**Motivation**

Study Higgs self coupling $\kappa_2$ and Higgs boson-Vector boson coupling $C_{\nu}$.

The charged lepton and invisible neutrino from W- or Z-boson decays in the VHiggs production provide a good trigger of signal events.

VH can directly distinguish ZZHH and WWHH by numbers of final states leptons.

**Background Modelling**

**Material Machine Learning based background modelling technology is adopted**

- In 2L channel (and Boosted topology), we use 2b-tagged MC events (failed selection events) to mimic the background events in reweighting regions.

- In hadronic channel, ResNet based NN is used to realise the data-driven BGs modelling for QCD process from 2b-tagged data.

**Events Selection**

4 analysis channels: based on the decay of vector bosons

- Double Leptons: Single Lepton: MET: Full Hadronic

DeepJet and ParticleNet are used for Jet tagging

Higgs decay to (largest BR) final states: $\mu \nu$ or $\nu \gamma$

Resolved and Boosted topologies

- Signal Region (SR): $hH < 25 GeV$
- Control Region (CR): $25 GeV < hH < 50 GeV$
- SideBand (SB): $50 GeV < hH$
- Failed Region (FR): $0.80 < Q_{bb} < 0.90$

- High Purity (HP): $D_{bb} > 0.94$
- Low Purity (LP): $0.90 < Q_{bb} < 0.94$

**Analysis Strategy**

**HLT/Object/Event Selections**

**KI Categorization**

Bring extra sensitivity over KI

- Samples used for training is $KI = 20$ vs $KI = 0$
- 3 year MCs are combined for training
- Variables and BDT models are optimized in all channels

**SvB Classifiers**

Trained separately in High KI/SM KI regions

- In V-Leptonic channel
- 3 channels $X$ 2 $K_I$ Cats = 6 SvB BDTs
- In V-Hadronic channel
- An ResNet based SvB Classifier is trained
- Optimized (inputs, models) in each channel

SvB Classifier scores will be used as the observables for template fit

**Result**

- First search for VHH production in CMS, published on Moriond 2023
- Complementary to previous analyses, strong sensitivity at $k_2$ around 5: 43(22)

- Observed excess at $2.6 \sigma$ SM, the observed (expected) upper limit at 95% CL is $294(124)$ times the cross section from SM prediction

- The observed (expected) allowed intervals from the search at 95% CL are:

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<th>$k_{1}$</th>
<th>$k_{12}$</th>
<th>$k_{2}$</th>
<th>$k_{122}$</th>
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<tbody>
<tr>
<td>Expected</td>
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<td>$k_{1}$ and $k_{2}$</td>
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