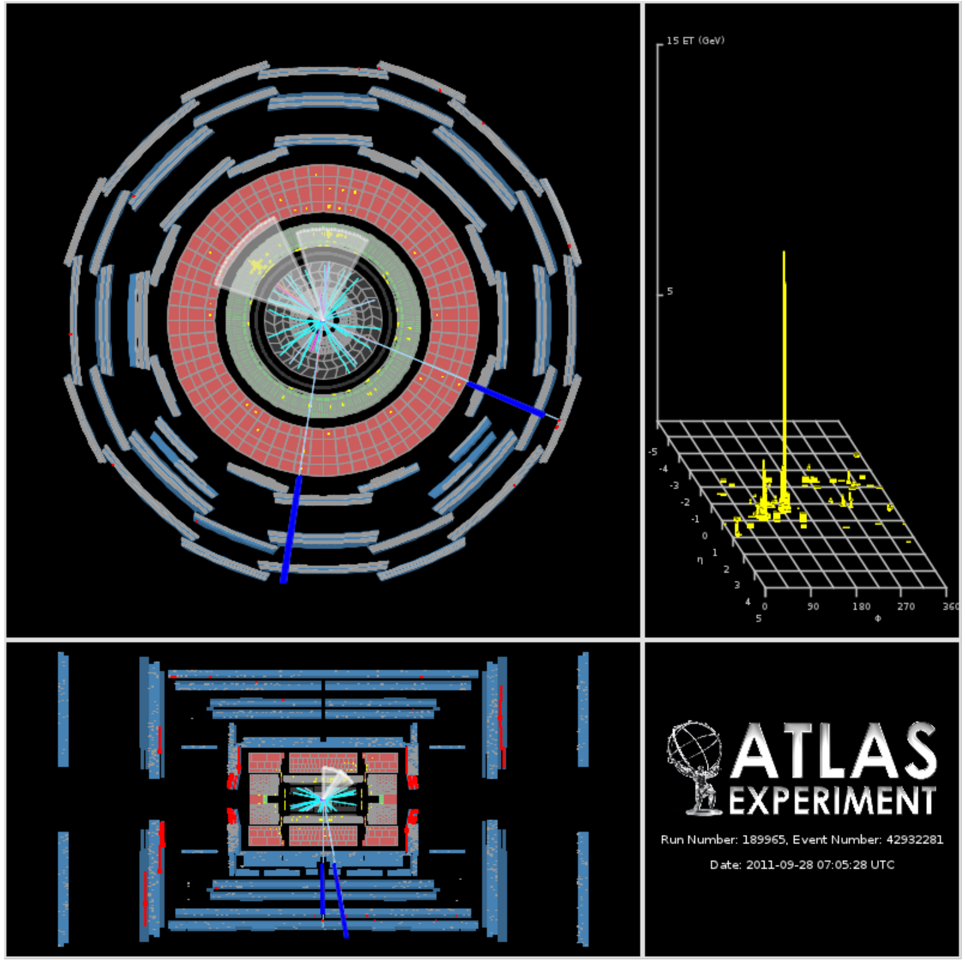

CMS muon system

Particle Physics Objects

Example for H→ ZZ → μμqq

What we calculate : → **What we measure :**



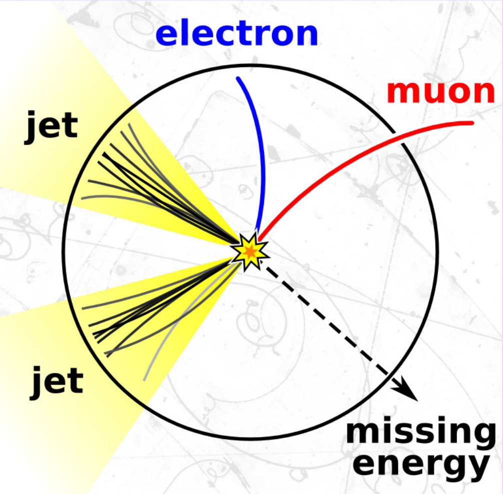


Run Number: 189965, Event Number: 42932281

Date: 2011-09-28 07:05:28 UTC

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

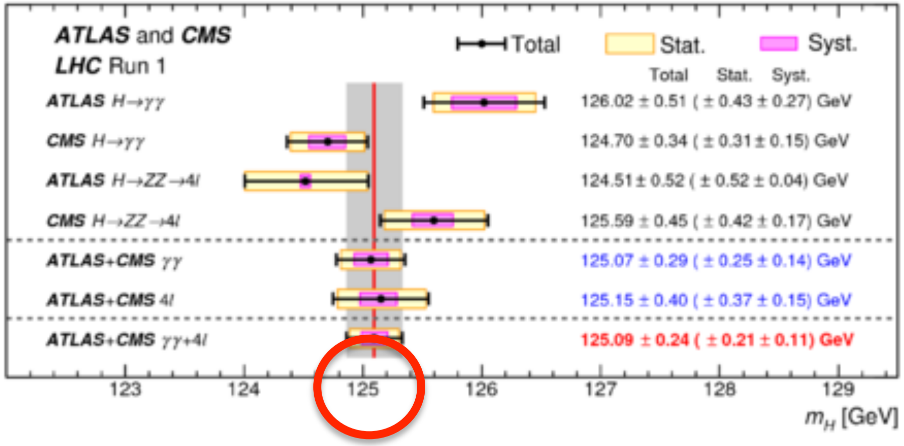
***Jet** = hadrons that are clustered together*



http://www.fnal.gov/pub/today/archive/archive_2011/today11-04-22.html

Run1 : BSM Higgs searches

- The main goal of Run1 to find the **Higgs boson** was reached:



arXiv:1503.07589

- In the **Higgs sector**, searches for BSM physics were performed in :

1) New Higgs decays

  - Higgs to **invisible particles**
  - Higgs to μτ (**lepton flavor violation**)
  - …

2) Other Higgs bosons

  - **Two Higgs doublet model**
  - **Di-Higgs resonances**
  - **Exotic** Higgs
  - …

Two Higgs doublet model (2HDM) :

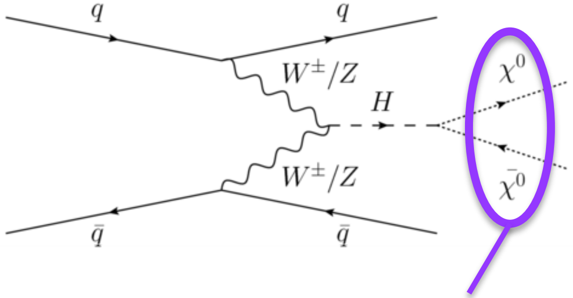
2 CP-even neutral Higgses: 1 CP-odd Higgs: 2 charged Higgses:

$$(m_h, m_H, m_A, m_{H^\pm})$$

Motivated by SUSY, axion models, *possible to generate a baryon asymmetry of the universe of sufficient size*

Search results in BSM Higgs (1)

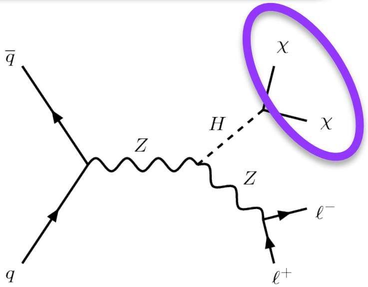
- **Higgs decaying to invisible particles**

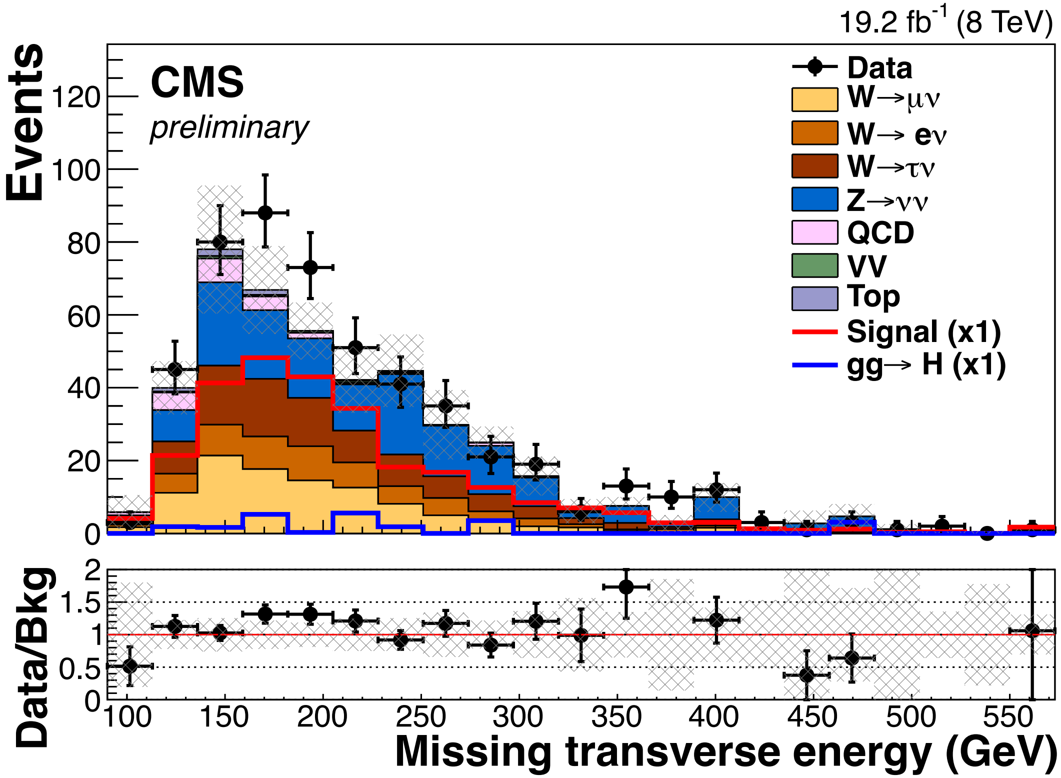


dark matter candidates

Higgs portal model

Higgs boson acts as mediator between the hidden sector and the SM particles





CMS PAS HIG-14-038

h→ invisible : **BR h→invisible < 29%**

ATLAS-CONF-2015-004

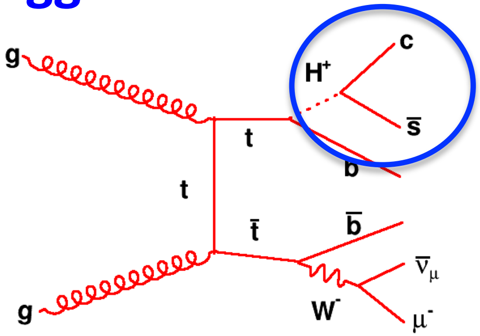
Zh→ll invisible : **BR h→invisible < 75%**

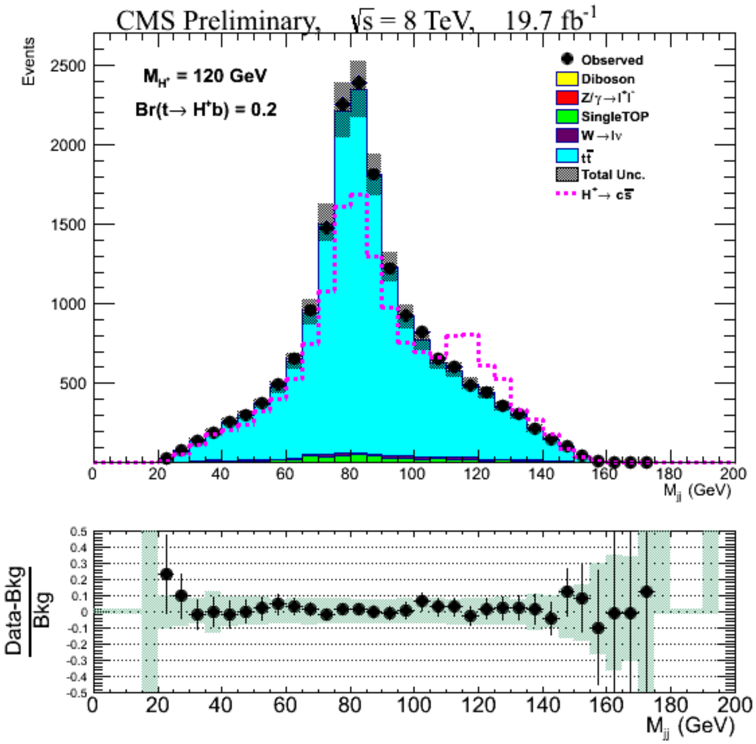
arXiv:1402.3244

Search results in BSM Higgs (2)

- **Charged Higgs boson**

$H^+ \to c\bar{s}$

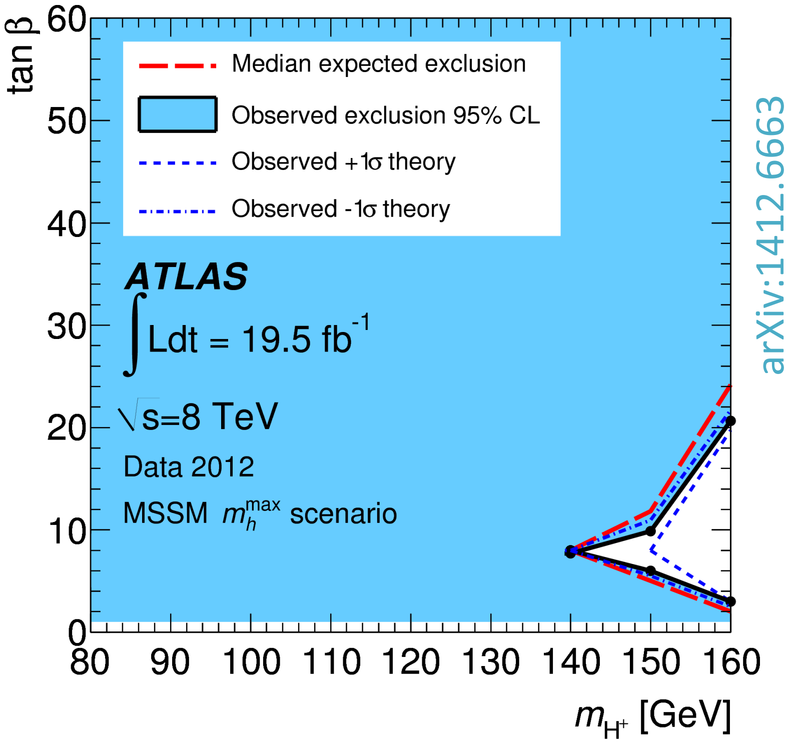




CMS PAS HIG-13-035

$H^+ \to \tau_{had}\nu$

tan(β) = *ratio of the two vacuum values of the 2 CP-even neutral Higgses (h,H)*



arXiv:1412.6663

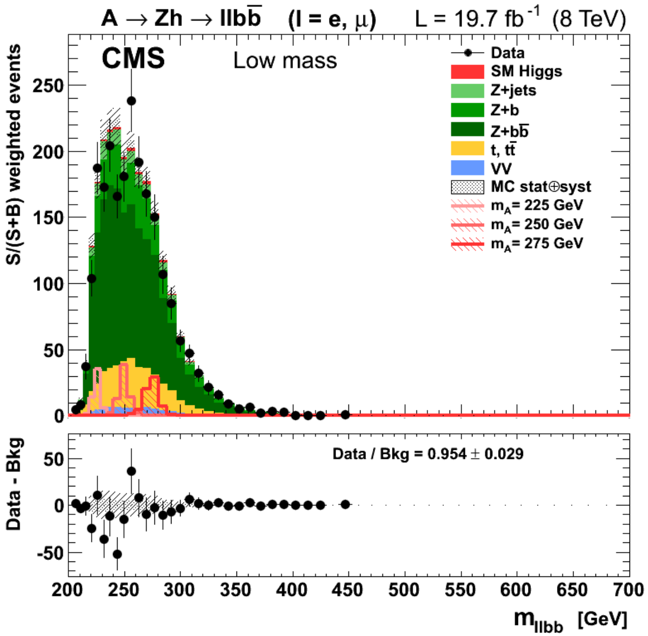
- **No significant excess** observed

- **Stringent limits** on tan(β), hence **on 2HDM**

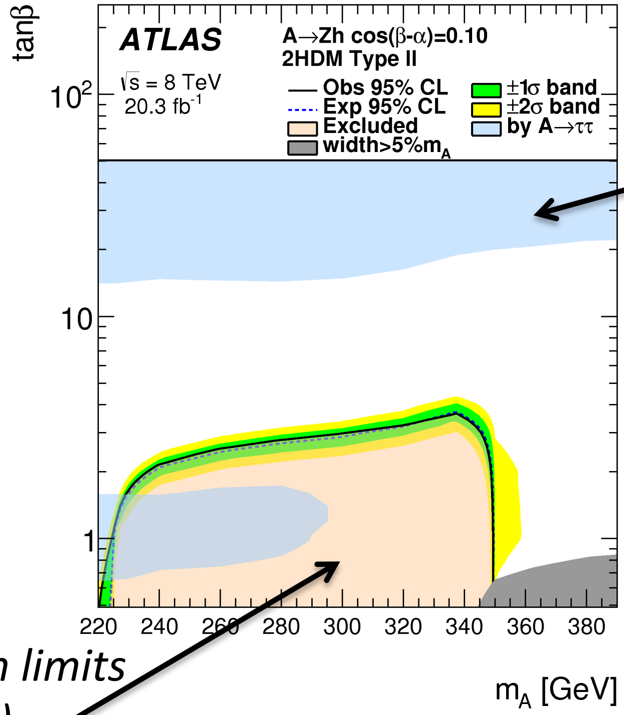
Search results in BSM Higgs (3)

- **CP-odd Higgs A**

$$A \to Zh \to llbb$$



arXiv:1504.04710v1



arXiv:1502.04478

complementarity with A→ττ limits

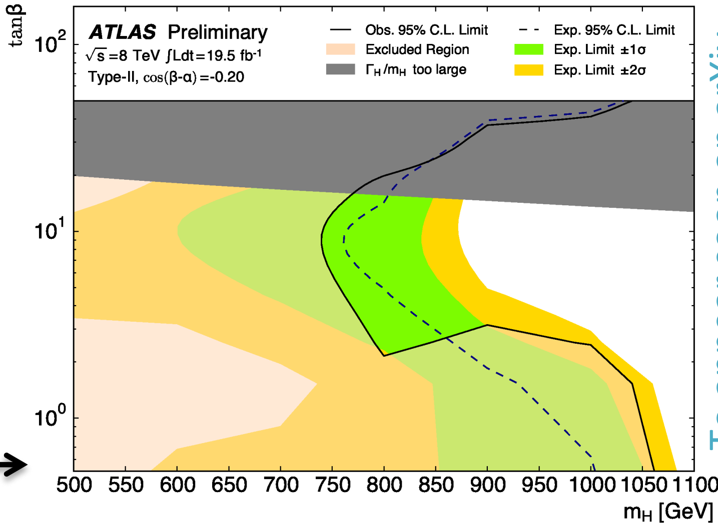
Exclusion limits on tan(β)

- **No excess** observed

- **di-Higgs resonances**

$$H \to hh \to b\bar{b}b\bar{b}(b\bar{b}\gamma\gamma)$$

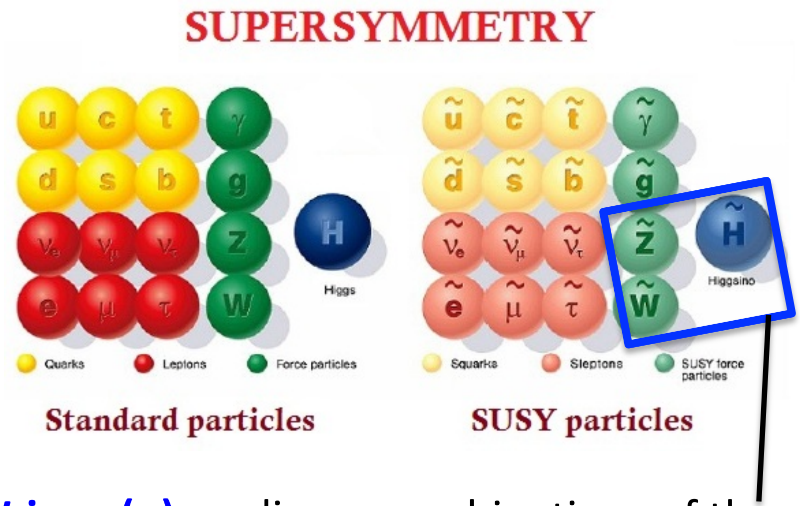
Allows to access **higher** masses



To appear soon on arXiv

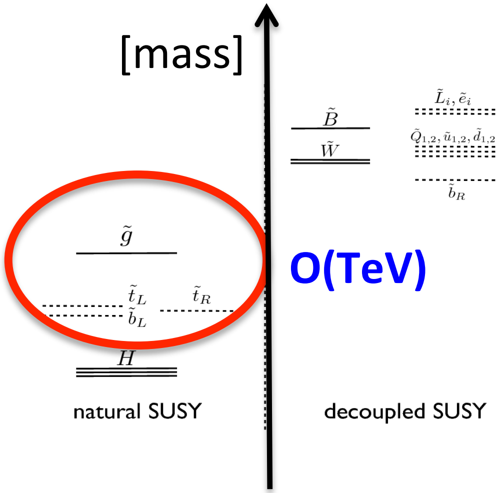
Run1 : SUSY searches

- Before Run1, **supersymmetry (SUSY)** was one of the most attractive BSM theories
  - **Solves the hierarchy problem** *(m_H unstable at short distances)*
  - *Dark matter candidate* (R-parity)
  - High-energy unification of weak, strong and EM couplings



EW-inos (χ) are linear combinations of these

- A **natural SUSY** scenario was favored because it involves a small tuning in the theory.
  - **Stop** needed to solve the **hierarchy problem** *(by cancelling the top loop)*
  - **Gluinos and 3rd-generation squarks** constrained to be **quite light, O(TeV)** (Higgs mass at ≈125 GeV)

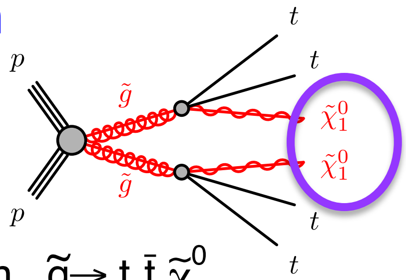


arXiv:1110.6926

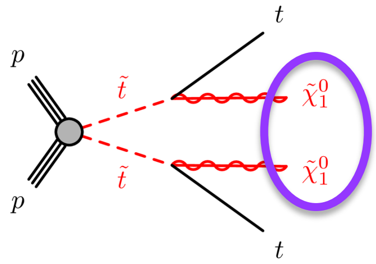
- At LHC, the strategy was to look first for **strongly-produced gluinos and 3rd-generation squarks**
  - Should be **produced copiously** *(hadron collider)*

Search results in SUSY (1)

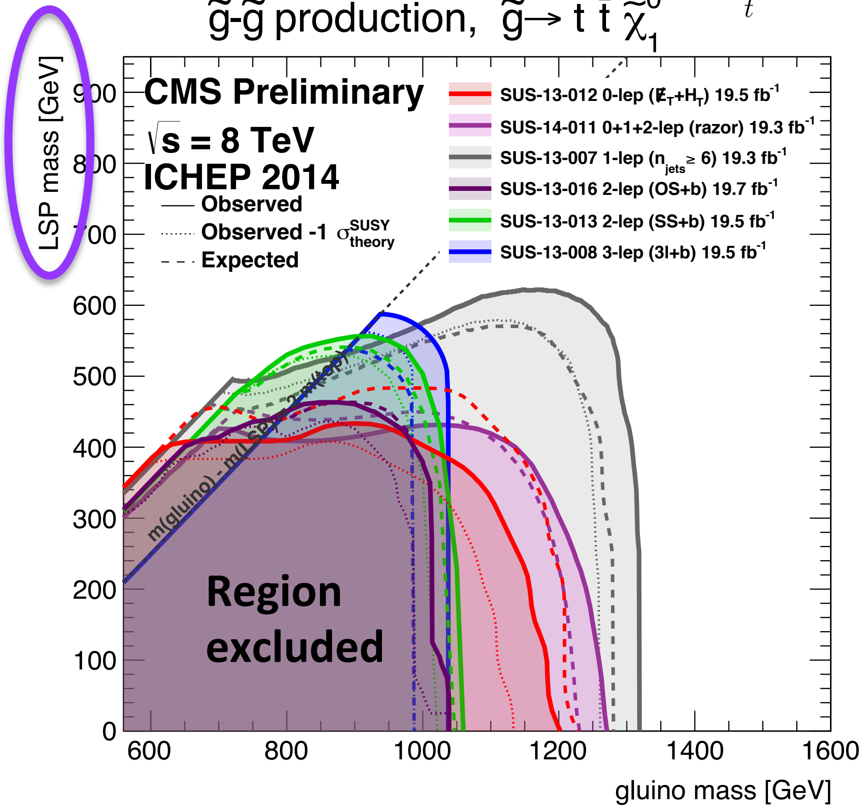
- **Strong production**



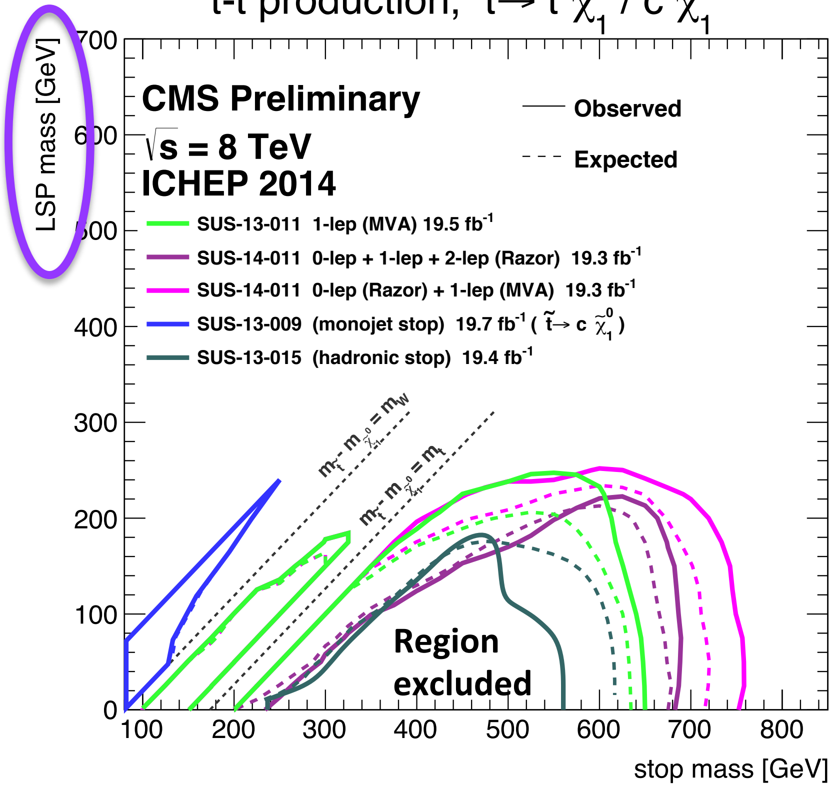
dark matter candidates



$\tilde{g}$-$\tilde{g}$ production, $\tilde{g} \rightarrow t\,\bar{t}\,\tilde{\chi}_1^0$



$\tilde{t}$-$\tilde{t}$ production, $\tilde{t} \rightarrow t\,\tilde{\chi}_1^0$ / $c\,\tilde{\chi}_1^0$



- Limits on **gluino mass** at ≈**1.3 TeV (302 GeV pre-LHC)**, limits on **stop mass** at ≈**750 GeV** (for m(LSP) = 0 GeV and for the most sensitive scenario)

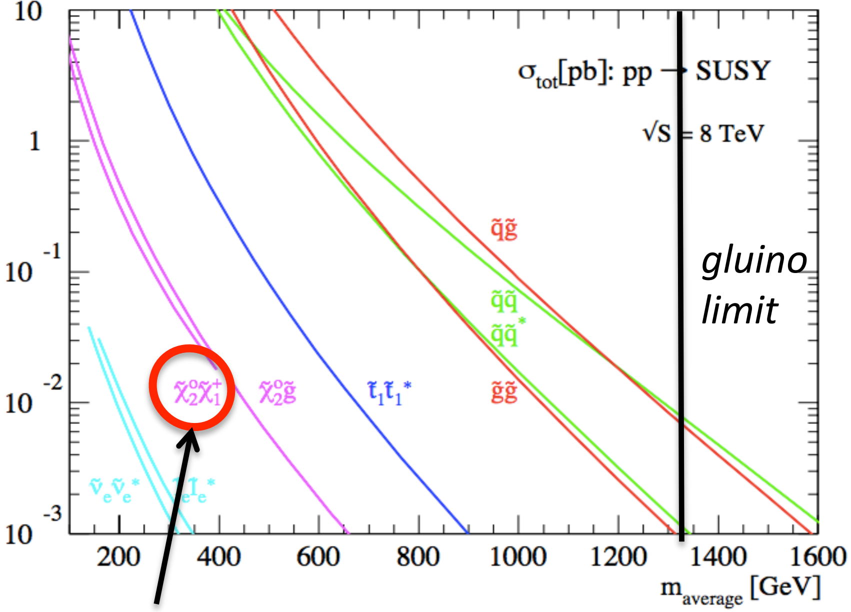
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS

Run1 : SUSY searches

In the **absence** of strongly-produced SUSY particles in Run1, **two alternatives** became more popular :

1) electroweak (EWK) production

Pair-production cross section of SUSY particles:

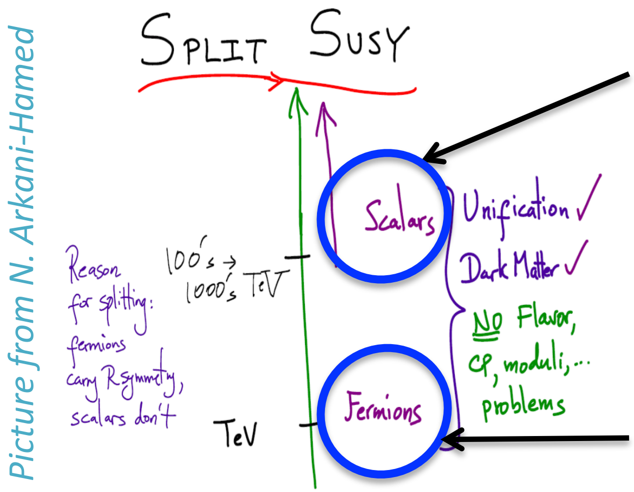


gluino limit

could be the **dominant production process** at the LHC, hence search for **EW-inos pairs**

Average mass of the pair-produced SUSY particles

2) Split SUSY

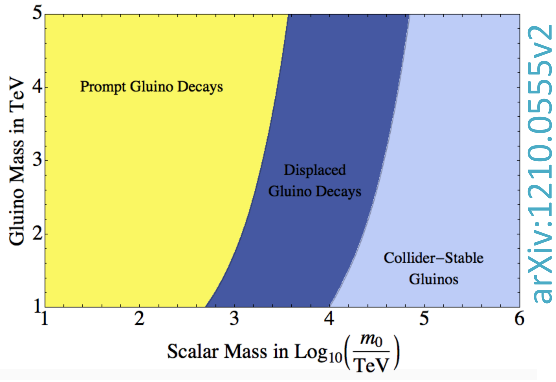


Picture from N. Arkani-Hamed

some level of **fine tuning** accepted, as stop mass can be quite high

only sfermions within LHC reach (gluinos, EW-inos)

Gluino lifetime depends on squark masses (m_0) :



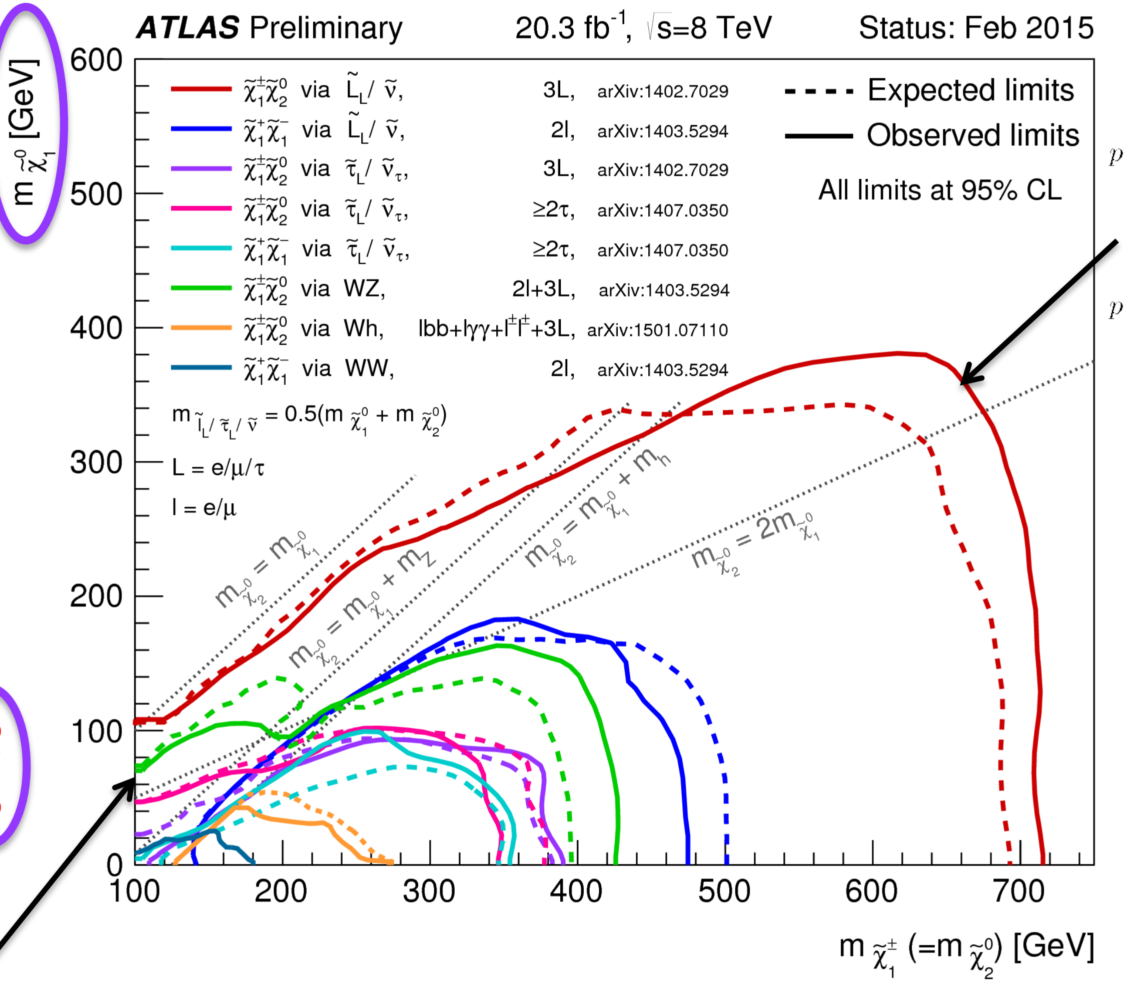
arXiv:1210.0555v2

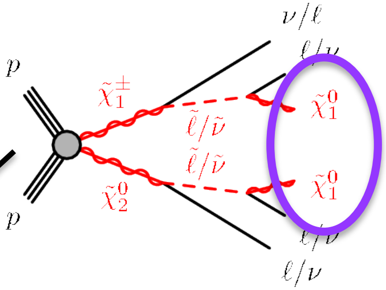
Search for **long-lived** strongly interacting particles

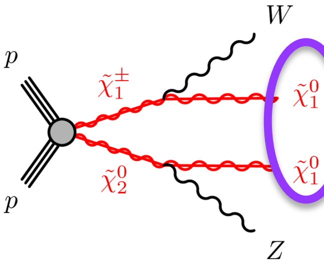
Search results in SUSY (2)

- **Electroweak production** : decays via **W/Z bosons** or **sleptons**

dark matter candidate







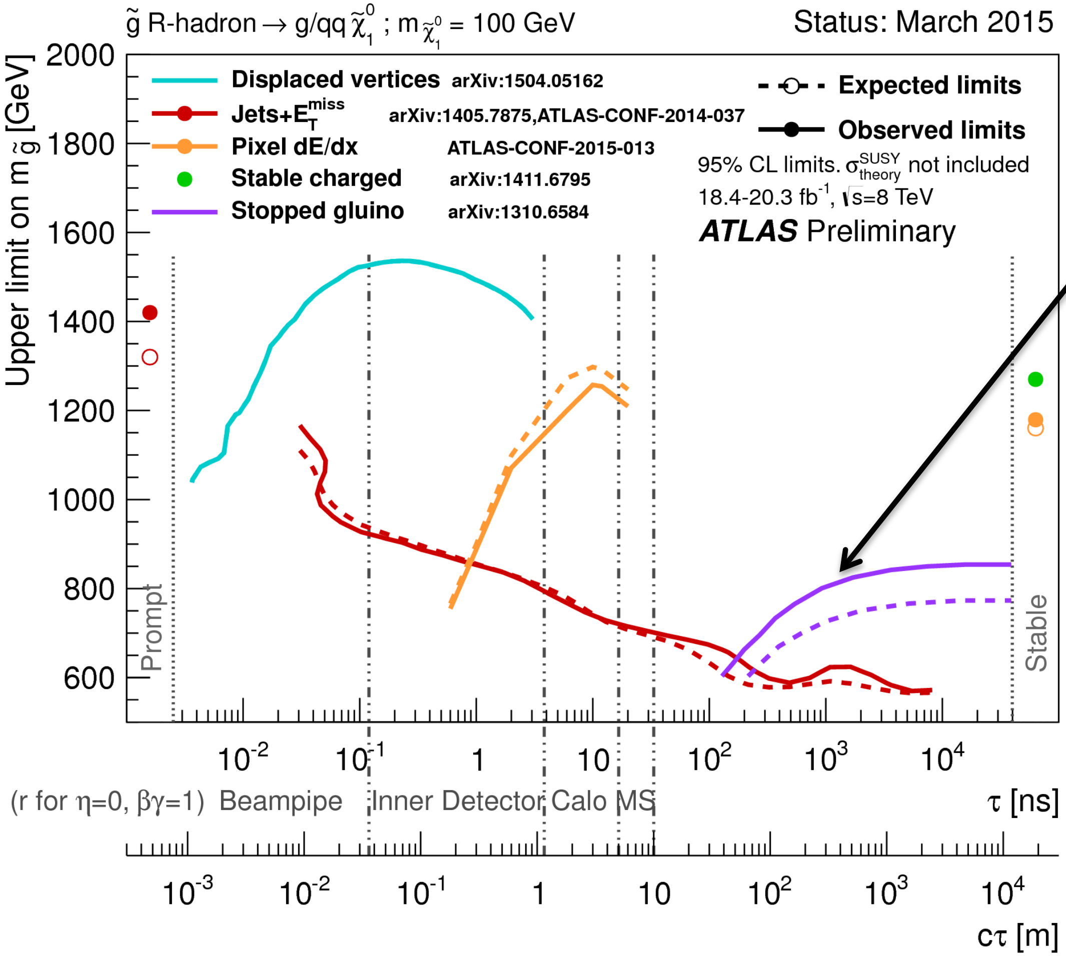
Limit on **χ_1^0 mass** up to ≈**80 GeV** (for m($\chi_2^0/\chi_1^{\pm}$) = 100 GeV and WZ scenario)

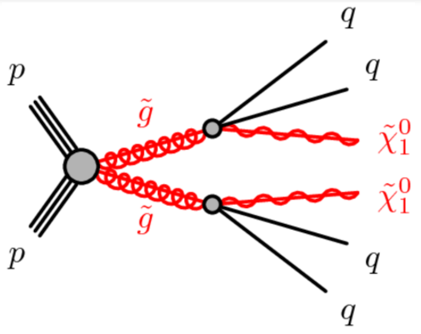
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults

Search results in SUSY (3)

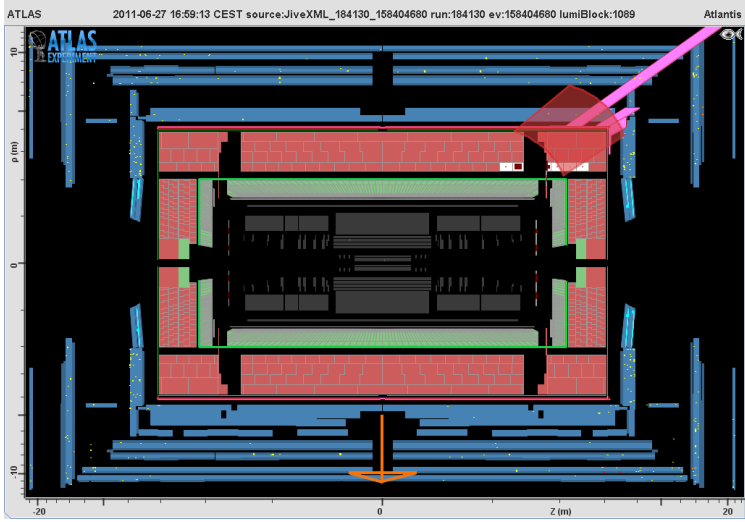
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults

- **Long-lived particles :**





Candidate event display :



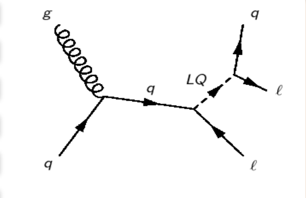
Phys. Rev. D 88, 112003 (2013)

- Nice **complementarity** of searches covering different lifetimes
- **Strongest limit** on gluinos with the displaced vertices analysis (≈1550 GeV)

Run1 : Exotics searches

Leptoquarks *(carry both L and B quantum numbers)*

- Appear in **various models**



RS gravitons

- **Randall-Sundrum (RS) model** *(explains **hierarchy** with a warped extra dimension)*

$G_{\mathrm{RS}_1} \to \gamma\gamma$

Di-boson mass distributions

Heavy gauge bosons *(W',Z')*

- In models with extended gauge sectors to **achieve gauge coupling unification**

$W' \to WZ$

Di-boson mass distributions

Excited fermions *(couple to ordinary SM fermions)*

- in **compositeness models**

$l^* \to lZ$

Multijet resonances

- Appear in **various models**

Events with lots of jets

Long-lived particles

- Appear in **various models**

Example given for SUSY in p.13

Dark Matter

- **All the models** try to accommodate for it

will be discussed in p.16

Large Extra Dimensions

- Appear in **string theories** *(provides **link to gravity** missing in the SM)*

Di-lepton mass distributions

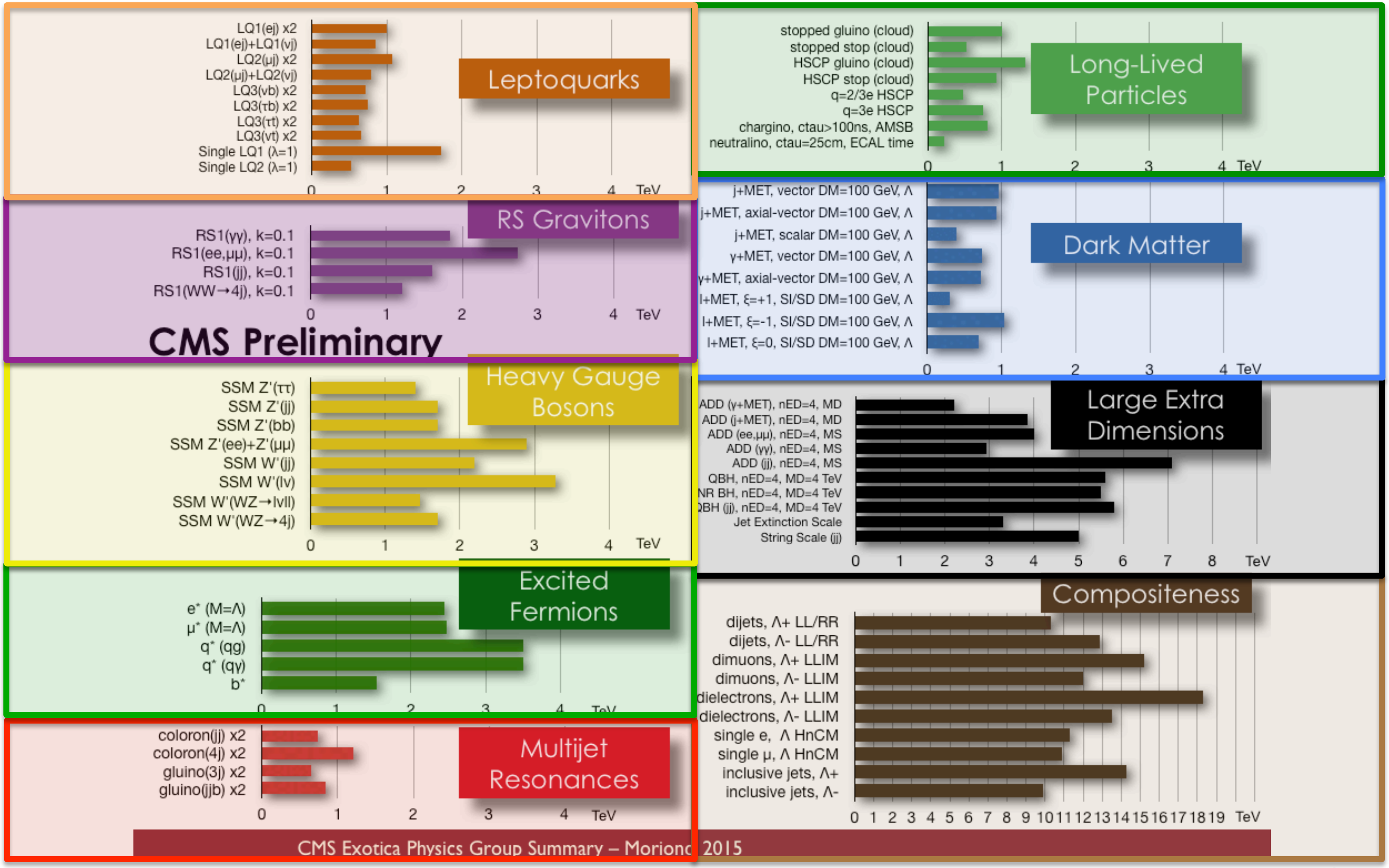
Compositeness (Model)

- quarks/leptons are made of more fundamental constituents (addresses the **number of quark/lepton generation, charges and masses)**

high energy part of the di-lepton/ jet mass spectra (non-resonant)

+ searches for **Higgs resonances (**Vh with V=W,Z**)**

Search results in Exotics

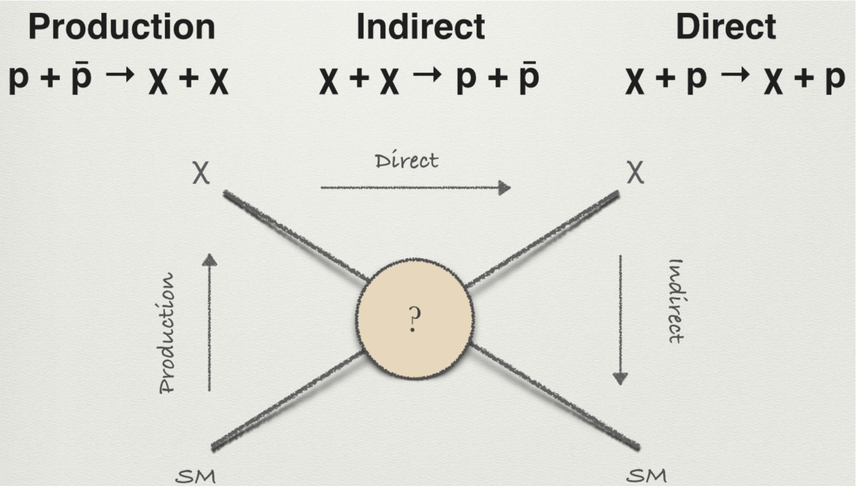


https://twiki.cern.ch/twiki/pub/CMSPublic/PhysicsResultsCombined/exo-limits_Moriond2015.pdf

Dark Matter Detection

- Dark Matter creation

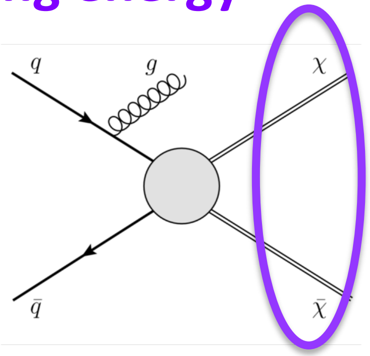
> *If WIMP interactions are sensitive to the spin of the nucleus, the cross section is* ***spin-dependent****. If not, the cross section is* ***spin-independent***



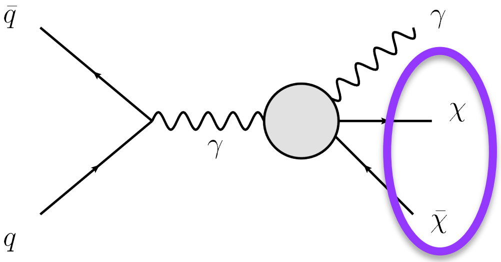
http://www.quantumdiaries.org/2014/10/22/have-we-detected-dark-matter-axions/

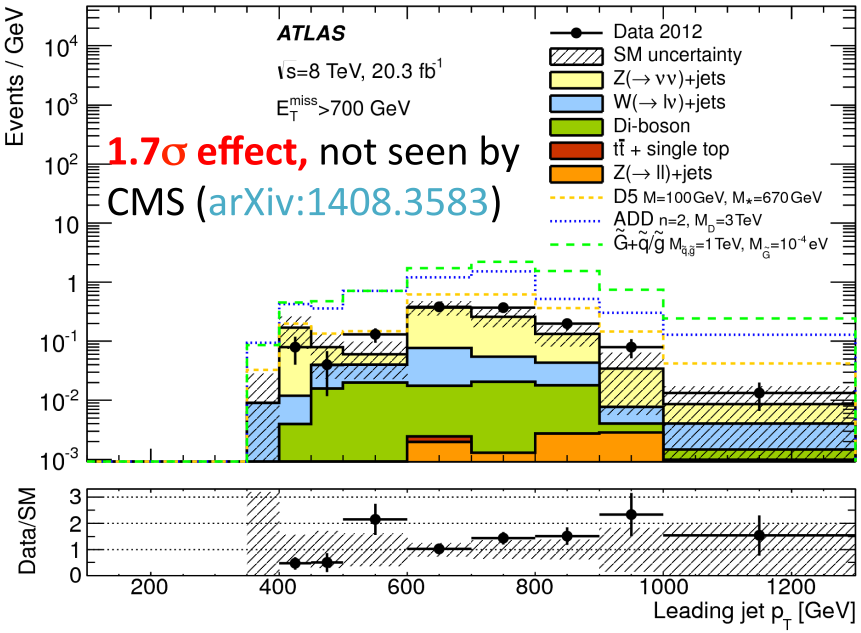
- At the LHC, look for **an energetic object** and **missing energy**

Energetic jet :



Energetic photon :





1.7σ effect, not seen by CMS (arXiv:1408.3583)

arXiv:1502.01518

Effective Field Theory (EFT) approach

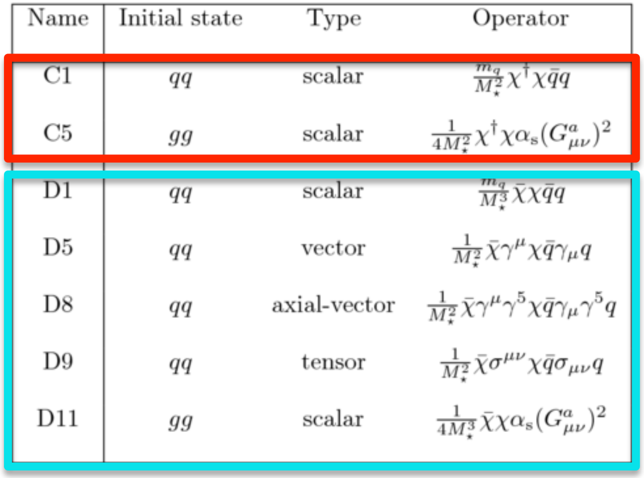
- SM-WIMP coupling via **a contact interaction :**
  - M_{med} = mass of the mediator
  - Q_{tr} = scale of the interaction *(=invariant mass of the two* χ*)*

- Condition : $M_{med} > Q_{tr}$
  - to ensure that the mediator cannot be produced directly in LHC collisions and can be integrated out with an EFT formalism
  - in the next slide : **truncated** = remove events that **do not satisfy** the condition
  - M_{med} depends on the **couplings** of the mediator to the SM/DM particles

- **Interaction couplings : WIMPs-SM**

WIMPs = scalars

WIMPs = Dirac fermions

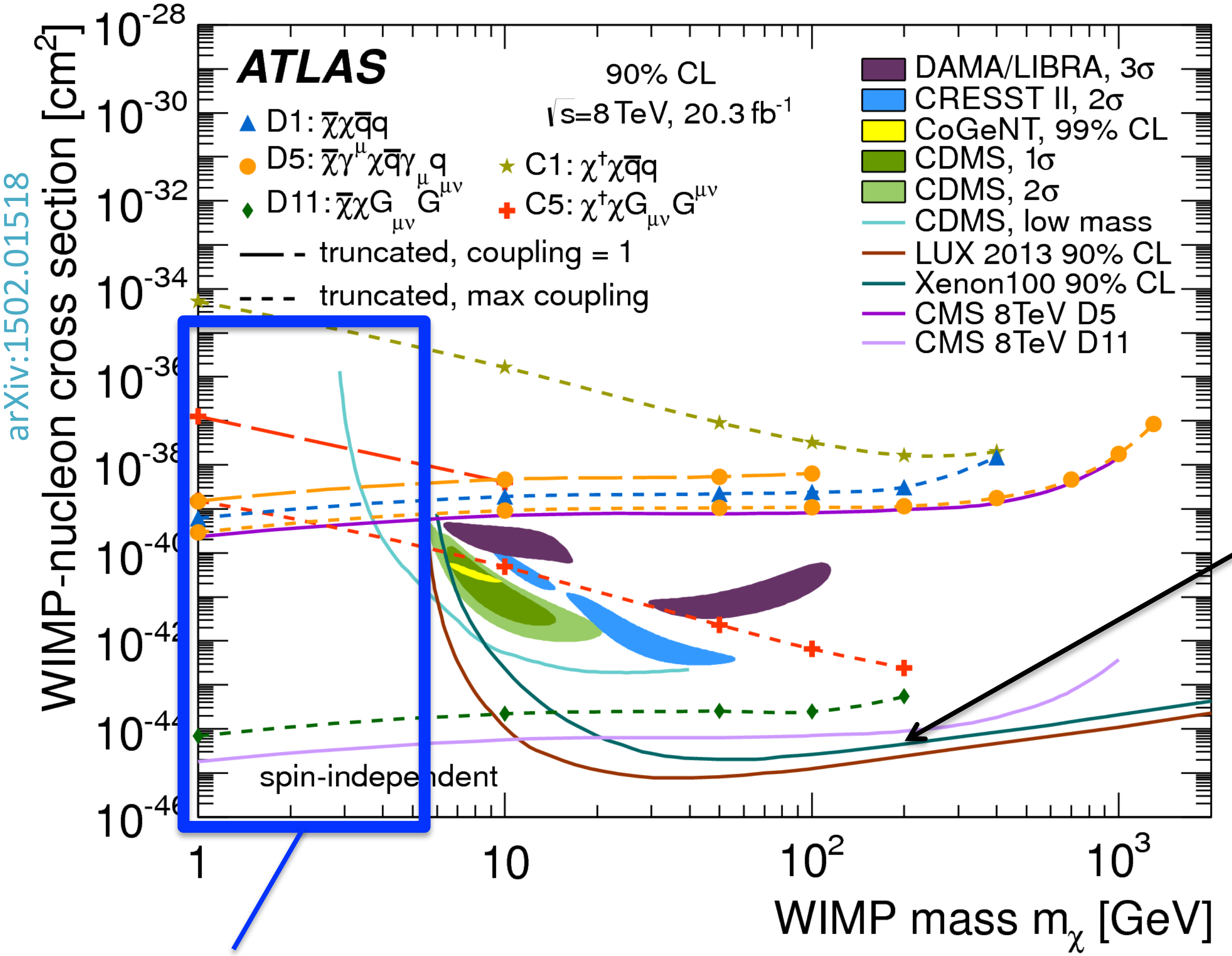


Name	Initial state	Type	Operator
C1	qq	scalar	$\frac{m_q}{M_\star^2}\chi^\dagger\chi\bar{q}q$
C5	gg	scalar	$\frac{1}{4M_\star^2}\chi^\dagger\chi\alpha_s(G^a_{\mu\nu})^2$
D1	qq	scalar	$\frac{m_q}{M_\star^3}\bar{\chi}\chi\bar{q}q$
D5	qq	vector	$\frac{1}{M_\star^2}\bar{\chi}\gamma^\mu\chi\bar{q}\gamma_\mu q$
D8	qq	axial-vector	$\frac{1}{M_\star^2}\bar{\chi}\gamma^\mu\gamma^5\chi\bar{q}\gamma_\mu\gamma^5 q$
D9	qq	tensor	$\frac{1}{M_\star^2}\bar{\chi}\sigma^{\mu\nu}\chi\bar{q}\sigma_{\mu\nu}q$
D11	gg	scalar	$\frac{1}{4M_\star^3}\bar{\chi}\chi\alpha_s(G^a_{\mu\nu})^2$

arXiv:1502.01518

- **EFT allows for direct comparison** with (in)direct DM results
  - improvements expected for Run2
    http://moriond.in2p3.fr/QCD/2015/WednesdayAfternoon/Landsberg.pdf

DM Search Results (1)

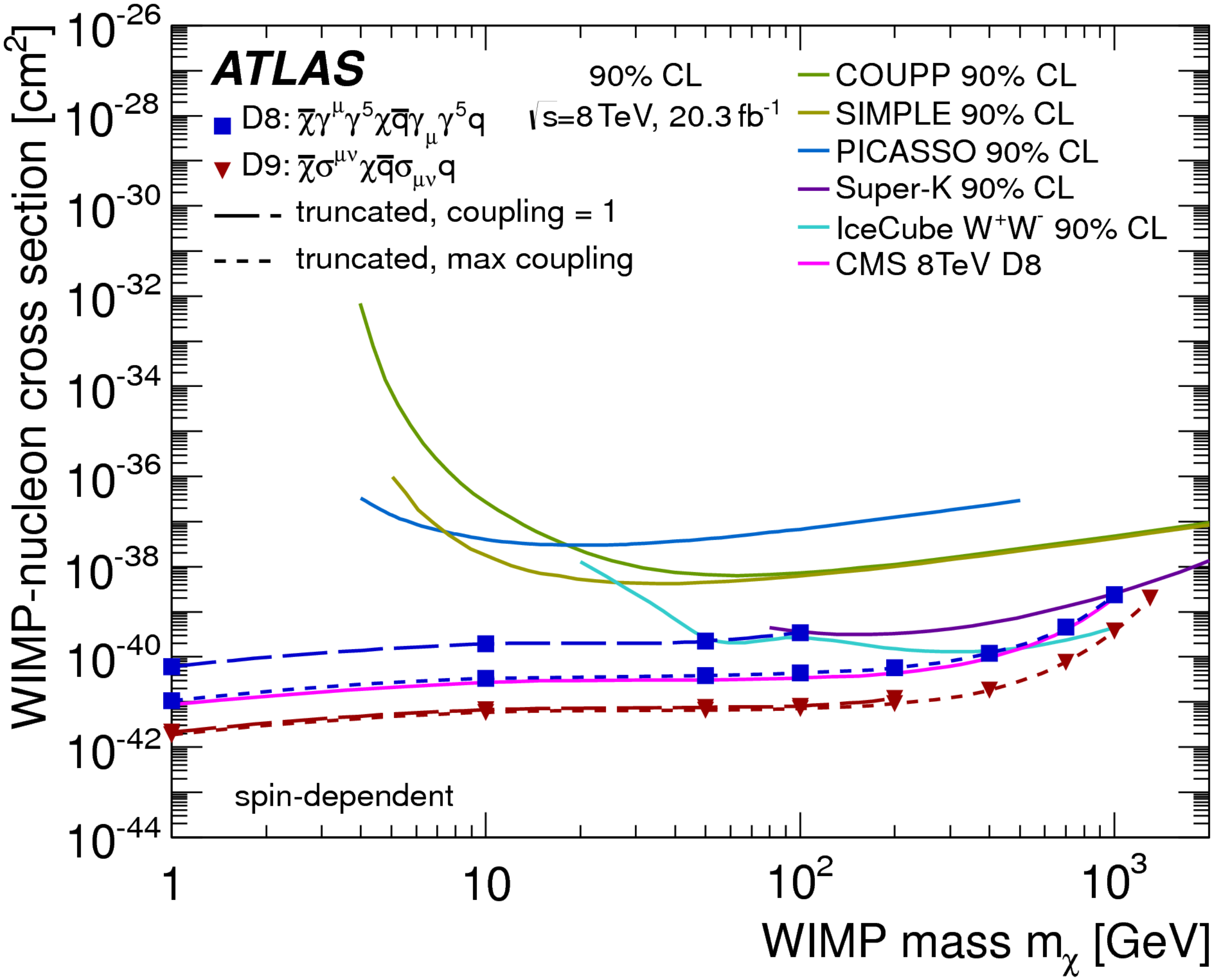


spin-independent (from energetic jet)

Best limits from LUX and Xenon100

LHC allows for access to **low-mass WIMP scenario**, which is nicely **complementary** to other types of experiments

DM Search Results (2)



arXiv:1502.01518

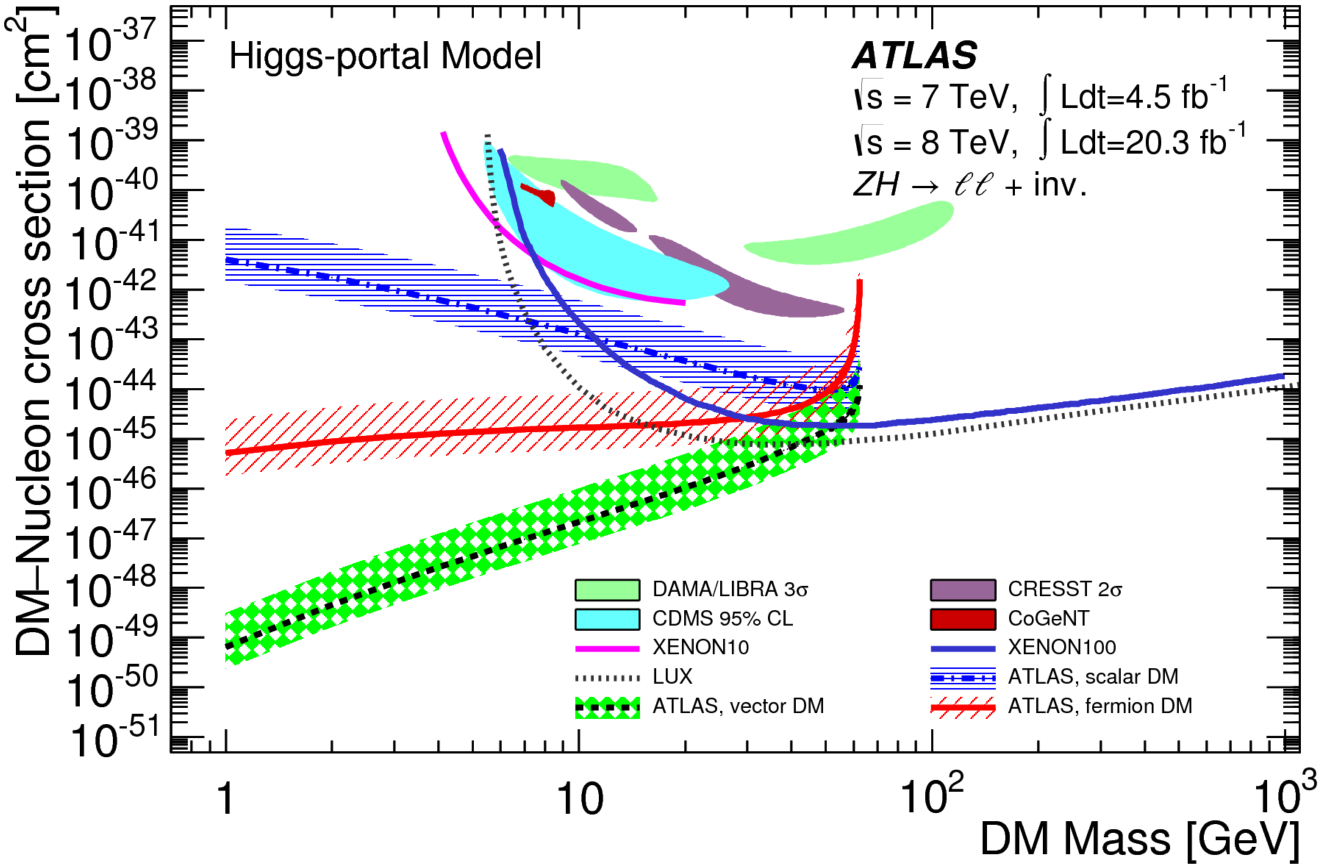
Spin-dependent (from energetic jet)

LHC has the best limits for **the whole range of WIMP masses**

DM Search Results (3)

From (Zh→ll invisible) analysis shown in page 6: arXiv:1402.3244

Higgs portal model



- WIMPs of **different nature considered** (scalar, vector or fermion)
- Direct detection : **spin-independent** results from searches for nuclei recoils from **elastic scattering of WIMPs**

LHC has the best limits for **WIMP masses below $m_H/2$** (vector DM)

Run1 : A few small excesses *left* (1)

As of May 11th, 2015 :

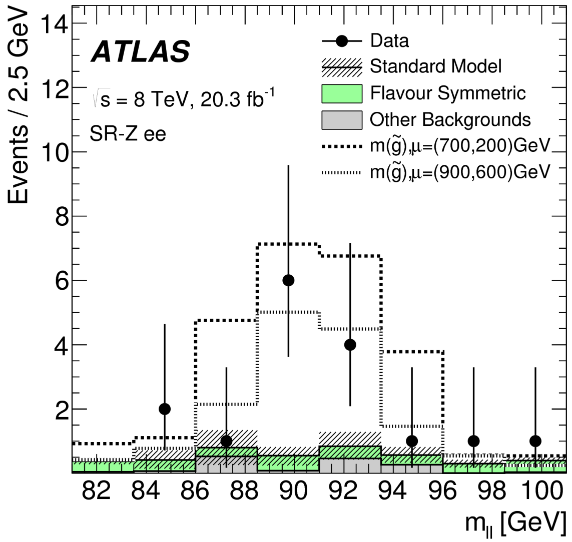
Areas	**ATLAS**	**CMS**
Higgs	- H → hh → bbγγ (back-up) - ttH	- Higgs to invisible (p.6) - ttH - LVF H → τμ (back-up)
SUSY	- Z+MET	- Di-lepton mass edge - Multilepton 3l+τ (back-up)
Exotics	- Dark Matter (p.16) - Same-sign + b-jets - Type III Seesaw heavy leptons (back-up)	- Di-jet mass search - Di-lepton mass search - Di-boson mass search - Heavy neutrinos and right-handed W bosons

- Analyses grouped together with color codes will be presented together in the following. For others, you can find information in the back-up slides.

SUSY Excesses (2)

2 leptons (on/off-Z) + jets + missing energy

- **ATLAS has an excess** ≈at the mass of the Z for the electron channel



arXiv:1503.03290v1

3.0σ for ee
1.7σ for μμ

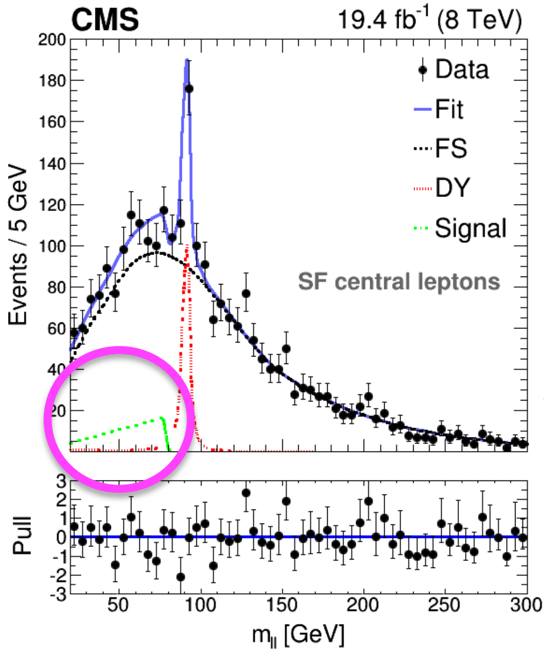
CMS does not see an excess at ≈m(Z)

- **CMS has an excess (edge)** at masses below the Z mass

Edge signal included in the fit to describe the data

In edge region :
- expected: 730± 40
- observed: 860

≈2.6σ



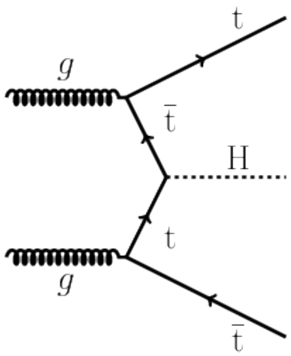
arXiv:1502.06031v1

ATLAS does not see an excess in the edge

- **Both experiments** have excesses, but **not at the same place** in m_{ll} mass !

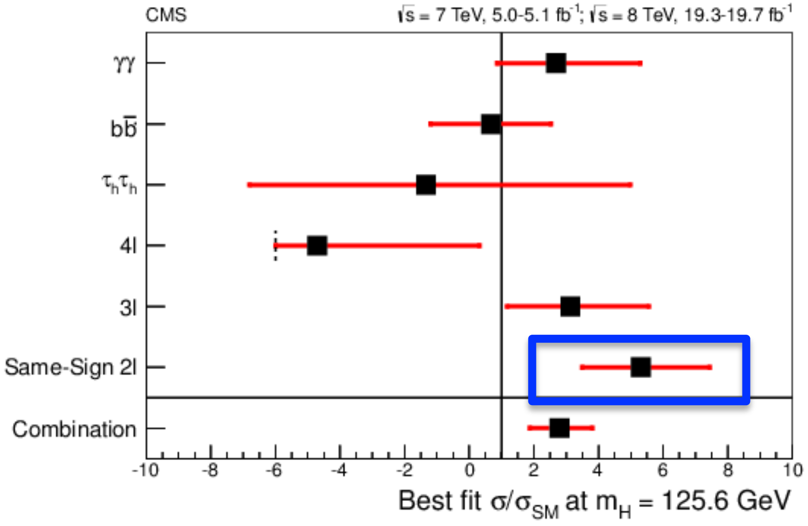
Higgs/Exotics Excesses (3)

ATLAS/CMS ttH and ATLAS exotic same-sign+b-jets



3 categories of decays :

1) H→hadrons (bb,ττ)
2) H→photons
3) H→leptons(from WW,ZZ,ττ)



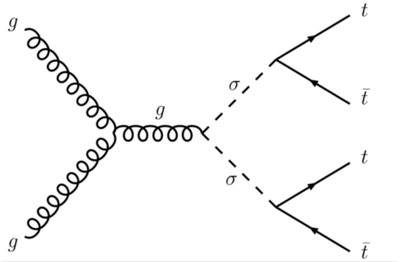
arXiv:1408.1682v2

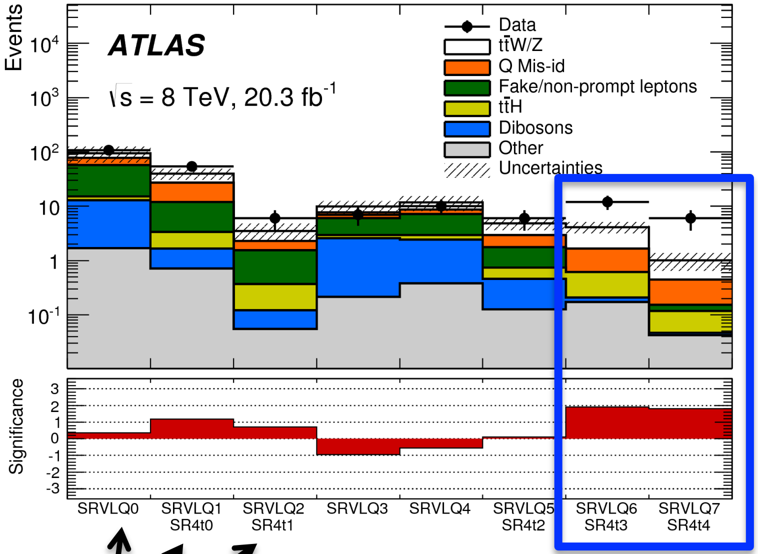
Largest discrepancy in the **same-sign channel :**

2σ

- An excess is **also observed in ATLAS** (dilepton channel). arXiv:1503.05066

Sgluon pair production :





arXiv:1504.04605

…

different regions designed to target different signals

ttH is one of the **most dominant bkgs**

2.5σ

Exotics Excess (4)

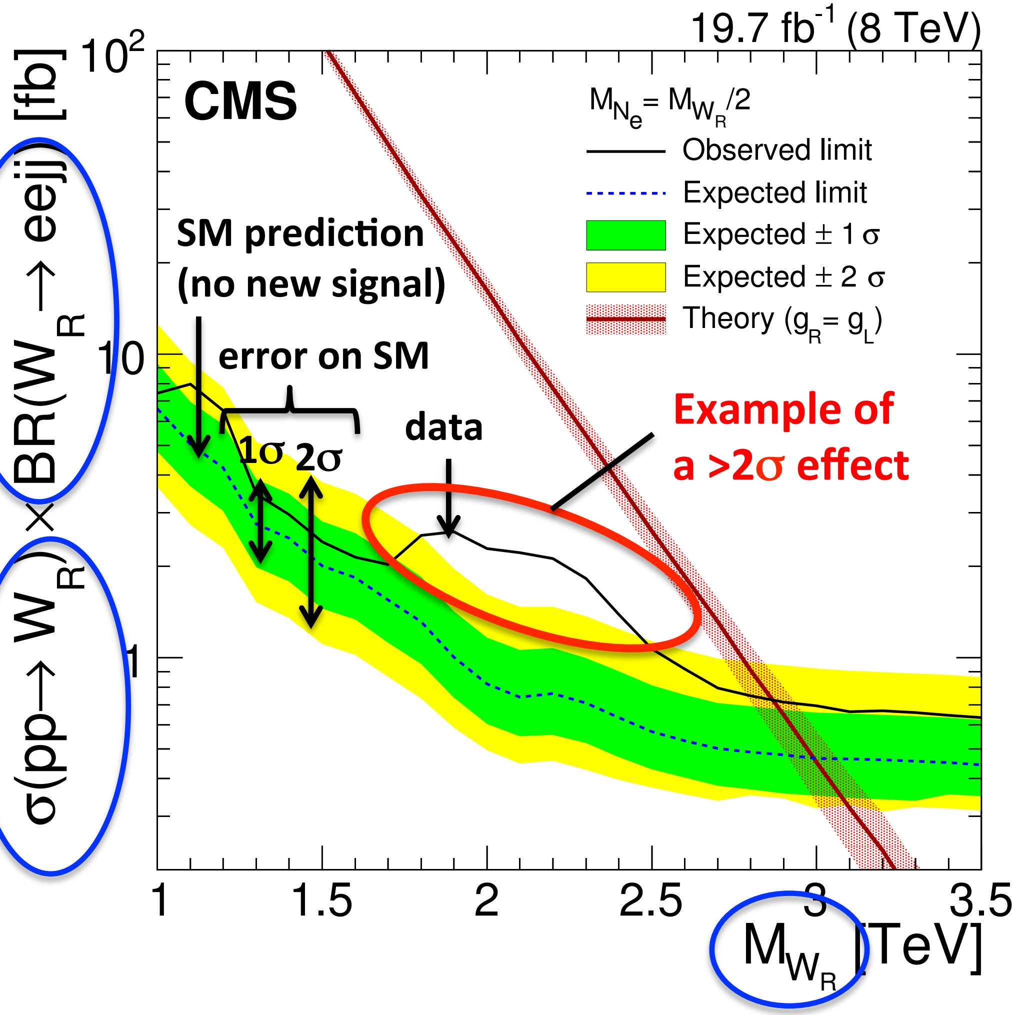
Heavy neutrinos and W bosons with right-handed couplings

arXiv:1407.3683

branching fraction to the final state of interest

$$W_R \to l_1 N_l \to l_1 l_2 W_R^* \to l_1 l_2 q\bar{q}$$

production cross section of the W_R



SM prediction (no new signal)

error on SM

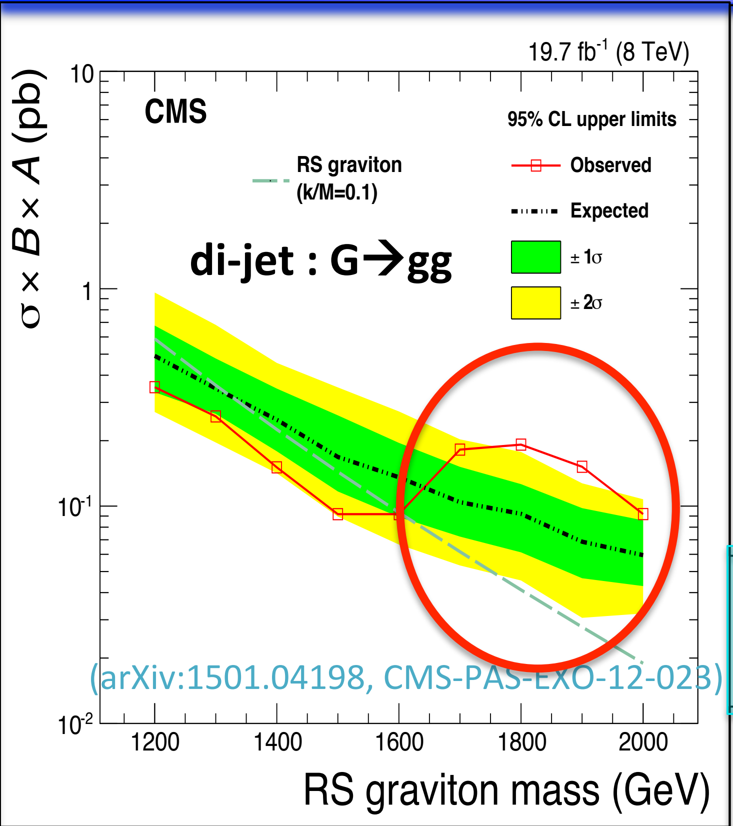
1σ 2σ

data

Example of a >2σ effect

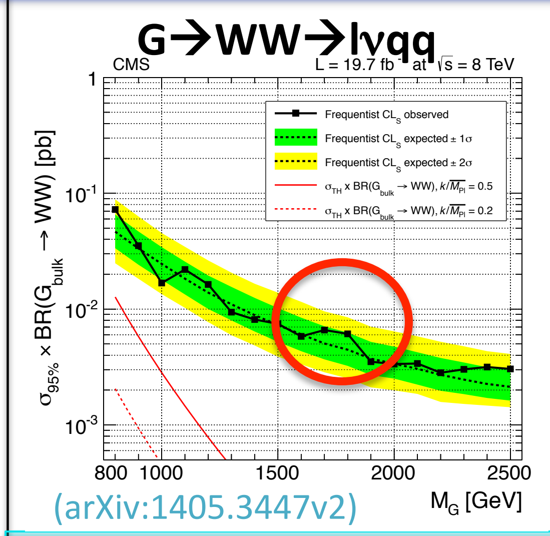
mass of the W_R

Exotics Excesses (5)



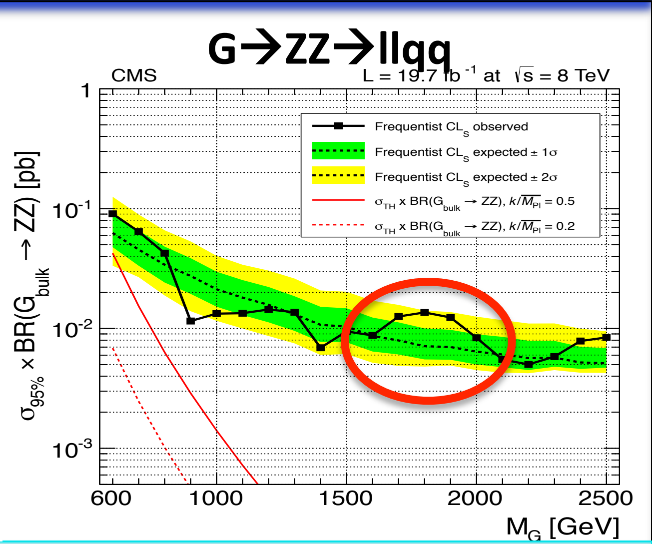
di-jet : G→gg

(arXiv:1501.04198, CMS-PAS-EXO-12-023)



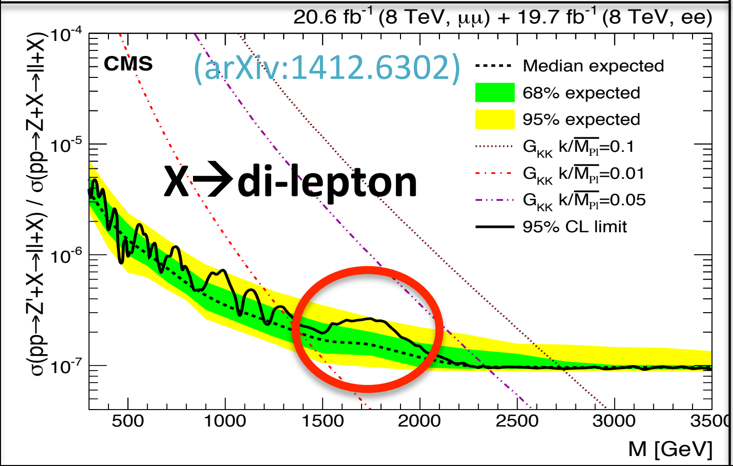
G→WW→lνqq

(arXiv:1405.3447v2)



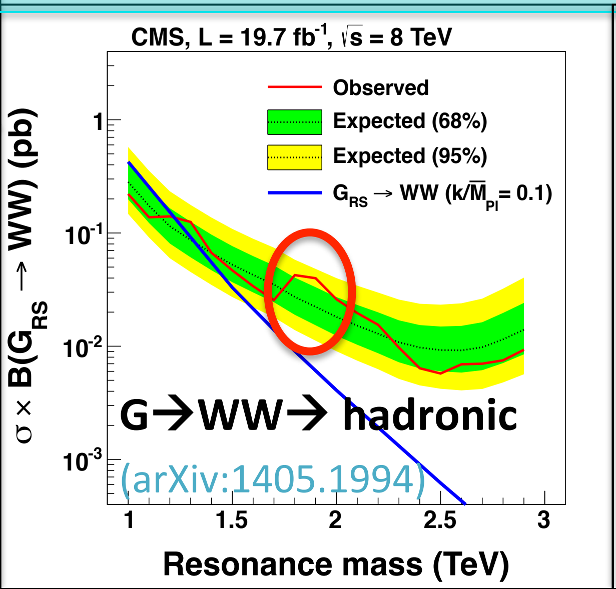
G→ZZ→llqq

Searches for resonances



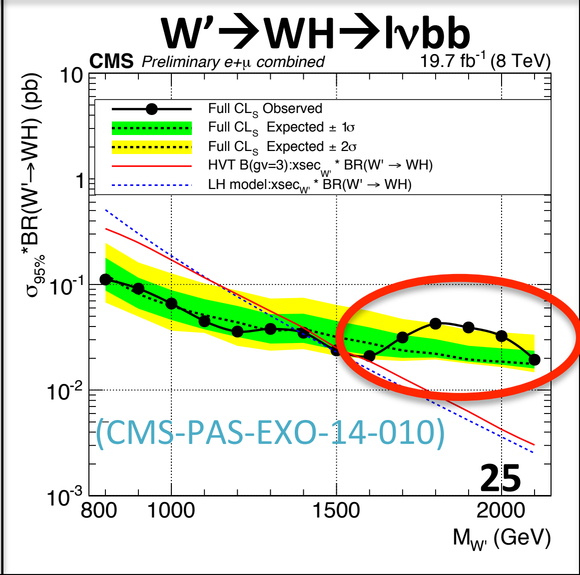
(arXiv:1412.6302)

X→di-lepton



G→WW→ hadronic

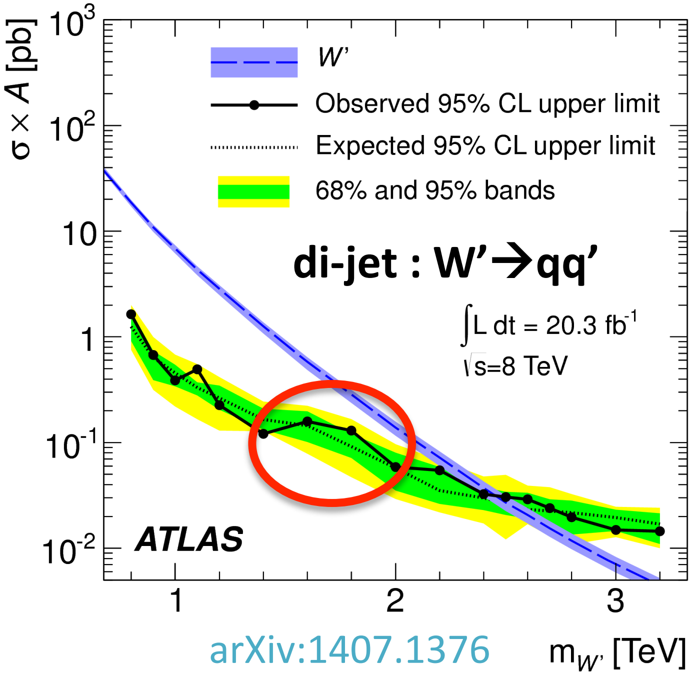
(arXiv:1405.1994)



W'→WH→lνbb

(CMS-PAS-EXO-14-010)

Exotics Excesses (5bis)



di-jet : W'→qq'

arXiv:1407.1376

(arXiv:1503.04677)

G→WW→lνqq

- **No excess in ATLAS**

(arXiv:1409.6190)

G→ZZ→ llqq

- **No excess in ATLAS**

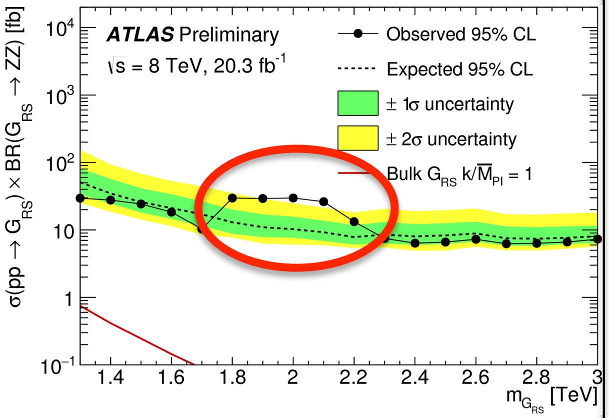
Searches for resonances

X→di-lepton

- **No excess in ATLAS**

(arXiv:1405.4123)

G→WW→ hadronic



To appear soon on arXiv

W'→WH→lνbb

- **No excess in ATLAS**, but the search stops at ≈1800 GeV

(arXiv:1503.08089)

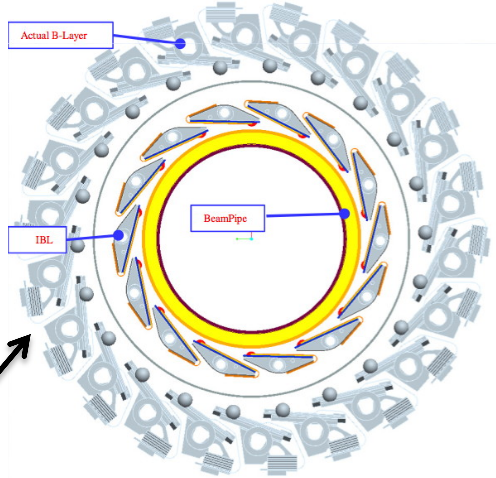
LHC Run 2, ATLAS and CMS

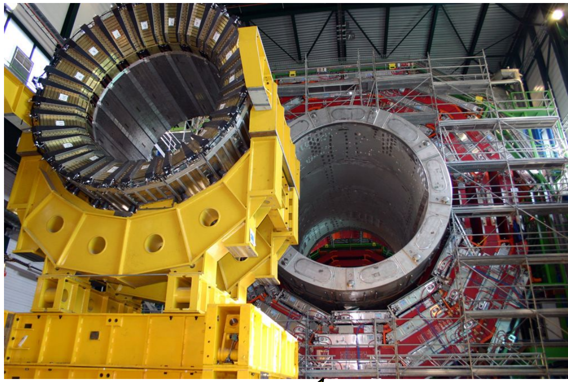
- **18-month LHC shutdown** to consolidate and add new components

- **LHC main improvements :**
  - **centre of mass energy** increased to **√s=13 TeV**

- **ATLAS main improvements :**
  - **Muon system** completion with chambers in barrel/endcap transition
  - Additional **innermost pixel layer (IBL)** to improve tracking, vertexing and b-tagging for high pileup, and smaller radius Be **beam pipe**

- **CMS main improvements :**
  - new **HCAL** Outer Barrel photo-detectors
  - **Muon system** completed *(fourth disk for RPC endcap region) and 72 CSC chambers added (on top of the 468 existing ones)*

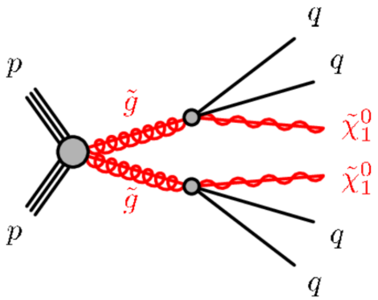




≈10 fb^{-1} of data in 2015

Run2 (early data) : SUSY searches

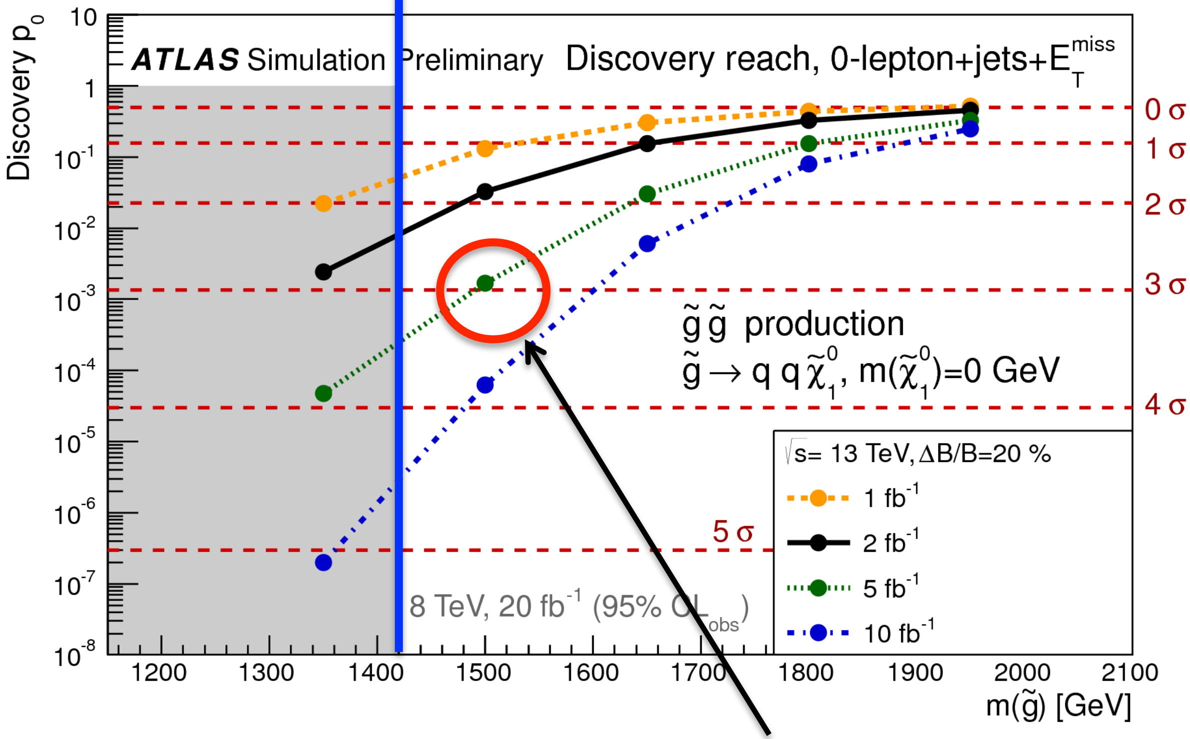
- **Gluino pair production** : large production increase (factor ~15 for 2 TeV gluinos, ~50 for 3 TeV gluinos)



ATL-PHYS-PUB-2015-005

Run1 limit

Run2 discovery potential for various datasets (from 1 fb^{-1} to 10 fb^{-1}) :



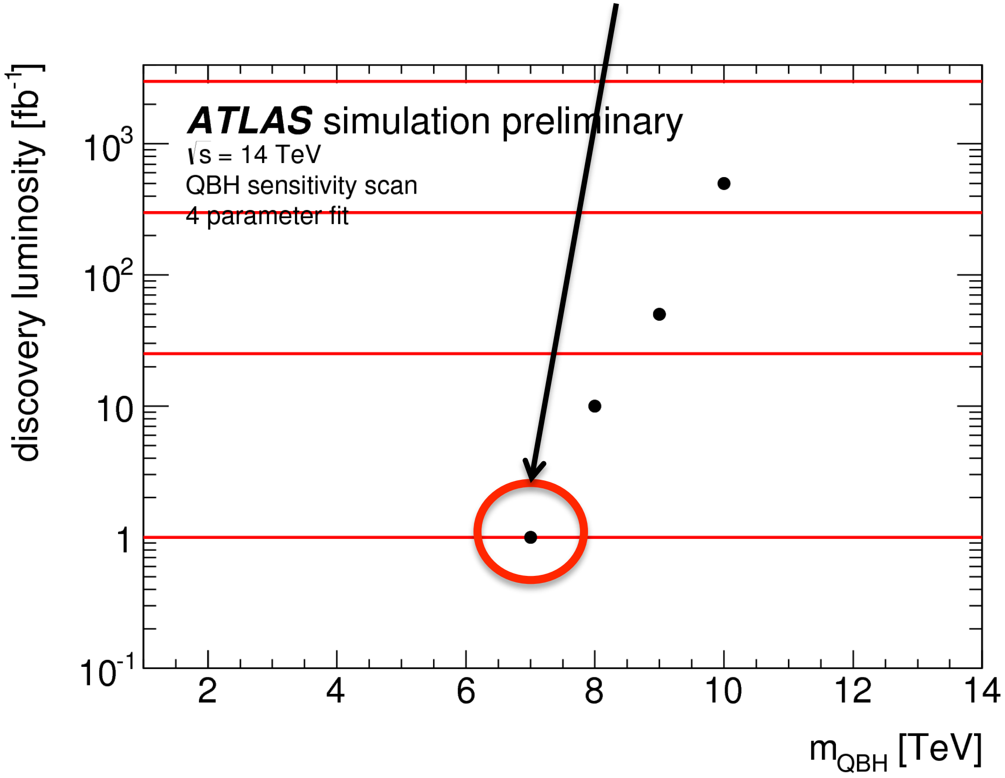
Number of sigmas in **discovery mode:**

3σ for evidence
4σ for observation
5σ for discovery

3σ evidence reach with 5 fb^{-1} for gluino masses < 1500 GeV

Run2 (early data) : Exotics searches

- **Dijet resonances search**
  - With **1 fb^{-1}** of 14 TeV data, **5 σ discovery potential** for :
    - **excited quarks** up to ≈**4 TeV**
    - **quantum black holes** up to ≈**7 TeV**

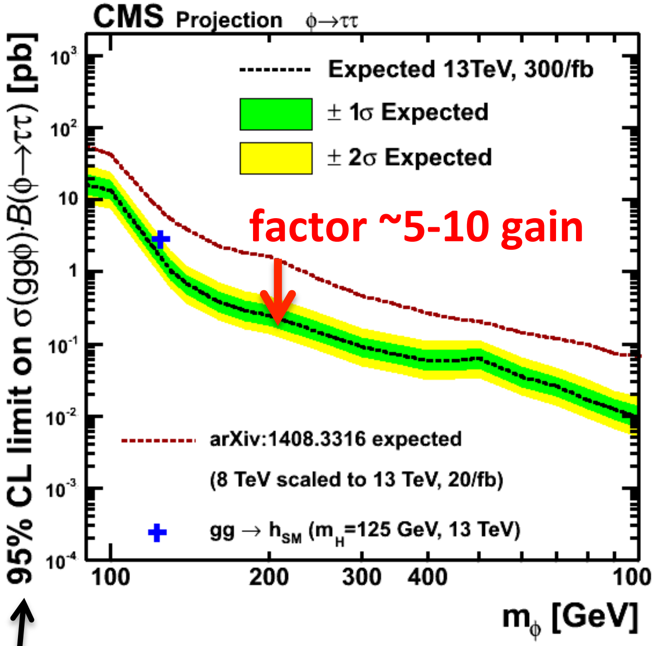


ATL-PHYS-PUB-2015-004

Run2 (and further) : Higgs searches

- Still quite **some room left** from Run1 results for BSM decays of the Higgs
- Both $H^+ \rightarrow \tau\nu$ and $A \rightarrow \tau\tau$ will have better sensitivity with **2-5 fb^{-1}** of data

- **Further into the future :**
  - **LHC Run3** planned in **2020-2022** (**300 fb^{-1}** of data)
  - **High-luminosity LHC (HL-LHC)** in **≈2025-2035** (**3000 fb^{-1}** of data)



factor ~5-10 gain

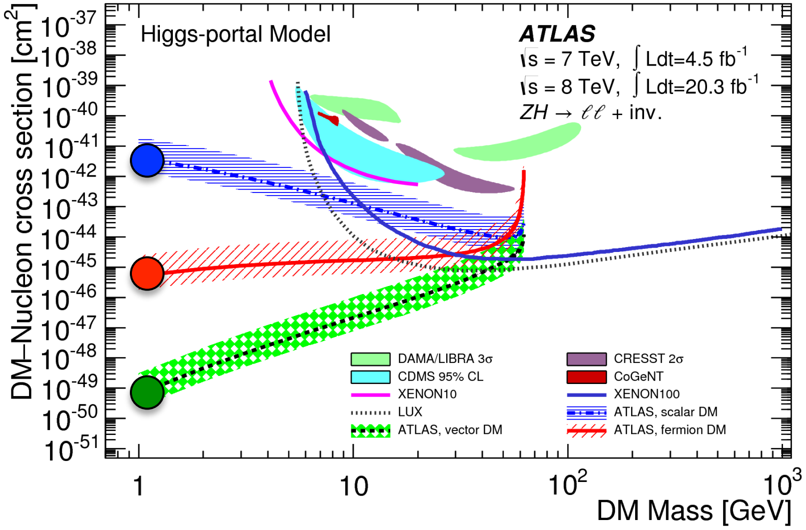
CMS-HIG-13-021

Limit on production times branching fraction for $A \rightarrow \tau\tau$

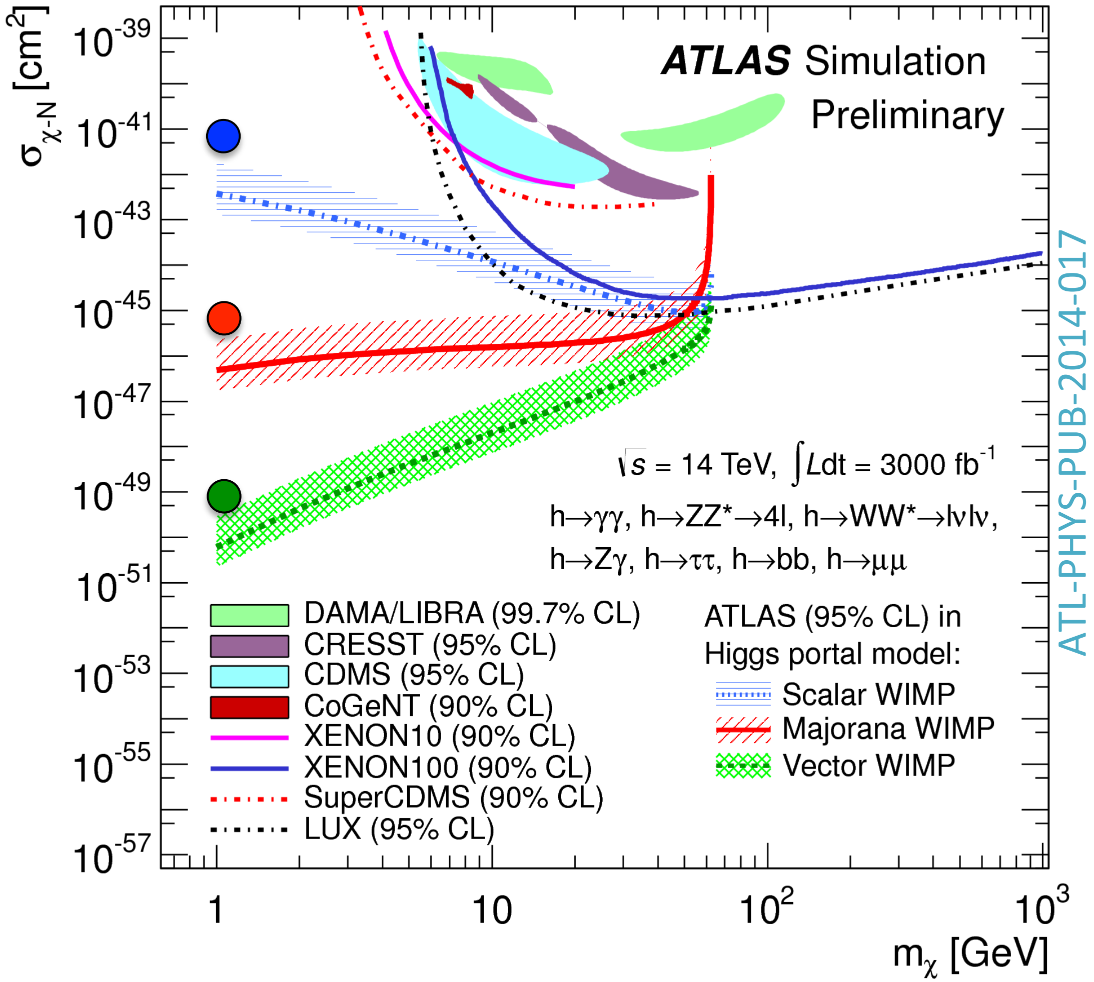
mass of the CP-odd Higgs

Dark Matter further into the future

Result in p.20 from Zh→ll invisible:



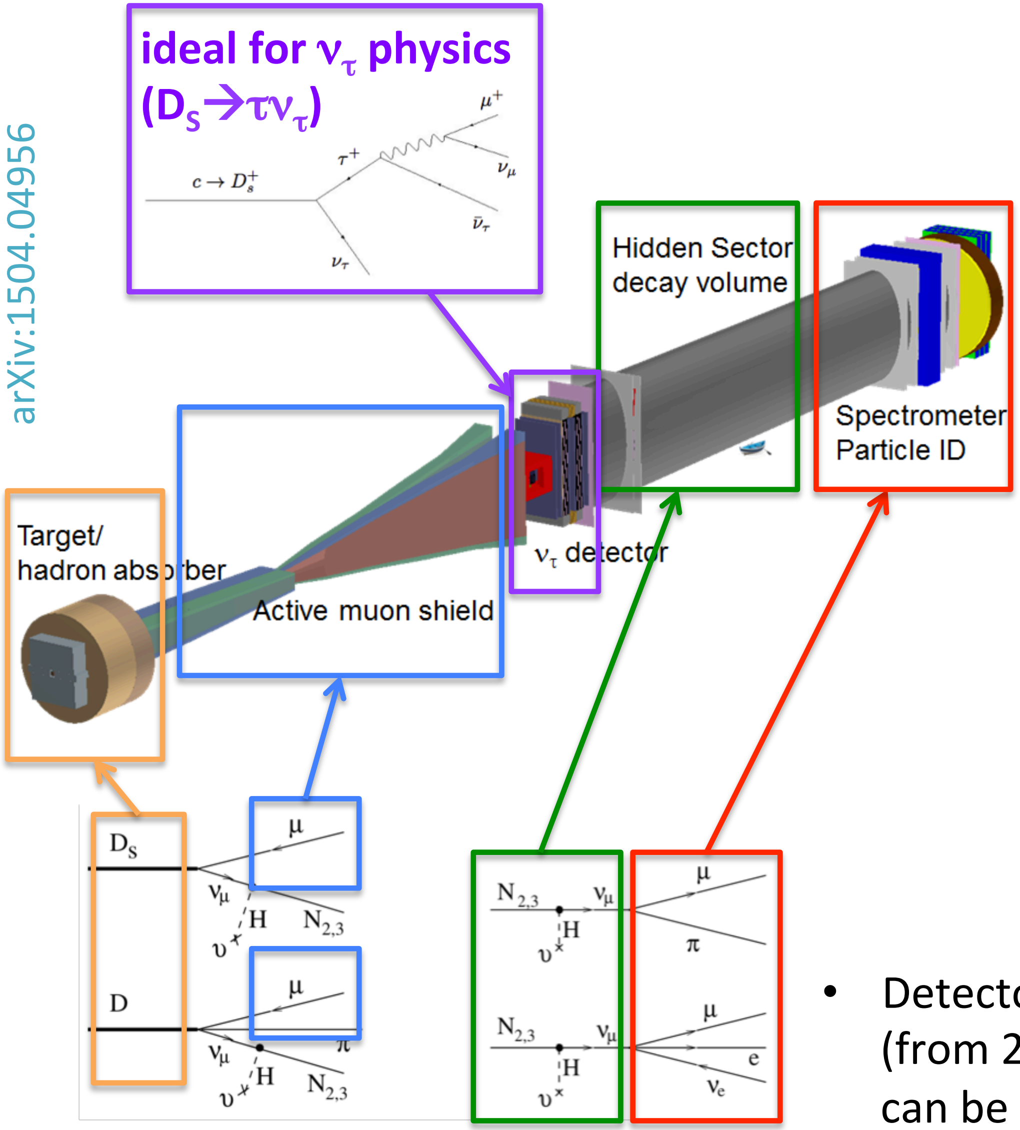
HL-LHC expectations :



One order of magnitude gain in DM-nucleon cross section at m_χ=1 GeV

Alternatives : Intensity Frontier

- **SHiP fixed target experiment** at the SPS ?



ideal for ν_τ physics ($D_S \rightarrow \tau\nu_\tau$)

Hidden Sector decay volume

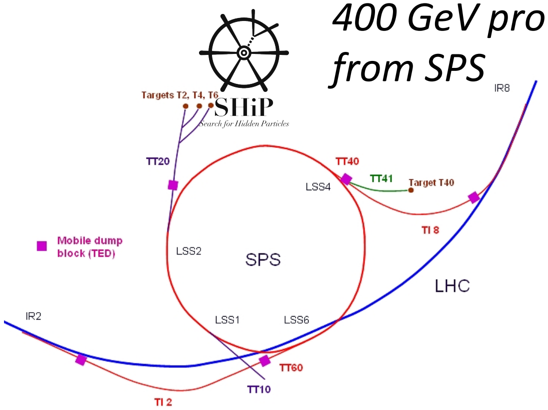
Spectrometer Particle ID

Target/ hadron absorber

Active muon shield

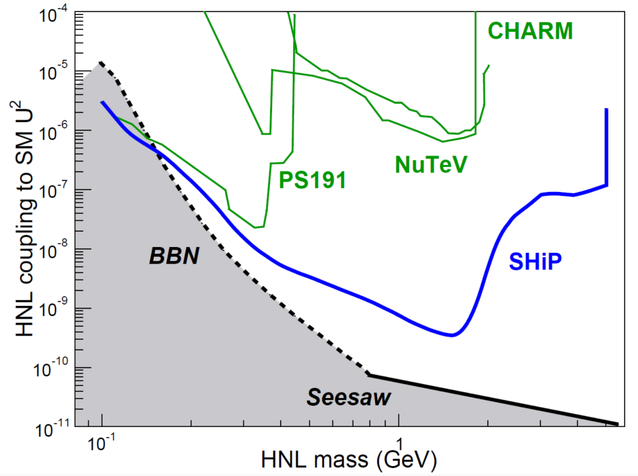
ν_τ detector

arXiv:1504.04956



400 GeV protons from SPS

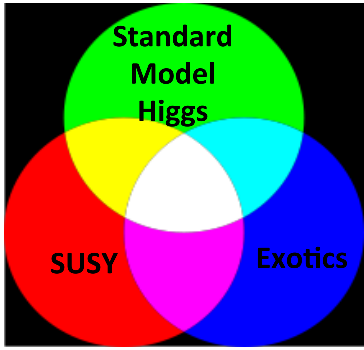
- Explore **heavy neutral leptons (HNL) with masses below O(10)GeV :**



arXiv:1504.04855

- Detector construction, 5 years of data taking (from 2022) and data analysis of $2*10^{20}$ pot can be achieved **in ~10 years**

Conclusions



- New physics searched for **in a lot of places during Run1**
  - *Not possible to highlight all of them today*

- The Higgs boson seems to be the **one predicted by the SM**
  - *Still room for new decays, new Higgses,…*

- “Natural” SUSY has suffered a lot with Run1, **split-SUSY** is now gaining more attention for Run2
  - *Analogy to EWSB model (by theorist N. Craig) ? minimal SU(2)xU(1) structure of the Glashow model (1961) is correct, but the model was missing a scalar field (Higgs) for EWSB (Weinberg in 1967) → non-minimal realization in nature*

- **A few excesses remaining,** some of them reported by **both ATLAS/CMS !**

- **pp collisions at 13 TeV** of Run2 will happen very shortly.
  - confirm/rule out the Run1 excesses
  - Explore a new window in energy with the **2015 dataset**, sensitivities will increase significantly in particular in **high mass regions** !

Back-Up Slides

LHC, ATLAS and CMS

The LHC Program

LHC goal for **2015 and for Run 2 and 3**

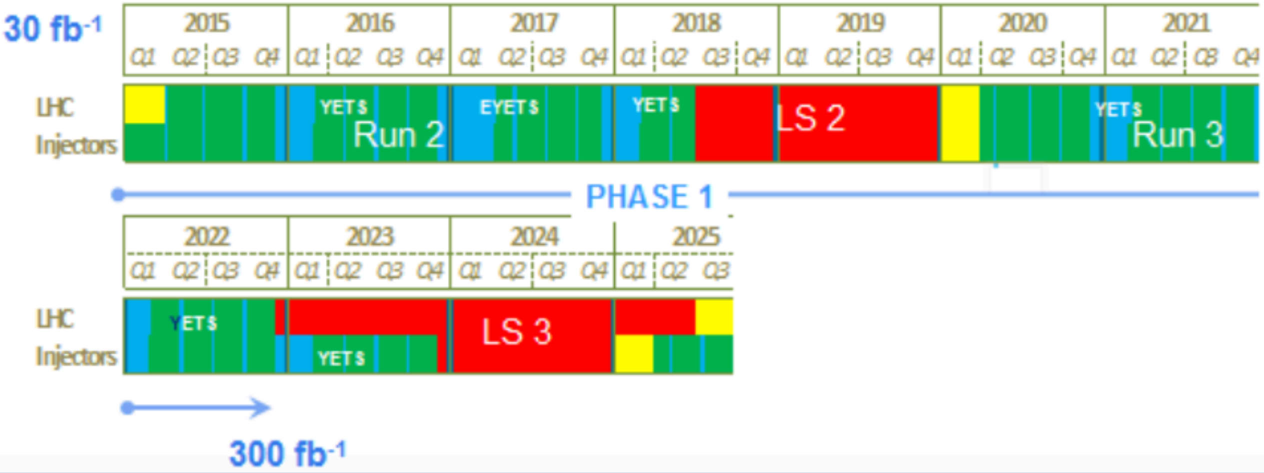
Integrated luminosity goal:

2015 : 10 fb^{-1}

Run2: ~100-120 fb^{-1}

(better estimation by end of 2015)

300 fb^{-1} before LS3



LHC Machine Sta
Frédérick Bordry
4th March 2015

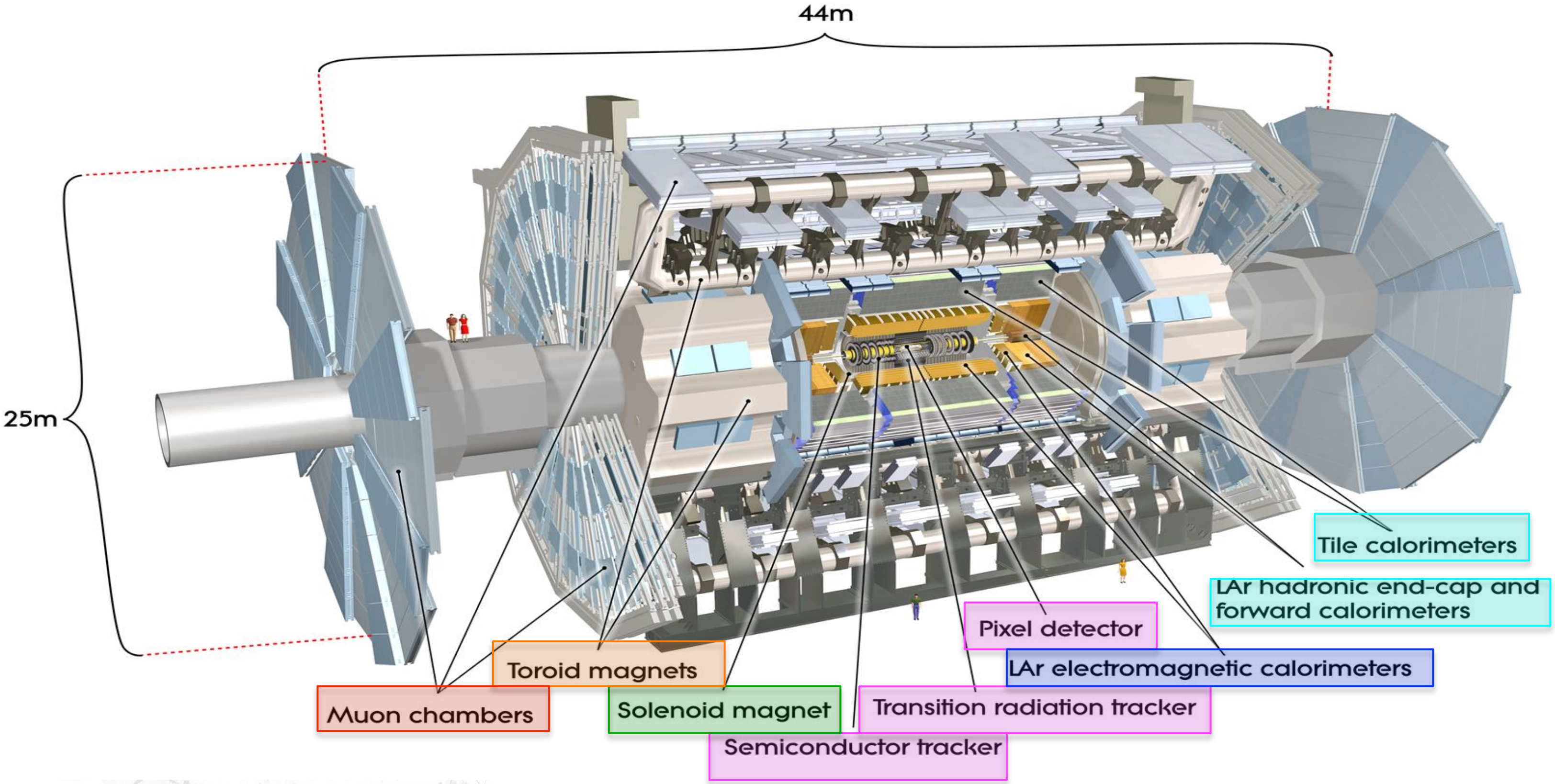
http://indico.cern.ch/event/373417/session/1/contribution/14/material/slides/1.pdf

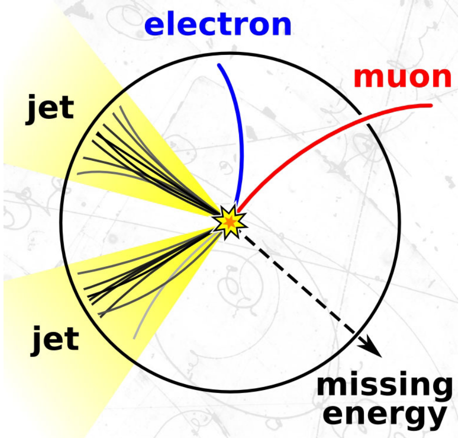
ATLAS and CMS : More details

- The **main differences** between the ATLAS and CMS detectors are:

	ATLAS	**CMS**
B-field	2T solenoid (Inner Tracker inside, HCAL outside of B-field) + toroid: 0.5T (barrel), 1T (endcap) → **good for jet resolution, worse for e/γ**	4T solenoid + return yoke (ECAL and part of HCAL inside) → **good for e/γ resolution, worse for jet**
Tracker	Si pixels and strips + transition radiation tracker → **high resolution, granularity, “continuous” tracking at large radii** $\sigma/p_T \sim 5 \times 10^{-4} p_T + 0.01$	Si pixels and strips (fully Silicon) → **high resolution, granularity** $\sigma/p_T \sim 1.5 \times 10^{-4} p_T + 0.005$
π with pT=1GeV	**84% reco efficiency (material budget, B-field)**	**80% reco efficiency**
e with pT=5GeV	**90% reco efficiency**	**85% reco efficiency**
EM calo	Liquid argon + Pb absorbers → **high granularity** $\sigma/E \sim 10\%/\sqrt{E} + 0.007$	$PbWO_4$ crystals → **high resolution** $\sigma/E \sim 3\%/\sqrt{E} + 0.003$
100 GeV γ	**1.0 - 1.5% E resolution**	**0.8% E resolution**
50 GeV e	**1.3 - 2.3% E resolution**	**2.0% E resolution**
Had calo	Fe + scintillator / Cu+Lar (10λ) $\sigma/E \sim 50\%/\sqrt{E} + 0.03$ GeV	Brass + scintillator (7λ + catcher) $\sigma/E \sim 100\%/\sqrt{E} + 0.05$ GeV
1000 GeV jets	**2%**	**5%**
2000 GeV MET	**20 GeV**	**40 GeV**
Muon	σ/p_T~2% at 50 GeV to 10% at 1 TeV (Inner Tracker + muon system)	σ/p_T~1% at 50 GeV to 10% at 1 TeV (Inner Tracker + muon system)

The ATLAS Detector



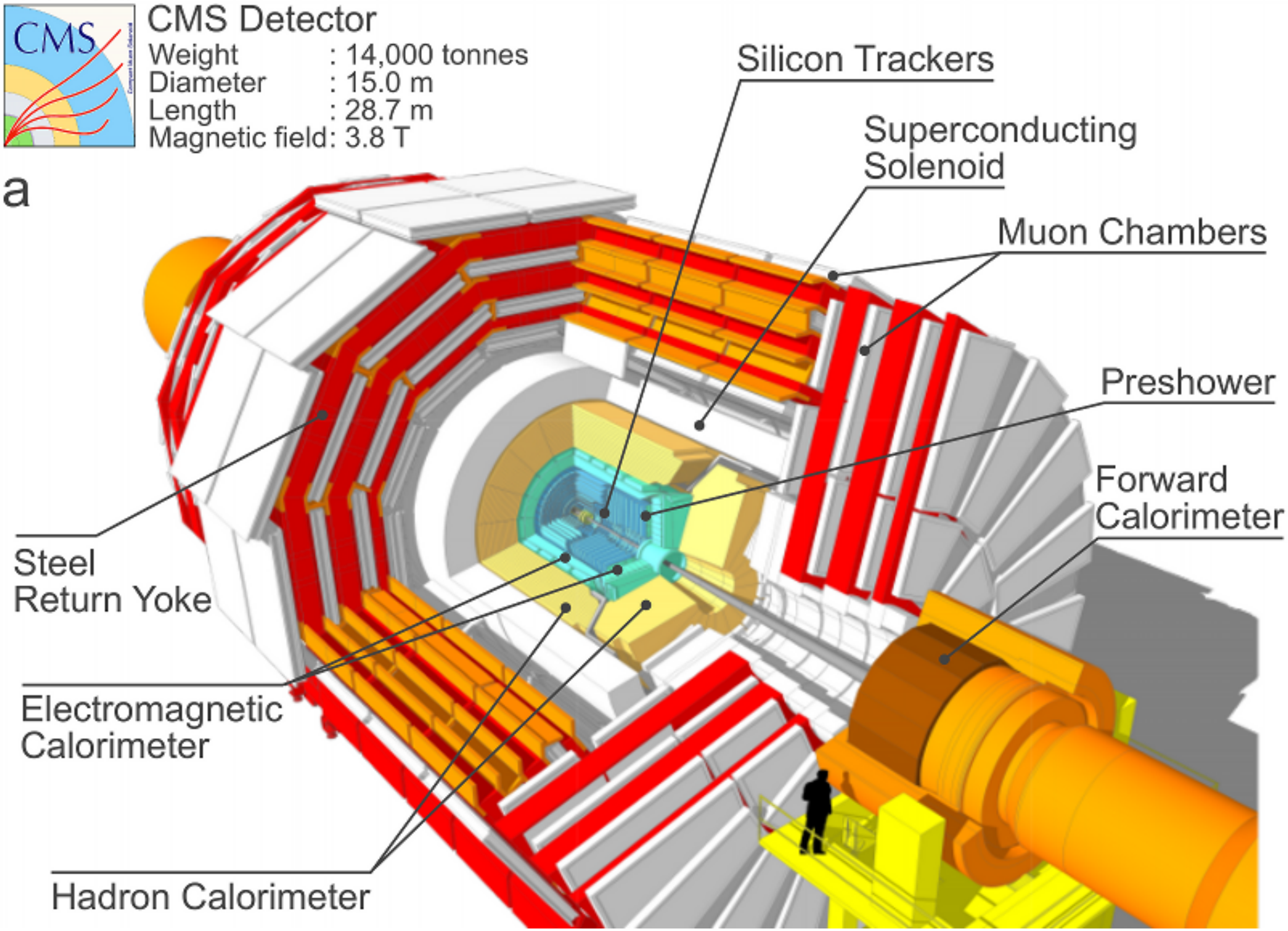


- **Inner tracker** → electrons, muons, jets
- **Solenoid B-field** → electrons, muons
- **Electromagnetic calorimeter** → electrons, photons, jets, missing energy

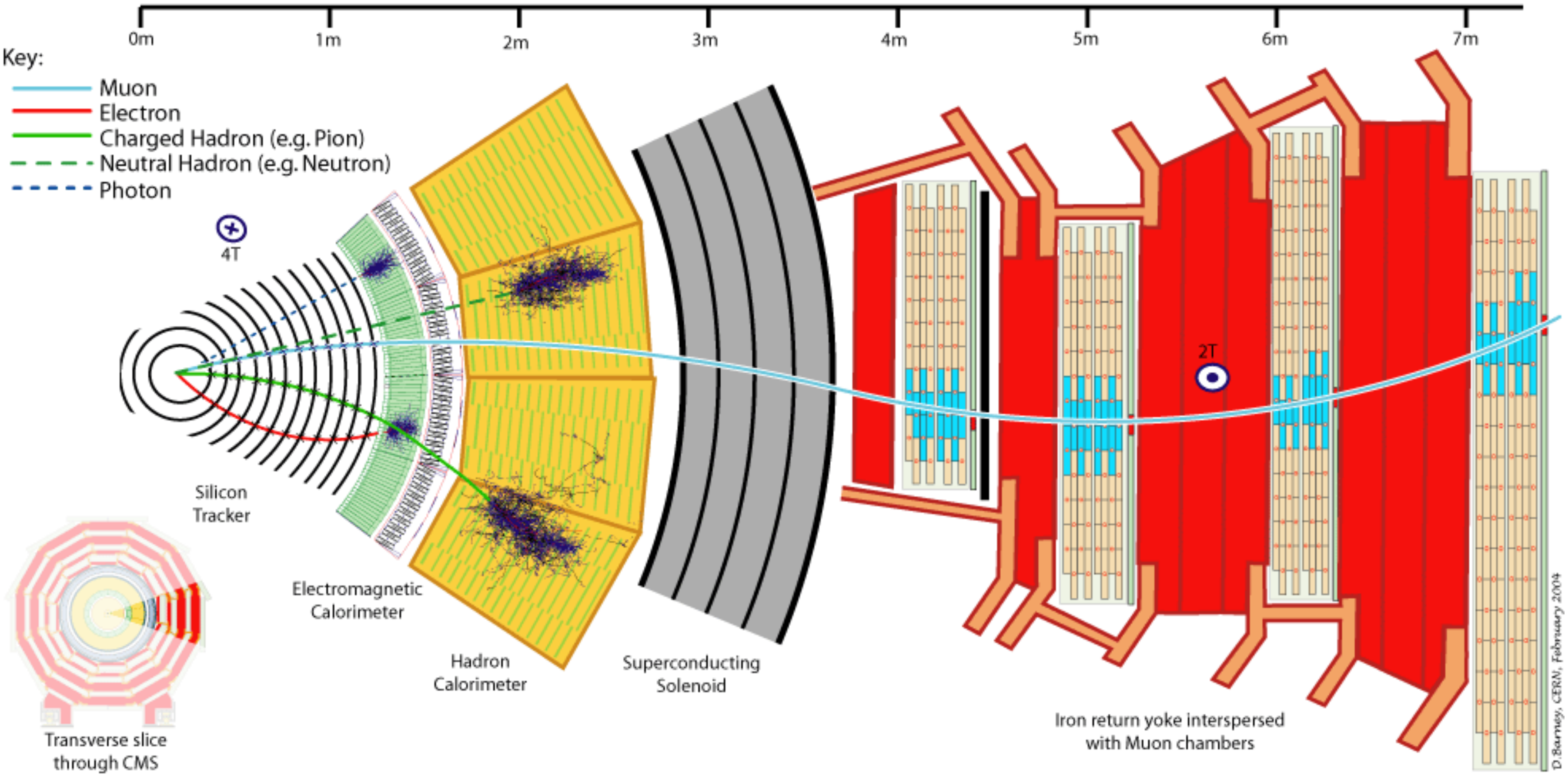
- **Hadronic calorimeter** → jets, missing energy
- **Toroid B-field** → muons
- **Muon chambers** → muons

http://www.fnal.gov/pub/today/archive/archive_2011/today11-04-22.html

The CMS Detector



Particle Physics Object Detection

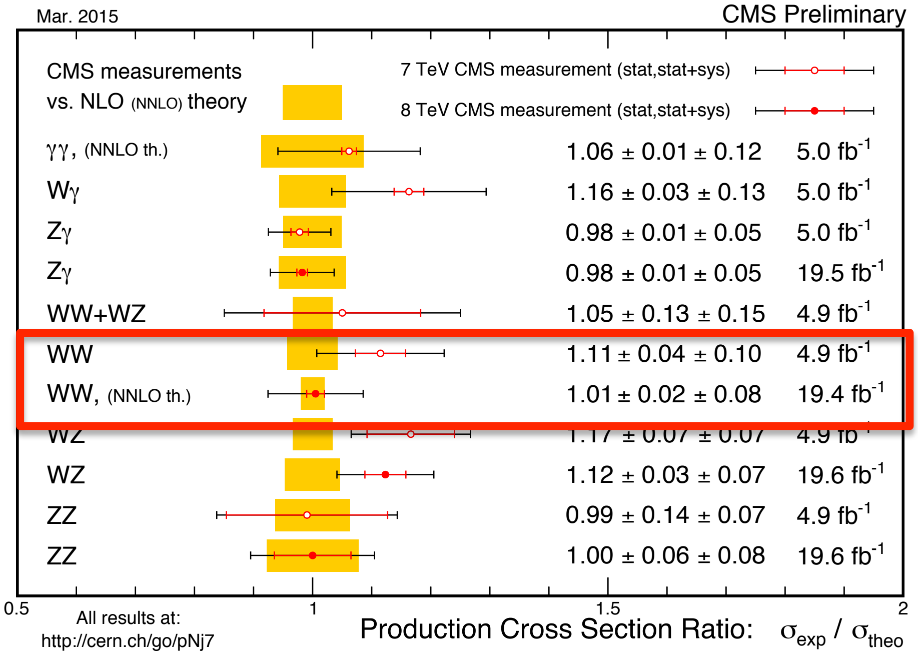


http://en.wikipedia.org/wiki/Compact_Muon_Solenoid

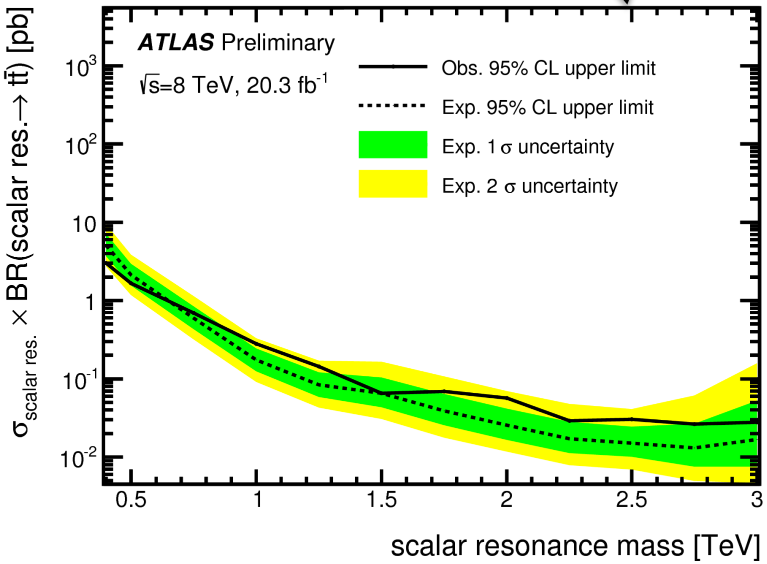
Searches for SM Deviations

Run1 : Search for deviations from the SM

- In the **Standard Model**, deviations were looked for in :
    - Cross section measurements
    - Anomalous couplings
    - Resonances (ttbar,…)
    - Indirect effects (B-physics)



CMS PAS SMP-14-016



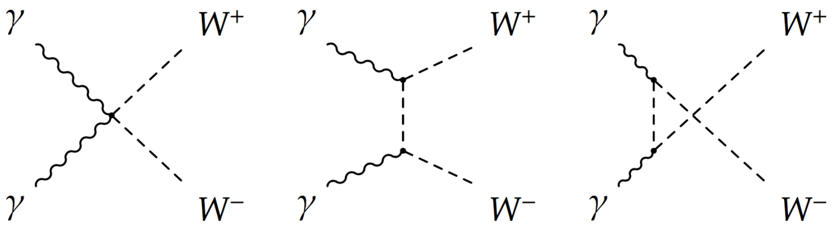
ATLAS-CONF-2015-009

- **WW production cross section** that was puzzling during Run1
    - **NNLO theory calculations** could explain the discrepancy observed

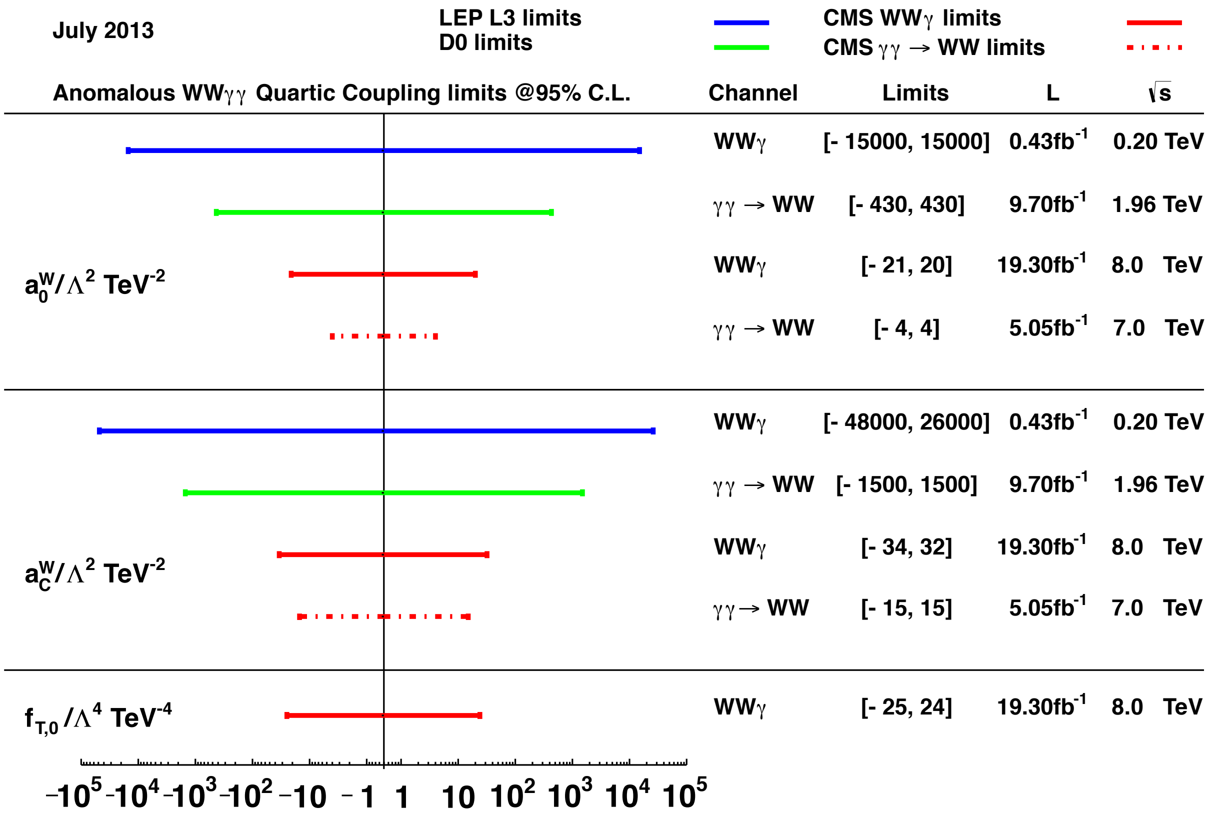
Run1 : Standard Model results

Anomalous couplings :

Quartic couplings in the SM :



- *Add **anomalous** quartic couplings via effective Lagrangian (independent of the SM ones)*



Anomalous WWγγ Quartic Coupling limits @95% C.L.

	Channel	Limits	L	√s
a_0^W/Λ^2 TeV^{-2}	WWγ	[- 15000, 15000]	0.43fb^{-1}	0.20 TeV
	γγ → WW	[- 430, 430]	9.70fb^{-1}	1.96 TeV
	WWγ	[- 21, 20]	19.30fb^{-1}	8.0 TeV
	γγ → WW	[- 4, 4]	5.05fb^{-1}	7.0 TeV
a_C^W/Λ^2 TeV^{-2}	WWγ	[- 48000, 26000]	0.43fb^{-1}	0.20 TeV
	γγ → WW	[- 1500, 1500]	9.70fb^{-1}	1.96 TeV
	WWγ	[- 34, 32]	19.30fb^{-1}	8.0 TeV
	γγ→ WW	[- 15, 15]	5.05fb^{-1}	7.0 TeV
$f_{T,0}/\Lambda^4$ TeV^{-4}	WWγ	[- 25, 24]	19.30fb^{-1}	8.0 TeV

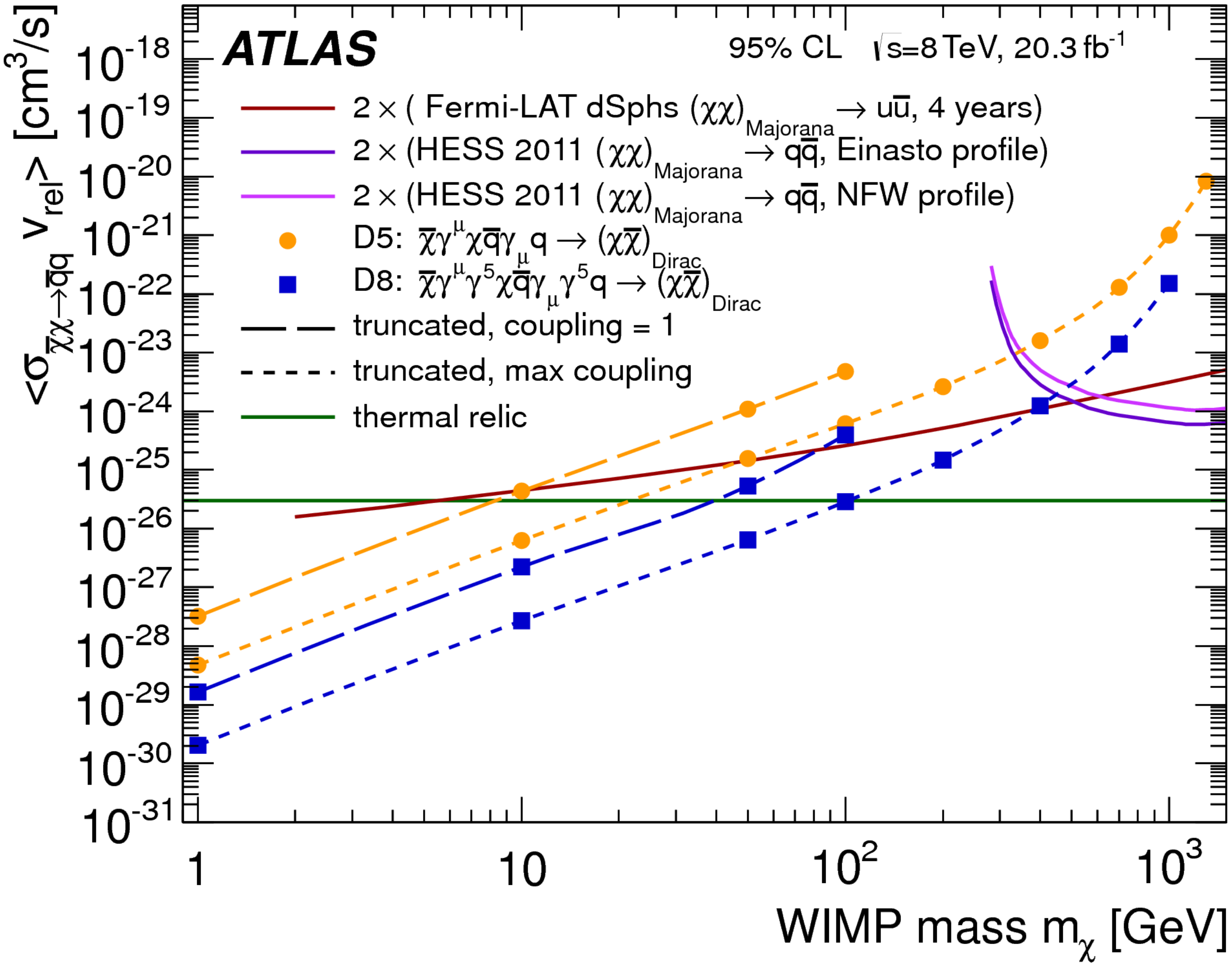
arXiv:1305.5596v3

- **≈20 times better than Tevatron**
- **≈2 orders of magnitude better than LEP**

More material on mono-object searches

Dark Matter Searches at LHC (3)

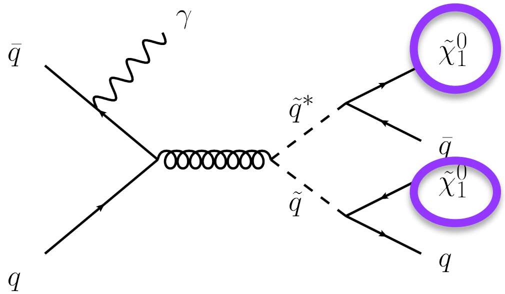
DM annihilation rate :

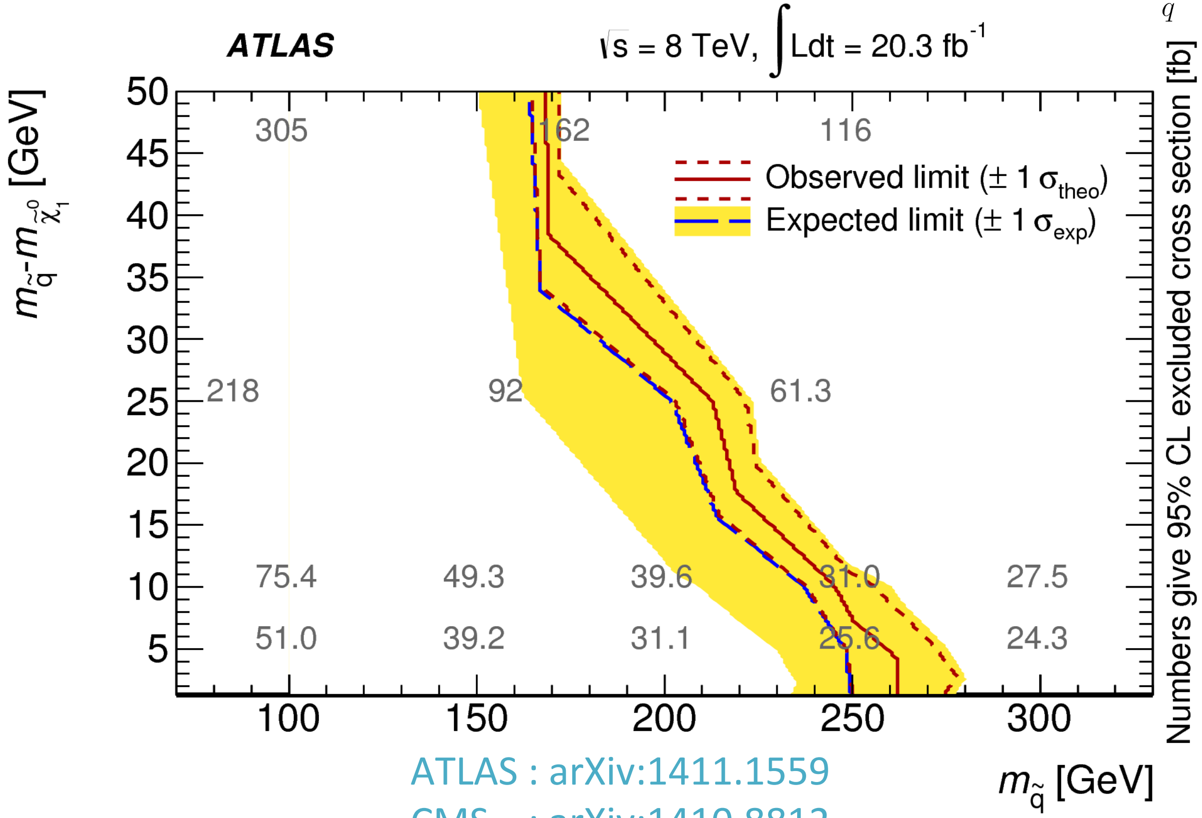


Mono-photon : Limits on SUSY

Limit on SUSY compressed result (from energetic photon)

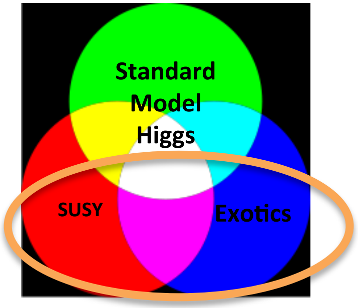
$$\sigma(pp \rightarrow \tilde{q}\tilde{q}^{*}\gamma + X)$$





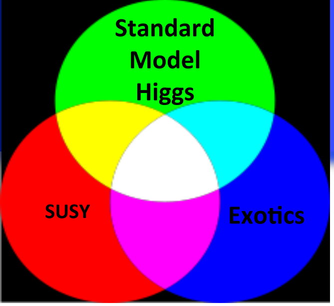
ATLAS : arXiv:1411.1559

CMS : arXiv:1410.8812



- **Squark masses** excluded up **to 250 GeV**

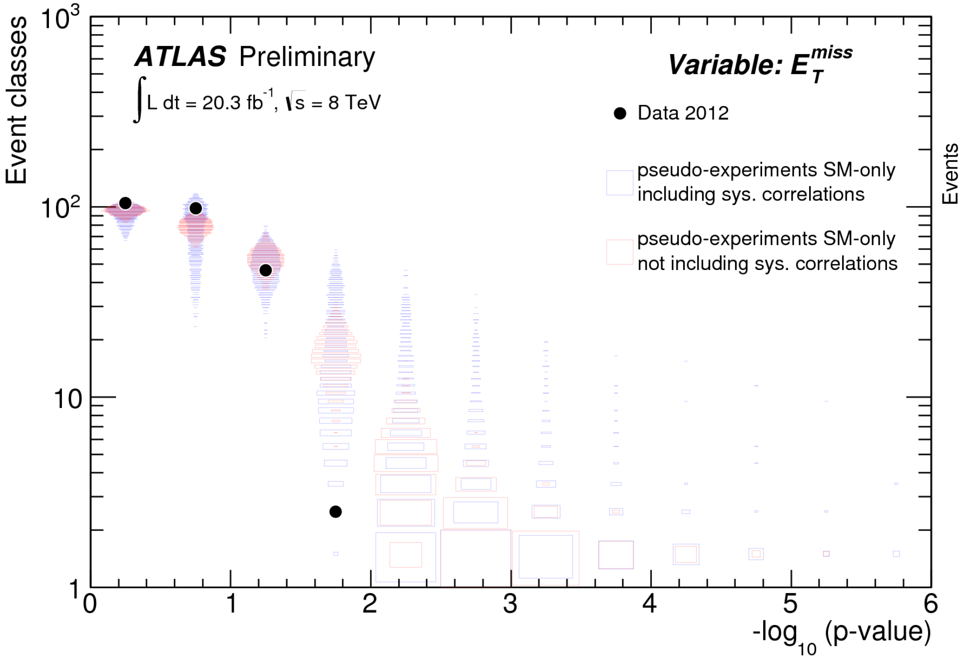
General search

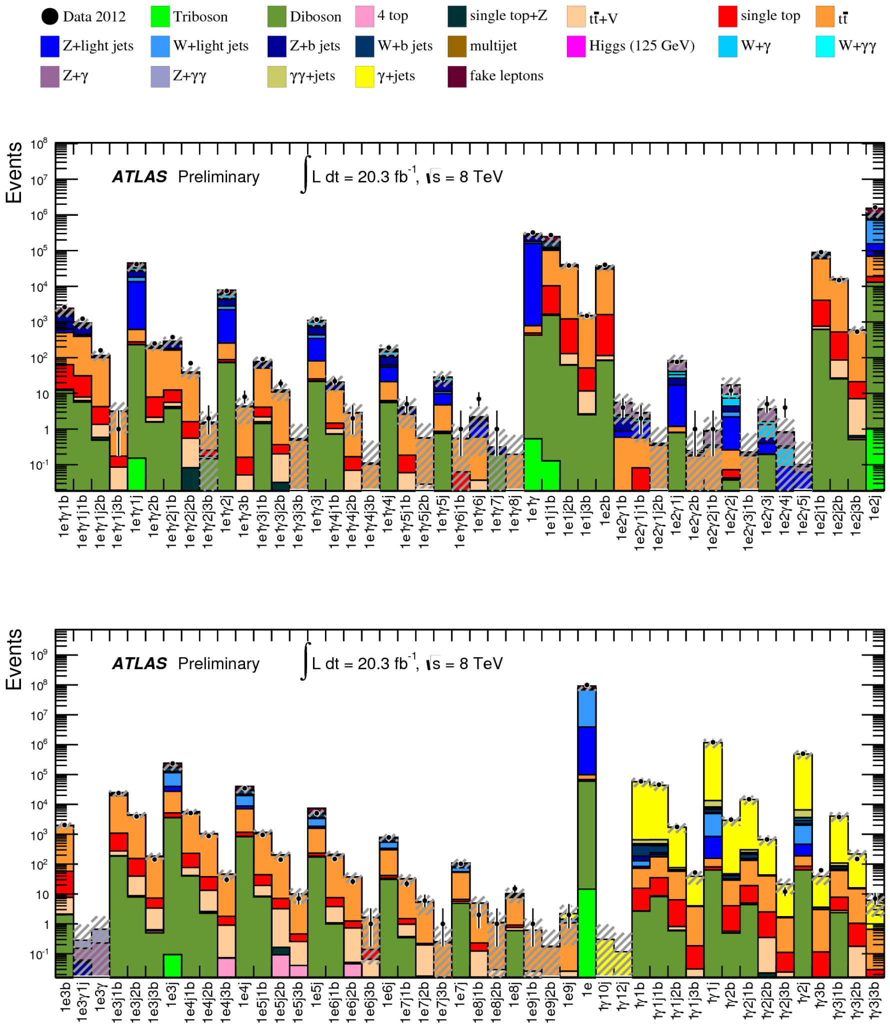


Run1 : Model-Independent General Search

- **697 final states** put together
- **Compare data to backgrounds**
  - Number of events
  - Distributions, like missing energy

ATLAS-CONF-2014-006

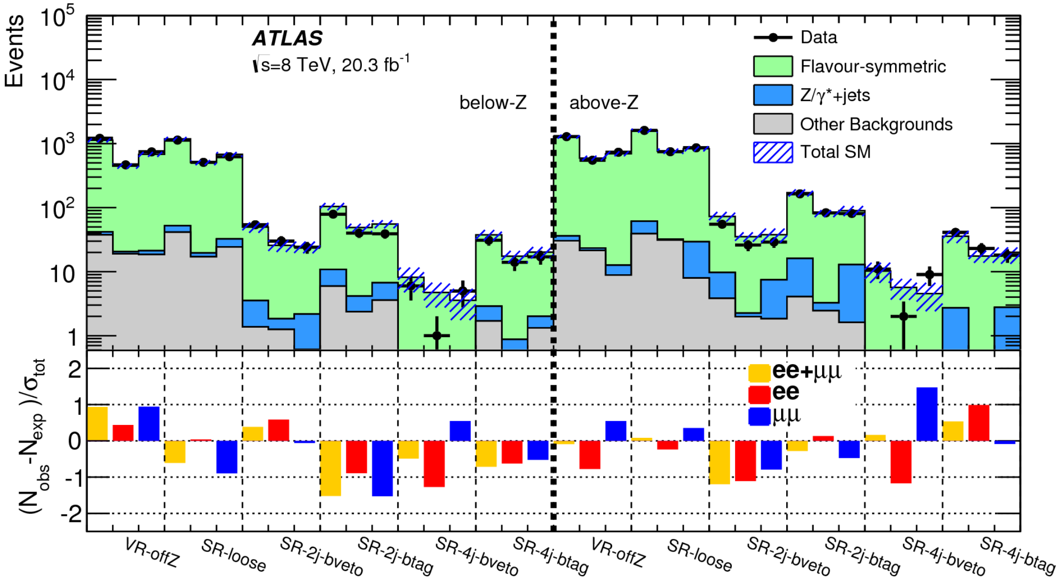




No significant deviation found

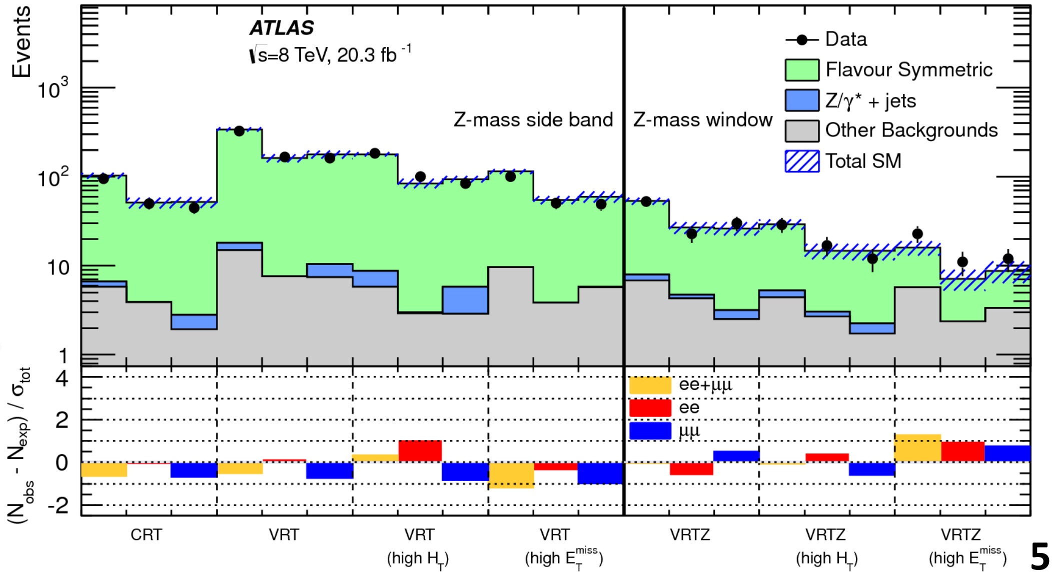
More material on excesses

2 leptons (on/off-Z) + jets + missing energy (ATLAS)

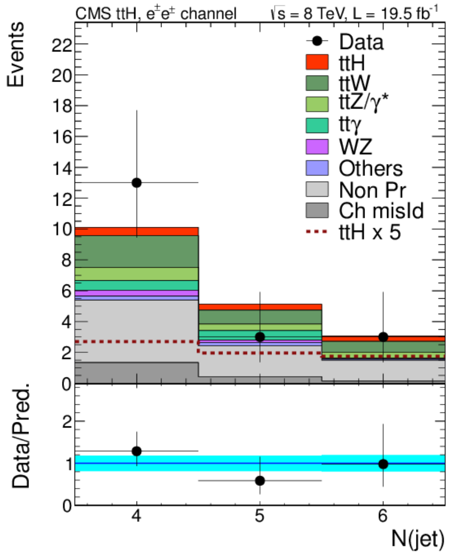


2 leptons (on/off-Z) + jets + missing energy

Background description ok everywhere

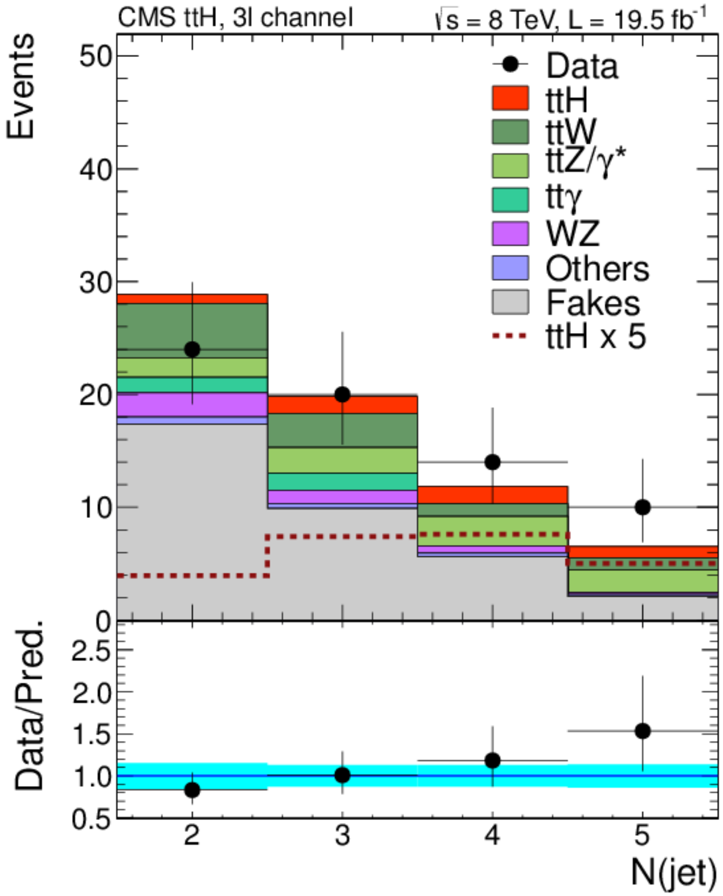


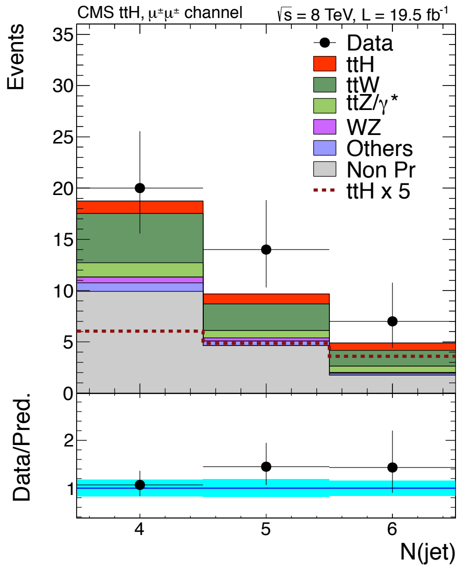
CMS ttH



arXiv:1408.1682v2 [hep-ex]

CMS ttH

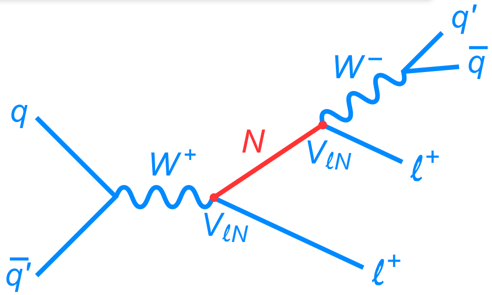


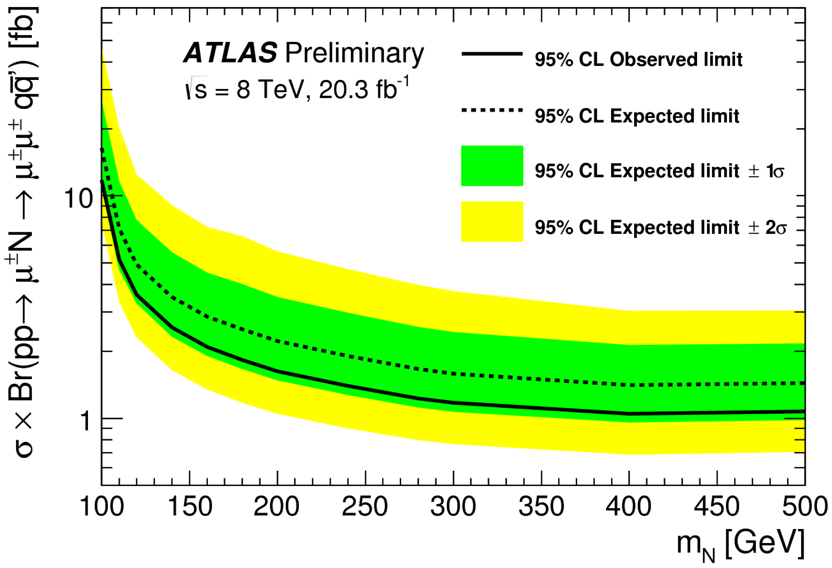


Majorana Neutrinos

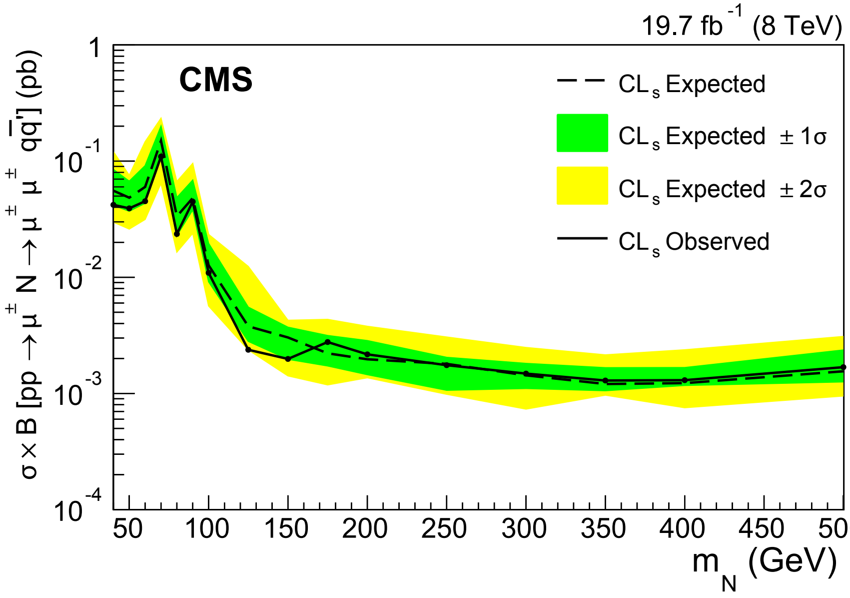
Heavy neutrinos and W bosons with right-handed couplings

Same-sign analysis :





to appear soon on ArXiv



arXiv:1501.05566

No excess observed in ATLAS nor CMS

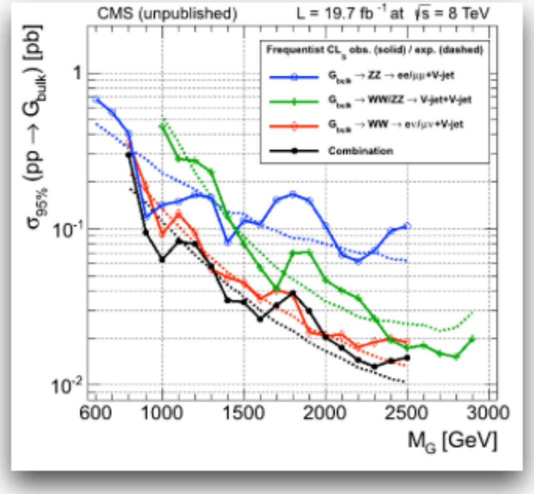
CMS Exotics

Searches for resonances

VV Combined Results

Full combination of X→VV results in the Bulk Graviton model

- Improves sensitivity to new physics!
- Best sensitivity from lepton+E_T^{miss}+V-jet channel over the whole mass range, followed by the all-hadronic channel at higher masses
- Good sensitivity from the 2 leptons+V-jet channel at low masses
- Interesting deviation from expected background (1.3σ) in all channels at M ~ 1.8 - 2 TeV!



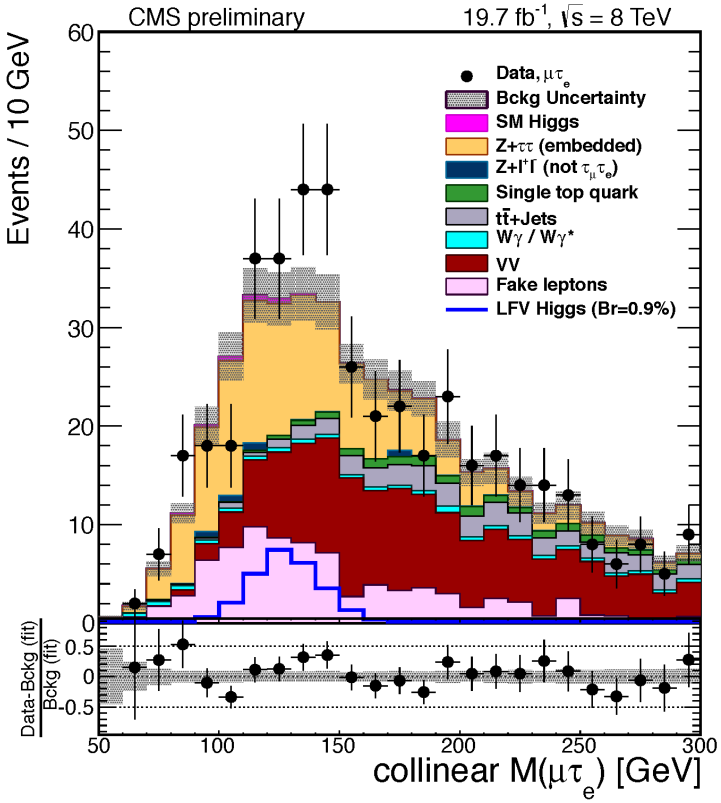
EXO-13-009 public twiki

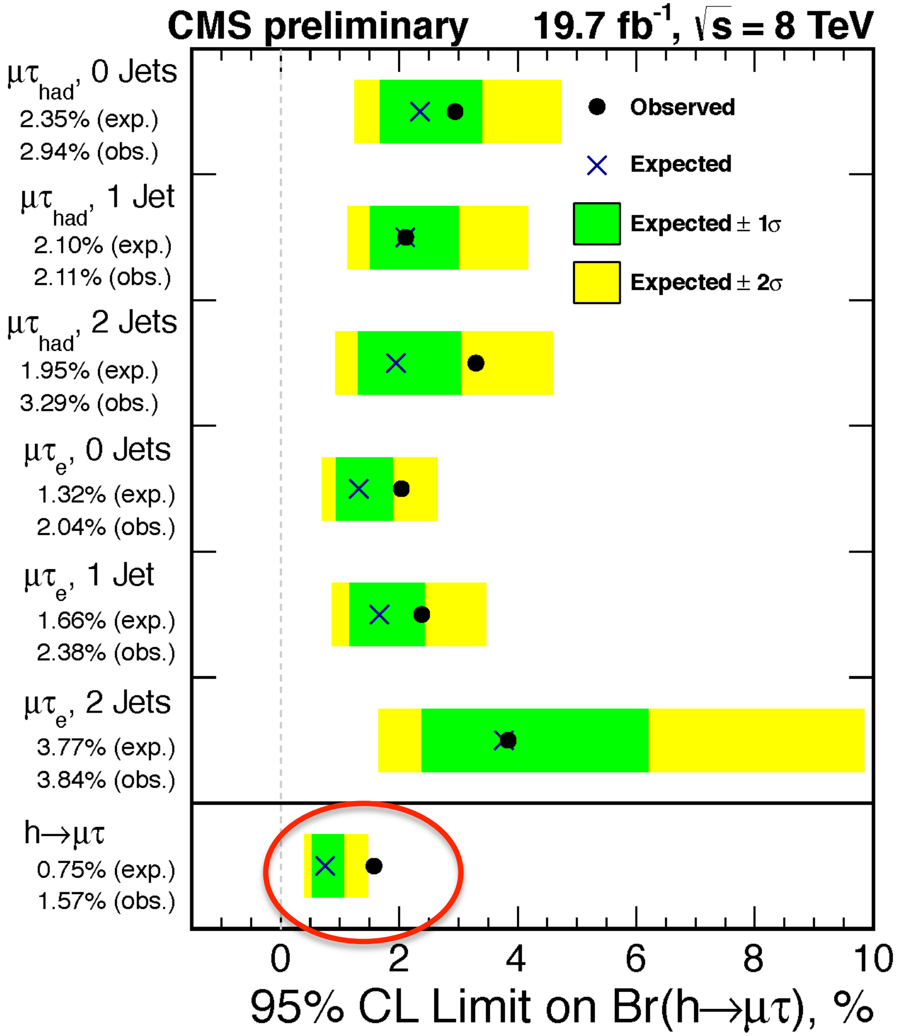
https://indico.cern.ch/event/364031/session/30/contribution/58/material/slides/0.pdf

CMS Higgs excess

- **CMS LFV H→μτ**

arXiv:1502.07400v1



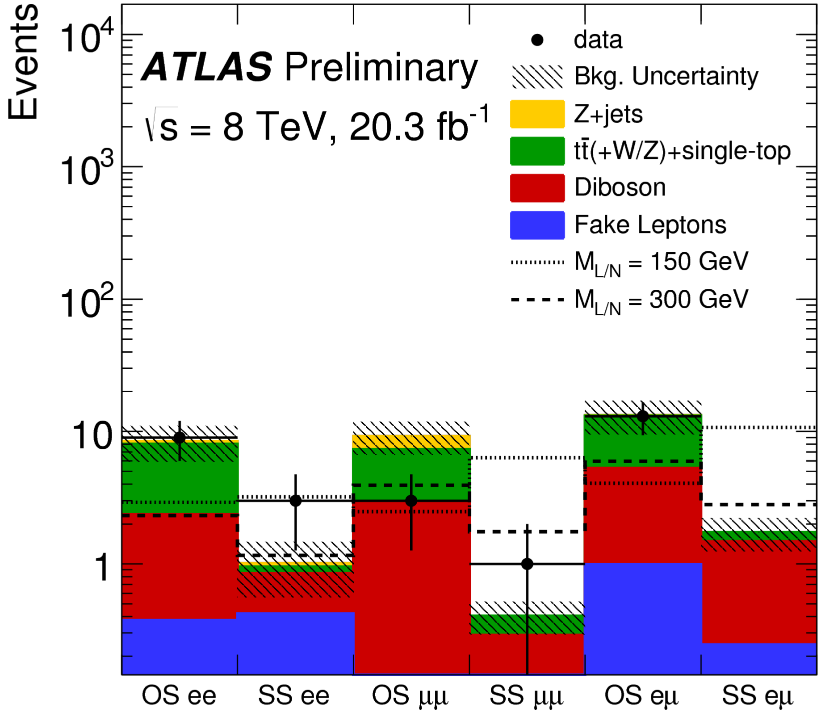


2.5σ excess

- **ATLAS result in preparation**

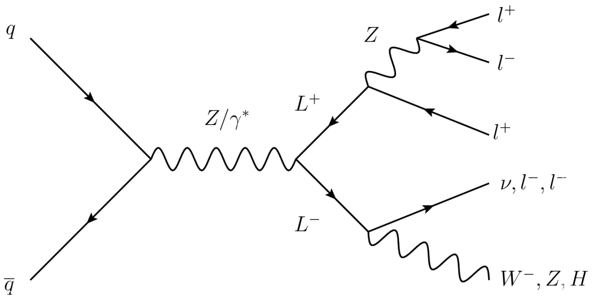
ATLAS Exotics Excess

Type III See-Saw heavy leptons in 2L+2J final state :



To appear soon on arXiv

No excess observed by CMS (3L final state):

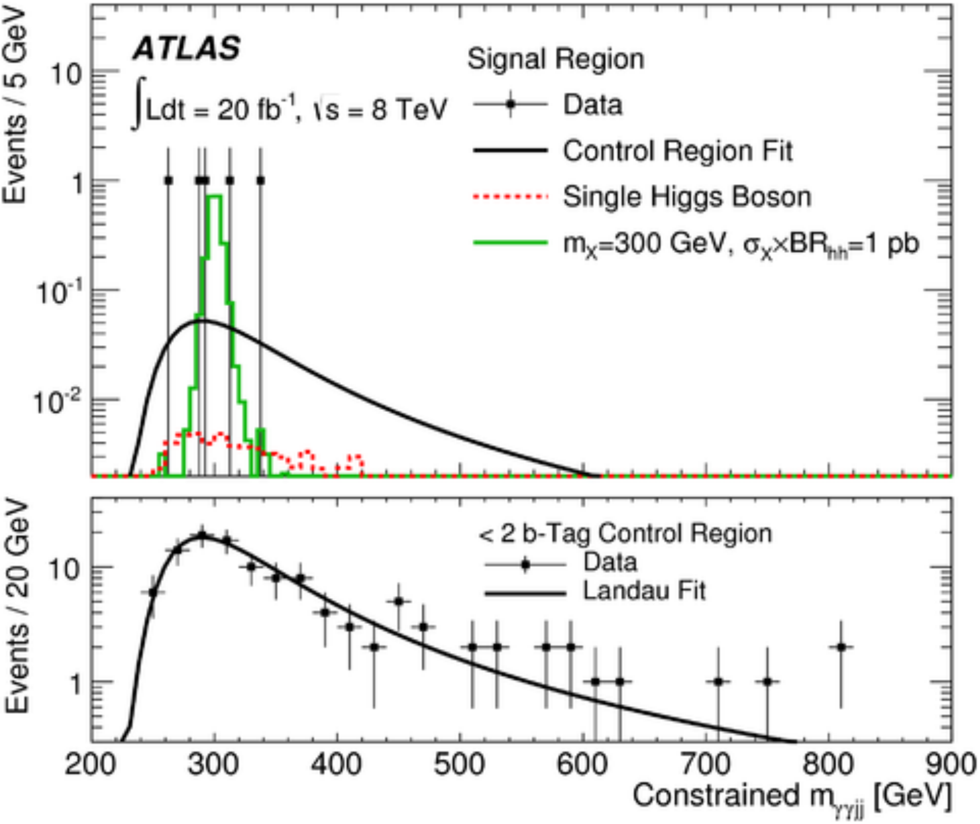


CMS PAS EXO-14-001

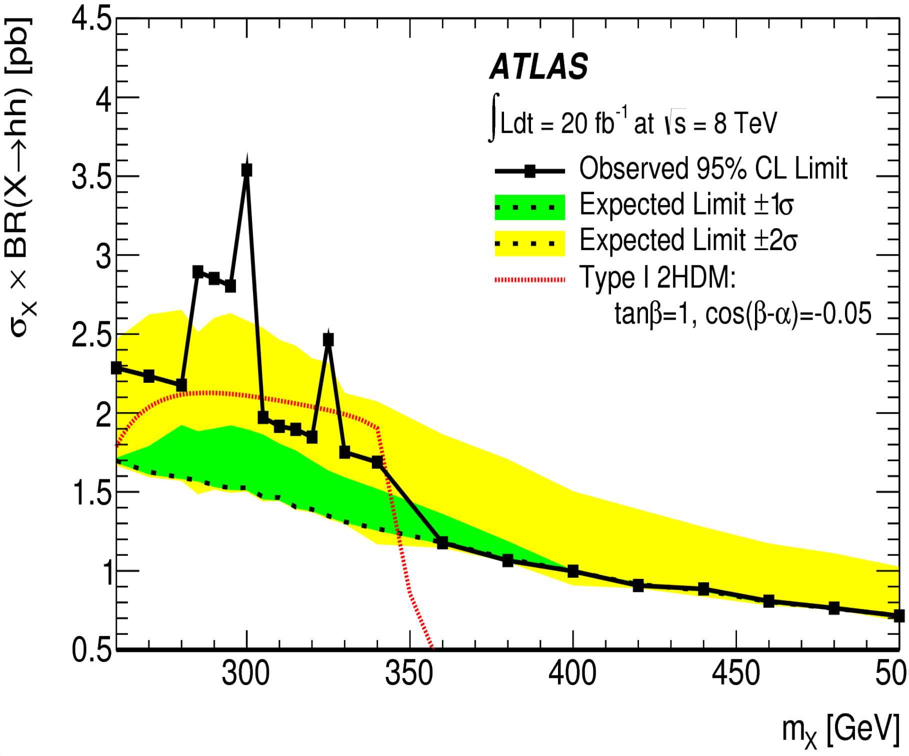
ATLAS Higgs excess

- **Di-Higgs resonances** $G^* \rightarrow HH \rightarrow b\bar{b}b\bar{b}(\mathrm{or}\ b\bar{b}\gamma\gamma)$

bbγγ final state :



Small statistics



arXiv:1406.5053

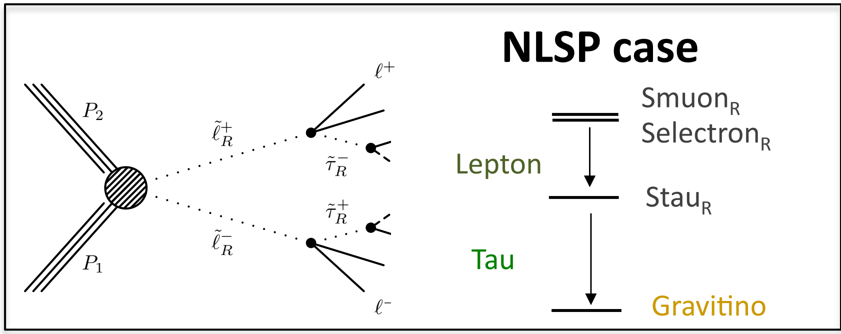
Excess not seen by CMS

(CMS PAS HIG-13-032)

CMS SUSY Excess

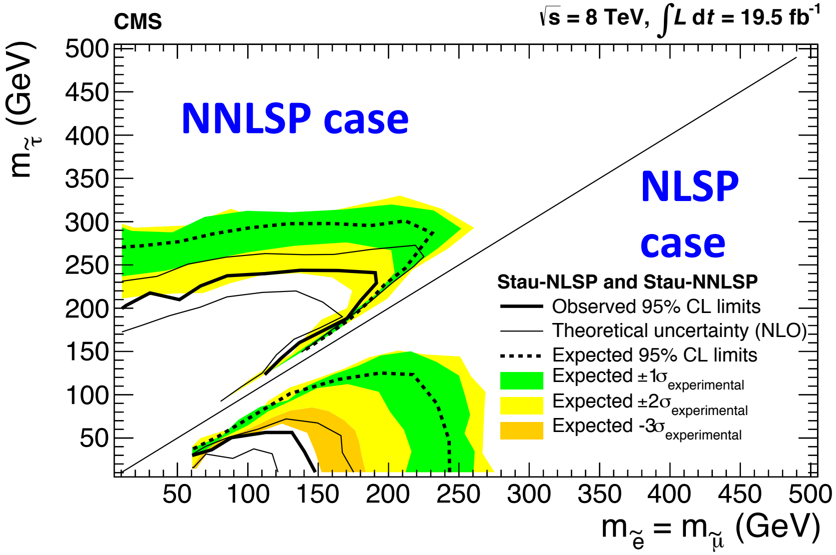
Multilepton 3l+τ

- **Right-handed stau lepton** is (N)NLSP



- Signal regions with off-shell Z, hadronic taus without b-jets

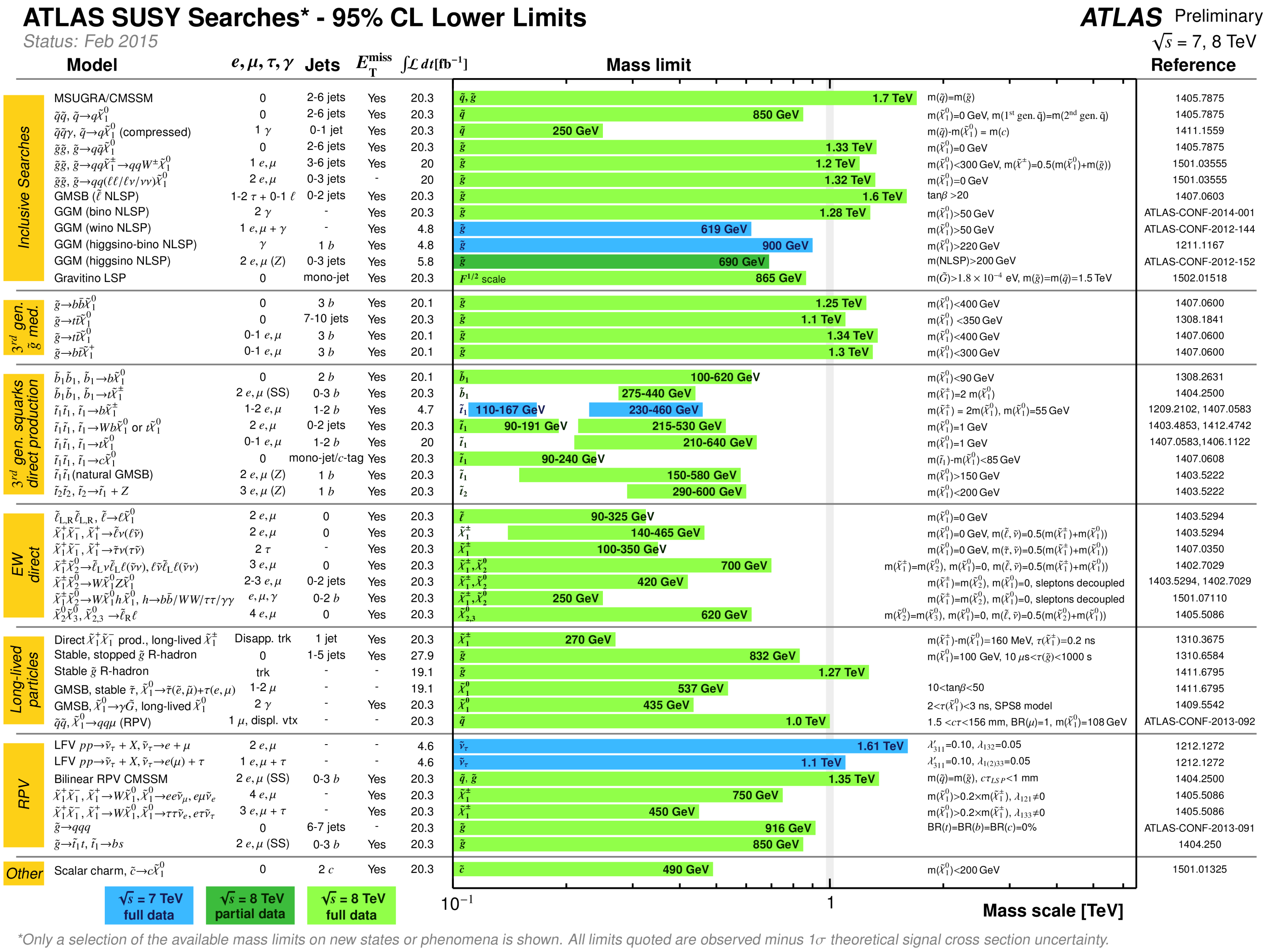
Missing energy (GeV)	H_T>200 GeV, observed	H_T>200GeV, expected	H_T<200 GeV, observed	H_T<200 GeV, expected
> 100	1	0.25±0.11	3	0.60±0.24
[50,100]	1	0.29±0.13	4	2.1±0.5
[0,50]	0	0.27±0.12	15	7.5±2.0



3σ for NLSP case

2σ for NNLSP case

Run1 : ATLAS SUSY searches



ATLAS SUSY Searches* - 95% CL Lower Limits

Status: Feb 2015

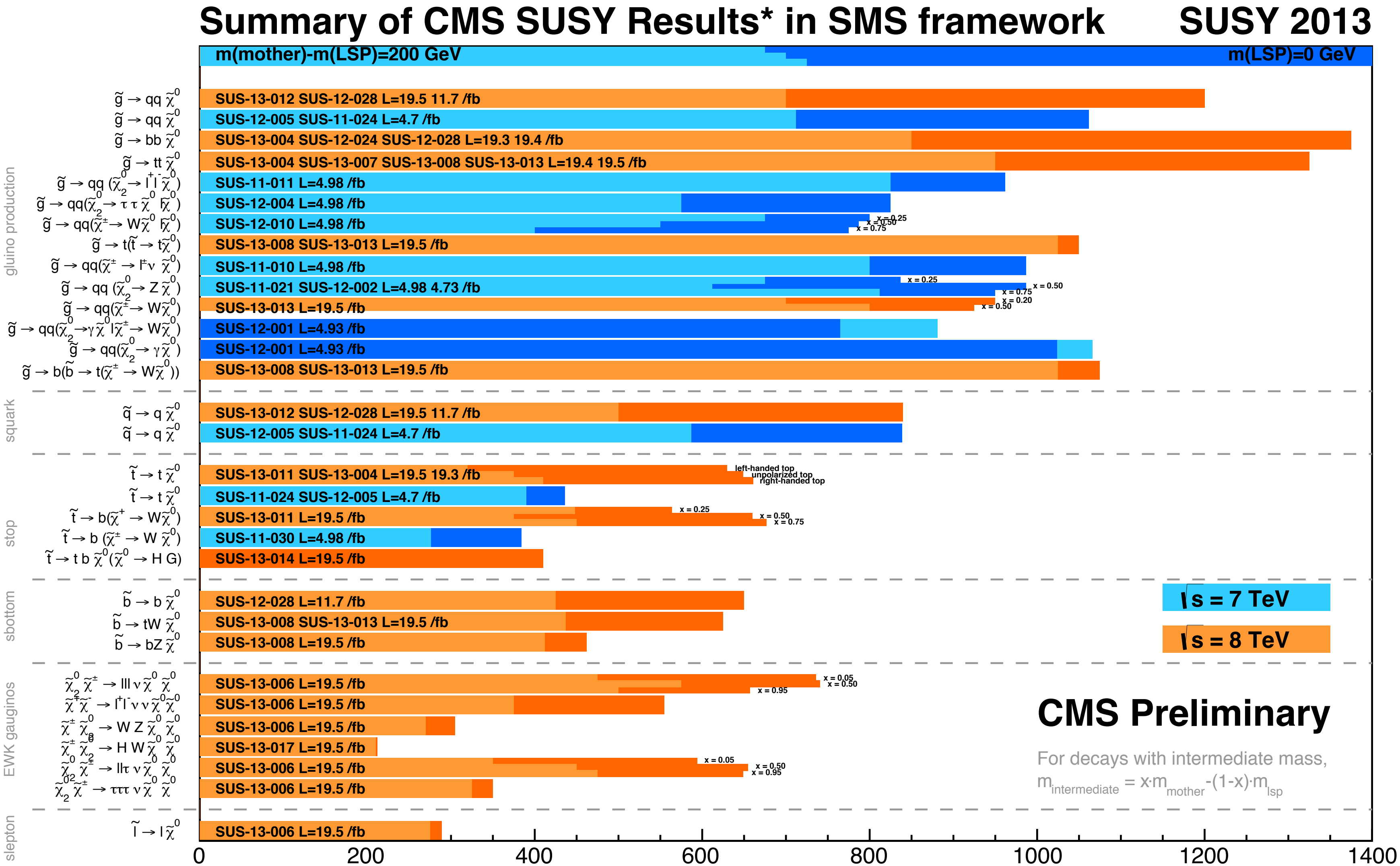
ATLAS Preliminary

$\sqrt{s}$ = 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
	$\tilde{q}\tilde{q},\ \tilde{q}\to q\tilde{\chi}^0_1$	0	2-6 jets	Yes	20.3	$\tilde{q}$	850 GeV	m($\tilde{\chi}^0_1$)=0 GeV, m(1st gen. $\tilde{q}$)=m(2nd gen. $\tilde{q}$)	1405.7875
	$\tilde{q}\tilde{q}\gamma,\ \tilde{q}\to q\tilde{\chi}^0_1$ (compressed)	1 γ	0-1 jet	Yes	20.3	$\tilde{q}$	250 GeV	m($\tilde{q}$)-m($\tilde{\chi}^0_1$) = m(c)	1411.1559
	$\tilde{g}\tilde{g},\ \tilde{g}\to q\bar{q}\tilde{\chi}^0_1$	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	$\tilde{g}$	1.2 TeV	m($\tilde{\chi}^0_1$)<300 GeV, m($\tilde{\chi}^\pm$)=0.5(m($\tilde{\chi}^0_1$)+m($\tilde{g}$))	1501.03555
	$\tilde{g}\tilde{g},\ \tilde{g}\to qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}^0_1$	2 e,μ	0-3 jets	-	20	$\tilde{g}$	1.32 TeV	m($\tilde{\chi}^0_1$)=0 GeV	1501.03555
	GMSB ($\tilde{\ell}$ NLSP)	1-2 τ + 0-1 ℓ	0-2 jets	Yes	20.3	$\tilde{g}$	1.6 TeV	tanβ >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,μ + γ	-	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	20.3	$F^{1/2}$ scale	865 GeV	m($\tilde{G}$)>1.8×10^{-4} eV, m($\tilde{g}$)=m($\tilde{q}$)=1.5 TeV	1502.01518
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
	$\tilde{t}_1\tilde{t}_1,\ \tilde{t}_1\to b\tilde{\chi}^\pm_1$	1-2 e,μ	1-2 b	Yes	4.7	$\tilde{t}_1$	110-167 GeV 230-460 GeV	m($\tilde{\chi}^\pm_1$) = 2m($\tilde{\chi}^0_1$), m($\tilde{\chi}^0_1$)=55 GeV	1209.2102, 1407.0583
	$\tilde{t}_1\tilde{t}_1,\ \tilde{t}_1\to Wb\tilde{\chi}^0_1$ or $t\tilde{\chi}^0_1$	2 e,μ	0-2 jets	Yes	20.3	$\tilde{t}_1$	90-191 GeV 215-530 GeV	m($\tilde{\chi}^0_1$)=1 GeV	1403.4853, 1412.4742
	$\tilde{t}_1\tilde{t}_1,\ \tilde{t}_1\to t\tilde{\chi}^0_1$	0-1 e,μ	1-2 b	Yes	20	$\tilde{t}_1$	210-640 GeV	m($\tilde{\chi}^0_1$)=1 GeV	1407.0583,1406.1122
	$\tilde{t}_1\tilde{t}_1,\ \tilde{t}_1\to c\tilde{\chi}^0_1$	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
	$\tilde{\chi}^\pm_1\tilde{\chi}^0_2\to W\tilde{\chi}^0_1Z\tilde{\chi}^0_1$	2-3 e,μ	0-2 jets	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
	$\tilde{\chi}^\pm_1\tilde{\chi}^0_2\to W\tilde{\chi}^0_1h\tilde{\chi}^0_1,\ h\to b\bar{b}/WW/\tau\tau/\gamma\gamma$	e,μ,γ	0-2 b	Yes	20.3	$\tilde{\chi}^\pm_1,\tilde{\chi}^0_2$	250 GeV	m($\tilde{\chi}^\pm_1$)=m($\tilde{\chi}^0_2$), m($\tilde{\chi}^0_1$)=0, sleptons decoupled	1501.07110
	$\tilde{\chi}^0_2\tilde{\chi}^0_3,\ \tilde{\chi}^0_{2,3}\to\tilde{\ell}_R\ell$	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, τ($\tilde{\chi}^\pm_1$)=0.2 ns	1310.3675
	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<τ($\tilde{g}$)<1000 s	1310.6584
	Stable $\tilde{g}$ R-hadron	trk	-	-	19.1	$\tilde{g}$	1.27 TeV		1411.6795
	GMSB, stable $\tilde{\tau}$, $\tilde{\chi}^0_1\to\tilde{\tau}(\tilde{e},\tilde{\mu})+\tau(e,\mu)$	1-2 μ	-	-	19.1	$\tilde{\chi}^0_1$	537 GeV	10<tanβ<50	1411.6795
	GMSB, $\tilde{\chi}^0_1\to\gamma\tilde{G}$, long-lived $\tilde{\chi}^0_1$	2 γ	-	Yes	20.3	$\tilde{\chi}^0_1$	435 GeV	2<τ($\tilde{\chi}^0_1$)<3 ns, SPS8 model	1409.5542
	$\tilde{q}\tilde{q},\ \tilde{\chi}^0_1\to qq\mu$ (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,μ + τ	-	-	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,μ + τ	-	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
	$\tilde{g}\to\tilde{t}_1t,\ \tilde{t}_1\to bs$	2 e,μ (SS)	0-3 b	Yes	20.3	$\tilde{g}$	850 GeV		1404.250
Other	Scalar charm, $\tilde{c}\to c\tilde{\chi}^0_1$	0	2 c	Yes	20.3	$\tilde{c}$	490 GeV	m($\tilde{\chi}^0_1$)<200 GeV	1501.01325

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.

Run1 : CMS SUSY searches (1)

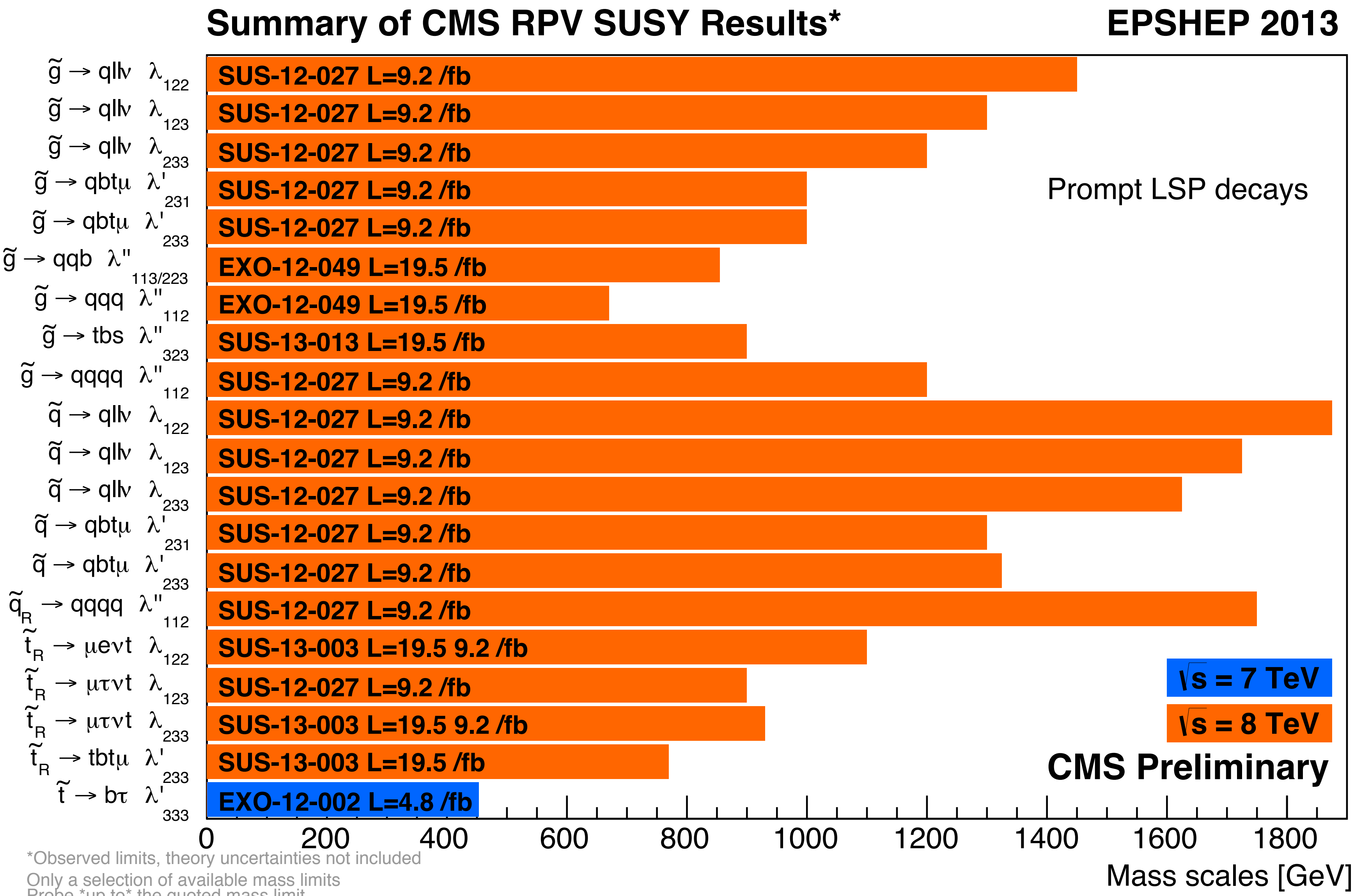


*Observed limits, theory uncertainties not included

Only a selection of available mass limits

Probe *up to* the quoted mass limit

Run1 : CMS SUSY searches (2)

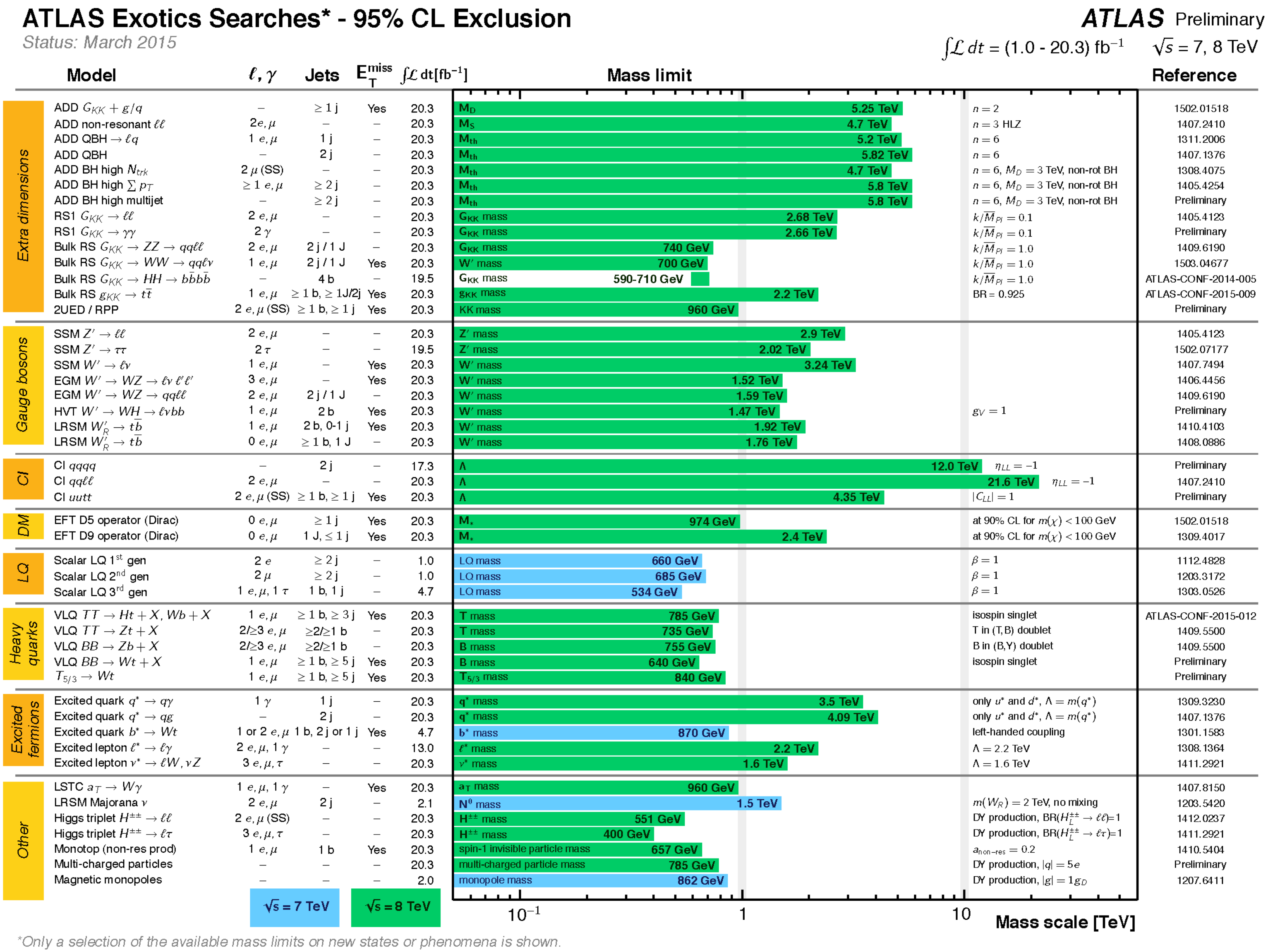


*Observed limits, theory uncertainties not included

Only a selection of available mass limits

Probe *up to* the quoted mass limit

Run1 : ATLAS Exotics searches (1)



ATLAS Exotics Searches* - 95% CL Exclusion

Status: March 2015

ATLAS Preliminary

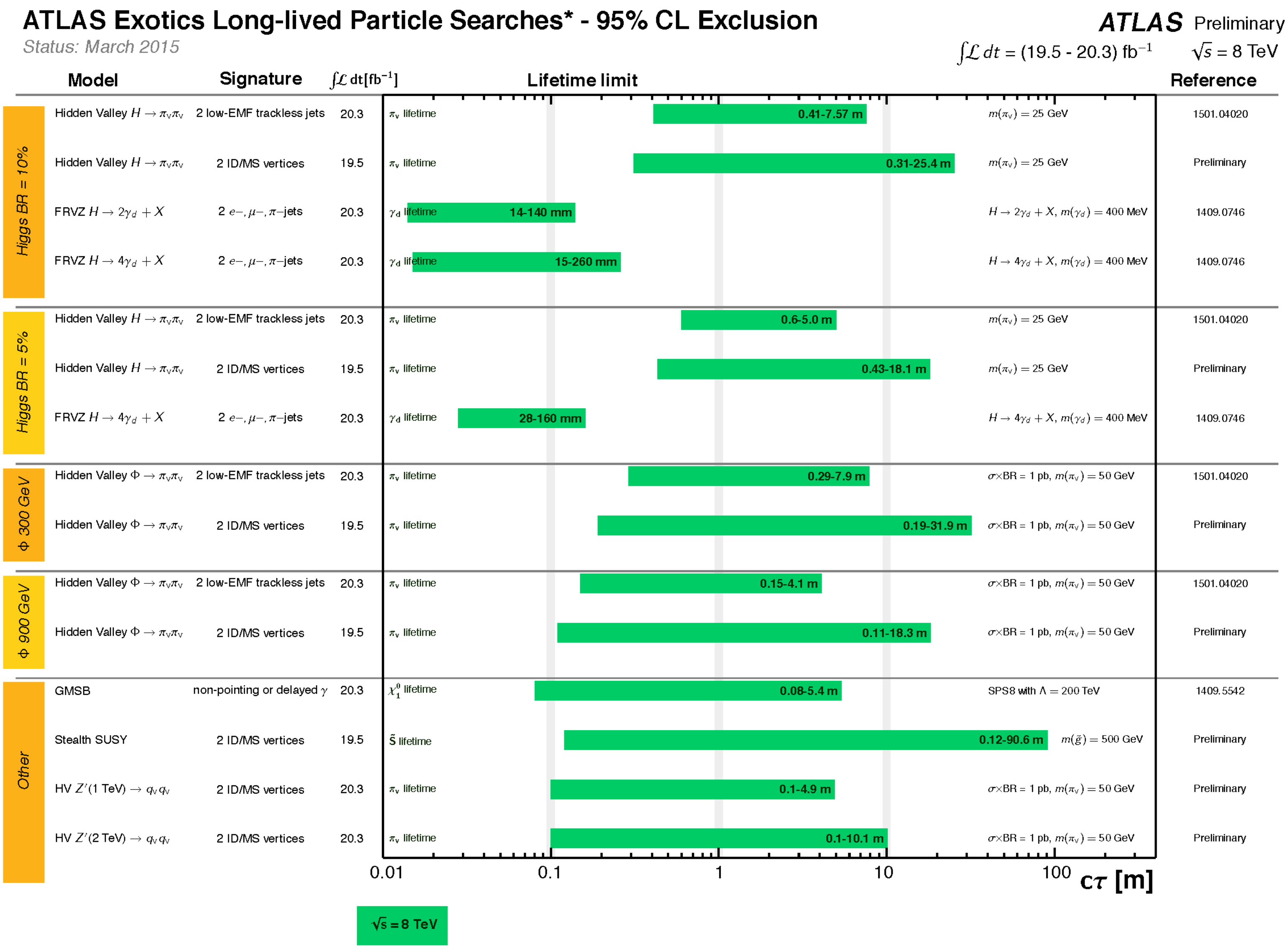
$\int\mathcal{L}\,dt = (1.0 - 20.3)\ \mathrm{fb}^{-1}$ $\sqrt{s} = 7, 8$ TeV

	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 j	Yes	20.3	M_D 5.25 TeV	$n = 2$	1502.01518
	ADD non-resonant $\ell\ell$	$2 e, \mu$	–	–	20.3	M_S 4.7 TeV	$n = 3$ HLZ	1407.2410
	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	$n = 6$	1407.1376
	ADD BH high N_{trk}	$2\ \mu$ (SS)	–	–	20.3	M_{th} 4.7 TeV	$n = 6$, $M_D = 3$ TeV, non-rot BH	1308.4075
	ADD BH high $\sum p_T$	$\geq 1\ e, \mu$	≥ 2 j	–	20.3	M_{th} 5.8 TeV	$n = 6$, $M_D = 3$ TeV, non-rot BH	1405.4254
	ADD BH high multijet	–	≥ 2 j	–	20.3	M_{th} 5.8 TeV	$n = 6$, $M_D = 3$ TeV, non-rot BH	Preliminary
	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 $G_{KK} \to \gamma\gamma$	$2\ \gamma$	–	–	20.3	G_{KK} mass 2.66 TeV	$k/\overline{M}_{Pl} = 0.1$	Preliminary
	Bulk RS $G_{KK} \to ZZ \to qq\ell\ell$	$2\ e, \mu$	2 j / 1 J	–	20.3	G_{KK} mass 740 GeV	$k/\overline{M}_{Pl} = 1.0$	1409.6190
	Bulk RS $G_{KK} \to WW \to qq\ell\nu$	$1\ e, \mu$	2 j / 1 J	Yes	20.3	W' mass 700 GeV	$k/\overline{M}_{Pl} = 1.0$	1503.04677
	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	20.3	g_{KK} mass 2.2 TeV	BR = 0.925	ATLAS-CONF-2015-009
	2UED / RPP	$2\ e, \mu$ (SS)	≥ 1 b, ≥ 1 j	Yes	20.3	KK mass 960 GeV		Preliminary
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 2.02 TeV		1502.07177
	SSM $W' \to \ell\nu$	$1\ e, \mu$	–	Yes	20.3	W' mass 3.24 TeV		1407.7494
	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		1409.6190
	HVT $W' \to WH \to \ell\nu bb$	$1\ e, \mu$	2 b	Yes	20.3	W' mass 1.47 TeV	$g_V = 1$	Preliminary
	LRSM $W'_R \to t\bar{b}$	$1\ e, \mu$	2 b, 0-1 j	Yes	20.3	W' mass 1.92 TeV		1410.4103
	LRSM $W'_R \to t\bar{b}$	$0\ e, \mu$	≥ 1 b, 1 J	–	20.3	W' mass 1.76 TeV		1408.0886
CI	CI $qqqq$	–	2 j	–	17.3	Λ 12.0 TeV	$\eta_{LL} = -1$	Preliminary
	CI $qq\ell\ell$	$2\ e, \mu$	–	–	20.3	Λ 21.6 TeV	$\eta_{LL} = -1$	1407.2410
	CI $uutt$	$2\ e, \mu$ (SS)	≥ 1 b, ≥ 1 j	Yes	20.3	Λ 4.35 TeV	$\lvert C_{LL}\rvert = 1$	Preliminary
DM	EFT D5 operator (Dirac)	$0\ e, \mu$	≥ 1 j	Yes	20.3	M_* 974 GeV	at 90% CL for $m(\chi) < 100$ GeV	1502.01518
	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	VLQ $TT \to Ht + X, Wb + X$	$1\ e, \mu$	≥ 1 b, ≥ 3 j	Yes	20.3	T mass 785 GeV	isospin singlet	ATLAS-CONF-2015-012
	VLQ $TT \to Zt + X$	2/≥3 e, μ	≥2/≥1 b	–	20.3	T mass 735 GeV	T in (T,B) doublet	1409.5500
	VLQ $BB \to Zb + X$	2/≥3 e, μ	≥2/≥1 b	–	20.3	B mass 755 GeV	B in (B,Y) doublet	1409.5500
	VLQ $BB \to Wt + X$	$1\ e, \mu$	≥ 1 b, ≥ 5 j	Yes	20.3	B mass 640 GeV	isospin singlet	Preliminary
	$T_{5/3} \to Wt$	$1\ e, \mu$	≥ 1 b, ≥ 5 j	Yes	20.3	$T_{5/3}$ mass 840 GeV		Preliminary
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^*, $\Lambda = m(q^*)$	1407.1376
	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
	Excited lepton $\nu^* \to \ell W, \nu Z$	$3\ e, \mu, \tau$	–	–	20.3	ν^* mass 1.6 TeV	$\Lambda = 1.6$ TeV	1411.2921
Other	LSTC $a_T \to W\gamma$	$1\ e, \mu, 1\ \gamma$	–	Yes	20.3	a_T mass 960 GeV		1407.8150
	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
	Higgs triplet $H^{\pm\pm} \to \ell\ell$	$2\ e, \mu$ (SS)	–	–	20.3	$H^{\pm\pm}$ mass 551 GeV	DY production, BR($H_L^{\pm\pm} \to \ell\ell$)=1	1412.0237
	Higgs triplet $H^{\pm\pm} \to \ell\tau$	$3\ e, \mu, \tau$	–	–	20.3	$H^{\pm\pm}$ mass 400 GeV	DY production, BR($H_L^{\pm\pm} \to \ell\tau$)=1	1411.2921
	Monotop (non-res prod)	$1\ e, \mu$	1 b	Yes	20.3	spin-1 invisible particle mass 657 GeV	$a_{\text{non-res}} = 0.2$	1410.5404
	Multi-charged particles	–	–	–	20.3	multi-charged particle mass 785 GeV	DY production, $\lvert q\rvert = 5e$	Preliminary
	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

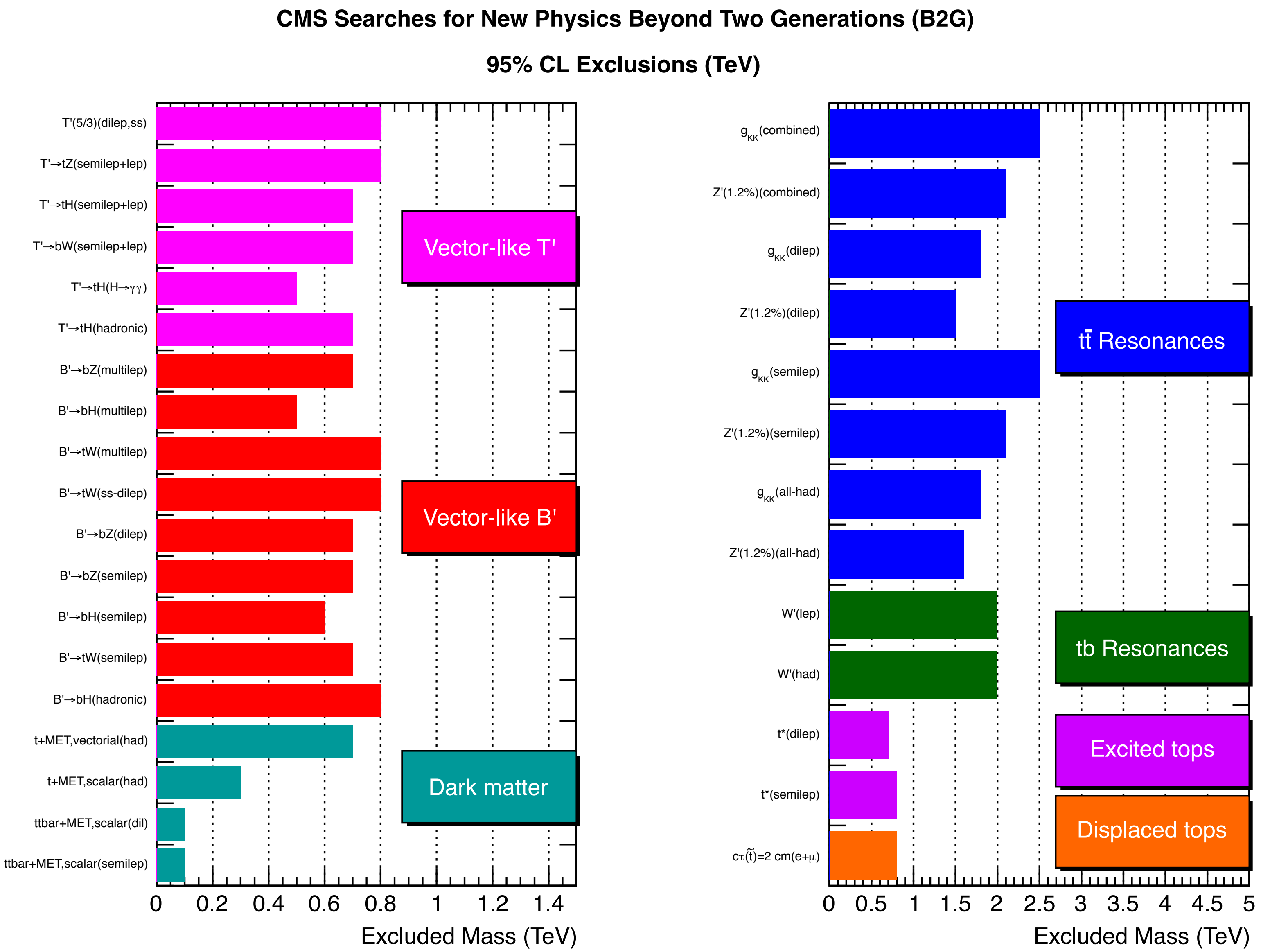
*Only a selection of the available mass limits on new states or phenomena is shown.

Run1 : ATLAS Exotics searches (2)



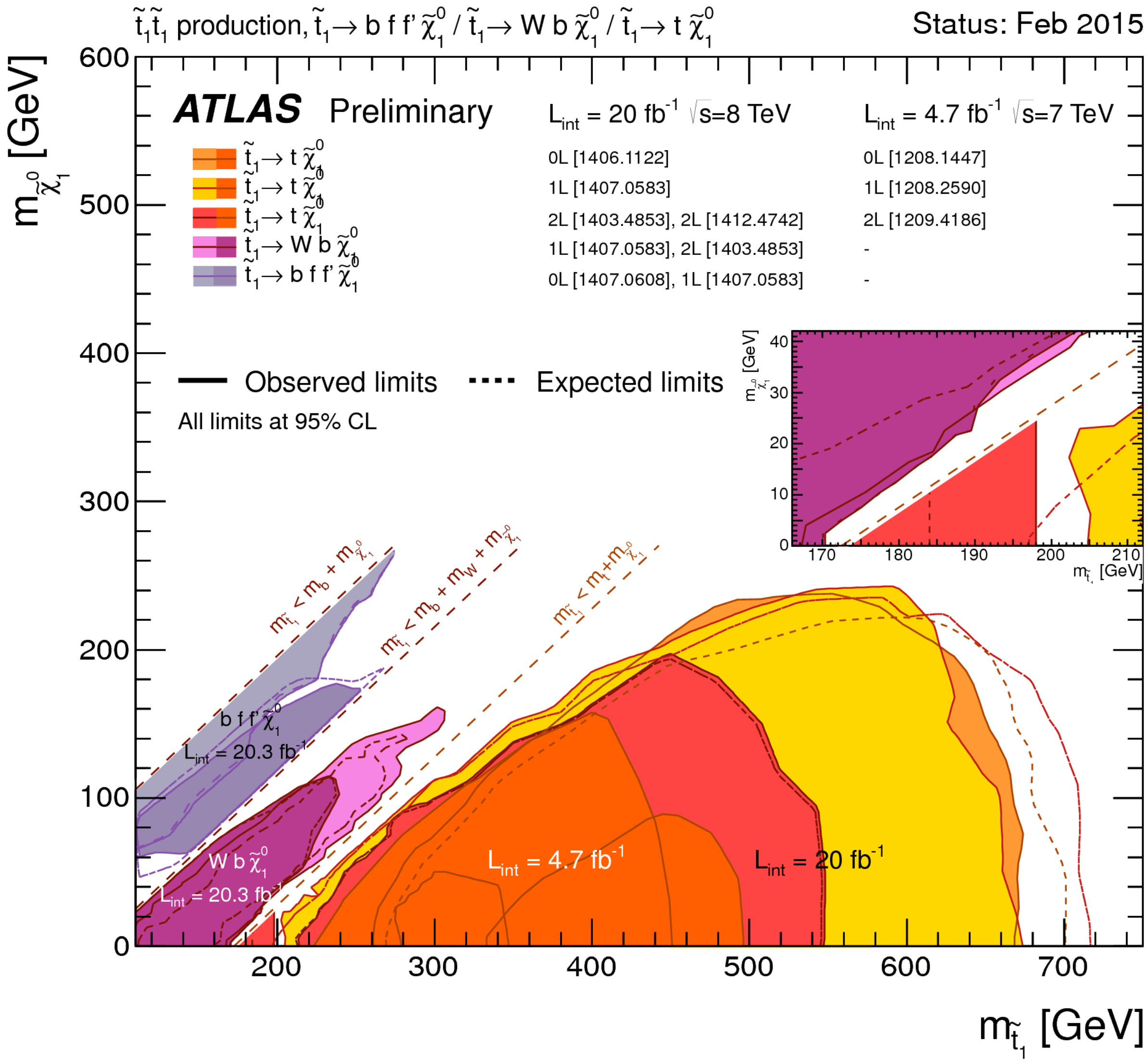
*Only a selection of the available lifetime limits on new states is shown.

Run1 : CMS Exotics searches (2)

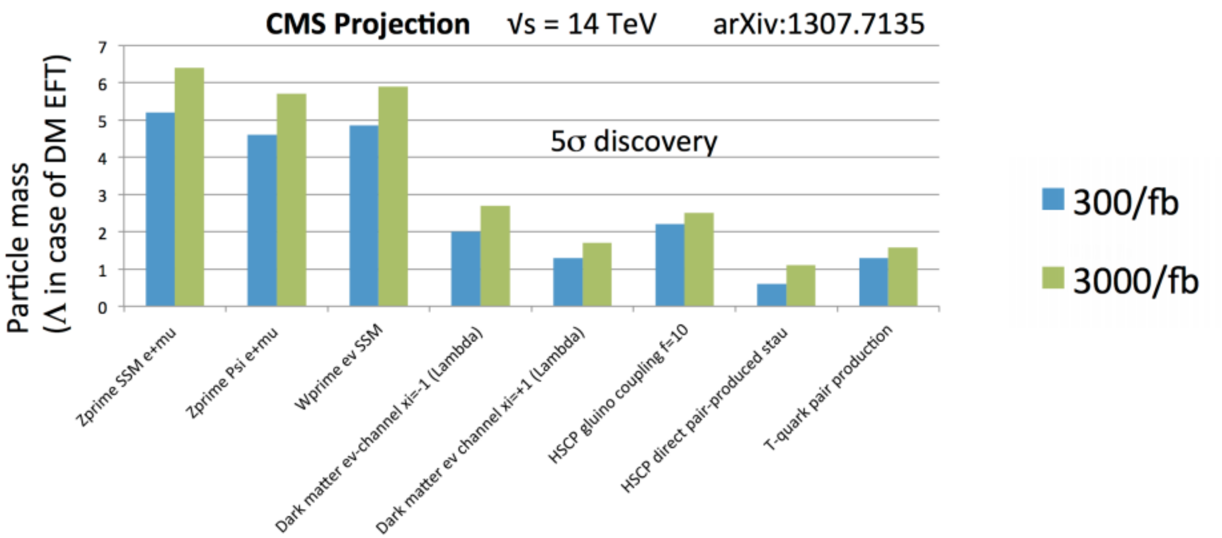


Run1 : Limits on SUSY (1)

- **Strong production**



CMS Exotic Discovery Reach : Run3/HL-LHC



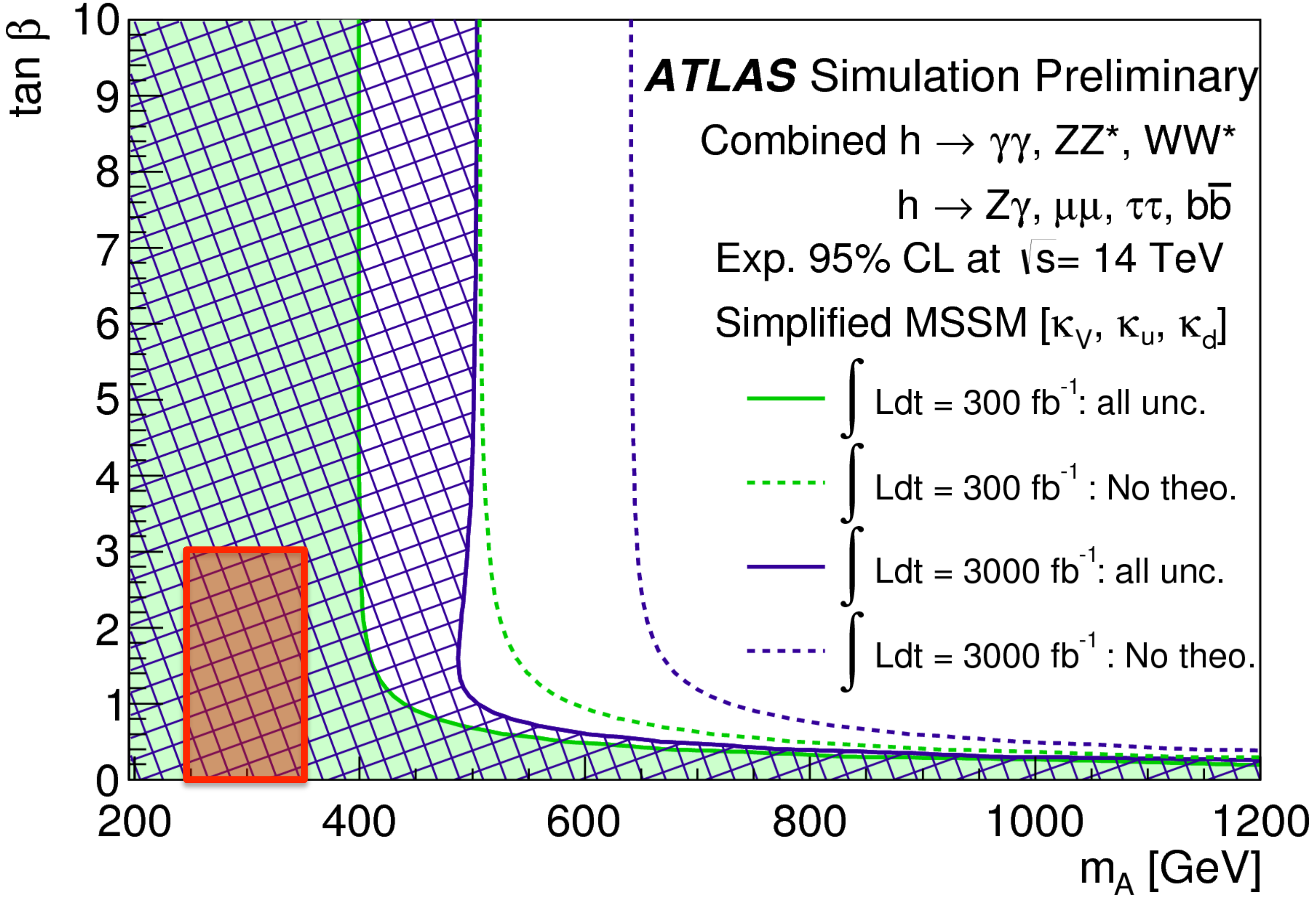
For the EFT description of pair-produced dark matter, the interesting parameter is the cut-off scale Λ = M/sqrt(g_{DM} g_{SM}) with M being the mediator mass (assumed to be high) and g being the DM and SM couplings, respectively. The chosen dark matter monolepton channel allows to study potentially different couplings to up- and down-type quarks parametrized by xi.

Projected performance of selected BSM searches with an upgraded CMS detector at the LHC and HL-LHC (arXiv: 1307.7135).

Except for dark matter, the 5 sigma discovery reach in terms of particle mass is shown. Selected models include new resonances Z′ and W′, heavy stable charged particles (HSCP) such as gluino or stau, and pair-produced T-quarks.

https://twiki.cern.ch/twiki/pub/CMSPublic/PhysicsResultsFP/ECFA-CMSPublicResults.pdf

Run2 (and further) : Higgs searches



ATL-PHYS-PUB-2014-017

≈ Run1 exclusion from p.12