Scientific highlights from ATLAS

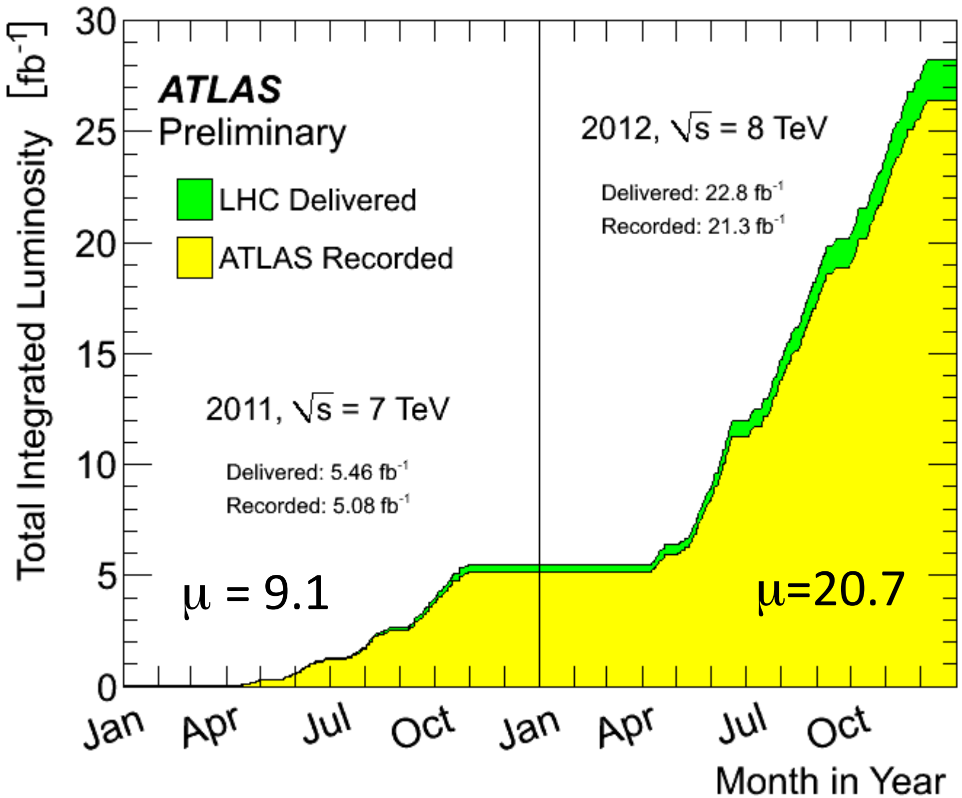
Scalars 2015

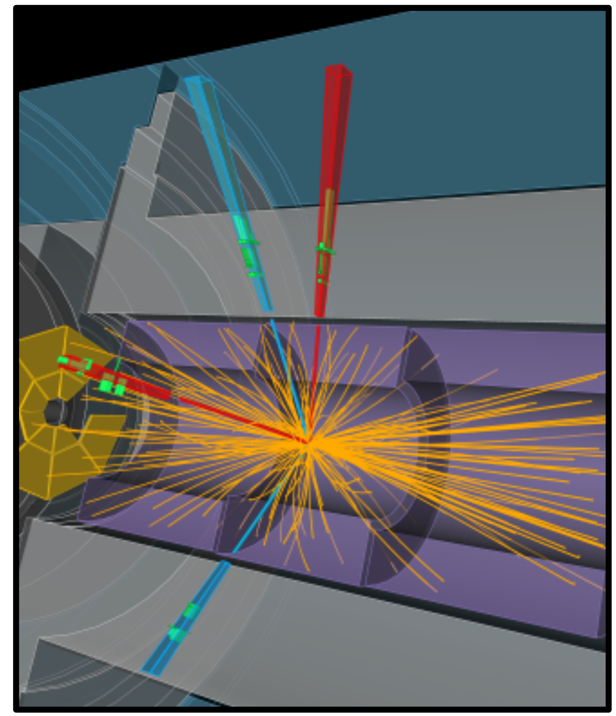
Alan Barr

University of Oxford

December 2015

A large dataset at 7-8 TeV





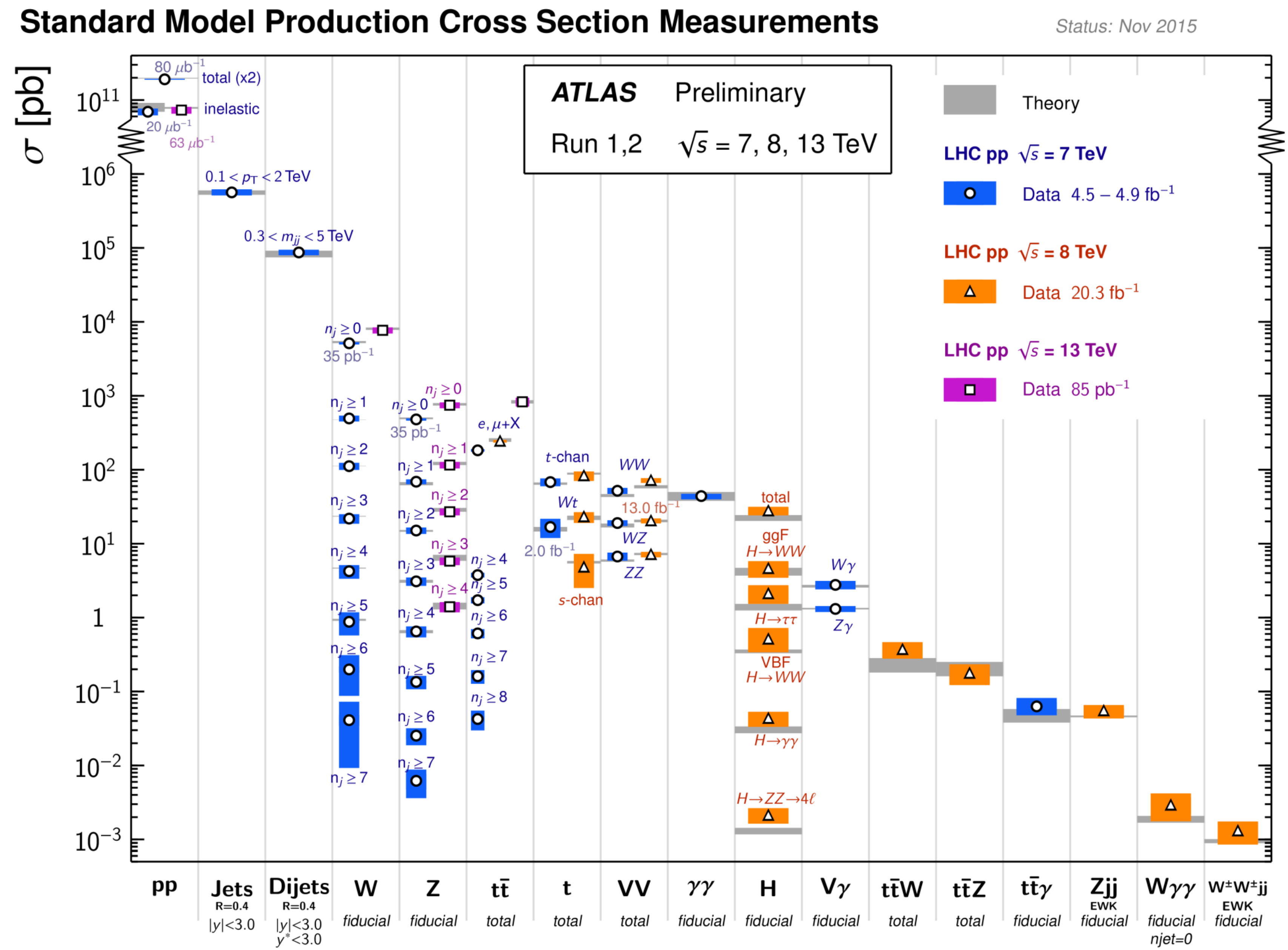
7 TeV: 5/fb

8 TeV: 21/fb

Remains the largest dataset for physics at $\sqrt{s} \approx 100$ GeV

Higgs results on these data

487 Papers Submitted


Standard Model Production Cross Section Measurements
Status: Nov 2015
ATLAS Preliminary
Run 1,2 $\sqrt{s}$ = 7, 8, 13 TeV
Theory
LHC pp $\sqrt{s}$ = 7 TeV
Data 4.5 – 4.9 fb^{-1}
LHC pp $\sqrt{s}$ = 8 TeV
Data 20.3 fb^{-1}
LHC pp $\sqrt{s}$ = 13 TeV
Data 85 pb^{-1}
σ [pb]
80 μb^{-1}
total (x2)
inelastic
20 μb^{-1}
63 μb^{-1}
$0.1 < p_T < 2$ TeV
$0.3 < m_{jj} < 5$ TeV
35 pb^{-1}
2.0 fb^{-1}
13.0 fb^{-1}
e, μ+X
t-chan
Wt
s-chan
WW
WZ
ZZ
total
ggF $H \to WW$
$H \to \tau\tau$
VBF $H \to WW$
$H \to \gamma\gamma$
$H \to ZZ \to 4\ell$
$W\gamma$
$Z\gamma$
pp
Jets R=0.4 |y|<3.0
Dijets R=0.4 |y|<3.0 y*<3.0
W fiducial
Z fiducial
$t\bar{t}$ total
t total
VV total
$\gamma\gamma$ fiducial
H fiducial
Vγ fiducial
$t\bar{t}W$ total
$t\bar{t}Z$ total
$t\bar{t}\gamma$ fiducial
Zjj EWK fiducial
W$\gamma\gamma$ fiducial njet=0
$W^\pm W^\pm jj$ EWK fiducial

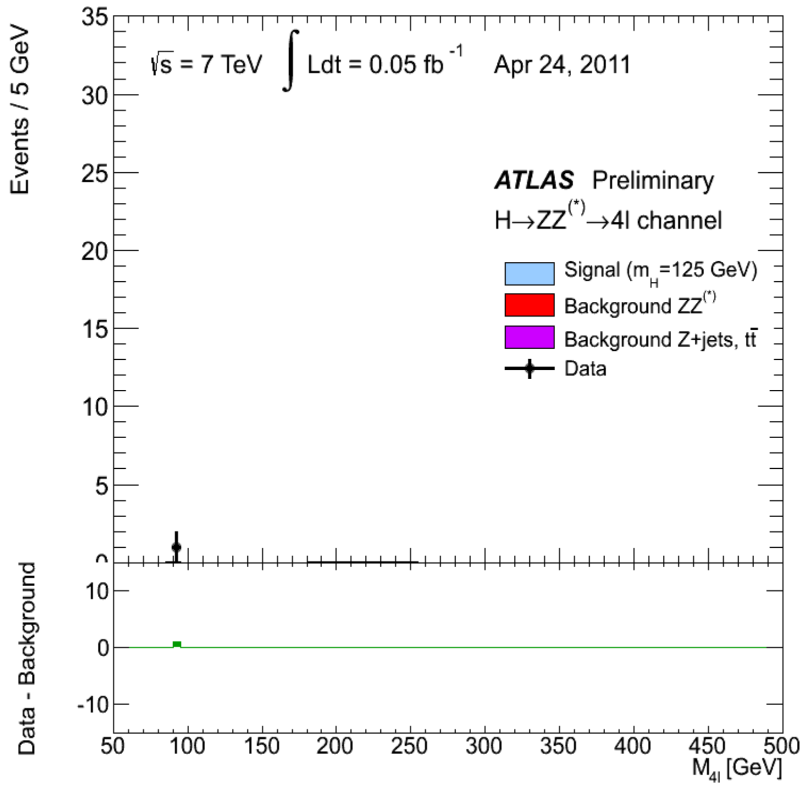
$$\mathcal{L} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu}$$

$$+ i \bar{\psi} \not{D} \psi + h.c.$$

$$+ \bar{\psi}_i y_{ij} \psi_j \phi + h.c.$$

$$+ |D_\mu \phi|^2 - V(\phi)$$

The new boson



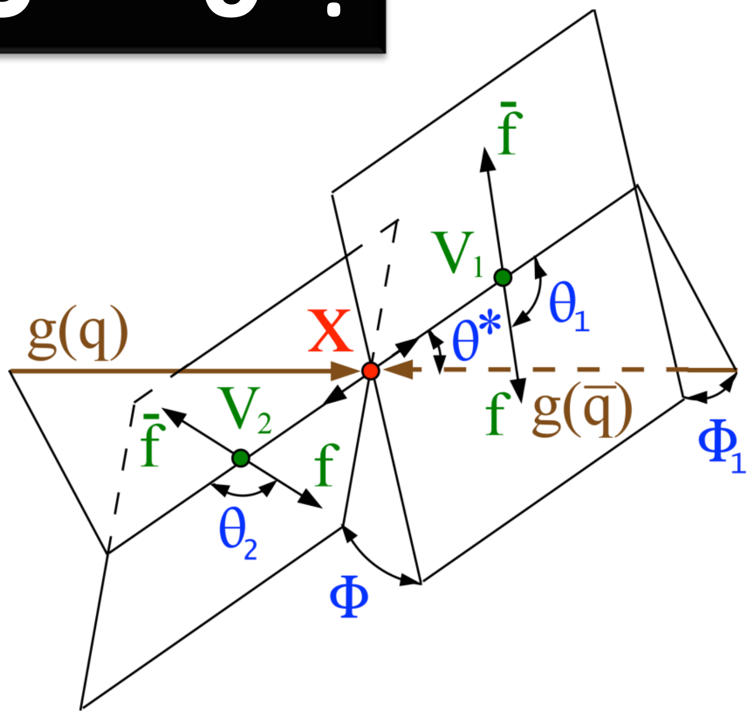
Interesting **decay modes**:

ZZ (2.6%)
WW (22%)
γγ (0.23%) } discovery
ττ (6.3%) (4.5σ) 1501.04943
bb (58%) (1.4σ) 1409.6212

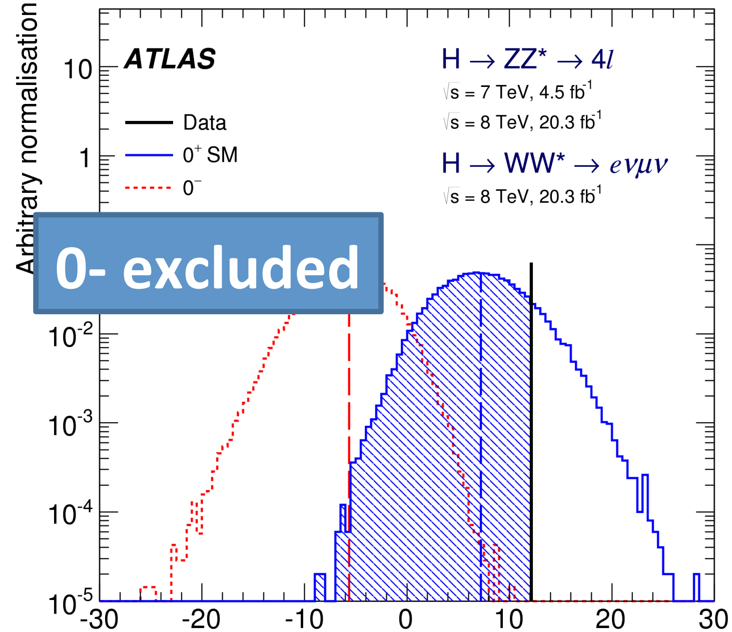
Interesting **production modes**:

gg fusion (discovery)
VV → H (4.3σ) 1507.04548
W/Z + H (2.5σ) 1506.06641
tt + H (2.5σ) 1506.05988

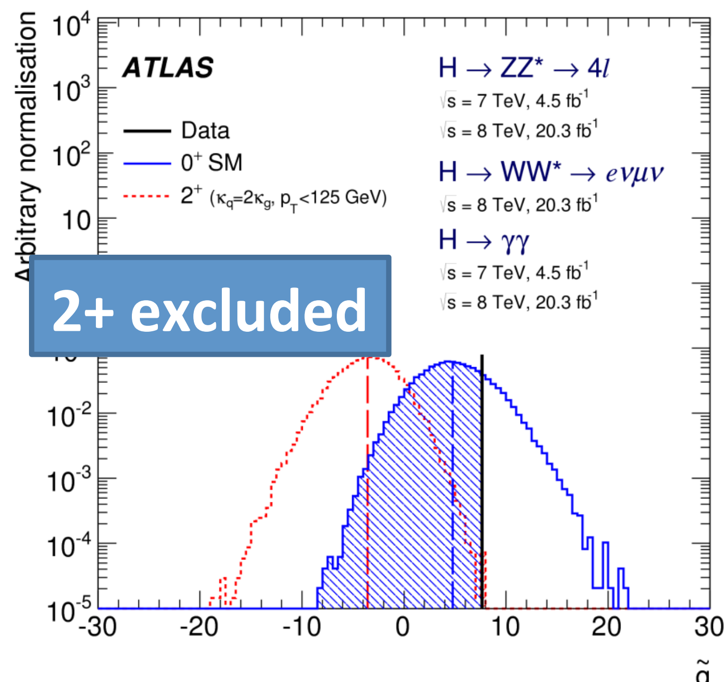
$J^P = 0^+$?



All tested alternative models excluded at **>99.9% CL**



0- excluded



2+ excluded

[1506.05669]()

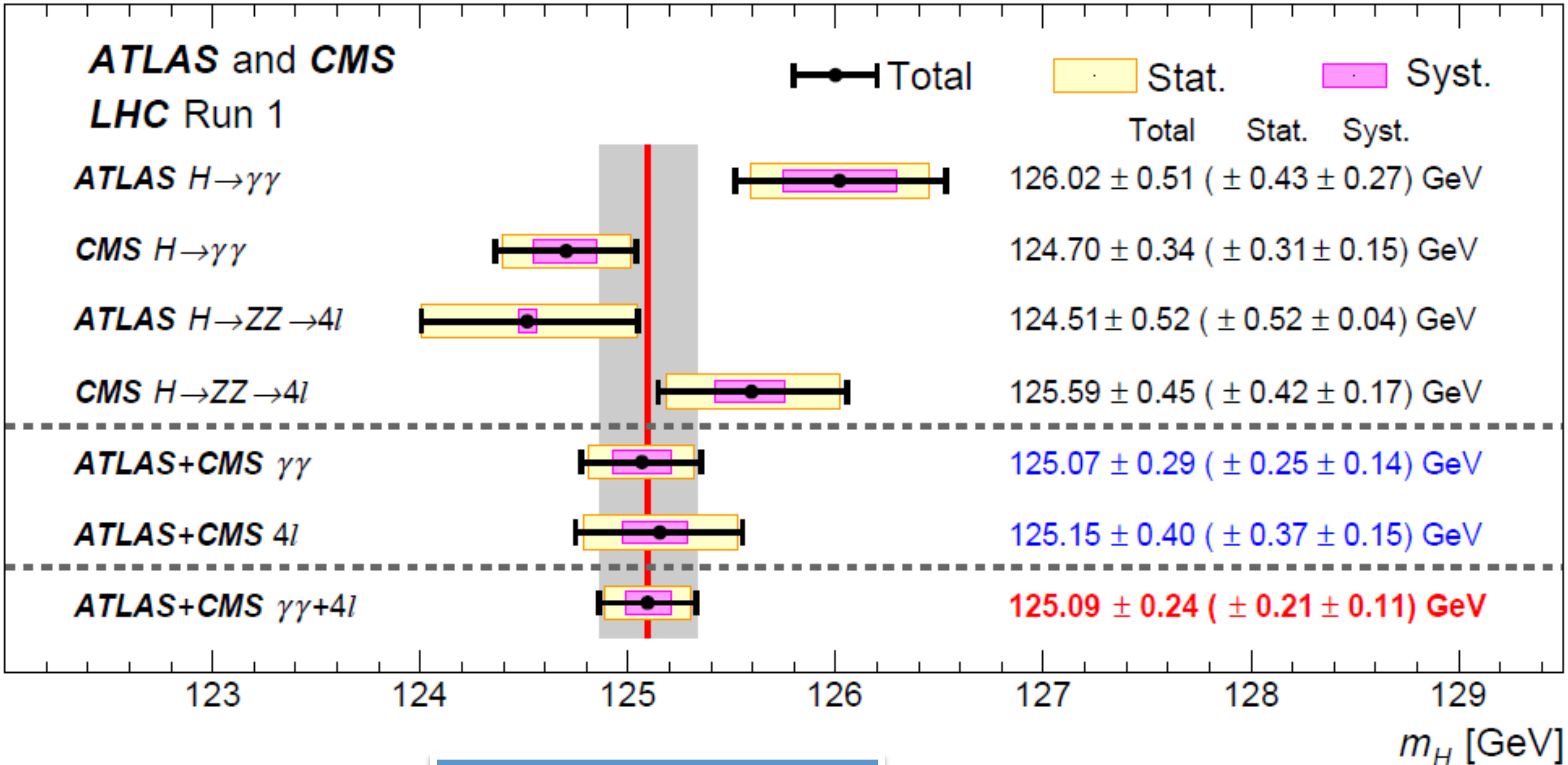
Also constraints on mixtures → see [paper]()

The previously unknown quantity…

$$\mathcal{L} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu}$$
$$+ i \bar{\psi} \not{D} \psi + h.c.$$
$$+ \bar{\psi}_i y_{ij} \psi_j \phi + h.c.$$
$$+ |D_\mu \phi|^2 - \boxed{V(\phi)}$$

$$\boxed{V(H^\dagger H) = \mu^2 H^\dagger H + \eta (H^\dagger H)^2}$$

Higgs boson mass



2 per mille
precision on mass

[arXiv:1503.07589]

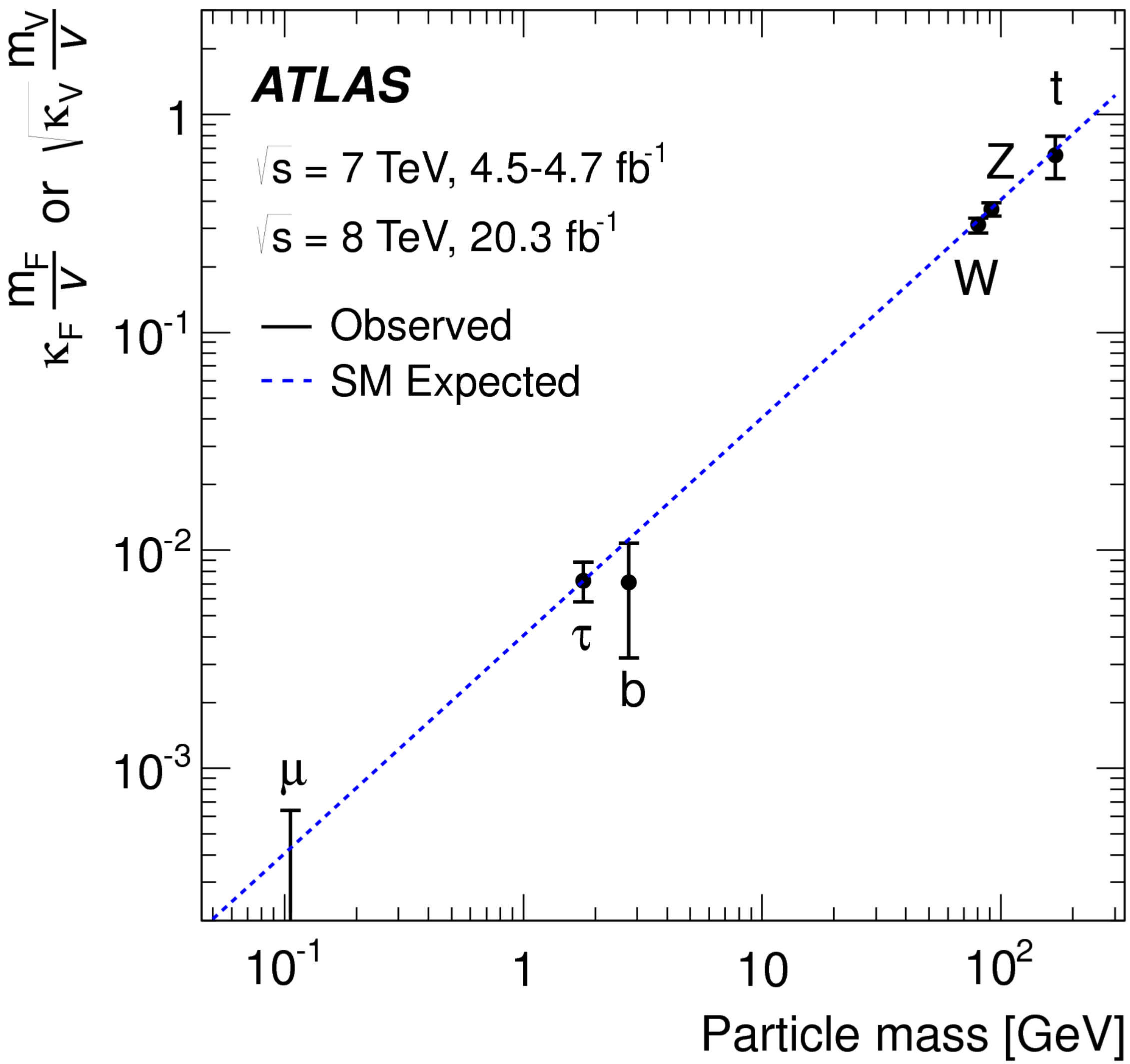
Couplings to SM particles…

$$
\begin{aligned}
\mathcal{L} = & -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} \\
& + i \bar{\Psi} \not{D} \psi + h.c. \\
& + \boxed{\bar{\psi}_i y_{ij} \psi_j \phi} + h.c. \\
& + \boxed{|D_\mu \phi|^2} - V(\phi)
\end{aligned}
$$

Scale factors κ_f for Yukawa interactions

Scale factors κ_V for W,Z interactions

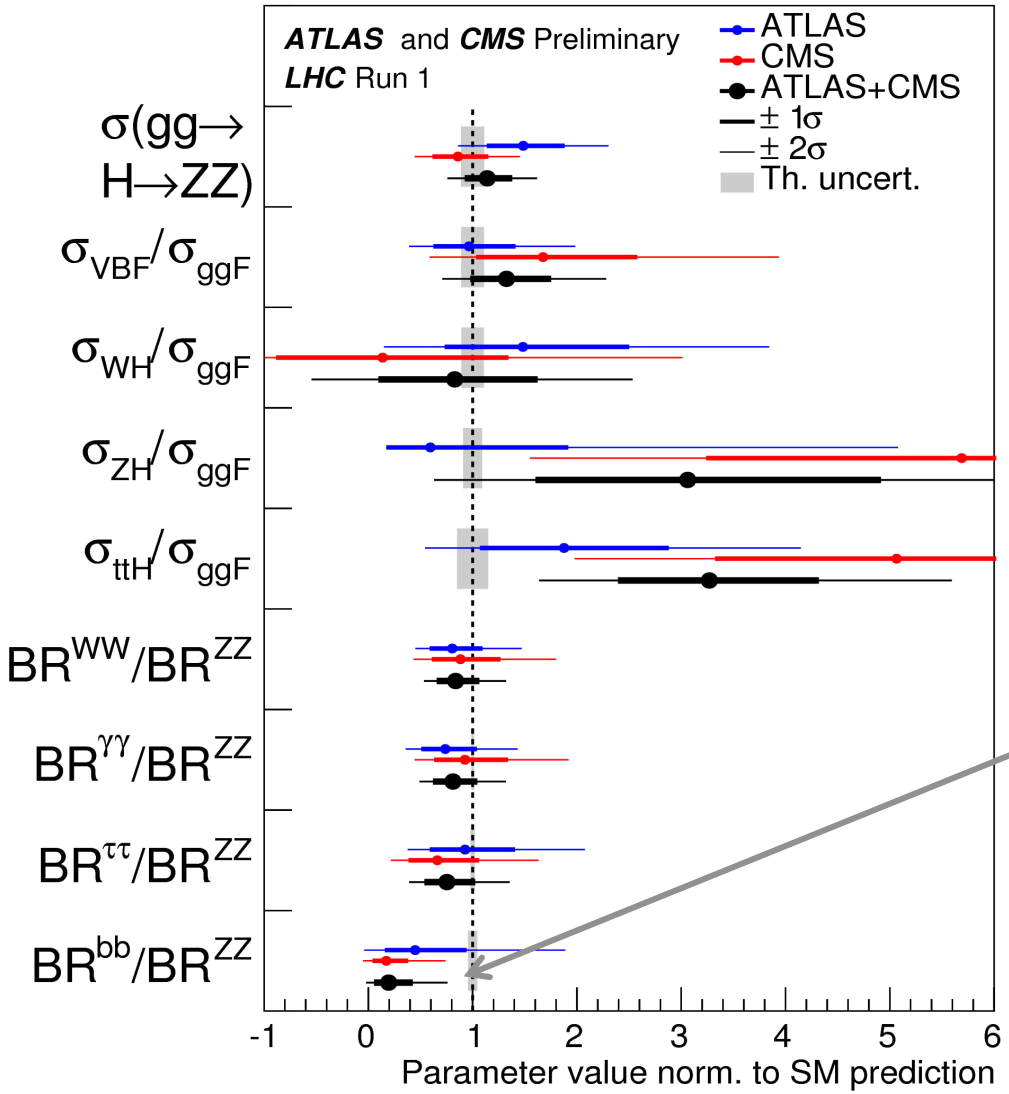
Couplings to other SM particles



First measurements
→ over three orders of magnitude

[1507.04548](https://arxiv.org/abs/1507.04548) (Jul 2015)

Higgs boson rates



+

4200 nuisance parameters

Reasonable agreement with SM @ O(1) level

Overall p-value 16%

BR^{bb}/BR^{ZZ} : 2.5 σ deficit

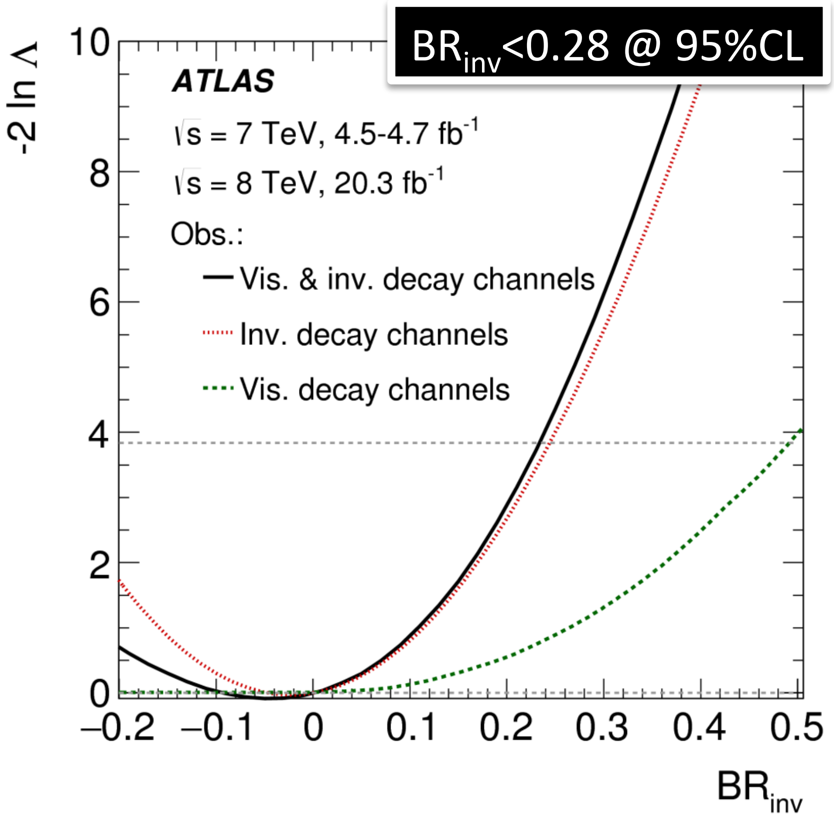
No time to discuss e.g.:
→ rare decays e.g. $Z\gamma$
→ Flavour violating decays

ATLAS-CONF-2015-044 (Sept 2015)

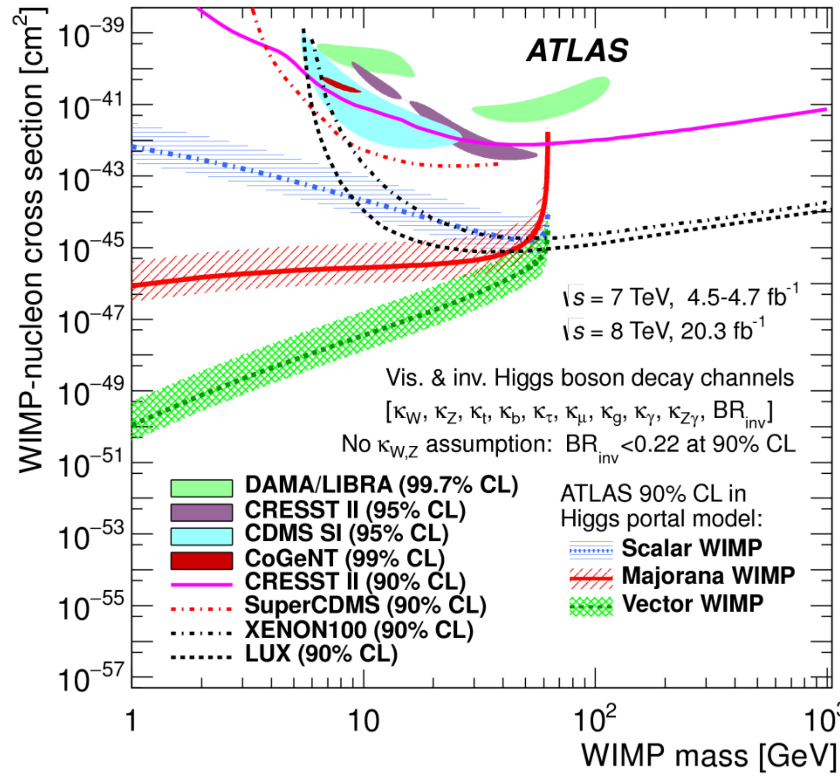
Couplings to invisibles?

[1508.07869](1508.07869)

[1509.00672](1509.00672)



Higgs portal model

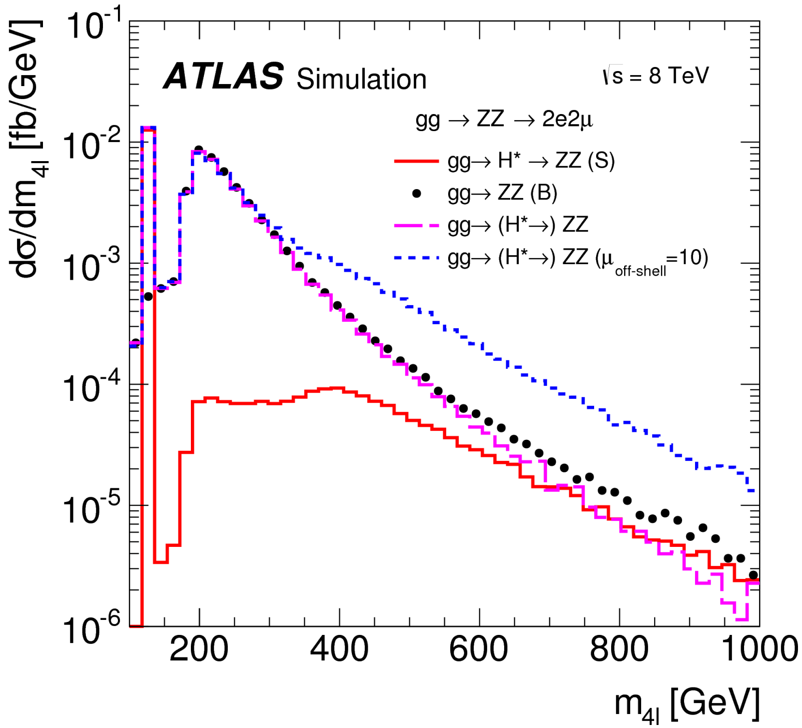


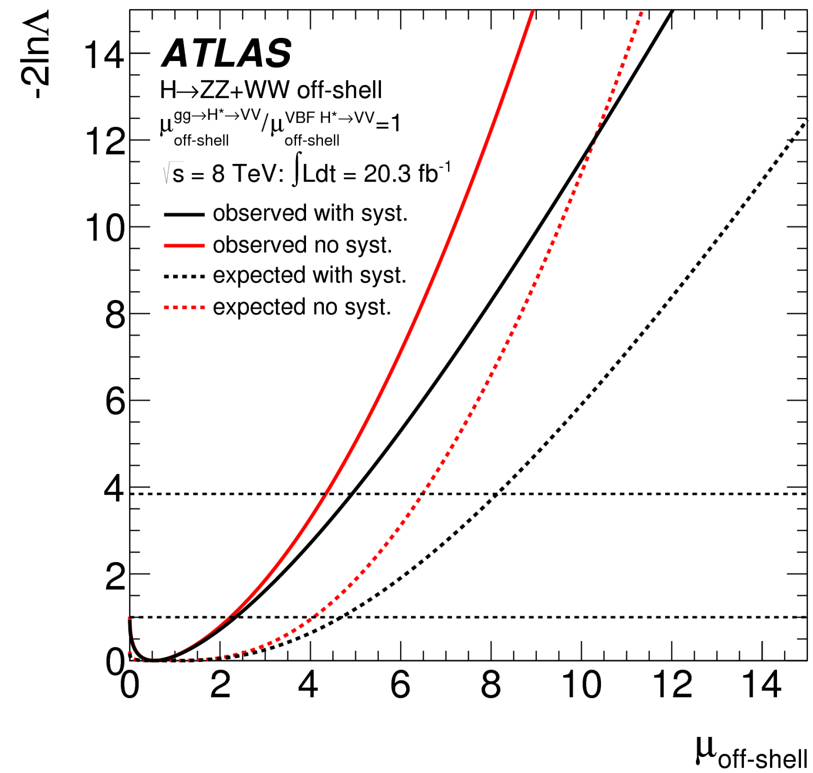
VBF production

V+H associated production

followed by H → invisible

Constraint on total width





$R^{B}_{H^*}$	Observed 0.5	**1.0**	2.0	Median expected 0.5	**1.0**	2.0	Assumption
Γ_H/Γ_H^{SM}	4.5	**5.5**	7.5	6.5	**8.0**	11.2	$\kappa_{i,\text{on-shell}} = \kappa_{i,\text{off-shell}}$
$R_{gg} = \kappa^2_{g,\text{off-shell}}/\kappa^2_{g,\text{on-shell}}$	4.7	**6.0**	8.6	7.1	**9.0**	13.4	$\kappa_{V,\text{on-shell}} = \kappa_{V,\text{off-shell}}, \Gamma_H/\Gamma_H^{SM}=1$

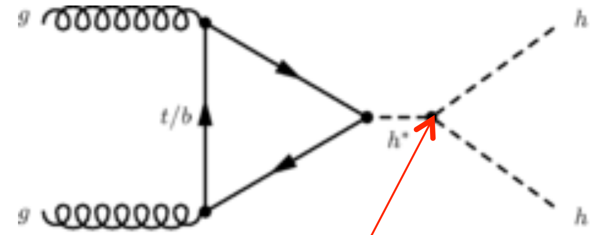
[1503.01060]

$$\mathcal{L} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu}$$

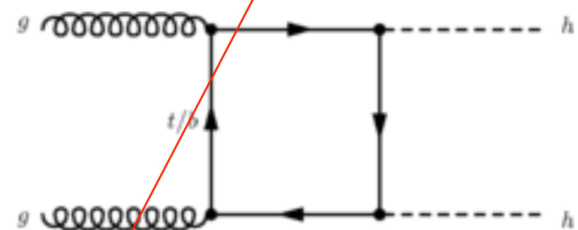
$$+ i\bar{\Psi} \not{D} \psi + h.c.$$

$$+ \bar{\Psi}_i y_{ij} \psi_j \phi + h.c.$$

$$+ |D_\mu \phi|^2 - \boxed{V(\phi)}$$



(a)



(b)

$$V(H^\dagger H) = \mu^2 H^\dagger H + \eta (H^\dagger H)^2$$

$$\to \frac{1}{2} m_h^2 h^2 + \boxed{\sqrt{\frac{\eta}{2}} m_h h^3} + \frac{\eta}{4} h^4 ,$$

Constraints on Higgs self-couplings

Higgs pair production

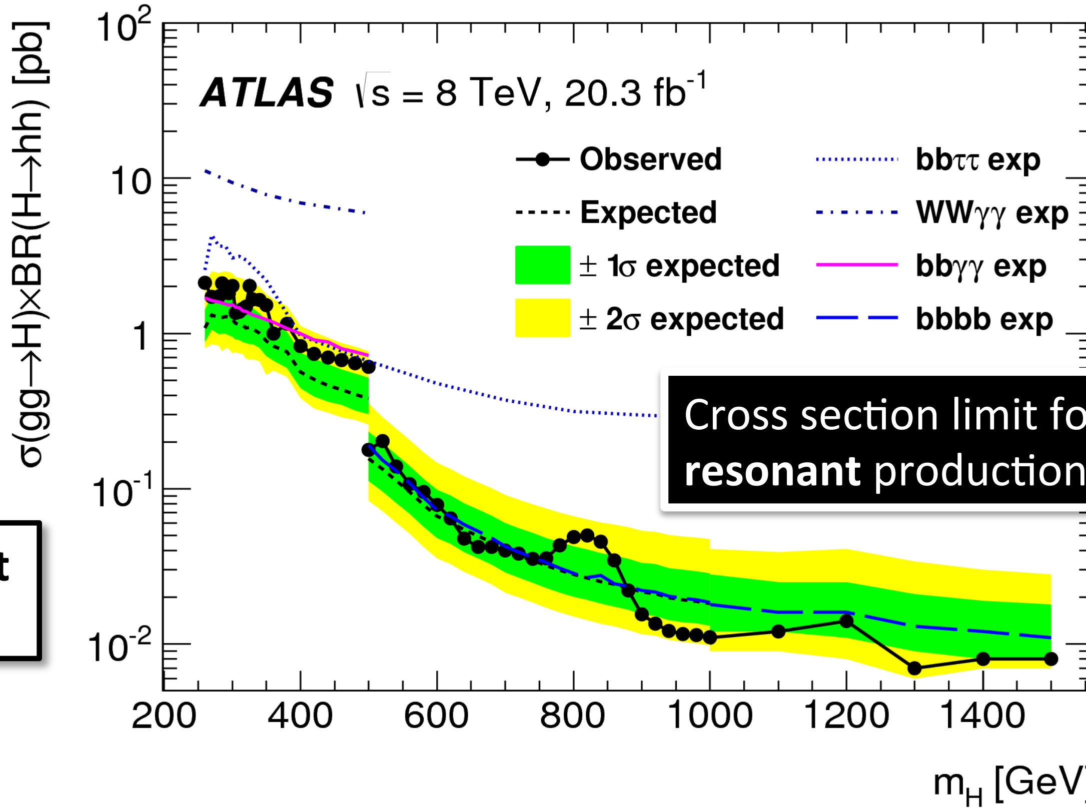
Four different final states

- bb $\gamma\gamma$
- bb $\tau\tau$
- WW $\gamma\gamma$
- bb bb

Standard Model **non-resonant** cross-section: **9.9 ± 1.3 fb**

Non-resonant: **σ_{obs} < 700 fb** (70 times SM value)

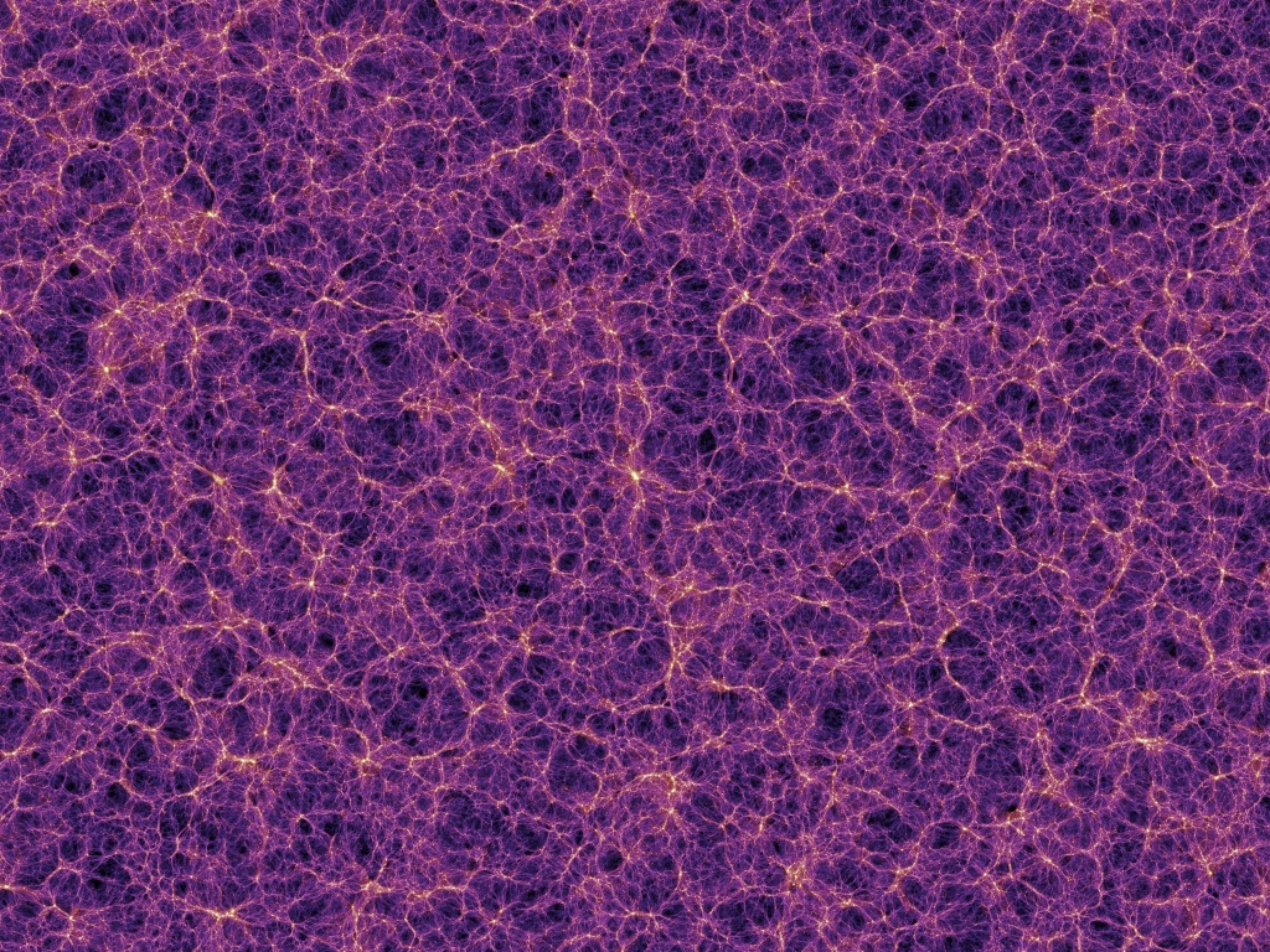
Not expected to be sensitive to SM coupling for some time…



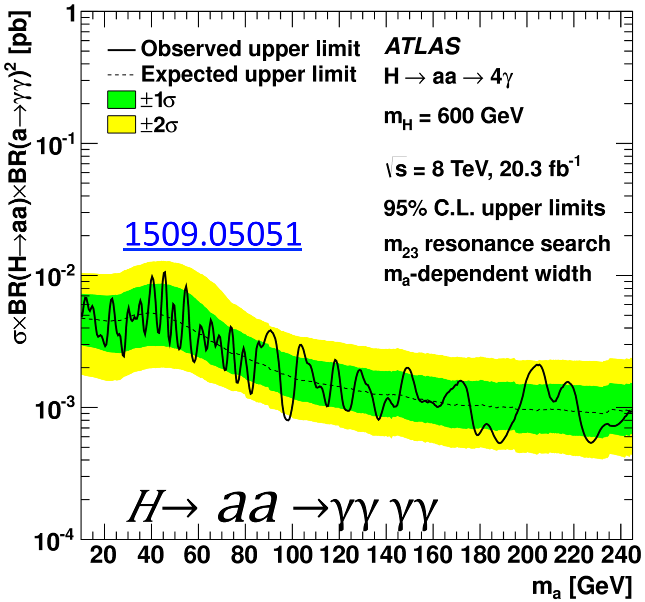
Cross section limit for resonant production

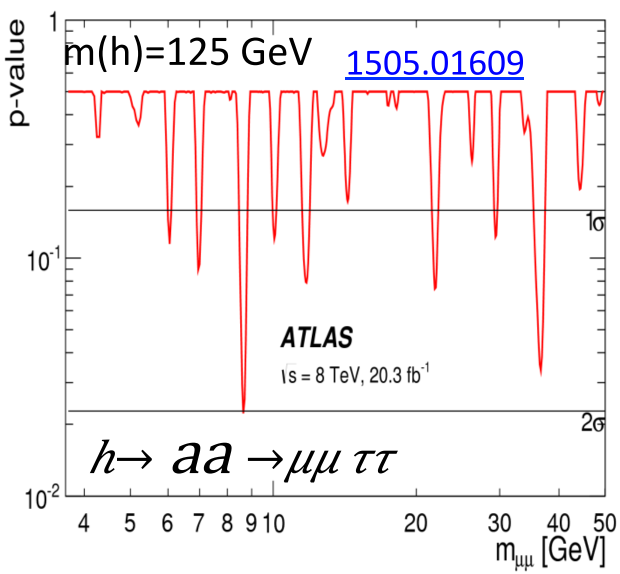
→ High Luminosity LHC
- ATL-PHYS-PUB-2014-019 (bb$\gamma\gamma$)
- ATL-PHYS-PUB-2015-046 (bb$\tau\tau$)

→ 3/ab 100 TeV future collider
- E.g. 1412.7154, 1504.02334, 1504.08042, 1506.08008, …

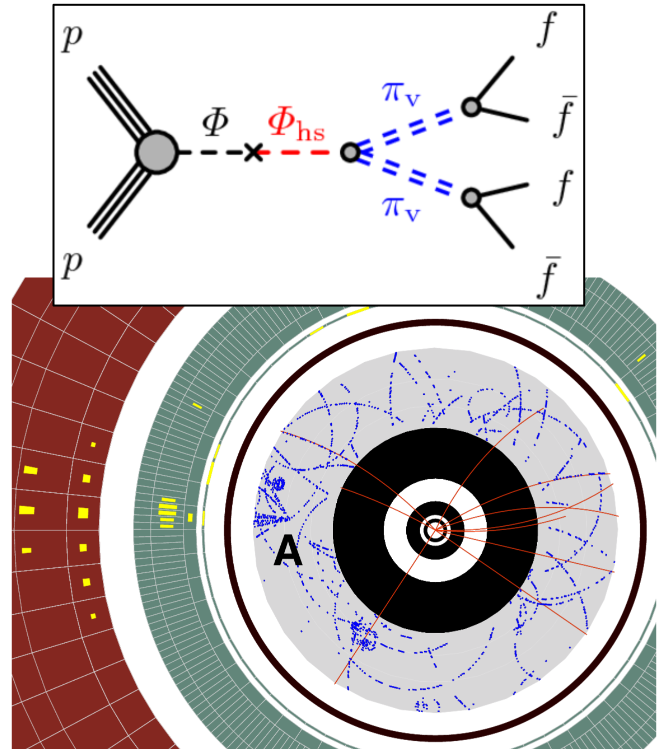


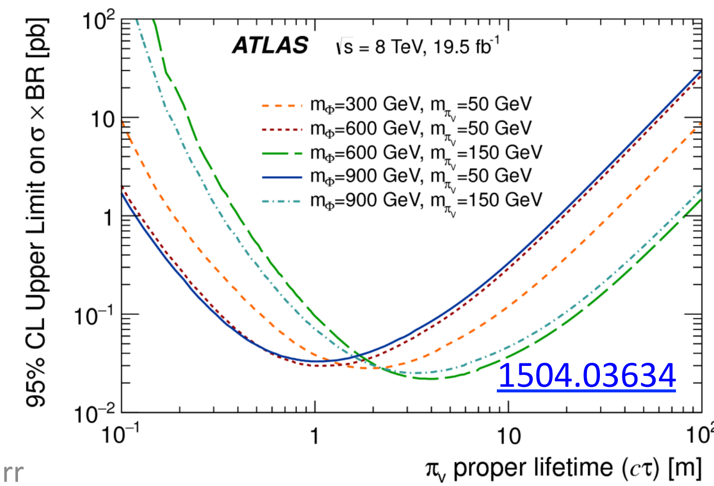
Decays to light scalars



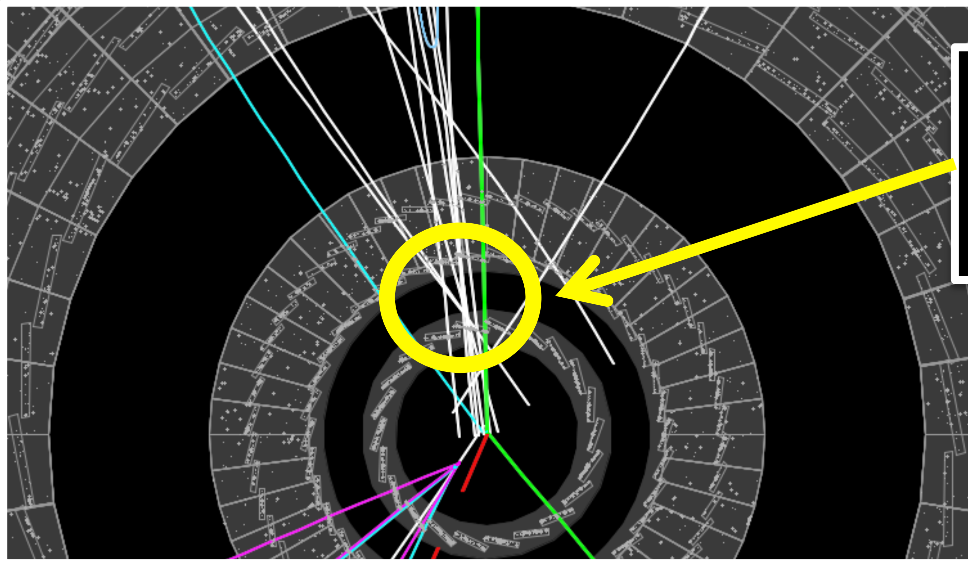


Limits up to m(h)=500 GeV

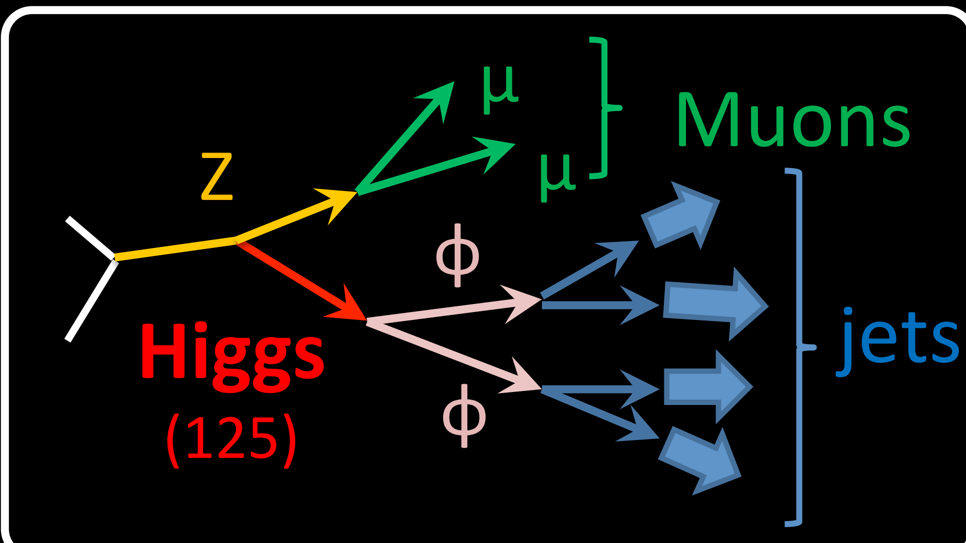




"Higgs Hunters" - Citizen Science Project



People good at spotting long-lived particle decays
(this one not found by algorithm)



7,000 different people
85,000 images
860,000 classifications

www.higgshunters.org

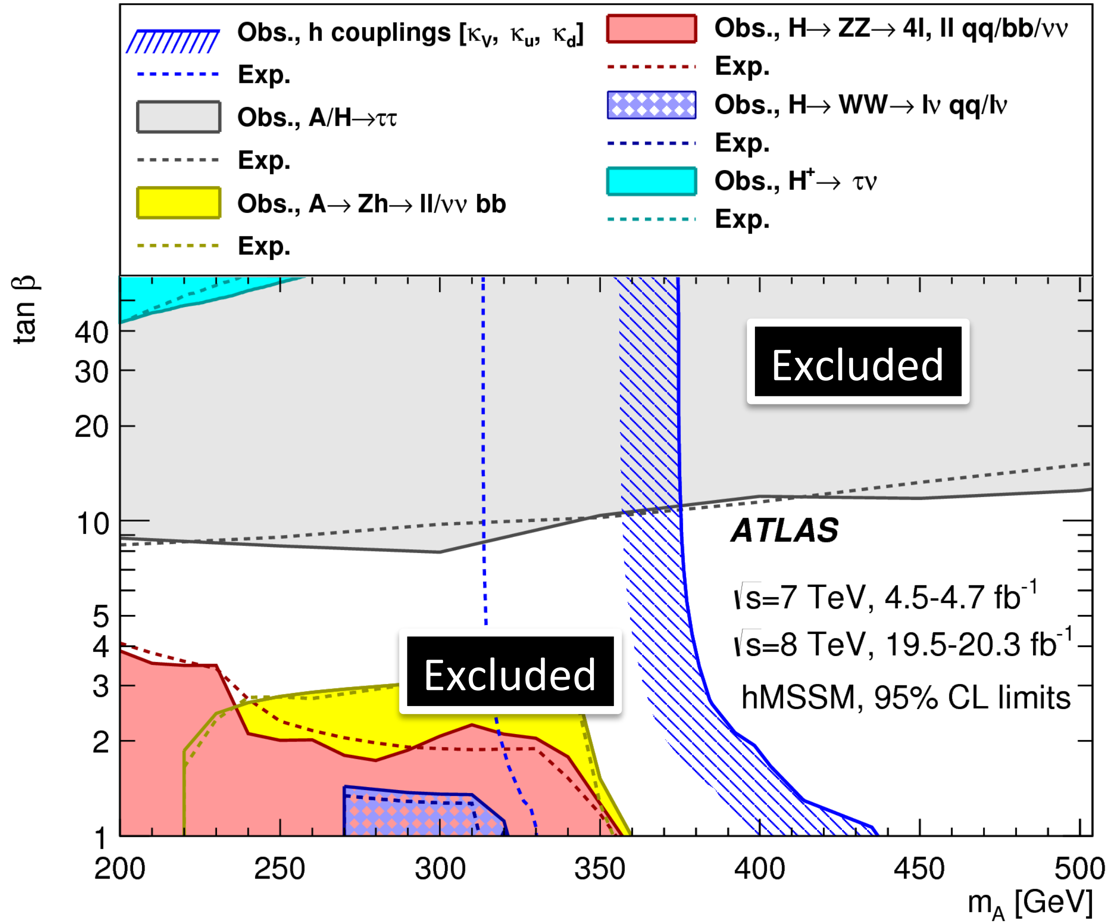
1509.00672

SUSY: Two-Higgs-doublet-model

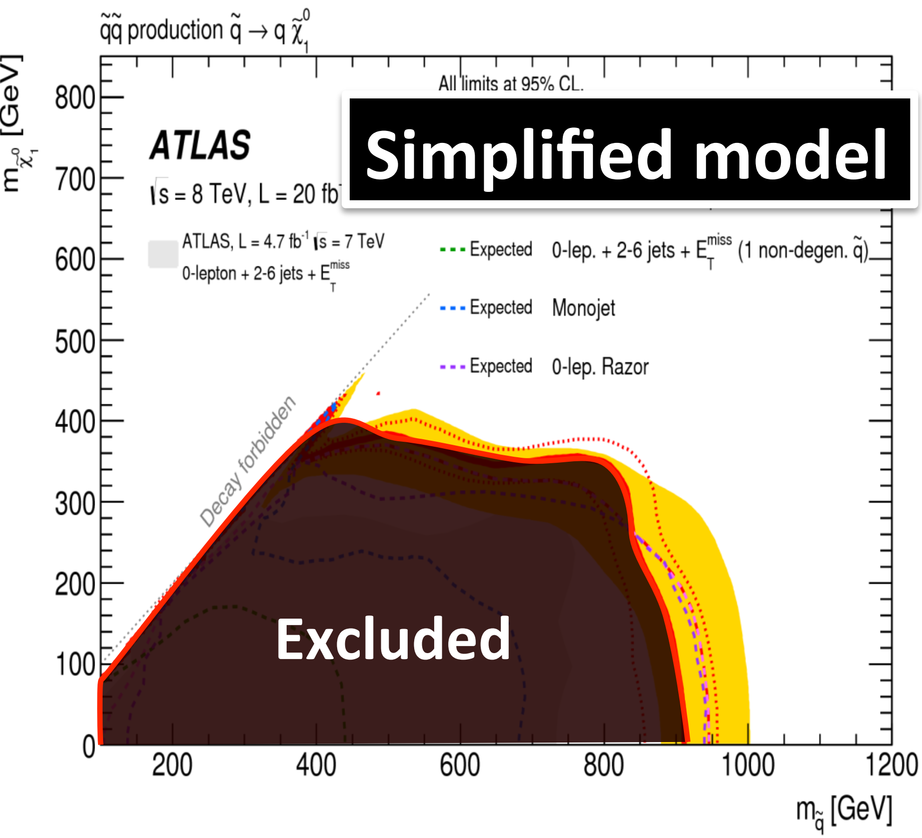
Two doublets in SUSY models
→ 8-3 = **5 states**:
h, H, A, $H^{\pm}$

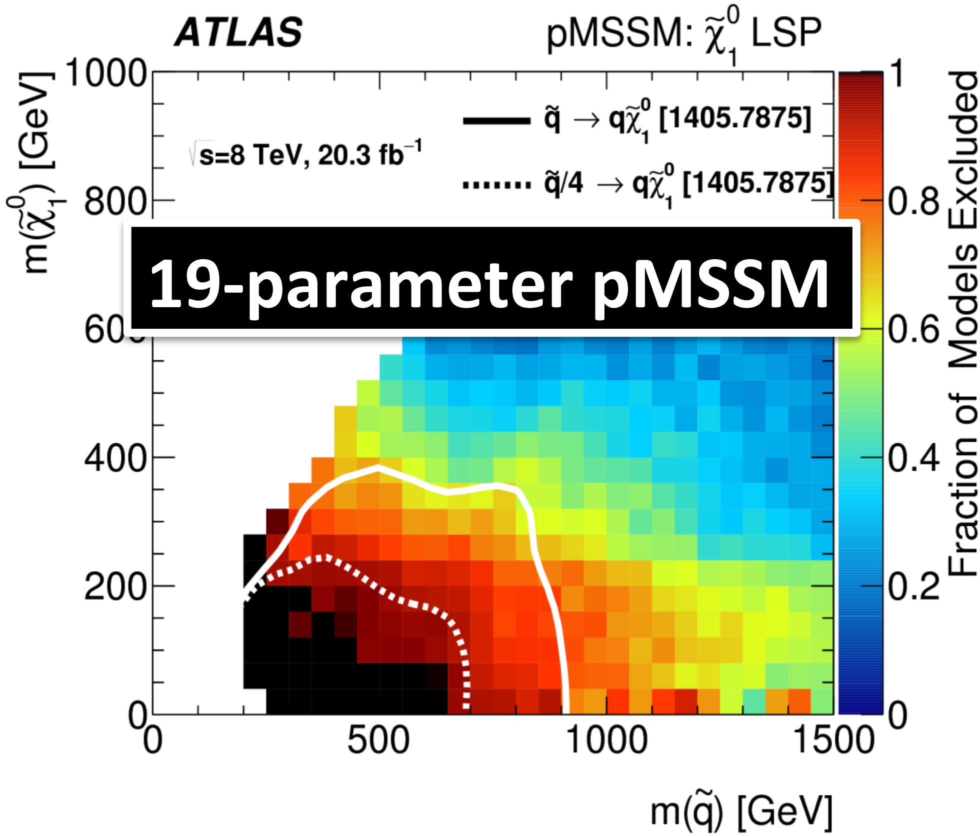
$\lambda_{Vu} = \kappa_V / \kappa_u$	Ratio of vector boson to up-type fermion ($t, c, \ldots$) coupling s.f.
$\kappa_{uu} = \kappa_u^2 / \kappa_h$	Ratio of squared up-type fermion coupling s.f. to total width s.f.
$\lambda_{du} = \kappa_d / \kappa_u$	Ratio of down-type fermion ($b, \tau, \ldots$) to up-type fermion coupling s.f.

2HD Type II, hMSSM



SUSY: Scalar quarks?

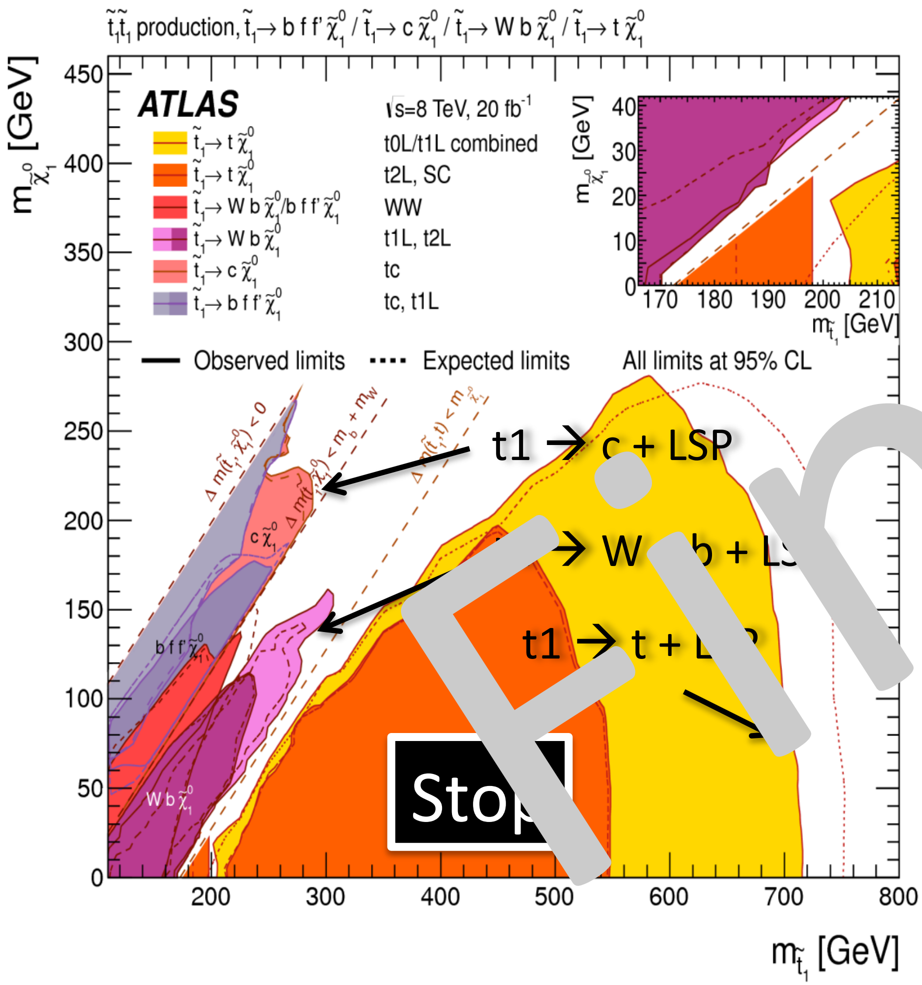


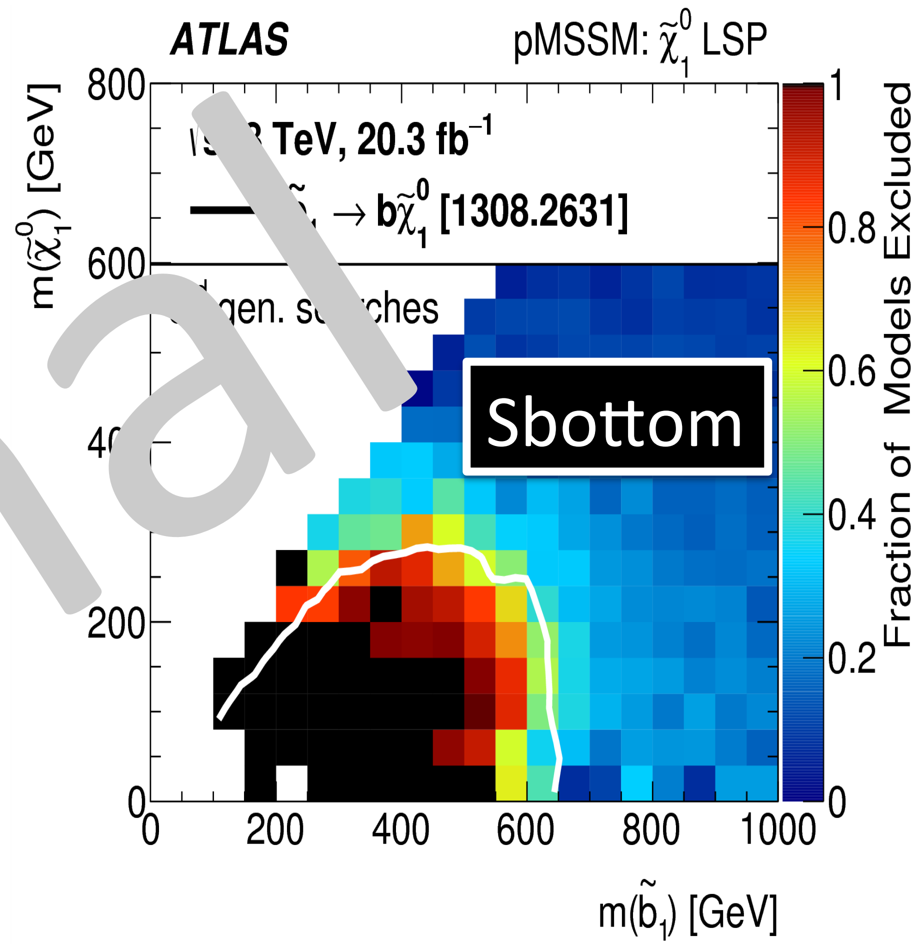


Squarks constrained below 500 GeV – 1 TeV

[1507.05525](https://arxiv.org/abs/1507.05525) [1508.06608](https://arxiv.org/abs/1508.06608)

SUSY: Scalar tops and bottoms?





Final

So…

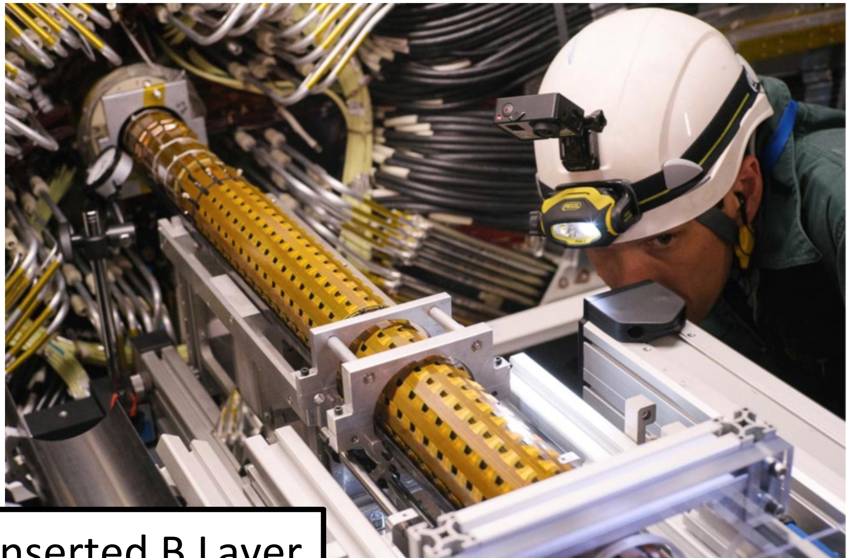
1506.08616

1508.06608

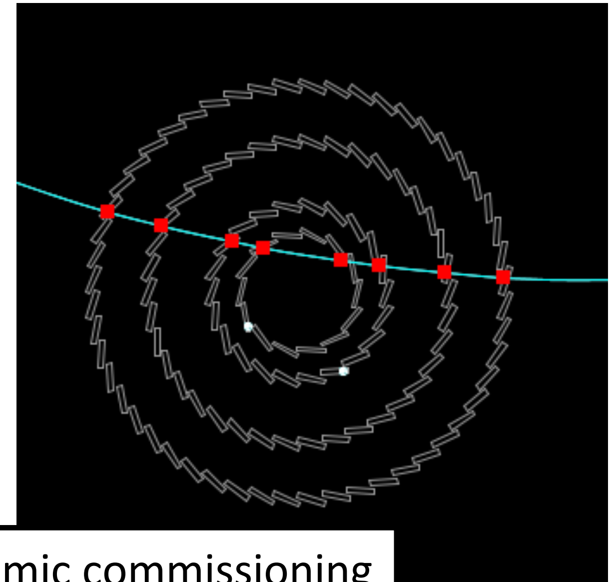
13 TeV collisions!

3 June 2015

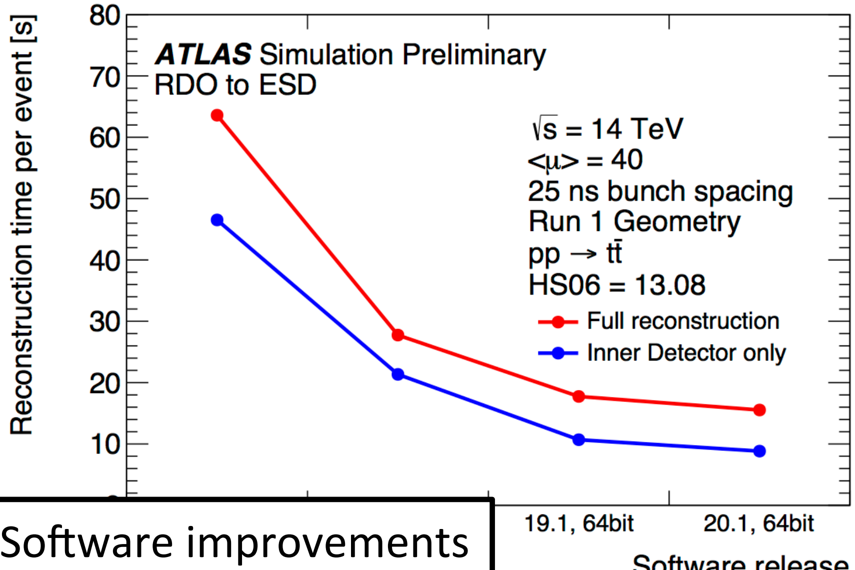
Run-2: Detector, Software, Trigger upgrades



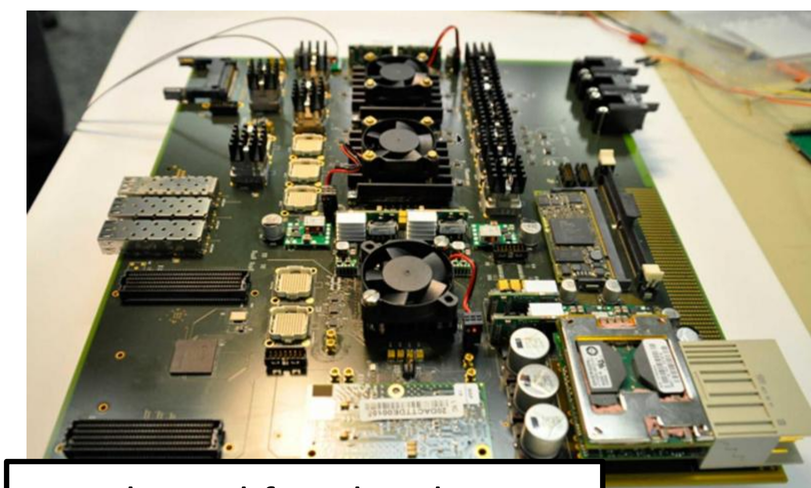
Inserted B Layer



Cosmic commissioning

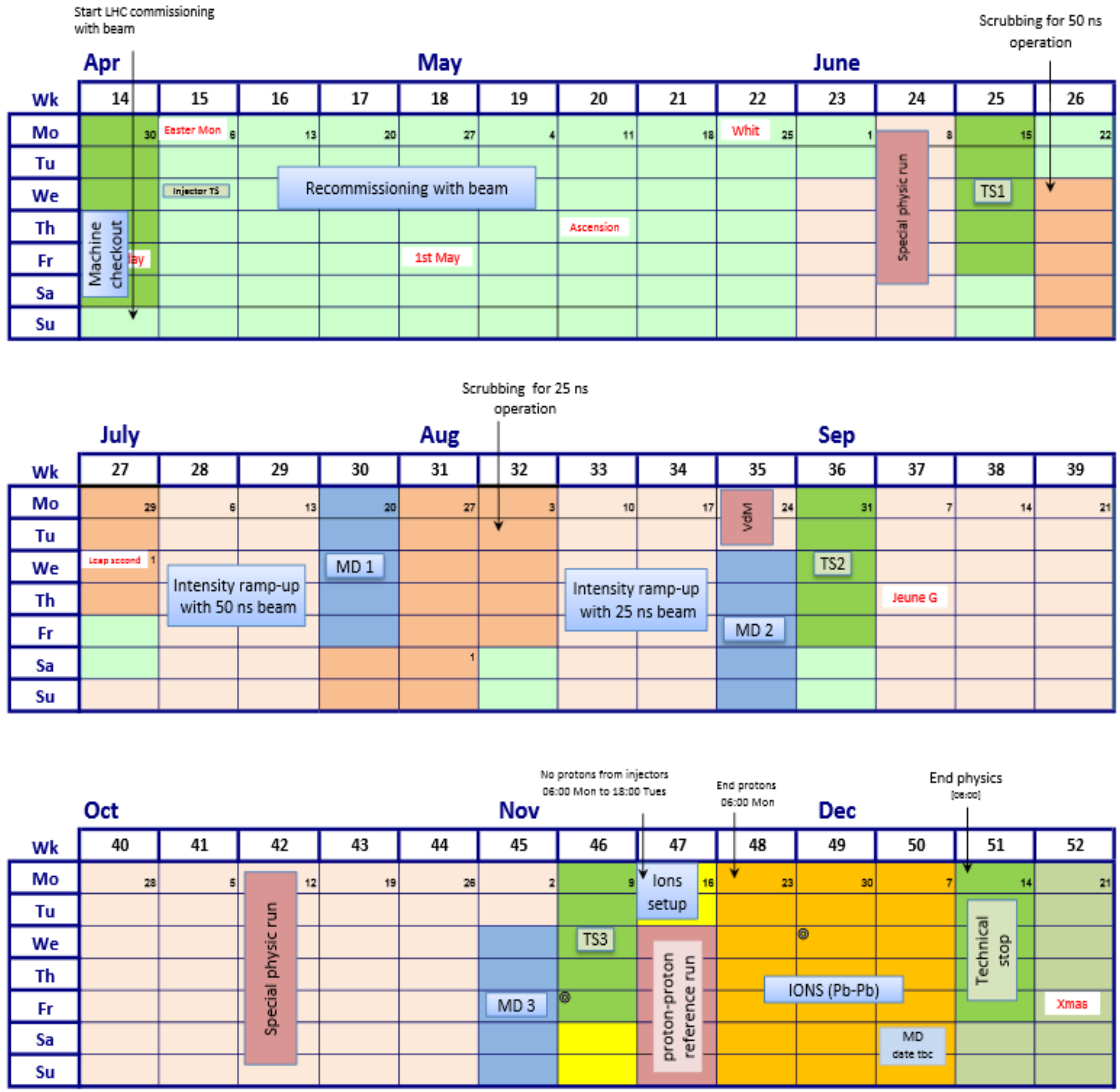


Software improvements



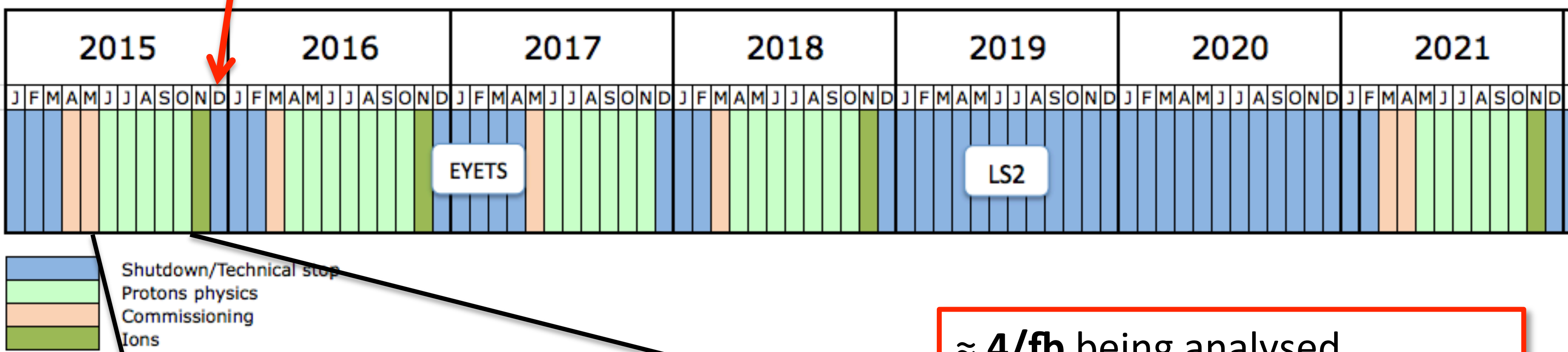
Topological first-level trigger

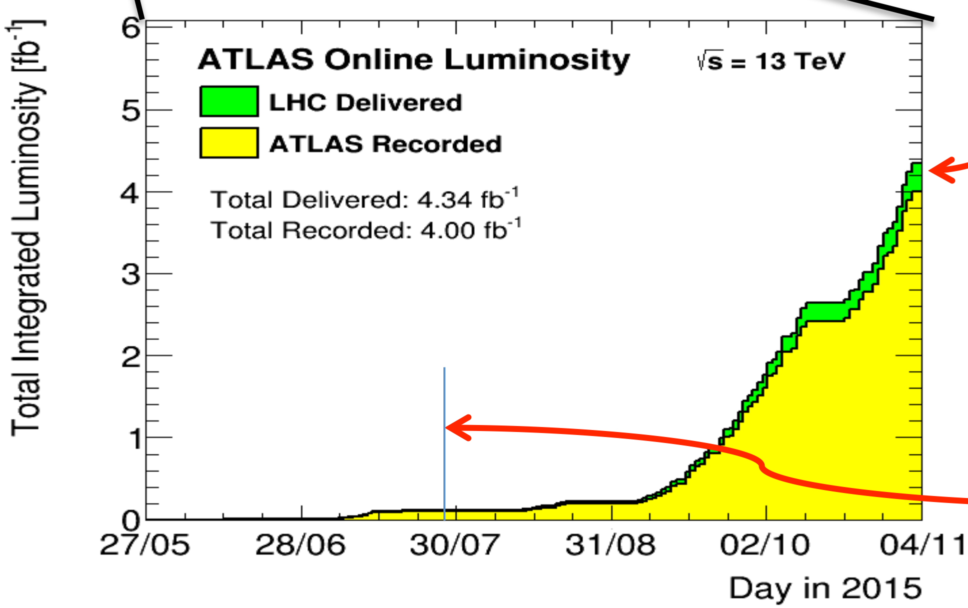
- Very rich and eventful period with diverse running conditions
  - 13 TeV
  - From few up to 2400 bunches
  - 50 ns, 25 ns, intensity ramp up
  - Limits on trigger rate for partially filled machine to avoid fixed frequencies (wire bond resonances on silicon detectors)
- Special Runs:
  - low pileup runs,
  - special combined trigger/running with LHCf
  - elastic and diffractive running with ALFA roman pots
- pp reference 5.02 TeV center of mass energy
- Heavy Ions 6.37*Z TeV



LHC schedule

We are here

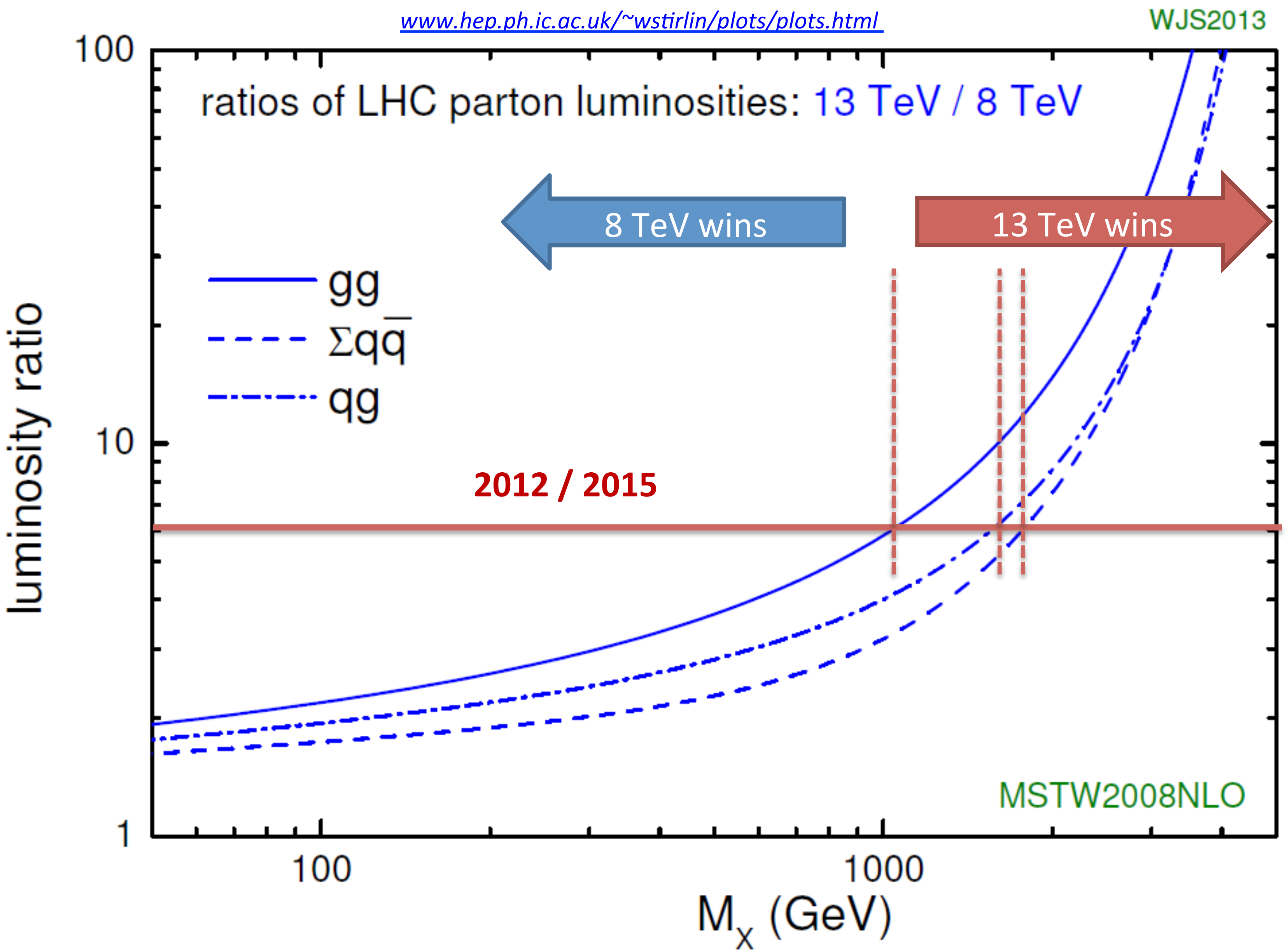


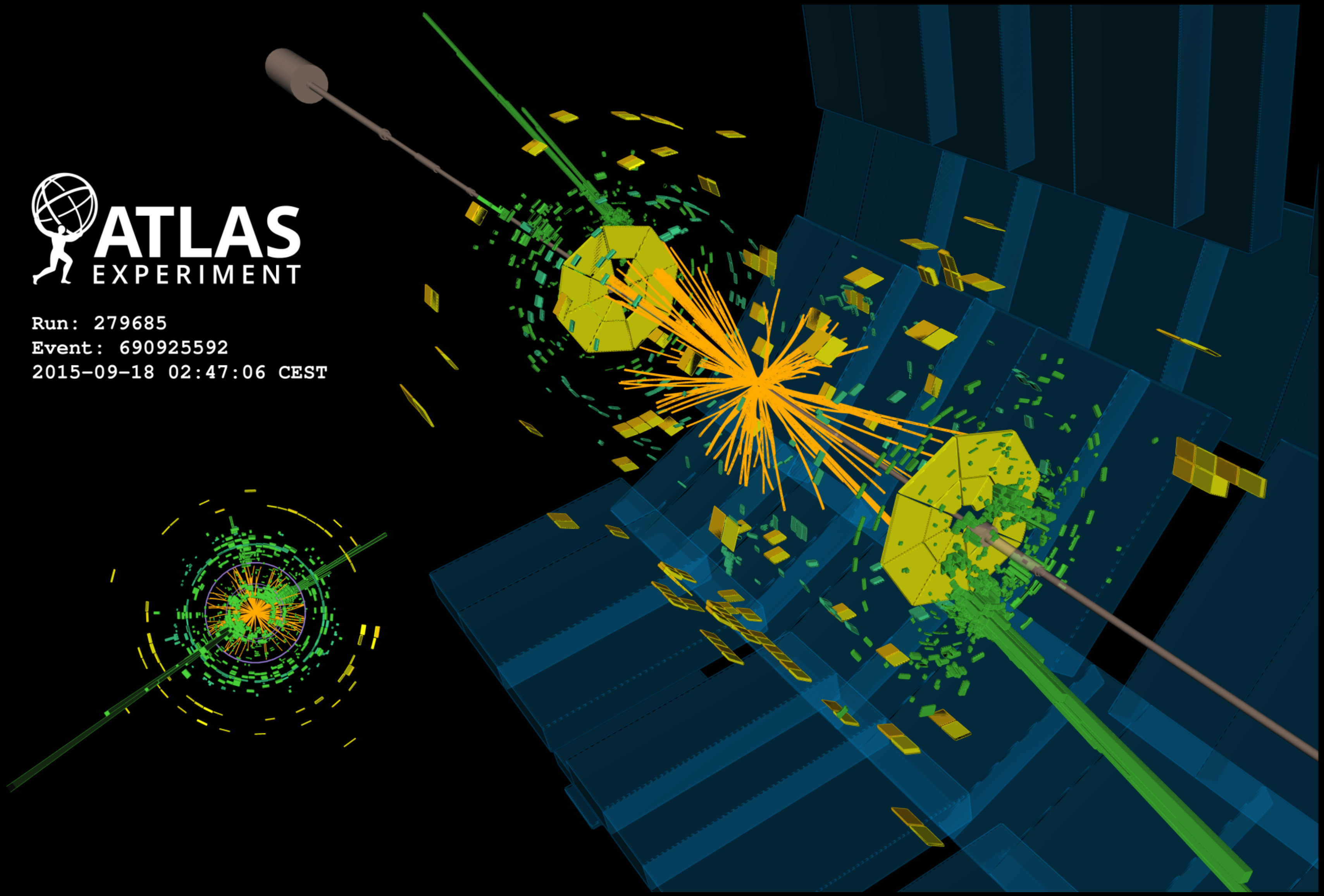


≈ **4/fb** being analysed

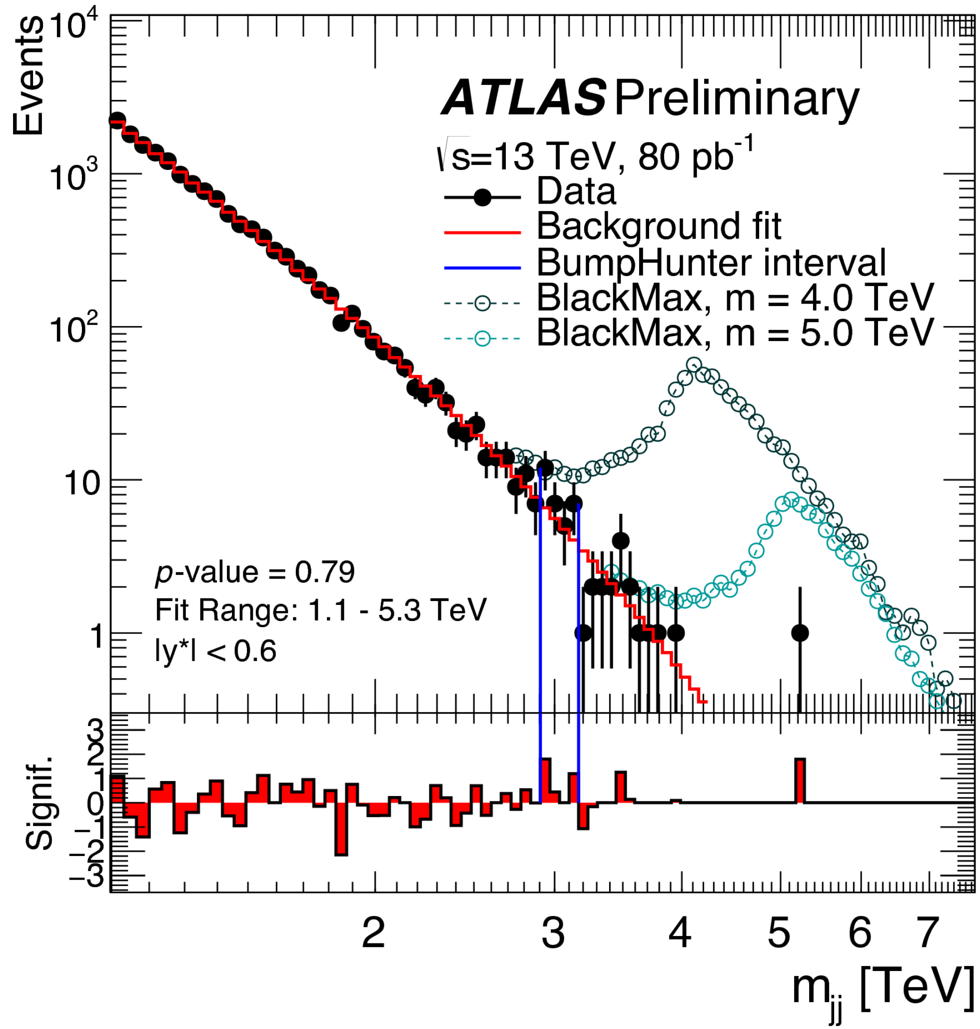
First results @ CERN seminar:
15 December, 3pm
https://indico.cern.ch/event/442432/

≈ **80/pb**
→ First results seen at this year's **Summer Conferences**


www.hep.ph.ic.ac.uk/~wstirlin/plots/plots.html
WJS2013
ratios of LHC parton luminosities: 13 TeV / 8 TeV
8 TeV wins
13 TeV wins
gg
Σqq̄
qg
2012 / 2015
MSTW2008NLO
luminosity ratio
100
10
1
100
1000
M_X (GeV)



Dijet invariant mass = 8.8 TeV



➔ Quantum Black Holes excluded for masses < 6.5 TeV

Much excitement about analyses in progress…

Conclusions

- We have an (apparently) fundamental **scalar**
- **Couplings** to SM particles are so far as predicted
  (within rather large uncertainties)
- Other scalars proving **elusive** at present
- Analysis of **Run-2** data well in progress
- Expect update at CERN end-of-year event

ATLAS EXPERIMENT

MERTON COLLEGE OXFORD

UNIVERSITY OF OXFORD

Science & Technology Facilities Council

ZOONIVERSE REAL SCIENCE ONLINE

SCALARS 2015
03-07 December 2015
Warsaw, Poland

Process	Branching ratio	Uncertainty	
$H \to bb$	5.77 x 10-1	+3.2%	-3.3%
$H \to \tau\tau$	6.32 x 10-2	+5.7%	-5.7%
$H \to \mu\mu$	2.20 x 10-4	+6.0%	-5.9%
$H \to cc$	2.91 x 10-2	+12.2%	-12.2%
$H \to gg$	8.57 x 10-2	+10.2%	-10.0%
$H \to \gamma\gamma$	2.28 x 10-3	+5.0%	-4.9%
$H \to Z\gamma$	1.54 x 10-3	+9.0%	-8.8%
$H \to WW$	2.15 x 10-1	+4.3%	-4.2%
$H \to ZZ$	2.64 x 10-2	+4.3%	-4.2%
Γ_H [GeV]	4.07 x 10-3	+4.0%	-3.9%

https://twiki.cern.ch/twiki/bin/view/LHCPhysics/CERNYellowReportPageBR2

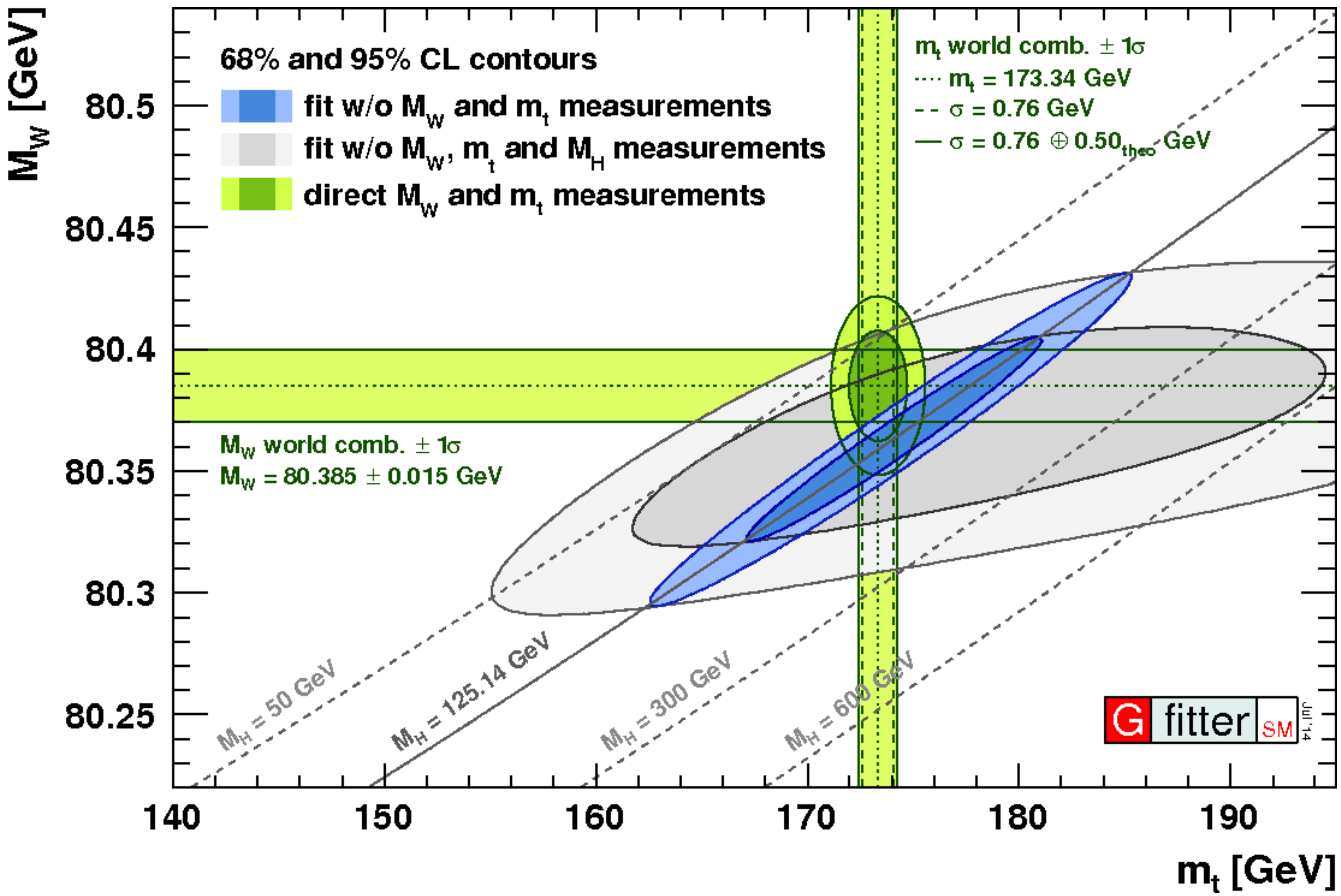
Spin-parity test Lagrangians

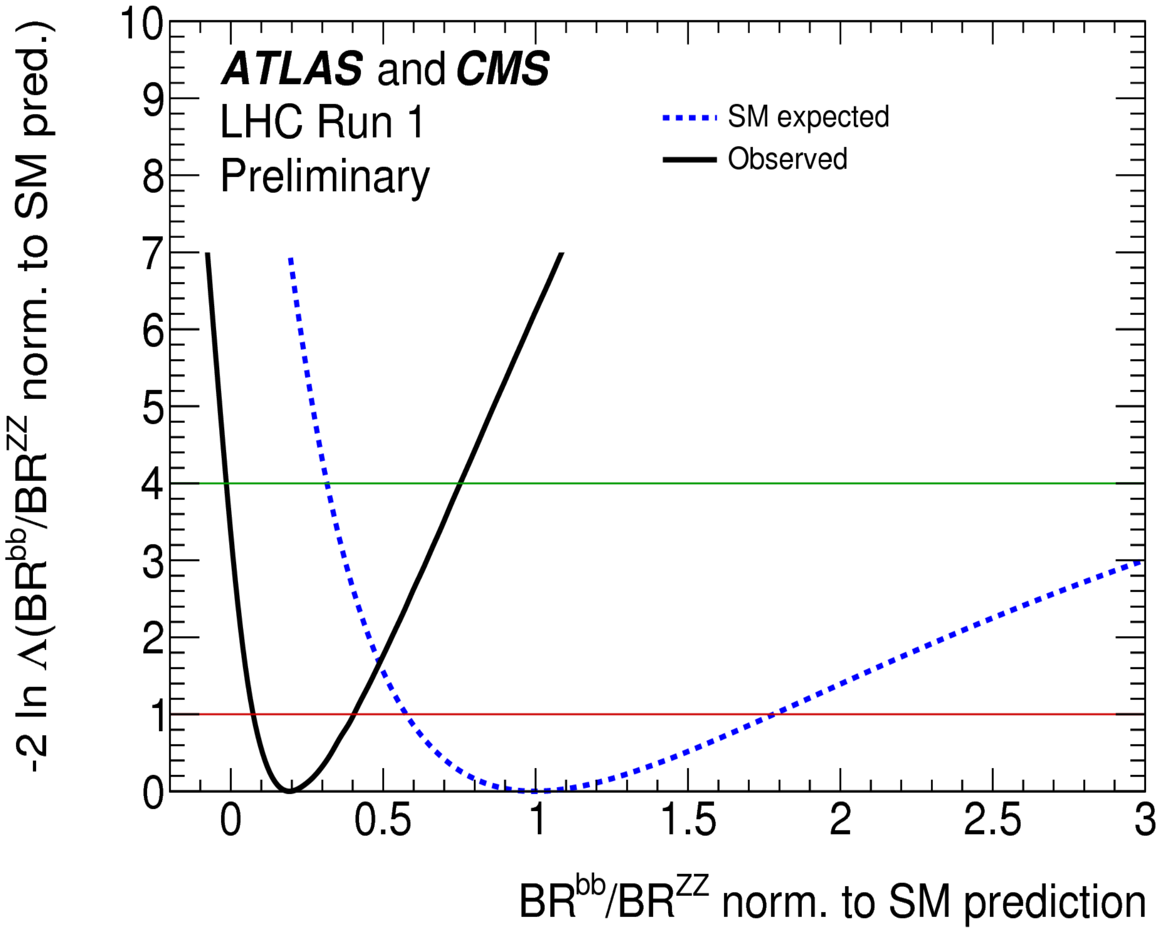
$$\mathcal{L}_0^V = \Big\{\cos(\alpha)\kappa_{\rm SM}\left[\tfrac{1}{2}g_{HZZ}Z_\mu Z^\mu + g_{HWW}W_\mu^+ W^{-\mu}\right] -\tfrac{1}{4}\tfrac{1}{\Lambda}\left[\cos(\alpha)\kappa_{HZZ}Z_{\mu\nu}Z^{\mu\nu} + \sin(\alpha)\kappa_{AZZ}Z_{\mu\nu}\tilde{Z}^{\mu\nu}\right] -\tfrac{1}{2}\tfrac{1}{\Lambda}\left[\cos(\alpha)\kappa_{HWW}W_{\mu\nu}^+ W^{-\mu\nu} + \sin(\alpha)\kappa_{AWW}W_{\mu\nu}^+\tilde{W}^{-\mu\nu}\right]\Big\}X_0.$$

$$\mathcal{L}_2 = -\frac{1}{\Lambda}\left[\sum_V \kappa_V \mathcal{T}_{\mu\nu}^V X^{\mu\nu} + \sum_f \kappa_f \mathcal{T}_{\mu\nu}^f X^{\mu\nu}\right].$$

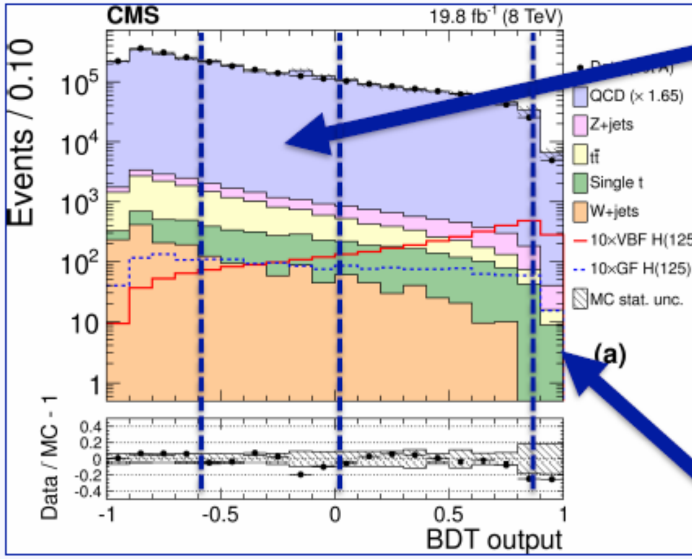
1506.05669

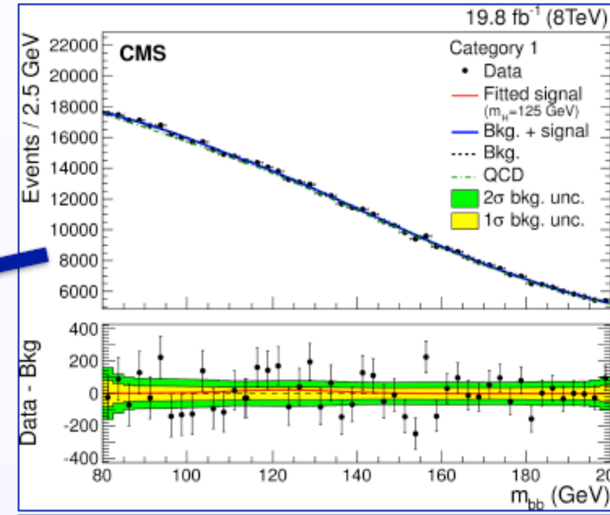
Global EW fit

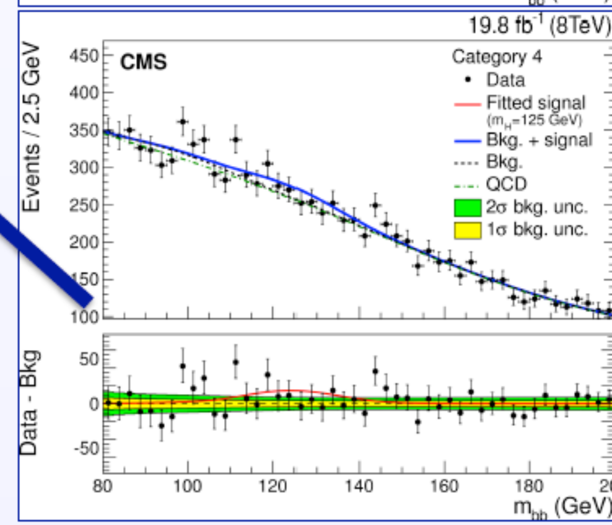



ATLAS and CMS
LHC Run 1
Preliminary
SM expected
Observed
-2 ln Λ(BR^bb/BR^ZZ norm. to SM pred.)
BR^bb/BR^ZZ norm. to SM prediction
0
1
2
3
4
5
6
7
8
9
10
0
0.5
1
1.5
2
2.5
3

- Alternative approach for $H\rightarrow bb$ search.
  - BDT base on event kinematics and *b* content
  - fit to m_{bb} spectrum

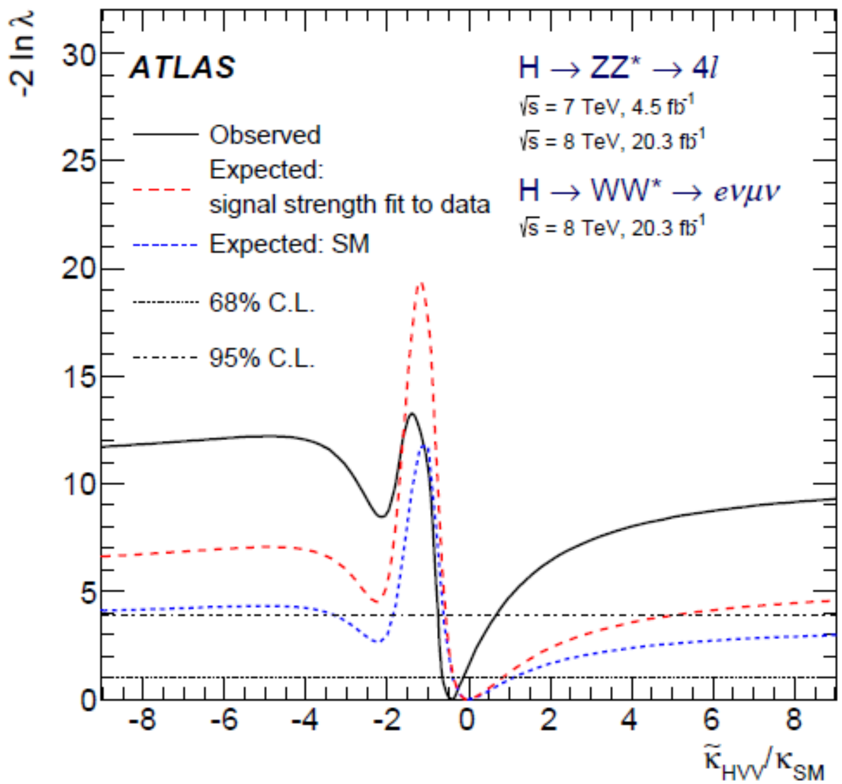


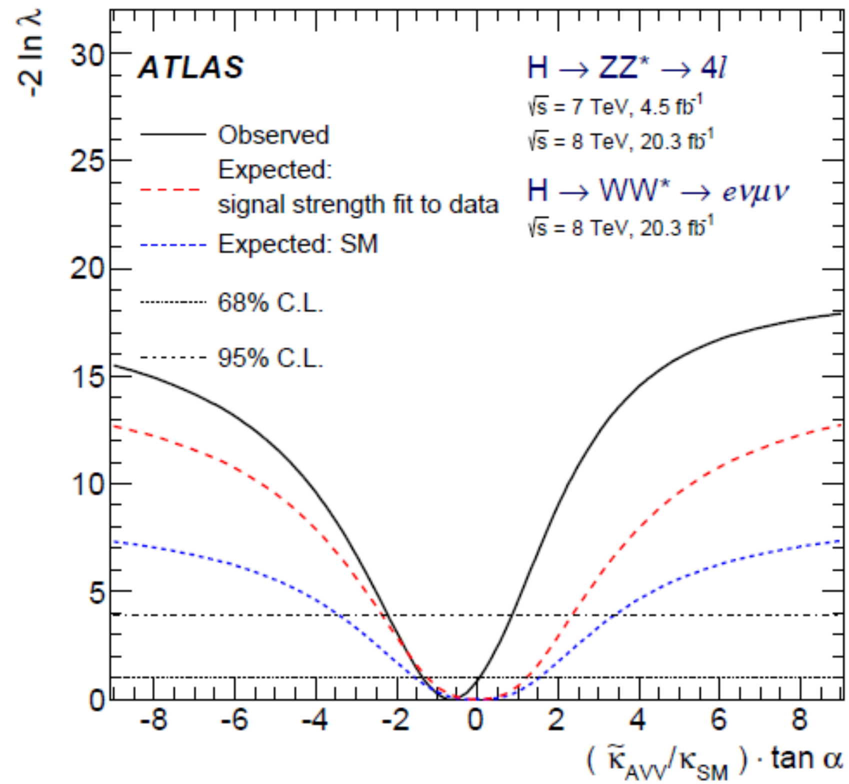




$H\rightarrow b\bar{b}$	Best fit (68% CL)	Upper limits (95% CL)		Signal significance	
Channel	Observed	Observed	Expected	Observed	Expected
VH	0.89 ± 0.43	1.68	0.85	2.08	2.52
$t\bar{t}$H	0.7 ± 1.8	4.1	3.5	0.37	0.58
VBF	$2.8^{+1.6}_{-1.4}$	5.5	2.5	2.20	0.83
Combined	$1.03^{+0.44}_{-0.42}$	1.77	0.78	2.56	2.70

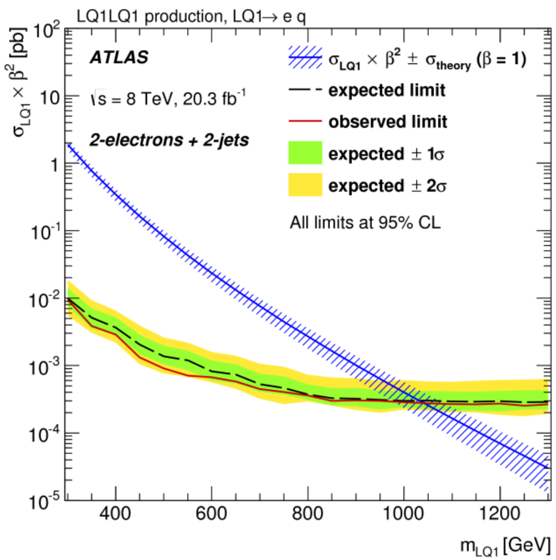
Constraints on BSM terms in L0



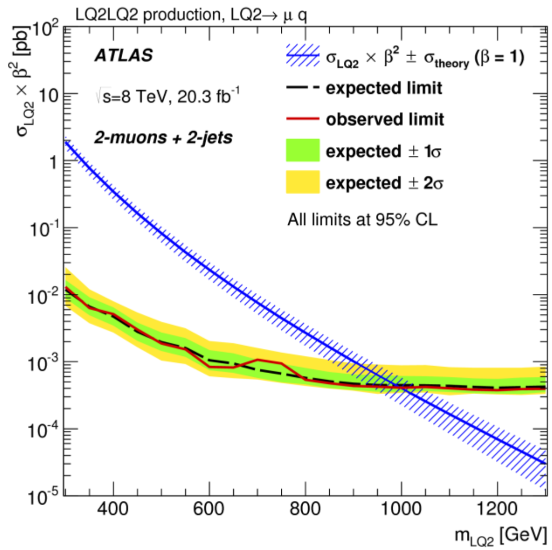


1506.05669

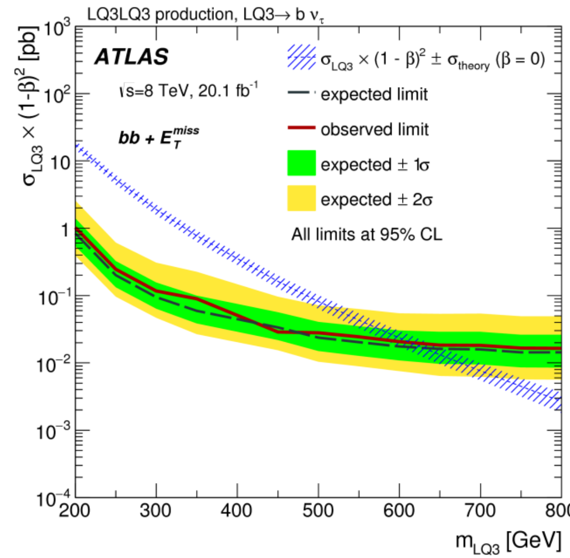
Scalar Leptoquarks - limits



1st Generation



2nd Generation



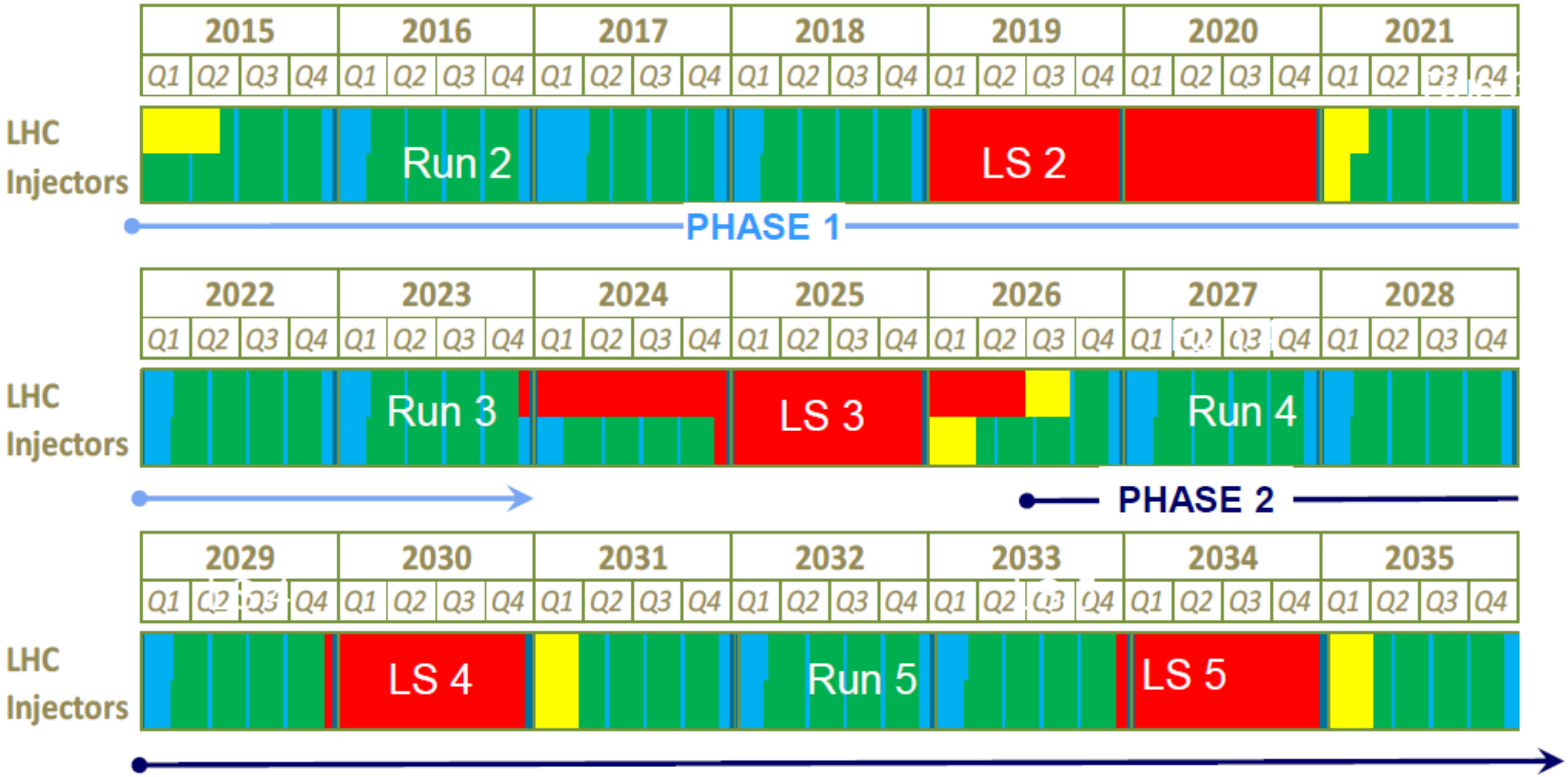
3rd Generation

[1508.04735](https://arxiv.org/abs/1508.04735)

LHC roadmap: according to MTP 2016-2020 V1

LS2 starting in 2019 => 24 months + 3 months BC
LS3 LHC: starting in 2024 => 30 months + 3 months BC
Injectors: in 2025 => 13 months + 3 months BC

- Physics
- Shutdown
- Beam commissioning
- Technical stop



$$\Gamma^{\text{inv}}_{H\to SS} = \frac{\lambda^2_{HSS} v^2 \beta_S}{64\pi m_H}, \tag{5}$$

$$\Gamma^{\text{inv}}_{H\to VV} = \frac{\lambda^2_{HVV} v^2 m_H^3 \beta_V}{256\pi m_V^4}\left(1 - 4\frac{m_V^2}{m_H^2} + 12\frac{m_V^4}{m_H^4}\right), \tag{6}$$

$$\Gamma^{\text{inv}}_{H\to ff} = \frac{\lambda^2_{Hff} v^2 m_H \beta_f^3}{32\pi\Lambda^2}, \tag{7}$$

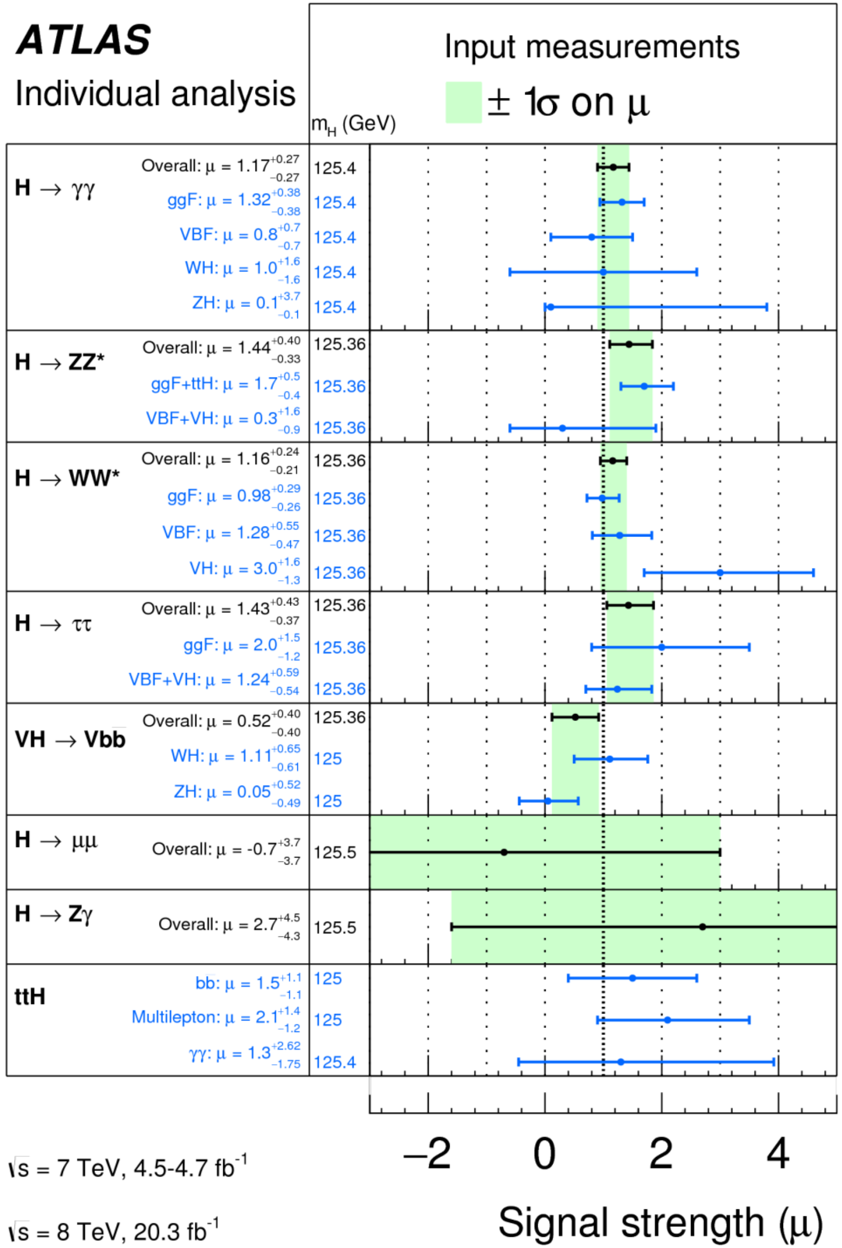
for the scalar, vector and Majorana-fermion dark matter, respectively. The parameters λ_{HSS}, λ_{HVV}, λ_{Hff}/Λ are the corresponding coupling constants, v is the vacuum expectation value of the SM Higgs doublet, $\beta_\chi = \sqrt{1 - 4m_\chi^2/m_H^2}$ ($\chi = S, V, f$), and m_χ is the WIMP mass. In the Higgs-portal model, the Higgs boson is assumed to be the only mediator in the WIMP–nucleon scattering, and the WIMP–nucleon cross section can be written in a general spin-independent form. Inserting the couplings and masses for each spin scenario gives:

$$\sigma^{\text{SI}}_{SN} = \frac{\lambda^2_{HSS}}{16\pi m_H^4}\frac{m_N^4 f_N^2}{(m_S + m_N)^2}, \tag{8}$$

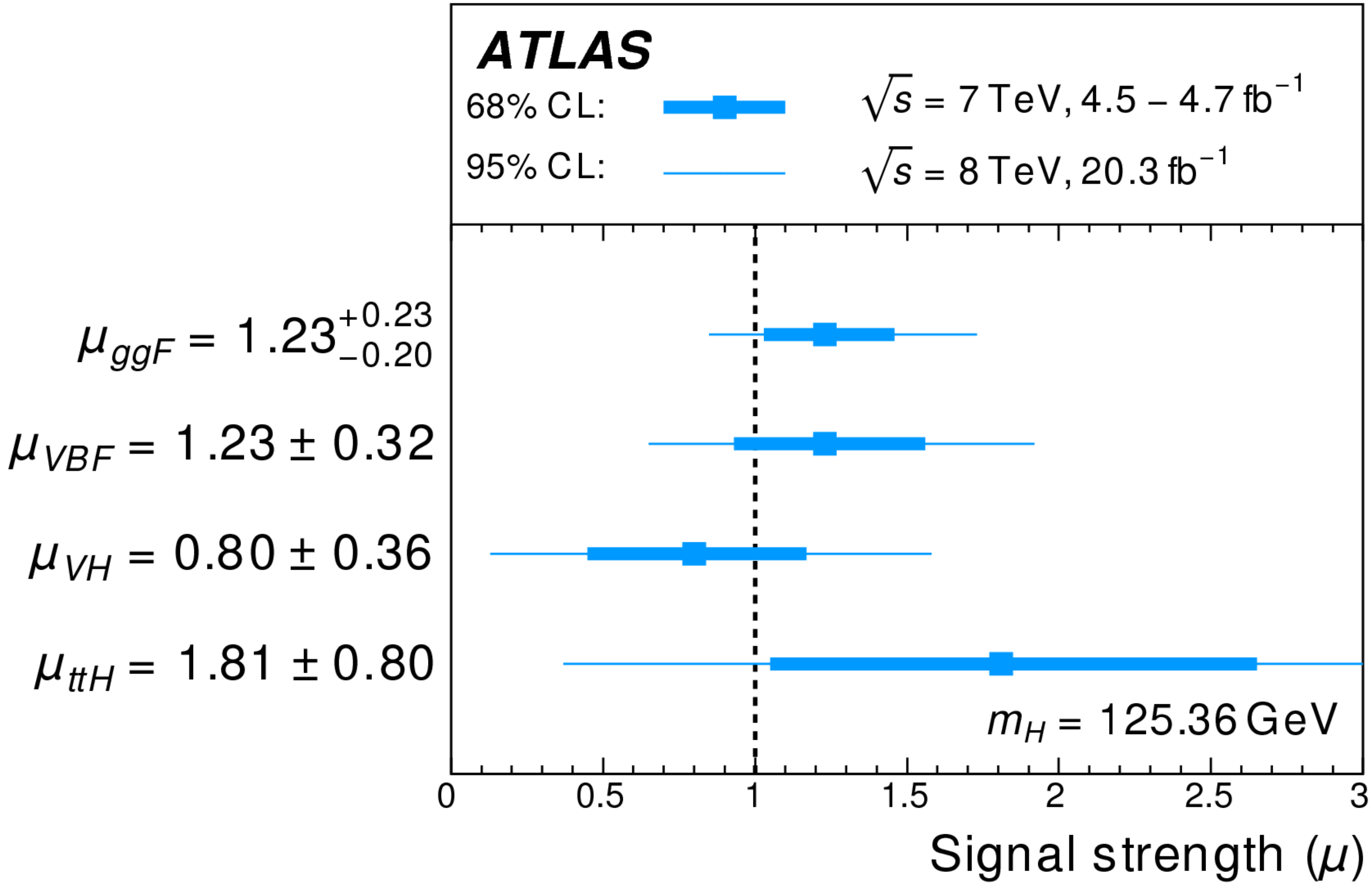
$$\sigma^{\text{SI}}_{VN} = \frac{\lambda^2_{HVV}}{16\pi m_H^4}\frac{m_N^4 f_N^2}{(m_V + m_N)^2}, \tag{9}$$

$$\sigma^{\text{SI}}_{fN} = \frac{\lambda^2_{Hff}}{4\pi\Lambda^2 m_H^4}\frac{m_N^4 m_f^2 f_N^2}{(m_f + m_N)^2}, \tag{10}$$

where m_N is the nucleon mass, and f_N is the form factor associated to the Higgs boson–nucleon coupling and computed using lattice QCD [10]. The numerical values for all the parameters in the equations above are given in Table 11.



https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/HIGG-2014-06

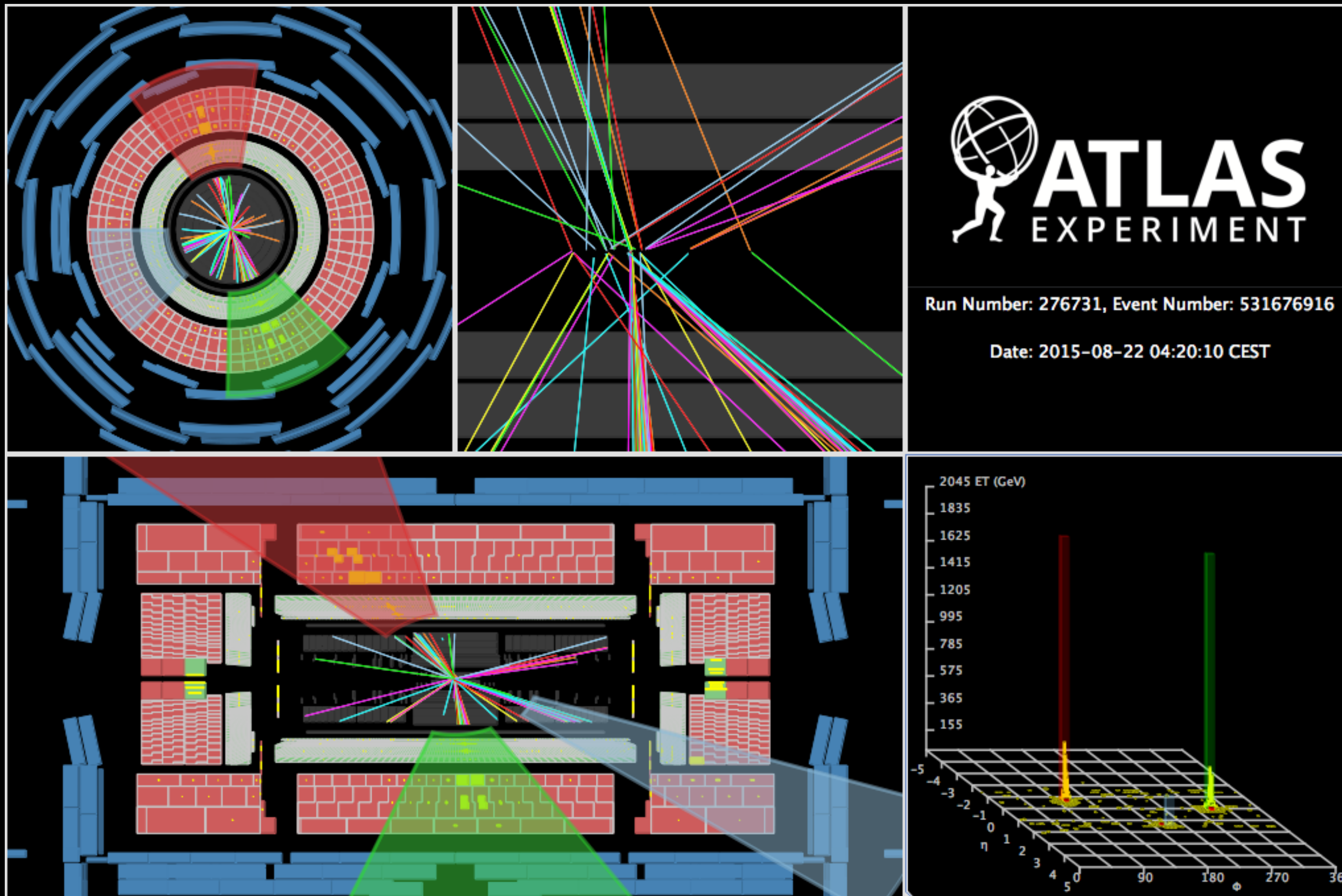


https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/HIGG-2014-06

1509.00672

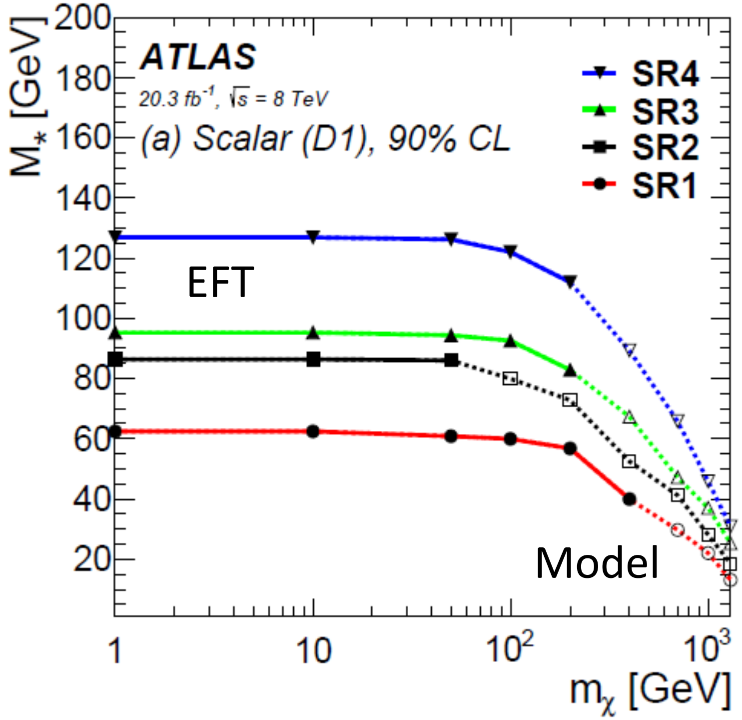
Model		Coupling Parameter	Description	Measurement
1	Mass scaling parameterisation	κ_Z	Z boson coupling s.f.	$[-1.06, -0.82] \cup [0.84, 1.12]$
		κ_W	W boson coupling s.f.	0.91 ± 0.14
		κ_t	t-quark coupling s.f.	0.94 ± 0.21
		κ_b	b-quark coupling s.f.	$[-0.90, -0.33] \cup [0.28, 0.96]$
		κ_τ	Tau lepton coupling s.f.	$[-1.22, -0.80] \cup [0.80, 1.22]$
		κ_μ	Muon coupling s.f.	< 2.28 at 95% CL
2	MCHM4, EW singlet	μ_h	Overall signal strength	$1.18^{+0.15}_{-0.14}$
3	MCHM5, 2HDM Type I	κ_V	Vector boson (W, Z) coupling s.f.	1.09 ± 0.07
		κ_F	Fermion $(t, b, \tau, \dots)$ coupling s.f.	1.11 ± 0.16
4	2HDM Type II, hMSSM	$\lambda_{Vu} = \kappa_V/\kappa_u$	Ratio of vector boson to up-type fermion $(t, c, \dots)$ coupling s.f.	$0.92^{+0.18}_{-0.16}$
		$\kappa_{uu} = \kappa_u^2/\kappa_h$	Ratio of squared up-type fermion coupling s.f. to total width s.f.	1.25 ± 0.33
		$\lambda_{du} = \kappa_d/\kappa_u$	Ratio of down-type fermion $(b, \tau, \dots)$ to up-type fermion coupling s.f.	$[-1.08, -0.81] \cup [0.75, 1.04]$
5	2HDM Lepton-specific	$\lambda_{Vq} = \kappa_V/\kappa_q$	Ratio of vector boson to quark $(t, b, \dots)$ coupling s.f.	$1.03^{+0.18}_{-0.15}$
		$\kappa_{qq} = \kappa_q^2/\kappa_h$	Ratio of squared quark coupling s.f. to total width s.f.	$1.03^{+0.24}_{-0.20}$
		$\lambda_{\ell q} = \kappa_\ell/\kappa_q$	Ratio of lepton (τ, μ, e) to quark coupling s.f.	$[-1.34, -0.94] \cup [0.94, 1.34]$
6	Higgs portal (Baseline config. of vis. & inv. Higgs boson decay channels: general coupling param., no assumption about κ_{WZ})	κ_Z	Z boson coupling s.f.	0.99 ± 0.15
		κ_W	W boson coupling s.f.	0.92 ± 0.14
		κ_t	t-quark coupling s.f.	$1.26^{+0.32}_{-0.34}$
		κ_b	b-quark coupling s.f.	0.61 ± 0.28
		κ_τ	Tau lepton coupling s.f.	$0.98^{+0.20}_{-0.18}$
		κ_μ	Muon coupling s.f.	< 2.25 at 95% CL
		κ_g	Gluon coupling s.f.	$0.92^{+0.18}_{-0.15}$
		κ_γ	Photon coupling s.f.	$0.90^{+0.16}_{-0.14}$
		$\kappa_{Z\gamma}$	$Z\gamma$ coupling s.f.	< 3.15 at 95% CL
		BR_{inv}	Invisible branching ratio	< 0.23 at 95% CL

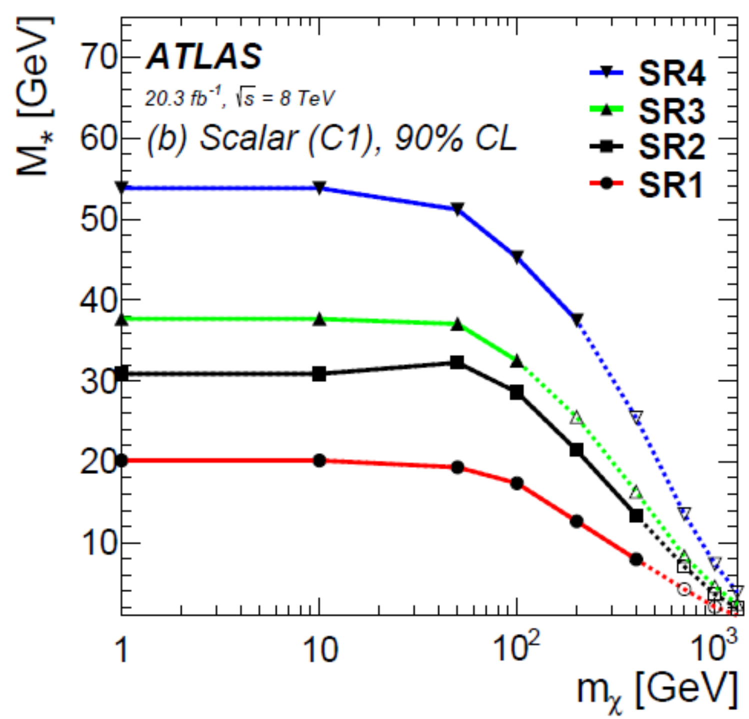
Table 1: Measurements of the overall signal strength, scale factors (s.f.) for the Higgs boson couplings and total width, and the Higgs boson invisible decay branching ratio, in different coupling parameterisations, along with the BSM models or parameterisations they are used to probe. The measurements quoted for Models 1–5 are derived in Ref. [10], while those for Model 6 are derived in this paper. The production modes are taken to be the same as those in the SM in all cases. In Models 1–3, decay modes identical to those in the SM are taken. For Models 4–5, the coupling parameterisations and measurements listed do not require such an assumption, which is however made when deriving limits on the underlying parameters of these BSM models. No assumption about the total width is made for Model 6.



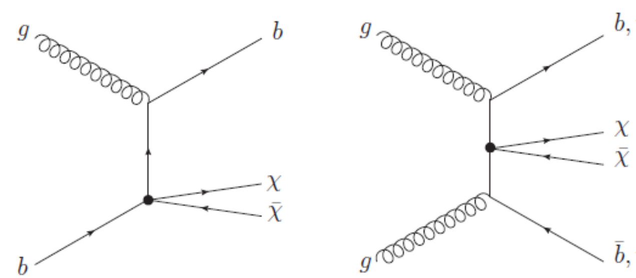
Dijet pair with m_{jj} = 5.2 TeV

Other Dark Matter searches



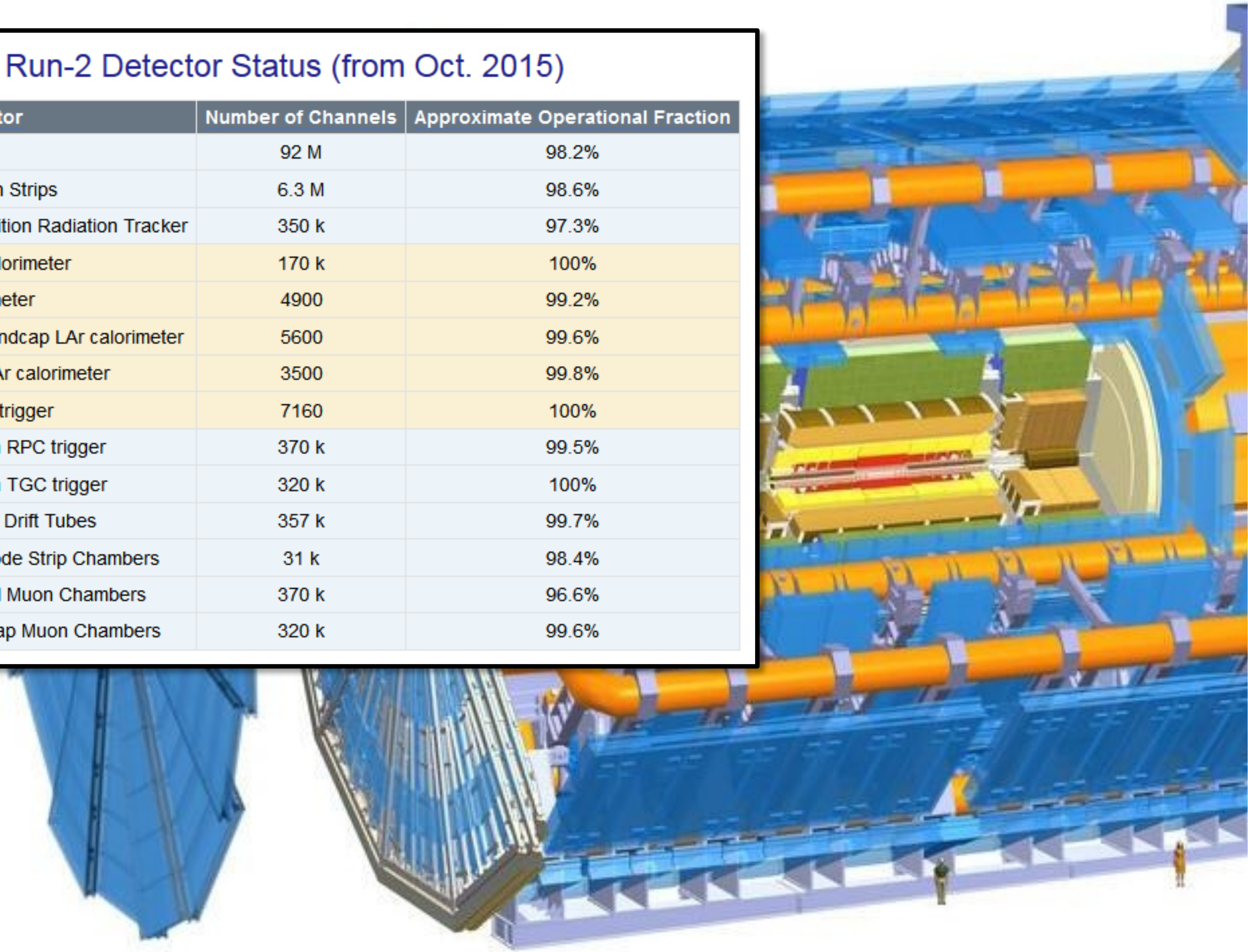


$$\mathcal{O}_{\text{scalar}} = \sum_q \frac{m_q}{M_*^N} \bar{q} q \bar{\chi} \chi,$$

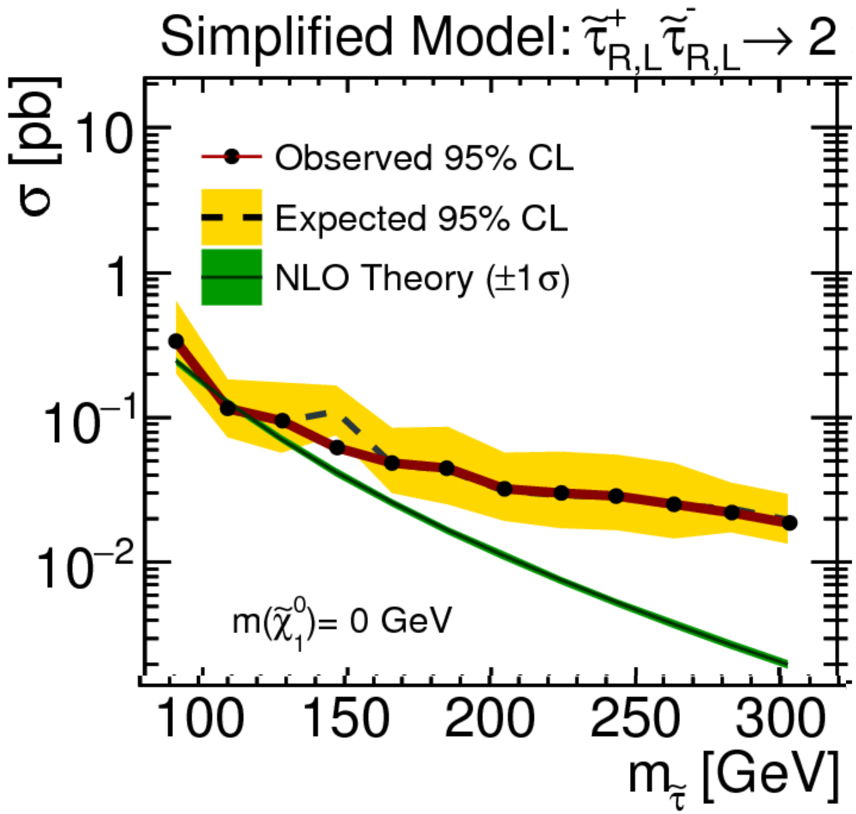


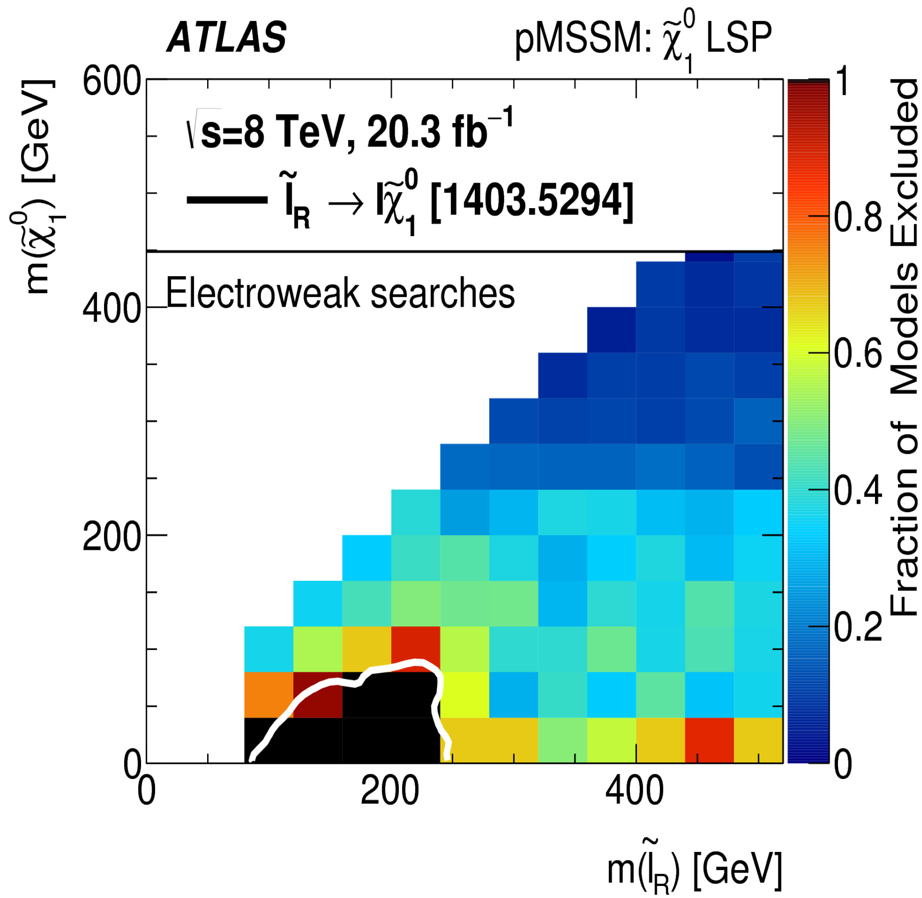
ATLAS Run-2 Detector Status (from Oct. 2015)

Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	92 M	98.2%
SCT Silicon Strips	6.3 M	98.6%
TRT Transition Radiation Tracker	350 k	97.3%
LAr EM Calorimeter	170 k	100%
Tile calorimeter	4900	99.2%
Hadronic endcap LAr calorimeter	5600	99.6%
Forward LAr calorimeter	3500	99.8%
LVL1 Calo trigger	7160	100%
LVL1 Muon RPC trigger	370 k	99.5%
LVL1 Muon TGC trigger	320 k	100%
MDT Muon Drift Tubes	357 k	99.7%
CSC Cathode Strip Chambers	31 k	98.4%
RPC Barrel Muon Chambers	370 k	96.6%
TGC Endcap Muon Chambers	320 k	99.6%



Scalar leptons?





On the edge of being able to constrain staus

Starting to constrain selectrons and smuons

1509.07152

1508.06608

Run-1 Summary of Supersymmetry

Interpreted in the general [19-parameter] **pMSSM**

- "phenomenological" MSSM
- R-parity conserving
- Neutralino LSP

Allow Sparticle masses up to **4 TeV**

- **500 million** models sampled

Apply prior experimental constraints:

- **EW** precision measurements
- Mass bounds e.g. from **LEP, Tevatron**
- $\Omega_{LSP} < \Omega_{Planck}$

Consider carefully the remainder

- **310,327** : models before Run-1
- **30 billion** : signal events simulated
- **44,559** : models required full simulation
- **600 million :** signal events thru GEANT

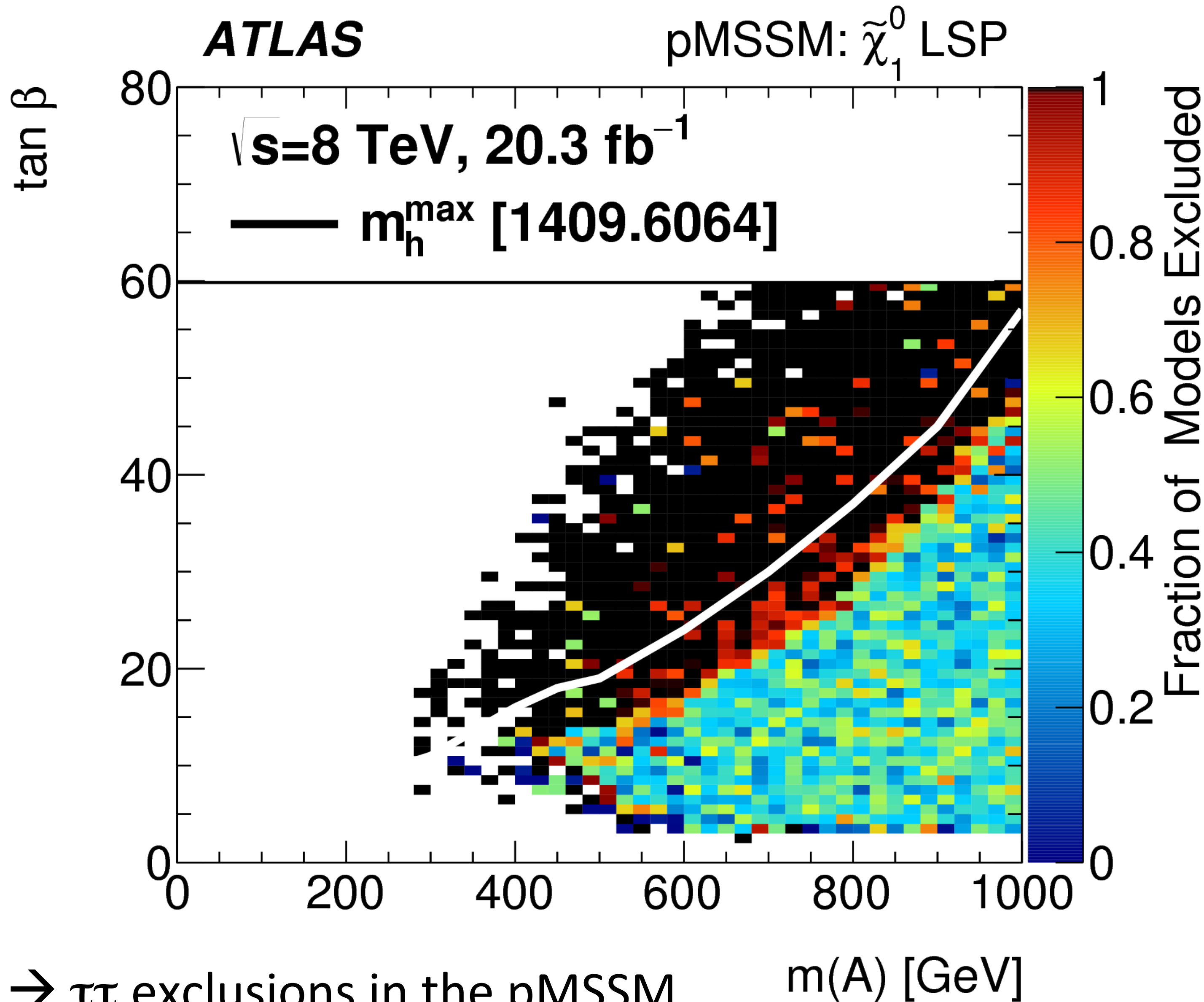
Present exclusion (fraction of models) in 2D or 1D projections

Overall summary of 22 different ATLAS Run-1 search papers

Inclusive	0-lepton + 2–6 jets + E_T^{miss}
	0-lepton + 7–10 jets + E_T^{miss}
	1-lepton + jets + E_T^{miss}
	$\tau(\tau/\ell)$ + jets + E_T^{miss}
	SS/3-leptons + jets + E_T^{miss}
	0/1-lepton + 3b-jets + E_T^{miss}
	Monojet
3rd generation	0-lepton stop
	1-lepton stop
	2-leptons stop
	Monojet stop
	Stop with Z boson
	2b-jets + E_T^{miss}
	$tb+E_T^{miss}$, stop
Electroweak	ℓh
	2-leptons
	2-τ
	3-leptons
	4-leptons
	Disappearing Track
Other	Long-lived particles
	$H/A \to \tau^+\tau^-$

Parameter	Min value	Max value	Note
$m_{\tilde{L}_1} (= m_{\tilde{L}_2})$	90 GeV	4 TeV	Left-handed slepton (first two gens.) mass
$m_{\tilde{e}_1} (= m_{\tilde{e}_2})$	90 GeV	4 TeV	Right-handed slepton (first two gens.) mass
$m_{\tilde{L}_3}$	90 GeV	4 TeV	Left-handed stau doublet mass
$m_{\tilde{e}_3}$	90 GeV	4 TeV	Right-handed stau mass
$m_{\tilde{Q}_1} (= m_{\tilde{Q}_2})$	200 GeV	4 TeV	Left-handed squark (first two gens.) mass
$m_{\tilde{u}_1} (= m_{\tilde{u}_2})$	200 GeV	4 TeV	Right-handed up-type squark (first two gens.) mass
$m_{\tilde{d}_1} (= m_{\tilde{d}_2})$	200 GeV	4 TeV	Right-handed down-type squark (first two gens.) mass
$m_{\tilde{Q}_3}$	100 GeV	4 TeV	Left-handed squark (third gen.) mass
$m_{\tilde{u}_3}$	100 GeV	4 TeV	Right-handed top squark mass
$m_{\tilde{d}_3}$	100 GeV	4 TeV	Right-handed bottom squark mass
$\|M_1\|$	0 GeV	4 TeV	Bino mass parameter
$\|M_2\|$	70 GeV	4 TeV	Wino mass parameter
$\|\mu\|$	80 GeV	4 TeV	Bilinear Higgs mass parameter
M_3	200 GeV	4 TeV	Gluino mass parameter
$\|A_t\|$	0 GeV	8 TeV	Trilinear top coupling
$\|A_b\|$	0 GeV	4 TeV	Trilinear bottom coupling
$\|A_\tau\|$	0 GeV	4 TeV	Trilinear τ lepton coupling
M_A	100 GeV	4 TeV	Pseudoscalar Higgs boson mass
$\tan\beta$	1	60	Ratio of the Higgs vacuum expectation values

Table 2: Scan ranges used for each of the 19 pMSSM parameters. Where the parameter is written with a modulus sign both the positive and negative values are permitted. In the above, "gen(s)" refers to generation(s).



H → ττ exclusions in the pMSSM

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/SUSY-2014-08/