Effective Field Theory Results from Higgs (and beyond) by ATLAS and CMS

Marco Battaglia

UNIVERSITY OF CALIFORNIA SANTA CRUZ

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Effective Field Theories, the Higgs Sector …

Leading effects of many BSM scenarios can be parametrized through operators of effective field theories (EFTs), with effects suppressed by new physics scale Λ corresponding to new particle masses;

Higgs measurements bring sensitivity from interplay of tree and loop-mediated couplings involving 3rd generation quarks and leptons, gluons and gauge bosons;

… and beyond

EFTs have become a standard tool allowing study of large experimental data sets, correlating Higgs, top and EW sectors probing same operators, without assuming underlying theory to be valid to arbitrarily high energies;

Interpretations of EFT results brings some caveats since effects of dim>6 operators are not precisely known and EFT validity is restricted within that of decoupling theorem where heavy fields decouple at low momenta.

Very active area for both extraction of new experimental results and their interpretation by theorists (JHEP06 (2018) 146, arXiv:2105.00006, …) and experimental collaborations;

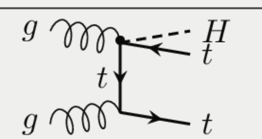
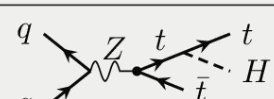
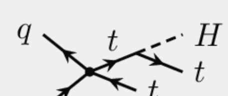
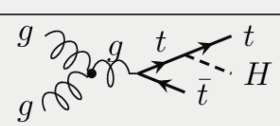
This talk reviews recent Higgs physics results relevant to studies in EFT framework and related EFT interpretation performed by ATLAS and CMS collaborations with a view on focusing on open problems and highlighting interplay with non-Higgs physics.

SMEFT and Dim-6 EFT Operators relevant to Higgs physics

If New Physics degrees of freedom can be integrated out, Higgs is SM-like and New Physics can manifest itself through higher-dimension effective interactions between SM fields;

Scale-dependent Wilson coefficients $C_i(Q^2)$ encode New Physics deviations from SM and can be probed by experimental measurements:

$$\mathcal{L}_{\rm Eff} = \mathcal{L}_{\rm SM} + \sum_i \frac{C_i^{(6)} O_i^{(6)}}{\Lambda^2} + \mathcal{O}(\Lambda^{-4})$$

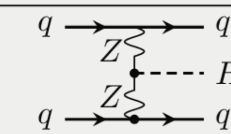
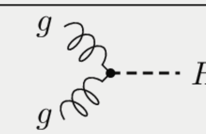
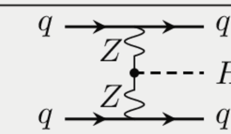
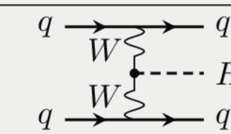
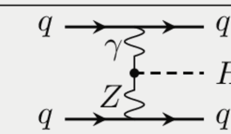
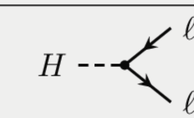
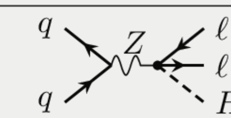
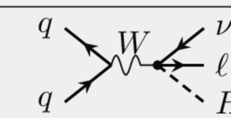
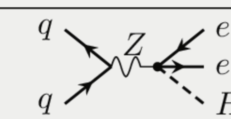
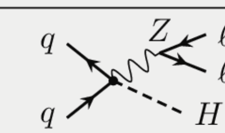
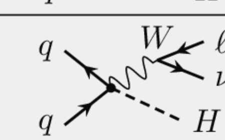
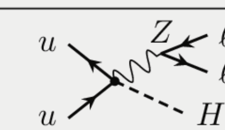
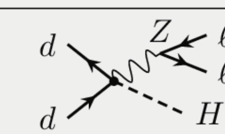
Coefficient	Operator	Example process
c_{uG}	$(\bar q_p \sigma^{\mu\nu} T^A u_r)\widetilde{H}\, G^A_{\mu\nu}$	
c_{uW}	$(\bar q_p \sigma^{\mu\nu} u_r)\tau^I \widetilde{H}\, W^I_{\mu\nu}$	
c_{uB}	$(\bar q_p \sigma^{\mu\nu} u_r)\widetilde{H}\, B_{\mu\nu}$	
$c^{(1)}_{qq}$	$(\bar q_p \gamma_\mu q_t)(\bar q_r \gamma^\mu q_s)$	
$c^{(3)}_{qq}$	$(\bar q_p \gamma_\mu \tau^I q_r)(\bar q_s \gamma^\mu \tau^I q_t)$	
c_{qq}	$(\bar q_p \gamma_\mu q_t)(\bar q_r \gamma^\mu q_s)$	
$c^{(31)}_{qq}$	$(\bar q_p \gamma_\mu \tau^I q_t)(\bar q_r \gamma^\mu \tau^I q_s)$	
c_{uu}	$(\bar u_p \gamma_\mu u_r)(\bar u_s \gamma^\mu u_t)$	
$c^{(1)}_{uu}$	$(\bar u_p \gamma_\mu u_t)(\bar u_r \gamma^\mu u_s)$	
$c^{(1)}_{qu}$	$(\bar q_p \gamma_\mu q_t)(\bar u_r \gamma^\mu u_s)$	
$c^{(8)}_{ud}$	$(\bar u_p \gamma_\mu T^A u_r)(\bar d_s \gamma^\mu T^A d_t)$	
$c^{(8)}_{qu}$	$(\bar q_p \gamma_\mu T^A q_r)(\bar u_s \gamma^\mu T^A u_t)$	
$c^{(8)}_{qd}$	$(\bar q_p \gamma_\mu T^A q_r)(\bar d_s \gamma^\mu T^A d_t)$	
c_G	$f^{ABC} G^{A\nu}_\mu G^{B\rho}_\nu G^{C\mu}_\rho$	

EFT with SM fields including SM Higgs doublet defines commonly used SMEFT (but see caveats in Tim Cohen's talk);

SM dim-2 and dim-4 interactions + higher dimensional interactions between allowed combinations of SM fields;

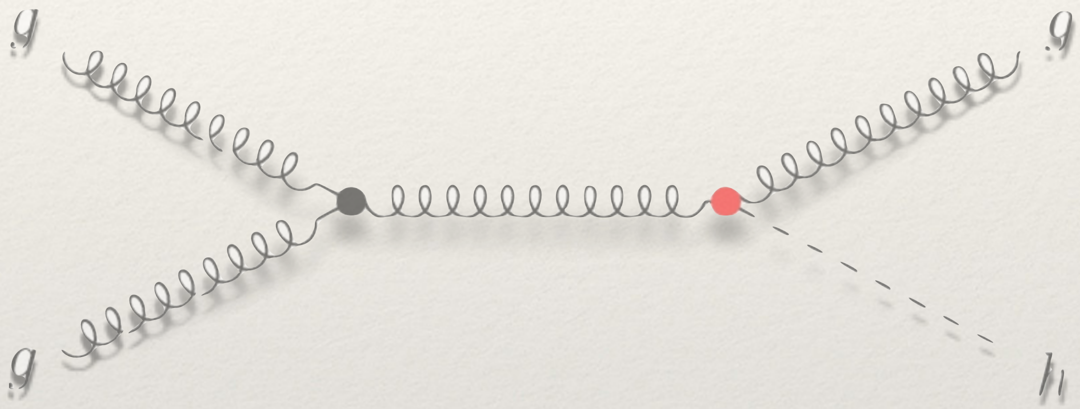
Non-redundant basis of operators defined by Warsaw basis generally used in extraction of experimental constraints by ATLAS and CMS:

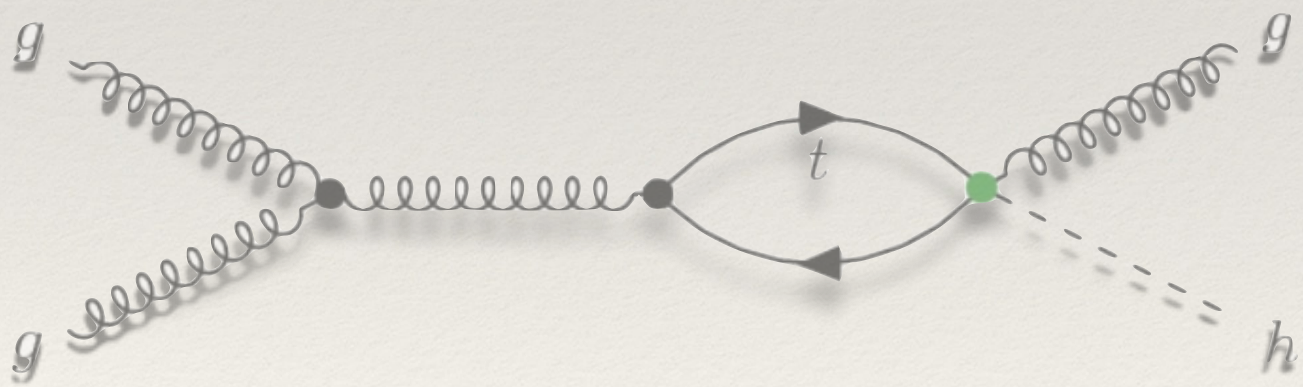
Buchmuller, Wyler Nucl.Phys. B268 (1986) 621
Grzadkowski et al arXiv:1008.4884
Brivio, Trott, arXiv:1706.08945

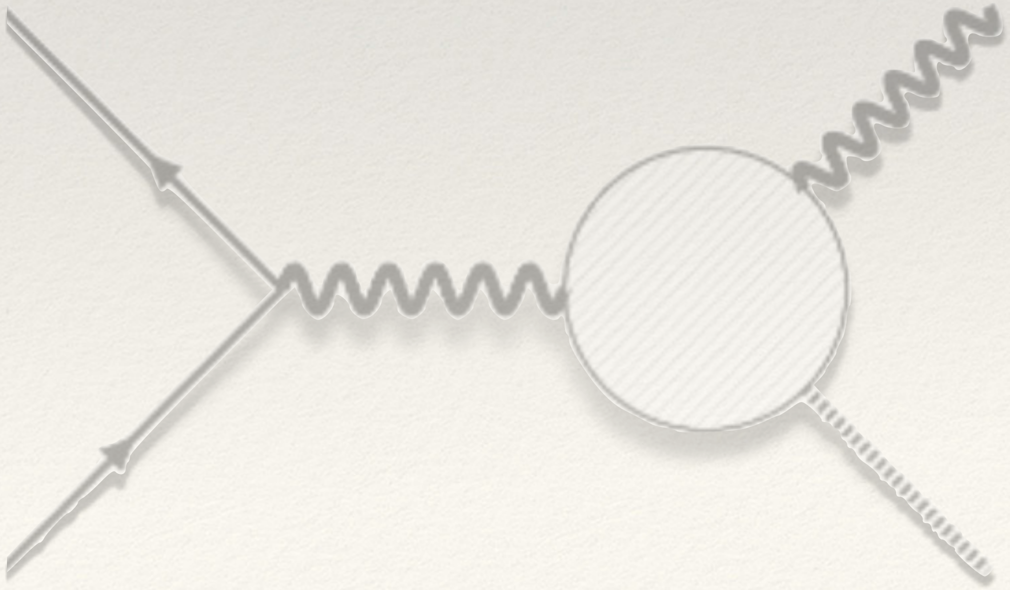
Coefficient	Operator	Example process
(T) c_{HDD}	$\left(H^\dagger D^\mu H\right)^* \left(H^\dagger D_\mu H\right)$	
c_{HG}	$H^\dagger H\, G^A_{\mu\nu} G^{A\mu\nu}$	
c_{HB}	$H^\dagger H\, B_{\mu\nu} B^{\mu\nu}$	
c_{HW}	$H^\dagger H\, W^I_{\mu\nu} W^{I\mu\nu}$	
(S) c_{HWB}	$H^\dagger \tau^I H\, W^I_{\mu\nu} B^{\mu\nu}$	
c_{eH}	$(H^\dagger H)(\bar l_p e_r H)$	
$c^{(1)}_{Hl}$	$(H^\dagger i \overleftrightarrow{D}_\mu H)(\bar l_p \gamma^\mu l_r)$	
$c^{(3)}_{Hl}$	$(H^\dagger i \overleftrightarrow{D}^I_\mu H)(\bar l_p \tau^I \gamma^\mu l_r)$	
c_{He}	$(H^\dagger i \overleftrightarrow{D}_\mu H)(\bar e_p \gamma^\mu e_r)$	
$c^{(1)}_{Hq}$	$(H^\dagger i \overleftrightarrow{D}_\mu H)(\bar q_p \gamma^\mu q_r)$	
$c^{(3)}_{Hq}$	$(H^\dagger i \overleftrightarrow{D}^I_\mu H)(\bar q_p \tau^I \gamma^\mu q_r)$	
c_{Hu}	$(H^\dagger i \overleftrightarrow{D}_\mu H)(\bar u_p \gamma^\mu u_r)$	
c_{Hd}	$(H^\dagger i \overleftrightarrow{D}_\mu H)(\bar d_p \gamma^\mu d_r)$	

(see Ilaria Brivio's talk)

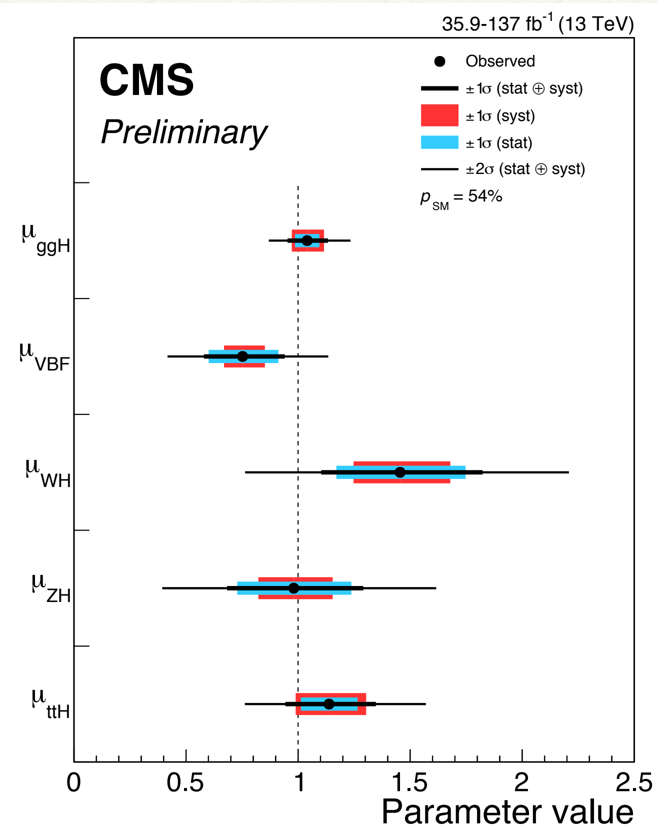
Higgs Analyses

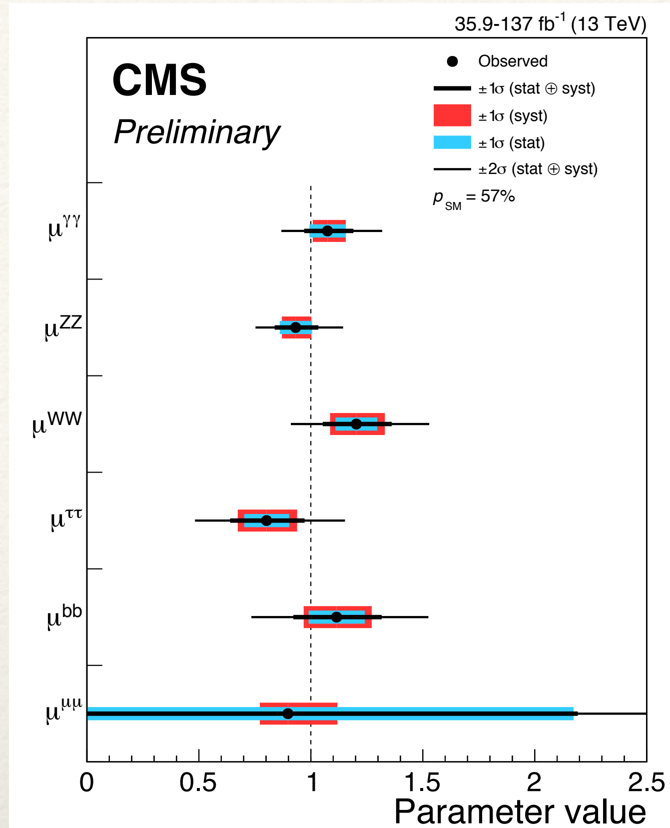


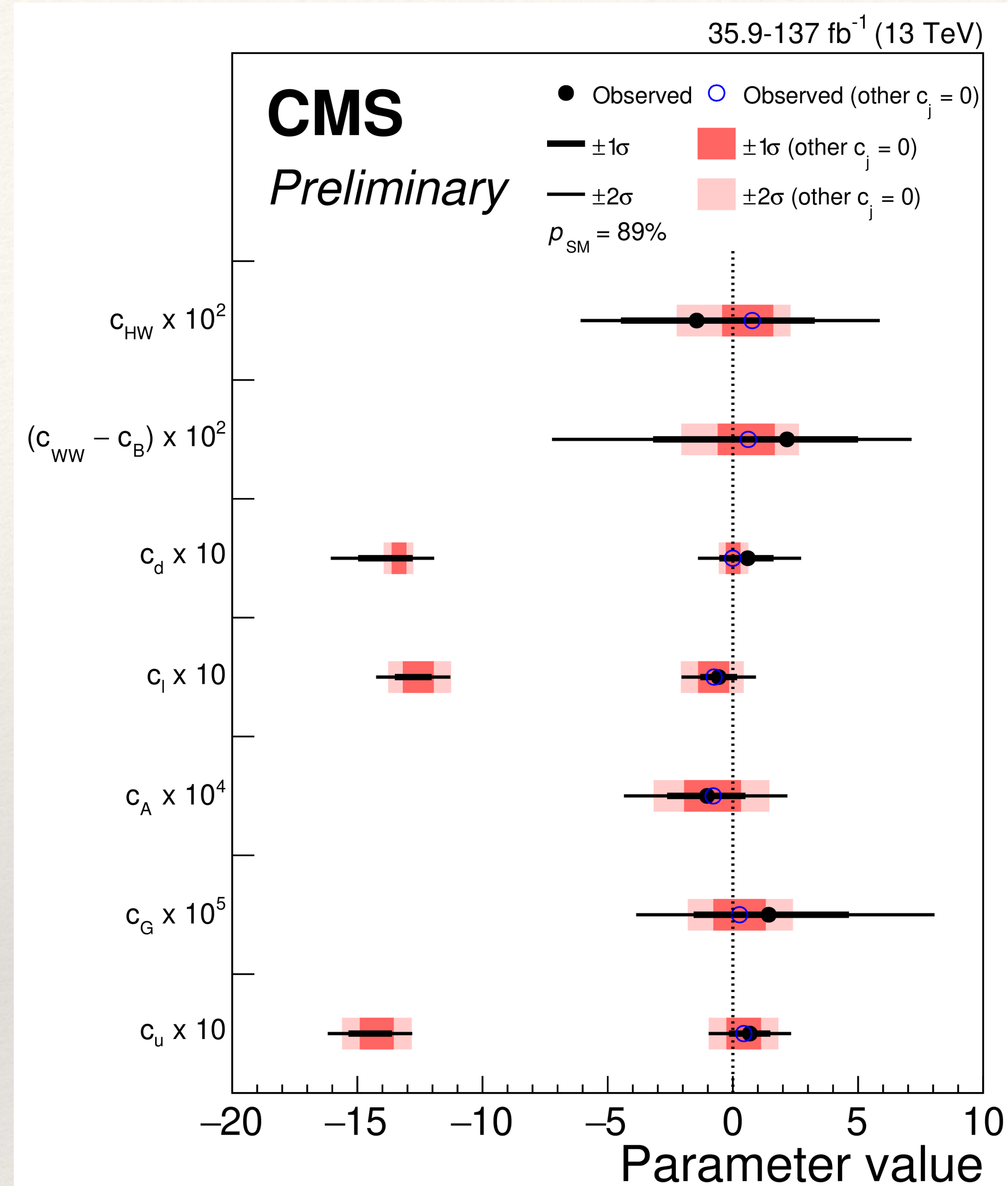




Combined CMS Higgs boson production and decay measurements







CMS-PAS-HIG-19-005

Relation between Higgs coupling modifiers in the k-framework and EFT Wilson coefficients computed from the sum of SM contribution, BSM ($1/\Lambda^4$) and interference ($1/\Lambda^2$) terms:

$$\mu_i(c_j) = \frac{\sigma_i^{\mathrm{EFT}}}{\sigma_i^{\mathrm{SM}}} = 1 + \sum_j A_j c_j + \sum_{jk} B_{jk} c_j c_k$$

Acceptance modifications and higher order missing term effects are ignored;

Simultaneous ML fit to eight coefficients leaving others fixed to SM, (C_{WW}-C_B combination in fit since C_{WW}+C_B constrained by EW data);

CMS Constraints on anomalous Higgs boson couplings to vector bosons and fermions in production and decay using four-ℓ final state

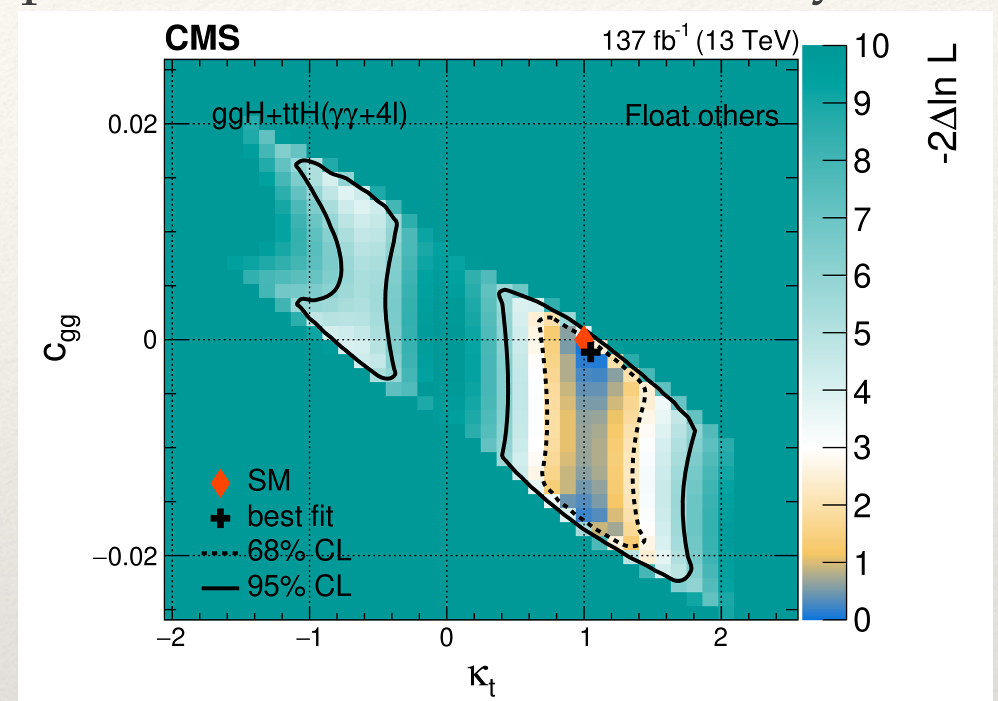
Comprehensive study of CP-violation, anomalous couplings, and tensor structure of Higgs interactions with gauge bosons, gluons, and fermions, using all accessible production mechanisms and H→4ℓ decay;

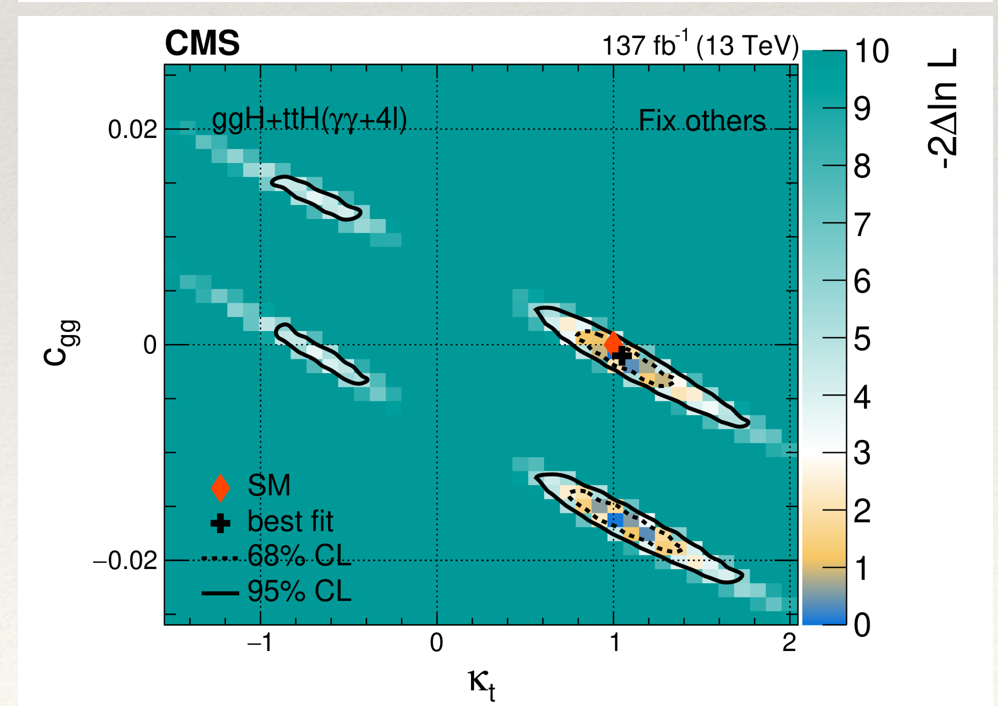
Detailed analysis of kinematics of particles associated with Higgs production in addition to decay kinematic distributions

Parameterization of H boson production and decay based on scattering amplitude then connected to SMEFT formulation;

Tensor structure of HVV coupling tested with VBF and VH in H→VV→4ℓ decay. Impose SU(2)×U(1) symmetry to relate parameters to SMEFT. Operator basis chosen as couplings of mass eigenstates: translation of SMEFT results to bosonic dim-6 operators in Warsaw basis for comparison with other results:

Channels	Coupling	Observed	Expected
VBF & VH & $H \to 4\ell$	$c_{H\Box}$	$0.04^{+0.43}_{-0.45}$	$0.00^{+0.75}_{-0.93}$
	c_{HD}	$-0.73^{+0.97}_{-4.21}$	$0.00^{+1.06}_{-4.60}$
	c_{HW}	$0.01^{+0.18}_{-0.17}$	$0.00^{+0.39}_{-0.28}$
	c_{HWB}	$0.01^{+0.20}_{-0.18}$	$0.00^{+0.42}_{-0.31}$
	c_{HB}	$0.00^{+0.05}_{-0.05}$	$0.00^{+0.03}_{-0.08}$
	$c_{H\tilde{W}}$	$-0.23^{+0.51}_{-0.52}$	$0.00^{+1.11}_{-1.11}$
	$c_{H\tilde{W}B}$	$-0.25^{+0.56}_{-0.57}$	$0.00^{+1.21}_{-1.21}$
	$c_{H\tilde{B}}$	$-0.06^{+0.15}_{-0.16}$	$0.00^{+0.33}_{-0.33}$





Phys. Rev. D 104 (2021) 052004

Interpretations of ATLAS combined measurement of Higgs boson production and decay

New

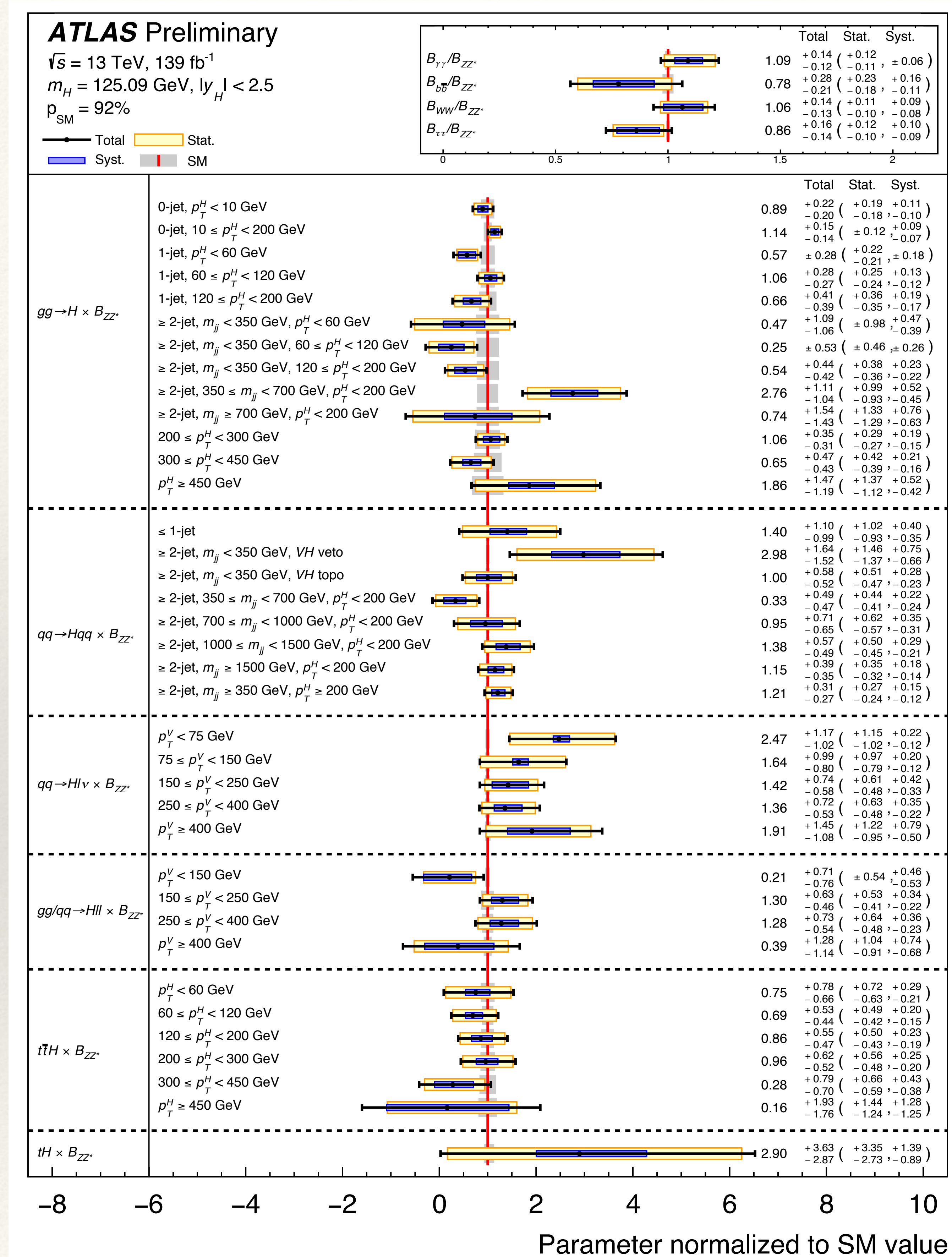
New combination of measurements of Higgs production and decay with full Run 2 stat;

Extended p_T^H reach of analyses

Measurements separated by production mode and kinematic template category (STXS) for different decay channels re-parametrised for SMEFT operators;

Measured signal strength for each STXS category used in EFT analysis to extract constraints on (combinations of) Wilson coefficients.

Probability to obtain observed data under SM-only hypothesis = 92%

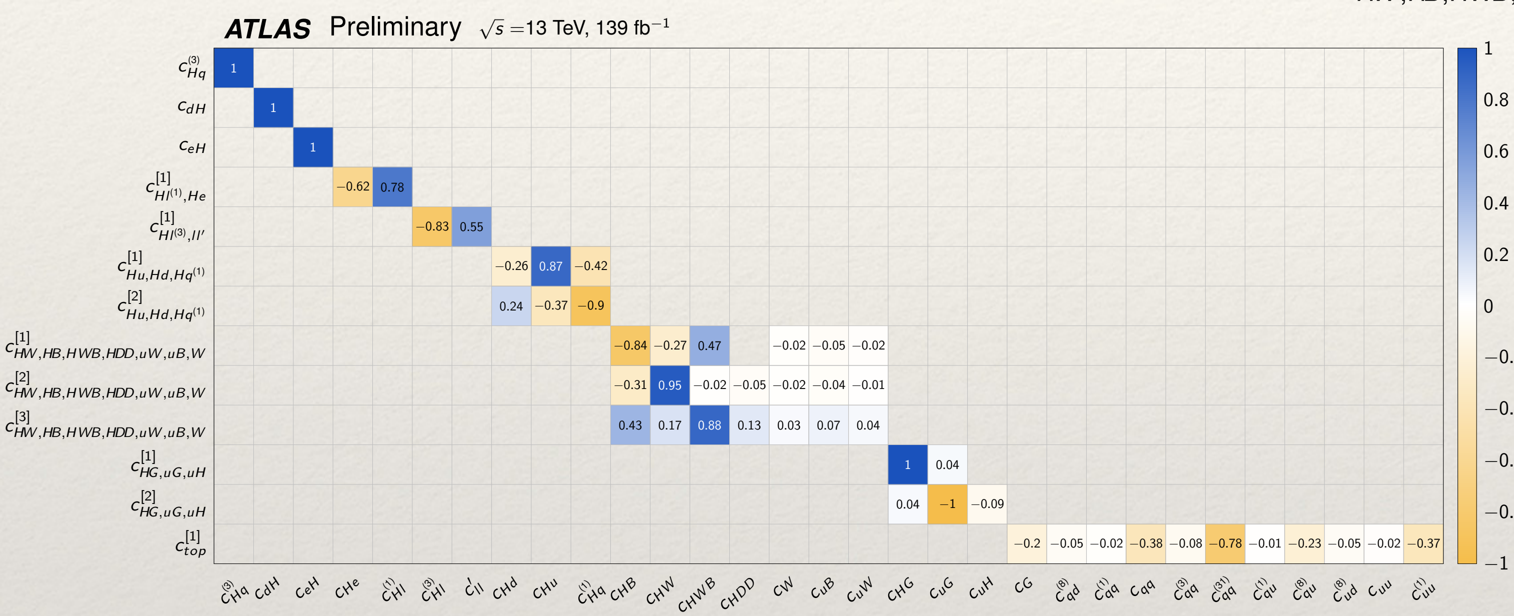


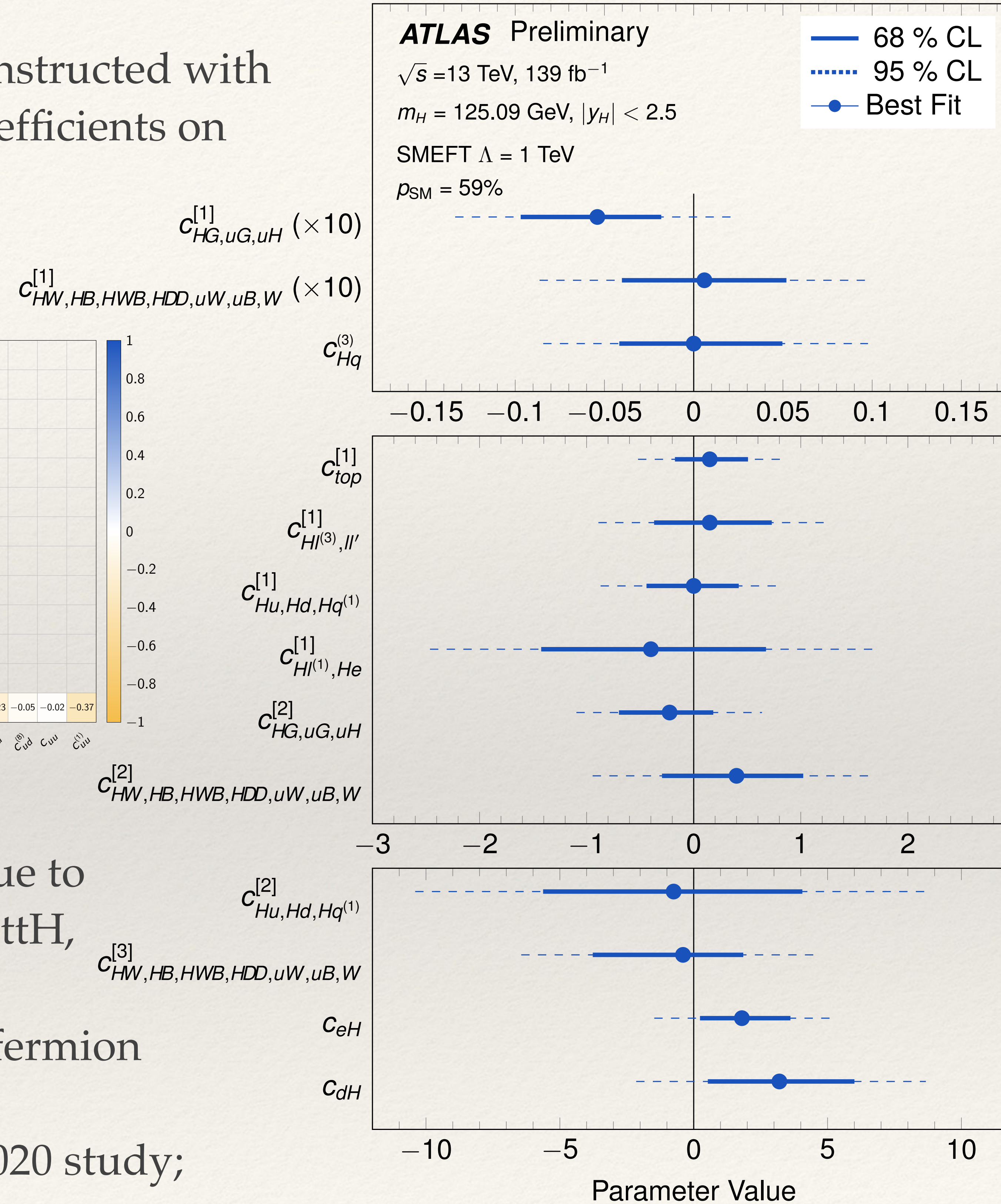
ATLAS-CONF-2021-053

Interpretations of ATLAS combined measurement of Higgs boson production and decay

New

New eigenvector decomposition in sub-spaces constructed with guidance from sensitivity of individual Wilson coefficients on inputs from available measurements;
All parameters fitted simultaneously;





Compared to previous analysis:

- Correlations between Wilson coeffs. reduced due to additional input from: H→ττ; VBF, H→bb and ttH, H→bb;
- first constraints on some combinations of four fermion top operators (c_{eH}, c_{dH} and c_{top});
- Sensitivity improved up to 70% compared to 2020 study;

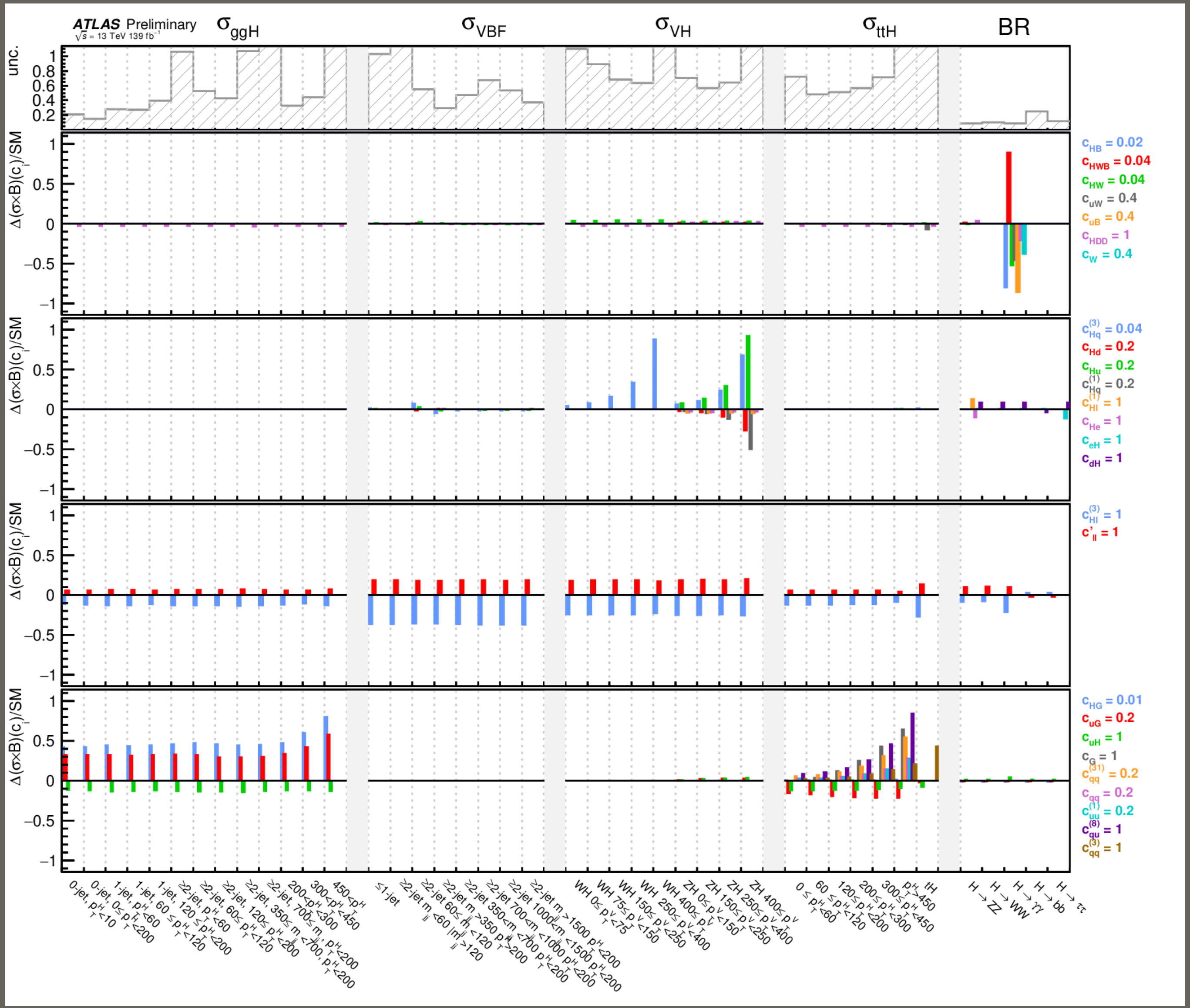
Measured parameters consistent with SM expectation within uncertainties.

ATLAS-CONF-2021-053

The Case for High p_T Higgs Measurements

While sensitivity to new physics scale Λ from static Higgs properties scales as ~ v/Λ, Higgs bosons produced at large p_T^H access regions where effects may be enhanced by powers of p_T^H/Λ.

Interpretations of ATLAS combined measurement of Higgs boson production and decay



ATLAS-CONF-2021-053

Measurements with extended energy reach may outperform lower-energy measurements of higher precision in their BSM sensitivity;

Furthermore S/B for Higgs processes typically increases with energy.

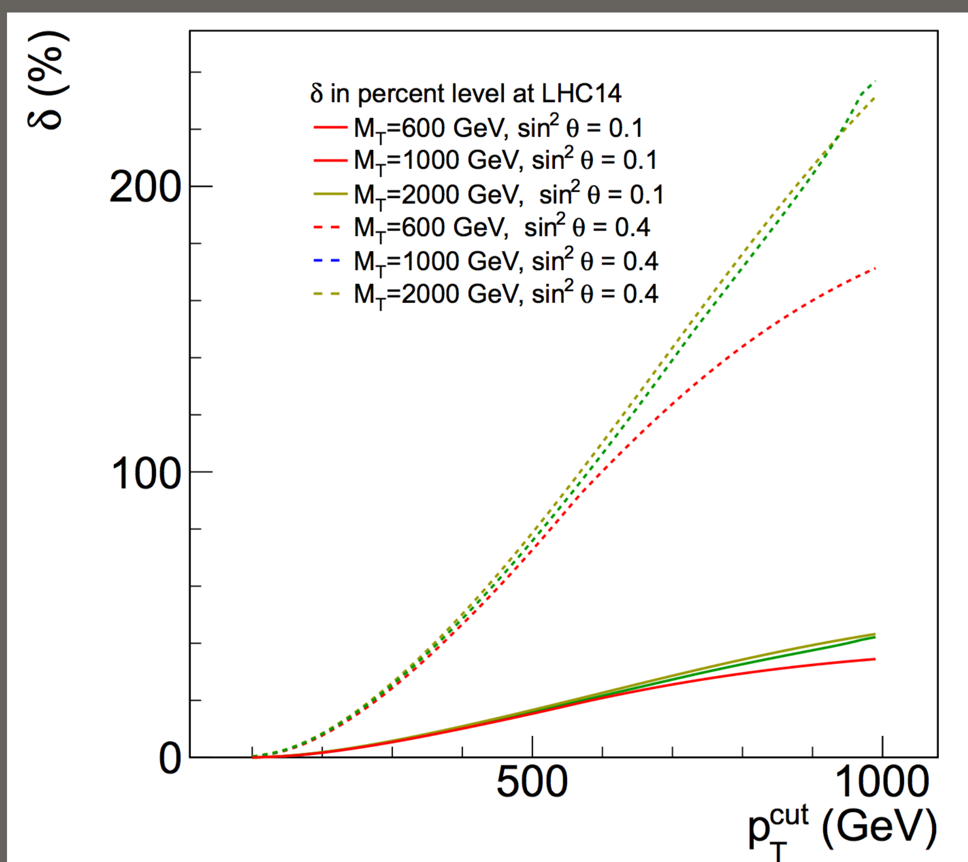
EFT and Explicit BSM Models

If new particle sufficiently heavy ($M \gg M_h$ and $M > p_T{}^H{}_{max}$) contribution can be matched to local EFT operators, scales with p_T x coupling;

Increasing to $p_T{}^H > M$ resolves contribution from new particles yielding terms of p_T/M but EFT approximation breaks down;

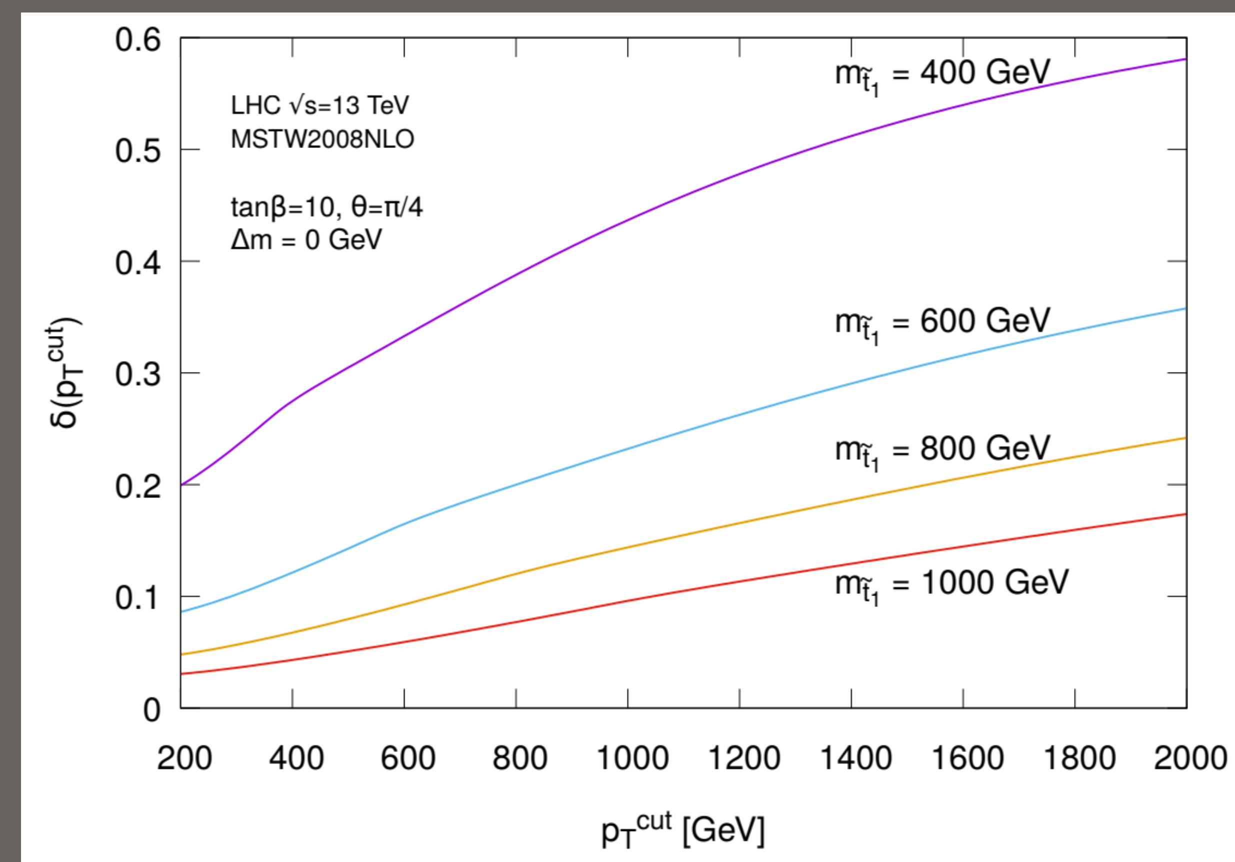
Heavy Top Partner

$$\mathcal{M}_{+++}\Big|_{m_t \ll p_T \ll M_T} \propto \frac{m_t^2\,\kappa_t}{p_T}\left(A_{t,0} + A_{t,1}\,\ln\left(\frac{p_T^2}{m_t^2}\right) + A_{t,2}\,\ln^2\left(\frac{p_T^2}{m_t^2}\right)\right) + \kappa_T\, p_T$$



SUSY Scalar Top Quarks

$$\mathcal{M}_{+++}\big|_{m_t \ll p_T \ll m_{\tilde{t}_1}, m_{\tilde{t}_2}} \frac{m_t^2}{p_T}\left(A_0 + A_1 \ln\left(\frac{p_T^2}{m_t^2}\right) + A_2 \ln^2\left(\frac{p_T^2}{m_t^2}\right)\right) + 8\frac{\Delta}{p_T^2} F_g$$



Grojean, Salvioni, Schaffer, Weiler, JHEP 05 (2014) 022

Banfi, Martin, Sanz, JHEP 08 (2014) 053

Banfi, Bond, Martin, Sanz, JHEP 11 (2018) 171

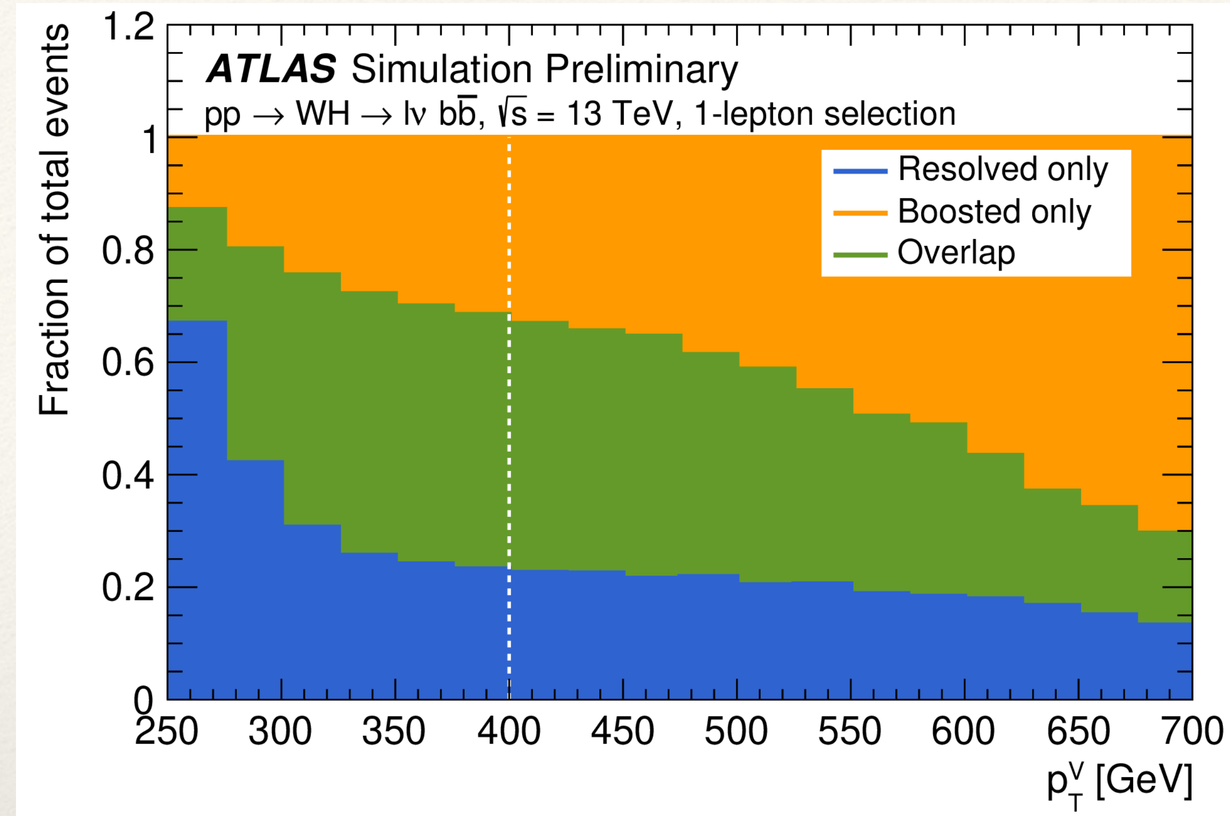
Combination of ATLAS measurements of Higgs boson production in association with W or Z boson in bb decay channel

New

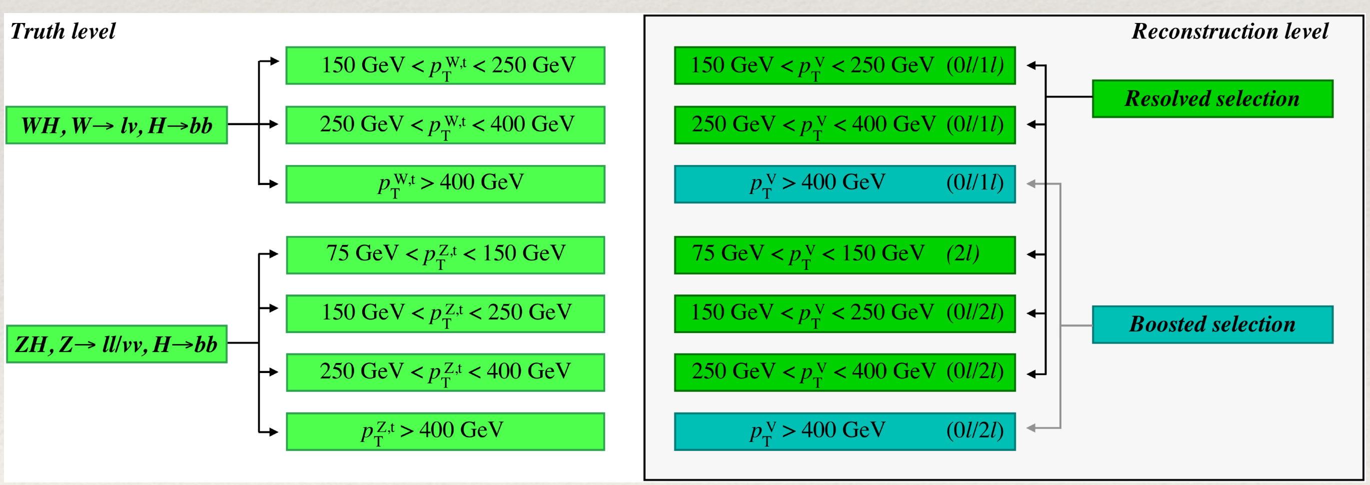
First combination of ATLAS measurements of associated VH production with H→bb; W, Z→ℓs in resolved and boosted topologies optimised for different p_T^V regimes:

- Resolved VH, H→bb with p_T^V<400 GeV with Higgs boson candidate reconstructed as two resolved jets
- Boosted VH, H→bb with p_T^V>400 GeV with Higgs boson candidate reconstructed as single large-radius jet.

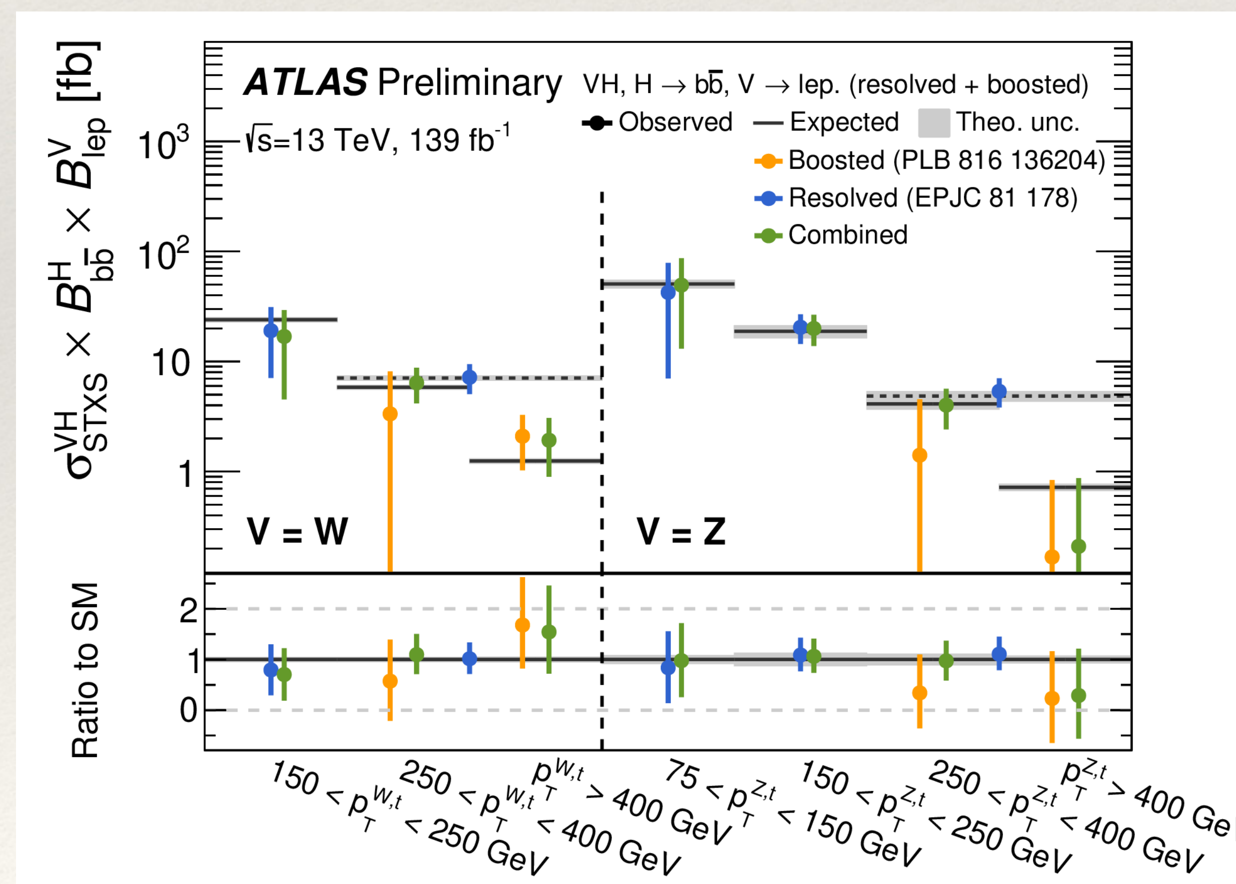
with Z →ℓℓ and W →ℓν



Cross-sections measured in fiducial STXS volumes:



Results compatible with SM within uncertainties of 30% to 300%:



Input analyses:
Eur. Phys. J. C 81 (2021) 178,
Phys. Lett. B 816 (2021) 136204

ATLAS-CONF-2021-051

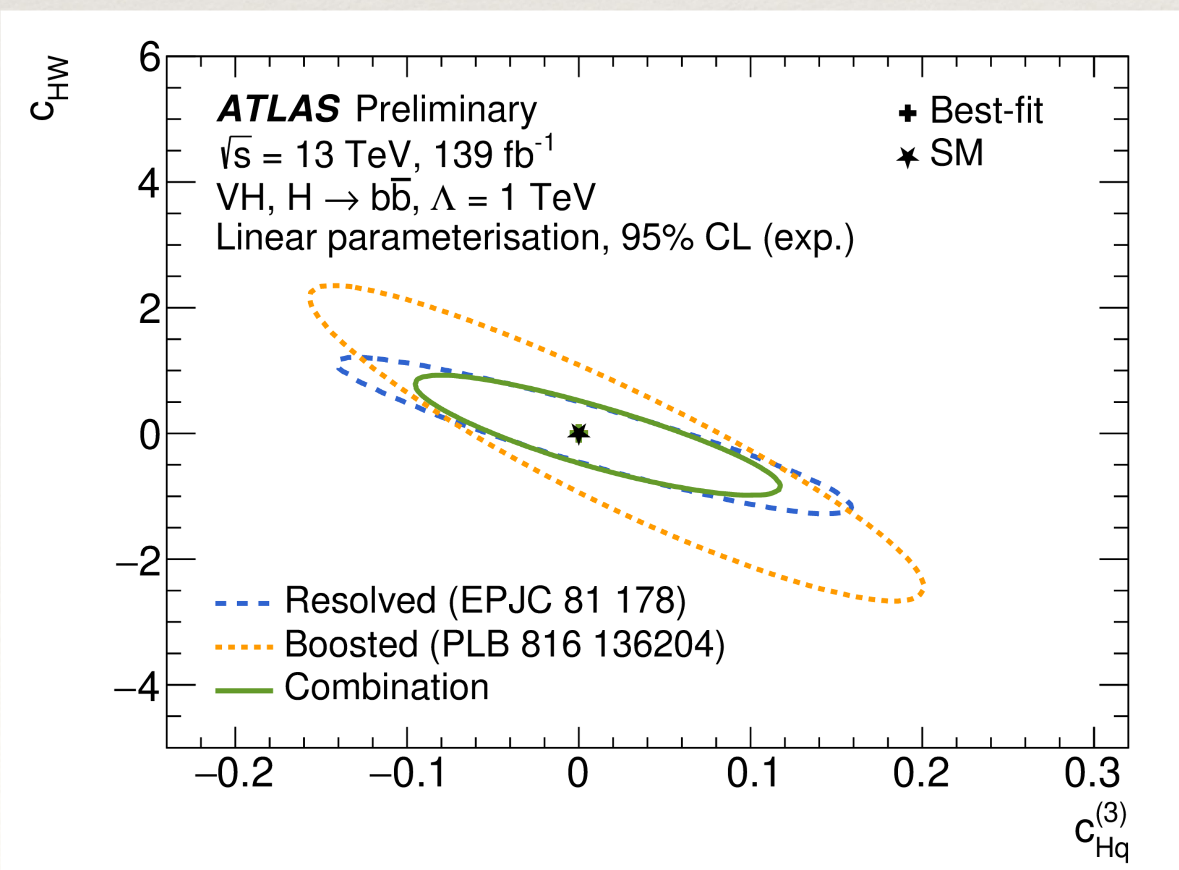
New

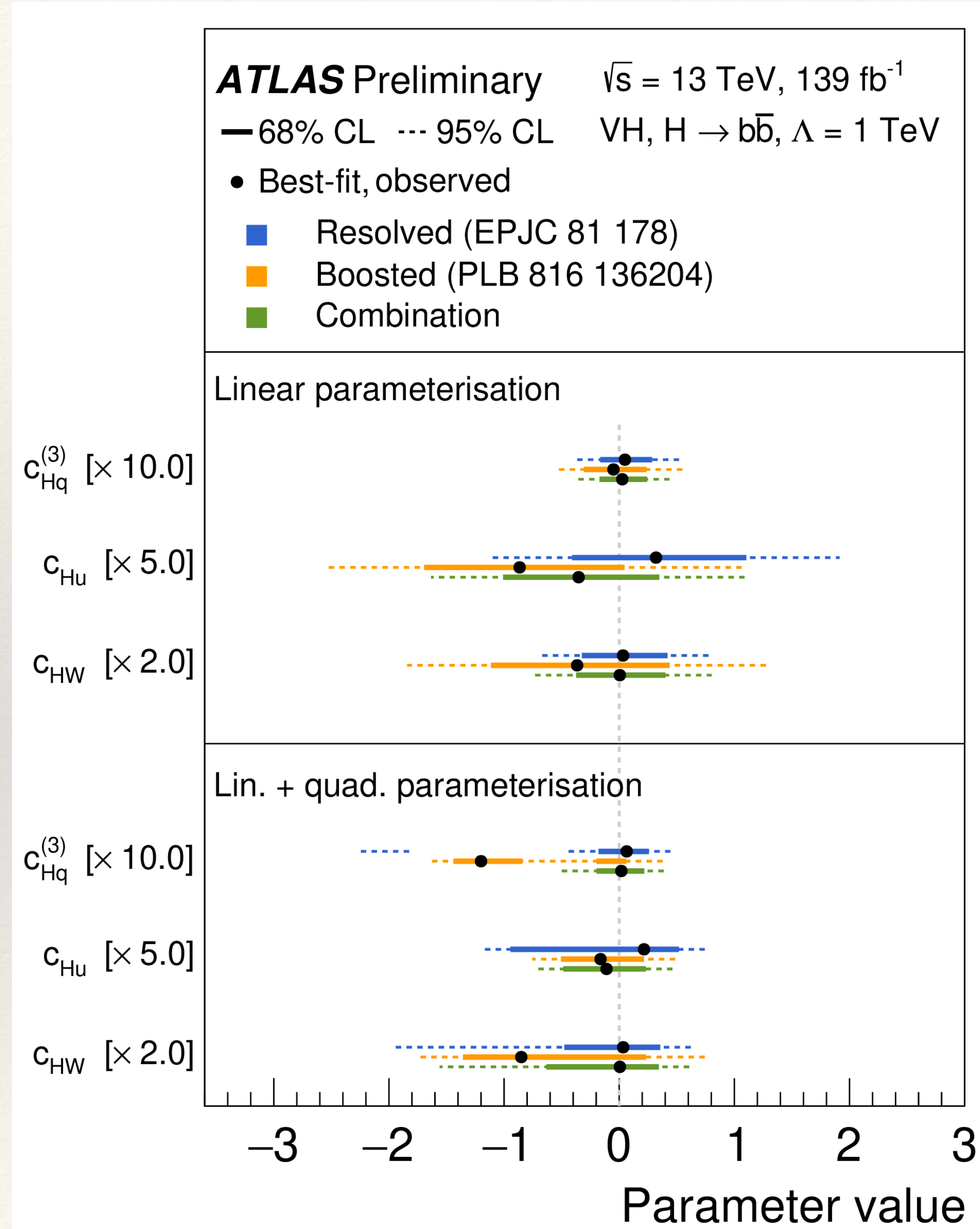
Combination of ATLAS measurements of Higgs boson production in association with W or Z boson in bb decay channel

Combination yields more stringent limits than individual analyses on EFT parameters strongly dependent on p_T^H.

VH-sensitive EFT operators pin down tensor structure of HVV couplings;

Study constraints on Wilson coefficients using linear and linear + quadratic EFT terms:



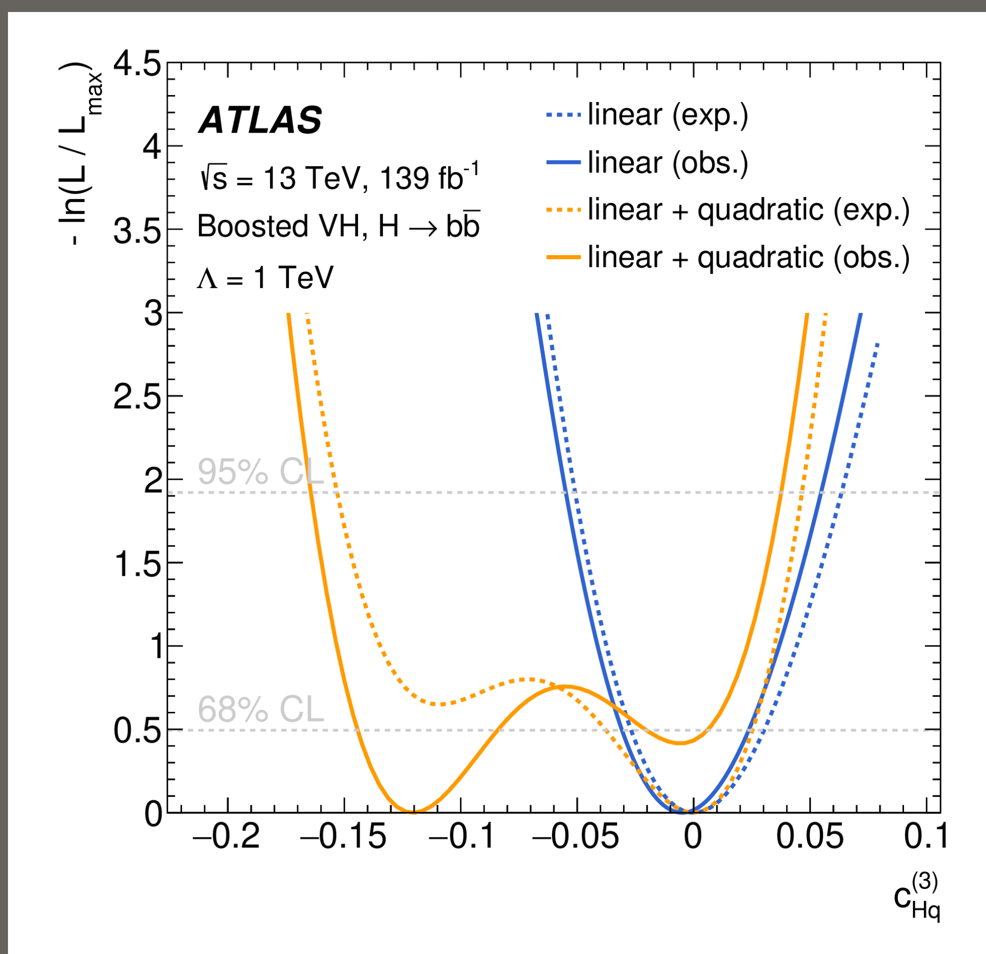


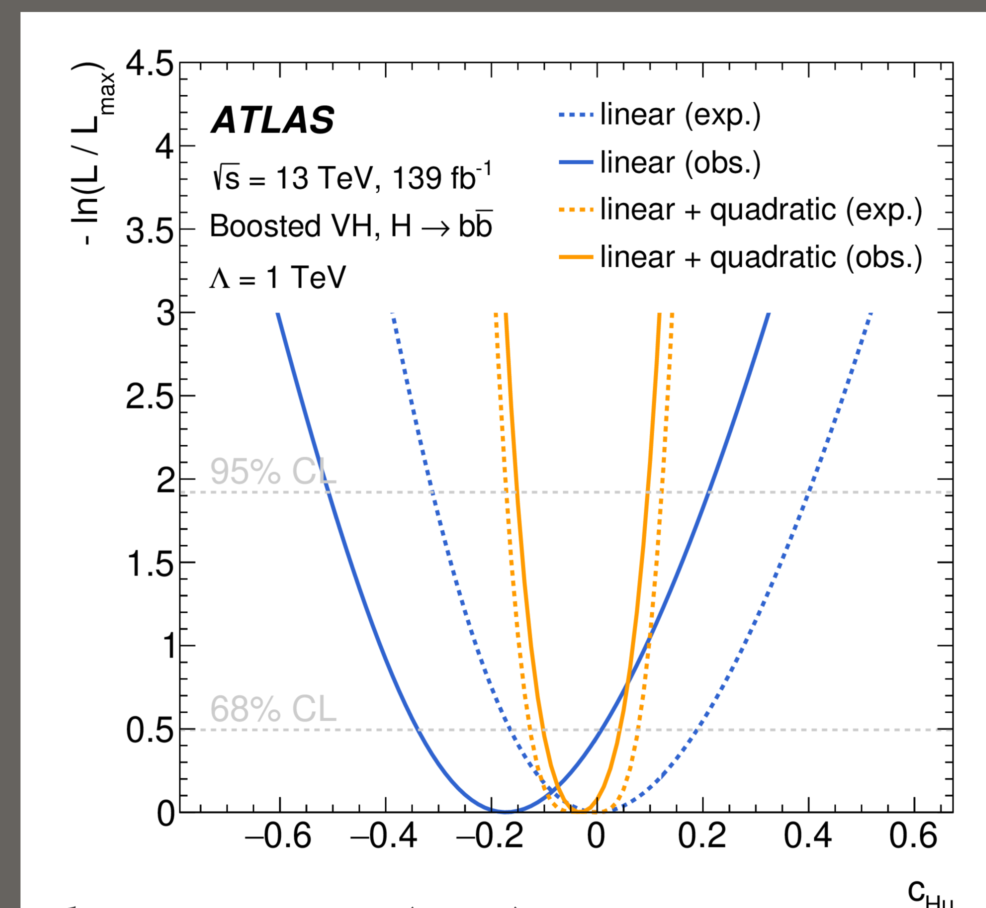
ATLAS-CONF-2021-051

Linear and Quadratic EFT terms

Whether quadratic terms should be included or not in dim-6 SMEFT analysis an open question: in SMEFT expansion, Λ^4 term not complete with dim-6 operators: difference of linear vs linear +quadratic may offer us way to estimate impact of dim-8 operators, whose precise contributions is unknown but has been estimated to be small;
Observe that inclusion can change fit results opening additional minima or shrinking allowed region for Wilson coefficients of some operators;

ATLAS Measurement of the associated production of a Higgs boson decaying into b-quarks with a vector boson at high transverse momentum





Phys. Lett. B 816 (2021) 136204

Answer may also be related to decoupling behaviour of underlying UV model as in case of non-decoupling models (e.g. heavy top partner) and decoupling models (e.g. MSSM with light scalar top and bottom quarks).

CMS Inclusive Search for Highly Boosted H → bb

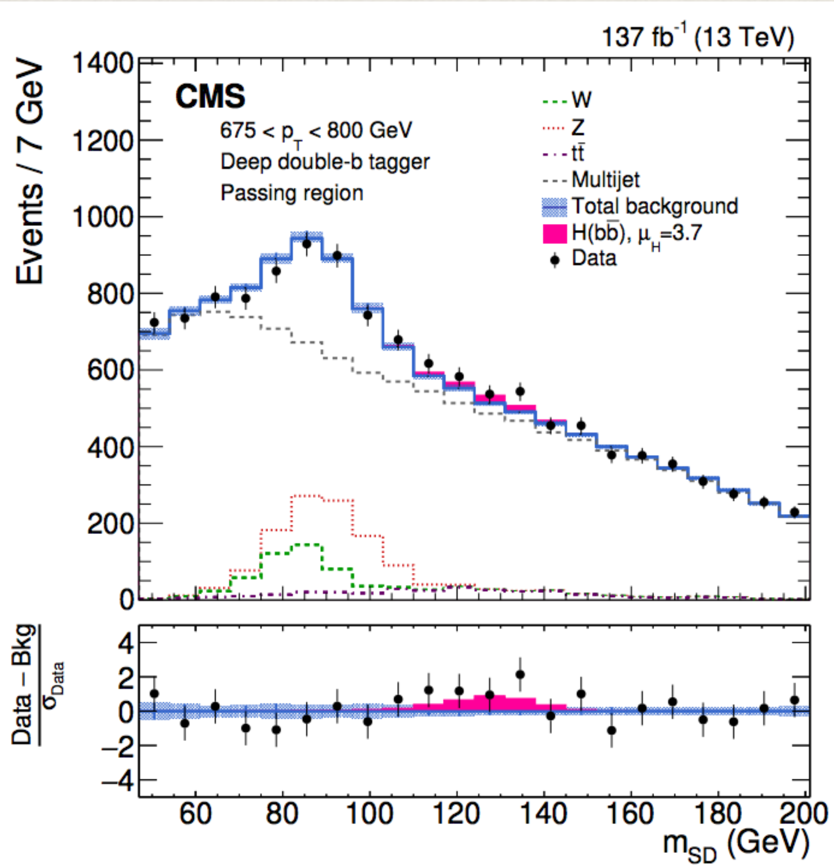
Pioneering study of boosted H → bb reconstructed as single large-radius jets with p_T>450 GeV:

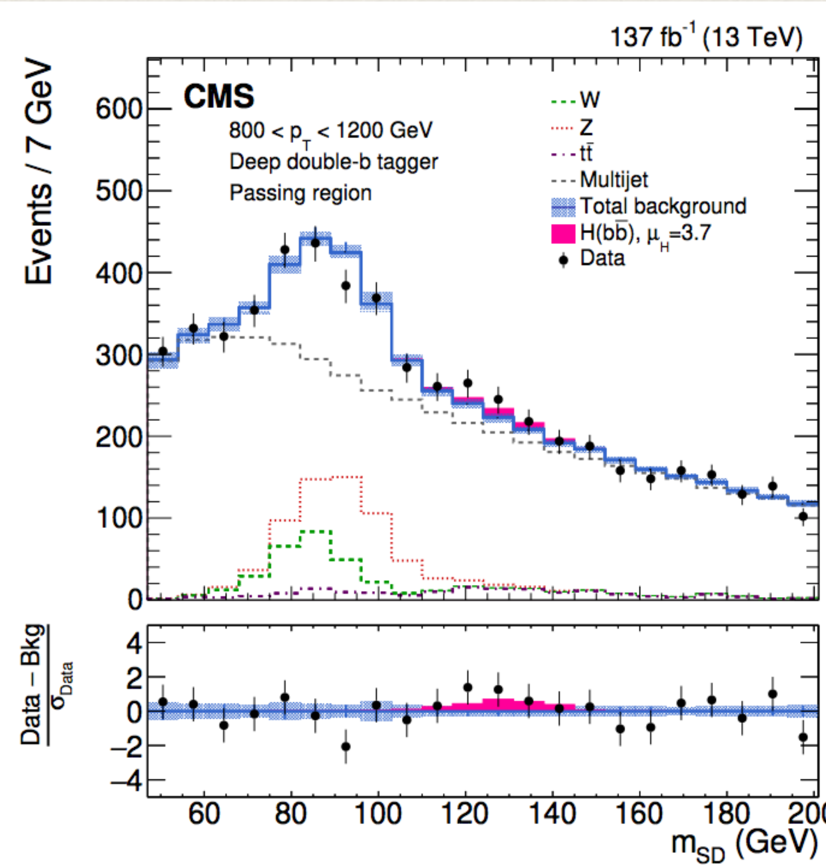
- Signal selected with jet substructure and dedicated b-tagging technique based on deep NN.
- Method validated using Z → bb decays.

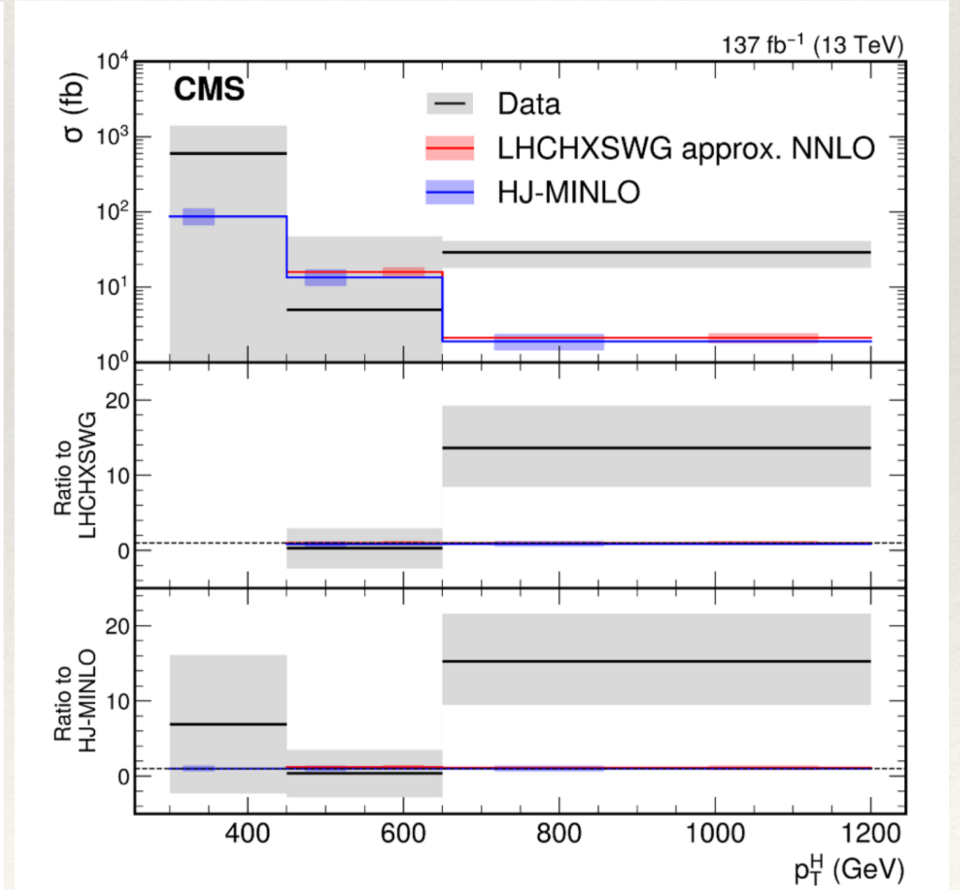
Excess of events above the background assuming no 125 GeV Higgs boson production observed with local significance of 2.5 σ (expectation 0.7):

- Signal strength μ_H (p_T>450 GeV) = 3.7 ± 1.2(stat) +0.8/−0.7 (syst) +0.8/−0.5 (theo).

Unfolded differential ggF cross section in p_T^H bins assuming other production modes at SM rates.







JHEP 12 (2020) 085

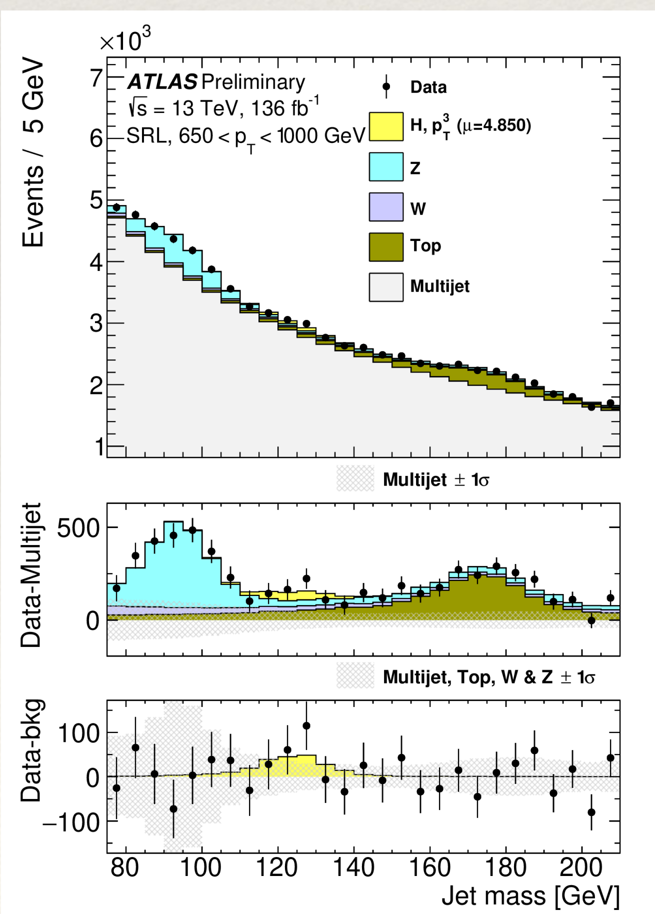
ATLAS Study of Higgs-boson production with large transverse momentum using H→bb

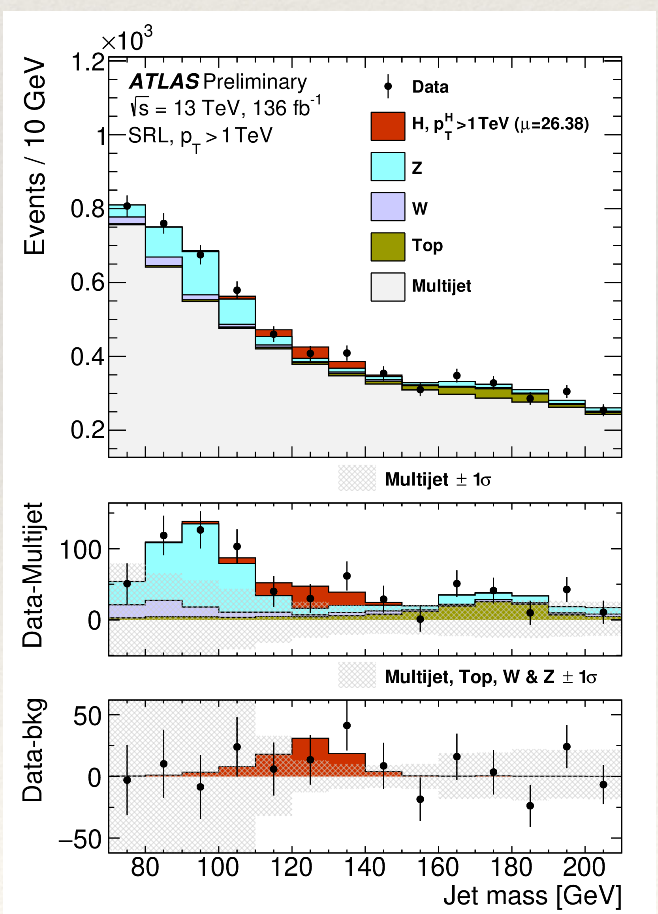
First ATLAS study of Higgs bosons production above 1 TeV in all-hadronic bb final state;

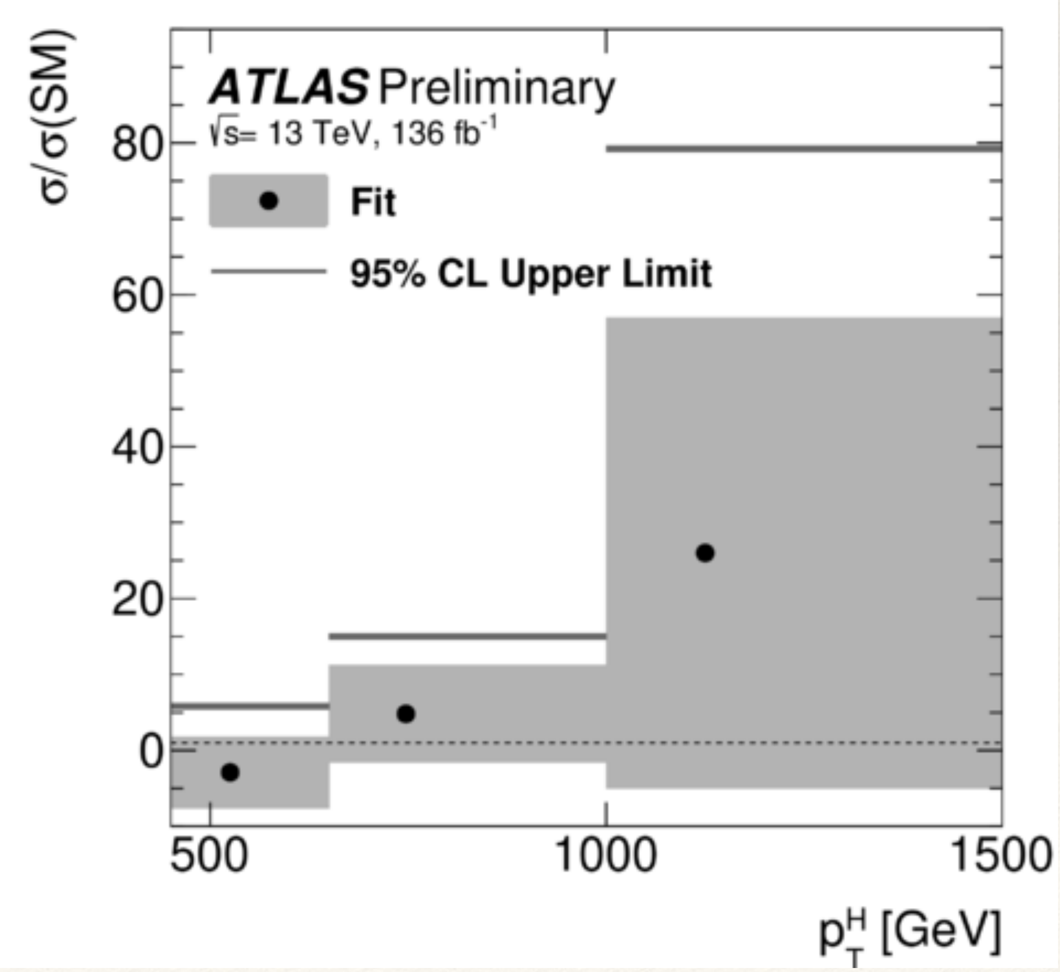
- H → bb reconstructed as single large-radius jets, with double b-tag of VR jets+recoil hadronic system.
- Experimental techniques validated in same kinematic regime using anti-tagged Validation Region and double b-tagged Z → bb;
- Top bkg constrained in dedicated Control Region, W/Z mass resolution measured vs p_T;

Inclusive analysis with no restrictions to select particular Higgs boson production mode aside from requiring energetic hadronic recoil system.

- Simultaneous fit of V+jets, QCD yield+mass spectrum shape and inclusive H → bb yield in multiple STXS-like p_T^H bins:
- Signal strength μ_H (p_T>450 GeV) = 0.7 ± 2.8 (stat) ± 1.7 (syst)





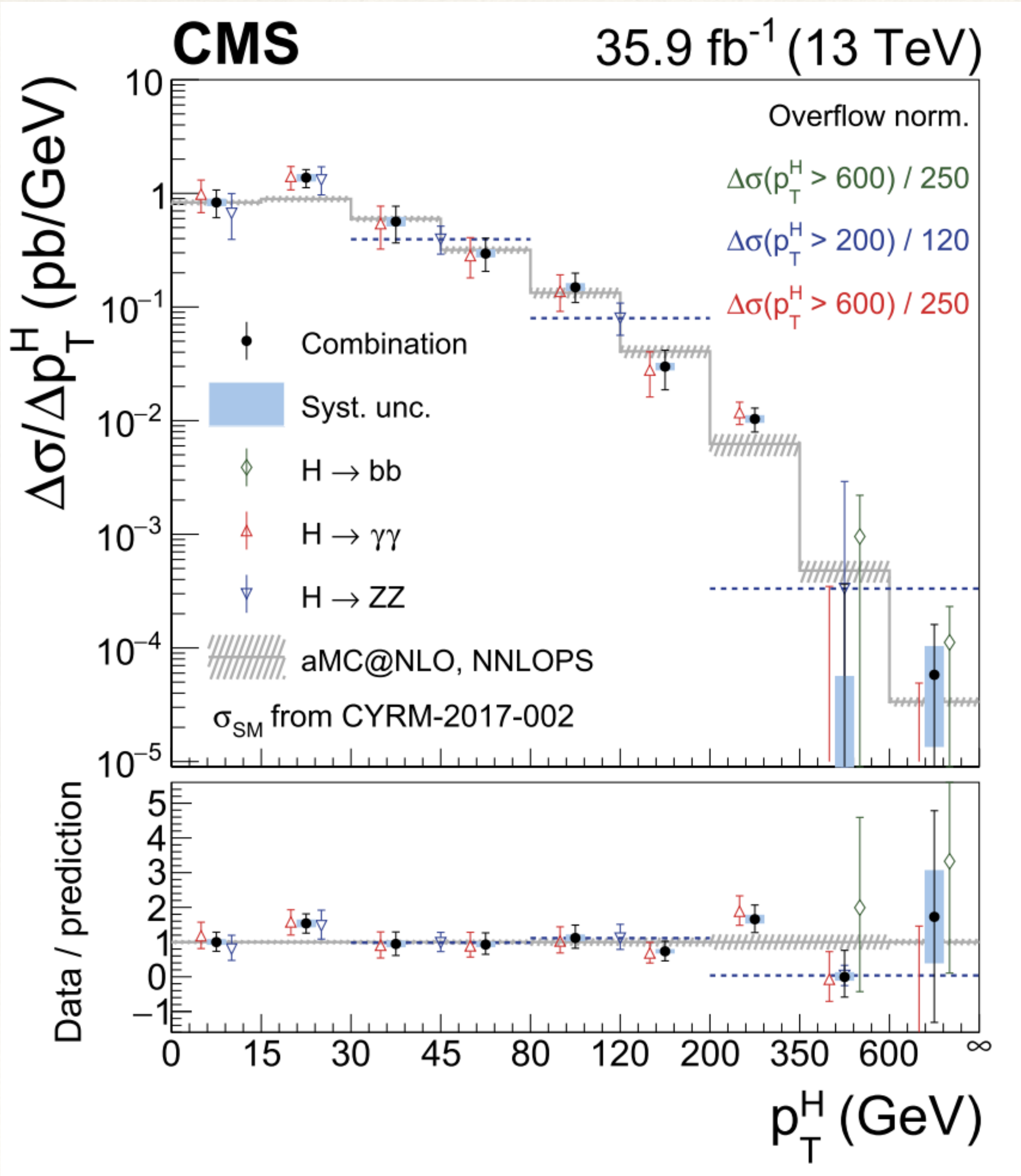


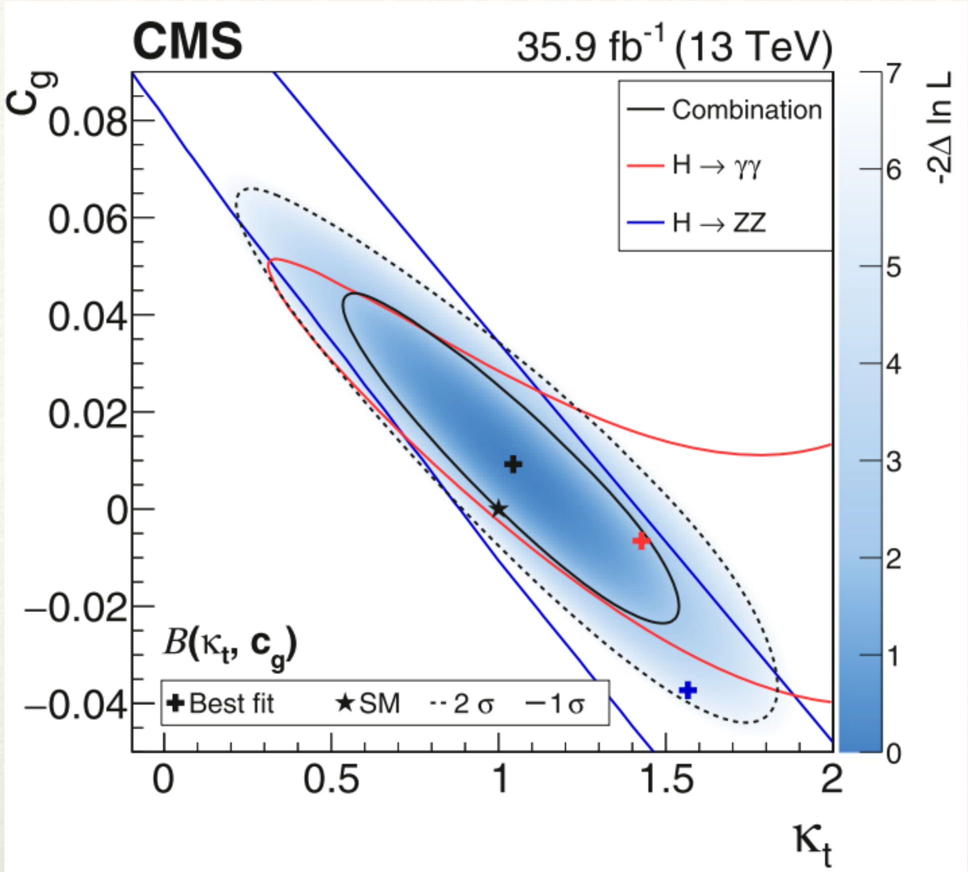
ATLAS-CONF-2021-010

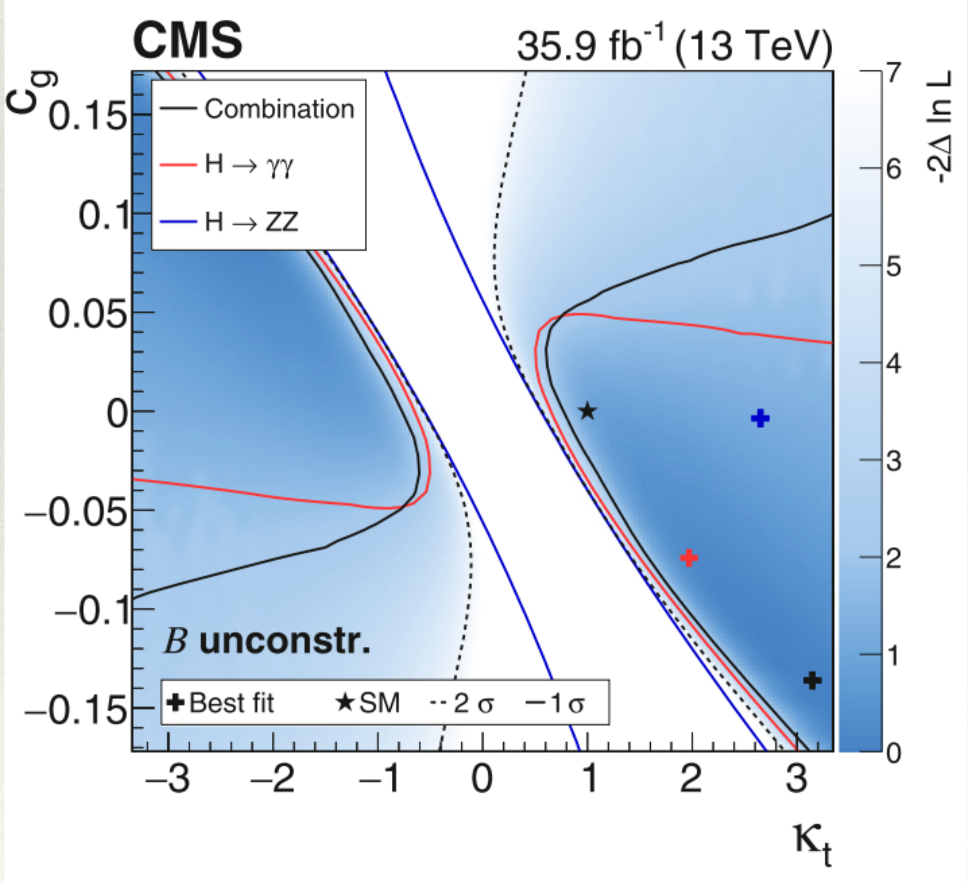
Interpretation of CMS differential cross sections for Higgs boson production and c_g

Combined $H \to \gamma\gamma$, $H \to ZZ$, and $H \to bb$ (resolved and preliminary first boosted analysis) decay channels;

Higgs p_T spectrum (including high pT bin from boosted $H \to bb$) used to set limits on couplings to top, bottom, and charm quarks, as well as c_g coupling to gluon field.







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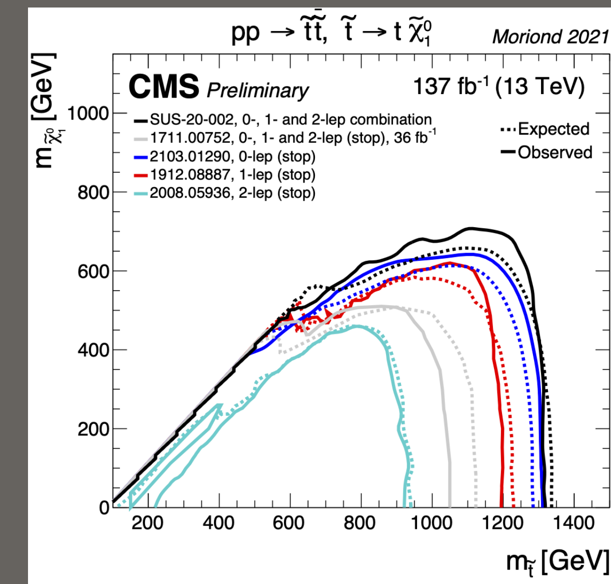
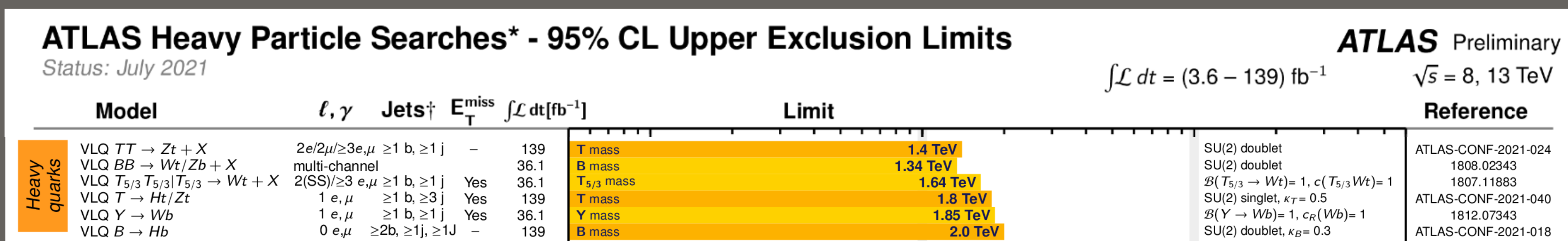
Experimental Sensitivity and the Limit of EFT validity

EFT explicitly assumes that BSM degrees of freedom can be integrated out;

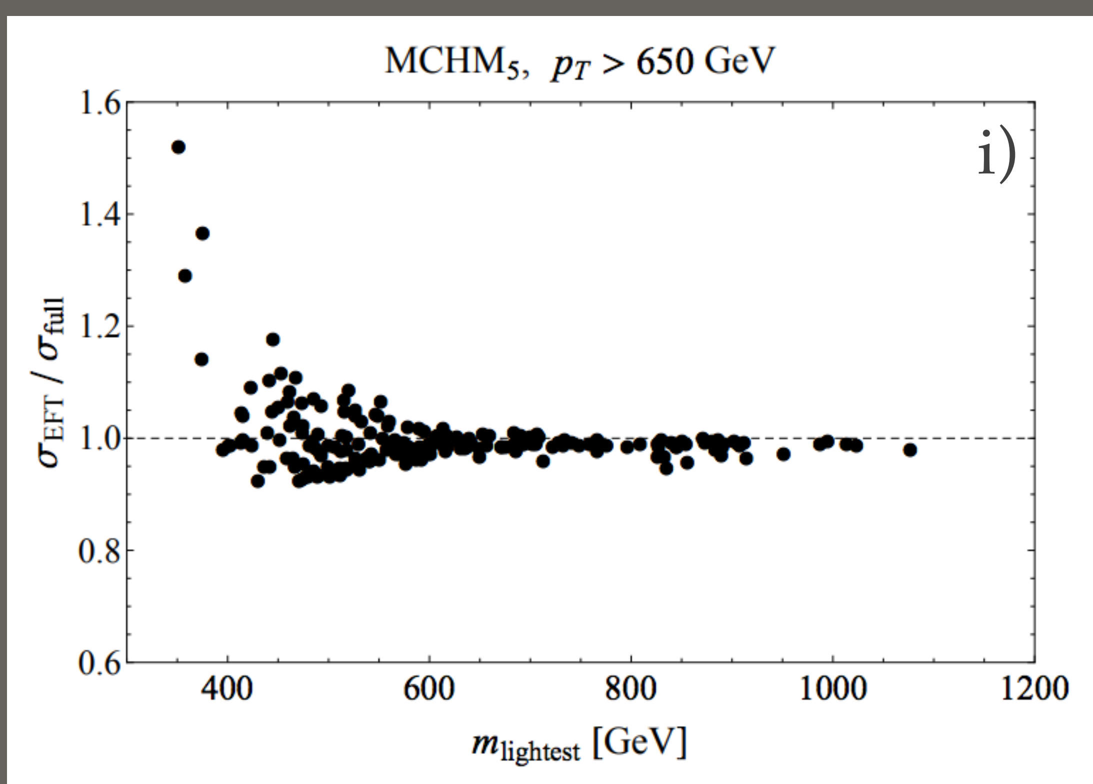
Validity of this assumption may become questionable as ATLAS and CMS extend sensitivity at (and beyond) 1 TeV, at scale comparable to (or higher than) direct search limits for relevant new particles:

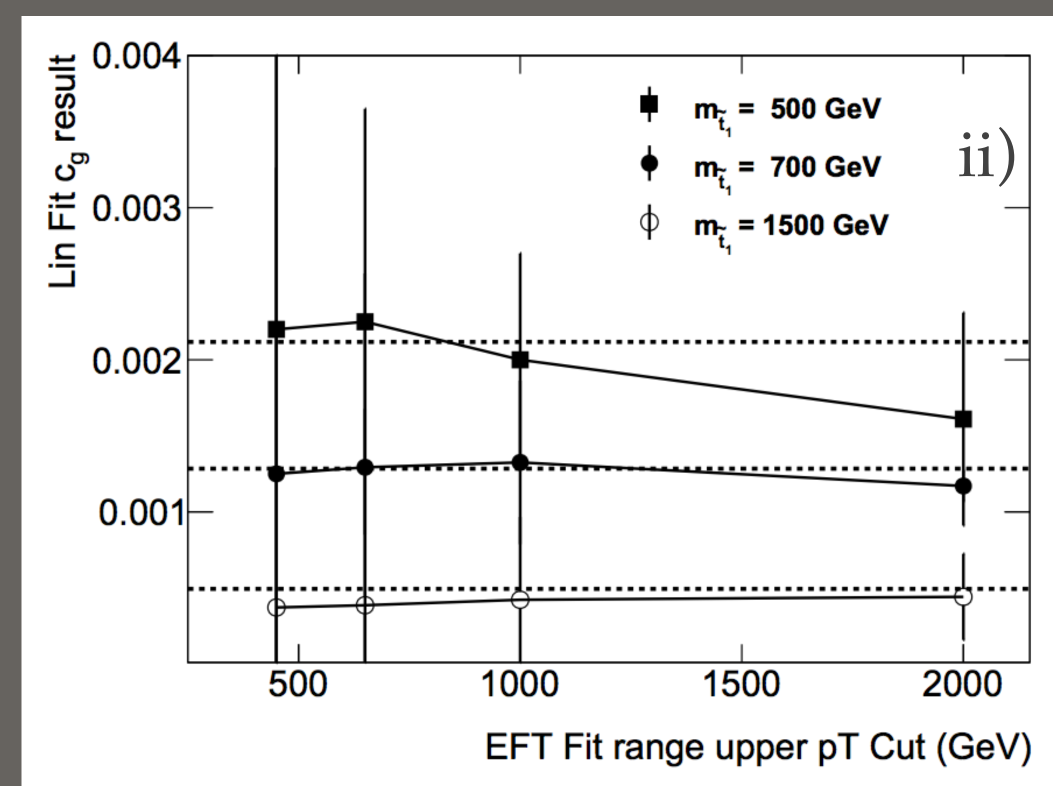




EFT break down observed from mismatch between i) Higgs cross section in EFT matching approximation and full theory and ii) Wilson coefficients extracted by EFT matching and theory:

Heavy Top Partner





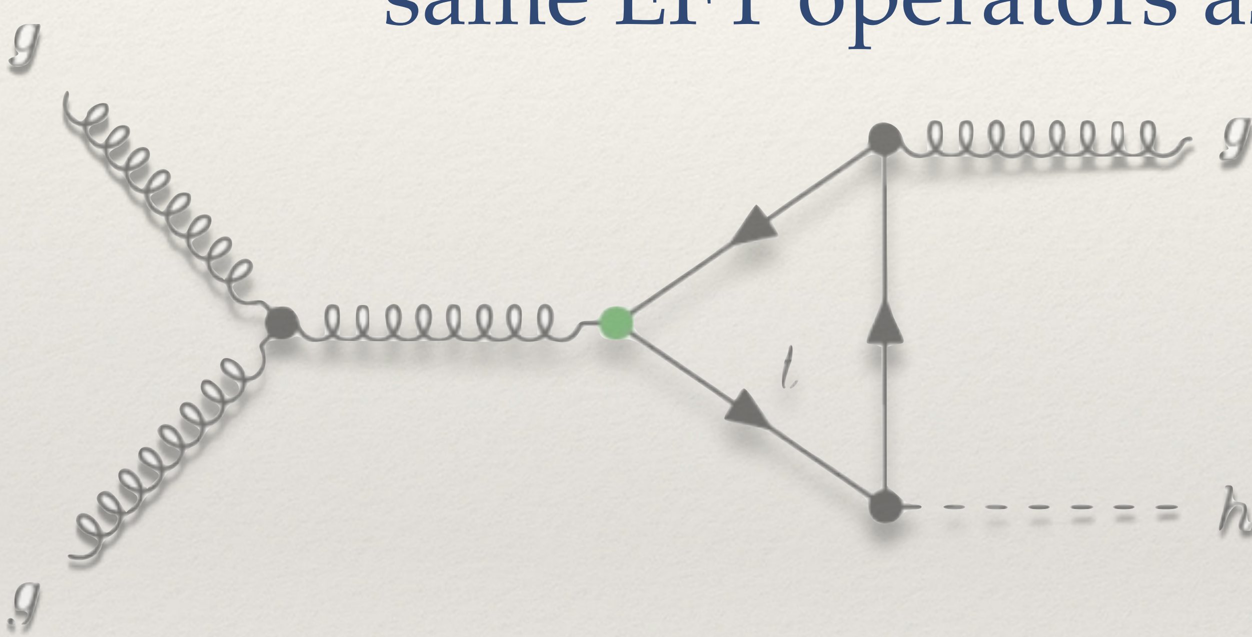
SUSY Scalar Top Quarks

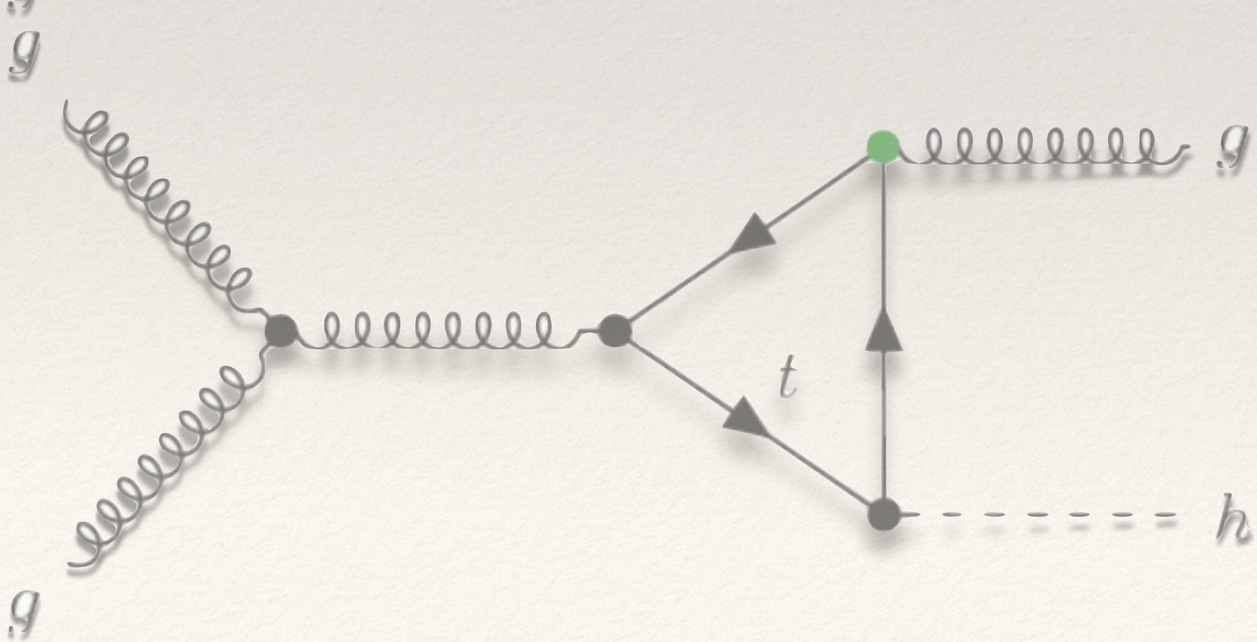
Grojean, Salvioni, Schaffer, Weiler, JHEP 05 (2014) 022

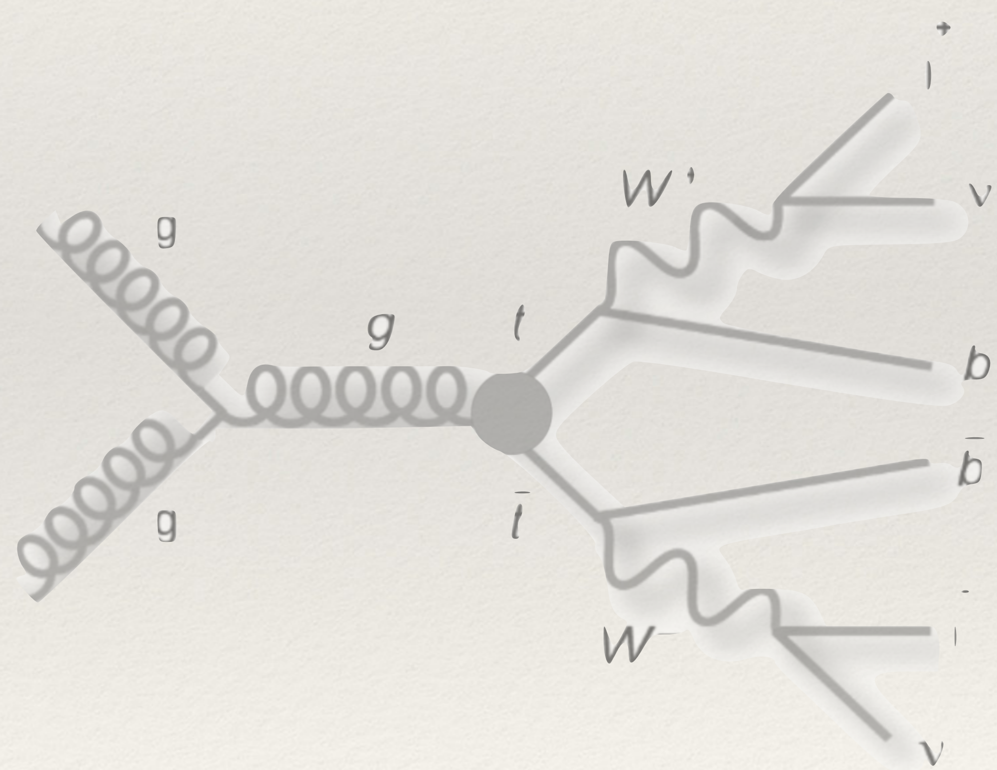
MB, Grazzini, Spira, Wiesemann, arXiv:2109.02987

… and beyond

(some analysis of Top and EW physics sensitive to same EFT operators as Higgs processes)

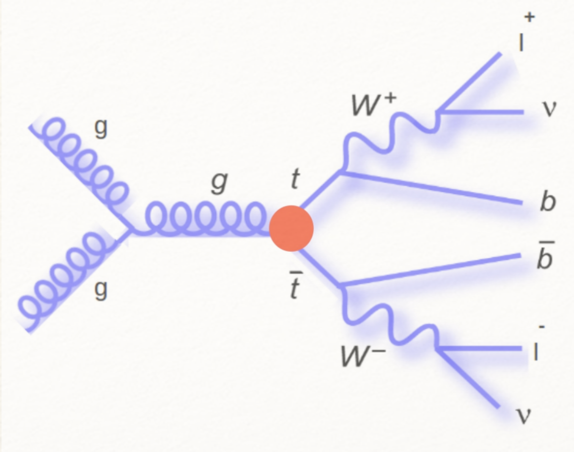




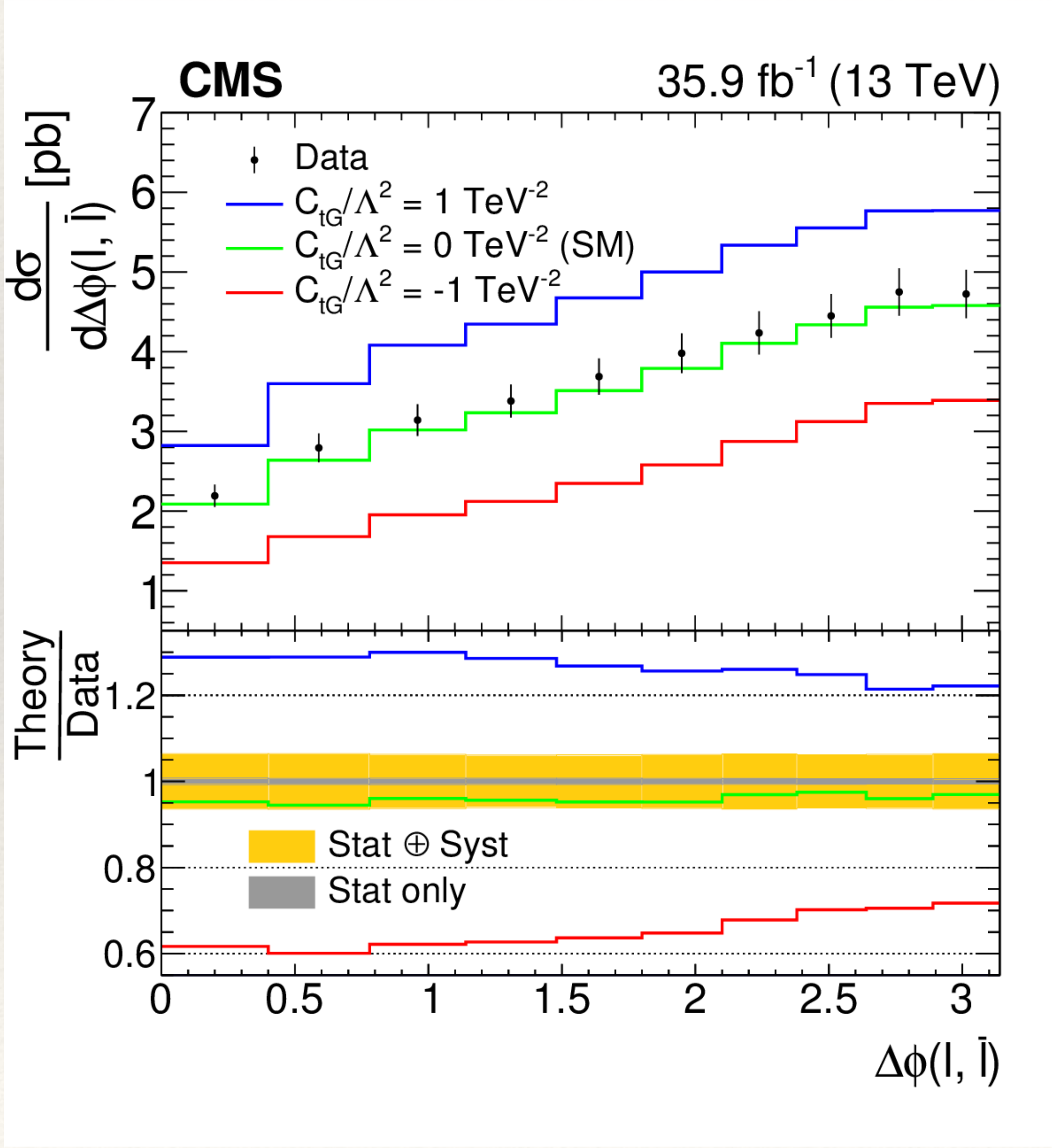


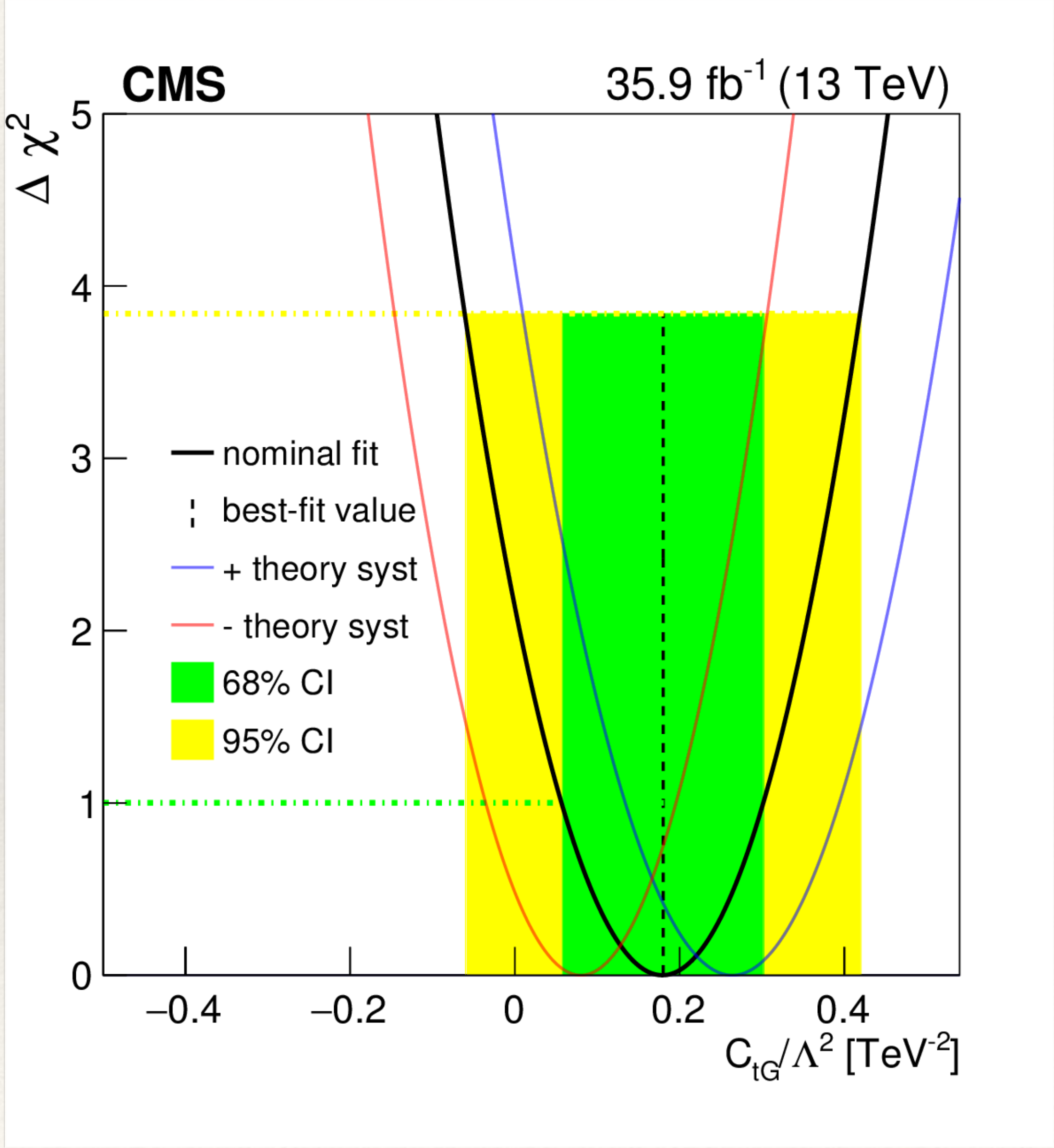
CMS Extractions of Chromo-magnetic operator Wilson coefficient constraints from measurements of ttbar differential cross sections using events containing two leptons

Chromo-magnetic dipole operator O_{tG} modifies gtt vertex inducing effects on ttbar production rate and $\Delta\phi(ll)$ for azimuthal angle between ℓs from di-leptonic ttbar events;



Probes interplay between top and Higgs sectors;





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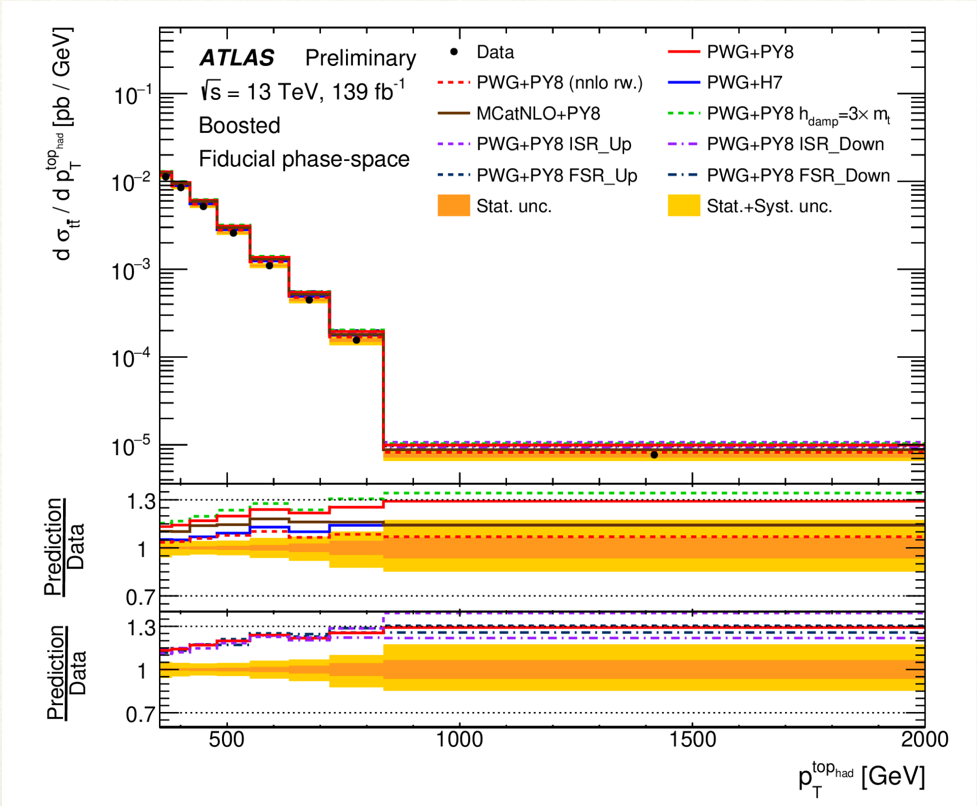
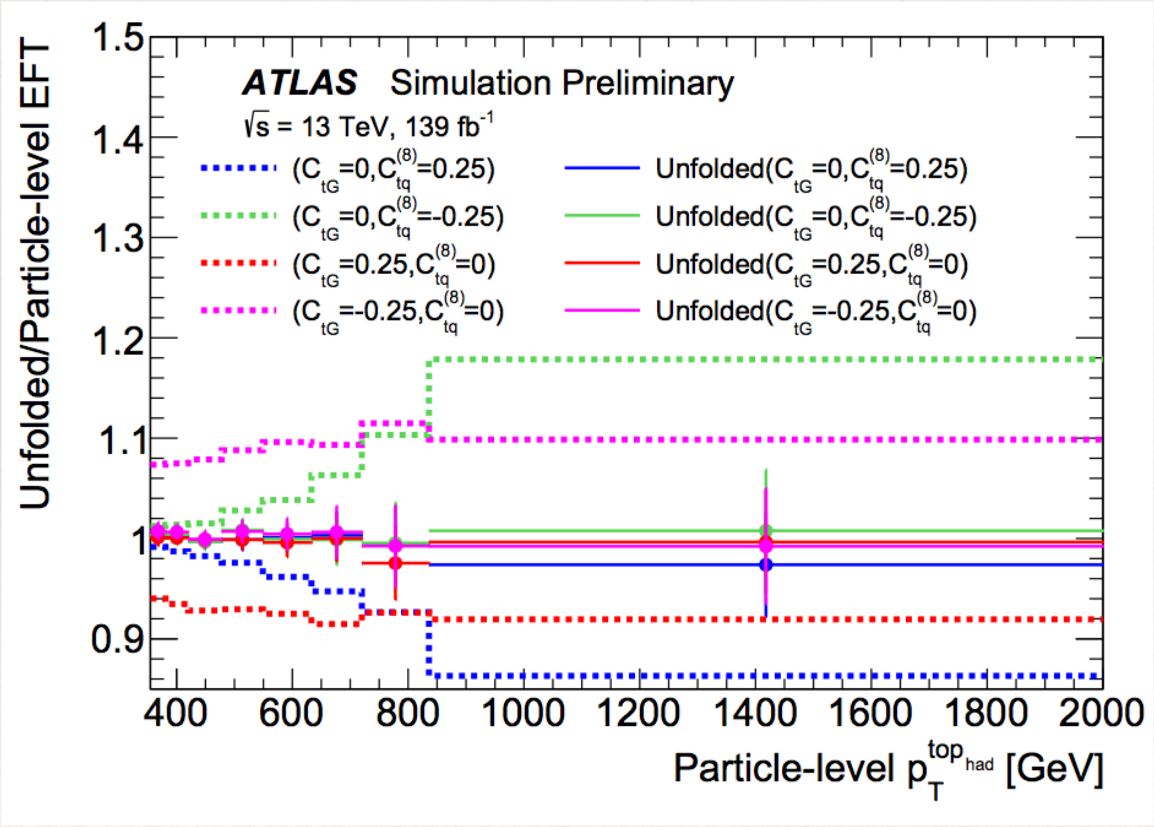
ATLAS Measurements of differential cross-sections in top-quark pair events with a high transverse momentum top quark and limits on BSM contributions to top-quark pair production



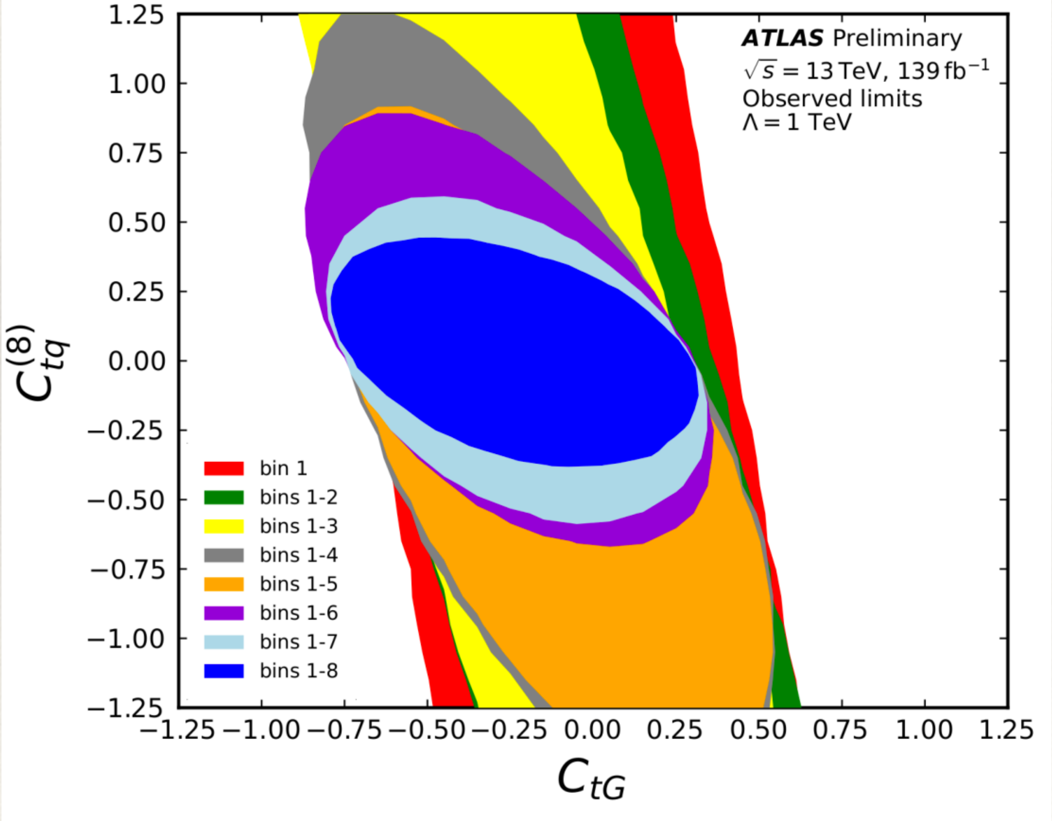
Precise cross-section measurements of ttbar events containing high-p_T hadronically decaying top:

- Distributions unfolded to particle level.
- Precision significantly improved by use of invariant mass of hadronic top decay jet to reduce impact of JES uncertainties.

Probes chromo-magnetic dipole + four-fermion top operators:



Evolution of 95% C.L. Wilson coeff. region when adding p_T bins in increasing value order

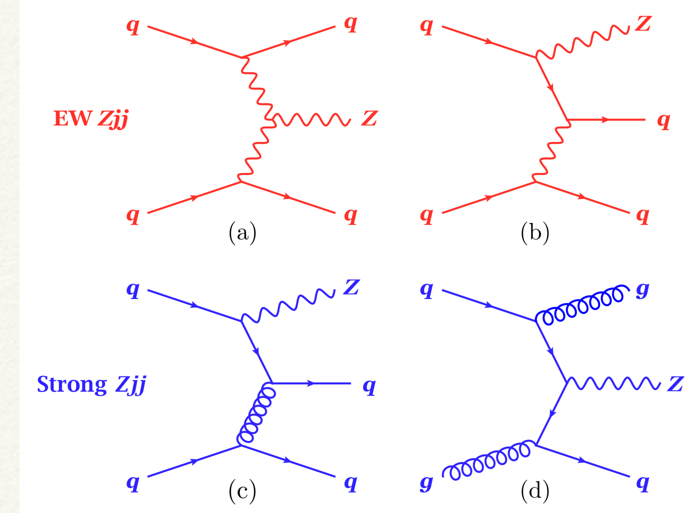


Wilson coefficient	Marginalised 95% intervals		Individual 95% intervals		
	Expected	Observed	Expected	Observed	Global fit [101]
C_{tG}	[-0.44, 0.44]	[-0.68, 0.21]	[-0.41, 0.42]	[-0.63, 0.20]	[0.007, 0.111]
$C_{tq}^{(8)}$	[-0.35, 0.35]	[-0.30, 0.36]	[-0.35, 0.36]	[-0.34, 0.27]	[-0.40, 0.61]

ATLAS-CONF-2021-031

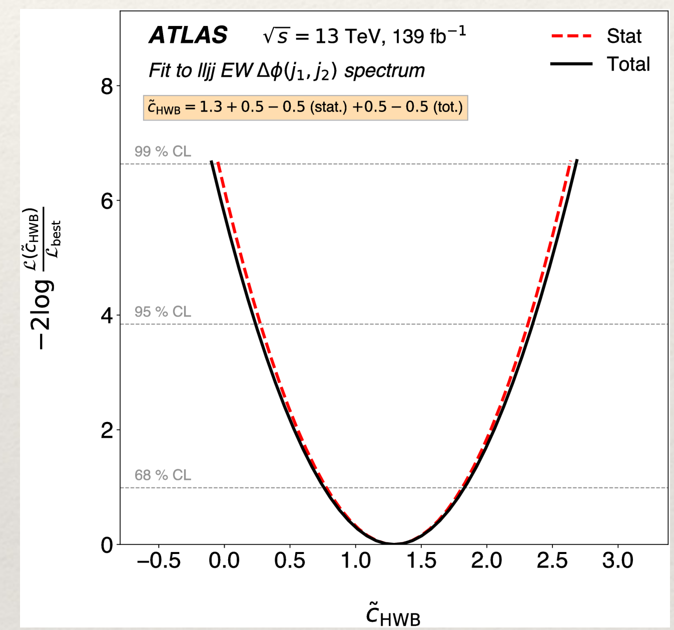
See also ATLAS-CONF-2021-050

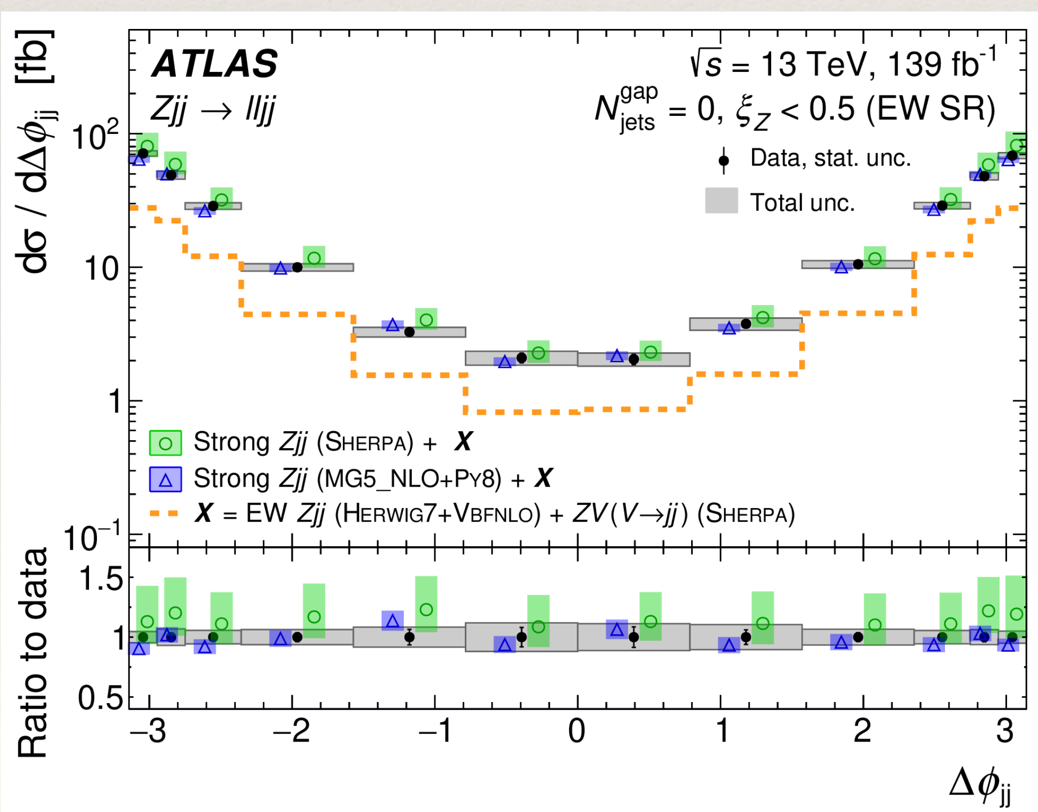
Differential ATLAS cross-section measurements for electro-weak production of dijets in association with Z boson

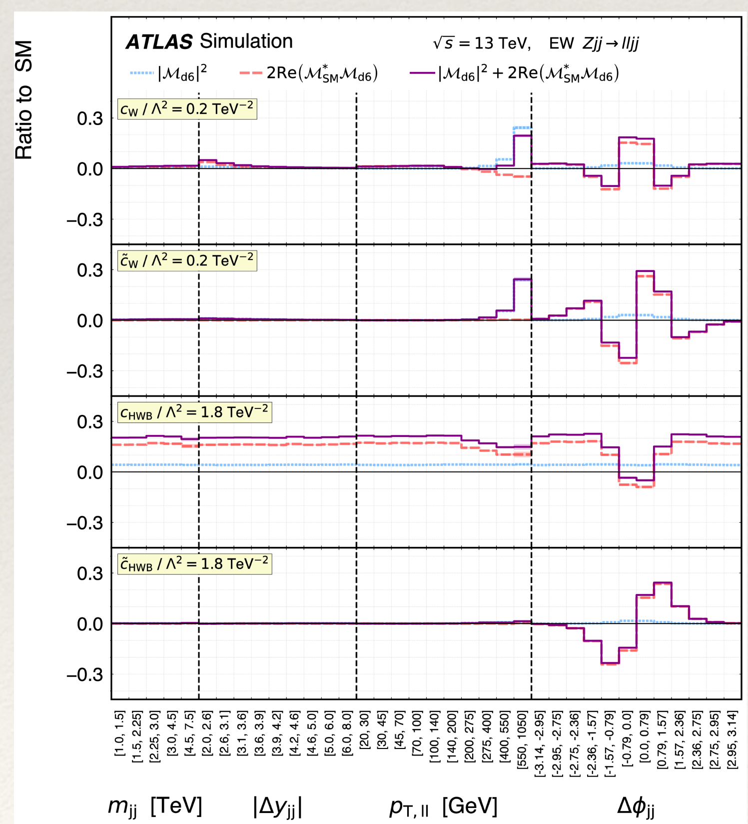


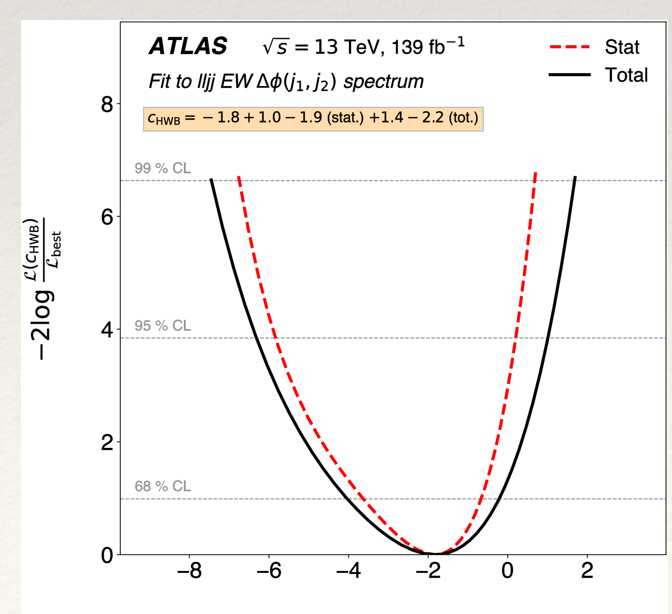
Differential cross-section measurements for EW production of two jets + Z; Measurements sensitive to vector-boson fusion production mechanism and provide a fundamental test of SM gauge structure;

Differential cross-sections used in search for anomalous weak-boson self-interactions bosonic dim-6 EFT operators. Signed azimuthal angle between two jets sensitive to interference between the SM and dim-6 scattering amplitudes.





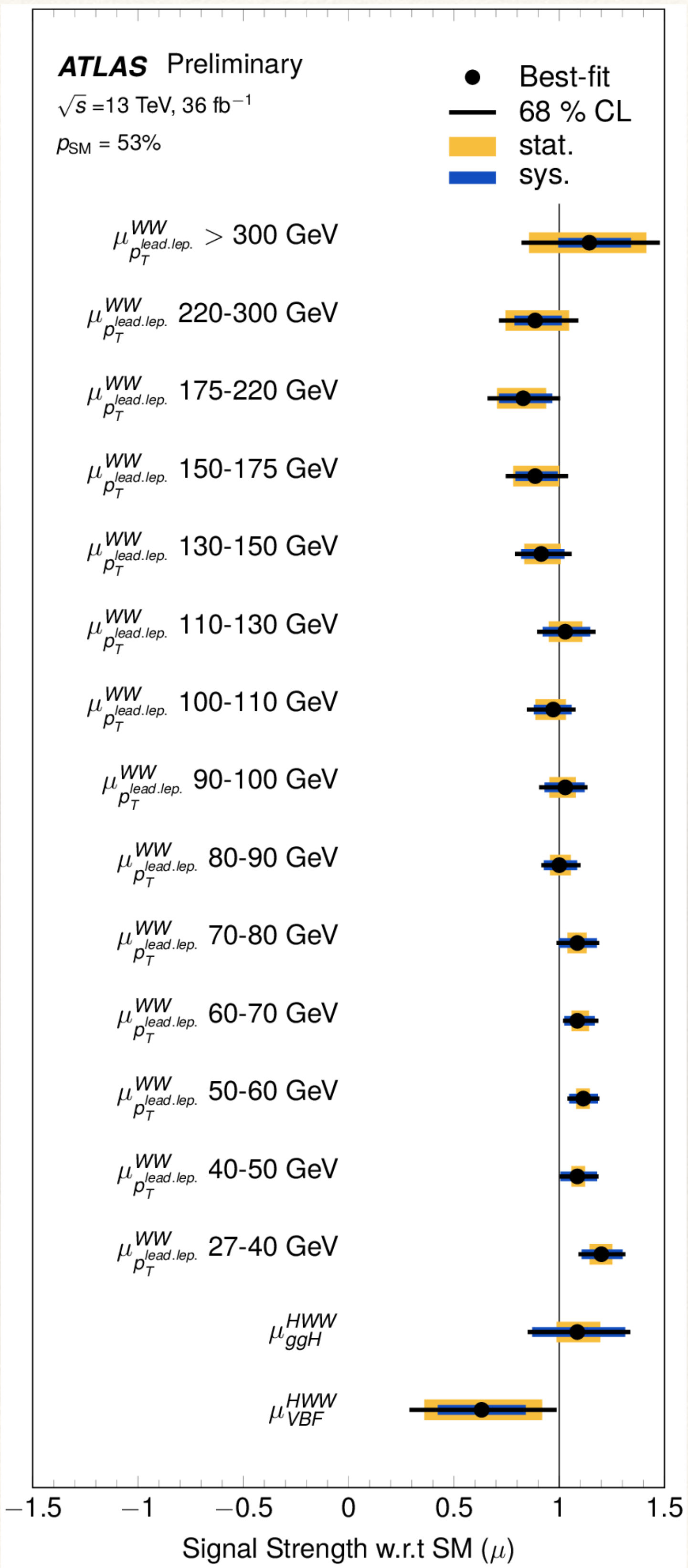




Eur. Phys. J. C 81 (2021) 163

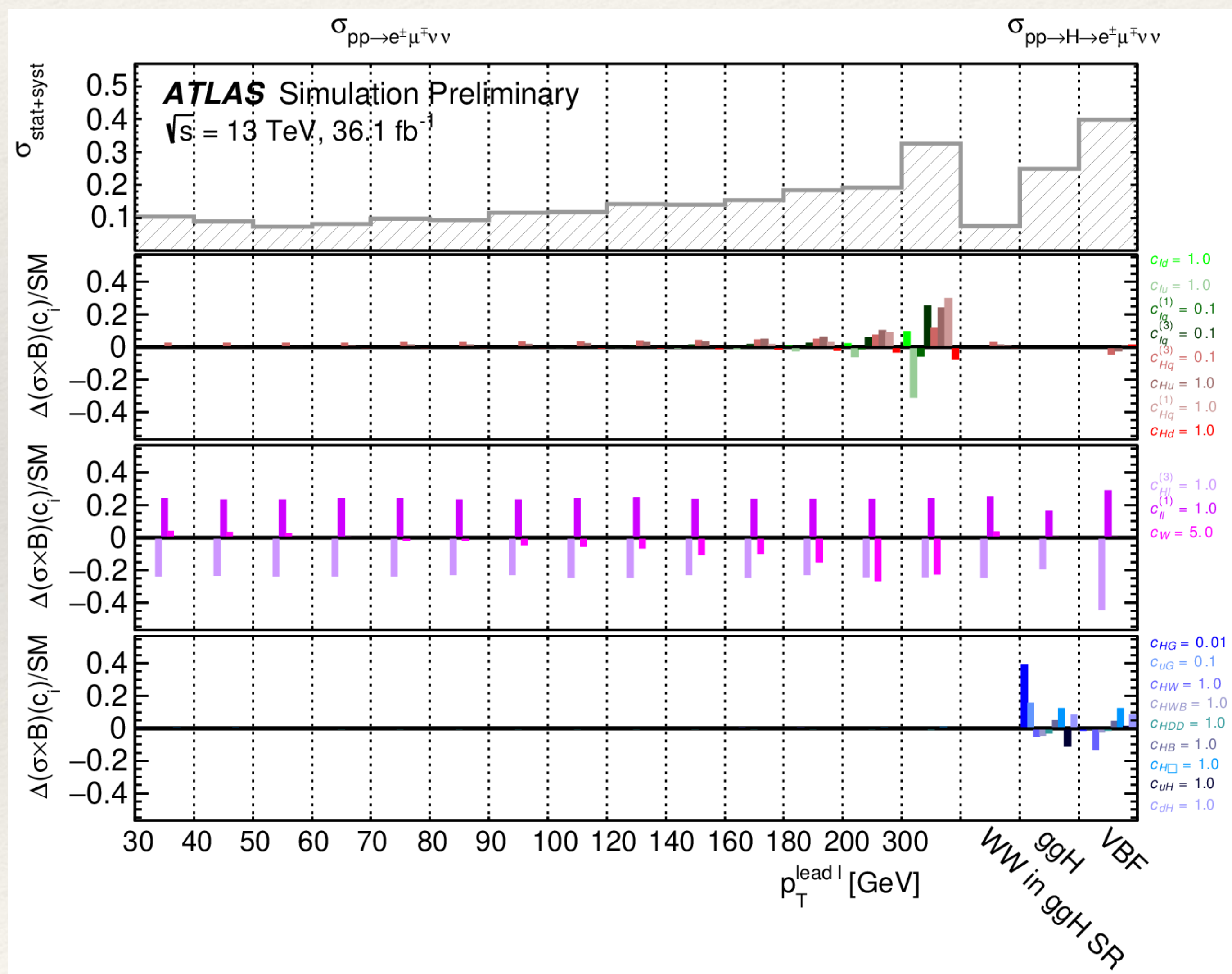
Combined effective field theory interpretation of ATLAS H→WW* and WW measurements

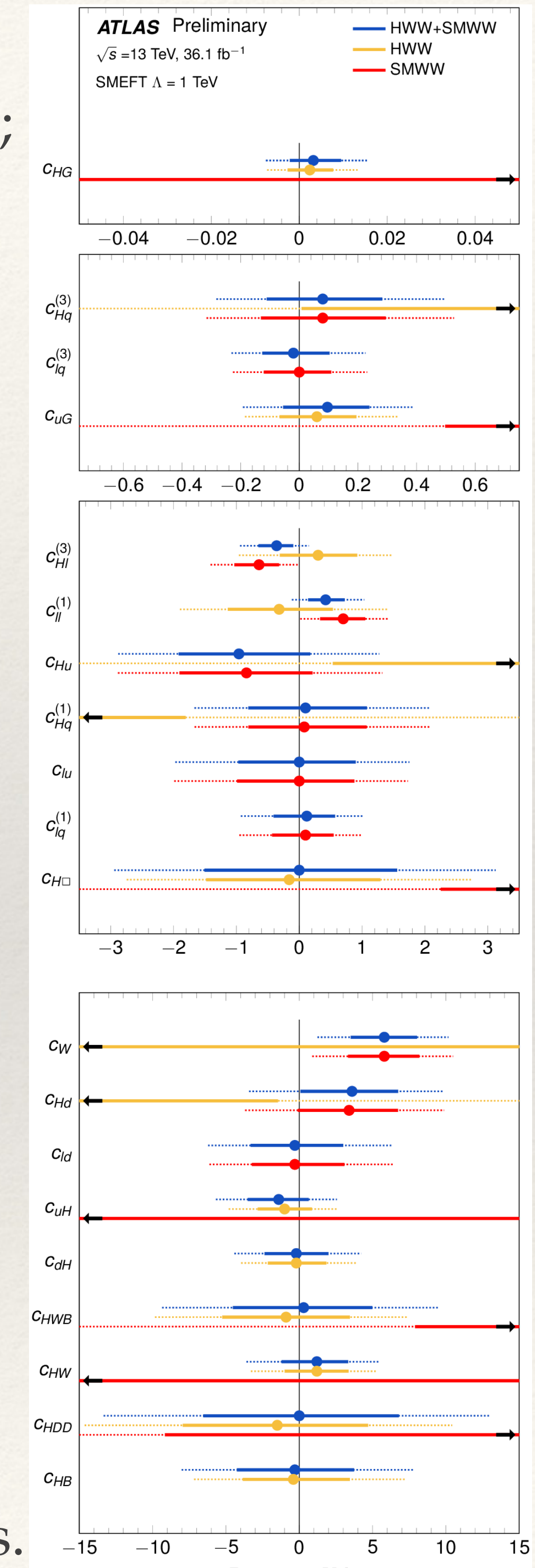
EFT constraints by combination of H→WW* in ggF and vector fusion production
with differential results on WW di-boson production in 0-jet channel.



Likelihood function from μ of Higgs measurement together with unfolded differential WW cross-sections;

Constrain 22 Wilson coeffs. of bosonic and two-fermion operators in SMEFT framework.





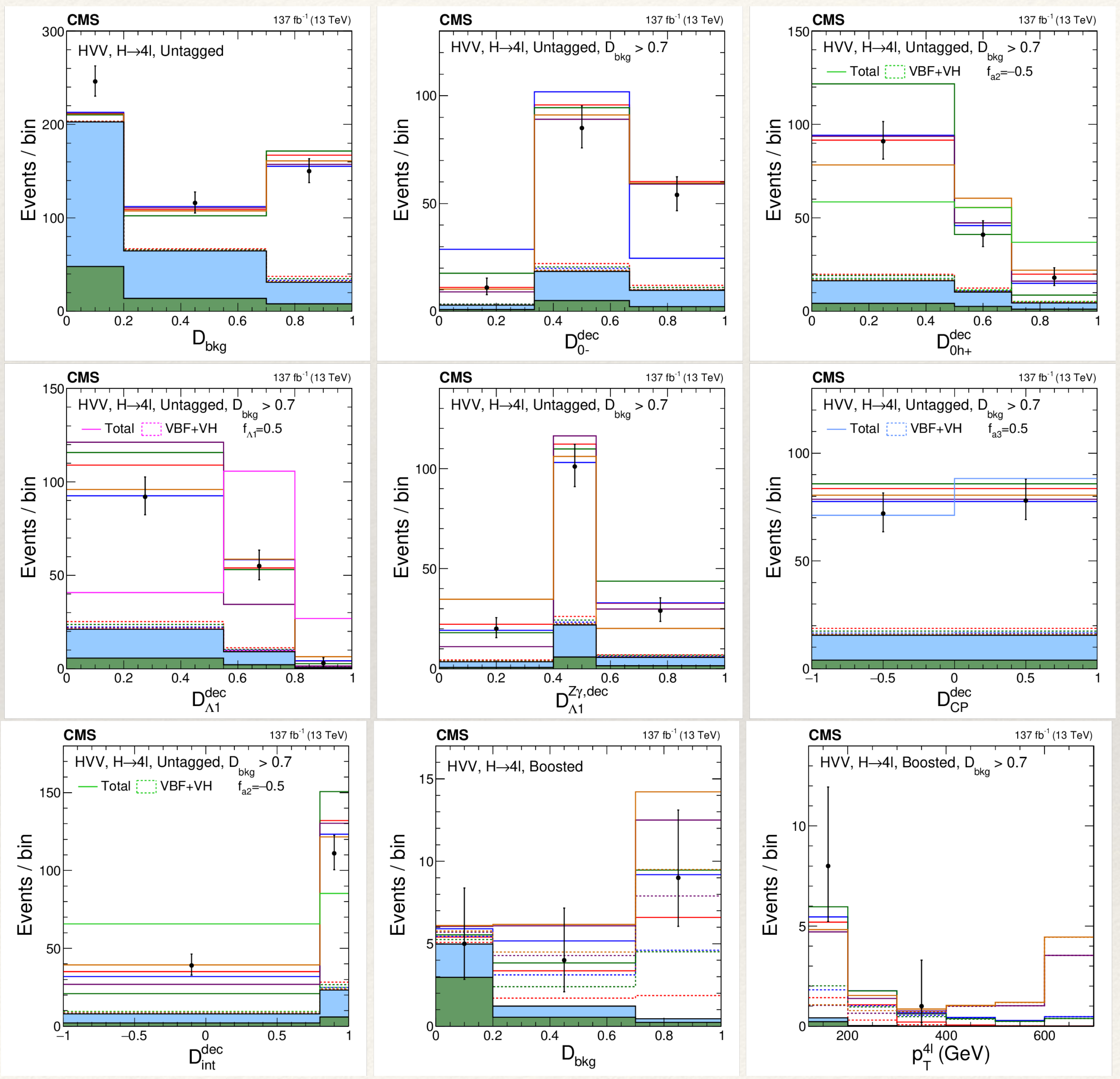
Stepping stone towards more global EFT combinations.

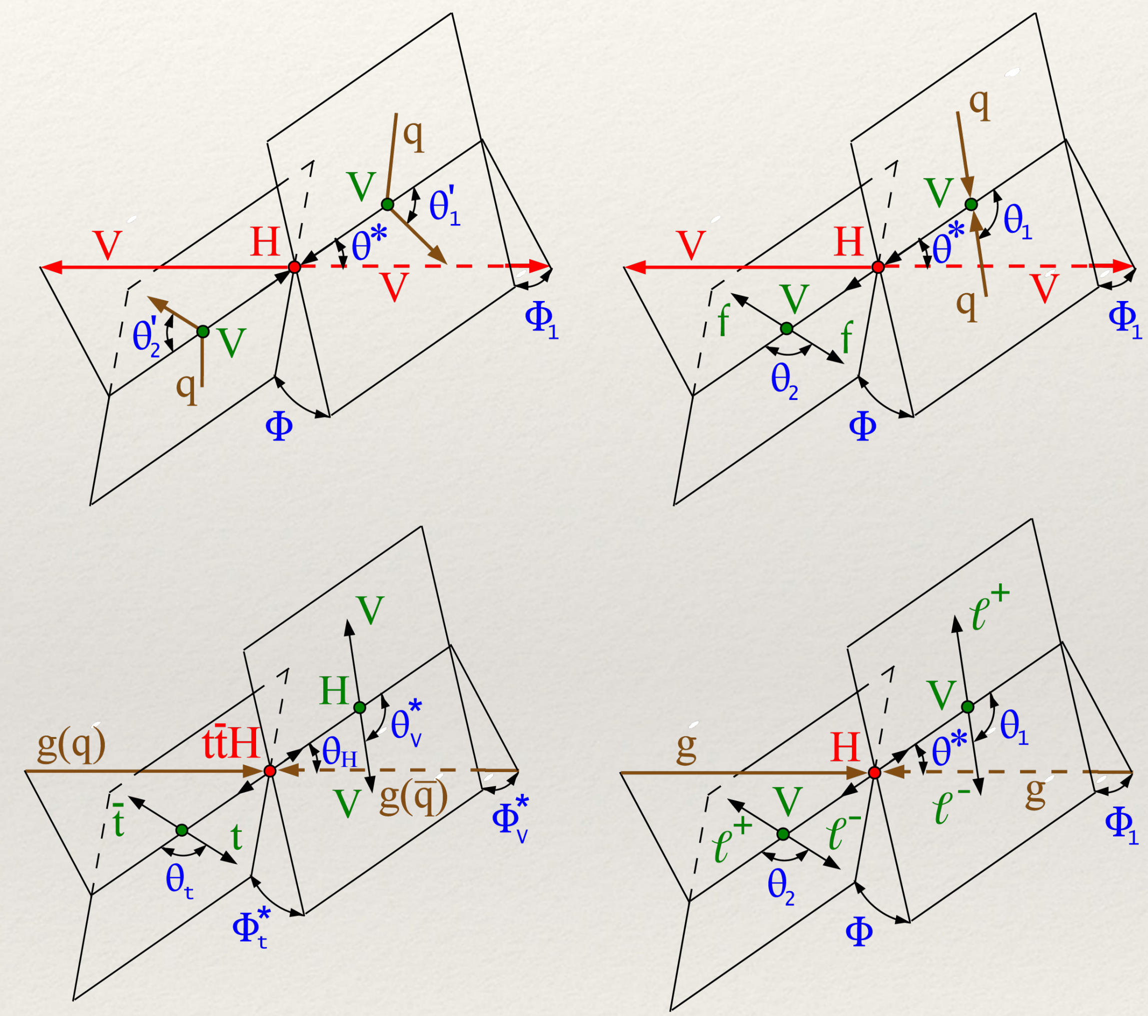
ATL-PHYS-PUB-2021-010

Additional Material

CMS Constraints on anomalous Higgs boson couplings to vector bosons and fermions in production and decay using four-ℓ final state

Discriminants from matrix element calculations





Phys. Rev. D 104 (2021) 052004

CMS Constraints on anomalous Higgs boson couplings to vector bosons and fermions in production and decay using four-ℓ final state

$$A(\mathrm{HVV}) = \frac{1}{v}\left[a_1^{\mathrm{VV}} + \frac{\kappa_1^{\mathrm{VV}} q_{\mathrm{V1}}^2 + \kappa_2^{\mathrm{VV}} q_{\mathrm{V2}}^2}{\left(\Lambda_1^{\mathrm{VV}}\right)^2} + \frac{\kappa_3^{\mathrm{VV}} (q_{\mathrm{V1}} + q_{\mathrm{V2}})^2}{\left(\Lambda_{\mathrm{Q}}^{\mathrm{VV}}\right)^2}\right] m_{\mathrm{V1}}^2 \epsilon_{\mathrm{V1}}^* \epsilon_{\mathrm{V2}}^* + \frac{1}{v} a_2^{\mathrm{VV}} f_{\mu\nu}^{*(1)} f^{*(2),\mu\nu} + \frac{1}{v} a_3^{\mathrm{VV}} f_{\mu\nu}^{*(1)} \tilde{f}^{*(2),\mu\nu},$$

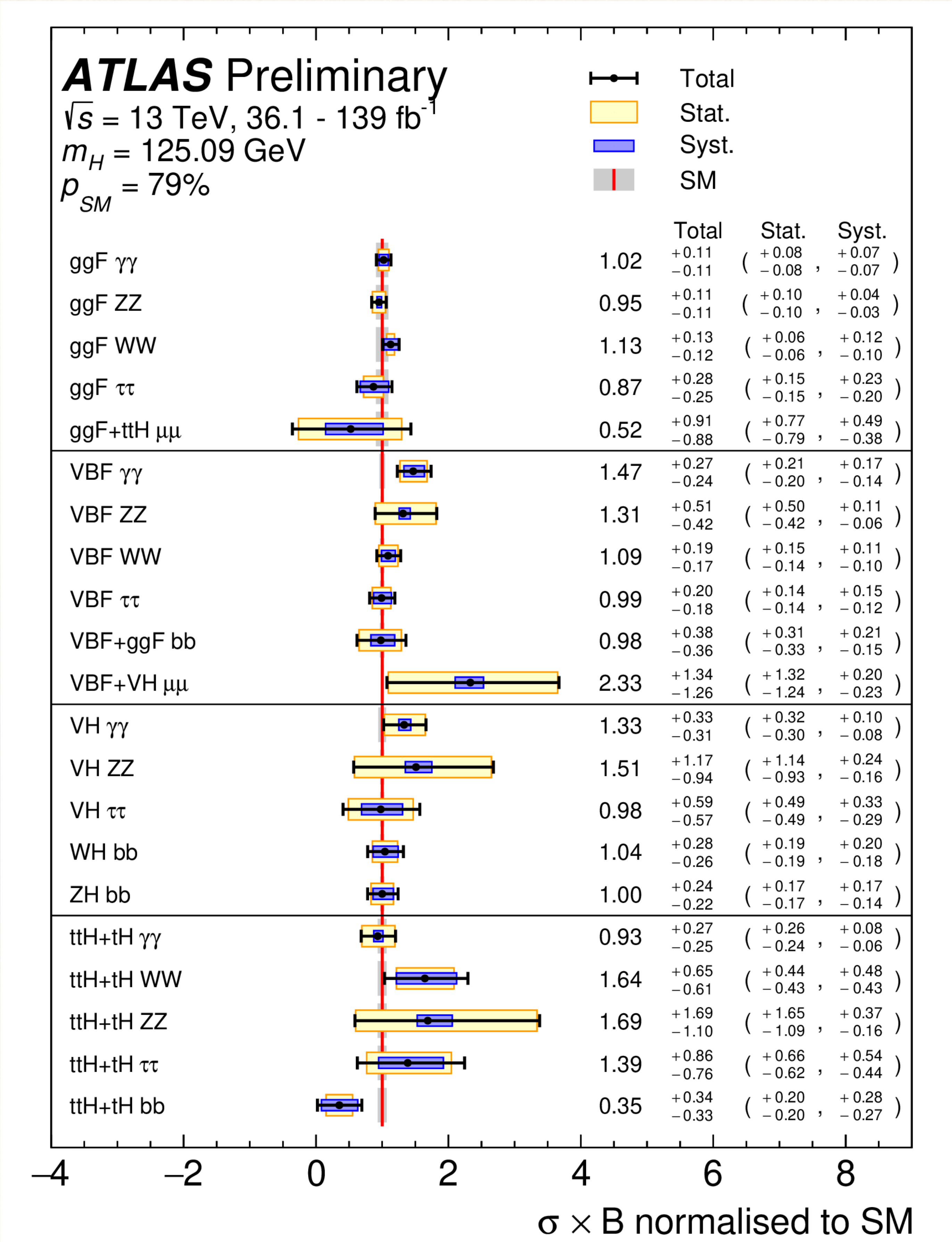
$$\begin{aligned}
a_1^{\mathrm{WW}} &= a_1^{\mathrm{ZZ}}, \\
a_2^{\mathrm{WW}} &= c_w^2 a_2^{\mathrm{ZZ}} + s_w^2 a_2^{\gamma\gamma} + 2 s_w c_w a_2^{\mathrm{Z}\gamma}, \\
a_3^{\mathrm{WW}} &= c_w^2 a_3^{\mathrm{ZZ}} + s_w^2 a_3^{\gamma\gamma} + 2 s_w c_w a_3^{\mathrm{Z}\gamma}, \\
\frac{\kappa_1^{\mathrm{WW}}}{(\Lambda_1^{\mathrm{WW}})^2}(c_w^2 - s_w^2) &= \frac{\kappa_1^{\mathrm{ZZ}}}{(\Lambda_1^{\mathrm{ZZ}})^2} + 2 s_w^2 \frac{a_2^{\gamma\gamma} - a_2^{\mathrm{ZZ}}}{m_{\mathrm{Z}}^2} + 2\frac{s_w}{c_w}(c_w^2 - s_w^2)\frac{a_2^{\mathrm{Z}\gamma}}{m_{\mathrm{Z}}^2}, \\
\frac{\kappa_2^{\mathrm{Z}\gamma}}{(\Lambda_1^{\mathrm{Z}\gamma})^2}(c_w^2 - s_w^2) &= 2 s_w c_w \left(\frac{\kappa_1^{\mathrm{ZZ}}}{(\Lambda_1^{\mathrm{ZZ}})^2} + \frac{a_2^{\gamma\gamma} - a_2^{\mathrm{ZZ}}}{m_{\mathrm{Z}}^2}\right) + 2(c_w^2 - s_w^2)\frac{a_2^{\mathrm{Z}\gamma}}{m_{\mathrm{Z}}^2},
\end{aligned}$$

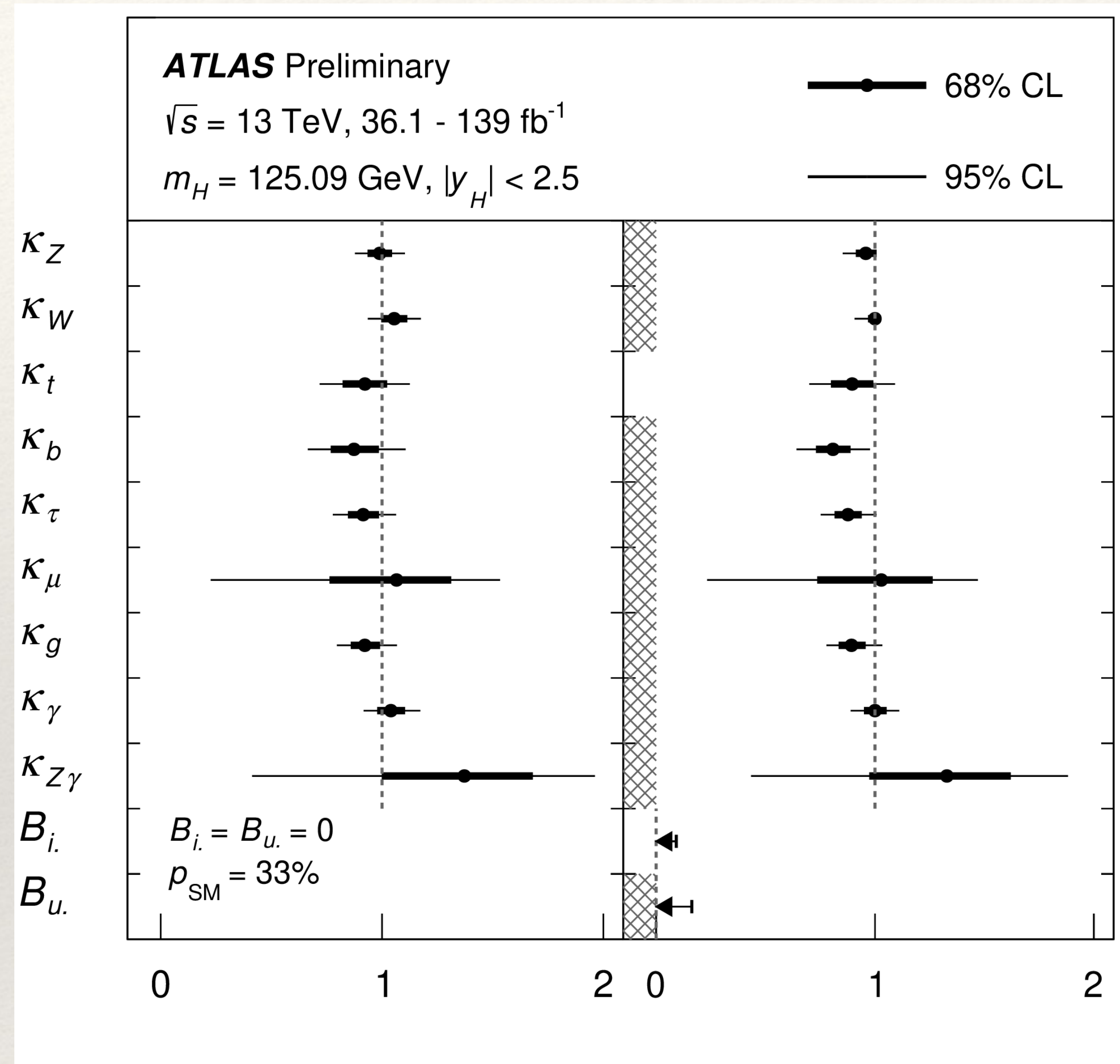
$$\begin{aligned}
\delta c_z &= \frac{1}{2} a_1 - 1, \\
c_{z\Box} &= \frac{m_{\mathrm{Z}}^2 s_w^2}{e^2} \frac{\kappa_1}{(\Lambda_1)^2}, \\
c_{zz} &= -\frac{2 s_w^2 c_w^2}{e^2} a_2, \\
\tilde{c}_{zz} &= -\frac{2 s_w^2 c_w^2}{e^2} a_3.
\end{aligned}$$

$$\begin{aligned}
c_{gg} &= -\frac{1}{2\pi\alpha_s} a_2^{gg}, \\
\tilde{c}_{gg} &= -\frac{1}{2\pi\alpha_s} a_3^{gg}.
\end{aligned}$$

Phys. Rev. D 104 (2021) 052004

Interpretations of ATLAS combined measurement of Higgs boson production and decay

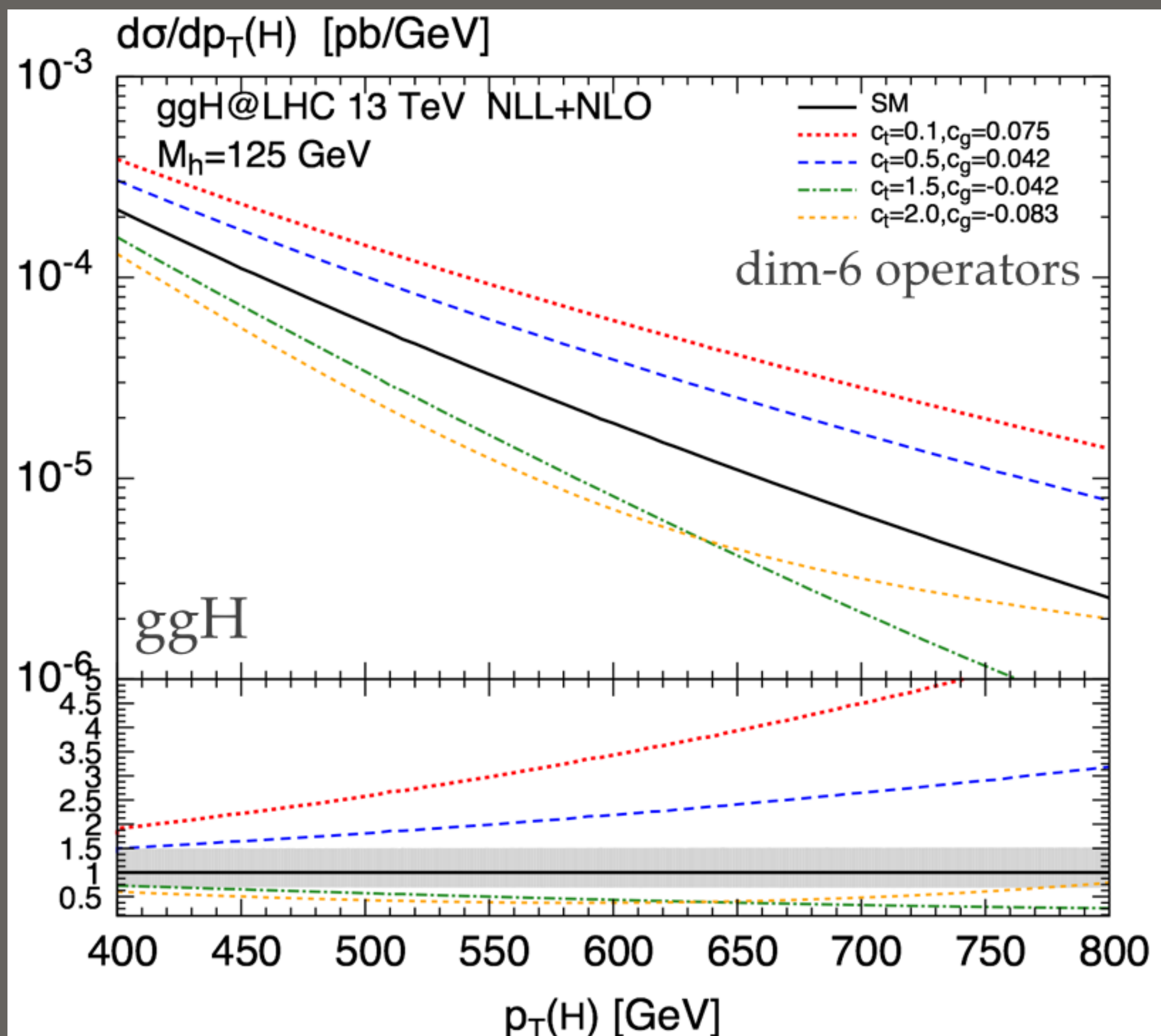


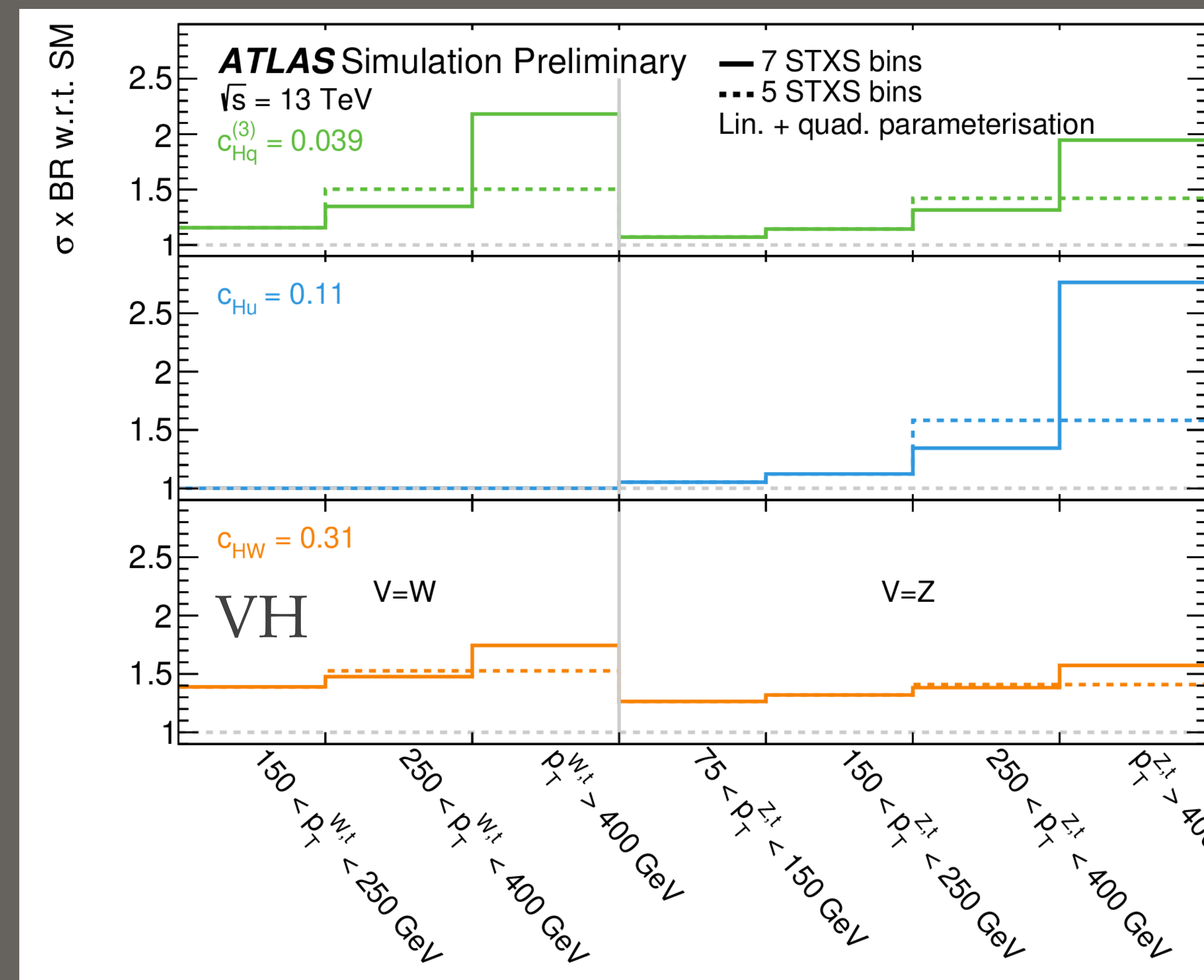


ATLAS-CONF-2021-053

The Case for High p_T Higgs Measurements

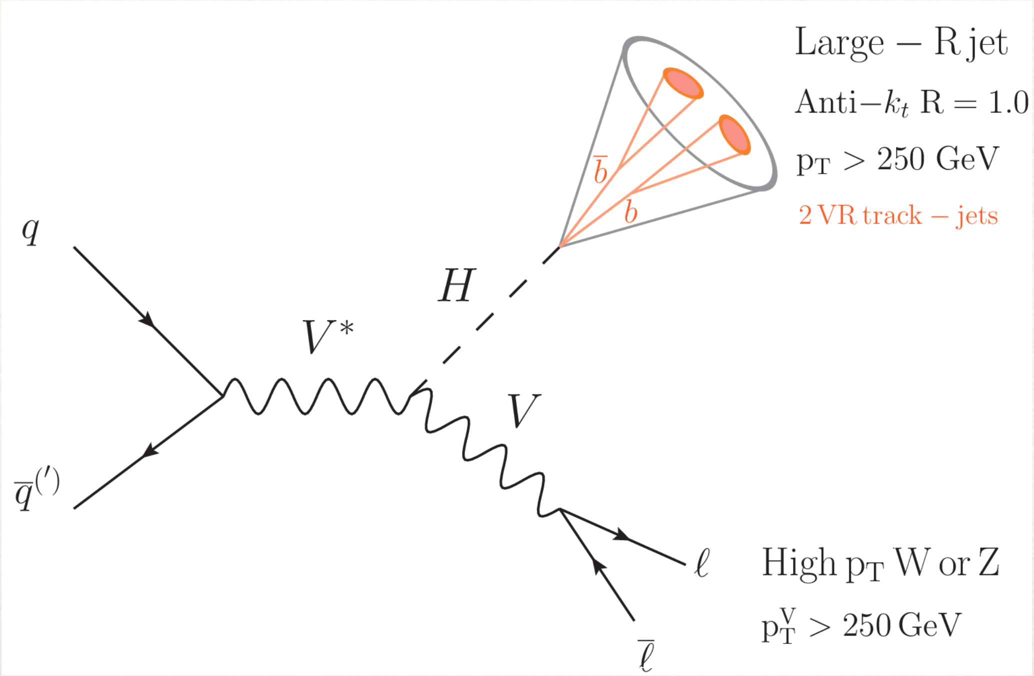
Grazzini, Ilnicka,Spira, Wiesemann, JHEP 03 (2017) 115

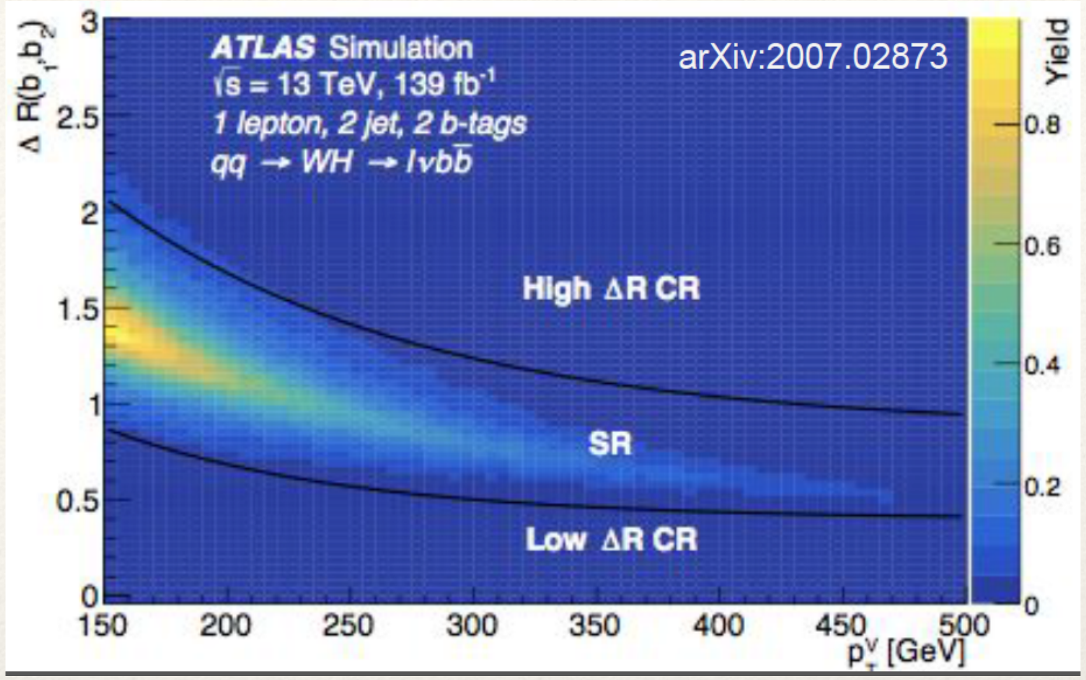


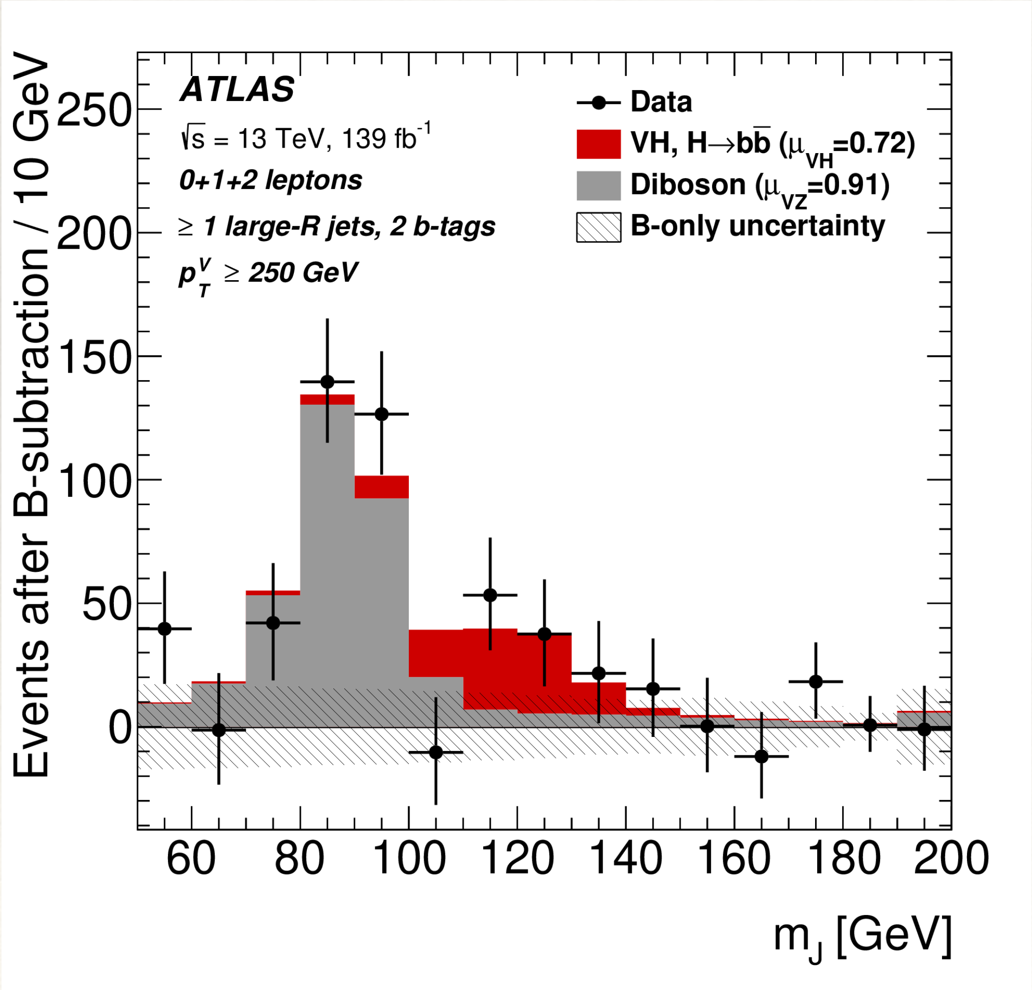


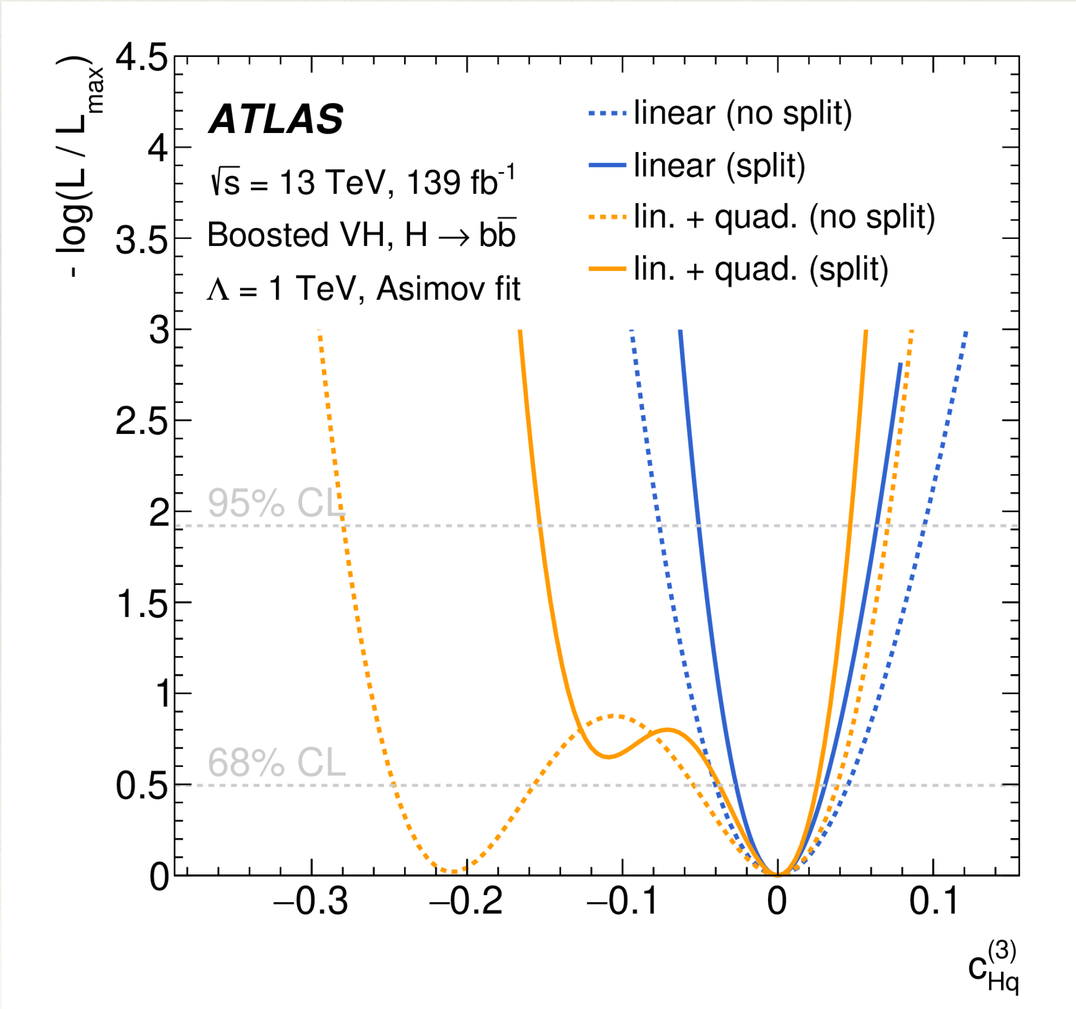
ATLAS-CONF-2021-051

ATLAS Measurement of the associated production of a Higgs boson decaying to b quarks with a vector boson at high transverse momentum



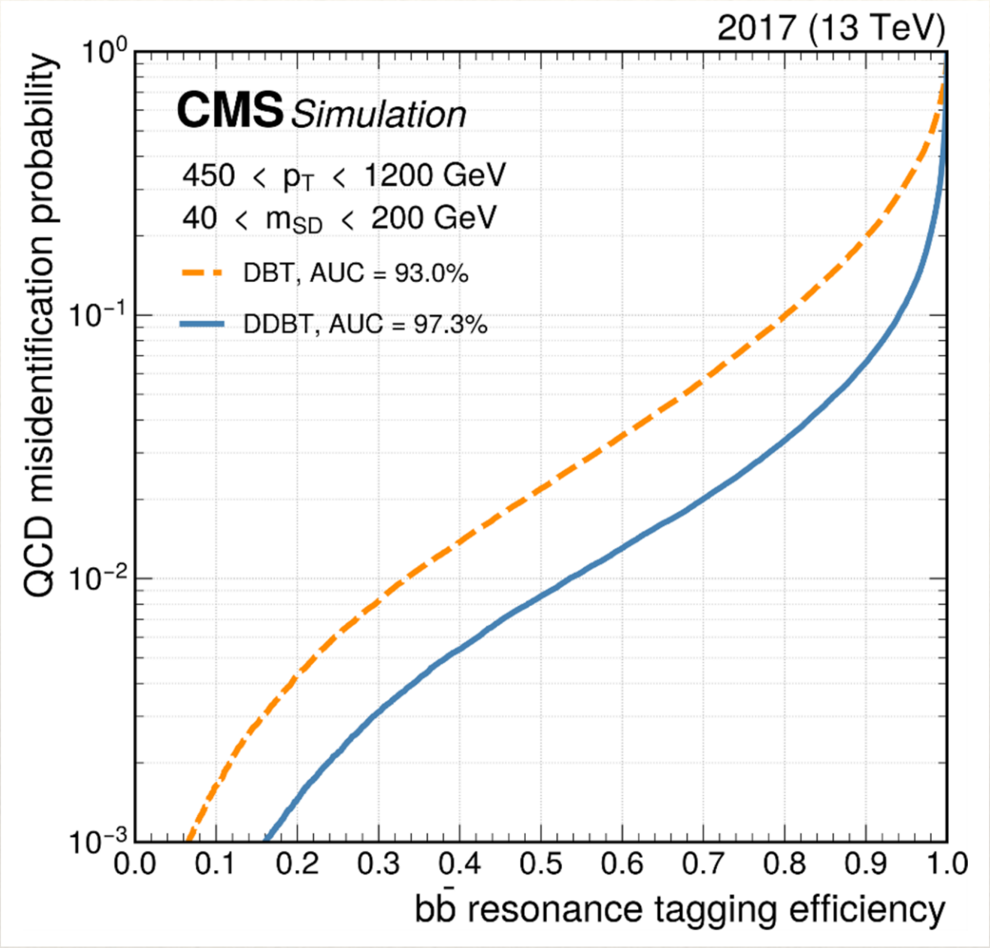


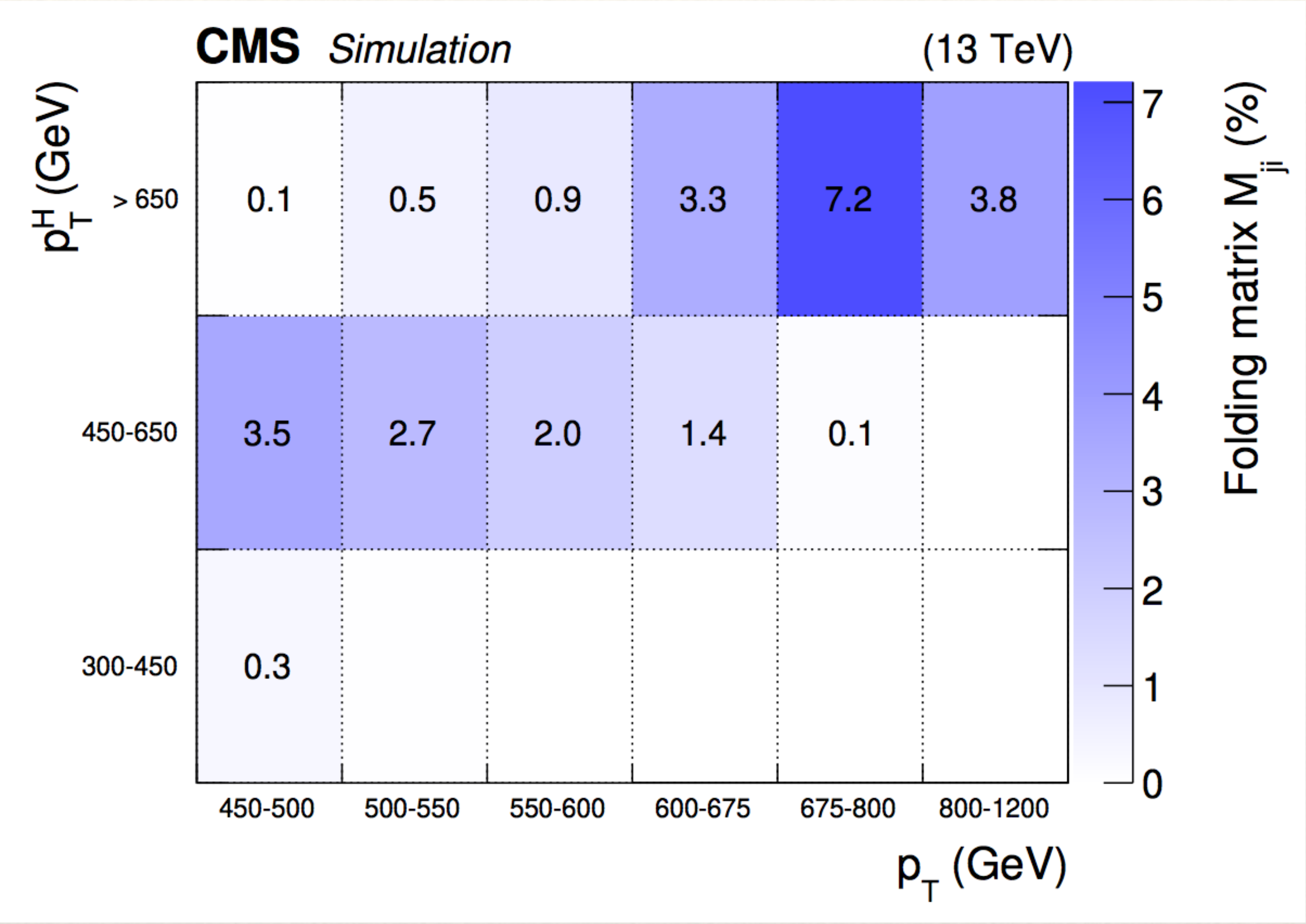




Phys. Lett. B 816 (2021) 136204

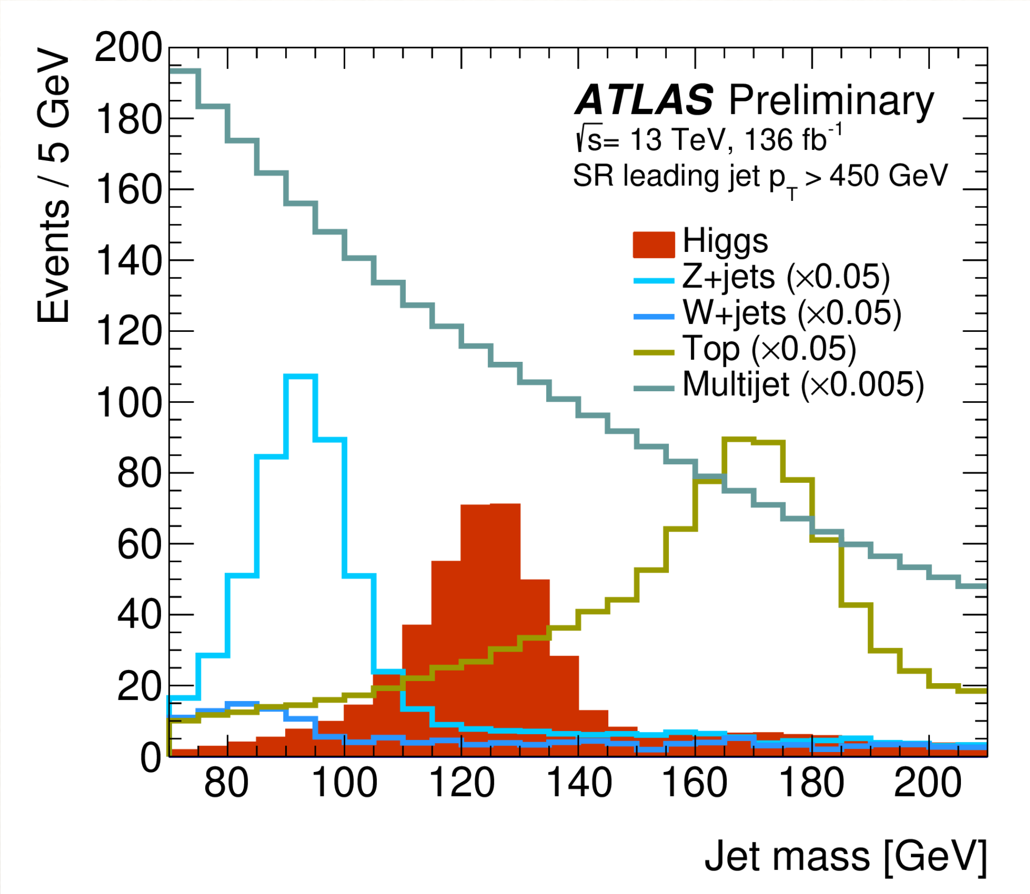
CMS Inclusive Search for Highly Boosted H → bb

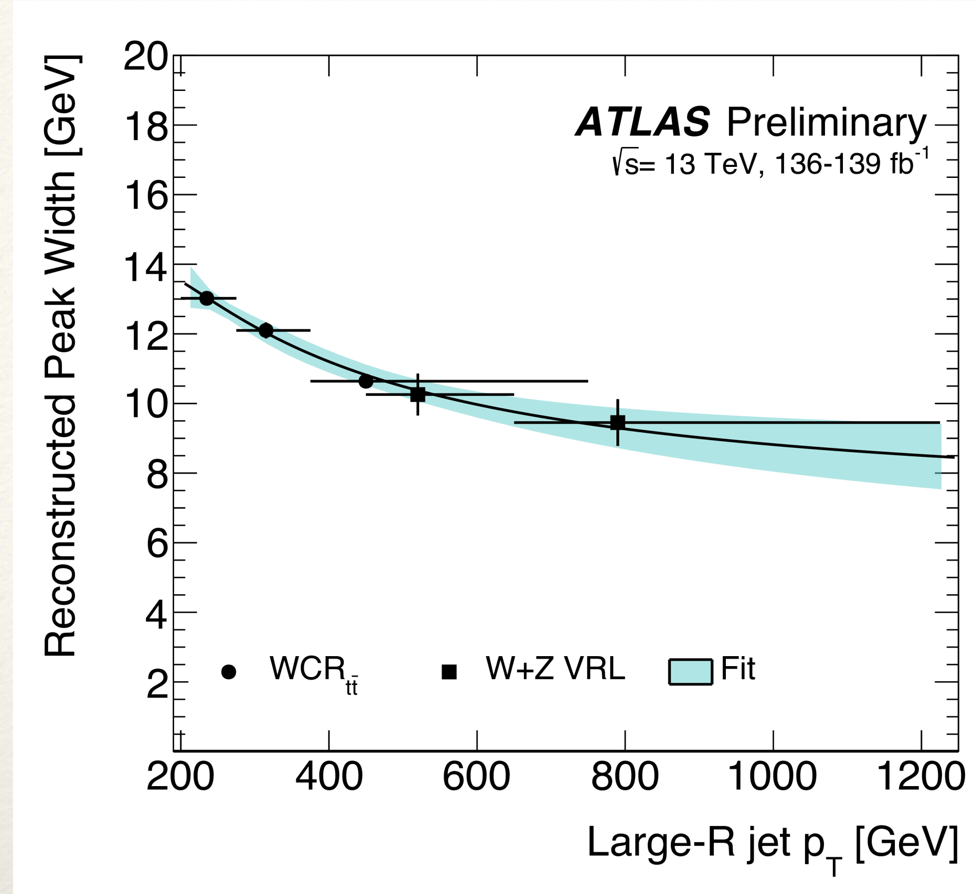


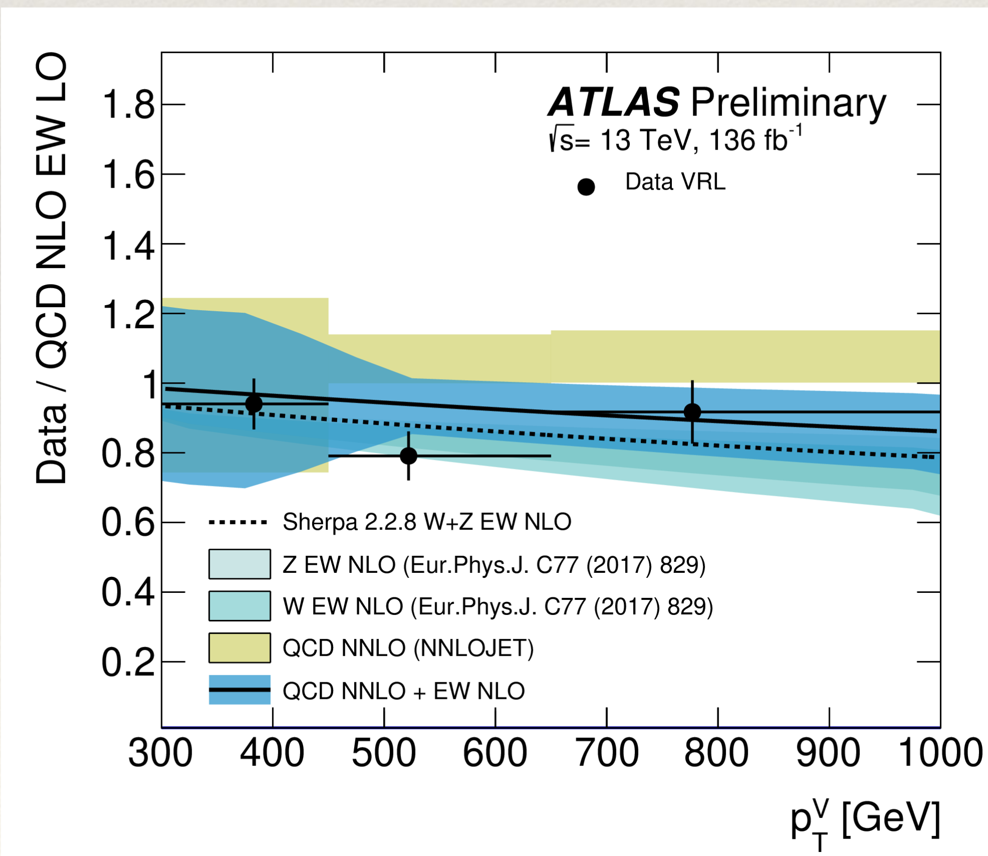


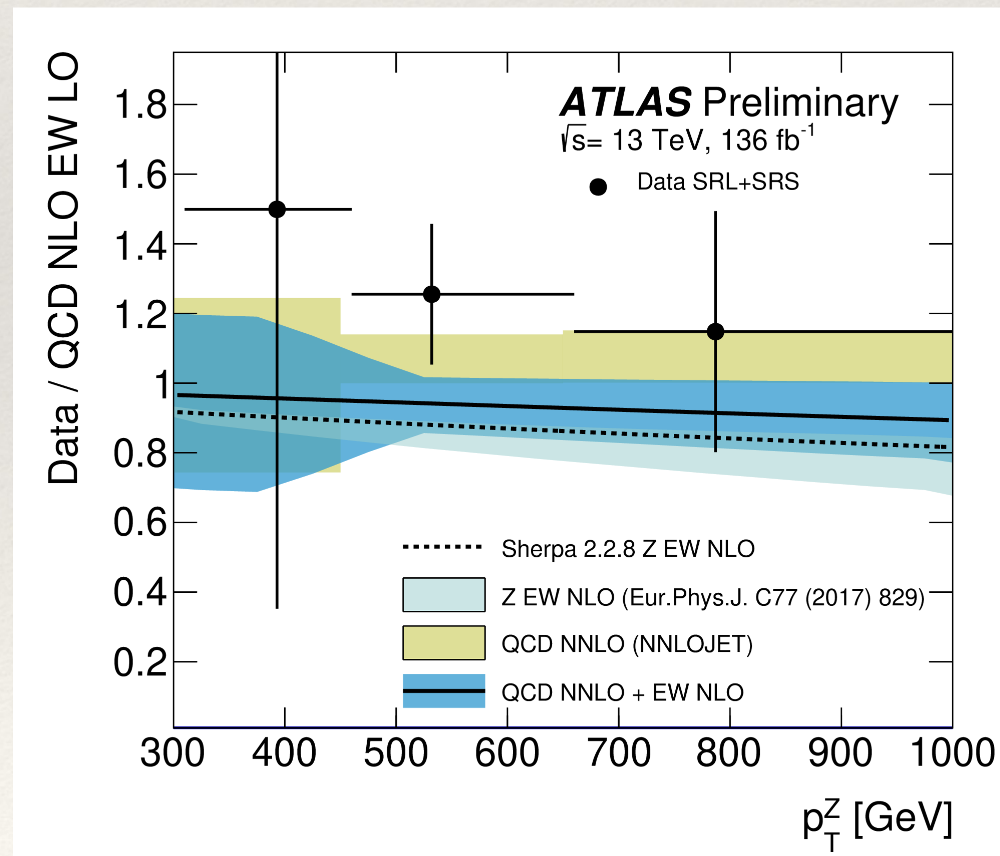
JHEP 12 (2020) 085

ATLAS Study of Higgs-boson production with large transverse momentum using H→bb



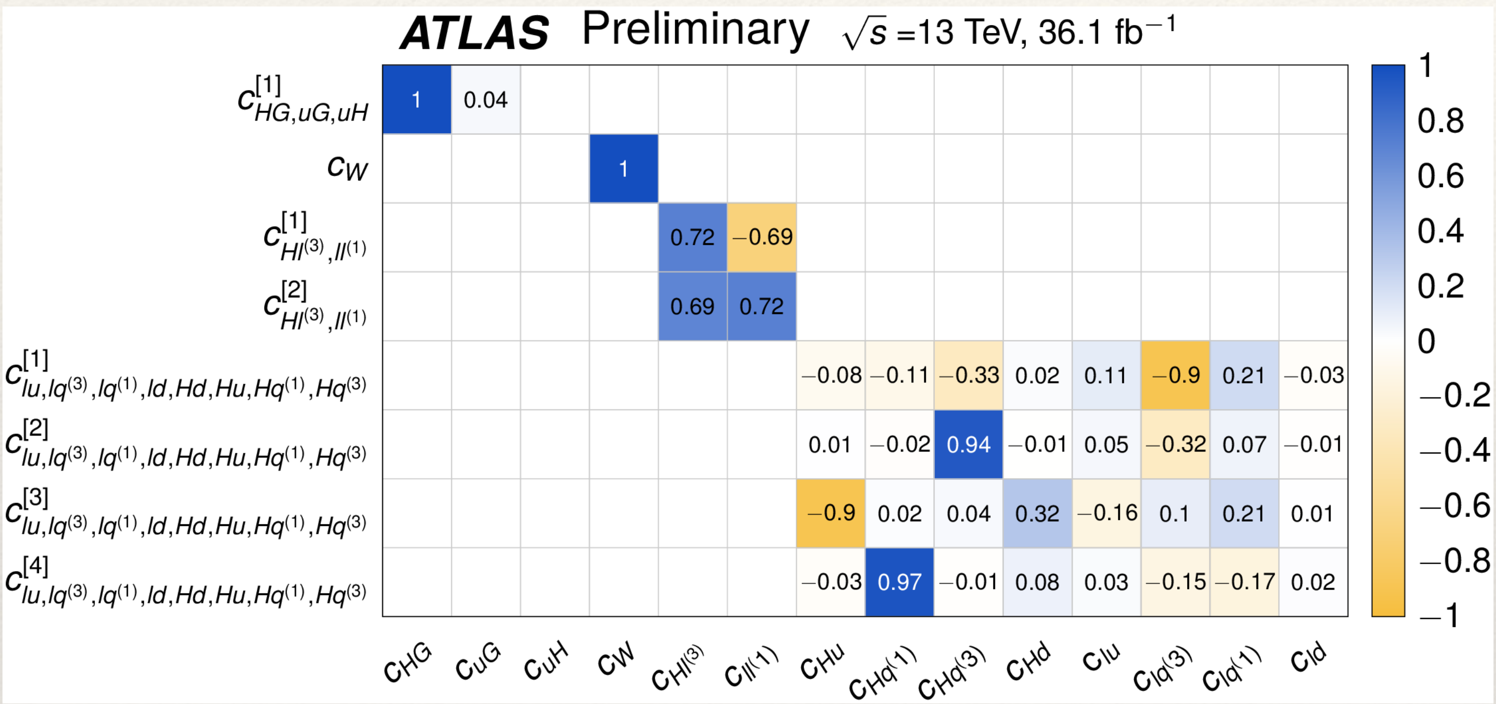


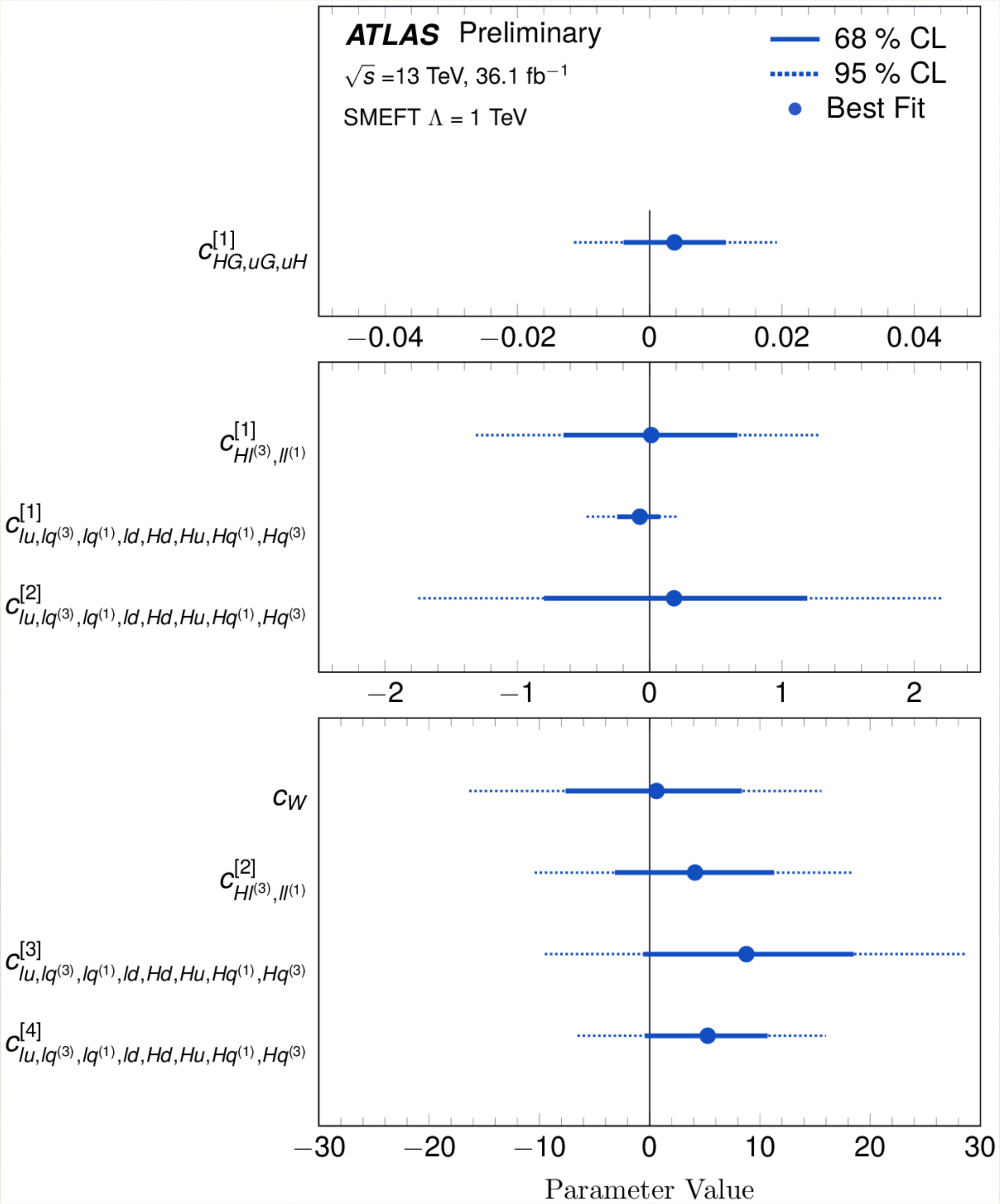




ATLAS-CONF-2021-010

Combined effective field theory interpretation of ATLAS H→WW* and WW measurements





ATL-PHYS-PUB-2021-010