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Effective-Field Theory interpretations of Higgs boson production and decay rates with the ATLAS experiment

Aleksei Lukianchuk On behalf of ATLAS experiment



Introduction

Article

discovery

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Check for updates

Open access

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the standard model.

• 10 years after Higgs discovery: <u>publication</u> in **Nature** with **combined Higgs analysis**





STXS measurements

oH (GeV

m" (GeV)

1 000

£ 500

Kappa-framework measurements

Introduction

Article

Open access

Check for updates

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Kappa-framework measurements

Input measurements

		SMEFT	Dedicated BSM
$H \rightarrow \gamma \gamma$	STXS-1.2	√ ∕(subset)	\checkmark
$H \rightarrow ZZ$	STXS-1.2	$\sqrt{(subset)}$	\checkmark
	STXS-0		\checkmark
$H \to \tau \tau$	STXS-1.2 STXS-0	\checkmark	\checkmark
$H \rightarrow WW^{(*)}$	STXS-1.2 STXS-0 STXS-0	\checkmark	
$H \rightarrow b \bar{b}$	STXS-1.2 STXS-1.2 STXS-1.2 STXS-1.2	$ \begin{array}{c} \checkmark \\ \checkmark \\ \checkmark \\ \checkmark \\ \checkmark \\ \checkmark \end{array} $	
$\begin{array}{c} H \rightarrow Z\gamma \\ H \rightarrow \mu\mu \end{array}$	STXS-0 STXS-0	\checkmark	\checkmark

SMEFT of Differential XS & comparison with STXS

> SMEFT of STXS

Not in this presentation

SMEFT methodology

SMEFT Lagrangian

$$\mathcal{L}_{SMEFT} = \mathcal{L}_{SM} + \sum \frac{\mathcal{C}_k^{(6)}}{\Lambda^2} \mathcal{O}_k + O(\Lambda^{-4})$$

 $\mathcal{M} = \mathcal{M}_{SM} + \mathcal{M}_{BSM}$

Jay <u>Sandesara</u> ("EFT interpretations using Higgs boson at ATLAS")

Victor Miralles ("Higgs global fits")

Angela Talierciolk ("Higgs boson anomalous couplings and EFT at CMS")

•
$$C_k^{(6)}$$
- Wilson coefficients (WC)

- First term kept in the expansion of the SM lagrangian is Dim=6.
- Dim-5 (7, ...) terms violate baryonic and leptonic numbers
- Impact of dim-8 terms might be crucial

+ [SM-
$$\mathcal{C}^{(8)}$$
] interference

SMEFT methodology

SMEFT Lagrangian

 $\sigma \approx |\mathcal{M}|^2 \approx$

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Cross-section (production rate, width) of a process:

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$$\underbrace{|\mathcal{M}_{SM}|^{2}}_{\text{SM}} + 2\mathcal{R}\left\{\sum_{k}\mathcal{M}_{SM}\frac{\mathcal{C}_{k}^{(6)}}{\Lambda^{2}}\mathcal{M}_{k}^{*}\right\}}_{\text{SM-D6 interference}} + \underbrace{\sum_{k}\left(\frac{\mathcal{C}_{k}^{(6)}}{\Lambda^{2}}\right)^{2}|\mathcal{M}_{k}|^{2}}_{\text{BSM}} + \underbrace{\sum_{i< j}\left(\frac{\mathcal{C}_{i}^{(6)}\mathcal{C}_{j}^{(6)}}{\Lambda^{4}}\right)\mathcal{M}_{i}\mathcal{M}_{j}^{*}}_{\text{Interference between WC}}$$

+ [SM- $\mathcal{C}^{(8)}$] interference

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Production modes



Production modes



Production modes



Production modes



STXS bins

Production modes



• Simultaneous WC measurement not feasible. Identify sensitive directions from information matrix

<mark>,</mark> [1]				0.01	-0.02	_	0.05	-0.47 0.0	02	0	.74 0).22 -	-0.41	-0.02	-0.01																																	
^[2]				-0.28	-0.03	-0.01 (0.06	0.84 <mark>-0</mark>	.03	0	.39 0).11	0.21	-0.01	-0.01																																	
[3]				0.96	-0.02	C	0.01	0.25 -0	.01	0	.11 0	0.03	0.06																																			
<mark>9</mark> [4]				0.01	0.99	0.04	0.15	0.03		0	.02	-	-0.01																										0.01	0.0	1							
[5]					-0.07	0.96	0.22	0.02		-(0.03 0	0.11	0.01				0.07	-0.03	3-0.0	2																		0.0	-0.0	1-0.0	01							
[6]					0.1	0.23	0.73	-0.05-0	.02	0	.32 -	0.44	0.31		0.01		0.01																					0.0	2 -0.0	3-0.0	0.0 60	2 0.01	0.01					
[7]					0.09	0.08	0.62	-0.04-0	.02	_(0.37 ().56 -	0.39		-0.02	2	-0.01																					0.0	2 -0.0	2-0.0	02 0.0	1 0.01	0.01	-0.01	1–0.01	0.01		
8]					-	0.09		-0.01-0	.28-	0.01	.04 0	0.12	0.13		-0.01		0.83	-0.32	2-0.2	6 0.01	-0.0	2-0.0	1		0.04	0.03	0.01	0.03	0.02	0.02	0.01	0.01	0.01					0.0	7 -0.0	5-0.0	05 0.0	4		-0.01	1-0.01	0.02	0.03	
9]					0.01	-0.02 (0.03	0.03 0.8	89 0	.12 0	.02 0	0.06	0.07		0.02		0.25	-0.09	9-0.0	8 0.01					-0.17	0.14	0.05	0.14	0.08	0.08	-0.05	-0.05	-0.04	-0.02	-0.01	0.01	0.01	-0.0	8			-0.0	1-0.0	1		0.03	-0.01	
וו					-	0.06	0.02		0	.01 0	.18 0).58	0.64	0.01	0.02		-0.18	0.15	0.02	2 0.02		-0.0	1		0.01	0.01												0.2	2 -0.2	1-0.2	21 0.1	4 0.03	0.04	-0.03	3-0.04		-0.02-	0.0
1]					-	-0.01 (0.05	-0	0.1 -	0.02 0	.09 0).26	0.3	0.01	0.01		-0.01		-0.0	1 0.03					-0.05	0.04	0.01	0.03	0.02	0.02	-0.01	-0.01	-0.01	-0.01				-0.3	7 0.55	0.5	4 -0.	29–0.0	3-0.0	3 0.02	0.02	0.01	0.01	
2]						(0.01	0.01 0.2	29 0	.08 0	.01 0	0.02	0.03	-0.01	-0.03	3	0.02								0.54	0.44	0.17	0.42	0.25	0.25	0.14	0.15	0.17	0.07	0.05	0.03	0.02 -0	.01 -0.	1 0.04	0.0/	4 -0.	03 0.02	2 0.02	0.01	1-0.01	0.03	0.01 -	0.0
3]					-0.01	_	0.01	-0	.01-	0.01-0	0.01-	0.03	0.02	-0.01	0.01		-0.04	-0.12	2 0.04	0.01		0.02	0.02		-0.03	0.02	0.01	0.02	0.01	0.01	-0.01	-0.01	-0.01					-0.0	9 0.01	0.0	1 -0.	02 0.52	0.52	-0.37	7–0.37	0.37	-0.12-	0.1
1		_				0.01		-0	.04 0	.12 –(0.01	0.05	0.05	-0.01	-0.01	0.01	0.22	0.85	-0.3	5 0.02	-0.0	4-0.0	4-0.03	0.02	-0.02	-	0.02						0.01					-0.1	4-0.0	2-0.0	02	-0.0	2-0.0	2-0.05	5-0.05	0.23	-0.1 -	0.0
5								-0	.02 0	.13					0.05		-0.01	-0.02	2						0.8	-0.33	0.23	0.28	0.16	0.14	-0.05	-0.06	-0.19	-0.1	-0.03	0.02	0.01	-0.0	7-0.0	2-0.0	02	-0.0	1-0.0	1 0.01	0.01	0.03	-0.01 0	J.O [.]
5]		_						-0	.02 0	.03	C	0.02	0.01	0.01	0.04		0.37	0.25	0.88	-0.0	7	0.05	0.04	-0.01	-0.01		-0.03											-0.	1 -0.0	2-0.0	06-0.	02 0.02	2 0.02	0.03	0.04	0.01	0.03 0).04
7]								0.0	03 -	0.21			0.02	0.01	-0.52	2	0.05	0.09	-0.0	1–0.0	6 0.04	0.02	0.01	-0.01	0.1	-0.13	0.65	0.12	0.07	0.07	0.03	-0.03	-0.13	-0.04	-0.01	0.01		-0.0	3-0.0	3-0.0	02-0.	02 0.06	0.06	-0.01	1-0.01	-0.03	0.41 -	0.0
8]								-0	.16 0	.75 0	.01 0	0.02	0.03	-0.01	-0.16	5	-0.11	-0.21	0.03	0.03	-0.0	8-0.0	3-0.02	0.01	-0.13	0.01	0.18		0.01	0.02		-0.01	-0.03			0.01		-0.	4 -0.1	4–0.1	16 0.0	5 -0.0	9-0.0	8 0.03	0.02	0.18	C	J.O
9]								0.0	03 0).1 -(0.01	0.04	0.04	-0.03	-0.21	0.01	0.02	-0.01	1 0.16	0.52	-0.2	1-0.1	8-0.11	0.07	0.05	-0.03	0.16	0.04	0.02	0.02	0.02	-0.02	0.01	0.01				0.4	2 0.24	0.1	8 0.2	2 -0.1	7-0.1	4-0.14	4-0.15	0.15	-0.3 0).O4
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ATLAS Preliminary $\sqrt{s} = 13$ TeV, 139 fb⁻¹

• Simultaneous WC measurement not feasible. Identify sensitive directions from information matrix

e ^[1]			0.01 -0	0.02	-0.0	05-0.47	7 0.02		0.74	0.22	-0.41	-0.02	2-0.01																																
e ^[2]			-0.28-0	0.03-0	0.01 0.0	6 0.84	-0.03	8	0.39	0.11	-0.21	-0.01	1-0.01																																
e ^[3]			0.96 –0).02	0.0	1 0.25	-0.01		0.11	0.03	-0.06	6																																	
e ^[4]			0.01 0.	.99 0 .	04 -0.1	15 0.03			0.02		-0.01																										0.01 C	0.01							
e ^[5]	_		-0) .07 0.	96 <mark>-0.</mark> 2	22 0.02			-0.03	0.11	0.01				0.07	-0.03	-0.02																			0.01	0.01-	0.01							
] [6]			0	0.1 0.	23 0.7	3 -0.05	5-0.02		0.32	-0.44	0.31		0.01		0.01																					0.02	0.03-	0.03	0.02	0.01 0).01				
^[7] و			0.	.09 0.	08 0.6	2 -0.04	4–0.02		-0.37	0.56	-0.39	9	-0.02		0.01																					0.02	0.02-	0.02	0.01	0.01 0).01 -	0.01–0	1.01 0.0	/1	
ə ^[8] e				-0	0.09	-0.01	1-0.28	-0.01	0.04	0.12	0.13		-0.01		0.83	-0.32	-0.26	0.01	-0.02	0.01		c	0.04 0	.03 0	.01 0	0.03 0	0.02	0.02	0.01 0	.01 0	0.01					0.07	0.05-	0.05	0.04		_	0.01-0	1.01 0.0	2 -0.0	3
, [9]			0.	.01 -0	0.02 0.03	3 0.03	0.89	0.12	0.02	0.06	0.07		0.02		0.25	-0.09	-0.08	0.01				-	0.17-	0.14-	0.05-	0.14-	80.0	80.0	0.05-	0.05-	0.04	0.02-	0.01-0	0.01-0.0	01	-0.08			-	0.01	0.01		0.0	3 -0.0	1
10]				-0	0.06-0.0	02		0.01	0.18	0.58	0.64	0.01	0.02		0.18	0.15	0.02	0.02		-0.01		(0.01 0	.01												0.22	0.21-	0.21	0.14	0.03 0).04 -	0.03-0).04	-0.0	2-0.0
11]				-0	0.01 0.0	5	-0.1	-0.02	0.09	0.26	0.3	0.01	0.01	-	0.01		-0.01	0.03				-	0.05-	0.04-	0.01-	0.03-	0.02	0.02	0.01-	0.01-	0.01-	0.01				-0.37	0.55 C	0.54 -	0.29	0.03-	0.03 C	0.02 0	.02 0.0	1 0.01	1
2]					0.0	1 0.01	0.29	0.08	0.01	0.02	0.03	-0.01	-0.03		0.02							(0.54 0	.44 0	.17 0	0.42 0	.25 (0.25	0.14 0	.15 0	0.17 0	0.07 0	0.05 0	03 0.0	2 -0.01	-0.1	0.04 C	0.04 -	0.03	0.02 0).02 -	0.01-0	J.01 0.0	3 0.01	0.0
3]			-0).01	-0.0	01	-0.01	-0.01	-0.01	-0.03	3-0.02	-0.01	0.01		0.04	-0.12	0.04	0.01		0.02	0.02		0.03-	0.02-	0.01-	0.02-	0.01	0.01	0.01-	0.01-	0.01					-0.09	0.01 0	0.01 -	0.02	0.52 0	0.52 -	0.37–0) <mark>.37 0.</mark> 3	7 -0.1	2-0.1
4]				0.	01		-0.04	0.12	-0.01	-0.05	5-0.05	5-0.01	1-0.01	0.01	0.22	0.85	-0.35	0.02	0.04	0.04	0.03 0	.02	0.02	-	0.02					0	0.01					-0.14	0.02-	0.02		0.02	0.02-	0.05-0	0.05 0.2	.3 -0.	1 -0.0
5]							-0.02	0.13					0.05		0.01	-0.02							0.8 -	0.33-	0.23-	0.28-	0.16	0.14	0.05	0.06-	0.19 -	0.1	0.03-0	0.02-0.0	01	-0.07-	0.02-	0.02		0.01	0.01 (0.01	.01 0.0	3 -0.0	1 0.0
6]							-0.02	0.03		0.02	0.01	0.01	0.04		0.37	0.25	0.88	-0.07		0.05	0.04 -	0.01	0.01	-	0.03											-0.1	0.02	0.06-	0.02	0.02 0).02 (0.03 0	.04 0.0	1 0.03	3 0.04
17]							0.03	-0.21			0.02	0.01	-0.52		0.05	0.09	-0.01	-0.06	0.04	0.02	0.01 -	0.01	0.1 -	0.13 <mark>0</mark>	.65 -	0.12	0.07	0.07	0.03-	0.03-	0.13-	0.04	0.01-0	0.01		-0.03-	0.03-	0.02	0.02	0.06 0).06 -	0.01-().01–0.	03 0.41	-0.0
8]							-0.16	0.75	0.01	0.02	0.03	-0.01	-0.16		0.11	-0.21	0.03	0.03	-0.08	0.03	0.02 0	.01	0.13 0	.01 0	.18	-	0.01	0.02	-	0.01-	0.03		-(0.01		-0.4	0.14	0.16	0.05	0.09-	0.08 (0.03 0	.02 0.1	8	0.0
19]							0.03	0.1	-0.01	-0.04	1-0.04	-0.03	3-0.21	0.01	0.02	-0.01	0.16	0.52	-0.21	0.18	0.11 0	.07 0	0.05 -	0.03	.16 -	0.04	0.02	0.02	0.02	0.02 0	0.01 0	0.01			-	0.42	0.24 (0.18	0.2	0.17	0.14-	0.14-() <mark>.15</mark> 0.1	5 -0.	3 0.04
10 ⁻³	10 ⁻² 10 ⁻¹ 1	0 ⁰ 10 ¹	Cettin	Cortigo	Con Con	Strice	o.e	Clift	ONB	CHIM	CHIMA	⁶ Clo	0112	92	CHI	Cha	CHO	Criligo	ON!	CYNO,50	Chilling .	CANO	cç i	6 6 9 9	C C C C S S	C/9	Col	Ce a	C/8	C(%)	Cog ®	63.0	6 20 9	Con Con	. Co	OHO	CHI.T.	CHIR	OII.12	Chiller,	CHIR	Che.TT	Citle, fl	100 Fre	CHO

ATLAS Preliminary $\sqrt{s} = 13$ TeV, 139 fb⁻¹

Wilson Coefficients (Warsaw basis)

Simultaneous WC measurement not feasible. Identify sensitive directions from information matrix



ATLAS Preliminary $\sqrt{s} = 13$ TeV, 139 fb⁻¹

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ATLAS Preliminary $\sqrt{s} = 13$ TeV, 139 fb⁻¹

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Wilson Coefficients (Warsaw basis)

Uncertainties

Not "full" rotation, but in groups of same "physics" •



ATLAS Preliminary $\sqrt{s} = 13$ TeV, 139 fb⁻¹

Not "full" rotation, but in groups of same "physics" •



ATLAS Preliminary $\sqrt{s} = 13$ TeV, 139 fb⁻¹

Wilson Coefficients (Warsaw basis)

Not "full" rotation, but in groups of same "physics"

C_{eH.22} 0.9 CeH,33 0.8 С_{На} 0.7 Сьн 0.6 $e_{ggF}^{[1]}$ -0.03 0.5 $e_{ggF}^{[2]}$ 0.03 0.99 0.11 0.4 $e_{ggf}^{[3]}$ -0.11 0.99 0.3 $e^{[1]}_{H\gamma\gamma,Z\gamma}$ 0.25 -0.47 -0.02 -0.01 0.2 $e^{[2]}_{H\gamma\gamma,Z\gamma}$ -0.49 0.73 -0.49 -0.02 0.1 $e^{[3]}_{H\gamma\gamma,Z\gamma}$ 0.22 0.64 0.74 0.01 0.02 0 $e_{ZH}^{[1]}$ -0.35 -0.27 0.02 -0.02 -0.01 -0.10.9 $e_{ZH}^{[2]}$ -0.2 0.21 -0.39 0.19 -0.05 -0.08 -0.06 0.03 $e_{ZH}^{[3]}$ -0.3 -0.32 -0.34 -0.58 0.66 -0.02 -0.08 -0.06 0.02 -0.4 $e_{ZH}^{[4]}$ 0.22 0.08 0.66 0.72 -0.02 -0.03 -0.02 -0.5 $e_{ttH}^{[1]}$ 0.46 0.17 0.45 0.27 0.27 0.16 0.16 0.14 0.06 0.05 0.03 0.02 -0.01 0.57 -0.6e[2] -0.23 -0.29 -0.16 -0.15 -0.05 -0.06 -0.2 -0.11 -0.03 -0.02 -0.01 -0.7 $e_{tth}^{[3]}$ 0.08 -0.15 0.95 -0.13 -0.08 -0.08 -0.03 -0.03 -0.17 -0.04 -0.02 -0.01 -0.01 -0.8 $e_{\text{glob}}^{[1]}$ 0.64 -0.48 -0.48 0.36 -0.9 $e_{HIII}^{[1]}$ 0.54 0.54 -0.39 -0.39 0.27 -0.14 -0.13 Contraction Contraction Contraction Cree Crus Crash Strang CX# CHO CO CO CHI 20 CO CITE I C (0) C (0) C(?) C(7) Can Can CHOO CHO 50

Wilson Coefficients (Warsaw basis)

ATLAS Preliminary $\sqrt{s} = 13$ TeV, 139 fb⁻¹

coefficients

SiS

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• Not "full" rotation, but in groups of same "physics"



coefficients

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pa

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Wilson Coefficients (Warsaw basis)

Not "full" rotation, but in groups of same "physics"

C_{eH.22} 0.9 CeH,33 0.8 ggF & ttH С_{На} 0.7 Сьн 0.6 BR H-> yy $e_{ggF}^{[1]}$ -0.03 0.5 $e_{ggF}^{[2]}$ 0.03 0.99 0.11 (ZY) 0.4 $e_{ggf}^{[3]}$ -**0.11** 0.99 0.3 $e^{[1]}_{H\gamma\gamma,Z\gamma}$ 0.25 -0.47 -0.02 -0.01 0.2 $e^{[2]}_{H\gamma\gamma,Z\gamma}$ -0.49 0.73 -0.49 -0.02 0.1 $e^{[3]}_{H\gamma\gamma,Z\gamma}$ 0.22 0.64 0.74 0.01 0.02 0 $e_{ZH}^{[1]}$ -0.35 -0.27 0.02 -0.02 -0.01 -0.1 $e_{ZH}^{[2]}$ -0.2 0.21 -0.39 0.19 -0.05 -0.08 -0.06 0.03 $e_{ZH}^{[3]}$ -0.3 -0.32 -0.34 -0.58 0.66 -0.02 -0.08 -0.06 0.02 -0.4 $e_{ZH}^{[4]}$ 0.22 0.08 0.66 0.72 -0.02 -0.03 -0.02 -0.5 $e_{ttH}^{[1]}$ 0.46 0.17 0.45 0.27 0.27 0.16 0.16 0.14 0.06 0.05 0.03 0.02 -0.01 0.57 -0.6e[2] -0.23 -0.29 -0.16 -0.15 -0.05 -0.06 -0.2 -0.11 -0.03 -0.02 -0.01 -0.7 $e_{tth}^{[3]}$ 0.08 -0.15 0.95 -0.13 -0.08 -0.08 -0.03 -0.03 -0.17 -0.04 -0.02 -0.01 -0.01 -0.8 $e_{\text{glob}}^{[1]}$ 0.64 -0.48 -0.48 0.36 -0.9 $e_{HIII}^{[1]}$ 0.54 0.54 -0.39 -0.39 0.27 -0.14 -0.13 Control Contro Crite Crilling Creese Chille CK# Cr C C C C C C C C C C C CHO CO CO CHI 20 CO Cree Choo Cho C & C & C & C / Cu Cu C 04

ATLAS Preliminary $\sqrt{s} = 13$ TeV, 139 fb⁻¹

Wilson Coefficients (Warsaw basis)

coefficients

SiS

pa

比

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Wilson Coefficients (Warsaw basis)

basis coefficients

比

STXS: fit basis results

Linear



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Grey -> Expected Blue -> Observed











STXS: fit basis results: Lin vs Lin + Quad

Quad



STXS: fit basis results: Lin vs Lin + Quad



Differential XS **EFT** interpretation (and comparison to STXS)

$\frac{d\sigma}{dp_T^H}$: Overview

• Hyy & H4I (parametrised independently) combined for final results

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• Observable: p_T^H

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- Observable: p_T^H
 - cHG => Higgs-gluon direct coupling
 - ctH => Yukawa top-like
 - **ctG** => top-gluon coupling modifier

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$$\mu_{bin} = \frac{1}{\sum\limits_{i \in prod} \sigma_{i,bin}^{SM}} \left(\sum\limits_{i \in prod} \frac{\sigma_{i,bin}^{SMEFT}(c)}{\sigma_{i,bin}^{SMEFT}(c=0)} \times \sigma_{i,bin}^{SM} \right)$$

— To benefit from accurate SM computations

$\frac{d\sigma}{dp_T^H}$: Principal Component Analysis

Define eigenvectors to absorb all **correlations** for the **differential cross-section** measurement. **Apply** the **same** "**rotation**" to the STXS (Hyy + H4I) results.

- $ev^{[1]} = 0.999c_{HG} 0.035c_{tG} 0.003c_{tH}$
- $ev^{[2]} = 0.035c_{HG} + 0.978c_{tG} + 0.205c_{tH}$
- $ev^{[3]} = -0.005c_{HG} 0.205c_{tG} + 0.979c_{tH}$



$\frac{d\sigma}{dp_T^H}$: PCA sensitivity (profiled case)

Compare performance of STXS and Diff XS => similar conditions required:

same dataset

same **basis**:

yy + 4l

Differential cross-section basis applied both to diff XS and STXS



- Comparable STXS and Differential performance for ev_01 (mainly constrained by ggH production mode)
- Much better STXS performance for ev_02 and ev_03 coming from the remaining production modes which can be probed separately in the STXS framework

Conclusion: results

- New SMEFT interpretation of the combined Higgs dataset
 - New channels included (Zy, mumu)
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Conclusion: results

- New SMEFT interpretation of the combined Higgs dataset
 - New channels included (Zy, mumu)
 - New linear & linear + quadratic results provided
- Comparison of the STXS and diff XS results (over Hyy + H4l) STXS is more sensitive
- No deviations wrt SM

Back-up

Break-down of uncertainties







Input measurements STXS

EFT matching

Coupling	Type I	Type II	Lepton-specific	Flipped
u,c,t		$s_{\beta-lpha} + c_{\beta-lpha}$	$_{\beta-lpha}/\tan\beta$	
d,s,b	$s_{\beta-lpha} + c_{\beta-lpha} / \tan\beta$	$s_{\beta-lpha} - c_{\beta-lpha} imes an eta$	$s_{\beta-lpha} + c_{\beta-lpha} / \tan\beta$	$s_{\beta-\alpha} - c_{\beta-\alpha} \times \tan\beta$
e,μ,τ	$s_{\beta-lpha} + c_{\beta-lpha} / \tan\beta$	$s_{\beta-lpha} - c_{\beta-lpha} imes \tan eta$	$s_{\beta-lpha} - c_{\beta-lpha} imes \tan\beta$	$s_{\beta-lpha} + c_{\beta-lpha} / \tan\beta$
W,~Z		s_{eta}	$\beta - \alpha$	
H	$s^3_{eta-lpha}$	$c_{\mu} + \left(3 - 2\frac{\bar{m}^2}{m_h^2}\right)c_{\beta-\alpha}^2 s_{\beta-\alpha}$	$_{\alpha} + 2\cot\left(2\beta\right)\left(1 - \frac{\bar{m}^2}{m_h^2}\right)$	$c^3_{eta-lpha}$





