

[Physics Results from ATLAS]



P. Conde Muíño

on behalf of the ATLAS Collaboration

Probing the Standard Model of Particle Physics at ATLAS

SM Overall Picture

W, Z, top

Cross sections, W mass
and Width, ...

The Higgs Boson

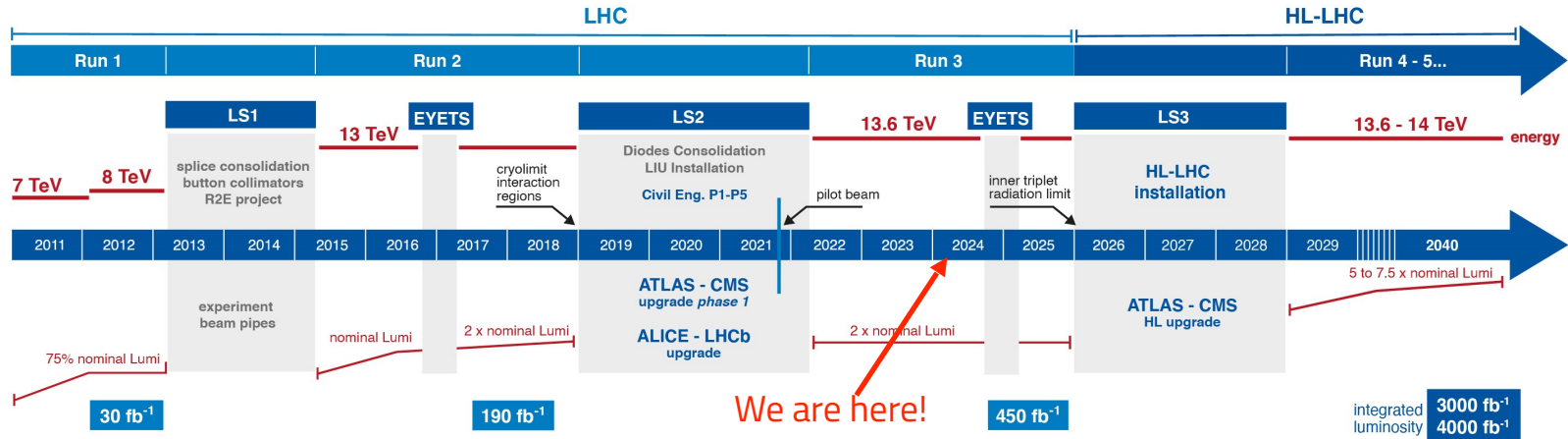
Couplings, mass, width,
invisible decays, Higgs
potential

Searches for new Physics

SUSY and exotic particles
Dark Matter
Unconventional signatures

EFT interpretation of Higgs
measurements
Search for CP-Violating Higgs
couplings

LHC schedule and ATLAS Data Taking statistics



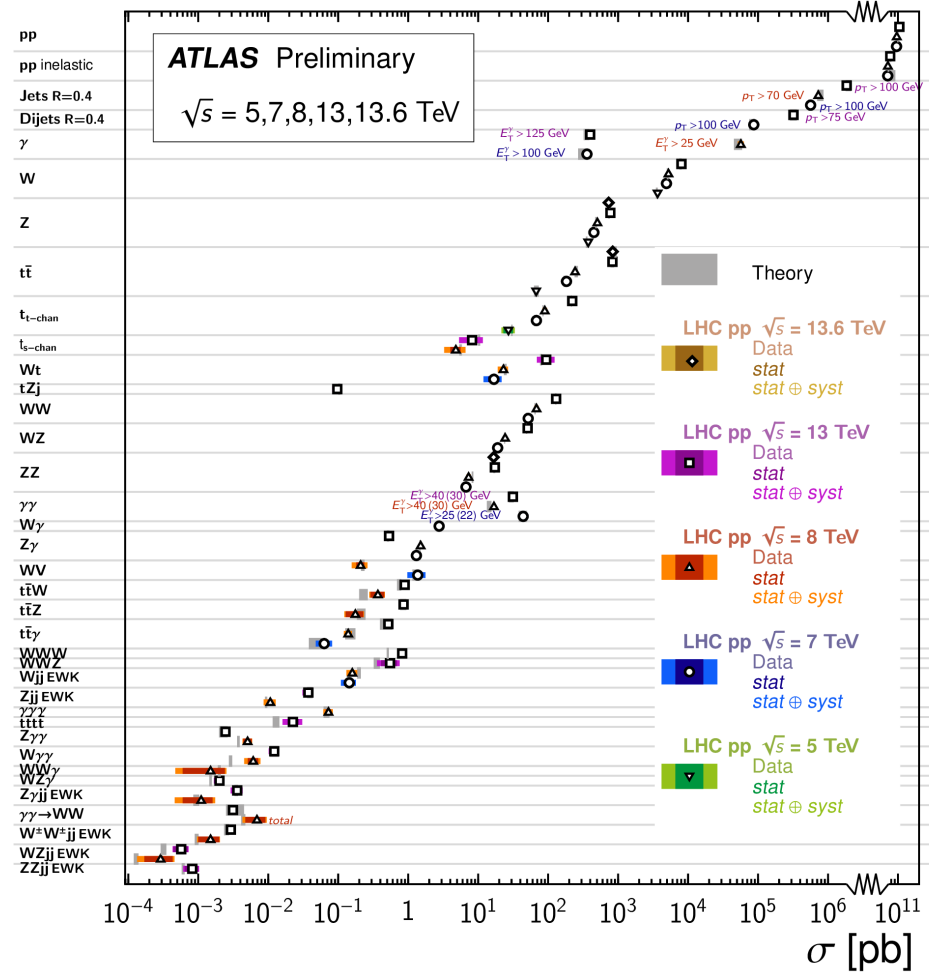
	Center of mass energy	Period	<pp col/BX>	Accumulated luminosity
Run 1	7, 8 TeV	2010-2011	20	35 fb ⁻¹
Run 2	13 TeV	2015-2018	34	147 fb ⁻¹
Run 3	13.6 TeV	2022-2025	48	84 fb ⁻¹
HL-LHC (Run 4 and beyond)	13.6-14 TeV	2029-2040	200	3000 fb ⁻¹

ATLAS pp Run-3: 2023

Trigger	Inner Tracker			Calorimeters		Muon Spectrometer			Magnets	
L1+HLT	Pixel	SCT	TRT	LAr	Tile	MDT	RPC	TGC	Solenoid	Toroid
97.5-99.6	99.8	99.7	100	99.5	99.6	99.7	99.9	99.8	100	100
Good for physics: 94.6%-96.5% (27.2-27.8 fb⁻¹)										

ATLAS Standard Model Measurements in a nutshell

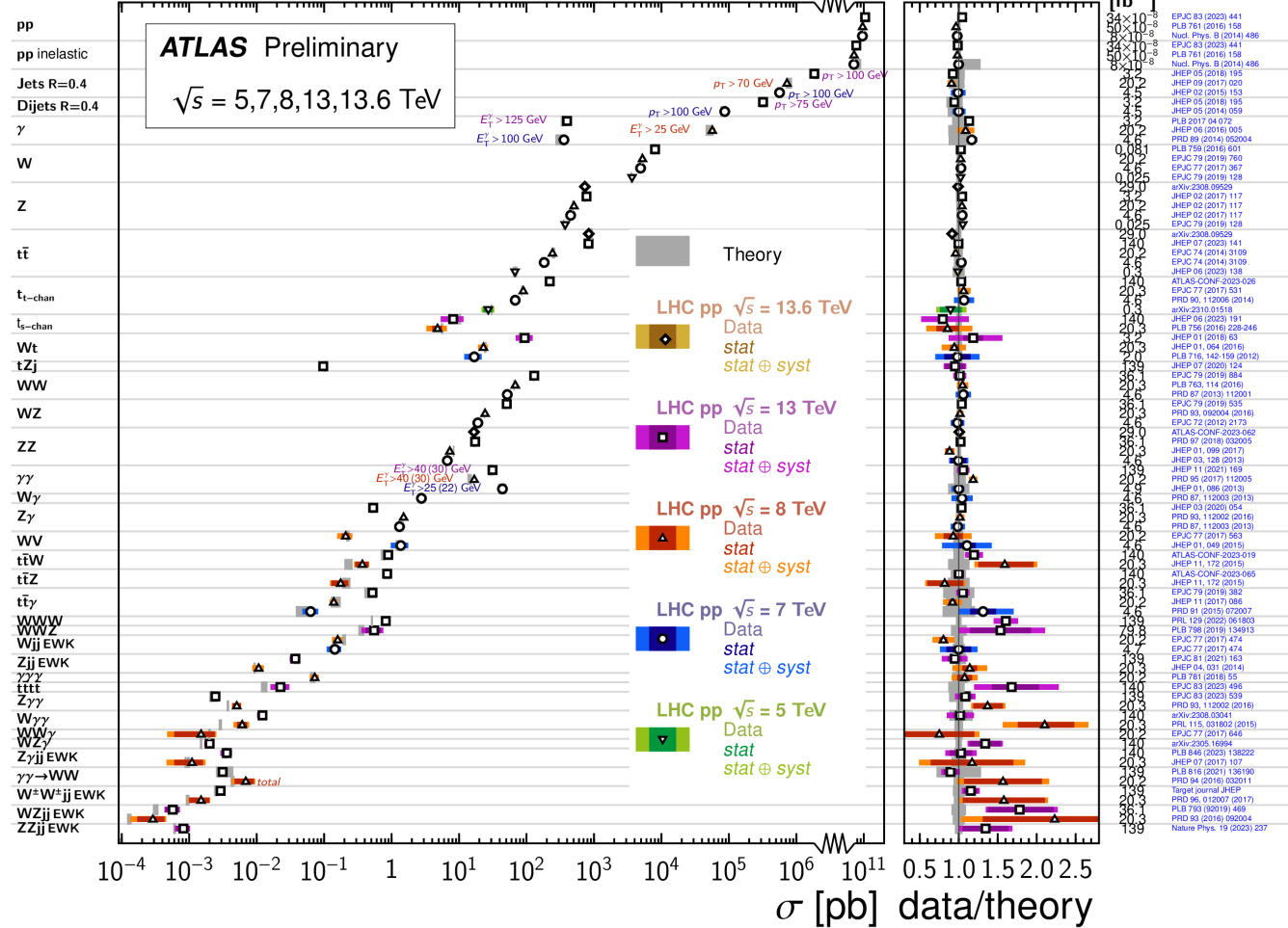
Standard Model Production Cross Section Measurements



ATLAS Standard Model Measurements in a nutshell

Standard Model Production Cross Section Measurements

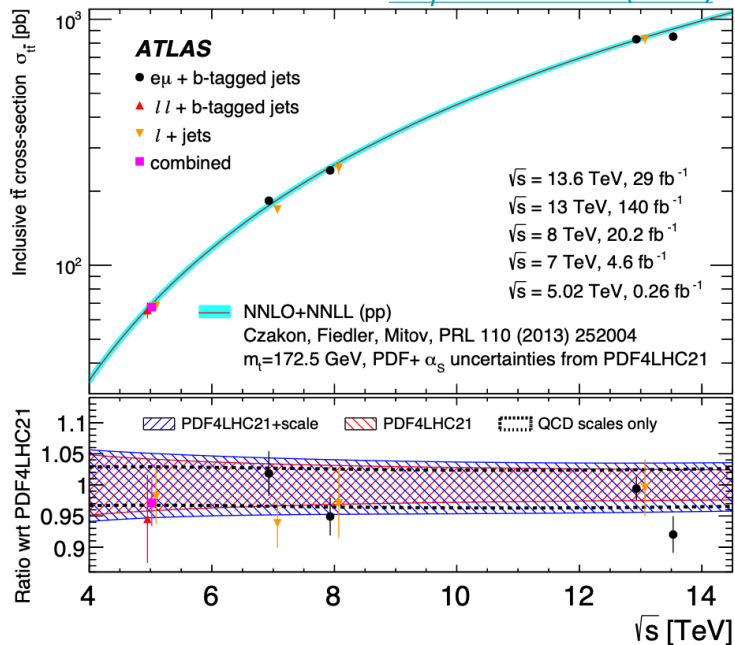
Status:
October 2023



Recent top-quark properties measurements

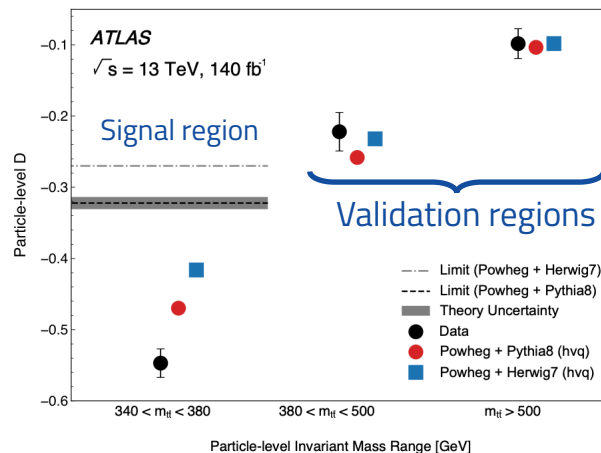
New $t\bar{t}$ production cross-section measurement at 13.6 TeV:

Phys. Lett. B 848 (2024)



First observation of quantum entanglement in $t\bar{t}$ pairs

- Measured using spin correlations
- Entanglement marker $D = -3 < \cos \phi >$
 - ϕ = angle between leptons in special rest frame
- $D = -0.547 \pm 0.002(\text{stat}) \pm 0.021(\text{syst})$



arXiv:2311.07288

Top-quark, W and Higgs mass measurements

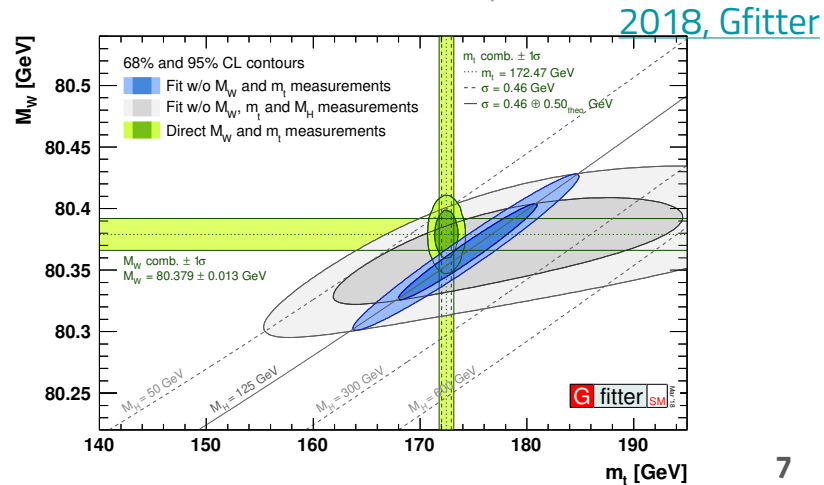
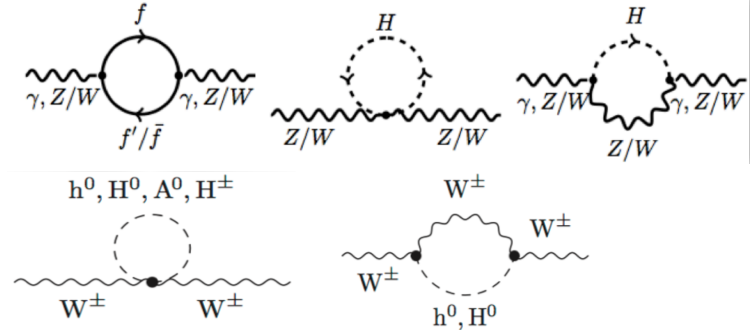
W-boson, top-quark and Higgs Boson mass interrelated in the SM

$$M_W^2 = \frac{M_Z^2}{2} \left(1 + \sqrt{1 - \frac{\sqrt{8}\pi\alpha(1 + \Delta r)}{G_F M_Z^2}} \right)$$

Tree level
Loop corrections

Probe the coherence of the SM results

- Precise measurements needed



Top-quark mass measurement

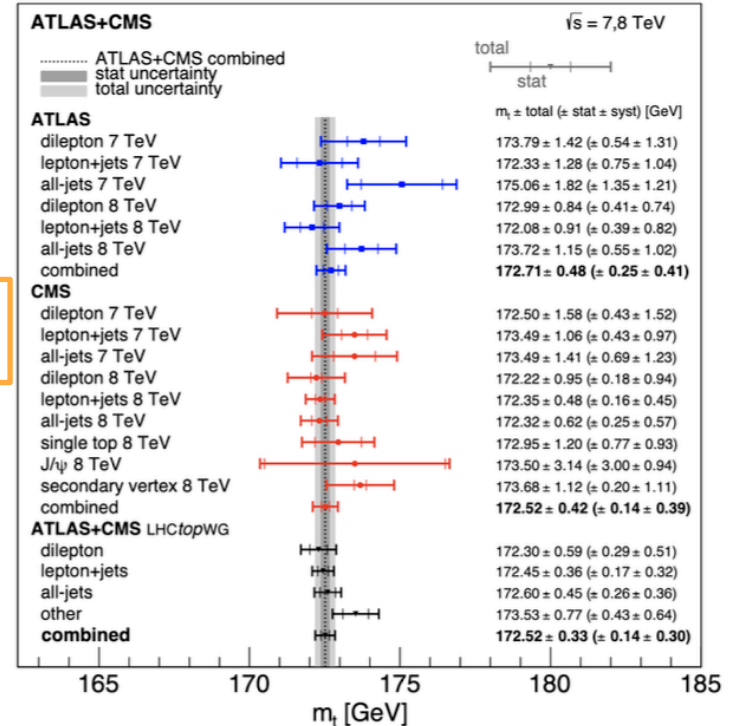
ATLAS and CMS mass combination using 7, 8 TeV analyses in different final states

- Using Best Linear Unbiased Estimator method (BLUE)

$$m_t = 172.52 \pm 0.14(\text{stat}) \pm 0.30(\text{syst}) = 172.52 \pm 0.33 \text{ GeV}$$

Best top quark mass measurement up-to-date

- Precision < 0.2%
- improvement of 31% in the total uncertainty relative to the most precise input measurement



W-boson mass and Width

Combined measurement of the W boson mass and width

Using Run 1, 7 TeV data

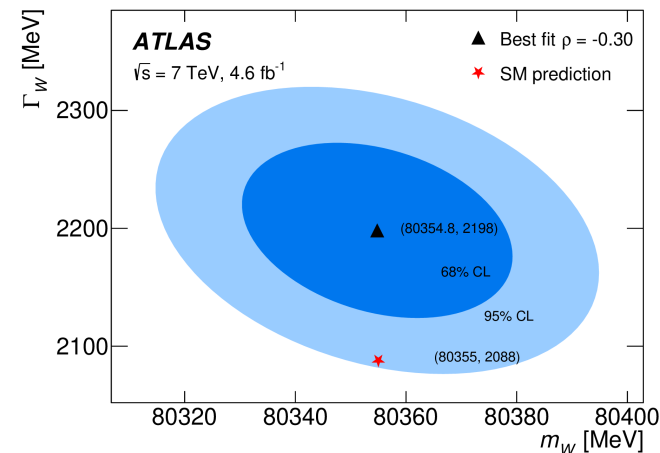
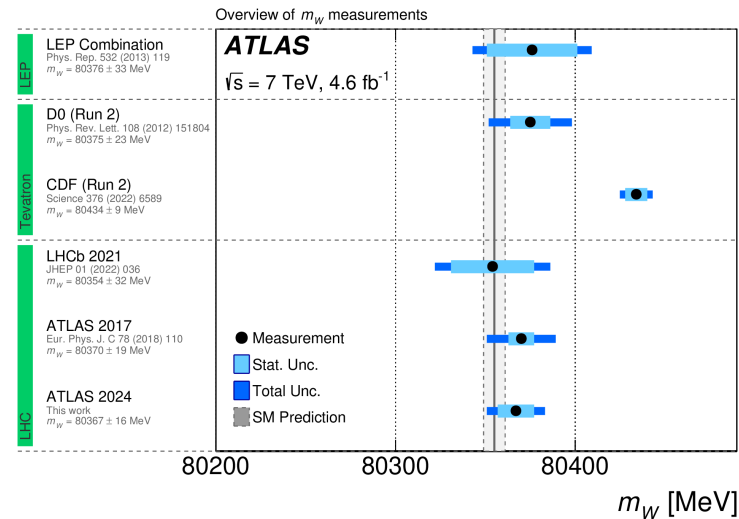
- re-analysis with an extensive list of updates to reduce the uncertainties
 - Including PDF updates, improved p_T^W modelling and improved fit

$$m_W = 80360 \pm 5(\text{stat}) \pm 15(\text{syst}) = 80360 \pm 16 \text{ MeV}$$

- Even closer to Standard Model expectations

$$\Gamma_W = 2195.8 \pm 32.2(\text{stat.}) \pm 34.1(\text{syst.}) = 2195.8 \pm 46.8 \text{ MeV}$$

- Most precise Γ_W measurement



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Becoming 12 years old

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Couplings, mass, width, invisible decays, Higgs potential



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The Standard Model is a very successful theory, but there are many questions that have not yet have an answer...

Is the Higgs boson potential as expected?

Why is there more matter than anti-matter?

Are the Higgs coupling to SM particles as expected?

Is there CP-violation in the Higgs sector?

What is Dark Matter?

Is the Higgs coupling to Dark Matter?

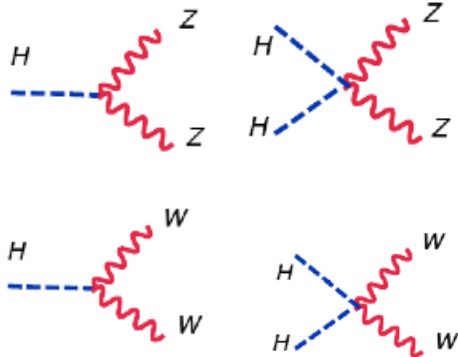
Are there new decay modes of the Higgs boson?

SM Higgs Lagrangian after symmetry breaking

$$\mathcal{L}_{SM} = D_\mu H^\dagger D_\mu H - (y_{ij} H \bar{\psi}_i \psi_j + h.c.) + \mu^2 H^\dagger H - \frac{\lambda}{2} (H^\dagger H)^2$$

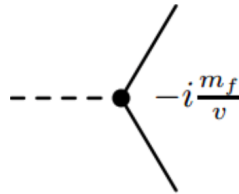
Bosons

$$(m_W^2 W^{\mu+} W_\mu^- + \frac{1}{2} m_Z^2 Z^{\mu 0} Z_\mu^0) (1 + \frac{h}{v})^2$$



Fermions

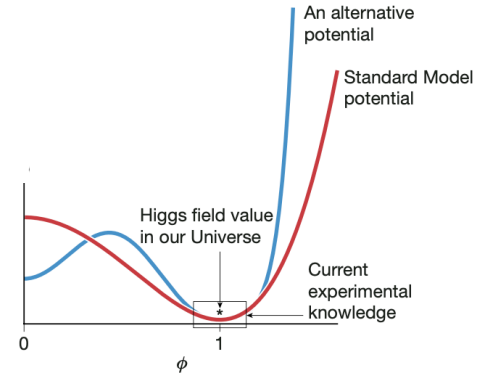
$$- \sum_f m_f \bar{f} f (1 + \frac{h}{v})$$



I	II	III
u	c	t
d	s	b
ν_e	ν_μ	ν_τ
e	μ	τ

Higgs potential

$$\frac{1}{2} m_h^2 h^2 + \lambda_3 v h^3 + \frac{1}{4} \lambda_4 h^4$$



Higgs Boson Mass

Fundamental parameter in the theory

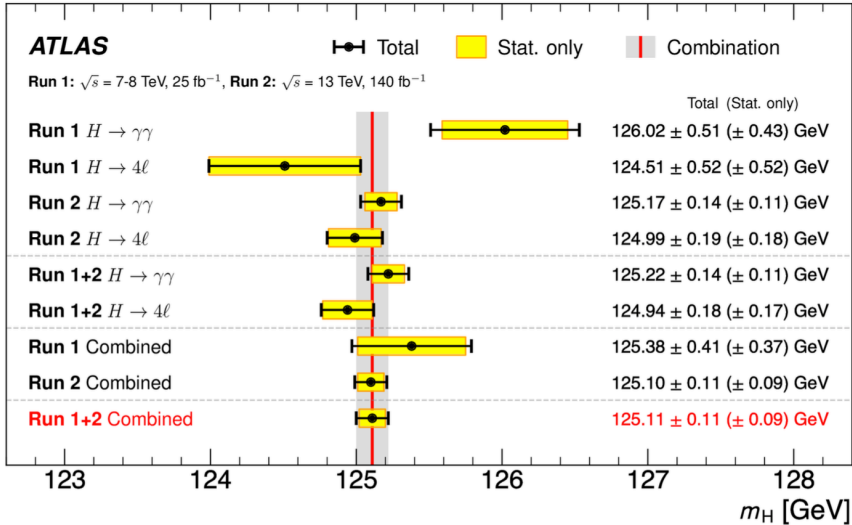
Measured in the $H \rightarrow \gamma\gamma$ and $H \rightarrow ZZ^* \rightarrow 4\ell$ decay channels

- Considerable effort to improve the $e/\gamma/\mu$ calibrations in Run 2
- e/γ calibration uncertainty reduced by a factor of 2–3
- μ momentum (resolution) precision down to 0.05% (0.1%)

Currently, most precise measurement:

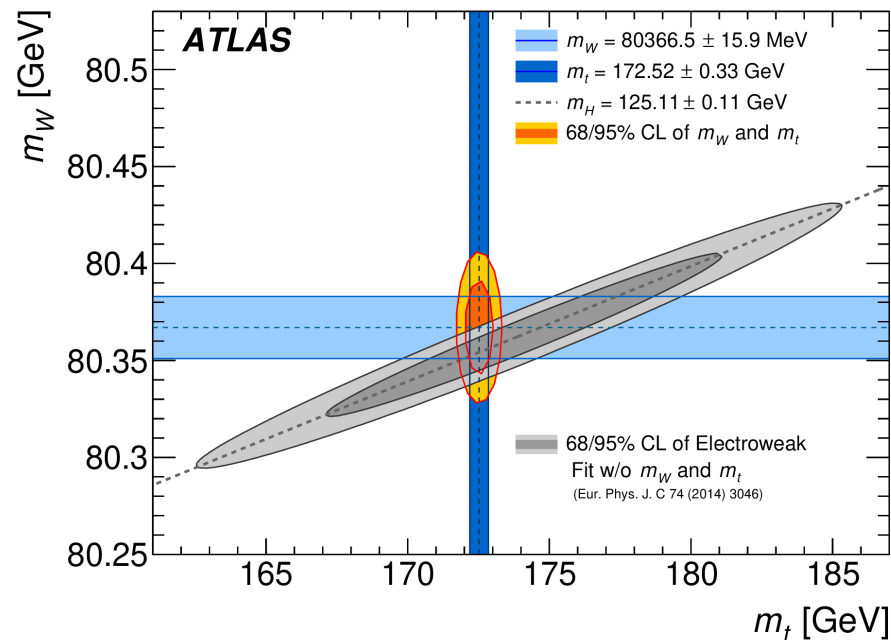
$$m_H = 125.11 \pm 0.09(\text{stat.}) \pm 0.06(\text{syst.}) = 125.11 \pm 0.11 \text{ GeV}$$

Uncertainty < per-mill level (0.09%)



ATLAS Top-quark, W and Higgs Bosons mass compatibility

Electroweak fit without m_W and m_t masses (grey) compared to the ATLAS measurements of m_W , m_t and m_H



Higgs Boson Width

SM prediction: $\Gamma_H = 4.1 \text{ MeV}$

Indirect measurement through the on-shell and off-shell

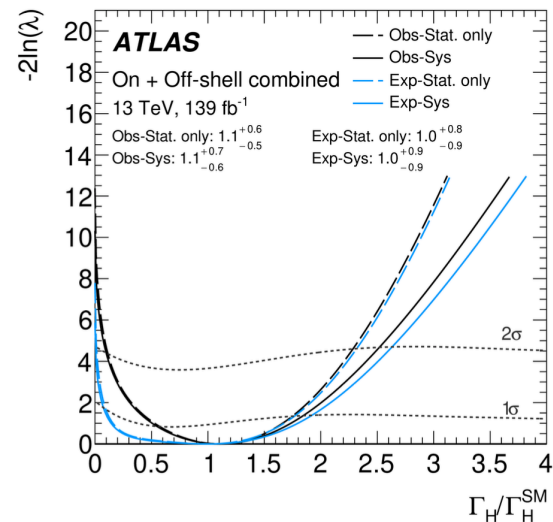
$H \rightarrow ZZ^* \rightarrow 4\ell$ production cross-section:

$$\frac{d\sigma_{pp \rightarrow H \rightarrow ZZ}}{dM_{4\ell}^2} \sim \frac{g_{Hgg}^2 g_{HZZ}^2}{(M_{4\ell}^2 - m_H^2)^2 + m_H^2 \Gamma_H^2} \begin{cases} \xrightarrow{\text{On-shell}} \frac{g_{Hgg}^2 g_{HZZ}^2}{m_H^2 \Gamma_H^2} \\ \xrightarrow{\text{Off-shell}} \frac{g_{Hgg}^2 g_{HZZ}^2}{(M_{4\ell}^2)^2} \end{cases}$$

- Assumes that Higgs production follows SM prediction

New off-shell Higgs production cross-section measurement

- Signal/background interference requires very good MC modelling
- Observed (expected) significance: 3.3σ (2.2σ)



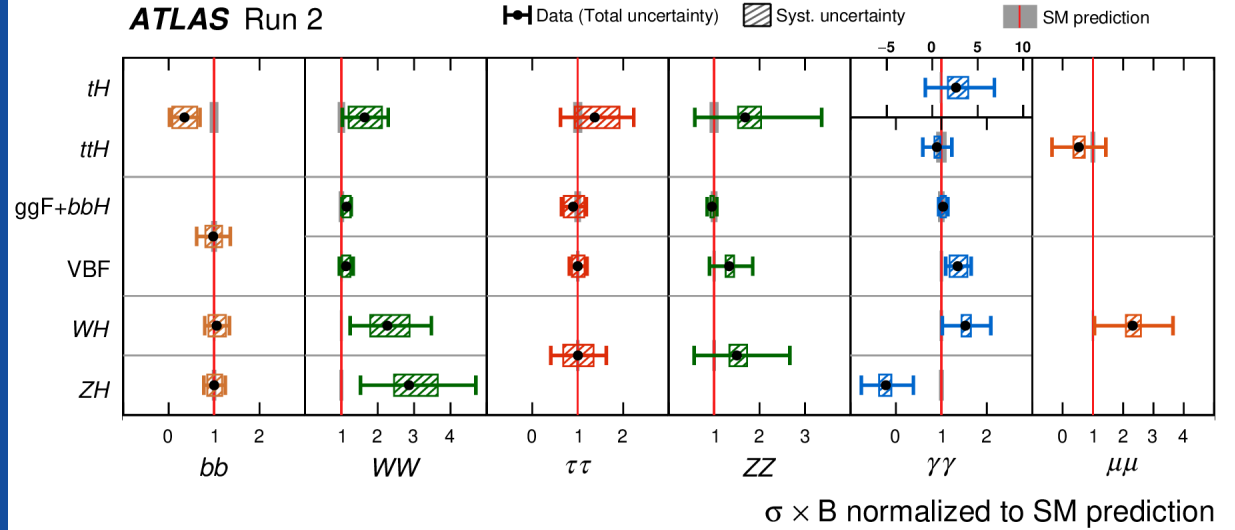
$$\Gamma_H = 4.5^{+3.3}_{-2.5} \text{ MeV}$$

Observed (expected) 95% CL limits:

$$0.5(0.1) < \Gamma_H < 10.5(10.9) \text{ MeV}$$

Higgs boson couplings combination

Direct measurement of $\sigma \times BR$



Good agreement with SM expectations (p-value 72%)

Improved precision:

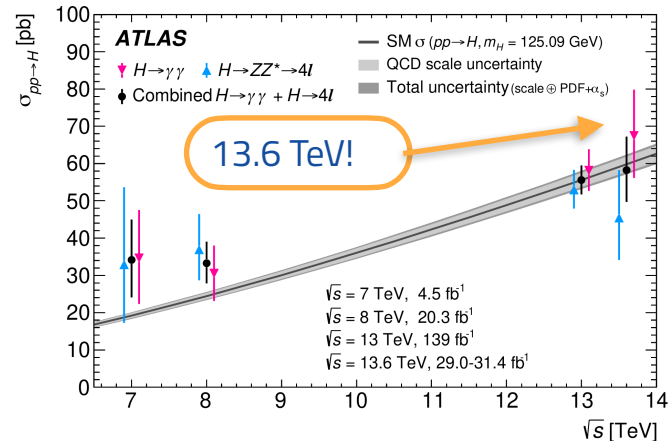
Cross section: 7-12%

Branching fractions: 10-12%

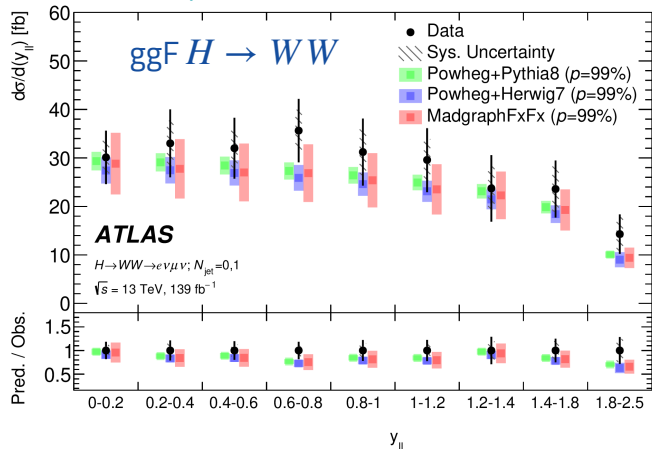
Recent cross section measurements

Total and differential cross-section measurements performed in different decay channels and for different variables

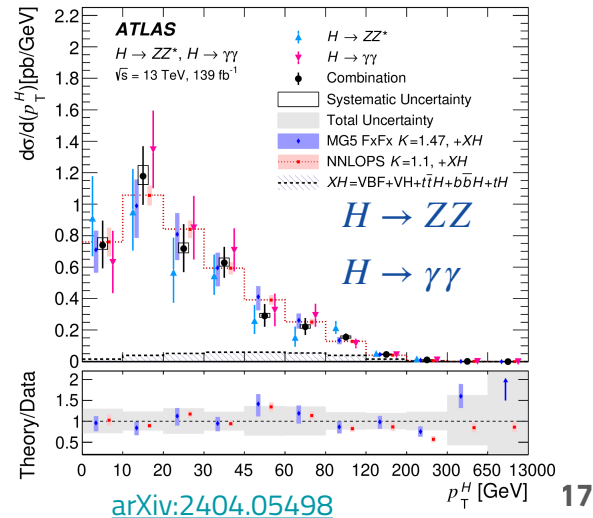
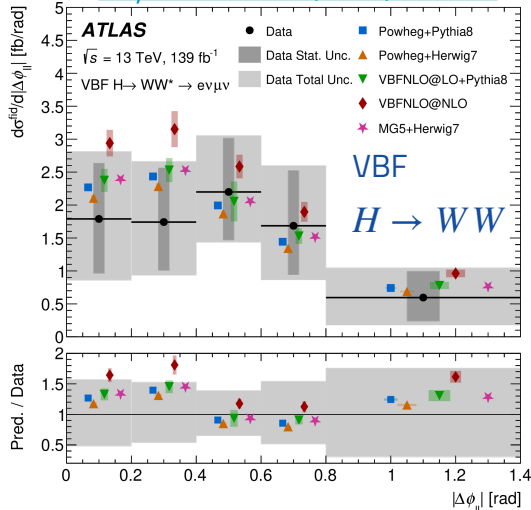
- Overall agreement with expectations within uncertainties



Eur. Phys. J. C 84 (2024) 78



Phys. Rev. D 108 (2023) 072003

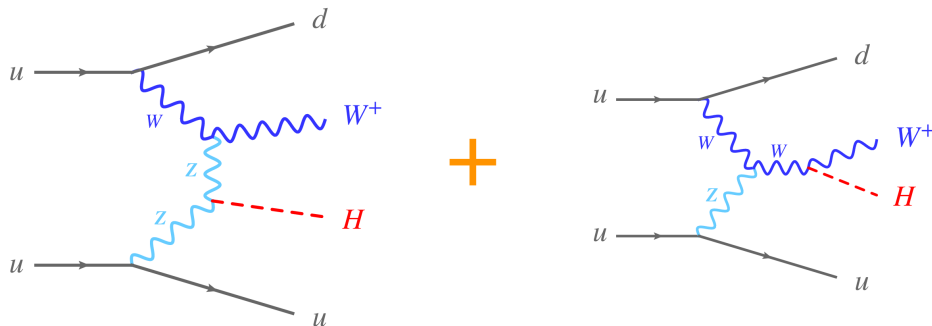


Relative sign of the HWW and HZZ couplings

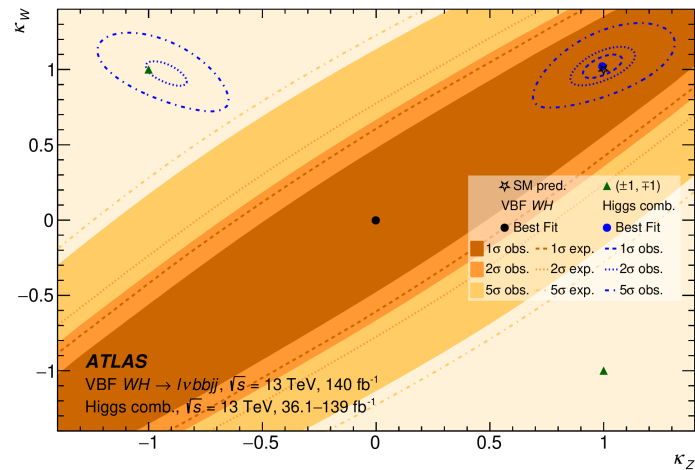
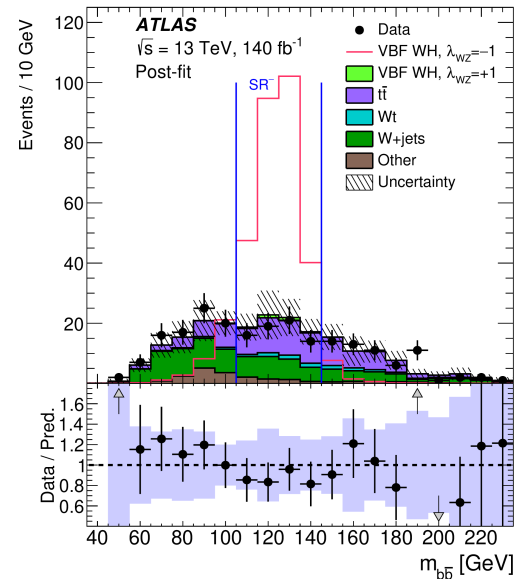
Vector boson fusion production of WH pairs disfavoured by the SM due to cancellation of two different contributions

- Could be enhanced with opposite relative sign

ATLAS Search for VBF WH production with $H \rightarrow bb$



Opposite sign excluded with significance much better than 5σ

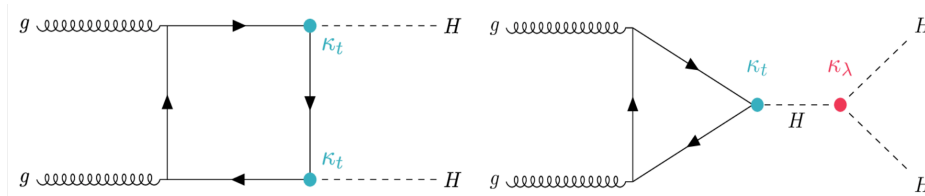


Higgs self coupling

- Determine the shape of the Higgs potential

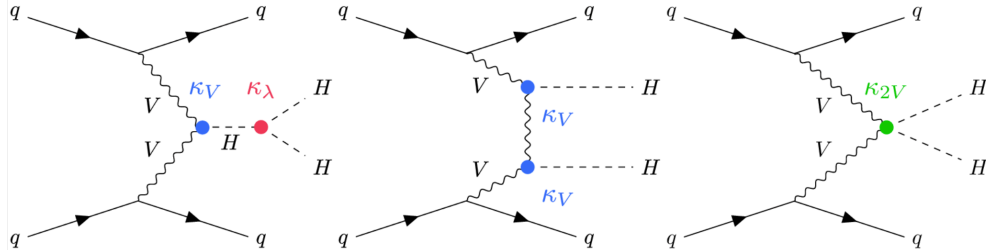
$$\frac{1}{2}m_h^2 h^2 + \lambda_3 v h^3 + \frac{1}{4}\lambda_4 h^4$$

- Di-Higgs production

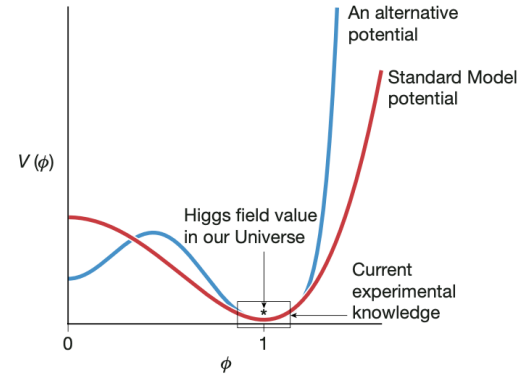


$$\sigma_{ggF}^{SM}(pp \rightarrow HH) = 31.05^{+1.9}_{-7.1} \text{ fb}$$

(Destructive interference in the SM)



$$\sigma_{VBF}^{SM}(pp \rightarrow HH) = 1.72 \pm 0.4 \text{ fb}$$



[G. Salam, L. T. Wang, J. Zanderighi](#)

Di-Higgs production

Updated results in some channels:

- $b\bar{b}\gamma\gamma$: obs (exp) 95% CL limit on μ_{HH} : 4σ (5σ)
- $b\bar{b}\tau^+\tau^-$: obs (exp) 95% CL limit on μ_{HH} : 5.9σ (3.2σ)

ATLAS di-Higgs search combination with Run 2 data:

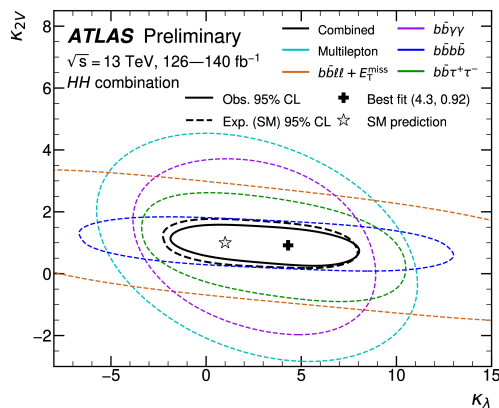
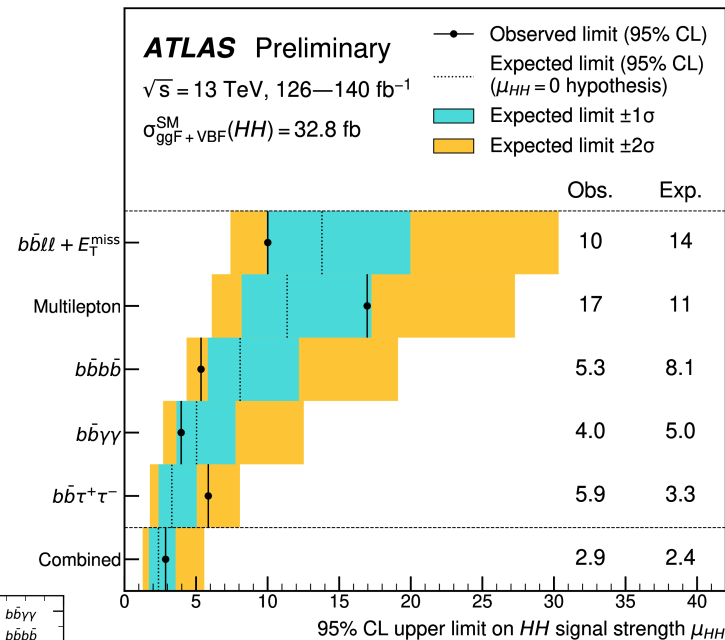
- Using $b\bar{b}b\bar{b}$, $b\bar{b}\gamma\gamma$, $b\bar{b}\tau\tau$, multilepton and $b\bar{b}\ell\ell + E_T^{miss}$

Observed 95% CL constraints

Best expected sensitivity in κ_λ

$$-1.2 < \kappa_\lambda < 7.2$$

$$0.57 < k_{2V} < 1.48$$



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Searches for new Physics

EFT interpretation of Higgs
measurements
Search for CP-Violating Higgs
couplings

EFT interpretations of the Higgs measurements

Effective Field Theory interpretation

- Extend the SM Lagrangian with additional operators

$$\mathcal{L}_{\text{SMEFT}} = \mathcal{L}_{\text{SM}} + \sum_i^{N_{d=6}} \frac{c_i}{\Lambda^2} \mathcal{O}_i^{(6)} + \sum_j^{N_{d=8}} \frac{b_j}{\Lambda^4} \mathcal{O}_j^{(8)} + \dots,$$

c_i = Wilson coefficients

$\mathcal{O}^{(n)}$ = operator of dimension n

Λ = new physics scale

- Calculate cross-sections: $\sigma_{\text{SMEFT}} = \sigma_{\text{SM}} + \sigma_{\text{int}} + \sigma_{\text{BSM}},$
- To reduce perturbative QCD uncertainties, use ratios:

$$\sigma_{\text{SMEFT}}^i = \sigma_{\text{SM}}^{i,((N)N)\text{NLO}} \times \left(1 + \frac{\sigma_{\text{int}}^{i,(N)\text{LO}}}{\sigma_{\text{SM}}^{i,(N)\text{LO}}} + \frac{\sigma_{\text{BSM}}^{i,(N)\text{LO}}}{\sigma_{\text{SM}}^{i,(N)\text{LO}}} \right)$$

ATLAS EFT interpretation:

- Measurements from 17 different papers from all channels used in the combination
- Using ~50 dimension-6 CP-even dominant coefficients

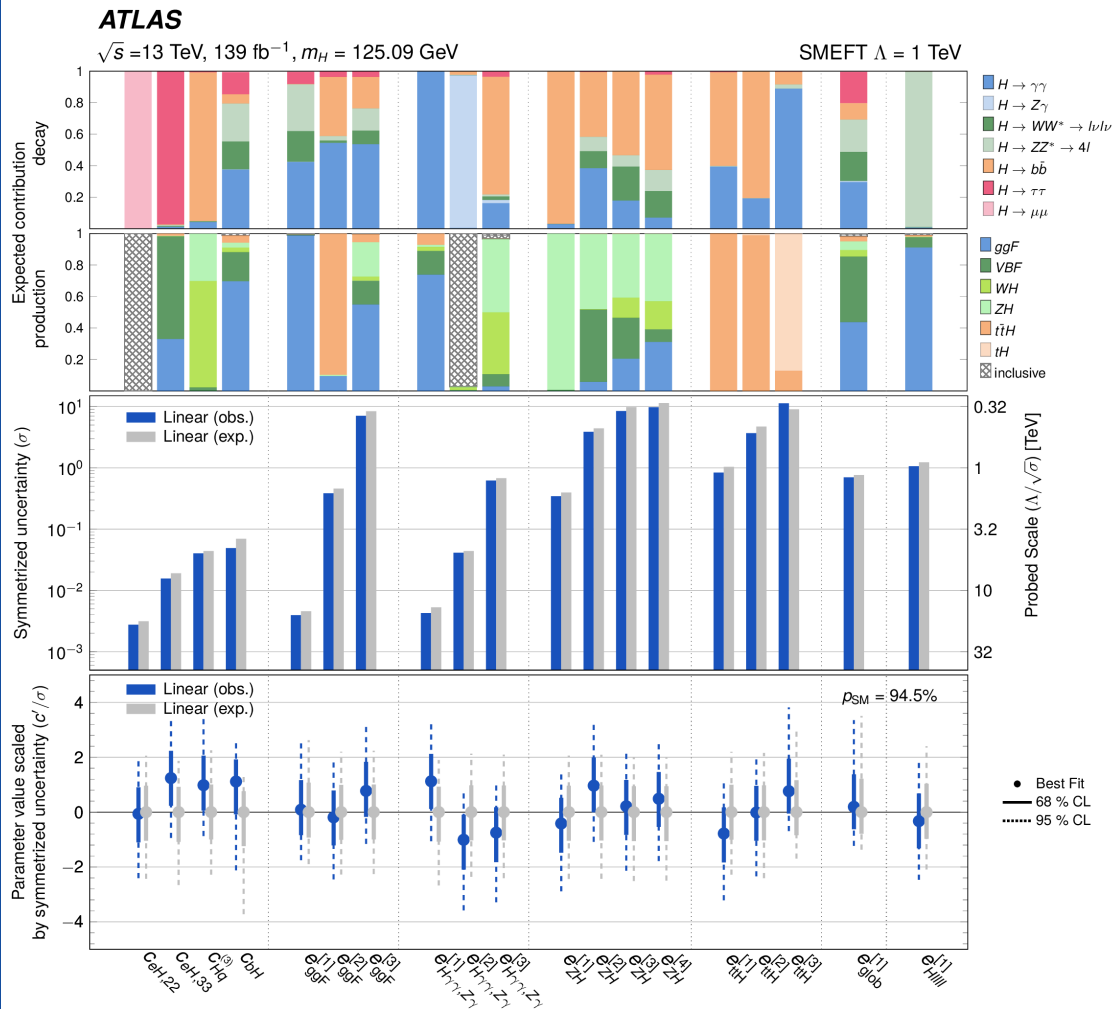
ATLAS EFT Higgs interpretation

Linearised model

Compatibility with the SM = 94.5%

Most parameters still dominated by statistical uncertainties

- But systematics might go up to 50% in some cases



Searching for CP Violation in the Higgs sector

Barion asymmetry of the Universe: still a mystery

Combined results demonstrated H to be mainly CP-even scalar

- There is still room for CP violation in the Higgs couplings

Searching for CP-odd components in the Higgs couplings

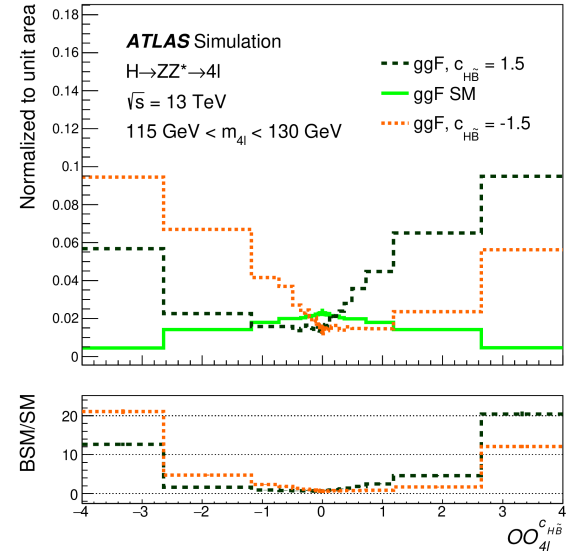
- Using CP-sensitive observables
 - Angular variables
 - Optimal observable:

$$OO = \frac{2\text{Re}(\mathcal{M}_{SM}^* \mathcal{M}_{CP-odd})}{|\mathcal{M}_{SM}|^2}$$

$$\sigma \sim |\mathcal{M}_{SM} + \mathcal{M}_{CP-odd}|^2 = |\mathcal{M}_{SM}|^2 + |\mathcal{M}_{CP-odd}|^2 + 2\text{Re}(\mathcal{M}_{SM}^* \mathcal{M}_{CP-odd})$$

Example OO in $H \rightarrow ZZ^* \rightarrow 4\ell$

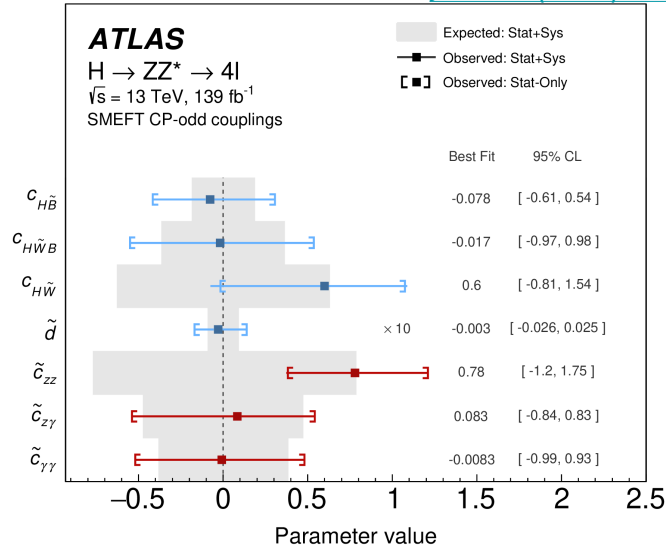
[JHEP 05 \(2024\) 105](#)



Searching for CP Violation in the Higgs sector

Couplings involving vector bosons

$$H \rightarrow ZZ^* \rightarrow 4\ell \quad \text{JHEP 05 (2024) 105}$$

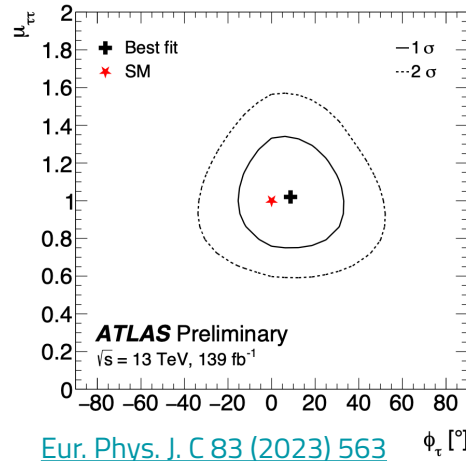


Yukawa couplings

- Typically parameterized with a mixing angle

$$\mathcal{L}_{H\tau\tau} = -\frac{m_\tau}{v} \kappa_\tau (\cos \phi_\tau \bar{\tau}\tau + \sin \phi_\tau \bar{\tau}i\gamma_5\tau)H$$

$$H \rightarrow \tau\tau$$



Using angular observables

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Dark Matter
Unconventional signatures

EFT interpretation of Higgs measurements
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Searches for SUSY Particles

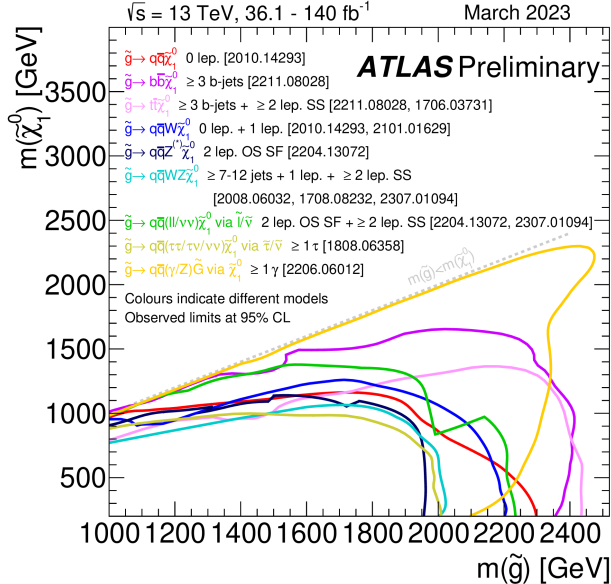
Nothing observed up to now...

Model	Signature	$\int \mathcal{L} dt$ [fb $^{-1}$]	Mass limit	Reference		
Inclusive Searches	$q\bar{q}, q \rightarrow q\tilde{\chi}_1^0$	0 e, μ mono-jet	2-6 jets E_T^{miss} 140	\tilde{q} [1x 8x Degen.] 1.0 \tilde{q} [8x Degen.] 0.9	$m(\tilde{\chi}_1^0) = 400$ GeV $m(\tilde{g}) - m(\tilde{\chi}_1^0) = 5$ GeV	2101.14293 2102.10874
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q}\tilde{\chi}_1^0$	0 e, μ 2-6 jets	E_T^{miss} 140	\tilde{g} 2.3 Forbidden 1.15-1.95	$m(\tilde{\chi}_1^0) = 0$ GeV $m(\tilde{\chi}_1^0) = 1000$ GeV	2101.14293 2101.14293
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q}W\tilde{\chi}_1^0$	1 e, μ 2-6 jets	E_T^{miss} 140	\tilde{g} 2.2	$m(\tilde{\chi}_1^0) = 600$ GeV	2101.01629
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q}(t\bar{t})\tilde{\chi}_1^0$	e, μ 2 jets	E_T^{miss} 140	\tilde{g} 2.2	$m(\tilde{\chi}_1^0) = 700$ GeV	2204.13072
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q}WZ\tilde{\chi}_1^0$	0 e, μ 7-11 jets	E_T^{miss} 140	\tilde{g} 1.97	$m(\tilde{\chi}_1^0) = 600$ GeV	2008.06032
		SS e, μ 6 jets	E_T^{miss} 140	\tilde{g} 1.15	$m(\tilde{g}) - m(\tilde{\chi}_1^0) = 200$ GeV	2307.01094
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$	0-1 e, μ 3 b	E_T^{miss} 140	\tilde{g} 2.45	$m(\tilde{\chi}_1^0) = 500$ GeV	2211.08028
		SS e, μ 6 jets	E_T^{miss} 140	\tilde{g} 1.25	$m(\tilde{g}) - m(\tilde{\chi}_1^0) = 300$ GeV	1909.08457
3 rd gen. squarks direct production	$\tilde{b}_1\tilde{b}_1$	0 e, μ 2 b	E_T^{miss} 140	\tilde{b}_1 1.255 \tilde{b}_1 0.68	$m(\tilde{\chi}_1^0) = 400$ GeV 10 GeV < $\Delta m(b, \tilde{\chi}_1^0)$ < 20 GeV	2101.12527 2101.12527
	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1 \rightarrow b\tilde{\chi}_2^0 \rightarrow b h\tilde{\chi}_1^0$	0 e, μ 6 b	E_T^{miss} 140	\tilde{b}_1 0.23-1.35	$\Delta m(\tilde{\chi}_2^0, \tilde{\chi}_1^0) = 130$ GeV, $m(\tilde{\chi}_1^0) = 100$ GeV	1908.03122
		2 τ 2 b	E_T^{miss} 140	\tilde{b}_1 0.13-0.85	$\Delta m(\tilde{\chi}_2^0, \tilde{\chi}_1^0) = 130$ GeV, $m(\tilde{\chi}_1^0) = 0$ GeV	2103.08189
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow c\tilde{\chi}_1^0$	0-1 e, μ ≥ 1 jet	E_T^{miss} 140	\tilde{t}_1 1.25	$m(\tilde{\chi}_1^0) = 0$ GeV	2004.14060, 2012.03799
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow Wb\tilde{\chi}_1^0$	1 e, μ 3 jets/1 b	E_T^{miss} 140	\tilde{t}_1 1.05	$m(\tilde{\chi}_1^0) = 500$ GeV	2012.03799, ATLAS-CONF-2023-043
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow \tilde{t}_1 b\nu, \tilde{t}_1 \rightarrow \tilde{t}_1 G$	1-2 τ 2 jets/1 b	E_T^{miss} 140	\tilde{t}_1 1.4	$m(\tilde{\chi}_1^0) = 800$ GeV	2108.07665
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow c\tilde{\chi}_1^0 / \tilde{c}\tilde{c}, \tilde{c} \rightarrow c\tilde{\chi}_1^0$	0 e, μ 2 c	E_T^{miss} 36.1	\tilde{t}_1 0.85	$m(\tilde{\chi}_1^0) = 0$ GeV	1805.01649
		0 e, μ mono-jet	E_T^{miss} 140	\tilde{t}_1 0.55	$m(\tilde{t}, \tilde{t}') - m(\tilde{\chi}_1^0) = 5$ GeV	2102.10874
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow t\tilde{\chi}_2^0, \tilde{\chi}_2^0 \rightarrow Z/h\tilde{\chi}_1^0$	1-2 e, μ 1-4 b	E_T^{miss} 140	\tilde{t}_1 0.067-1.18	$m(\tilde{\chi}_2^0) = 500$ GeV	2006.05880
		3 e, μ 1 b	E_T^{miss} 140	\tilde{t}_2 0.86	$m(\tilde{\chi}_2^0) = 360$ GeV, $m(\tilde{t}_1) - m(\tilde{\chi}_1^0) = 40$ GeV	2006.05880
EW direct	$\tilde{\chi}_1^+\tilde{\chi}_2^0$ via WZ	Multiple l /jets	E_T^{miss} 140	$\tilde{\chi}_1^+\tilde{\chi}_2^0$ 0.96	$m(\tilde{\chi}_1^0) = 0$, wino-bino	2106.01676, 2108.07586
		e, μ ≥ 1 jet	E_T^{miss} 140	$\tilde{\chi}_1^+\tilde{\chi}_2^0$ 0.205	$m(\tilde{\chi}_1^0) - m(\tilde{\chi}_2^0) = 5$ GeV, wino-bino	1911.12606
	$\tilde{\chi}_1^+\tilde{\chi}_1^0$ via W ν	2 e, μ	E_T^{miss} 140	$\tilde{\chi}_1^+\tilde{\chi}_1^0$ 0.42	$m(\tilde{\chi}_1^0) = 0$, wino-bino	1908.08215
	$\tilde{\chi}_1^+\tilde{\chi}_1^0$ via W h	Multiple l /jets	E_T^{miss} 140	$\tilde{\chi}_1^+\tilde{\chi}_1^0$ 1.06	$m(\tilde{\chi}_1^0) = 70$ GeV, wino-bino	2004.10894, 2108.07586
	$\tilde{\chi}_1^+\tilde{\chi}_1^0$ via $Z_0\tilde{\nu}$	2 e, μ	E_T^{miss} 140	$\tilde{\chi}_1^+\tilde{\chi}_1^0$ 1.0	$m(\tilde{\chi}_1^0) = 0$, wino-bino	1908.08215
	$\tilde{\chi}_1^+\tilde{\chi}_1^0$ via $Z_0\tilde{\nu}$	2 τ	E_T^{miss} 140	$\tilde{\chi}_1^+\tilde{\chi}_1^0$ 0.34, 0.48	$m(\tilde{\chi}_1^0) = 0$	ATLAS-CONF-2023-029
	$\tilde{\chi}_1^+\tilde{\chi}_1^0$ via $Z_0\tilde{\nu}$	2 e, μ 0 jets	E_T^{miss} 140	$\tilde{\chi}_1^+\tilde{\chi}_1^0$ 0.7	$m(\tilde{\chi}_1^0) = 0$	1908.08215
	$\tilde{\chi}_1^+\tilde{\chi}_1^0$ via $Z_0\tilde{\nu}$	e, μ ≥ 1 jet	E_T^{miss} 140	$\tilde{\chi}_1^+\tilde{\chi}_1^0$ 0.26	$m(\tilde{\chi}_1^0) - m(\tilde{\chi}_2^0) = 10$ GeV	1911.12606
	$\tilde{H}\tilde{H}, \tilde{H} \rightarrow hG/ZG$	0 e, μ ≥ 3 b	E_T^{miss} 140	\tilde{H} 0.94	$BR(\tilde{H}^0 \rightarrow hG) = 1$	To appear
		4 e, μ 0 jets	E_T^{miss} 140	\tilde{H} 0.55	$BR(\tilde{H}^0 \rightarrow ZG) = 1$	2103.11684
	0 e, μ ≥ 2 large jets	E_T^{miss} 140	\tilde{H} 0.45-0.93	$BR(\tilde{H}^0 \rightarrow ZG) = 1$	2108.07586	
	2 e, μ ≥ 2 jets	E_T^{miss} 140	\tilde{H} 0.77	$BR(\tilde{H}^0 \rightarrow ZG) = BR(\tilde{H}^0 \rightarrow hG) = 0.5$	2204.13072	
Long-lived particles	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^0$ prod., long-lived $\tilde{\chi}_1^+$	Disapp. trk	1 jet E_T^{miss} 140	$\tilde{\chi}_1^+$ 0.66	Pure Wino Pure higgsino	2201.02472 2201.02472
	Stable \tilde{g} R-hadron	pixel dE/dx	E_T^{miss} 140	\tilde{g} 2.05	$m(\tilde{\chi}_1^0) = 100$ GeV	2205.06013
	Metastable \tilde{g} R-hadron, $\tilde{g} \rightarrow q\tilde{q}\tilde{\chi}_1^0$	pixel dE/dx	E_T^{miss} 140	\tilde{g} [r(\tilde{g}) = 10 ns] 2.2	$m(\tilde{\chi}_1^0) = 100$ GeV	2205.06013
	$\tilde{l}, \tilde{l}, \tilde{l} \rightarrow tG$	Displ. lep	E_T^{miss} 140	\tilde{l}, \tilde{l} 0.7	$\tau(\tilde{l}) = 0.1$ ns $\tau(\tilde{l}) = 0.1$ ns	2011.07812 2011.07812
		pixel dE/dx	E_T^{miss} 140	\tilde{l}, \tilde{l} 0.36	$\tau(\tilde{l}) = 10$ ns	2205.06013
RPV	$\tilde{\chi}_1^+\tilde{\chi}_1^0/\tilde{\chi}_1^0/\tilde{\chi}_1^0, \tilde{\chi}_1^+ \rightarrow Zll$	3 e, μ	140	$\tilde{\chi}_1^+\tilde{\chi}_1^0$ [BR(Z τ)=1, BR(Z e)=1] 0.625, 1.05	Pure Wino	2111.10543
	$\tilde{\chi}_1^+\tilde{\chi}_1^0/\tilde{\chi}_1^0/\tilde{\chi}_1^0 \rightarrow WWZll\ell\nu$	4 e, μ 0 jets	E_T^{miss} 140	$\tilde{\chi}_1^+\tilde{\chi}_1^0$ [$A_{33} \neq 0, A_{12} \neq 0$] 0.95, 1.55	$m(\tilde{\chi}_1^0) = 200$ GeV	2103.11684
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q}\tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow qq\tilde{q}$	≥ 8 jets	E_T^{miss} 140	\tilde{g} [$m(\tilde{\chi}_1^0) = 50$ GeV, 1250 GeV] 1.6, 2.25	Large A_{112}	To appear
	$\tilde{u}, \tilde{t} \rightarrow \tilde{\chi}_1^0\tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow q\tilde{q}$	Multiple	36.1	\tilde{u} [$A_{11} = 2e-4, 1e-2$] 0.55, 1.05	$m(\tilde{\chi}_1^0) = 200$ GeV, bino-like	ATLAS-CONF-2018-003
	$\tilde{u}, \tilde{t} \rightarrow b\tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow bbs$	$\geq 4b$	140	\tilde{u} 0.95	$m(\tilde{\chi}_1^0) = 500$ GeV	2010.01015
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow bs$	2 jets + 2 b	36.7	\tilde{t}_1 [qq, b \bar{s}] 0.61		1710.07171
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow q\ell$	2 e, μ 2 b	36.1	\tilde{t}_1 0.42	$BR(\tilde{t}_1 \rightarrow b\ell) > 20\%$	1710.05544
		1 μ DV	136	\tilde{t}_1 [1e-10 < $A_{23}^0 < 1e-8, 3e-10 < A_{23}^+ < 3e-9$] 1.0, 1.6	$BR(\tilde{t}_1 \rightarrow q\tilde{q}) = 100\%, \cos\theta_{\tilde{t}_1} = 1$	2003.11956
$\tilde{\chi}_1^0/\tilde{\chi}_2^0/\tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow nbs, \tilde{\chi}_1^+ \rightarrow bbs$	1-2 e, μ ≥ 6 jets	140	$\tilde{\chi}_1^0$ 0.2-0.32	Pure higgsino	2106.09609	

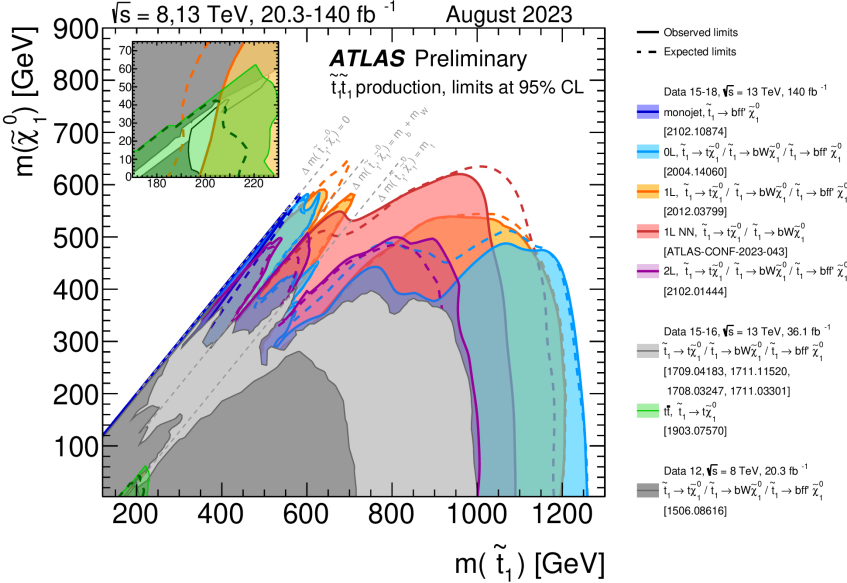
*Only a selection of the available mass limits on new states or phenomena is shown. Many of the limits are based on simplified models, c.f. refs. for the assumptions made.

Selected Summary Results from SUSY Searches

Limits from simplified models featuring the decay of the gluino to the lightest supersymmetric particle



Searches for top squark (stop) pair production



Search for Exotic Particles

ATLAS Exotics Searches* - 95% CL Upper Exclusion Limits

Status: May 2020

$$\int \mathcal{L} dt = (3.2 - 139) \text{ fb}^{-1}$$

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

Model	ℓ, γ	Jets [†]	E_T^{miss}	$\int \mathcal{L} dt [\text{fb}^{-1}]$	Limit	Reference	
Extra dimensions	ADD $G_{KK} + g/q$	$0, e, \mu$	1-4 j	Yes	36.1	M_0 7.7 TeV	$n=2$ 1711.03901
	ADD non-resonant $\gamma\gamma$	$2, \gamma$	-	-	36.7	M_5 8.6 TeV	$n=3$ HLZ NLO 1707.04147
	ADD QBH	-	2j	-	37.0	M_{th} 8.9 TeV	$n=6$ 1703.09127
	ADD BH high Σp_T	$\geq 1, e, \mu$	$\geq 2j$	-	3.2	M_{th} 8.2 TeV	$n=6, M_0 = 3 \text{ TeV, rot BH}$ 1606.02265
	ADD BH multijet	-	$\geq 3j$	-	3.6	M_{th} 9.55 TeV	$n=6, M_0 = 3 \text{ TeV, rot BH}$ 1512.02586
	RS1 $G_{KK} \rightarrow \gamma\gamma$	$2, \gamma$	-	-	36.7	G_{KK} mass 4.1 TeV	$k/\bar{M}_p = 0.1$ 1707.04147
	Bulk RS $G_{KK} \rightarrow WW/ZZ$	multi-channel	-	-	36.1	G_{KK} mass 2.3 TeV	$k/\bar{M}_p = 1.0$ 1808.02380
	Bulk RS $G_{KK} \rightarrow WV \rightarrow \ell\nu q\bar{q}$	$1, e, \mu$	2j/1J	Yes	139	G_{KK} mass 2.0 TeV	$k/\bar{M}_p = 1.0$ 2004.14636
	Bulk RS $g_{KK} \rightarrow t\bar{t}$	$1, e, \mu$	$\geq 1b, \geq 1J/2j$	Yes	36.1	g_{KK} mass 3.8 TeV	$\Gamma/m = 15\%$ 1804.10823
	2UED / RPP	$1, e, \mu$	$\geq 2b, \geq 3j$	Yes	36.1	KK mass 1.8 TeV	Tier (1,1), $\mathcal{B}(A^{(1,1)} \rightarrow t\bar{t}) = 1$ 1803.09678
Gauge bosons	SSM $Z' \rightarrow \ell\ell$	$2, e, \mu$	-	-	139	Z' mass 5.1 TeV	1903.06248
	SSM $Z' \rightarrow \tau\tau$	$2, \tau$	-	-	36.1	Z' mass 2.42 TeV	1709.07242
	Leptophobic $Z' \rightarrow b\bar{b}$	-	2b	-	36.1	Z' mass 2.1 TeV	1805.92999
	Leptophobic $Z' \rightarrow t\bar{t}$	$0, e, \mu$	$\geq 1b, \geq 2J$	Yes	139	Z' mass 4.1 TeV	$\Gamma/m = 1.2\%$ 2005.05138
	SSM $W' \rightarrow \ell\nu$	$1, e, \mu$	-	Yes	139	W' mass 6.0 TeV	1906.05609
	SSM $W' \rightarrow \nu\nu$	$1, \tau$	-	Yes	36.1	W' mass 3.7 TeV	1801.06992
	HVT $W' \rightarrow WZ \rightarrow \ell\nu q\bar{q}$ model B	$1, e, \mu$	2j/1J	Yes	139	W' mass 4.3 TeV	$g_V = 3$ 2004.14636
	HVT $V' \rightarrow WV \rightarrow qq\bar{q}\bar{q}$ model B	$0, e, \mu$	2J	-	139	V' mass 3.8 TeV	$g_V = 3$ 1906.98589
	HVT $W' \rightarrow WH/ZH$ model B	multi-channel	-	-	36.1	V' mass 2.93 TeV	$g_V = 3$ 1712.06518
	LRSM $W_R \rightarrow t\bar{b}$	$0, e, \mu$	$\geq 1b, \geq 1J$	Yes	36.1	W_R mass 3.2 TeV	$g_V = 3$ CERN-EP-2020-073
LRSM $W_R \rightarrow \mu N_R$	multi-channel	2j	-	80	W_R mass 3.25 TeV	1807.10473 1904.12679	
CI	CI $qqqq$	-	2j	-	37.0	A 21.8 TeV η_{LL}	1703.09127
	CI $\ell\ell qq$	$2, e, \mu$	-	-	139	A 35.8 TeV η_{LL}	CERN-EP-2020-066
	CI $t\bar{t}t\bar{t}$	$\geq 1, e, \mu$	$\geq 1b, \geq 1j$	Yes	36.1	A 2.57 TeV $ C_{41} = 4\pi$	1811.02305
DM	Axial-vector mediator (Dirac DM)	$0, e, \mu$	1-4 j	Yes	36.1	m_{medi} 1.55 TeV	$g_a=0.25, g_v=1.0, m(\chi) = 1 \text{ GeV}$ 1711.03901
	Colored scalar mediator (Dirac DM)	$0, e, \mu$	1-4 j	Yes	36.1	m_{medi} 1.67 TeV	$g=1.0, m(\chi) = 1 \text{ GeV}$ 1711.03901
	VV $\chi\chi$ EFT (Dirac DM)	$0, e, \mu$	1J, $< 1j$	Yes	3.2	M_χ 700 GeV	$m(\chi) < 150 \text{ GeV}$ 1608.02372
	Scalar reson. $\phi \rightarrow t\chi$ (Dirac DM)	$0-1, e, \mu$	1b, 0-1J	Yes	36.1	m_ϕ 3.4 TeV	$y = 0.4, \lambda = 0.2, m(\chi) = 10 \text{ GeV}$ 1812.09743
LQ	Scalar LQ 1 st gen	$1, 2, e$	$\geq 2j$	Yes	36.1	LQ mass 1.4 TeV	$\beta = 1$ 1902.00377
	Scalar LQ 2 nd gen	$1, 2, \mu$	$\geq 2j$	Yes	36.1	LQ mass 1.56 TeV	1902.00377
	Scalar LQ 3 rd gen	$2, \tau$	2b	-	36.1	LQ_3^+ mass 1.03 TeV	$\mathcal{B}(LQ_3^+ \rightarrow b\tau) = 1$ 1902.08103
	Scalar LQ 3 rd gen	$0-1, e, \mu$	2b	Yes	36.1	LQ_3^+ mass 970 GeV	$\mathcal{B}(LQ_3^+ \rightarrow t\tau) = 0$ 1902.08103
Heavy quarks	VLO $TT \rightarrow Ht/Zt/Wb + X$	multi-channel	-	-	36.1	T mass 1.37 TeV	SU(2) doublet 1808.02343
	VLO $BB \rightarrow Wt/Zb + X$	multi-channel	-	-	36.1	B mass 1.34 TeV	SU(2) doublet 1808.02343
	VLO $T_{5/3} T_{5/3} T_{5/3} \rightarrow Wt + X$	$2(SS)/3, 6, \mu$	$\geq 1b, \geq 1j$	Yes	36.1	$T_{5/3}$ mass 1.64 TeV	$\mathcal{B}(T_{5/3} \rightarrow Wb) = 1, c(T_{5/3}Wt) = 1$ 1807.11883
	VLO $Y \rightarrow Wb + X$	$1, e, \mu$	$\geq 1b, \geq 1j$	Yes	36.1	Y mass 1.85 TeV	$\mathcal{B}(Y \rightarrow Wb) = 1, c_R(Wb) = 1$ 1812.07343
	VLO $B \rightarrow Hb + X$	$0, e, \mu, 2, \gamma$	$\geq 1b, \geq 1j$	Yes	79.8	B mass 1.21 TeV	$\kappa_B = 0.5$ ATLAS-CONF-2018-024
	VLO $QQ \rightarrow WqWq$	$1, e, \mu$	$\geq 4j$	Yes	20.3	Q mass 690 GeV	1509.04261
Excited fermions	Excited quark $q^* \rightarrow qg$	-	2j	-	139	q^* mass 6.7 TeV	only u' and d' , $\Lambda = m(q^*)$ 1910.08447
	Excited quark $q^* \rightarrow q\gamma$	$1, \gamma$	1j	-	36.7	q^* mass 5.3 TeV	only u' and d' , $\Lambda = m(q^*)$ 1709.10440
	Excited quark $b^* \rightarrow bg$	-	1b, 1j	-	36.1	b^* mass 2.6 TeV	1805.92999
	Excited lepton ℓ^*	$3, e, \mu$	-	-	20.3	ℓ^* mass 3.0 TeV	$\Lambda = 3.0 \text{ TeV}$ 1411.2921
	Excited lepton ν^*	$3, e, \mu, \tau$	-	-	20.3	ν^* mass 1.6 TeV	$\Lambda = 1.6 \text{ TeV}$ 1411.2921
Other	Type III Seesaw	$1, e, \mu$	$\geq 2j$	Yes	79.8	N^0 mass 560 GeV	ATLAS-CONF-2018-020
	LRSM Majorana ν	$2, \mu$	2j	-	36.1	N_R mass 3.2 TeV	$m(W_R) = 4.1 \text{ TeV, } g_L = g_R$ 1809.11105
	Higgs triplet $H^{\pm\pm} \rightarrow \ell\ell$	$2, 3, 4, e, \mu$ (SS)	-	-	36.1	$H^{\pm\pm}$ mass 870 GeV	DY production 1710.09748
	Higgs triplet $H^{\pm\pm} \rightarrow \ell\tau$	$3, e, \mu, \tau$	-	-	20.3	$H^{\pm\pm}$ mass 400 GeV	DY production, $\mathcal{B}(H^{\pm\pm} \rightarrow \ell\tau) = 1$ 1411.2921
	Multi-charged particles	-	-	-	36.1	multi-charged particle mass 1.22 TeV	DY production, $ q = 5e$ 1812.03673
	Magnetic monopoles	-	-	-	34.4	monopole mass 2.37 TeV	DY production, $ g = 1g_D, \text{spin } 1/2$ 1905.10130

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

†Small-radius (large-radius) jets are denoted by the letter j (J).

Nothing either...

$\sqrt{s} = 8 \text{ TeV}$ $\sqrt{s} = 13 \text{ TeV}$ partial data $\sqrt{s} = 13 \text{ TeV}$ full data

10⁻¹ 1 10 Mass scale [TeV]

Search for Dark Matter

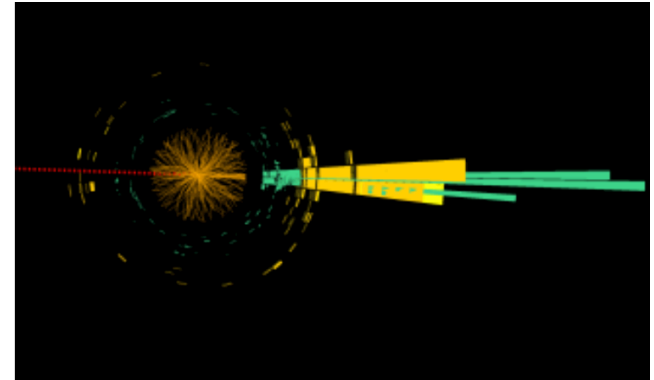
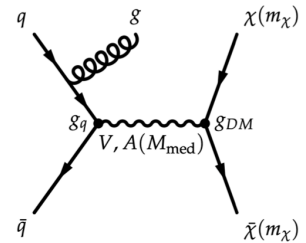
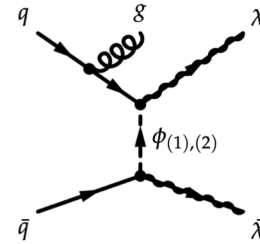
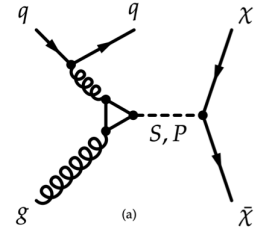
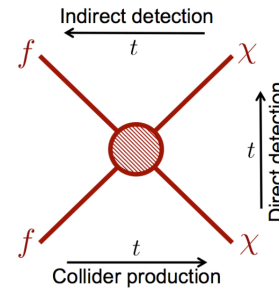
There is compelling cosmological evidence for the existence of Dark Matter

- Yet, we don't know anything about it

Searches at colliders are complementary to direct/indirect observations

Simplified models

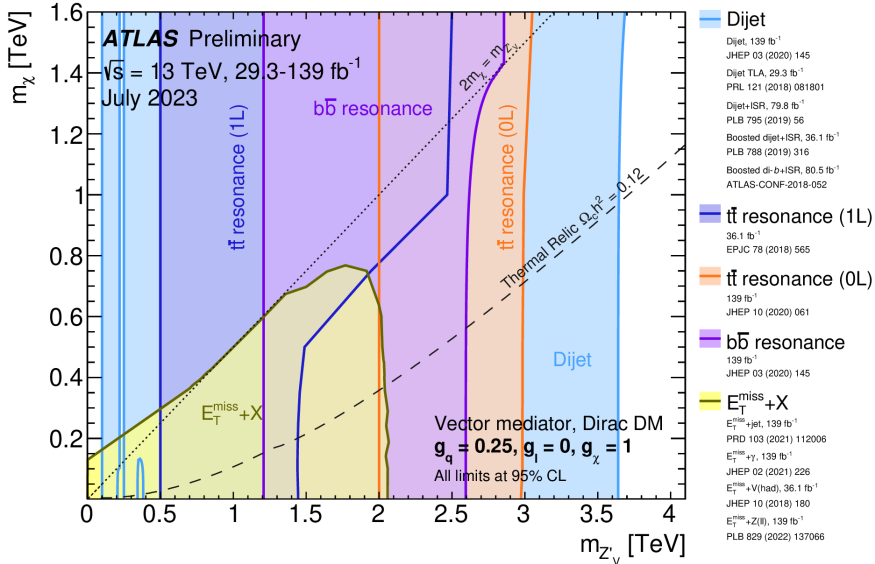
- DM assumed to be a Dirac fermion WIMP χ
- New particle mediator coupling χ to the SM
- Minimal set of parameters $\{M_{med}, m_\chi, g_\chi, g_q, g_\ell\}$



Dark matter searches

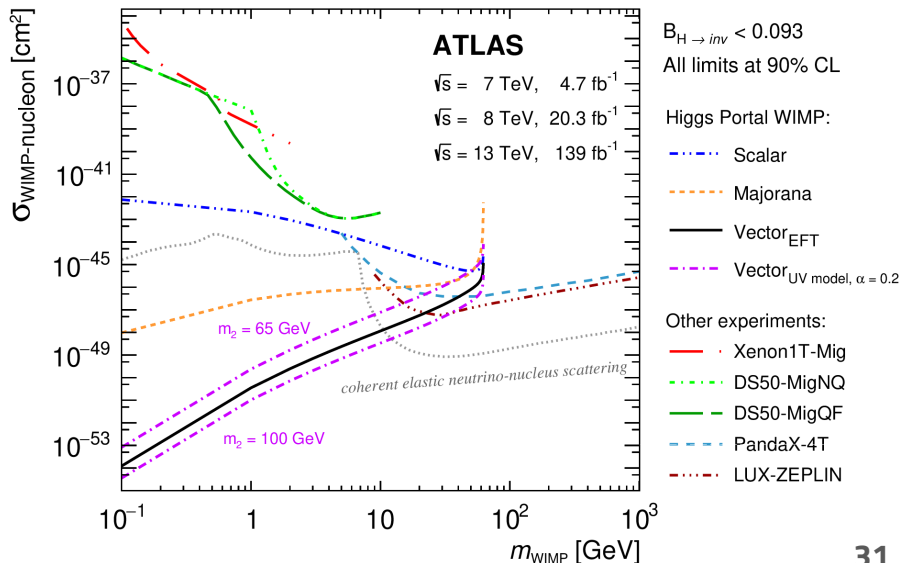
Few selected results

95% CL exclusion limits for DM leptophobic vector mediator simplified models



Higgs Portal WIMP

90% CL limits from $H \rightarrow \text{invisible}$ decays



Summary and conclusions

ATLAS is exploiting the Run 1, Run 2 and Run 3 pp collisions data with a comprehensive physics programme

- Standard Model measurements
- Searches for new physics

Measurements of the Higgs Boson are probing the Standard Model prediction and constraining new physics models

Direct searches for new physics have not yet shown any evidence for new particles

However the HL-LHC period will provide a 10 fold increase in statistics

- Increased precision and sensitivity to new physics

Thanks!

Acknowledgments:



REPÚBLICA
PORTUGUESA

FCT Fundação
para a Ciência
e a Tecnologia

ATLAS Search for low mass $\gamma\gamma$ resonances

