

Windows on the Universe Higgs couplings

on behalf of the ATLAS and CMS collaborations

Rencontres du Vietnam 30th Anniversary

Introduction

The Standard Model Lagrangian

- gauge sector tested through Electroweak Precision measurement at LEP/LHC
- Higgs sector testable only at LHC: strong constraints from the requirement to have a spontaneously broken gauge theory (therefore re-normalisable): particle masses and Higgs boson couplings strongly related
- Measuring the Higgs couplings is a test of the SM in the Higgs boson sector



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Higgs boson couplings overview



k framework

- · define couplings at vertices for tree-level diagrams
- $\kappa = g/g_{SM}$ parametrise deviation from SM of production and decay modes



Propagate couplings to branching fraction through:

$$\Gamma(H \to XX) = \kappa^2 \Gamma(H \to XX)_{\rm SM}$$

$$\Gamma_H = \sum_i \Gamma_i = \sum_i \kappa_i^2 \Gamma_{\rm SM}^i$$

all couplings affect branching fraction through the Higgs boson total width

In this talks combination results for all channels published in nature 2022 will be shown plus last year updates

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Production mode and branching fractions

Nature 607 (2022) 60 Nature 607, pages 52–59 (2022) CMS 138 fb⁻¹ (13 TeV) Branching fraction ¹-01 ²-01 ²-01 AS and ATLAS Run 2 ATLAS Run 2 _CMS^{_}measure ecross section gand oppranching ဖ္တfraction as Signal strength parameters 🚺 Data (Total uncertainty) Data (Total uncertainty) 10⁻³ Syst. uncertainty Syst. uncertainty μ_{ι}^{0} - SM prediction SM prediction $\sigma_{
m Sh}$ Hatio to SM μ_f 1.5 Ratio to SM 10 1.2 3 2 0 0.8[|] $\mathrm{Br}_{\mathrm{SM}}$ 0.5 -10 μμ WH ZΗ ttH tΗ ΖZ Ζγ ggF + bbH VBF WW γγ bb $\tau \tau$ ō **Production process** Decay mode

one plot for each experiment shown, the second is in backup

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Coupling measurements



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 $k_f \frac{m_f}{\upsilon}$ or $\sqrt{k_V} \frac{m_V}{\upsilon}$

Ratio to SM

WH, H→WW



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$H \rightarrow Z\gamma$

Sensitive to loop induced BSM physics:



• 1 lepton (VH + ttH), 3 VBF, 4

BDT based kinematic

CMS analysis

8 categories

ATLAS-CONF-2023-025 CMS-PAS-HIG-23-002

- ATLAS + CMS

CMS

ATLAS analysis

- 6 categories
- 1 VBF + 5 lepton flavour and Zγ kinematic



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ATLAS and CMS Preliminary

20

16

18 *LHC* Run 2

-2InA

μ

VBF H→ bb

CMS PAS HIG-22-009



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ATLAS: Phys. Lett. B 842 (2023) 137963 CMS: Nature Physics 18 (2022) 1329



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EFT-BSM interpretation of off-shell couplings



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CMS search

Events

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100

- Br(H \rightarrow e⁺ e⁻) = 5 × 10⁻⁹ in the SM
- Impossible to access at LHC or HL-LHC
- look for BSM effects that enhance the bra •
- search for ggF and VBF production modes, _ analysis categorised according to the BDT score
- BDT validated in a $Z \rightarrow e^+e^-$ enriched region





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Higgs couplings to invisible particles

- CMS-HIG-21-007 Phys. Lett. B 842 (2023) 137963
- · The Higgs boson could act as a portal between SM and a dark sector
- Look for $H \rightarrow X X$ decay
- · Constraints on Higgs portal models
- searched in several production modes in ATLAS
- CMS focuses on 2 main production modes:

Z/W + H with $Z/W \rightarrow jj$, ttH

 $Br(H \to \text{inv})_{\text{SM}} = Br(H \to ZZ^* \to 4\nu) = 0.1\%$

any higher value would indicate DM presence

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Higgs to invisible results

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·2 Δ Log(L)

Upper limit and DM-nucleon constraints

- Using a specific model is possible to translate the upper limit on the branching fraction to a DM nucleon cross section
- results competitive with direct searches and outperforming at low masses

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Phys. Lett. B 843 (2023) 137745 20000 Higgs boson self-coup

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- production cross sections divided by STXS bins
- single Higgs boson production add a bit with respect to HH, but it mainly reduces model dependence from κ_t

see more details in the talk by V. Senthilkumar in HEP parallel session W2 on Wednesday morning

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k₂v and CMS results

Nature 607 (2022) 60

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Conclusions

- LHC is continuing to deliver data, the run will continue to Run-III and HL-LHC
- Higgs boson couplings are measured with 5% level accuracy
- Rare Higgs boson decays start to become accessible with the increasing of the collected data samples
- the high collected luminosity starts to make feasible testing of the Higgs sector in differential distributions (STXS)
- no deviation observed so far, but we are still far from high precision (~ 1%) Higgs coupling measurements
- Higgs boson self-coupling constraints start to reach a region of order 1, exclusion of nullself coupling could become accessible in the next dew years