Electroweak and Higgs fits in the SM and beyond with HEPfit

EW and Flavor Physics @ CEPC

Beijing, November 9th 2017

Otto Eberhardt

Instituto de Física Corpuscular, Valencia, Spain

IFIC INSTITUT DE FÍSICA CORPUSCULAR

CSIC CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

VNIVERSITAT DE VALÈNCIA

EXCELENCIA SEVERO OCHOA

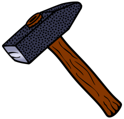
SM and the search beyond

SM is complete and no direct hint for New Physics at LHC energy.
Two possibilities to search for new physics:

SM and the search beyond

SM is complete and no direct hint for New Physics at LHC energy.
Two possibilities to search for new physics:

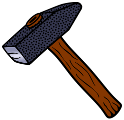
More energy



SM and the search beyond

SM is complete and no direct hint for New Physics at LHC energy.
Two possibilities to search for new physics:

More energy

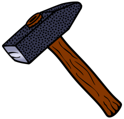


More precision

SM and the search beyond

SM is complete and no direct hint for New Physics at LHC energy.
Two possibilities to search for new physics:

More energy



(e.g. HE-LHC)

More precision

(e.g. ILC)

SM and the search beyond

SM is complete and no direct hint for New Physics at LHC energy.
Two possibilities to search for new physics:

More energy & More precision

(e.g. CEPC, FCC)

SM and the search beyond

SM is complete and no direct hint for New Physics at LHC energy.
Two possibilities to search for new physics:

More energy & More precision

(e.g. CEPC, FCC)

Future colliders

Different concepts: HE-LHC, ILC, CLIC, CEPC/SppC, FCC(ee)

They all have in common that we will have to wait for decades:

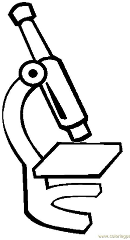
[XinChou Lou]

For the time being...

Let's try to scrutinize as well as possible the SM.

New Physics might hide in the details.

However, we need to combine all information
as consistently as possible.



Introduction

HEPfit

EW physics

Higgs physics

Summary

HEPfit

What?

Why?

Where?

Who?

When?

HEPfit

What?	High energy physics observables	
Why?	in the SM and beyond	
Where?	featuring	Flavour observables,
Who?		Electroweak precision observables and
		Higgs observables
When?	at best available precision	

HEPfit

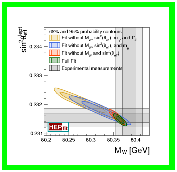
What? Stand-alone library or global fits for

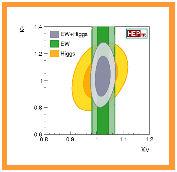
Why? SM EFT 2HDM MSSM ...

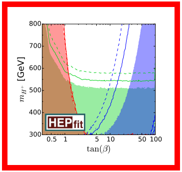
Where?

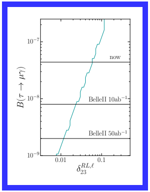
Who?

When?









HEPfit

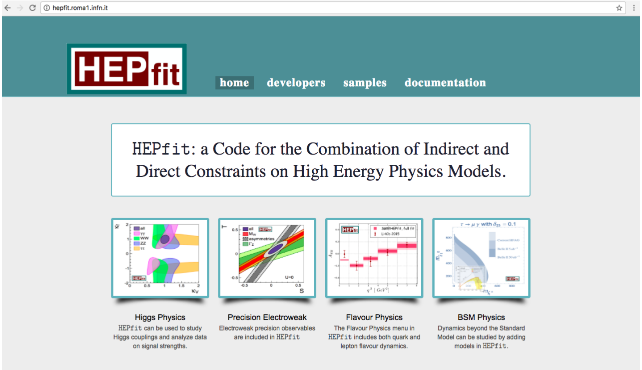
What?

Why?

Where?

Who?

When?



http://hepfit.roma1.infn.it

HEPfit

What?

Why?

Where?

Who?

When?

HEPfit was used for:

PoS EPS-HEP2015 187

JHEP 1611 (2016) 026

JHEP 1612 (2016) 135

PoS ICHEP2016 (2017) 690

EPJC 77 (2017) 10, 688

PoS EPS-HEP2017 281

arXiv:1710.05402

arXiv:1711.02095

HEPfit

- What?
- Why?
- Where?
- Who?
- When?

CERN	**Padova University**	**São Paulo**
Maurizio Pierini	Jorge de Blas	Giovanni Grilli
Florida State U.	**Rome I&III**	**EP Paris**
Laura Reina	Marco Ciuchini	Debtosh Chowdhury
IFIC Valencia	António Coutinho	**Tehran University**
Otto Eberhardt	Marco Fedele	Shehu AbdusSalam
KEK	Enrico Franco	**Tohoku University**
Satoshi Mishima	Luca Silvestrini	Norimi Yokozaki
Lanzhou University	Mauro Valli	**HU Berlin**
Fu-Sheng Yu		Ayan Paul

HEPfit

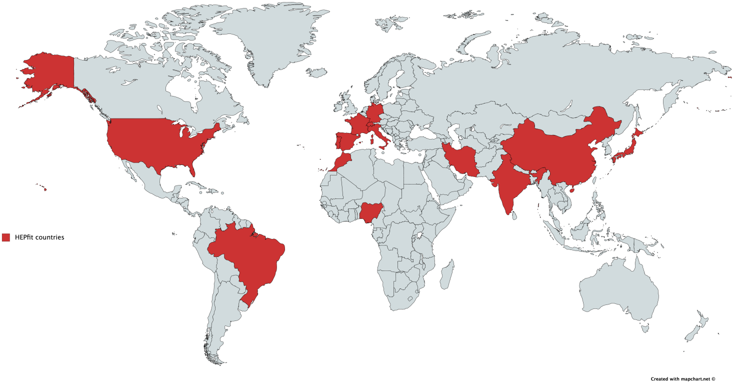
What?

Why?

Where?

Who?

When?



HEPfit

What?

Why?

Where?

Who?

When?

Already now: development version

https://github.com/silvest/HEPfit

Winter 2017/18: first fully documented release

http://hepfit.roma1.infn.it

HEPfit

What?

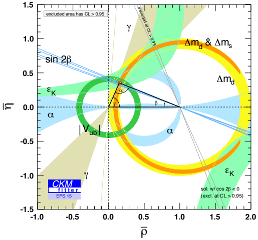
Why?

Where?

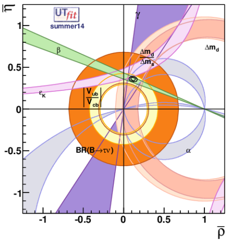
Who?

When?

How fast?



[CKMfitter ’15]



[UTfit ’14]

∼days

HEPfit

What?

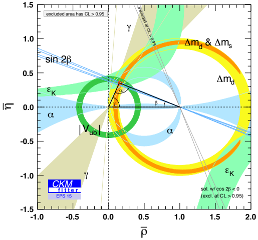
Why?

Where?

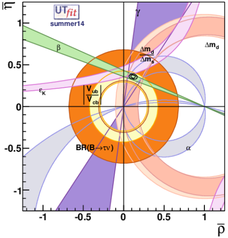
Who?

When?

How fast?

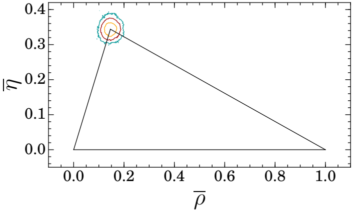


[CKMfitter '15]



[UTfit '14]

∼days



∼hours

HEPfit

What?

Why?

Where?

Who?

When?

How fast?

How much?

It's free and it's open-source!

General overview

Model $\longrightarrow$ Parameters & Observables

Priors $\pi(\boldsymbol{\theta})$ Likelihoods $L(\boldsymbol{x}|\boldsymbol{\theta})$

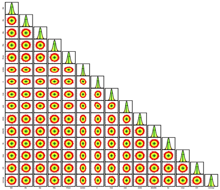
Output:

General overview

Model ⟶ Parameters & Observables

Priors $\pi(\boldsymbol{\theta})$ Likelihoods $L(\boldsymbol{x}|\boldsymbol{\theta})$

Output: Parameter and observable posterior distributions

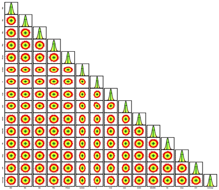


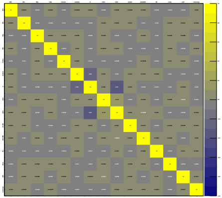
General overview

Model ⟶ Parameters & Observables

Priors $\pi(\boldsymbol{\theta})$ Likelihoods $L(\boldsymbol{x}|\boldsymbol{\theta})$

Output: Parameter and observable posterior distributions
Parameter correlations



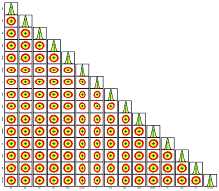


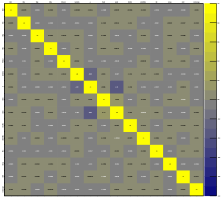
General overview

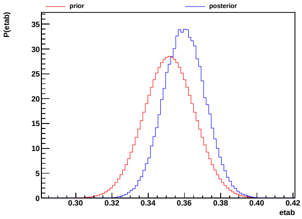
Model ⟶ Parameters & Observables

Priors $\pi(\boldsymbol{\theta})$ Likelihoods $L(\boldsymbol{x}|\boldsymbol{\theta})$

Output: Parameter and observable posterior distributions
Parameter correlations
Comparison of prior and posterior





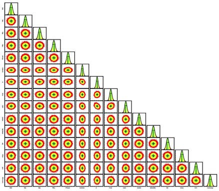


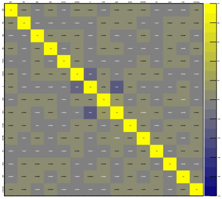
General overview

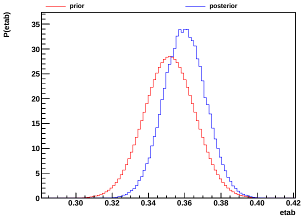
Model ⟶ Parameters & Observables

Priors $\pi(\boldsymbol{\theta})$ Likelihoods $L(\boldsymbol{x}|\boldsymbol{\theta})$

Output: Parameter and observable posterior distributions
Parameter correlations
Comparison of prior and posterior
Global mode and normalisation







HEPfit – models

- Standard Model
- "Model independent models":
  EW oblique parameters (S, T, U; ϵ_i)
  Modified $Zb\bar{b}$ vertex ($\delta g^b_{L,R}$, $\delta g^b_{V,A}$)
  Higgs signal strengths μ_i
  Mod. Higgs couplings κ_i (with and w/o universal V and f couplings)
  Various dim-6 bases (GIMR, BS with and w/o QFU,LFU)
  Flavour Wilson coefficients
- $\mathbb{Z}_2$ symmetric 2HDM's
- MSSM with complex couplings

In development: General 2HDM, LRSM,
Georgi-Machacek, Manohar-Wise

HEPfit – observables

HEPfit name	Model(s)	Comments
MtMSbar	SM	
Mw	SM	
GammaW	SM	
GammaZ	SM	
sigmaHadron	SM	
sin2thetaEff	SM	
PtauPol	SM	
Alepton	SM	
Acharm	SM	
Abottom	SM	
AFBlepton	SM	
AFBcharm	SM	
AFBbottom	SM	
Rlepton	SM	
Rcharm	SM	
Rbottom	SM	
ggHx	SM	$x \in 7, 8, 13, 14, 100, 196$; without x default is 8
VBFx	SM	$x \in 7, 8, 13, 14, 100, 196$; without x default is 8
WHx	SM	$x \in 7, 8, 13, 14, 100$; without x default is 8
ZHx	SM	$x \in 7, 8, 13, 14, 100$; without x default is 8
VHx	SM	$x \in 7, 8, 13, 14, 100, 196$; without x default is 8
ggH+ttHx	SM	$x \in 8, 13, 14, 100$; without x default is 8
VBF+VHx	SM	$x \in 8, 13, 14, 100$; without x default is 8
ttHx	SM	$x \in 7, 8, 13, 14, 100, 196$; without x default is 8
eeZHx	SM	$x \in 240, 250, 500, 1000$
eeWBFx	SM	$x \in 250, 350, 500, 1000$
eettHx	SM	$x \in 500, 1000$
BrHggRatio	SM	
BrHWWRatio	SM	
BrHZZRatio	SM	
BrHZgaRatio	SM	
BrHgagaRatio	SM	
BrHmumuRatio	SM	
BrHtautauRatio	SM	
BrHccRatio	SM	
BrHbbRatio	SM	
epsilonx	SM	$x = 1, 2, 3, b$
DmBd	SM	
DmBs	SM,THDM	
SJPsiK	SM	
Betas_JPsiPhi	SM	
EpsilonK	SM	
DmK	SM	
Vij	SM	$i = u, c, t$; $j = d, s, b$
alpha	SM	
alpha_2a	SM	
gamma	SM	
beta	SM	
betas	SM	
2betapgamma	SM	
s2beta	SM	
c2beta	SM	
CKM_rho	SM	
CKM_eta	SM	
sintheta12	SM	
sintheta13	SM	
sintheta23	SM	
ckmdelta	SM	
J_CP	SM	
Rt	SM	
Rts	SM	
Rb	SM	
VtdoVts	SM	
Abslam_x	SM	$x \in u, c, t, ud, cd, td, us, cs, ts$
Relam_x	SM	$x \in u, c, t, ud, cd, td, us, cs, ts$
Imlam_x	SM	$x \in u, c, t, ud, cd, td, us, cs, ts$
BR_Bdmumu	SM	
BRbar_Bdmumu	SM	
Amumu_Bd	SM	
Smumu_Bd	SM	
BR_Bsmumu	SM	
BRbar_Bsmumu	SM	
Amumu_Bs	SM	
Smumu_Bs	SM	
BR_BdmumuOBR_Bsmumu	SM	

HEPfit name	Model(s)	Comments
BR_bsgamma	SM	
ACP_bsgamma	SM	
BR_bdgamma	SM	
ACP_bdgamma	SM	
BR_bqgamma	SM	
ACP_bqgamma	SM	
P_i_BdKstmu	SM	$i \in 1, 2, 3, 4p, 5p, 6p, 8p$
P_i_BdKste	SM	$i \in 1, 2, 3$
Gammap_BdKstmu	SM	
A_FB_BdKstmu	SM	
BR_BdKstmu	SM	
BR_BdKste	SM	
RKst_BdKstll	SM	
RKstL_BdKstll	SM	
RKstT_BdKstll	SM	
R6_BdKstll	SM	
ACP_BdKstmu	SM	
P3CP_BdKstmu	SM	
F_L_BdKstmu	SM	
F_L_BdKste	SM	
M_i_BdKstmu	SM	$i \in 1p, 2p$
S_i_BdKstmu	SM	$i \in 3, 4, 5, 7, 8, 9$
A_i_BdKstmu	SM	$i \in 6, 9$
P_if_BdKstmu	SM	$i \in 1, 2, 3, 4p, 5p, 6p, 8p$
Gammapf_BdKstmu	SM	
BRf_BdKstmu	SM	
A_FBf_BdKstmu	SM	
F_Lf_BdKstmu	SM	
S_if_BdKstmu	SM	$i \in 3, 4, 5, 7, 8, 9$
P_relationf	SM	
P_relation_exactf	SM	
Vx_BdKstmu	SM	$x \in 0, p, m$
Tx_BdKstmu	SM	$x \in 0, p, m$
S_BdKstmu	SM	
QCDfC9_if_BdKstmu	SM	$i \in 1, 2, 3$
QCDfC9p_if_BdKstmu	SM	$i \in 1, 2, 3$
Regtilde_i_BdKstmu	SM	$i \in 1, 2, 3$
Imgtilde_i_BdKstmu	SM	$i \in 1, 2, 3$
Absgtilde_i_BdKstmu	SM	$i \in 1, 2, 3$
Arggtilde_i_BdKstmu	SM	$i \in 1, 2, 3$
Reh_x_BdKstmu	SM	$x \in 0, p, m$
Imh_x_BdKstmu	SM	$x \in 0, p, m$
Absh_x_BdKstmu	SM	$x \in 0, p, m$
Argh_x_BdKstmu	SM	$x \in 0, p, m$
A_FB_BpKstmu	SM	
F_L_BpKstmu	SM	
BR_BpKstmu	SM	
BR_BKstgamma	SM	
C_BKstgamma	SM	
S_BKstgamma	SM	
ADG_BKstgamma	SM	
DC7_i	SM	$i \in 1, 2$
AbsDC7_x	SM	$x \in L, R$
ReDC7_x	SM	$x \in L, R$
ImDC7_x	SM	$x \in L, R$
hp0_hm0	SM	
BR_BpKstgamma	SM	
P_i_Bsphimu	SM	$i \in 1, 2, 3, 4p, 5p, 6p, 8p$
Gammap_Bsphimu	SM	
A_FB_Bsphimu	SM	
BR_Bsphimu	SM	
Rphi_Bsphill	SM	
RphiL_Bsphill	SM	
RphiT_Bsphill	SM	
R6_Bsphill	SM	
ACP_Bsphimu	SM	
P3CP_Bsphimu	SM	
F_L_Bsphimu	SM	
M_i_Bsphimu	SM	$i \in 1p, 2p$
S_i_Bsphimu	SM	$i \in 3, 4, 5, 7, 8, 9$
A_i_Bsphimu	SM	$i \in 6, 9$
BR_Bsphigamma	SM	
C_Bsphigamma	SM	
S_Bsphigamma	SM	
ADG_Bsphigamma	SM	
BR_BKmu	SM	
BR_BKe	SM	
RK_BKll	SM	
btaunu	SM,THDM	

HEPfit name	Model(s)	Comments
mu_e_gamma	SUSY	
log_meg	SUSY	
tau_mu_gamma	SUSY	
log_tmg	SUSY	
tau_e_gamma	SUSY	
log_teg	SUSY	
mu_3e	SUSY	
tau_3mu	SUSY	
tau_3e	SUSY	
gminus2_mu	SUSY	
Robs_mu_e_gamma	SUSY	
Robs_tau_mu_gamma	SUSY	
Robs_tau_mu_gamma_BelleII	SUSY	
Robs_tau_e_gamma	SUSY	
deltaLLi_f	SUSY	$i = 1, 2, 3,\ f = q, l$
deltaRL_ij_u	SUSY	$ij = 12, 13, 23$
deltaRL_ij_e	SUSY	$ij = 12, 13, 23, 21, 31, 32$
deltaRRi_f	SUSY	$i = 1, 2, 3,\ f = u, d, e$
CCBfij	SUSY	$f = u, d, e,\ ij = 11, 22, 33, 12, 13, 23$
MHl	SUSY	
MHh	SUSY	
MHa	SUSY	
MHp	SUSY	
Msfi	SUSY	$f = u, d, l,\ i = 1, 2, 3, 4, 5, 6$
Msnui	SUSY	$i = 1, 2, 3$
Mchi	SUSY	$i = 1, 2$
Msneui	SUSY	$i = 1, 2, 3, 4$
Mw_dRho	SUSY	
mHl_THDM	THDM	
mHh	THDM	
mA	THDM	
mHp	THDM	
mHlmmA	THDM	
mAmmHl	THDM	
mHlmmHp	THDM	
mHpmmHl	THDM	
mHhmmA	THDM	
mAmmHh	THDM	
mHhmmHp	THDM	
mHpmmHh	THDM	
mAmmHp	THDM	
mHpmmA	THDM	
mii_2	THDM	$ii = 11, 22$
lambdai	THDM	$i = 1, 2, 3, 4, 5$
lambda345	THDM	
g_hhh	THDM	
g_hhHh	THDM	
g_hHhHh	THDM	
g_HhHhHh	THDM	
g_hAA	THDM	
g_HhAA	THDM	
g_hHpHm	THDM	
g_HhHpHm	THDM	
Yi_THDM	THDM	$i = 1, 2, 3$
Zi_THDM	THDM	$i = 1, 2, 3, 4, 5, 6, 7$
xin_THDM	THDM	$n = 0, 1, 3$
etax_THDM	THDM	$x = 00, 3$
Eii_THDM	THDM	$ii = 11, 22, 33$
HHlambdai	THDM	$i = 1, 2, 3, 4, 5, 6$
Q_st	THDM	
DeltaQ_THDM	THDM	
giatQ	THDM	$i = 1, 2, 3$
YtopatQ	THDM	
YbottomatQ	THDM	
YtauatQ	THDM	
mij_2atQ	THDM	$ij = 11, 22, 12$
lambdaiatQ	THDM	$i = 1, 2, 3, 4, 5$
positivityi	THDM	$i = 1, 2$
globalminimum	THDM	
unitarityi	THDM	$i = \{1 \ldots 12\}$
unitarityalσodd	THDM	$\sigma = 0, 1$
unitarityalσoddRe	THDM	$\sigma = 0, 1$
unitarityalσoddIm	THDM	$\sigma = 0, 1$
unitaritya$Y\sigma\mathbb{Z}_2 s$	THDM	$Y\sigma = 00, 01, 11,\ \mathbb{Z}_2 = odd, even,\ s = p, m$
unitaritya$Y\sigma\mathbb{Z}_2 s$Re	THDM	$Y\sigma = 00, 01, 11,\ \mathbb{Z}_2 = odd, even,\ s = p, m$
unitaritya$Y\sigma\mathbb{Z}_2 s$Im	THDM	$Y\sigma = 00, 01, 11,\ \mathbb{Z}_2 = odd, even,\ s = p, m$
unitarityRpi	THDM	$i = 1, 2, 3, 4, 5, 6, 9, 10, 13, 14, 19, 20$
unitarityRi	THDM	$i = 1, 2, 3, 4, 5, 6, 9, 10, 13, 14, 19, 20$
ggF_tth_htobb	THDM	
ggF_tth_htoWW	THDM	
ggF_tth_htotautau	THDM	
ggF_tth_htoZZ	THDM	
ggF_tth_htogaga	THDM	
VBF_Vh_htobb	THDM	
VBF_Vh_htoWW	THDM	
VBF_Vh_htotautau	THDM	
VBF_Vh_htoZZ	THDM	
VBF_Vh_htogaga	THDM	
Gamma_h_THDM	THDM	
rh_gaga_THDM	THDM	
rh_gg_THDM	THDM	

HEPfit name	Model(s)	Comments
Robs_$B\sigma$	THDM	$B\sigma \in$ ggF_H_tautau_ATLAS, ggF_H_tautau_CMS, bbF_H_tautau_ATLAS, bbF_H_tautau_CMS, pp_H_gaga_ATLAS, ggF_H_gaga_CMS, mu_pp_H_VV_CMS, ggF_H_ZZ_ATLAS, VBF_H_ZZ_ATLAS, ggF_H_WW_ATLAS, VBF_H_WW_ATLAS, ggF_H_hh_ATLAS, pp_H_hh_CMS, ggF_H_hh_bbtautau_CMS, pp_H_hh_bbbb_CMS, pp_H_hh_gagabb_CMS, ggF_H_tt_ATLAS, bbF_H_bb_CMS
log10_$B\sigma$	THDM	$B\sigma \in$ ggF_H_tautau_TH, bbF_H_tautau_TH, pp_H_gaga_TH, ggF_H_gaga_TH, mu_pp_H_VV_TH, ggF_H_ZZ_TH, VBF_H_ZZ_TH, ggF_H_WW_TH, VBF_H_WW_TH, ggF_H_hh_TH, pp_H_hh_TH, ggF_H_hh_bbtautau_TH, pp_H_hh_bbbb_TH, pp_H_hh_gagabb_TH, ggF_H_tt_TH, bbF_H_bb_TH
Gamma_HH_THDM	THDM	
rHH_gg_THDM	THDM	
BR_HH_hh_THDM	THDM	
BR_HH_AA_THDM	THDM	
BR_HH_HpHm_THDM	THDM	
BR_HH_AZ_THDM	THDM	
BR_HH_HpW_THDM	THDM	
Robs_$B\sigma$	THDM	$B\sigma \in$ ggF_A_tautau_ATLAS, ggF_A_tautau_CMS, bbF_A_tautau_ATLAS, bbF_A_tautau_CMS, pp_A_gaga_ATLAS, ggF_A_gaga_CMS, pp_A_Zga_llga_CMS, ggF_A_hZ_bbll_CMS, ggF_A_hZ_bbZ_ATLAS, ggF_A_hZ_tautaull_CMS, ggF_A_hZ_tautauZ_ATLAS, ggF_A_tt_ATLAS, bbF_A_bb_CMS
log10_$B\sigma$	THDM	$B\sigma \in$ ggF_A_tautau_TH, bbF_A_tautau_TH, pp_A_gaga_TH, ggF_A_gaga_TH, pp_A_Zga_llga_TH, ggF_A_hZ_bbll_TH, ggF_A_hZ_bbZ_TH, ggF_A_hZ_tautaull_TH, ggF_A_hZ_tautauZ_TH, ggF_A_tt_TH, bbF_A_bb_TH
Gamma_A_THDM	THDM	
rA_gg_THDM	THDM	
BR_A_HZ_THDM	THDM	
BR_A_hZ_THDM	THDM	
BR_A_HpW_THDM	THDM	
DeltaS	THDM	
DeltaT	THDM	
DeltaU	THDM	
B_BtoXsgammaTHDM	THDM	Interpolation of tabled values

HEPfit – observables

EWPO

Higgs

Flavour

HEPfit name	Model(s)	Comments
MtMSbar	SM	
Mw	SM	
GammaW	SM	
GammaZ	SM	
sigmaHadron	SM	
sin2thetaEff	SM	
PtauPol	SM	
Alepton	SM	
Acharm	SM	
Abottom	SM	
AFBlepton	SM	
AFBcharm	SM	
AFBbottom	SM	
Rlepton	SM	
Rcharm	SM	
Rbottom	SM	
ggHx	SM	$x \in 7, 8, 13, 14, 100, 196$; without x default is 8
VBFx	SM	$x \in 7, 8, 13, 14, 100, 196$; without x default is 8
WHx	SM	$x \in 7, 8, 13, 14, 100$; without x default is 8
ZHx	SM	$x \in 7, 8, 13, 14, 100$; without x default is 8
VHx	SM	$x \in 7, 8, 13, 14, 100, 196$; without x default is 8
ggH+ttHx	SM	$x \in 8, 13, 14, 100$; without x default is 8
VBF+VHx	SM	$x \in 8, 13, 14, 100$; without x default is 8
ttHx	SM	$x \in 7, 8, 13, 14, 100, 196$; without x default is 8
eeZHx	SM	$x \in 240, 250, 500, 1000$
eeWBFx	SM	$x \in 250, 350, 500, 1000$
eettHx	SM	$x \in 500, 1000$
BrHggRatio	SM	
BrHWWRatio	SM	
BrHZZRatio	SM	
BrHZgaRatio	SM	
BrHgagaRatio	SM	
BrHmumuRatio	SM	
BrHtautauRatio	SM	
BrHccRatio	SM	
BrHbbRatio	SM	
epsilonx	SM	$x = 1, 2, 3, b$
DmBd	SM	
DmBs	SM,THDM	
SJPsiK	SM	
Betas_JPsiPhi	SM	
EpsilonK	SM	
DmK	SM	
Vij	SM	$i = u, c, t$; $j = d, s, b$
alpha	SM	
alpha_2a	SM	
gamma	SM	
beta	SM	
betas	SM	
2betapgamma	SM	
s2beta	SM	
c2beta	SM	
CKM_rho	SM	
CKM_eta	SM	
sintheta12	SM	
sintheta13	SM	
sintheta23	SM	
ckmdelta	SM	
J_CP	SM	
Rt	SM	
Rts	SM	
Rb	SM	
VtdoVts	SM	
Abslam_x	SM	$x \in u, c, t, ud, cd, td, us, cs, ts$
Relam_x	SM	$x \in u, c, t, ud, cd, td, us, cs, ts$
Imlam_x	SM	$x \in u, c, t, ud, cd, td, us, cs, ts$
BR_Bdmumu	SM	
BRbar_Bdmumu	SM	
Amumu_Bd	SM	
Smumu_Bd	SM	
BR_Bsmumu	SM	
BRbar_Bsmumu	SM	
Amumu_Bs	SM	
Smumu_Bs	SM	
BR_BdmumuOBR_Bsmumu	SM	

Flavour

HEPfit name	Model(s)	Comments
BR_bsgamma	SM	
ACP_bsgamma	SM	
BR_bdgamma	SM	
ACP_bdgamma	SM	
BR_bqgamma	SM	
ACP_bqgamma	SM	
P_i_BdKstmu	SM	$i \in 1, 2, 3, 4p, 5p, 6p, 8p$
P_i_BdKste	SM	$i \in 1, 2, 3$
Gammap_BdKstmu	SM	
A_FB_BdKstmu	SM	
BR_BdKstmu	SM	
BR_BdKste	SM	
RKst_BdKstll	SM	
RKstL_BdKstll	SM	
RKstT_BdKstll	SM	
R6_BdKstll	SM	
ACP_BdKstmu	SM	
P3CP_BdKstmu	SM	
F_L_BdKstmu	SM	
F_L_BdKste	SM	
M_i_BdKstmu	SM	$i \in 1p, 2p$
S_i_BdKstmu	SM	$i \in 3, 4, 5, 7, 8, 9$
A_i_BdKstmu	SM	$i \in 6, 9$
P_if_BdKstmu	SM	$i \in 1, 2, 3, 4p, 5p, 6p, 8p$
Gammapf_BdKstmu	SM	
BRf_BdKstmu	SM	
A_FBf_BdKstmu	SM	
F_Lf_BdKstmu	SM	
S_if_BdKstmu	SM	$i \in 3, 4, 5, 7, 8, 9$
P_relationf	SM	
P_relation_exactf	SM	
Vx_BdKstmu	SM	$x \in 0, p, m$
Tx_BdKstmu	SM	$x \in 0, p, m$
S_BdKstmu	SM	
QCDfC9_if_BdKstmu	SM	$i \in 1, 2, 3$
QCDfC9p_if_BdKstmu	SM	$i \in 1, 2, 3$
Regtilde_i_BdKstmu	SM	$i \in 1, 2, 3$
Imgtilde_i_BdKstmu	SM	$i \in 1, 2, 3$
Absgtilde_i_BdKstmu	SM	$i \in 1, 2, 3$
Arggtilde_i_BdKstmu	SM	$i \in 1, 2, 3$
Reh_x_BdKstmu	SM	$x \in 0, p, m$
Imh_x_BdKstmu	SM	$x \in 0, p, m$
Absh_x_BdKstmu	SM	$x \in 0, p, m$
Argh_x_BdKstmu	SM	$x \in 0, p, m$
A_FB_BpKstmu	SM	
F_L_BpKstmu	SM	
BR_BpKstmu	SM	
BR_BKstgamma	SM	
C_BKstgamma	SM	
S_BKstgamma	SM	
ADG_BKstgamma	SM	
DC7_i	SM	$i \in 1, 2$
AbsDC7_x	SM	$x \in L, R$
ReDC7_x	SM	$x \in L, R$
ImDC7_x	SM	$x \in L, R$
hp0_hm0	SM	
BR_BpKstgamma	SM	
P_i_Bsphimu	SM	$i \in 1, 2, 3, 4p, 5p, 6p, 8p$
Gammap_Bsphimu	SM	
A_FB_Bsphimu	SM	
BR_Bsphimu	SM	
Rphi_Bsphill	SM	
RphiL_Bsphill	SM	
RphiT_Bsphill	SM	
R6_Bsphill	SM	
ACP_Bsphimu	SM	
P3CP_Bsphimu	SM	
F_L_Bsphimu	SM	
M_i_Bsphimu	SM	$i \in 1p, 2p$
S_i_Bsphimu	SM	$i \in 3, 4, 5, 7, 8, 9$
A_i_Bsphimu	SM	$i \in 6, 9$
BR_Bsphigamma	SM	
C_Bsphigamma	SM	
S_Bsphigamma	SM	
ADG_Bsphigamma	SM	
BR_BKmu	SM	
BR_BKe	SM	
RK_BKll	SM	
btaunu	SM,THDM	

SUSY

2HDM

HEPfit name	Model(s)	Comments
mu_e_gamma	SUSY	
log_meg	SUSY	
tau_mu_gamma	SUSY	
log_tmg	SUSY	
tau_e_gamma	SUSY	
log_teg	SUSY	
mu_3e	SUSY	
tau_3mu	SUSY	
tau_3e	SUSY	
gminus2_mu	SUSY	
Robs_mu_e_gamma	SUSY	
Robs_tau_mu_gamma	SUSY	
Robs_tau_mu_gamma_BelleII	SUSY	
Robs_tau_e_gamma	SUSY	
deltaLLi_f	SUSY	$i = 1, 2, 3$, $f = q, l$
deltaRL_ij_u	SUSY	$ij = 12, 13, 23$
deltaRL_ij_e	SUSY	$ij = 12, 13, 23, 21, 31, 32$
deltaRRi_f	SUSY	$i = 1, 2, 3$, $f = u, d, e$
CCBfij	SUSY	$f = u, d, e$, $ij = 11, 22, 33, 12, 13, 23$
MH1	SUSY	
[illegible]	SUSY	
MHa	SUSY	
MHp	SUSY	
Msfi	SUSY	$f = u, d, l$, $i = 1, 2, 3, 4, 5, 6$
Msnui	SUSY	$i = 1, 2, 3$
Mchi	SUSY	$i = 1, 2$
Msneui	SUSY	$i = 1, 2, 3, 4$
Mw_dRho	SUSY	
mH1_THDM	THDM	
mHh	THDM	
mA	THDM	
mHp	THDM	
mH1mmA	THDM	
mAmmH1	THDM	
mH1mmHp	THDM	
mHpmmH1	THDM	
mHhmmA	THDM	
mAmmHh	THDM	
mHhmmHp	THDM	
mHpmmHh	THDM	
mAmmHp	THDM	
mHpmmA	THDM	
mii_2	THDM	$ii = 11, 22$
lambdai	THDM	$i = 1, 2, 3, 4, 5$
lambda345	THDM	
g_hhh	THDM	
g_hhHh	THDM	
g_hHhHh	THDM	
g_HhHhHh	THDM	
g_hAA	THDM	
g_HhAA	THDM	
g_hHpHm	THDM	
g_HhHpHm	THDM	
Yi_THDM	THDM	$i = 1, 2,$ [illegible]
Zi_THDM	THDM	$i = 1, 2, 3, 4, 5, 6, 7$
xin_THDM	THDM	$n = 0, 1, 3$
etax_THDM	THDM	$x = 00, 3$[illegible]
Eii_THDM	THDM	$ii = 11, 22, 33$
[illegible]lambdai	THDM	$i = 1, 2, 3, 4, 5, 6$
Q_[illegible]t	THDM	
DeltaQ_THDM	THDM	
giatQ	THDM	$i = 1, 2, 3$
YtopatQ	THDM	
YbottomatQ	THDM	
YtauatQ	THDM	
mij_2atQ	THDM	$ij = 11, 22, 12$
lambdaiatQ	THDM	$i = 1, 2, 3, 4, 5$
positivityi	THDM	$i = 1, 2$
globalminimum	THDM	
unitarityi	THDM	$i = \{1 \ldots 12\}$
unitaritya1σodd	THDM	$\sigma = 0, 1$
unitaritya1σoddRe	THDM	$\sigma = 0, 1$
unitaritya1σoddIm	THDM	$\sigma = 0, 1$
unitarityaYσZ2s	THDM	$Y\sigma = 00, 01, 11$, $\mathbb{Z}_2 = odd, even$, $s = p, m$
unitarityaYσZ2sRe	THDM	$Y\sigma = 00, 01, 11$, $\mathbb{Z}_2 = odd, even$, $s = p, m$
unitarityaYσZ2sIm	THDM	$Y\sigma = 00, 01, 11$, $\mathbb{Z}_2 = odd, even$, $s = p, m$
unitarityRpi	THDM	$i = 1, 2, 3, 4, 5, 6, 9, 10, 13, 14, 19, 20$
unitarityRi	THDM	$i = 1, 2, 3, 4, 5, 6, 9, 10, 13, 14, 19, 20$
ggF_tth_htobb	THDM	
ggF_tth_htoWW	THDM	
ggF_tth_htotautau	THDM	
ggF_tth_htoZZ	THDM	
ggF_tth_htogaga	THDM	
VBF_Vh_htobb	THDM	
VBF_Vh_htoWW	THDM	
VBF_Vh_htotautau	THDM	
VBF_Vh_htoZZ	THDM	
VBF_Vh_htogaga	THDM	
Gamma_h_THDM	THDM	
rh_gaga_THDM	THDM	
rh_gg_THDM	THDM	

2HDM

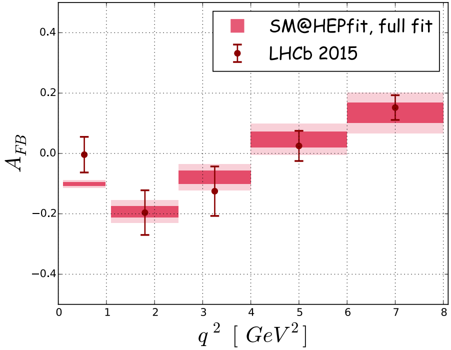
HEPfit name	Model(s)	Comments
Robs_Bσ	THDM	$B\sigma \in$ ggF_H_tautau_ATLAS, ggF_H_tautau_CMS, bbF_H_tautau_ATLAS, bbF_H_tautau_CMS, pp_H_gaga_ATLAS, ggF_H_gaga_CMS, mu_pp_H_VV_CMS, ggF_H_ZZ_ATLAS, VBF_H_ZZ_ATLAS, ggF_H_WW_ATLAS, VBF_H_WW_ATLAS, ggF_H_hh_ATLAS, pp_H_hh_CMS, ggF_H_hh_bbtautau_CMS, pp_H_hh_bbbb_CMS, pp_H_hh_gagabb_CMS, ggF_H_tt_ATLAS, bbF_H_bb_CMS
log10_Bσ	THDM	$B\sigma \in$ ggF_H_tautau_TH, bbF_H_tautau_TH, pp_H_gaga_TH, ggF_H_gaga_TH, mu_pp_H_VV_TH, ggF_H_ZZ_TH, VBF_H_ZZ_TH, ggF_H_WW_TH, VBF_H_WW_TH, ggF_H_hh_TH, pp_H_hh_TH, ggF_H_hh_bbtautau_TH, pp_H_hh_bbbb_TH, pp_H_hh_gagabb_TH, ggF_H_tt_TH, bbF_H_bb_TH
Gamma_HH_THDM	THDM	
rHH_gg_THDM	THDM	
BR_HH_hh_THDM	THDM	
BR_HH_AA_THDM	THDM	
BR_HH_HpHm_THDM	THDM	
BR_HH_AZ_THDM	THDM	
BR_HH_HpW_THDM	THDM	
Robs_Bσ	THDM	$B\sigma \in$ ggF_A_tautau_ATLAS, ggF_A_tautau_CMS, bbF_A_tautau_ATLAS, bbF_A_tautau_CMS, pp_A_gaga_ATLAS, ggF_A_gaga_CMS, pp_A_Zga_llga_CMS, ggF_A_hZ_bbll_CMS, ggF_A_hZ_bbZ_ATLAS, ggF_A_hZ_tautaull_CMS, ggF_A_hZ_tautauZ_ATLAS, ggF_A_tt_ATLAS, bbF_A_bb_CMS
log10_Bσ	THDM	$B\sigma \in$ ggF_A_tautau_TH, bbF_A_tautau_TH, pp_A_gaga_TH, ggF_A_gaga_TH, pp_A_Zga_llga_TH, ggF_A_hZ_bbll_TH, ggF_A_hZ_bbZ_TH, ggF_A_hZ_tautaull_TH, ggF_A_hZ_tautauZ_TH, ggF_A_tt_TH, bbF_A_bb_TH
Gamma_A_THDM	THDM	
rA_gg_THDM	THDM	
BR_A_HZ_THDM	THDM	
BR_A_hZ_THDM	THDM	
BR_A_HpW_THDM	THDM	
DeltaS	THDM	
DeltaT	THDM	
DeltaU	THDM	
B_BtoXsgammaTHDM	THDM	Interpolation of tabled values

Flavour observables

- B-$\overline{B}$ and K-$\overline{K}$ mixing
- $B \to \tau\nu$
- $B \to \mu^+\mu^-$
- $b \to q\gamma$
- $B \to K^*\ell\ell$, $B \to K^*\gamma$
- $B \to K\ell\ell$
- $B \to \phi\ell\ell$, $B \to \phi\gamma$
- CKM matrix parametrizations

Flavour observables

- B-$\overline{B}$ and K-$\overline{K}$ mixing
- $B \to \tau\nu$
- $B \to \mu^+\mu^-$
- $b \to q\gamma$
- $B \to K^*\ell\ell$, $B \to K^*\gamma$
- $B \to K\ell\ell$
- $B \to \phi\ell\ell$, $B \to \phi\gamma$
- CKM matrix parametrizations



[1512.07157]

Introduction

HEPfit

EW physics

Higgs physics

Summary

EW physics – precision observables

Experiment		Observables		Theory
Z resonance Cross sections (total and differential) Asymmetries (LR, FB)	$\rightarrow$	m_Z, Γ_Z, σ^0_{had} $R^0_{b/c/\ell}$, $A^{0,b/c/\ell}_{\text{FB}}$ $\mathcal{A}_{b/c/\ell}$, $\sin^2\theta^{\text{eff}}_\ell$	$\leftarrow$	SM calculations up to 3-loop precision
W resonance	$\rightarrow$	m_W, Γ_W		
t resonance	$\rightarrow$	m_t		
$(g-2)_\mu$	$\rightarrow$	$\Delta\alpha^{(5)}_{\text{had}}$		
τ decays	$\rightarrow$	α_s		
h resonance	$\rightarrow$	m_h		

EWPO – SM fit with HEPfit

	Measurement	Posterior	Prediction	Pull
$\alpha_s(M_Z)$	0.1180 ± 0.0010	0.1180 ± 0.0009	0.1184 ± 0.0028	-0.1
$\Delta\alpha^{(5)}_{\rm had}(M_Z)$	0.02750 ± 0.00033	0.02743 ± 0.00025	0.02734 ± 0.00037	0.3
M_Z [GeV]	91.1875 ± 0.0021	91.1880 ± 0.0021	91.198 ± 0.010	-1.0
m_t [GeV]	$173.1 \pm 0.6 \pm 0.5$	173.43 ± 0.74	176.1 ± 2.2	-1.3
m_H [GeV]	125.09 ± 0.24	125.09 ± 0.24	100.6 ± 23.6	1.0
M_W [GeV]	80.379 ± 0.012	80.3643 ± 0.0058	80.3597 ± 0.0067	1.4
Γ_W [GeV]	2.085 ± 0.042	2.08873 ± 0.00059	2.08873 ± 0.00059	-0.1
$\sin^2\theta^{\rm lept}_{\rm eff}(Q^{\rm had}_{\rm FB})$	0.2324 ± 0.0012	0.231454 ± 0.000084	0.231449 ± 0.000085	0.8
$P^{\rm pol}_\tau = A_\ell$	0.1465 ± 0.0033	0.14756 ± 0.00066	0.14761 ± 0.00067	-0.3
Γ_Z [GeV]	2.4952 ± 0.0023	2.49424 ± 0.00056	2.49412 ± 0.00059	0.5
σ^0_h [nb]	41.540 ± 0.037	41.4898 ± 0.0050	41.4904 ± 0.0053	1.3
R^0_ℓ	20.767 ± 0.025	20.7492 ± 0.0060	20.7482 ± 0.0064	0.7
$A^{0,\ell}_{\rm FB}$	0.0171 ± 0.0010	0.01633 ± 0.00015	0.01630 ± 0.00015	0.8
A_ℓ (SLD)	0.1513 ± 0.0021	0.14756 ± 0.00066	0.14774 ± 0.00074	1.6
R^0_b	0.21629 ± 0.00066	0.215795 ± 0.000027	0.215793 ± 0.000027	0.7
R^0_c	0.1721 ± 0.0030	0.172228 ± 0.000020	0.172229 ± 0.000021	-0.05
$A^{0,b}_{\rm FB}$	0.0992 ± 0.0016	0.10345 ± 0.00047	0.10358 ± 0.00052	-2.6
$A^{0,c}_{\rm FB}$	0.0707 ± 0.0035	0.07394 ± 0.00036	0.07404 ± 0.00040	-0.9
A_b	0.923 ± 0.020	0.934787 ± 0.000054	0.934802 ± 0.000061	-0.6
A_c	0.670 ± 0.027	0.66813 ± 0.00029	0.66821 ± 0.00032	0.1
$\sin^2\theta^{\rm lept}_{\rm eff}$(Tev/LHC)	0.23166 ± 0.00032	0.231454 ± 0.000084	0.231438 ± 0.000087	0.7

[1710.05402]

EW physics – precision observables for New Physics

Experiment		Observables		Theory
Z resonance				
Cross sections		m_Z, Γ_Z, σ^0_{had}		NP calculations
(total and differential)	$\rightarrow$	$R^0_{b/c/\ell}$, $A^{0,b/c/\ell}_{\text{FB}}$		
Asymmetries (LR, FB)		$\mathcal{A}_{b/c/\ell}$, $\sin^2\theta^{\text{eff}}_\ell$		$\downarrow$
W resonance	$\rightarrow$	m_W, Γ_W	$\rightarrow$	EW pseudo-observables
t resonance	$\rightarrow$	m_t		
$(g-2)_\mu$	$\rightarrow$	$\Delta\alpha^{(5)}_{\text{had}}$		
τ decays	$\rightarrow$	α_s		
h resonance	$\rightarrow$	m_h		

EWPO – pseudo-observables

ρ parameter [Kennedy, Lynn]

Peskin-Takeuchi parameters (oblique paramters) S, T, U

Altarelli-Barbieri parameters ϵ_1, ϵ_2, ϵ_3, ϵ_b

[Kennedy-Langacker parameters h_V, h_{AZ}, h_{AW}]

EWPO – pseudo-observables

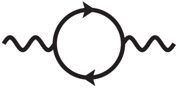
ρ parameter [Kennedy, Lynn]

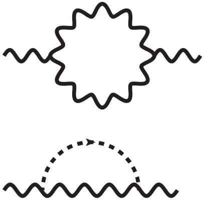
Peskin-Takeuchi parameters (oblique paramters) S, T, U

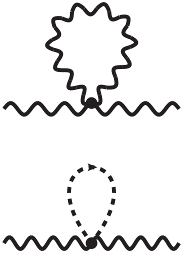
Altarelli-Barbieri parameters ϵ_1, ϵ_2, ϵ_3, ϵ_b

[Kennedy-Langacker parameters h_V, h_{AZ}, h_{AW}]

depend on

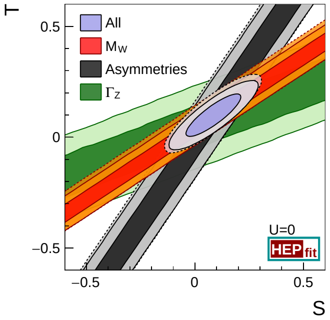






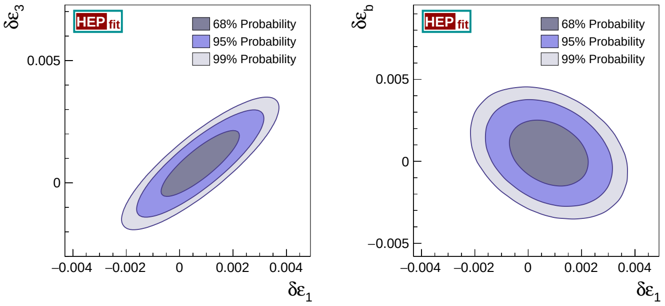
EWPO – STU

	Result	Correlation Matrix		
S	0.09 ± 0.10	1.00		
	(0.08 ± 0.10)			
T	0.11 ± 0.12	0.86	1.00	
	(0.11 ± 0.12)	(0.85)		
U	-0.01 ± 0.09	-0.56	-0.84	1.00
	(0.00 ± 0.09)	(-0.49)	(-0.79)	
S	0.09 ± 0.08	1.00		
	(0.08 ± 0.09)			
T	0.10 ± 0.06	0.87	1.00	
	(0.11 ± 0.07)	(0.86)		
$(U = 0)$				



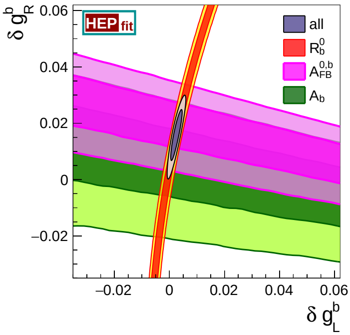
[1710.05402]

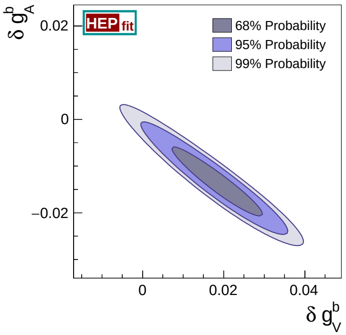
EWPO – $\delta\varepsilon_1$, $\delta\varepsilon_2$, $\delta\varepsilon_3$, $\delta\varepsilon_b$



[1608.01509]

EWPO – δg_L, δg_R, δg_V, δg_A



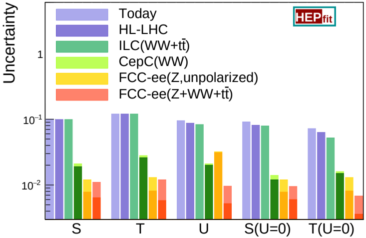


$$g_i^b = g_{i,SM}^b + \delta g_i^b \text{ for } i = L, R \text{ or } V, A$$

[1608.01509]

EWPO at future colliders

	Current Data	CepC
$\alpha_s(M_Z)$	0.1179 ± 0.0012	
$\Delta\alpha^{(5)}_{\rm had}(M_Z)$	0.02750 ± 0.00033	
M_Z [GeV]	91.1875 ± 0.0021	±0.0005
m_t [GeV]	173.34 ± 0.76	
m_H [GeV]	125.09 ± 0.24	±0.0059
M_W [GeV]	80.385 ± 0.015	±0.003
Γ_W [GeV]	2.085 ± 0.042	
Γ_Z [GeV]	2.4952 ± 0.0023	±0.0005
σ_h^0 [nb]	41.540 ± 0.037	±0.037
$\sin^2\theta_{\rm eff}^{\rm lept}$	0.2324 ± 0.0012	±0.000023
$P_\tau^{\rm pol}$	0.1465 ± 0.0033	
A_ℓ	0.1513 ± 0.0021	
A_c	0.670 ± 0.027	
A_b	0.923 ± 0.020	
$A_{\rm FB}^{0,\ell}$	0.0171 ± 0.0010	±0.0010
$A_{\rm FB}^{0,c}$	0.0707 ± 0.0035	
$A_{\rm FB}^{0,b}$	0.0992 ± 0.0016	±0.00014
R_ℓ^0	20.767 ± 0.025	±0.007
R_c^0	0.1721 ± 0.0030	
R_b^0	0.21629 ± 0.00066	±0.00018



	Current	HL-LHC	ILC		FCCee Z (no pol)		FCCee Z (pol)		FCCee WW		FCCee $t\bar{t}$		CepC	
ΔS $[\times10^{-3}]$	100	99	99	99	12	7.8	11	6.4	11	6.4	11	6.3	21	19
ΔT $[\times10^{-3}]$	120	120	120	120	13	8.1	13	7.9	13	7.9	12	5.8	28	26
ΔU $[\times10^{-3}]$	95	87	83	82	32	31	32	31	9.8	5.4	9.6	5.2	21	20
ΔS $[\times10^{-3}]$	91	81	79	79	12	7.8	11	6.4	9.5	6.1	9.5	6	14	12
ΔT $[\times10^{-3}]$ $(U=0)$	72	63	52	52	13	8.1	13	7.9	10	7.4	6.8	3.6	16	15
$\Delta\varepsilon_1^{\rm NP}[\times10^{-5}]$	96	96	96	95	11	7.3	11	7.2	11	7.2	9.5	4.7	25	23
$\Delta\varepsilon_2^{\rm NP}[\times10^{-5}]$	86	81	77	76	29	28	28	28	8.6	4.8	8.5	4.7	21	19
$\Delta\varepsilon_3^{\rm NP}[\times10^{-5}]$	91	87	88	87	9.9	6.6	9.3	5.5	9.2	5.5	9.3	5.5	20	18
$\Delta\varepsilon_b^{\rm NP}[\times10^{-5}]$	130	130	130	130	15	12	15	12	15	12	14	11	41	37
$\Delta\delta g_L^b$ $[\times10^{-4}]$	14	14	14	14	1.5	1.3	1.2	1.1	1.2	1.1	1.2	1.1	2.4	2.2
$\Delta\delta g_R^b$ $[\times10^{-4}]$	72	70	70	70	7.1	6.6	5.3	5.3	5.3	5.3	5.3	5.3	8.9	8.6

[1608.01509]

Introduction

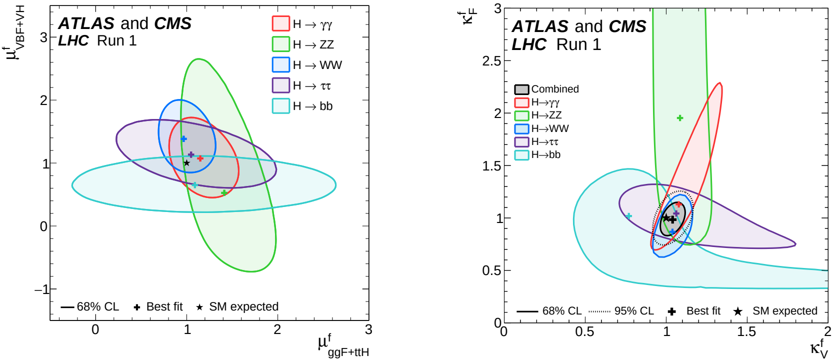
HEPfit

EW physics

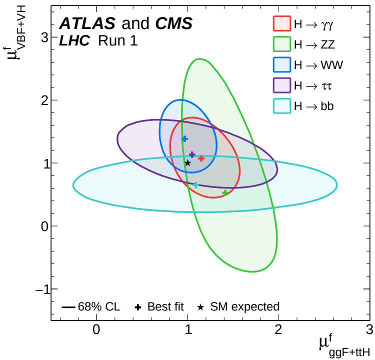
Higgs physics

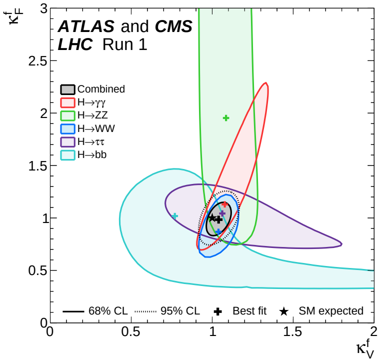
Summary

The completion of the SM?



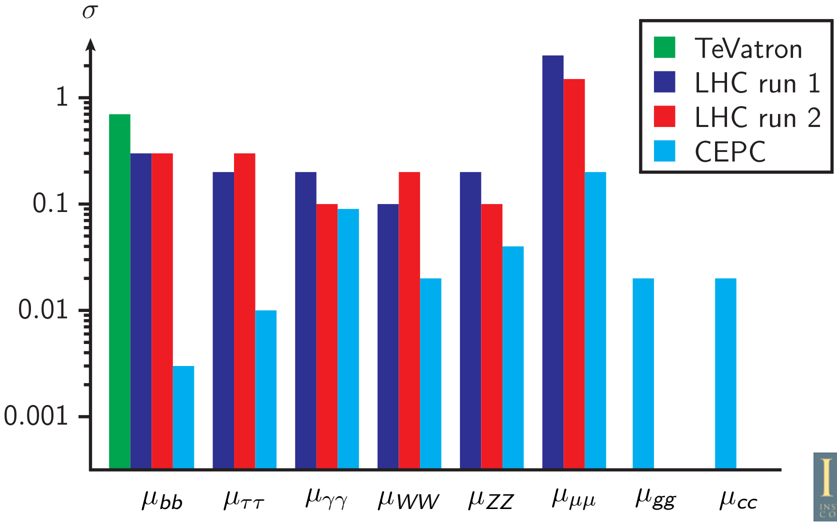
The completion of the SM?





...or is it the first sign of New Physics?

Current and future signal strength sensitivity



Effective field theories

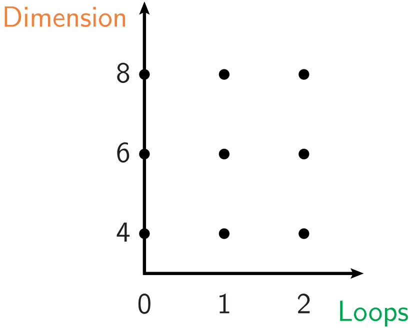
Description of New Physics at Λ in a generic way:

Linear EFT $(v \ll \Lambda)$

SMEFT extends the SM
by higher dimensional operators.

Non-linear EFT $(v \lesssim \Lambda)$

Electroweak chiral Lagrangian
with scalar h and expansion in loops.



SM effective field theory I

$$\mathcal{L}_{\text{SMEFT}} = \mathcal{L}_{\text{SM}} \ (+\mathcal{L}_5) \ + \frac{1}{\Lambda^2} \sum_i c_i Q_i^{(6)} + \ldots$$

X^3		φ^6 and $\varphi^4 D^2$		$\psi^2\varphi^3$	
Q_G	$f^{ABC} G_\mu^{A\nu} G_\nu^{B\rho} G_\rho^{C\mu}$	Q_φ	$(\varphi^\dagger\varphi)^3$	$Q_{e\varphi}$	$(\varphi^\dagger\varphi)(\bar l_p e_r \varphi)$
$Q_{\widetilde G}$	$f^{ABC} \widetilde G_\mu^{A\nu} G_\nu^{B\rho} G_\rho^{C\mu}$	$Q_{\varphi\Box}$	$(\varphi^\dagger\varphi)\Box(\varphi^\dagger\varphi)$	$Q_{u\varphi}$	$(\varphi^\dagger\varphi)(\bar q_p u_r \widetilde\varphi)$
Q_W	$\varepsilon^{IJK} W_\mu^{I\nu} W_\nu^{J\rho} W_\rho^{K\mu}$	$Q_{\varphi D}$	$\left(\varphi^\dagger D^\mu\varphi\right)^\star \left(\varphi^\dagger D_\mu\varphi\right)$	$Q_{d\varphi}$	$(\varphi^\dagger\varphi)(\bar q_p d_r \varphi)$
$Q_{\widetilde W}$	$\varepsilon^{IJK} \widetilde W_\mu^{I\nu} W_\nu^{J\rho} W_\rho^{K\mu}$				

$X^2\varphi^2$		$\psi^2 X\varphi$		$\psi^2\varphi^2 D$	
$Q_{\varphi G}$	$\varphi^\dagger\varphi\, G_{\mu\nu}^A G^{A\mu\nu}$	Q_{eW}	$(\bar l_p \sigma^{\mu\nu} e_r)\tau^I \varphi W_{\mu\nu}^I$	$Q_{\varphi l}^{(1)}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu \varphi)(\bar l_p \gamma^\mu l_r)$
$Q_{\varphi\widetilde G}$	$\varphi^\dagger\varphi\, \widetilde G_{\mu\nu}^A G^{A\mu\nu}$	Q_{eB}	$(\bar l_p \sigma^{\mu\nu} e_r)\varphi B_{\mu\nu}$	$Q_{\varphi l}^{(3)}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu^I \varphi)(\bar l_p \tau^I \gamma^\mu l_r)$
$Q_{\varphi W}$	$\varphi^\dagger\varphi\, W_{\mu\nu}^I W^{I\mu\nu}$	Q_{uG}	$(\bar q_p \sigma^{\mu\nu} T^A u_r)\widetilde\varphi\, G_{\mu\nu}^A$	$Q_{\varphi e}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu \varphi)(\bar e_p \gamma^\mu e_r)$
$Q_{\varphi\widetilde W}$	$\varphi^\dagger\varphi\, \widetilde W_{\mu\nu}^I W^{I\mu\nu}$	Q_{uW}	$(\bar q_p \sigma^{\mu\nu} u_r)\tau^I \widetilde\varphi\, W_{\mu\nu}^I$	$Q_{\varphi q}^{(1)}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu \varphi)(\bar q_p \gamma^\mu q_r)$
$Q_{\varphi B}$	$\varphi^\dagger\varphi\, B_{\mu\nu} B^{\mu\nu}$	Q_{uB}	$(\bar q_p \sigma^{\mu\nu} u_r)\widetilde\varphi\, B_{\mu\nu}$	$Q_{\varphi q}^{(3)}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu^I \varphi)(\bar q_p \tau^I \gamma^\mu q_r)$
$Q_{\varphi\widetilde B}$	$\varphi^\dagger\varphi\, \widetilde B_{\mu\nu} B^{\mu\nu}$	Q_{dG}	$(\bar q_p \sigma^{\mu\nu} T^A d_r)\varphi\, G_{\mu\nu}^A$	$Q_{\varphi u}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu \varphi)(\bar u_p \gamma^\mu u_r)$
$Q_{\varphi WB}$	$\varphi^\dagger\tau^I\varphi\, W_{\mu\nu}^I B^{\mu\nu}$	Q_{dW}	$(\bar q_p \sigma^{\mu\nu} d_r)\tau^I \varphi\, W_{\mu\nu}^I$	$Q_{\varphi d}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu \varphi)(\bar d_p \gamma^\mu d_r)$
$Q_{\varphi\widetilde WB}$	$\varphi^\dagger\tau^I\varphi\, \widetilde W_{\mu\nu}^I B^{\mu\nu}$	Q_{dB}	$(\bar q_p \sigma^{\mu\nu} d_r)\varphi\, B_{\mu\nu}$	$Q_{\varphi ud}$	$i(\widetilde\varphi^\dagger D_\mu\varphi)(\bar u_p \gamma^\mu d_r)$

$(\bar L L)(\bar L L)$	
Q_{ll}	$(\bar l_p \gamma_\mu l_r)(\bar l_s \gamma^\mu l_t)$
$Q_{qq}^{(1)}$	$(\bar q_p \gamma_\mu q_r)(\bar q_s \gamma^\mu q_t)$
$Q_{qq}^{(3)}$	$(\bar q_p \gamma_\mu \tau^I q_r)(\bar q_s \gamma^\mu \tau^I q_t)$
$Q_{lq}^{(1)}$	$(\bar l_p \gamma_\mu l_r)(\bar q_s \gamma^\mu q_t)$
$Q_{lq}^{(3)}$	$(\bar l_p \gamma_\mu \tau^I l_r)(\bar q_s \gamma^\mu \tau^I q_t)$
	$\ldots$

[GIMR 1008.4884]

SM effective field theory I

$$\mathcal{L}_{\mathsf{SMEFT}} = \mathcal{L}_{\mathsf{SM}} \; (+\mathcal{L}_5) \; + \frac{1}{\Lambda^2} \sum_i c_i Q_i^{(6)} + \dots$$

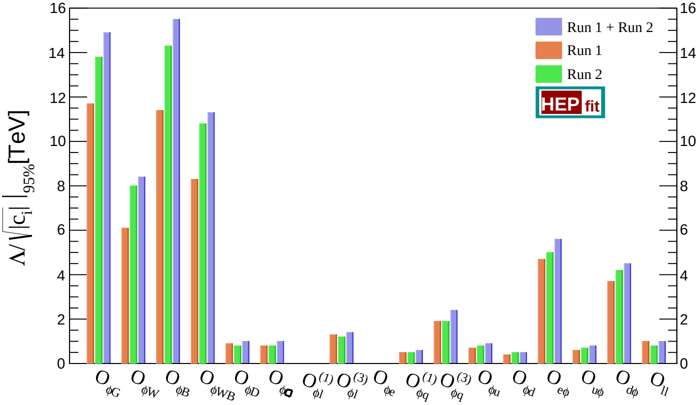
X^3		φ^6 and $\varphi^4 D^2$		$\psi^2\varphi^3$	
Q_G	$f^{ABC} G_\mu^{A\nu} G_\nu^{B\rho} G_\rho^{C\mu}$	Q_φ	$(\varphi^\dagger\varphi)^3$	$Q_{e\varphi}$	$(\varphi^\dagger\varphi)(\bar l_p e_r \varphi)$
$Q_{\widetilde G}$	$f^{ABC} \widetilde G_\mu^{A\nu} G_\nu^{B\rho} G_\rho^{C\mu}$	$Q_{\varphi\Box}$	$(\varphi^\dagger\varphi)\Box(\varphi^\dagger\varphi)$	$Q_{u\varphi}$	$(\varphi^\dagger\varphi)(\bar q_p u_r \widetilde\varphi)$
Q_W	$\varepsilon^{IJK} W_\mu^{I\nu} W_\nu^{J\rho} W_\rho^{K\mu}$	$Q_{\varphi D}$	$\left(\varphi^\dagger D^\mu\varphi\right)^\star \left(\varphi^\dagger D_\mu\varphi\right)$	$Q_{d\varphi}$	$(\varphi^\dagger\varphi)(\bar q_p d_r \varphi)$
$Q_{\widetilde W}$	$\varepsilon^{IJK} \widetilde W_\mu^{I\nu} W_\nu^{J\rho} W_\rho^{K\mu}$				

$X^2\varphi^2$		$\psi^2 X\varphi$		$\psi^2\varphi^2 D$	
$Q_{\varphi G}$	$\varphi^\dagger\varphi\, G_{\mu\nu}^A G^{A\mu\nu}$	Q_{eW}	$(\bar l_p \sigma^{\mu\nu} e_r)\tau^I \varphi W_{\mu\nu}^I$	$Q_{\varphi l}^{(1)}$	$(\varphi^\dagger i \overleftrightarrow{D}_\mu \varphi)(\bar l_p \gamma^\mu l_r)$
$Q_{\varphi\widetilde G}$	$\varphi^\dagger\varphi\, \widetilde G_{\mu\nu}^A G^{A\mu\nu}$	Q_{eB}	$(\bar l_p \sigma^{\mu\nu} e_r)\varphi B_{\mu\nu}$	$Q_{\varphi l}^{(3)}$	$(\varphi^\dagger i \overleftrightarrow{D}_\mu^I \varphi)(\bar l_p \tau^I \gamma^\mu l_r)$
$Q_{\varphi W}$	$\varphi^\dagger\varphi\, W_{\mu\nu}^I W^{I\mu\nu}$	Q_{uG}	$(\bar q_p \sigma^{\mu\nu} T^A u_r)\widetilde\varphi\, G_{\mu\nu}^A$	$Q_{\varphi e}$	$(\varphi^\dagger i \overleftrightarrow{D}_\mu \varphi)(\bar e_p \gamma^\mu e_r)$
$Q_{\varphi\widetilde W}$	$\varphi^\dagger\varphi\, \widetilde W_{\mu\nu}^I W^{I\mu\nu}$	Q_{uW}	$(\bar q_p \sigma^{\mu\nu} u_r)\tau^I \widetilde\varphi\, W_{\mu\nu}^I$	$Q_{\varphi q}^{(1)}$	$(\varphi^\dagger i \overleftrightarrow{D}_\mu \varphi)(\bar q_p \gamma^\mu q_r)$
$Q_{\varphi B}$	$\varphi^\dagger\varphi\, B_{\mu\nu} B^{\mu\nu}$	Q_{uB}	$(\bar q_p \sigma^{\mu\nu} u_r)\widetilde\varphi\, B_{\mu\nu}$	$Q_{\varphi q}^{(3)}$	$(\varphi^\dagger i \overleftrightarrow{D}_\mu^I \varphi)(\bar q_p \tau^I \gamma^\mu q_r)$
$Q_{\varphi\widetilde B}$	$\varphi^\dagger\varphi\, \widetilde B_{\mu\nu} B^{\mu\nu}$	Q_{dG}	$(\bar q_p \sigma^{\mu\nu} T^A d_r)\varphi\, G_{\mu\nu}^A$	$Q_{\varphi u}$	$(\varphi^\dagger i \overleftrightarrow{D}_\mu \varphi)(\bar u_p \gamma^\mu u_r)$
$Q_{\varphi WB}$	$\varphi^\dagger\tau^I\varphi\, W_{\mu\nu}^I B^{\mu\nu}$	Q_{dW}	$(\bar q_p \sigma^{\mu\nu} d_r)\tau^I \varphi\, W_{\mu\nu}^I$	$Q_{\varphi d}$	$(\varphi^\dagger i \overleftrightarrow{D}_\mu \varphi)(\bar d_p \gamma^\mu d_r)$
$Q_{\varphi\widetilde WB}$	$\varphi^\dagger\tau^I\varphi\, \widetilde W_{\mu\nu}^I B^{\mu\nu}$	Q_{dB}	$(\bar q_p \sigma^{\mu\nu} d_r)\varphi\, B_{\mu\nu}$	$Q_{\varphi ud}$	$i(\widetilde\varphi^\dagger D_\mu \varphi)(\bar u_p \gamma^\mu d_r)$

$(\bar L L)(\bar L L)$	
Q_{ll}	$(\bar l_p \gamma_\mu l_r)(\bar l_s \gamma^\mu l_t)$
$Q_{qq}^{(1)}$	$(\bar q_p \gamma_\mu q_r)(\bar q_s \gamma^\mu q_t)$
$Q_{qq}^{(3)}$	$(\bar q_p \gamma_\mu \tau^I q_r)(\bar q_s \gamma^\mu \tau^I q_t)$
$Q_{lq}^{(1)}$	$(\bar l_p \gamma_\mu l_r)(\bar q_s \gamma^\mu q_t)$
$Q_{lq}^{(3)}$	$(\bar l_p \gamma_\mu \tau^I l_r)(\bar q_s \gamma^\mu \tau^I q_t)$
	$\dots$

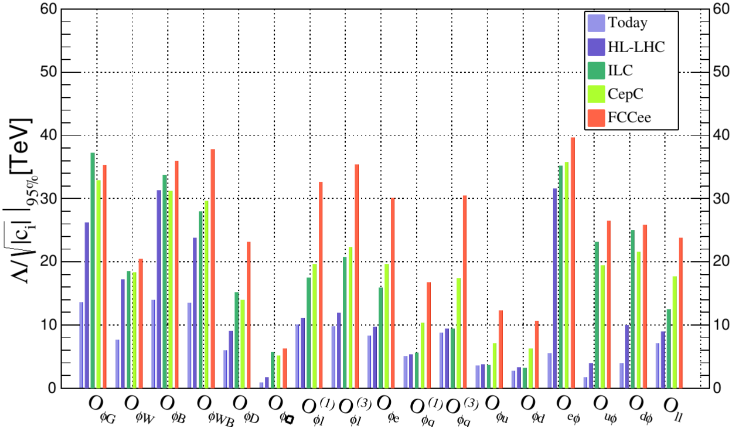
[GIMR 1008.4884]

SM effective field theory II



[1608.01509,1710.05402]

SM effective field theory II



[1608.01509,1710.05402]

Non-linear effective field theory I

Leading order Lagrangian:

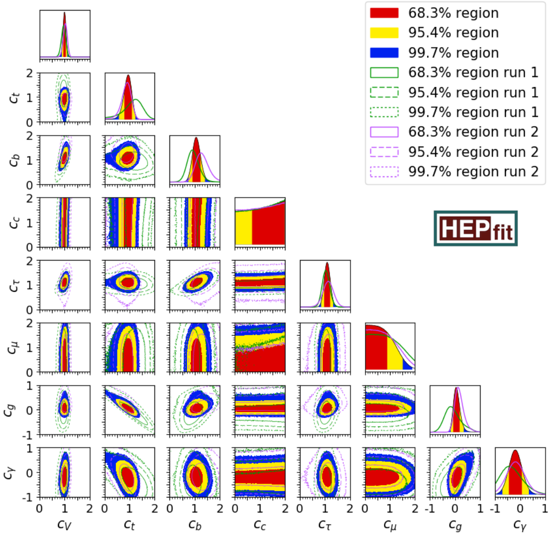
$$\mathcal{L}_{\mathrm{NLEFT}} = 2c_V \left(m_W^2 W_\mu^+ W^{-\mu} + \tfrac{1}{2} m_Z^2 Z_\mu Z^\mu \right) \frac{h}{v} - \sum_f c_f Y_f \bar{f} f \, h$$
$$+ \frac{e^2}{16\pi^2} c_{\gamma\gamma} F_{\mu\nu} F^{\mu\nu} \frac{h}{v} + \frac{e^2}{16\pi^2} c_{Z\gamma} Z_{\mu\nu} F^{\mu\nu} \frac{h}{v} + \frac{g_s^2}{16\pi^2} c_{gg} \mathrm{Tr}[G_{\mu\nu} G^{\mu\nu}] \frac{h}{v}$$

with

$$c_i = \begin{cases} 1 + \mathcal{O}(\frac{v^2}{\Lambda^2}) & \text{for } i = V, t, b, c, \tau, \mu \\ \mathcal{O}(\frac{v^2}{\Lambda^2}) & \text{for } i = gg, \gamma\gamma, Z\gamma \end{cases}$$

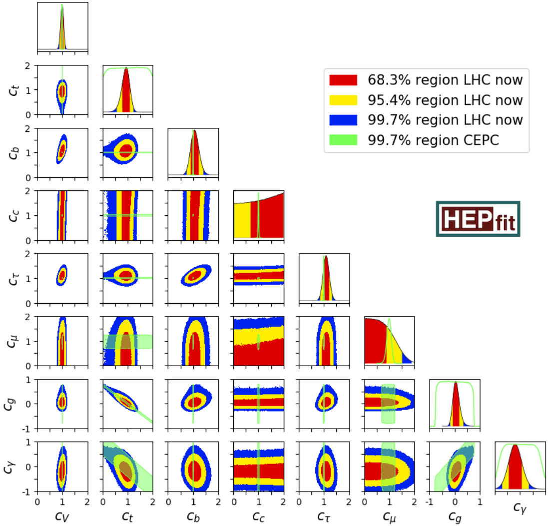
[Buchalla, Cata, Celis, Krause, '15]

Non-linear effective field theory II



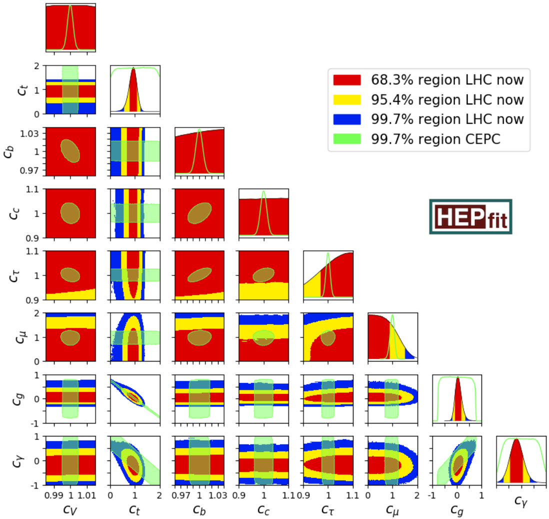
[De Blas, OE, Krause, preliminary]

Non-linear effective field theory II



[De Blas, OE, Krause, preliminary]

Non-linear effective field theory II



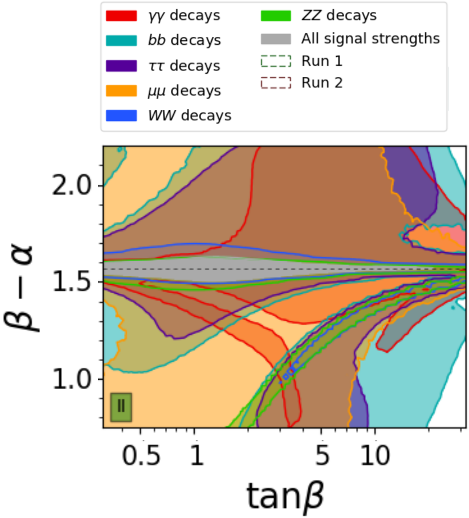
[De Blas, OE, Krause, preliminary]

The $\mathbb{Z}_2$ symmetric 2HDM of type II

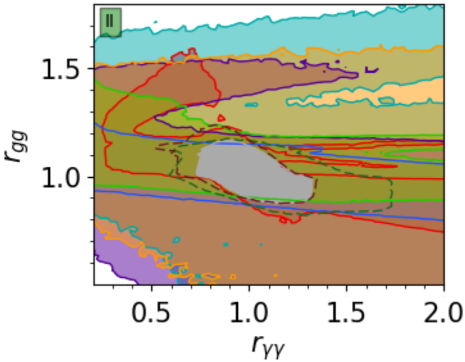
$$
\begin{aligned}
V_H^{2\text{HDM}} = {} & m_{11}^2 \Phi_1^\dagger \Phi_1 + m_{22}^2 \Phi_2^\dagger \Phi_2 - m_{12}^2 \left(\Phi_1^\dagger \Phi_2 + \Phi_2^\dagger \Phi_1 \right) \\
& + \frac{\lambda_1}{2} \left(\Phi_1^\dagger \Phi_1 \right)^2 + \frac{\lambda_2}{2} \left(\Phi_2^\dagger \Phi_2 \right)^2 + \lambda_3 \left(\Phi_1^\dagger \Phi_1 \right) \left(\Phi_2^\dagger \Phi_2 \right) \\
& + \lambda_4 \left(\Phi_1^\dagger \Phi_2 \right) \left(\Phi_2^\dagger \Phi_1 \right) + \frac{\lambda_5}{2} \left[\left(\Phi_1^\dagger \Phi_2 \right)^2 + \left(\Phi_2^\dagger \Phi_1 \right)^2 \right]
\end{aligned}
$$

Type II: b, τ couple to Φ_1, t couples to Φ_2
Physical parameters: v, m_h, m_H, m_A, m_{H^+}, m_{12}^2, α, β

2HDM – current limits

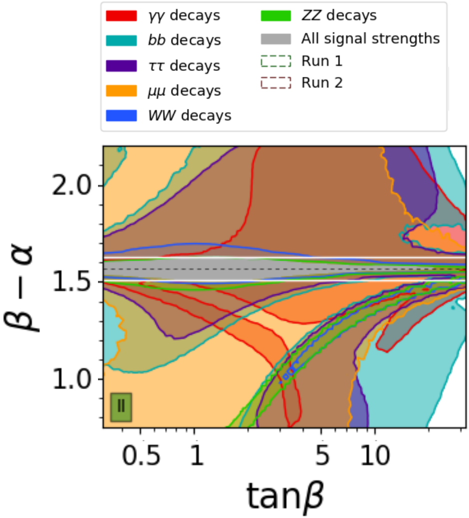


$$r_x = \frac{\Gamma_{2HDM}(h \to x)}{\Gamma_{SM}(h \to x)}$$

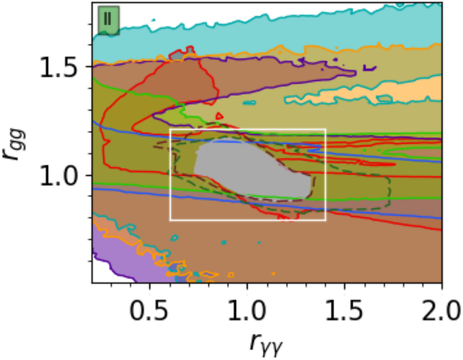


[Chowdhury, OE, arXiv:1711.02095]

2HDM – current limits

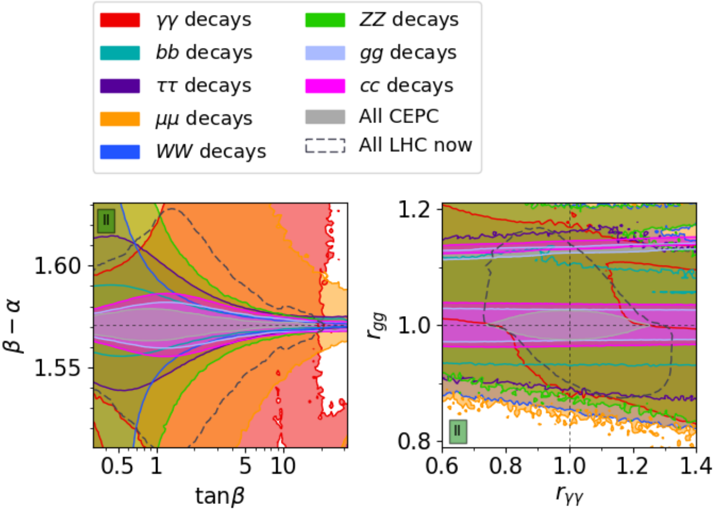


$$r_x = \frac{\Gamma_{\rm 2HDM}(h \to x)}{\Gamma_{\rm SM}(h \to x)}$$



[Chowdhury, OE, arXiv:1711.02095]

2HDM – CEPC projections



Further extended Higgs sectors

We are implementing further extensions in the scalar sector:

- Three other types of $\mathbb{Z}_2$ symmetric 2HDM
- Flavour-aligned 2HDM
- General 2HDM
- Manohar-Wise model: SM $(1{,}2)_1 + (8{,}2)_1$
- Manohar-Wise 2HDM: 2HDM $+ (8{,}2)_1$
- Left-Right symmetric models

Summary

EW and Higgs physics will be measured precisely by future colliders.

It is important to combine all information that we have
as consistently as possible.

Only then, we can make reliable statements on the validity of the SM
and constrain (or find hints for) New Physics.

HEPfit is a comprehensive tool which covers many aspects
of EW, Higgs and flavour physics.

Summary

Projected CEPC fits:

- EW pseudo-observables will change by a factor of 2 to 8
- EFT probed NP scales will increase by a factor of 2 to 6
- NLEFT coefficients will be up to 100 times as precise
- 2HDM alignment will be 30 times as precise