

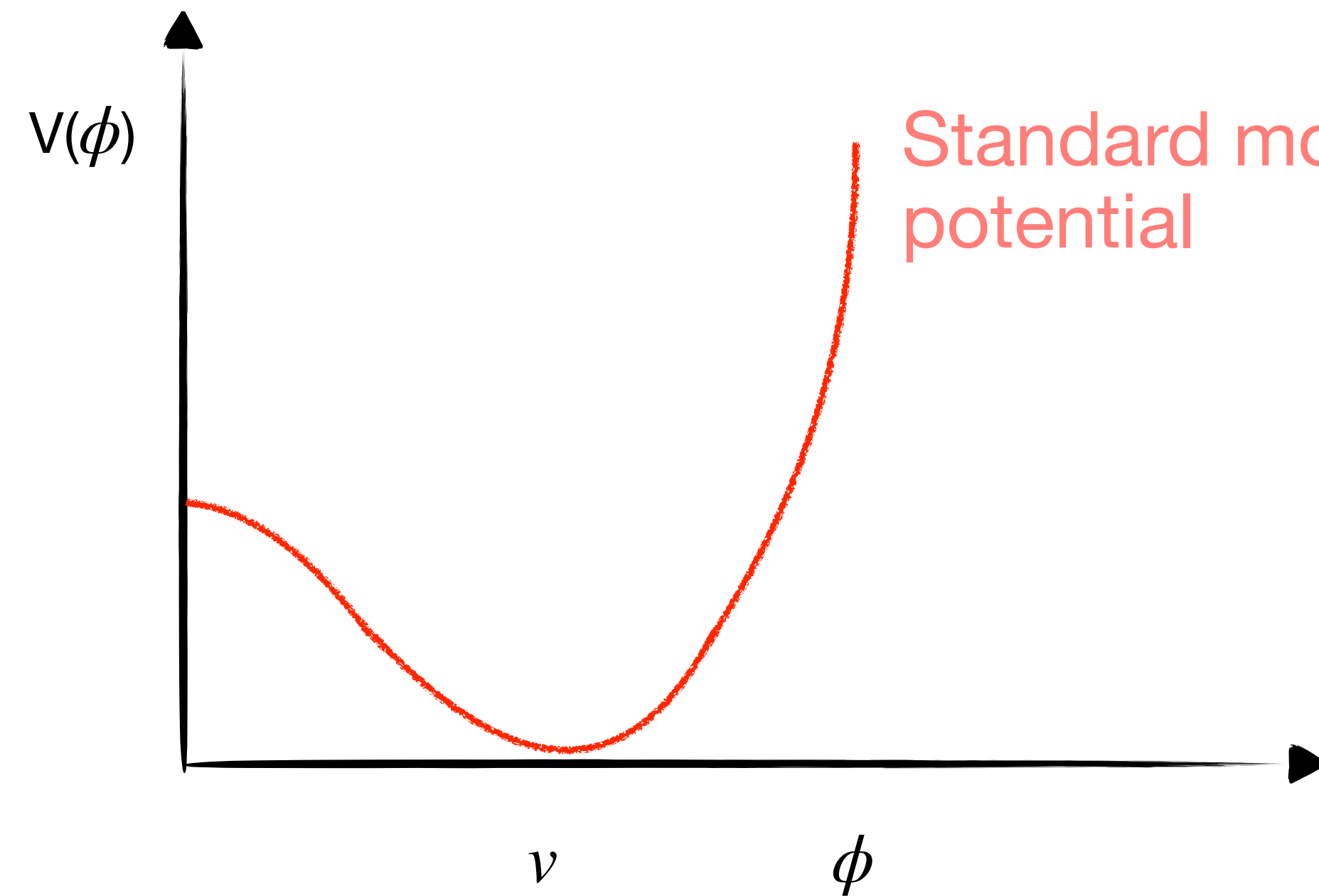
Higgs self coupling and pair production from CMS experiment

Soumya Mukherjee

University of California, San Diego (USA)
On behalf of the CMS collaboration



- The shape of the Higgs potential is determined by λ , the trilinear Higgs self coupling
- Non-resonant HH production gives direct and most sensitive access to λ



Standard model
potential

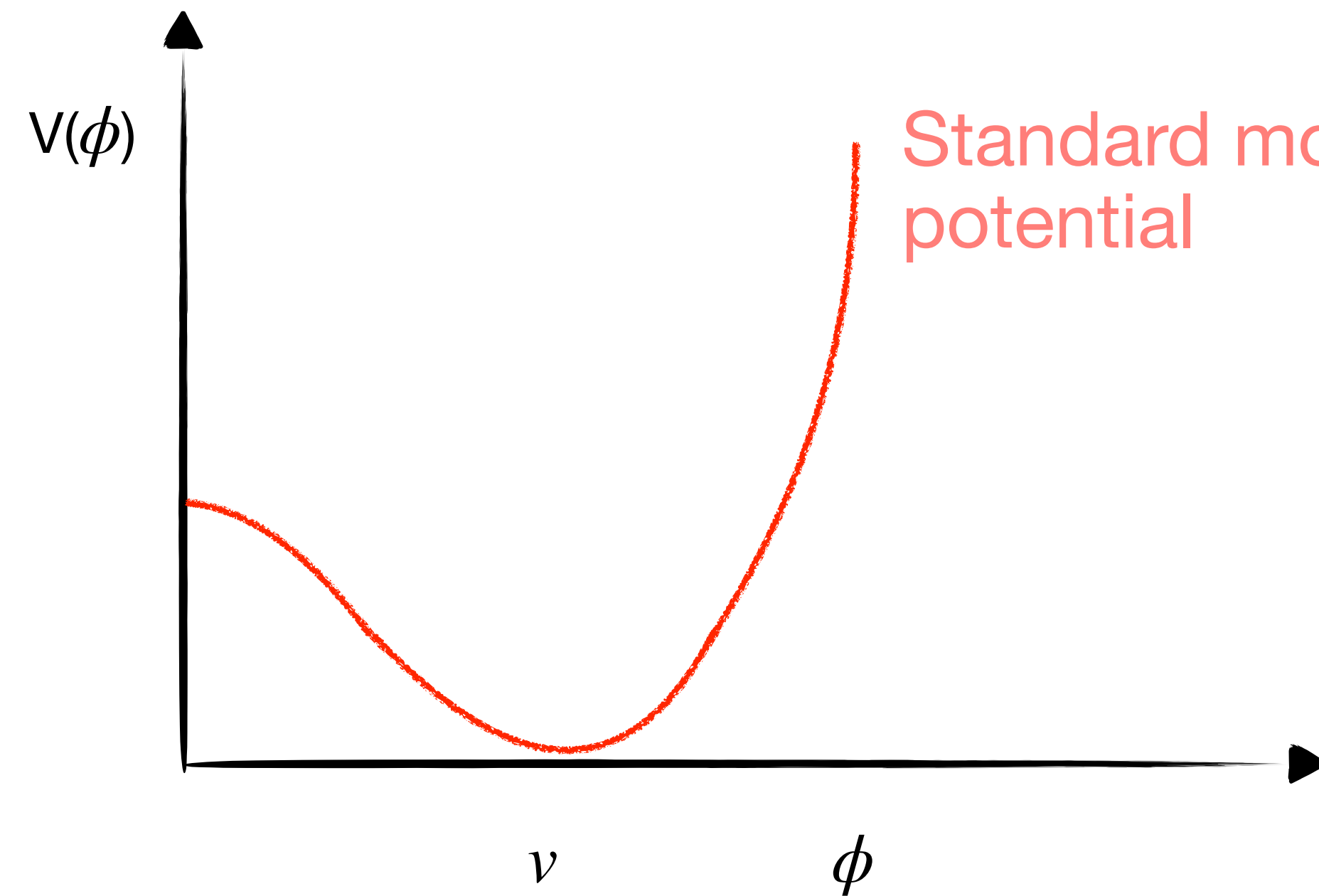
$$V(\phi) = -\mu^2\phi^2 + \lambda\phi^4$$

After the Electroweak (EWK) symmetry breaking, the minima is at v (Vacuum expectation value 246 GeV)

HH search at the LHC



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The expansion of $V(\phi)$ around the v can be written in terms of the Higgs field h , where $\phi = h + v$

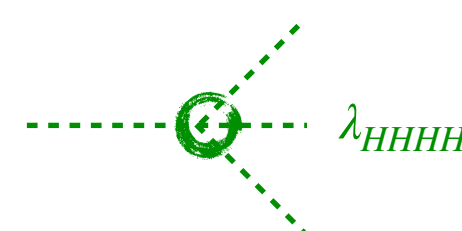
$$V(v + h) = \frac{m_h^2}{2}h^2 + \lambda_3vh^3 + \frac{\lambda_4}{4}h^4$$

$$\lambda_3 = \lambda_4 = \frac{m_H^2}{2v^2} = 0.13$$

Higgs mass term



Trilinear Higgs self coupling, interaction of three Higgs bosons (λ)

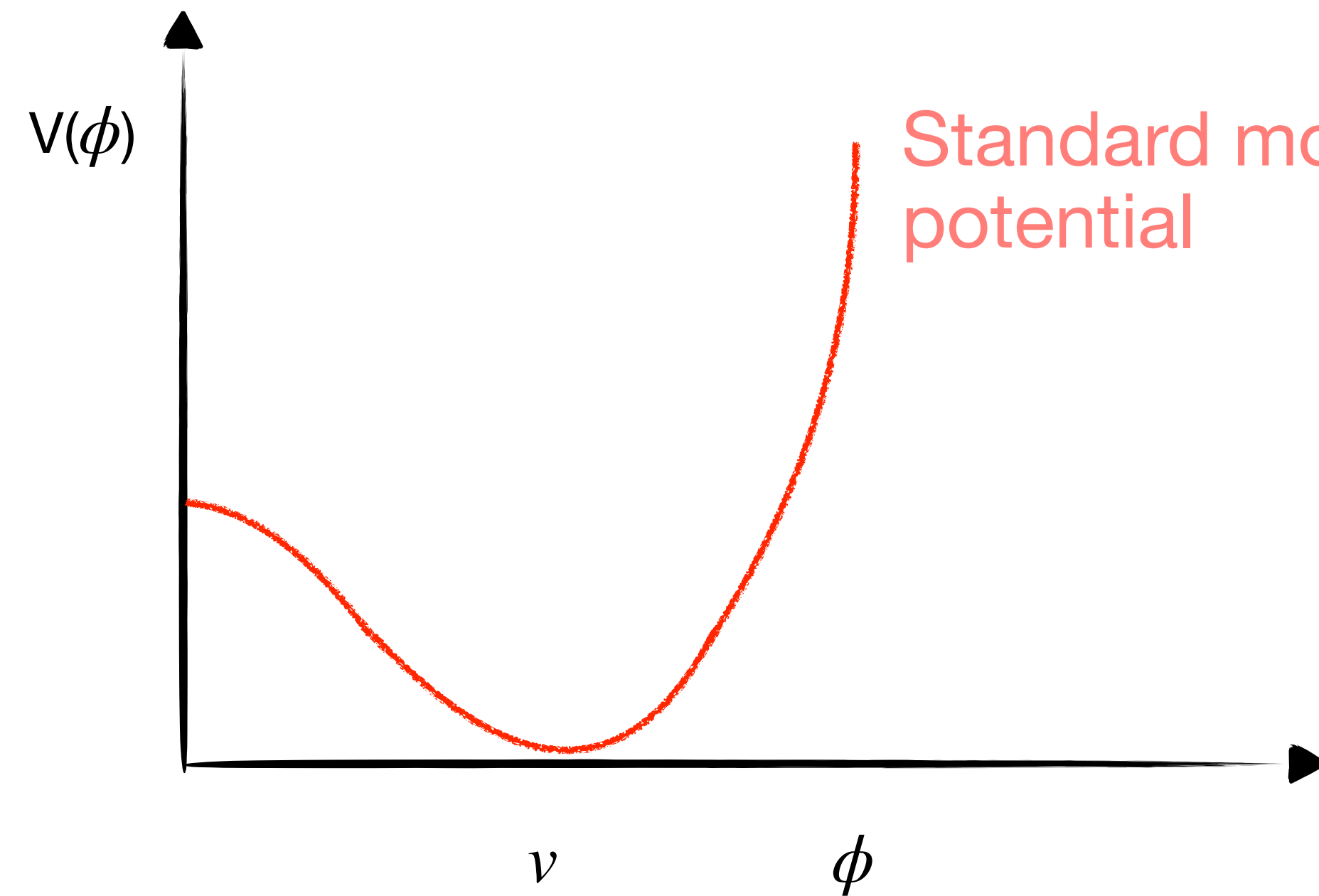


Quartic Higgs self coupling, Interaction of four Higgs bosons (λ/v)

HH search at the LHC



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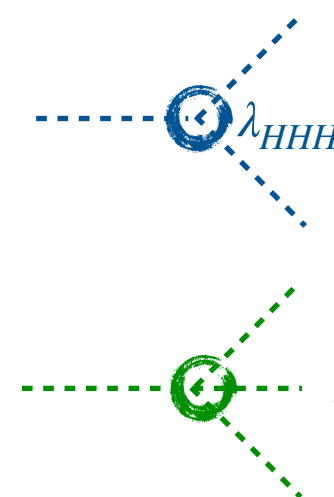
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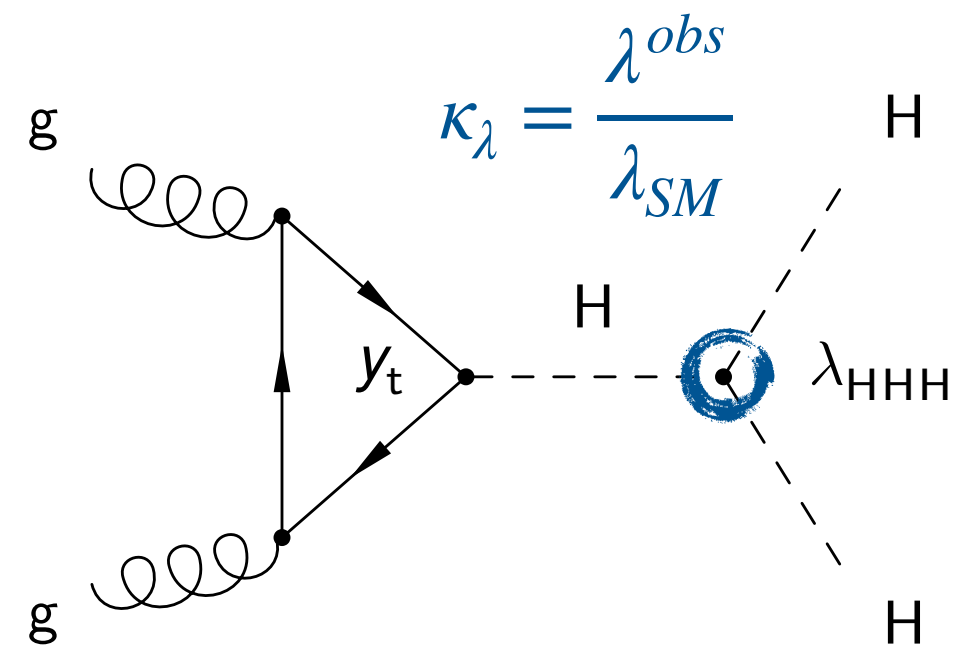
Quartic Higgs self coupling, Interaction of four Higgs bosons (λ/v)

Details about CMS HHH Program by Xinyue



HH production modes

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Gluon-Gluon Fusion “ggHH” : production mode of HH at the LHC.

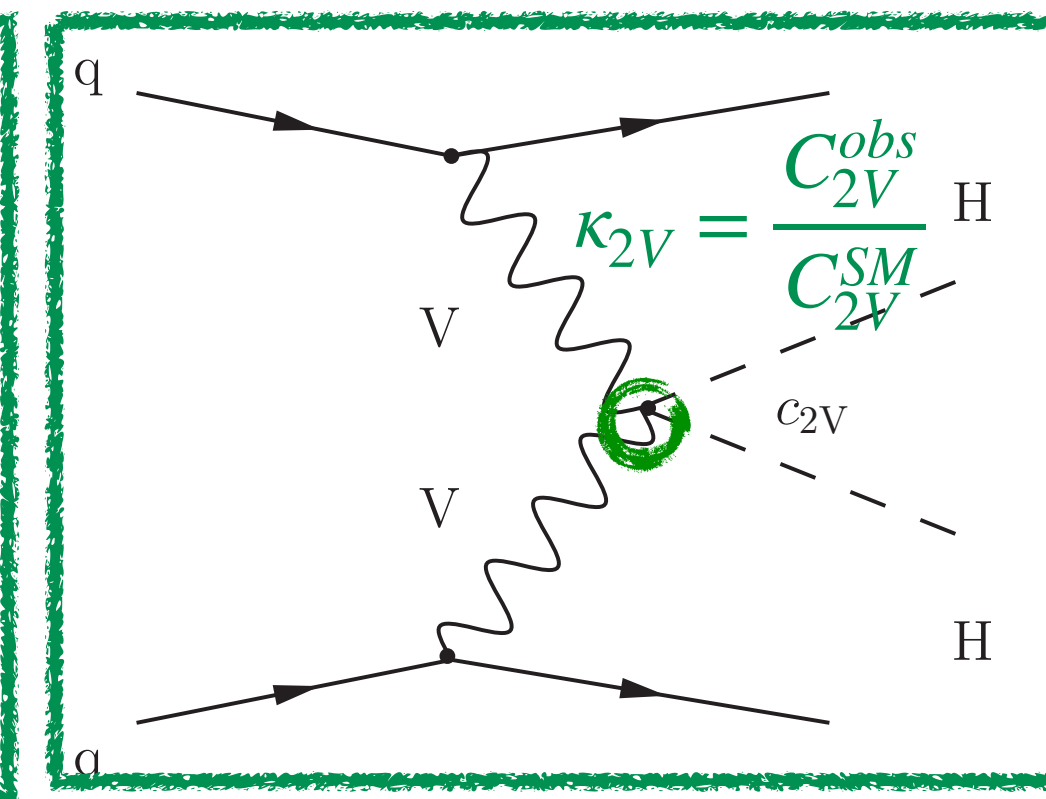
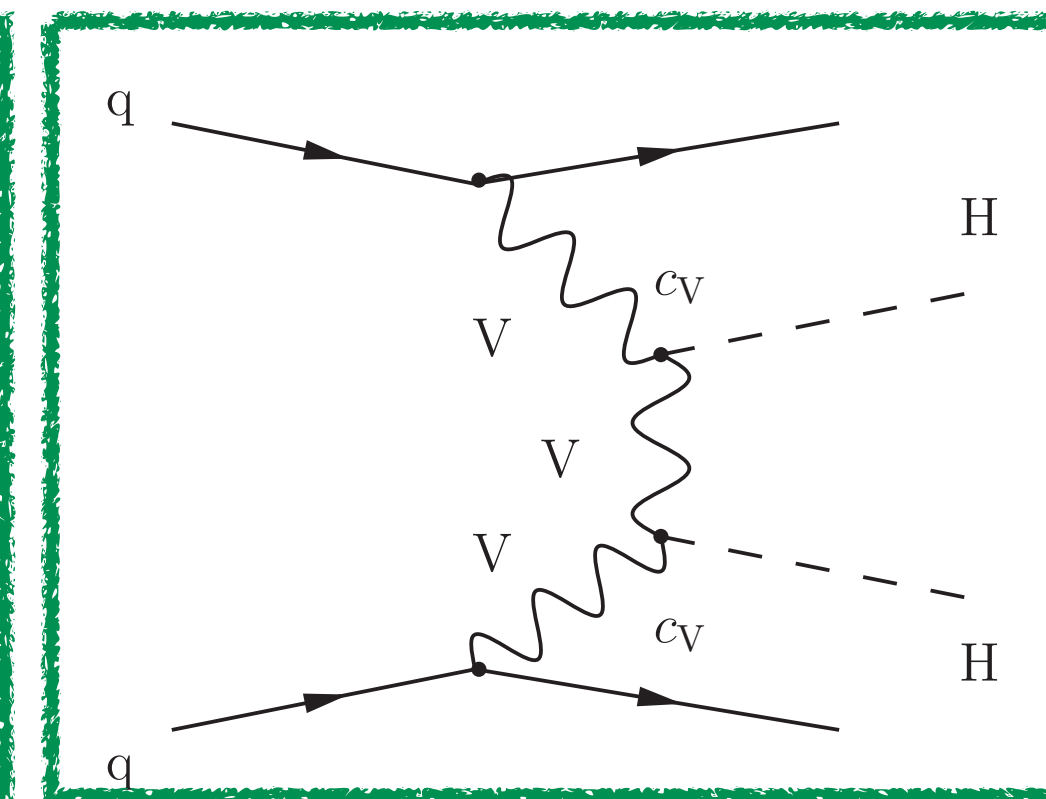
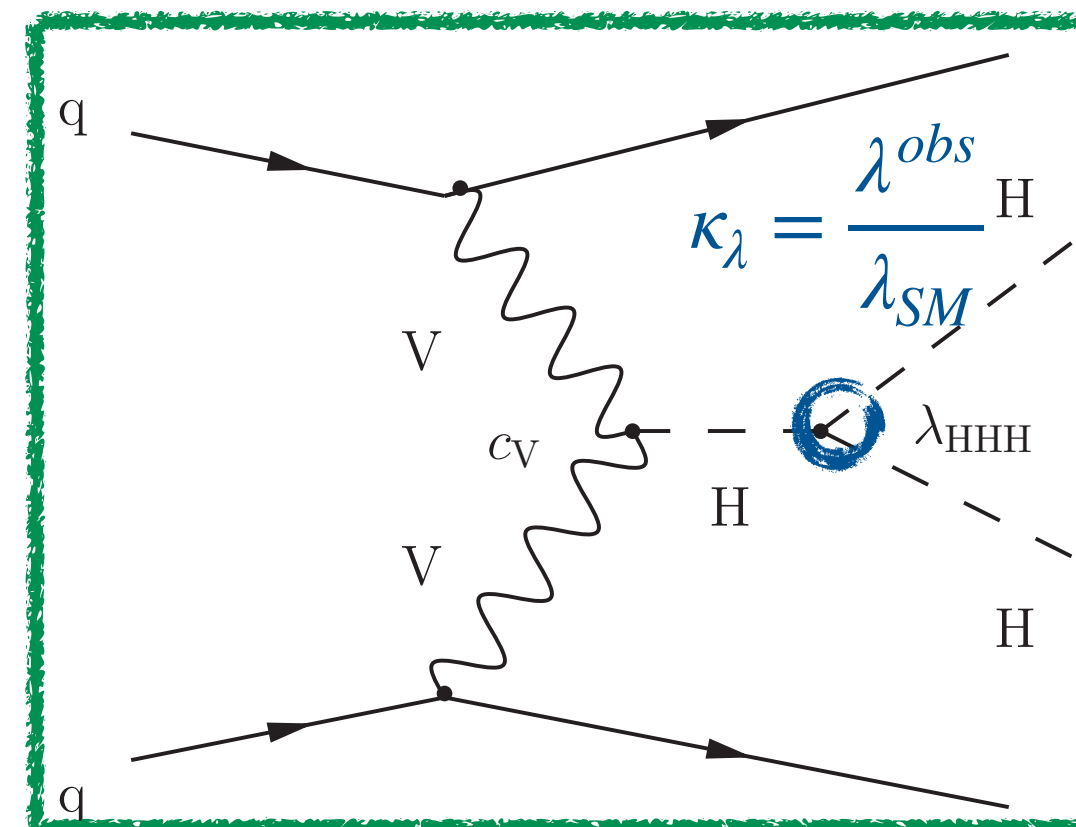
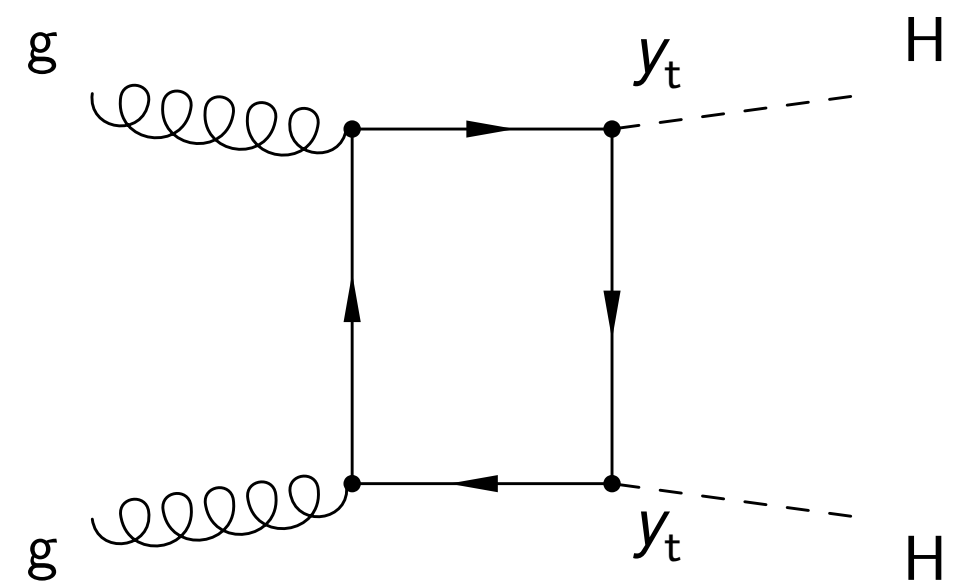
$\sigma = 34 \text{ fb @ } \sqrt{s} = 13.6 \text{ TeV.}$

Production rate $\sim 1000 \text{ times smaller}$ than single Higgs boson production

Vector Boson Fusion “qqHH” is the secondary production mode.

$\sigma = 1.84 \text{ fb @ } 13.6 \text{ TeV.}$

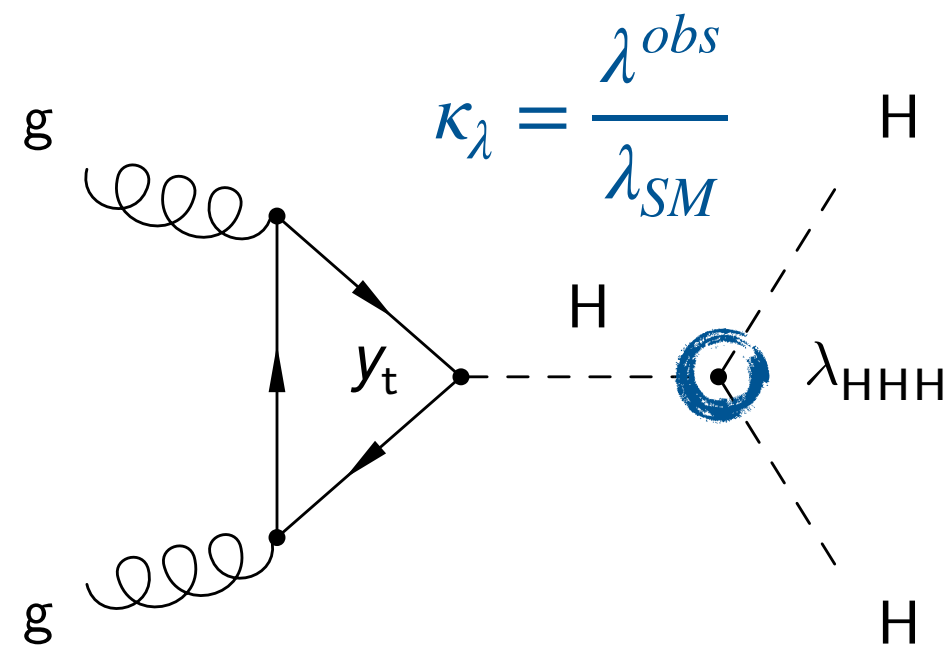
Provide unique access to the coupling between **two Higgs boson and two Vector boson** (C_{2V})



HH production modes



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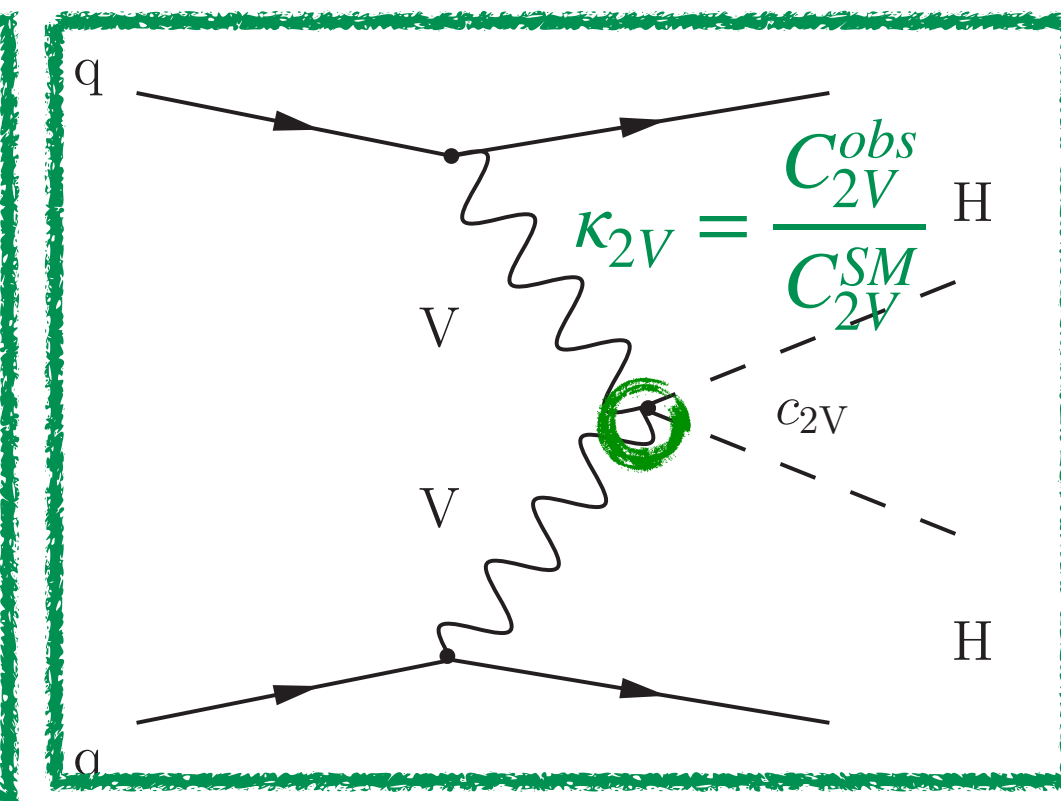
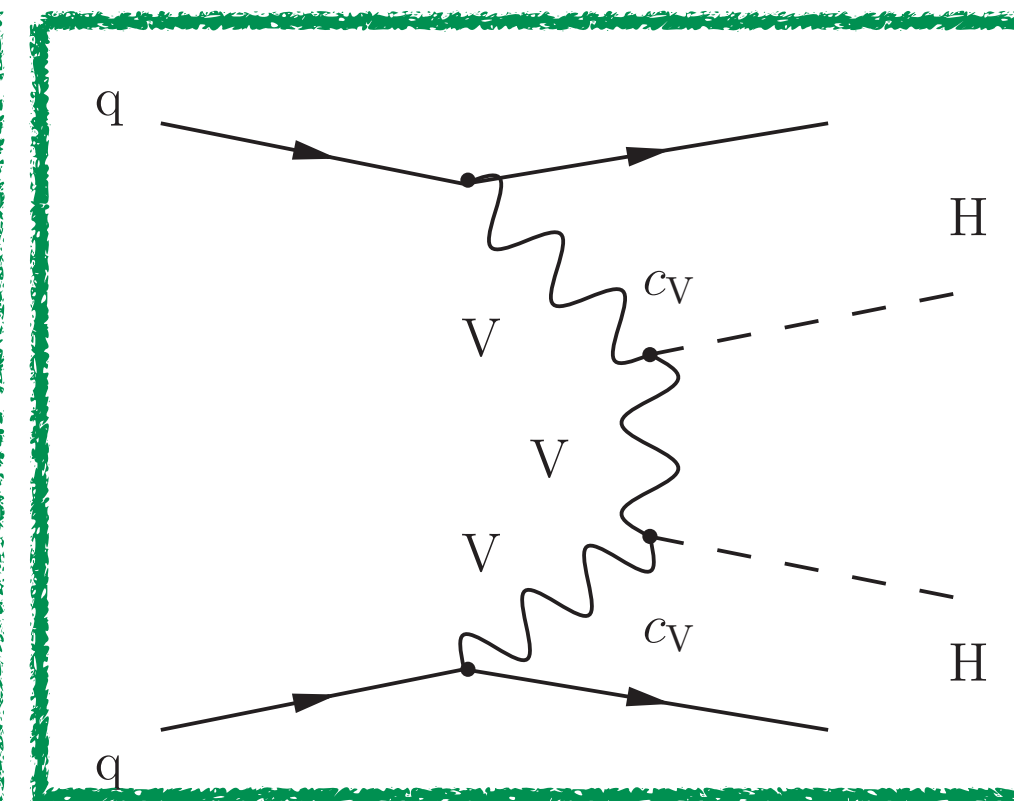
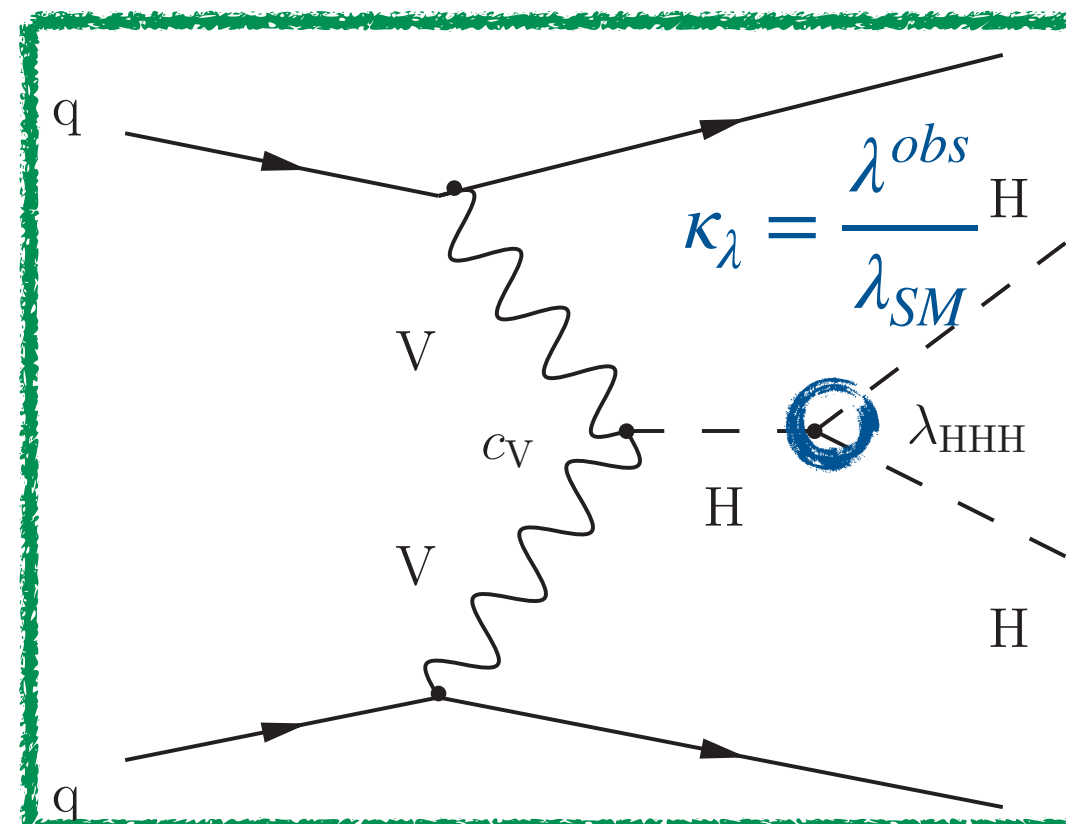
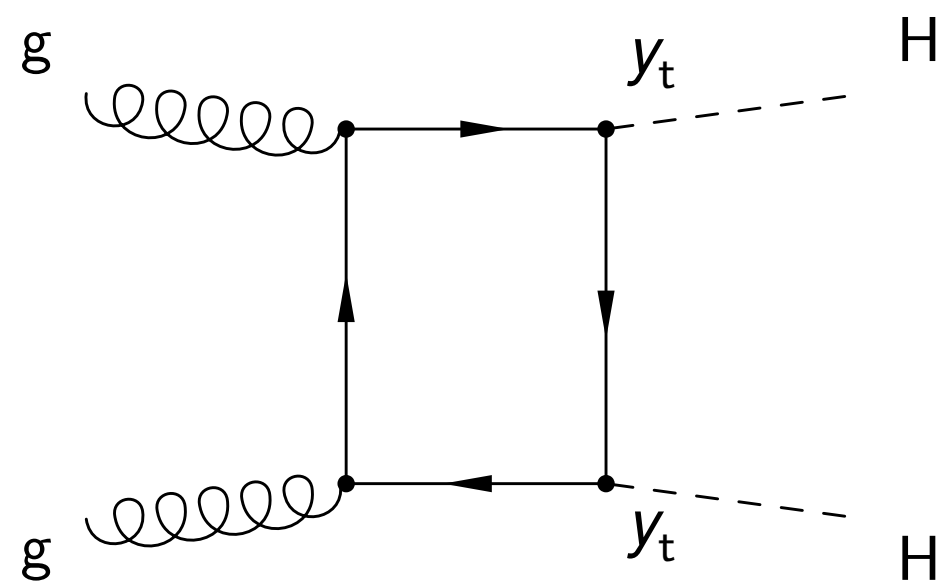
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Provide unique access to the coupling between **two Higgs boson and two Vector boson** (C_{2V})



$\kappa_{2V} = 0$ has already been excluded in Run 2 [Phys. Rev. Lett. 131 \(2023\) 041803](#)

Recapitulation of Run 2 CMS HH results

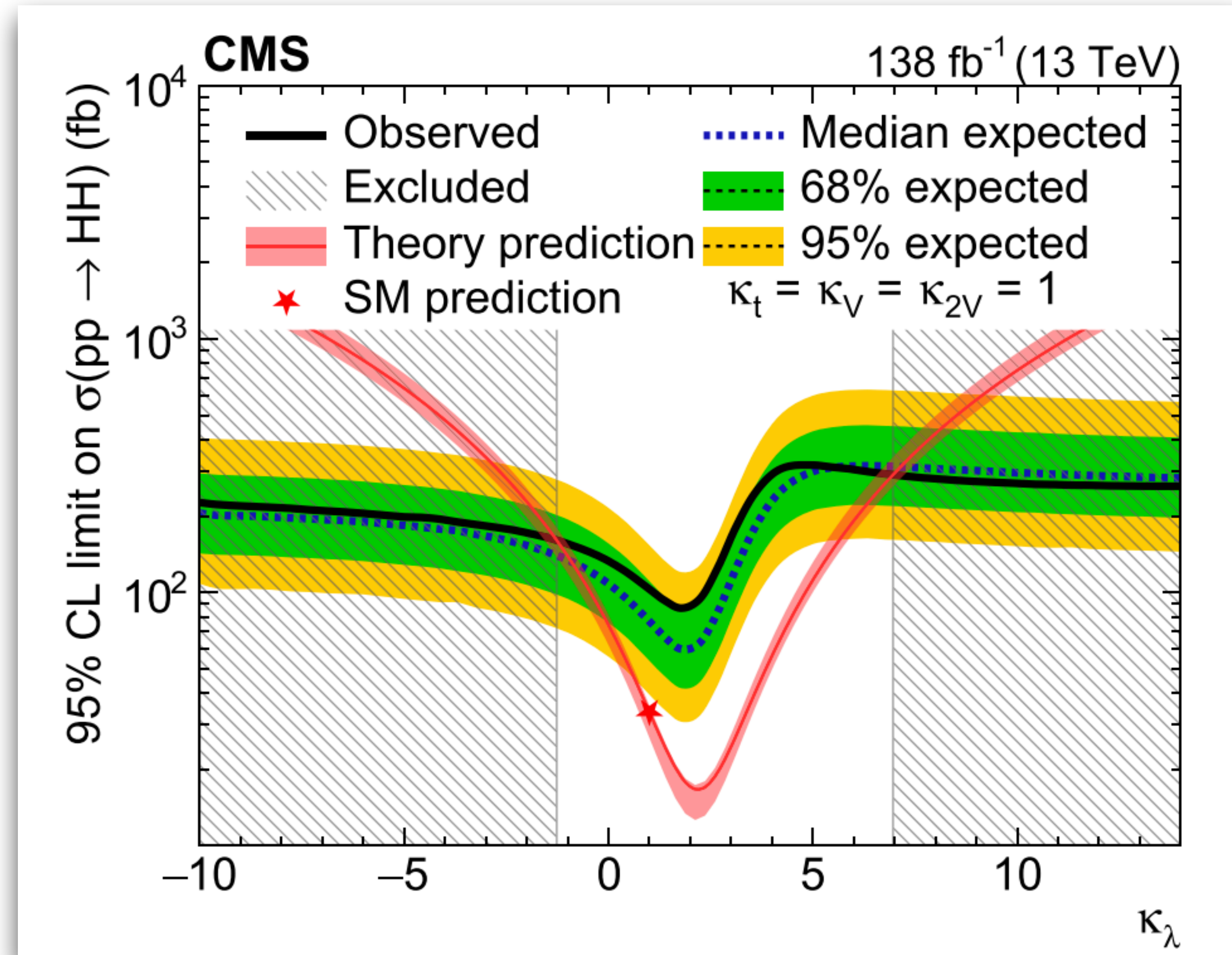


CMS combination of Run2 analyses @ $\sqrt{s} = 13\text{TeV}$, using 138 fb^{-1} of data: Observed (expected) 95% CL constraints on the coupling modifiers, derived from the upper limits on the HH signal strength:

Observed : $\kappa_\lambda \in [-1.39, 7.02]$

Expected : $\kappa_\lambda \in ([-1.02, 7.19])$

[J. Phys. G: Nucl. Part. Phys. 53 095001](#)



Recapitulation of Run 2 CMS HH results



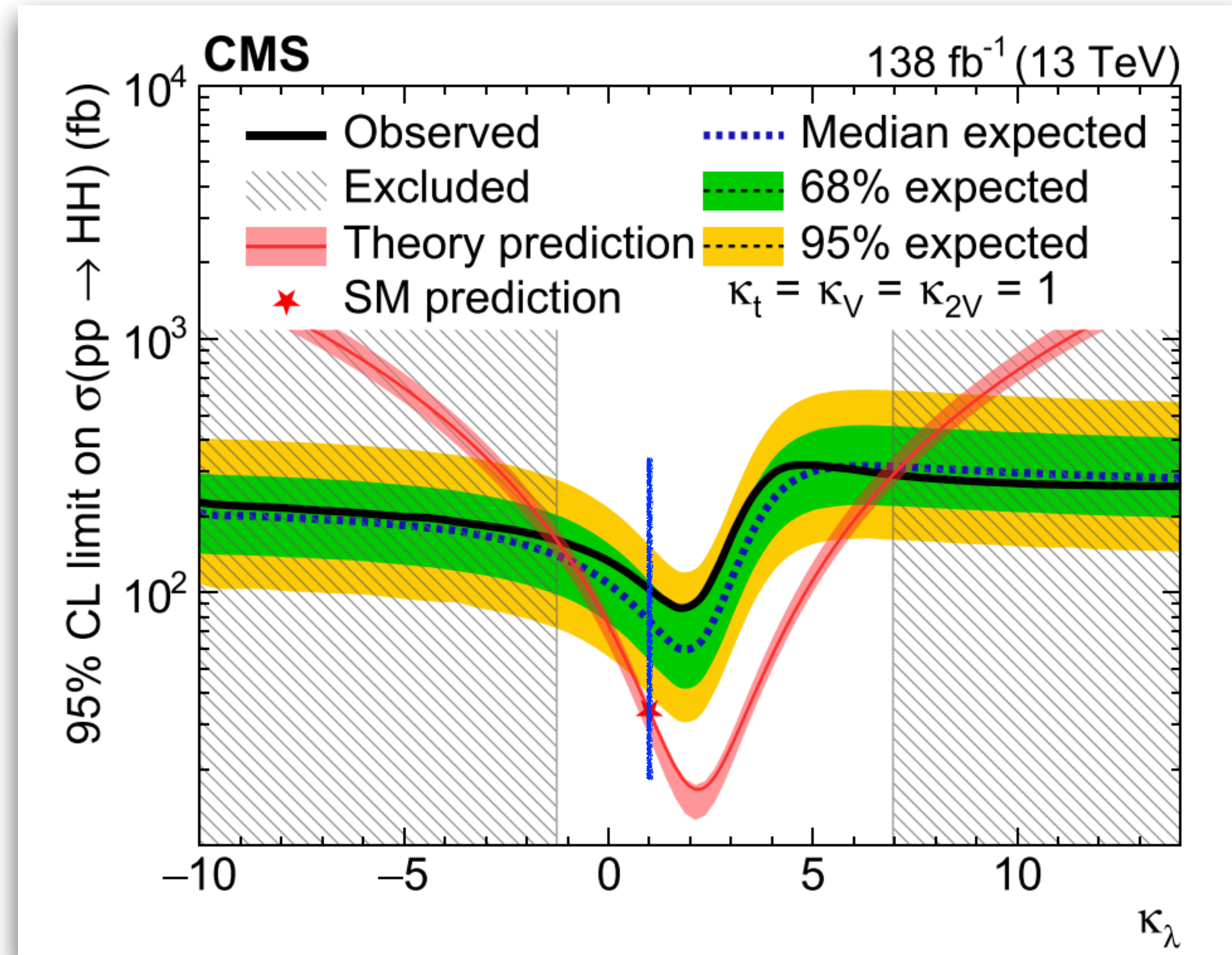
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Observed : $\kappa_\lambda \in [-1.39, 7.02]$

Expected : $\kappa_\lambda \in ([-1.02, 7.19])$

- Observed (expected) 95% confidence level Upper limit (UL) on $\sigma_{\text{HH}} < 3.5(2.5) \times \sigma_{\text{SM}}$

[J. Phys. G: Nucl. Part. Phys. 53 095001](#)



$$\sigma_{\text{SM}}^{\text{HH}} = 31 \text{ fb @13 TeV}$$

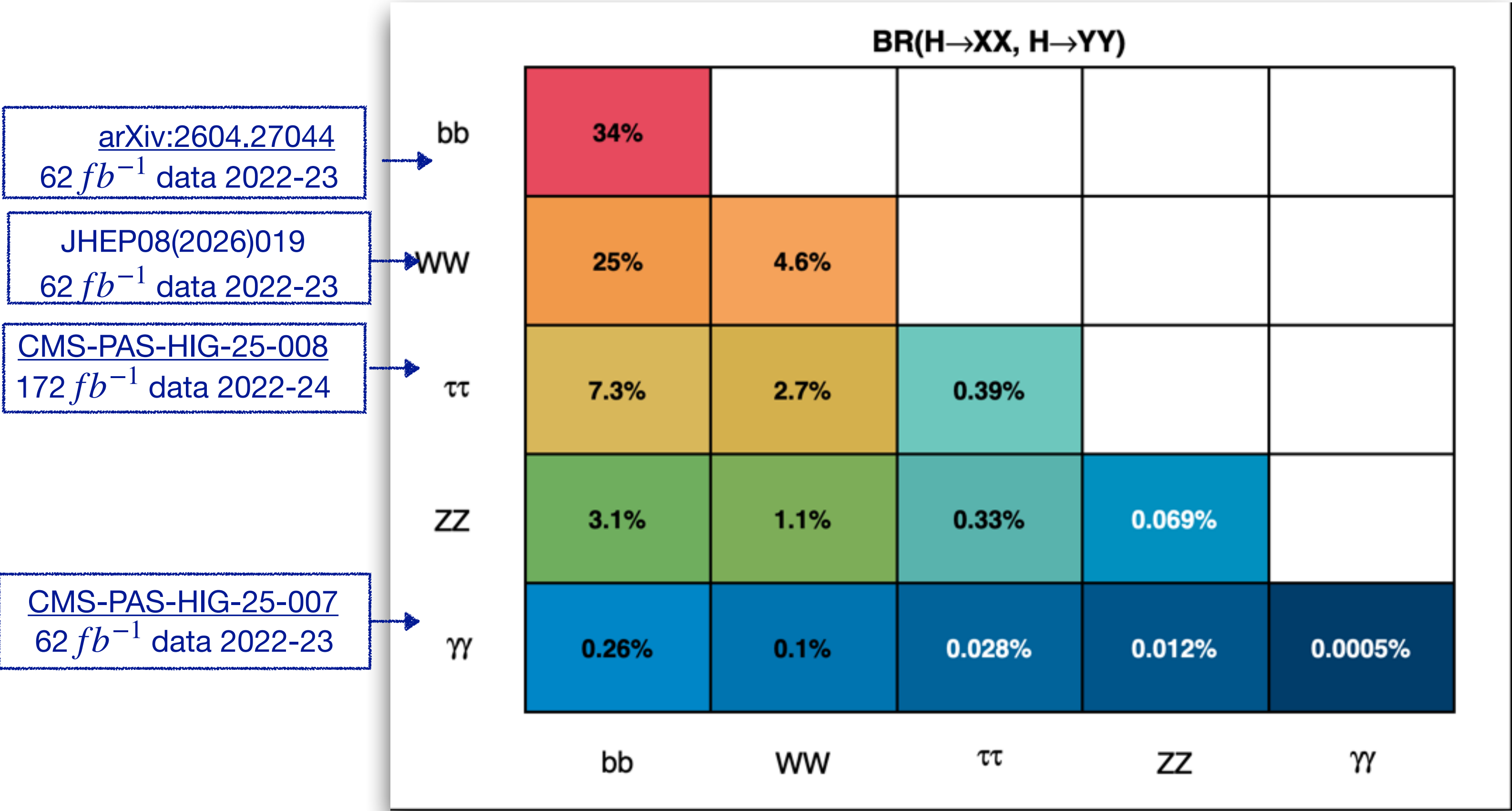
CMS HH analyses in early Run 3



- Run 3 improvements go well beyond the increased dataset, with major advances in several analysis techniques .
- CMS already performed the analyses using early Run 3 data in all of the three major channels;
 $HH \rightarrow b\bar{b}b\bar{b}, b\bar{b}\tau\tau, b\bar{b}\gamma\gamma$

Detailed discussion by Zak

Highlights of Today's Talk



$$HH \rightarrow b\bar{b}b\bar{b}$$

 **Most improved CMS HH analysis in Run 3 compared to Run 2.**

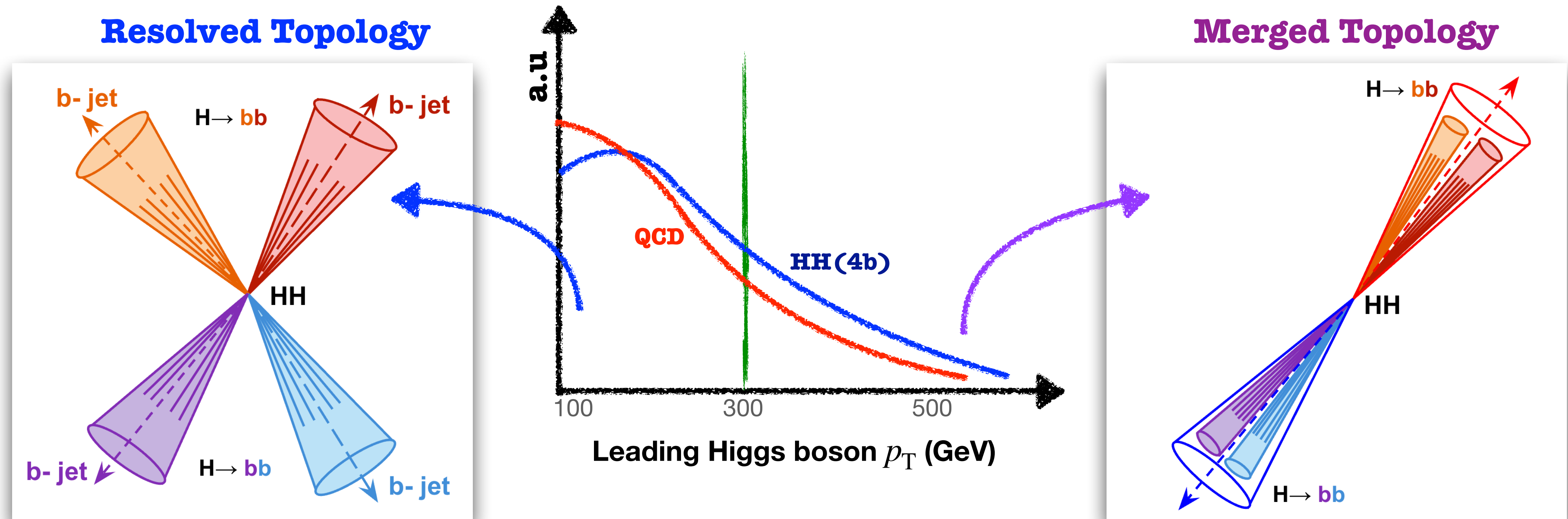
[arXiv:2604.27044](https://arxiv.org/abs/2604.27044) , Accepted by *Phys. Rev. D* <https://doi.org/10.1103/w2zp-fckl>

$HH \rightarrow b\bar{b}b\bar{b}$: Key features

arXiv:2604.27044



- This decay channel of HH, has the largest branching ratio (30% of total HH decays)
- Despite having the largest branching ratio, this channel is challenged by overwhelming QCD multijet background
 - The small expected S/B makes the signal extraction particularly difficult.
 - The QCD background is poorly modelled from simulation and lacks higher-order corrections
- Allows to access and explore **merged topology with (better S/B), depending on the Higgs boson p_T**



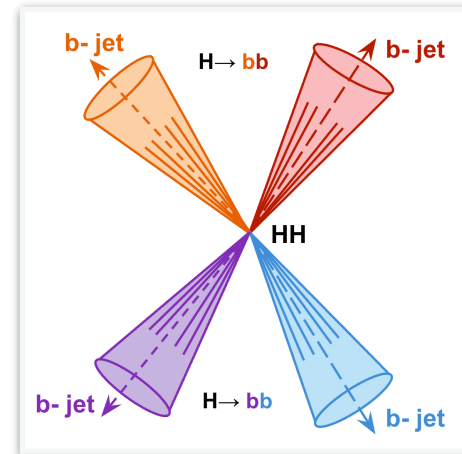
Higgs candidates are reconstructed from four AK4 jets

Higgs candidates are reconstructed from two AK8 jets

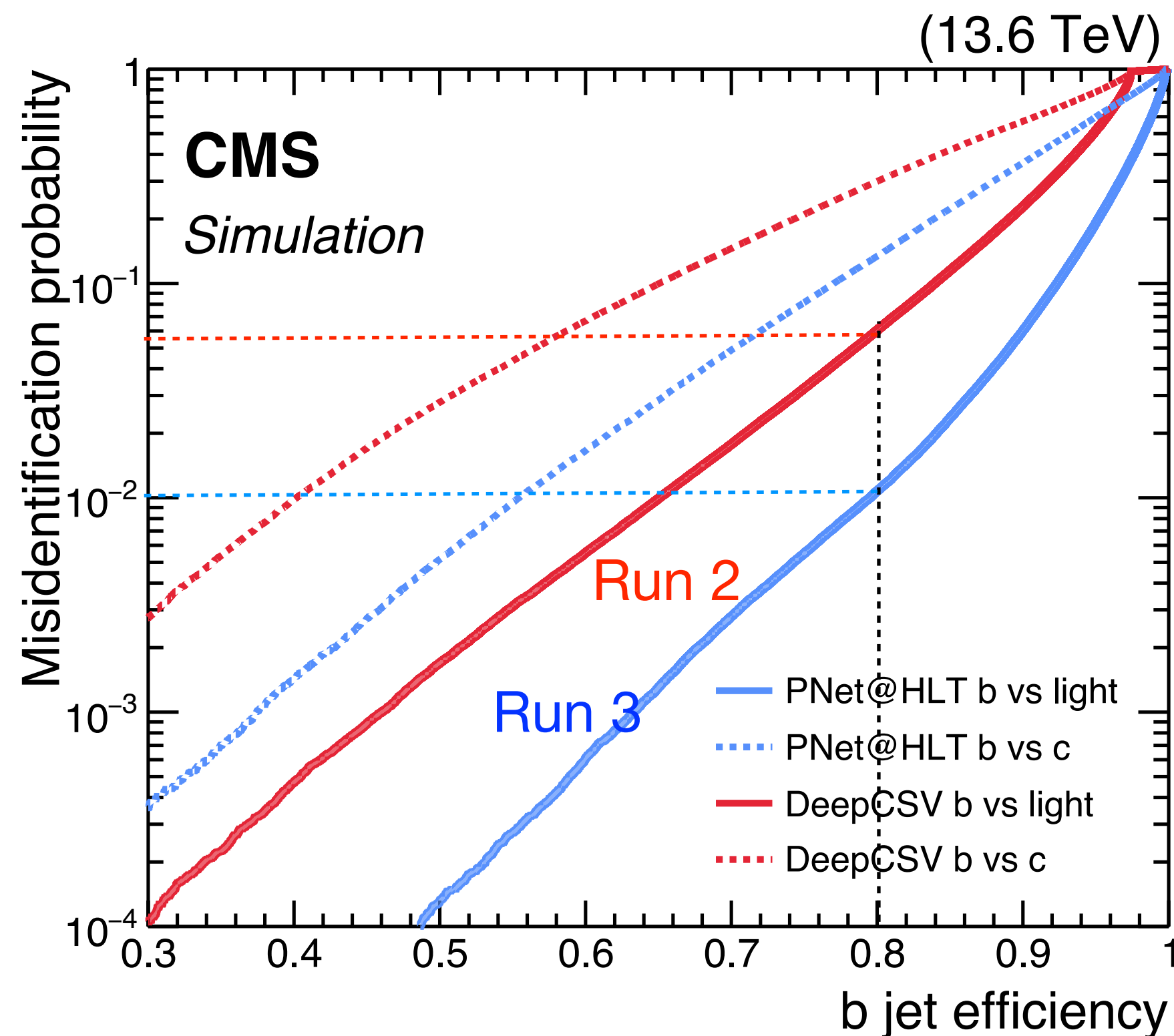
HH $\rightarrow$ $b\bar{b}b\bar{b}$: Improvements for online flavour jet flavour tagger arXiv:2604.27044



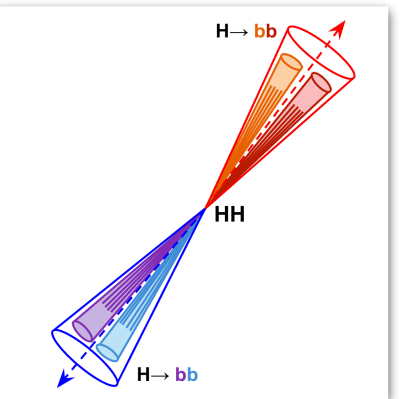
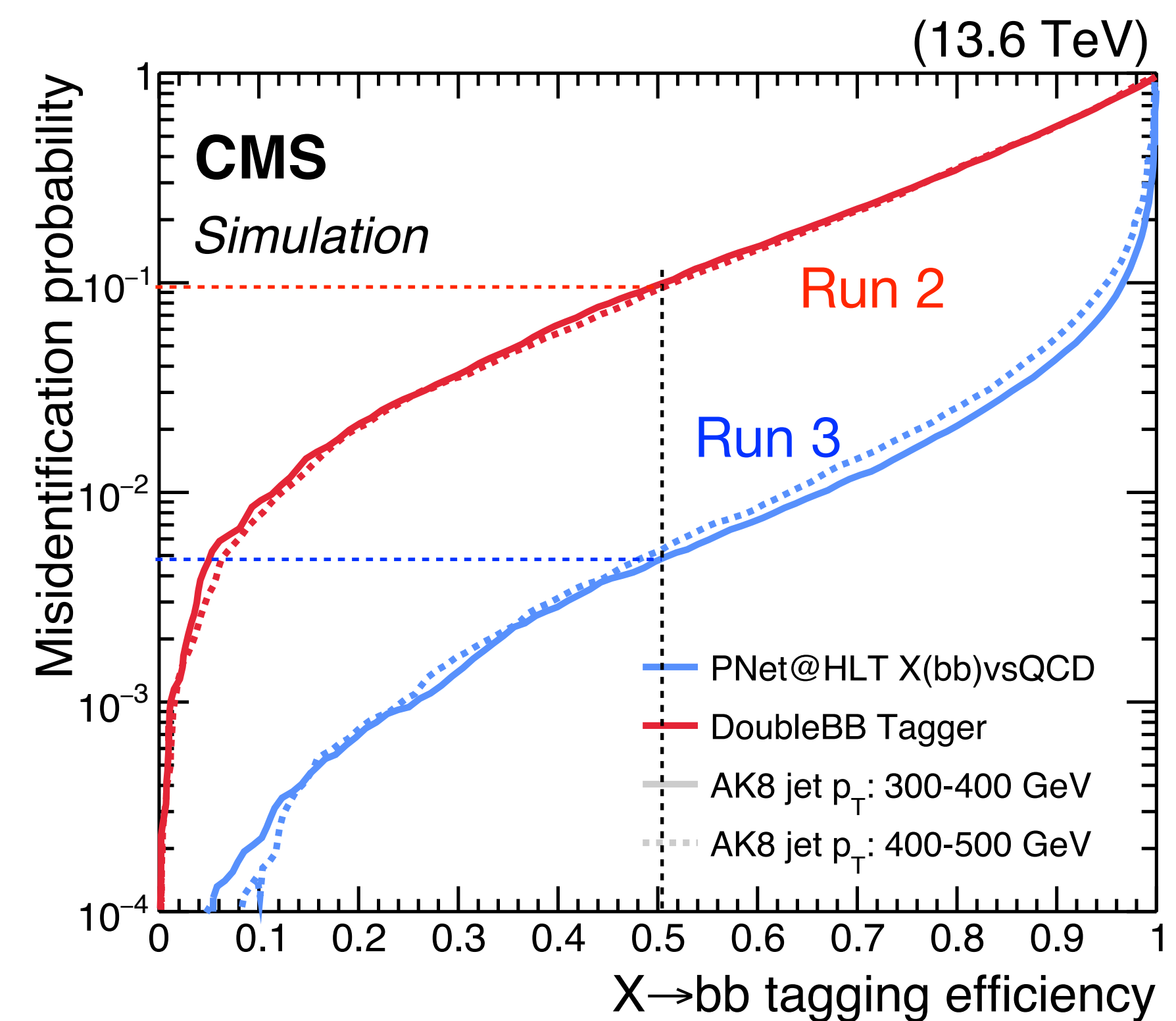
- Tremendous improvement in the key aspects on the both HH topology
- Graph Neural Network based ParticleNet flavor tagger trained with online HLT jets (both AK4 and AK8) has been deployed at the HLT beginning of Run 3 data taking period



Better AK4 flavour tagger @HLT level



Better AK8 flavour tagger @HLT level



Outperforms previous HLT flavour tagger performance: Reject more background at the same signal efficiency

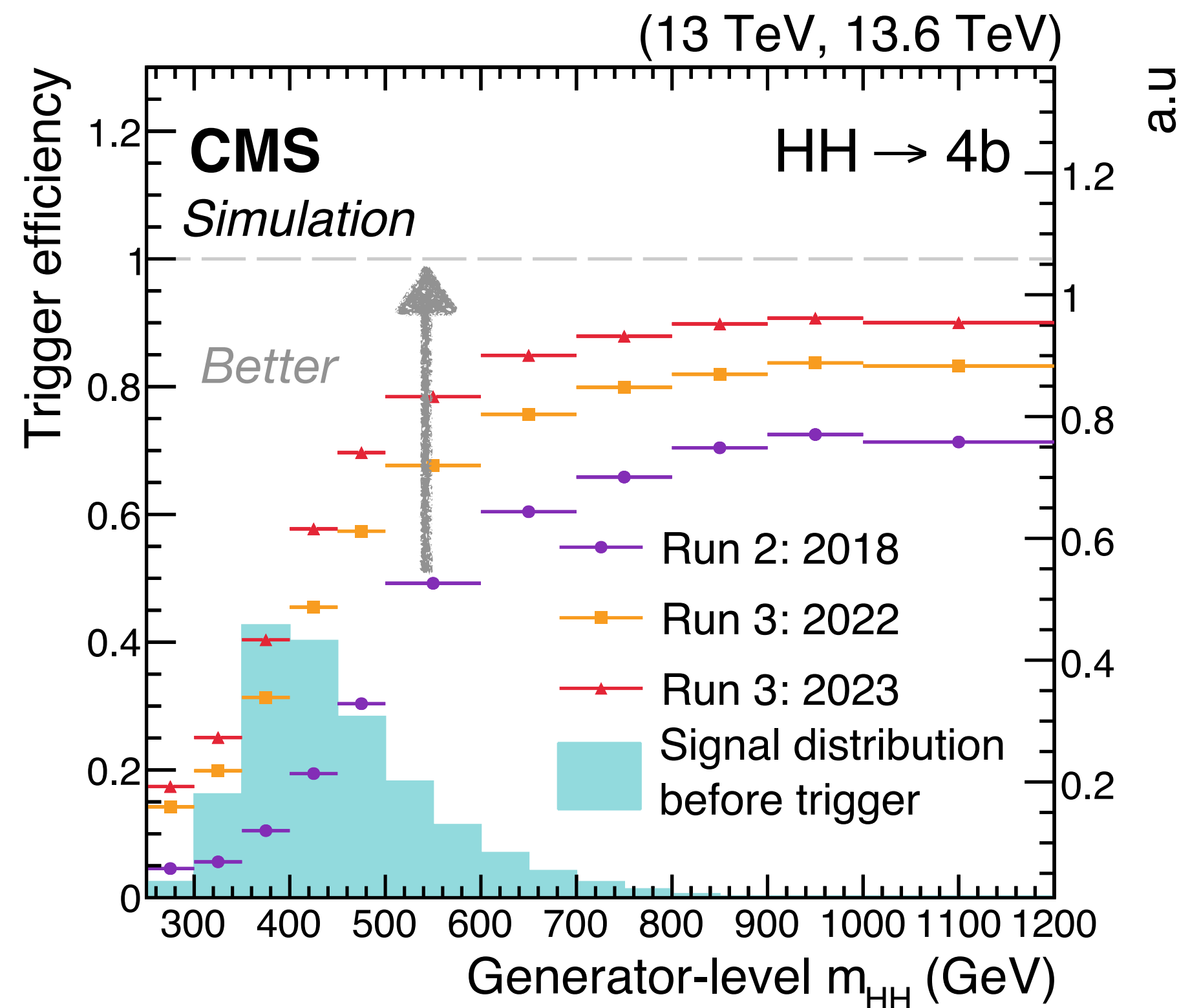
$HH \rightarrow b\bar{b}b\bar{b}$: Improvements in HLT

arXiv:2604.27044

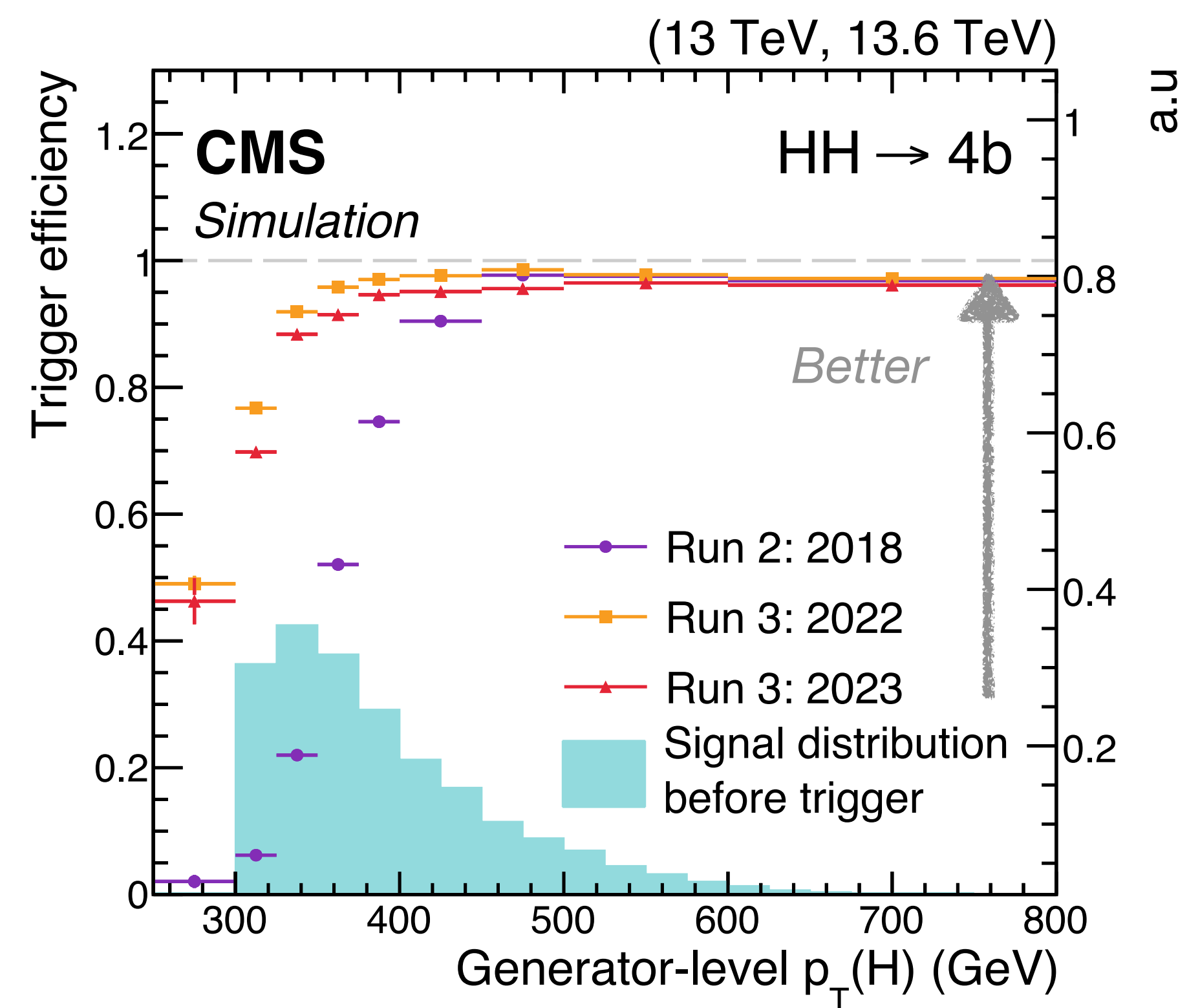


- Outperform previous HLT flavor tagger performance
- Reduce fake contributions → Loosening the kinematic thresholds at same bandwidth
- Significant gain of signal efficiency at the HLT level
- In 2023, high rate (150 Hz) data taking stream (ParkingHH) → allows to reduce the online thresholds → further gain on signal

Resolved topology



Boosted topology

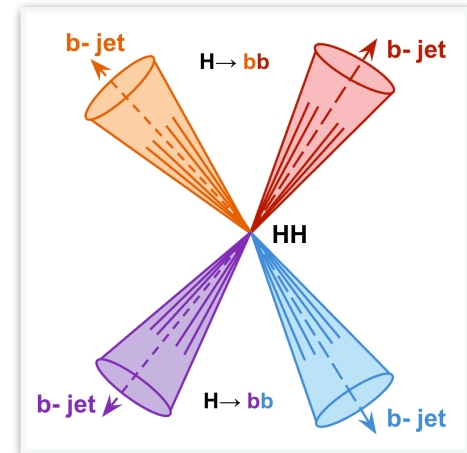


$HH \rightarrow b\bar{b}b\bar{b}$: Offline jet-flavour tagger

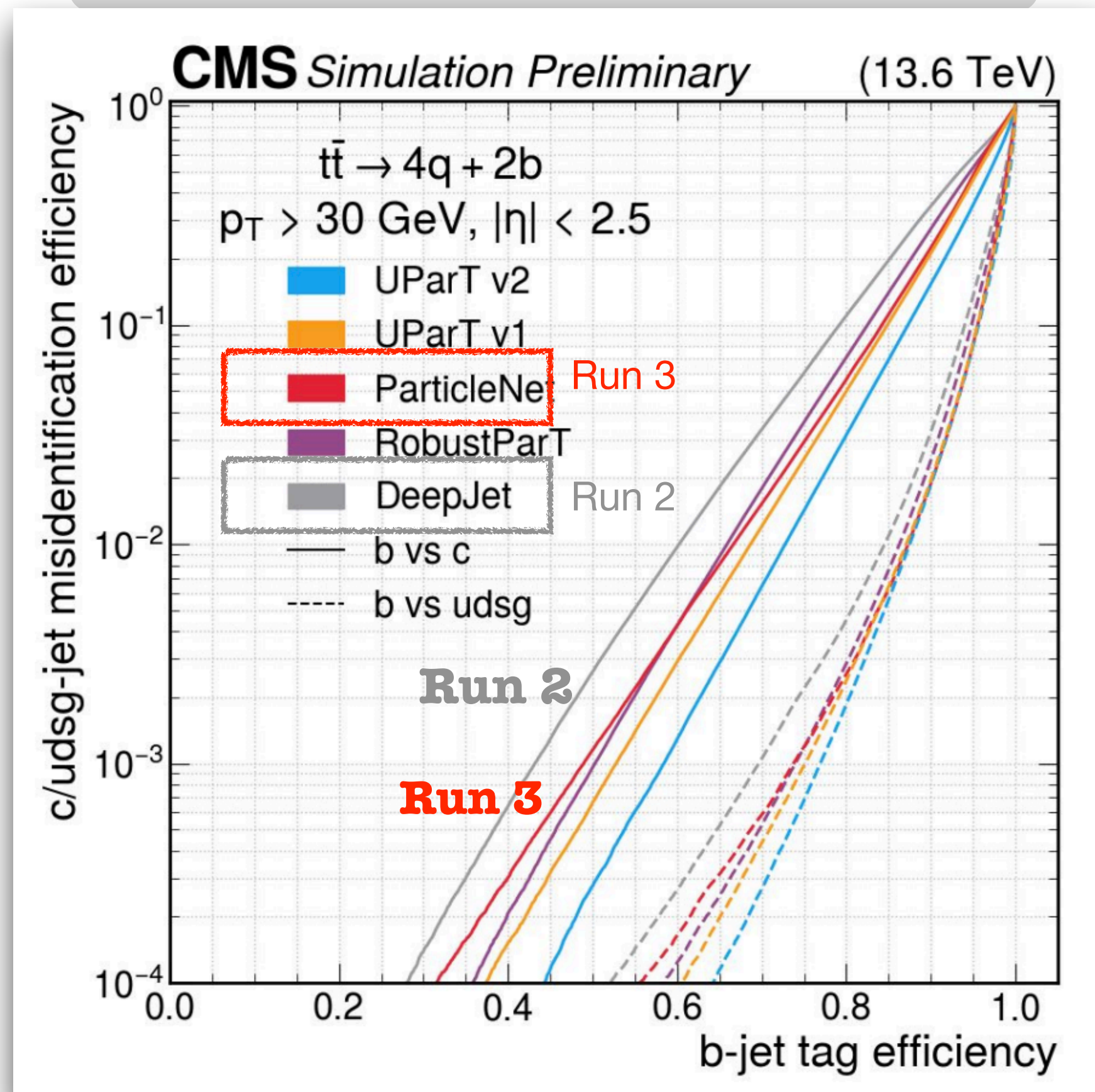
arXiv:2604.27044



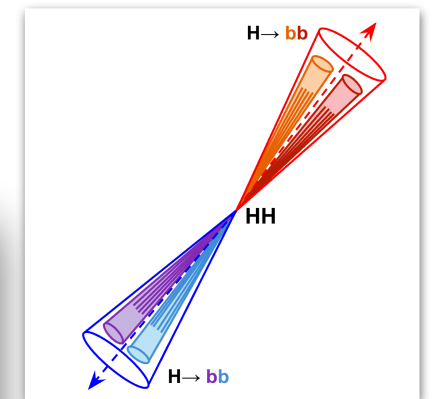
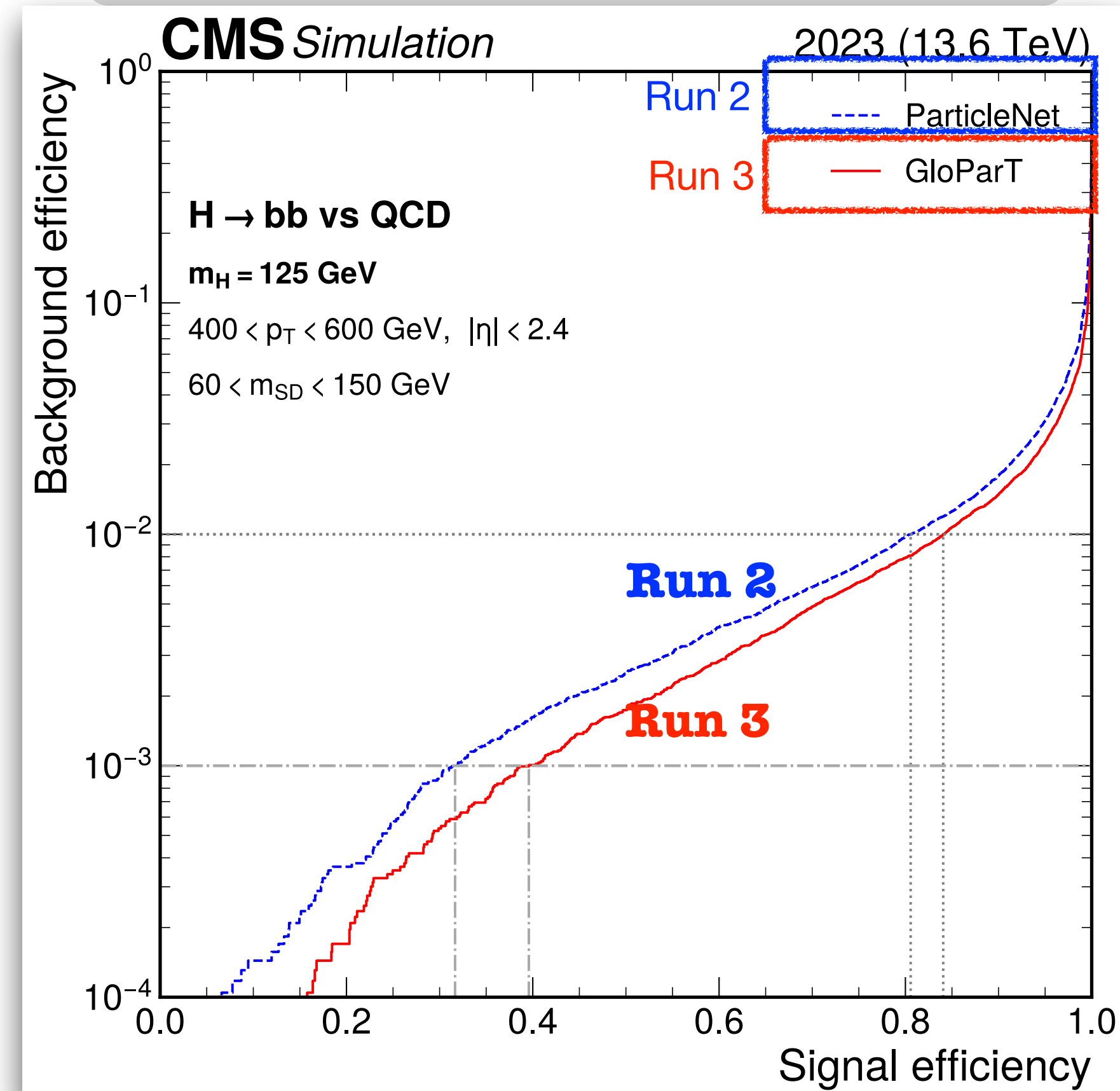
- Offline flavour taggers in Run 3 both AK4 (ParticleNet) & AK8 (GloParT) improve the performance substantially over Run 2 tagger.
- Suppress the backgrounds (mis-identified as b-jets) more than Run 2, for same signal efficiency.



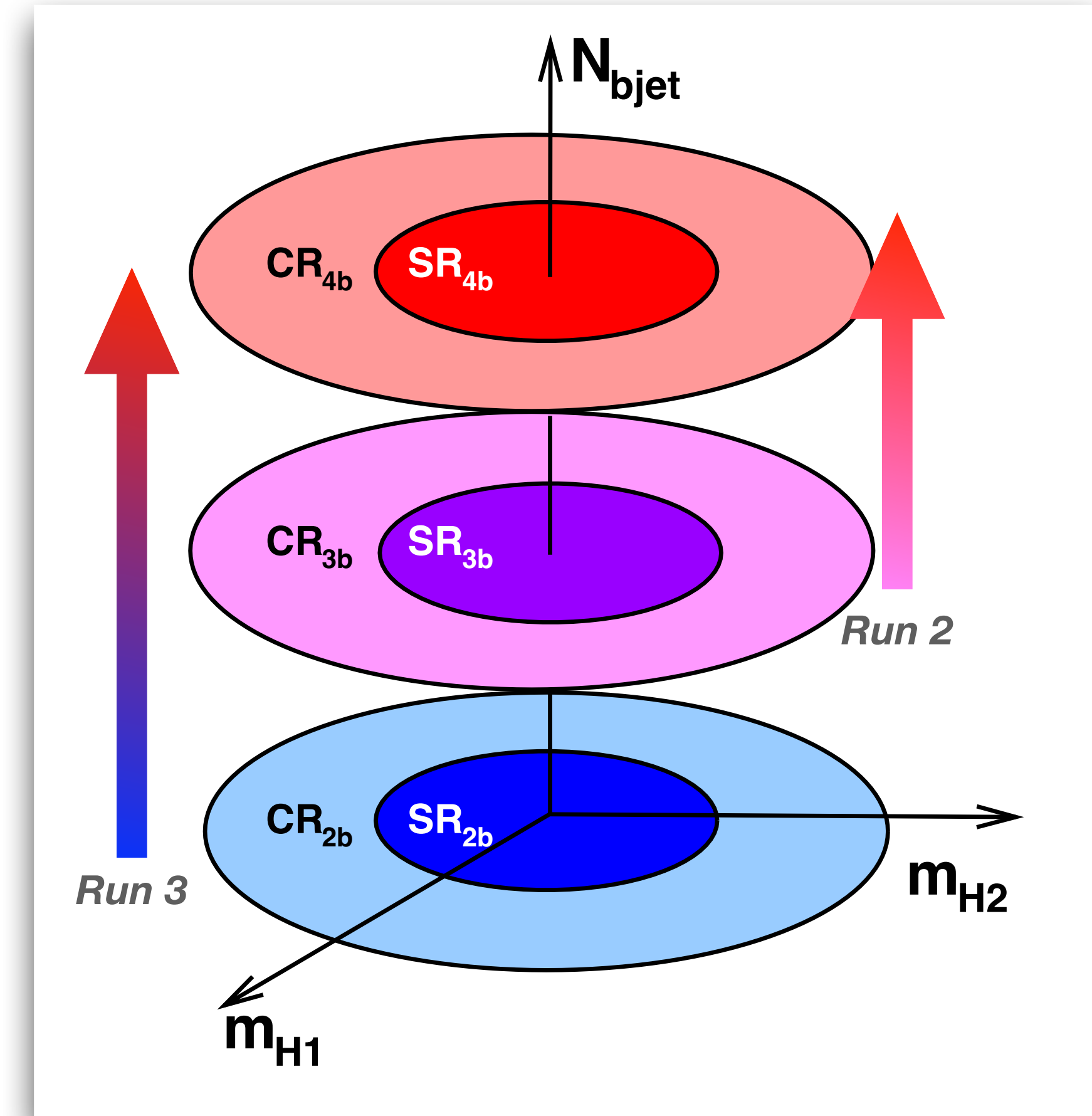
Better AK4 flavour tagger



Better AK8 flavour tagger



- For both resolved and merged topology the major background is QCD (+ $t\bar{t}$) estimated from data.
- DNN based multivariate re-weighting has been performed to estimate the background in **signal region** from **the background dominated control regions**.



Run 3 HLT allows to access 10 times more stat **2b**-tag dataset than **3b** to estimate background in **4b**, (key limiting factor for Run 2 for the background estimation in resolved regime)

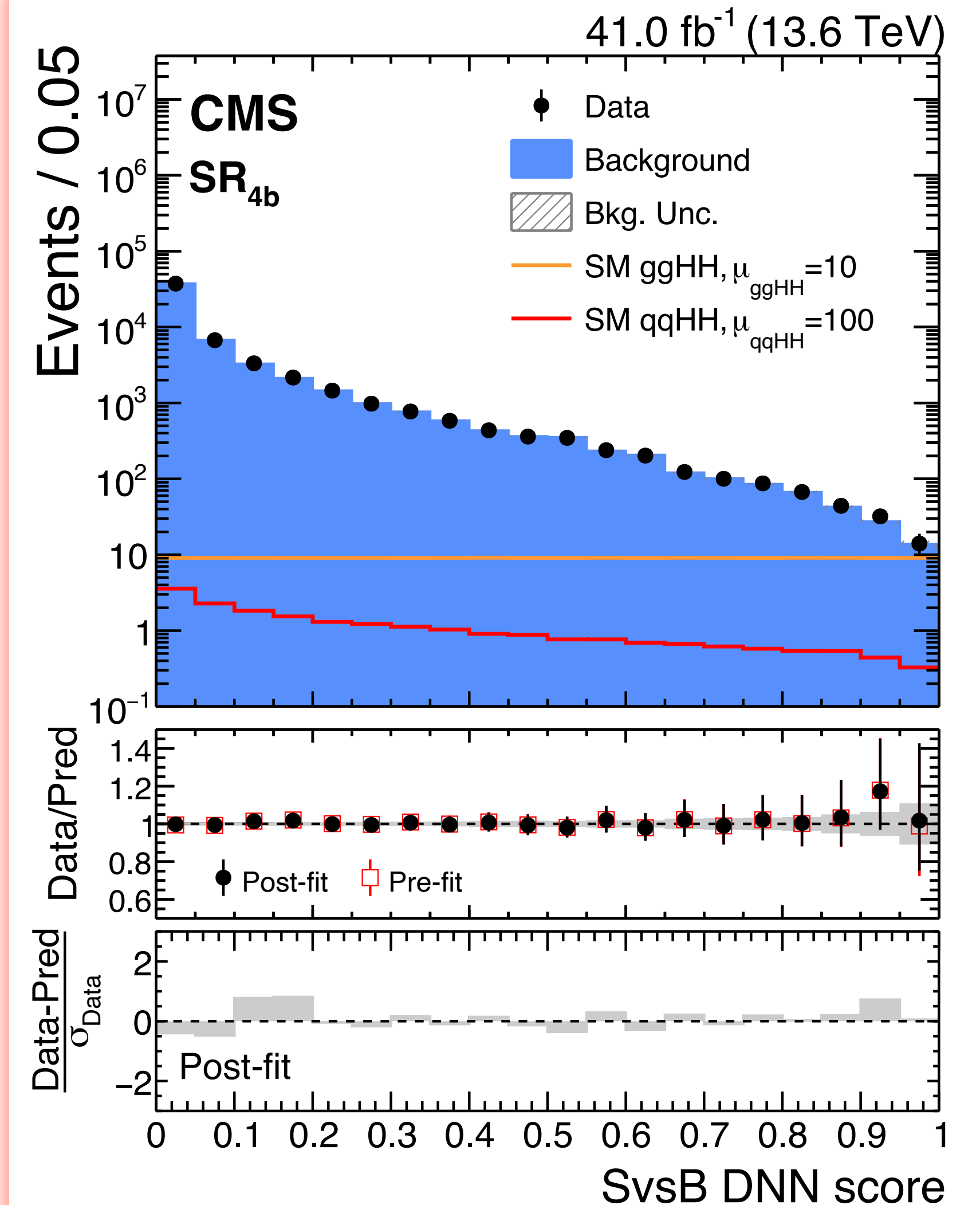
$HH \rightarrow b\bar{b}b\bar{b}$: Background estimation & signal extraction

arXiv:2604.27044



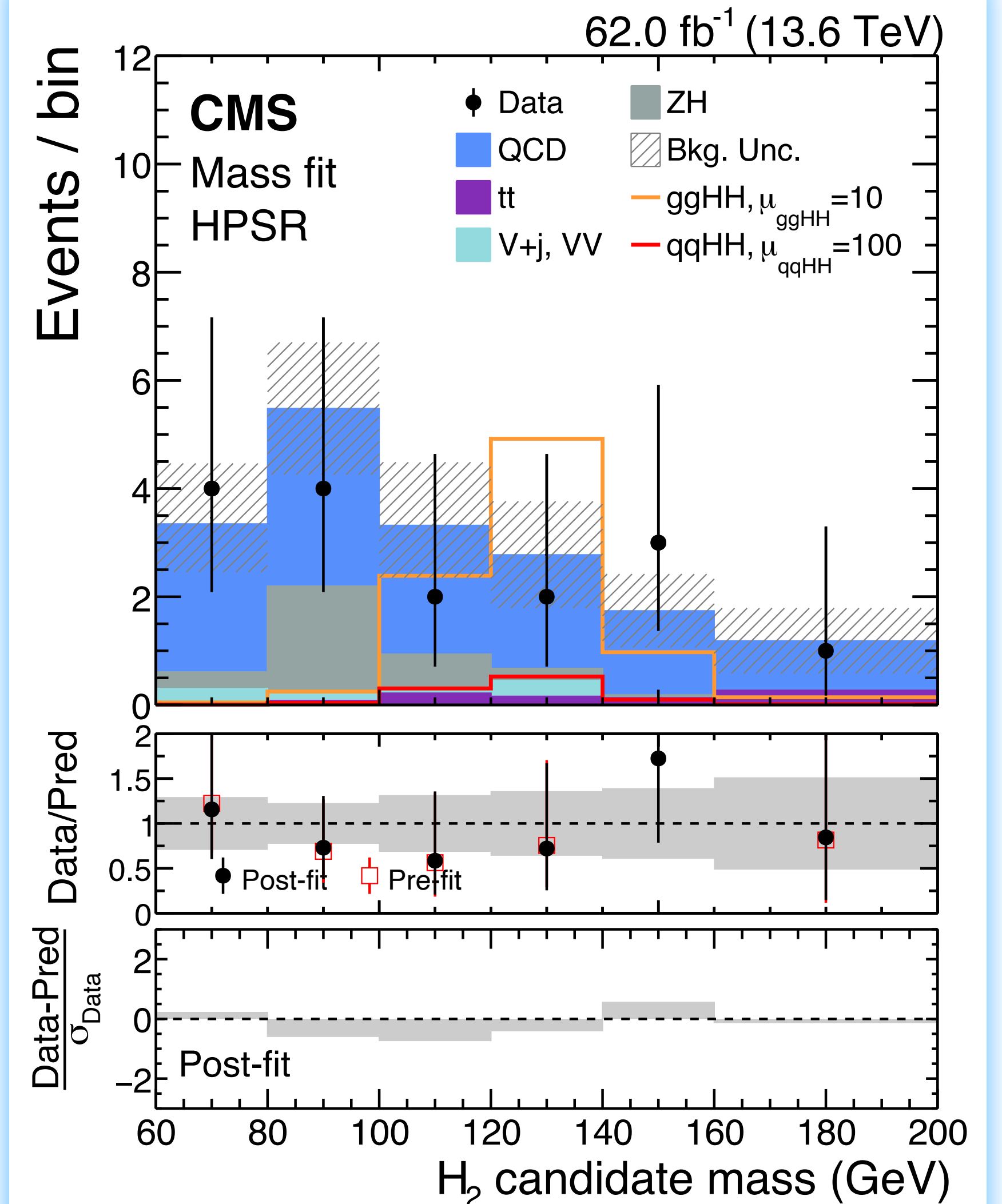
- For both resolved and merged topology the major background is QCD (+ $t\bar{t}$) estimated from data.
- DNN based multivariate re-weighting has been performed to estimate the background in **signal region** from **the background dominated control regions**.
- Separate Signal to background separation (SvsB) DNN has been used for the ggHH and VBFHH tagged categories.
 - Exploiting full event kinematics for both **resolved** and **merged** topology.
- A binned profile likelihood fit to the DNN distribution is used to extract the signal in the **resolved topology**

Post-fit DNN distribution in the resolved regime



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- Separate Signal to background separation (SvsB) DNN has been used for the ggHH and VBFHH tagged categories.
 - Exploiting full event kinematics for both **resolved** and **merged** topology.
- A binned profile likelihood fit to the DNN distribution is used to extract the signal in the **resolved topology**
- In the merged topology:** Events are first categorized based on the DNN score, followed by a binned profile likelihood fit to the **subleading Higgs boson mass distribution** in each category.

Post-fit m_{H_2} distribution in the High Purity Signal Region (HPSR) for the merged regime



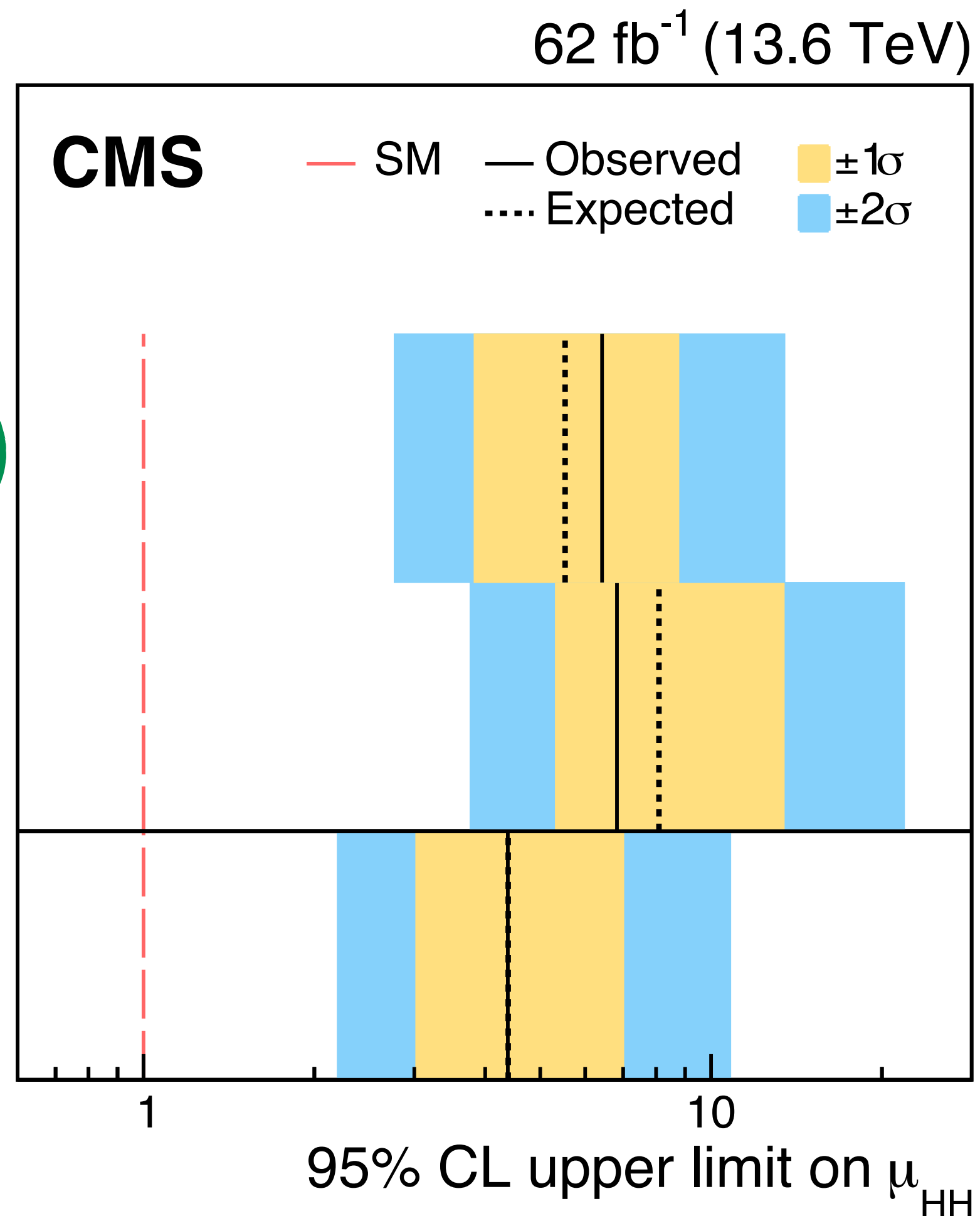
95% CL UL on the HH signal

Run 3
2022,23

Resolved
Obs. 6.4
Exp. 5.5

Merged
Obs. 6.8
Exp. 8.1

Combination
Obs. 4.4
Exp. 4.4



Resolved analysis improves the analysis sensitivity by **200%** compared to the previous Run 2 result [Phys. Rev. Lett. 129 \(2022\) 081802](#)

Significantly better sensitivity achieved for the VBFHH production mode also.

The Run 3 merged analysis is also more sensitive than Run 2

HH $\rightarrow$ $b\bar{b}b\bar{b}$: Combination of Run 3 with Run2

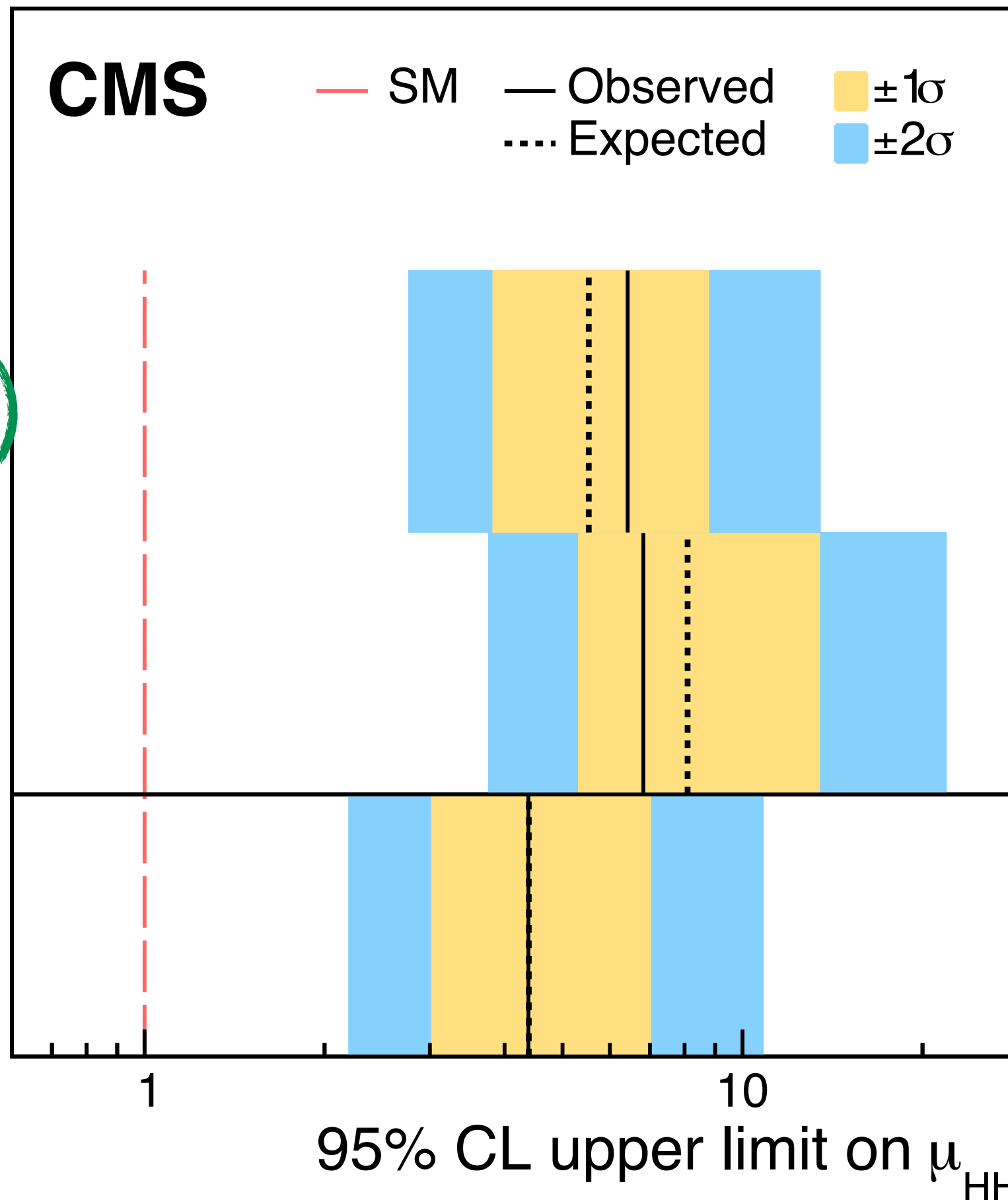
arXiv:2604.27044



95% CL UL on the HH signal

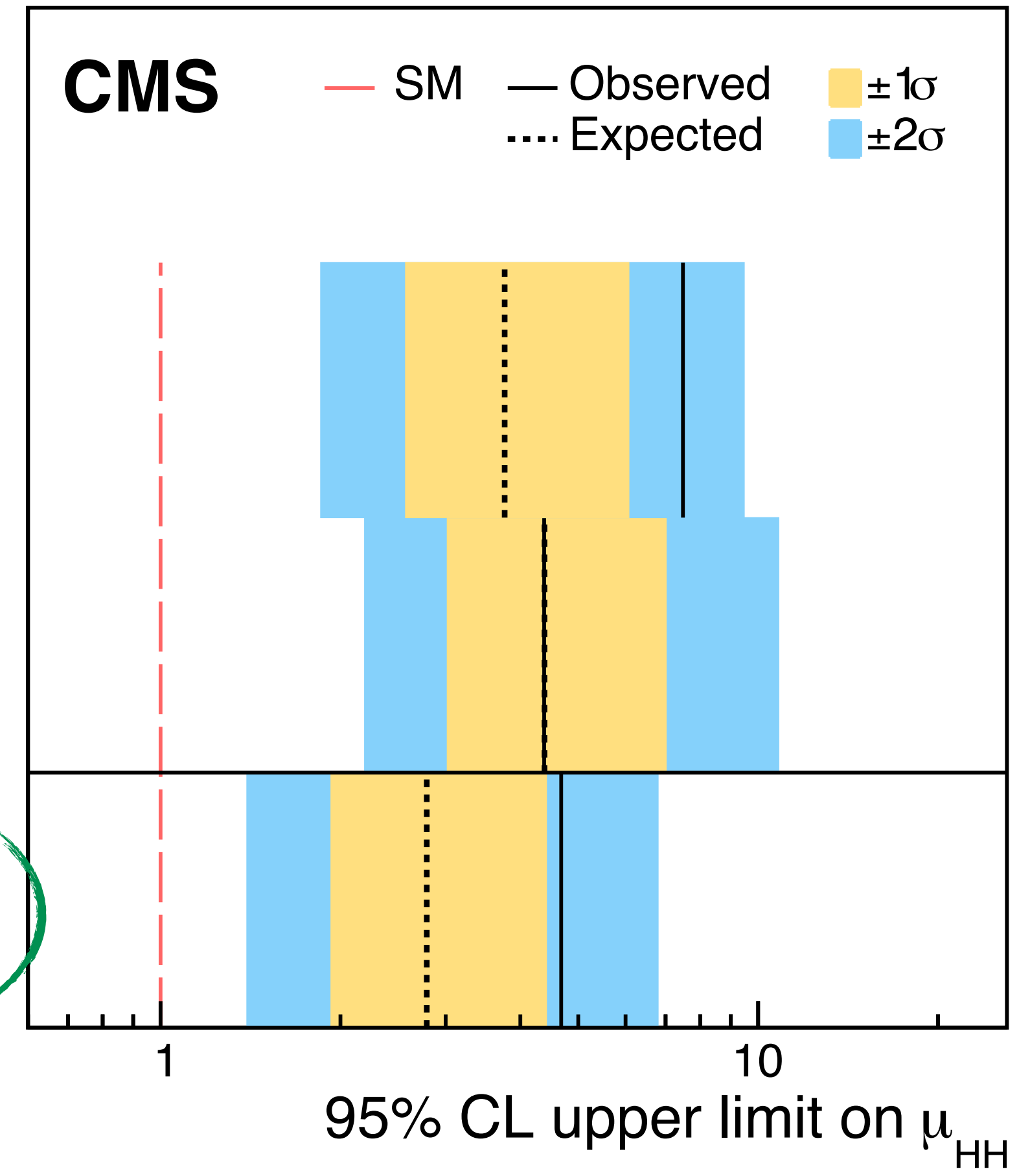
Run 3
2022,23

62 fb⁻¹ (13.6 TeV)



Run 3
+
Run 2

138 fb⁻¹ (13 TeV) + 62 fb⁻¹ (13.6 TeV)



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 $b\bar{b}\tau\tau$

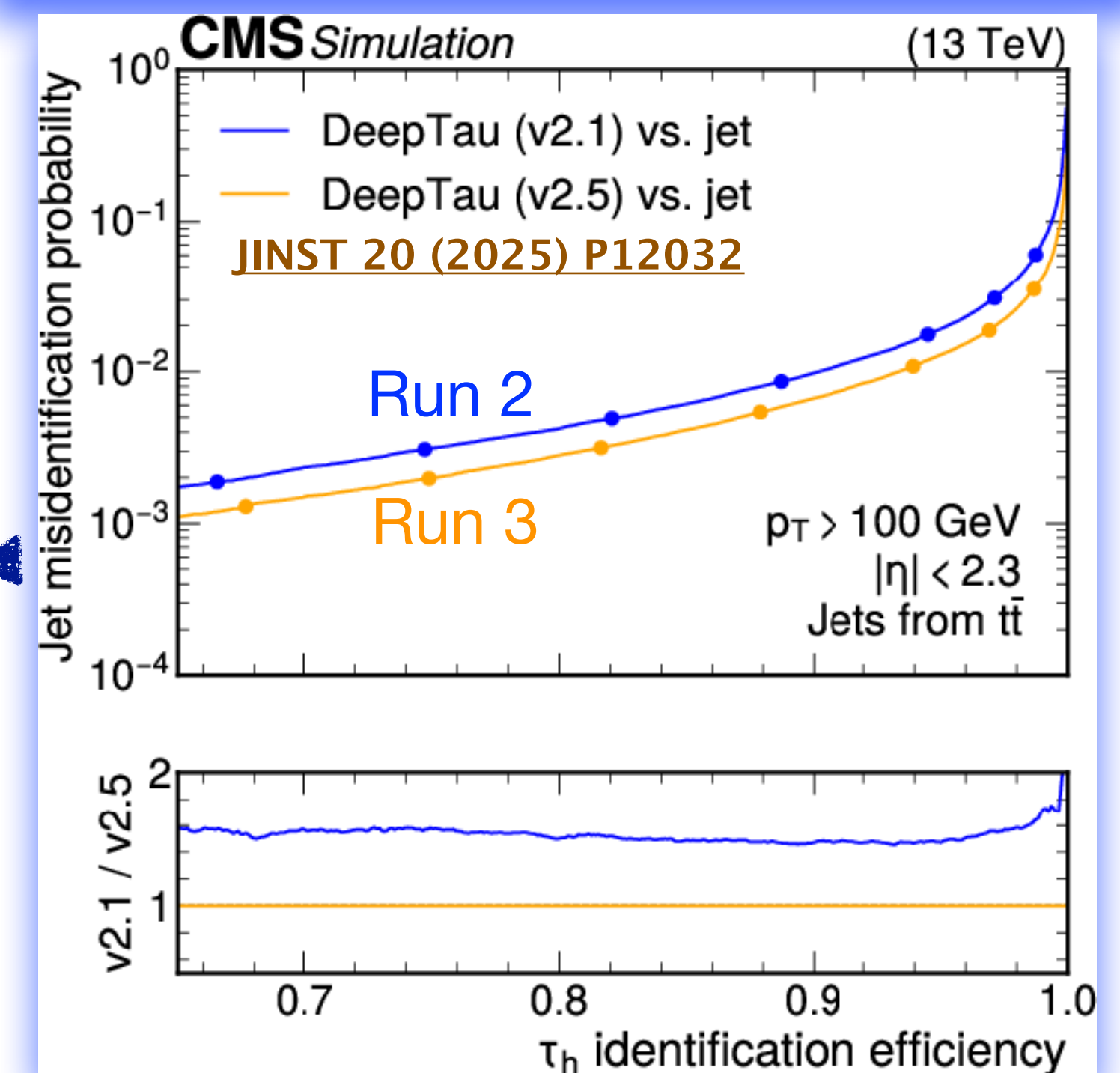
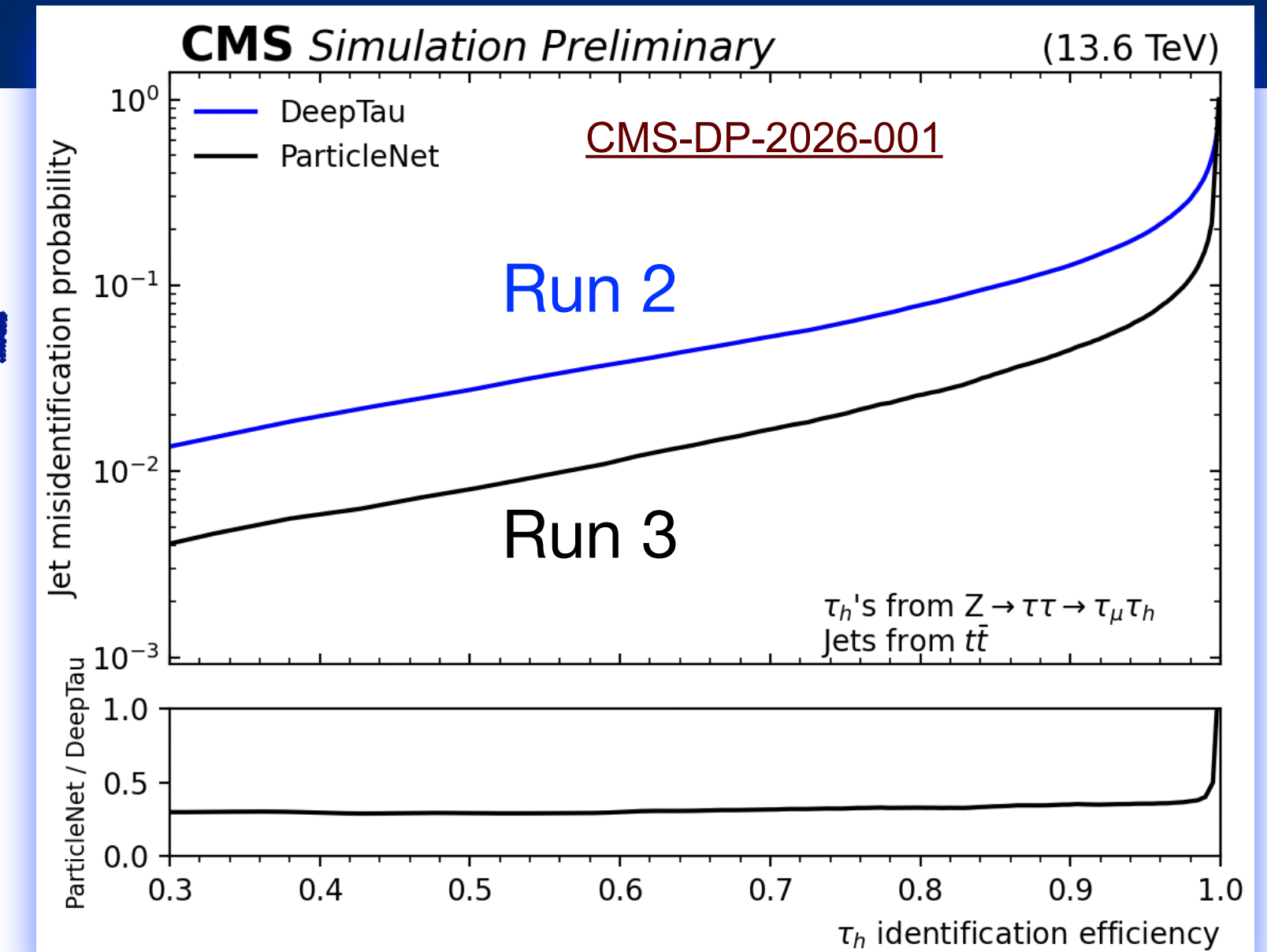
$$HH \rightarrow b\bar{b}\tau\tau$$

$HH \rightarrow b\bar{b}\tau\tau$: Key features

CMS-PAS-HIG-25-008



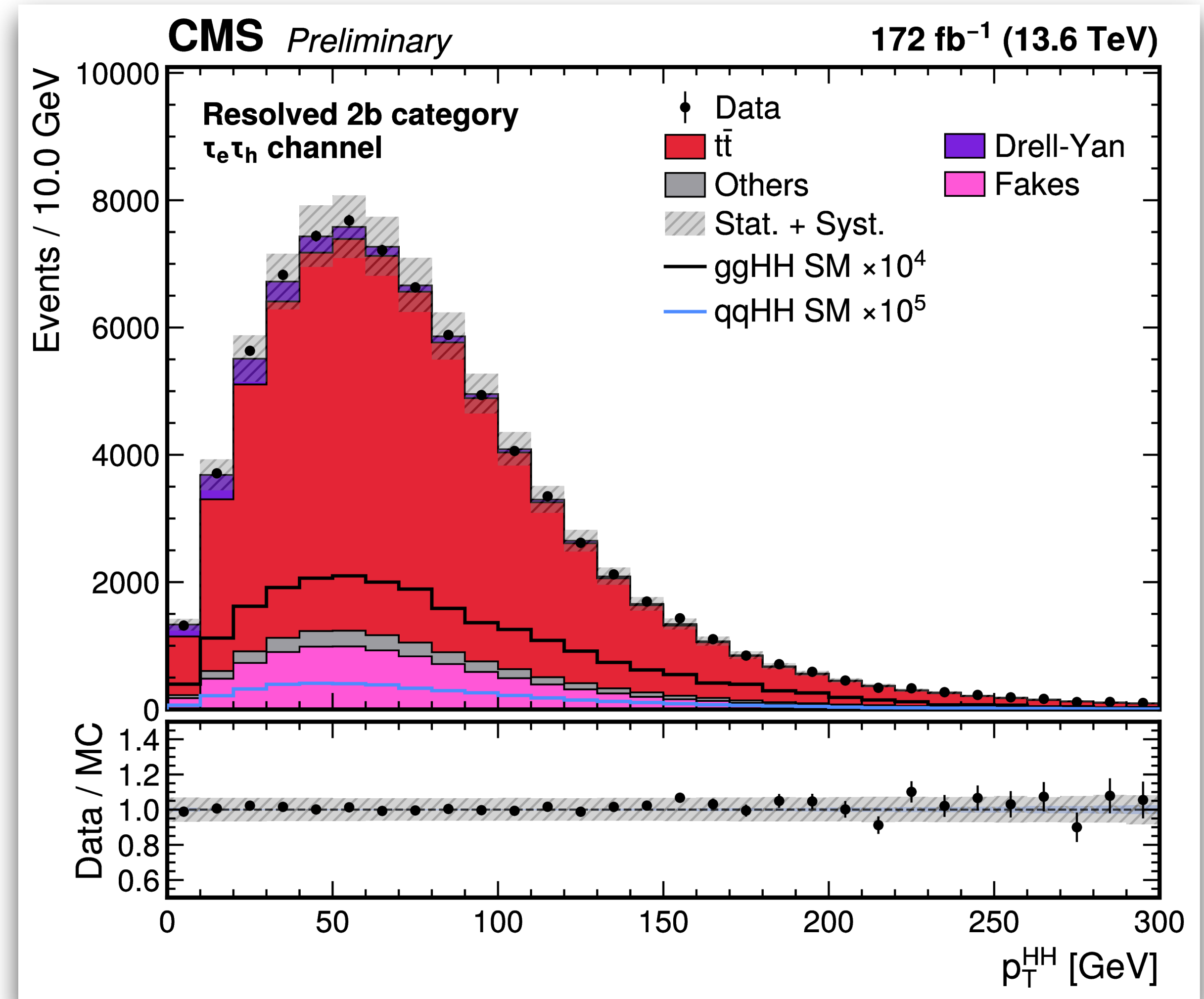
- Sizeable branching fraction (7.3%)
- Excellent balance between yield and purity : $H \rightarrow b\bar{b}$ provides the large branching fraction, while $H \rightarrow \tau\tau$ gives clean experimental signature
- Targets all possible decay modes of τ leptons ($e\tau_h, \mu\tau_h, \tau_h\tau_h$)
- Several improvements over the Run 2 analyses:
 - Improved online (HLT) and offline τ identification
 - More inclusive HLT paths, enhancing signal acceptance
 - Inclusion of merged event topologies, accessing merged $\tau_h\tau_h$
 - Improved τ_h momentum assignment with a DNN regression



Main background contributions

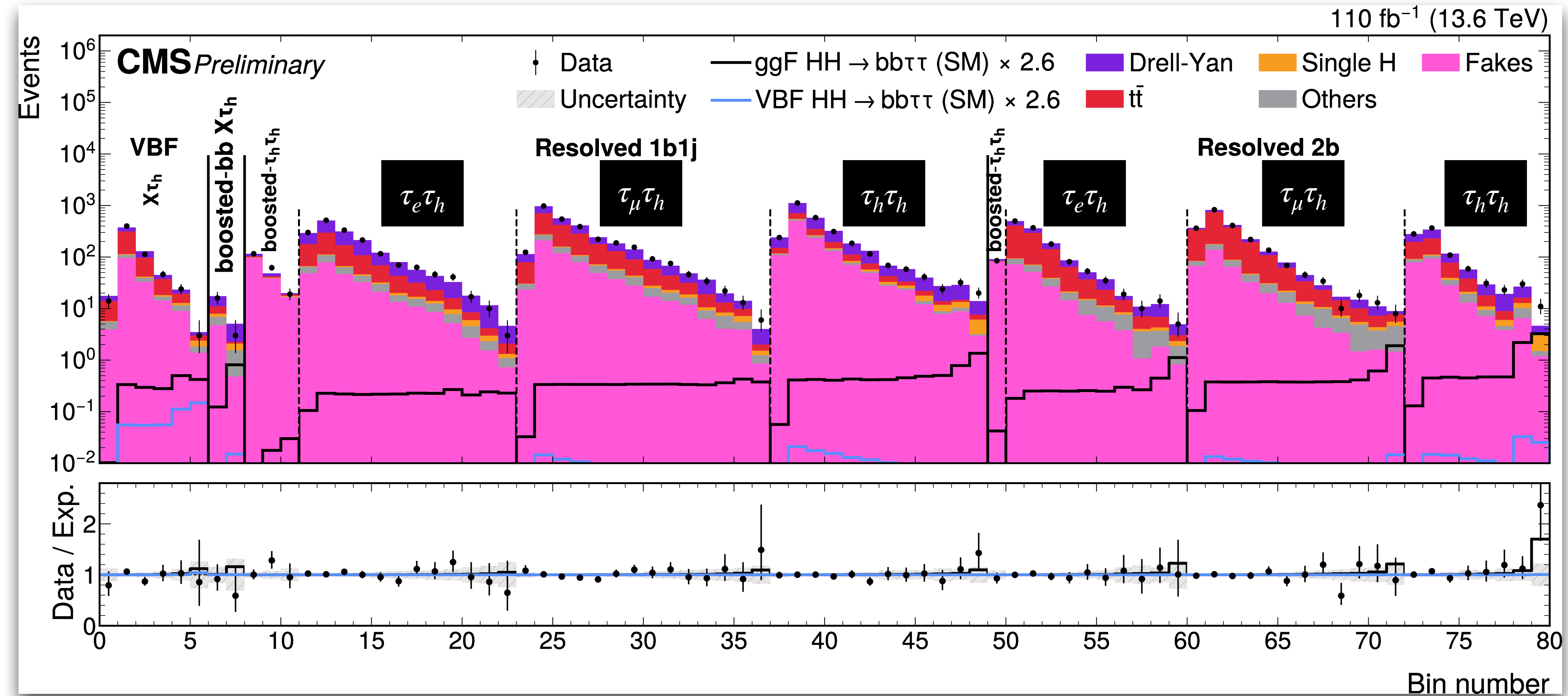
- $t\bar{t}$ and single Higgs backgrounds with genuine τ_h is modelled from simulation
- Irreducible Drell-Yan $Z/\gamma^* \rightarrow \tau\tau$ estimated from simulation and validated in the **Z enriched dedicated control region (CR)**
- Non prompt τ_h background from QCD, W + jets, $t\bar{t}$ derived using *fake factor (FF) methods from dedicated CR*.
- Dedicated DNN, based on **LorentzBoost Network** has been used to separate ggHH & VBFHH signals, from all classes of backgrounds.

Distributions of the reconstructed HH transverse momentum



HH $\rightarrow$ $b\bar{b}\tau\tau$: Post-fit DNN score

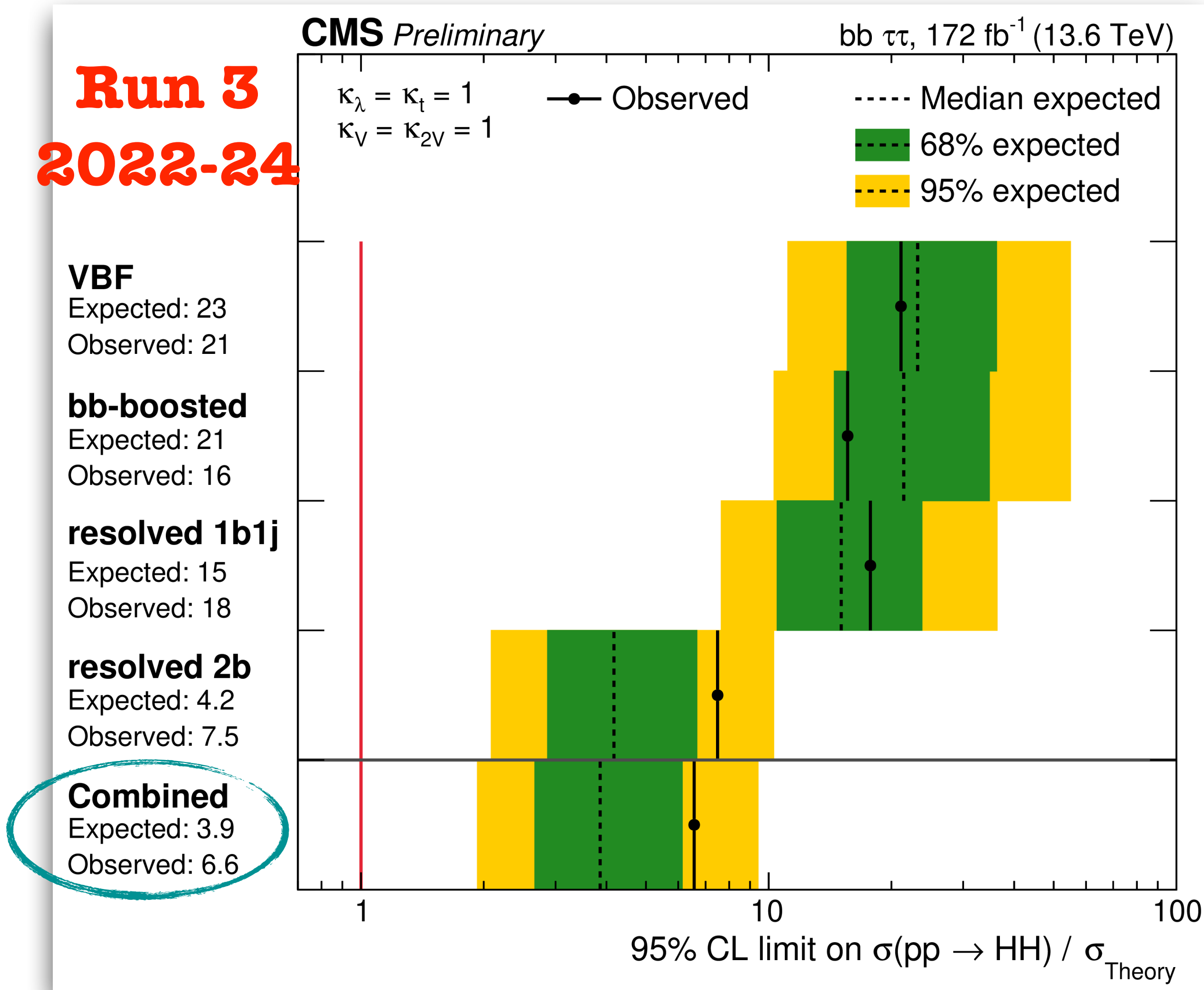
CMS-PAS-HIG-25-008



Binned Likelihood fit has been used to extract the results from the backgrounds.



95% CL UL on the HH signal



The analysis category having two b -tagged jets in the resolved topology drives the maximum sensitivity

Dominant uncertainties are from the fake factor calculation of the τ_h and b -tagging.

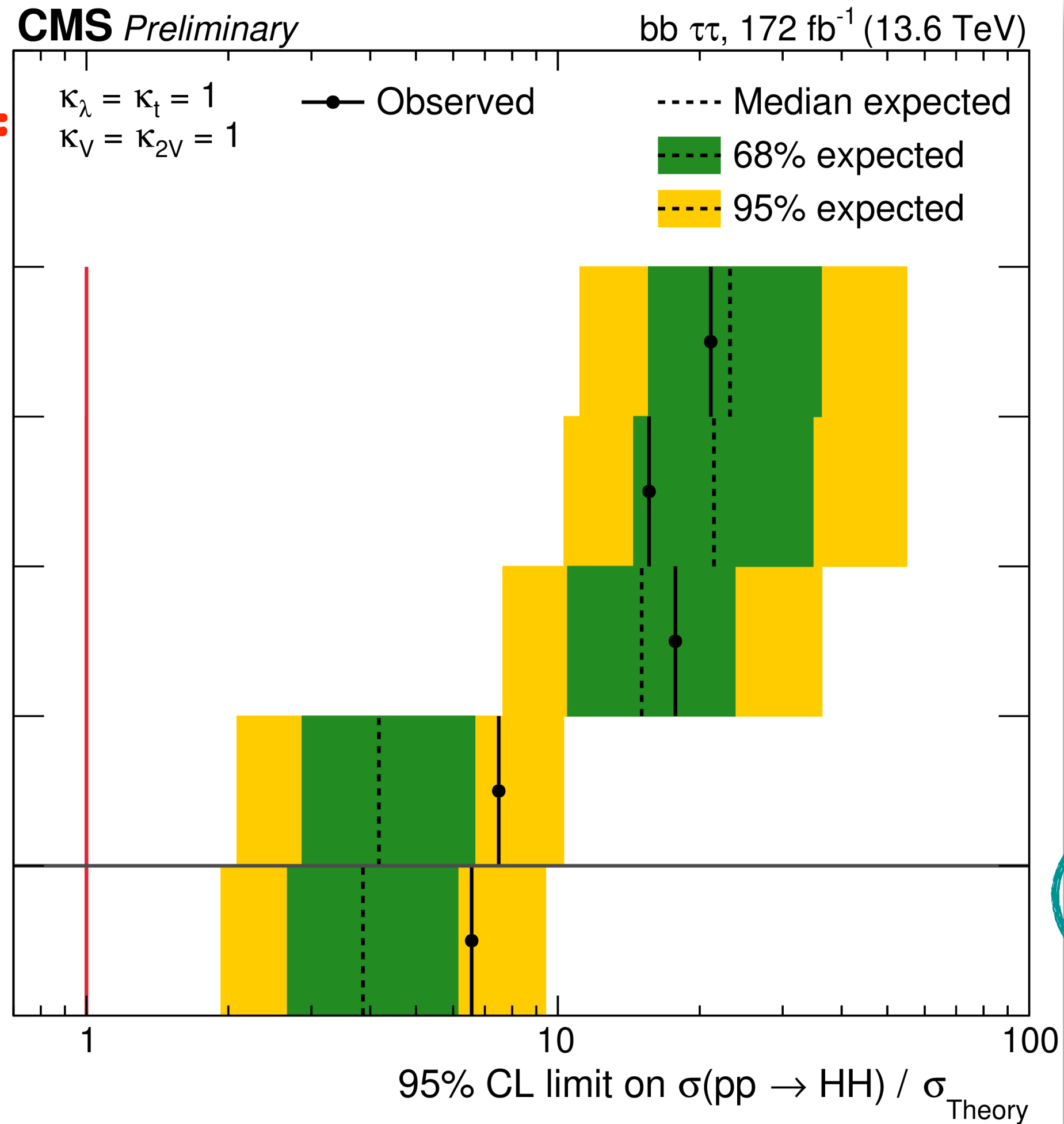
HH $\rightarrow$ $b\bar{b}\tau\tau$: Results combination with Run 2

CMS-PAS-HIG-25-008

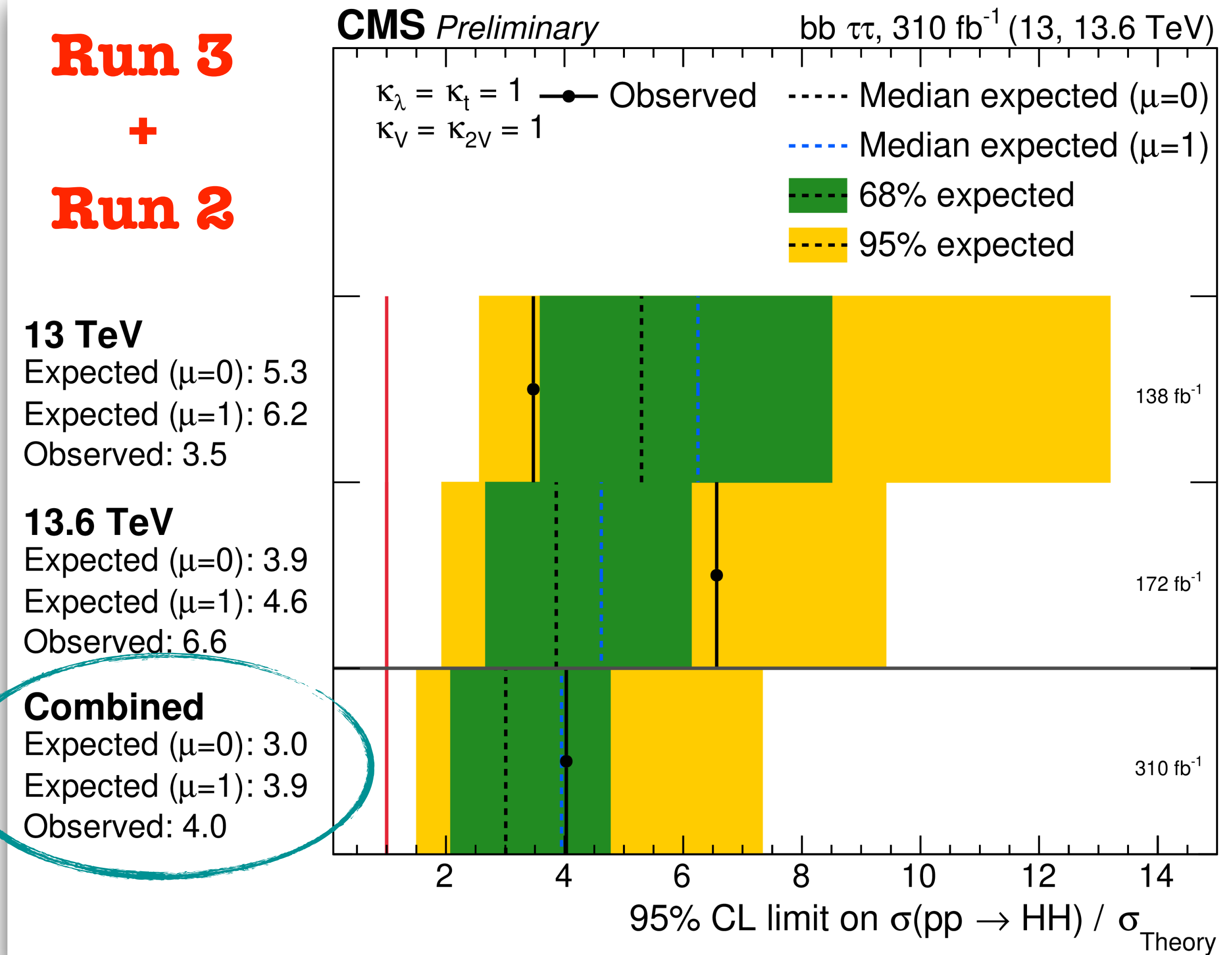


95% CL UL on the HH signal

Run 3
2022-24



Run 3
+
Run 2

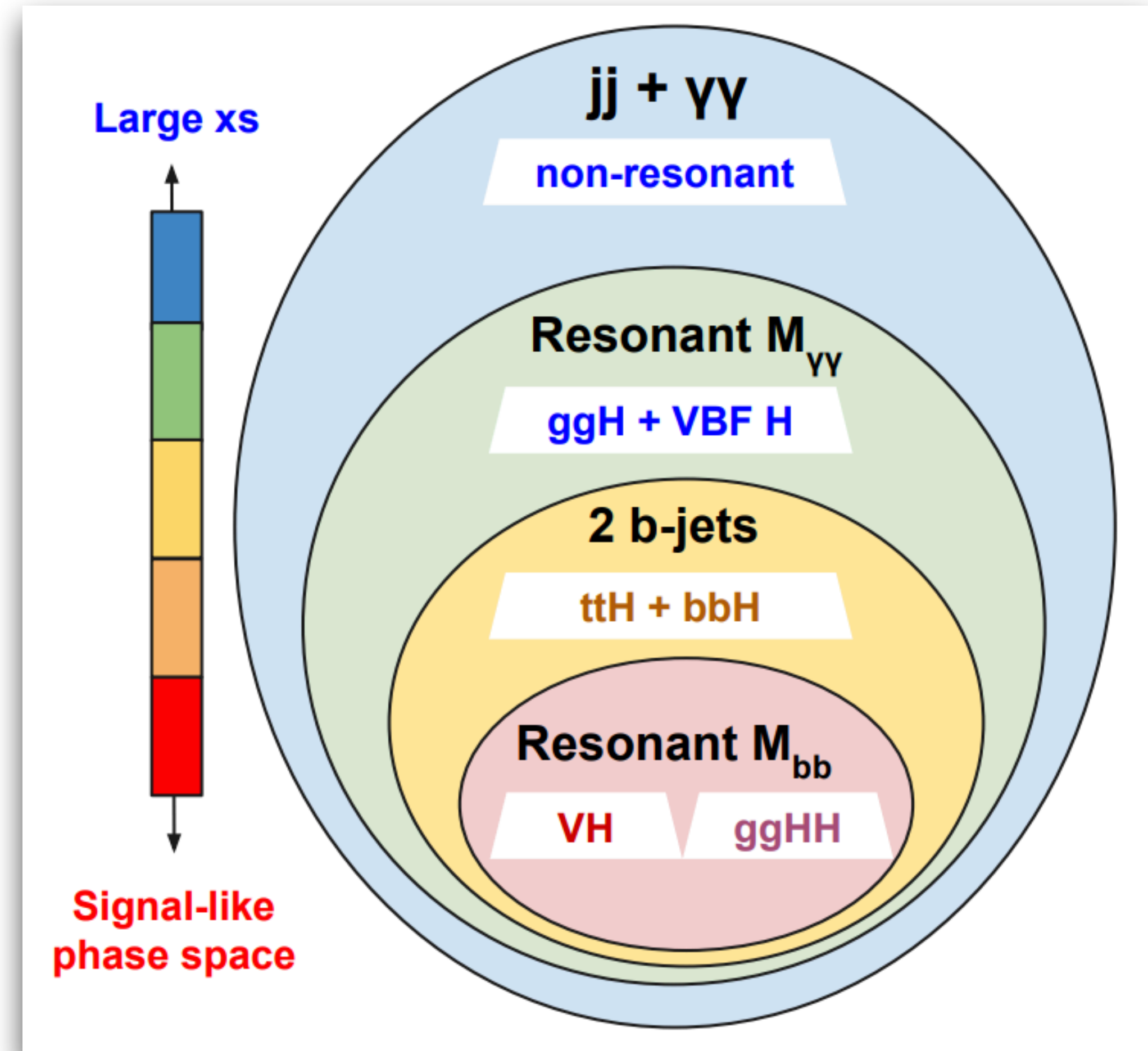


The Run 3 HH $\rightarrow$ $b\bar{b}\tau\tau$ results is almost 20% better compared to the published Run 2 results ([Phys. Lett. B 842 \(2023\) 137531](#))

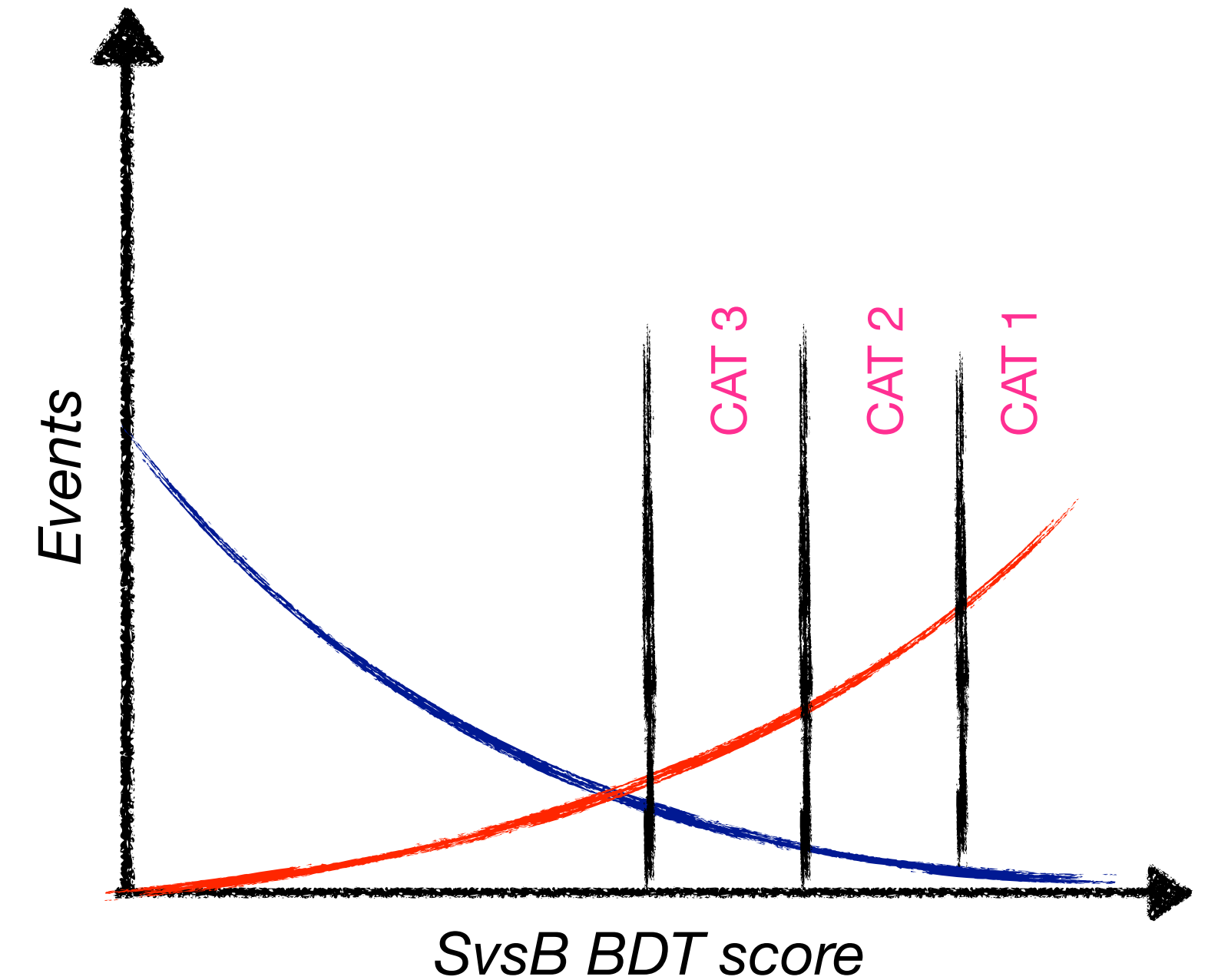
$$HH \rightarrow b\bar{b}\gamma\gamma$$

HH $\rightarrow$ $b\bar{b}\gamma\gamma$: Key features

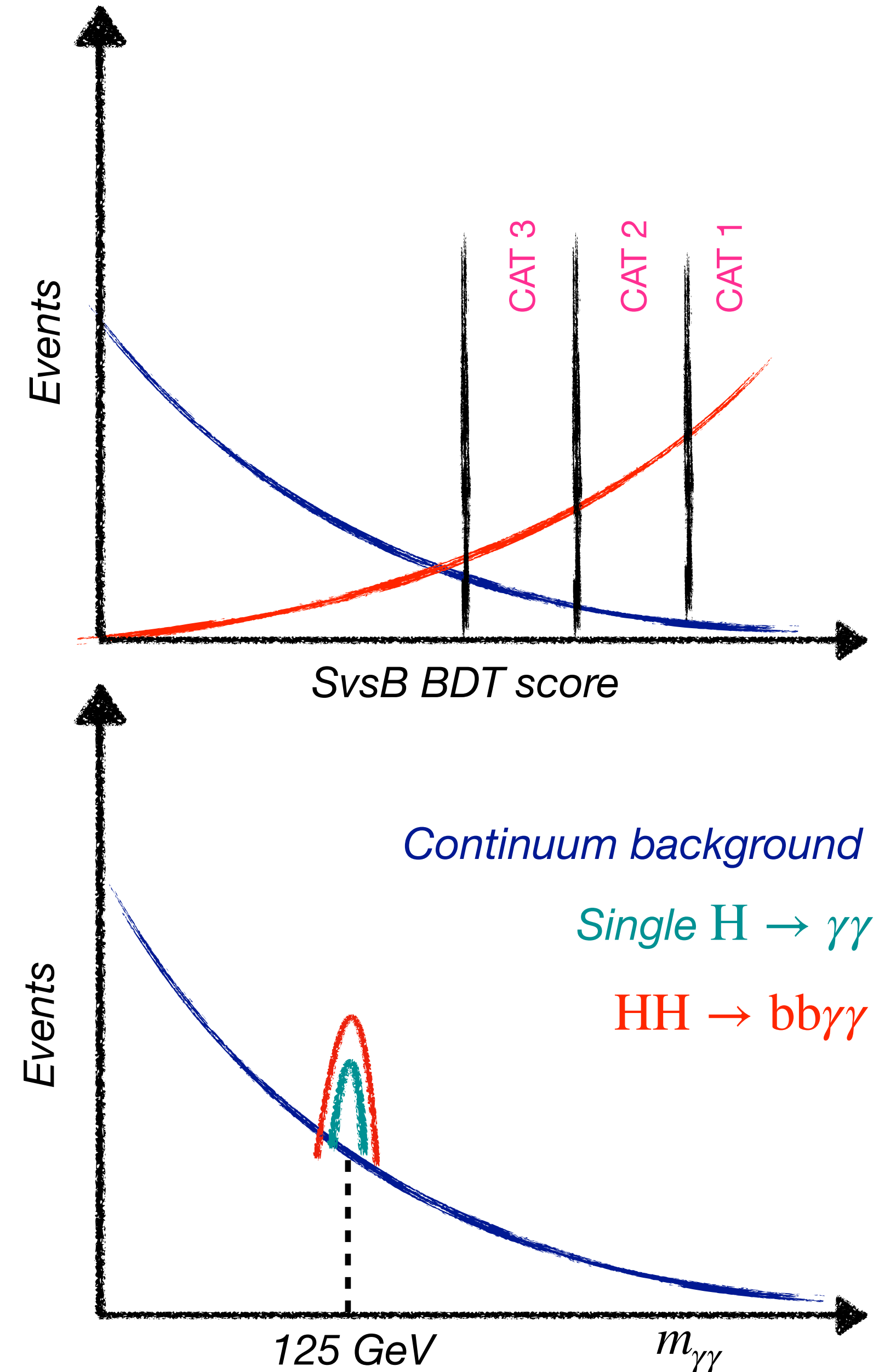
- Comparatively small branching ratio of HH $\rightarrow$ $b\bar{b}\gamma\gamma$ (only 0.3%)
- Despite being small branching ratio, very high mass resolution ($m_{\gamma\gamma}$) 1-2% from the $H \rightarrow \gamma\gamma$ decay
- Easy to distinguish signal over falling continuum background distribution
- Contributing backgrounds can be classified into three classes
 - Non resonant QCD, $\gamma(\gamma)$ + jets**
 - Single Higgs boson ($H \rightarrow \gamma\gamma$) processes ggH , $VBFH$, ttH (providing true b-jets)**
 - $V(bb)H(\gamma\gamma)$ also providing m_{bb} resonance**



- Multiclass **multivariate analysis (MVA) technique** has been used to separated $HH \rightarrow b\bar{b}\gamma\gamma$ signal (SvsB BDT score) simultaneously from all possible background classes.
- MVA is uncorrelated with the $m_{\gamma\gamma}$ distribution, used for the final signal extraction.
- The sensitivity of the analysis is further enhanced by *categorising the events based on the MVA scores*



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- MVA is uncorrelated with the $m_{\gamma\gamma}$ distribution, used for the final signal extraction.
- The sensitivity of the analysis is further enhanced by *categorising the events based on the MVA scores*
- **In each analysis categories:**
 - Continuum background is estimated by fitting the sidebands of the mass distribution ($m_{\gamma\gamma}$) with polynomial functions.
 - Single Higgs ($H \rightarrow \gamma\gamma$) and **HH signals** are modelled from simulation using by double sided crystal ball (DSCB) and a multi gaussian and fit.



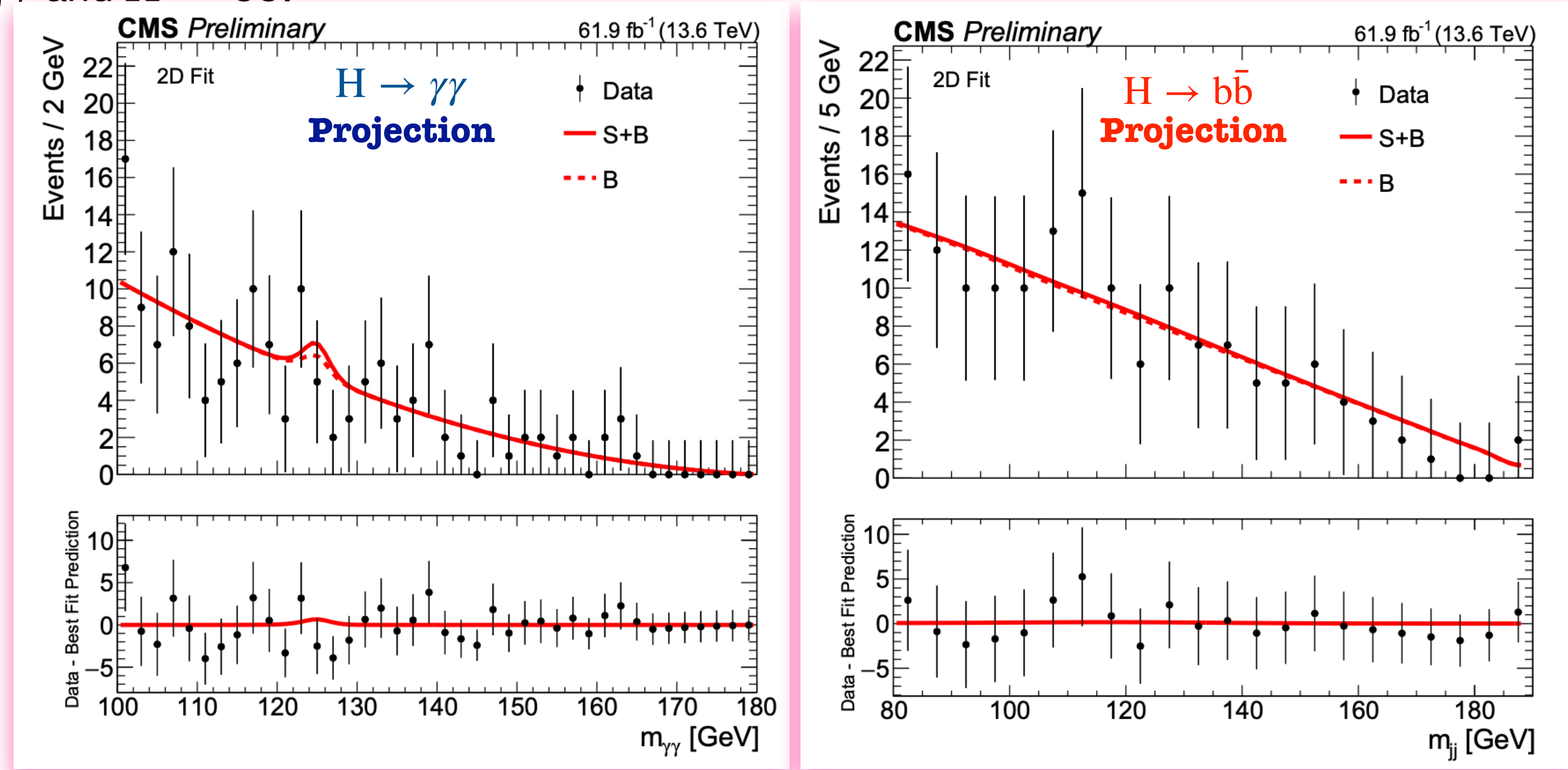
$HH \rightarrow b\bar{b}\gamma\gamma$: 2D Fit analysis approach

CMS-PAS-HIG-25-007



Results are extracted in two ways (a) 1D Fit of $m_{\gamma\gamma}$ and (b) 2D Fit of $m_{\gamma\gamma}$ and $m_{b\bar{b}}$.

2D Fit approach: Simultaneous fit of $m_{\gamma\gamma}$ and $m_{b\bar{b}}$ distribution, assuming minimal correlation between $H \rightarrow \gamma\gamma$ and $H \rightarrow b\bar{b}$.



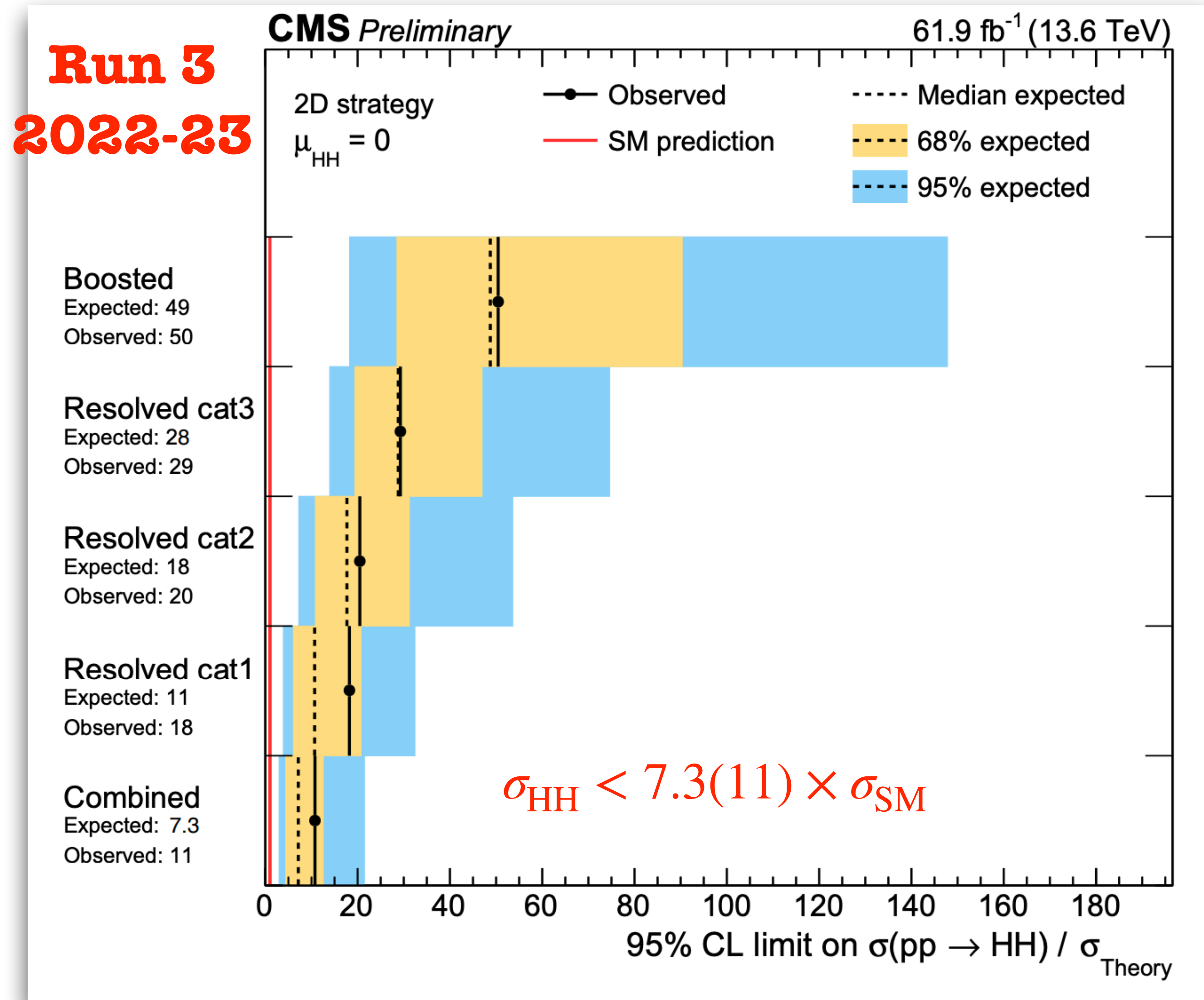
Analysis has also been performed in 1D Fit as well by fitting only $H \rightarrow \gamma\gamma$, consistent results.

HH $\rightarrow b\bar{b}\gamma\gamma$: Results from Run 3 (2022 and 2023)

CMS-PAS-HIG-25-007

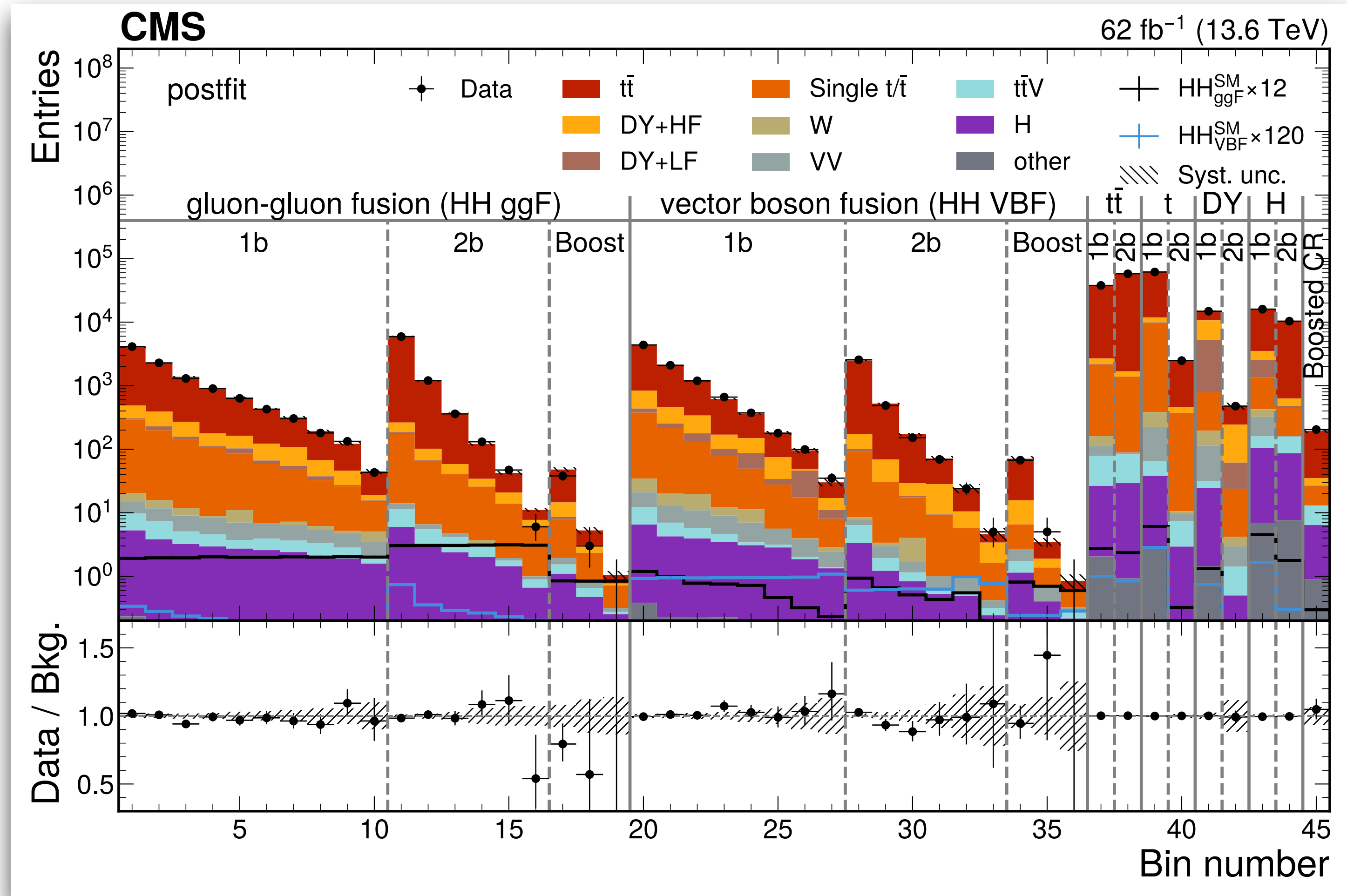


95% CL UL on the HH signal



- The improvement of about 5-7% at equivalent luminosity compared with the Run 2 results

- Events with exactly two leptons from both W decays are considered (e^+e^- , $\mu^+\mu^-$, $e^\pm\mu^\mp$)
- Each events are assigned to ggHH, qqHH or background dominated classes ($t\bar{t}$, single-top, DY, single Higgs) based on a multi-class DNN score.

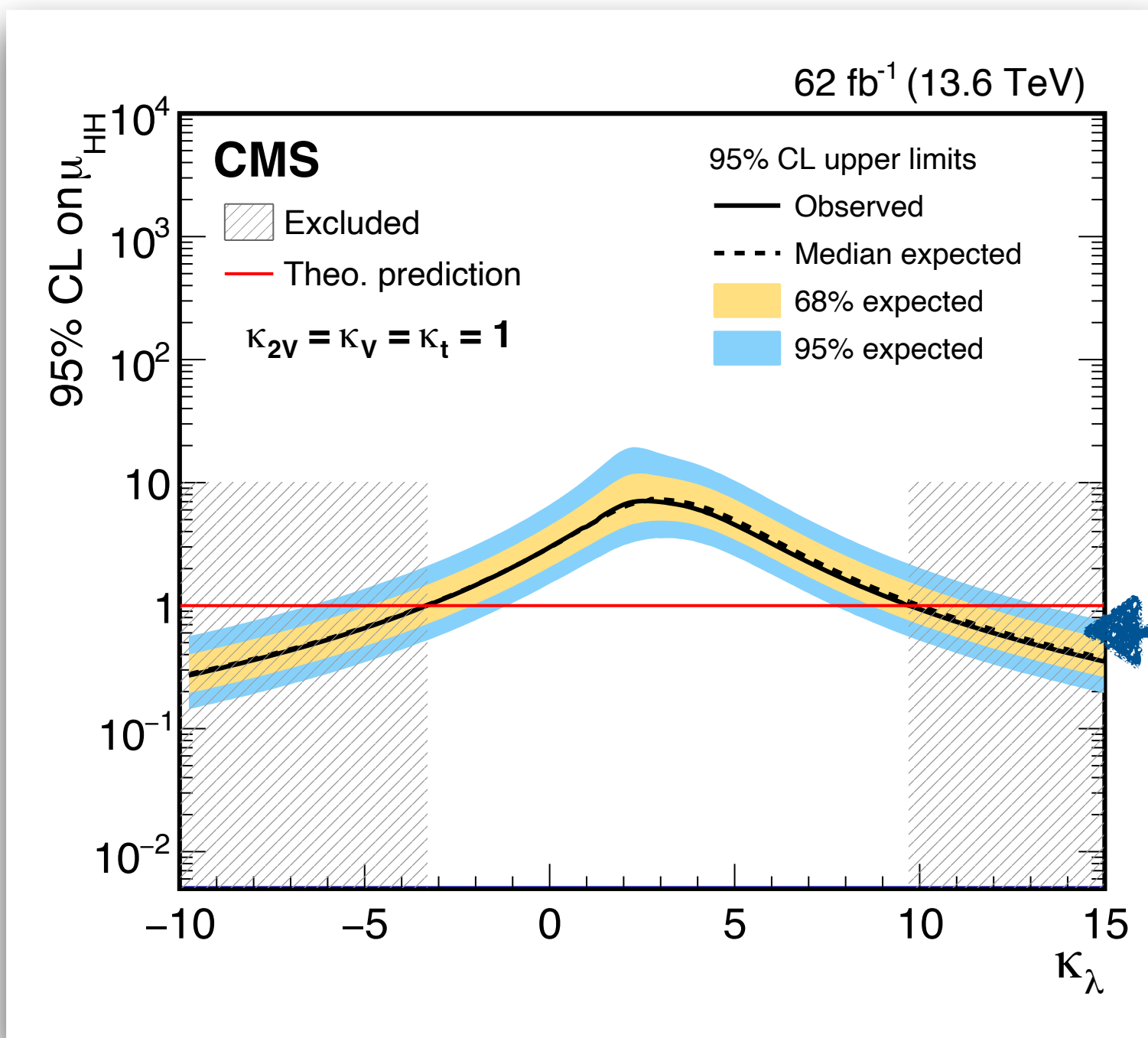


95% CL Upper limit on $\sigma_{HH} < 12.0(18.5) \times \sigma_{SM}$

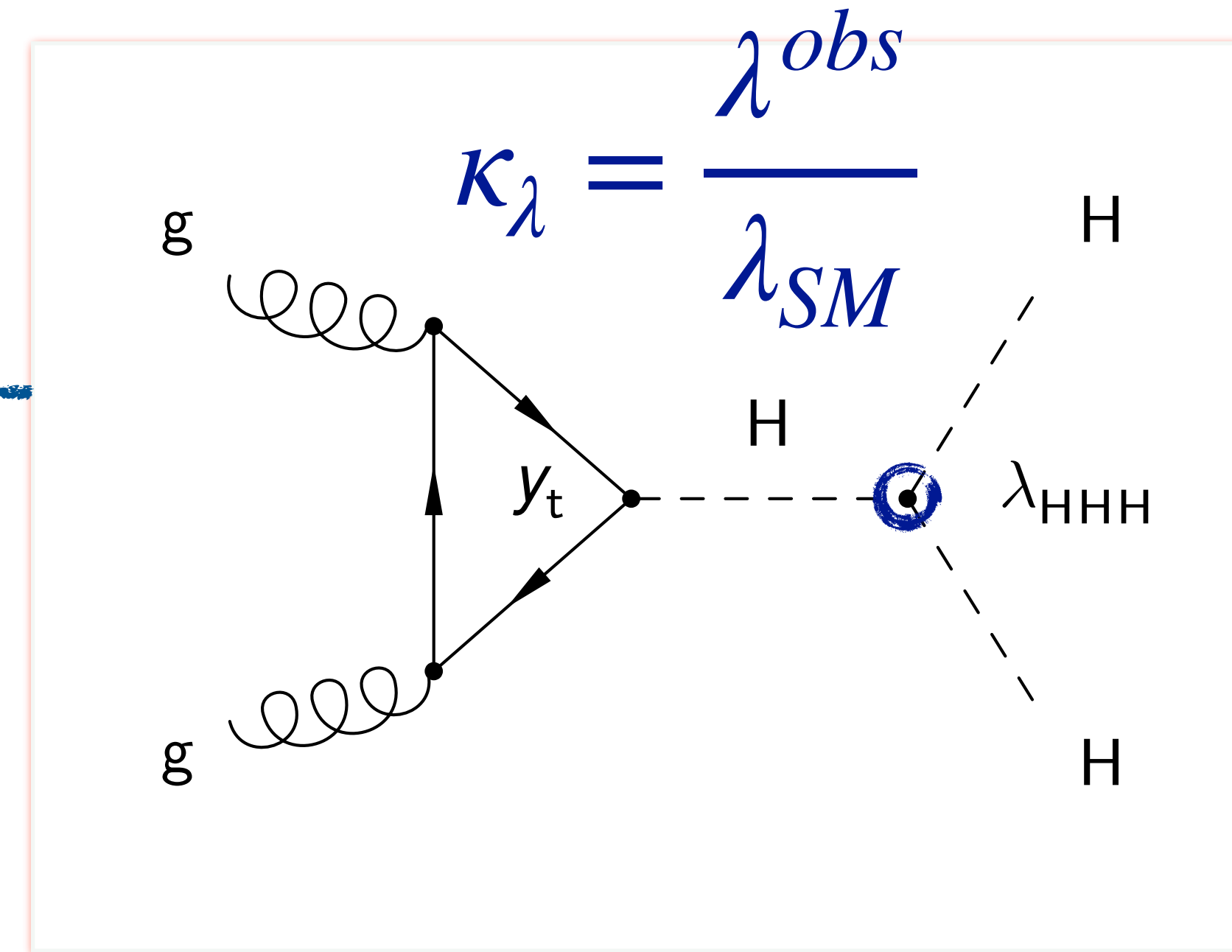
Combination of Run 3 results with Run2
HH $\rightarrow$ $b\bar{b}WW$ with at least one leptons :
 $\sigma_{HH} < 7.9(12.7) \times \sigma_{SM}$

Summary : Constrains on κ_λ from early Run 3 analyses

HH $\rightarrow$ 4b



The constraints has been measured as a function of **signal strength** ($\mu=1$)



Observed : $\kappa_\lambda \in [-3.3, 9.7]$

Expected : $\kappa_\lambda \in [-3.4, 10.0]$

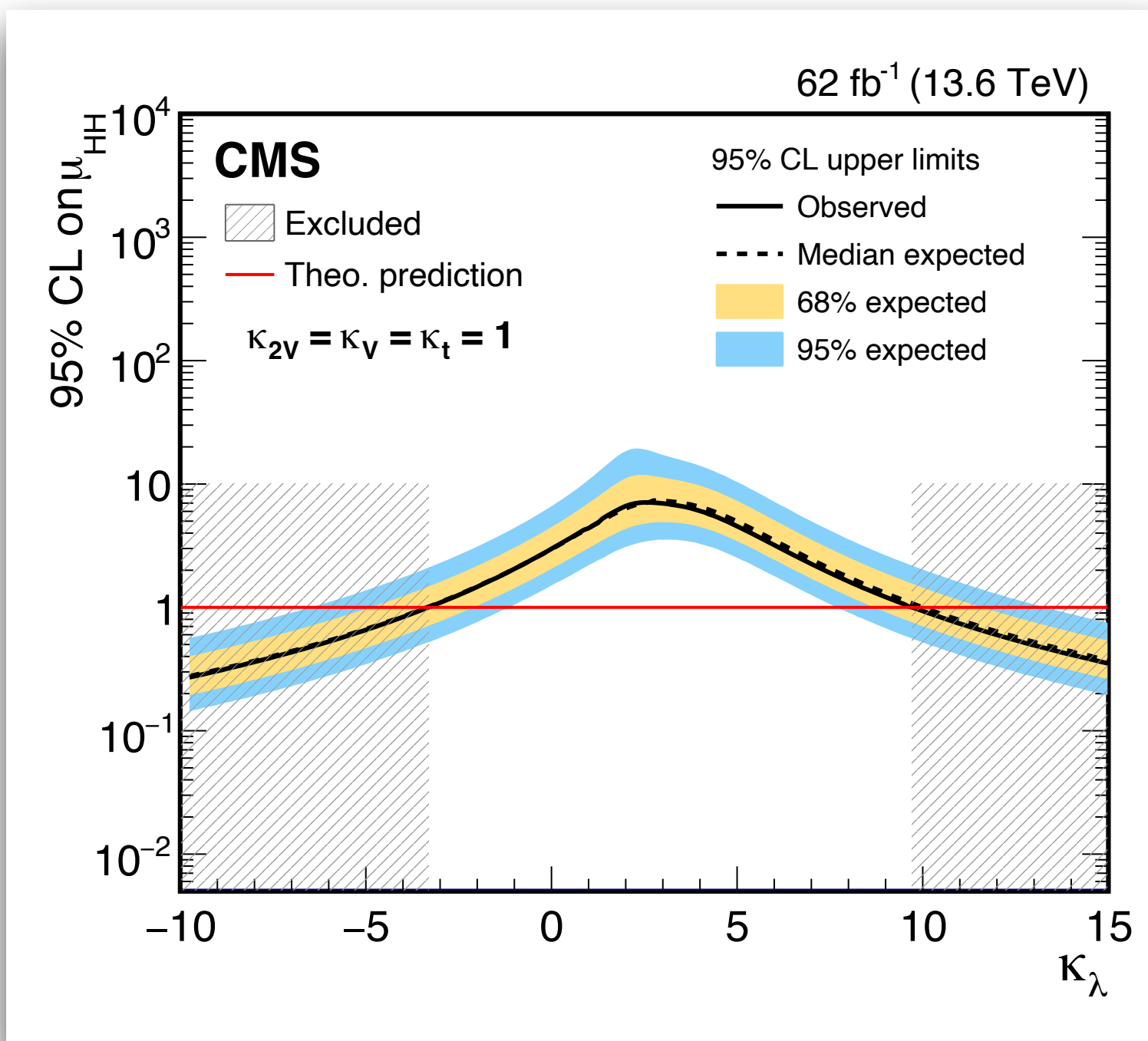
Summary : Constrains on κ_λ from early Run 3 analyses

HH $\rightarrow$ 4b

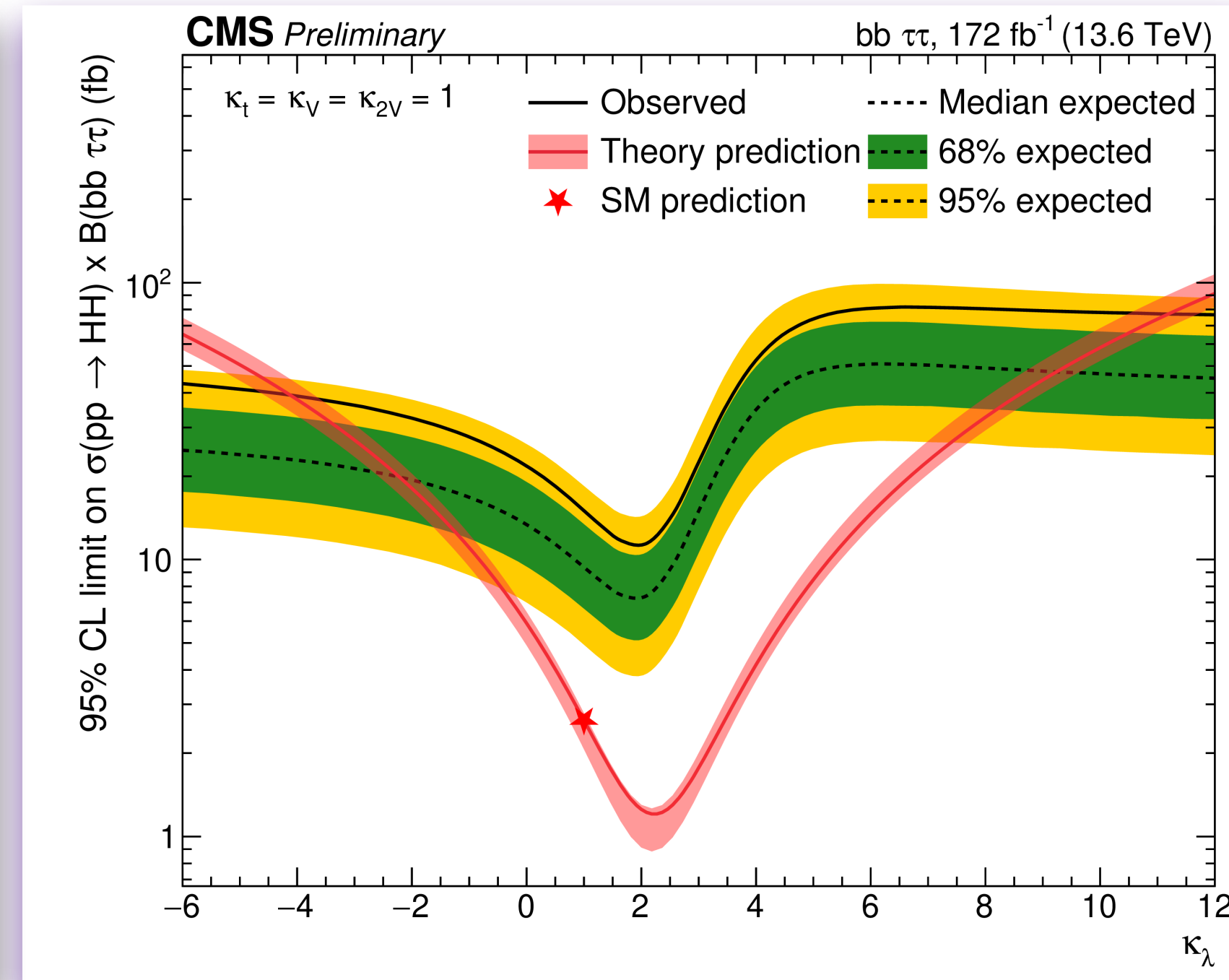
HH $\rightarrow$ 2b2 τ

HH $\rightarrow$ 2b2 γ

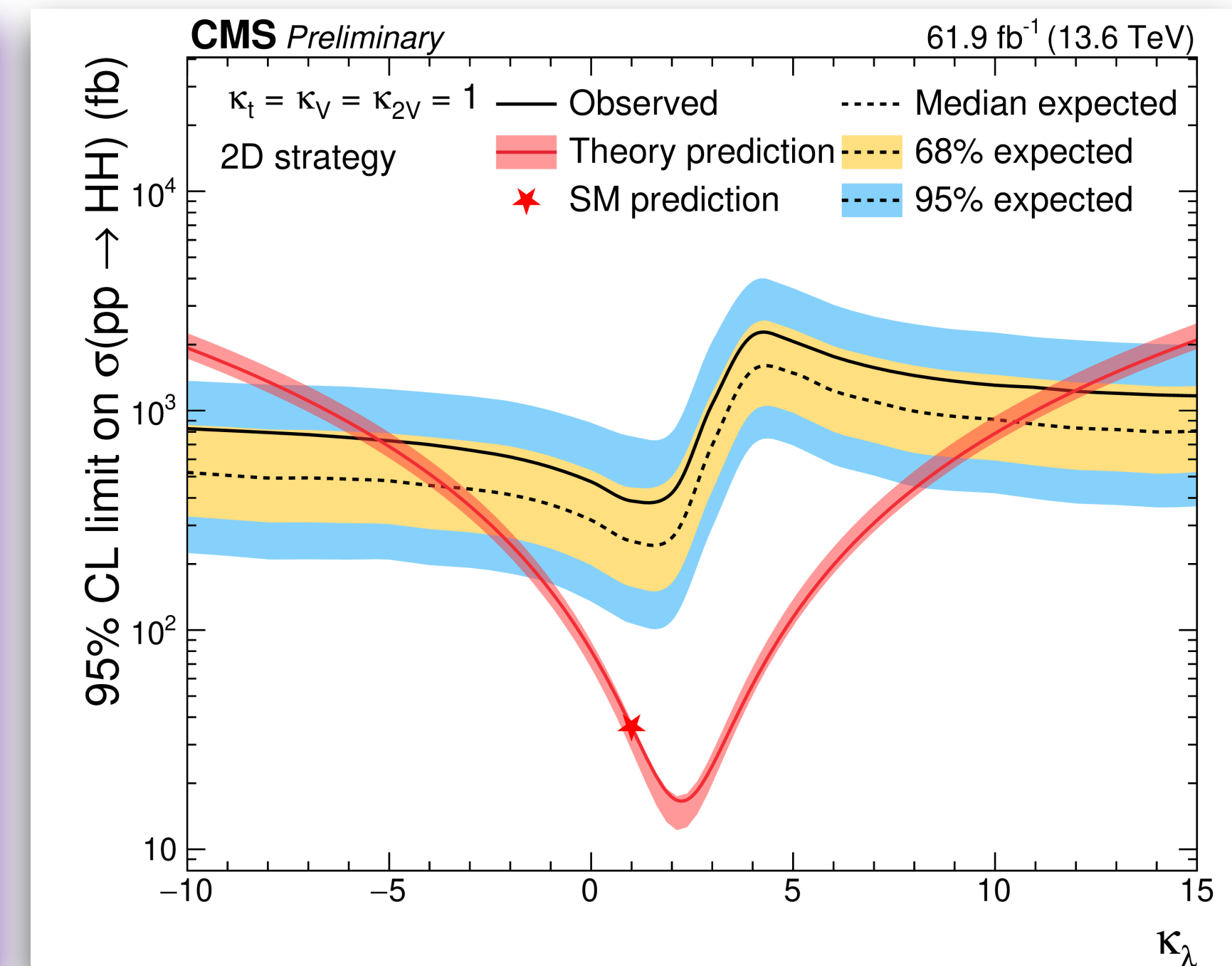
The constraints has been measured as a function of cross section



Observed : $\kappa_\lambda \in [-3.3, 9.7]$
Expected : $\kappa_\lambda \in [-3.4, 10.0]$



Observed : $\kappa_\lambda \in [-4.1, 11.2]$
Expected : $\kappa_\lambda \in [-2.2, 9.2]$



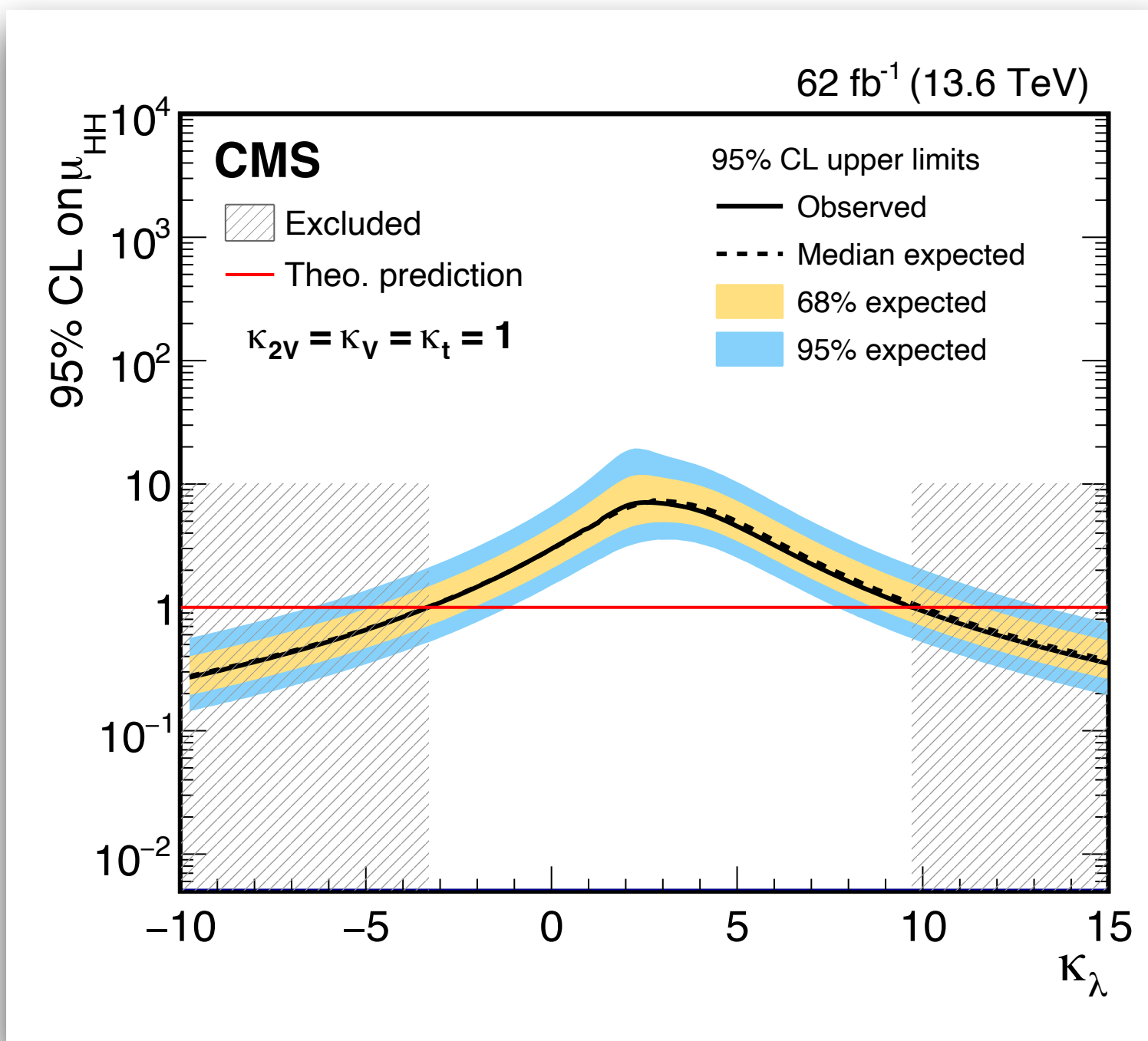
Observed : $\kappa_\lambda \in [-6.1, 12.8]$
Expected : $\kappa_\lambda \in [-3.6, 10.5]$

Summary : Constrains on κ_λ from early Run 3 analyses

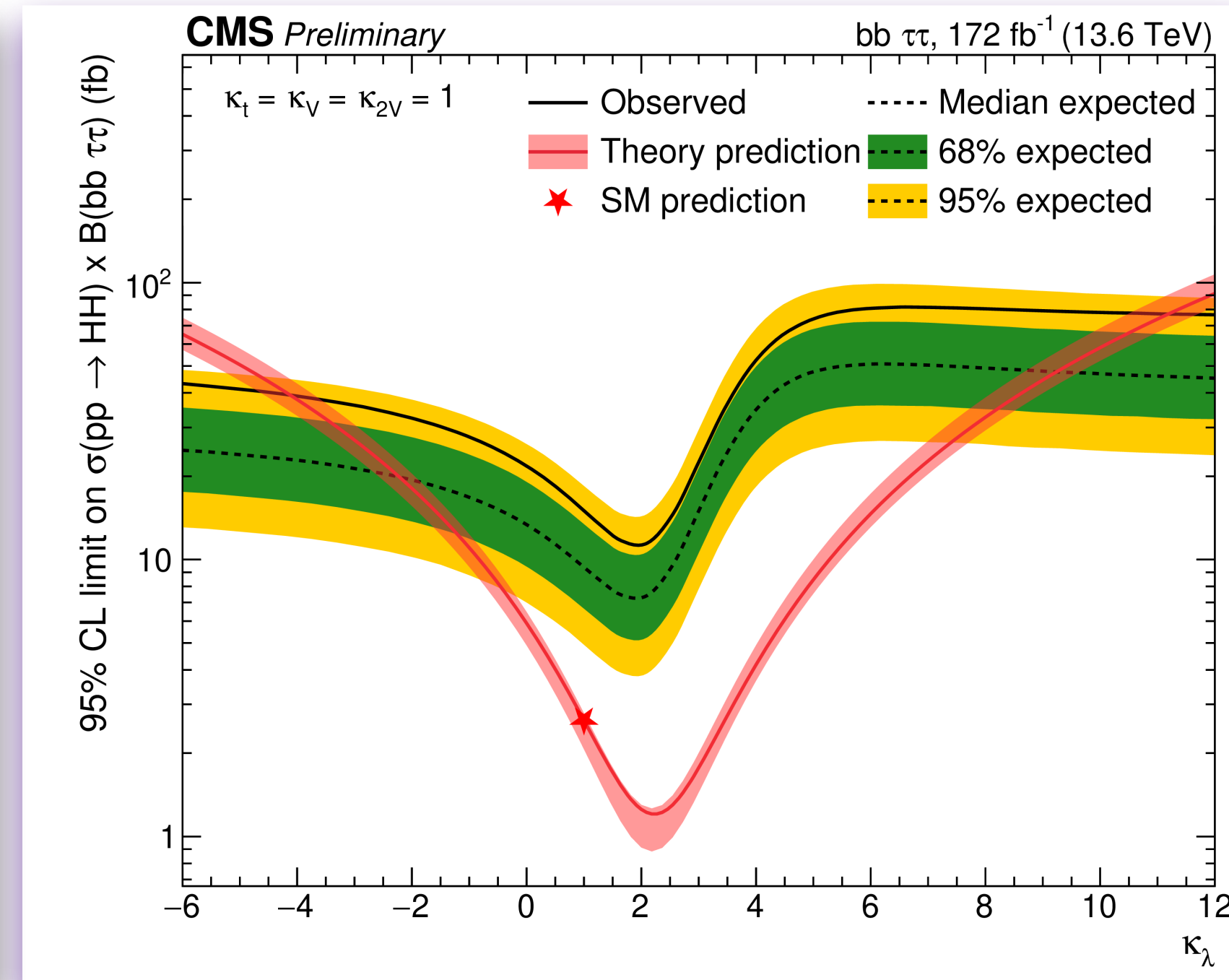
$HH \rightarrow 4b$

$HH \rightarrow 2b2\tau$

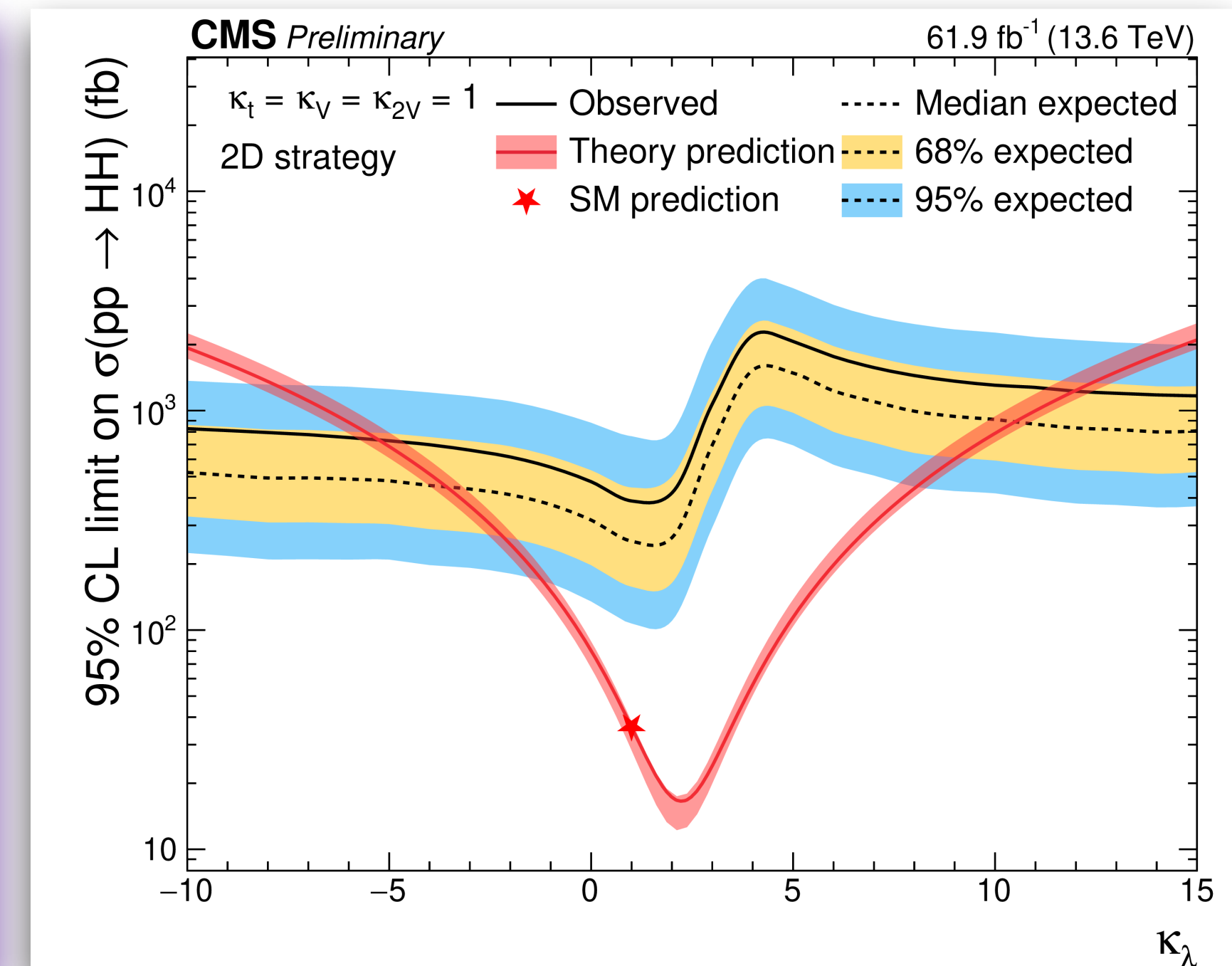
$HH \rightarrow 2b2\gamma$



Observed : $\kappa_\lambda \in [-3.3, 9.7]$
Expected : $\kappa_\lambda \in [-3.4, 10.0]$



Observed : $\kappa_\lambda \in [-4.1, 11.2]$
Expected : $\kappa_\lambda \in [-2.2, 9.2]$



Observed : $\kappa_\lambda \in [-6.1, 12.8]$
Expected : $\kappa_\lambda \in [-3.6, 10.5]$

- Very promising results from the CMS with early Run 3 results, significant improvement over Run2
- Full Run3 analysis is in progress, *please stay tuned*.

Thank you – happy to discuss!

Additional Materials

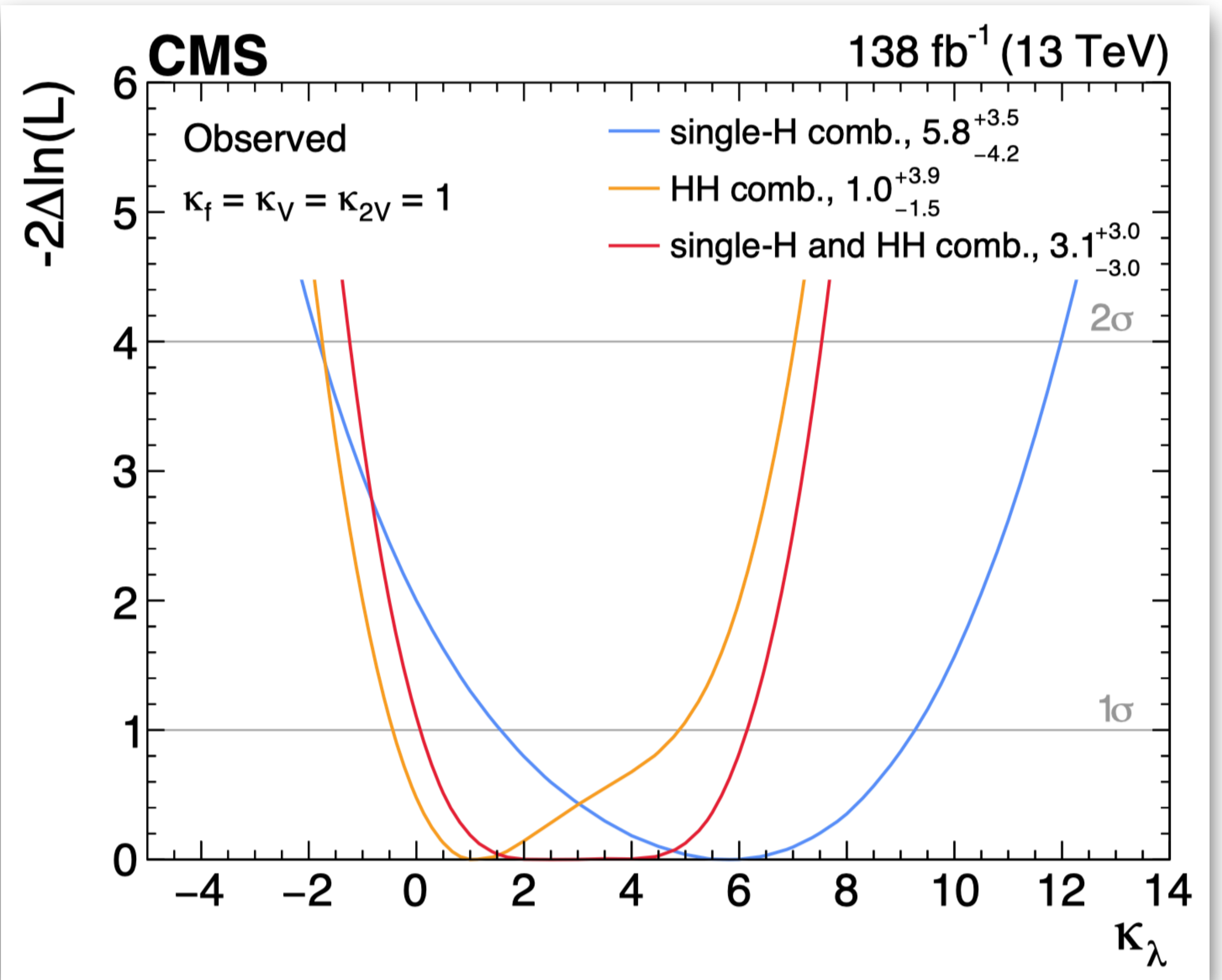
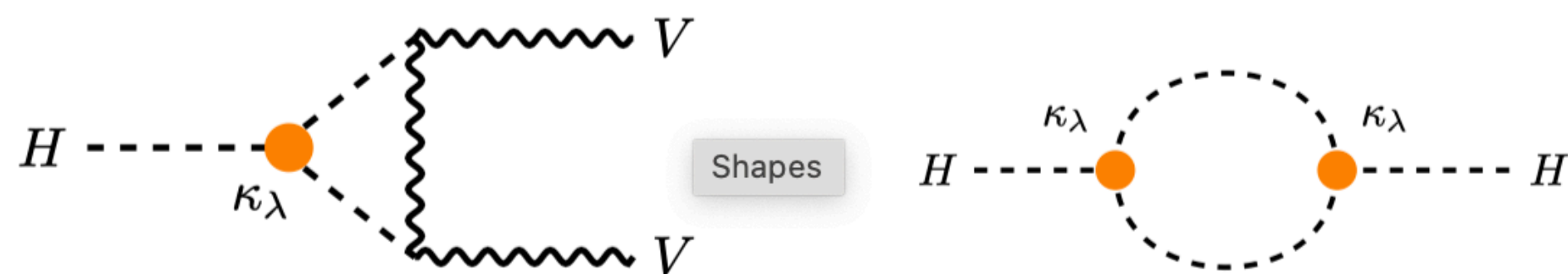
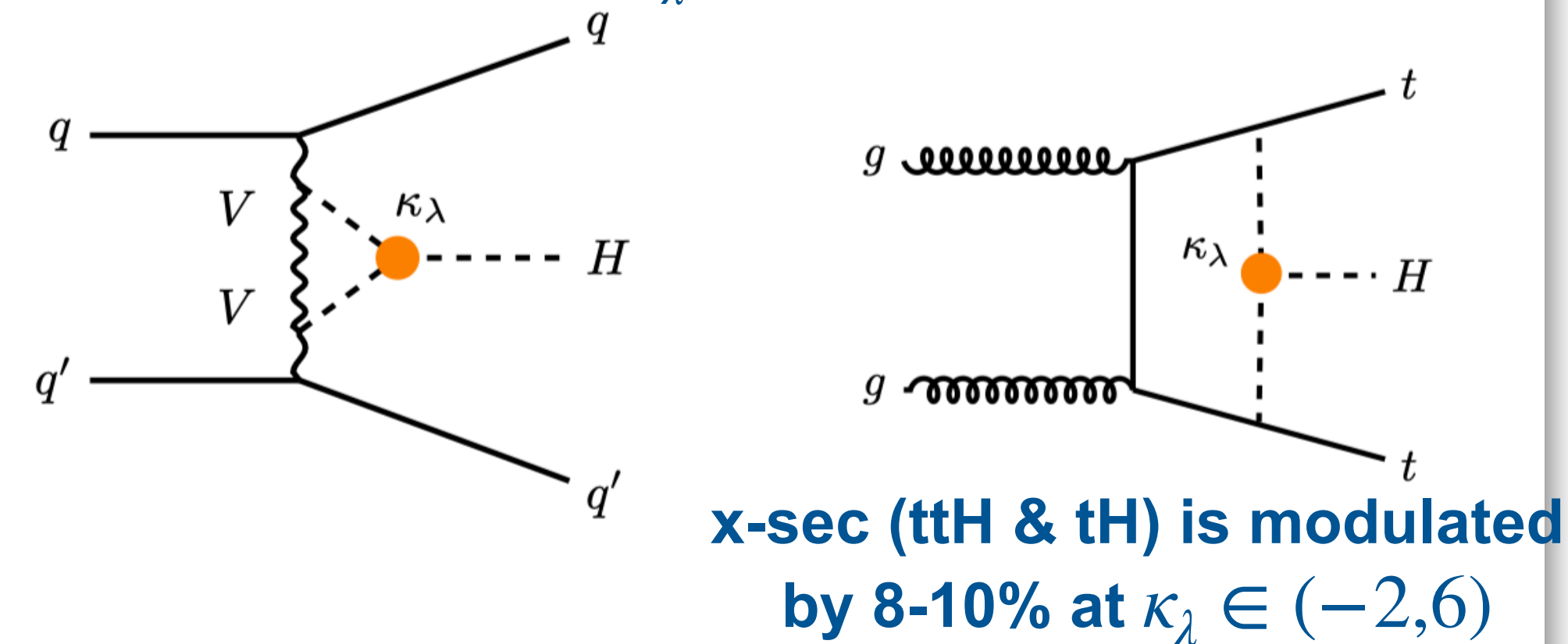
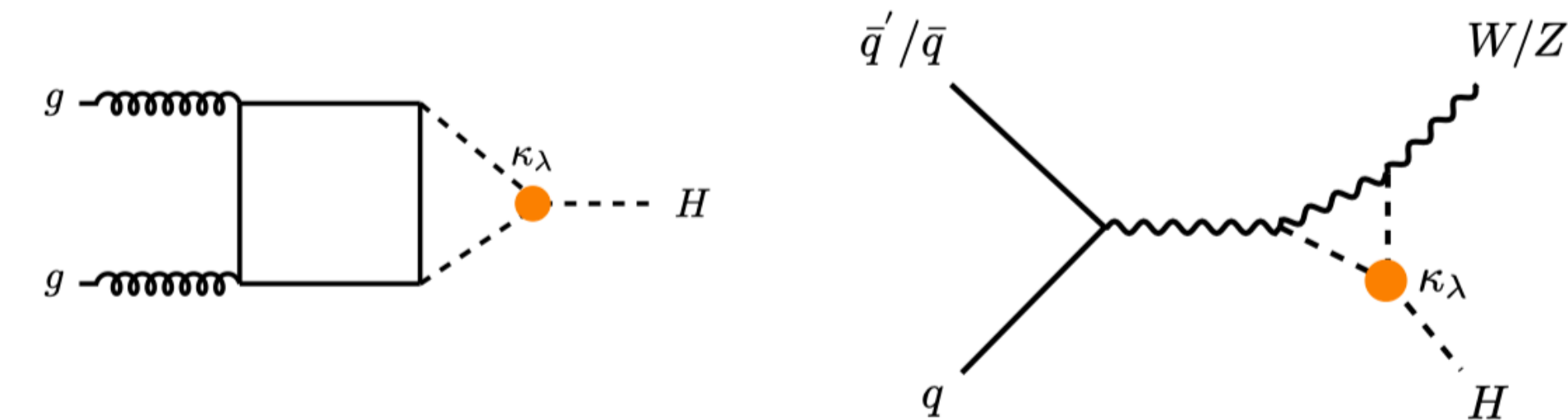
Extra materials: Run 2 combination results

κ_λ constrains from the Single Higgs Boson production

κ_λ appears in the Single Higgs at NLO EWK

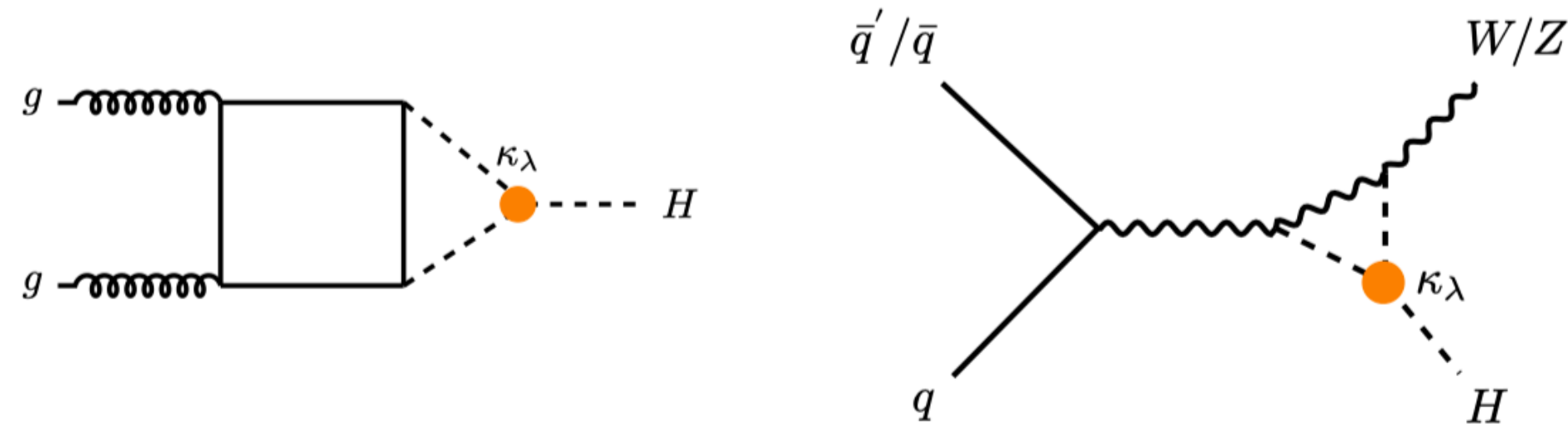
Sensitivity is mostly driven by HH

x-sec (ggH & VBFH) is modulated by 2-3% at $\kappa_\lambda \in (-2,6)$

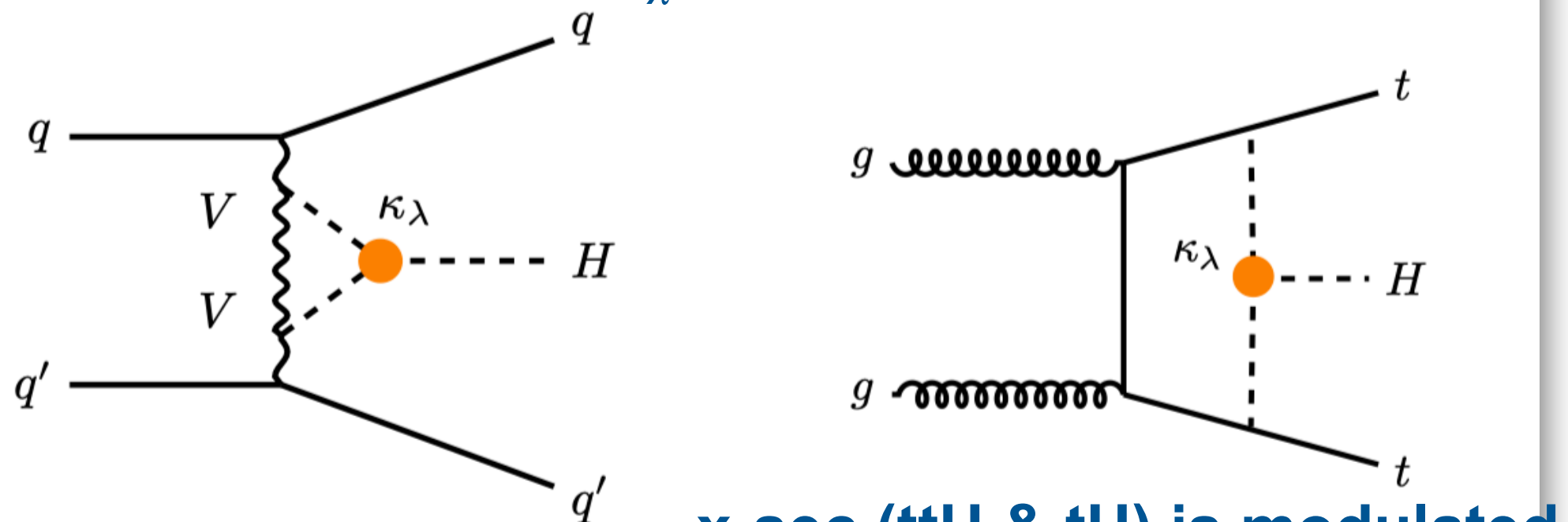


κ_λ constrains from the Single Higgs Boson production

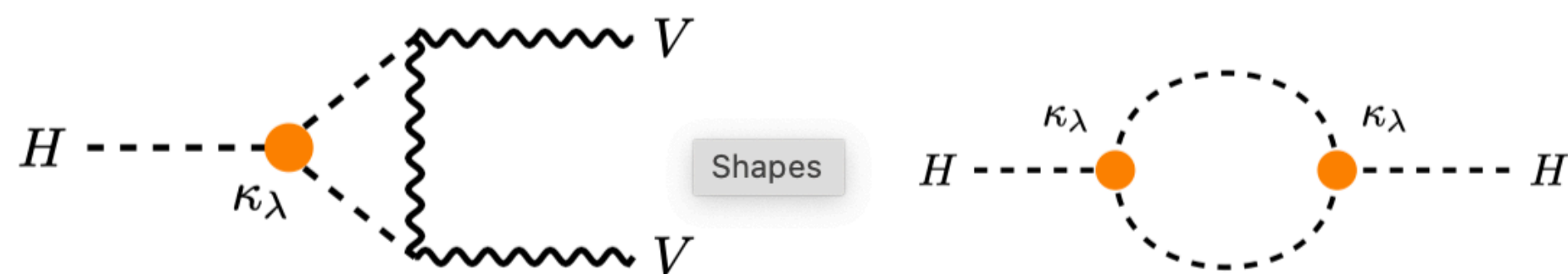
κ_λ appears in the Single Higgs at NLO EWK



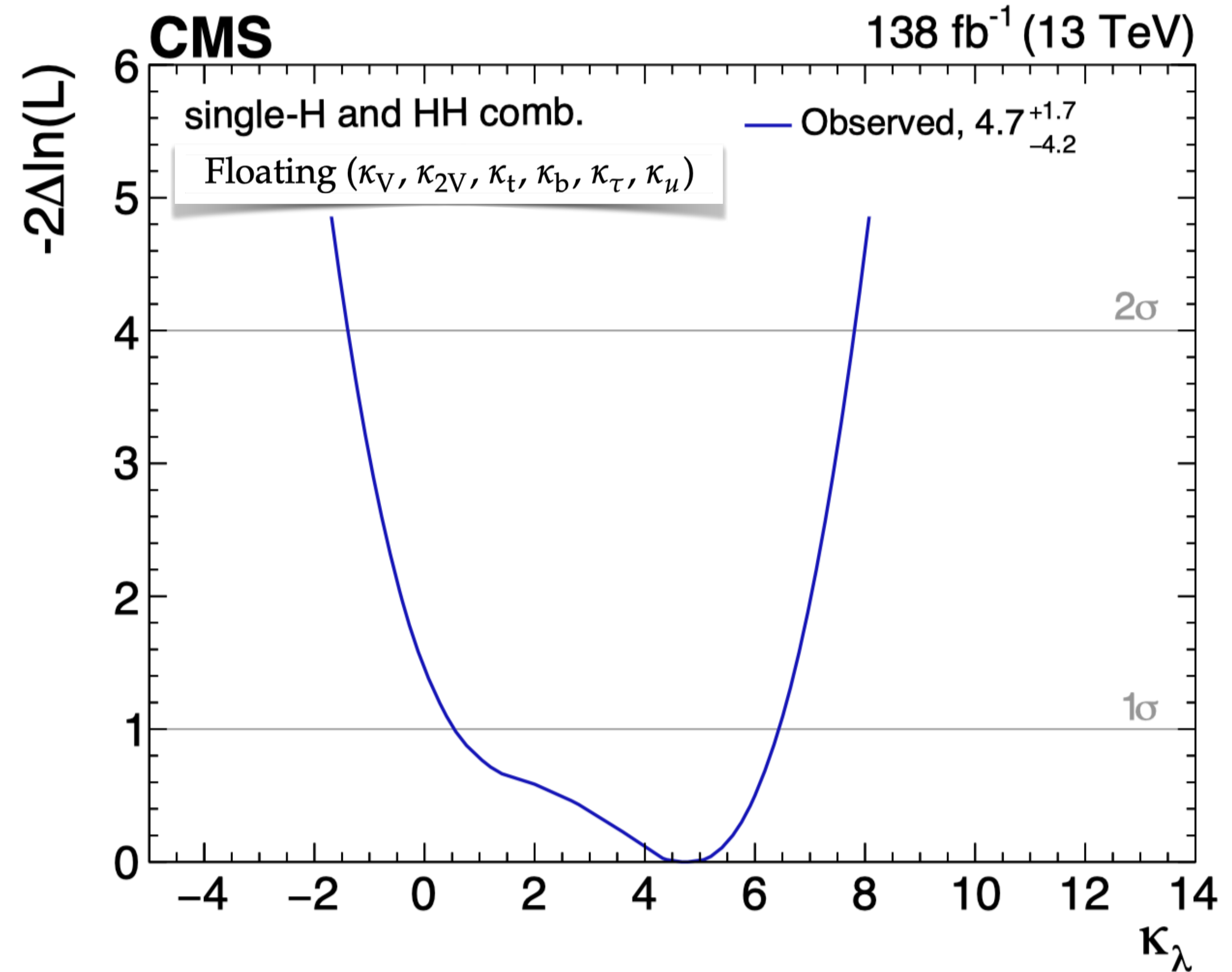
x-sec (ggH & VBFH) is modulated by 2-3% at $\kappa_\lambda \in (-2, 6)$



x-sec (ttH & tH) is modulated by 8-10% at $\kappa_\lambda \in (-2, 6)$

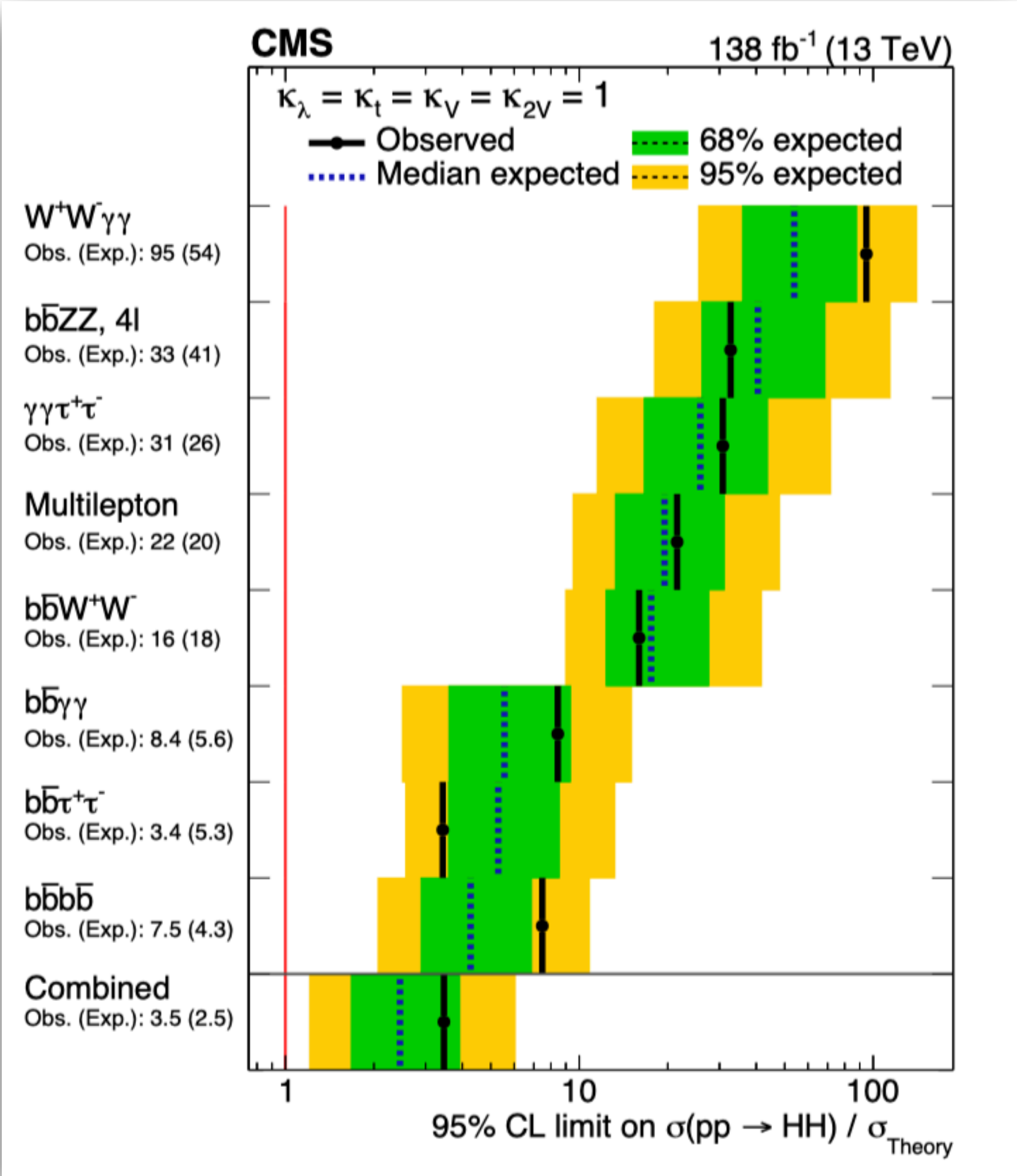


Sensitivity is mostly driven by HH

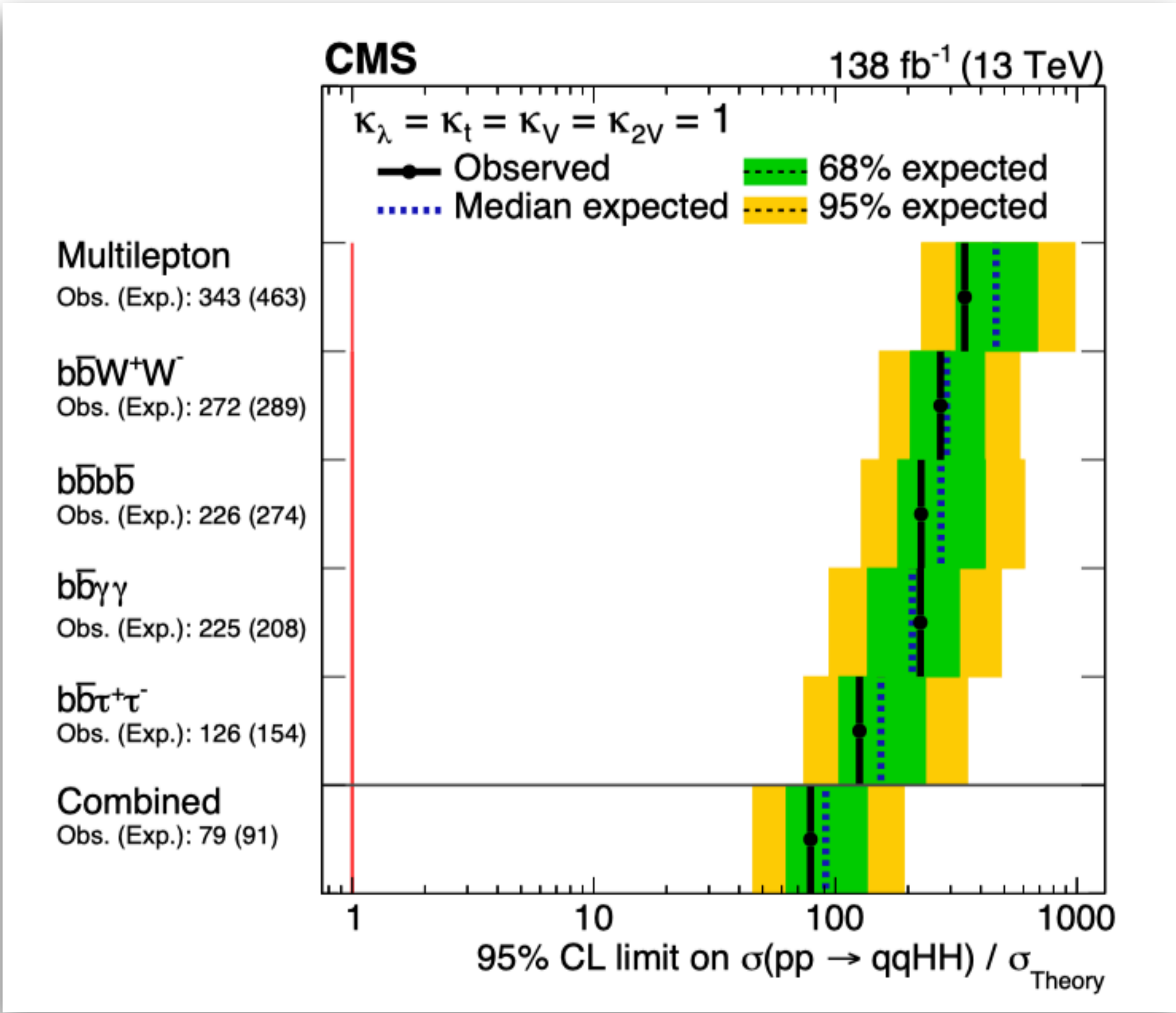




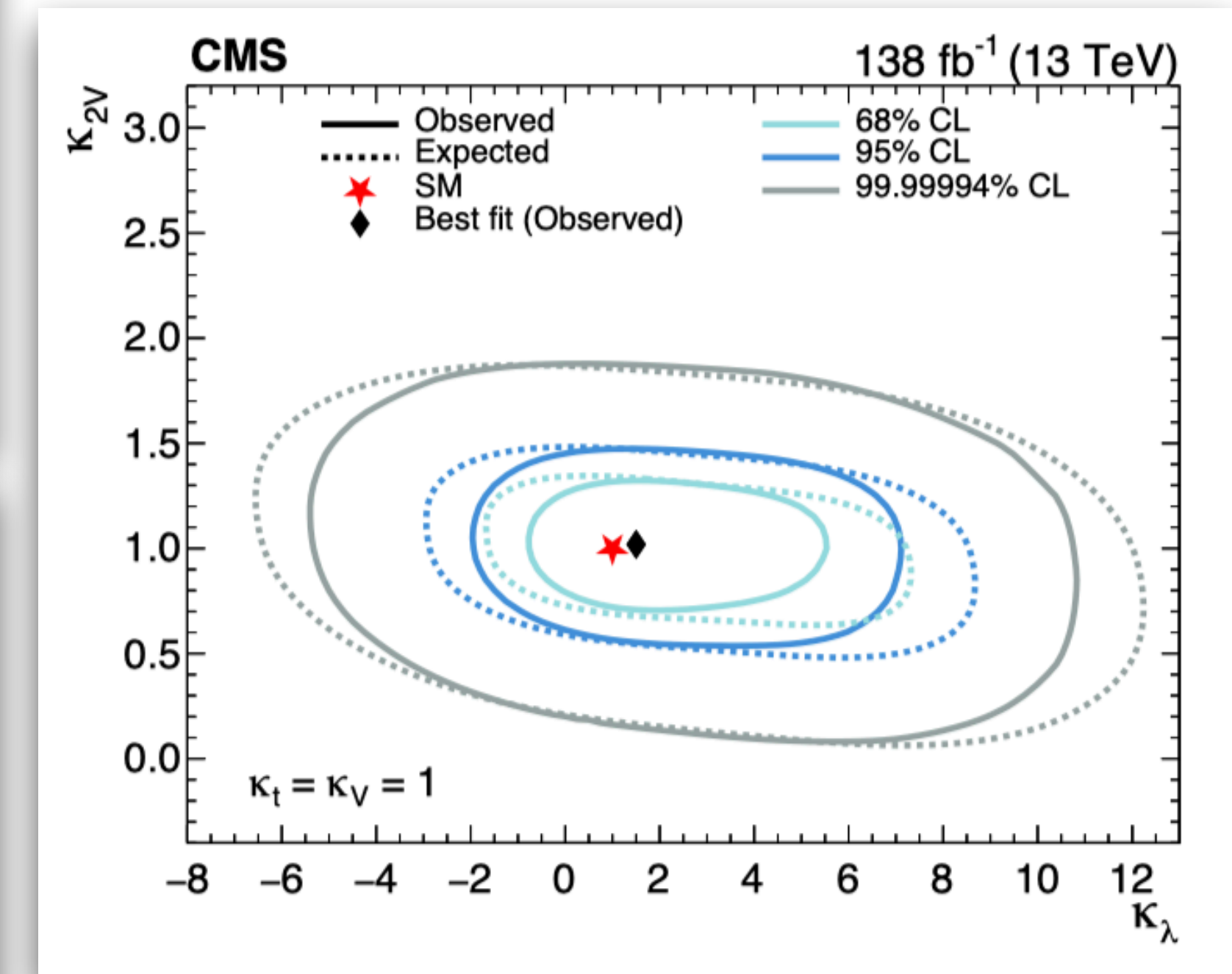
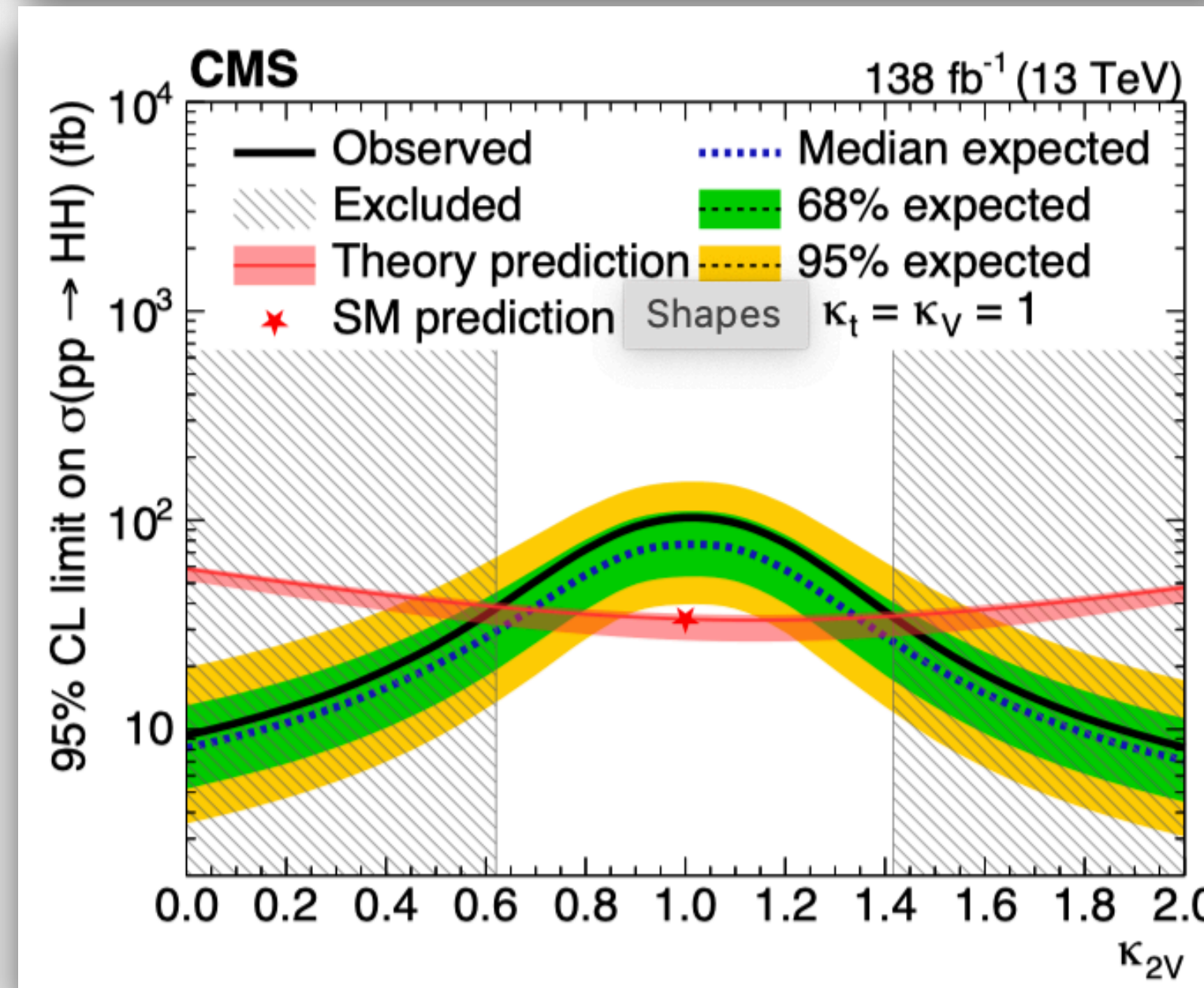
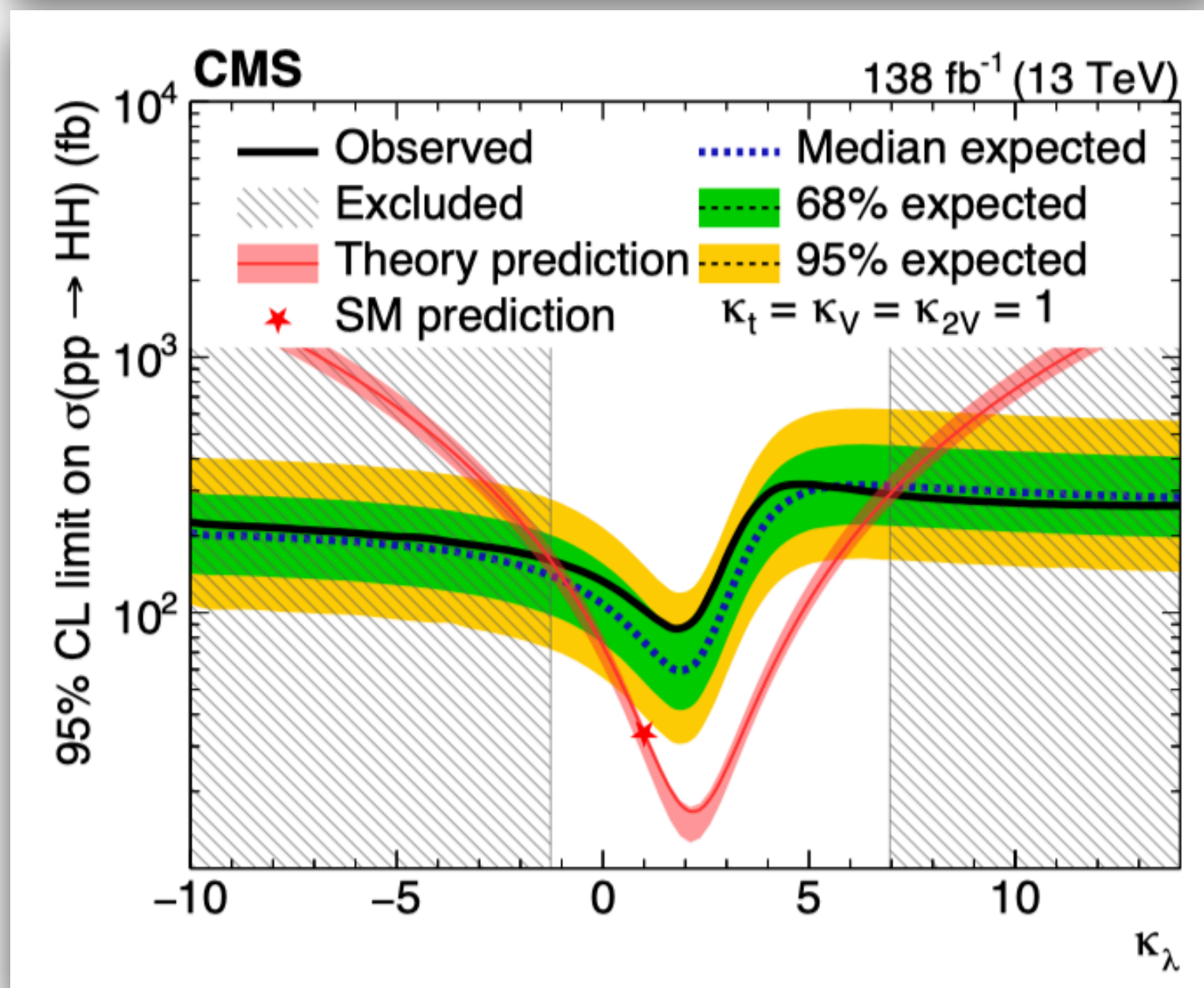
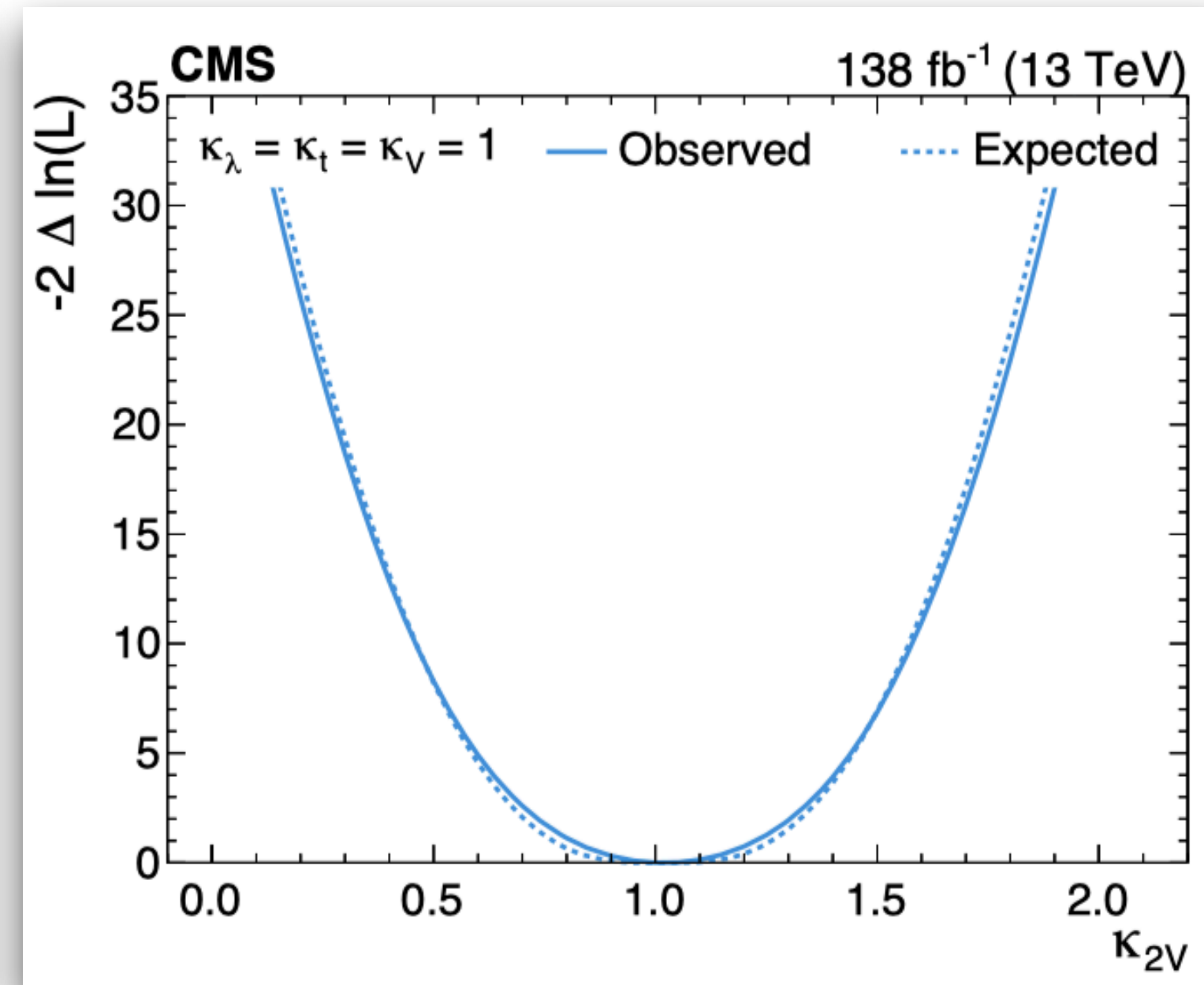
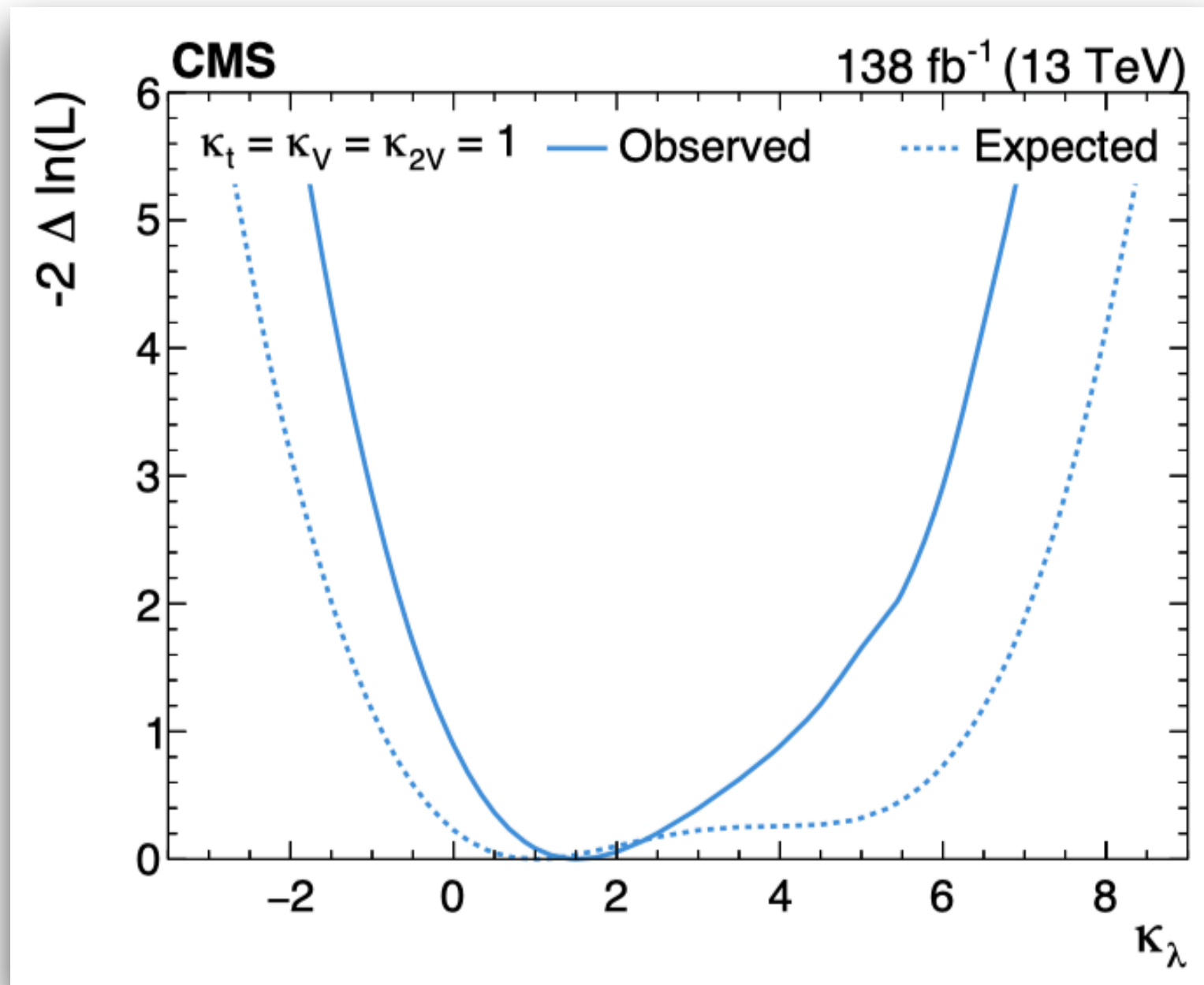
UL on the inclusive HH at 95%



UL on the VBFHH at 95%



CMS combination of Run 2 analyses



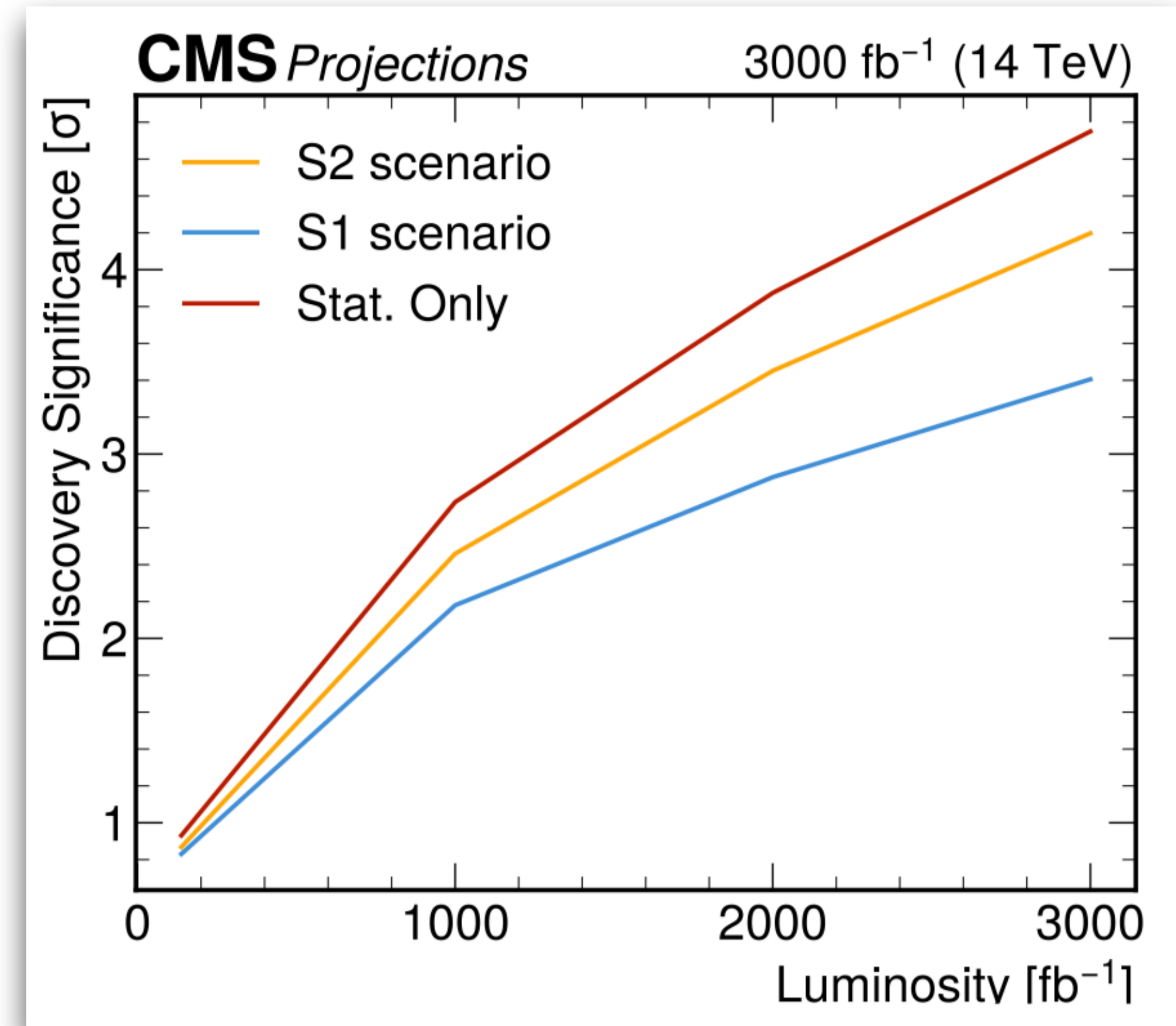
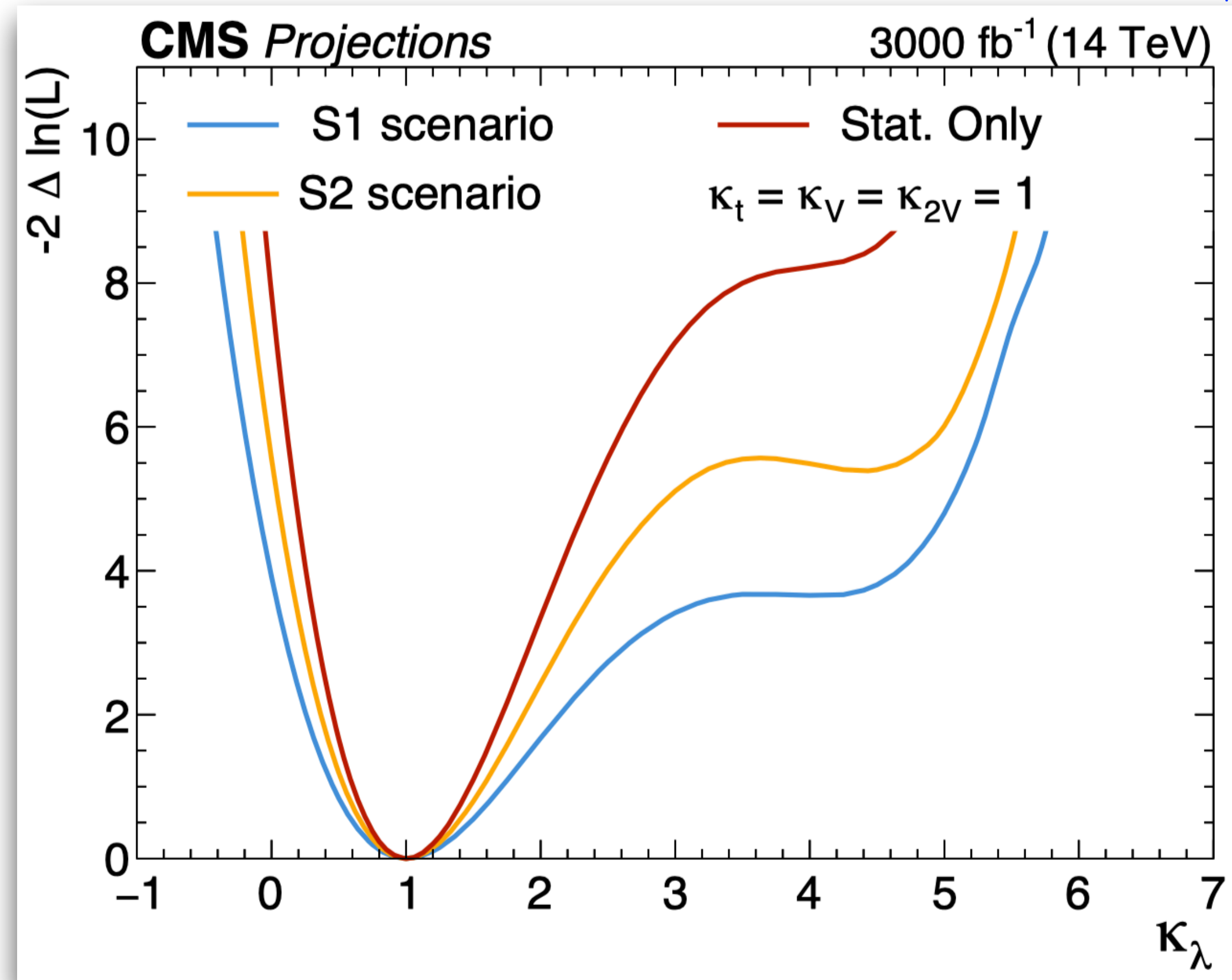
Prospects of HH in HL-LHC



Projections are based on the Run 2 only datacards, so the projection doesn't know the improvements for the Run3

S1 : Same uncertainty impacts as of Run 2

S2 : statistical component of uncertainties are scaled by $1/\sqrt{L}$

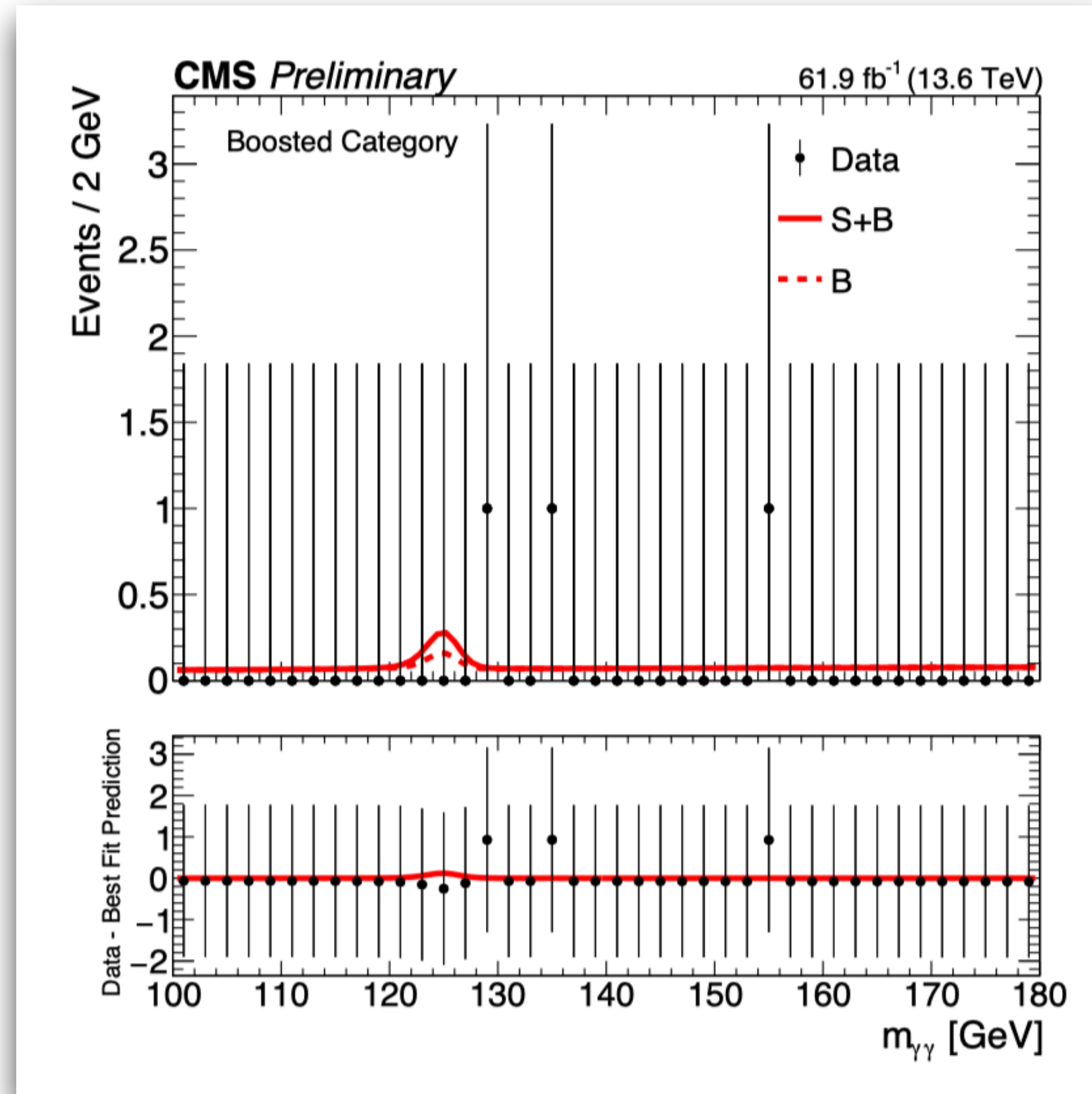


Extra materials: $HH \rightarrow b\bar{b}\gamma\gamma$

Inclusion of merged analysis in the $HH \rightarrow bb\gamma\gamma$



- The boosted channel is included for the $HH \rightarrow bb\gamma\gamma$ for the very first time for this decay mode
- Selected by considering an AK8 jets with $p_T > 250$ GeV and soft-drop mass (m_{SD}) 30-210 GeV
- A bb-tagging condition is required on the AK8 jet to reduce the fake backgrounds.

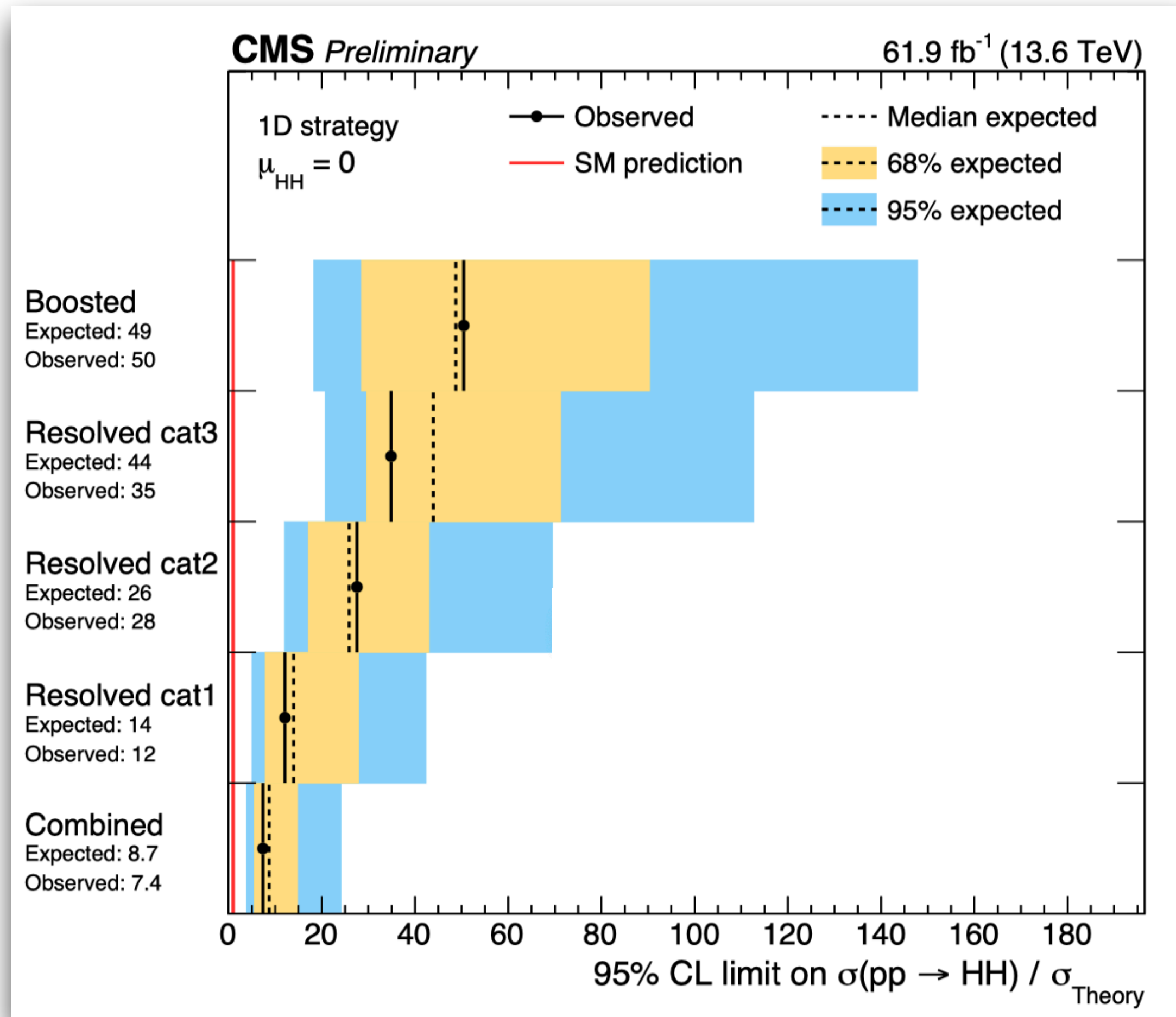


The analysis is suffered by statistics in the boosted phase space

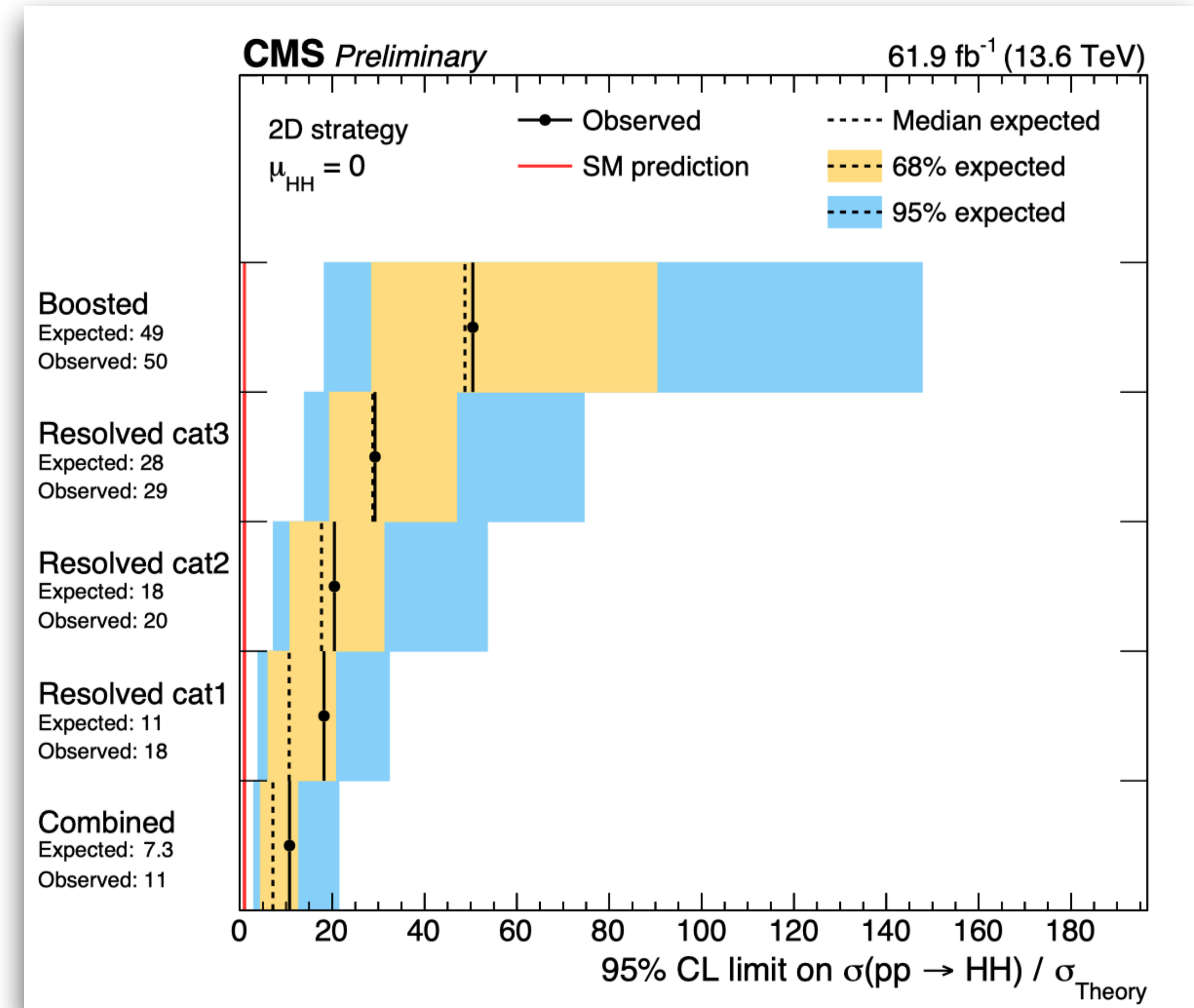
Comparison of two different Run 3 HH $\rightarrow$ $b\bar{b}\gamma\gamma$ approaches



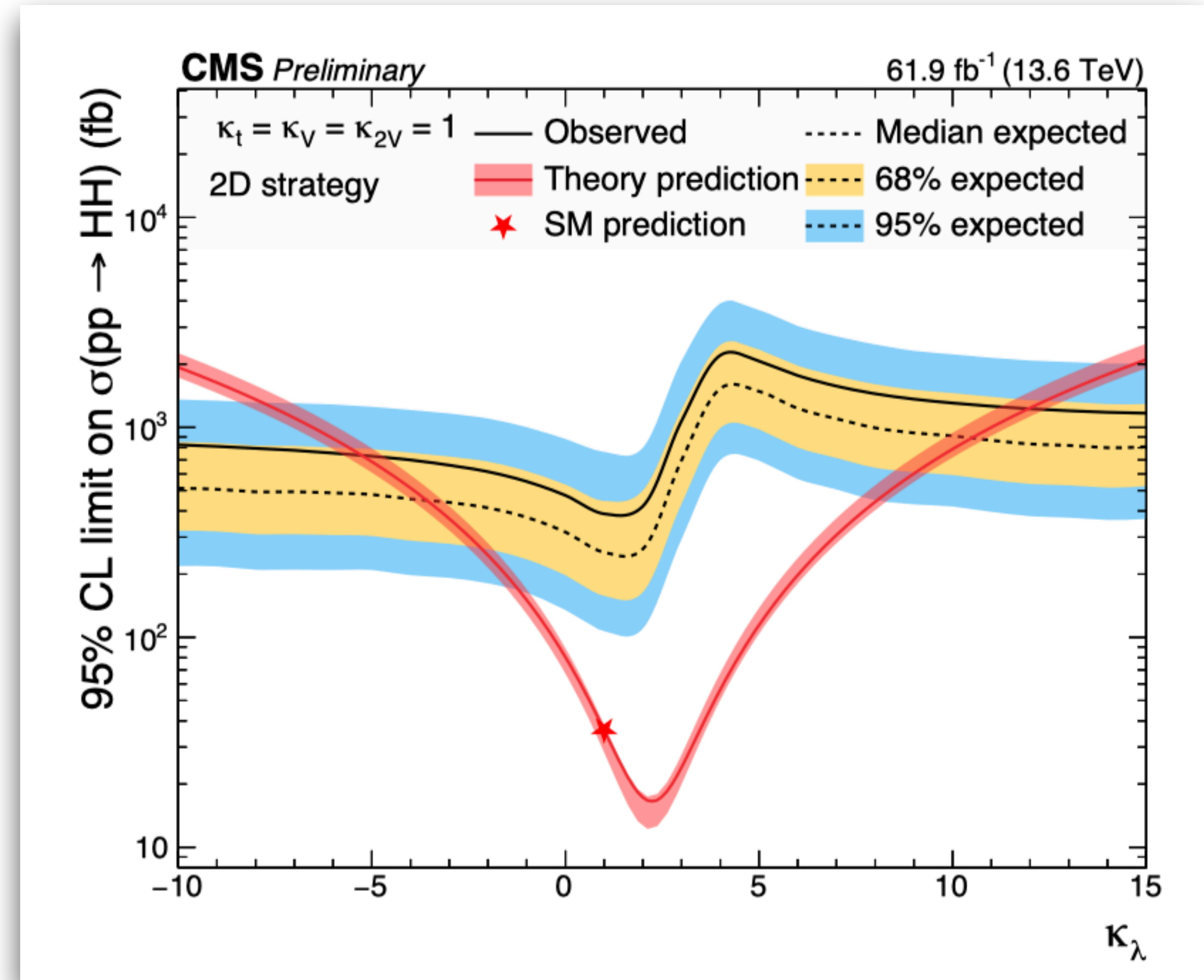
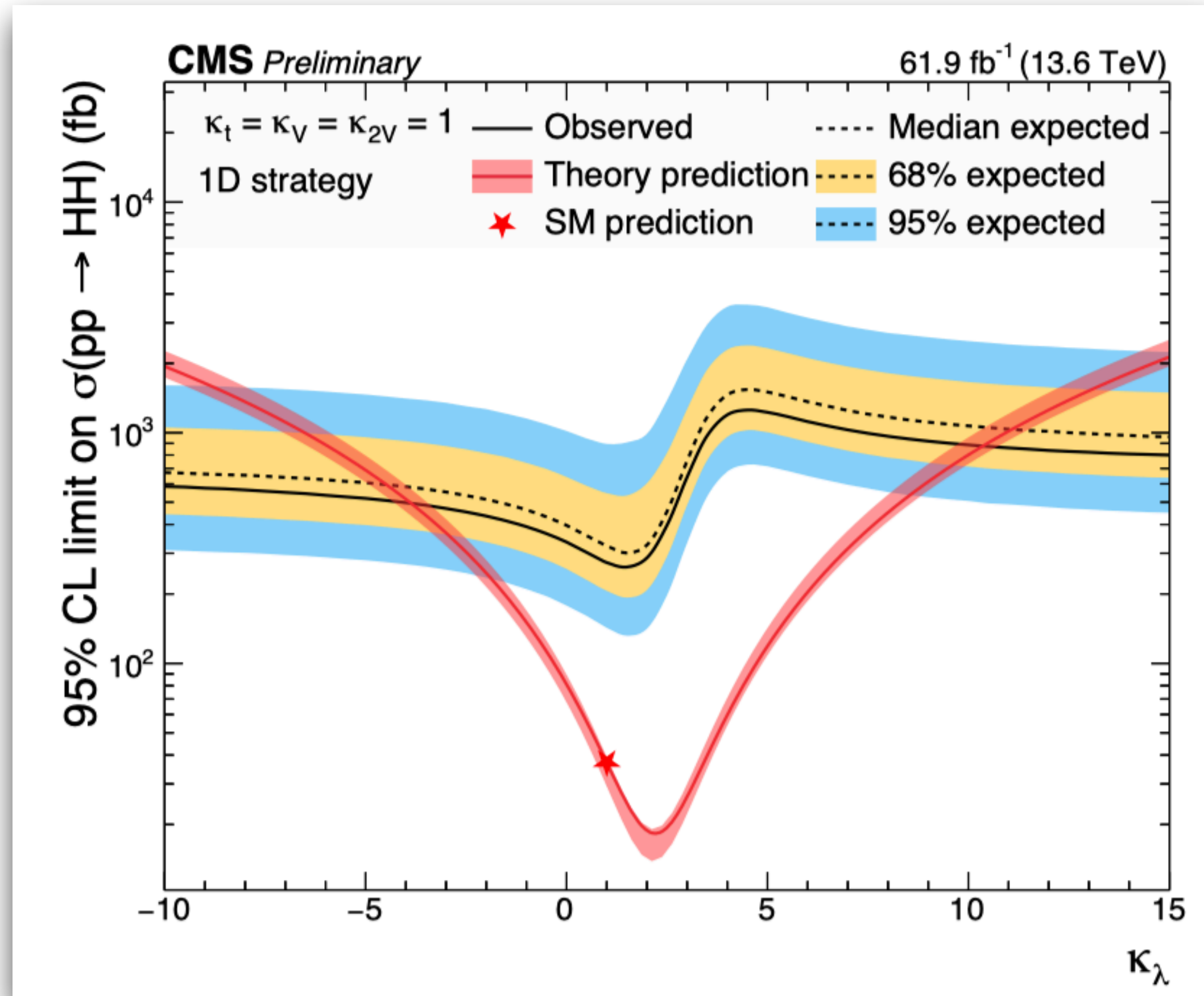
1D: UL on the inclusive HH at 95%



2D: UL on the inclusive HH at 95%



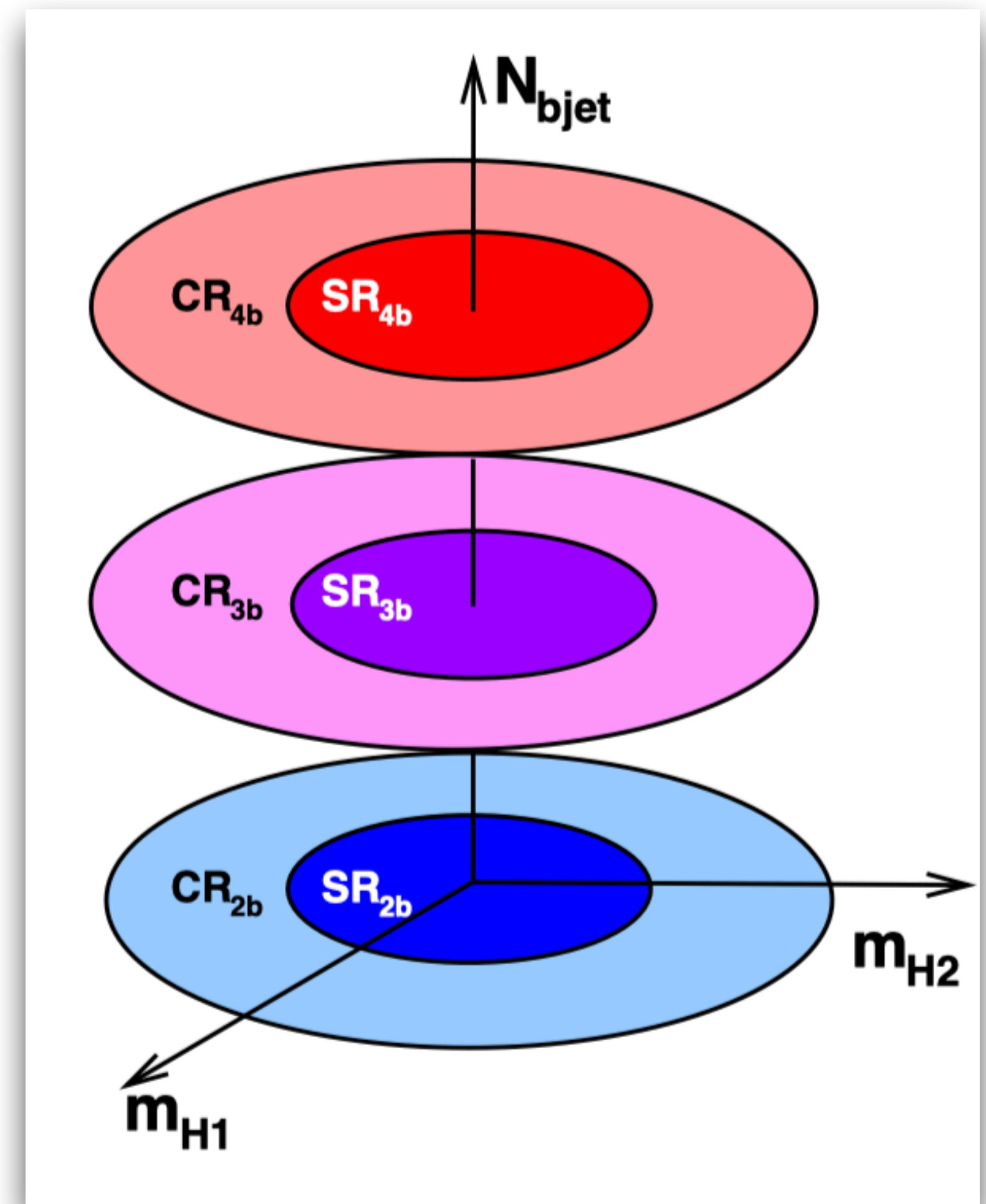
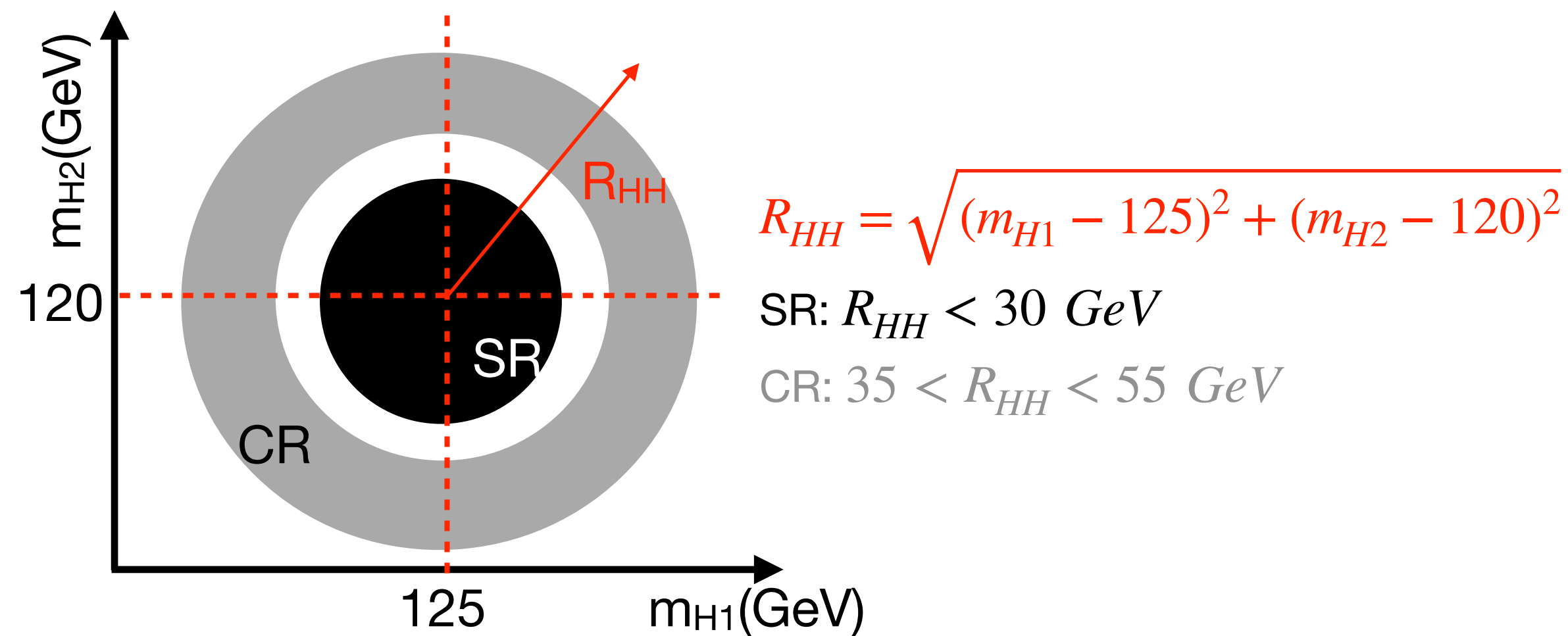
Comparison of two different Run 3 HH $\rightarrow$ $b\bar{b}\gamma\gamma$ approaches



Extra materials: $HH \rightarrow bbbb$

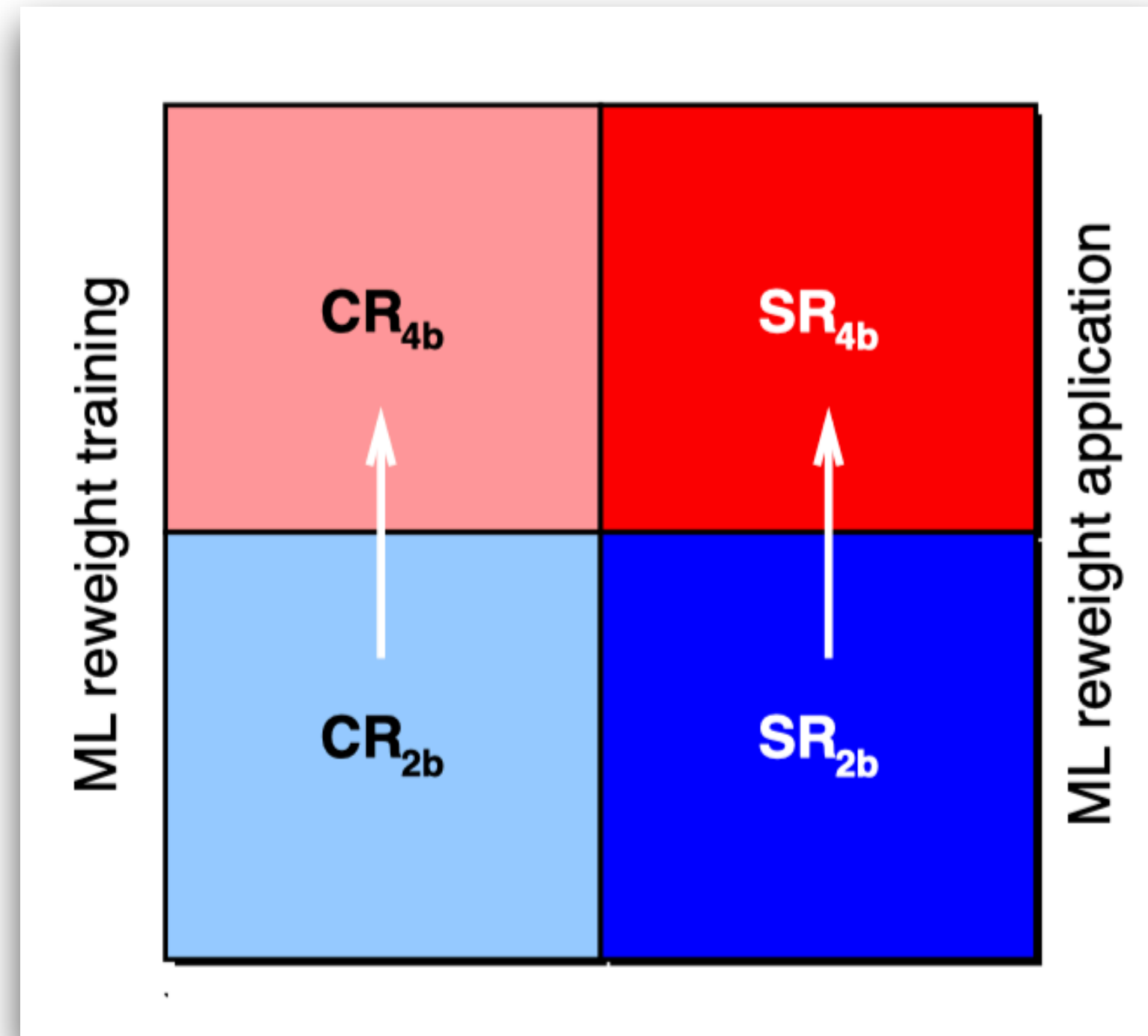
Back ground estimation in the resolved topology

- QCD simulation is not perfect to model data due to the lack of high order correction.
- Events are categorised based on b-tag exclusive categories 2b, 3b and 4b based on the b-tag jets availability in the event.
- Base on the signal population signal region (SR) and control region (CR) are created



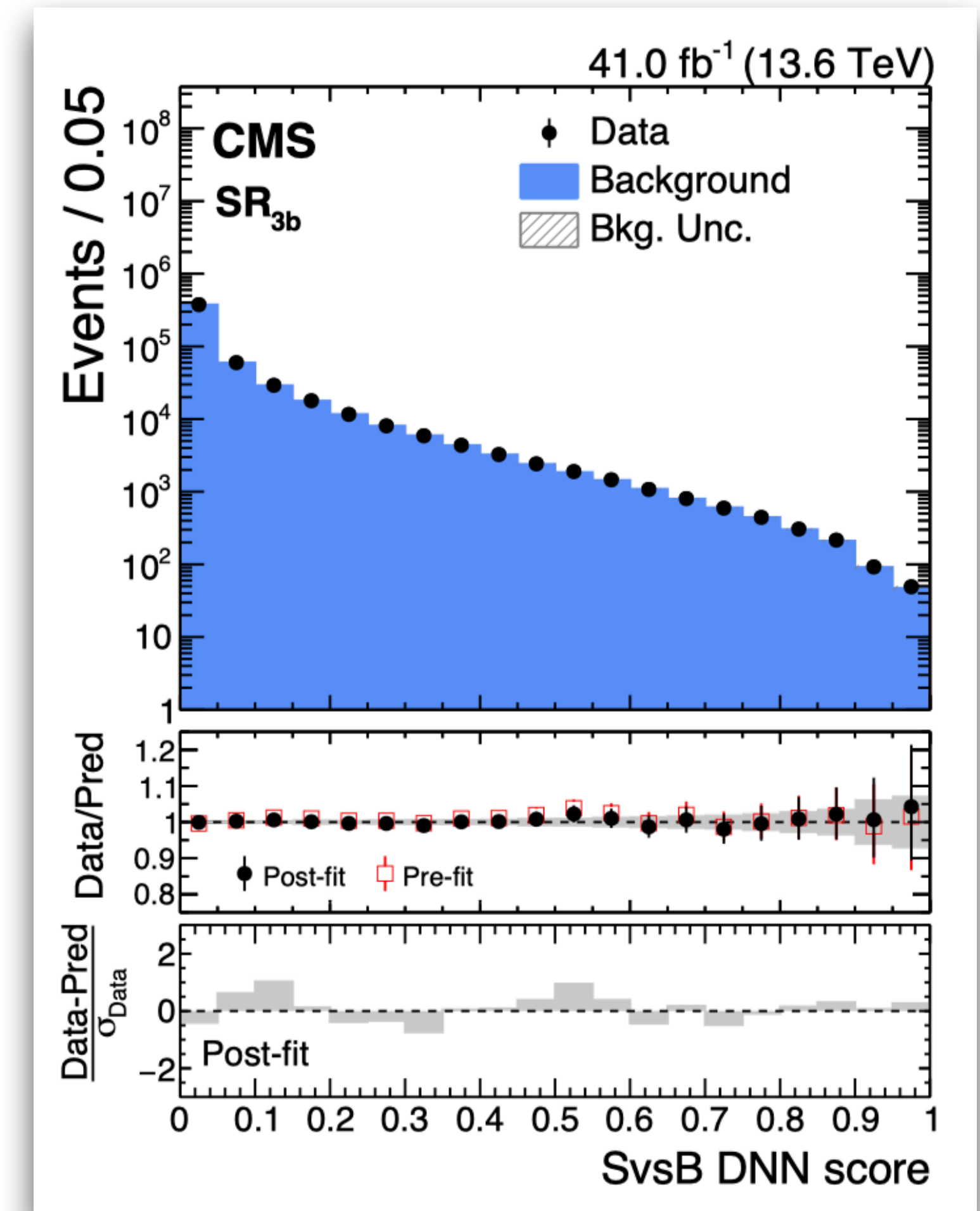
Back ground estimation in the resolved topology

- Machine learning (ML) based DNN reweighting has been used to use the data in low b-tag region to higher b-tag region
- Network has been trained in the CR.
- The trained has been used in the SR to model the background in the SR_{4b}

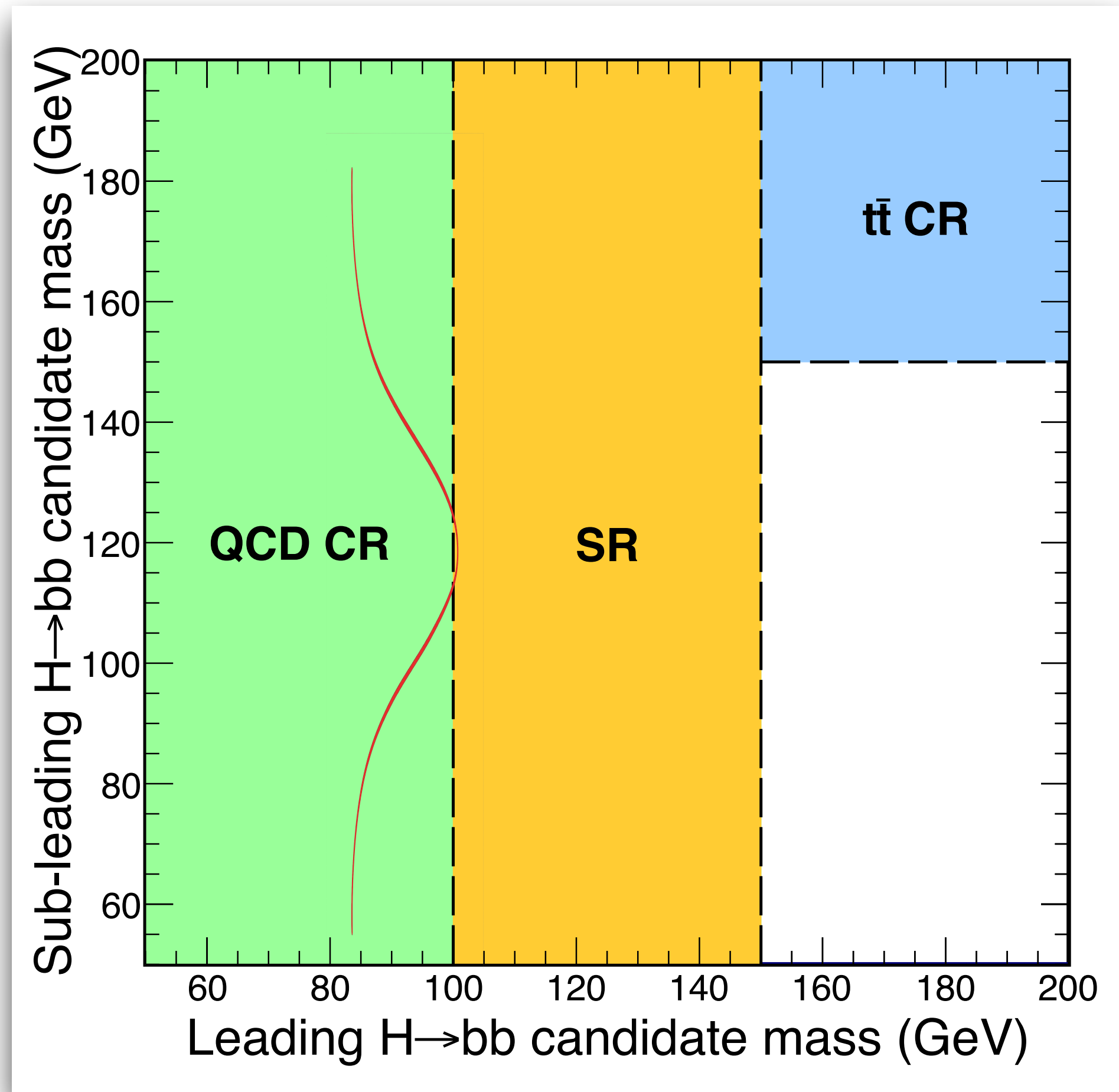


$$\text{weight} = \frac{\text{score}}{1 - \text{score}} = \frac{\mathcal{P}_{CR_{4b}}}{1 - \mathcal{P}_{CR_{4b}}} = \frac{\mathcal{P}_{CR_{4b}}}{\mathcal{P}_{CR_{2b}}}$$

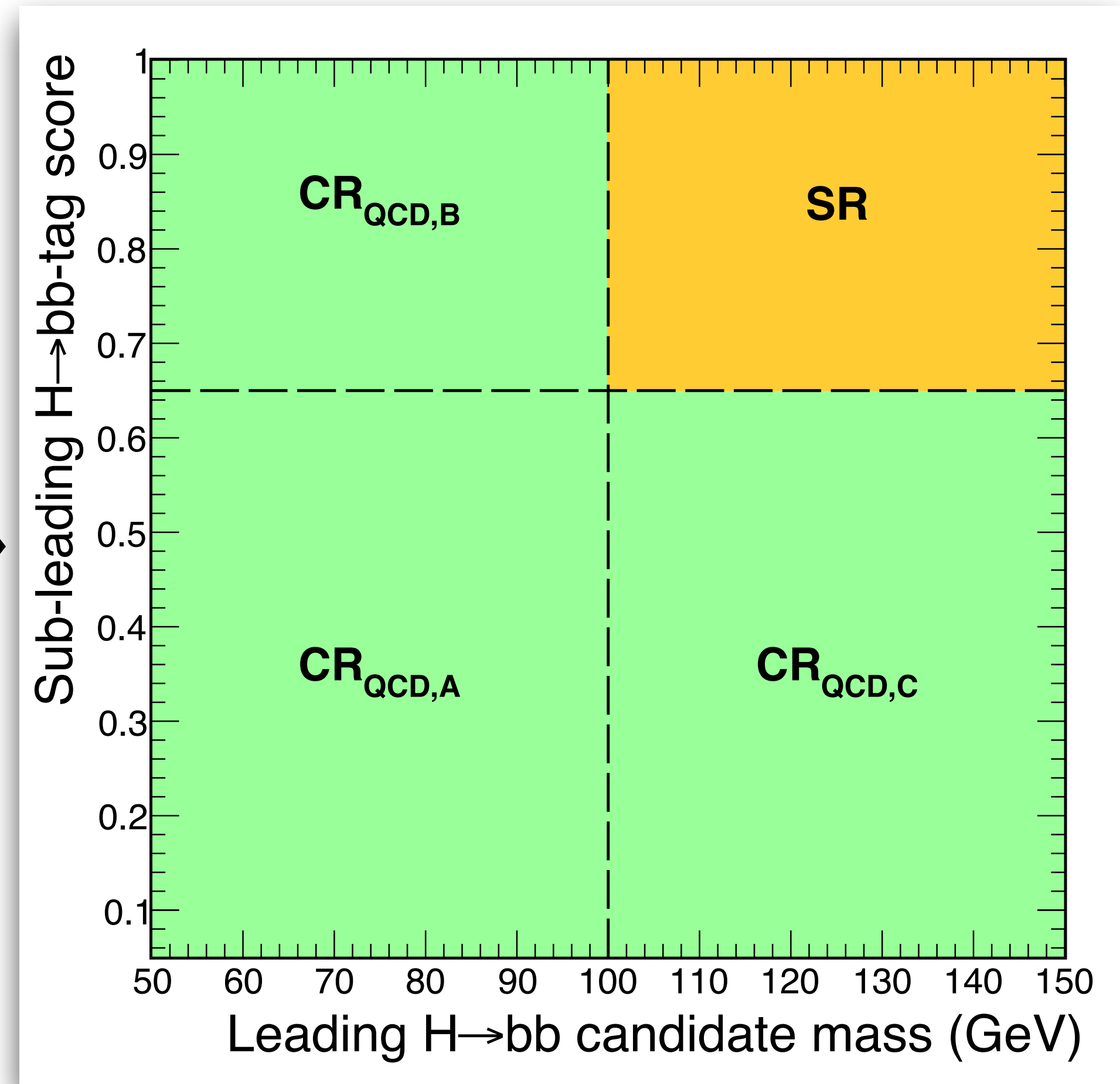
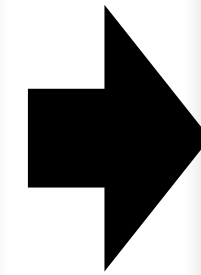
The background modelling has been validated in the SR_{3b}



Back ground estimation in the merged topology



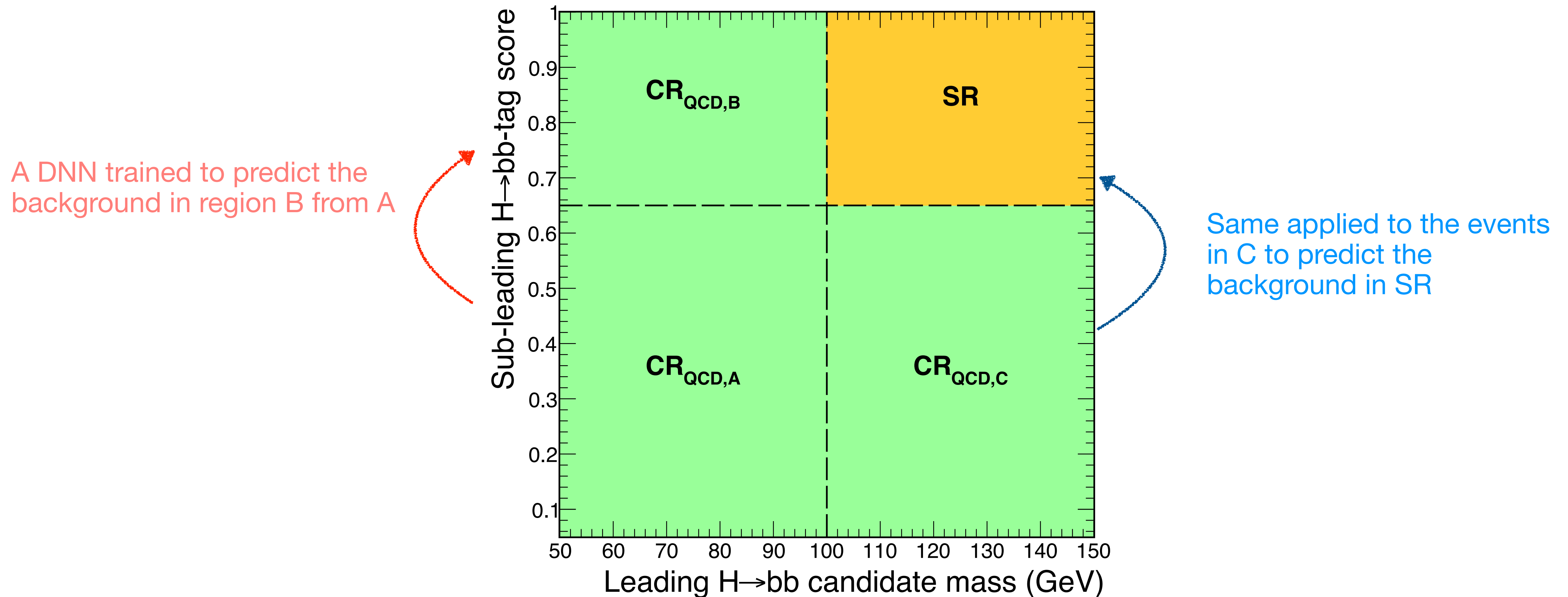
No requirement on sub leading jet,
As m_{H2} is the final fit variable,
still too much QCD



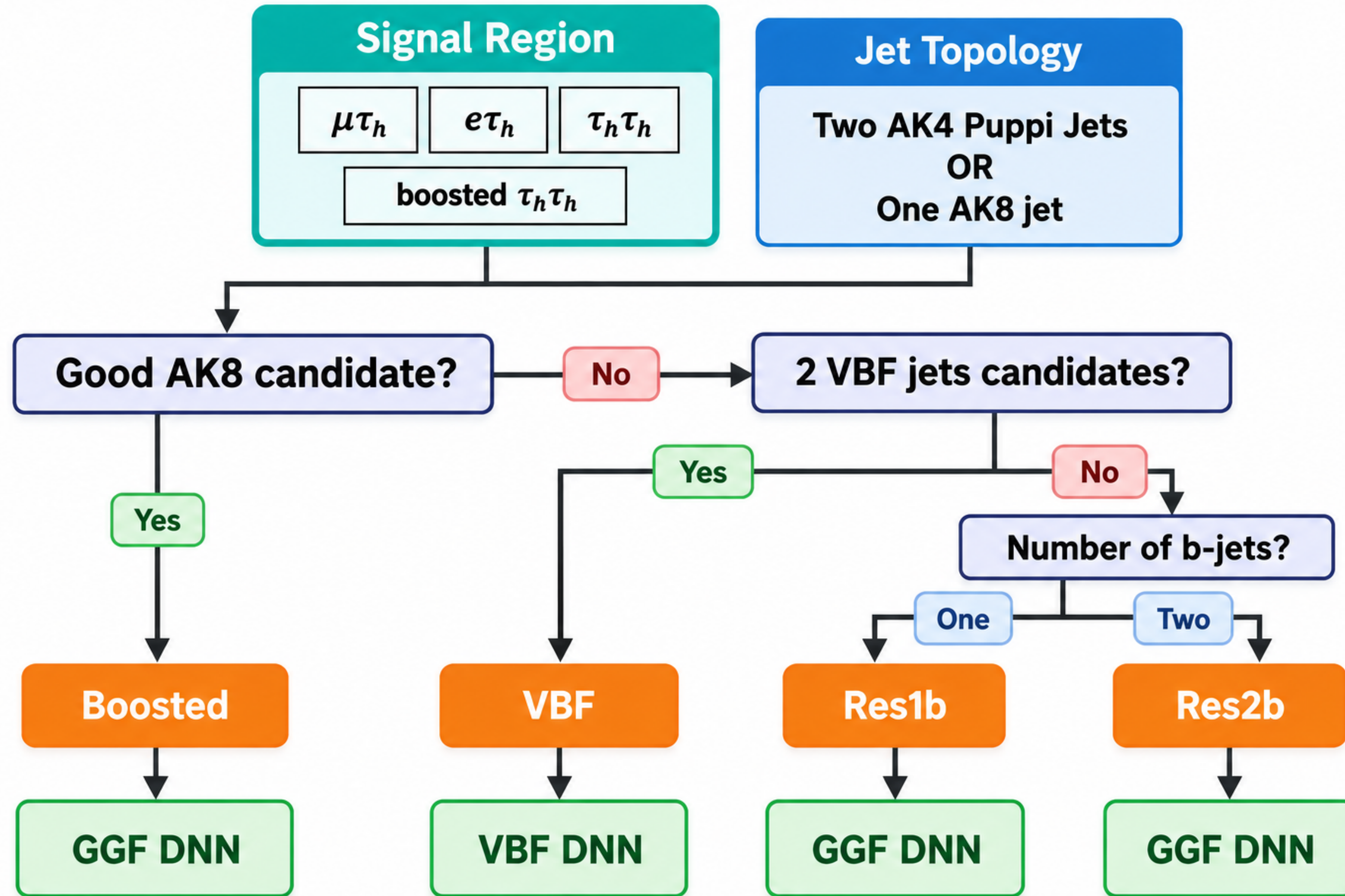
Additional cuts on bb -tag score to purify the
SR, QCD MC is not perfect in the SR

Back ground estimation in the merged topology

- ~ “Merged” analysis targets the scenario where both the two Higgs bosons are boosted.
- ~ Higgs candidates are reconstructed from the two AK8 jets.
- ~ “Merged” topology has fewer events (statistically limited), but offers a better signal-to-background ratio.
- ~ Significant background contribution coming from QCD and $t\bar{t}$



$$HH \rightarrow bb\tau\tau$$





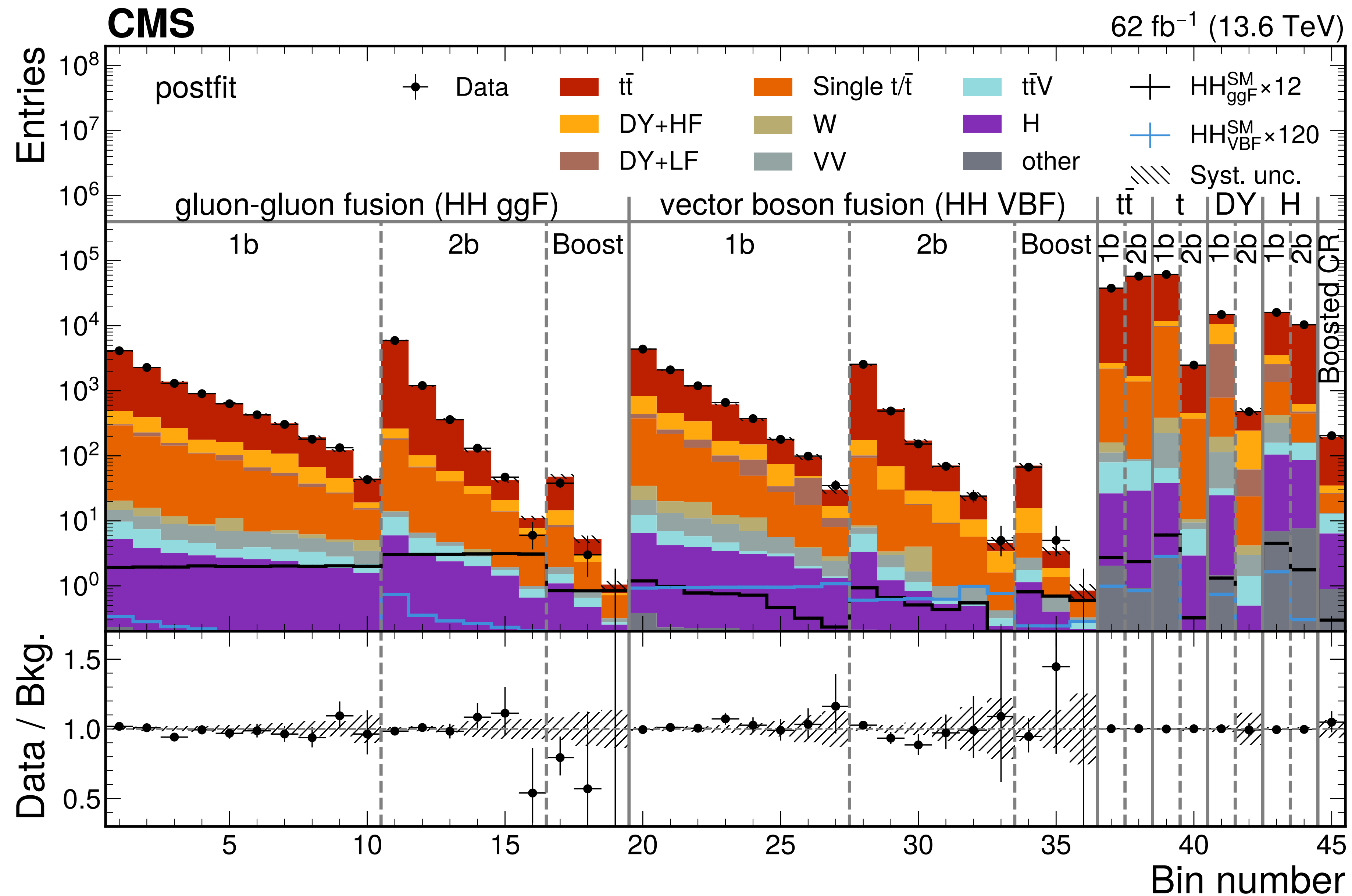
Uncertainty source	Relative contribution to $\Delta\mu_{HH}$
Experimental	
Fake factors	25%
b-tagging	10%
Lepton corrections and triggers	9%
Jet energy corrections	7%
Other experimental	3%
Statistical	
Overall	74%
Bin-by-bin variations	35%
Theoretical	
HH	31%
single-H	27%
Background	14%

$HH \rightarrow bbWW$ Dileptonic search



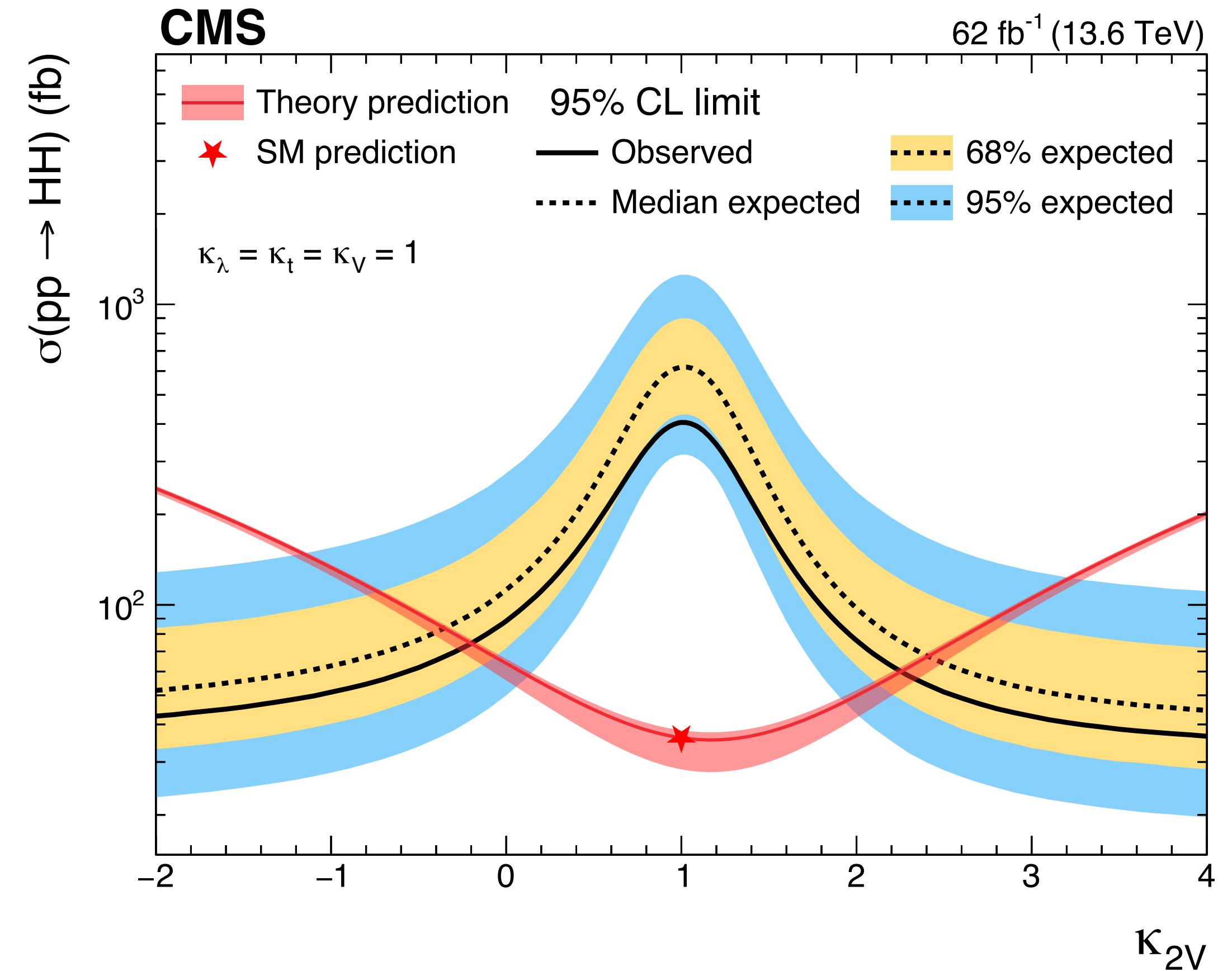
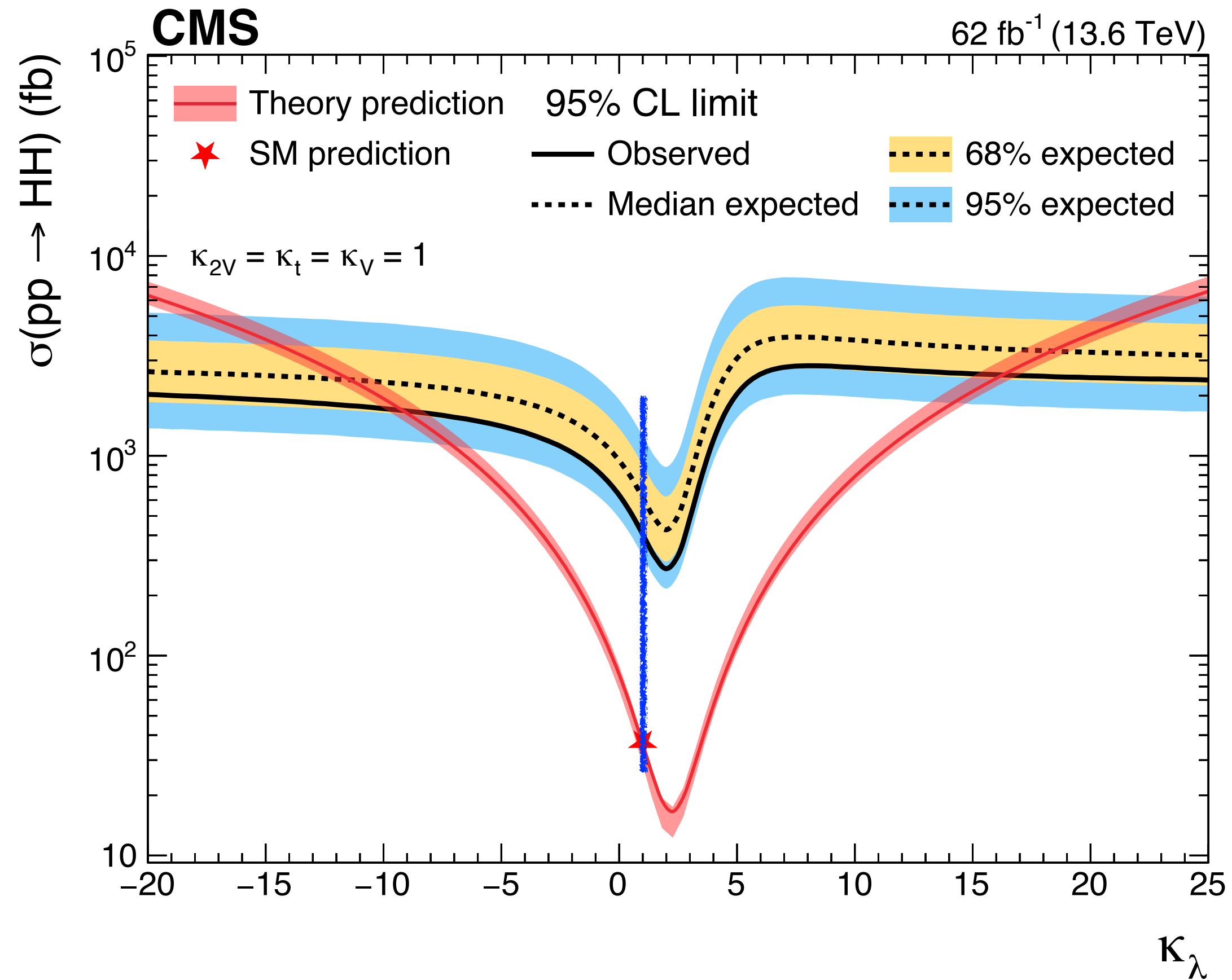
$HH \rightarrow b\bar{b}WW$: Post-fit distributions

JHEP 08 (2026) 019



HH $\rightarrow$ $b\bar{b}WW$: Results

JHEP 08 (2026) 019



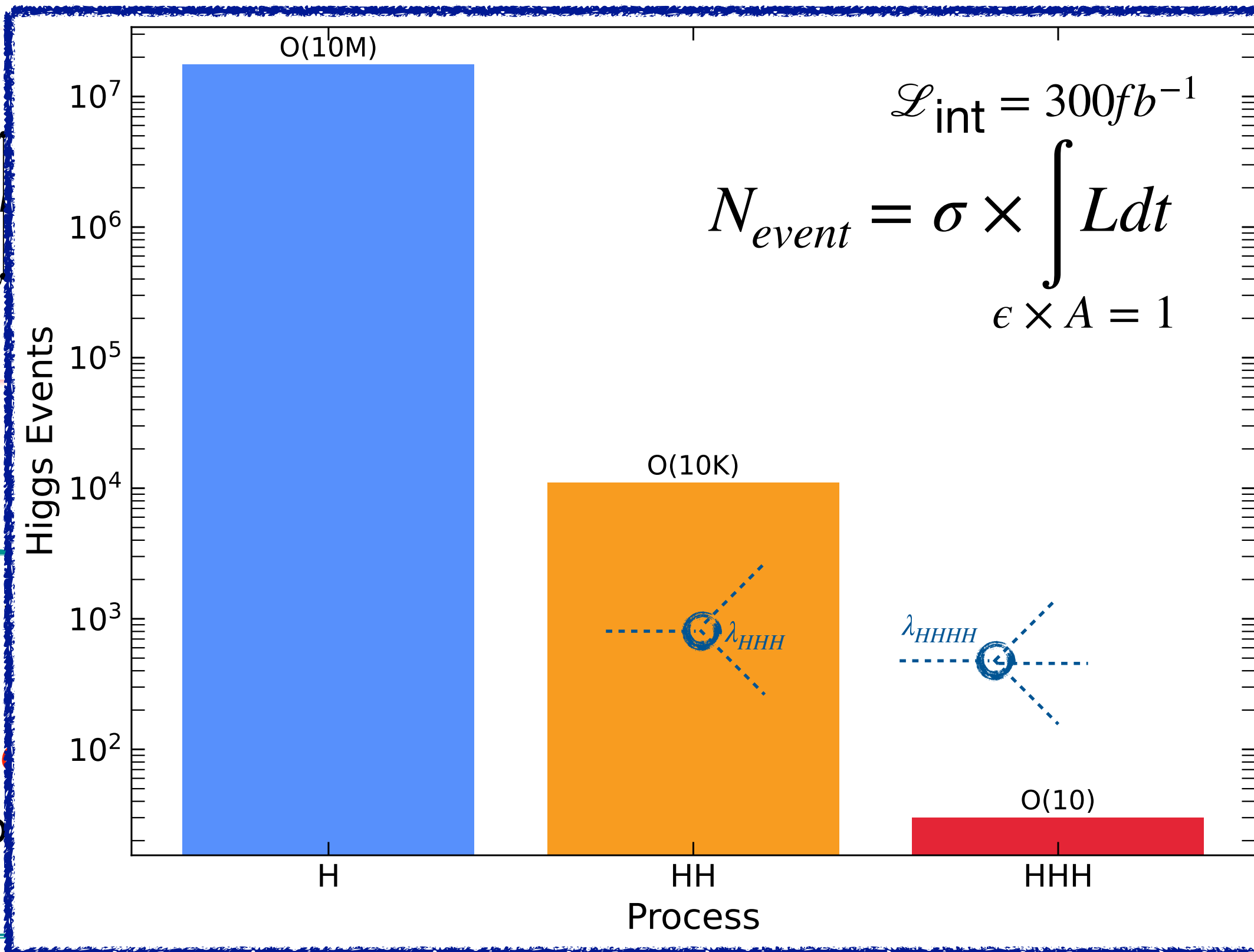
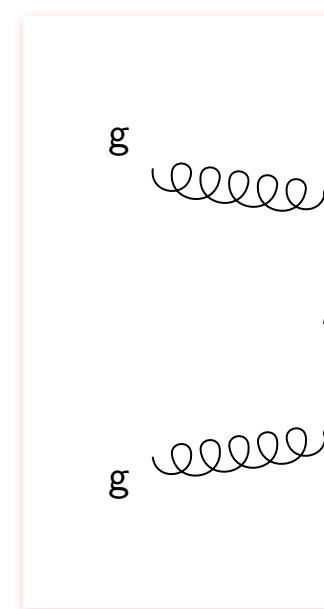
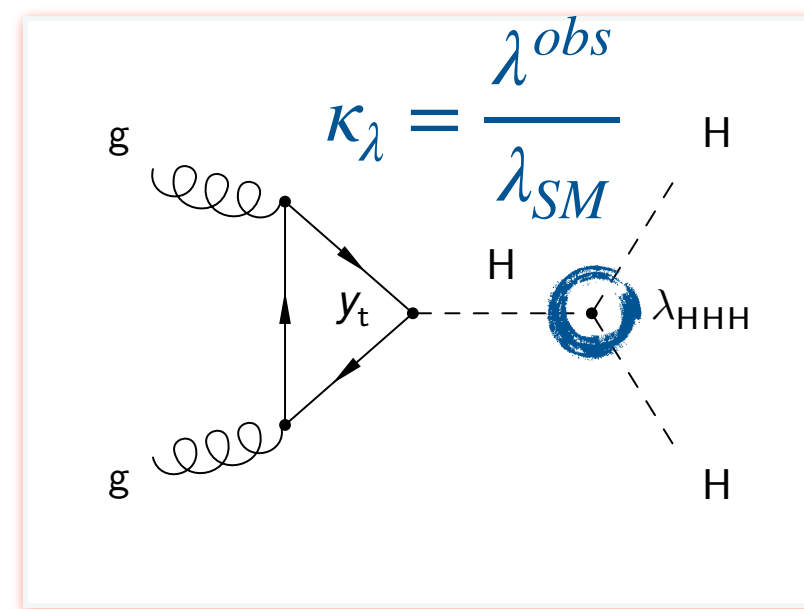
95% CL upper limit
Observed : 12
Expected : 18.5

Combination with Run 2 in final states with one or two leptons UL at 95%
CL: 7.9 (12.7) times SM

HH search at the LHC



- The Higgs self coupling λ , directly probes the shape of the Higgs potential.
- At the LHC, λ can be directly constrained through non-resonant Higgs boson pair (HH) production.

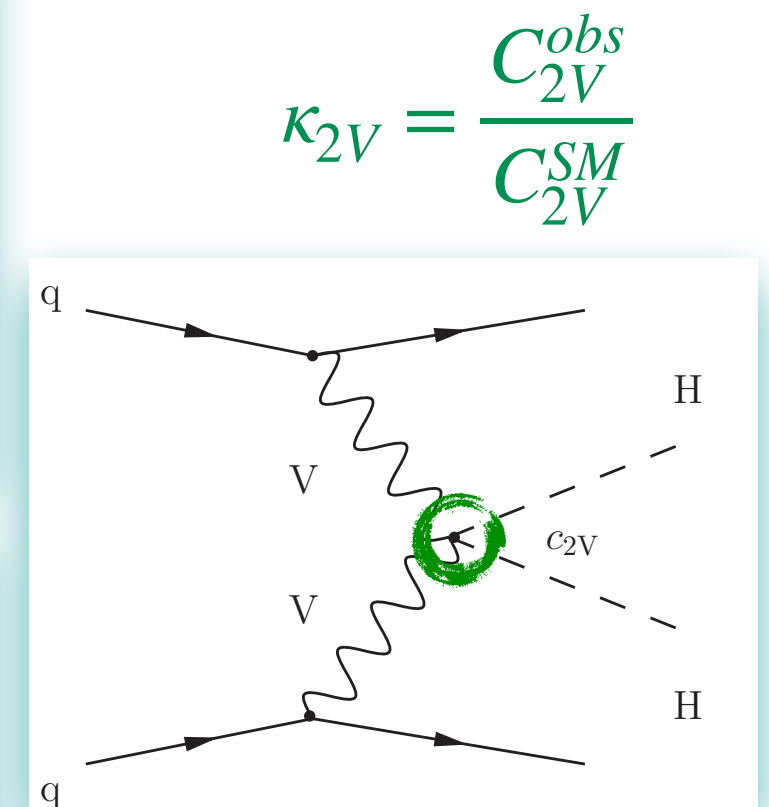
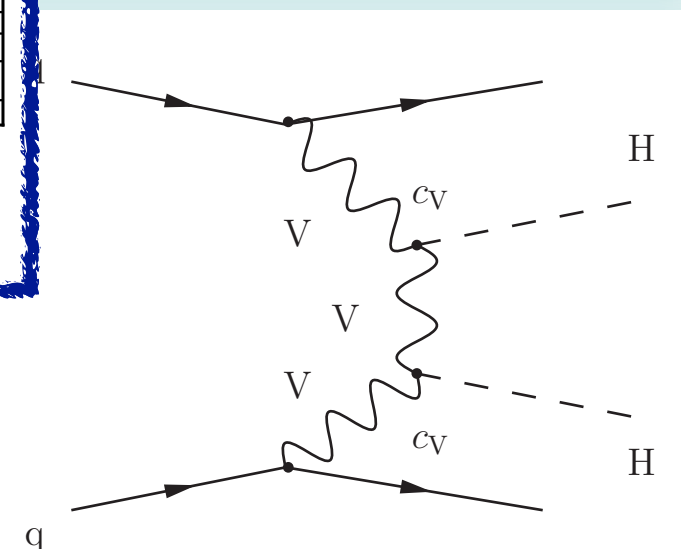
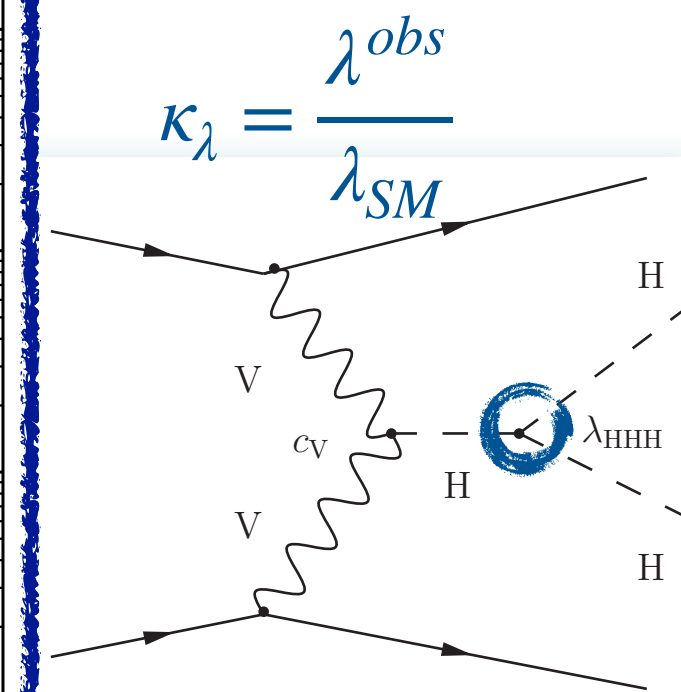


production mode of HH at the LHC.

er than single Higgs boson production

- Vector Boson Fusion “qqHH”** i
- $\sigma = 1.84 \text{ fb @ } 13.6 \text{ TeV.}$
- Production rate is almost **15 times**
- Provide unique access to the co

(C_{2V})

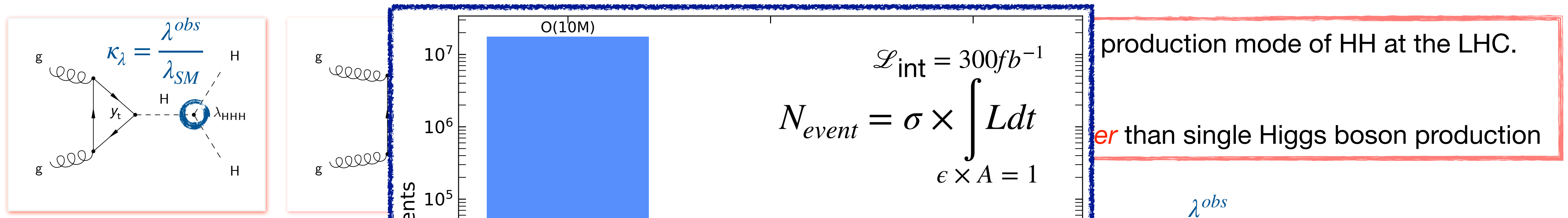


$$\kappa_{2V} = \frac{C_{2V}^{\text{obs}}}{C_{2V}^{\text{SM}}}$$

HH search at the LHC

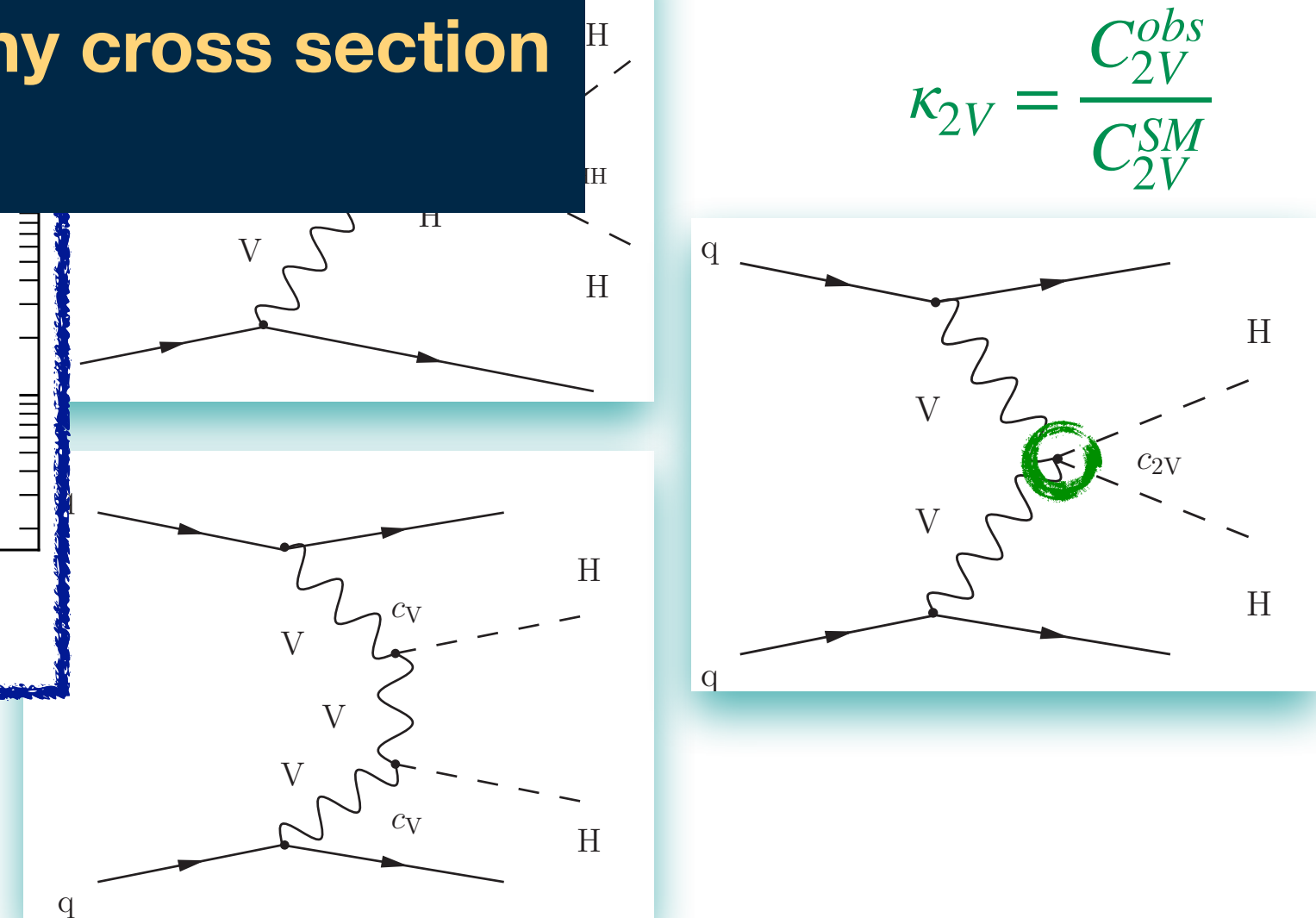
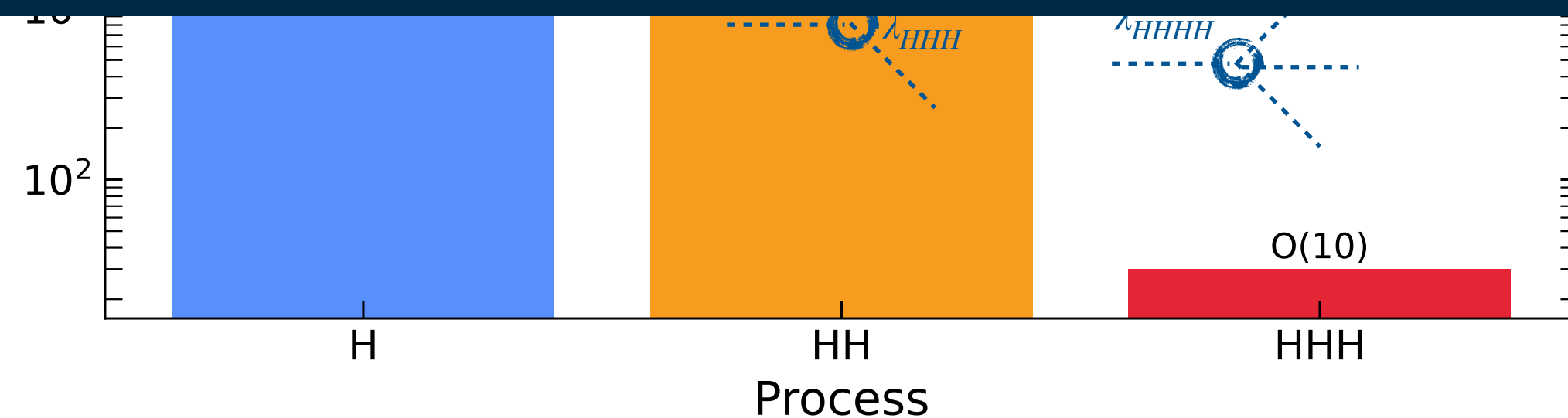


- The Higgs self coupling λ , directly probes the shape of the Higgs potential.
- At the LHC, λ can be directly constrained through non-resonant Higgs boson pair (HH) production.



Extremely difficult to probe HH process experimentally due to tiny cross section

- Vector Boson Fusion
- $\sigma = 1.84 \text{ fb @ } 13.6 \text{ TeV}$.
- Production rate is almost *15 times*
- Provide unique access to the coefficient (C_{2V})

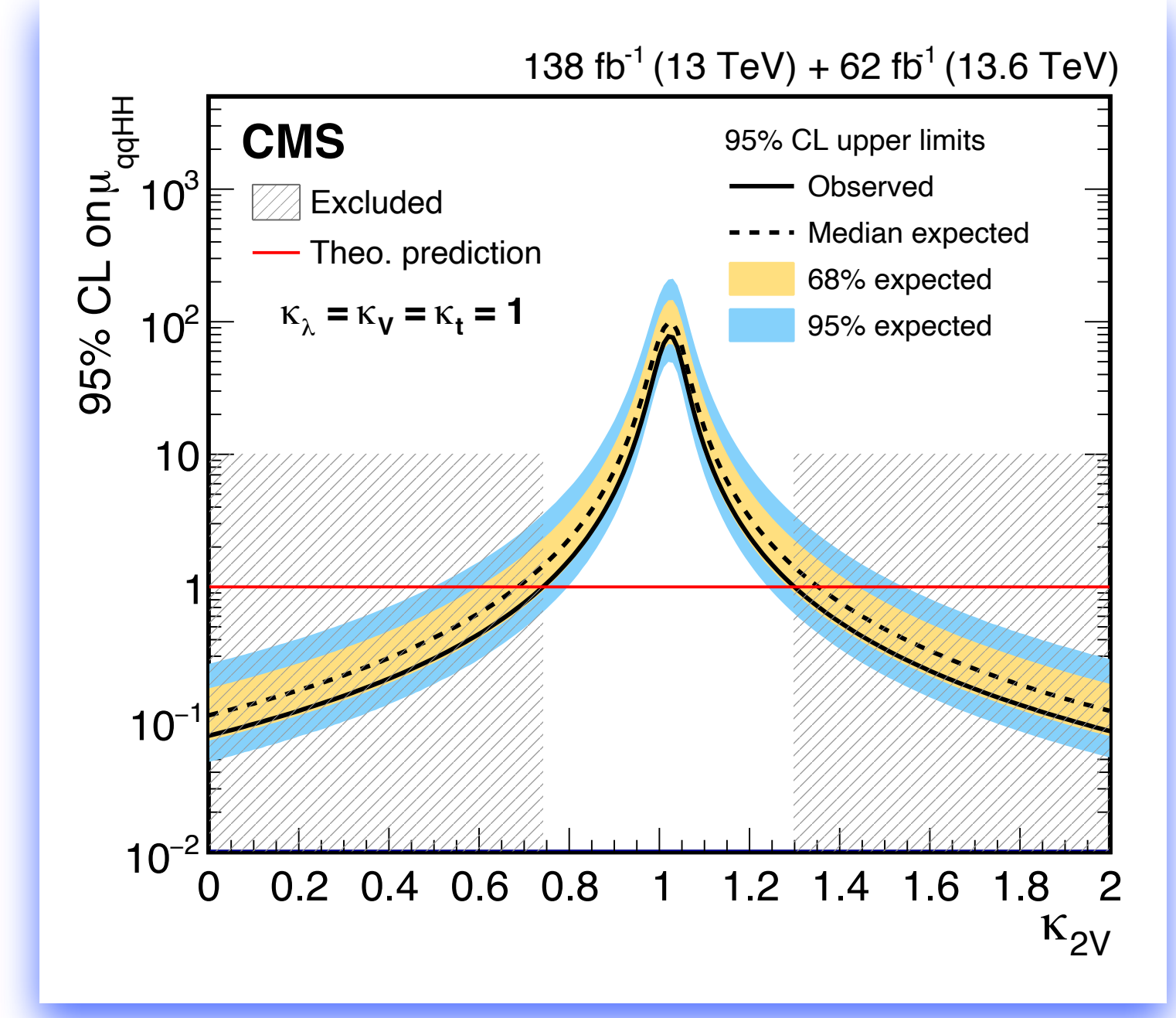
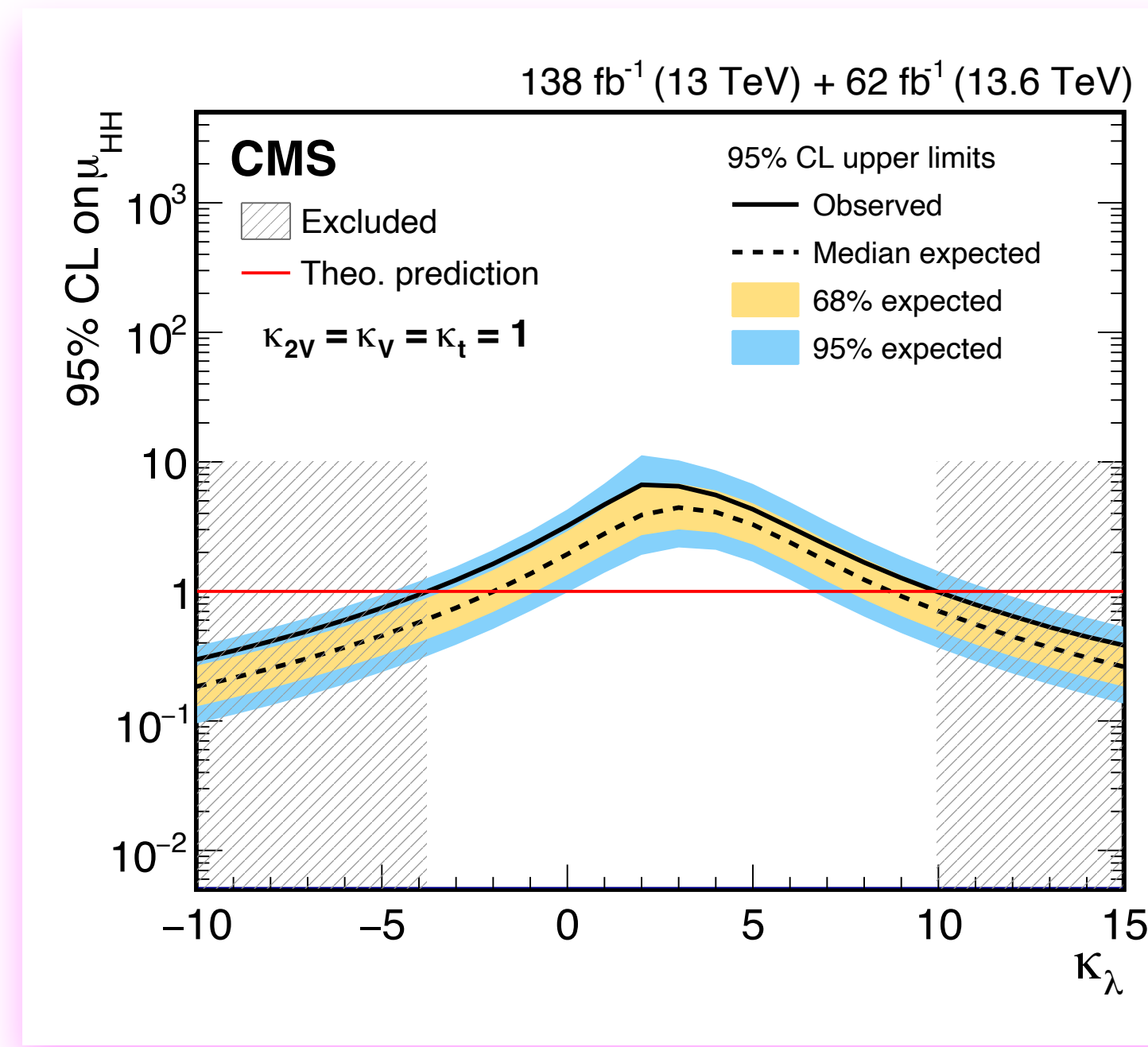
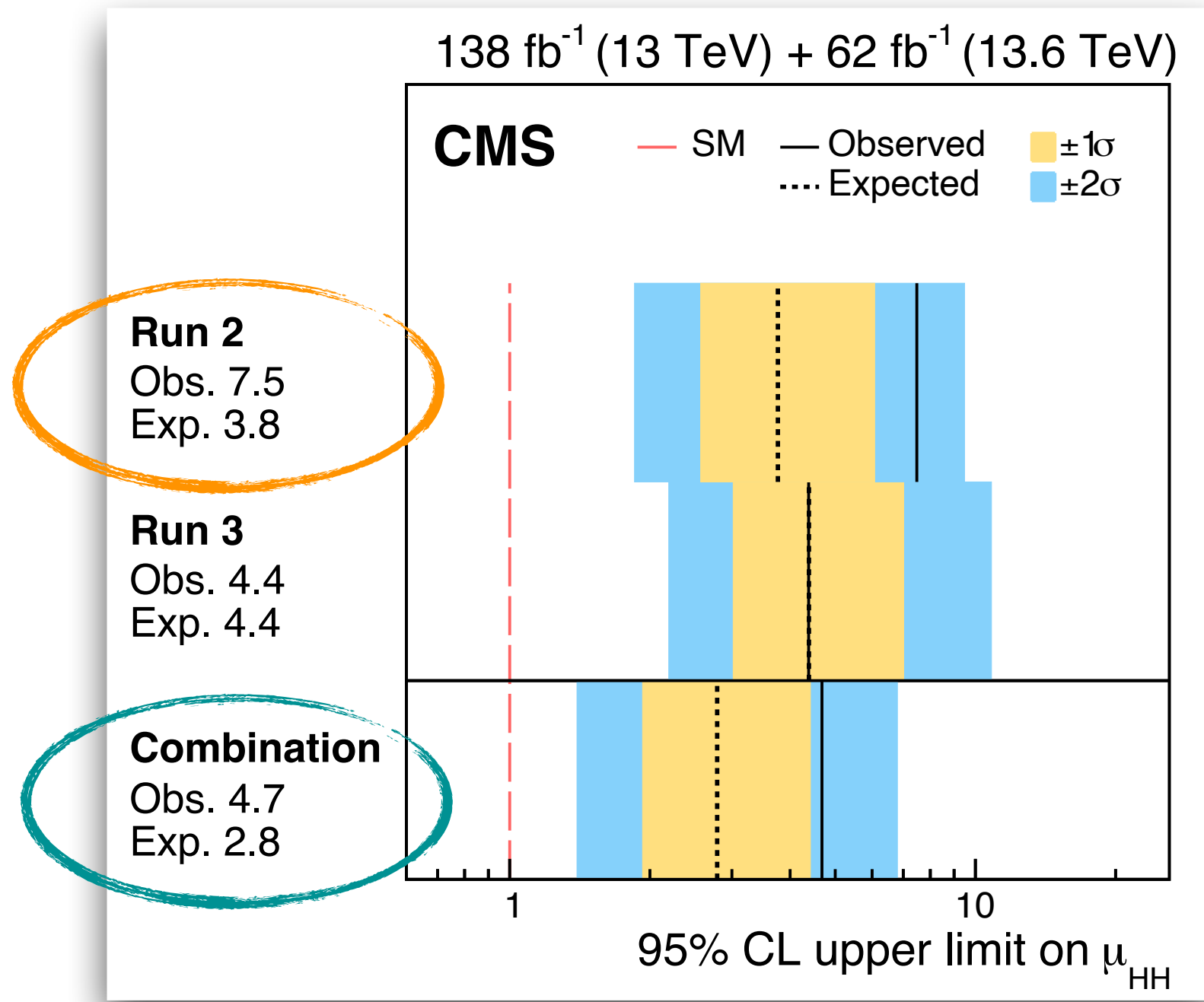


HH $\rightarrow$ $b\bar{b}b\bar{b}$: Combination with Run 2 dataset

arXiv:2604.27044



Combining the resolved & merged 22-23 analyses:



Reanalysis of Run 2 resolved analysis

Observed (expected) UL @95% CL:

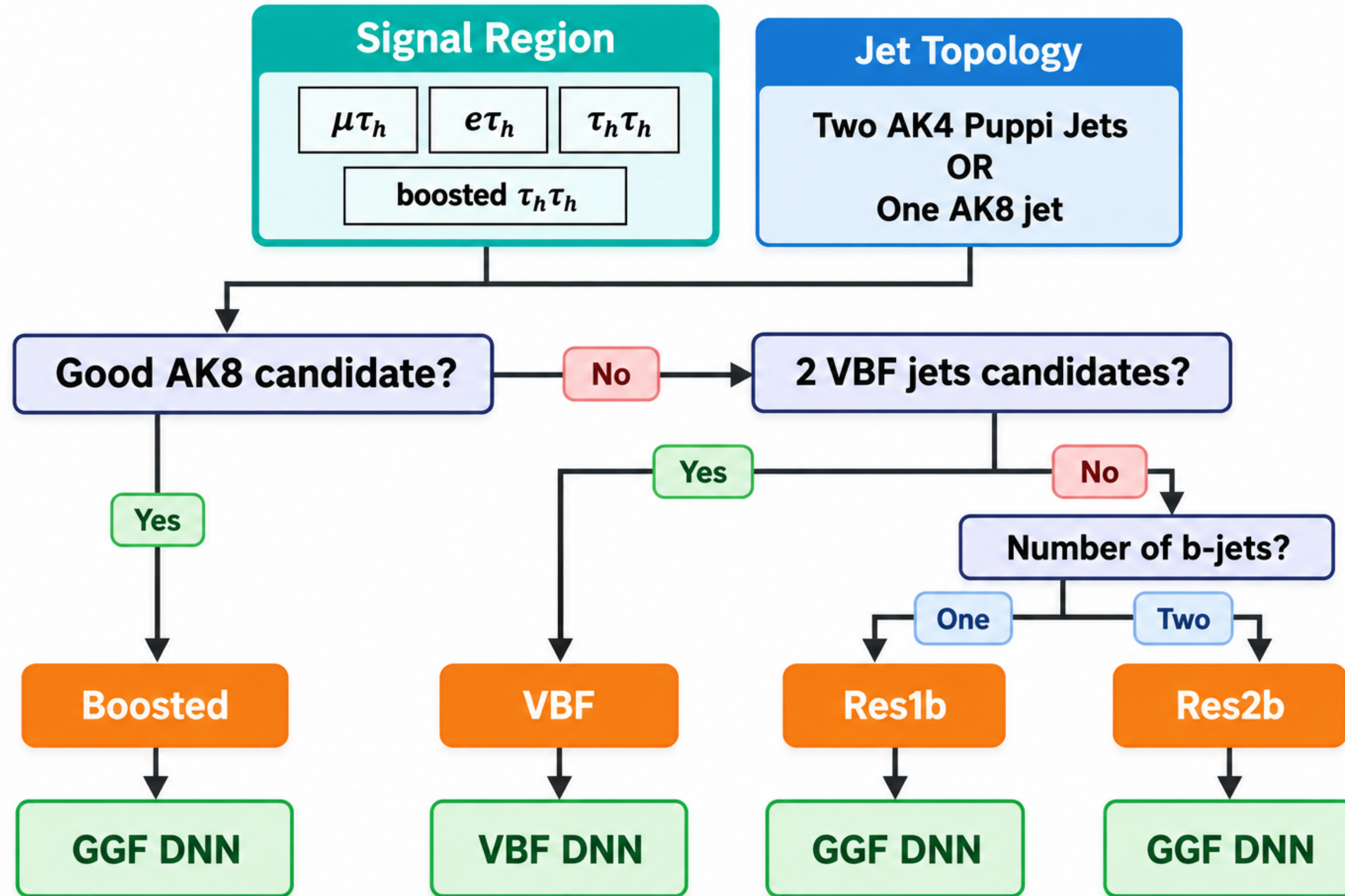
$$\sigma_{HH} < 4.7(2.8) \times \sigma_{HH}^{SM} \quad \text{While,} \quad \sigma_{VBFHH} < 54(80) \times \sigma_{VBFHH}^{SM}$$

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 constraints 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 $bb\gamma\gamma$ and $bb\tau\tau$

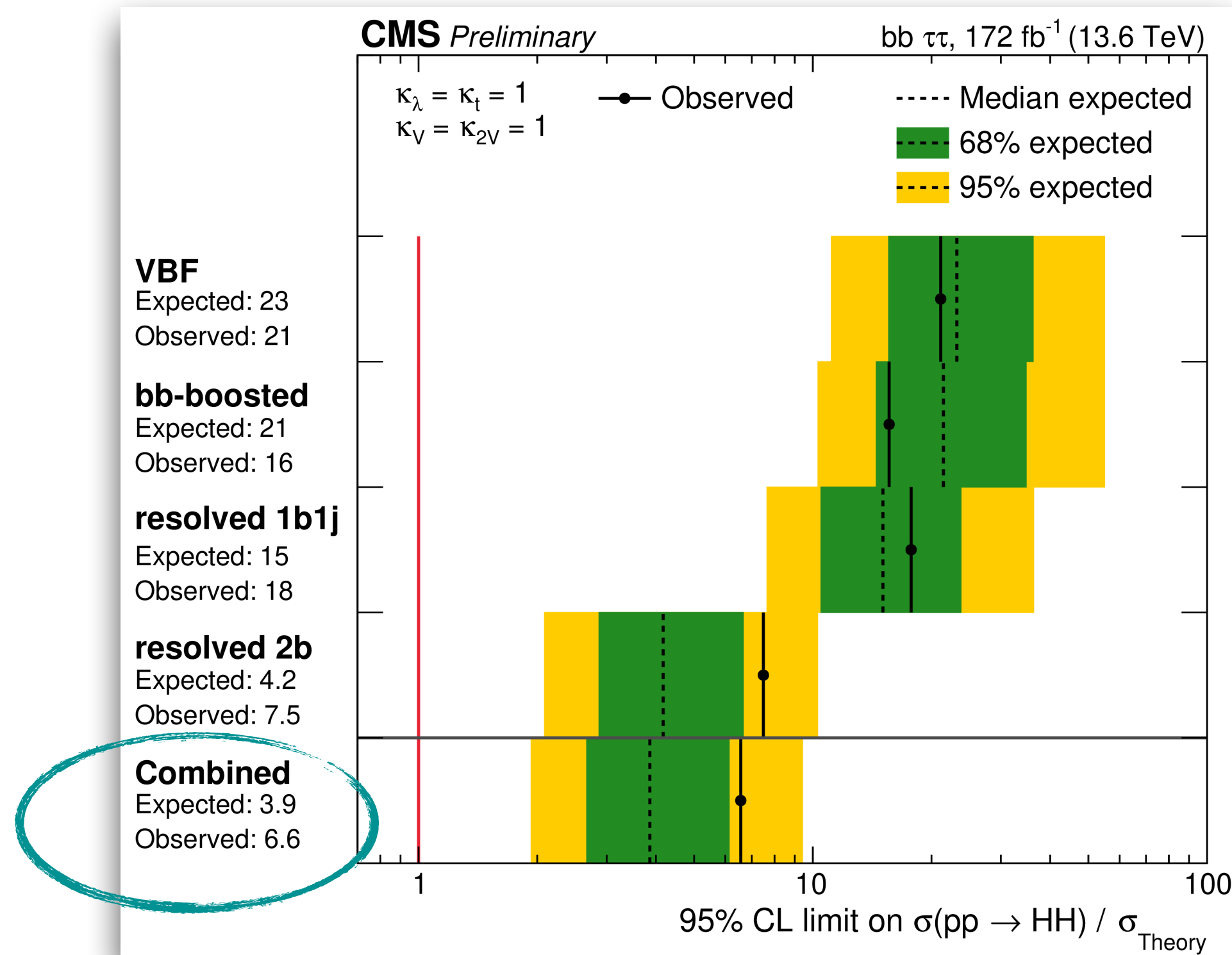


HH $\rightarrow$ $b\bar{b}\tau\tau$: Results from Run 3

CMS-PAS-HIG-25-008

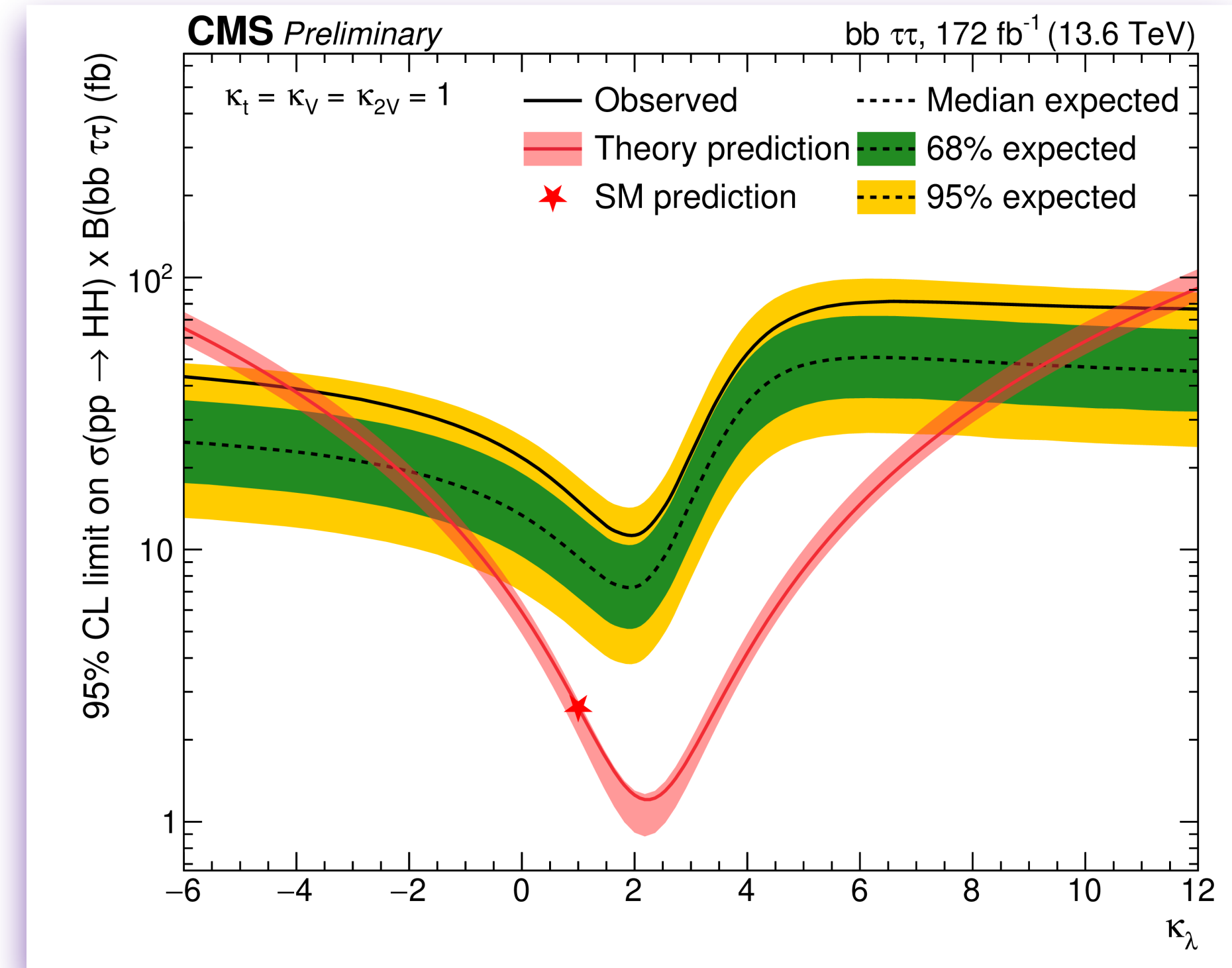


Combining the resolved & merged 22-23 analyses:



Observed (expected) UL @95% CL:

$$\sigma_{HH} < 3.9(6.6) \times \sigma_{HH}^{\text{SM}} \quad \text{While, } \sigma_{\text{VBF}HH} < 85(81) \times \sigma_{\text{VBF}HH}^{\text{SM}}$$



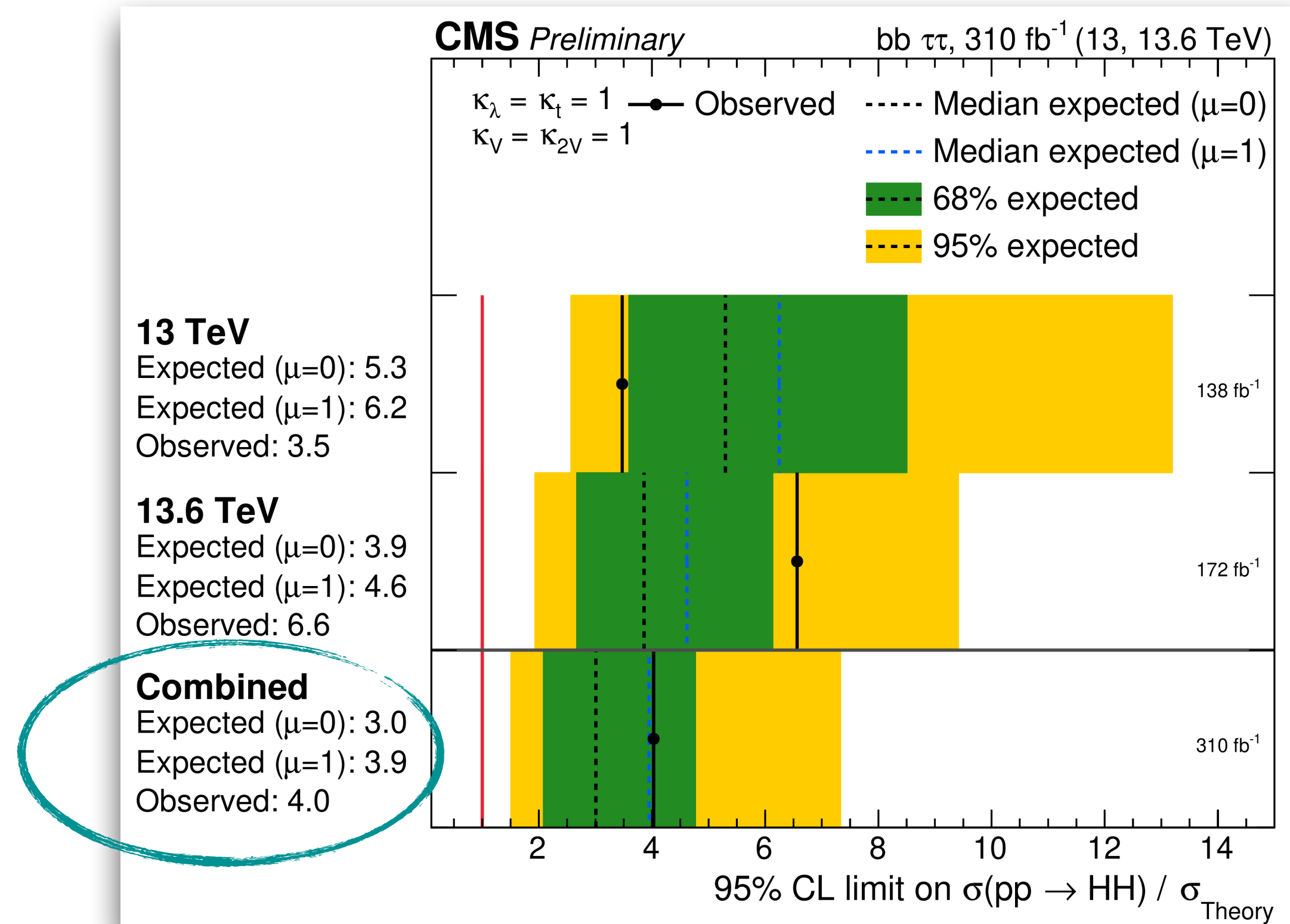
95% CL constraints on the coupling modifiers:

$$\kappa_\lambda \in [-4.1, 11.2] \quad ([-2.2, 9.2])$$

The Run 3 HH $\rightarrow$ $b\bar{b}\tau\tau$ results is almost 20% better compared to the published Run 2 results ([Phys. Lett. B 842 \(2023\) 137531](#))

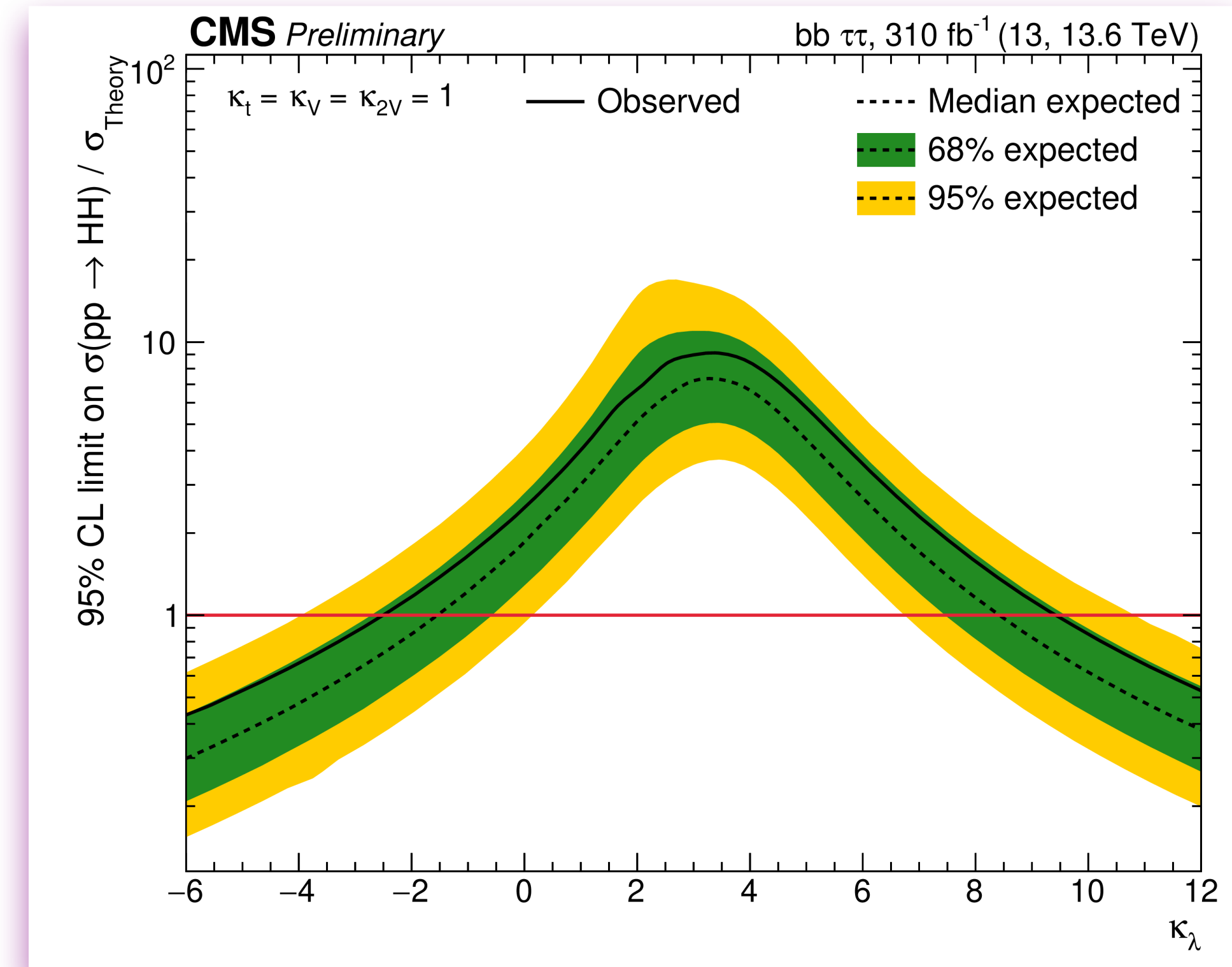
HH $\rightarrow$ $b\bar{b}\tau\tau$: Combination with Run 2 dataset

CMS-PAS-HIG-25-008



Observed (expected) UL @95% CL:

$$\sigma_{HH} < 4.40(3.9) \times \sigma_{HH}^{\text{SM}} \quad \text{While, } \sigma_{\text{VBFHH}} < 62(70) \times \sigma_{\text{VBFHH}}^{\text{SM}}$$



95% CL constraints on the coupling modifiers:

$$\kappa_\lambda \in [-2.5, 9.4] \quad ([-1.5, 8.4]) \quad \kappa_{2V} \in [0.02, 2.1] \quad ([-0.1, 2.2])$$