Measurement of the Higgs boson width in ZZ final states at CMS

Li Yuan
Beihang University

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Outline

- Introduction
- Analysis Strategies
  - H→ZZ→4*l* on-shell analysis
  - H→ZZ→4*l* off-shell analysis
  - H→ZZ→2*l*2*ν* off-shell analysis (more details)
- Summary

Higgs Width

- **Predicted width in SM Γ_H: 4.1MeV**

- **Due to detector response, the mass of Higgs is smeared $\sigma \sim$ 1-2GeV**

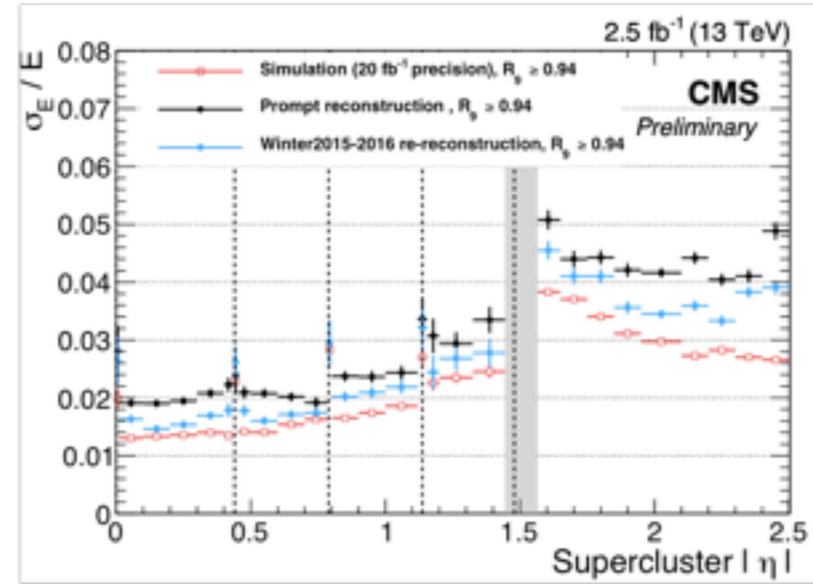
e.g for an electron E_e~50GeV, σ_e~1GeV

$$m_H = \sqrt{(E_{e1} + E_{e2} + E_{e3} + E_{e4})^2 - (\overrightarrow{p_{4e}})^2}$$

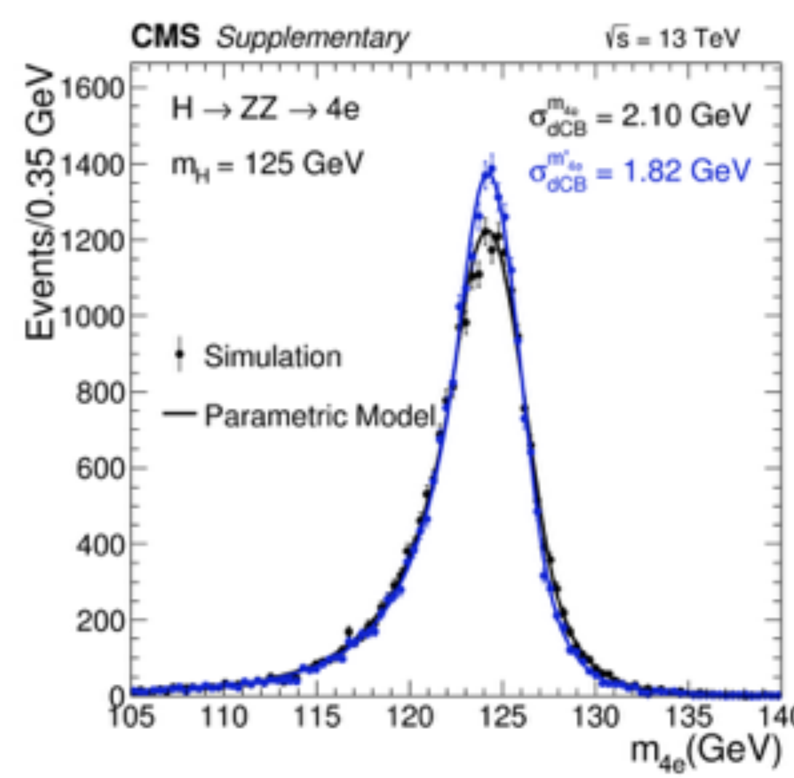
$$\sigma_{mH} \sim 2 \times \sigma_e = 2\text{GeV}$$

500 times SM $\Gamma_H \sim$ 4.1MeV

Unable to measure Higgs Width through on-shell pole



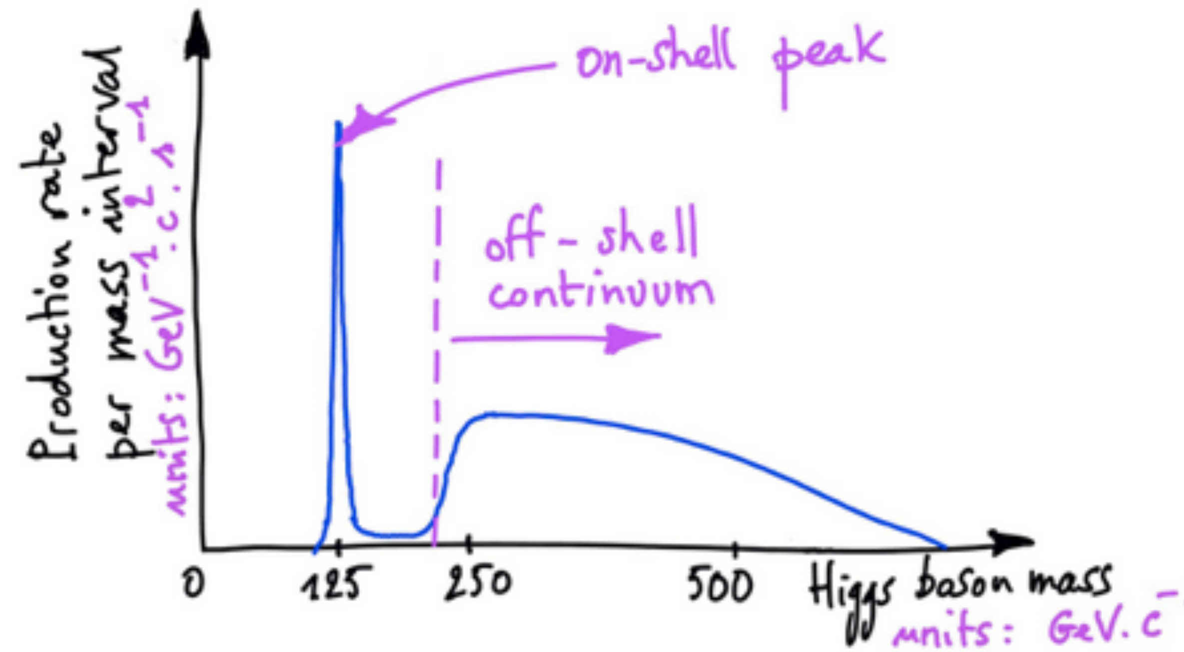
relative energy resolution for e



Indirect way to measure Γ_{H}

- **Higgs production rate:**

$$d\sigma \propto \frac{g_{\mathrm{prod}}^2 g_{\mathrm{dec}}^2}{\left(q_H^2 - m_H^2\right)^2 + m_H^2 \Gamma_{\mathrm{H}}^2} dq_H^2$$



$$\Rightarrow \quad \sigma^{\text{on-shell}} \propto \frac{g_{\mathrm{prod}}^2 g_{\mathrm{dec}}^2}{\Gamma_{\mathrm{H}}} \propto \boxed{\mu_{\text{on-shell}}}$$

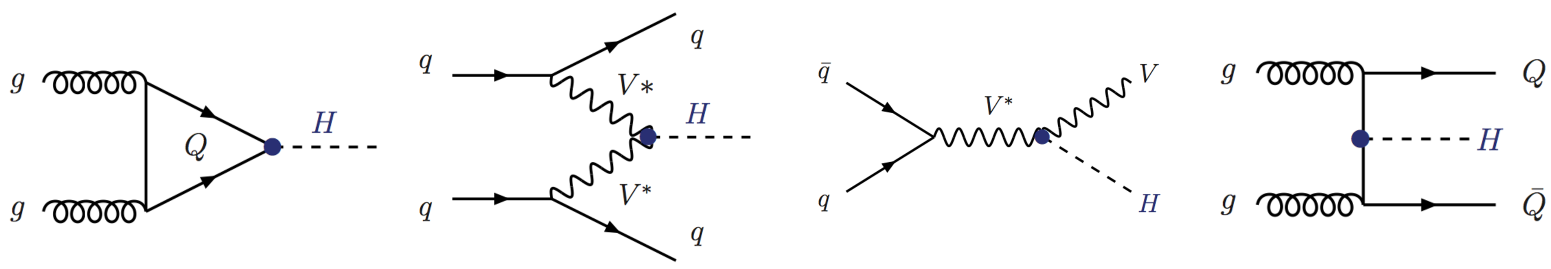
$$\Rightarrow \quad \sigma^{\text{off-shell}} \propto \int \frac{g_{\mathrm{prod}}^2 g_{\mathrm{dec}}^2}{\left(q_H^2 - m_H^2\right)^2} dq_H^2 \propto \boxed{\mu_{\text{off-shell}} \propto \mu_{\text{on-shell}} \times \Gamma_{\mathrm{H}} / \Gamma_{\mathrm{SM}}}$$

- **By measuring the signal strengths in on-shell and off-shell, and take their ratio, we could measure Γ_{H}**

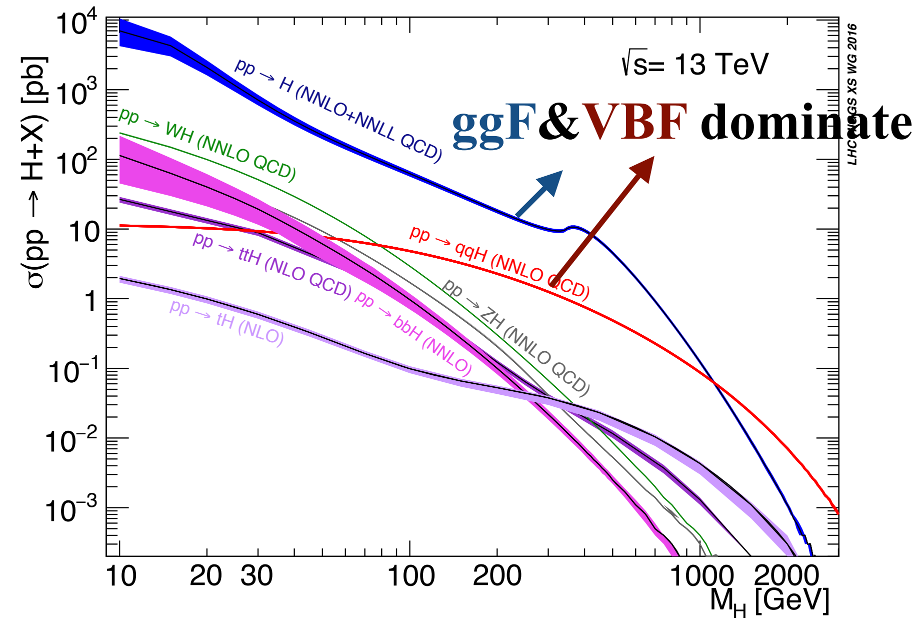
$$\Gamma_H / \Gamma_{SM} = \frac{\mu_{off-shell}}{\mu_{on-shell}}$$

Off-shell Higgs

- **Production modes for both on-shell and off-shell:**
  ggF, VBF, VH, ttH

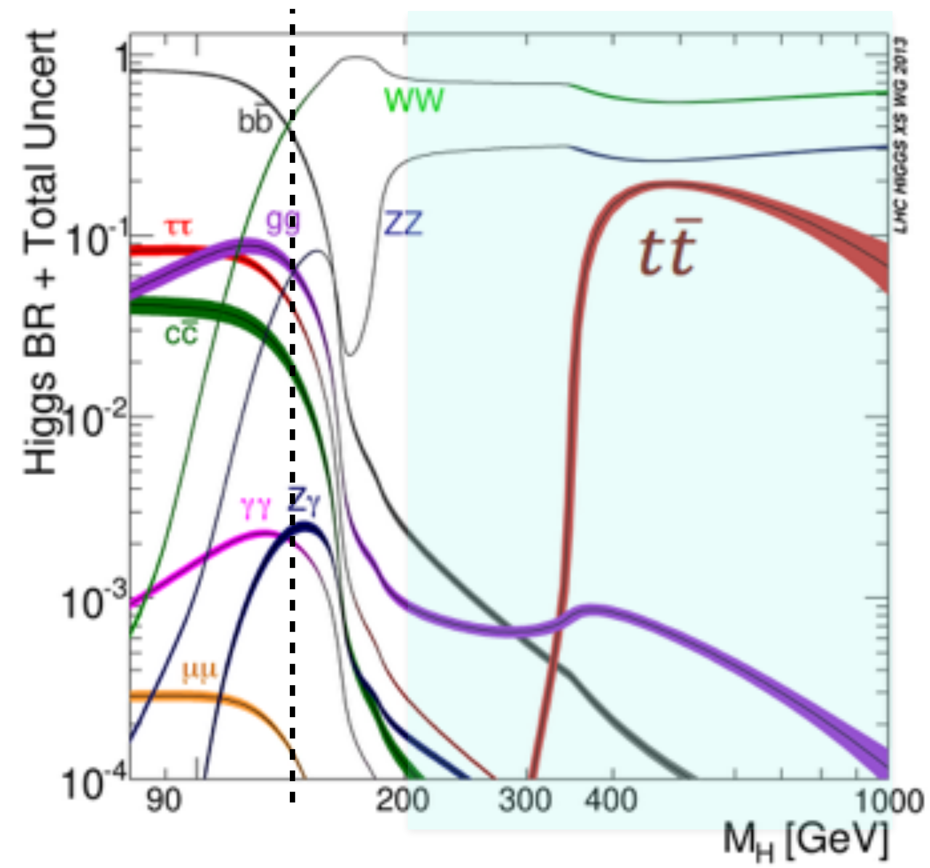


ggF **VBF** **VH** **ttH**



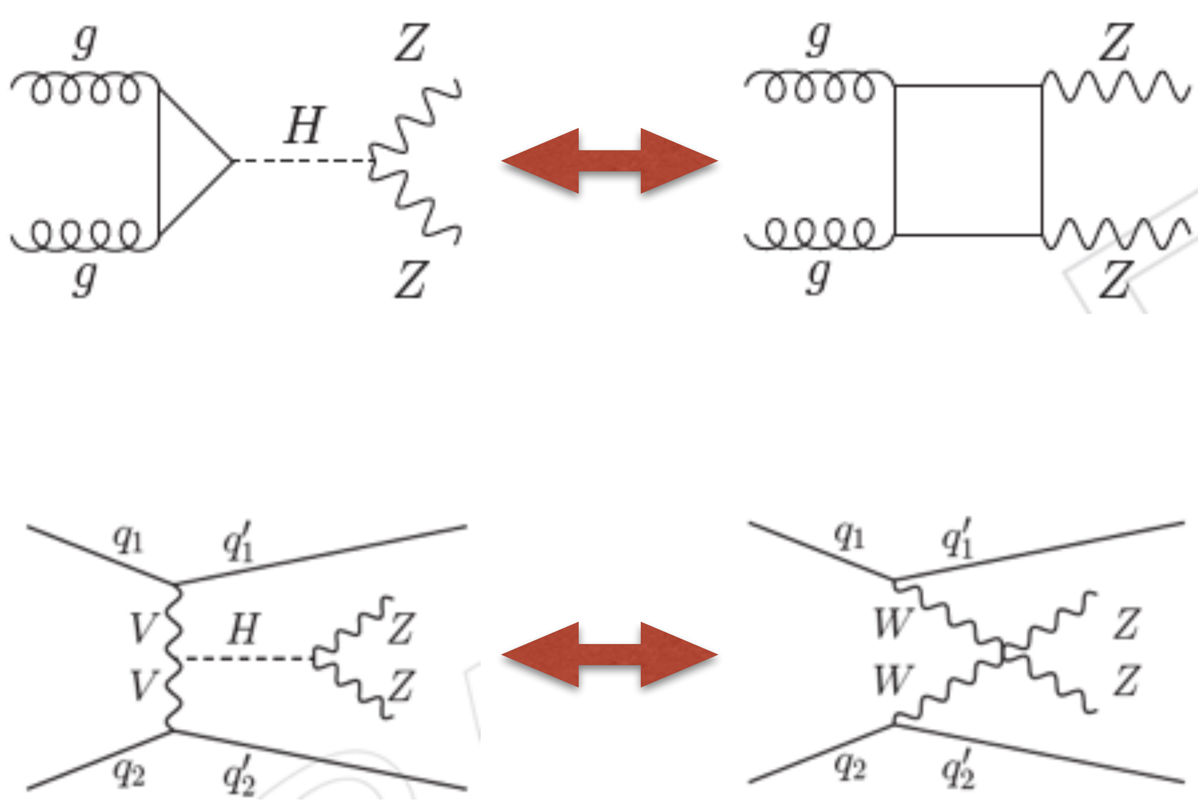
- **Main decay modes for off-shell Higgs:**
  WW, ZZ, tt

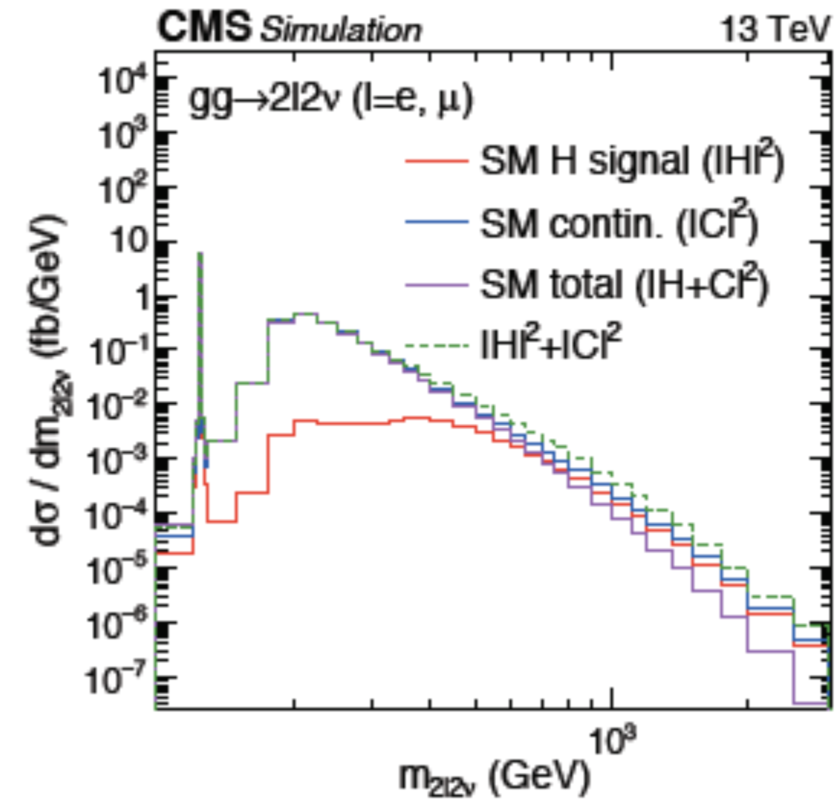
- **For width measurement, since we need to combine with on-shell, the best decay channel to be studied: ZZ**

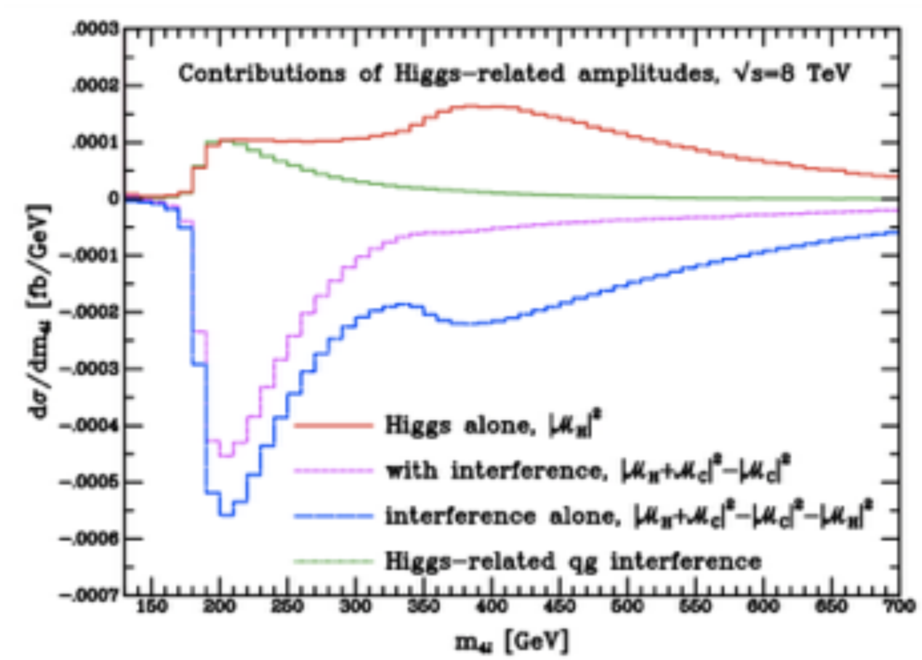


Off-shell Higgs in ZZ channel

- **Difficulties for probing off-shell Higgs:**
  - low production rate: ~10% of total xs
  - large destructive interference with continuum background

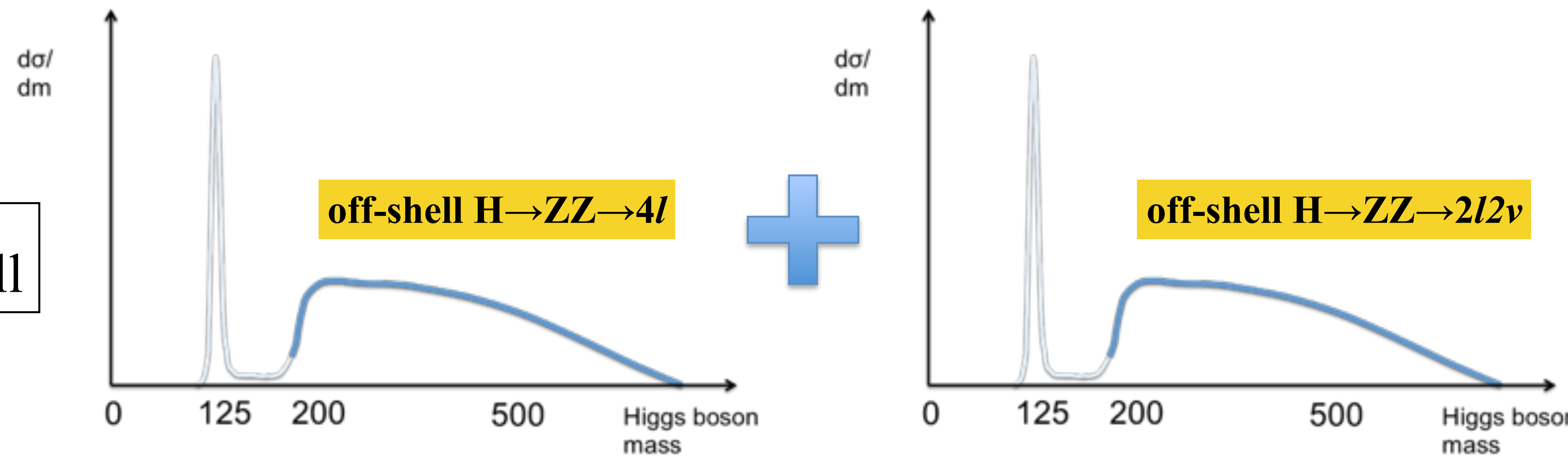




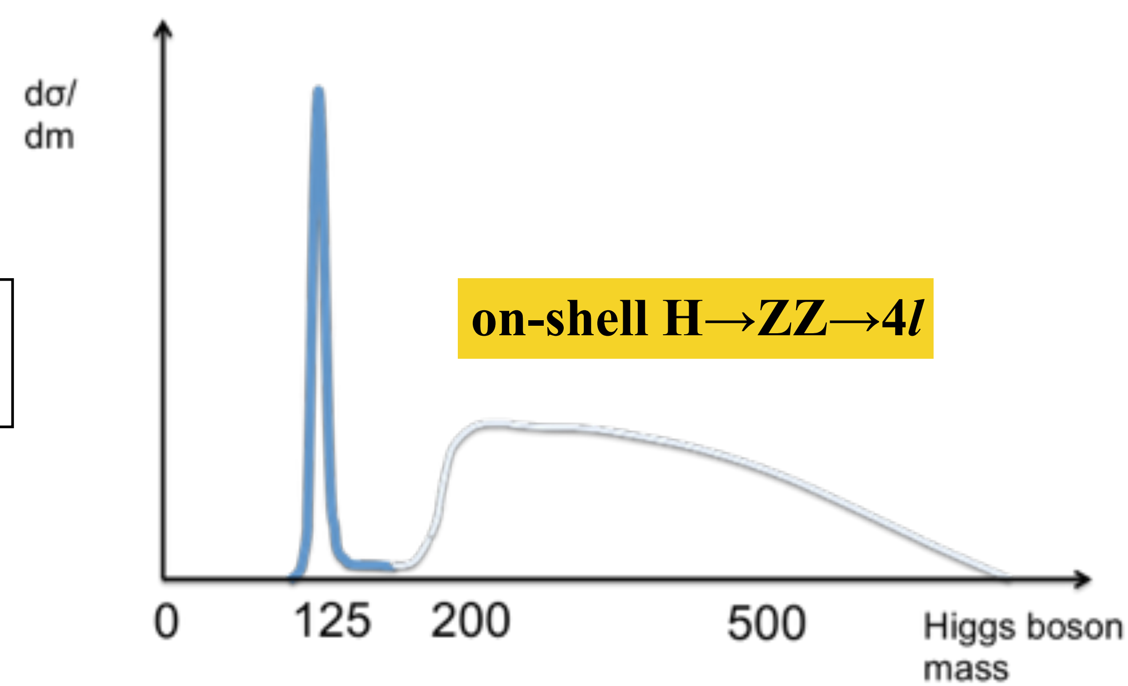


Analyses Involved

$\mu_{\text{off-shell}}$



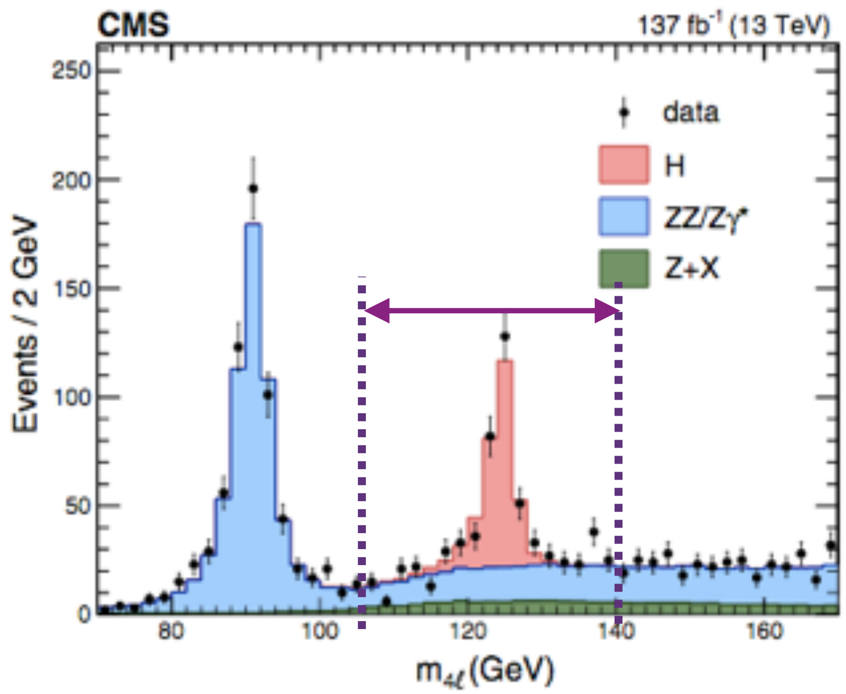
$\mu_{\text{on-shell}}$

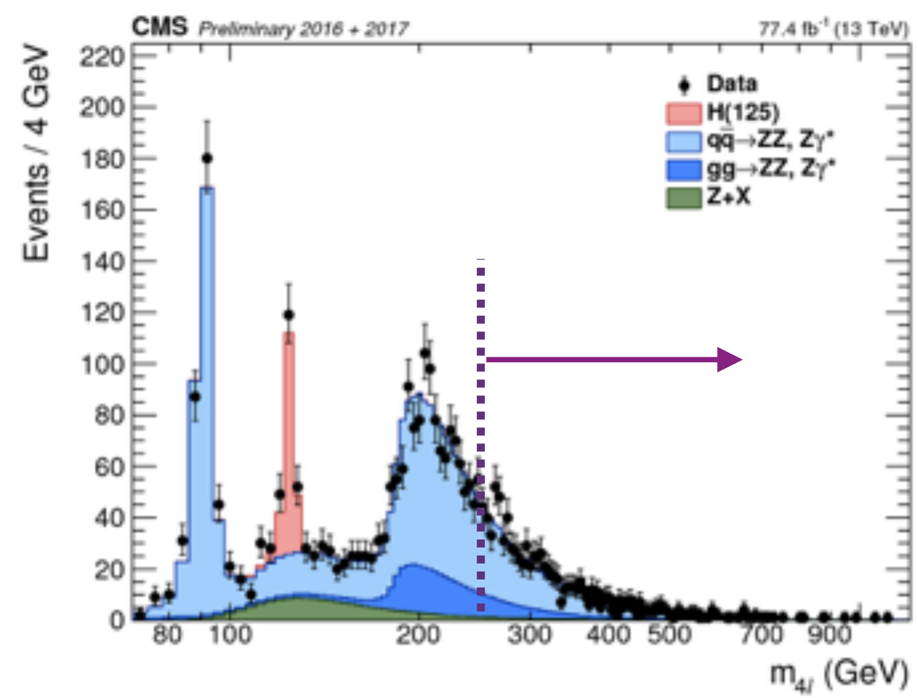


Object/Event selection for H→ZZ→4l

- Loose ID and isolated e(μ) with $p_T > 7(5)$GeV, $|\eta| < 2.5(2.4)$
- Vertex $d_{xy} < 0.5$cm, $d_z < 1$ cm, $SIP_{3D} < 3$
- Any OS-SF pair $12 < m_{ll\gamma} < 120$ GeV
- For any ZZ candidates, define Z_1 candidate with $m_{ll\gamma}$ closest to m_Z:
  - $m_{Z1} > 40$ GeV; pT(l1) > 20 GeV; pT(l2) > 10 GeV
  - $\Delta R > 0.02$ between each of the four leptons
  - $m$ll > 4 GeV for OS pairs (regardless of flavour)
  - Reject 4μ and 4e candidates where the alternative pair ZaZb satisfies $m_{Za} - m_Z < |m_{Z1} - m_Z|$ and $m_{Zb} < 12$ GeV
  - $m_{4l} > 70$ GeV
- If more than one ZZ candidate is left, choose the one of highest $\mathcal{D}bkg^{kin}$.
- If $\mathcal{D}bkg^{kin}$ is the same, take the one with Z_1 mass closest to m_Z.

Analysis strategies for H→ZZ→4*l*





inclusive m_{4l}

- **105 < m_{4l} < 140 GeV is used in the on-shell analysis.**
- **Event categorisation:** VBF-2jet, else VH-hadronic, else VH-leptonic, else VBF-1jet, else boosted, or else untagged.
- Use several observables for fit.

- **m_{4l} > 220 GeV is used in the off-shell analysis.**
- **Event categorisation:** VBF-tagged, else VH-hadronic, else untagged.
- Also use several MELA discriminants in the fit.

Object/Event selection for H→ZZ→2l2ν

Quantity	Requirement
p_{T}^{ℓ}	$p_{\mathrm{T}}^{\ell} \geq 25\,\mathrm{GeV}$ on both leptons
$\|\eta_{\ell}\|$	< 2.4 on μ, < 2.5 on e
$m_{\ell\ell}$	$\|m_{\ell\ell} - 91.2\| < 15\,\mathrm{GeV}$
$p_{\mathrm{T}}^{\ell\ell}$	$\geq 55\,\mathrm{GeV}$
N_{ℓ}	Exactly two leptons with tight isolation, no extra leptons with loose isolation and $p_{\mathrm{T}} \geq 5\,\mathrm{GeV}$
N_{trk}	No isolated tracks satisfying the selection requirements
N_{γ}	No photons with $p_{\mathrm{T}} \geq 20\,\mathrm{GeV}$, $\|\eta\| < 2.5$ satisfying the baseline selection requirements
p_{T}^{j}	$\geq 30\,\mathrm{GeV}$, used in selecting jets
$\|\eta_{j}\|$	< 4.7, used in selecting jets
N_{b}	No b-tagged jets based on the loose working point
$p_{\mathrm{T}}^{\mathrm{miss}}$	$\geq 125\,\mathrm{GeV}$ if $N_j < 2$, $\geq 140\,\mathrm{GeV}$ otherwise
$\Delta\phi_{\mathrm{miss}}^{\ell\ell}$	> 1.0 between $\vec{p}_{\mathrm{T}}^{\ell\ell}$ and $\vec{p}_{\mathrm{T}}^{\mathrm{miss}}$
$\Delta\phi_{\mathrm{miss}}^{\ell\ell+\mathrm{jets}}$	> 2.5 between $\vec{p}_{\mathrm{T}}^{\ell\ell} + \sum \vec{p}_{\mathrm{T}}^{\mathrm{j}}$ and $\vec{p}_{\mathrm{T}}^{\mathrm{miss}}$
$\min \Delta\phi_{\mathrm{miss}}^{\mathrm{j}}$	> 0.25 if $N_j = 1$, > 0.5 otherwise among all $\vec{p}_{\mathrm{T}}^{\mathrm{j}}$ and $\vec{p}_{\mathrm{T}}^{\mathrm{miss}}$ combinations

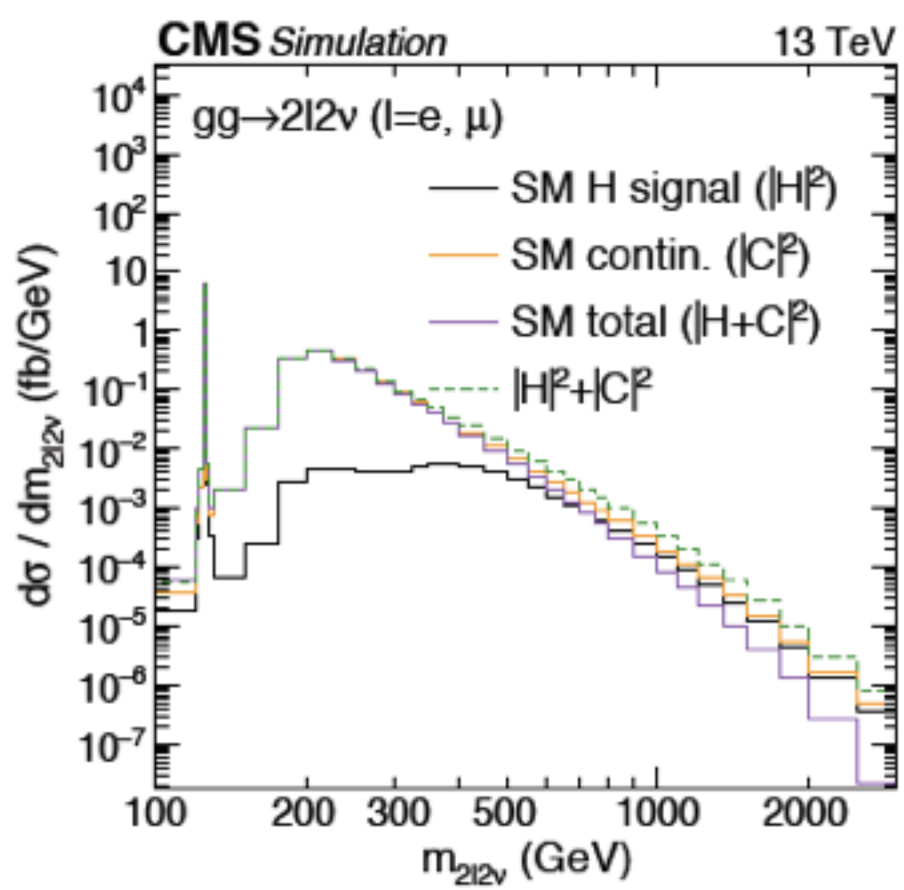
Signal and backgrounds

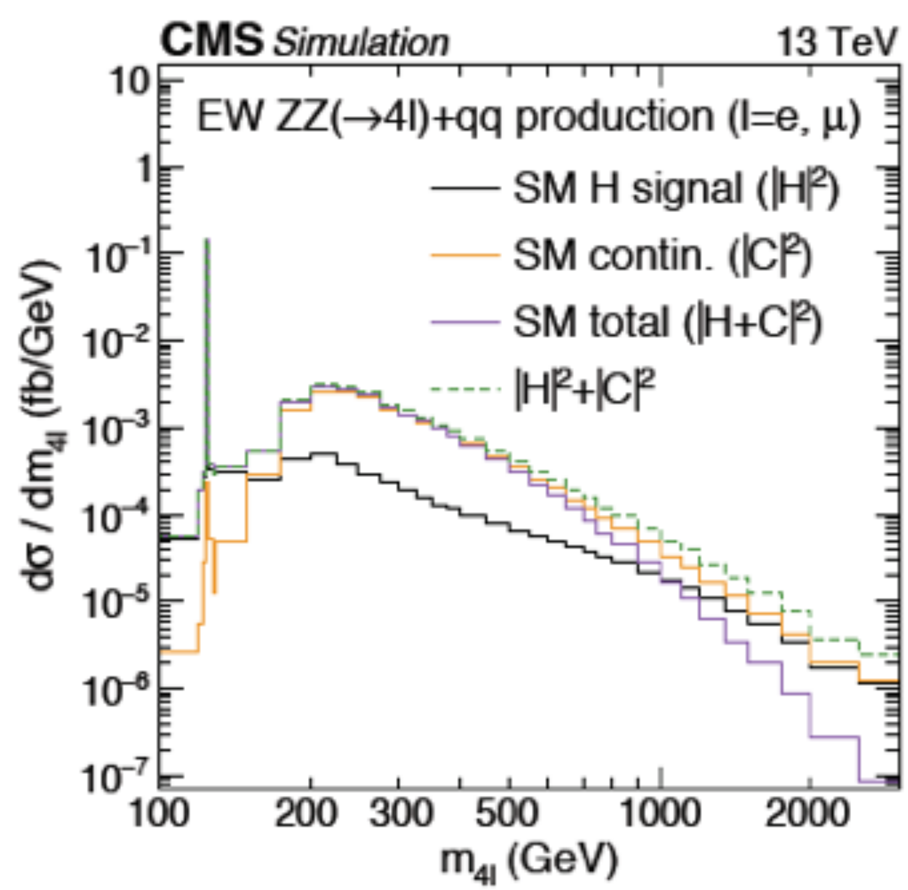
- **ggF and VBF/VH signal**

- **ggZZ and VBS ZZ (interfering backgrounds)**
- **qq→ZZ, WZ**
  - dominant background, constrained by 3l WZ Control Region (CR)
- **Instrumental** $p_{\mathrm{T}}^{\mathrm{miss}}$
  - mostly from Z+jets events, estimated from single photon CR
- **Non-resonant (ttbar, WW)**
  - reweighting eμ events from Data
- **tZ+X:** very small contribution, estimated fully from MC.

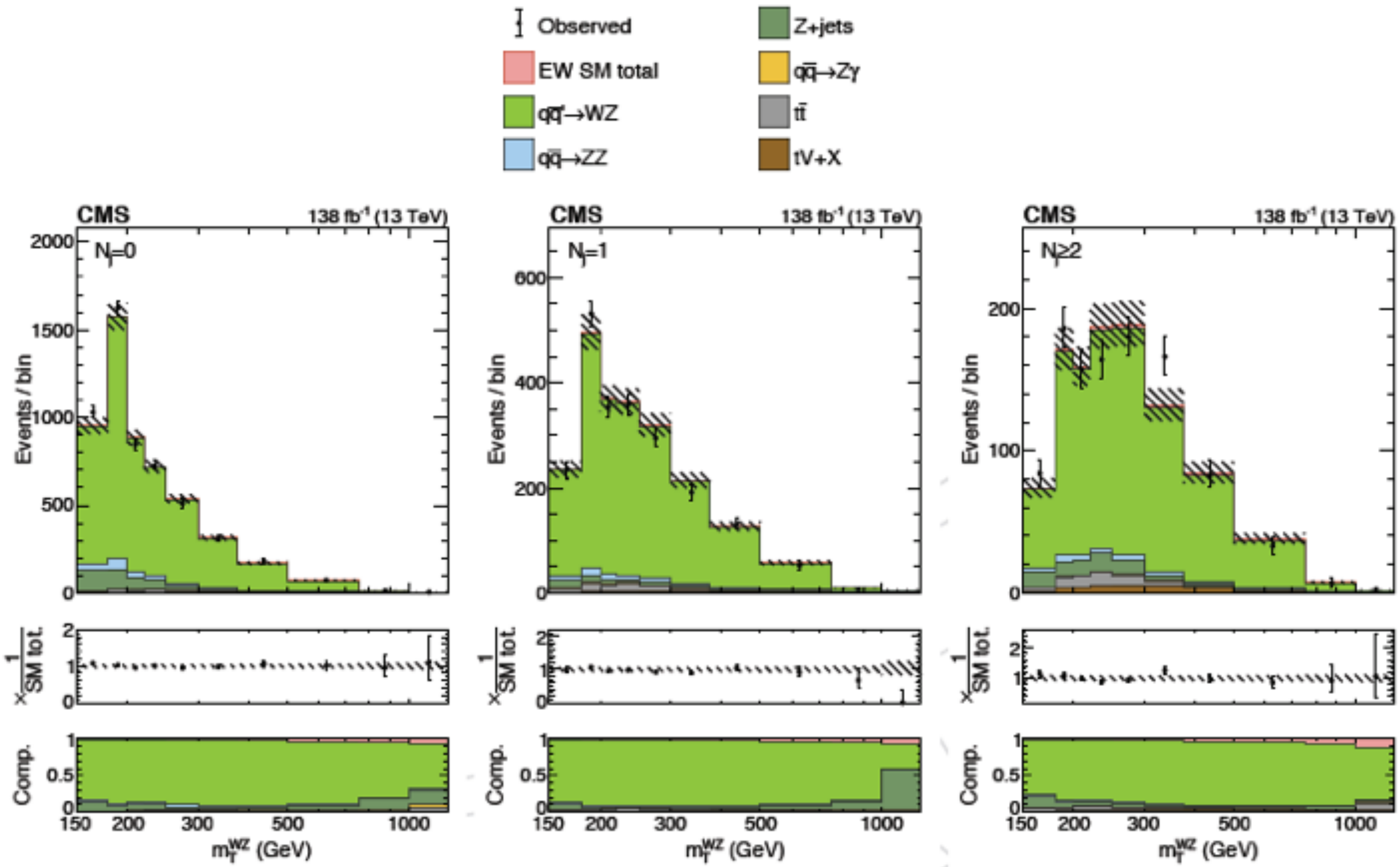
Signal and interfering backgrounds

- **Signals (ggH, VBF), interfering backgrounds (ggZZ, VBS ZZ) and their interference obtained by:**
  - POWHEG samples (NLO) with different Higgs pole mass (from 125GeV to 3TeV) for Higgs production and JHUGen for Higgs decay
  - Reweighting by MELA package and Stitching together





qq→ WZ/ZZ background

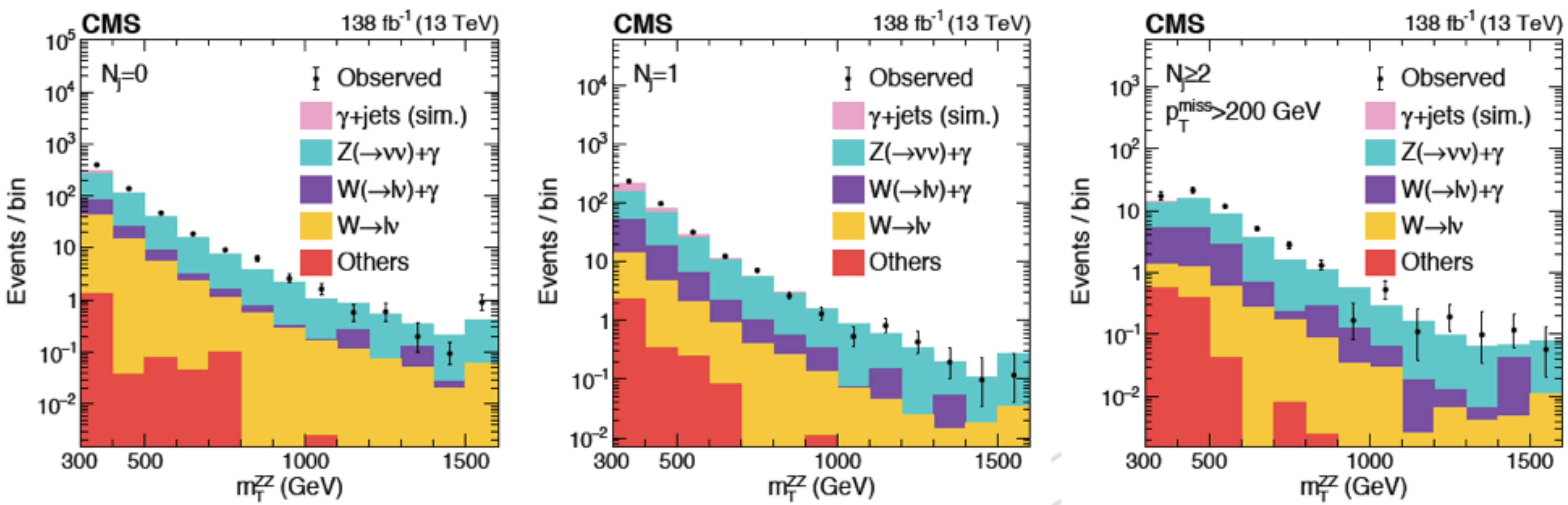


- Select 3*l* WZ CR in data.
- Joint fit of m_T^{WZ} in this CR
- Constrain both the normalisation and the shapes for WZ/ZZ in SR.

Instrumental $p_{\mathrm{T}}^{\mathrm{miss}}$

- **Significant contribution from Z+jets events in SR**
  - large cross section of Z+jets process
  - miscalibration of jets or neutrinos from hadrons
- **Estimated with γ+jets CR (γ as a proxy for Z)**
  - bad modelling of $p_{\mathrm{T}}^{\mathrm{miss}}$ in MC Z+jets
  - single, isolated γ expected to preserve similar kinematics as Z boson.
  - relatively higher statistics in γ+jets CR than Z+jets events.
- **Transfer factors derived in terms of Vertices, boson η and boson p_T**
- **Genuine MET contributions for high MET region subtracted:**
  - $Z(\rightarrow\nu\nu)\gamma$: estimated by $ll\gamma$ CR
  - W+jets: estimated by single electron CR
  - others: from MC

γ+jets CR distributions

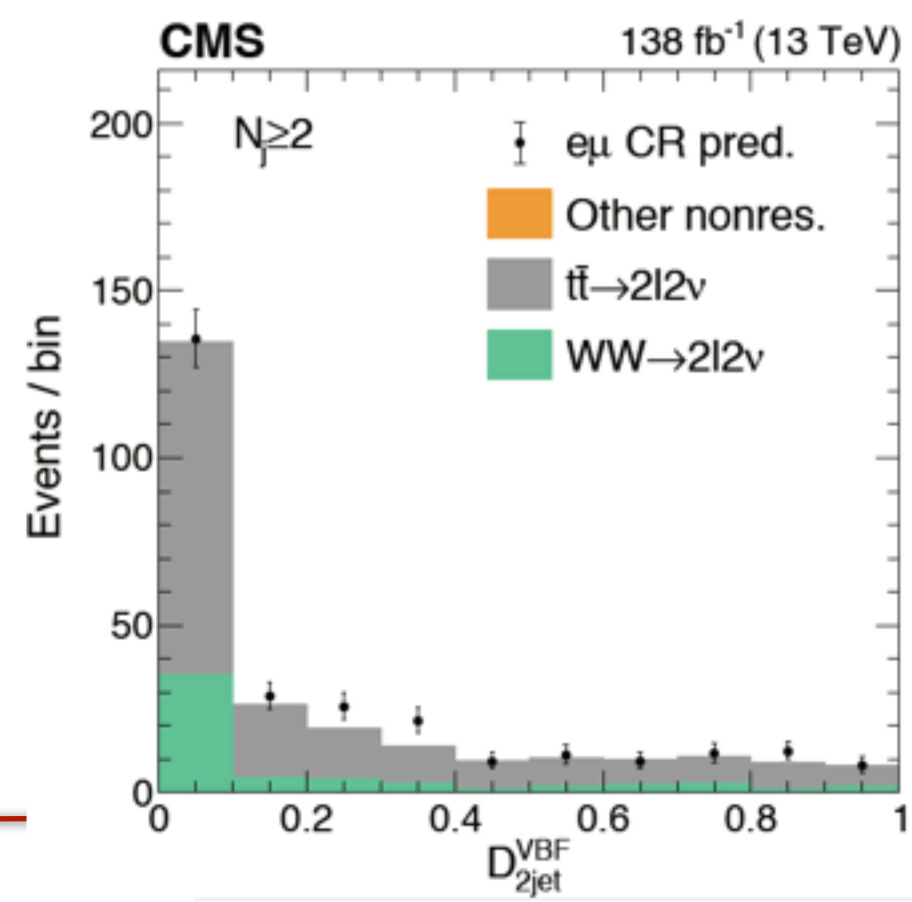


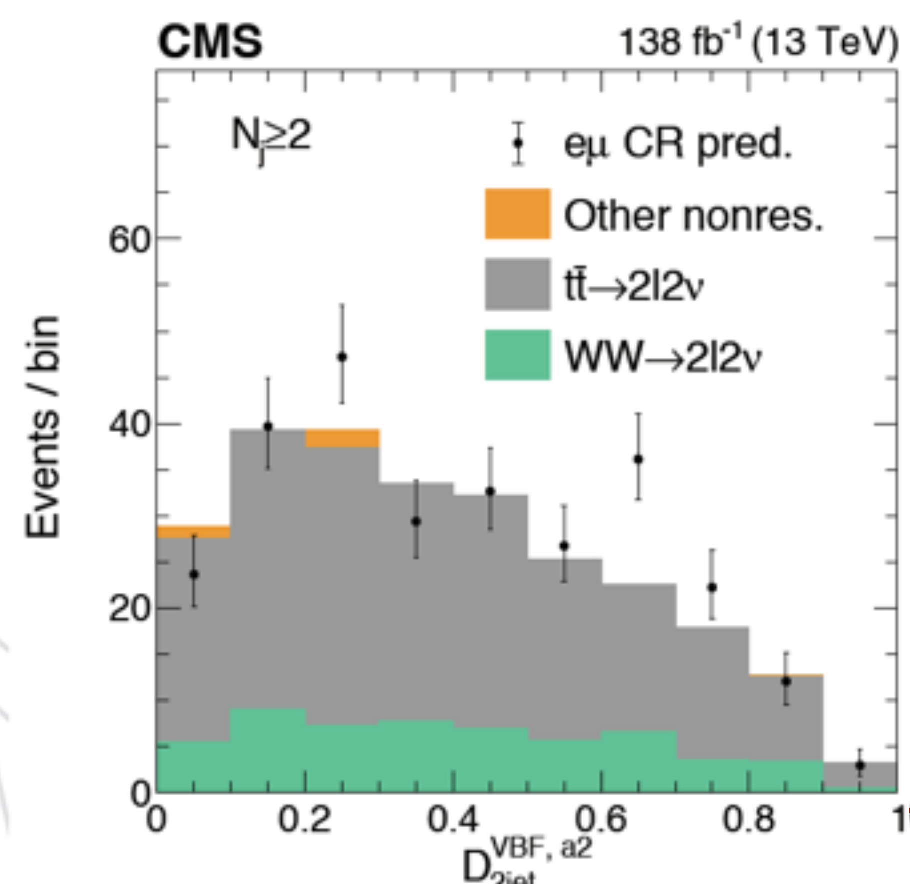
- γ+jets simulation could not model well data since it is LO!
- We are estimating the size of the Z+jets contribution by γ+jets in data.

Non-resonant background (tt, WW, H→WW, ττ)

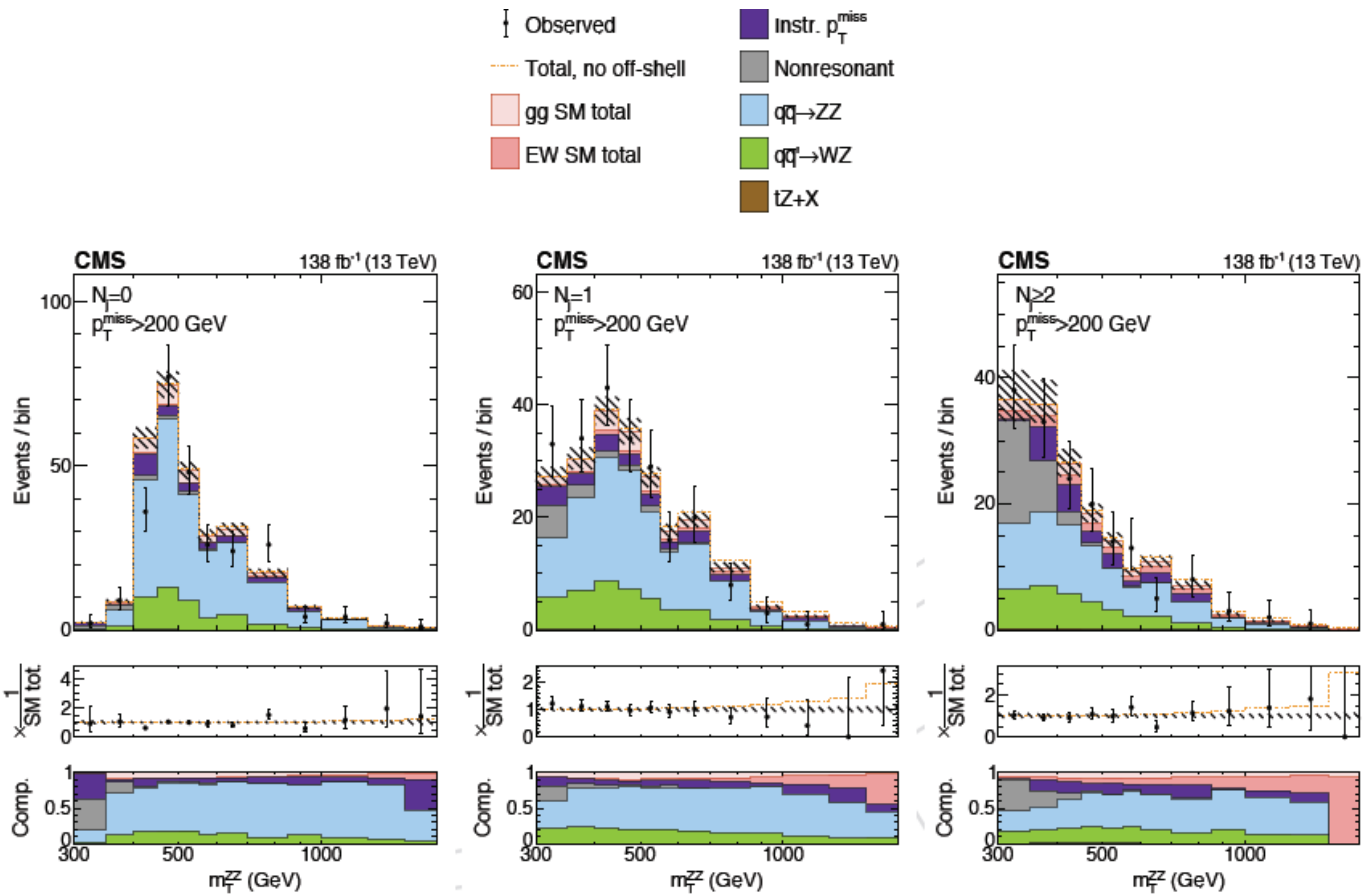
- Two isolated leptons not from the same mother particle, thus no Z peak
- Flavour symmetry: $N_{ee} = N_{\mu\mu} = 1/2\ N_{e\mu}$
- Use eμ CR, reweighted by the trigger and lepton efficiencies:

$$w_{e\mu}^{1\ell 2} = \frac{1}{2} \times \frac{\epsilon_{\ell 1}^{\mathrm{reco}} \cdot \epsilon_{\ell 2}^{\mathrm{reco}}}{\epsilon_{\mu}^{\mathrm{reco}} \cdot \epsilon_{e}^{\mathrm{reco}}} \times \frac{\epsilon_{\ell\ell}^{\mathrm{trigger}}}{\epsilon_{\mu e}^{\mathrm{trigger}}} \times f_{\mathrm{corr}}^{\ell 1 \ell 2}(p_{\mathrm{T}}^{\mathrm{miss}})$$





m_T^{ZZ} distribution after all selections

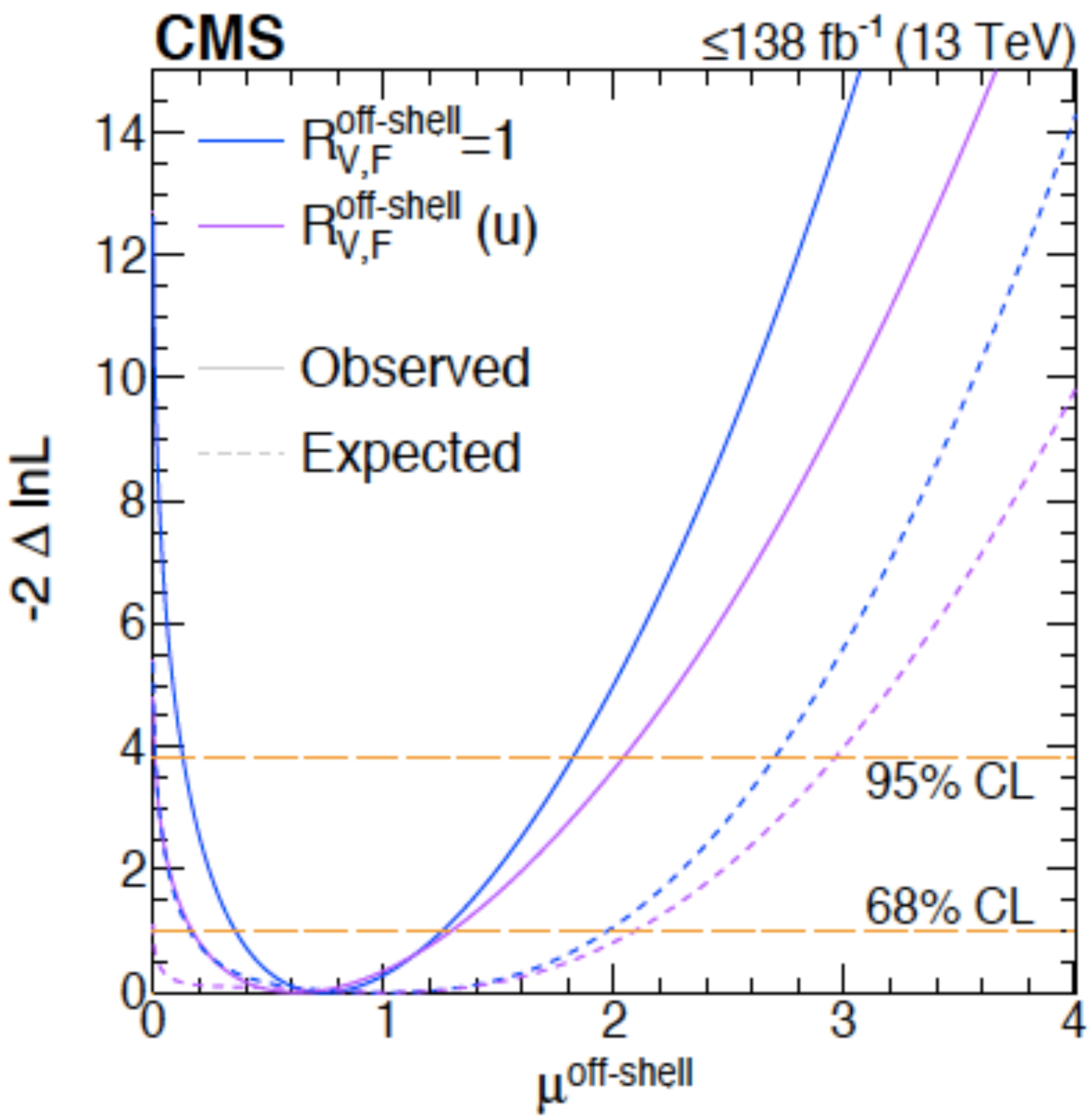


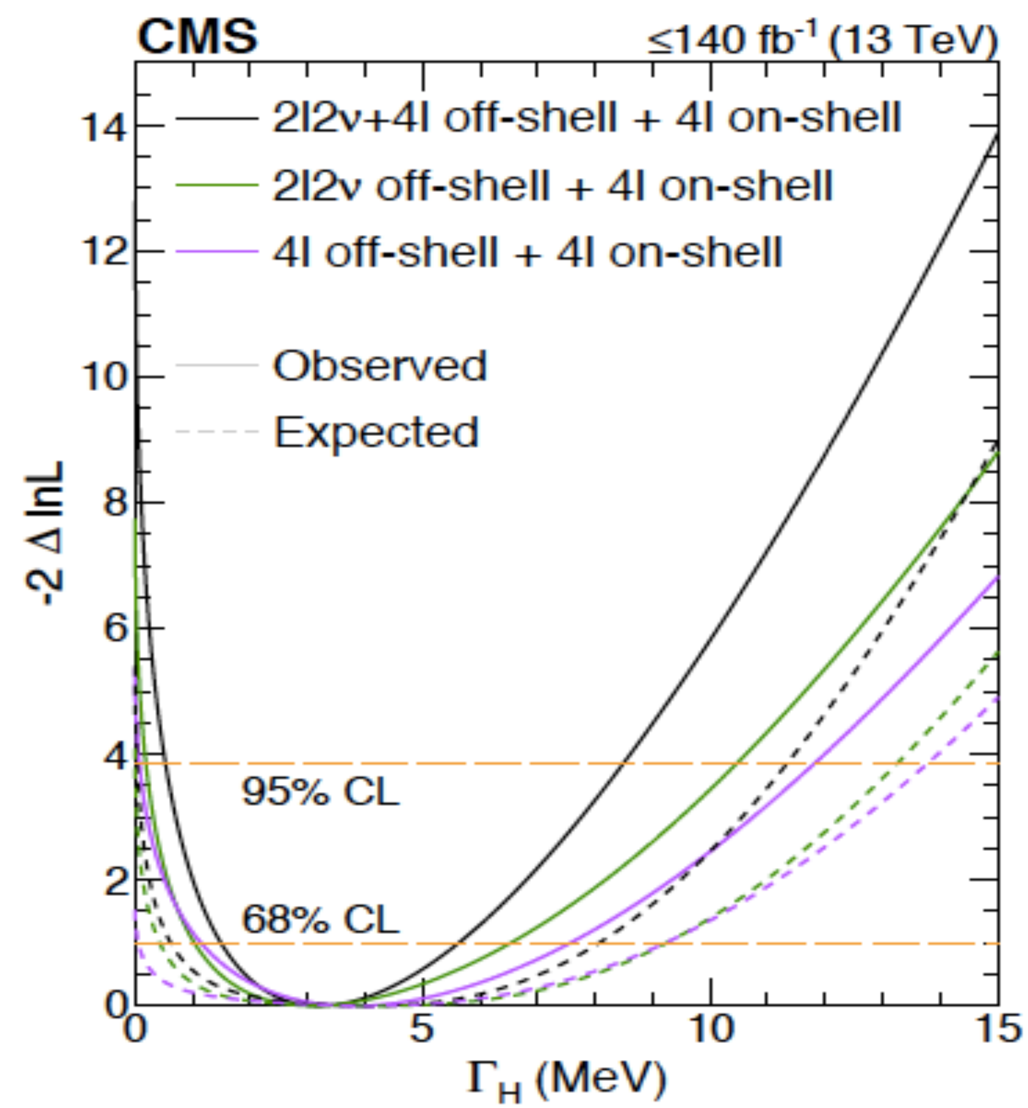
Systematic Uncertainties

Uncertainties on both normalisation and shape are accounted.

- **Theoretical uncertainties**
  - renormalisation scale and factorisation scale (up to 30%)
  - αs (mZ) and PDF variations (up to 20%)
  - simulation of the second jet in gg samples (up to 20%)
  - scale and tune variations of PYTHIA
  - NLO EW corrections ($qq \rightarrow ZZ$, WZ)
  - uncorrelated uncertainties for normalisation in 3l WZ CR
- **Experimental uncertainties**
  - Luminosity (between 1.2% and 2.5%)
  - Pile-up, JES, JER, and MET resolution uncertainty
  - simulation of the second jet in gg samples (up to 20%)
  - uncertainties on lepton, trigger, pile-up jet ID, b-tagging efficiencies

Evidence for off-shell Higgs and Measured Width





- **No off-shell hypothesis ($\mu_{\text{off-shell}}$=0) excluded by more than 99.9% CL, i.e off-shell Higgs sensitivity 3.6σ**
- **Observed** $\Gamma_H = 3.2^{+2.4}_{-1.7}\text{MeV}$

Summary

- Combination of H→ZZ→2*l*2*v* and H→ZZ→4*l* off-shell analyses results in finding the **first evidence of off-shell Higgs production at LHC**
- Highlight in the Higgs width measurement.

$$\Gamma_H = 3.2^{+2.4}_{-1.7}\text{MeV}$$

Reaching ~50% precision for the first time!

- Off-shell events further constrain HVV anomalous couplings.


thank you

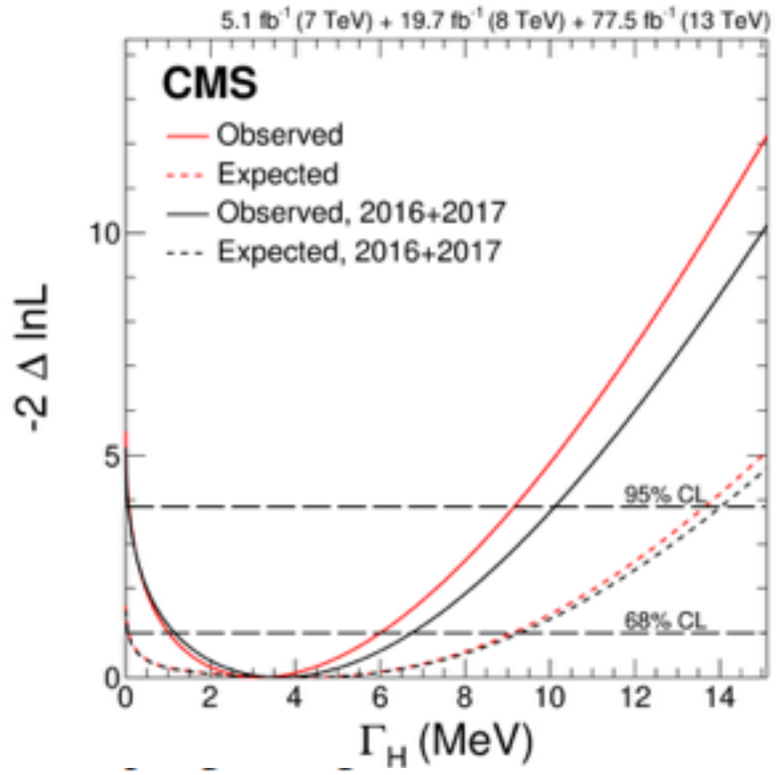
- backup

Previous results on width measurement

- **CMS: H→ZZ→4*l***

on-shell: Run 1 + Run 2 (77.5fb^{-1})

off-shell: Run 2 (77.5fb^{-1})



68% [95%]

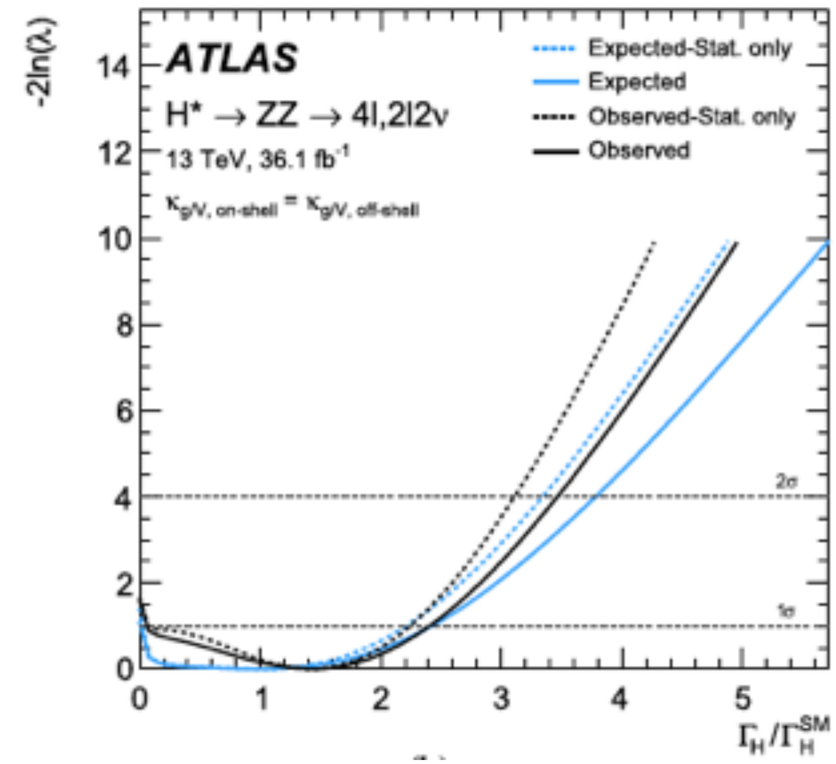
Parameter	Observed	Expected
Γ_H (MeV)	$3.2^{+2.8}_{-2.2}$ [0.08, 9.16]	$4.1^{+5.0}_{-4.0}$ [0.0, 13.7]

Parameter	Observed	Expected
$\mu^{\text{off-shell}}$	$0.78^{+0.72}_{-0.53}$ [0.02, 2.28]	$1.00^{+1.20}_{-0.99}$ [0.0, 3.2]
$\mu_F^{\text{off-shell}}$	$0.86^{+0.92}_{-0.68}$ [0.0, 2.7]	$1.0^{+1.3}_{-1.0}$ [0.0, 3.5]
$\mu_V^{\text{off-shell}}$	$0.67^{+1.26}_{-0.61}$ [0.0, 3.6]	$1.0^{+3.8}_{-1.0}$ [0.0, 8.4]

- **ATLAS: H→ZZ→4*l* & H→ZZ→2*l*2*v***

on-shell: Run 2 (36.1fb^{-1})

off-shell: Run 2 (36.1fb^{-1})



The 95% CL upper limits on $\mu_{\text{off-shell}}$, Γ_H/Γ_H^{SM} and R_{gg}. Both the observed and expected limits are given. The 1σ (2σ) uncertainties represent 68% (95%) confidence intervals for the expected limit. The upper limits are evaluated using the CL$_s$ method, with the SM values as the alternative hypothesis for each interpretation.

		Observed	Expected		
			Median	±1 σ	±2 σ
$\mu_{\text{off-shell}}$	$ZZ \to 4\ell$ analysis	4.5	4.3	[3.3, 5.4]	[2.7, 7.1]
	$ZZ \to 2\ell 2\nu$ analysis	5.3	4.4	[3.4, 5.5]	[2.8, 7.0]
	Combined	3.8	3.4	[2.7, 4.2]	[2.3, 5.3]
Γ_H/Γ_H^{SM}	Combined	3.5	3.7	[2.9, 4.8]	[2.4, 6.5]
R_{gg}	Combined	4.3	4.1	[3.3, 5.6]	[2.7, 8.2]

Additional results on $\mu_{\text{off-shell}}$

Table 4: Constraints on the $\mu_F^{\text{off-shell}}$, $\mu_V^{\text{off-shell}}$, and $\mu^{\text{off-shell}}$ parameters are summarized. The constraints on $\mu^{\text{off-shell}}$ are obtained with $R_{V,F}^{\text{off-shell}}$ unconstrained or $= 1$. The measurements are presented using the $2\ell 2\nu$ analysis alone, or with the inclusion of off-shell 4ℓ events. The designation 'c.v.' stands for the central value obtained in the likelihood scan, and the expected central value is always unity, so it is not quoted explicitly.

Parameter	Condition	c.v.	Observed 68% | 95% CL	Expected 68% | 95% CL
$\mu_F^{\text{off-shell}}$ $(2\ell 2\nu + 4\ell)$	$\mu_V^{\text{off-shell}}$ unconst.	0.62	$[0.17, 1.3]$ | $[0.0060, 2.0]$	$[2\cdot 10^{-5}, 2.1]$ | < 3.0
$\mu_F^{\text{off-shell}}$ $(2\ell 2\nu)$	$\mu_V^{\text{off-shell}}$ unconst.	0.41	$[0.014, 1.4]$ | < 2.6	< 2.5 | < 3.7
$\mu_V^{\text{off-shell}}$ $(2\ell 2\nu + 4\ell)$	$\mu_F^{\text{off-shell}}$ unconst.	0.90	$[0.31, 1.8]$ | $[0.051, 2.9]$	$[0.11, 3.0]$ | < 4.5
$\mu_V^{\text{off-shell}}$ $(2\ell 2\nu)$	$\mu_F^{\text{off-shell}}$ unconst.	1.1	$[0.28, 2.4]$ | $[0.016, 3.8]$	$[0.07, 3.2]$ | < 4.8
$\mu^{\text{off-shell}}$ $(2\ell 2\nu + 4\ell)$	$R_{V,F}^{\text{off-shell}} = 1$	0.74	$[0.36, 1.3]$ | $[0.13, 1.8]$	$[0.16, 2.0]$ | $[0.0086, 2.7]$
	$R_{V,F}^{\text{off-shell}}$ unconst.	0.62	$[0.17, 1.3]$ | $[0.0061, 2.0]$	$[4\cdot 10^{-5}, 2.1]$ | $[1\cdot 10^{-5}, 3.0]$
$\mu^{\text{off-shell}}$ $(2\ell 2\nu)$	$R_{V,F}^{\text{off-shell}} = 1$	0.74	$[0.25, 1.5]$ | $[0.043, 2.3]$	$[0.11, 2.3]$ | $[2\cdot 10^{-4}, 3.2]$
	$R_{V,F}^{\text{off-shell}}$ unconst.	0.41	$[0.014, 1.4]$ | $[2\cdot 10^{-5}, 2.6]$	$[3\cdot 10^{-5}, 2.5]$ | $[6\cdot 10^{-6}, 3.7]$

HVV anomalous couplings

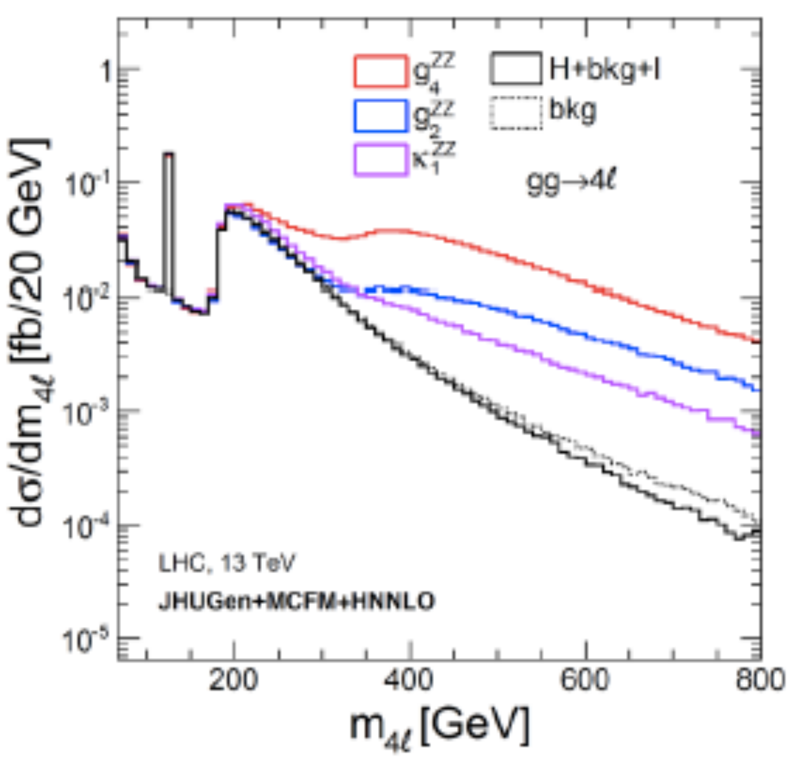
- **Could probe the HVV anomalous couplings in ZZ final states**

$$A(HVV) \sim \left[\boldsymbol{a_1} - e^{i\phi_{\Lambda 1}} \frac{(q_{V1}^2 + q_{V2}^2)}{\Lambda_1^2} + \cdots \right] m_V^2 \epsilon_{V1}^* \epsilon_{V2}^* + |\mathrm{a}_2|\, e^{i\phi_{a2}}\, \mathrm{f}_{\mu\nu}^{*(1)} f^{*(2),\mu\nu} + |\mathrm{a}_3|\, e^{i\phi_{a3}}\, \mathrm{f}_{\mu\nu}^{*(1)} \tilde{f}^{*(2),\mu\nu}$$

In SM, a_1=2 and the rest are 0.

- **Define:** $$f_{ai} = \frac{|a_i|^2 \sigma_i}{\sum_j |a_j|^2 \sigma_j}, \quad a_j = a_1, a_2, a_3, \frac{1}{\Lambda_1^2}$$

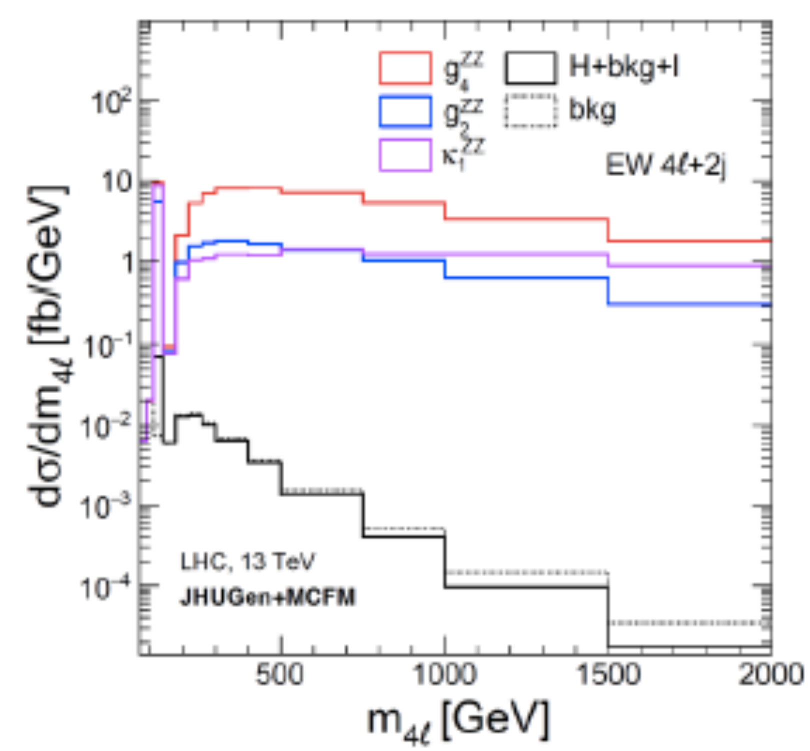
- **Measure** $f_{ai} \cos(\Phi_{ai})$ **by assuming** $a_i \geq 0, \cos(\Phi_{ai}) = \pm 1$ **to probe HVV Anomalous couplings**



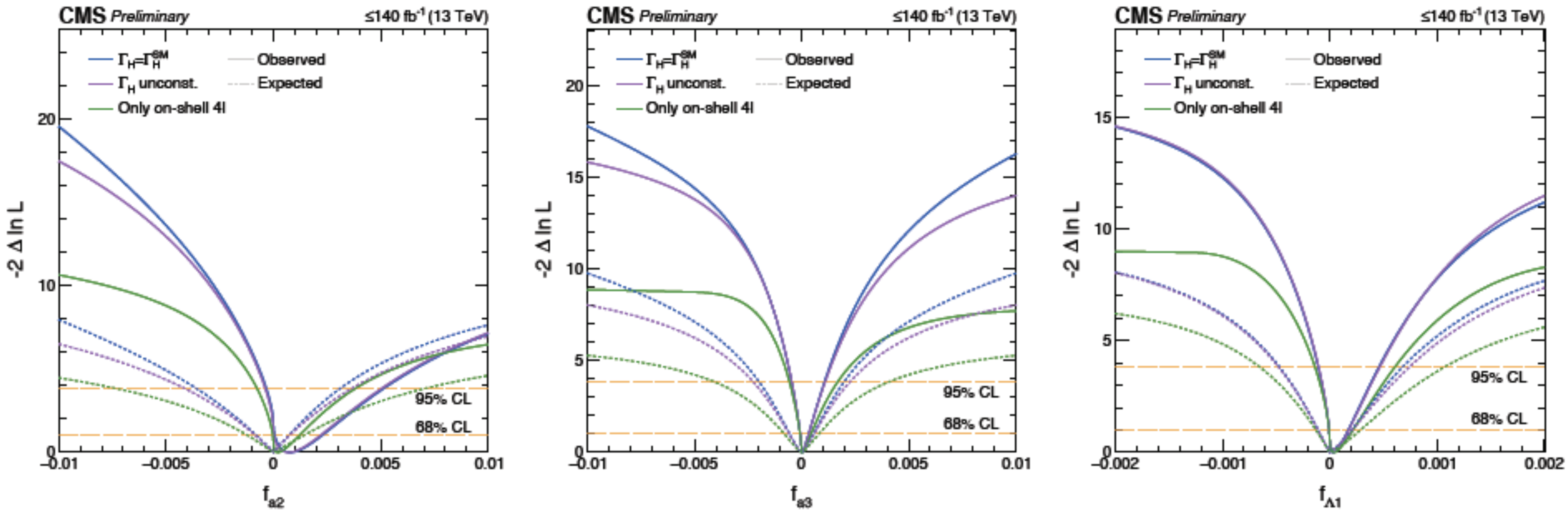
$\kappa_1 \sim \Lambda_1^{-2}$

$g_2 \sim a_2$

$g_4 \sim a_3$



HVV anomalous coupling limits



Parameter ($\times 10^5$)	Scenario	b.f.	Observed 68% | 95% CL	Expected 68% | 95% CL
f_{a2}	$\Gamma_H = \Gamma_H^{SM}$	79	$[6.6, 225] \mid [-32, 514]$	$[-78, 70] \mid [-359, 311]$
	Γ_H unconst.	72	$[2.7, 216] \mid [-38, 503]$	$[-82, 73] \mid [-413, 364]$
f_{a3}	$\Gamma_H = \Gamma_H^{SM}$	2.2	$[-6.4, 32] \mid [-46, 107]$	$[-55, 55] \mid [-198, 198]$
	Γ_H unconst.	2.4	$[-6.2, 33] \mid [-46, 110]$	$[-58, 58] \mid [-225, 225]$
$f_{\Lambda 1}$	$\Gamma_H = \Gamma_H^{SM}$	2.9	$[-0.62, 17] \mid [-11, 46]$	$[-11, 20] \mid [-47, 68]$
	Γ_H unconst.	3.1	$[-0.56, 18] \mid [-10, 47]$	$[-11, 21] \mid [-48, 75]$

best fit values

- **Improvement from adding off-shell information is of O(10%) at 95% CL**

HVV anomalous coupling from on-shell

CMS-HIGS-19-009

Parameter	Scenario		Observed	Expected
f_{a3}	Approach 1	best fit	0.00004	0.00000
	$f_{a2} = f_{\Lambda1} = f_{\Lambda1}^{Z\gamma} = 0$	68% CL	$[-0.00007, 0.00044]$	$[-0.00081, 0.00081]$
		95% CL	$[-0.00055, 0.00168]$	$[-0.00412, 0.00412]$
	Approach 1	best fit	-0.00805	0.00000
	float $f_{a2}, f_{\Lambda1}, f_{\Lambda1}^{Z\gamma}$	68% CL	$[-0.02656, 0.00034]$	$[-0.00086, 0.00086]$
		95% CL	$[-0.07191, 0.00990]$	$[-0.00423, 0.00422]$
	Approach 2	best fit	0.00005	0.0000
	float $f_{a2}, f_{\Lambda1}$	68% CL	$[-0.00010, 0.00061]$	$[-0.0012, 0.0012]$
		95% CL	$[-0.00072, 0.00218]$	$[-0.0057, 0.0057]$
f_{a2}	Approach 1	best fit	0.00020	0.0000
	$f_{a3} = f_{\Lambda1} = f_{\Lambda1}^{Z\gamma} = 0$	68% CL	$[-0.00010, 0.00109]$	$[-0.0012, 0.0014]$
		95% CL	$[-0.00078, 0.00368]$	$[-0.0075, 0.0073]$
	Approach 1	best fit	-0.24679	0.0000
	float $f_{a3}, f_{\Lambda1}, f_{\Lambda1}^{Z\gamma}$	68% CL	$[-0.41087, -0.15149] \cup [-0.00008, 0.00065]$	$[-0.0017, 0.0014]$
		95% CL	$[-0.66842, -0.08754] \cup [-0.00091, 0.00309]$	$[-0.0082, 0.0073]$
	Approach 2	best fit	-0.00002	0.0000
	float $f_{a3}, f_{\Lambda1}$	68% CL	$[-0.00178, 0.00103]$	$[-0.0060, 0.0033]$
		95% CL	$[-0.00694, 0.00536]$	$[-0.0206, 0.0131]$
$f_{\Lambda1}$	Approach 1	best fit	0.00004	0.00000
	$f_{a3} = f_{a2} = f_{\Lambda1}^{Z\gamma} = 0$	68% CL	$[-0.00002, 0.00022]$	$[-0.00016, 0.00026]$
		95% CL	$[-0.00014, 0.00060]$	$[-0.00069, 0.00110]$
	Approach 1	best fit	0.18629	0.00000
	float $f_{a3}, f_{a2}, f_{\Lambda1}^{Z\gamma}$	68% CL	$[-0.00002, 0.00019] \cup [0.07631, 0.27515]$	$[-0.00017, 0.00036]$
		95% CL	$[-0.00523, 0.35567]$	$[-0.00076, 0.00134]$
	Approach 2	best fit	0.00012	0.0000
	float f_{a3}, f_{a2}	68% CL	$[-0.00021, 0.00141]$	$[-0.0013, 0.0030]$
		95% CL	$[-0.00184, 0.00443]$	$[-0.0056, 0.0102]$
$f_{\Lambda1}^{Z\gamma}$	Approach 1	best fit	-0.00001	0.0000
	$f_{a3} = f_{a2} = f_{\Lambda1} = 0$	68% CL	$[-0.00099, 0.00057]$	$[-0.0026, 0.0020]$
		95% CL	$[-0.00387, 0.00301]$	$[-0.0096, 0.0082]$
	Approach 1	best fit	-0.02884	0.0000
	float $f_{a3}, f_{a2}, f_{\Lambda1}$	68% CL	$[-0.09000, -0.00534] \cup [-0.00068, 0.00078]$	$[-0.0027, 0.0026]$
		95% CL	$[-0.29091, 0.03034]$	$[-0.0099, 0.0096]$

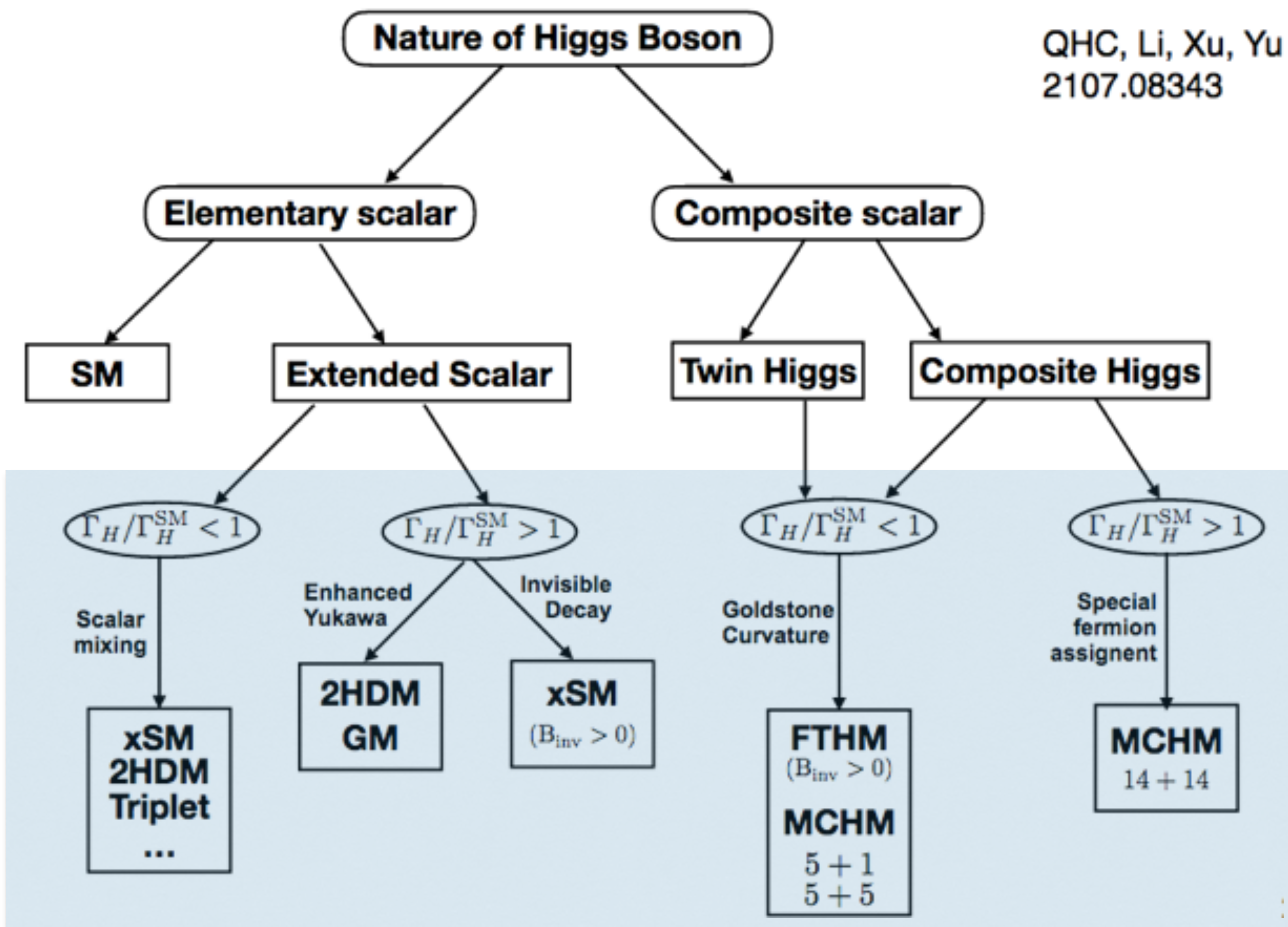
HVV anomalous coupling from 4l on-shell + off-shell

TABLE VI. Summary of allowed 68% C.L. (central values with uncertainties) and 95% C.L. (in square brackets) intervals for the anomalous coupling parameters $f_{ai}\cos(\phi_{ai})$ obtained from the analysis of the combination of Run 1 (only on-shell) and Run 2 (on-shell and off-shell) data sets. Three constraint scenarios are shown: using only on-shell events, using both on-shell and off-shell events with the Γ_H left unconstrained, or with the constraint $\Gamma_H = \Gamma_H^{\mathrm{SM}}$.

Parameter	Scenario	Observed	Expected
$f_{a3}\cos(\phi_{a3})$	On-shell	$-0.0001^{+0.0004}_{-0.0015}$ [−0.163, 0.090]	$0.0000^{+0.0019}_{-0.0019}$ [−0.082, 0.082]
	Any Γ_H	$0.0000^{+0.0003}_{-0.0010}$ [−0.0165, 0.0087]	$0.0000^{+0.0015}_{-0.0015}$ [−0.038, 0.038]
	$\Gamma_H = \Gamma_H^{\mathrm{SM}}$	$0.0000^{+0.0003}_{-0.0009}$ [−0.0067, 0.0050]	$0.0000^{+0.0014}_{-0.0014}$ [−0.0098, 0.0098]
$f_{a2}\cos(\phi_{a2})$	On-shell	$0.0004^{+0.0026}_{-0.0006}$ [−0.0055, 0.0234]	$0.0000^{+0.0030}_{-0.0023}$ [−0.021, 0.035]
	Any Γ_H	$0.0004^{+0.0026}_{-0.0006}$ [−0.0035, 0.0147]	$0.0000^{+0.0019}_{-0.0017}$ [−0.015, 0.021]
	$\Gamma_H = \Gamma_H^{\mathrm{SM}}$	$0.0005^{+0.0025}_{-0.0006}$ [−0.0029, 0.0129]	$0.0000^{+0.0012}_{-0.0016}$ [−0.010, 0.012]
$f_{\Lambda 1}\cos(\phi_{\Lambda 1})$	On-shell	$0.0002^{+0.0030}_{-0.0009}$ [−0.209, 0.089]	$0.0000^{+0.0012}_{-0.0006}$ [−0.059, 0.032]
	Any Γ_H	$0.0001^{+0.0015}_{-0.0006}$ [−0.090, 0.059]	$0.0000^{+0.0013}_{-0.0007}$ [−0.017, 0.019]
	$\Gamma_H = \Gamma_H^{\mathrm{SM}}$	$0.0001^{+0.0015}_{-0.0005}$ [−0.016, 0.068]	$0.0000^{+0.0013}_{-0.0006}$ [−0.015, 0.018]
$f_{\Lambda 1}^{Z\gamma}\cos(\phi_{\Lambda 1}{}^{Z\gamma})$	On-shell	$0.0000^{+0.3554}_{-0.0087}$ [−0.17, 0.61]	$0.0000^{+0.0091}_{-0.0100}$ [−0.098, 0.343]

What if Γ_H deviates from SM

4. Higgs boson width



- Stay tuned for more exciting results with more data and more advanced analysis techniques.

https://indico.ihep.ac.cn/event/14180/session/0/contribution/93/material/slides/0.pdf