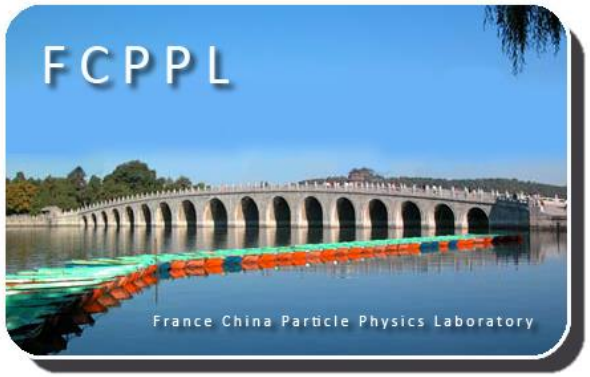
Measurement of b-tagging efficiency and search for $\mathrm{H} \to b\bar{b}$ decay

Yanwen Liu on behalf of the LPNHE(Paris) and USTC(Hefei) team

Giovanni Marchiori, Paolo Francavilla, Giovanni Calderini, Carlo Pandini

YL, Cheng Chen, Changqiao Li

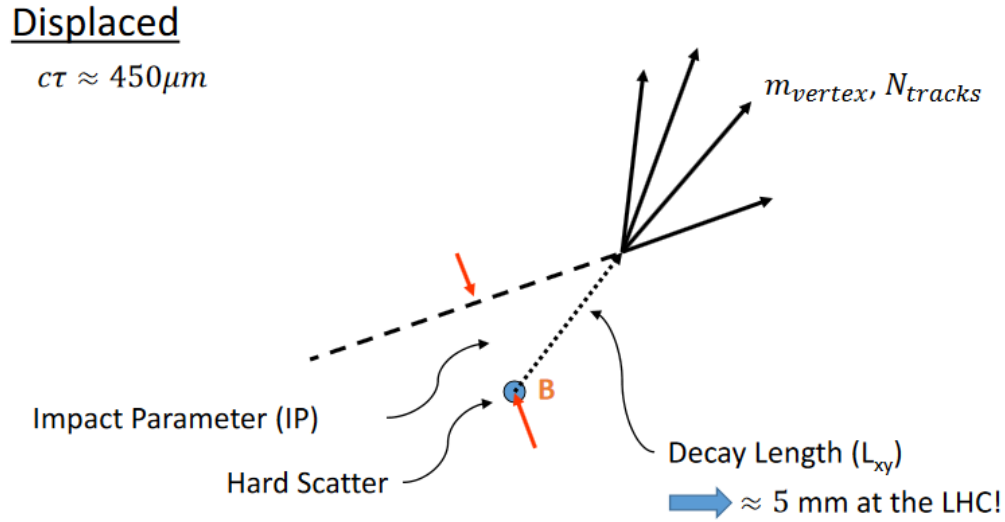


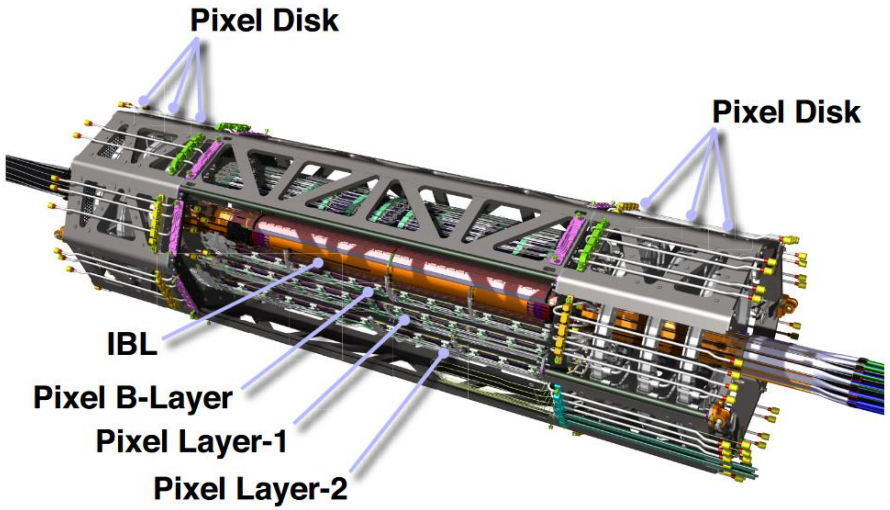
Outline

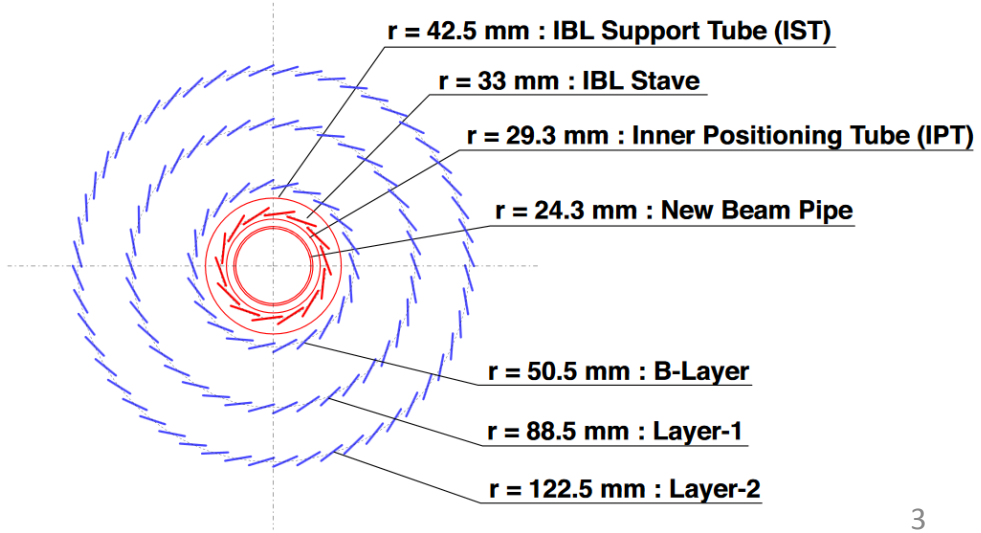
- Two groups working together since 2010 (photon ID, $\mathrm{H} \to \gamma\gamma$, $\mathrm{Z}\gamma$)
- Activities in 2016
  - Measurement of the b-tagging efficiency
  - Search for the $\mathrm{H} \to b\bar{b}$ decay
- Plan (proposal) for 2017

B-tagging at ATLAS

- Jets originating from b-quark (b-jets) important signature
  - Higgs property, BR($H \rightarrow b\bar{b}$) = 58%
  - Top properties, BR($t \rightarrow Wb$) ≈100%
- Tagger: Boosted Decision Tree that combines info. from
  - Impact parameter of tracks
  - Secondary vertices
  - Reconstructed decay chain(multiple vertices)

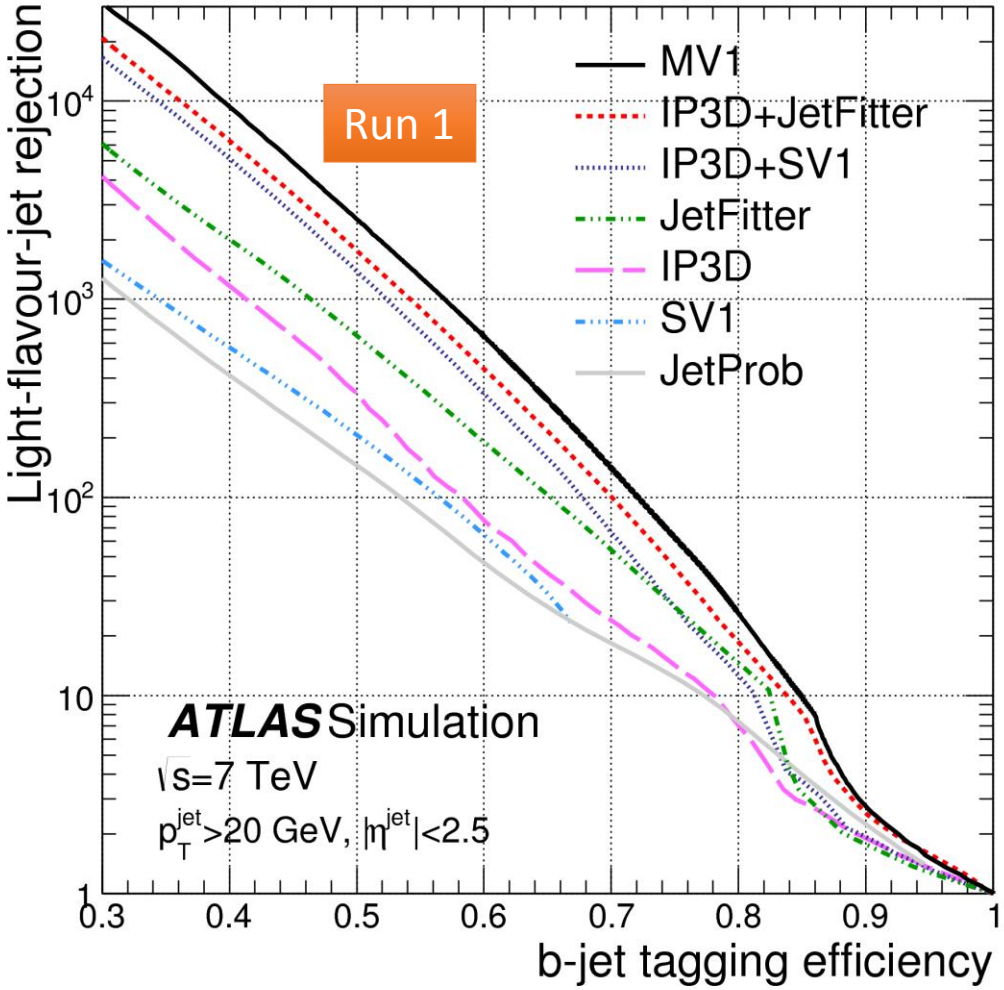


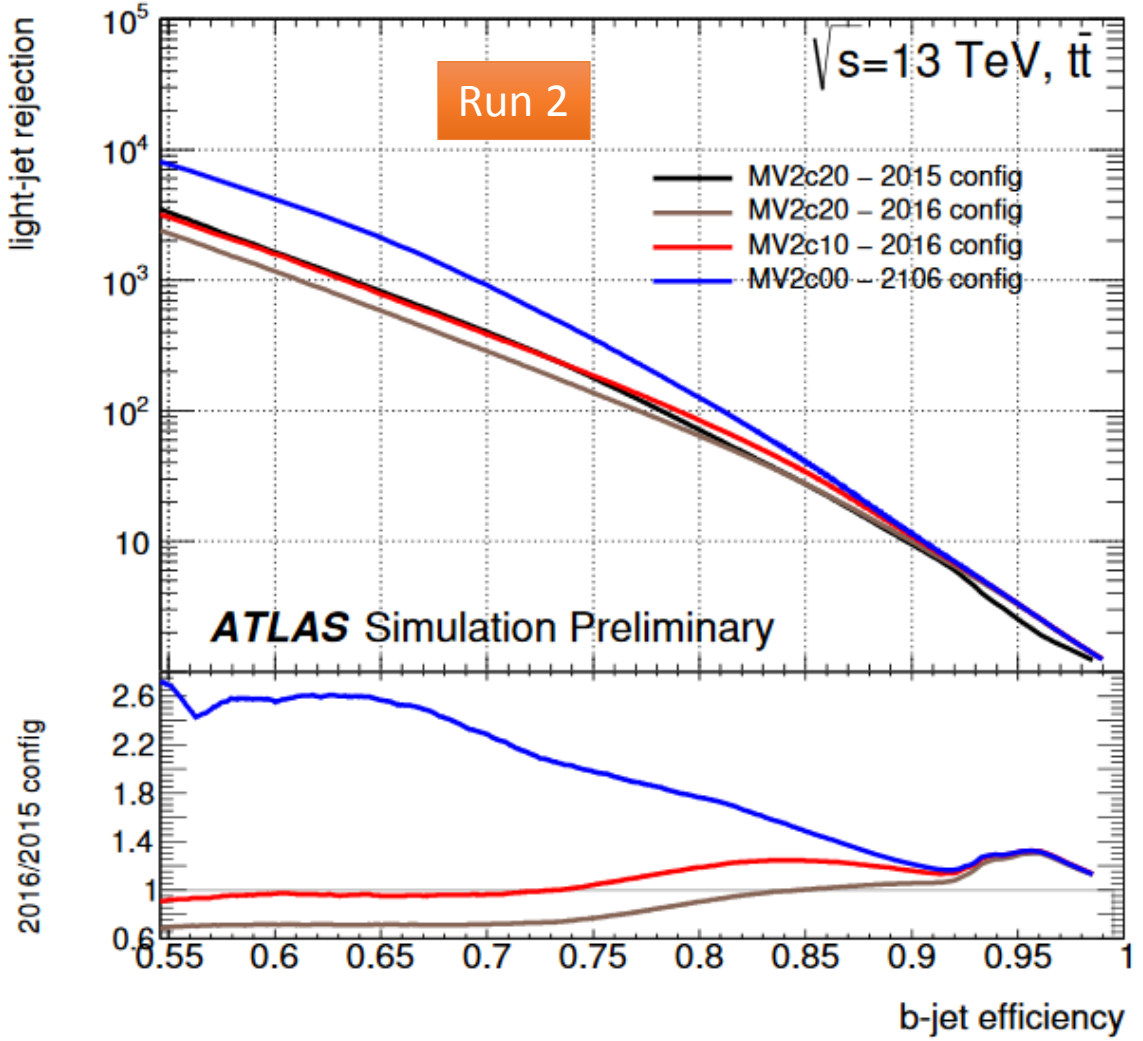




Performances

"MV2c10": BDT trained for Run 2(10% of charm in background sample)
At efficiency of 80%, roughly a factor of 5 improvement on rejection
Vital to measure the performance with real data





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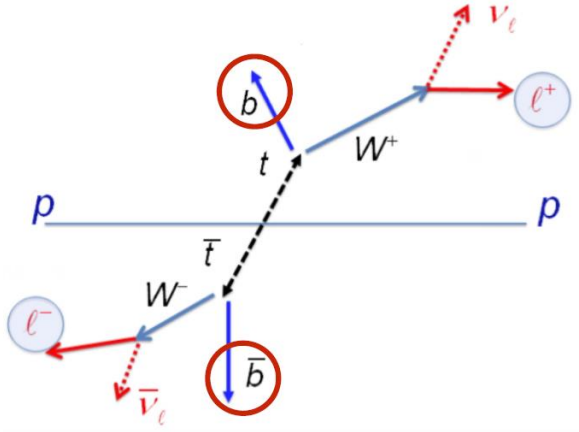
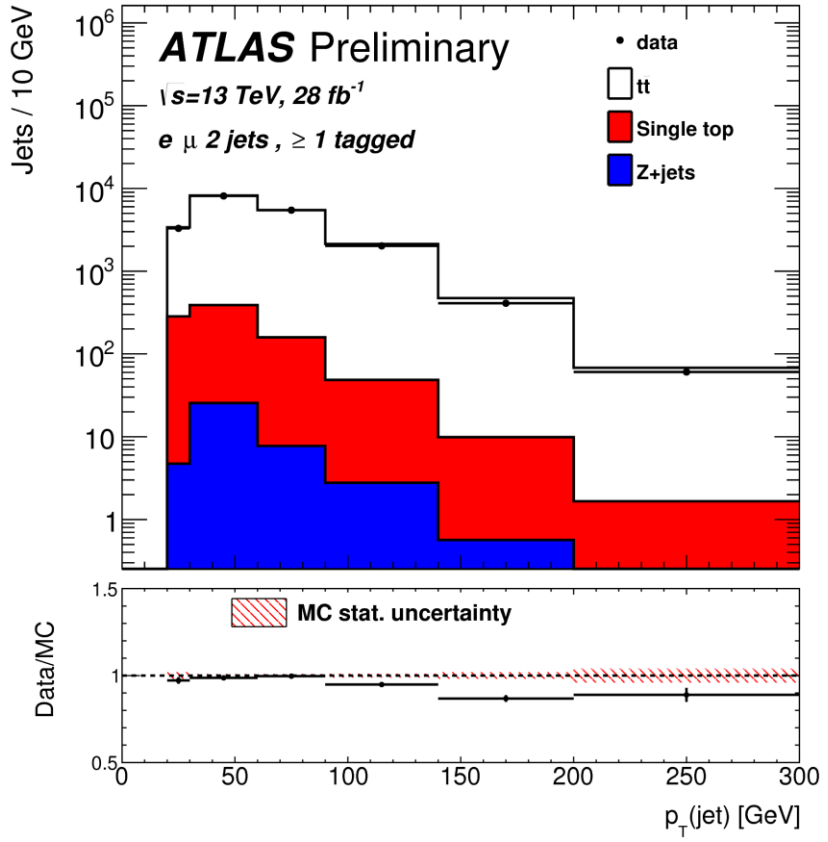
Tag and probe method with $t\bar{t}$ events

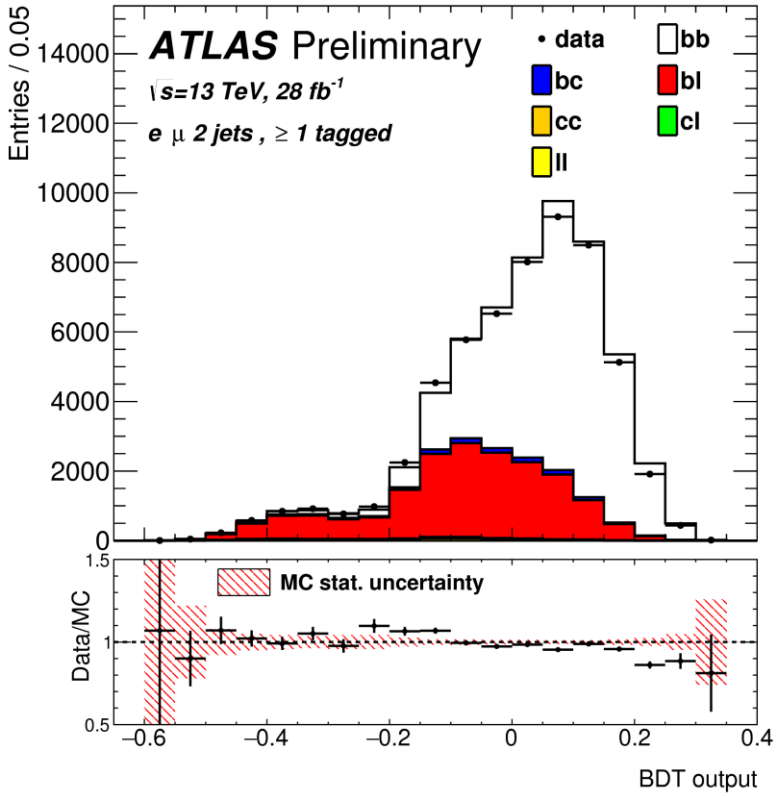




Abundant b-jets in $t\bar{t}$ events at the LHC (cross section of 830 pb)
Select with $e\mu$ of opposite signs, and 2-jets
At least one jet is tagged (with a MV2 cut corresponding to 85% efficiency)
Important contamination of light jets in the lowest and highest p_T bin
Suppressed with a "purity" BDT based on the kinematic features
Show here results presented at the poster session of LHCC in February 2017
Results of full 2015+2016 dataset for calorimeter- and track-jets are being reviewed for publication

“Purity” BDT and Efficiency Extraction

Optimize the cut on the “Purity” score for the lowest uncertainty on the measured b-tagging efficiency.



In the first step we subtracted the no-ttbar events

Subtract non-tt

$$\varepsilon_{\text{data}}^{\text{Uncorr}} = \frac{N_{\text{data}}^{\text{pass}} - N_{\text{non-t}\bar{\text{t}}}^{\text{pass}}}{N_{\text{data}} - N_{\text{non-t}\bar{\text{t}}}}$$

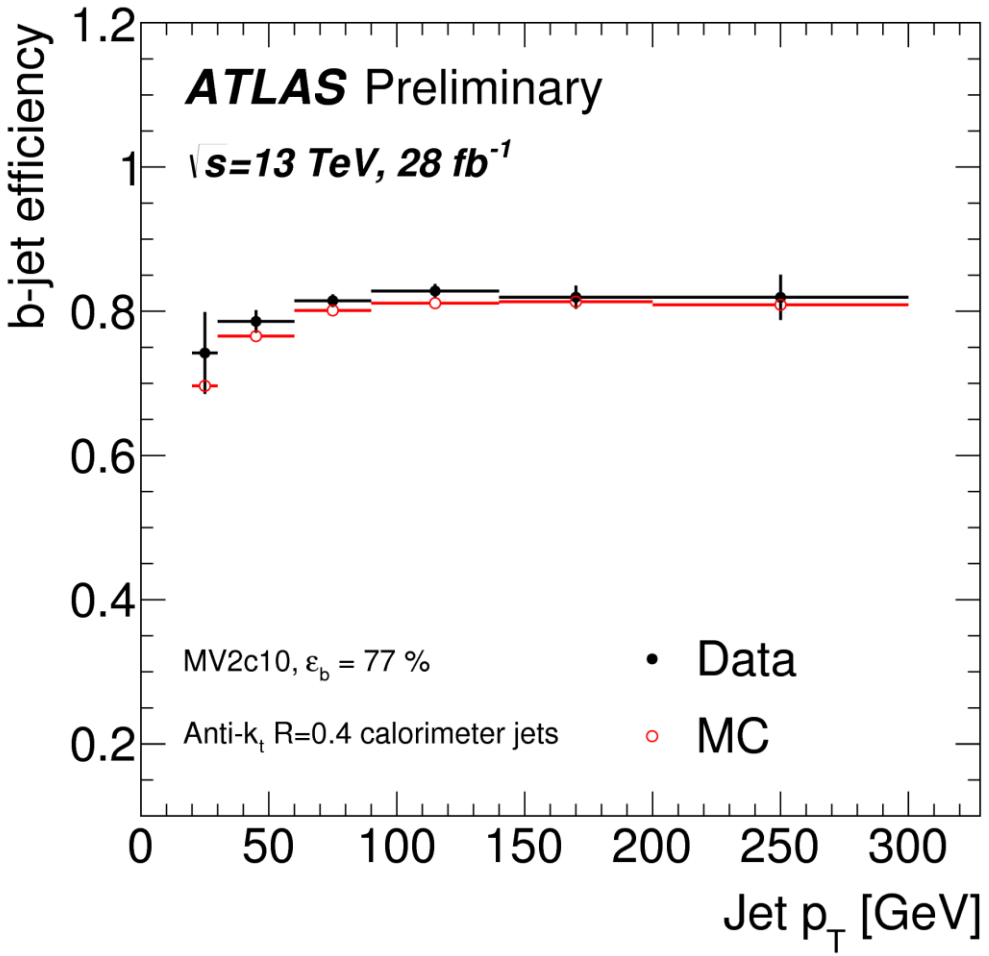
Then we subtracted the contamination of non b jets

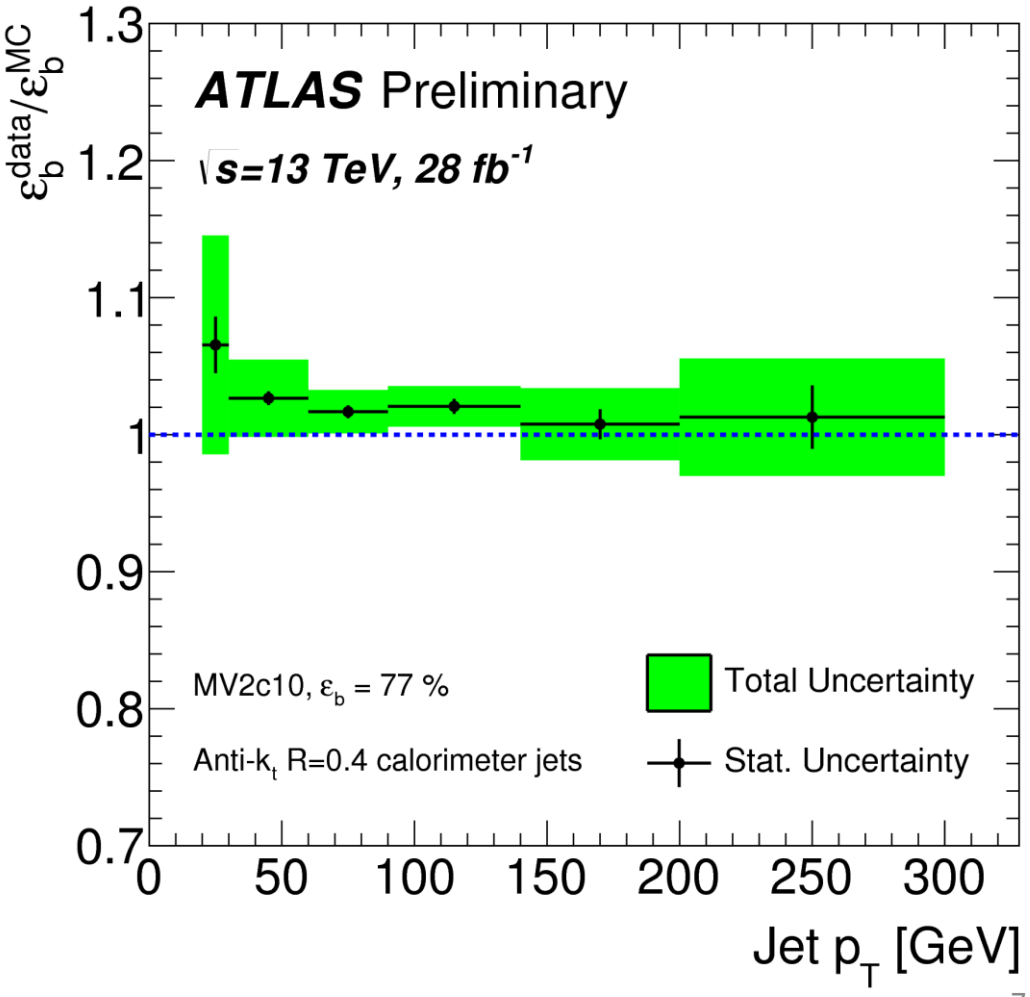
Subtract non-b

$$\varepsilon_{\text{data}}^{\text{Uncorr}} = f_b^{t\bar{t}}\,\varepsilon_{\text{data}} + (1 - f_b^{t\bar{t}})\,\varepsilon_{\text{nonb}}^{t\bar{t}\,\text{MC}}$$

(2) $\Rightarrow$ $$\varepsilon_{\text{data}} = \frac{\varepsilon_{\text{data}}^{\text{Uncorr}} - (1 - f_b^{t\bar{t}})\,\varepsilon_{\text{nonb}}^{t\bar{t}\,\text{MC}}}{f_b^{t\bar{t}}}$$

Measured efficiencies





Calibrated the working points of efficiencies at 60%, 70%, 77%, 85% for track- and calorimeter-jets

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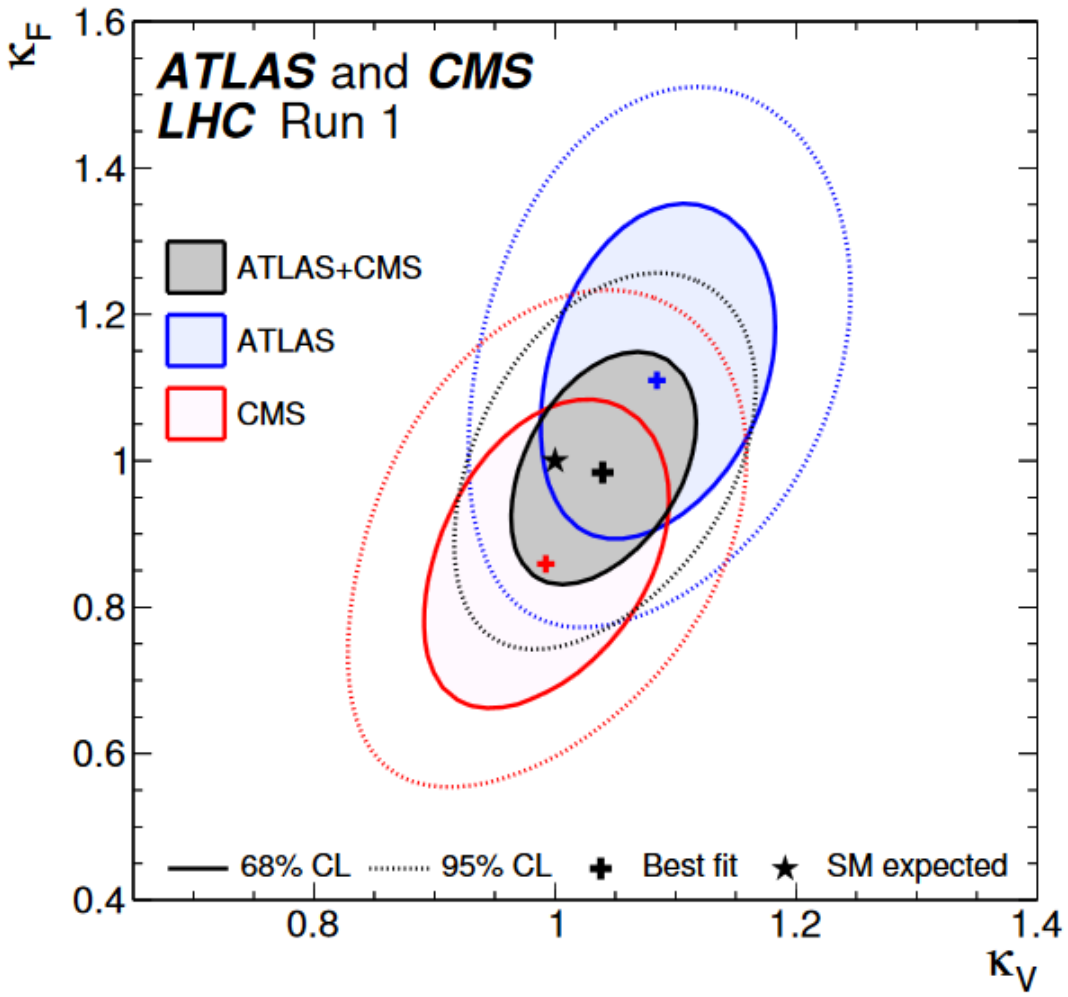
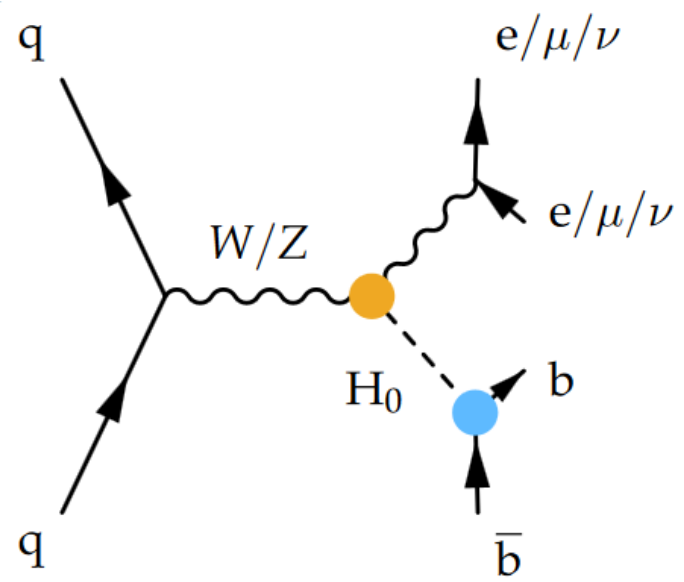
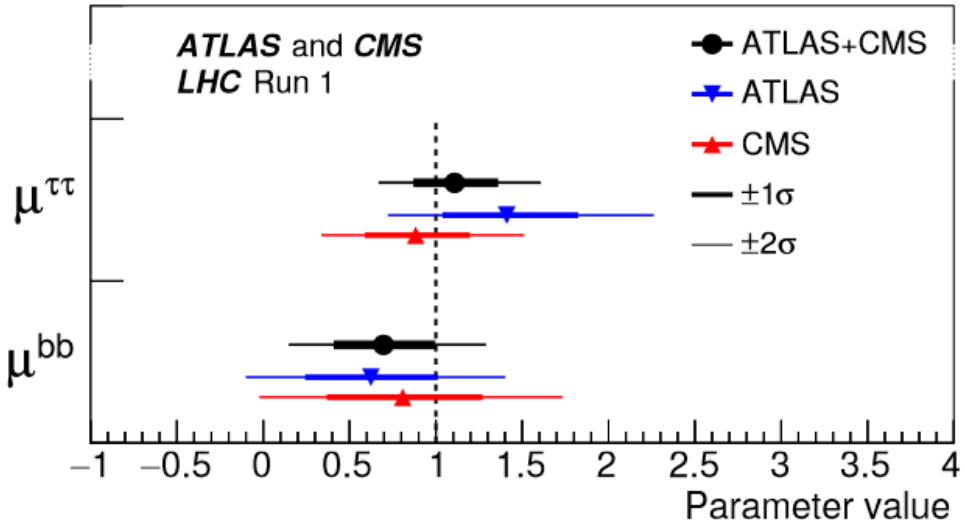
Search for the $H \to b\bar{b}$ decay







- The $Hf\bar{f}$ couplings constrained (in)directly in Run 1
- $H \to b\bar{b}$ decay still to be observed
- VH associate production the most promising

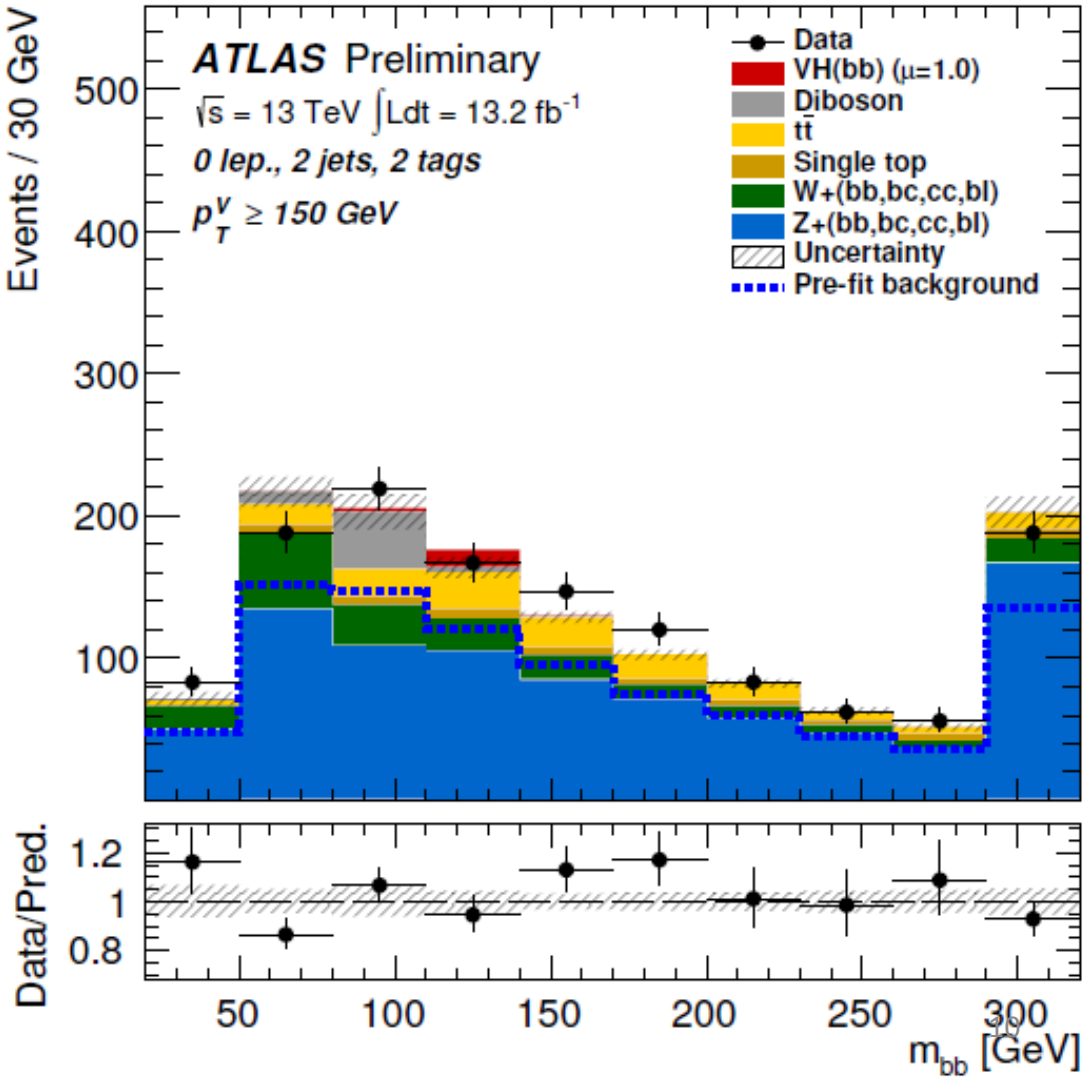
Event selection

Selection	0-lepton	1-lepton	2-lepton
Trigger	$E_{\mathrm{T}}^{\mathrm{miss}}$	$E_{\mathrm{T}}^{\mathrm{miss}}$ (μ sub-channel)	
		Lowest unprescaled single lepton	
Leptons	0 loose lepton	1 tight lepton	2 loose leptons ($\geq$ 1 medium lepton)
Lepton pair	-	-	Same flavour opposite-charge for $\mu\mu$
$E_{\mathrm{T}}^{\mathrm{miss}}$	> 150 GeV	> 30 GeV (e sub-channel)	-
m_{ll}	-	-	$71 < m_{ll} < 121$ GeV
S_{T}	> 120 (2 jets), >150 GeV (3 jets)	-	-
Jets	Exactly 2 or 3 signal jets		Exactly 2 or $\geq$ 3 signal jets
b-jets	2 b-tagged signal jets		
Leading jet p_{T}	> 45 GeV		
min$\Delta\phi(E_{\mathrm{T}}^{\mathrm{miss}}$, jet)	> 20°	-	-
$\Delta\phi(E_{\mathrm{T}}^{\mathrm{miss}}, h)$	> 120°	-	-
$\Delta\phi$(jet1,jet2)	< 140°	-	-
$\Delta\phi(E_{\mathrm{T}}^{\mathrm{miss}}, E_{\mathrm{T},trk}^{\mathrm{miss}})$	< 90°	-	-
p_{T}^{V} regions	[0, 150] GeV (2-lepton), [150, ∞] GeV		

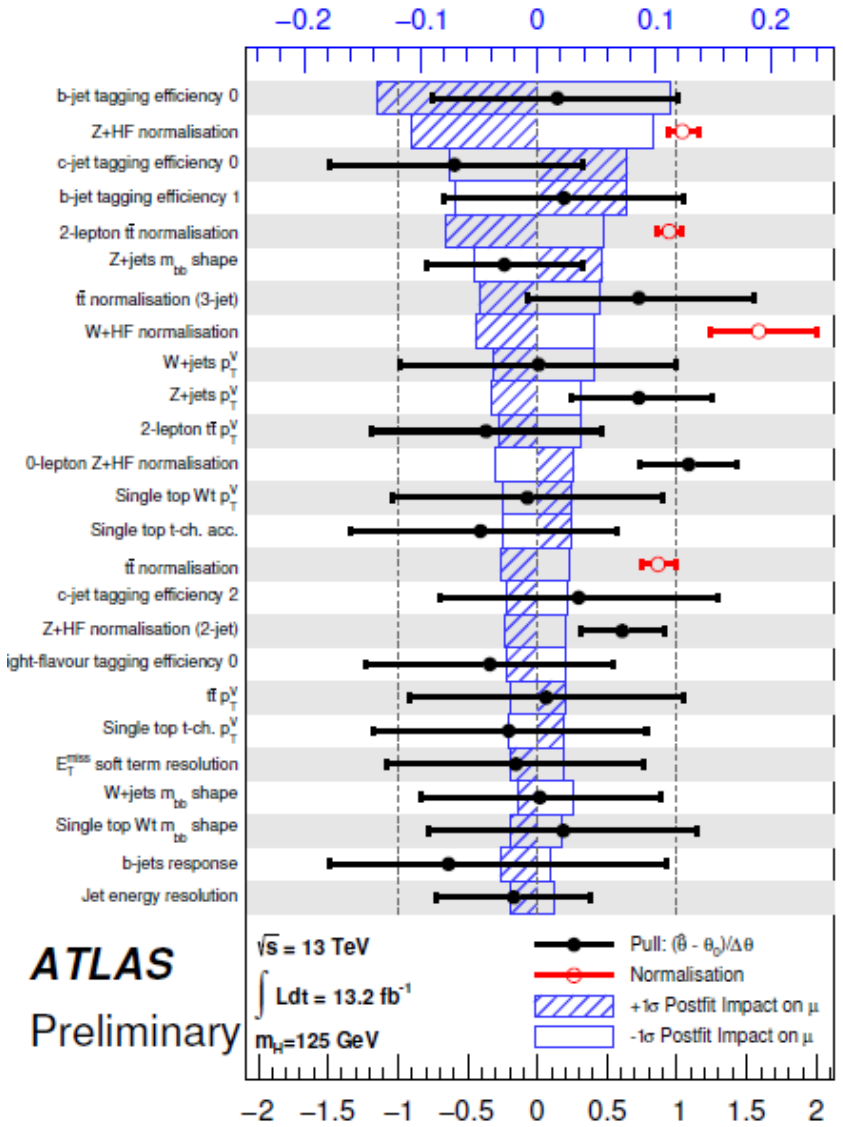
Discriminant BDT(fitted to extract signal)

- Kinematic variables as input
- Distributions of BDT fitted simultaneously
- Very important to validate the fit
  (sizeable shift on the normalizations from the fit)

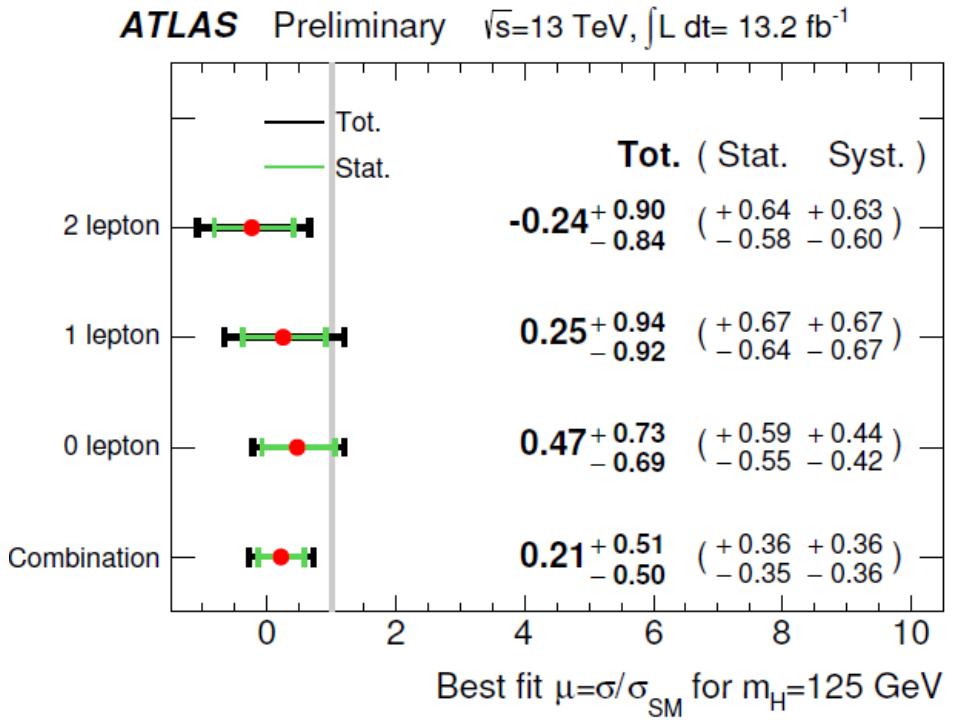
Sub-channel	Fit Regions
0-lepton	2-jet + 3-jet
1-lepton	2-jet + 3-jet
2-lepton	(2-jet+3-jet) ×(low or high p_T^V)



Results: Pulls, ranking, scale of normalizations



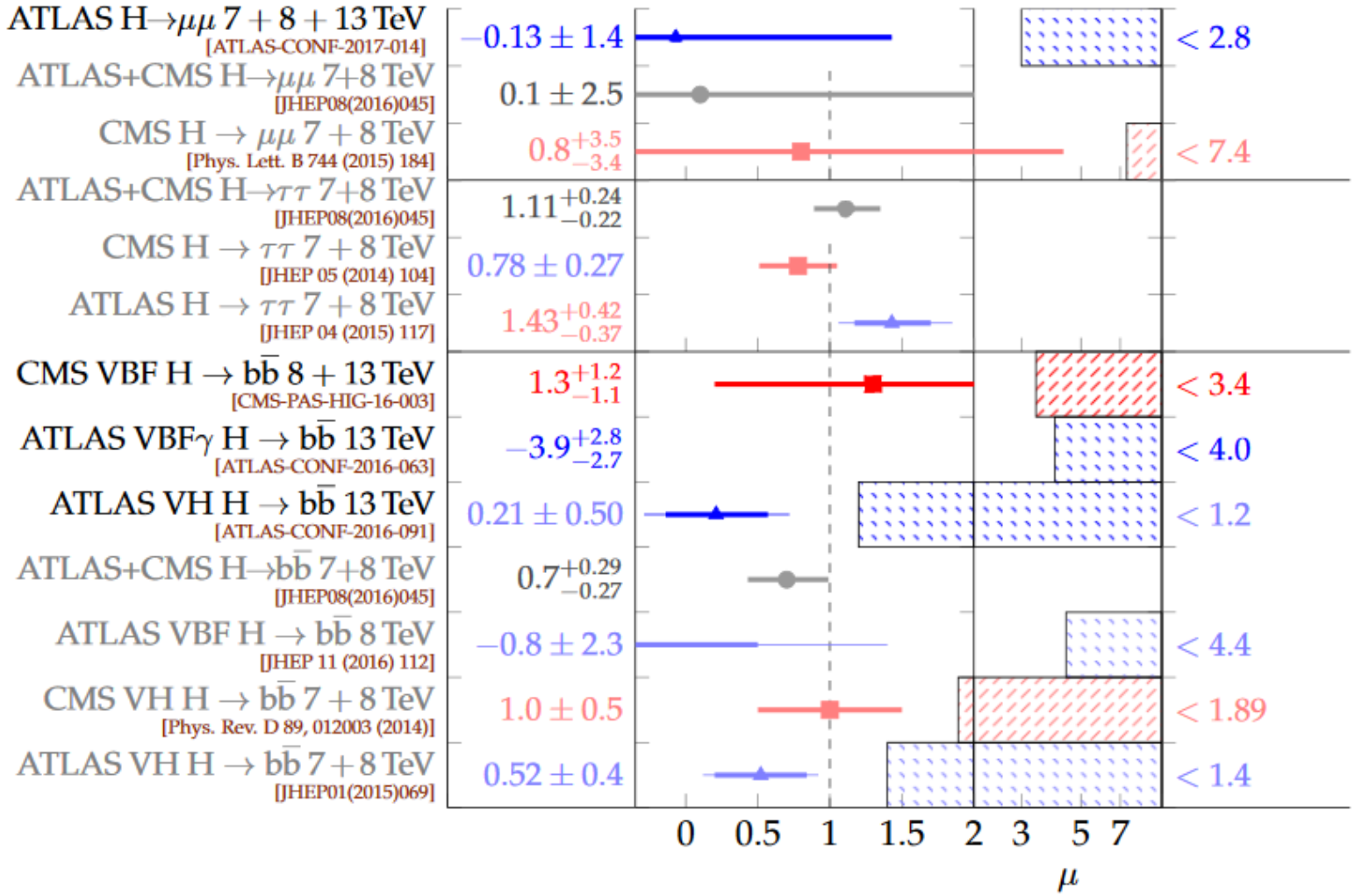
- b-tagging efficiency has the largest impact on signal strength
- V+HF sub-leading: normalizations shifted
- Method/machinery validated with VZ(bb)



Signal significance: 0.4 s.d. (obs), 1.9 s.d. (exp)
Run 1: significance: 1.4 s.d. (obs), 2.6 s.d. (exp)

2nd, 3rd generation couplings

Measured signal strength μ and 95% CL limit on $\sigma \times$ Br relative to the SM expectation for $m_{\mathrm{H}} = 125\,\mathrm{GeV}$:



List of publications

[1] C. Chen, C. Li, Y. Liu, G. Marchiori, *Measurement of the b-tagging efficiency of the MV2c10 discriminant using ttbar events decaying to different-flavour leptons produced in pp collisions at sqrt(s)=13 TeV*, ATL-COM-PHYS-2016-1796.

[2] ATLAS Collaboration, *Search for new resonances decaying to a W or Z boson and a Higgs boson in the llbb, lvbb, and vvbb channels with pp collisions at sqrt(s)=13 TeV with the ATLAS detector*, Phys. Lett. B765 (2017) 32-52

[3] ATLAS Collaboration, *Search for a CP-odd Higgs boson decaying to Zh in pp collisions at √s = 13 TeV with the ATLAS detector*, ATLAS-CONF-2016-015

[4] ATLAS Collaboration, *Search for the Standard Model Higgs boson produced in association with a vector boson and decaying to a bb pair in pp collisions at 13 TeV using the ATLAS detector*, ATLAS-CONF-2016-091

Plans for 2017 (and ahead)

- Search for $\mathrm{H} \to b\bar{b}$ (Giovanni, Paolo, Ilaria, YL, Changqiao, Cheng)
  - Publish the analysis with full data of 2015+2016 (anticipate discovery!)
  - Publish the measurement of b-tagging efficiency
- Search for $\gamma\gamma$ resonances (Lydia Roos, Yufeng Wang, YL)
  - New project and new (old) members (friends)
  - Scan the mass range of 60-120 GeV for peaks (extra scalars in 2HDM,NMSSM)
  - Yufeng's qualification task : validating the uncertainty of the photon energy calibration due to shower leakage (differences in data/mc, electron/photon)

Summary

- Measurement of b-tagging efficiency being finalized for publication
- Search for $\mathrm{H} \rightarrow b\bar{b}$ decay in progress
- Team has expanded to include new members and new projects:
  - Photon energy calibration uncertainty due to shower leakage
  - Search for low mass $\gamma\gamma$ resonances