Measurements of Higgs Bosons Decaying to Bottom Quarks from Vector Boson Fusion Production with the ATLAS Experiment at $\sqrt{s}$=13 TeV

ATLAS Paper Draft
HIGG-2019-04
Version 1.0
Target journal: EPJC

Comments are due by: 24 Sept 2020

Supporting internal notes

Measurements of Higgs Boson Decays to *b*-quarks via Weak Boson Fusion Production:
https://cds.cern.ch/record/2703147

Analysis Team
[*email:* atlas-HIGG-2019-04-editors@cern.ch]

Shraddha Anand, Han Cui, Carolyn Gee, Zhijun Liang, Bo Liu, XinChou Lou, Matthew Henry Klein, Jason Nielsen, Christian Nunez, Liaoshan Shi, Lauren Tompkins, Song-Ming Wang

Editorial Board
[*email:* atlas-HIGG-2019-04-editorial-board@cern.ch]

Kathrin Becker (chair), Antonio de Maria, Carlo Varni

Paper Draft:
https://cds.cern.ch/record/2730395/

Includes combination with VBF Hbb+ɣ result:
https://cds.cern.ch/record/2729658/

Matthew Klein (University of Michigan),
Lauren Tompkins (Stanford University)
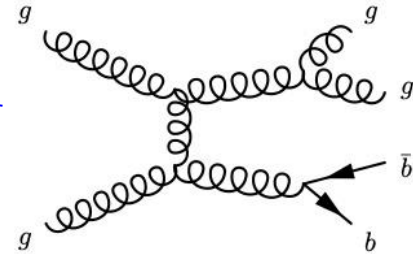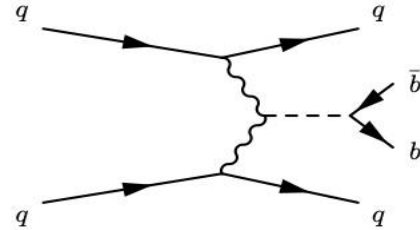o.b.o. the analysis team

PAM time not set

Motivation

Measure Higgs decays to b-quarks in **complementary production mode** to dominant measurement (VH).

- All-hadronic final state:

  - Signature: 2 b-jets, 2 VBF jets

  - Backgrounds: Non-resonant (NR) bbjj, Zjj

  - VBF topology allows for discrimination against QCD background

- Previous iteration: <u>HIGG-2016-30</u> (30.6 fb^{-1})

  - $\mu_{Hbb} = 2.7^{+2.2}_{-2.0}$; $\mu_{VBFHbb} = 4.1^{+3.2}_{-2.9}$ (all-hadronic only)

- Opportunity for **significant analysis improvements** and dramatically increased sensitivity for full Run 2 (126 fb^{-1}) analysis
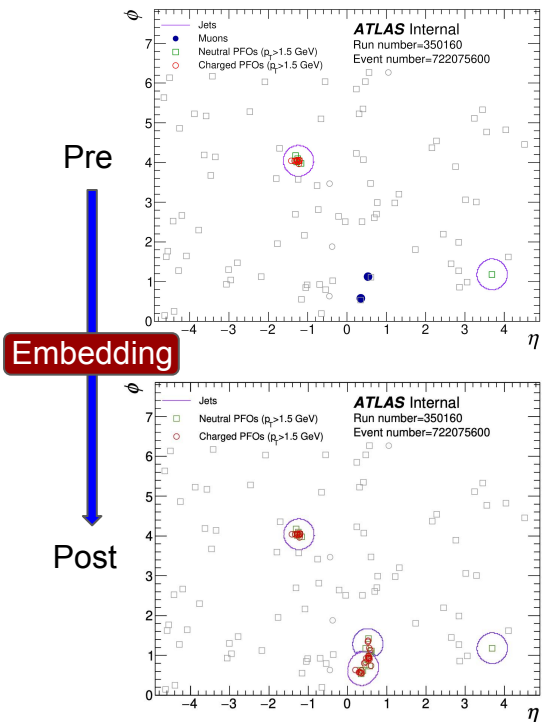
Strategy

In brief: use MVA to divide events into signal regions of varying sensitivity, do simultaneous fit of Z, NR background, Higgs to m_{bb} to extract signal

- Key innovations/improvements:

Problem: Z→ bb + 2 jet MC not reliable in analysis phasespace

Solution: Use *embedded* data Z → $\mu\mu$ events to constrain Z → bb contribution

Embedding

Pre

Post

Problem: m_{bb} fit has too many free parameters

Solution: Use an *Adversarial NN* to decorrelate m_{bb} from classifier → use same NR shape in all regions, reducing free params, boosting statistical power of fit

No ANN

With ANN

Bkgd shape

Results

10 SR
+
10 CR
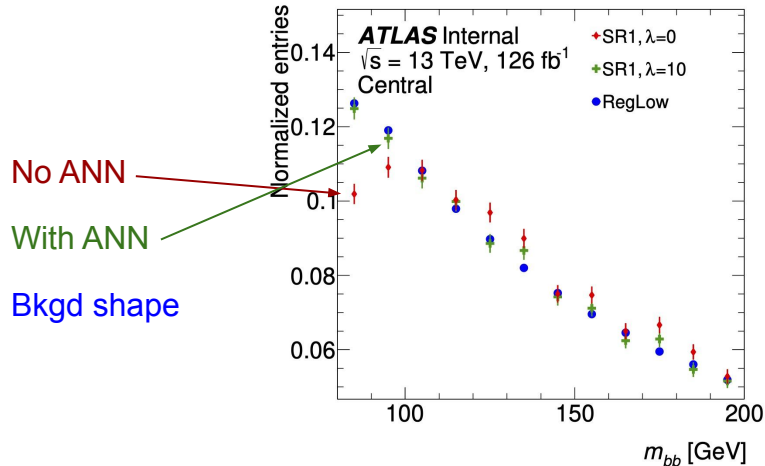
This analysis

| Results	Inclusive Production	VBF Production
Expected significance	2.85σ	2.77σ
Observed significance	2.71σ	2.63σ
Expected signal strength	$1^{+0.37}_{-0.36}$	$1^{+0.38}_{-0.37}$
Observed signal strength	$0.96^{+0.37}_{-0.36}$	$0.96^{+0.38}_{-0.37}$

Note expected sig increase (VBF production):
0.4σ (2016) → 2.8σ (Full Run 2)

Combination with VBF Hbb+γ

Results	Inclusive Production	VBF Production
Expected significance	3.01σ	2.93σ
Observed significance	3.00σ	2.92σ
Expected signal strength	$1^{+0.35}_{-0.34}$	$1^{+0.36}_{-0.35}$
Observed signal strength	$1.00^{+0.35}_{-0.34}$	$1.00^{+0.36}_{-0.35}$

3σ Hbb prod, 2.9σ for VBF
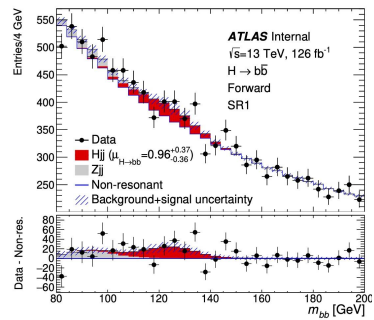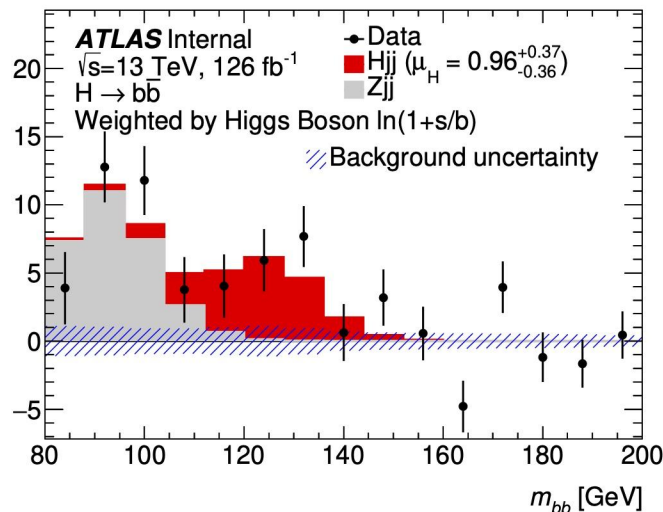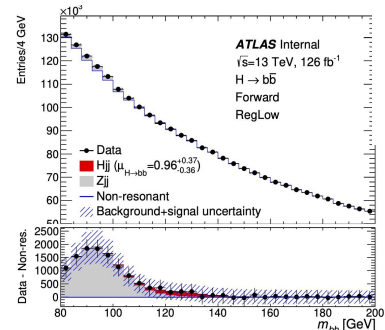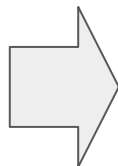
Paper additionally presents results for $p_T^H > 200$ GeV, inclusive and fiducial ($|Y_H| < 2.5$) cross-sections.