Search for non-resonant di-Higgs production in the $b\bar{b}b\bar{b}$ final state at 13 TeV with the ATLAS experiment

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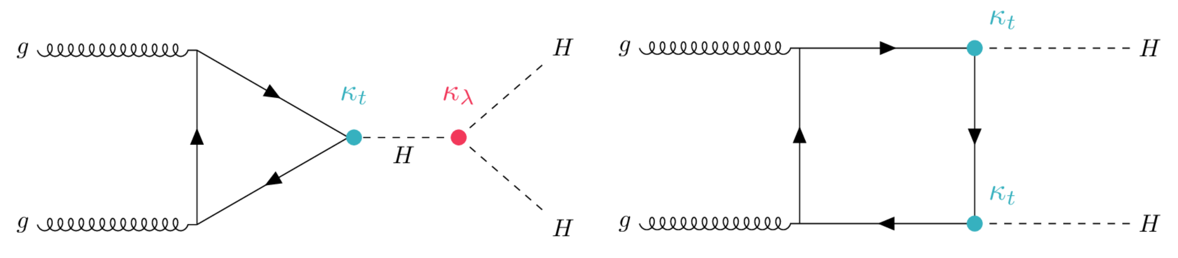
After the Higgs boson discovery, it is strongly motivated to measure the properties of the Higgs boson to test the Higgs mechanism in the Standard Model (SM) of particle physics. We searched for non-resonant di-Higgs production in the $b\bar{b}b\bar{b}$ final state using full Run-2 datasets corresponding to 126 fb^{-1} at $\sqrt{s} = 13$ TeV accumulated with the ATLAS detector and gave constraints on the signal strength, the trilinear Higgs self-coupling (κ_λ) and the di-Higgs di-vector boson coupling (κ_{2V}). This poster shows the analysis strategy and the latest results.

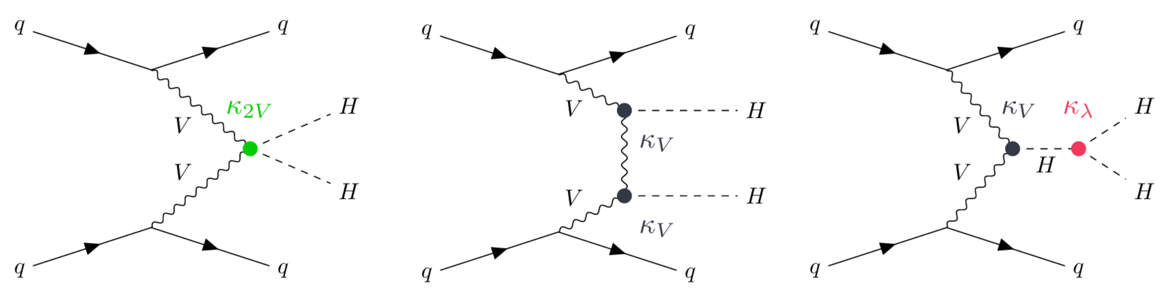
1. Di-Higgs Production

- Target: Non-resonant di-Higgs (HH) production in both gluon-gluon fusion (ggF) and vector-boson fusion (VBF) processes.

ggF NNLO $\sigma_{SM} \approx 31.05$ fb at $\sqrt{s} = 13$ TeV



VBF N3LO $\sigma_{SM} \approx 1.726$ fb at $\sqrt{s} = 13$ TeV

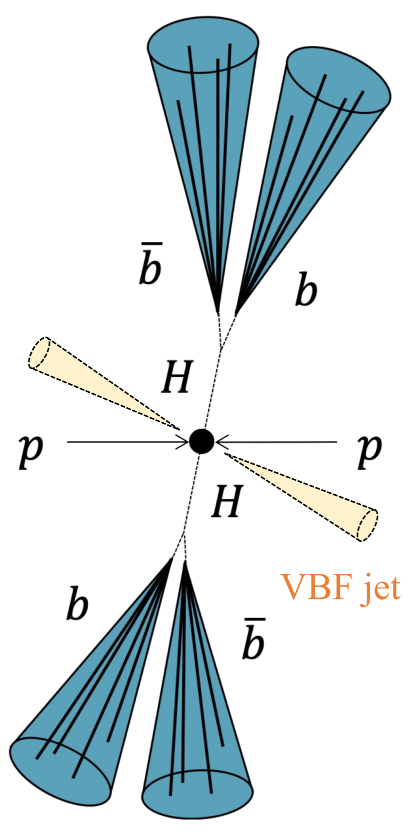


→ Can directly access the trilinear Higgs self-coupling (κ_λ) and the di-Higgs di-vector boson coupling (κ_{2V}).

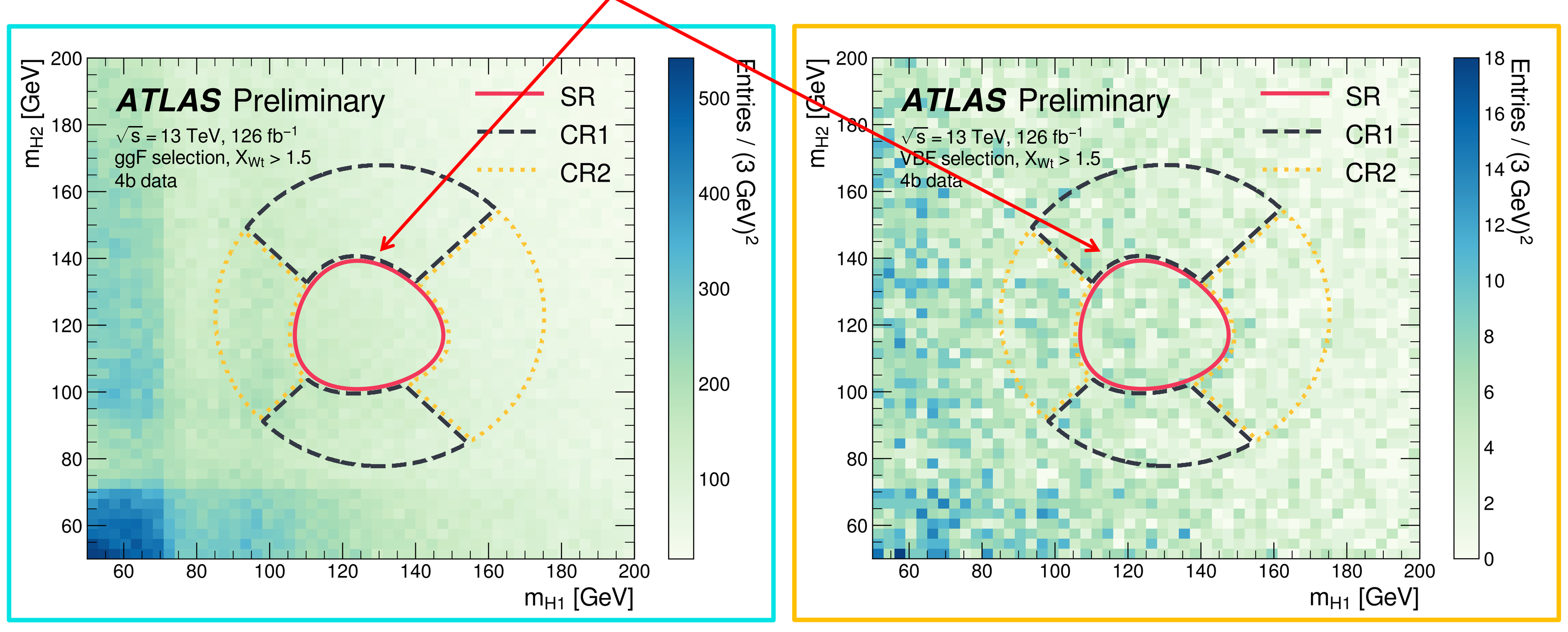
- The $b\bar{b}b\bar{b}$ final state is one of the most sensitive channels, thanks to the highest branching ratio ~34%.

2. Event Selection

- Two orthogonal selections targeting ggF events and VBF events:
  1. multi b-jet triggers
  2. ≥ 4 b-jets with $p_T > 40$ GeV & $|\eta| < 2.5$
  3. Reconstruct two Higgs Candidates (HC)
  4. ggF or VBF event separation
     # of jets ≥ 6 & $m_{jj} > 1$ TeV & $|\Delta\eta_{jj}| > 3.0$ etc
     If true/false, pass to VBF/ggF selection.
  5. Background reduction
     ggF selection : $|\Delta\eta_{HH}| < 1.5$ and $t\bar{t}$ veto
     VBF selection: only $t\bar{t}$ veto
  6. Signal Region (SR) definition

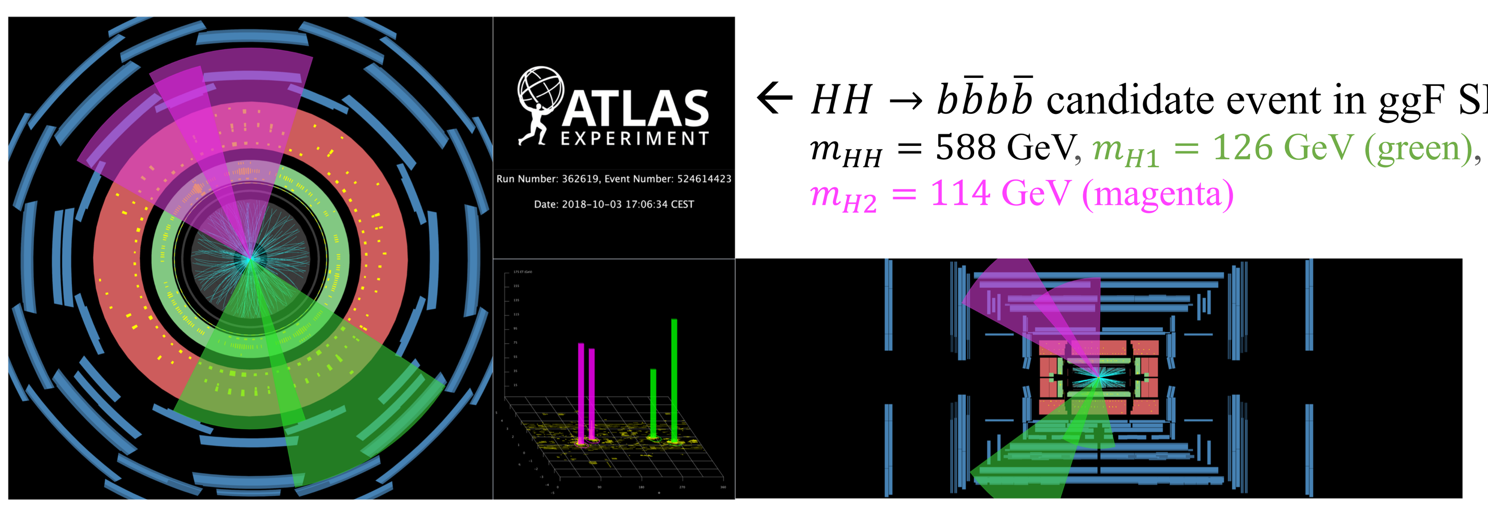


$$X_{HH} = \sqrt{\left(\frac{m_{H1} - 124\text{ GeV}}{0.1\, m_{H1}}\right)^2 + \left(\frac{m_{H2} - 117\text{ GeV}}{0.1\, m_{H2}}\right)^2} < 1.6$$



- Analysis categorization is adopted to enhance sensitivity.
  - ggF SR : $|\Delta\eta_{HH}|$ and X_{HH} (3×2) categorization
  - VBF SR: $|\Delta\eta_{HH}|$ categorization (split on 1.5)

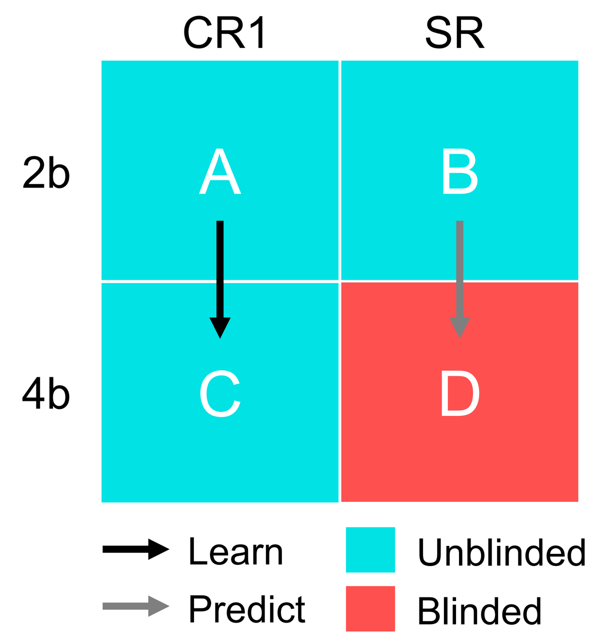
→ ~40% improvement on SM ggF+VBF HH cross-section



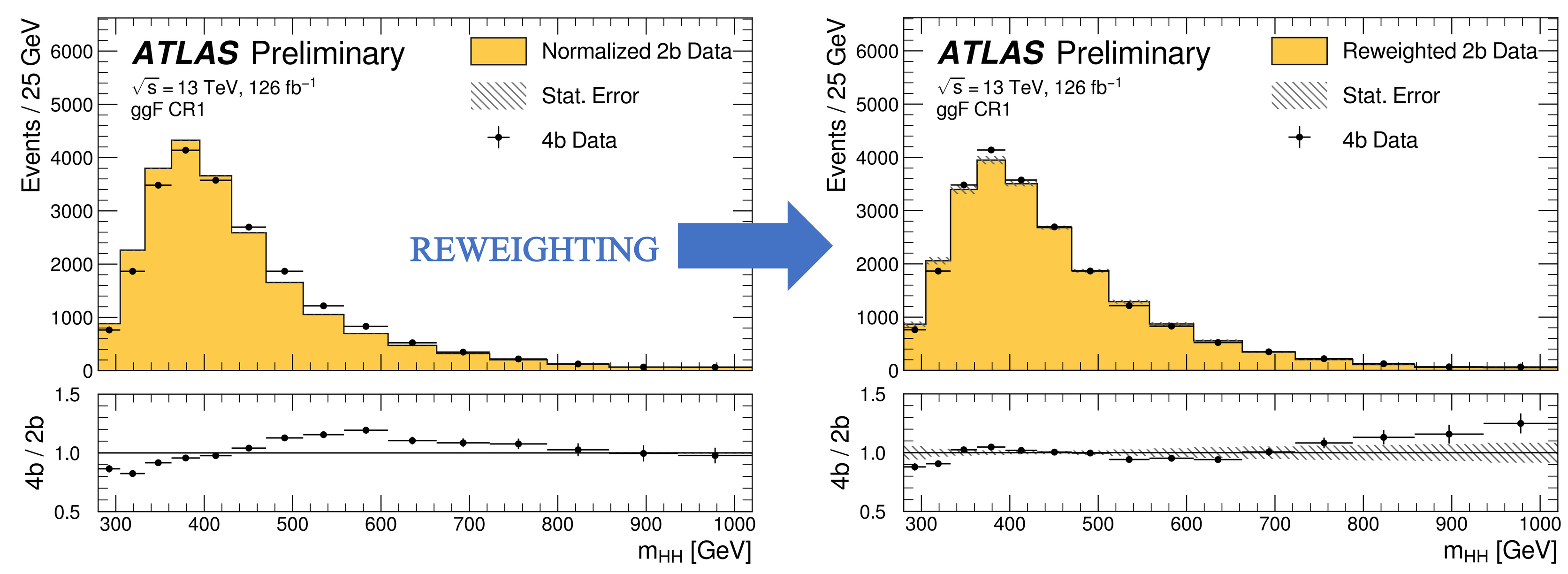
← $HH \to b\bar{b}b\bar{b}$ candidate event in ggF SR
$m_{HH} = 588$ GeV, $m_{H1} = 126$ GeV (green), $m_{H2} = 114$ GeV (magenta)

3. Background Estimation

- Main backgrounds: QCD (~90%) and $t\bar{t}$ (~10%).
- Fully data-driven approach using Neural Network (NN) to estimate background events inclusively.
  - 2b events are used to estimate 4b events.
  - 4b/2b density ratio (weight) is derived from Control Region (CR) using NN.
  - 2b events are reweighted by the weight and performed as 4b background prediction.

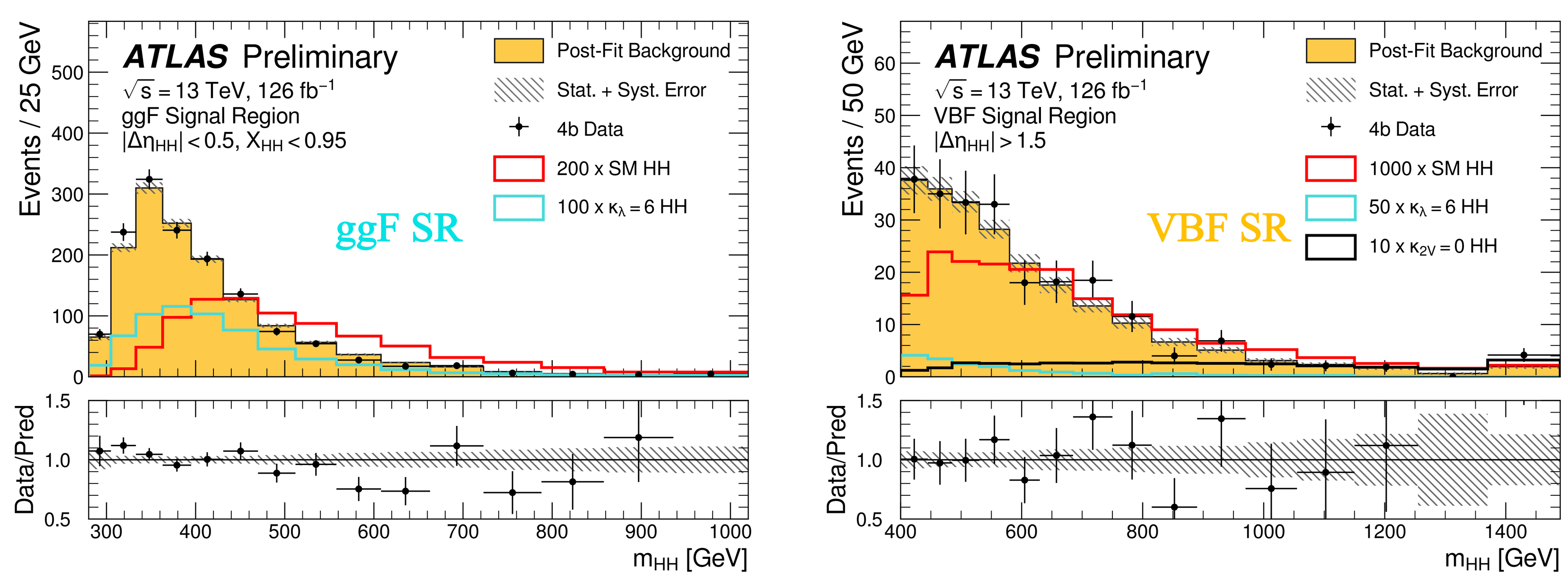


- Validated it works in our SR using 3b events and shifted regions etc.



4. Results

- A simultaneous fit is performed on m_{HH} across ggF SRs and VBF SRs to test signal hypotheses with various κ_λ, κ_{2V} values.
- No significant excess is observed in data.

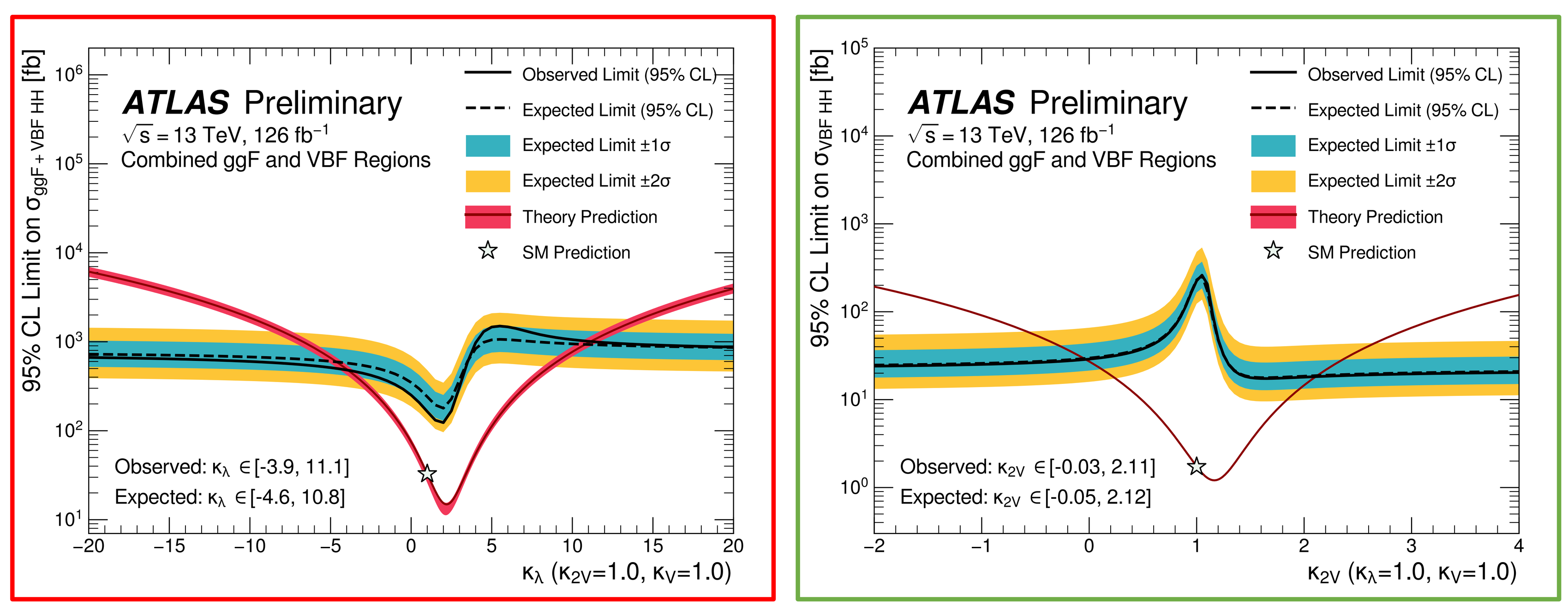


- The observed (expected) upper limits on SM HH cross-section:

	Observed Limit	-2σ	-1σ	Expected Limit	$+1\sigma$	$+2\sigma$
$\sigma_{\text{ggF}}/\sigma_{\text{ggF}}^{\text{SM}}$	5.5	4.4	5.9	8.2	12.4	19.6
$\sigma_{\text{VBF}}/\sigma_{\text{VBF}}^{\text{SM}}$	130.5	71.6	96.1	133.4	192.9	279.3
$\sigma_{\text{ggF+VBF}}/\sigma_{\text{ggF+VBF}}^{\text{SM}}$	5.4	4.3	5.8	8.1	12.2	19.1

  - 2.5× improvement wrt. previous 36.1 fb^{-1} ggF result (11.1(20.7)×SM)[1]
  - 4.1× improvement wrt. previous full Run-2 VBF result (840(550)×SM)[2]

- The observed and expected constraints on κ_λ and κ_{2V}:



[1] JHEP01(2019)030, [2] JHEP07(2020)108

Full details : ATLAS-CONF-2022-035 (released on 02 June 2022)