Higgs differential measurements with ATLAS and CMS

Andrea Gabrielli - CERN
on behalf of ATLAS and CMS experiments

LHCP2020
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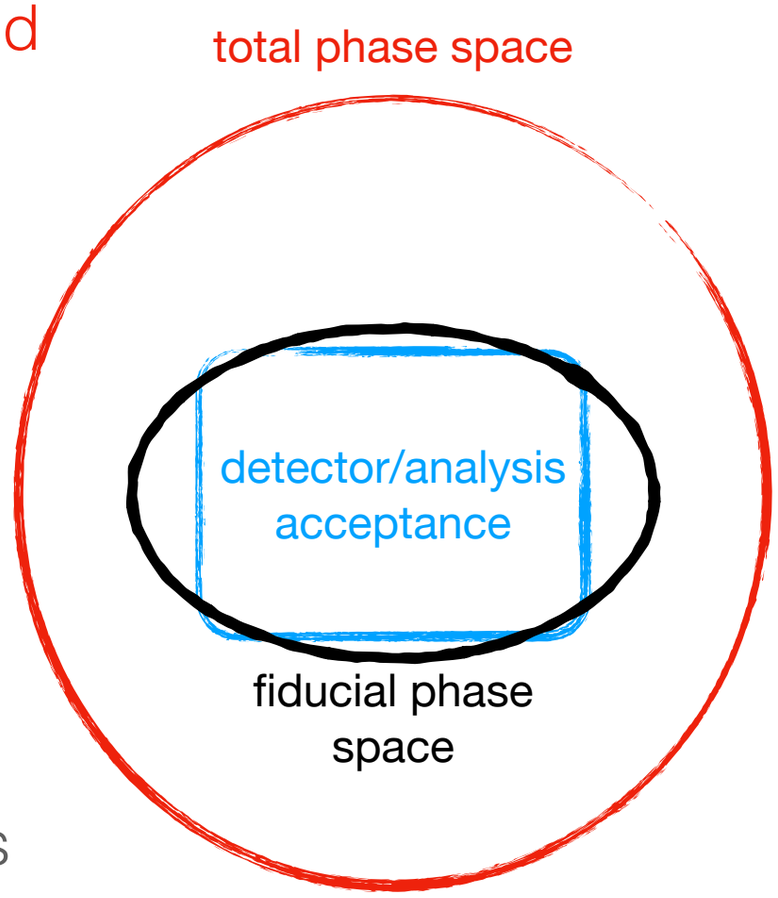
fiducial cross-sections

- fiducial phase space based on the real analysis and detector acceptance and extrapolation effects are minimised
- fiducial cross-sections are the most model independent way to measure Higgs interactions at LHC
- limitations:
  - to combine more channels the extrapolation to the total phase space is needed (including BR)
  - less sensitive exclusion limits on BSM couplings compared to a dedicated analysis

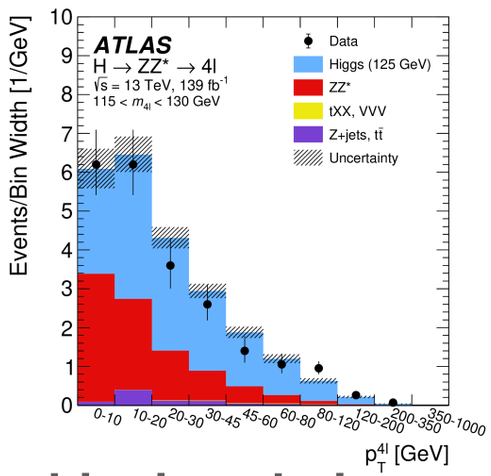


- **unfolded quantities:**
  - Higgs boson kinematics in production and decay e.g p_T, Y_H, $\cos\vartheta^*$, m_{34}
  - jet produced in association with an Higgs e.g. n_{jets}, m_{jj}, $p_T^{lead,jet}$
  - Higgs boson and jets e.g. $p_{T,\,4\ell jj}$

analysis flow

step #1

reconstructed quantity

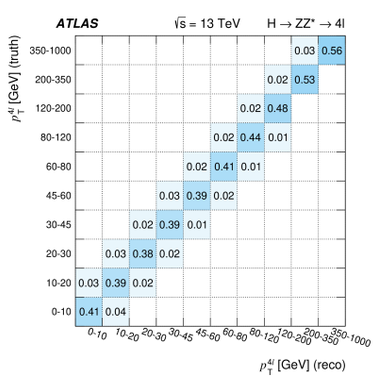


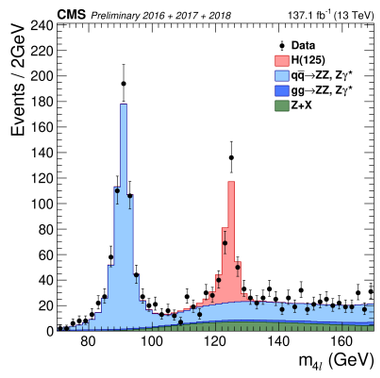
binning choice: expected number of events, detector resolution, S/B, …..

step #2

unfolding method: matrix inversion, bin-by-bin correction, regularised, bayesian …

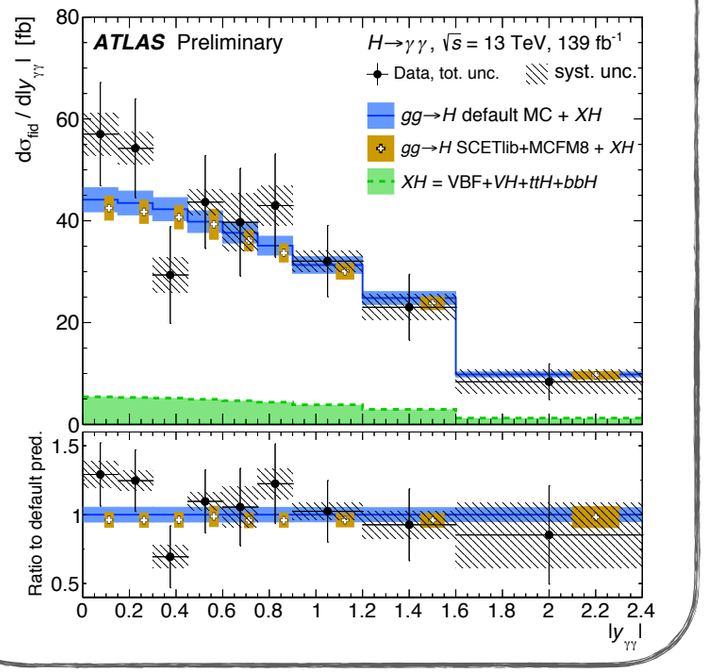
observable: $m_{4\ell}$, $m_{\gamma\gamma}$, m_T, counting, …





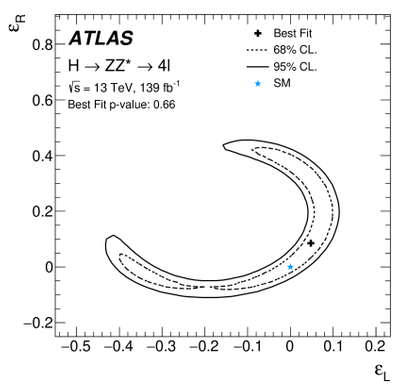
step #3

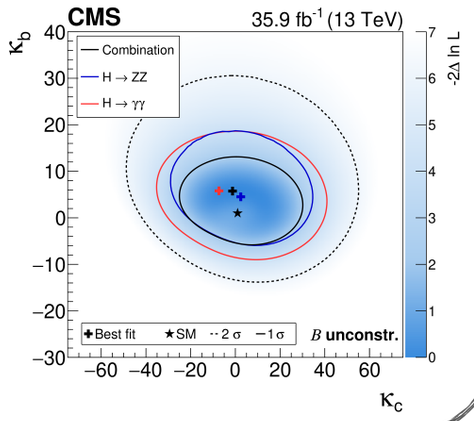
unfolded results



step #4

interpretation: k-framework, eft, PO

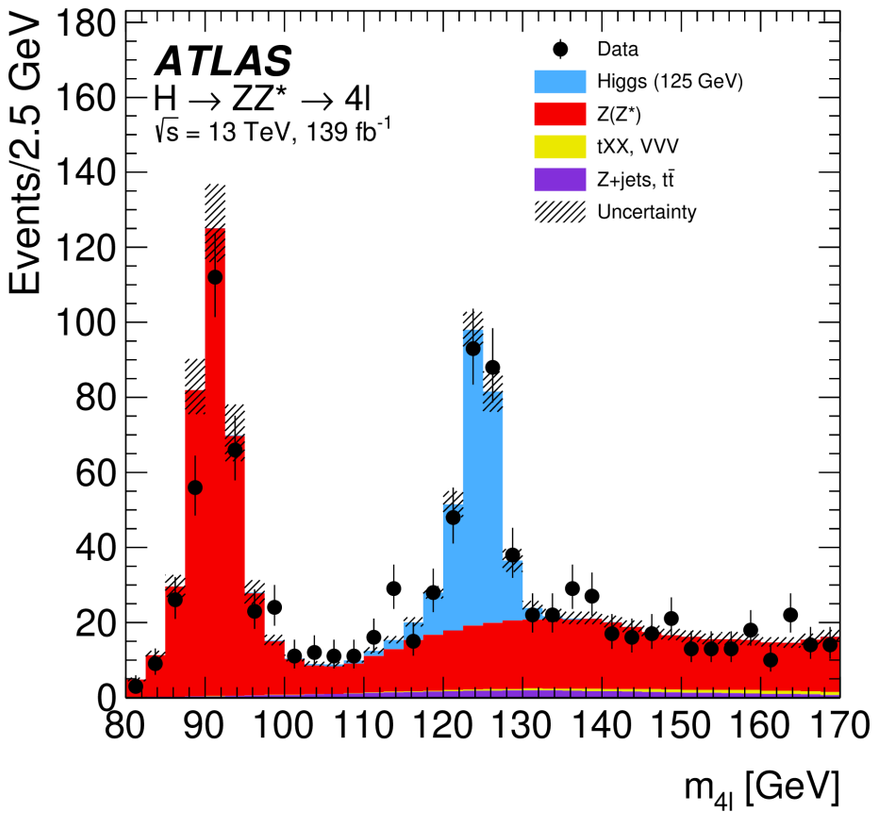


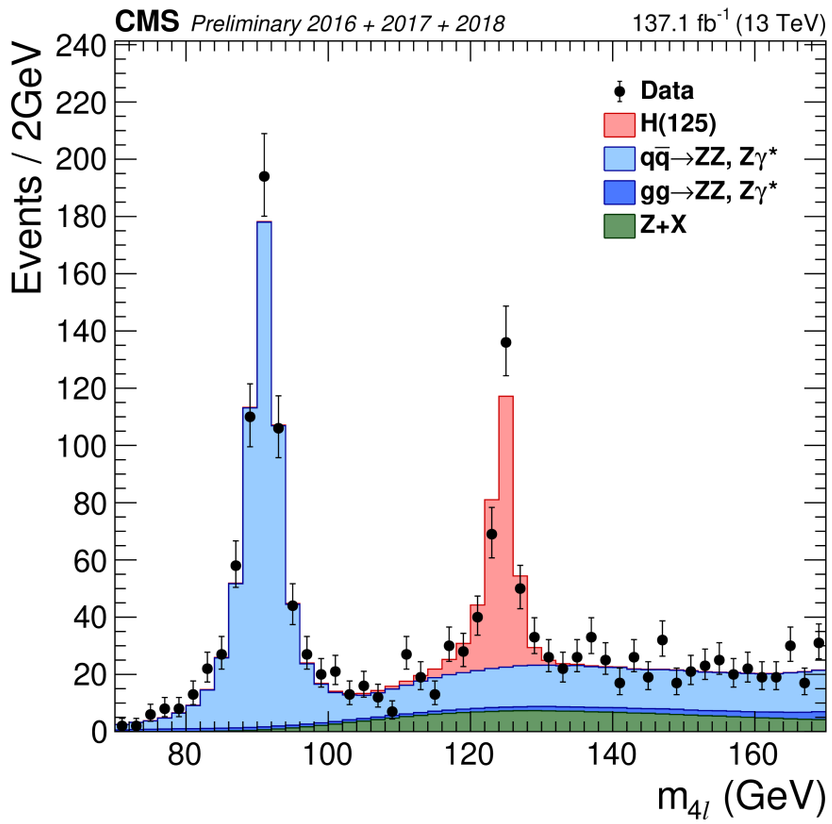


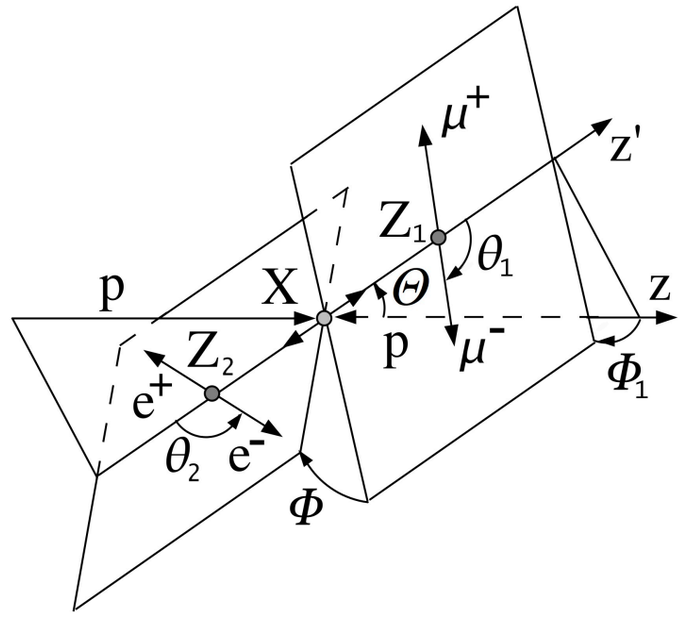
$H \to ZZ^* \to 4\ell$

final RUN2 paper!!
arXiv:2004.03969 submitted EPJC

CMS-PAS-HIG-19-001



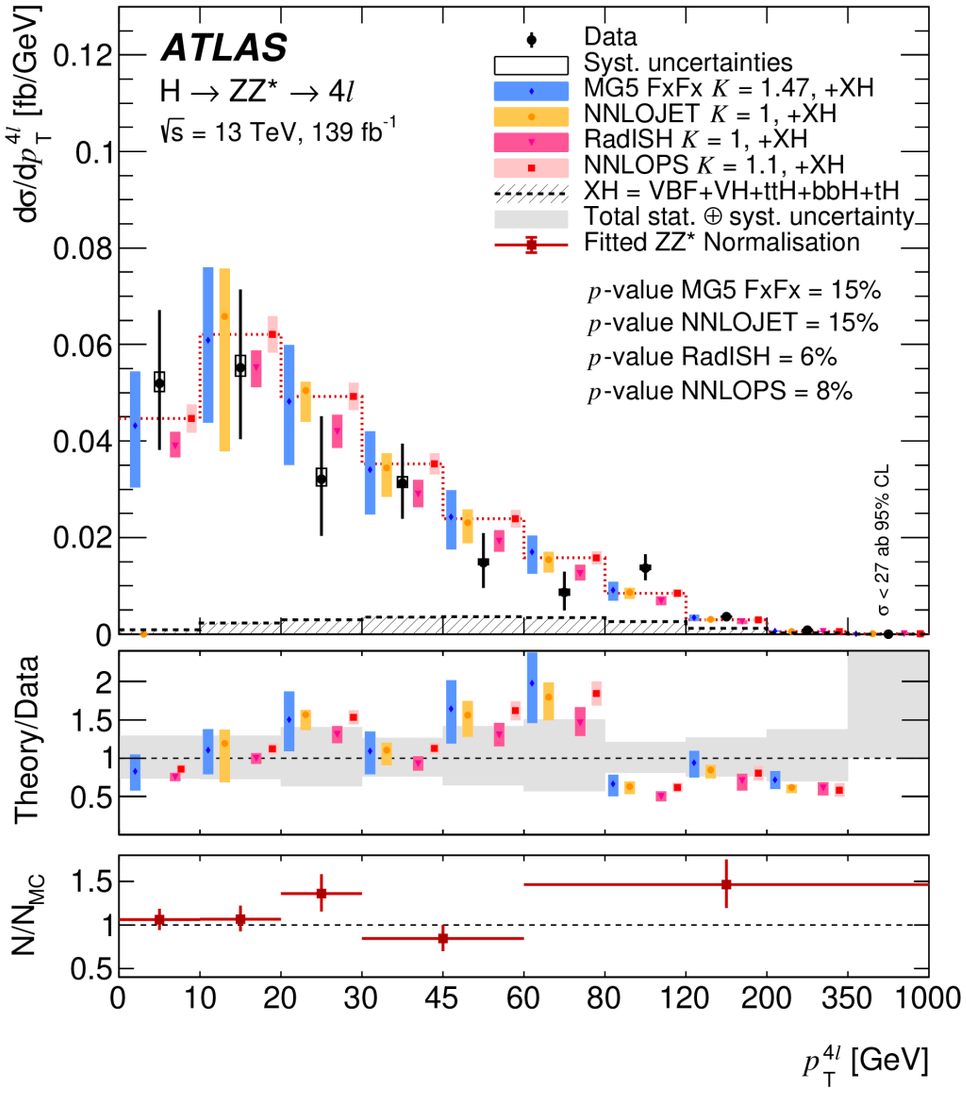


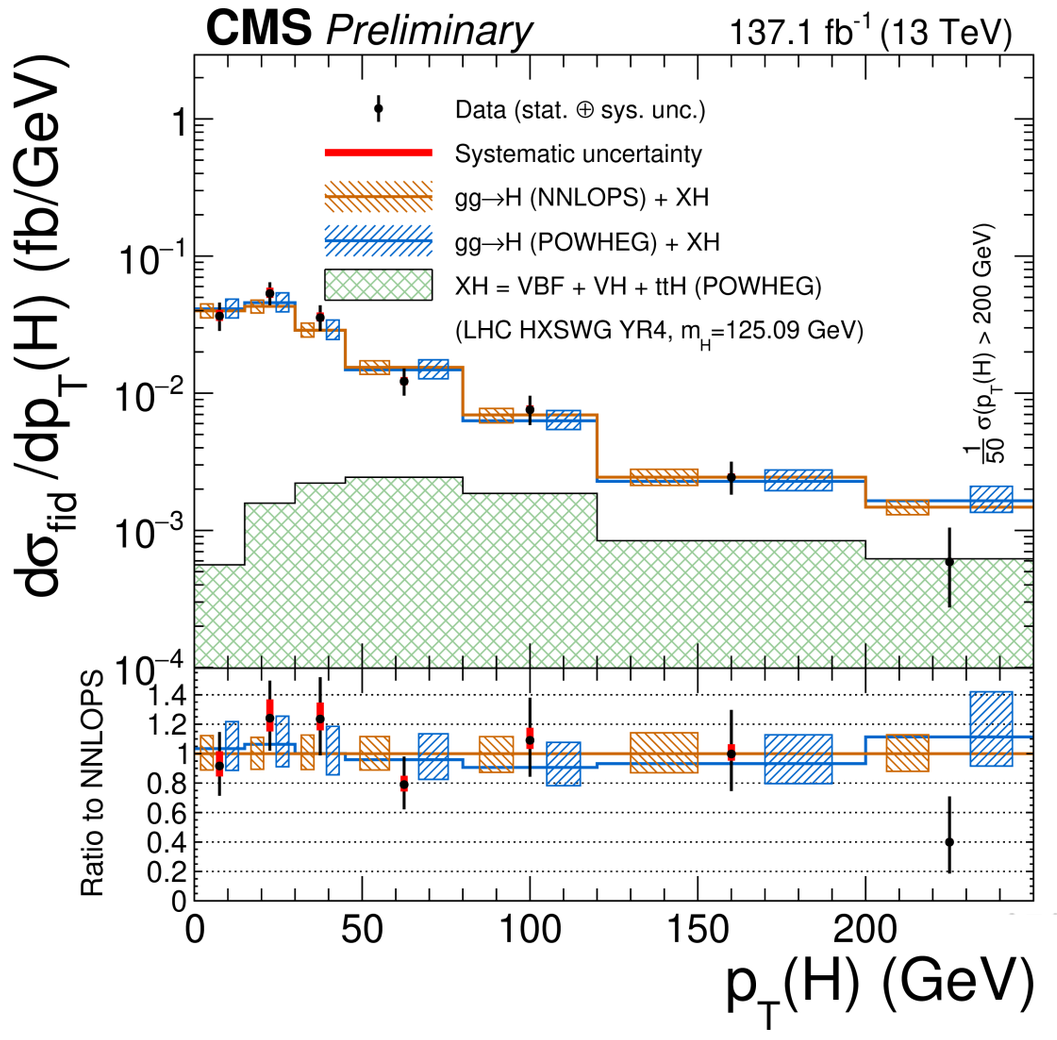


- fully reconstructible final state and very high S/B ~ 2
- signal signature: 4 isolated leptons (μ,e) at "low" p_T (5-20 GeV) 2 lepton pairs same flavour opposite sign
- excellent mass resolution 1-2% m_H
- main background: qq(gg)→ZZ* estimated using only MC in case of CMS or data sidebands and MC for ATLAS

H→4ℓ: differential cross sections

- high p_T region is sensitive to heavy additional particles in the ggF loop
- low p_T region is sensitive to the Yukawa coupling of the b and charm quark



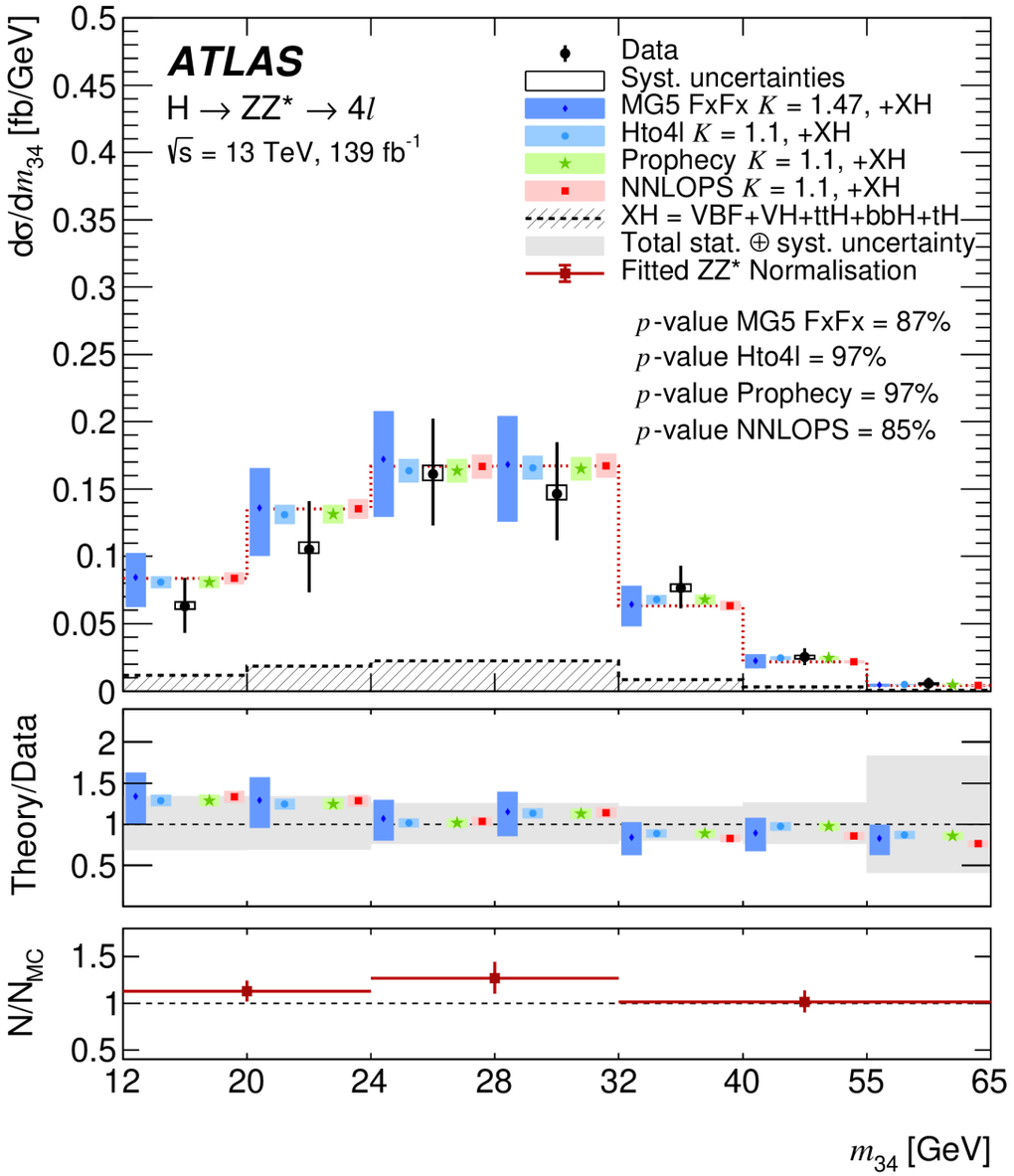


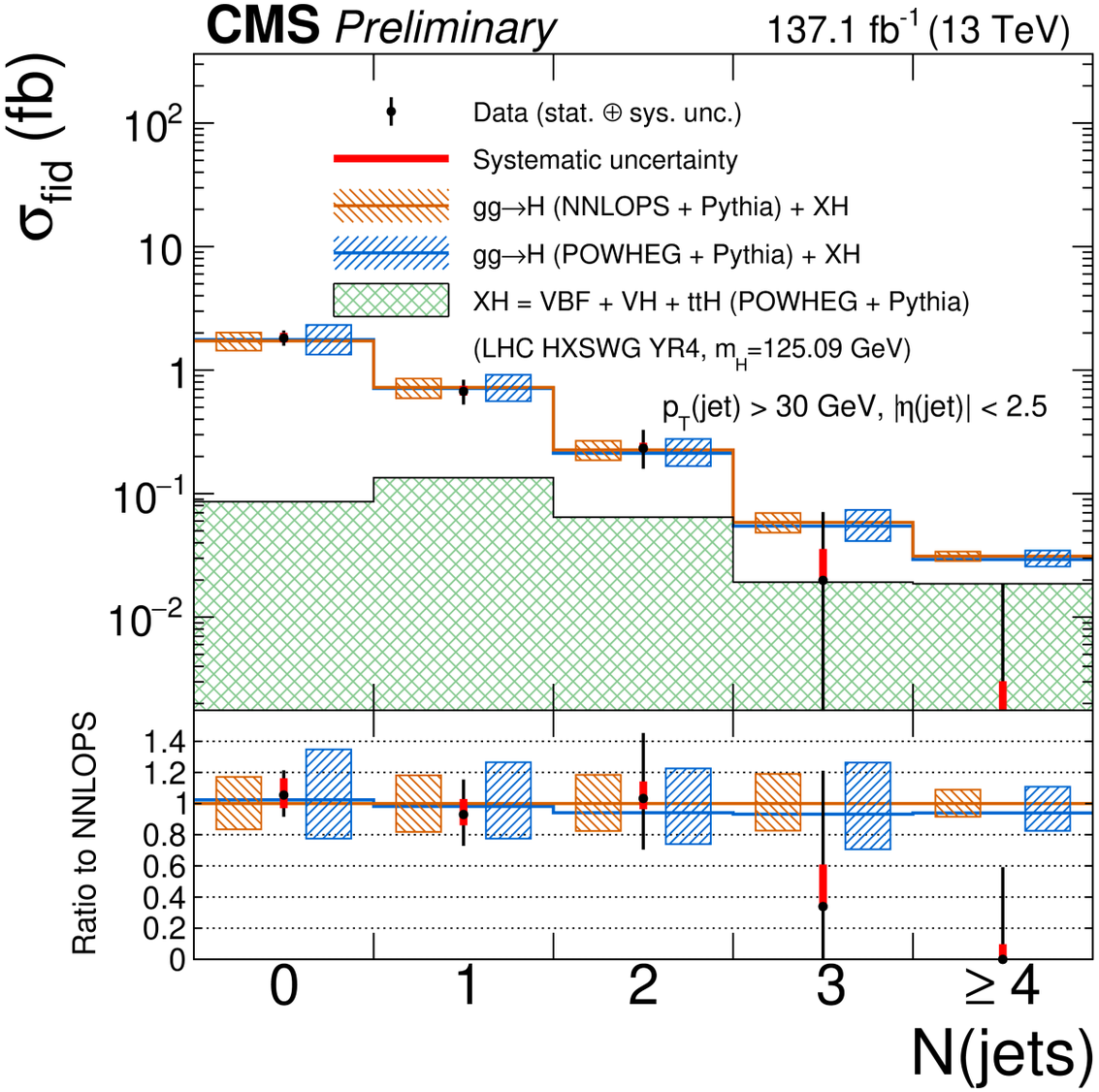
ATLAS limit on κ_c (κ_b *free*) @139 fb^{-1}

- p_T shape only $\kappa_c \in$ (-12,11) @95% CL
- p_T shape and prediction $\kappa_c \in$ (-7.5,9.3) @95% CL

H→4ℓ: differential cross sections

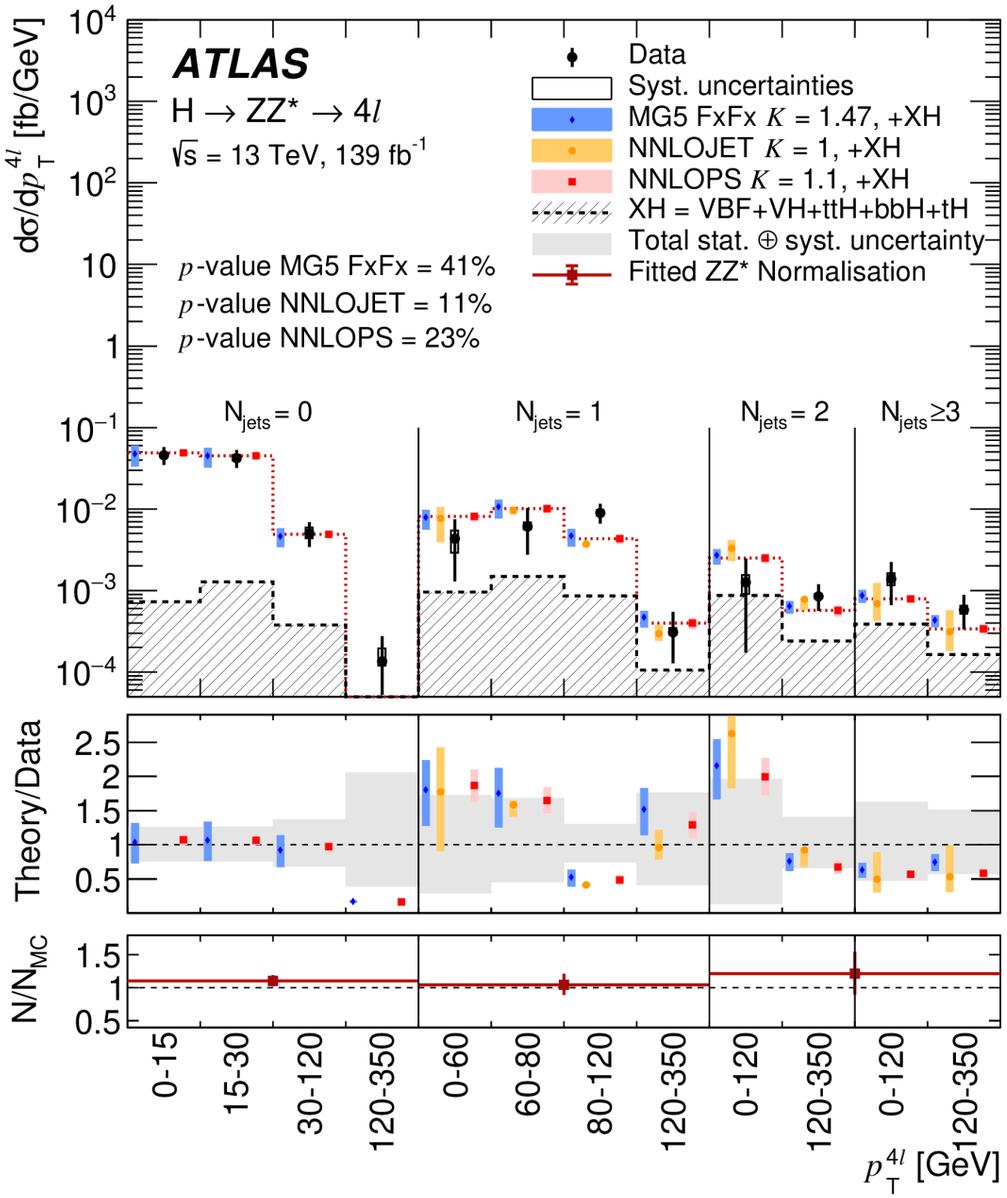
- m_{34} mass of the sub-leading pair: BSM contributions can distort the shape (EFT operators or light resonances)
- n_{jets} is sensitive to production mode composition and gluon emission



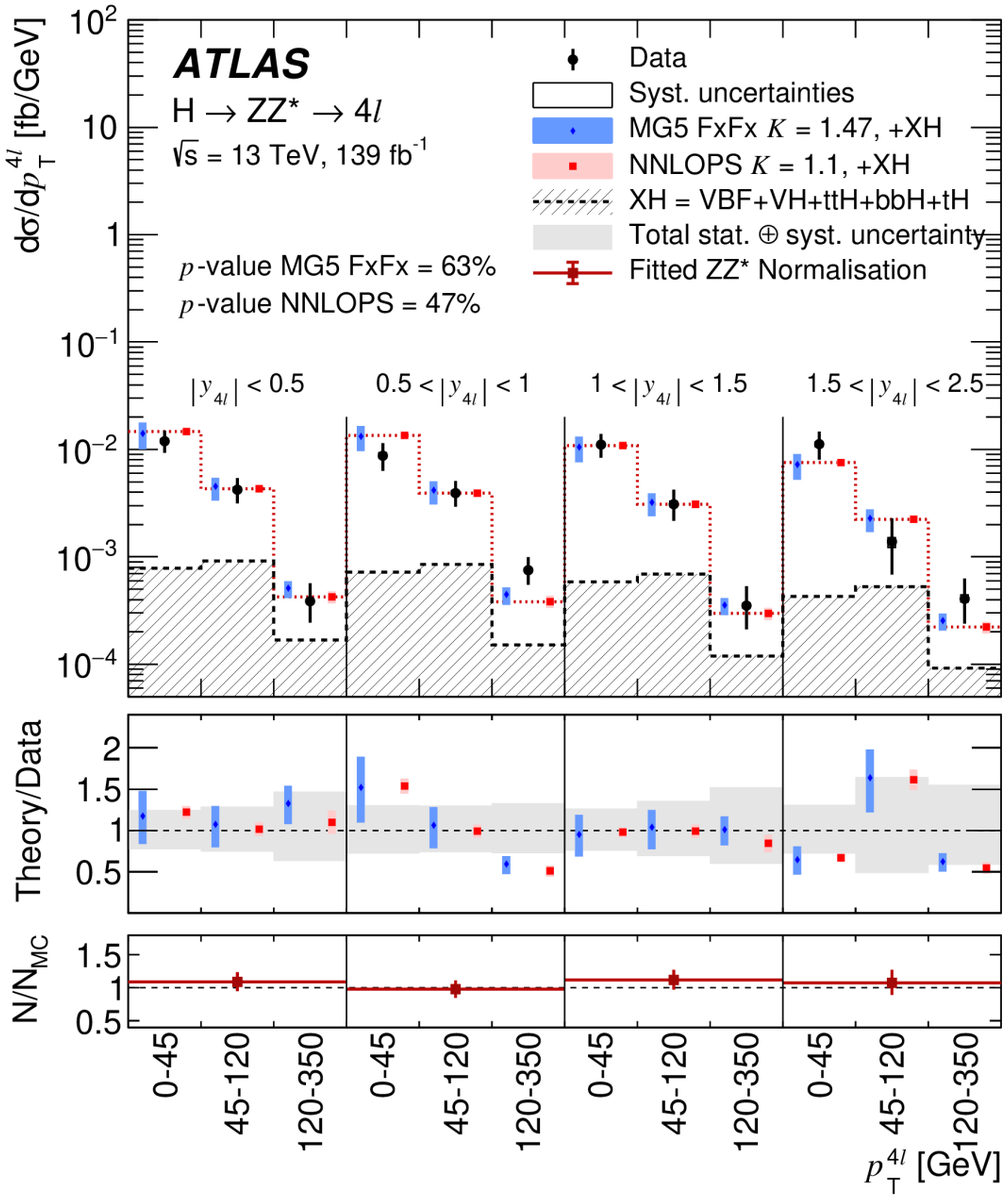


H→4ℓ: double-differential cross-sections

p_T vs n_{jet}



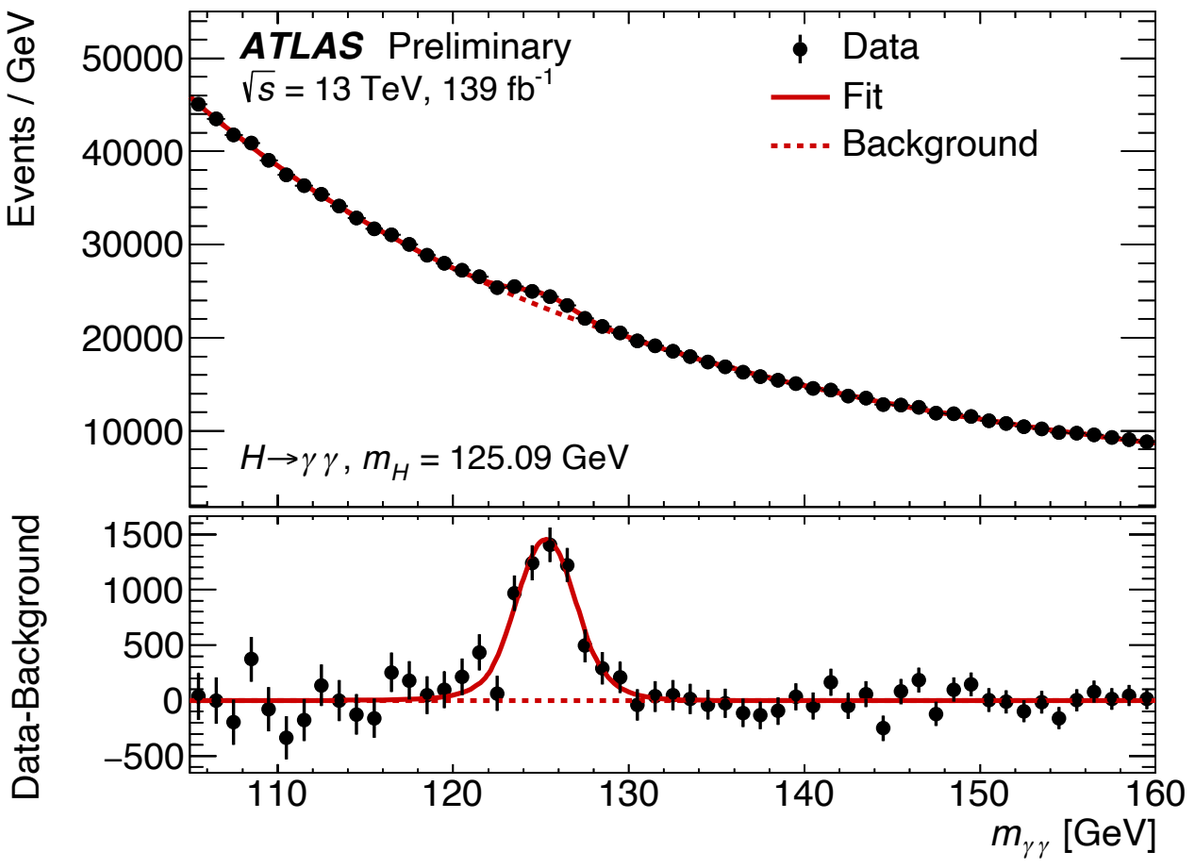
p_T vs |y|



granularity mainly limited by data statistics. with RUN3 and HL-LHC will be possible to have finer binning

$H \to \gamma\gamma$

ATLAS-CONF-2019-029



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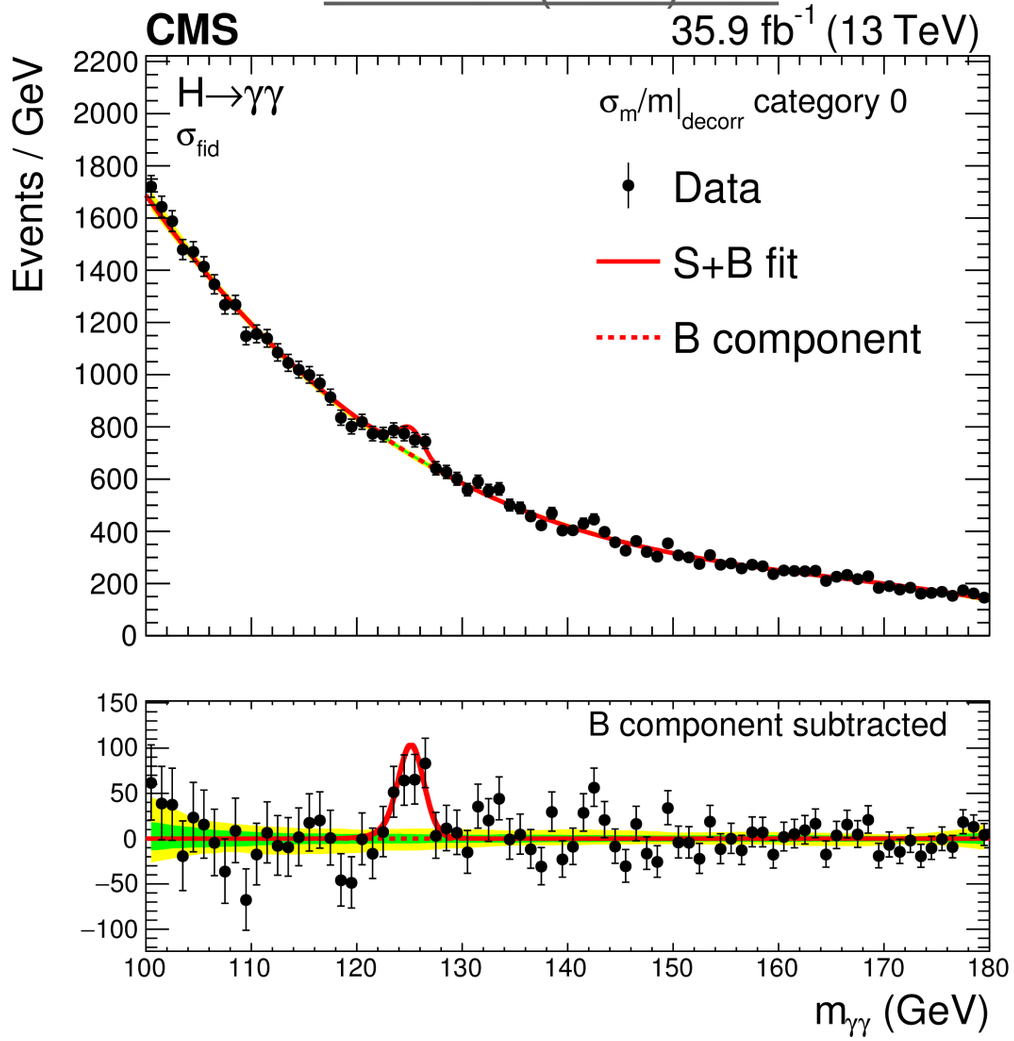
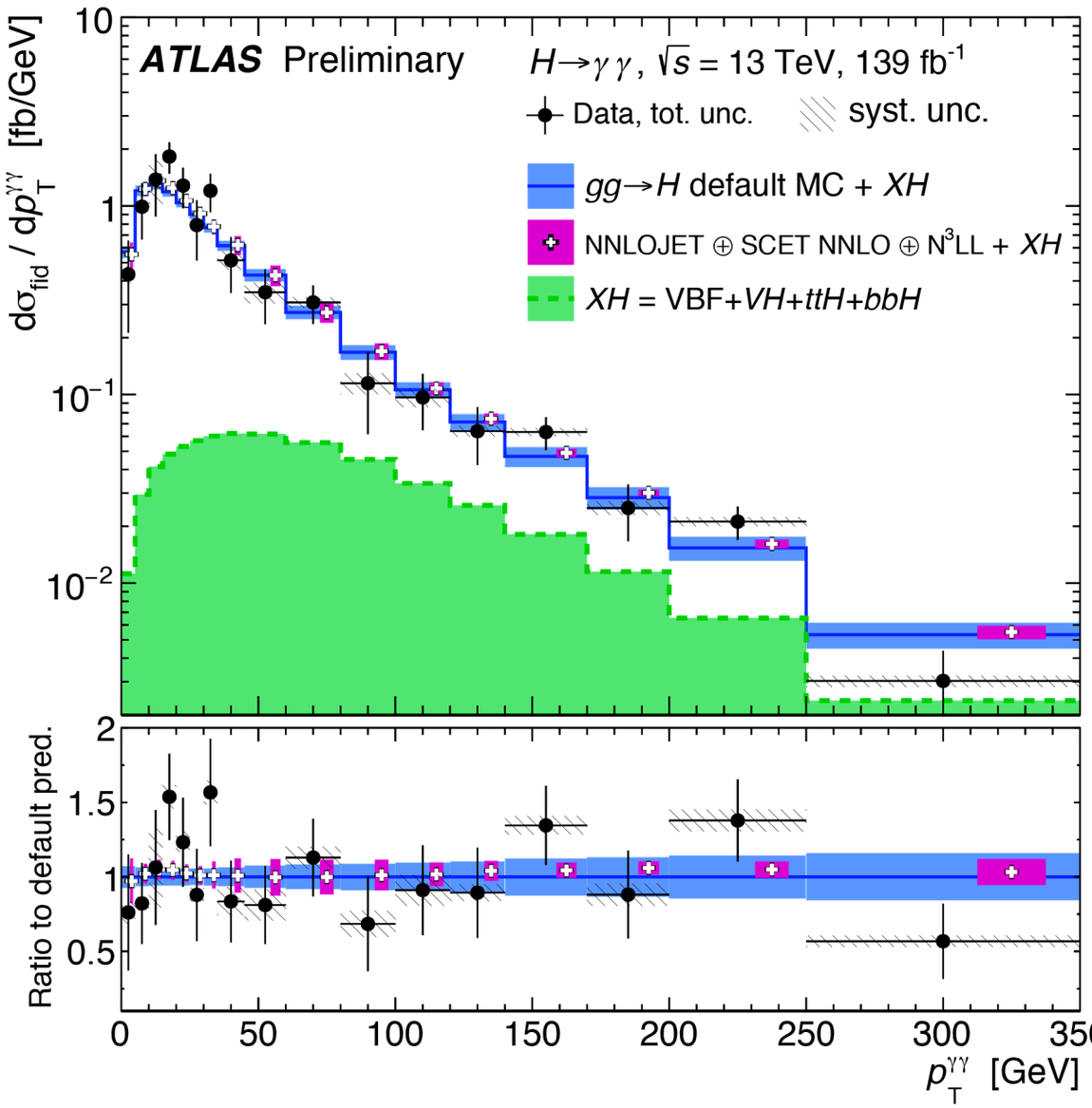
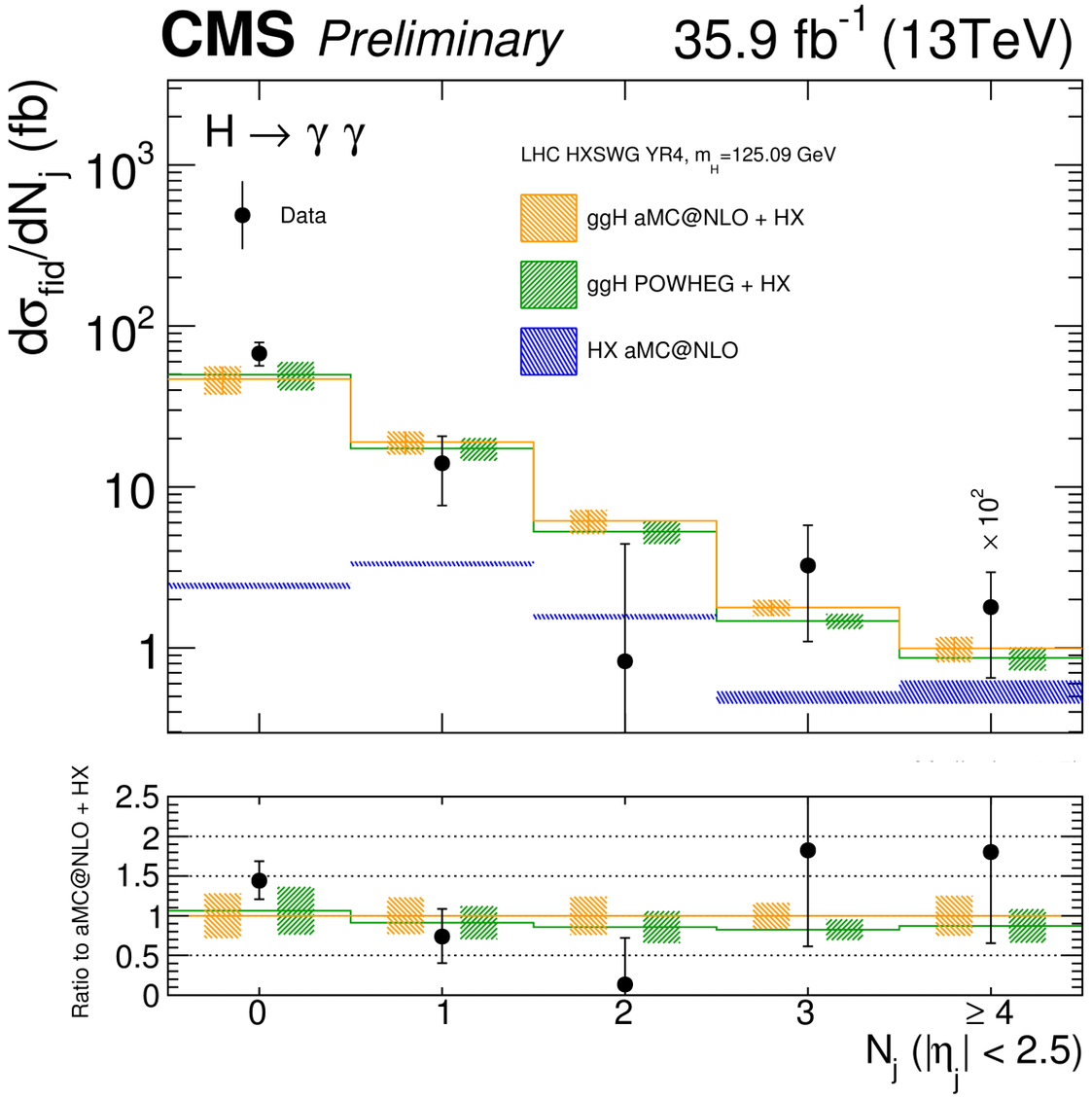


- fully reconstructible final state but lower S/B compared to 4ℓ ~10^{-1}-10^{-2}
- signal signature: 2 isolated photons
- excellent mass resolution 1-2% m_H
- main background: continuum $\gamma\gamma$ production estimated from data sidebands

H→γγ: differential cross-sections

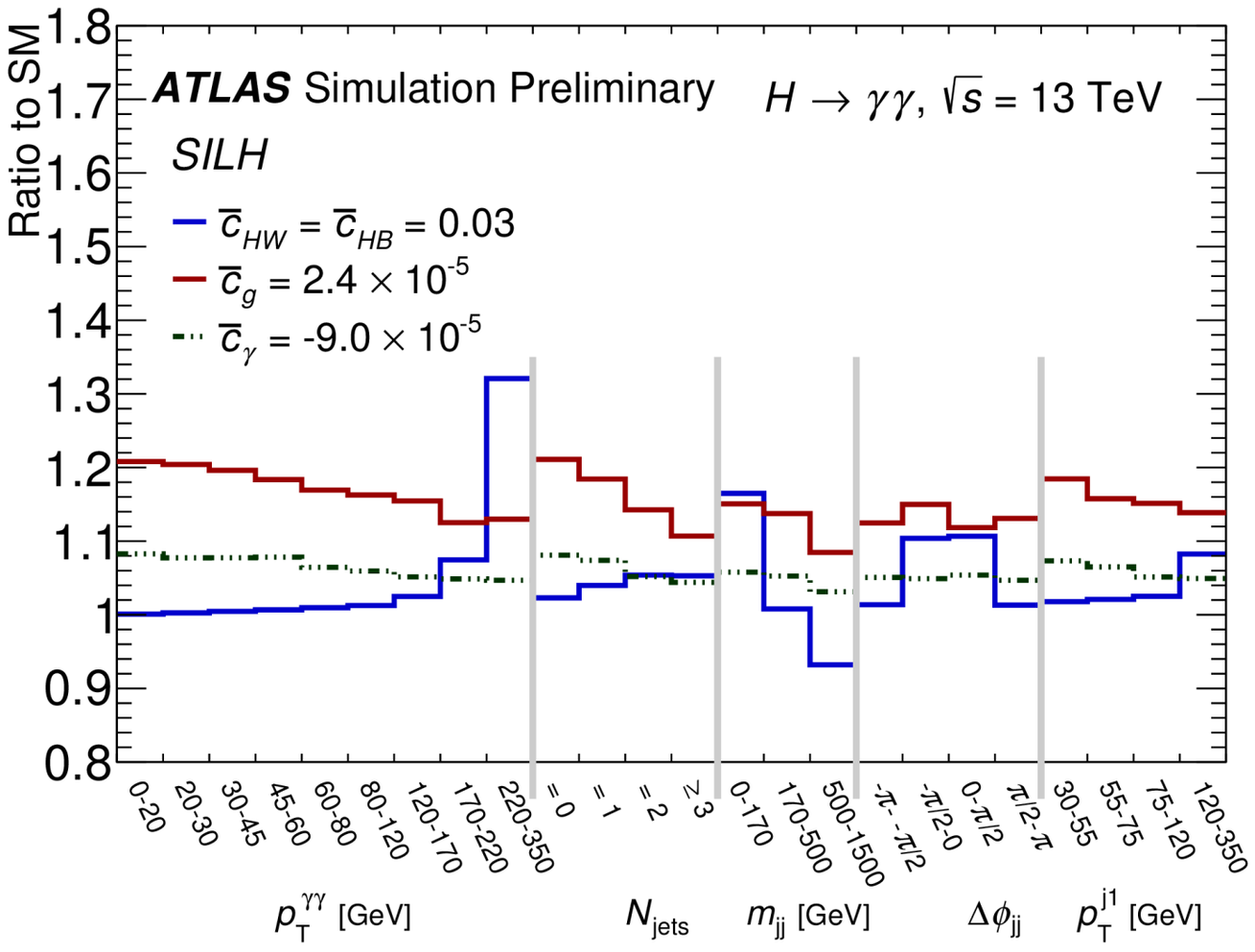


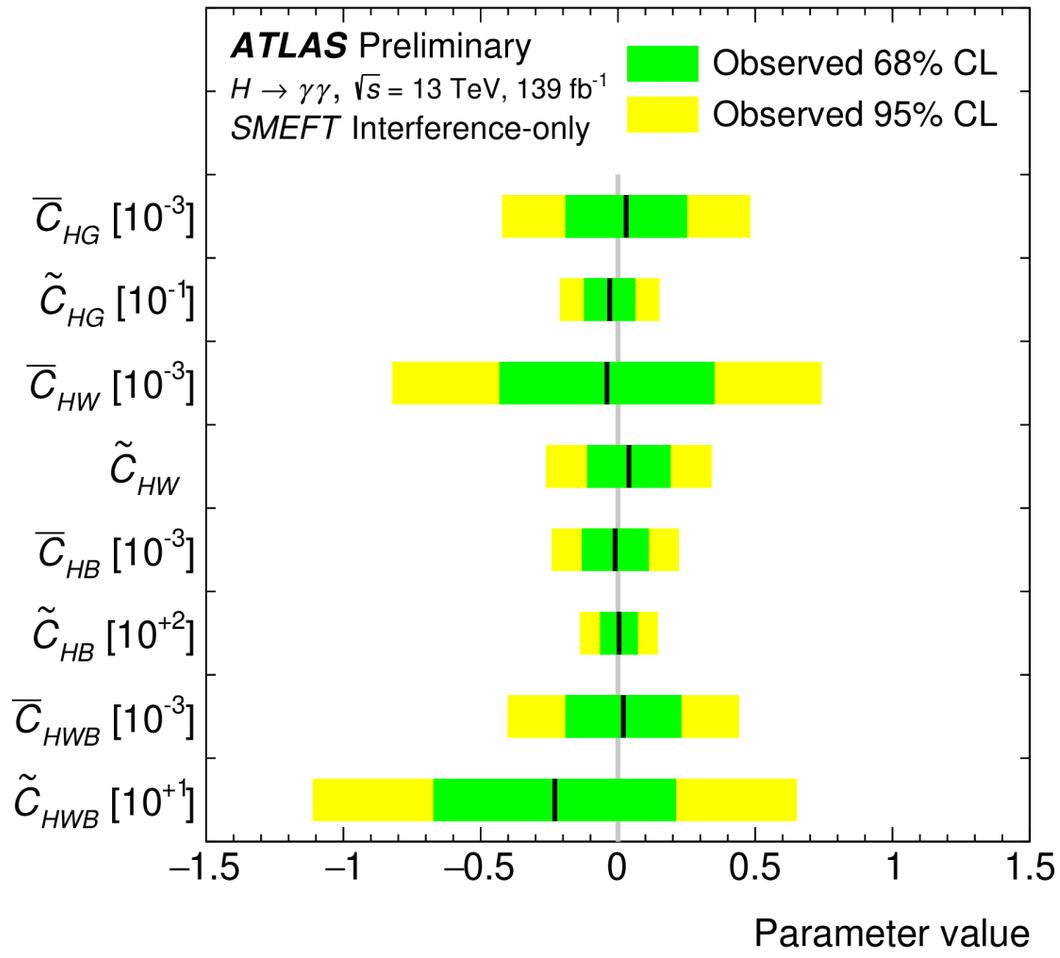


- measurement of the differential cross section still statistically dominated
- **ATLAS** limit on κ_c @139 fb^{-1}, p_T shape only $\kappa_c \in$ (-19,24) @95% CL

H→γγ: EFT interpretation

limits are derived fitting one coefficient at a time setting other coefficients to zero



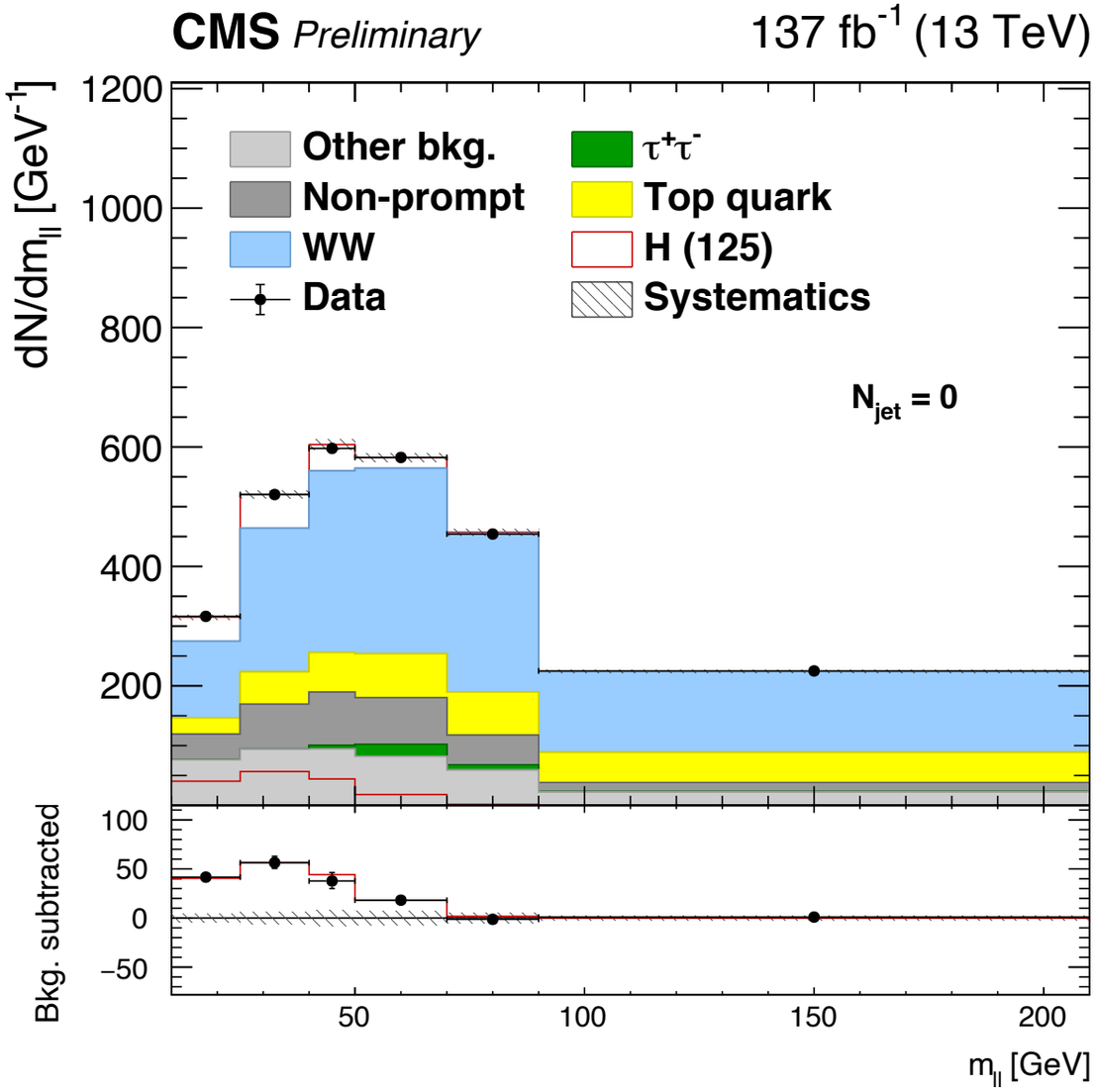


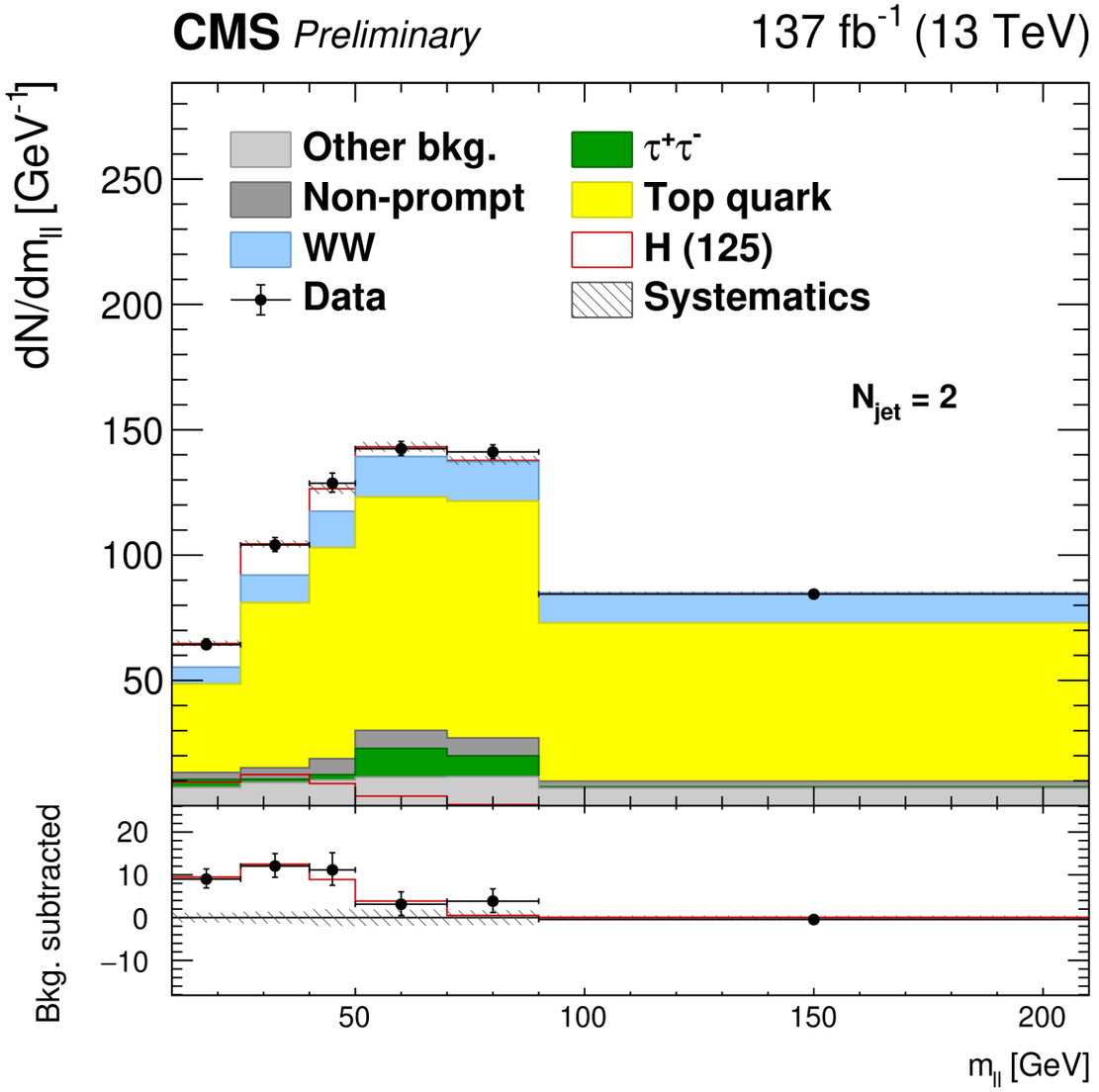
- constrain dimensionless Wilson coefficients of dimension-6 anomalous interactions of EFT Lagrangian using observed differential: p_T, n_{jets}, m_{jj}, $\Delta\phi_{jj}$, $p_T^{lead,jet}$
- **no significant new physics contributions are observed**

EFT talk: Nikita Belyaev Fri 15:15

H→WW

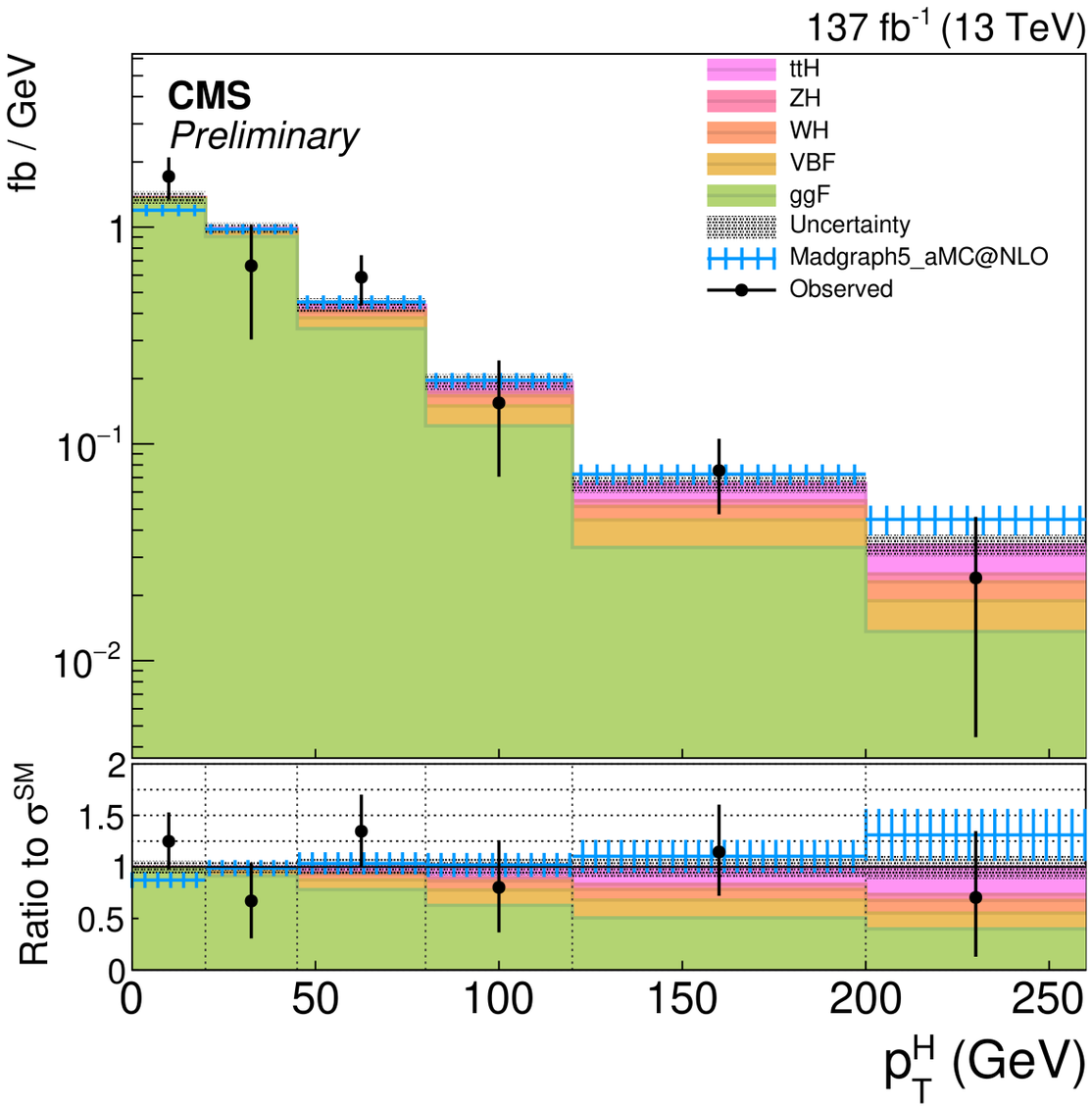
CMS-PAS-HIG-19-002

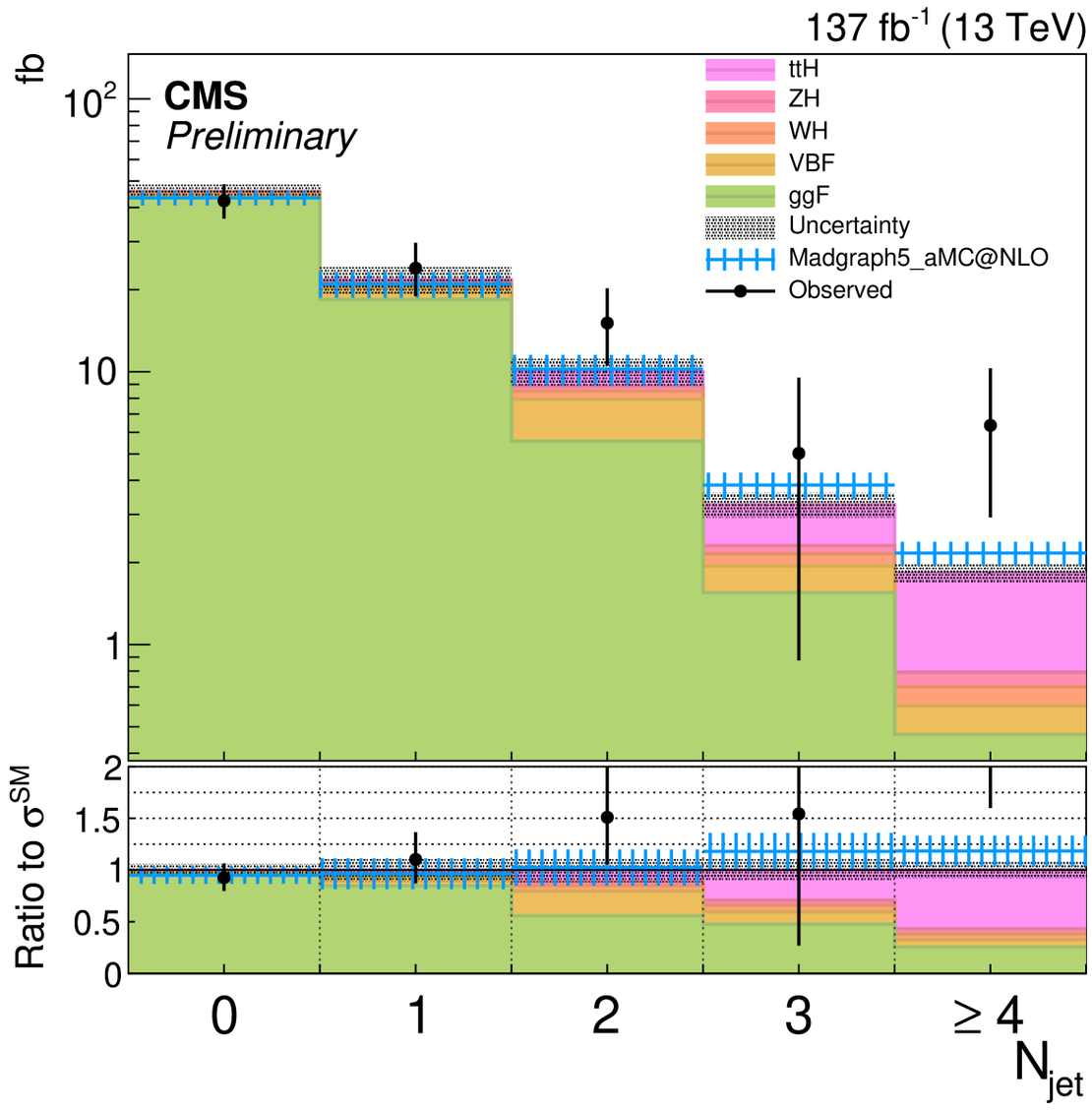




- large signal but not fully reconstructible final state and low S/B ~ 10^{-1}-10^{-2}
- main backgrounds: WW*, tt shapes evaluated with MC and normalisation from data

H→WW: differential cross-sections

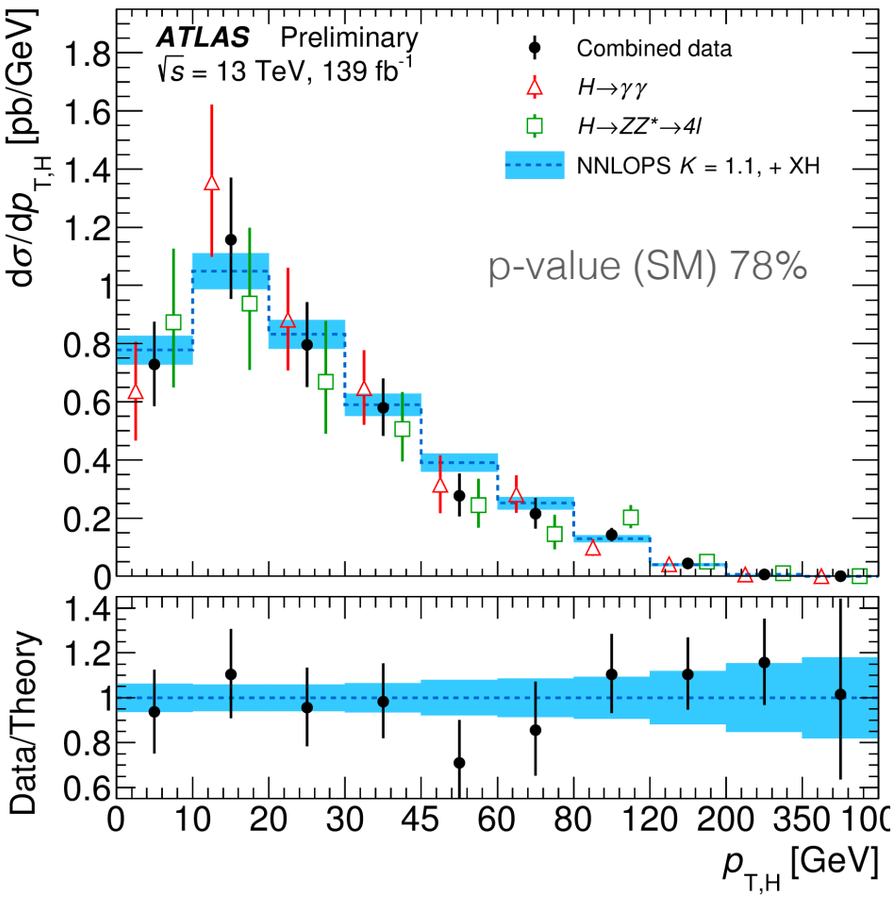


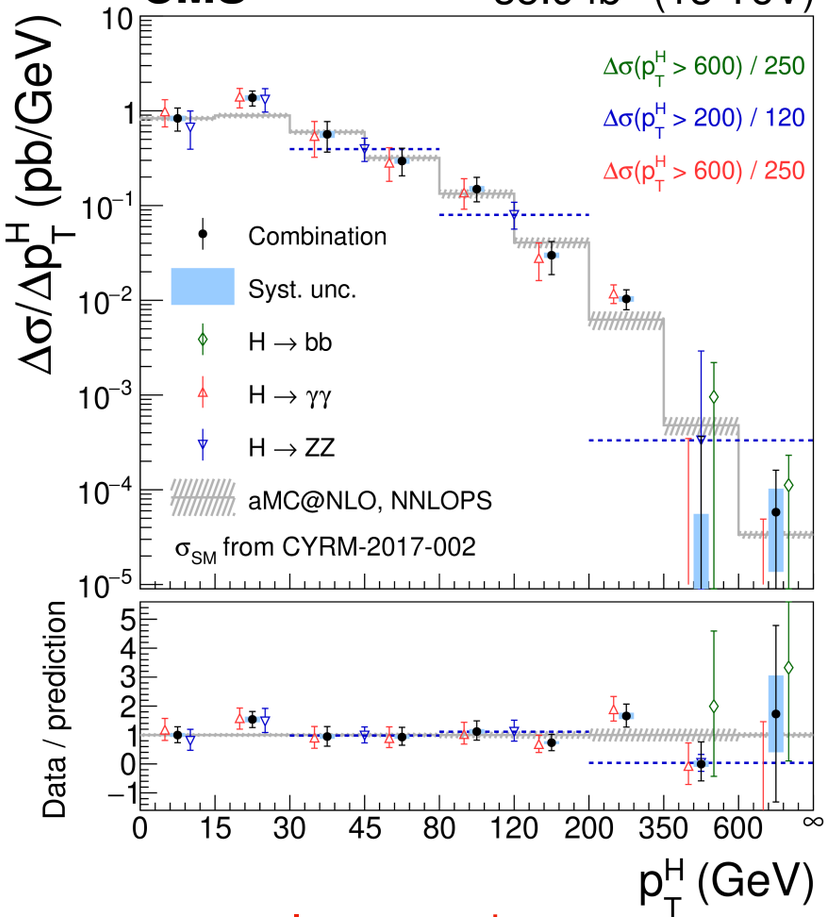


- cross section extracted by fitting two dimensional distribution (m_T, $m_{\ell\ell}$) in each bin $m_{\mathrm{T}}^{\mathrm{H}} = \sqrt{2 p_{\mathrm{T}}^{\ell\ell} p_{\mathrm{T}}^{\mathrm{miss}} \left[1 - \cos\Delta\phi(\vec{p}_{\mathrm{T}}^{\ell\ell}, \vec{p}_{\mathrm{T}}^{\mathrm{miss}})\right]}$
- **competitive channel with γγ at high p_T and high jet multiplicity:** uncertainties < 100% for $n_{jet} \geq 3$ and $p_T > 200$ GeV

combined differential cross sections

ATLAS-CONF-2019-032





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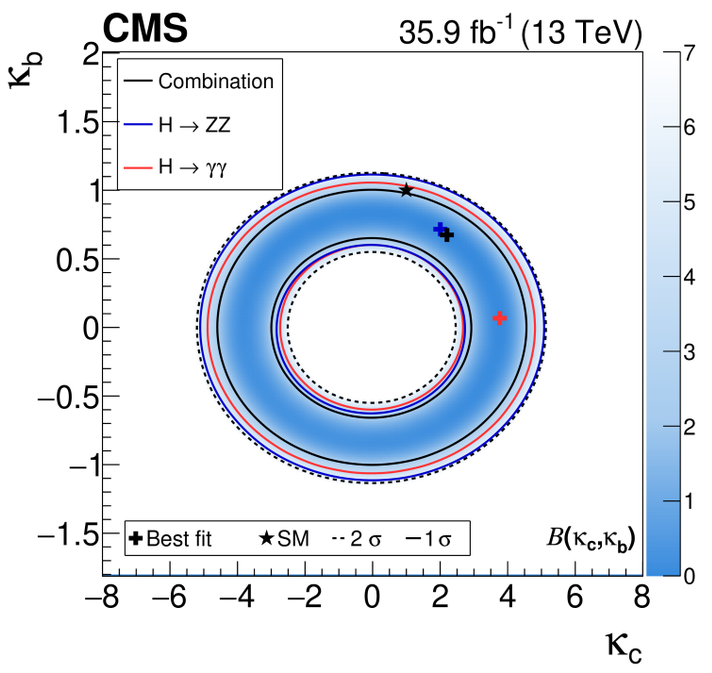
Higgs p_T interpretation using shape and BR effects



- extrapolation to the full phase space: larger theory uncertainties with respect to fiducial measurements (including BR)
- **ATLAS:** $p_{T,H}$ combination 4ℓ and $\gamma\gamma$ @ 139 fb^{-1}, n_{jets}, y_H, lead jet p_T @ 36fb^{-1}
- **CMS:** $p_{T,H}$, n_{jets}, y_H, lead jet p_T combination 4ℓ, $\gamma\gamma$ and bb @36 fb^{-1}
- **CMS:** light Yukawa couplings interpretation using 4ℓ, $\gamma\gamma$

Hbb talk: Stephen Jiggins Thu 14:30

Combination: Jonathon Langford Fri 13:00

conclusions

- several differential cross sections measurements of the Higgs Boson have been performed in ATLAS and CMS (dominated by statistical uncertainties)
- **very good agreement between Standard Model predictions and experimental results**
- measurements have been interpreted via: κ-framework (light Yukawa couplings), pseudo-observables, EFT. no significant new physics contributions are observed
- many new results with full Run2 dataset still to come: stay tuned!