# Search for Higgs boson pair production in the CN **NCPB** bbWW\* final state in proton-proton collisions with the full Run2 CMS data

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# 1. Introduction

- Higgs boson self-coupling,  $\lambda$ , gives access to the Higgs potential.
- It can be accessed directly through HH production.
- Dominating processes of HH at LHC: gluon-gluon fusion(GGF) with cross section( $\sigma$ ) ~31fb, vector boson fusion(VBF) with  $\sigma$  ~1.7fb.
- CMS is approaching sensitivity to Standard Model(SM) HH cross section, currently  $\sigma_{\rm CMS}$  < 3.4 times  $\sigma_{\rm SM}$ .
- $\sigma$  can be enhanced in Beyond Standard Model(BSM) physics:

  - Deviation from SM is quantified by \$\vec{k}\_{\lambda}\$ = \$\lambda / \lambda\_{\mathcal{SM}}\$.
    Current exclusion limit: -1.24 < \$\vec{k}\_{\lambda \comessful \mathcal{CMS}}\$ < 6.49.</li>
    Non-resonant: New couplings, 5D study of \$\vec{k}\_{\lambda}\$, \$\vec{k}\_{2V}\$, \$\mathcal{C}\_{2}\$, \$\mathcal{C}\_{g}\$,
    - C<sub>2g</sub> in Effective Field Theory(EFT).
  - Resonant(X): spin-0 Radion, spin-2 Graviton.





2. Why bbWW\*

- **No Golden channel**→Need to study in as many channels as possible.
  - bbWW\*→Second highest branching ratio.
    - Pros: Large signal.
    - **Cons:** Huge background.



# 4. Background Estimation

• **Misidentified leptons:** data driven using fake factor\* method.

• **DY**: data driven, only in DL final state.



• Other backgrounds: from simulation.

\*JHEP08(2018)0

### 5. Signal Extraction

- Multiclassifier Deep Neural Network(DNN): Used to separate signal and background.
- Heavy Mass Estimator(HME)\*: Used to reconstruct mass of resonant particle in DL final state.



#### 6. Results at 95% confidence level, Observed(Expected)

• Non-resonant:  $\sigma_{\rm GGF+VBF}$  <

14(18) 
$$\sigma_{GGE+VBE}(SM)$$
,  $\sigma_{VBE} < 277(301) \sigma_{VBE}(SM)$ 

• **Resonant:** Exclusion limit depends on parameter value of the model.







EFT interpretation\*

\*JHEP04(2016)126, JHEP09(2018)057, JHEP03(2020)091

#### 7. Conclusion

- No excess is observed  $\rightarrow$  exclusion limit is set on  $\sigma$ (HH) both in non-resonant and resonant productions.
- Sensitivity is improved(5 times) significantly compared to previous analysis, <u>JHEP01(2018)054</u>.

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 $-7.2(-8.7) < k_1 < 13.8(15.2) -1.1(-1.4) < k_{21} < 3.2(3.5)$ 

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