CHRIS MURPHY

SMEFT AT HL/HE LHC

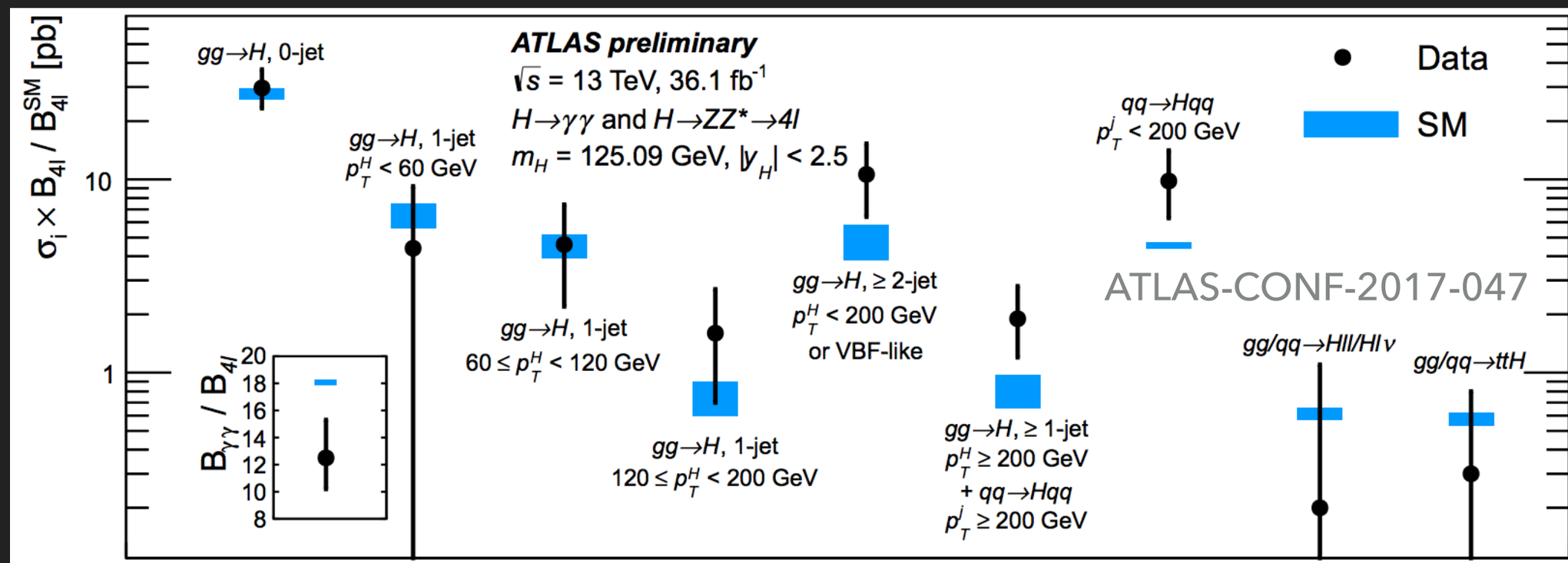
UPDATED GLOBAL SMEFT FIT TO HIGGS, DIBOSON, AND ELECTROWEAK DATA

- Global fit to precision electroweak data, W^+W^- at LEP 2, Higgs and diboson data from LHC Runs 1 and 2
- Results in Warsaw (this talk) and SILH bases / improvement in the constraints from LHC Run 2
- Projected (preliminary) constraints for HL- and HE-LHC
- Constraints on BSM models (if time)
- Higgs production in SMEFT at 27 vs. 13 TeV (if time)

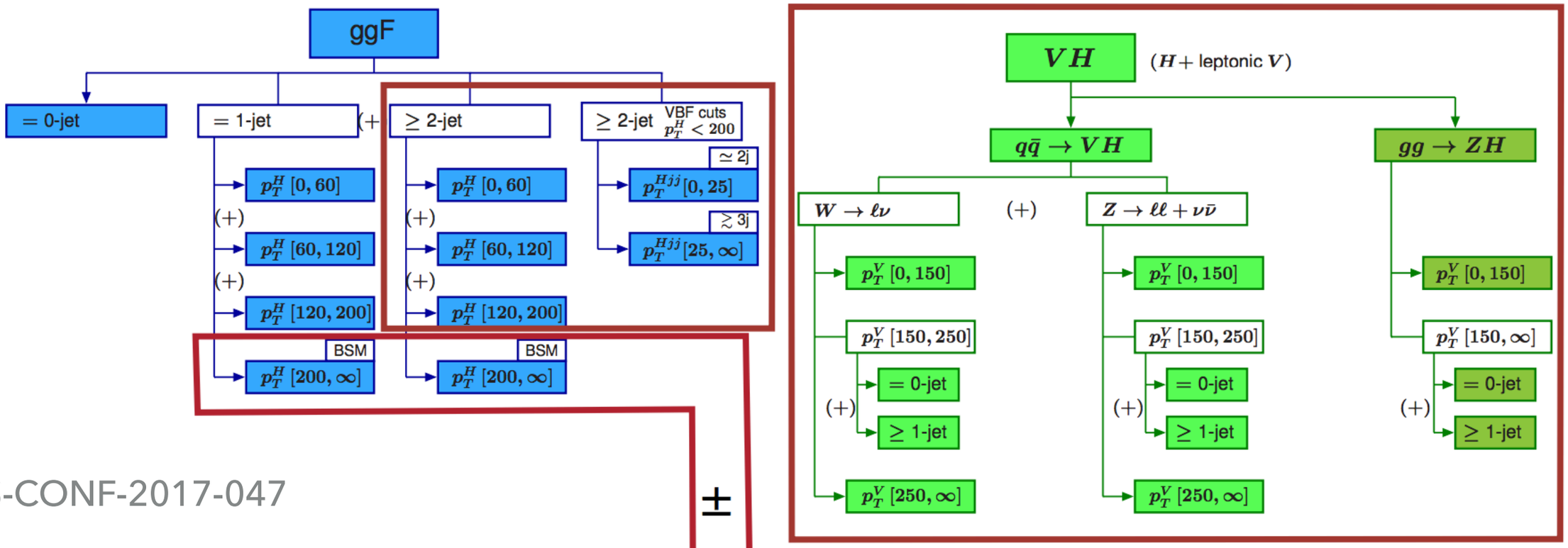
John Ellis, CM, Verónica Sanz, & Tevong You, arXiv:1803.03252

NEXT-GENERATION ANALYSIS

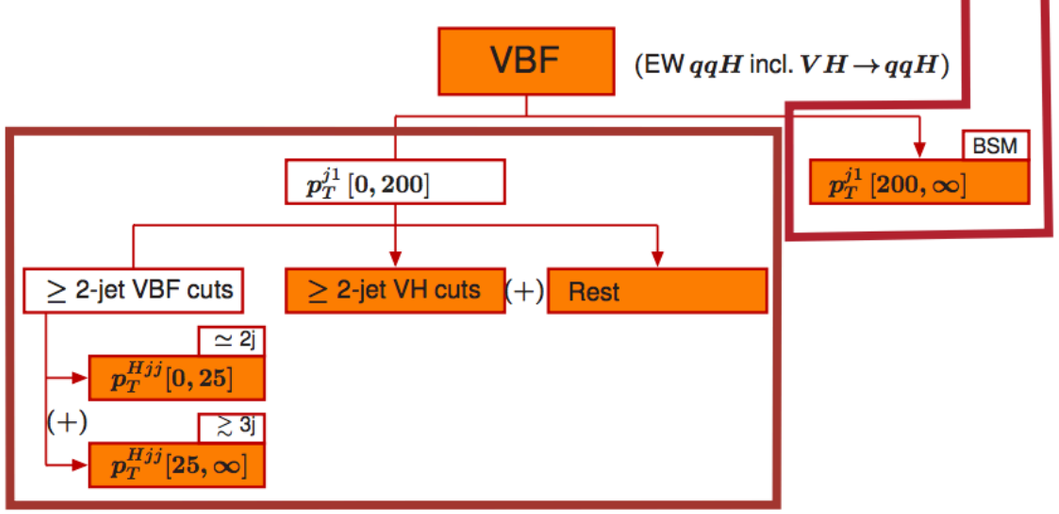
- Previously assumed:
  - EWPD >> diboson >> Higgs
- No longer justified, theoretically unsatisfactory
- Kinematic information encoded in Simplified Template Cross Sections (STXS)



SIMPLIFIED TEMPLATE CROSS SECTIONS



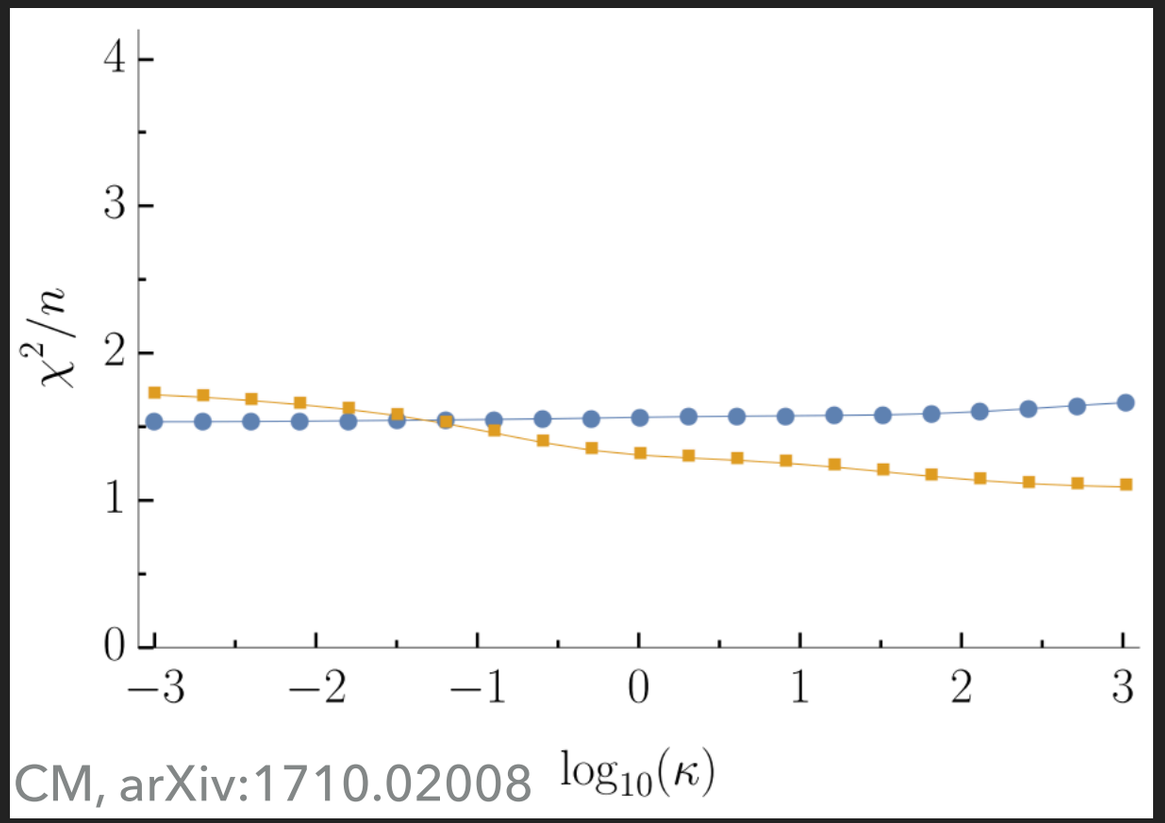
ATLAS-CONF-2017-047



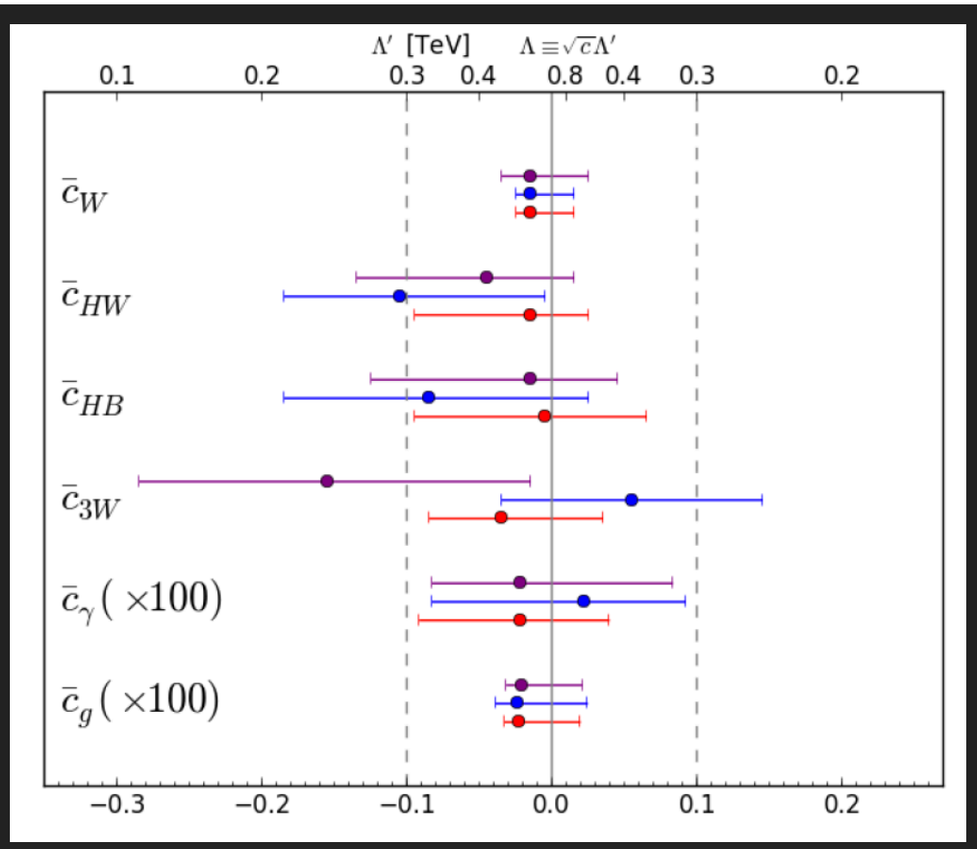
Merged STXS Stage-1 regions enclosed by red boxes

FIT TO HIGGS EFT COEFFICIENTS

- Results consistent w/ SM
- Next steps:
  - combine w/ EWPD
  - combine w/ diboson data



CM, arXiv:1710.02008



Ellis, Sanz, You, arXiv:1411.7703

ANALYSIS FRAMEWORK

- Focus on leading dimension-6 operators

$$\mathcal{L}_{\mathrm{SMEFT}} \supset \mathcal{L}_{\mathrm{SM}} + \sum_i \frac{c_i}{\Lambda_i^2} \mathcal{O}_i$$

- Work to linear order in Wilson coefficients
- Impose $U(3)^5$ flavor symmetry for fermionic operators
- Use α_{EM}, G_F, M_Z, as input parameters

DIMENSION-6 OPERATORS IN WARSAW BASIS

$$\mathcal{L}_{\rm SMEFT}^{\rm Warsaw} \supset \frac{\bar{C}_{Hl}^{(3)}}{v^2}(H^\dagger i\overleftrightarrow{D}^I_\mu H)(\bar{l}\tau^I\gamma^\mu l) + \frac{\bar{C}_{Hl}^{(1)}}{v^2}(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{l}\gamma^\mu l) + \frac{\bar{C}_{ll}}{v^2}(\bar{l}\gamma_\mu l)(\bar{l}\gamma^\mu l)$$
$$+ \frac{\bar{C}_{HD}}{v^2}\left|H^\dagger D_\mu H\right|^2 + \frac{\bar{C}_{HWB}}{v^2}H^\dagger\tau^I H\, W^I_{\mu\nu}B^{\mu\nu}$$
$$+ \frac{\bar{C}_{He}}{v^2}(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{e}\gamma^\mu e) + \frac{\bar{C}_{Hu}}{v^2}(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{u}\gamma^\mu u) + \frac{\bar{C}_{Hd}}{v^2}(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{d}\gamma^\mu d)$$
$$+ \frac{\bar{C}_{Hq}^{(3)}}{v^2}(H^\dagger i\overleftrightarrow{D}^I_\mu H)(\bar{q}\tau^I\gamma^\mu q) + \frac{\bar{C}_{Hq}^{(1)}}{v^2}(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{q}\gamma^\mu q) + \frac{\bar{C}_W}{v^2}\epsilon^{IJK}W^{I\nu}_\mu W^{J\rho}_\nu W^{K\mu}_\rho$$

$$\bar{C} \equiv \frac{v^2}{\Lambda^2}C$$

$$\mathcal{L}_{\rm SMEFT}^{\rm Warsaw} \supset \frac{\bar{C}_{eH}}{v^2}y_e(H^\dagger H)(\bar{l}eH) + \frac{\bar{C}_{dH}}{v^2}y_d(H^\dagger H)(\bar{q}dH) + \frac{\bar{C}_{uH}}{v^2}y_u(H^\dagger H)(\bar{q}u\widetilde{H})$$
$$+ \frac{\bar{C}_G}{v^2}f^{ABC}G^{A\nu}_\mu G^{B\rho}_\nu G^{C\mu}_\rho + \frac{\bar{C}_{H\Box}}{v^2}(H^\dagger H)\Box(H^\dagger H) + \frac{\bar{C}_{uG}}{v^2}y_u(\bar{q}\sigma^{\mu\nu}T^A u)\widetilde{H}\, G^A_{\mu\nu}$$
$$+ \frac{\bar{C}_{HW}}{v^2}H^\dagger H\, W^I_{\mu\nu}W^{I\mu\nu} + \frac{\bar{C}_{HB}}{v^2}H^\dagger H\, B_{\mu\nu}B^{\mu\nu} + \frac{\bar{C}_{HG}}{v^2}H^\dagger H\, G^A_{\mu\nu}G^{A\mu\nu}\,.$$

results of EMSY 1803.03252 expressed in both SILH and Warsaw bases

PRECISION ELECTROWEAK MEASUREMENTS USED IN SMEFT FIT

- 12 Z-pole measurements
- 74 LEP 2 W^+W^- measurements
- New M_W measurement from ATLAS
- Probes 11 SMEFT directions

Observable	Measurement	Ref.	SM Prediction	Ref.
Γ_Z [GeV]	2.4952 ± 0.0023	[41]	2.4943 ± 0.0005	[40]
$\sigma^0_{\rm had}$ [nb]	41.540 ± 0.037	[41]	41.488 ± 0.006	[40]
R^0_ℓ	20.767 ± 0.025	[41]	20.752 ± 0.005	[40]
$A^{0,\ell}_{\rm FB}$	0.0171 ± 0.0010	[41]	0.01622 ± 0.00009	[118]
$\mathcal{A}_\ell\,(P_\tau)$	0.1465 ± 0.0033	[41]	0.1470 ± 0.0004	[118]
$\mathcal{A}_\ell\,(\mathrm{SLD})$	0.1513 ± 0.0021	[41]	0.1470 ± 0.0004	[118]
R^0_b	0.021629 ± 0.00066	[41]	0.2158 ± 0.00015	[40]
R^0_c	0.1721 ± 0.0030	[41]	0.17223 ± 0.00005	[40]
$A^{0,b}_{\rm FB}$	0.0992 ± 0.0016	[41]	0.1031 ± 0.0003	[118]
$A^{0,c}_{\rm FB}$	0.0707 ± 0.0035	[41]	0.0736 ± 0.0002	[118]
$\mathcal{A}_b$	0.923 ± 0.020	[41]	0.9347	[118]
$\mathcal{A}_c$	0.670 ± 0.027	[41]	0.6678 ± 0.0002	[118]
M_W [GeV]	80.387 ± 0.016	[42]	80.361 ± 0.006	[118]
M_W [GeV]	80.370 ± 0.019	[98]	80.361 ± 0.006	[118]

EMSY 1803.03252

ATLAS+CMS HIGGS DATA FROM RUN 1

Production	Decay	Signal Strength	Production	Decay	Signal Strength
ggF	$\gamma\gamma$	$1.10^{+0.23}_{-0.22}$	Wh	$\tau\tau$	-1.4 ± 1.4
ggF	ZZ	$1.13^{+0.34}_{-0.31}$	Wh	bb	1.0 ± 0.5
ggF	WW	0.84 ± 0.17	Zh	$\gamma\gamma$	$0.5^{+3.0}_{-2.5}$
ggF	$\tau\tau$	1.0 ± 0.6	Zh	WW	$5.9^{+2.6}_{-2.2}$
VBF	$\gamma\gamma$	1.3 ± 0.5	Zh	$\tau\tau$	$2.2^{+2.2}_{-1.8}$
VBF	ZZ	$0.1^{+1.1}_{-0.6}$	Zh	bb	0.4 ± 0.4
VBF	WW	1.2 ± 0.4	tth	$\gamma\gamma$	$2.2^{+1.6}_{-1.3}$
VBF	$\tau\tau$	1.3 ± 0.4	tth	WW	$5.0^{+1.8}_{-1.7}$
Wh	$\gamma\gamma$	$0.5^{+1.3}_{-1.2}$	tth	$\tau\tau$	$-1.9^{+3.7}_{-3.3}$
Wh	WW	$1.6^{+1.2}_{-1.0}$	tth	bb	1.1 ± 1.0
pp	$Z\gamma$	$2.7^{+4.6}_{-4.5}$	pp	$\mu\mu$	0.1 ± 2.5

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RUN 2 HIGGS MEASUREMENTS USED IN SMEFT FIT

- Include all available kinematical information
- Include 1 W^+W^- measurement at high p_T
- Probe 13 SMEFT directions

	CMS				ATLAS		
	Production	Decay	Sig. Stren.		Production	Decay	Sig. Stren.
[100]	1-jet, $p_T > 450$	$b\bar{b}$	$2.3^{+1.8}_{-1.6}$	[109]	pp	$\mu\mu$	-0.1 ± 1.5
[101]	Zh	$b\bar{b}$	0.9 ± 0.5	[110]	Zh	$b\bar{b}$	$0.69^{+0.35}_{-0.31}$
[101]	Wh	$b\bar{b}$	1.7 ± 0.7	[110]	Wh	$b\bar{b}$	$1.21^{+0.45}_{-0.42}$
[102]	$t\bar{t}h$	$b\bar{b}$	$-0.19^{+0.80}_{-0.81}$	[111]	$t\bar{t}h$	$b\bar{b}$	$0.84^{+0.64}_{-0.61}$
[103]	$t\bar{t}h$	$1\ell + 2\tau_h$	$-1.20^{+1.50}_{-1.47}$	[112]	$t\bar{t}h$	$2\ell os + 1\tau_h$	$1.7^{+2.1}_{-1.9}$
[103]	$t\bar{t}h$	$2\ell ss + 1\tau_h$	$0.86^{+0.79}_{-0.66}$	[112]	$t\bar{t}h$	$1\ell + 2\tau_h$	$-0.6^{+1.6}_{-1.5}$
[103]	$t\bar{t}h$	$3\ell + 1\tau_h$	$1.22^{+1.34}_{-1.00}$	[112]	$t\bar{t}h$	$3\ell + 1\tau_h$	$1.6^{+1.8}_{-1.3}$
[104]	$t\bar{t}h$	$2\ell ss$	$1.7^{+0.6}_{-0.5}$	[112]	$t\bar{t}h$	$2\ell ss + 1\tau_h$	$3.5^{+1.7}_{-1.3}$
[104]	$t\bar{t}h$	3ℓ	$1.0^{+0.8}_{-0.7}$	[112]	$t\bar{t}h$	3ℓ	$1.8^{+0.9}_{-0.7}$
[104]	$t\bar{t}h$	4ℓ	$0.9^{+2.3}_{-1.6}$	[112]	$t\bar{t}h$	$2\ell ss$	$1.5^{+0.7}_{-0.6}$
[105]	0-jet	WW	$0.9^{+0.4}_{-0.3}$	[113]	VBF	WW	$1.7^{+1.1}_{-0.9}$
[105]	1-jet	WW	1.1 ± 0.4	[113]	Wh	WW	$3.2^{+4.4}_{-4.2}$
[105]	2-jet	WW	1.3 ± 1.0	[114]	$\mathrm{B}(h \to \gamma\gamma)/\ \mathrm{B}(h \to 4\ell)$		$0.69^{+0.15}_{-0.13}$
[105]	VBF 2-jet	WW	1.4 ± 0.8	[114]	0-jet	4ℓ	$1.07^{+0.27}_{-0.25}$
[105]	Vh 2-jet	WW	$2.1^{+2.3}_{-2.2}$	[114]	1-jet, $p_T < 60$	4ℓ	$0.67^{+0.72}_{-0.68}$
[105]	Wh 3-lep	WW	-1.4 ± 1.5	[114]	1-jet, $p_T \in (60, 120)$	4ℓ	$1.00^{+0.63}_{-0.55}$
[106]	ggF	$\gamma\gamma$	$1.11^{+0.19}_{-0.18}$	[114]	1-jet, $p_T \in (120, 200)$	4ℓ	$2.1^{+1.5}_{-1.3}$
[106]	VBF	$\gamma\gamma$	$0.5^{+0.6}_{-0.5}$	[114]	2-jet	4ℓ	$2.2^{+1.1}_{-1.0}$
[106]	$t\bar{t}h$	$\gamma\gamma$	2.2 ± 0.9	[114]	"BSM-like"	4ℓ	$2.3^{+1.2}_{-1.0}$
[106]	Vh	$\gamma\gamma$	$2.3^{+1.1}_{-1.0}$	[114]	VBF, $p_T < 200$	4ℓ	$2.14^{+0.94}_{-0.77}$
[107]	ggF	4ℓ	$1.20^{+0.22}_{-0.21}$	[114]	Vh lep	4ℓ	$0.3^{+1.3}_{-1.2}$
[108]	0-jet	$\tau\tau$	0.84 ± 0.89	[114]	$t\bar{t}h$	4ℓ	$0.51^{+0.86}_{-0.70}$
[108]	boosted	$\tau\tau$	$1.17^{+0.47}_{-0.40}$				
[108]	VBF	$\tau\tau$	$1.11^{+0.34}_{-0.35}$				

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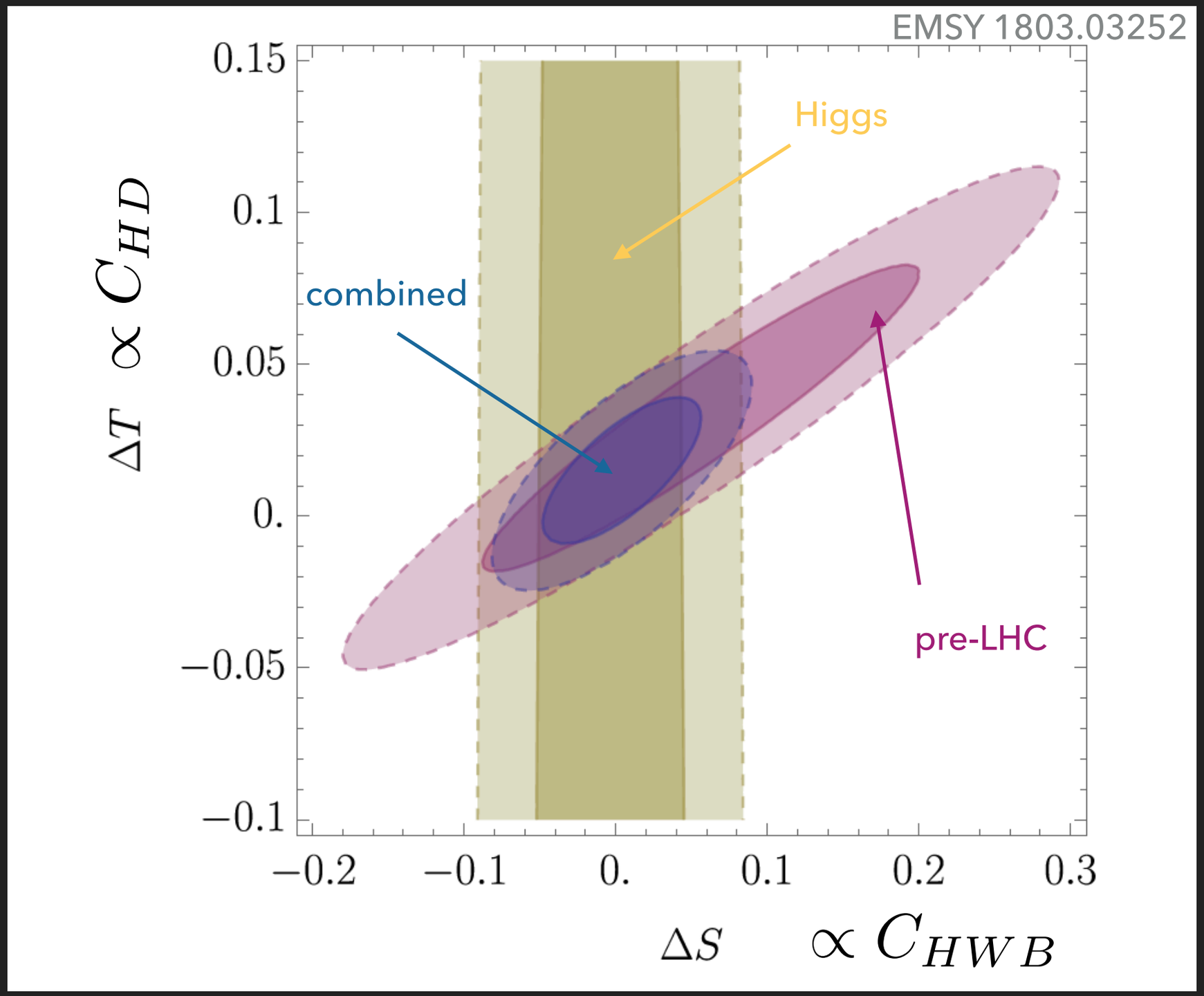
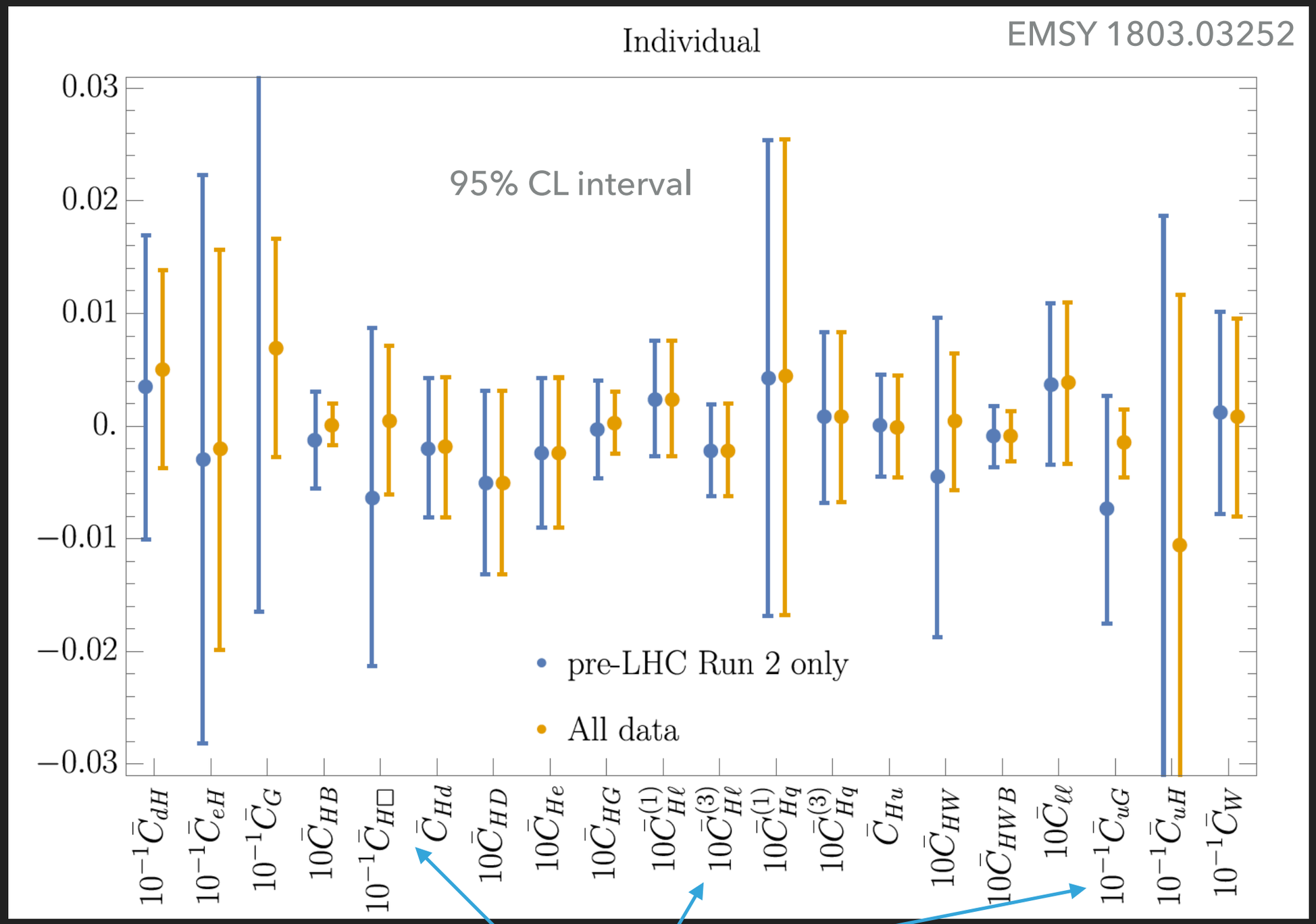
CONSTRAINTS ON OBLIQUE PARAMETERS

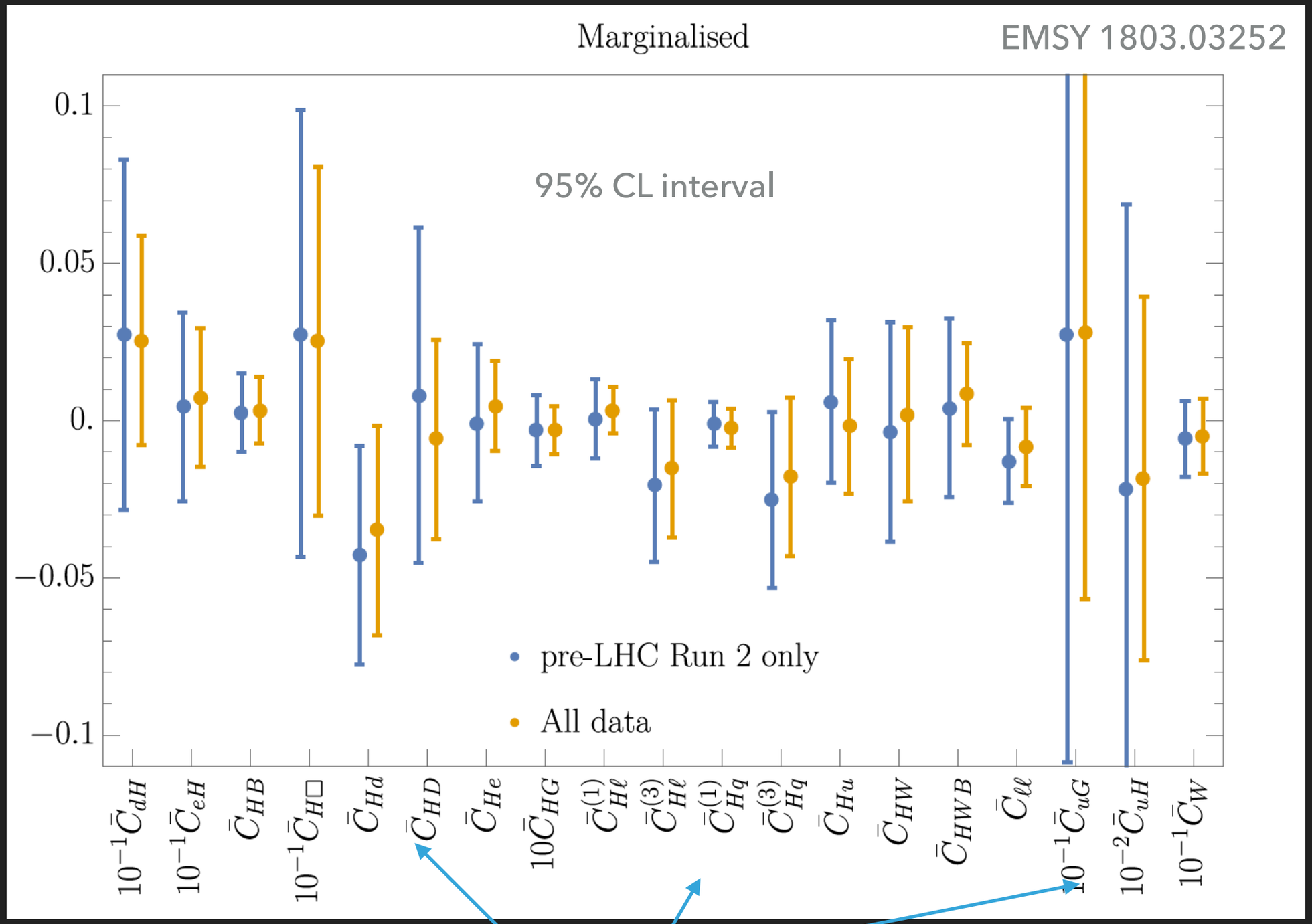


FIT TO EACH OPERATOR INDIVIDUALLY



different powers of 10

FIT TO ALL OPERATORS SIMULTANEOUSLY

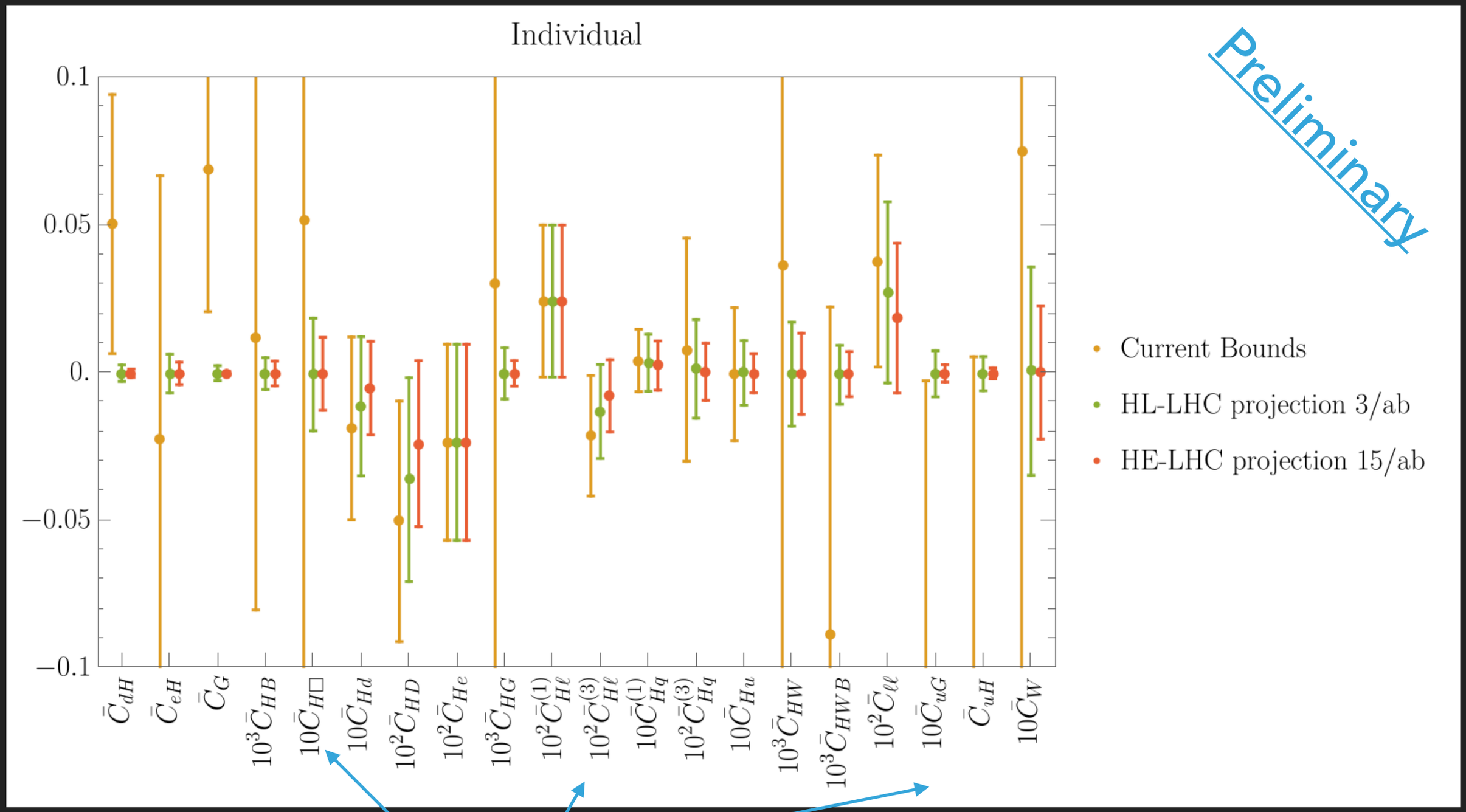


different powers of 10

PROJECTION STRATEGY

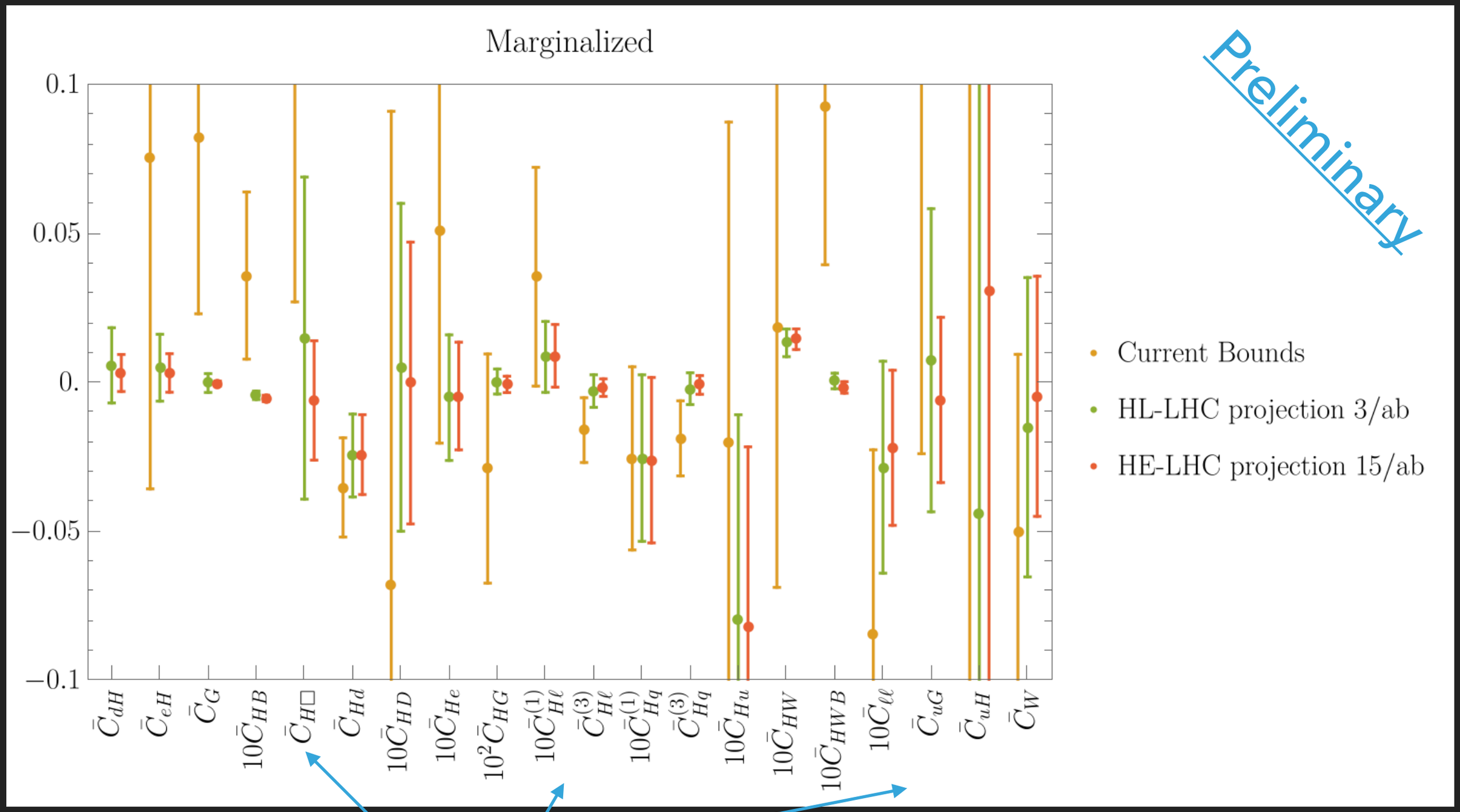
- For each LHC Run-2 measurement used in the fit of 1803.03252
  - Set central value to SM prediction
  - Scale all uncertainties for the *i*th measurement by…
    - HL-LHC: $\sqrt{\frac{L_i}{3/\mathrm{ab}}}$
    - HE-LHC: $\sqrt{\frac{\sigma_{13,i}}{\sigma_{27,i}}\frac{L_i}{15/\mathrm{ab}}}$
  - Leave correlations unchanged

PROJECTION: ONE COEFFICIENT AT A TIME



different powers of 10

PROJECTION: ALL COEFFICIENTS SIMULTANEOUSLY



different powers of 10

SIMPLE EXTENSIONS OF THE SM

Name	Spin	$SU(3)$	$SU(2)$	$U(1)$	Name	Spin	$SU(3)$	$SU(2)$	$U(1)$
$\mathcal{S}$	0	1	1	0	Δ_1	$\frac{1}{2}$	1	2	$-\frac{1}{2}$
$\mathcal{S}_1$	0	1	1	1	Δ_3	$\frac{1}{2}$	1	2	$-\frac{1}{2}$
φ	0	1	2	$\frac{1}{2}$	Σ	$\frac{1}{2}$	1	3	0
Ξ	0	1	3	0	Σ_1	$\frac{1}{2}$	1	3	-1
Ξ_1	0	1	3	1	U	$\frac{1}{2}$	3	1	$\frac{2}{3}$
$\mathcal{B}$	1	1	1	0	D	$\frac{1}{2}$	3	1	$-\frac{1}{3}$
$\mathcal{B}_1$	1	1	1	1	Q_1	$\frac{1}{2}$	3	2	$\frac{1}{6}$
$\mathcal{W}$	1	1	3	0	Q_5	$\frac{1}{2}$	3	2	$-\frac{5}{6}$
$\mathcal{W}_1$	1	1	3	1	Q_7	$\frac{1}{2}$	3	2	$\frac{7}{6}$
N	$\frac{1}{2}$	1	1	0	T_1	$\frac{1}{2}$	3	3	$-\frac{1}{3}$
E	$\frac{1}{2}$	1	1	-1	T_2	$\frac{1}{2}$	3	3	$\frac{2}{3}$

de Blas, Criado, Perez-Victoria, Santiago 1711.10391

NUMERICAL CONSTRAINTS ON EXTENSIONS

improve χ^2 & χ^2/n_d

only improve χ^2

improve neither

Model	χ^2	χ^2/n_d	Coupling	Mass / TeV
SM	152.6	0.972	-	-
$\mathcal{S}_1$	151	0.971	$\lvert y_{\mathcal{S}_1}\rvert^2 = (6.3 \pm 5.9) \cdot 10^{-3}$	$M_{\mathcal{S}_1} = (9.1,\ 53)$
Ξ	151	0.968	$\lvert \kappa_\Xi\rvert^2 = (4.1 \pm 3.4) \cdot 10^{-3}$	$M_\Xi = (12,\ 36)$
N	150	0.963	$\lvert \lambda_N\rvert^2 = (1.8 \pm 1.2) \cdot 10^{-2}$	$M_N = (5.8,\ 13)$
$\mathcal{W}_1$	151	0.968	$\left\lvert \hat{g}^{\phi}_{\mathcal{W}_1}\right\rvert^2 = (3.3 \pm 2.7) \cdot 10^{-3}$	$M_{\mathcal{W}_1} = (4.1,\ 13)$
φ, Type I	152	0.976	$Z_6 \cdot \cos\beta = -0.41 \pm 0.66$	$M_\varphi = (1.0,\ \infty)$
E	152.5	0.978	$\lvert \lambda_E\rvert^2 = (2.0 \pm 9.7) \cdot 10^{-3}$	$M_E = (9.2,\ \infty)$
Δ_3	152	0.975	$\lvert \lambda_{\Delta_3}\rvert^2 = (0.8 \pm 1.1) \cdot 10^{-2}$	$M_{\Delta_3} = (7.3,\ \infty)$
Σ	152	0.977	$\lvert \lambda_\Sigma\rvert^2 = (0.9 \pm 2.0) \cdot 10^{-2}$	$M_\Sigma = (5.9,\ \infty)$
Q_5	152	0.975	$\lvert \lambda_{Q_5}\rvert^2 = 0.07 \pm 0.10$	$M_{Q_5} = (2.4,\ \infty)$
T_2	152	0.977	$\lvert \lambda_{T_2}\rvert^2 = (1.8 \pm 5.1) \cdot 10^{-2}$	$M_{T_2} = (3.8,\ \infty)$
$\mathcal{S}$	152.6	0.978	$\lvert y_{\mathcal{S}}\rvert^2 < 0.47$	$M_{\mathcal{S}} > 1.5$
Δ_1	152.6	0.978	$\lvert \lambda_{\Delta_1}\rvert^2 < 5.7 \cdot 10^{-3}$	$M_{\Delta_1} > 13$
Σ_1	152.6	0.978	$\lvert \lambda_{\Sigma_1}\rvert^2 < 7.3 \cdot 10^{-3}$	$M_{\Sigma_1} > 12$
U	152.6	0.978	$\lvert \lambda_U\rvert^2 < 3.1 \cdot 10^{-2}$	$M_U > 5.7$
D	152.6	0.978	$\lvert \lambda_D\rvert^2 < 1.5 \cdot 10^{-2}$	$M_D > 8.2$
Q_7	152.6	0.978	$\lvert \lambda_{Q_7}\rvert^2 < 7.2 \cdot 10^{-2}$	$M_{Q_7} > 3.7$
T_1	152.6	0.978	$\lvert \lambda_{T_1}\rvert^2 < 0.11$	$M_{T_1} > 3.0$
$\mathcal{B}_1$	152.6	0.978	$\left\lvert \hat{g}^{\phi}_{\mathcal{B}_1}\right\rvert^2 < 2.4 \cdot 10^{-3}$	$M_{\mathcal{B}_1} > 20$

← 2HDM

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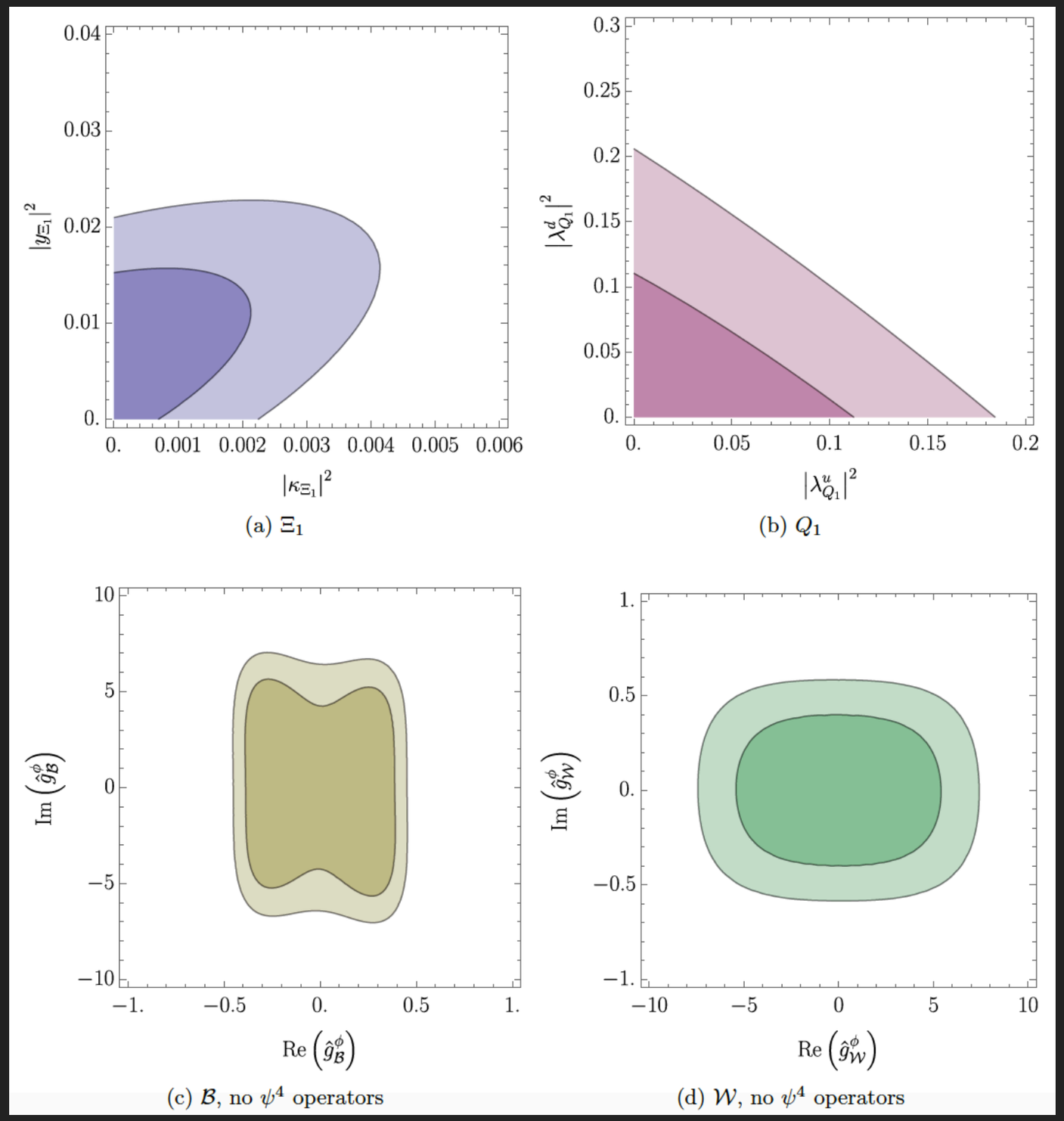
CONSTRAINTS ON SM EXTENSIONS



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GLUON FUSION

- Probes small # of coefficients

ggF, $\sqrt{s} = 27$ TeV	$\sigma_{SMEFT}/\sigma_{SM}$
0-jet	$1 + 5.9 \cdot 10^2 \bar{C}_{HG}$
1-jet, $p_T^h \in (20, 60)$ GeV	$1 + 5.2 \cdot 10^2 \bar{C}_{HG} + 0.15 \bar{C}_G$
1-jet, $p_T^h \in (60, 120)$ GeV	$1 + 5.1 \cdot 10^2 \bar{C}_{HG} + 0.72 \bar{C}_G$
1-jet, $p_T^h \in (120, 200)$ GeV	$1 + 4.6 \cdot 10^2 \bar{C}_{HG} + 2.0 \bar{C}_G$
1-jet, $p_T^h > 200$ GeV	$1 + 4.7 \cdot 10^2 \bar{C}_{HG} + 9.3 \bar{C}_G$

independent of collider energy

slightly enhanced sensitivity @ 27 vs. 13 TeV

computations done using *SMEFTsim*: Brivio, Trott 1709.06492

ASSOCIATED PRODUCTION

- Probes many (, many) coefficients
- Generally good sensitivity already in inclusive rates

$\sqrt{s} = 27$ TeV	$\sigma_{SMEFT}/\sigma_{SM}$
Wh	$1 + 2.0\bar{C}_{H\Box} - 2.8\bar{C}_{HD} + 15\bar{C}_{HW} - 5.3\bar{C}_{HWB} - 7.0\bar{C}^{(3)}_{H\ell} + 35\bar{C}^{(3)}_{Hq} + 3.2\bar{C}_{\ell\ell}$
Zh	$1 + 2.0\bar{C}_{H\Box} - 0.24\bar{C}_{HD} + 12\bar{C}_{HW} + 1.7\bar{C}_{HB} + 3.7\bar{C}_{HWB}$ $-5.0\bar{C}^{(3)}_{H\ell} - 1.5\bar{C}^{(1)}_{Hq} + 33\bar{C}^{(3)}_{Hq} + 8.5\bar{C}_{Hu} - 3.1\bar{C}_{Hd} + 2.5\bar{C}_{\ell\ell}$
$t\bar{t}h$	$1 + 2.4\bar{C}_{G} + 1.9\bar{C}_{H\Box} - 0.48\bar{C}_{HD} + 8.7\bar{C}_{HG} - 2.4\bar{C}_{uH}$ $-15\bar{C}_{uG} - 0.49\bar{C}^{(1)}_{Hq} - 0.44\bar{C}^{(3)}_{Hq} - 0.48\bar{C}_{Hu} + 0.49\bar{C}_{\ell\ell} + \ldots$

plus additional dipole & 4-fermion operators

ASSOCIATED PRODUCTION

- Enhancements of certain coefficients at high-p_T
- Similar to high-p_T diboson production at LHC

$\sqrt{s} = 27$ TeV	$\sigma_{SM,LO}$	$\sigma_{SMEFT}/\sigma_{SM}$
Wh, $p_T^h > 250$ GeV	85 fb	$1 + 2.0\bar{C}_{H\Box} - 2.8\bar{C}_{HD} + 18\bar{C}_{HW}$ $-5.2\bar{C}_{HWB} - 7.0\bar{C}_{H\ell}^{(3)} + 2.3 \cdot 10^2\bar{C}_{Hq}^{(3)} + 3.2\bar{C}_{\ell\ell}$
Zh, $p_T^h > 250$ GeV	46 fb	$1 + 2.0\bar{C}_{H\Box} - 0.24\bar{C}_{HD} + 14\bar{C}_{HW} + 2.6\bar{C}_{HB} + 5.2\bar{C}_{HWB}$ $-5.0\bar{C}_{H\ell}^{(3)} - 17\bar{C}_{Hq}^{(1)} + 2.1 \cdot 10^2\bar{C}_{Hq}^{(3)} + 55\bar{C}_{Hu} - 18\bar{C}_{Hd} + 2.5\bar{C}_{\ell\ell}$

VECTOR BOSON FUSION

- Probes many coefficients
- Gain in sensitivity with increase in collider energy

VBF	$\sigma_{SMEFT}/\sigma_{SM}$
8 TeV	$1 + 0.12\bar{C}_{H\Box} - 0.20\bar{C}_{HD} - 0.64\bar{C}^{(3)}_{H\ell} - 0.13\bar{C}^{(3)}_{Hq} - 0.44\bar{C}_{HWB} + 0.27\bar{C}_{\ell\ell} + \ldots$
13 TeV	$1 + 0.19\bar{C}_{H\Box} - 0.31\bar{C}_{HD} - 0.98\bar{C}^{(3)}_{H\ell} - 0.29\bar{C}^{(3)}_{Hq} - 0.67\bar{C}_{HWB} + 0.42\bar{C}_{\ell\ell} + \ldots$
27 TeV	$1 + 0.94\bar{C}_{H\Box} - 1.5\bar{C}_{HD} - 4.8\bar{C}^{(3)}_{H\ell} - 2.3\bar{C}^{(3)}_{Hq} - 3.2\bar{C}_{HWB} + 2.0\bar{C}_{\ell\ell} + \ldots$

only 6 largest coefficients shown

VBF cuts: $m_{jj} > 130$ GeV, $|\Delta\eta_{jj}| > 3$

VECTOR BOSON FUSION

- Cut on $p_{T,j1}$ does not enhance sensitivity as much as p_T cut on Vh production

VBF, $\sqrt{s} = 27$ TeV	$\sigma_{SM,LO}$	$\sigma_{SMEFT}/\sigma_{SM}$
$p_T^{j1} < 200$ GeV	1.52 pb	$1 + 0.97\bar{C}_{H\Box} - 1.5\bar{C}_{HD} - 4.9C_{H\ell}^{(3)} - 1.9\bar{C}_{Hq}^{(3)} - 3.3\bar{C}_{HWB} + 2.1\bar{C}_{\ell\ell} + \ldots$
$p_T^{j1} > 200$ GeV	0.09 pb	$1 + 0.70\bar{C}_{H\Box} - 1.0\bar{C}_{HD} - 3.3C_{H\ell}^{(3)} - 8.6\bar{C}_{Hq}^{(3)} - 2.0\bar{C}_{HWB} + 1.5\bar{C}_{\ell\ell} + \ldots$

only 6 largest coefficients shown

VBF cuts: $m_{jj} > 130$ GeV, $|\Delta\eta_{jj}| > 3$

SUMMARY

- SMEFT: model-independent way to search for heavy new physics
- Higgs measurements currently compete w/ EWPD
- Higgs and diboson (differential) measurements at HL- or HE-LHC will exceed EWPD precision in many cases

Theory	χ^2	χ^2/n_d	p-value
SM	153	0.972	0.585
SMEFT	133	0.973	0.572
SMEFT*	139	0.963	0.609

20 coefficients

*13 coefficients