

The background of the slide is a reproduction of the painting 'The Starry Night' by J.M.W. Turner. Overlaid on the painting are several technical diagrams. In the upper left, there is a green circle with a crosshair. In the center, there is a blue circle with a purple outline and a small pink crosshair. In the upper right, there is a yellow crescent shape with a green arc inside it. A thin green horizontal line runs across the middle of the slide.

WG2 Status and Plans

Jorge de Blas (Durham)
Predrag Milenovic (Belgrade)
Giuliano Panico (Florence)
Nicolas Berger (Annecy)

WG2 - Higgs properties

- **WG2 Conveners:** J. de Blas (TH), G. Panico (TH), N. Berger (ATLAS), P. Milenovic (CMS)
Recent change: M. Delmastro → N. Berger (ATLAS) - Thanks Marco!
Upcoming change: P. Milenovic → M. Donega (CMS)
- **Sub-group** dedicated to Fiducial/differential and simplified template XS measurements/guidelines
Conveners: F. Tackmann (TH), L. Villiani (CMS), H. Yang (ATLAS)
Recent change: N. Berger → H. Yang (ATLAS) - Welcome Hongtao!
- **WG Twiki:** <https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCHXSWG2>

Scope of WG2 activities

STXS

- Definition of Stage 1.2
- QCD/EW uncertainties
- Experimental fits to STXS
- Extension to H decays

Differential XS :

- Variables and binning definitions
- Methodology

EFT Interpretations

- Frameworks & guidelines
- Parameterization of STXS

BSM interpretations

Offshell interpretations

POs

Topic	ShortDescription
STXS & differential XS	STXS stage 1.2 and TH uncertainties treatment recommendation
STXS & differential XS	STXS stage 1.1 binning recommendation
PO	PO Summary for experiments. Scenarios for $h \rightarrow 4l$ decays. Mapping to other frameworks.
EFT	BSM Benchmarks and mapping to EFT. Determine benchmarks sensitive to differential and coupling measurements, define relevant EFT parameters
EFT	Interpretation Workflow Summary: Processes, Operators and BSM Interpretations
EFT	Fit to STXS using a standardized mapping of STXS stage 1.0
EFT	Global Fit in EFT Framework; inclusion of top and Electroweak measurements
EFT	High-Energy Higgs Probes: Longitudinal multiboson processes as tests of Higgs physics

Shown this week

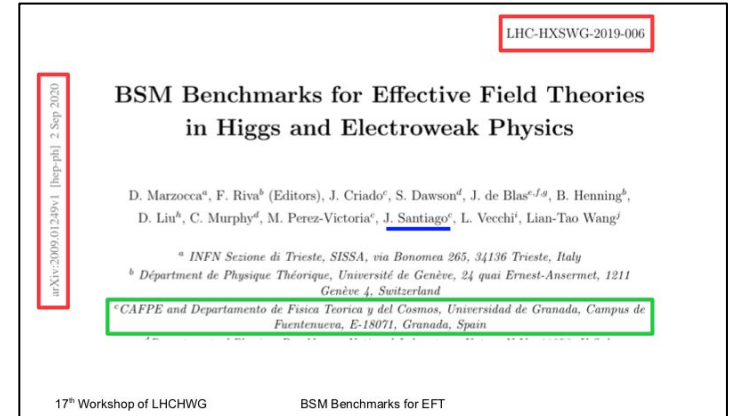
16:10	BSM Benchmarks for Effective Field Theories in Higgs and Electroweak Physics Speaker: Jose Santiago (Granada University) BSM_Benchmarks...	BSM Benchmarks
16:35	High-energy probes of Higgs EFT Interactions Speaker: Francesco Riva HXSWG2_2020.pdf	High-E
17:00	Status of STXS (stage 1.2) and differential measurements Speakers: Hongtao Yang (Lawrence Berkeley National Lab., (US)), Lorenzo Viliani (Universita e INFN, Firenze (IT)) STXS_differentialLu...	STXS
17:25	Simplified template bins in Higgs decays Speaker: Michael Duehrssen-Debling (CERN) Draft_document_S... STXS_and_decay_i...	
17:50	EFT Interpretation workflow: Introduction Speaker: Andrew Gilbert (Northwestern University (US)) LHCHWG-091120...	EFT
18:15	EFT Interpretation workflow: BSM perspective Speaker: Christophe Grojean (DESY (Hamburg) and Humboldt University (Berlin)) Grojean_HXSWG.pdf	
18:40	EFT Interpretation workflow: QCD, higher-orders and tools Speaker: Eleni Vryonidou Vryonidou_LHCHW...	

Cross-topic session

16:10	On the y_b sensitivity of bbH Speaker: Marco Zaro (Università degli Studi e INFN Milano (IT))	
16:30	Top mass scheme and scale uncertainties Speaker: Michael Spira (Paul Scherrer Institute (CH))	
17:00	ggF uncertainty Speakers: Jonathon Mark Langford (Imperial College (GB)), Syed Haider Abidi (Brookhaven National Laboratory (US))	STXS
17:30	STXS uncertainties in VBF/VH/ttH bins Speaker: Yacine Haddad (Northeastern University (US))	
18:00	STXS EFT Interpretation Speaker: Ana Rosario Cueto Gomez (Centre National de la Recherche Scientifique (FR))	EFT
18:30	Higgs boson cross sections across a wide range of masses: use cases and plans Speakers: Fabrizio CAOLA (Oxford), Giuliano Panico (University of Florence and INFN Florence), Pietro SLAVICH (LPTHE)	

BSM Benchmarks

- Document recently released on the arXiv: [2009.01249](https://arxiv.org/abs/2009.01249) [hep-ph]
- **Comprehensive list of EFT benchmarks capturing generic features**
 - Weakly coupled BSM
 - Tree-level new scalars, fermions and vectors
 - One-loop effects
 - Strongly coupled BSM
- **Importance of EFT benchmarks:**
 - Bridge between theory and experiment
 - Roadmap for bottom-up EFT analyses (allows for model discrimination)



[From J. Santiago](#)

High-energy probes

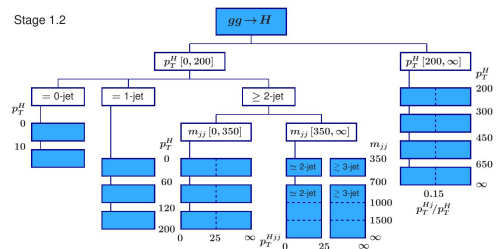
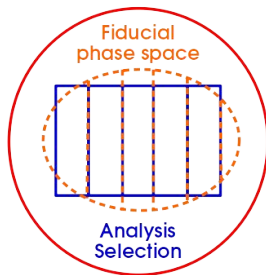
- Modifications in Higgs couplings can be also tested in high-energy processes (*not necessarily containing the Higgs*)
 - modifications of Higgs couplings induce energy-growing effects
- Processes with multi-boson final states can provide precision not far from low-energy single-Higgs probes (eg. top Yukawa, Higgs self-coupling)

HWH Program		$\sim const$	$\sim E^2$
κ_t	$ H ^2 Q \tilde{H} t_R$		
κ_λ	$ H ^6$		
κ_G	$ H ^2 G_{\mu\nu}^a G^{a\mu\nu}$		
κ_γ	$ H ^2 B_{\mu\nu} B^{\mu\nu}$		
$\kappa_{Z\gamma}$	$ H ^2 W_{\mu\nu}^a W^{a\mu\nu}$		
κ_V	$ H ^2 \partial_\mu H^\dagger \partial^\mu H$		

From F. Riva



Cross-section measurements: fiducial vs STXS



→ **Fiducial** : selection matching experimental selection as much as possible, variables chosen for BSM sensitivity and to probe SM kinematics.

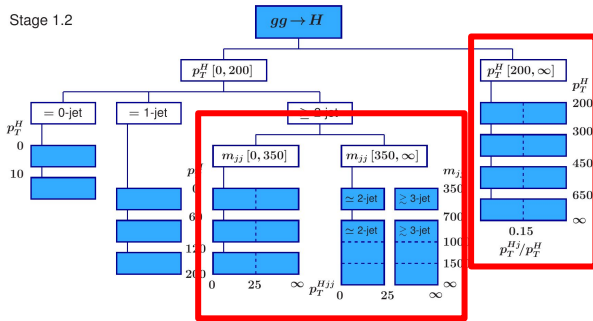
- ⊕ **Minimizes model-dependence to a large extent**
- ⊖ **Simple experimental selections only (matches truth)**
- ⊕ **Long measurement lifetime**
- ⊖ **Based on only 1-2 variables at a time**
- ⊖ **Depends on final state, non-trivial combination**
 - ⇒ needs extrapolation to larger phase space

STXS : regions within $|\gamma_H| < 2.5$, compromise between

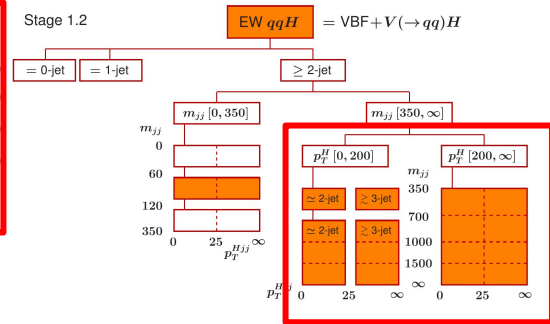
- **match to experimental selections**
- **not-too-strong theory extrapolations**
- **BSM sensitivity**
- ⊖ **Larger model-dependence**
- ⊕ **Only loosely tied to expt. selection (MVAs)**
- ⊕ **Splits along multiple variables**
- ⊖ **Larger bins, only limited number of variables**
- ⊕ **Measured in all decay modes ⇒ Combination**

STXS Stage 1.2

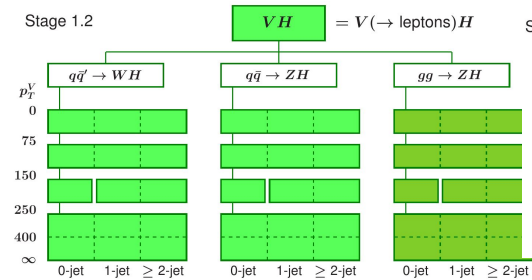
Stage 1.2



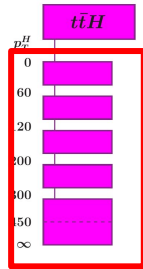
Stage 1.2



Stage 1.2



Stage 1.2



Stage 1.2 definition now final

- Documentation <https://arxiv.org/abs/1906.02754> to be updated (currently for Stage 1.1)
- Uncertainties still under discussion (see next slides)

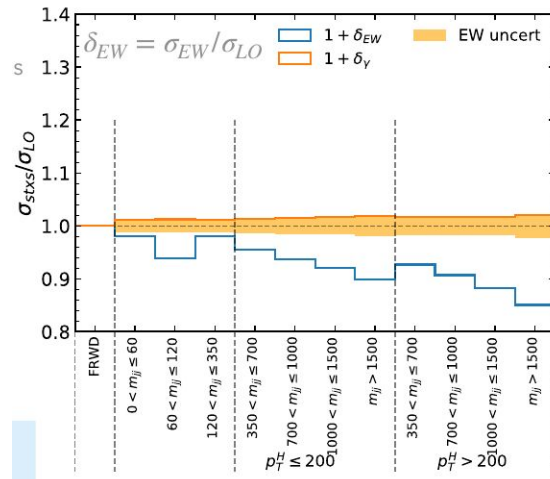
Next iteration : what to add ?

- New variables to probe ? ($\Delta\phi_{jj}$, CP-odd sensitivity ?)
- More bins (e.g. high- p_T^V region in VH ?)
- New splits to better account for theory uncertainties (VBF-like region ?)

STXS Stage 1.2 Uncertainties : $qq \rightarrow H(qq/l\bar{l}/l\nu) + ttH$

Uncertainties nearing finalization:

- **$qq \rightarrow Hl\nu, Hll$**
 - Scheme unchanged since 2019
 - New computation of QCD uncertainty values using GENEVA generator
- **$qq \rightarrow Hqq$**
 - QCD uncertainties finalized, now available as tool
 - EW corrections and uncertainties also included
- **ttH**
 - QCD uncertainties computed using similar technique as $Hll/Hl\nu$
 - Subleading PS and NLO matching uncertainties also available



See [Yacine Haddad's talk](#) for details

Frameworks and numbers are in place

Finalization of documentation and tools underway

ttH

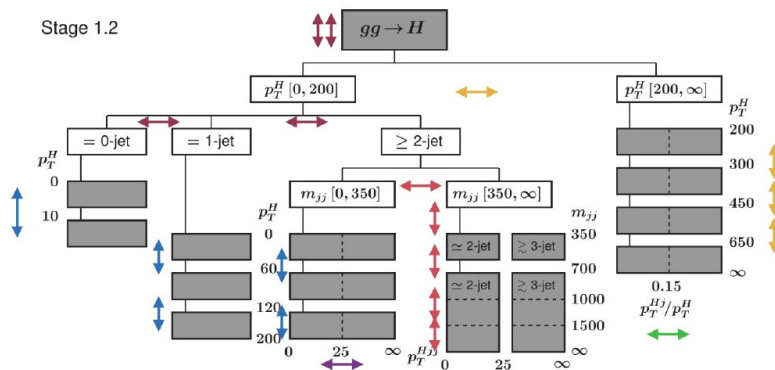
$p_T(H)$ [GeV]	Δ_γ (%)	Δ_{60} (%)	Δ_{120} (%)	Δ_{200} (%)	Δ_{300} (%)	Δ_{450} (%)	Total (%)
0-60	9.2	-9.2	0.0	0.0	0.0	0.0	13.0
60-120	9.2	2.0	-4.6	0.0	0.0	0.0	10.5
120-200	9.2	0.0	6.8	-1.3	0.0	0.0	11.5
200-300	9.2	0.0	6.8	7.1	-0.4	0.0	13.5
300-450	9.2	0.0	6.8	7.1	7.4	-0.1	15.4
450-inf	9.2	0.0	6.8	7.1	7.4	7.6	17.2

STXS Stage 1.2 Uncertainties : gg→H

Update needed for Stage 1.0 scheme, in particular for p_T^H bins and new m_{jj} bins.

Framework still being elaborated,
open questions remain:

- **High p_T^H region**: use of recent computations, m_t treatment.
- **VBF-like regions**: computation of p_T^{Hjj} (2 jet vs. 3 jet) uncertainties.
- **“Dashed boundaries”** : splits to account for within-bin uncertainties



See [Jonathon Langford's talk](#) for details

Feedback welcome on this and other topics

Aim to finalize framework in coming weeks and make available for full-Run 2 analyses.

STXS in decays

STXS defined for production in $|\ln y_H| < 2.5$, but can bin *decay* kinematics, in particular for $H \rightarrow 4\ell$:

- Access information in final-state dynamics
- Decrease model-dependence of experimental acceptance
(currently acceptance corrections needed for $H \rightarrow 4\ell$ EFT interpretation, see [Ana Cueto's presentation](#))

“Stage 0” : provide fiducial definitions for $H \rightarrow ff$, $H \rightarrow ZZ$, $H \rightarrow Z\gamma$, $H \rightarrow \gamma\gamma$... that

- a) allows reliable computation of BR predictions
- b) can be implemented in MC tools
- c) matches the experimental definitions

“Stage 1” : kinematic spits relevant for BSM tests (e.g. m_{34})

m_{34}	[10,20)	[20,35)	[35, m_{12})
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Table 2: Bin definitions for $H \rightarrow 4\ell$

More details in the [draft document](#) and [Michael Dührssen's presentation](#), contributions to design and implementations are welcome!

Off-shell Interpretations

- Flat direction in Higgs couplings measurement from interplay between coupling modifiers and total width

→ Partial width from “undetected”

decays (e.g. $H \rightarrow gg$) not measurable in on-shell Higgs decays at LHC.

- Off-shell decays lift the degeneracy, but model-dependent relations between on-shell and off-shell couplings

⇒ Important ingredient to SMEFT fits and other BSM constraints

→ Effort well underway, documentation in preparation

$$\sigma(XX \rightarrow h) \text{BR}(h \rightarrow YY) \propto g_{hXX}^2 \frac{g_{hYY}^2}{\Gamma_h}$$

$$g_{hii} = \kappa_{\text{univ}} g_{hii}^{\text{SM}} \quad \rightarrow \quad \text{all on-shell rates unchanged}$$

$$\Gamma_h = \kappa_{\text{univ}}^4 \Gamma_h^{\text{SM}} \quad \rightarrow \quad \Gamma_h = \kappa_{\text{univ}}^2 \Gamma_h^{\text{SM}} + \Gamma_h^{\text{exo}} \quad \rightarrow \quad \text{BR}_{\text{exo}} = \frac{\kappa_{\text{univ}}^2 - 1}{\kappa_{\text{univ}}^2}$$

Going to off-shell region: From Ennio Salvioni

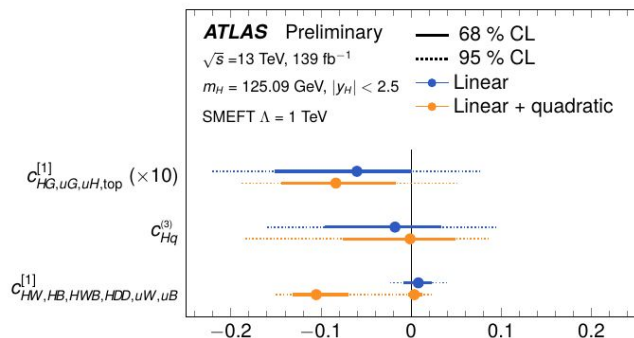
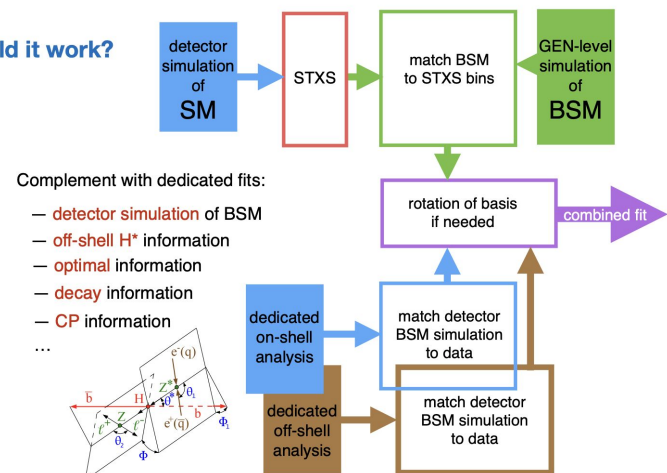
$$\frac{d\sigma_{gg \rightarrow h^* \rightarrow ZZ}}{ds} \propto \frac{g_{hgg}^2 g_{hZZ}^2}{(s - m_h^2)^2 + \Gamma_h^2 m_h^2} \sim \frac{g_{hgg}^2 g_{hZZ}^2}{s^2} \quad \text{which grows as } \kappa_{\text{univ}}^4$$

SMEFT fits to Higgs data

Ongoing efforts on SMEFT interpretations of Higgs data:

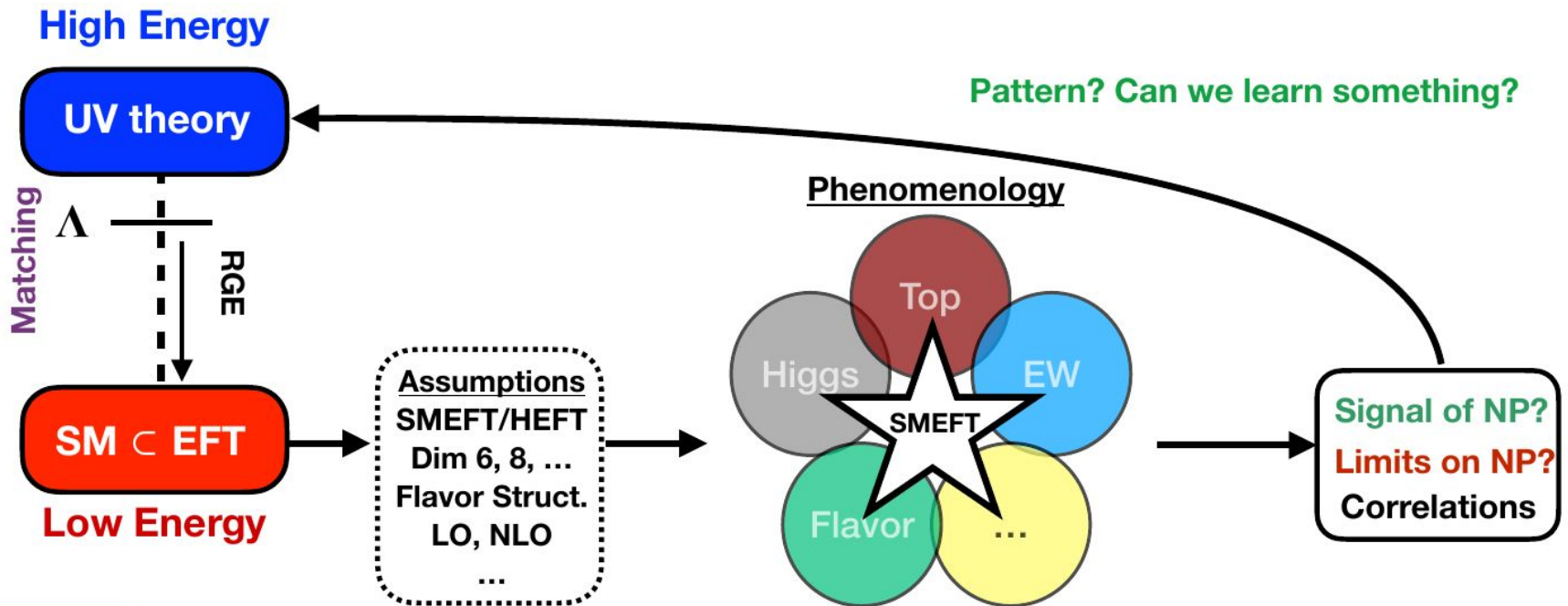
- **Inputs:**
 - Re-interpretable results (e.g. differential XS, STXS)
 - Dedicated EFT analyses (CP/anomalous/off-shell/...)
- **Framework & guidelines**
 - Which EFT ?
 - Which operators ?
 - All with given flavor/CP symmetries
 - Subsets motivated by BSM benchmark models
 - How to model, which tools ?
- **Fits**
 - Increasing progress in experimental results
 - How to report reusable results ?
 - How to include “external” knowledge (LEP, flavour, etc.) ?

How could it work?



From [Ana Cueto's presentation](#)

EFT Interpretation Workflow



EFT Interpretation Workflow Implementation

- **Topics covered:**

- (SM)EFT basics/framework
- (SM)EFT modeling and data analysis
- MC tools
- EWK/QCD higher-order effects
- Incorporating “global” knowledge

- See [TWiki](#) for more details

- Work done in close contact with the newly-created LHC EFT WG, focusing on Higgs measurements.

- [Google doc](#) to organize the effort : please sign up if interested

EFT Interpretation Workflow: Non-exhaustive list of aspects for discussion/clarification from the LHC Higgs Working Group

General:

Aspects & questions for discussion and clarification:

(SM)EFT basics:

(SM)EFT modeling and data analysis:

Monte Carlo Tools:

Interplay with EWK/QCD higher-order effects:

Incorporating “global” knowledge in EFT analyses

Other topics

An incomplete wish-list for tools/features (EXP to TH):

General:

The following Twiki collects the questions related to the EFT interpretation of the Higgs measurements. The initial list of questions was presented during the [July 1st, 2020 meeting](#) of the LHC Higgs WG (WG2). A request to collect similar questions related to other possible types of processes was passed to the other LHC Physics WGs (Electroweak, Top) and the corresponding questions will be added here as well. The list of questions will evolve, and relevant TH groups will be welcomed to help to formulate the answers/clarifications and guiding principles/recommendations. All the effort will be in sync. with the work of the LHC EFT WG as well.

EFT Interpretation Workflow Implementation

- **Next Steps:** Use information in [Google doc](#) to
 - Identify groups of people interested in contributing to each topic
 - Form teams/sub-groups
- List of topics to be updated with feedback/input from LHC Top & EW Working Groups
- Organize dedicated meetings for each of the teams to discuss the topics
- Creation of WG note (in coordination with other LHC WG) with results from the initiative

EFT Interpretation Workflow: Non-exhaustive list of aspects for discussion/clarification from the LHC Higgs Working Group

General:

Aspects & questions for discussion and clarification:

(SM)EFT basics:

(SM)EFT modeling and data analysis:

Monte Carlo Tools:

Interplay with EW/QCD higher-order effects:

Incorporating "global" knowledge in EFT analyses

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Contributions to these efforts very welcome!

Feel free to contact us at
lhc-higgs-properties@cern.ch

Thanks for your attention!