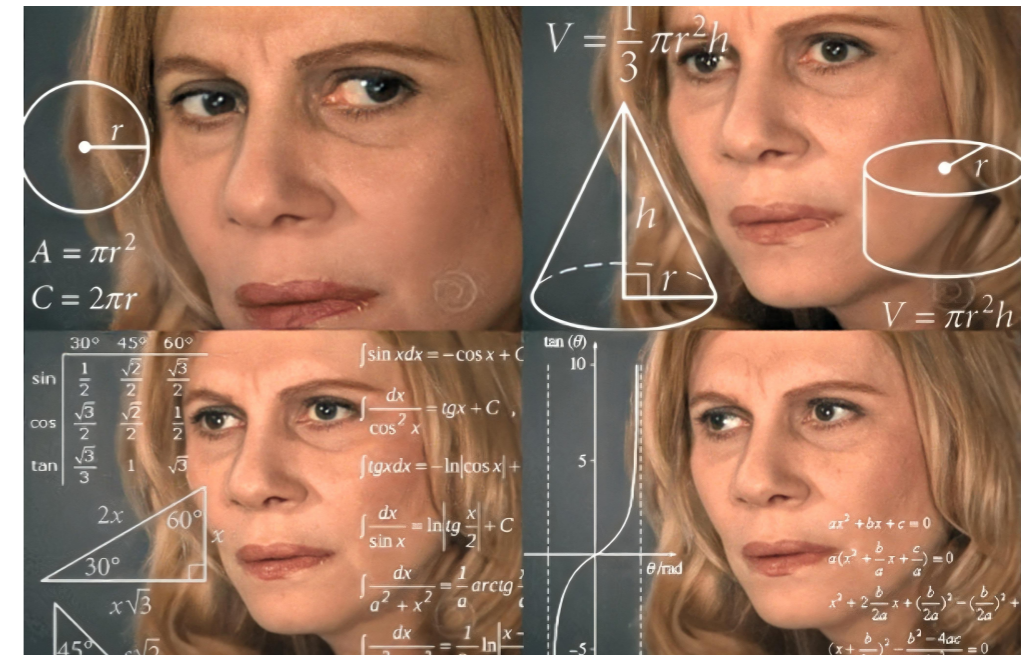


# Simplified template and differential cross section measurements at CMS, fermionic channels

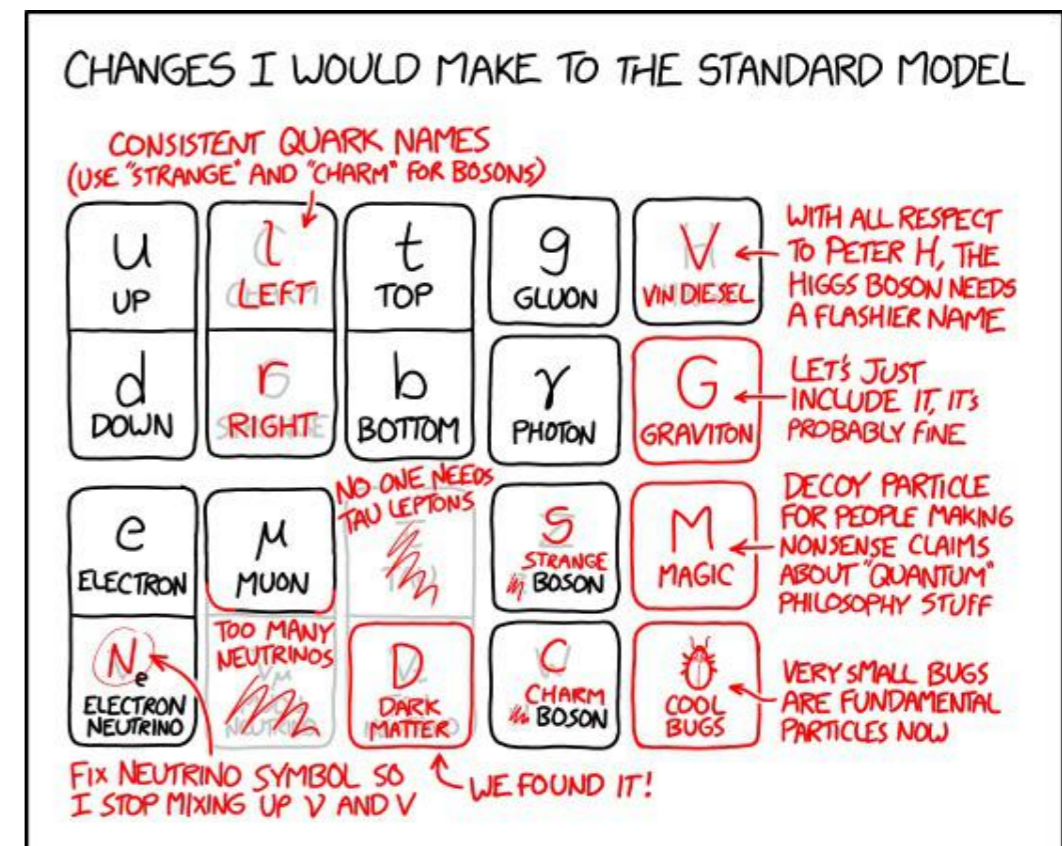
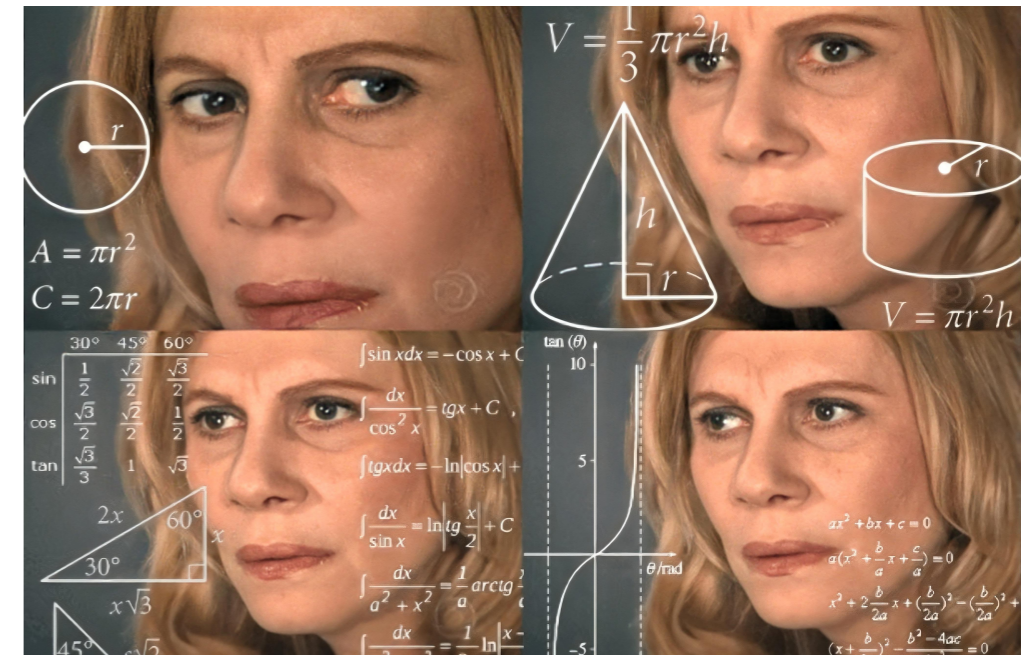
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S. Gennai on behalf of the CMS Collaboration

- Fiducial cross sections minimize the extrapolation uncertainty
  - between the reconstructed (experimental) phase space and the theoretical computation



- Fiducial cross sections minimize the extrapolation uncertainty
  - between the reconstructed (experimental) phase space and the theoretical computation
  
- Differential cross section probes more aspects of the theory than just a single number
  - More helpful for probing BSM theories, for example
  
- STXS bins reduce the theoretical uncertainties and provide a common framework to ease the combination of several measurements

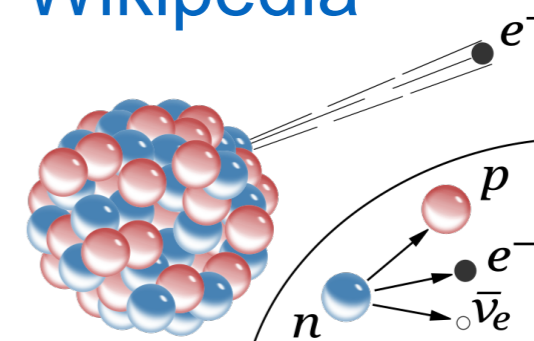




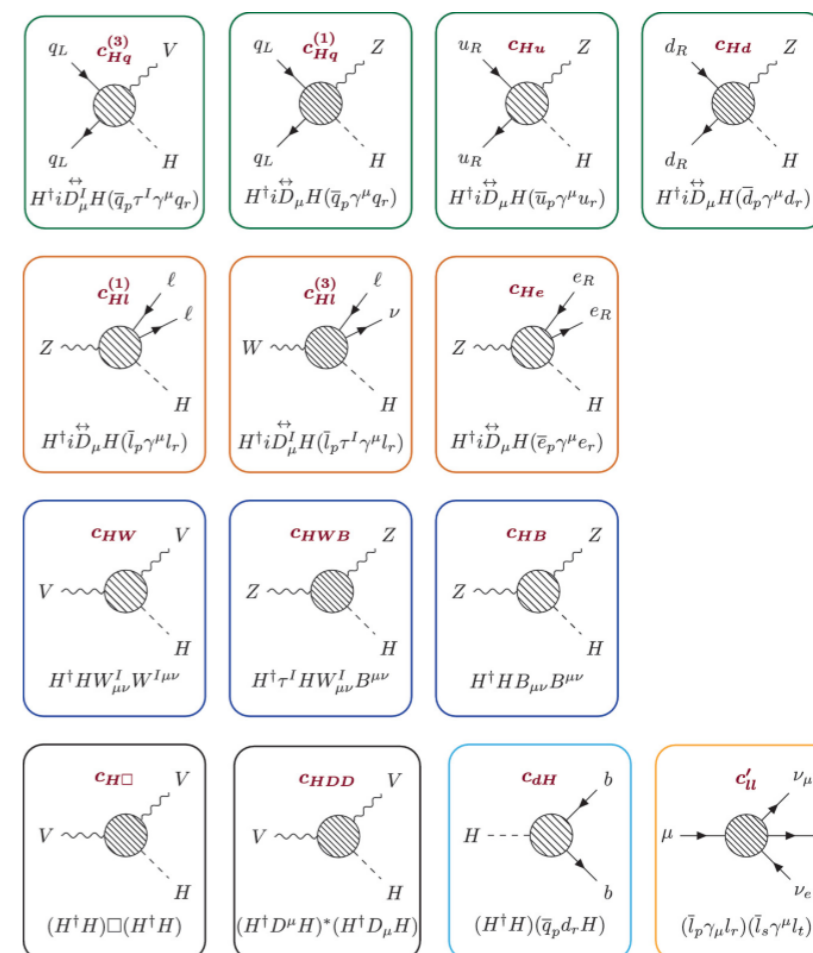
# Effective Field Theory

- A model independent approach to study contributions from beyond the SM theories
  - The, maybe, most famous example of EFT is the beta decay model by Fermi
- It is gaining more and more importance in our analysis and their combinations
- Not all the operators are considered, only those affecting the main observables of the final state are constrained

Wikipedia



$$\mathcal{L}_{\text{EFT}} = \mathcal{L}_{\text{SM}} + \sum_i \frac{c_i^{(5)}}{\Lambda} \mathcal{O}_{5,i} + \sum_i \frac{c_i^{(6)}}{\Lambda^2} \mathcal{O}_{6,i} + \dots$$

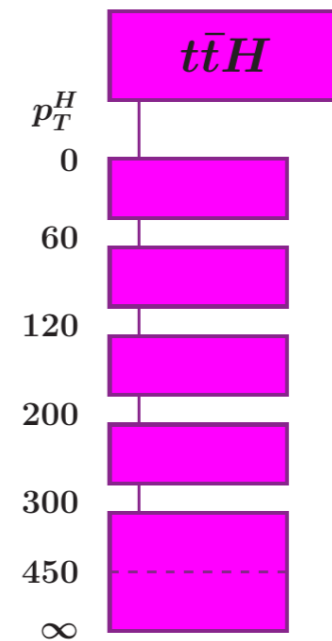
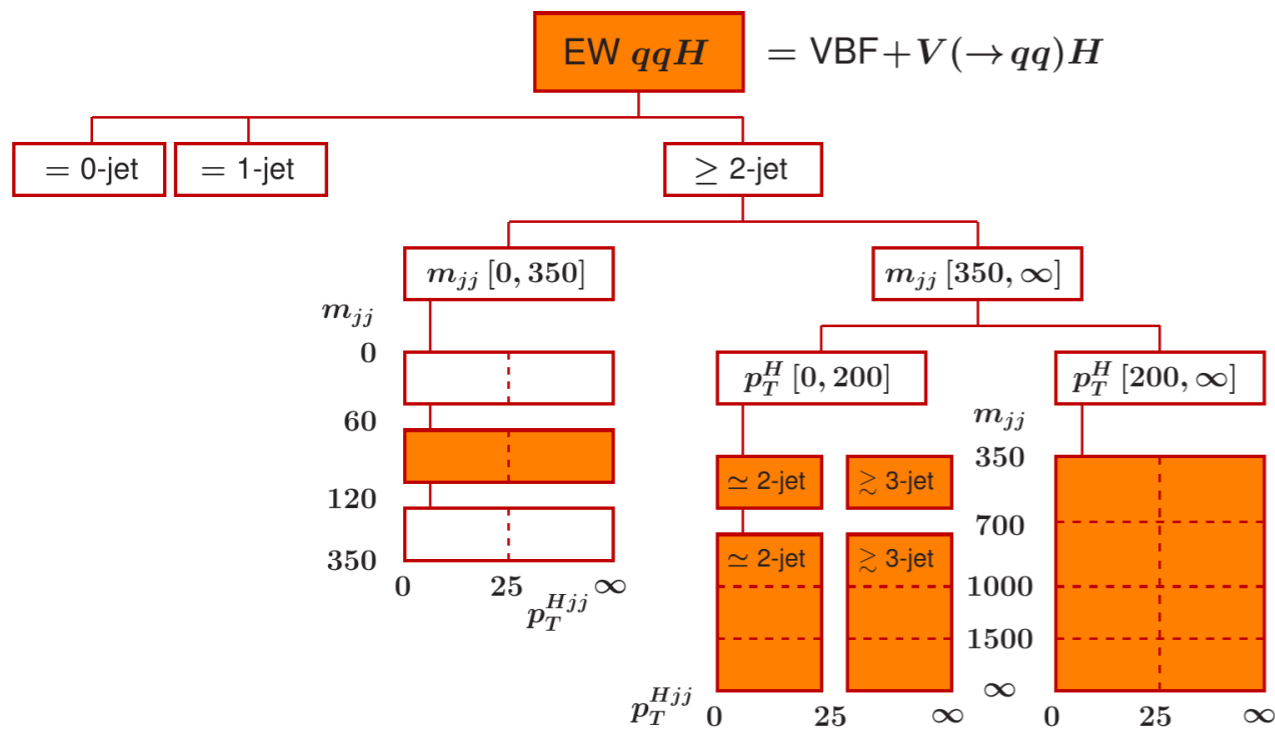
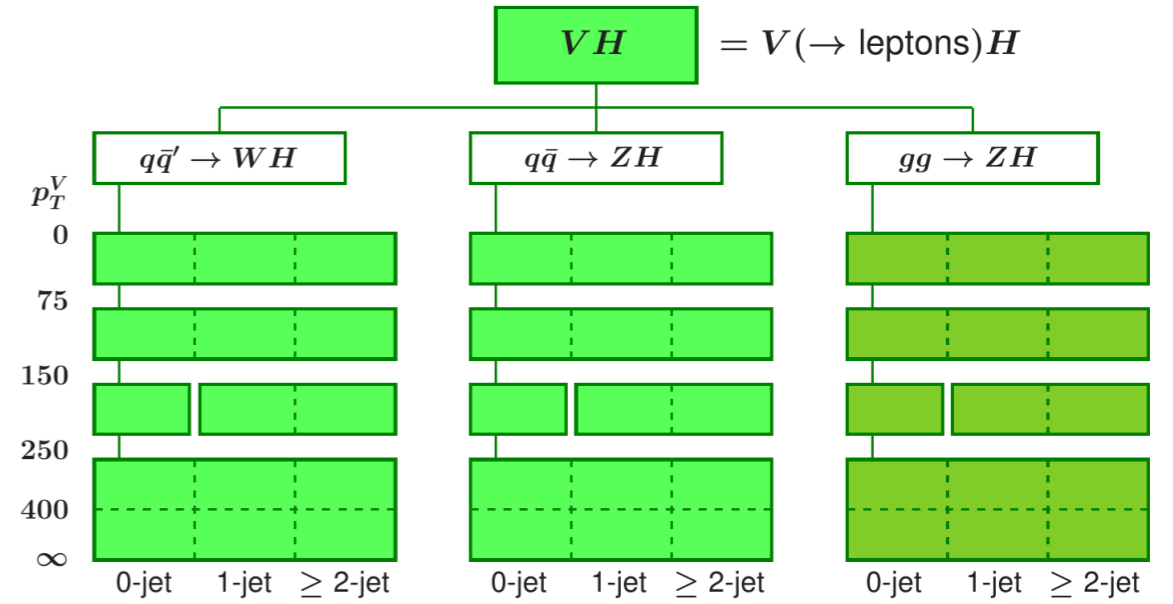
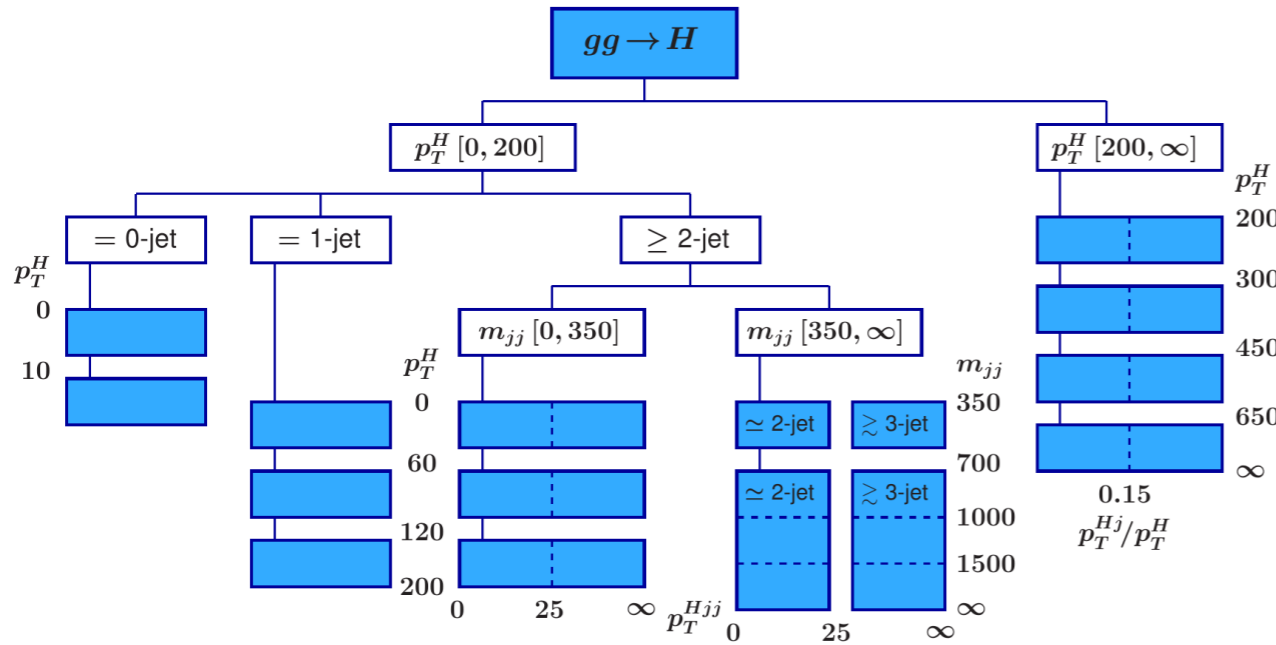


Feynman diagrams from:

Moser, B. (2023). (SM) EFT Interpretation. In: The Beauty and the Boost: A Higgs Boson Tale. Springer Theses. Springer, Cham. [https://doi.org/10.1007/978-3-031-39442-3\\_8](https://doi.org/10.1007/978-3-031-39442-3_8)



# STXS binning v1.2



# STXS mapping

$ggH$

$H \rightarrow \tau\tau$

*Phys. Rev. Lett.* 128 (2022) 081805

*Eur. Phys. J. C* 83 (2023) 562

*Phys. Lett. B* 857 (2024) 138964

$VH$

$H \rightarrow \tau\tau$

*Eur. Phys. J. C* 83 (2023) 562

$H \rightarrow bb$

*Phys. Rev. D* 109 (2024) 092011

$VBF H$

$H \rightarrow \tau\tau$

*Eur. Phys. J. C* 83 (2023) 562

$H \rightarrow bb$

*arXiv:2407.08012 submitted to JHEP*

*CMS-PAS-HIG-23-016*

$t/tt H$

$Z/H \rightarrow bb$

*Phys. Rev. D* 108 (2023) 032008

$H \rightarrow bb$

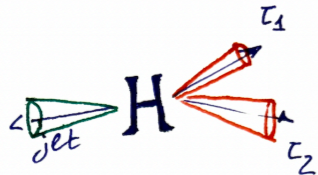
*arXiv:2407.10896 submitted to JHEP*

$H \rightarrow$  multi leptons

(See dedicated talk in agenda)

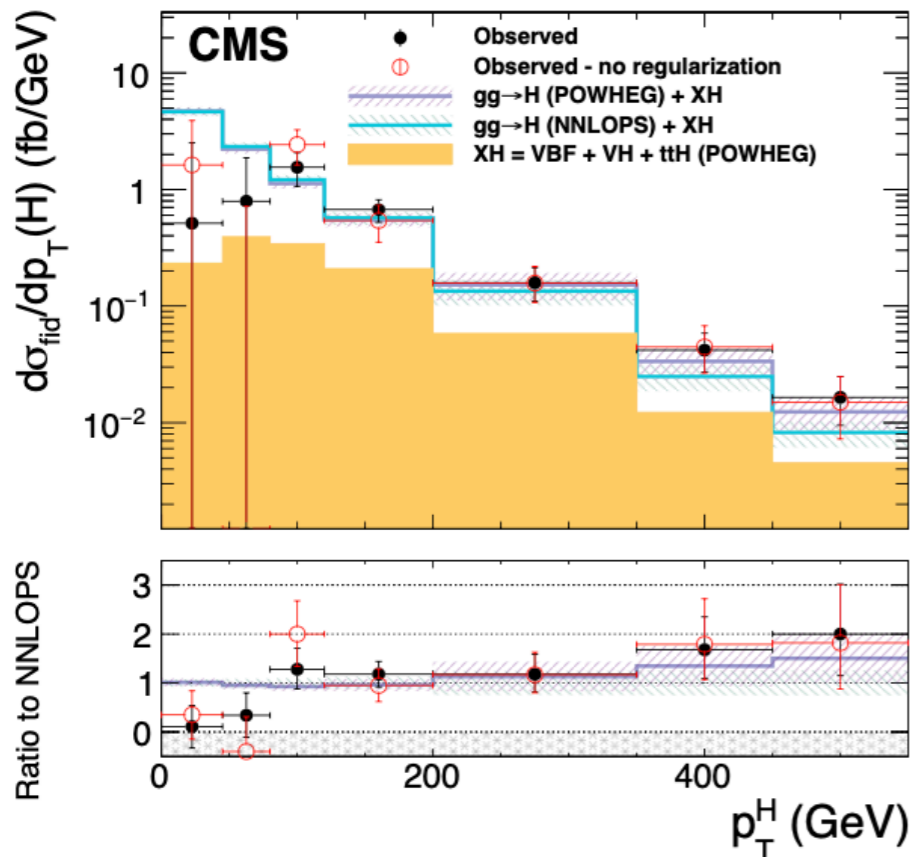
# H $\rightarrow$ $\tau\tau$ vs Higgs $p_T$

- Differential cross section vs Higgs  $p_T$ 
  - Two different regimes: resolved and boosted taus
  - One of the first applications of boosted tau ID developed to recover efficiency at large boost



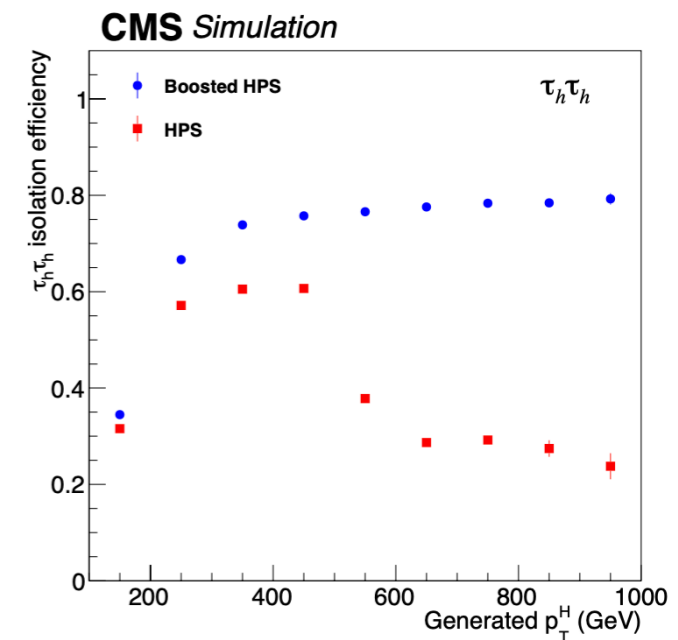
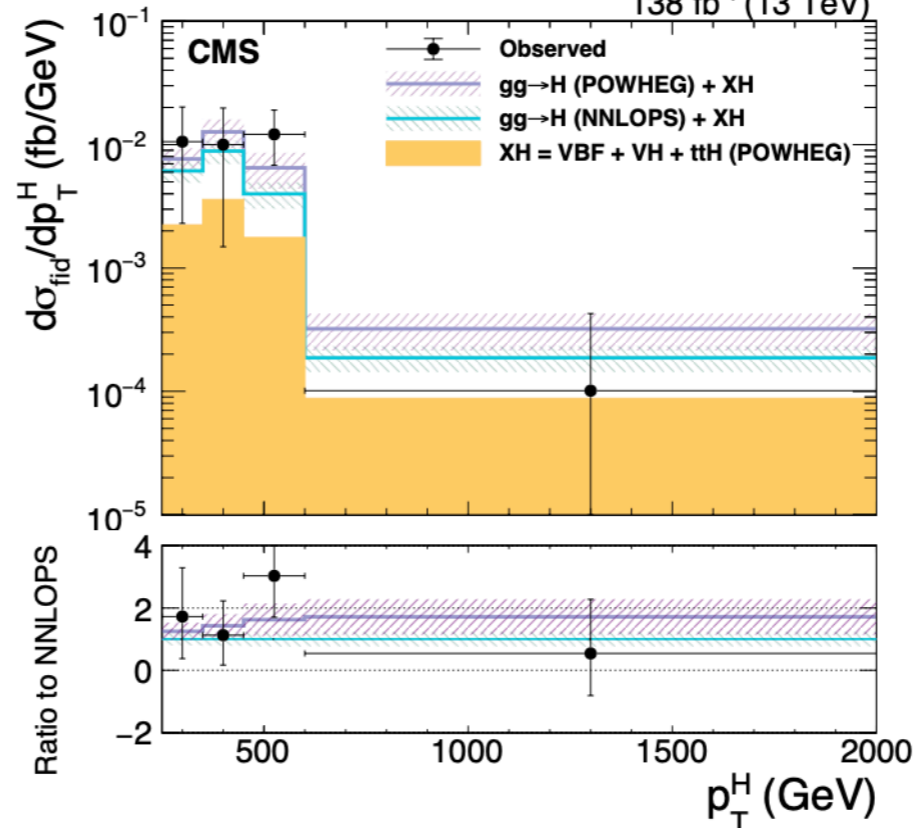
*Phys. Rev. Lett.* 128 (2022) 081805

138 fb<sup>-1</sup> (13 TeV)



*Phys. Lett. B* 857 (2024) 138964

138 fb<sup>-1</sup> (13 TeV)

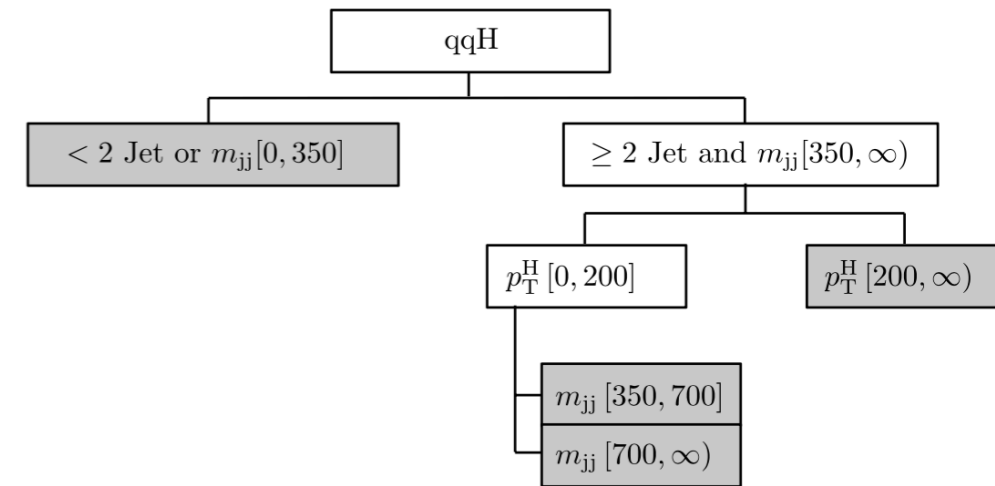
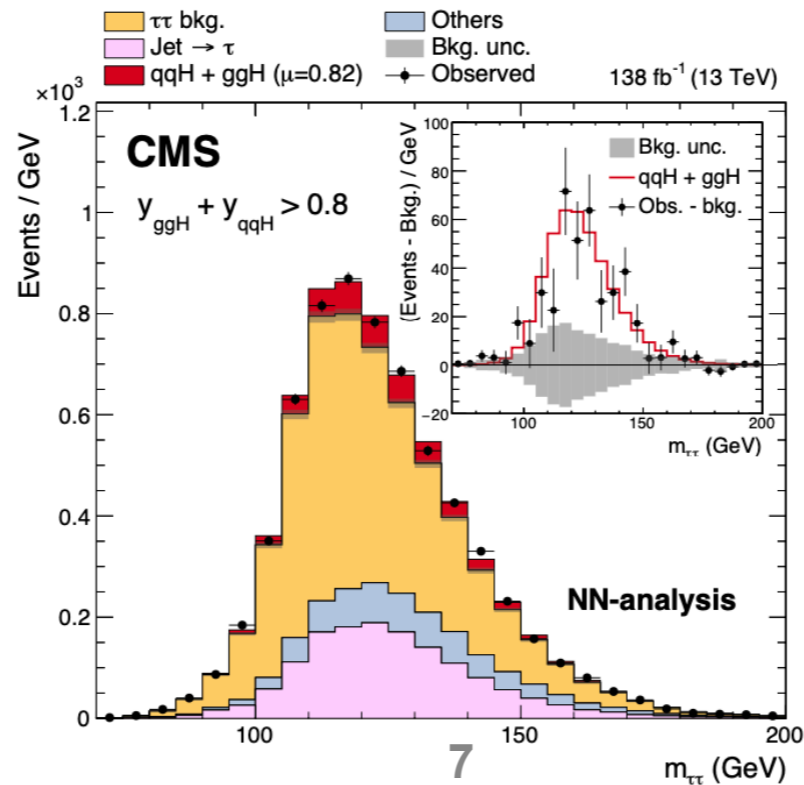
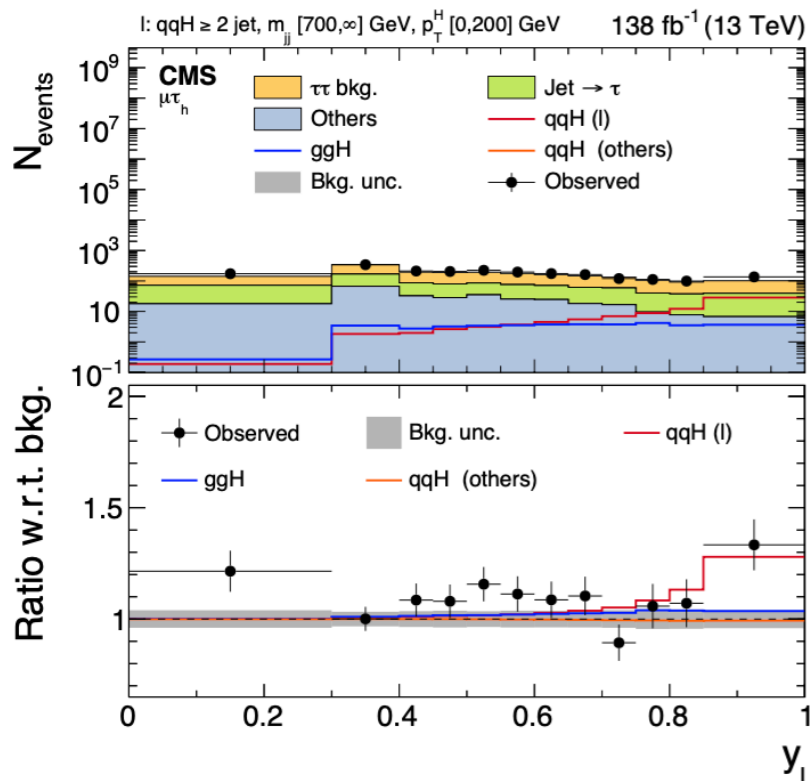
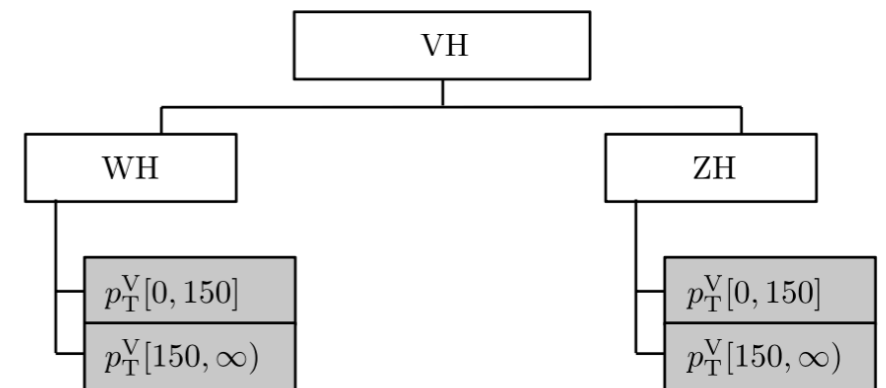
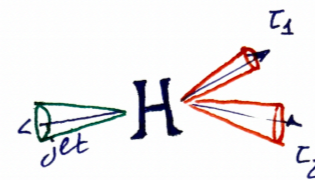
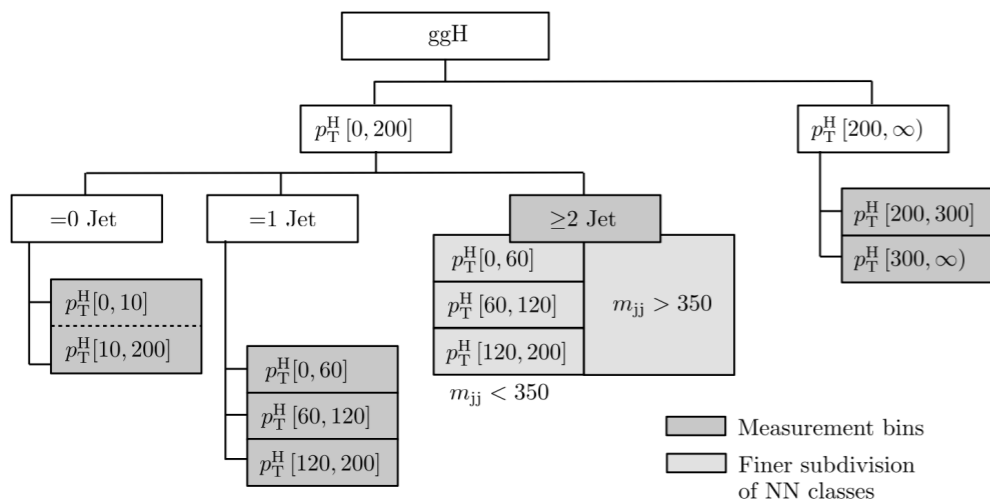




# H $\rightarrow$ $\tau\tau$ STXS measurements

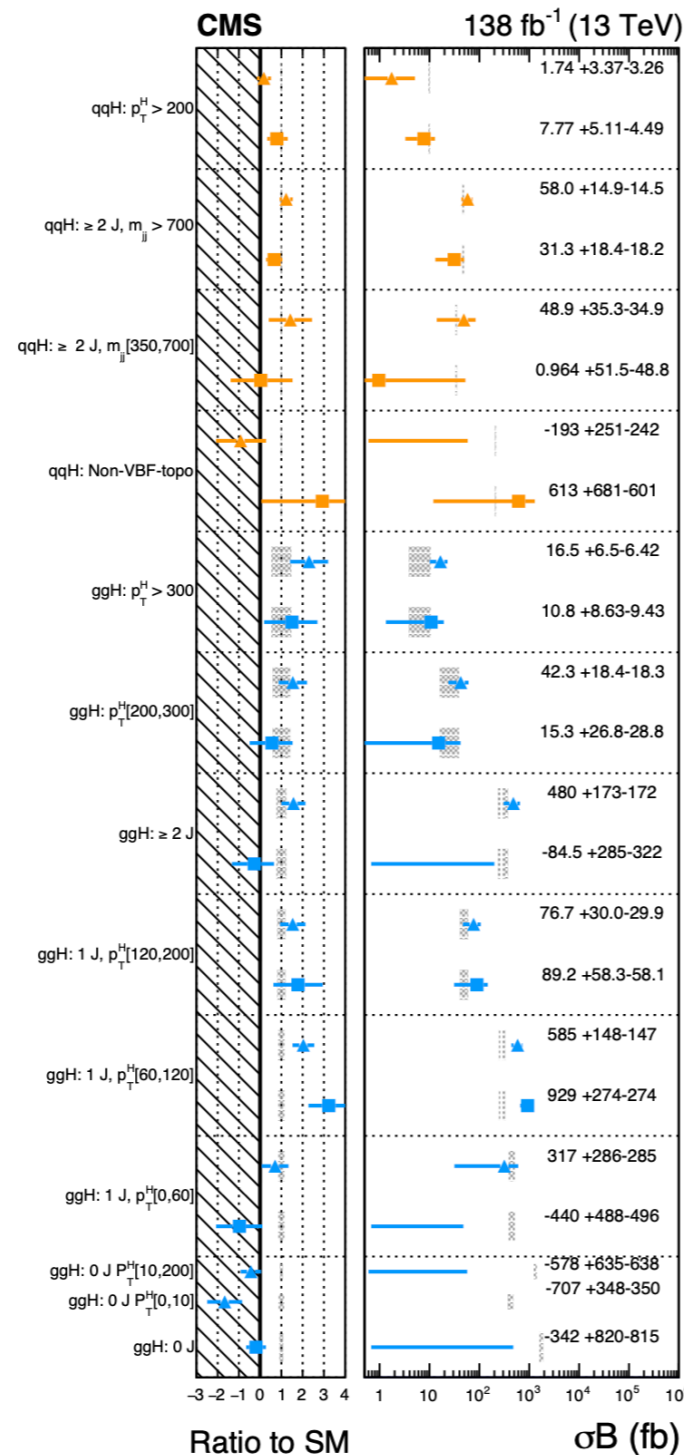
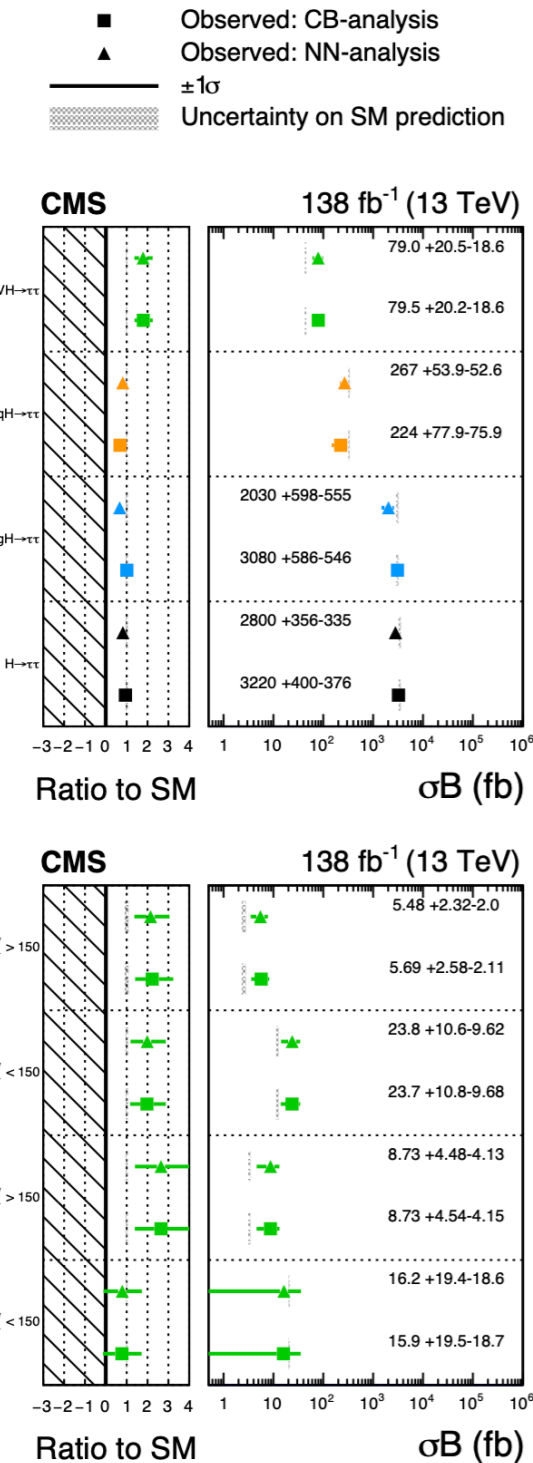
- Full NN based analysis showing superior performance wrt a cut based approach
  - Possibility to check the correlation between analysis categories
- Inference based on the output of classes in the final layer of the NN

Eur. Phys. J. C 83 (2023) 562

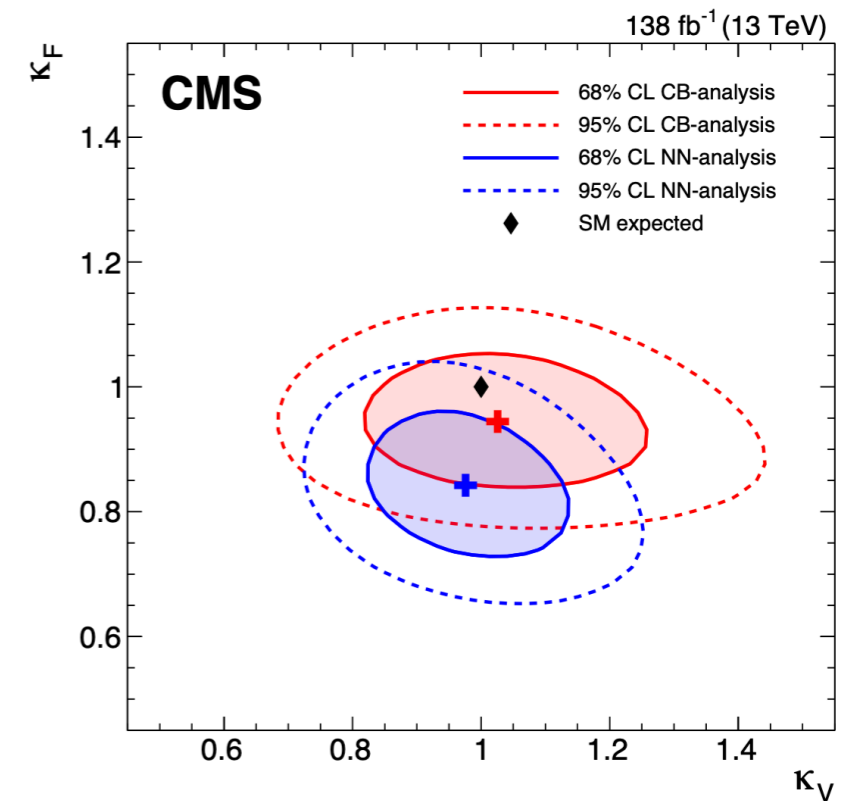


# H $\rightarrow$ $\tau\tau$ STXS measurements

Eur. Phys. J. C 83 (2023) 562



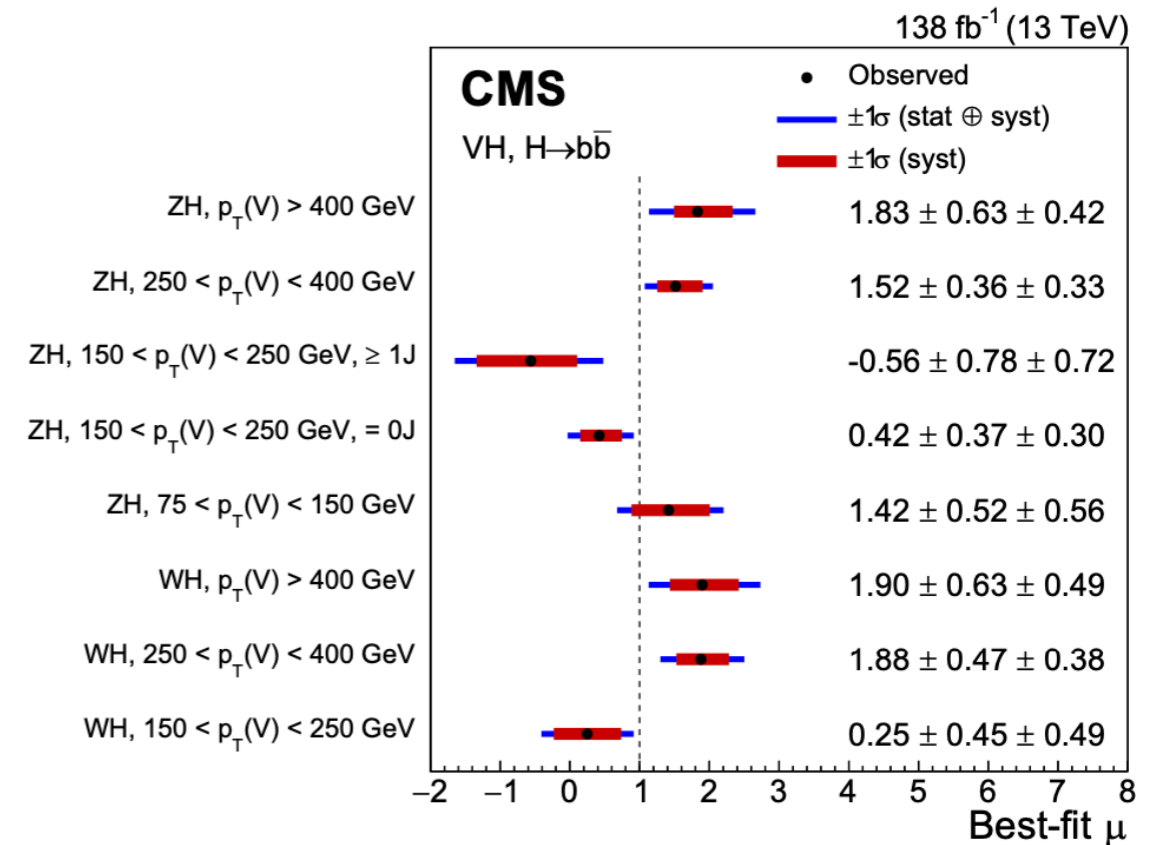
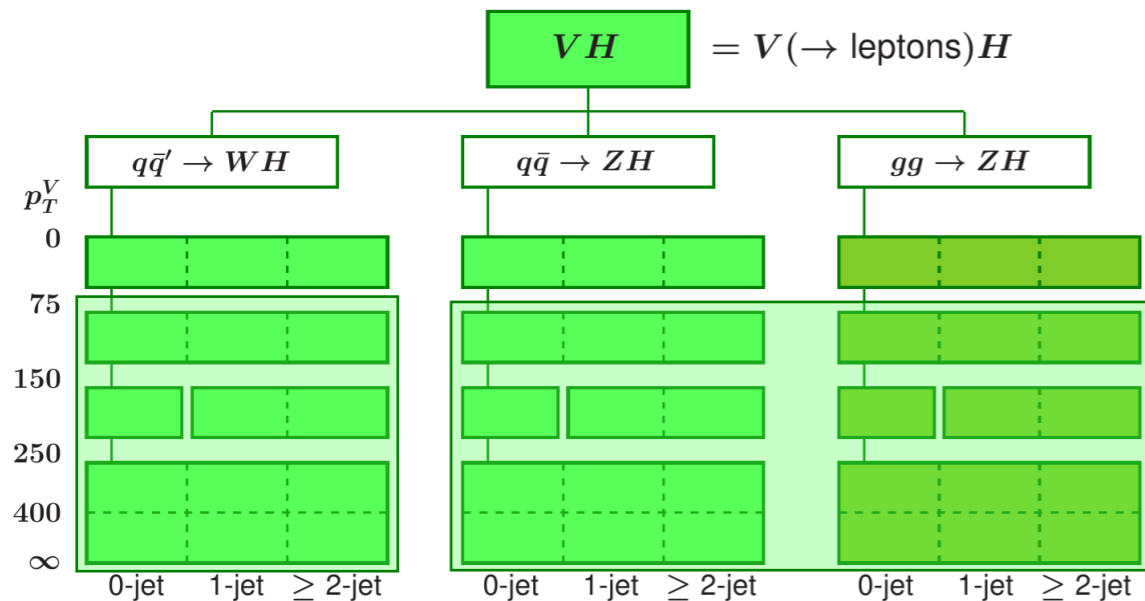
Perfect compatibility between cut based and NN approach  
NN results in smaller uncertainties



# VH $\rightarrow$ bb STXS measurement

- Resolved and boosted categories
  - Optimized taggers for each category
    - 0,1 and 2 leptons final states

*Phys. Rev. D 109 (2024) 092011*

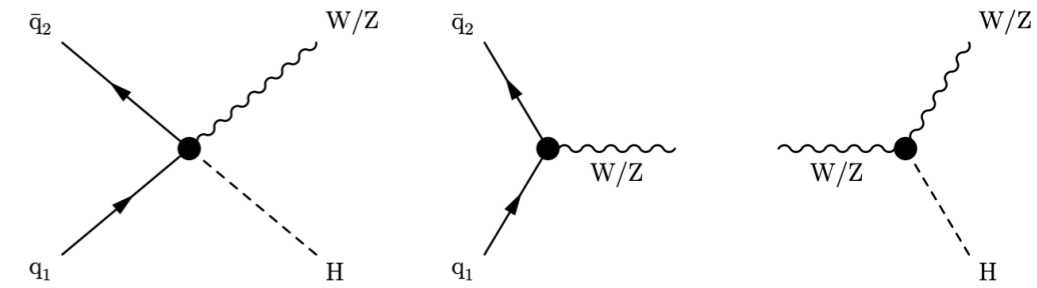
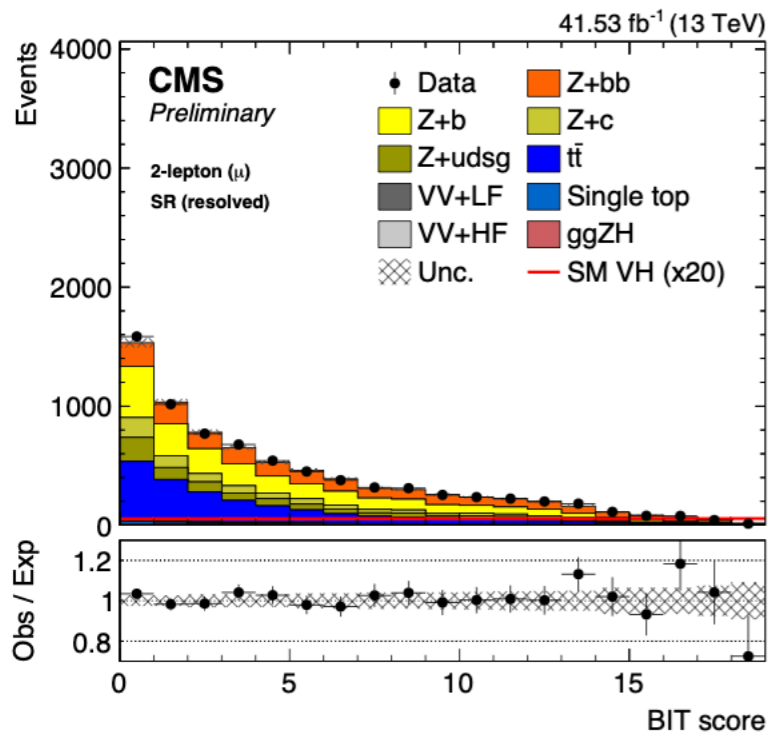
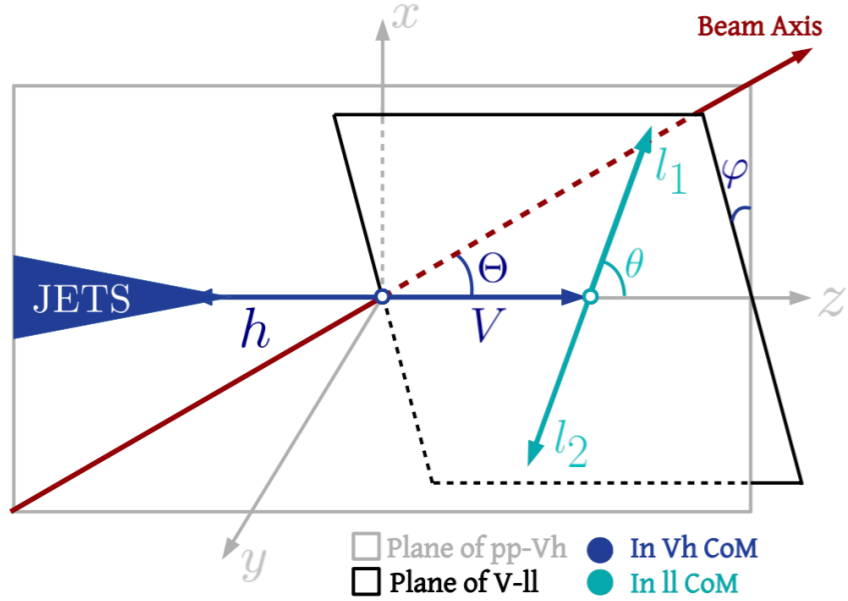




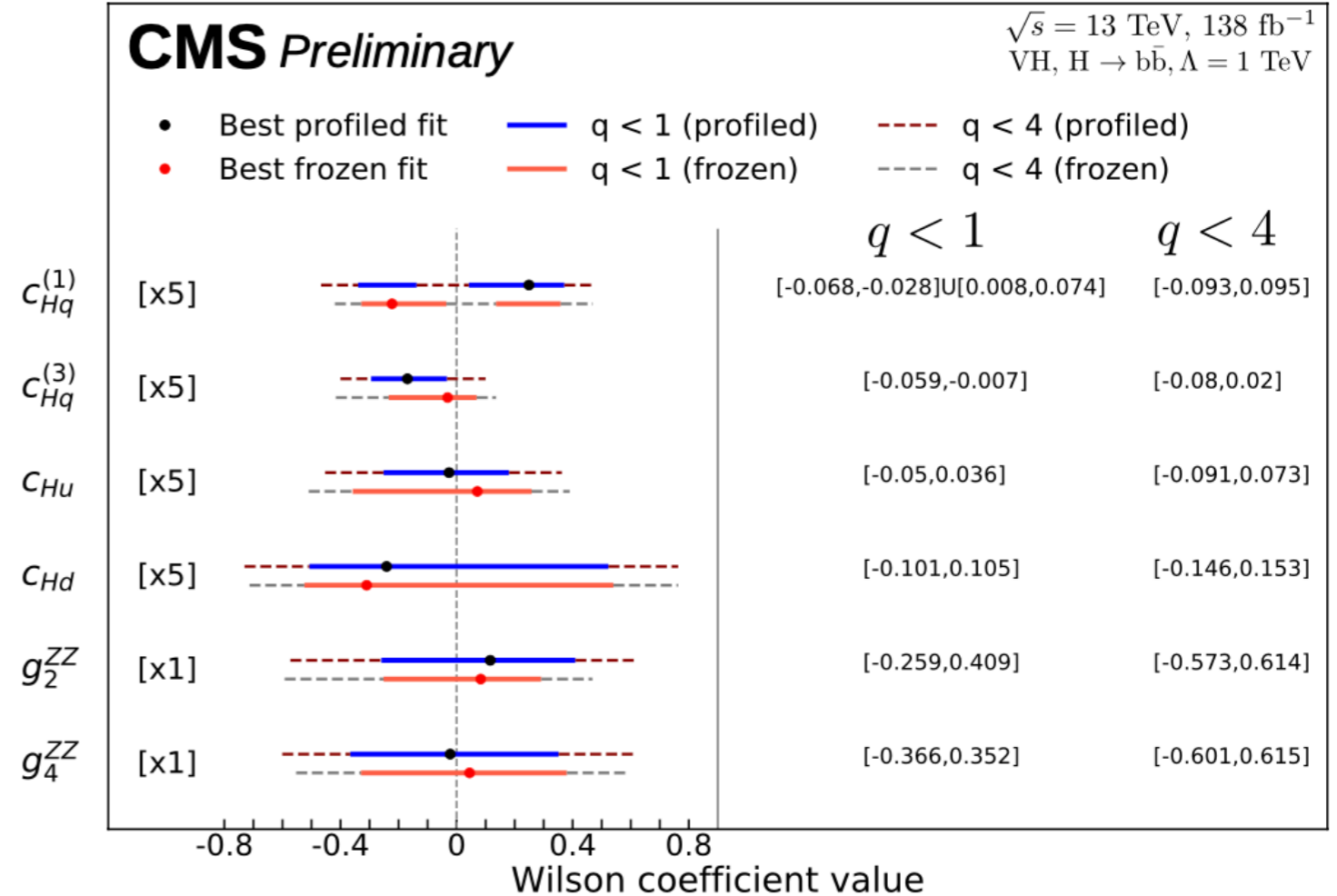
# VH $\rightarrow$ bb EFT interpretation

□ STXS may not provide the best sensitivity for the WC extraction

- VH analysis exploits a Boosted Information Tree to improve the sensitivity
- Resolved and boosted regime



CMS-PAS-HIG-23-016



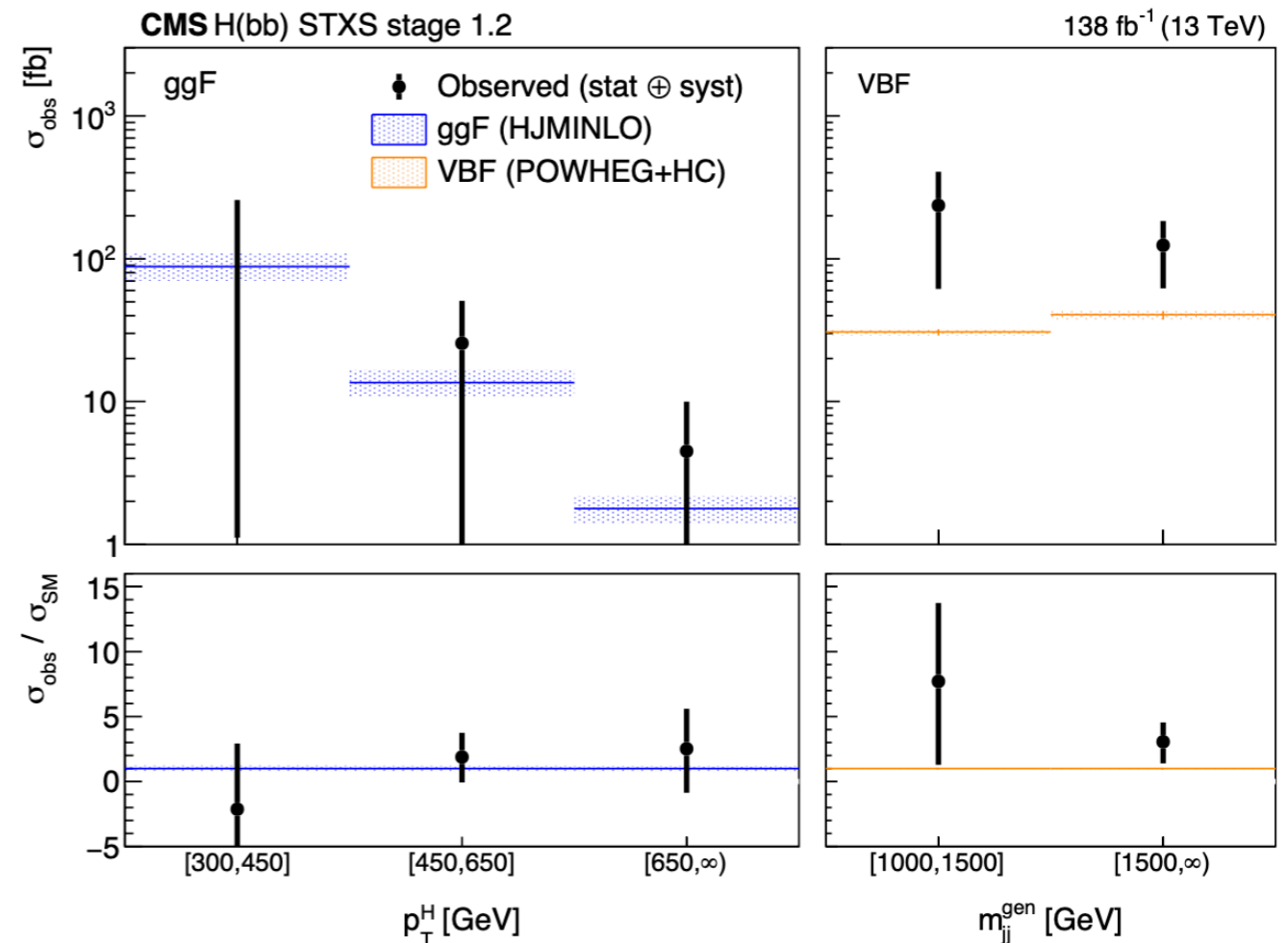
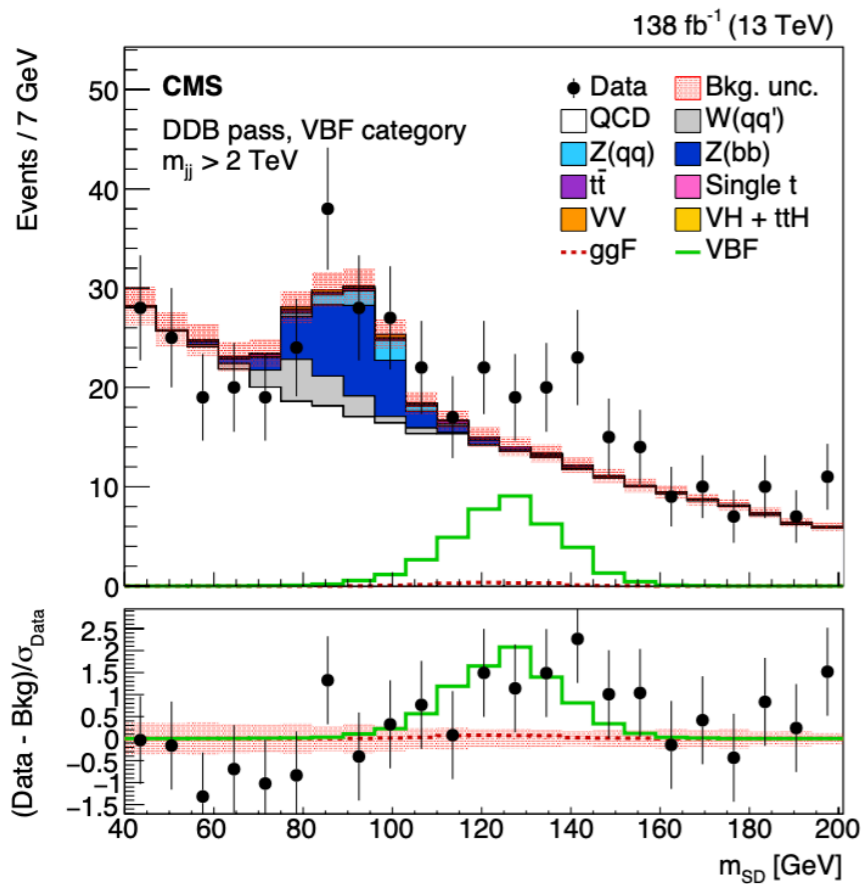
Because the yields in analysis bins have quadratic dependence on the Wilson coefficients, the correct coverage in terms of CL is not guaranteed.

# VBF H $\rightarrow$ bb STXS measurement

## Resolved and boosted categories

- As for the other analysis optimized taggers are use in each category

arXiv:2407.08012 submitted to JHEP



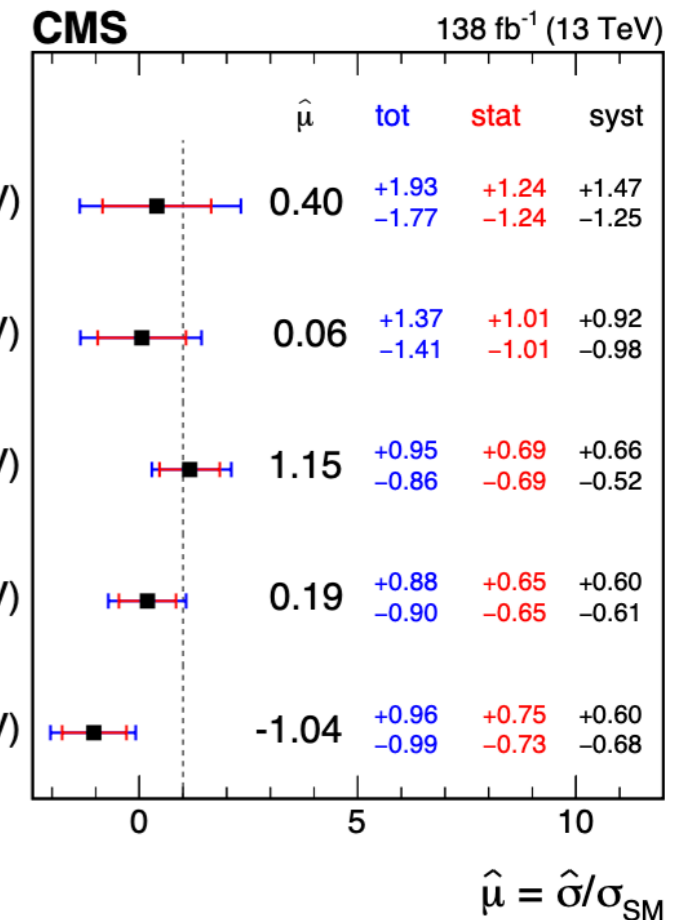
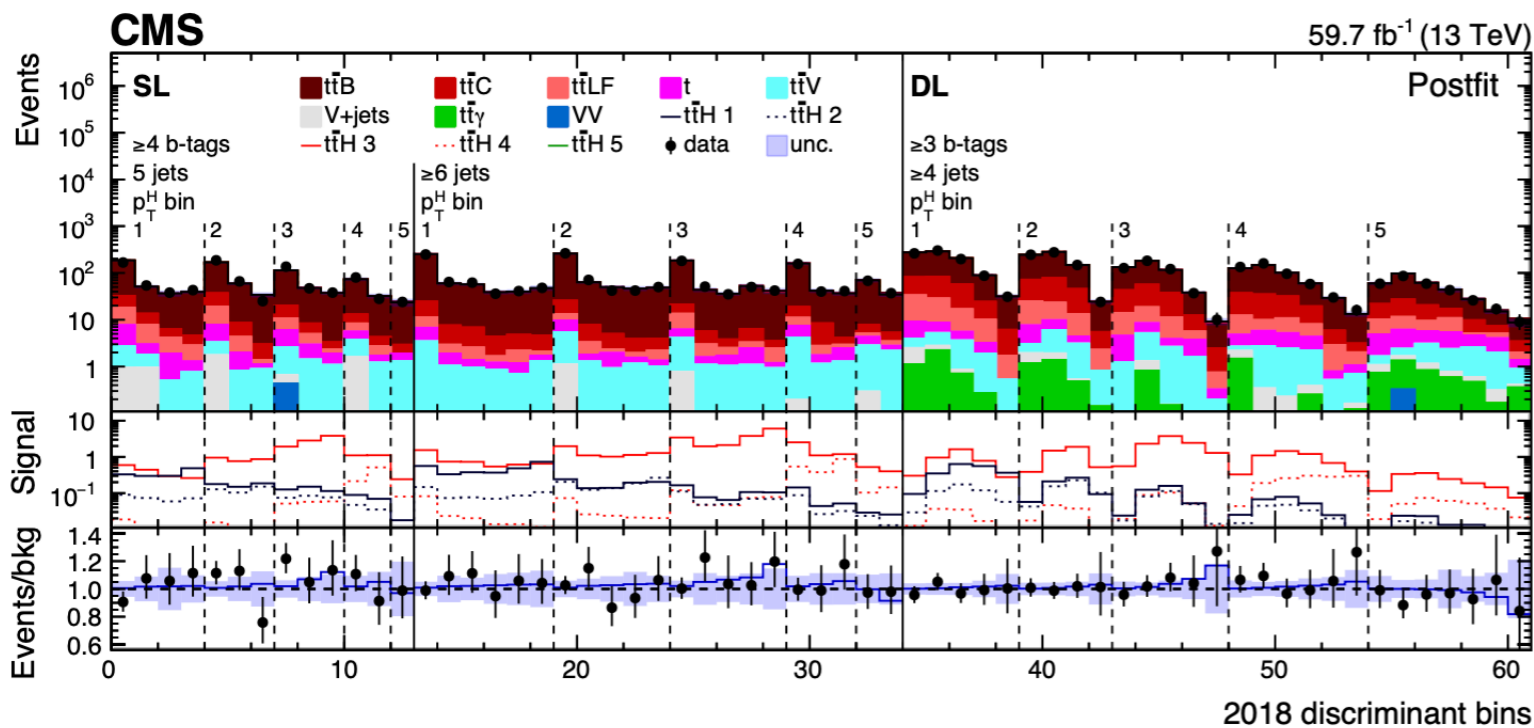
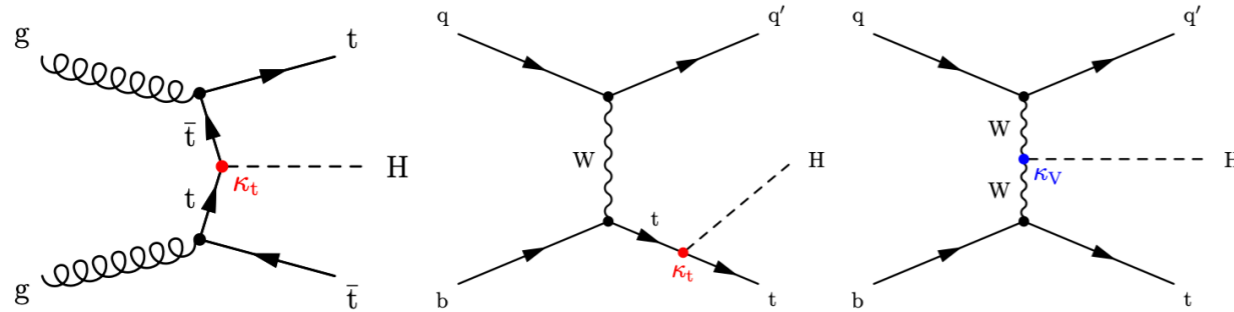
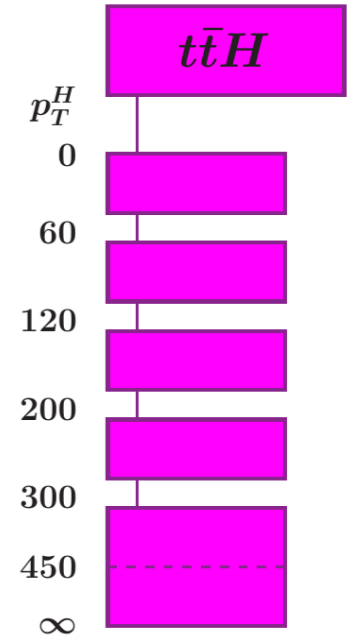
# t/ttH → bb

arXiv:2407.10896 submitted to JHEP

## □ Higgs p<sub>T</sub> STXS bins

□ Di-lepton, single lepton and full hadronic channels

□ Further category splitting according to final state





# t/ttH $\rightarrow$ bb

- Measuring  $\kappa_t$  and  $\kappa_V$  relative sign fitting tH and ttH
  - Probing the CP structure of the top-Higgs interactions

arXiv:2407.10896 submitted to JHEP

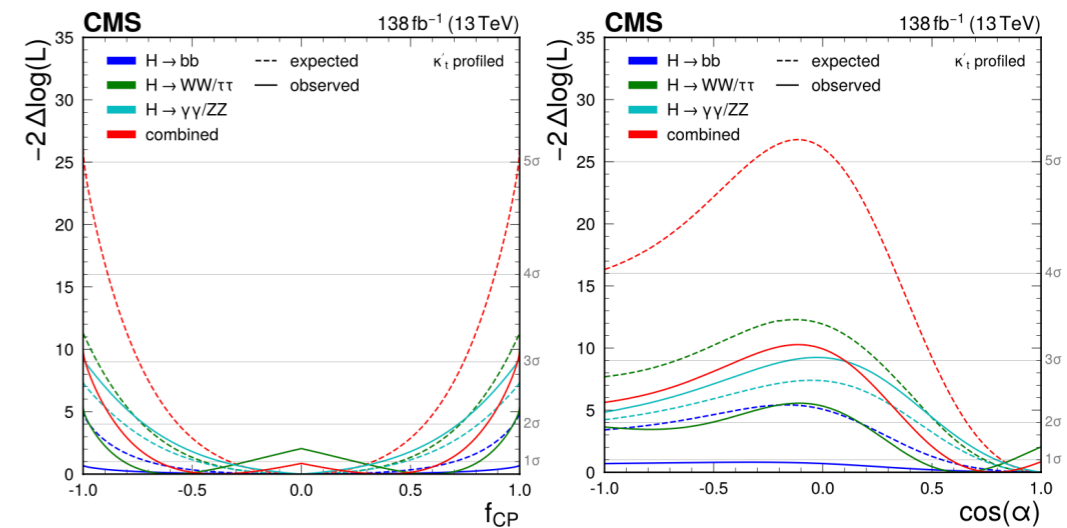
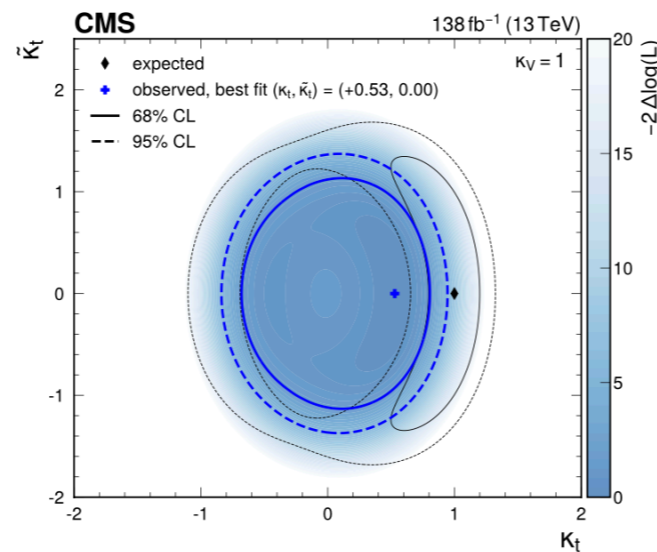
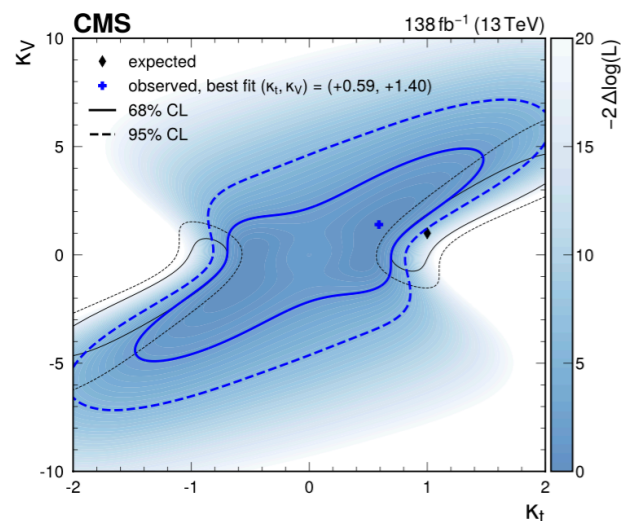
$$\sigma_{tHq} = \left( 2.63\kappa_t^2 + 3.58\kappa_V^2 - 5.21\kappa_t\kappa_V \right) \sigma_{tHq}^{\text{SM}}$$

$$\sigma_{tHW} = \left( 2.91\kappa_t^2 + 2.31\kappa_V^2 - 4.22\kappa_t\kappa_V \right) \sigma_{tHW}^{\text{SM}}$$

$$\mathcal{A}(Ht\bar{t}) = -\frac{m_t}{v} \bar{\psi}_t \left( \kappa_t + i\tilde{\kappa}_t \gamma_5 \right) \psi_t$$

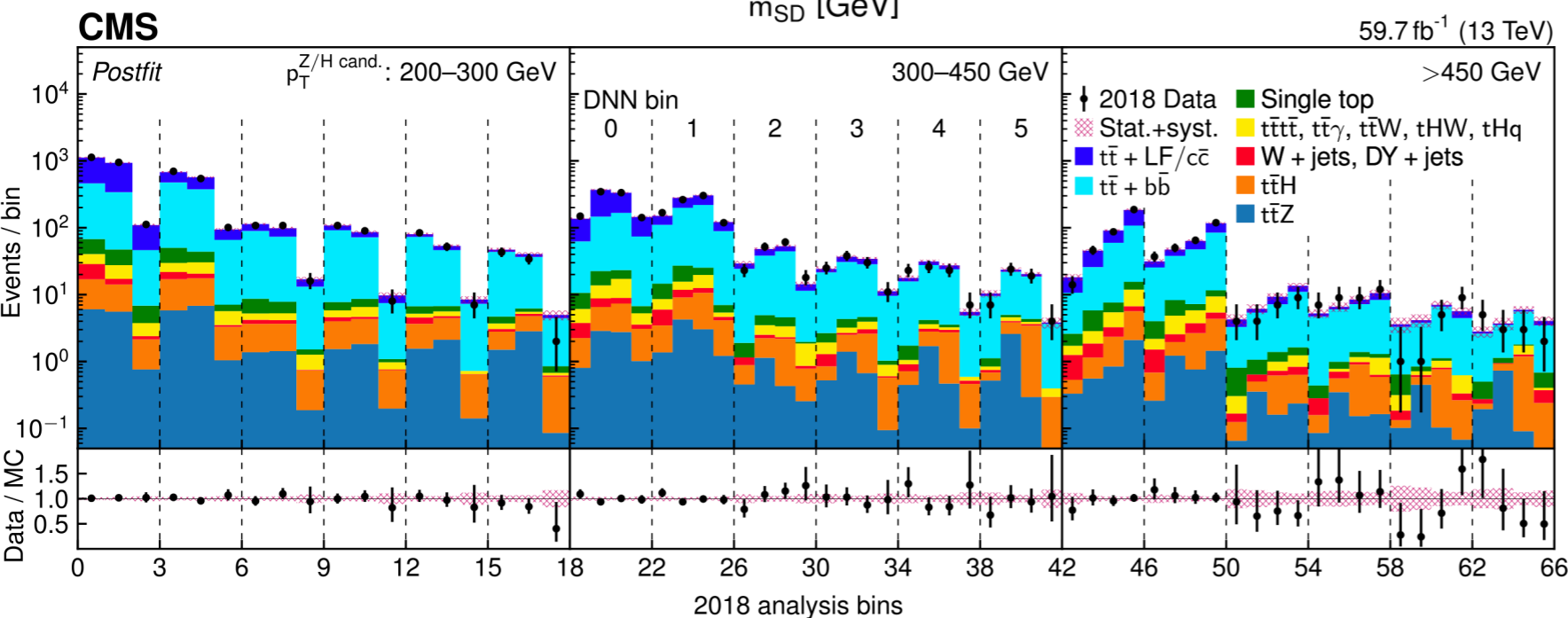
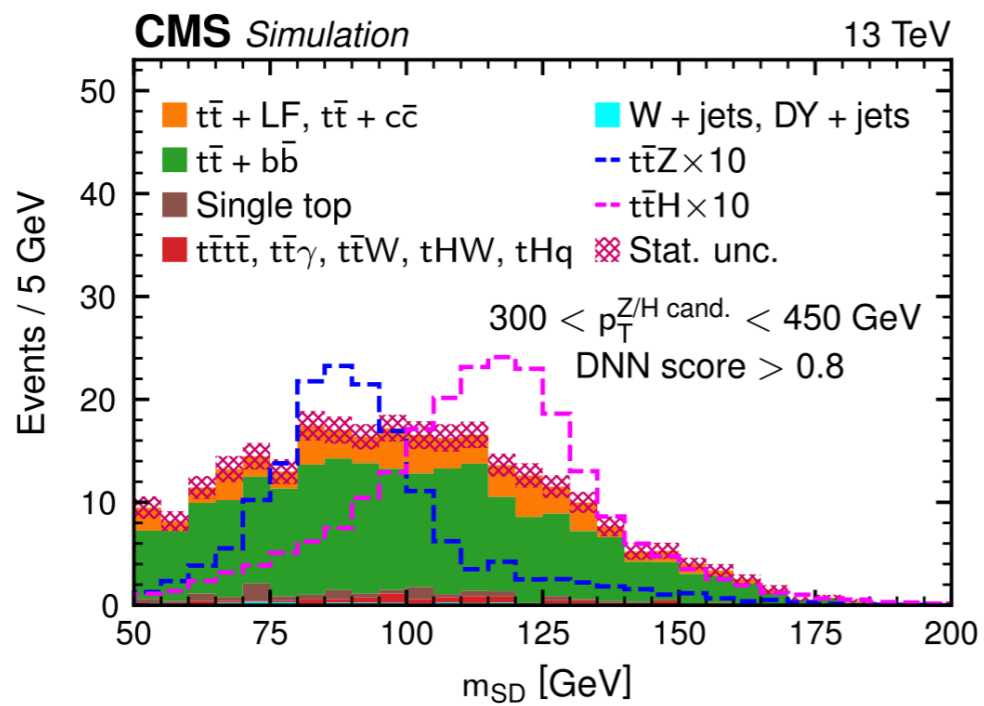
$$f_{\text{CP}} = \frac{\tilde{\kappa}_t^2}{\tilde{\kappa}_t^2 + \kappa_t^2} \text{sign} \left( \tilde{\kappa}_t / \kappa_t \right)$$

$$\cos \alpha = \frac{\kappa_t}{\sqrt{\tilde{\kappa}_t^2 + \kappa_t^2}}$$

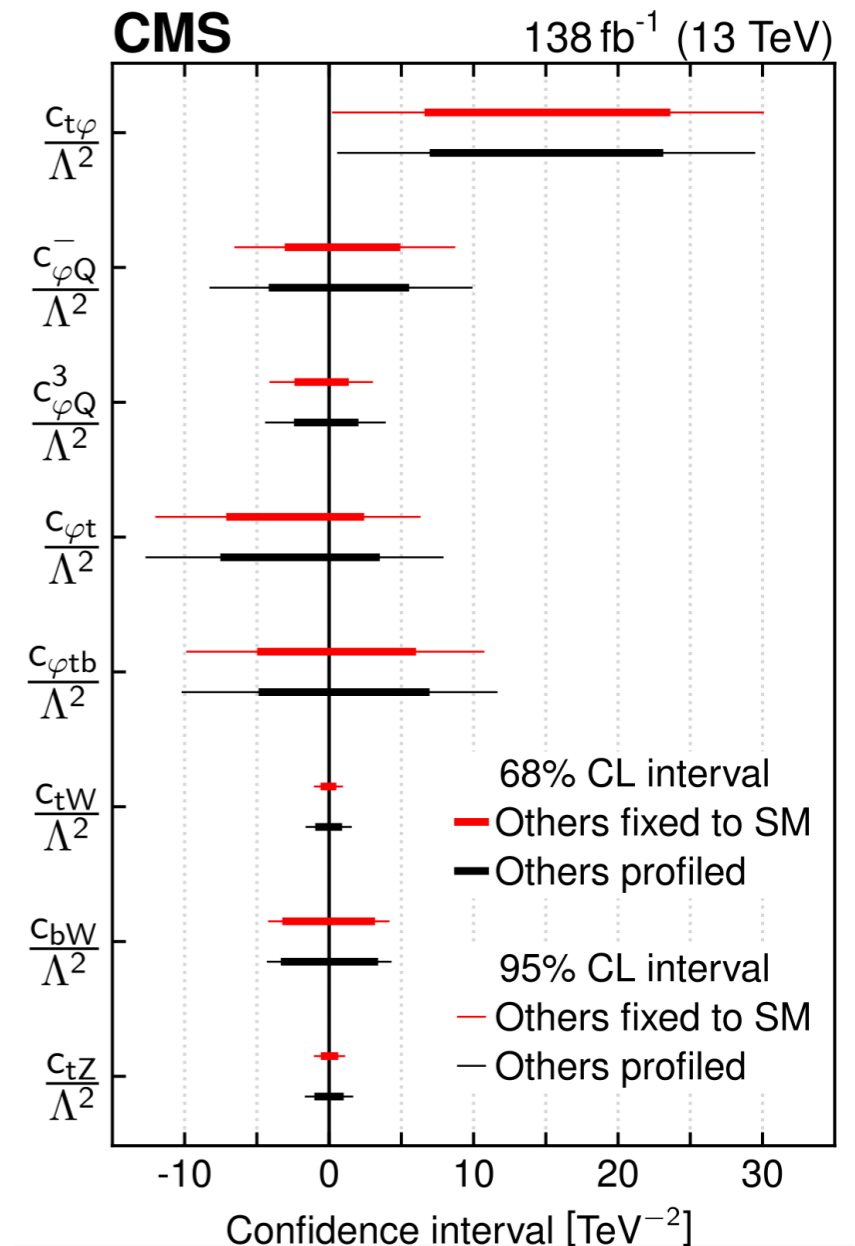


# $ttZ/H \rightarrow bb$

- Multivariate analysis to extract limits on EFT operators
- Rely on DNN score in several categories as well as  $m_{SD}$  to separate Z from H



Phys. Rev. D 108 (2023) 032008



# Conclusions

- Since the discovery of the Higgs boson the ATLAS and CMS collaborations started to study its properties
- Thanks to the increased data sample as well as improved tools we managed to probe the SM structure through differential distributions
  - With the hope to find possible deviations from the SM
- New theoretical tools for both cross section measurement and BSM contributions investigation have helped us to scan more and more of the available phase space

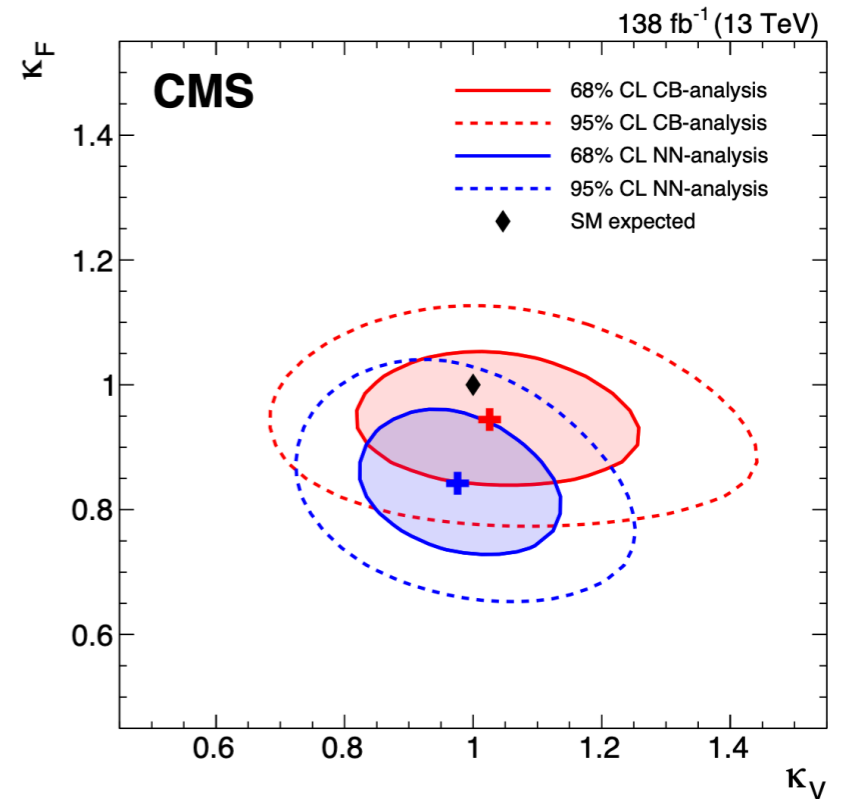
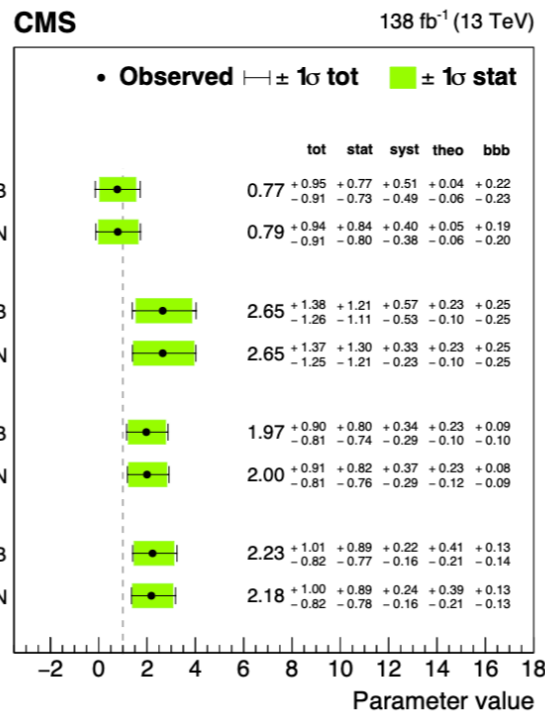
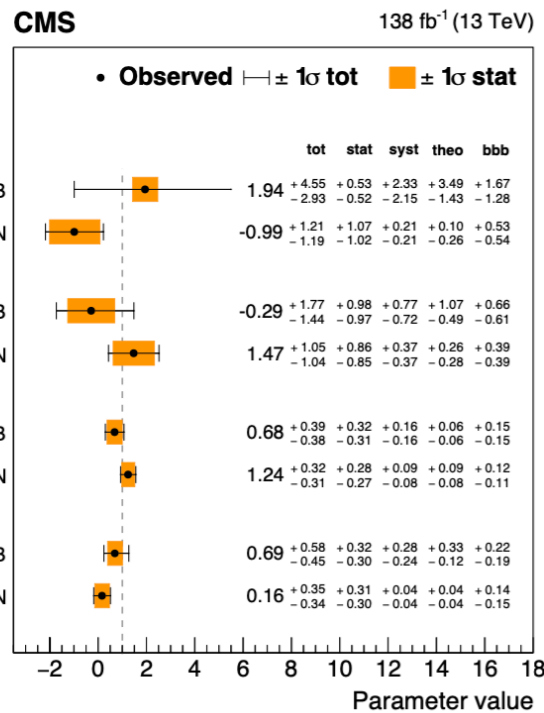
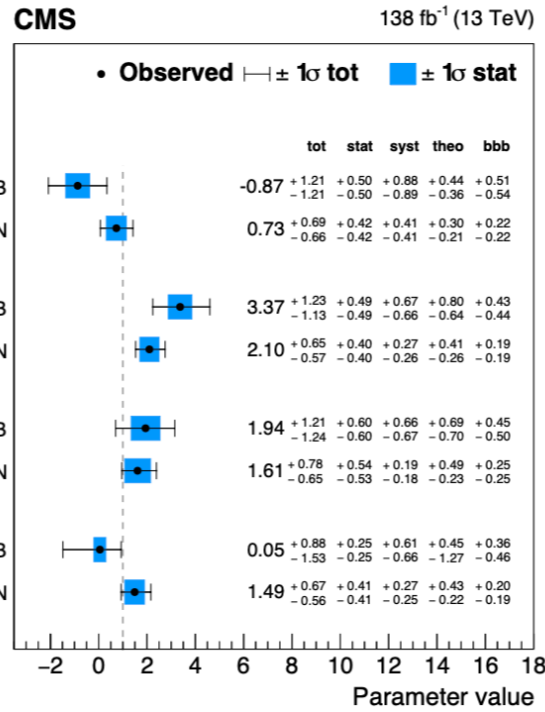
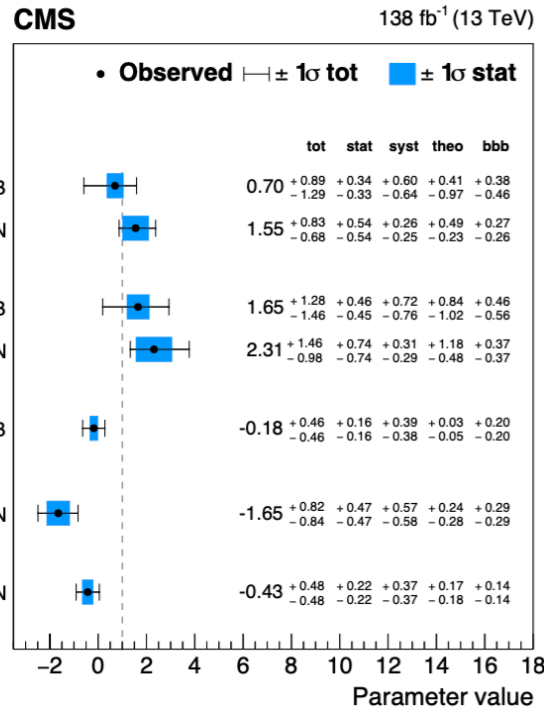


# Back-up

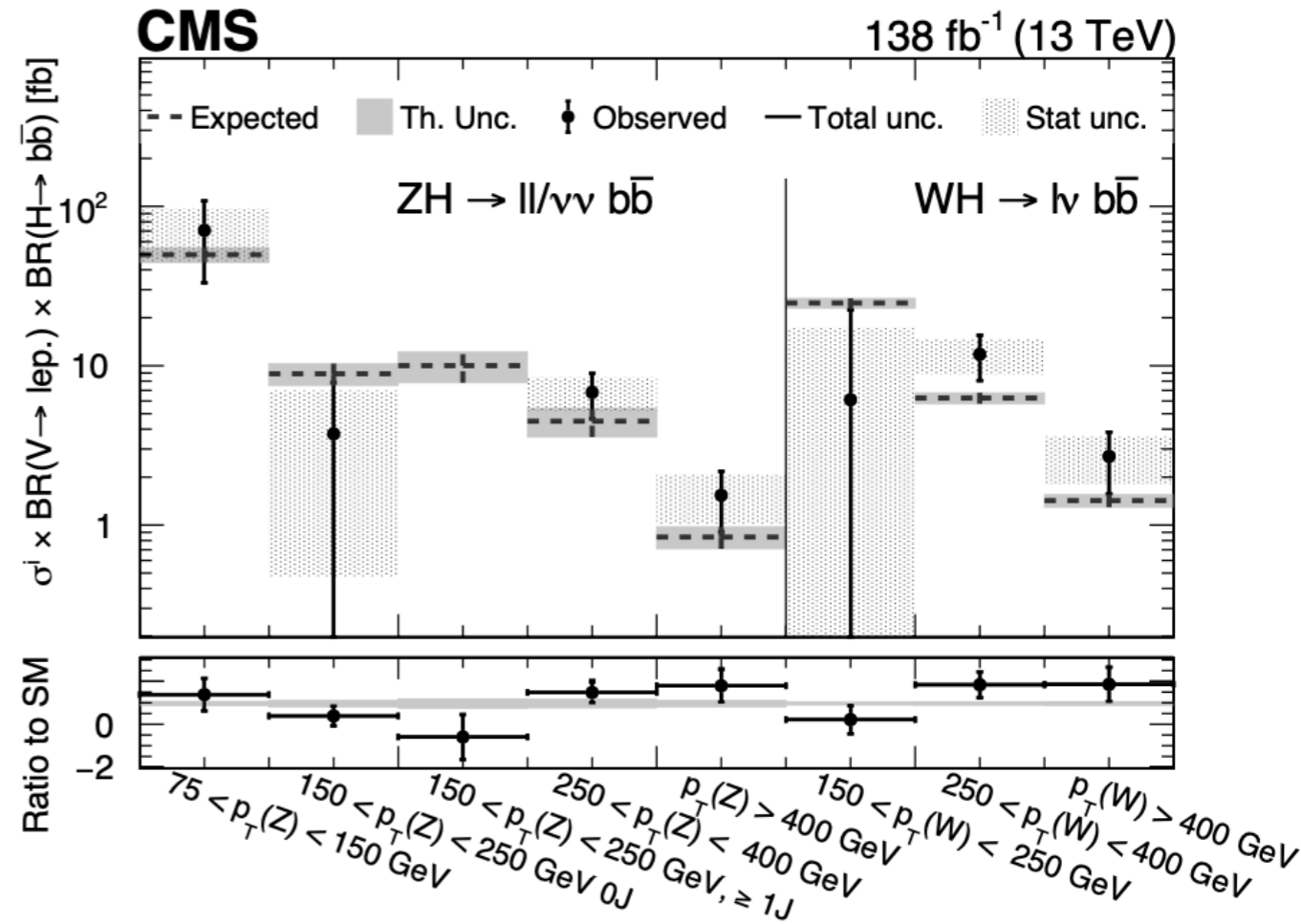
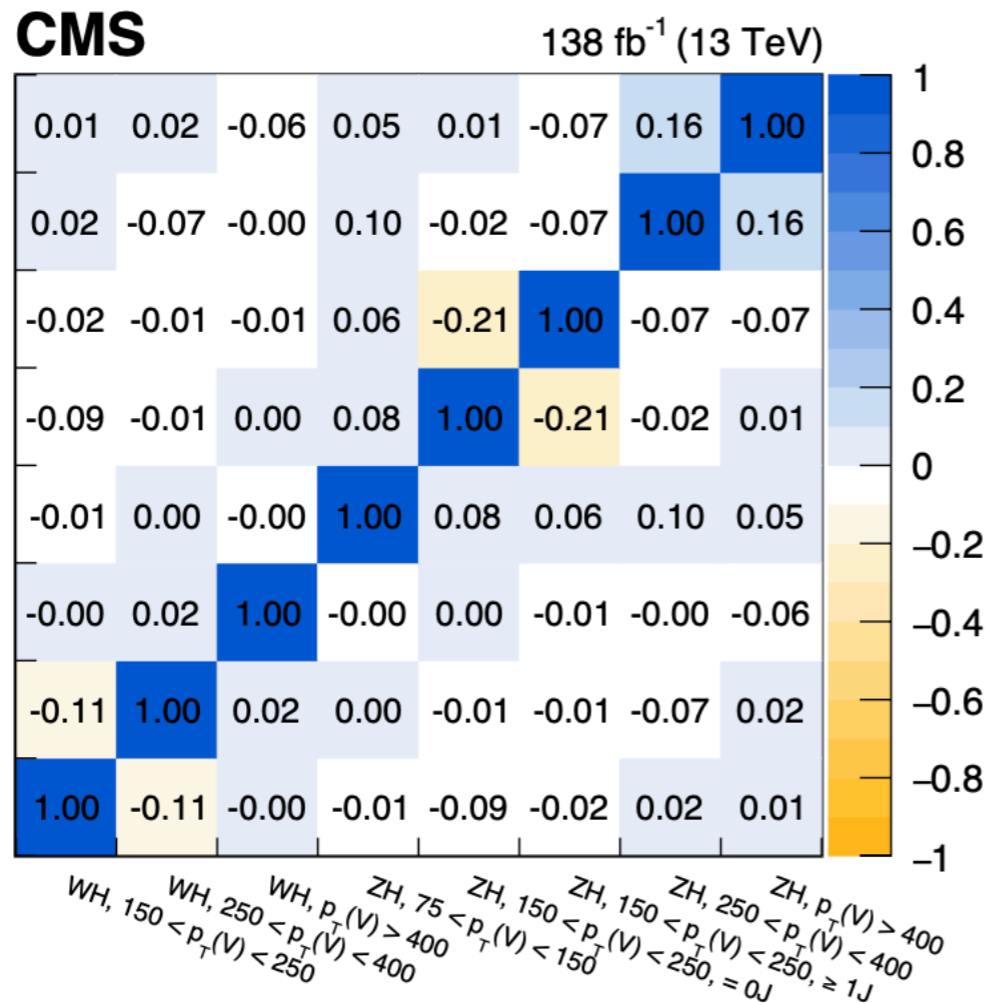
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# H $\rightarrow$ $\tau\tau$

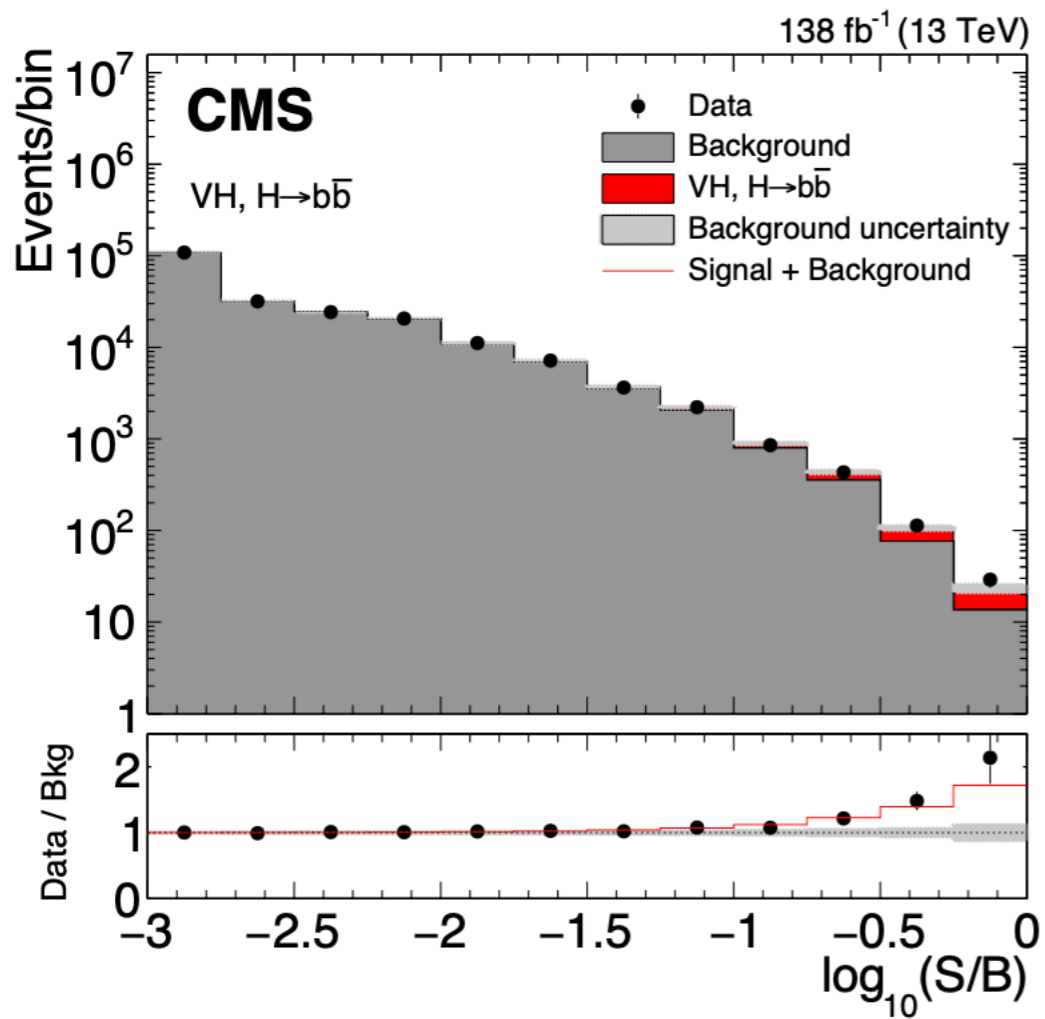
Perfect compatibility between cut based and NN approach  
NN results in small uncertainties



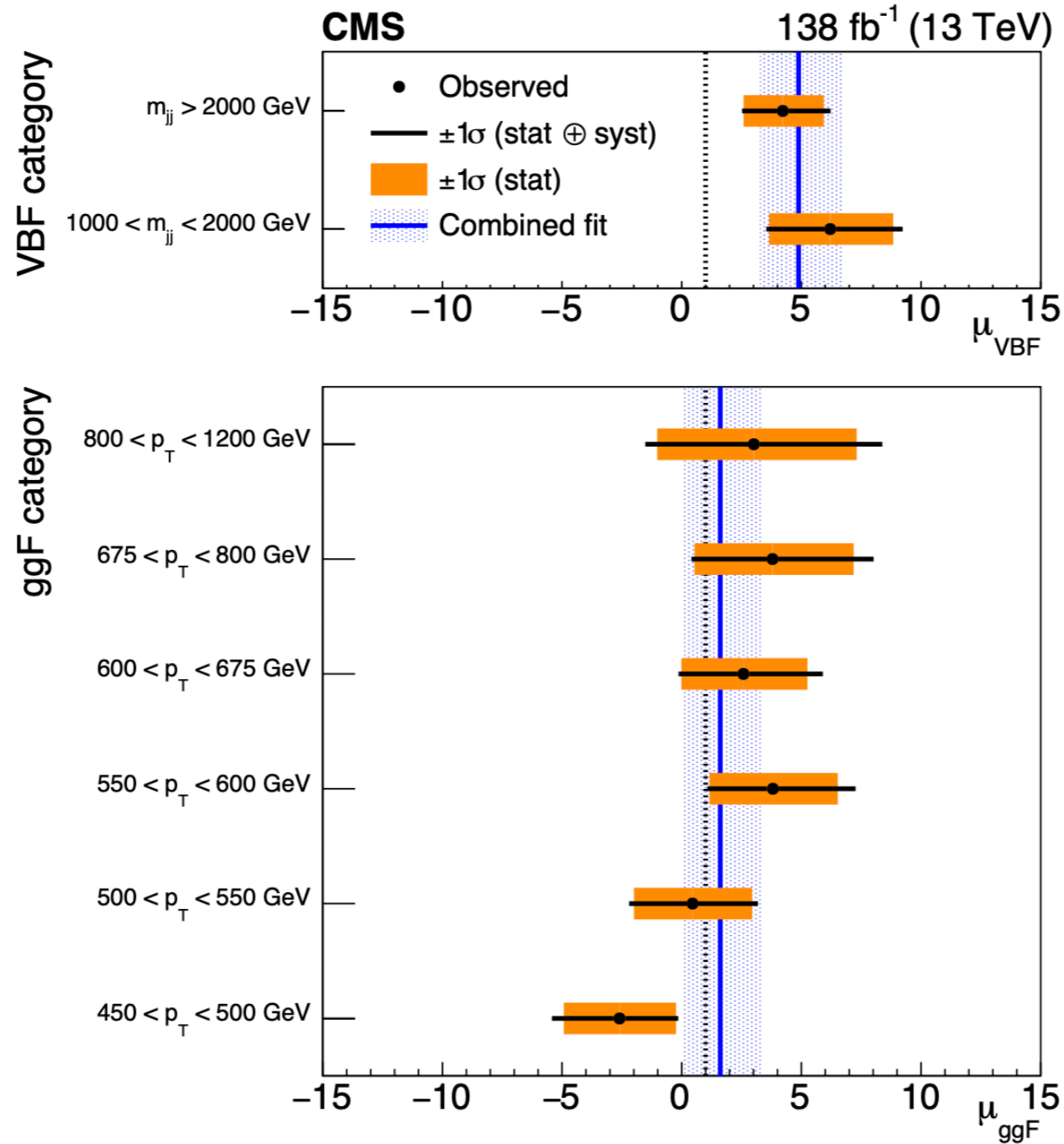
# VH $\rightarrow$ bb Backup



# VH $\rightarrow$ bb Backup



# VBF H $\rightarrow$ bb Backup

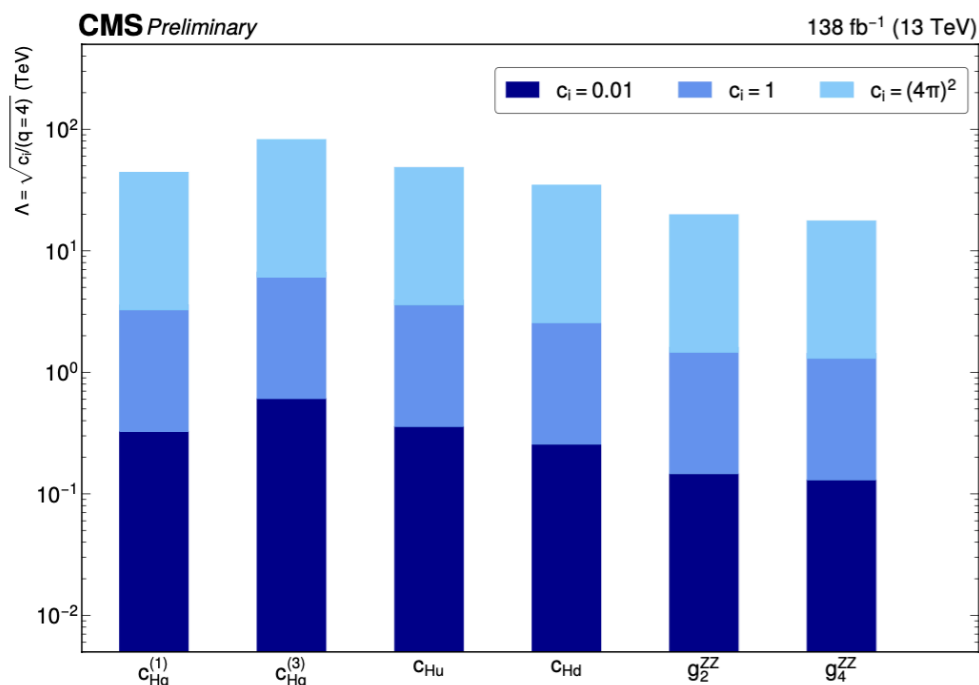
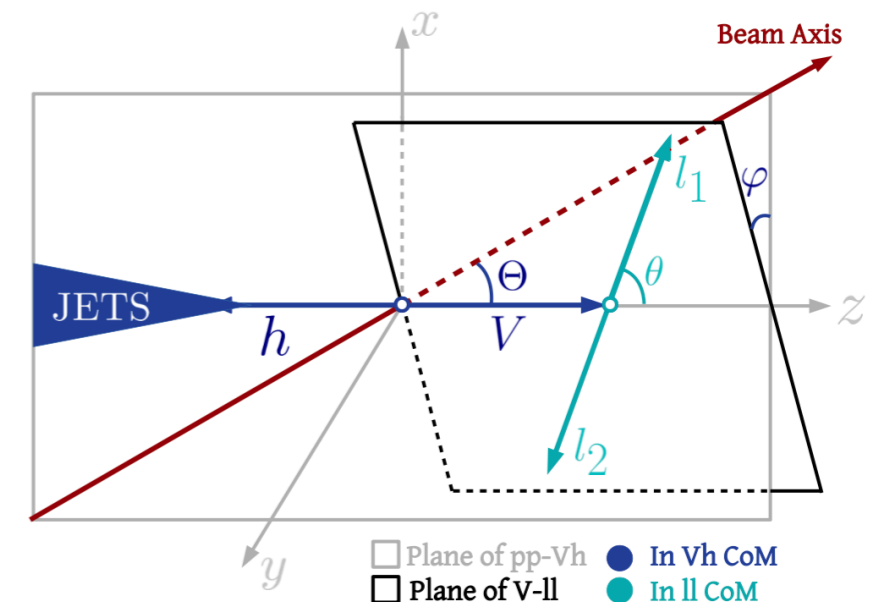
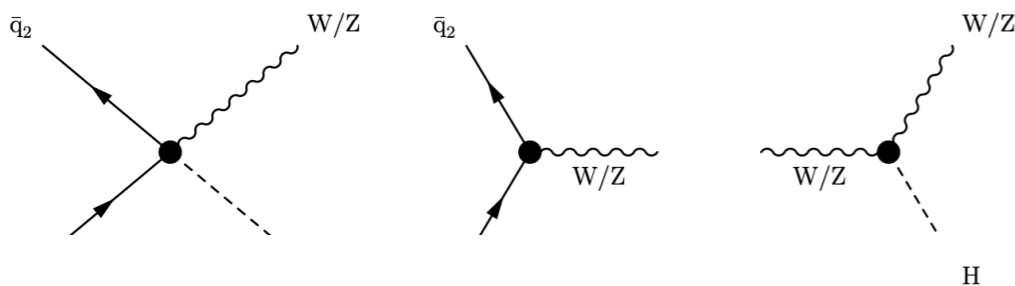




# VH $\rightarrow$ bb EFT interpretation

- STXS may not provide the best sensitivity for the WC extraction

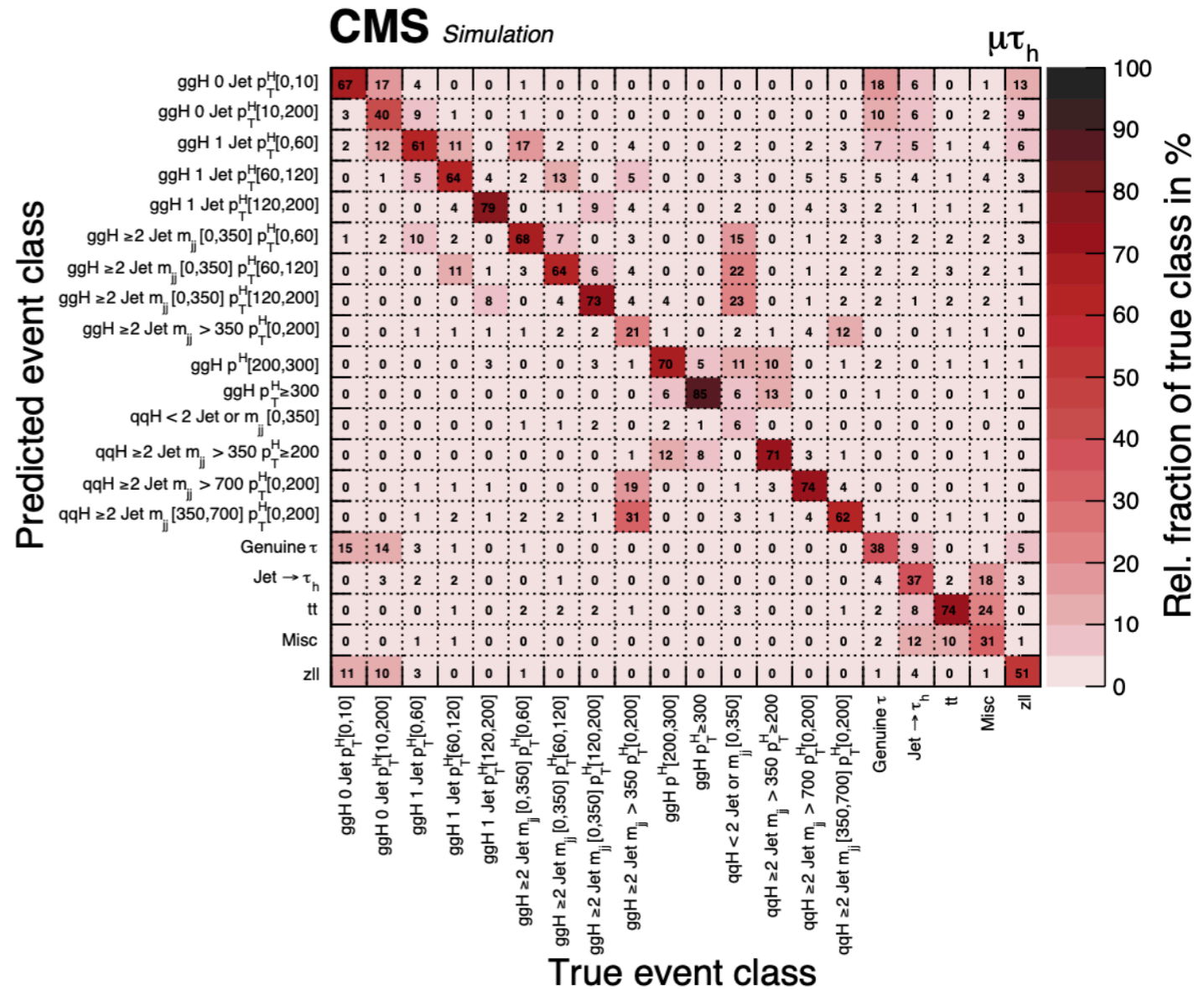
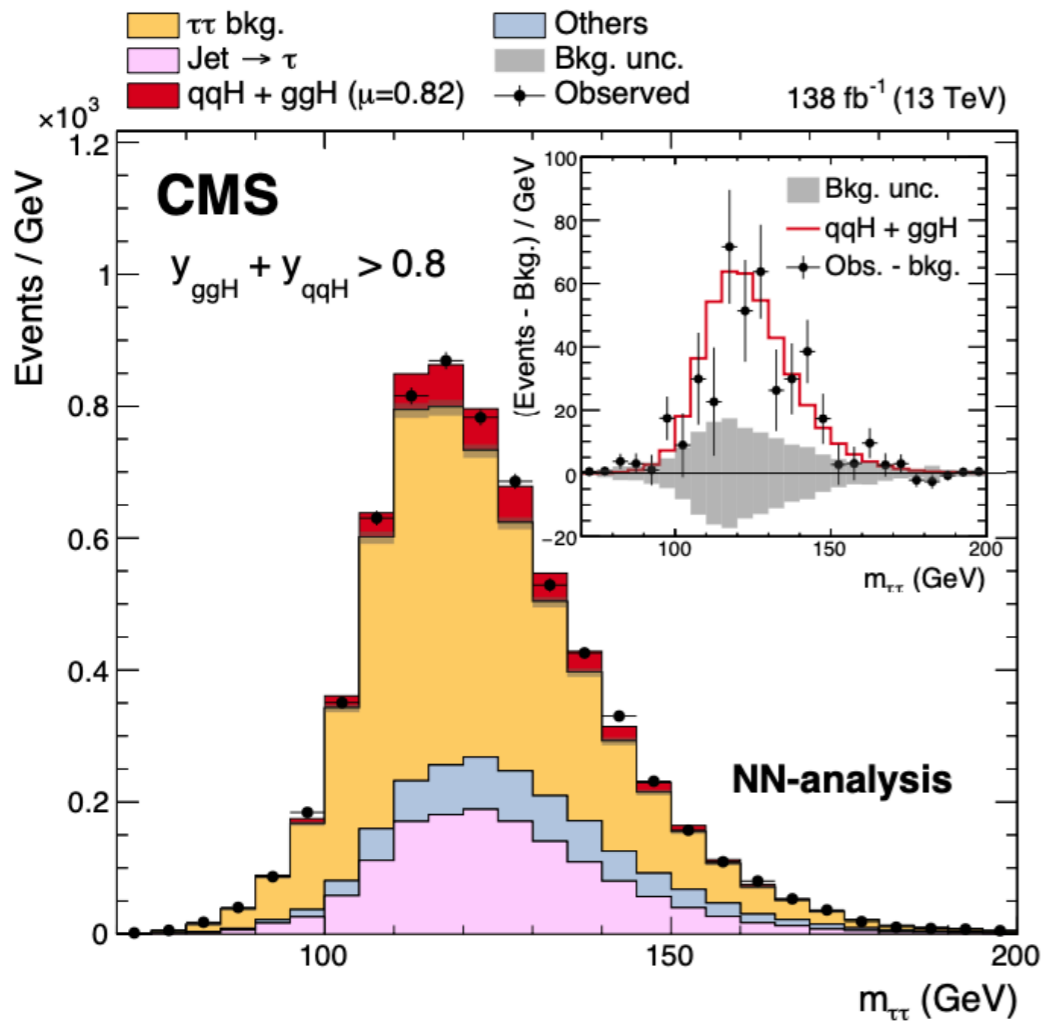
- VH analysis exploits a Boosted Information Tr



HIG-23-016

# H $\rightarrow$ $\tau\tau$ STXS measurements

- Full NN based analysis showing superior performance wrt a cut based approach
  - Possibility to check the correlation between analysis categories
- Inference based on the output of classes in the final layer of the NN



# VH $\rightarrow$ bb EFT interpretation

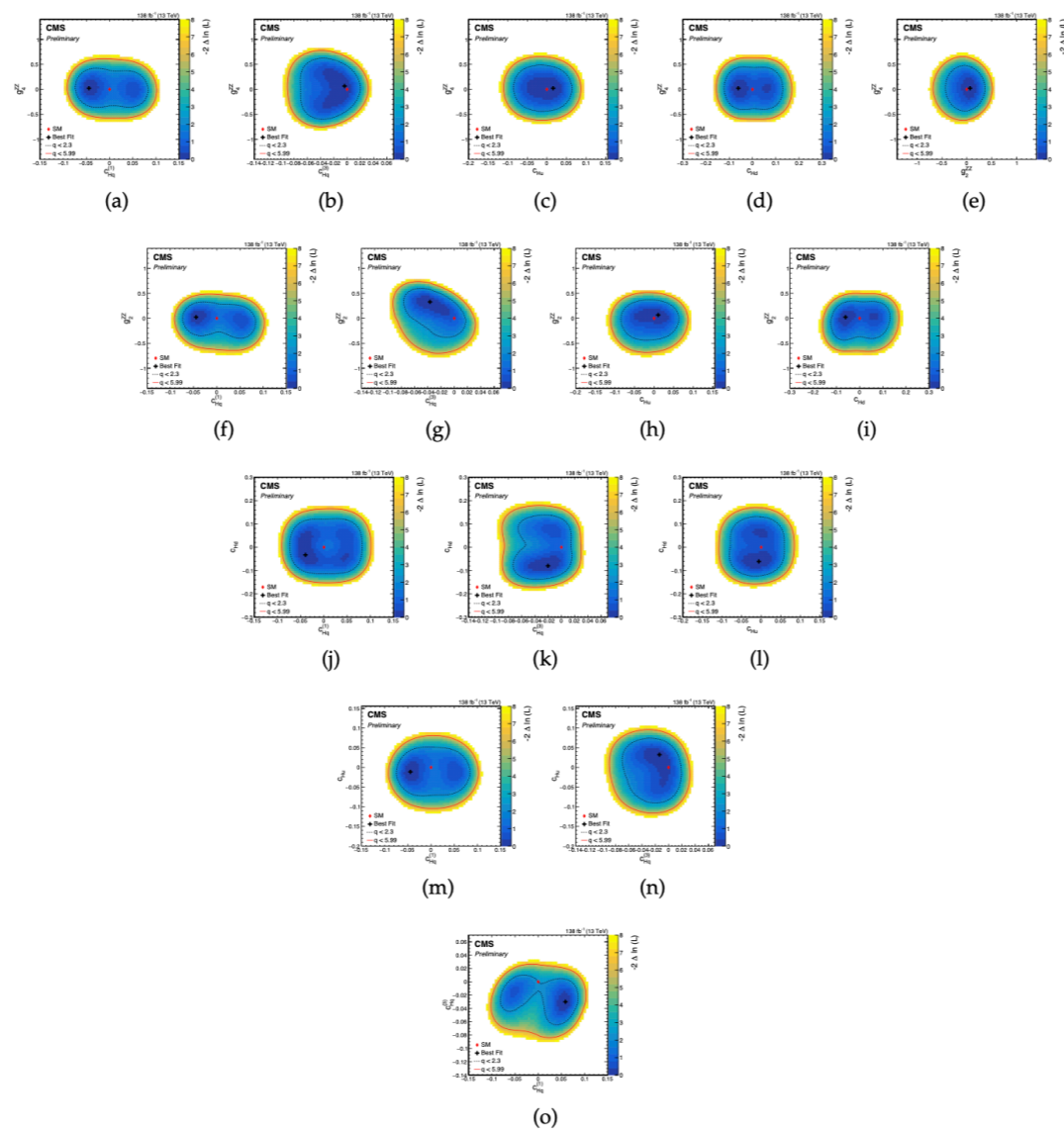
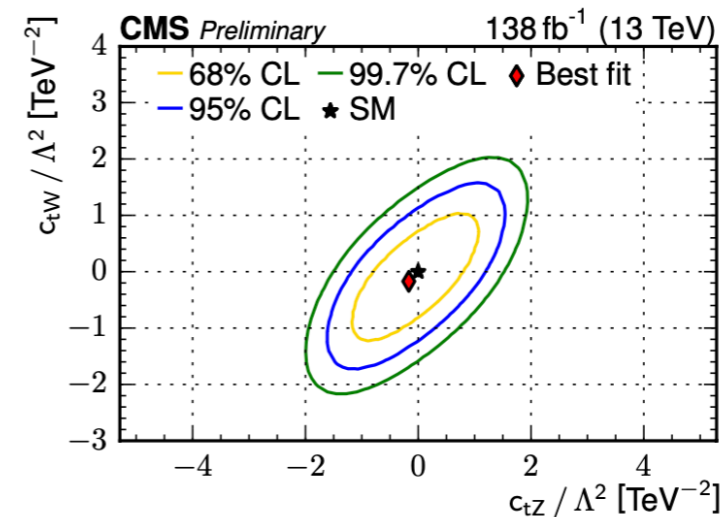
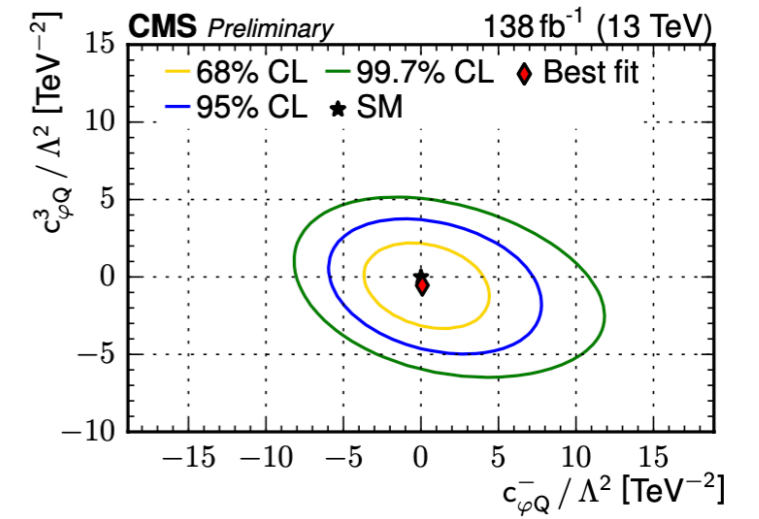
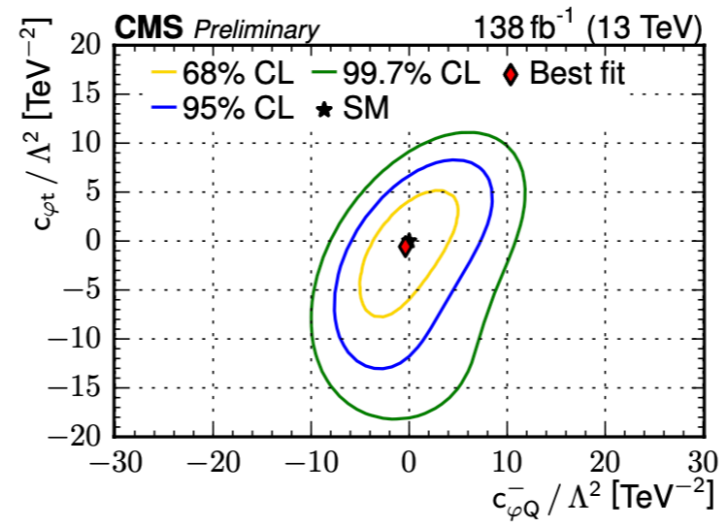
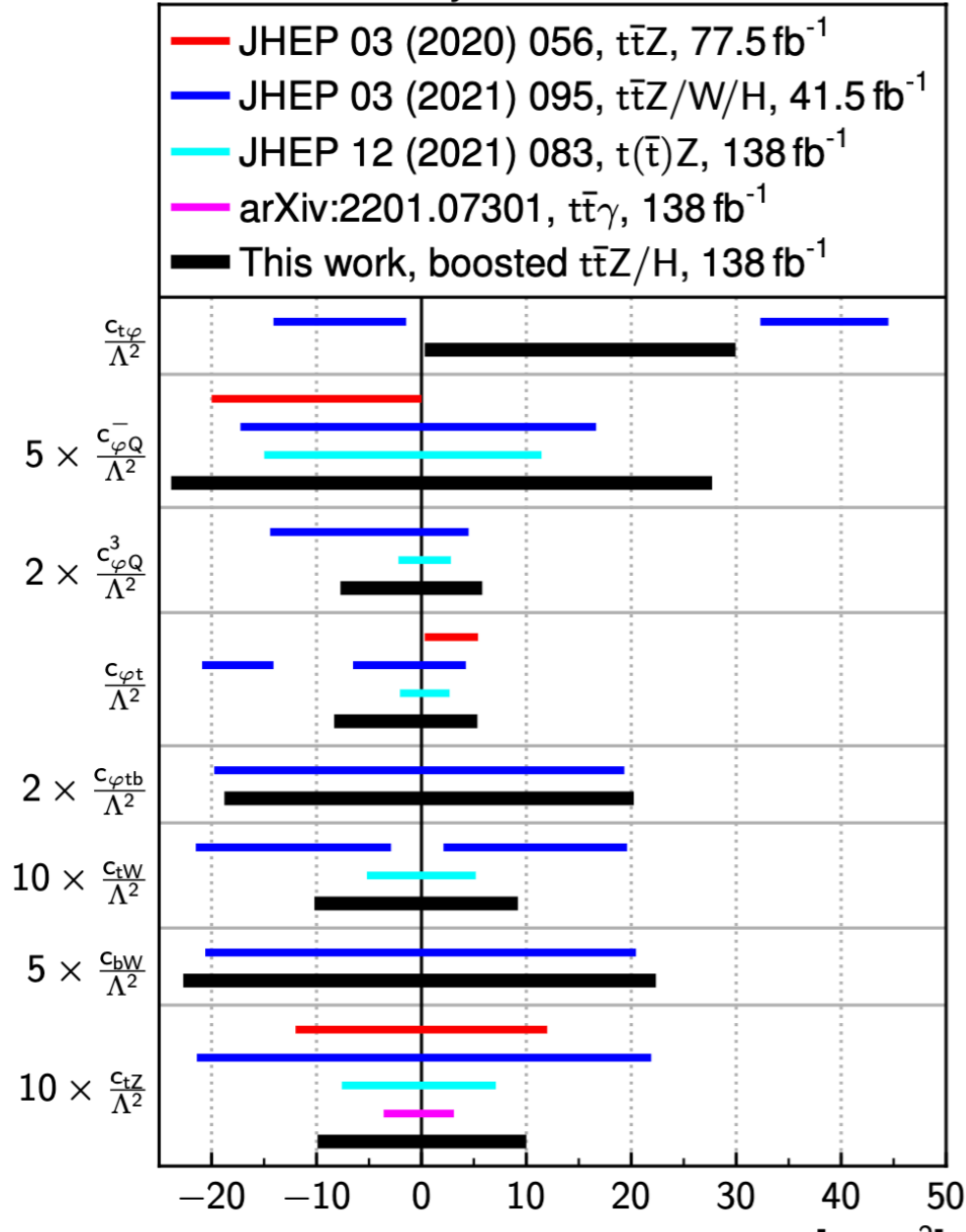


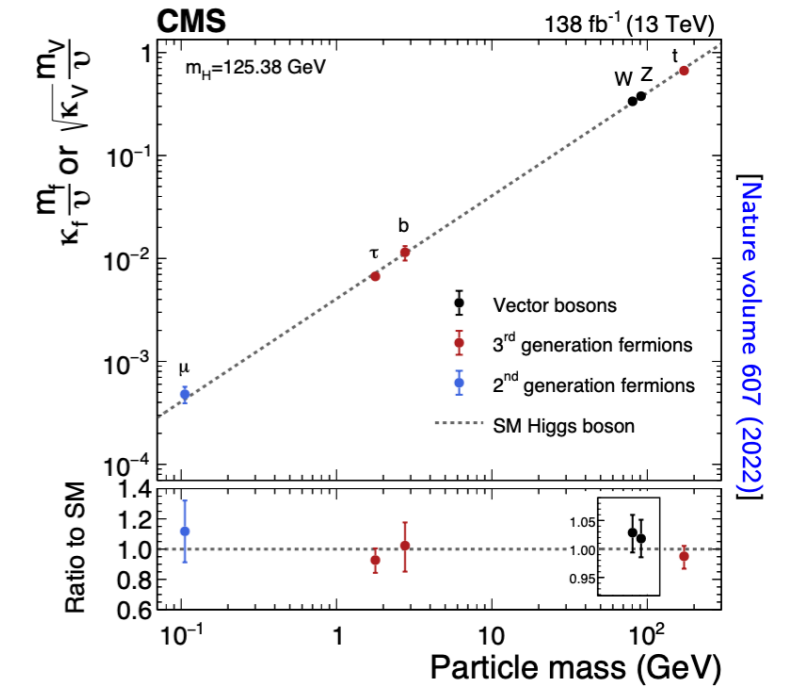
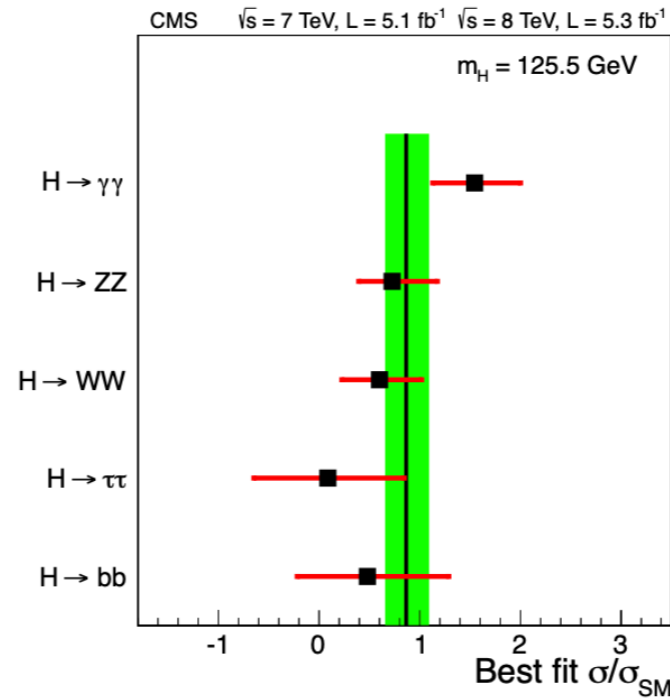
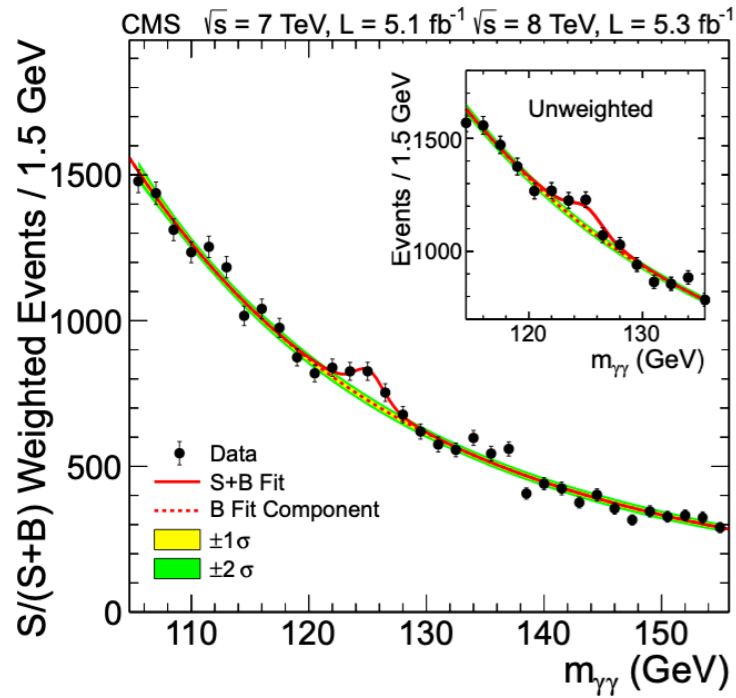
Figure 9: Observed two-dimensional likelihood scans for different pairs of Wilson coefficients with other Wilson coefficients fixed at their SM values after combining results from all eras and final states.

HIG-21-020

- Measuring cross section
- EFT

**CMS Preliminary** 13 TeV





From discovery to precision measurements ... and more

