

Search for non-resonant Higgs Boson pairs production in the $bb\tau\tau$ final state

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On behalf of the CMS Collaboration

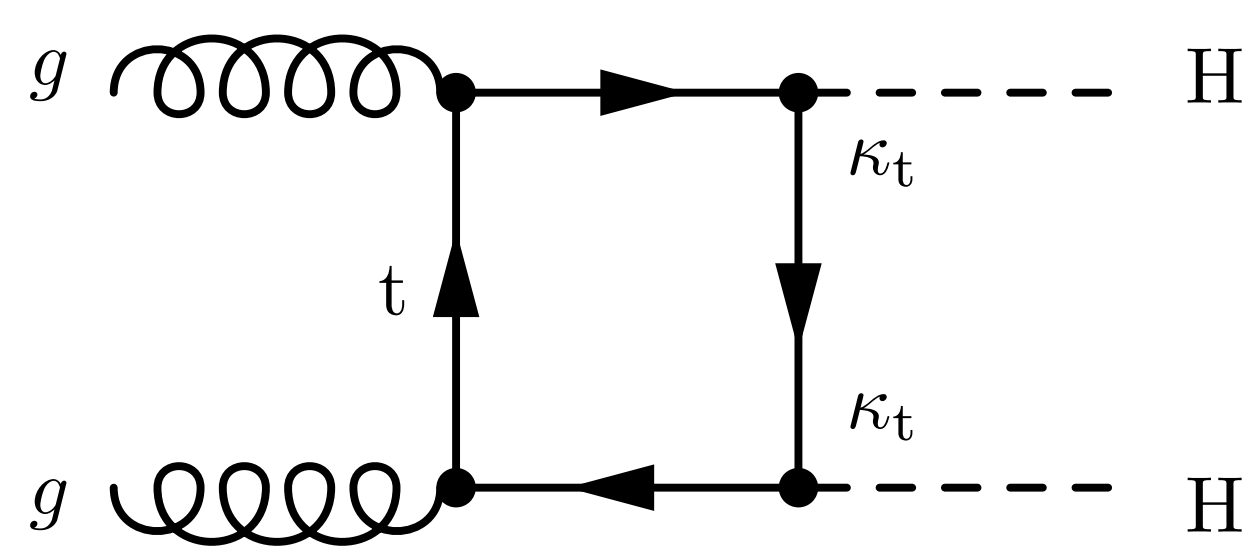


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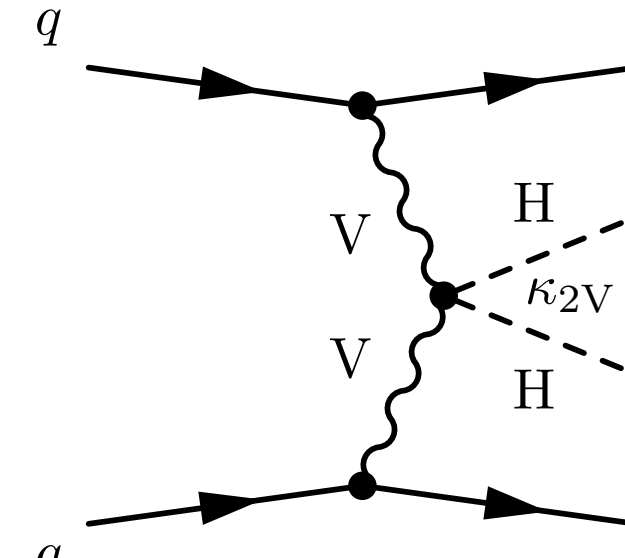
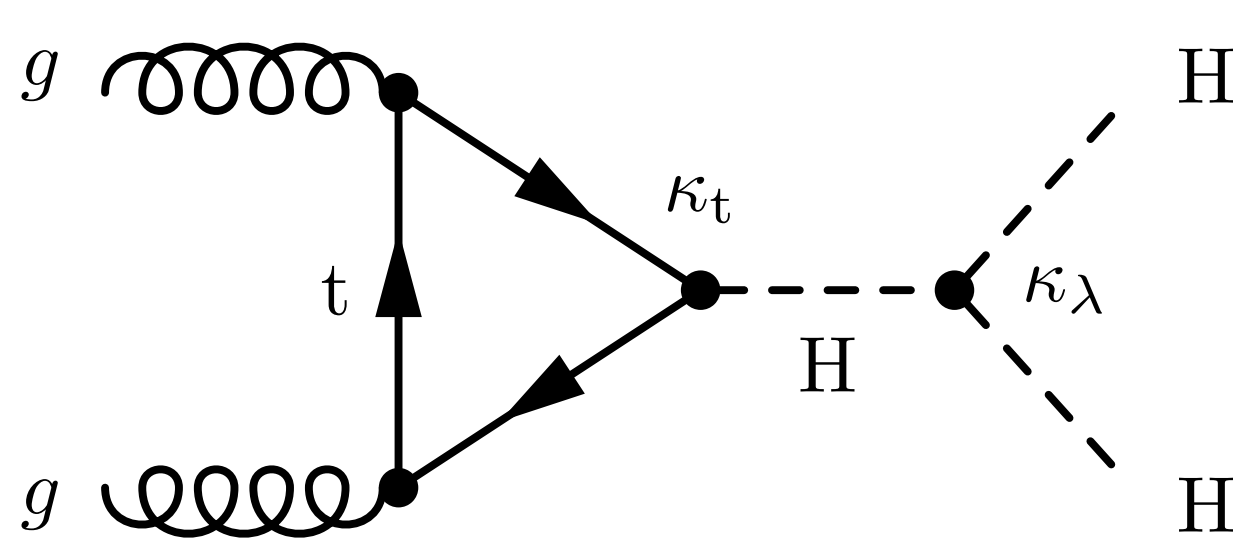
The measurement of σ_{HH} is the best way to extract the Higgs self-coupling λ_{HHH}

The production cross section of the single Higgs processes also depends on λ_{HHH} as a result of NLO electroweak corrections

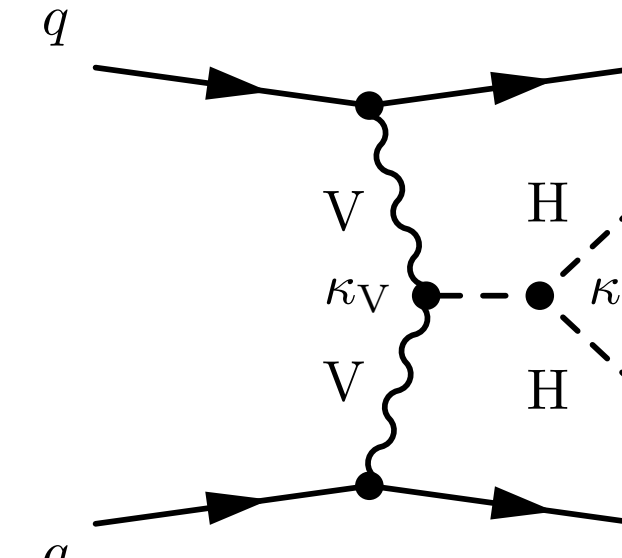
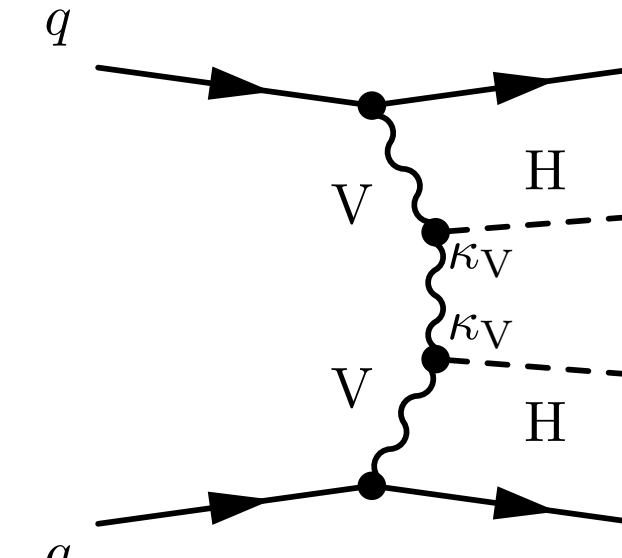
Shape of the Higgs potential defined by m_H (measured with high precision) and the vacuum expectation value (v , calculated with high precision) → need experimental measurement of λ_{HHH} to test model prediction: $\lambda_{HHH} = \frac{m_H^2}{2v^2}$



Gluon-Gluon Fusion (GGF): Destructive interference between the two diagrams leads to a small cross section (31.05 fb)



Vector Boson Fusion (VBF): Second most frequent process (cross section 1.726 fb)
Unique handle to probe $VVHH$ coupling (C_{2V})

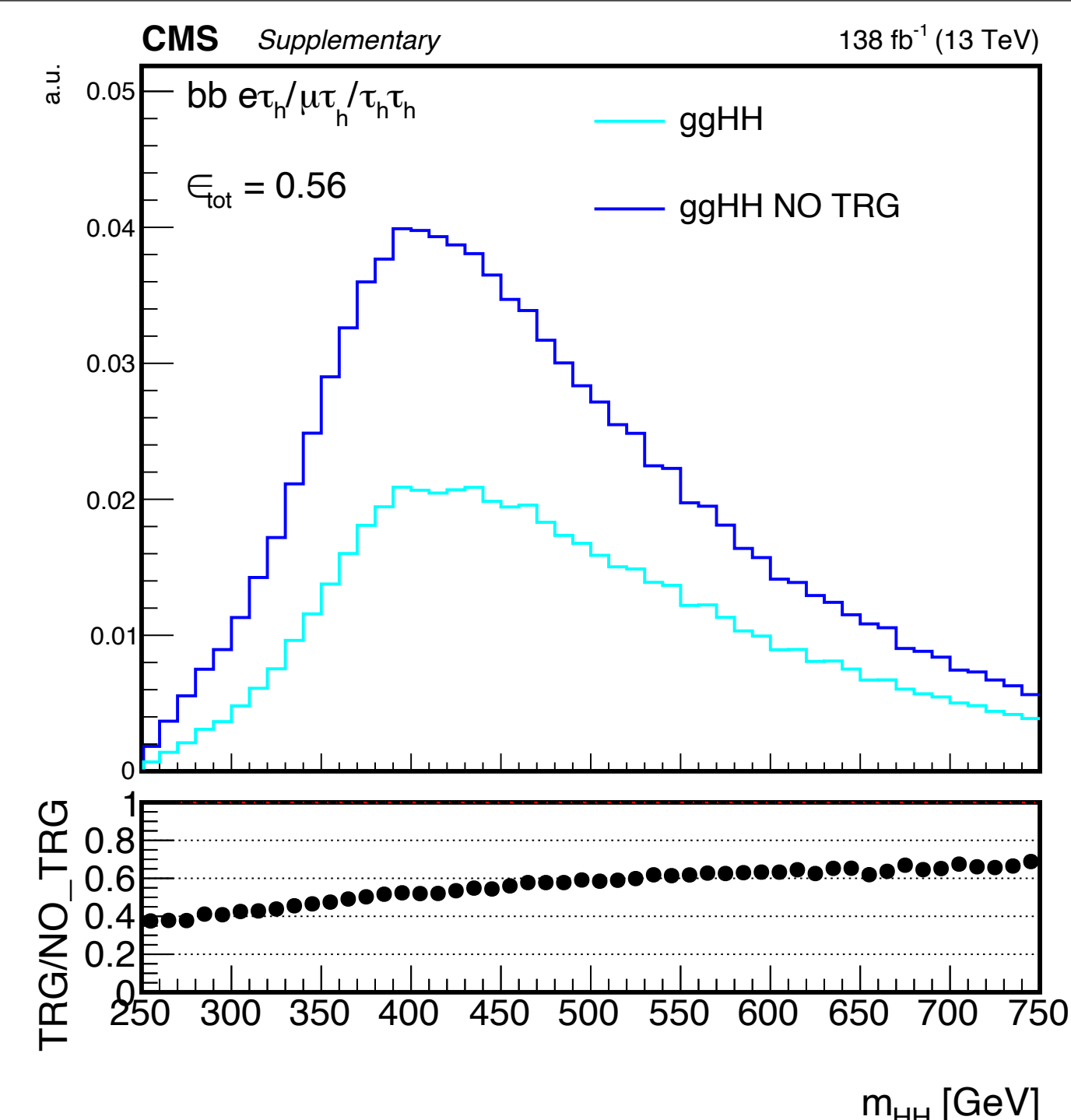


HH → bbττ

- Good trade-off between BR (bb) and signal purity (ττ)
- $H \rightarrow bb$: highest BR (54%), efficient DNN-based b-jets tagging (deepFlavour)
- $H \rightarrow \tau\tau$: challenging reconstruction (neutrinos in all decay modes), DNN-based identification (deepTau)
- $\tau_e\tau_h, \tau_\mu\tau_h, \tau_h\tau_h$ final states are considered (87.6% of the $\tau\tau$ pair decays)
- Main backgrounds:
 - $t\bar{t}$ in semi-leptonic channels
 - DY and QCD multi-jet in hadronic channel
- Backgrounds estimation:
 - QCD multi jet fully data-driven
 - DY and $t\bar{t}$ normalization corrected from CRs

Online trigger selections

- Require the presence of a single isolated lepton (electron or muon) OR a lepton and an hadronically decaying tau OR two hadronically decaying taus.
- Dedicated trigger targeting the VBF production production mechanism developed by the analysis team and adopted in late 2017 and 2018 runs



Efficiency of the online trigger selection as a function of the HH pair reconstructed mass

Offline selections

Reconstruct a $\tau\tau$ and a bb pair in each event

b-jet pair selections

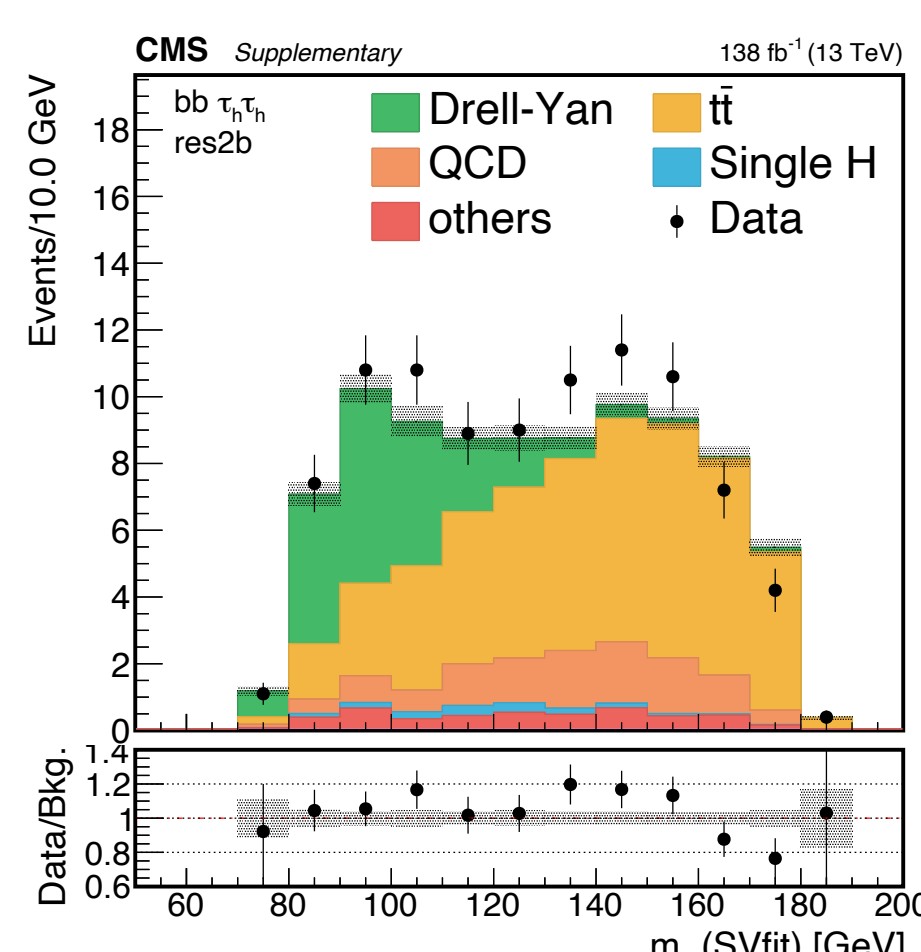
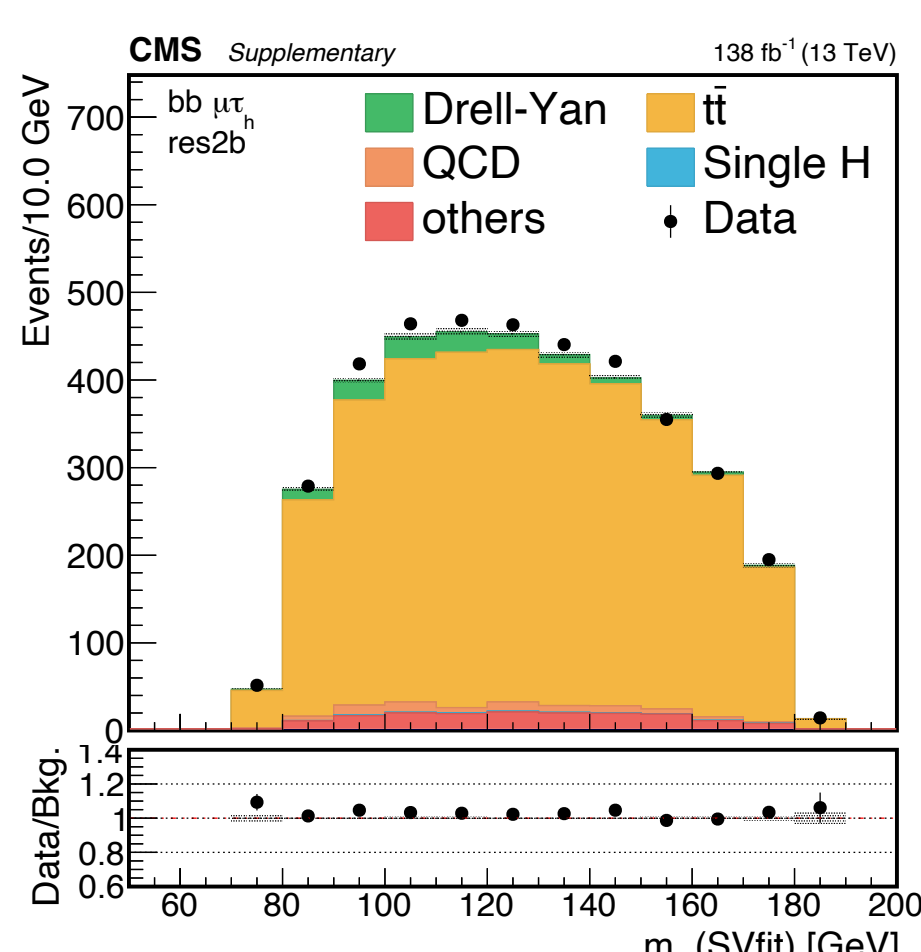
- Jets with $p_T > 20$ GeV within the tracker acceptance
- HH-BTag: DNN-based algorithm**, developed to identify the b-jets coming from the decay of one Higgs boson in the final state $bb\tau\tau$
- The two candidates with the highest HH-Btag score are selected as b-jets

Tau pair selections

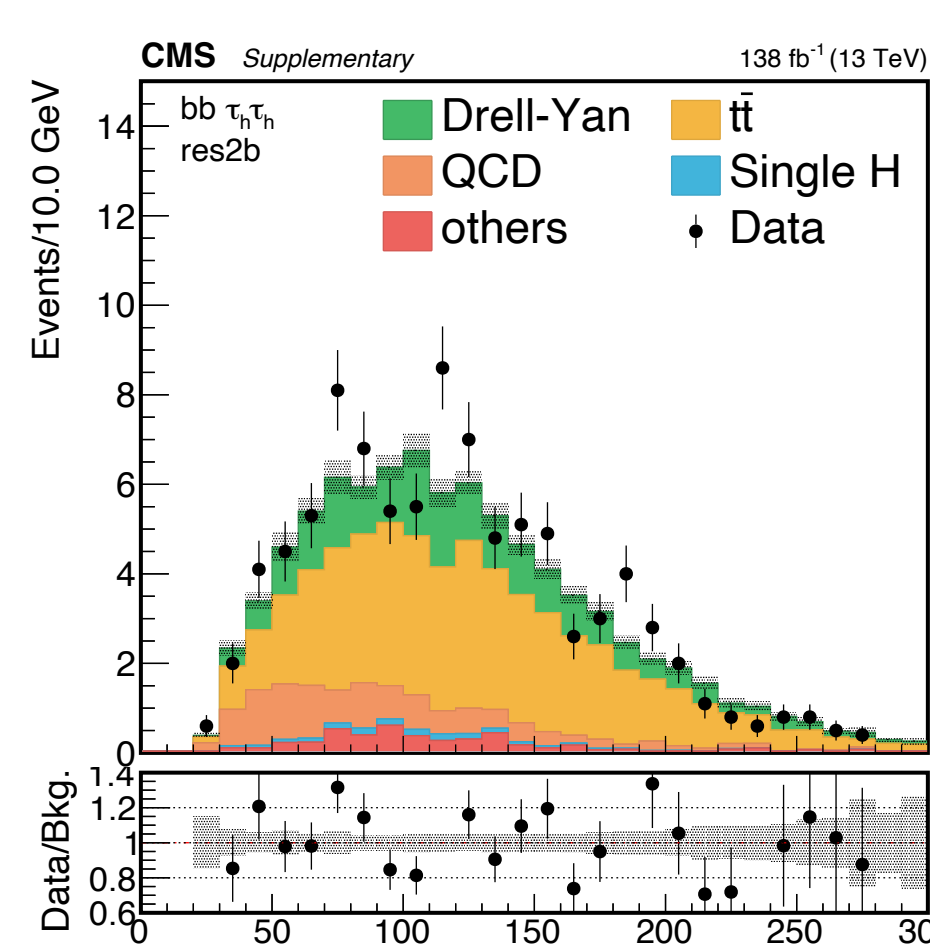
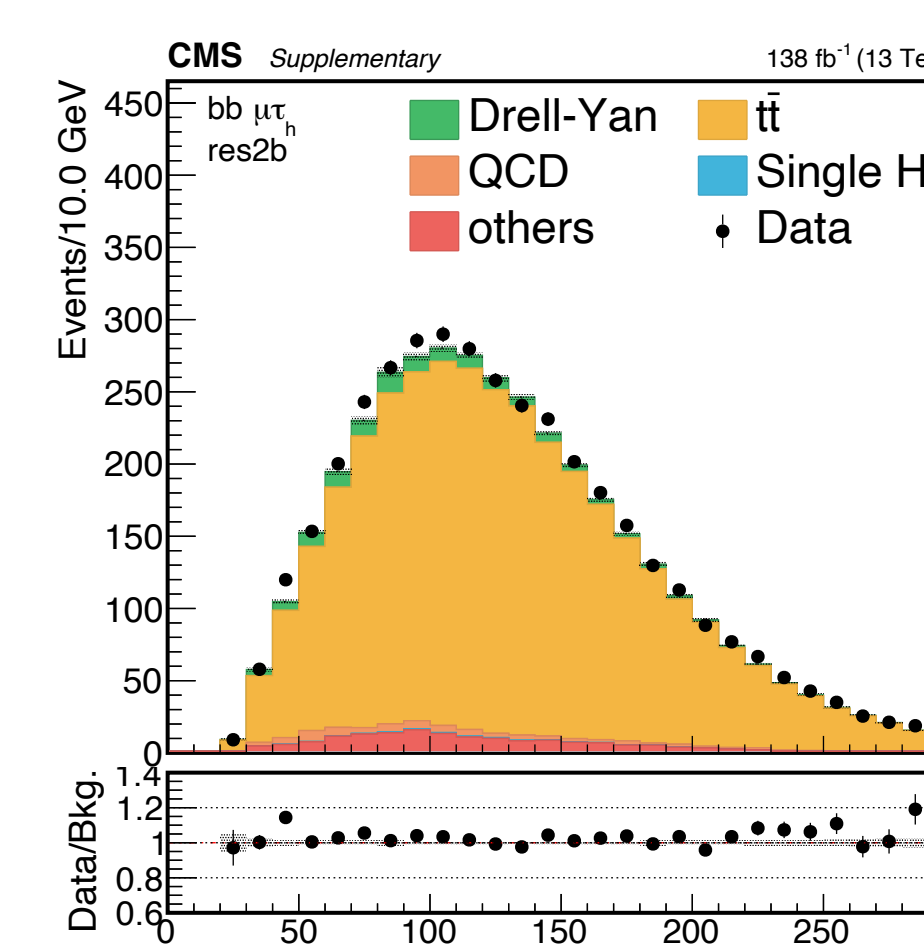
- match with trigger objects with an additional threshold on the p_T (+5 GeV for tau and +1 GeV for ele/muon)
- Most isolated leptons with opposite charge and $\Delta R > 0.5$
- Veto events with additional electrons or muons

Additional selections

- VBF jet selections:** jets with $p_T > 30$ GeV in the experiment acceptance → the pair with the largest invariant mass is selected
- Elliptical mass cut on $m_{\tau\tau}$ and m_{bb}** to remove outlying background events in regions where no signal is expected prior to DNN prediction.
 - optimised requiring minimal background acceptance for 90% signal efficiency
- Kinematic fit** to reconstruct the HH mass



Distributions of the reconstructed mass of the tau pair



Distributions of the reconstructed mass of the b-jet pair

VBF Multiclassifier

- Two signal and three background categories
- Enhance signal purity
- Constrain background uncertainties

DNN Discriminant

- Trained using SM signal and background MC samples
- Single training used for all the categories/channels/years
- HH KinFit mass and chi2, $m_{\tau\tau}$ and m_{bb} among the most important variables

Triggers
H → TauTau candidate
H → bb candidate

2 VBF cand.?

VBF tag?

boosted?

VBF

ggF

ttH

TT

DY

DNN

DNN

DNN

DNN

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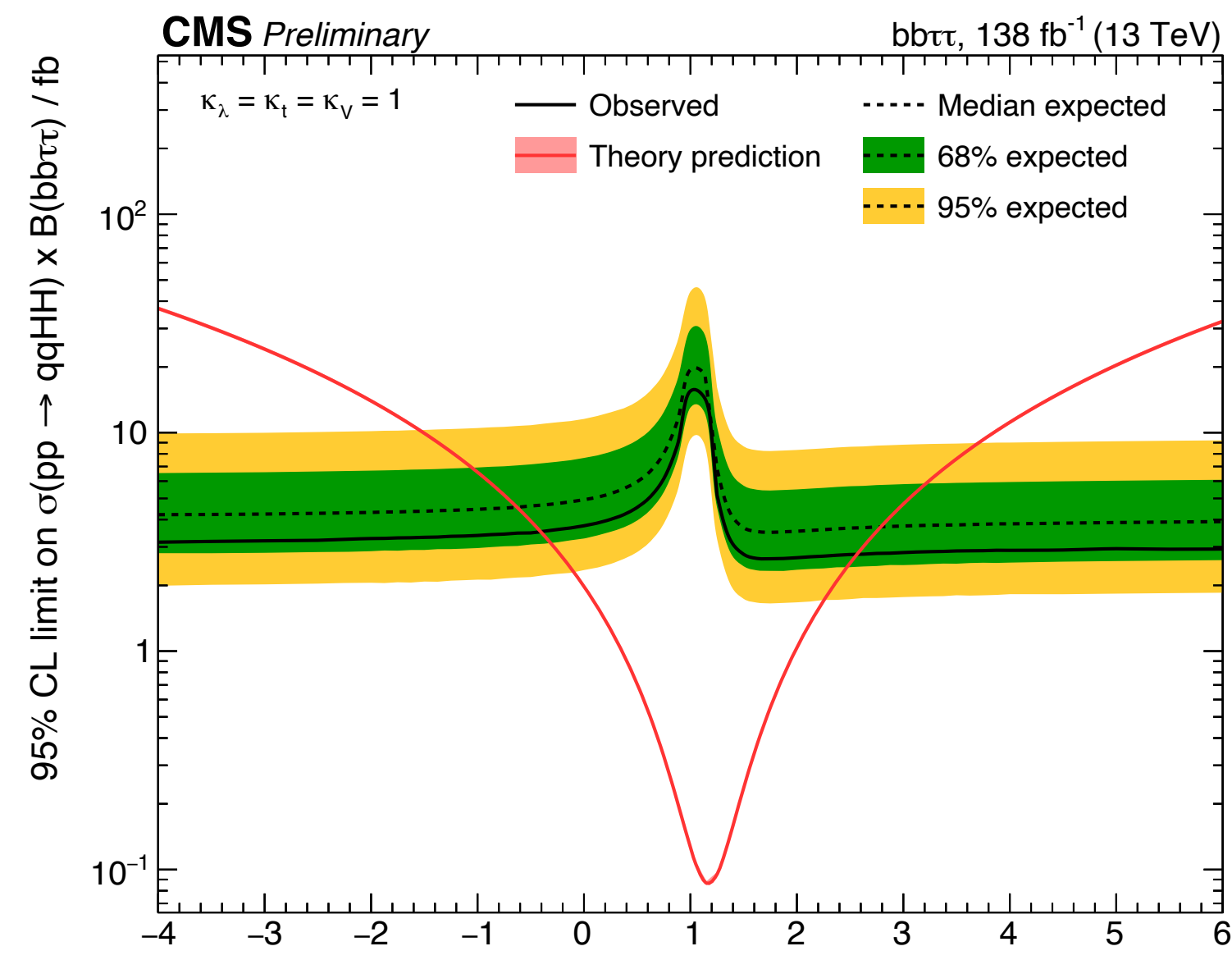
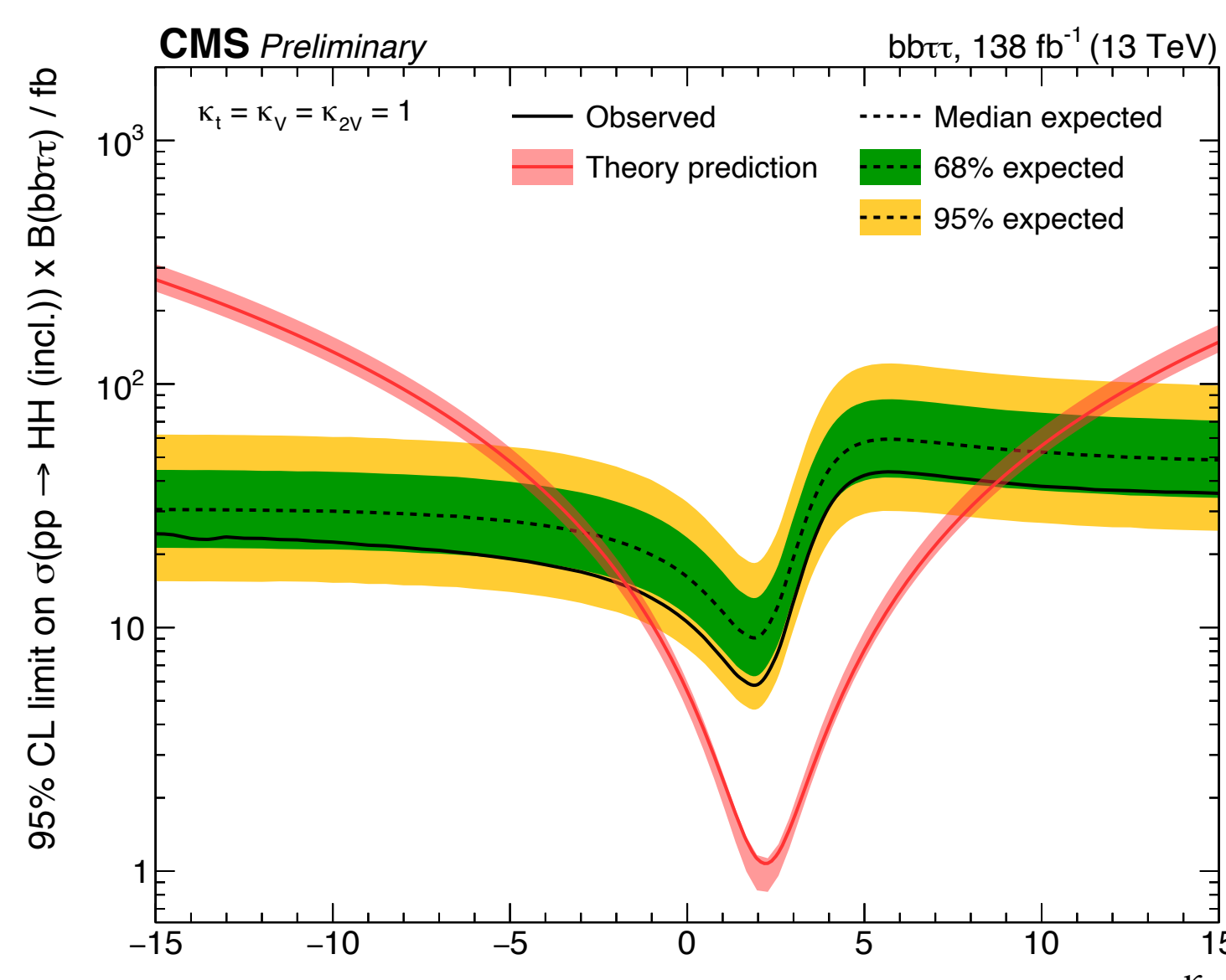
DNN

DNN

DNN

DNN

DNN



GFF+VBF inclusive production

- Cross sections larger than **5.2 (3.3) x σ_{SM}** are excluded at 95% Confidence Level (CL)
- k_λ constrained at 95% CL in the interval **-1.8 < k_λ < 8.8**

VBF production

- Cross sections larger than **154 (124) x $\sigma_{SM,VBF}$** are excluded at 95% CL
- k_{2V} constrained at 95% CL in the interval **-0.4 < k_{2V} < 2.6**
- Strongest constraint on $pp \rightarrow VBF-HH$ cross section measured so far**