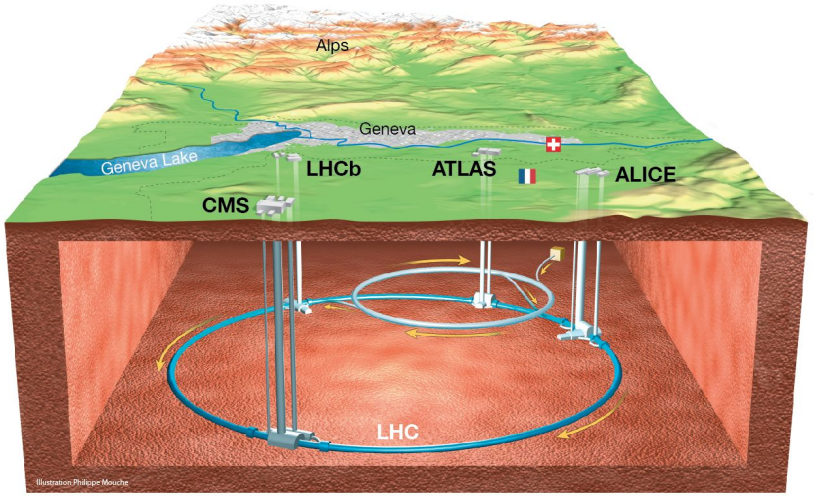
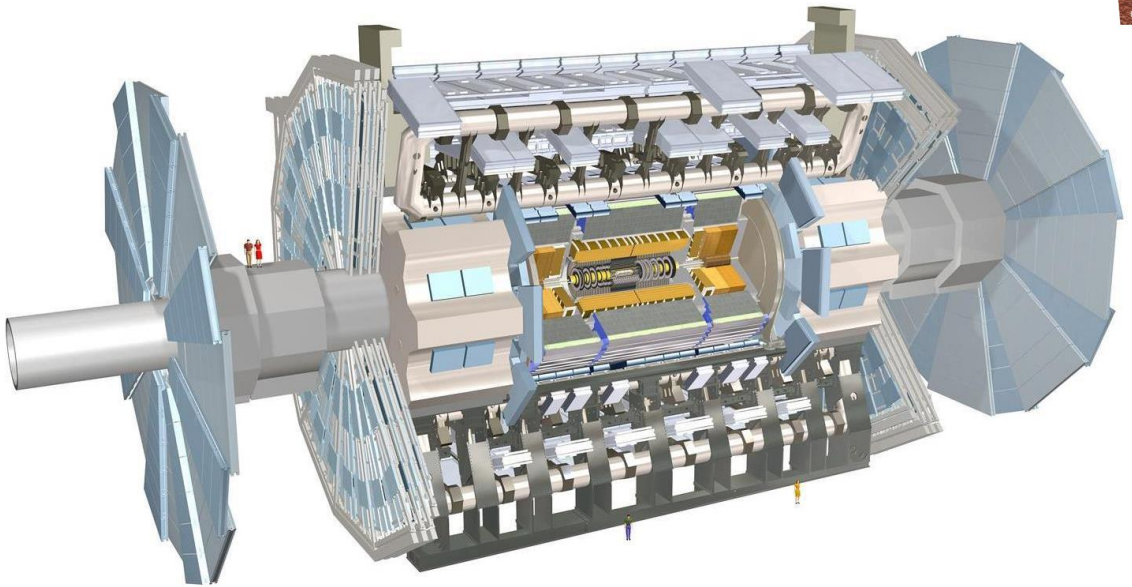
Studies on H → bb̄ decays and VH production with the ATLAS detector

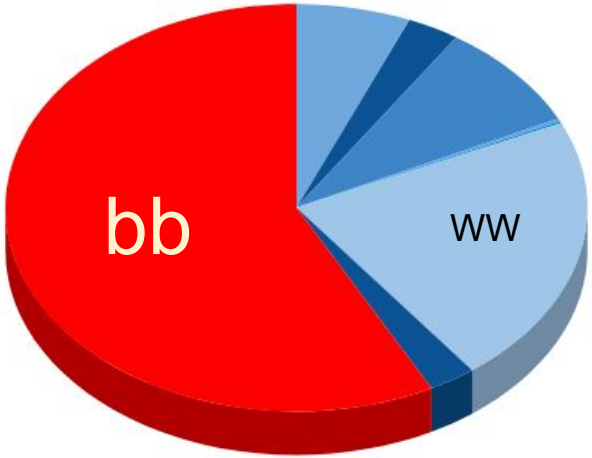
Milène Calvetti

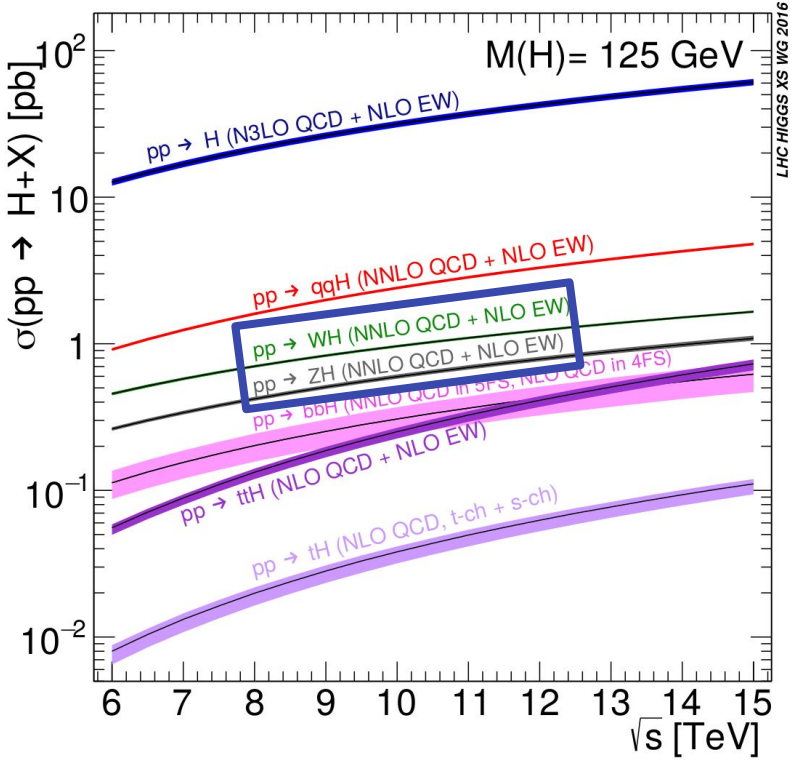
The ATLAS detector





VH, H→bb channel



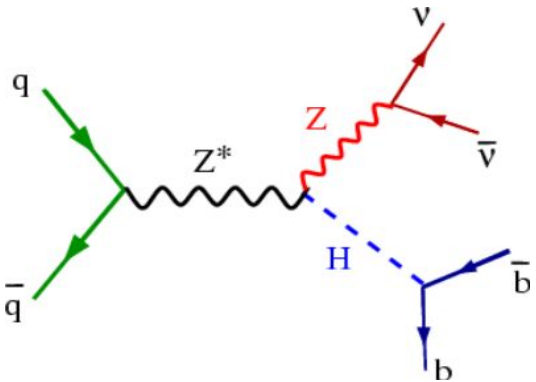


- BR(H → bb) ~ 58 % (expected) YR4, CERN-2017-002-M
- multijet background→ large production cross section at LHC
  → background rejection impossible in pp→H
- Associated production VH (V=W o Z),
  V leptonic decay → clear signature, easier background rejection

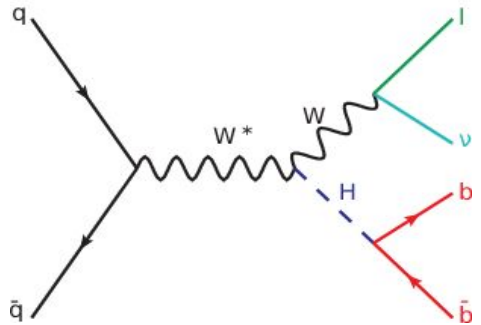
Event classification

Three topologies studied (0, 1, 2 charged leptons):

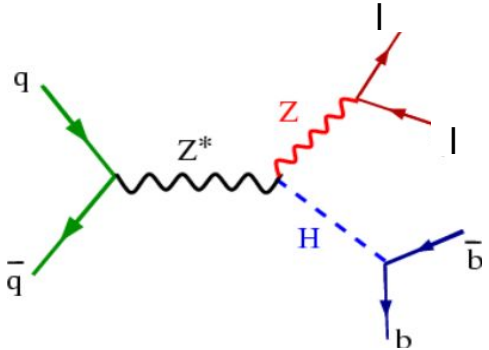
- H→ bb Z →$\nu\nu$
- H→ bb W → lν (l=e,μ)
- H→ bb Z → ll (l=e, μ)



- Trigger: p_T^{miss}



- Trigger: electron or p_T^{miss}

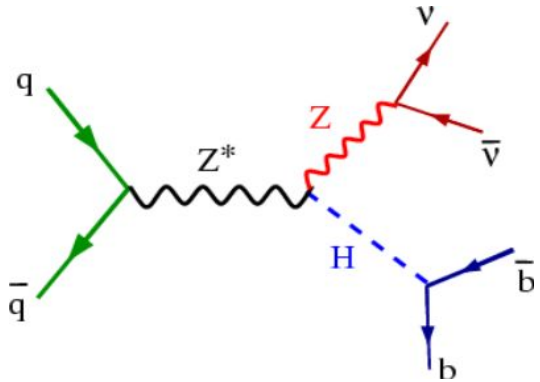


- Trigger: lepton

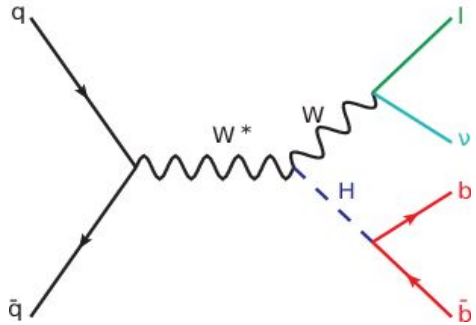
Event selection

Higgs decay product selection

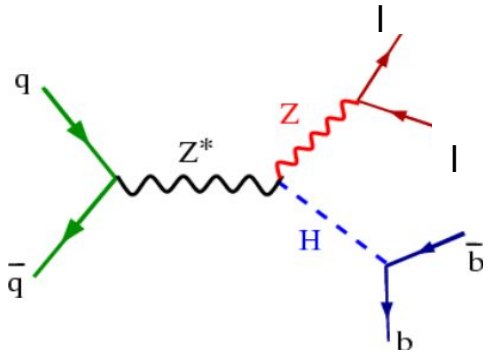
- 2 or 3 jets
- exactly two **b-jet**



- p_T^{miss} > 150 GeV
- 0 charged leptons
- Angular selections → reduce multijet background



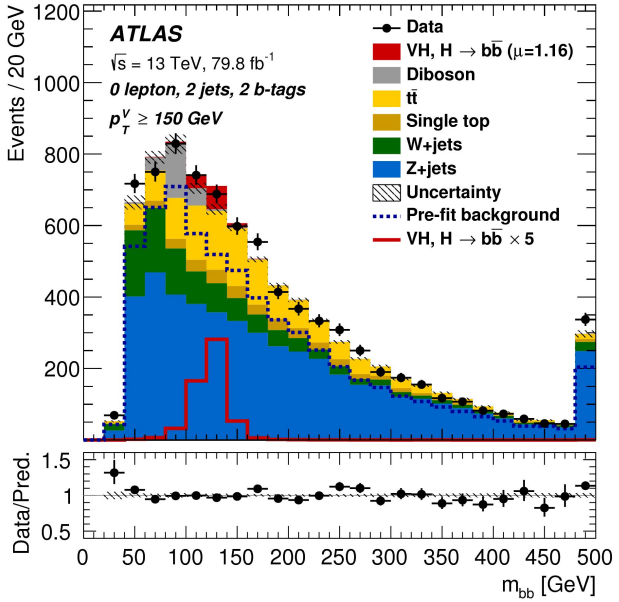
- p_T^{W} > 150 GeV
- Only 1 charged lepton



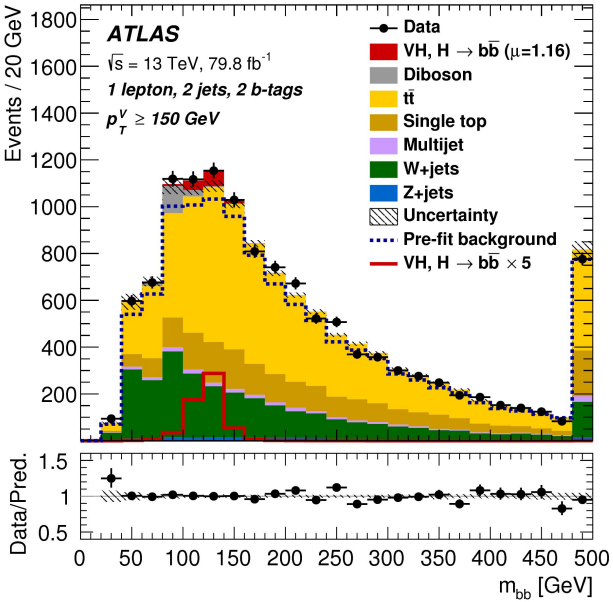
- p_T^{Z} > 75 GeV
- 2 charged leptons
- Z mass: 81 < m_{ll} < 101 GeV

Main backgrounds

- Data
- VH, H → bb̄
- Diboson
- tt̄
- Single top
- Multijet
- W+jets
- Z+jets
- Uncertainty



0 leptons



1 lepton

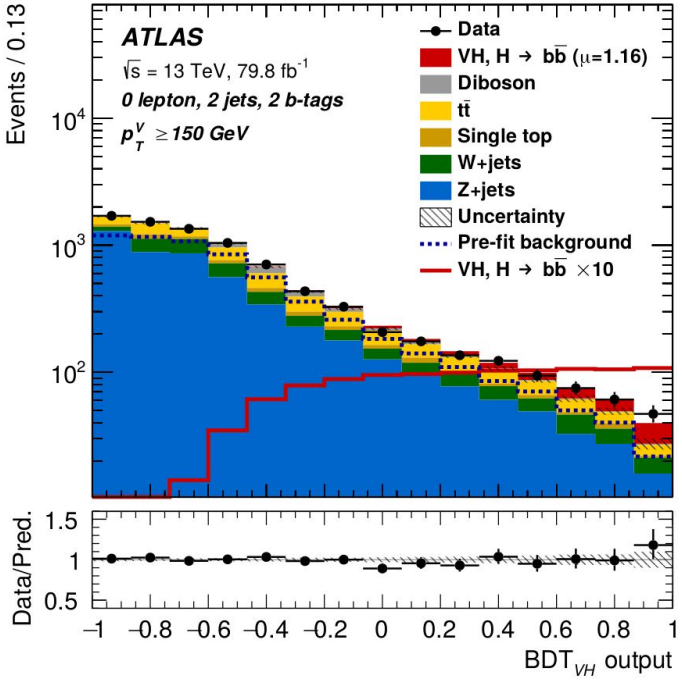
- **Z+heavy flavour**, **W+heavy flavour** → dedicated control region in 1-lep channel
- top (**ttbar** e **single-top**) → dedicated control region in 2-lep channel
- **Multijet** → suppressed with dedicated cuts, estimated with data-driven methods in 1-lep channel
- **WZ, ZZ** → final state similar to WH, estimated from simulation

Multivariate analysis

Variable	0-lepton	1-lepton	2-lepton
p_{T}^{V}	$\equiv E_{\mathrm{T}}^{\mathrm{miss}}$	×	×
$E_{\mathrm{T}}^{\mathrm{miss}}$	×	×	
$p_{\mathrm{T}}^{b_1}$	×	×	×
$p_{\mathrm{T}}^{b_2}$	×	×	×
m_{bb}	×	×	×
$\Delta R(\vec{b}_1, \vec{b}_2)$	×	×	×
$\lvert\Delta\eta(\vec{b}_1, \vec{b}_2)\rvert$	×		
$\Delta\phi(\vec{V}, \vec{bb})$	×	×	×
$\lvert\Delta\eta(\vec{V}, \vec{bb})\rvert$			×
m_{eff}	×		
$\min[\Delta\phi(\vec{\ell}, \vec{b})]$		×	
m_{T}^{W}		×	
$m_{\ell\ell}$			×
$E_{\mathrm{T}}^{\mathrm{miss}}/\sqrt{S_{\mathrm{T}}}$			×
m_{top}		×	
$\lvert\Delta Y(\vec{V}, \vec{bb})\rvert$		×	
	Only in 3-jet events		
$p_{\mathrm{T}}^{\mathrm{jet}_3}$	×	×	×
m_{bbj}	×	×	×

Boosted Decision Tree (BDT):

- Input: kinematic variables
- Output: BDT optimised in signal/background separation

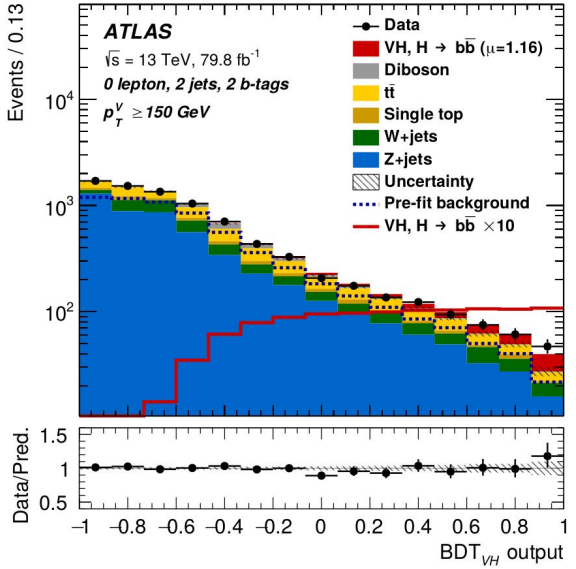


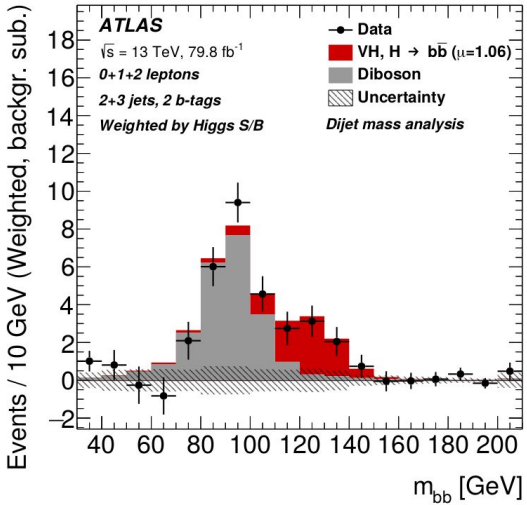
Multivariate analysis

Signal extracted using likelihood fit to data using **templates**.

Signal strength $\mu = \dfrac{\sigma_{\text{measured}}}{\sigma_{\text{expected(SM)}}}$

Systematic **uncertainties** (experimental and modelisation) described in the likelihood $\mathcal{L}(\mu, \theta)$ with **nuisance parameters Θ**

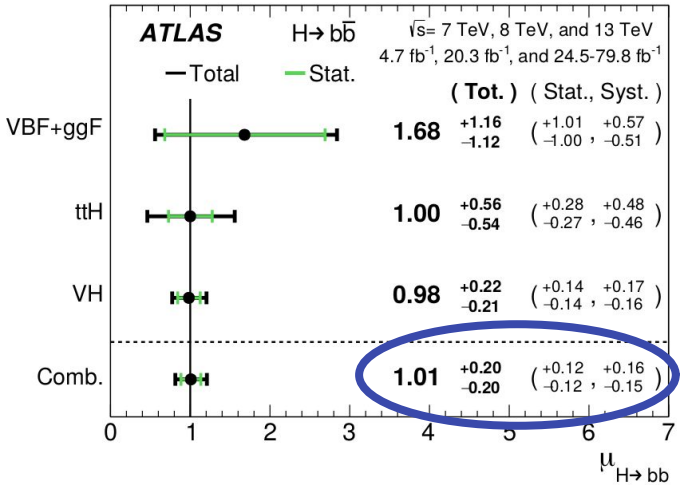




Cut-based selection to validate the multivariate analysis

80fb^{-1} - First H→bb observation!

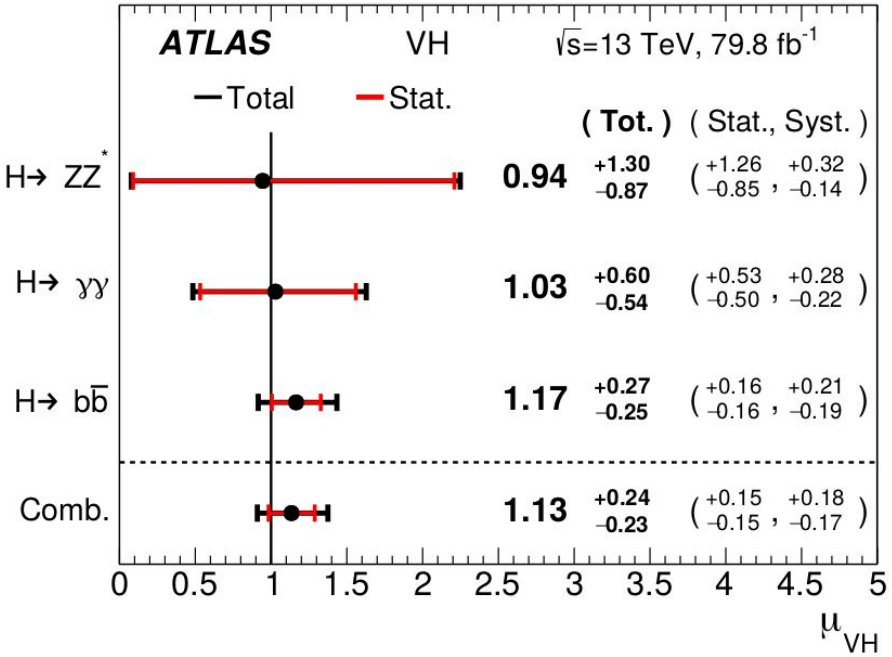
Signal strength	Signal strength	Significance	
		Exp.	Obs.
0-lepton	$1.04^{+0.34}_{-0.32}$	3.1	3.3
1-lepton	$1.09^{+0.46}_{-0.42}$	2.4	2.6
2-lepton	$1.38^{+0.46}_{-0.42}$	2.6	3.4
$VH, H \to b\bar{b}$ combination	$1.16^{+0.27}_{-0.25}$	4.3	4.9



Combination with other production channel. Observed significance: 5.4 σ (expected 5.5σ)

Observation of the VH production

Study of the VH **production** →**combination** with searches in other decay channels



Channel	Significance	
	Exp.	Obs.
$H \to ZZ^* \to 4\ell$	1.1	1.1
$H \to \gamma\gamma$	1.9	1.9
$H \to b\bar{b}$	4.3	4.9
VH combined	4.8	5.3

Main contribution from H→bb

What’s next?

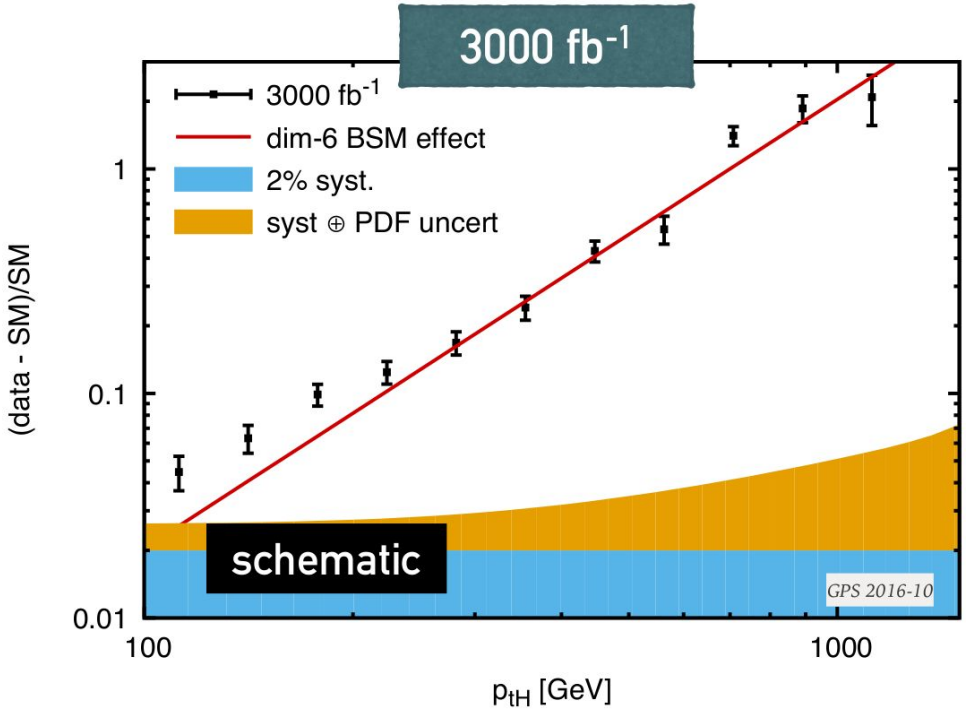
Beyond the standard model: effective field theories

$$\mathcal{L} = \mathcal{L}_{\mathrm{SM}} + \sum_i c_i^{(6)} O_i^{(6)} / \Lambda^2$$

Operator	Expression	HEL coefficient	Vertices
O_g	$\lvert H\rvert^2 G^A_{\mu\nu} G^{A\mu\nu}$	$\mathtt{cG} = \frac{m_W^2}{g_s^2}\bar{c}_g$	Hgg
O_γ	$\lvert H\rvert^2 B_{\mu\nu} B^{\mu\nu}$	$\mathtt{cA} = \frac{m_W^2}{g'^2}\bar{c}_\gamma$	$H\gamma\gamma, HZZ$
O_u	$y_u \lvert H\rvert^2 \bar{u}_l H u_R + \mathrm{h.c.}$	$\mathtt{cu} = v^2 \bar{c}_u$	$Ht\bar{t}$
O_{HW}	$i\left(D^\mu H\right)^\dagger \sigma^a \left(D^\nu H\right) W^a_{\mu\nu}$	$\mathtt{cHW} = \frac{m_W^2}{g}\bar{c}_{HW}$	HWW, HZZ
O_{HB}	$i\left(D^\mu H\right)^\dagger \left(D^\nu H\right) B_{\mu\nu}$	$\mathtt{cHB} = \frac{m_W^2}{g'^2}\bar{c}_{HB}$	HZZ
O_W	$i\left(H^\dagger \sigma^a D^\mu H\right) D^\nu W^a_{\mu\nu}$	$\mathtt{cWW} = \frac{m_W^2}{g}\bar{c}_W$	HWW, HZZ
O_B	$i\left(H^\dagger D^\mu H\right) \partial^\nu B_{\mu\nu}$	$\mathtt{cB} = \frac{m_W^2}{g'^2}\bar{c}_B$	HZZ

Physics beyond the standard model (e.g. new resonance) → possible deviations

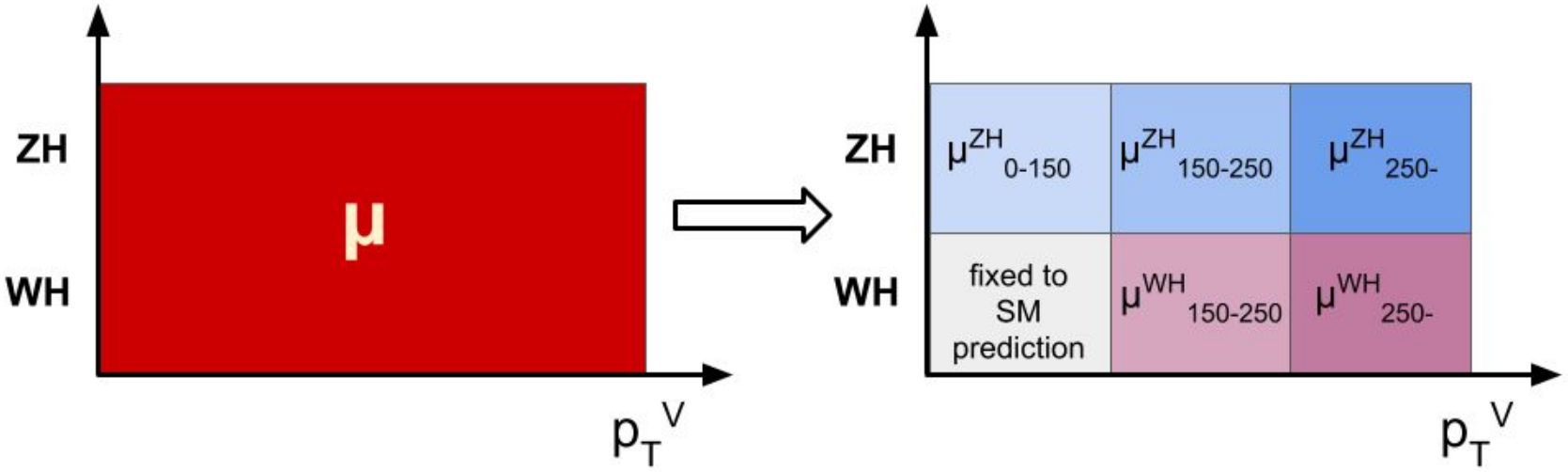
Higher deviations at high energies



- Design a new analysis optimized for BSM studies
- Exploit the current analysis and isolate possible BSM deviations

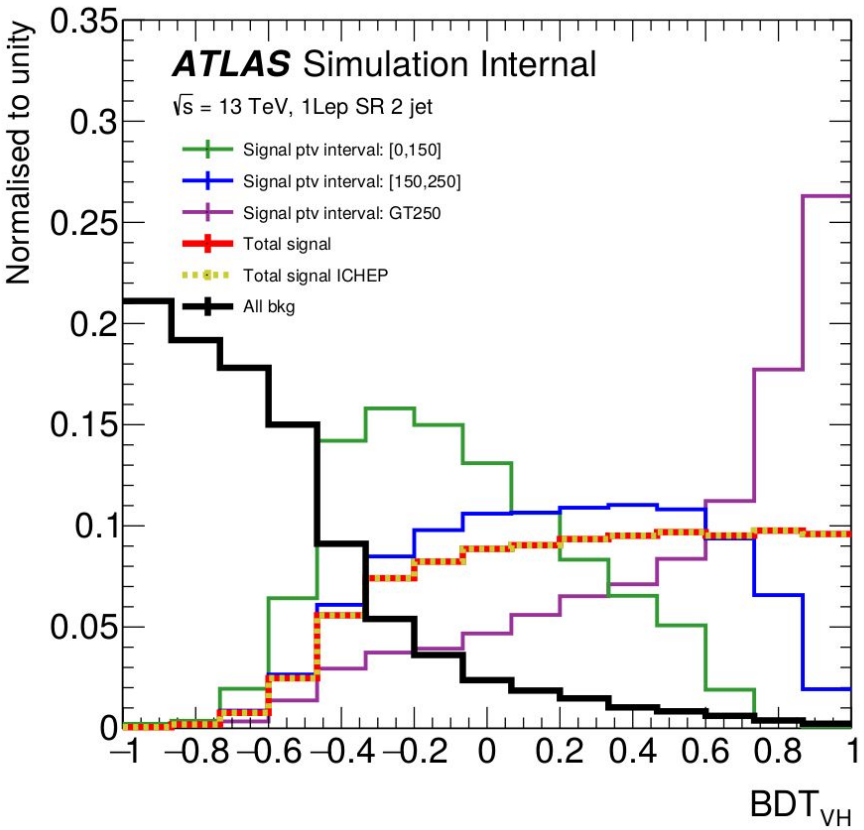
Simplified template cross sections (STXS)

- same event selection and background modelisation;
- splitted signal.

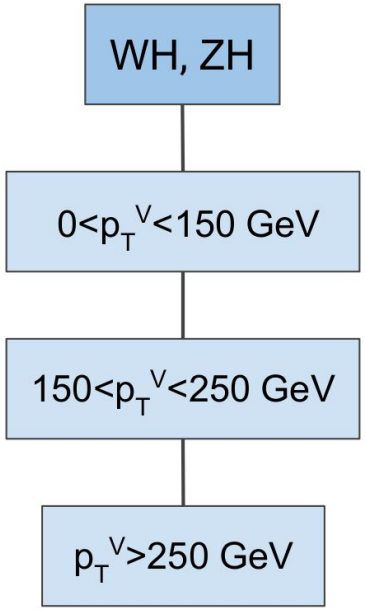


- isolate possible BSM effects
- easy combination with other decay channels.

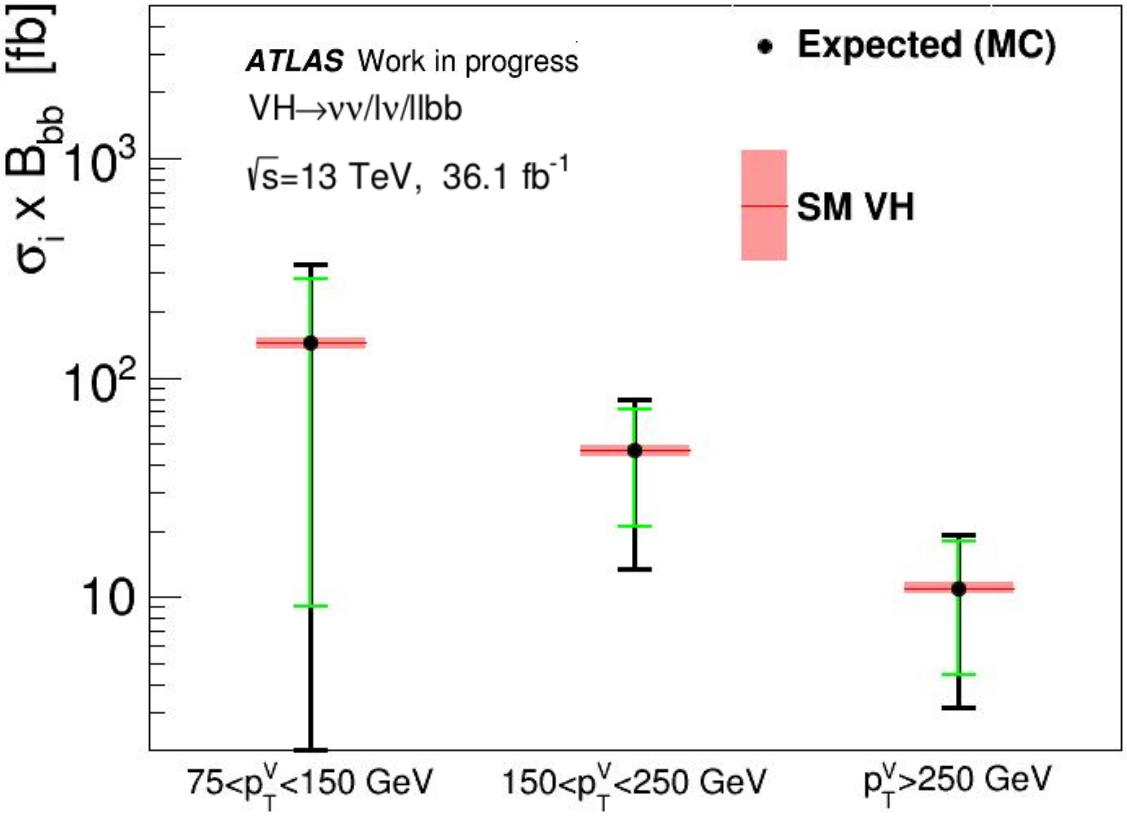
Studies on BDT shape



- Using the BDT shape it is possible to distinguish the different contributions



Preliminary studies, expected results



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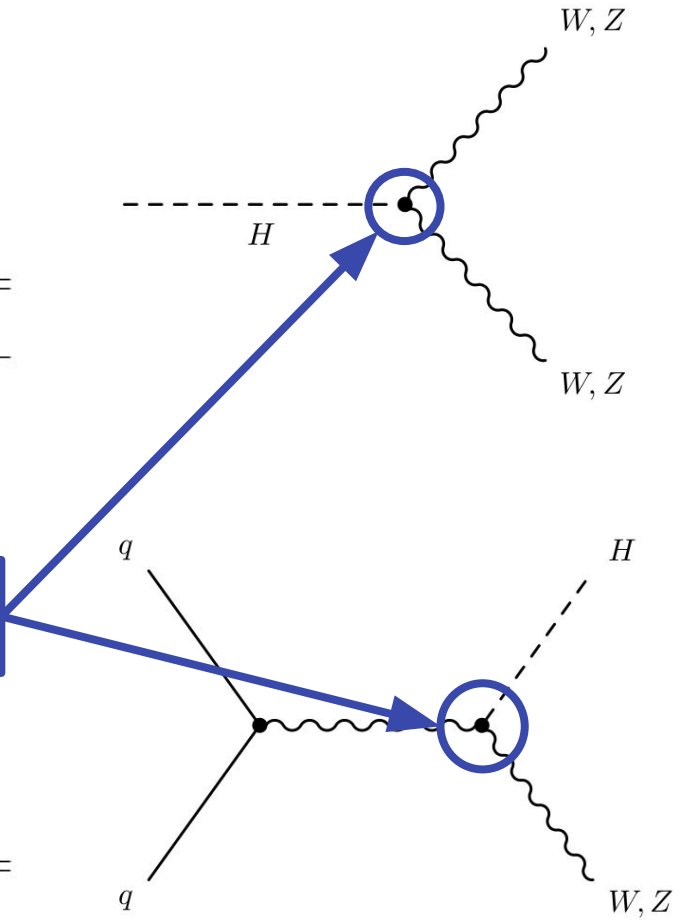
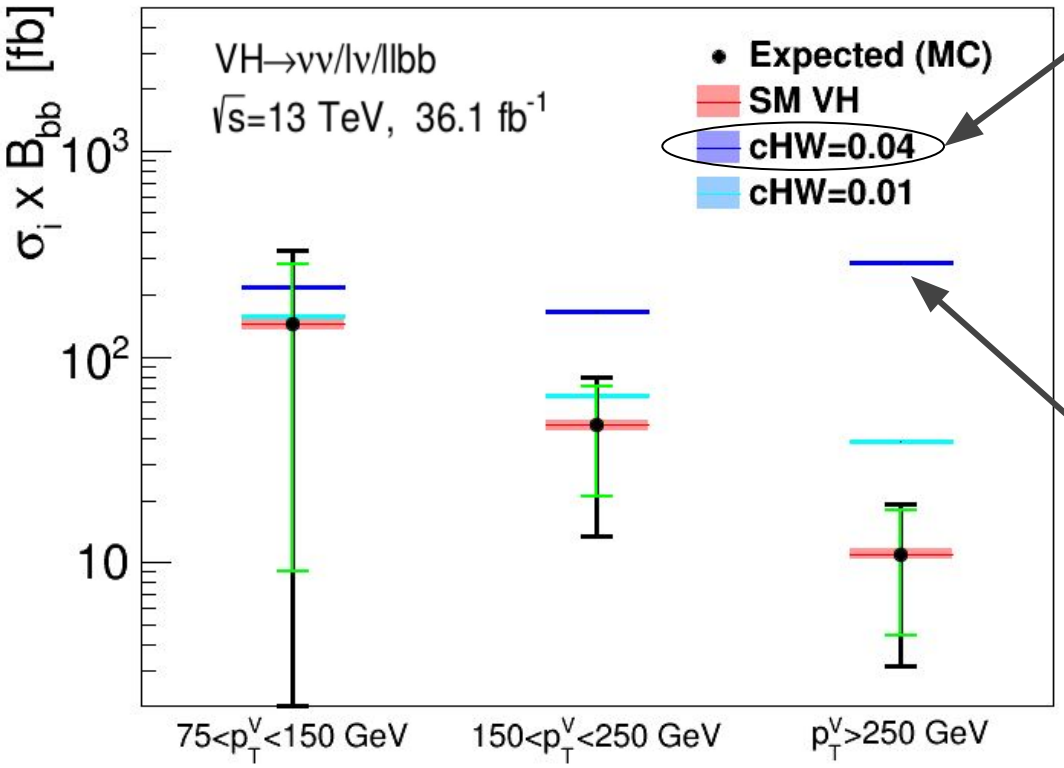


Beyond the standard model

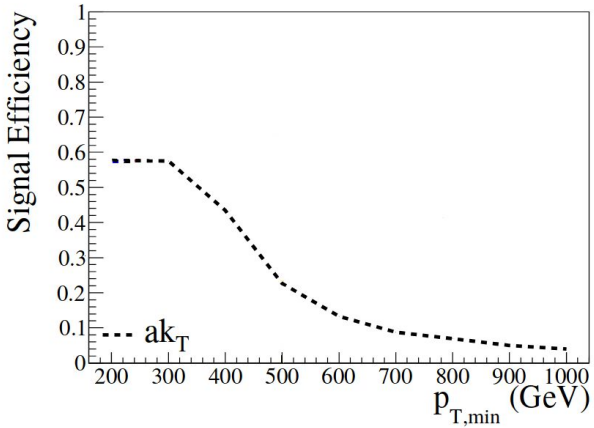


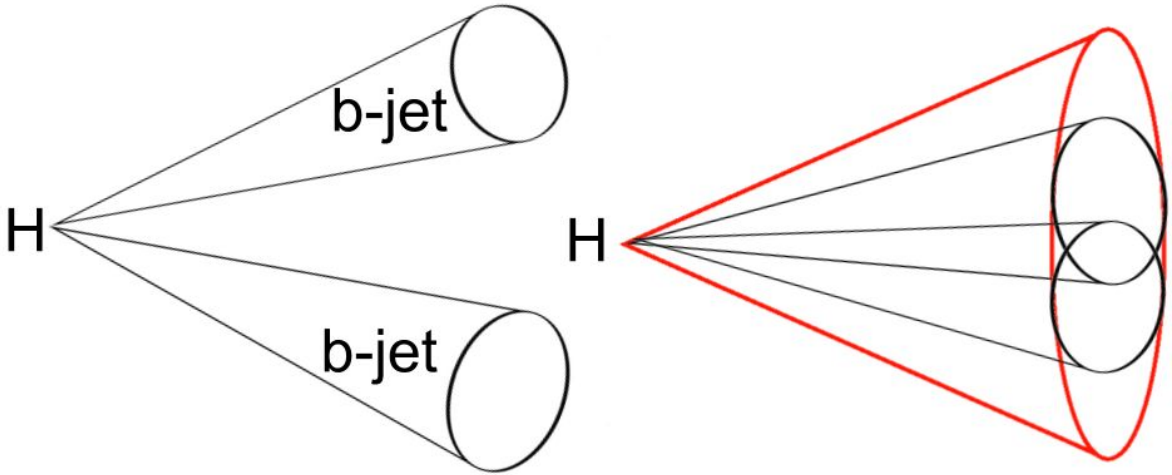
expected limit in ATLAS

Larger deviations at higher energies

High energy events

- currently working on 80 fb^{-1}; 120-150 fb^{-1} available at the end of this year, could add a very high energy bin
- Possibility to add a dedicated event selection for high energy events





Preliminary studies in 1 lepton channel S/√B ~ 1.8

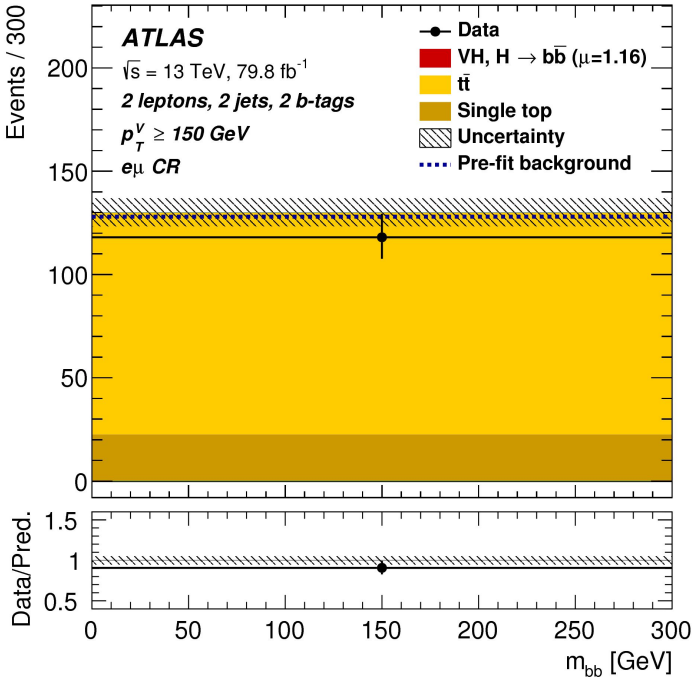
Conclusions

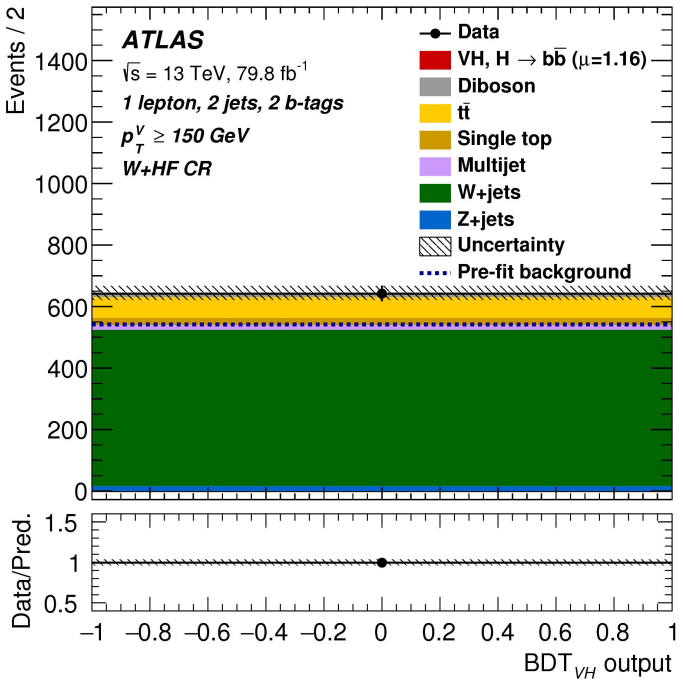
- *Recent observation of H→bb decay!*
- *Recent observation of VH production!*

- Exploit the current analysis to study BSM effects → STXS differential in p_T^V
- Improvements with 120-150 fb^{-1}?
- Future dedicated selection for high energy events

Backup

Control regions





top control region:
leptons with opposite flavour

W+HF control region:
m_{bb} < 75 GeV and m_{top} > 225 GeV