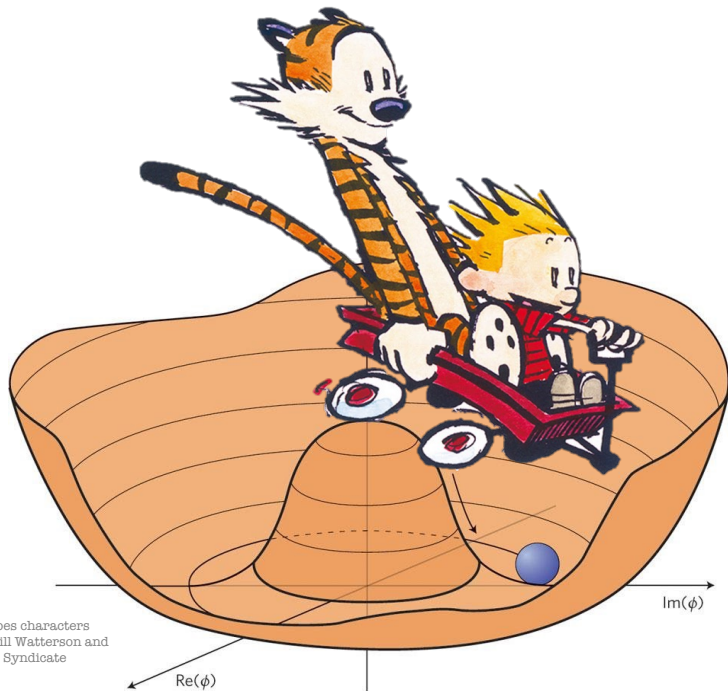


Living with a *teenager* Higgs boson

Higgs Hunting 2026 Experimental Summary



Calvin and Hobbes characters
copyright by Bill Watterson and
Universal Press Syndicate

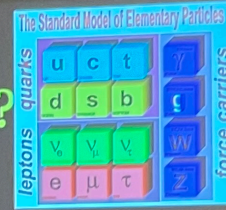
Marco Delmastro

marco.delmastro@cern.ch



Paris, 18/9/2026

WHAT HAVE WE LEARNED FROM THE STANDARD MODEL?



MATTER = Charged Spin 1/2 Fermions

FORCES - Described by Quantum Gauge Field Theories

Three Phases :

1. EM: $U(1)$ Coulomb—Long Range
2. WEAK: $SU(2)$ Screened or Higgsed
by an unnatural scalar field sector
3. STRONG: $SU(3)$ Confined

THE HIGGS
BOSON IS
ALREADY
14 YEARS
OLD!



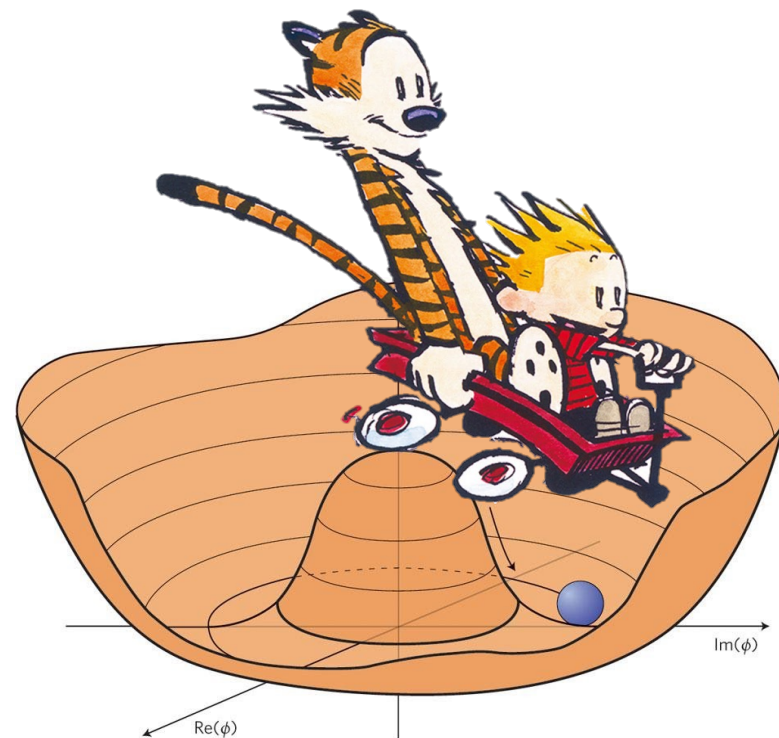
Living with a 14-year-old: 6 familiar themes...

- **They grow faster than expected**
- **Hidden personality traits strongly emerge**
- **Passion and talent shown during childhood consolidate**
- **Despite all appearances, they are not adult yet...**
- **Searching alternative identities is still a daily job**
- **Future might seem far away, but adulthood is not that far**



Living with a 14-year-old Higgs boson: 6 themes from HH2026

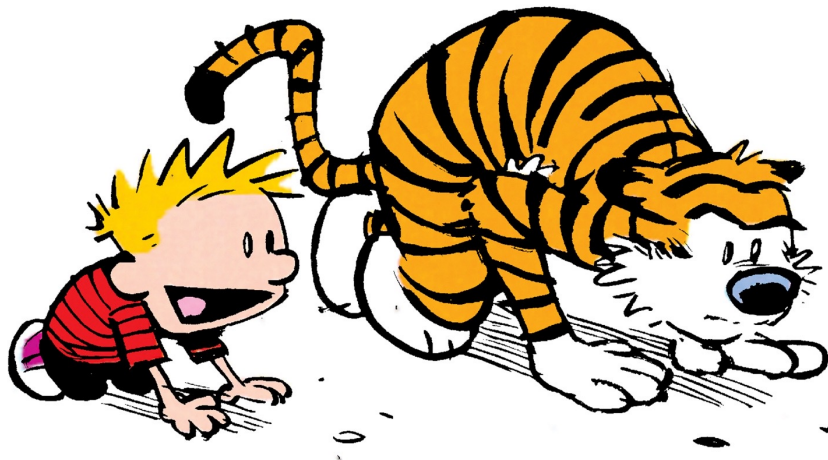
- *They grow faster than expected*
 - ✓ **1. Run 3 is already closing the gap on Run 2**
- *Hidden personality traits strongly emerge*
 - ✓ **2. Rare decays and boosted regimes are becoming real**
- *Passion and talent shown during childhood consolidate*
 - ✓ **3. Precision is turning into structure (including genuinely new questions, e.g. entanglement)**
- *Despite all appearances, they are not adult yet...*
 - ✓ **4. The still-open heart of the story: the shape of the potential...**
- *Searching alternative identities is still a daily job*
 - ✓ **5. Widening the net, nothing found (yet)**
- *Future might seem far away, but adulthood is not that far*
 - ✓ **6. What's next: HL-LHC, future colliders...**



1.

“They grow faster than expected”

Run 3 is already closing the gap on Run 2



H → ZZ* → 4l fiducial & differential cross-section

- Observed** number of events is comparable to the **expected** signal and background yields for each of the four-lepton final states (4μ, 4e, 2e2μ, 2μ2e):

Final state	Signal	ZZ*	Other Backgrounds	Total SM	Observed
4μ	90.5 ± 5.3	41.2 ± 1.6	4.5 ± 0.3	136 ± 6	136
2e2μ	63.4 ± 4.0	30.0 ± 1.3	4.7 ± 0.5	98 ± 5	98
2μ2e	40.7 ± 9.1	15.6 ± 4.4	5.6 ± 0.2	62 ± 13	67
4e	36.5 ± 9.2	14.1 ± 4.3	5.3 ± 0.3	56 ± 13	59
Total	231 ± 23	101 ± 10	20.1 ± 1.3	352 ± 32	360

- Observed (expected) inclusive fiducial cross-section** extracted from the $m_{4\ell}$ fit:

$$\sigma_{\text{comb}} = 3.65 \pm 0.30 \text{ (stat.) } {}^{+0.18}_{-0.16} \text{ (sys.) fb} = 3.65 {}^{+0.35}_{-0.33} \text{ fb}$$

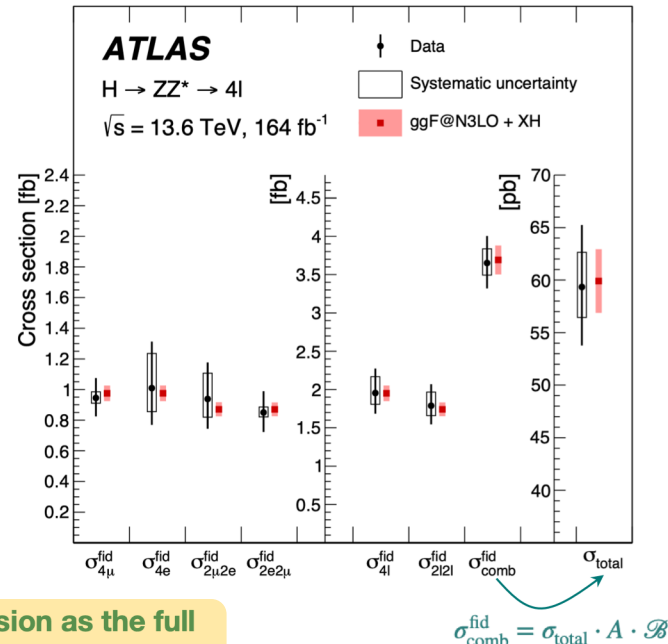
$$\sigma_{\text{comb}}^{\text{SM}} = 3.68 \pm 0.17 \text{ fb}$$

- Total cross-section extrapolated from the inclusive XS

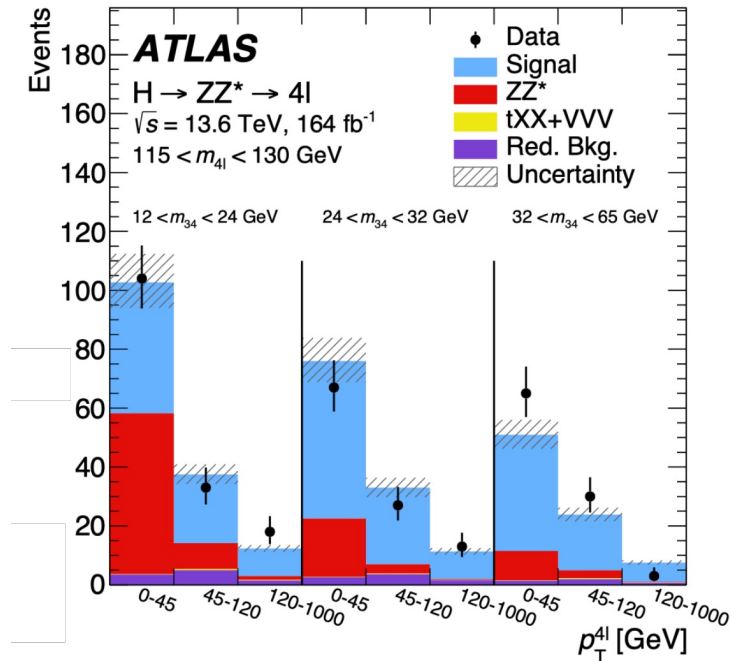
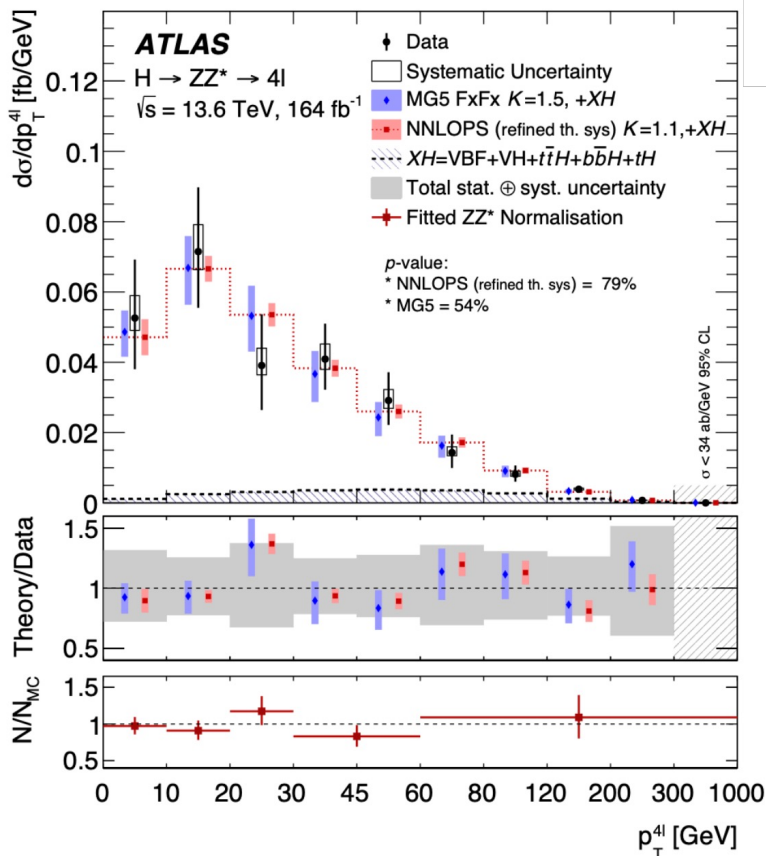
$$\sigma_{\text{total}} = 59.3 \pm 4.8 \text{ (stat.) } \pm 3.1 \text{ (sys.) pb} = 59.3 \pm 5.7 \text{ pb}$$

$$\sigma_{\text{total}}^{\text{SM}} = 59.9 \pm 3.0 \text{ pb}$$

Same precision as the full Run 2 measurement!



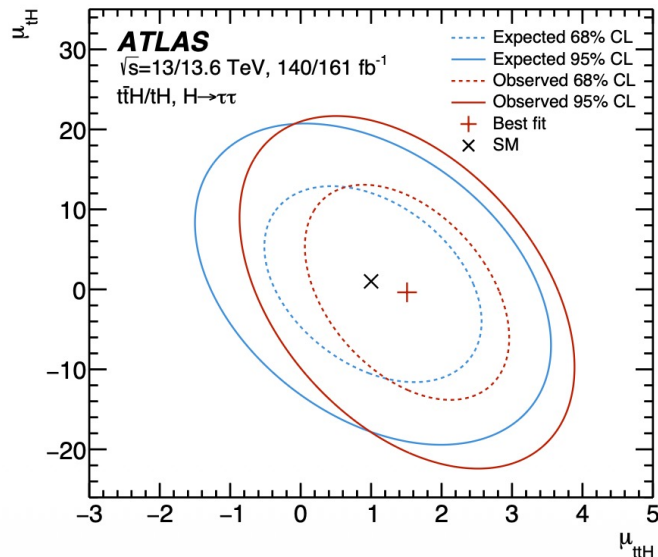
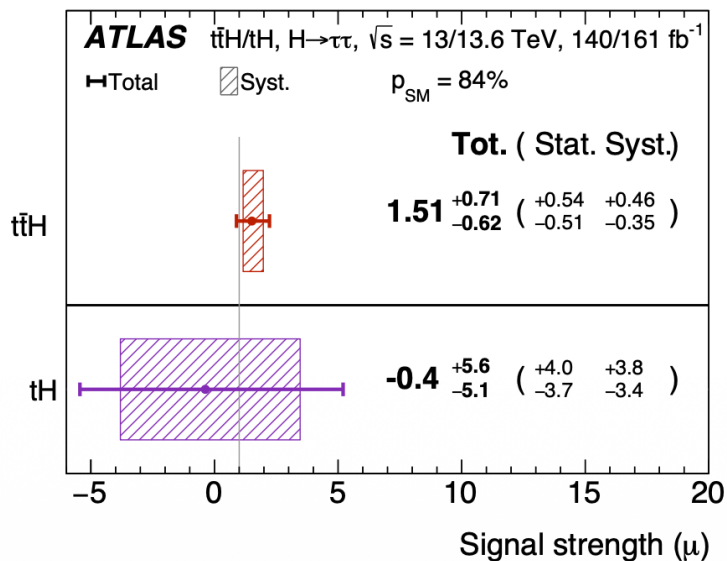
The differential picture in Run 3



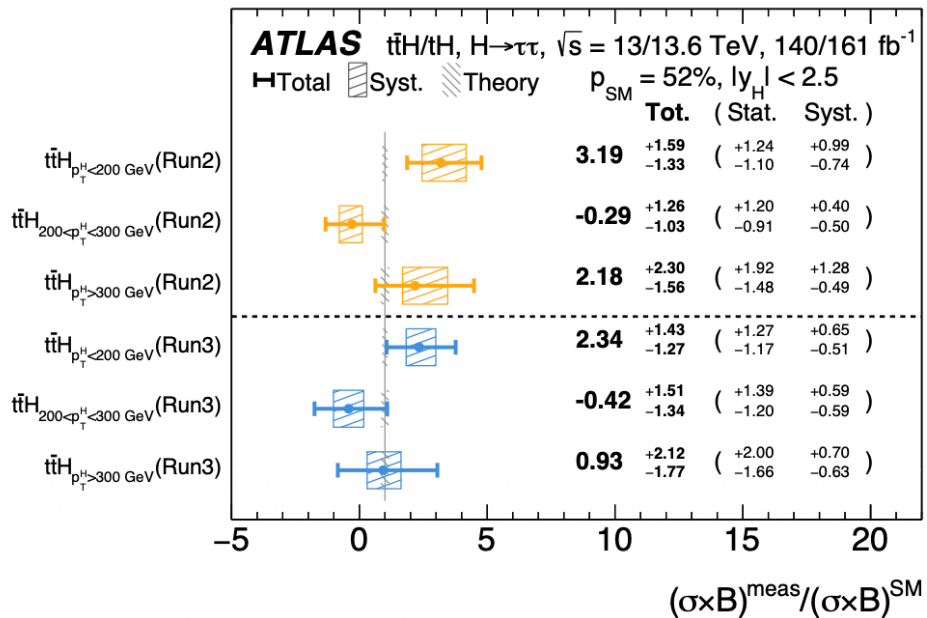
- Not only Run 3 catches up with Run 2 in precision: also doubly-differential observables, e.g. useful for the SMEFT interpretation of CP-even/odd HVV couplings

Another example: first simultaneous $t\bar{t}H + tH \rightarrow \tau\tau$ (fully had)

- 140 fb⁻¹ Run 2 + 161 fb⁻¹ Run 3 combined
- First ATLAS analysis to use new GNTau tau-ID (graph “transformer”, more on this later...)
 - ✓ $\mu(t\bar{t}H) = 1.51^{+0.71}_{-0.62} \rightarrow 2.6\sigma$ obs (1.8 σ exp)
 - ✓ $\mu(tH) = -0.4^{+5.6}_{-5.1} \rightarrow$ compatible with SM
 - ✓ Still stat-limited in every bin $\rightarrow$ full Run 3 will translate almost directly into precision



$t\bar{t}H + tH \rightarrow \tau\tau$ (fully had)



$t\bar{t}H$
 $[pp \rightarrow t\bar{t}H]$

$p_T^H < 60 \text{ GeV}$

$60 \leq p_T^H < 120 \text{ GeV}$

$120 \leq p_T^H < 200 \text{ GeV}$

$200 \leq p_T^H < 300 \text{ GeV}$

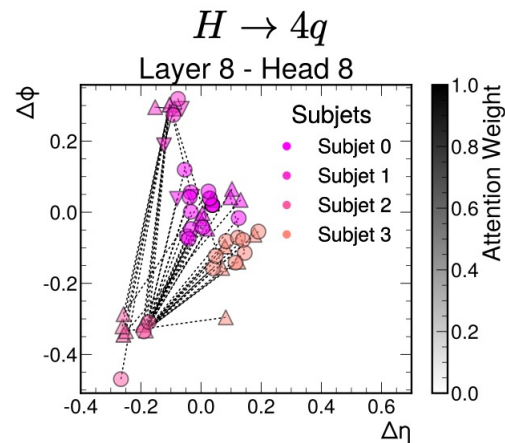
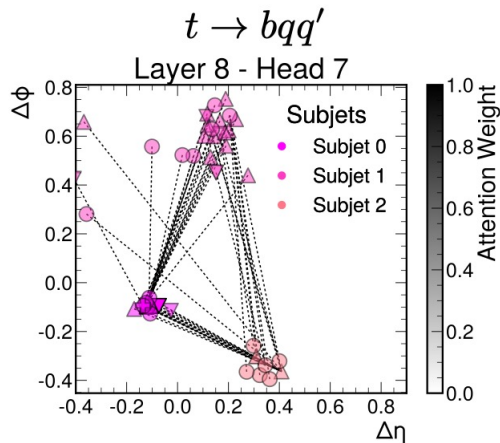
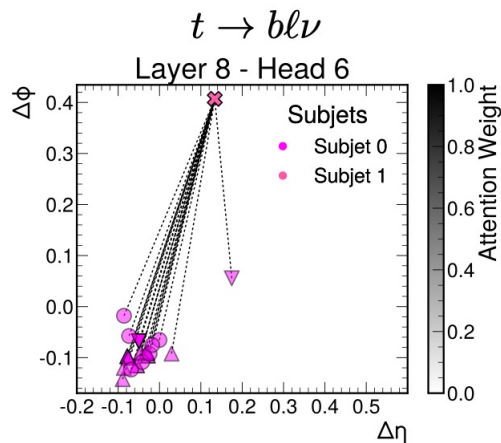
$300 \leq p_T^H < 450 \text{ GeV}$

$p_T^H \geq 450 \text{ GeV}$

tH
 $[pp \rightarrow tH + X]$

New technique intermezzo: what's a “transformer”?

- **Assuming you know what a BDT or a NN is...**
 - ✓ BDT/NN: fixed input vector, static architecture applied the same way every event
 - ✓ Transformer: works on a **variable-length set of “tokens”** (jet constituents, tracks), no padding needed
- **Core trick: self-attention**
 - ✓ Each token computes a **similarity** to every other token, softmax to weights, then takes a weighted sum of their values: a **learned, per-event correlation matrix** instead of fixed weights
 - ✓ Permutation-invariant, but lets particles interact pairwise first
 - Closer to graph-NN message passing with a fully-connected, learned adjacency
 - ✓ Multiple attention heads run in parallel: layers stack to refine representations iteratively



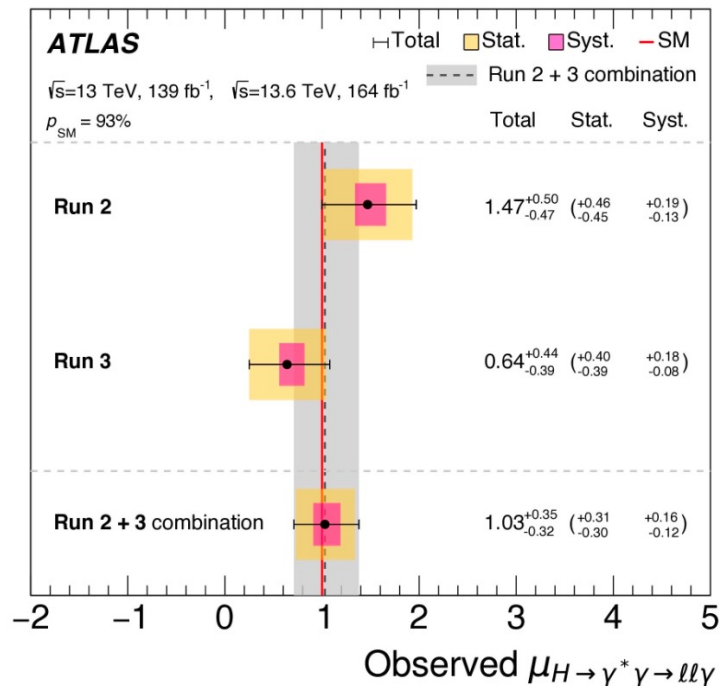
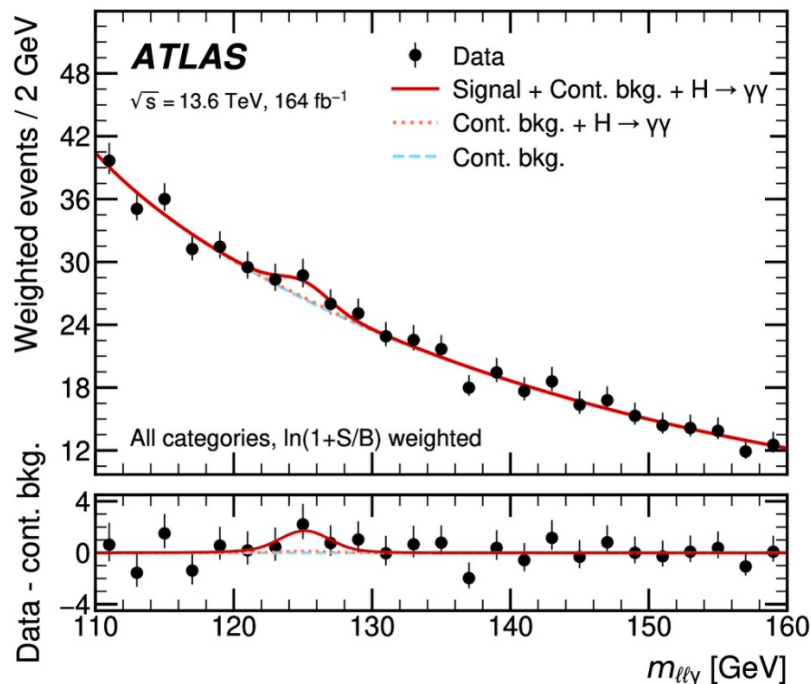
2.

“Hidden personality traits strongly emerge”

Rare decays and boosted regimes are becoming real



$H \rightarrow \gamma^* \gamma \rightarrow \ell \ell \gamma$: probing CP via the off-shell photon

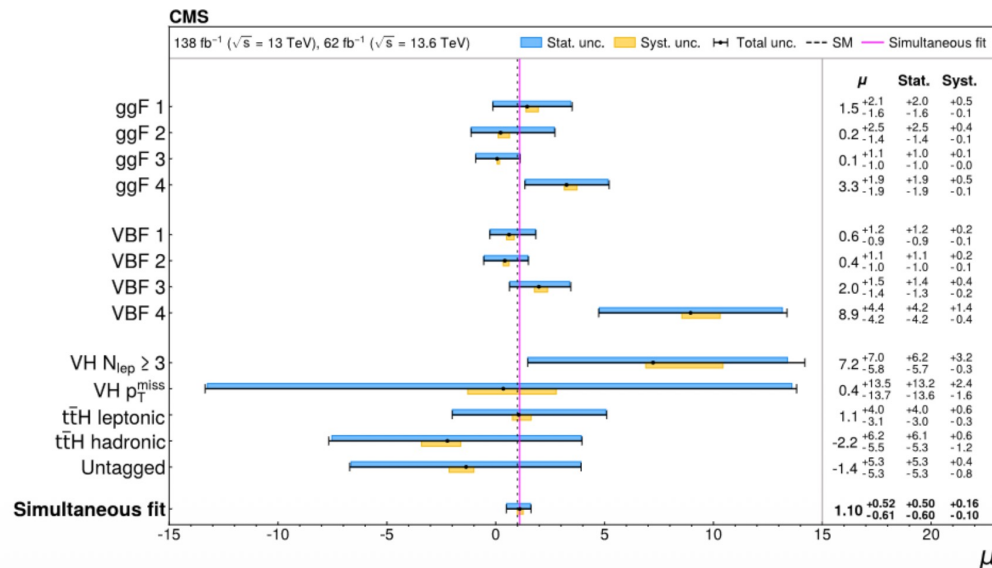
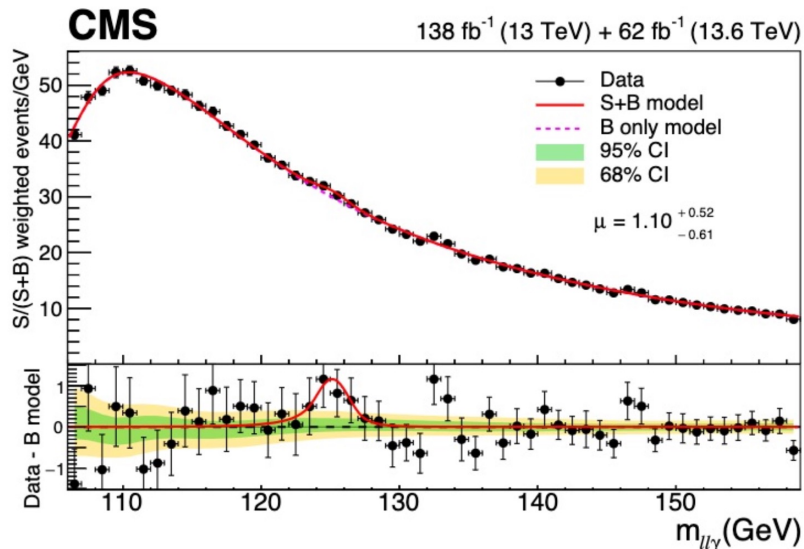


- ATLAS: dilepton invariant mass $< 30 \text{ GeV}$; $\mu\mu$ + resolved/merged ee channels
- **3.4 σ** observed (**3.3 σ** expected) combined with Run-2 measurement
- *Off-shell photon makes this decay uniquely sensitive to the CP structure of the Higgs–photon coupling...*

A rarer companion: the γ -associated / $Z\gamma$ channel

- CMS: excess significance 1.9σ observed (2.3σ expected)

✓ $\mu = 1.10^{+0.52}_{-0.61}$



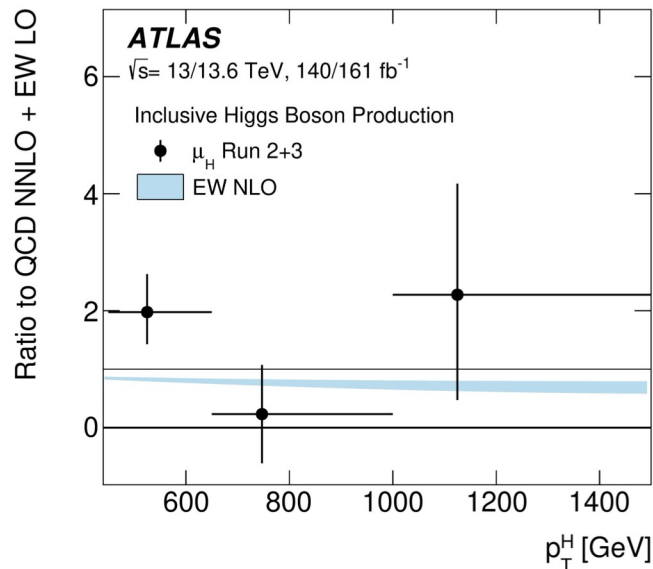
- ATLAS+CMS Run 2

✓ 3.4σ

✓ $\mu = 2.2 \pm 0.7$

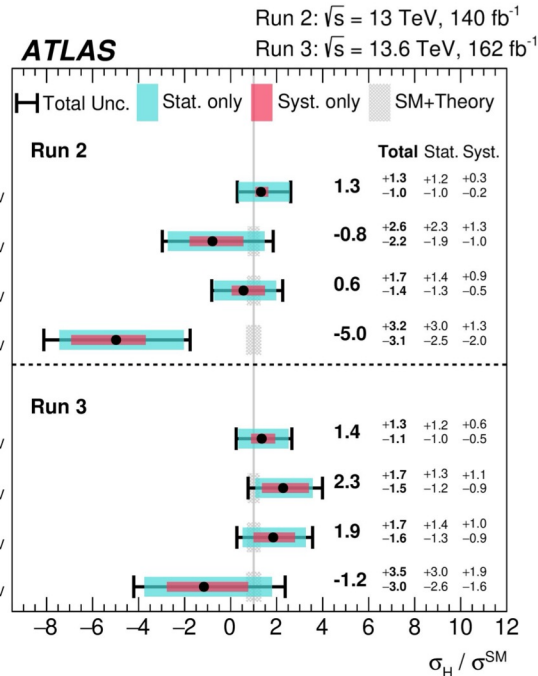
Boosted $H \rightarrow b\bar{b}$ and $H \rightarrow \tau\tau$: evidence at high p_T^H

PRL 137 (2026) 071801



$$\mu_H = 1.53 \pm 0.27 \text{ (stat.) } {}^{+0.33}_{-0.27} \text{ (syst.) } \pm 0.17 \text{ (theo.)}$$

Observed (expected) significance of **3.8 (2.5) σ** $\rightarrow$ **evidence** for Higgs boson production with Higgs $p_T > 450$ GeV (**7–10 $\times$ improvement** over Run 2!)



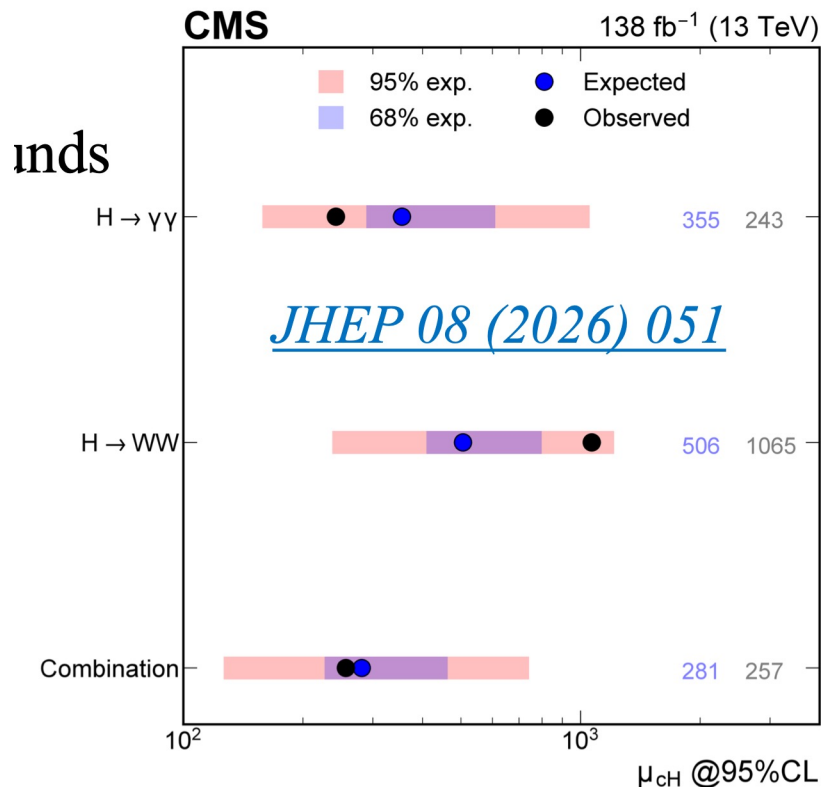
Observed (expected) significance of **3.8 (3.3) σ** $\rightarrow$ **also evidence**, for Higgs $p_T > 300$ GeV

- Better taggers unlock rare kinematic regimes!

HIGP-2024-49

2nd-generation quark Yukawa: still just exclusions...

- A recent example: CMS H+c in Hyy + HWW



- Combined results at 95% CL
 - ✓ constraints from production-side
 - ✓ complementary to Hcc
- $\mu_{cH} < 257$ (281)
- $|\kappa_c| < 47$ (51)

3.

“Passion and talent shown during childhood consolidate”

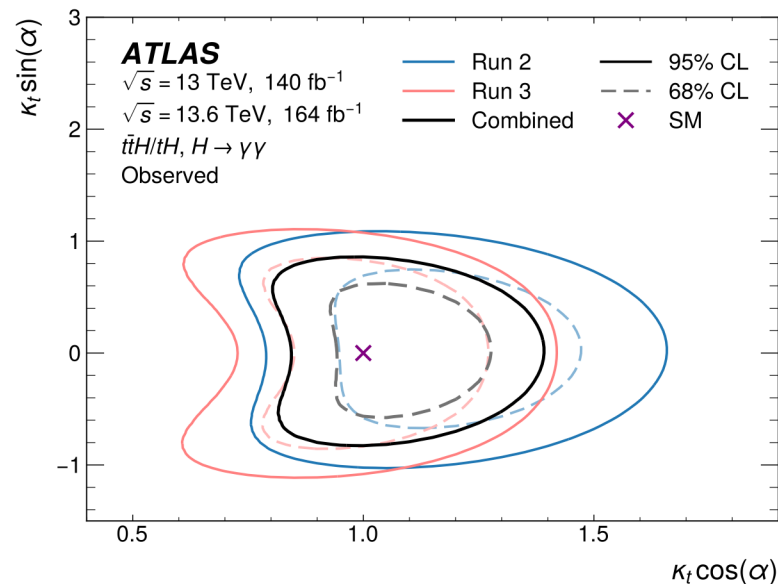
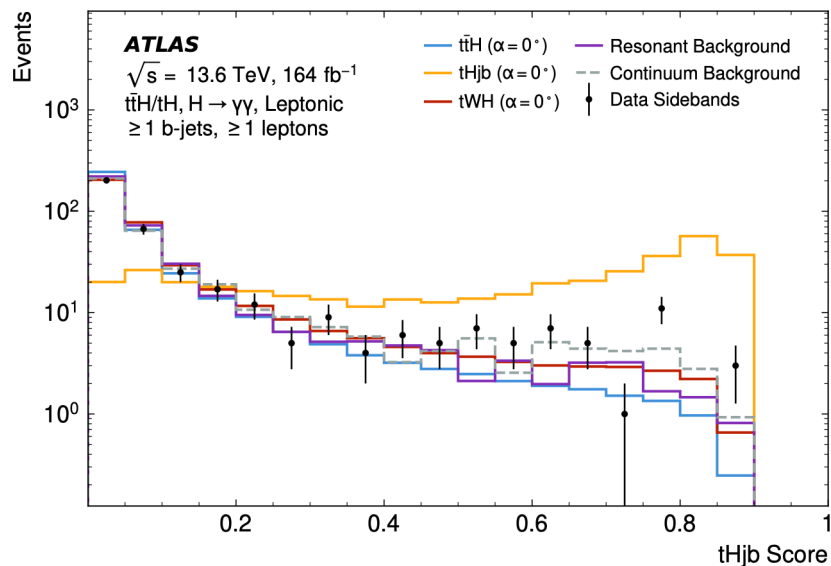
Precision is turning into structure



CP structure e.g. via $t\bar{t}H/tH \rightarrow \gamma\gamma$

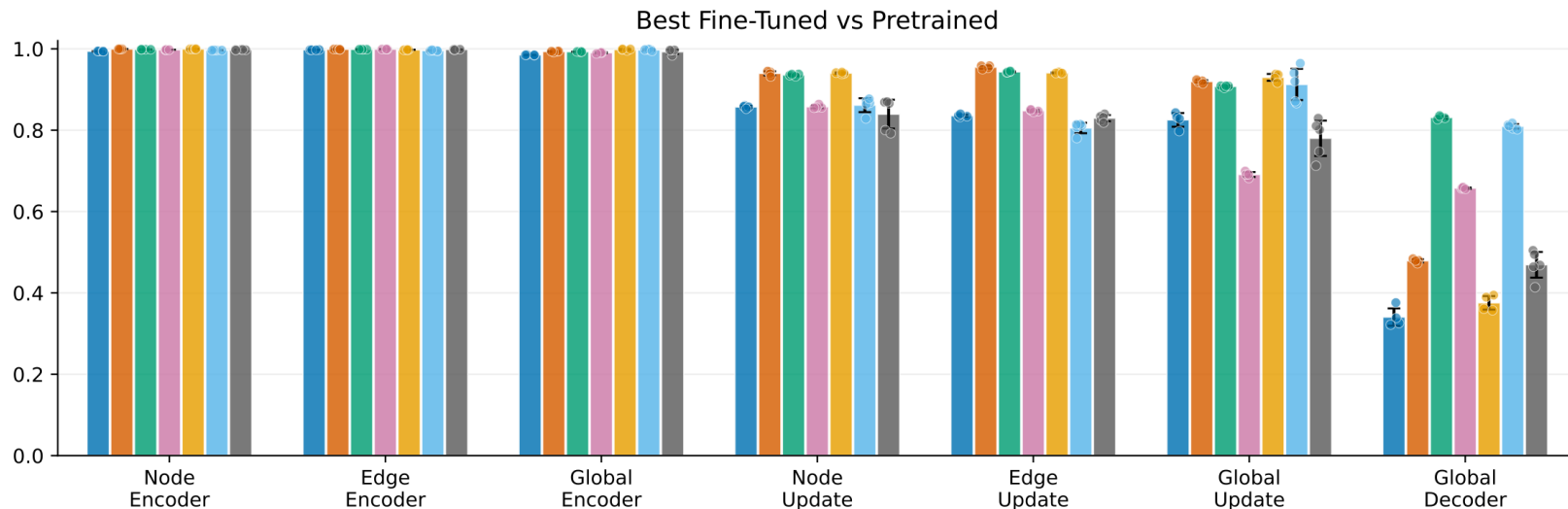
- Multi-classifier GNN

- ✓ 3 $t\bar{t}H/tH$ classes (reduce $t\bar{t}H/tH$ correlation) + top-process background + continuum $\gamma\gamma$, with separate binary CP-GNN for categorization
- ✓ $|\alpha| < 38^\circ$ @ 95% CL
- ✓ 5.0σ obs (4.7σ exp) for $t\bar{t}H$, 0.87σ (0.54σ exp) for tH , both consistent with SM



New technique intermezzo: pre-training on FastSim or truth

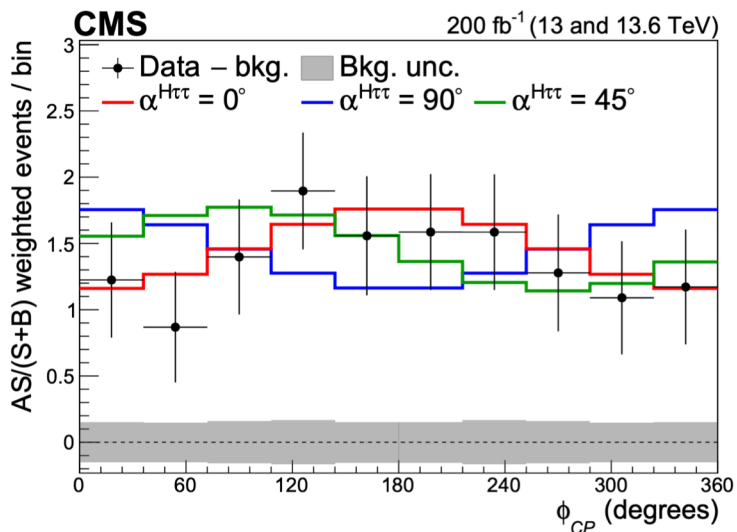
- Classification training initialized from **independent pre-training** with Delphes simulation
 - ✓ FastSim (or truth MC) allows model to learn most of underlying physics
 - ✓ Additional training on FullSim tune result to detector performance specifics (acceptances, ...)
- Training time can be reduced by ~50%
 - ✓ <https://arxiv.org/abs/2412.10665> for details...



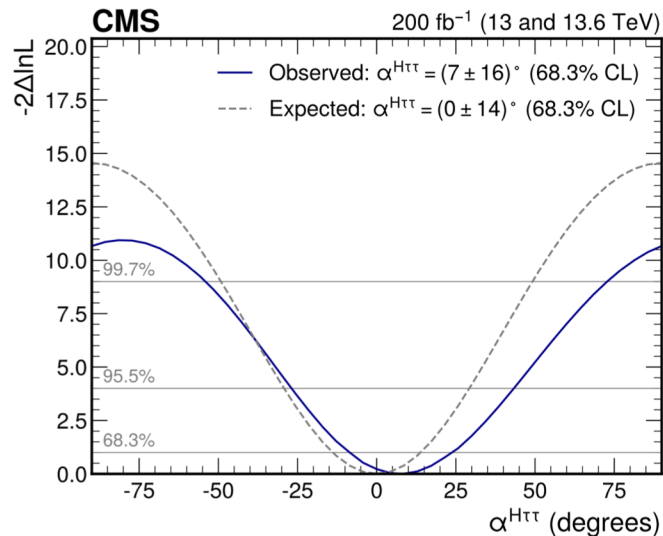
CP structure e.g. $H \rightarrow \tau\tau$

- Combination with $\sqrt{s} = 13$ TeV analysis [1]:

$$\alpha^{H\tau\tau} = 7 \pm 16 \text{ (stat)} \text{ } _{-2}^{+3} \text{ (bbb)} \pm 2 \text{ (syst)}^\circ$$



Background-subtracted ϕ_{CP} distribution (combined)



Likelihood scan of $\alpha^{H\tau\tau}$ (combined)

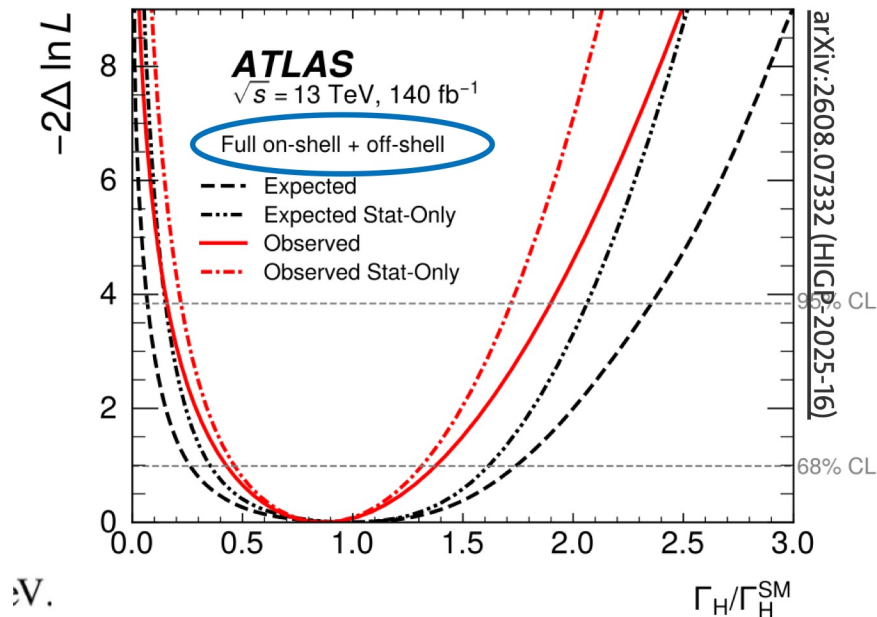
- Most precise measurement by CMS to date of the CP nature of the Higgs to τ lepton coupling, and the best expected precision by any experiment (ATLAS $\sqrt{s} = 13$ TeV: Obs. $9 \pm 16^\circ$, Exp $0 \pm 28^\circ$ [2])**

[1]: [JHEP 06 \(2022\) 12](#)
 [2]: [EPJC 83 \(2023\) 563](#)

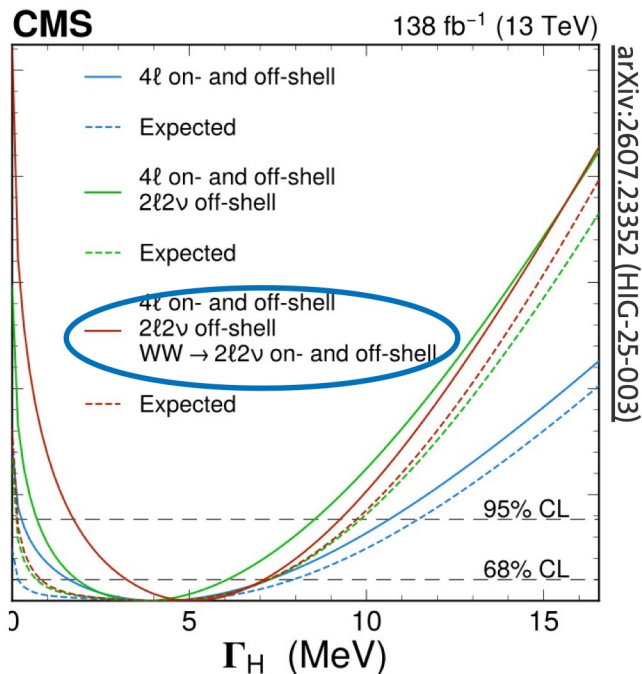
Higgs width

Best precision from **ratio of off-shell and on-shell cross section $\sim \Gamma_H$**

Indirect – assumption about couplings in on-shell and off-shell region



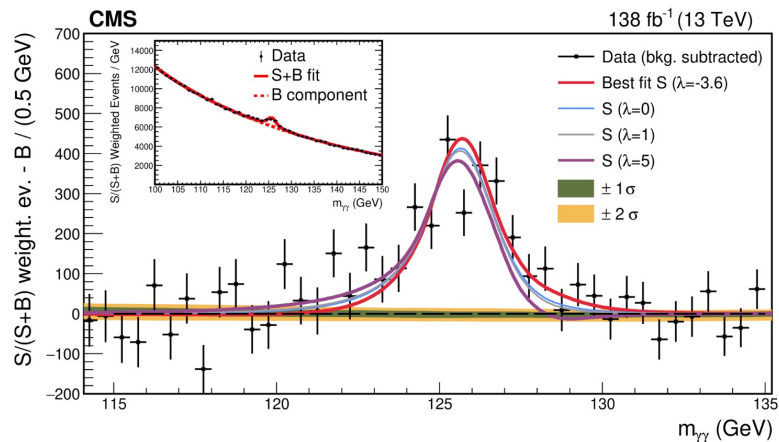
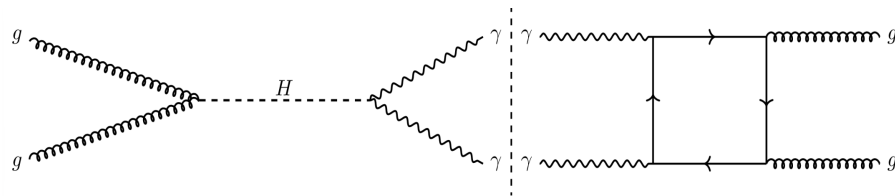
$$\Gamma_H = 3.6^{+2.1}_{-1.6} \text{ MeV}$$



$$\Gamma_H = 5.1^{+2.0}_{-1.8} \text{ MeV}$$

Higgs width with on-shell $H \rightarrow \gamma\gamma$ interference

- Not competitive with off-shell measurement, but model independent...

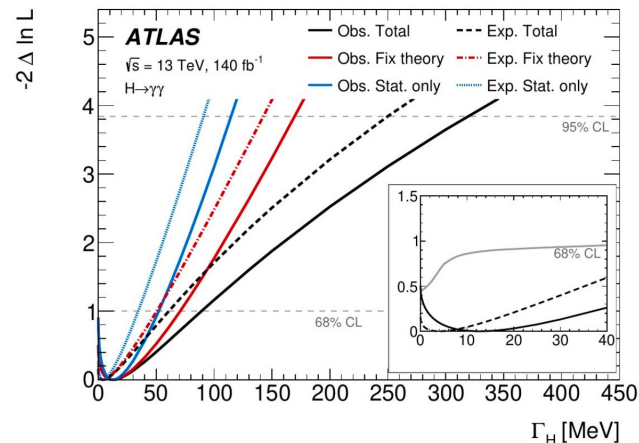


CMS

$\Gamma_H < 92$ (138) MeV observed (expected) @ 95% CL

Signal: $gg \rightarrow H \rightarrow \gamma\gamma$

Background: $gg \rightarrow \gamma\gamma$



ATLAS

$\Gamma_H < 307$ (258) MeV observed (expected) @ 95% CL

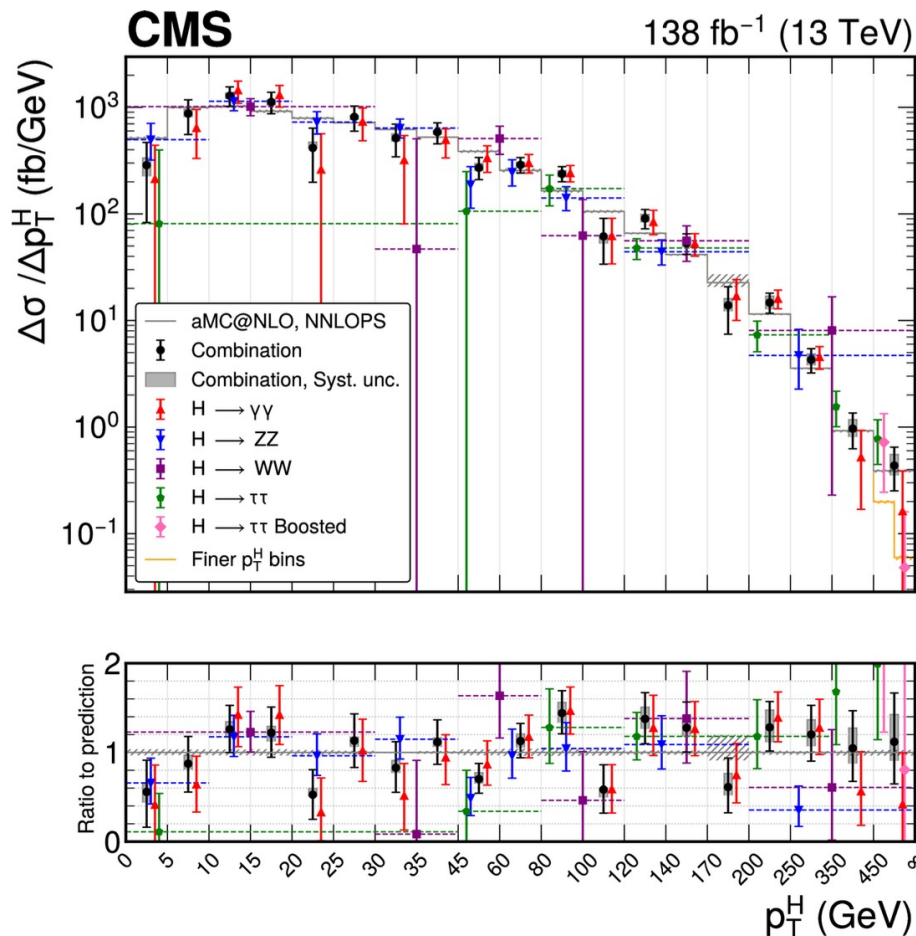
- What drive the sensitivity difference?

Higgs width with on-shell $H \rightarrow \gamma\gamma$ interference

#	Topic	ATLAS-HIGP-2024-12-001	CMS (arXiv:2609.01385)	Why it matters
1	Observed limit	$\Gamma_H < 307$ (258) MeV obs.(exp.)	$\Gamma_H < 92$ (138) MeV obs.(exp.)	Observed ratio 3.3×, but expected ratio only 1.9× for the fairer comparison
2	Categorisation	$p_T(\gamma\gamma)$ only, 2 categories (single 30 GeV split)	jet mult. $\times p_T(\gamma\gamma)$ (5 bins) $\times$ BDT — 11 categories	Does not affect much sensitivity difference ?
3	Interference K-factor	$K_I = 1.64$ (NNLOsv) applied, 39% uncertainty (largest systematic) for difference NNLOsv vs NLO	No K-factor applied (Sherpa NLO kept), 7% uncertainty in NLO QCD	Same theory calc. evaluated 5.6× differently — major debatable point.
4	Statistical boundary treatment	Modified CL_s (denominator at SM point); v1.0 newly discloses asymptotic-vs-toy differ ~10% near $\Gamma_H=0$	Feldman-Cousins, $\lambda = \sqrt{(\Gamma_H / \Gamma_H^{SM})}$, negative values allowed	Different statistical philosophies; ATLAS modified CL_s , CMS Feldman-Cousins

- A good example of when the different treatment of theory (uncertainties) can have a *huge* impact!

Still a word on measurement vs. theory...



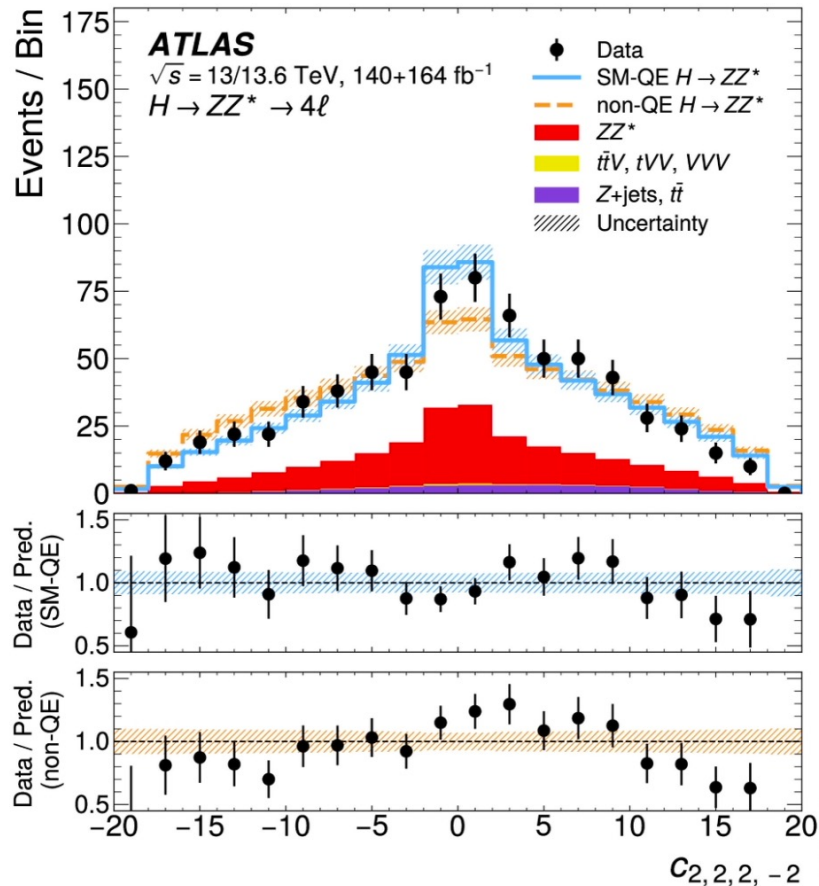
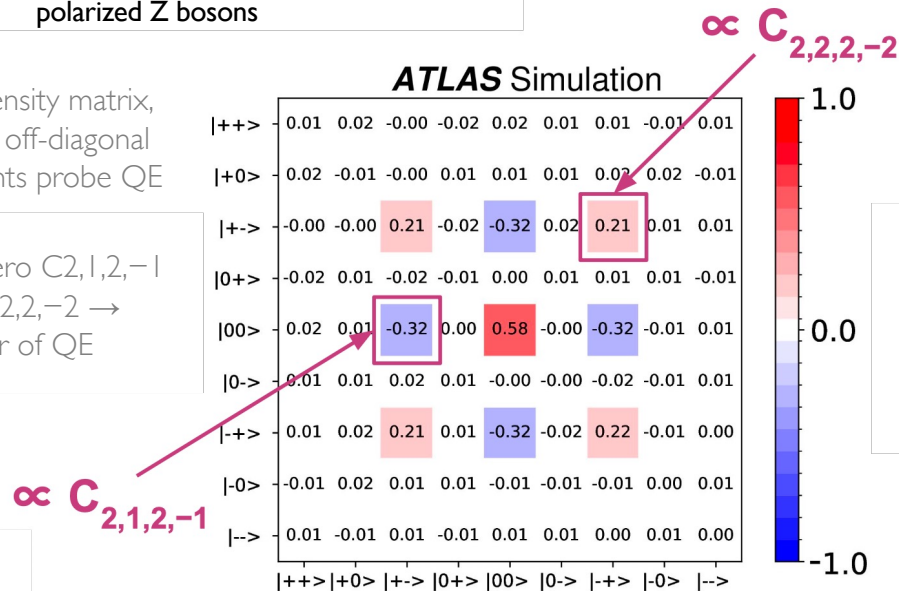
- Greater precision allows for e.g. finer p_T^H bins
- ... but comparison with appropriate theory important (e.g. resummation at low p_T^H)

A new question: entanglement in $H \rightarrow ZZ^* \rightarrow 4\ell$

- Higgs doesn't just tell us it couples to Z the SM way, its decay products carry quantum correlations we can now measure directly
- Anomalous-coupling / CP-violation tests in Z-boson polarization can be framed as an **entanglement probe of the two Z bosons** from the Higgs decay
 - ✓ $C_{2,1,2,-1} = -0.71 \pm 0.45$ (SM: -0.97)
 - ✓ $C_{2,2,2,-2} = 0.08 \pm 0.44$ (SM: 0.64) $\rightarrow$ test QE vs. longitudinal-only polarized Z bosons

spin density matrix, whose off-diagonal elements probe QE

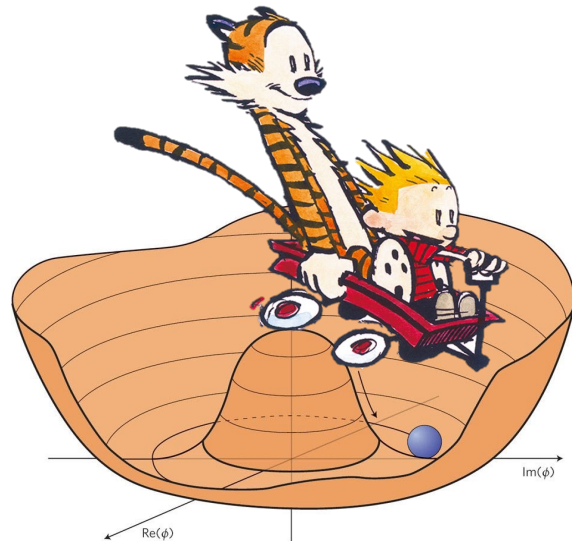
Nonzero $C_{2,1,2,-1}$ or $C_{2,2,2,-2} \rightarrow$ marker of QE



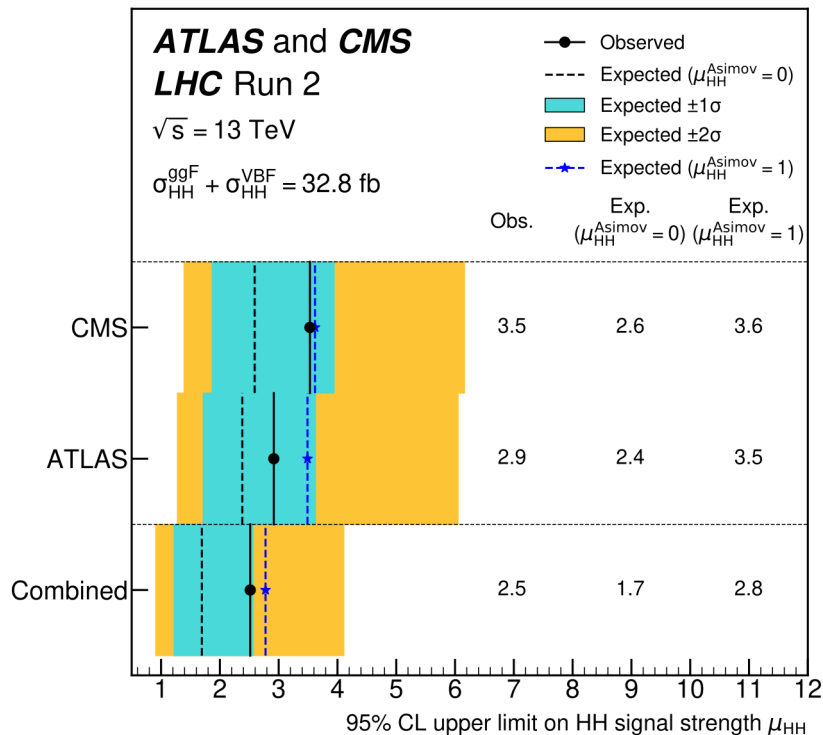
4.

“Despite all appearances, they are not adult yet...”

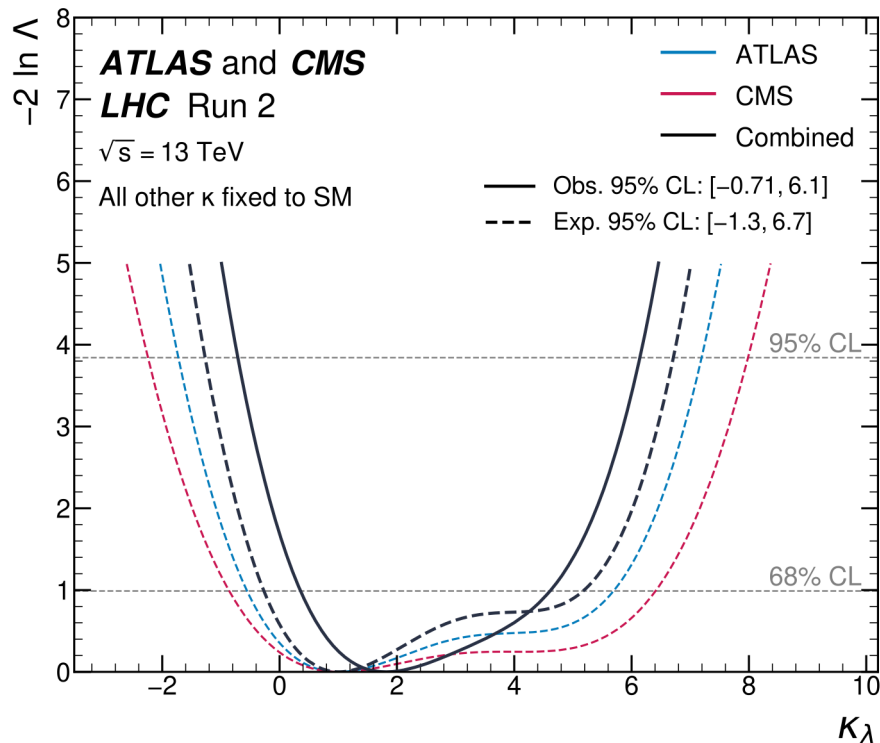
The still-open
heart of the story:
the shape of the potential



ATLAS-CMS Run-2 HH combination: the starting line

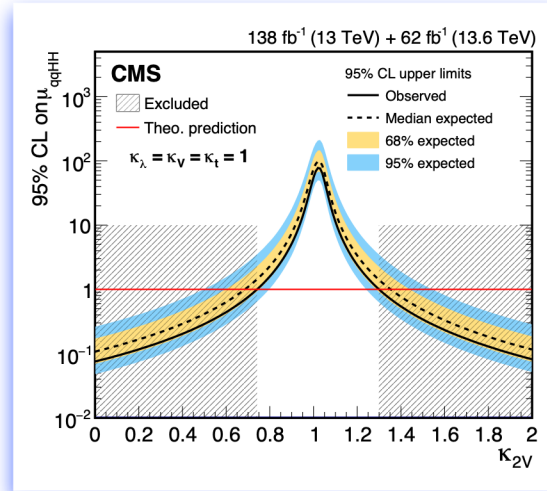
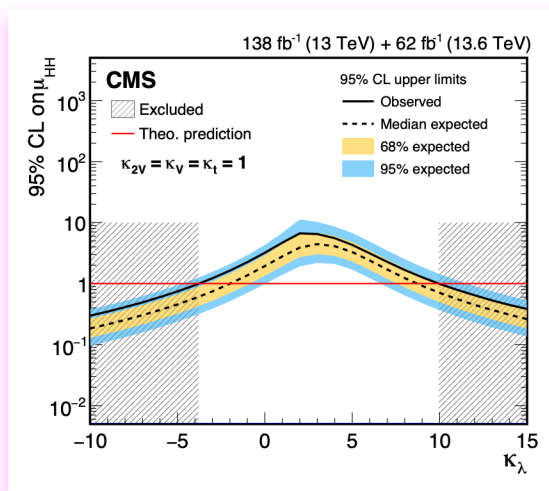
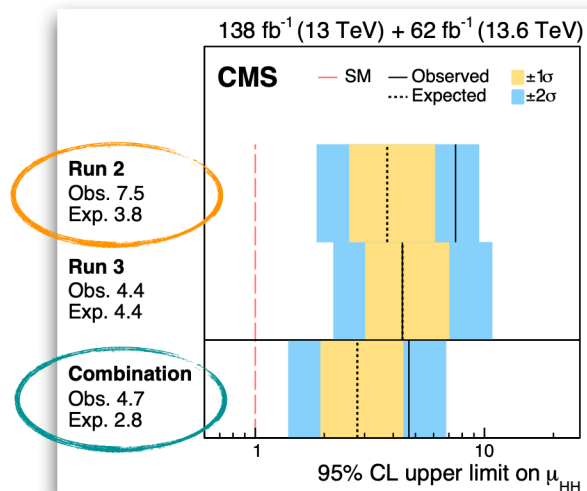


ATLAS +CMS
 $\mu_{HH} < 2.5$ @ 95% CL



ATLAS +CMS
 $-0.71 < \kappa_\lambda < 6.1$ @ 95% CL

Run 2 + Run 3 HH analyses: CMS HH $\rightarrow$ b $\bar{b}$ b $\bar{b}$



Reanalysis of Run 2 resolved analysis

Observed (expected) UL @95% CL:

$$\sigma_{HH} < 4.7(2.8) \times \sigma_{HH}^{SM} \quad \text{While, } \sigma_{VBFHH} < 54(80) \times \sigma_{VBFHH}^{SM}$$

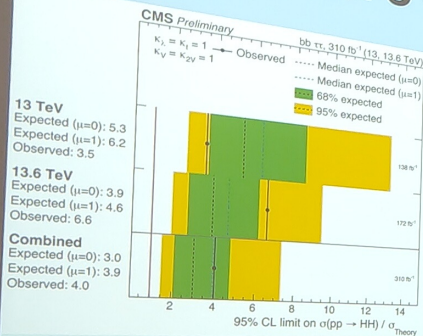
95% CL constraints on the coupling modifiers:

$$\kappa_\lambda \in [-3.8, 10.0] \quad ([-2.0, 8.7]) \quad \kappa_{2V} \in [0.74, 1.30] \quad ([0.69, 1.35])$$

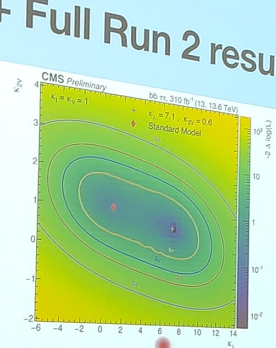
Most stringent constrains on the κ_{2V}

With 62 fb⁻¹, HH $\rightarrow$ 4b achieves a comparable sensitivity with Run 2 (138 fb⁻¹), and better than the Run 2 searches in $b\bar{b}\gamma\gamma$ and $b\bar{b}\tau\tau$

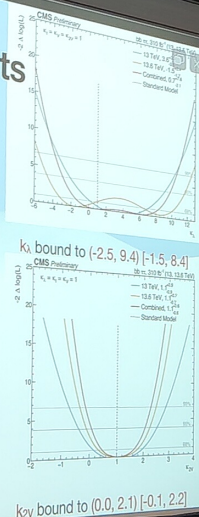
Partial Run 3 + Full Run 2 results



Excluding cross sections larger than $3.0 \times \text{SM}$ at 95% CL $\rightarrow$ observed compatible with expected assuming $\mu=1$



Correlation visibly reduced wrt Full Run 2



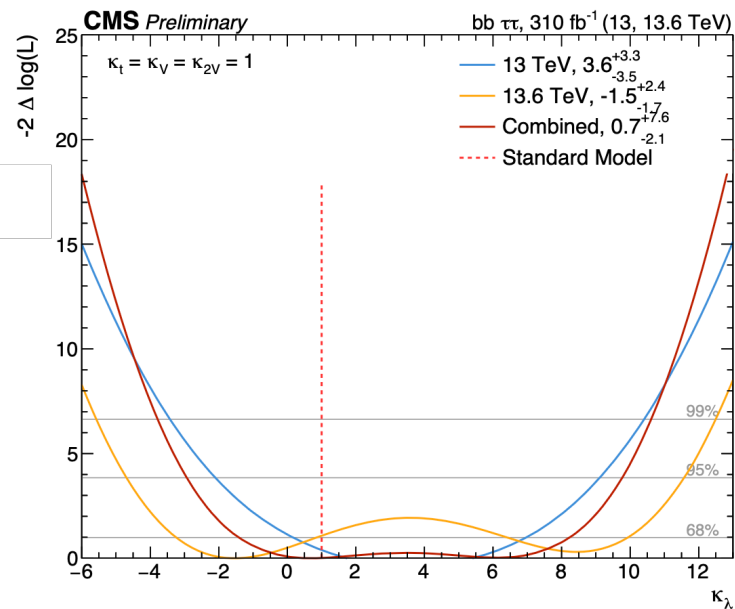
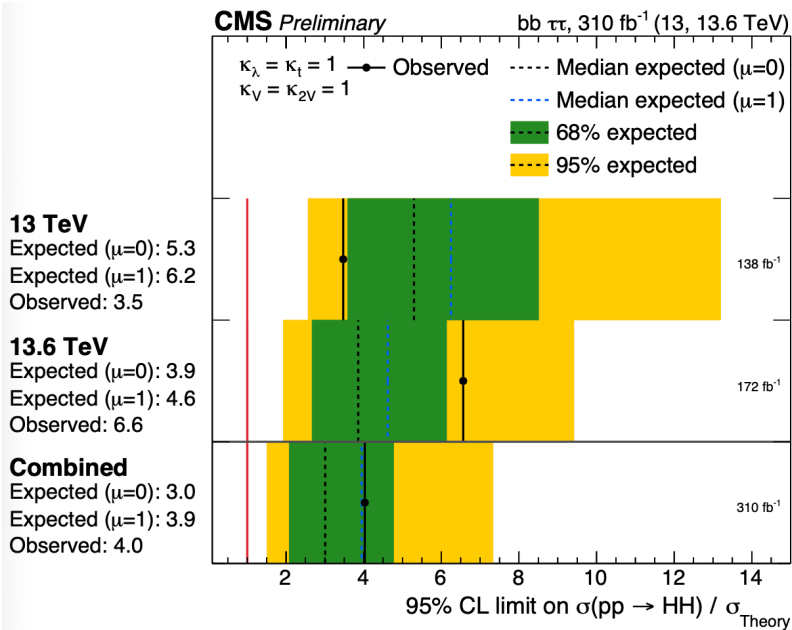
ALLELUJA!

?

Run 2 + Run 3 HH analyses: CMS $HH \rightarrow b\bar{b}\tau\tau$

• CMS

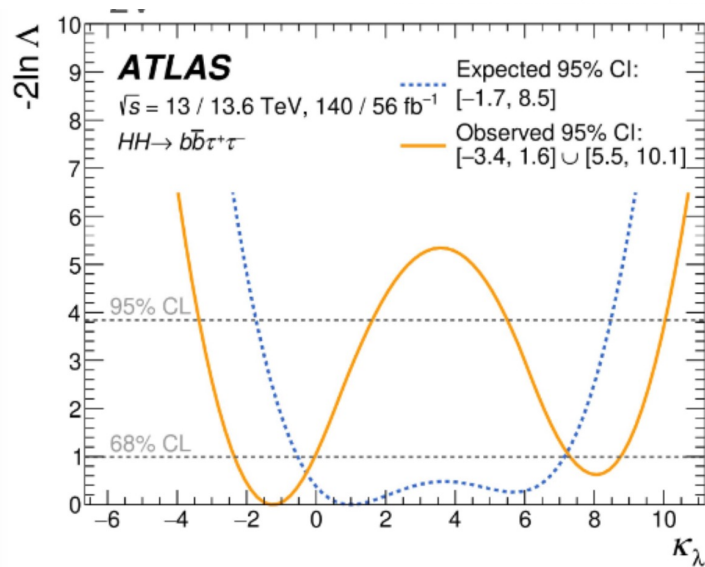
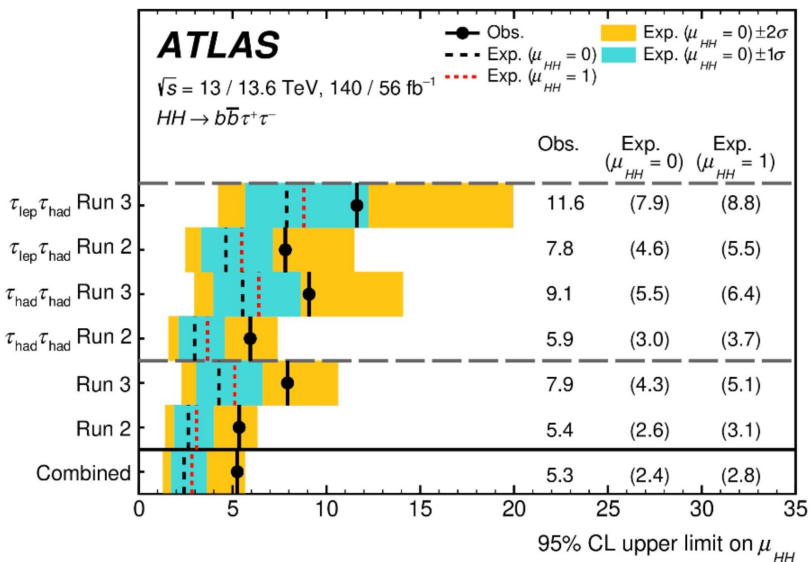
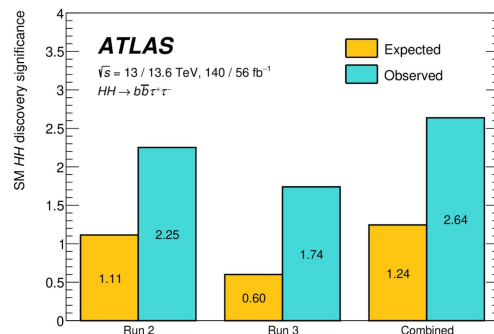
- ✓ Run 3 only (172 fb⁻¹): **3.9 (6.6) × SM**
 - ~20% better than the published Run-2 result alone
- ✓ Run 2+3 combined (310 fb⁻¹): **4.40 (3.9) × SM**
 - $\kappa_\lambda \in [-2.5, 9.4]$ $([-1.5, 8.4])$
 - $\kappa_{2V} \in [0.02, 2.1]$ $([-0.1, 2.2])$



Run 2 + Run 3 HH analyses: ATLAS HH $\rightarrow$ b $\bar{b}$ $\tau\tau$

• ATLAS

- ✓ 196 fb $^{-1}$: full Run 2 + partial Run 3
- ✓ Combined significance: **2.64 σ obs** / **1.24 σ exp**
 - 50% higher expected significance than CMS's equivalent channel (37% less luminosity)
 - 19% higher than ATLAS HH $\rightarrow$ b $\bar{b}\gamma\gamma$ (36% less luminosity)
- ✓ $\kappa\lambda \in [-3.4, 1.6] \cup [5.5, 10.1]$, $\kappa 2V \in [-0.2, 2.4]$.



$HH \rightarrow b\bar{b}\tau\tau$: do we understand the difference between ATLAS vs CMS, and should we get excited?

- ATLAS

- ✓ Run 2+3 combined lumi: 196 fb^{-1}
- ✓ Exp sensitivity: $2.8 \times \text{SM}$
- ✓ Exp discovery significance: 1.24σ

- CMS

- ✓ Run 2+3 combined lumi: 310 fb^{-1}
- ✓ Exp sensitivity: $3.9 \times \text{SM}$
- ✓ Exp discovery significance: 0.8σ

- ... **not really**

- ✓ Different trigger strategy, object reconstruction and selection, categorization, background treatments, ...
- ✓ Can we do anything to better understand?

- ... **probably not (yet)**



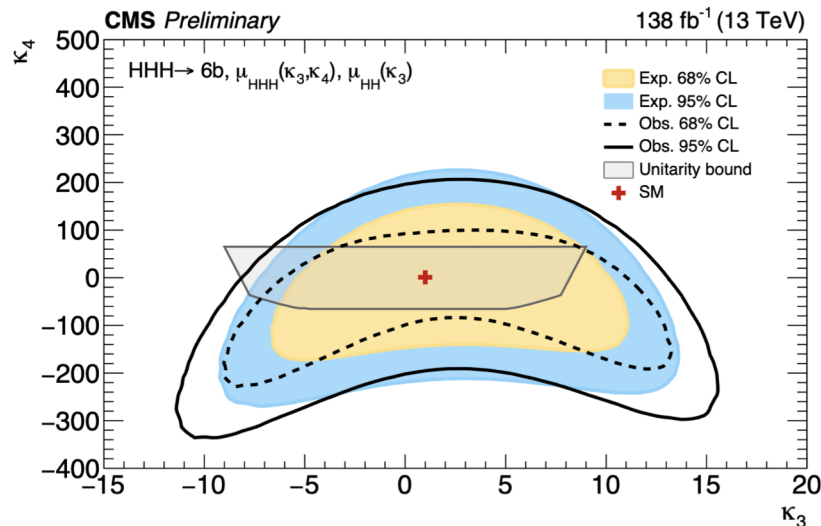
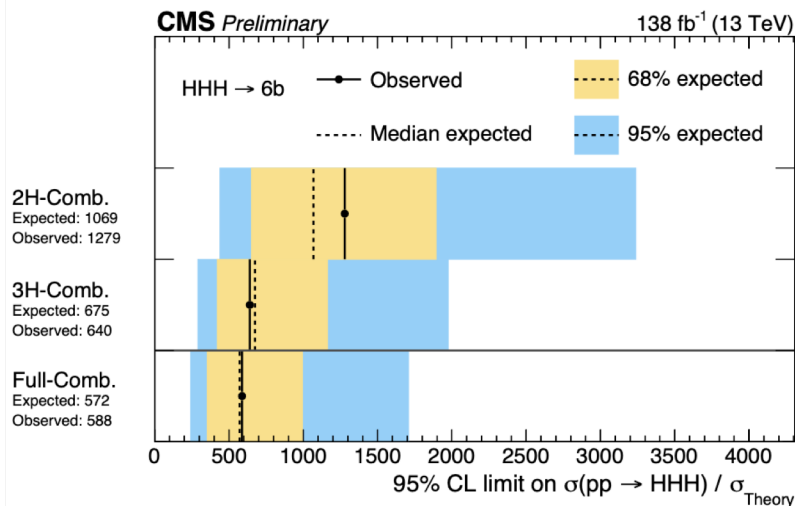
- **A few thoughts from the discussions...**

- ✓ HH production is almost certainly there (if there's ggH there's ggHH)
- ✓ Can we better optimize for κ_λ (other than m_{HH} split)?
- ✓ Can we optimize for HH significance, not only limit (and always report p_0)?

Bringing in λ_4 : HHH and the full shape of the potential

- Di-Higgs almost purely sensitive to λ_3 , triple-Higgs brings in λ_4 : full determination of the potential only possible through combined measurement (but SM not accessible at LHC)
- CMS HHH $\rightarrow$ 6b
 - ✓ First CMS combined-category HHH result; +18% sensitivity from adding 2-Higgs categories, +20% from semi-boosted/boosted topologies
 - ✓ Obs (exp) $\mu < 588$ (572) $\times$ SM @ 95% CL

- Combinatorics challenging, could be reduced in 4b2tau
- Drive development of new tools i.e jet-charge tagger



5.

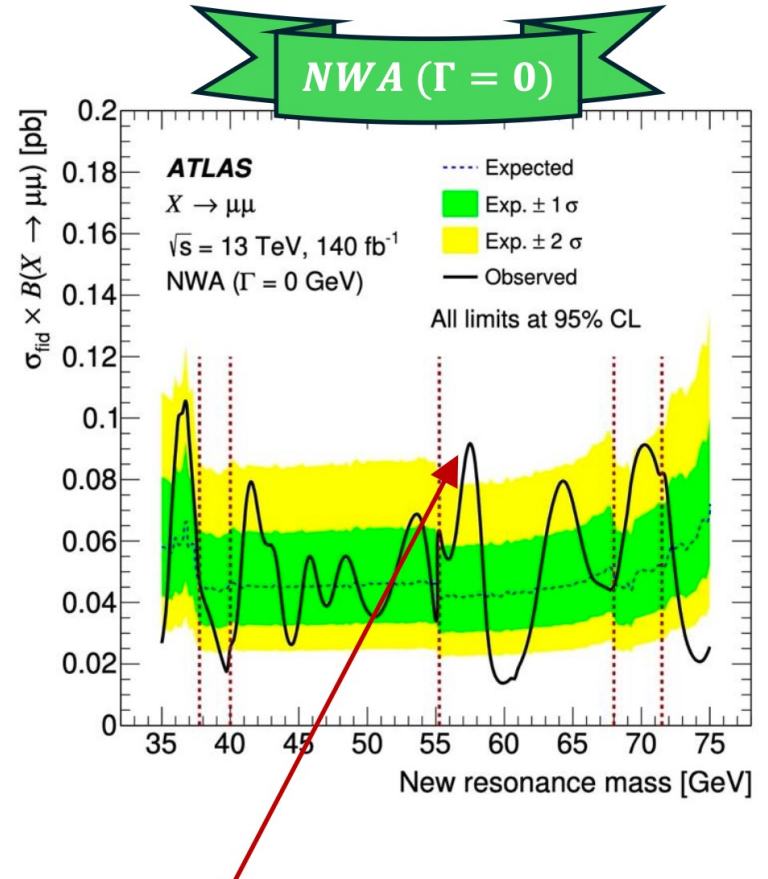


“Searching alternative identities is still a daily job”

Widening the net, nothing found (yet)

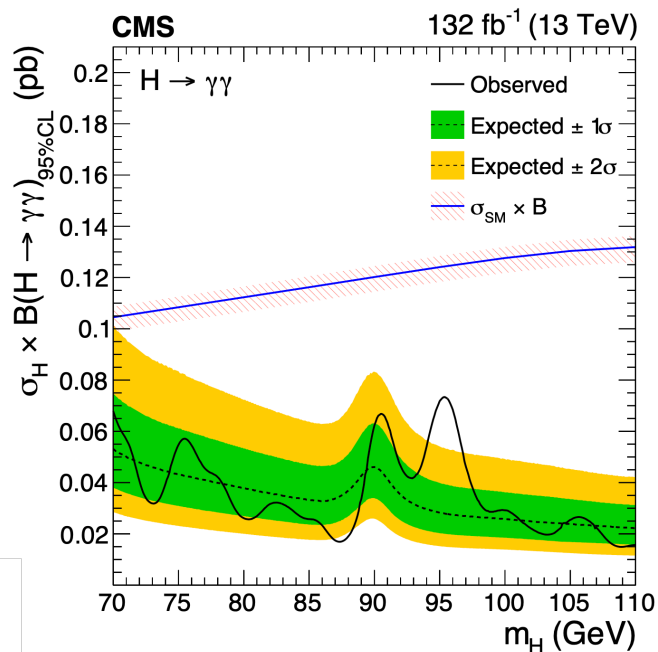
ATLAS BSM scalars: overall a clean null result

- A broad program
 - ✓ light pseudoscalar a ($H \rightarrow aa$, 4–60 GeV mass range)
 - ✓ $X \rightarrow \mu\mu$ model-independent bump hunt (35–75 GeV)
 - ✓ Z' /dark-matter-portal searches
 - ✓ charged-Higgs/LFV channels
- No significant excess over SM background in any of these ATLAS analyses
- Largest local excess: 2.3σ local in $X \rightarrow \mu\mu$ search at $m = 57.5$ GeV

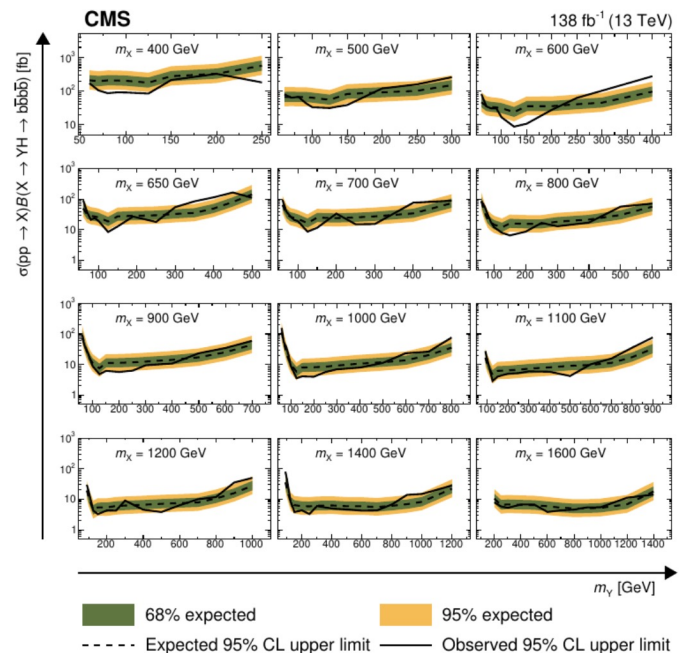


CMS BSM scalars: a busier excess landscape...

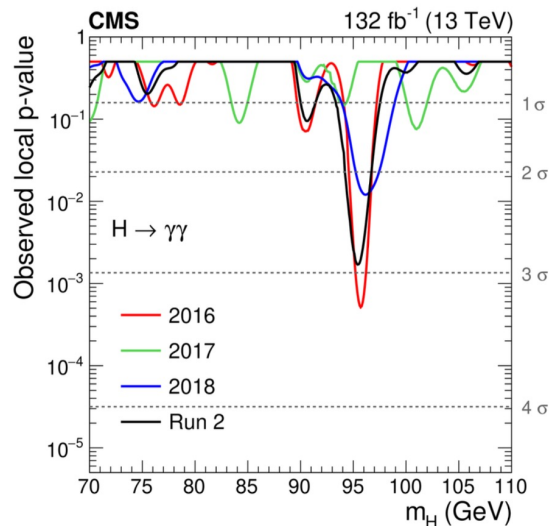
- The 95 GeV diphoton excess:
 - ✓ **2.9 σ local / 1.3 σ global**
 - ✓ $m_H = 95.4$ GeV
 - ✓ the “well-known” excess...



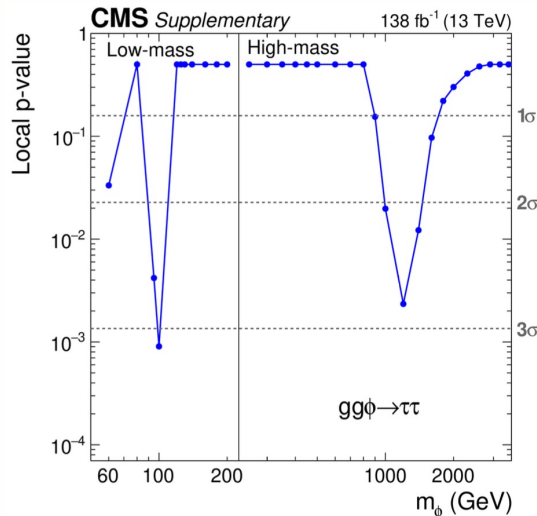
- Hidden-sector $X \rightarrow YH \rightarrow 4b$ cascade excess:
 - ✓ **3.47 σ local / 2.44 σ global**
 - ✓ $(m_X, m_Y) \sim (600, 400)$ GeV, 4b final state
 - ✓ one of largest local deviations shown...



Coincidences at ~95-100 GeV?



CMS $H \rightarrow \gamma\gamma$ local p -value scan (132.2 fb^{-1}) [HIG-20-002, Fig. 7]



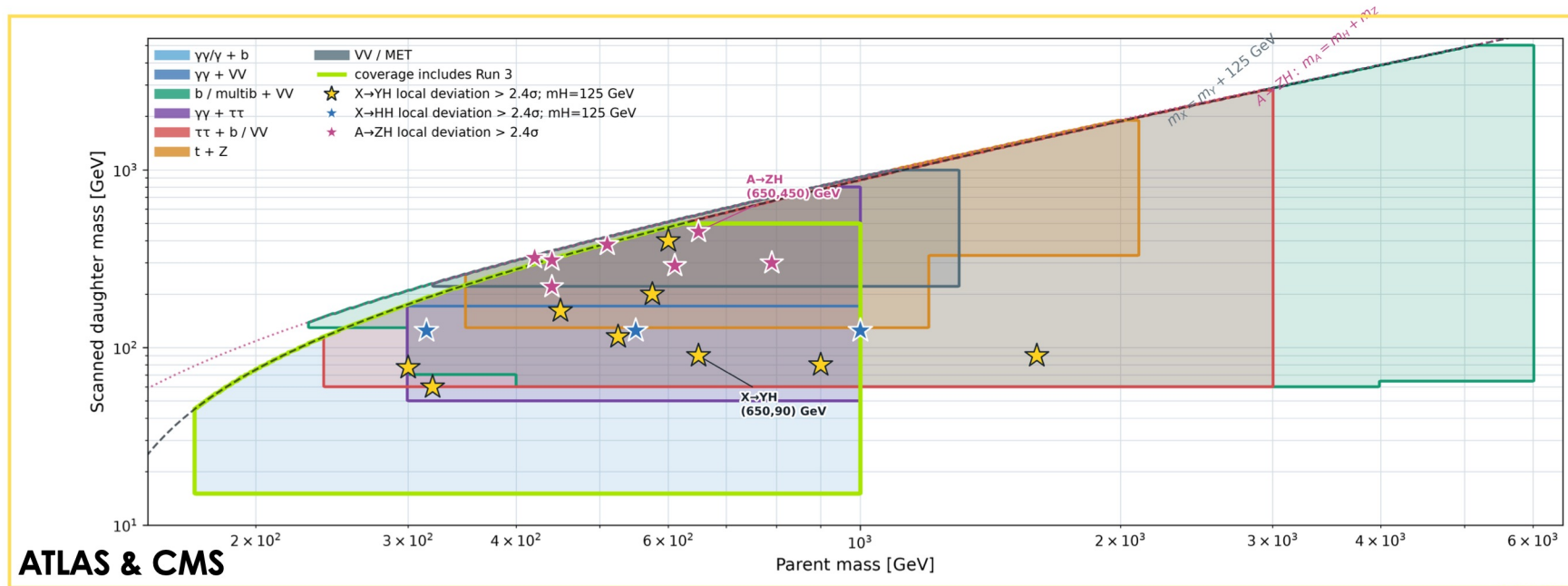
Observed local p -value scan for $gg\phi$ ($b\bar{b}\phi$ profiled) [CMS HIG-21-001, Additional Fig. 31]

- Run-2 search for extra neutral scalars, 138 fb^{-1} , four $\tau\tau$ decay channels, mass range 60 GeV–3.5 TeV
- Largest deviation at ~100 GeV: 3.1 σ local (2.7 σ global)**
 - ✓ **At 95 GeV: 2.6 σ local (2.3 σ global)**
 - ✓ Broad $m_{\tau\tau}$ resolution: if you want to dream, 95-100 GeV difference could be consistent with a common hypothesis
- CMS Run 3 analysis ongoing, but no public result yet...**

Channel / Experiment	Mass Hypothesis	Observed Excess	Reference
CMS $H \rightarrow \tau\tau$	100 GeV (95 GeV)	3.1σ local (2.6 σ)	JHEP 07 (2023) 073
CMS $H \rightarrow \gamma\gamma$	95.4 GeV	2.9σ local (1.3 σ global)	PLB 860 (2025) 139067
LEP $e^+e^- \rightarrow Z(b\bar{b})$	≈ 98 GeV	2.3σ local (1 – CL _b)	PLB 565 (2003) 61

How wide the search really is?

- 179 scoped BSM-analysis entries (98 CMS / 80 ATLAS), 42 unique references with $>2.4\sigma$ local deviation
- Two more named excesses beyond the 95 GeV one
 - ✓ ATLAS $X \rightarrow SH \rightarrow b\bar{b}\gamma\gamma$: $(m_X, m_S) = (575, 200)$ GeV, 3.5σ local / 2.0σ global
 - ✓ CMS $X \rightarrow HY \rightarrow \gamma\gamma b\bar{b}$: $(m_X, m_Y) = (650, 90)$ GeV, 3.8σ local / 2.8σ global



Asking the right question: when and how observed excess should drive future search?

1

Global context

How much does the look-elsewhere effect reduce the local feature?

2

Internal stability

Does the feature persist across years, categories, and reconstruction choices?

3

Independent test

Can the other experiment test the same mass point and signal hypothesis?

4

Physics coherence

Do other final states imply compatible rates and quantum numbers?

5

Independent new data

Does new data (e.g. Run 3) reproduce the feature with a predefined strategy?

A concrete checklist for Run 3

A decisive update uses a fixed signal hypothesis and an independent dataset. Nearby structures remain supporting information.

FEATURE	RUN 2 EVIDENCE	INDEPENDENT INFORMATION	DECISIVE RUN 3 TEST
95 GeV light scalar	CMS HIG-20-002: $\gamma\gamma$ 95.4 GeV, 2.9 (1.3) σ CMS HIG-21-001: $\tau\tau$ 95 GeV, 2.6 (2.3) σ ; 100 GeV, 3.1 (2.7) σ	ATLAS arXiv:2407.07546: $\gamma\gamma$ at 95.4 GeV, 1.7 σ ATLAS $\tau\tau$ searches cover the region without a comparable maximum	Run 3-only fits at fixed 95.4 and 100 GeV. Keep $\gamma\gamma$ and $\tau\tau$ separate. Combine only under one specified signal model.
X$\rightarrow$YH (650,90) GeV	CMS HIG-21-011: $\gamma\gamma b\bar{b}$, 3.8 (2.8) σ	ATLAS arXiv:2510.02857 tests the same point with Run 2+3. The fixed-point result gives $p_0 = 0.5$.	CMS full Run 3 update. ATLAS full Run 3-only result at the fixed point with the same narrow-width hypothesis.
X$\rightarrow$WW 650 GeV	CMS HIG-20-016: 3.8 σ local Global: 2.6 σ for VBF-only; 2.4 σ with floating tVBF	ATLAS CONF-2022-066 covers 300-4000 GeV with no feature near 650 GeV. Production categories are not identical.	Match ggF/VBF categories, spin-0 width, event selection and trial range before comparing the Run 3 results.
X$\rightarrow e\mu$ 146 GeV	CMS HIG-22-002: 3.8 (2.8) σ	No exact ATLAS $e\mu$ scan in the inventory. ATLAS H125 $\rightarrow e\tau/\mu\tau$ is complementary, not a replication.	ATLAS $e\mu$ scan over 110-160 GeV and CMS full Run 3 update. Retain 146 GeV as a predefined test.
A$\rightarrow$ZH$\rightarrow$Zhh (420,320) GeV	ATLAS arXiv:2210.05415: Z4b with $\Gamma_A/m_A = 20\%$, 3.8 (2.8) σ	No CMS A $\rightarrow$ ZH $\rightarrow$ Zhh $\rightarrow$ Z4b counterpart is recorded in the inventory.	CMS 2D scan with narrow and 20% width hypotheses. ATLAS full Run 3 update at the same coordinate.

Numbers are local (global) significance. Different production, spin, width or daughter-mass hypotheses are not treated as confirmations.



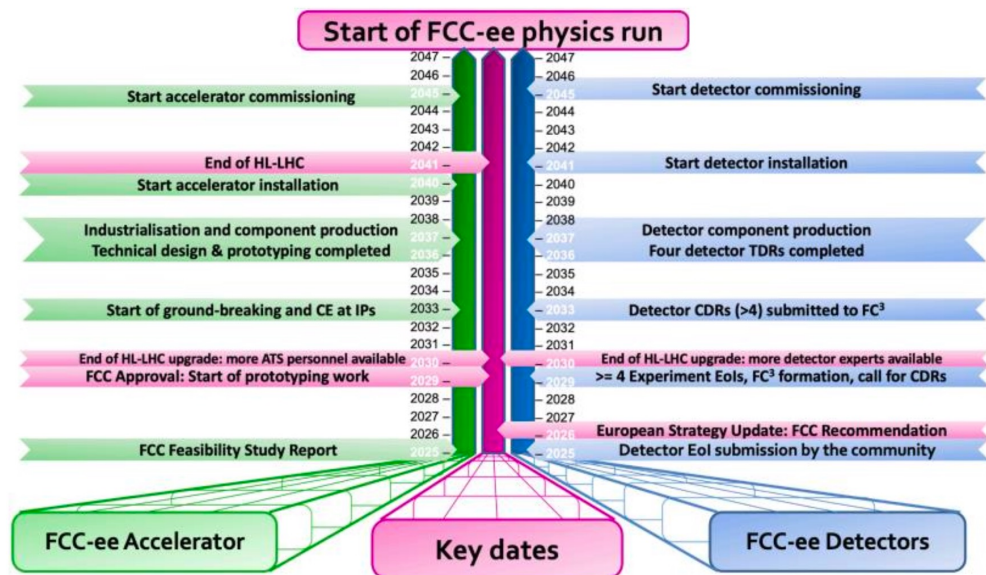
6.

“Future might seem far away,
but adulthood is not that far”

What's next

International consensus, and a decision point by 2028

- ESPPU (European Strategy for Particle Physics Update) recommends the e^+e^- Future Circular Collider (FCC-ee) as the preferred option for the next CERN flagship collider
- **Approved by CERN Council in June 2026. Goal: assemble all material for a construction decision by early 2028**
- CEPC (China): no longer pursued as a standalone competing project, repositioning to “continue CEPC while looking forward to being a major partner of FCC”



“Our clear aim is to be ready for a decision on FCC-ee in 2028”
DG, plenary ECFA, Amsterdam, 9/7/26

What this means is that all material for a decision needs to be assembled by early 2028 – dictates current planning.

Why an e^+e^- Higgs factory after (HL-)LHC?

- **A (partial) selection of FCC-ee Higgs results**

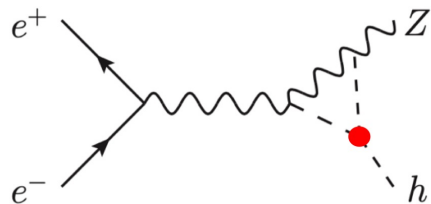
- ✓ Higgs mass to 3.97 MeV via the recoil-mass method ($e^+e^- \rightarrow ZH$, clean initial state; dominated by beam-energy-spread systematics)
- ✓ ZH cross-section (and so g_{HZZ}) model-independently to 0.28% at 240 GeV and 0.49% at 365 GeV (and from this, model independent Higgs width at O(5%) precision)
- ✓ Most couplings reachable at O(0.1–0.5)% precision, including second-generation quarks for the first time!

Coupling	HL-LHC	FCC-ee	FCC-ee + FCC-hh
κ_Z (%)	1.3*	0.10	0.10
κ_W (%)	1.5*	0.29	0.25
κ_b (%)	2.5*	0.38 / 0.49	0.33 / 0.45
κ_g (%)	2*	0.49 / 0.54	0.41 / 0.44
κ_τ (%)	1.6*	0.46	0.40
κ_c (%)	–	0.70 / 0.87	0.68 / 0.85
κ_γ (%)	1.6*	1.1	0.30
$\kappa_{Z\gamma}$ (%)	10*	4.3	0.67
κ_t (%)	3.2*	3.1	0.75
κ_μ (%)	4.4*	3.3	0.42
$ \kappa_s $ (%)	–	+29 –67	+29 –67
Γ_H (%)	–	0.78	0.69
$\mathcal{B}_{\text{inv}} (<, 95\% \text{ CL})$	$1.9 \times 10^{-2} *$	5×10^{-4}	2.3×10^{-4}
$\mathcal{B}_{\text{unt}} (<, 95\% \text{ CL})$	$4 \times 10^{-2} *$	6.8×10^{-3}	6.7×10^{-3}

Feasibility Study Report Volume I | Physics, Experiments, Detectors | [arXiv:2505.00272](https://arxiv.org/abs/2505.00272)

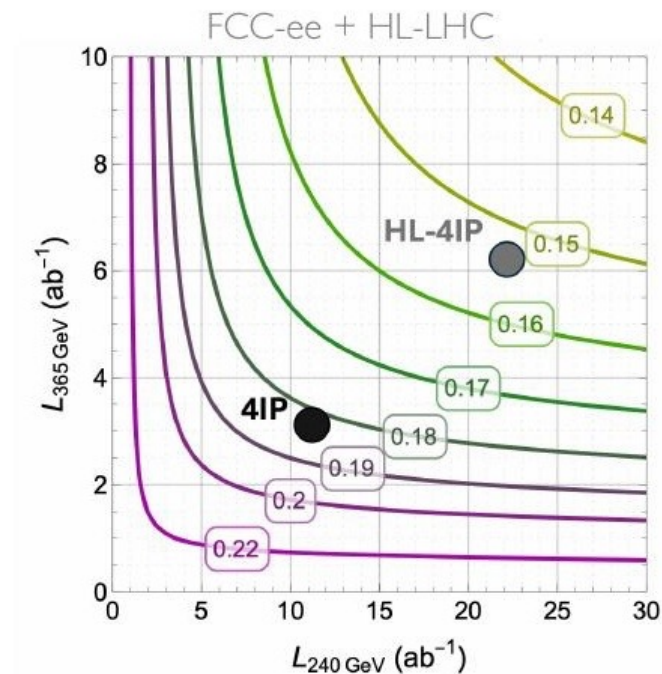
- **Higgs precision at FCC-ee will translate into indirect limits on Higgs-coupled BSM for scales $\Lambda > 5\text{--}100 \text{ TeV}$**

HL-LHC and FCC-ee are complementary! An example



- Radiative corrections to $e^+e^- \rightarrow H$ involve κ_λ
- Corrections several % in SM at 240 GeV and **depend strongly on c.o.m. energy!**
 - ✓ Sub-percent precision of FCC-ee cross-section measurements at 240 and 365 GeV exploits energy dependence to **disentangle NP in the HZZ coupling from κ_λ**

- HL-LHC measure κ_λ directly via HH production, but will stay at $O(1)$ precision even by the end of HL-LHC
- FCC-ee has no direct self-coupling reach, but κ_λ enters radiative corrections to $e^+e^- \rightarrow H$: combining the two improves overall κ_λ precision from **$\sim 28\%$** (FCC-ee alone) to **$\sim 18\%$**
- A high-luminosity FCC-ee scenario (double luminosity at 240/365 GeV) could reach **$\sim 15\%$** in **combination with HL-LHC**



Fourteen, and counting

- **Out teenager Higgs boson grew up fast!**

- ✓ Run 3 catching Run 2 (and there's more data to analyze)
- ✓ Evidence-level rare decays
- ✓ A real (if not yet significant) HH excess
- ✓ A new question on the table: entanglement
- ✓ A lot of cutting-edge technologies enabling all this!

- **What hasn't changed since childhood...**

- ✓ Still no crack in the SM picture (but we have a plan, or at least a checklist. And EFT...)
- ✓ The Higgs potential's true shape is still an open question (but we might get some answers already with Run 3 data, and most certainly at HL-LHC)

- *Thanks to the organizers, and to everyone whose slides made this summary possible*



$$\mathcal{L} = \phi^\dagger \partial_\mu \phi + \mu^2 \phi^\dagger \phi - \lambda (\phi^\dagger \phi)^2$$

$$-ie (\phi \partial_\mu \phi^\dagger A_\mu - \phi^\dagger \partial_\mu \phi) A_\mu - e^2 \phi^\dagger \phi A_\mu A_\mu$$

$$\phi = \frac{1}{\sqrt{2}} (\phi_1 + i\phi_2)$$

$$\phi_1 = \langle \phi_1 \rangle + \varphi_1$$
~~$$\phi_2 = \varphi_2$$~~

$$\mu = 0, \dots, 3$$

$$m = 4, \dots, 9$$

$$B_{\mu m}^- = \mathcal{E}^-(x_1 dx_2 - x_3 dx_4 - x_5 dx_6)$$

$$B_{\mu m}^+ = \mathcal{E}^+(x_1 dx_2 - x_3 dx_4 + x_5 dx_6)$$

$$B_{\mu m}^+ = \mathcal{E}^+(x_1 dx_2 - x_3 dx_4 - x_5 dx_6)$$

$$B_{\mu m}^+ = \mathcal{E}^+(x_1 dx_2 - x_3 dx_4 - x_5 dx_6)$$

$$B_{\mu m}$$

$$\mathcal{E}_1 + \mathcal{E}_2$$

$$\frac{\mathcal{E}_1 + \mathcal{E}_2}{2}$$

In memoriam — François Englert, 1932–2026

