Full Run 2 analysis of Higgs boson decay to b-quarks in CMS

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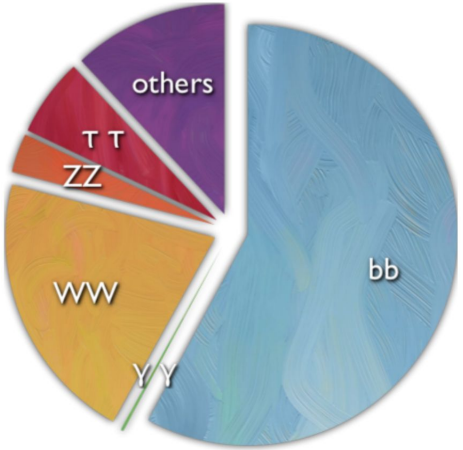
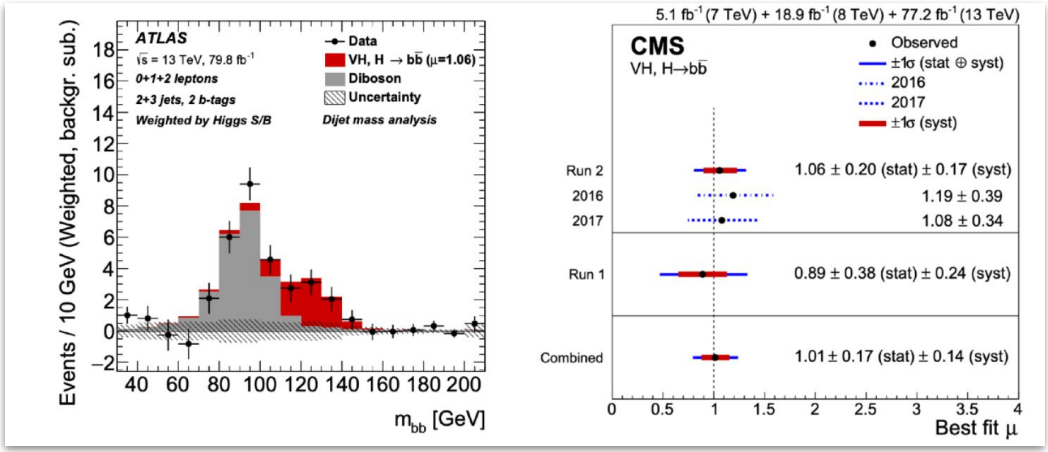
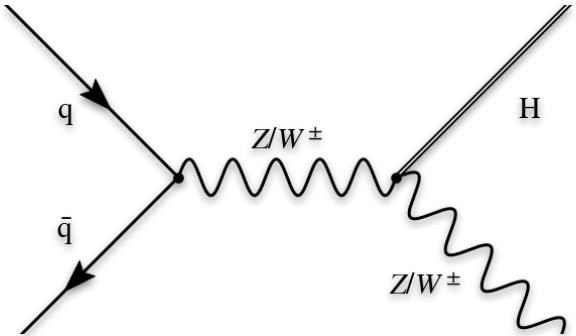
HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

Introduction

- H⟶ bb uniquely measures Yukawa coupling to b quarks
- Largest branching fraction ~58%
- VH production: best triggering and background rejection
- H->bb first observed in 2018, by ATLAS and CMS
- Here: Run 2 legacy result, focus on measurement of Simplified Template Cross Sections







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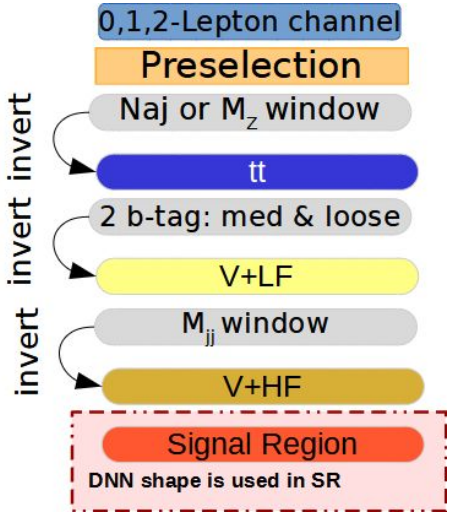
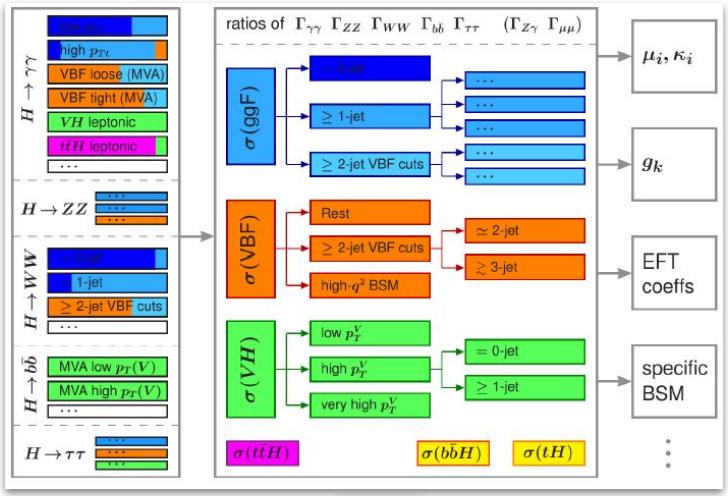
VHbb Analysis

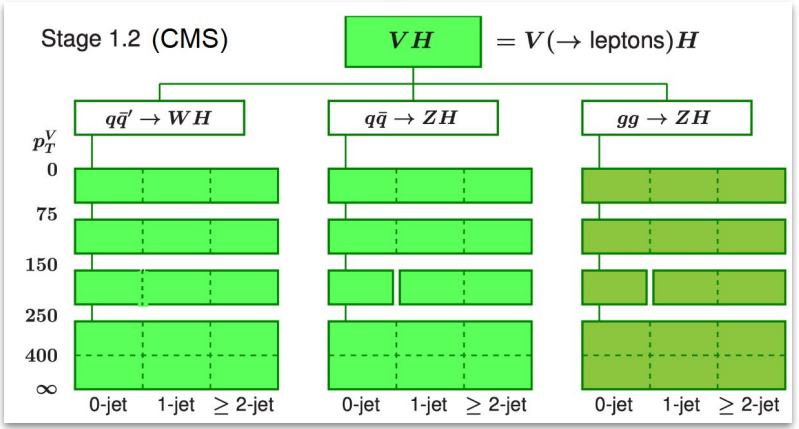
- 3 channels are considered:
  - 0-lepton (Z->***νν***), 1-lepton (W->l***ν***) and 2 lepton (Z->l+l-)
- 2 Higgs decay topologies:
  - two distinct b-quark jets ("resolved")
  - one "fat" jet containing two b candidates ("boosted")
- Background normalisation for the signal region (SR) is derived from orthogonal control regions (CR) :
  - $t\bar{t}$
  - V+HF(heavy flavor)
  - V+LF (lighter flavors)
  - SR (DNN (resolved)/BDT (boosted))
- Extensive use of machine learning both for V+HF CR and SR
- Using the S/B separating DNN discriminant as the observable
- Analysis in STXS stage 1.2 bins for the VH process



STXS Framework

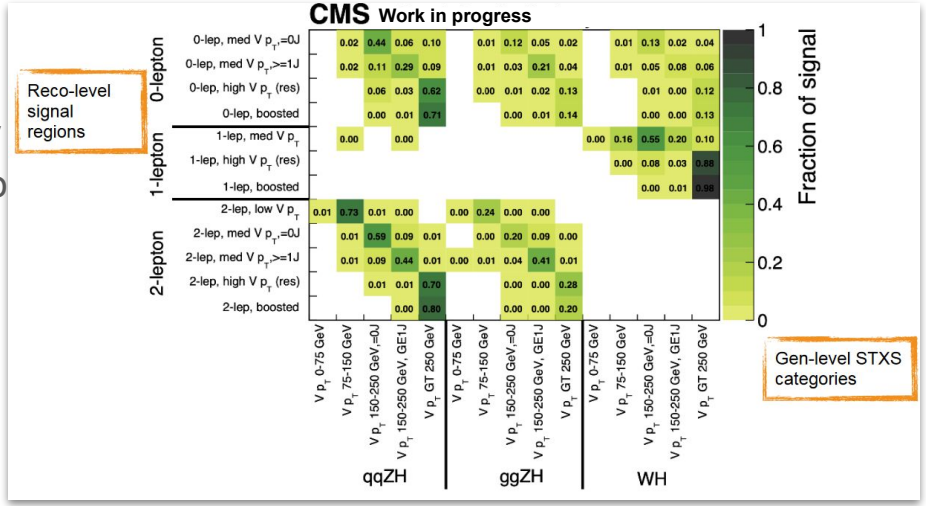
- Allows combination of all Higgs decay channels
- Minimises dependence on theory systematics entering the measurement
- Measurements can be easily interpreted using various theory frameworks





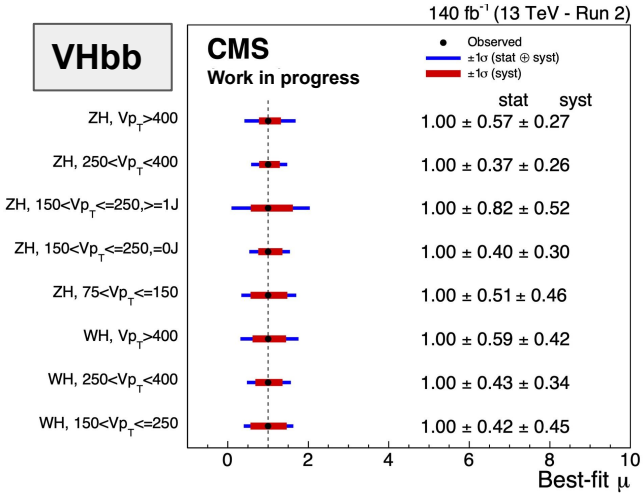
VHbb Run 2 Analysis signal STXS bins

- VHbb Run 2 Analysis signal STXS bins (deviations from the default scheme):
  - Modified based on experimental sensitivity
  - Reco-level signal regions are introduced to match gen-reco categories
  - Higgs boosted topology is included to the signal categories with $p_T(V)$ > 250 GeV



Full Run 2 expected sensitivity for VH(H->bb) and VZ(Z->bb)

- On the right, the VZ(Z->bb) cross-check blinded results:
  - similar topology (besides mass) with higher cross section
  - same analysis strategy (only differences: mass window, dedicated, re-trained DNNs/BDTs)
- On the bottom, current status of the measurement for the expected signal strength(setting mu to 1)



Expected signal strength:

$ZH = 1.000^{+0.216}_{-0.204}$

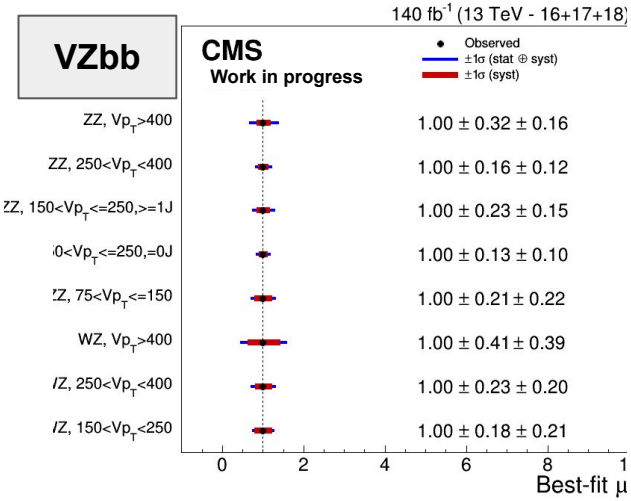
$ZH = 1.000^{+0.126}_{-0.110}(\text{Syst})^{+0.175}_{-0.172}(\text{Stat})$

$WH = 1.000^{+0.273}_{-0.266}$

$WH = 1.000^{+0.147}_{-0.138}(\text{Syst})^{+0.231}_{-0.227}(\text{Stat})$

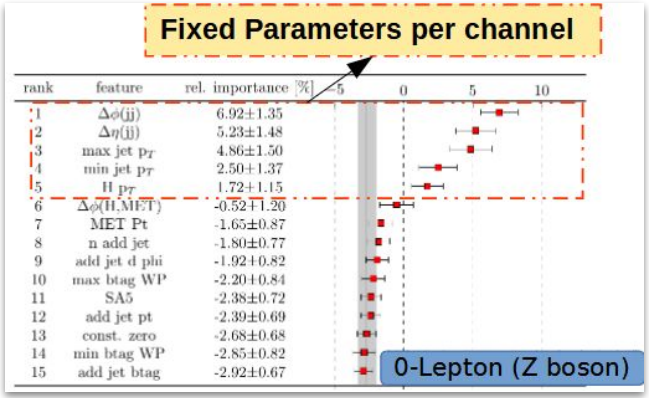
$\text{Inclusive} = 1.000^{+0.166}_{-0.160}$

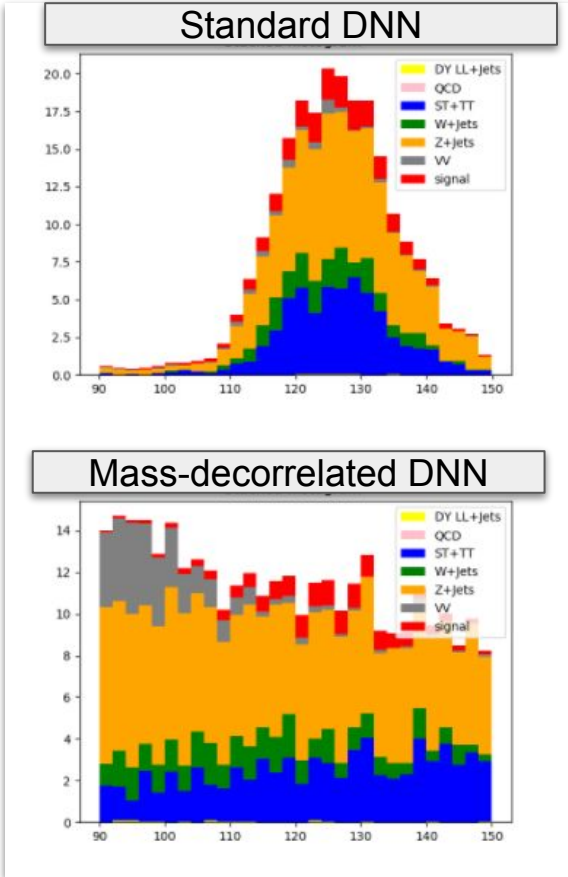
$\text{Inclusive} = 1.000^{+0.100}_{-0.091}(\text{Syst})^{+0.133}_{-0.132}(\text{Stat})$



m(bb) based cross-check analysis

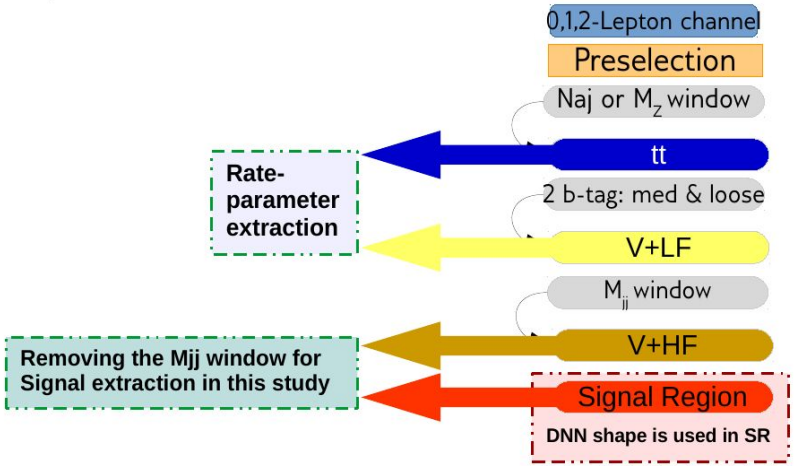
- DNN discriminant as an observable strongly "sculpts" the invariant mass distribution
  - Solution: decorrelate the DNN from mass-related quantities
  - Find mass-decorrelated variables -> fix to the mean values
- Unbiased m(bb) distribution as analysis observable
- This method keeps the DNN discrimination power





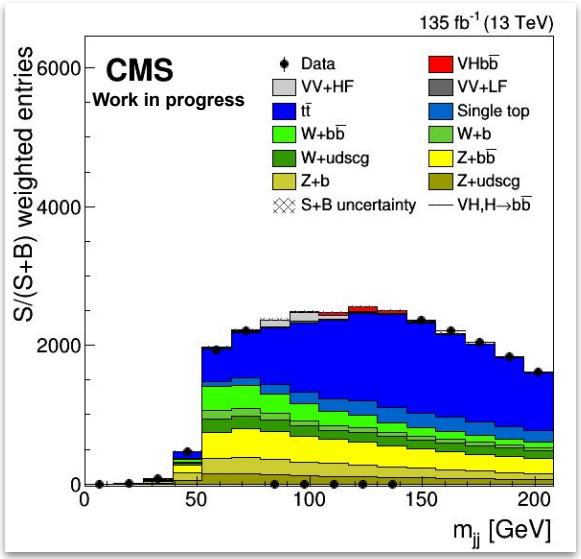
m(bb) cross-check analysis strategy

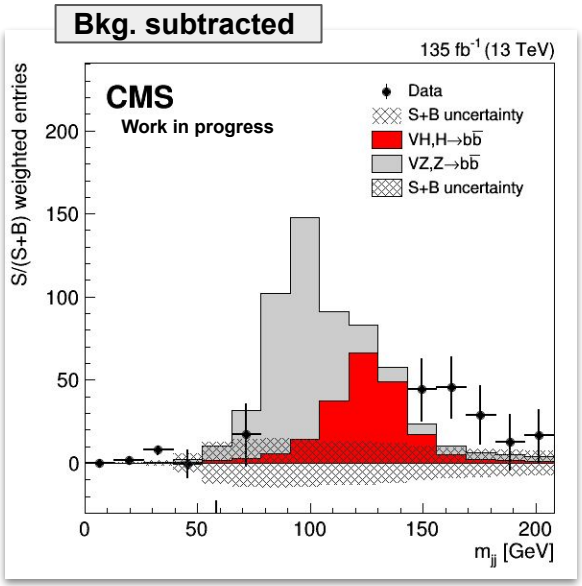
- Only 2 control regions (since V+HF cannot be used):
  - $t\bar{t}$
  - V+LF
- 3 signal regions with different purity:
  - defined as intervals of mass-decorrelated DNN discriminant
  - 2 Cuts on Mass decorelated DNN
  - Cuts found by maximizing Assimov median significance
  - Simultaneous fit of SR+CR for m(bb)



m(bb) based analysis result

- the blinded m(bb) cross-check analysis plot for combined results





Process	combination
2018 analysis	
Expected	$+1.000^{+0.450}_{-0.442}$
2017 analysis	
Expected	$+1.000^{+0.608}_{-0.595}$

Xsec*BR relative to SM

Summary

- Analysis strategy and the expected sensitivity presented for full
- Run 2 VHbb STXS measurement
- VZ(Z->bb) and m(bb) cross-check analyses also shown
- One can clearly see an improvement wrt. the previous VHbb analysis
- Strategy is converged. Significant improvement wrt. the previous VHbb analysis
    - In the process of unblinding all the regions
- The full Run 2 STXS measurement of VH process will provide an important input for further theoretical interpretations and for the combination with ATLAS results