Recent boosted Higgs results with the CMS experiment

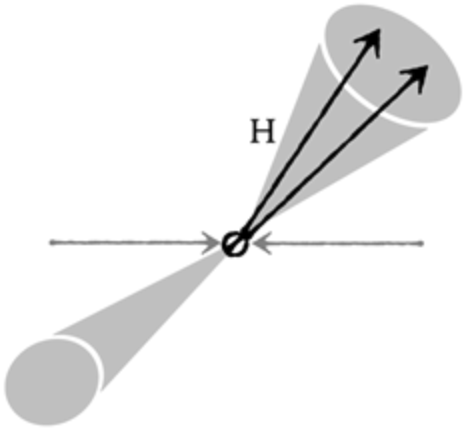
Cristina Mantilla Suarez (U. Virginia)

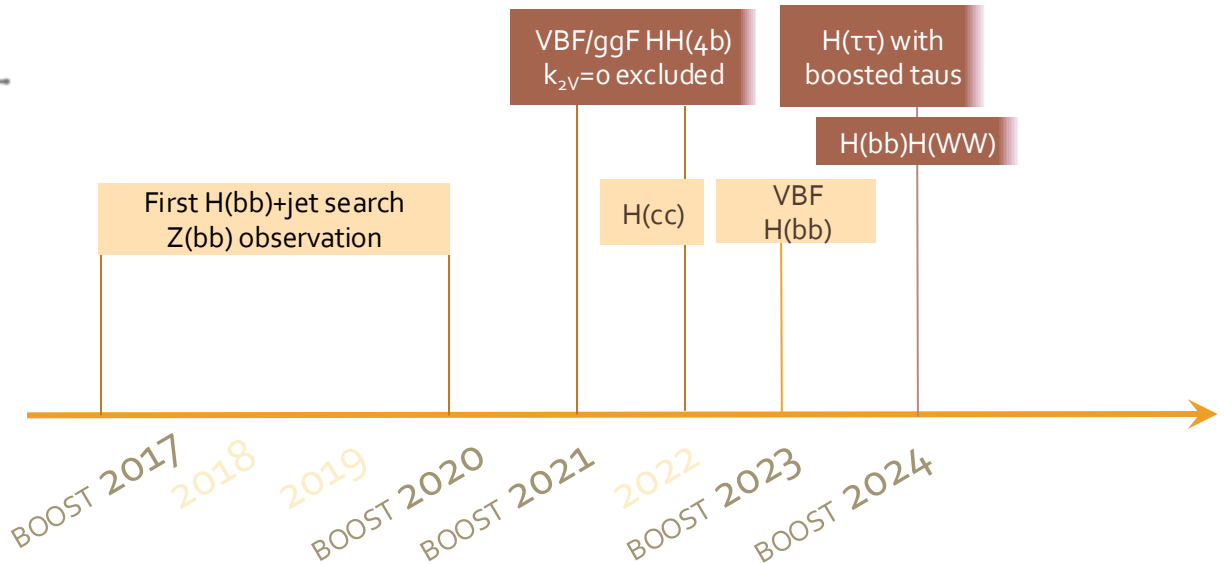
On behalf of the CMS collaboration

UNIVERSITY of VIRGINIA

July 30, 2025

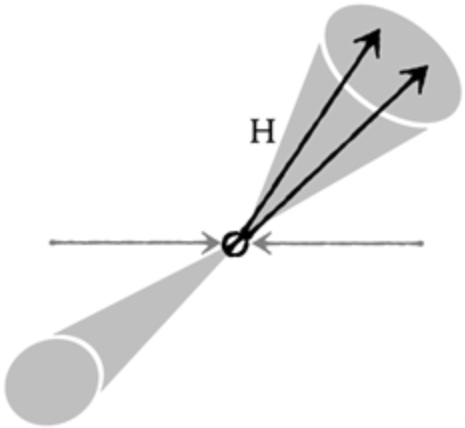
Boosted Higgs at *BOOST*

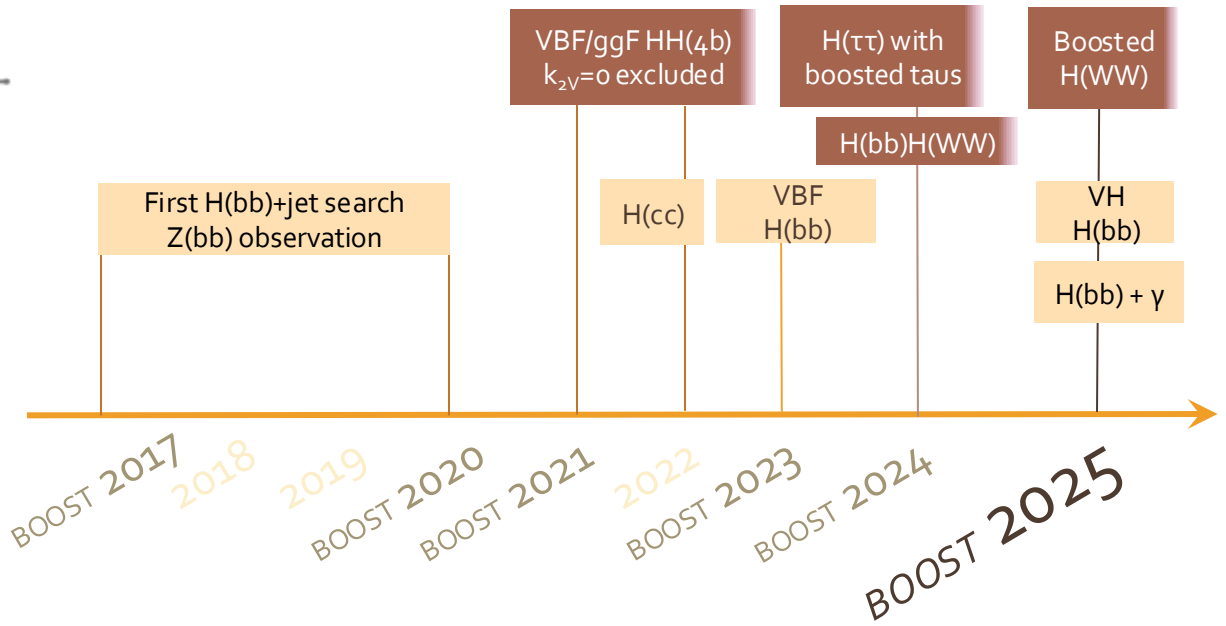




HIG-19-003, *JHEP 12 (2020) 085*
B2G-21-001/22-003, Phys. Rev. Lett. 131 (2023) 041803
HIG-21-020, JHEP 12 (2024) 035
HIG-21-012, Phys. Rev. Lett. 131 (2023) 041801
HIG-21-017, Phys. Lett. B 857 (2024) 138964

Boosted Higgs at *BOOST* (results for this talk)

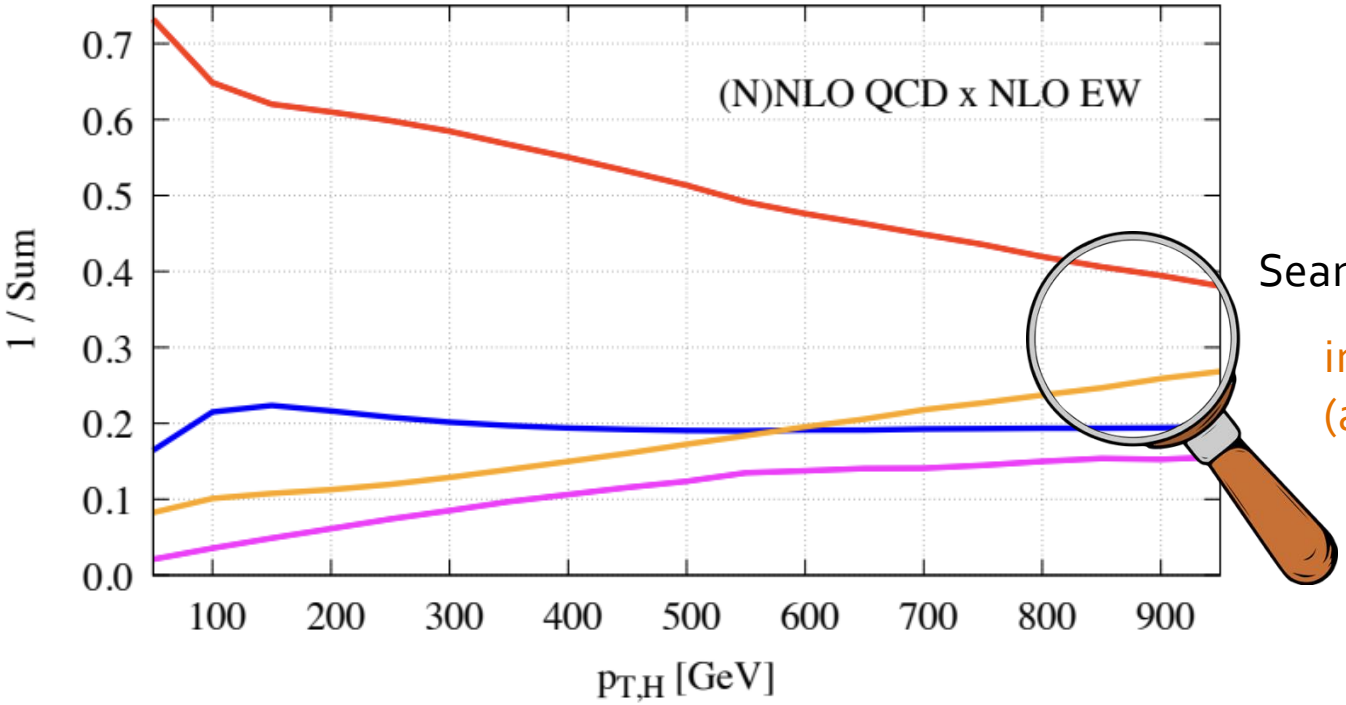




HIG-23-011, HIG-23-011-PAS
HIG-24-008, *HIG-24-008-PAS*
HIG-24-017, *HIG-24-017-PAS*

Why measure Higgs at high p_T ?

arXiv:2105.11399

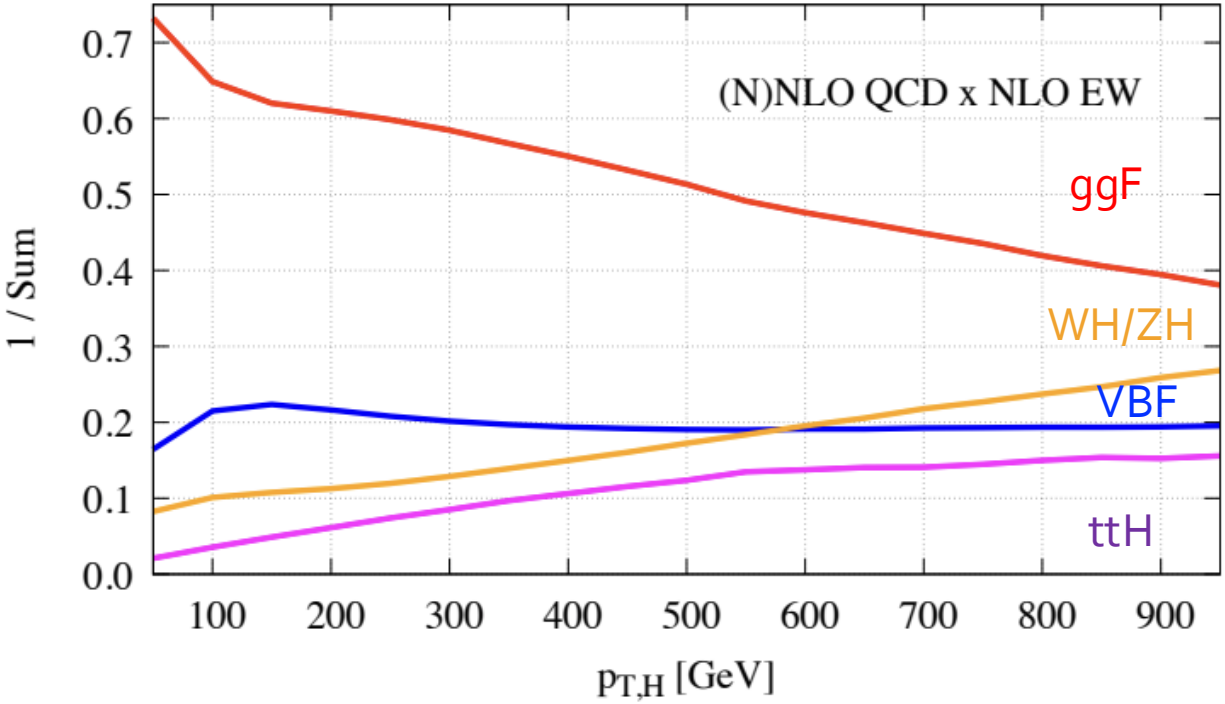


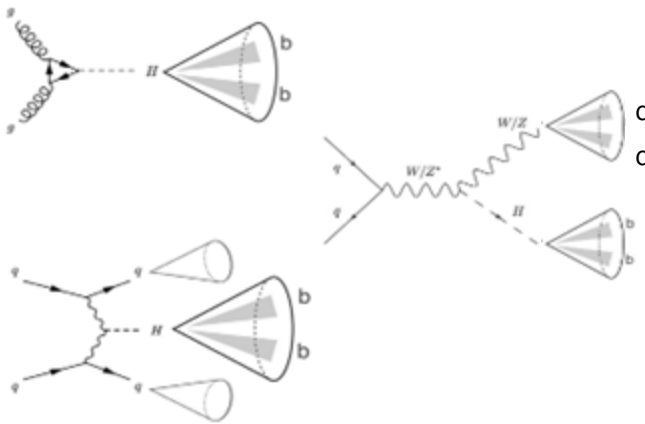
Search for a rare SM process

in a regime sensitive to BSM (anomalous couplings)

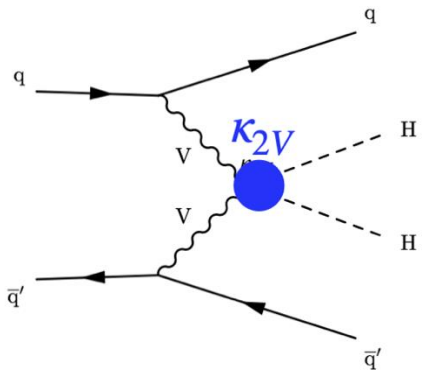
Single Higgs production: all production modes contribute!

arXiv:2105.11399

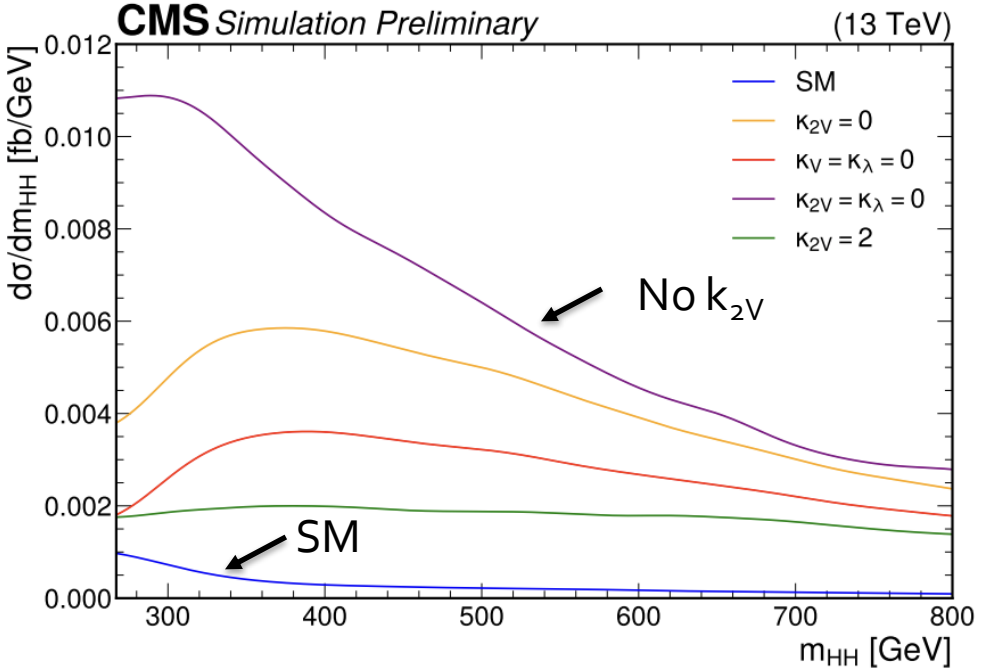




Double Higgs production: sensitivity to new couplings unlocked

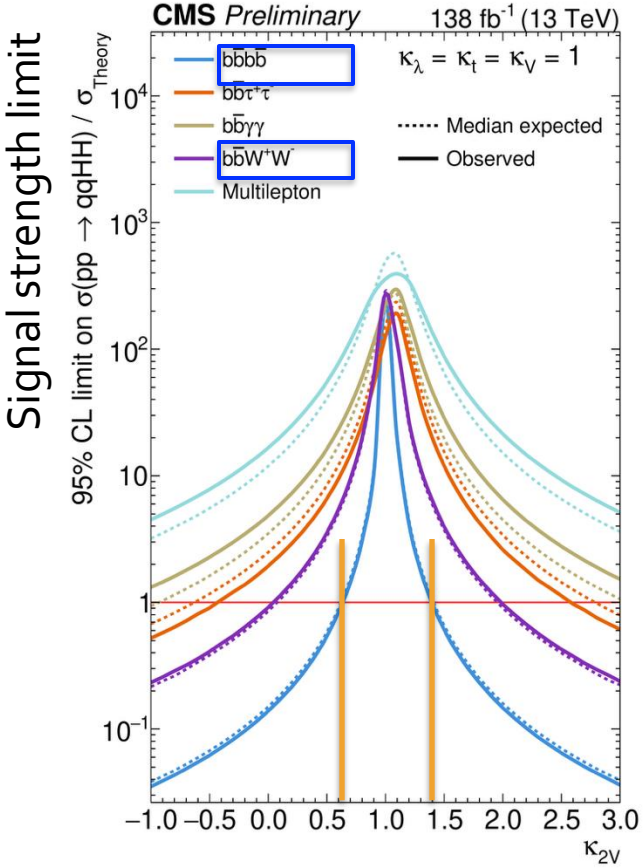


Low H momentum



High H momentum

Boosted H(bb)H(bb) and H(bb)H(WW → 4q): best sensitivity to k_{2V}



HIG-20-011

Experimental view of hadronic Higgs at *BOOST*

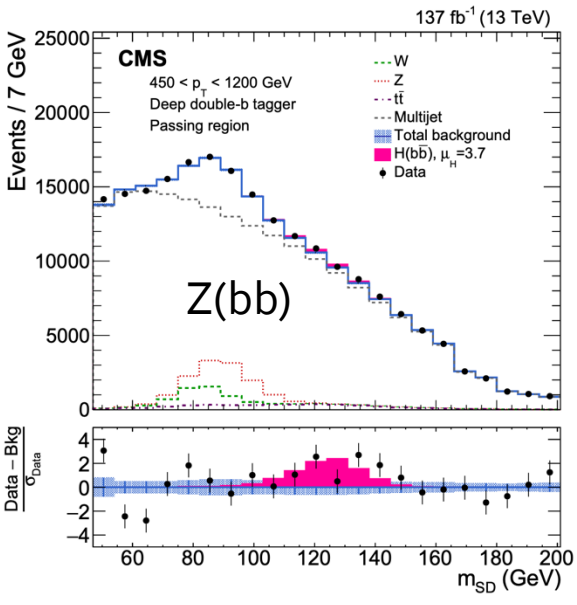
1 BIG advantage:

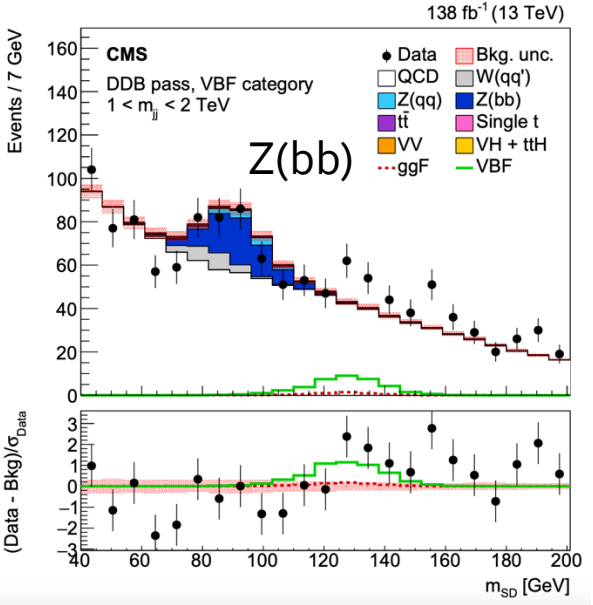
- **BOOST!:** Exponentially falling background with p_T, increased jet tagging efficiency

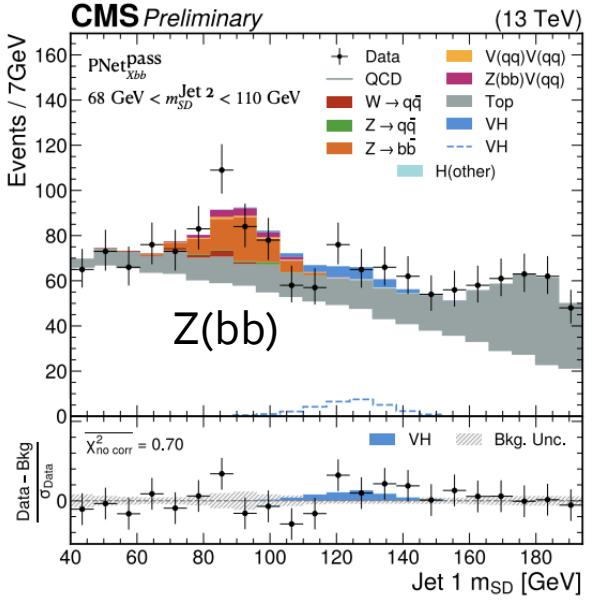
3 challenges:

- **Trigger:** Restricts lower bound on H p_T (Run-2)
- **Background:**
  - Still large …
  - Still hard to model … e.g. data-driven prediction for QCD

Evolution of Higgs(bb) at high p_T







ggF: 1.2 $(0.9\ \sigma)$
JHEP 12 (2020) 085

VBF: 3.0 $(0.9\ \sigma)$
JHEP 12 (2024) 035

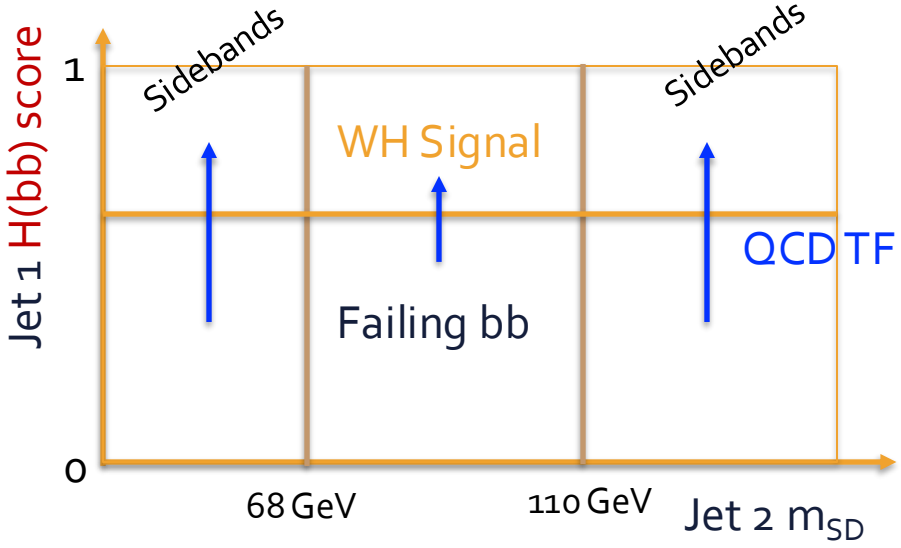
VH: 1.0 $(1.6\ \sigma)$
HIG-24-017

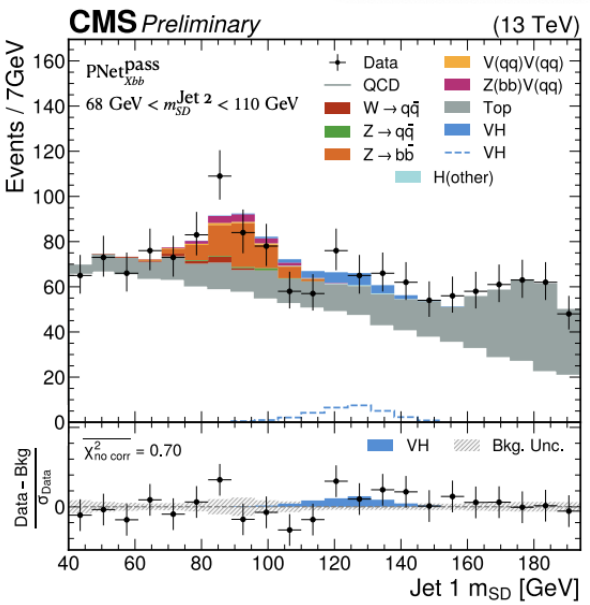
NEW for *BOOST*!

Associated production of H(bb) with **W(qq)/Z(qq)**

Jet 1 ⟶ H-candidate bb-tagged
QCD from parametric fit

$$PN^{MD}_{BBvsQQ} = \frac{PN^{MD}_{Xbb}}{PN^{MD}_{Xbb} + PN^{MD}_{Xcc} + PN^{MD}_{Xqq}}$$

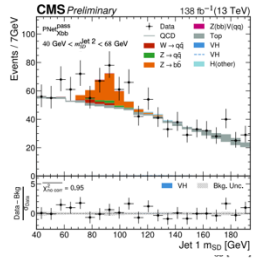


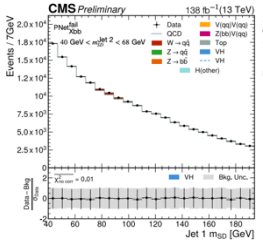


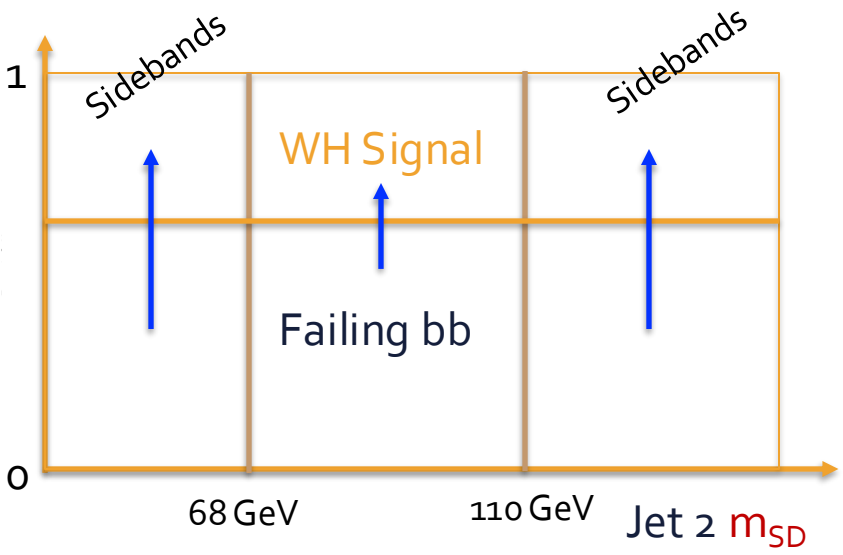
Associated production of H(bb) with **W(qq)/Z(qq)**

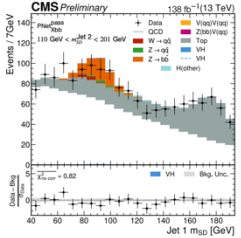
Jet 2 ⟶ W/Z-candidate bb-tagged

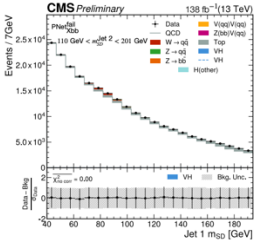
$$PN^{MD}_{QCD} = 1 - (PN^{MD}_{Xbb} + PN^{MD}_{Xcc} + PN^{MD}_{Xqq})$$
$$= 1 - PN^{MD}_{\text{2-prong}}$$







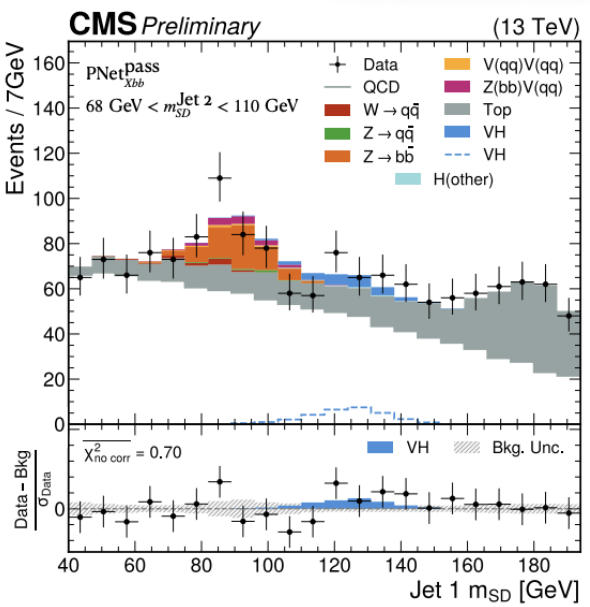




Associated production of H(bb) with **W(qq)/Z(qq)**

	$\mathcal{L}$ [fb^{-1}]	VH signal strength	VZ signal strength
Early 2016	19.5	$1.02^{+2.52}_{-2.23}$	$-0.15^{+1.77}_{-1.77}$
Late 2016	16.8	$1.34^{+2.20}_{-1.87}$	$-0.83^{+1.53}_{-1.53}$
2017	41.5	$0.00^{+1.26}_{-1.18}$	$1.20^{+1.28}_{-1.28}$
2018	59.8	$1.04^{+1.22}_{-1.10}$	$-0.40^{+0.92}_{-0.92}$
Combined	138	$0.72^{+0.75}_{-0.71}$	$0.09^{+0.63}_{-0.63}$
		$(1.64\ \sigma)$	$(1.76\ \sigma)$

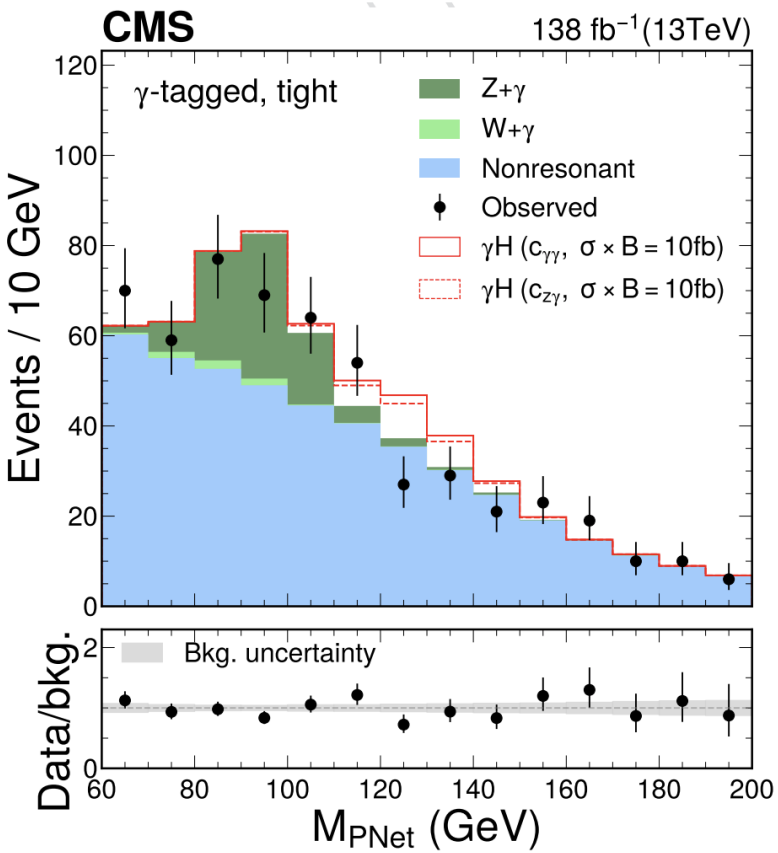
Comparable VZ/VH sensitivity: these processes will become standard candles



VH: 1.0 $(1.6\ \sigma)$

HIG-24-017

Associated production of H(bb) with **a photon**



H+ γ: σ< 15.7 fb
SM cross section extremely low
and **γ p_T peaks at 1 GeV**
HIG-23-011

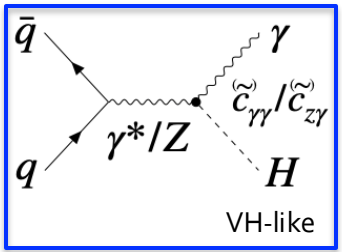
NEW for *BOOST*!

H(bb)+ γ: γ p_T > 300 GeV
H(4l)+ γ: γ p_T > 150 GeV

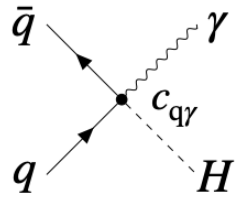
While SM sensitivity is poor, this region is the same H(bb)+Jet: may use both regions for calibration!

Associated production of H(bb) with **a photon**

Non-Zero Wilson coefficients greatly enhance this interaction (**γ p_T peaks at 50 GeV**):



VH-like



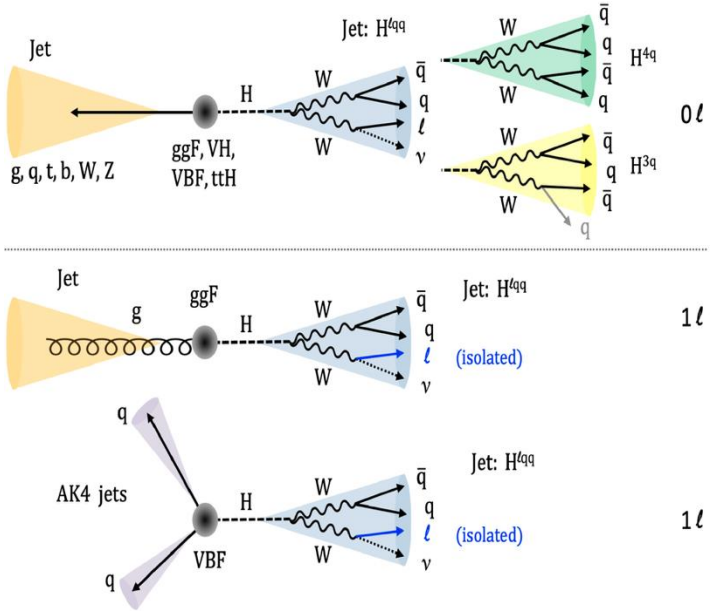
Well-constrained by EW data (DY processes)

Parameter	Scenario	Observed		Expected	
		68% CL	95% CL	68% CL	95% CL
$\sigma_{\gamma H}$ (fb)	$c_{z\gamma} = \tilde{c}_{z\gamma} = 0$	$-7.5^{+8.9}_{-8.8}$	<11.8	$0.0^{+6.3}_{-6.3}$	<16.1
$\sigma_{\gamma H}$ (fb)	float all	$-9.3^{+11.3}_{-11.2}$	<16.4	$0.0^{+8.0}_{-8.0}$	<21.5
$\sigma_{\gamma H}\,\mathcal{B}_{b\bar{b}}$ (fb)	float all	$-5.4^{+6.5}_{-6.5}$	<9.5	$0.0^{+4.6}_{-4.6}$	<12.4
$\sigma_{\gamma H}\,\mathcal{B}_{4\ell}$ (fb)	float all	$0.09^{+0.32}_{-0.10}$	<0.52	$0.00^{+0.18}_{-0.00}$	<0.38
$c_{\gamma\gamma}$	float all	0.00 ± 0.50	$[-0.84, 0.84]$	0.00 ± 0.63	$[-0.90, 0.90]$
$c_{\gamma\gamma}$	fix others	0.00 ± 0.46	$[-0.77, 0.77]$	0.00 ± 0.58	$[-0.83, 0.83]$
$c_{z\gamma}$	float all	0.00 ± 0.18	$[-0.30, 0.30]$	0.00 ± 0.22	$[-0.32, 0.32]$
$c_{z\gamma}$	fix others	0.00 ± 0.16	$[-0.27, 0.27]$	0.00 ± 0.21	$[-0.29, 0.29]$
$\tilde{c}_{\gamma\gamma}$	float all	0.00 ± 0.50	$[-0.84, 0.84]$	0.00 ± 0.63	$[-0.90, 0.90]$
$\tilde{c}_{\gamma\gamma}$	fix others	0.00 ± 0.46	$[-0.77, 0.77]$	0.00 ± 0.58	$[-0.83, 0.83]$
$\tilde{c}_{z\gamma}$	float all	0.00 ± 0.18	$[-0.30, 0.30]$	0.00 ± 0.22	$[-0.32, 0.32]$
$\tilde{c}_{z\gamma}$	fix others	0.00 ± 0.16	$[-0.27, 0.27]$	0.00 ± 0.21	$[-0.29, 0.29]$

Same region (4l channel) can be used to set constraints on light quark couplings:

$$\kappa_u = (0.0 \pm 1.5) \times 10^3$$
$$\kappa_d = (0.0 \pm 7.1) \times 10^2$$
$$\kappa_s = 0^{+33}_{-34}$$
$$\kappa_c = 0.0^{+2.7}_{-3.0}$$

First search for boosted H(WW)



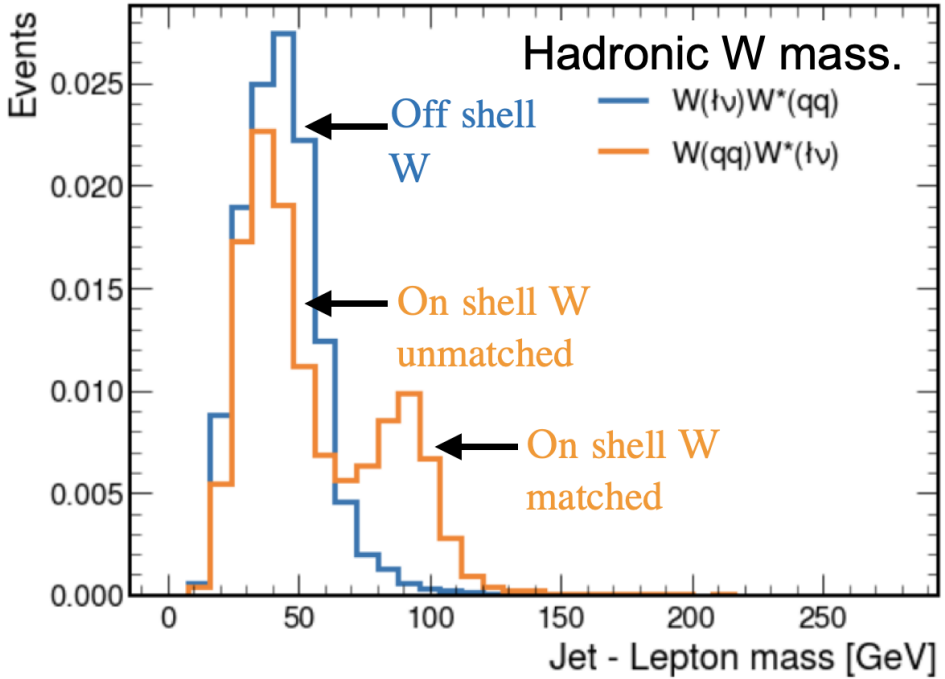
HIG-24-008

NEW for *BOOST*!

Single H(WW) jet, p_T > 250 GeV tagged with GloParT

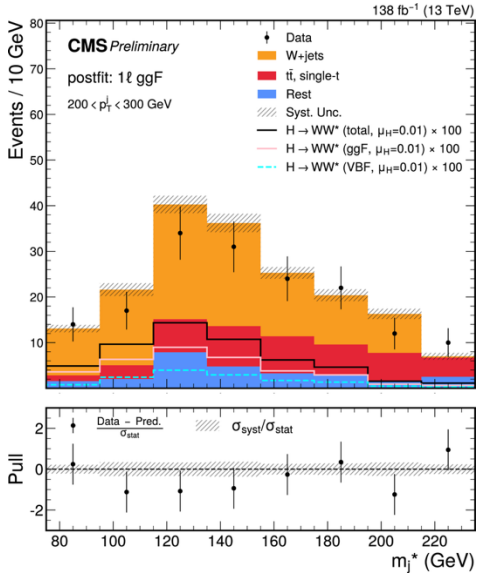
- Assume all/nearly-all decay products are reconstructed inside the jet
  - Results in different "classes" H^{3q}, H^{4q}
- Lepton "mini-isolation" splits analysis categories: 0l and 1l
  - "0l" still has a H^{lqq} component

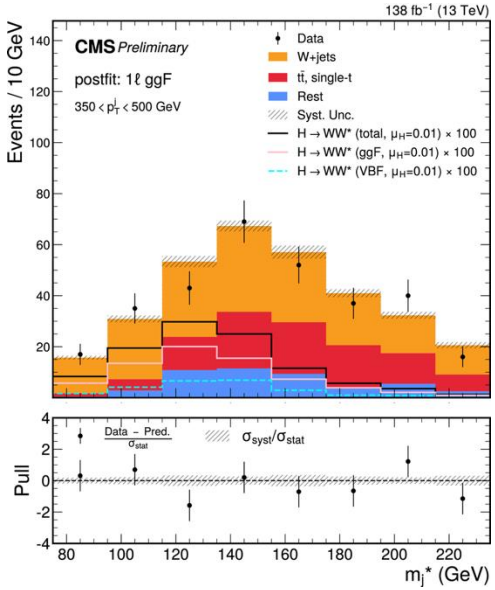
1l strategy: selection bias toward H →W(lν)W*(qq)

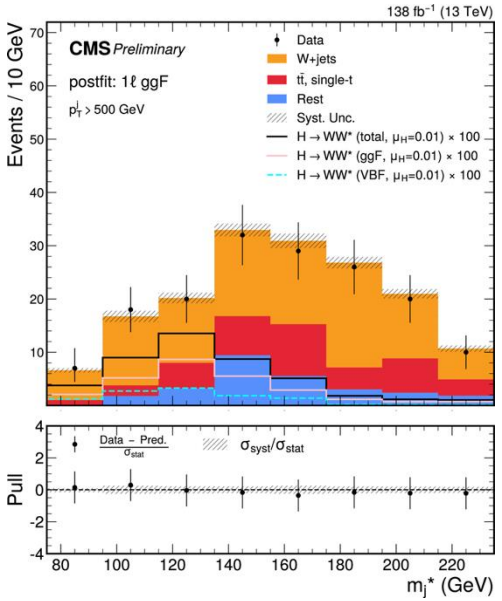


- Trigger dominated by non-isolated muon/electron triggers results in high p_T leptons p_T>50/110 GeV

1l strategy: fine-tuning ParT for dedicated background discrimination







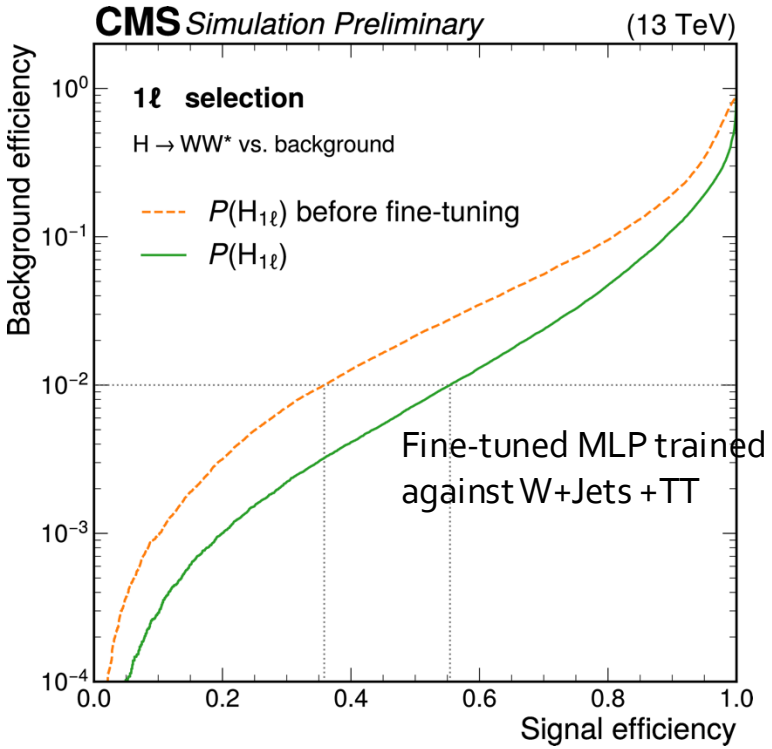
Increasing H p_T

- Very broad mass distribution mj* : Jet+MET collinear approximation.
- Dominated by W+Jets and TT backgrounds => somewhat reliable simulation.

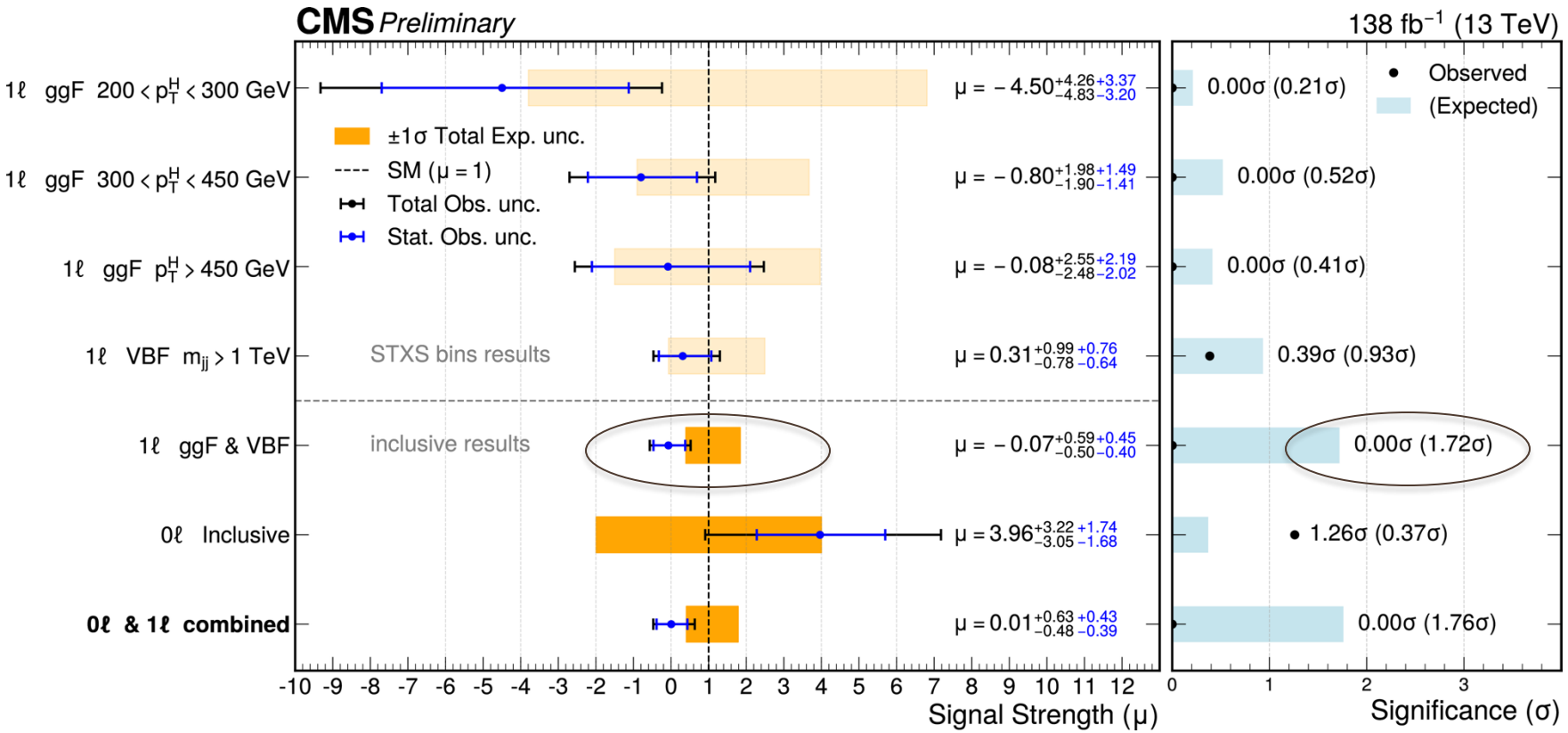
1l strategy: fine-tuning ParT for dedicated background discrimination

- Fine-tuned ParT: Use *output of the last hidden layer of ParT* to train W+Jets discriminator.

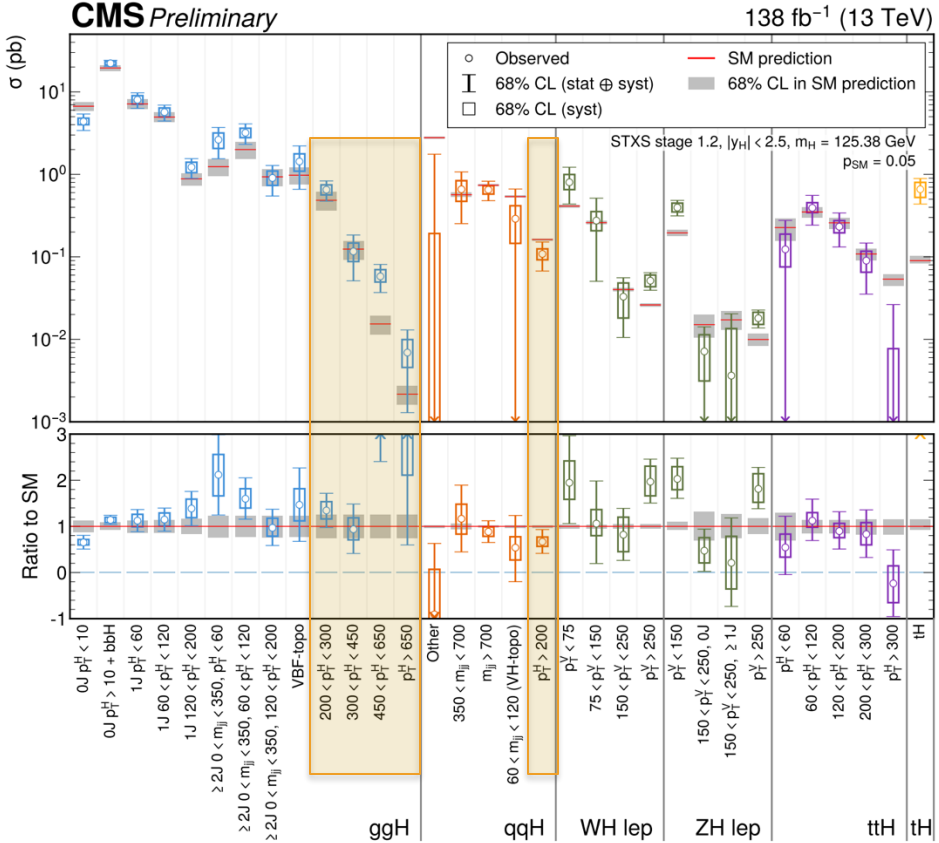
- Tagger calibration uses per-subjet correction **"Lund jet plane reweighting"** (shown at BOOST 2023!)
  - Lepton is subtracted from jet before re-clustering.
  - Use TT region to validate.
  - Asymmetric uncertainty (up to 30%) dominates the measurement: related to "unclustered" component.



Sensitivity dominated by H^{lqq}



Towards an STXS measurement



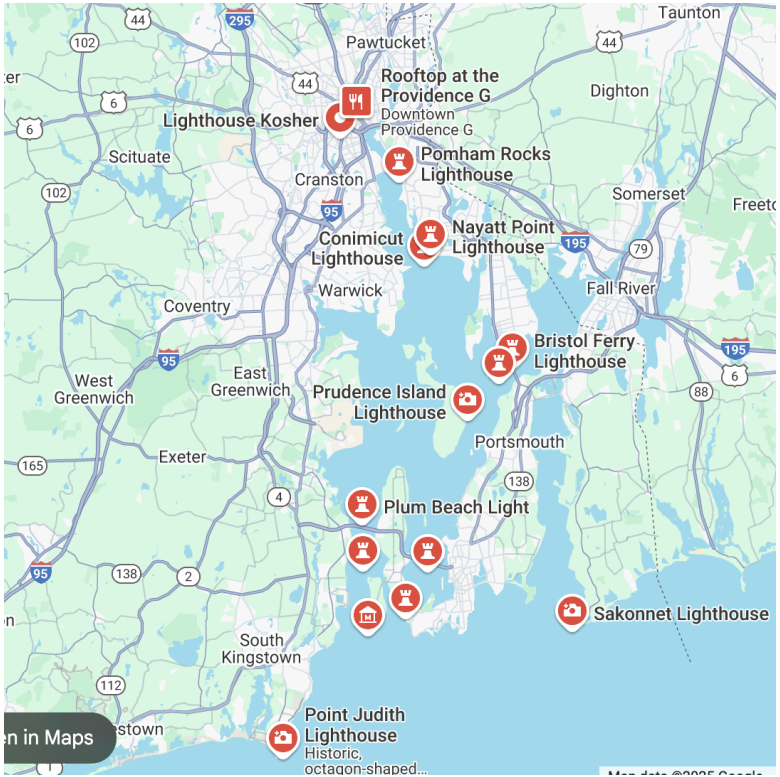
	$H \to b\bar{b}$	$H \to \tau\bar{\tau}$	$H \to WW$	$H \to cc$
ggH	$(0.9\,\sigma)$	$(2.2\,\sigma)$	$(0.7\,\sigma)$	39 ×SM
VBF	$(0.9\,\sigma)$		$(1.0\,\sigma)$	
VH	$(1.6\,\sigma)$			
ttH				

End goals: Measure H p_T distribution
Search for anomalous couplings
Constrain HH?

Run-2 got us very close, promising prospects with Run-3 data**!**

Thanks!

What should you do on Thursday/Weekend?



https://en.wikipedia.org/wiki/List_of_lighthouses_in_Rhode_Island