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DIFFERENTIAL MEASUREMENTS OF HIGGS PRODUCTION AT ATLAS AND CMS

Toni Šćulac

on behalf of ATLAS and CMS Collaborations

LHCP2019 Puebla, Mexico 21 May 2019

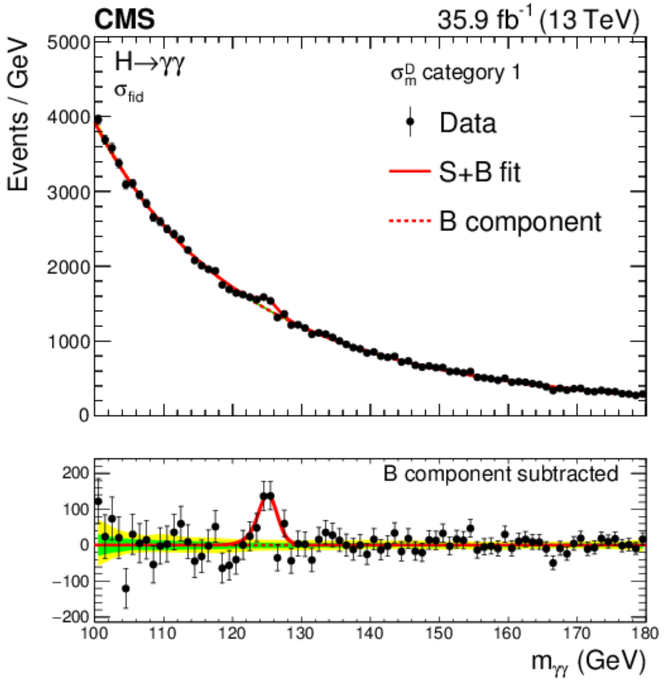
INTRODUCTION

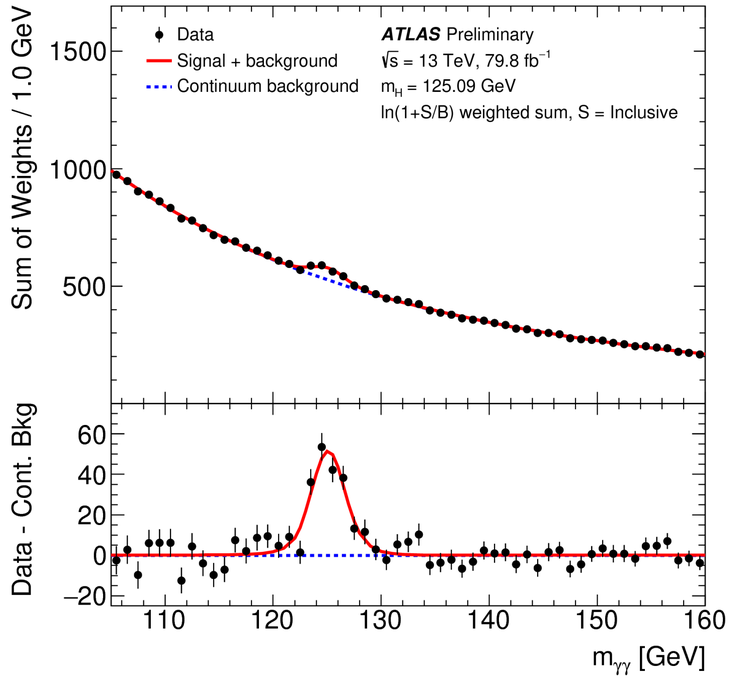
- Differential cross sections measured in fiducial phase spaces:
  - Extrapolation to full phase space minimized
  - Reproducibility in calculations for future comparisons
- Exploring Higgs production differentially key to:
  - test SM predictions for full spectra of observables of interest
  - probe for BSM hints
- Three channels considered with latest public results from ATLAS and CMS:

	Channel	Dataset	Publication
ATLAS	$H\to\gamma\gamma$	35.9 fb^{-1}(2016)	Phys. Rev. D 98 (2018) 052005
ATLAS	$H\to\gamma\gamma$	79.8 fb^{-1} (2015+2016+2017)	ATLAS-CONF-2018-028
CMS	$H\to\gamma\gamma$	35.9 fb^{-1}(2016)	JHEP01(2019)183
ATLAS	$H\to ZZ\to 4l$	79.8 fb^{-1} (2015+2016+2017)	ATLAS-CONF-2018-018
ATLAS	$H\to\gamma\gamma$ $H\to ZZ\to 4l$	36.1 fb^{-1}(2015+2016)	Phys. Lett. B 786 (2018) 114
CMS	$H\to\gamma\gamma$ $H\to ZZ\to 4l$ $H\to bb$	35.9 fb^{-1}(2016)	Phys. Lett. B 792 (2019) 369
CMS	$H\to ZZ\to 4l$	137.1 fb^{-1} (2016+2017+**2018**)	CMS-PAS-HIG-19-001
ATLAS	$H\to\gamma\gamma$ $H\to ZZ\to 4l$	3 ab^{-1}(HL-LHC prospects)	ATL-PHYS-PUB-2018-040
CMS	$H\to\gamma\gamma$ $H\to ZZ\to 4l$ $H\to bb$	3 ab^{-1}(HL-LHC prospects)	CMS-PAS-FTR-18-011

H→γγ

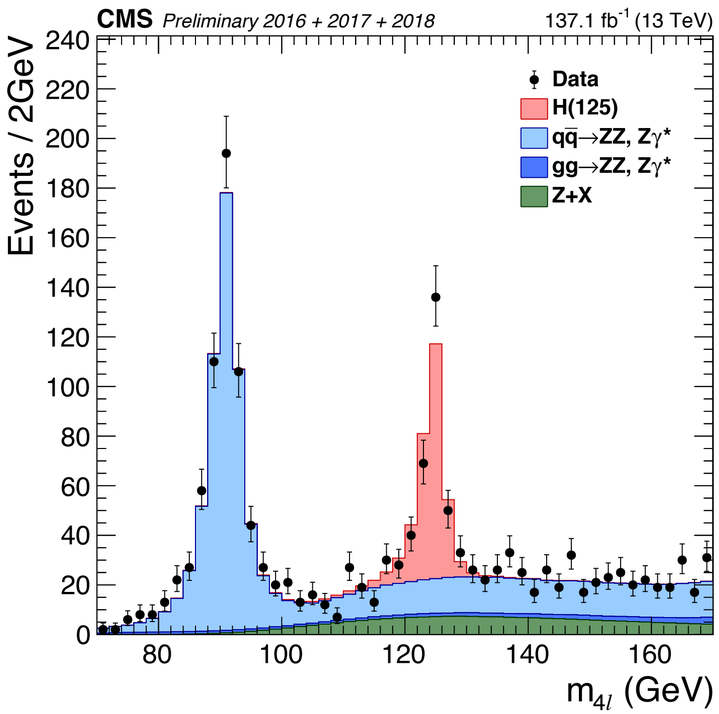
- Signal is reconstructed by two energetic photons
- Backgrounds are from SM γγ,γj, and jj
- Vertex assignment
  - ATLAS : neural network(vertex/track, calorimeter pointing)
  - CMS: BDT combines tracking and calorimeter information
- CMS: Categorization in mass resolution
- Signal is extracted from a fit to di-photon mass spectrum

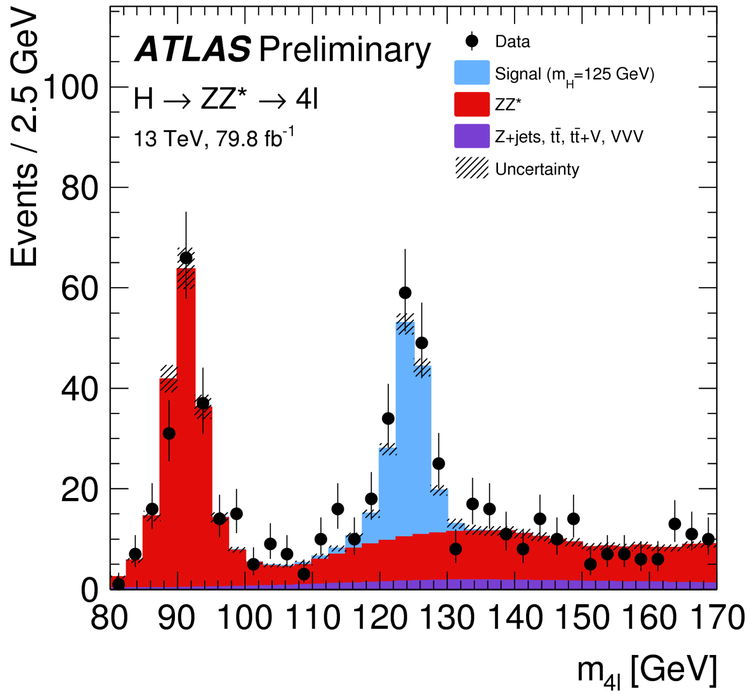




H→ZZ→4L

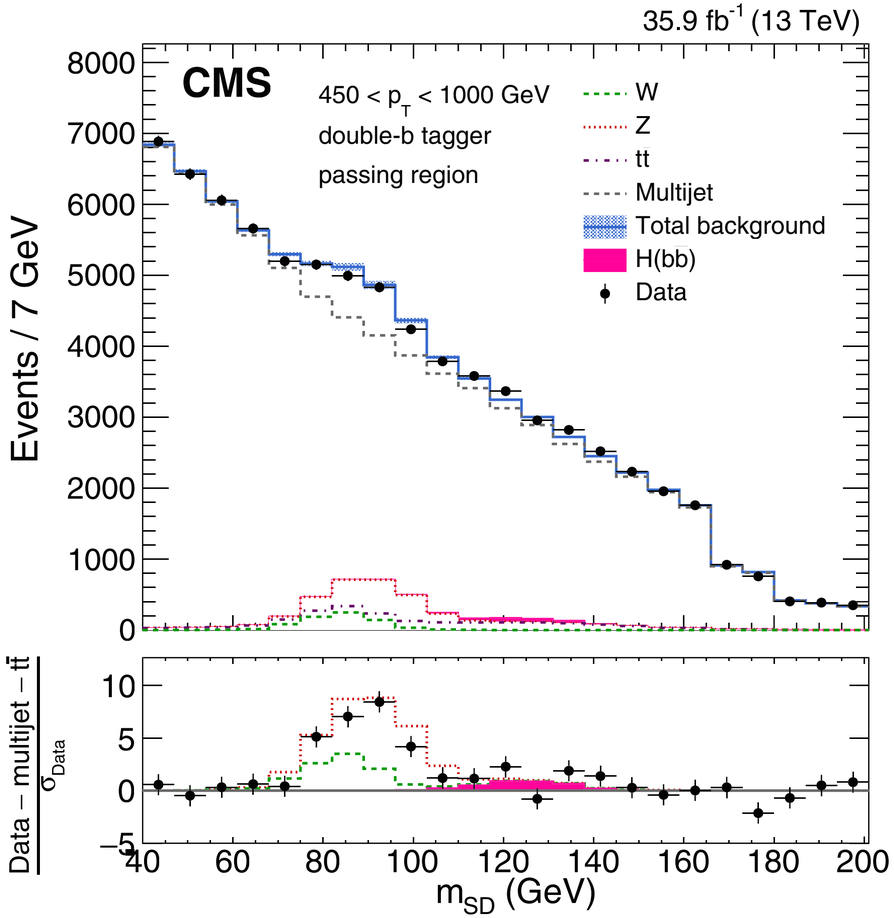
- Signal is fully reconstructed using four lepton with good momentum resolution
- SM backgrounds: qqZZ, ggZZ and Z+X
- Large S/B ratio ~2:1 under the Higgs peak
- Kinematic information for further S/B separation:
  - ATLAS: BDT Kinematic discriminant
  - CMS: Matrix-element Kinematic discriminant
  - not used in the differential cross section measurements
- Categorization in lepton flavour





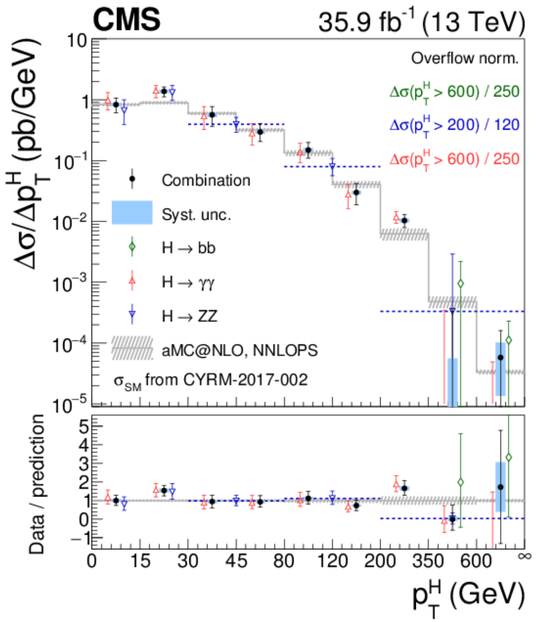
H→BB

- Boosted ggH reconstructed from fat jet
- SM background: QCD multijet, W/Z+jets, and tt
- Categorization in jet substructure
- Fit to m_{SD} mass distribution
- Combined in differential $p_T(H)$ measurement
  - Brings improved sensitivity for high p_T bins

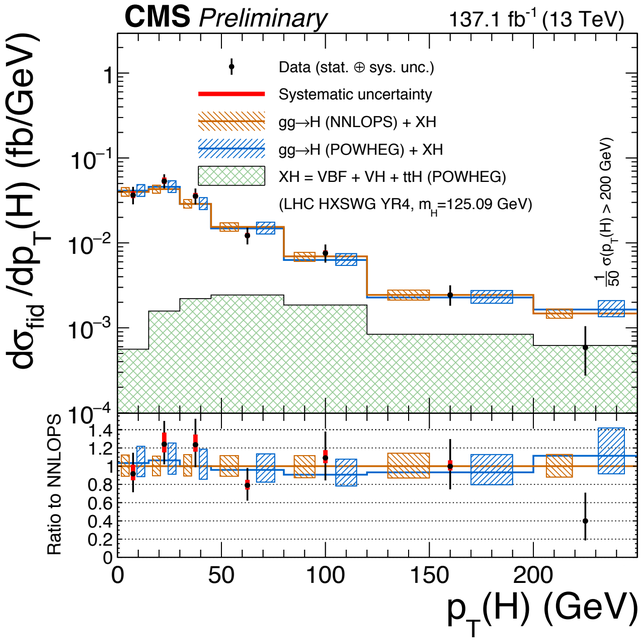


HIGGS P_T

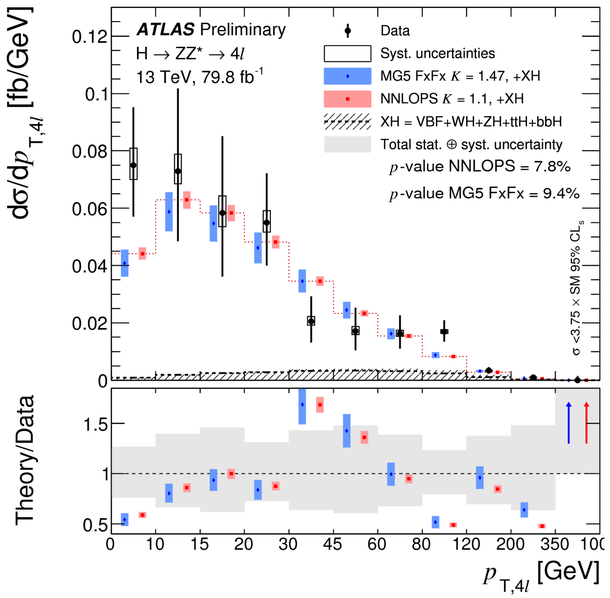
- $p_T(H)$ probes the perturbative QCD modeling of Higgs production
  - 20 - 30% precision with full Run 2 statistics
- Variations of couplings distort the shape of $p_T(H)$
- Different models are provided by theorists to describe the shape distortions



COMBINATION



H→ZZ→4l



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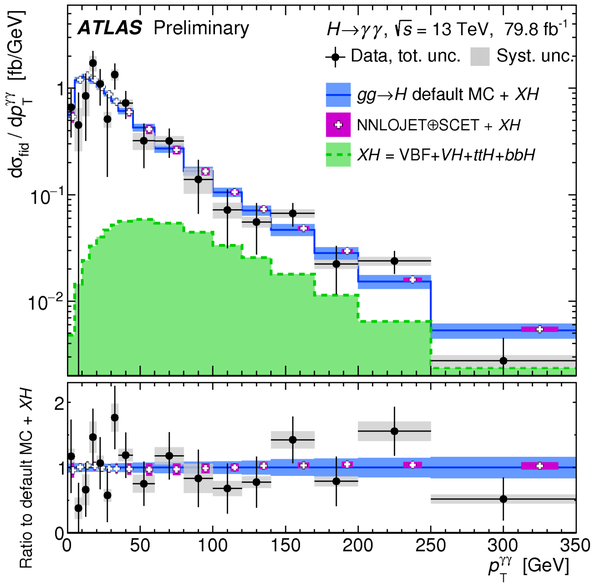
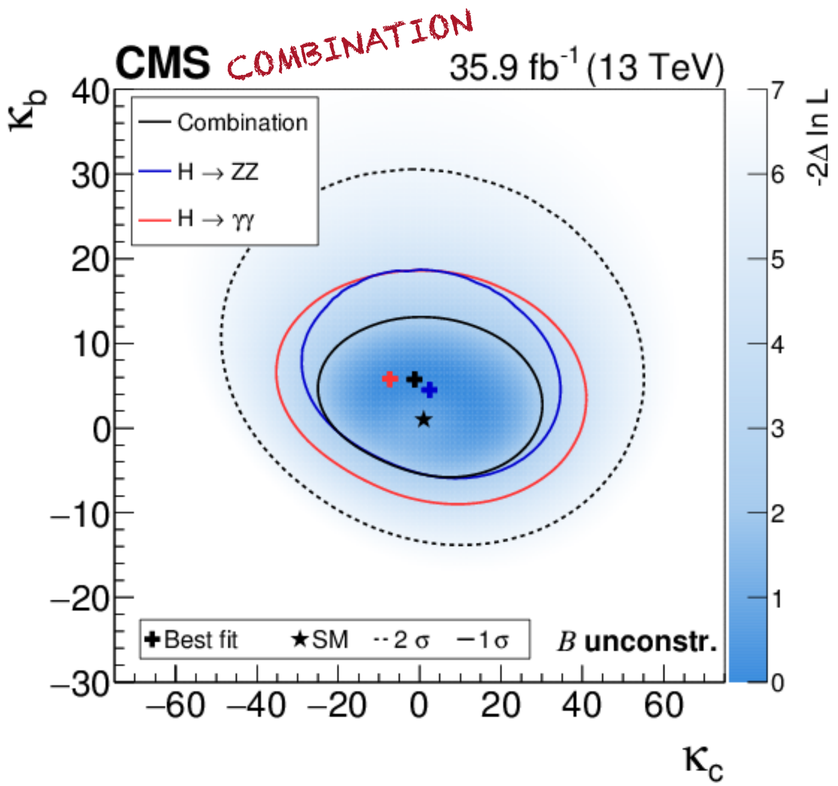
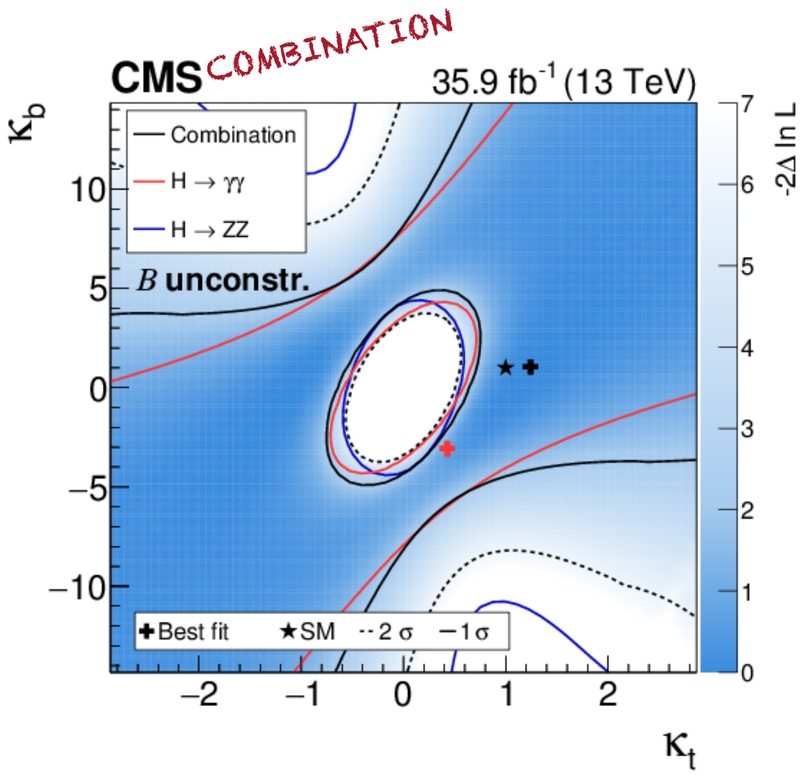


H→γγ

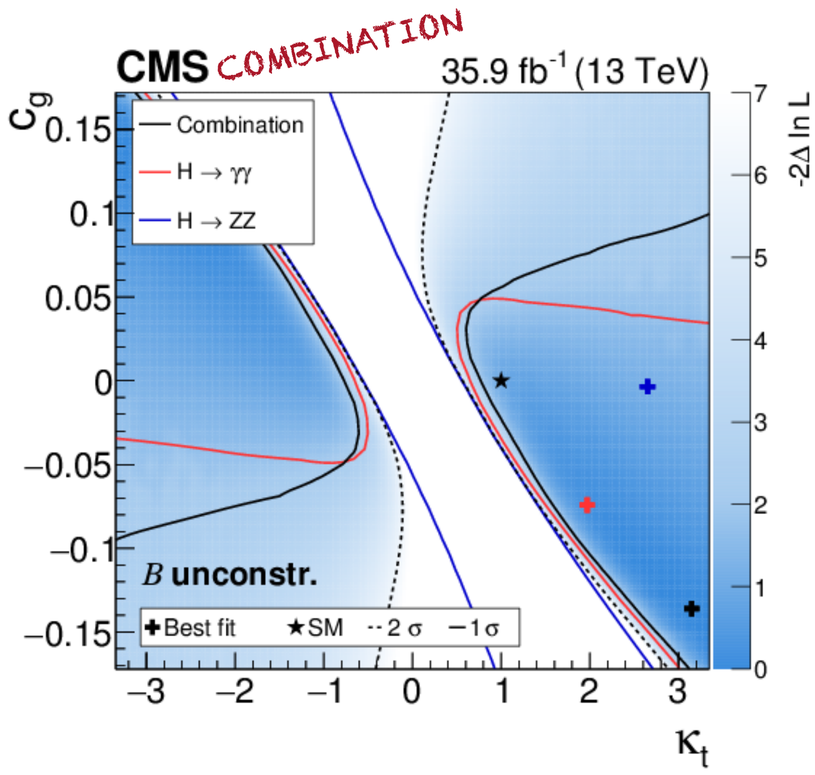
HIGGS P_T

- Results are dependent on the assumptions about BR under coupling variations, two scenarios studied:
  1) BR freely floating





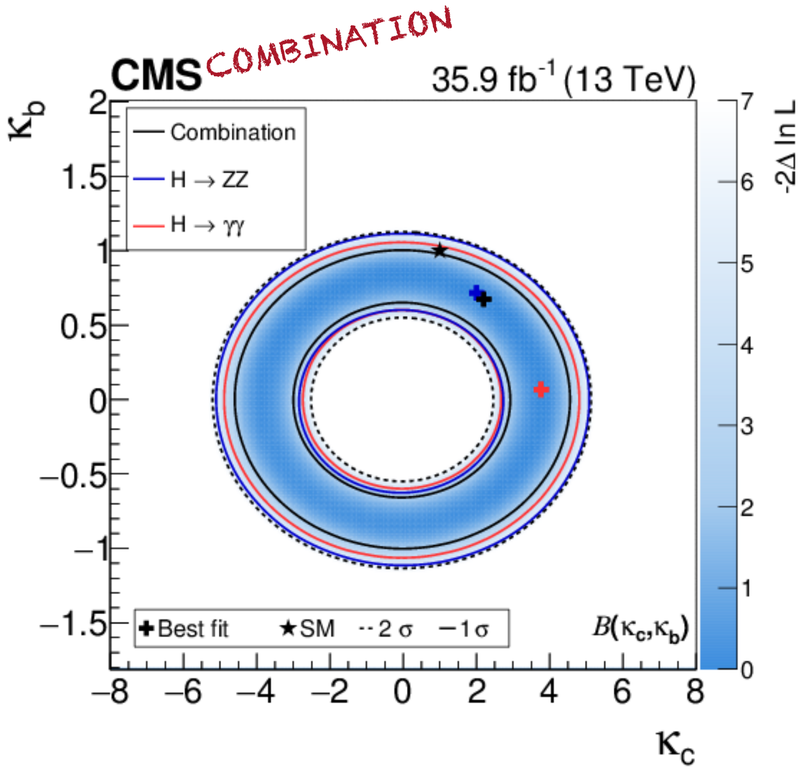
coupling to t, b, c quarks in k-framework

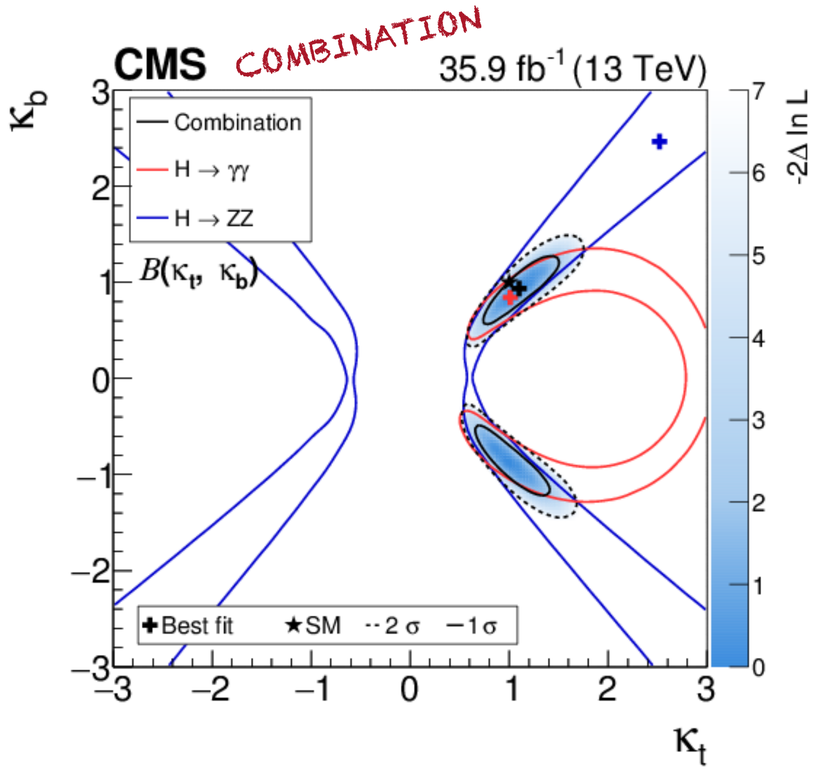


coupling to gluon with dim-6 operator

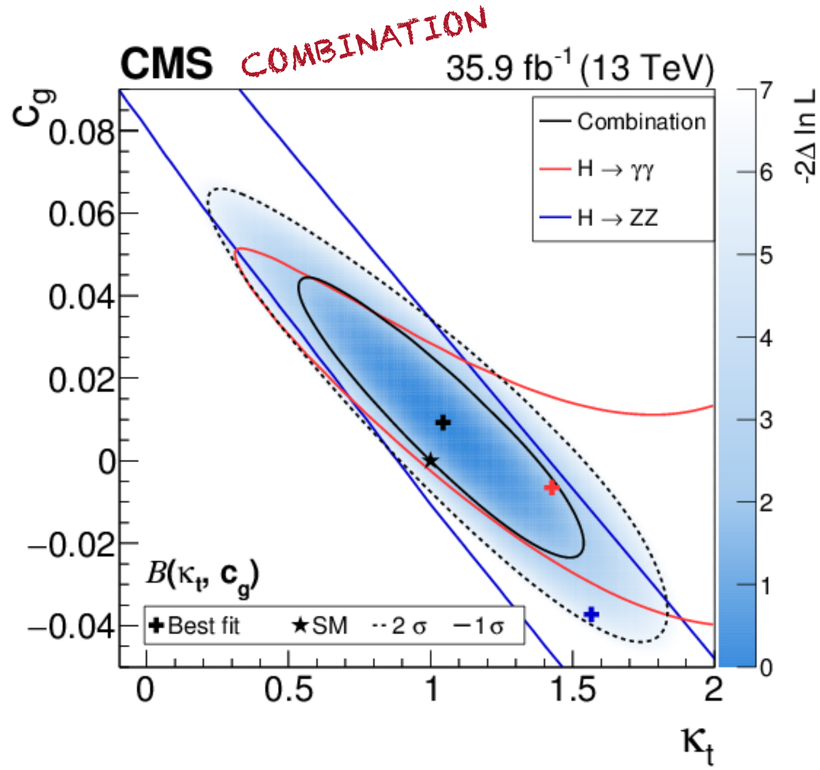
HIGGS P_T

- Results are dependent on the assumptions about BR under coupling variations, two scenarios studied:
  1) BR freely floating
  2) BR scaling with couplings





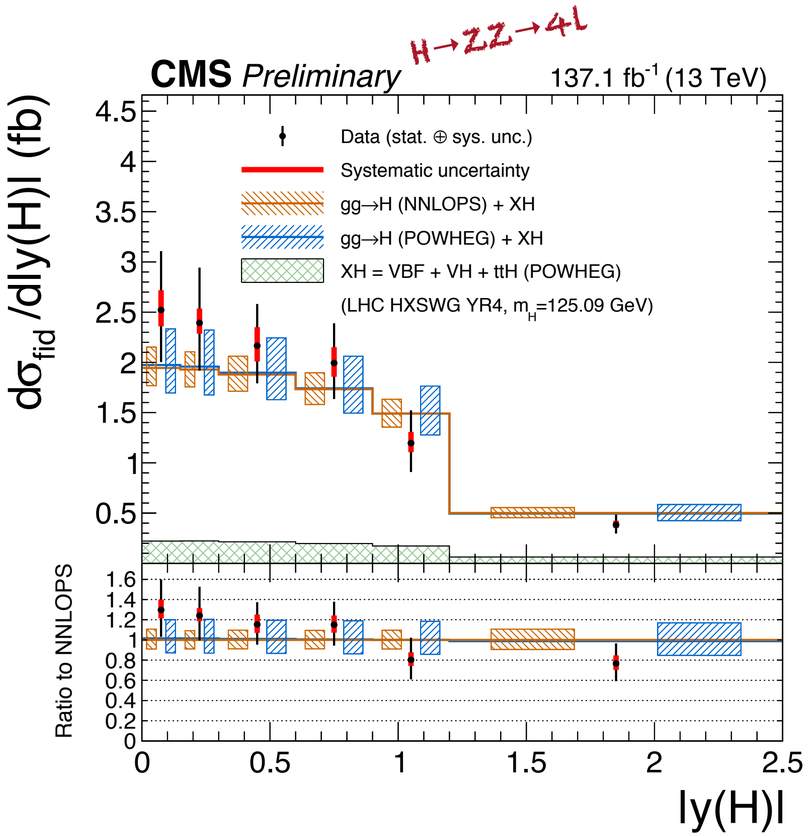
coupling to t, b, c quarks in k-framework

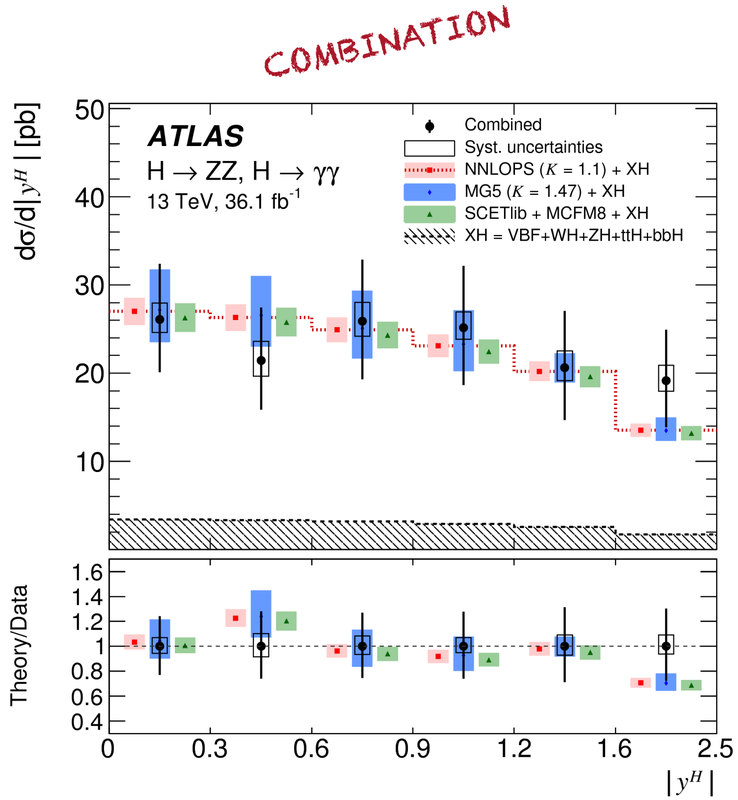


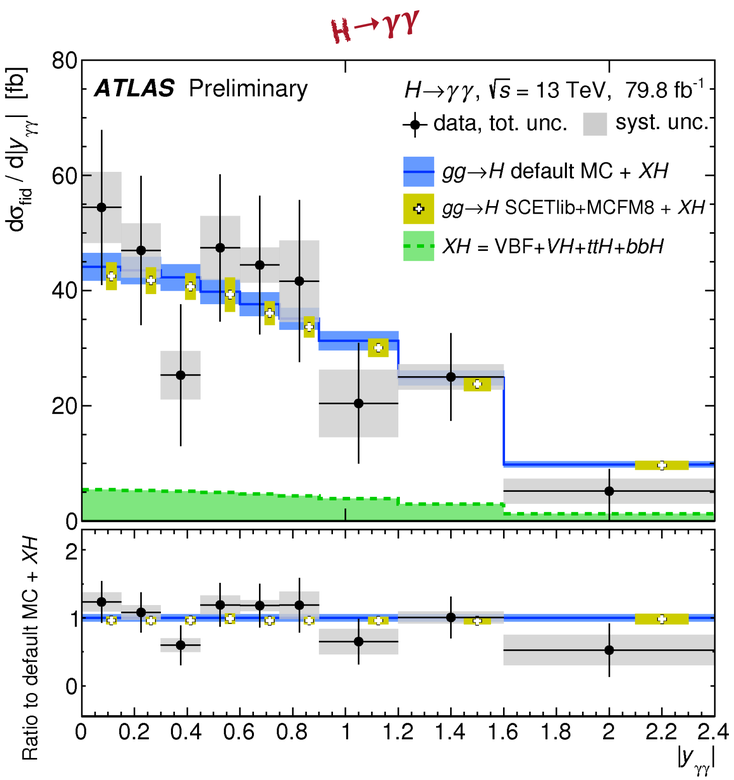
coupling to gluon with dim-6 operator

HIGGS RAPIDITY

- y(H) probes the PDFs and Higgs production mode
  - measurement precision statistically dominated
  - 20 - 30% precision with full Run 2 statistics

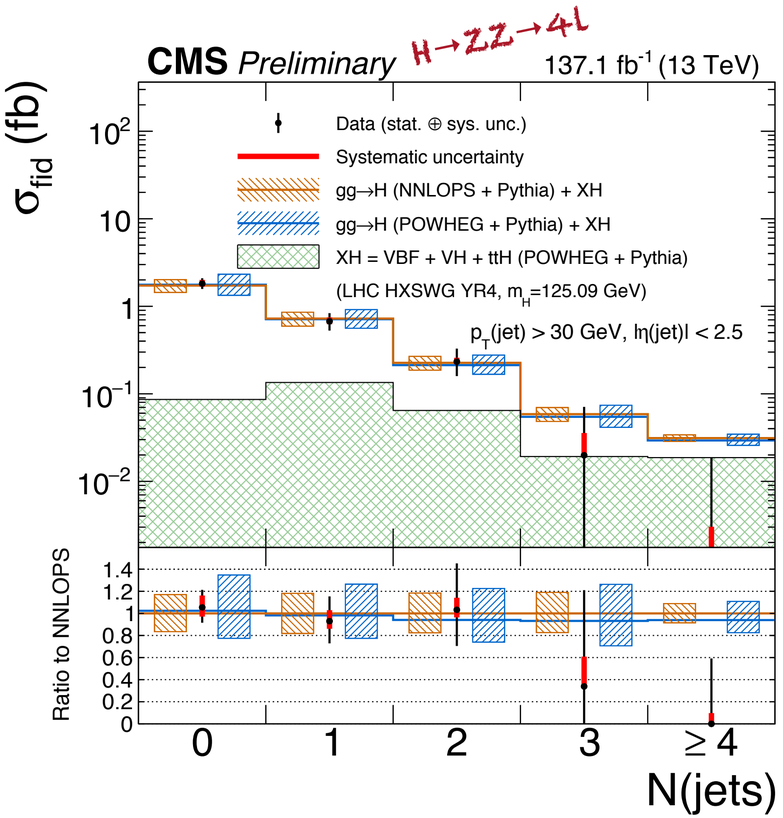


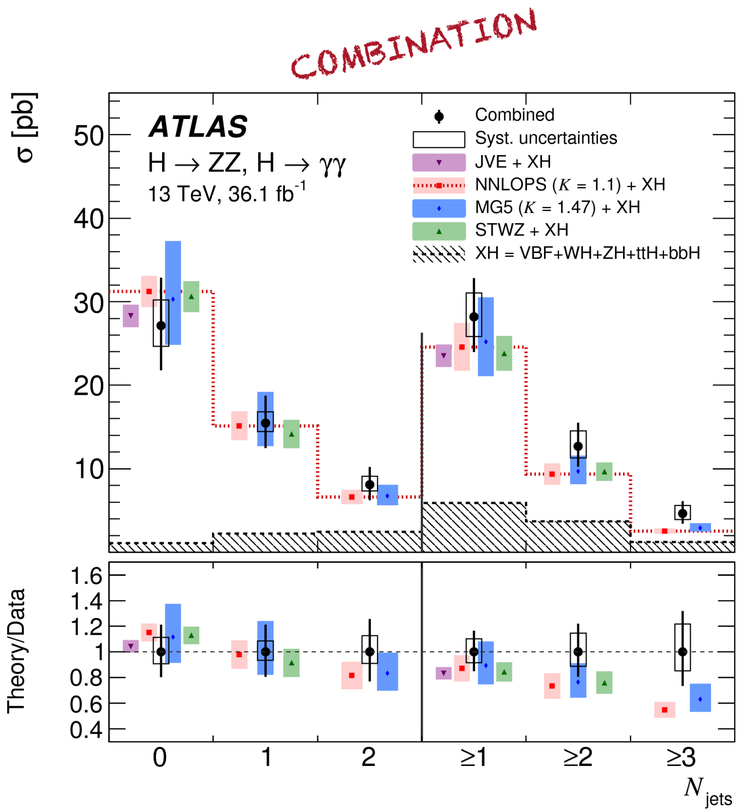


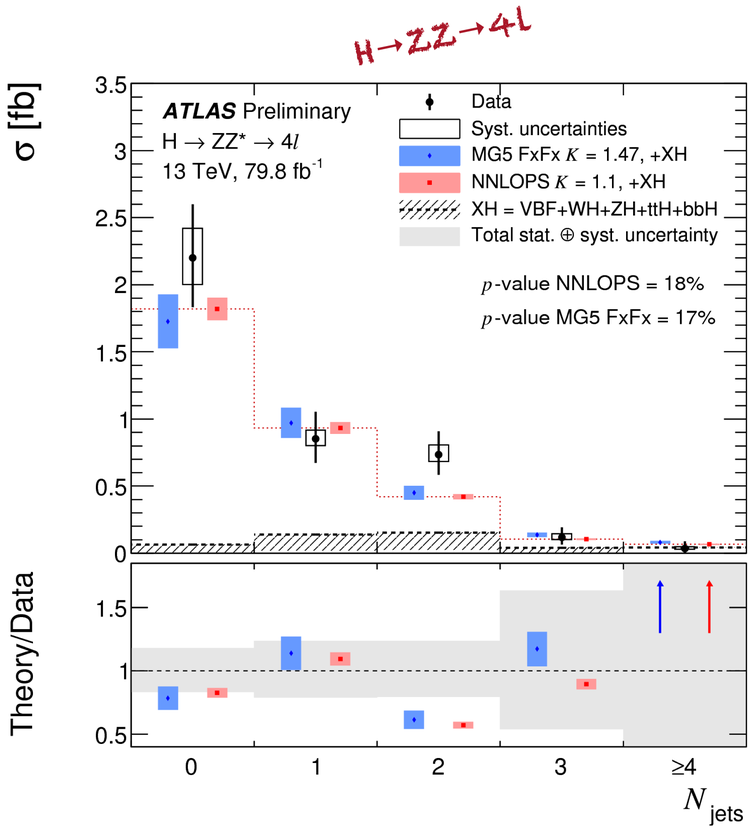


NUMBER OF JETS

- Jet kinematics useful for test of modelling of QCD radiation, production mechanism:
  1) Number of central jets

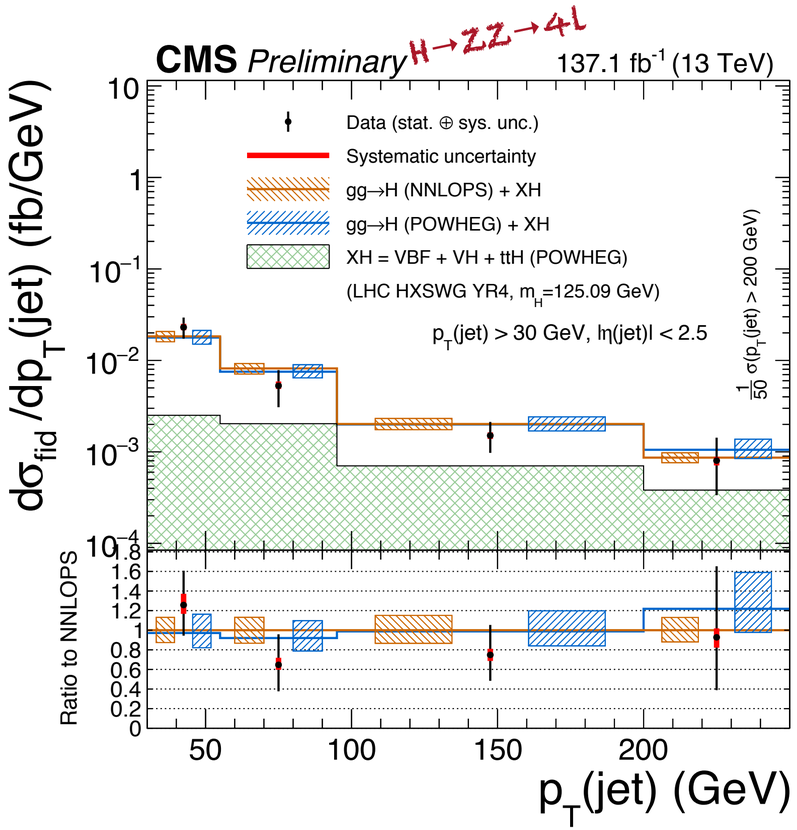


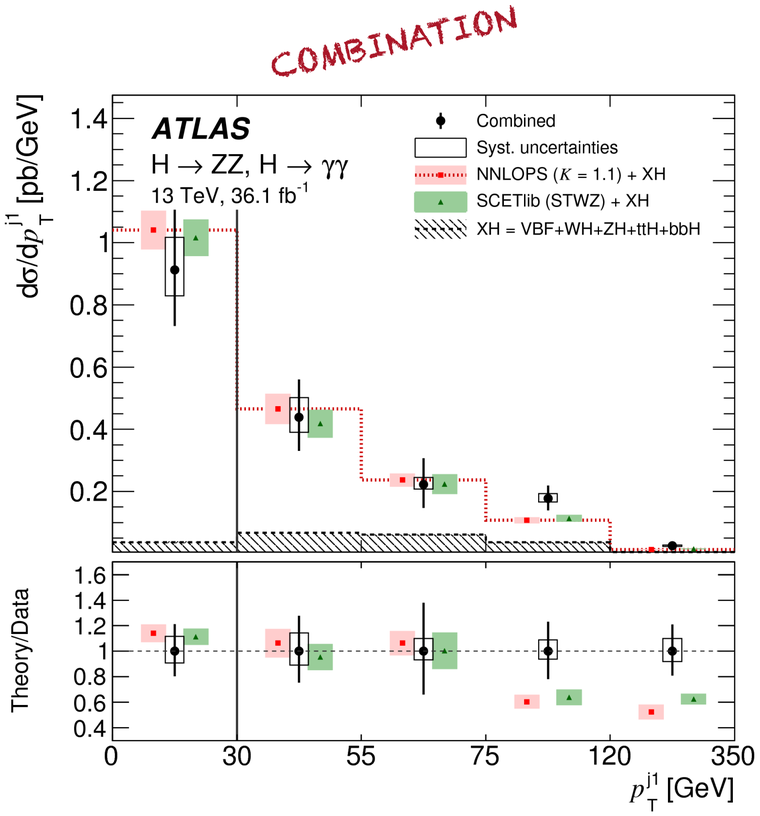


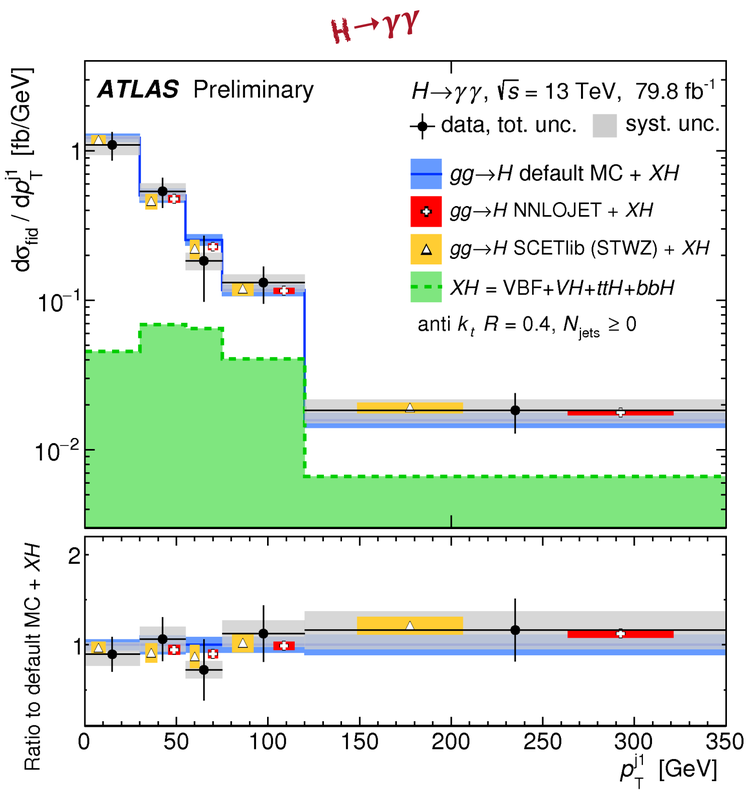


P_T OF LEADING JET

- Jet kinematics useful for test of modelling of QCD radiation, production mechanism:
  1) Number of central jets
  2) p_T of leading jet

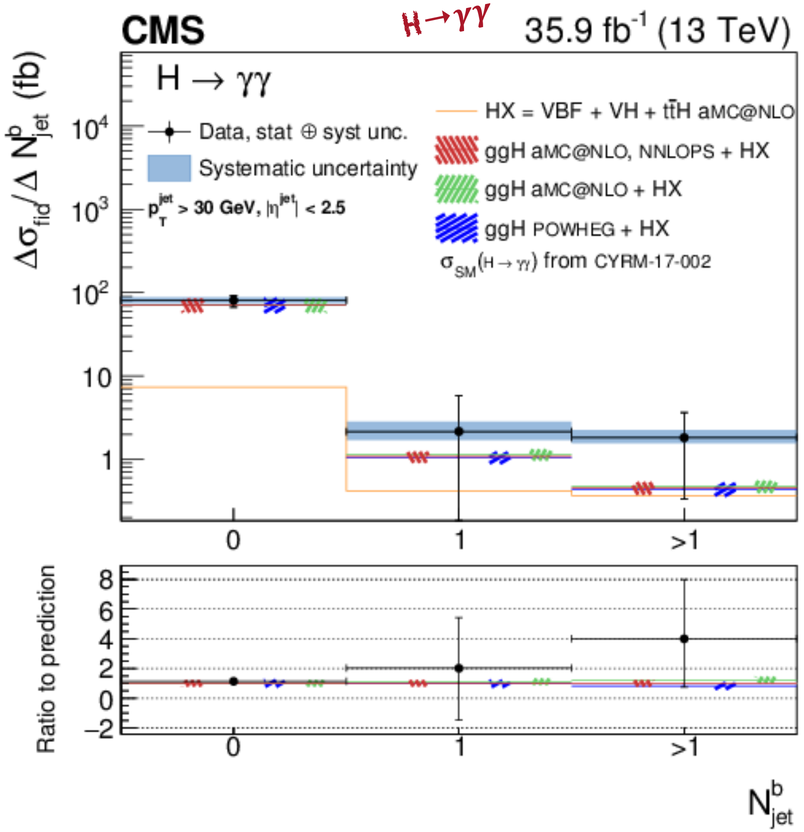


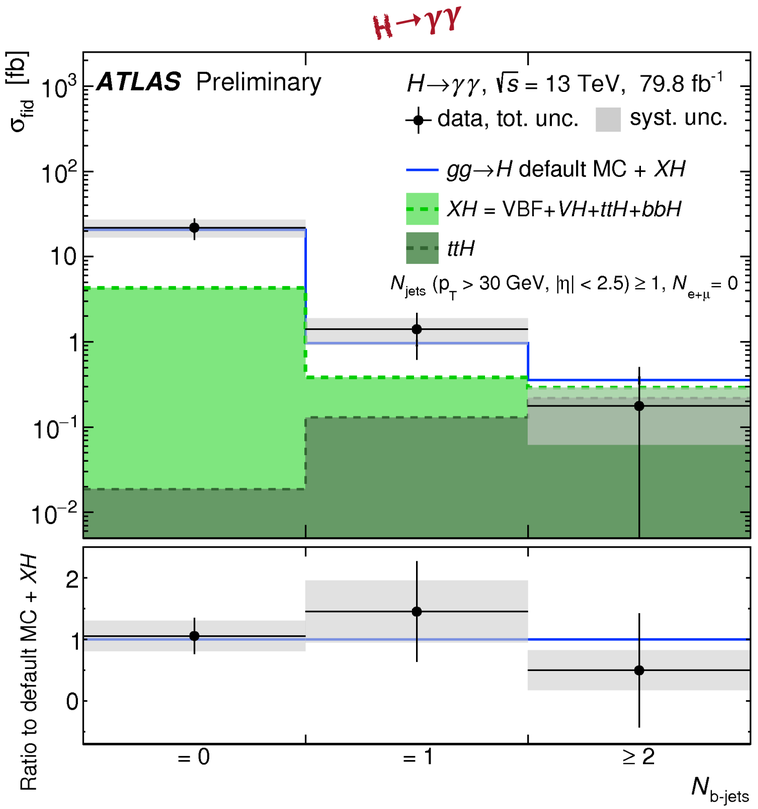




NUMBER OF B-JETS

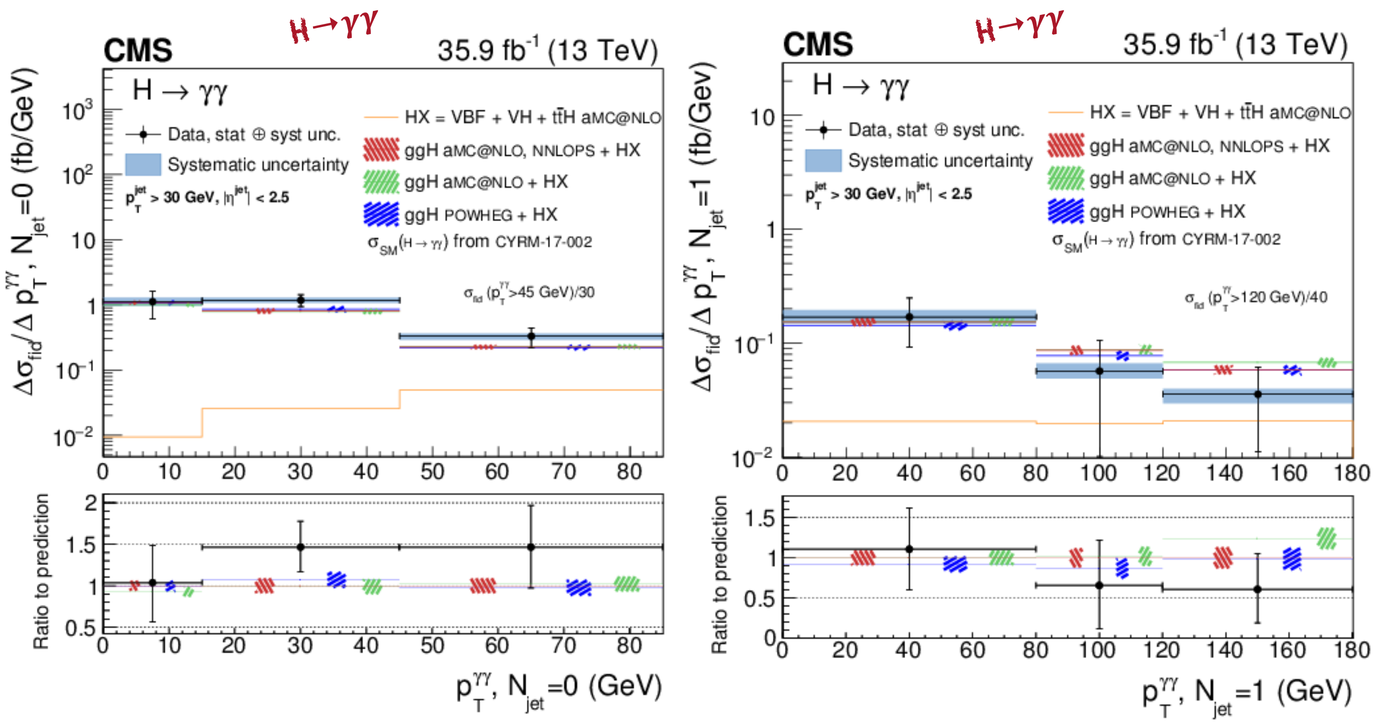
- Jet kinematics useful for test of modelling of QCD radiation, production mechanism:
  1) Number of central jets
  2) p_T of leading jet
  3) Number of b-jets

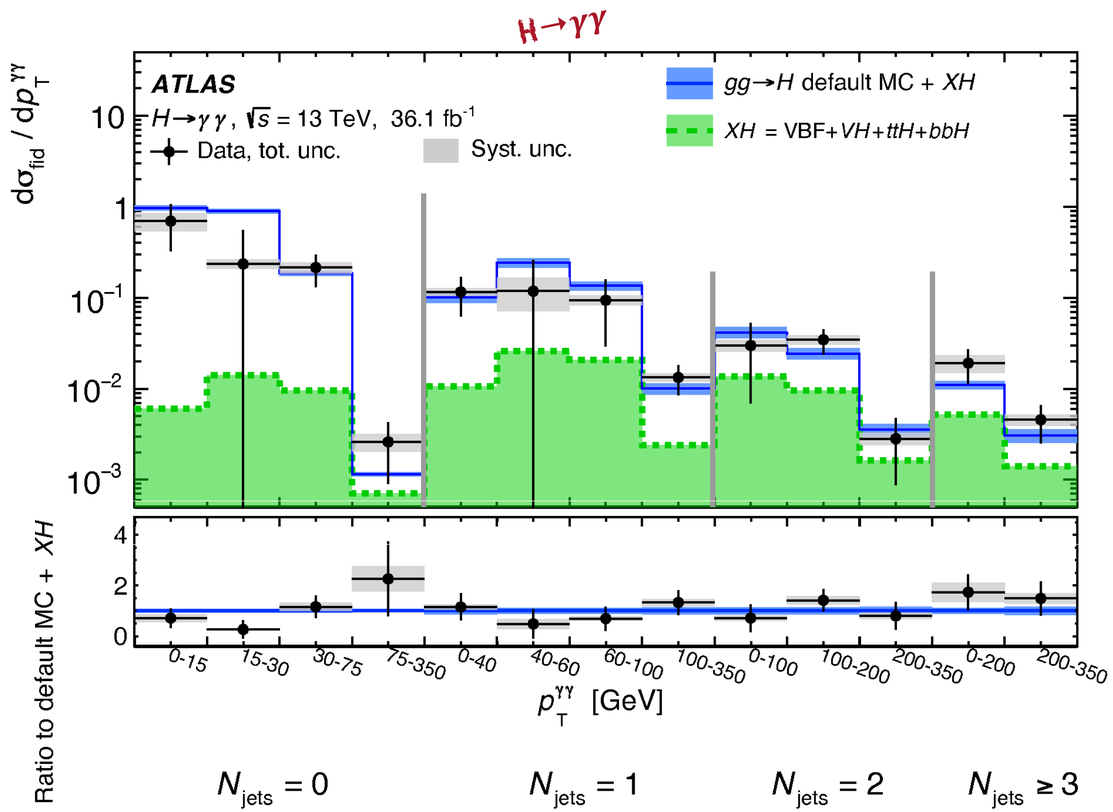




OTHER VARIABLES

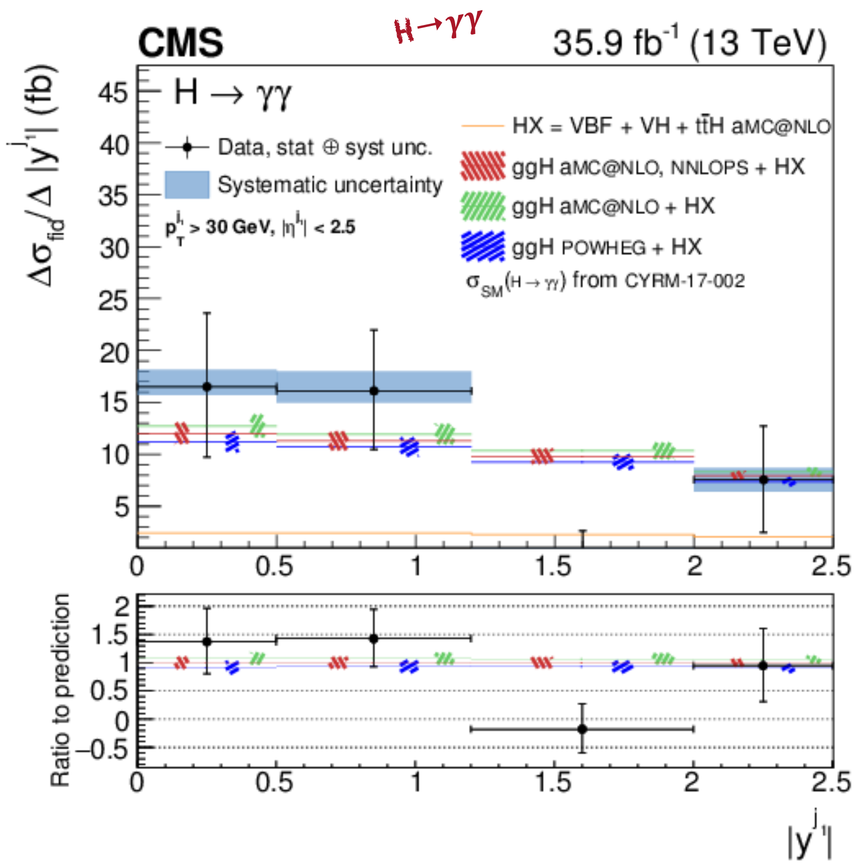
1) Double-differential measurement as a function of p_T(H)xN(jets)

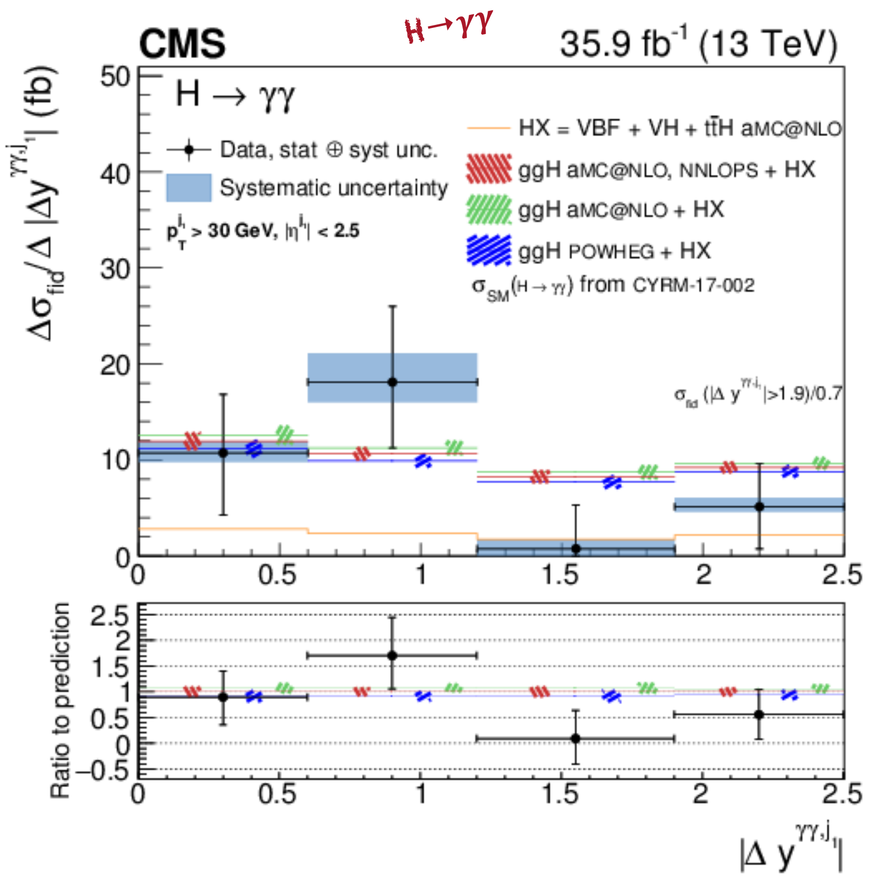




OTHER VARIABLES

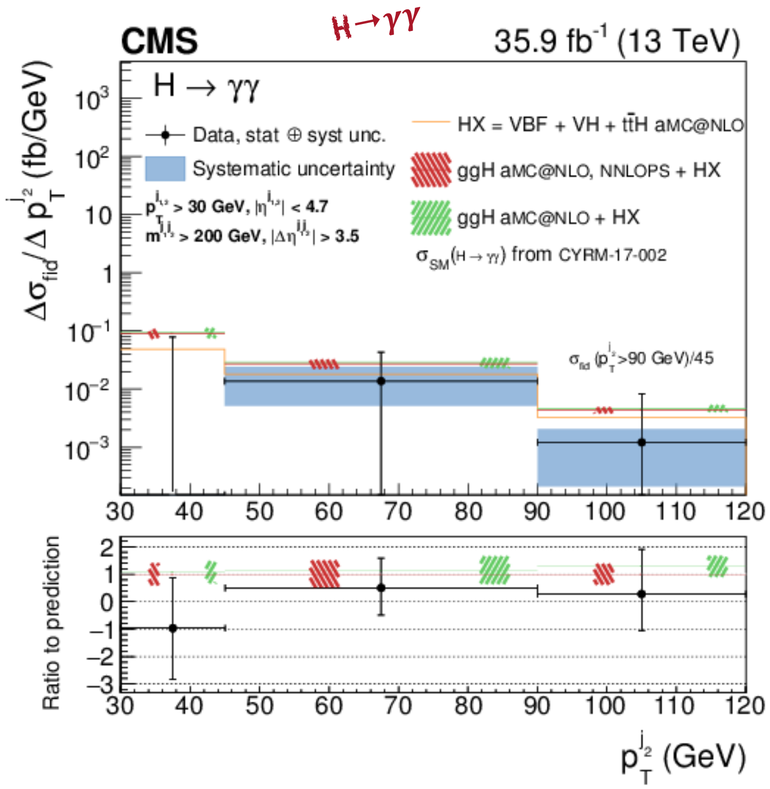
1) Double-differential measurement as a function of p_T(H)xN(jets)
2) Characterization of the highest-p_T jet produced in association with the H

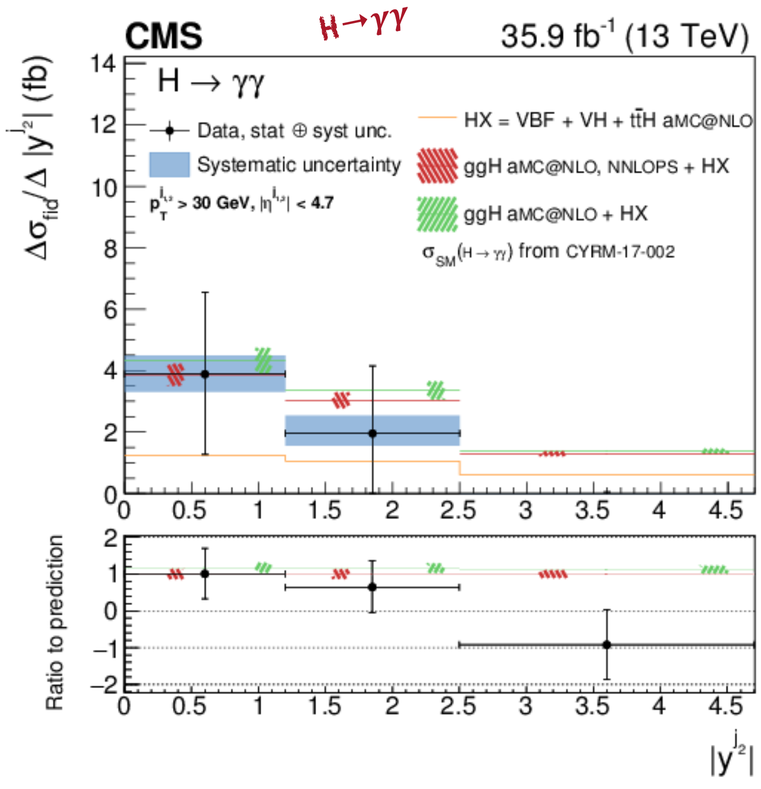


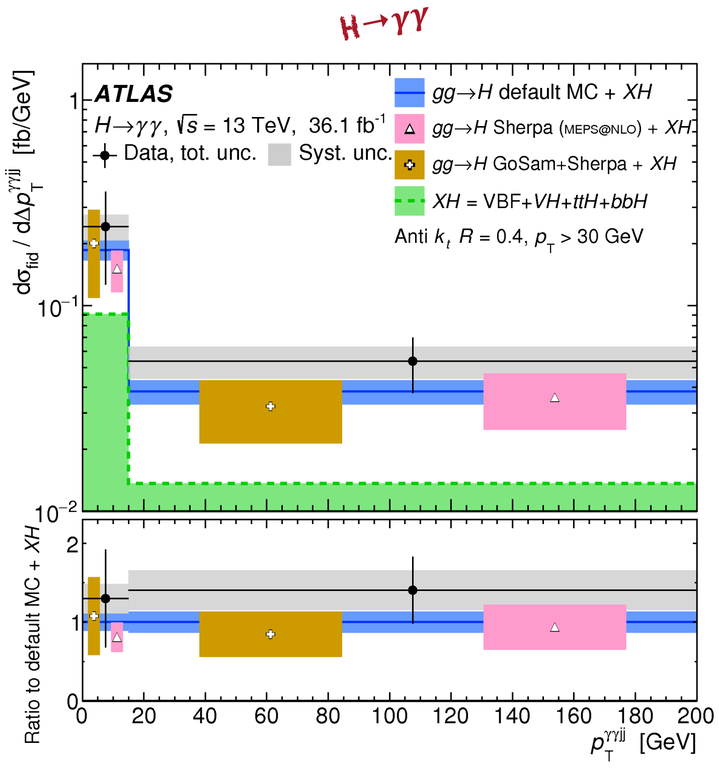


OTHER VARIABLES

1) Double-differential measurement as a function of p_T(H)xN(jets)
2) Characterization of the highest-p_T jet produced in association with the H
3) Measurements related to the second jet associated with H and to the di-jet system

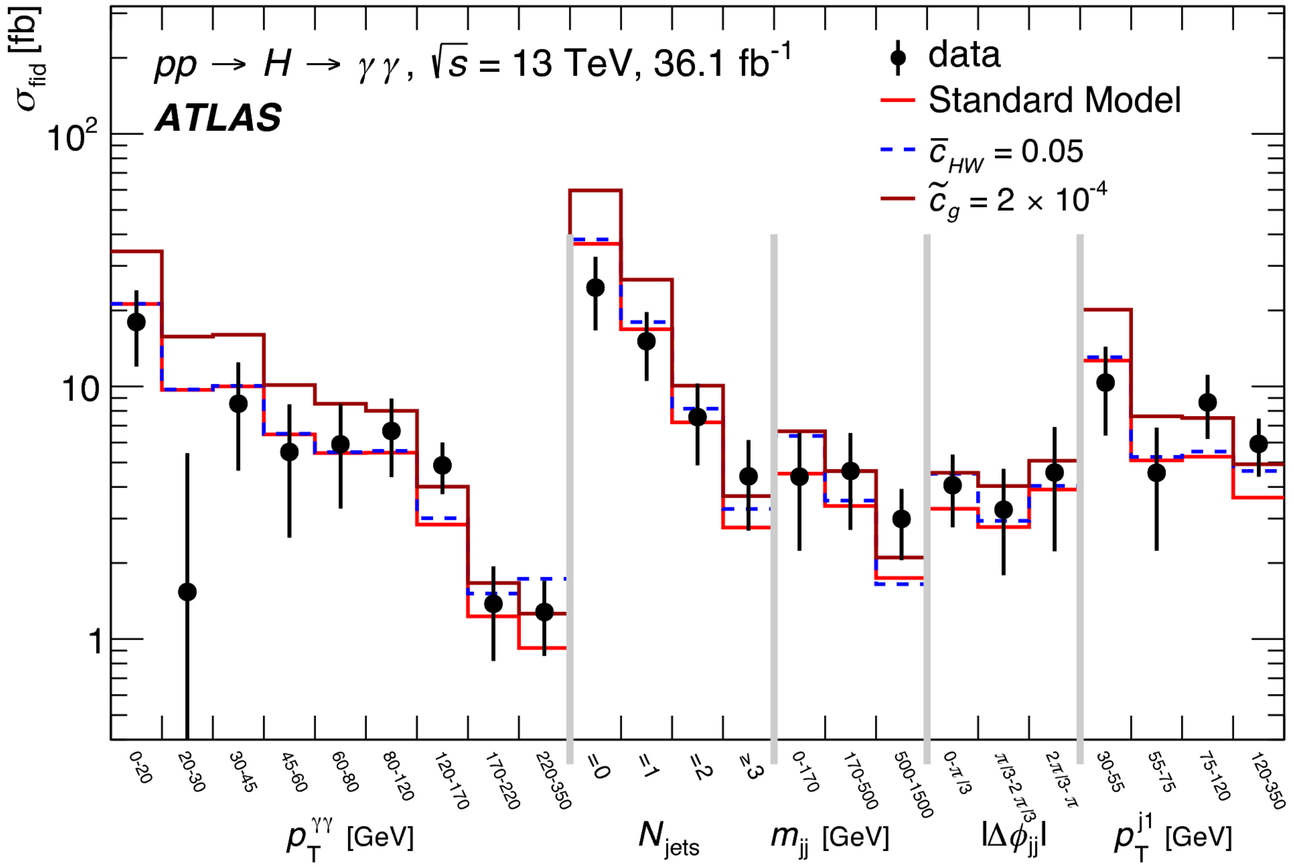


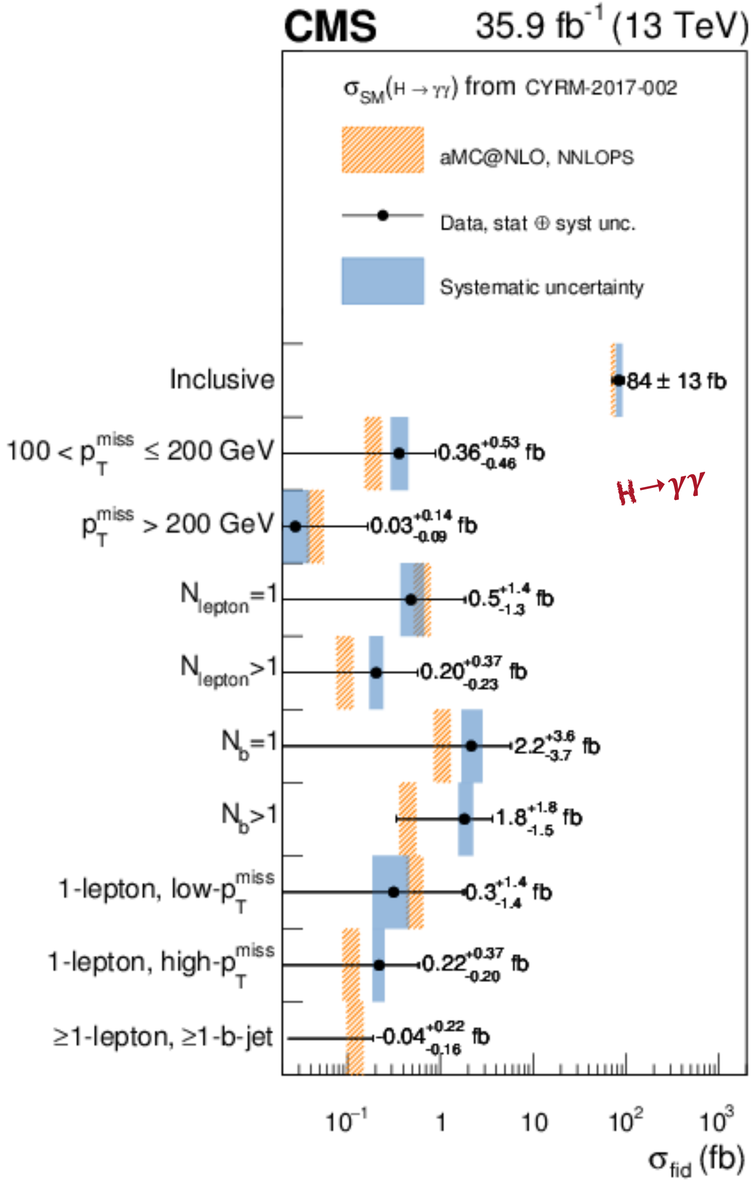




OTHER VARIABLES

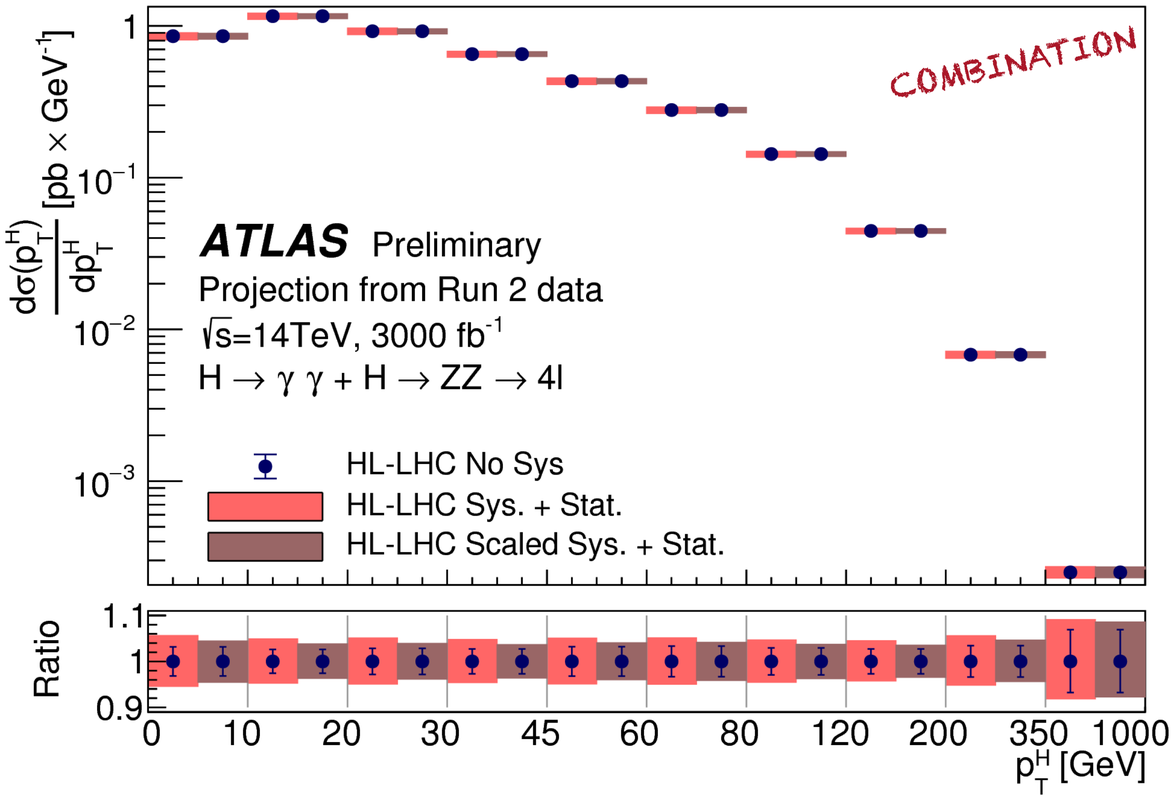
1) Double-differential measurement as a function of p_T(H)xN(jets)
2) Characterization of the highest-p_T jet produced in association with
3) Measurements related to the second jet associated with H and to t
4) As a function of many other interesting variables

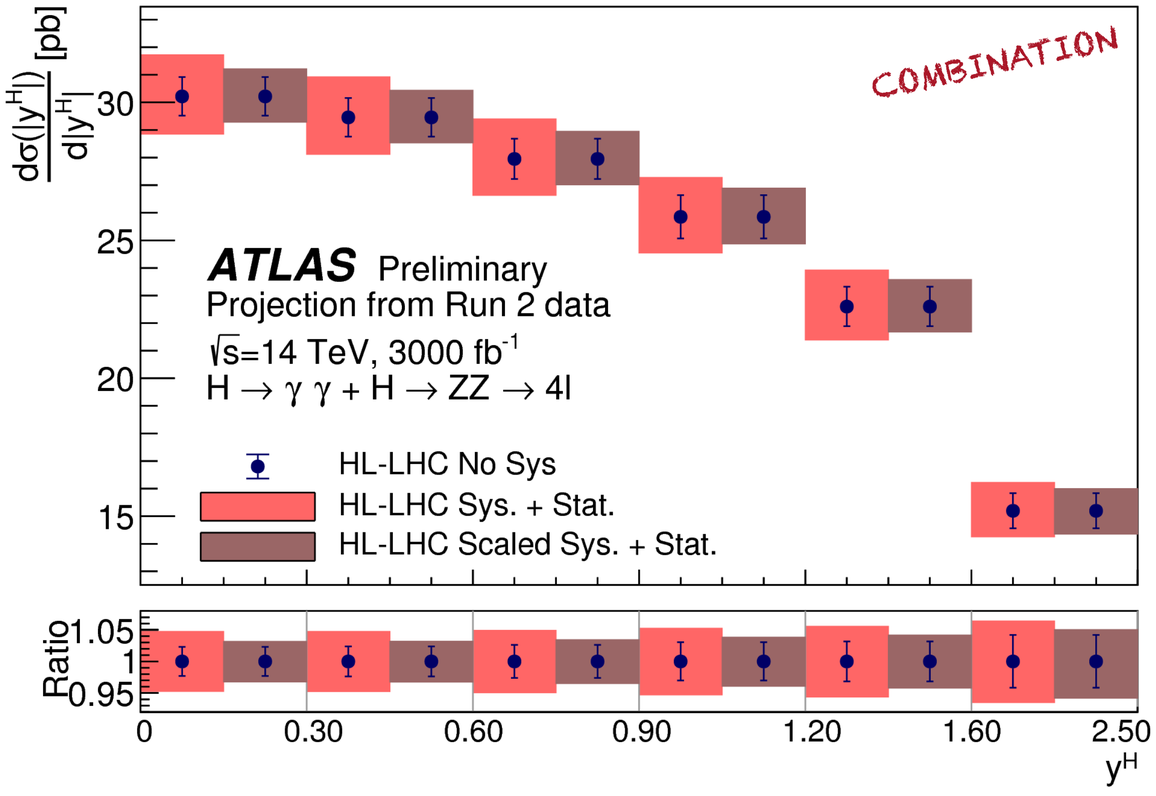




HL-LHC PROSPECTS

- Assumed the performance of the future detector to be comparable to the one in Run2
- Two different scenarios in the context of the HL-LHC are studied:
  - systematic uncertainties considered to be the same as the Run2
  - expected improvements in systematic uncertainties are taken into account. with scaling





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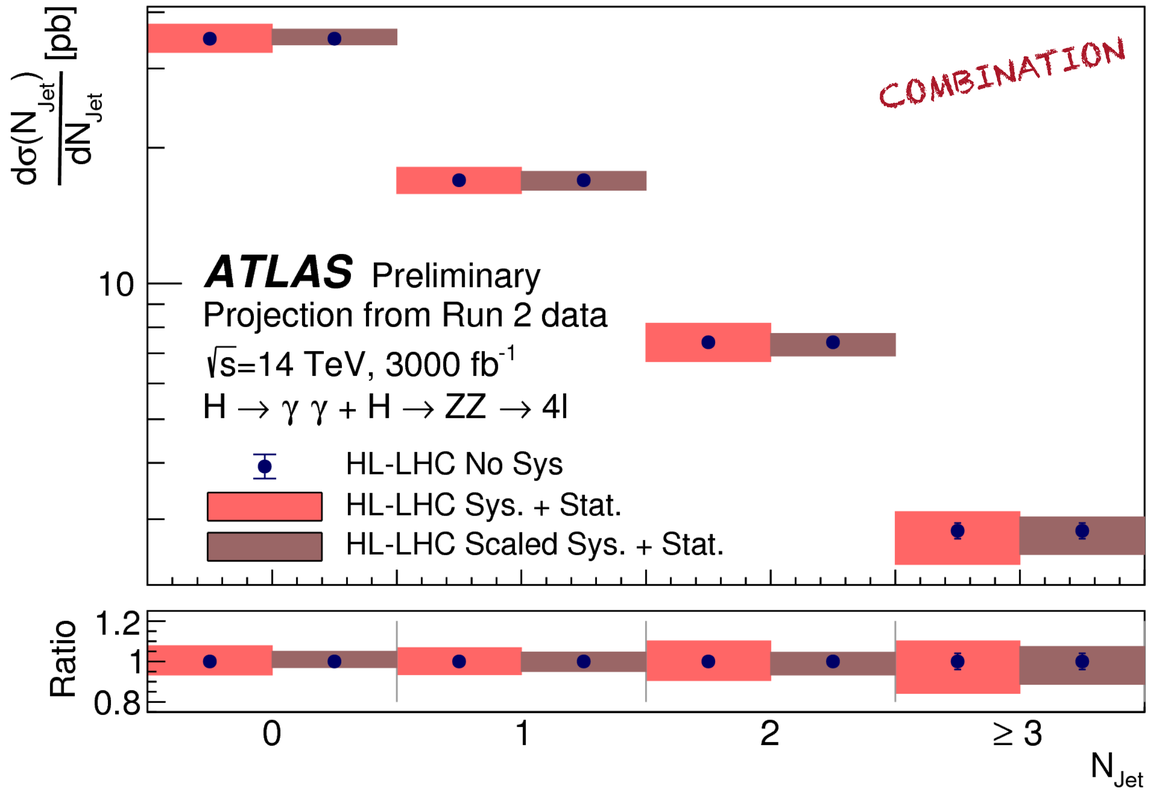

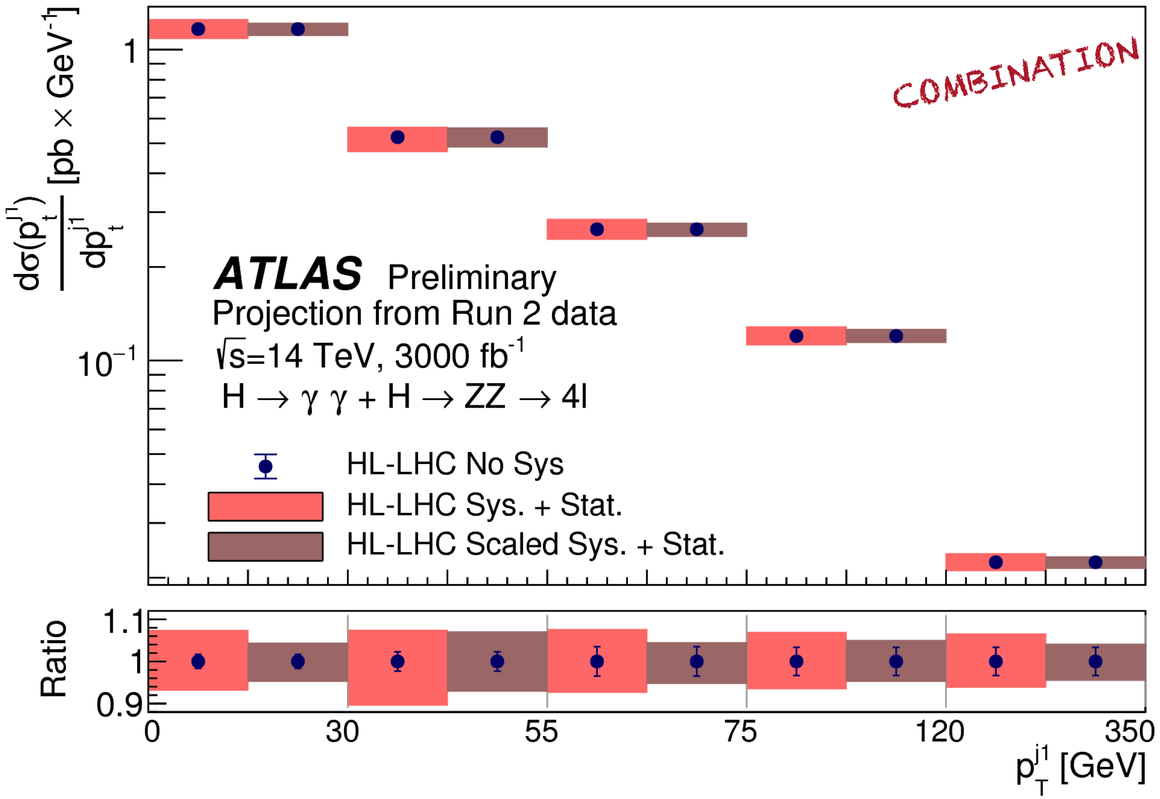

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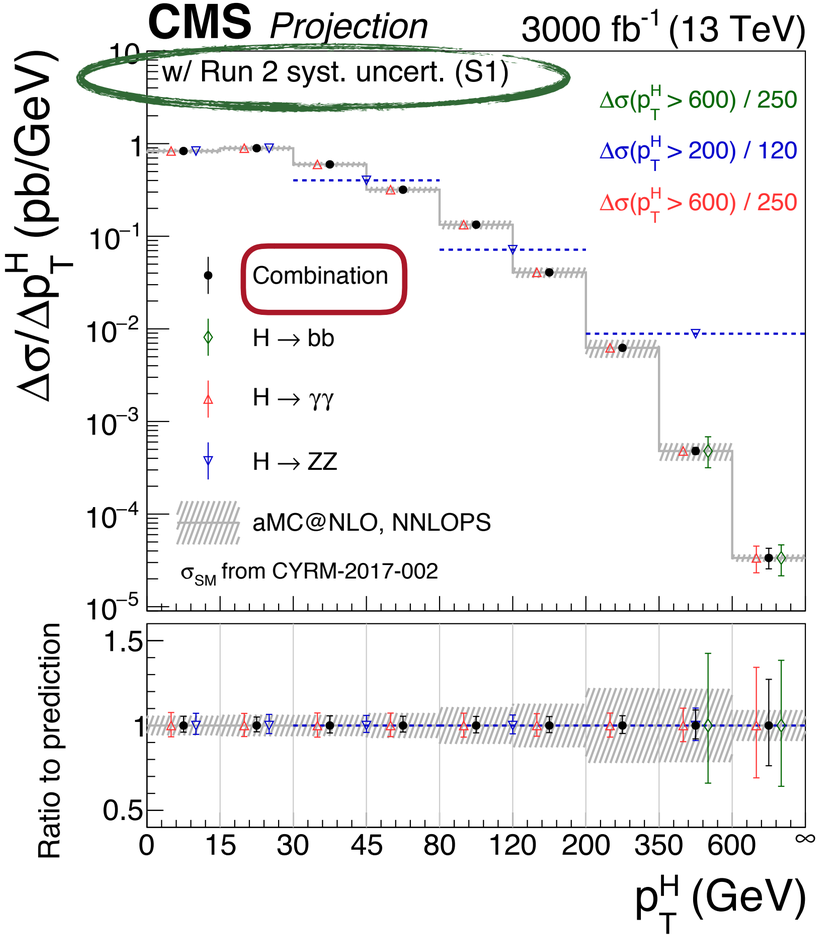

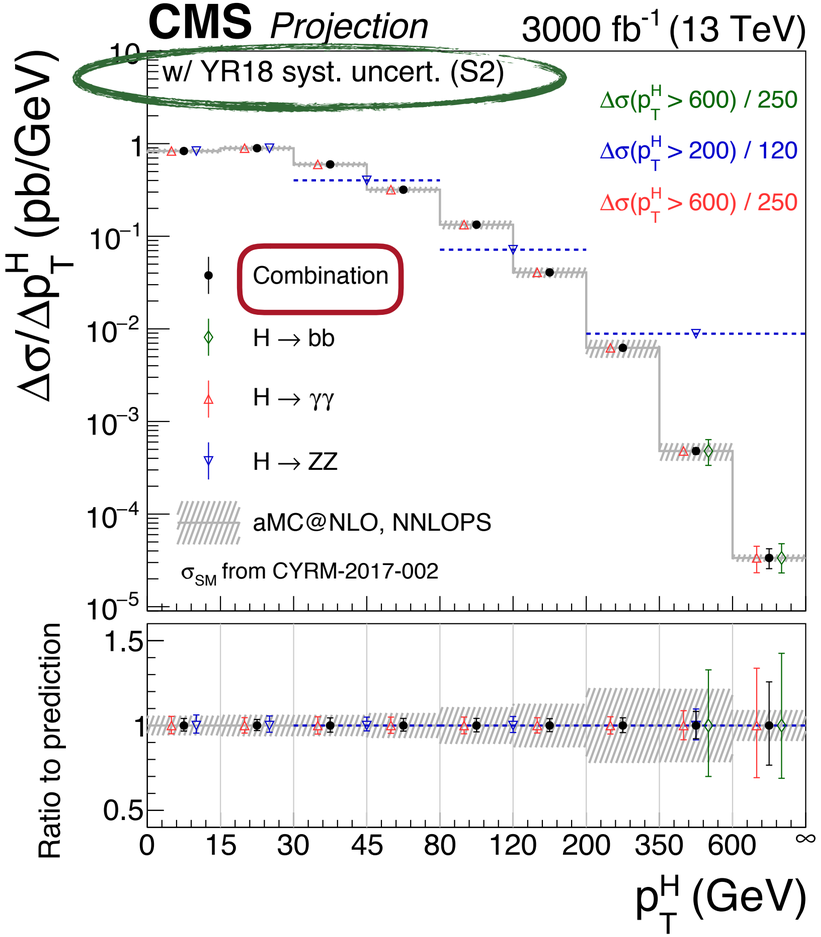

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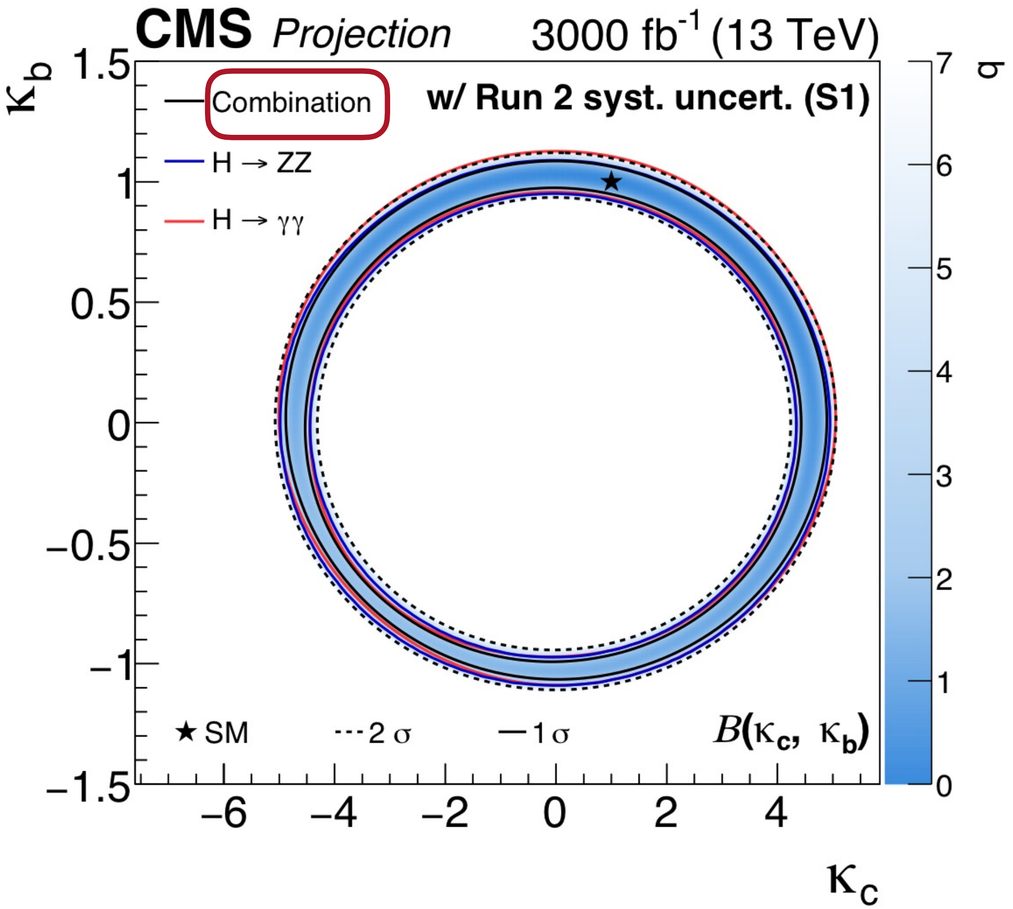

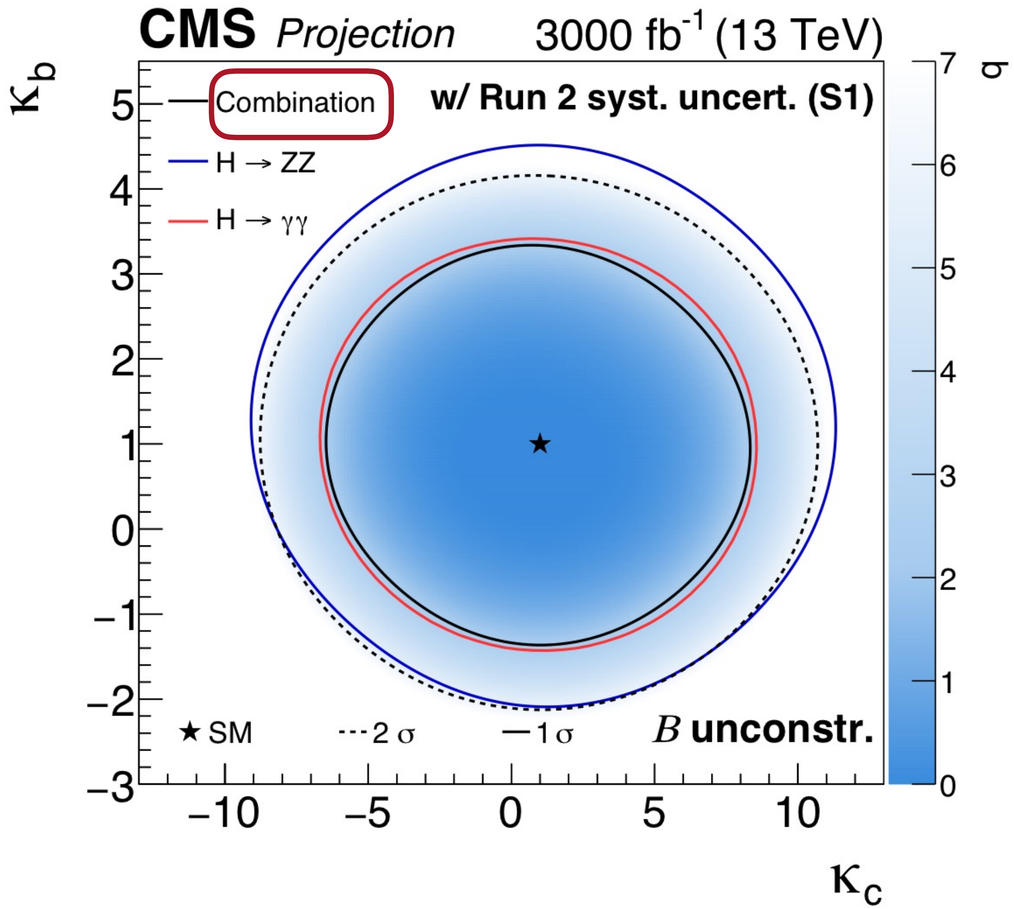

CONCLUSION

- Run2 data set allows extensive study of differential Higgs boson cross sections

- A variety of measurements are reported using the $H \to \gamma\gamma$, $H \to ZZ^* \to 4l$ and their combinations (together with boosted $H \to bb$) from ATLAS and CMS Collaborations:
  - $p_T(H)$,$y(H)$,$N(jets)$,$p_T(jet)$
  - Double differential cross sections
  - Many other interesting variables, not all results shown in this talk

- $p_T(H)$ distribution provides a handle to set limits on coupling modifiers variations

- Precision on measurements is still largely statistically limited
  - Improved set of results expected from full Run 2 combinations

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