Global SMEFT Fits at Future Colliders A Snomwass 2021 Whitepaper

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- 4 Improved EFT analysis for $e^+e^- \rightarrow WW$ [<u>J. Gu</u>
 - 4.1
 - BR has no correlation? 4.2
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main goal: coherent projections on precision EW/Higgs/Top couplings @ future colliders welcome to join the team and to make your contribution

<u>, 2021.9]</u>	7	The top-quark sector in the global EFT fit [V. Miralles
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<u>, 2021.9]</u>		9.2 Prospects for sensitivity at NLO
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recent progress

- conventions / basis: independent fitting codes, same basis (original Warsaw), same assumptions, same inputs (nominal, statistically consistent, to be updated with EF01/03/04)
- exploring various flavor assumptions (promising without any flavor universality in some fits)
- preliminary result on Fit-1: Higgs/EW sector for HL-LHC, low energy stage of future linear & circular e+e-
- global fit of 4-fermion operators & 2-fermion at Z-pole / W-pole
- developing strategy for top-quark sector fit & interplay with Higgs/EW

Fit-1: Higgs/EW

observables

Electroweak Precision Observables $(\alpha, G_F, m_Z...)$ + $e+e- \longrightarrow WW$ (Optimal Obv.)++($\sigma, \sigma x BR$)Higgs observables at LHC & e+e- $(\sigma, \sigma x BR)$ Drell-Yan at LHC(WW, AFB...)

assumptions

w/o 4-f contact interactions flavor diagonal CP-even w/ & w/o lepton flavor univ. w/ & w/o Higgs exotic decays

operators (Warsaw)

$$\begin{split} \mathscr{L}_{\mathrm{SMEFT}_{\mathrm{ND},\mathrm{FU}}} &= \frac{C_{\phi}}{\Lambda^{2}} \left(\phi^{\dagger}\phi\right)^{3} + \frac{C_{\phi\Box}}{\Lambda^{2}} \left(\phi^{\dagger}\phi\right) \Box \left(\phi^{\dagger}\phi\right) \\ &+ \frac{C_{W}}{\Lambda^{2}} \varepsilon_{abc} W_{\mu}^{a\nu} W_{\nu}^{b\rho} W_{\rho}^{c\mu} \\ &+ \frac{C_{\phi B}}{\Lambda^{2}} \phi^{\dagger}\phi B_{\mu\nu} B^{\mu\nu} + \frac{C_{\phi W}}{\Lambda^{2}} \phi^{\dagger}\phi W_{\mu\nu}^{a} W^{a\mu\nu} + \frac{C_{\phi G}}{\Lambda^{2}} \phi^{\dagger}\phi G_{\mu\nu}^{A} G^{A\mu\nu} \\ &+ \frac{C_{\phi D}}{\Lambda^{2}} \left(\phi^{\dagger} D_{\mu}\phi\right) \left(\left(D^{\mu}\phi\right)^{\dagger}\phi\right) + \frac{C_{\phi WB}}{\Lambda^{2}} \phi^{\dagger}\sigma_{a}\phi W_{\mu\nu}^{a} B^{\mu\nu} \\ &+ \left(\frac{\left(C_{e\phi}\right)_{ii}}{\Lambda^{2}} \left(\phi^{\dagger}\phi\right) \left(\overline{l}_{L}^{i}\phi e_{R}^{i}\right) + \frac{\left(C_{d\phi}\right)_{ii}}{\Lambda^{2}} \left(\phi^{\dagger}\phi\right) \left(\overline{q}_{L}^{i}\phi d_{R}^{i}\right) + \frac{\left(C_{u\phi}\right)_{ii}}{\Lambda^{2}} \left(\phi^{\dagger}\phi\right) \left(\overline{q}_{L}^{i}\tilde{\phi} u_{R}^{i}\right) - \\ &+ \frac{\left(C_{\phi l}^{(1)}\right)_{ii}}{\Lambda^{2}} \left(\phi^{\dagger}i\overline{D}_{\mu}\phi\right) \left(\overline{l}_{L}^{i}\gamma^{\mu} e_{R}^{i}\right) \\ &+ \frac{\left(C_{\phi q}^{(1)}\right)_{ii}}{\Lambda^{2}} \left(\phi^{\dagger}i\overline{D}_{\mu}\phi\right) \left(\overline{q}_{L}^{i}\gamma^{\mu} u_{R}^{i}\right) + \frac{\left(C_{\phi l}^{(3)}\right)_{ii}}{\Lambda^{2}} \left(\phi^{\dagger}i\overline{D}_{\mu}\phi\right) \left(\overline{q}_{L}^{i}\gamma^{\mu} a_{R}^{i}\right) \\ &+ \frac{\left(C_{\phi q}^{(1)}\right)_{ii}}{\Lambda^{2}} \left(\phi^{\dagger}i\overline{D}_{\mu}\phi\right) \left(\overline{q}_{L}^{i}\gamma^{\mu} u_{R}^{i}\right) + \frac{\left(C_{\phi l}^{(3)}\right)_{ii}}{\Lambda^{2}} \left(\phi^{\dagger}i\overline{D}_{\mu}\phi\right) \left(\overline{d}_{R}^{i}\gamma^{\mu} u_{R}^{i}\right) \\ &+ \frac{\left(C_{\phi u}\right)_{ii}}{\Lambda^{2}} \left(\phi^{\dagger}i\overline{D}_{\mu}\phi\right) \left(\overline{u}_{R}^{i}\gamma^{\mu} u_{R}^{i}\right) + \frac{\left(C_{\phi d}\right)_{ii}}{\Lambda^{2}} \left(\phi^{\dagger}i\overline{D}_{\mu}\phi\right) \left(\overline{d}_{R}^{i}\gamma^{\mu} d_{R}^{i}\right) \\ &+ \frac{\left(C_{\mu u}\right)_{ii}}{\Lambda^{2}} \left(\phi^{\dagger}i\overline{D}_{\mu}\phi\right) \left(\overline{u}_{R}^{i}\gamma^{\mu} u_{R}^{i}\right) + \frac{\left(C_{\phi d}\right)_{ii}}{\Lambda^{2}} \left(\phi^{\dagger}i\overline{D}_{\mu}\phi\right) \left(\overline{d}_{R}^{i}\gamma^{\mu} d_{R}^{i}\right) \\ &+ \frac{\left(C_{\mu u}\right)_{ii}}{\Lambda^{2}} \left(\overline{u}_{1}\gamma \mu_{l}^{i}\right) \left(\overline{u}_{R}^{i}\gamma^{\mu} u_{R}^{i}\right) + \frac{\left(C_{\phi d}\right)_{ii}}{\Lambda^{2}} \left(\phi^{\dagger}i\overline{D}_{\mu}\phi\right) \left(\overline{d}_{R}^{i}\gamma^{\mu} d_{R}^{i}\right) \\ &+ \frac{\left(C_{\mu u}\right)_{ii}}{\Lambda^{2}} \left(\overline{u}_{1}\gamma \mu_{l}^{i}\right) \left(\overline{u}_{R}^{i}\gamma^{\mu} u_{R}^{i}\right) + \frac{\left(C_{\phi d}\right)_{ii}}{\Lambda^{2}} \left(\phi^{\dagger}i\overline{D}_{\mu}\phi\right) \left(\overline{d}_{R}^{i}\gamma^{\mu} d_{R}^{i}\right) \\ &+ \frac{\left(C_{\mu u}\right)_{ii}}{\Lambda^{2}} \left(\overline{u}_{R}^{i}\psi^{\mu} u_{R}^{i}\right) + \frac{\left(C_{\mu u}\right)_{ii}}{\Lambda^{2}} \left(\overline{u}_{R}^{i}\psi^{\mu} d_{R}^{i}\right) \\ &+ \frac{\left(C_{\mu u}\right)_{ii}}{\Lambda^{2}} \left(\overline{u}_{R}^{i}\psi^{\mu} u_{R}^{i}\right) \left(\overline{u}_{R}^{i}\psi^{\mu} u_{R}^{i}\right) \\ &+ \frac{\left(C_{\mu u}\right)_{ii}}{\Lambda^{2}} \left(\overline{u}_{R}^{i}\psi^{\mu} u_{R}^{i}\right) \left(\overline{u}_{R}^{i}\psi^{\mu$$



Input: EWPO @ future e+e-

	ILC	FCC-ee
Δα-1	0.0178	0.00387
ΔG _F	6.0x10 ⁻⁷	6.0x10 ⁻⁷
Δmw	2.4MeV	0.5MeV
Δmz	2.1MeV	0.1MeV
Δm _H	14MeV	11MeV
ΔΓω	2MeV	1.2MeV
ΔΓΖ	2.3MeV	0.1MeV
ΔΑe	0.00014	0.000017
ΔΑμ	0.00082	0.00023
ΔΑτ	0.00086	0.000045
ΔΑ _b	0.00060	0.0028
ΔΑ _c	0.0014	0.0053
δR _e	0.0011	0.0003
δR _µ	0.0011	0.00005
δRτ	0.0011	0.0001
δR _b	0.0011	0.0003
δR _c	0.0050	0.0015

Δ : absolute error δ : relative error

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Δm _H	14MeV	11MeV	
ΔΓω	2MeV	1.2MeV	
ΔΓΖ	2.3MeV	0.1MeV	
ΔAe	0.00014	0.000017	
ΔΑμ	0.00082	0.00023	
ΔΑτ	0.00086	0.000045	
ΔA _b	0.00060	0.0028	
ΔΑ _c	0.0014	0.0053	
δR _e	0.0011	0.0003	
δR _μ	0.0011	0.00005	
δR _τ	0.0011 0.0001		
δR _b	0.0011 0.0003		
δR _c 0.0050 0.0015		0.0015	

Δ : absolute error δ: relative error

wishlist: agreed treatment on experimental systematics

Input: Higgs @ HL-LHC

HL-LHC	3 ab-1 @ 14 TeV ATLAS+CMS (S2)					
prod.	ggH	VBF	WH	ZH	ttH	
σ	_	-	-	_		
$\sigma x B R_{bb}$	19.1	-	8.3	4.6	10.2	
σxBR _{cc}	_	-	-	_	-	
σxBR _{gg}	_	-	_	_	_	
σxBRzz	2.5	9.5	32.1	58.3	15.2	
σxBRww	2.5	5.5	9.9	12.8	6.6	
σxBR _{ττ}	4.5	3.9	_	_	10.2	
σxBR _{γγ}	2.5	7.9	9.9	13.2	5.9	
σxBR _{γZ}	24.4	51.2	_	_	_	
σxBR _{µµ}	11.1	30.7	_	_	_	
σxBR _{inv} .	_	2.5	_	_	_	
mн			10-20MeV			

wishlist: correlation matrix; differential x-section is not included now, but can be accommodated if available

Input: Higgs @ future e+e-

250GeV	0.9 ab ⁻¹ @ (-0.8,+0.3)		0.9 ab ⁻¹ @ (+0.8,-0.3)		5 ab ⁻¹ @ (0,0)	
prod.	ZH	vvH	ZH	vvH	ZH	vvH
σ	1.07	_	1.07	_	0.537	_
$\sigma x B R_{bb}$	0.714	4.27	0.714	17.4	0.380	2.78
σxBR _{cc}	4.38	_	4.38	_	2.08	_
σxBR _{gg}	3.69	_	3.69	_	1.75	_
σxBRzz	9.49	_	9.49	_	4.49	_
σxBRww	2.43	_	2.43	_	1.16	_
σxBR _{ττ}	1.70	_	1.70	-	0.822	-
σxBR _{γγ}	17.9	_	17.9	_	8.47	_
σxBR _{µµ}	37.9	_	37.9	_	17.9	_
σxBR _{inv} .	0.336	_	0.277	_	0.226	_

***toy fit: inputs are consistently extrapolated from same set of full simulation analyses for both polarized and unpolarized cases, including common 0.2% systematic errors for all channels except for H—>bb (0.3%)

in unit of %

Input: Higgs @ future e+e-

350GeV	135 fb ⁻¹ @ (-0.8,+0.3)		45 fb ⁻¹ @ (+0.8,-0.3)		1.5 ab ⁻¹ @ (0,0)	
prod.	ZH	vvH	ZH	vvH	ZH	vvH
σ	2.46	_	4.25	_	0.842	_
σxBR_{bb}	2.05	2.46	3.54	17.7	0.711	1.14
σxBR _{cc}	15.0	25.9	25.9	186	5.00	11.9
σxBR _{gg}	11.4	10.5	19.8	75.4	3.82	4.82
σxBRzz	34.0	27.2	58.9	191	11.4	12.5
σxBRww	7.62	7.76	13.2	56.6	2.55	3.57
σxBR _{ττ}	5.45	21.8	9.43	156	1.83	10
σxBR _{γγ}	53.1	61.2	91.9	424	17.7	28.1
σxBR _{µµ}	118	218	205	1580	39.6	100
σxBR _{inv} .	1.15	_	1.83	-	0.416	—

***to be updated later with exact running scenarios, e.g. 365 GeV for FCC-ee

in unit of %

Input: Higgs @ future e+e-

500GeV	1.6 ab ⁻¹ @ (-0.8,+0.3)		1.6 fb ⁻¹ @	(+0.8,-0.3)
prod.	ZH	vvH	ZH	vvH
σ	1.67	_	1.67	_
σxBR_{bb}	1.01	0.418	1.01	1.52
σxBR _{cc}	7.12	3.48	7.12	14.2
σxBR _{gg}	5.93	2.30	5.93	9.49
σxBRzz	13.8	4.75	13.8	19.0
σxBR _{ww}	3.05	1.36	3.05	5.54
σxBR _{ττ}	2.42	3.88	2.42	15.8
σxBR _{γγ}	18.6	10.7	18.6	43.5
σxBR _{µµ}	47.4	39.5	47.4	166
σxBR _{inv} .	0.825	-	0.599	_

in unit of %

***to be added: angular measurements in e+e- -> ZH

Preliminary results: bounds on operators

U(2) on 1&2 generation quarks are assumed for now

likely to be completely eased

$$+\frac{\left(C_{\phi q}^{(1)}\right)_{ii}}{\Lambda^{2}}(\phi^{\dagger}i\overset{\leftrightarrow}{D}_{\mu}\phi)(\bar{q}_{L}^{i}\gamma^{\mu}q_{L}^{i})+\frac{\left(C_{\phi l}^{(3)}\right)_{ii}}{\Lambda^{2}}(\phi^{\dagger}i\overset{\leftrightarrow}{D}_{\mu}\phi)(\bar{q}_{L}^{i}\gamma^{\mu}\sigma_{a}q_{L}^{i})$$
$$+\frac{\left(C_{\phi u}\right)_{ii}}{\Lambda^{2}}(\phi^{\dagger}i\overset{\leftrightarrow}{D}_{\mu}\phi)(\bar{u}_{R}^{i}\gamma^{\mu}u_{R}^{i})+\frac{\left(C_{\phi d}\right)_{ii}}{\Lambda^{2}}(\phi^{\dagger}i\overset{\leftrightarrow}{D}_{\mu}\phi)(\bar{d}_{R}^{i}\gamma^{\mu}d_{R}^{i})$$

for each gen., 4 ops. using Γ (Z->f), Γ (W->f), $+A_{LR}$ for c,s; $+R^{uc} + ?$ for u,d





precision reach on Wilson coefficients in the Warsaw basis

precision reach on Wilson coefficients in the Warsaw basis

Preliminary results: bounds on effective couplings

precision reach on EW couplings from full EFT global fit



defined from Z/W/H partial decay width

Solid shade: no 10^{-1} 10^{-2} 10^{-4} 10^{-4} δg_{H}^{ZZ} δg_{H}^{WW} δg_{H}^{YY} δg_{H}^{YY} δg_{H}^{ZY} δg_{H}^{ZY} δg_{H}^{ZY} δg_{H}^{ZY} δg_{H}^{ZY}

precision reach on effective couplings from full EFT global fit

