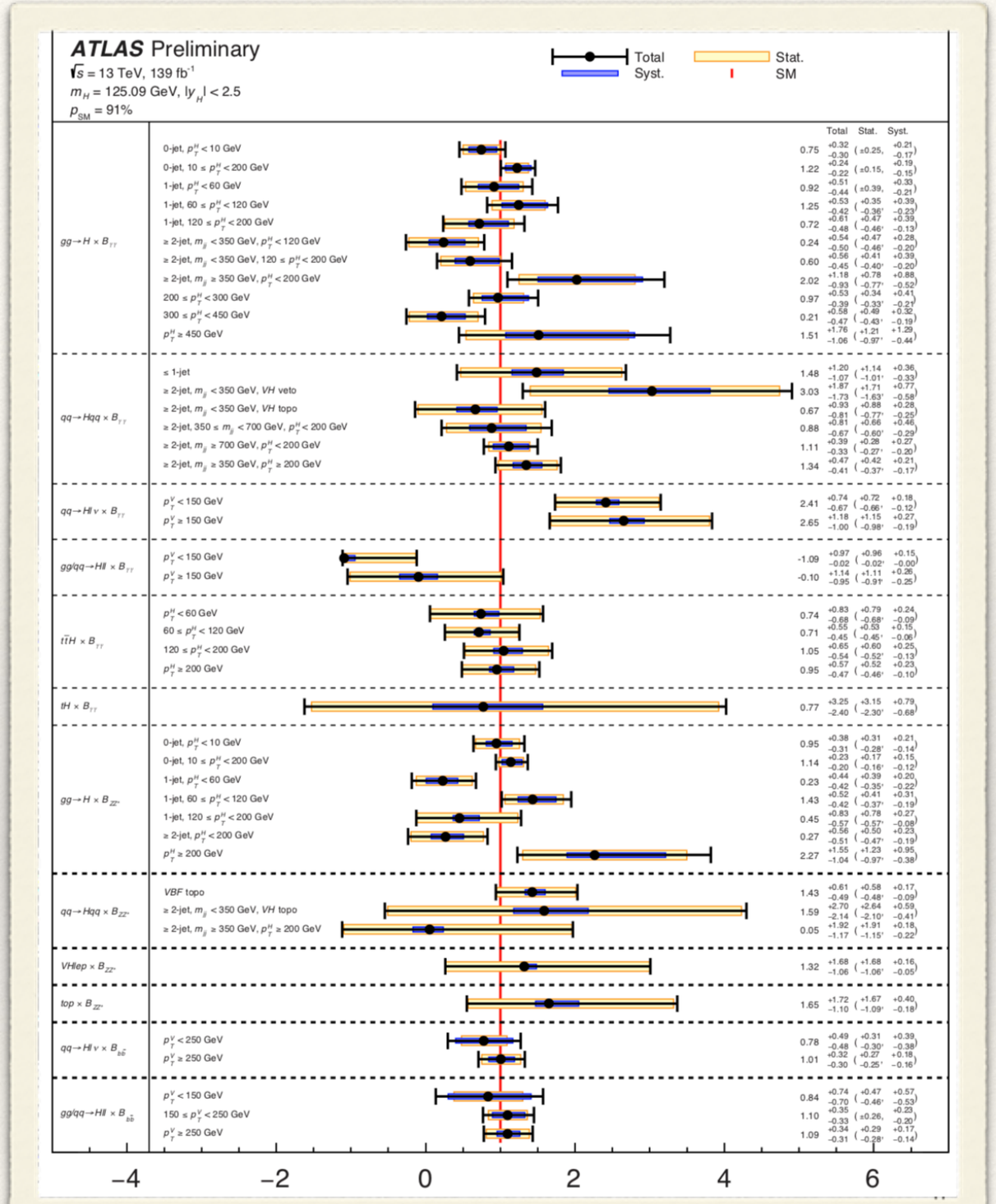
4th RED LHC workshop, 4.10.20

Higgs EFT: What's new?

Veronica Sanz (IFIC-UV and Sussex)

includes some preliminary results with John Ellis, Maeve Madigan, Ken Mimasu and Tevong You (CERN/Cambridge/King's)



EFT is the new black

I assume you roughly know what is an EFT
and also know this is a word increasingly present in
LHC analyses

There are good theoretical reasons to adopt (NOW) an EFT
interpretation of the LHC data
no light NP, nice/tractable framework…

And experiments, after lots of tensioning and some reticence,
are also adopting it as a default option to re-interpret SM
measurements

Fear not! I won't bore you with details
but I want to give you a few pointers to where things are going

Coordinated LHC activities

From my view at the SC of the LHC Higgs WG (former HXSWG)

WG1 -> SM-like stuff (precision calculations)

WG2-> indirect BSM by coupling measurements etc

WG3-> BSM Higgs (MSSM-like etc)

Our annual meeting next week (WG2)

EFT

EFT

STXS

STXS

EFT

EFT

EFT

	BSM Benchmarks for Effective Field Theories in Higgs and Electroweak Physics — *6/2-024 - BE Auditorium Meyrin, CERN*	*Jose Santiago* 16:10 - 16:30
	High-energy probes of Higgs EFT interactions — *6/2-024 - BE Auditorium Meyrin, CERN*	*Francesco Riva* 16:35 - 16:55
17:00	**Status of STXS (stage 1.2) and differential measurements** — *6/2-024 - BE Auditorium Meyrin, CERN*	*Hongtao Yang et al.* 17:00 - 17:20
	Simplified template bins in Higgs decays — *6/2-024 - BE Auditorium Meyrin, CERN*	*Michael Duehrssen-Debling* 17:25 - 17:45
	EFT interpretation workflow: Introduction — *6/2-024 - BE Auditorium Meyrin, CERN*	*Andrew Gilbert* 17:50 - 18:10
18:00	**EFT interpretation workflow: BSM perspective** — *6/2-024 - BE Auditorium Meyrin, CERN*	*Christophe Grojean* 18:15 - 18:35
	EFT interpretation workflow: QCD, higher-orders and tools — *6/2-024 - BE Auditorium Meyrin, CERN*	*Eleni Vryonidou* 18:40 - 19:00
19:00		

previously: kappa, POS…

Coordinated LHC activities

A few months ago a new group appeared

led by MLM, Dawson et al (including J. de Blas)

whose mandate is to co-ordinate **EFT interpretation efforts** from the Higgs, Top, EW existing WG at the LHC

I think this is the correct move:
Why EFT and why now? Because EFT is a well-accepted framework for **combination** of different experimental inputs and it is **now,** with more upcoming luminosity, that this combination makes sense

we are moving towards **GLOBAL EFT ANALYSES**:
more operators, more inputs

Example I: recent experimental analysis

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29 October 2020

Presented yesterday at CERN

Combination Higgs channels,
full Run2 lumi

Exhaustive **STXS** combination used to interpret as an **EFT**

this is going to be a
standard analysis

STXS Region Stage-0	STXS Region Stage-1.2	$H\to\gamma\gamma$	$H\to ZZ^*\to 4\ell$	$H\to b\bar{b}$ (VH)
ggH	$N_{jets}=0$, $p_T^H<10$	$N_{jets}=0$, $p_T^H<10$	$N_{jets}=0$, $p_T^H<10$	
	$N_{jets}=0$, $10<p_T^H$	$N_{jets}=0$, $10<p_T^H$	$N_{jets}=0$, $10<p_T^H$	
	$N_{jets}=1$, $p_T^H<60$	$N_{jets}=1$, $p_T^H<60$	$N_{jets}=1$, $p_T^H<60$	
	$N_{jets}=1$, $60<p_T^H<120$	$N_{jets}=1$, $60<p_T^H<120$	$N_{jets}=1$, $60<p_T^H<120$	
	$N_{jets}=1$, $120<p_T^H<200$	$N_{jets}=1$, $120<p_T^H<200$	$N_{jets}=1$, $120<p_T^H<200$	
	$N_{jets}\geq 2$, $m_{jj}<350$, $p_T^H<60$	$N_{jets}\geq 2$, $m_{jj}<350$, $p_T^H<120$	$N_{jets}\geq 2$, $p_T^H\leq 200$	
	$N_{jets}\geq 2$, $m_{jj}<350$, $60<p_T^H<120$	$N_{jets}\geq 2$, $m_{jj}<350$, $p_T^H<120$	$N_{jets}\geq 2$, $p_T^H\leq 200$	
	$N_{jets}\geq 2$, $m_{jj}<350$, $120<p_T^H<200$	$N_{jets}\geq 2$, $m_{jj}<350$, $120<p_T^H<200$	$N_{jets}\geq 2$, $p_T^H\leq 200$	
	$N_{jets}\geq 2$, $350<m_{jj}<700$, $p_T^H<200$, $p_T^{Hjj}<25$	$N_{jets}\geq 2$, $350<m_{jj}$, $p_T^H<200$	$N_{jets}\geq 2$, $p_T^H\leq 200$	
	$N_{jets}\geq 2$, $350<m_{jj}<700$, $p_T^H<200$, $25<p_T^{Hjj}$	$N_{jets}\geq 2$, $350<m_{jj}$, $p_T^H<200$	$N_{jets}\geq 2$, $p_T^H\leq 200$	
	$N_{jets}\geq 2$, $700<m_{jj}$, $p_T^H<200$, $p_T^{Hjj}<25$	$N_{jets}\geq 2$, $350<m_{jj}$, $p_T^H<200$	$N_{jets}\geq 2$, $p_T^H\leq 200$	
	$N_{jets}\geq 2$, $700<m_{jj}$, $p_T^H<200$, $25<p_T^{Hjj}$	$N_{jets}\geq 2$, $350<m_{jj}$, $p_T^H<200$	$N_{jets}\geq 2$, $p_T^H\leq 200$	
	$200<p_T^H<300$	$200<p_T^H<300$	$200<p_T^H$	
	$300<p_T^H<450$	$300<p_T^H<450$	$200<p_T^H$	
	$450<p_T^H<650$	$450<p_T^H$	$200<p_T^H$	
	$650<p_T^H$	$450<p_T^H$	$200<p_T^H$	
qqH "VBF", "qqH had"	$N_{jets}=0$	$N_{jets}\leq 1$		
	$N_{jets}=1$	$N_{jets}\leq 1$		
	$N_{jets}\geq 2$, $m_{jj}<60$	$N_{jets}\geq 2$, $m_{jj}<60 \vee 120<m_{jj}<350$	VBF	
	$N_{jets}\geq 2$, $60<m_{jj}<120$	$N_{jets}\geq 2$, $60<m_{jj}<120$	$N_{jets}\geq 2$, $60<m_{jj}<120$	
	$N_{jets}\geq 2$, $120<m_{jj}<350$	$N_{jets}\geq 2$, $m_{jj}<60 \vee 120<m_{jj}<350$	VBF	
	$N_{jets}\geq 2$, $350<m_{jj}$ $200<p_T^H$	$N_{jets}\geq 2$, $350<m_{jj}$, $200<p_T^H$	$N_{jets}\geq 2$, $350<m_{jj}$, $200<p_T^H$	
	$N_{jets}\geq 2$, $350<m_{jj}<700$, $p_T^H<200$, $p_T^{Hjj}<25$	$N_{jets}\geq 2$, $350<m_{jj}<700$, $p_T^H<200$	VBF	
	$N_{jets}\geq 2$, $350<m_{jj}<700$, $p_T^H<200$, $25<p_T^{Hjj}$	$N_{jets}\geq 2$, $350<m_{jj}<700$, $p_T^H<200$	VBF	
	$N_{jets}\geq 2$, $700<m_{jj}$, $p_T^H<200$, $p_T^{Hjj}<25$	$N_{jets}\geq 2$, $700<m_{jj}$, $p_T^H<200$	VBF	
	$N_{jets}\geq 2$, $700<m_{jj}$, $p_T^H<200$, $25<p_T^{Hjj}$	$N_{jets}\geq 2$, $700<m_{jj}$, $p_T^H<200$	VBF	
$qq\to H\ell\nu$ "qqWH lep"	$p_T^V<75$ ($N_{jets}=0$ / $N_{jets}=1$ / $N_{jets}\geq 2$)	WH $p_T^V<150$	VH lep	WH $p_T^V<250$
	$75<p_T^V<150$ ($N_{jets}=0$ / $N_{jets}=1$ / $N_{jets}\geq 2$)	WH $p_T^V<150$	VH lep	WH $p_T^V<250$
	$150<p_T^V<250$ ($N_{jets}=0$ / $N_{jets}=1$ / $N_{jets}\geq 2$)	WH $150<p_T^V$	VH lep	WH $p_T^V<250$
	$250<p_T^V<400$ ($N_{jets}=0$ / $N_{jets}=1$ / $N_{jets}\geq 2$)	WH $150<p_T^V$	VH lep	WH $250<p_T^V$
	$400<p_T^V$ ($N_{jets}=0$ / $N_{jets}=1$ / $N_{jets}\geq 2$)	WH $150<p_T^V$	VH lep	WH $250<p_T^V$
$qq\to H\ell\ell$ "qqZH lep"	$p_T^V<75$ ($N_{jets}=0$ / $N_{jets}=1$ / $N_{jets}\geq 2$)	ZH $p_T^V<150$	VH lep	ZH $p_T^V<150$
	$75<p_T^V<150$ ($N_{jets}=0$ / $N_{jets}=1$ / $N_{jets}\geq 2$)	ZH $p_T^V<150$	VH lep	ZH $p_T^V<150$
	$150<p_T^V<250$ ($N_{jets}=0$ / $N_{jets}=1$ / $N_{jets}\geq 2$)	ZH $150<p_T^V$	VH lep	ZH $150<p_T^V<250$
	$250<p_T^V<400$ ($N_{jets}=0$ / $N_{jets}=1$ / $N_{jets}\geq 2$)	ZH $150<p_T^V$	VH lep	ZH $250<p_T^V$
	$400<p_T^V$ ($N_{jets}=0$ / $N_{jets}=1$ / $N_{jets}\geq 2$)	ZH $150<p_T^V$	VH lep	ZH $250<p_T^V$
$gg\to H\ell\ell$ "ggZH lep"	$p_T^V<75$ ($N_{jets}=0$ / $N_{jets}=1$ / $N_{jets}\geq 2$)	ZH $p_T^V<150$	VH lep	ZH $p_T^V<150$
	$75<p_T^V<150$ ($N_{jets}=0$ / $N_{jets}=1$ / $N_{jets}\geq 2$)	ZH $p_T^V<150$	VH lep	ZH $p_T^V<150$
	$150<p_T^V<250$ ($N_{jets}=0$ / $N_{jets}=1$ / $N_{jets}\geq 2$)	ZH $150<p_T^V$	VH lep	ZH $150<p_T^V<250$
	$250<400$ ($N_{jets}=0$ / $N_{jets}=1$ / $N_{jets}\geq 2$)	ZH $150<p_T^V$	VH lep	ZH $250<p_T^V$
	$250<p_T^V$ ($N_{jets}=0$ / $N_{jets}=1$ / $N_{jets}\geq 2$)	ZH $150<p_T^V$	VH lep	ZH $250<p_T^V$
$t\bar{t}H$	$p_T^H<60$	$p_T^H<60$	$t(t)H$	
	$60<p_T^H<120$	$60<p_T^H<120$	$t(t)H$	
	$120<p_T^H<200$	$120<p_T^H<200$	$t(t)H$	
	$200<p_T^H<300$	$200<p_T^H$	$t(t)H$	
	$300<p_T^H$	$200<p_T^H$	$t(t)H$	
	$b\bar{b}H$	merged with ggH		
	tH	tH	$t(t)H$	

Example I: recent experimental analysis

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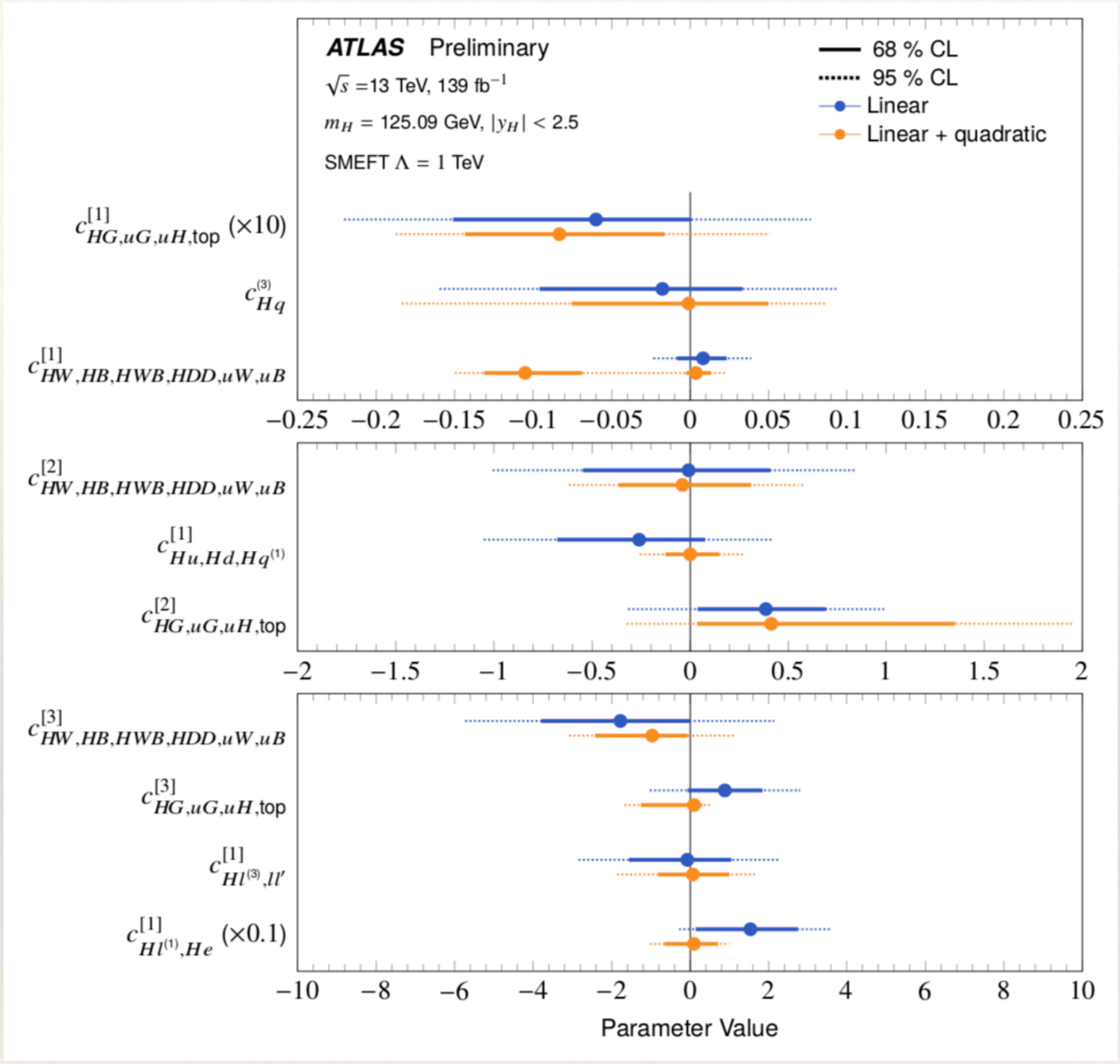
Exhaustive **STXS** combination used to interpret as an **EFT**

limits on sets of coefficients, at linear (blue) and quadratic (orange) level



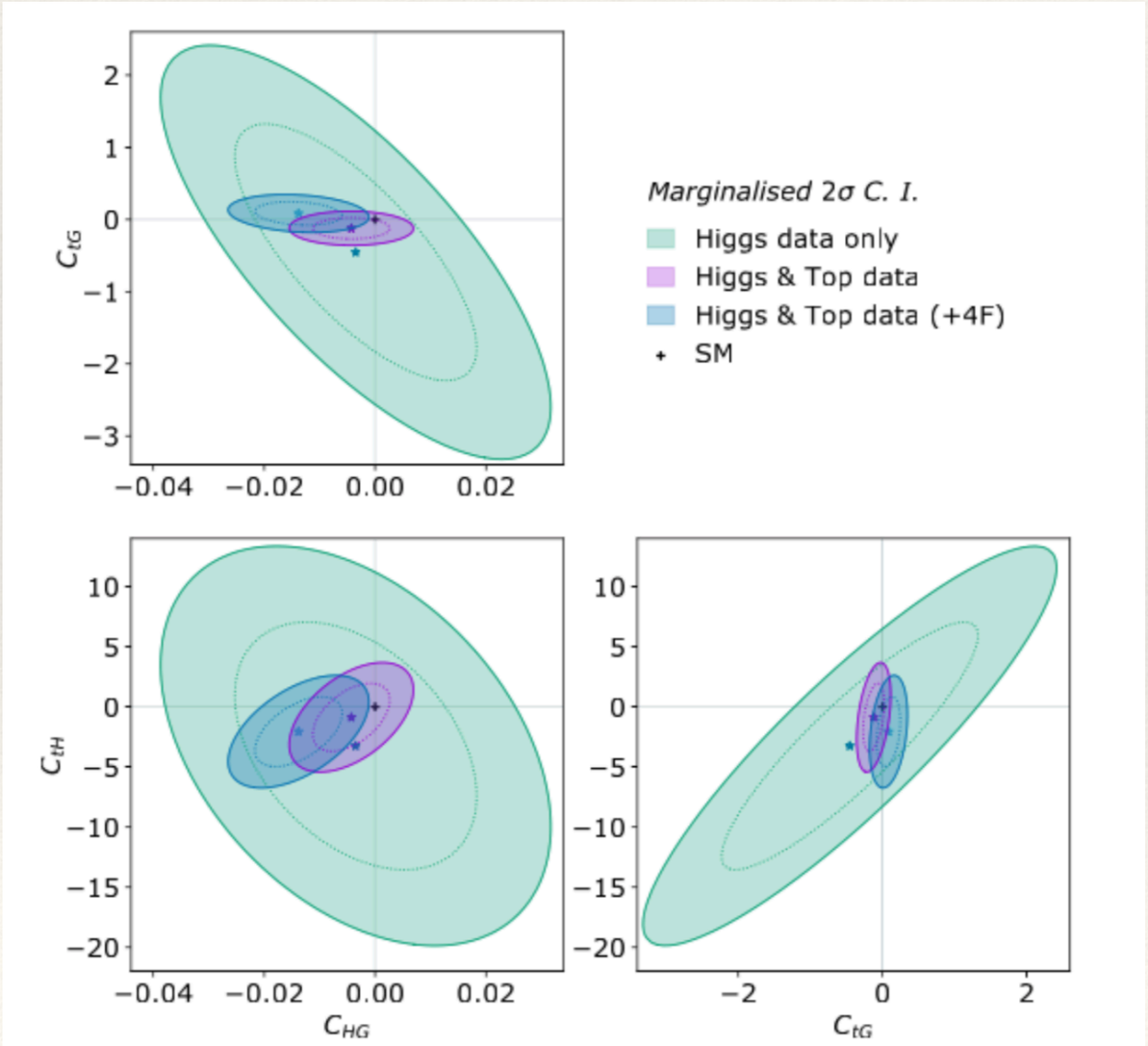
sets of ops grouped by their dependence on observables and correlations
***multi-TeV** limits for most of these possible BSM effects*

Example II: Global analyses

Ellis, Madigan, Mimasu, VS, You. In prep.

The previous example shows that **experiments** with Run2 data are already able to do a Higgs global analysis: many channels, many operators

Experimental Top groups also have been developing an EFT framework, EW groups has long interpreted analyses in terms of aTGCs/aQGCs which are essentially analogous to EFT effects



A truly global EFT analysis is possible with Run2 data (+LEP)

This is an example of the interplay between Higgs (green) and Higgs+Top (pink) information

These combinations and *public* frameworks to do fits (like our ***Fitmaker***)

are going to become state-of-the-art

Summary

LHC quo vadis? or how do we make the best use of
what is coming next? (~ E, more lumi)
Indirect searches for NP has a lot of traction at the LHC

EFT Higgs and, in general, LHC EFT analyses seem now
the preferred way to interpret SM measurements

STXS, and not simply differential measurements,
seem like a good candidate for communication
theory-experiment (more trustable for thy and exp)

New analyses show the pathway STXS->EFT
Results with Run2 *Higgs* EFT lead to multi-TeV limits
on the scale of NP for many of these effects

Much more can be gained combining
LHC (Higgs+EW+Top)+LEP legacy
hope: global EFT analyses pinpoint to new phenomena