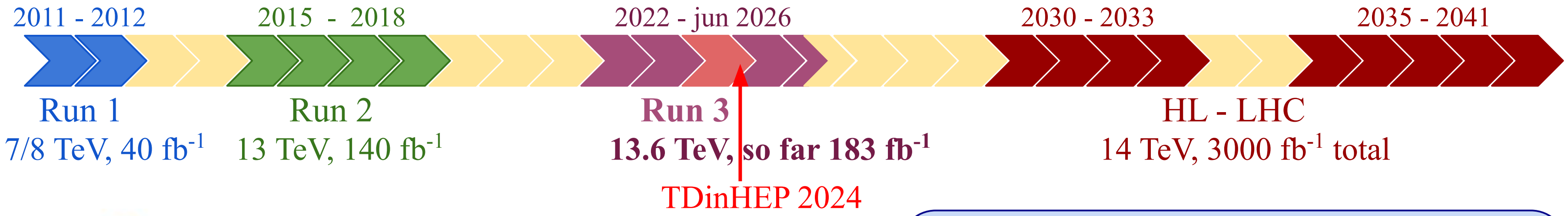
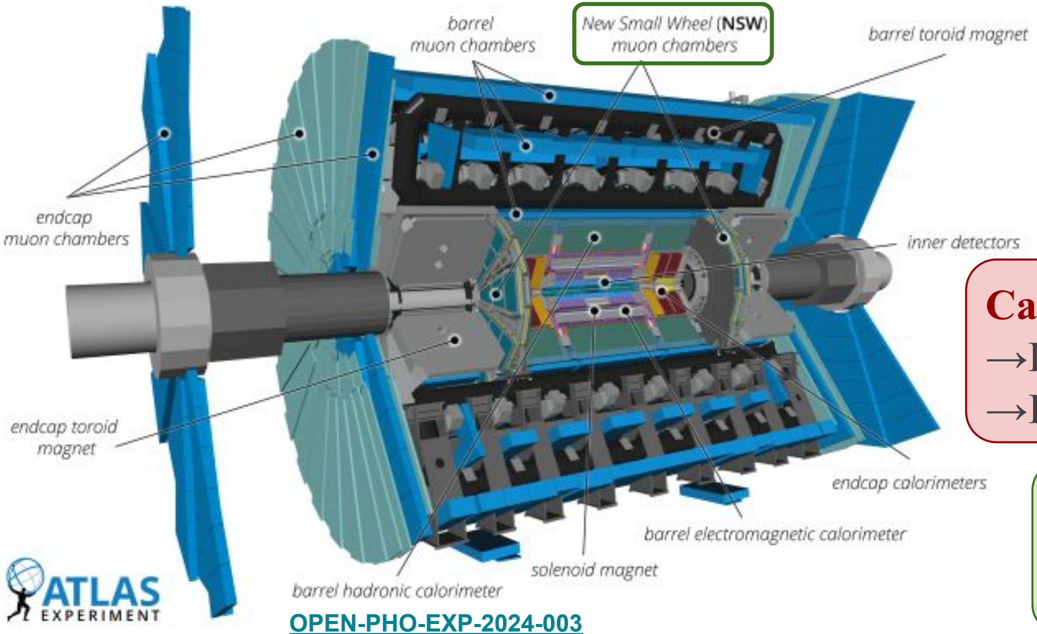
ATLAS physics

Pavol Bartoš (Comenius University)
on behalf of the ATLAS collaboration

Triggering Discoveries in High Energy Physics III
10 December, 2024

ATLAS detector





OPEN-PHO-EXP-2024-003

Inner Detectors (coverage: $|\eta| < 2.5$)
→Insertable B-layer, silicon pixel & strip tracker, transition radiation tracker
→Inside 2T magnetic field

Calorimeters
→Liquid argon EM: high-granularity $|\eta| < 2.5$
→Iron-scintillator tile hadronic calorimeter $|\eta| < 4.9$

Muon spektrometers (coverage: $|\eta| < 2.7$)
→tracking chambers, **New small wheel**
→Inside toroidal magnetic field

Collecting the data

	Run 2	Run 3
• Recorded luminosity	147 fb^{-1}	183 fb^{-1} (end of 2024)
• Good for physics	95.6%	93.1-96.5%
• Number of interactions per bunch crossing	34	54
• Luminosity uncertainty	0.83%	2%*Preliminary
	Eur. Phys. J. C 83 (2023) 982	ATL-DAPR-PUB-2024-001

Trigger rates

Level 1 trigger **100 kHz**

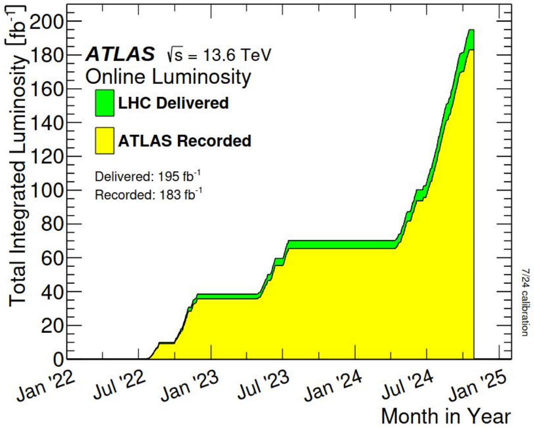
High-level trigger reduces the rate down to **3 kHz** (recording to disk)

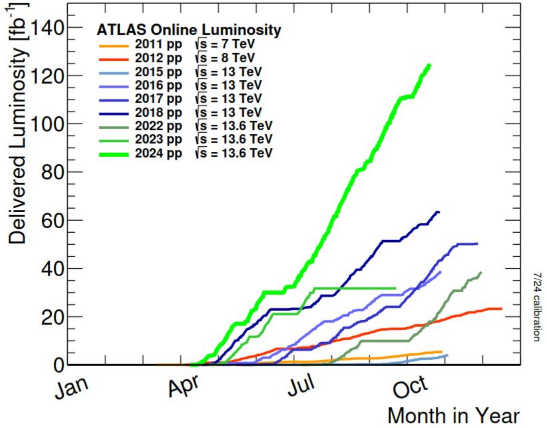
JINST 19 P05063 2024

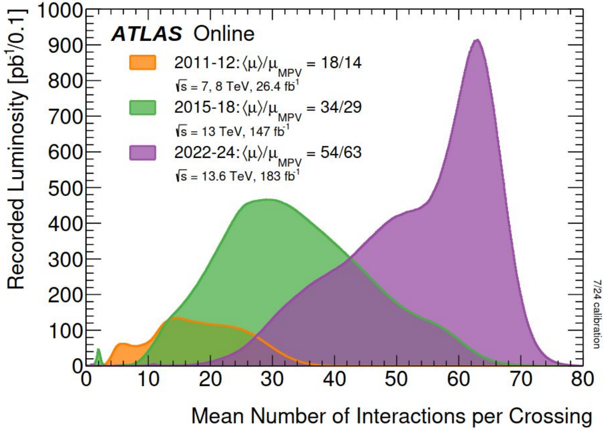
More about triggers:

J. Bracinik's, S. Hillier's talks

public web pages for Data Quality and Luminosity

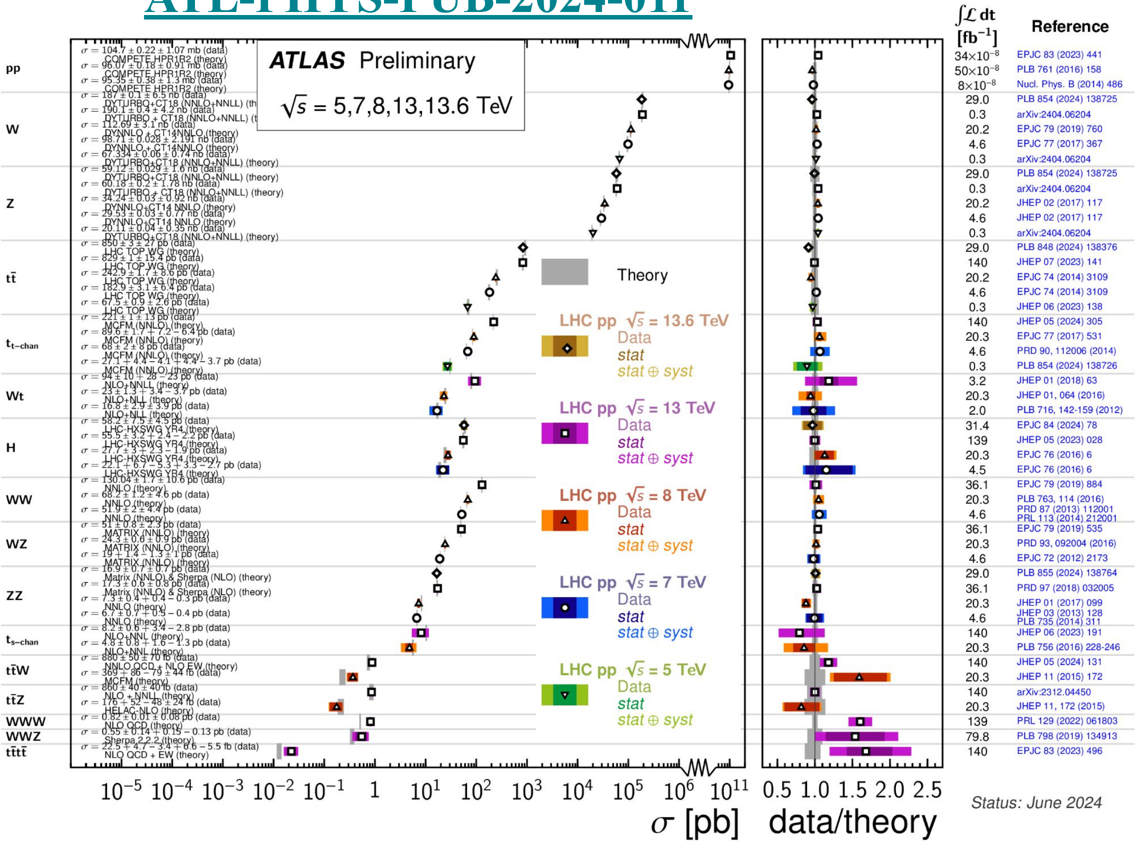




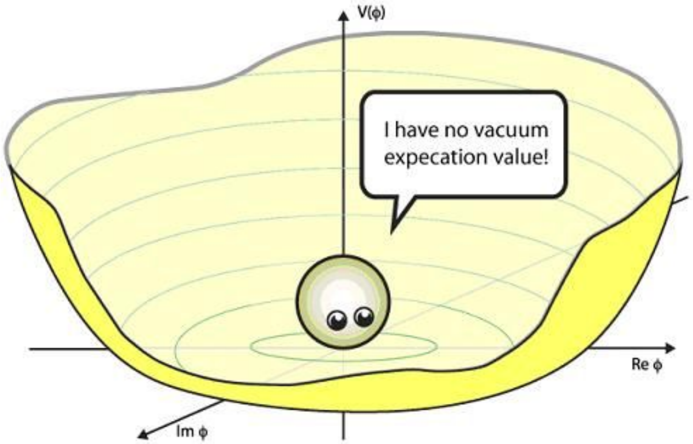


SM total production cross section measurements

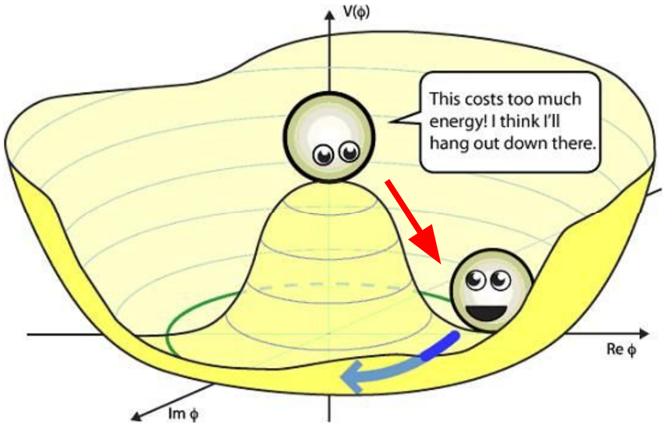
ATL-PHYS-PUB-2024-011



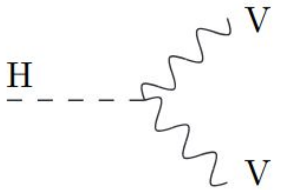
Higgs boson sector



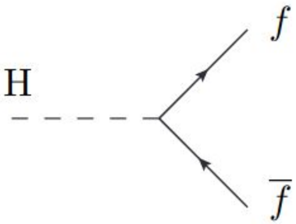
Electroweak symmetry breaking



SM Higgs coupling to vector bosons and fermions

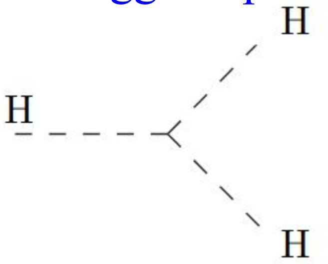


$$\frac{2m_V^2}{v}$$

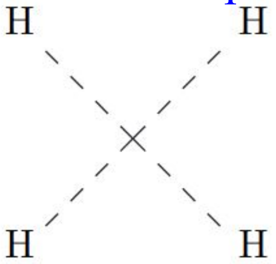


$$\frac{m_f}{v}$$

Higgs triple and quartic self-couplings



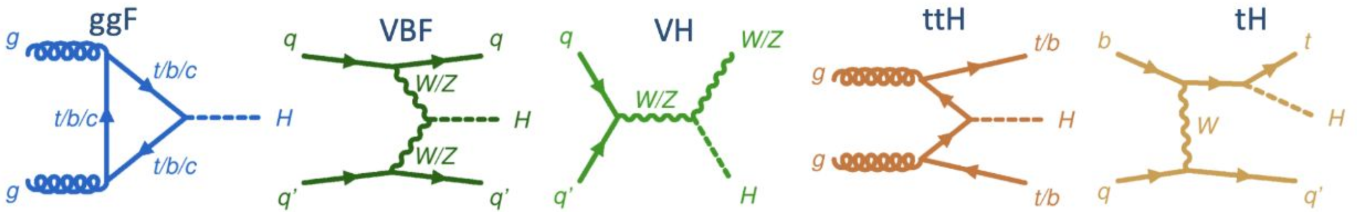
$$\frac{3m_H^2}{v}$$



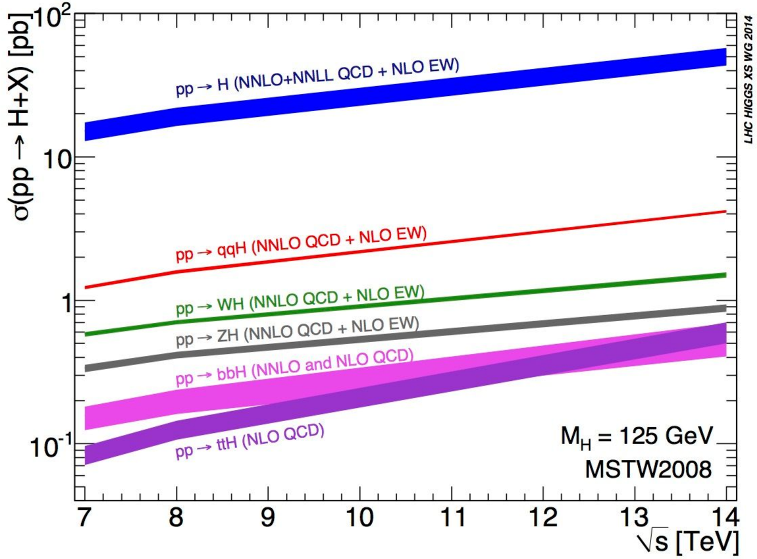
$$\frac{3m_H^2}{v^2}$$

Higgs boson production and decay channels

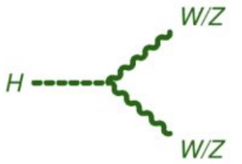
Production processes

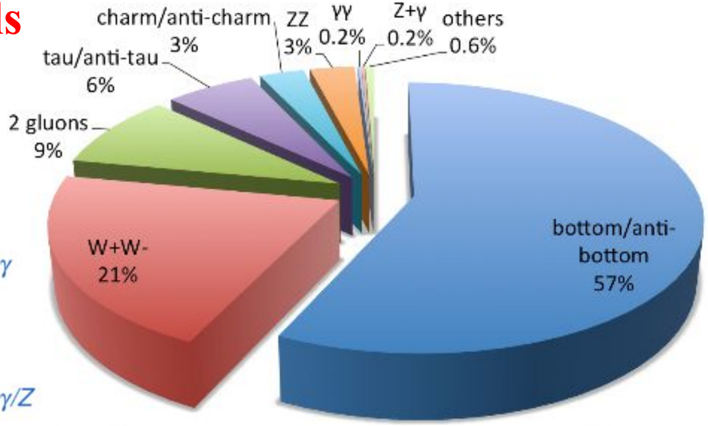


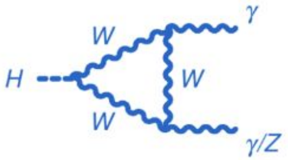
for 13 TeV: 87.2% 6.8% 3.79% 0.92% 0.16%

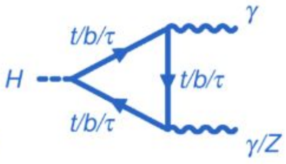


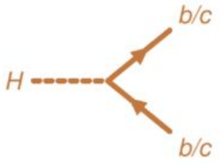
Decay channels

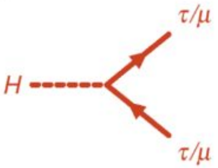












Higgs boson production and decay channels

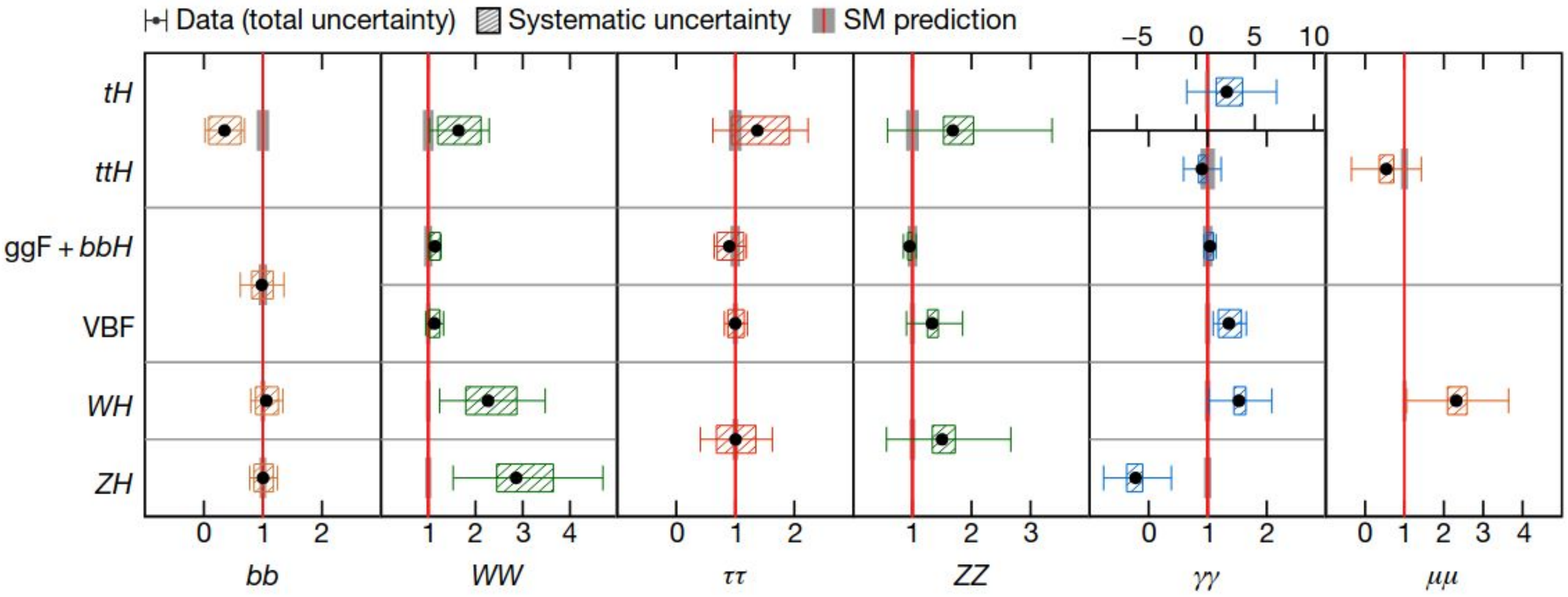
Signal strength

Measured $\sigma \cdot B$

SM prediction $\sigma_{SM} \cdot B_{SM}$

$$\frac{\sigma \cdot B}{\sigma_{SM} \cdot B_{SM}}$$

Nature **607** 52-59 (2022)



ATLAS Run 2 summary: Measurements in agreement with the SM predictions

Re-discovering Higgs boson

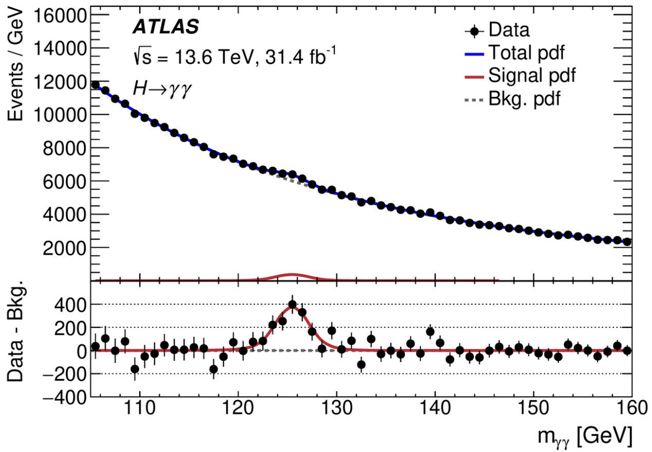
Eur. Phys. J. C 84 (2024) 78

Higgs boson discovery was announced by ATLAS and CMS Collaborations in 2012

2024: Re-discovering Higgs in the same decay channels **using first Run 3 data (2022)**

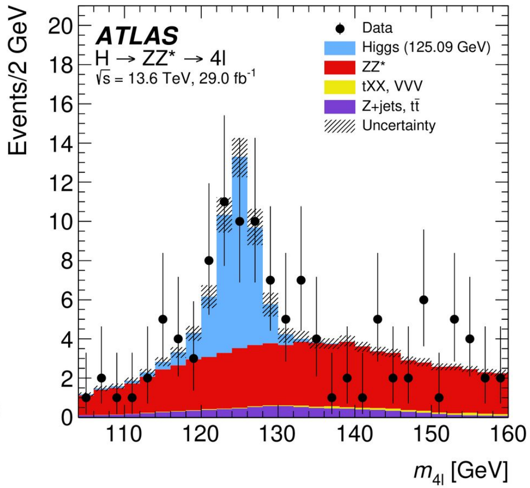
Each channel measured in fiducial phase space and extrapolated to full phase space for combination

$H\to\gamma\gamma$, 31.4 fb^{-1}



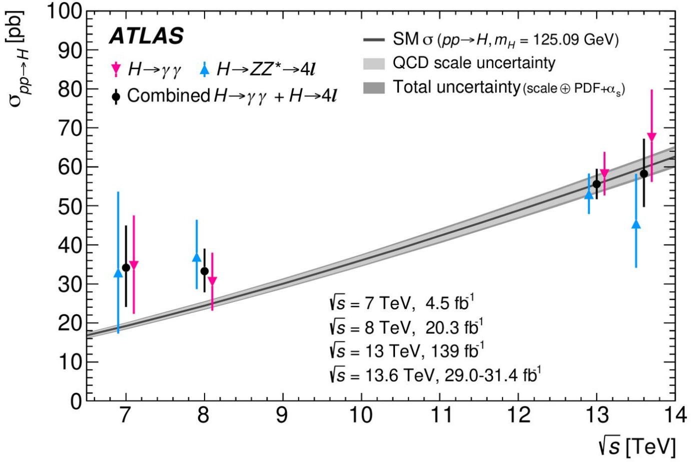
$$\sigma(pp \to H) = 67^{+12}_{-11}\ \text{pb}$$

$H\to ZZ^*\to 4\ell$, 29.0 fb^{-1}



$$\sigma(pp \to H) = 46 \pm 12\ \text{pb}$$

Summary



Good agreement with the SM

Higgs → ττ differential cross-section

[arXiv:2407.16320](https://arxiv.org/abs/2407.16320)

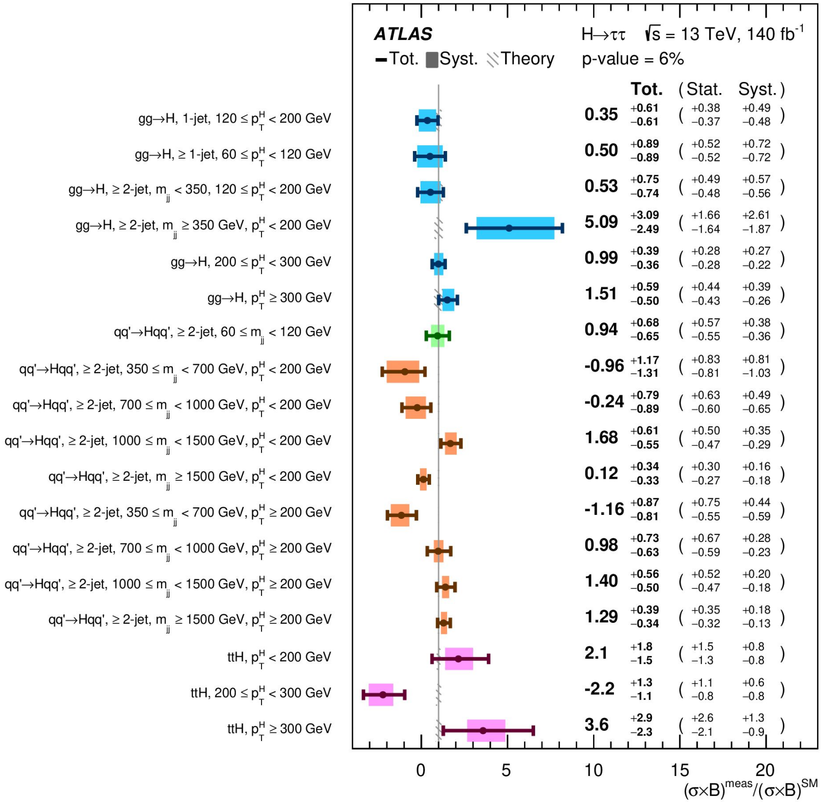
Previously: $H \rightarrow \tau\tau$ provided the most sensitive measurement of vector-boson fusion (VBF)
=> used to further investigation

compatibility with the SM:
overall p-value of 6% (reasonable agreement)

For vector boson fusion:

→first measurements for higher p_T^H

→**most precise for $p_T^H < 200$ GeV**



gg fusion

VH

VBF

ttH

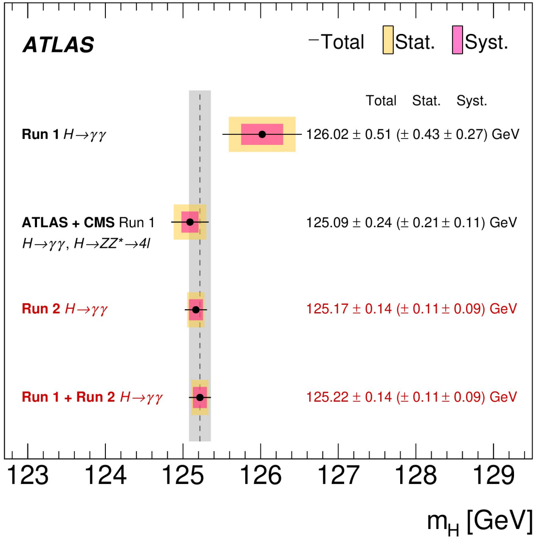
signal strength

Higgs boson mass

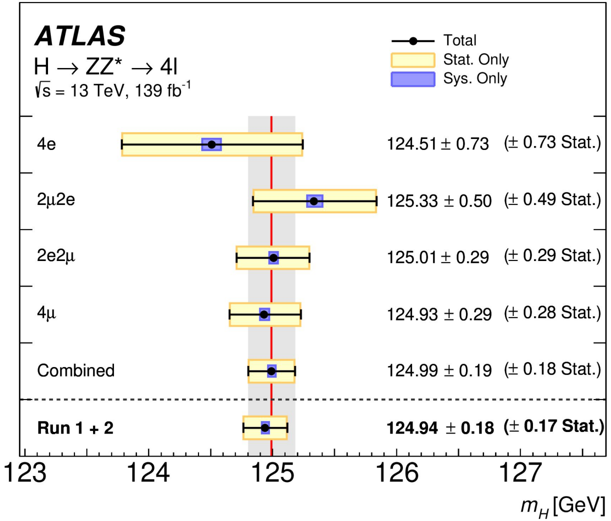
Full Run 2 data set is used to measure the mass of Higgs boson

Improved precision: Combination of Run 1 and Run 2 data

$H\to\gamma\gamma$ Phys. Lett. B 847 (2023) 138315



$H\to ZZ^*\to 4\ell$ Phys. Lett. B 843 (2023) 137880



Precision 0.11%

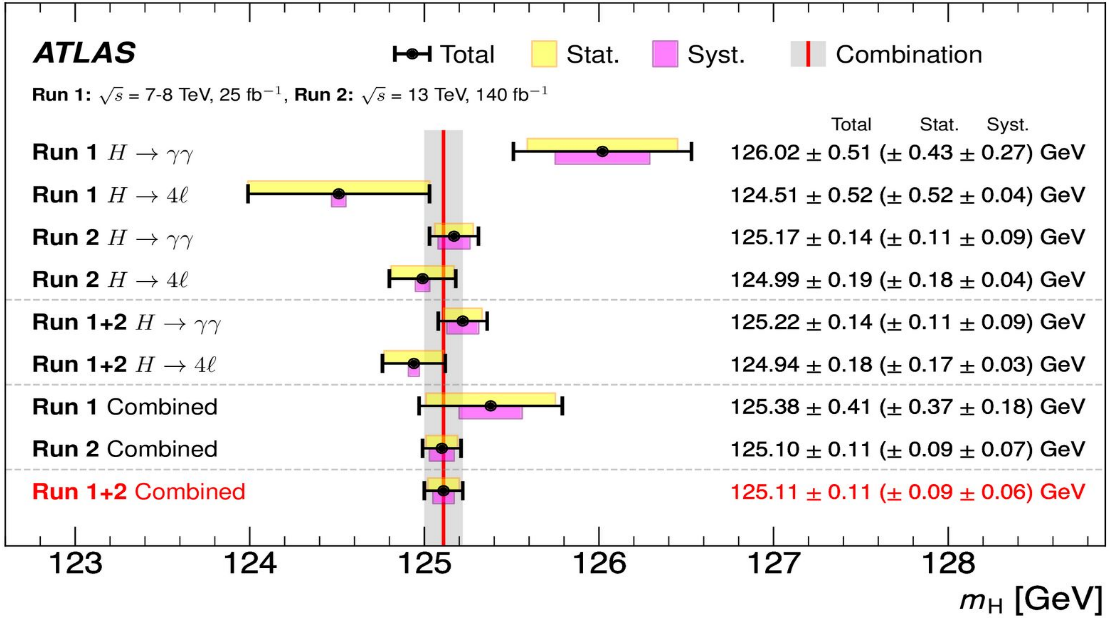
$H\to\gamma\gamma$ mass resolution systematic reduced by a factor 4!

Higgs boson mass

Phys. Rev. Lett. 131 (2023) 251802

Full Run 2 data set is used to measure the mass of Higgs boson

Improved precision: Combination of Run 1 and Run 2 data



Precision 0.09%

ttH production

arXiv:2407.10904

Main challenge: How to separate signal

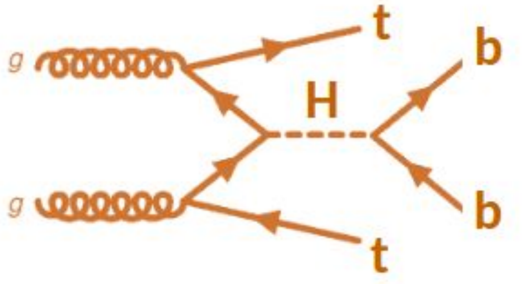
Pushing our understanding on *ttH(bb)*

→Improved reconstruction and particle identification: PFlow jets, DL1r *b*-tagging

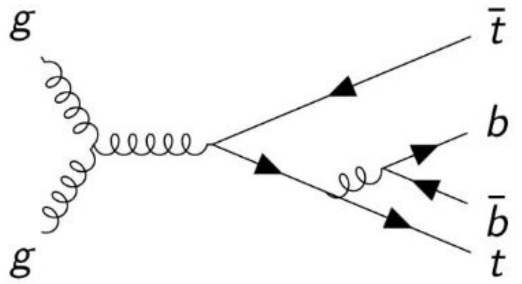
→ Improved modelling of background: data-driven corrections, systematic model

→ Machine learning:
Better signal / background classification
Improved Higgs reconstruction

***ttH* signal**



***ttbb* background**



ttH production

arXiv:2407.10904

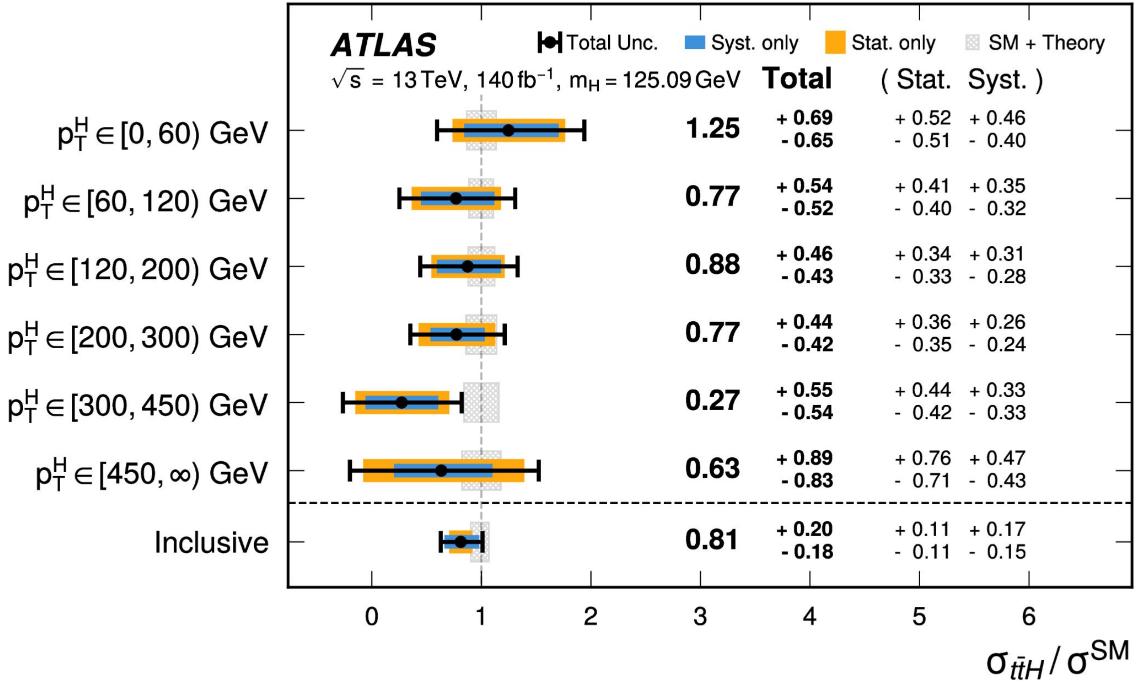
→**Measure σ_{ttH} in p_T^H bins** up to 450 GeV

→**Inclusive:**

$$\sigma_{t\bar{t}H} = 411\ ^{+101}_{-92}\ \text{fb}$$

→Overall **uncertainty reduced by factor** of **1.8**

→**Observed** (expected) **sensitivity 4.6σ** (5.4σ)



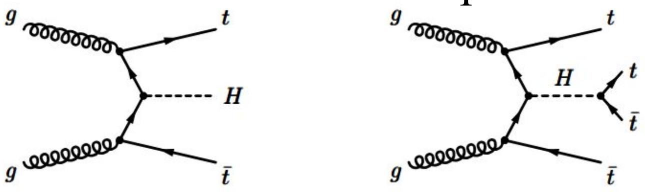
Best single measurement to date!

Higgs decay width from ttH and tttt

Constraints on Higgs decay width Γ_H use to be obtained from ZZ^* final state

NEW: Using combined measurement of

ttH and ***tttt*** productions

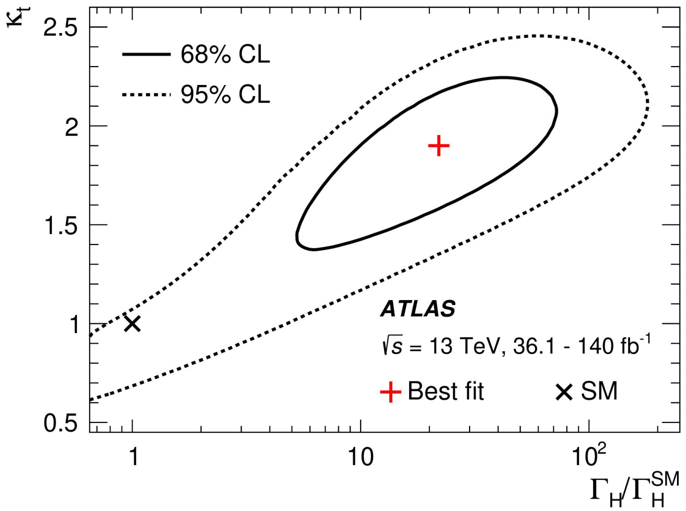


Target processes	
Off-shell measurement	
$pp \to t\bar{t}t\bar{t}$	
On-shell measurement	
Production	Decay
ggF, VBF, WH, ZH, $t\bar{t}H$, tH	$H \to \gamma\gamma$
$t\bar{t}H + tH$	$H \to b\bar{b}$
WH, ZH	$H \to b\bar{b}$
VBF	$H \to b\bar{b}$
ggF, VBF, $WH + ZH$, $t\bar{t}H + tH$	$H \to ZZ$
ggF, VBF	$H \to WW$
WH, ZH	$H \to WW$
ggF, VBF, $WH + ZH$, $t\bar{t}H + tH$	$H \to \tau\tau$
ggF+ $t\bar{t}H + tH$, VBF+ $WH + ZH$	$H \to \mu\mu$
Inclusive	$H \to Z\gamma$

$$\Gamma_H = 86^{+110}_{-49}\ \text{MeV}$$

Difference 2σ from the SM predictions primary caused by the tttt cross-section

arXiv:2407.10631



arXiv:2412.01548

Constraints on Γ_H from off-shell Higgs production

$4.3^{+2.7}_{-1.9}$ $(4.1^{+3.5}_{-3.4})$ MeV. obs. (exp.)

Higgs couplings to fermions and vector bosons

→Higgs boson coupling

to fermion **vector bosons**

$$g_F = \kappa_F \frac{m_F}{\eta} \qquad g_V = \sqrt{\kappa_V}\frac{m_V}{\eta}$$

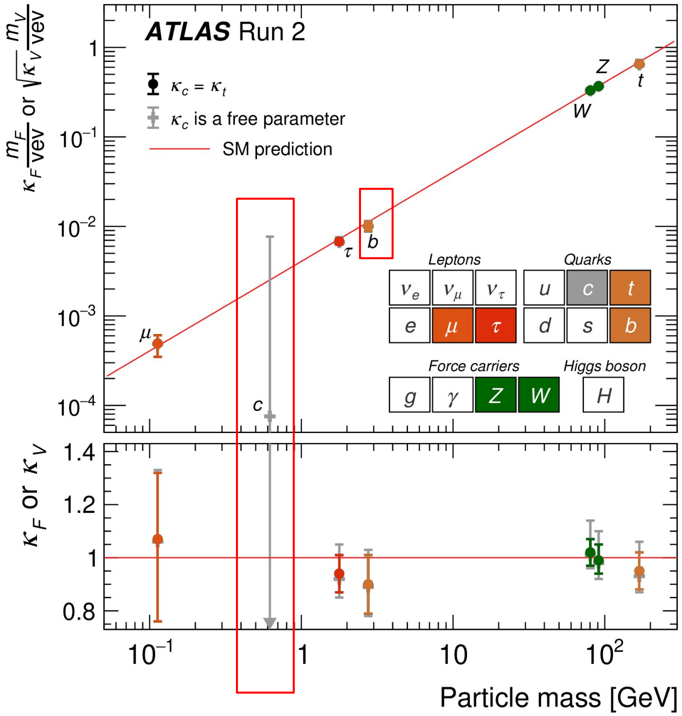
SM: $\kappa_F = 1, \kappa_V = 1$

New physics: $\kappa_F \neq 1, \kappa_V \neq 1$

Measurement of Yukawa coupling to bottom is reaching precision era!

Growing interest towards the second generation (Yukawa coupling to charm)

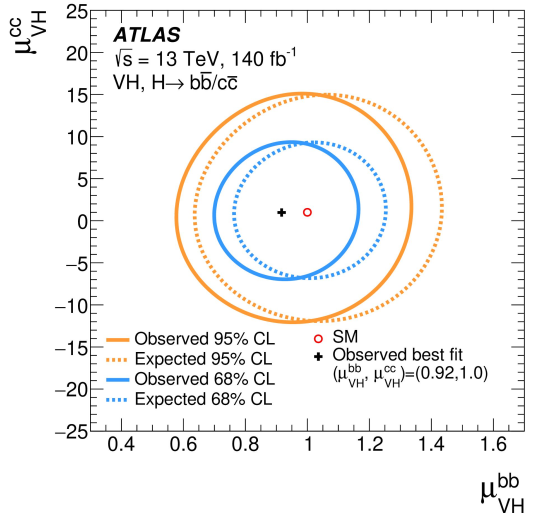
Nature **607** 52-59 (2022)



The Yukawa couplings to bottom and charm

→Legacy *VH* (*H*→*bb*/*cc*) improves and combines previous full Run 2 results:
VH(cc), *VH (bb)*, boosted *VH (bb)*

- better reconstruction and calibration, extended acceptance of events
- improved flavour tagging, that combines *b*- and *c*-jet identification
- Complex fit model (~50) SRs and (~100) CRs defined by tagging and kinematic criteria



arXiv:2410.19611

$|\kappa_C| < 4.2$ 95% CL

factor of 2 improvement

w.r.t previous result

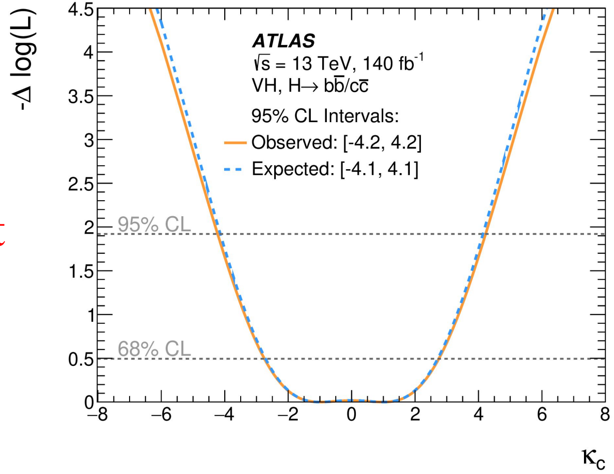
improvement

$$\mu_{VH}^{bb} = 0.92^{+0.16}_{-0.15}$$

15 %

$$\mu_{VH}^{cc} = 1.0^{+5.4}_{-5.2}$$

factor of ~3



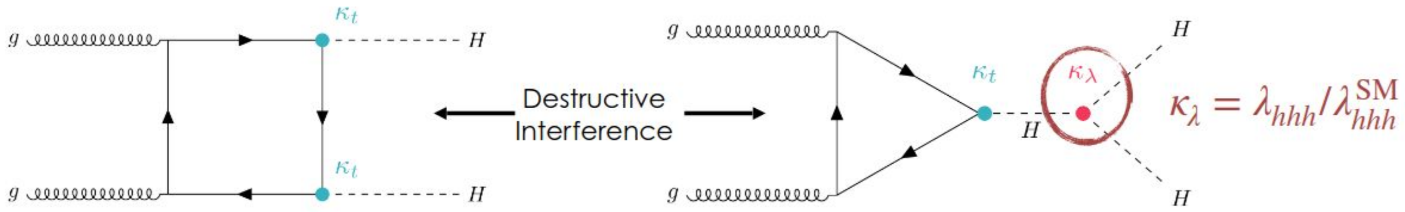
di-Higgs production

Challenging: *pp→HH* cross-section **1000× smaller than *pp→H***

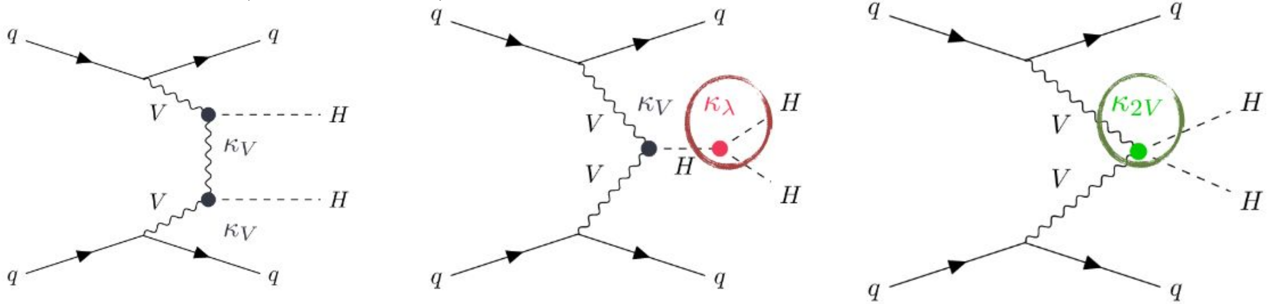
Access to trilinear λ_{hhh} coupling, unique probe of *VVhh* interaction κ_{2V}

Dominant SM processes:

- **gluon-gluon fusion** (σ=31.05 fb)



- **vector boson fusion** (σ=1.73 fb)



di-Higgs production

[Phys. Rev. Lett. 133 (2024) 101801]

Combination

$$\mu_{HH} = 0.5^{+1.2}_{-1.0}\left(^{+0.7}_{-0.6}\ \text{syst.}\right)$$

Uncertainty comparable to SM signal!

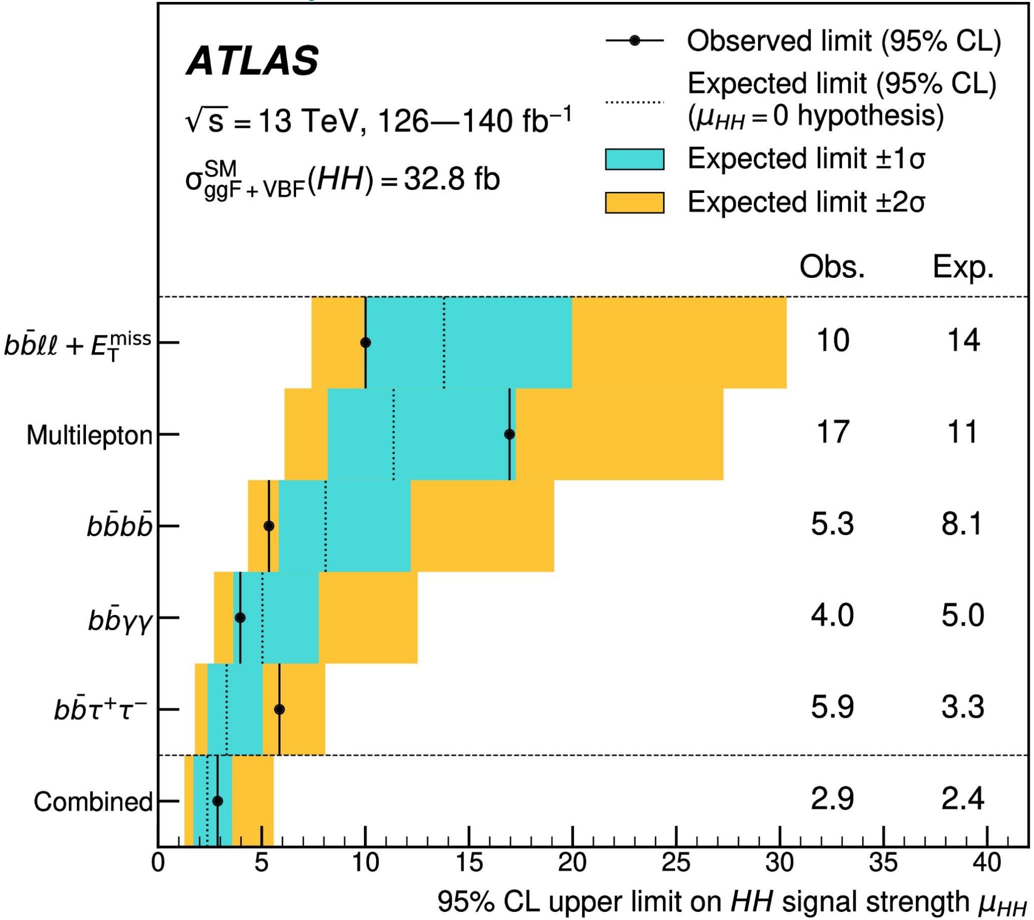
-1.2 < κ_λ <7.2 95% CL

Best constrian on λ_{hhh}

0.6 < κ_{2V} <1.5 95% CL

CMS: 0.67 < κ_{2V} <1.38 95% CL

[Nature **607**, 60-68 (2022)]



New

New

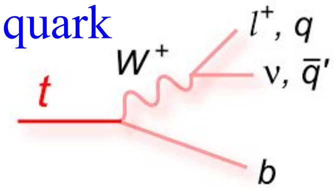
New boosted part

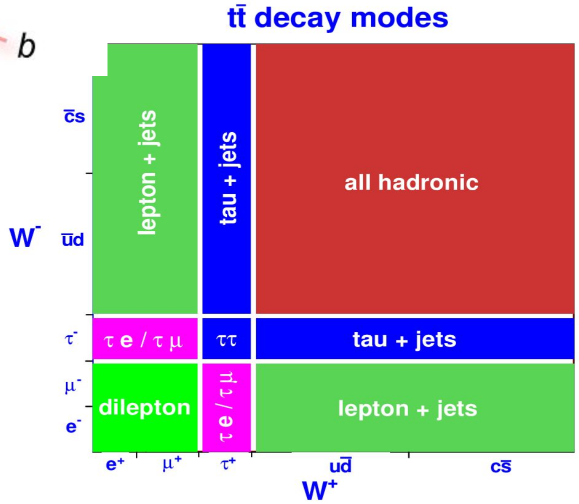
Improved

Improved

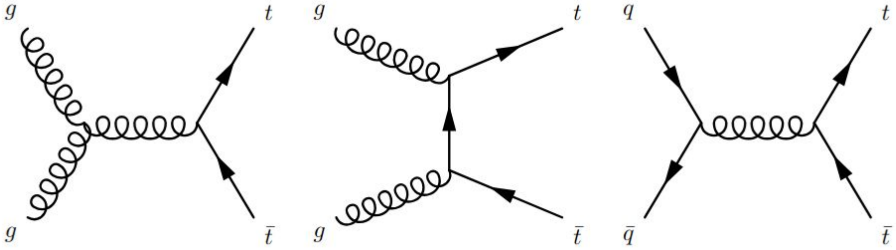
Top quark sector

SM top quark decay

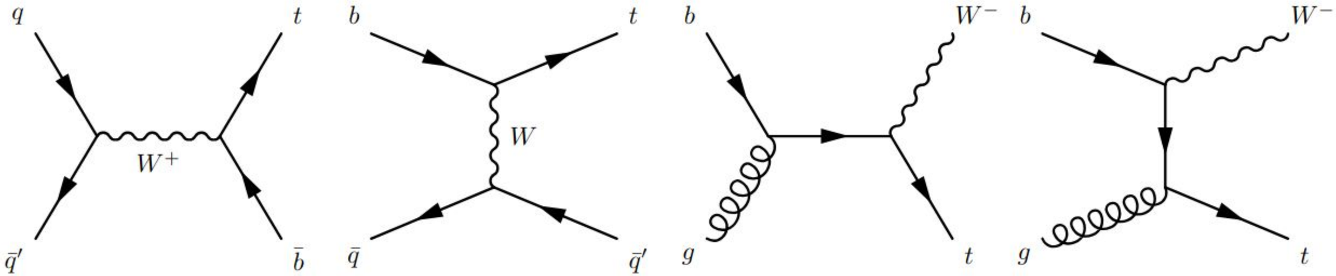




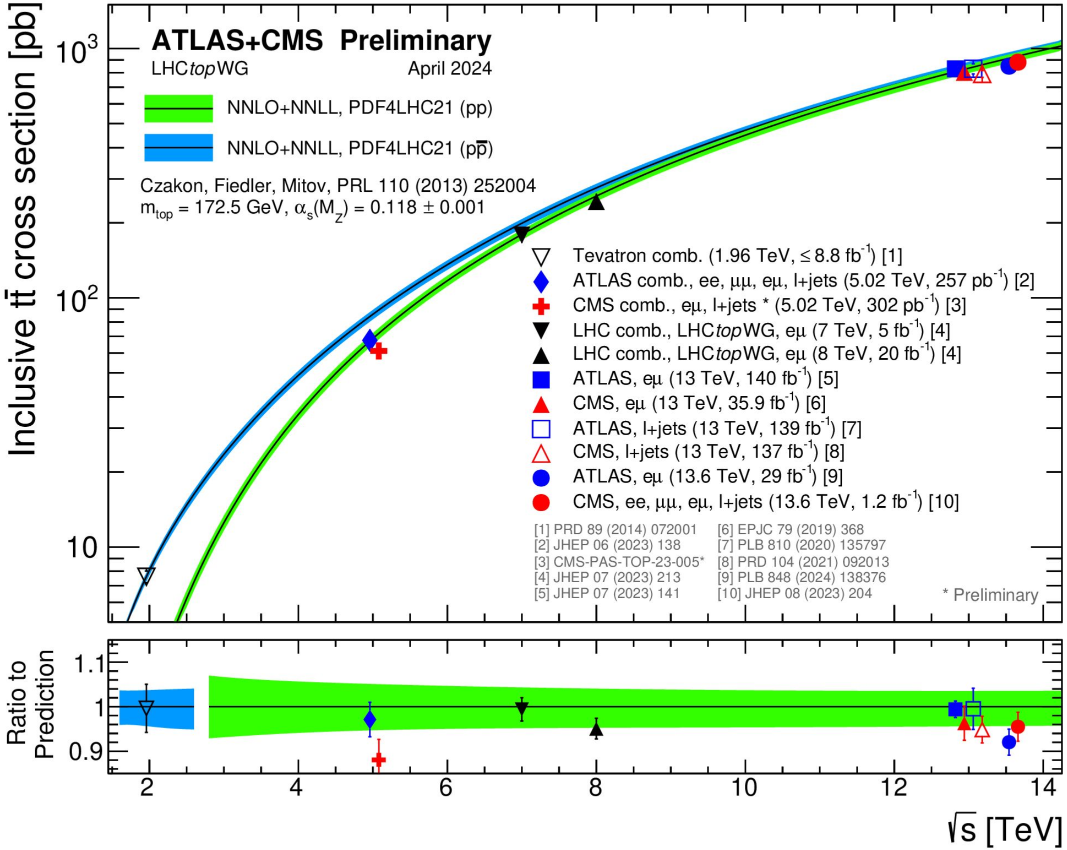
Top-quark pair production via strong interaction



Single top production via weak interaction



Top quark pair production



Phys. Lett. B 848 (2024) 138376

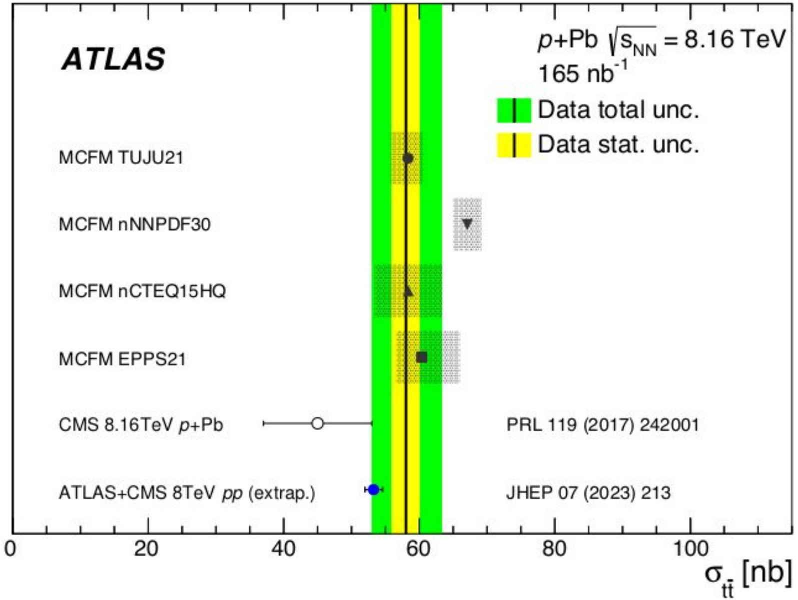
First Run 3 measurement, using 2022 data, dilepton decay channel

→ σ_{tt}/σ_{Z} => uncertainty reduction

→ compatible with SM predictions

Top quark pair production in p+Pb and Pb+Pb

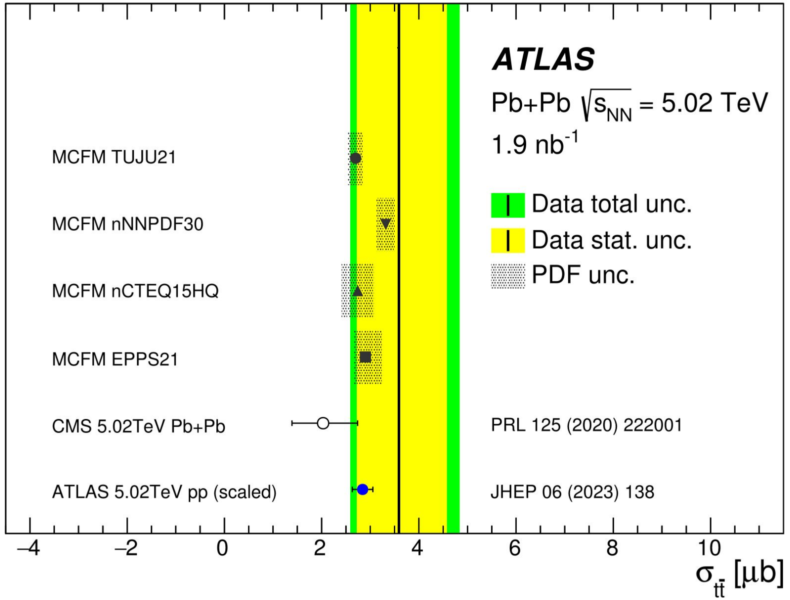
JHEP 11 (2024) 101



Observed with significance > 5σ

in each of used channels

arXiv:2411.10186



Obs (exp) significance 5σ (4.1σ)

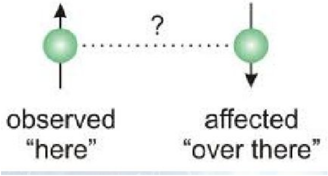
Consistent with different nuclear PDFs!

Top quark entanglement

Quantum state of one particle cannot be described independently from another particle.

⇒ **Correlations** of observed physical properties of both systems

⇒ **Measurement** performed on one system seems to be influencing other system entangled with it.

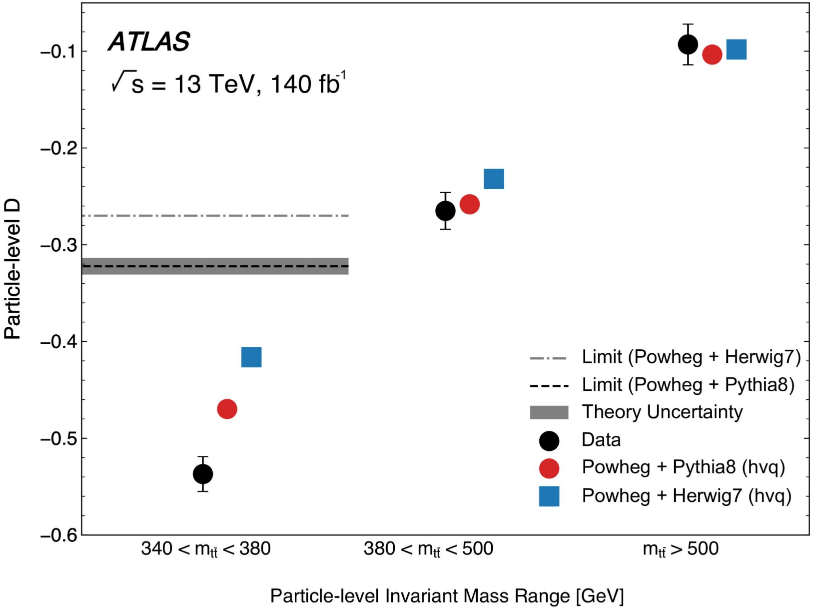


Nature 633 (2024) 542

Single observable *D*:

→depends on the angle between leptons measured in the parent top/antitop rest frame

if D < – ⅓ => entanglement



Entanglement is observed with sensitivity of more than 5σ

observed $D = -0.537 \pm 0.002$ [stat.] ± 0.019 [syst.]

expected $D = -0.470 \pm 0.002$ [stat.] ± 0.017 [syst.]

Main source of systematic uncertainty is signal modelling.

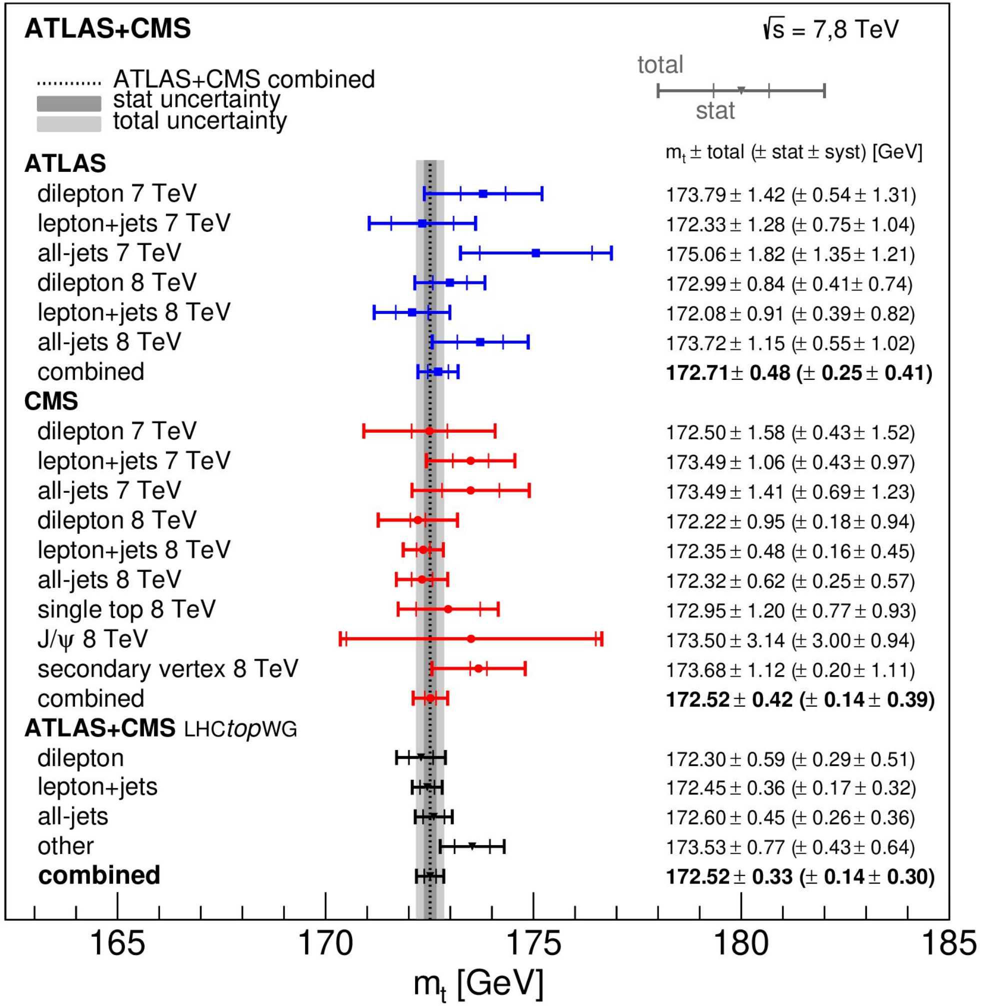
Top quark mass

[Phys. Rev. Lett. 132 (2024) 261902]

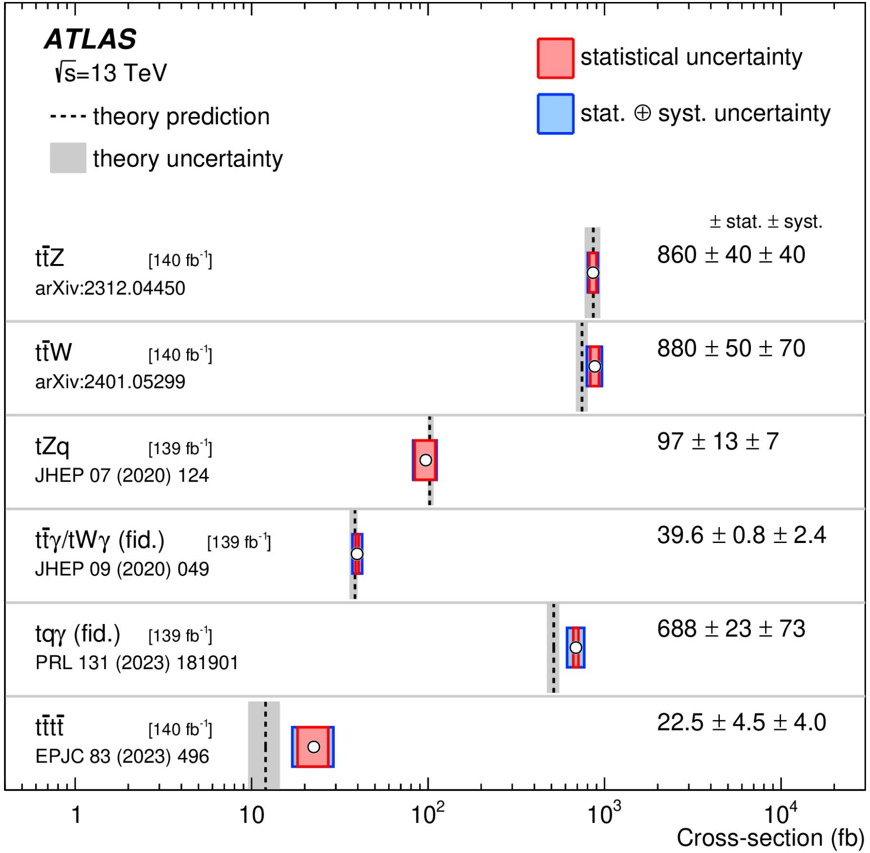
ATLAS+CMS combination
7 & 8 TeV data

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

Relative precision of 0.2%!



Top quark associated production



arXiv:2404.10674

ttZ – result reaches the precision of the theory

ttW – slightly above the SM prediction (1.4σ)

tZq – precision well > 5σ

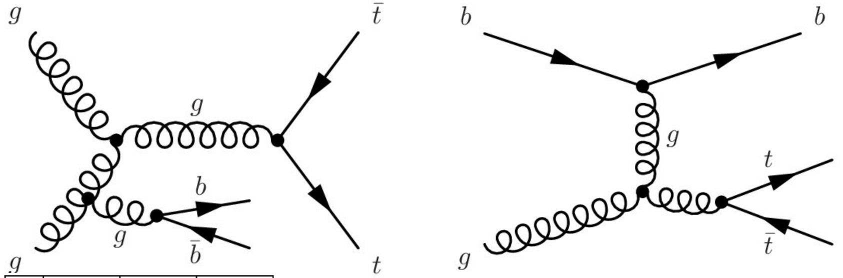
ttγ/tWγ – differential distr. agree with the SM

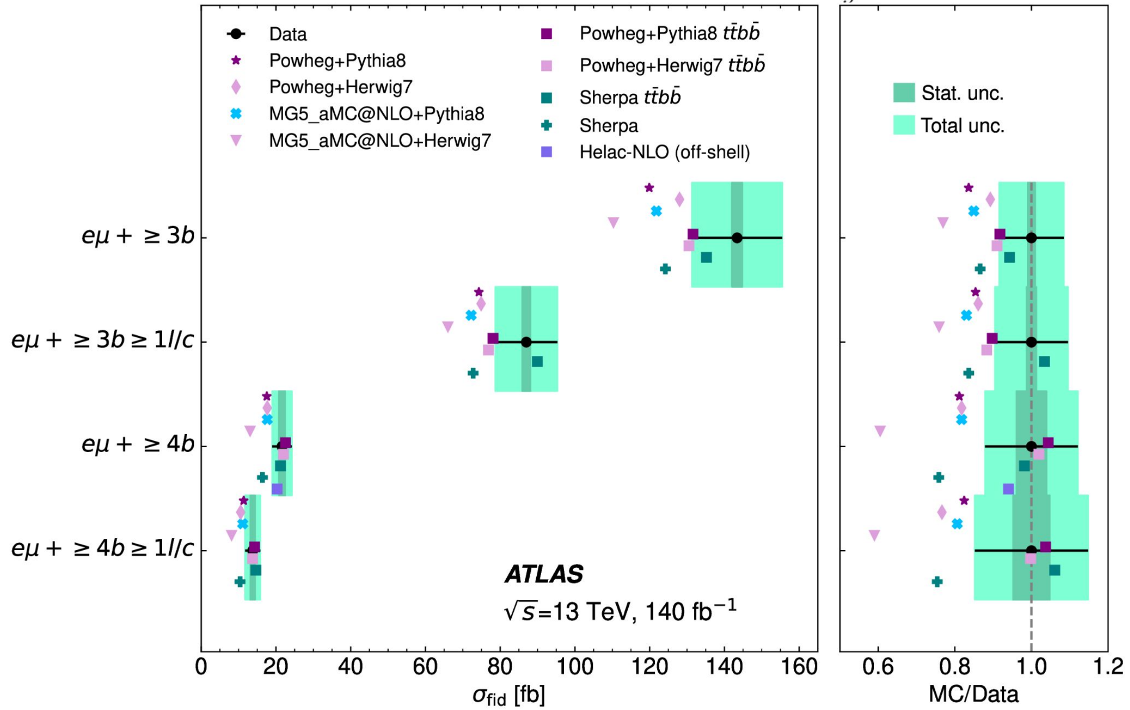
tqγ – first observation (obs. significance > 9.3σ)

4 tops – first observation (obs. significance > 6.1σ)

ttbb production

[arXiv:2407.13473]





→large irreducible background for *ttH(bb)*

→using events with 1e and 1μ from tt-bar decay

→inclusive cross-section

→precision higher than in theory predictions

→differential cross section

→difference between any 2 models smaller than measured uncertaint and theor. QCD scale uncer.

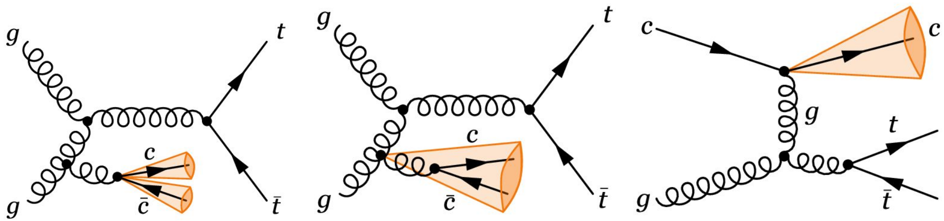
Dominant systematic uncert.: b-tagging, JES, tt-bar modelling.

ttcc production

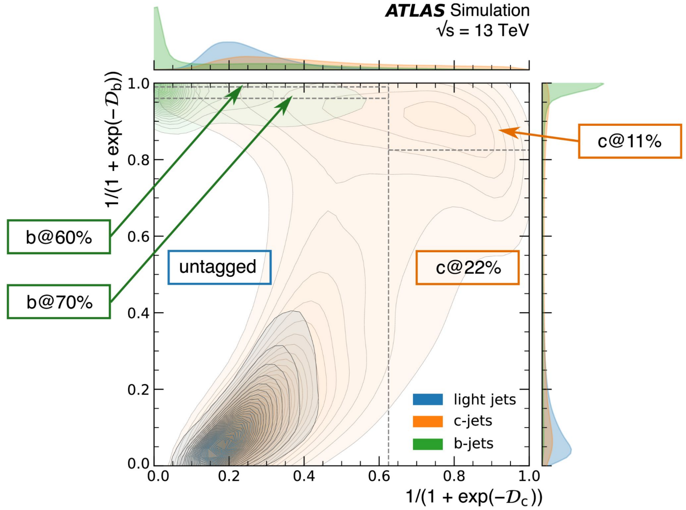
→using $1\ell + 2\ell$ *tt-bar* decay channels

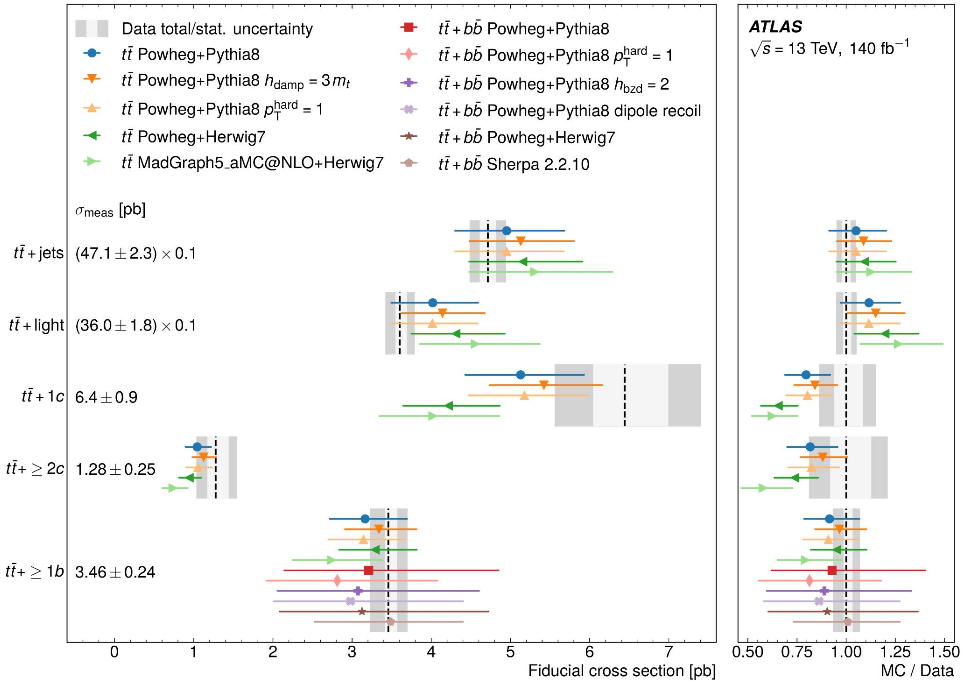
→***b/c* tagger**→simultaneous identification of *c*-jet and *b*-jet

→used to define regions sensitive for *tt* + *1c* and *tt* + ≥*2c* production



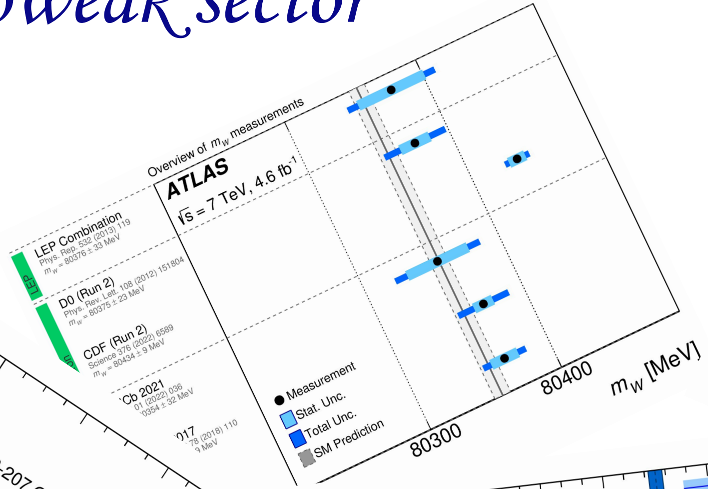
arXiv:2409.11305

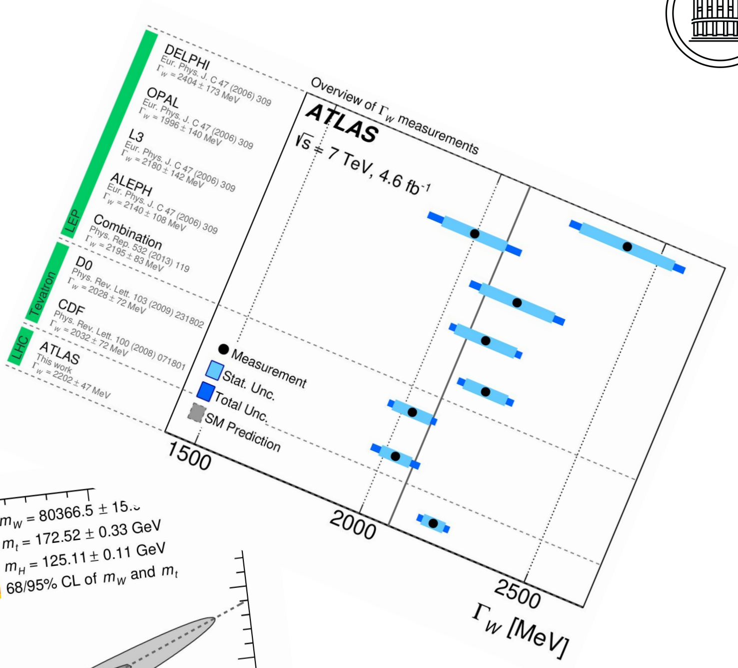


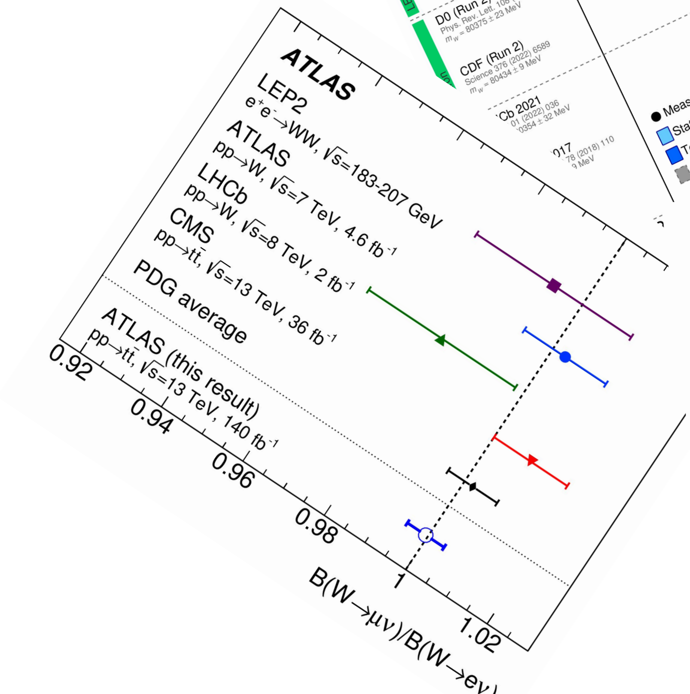


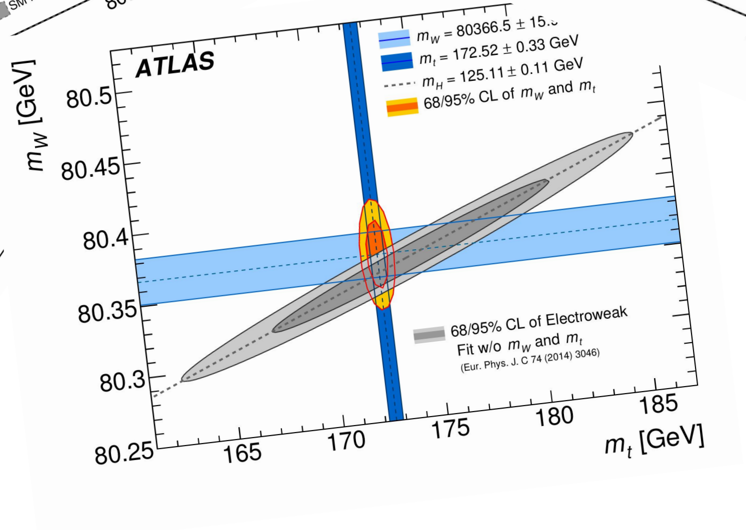
NLO+PS prediction unpredicts the observed results, but are compatible with them

Electroweak sector







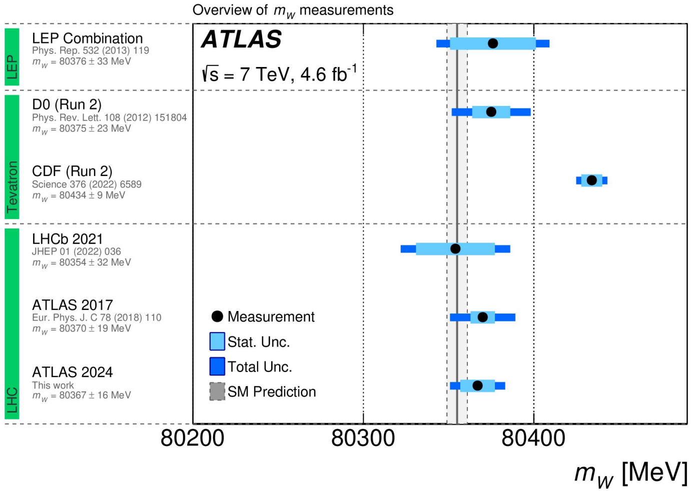


W boson mass and width

arXiv: 2403.15085
CERN press release

7 TeV *pp*-collision data re-analyzed (improved fitting techniques, updated PDFs)

Improved *W*-boson mass



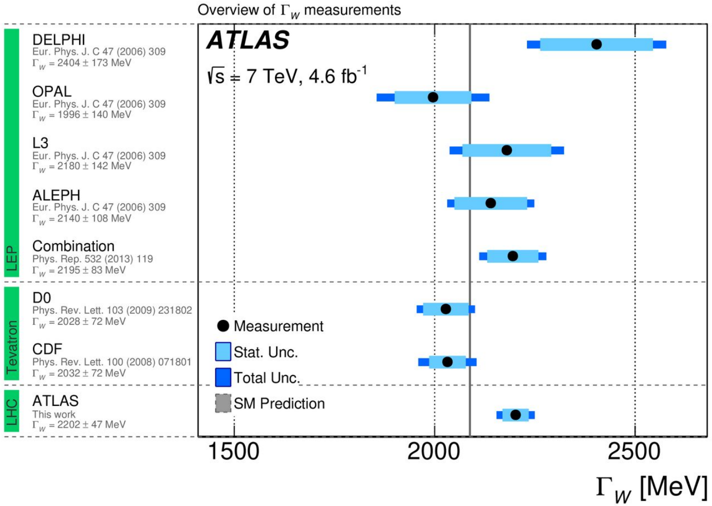
ATLAS, 7 TeV: m_W = 80366.5 ± 15.9 MeV

CMS, 13 TeV (2016 data only):

m_W = 80360.2 ± 9.9 MeV

Tension between the CDF and LHC results!

First measurement of *W*-boson width at LHC



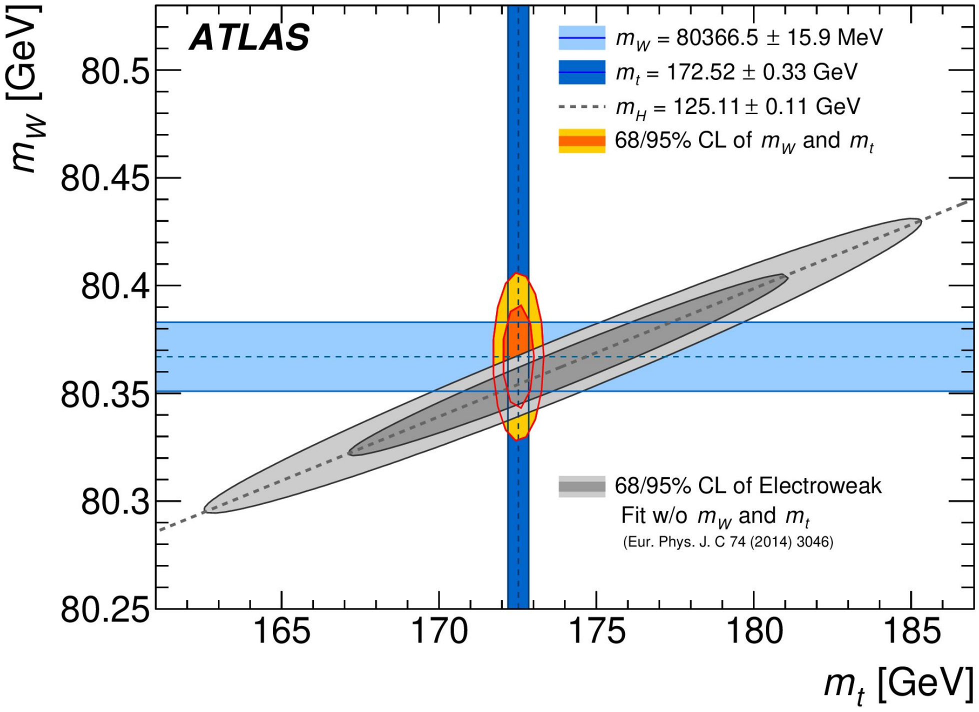
ATLAS, 7 TeV: Γ_W = 2202 ± 47 MeV

Most precise single measurement!

Compatible with SM within 2σ

Global electroweak fit

SM electroweak fit compared to the recent ATLAS results



***W* boson mass (0.02%)**
arXiv: 2403.15085
→re-analysed 7 TeV *pp* data

Top quark mass (0.2%)
Phys. Rev. Lett. 132 (2024) 261902
→LHC comb of 7 and 8 TeV meas.

Higgs boson mass (0.09%)
Phys. Rev. Lett. 131 (2023) 251802
→ATLAS combination of Run 1 and Run 2 *pp* data

Lepton Flavour Universality

[Eur. Phys. J. C 84 (2024) 993]

CERN [press release]

Assumption:

W/Z couplings are independent of mass

→LFU is fundamental axiom in the SM

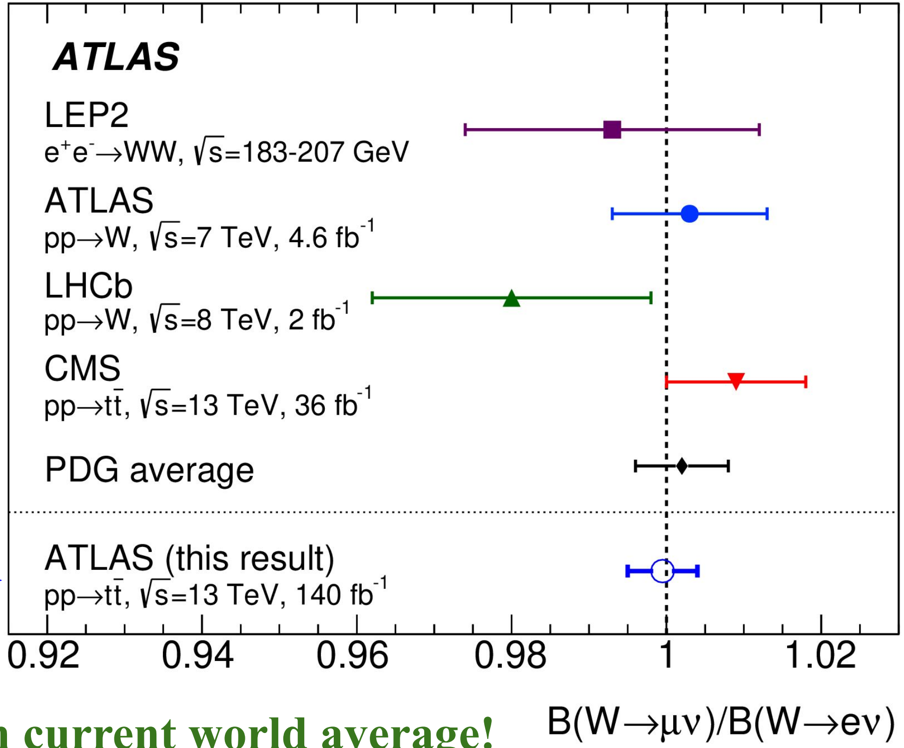
Test:

Measure the ratio of boson decay rates

→Using $W \rightarrow e\nu_e$ and $W \rightarrow \mu\nu_\mu$

→Analyze W-bosons from top quark decays

$$R_W^{\mu/e} = 0.9995 \pm 0.0045$$

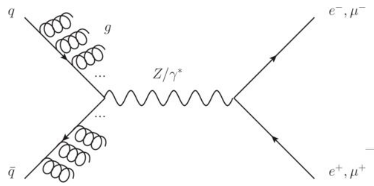


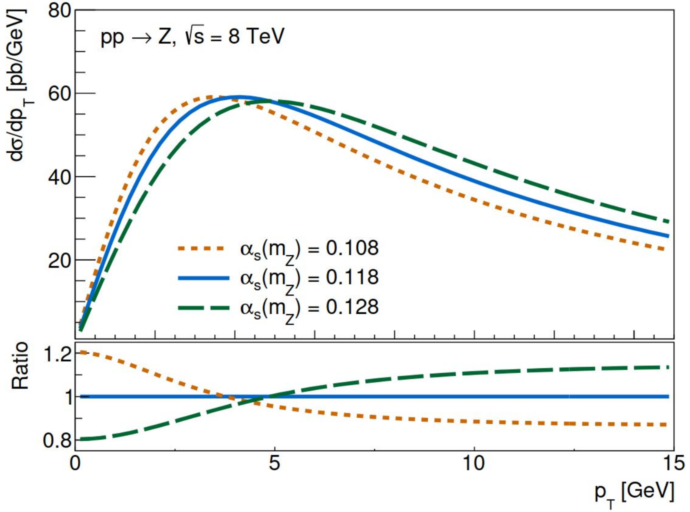
Higher precision than current world average!

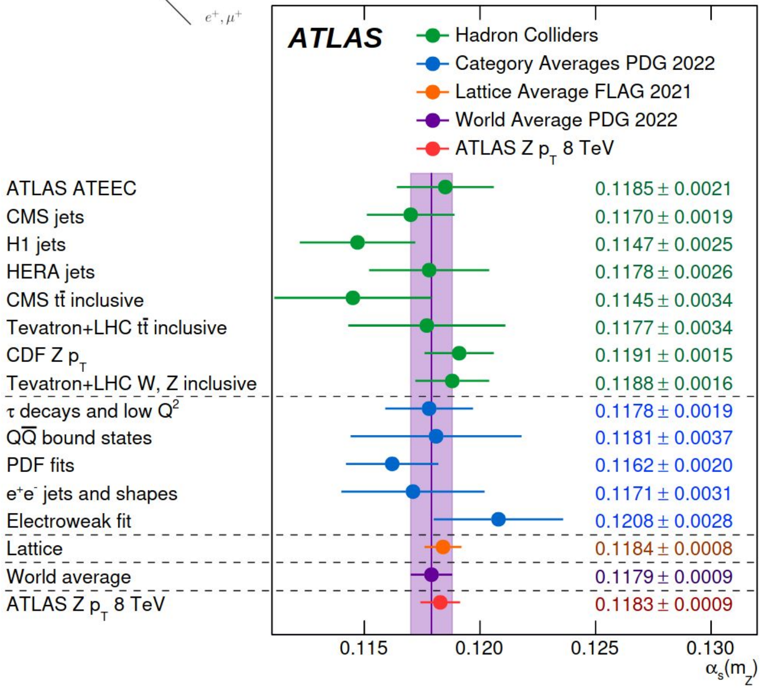
α_s from recoil of Z boson

arXiv:2309.12986

- Using 20.2 fb^{-1} of 8 TeV *pp* collisions data
- Based on Sudakov peak in *Z*-boson p_T
- *Z*-boson p_T measure strength of recoil of *Z*-boson, which is proportional to α_s
- Precision depends on precise theory predictions





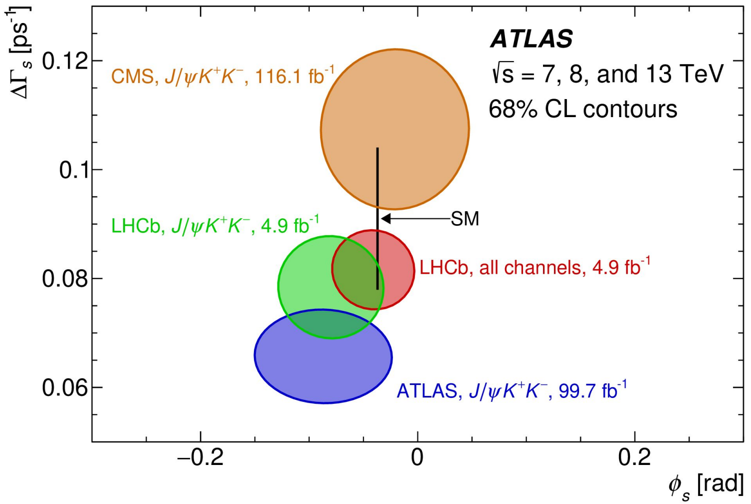


Most precise experimental determination achieved!

B-physics

CP-violation phase ϕ_s in $B^0_s \to J/\psi\phi$

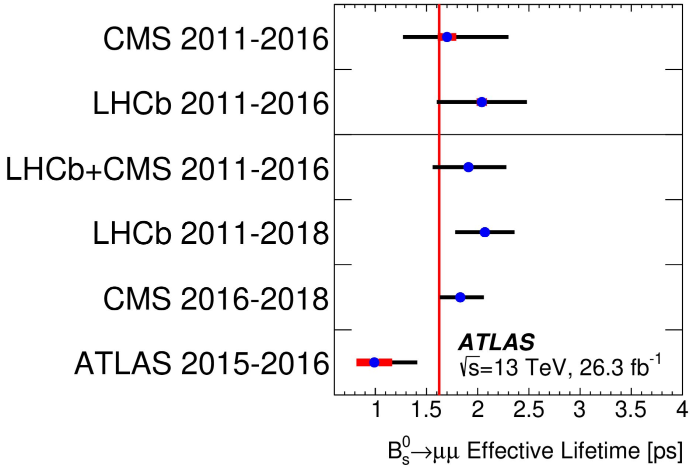
Eur. Phys. J. C 81 (2021) 342



$$\phi_s = -0.087 \pm 0.036\ (\text{stat.}) \pm 0.021\ (\text{syst.})\ \text{rad}$$
$$\Delta\Gamma_s = 0.0657 \pm 0.0043\ (\text{stat.}) \pm 0.0037\ (\text{syst.})\ \text{ps}^{-1}$$
$$\Gamma_s = 0.6703 \pm 0.0014\ (\text{stat.}) \pm 0.0018\ (\text{syst.})\ \text{ps}^{-1}$$

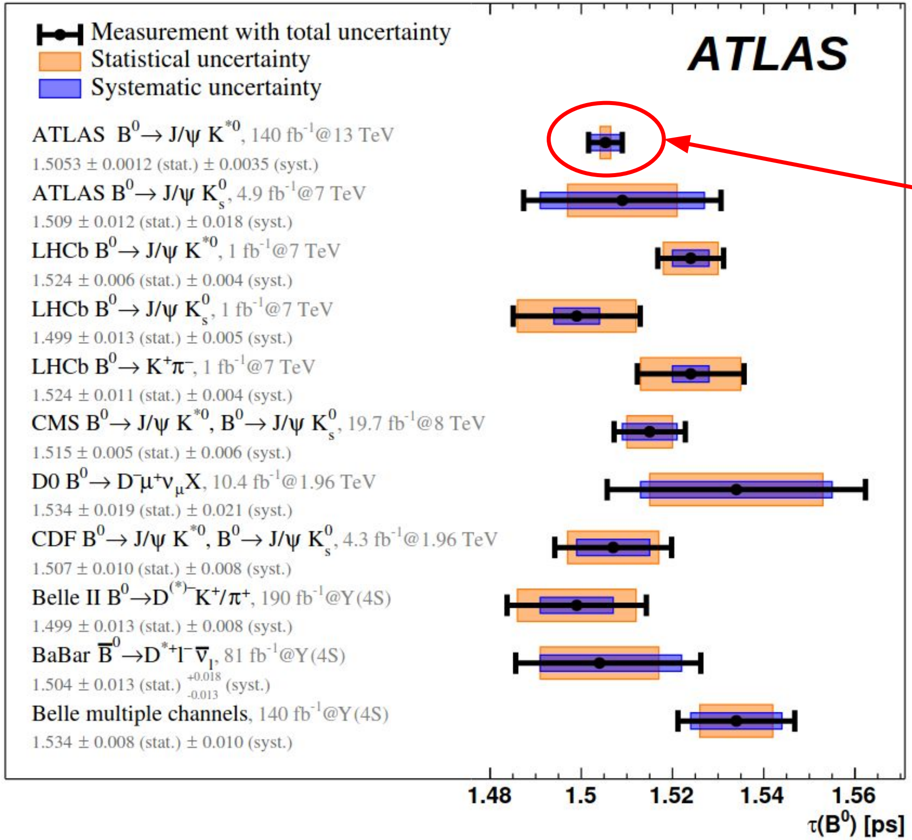
$B^0_s \to \mu\mu$ effective lifetime

JHEP 09 (2023) 199



$$\tau_{\mu\mu}^{\text{Obs}} = 0.99^{+0.42}_{-0.07}\ (\text{stat.}) \pm 0.17\ (\text{syst.})\ \text{ps}$$

B^0 meson lifetime



arXiv:2411.09962

- Using $B^0 \to J/\psi K^{*0}$ decays
- full Run 2 of 13 TeV *pp* collisions

- $\tau(B^0)$
- **average decay width:**

$$\Gamma_D = 0.6639 \pm 0.0005\ (\text{stat.}) \pm 0.0016\ (\text{syst.}) \pm 0.0038\ (\text{ext.})$$

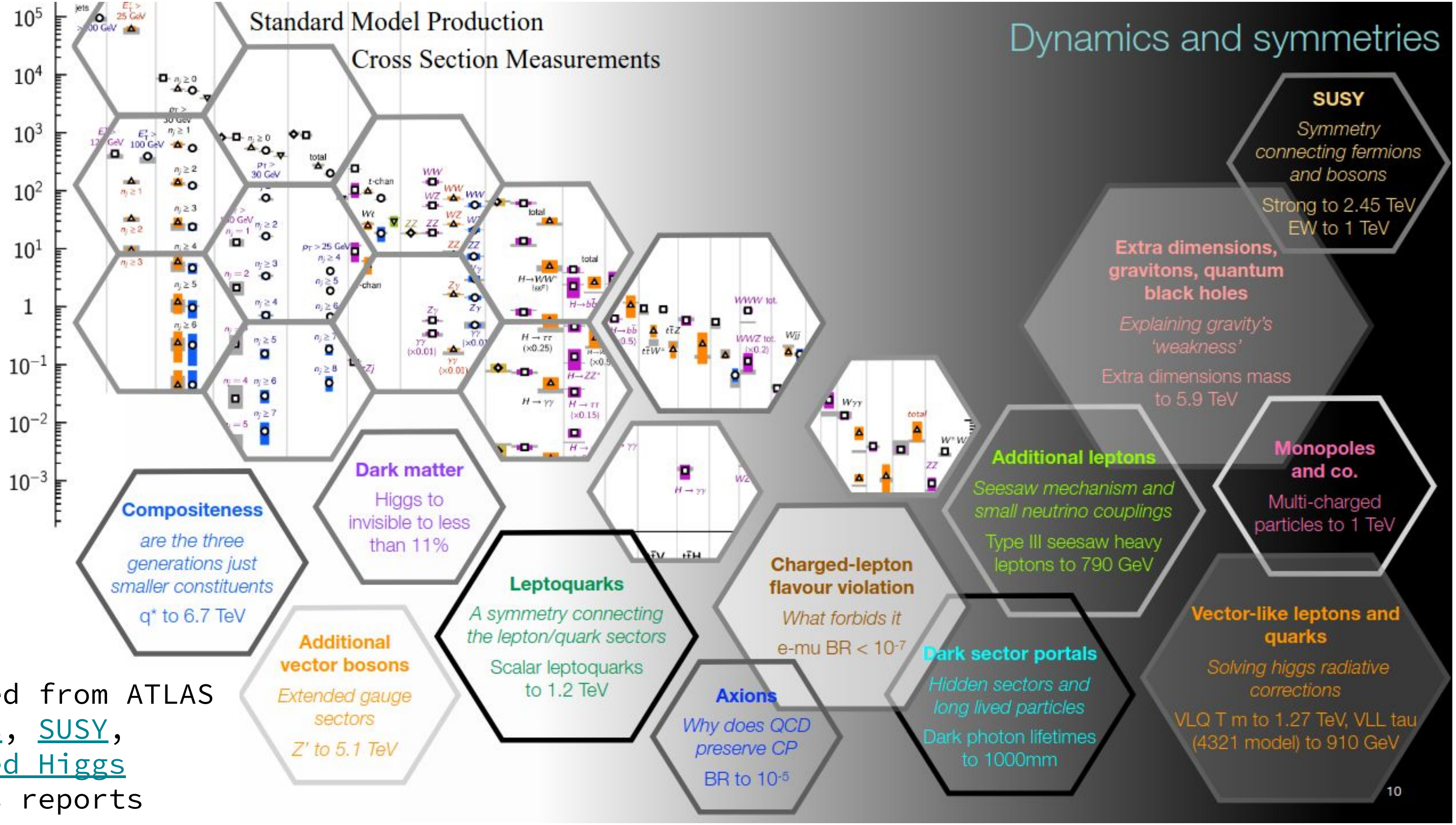
- **ratio of average decay width:**

$$\frac{\Gamma_d}{\Gamma_s} = 0.9905 \pm 0.0022\ (\text{stat.}) \pm 0.0036\ (\text{syst.}) \pm 0.0057\ (\text{ext.}).$$

Results are in agreement with theoretical predictions and with measurements from other experiments.

Searches

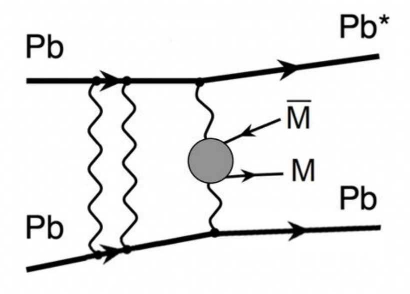
Very nice summary from Monica Dunford



Inspired from ATLAS Exotics, SUSY, extended Higgs physics reports

Magnetic monopoles

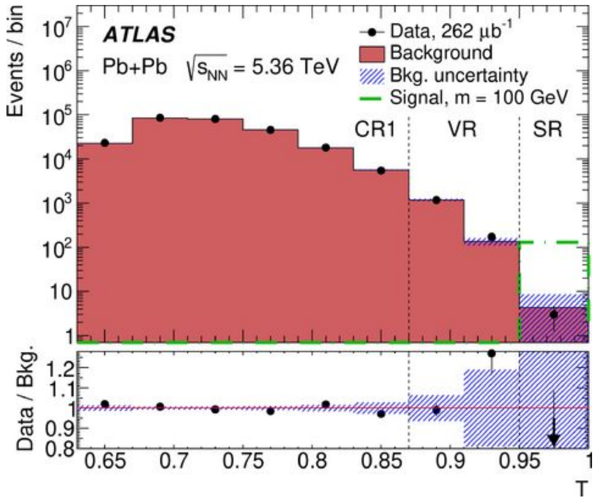
[arXiv:2408.11035](https://arxiv.org/abs/2408.11035)

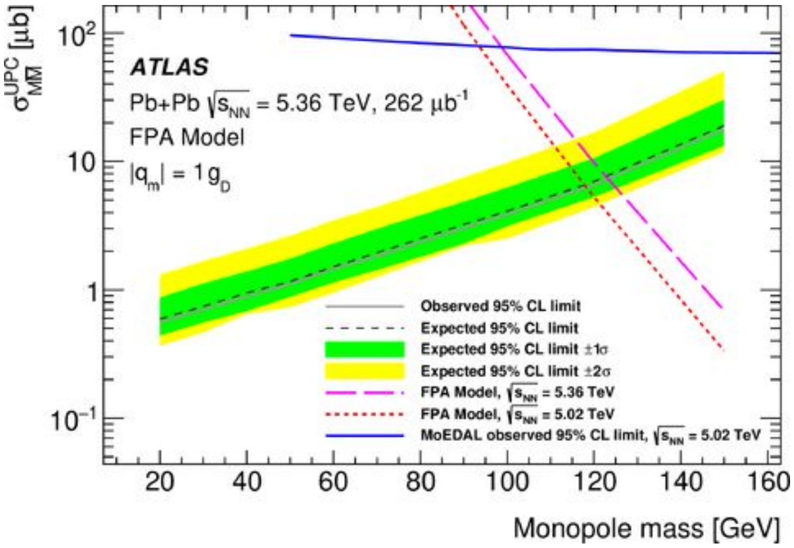


Ultra peripheral collisions (UPC) in Pb-Pb

UPC used to search for magnetic monopole pair production

- 262 μb^{-1} data collected in 2023, $\sqrt{s_{NN}} = 5.36$ TeV
- Looking at high pixel activity with no associated tracks

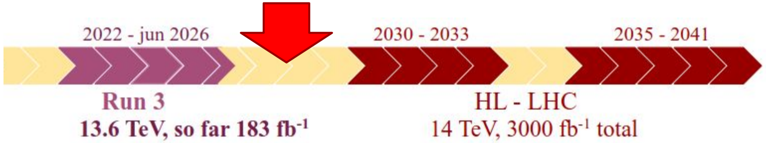




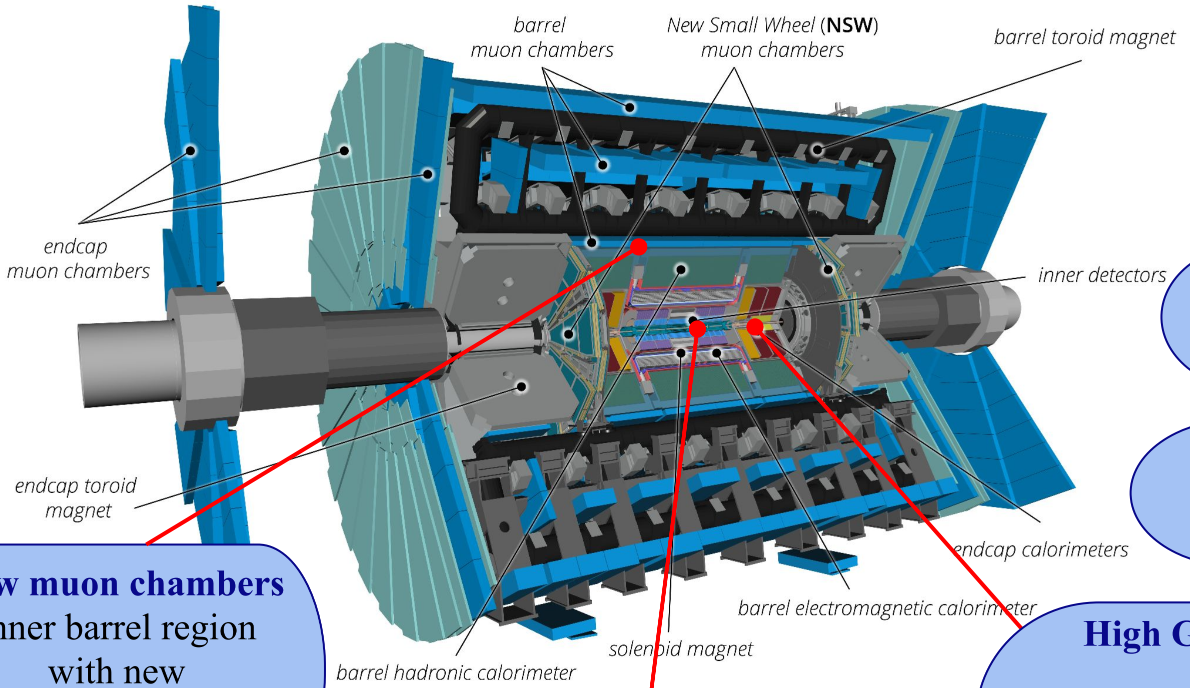
Magnetic monopoles with mass < 120 GeV excluded at 95% CL

Improves on limits reported by MoEDAL

ATLAS Upgrade II



Trigger and data acquisition
Level 1 trigger at 1 MHz
Improved High-Level Trigger
(150 kHz full-scan tracking)



Electronics Upgrades
LAr & Tile calorimeters
Muon systems

Additional small upgrades
Luminosity detectors (1% precision)
HL-ZDC

New muon chambers
Inner barrel region
with new
RPC and sMDT
detectors

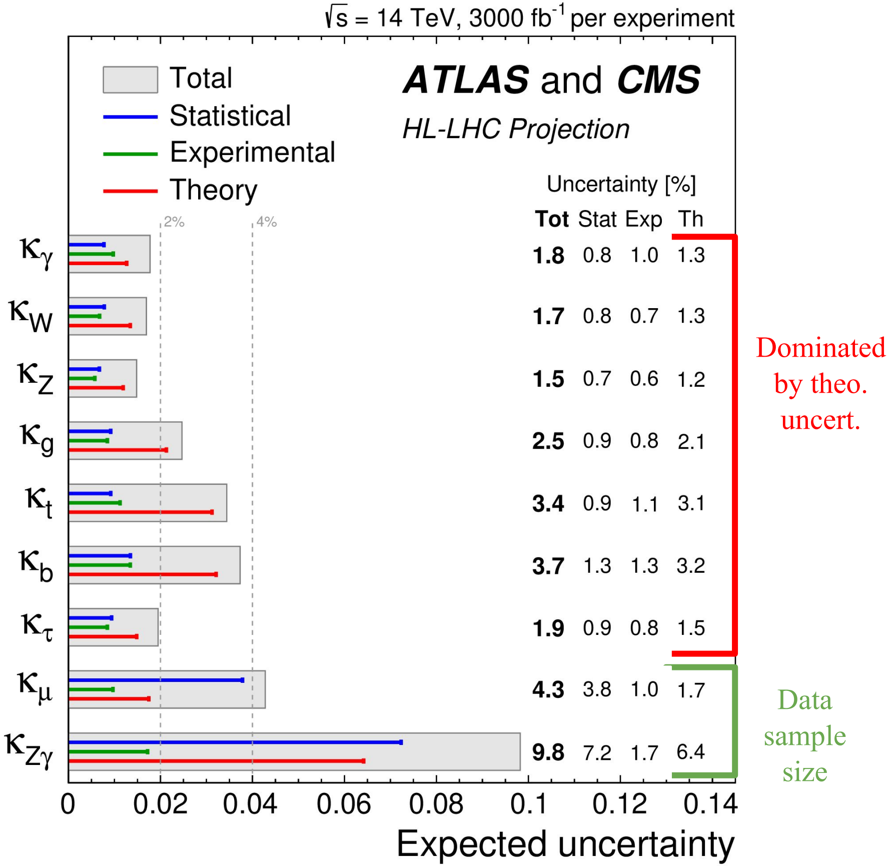
New Inner Tracking detector (ITk)
all silicon, $|\eta| < 4$

High Granularity Timing Detector (HGTD)
forward region $2.4 < |\eta| < 4$
Low-Gain Avalanche Detectors (LGAD)
with 30 ps track resolution

Higgs coupling to SM particles

ATL-PHYS-PUB-2022-018

- $H \to \mu\mu$ and $H \to Z\gamma$ measurements still limited by size of the collected dataset
- Other couplings dominated by theoretical uncertainties (despite assumed /2 improvement)
  - Impressive projected precisions
    - 1.5% for boson couplings
    - 2-4% for fermion couplings



Di-Higgs production

Multiple updates since the European strategy

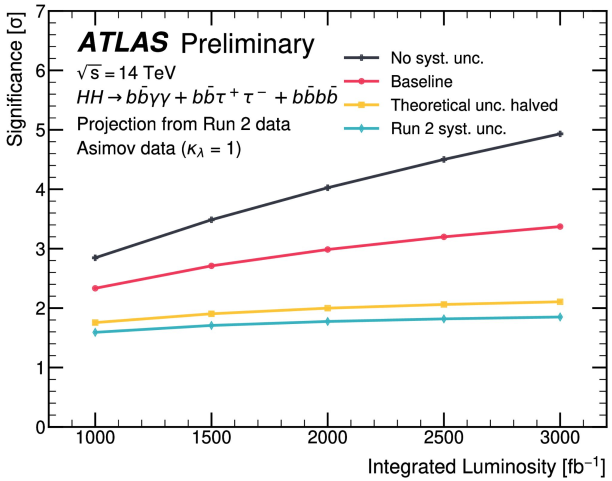
→Update of $bb\tau\tau$ and $bb\gamma\gamma$ for Snowmass
(ATL-PHYS-PUB-2022-018)

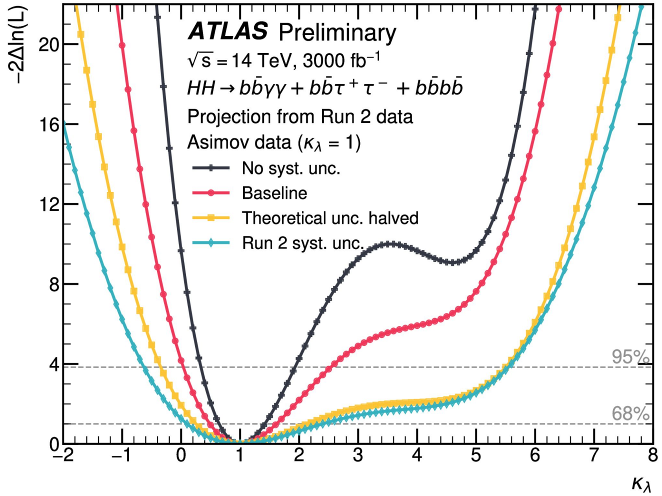
→Updated of bbbb (ATL-PHYS-PUB-2022-053)
combined with $bb\tau\tau$ and $bb\gamma\gamma$

- Di-Higgs significance for 1 experiment
  - Reach 4.9σ stat-only
  - **3.4 σ** with systematics (wrt 3.0σ at ESPP)
- Constraints on self-coupling
  - **$\kappa_\lambda \in$ [0.5, 1.6]** at 68% CL (wrt [0.25, 1.9])

→Recent update of $bb\tau\tau$ (single channel)
ATL-PHYS-PUB-2024-016

- Di-Higgs significance for 1 experiment
  - Reach 4.6σ stat-only
  - **3.5 σ** with systematics (wrt 3.0σ at ESPP)
- Constraints on self-coupling
  - **$\kappa_\lambda \in$ [-0.1, 2.7] ∪ [4.5, 6.4]** at 95% CL



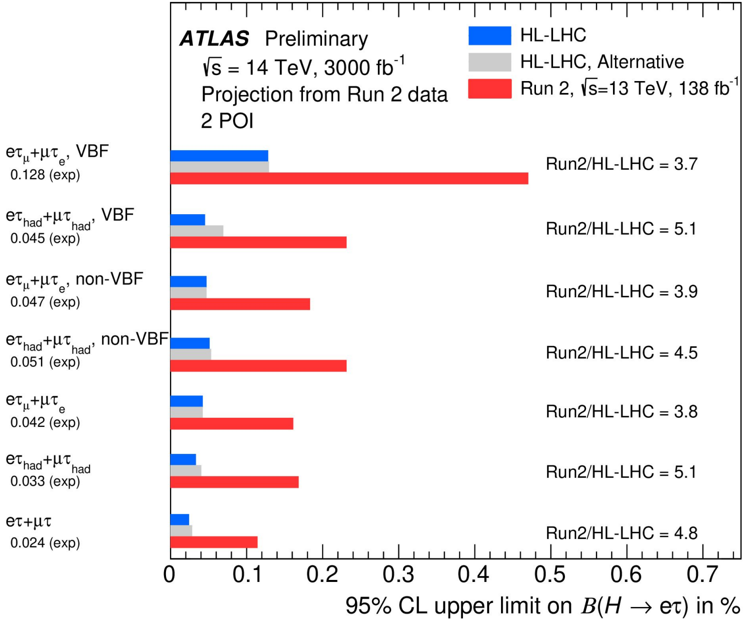


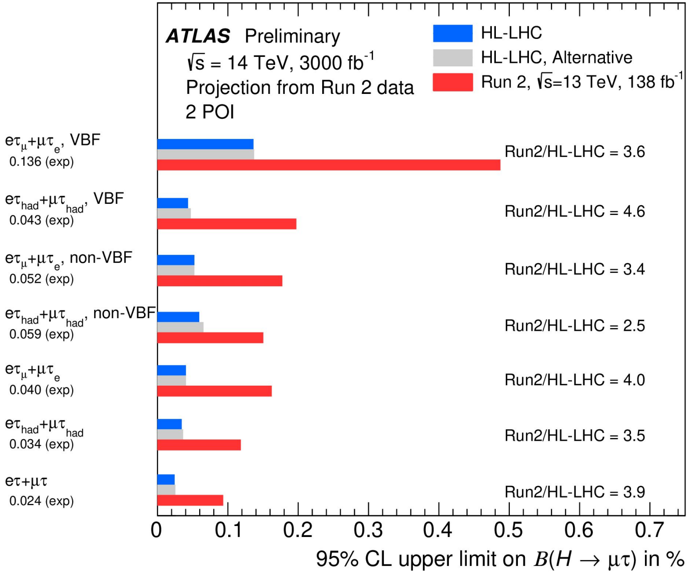
Lepton flavour violation decays

H→$e\tau$ and H→$\mu\tau$ latest results published in JHEP 07 (2023) 166

At HL-LHC we expect the limits to be improved by factor of 4-5

ATL-PHYS-PUB-2022-054





Conclusions

- Small part of very interesting results provided by the ATLAS Collaboration have been presented
- Results based mainly on full Run 2 datasets (many refined analysis)
- So far, no significant sign of new physics
- We can expect many Run 3 results with improved techniques
- Prospects for HL-LHC promise bright future :)

Thanks you for your attention!

Extra slides

Re-discovering Higgs boson

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

H→γγ, 31.4 fb^{-1}

Photons	
Leading (sub-leading) p_T^γ	$p_T^\gamma/m_{\gamma\gamma} > 0.35(0.25)$
Pseudorapidity	$\|\eta\| < 2.37$ and outside $1.37 < \|\eta\| < 1.52$
Isolation ($\Delta R = 0.2$)	$E_T^{iso}/E_T^\gamma < 0.05$
Di-photon system	
Mass window	$105\text{ GeV} < m_{\gamma\gamma} < 160\text{ GeV}$

$$\sigma_{fid,\gamma\gamma} = 76^{+14}_{-13}\text{ fb}$$

Source	Uncertainty [%]
Statistical uncertainty	14.0
Systematic uncertainty	10.3
Background modelling (spurious signal)	6.0
Photon trigger and selection efficiency	5.8
Photon energy scale & resolution	5.5
Luminosity	2.2
Pile-up modelling	1.2
Higgs boson mass	0.1
Theoretical (signal) modelling	<0.1
Total	17.4

H→ZZ*→4ℓ, 29.0 fb^{-1}

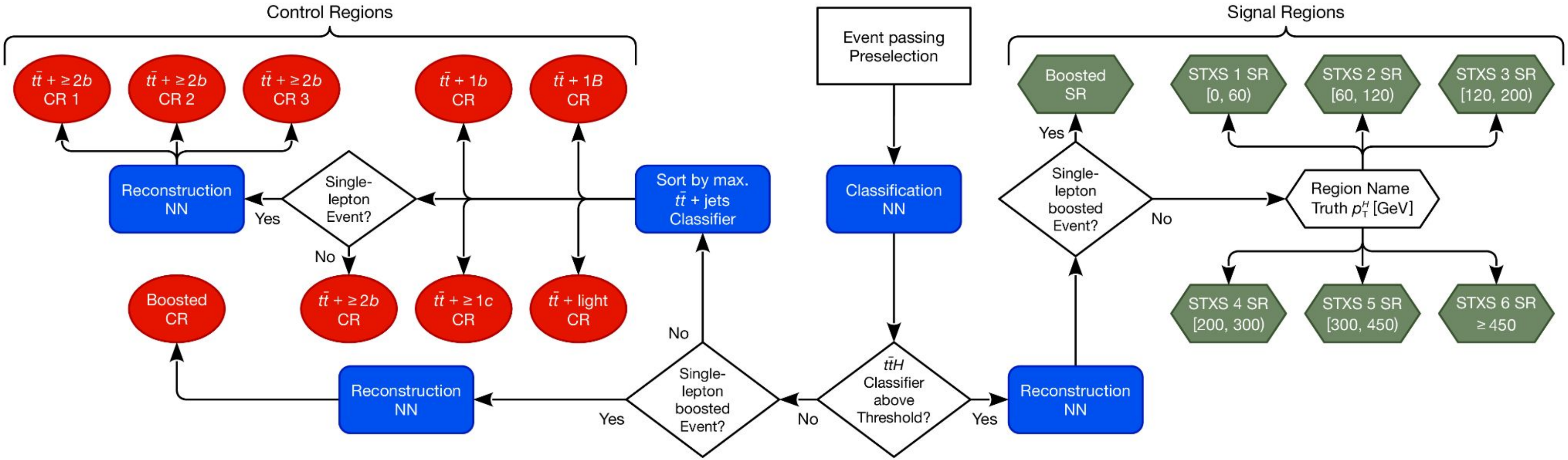
Leptons	
Leptons	$p_T > 5$ GeV, $\|\eta\| < 2.7$
Lepton selection and pairing	
Lepton kinematics	$p_T > 20, 15, 10$ GeV
Leading pair (m_{12})	SFOC lepton pair with smallest $\|m_Z - m_{\ell\ell}\|$
Subleading pair (m_{34})	remaining SFOC lepton pair with smallest $\|m_Z - m_{\ell\ell}\|$
Event selection (at most one quadruplet per event)	
Mass requirements	$50\text{ GeV} < m_{12} < 106\text{ GeV}$ and $12\text{ GeV} < m_{34} < 115\text{ GeV}$
Lepton separation	$\Delta R(\ell_i, \ell_j) > 0.1$
J/ψ veto	$m(\ell_i, \ell_j) > 5$ GeV for all SFOC lepton pairs
Mass window	$105\text{ GeV} < m_{4\ell} < 160\text{ GeV}$
If extra lepton with $p_T > 12$ GeV	quadruplet with largest matrix element value

$$\sigma_{fid,4\ell} = 2.80 \pm 0.74\text{ fb}$$

Source	Uncertainty [%]
Statistical uncertainty	25.1
Systematic uncertainty	7.9
Electron uncertainties	6.3
Muon uncertainties	3.8
Luminosity	2.2
ZZ^* theoretical uncertainties	0.7
Reducible background estimation	0.6
Other uncertainties	<1.0
Total	26.4

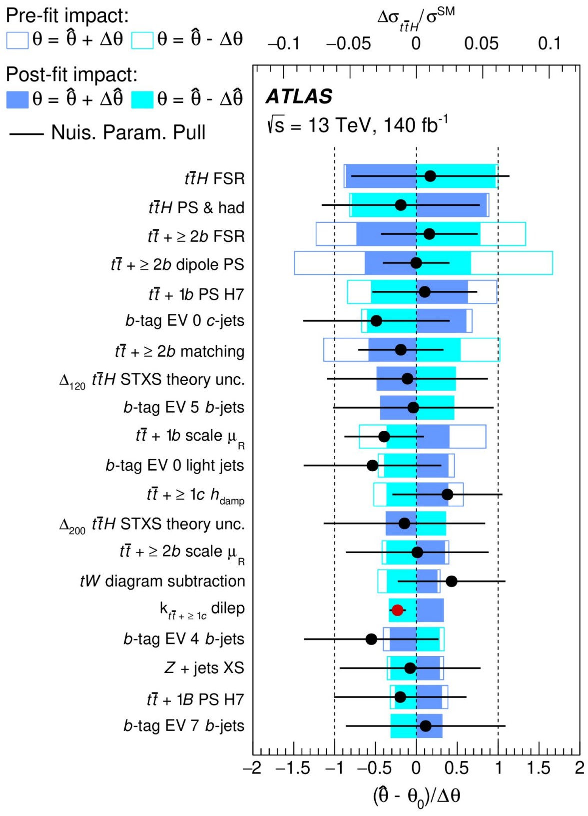
ttH production

arXiv:2407.10904 submitted to EPJC



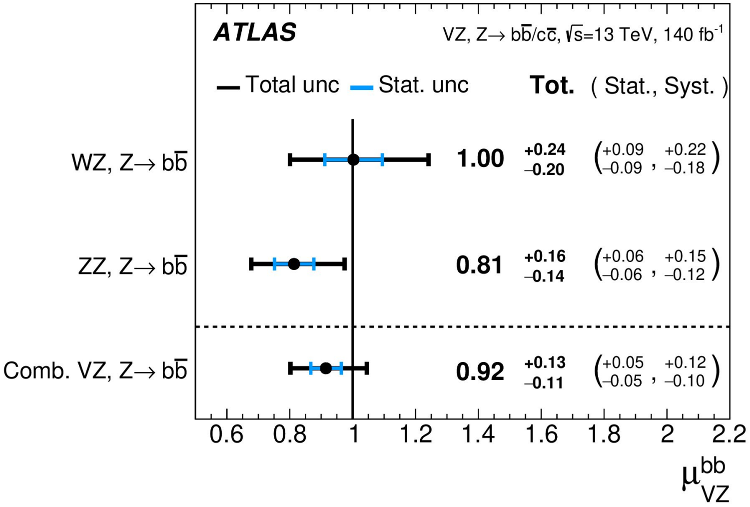
$t\bar{t}H$ production

arXiv:2407.10904 submitted to EPJC



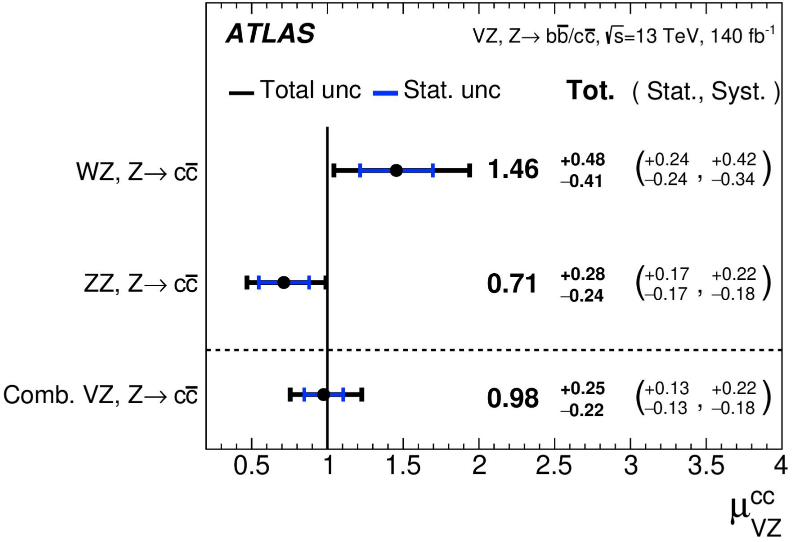
Uncertainty source	$\Delta\sigma_{t\bar{t}H}$ (fb)		$\Delta\sigma_{t\bar{t}H}/\sigma_{t\bar{t}H}$ (%)	
Process modelling				
$t\bar{t}H$ modelling				
$t\bar{t}H$ radiation	+35	−21	+9	−5
$t\bar{t}H$ parton shower	+32	−19	+8	−5
$t\bar{t}H$ matching	<0.1	−0.3	<0.1	−0.1
$t\bar{t}H$ theory	+25	−17	+6	−4
$t\bar{t}+\geq 1b$ modelling				
$t\bar{t}+\geq 1b$ radiation	±31		±8	
$t\bar{t}+\geq 1b$ parton shower	±29		±7	
$t\bar{t}+\geq 1b$ matching	±19		±5	
$t\bar{t}+\geq 1c$ modelling	±18		±4	
$t\bar{t}+$light modelling	±5		±1	
tW modelling	±16		±4	
Minor background modelling	±19		±5	
Flavour tagging	±36		±9	
Jet modelling	±22		±5	
Monte-Carlo statistics	±17		±4	
Other instrumental	±10		±2	
Total systematic uncertainty	+85	−75	+21	−18
Normalisation factors	±21		±5	
Total statistical uncertainty	±54		±13	
Total uncertainty	+101	−92	+25	−22

The Yukawa couplings to bottom and charm



6.4σ

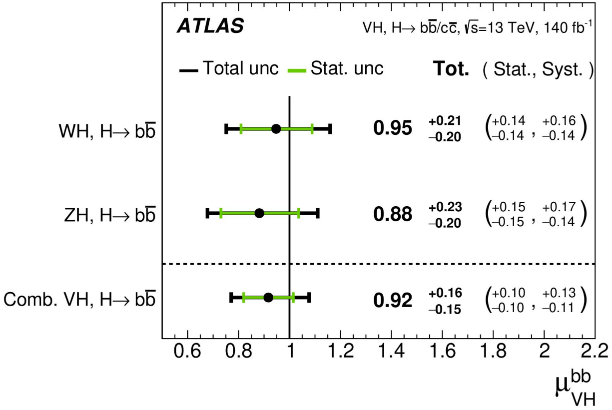
> 10σ



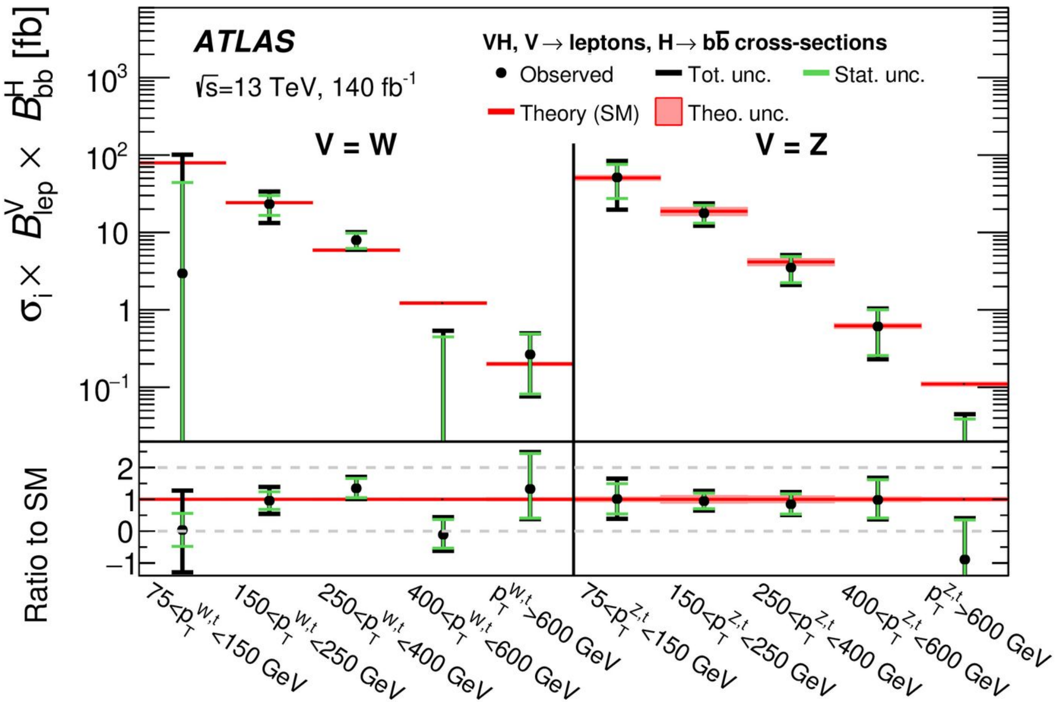
for the first time > 5σ

The Yukawa couplings to bottom and charm

First observation of $WH \rightarrow bb$ (5.3 σ)



Results compatible with SM



Probe p_T^V spectrum up to 600 GeV

di-Higgs production

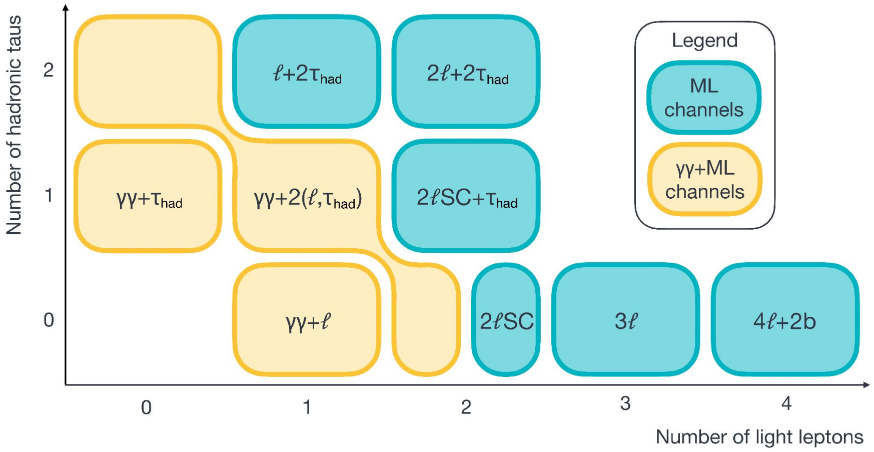
Many possible decay channels:

- $b\bar{b}b\bar{b}$
- $b\bar{b}\tau\tau$
- $b\bar{b}\gamma\gamma$
- $b\bar{b}\ell^+\ell^- + E_T^{miss}$
- **Multileptons**

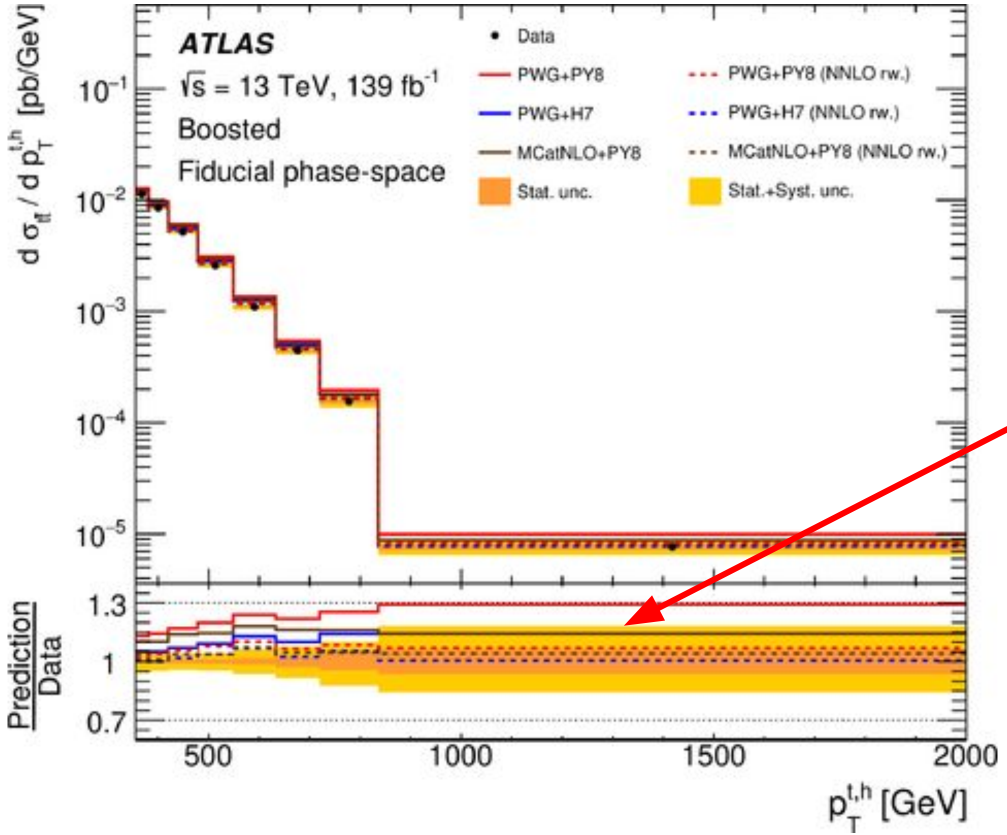
	bb	WW	ττ	ZZ	γγ
bb	34%				
WW	25%	4.6%			
ττ	7.3%	2.7%	0.39%		
ZZ	3.1%	1.1%	0.33%	0.069%	
γγ	0.26%	0.10%	0.028%	0.012%	0.0005%

- $b\bar{b}\ell^+\ell^- + E_T^{miss}$
    - H→$b\bar{b}$ and $H \to ZZ^*/WW^*/\tau\tau$

- **Multileptons**



Top quark pair production



[arXiv:2404.10674](https://arxiv.org/abs/2404.10674)

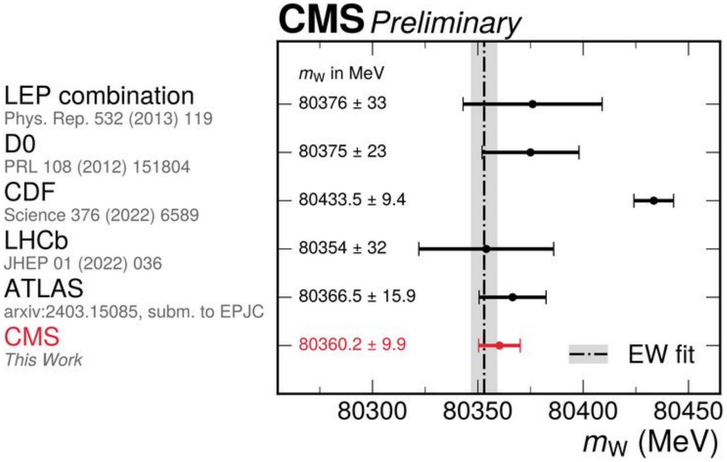
In the differential measurements: agreement between measurement and prediction improved when comparing to NNLO QCD fixed order predictions (or after NNLO reweighting of MC)

W boson mass and width

arXiv: 2403.15085 submitted to EPJC
CERN press release

7 TeV *pp*-collision data re-analyzed (improved fitting techniques, updated PDFs)

Improved *W*-boson mass



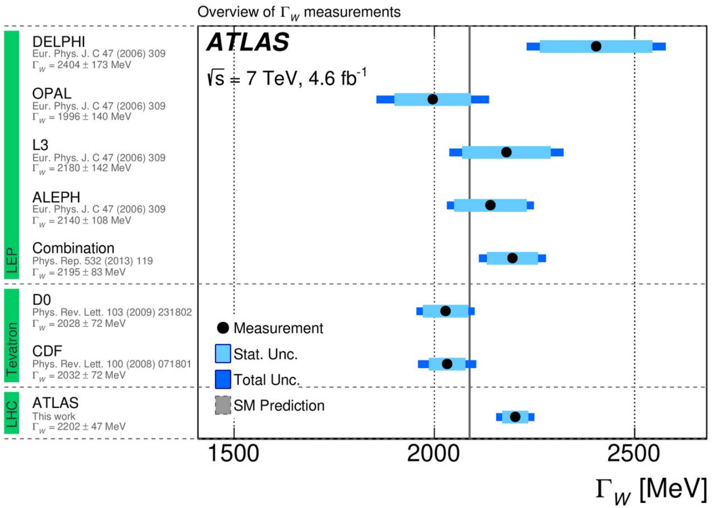
ATLAS, 7 TeV: m_W = 80366.5 ± 15.9 MeV

CMS, 13 TeV (2016 data only):

m_W = 80360.2 ± 9.9 MeV

Tension between the CDF and LHC results!

First measurement of *W*-boson width at LHC



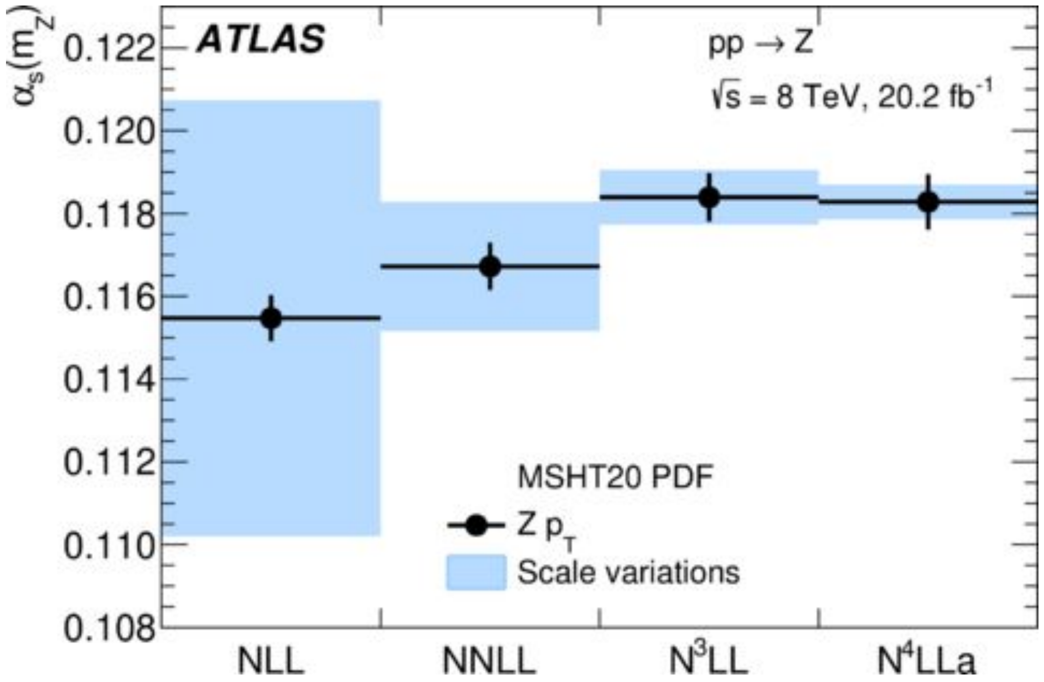
ATLAS, 7 TeV: Γ_W = 2202 ± 47 MeV

Most precise single measurement!

Compatible with SM within 2σ

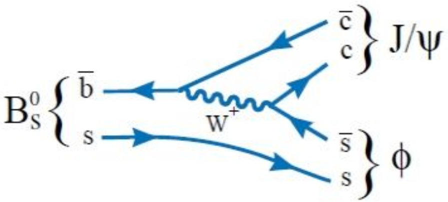
α_s *from recoil of Z boson*

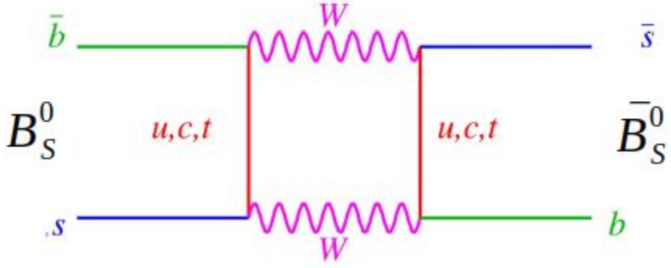
arXiv:2309.12986



B physics

→ **CP violation** in the $B_S^0 \to J/\psi\varphi$ decay occurs due to interference of **direct decays** and **decays occurring through $B_S^0 - \bar{B}_S^0$ mixing**





oscillation frequency is characterized by Δm_s, mass difference of heavy (B_H) and light (B_L) mass eigenstates

→ quantities involved in $B_S^0 - \bar{B}_S^0$ mixing:

CP-violating phase ϕ_S – weak phase difference between amplitudes of B-mixing and direct decay

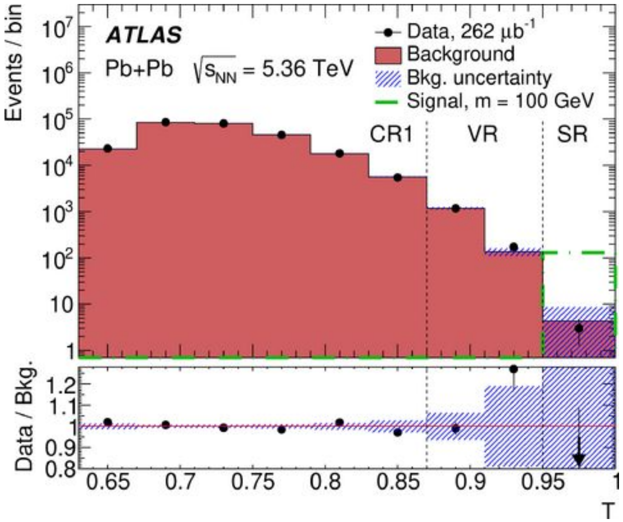
→ some New Physics models predict large values, while satisfying all existing constrains

Width difference $\Delta\Gamma_S$ = $\Gamma(B_L) - \Gamma(B_H)$:

→ should not be affected as significantly as ϕ_S by beyond-SM physics

Average decay width Γ_S = $[\Gamma(B_L) + \Gamma(B_H)] / 2$

Magnetic monopoles

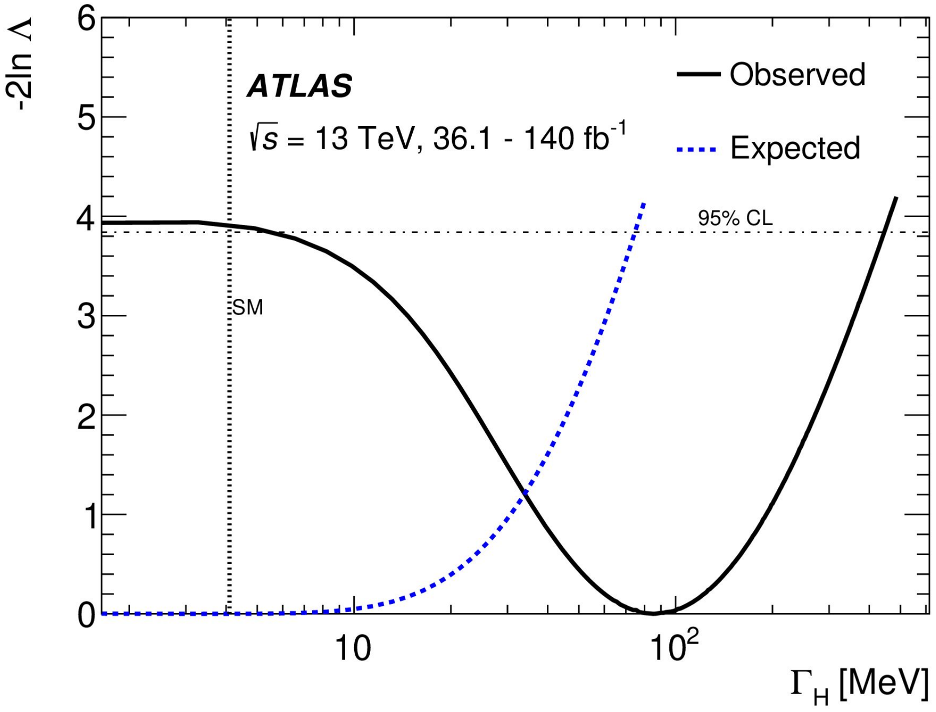


T, inspired by the *transverse thrust*

$$T = (1/n_{\mathrm{PixCl}}) \sum_{i=1}^{n_{\mathrm{PixCl}}} |\hat{r}_i \cdot \hat{n}|$$

where $\hat{r}_i$ is the direction (unit vector) of a given pixel cluster in the transverse plane with respect to the origin of the ATLAS coordinate system, and the transverse direction $\hat{n}$ maximizes the expression and corresponds to an azimuthal angle ϕ_T. The solution for $\hat{n}$ (or ϕ_T) is found iteratively. The direction of $\hat{n}$ roughly aligns in $r-\phi$ with the monopole's trajectory. The T variable has a maximum value of 1, for a set of fully aligned pixel clusters, and a minimum value of around $2/\pi$, for a uniform distribution of clusters in the transverse plane.

Higgs decay width from ttH and tttt



arXiv:2407.10631

Off-shell Higgs production

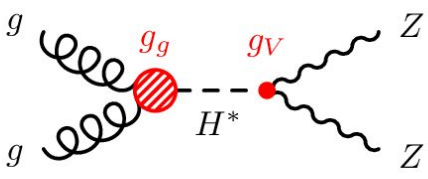
Higgs **on-shell** and **off-shell** production are connected to **Higgs decay width**

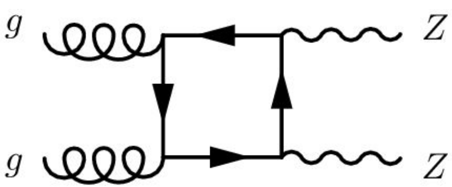
$$\sigma^{pp\to H\to ZZ}_{onshell} \sim \frac{g^2_{Hgg}\, g^2_{HZZ}}{m_H \Gamma_H}$$

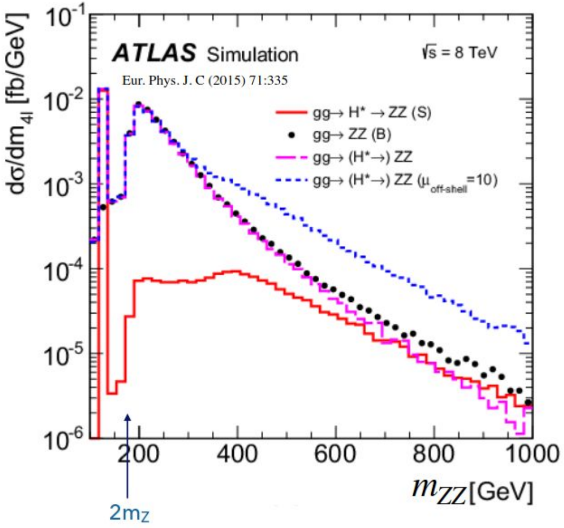
$$\sigma^{pp\to H\to ZZ}_{offshell} \sim \frac{g^2_{Hgg}\, g^2_{HZZ}}{M_{ZZ} - m_H}$$

$$\frac{\sigma_{offshell}}{\sigma_{onshell}} \propto \Gamma_H$$

Experimentally unable to distinguish H production from $gg\to ZZ$ background:





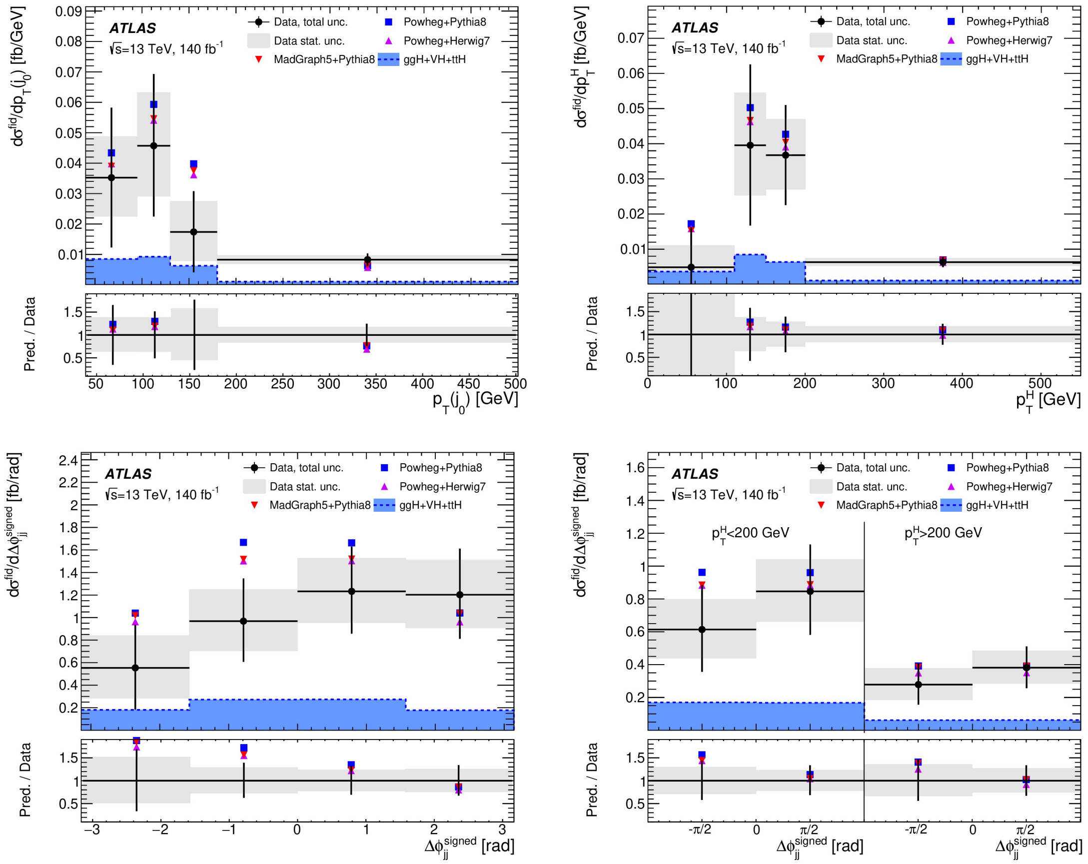


interference effect => deficit of $gg\to ZZ$, which depends on the off-shell signal strength

13 TeV result arXiv:2412.01548:
off-shell Higgs production measured **with 3.7σ significance**

$Higgs \rightarrow \tau\tau$ differential cross-section

arXiv:2407.16320



Flavour tagging

FTAG-2023-01