Higgs Hunting 2025, Paris & Orsay, 15-17 July 2025

EFT Measurements at ATLAS

Run 2 Higgs and di-Higgs combinations and path towards a global fit

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On behalf of the ATLAS Collaboration

Introduction

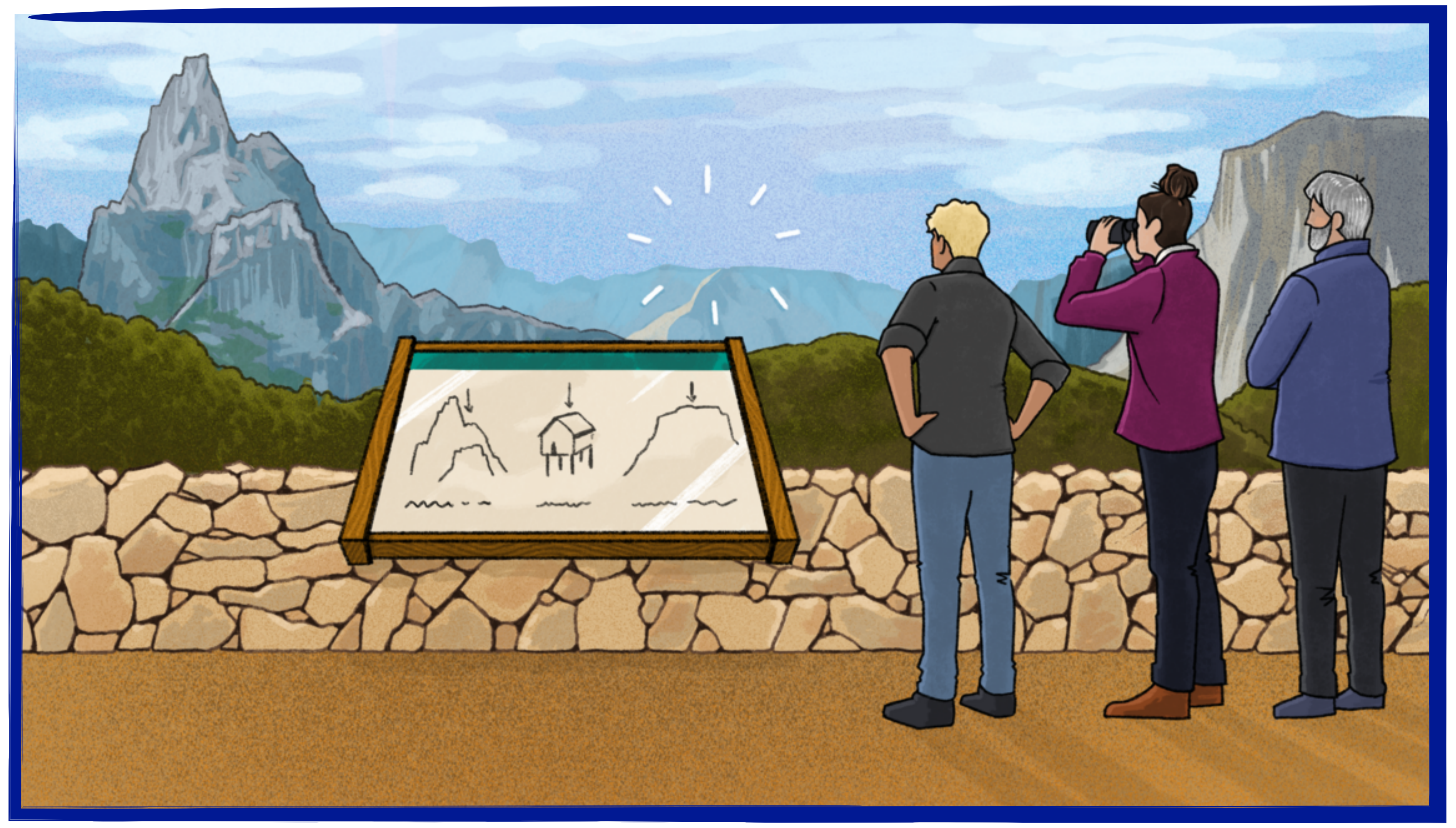
Observation of the Higgs boson by ATLAS and CMS ($H \to \gamma\gamma$ and $H \to ZZ^* \to 4l$ channels)

Ongoing campaign of **measurements** of the Higgs boson **properties**… → **Excellent agreement** with the **Standard Model** (**SM**)!

2012 — 2018 — Now

End of Run 2 = **140 fb^{-1}** of data

Now = **Run 3 ongoing**, reached ≈ **200 fb^{-1}** of data!



- **No new fundamental particles** have been observed at the LHC since the Higgs boson.
- New physics may exist at **higher energy scales**. → **Beyond LHC's reach!**

⇨ **Question**: how can we probe this new physics?

⇨ **Effective Field Theory** (**EFT**) is a **very powerful tool** to probe new physics effects, **without** having to **know exactly** the underlying **UV-complete theory**!

$$\mathcal{L}_{\text{EFT}} = \mathcal{L}_{\text{SM}-\text{like}} + \sum_i \frac{c_i^{(d)}}{\Lambda^{d-4}} \mathcal{O}_i^{(d)} + \cdots$$

Dimensionless Wilson coefficient, describes the "strength" of the anomalous interaction.

Operator of dimension *d*, describing the new physics interactions.

Describes SM-like interactions (might simplify SM structure)

Energy scale where new physics manifests.

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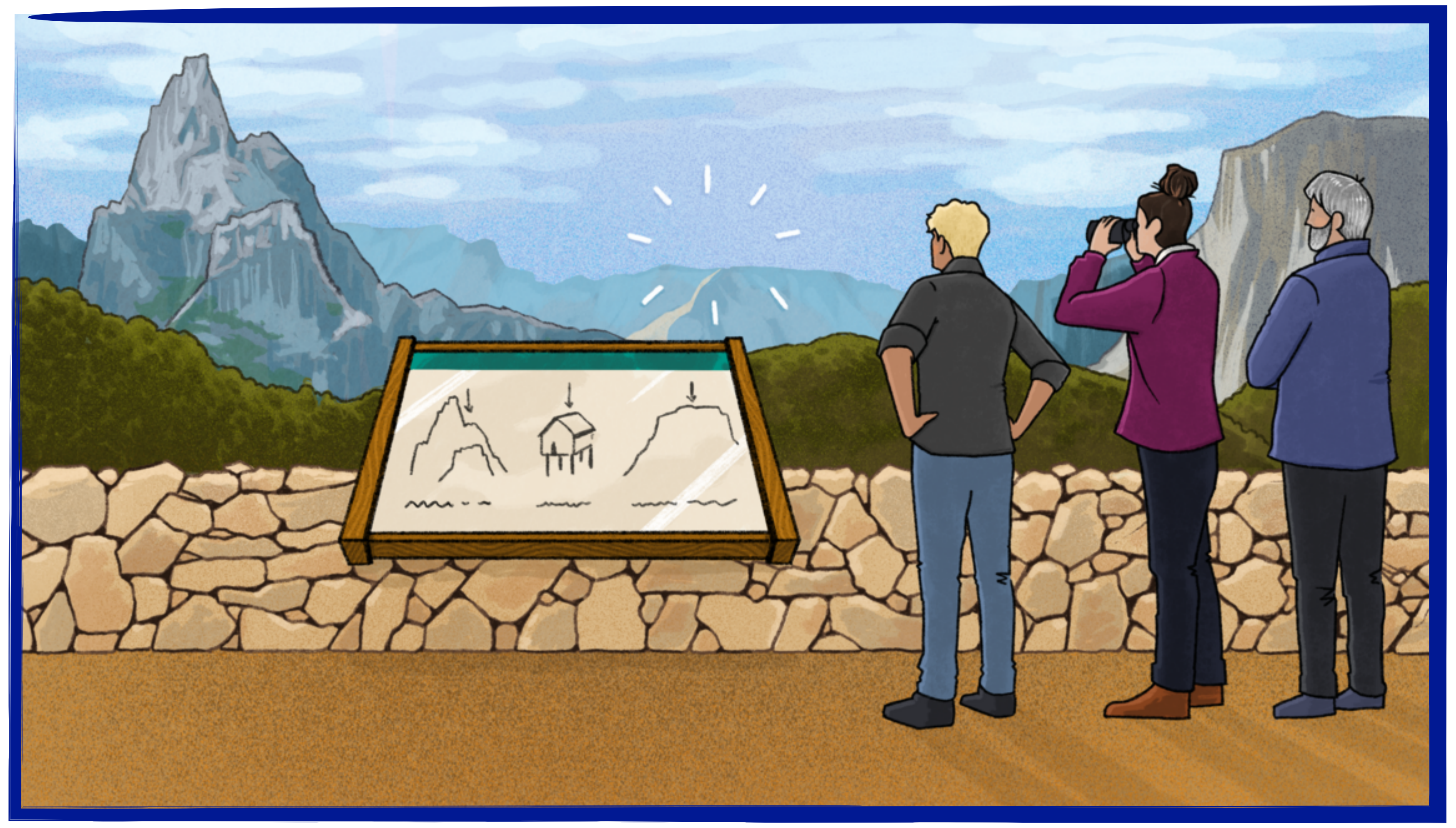

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$$\mathcal{L}_{\mathrm{EFT}} = \mathcal{L}_{\mathrm{SM-like}} + \sum_i \frac{C_i^{(d)}}{\Lambda^{d-4}} \mathcal{O}_i^{(d)} + \cdots$$

- Parametrization of new physics in terms of **Wilson coefficients** × **local operators**, to capture its low energy effects. → $\ll \Lambda$!
- **Works better** when there is a **lot of data** available to **constrain several Wilson coefficients**!

Natural to combine different processes & final states!

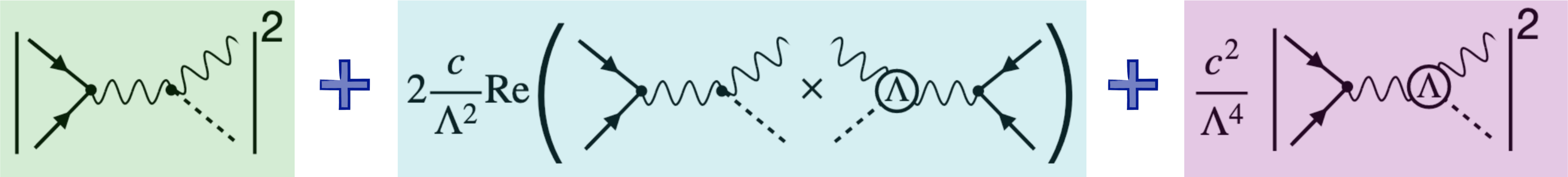
SMEFT parametrisation for Higgs boson cross section and decay rates

$$\mathcal{L}_{SMEFT} = \mathcal{L}_{SM} + \sum_i \frac{\mathcal{C}_i^{(6)}}{\Lambda^2}\mathcal{O}_i^{(6)}$$

- **SMEFT expansion** of the Lagrangian including operators **up to dimension-6**.
- **New physics scale** set to **Λ = 1 TeV**.
- "**Warsaw**" basis used, preserving SM gauge symmetries.

Linear term. **Quadratic term.**

$\sigma_{SMEFT} \approx$



SM

Interference between the SM and BSM physics (= described by dim.-6 operator C_i).

Purely BSM contribution + interference between SM and 2 dim.-6 operators

- Missing contribution of interference between SM and dim.-8 operators at order Λ^{-4}.

- **Both σ_{SMEFT}** and the **inclusive** and **partial Higgs boson decay width** (divided by the corresponding SM quantities) can be written as second-order polynomials of Wilson coefficients.
  - "**Signal strength**" for **H→X signal** with **production mode** i in **particle-level kinematic bin** k':

$$\mu_{i,k'}^{H\rightarrow X} = \frac{(\sigma \times \mathcal{BR})_{i,k'}^{H\rightarrow X}|_{SMEFT}}{(\sigma \times \mathcal{BR})_{i,k'}^{H\rightarrow X}|_{SM}}$$

= truncated to a linear ($\propto \mathcal{O}(\Lambda^{-2})$) + quadratic ($\propto \mathcal{O}(\Lambda^{-4})$) term.

HEFT parametrisations for di-Higgs couplings

$$\mathcal{L}_{HEFT} = \mathcal{L}_0 + \Delta\mathcal{L} + \cdots$$

- SM-like Lagrangian.
- The **Higgs** field is a **complex scalar singlet = no SU(2)$_L$ doublet** structure.
  - ➡ All the **Higgs couplings** are **parametrised independently**.

- **Deviations** from "leading order" Lagrangian.
- Validity regime allows to probe **larger deviations from SM** w.r.t. SMEFT.
  - ➡ **HH** is ideal for testing **BSM effects in HEFT**.
    - ➡ **Disentangled** from **single Higgs couplings** = already constrained to be SM-like.

Terms relevant for ggF HH production

$$\mathcal{L}_{HEFT} = -\, m_t \left(c_{tth}\frac{h}{v} + c_{tthh}\frac{h^2}{v^2} \right) \cdot t\bar{t}$$

$$- \, c_{hhh}\frac{2m_h^2}{v^2}h^3 \longrightarrow \text{Trilinear self-coupling.}$$

$$+ \frac{\alpha_s}{8\pi}\left(c_{ggh}\frac{h}{v} + c_{gghh}\frac{h^2}{v^2} \right) \cdot G^a_{\mu\nu}G^{a,\mu\nu}$$

- Deviations in c_{ggh} and c_{tth} w.r.t. 1 affect strongly single Higgs production.
  - ➡ **Weakly constrained in HH analyses.** ⟶ **Fixed to SM.**
- ggF HH cross section is a second-order polynomial of c_{hhh}, c_{tthh}, and c_{gghh}.
  - ➡ **Signal yields and kinematics parametrised** as functions of HEFT couplings using weights derived using σ_{HEFT} / σ_{SM} as a function of di-Higgs invariant mass $\mathbf{m_{hh}}$.

Outline

1. SMEFT interpretation in CP-violating scenarios with Run 2 data

- VBF H→ττ differential cross sections [JHEP 03 (2025) 010] & CP properties [arXiv:2506.19395] **measurements**
  - VBF variables (= $\Delta\phi_{jj}^{signed}$ and p_T^H) & Optimal Observables sensitive to BSM effects. → **Modified** by CP-even and CP-odd Wilson coefficients = C_{HW}, C_{HB}, C_{HWB} and $C_{H\tilde{W}}$, $C_{H\tilde{B}}$, $C_{H\tilde{W}B}$.

- ggF + VBF H→WW*→ℓνℓν STXS$_{CP}$ [arXiv:2504.07686] **measurements**
  - Additional **step in STXS binning**, using $\Delta\phi_{jj}^{signed}$ variable (= affecting mostly VBF production and sensitive to BSM effects).
    - **Sensitive to CP-even** and **CP-odd** Wilson coefficients = C_{HG}, C_{HW}, and $C_{H\tilde{G}}$, $C_{H\tilde{W}}$.

Outline

2. Run 2 Higgs combination [JHEP 11 (2024) 097]

STXS and **differential cross section** measurements from the combination of **all available Higgs decay channels** interpreted using the **SMEFT parametrisation**.

Most complete picture of **subtle BSM effects** in **Higgs physics** via EFT interpretations in Run 2 data! 🎉

3. Run 2 di-Higgs combination [Phys. Rev. Lett. 133 (2024) 101801]

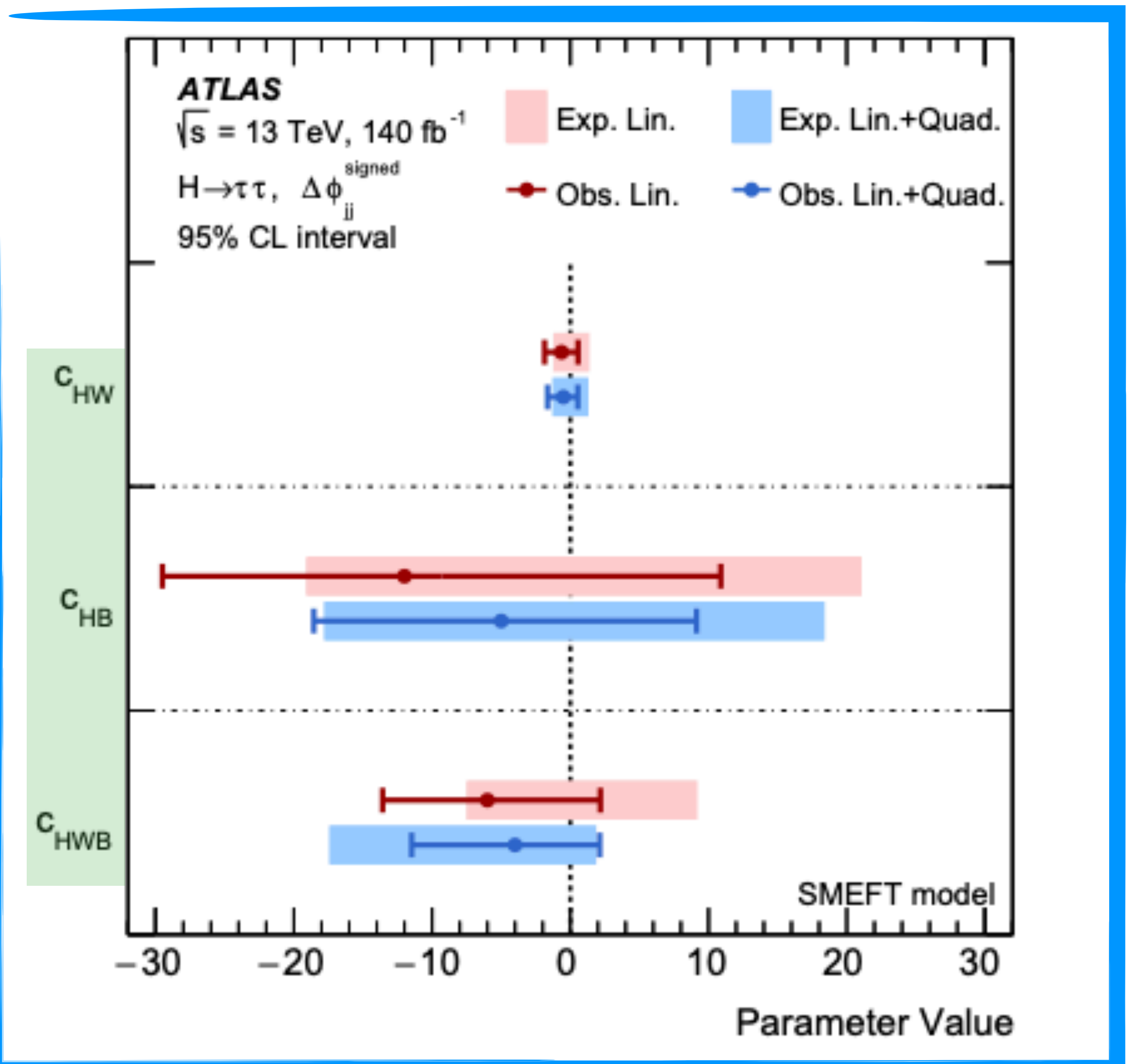
- **Constraints** on **ggF HH cross section** (using the **bbbb**, **bbττ**, and **bbγγ** channels) are reinterpreted using the **HEFT parametrisation**.

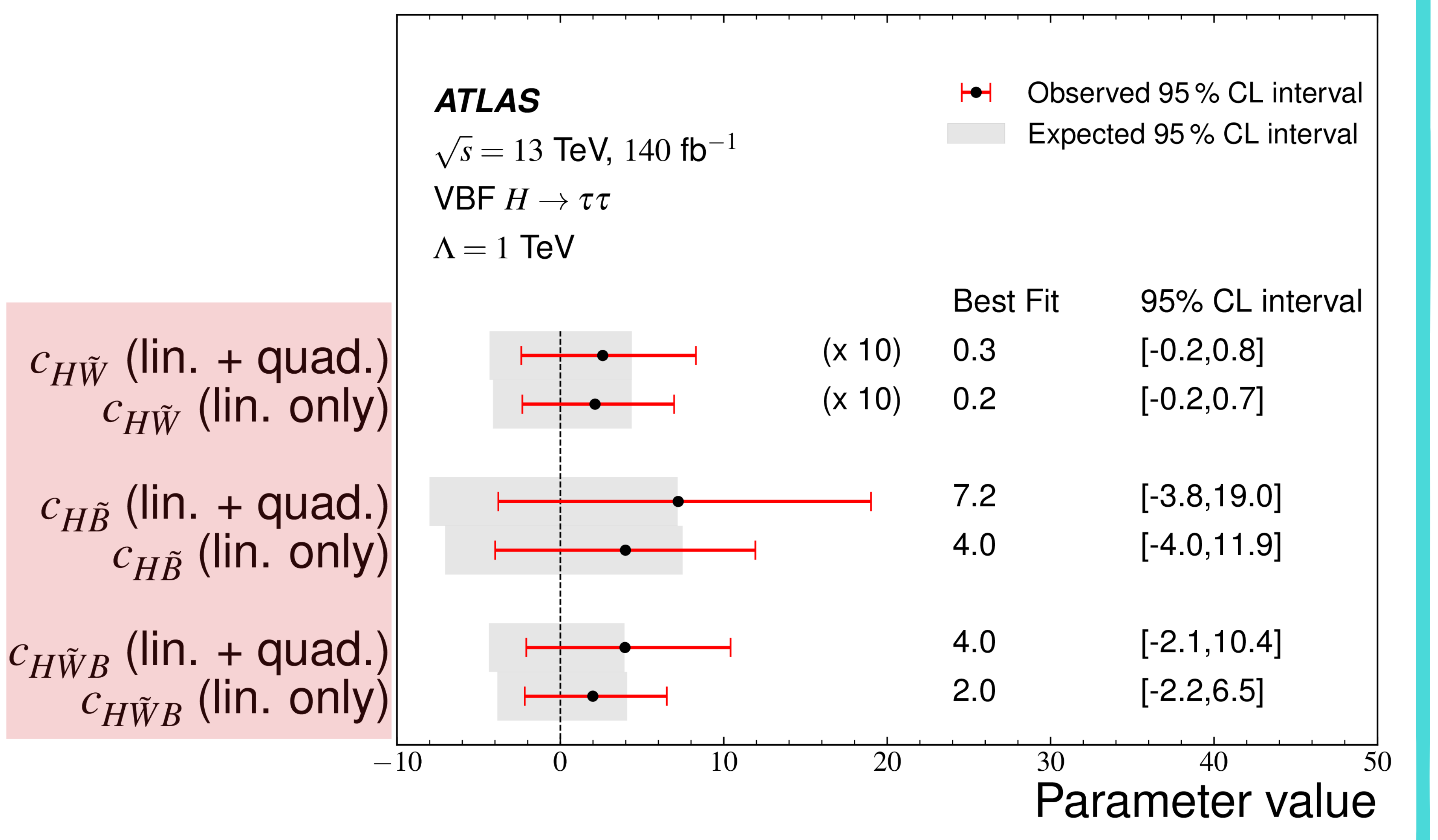
Sensitive to c_{gghh}, c_{tthh}, and c_{hhh}. → Affecting only HH production.

SMEFT interpretation in CP-violating scenarios with Run 2 data

1-dimensional measurements

JHEP 03 (2025) 010 arXiv:2506.19395 arXiv:2504.07686

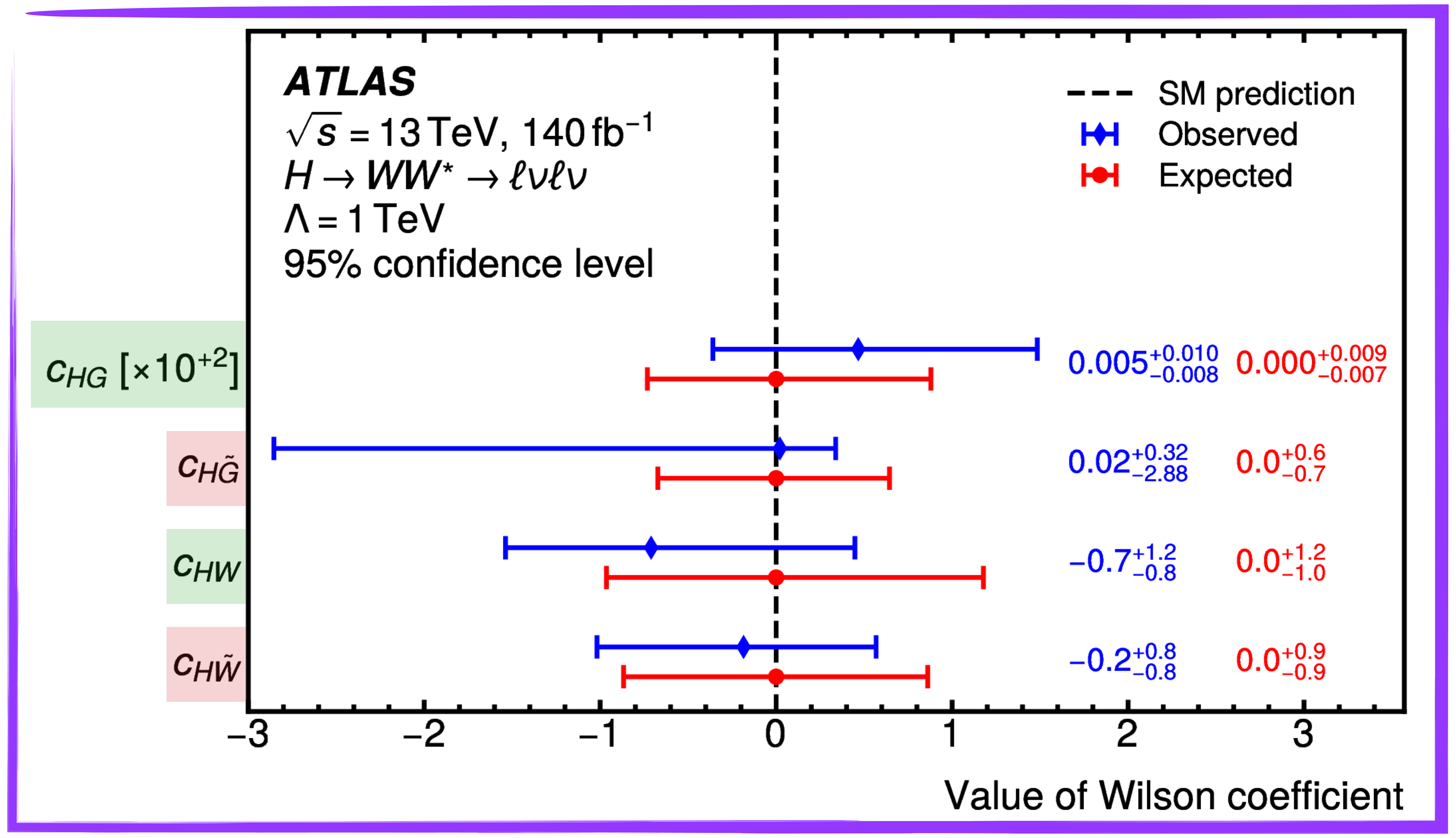




- Constraints on **CP-even** and **CP-odd** **Wilson coefficients** extracted from **VBF $H\rightarrow\tau\tau$ differential cross section** and **CP properties** measurements.

  ➡ Each coupling treated **individually**.

- Both **linear only** and **linear + quadratic** SMEFT terms **considered**.
- **Tightest constraints** on $C_{H\tilde{W}}$ from **VBF $H\rightarrow\tau\tau$ CP measurement**! 🎉

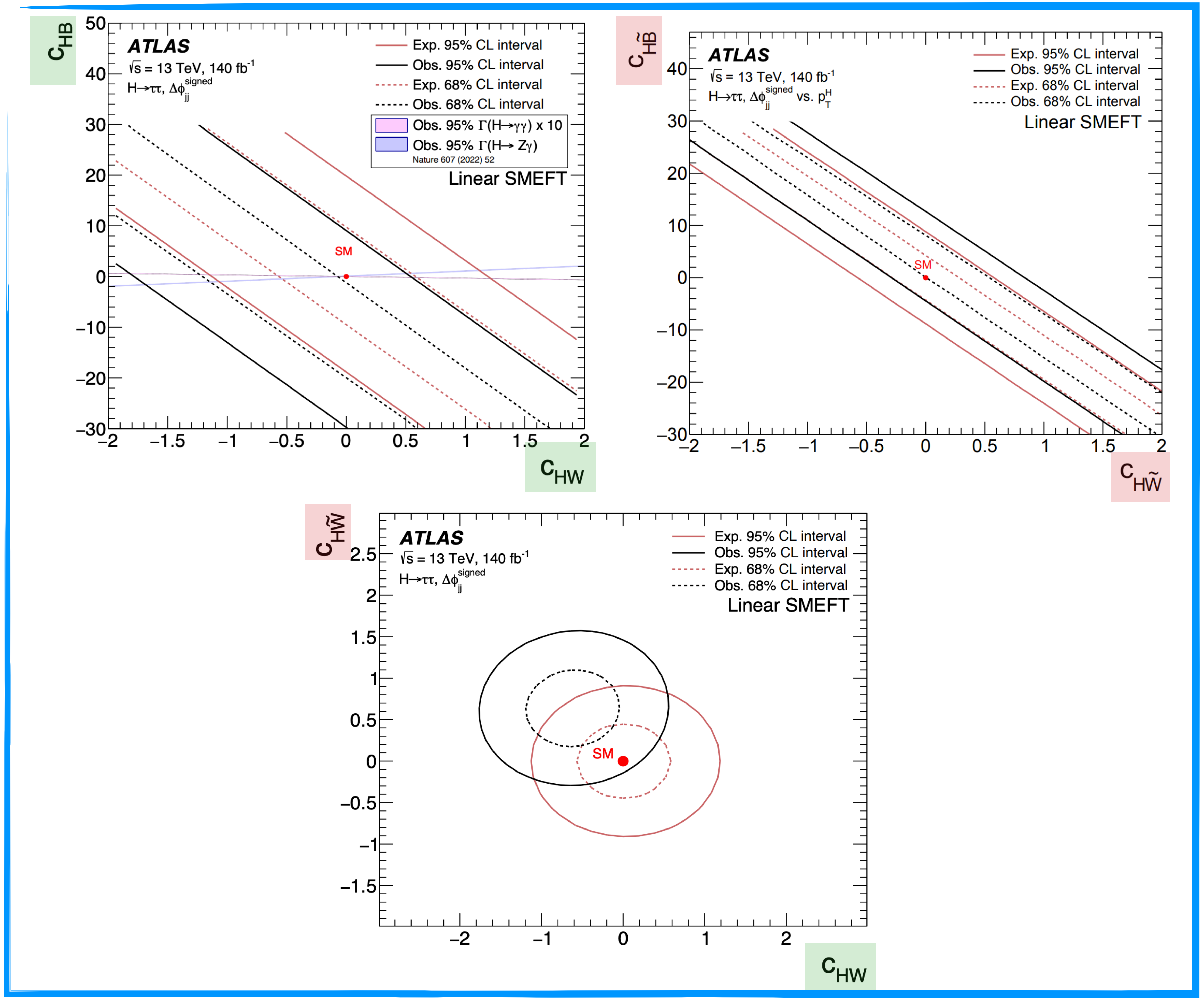


- Constraints on **CP-even** and **CP-odd** **Wilson coefficients** extracted from **$H\rightarrow WW^*\rightarrow \ell\nu\ell\nu$ STXS$_{CP}$** measurement.

  ➡ All couplings fitted **simultaneously**.

- Both **linear only** and **linear + quadratic** SMEFT terms **considered.**
- **Comparable** sensitivity on C_{HG} and **significantly enhanced sensitivity (~ $\times 2$) on** C_{HW} compared w.r.t. STXS interpretation of the same channel.

2-dimensional measurements



- **From VBF H→ττ differential cross sections [JHEP 03 (2025) 010].**
- Linear only SMEFT parametrisation.
- (C_{HW}, C_{HB}) and ($C_{H\tilde{W}}$, $C_{H\tilde{B}}$) **planes**:
  - Effects of the **two operators cancel out** in one "**flat direction**" in the 2-dimensional plane.
    - **No sensitivity** there!
    - **Crucial** to **combine** with other analyses, which have a different "flat direction".
- (C_{HW}, $C_{H\tilde{W}}$) **plane**:
  - The two **operators modify differently** the $\Delta\phi_{jj}^{signed}$ **shape**.
    - **Effects** do **not cancel out**.
    - **No loss of sensitivity**.

Run 2 Higgs combination

Inputs to the combination

JHEP 11 (2024) 097

Decay channel	Analysis Production mode	$\mathcal{L}$ [fb^{-1}]	Binning
$H \to \gamma\gamma$	(ggF, VBF, WH, ZH, ttH, tH)	139	STXS-1.2 differential
$H \to ZZ^*$	($ZZ^* \to 4\ell$: ggF, VBF, $WH+ZH$, $ttH+tH$)	139	STXS-1.2 differential
	($ZZ^* \to \ell\ell\nu\bar{\nu}/\ell\ell q\bar{q}$: ttH multileptons)	36.1	STXS-0*
$H \to \tau\tau$	(ggF, VBF, $WH+ZH$, $ttH+tH$)	139	STXS-1.2
	(ttH multileptons)	36.1	STXS-0*
$H \to WW^*$	(ggF, VBF)	139	STXS-1.2
	(WH, ZH)	36.1	STXS-0*
	(ttH multileptons)	36.1	STXS-0*
$H \to bb$	(WH, ZH)	139	STXS-1.2
	(VBF)	126	STXS-1.2
	($ttH+tH$)	139	STXS-1.2
	(boosted Higgs bosons: inclusive production)	139	STXS-1.2
$H \to Z\gamma$	(inclusive production)	139	STXS-0*
$H \to \mu\mu$	(ggF + ttH + tH, VBF + WH + ZH)	139	STXS-0*

Combination of **three types of Higgs boson measurements** for **different decay channels**:

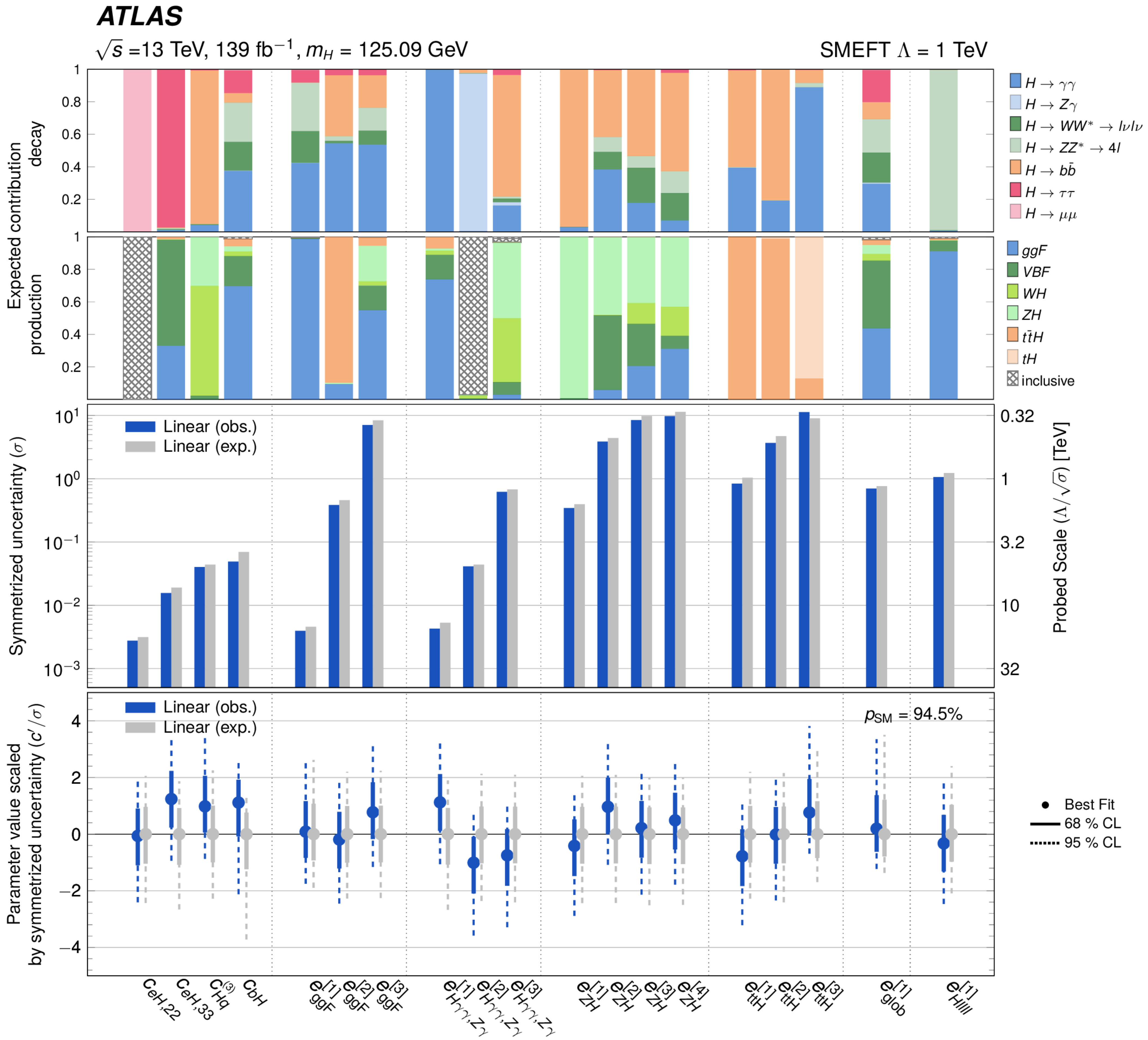
1. **Inclusive cross section** measurement (= STXS-0*).
2. **Cross section** and **decay rates measurements** in granular STXS bins (= STXS-1.2).
3. **Differential cross section** measurements as a function of p_T^H (= differential).

SMEFT interpretation of STXS measurements

JHEP 11 (2024) 097

STXS measurements **interpreted** using a **modified set of Wilson coefficients**, w.r.t. the standard "Warsaw" basis.

$\{\mathcal{C}_i\}_{i=1}^{54} \Rightarrow \{\mathcal{C}'_j\}_{j=1}^{19}$ → **Best compromise** between **interpretability** and **ability to set meaningful constraints** with the available data (see backup for details)!



1-dimensional measurements using linear SMEFT terms

- For each measurement, all the **other Wilson coefficients** are **profiled** on data.
- **Uncertainties** range from ~10^{-3} to ~10.
  - Most measurements still **stat. dominated**.
    - Larger effects of syst. unc. on $c_{eH,33}$, e_{glob}, and e_{HIll}[1].

H→ZZ* coupling

H→ττ coupling

- Including **quadratic terms** typically results in **best-fit value compatible w.r.t. linear only terms** (except for $e_{H\gamma\gamma Z\gamma}$[1]).
  - Quadratic terms also create **more complicated likelihood** shape (with multiple minima).

SMEFT interpretation of differential cross section measurements

- **Differential cross section** as a function of p_T^H from **H→γγ** and **H→ZZ*→4ℓ channels**.
- Parametrisation involves **three Wilson coefficients**:

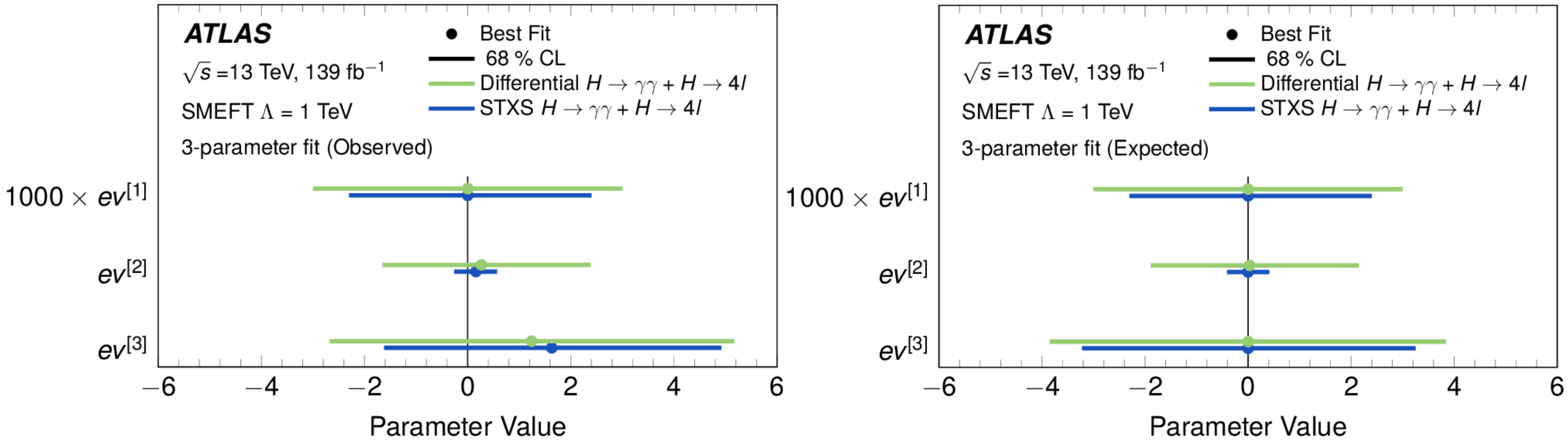
JHEP 11 (2024) 097

C_{HG}	Higgs-gluon point like contact term	- Modifies the ggF cross section and its pTH dependence - Affects the partial width for the H→gg decay
C_{tG}	Chromomagnetic dipole operator (= introducing ttHg vertex)	Modifies ttH production and partial width for H→gg decay
C_{tH}	Top Yukawa coupling modifier	Modifies ttH vertex (contributing to the top quark loop in ggF production and in the H→γγ decay)

Results presented in terms of **new fit basis** which **minimizes correlations**.

➡ **$ev^{[1]}$, $ev^{[2]}$, $ev^{[3]}$.**

➡ Mostly C_{HG}, C_{tG}, C_{tH} respectively.



- **1-dimensional measurements** considering **linear SMEFT** terms.
- **STXS** has typically **better sensitivity** than differential measurement.

➡ **Less granular** in p_T^H, but **able to separate production and decay modes** affected differently by Wilson coefficients.

Mapping to 2HDM model

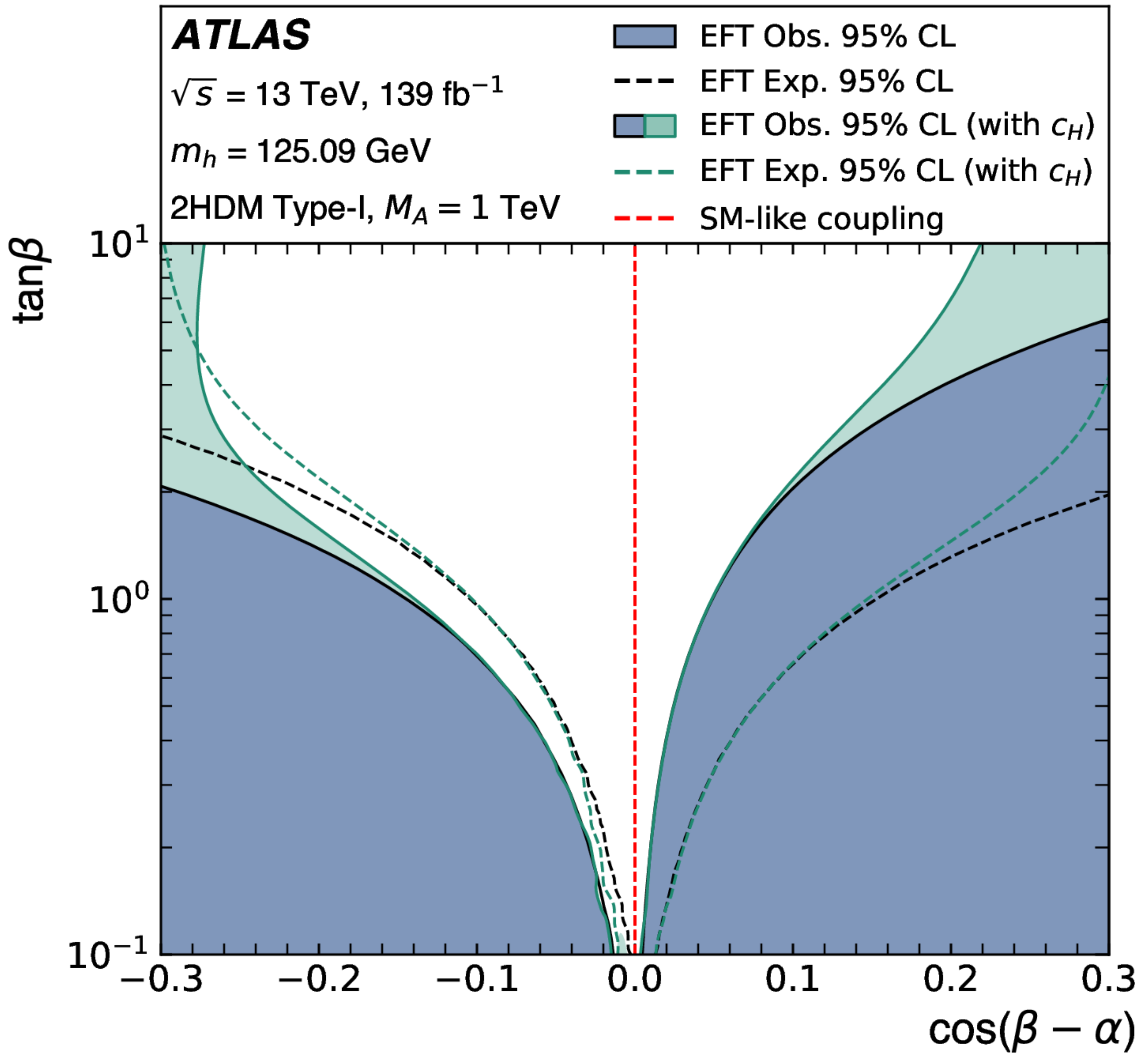
JHEP 11 (2024) 097

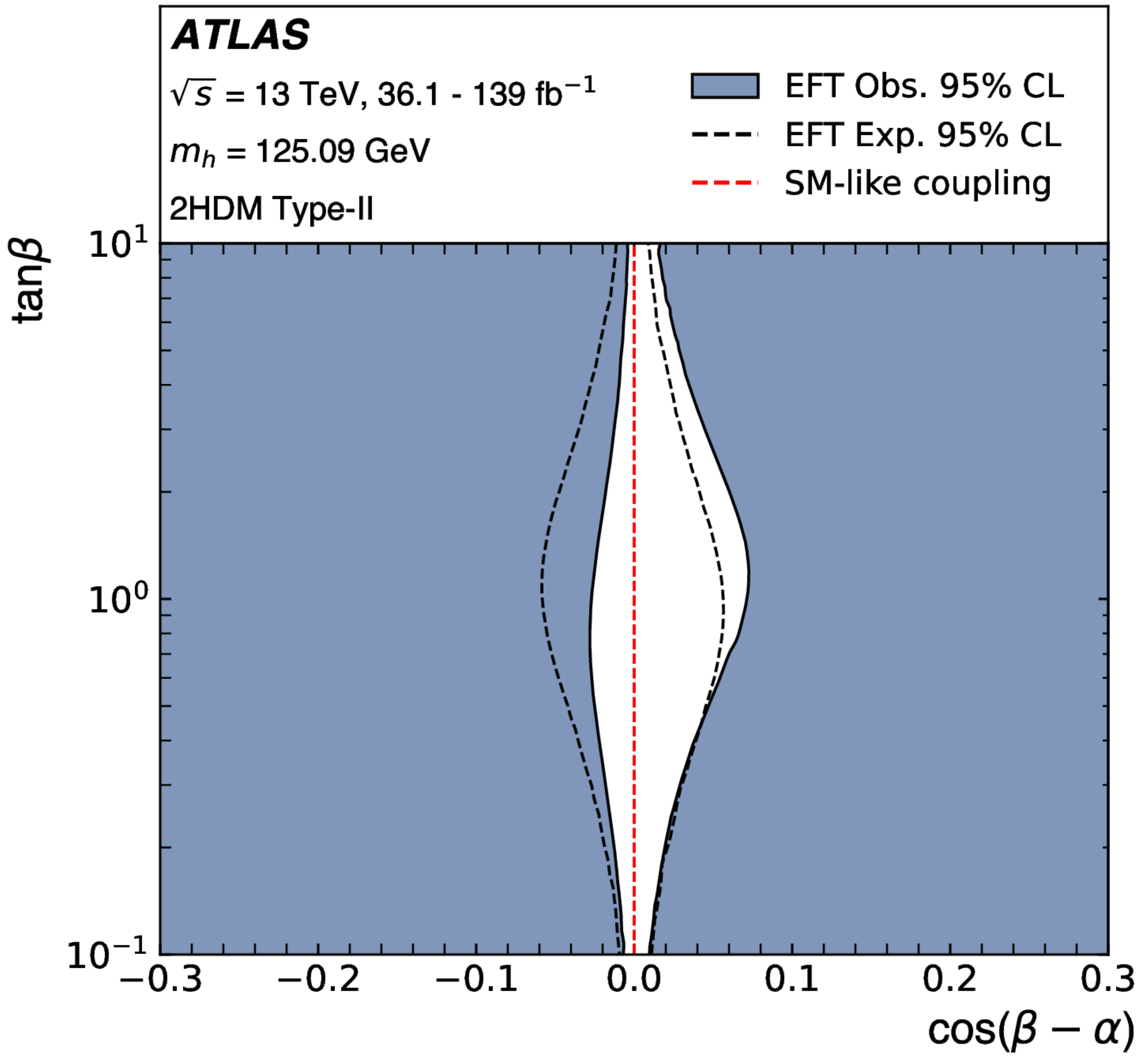
2HDM model → Extension of the SM Higgs sector to **two Higgs fields** (= Φ_1 and Φ_2).

- **Spontaneously broken EW symmetry** with v.e.v. v_1 and v_2.
- 5 physical states (= $h, H, A, H^{\pm}$).
- **2 mixing angles** α (= sector of neutral CP-even h and H) and $\beta = \tan^{-1}(v_1/v_2)$.
- In the **alignment limit (=** $|\cos(\beta-\alpha)| \ll 1$**)**, **$h$ is SM-like**.

→ The **2HDM Lagrangian** can be written as a **SMEFT expansion**!

We can **translate constraints** on Wilson coefficients $\mathscr{C}_{bH}$, $\mathscr{C}_{tH}$, $\mathscr{C}_{\tau H}$, and $\mathscr{C}_{H}$ to **constraints** on **($\cos(\beta-\alpha)$, $\tan\beta$)**.





→ Constraints set on specific UV-complete models using **SMEFT expansion** (= agnostic w.r.t. the exact form of new physics).

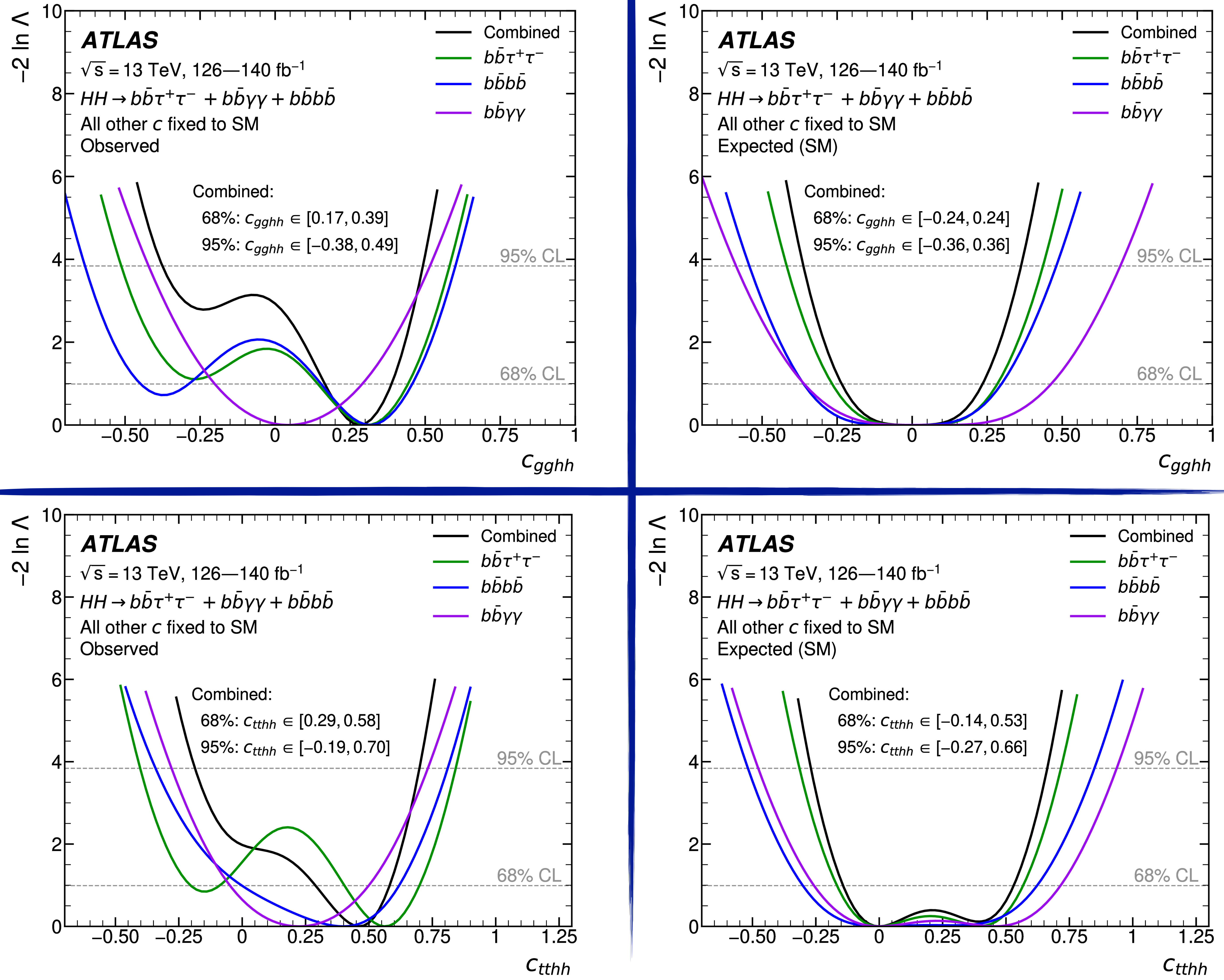
Run 2 di-Higgs combination

HEFT intepretations of ggF HH cross section

Phys. Rev. Lett. 133 (2024) 101801

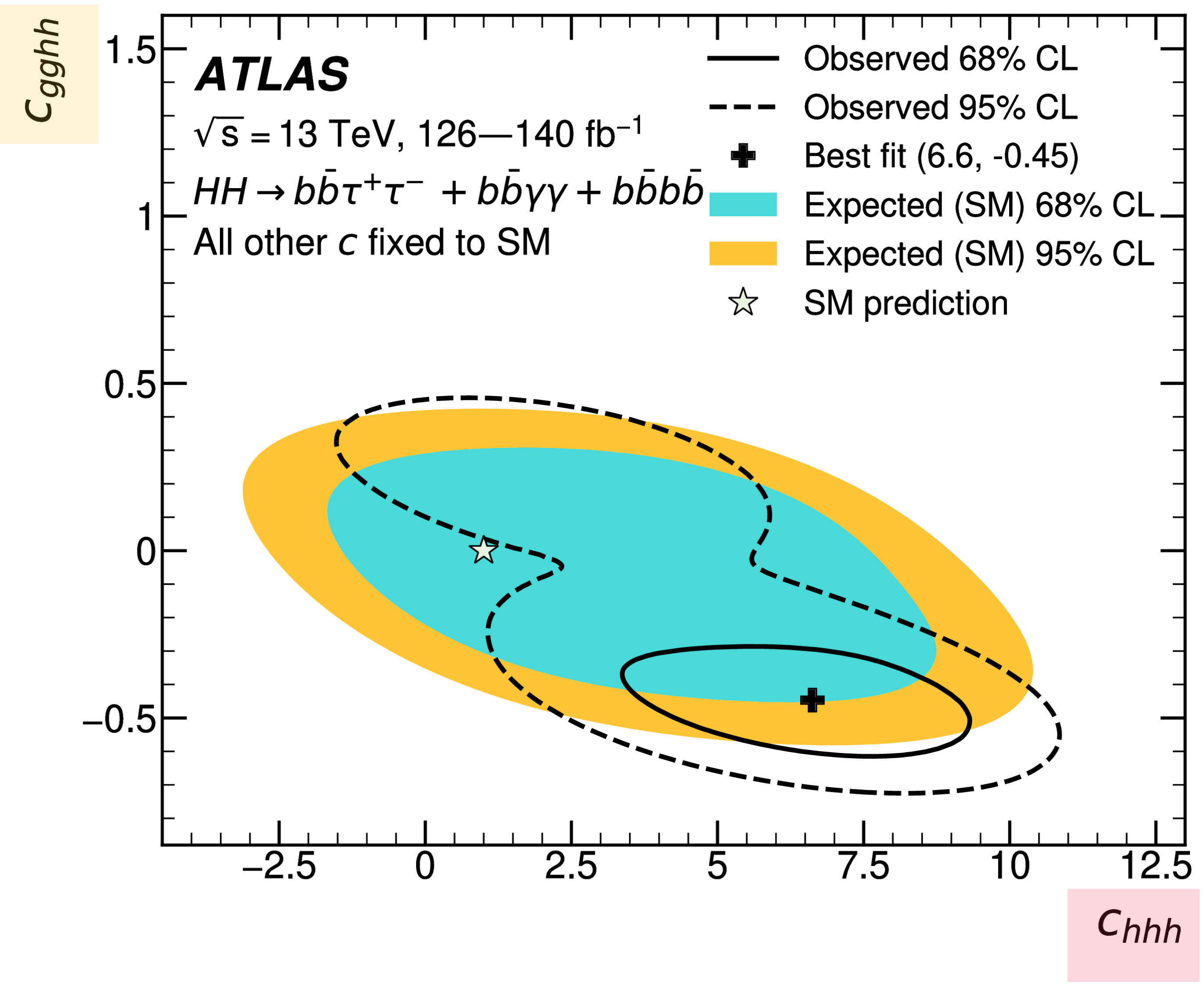
Observed — Expected

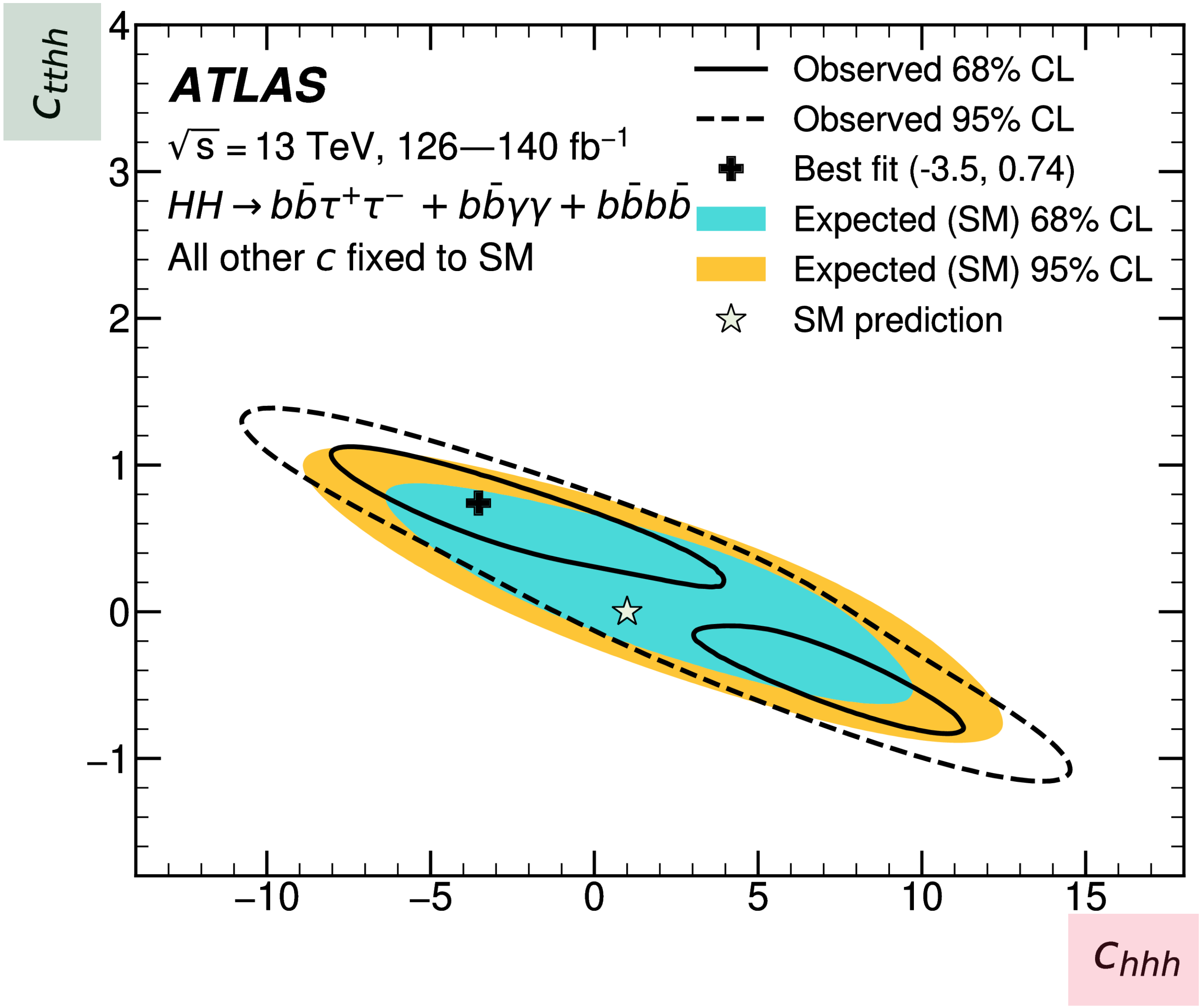
c_{gghh} / c_{tthh}



1-dimensional measurements of HEFT couplings

- **ggF HH cross section** parametrized as a function of c_{gghh} and c_{tthh}.
  - For each measurement, all of the other HEFT couplings are fixed to SM.
- Only three most sensitive final states considered (= **bbττ**, **bbbb**, **bbγγ**).
- Double minima seen for **bbττ** and **bbbb**, for both c_{gghh} and c_{tthh}.
  - Due to quadratic dependence of ggF HH cross section from c_{gghh} and c_{tthh}.
    - Minima can be partially resolved due to difference in shapes!
- **Observed best-fit value** for **bbγγ** found at **minimum** of the ggF HH cross section (**deficit** observed in data w.r.t. SM expectations).

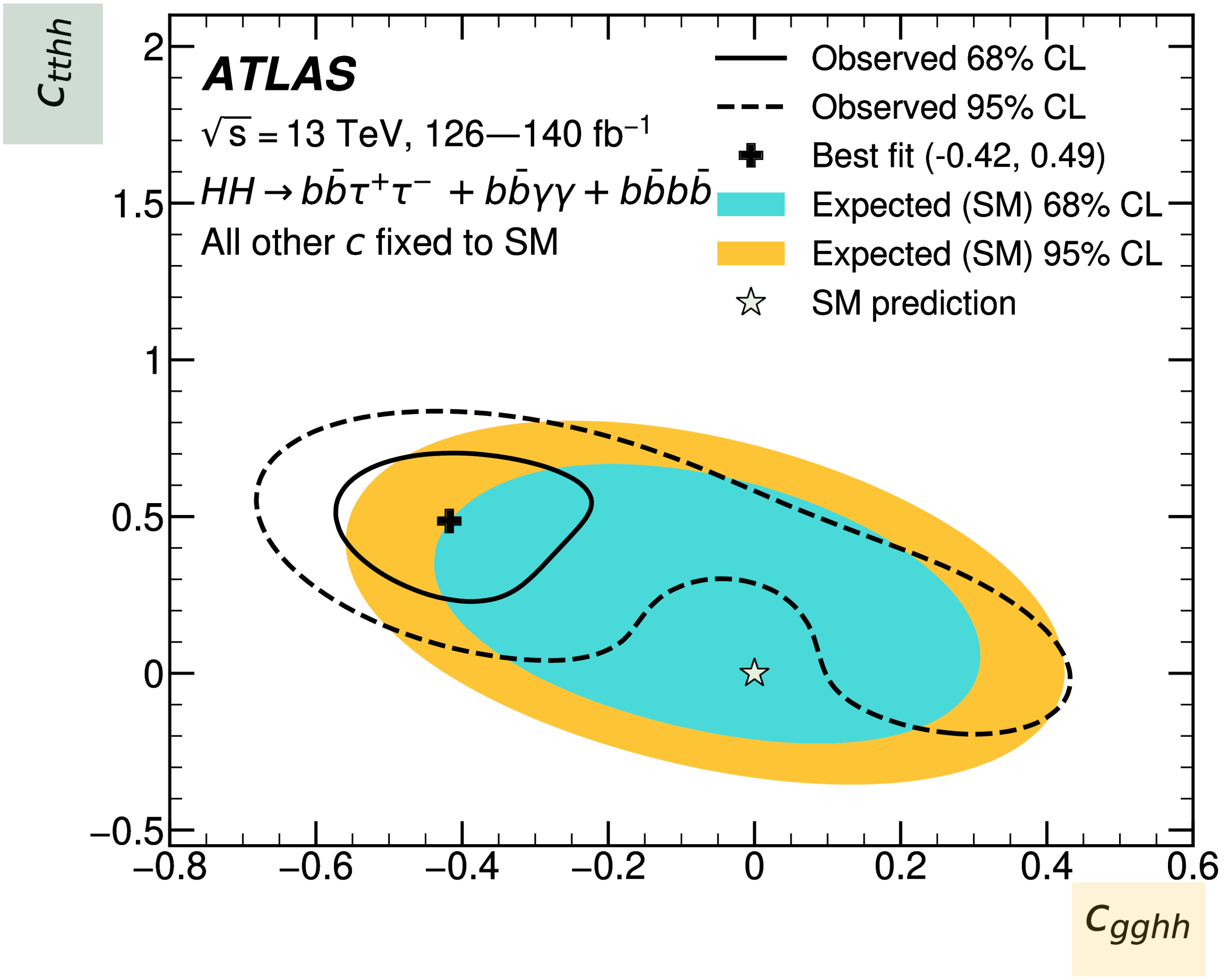




2-dimensional measurements of HEFT couplings

ggF HH cross section parametrized as a function of c_{gghh}, c_{tthh}, and c_{hhh}.

= Trilinear self-coupling.



Summary & outlook

Summary & outlook

- **EFT** is a powerful tool to **probe subtle effects of new physics at low energy**, without having to commit to a precise UV-complete model.

  - **CP-odd operators** in **VBF $H \to \tau\tau$ and $H \to WW^*$**.
  - **Higgs combination.**

  → **SMEFT** →

  - Set of **operators** following SM gauge symmetry.
  - **Acting consistently** on **Higgs & electroweak and top processes**.
  - **Natural choice** when we have **a lot of data** from different processes / final states, to **capture potential small deviations from SM**.

  - **di-Higgs combination.** → **HEFT**

  - Highlights **new physics** effects in **Higgs couplings**.
    - → Defined **independently** from **$SU(2)_L$ doublet** structure.
  - Regime of validity **wider w.r.t. SMEFT**.
    - → Particularly useful in regions of phase space where **BSM effects are still weakly constrained** (e.g. HH production).

- **No evidence** of **new physics** emerges from these analyses. 🙁

Summary & outlook

- **Question:** can we do more?

1. **Global combinations!** → **First ATLAS global SMEFT combination:**
   - Higgs + ATLAS electroweak + precision electroweak @ LEP & SLC (ATL-PHYS-PUB-2022-037).
   - **Crucial to achieve optimal sensitivity to new physics effects.**
     - **Disentangle** effects from different operators.
   - **Challenges:**
     - **Consistent parametrisations** of processes in each input analysis!
       - Constraints on Wilson coefficient might also come from background processes (e.g. $t\bar{t}$ background in Higgs analyses).
     - **Technical side**: harmonisation of systematics, resolving overlaps, …
2. Reinterpreting **Run 3 data**!
   - **SMEFT interpretation** becoming ~**baseline** in many **Higgs cross section measurements** (= see brand new **Run 3 $H\rightarrow ZZ^*\rightarrow 4\ell$ STXS and differential cross section measurement** [ATLAS-CONF-2025-002]).

Thank you for your attention!

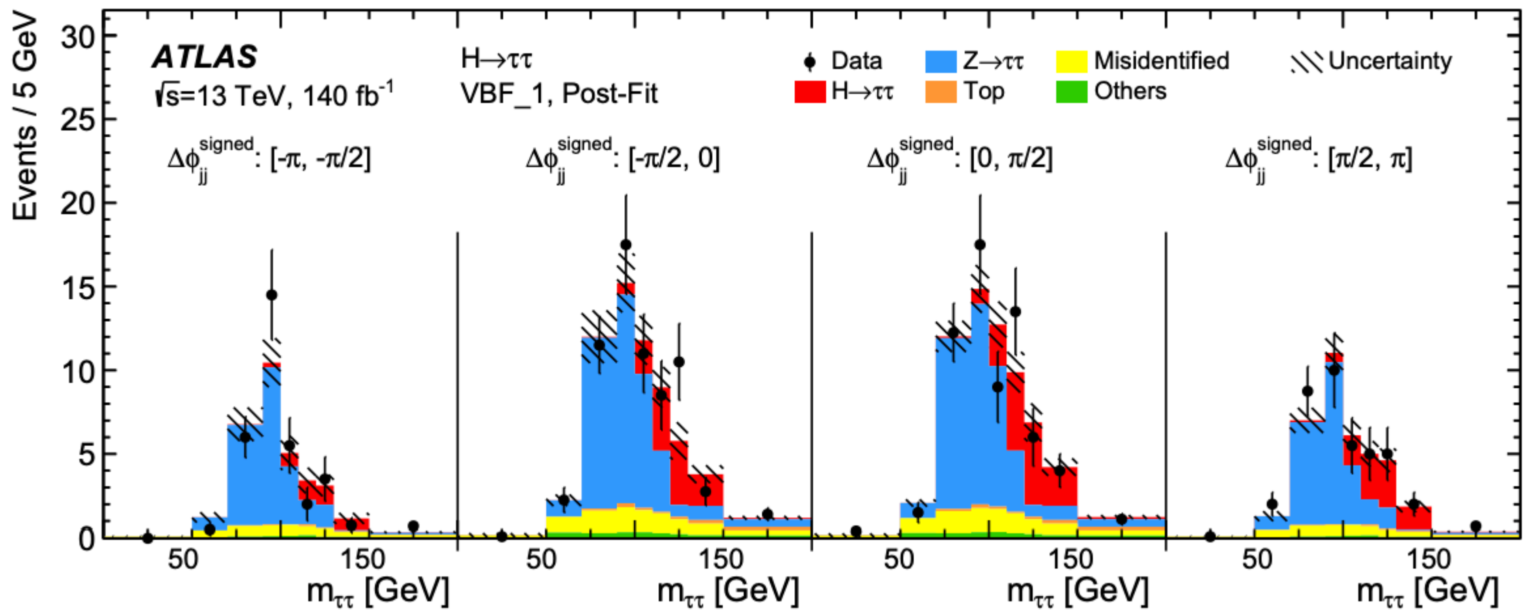
Backup

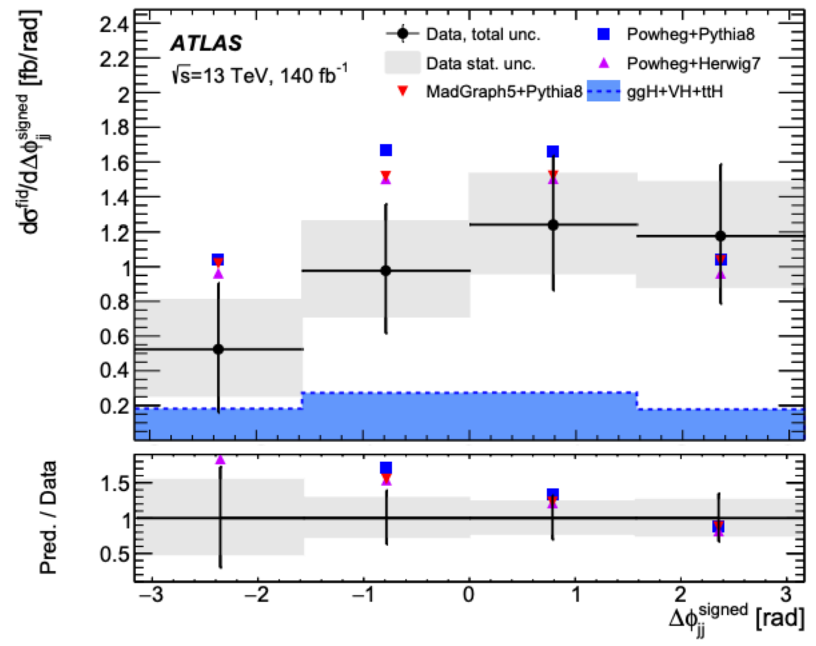
Analysis recipe for VBF H→ττ differential cross sections

[JHEP 03 (2025) 010]

- **Select events** targeting **H→ττ** decay mode.
  - **Four regions** based on **τ decay** + **kinematic requirements** on leptons, jets, E_T^{miss} + ***b*-jet veto**.
    - **$\tau_{had}\tau_{had}$** | No e or μ, 2 $\tau_{had\text{-}vis}$
    - **$\tau_{e(\mu)}\tau_{had}$** | 1 soft e(μ) + 1 $\tau_{had\text{-}vis}$
    - **$\tau_e\tau_\mu$** | 1 soft e + 1 soft μ
- Define **category** targeting **VBF production mode**.
  - 2 high pT, well separated, forward jets with m_{jj} > 600 GeV and $\eta^{j_1} \times \eta^{j_2} < 0$ + lepton centrality + $p_T(Hjj)$ < 60 GeV.
  - Further split into VBF 1 and VBF 0 categories, using a BDT.
- **Background estimation**.
  - Z→**ττ** + jets and **$t\bar{t}$** constrained in dedicated control regions.
  - Data-driven estimates of fake-**τ** background.
- Measure the **differential cross sections** in a **fiducial region** (mirroring the reco-level requirements).
  - **Variables** = p_T(leading jet), $\Delta\phi_{jj}^{signed}$, p_T^H, and $\Delta\phi_{jj}^{signed}$ vs p_T^H.
  - Signal and background estimated in each bin from **fit to $m_{\tau\tau}$ distribution**.

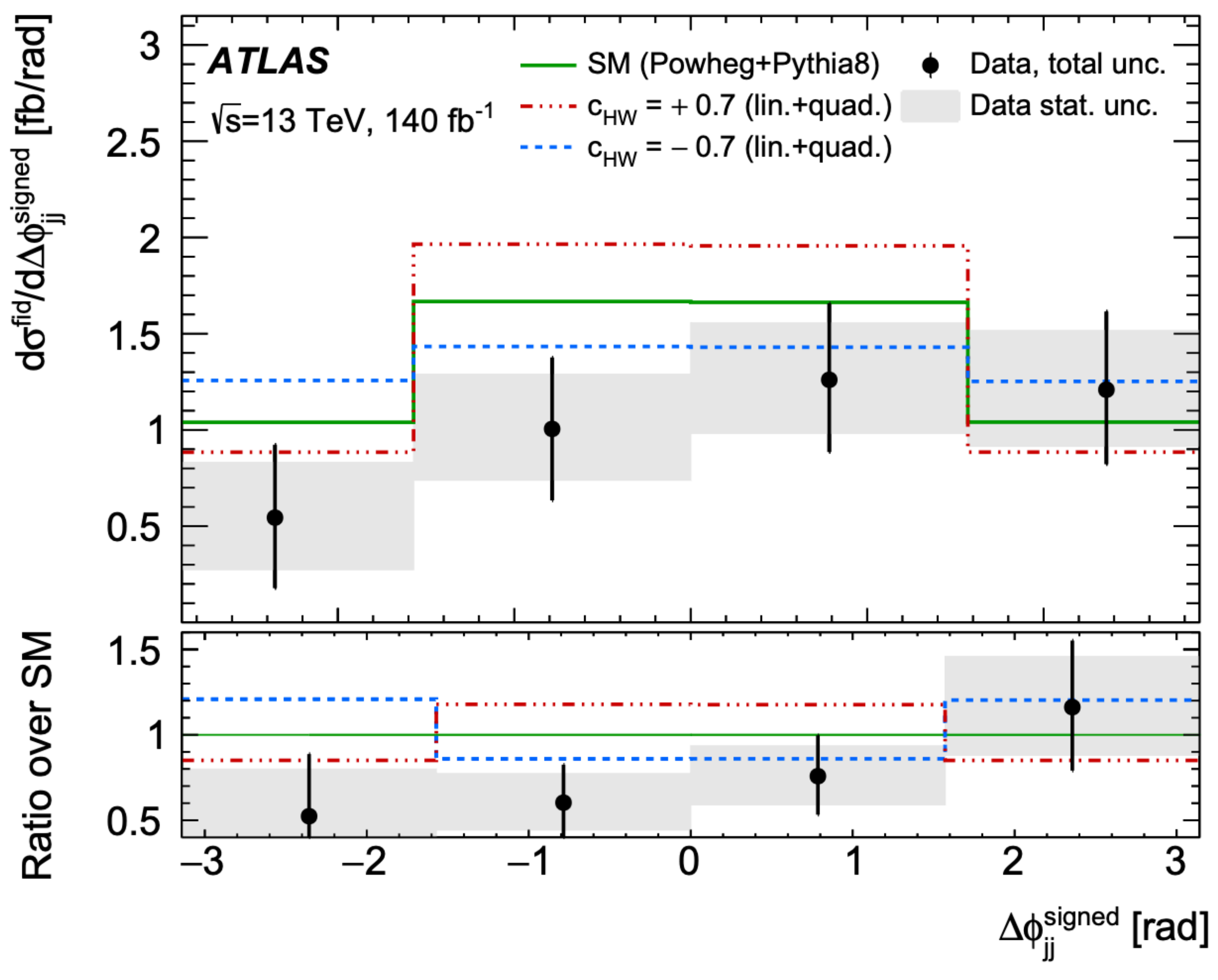
Event selection + VBF categorization



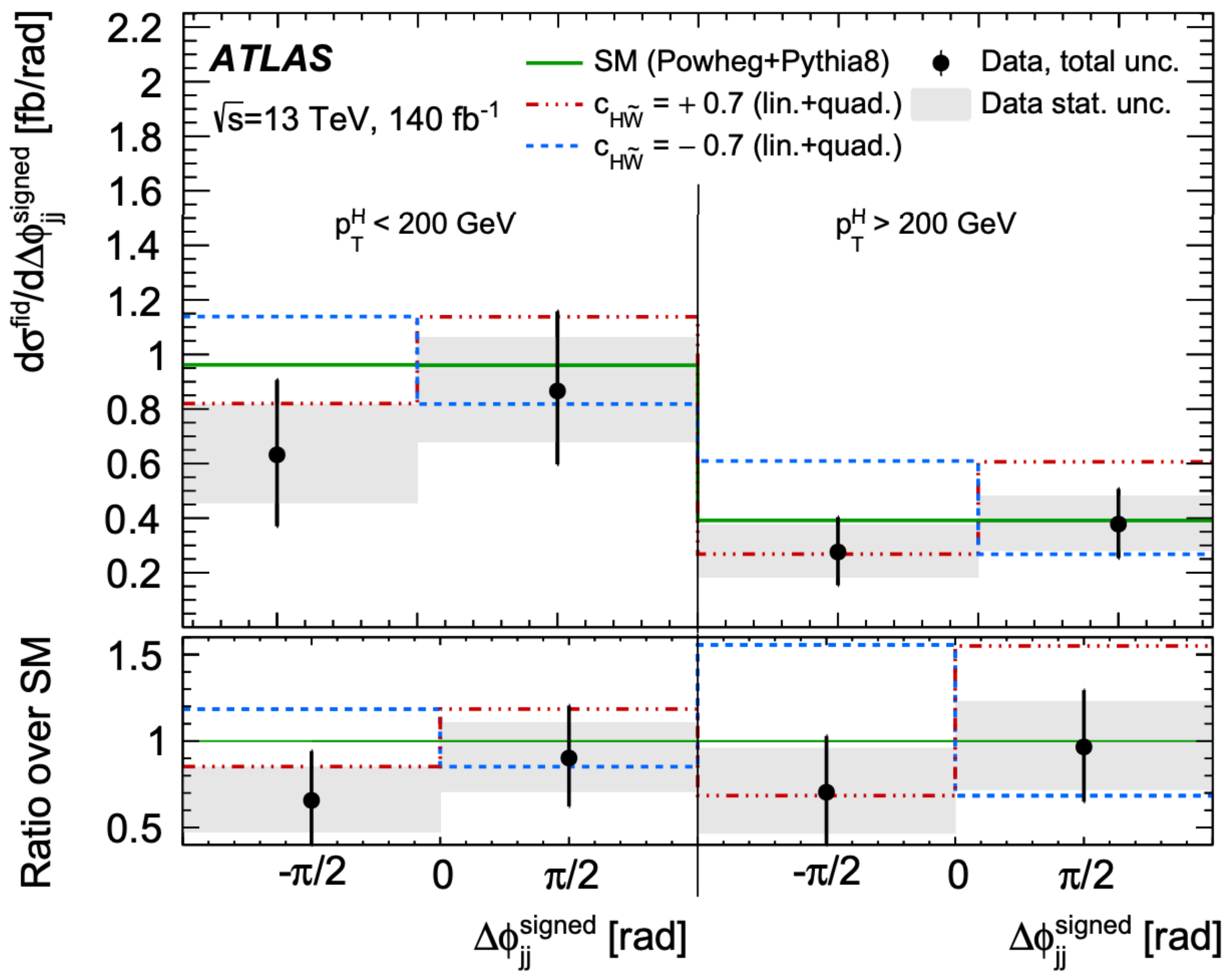


SMEFT interpretation of VBF H→ττ differential cross sections

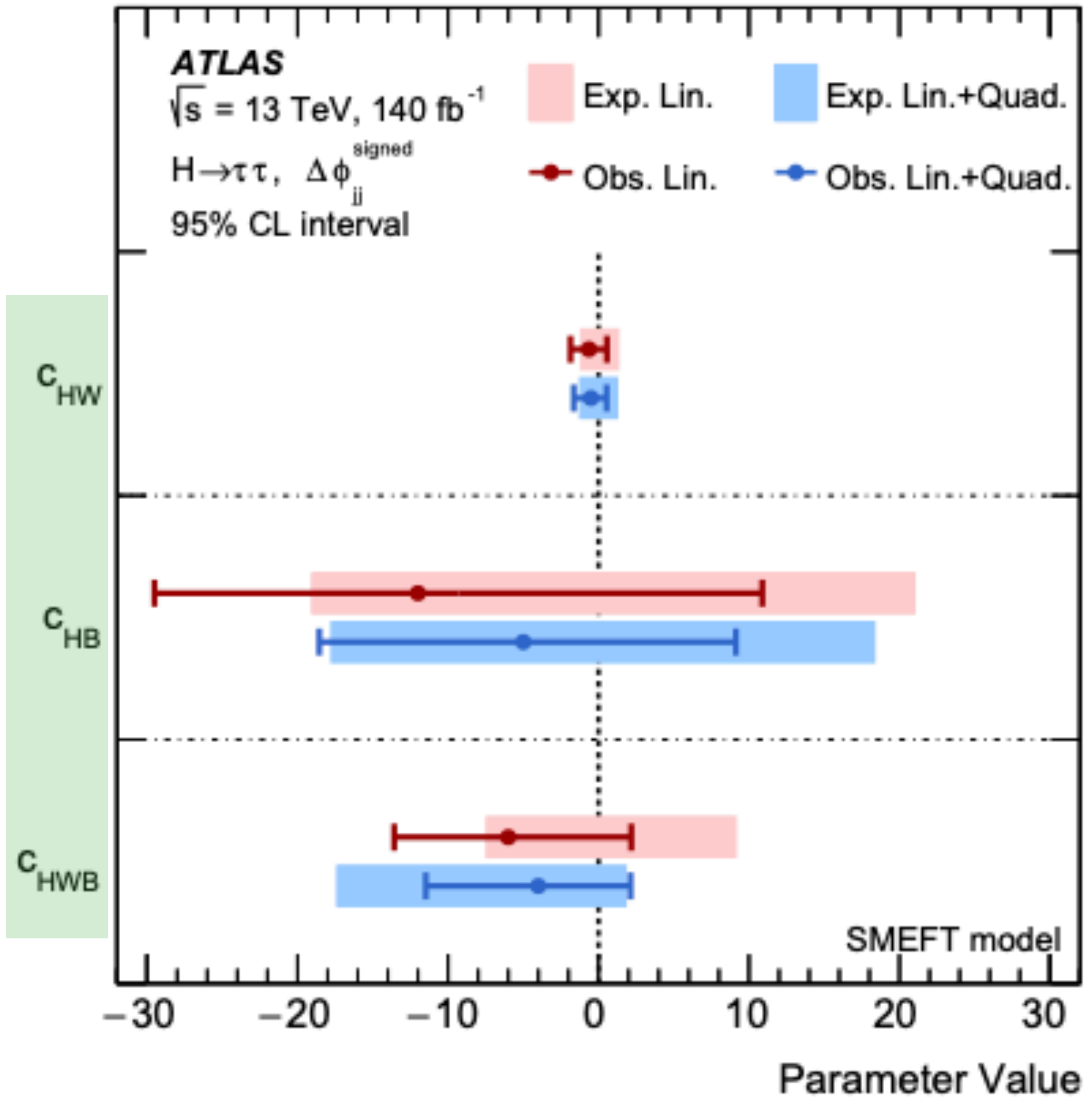
CP-even operator C_{HW}

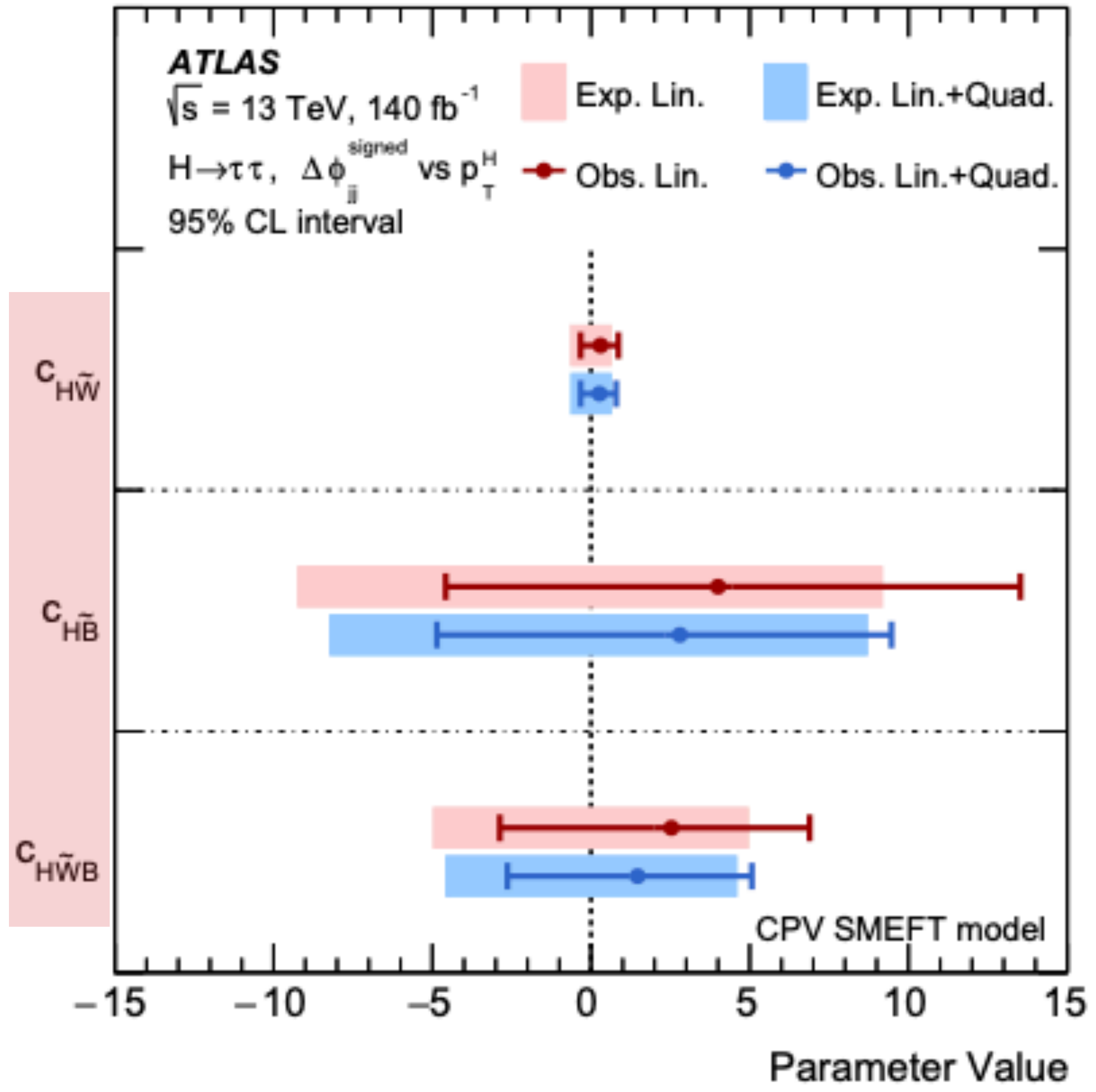


CP-odd operator $C_{H\tilde{W}}$



- Variables $\Delta\phi_{jj}^{signed}$ and p_T^H **sensitive to anomalous values of Wilson coefficients**.
  - **Non-zero** values of **CP-odd operators** have an **asymmetric effect** on $\Delta\phi_{jj}^{signed}$, **more evident when cutting on** p_T^H!
- **CP-even operators** = measured using $\Delta\phi_{jj}^{signed}$.
- **CP-odd operators** = measured using $\Delta\phi_{jj}^{signed}$ vs p_T^H.



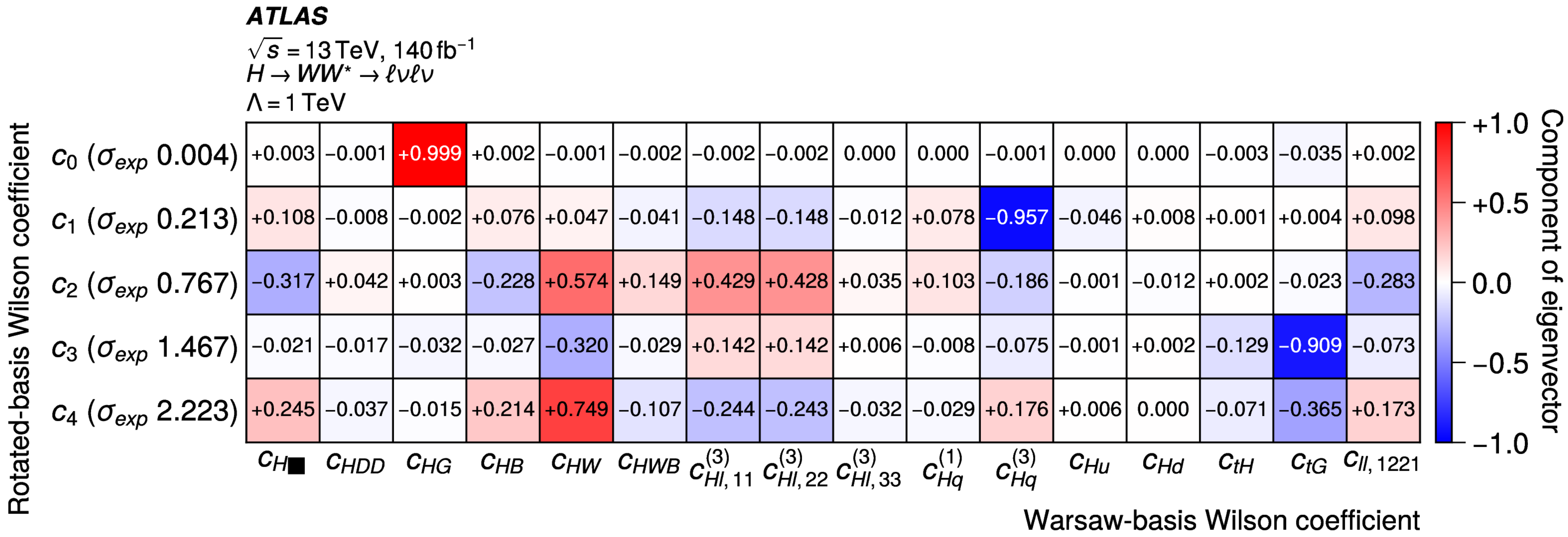


1-dimensional measurements of Wilson coefficients

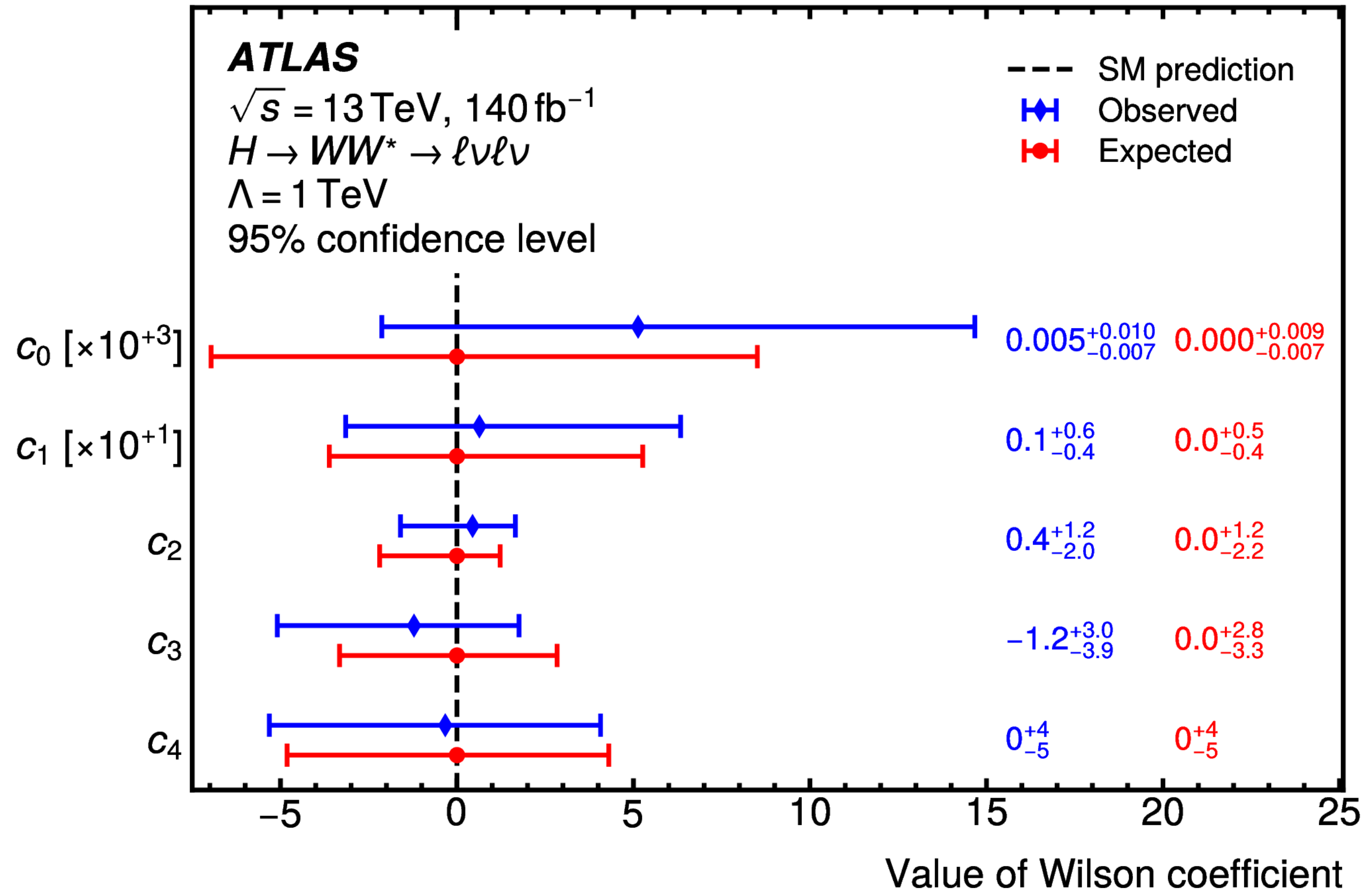
- Both linear only and linear + quadratic SMEFT terms **considered**
  - **Very similar everywhere** except for the expected constraints on C_{HWB}.

[JHEP 03 (2025) 010]

SMEFT interpretation of H→WW*→ STXS measurement



- Baseline STXS measurements **interpreted** using a **modified set of Wilson coefficients**.
- Considering set of **CP-even operators**, and rotating them to a "**fit basis**" which diagonalizes the expected SM STXS covariance matrix (= $\mathbf{V}^{-1}_{\mathbf{STXS}}$).



- Both linear only and linear + quadratic SMEFT terms **considered**.
- All operators fitted simultaneously.

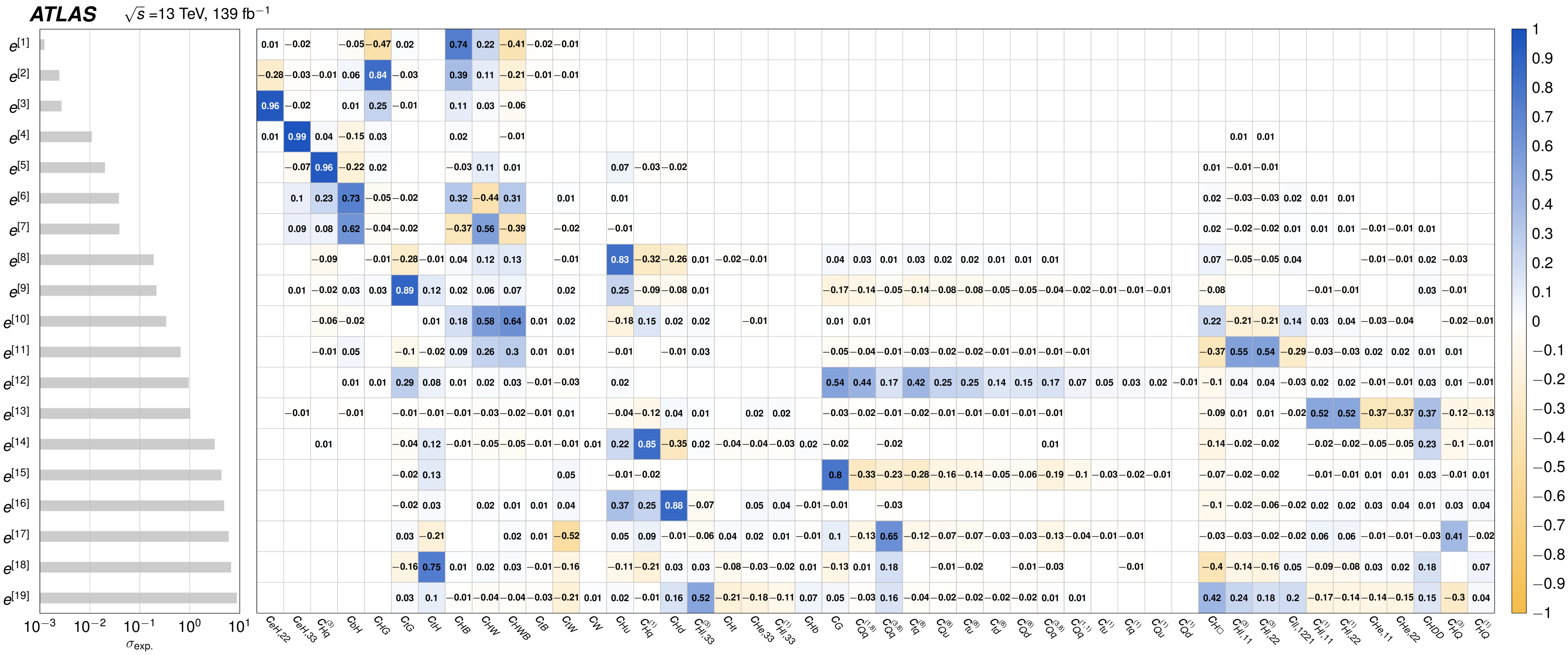
Combined Higgs STXS measurement: fit basis

Wilson coefficient	Operator
c_H	$(H^\dagger H)^3$
$c_{H\Box}$	$(H^\dagger H)\Box(H^\dagger H)$
c_G	$f^{abc}G_\mu^{a\nu}G_\nu^{b\rho}G_\rho^{c\mu}$
c_W	$\epsilon^{IJK}W_\mu^{I\nu}W_\nu^{J\rho}W_\rho^{K\mu}$
c_{HDD}	$(H^\dagger D^\mu H)^*(H^\dagger D_\mu H)$
c_{HG}	$H^\dagger H\, G_{\mu\nu}^A G^{A\mu\nu}$
c_{HB}	$H^\dagger H\, B_{\mu\nu}B^{\mu\nu}$
c_{HW}	$H^\dagger H\, W_{\mu\nu}^I W^{I\mu\nu}$
c_{HWB}	$H^\dagger \tau^I H\, W_{\mu\nu}^I B^{\mu\nu}$
$c_{Hl,11}^{(1)}$	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{l}_1\gamma^\mu l_1)$
$c_{Hl,22}^{(1)}$	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{l}_2\gamma^\mu l_2)$
$c_{Hl,33}^{(1)}$	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{l}_3\gamma^\mu l_3)$
$c_{Hl,11}^{(3)}$	$(H^\dagger i\overleftrightarrow{D}_\mu^I H)(\bar{l}_1\tau^I\gamma^\mu l_1)$
$c_{Hl,22}^{(3)}$	$(H^\dagger i\overleftrightarrow{D}_\mu^I H)(\bar{l}_2\tau^I\gamma^\mu l_2)$
$c_{Hl,33}^{(3)}$	$(H^\dagger i\overleftrightarrow{D}_\mu^I H)(\bar{l}_3\tau^I\gamma^\mu l_3)$
$c_{He,11}$	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{e}_1\gamma^\mu e_1)$
$c_{He,22}$	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{e}_2\gamma^\mu e_2)$
$c_{He,33}$	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{e}_3\gamma^\mu e_3)$
$c_{Hq}^{(1)}$	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{q}\gamma^\mu q)$
$c_{Hq}^{(3)}$	$(H^\dagger i\overleftrightarrow{D}_\mu^I H)(\bar{q}\tau^I\gamma^\mu q)$
c_{Hu}	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{u}_p\gamma^\mu u_r)$
c_{Hd}	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{d}_p\gamma^\mu d_r)$
$c_{HQ}^{(1)}$	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{Q}\gamma^\mu Q)$
$c_{HQ}^{(3)}$	$(H^\dagger i\overleftrightarrow{D}_\mu^I H)(\bar{Q}\tau^I\gamma^\mu Q)$
c_{Ht}	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{t}\gamma^\mu t)$
c_{Hb}	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{b}\gamma^\mu b)$

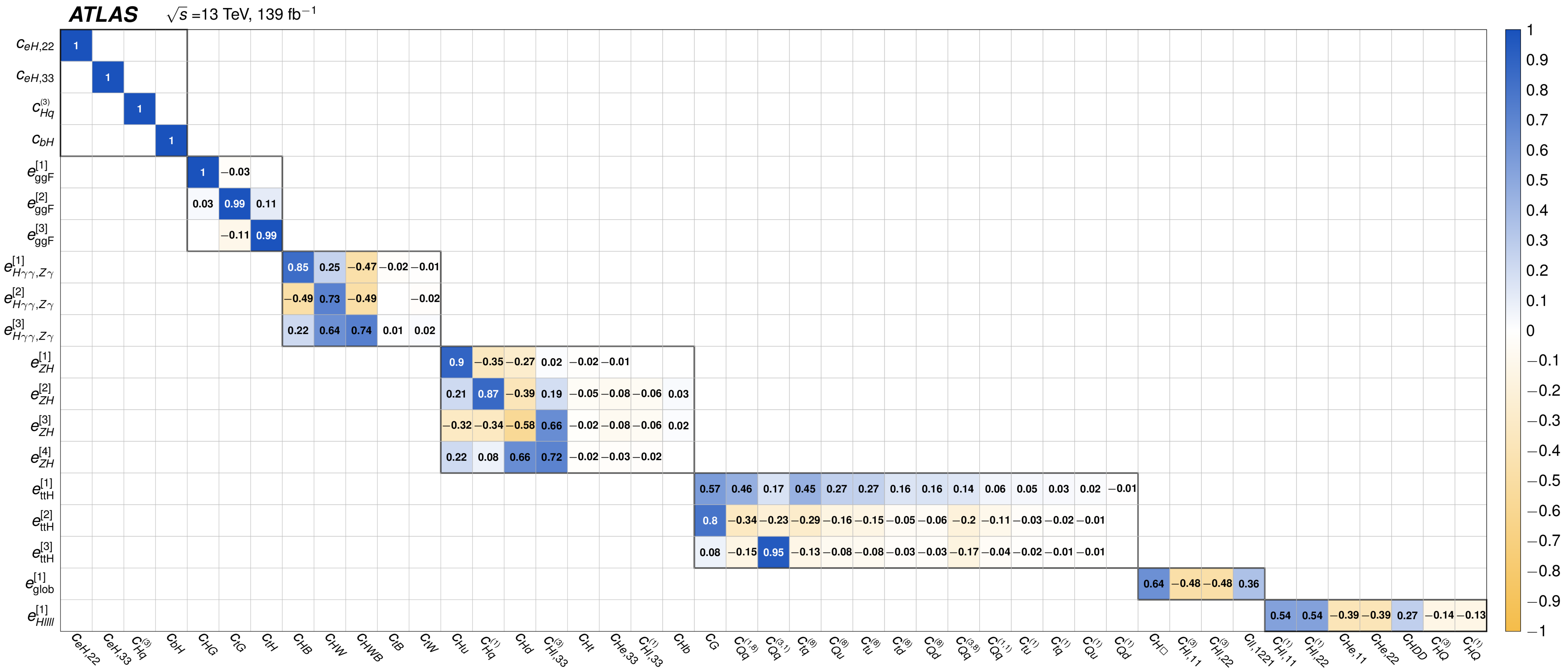
Wilson coefficient	Operator
$c_{Qq}^{(1,1)}$	$(\bar{Q}\gamma_\mu Q)(\bar{q}\gamma^\mu q)$
$c_{Qq}^{(1,8)}$	$(\bar{Q}T^a\gamma_\mu Q)(\bar{q}T^a\gamma^\mu q)$
$c_{Qq}^{(3,1)}$	$(\bar{Q}\sigma^i\gamma_\mu Q)(\bar{q}\sigma^i\gamma^\mu q)$
$c_{Qq}^{(3,8)}$	$(\bar{Q}\sigma^i T^a\gamma_\mu Q)(\bar{q}\sigma^i T^a\gamma^\mu q)$
$c_{qq}^{(3,1)}$	$(\bar{q}\sigma^i\gamma_\mu q)(\bar{q}\sigma^i\gamma^\mu q)$
$c_{tu}^{(1)}$	$(\bar{t}\gamma_\mu t)(\bar{u}\gamma^\mu u)$
$c_{tu}^{(8)}$	$(\bar{t}T^a\gamma_\mu t)(\bar{u}T^a\gamma^\mu u)$
$c_{td}^{(1)}$	$(\bar{t}\gamma_\mu t)(\bar{d}\gamma^\mu d)$
$c_{td}^{(8)}$	$(\bar{t}T^a\gamma_\mu t)(\bar{d}T^a\gamma^\mu d)$
$c_{Qu}^{(1)}$	$(\bar{Q}\gamma_\mu Q)(\bar{u}\gamma^\mu u)$
$c_{Qu}^{(8)}$	$(\bar{Q}T^a\gamma_\mu Q)(\bar{u}T^a\gamma^\mu u)$
$c_{Qd}^{(1)}$	$(\bar{Q}\gamma_\mu Q)(\bar{d}\gamma^\mu d)$
$c_{Qd}^{(8)}$	$(\bar{Q}T^a\gamma_\mu Q)(\bar{d}T^a\gamma^\mu d)$
$c_{tq}^{(1)}$	$(\bar{q}\gamma_\mu q)(\bar{t}\gamma^\mu t)$
$c_{tq}^{(8)}$	$(\bar{q}T^a\gamma_\mu q)(\bar{t}T^a\gamma^\mu t)$
$c_{eH,22}$	$(H^\dagger H)(\bar{l}_2 e_2 H)$
$c_{eH,33}$	$(H^\dagger H)(\bar{l}_3 e_3 H)$
c_{uH}	$(H^\dagger H)(\bar{q}Y_u^\dagger u\tilde{H})$
c_{tH}	$(H^\dagger H)(\bar{Q}\tilde{H}t)$
c_{bH}	$(H^\dagger H)(\bar{Q}Hb)$
c_{tG}	$(\bar{Q}\sigma^{\mu\nu}T^A t)\tilde{H}\,G_{\mu\nu}^A$
c_{tW}	$(\bar{Q}\sigma^{\mu\nu}t)\tau^I\tilde{H}\,W_{\mu\nu}^I$
c_{tB}	$(\bar{Q}\sigma^{\mu\nu}t)\tilde{H}\,B_{\mu\nu}$
$c_{ll,1221}$	$(\bar{l}_1\gamma_\mu l_2)(\bar{l}_2\gamma^\mu l_1)$

- **Very large number** of operators affecting **Higgs physics** (even when limiting to CP-even operators).
  - ➡ Cannot **all** be constrained effectively from data!
    - ➡ **Question:** how to obtain an **appropriate fit basis**, as the best compromise between fit stability and interpretability?
- A new fit basis $\mathscr{C}'$ is defined.
  - ➡ - Built using **eigenvectors** of $\mathbf{V^{-1}_{SMEFT}}$.
    - ➡ **Reparametrisation** of the **expected SM Hessian matrix** of the STXS cross section measurement (= $\mathbf{V^{-1}_{STXS}}$) in terms of Wilson coefficients.
  - - The **expected uncertainty** (estimated using V^{-1}_{STXS}) is required to be < 10.
    - ➡ From 54 Wilson coefficients to 19 Wilson coefficients!

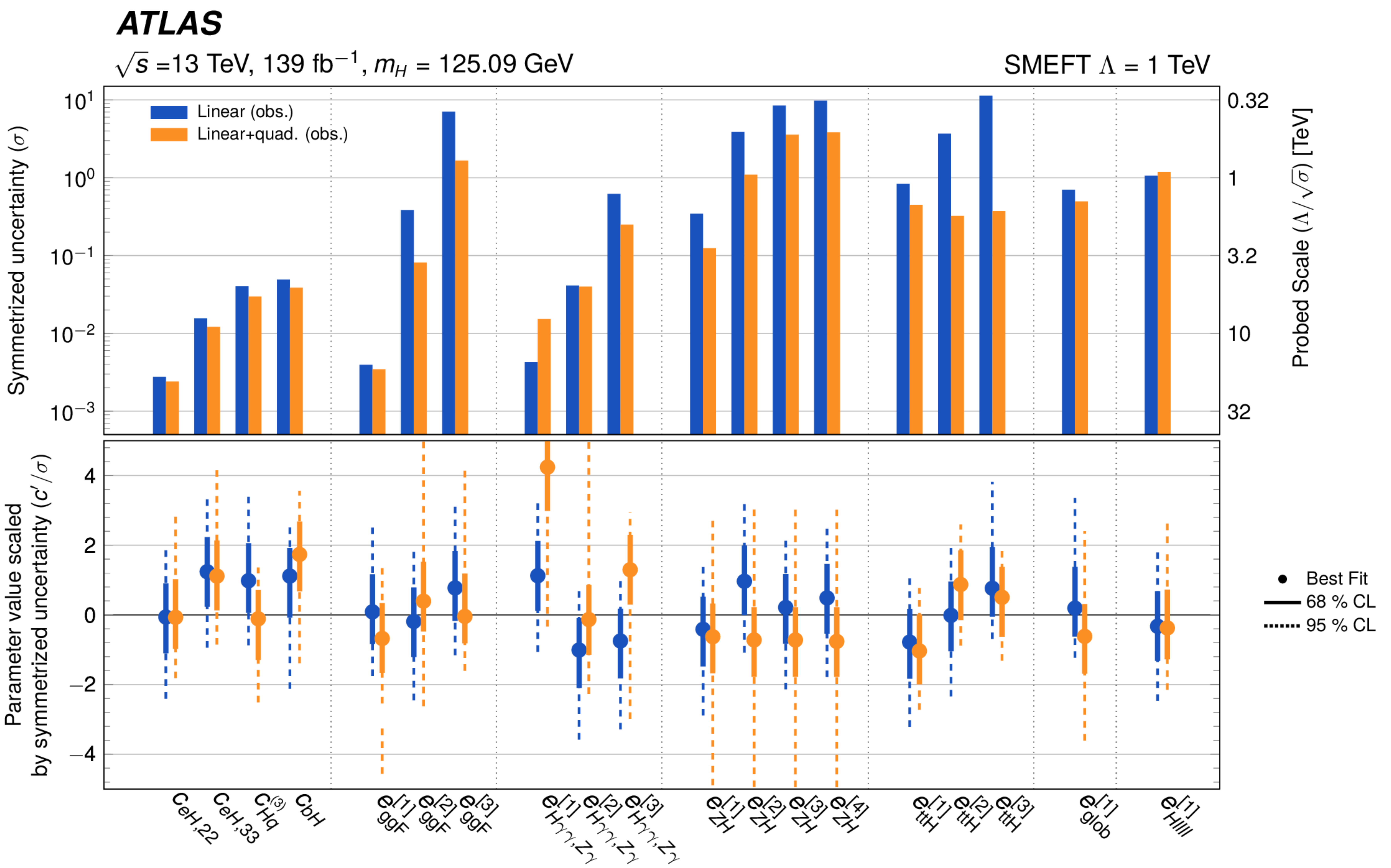
Combined Higgs STXS measurement: fit basis



Combined Higgs STXS measurement: fit basis

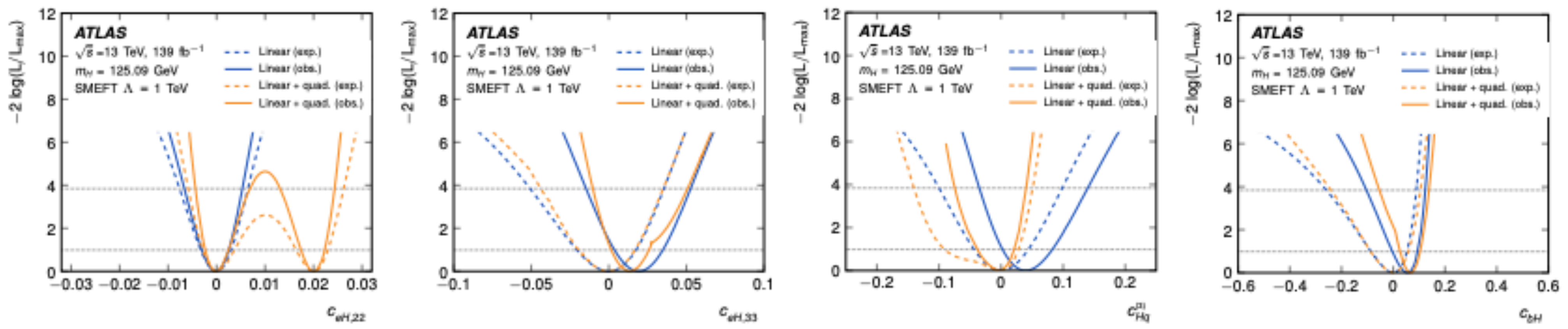


Combined Higgs STXS measurement: linear vs. linear + quad.



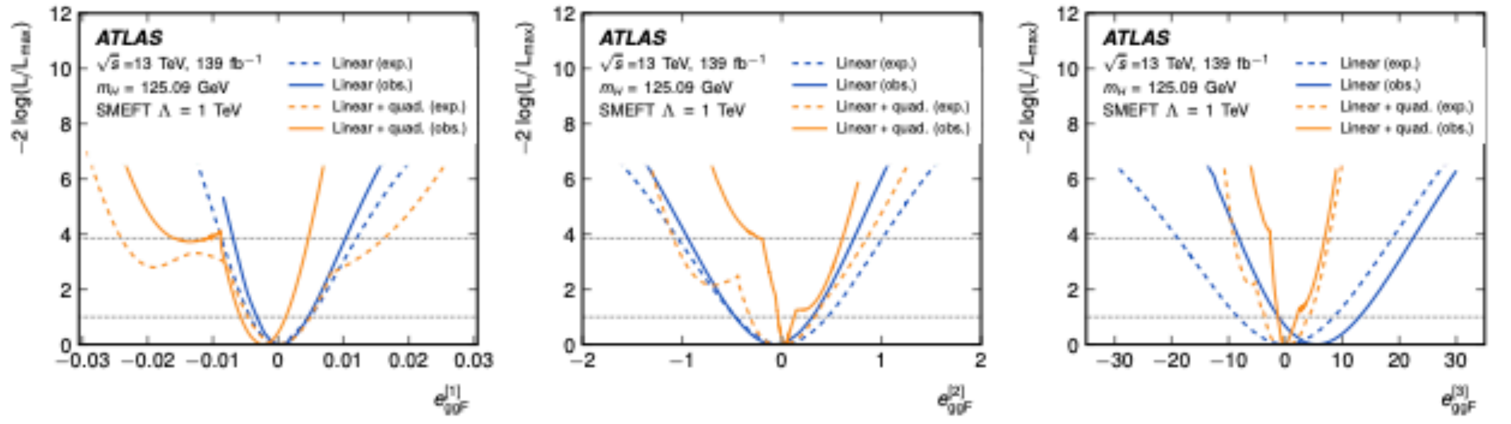
Combined Higgs STXS measurement: linear vs. linear + quad.

Operators in Warsaw basis: $c_{eH,22}$, $c_{eH,33}$, $c_{Hq}^{(3)}$ and c_{bH}



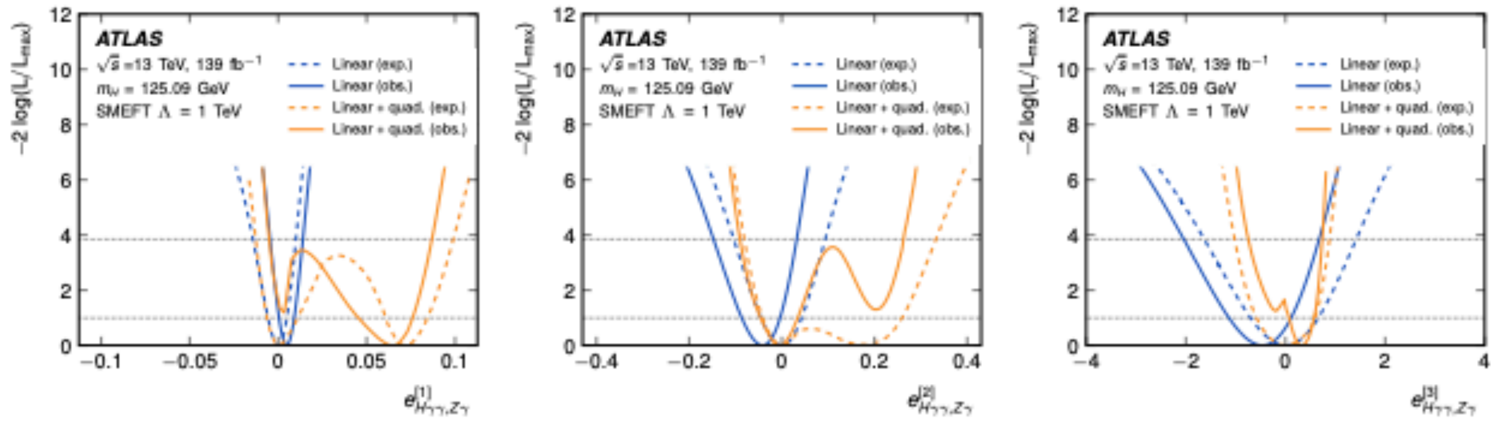
(a) (b) (c) (d)

Eigenvector group ggF



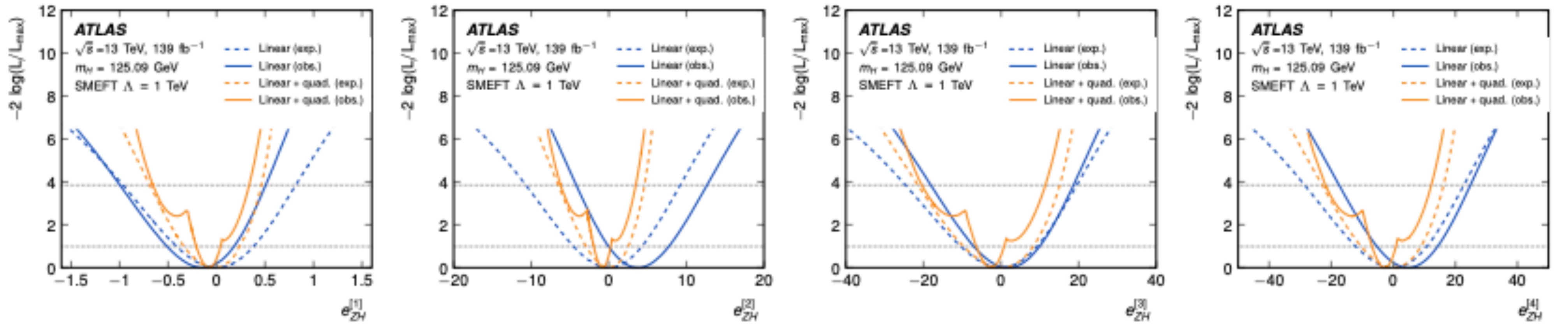
(e) (f) (g)

Eigenvector group $H \to \gamma\gamma, Z\gamma$



(h) (i) (j)

Eigenvector group ZH



(k) (l) (m) (n)

Combined Higgs STXS measurement: uncertainties