ATLAS EXPERIMENT

First Measurement of VH in Full Hadronic Final State with the ATLAS Detector

DPF-PHENO 2024 (Pittsburgh)

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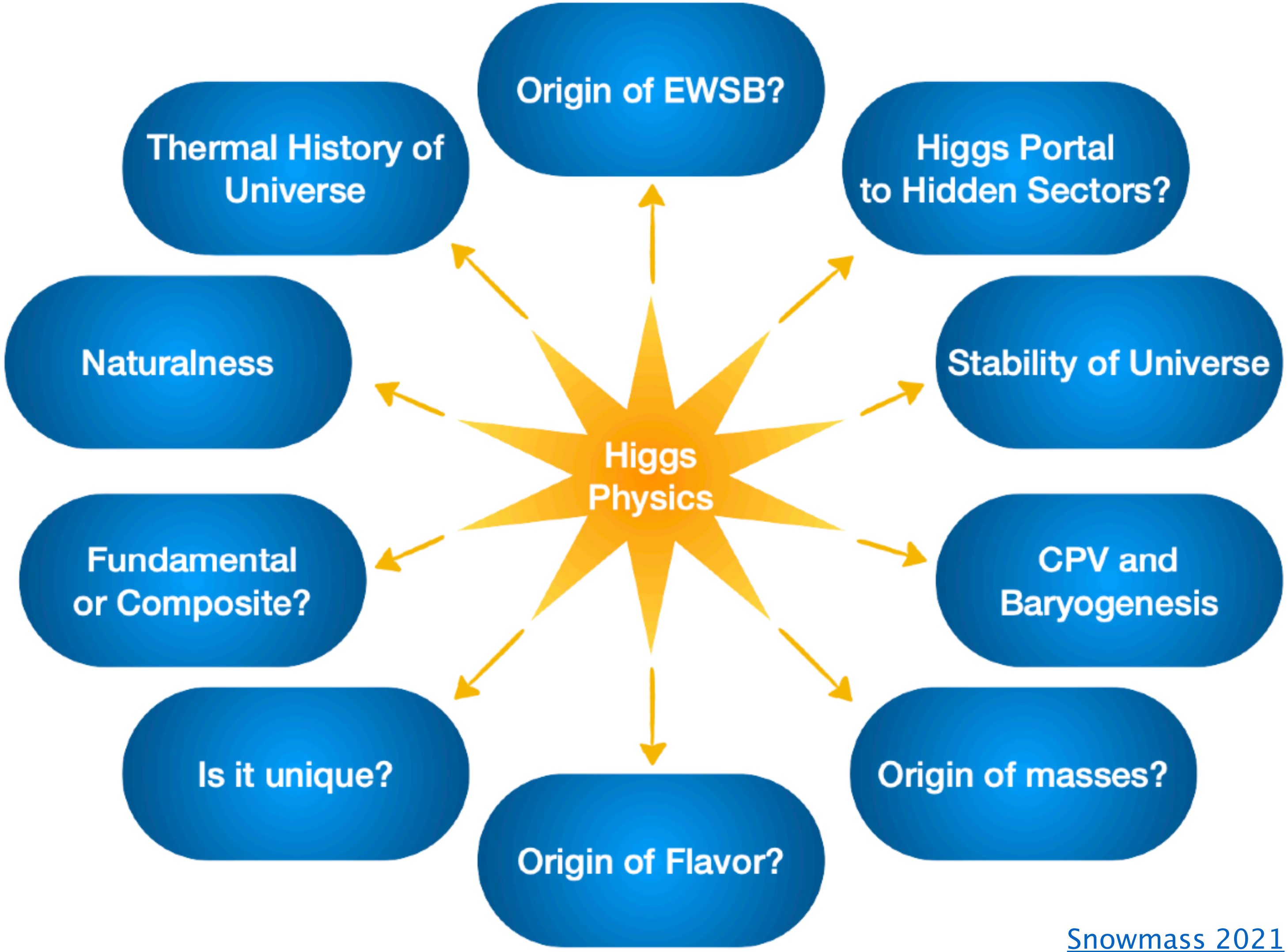
SLAC NATIONAL ACCELERATOR LABORATORY

Stanford University | U.S. DEPARTMENT OF ENERGY

Higgs: touches most of our deepest question in the universe

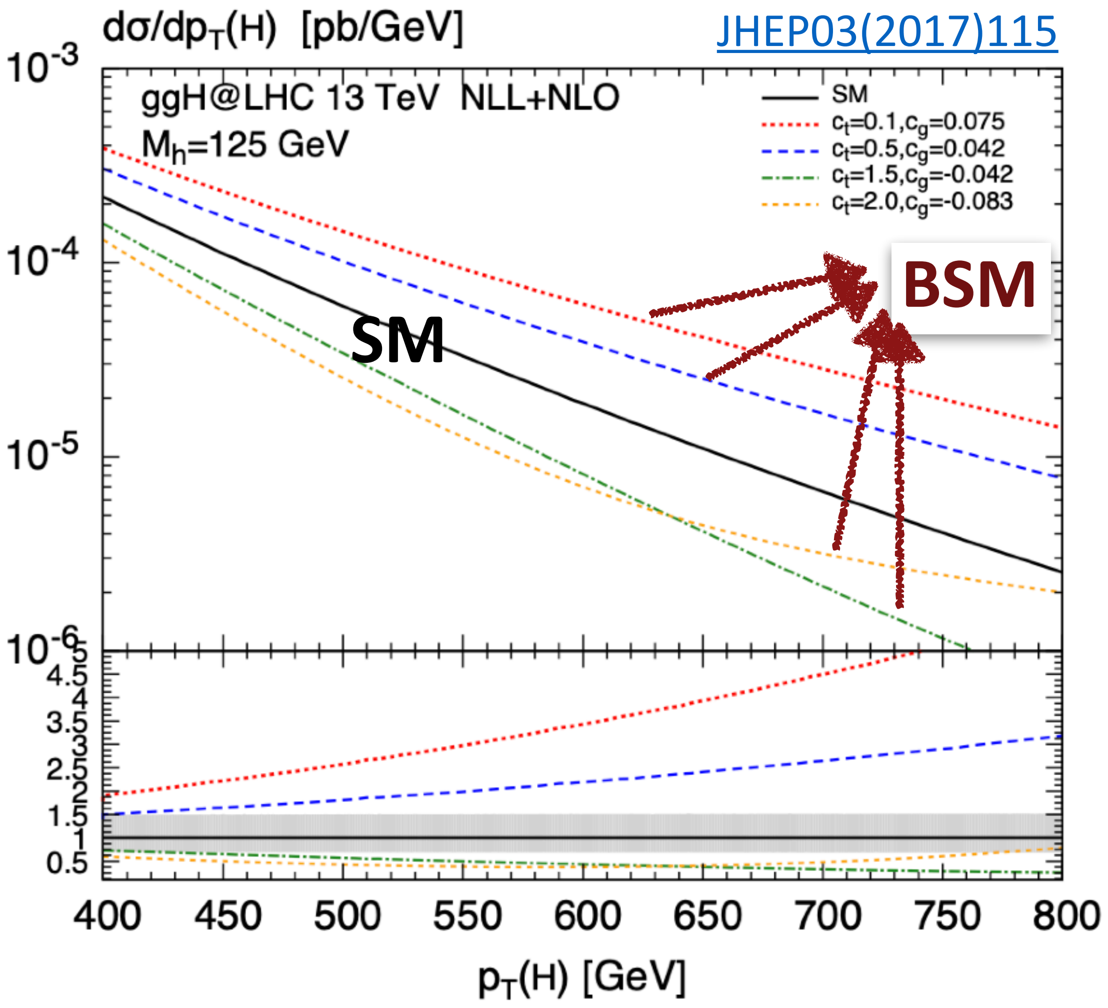


Snowmass 2021

Higgs as a probe to New Physics

Differential measurements might uncover Beyond Standard Model (BSM) phenomena hidden within the cross-section measurements.

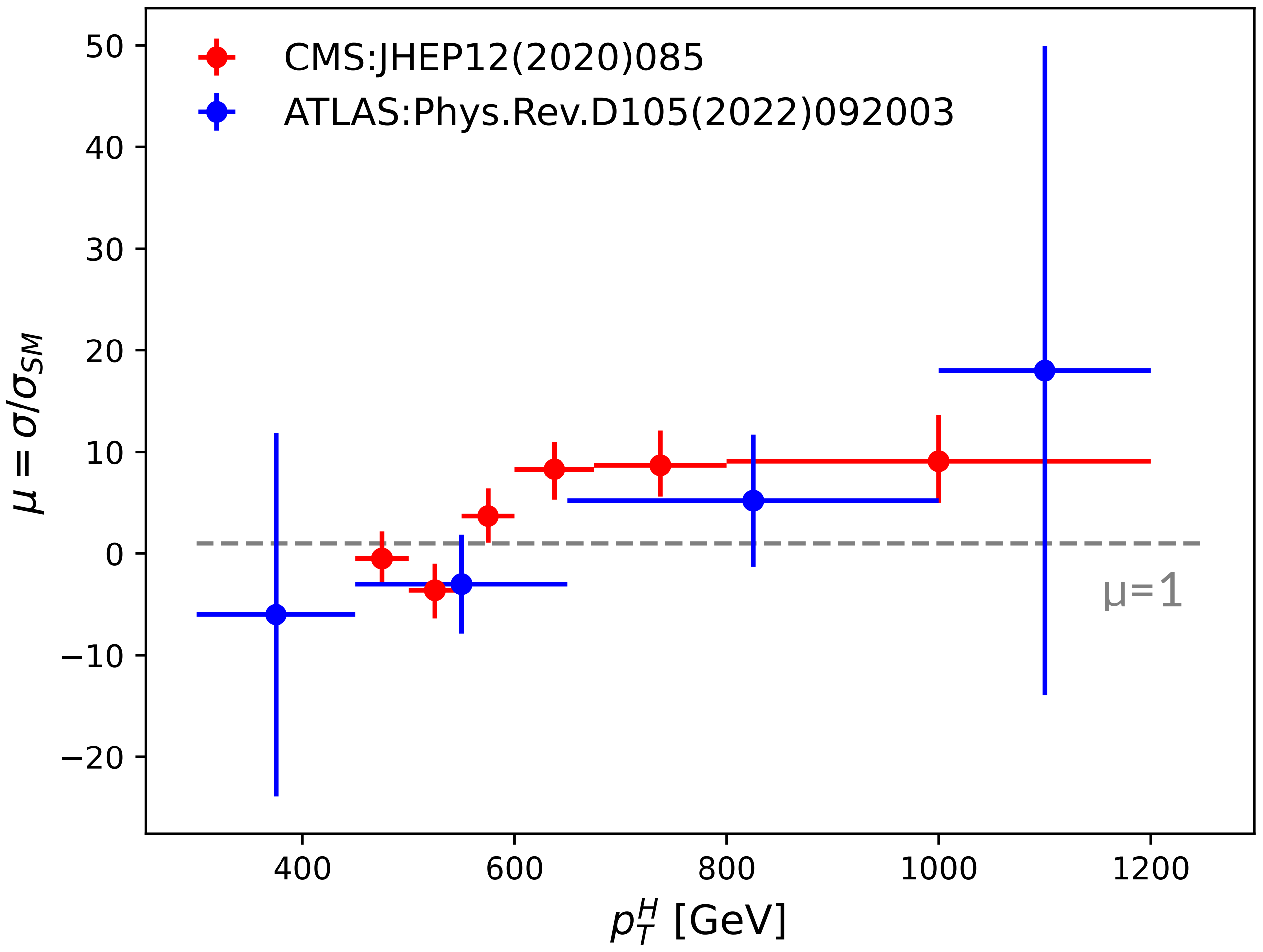
- Higgs p_T is one of the key observables
- Higgs in the High p_T region are sensitive to BSM effect



Why All-Hadronic Higgs in Boost region

Increased interests in understanding dynamic properties of the Higgs

- $b\bar{b}$ decay is the largest branching fraction (~60%), and has statistics to check Higgs in the high p_T region
- p_T^H differential measurement of Higgs boson in $b\bar{b}$ decay channel in both ATLAS and CMS



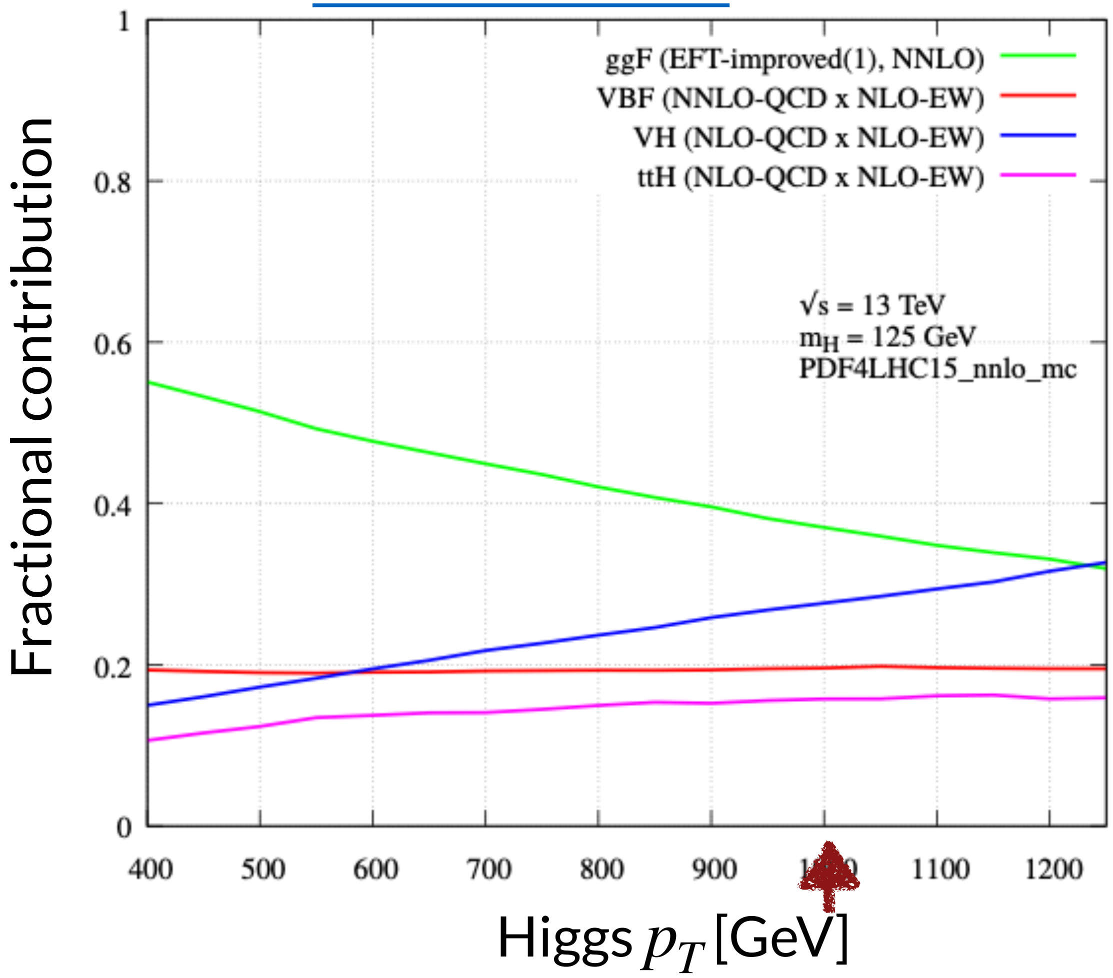
Why All-Hadronic Higgs in Boost region

Increased interests in understanding dynamic properties of the Higgs

- All production modes contribution similarly toward p_T^H ~ 1 TeV

Understanding each production mechanism in High p_T regime for Higgs Boson is important

arXiv:2005.07762



Higgs in the Boost Region: ttH

Understanding each production mechanism in high p_T regime for the Higgs boson

- ATLAS measured Higgs p_T in ttH production

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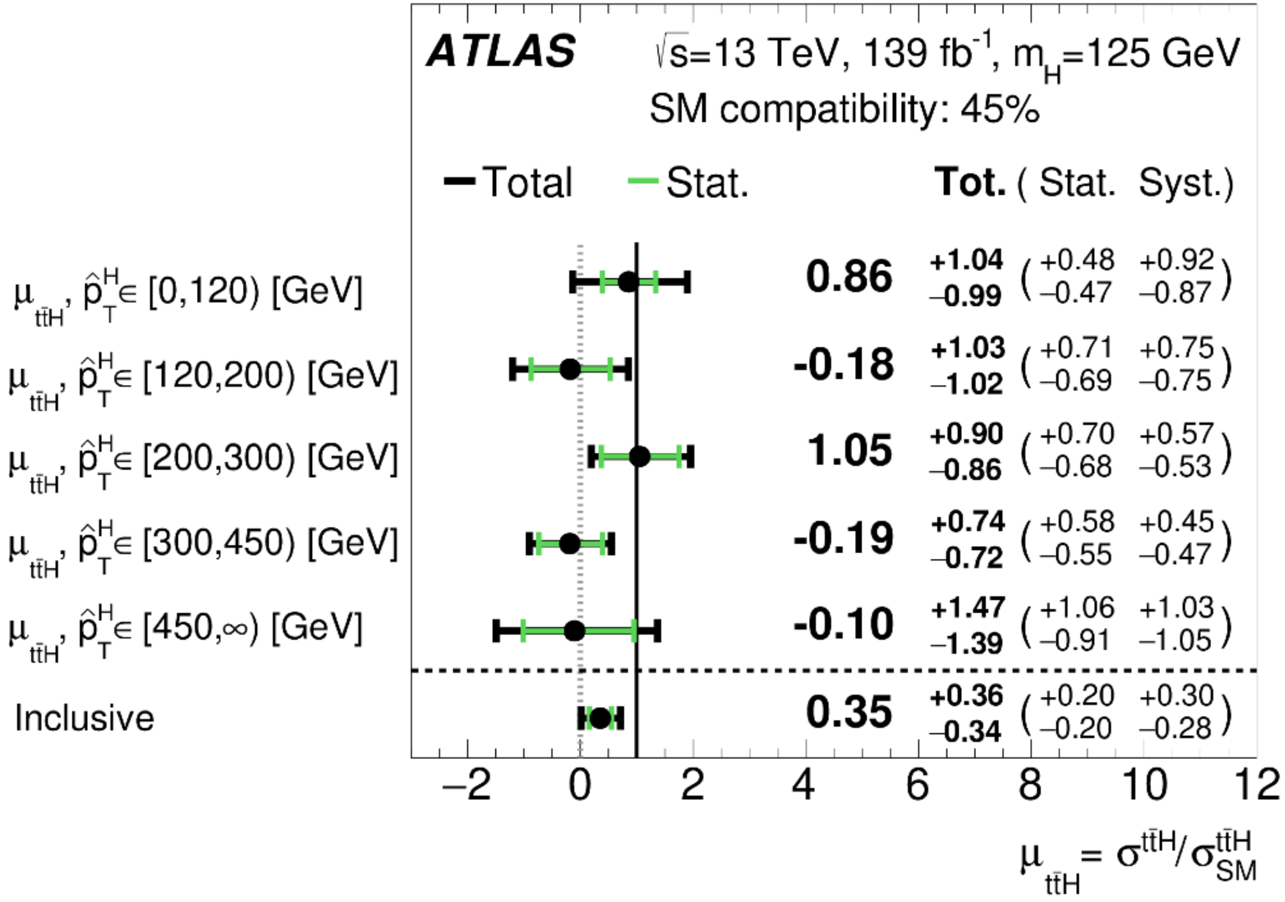
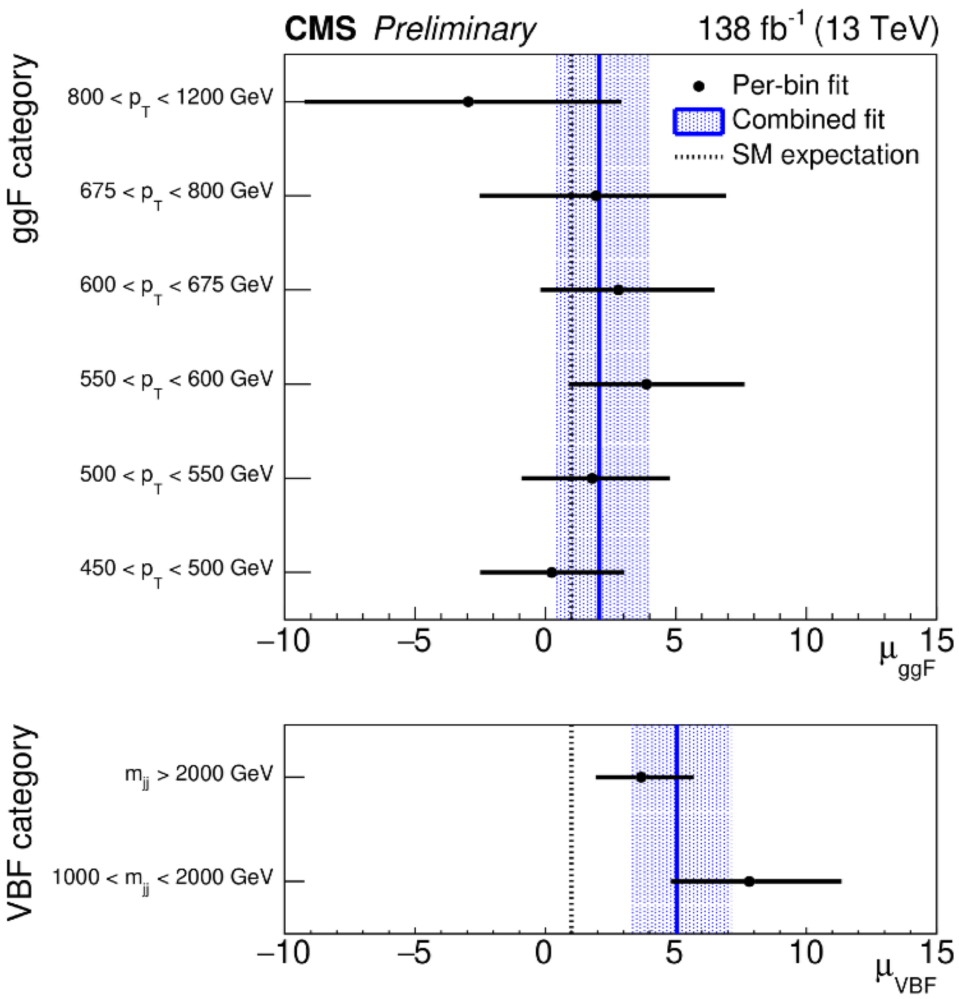


Higgs in the Boost Region: VBF and ggF

Understanding each production mechanism in high p_T regime for the Higgs boson

- Recent result by CMS on VBF and ggF production in high momentum regime

CMS-PAS-HIG-21-020



Slight tension

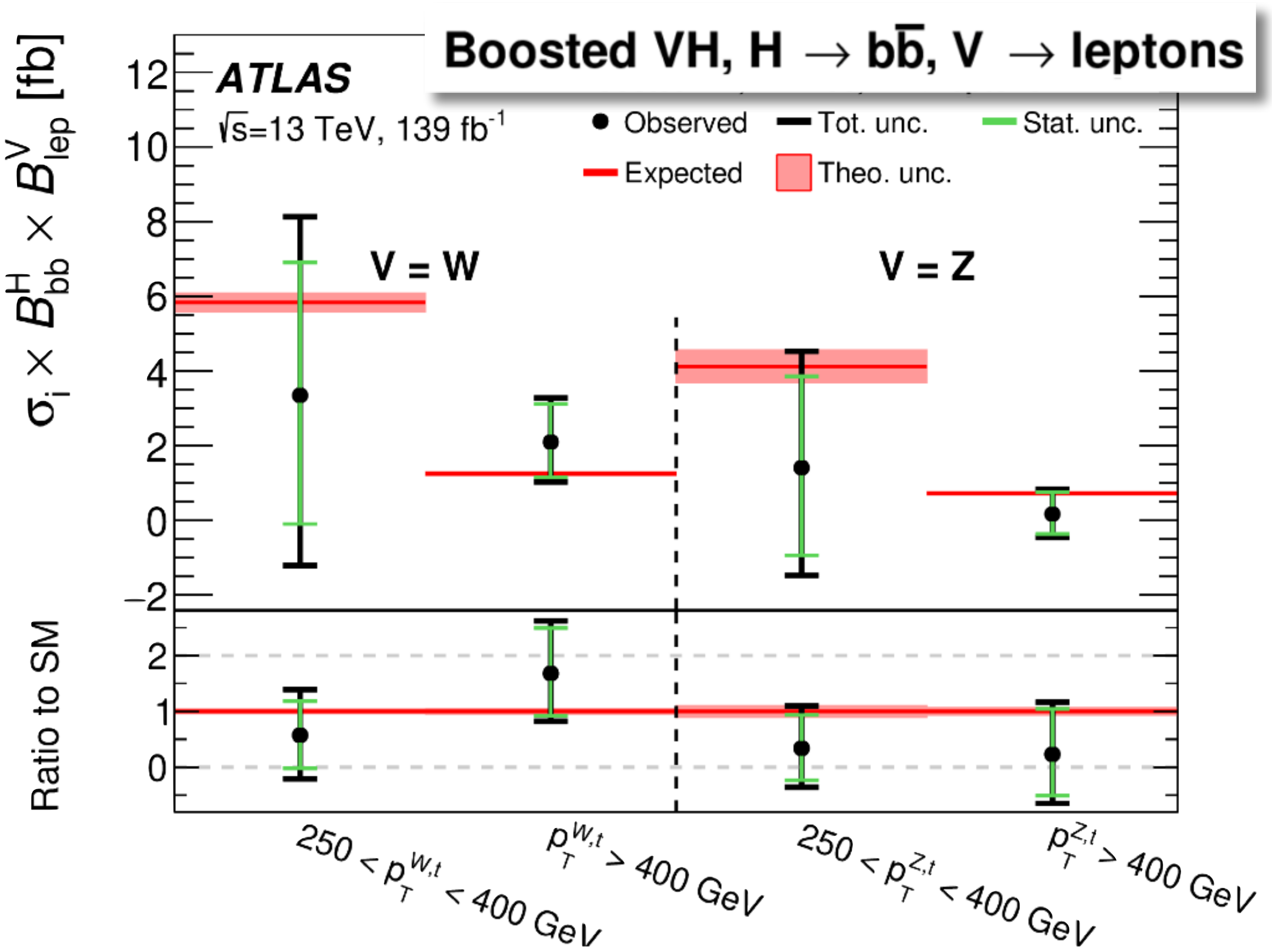
Higgs in the Boost Region: V(→leptons)H

Understanding each production mechanism in high p_T regime for the Higgs boson

ATLAS boosted **VH**

- Observed (expected) significance for p_T^V > 250 GeV: 2.1(2.7) σ

Phys. Lett. B 816 (2021) 136204



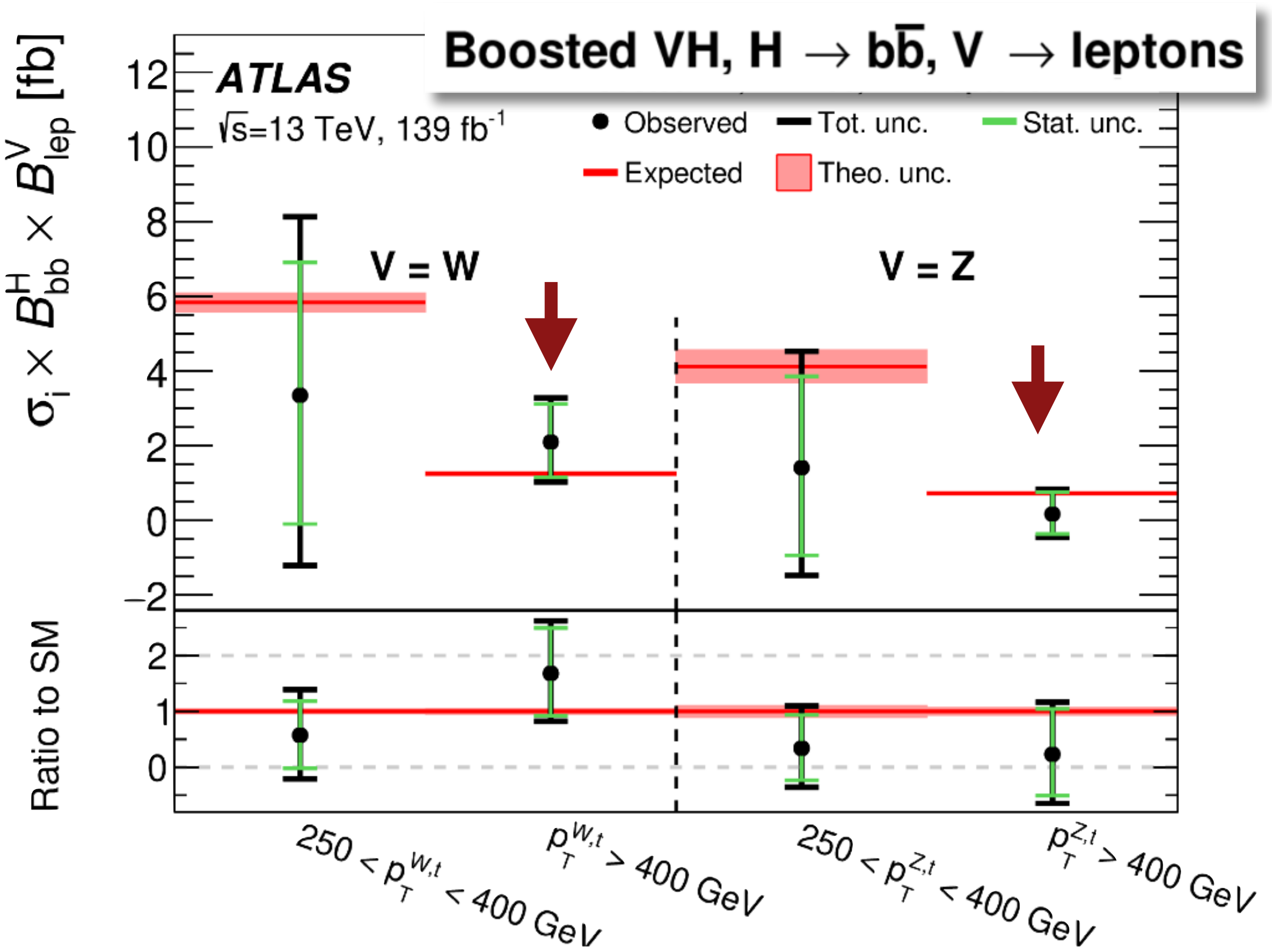
Higgs in the Boost Region: V(→leptons)H

Understanding each production mechanism in high p_T regime for the Higgs boson

ATLAS boosted **VH**

- Limited stats in the p_T^H > 400 GeV

Phys. Lett. B 816 (2021) 136204

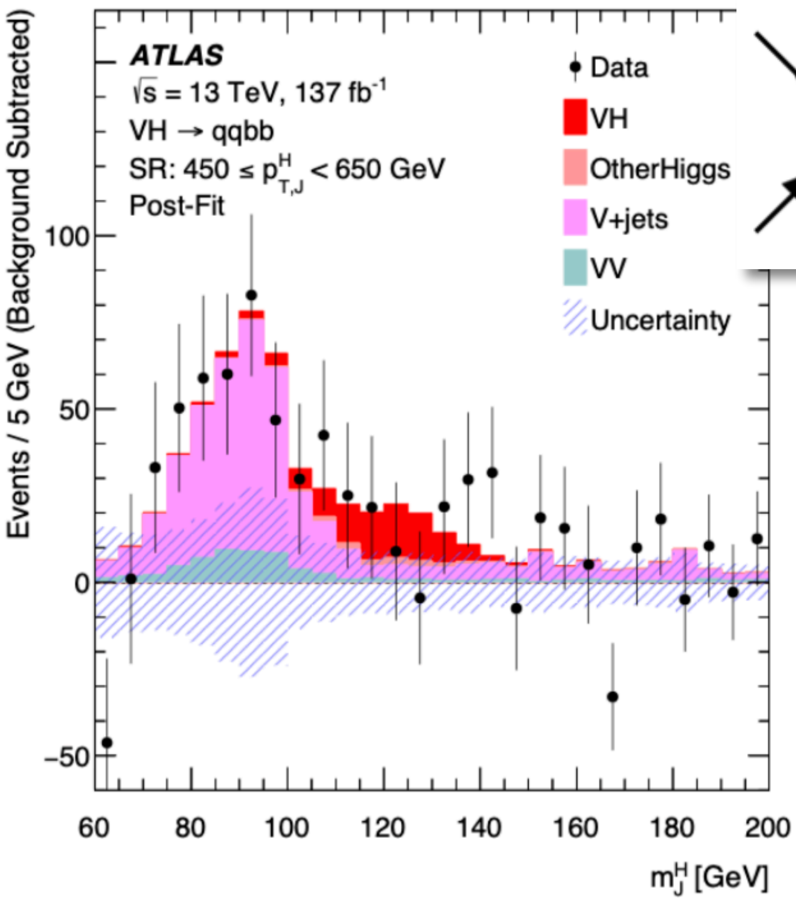


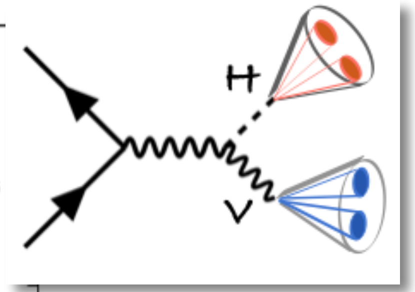
Higgs in the Boost Region: V(→qq)H

Understanding each production mechanism in high p_T regime for the Higgs boson

- Why **V(→qq)H?**
  - Signal events increase by **a factor of two** in all hadronic channel compare with V(→ leptons) H

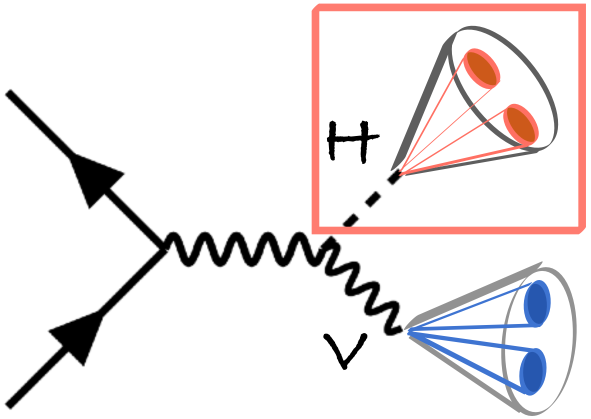
[Phys. Rev. Lett. 132 (2024) 131802]

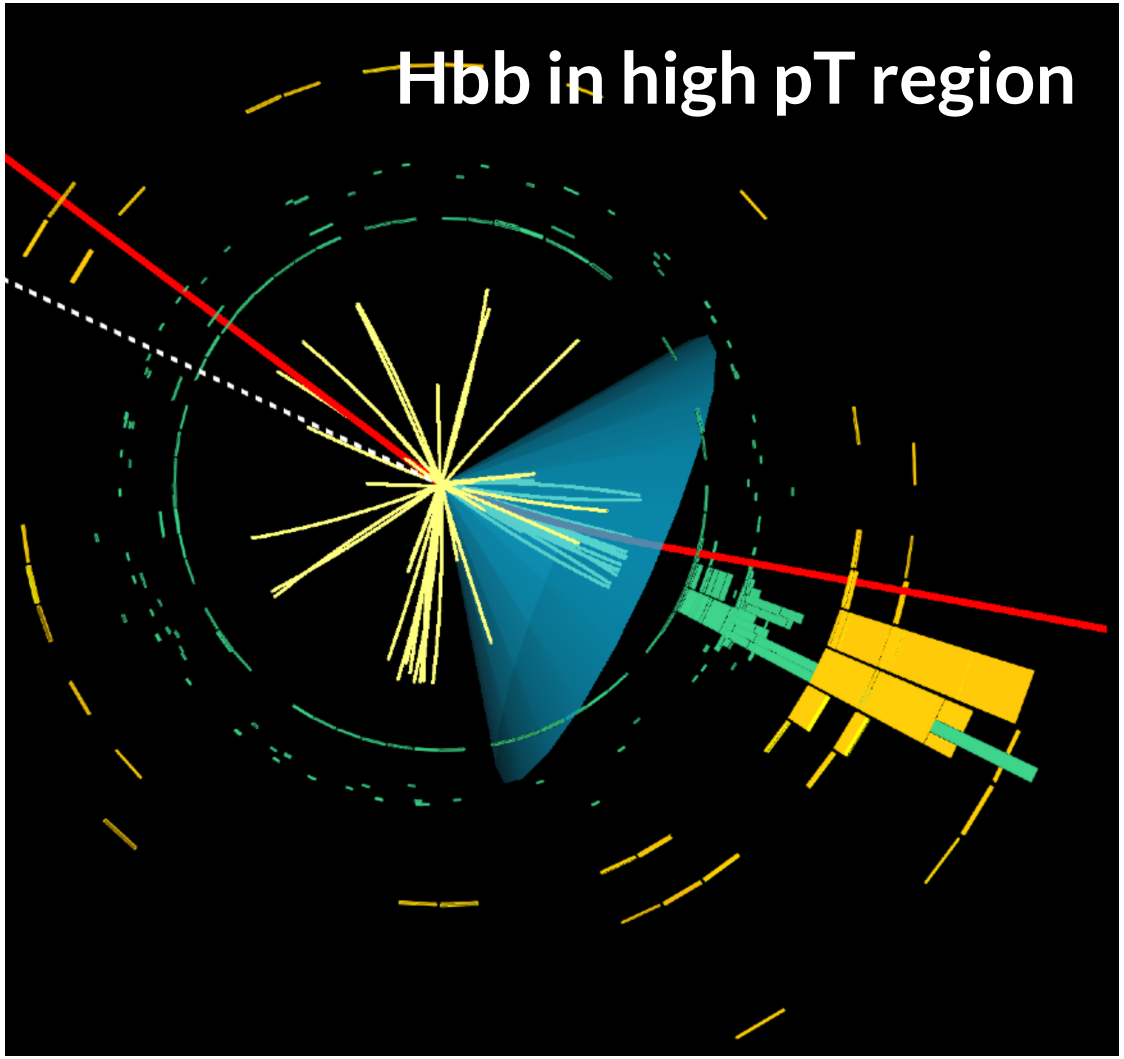




Why VH → qqbb: Anti-kt (R=1.0) Jets

Advancement of **novel jets substructure** enabled searches for $H \to bb$ in hadronic final states despite the large irreducible QCD background

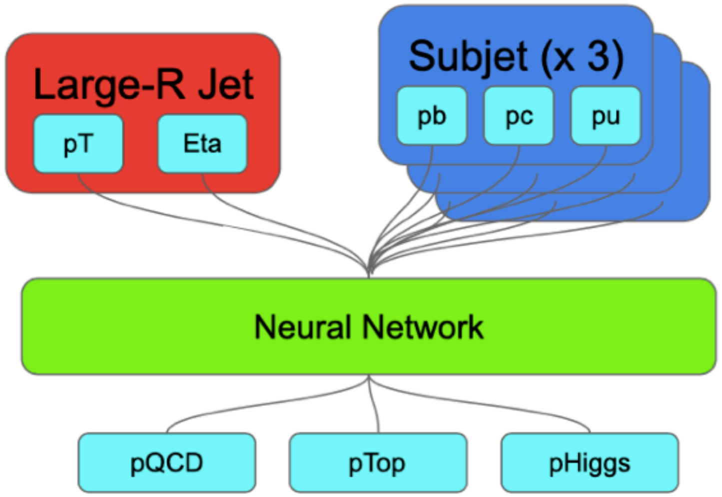


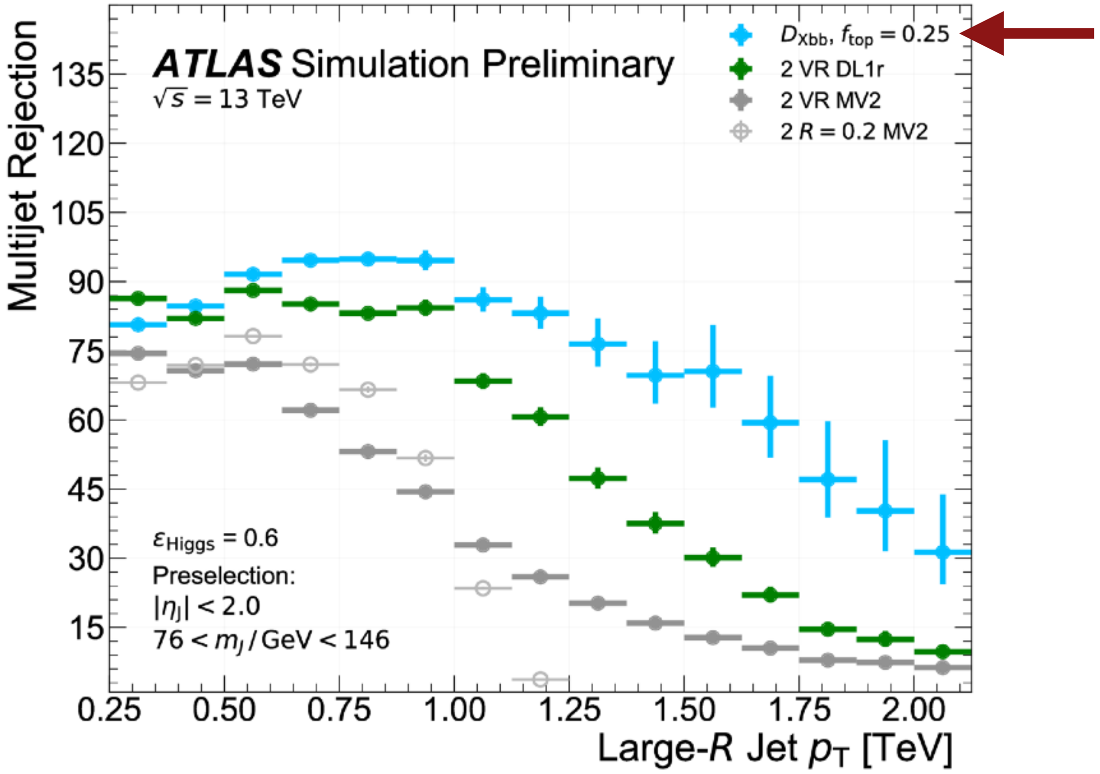


H→ bb tagger

H→$b\bar{b}$ tagger: [ATL-PHYS-PUB-2020-019]

- Neural Network using track & vertex info associated to variable radius track-jets
- Fixed 60% H → $b\bar{b}$ efficiency used

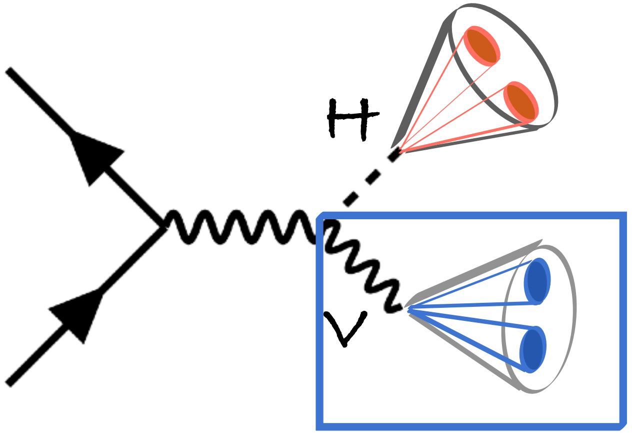


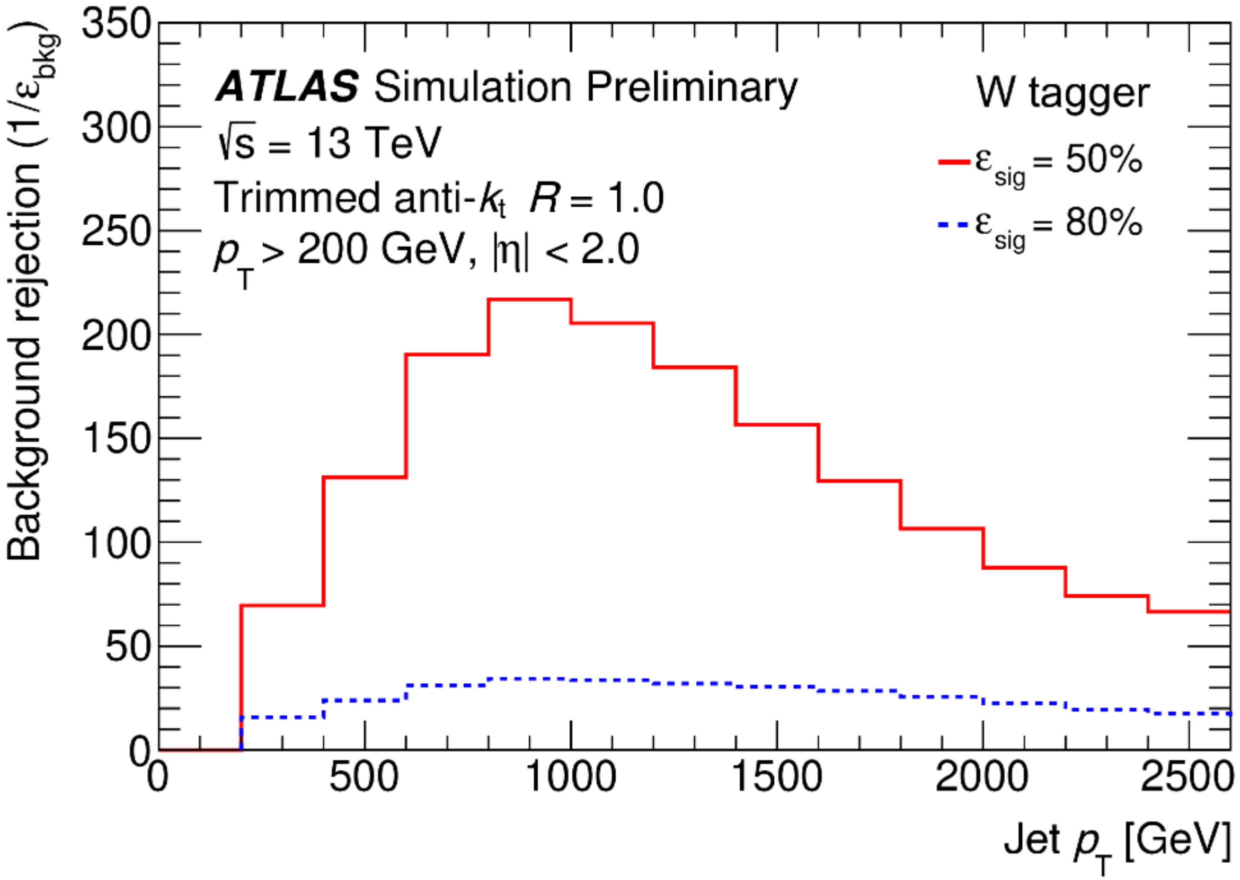


V tagger:

V tagger: [ATL-PHYS-PUB-2020-017]

- Requirements on jet mass, two-prongness & number of tracks yields a signal efficiency of 50%





Event Selection

Proton-proton collision data collected by ATLAS detector from 2015-2018

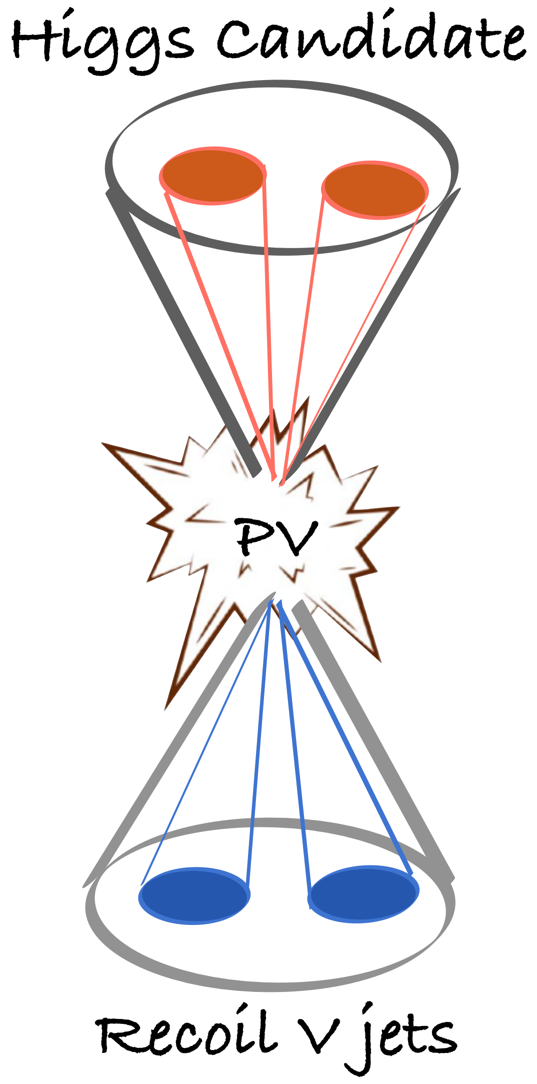
- Integrated luminosity of 137 fb^{-1} at 13 TeV

Single large-R (R=1.0 anti-k_t) jet trigger with Mass and p_T threshold

At least **two large-R jets** p_T > 200 GeV & $|\eta|$ <2

- p_T- leading jet: p_T > 450, M_J > 60 GeV
- Second p_T- leading jet: M_J > 40 GeV

Events with isolated charges leptons are rejected



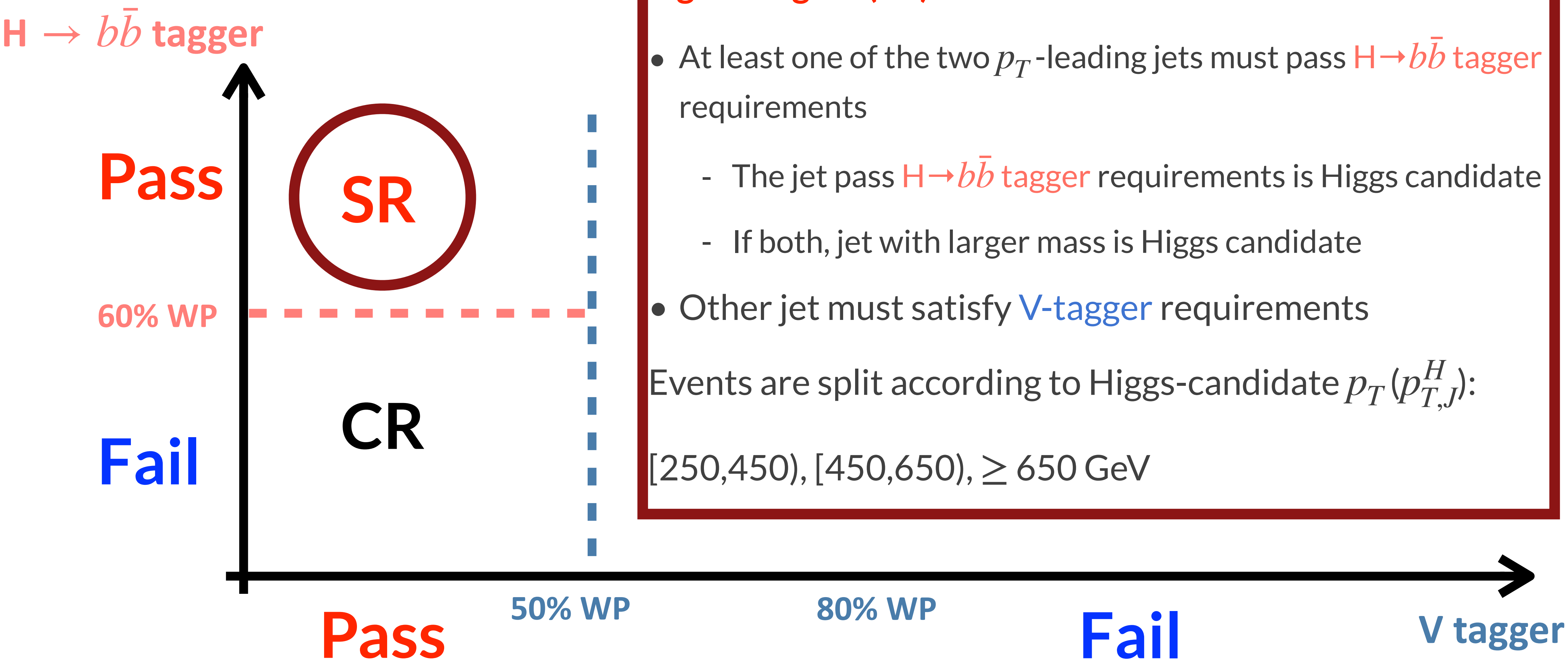
Event Selection:

Signal Region (SR):

- At least one of the two p_T-leading jets must pass H→$b\bar{b}$ tagger requirements
  - The jet pass H→$b\bar{b}$ tagger requirements is Higgs candidate
  - If both, jet with larger mass is Higgs candidate
- Other jet must satisfy V-tagger requirements

Events are split according to Higgs-candidate p_T ($p_{T,J}^{H}$):

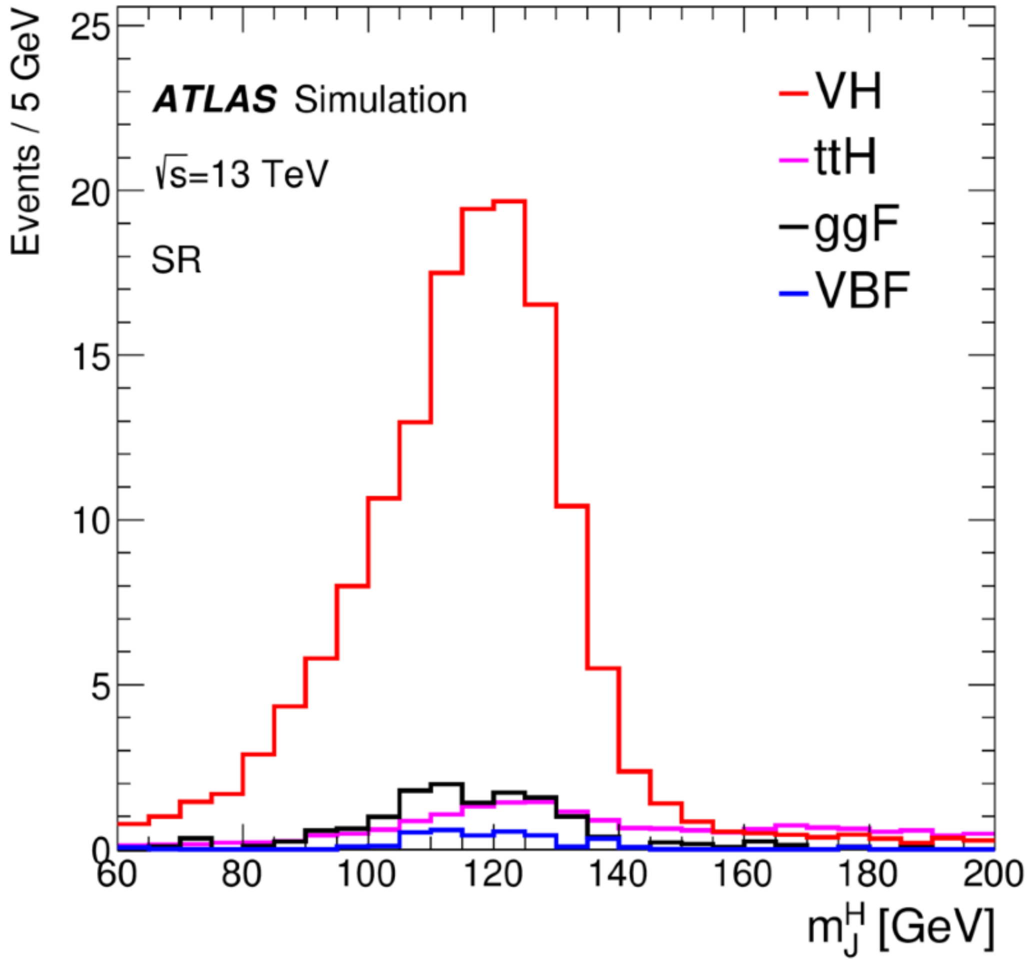
[250,450), [450,650), $\geq$ 650 GeV



Signal Region: Signal & Background composition

In SR, **VH** production mechanism dominates: **~ 85%**

- $t\bar{t}H$ (8%), ggF (6%), VBF (1.4%)



Signal Region: Signal & Background composition

In SR, **VH** production mechanism dominates: **~ 85%**

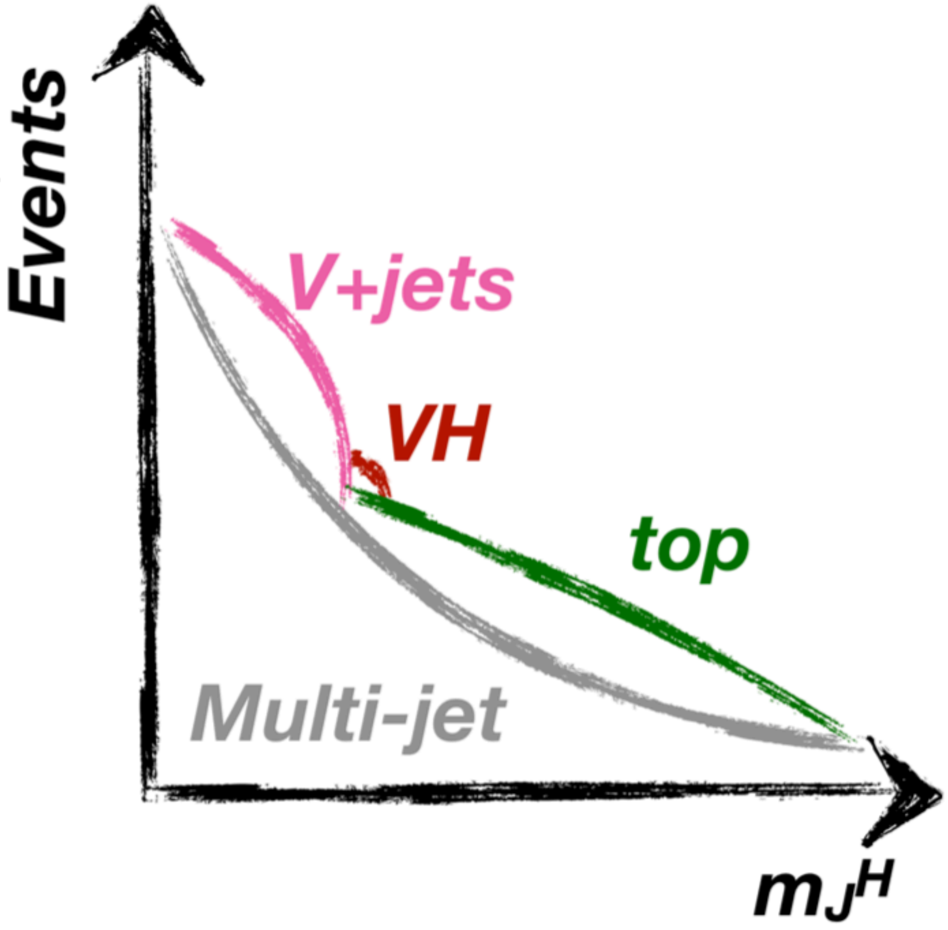
- $t\bar{t}H$ (8%), ggF (6%), VBF (1.4%)

Background dominated by multi-jets production **(90%)**

- $t\bar{t}$ (5%), VV(0.7%), V+jets (3.6%)

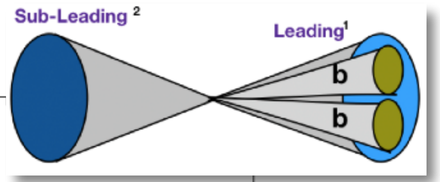
Key is to have full control of multi-jets background estimation

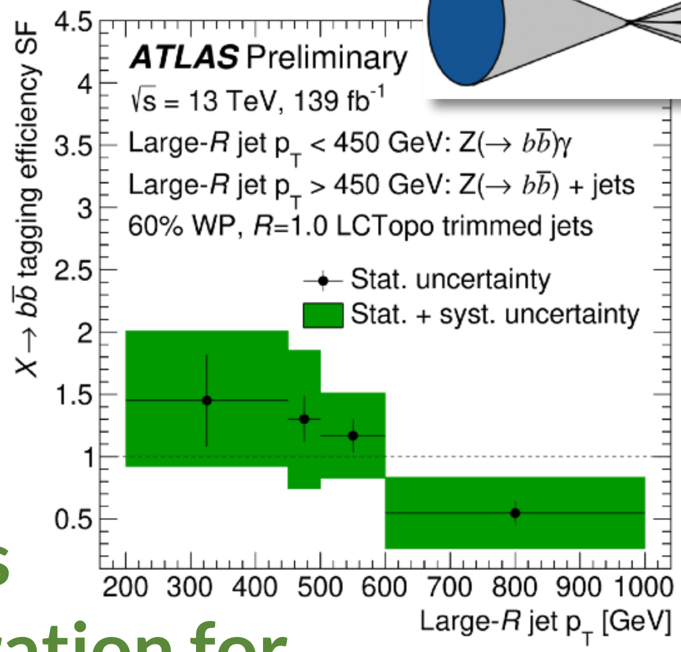
- Two **data-driven** estimations in place



Analysis Strategy

ATL-PHYS-PUB-2021-035





$H \rightarrow b\bar{b}$ tagger

	Pass (V tagger)			Fail (V tagger)
Pass ($H \rightarrow b\bar{b}$ tagger)	SR	VR		
60% WP				
Fail ($H \rightarrow b\bar{b}$ tagger)	CR Derive multi-jets background	Validate multi-jet background estimation method		Z+jets Calibration for H→ bb tagger
		50% WP	80% WP	

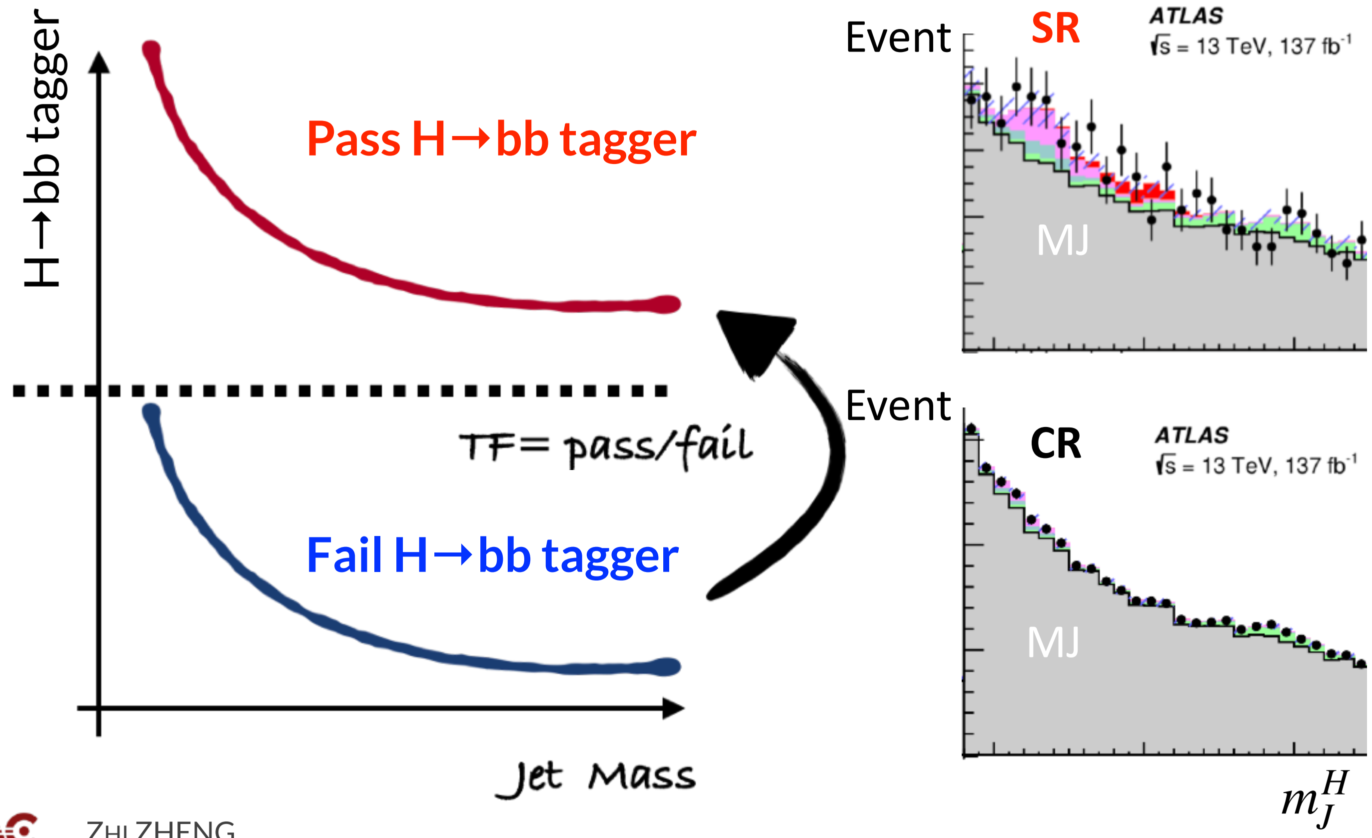
V tagger

*SR: Signal Region
*CR: Control Region
*VR: Validation Region

Multi-Jet Background Estimation

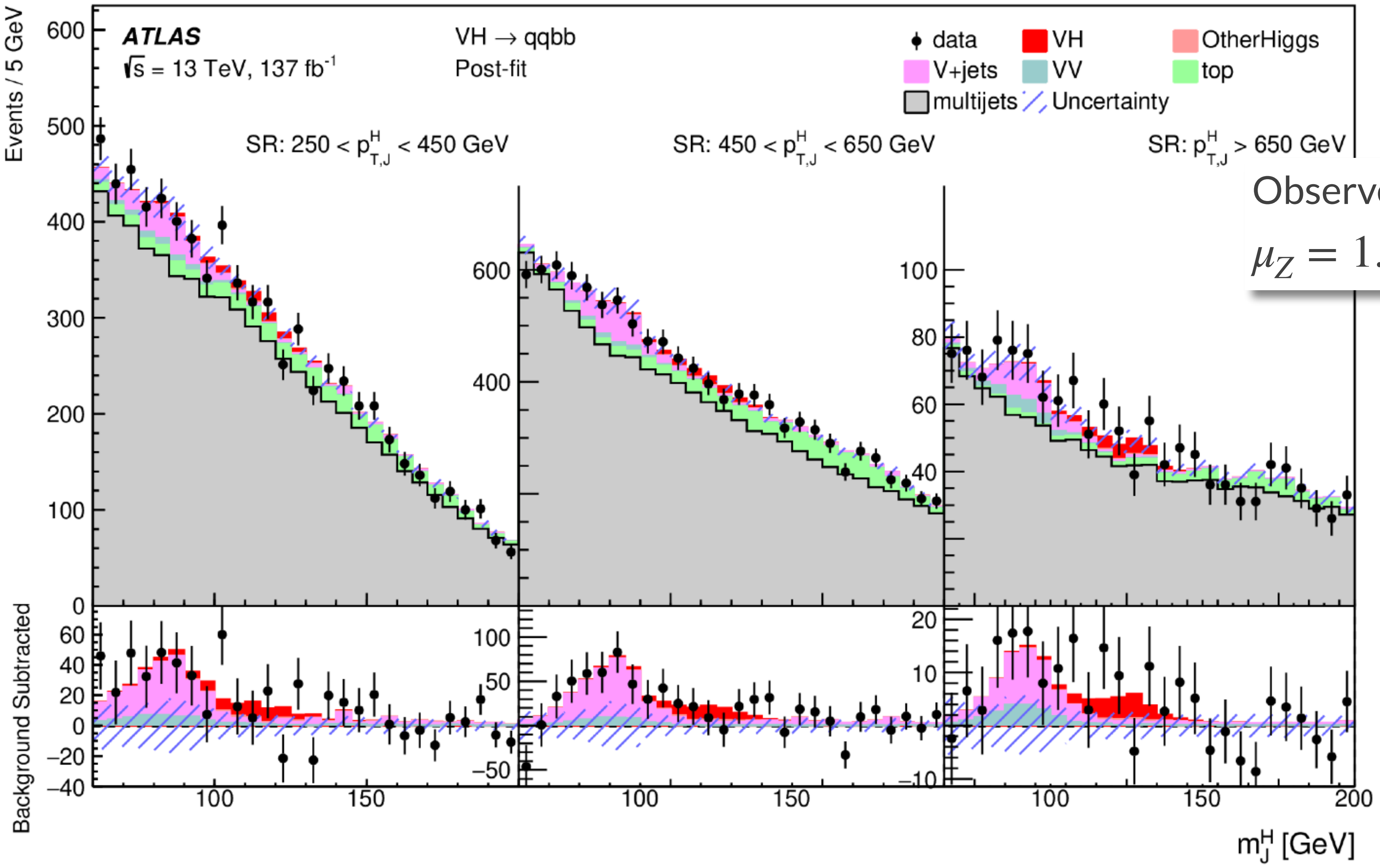
Aim to predict the multijet mass distribution in the pass H→ bb tagger using event in fail-H→bb tagger region:

Events passing H→bb tagger = events failing the H→bb tagger ×transfer factor (TF)



- TF as a function of $\rho = \log(m^2/p_T^2)$ and pT
- Polynomial order determined via Fisher F-test
  - 1 st in both p_T and ρ

First measurement of VH in full hadronic channel



Observed Z+jets normalization:

$\mu_Z = 1.41^{+0.80}_{-0.58}$

Fit results

First measurement of VH in full hadronic channel

Observed VH signal strength: $\mu_{VH} = 1.39^{+1.02}_{-0.88}$

- Observed significance for rejection of null-signal hypothesis 1.7σ (1.2σ expected)
- Corresponding to an observed cross-cross section: $3.1 \pm 1.3(\text{stat})^{+1.8}_{-1.4}(\text{syst})$ pb

Systematics uncertainties dominate by **shape of multi-jet data-driven estimate (statistically nature)** & **H→ $b\bar{b}$ tagger scale factors**

Kinematic region	Observed μ	Observed σ [fb]		Expected σ [fb]
$250 \leq p_T^H < 450$ GeV, $\|y_H\| < 2$	$0.8^{+2.2}_{-1.9}$	47^{+125}_{-109}	(<363)	57.0
$450 \leq p_T^H < 650$ GeV, $\|y_H\| < 2$	$0.4^{+1.7}_{-1.5}$	2^{+10}_{-9}	(< 24)	5.9
$p_T^H \geq 650$ GeV, $\|y_H\| < 2$	$5.3^{+11.3}_{-3.2}$	6^{+13}_{-4}	(< 43)	1.2

Summary

There are many efforts to study regions highly sensitive to the new physics:

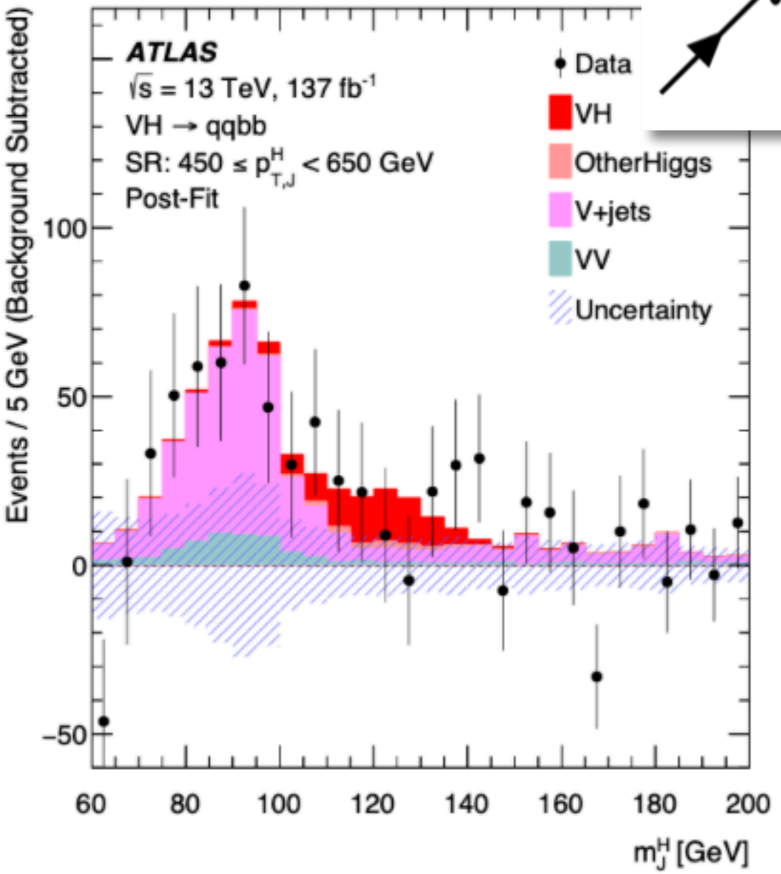
especially high p_T^H region

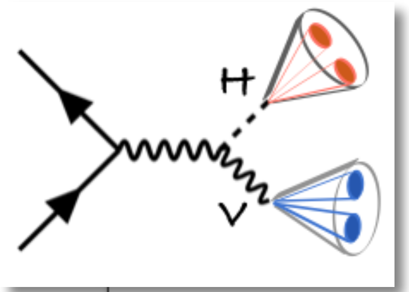
We have presented the first measurement of VH in full hadronic channel

Observed VH signal strength:

$$\mu_{VH} = 1.39^{+1.02}_{-0.88}$$

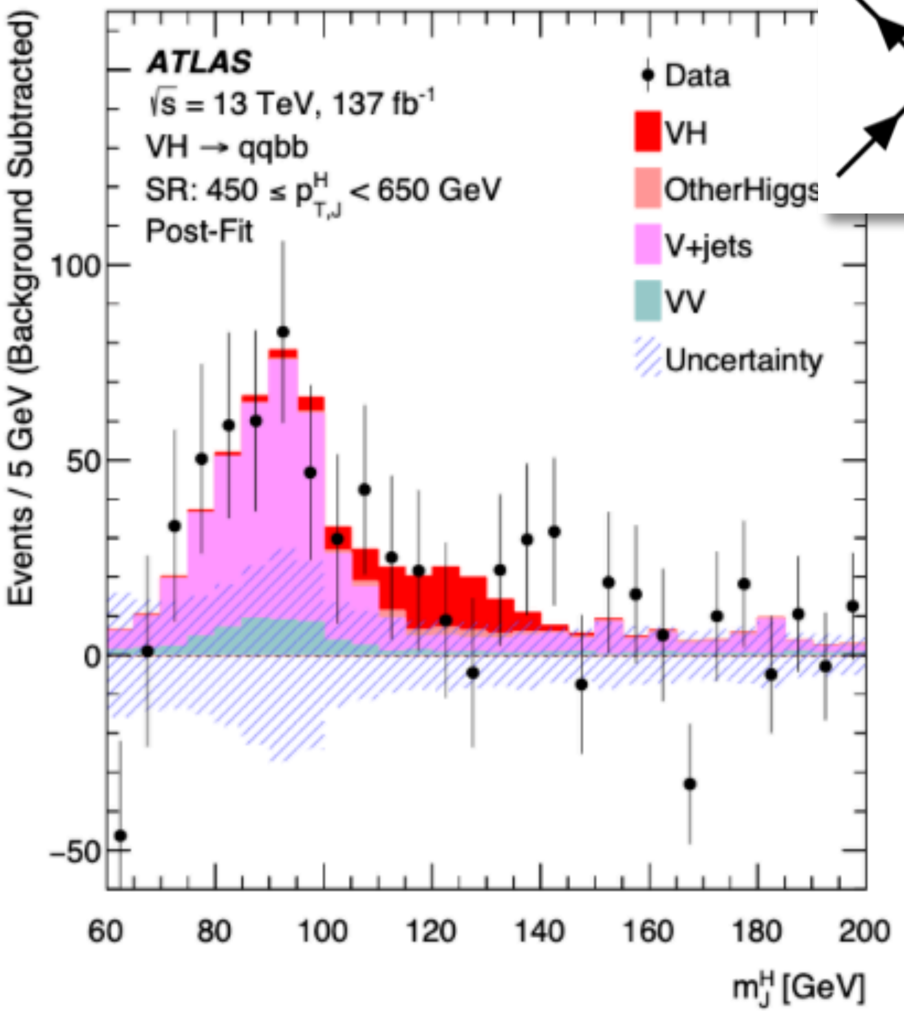
Further details in [Phys. Rev. Lett. 132 (2024) 131802]

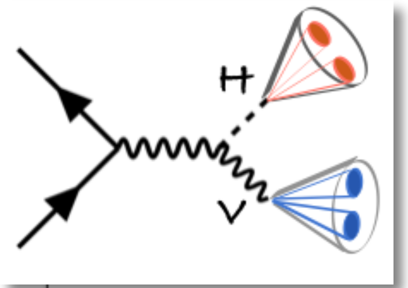




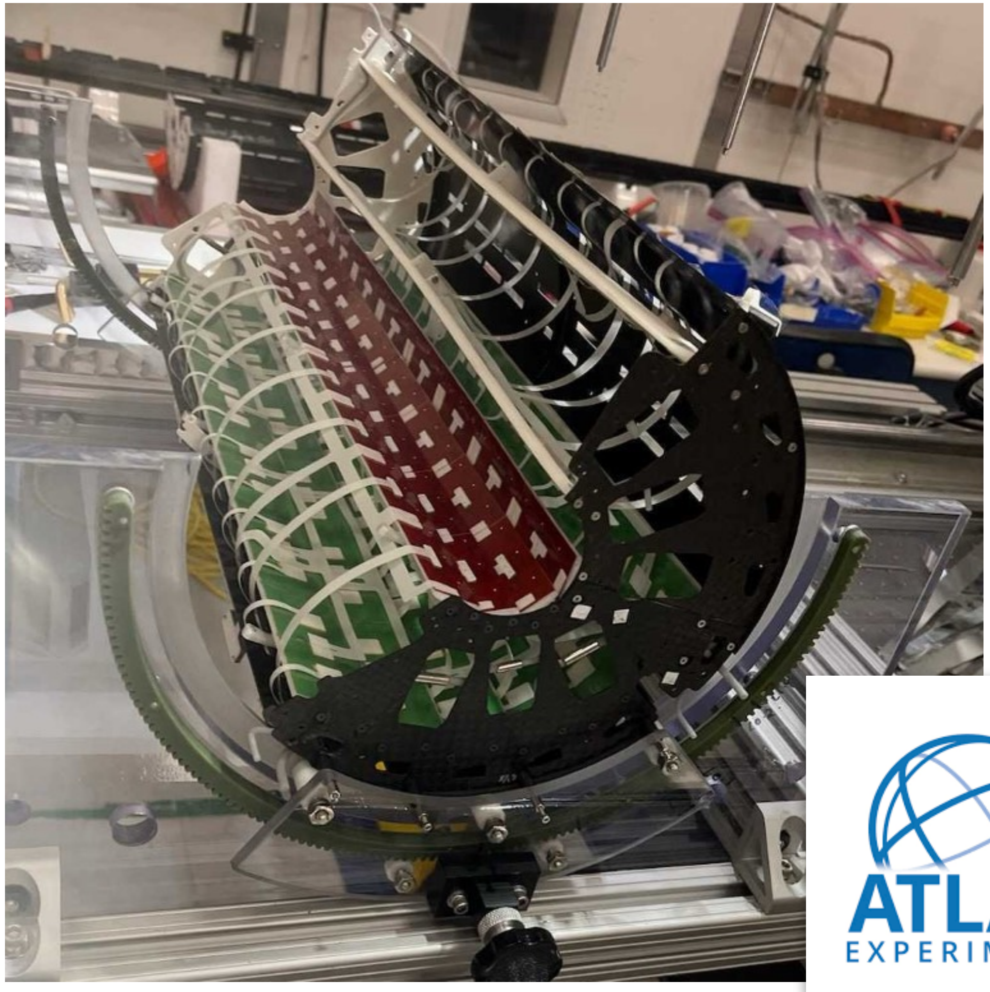
THANK YOU FOR LISTENING

Phys. Rev. Lett. 132 (2024) 131802



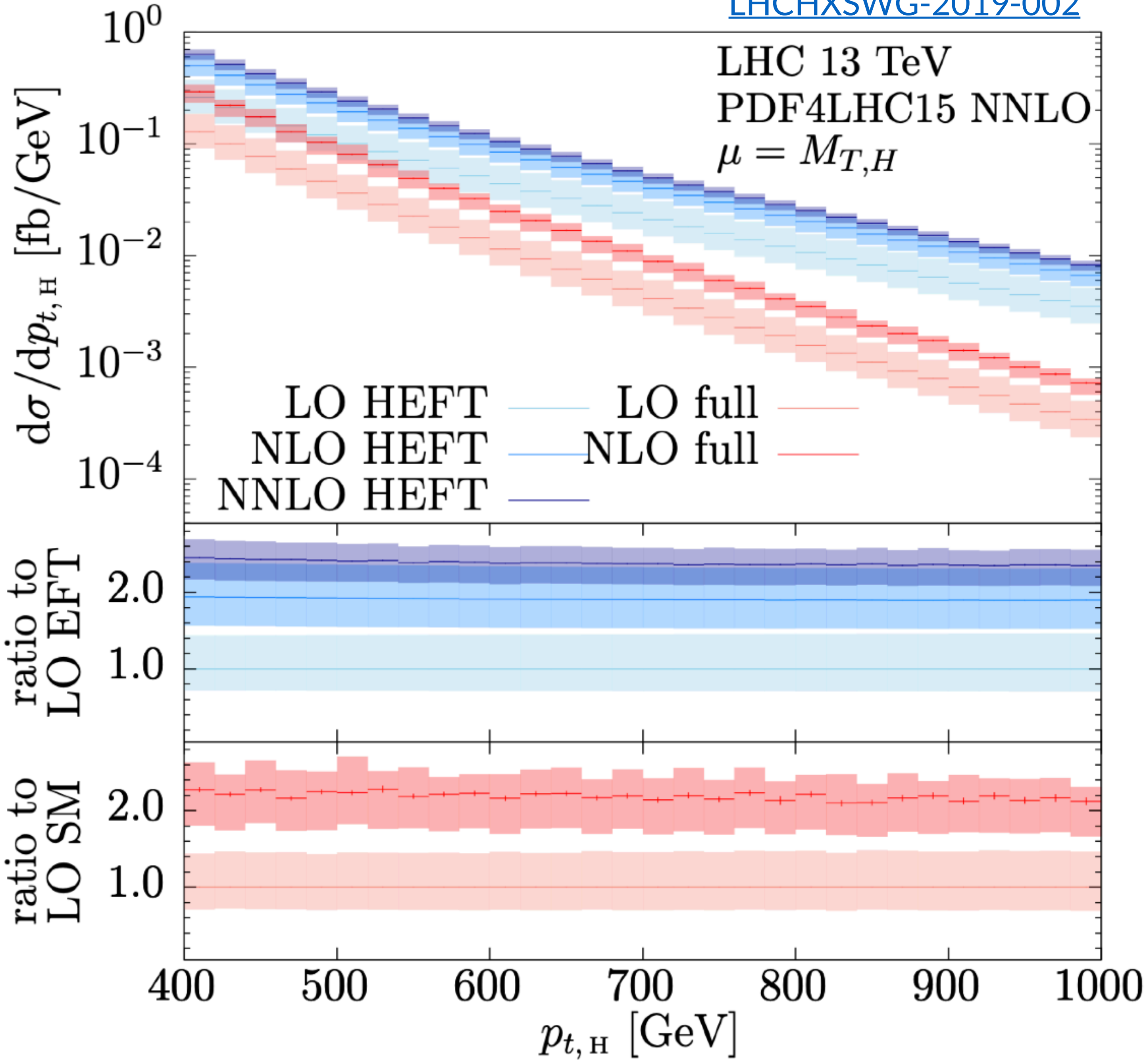


HL-LHC (Inner TracKer)



ATLAS EXPERIMENT

LHCHXSWG-2019-002



Simplified Template Cross Section (STXS)

STXS is an approach to categorize the Higgs-boson candidate events according to the properties associated with the Higgs production mode

Aim to **minimize theory dependency** while **maximizing sensitivity to BSM effects**

On-going effects to cooperate V(→qq) H into next stage STXS

- Include more sensitive region for EFT interpretation

JHEP 1911 (2019) 034