Differential cross section of the Higgs boson measured in the diphoton decay channel with the ATLAS detector --- 8 TeV proton-proton collision data







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Outline

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- Observables
- Analysis results
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 - ♦ Systematic uncertainties
 - ♦ Signal yield at reconstructed level
 - ♦ Measurement of fiducial cross section at particle level
- Conclusion

Introduction



Motivation for differential cross section measurement

- For the first time, directly measure several kinematic distributions of the Higgs boson in robust and close to model independent way
- Many of the current Higgs results make assumptions on the Higgs kinematics, these results provide a cross check of the validity of these assumptions
- Correct measured spectra for detector effects to provide easy and direct comparison with theoretical predictions at particle level



p⊤ of the Higgs, constructed from the two photons.
The coupling measurement is sensitive to the kinematics of this variable.

In this talk, the measurement of this variable is shown!

Observables



We cannot really constrain precise SM calculations yet with current data statistics, but rather test if there are significant deviations from the SM in any of the kinematic distributions.

Analysis overview

unbinned Likelihood function definition

$$\mathcal{L}(\boldsymbol{m}_{\boldsymbol{\gamma}\boldsymbol{\gamma}};\boldsymbol{v}^{\mathrm{sig}},\boldsymbol{v}^{\mathrm{bkg}},\boldsymbol{m}_{H}) = \prod_{i} \left\{ \frac{e^{-\nu_{i}}}{n_{i}!} \prod_{j}^{n_{i}} \left[\nu_{i}^{\mathrm{sig}} \mathcal{S}_{i}(\boldsymbol{m}_{\boldsymbol{\gamma}\boldsymbol{\gamma}}^{j};\boldsymbol{m}_{H}) + \nu_{i}^{\mathrm{bkg}} \mathcal{B}_{i}(\boldsymbol{m}_{\boldsymbol{\gamma}\boldsymbol{\gamma}}^{j}) \right] \right\} \times \prod_{k}$$

 v_{i}^{sig} : # of signal in ith bin

 v_i^{bkg} : # of background in ith bin

 \mathcal{G}_k : Constrain term of the kth nuisance parameter

Signal extracted with S+B unbinned likelihood fit of $m_{\gamma\gamma}$ separately for each bin of the observable.

Fiducial photon definition

- $p_T/m_{\gamma\gamma} > 0.35$ (0.25) for leading(sub-leading) photon
- $|\eta| < 2.37$ (without $1.37 \ge |\eta| \ge 1.56$ for reco)
- Jet definition
- Anti- $k_t R = 0.4, p_T > 30 \text{ GeV}, |y| < 4.4$

Selected data are divided in bins of observable



Analysis overview



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Selected data are divided in bins of observable







Potential biases of bin-by-bin correction have been carefully studied and the systematic uncertainties are evaluated.



and signal/background modelling

Statistical uncertainty dominates.





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Fiducial differential cross section

-- Higgs *p*т









- More conservative uncertainty estimation with the procedure of reference [Phys. Rev. D 85, 034011 (2012)] using input uncertainties from MCFM.
- Good agreement on the jet veto fraction distribution indicates that we have a fair understanding.

N_{Jets}



- Theory predictions describe the spectrum well
- Comparison is made with the predictions with STWZ [PRL. 109, 202001 (2012)] and JETVHETO [hep-ph:1307.1808] calculation, which are precise to NNLO +NNLL' and NNLO+NNLL respectively.



• Largest excess in last $\Delta \phi_{jj}$ bin. Carefully checked for systematic biases.

• Predictions for both distributions are consistent with the observed spectra.

Conclusion

- First measurements of Higgs differential cross sections with the full 2012 dataset and comparisons with several MC predictions are presented.
- The measured spectra of 7 observables and the jet veto fraction are sensitive to the fundamental kinematic properties of Higgs boson, probe its spin and parity and test the QCD theoretical prediction.
- Except for possible global excess as signal strength measurement, with the limited statistics of the measurement, the predicted shapes agree with the observation, and no significant deviation from the SM expectation is observed.

Observables of interest

Class	Conf.	Variable			
Inclusive (Higgs)	EPS	$Pt_{\gamma\gamma}, \underline{v}_{\gamma\gamma}, \underline{cos\theta}^*$			
	Pending	$\begin{array}{c c} \underline{Ptt}, \underline{\phi}^*, \underline{\Delta \phi}_{\underline{\gamma}\underline{\gamma}} \\ \underline{Pt}_{\underline{\gamma}\underline{\gamma}}(\underline{N}_{iet}=0), \underline{Pt}_{\underline{\gamma}\underline{\gamma}}(\underline{N}_{iet}=1), \underline{Pt}_{\underline{\gamma}\underline{\gamma}}(\underline{N}_{iet}=2) \\ \underline{Pt}_{\underline{\gamma}\underline{\gamma}}(N_{jet}\geq 1), \underline{Pt}_{\underline{\gamma}\underline{\gamma}}(N_{jet}\geq 2) \end{array}$			
Inclusive (N_{ict})	Moriond	Inclusive cross section ($N_{jet} \ge 0$ with abs. pt cut)			
	EPS	Exclusive jet multiplicity (N=i) Jet veto fraction (N=i/N>i)			
1-jet	EPS	P _{t,1j}			
20250	Pending	$y_{1j}, \underline{P}_{LHJ}, \underline{m}_{HJ}, \underline{\tau}_{j}$			
2-jet	EPS	$\Delta \phi_{ii}, \underline{P}_{t,Hii}$			
	Pending	$\begin{array}{c} P_{t,2j}, y_{2j} \\ \underline{y}_{ii}, \underline{m}_{ii}, \underline{\Delta y}_{ii}, \underline{\Delta y}_{H,ii}, \underline{\Delta \phi}_{H,ii}, \underline{m}_{HII}, \underline{Zeppenfelder} \end{array}$			

Any suggestion on the observables of interest is welcome.

More theoretical comparison?

Comparison with theoretical predictions

ggH prediction:

- ► POWHEG H @ NLO + Py8
- MINLO H + 1jet @ NLO + Py8
- ► HRES H & NNLO + approx. NNLL.
- JetVheto H @ NNLO/NNLL
- STWZ H + 1jet @NNLO/NNLL'

XH prediction:

- ► VBF: POWHEG H @ NLO + Py8
- Other: Py8 @ LO
- All scaled with k-factor of the Higgs

***Theoretical prediction uncertainties** (Stat. \oplus (Scale+PDF) \oplus UE \oplus BR):

- Sum in quadrature of PDF+ α_s variations
- Envelop of Renormalization/factorization/ resummation
- Underlying event modeling
- Branching ratio of Higgs decay

Probabilities from chi2 test, taking into account the full covariance between bins

	N _{jets}	$p_{\mathrm{T}}^{\gamma\gamma}$	$ y^{\gamma\gamma} $	$ \cos\theta^* $	$p_{\mathrm{T}}^{j_1}$	$\Delta \phi_{jj}$	$p_{\mathrm{T}}^{\gamma\gamma jj}$
POWHEG	0.54	0.55	0.38	0.69	0.79	0.42	0.50
MINLO	0.44	_	_	0.67	0.73	0.45	0.49
HRes 1.0	_	0.39	0.44	_	_	_	_

Predicted shapes mostly agree well with the observation.

Signal extraction



Fiducial differential cross section --Jet multiplicity



Unfolding treatment

- Bin-by-bin unfolding method is used to correct for detector effect.
- Unfolding factor : $C_i = n_i^{\text{particle}}/n_i^{\text{reconstructed}}$, is derived bin-by-bin. This unfolding procedure corrects for all efficiencies, acceptances and resolution effects.



- The distributions at particle level are restored by multiplying the extracted binned signal yield by unfolding factor.
- Potential biases have been carefully studied and systematic uncertainties are evaluated.