



TDLI?
李政道研究所



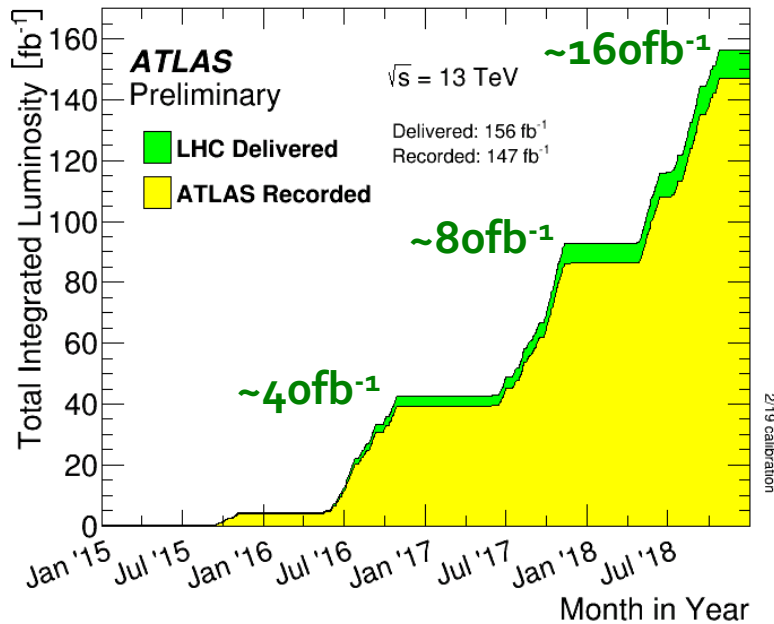
Recent ATLAS results on the search for BSM physics with boosted $H \rightarrow bb$ decays

Shu Li

Tsung-Dao Lee Institute &
School of Physics and Astronomy
Shanghai Jiao Tong University

On behalf of ATLAS Collaboration

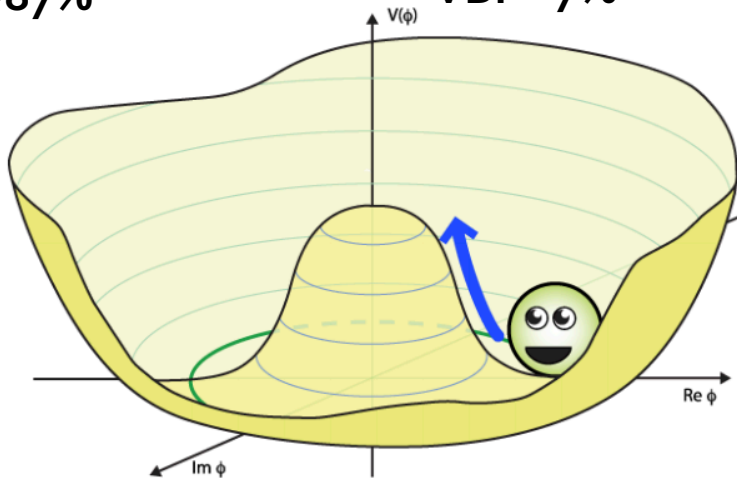
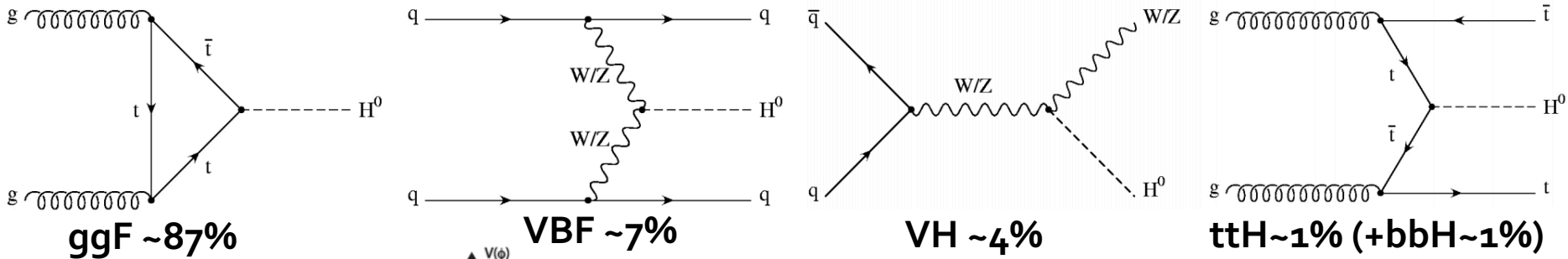
LHC data-taking at 13 TeV



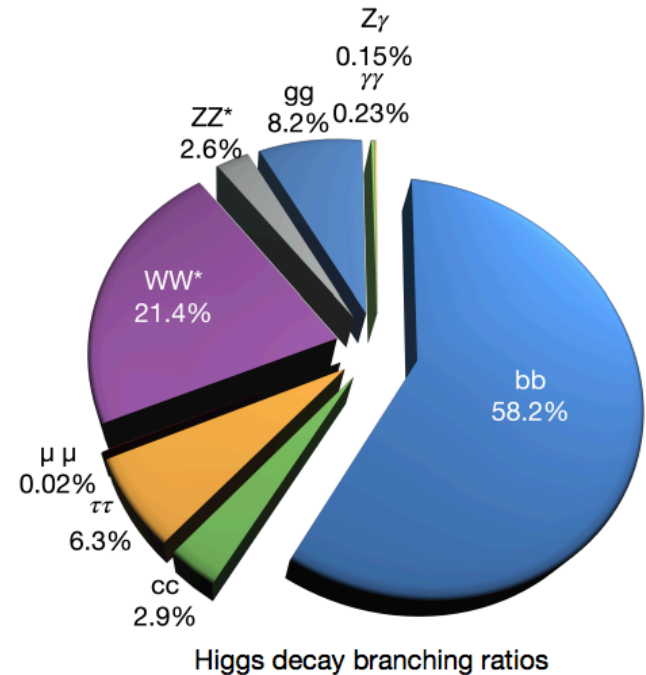
- LHC Run-II provide great opportunity to revisit Run-I Higgs Legacy
- Observation → measurements!
- SM → BSM?



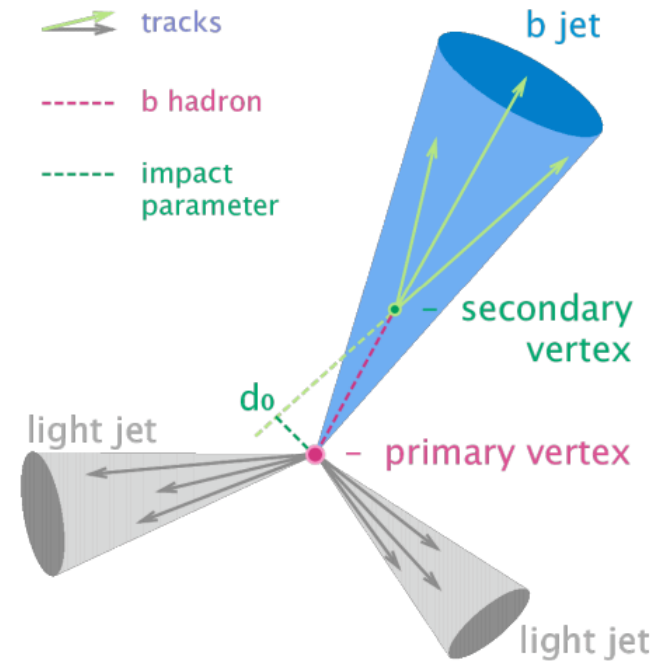
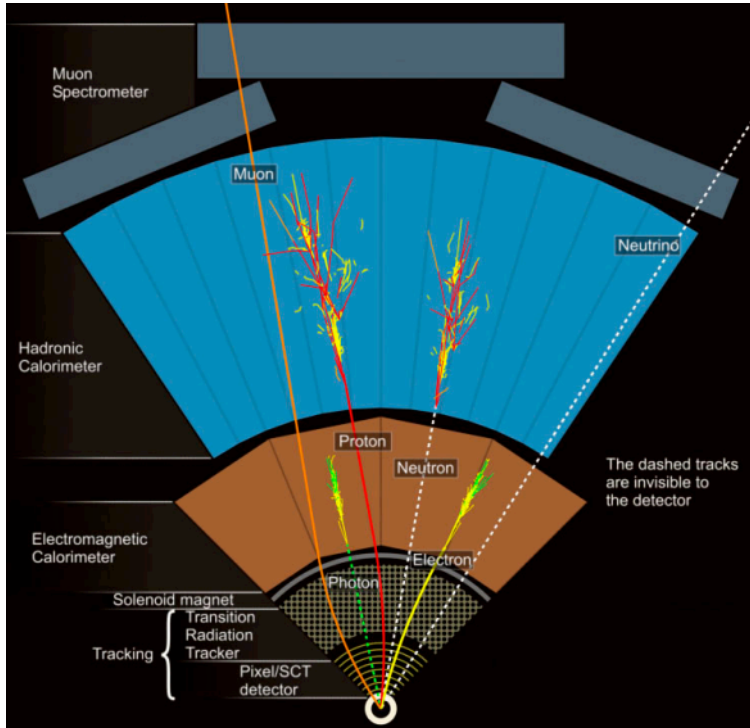
Why $H \rightarrow bb$?



- Higgs as major LHC physics legacy of Run-1
- Many production mechanism and decay channels: Spanning 3 orders of magnitude in σ -sec and BR
- Run-2 emphasis: precision ($\gamma\gamma$, $4l$), new exploration (bb , $\tau\tau$, ttH ,...), combination, kinematics, properties ...

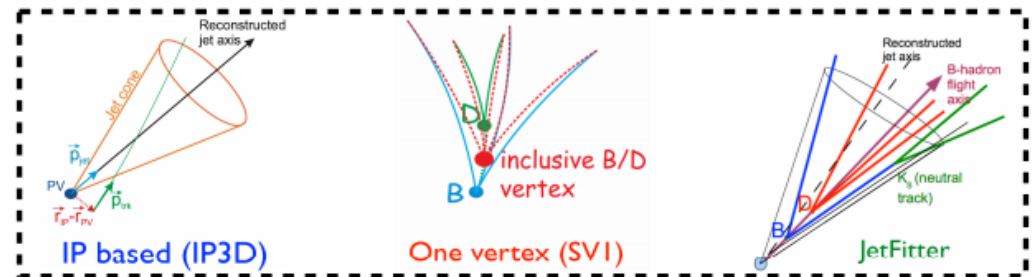


B-jet identification at ATLAS



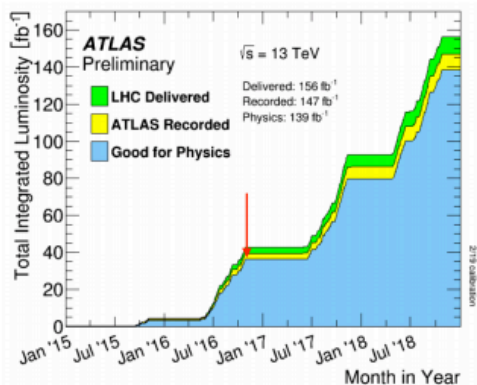
b-jet efficiency	light jet rejection rate	c-jet rejection rate
85%	33	3.1
77%	134	6
70%	381	12
60%	1538	34

MV2c10 tagger
(10% c-jet in the background sample)

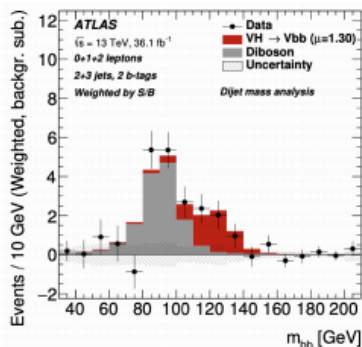


Roadmap of Hbb and VH observation at ATLAS: LHC Run-2 physics highlight

Evidence (36.1 ifb)

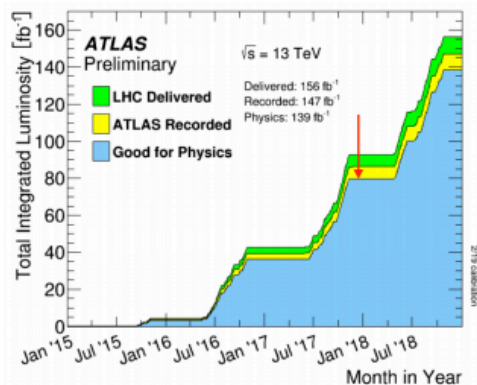


JHEP12(2017)024

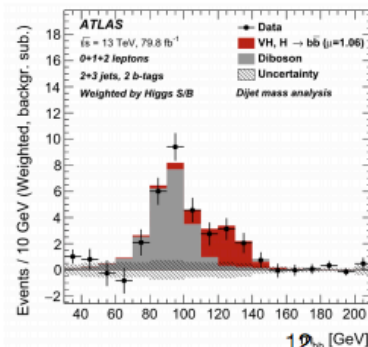


Obs. (exp.)
 significance
3.5 (3.0) σ

Observation (79.8 ifb)



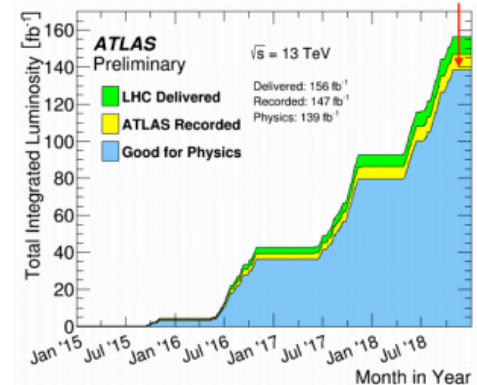
Physics Letters B 786 (2018) 59–86



Combined with other production modes (Run1+Run2), VH dominant
 H→bb observed, **5.4 (5.5) σ**

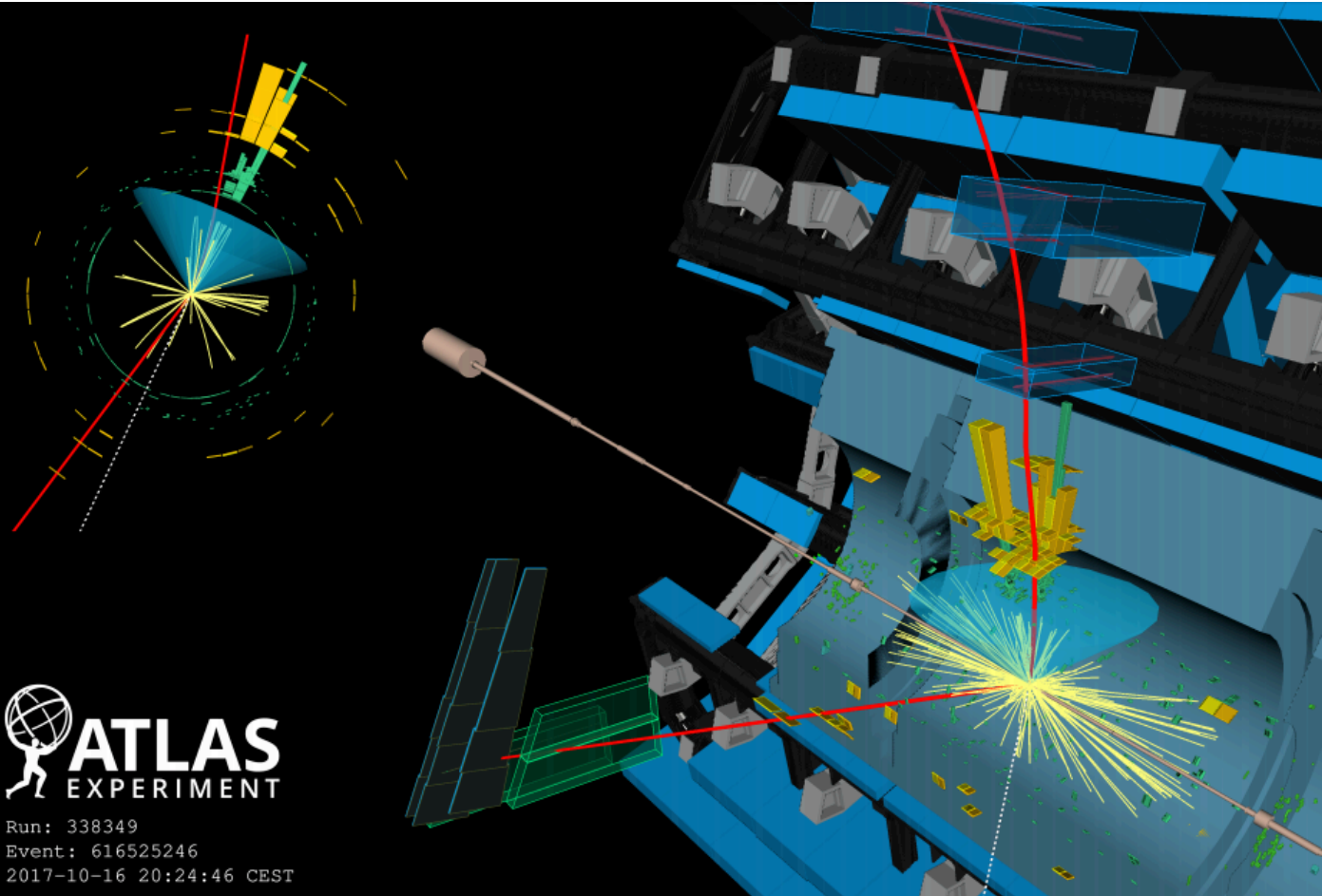
Combined with other decay modes (Run2 only)
 VH observed, **5.3 (4.8) σ**

Full Run-2 (139 ifb)

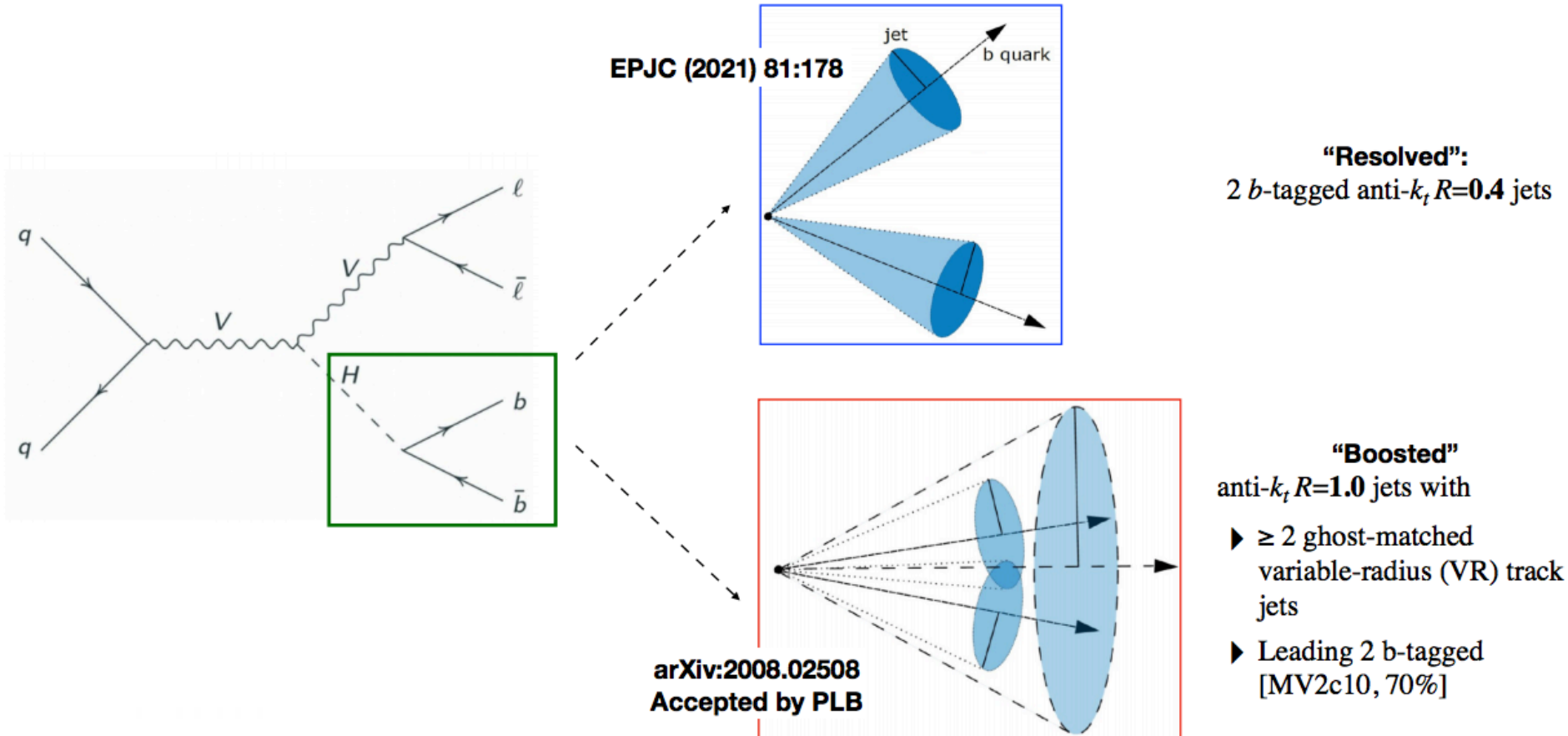


Precise Measurement Era

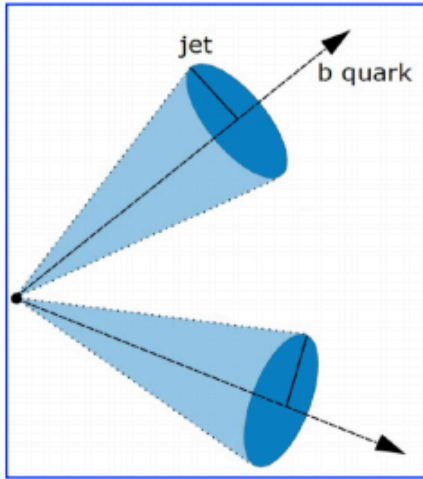
Event display of $WH \rightarrow \mu\nu bb$ candidate



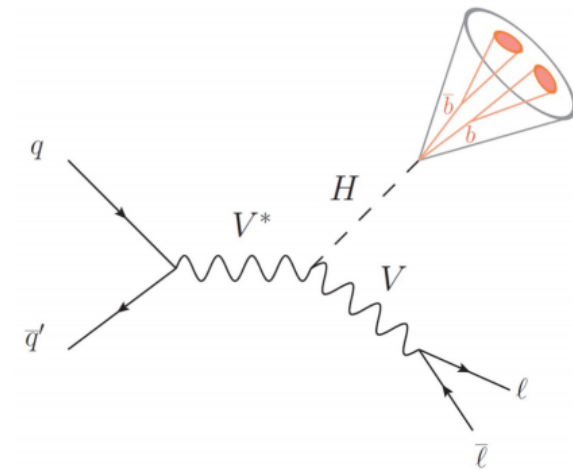
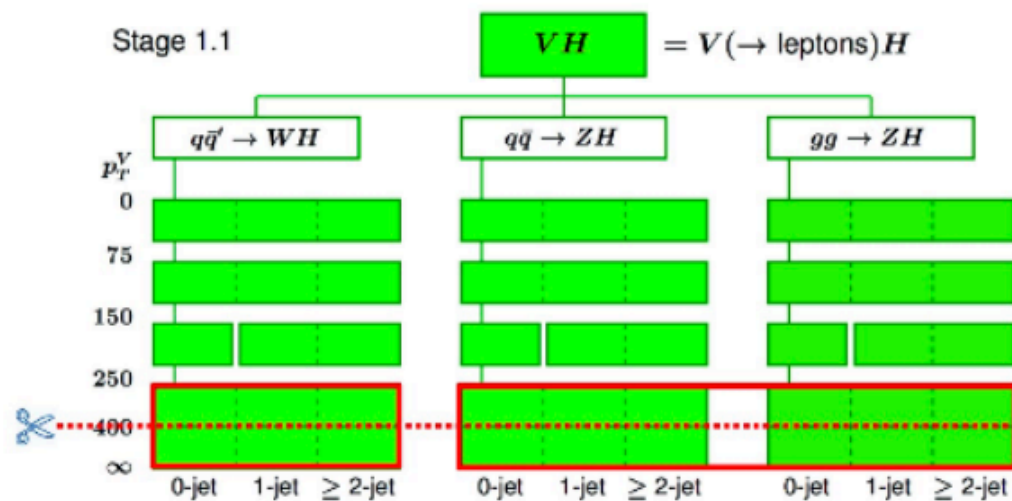
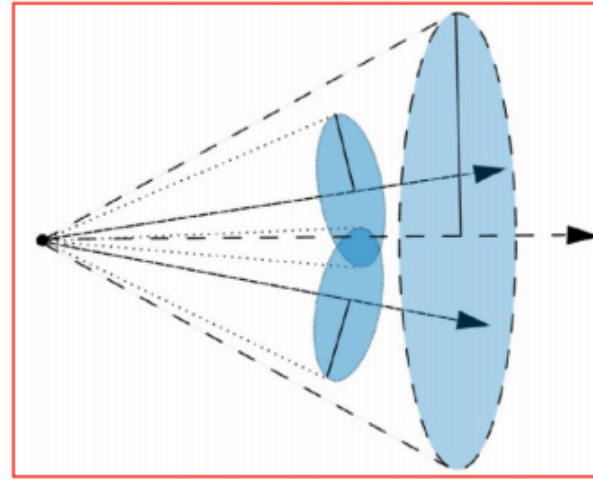
H(bb) reconstruction in a nutshell



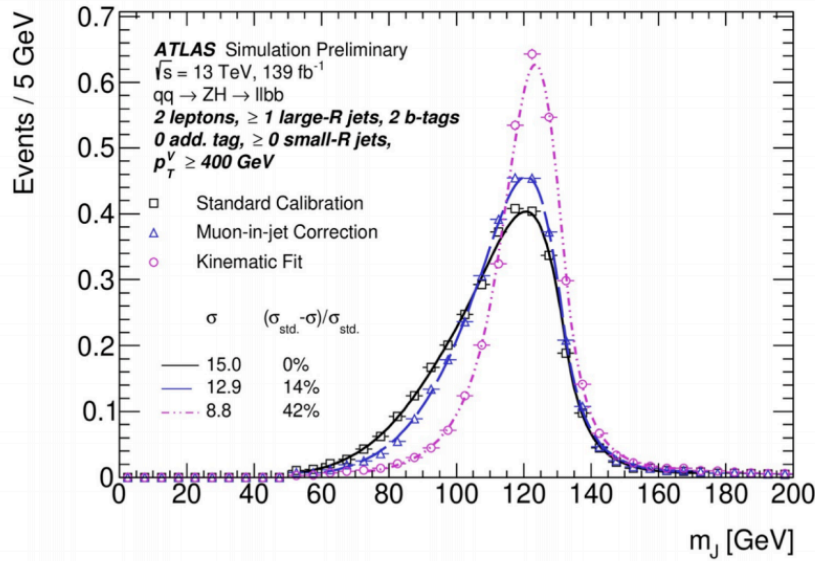
Boosted Hbb categorization in VH analysis at ATLAS



Boost
→



Boosted Large-R jet mass resolution



Final discriminant: large-R jet mass m_j

Combined(*) mass resolution: $\sim 15\%$

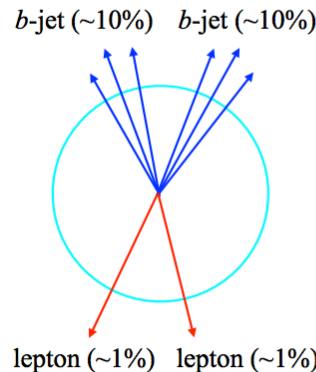
Improve m_j resolution through

- i. **Muon-in-jet correction: 6-14%**
 - correct for semimuonic heavy hadron decays
- ii. **Kinematic Fit in 2L: 30-40%**
 - exploit excellent energy resolution of leptons

arXiv:2008.02508

- Tackling the boosted bb large-R jet mass resolution: kinematic constrained fit

- Constrains llbb system to be balanced in the transverse plane and improve b-jet energy correction

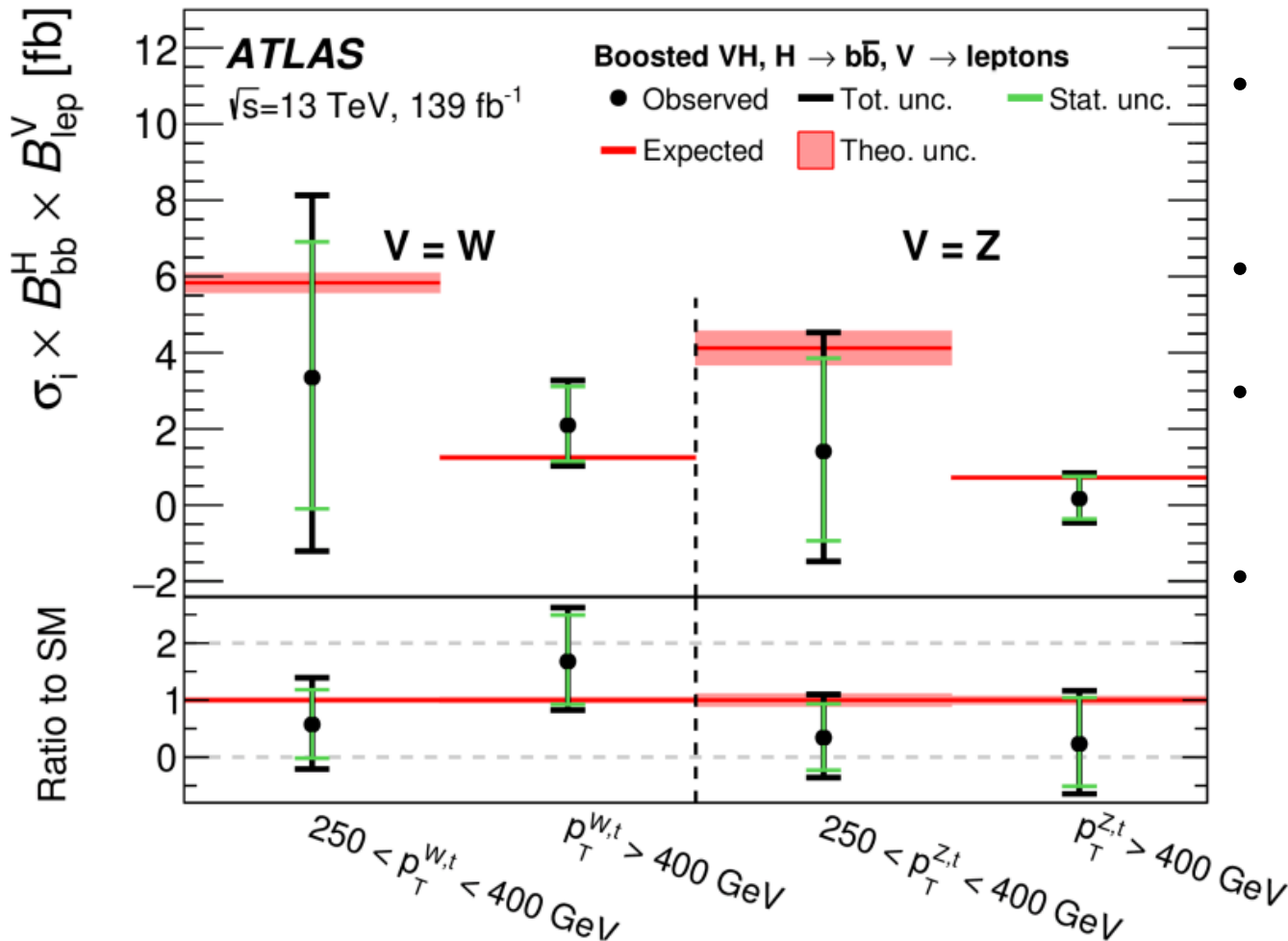


$$\begin{aligned}
 -2\ln L = & \quad \leftarrow \text{Maximize likelihood} \\
 & \sum_i \frac{(p_T - p_T^{\text{fit}})^2}{\sigma^2} \quad \leftarrow \text{Leptons, 3rd jet, MET soft term: Gaussian} \\
 & -\sum_j 2\ln L(p_T, p_T^{\text{fit}}) \quad \leftarrow \text{b-jets: Transfer Functions} \\
 & + \frac{(\sum_{i,j} p_x)^2}{\sigma_{\text{bal}}^2} + \frac{(\sum_{i,j} p_y)^2}{\sigma_{\text{bal}}^2} \quad \leftarrow \text{Balance constraint: Gaussian} \\
 & + 2\ln\{(m_{ll}^2 - m_Z^2)^2 + m_Z^2 \Gamma_Z^2\} \quad \leftarrow \text{Z mass constraint: Breit-Wigner}
 \end{aligned}$$

- Newly using MET soft term $\rightarrow 10\%$ improvement in ggZH

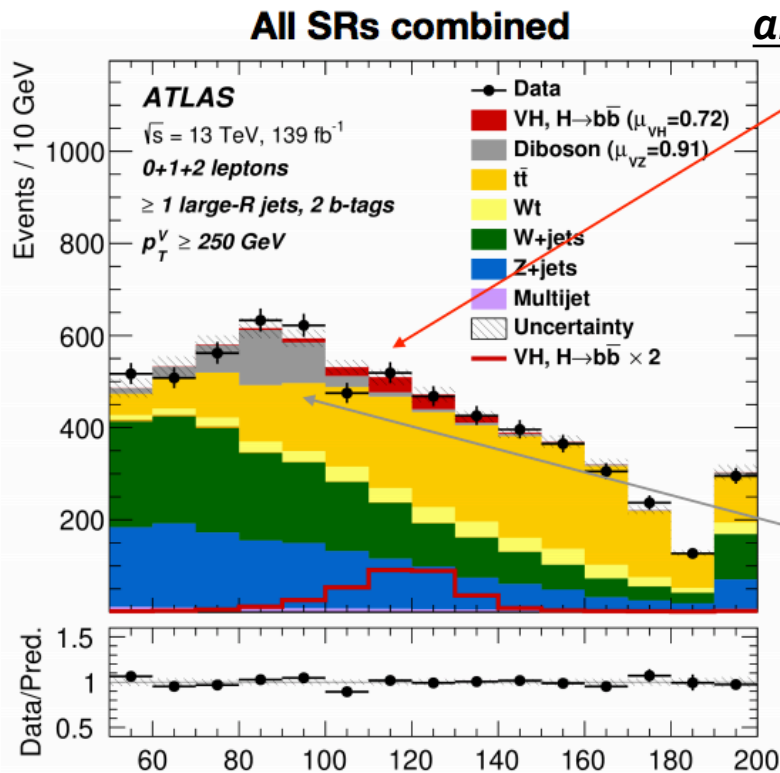
Latest boosted VH(bb) measurement

arXiv:2008.02508



- First measurement of $p_T(V, \text{truth}) > 400$ GeV!
- Uncertainties 70-90%
- In good agreement with the SM prediction
- No evidence of new physics in boosted VH(bb) final states

VH and VZ extraction in boosted bb final states



arXiv:2008.02508

$$\mu_{VH}^{bb} = 0.72^{+0.39}_{-0.36} = 0.72^{+0.29}_{-0.28}(\text{stat.})^{+0.26}_{-0.22}(\text{syst.})$$

Obs. (exp.) significance: 2.1 (2.7) σ

$$\mu_{VZ}^{bb} = 0.91^{+0.29}_{-0.23} = 0.91 \pm 0.15(\text{stat.})^{+0.25}_{-0.17}(\text{syst.})$$

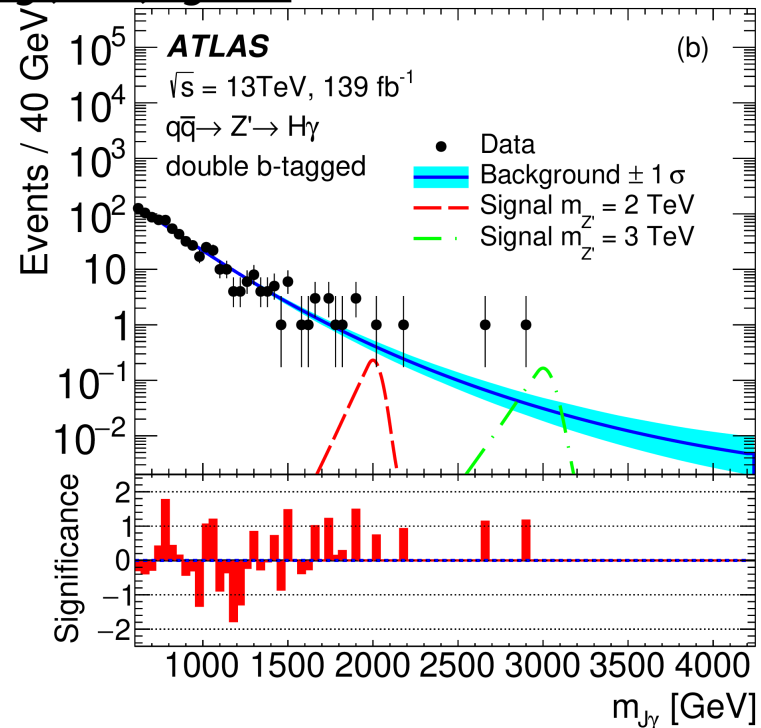
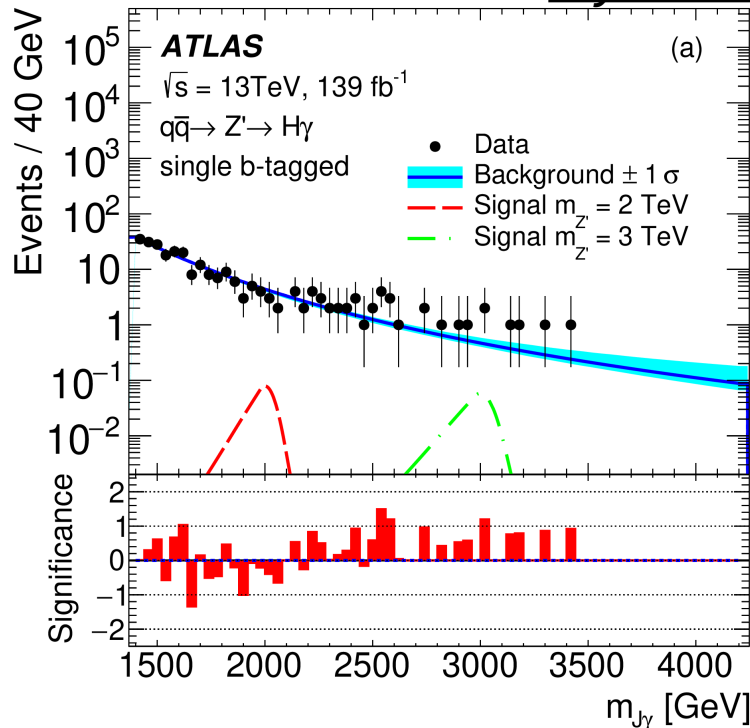
Obs. (exp.) significance: 5.2 (5.7) σ

- Simultaneously extract VH(bb) and VZ(bb) signal strength
- Binned profile likelihood fit in 14 regions

Channel	Categories					
	$250 < p_T^V < 400 \text{ GeV}$			$p_T^V \geq 400 \text{ GeV}$		
	0 add. b -track-jets		≥ 1 add. b -track-jets	0 add. b -track-jets		≥ 1 add. b -track-jets
	0 add. small- R jets	≥ 1 add. small- R jets		0 add. small- R jets	≥ 1 add. small- R jets	
0-lepton	HP SR	LP SR	CR	HP SR	LP SR	CR
1-lepton	HP SR	LP SR	CR	HP SR	LP SR	CR
2-lepton	SR			SR		

Boosted bb in new physics searches: H+photon heavy resonances

Phys. Rev. Lett. 125 (2020) 251802

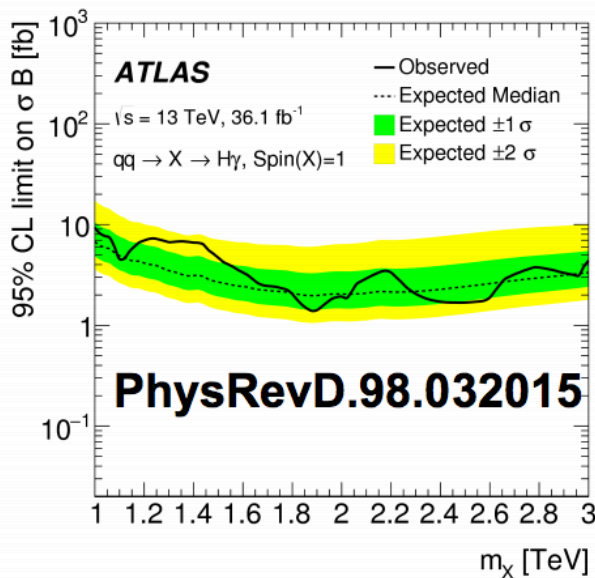


- Heavy resonance search for spin-1 $X \rightarrow H + \gamma$ process with toy model:
 - start from Z' benchmark, add a contact interaction $X-H-\gamma$, i.e. at the level of the FeynRules, add in a new $U(1)$, and then a dim-6 term (thanks to Prof. K. Mawatari)
- Boosted large-R jet reconstruction for SM Higgs candidate: 1/2-btagged categorized
- Novel methodology: based on information about the jet constituents calculated in the center-of-mass frame of the jet

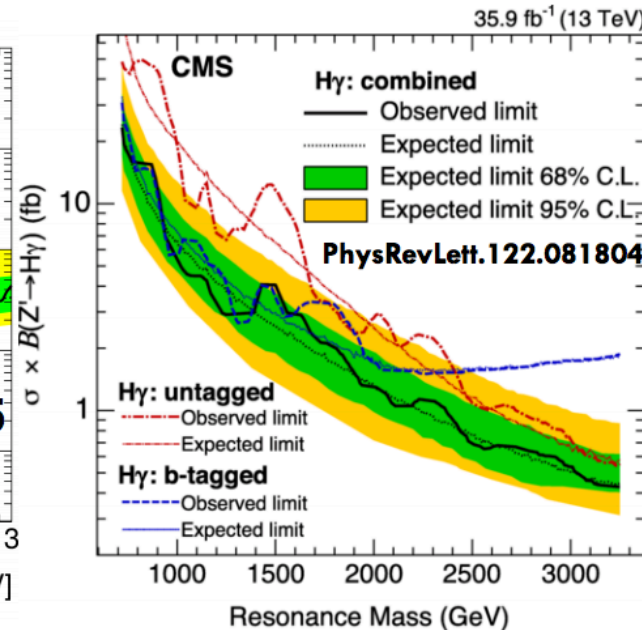
Boosted bb in new physics searches: H+photon heavy resonances

Phys. Rev. Lett. **125** (2020) 251802

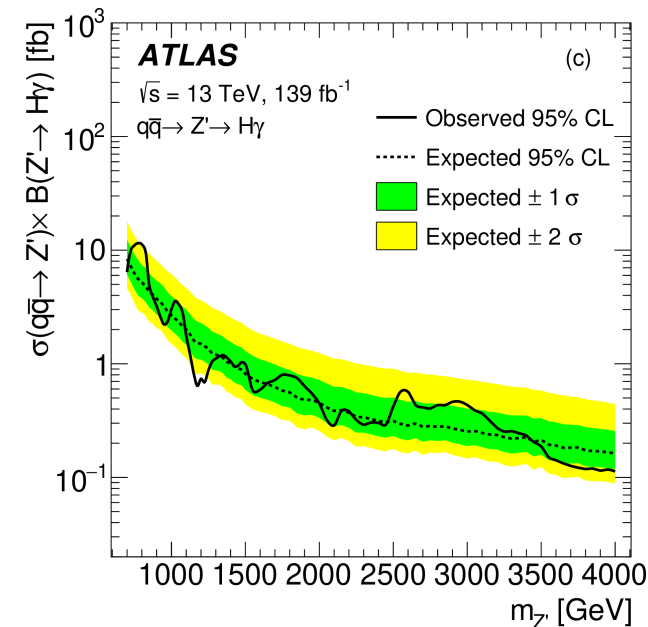
Previous ATLAS result



Previous CMS result



This work

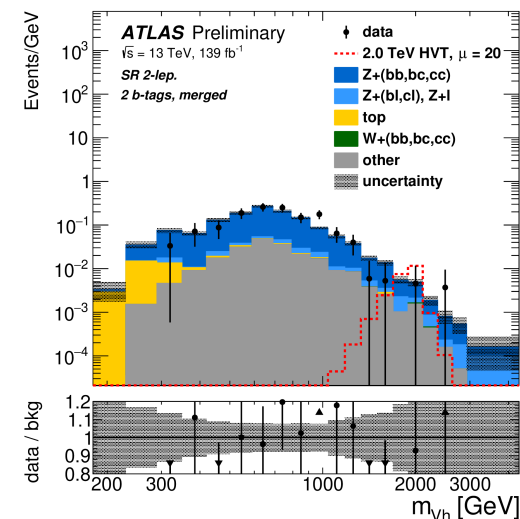
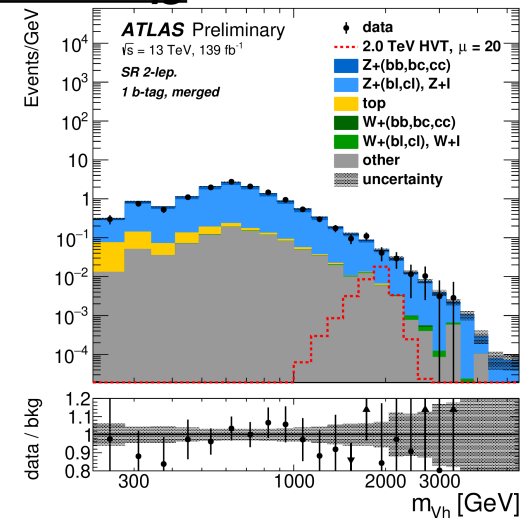
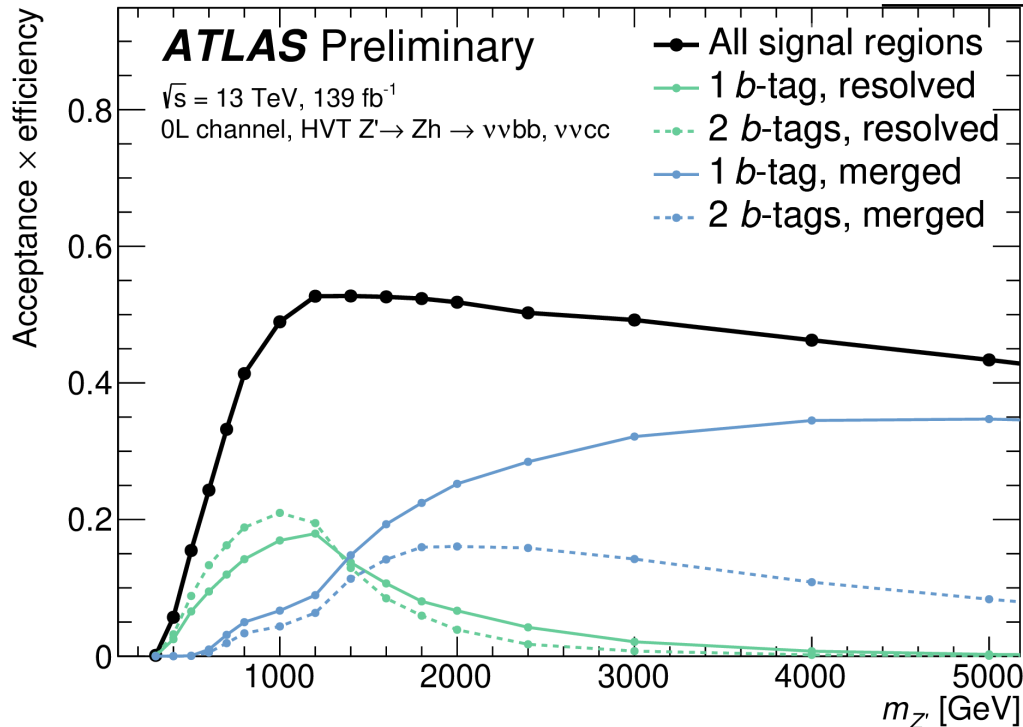


Limit ratio comparison:

- ATLAS: new result / previous result $\sim 1/15$ ($\sim 1/3$) for $M(Z')=2.5(1.2)\text{TeV}$
- CMS: partial dataset with TMVA treatment applied, based on BDT for $H \rightarrow bb$ + fatjet substructure information, ratio w.r.t. ATLAS new results $2/5 \sim 1/3$ below 2.5 TeV

Boosted bb in new physics searches: VH heavy resonances

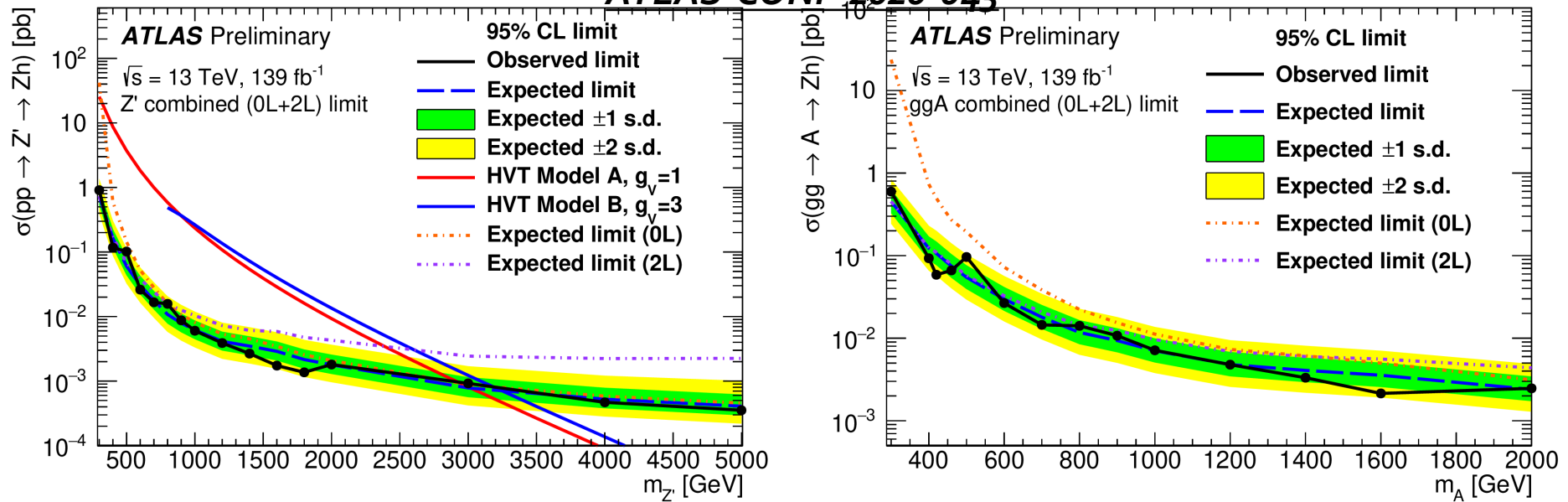
ATLAS-CONF-2020-043



- Search for heavy resonances decaying into $ZH(bb)$ final states
- Benchmark models: HVT Z' , CP-odd scalar A from 2HDM
- Significant recovery of signal efficiency in merged (boosted) regime at high p_T

Boosted bb in new physics searches: VH heavy resonances

ATLAS-CONF-2020-043



- Upper limits at the 95% CL on the product of the cross section for $pp \rightarrow Z'$ and $gg \rightarrow A$ and their respective branching fraction to $Z h$ from the combination of the 0-lepton and 2-lepton channels.
- $gg \rightarrow A$ search
 - assuming pure gluon-gluon fusion production and $h \rightarrow bb^-$ BR=0.569
- $pp \rightarrow Z'$ search
 - $h \rightarrow bb^-, cc^-$ BR = 0.598 is assumed.

Summary

- Boosted bb driven analysis after becoming new hotspots at LHC after H(bb) observation and more data to probe the highly boosted regime
- Sophisticated treatment using large radius jet substructure info to enhance the boosted Hbb tagging are being carried out with machine learning techniques
- Boosted SM H(bb) are measured for the 1st time at ATLAS with no significant derivation at high p_T regime
- BSM searches with boosted H(bb) are being carried out with by far no hints of SP but more search results are yet to come so stay tuned 😊