UCLouvain

Institut de recherche en mathématique et physique Centre de Cosmologie, Physique des Particules et Phénoménologie





Plan

- Introduction : a short recap
- Future colliders projections
- Self-coupling
- Invisible width
- CP
- Outlook

Not a complete list

Introduction

The Standard Model : pre-H-story







All massless

The Standard Model: symmetry breaking



Is the H boson SM-like?



But only one unknown prior to the H discovery C. Degrande

How well do we know the SM?



Why does it matters?

DE

DF

- Only source of CPV (Baryon Asym.)
- Phase transition (History of the Universe)
- 2/3 portals towards DM, ν ,...
- Understanding flavour



What is the future of the H boson?

What is the future of the H boson?



I don't know

Exp. Projections

LHC projection



Couplings at future colliders



Couplings at future colliders



Self-coupling

H boson and **EWPhT**





HH



1807.04873

C. Degrande

20

 κ_{λ}

HH in the future



LHC prospect $\lambda_3 \lesssim 1.5 \lambda_3^{SM}$

No dependence on the top coupling

Direct vs indirect

$$V(\Phi,S) = -m^2 \Phi^{\dagger} \Phi - \mu^2 S^2 + \lambda_1 (\Phi^{\dagger} \Phi)^2 + \lambda_2 S^4 + \lambda_3 \Phi^{\dagger} \Phi S^2$$

 $m_h, m_H, \sin \alpha, \tan \beta, v_h$



Indirect HHH

g 9000000	$\begin{array}{c} t \\ \bullet &H \\ \bullet & -H \\ t \end{array}$		
g 000000 g 000000		$H \rightarrow \gamma$ $H \rightarrow \gamma$ $H \rightarrow \gamma$	
1312.3322	M.McCullough	e+e- → ZH	applications at future colliders
<u>1607.03773</u>	M.Gorbahn, U.Haisch	gg→H, H→γγ	approx. two-loop results $mh \rightarrow 0$
1607.04251	G.Degrassi, P.P. Giardino, F.M., D.Pagani	gg→H,WH,ZH,VBF, ttH H→vv,WW*/ZZ*→41, gg	total and diff.
<u>1610.05771</u>	W.Bizon, M.Gorbahn, U.Haisch, G.Zanderighi	WH,ZH,VBF	total and diff. + effects of QCD corrections
1702.01737	G. Degrassi, M. Fedele, P.P. Giardino	EWPO	two-loop effects
1702.07678	G. Kribs, A. Maier, H. Rzehak, M. Spannowksy, P. Waite	EWPO	two-loop effects
1704.01953	S. Di Vita, C. Grojean, G. Panico, M. Riembau, T. Vantalon	Direct+indirect	global fit in the EFT including differential
1709.08649	F. Maltoni, D. Pagani, A. Shivaji, X. Zhao	VBF, VH, tHj ttH and $H\rightarrow 41$.	Differential distributions with EW corrections. Release of MC codes
1711.03978	Di Vita, et al.	$e+e- \rightarrow ZH$, ZHH	Future colliders

Invisible decay

NP and the H boson



Invisible decay

CMS-HIG-17-023



$$\mathcal{L} = \mathcal{L}_{SM} - rac{1}{2} \partial_\mu \phi \partial^\mu \phi - rac{1}{2} M^2 \phi^2 - c_\phi |H|^2 \phi^2$$

Immediate implications for any model with

Simplest extension of the SM: The H portal

 $Br(H \to Inv.) < 0.19 (0.15)$ at 95% CL

Invisible decay

CMS-HIG-17-023

$$\mathcal{L}_{\rm SHP} = \mathcal{L}_{\rm SM} + \frac{1}{2} \partial_{\mu} S \partial^{\mu} S - \frac{1}{2} m_0^2 S^2 - \frac{1}{2} \lambda_S |H|^2 S^2 - \frac{1}{4!} \lambda_4 S^4.$$



 $Br(H \to Inv.) < 0.19 (0.15) \text{ at } 95\% \text{ CL}$



HVV CPV interaction

SM-like? strength and nature of the interactions

$$\mathcal{O}_{W\widetilde{W}} = -\frac{g^2}{4} \left(\phi^{\dagger}\phi\right) \widetilde{W}^k_{\mu\nu} W^{\mu\nu\,k} \equiv -\frac{g^2}{4} \left(\phi^{\dagger}\phi\right) \epsilon_{\mu\nu\rho\sigma} W^{\rho\sigma\,k} W^{\mu\nu\,k}$$



Vanishing rates but affect distribution

H-top CPV interaction



Outlook

- The H boson is compatible with the SM ... so far
 - Not all the couplings have been measured yet
 - No precision measurements yet
 - Go differential
- The H boson could be the portal to New Physics



We don't know

Outlook

- The H boson is compatible with the SM ... so far
 - Not all the couplings have been measured yet
 - No precision measurements yet
 - Go differential
- The H boson could be the portal to New Physics



We don't know

Thank you!

H boson mass



ATLAS-CONF-2017-046