

New Physics Experimental Results at the LHC

Juan Alcaraz Maestre, for the ATLAS&CMS Collaborations

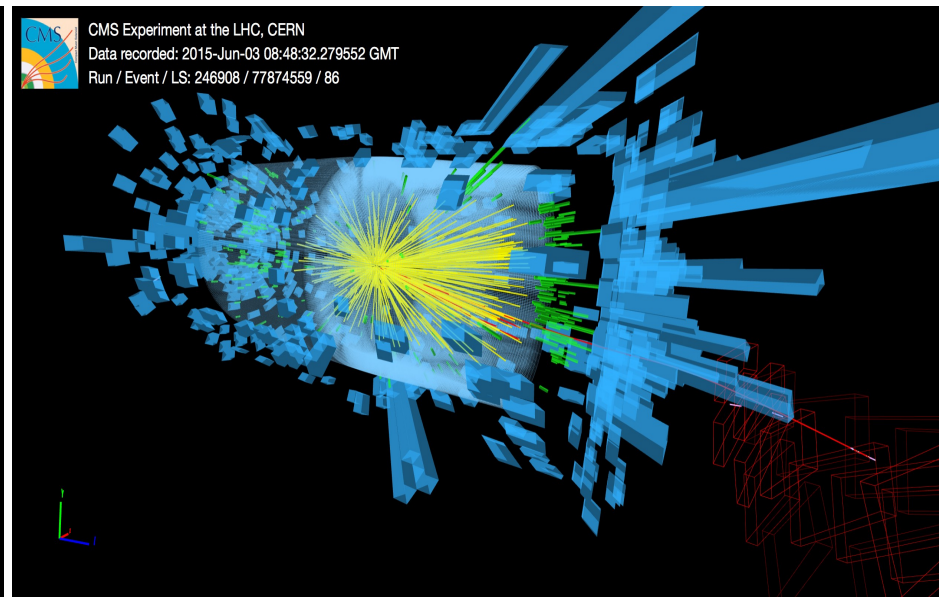
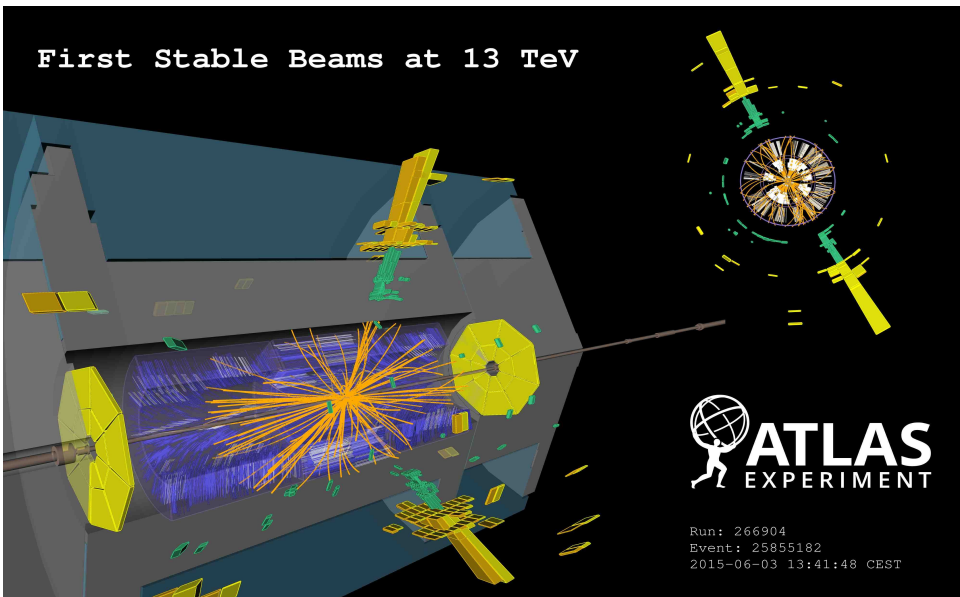
MADRID-CIEMAT

String Pheno 15

9 June 2015

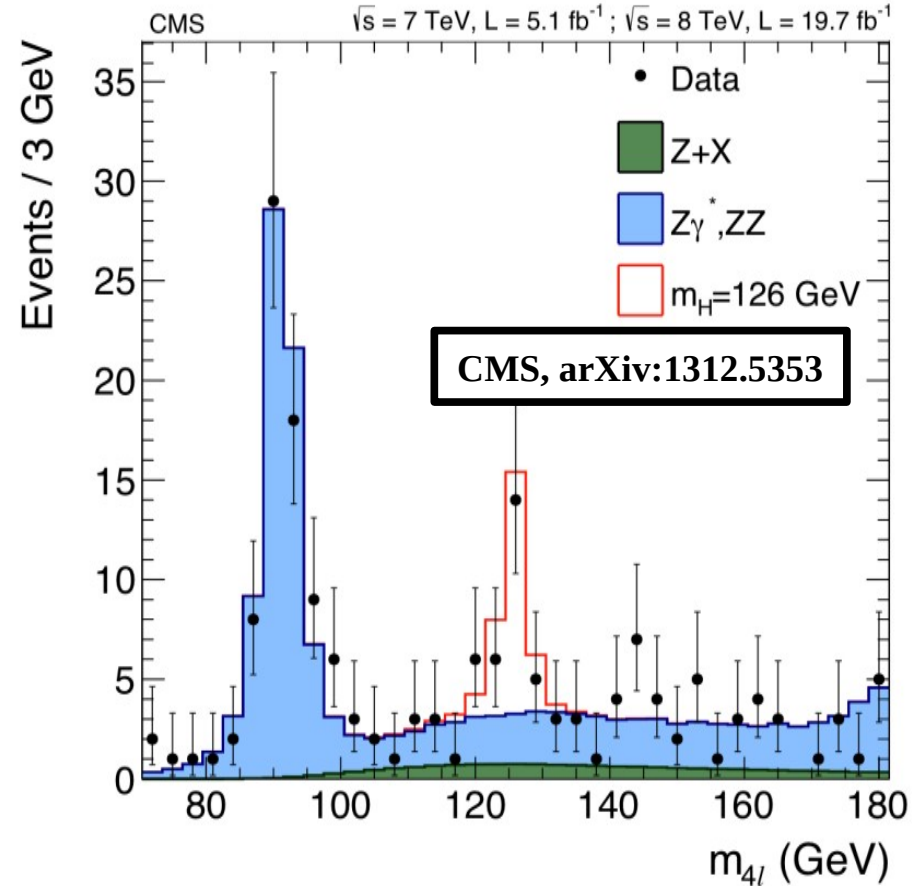
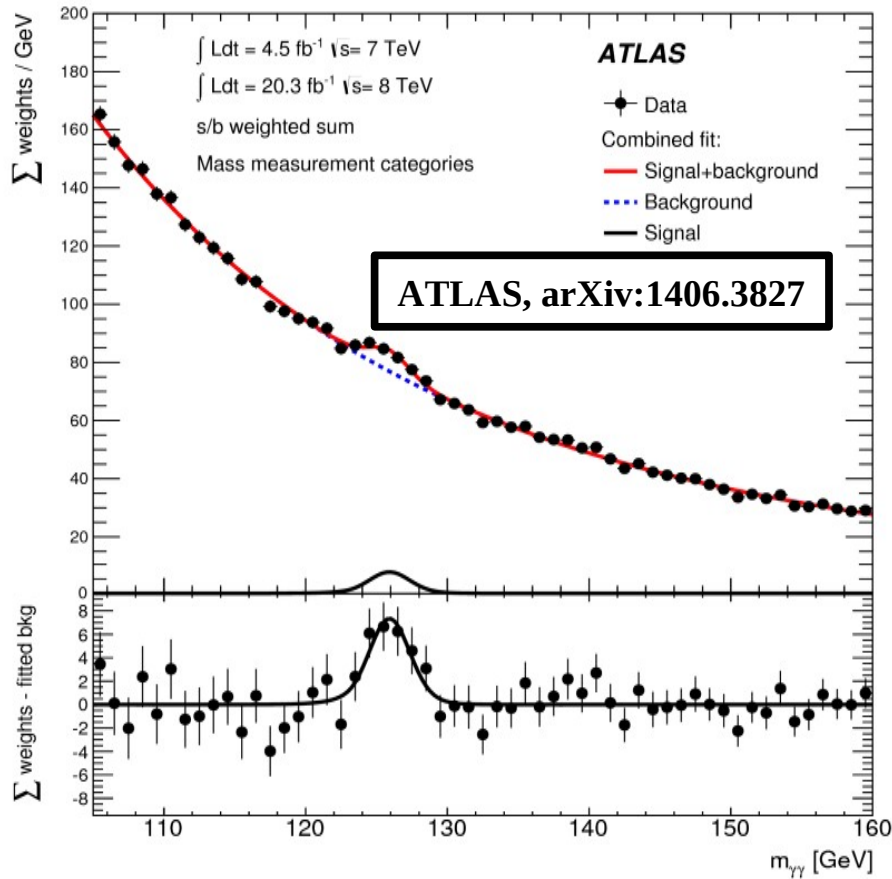
Outline

- No time to cover in detail the enormous search program of the LHC in Run1!! I will focus (briefly) on a few areas:
 - Higgs: basic status as of today
 - Supersymmetry: basics and current 'natural' directions
 - Exotics: dark matter + first signatures to search for at Run2 (starting now!)



HIGGS

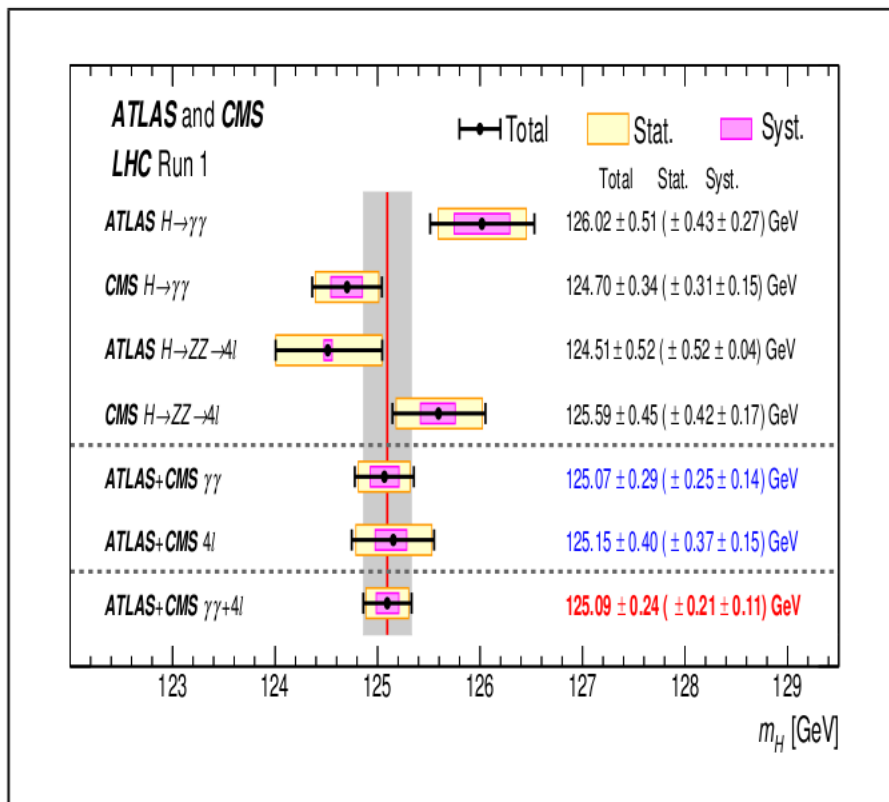
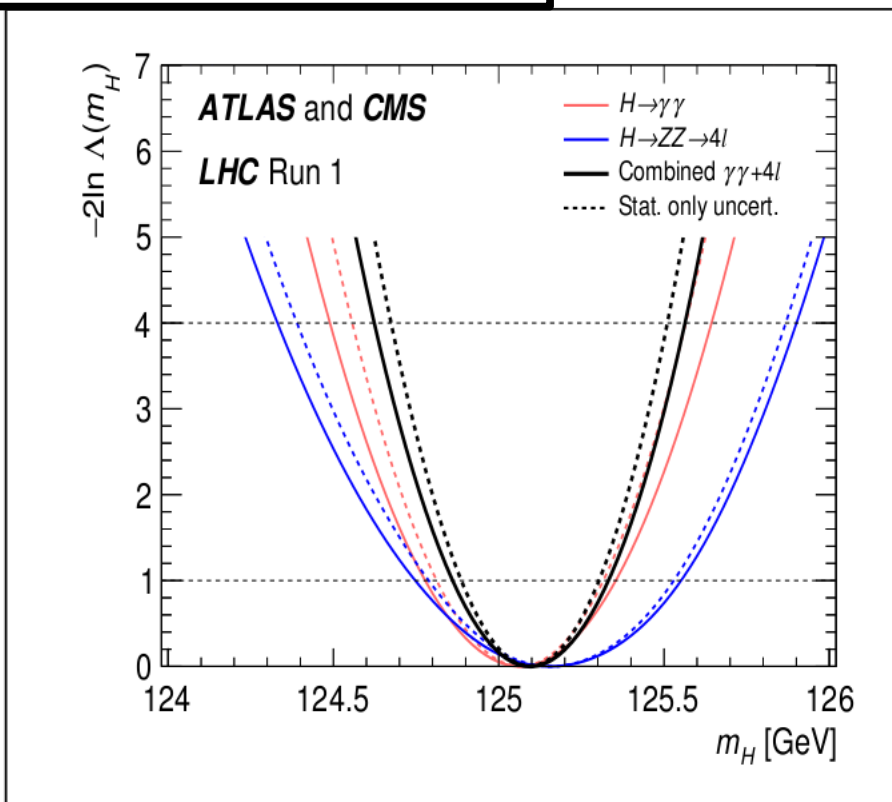
A 'standard' Higgs resonance



- $H \rightarrow \gamma\gamma$ and $H \rightarrow ZZ^* \rightarrow 4l$ are the cleanest channels to 'see' the Higgs resonance 'bump'. They are actually the ones used to determine the mass with high precision.

Its mass

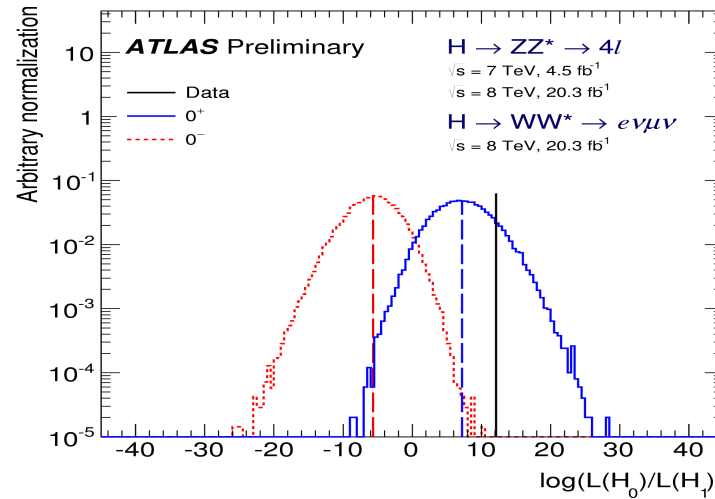
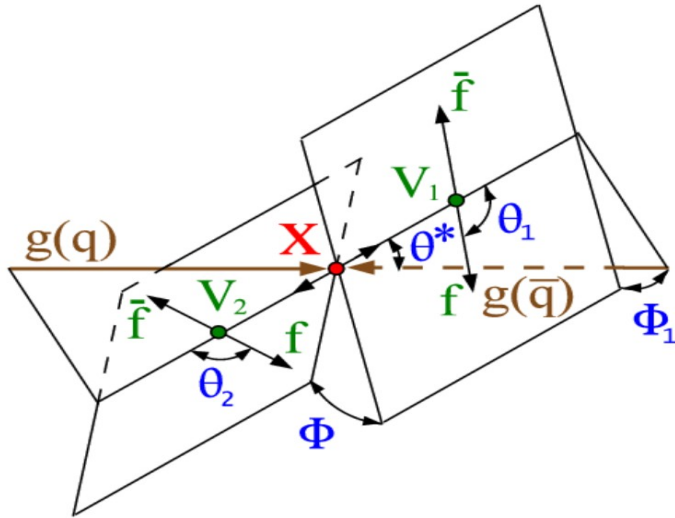
ATLAS+CMS, arXiv:1503.07589



$$m_H = 125.09 \pm 0.21 \text{ (stat.)} \pm 0.11 \text{ (syst.) GeV}$$

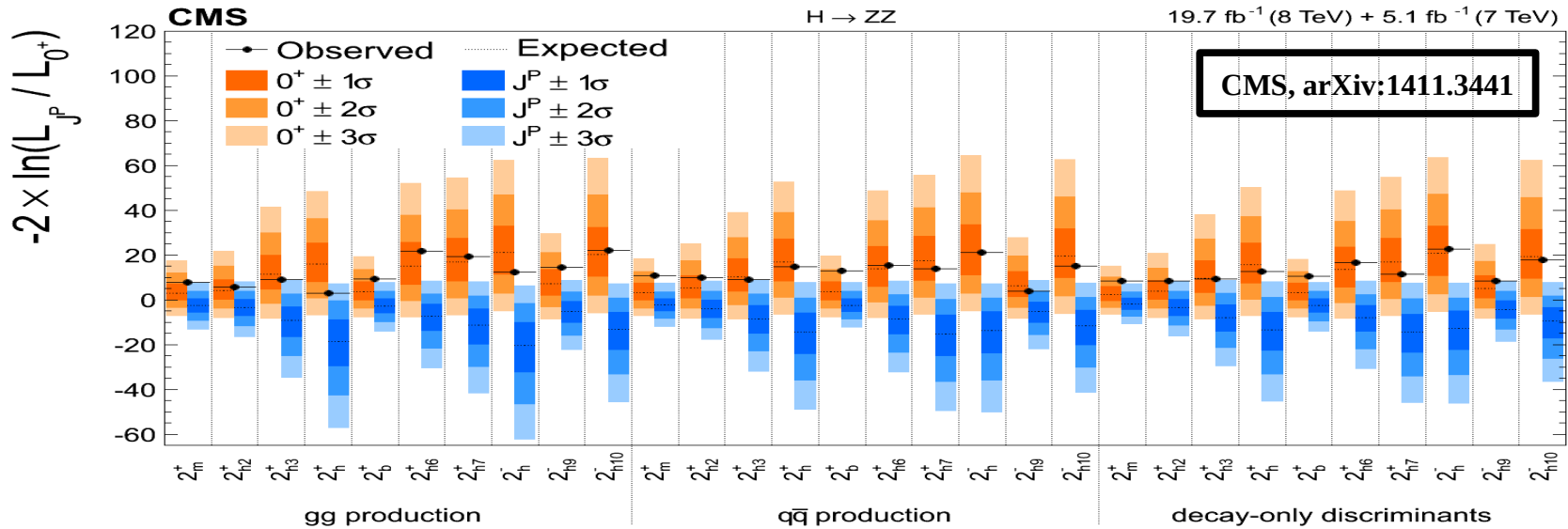
- A – very precise – value that can be considered to be “low” or “high”, depending on your preferred theory beyond the SM...

It really looks like a 'scalar'...



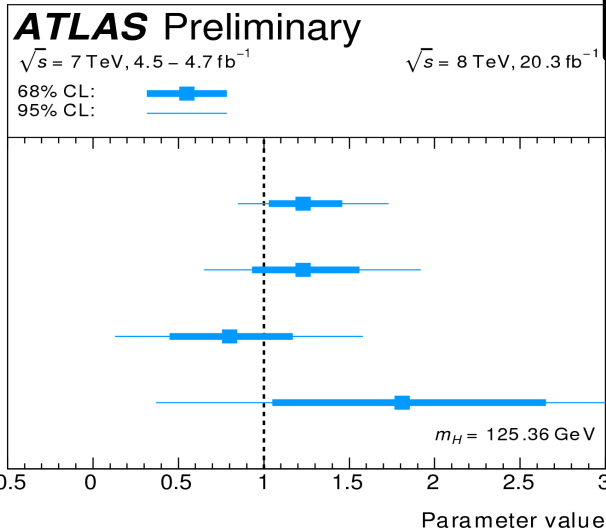
■ **Scalar (0^+)**
VS.
pseudoscalar (0^-)

ATLAS-CONF-2015-008

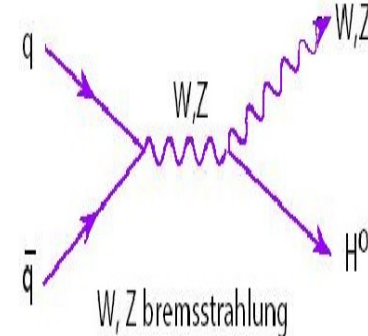
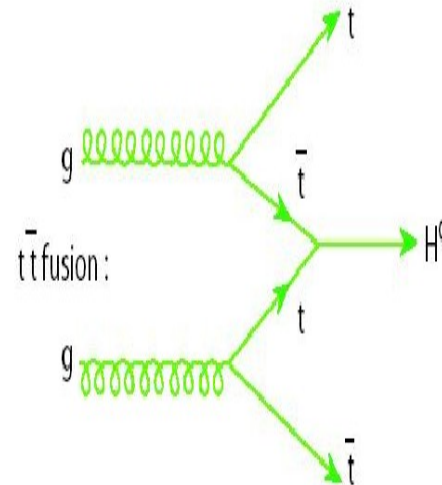
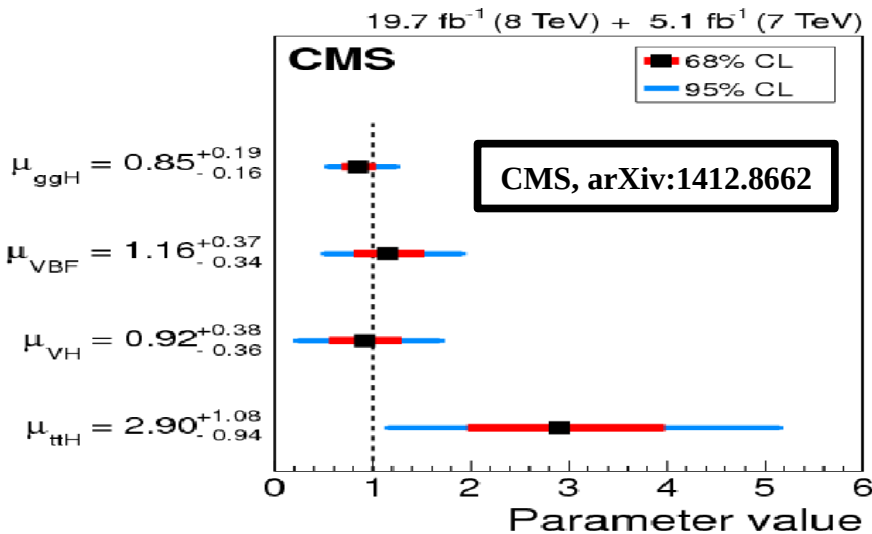
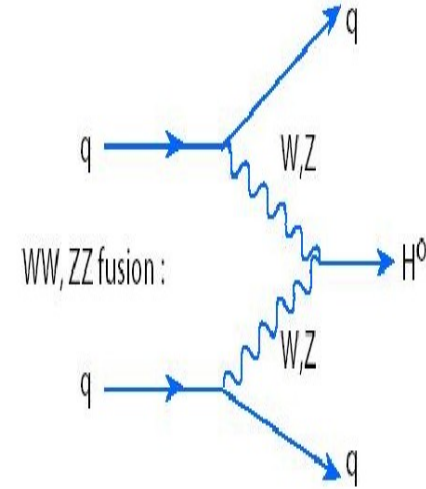
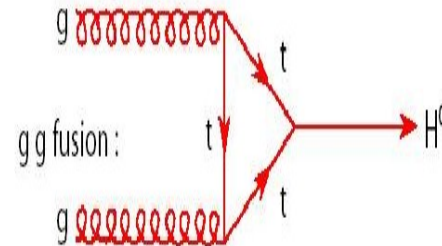


■ Likelihood tests in data consistent with a 0^+ hypothesis (orange bands) when tested against different spin 2 coupling hypotheses (blue bands)

Production properties

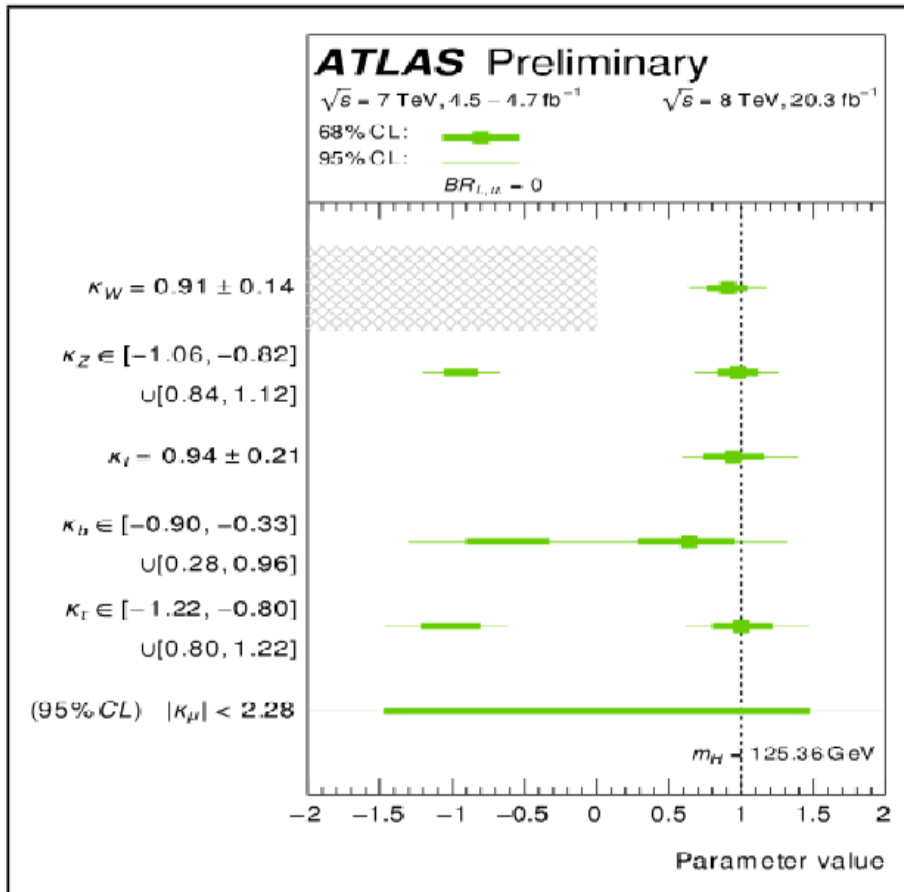


ATLAS-CONF-2015-007

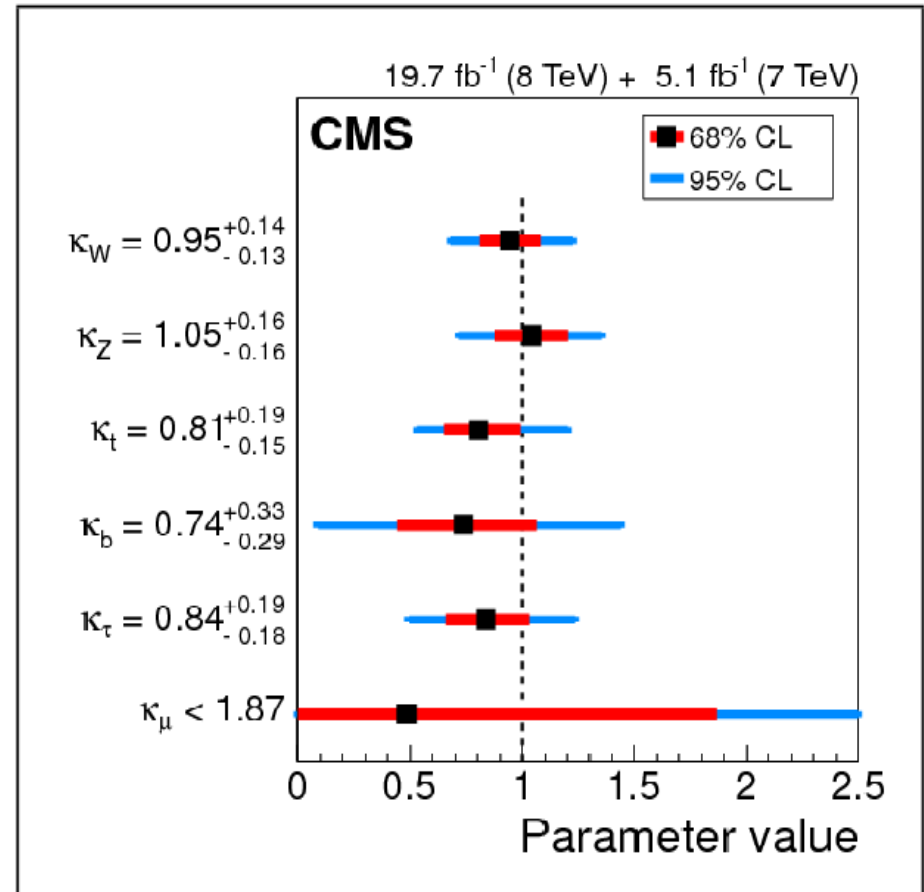


- Only a suggestive deviation in the $t\bar{t}H$ case, but with a large uncertainty

Decay and global coupling properties



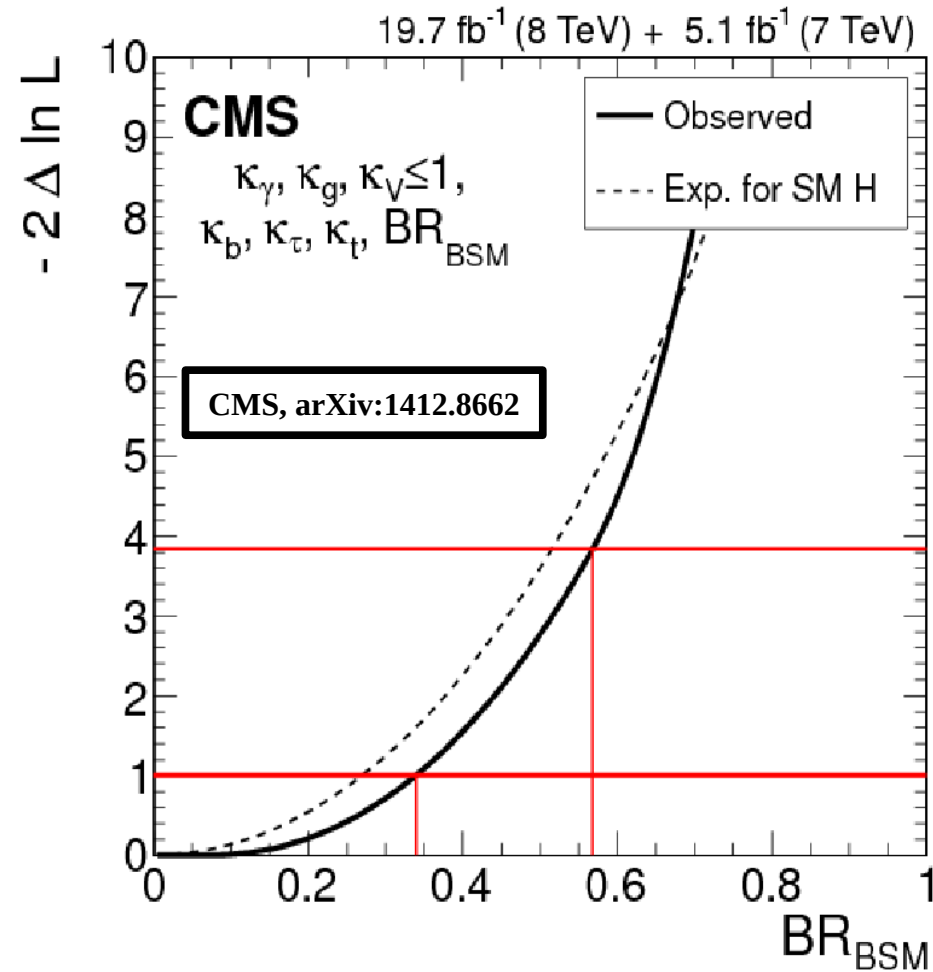
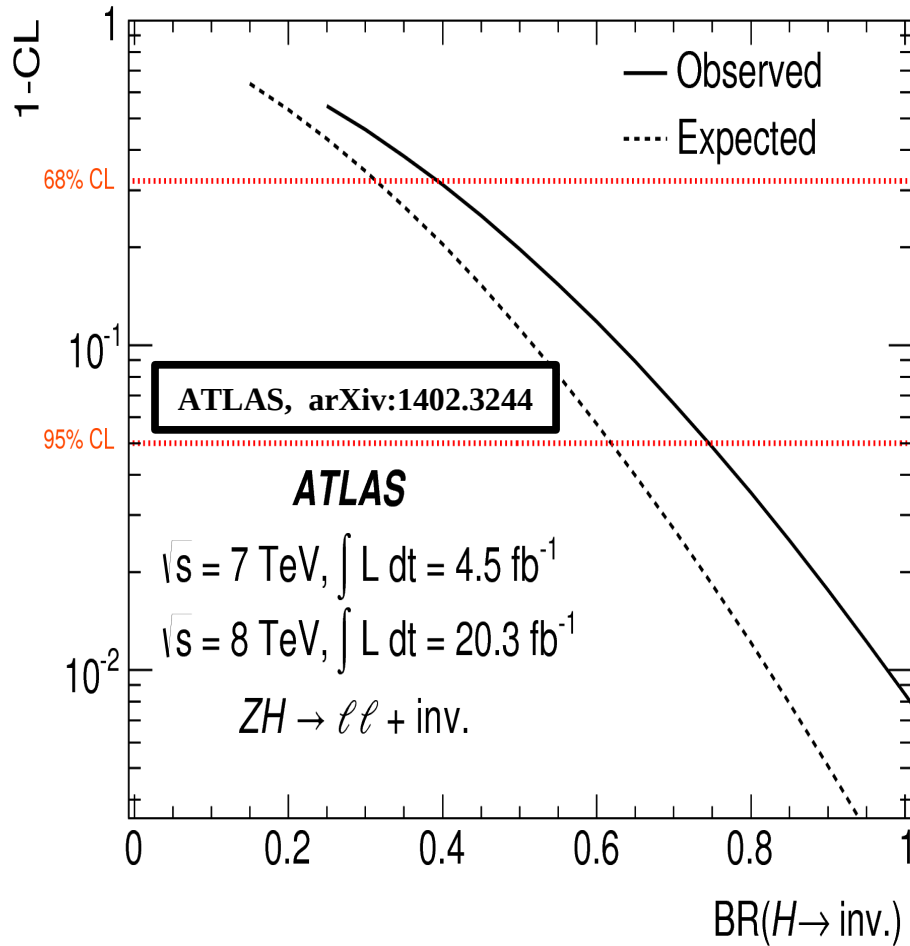
ATLAS-CONF-2015-007



CMS, arXiv:1412.8662

- 6 parameter fit (initial and final state couplings for all channels considered)
 - Not so many channels 'observed' (i.e. $>5\sigma$), but properties agree remarkably well with SM predictions !

Invisible and BSM decays?

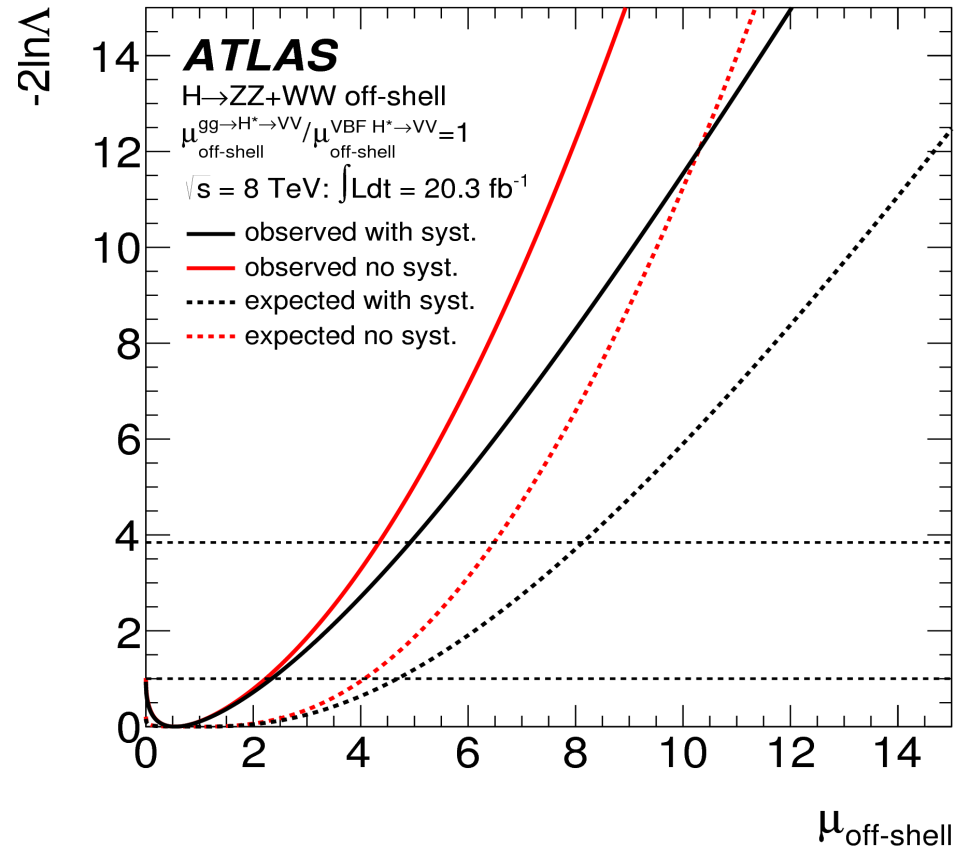
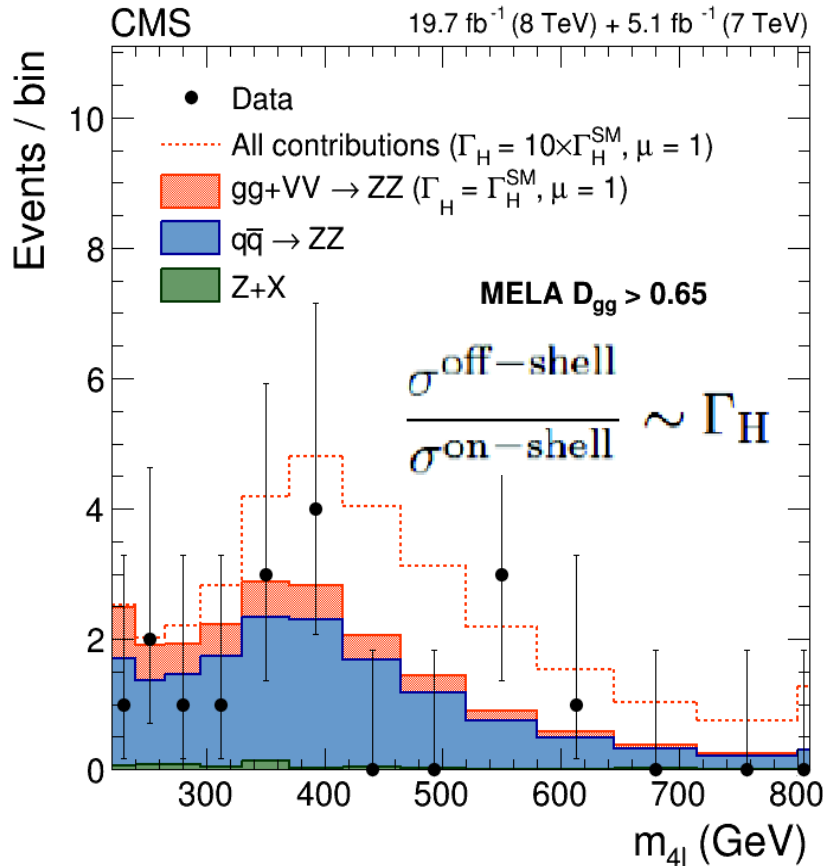


- Branching fraction limits still in the 30% (invisible) - 50% (BSM) range.
- Direct and indirect approaches used to constrain the invisible BR

The Higgs width

CMS, arXiv:1405.3455

ATLAS, arXiv:1503.01060

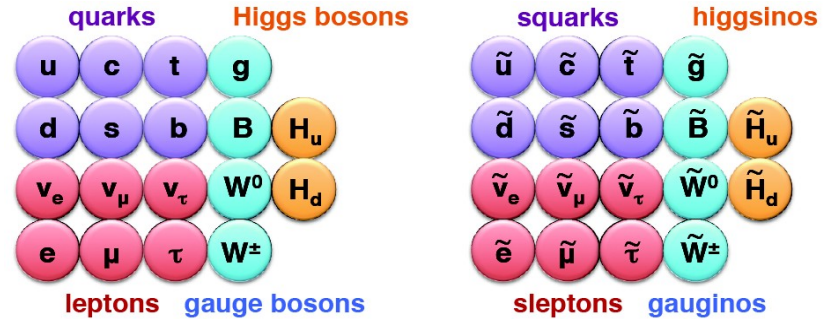


- Higgs production does not vanish so rapidly away from the Higgs resonance region, due to resonant enhancements (ZZ, WW, t \bar{t}):
 - Off-shell/on-shell event ratio proportional to Γ_H
 - Not fully model independent, but 'almost': gg \rightarrow H mode dominating, 0⁺ coupling structure, no coupling evolution in 125-400 GeV range, ...

SUSY

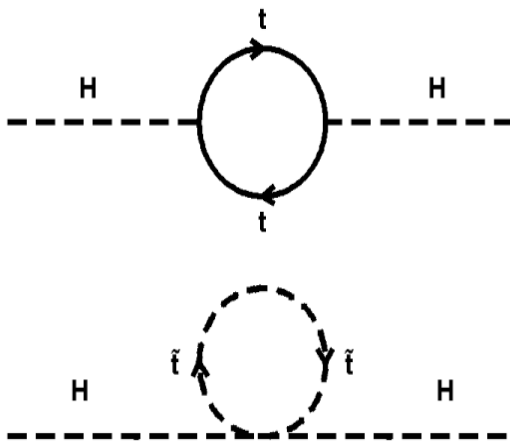
SUSY?

- SuperSymmetry is a new symmetry relating bosons and fermions. For each known particle, we expect a super-symmetric partner, of spin differing by 1/2

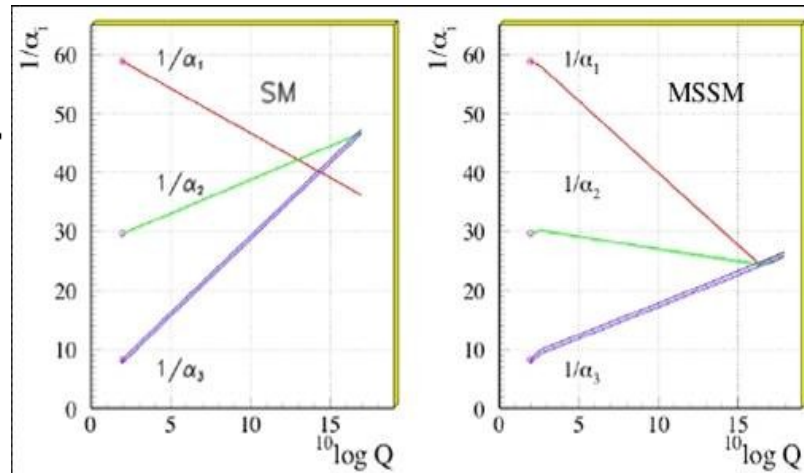


- Reasons to have SUSY realized in nature: maximal possible symmetry, connection with space-time&gravity, nicely consistent with a light Higgs boson, ...

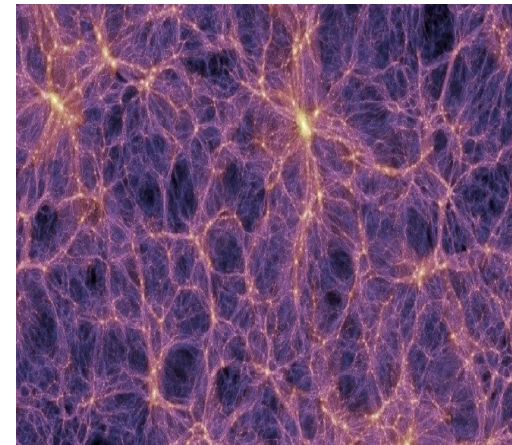
But why SUSY at the TeV scale?



Hierarchy problem solved

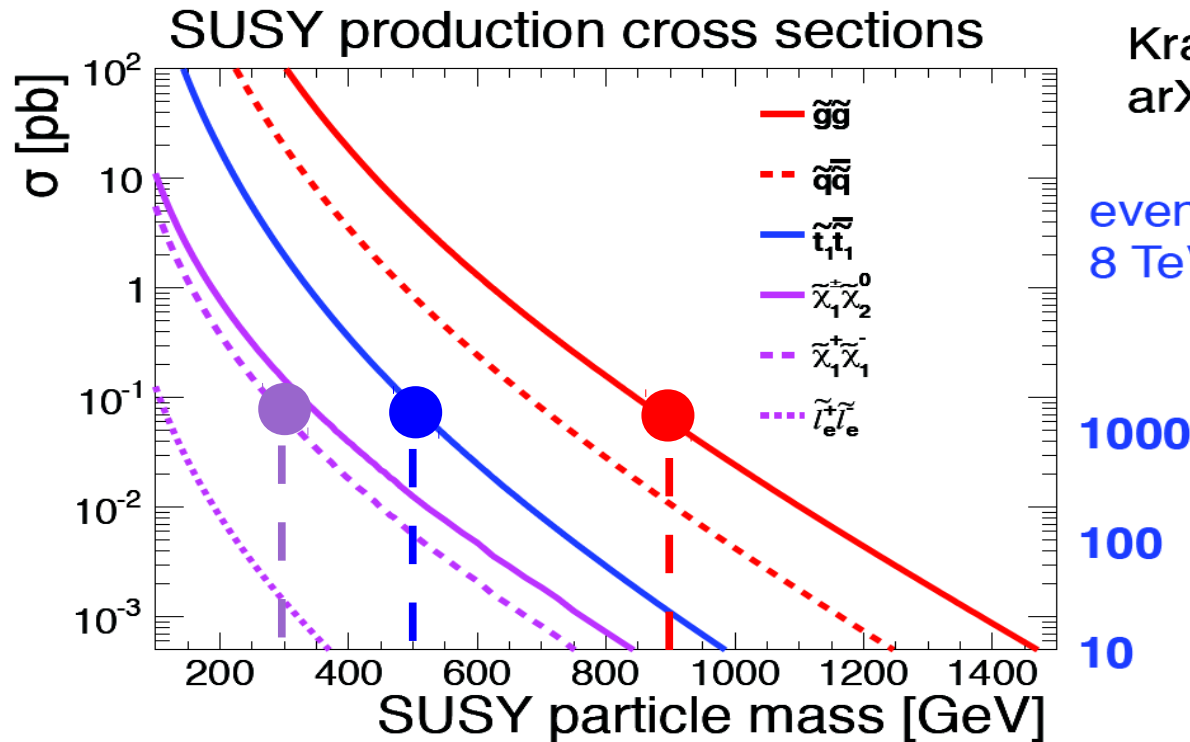


Natural unification of forces



Dark matter candidate

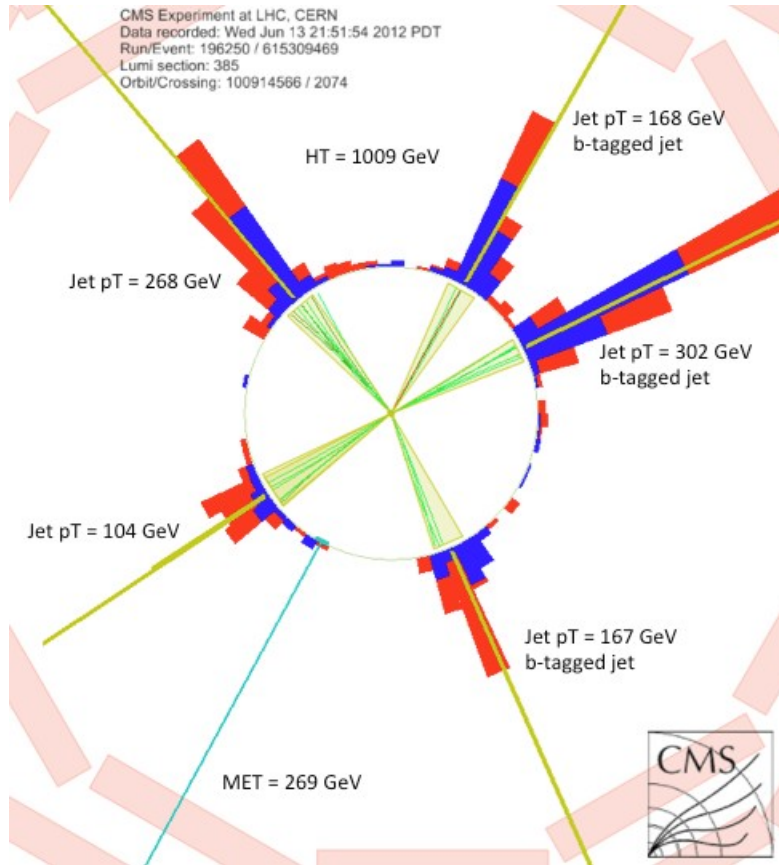
What about SUSY at the LHC?



Kramer et. al.
arXiv:1206.2892

- Production of SUSY particles fully specified by SM couplings for a mass hypothesis
- Gluino-gluino and squark-squark production: QCD driven ($\sigma > 100$ pb at $m = 200$ GeV)
- Ewino and slepton pair production: EWK driven ($\sigma \sim 0.1$ -10 pb at $m = 100$ GeV)
- The most stringent SUSY mass limits at the LHC are obtained by searches for gluino pair production and squark pair production, particularly if all the squarks from the different generations get similar masses.

Looking for SUSY at the LHC

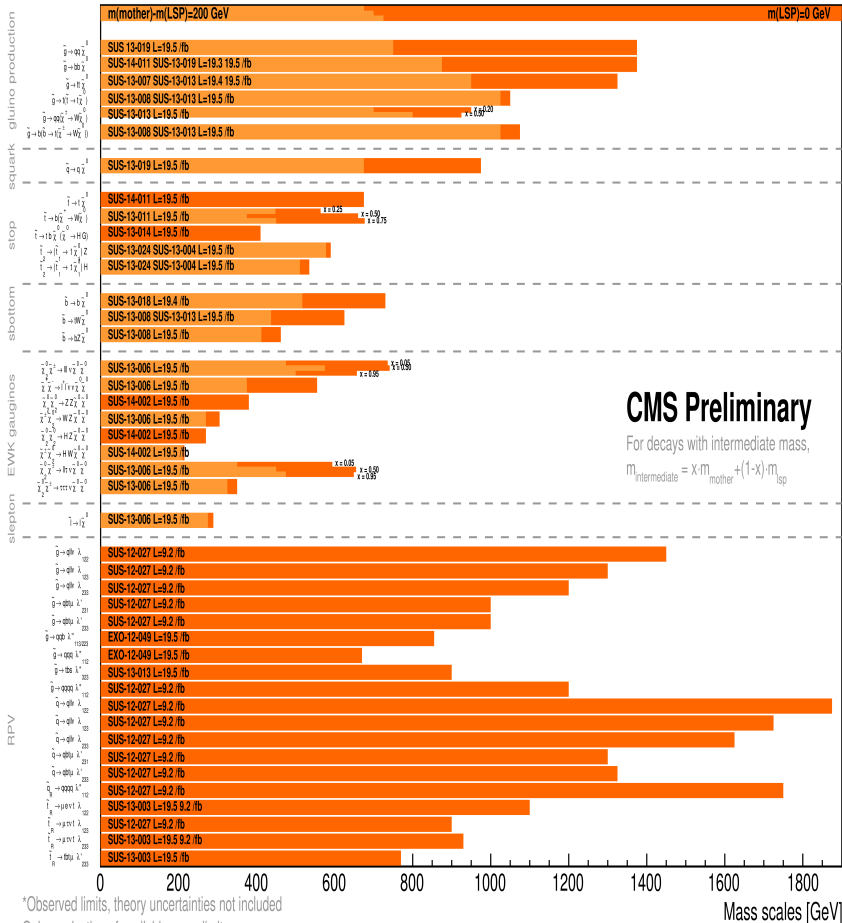


- Basic feature of SUSY signals in many scenarios at the largest explored masses:
 - High visible mass
 - High missing transverse energy/masses when there is a neutral lightest stable particle (LSP)
 - B-tagged jets for 3rd generation focused searches
 - Final states with electrons, muons, taus, lepton pairs (same-sign), or even multileptons for searches with ewkinos, sleptons and tops in the final state

Summary of SUSY searches at the LHC

Summary of CMS SUSY Results* in SMS framework

ICHEP 2014



ATLAS SUSY Searches* - 95% CL Lower Limits

Status: Feb 2015

ATLAS Preliminary

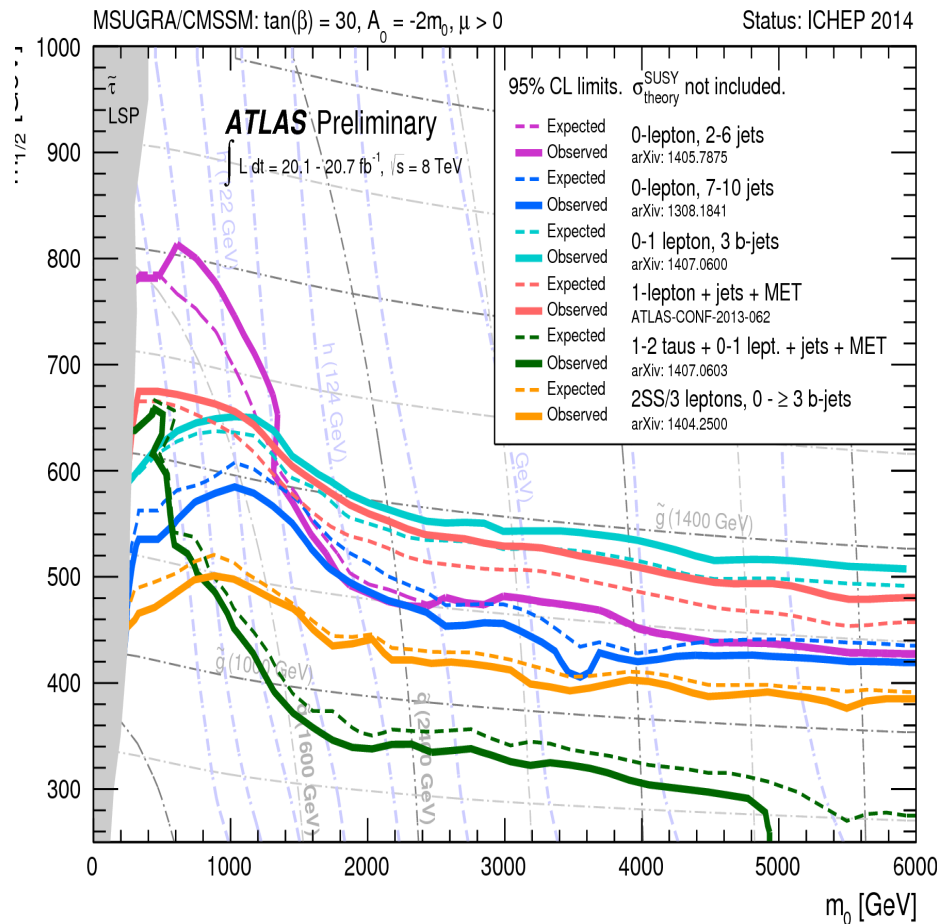
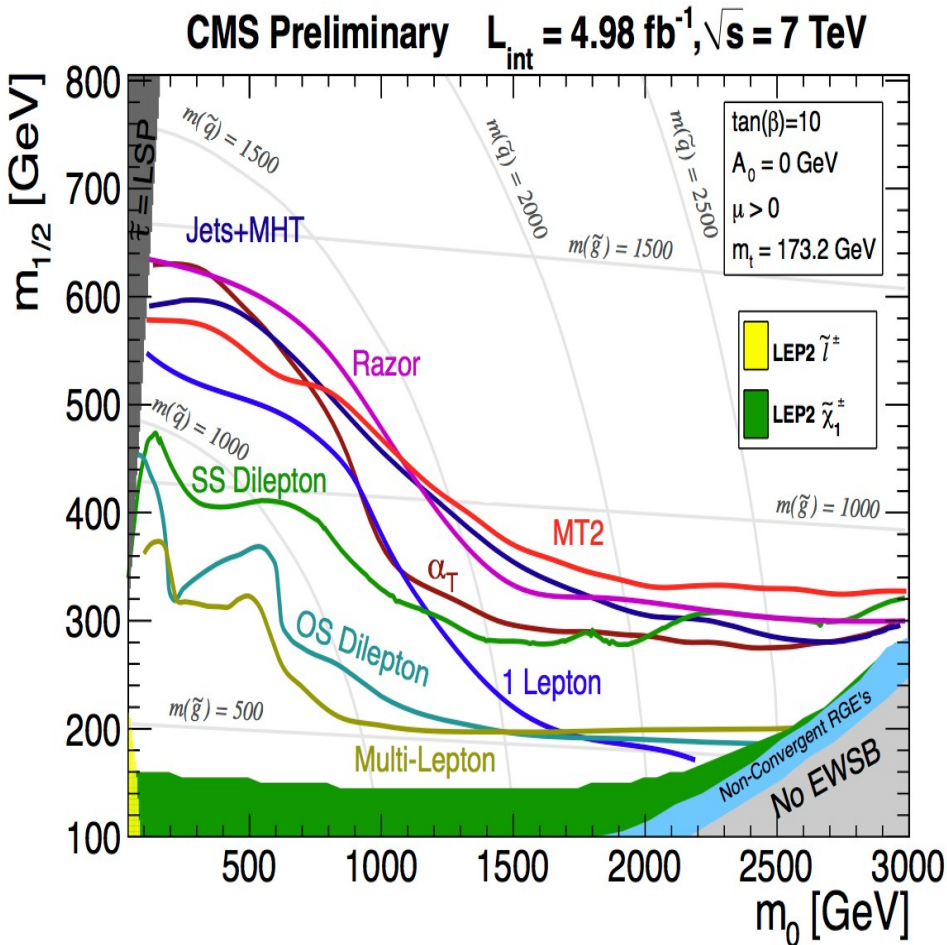
$\sqrt{s} = 7, 8 \text{ TeV}$

Model	e, μ, τ, γ	Jets	$E_{\text{T}}^{\text{miss}}$	$[\mathcal{L} \text{ d}t(\text{fb}^{-1})]$	Mass limit	Reference	
Inclusive Searches	MSUGRA/CMSSM	0 2-6 jets	Yes	20.3	\tilde{g}, \tilde{q} 1.7 TeV	$m(\tilde{g})=m(\tilde{q})$ 1405.7875	
$\tilde{q}\tilde{q}, \tilde{q} \rightarrow \tilde{q}\tilde{g}$	0 2-6 jets	Yes	20.3	\tilde{g} 850 GeV	$m(\tilde{g})=0 \text{ GeV}, m(\tilde{q})=m(\tilde{g})$ 1405.7875		
$\tilde{q}\tilde{q}, \tilde{q} \rightarrow \tilde{q}\tilde{g}$ (compressed)	1 γ 0-1 jet	Yes	20.3	\tilde{g} 250 GeV	$m(\tilde{g})=m(\tilde{q})=m(\nu)$ 1411.1559		
$\tilde{q}\tilde{q}, \tilde{q} \rightarrow \tilde{q}\tilde{g}$	0 2-6 jets	Yes	20.3	\tilde{g} 1.33 TeV	$m(\tilde{g})=0 \text{ GeV}$ 1405.7875		
$\tilde{g}\tilde{g}, \tilde{g} \rightarrow \tilde{q}\tilde{q}\tilde{g}$	1 e, μ 3-6 jets	Yes	20.3	\tilde{g} 1.2 TeV	$m(\tilde{g}) < 200 \text{ GeV}, m(\tilde{q})=0.5(m(\tilde{g})+m(\tilde{q}))$ 1501.03555		
$\tilde{g}\tilde{g}, \tilde{g} \rightarrow \tilde{q}\tilde{q}\tilde{g} \rightarrow \tilde{q}\tilde{q}W\tilde{Z}$	2 e, μ 0-3 jets	Yes	20	\tilde{g} 1.32 TeV	$m(\tilde{g})=0 \text{ GeV}$ 1501.03555		
GMSB (\tilde{g} NLSP)	1-2 $\tau + 0-1 \ell$ 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	$m(\tilde{g}) > 50 \text{ GeV}$ ATLAS-CONF-2014-001		
GGM (wino NLSP)	1 $e, \mu + \gamma$ -	Yes	4.8	\tilde{g} 619 GeV	$m(\tilde{g}) > 50 \text{ GeV}$ ATLAS-CONF-2012-144		
GGM (higgsino-bino NLSP)	7 $1 b$ -	Yes	4.8	\tilde{g} 900 GeV	1211.1167		
GGM (higgsino NLSP)	2 $e, \mu (Z)$ 0-3 jets	Yes	5.8	\tilde{g} 690 GeV	$m(\text{NLSP})=200 \text{ GeV}$ ATLAS-CONF-2012-152		
Gravitino LSP	0 mono-jet	Yes	20.3	\tilde{g} 865 GeV	$m(\tilde{g})=1.8 \times 10^{-4} \text{ eV}, m(\tilde{g})=m(\tilde{g})=1.5 \text{ TeV}$ 1502.01518		
3rd gen. & med.	$\tilde{g} \rightarrow b\tilde{b}, \tilde{t} \rightarrow b\tilde{t}$	0 3 b	Yes	20.1	\tilde{g} 1.25 TeV	$m(\tilde{g}) < 400 \text{ GeV}$ 1407.0600	
$\tilde{g} \rightarrow t\tilde{t}$	0 7-10 jets	Yes	20.3	\tilde{g} 1.1 TeV	$m(\tilde{g}) < 350 \text{ GeV}$ 1308.1841		
$\tilde{g} \rightarrow t\tilde{t}$	0-1 e, μ 3 b	Yes	20.1	\tilde{g} 1.34 TeV	$m(\tilde{g}) < 400 \text{ GeV}$ 1407.0600		
$\tilde{g} \rightarrow b\tilde{t}$	0-1 e, μ 3 b	Yes	20.1	\tilde{g} 1.3 TeV	$m(\tilde{g}) < 300 \text{ GeV}$ 1407.0600		
3rd gen. squarks direct production	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1 \rightarrow b\tilde{t}$	0 2 b	Yes	20.1	\tilde{b}_1 100-620 GeV	$m(\tilde{g}) < 90 \text{ GeV}$ 1308.2851	
$\tilde{b}_1\tilde{b}_1, \tilde{b}_1 \rightarrow b\tilde{t}$	2 e, μ (SS)	0-3 b	Yes	20.3	\tilde{b}_1 275-440 GeV	1404.2630	
$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow W\tilde{b}$ or \tilde{t}_1^0	1-2 e, μ 1-2 b	Yes	4.7	\tilde{t}_1 110-167 GeV	$m(\tilde{g}) = 2m(\tilde{t}_1), m(\tilde{t}_1) = 55 \text{ GeV}$ 1209.2102, 1407.0583		
$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow W\tilde{b}$ or \tilde{t}_1^0	2 e, μ 0-2 jets	Yes	20.3	\tilde{t}_1 90-191 GeV	$m(\tilde{g}) = 1 \text{ GeV}$ 1403.6853, 1412.4742		
$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow W\tilde{b}$	0-1 e, μ 1-2 b	Yes	20	\tilde{t}_1 210-640 GeV	$m(\tilde{g}) = 1 \text{ GeV}$ 1407.0583, 1406.1122		
$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow W\tilde{b}$	0 mono-jet+tag	Yes	20.3	\tilde{t}_1 90-240 GeV	$m(\tilde{g}) = 1 \text{ GeV}$ 1407.0608		
$\tilde{t}_1\tilde{t}_1$ (natural GMSB)	2 $e, \mu (Z)$ 1 b	Yes	20.3	\tilde{t}_1 150-580 GeV	$m(\tilde{g}) > 150 \text{ GeV}$ 1403.5222		
$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow \tilde{t}_1 + Z$	3 $e, \mu (Z)$ 1 b	Yes	20.3	\tilde{t}_1 290-600 GeV	$m(\tilde{g}) > 200 \text{ GeV}$ 1403.5222		
EW direct	$\tilde{L}_R \tilde{L}_R, \tilde{L} \rightarrow \tilde{L}\tilde{L}$	2 e, μ 0	Yes	20.3	\tilde{L} 90-325 GeV	$m(\tilde{g}) = 0 \text{ GeV}$ 1403.5294	
$\tilde{X}_1^0 \tilde{X}_1^0, \tilde{X}_1^0 \rightarrow \tilde{L}\tilde{L}(\nu)$	2 e, μ 0	Yes	20.3	\tilde{X}_1^0 140-465 GeV	$m(\tilde{g}) = 0 \text{ GeV}, m(\tilde{L}) = 0.5(m(\tilde{L}) + m(\tilde{L}))$ 1403.5294		
$\tilde{X}_1^0 \tilde{X}_1^0, \tilde{X}_1^0 \rightarrow \tilde{L}\tilde{L}(\nu)$	2 τ -	Yes	20.3	\tilde{X}_1^0 100-350 GeV	$m(\tilde{g}) = 0 \text{ GeV}, m(\tilde{L}) = 0.5(m(\tilde{L}) + m(\tilde{L}))$ 1407.0350		
$\tilde{X}_1^0 \tilde{X}_1^0 \rightarrow \tilde{L}\tilde{L}(\nu), \tilde{X}_1^0 \rightarrow \tilde{L}\tilde{L}(\nu)$	3 e, μ 0	Yes	20.3	$\tilde{X}_1^0, \tilde{X}_1^0$ 700 GeV	$m(\tilde{g}) = m(\tilde{L}), m(\tilde{L}) = 0, m(\tilde{L}) = 0.5(m(\tilde{L}) + m(\tilde{L}))$ 1402.7029		
$\tilde{X}_1^0 \tilde{X}_1^0 \rightarrow W\tilde{Z}, \tilde{X}_1^0 \rightarrow \tilde{L}\tilde{L}(\nu)$	2-3 e, μ 0-2 jets	Yes	20.3	$\tilde{X}_1^0, \tilde{X}_1^0$ 420 GeV	$m(\tilde{g}) = m(\tilde{L}), m(\tilde{L}) = 0$, sleptons decoupled 1403.5294, 1402.7029		
$\tilde{X}_1^0 \tilde{X}_1^0 \rightarrow W\tilde{Z}, \tilde{X}_1^0 \rightarrow \tilde{L}\tilde{L}(\nu)$	0 e, μ, γ 0-2 b	Yes	20.3	$\tilde{X}_1^0, \tilde{X}_1^0$ 250 GeV	$m(\tilde{g}) = m(\tilde{L}), m(\tilde{L}) = 0$, sleptons decoupled 1501.0710		
$\tilde{X}_1^0 \tilde{X}_1^0, \tilde{X}_1^0 \rightarrow \tilde{L}\tilde{L}(\nu)$	4 e, μ 0	Yes	20.3	$\tilde{X}_1^0, \tilde{X}_1^0$ 620 GeV	$m(\tilde{g}) = m(\tilde{L}), m(\tilde{L}) = 0, m(\tilde{L}) = 0.5(m(\tilde{L}) + m(\tilde{L}))$ 1405.5086		
Long-lived particles	Direct $\tilde{X}_1^0 \tilde{X}_1^0$ prod., long-lived \tilde{X}_1^0	Disapp. trk	1 jet	Yes	20.3	\tilde{X}_1^0 270 GeV	1310.3675
Stable, stopped \tilde{g} R-hadron	0 1-5 jets	Yes	27.9	\tilde{g} 832 GeV	$m(\tilde{g}) = 100 \text{ GeV}, 10 \mu\text{s} < \tau(\tilde{g}) < 1000 \text{ s}$ 1310.6584		
Stable \tilde{g} R-hadron	trk -	-	19.1	\tilde{g} 1.27 TeV	1411.6795		
GMSB, stable $\tilde{g}, \tilde{X}_1^0 \rightarrow \tilde{L}\tilde{L}(\nu), \tau(e, \mu)$	1-2 μ -	-	19.1	\tilde{X}_1^0 537 GeV	$10^{-4} \text{ tan}\beta < 50$ 1411.6795		
GMSB, $\tilde{X}_1^0 \rightarrow \tilde{g}\tilde{g}$, long-lived \tilde{X}_1^0	2 γ -	Yes	20.3	\tilde{X}_1^0 435 GeV	$2 < \tau(\tilde{X}_1^0) < 3 \text{ ns}$, SPSS model 1409.5542		
$\tilde{q}\tilde{q}, \tilde{X}_1^0 \rightarrow \tilde{q}\tilde{q}$ (RPV)	1 μ , displ. vtx	-	20.3	\tilde{X}_1^0 1.0 TeV	$1.5 < \tau < 156 \text{ mm}$, BR(μ)=1, $m(\tilde{X}_1^0)=108 \text{ GeV}$ ATLAS-CONF-2013-092		
RPV	LFV $pp \rightarrow \tilde{\nu}_i + X, \tilde{\nu}_i \rightarrow e + \mu$	2 e, μ -	-	4.6	$\tilde{\nu}_i$ 1.61 TeV	$A_{111} = 0.10, A_{121} = 0.05$ 1212.1272	
LFV $pp \rightarrow \tilde{\nu}_i + X, \tilde{\nu}_i \rightarrow e(\mu) + \tau$	1 $e, \mu + \tau$ -	-	4.6	$\tilde{\nu}_i$ 1.1 TeV	$A_{111} = 0.10, A_{121} = 0.05$ 1212.1272		
Bilinear RPV CMSSM	2 e, μ (SS)	0-3 b	Yes	20.3	\tilde{g}, \tilde{q} 1.35 TeV	$m(\tilde{g}) = m(\tilde{q}), \tau_{121} < 1 \text{ mm}$ 1404.2500	
$\tilde{X}_1^0 \tilde{X}_1^0, \tilde{X}_1^0 \rightarrow W\tilde{Z}, \tilde{X}_1^0 \rightarrow e\tilde{\nu}_e, \mu\tilde{\nu}_\mu$	4 e, μ -	Yes	20.3	\tilde{X}_1^0 750 GeV	$m(\tilde{g}) > 0.2 m(\tilde{X}_1^0), A_{121} = 0$ 1405.5086		
$\tilde{X}_1^0 \tilde{X}_1^0, \tilde{X}_1^0 \rightarrow W\tilde{Z}, \tilde{X}_1^0 \rightarrow \tau\tilde{\nu}_\tau, e\tilde{\nu}_e$	3 $e, \mu + \tau$ -	Yes	20.3	\tilde{X}_1^0 450 GeV	$m(\tilde{g}) > 0.2 m(\tilde{X}_1^0), A_{121} = 0$ 1405.5086		
$\tilde{g} \rightarrow \tilde{q}\tilde{q}$	0 6-7 jets	-	20.3	\tilde{g} 916 GeV	BR(μ)=BR(ν)=BR(τ)=0% ATLAS-CONF-2013-091		
$\tilde{g} \rightarrow \tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow b\tilde{t}$	2 e, μ (SS)	0-3 b	Yes	20.3	\tilde{g} 850 GeV	1404.2500	
Other	Scalar charm, $\tilde{c} \rightarrow \tilde{c}\tilde{g}$	0 2 c	Yes	20.3	\tilde{c} 490 GeV	$m(\tilde{g}) > 200 \text{ GeV}$ 1501.01325	

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

- Many possible signals explored. No evidence of SUSY yet. Several lower limits to masses are already around the TeV.

Naive approaches already exhausted

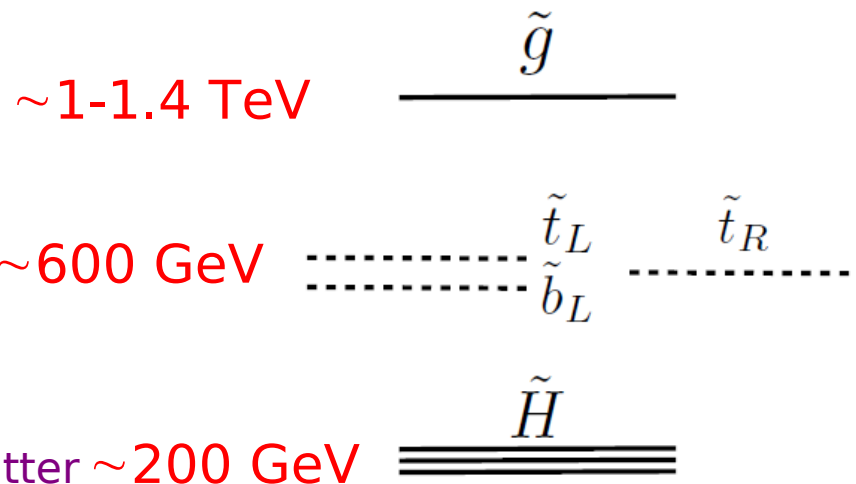


- A significant fraction of the available phase space in the “Constrained” Minimal Supersymmetric Standard Model (CMSSM) was already excluded with 7 TeV data, and also in the post-Higgs era for scenarios consistent with $m_H \approx 126 \text{ GeV}$

Still 'natural' SUSY?

- Minimal conditions to be satisfied:
 - The MSSM imposes tight constraints on the masses of Higgsinos and stop sector, since they are directly related to the EWK scale:

$$M_Z^2 = \underbrace{-2\mu^2}_{\text{Higgsino}} + 2 \frac{m_{H_d}^2 - t_\beta^2 \underbrace{m_{H_u}^2}_{\text{Stop, gluino}}}{t_\beta^2 - 1}$$



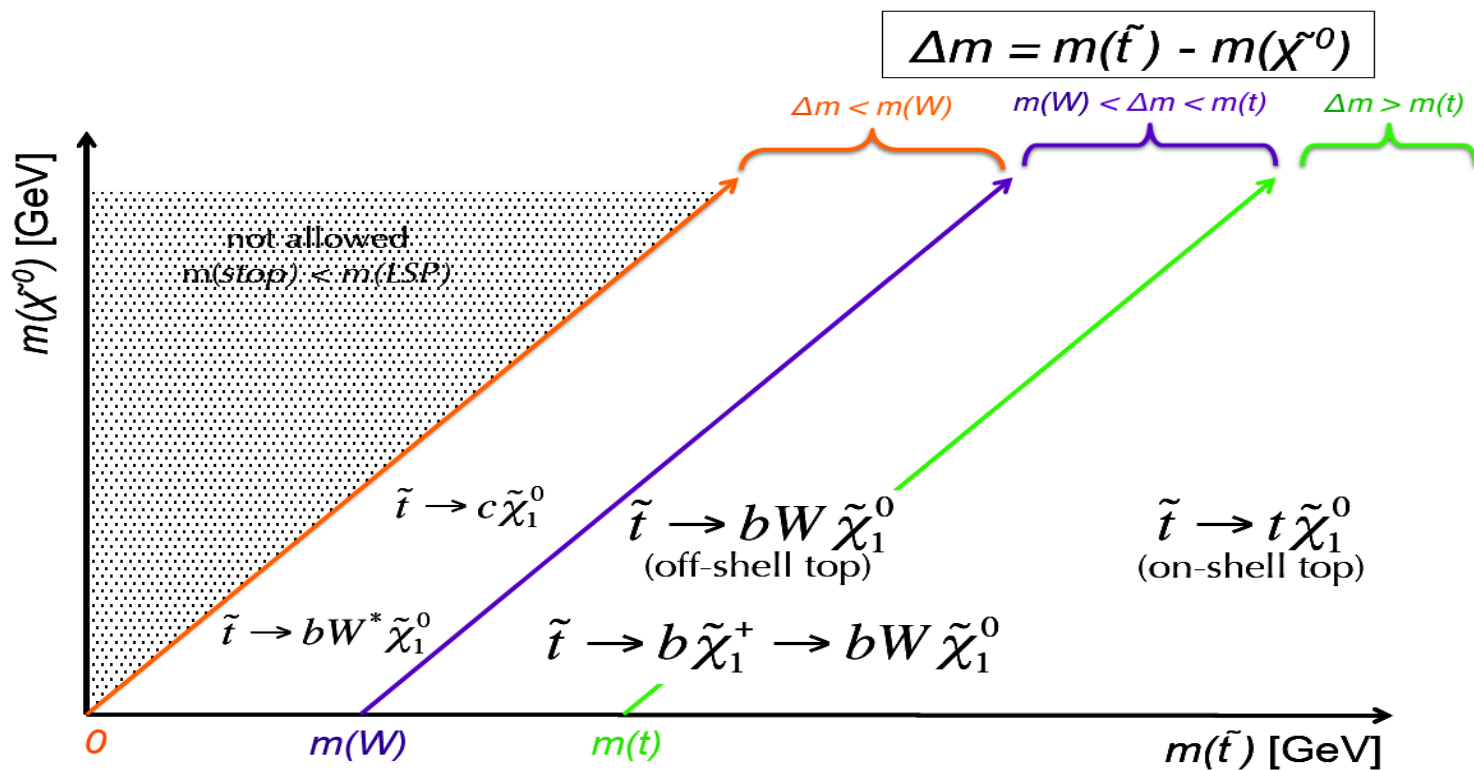
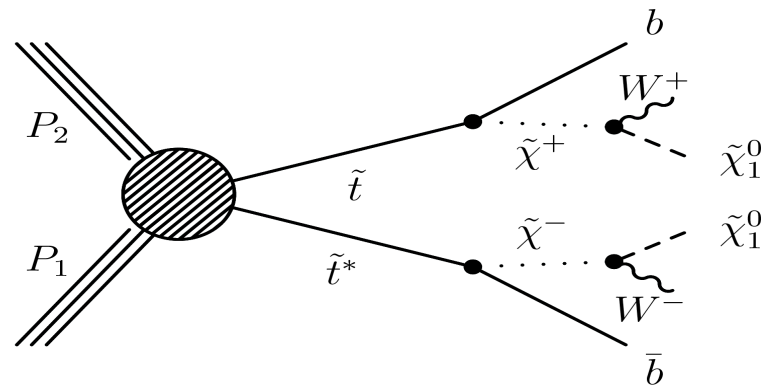
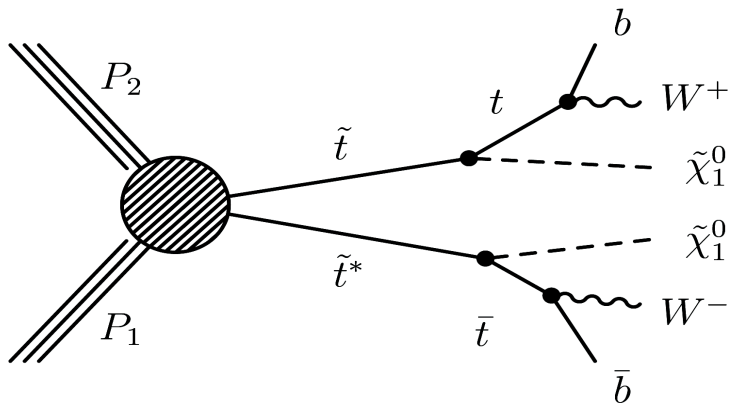
- The gluino can not be too massive (it contributes to the stop mass via loops)
- One of the Higgsinos can be a dark matter candidate if it is the lightest stable particle (LSP).
- The sbottom-left and the stop-left masses are related

natural SUSY

(example from arXiv:1110.6926)

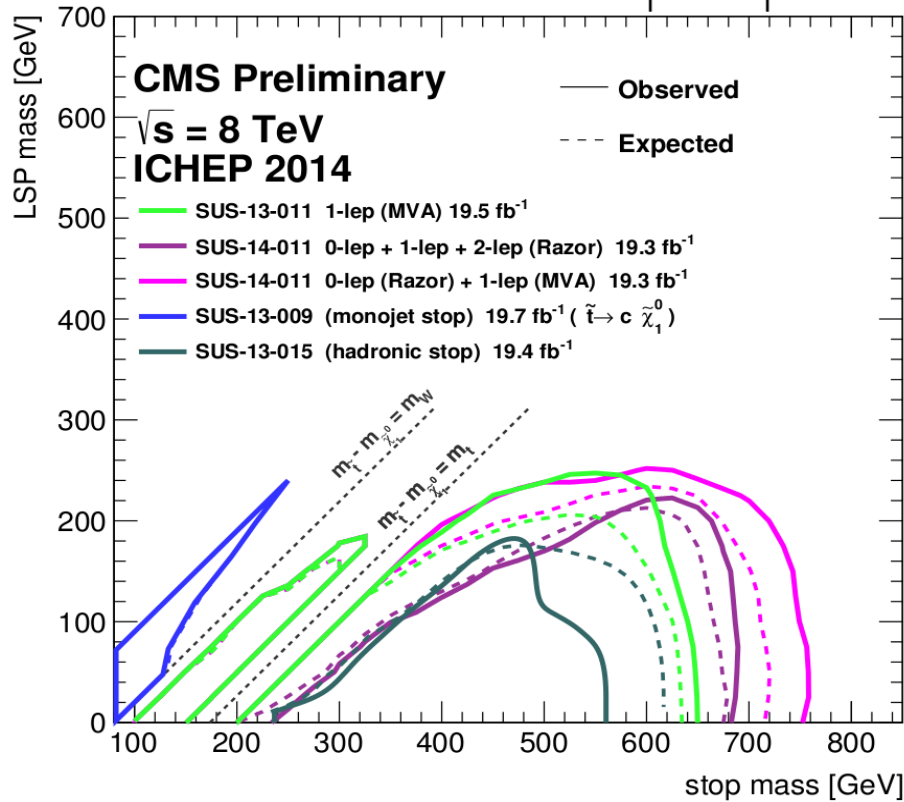
- The rest of the SUSY spectrum can be decoupled (\Rightarrow much higher masses) without being in contradiction with low energy physics constraints

Direct scalar top searches

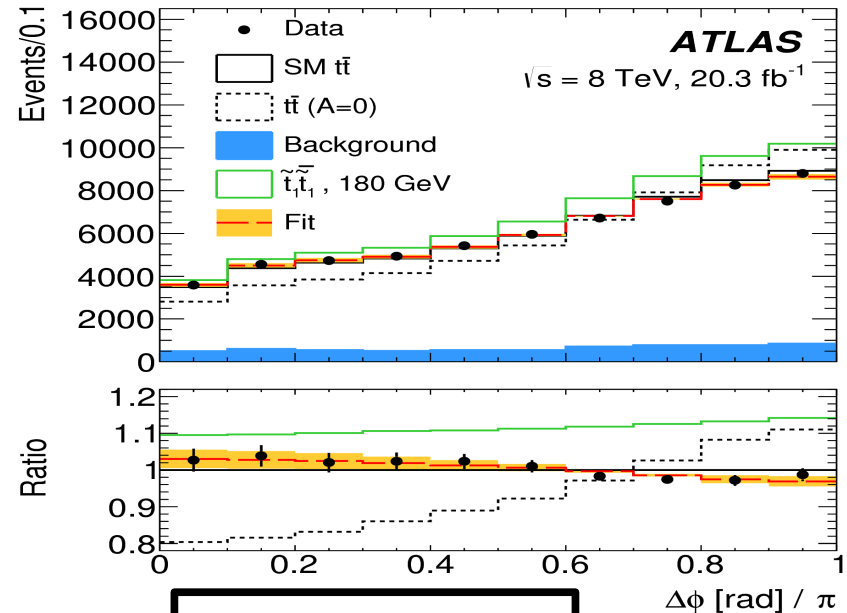
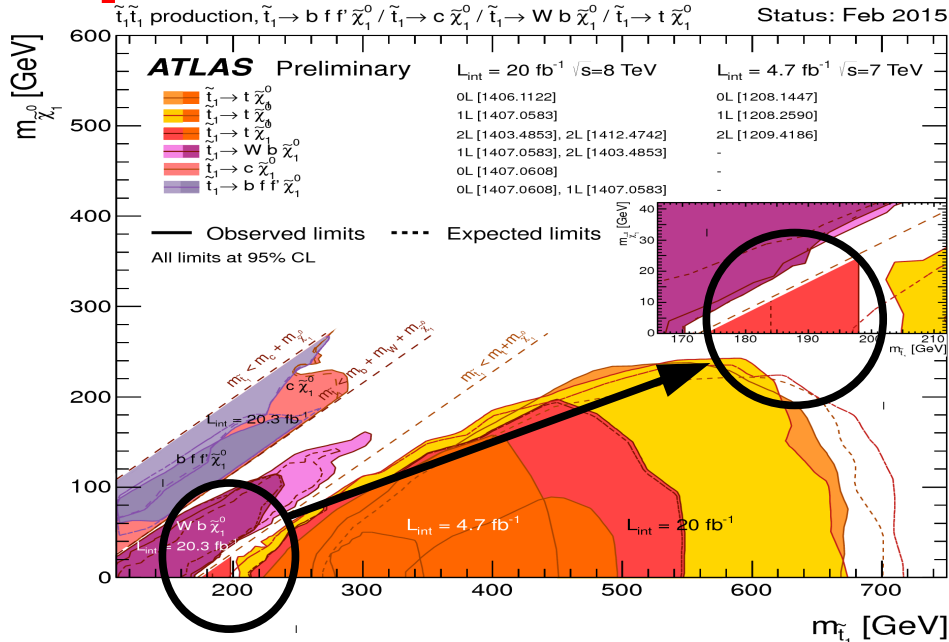


Direct scalar top searches

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



- Maximal reach at Run1 $\sim 750 \text{ GeV}$
- Looking for stop $\rightarrow t + X$ even in regions where it can be hardly distinguished from pure $t\bar{t}$ production (helicity studies)



ATLAS, arXiv:1412.4742

What do we expect this year?

2015 commissioning strategy

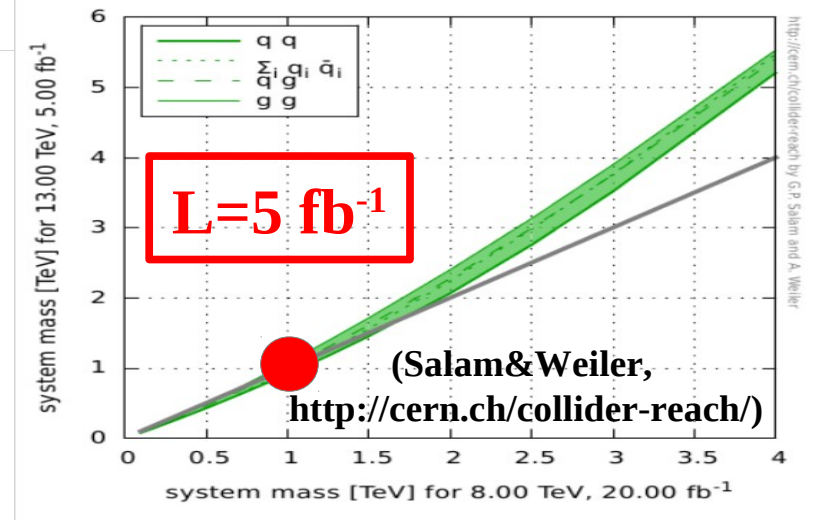
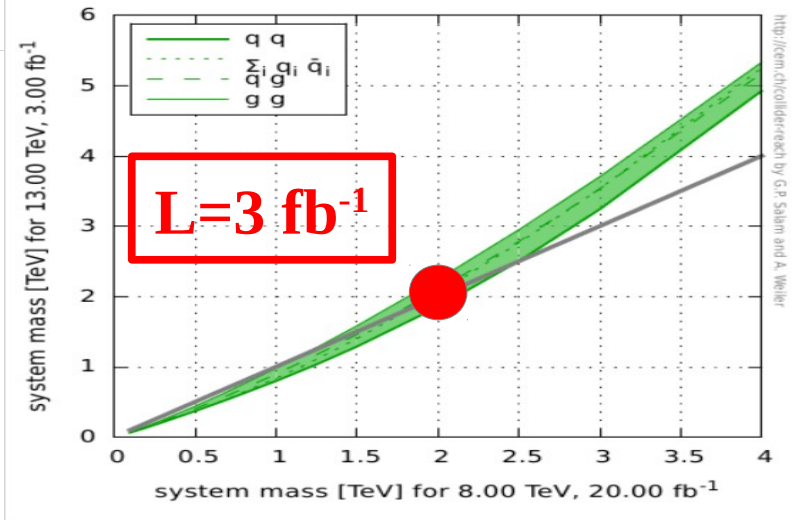
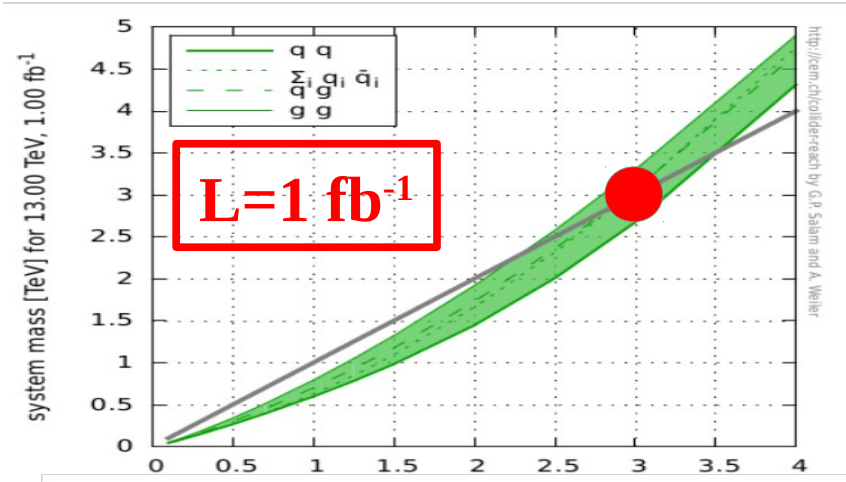
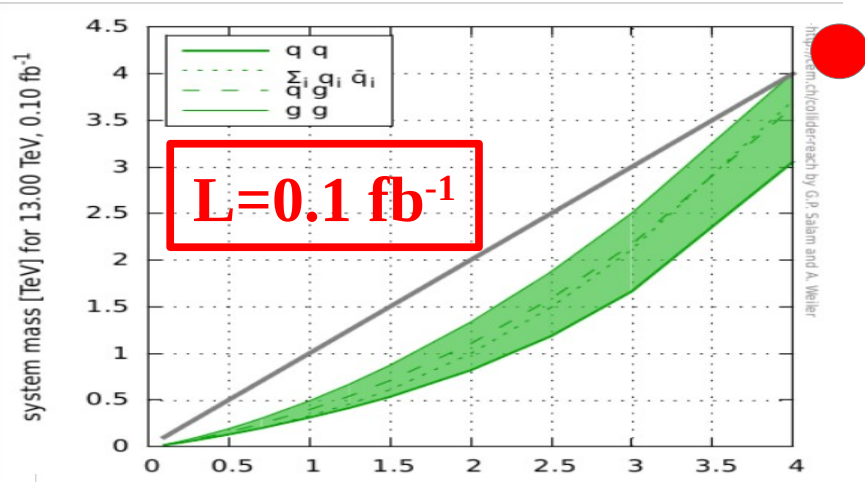
- Low intensity commissioning of full cycle – 8 weeks
- Pilot physics – low number of bunches
- Special physics run: LHCf and luminosity calibration
- Scrubbing for 50 ns
- Intensity ramp-up with 50 ns
 - Characterize vacuum, heat load, electron cloud, losses, instabilities, UFOs, impedance
- Scrubbing for 25 ns
- Ramp-up 25 ns operation with relaxed beta*
- Possibly commission lower beta*
- 25 ns operation

■ Basic target in 2015:

- 1 fb^{-1} of integrated luminosity with 50 ns bunch spacing
- 5-10 fb^{-1} of integrated luminosity with 25 ns bunch spacing

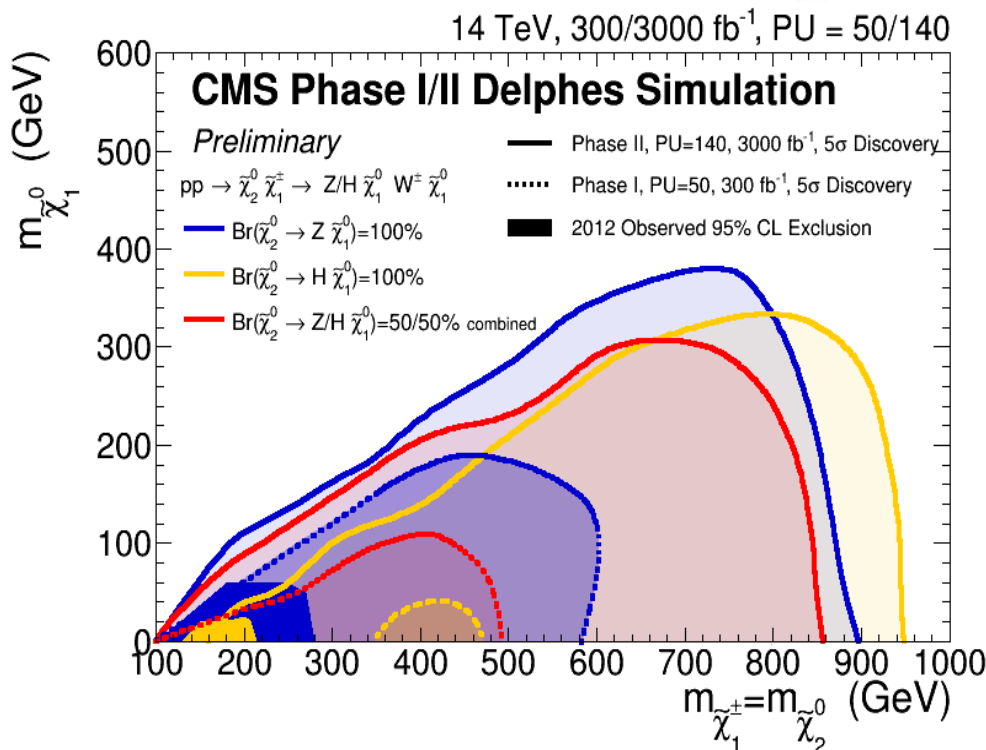
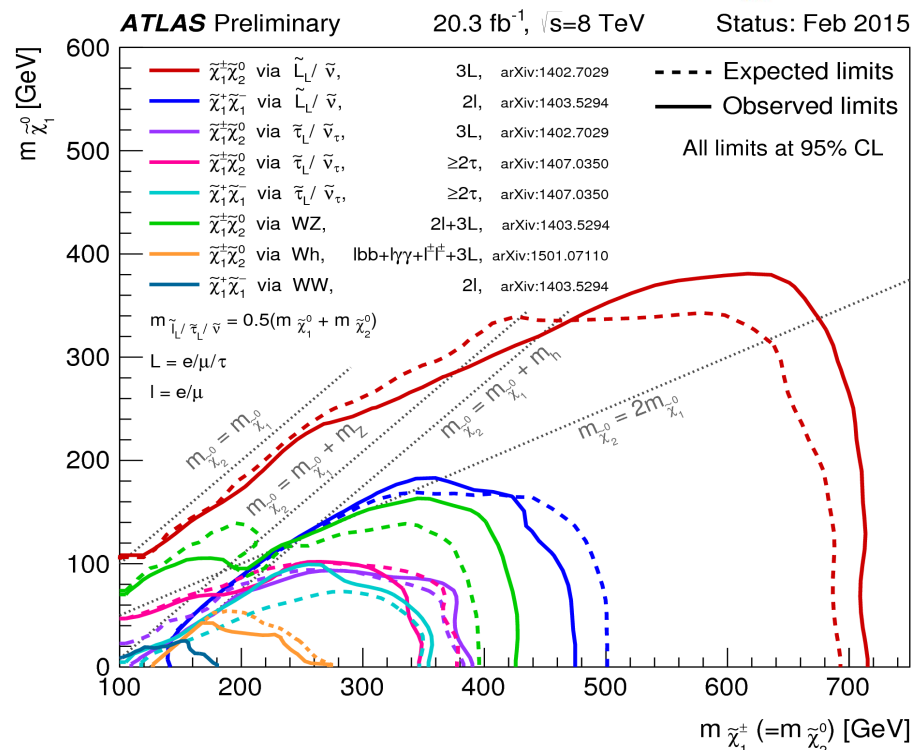
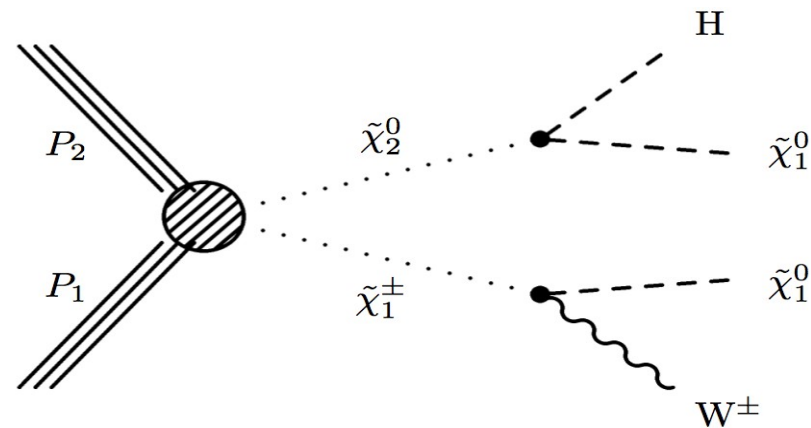
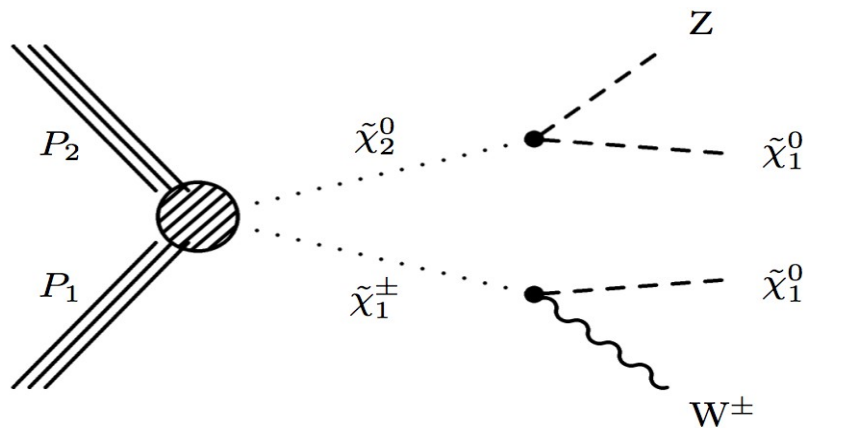
Enough to improve over all existing LHC Run1 searches for masses/scales > 1 TeV

LHC reach in 2015



- More sensitive than Run1 to masses $\gtrsim 3$ TeV with just 1 fb⁻¹ in Run2
- Essentially better than Run1 for most searches with 5 fb⁻¹:
 - Improved sensitivity to gluinos and stops already in 2015.

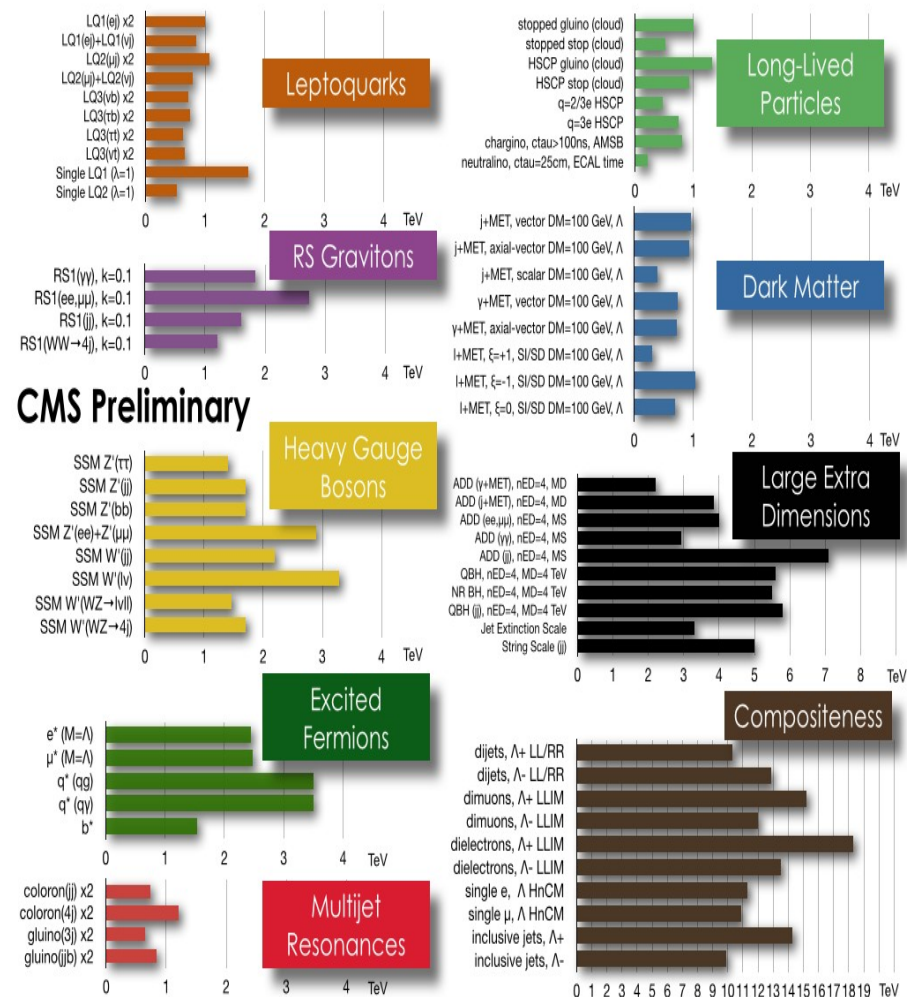
SUSY reach in LHC for ewkinos



■ Direct chargino / neutralino searches need more luminosity to improve

EXOTICA

Exotica as alternative



CMS Exotica Physics Group Summary – Moriond, 2015

ATLAS Exotics Searches* - 95% CL Exclusion

Status: March 2015

ATLAS Preliminary

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

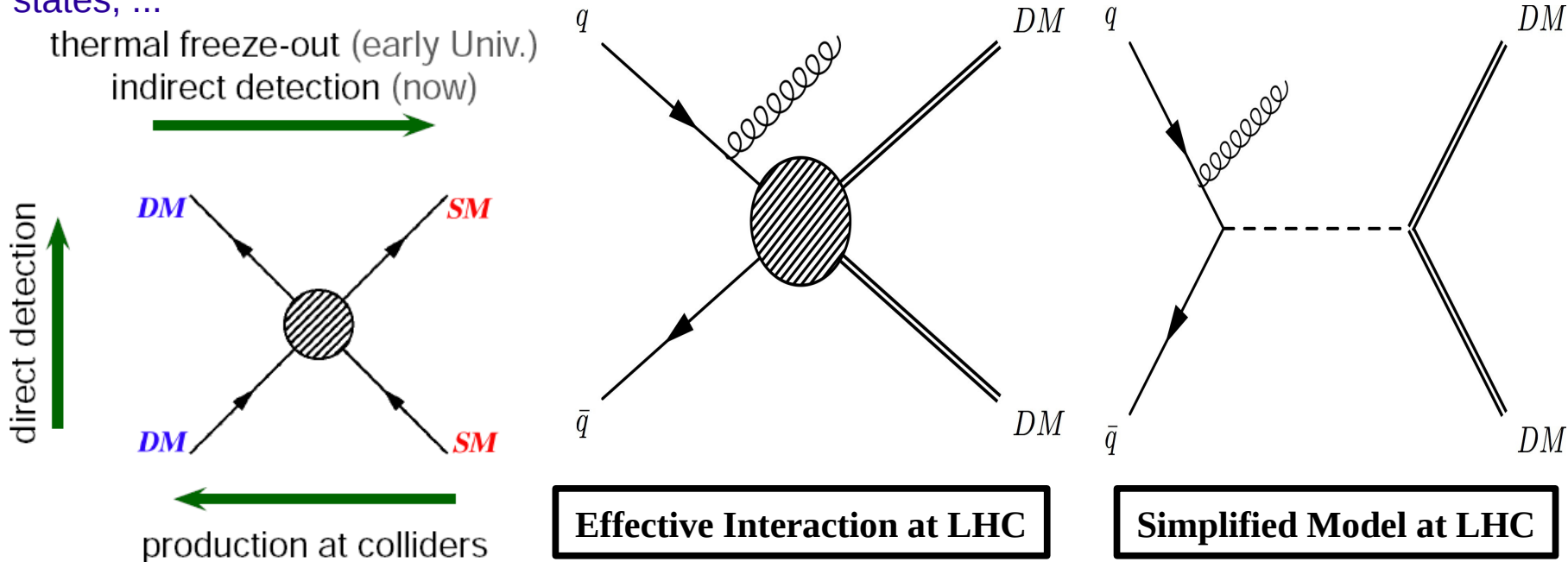
Model	ℓ, γ	Jets	$E_{\text{miss}}^{\text{EM}}$ [$\mathcal{L} dt [\text{fb}^{-1}]$]	Mass limit	Reference	
Extra dimensions	ADD $G_{GG} + g/q$	-	$\geq 1j$ Yes	20.3	M_0 5.25 TeV	$n=2$ 1502.0158
	ADD non-resonant $\ell\ell$	$2e, \mu$	-	20.3	M_k 4.7 TeV	$n=3$ HRZ 1407.2410
	ADD OBH $\rightarrow \ell q$	$1e, \mu$	$1j$ -	20.3	M_h 5.2 TeV	$n=6$ 1911.2006
	ADD OBH	-	$2j$ -	20.3	M_h 5.82 TeV	$n=6$ 1407.1376
	ADD BH high N_{jet}	2μ (SS)	-	20.3	M_h 4.7 TeV	$n=6, M_0 = 3 \text{ TeV}$, non-rot BH 1308.4075
	ADD BH high $\sum p_T$	$\geq 1e, \mu$	$\geq 2j$ -	20.3	M_h 5.8 TeV	$n=6, M_0 = 3 \text{ TeV}$, non-rot BH 1405.4254
	ADD BH high multijet	-	$\geq 2j$ -	20.3	M_h 5.8 TeV	$n=6, M_0 = 3 \text{ TeV}$, non-rot BH Preliminary
	RS1 $G_{GG} \rightarrow \ell\ell$	$2e, \mu$	-	20.3	excl. mass 2.68 TeV	$k/\bar{M}_n = 0.1$ 1405.4123
	RS1 $G_{GG} \rightarrow \gamma\gamma$	2γ	-	20.3	excl. mass 2.66 TeV	$k/\bar{M}_n = 0.1$ Preliminary
	Bulk RS $G_{GG} \rightarrow ZZ \rightarrow q\bar{q}\ell$	$2e, \mu$	$2j/1j$ -	20.3	excl. mass 740 GeV	$k/\bar{M}_n = 1.0$ 1409.6190
	Bulk RS $G_{GG} \rightarrow WW \rightarrow q\bar{q}\nu$	$1e, \mu$	$2j/1j$ Yes	20.3	excl. mass 700 GeV	$k/\bar{M}_n = 1.0$ 1501.04677
	Bulk RS $G_{GG} \rightarrow HH \rightarrow b\bar{b}b\bar{b}$	-	$4b$ -	19.5	excl. mass 590-710 GeV	$k/\bar{M}_n = 1.0$ ATLAS-CONE-2014-005
	Bulk RS $G_{GG} \rightarrow \ell\bar{\ell}$	$1e, \mu$	$\geq 1b, \geq 1WJ$ Yes	20.3	excl. mass 2.2 TeV	$BR = 0.925$ ATLAS-CONE-2015-009
	2UED / RPP	$2e, \mu$ (SS)	$\geq 1b, \geq 1j$ Yes	20.3	excl. mass 960 GeV	Preliminary
Gauge bosons	SSM $Z' \rightarrow \ell\ell$	$2e, \mu$	-	20.3	Z' mass 2.9 TeV	1405.4123
	SSM $Z' \rightarrow \tau\tau$	2τ	-	19.5	Z' mass 2.02 TeV	1502.07177
	SSM $W' \rightarrow \ell\nu$	$1e, \mu$	Yes	20.3	W' mass 3.24 TeV	1407.7494
	EGM $W' \rightarrow WZ \rightarrow \ell\nu \ell'\ell'$	$3e, \mu$	Yes	20.3	W' mass 1.32 TeV	1406.4456
	EGM $W' \rightarrow WZ \rightarrow q\bar{q}\ell\ell$	$2e, \mu$	$2j/1j$ -	20.3	W' mass 1.59 TeV	1409.6190
	HVT $W' \rightarrow WH \rightarrow \ell\nu b\bar{b}$	$1e, \mu$	$2b$ Yes	20.3	W' mass 1.47 TeV	Preliminary
	LRSM $W'_2 \rightarrow \ell\nu$	$1e, \mu$	$2b, 0j$ Yes	20.3	W' mass 1.92 TeV	1410.4108
	LRSM $W'_2 \rightarrow \ell\nu$	$0e, \mu$	$\geq 1b, 1j$ -	20.3	W' mass 1.76 TeV	1408.0886
CI	CI $qqqq$	-	$2j$ -	17.3	Λ 12.0 TeV	$q_{LL} = -1$ Preliminary
	CI $qq\ell\ell$	$2e, \mu$	-	20.3	Λ 21.6 TeV	$q_{LL} = -1$ 1407.2410
	CI $uutt$	$2e, \mu$ (SS)	$\geq 1b, \geq 1j$ Yes	20.3	Λ 4.35 TeV	$ C_{LL} = 1$ Preliminary
DM	EFT D5 operator (Dirac)	$0e, \mu$	$\geq 1j$ Yes	20.3	M_* 974 GeV	at 90% CL for $m_{\chi^0} < 100 \text{ GeV}$ 1502.01518
	EFT D0 operator (Dirac)	$0e, \mu$	$1j, \leq 1j$ Yes	20.3	M_* 2.4 TeV	at 90% CL for $m_{\chi^0} < 100 \text{ GeV}$ 1309.4017
LQ	Scalar LQ 1 st gen	$2e$	$\geq 2j$ -	1.0	LQ mass 660 GeV	$\beta = 1$ 1112.4828
	Scalar LQ 2 nd gen	2μ	$\geq 2j$ -	1.0	LQ mass 685 GeV	$\beta = 1$ 1203.3172
	Scalar LQ 3 rd gen	$1e, \mu, 1\tau$	$1b, 1j$ -	4.7	LQ mass 534 GeV	$\beta = 1$ 1303.0262
Heavy quarks	VLO $TT \rightarrow Ht + X, Wb + X$	$1e, \mu$	$\geq 1b, \geq 3j$ Yes	20.3	T mass 785 GeV	isospin singlet ATLAS-CONE-2015-012
	VLO $TT \rightarrow Zt + X$	$2\beta, 3e, \mu$	$\geq 2b, 1b$ -	20.3	T mass 735 GeV	T in (T, B) doublet 1409.5000
	VLO $BB \rightarrow Zb + X$	$2\beta, 3e, \mu$	$\geq 2b, 1b$ -	20.3	B mass 755 GeV	B in (B, Y) doublet 1409.5000
	VLO $BB \rightarrow Wt + X$	$1e, \mu$	$\geq 1b, \geq 5j$ Yes	20.3	B mass 640 GeV	isospin singlet Preliminary
	$T_{3/2} \rightarrow Wt$	$1e, \mu$	$\geq 1b, \geq 5j$ Yes	20.3	$T_{3/2}$ mass 840 GeV	isospin singlet Preliminary
Excited fermions	Excited quark $q^* \rightarrow q\gamma$	1γ	$1j$ -	20.3	q^* mass 3.5 TeV	only u^* and d^* , $A = m(q^*)$ 1309.3220
	Excited quark $q^* \rightarrow qg$	-	$2j$ -	20.3	q^* mass 4.09 TeV	only u^* and d^* , $A = m(q^*)$ 1407.1376
	Excited quark $b^* \rightarrow Wt$	1 or $2e, \mu, 1b, 2j$ or $1j$	Yes	4.7	b^* mass 870 GeV	left-handed coupling 1301.1383
	Excited lepton $\ell^* \rightarrow \ell\gamma$	$2e, \mu, 1\gamma$	-	13.0	ℓ^* mass 2.2 TeV	$A = 2.2 \text{ TeV}$ 1308.1354
	Excited lepton $\nu^* \rightarrow \ell W, \nu Z$	$3e, \mu, \tau$	-	20.3	ν^* mass 1.6 TeV	$A = 1.6 \text{ TeV}$ 1411.2921
Other	LSTC $a\tau \rightarrow W\gamma$	$1e, \mu, 1\gamma$	-	Yes	$a\tau$ mass 960 GeV	$m(W_2) = 2 \text{ TeV}$, no mixing 1407.8150
	LRSM Majorana ν	$2e, \mu$	$2j$ -	2.1	N^0 mass 1.5 TeV	DM production, $BR(H^{1,2} \rightarrow \ell\beta) = 1$ 1203.5420
	Higgs triplet $H^{++} \rightarrow \ell\ell$	$2e, \mu$ (SS)	-	20.3	H^{++} mass 551 GeV	DM production, $BR(H^{1,2} \rightarrow \ell\beta) = 1$ 1412.0257
	Higgs triplet $H^{++} \rightarrow \ell\tau$	$3e, \mu, \tau$	-	20.3	H^{++} mass 400 GeV	DM production, $BR(H^{1,2} \rightarrow \ell\beta) = 1$ 1411.2921
	Monopole (non-res prod)	$1e, \mu$	$1b$ Yes	20.3	spin-1 invisible particle mass 657 GeV	$a_{\text{had}} = 0.2$ 1410.5404
	Multi-charged particles	-	-	20.3	multi-charged particle mass 785 GeV	DM production, $ g = 5e$ Preliminary
	Magnetic monopoles	-	-	2.0	monopole mass 862 GeV	DM production, $ g = 1.5e$ 1207.6411

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

- No evidence (yet) for alternative solutions to the BSM puzzle. Nevertheless, we keep looking for new effects. This talk is just giving a very brief overview of the most relevant search strategies today and next plans.

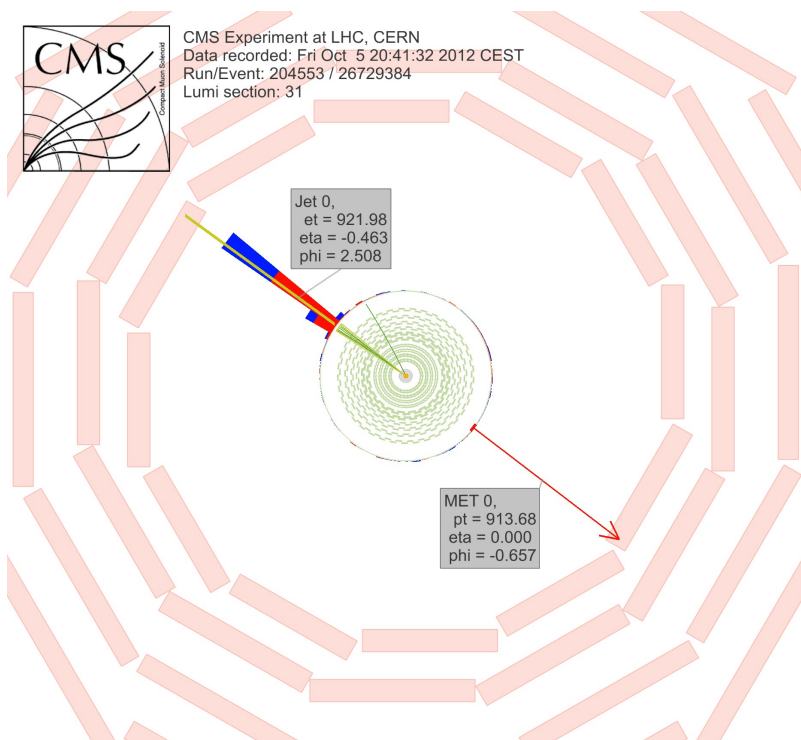
Dark matter (DM) fever

- Lots of interest and hope to find evidence of dark matter production in LHC Run2 !!
- LHC approach is complementary to direct/indirect searches:
 - Main signature exploited at the LHC: missing transverse energy associated to visible jets, EWK bosons, ...
 - Recent developments in the theory front to improve the theoretical description and to better match direct detection interpretations:
 - Effective Lagrangians -> Simplified Models -> True Models (SUSY, ...)
- Not necessarily the next hint of dark matter connections at the LHC. We can get first an observation in SUSY decay chains, or the discovery of a new mediator in dijet or dilepton final states, ...

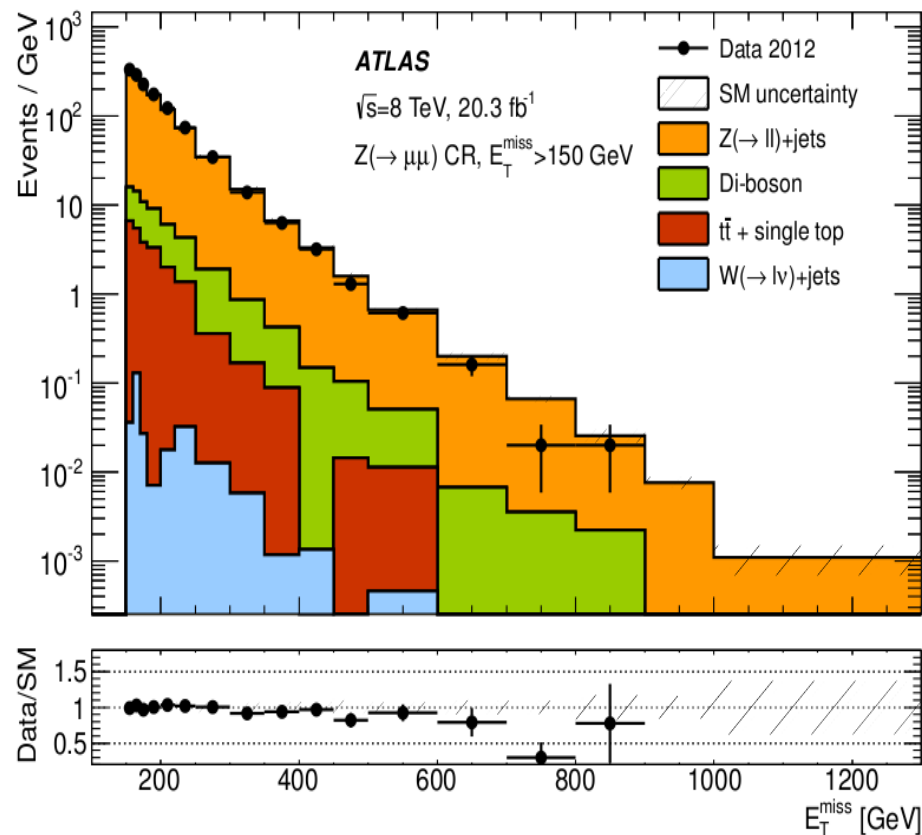


DM searches at Run1: monojet signature

- Most sensitive channel in most scenarios (sizable ISR QCD radiation):
 - Large missing transverse energy recoiling against a high p_T jet
 - Critical points: trigger thresholds, missing E_T tails, controlling backgrounds (jets+Z($\bar{\nu}\nu$), ...)

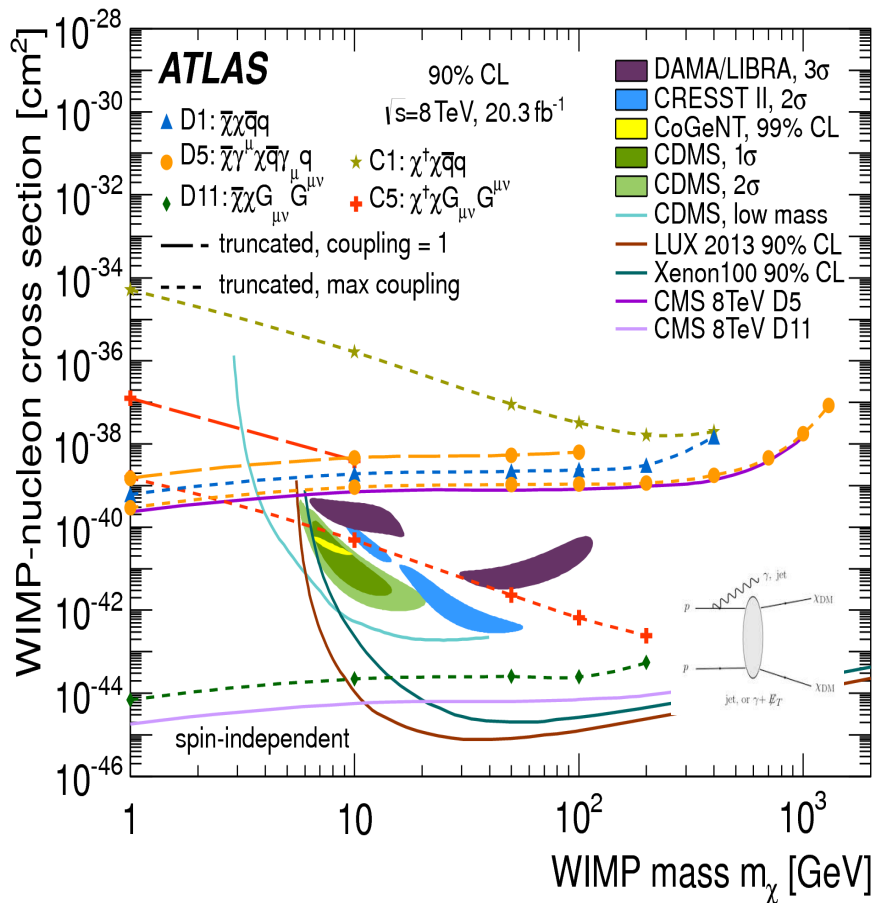


CMS, arXiv:1408.3583

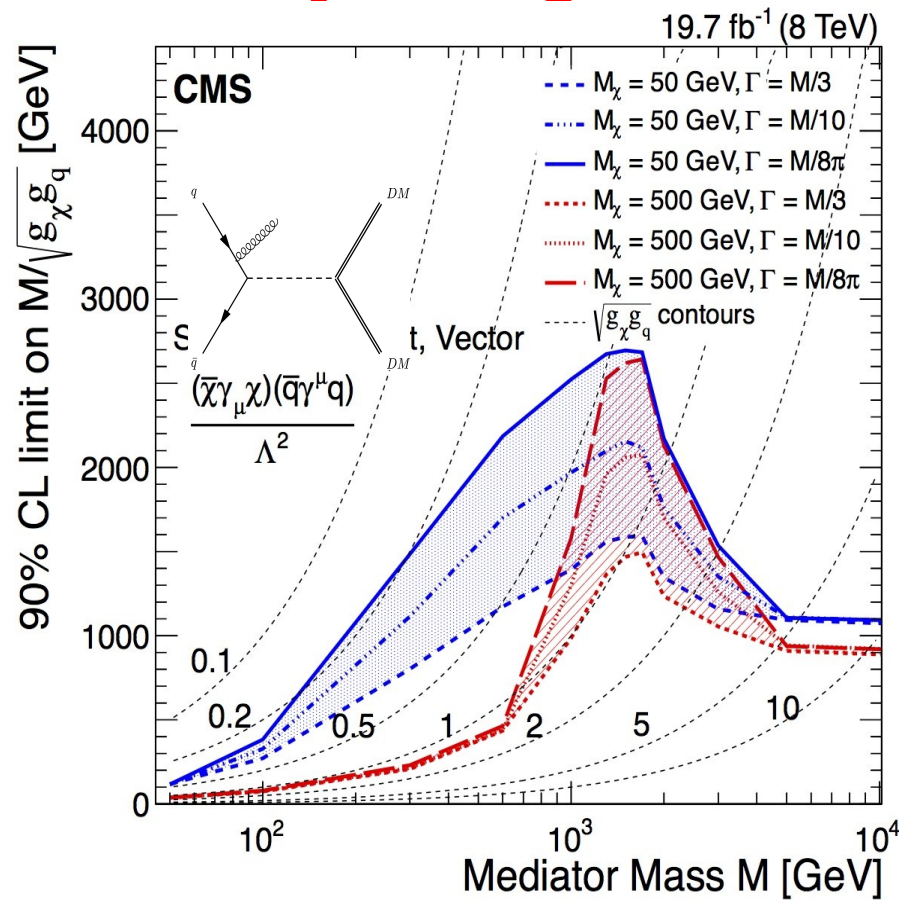


ATLAS, arXiv:1502.01518

DM searches at Run1: monojet signature



Effective Model (truncated at Q=mediator mass => conservative for comparisons with direct detection limits)



Simplified Model (closer to a real scenario with a dominant mediator resonance)
More free parameters to play with: M, Γ

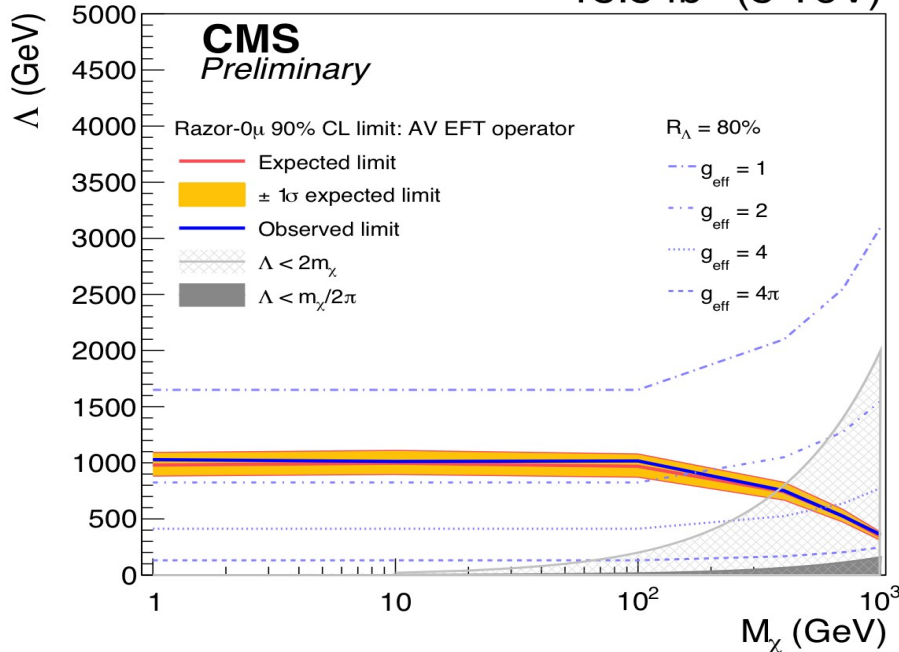
- Current limits on scale/mediator mass: $\geq 1\text{ TeV}$.
- Improving limits in Run2 already with 5 fb^{-1} of integrated luminosity.

More DM + X searches at Run1

- Similar production mechanisms when compared to the monojet case, but :
 - Dijets + DM production (recycling multijets+missing energy SUSY searches, for instance)
 - Different coupling strength to u and d quarks in the W/Z/ γ + DM case
 - Special connections with 3rd generation? $t\bar{t}$ +DM, $b\bar{b}$ +DM, FCNC leading to t+DM, b+DM, ...
 - Higgs to DM ? Dark sector connection? ...

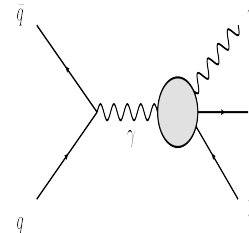
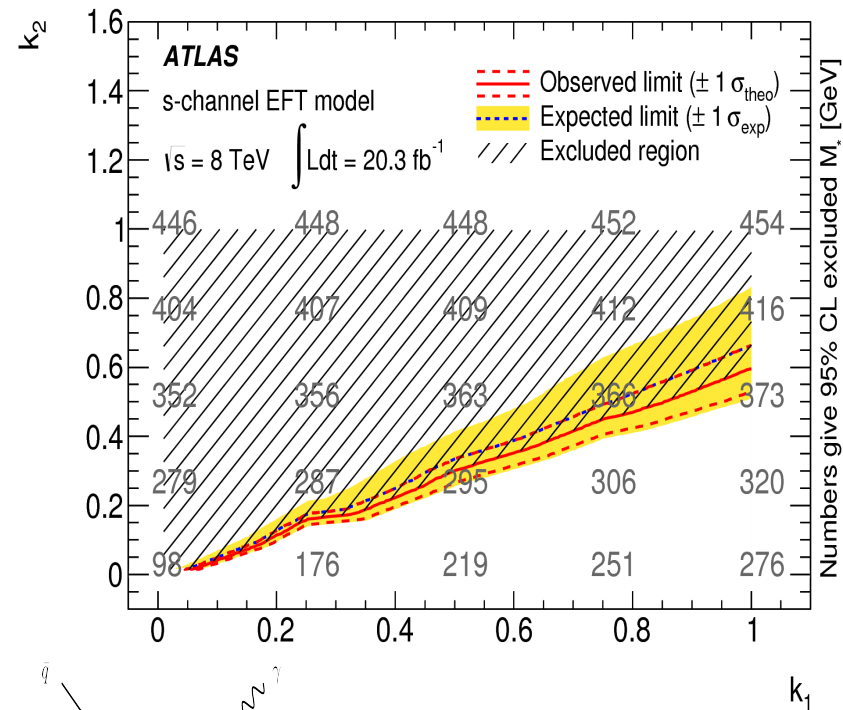
Razor 2j+DM: CMS-PAS-EXO-14-004

18.8 fb⁻¹ (8 TeV)



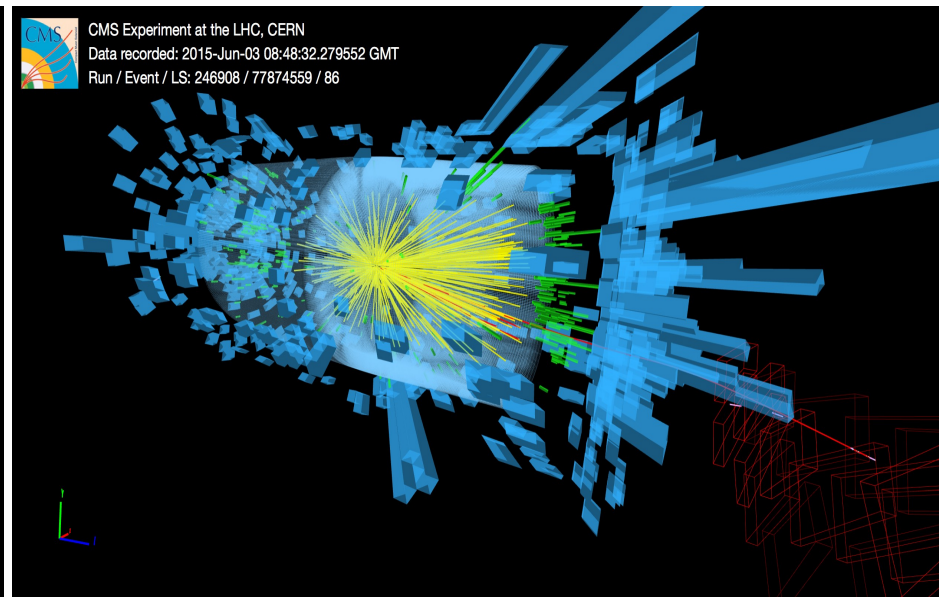
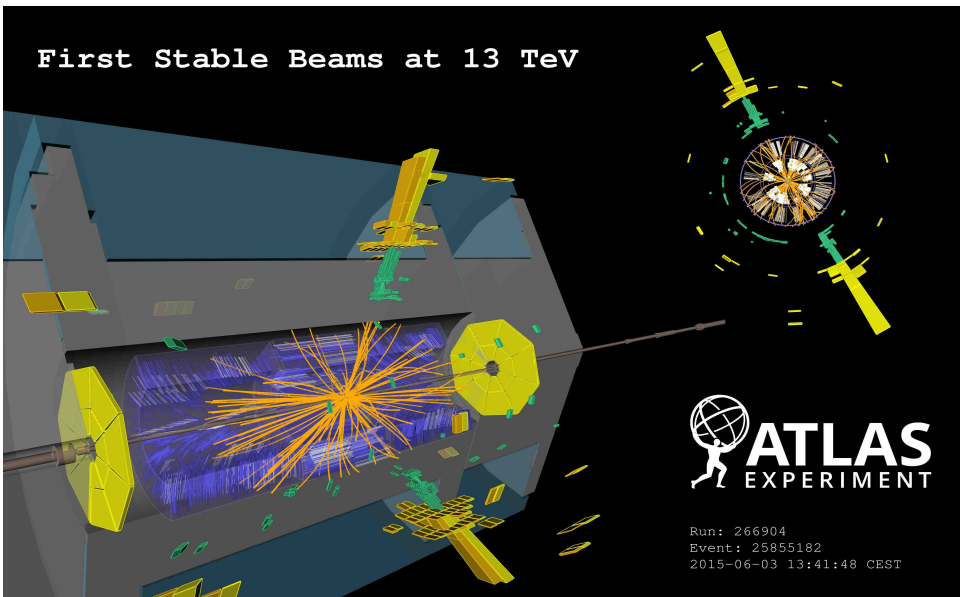
Sensitivity similar to monojet+DM analysis

ATLAS γ +DM: arXiv:1411.1559



Probing $\gamma\gamma\chi\chi$ interactions too (Fermi-LAT motivated)

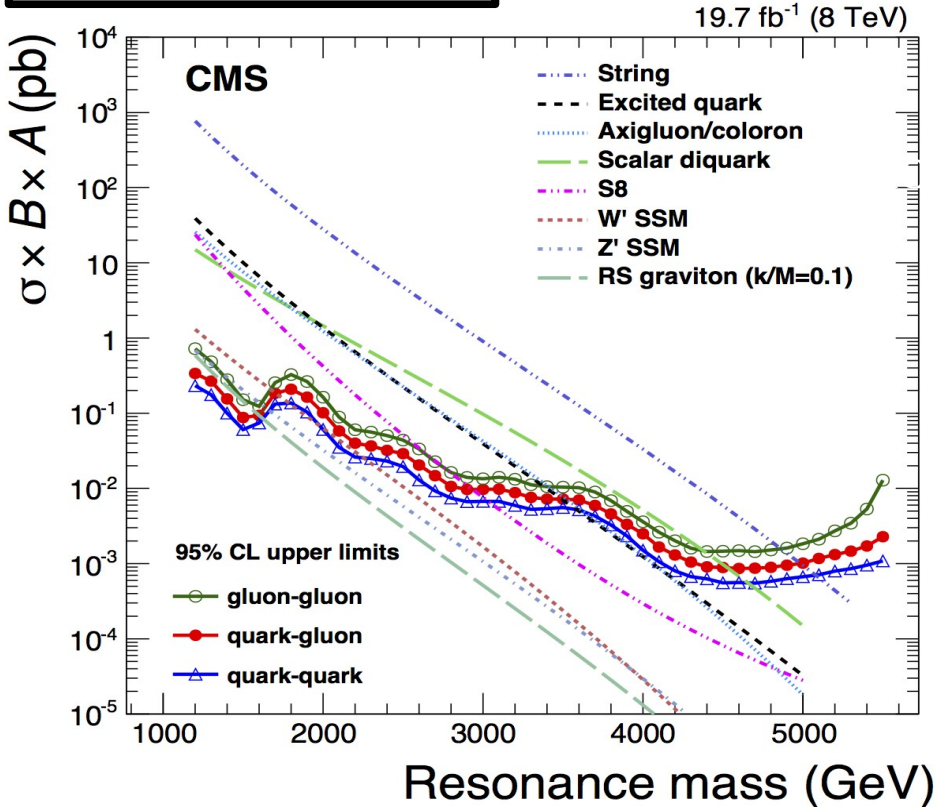
VERY EARLY SEARCHES



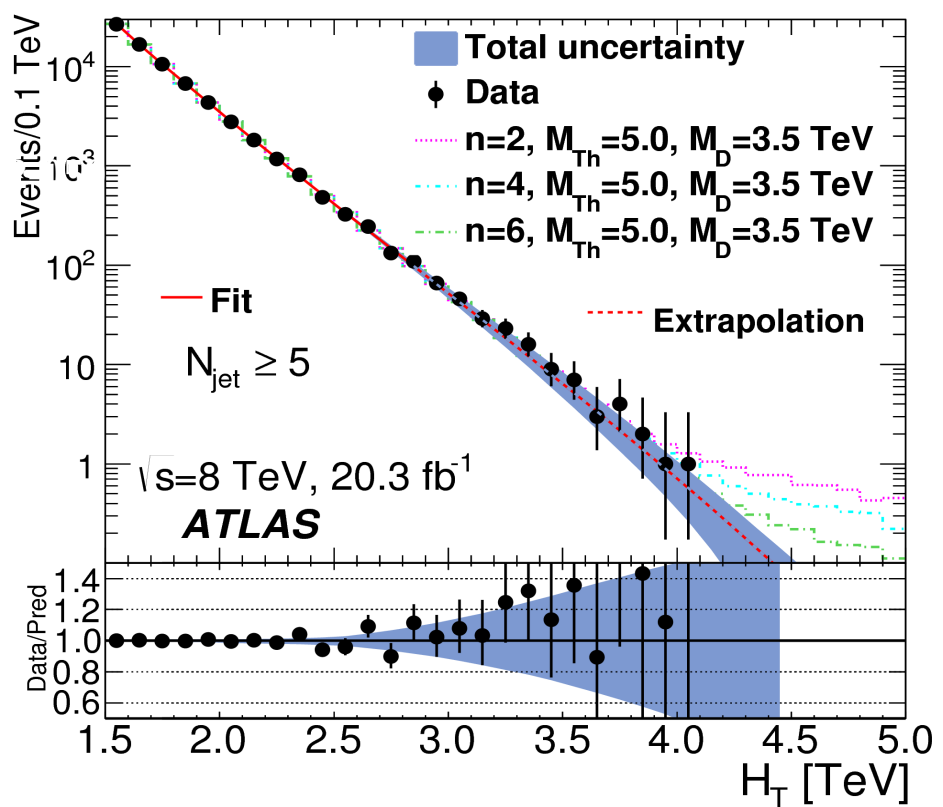
Classic Exotics: pure hadronic, highest scales

- Hadronic (relatively) narrow resonances and black hole searches:
 - Cross sections may be huge: far reach in terms of physics scales/masses
 - Almost fully data driven: assume a smooth background and then look for bumps or excesses at the highest transverse energies/multiplicities

CMS: arXiv:1501.04198



ATLAS, arXiv:1503.08988



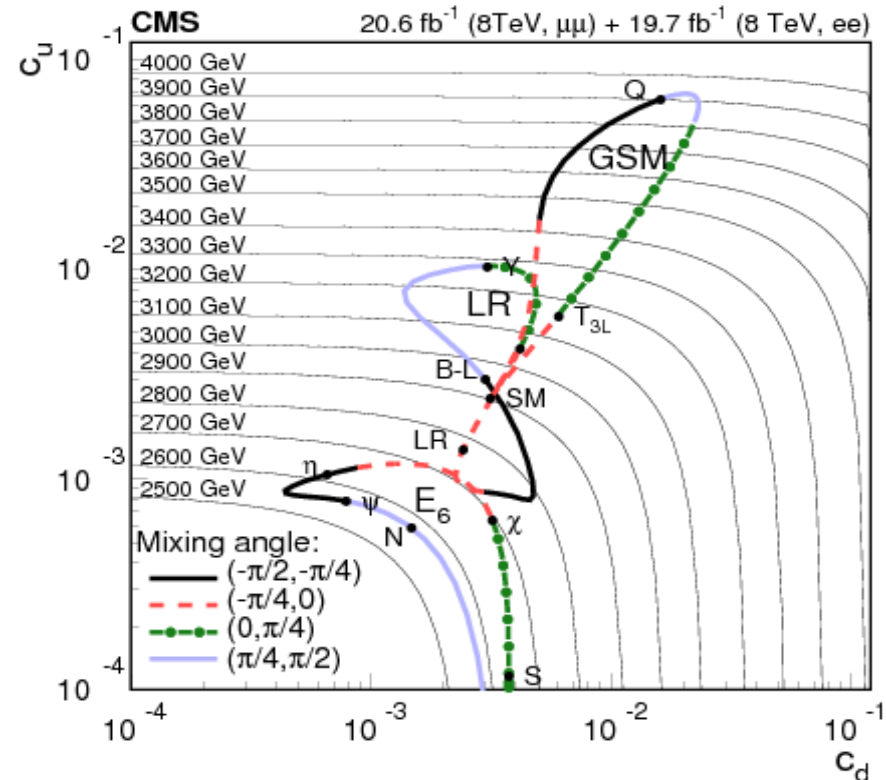
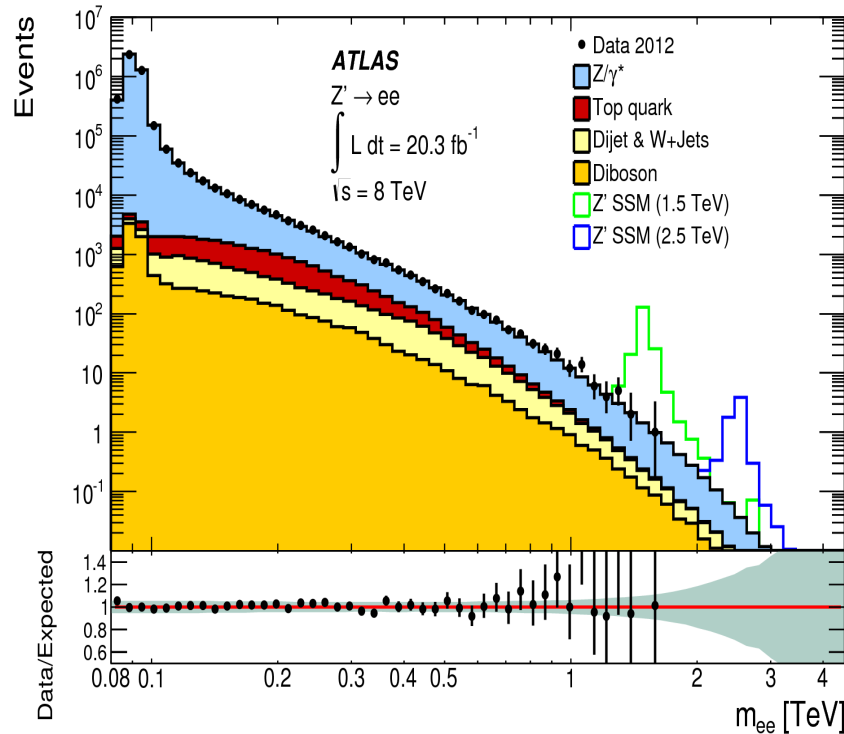
Classic Exotics: narrow resonances

Dilepton resonances:

- Clean, excellent resolution even at higher masses (but a delicate business to get there)
- Non-resonant background: EWK corrections to DY and $\gamma^*\gamma^* \rightarrow ll$ matter at high mass
- Many possible theory scenarios (different group extensions \rightarrow different couplings)

ATLAS, arXiv:1405.4123

CMS, arXiv:1412.6302



Summary

- No evidence for new physics beyond the SM in Run1:
 - A few interesting excesses here and there to be followed, as expected, although not very significant
- Huge physics program covered already in Run1:
 - Characterization of the recently discovered scalar: no significant deviations observed.
 - SUSY being explored in new corners, trying to keep it 'natural' at the TeV scale.
 - Many BSM excluded models, most of them at masses/scales in the 1-3 TeV range.
- The energy jump of LHC Run2 may lead to early discoveries:
 - We will surpass the Run1 sensitivity soon (2015) in most searches
 - Likely the biggest jump in new physics reach in the next years.

EXCITING TIMES AHEAD!