

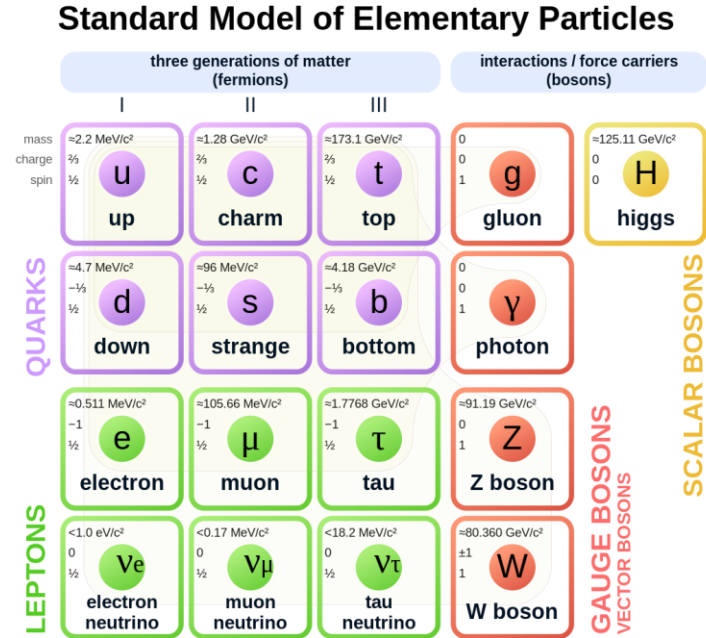
Standard Model, Higgs, and di-Higgs precision physics with ATLAS at the LHC

CAP Congress 2026
UOttawa / Carleton, June 22, 2026
Matthew Basso (TRIUMF)



Introduction: Standard Model of particle physics

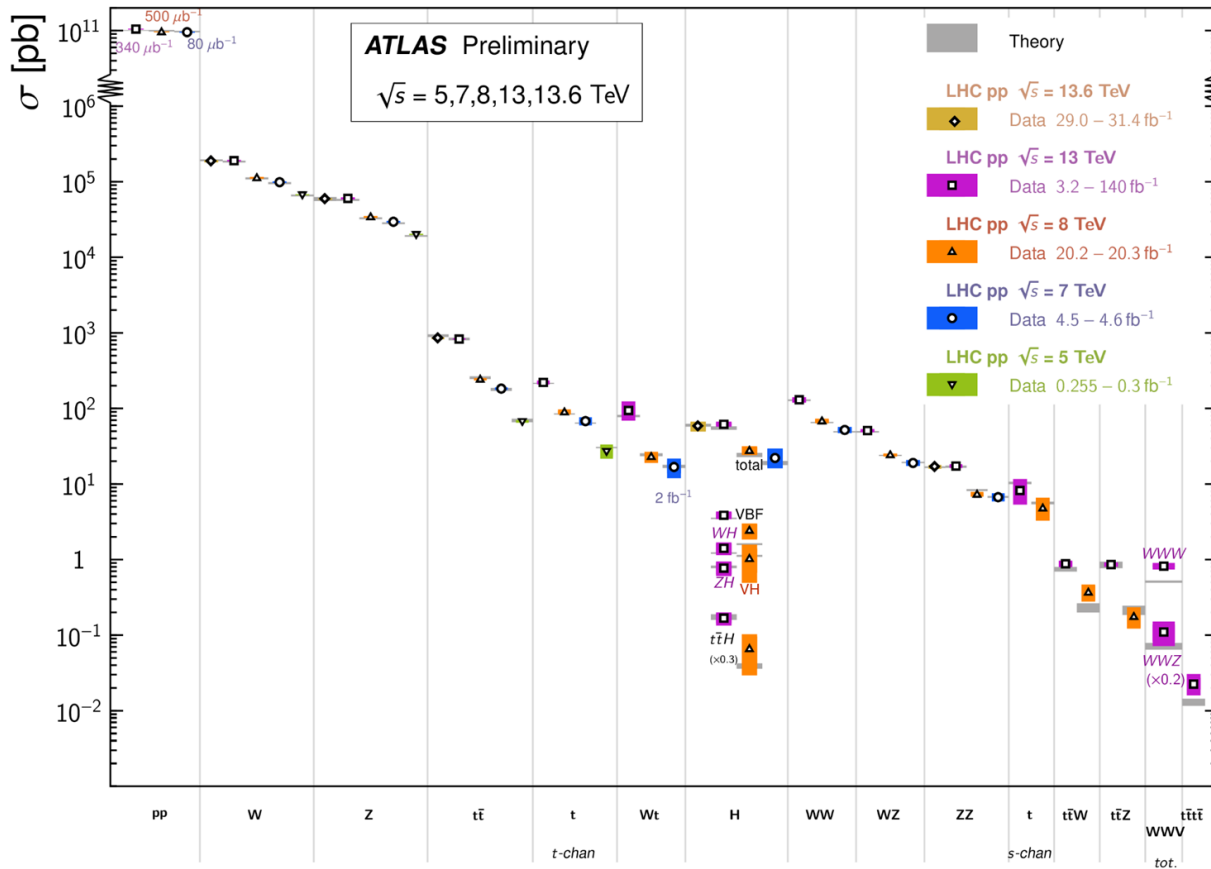
- **Standard Model (SM):** theoretical framework for making predictions in particle physics
- SM has been **extremely successful** at describing experimental observations from the past 50 years
- **Higgs boson**, the particle whose associated field gives mass to the fundamental constituents of matter, was the **last missing piece**



[ATLAS Open Data](#)

Standard Model Total Production Cross Section Measurements

Status: June 2024

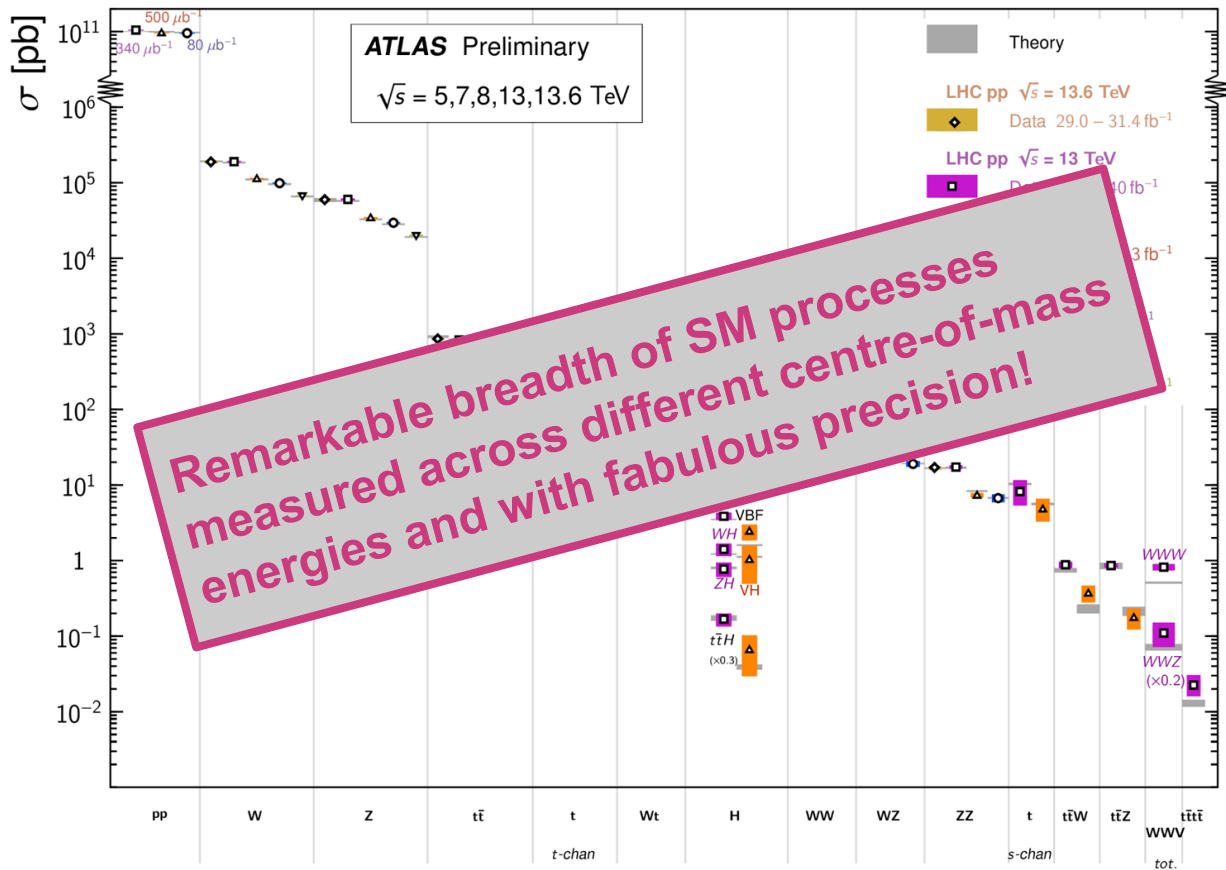


ATL-PHYS-PUB-2024-011



Standard Model Total Production Cross Section Measurements

Status: June 2024



ATL-PHYS-PUB-2024-011

Lots can be accomplished with precision physics!

The Nobel Prize

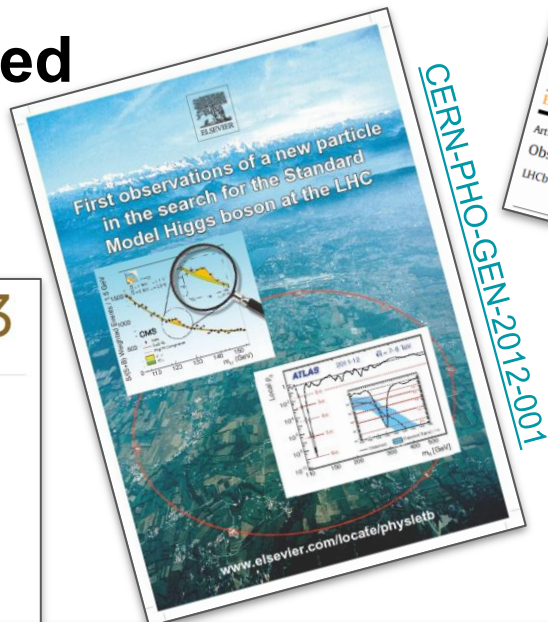
Nobel Prize in Physics 2013



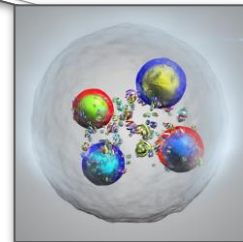
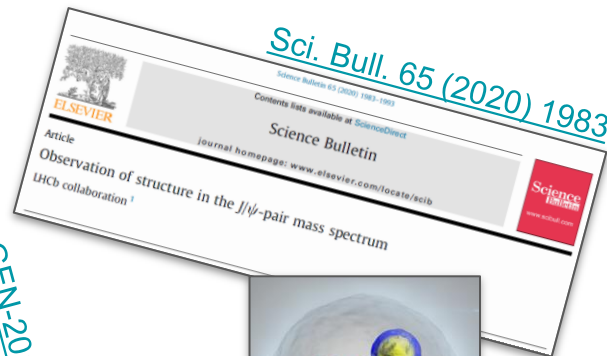
© Nobel Prize Outreach. Photo: A. Mahmoud
François Englert
Prize share: 1/2



© Nobel Prize Outreach. Photo: A. Mahmoud
Peter W. Higgs
Prize share: 1/2



CERN-PHO-GEN-2012-001



CERN-GRAPHICS-2025-006

The Breakthrough Prize

The 2025 Breakthrough Prize in Fundamental Physics is awarded co-authors of publications based on CERN's Large Hadron Collider Run-2 data released between 2015 and July 15, 2024, at the experimental collaborations ATLAS, CMS, ALICE and LHCb. (ATLAS – 5,345 researchers; CMS – 4,550; ALICE – 1,869; LHCb – 1,744).

The \$3 million prize is allocated to ATLAS (\$1 million), CMS (\$1 million), ALICE (\$500,000) and LHCb (\$500,000). In consultation with the leaders of the experiments, the Breakthrough Prize Foundation donated 100 percent of the prize funds to the CERN & Society Foundation. The prize money will be used by the collaborations to offer grants for doctoral students from member institutes to spend research time at CERN, giving the students experience working at the forefront of science and new expertise to bring back to their home countries and regions. The name of each winner can be found on the experiment pages below.



[ALICE Collaboration](#)



[ATLAS Collaboration](#)



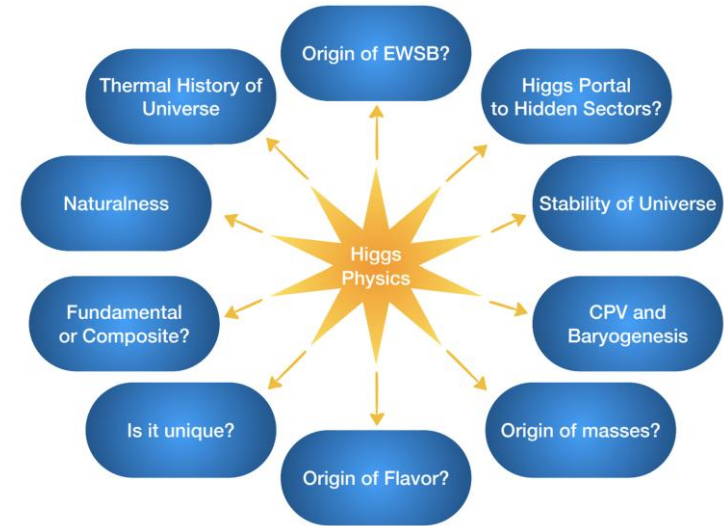
[CMS Collaboration](#)



[LHCb Collaboration](#)

Precision measurements → constraints on new physics

- Despite the SM's successes, it cannot be the whole story: there must be undiscovered **Beyond the SM (BSM)** physics
- Precision measurements serve as “stress tests” of the SM → reveal subtle differences between our predictions and measurements as well as provide new input to our models
- **Today, I'll present an overview of recent SM measurements performed by ATLAS**



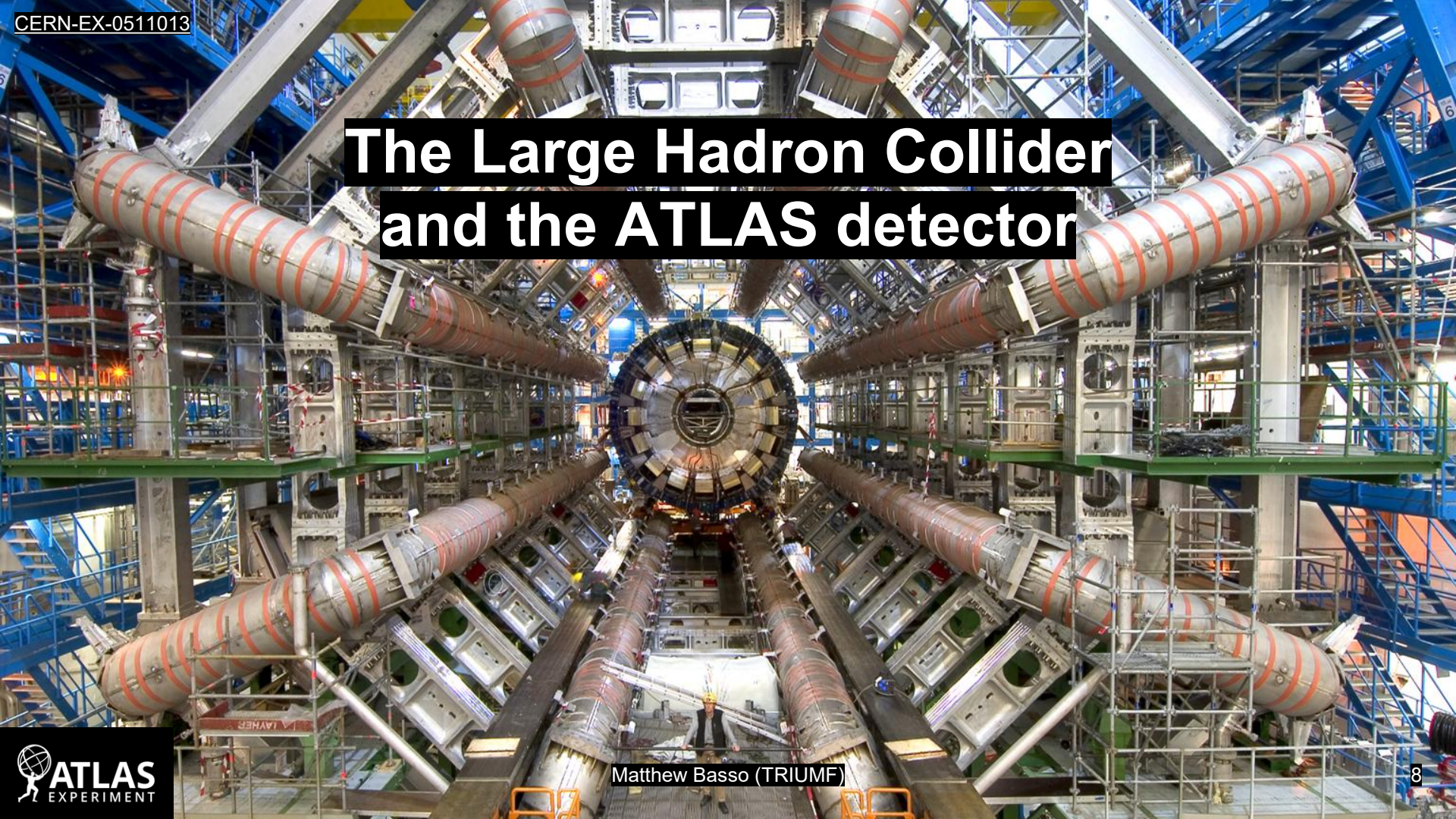
[arXiv:2209.07510](https://arxiv.org/abs/2209.07510)

A note about the selected measurements

- Physicists from Canadian institutions contribute in many different ways to ATLAS: maintenance, operation, reconstruction, analysis, and upgrades
 - (And this is why all ATLAS authors are included on all papers!)
- Physicists from Canadian institutions were **members of the teams** directly responsible for performing all the measurements presented today



The Large Hadron Collider and the ATLAS detector



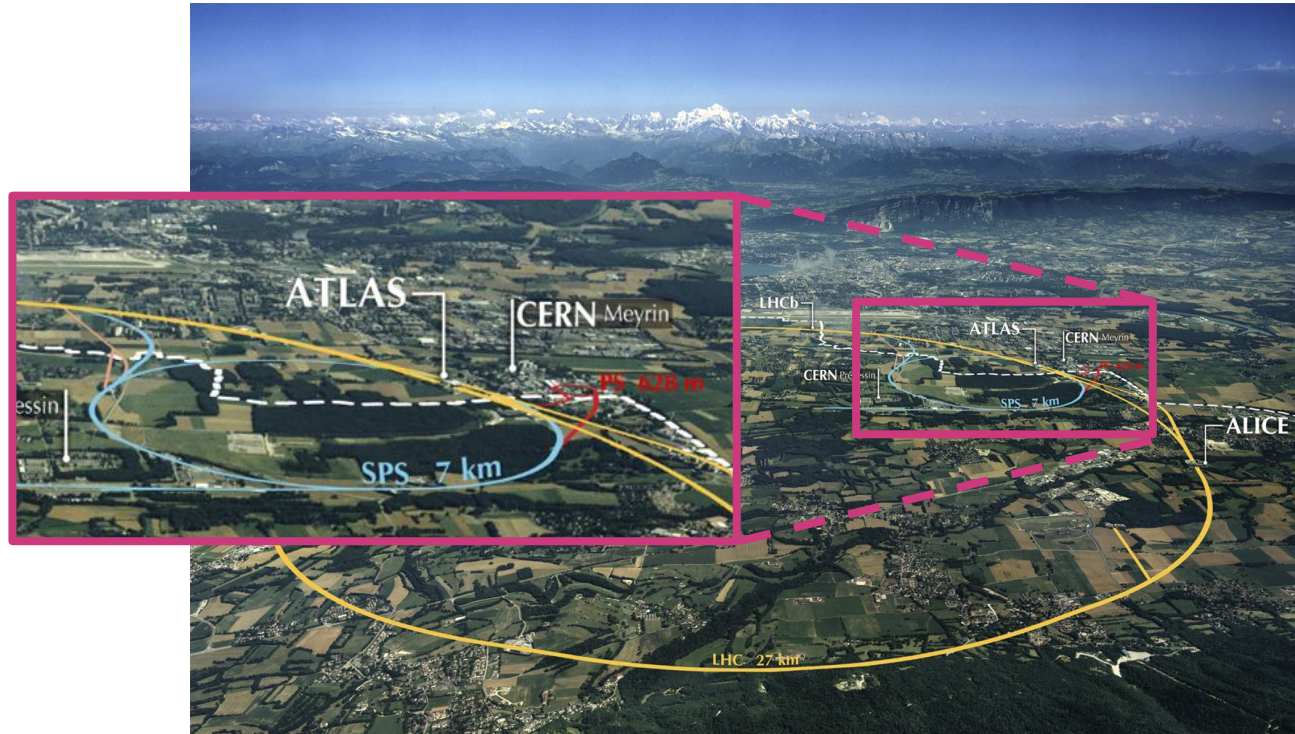
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The Large Hadron Collider (LHC)



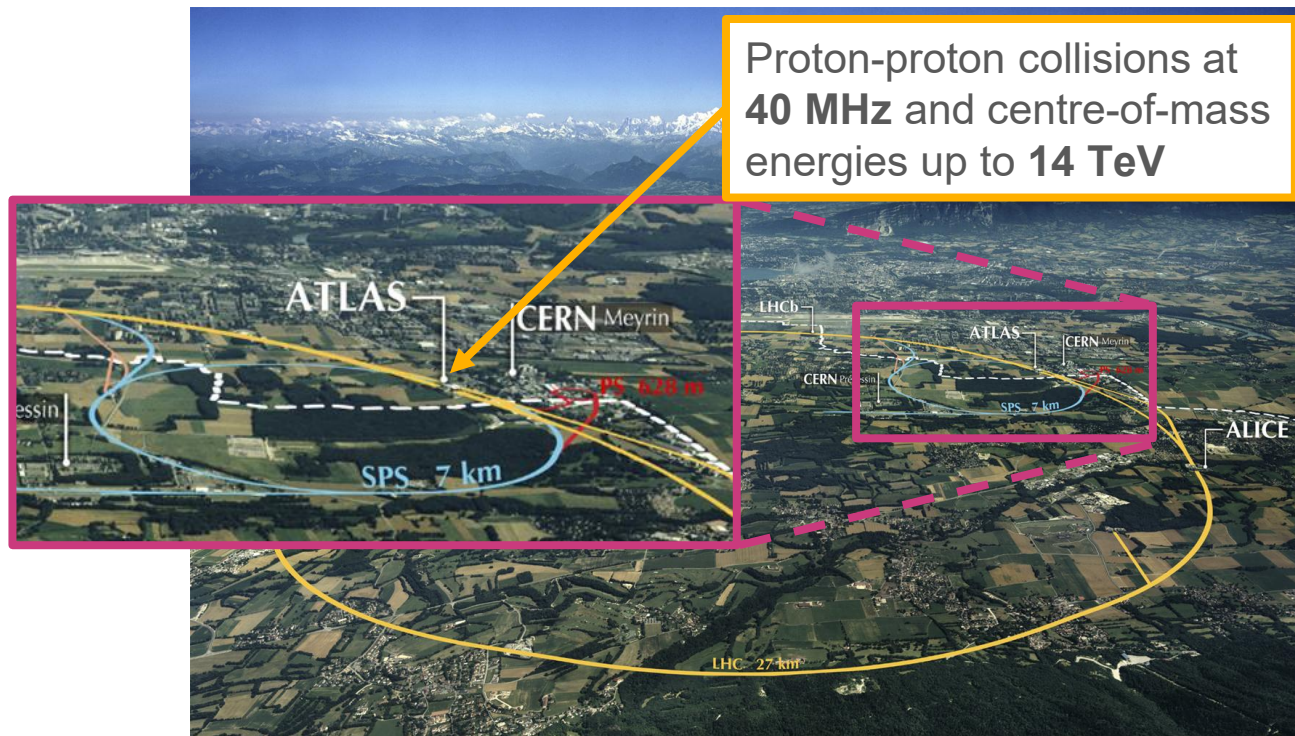
CERN-MI-0807031

The Large Hadron Collider (LHC)



CERN-MI-0807031

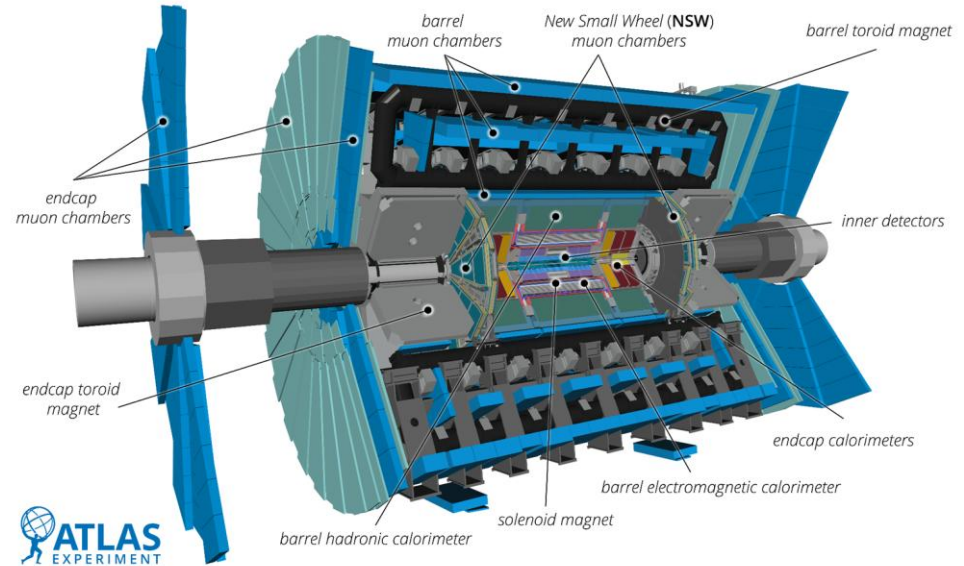
The Large Hadron Collider (LHC)



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The ATLAS detector at the LHC

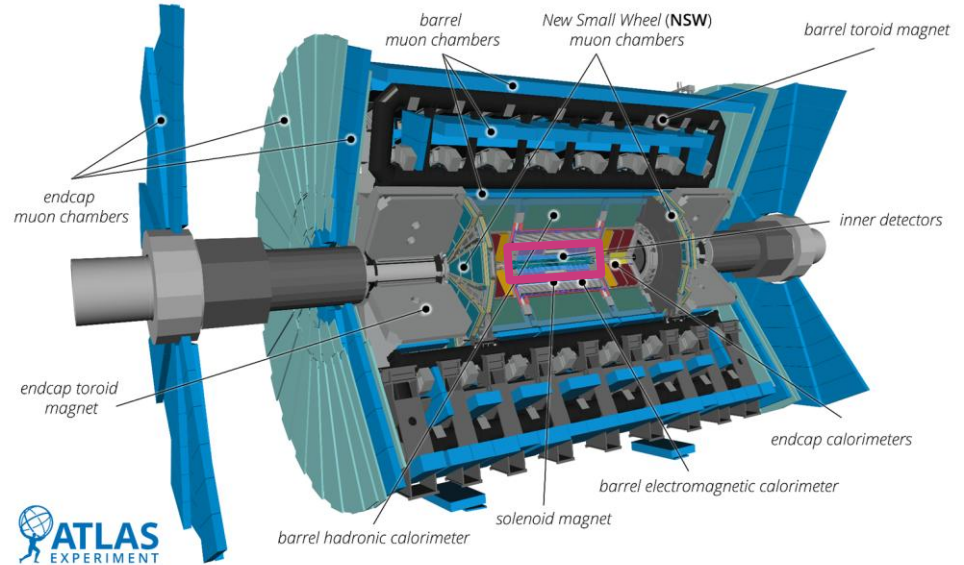
- General purpose particle detector, with subsystems including:



[ATLAS-PHOTO-2022-055](#)

The ATLAS detector at the LHC

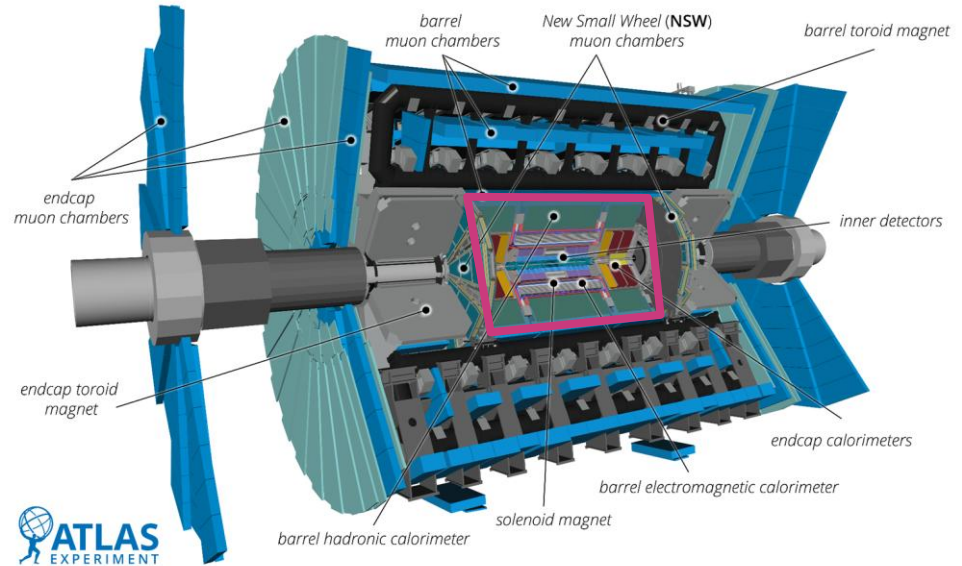
- General purpose particle detector, with subsystems including:
 - Inner detector for charged particle tracking in a 2 T field



[ATLAS-PHOTO-2022-055](#)

The ATLAS detector at the LHC

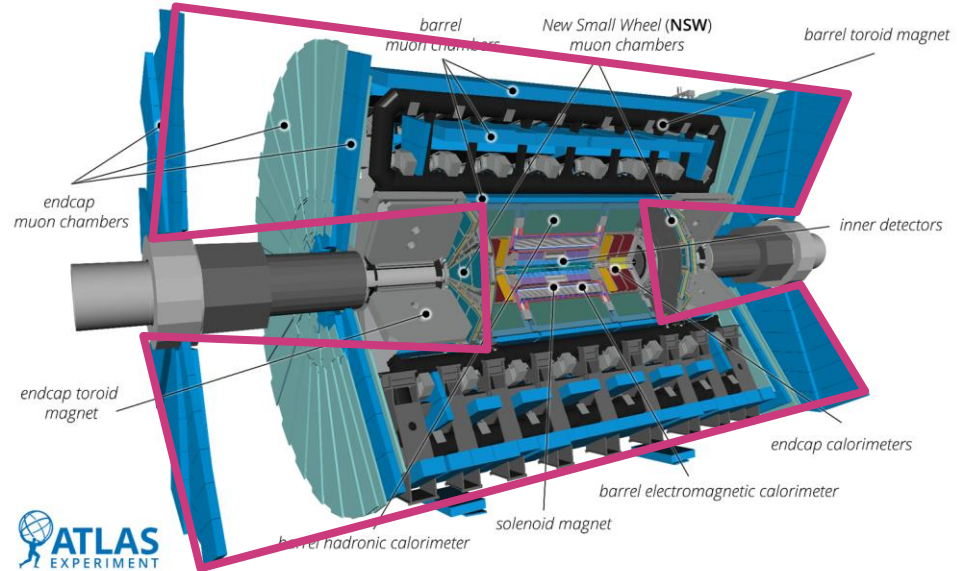
- General purpose particle detector, with subsystems including:
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 - Calorimeters for reconstructing electron/photons and hadronic showers (“jets”)



[ATLAS-PHOTO-2022-055](#)

The ATLAS detector at the LHC

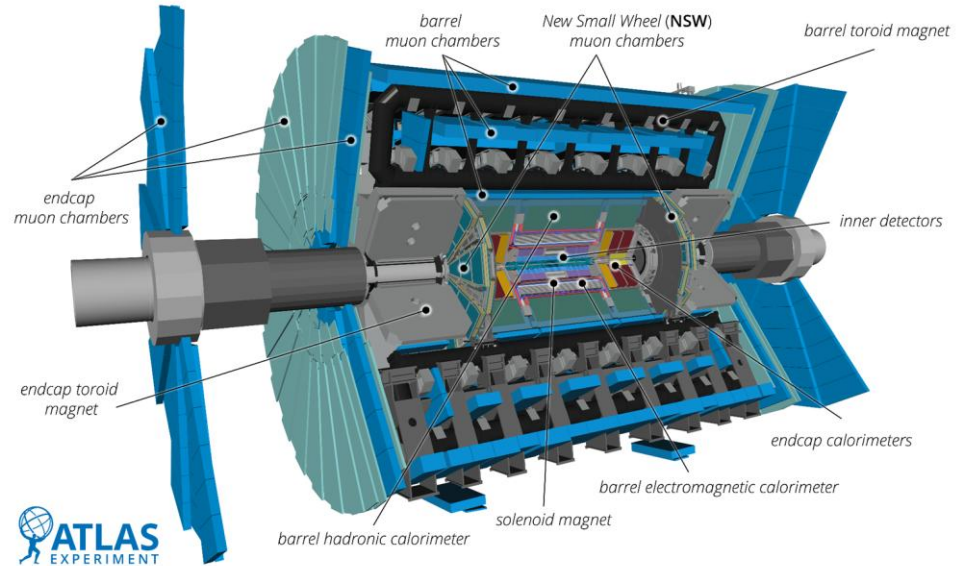
- General purpose particle detector, with subsystems including:
 - Inner detector for charged particle tracking in a 2 T field
 - Calorimeters for reconstructing electrons/photons and hadronic showers (“jets”)
 - Muon spectrometer built around toroid magnet field



[ATLAS-PHOTO-2022-055](#)

The ATLAS detector at the LHC

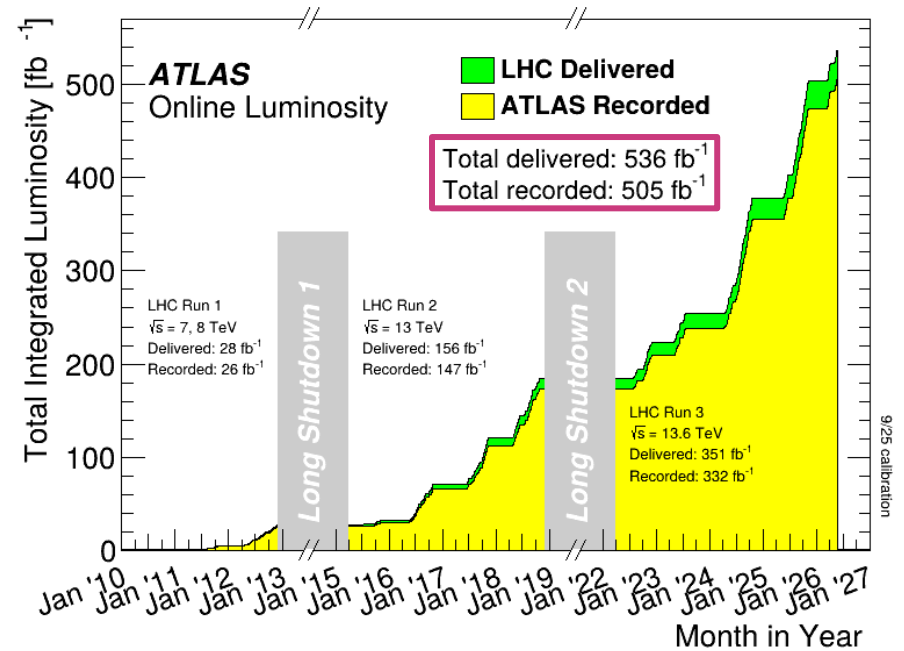
- General purpose particle detector, with subsystems including:
 - Inner detector for charged particle tracking in a 2 T field
 - Calorimeters for reconstructing electron/photons and hadronic showers (“jets”)
 - Muon spectrometer built around toroid magnet field
- 100 kHz hardware trigger, reduced to 3 kHz event rate by software trigger



[ATLAS-PHOTO-2022-055](#)

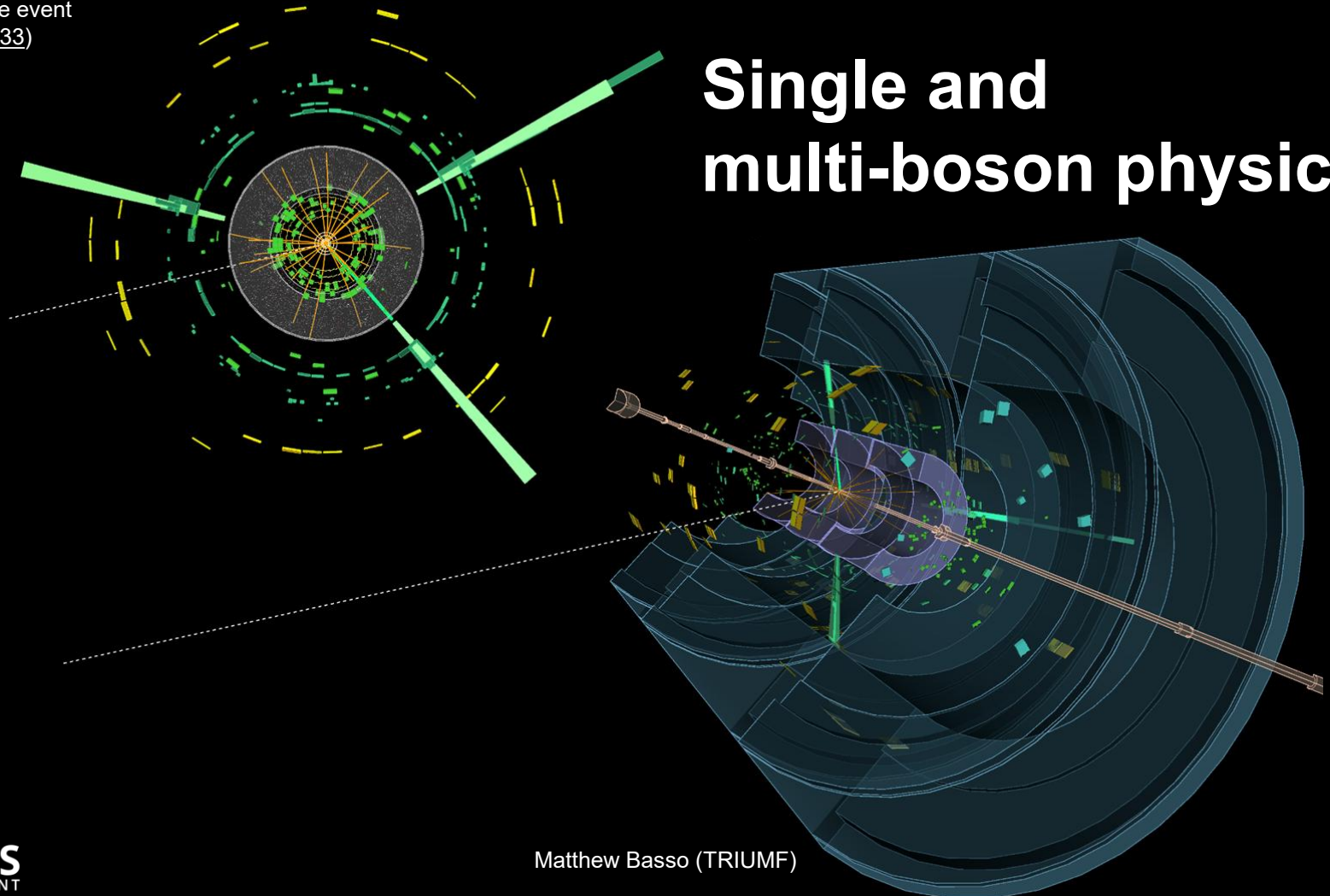
Data collected by ATLAS thus far

- Precision measurements benefit from **large datasets**, and ATLAS has collected a large dataset!
- For proton-proton collisions, the integrated luminosities are:
 - “Full” Run 2 (2015–18): 140 fb⁻¹
 - “Early” Run 3 (2022–24): 164 fb⁻¹
 - 1 fb⁻¹ of data ~ 100 trillion collisions
- **“Final laps at the LHC”**: LHC is concluding Run 3 this week!



[ATLAS online luminosity plots](#)

Single and multi-boson physics



Measurement of W boson angular coefficients

- Differential cross section for W+jets can be decomposed into **harmonic polynomials** as a function of lepton polar and azimuthal angles, θ and ϕ
 - Along with **unpolarized cross section** as a prefactor
- Measurements of angular coefficients, $\{A_i\}$, enable **stringent comparisons** with state-of-the-art QCD predictions, in addition to being model independent
 - Already measured for [Z bosons by ATLAS](#)

$$\frac{d\sigma}{dp_T^W dy^W dm^W d\cos\theta d\phi} = \text{EPJC 86 (2026) 483}$$

$$\frac{3}{16\pi} \frac{d\sigma^{U+L}}{dp_T^W dy^W dm^W}$$

$$\left\{ (1 + \cos^2 \theta) + \frac{1}{2} A_0 (1 - 3 \cos^2 \theta) + A_1 \sin 2\theta \cos \phi + \frac{1}{2} A_2 \sin^2 \theta \cos 2\phi + A_3 \sin \theta \cos \phi + A_4 \cos \theta + A_5 \sin^2 \theta \sin 2\phi + A_6 \sin 2\theta \sin \phi + A_7 \sin \theta \sin \phi \right\}.$$

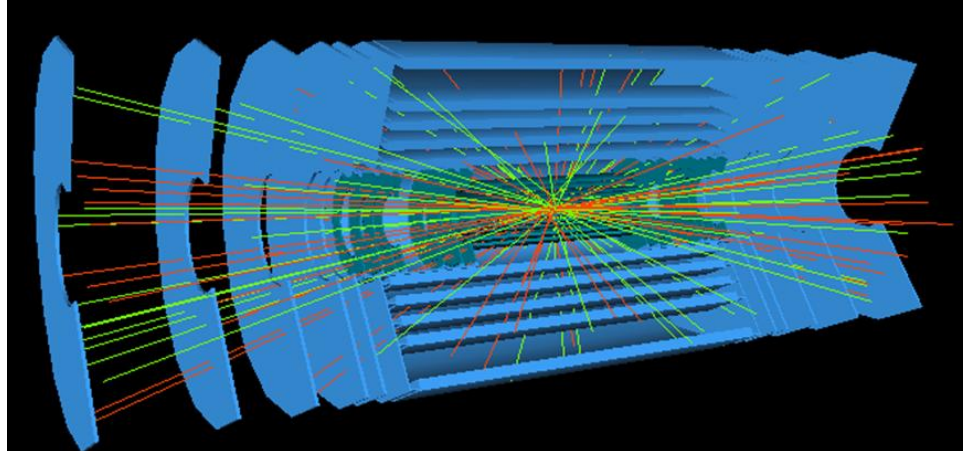
Strategy for measuring angular coefficients

- Use 338 pb^{-1} of low pile-up data and selecting for $W \rightarrow e\nu/\mu\nu \rightarrow$ **excellent** experimental conditions

Aside #1: pile-up interactions

- Additional proton-proton interactions, beyond the interesting hard-scatter collision, are referred to as **pile-up** → **pollute** our collision environment
- For the majority of Run 2, the number of pile-up collisions per bunch crossing was ~ 40 versus ~ 2 for the special dataset on the previous slide

*23 collisions per
bunch crossing*

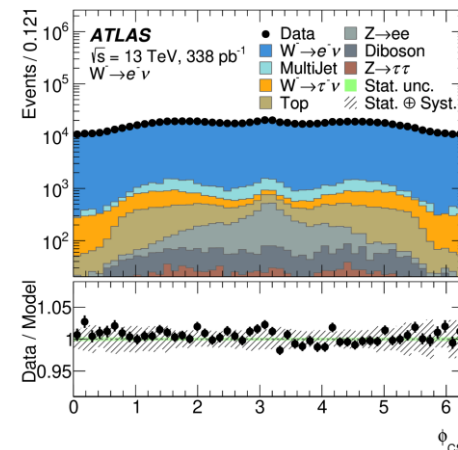
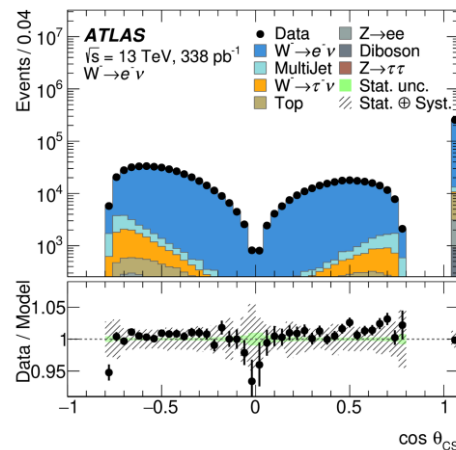
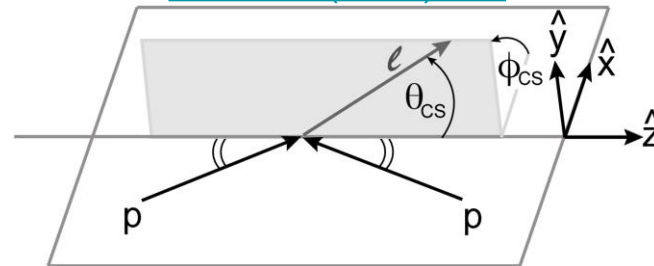


ATL-UPGRADE-PROC-2012-003

Strategy for measuring angular coefficients

- Use 338 pb^{-1} of low pile-up data and selecting for $W \rightarrow e\nu/\mu\nu \rightarrow$ **excellent** experimental conditions
- Build and fit templates for each coefficient, binned in $\cos(\theta)$ and ϕ in the Collins-Soper (CS) frame, as a function of the p_T of the W boson
 - Ambiguity in reconstruction of neutrino momentum and therefore on the sign of $\cos(\theta)$ resolved using a W boson mass constraint

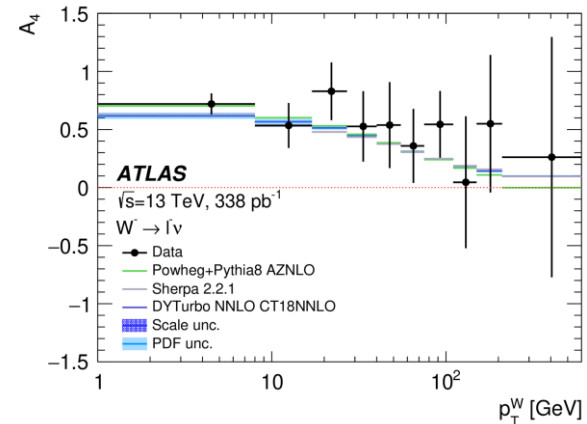
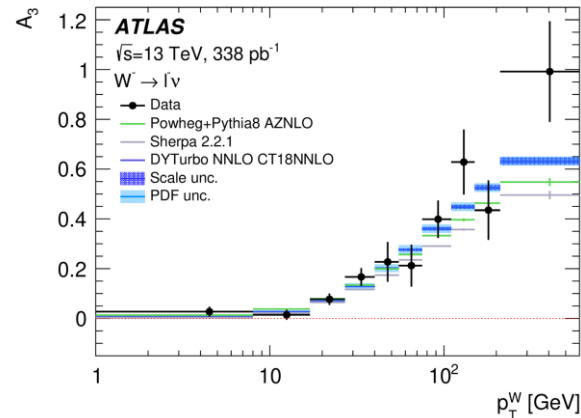
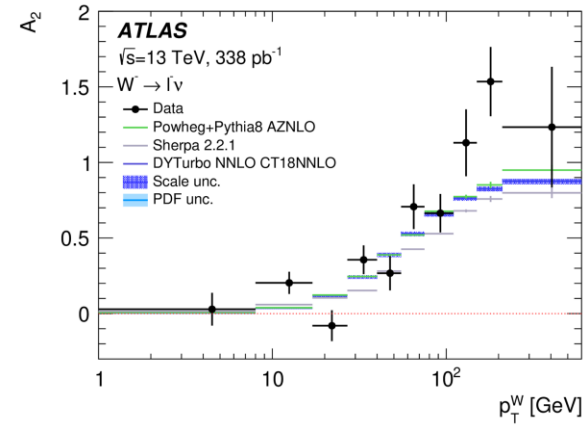
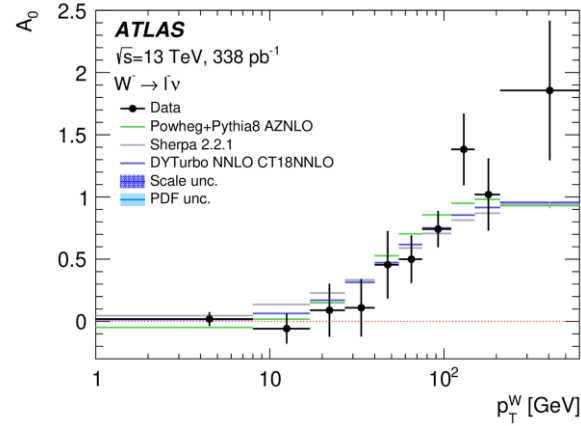
[JHEP 08 \(2016\) 159](#)



[EPJC 86 \(2026\) 483](#)

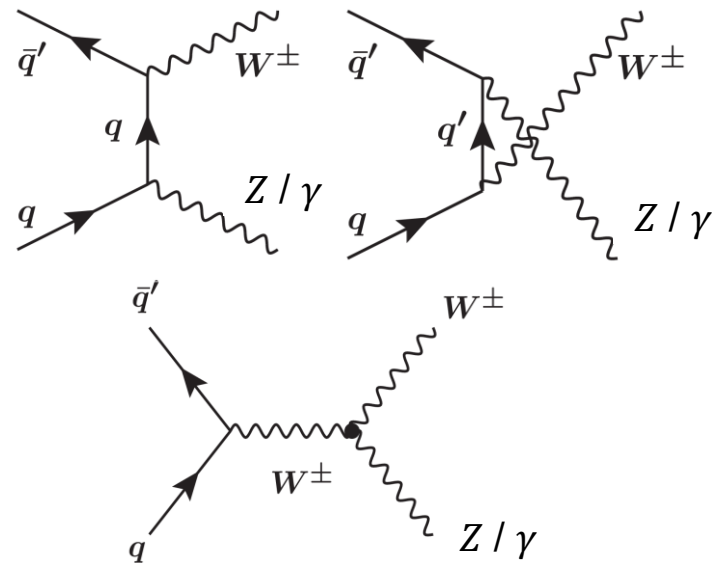
Measured W^- angular coefficients

- Separately fit $\{A_i\}$ for W^- and W^+ candidates
- **Excellent** agreement with theory predictions
 - Theory predictions are convolved with detector effects
 - $i = 1, 5-7$ coefficients consistent with 0
- **First measurement of full set of $\{A_i\}$ for W s**



Inclusive WZ and W γ production

- Measurements of WZ and W γ offer probes of **triple gauge couplings (TGCs)**, tests of **charge-parity (CP) violation**, and searches for **new physics**
- Each process has **clean** experimental signatures: leptonically-decaying vector bosons and (for W γ) a photon
- Utilize the full Run 2 dataset, 140 fb⁻¹, which enable fine-grained measurements of **differential observables**...



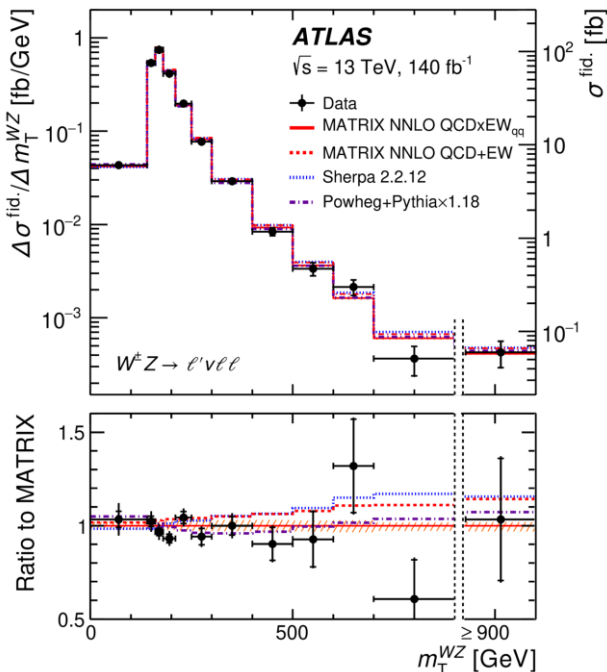
Modified from [JHEP 11 \(2025\) 006](#)

Aside #2: fiducial cross sections, a tool for precision

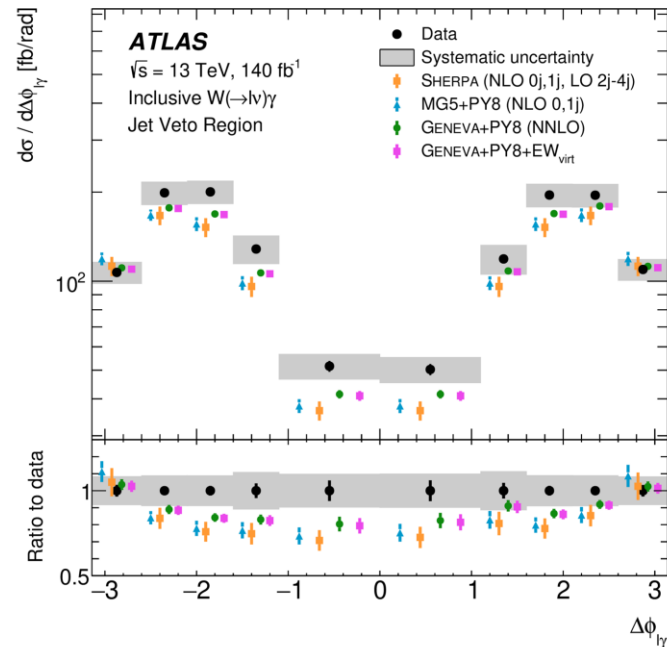
- **Fiducial cross section measurements:** deconvolve or “unfold” detector effects from reconstructed data – background to yield a particle-level signal cross section
 - Unfold to a fiducial phase space **closely matching** the reconstructed phase space
 - Typically proceeds via an [iterative procedure](#)
 - Contrast **total cross section measurements** using reconstructed data without unfolding
- **Differential cross section measurements:** fiducial cross section measurements differential in some observable
 - Can be directly compared to calculations from **state-of-the-art generators**

Differential cross section results for WZ and Wy

JHEP 11 (2025) 006



Transverse mass of the WZ system

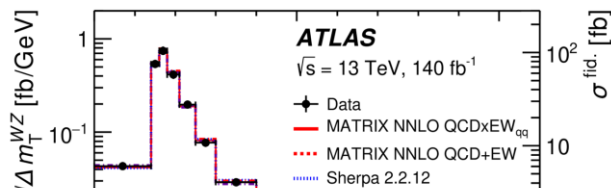


Pseudorapidity-ordered azimuthal separation between the lepton and photon

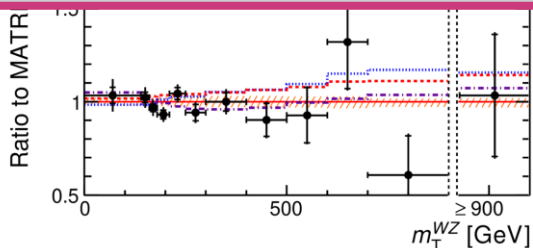
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Differential cross section results for WZ and Wy

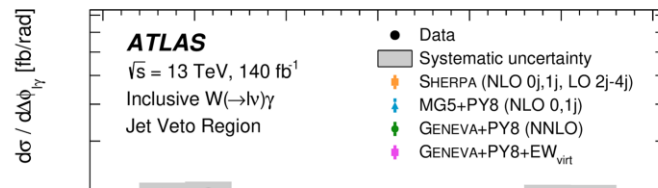
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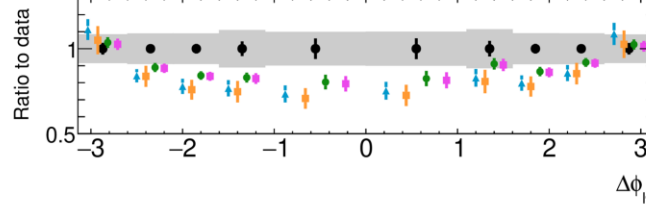
High energy tails are sensitive to new physics (e.g., anomalous TGCs)



Transverse mass of the WZ system



CP-sensitive, parity-odd observable

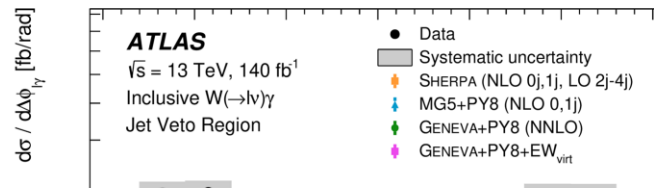
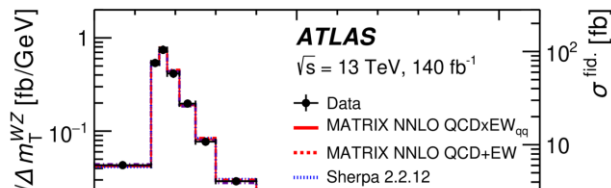


Pseudorapidity-ordered azimuthal separation between the lepton and photon

STD-2022-15

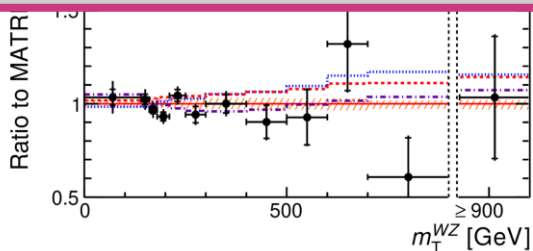
Differential cross section results for WZ and Wy

JHEP 11 (2025) 006

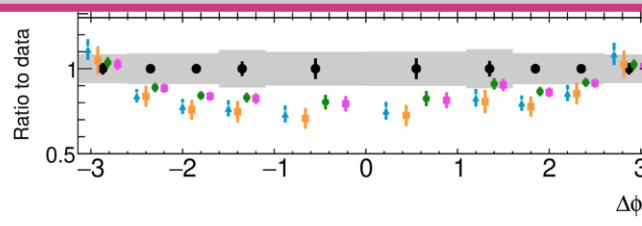


These observables can be used to constrain the structure new physics by way of effective field theory...

STDm-2022-15



Transverse mass of the WZ system



Pseudorapidity-ordered azimuthal separation between the lepton and photon

Aside #3: effective field theory, a tool for new physics

- **Effective field theory (EFT):** add **higher-dimensional** ($d > 4$) operators to the SM Lagrangian which capture the unknown physics above some energy cut-off scale Λ (typically 1 TeV) and which are ordered in inverse powers of Λ :

$$\mathcal{L} = \mathcal{L}_{\text{SM}} + \mathcal{L}_{\text{EFT}} = \mathcal{L}_{\text{SM}} + \sum_i \frac{c_i^{(6)}}{\Lambda_i^2} \mathcal{O}_i^{(6)} + \dots, \quad \text{Modified from [JHEP 11 \(2025\) 006](#)}$$

- **Leading higher-dimensional order is 6** (operators of odd mass dimensions violate lepton/baryon number conservation)
- **Standard Model Effective Field Theory (SMEFT)** builds the effective operators using **only SM fields**

Aside #2: effective field theory, a tool for new physics

- **Effective field theory (EFT):** add **higher-dimensional** ($d > 4$) operators to the SM Lagrangian which capture the unknown physics above some energy cut-off scale Λ (typically 1 TeV) and which are ordered in inverse powers of Λ :

Typically report
Wilson coefficients

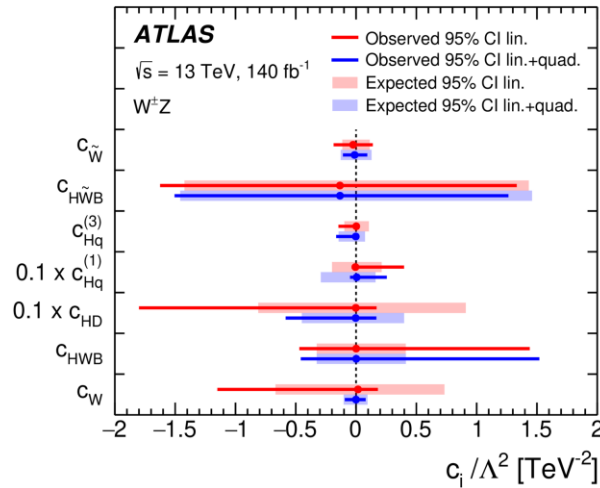
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- **Leading higher-dimensional order is 6** (operators of odd mass dimensions violate lepton/baryon number conservation)
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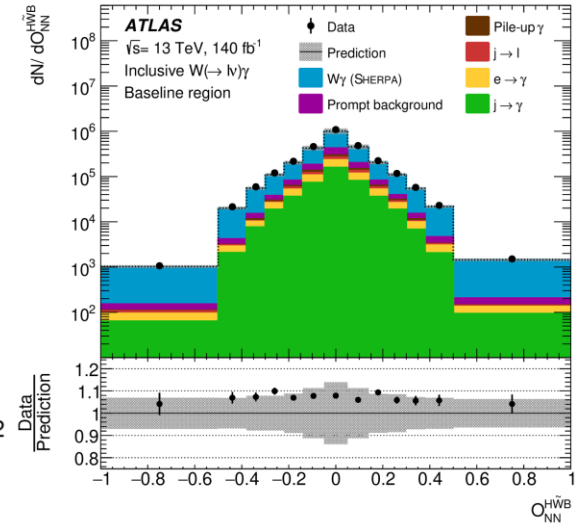
Inclusive WZ and Wy production

- Constraints on CP-even operators obtained by parameterizing their effects on m_T^{WZ} or angular observables
- Constraints on CP-odd operators obtained by parameterizing their effects on [novel neural network observables](#)

[JHEP 11 \(2025\) 006](#)



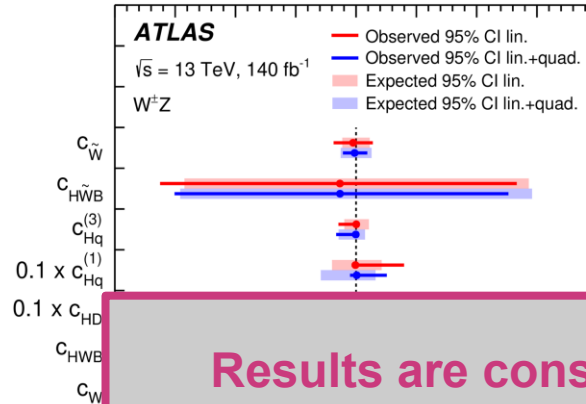
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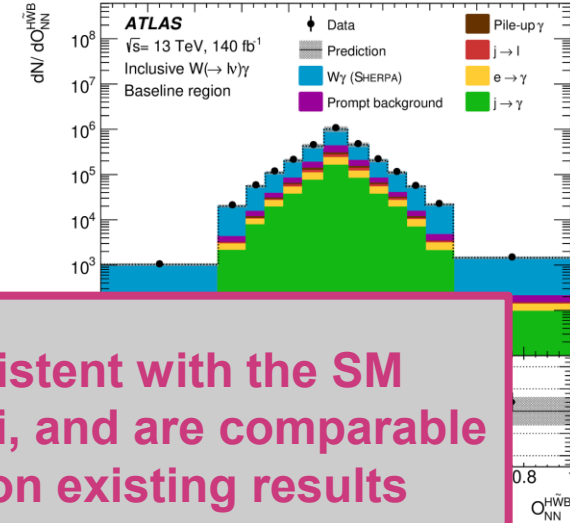
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[JHEP 11 \(2025\) 006](#)



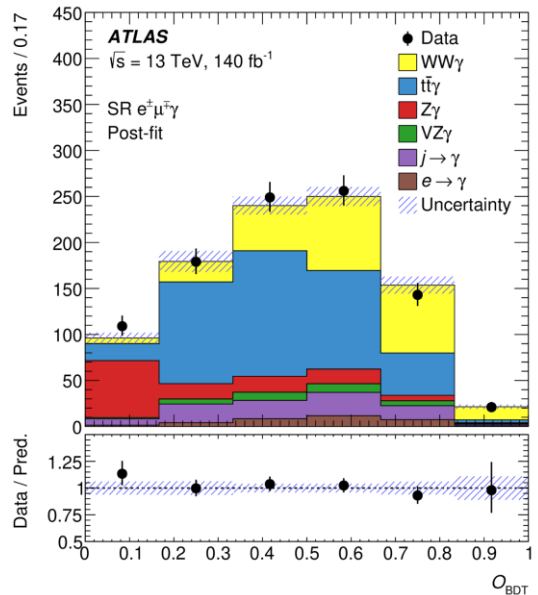
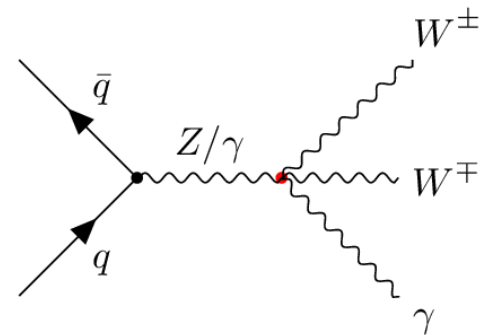
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Results are consistent with the SM expectation, $c_i = 0 \forall i$, and are comparable to or improve upon existing results

Observation of $WW\gamma$ production

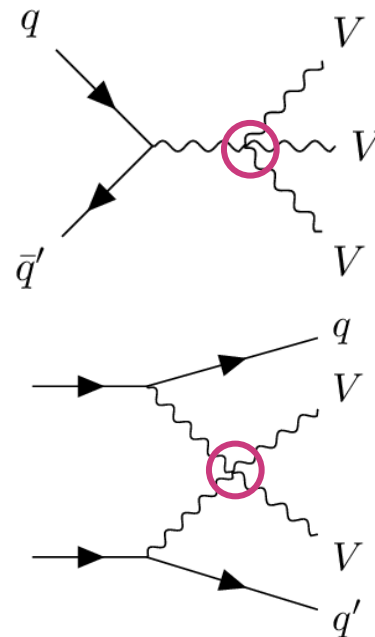
- Measurements of triboson production are stringent tests of gauge structure
 - Already observed: [VVZ](#), [W \$\gamma\gamma\$](#) , [WZ \$\gamma\$](#) , [Z \$\gamma\gamma\$](#) , [WWW](#), ...
- Targets different-flavour leptonic decays of the W bosons + a photon, with a BDT separating signal from all other backgrounds
- Fiducial cross section: 6.2 ± 1.0 fb, consistent with the SM prediction of $6.1^{+1.0}_{-0.7}$ fb
 - Limited by availability of data (12%), with modelling of non-prompt photon background subleading (5.4%)
 - **5.9 σ significance** over background-only hypothesis



PLB 873 (2026) 140050

Combined interpretation of anomalous quartic gauge couplings

- Many >TeV-scale BSM models predict **anomalous quartic gauge couplings** (aQGCs)
 - Can be described by EFTs, but unlike the previous interpretations, operators affecting QGCs enter at **dimension-8**, of which there are **$\mathcal{O}(10^5)$** !
- [Éboli model](#) isolates dimension-8 operators respecting SM symmetries and producing aQGCs
- **Seventeen** such operators are reported as part of a combined interpretation of **seven vector boson scattering (VBS) measurements** from Run 2



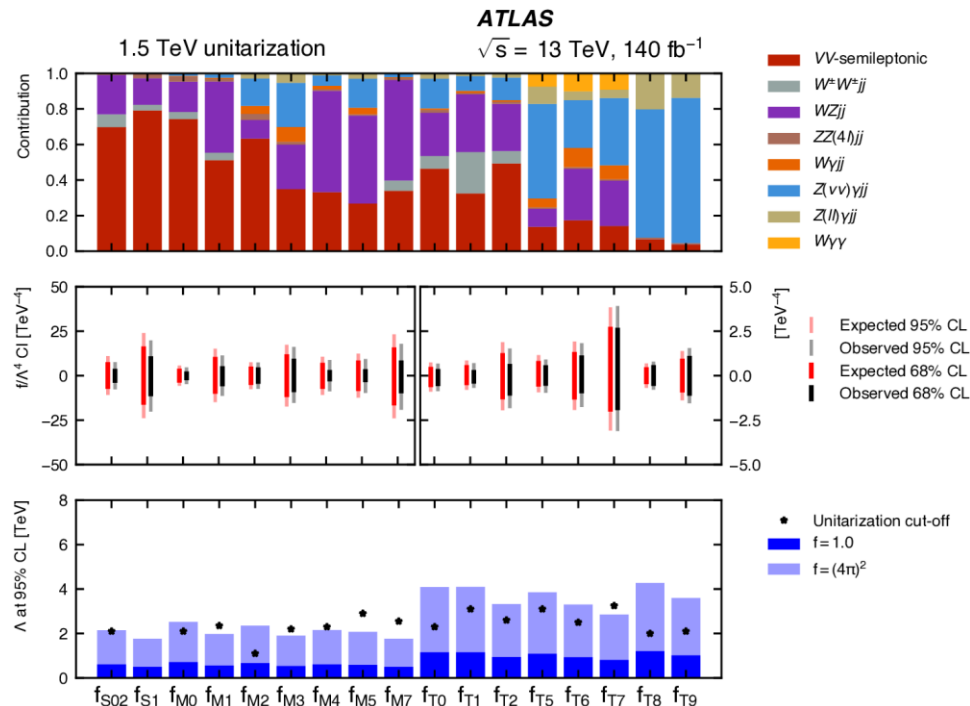
STDM-2023-21

$$\mathcal{L}_{\text{Eff}} \approx \mathcal{L}_{\text{SM}}^{(4)} + \sum_j \frac{f_j^{(8)}}{\Lambda^4} \mathcal{O}_j^{(8)}$$

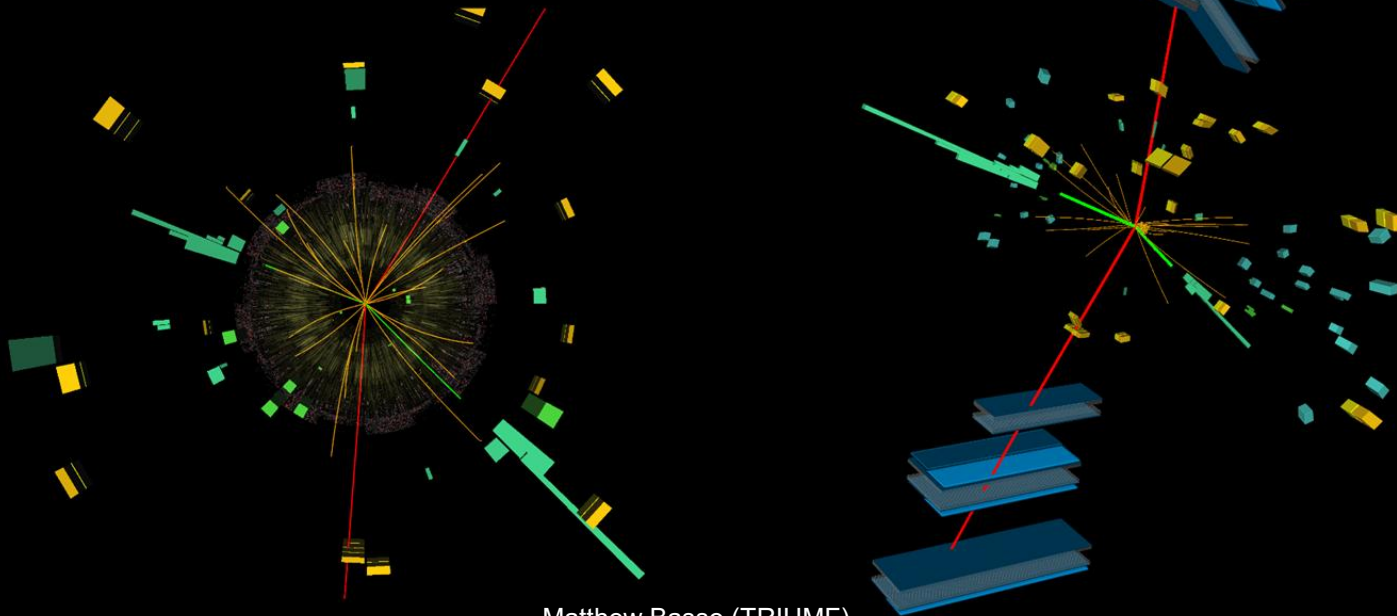
Combined limits with unitarity constraints

STDM-2023-21

- **Most comprehensive set of aQGC EFT results to date**
 - Combination improves upon individual results by 20%
- **Impose unitarity by setting EFT effects to 0 for energy scales above 1.5 TeV ([Backup](#))** → combined bounds **improve by up to 96%** and are more even
- **Results consistent with the SM**

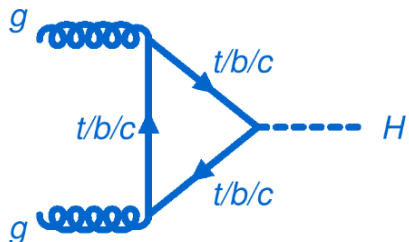


Higgs boson physics



Matthew Basso (TRIUMF)

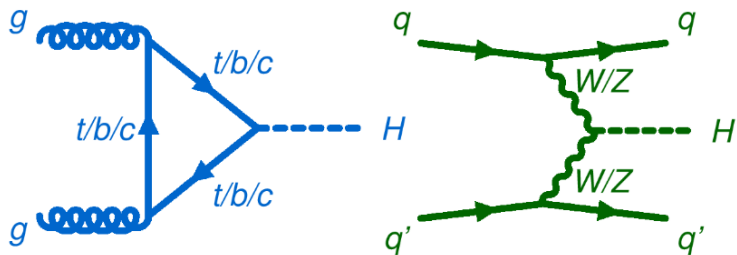
Production of Higgs bosons



Gluon-gluon fusion (ggF)

[ATLAS-CONF-2025-006](#)

Production of Higgs bosons

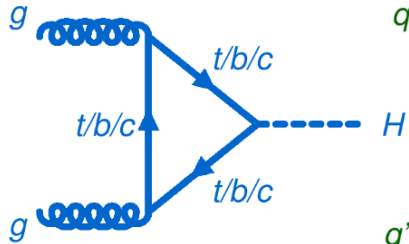


Gluon-gluon fusion (ggF)

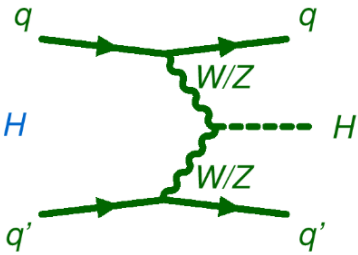
Vector-boson fusion (VBF)

[ATLAS-CONF-2025-006](#)

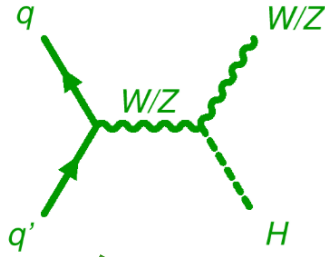
Production of Higgs bosons



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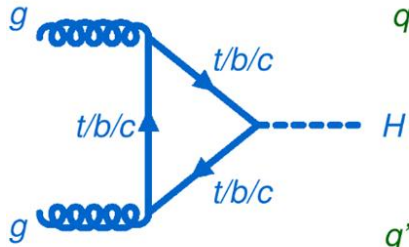
Vector-boson fusion (VBF)



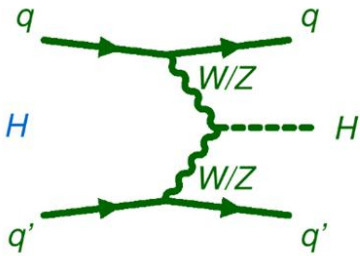
Production in association with a W/Z boson (WH/ZH)

[ATLAS-CONF-2025-006](#)

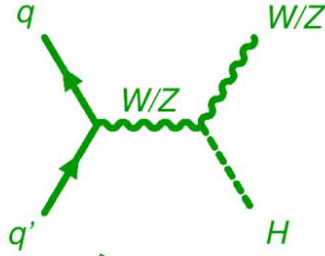
Production of Higgs bosons



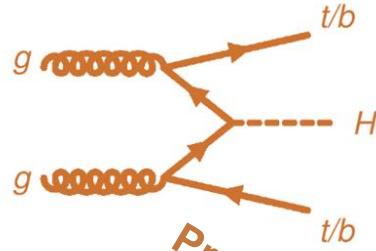
Gluon-gluon fusion (ggF)



Vector-boson fusion (VBF)



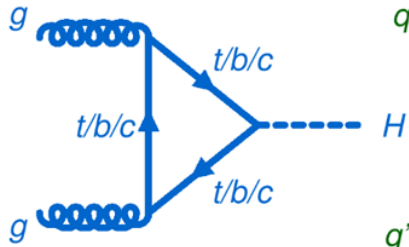
Production in association with a W/Z boson (WH/ZH)



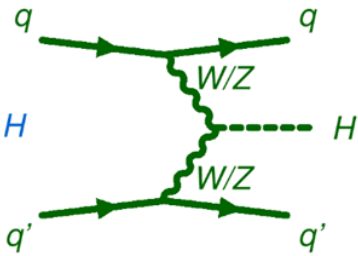
Production in association with a top/bottom quark pair (ttH/bbH)

[ATLAS-CONF-2025-006](#)

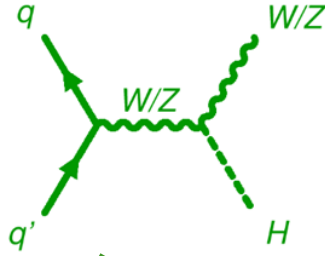
Production of Higgs bosons



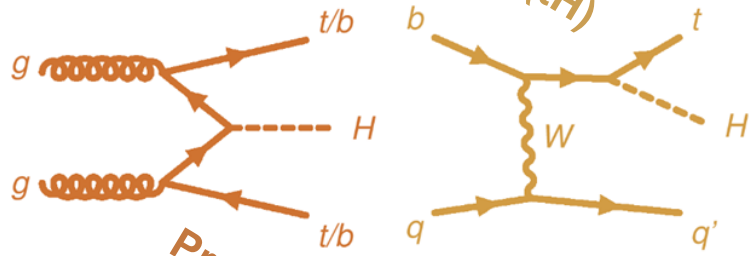
Gluon-gluon fusion (ggF)



Vector-boson fusion (VBF)



Production in association with a W/Z boson (WH/ZH)



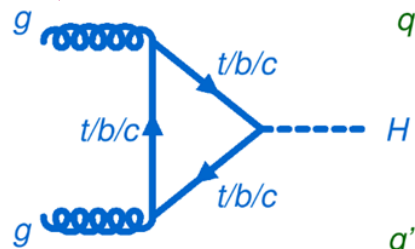
Production in association with a top/bottom quark pair (ttH/bbH)

Production in association with a single top quark (tH)

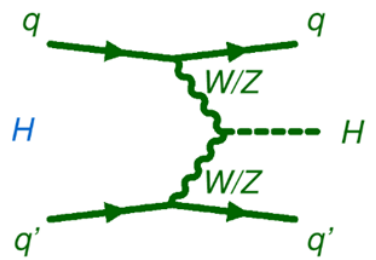
[ATLAS-CONF-2025-006](#)

Production of Higgs bosons

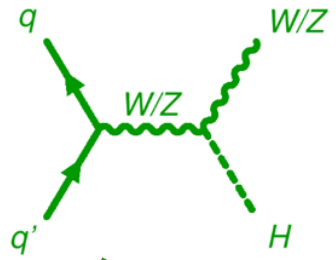
Increasing cross section (numbers in the [Backup](#))



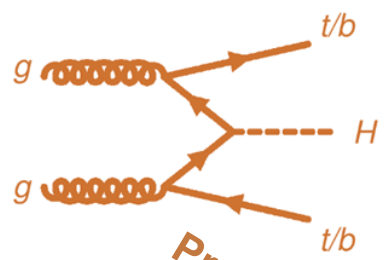
Gluon-gluon fusion (ggF)



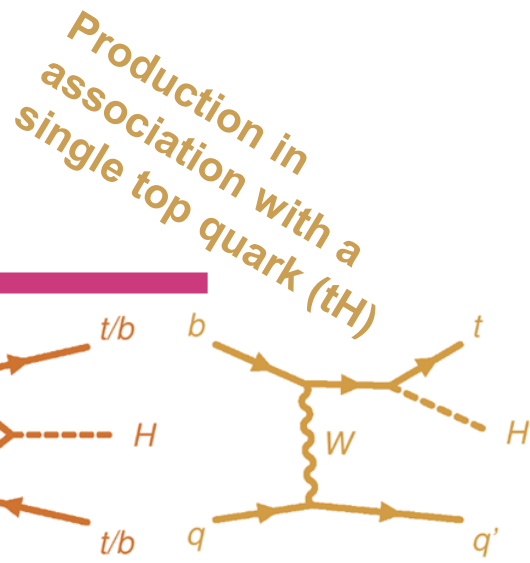
Vector-boson fusion (VBF)



Production in association with a W/Z boson (WH/ZH)



Production in association with a top/bottom quark pair (ttH/bbH)

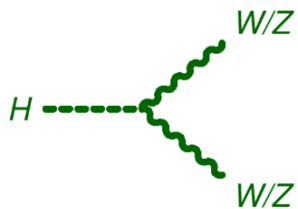


Production in association with a single top quark (tH)

[ATLAS-CONF-2025-006](#)

Decays of Higgs bosons

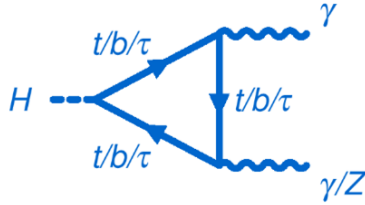
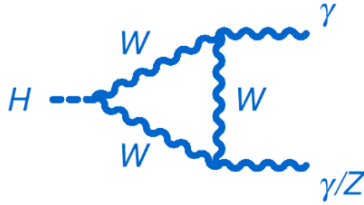
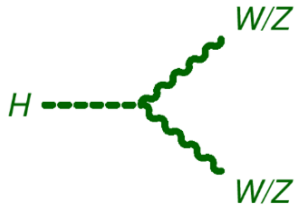
[ATLAS-CONF-2025-006](#)



Decays to pairs of W/Z
bosons ($H \rightarrow WW/ZZ$)

Decays of Higgs bosons

[ATLAS-CONF-2025-006](#)

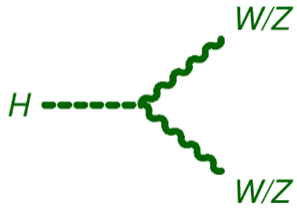


Decays to pairs of W/Z bosons ($H \rightarrow WW/ZZ$)

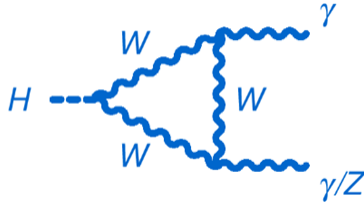
Decays to pairs of photon ($H \rightarrow \gamma\gamma$) or Z+photon ($H \rightarrow Z\gamma$)

Decays of Higgs bosons

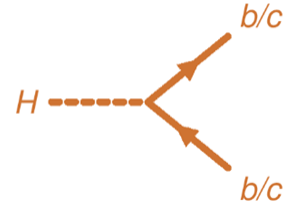
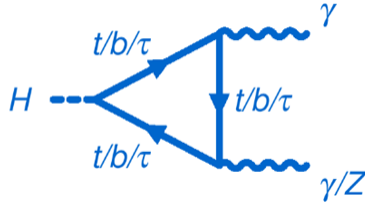
[ATLAS-CONF-2025-006](#)



Decays to pairs of W/Z bosons ($H \rightarrow WW/ZZ$)



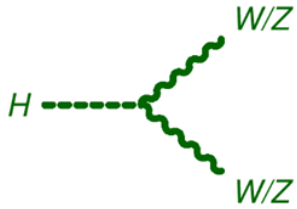
Decays to pairs of photon ($H \rightarrow \gamma\gamma$) or Z+photon ($H \rightarrow Z\gamma$)



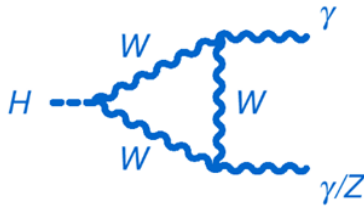
Decays to quark pairs ($H \rightarrow qq$)

Decays of Higgs bosons

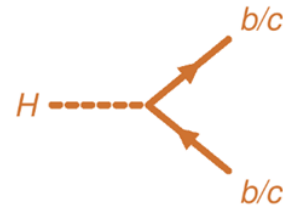
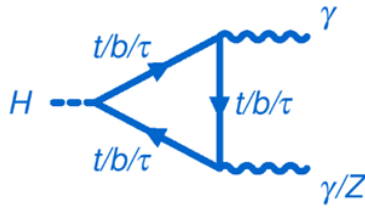
[ATLAS-CONF-2025-006](#)



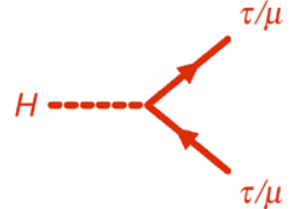
Decays to pairs of W/Z bosons ($H \rightarrow WW/ZZ$)



Decays to pairs of photon ($H \rightarrow \gamma\gamma$) or Z+photon ($H \rightarrow Z\gamma$)



Decays to quark pairs ($H \rightarrow qq$)

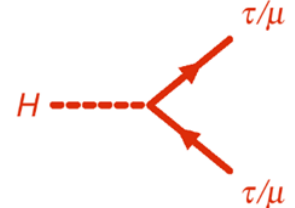
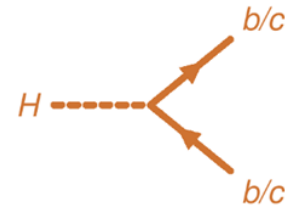
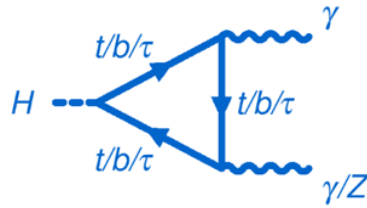
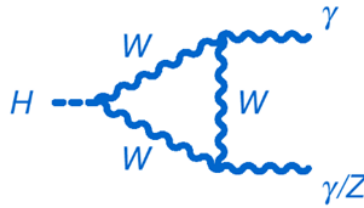
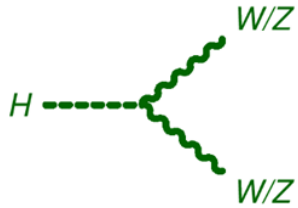


Decays to lepton pairs ($H \rightarrow \ell\ell$)

Decays of Higgs bosons

[ATLAS-CONF-2025-006](#)

(exact numbers in the [Backup](#))



Decays to pairs of W/Z bosons ($H \rightarrow WW/ZZ$)

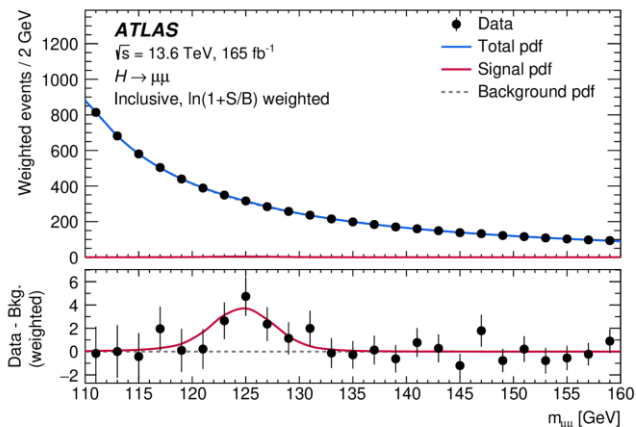
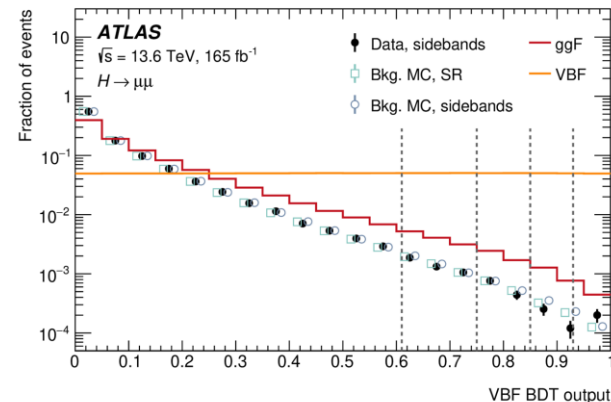
Decays to pairs of photon ($H \rightarrow \gamma\gamma$) or Z+photon ($H \rightarrow Z\gamma$)

Decays to quark pairs ($H \rightarrow qq$)

Decays to lepton pairs ($H \rightarrow \ell\ell$)

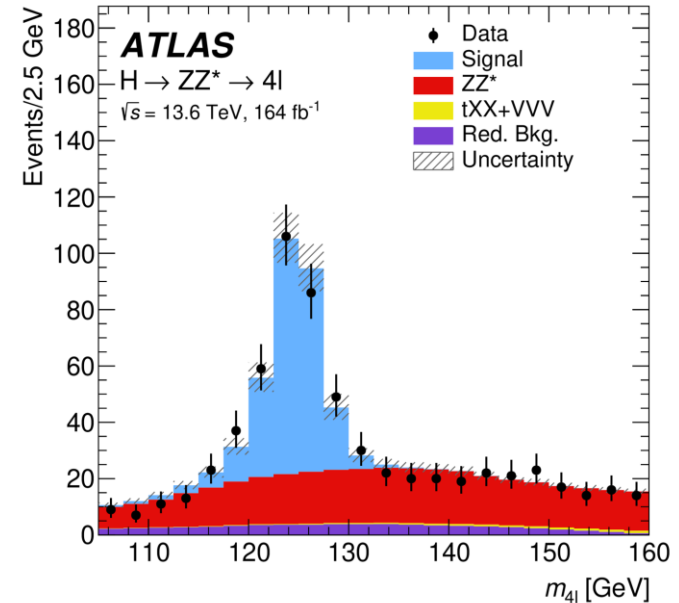
Fermion couplings: evidence for $H \rightarrow \mu\mu$

- Second-generation Yukawa couplings like $H \rightarrow \mu\mu$ are *not* firmly established
 - Difficult due to tiny branching ratio, $\mathcal{O}(10^{-4})$
- Analysis fits dimuon invariant mass, corrected for final state radiation, in 23 categories of different production modes and purities
- Combined with the [Run 2 result](#) to yield a signal strength modifier $\mu = 1.4 \pm 0.4$
 - Dominated by the availability of data
 - Corresponds **3.4σ significance** over the background-only hypothesis



Boson couplings: $H \rightarrow ZZ^* \rightarrow 4\ell$ in Run 3

- Measurement utilizes the partial (2022–24) Run 3 dataset but precision is already comparable to the [full Run 2 measurement](#)
- Four-lepton final state provides a clean signature, excellent signal-to-background, and full reconstruction of the final state
- Dominant backgrounds (ZZ and tXX) normalized via sidebands, data-driven estimate of non-prompt leptons

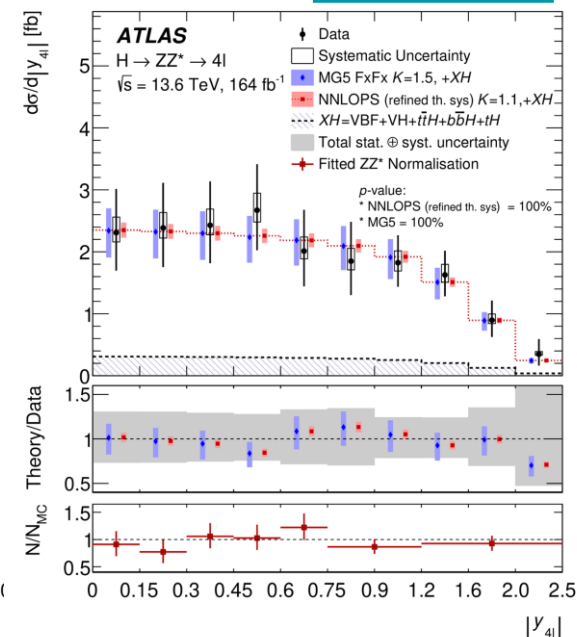
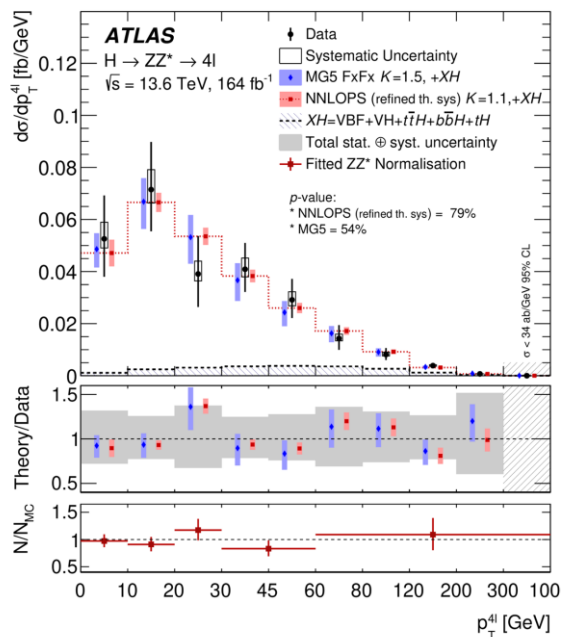


[HIGP-2025-09](#)

Differential measurements of $H \rightarrow ZZ^* \rightarrow 4\ell$

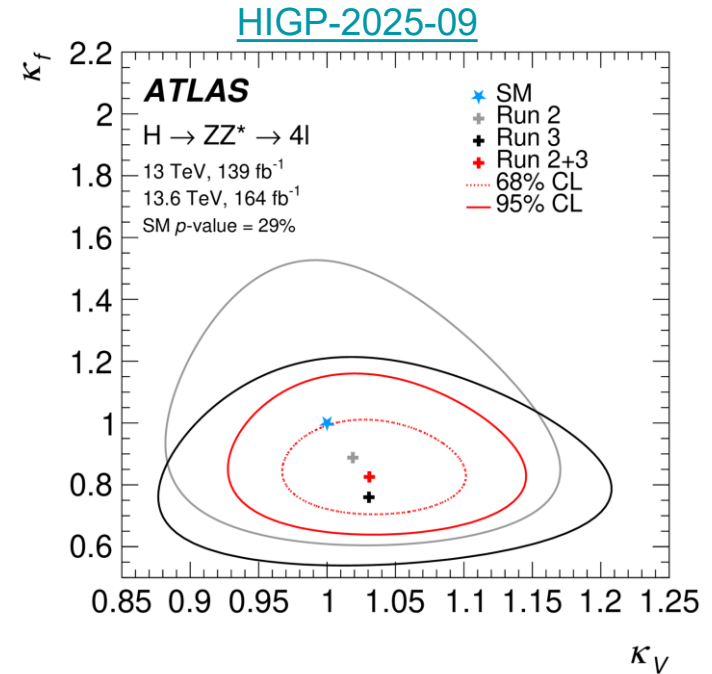
- Measured fiducial cross sections as a function of seven observables
 - $p_T^{4\ell} \rightarrow$ sensitive to perturbative QCD calculations; $|y_H| \rightarrow$ sensitive to parton distribution functions
 - Also studied differential production through Simplified Template Cross Sections ([Backup](#))

HIGP-2025-09



Coupling modifier results

- For the measurement of the production mode cross sections: correlate boson couplings as κ_V and separately correlate fermion couplings as κ_F
- Combine the Run 2 and 3 measurements → improve the sensitivity of the Run 2 results by **40%** and **20%** for κ_V and κ_F , respectively
 - Also apply a [novel approach](#) for constraining the Higgs trilinear self-coupling



Combination of single Higgs boson measurements

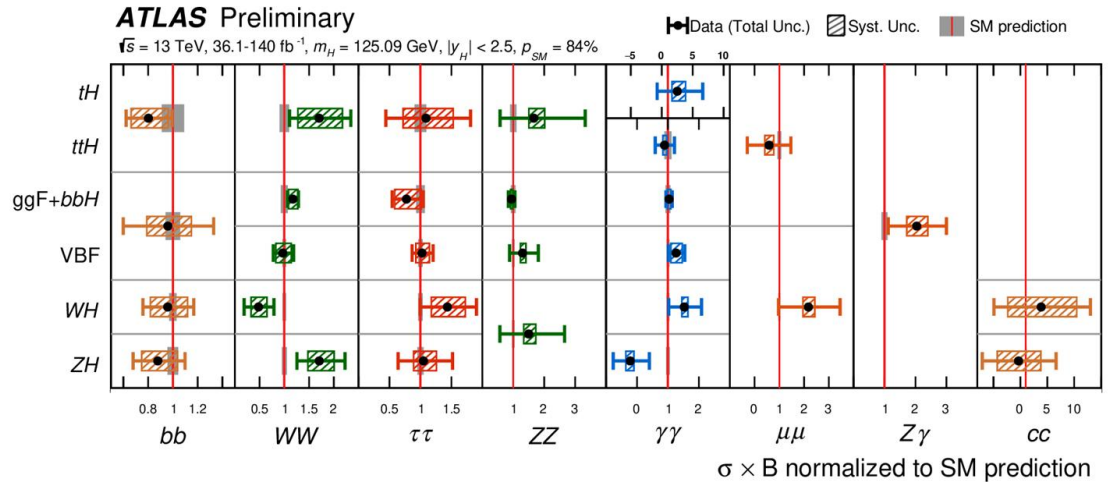
- Statistical combinations of single Higgs boson measurements exercised using the “**legacy**” Run 2 measurements as well as **new/expanded** measurements
 - Provide a holistic picture of Higgs boson production as measured by ATLAS
 - Previous combination: [Nature 607 \(2022\) 52](#)
- Measure total cross sections (inclusively and split by production mode), couplings, differential information, ...

Analysis	Prod. modes	\mathcal{L} (fb^{-1})	Reference	STXS stage	Improvements relative to Ref.
$H \rightarrow ZZ^* \rightarrow 4\ell$	All	140		1.2	-
$H \rightarrow WW^* \rightarrow \ell\nu\ell\nu$	ggF,VBF	140		0	Reanalysis
$H \rightarrow WW^* \rightarrow \ell\nu\ell\nu$	VH	140		1.2	Full Run 2
$H \rightarrow \gamma\gamma$	All	140		1.2	-
$H \rightarrow Z\gamma$	All	140		0	-
$H \rightarrow \tau\tau$	All	140		1.2	Reanalysis
$H \rightarrow \tau\tau$	VH	140		0	New analysis
$H \rightarrow \mu\mu$	All	140		0	-
$H \rightarrow bb$	VBF	126		1.2	-
$H \rightarrow bb, cc$	VH	140		1.2	Reanalysis
$H \rightarrow \text{multileptons}$	$t\bar{t}H$	36.1		0	-
$H \rightarrow bb$	$t\bar{t}H$	140		1.2	Reanalysis

[ATLAS-CONF-2025-006](#)

Production mode results for different decay channels

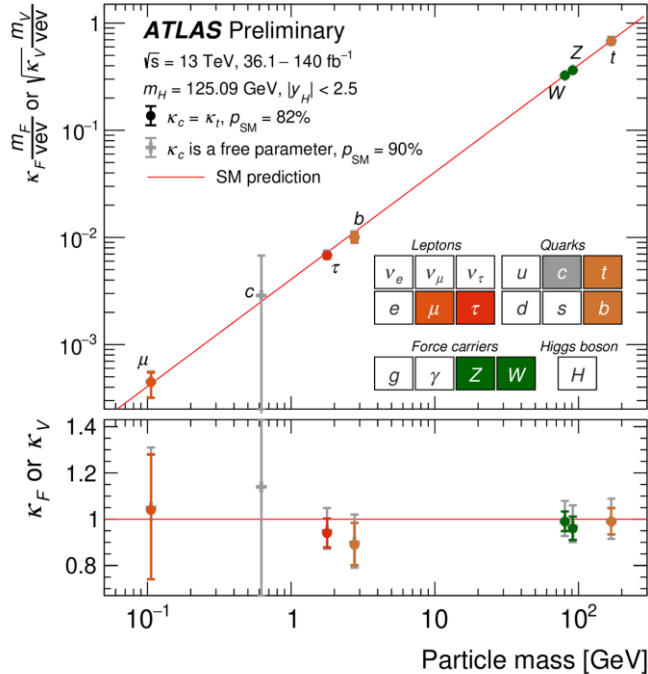
- Owing to the reanalysis and new data, relative to the previous result:
 - Uncertainties on **WH**, **ZH**, and **ttH+tH** cross sections are reduced by **30%**, **20%**, and **40%**, respectively
 - Uncertainties on **H**→**bb**, **H**→**WW***, and **H**→**ττ** branching ratios reduced by **20%**, **20%**, and **10%**, respectively



[ATLAS-CONF-2025-006](#)

Higgs boson couplings vs. particle mass

Couplings exhibit excellent agreement with the expected scaling as a function of particle mass



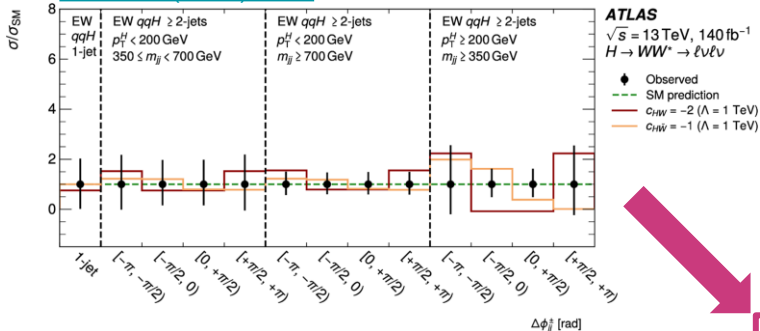
ATLAS-CONF-2025-006

CP properties of Higgs bosons

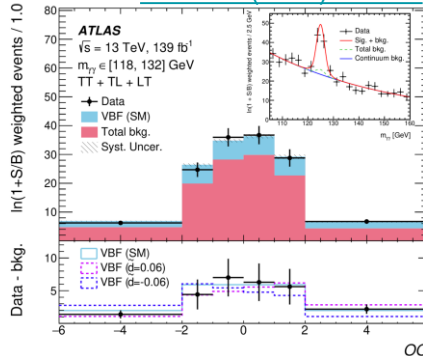
- Higgs boson is predicted to be a CP-even scalar
 - However, CP-violation could enter through its interactions with other particles
- Latest CP combination ([HIGP-2024-26](#)) studied the **Higgs boson's CP-violating effective couplings to gauge fields**, with Wilson coefficients $c_{H\tilde{W}}$, $c_{H\tilde{B}}$, and $c_{H\tilde{W}B}$
- CP violation manifests as an asymmetry in a CP-odd observable (e.g., angular variables or optimal observables) → tested through a combined **shape-only** fit of CP-odd observables from several measurements
 - “Shape-only”: signal normalization is **float**ed in the fit, to decouple changes to the total cross section from those affecting the shapes

Observables sensitive to CP-violating effects

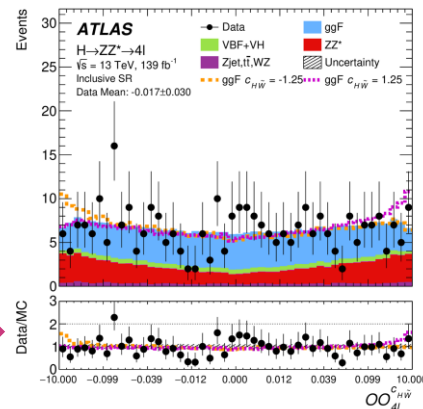
EPJC 85 (2025) 1403



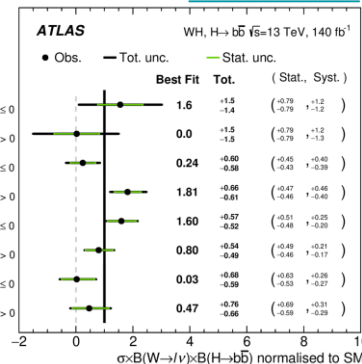
PRL 131 (2023) 061802



JHEP 05 (2024) 105

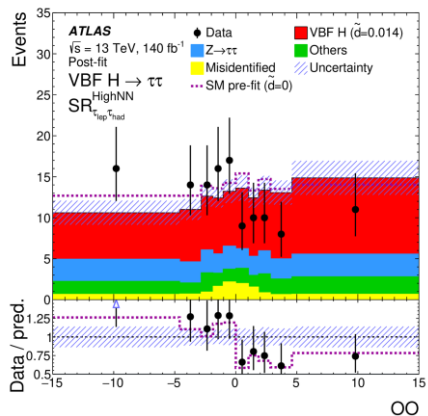


HIGP-2024-26



$$\frac{c_{H\tilde{W}}}{\Lambda^2} H^\dagger H \tilde{W}^I_{\mu\nu} W^{\mu\nu I}$$

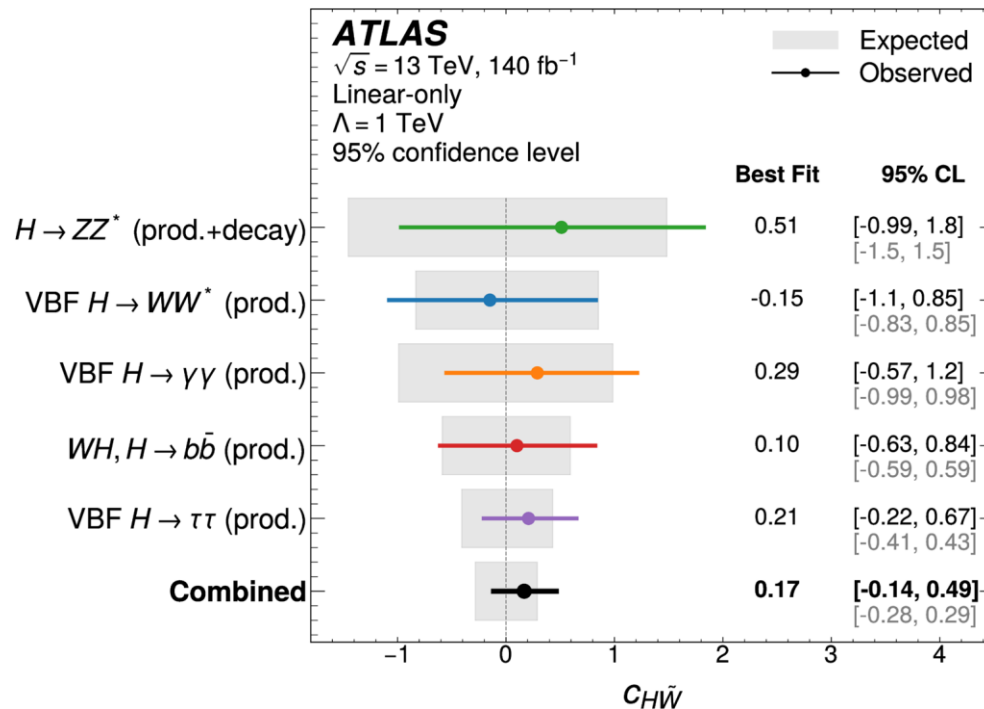
JHEP 10 (2025) 92



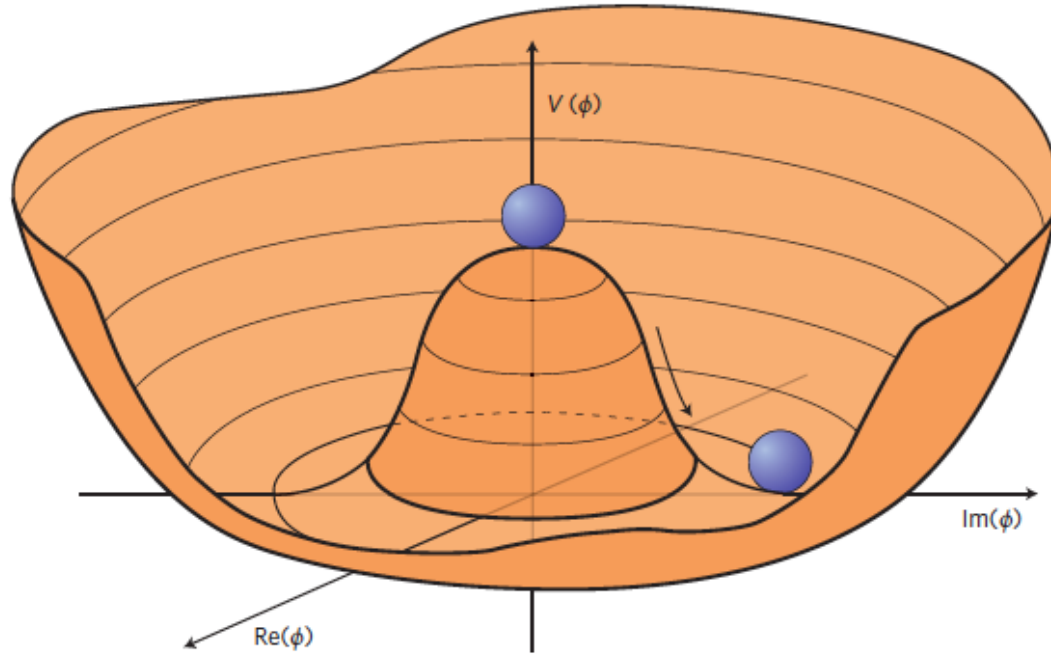
Combined results for CP-violating operators

HIGP-2024-26

- **First ever** simultaneous fit of $c_{H\tilde{W}}$, $c_{H\tilde{B}}$, and $c_{H\tilde{W}B}$
- **Most stringent limits** on $c_{H\tilde{W}}$ (with $c_{H\tilde{B}} = c_{H\tilde{W}B} = 0$) to date: **$[-0.14, +0.49]$** at 95% confidence level
 - Improve upon single channel results from $H \rightarrow \tau\tau$ by **40%**
- Consistent with **no CP-violating couplings**



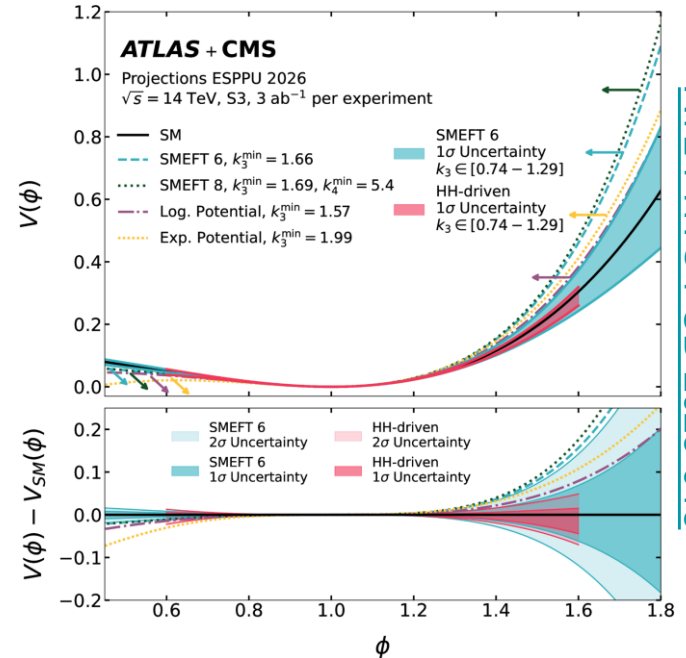
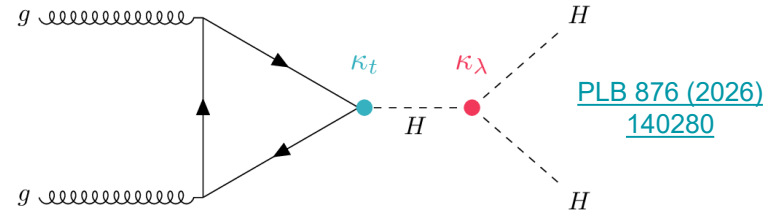
The Higgs potential



Borrowed from: J. Ellis, M.K. Gaillard, and D.V. Nanopoulos ([arXiv:1504.07217](https://arxiv.org/abs/1504.07217))

Combination of di-Higgs boson measurements

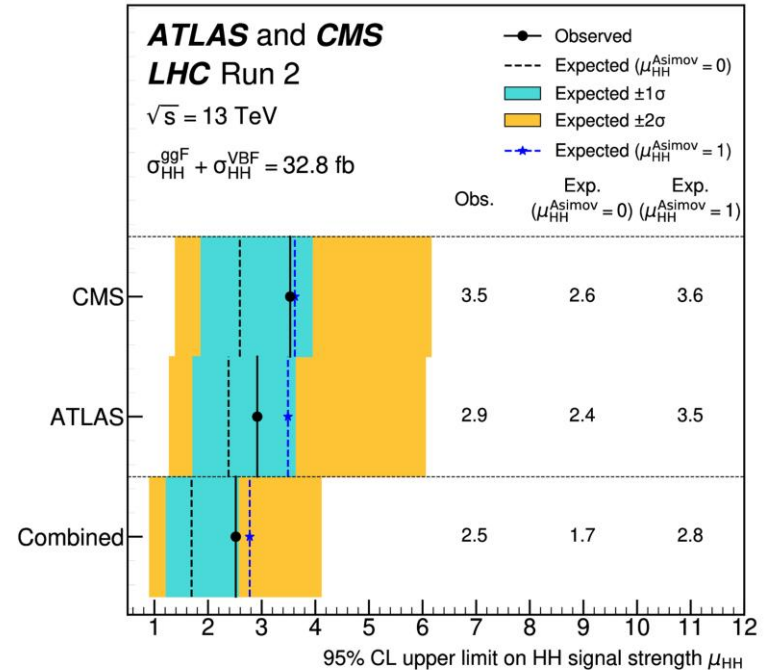
- Di-Higgs boson production is sensitive to the Higgs trilinear self-coupling κ_λ
- **Informs of physics in the early universe:** if a particular BSM model predicting a first-order phase transition (FOPT) deforms the Higgs potential ϕ , constraints on those models can be achieved using measurements (or interpretations) of κ_λ
 - With 3 ab^{-1} of data, **all four** FOPT scenarios on the right can be excluded at the 95% confidence level → **constraints on electroweak baryogenesis**



Di-Higgs signal strength results

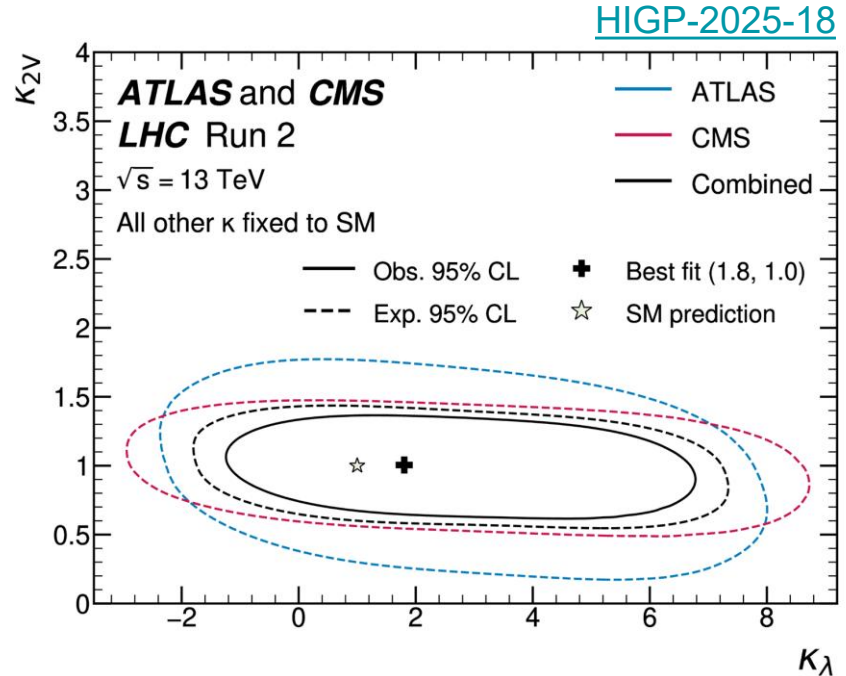
- Measuring the Higgs trilinear self-coupling is one of the **LHC's primary goals**
- For the first time, ATLAS and CMS di-Higgs results using the Run 2 dataset have been combined
 - Includes ten measurements across $bbbb$, $bb\tau\tau$, $bb\gamma\gamma$, $bb\ell\ell$, and multilepton final states
- **95% upper limit** on HH signal strength modifier μ_{HH} of **2.5**

HIGP-2025-18



Di-Higgs coupling modifier results

- Combination can be interpreted in the context of κ_λ and the HHVV coupling modifier κ_{2V}
 - Example diagrams in the [Backup](#)
- Observed 95% confidence level intervals of $\kappa_\lambda \in [-0.71, +6.1]$ and $\kappa_{2V} \in [-0.73, +1.3]$
- Compatible with the SM and **most sensitive constraints** to date

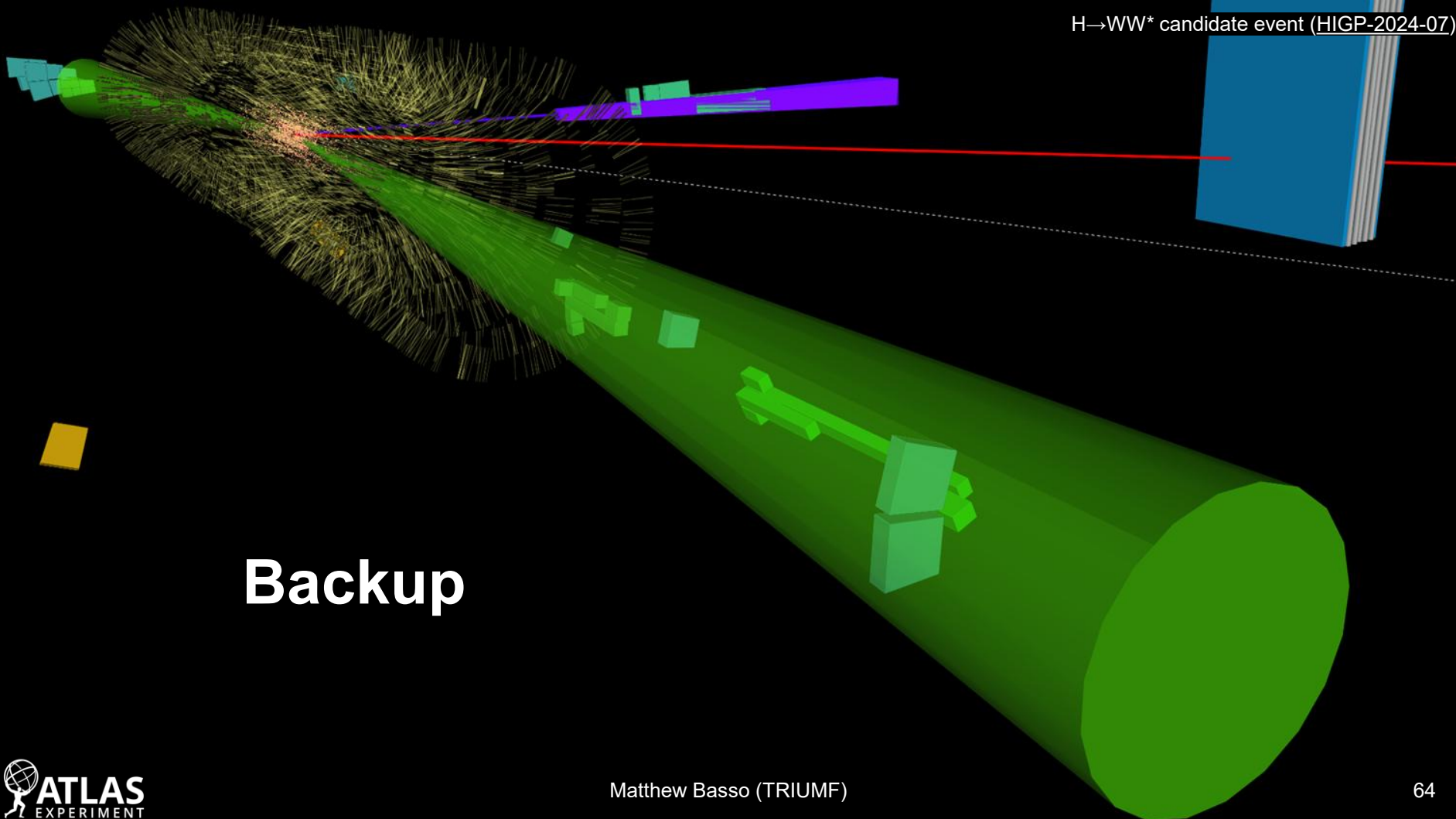


Wrapping it up

- **Comprehensive program of SM measurements pursued by ATLAS**, from single/multi-boson to Higgs boson to [top quark physics](#) → **spectacular precision**, owing to ATLAS's large dataset and innovative analysis strategies
 - What I presented today is just a snapshot of the ongoing as well as the historic program
- **Physicists from Canadian institutions** have and continue to play **important roles** in performing these measurements
- **No deviations from the SM predictions have been observed (yet!)**
 - At least not in the measurements presented today

Thank you for listening!
Any questions?

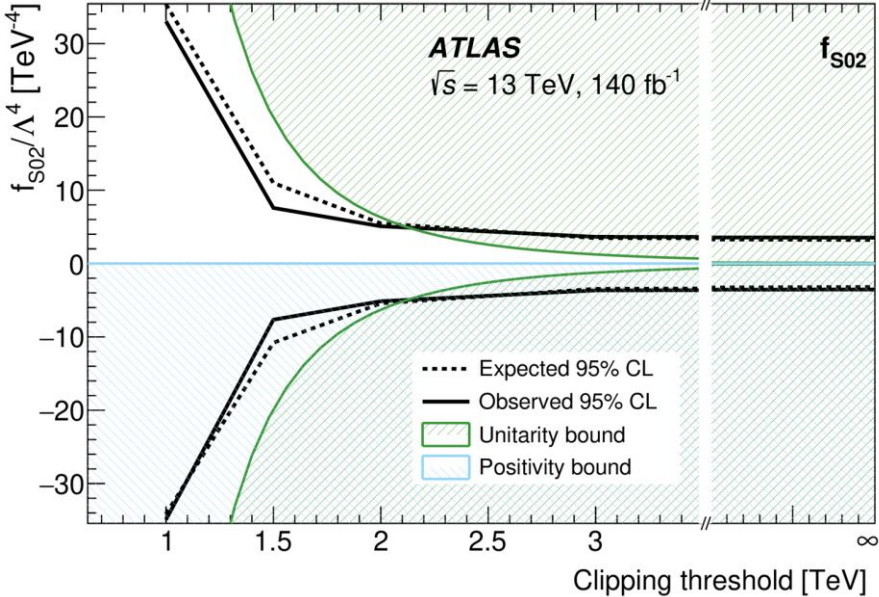




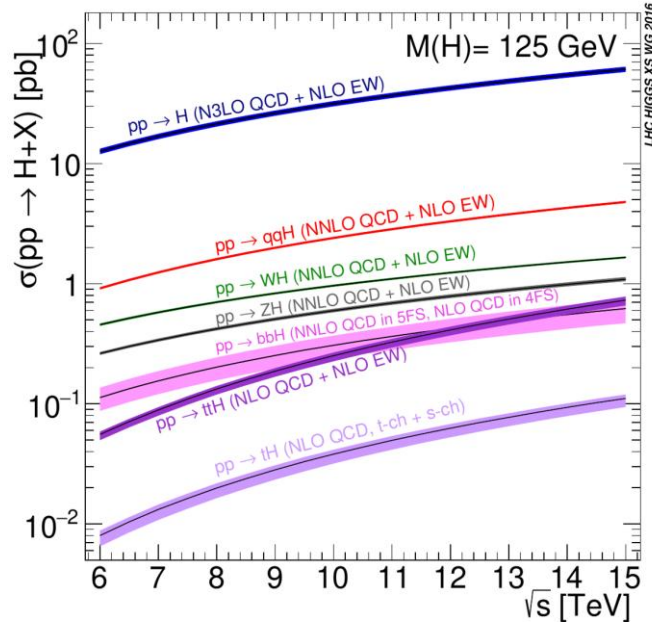
Backup

Unitarity constraints in aQGC interpretation

[STDM-2023-21](#)



Higgs boson cross sections and branching ratios

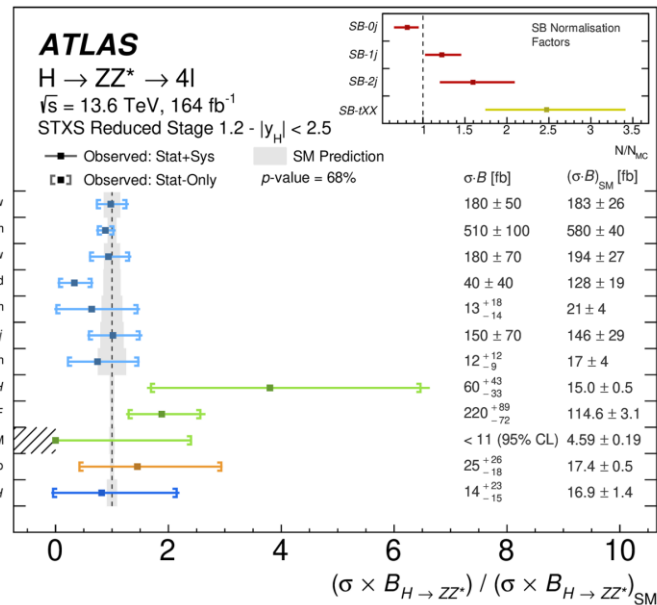
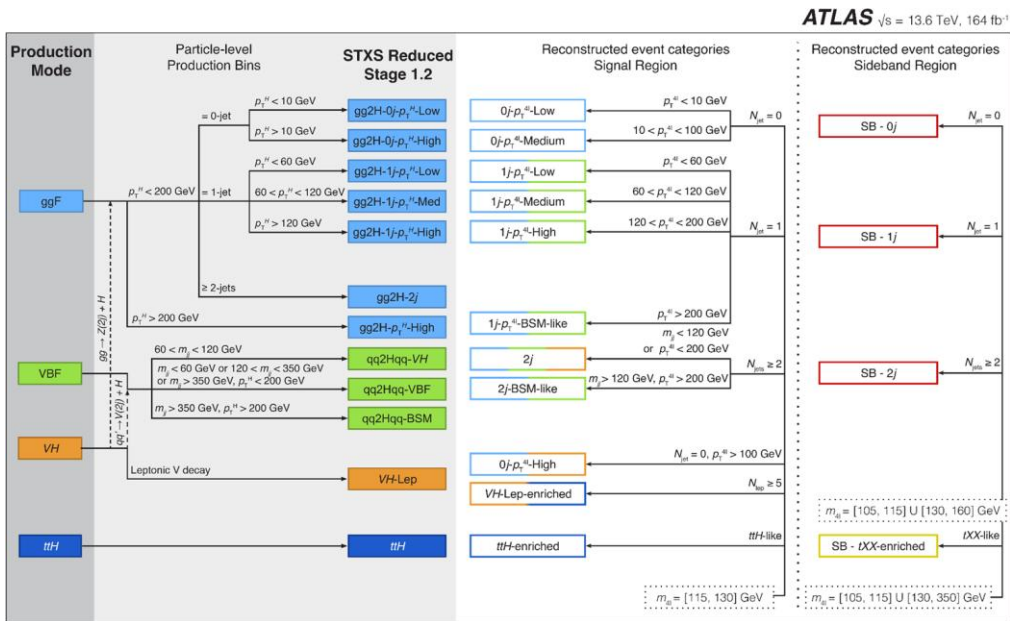


Decay channel	Branching ratio	Uncertainty [%]
$H \rightarrow b\bar{b}$	5.81×10^{-1}	± 1.7
$H \rightarrow WW^*$	2.15×10^{-1}	+2.2 / -2.1
$H \rightarrow gg$	8.18×10^{-2}	+7.3 / -7.2
$H \rightarrow \tau\bar{\tau}$	6.26×10^{-2}	± 2.3
$H \rightarrow c\bar{c}$	2.88×10^{-2}	+6.6 / -2.8
$H \rightarrow ZZ^*$	2.64×10^{-2}	+2.2 / -2.1
$H \rightarrow \gamma\gamma$	2.27×10^{-3}	+2.9 / -2.8
$H \rightarrow Z\gamma$	1.54×10^{-3}	+6.8 / -6.9
$H \rightarrow \mu\bar{\mu}$	2.17×10^{-4}	± 2.4

(assumes $m_H = 125.09$ GeV)

[arXiv:1610.07922](https://arxiv.org/abs/1610.07922)

Run 3 $H \rightarrow ZZ^* \rightarrow 4\ell$: Simplified Template Cross Sections

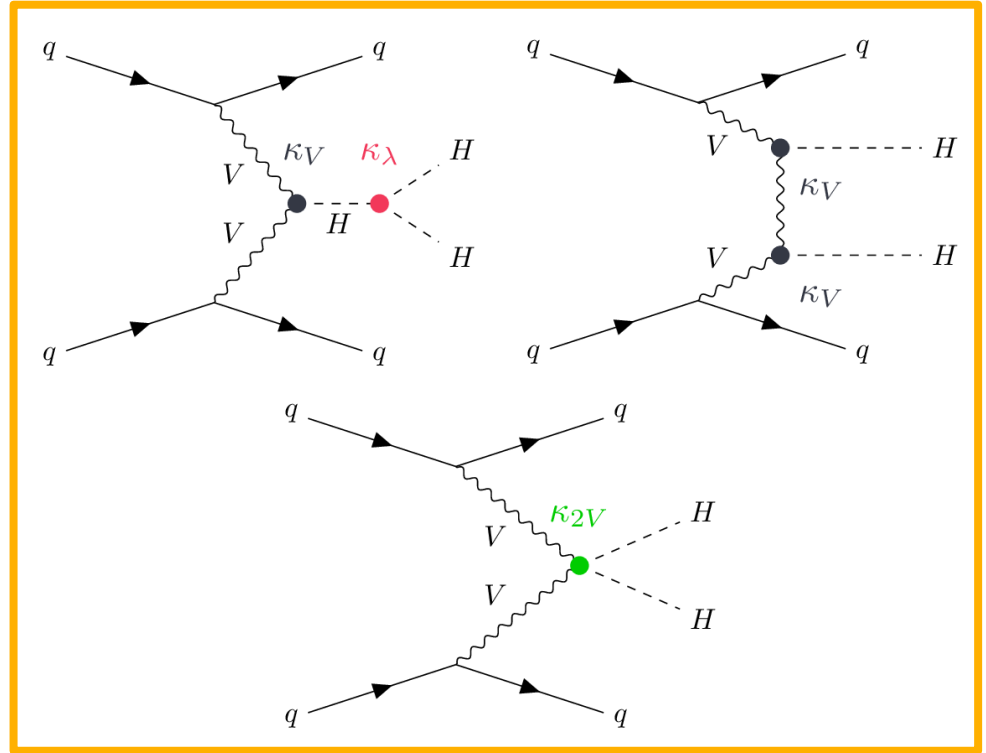
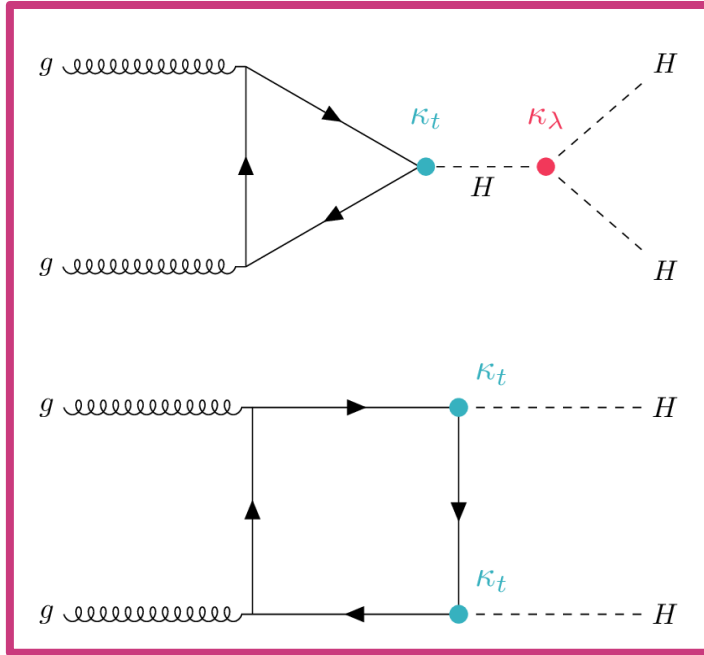


HIGP-2025-09

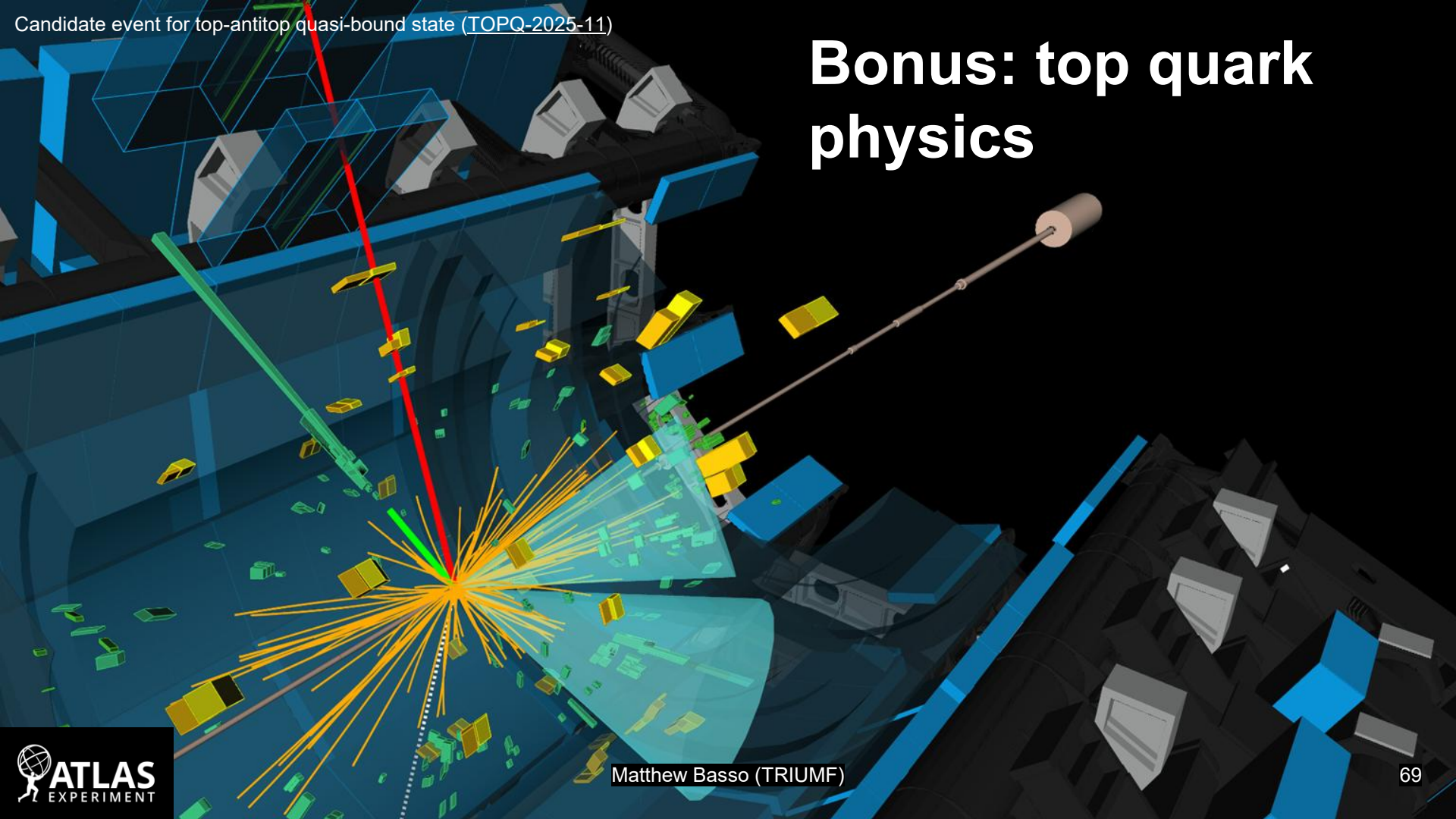
Leading di-Higgs boson production mechanisms

ggF and VBF production

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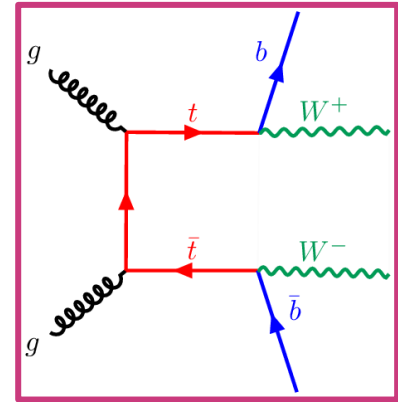
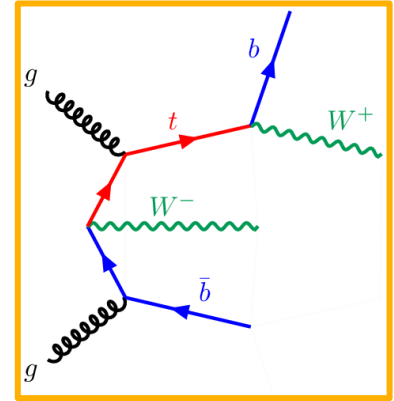


Bonus: top quark physics



Measurements of WbWb production

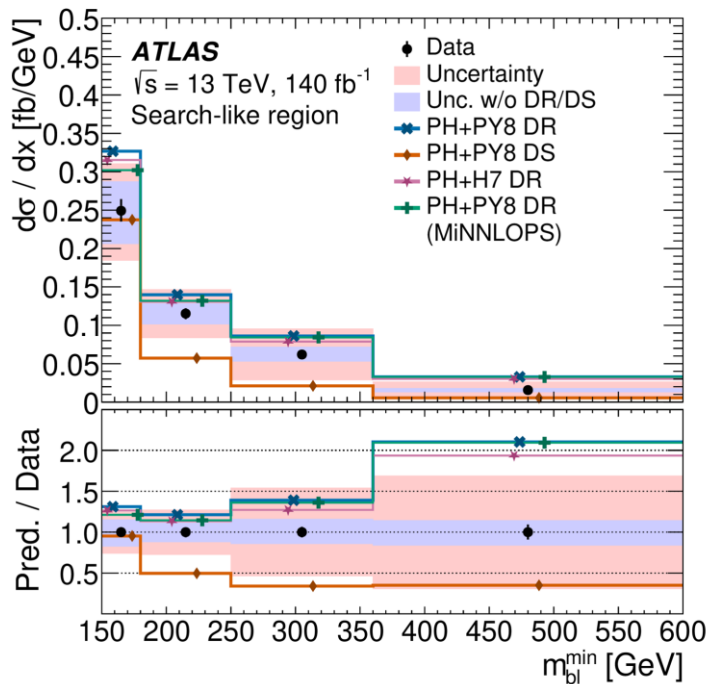
- Theoretical separation of **single** and **double** top quark production subject to arbitrariness relating to treatment of interference and finite width effects
 - **Significant source** of uncertainty for many measurements
 - Coherent treatment of both mechanisms is **desirable**
- WbWb production: arises from single/double top quark processes and processes without top quarks
- ATLAS measured WbWb production in both semileptonic and dileptonic ($e\mu$) final and ≥ 2 jets with bottom quarks
 - Unfolded to yield integrated and differential fiducial cross sections



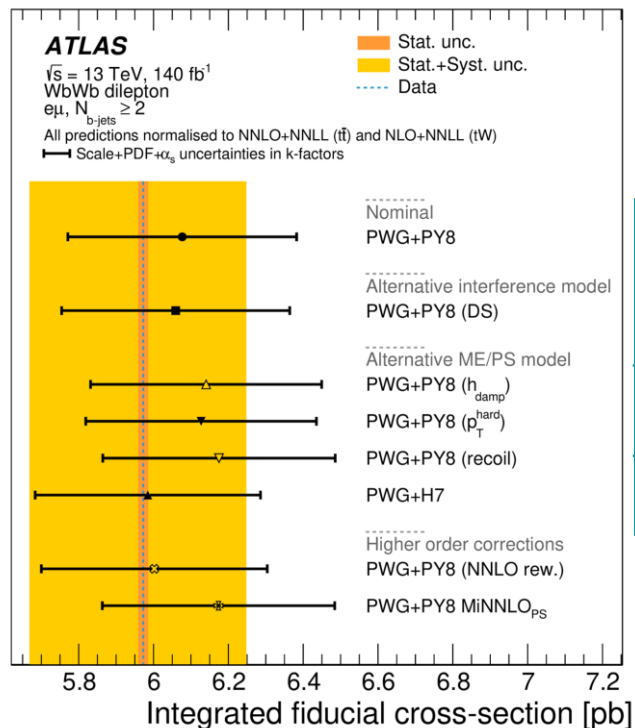
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WbWb cross section results

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Semileptonic channel

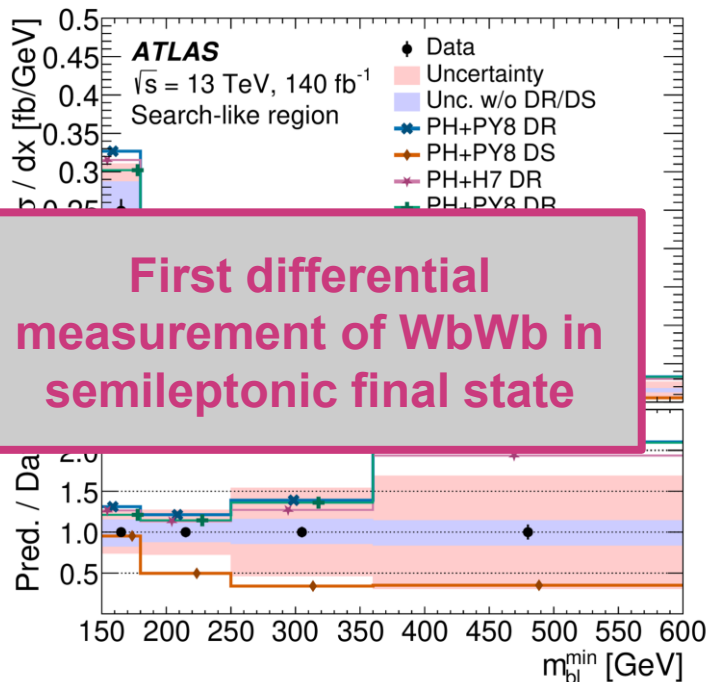


Fully leptonic channel

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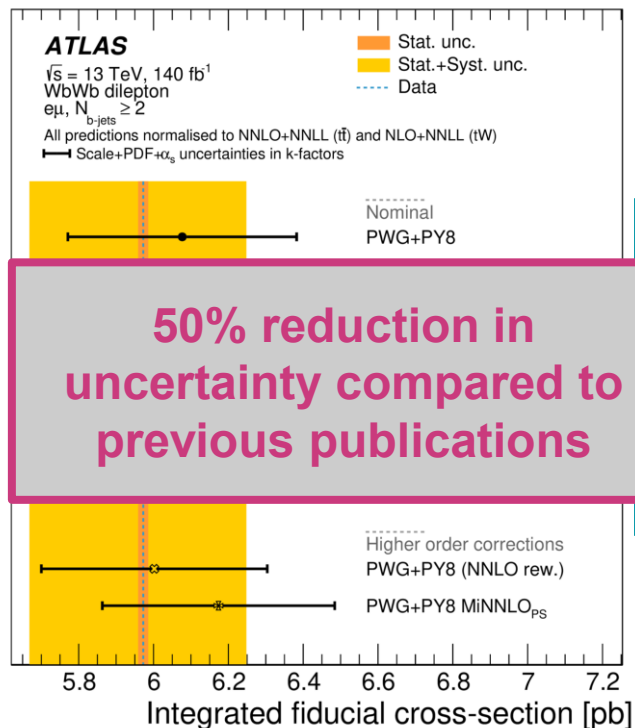
WbWb cross section results

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First differential measurement of WbWb in semileptonic final state

Semileptonic channel



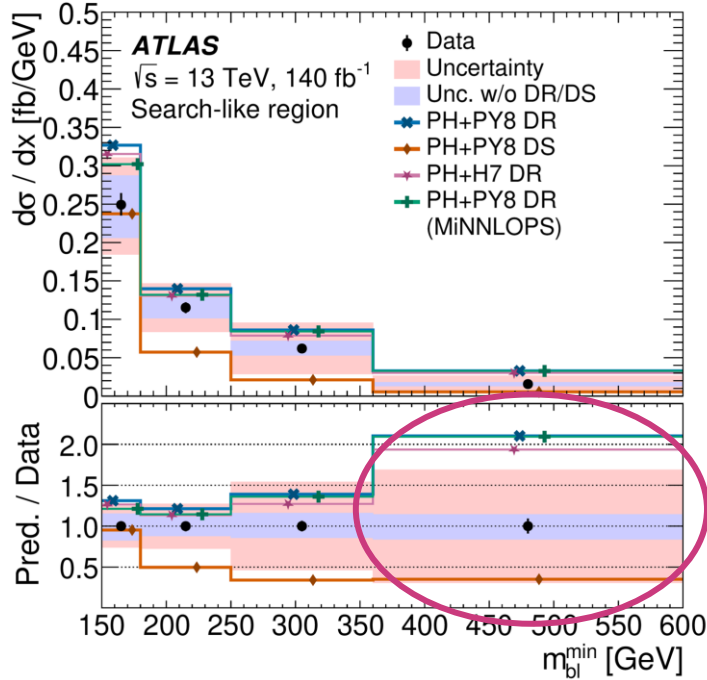
50% reduction in uncertainty compared to previous publications

Fully leptonic channel

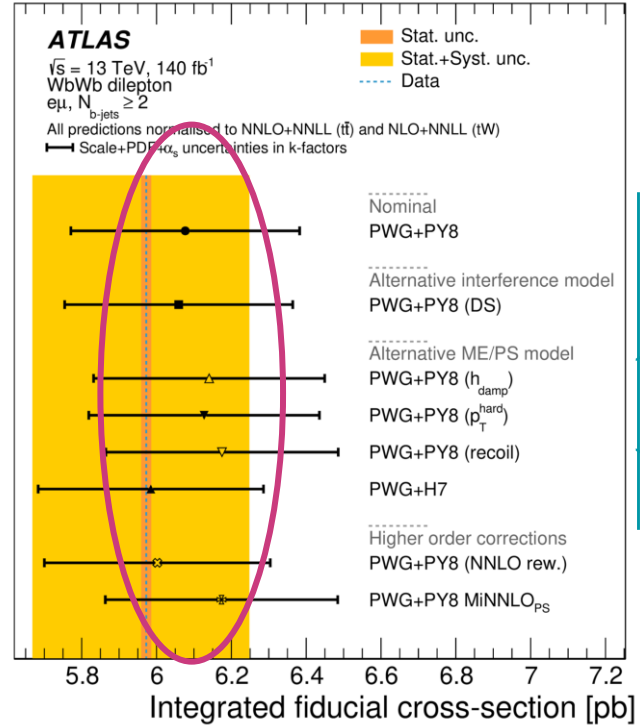
JHEP
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WbWb cross section results

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Semileptonic channel

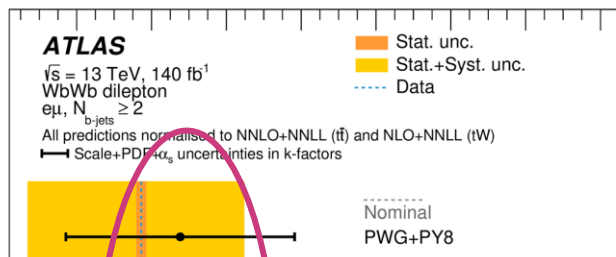
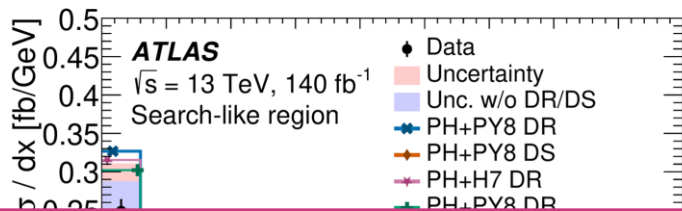


Fully leptonic channel

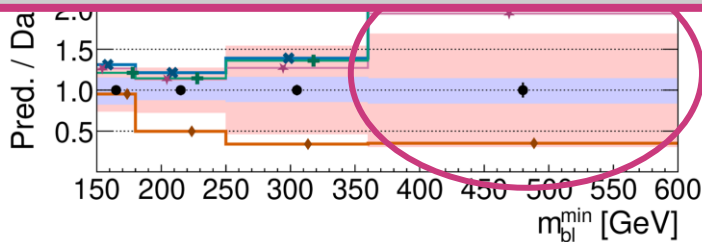
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WbWb cross section results

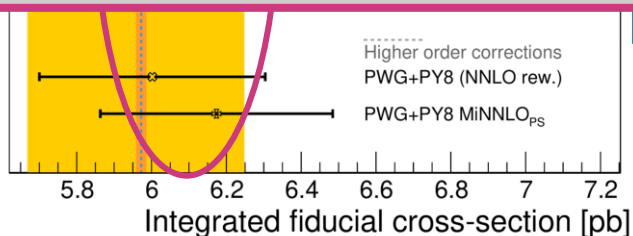
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Studied various models, but none can accurately describe all observables (but mitigated with modelling uncertainties) → results provide valuable input for tuning future simulation



Semileptonic channel



Fully leptonic channel

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