Measurements of the Higgs boson inclusive and differential fiducial cross-sections in the diphoton decay channel with pp collisions at  $\sqrt{s} = 13$  TeV with the ATLAS detector

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### **Motivation**

Among the possible studies of the properties of the Higgs boson, the measurement of its production crosssection in fiducial regions defined by detector acceptance minimizes the physics assumptions that is needed for extrapolation to the full phase space.

Besides, the measured cross-sections are not split by production process in favor of a production-inclusive measurement, hence further minimizing SM assumptions.

Despite the small branching ratio of the Higgs boson decay to two photons of  $(2.27 \pm 0.01) \times 10^{-3}$ , the excellent photon reconstruction and identification efficiency of the ATLAS detector enable extraction of the Higgs/boson signal.



# Fiducial phase space sensitive to specific Higgs production modes



Subsets of the diphoton baseline fiducial region are defined to provide phase-space regions sensitive to particular Higgs production modes

- VBF-enhanced: sensitive to VBF
- $N_{\text{lepton}} \ge 1$ : sensitive to VH,  $t\bar{t}H$  and tH
- High  $E_T^{\text{miss}}$ : sensitive to VH,  $t\bar{t}H$  and BSM effects
- $t\bar{t}H$ -enhanced: sensitive to  $t\bar{t}H$  and tH

## **Inclusive fiducial cross-section measurements**



## **Differential fiducial cross-section measurements**

**Jet-related Double differential Kinematic VBF-enhanced** Multiple observables chosen in the đ **ATLAS** Work in Progress  $= qq \rightarrow H$  default MC + XH ATLAS Work in Progress  $H \rightarrow \gamma \gamma$ ,  $\sqrt{s} = 13 \text{ TeV}$ , 139 fb<sup>-1</sup>  $H \rightarrow \gamma \gamma$ ,  $\sqrt{s} = 13$  TeV, 139 fb<sup>-1</sup> [fb/GeV]  $aa \rightarrow H$  SCETlib::aT + XH dfid VBF default MC + XH  $qq \rightarrow H$  default MC + XH ATLAS Work in Progress 60 ATLAS Work in Progress 10 + Data, tot. unc. Syst. unc. + Data, tot. unc. Syst. unc.  $qq \rightarrow H$  RadISH+NNLOJET + XH- $H \rightarrow \gamma \gamma$ ,  $\sqrt{s} = 13 \text{ TeV}$ , 139 fb<sup>-1</sup> VBF proVBF NNLO + XH  $H \rightarrow \gamma \gamma$ ,  $\sqrt{s} = 13$  TeV, 139 fb<sup>-1</sup> measurement of --- XH = VBF+VH+ttH+bbH+tH  $\rightarrow$  Data, tot. unc. Syst. unc. XH = ggH+VH+ttH+bbH+tH  $aa \rightarrow H$  default MC + XH ÷ - Data tot unc. Svst. unc.  $aa \rightarrow H$  ResBos2 + XH ∇  $gg \rightarrow H$  Sherpa+MCFM+OpenLoops + XH  $dp_{T}^{\chi\chi}$ H LHCXSWG (2005.07762) + XH differential and fiducial  $aa \rightarrow H NNI OJET + XH$ VBF fiducial region do<sub>fid</sub> / ر  $qg \rightarrow H$  GoSam+Sherpa + XH ♦  $aa \rightarrow H$  STWZ, BLPTW + XH cross-sections XH = VBF+VH+ttH+bbH+tH  $10^{-2}$ 10 All differential measurements are 120-350 200-350  $p_{\tau}^{\gamma\gamma}$  [GeV] limited by statistical 20 25 30 35 45 60 80 100 120 140 170 200 250 300 450 650 1300  $0 \le \tau_{\star} < 15 \text{ GeV}$   $15 \le \tau_{\star} < 25 \text{ GeV}$   $25 \le \tau_{\star} < 40 \text{ GeV}$   $40 \le \tau_{\star} < 400 \text{ GeV}$ N,=0  $p_{\tau}^{\gamma\gamma}$  [GeV] uncertainties **ATLAS** Work in Progress  $= gg \rightarrow H$  default MC + XH ATLAS Work in Progress  $H \rightarrow \gamma \gamma$ ,  $\sqrt{s} = 13$  TeV, 139 fb<sup>-1</sup> [fb/GeV]  $gg \rightarrow H$  default MC + XH ATLAS Work in Progress ATLAS Work in Progress VBF default MC + XH  $H \rightarrow \gamma \gamma$ ,  $\sqrt{s} = 13$  TeV, 139 fb<sup>-1</sup> gq→H SCETlib::qT + XH - Data, tot. unc. Syst. unc.  $H \rightarrow \gamma \gamma$ ,  $\sqrt{s} = 13$  TeV, 139 fb<sup>-1</sup> ÷.  $H \rightarrow \gamma \gamma$ ,  $\sqrt{s} = 13$  TeV, 139 fb<sup>-1</sup> VBF proVBF NNLO + XH 0.04 Besides default MC, the Data, tot, unc. Svst, unc. - XH = VBF+VH+ttH+bbH+tH  $aa \rightarrow H$  ResBos2 + XH <sup>fid</sup> / d∆  $gg \rightarrow H$  default MC + XH - Data, tot. unc. Syst. unc. + Data, tot. unc. Syst. unc. XH = aaH+VH+ttH+bbH+tH $ag \rightarrow H$  SCETlib:::gT + XH XH = VBF+VH+ttH+bbH+tH ∇  $gg \rightarrow H$  Sherpa+MCFM+OpenLoops + XH  $dp_T^{XX}$ 0.03 measurements are XH = VBF + VH + ttH + bbH + tHdσ<sub>fid</sub> / ,  $N_{\text{late}}^{p_{\text{T}} > 30 \text{ GeV}} \ge 2$ 10 compatible with many 0.02 10theoretical predictions 0.01 (such as MATRIX+RadISH, 2 9 RadISH+NNLOjet, atio. 0-45 45-120 120-350 0-45 45-120 120-350 0-45 45-120 120-350 0-45 45-120 120-350  $p_{-}^{\gamma\gamma}$ [GeV] ResBos2, GoSam). 3000 13000 0.00 0.15 0.30 0.45 0.60 0.75 0.90 1.20 1.60 2.00 2.50 120 450  $1.5 \leq |v^{\gamma\gamma}| < 2.5$  $0.0 \leq |v^{\gamma\gamma}| < 0.5$  $0.5 \le |y^{\gamma\gamma}| < 1.0$  $1.0 \le |y^{\gamma\gamma}| < 1.5$ m<sub>ii</sub> [GeV]

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## Interpretations

### Limits on the *b*- and *c*-quark Yukawa coupling



Probe  $\kappa_b$  and  $\kappa_c$  indirectly through the measured  $p_T^{\gamma\gamma}$  spectrum, not limited by tagging efficiency of jets originating from *b*- and *c*-quarks.

Two fitting strategy studied:

- Only consider shape (shape)
- Consider also the normalization of crosssection times branching ratio (shape+XS+BR)

	fit-setup	к	Observed 95% CL	Expected 95% CL
	Shape-only	К <sub>С</sub> КЪ	[-9.9, 13.3] [-2.7, 7.9]	[-10.0, 15.1] [-2.6, 7.6]
•	Shape+Normalisation (with Branching ratio variations)	К <sub>С</sub> КЪ	[-3.9, 3.9] [-1.3, -1.0] ∪ [0.9, 1.3]	[-3.1, 3.1] [-1.2, -0.9] ∪ [0.8, 1.2]

 $\kappa_b$  limits are comparable with direct searches , while constraints on  $\kappa_c$  improve (no upper limits on  $\kappa_c$  in direct searches )

### **Effective Field Theory (EFT) interpretation**

In EFT approach, an effective Lagrangian is defined by  $\mathcal{L}_{SM}$  supplemented by additional dimention-6 operators:

$$\mathcal{L}_{\rm EFT} = \mathcal{L}_{\rm SM} + \sum_{i} \frac{c_i}{\Lambda^2} O_i^{(6)}$$

Limits on the Wilson coefficients are obtained using a simultaneous fit to 5 measured cross-sections and their correlations:  $p_T^{\gamma\gamma}$ ,  $N_{jets}$ ,  $m_{jj}$ ,  $\Delta \phi_{jj}$  and  $p_T^{j_1}$ 

