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Search for H→bb¯ decays in VBF+gamma final state with the ATLAS detector

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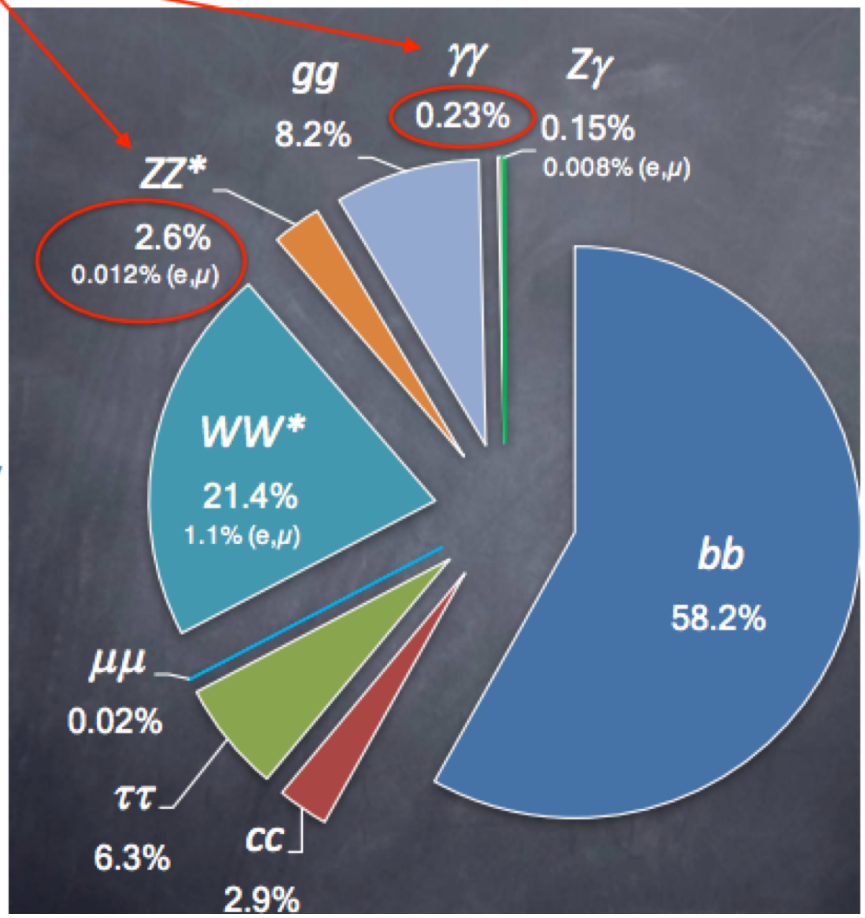
Introduction

- H→bb is the Dominant Decay mode of Higgs Boson(58%)
- Motivation: Search H→bb decay mode in VBF final state

ZZ, γγ: high mass resolution channels mass and precise differential measurements



WW: High BR, but low mass resolution

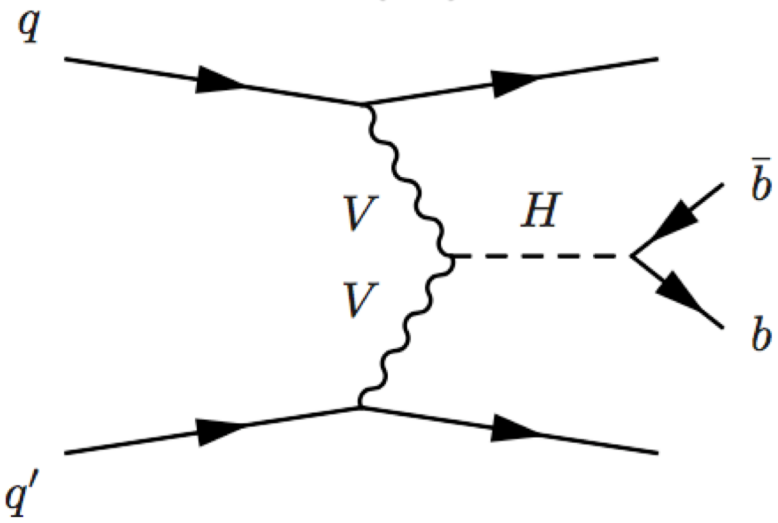
μμ: very small BR, but access to coupling to 2nd generation fermions

bb, ττ: high BR, but low S/B, important to directly probe Higgs boson coupling to fermions

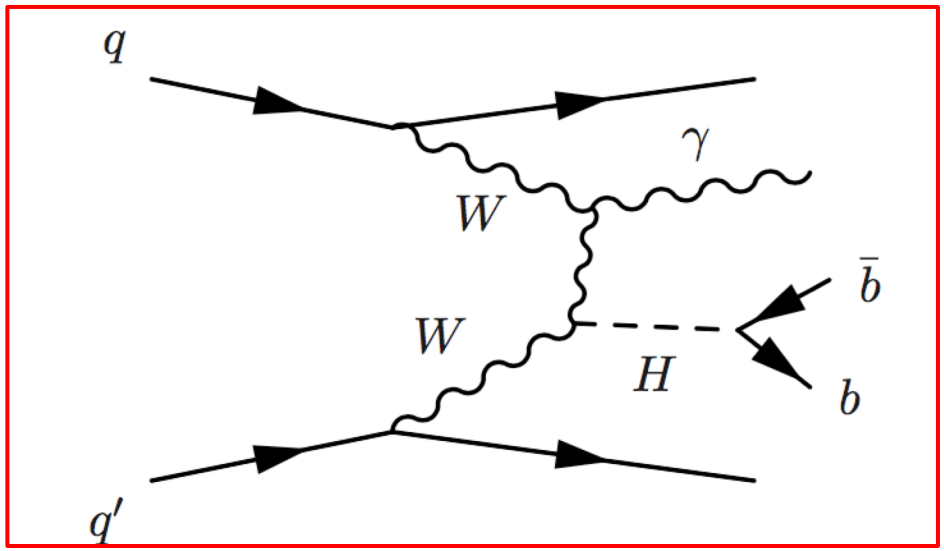
VBF H(bb) analysis

- IHEP team propose Search for H->bb in VBF events containing a central photon
- Advantages of requiring a photon
  - extra handle for trigger
  - suppresses QCD background
  - Sensitive to WWH VBF production
  - not sensitive to ZZH VBF

VBF H(bb)



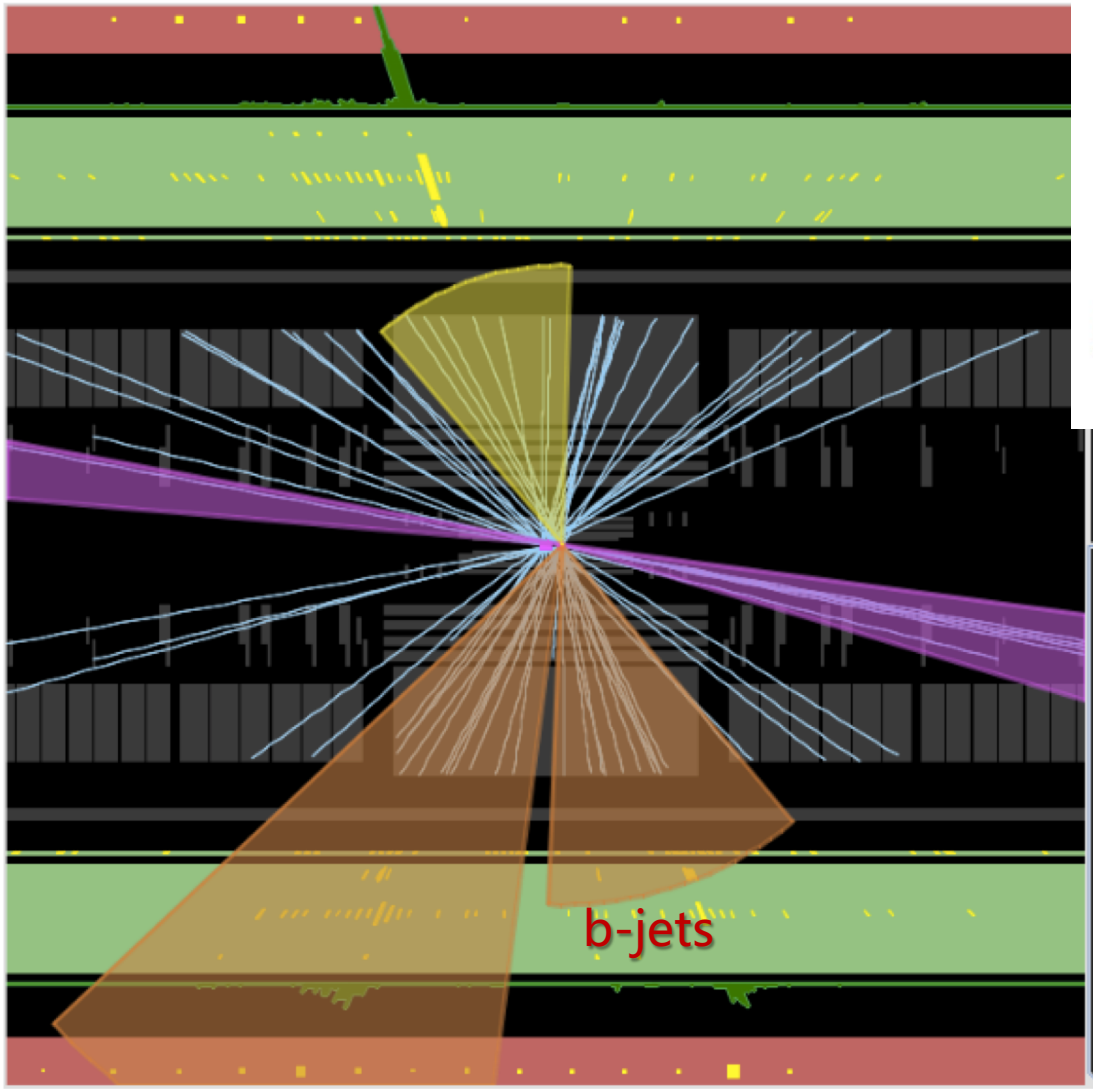
VBF H(bb) +γ



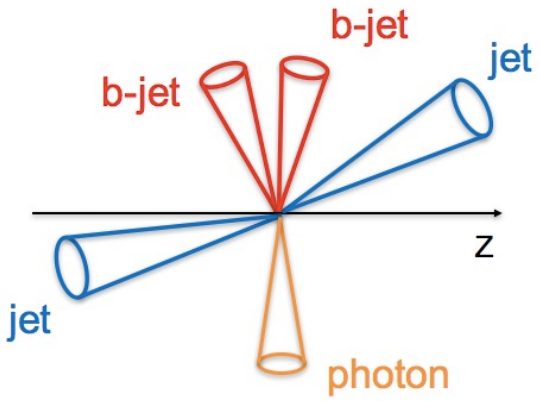
Event display for VBF H(bb)+γ

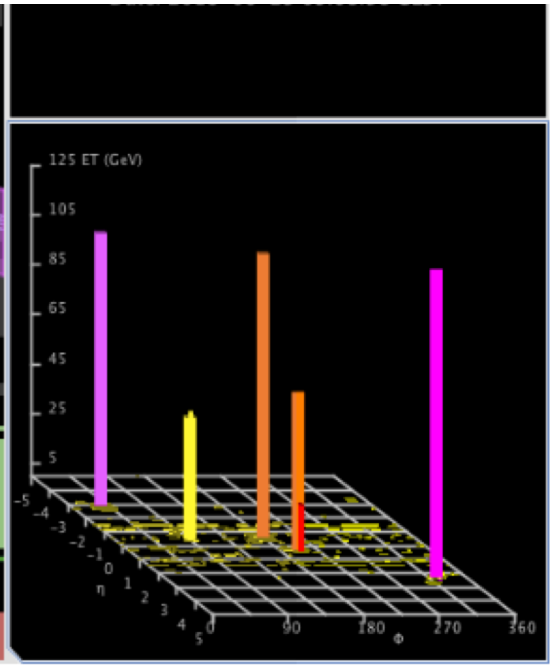
Photon

VBF jets



b-jets

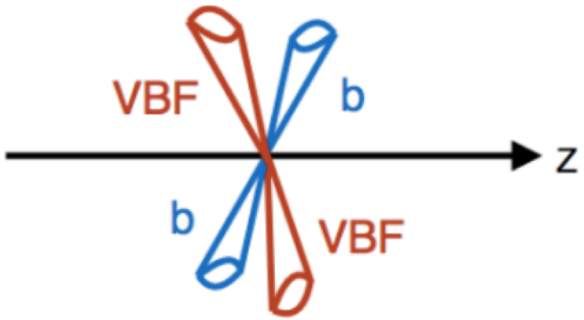




Trigger

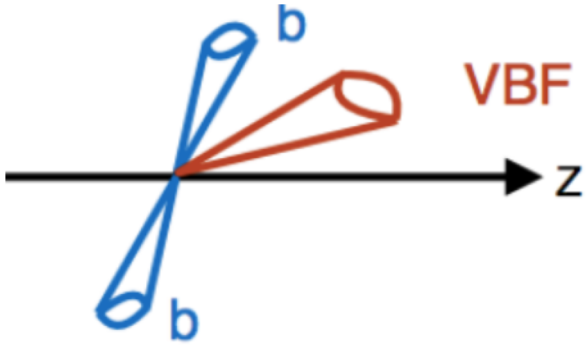
- divided into 3 channels based on triggers:
  - VBF inclusive
    - Two central : 4 central jets with 2 bjet(2b+2j)
    - Four central: 2 central + 1 forward trigger jet (1fj+2b)
  - VBF+photon
    - Photon: photon + 2bjet+2 forward jets (γ+2b+2fj)

L1 trigger: 4 central Jet



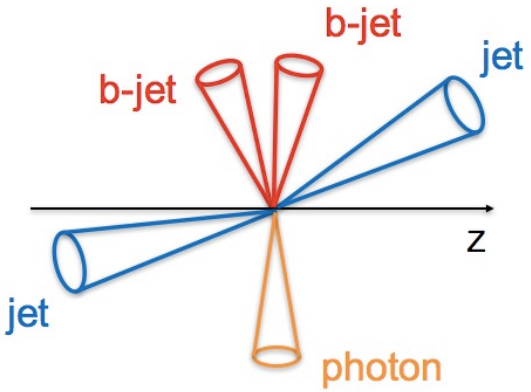
Four central
Channel (2b+2j)

L1: 1 forward jet
+2 central jets



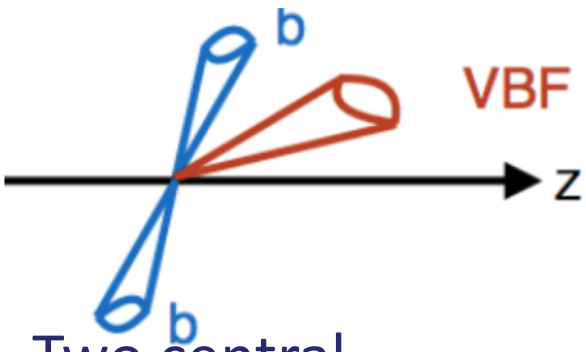
Two central
Channel (1fj+2b)

L1: 1 EM object

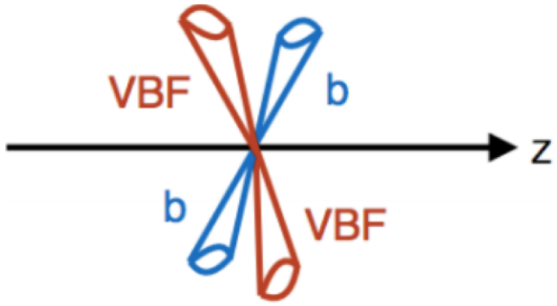


Photon channel
γ+2b+2fj

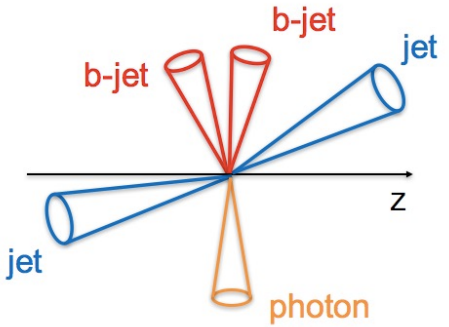
Event Selection



Two central Channel (1fj+2b)



Four central Channel (2b+2j)



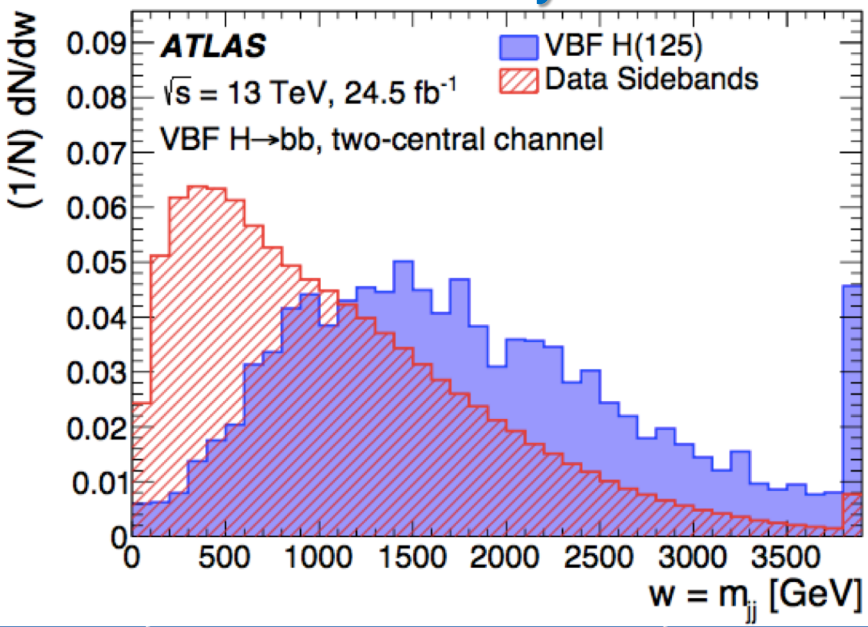
Photon channel γ+2b+2fj

	Two central	Four central	Photon
2 b-jet	p_T>95GeV p_T>70GeV	p_T>55GeV	p_T>40GeV
2 VBF jets	p_T>60GeV, 3.2<|η|<4.4 p_T>20GeV, |η|<4.4	p_T>55 GeV,|η|<4.4 Veto event with jet p_T >60GeV, 3.2<|η|<4.4	p_T>40GeV |η|< 4.4
Photon			E_T>30GeV
Event topology	p_T(bb)>160GeV	p_T(bb)>150GeV	p_T(bb)>80GeV M(jj) >800GeV

Inclusive analysis veto data events in photon channel orthogonality between different channels

Boosted Decision Tree Analysis

- 11 variables used in BDT analysis

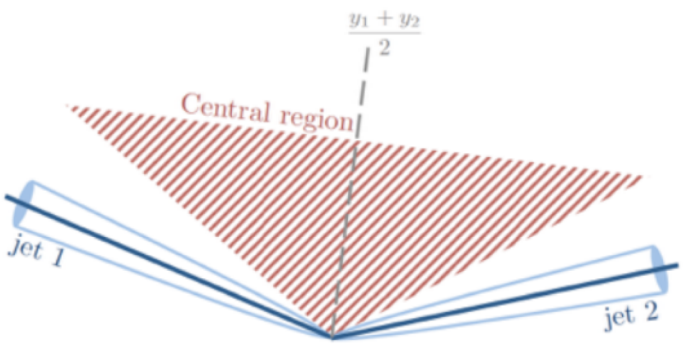


	VBF H(bb) Inclusive	VBF H(bb)+Photon
g/q seperation	Ntrk(j1),Ntrk(j2) minΔR(J1),minΔR(J2)	Ntrk(j1),Ntrk(j2)
VBF jets	p_T(JJ), M(JJ),ΔM(JJ) Max(η(J1), η(J2))	p_T(JJ), M(JJ), Δη(JJ)
Color connection	p balance η^*_T (Higgs centrality)	p balance Photon Centrality
Angular	cos θ(bb,jj)	ΔR(b1,γ),ΔR(b2,γ),Δϕ(bb,jj),cos θ

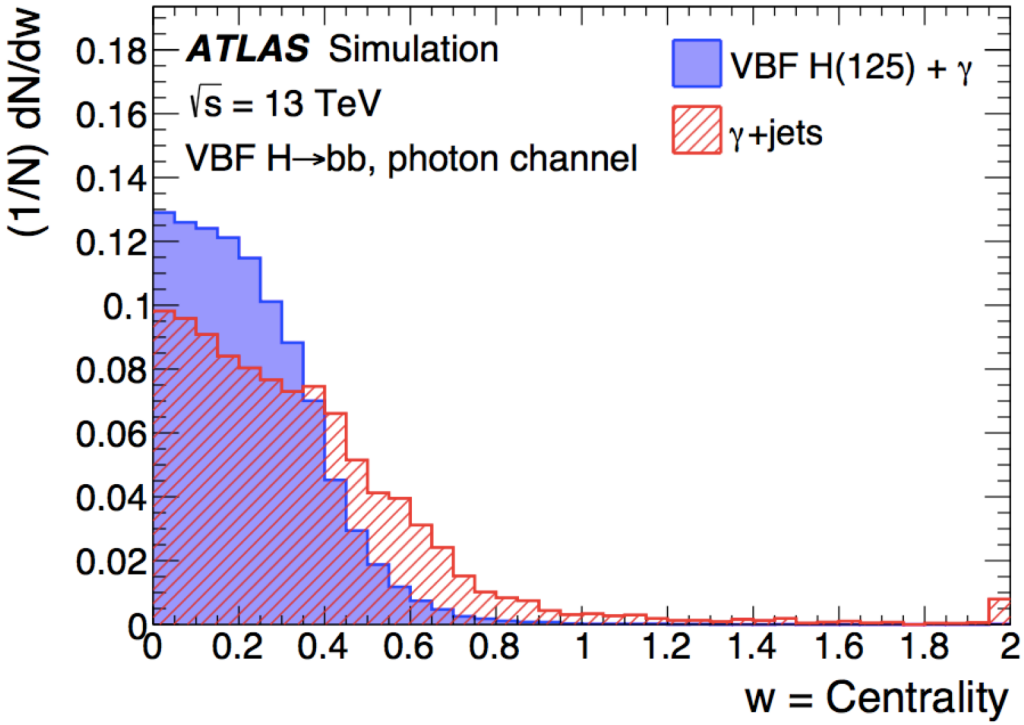
MVA Input variable: photon centrality

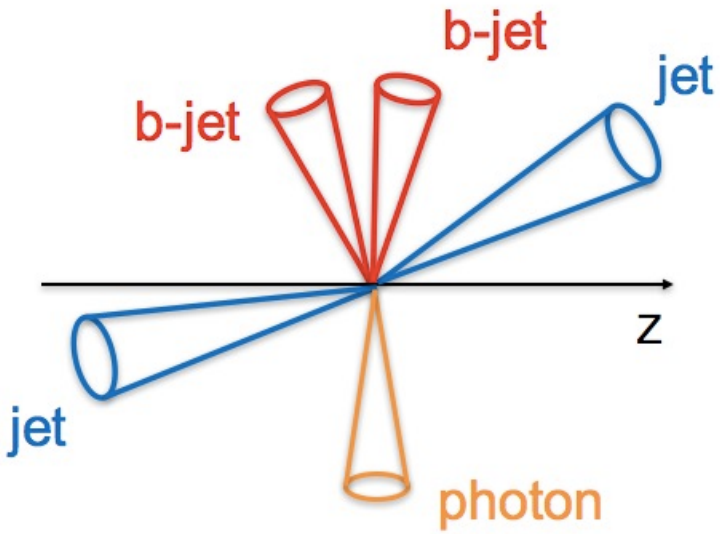
Use 11 variables used in BDT analysis

$$centrality(\gamma) = \left| \frac{y_\gamma - \frac{y_{j_1}+y_{j_2}}{2}}{y_{j_1} - y_{j_2}} \right|$$



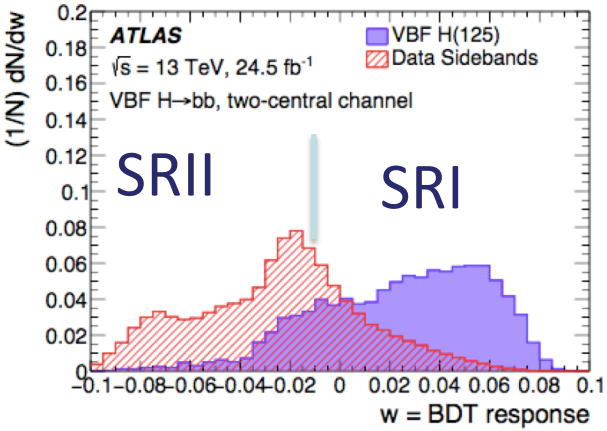
No color connection between VBF jets and b jets in signal



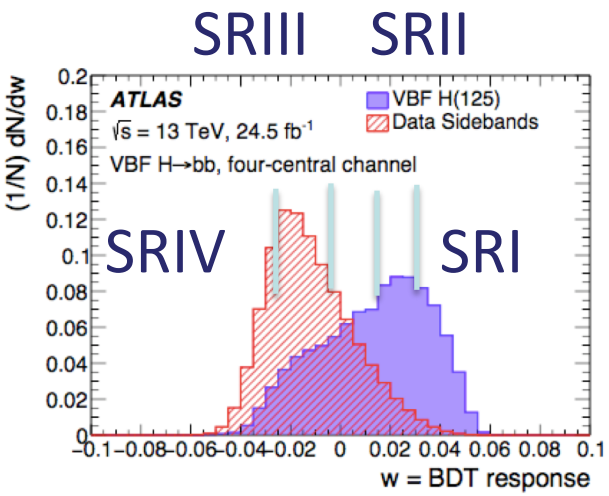


BDT response

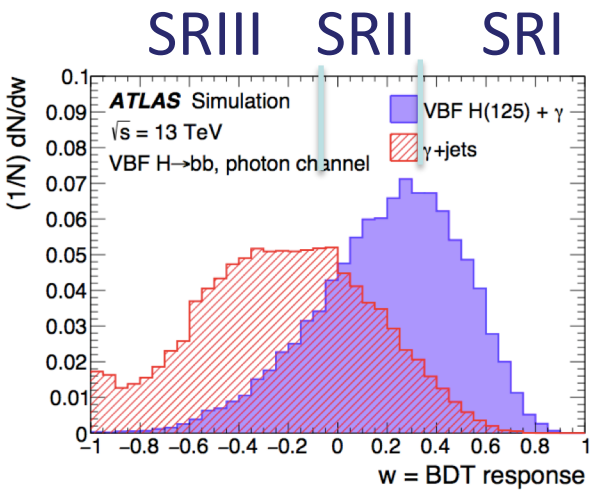
- Divide into 9 categories based on BDT weight
  - Expected Higgs and Z events in 100GeV<m(bb)<140GeV



Two central



Four central



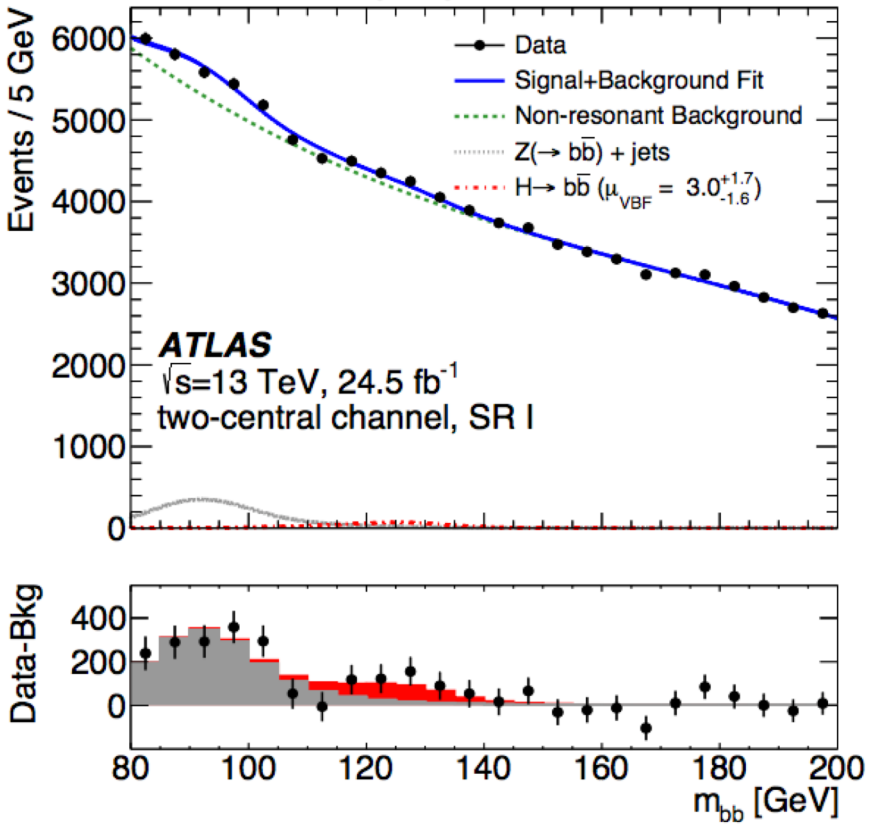
Photon channel

Channel	*two-central*		*four-central*				*photon*		
Region	SR I	SR II	SR I	SR II	SR III	SR IV	SR I	SR II	SR III
Higgs									
VBF	101.2±2.0	22.2±0.9	51.6±1.1	28.4±0.9	43.1±1.0	41.9±1.1	6.2±0.1	5.5±0.1	2.3±0.1
ggF	23.8±2.6	75.7±6.1	11.3±2.2	13.2±1.5	43.4±3.8	127.0±6.5	0.5±0.2	0.3±0.1	0.8±0.3
VH	0.2±0.2	6.0±1.2	1.2±0.9	0.7±0.3	3.9±0.8	28.9±2.6	<0.1	<0.1	<0.1
ttH	2.0±0.2	14.6±0.7	0.3±0.1	1.0±0.1	5.7±0.3	20.2±0.5	<0.1	<0.1	0.4±0.1
Z + jets ($Z\gamma$)	183.1±50.6	515.1±73.4	76.42±14.8	119.4±21.9	385.4±48.5	1224.6±97.9	2.4±0.1	6.9±0.1	13.0±0.1

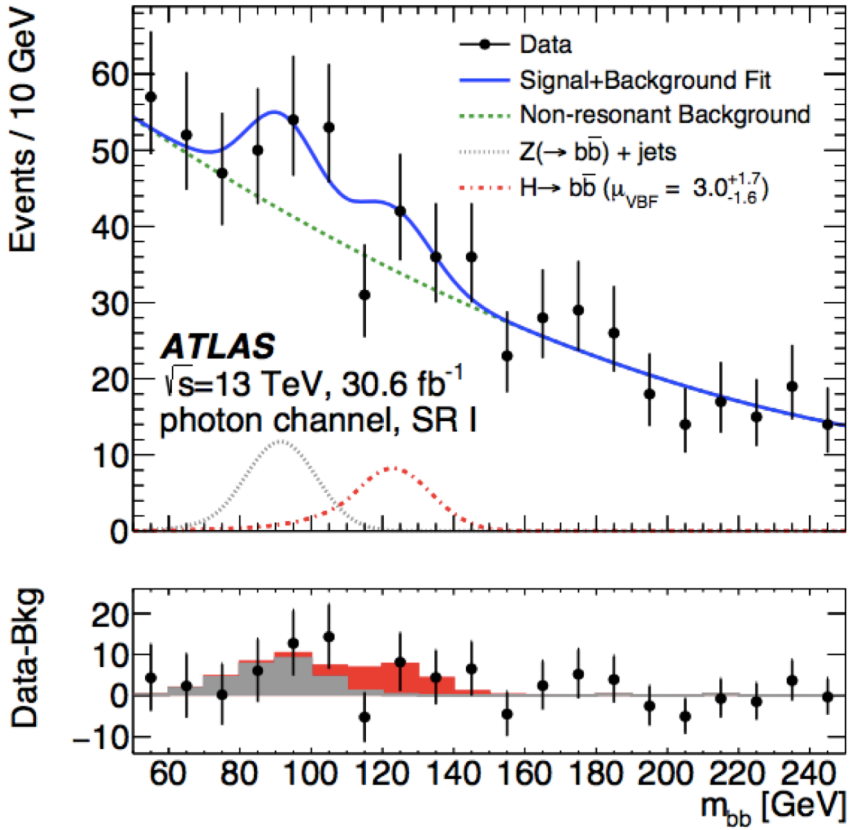
VBF H(bb) background fit

- Simultaneous m(bb) Fit to all 9 regions Phys. Rev. D 98 (2018) 052003
  - Signal shape is modelled by crystal ball function
  - Background shape is modelled by polynomial function

VBF H(bb)



VBF H(bb) $+\gamma$



VBF H(bb) result and major issue

- 1.9σ (0.7σ) Obs(Exp) significance using VBF H(bb)
  - Statistics uncertainty dominated
- Inclusive VBF H(bb) is limited by
  - Jet Trigger p_T threshold too high
  - Need very high p_T(bb) cut to reduce trigger bias
  - Z+jets modelling unc. in high p_T(bb) is large

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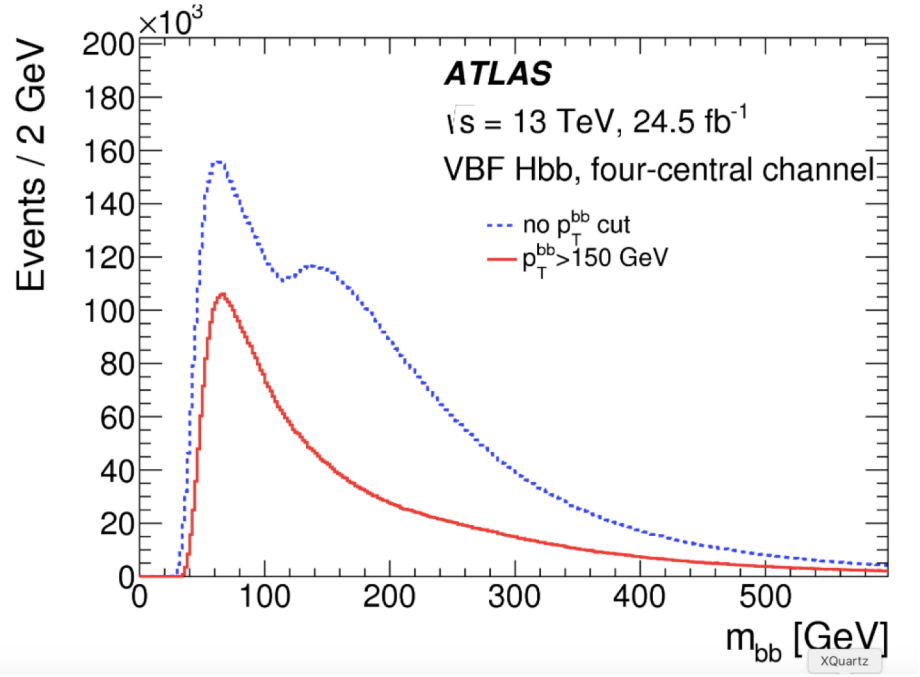

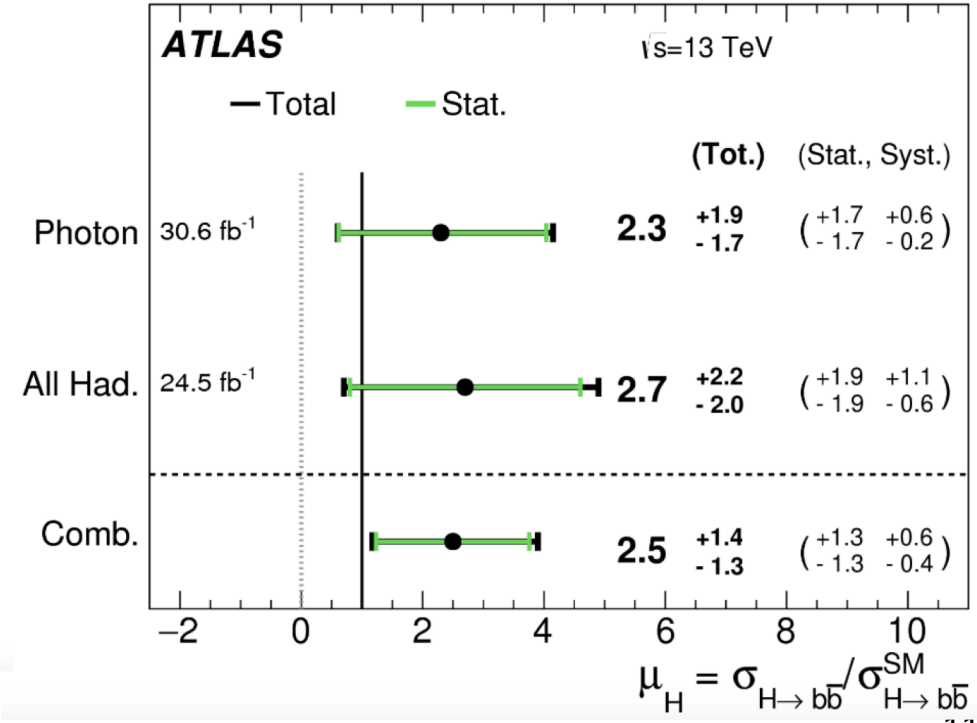

Systematics in VBF H(bb) search

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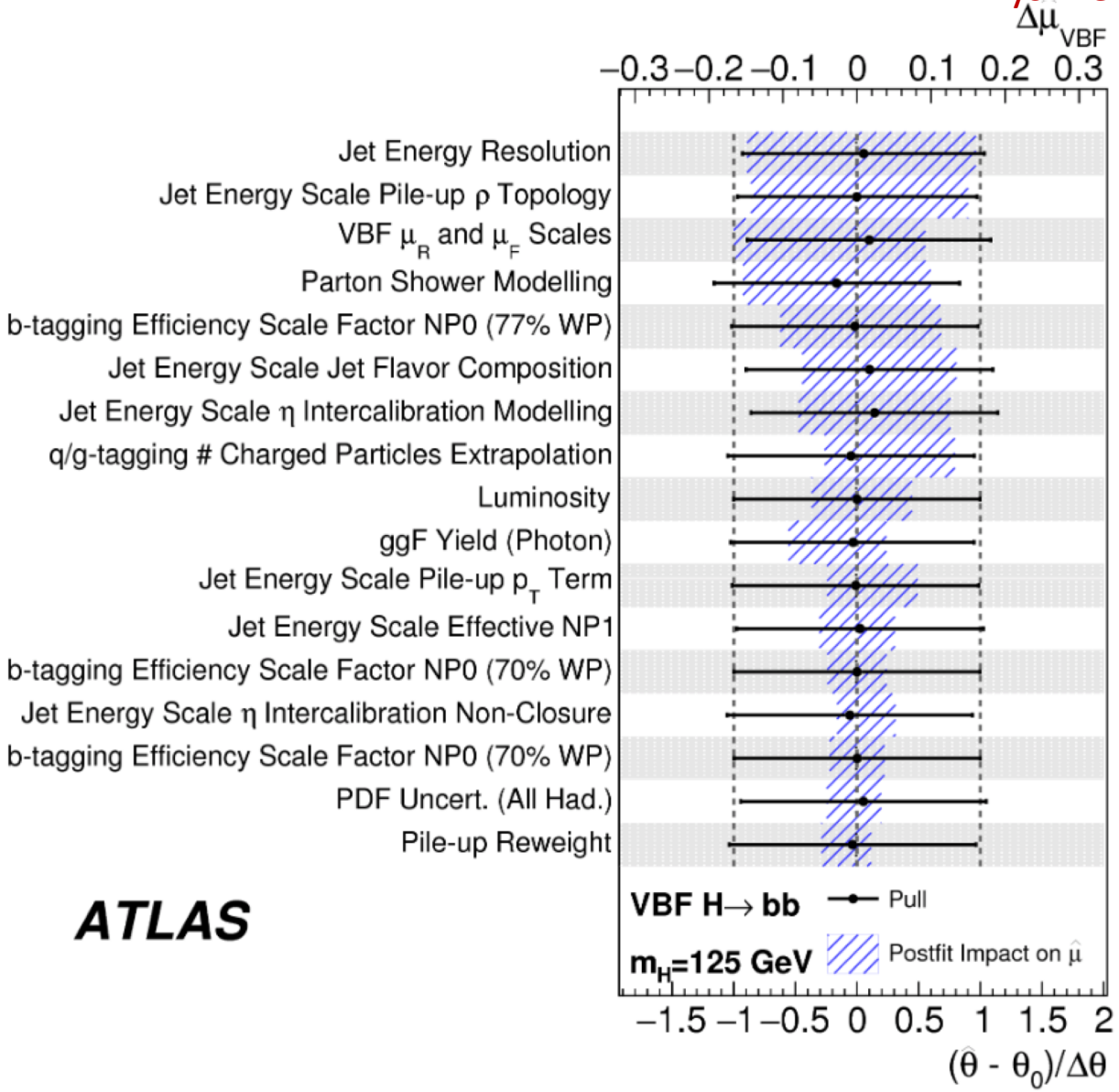
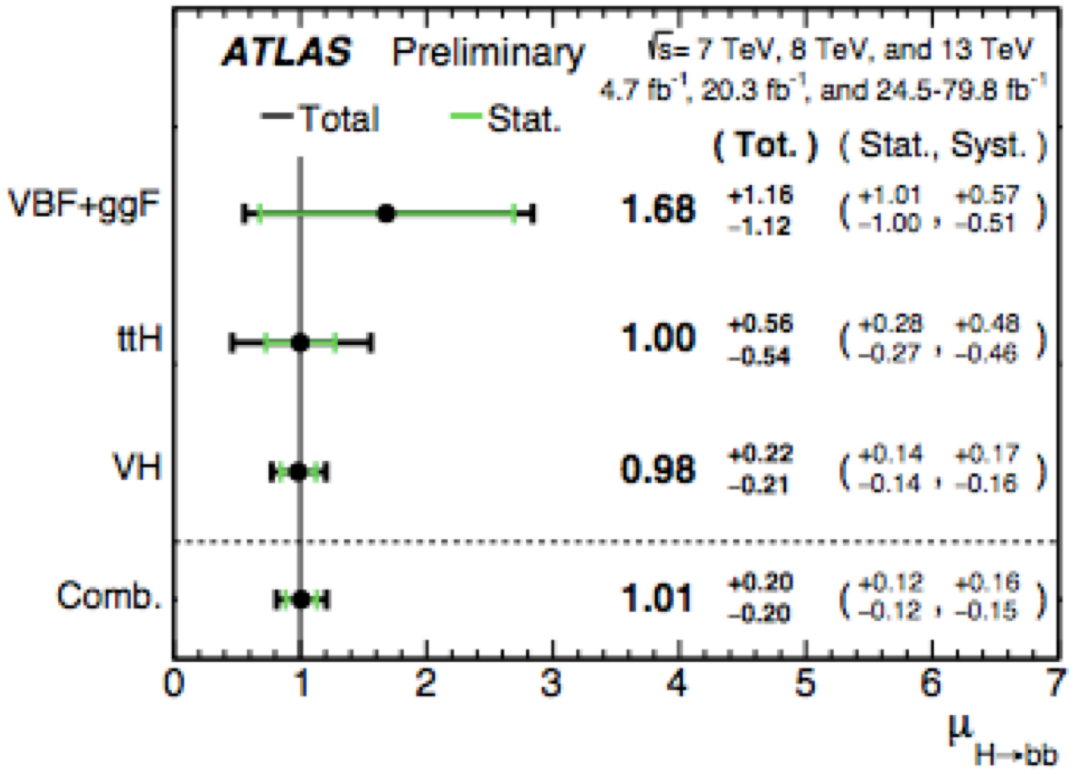


Summary

- ATLAS presented H→bb observation in ICHEP2018 (5.4σ)
  - VBF+ggF channel contributed 1.9σ (0.7) Obs(Exp) significance

H → bb combination

NEW



Significance:
5.4σ observed
(5.5σ expected)

Observation of H → bb!!