ATLAS Higgs
Cross-sections and Decays

Andrew Mehta

on behalf of the ATLAS Collaboration

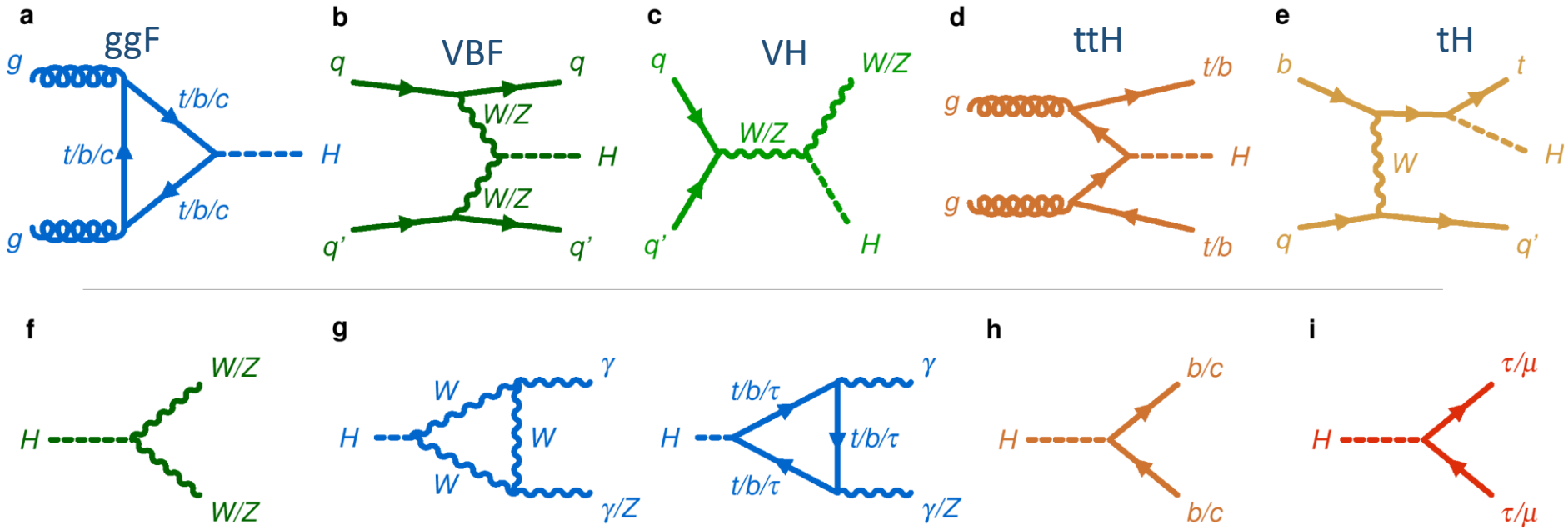
Lepton–photon 2023, Melbourne, Australia

UNIVERSITY OF LIVERPOOL

ATLAS Higgs Cross-sections and Decays

Higgs production and decay
Higgs coupling overview
New 13.6 TeV measurements
$H \to \gamma\gamma$
$H \to WW$
$H \to \tau\tau$
$H \to bb$
Rare decays
Higgs combination

Higgs Production and Decay



Couplings are probed both in production and decay

Loop contributions are in many cases more important than tree level

Gluon-gluon fusion (ggF) the dominant production mode

Vector boson fusion (VBF) subdominant

ttH offers direct measurement of top –Higgs coupling

Higgs Couplings Overview

Direct measurements of all particles with mass ≥m_T

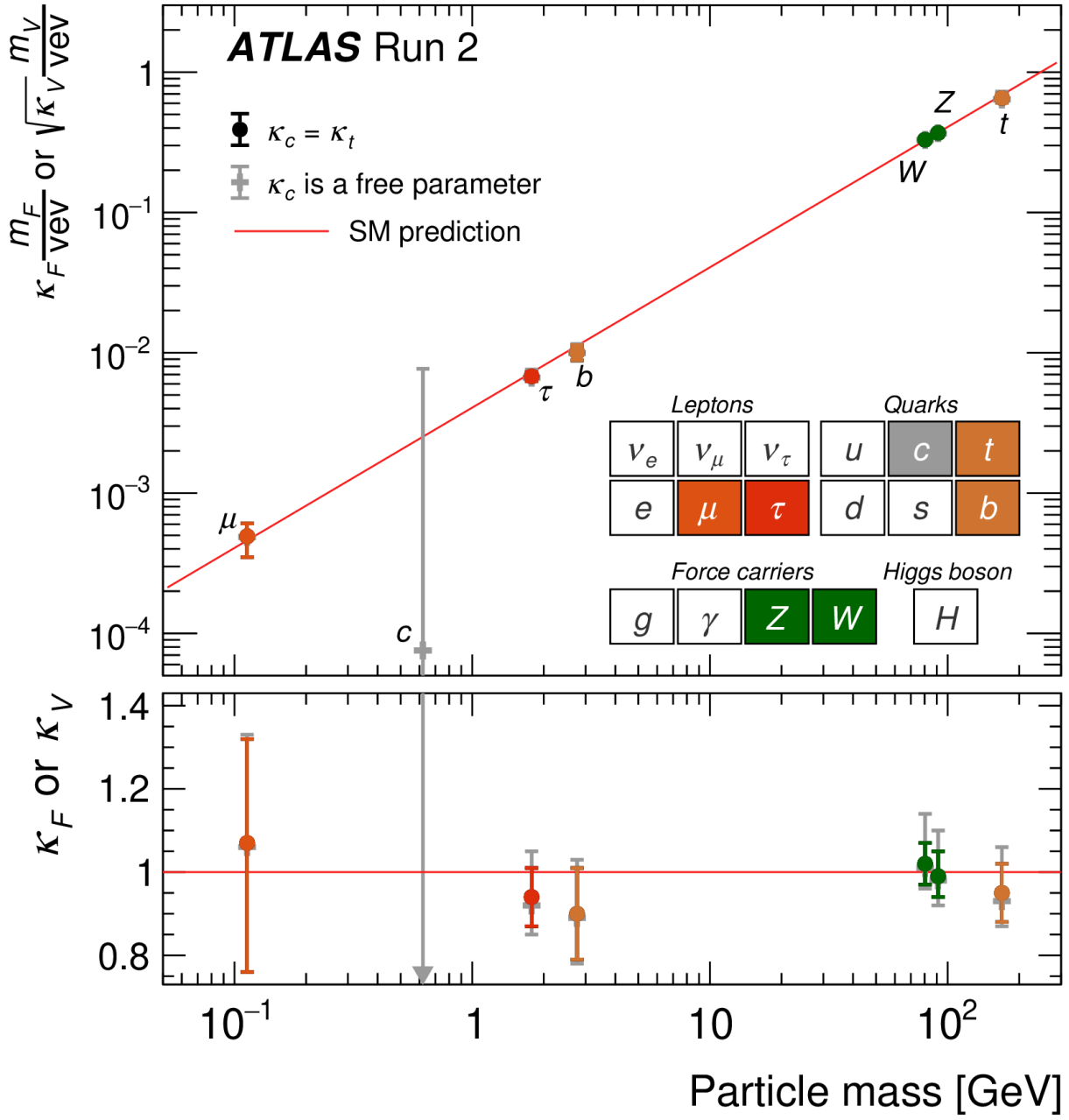
Indirect constraints for many in addition

Limits on charm and 2σ measurement of muon

Testing 3 orders of magnitude in coupling and 4 orders in mass

In addition searches for H→ invisible and flavour changing decays

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/HIGG-2021-23/



Run 3 H →γγ and H → ZZ

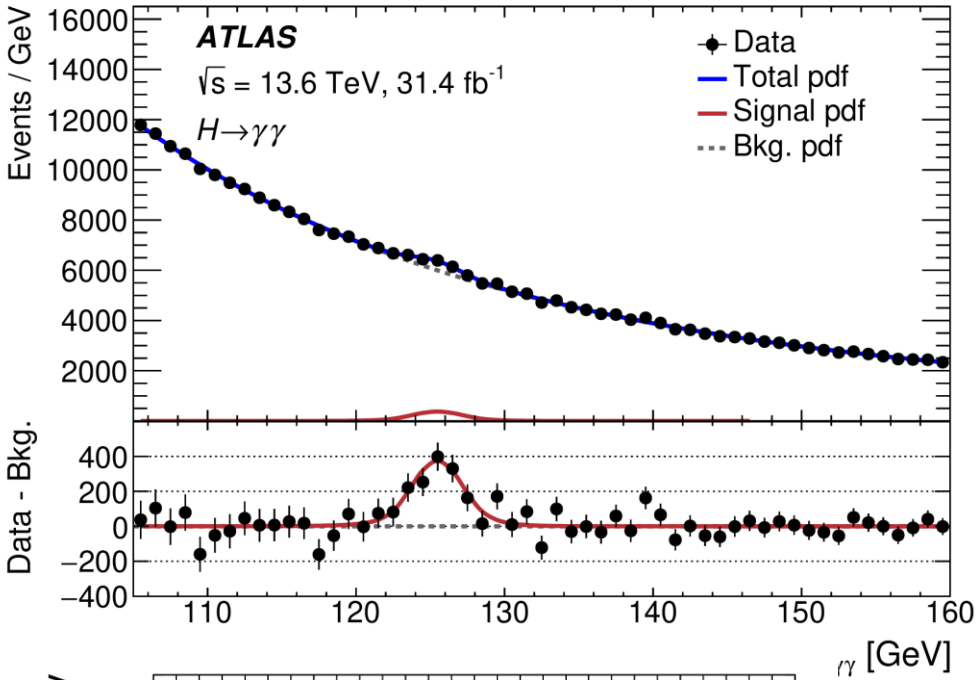
New measurements at 13.6 TeV

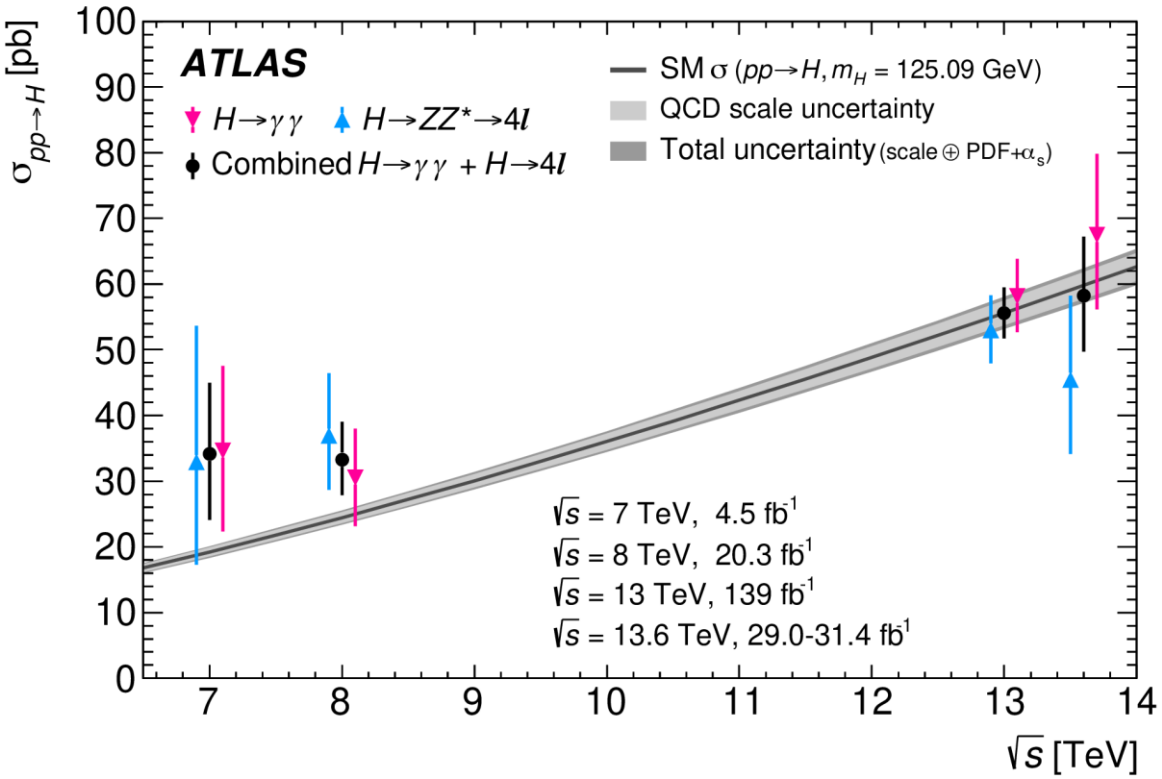
Predominately ggF and VBF production

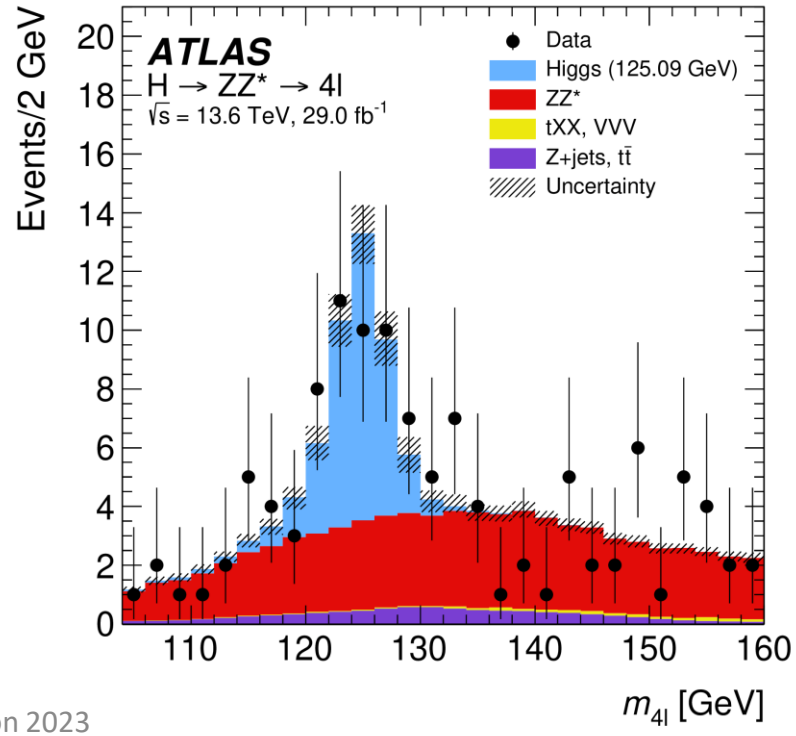
Fiducial cross-section measurements

Extension to full phase space – agrees with each other and SM

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/HIGG-2022-12/







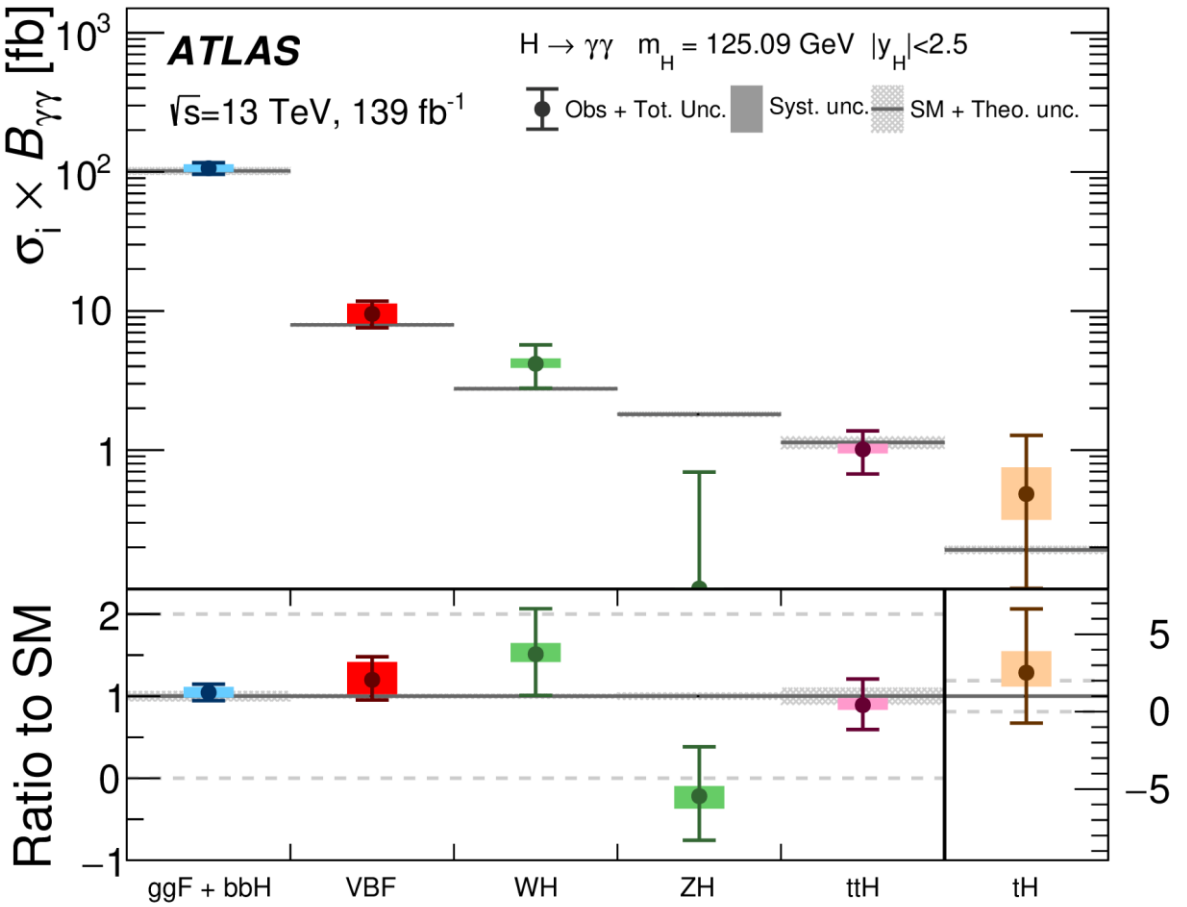
H →γγ 13 TeV

Large Run 2 dataset

Rare decay but clean so allows most production modes to be measured in one channel

All show agreement with SM so far

Differential cross section measurements also possible



https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/HIGG-2020-16/

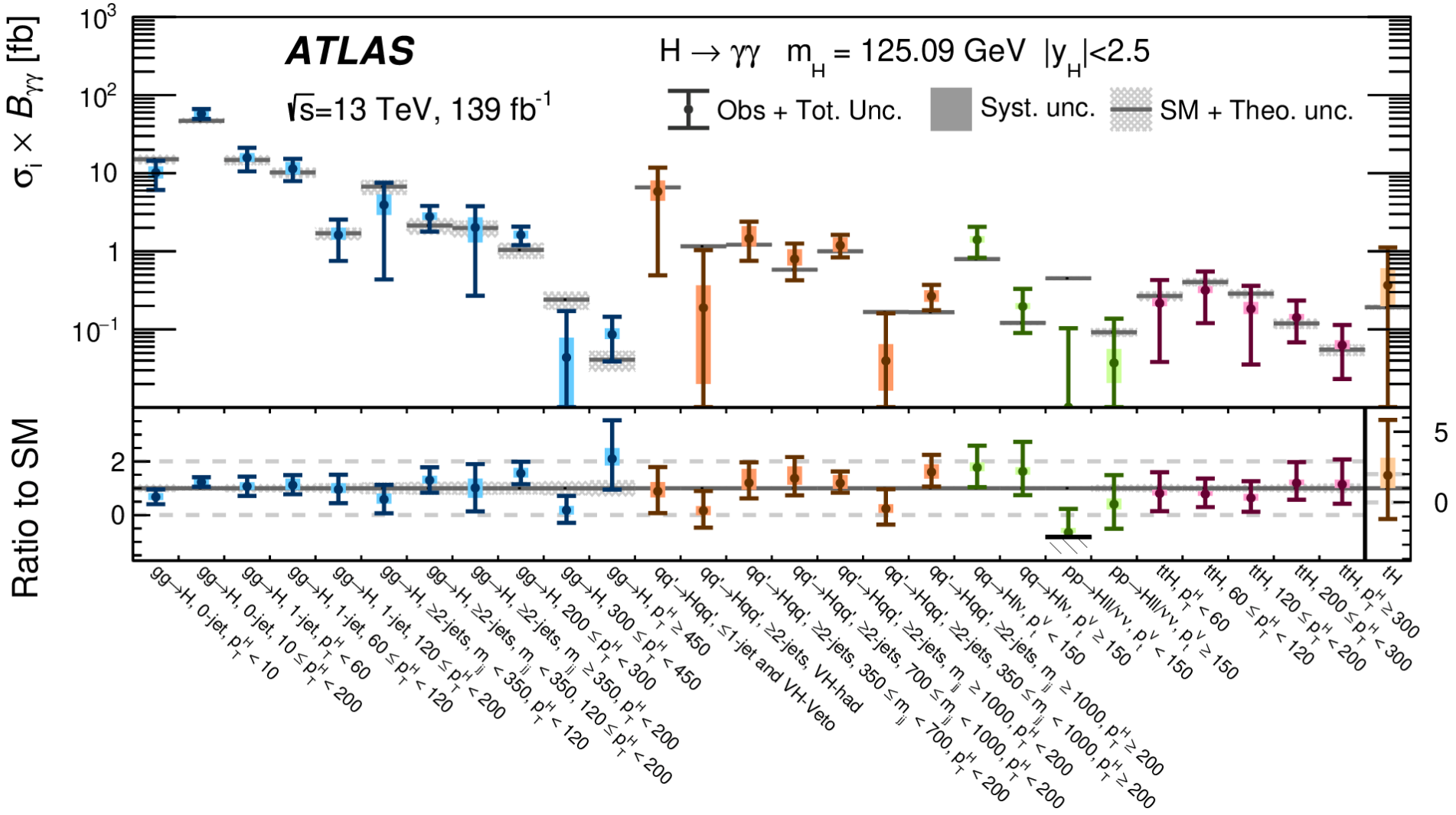
H →γγ 13 TeV

Differential cross section measurements also possible

Comprehensive set of measurements from a single decay

New physics could come in at high p_T

No deviations from SM seen



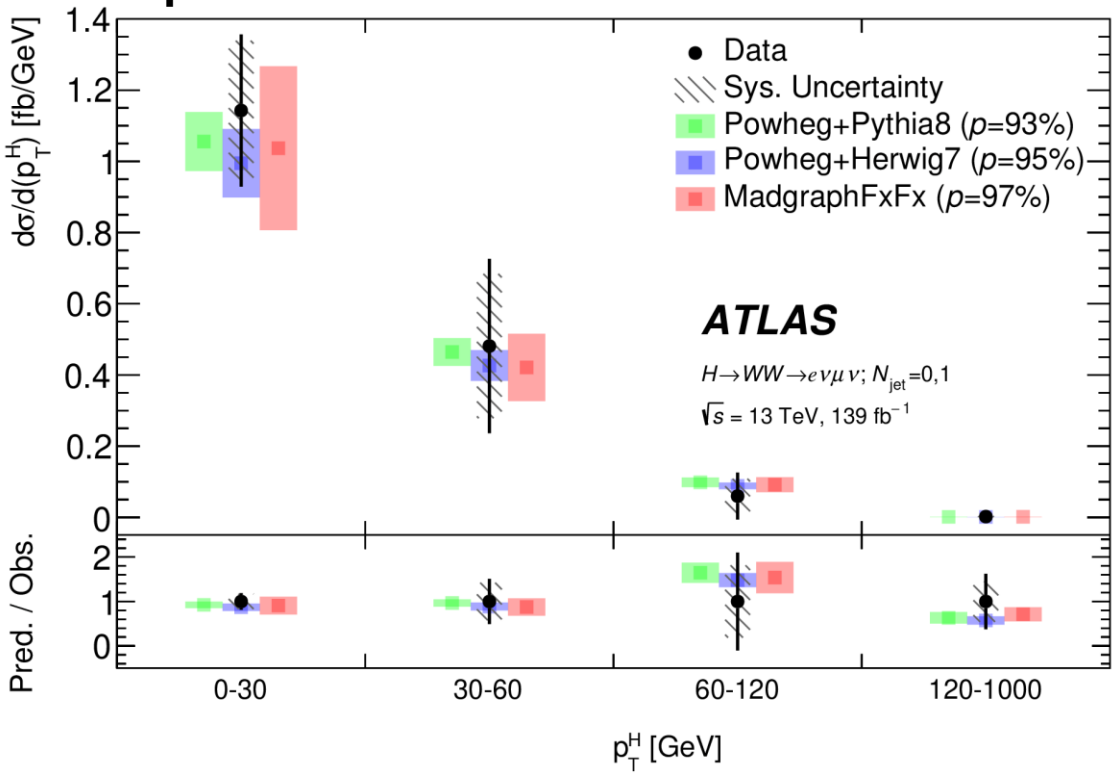
H→WW

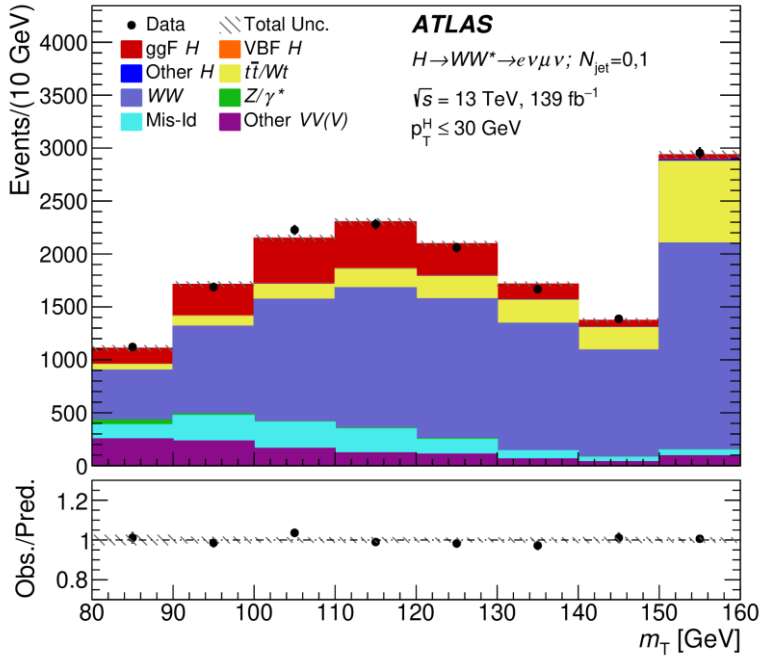
Large cross section

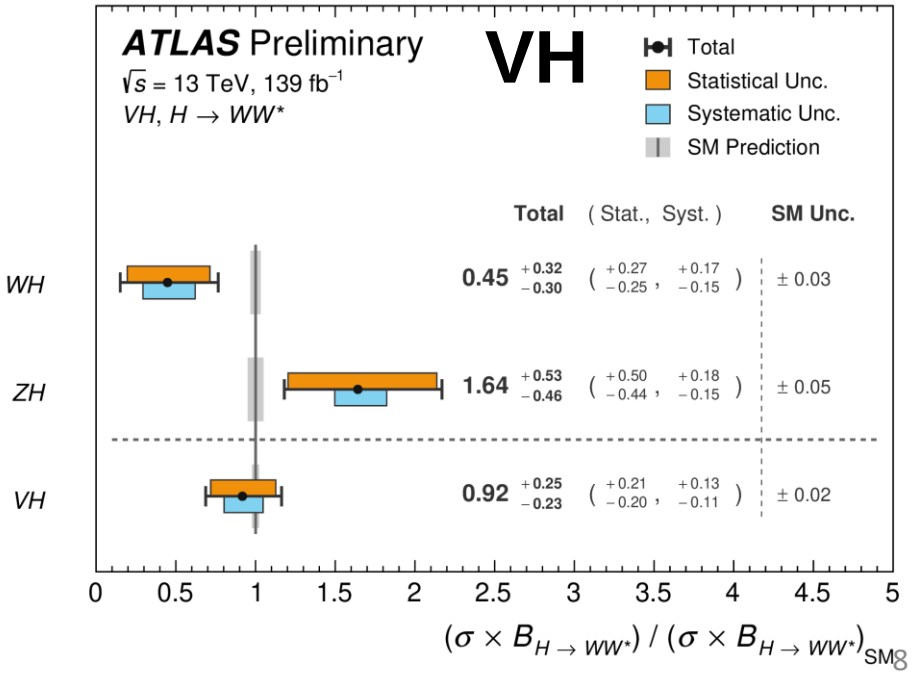
But large WW background and mass can't be fully reconstructed

Comprehensive measurements possible in ggF, VBF and VH

All production channels Fiducial cross section







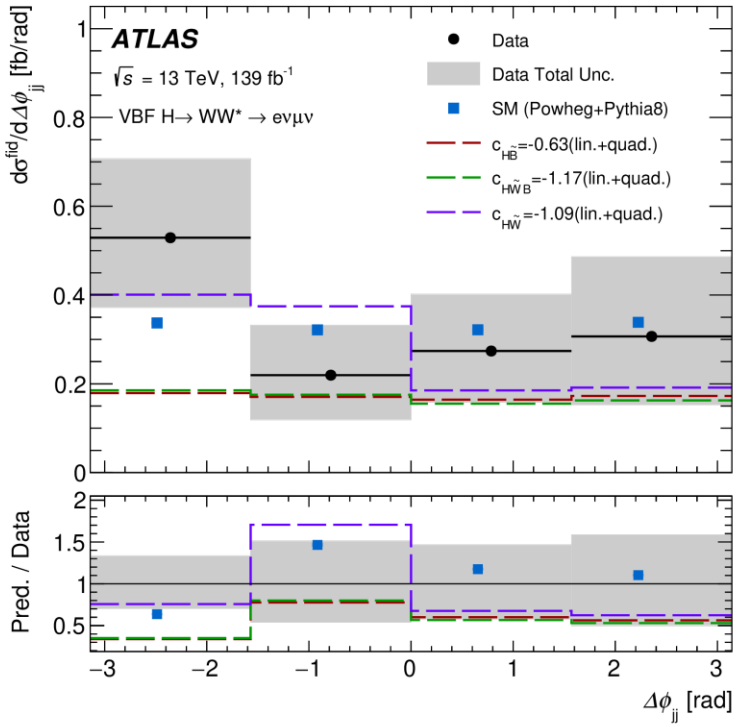
https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/HIGG-2021-20/
https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/HIGG-2018-49/
https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2022-067/

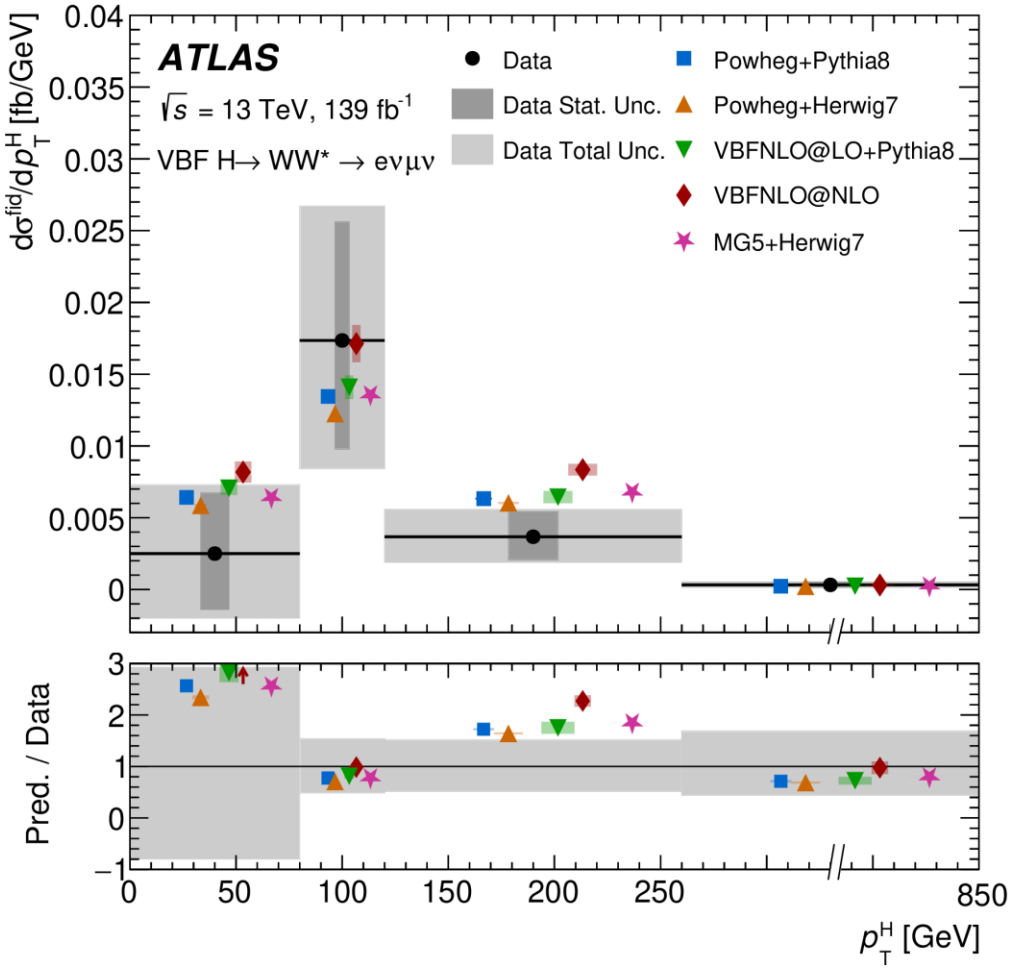
H→WW VBF in more detail

Large set of differential measurements in many variables

Allows comparisons to different SM predictions

EFT couplings can be better constrained than in inclusive measurement





https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/HIGG-2020-25/

H→ττ

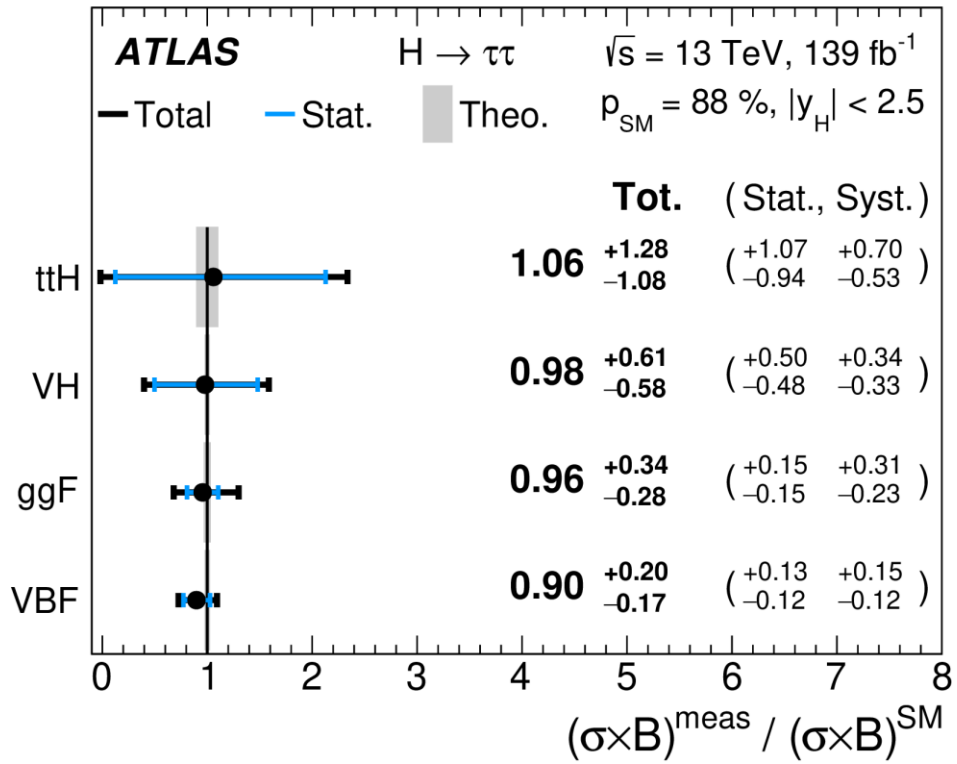
Relies on ATLAS tau hadronic identification to separate out large jet background

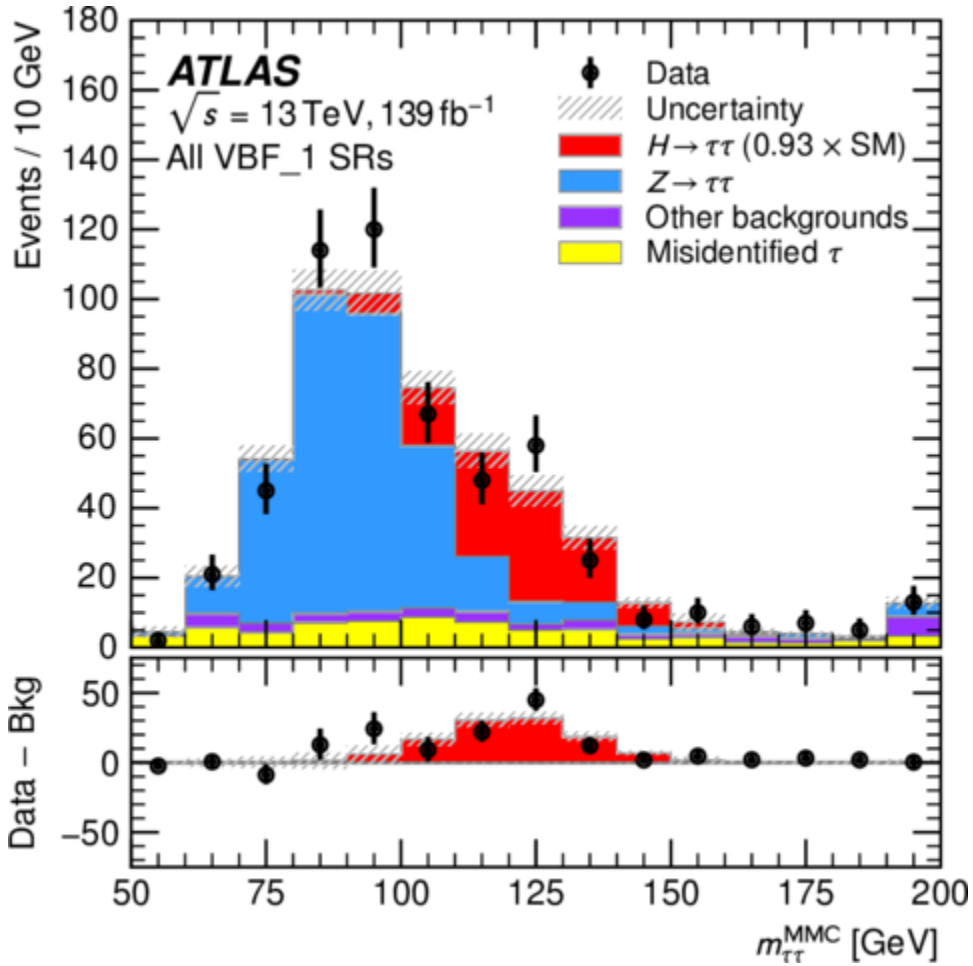
Higgs mass reconstructed accounting for missing neutrinos

Boosted measurements allow extension to high pT

Some signal regions have low background especially VBF

Very good ggF and VH measurements





https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/HIGG-2019-09/

H→bb

Has highest branching fraction

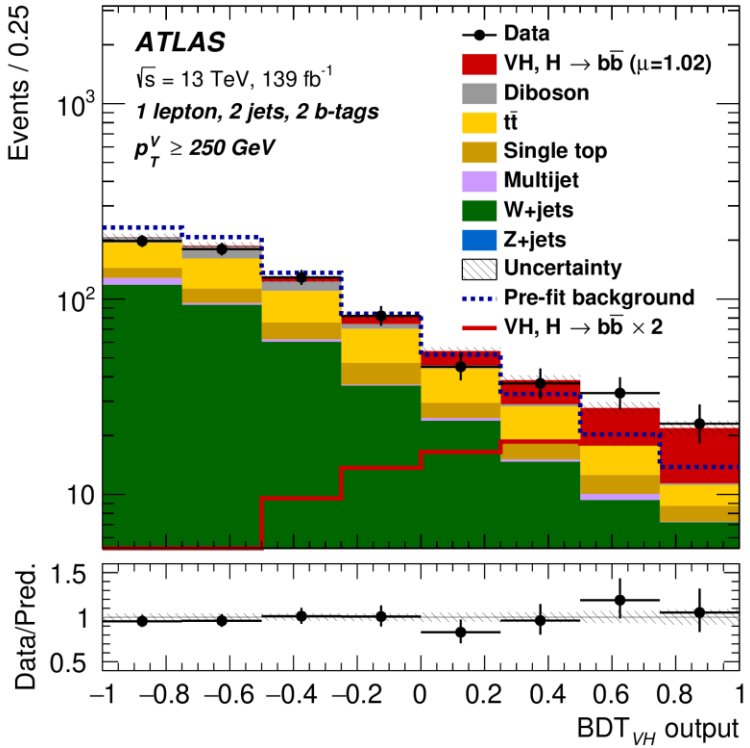
Difficult due to large b-jet background

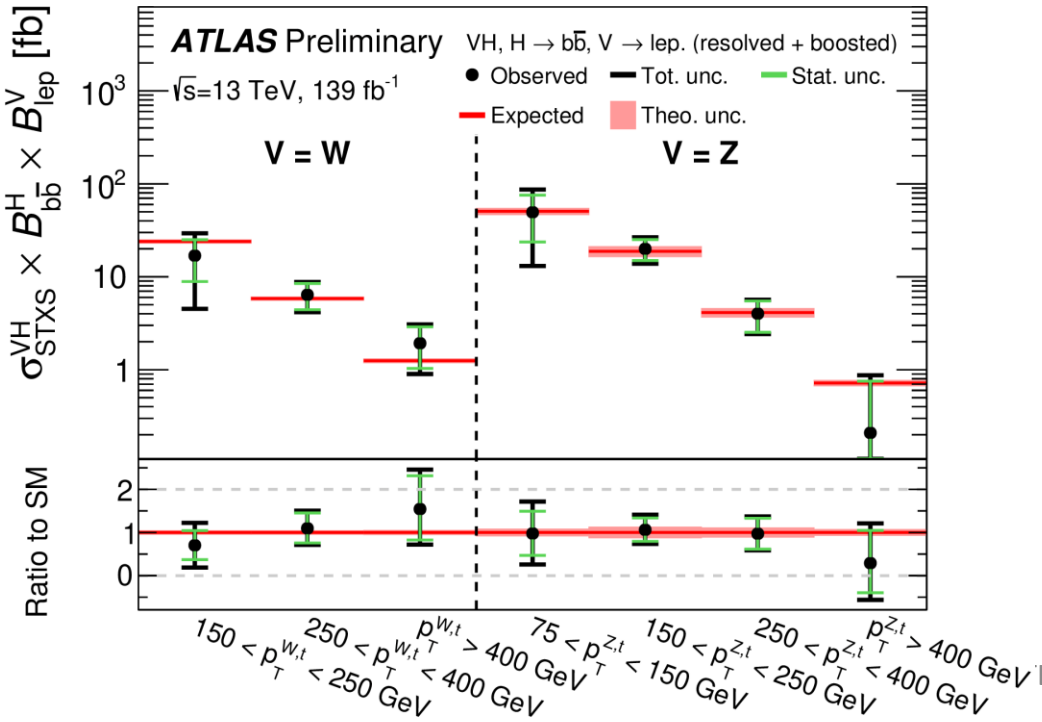
VH modes at high pT offer best measurements

Combination with boosted measurements allow extension to higher pT

Relies on ATLAS b-jet identification

Multi-varient techniques employed to separate out large background

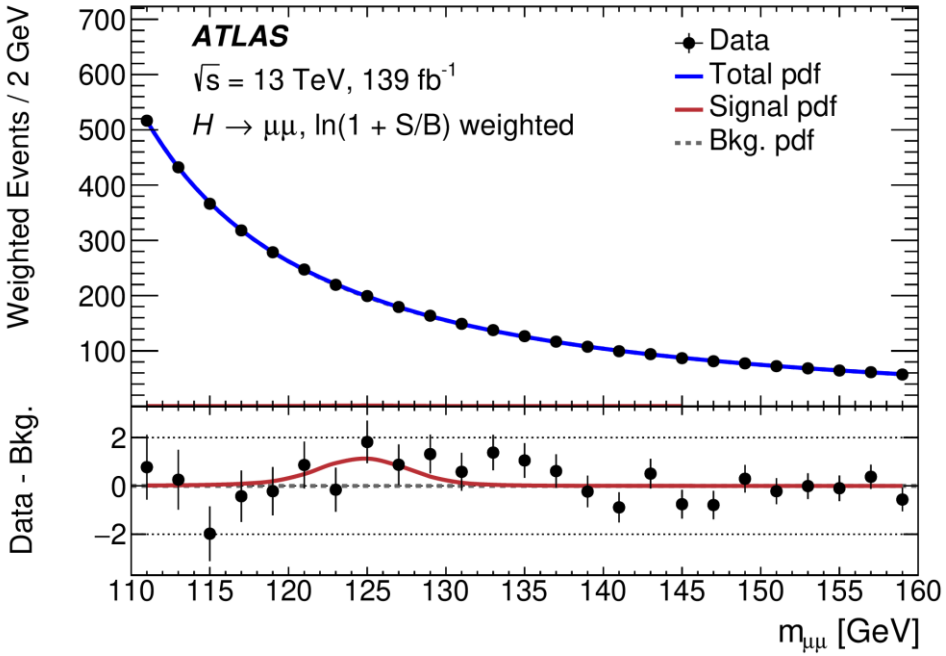


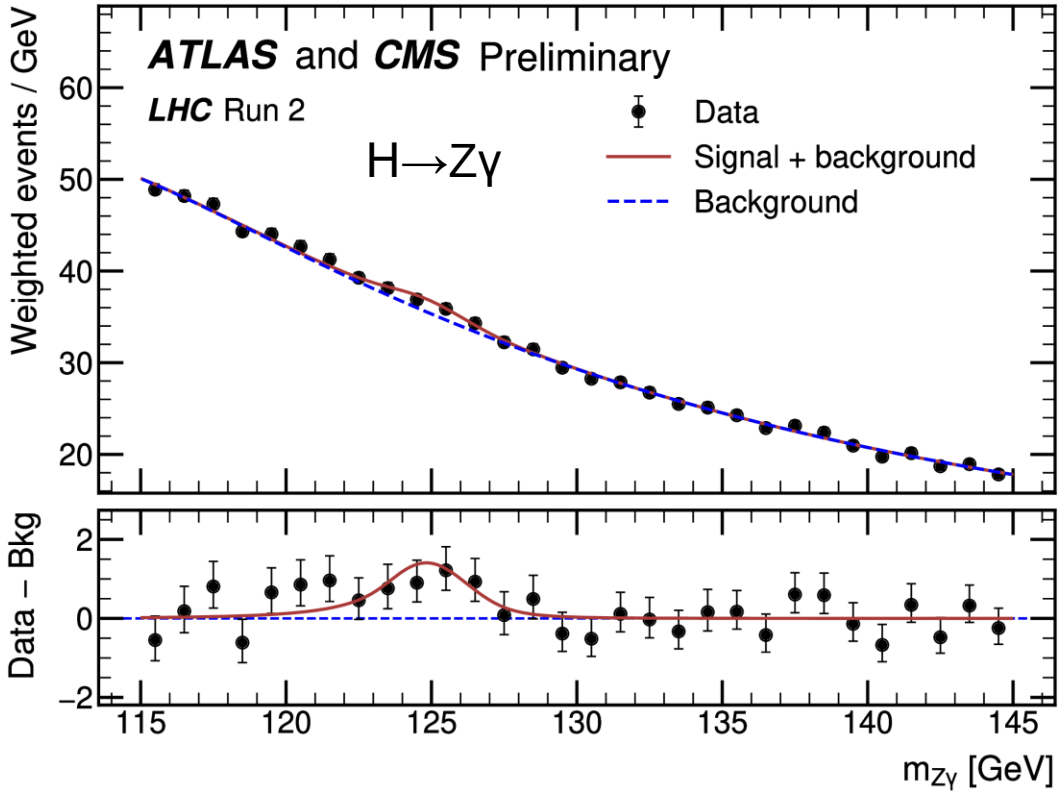


Overall good agreement in both channels at all pT

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/HIGG-2018-51/
https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/HIGG-2021-08/
https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2021-051/

Rare Higgs decays





First evidence for H →Zγ with ATLAS and CMS combination

H →μμ has BF of 2×10^{-4}

ATLAS measures 2σ

(CMS over 3σ)

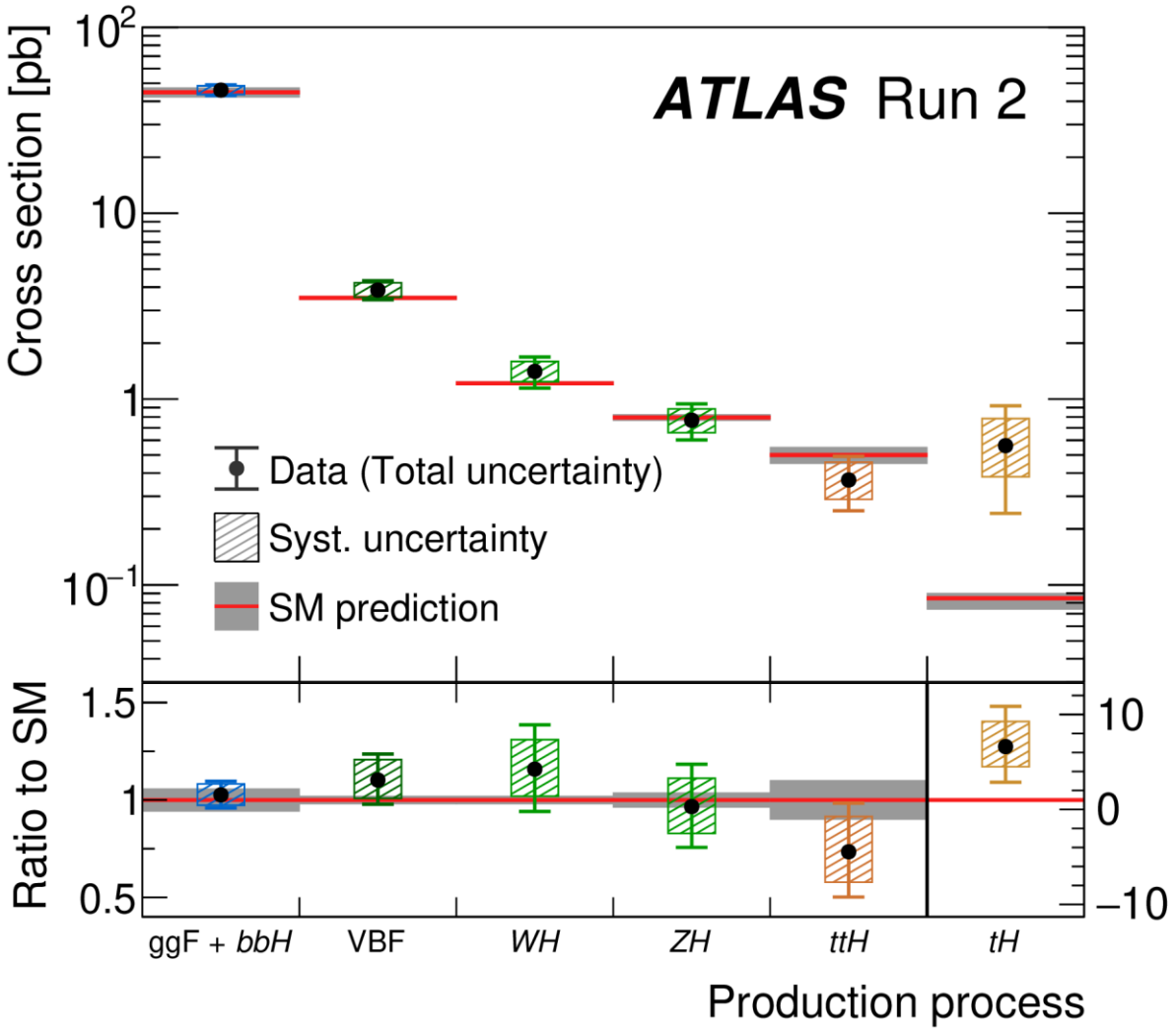
ATLAS 2.2 σ
CMS 2.8 σ
ATLAS+CMS 3.4σ

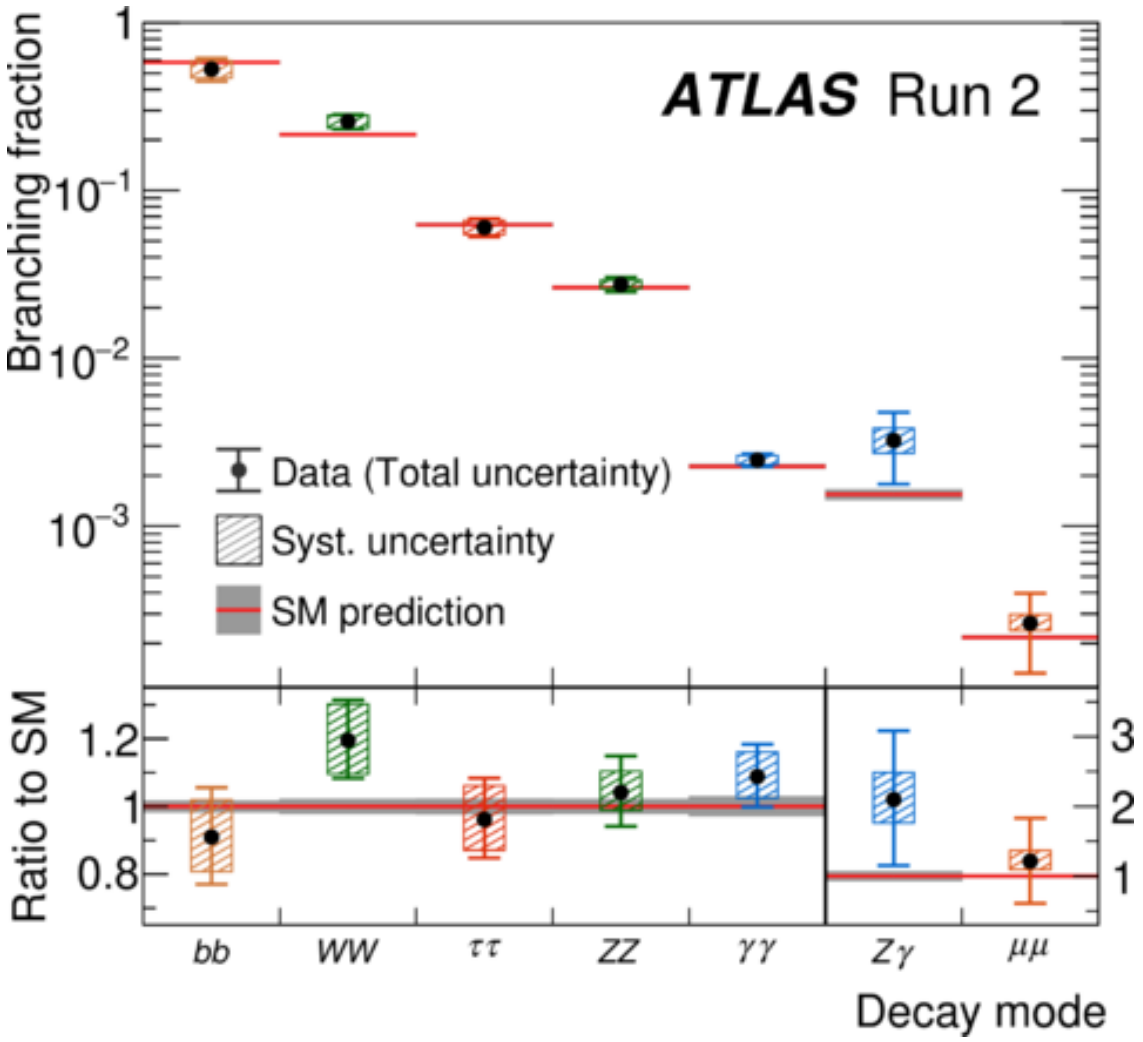
https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2023-025/

Putting it all together

Combination of all ATLAS measurements

Impressive test of SM





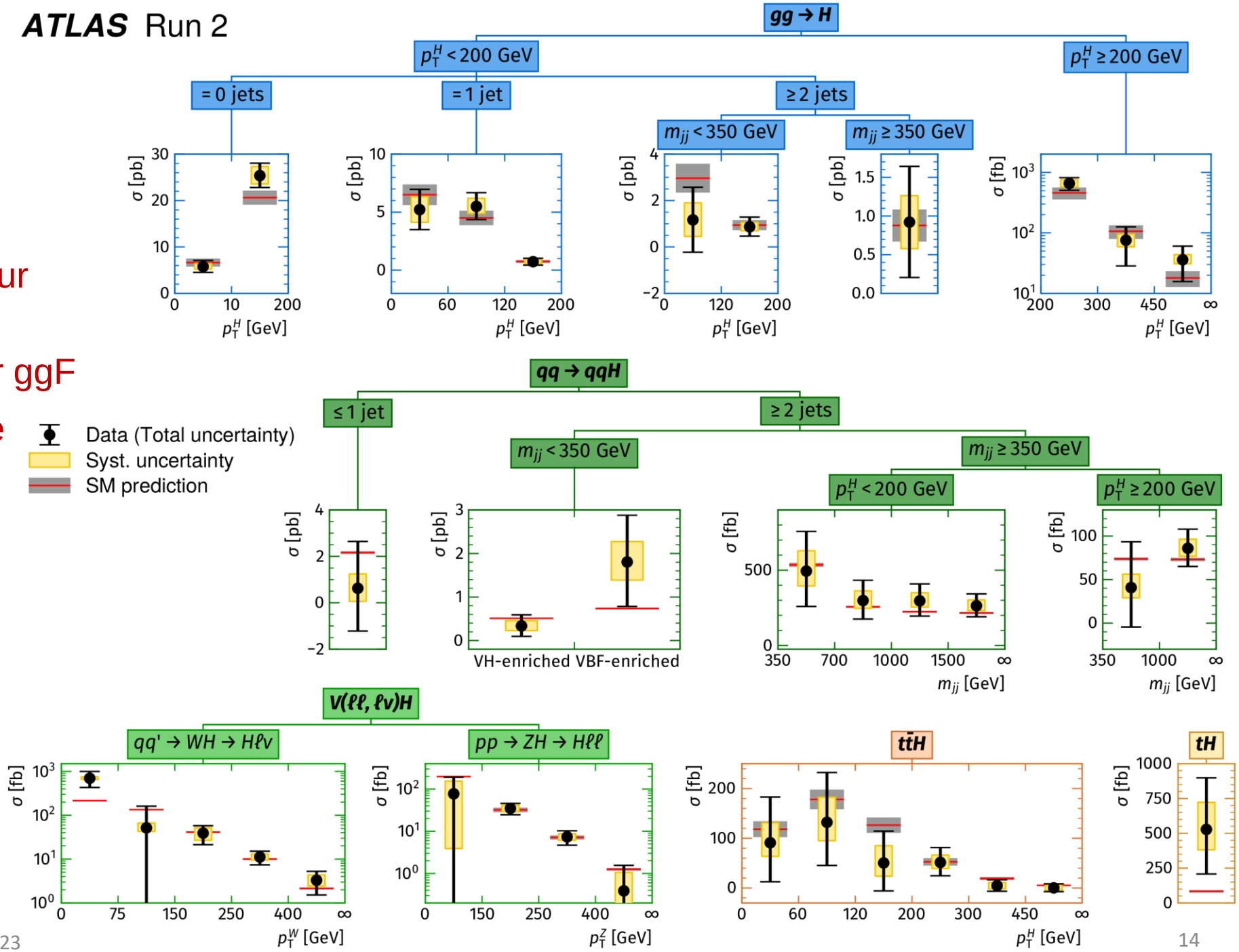
https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/HIGG-2021-23/

Higgs Combination

Differential combination in four main production processes

Differential in N_{Jet} and p^H_T for ggF

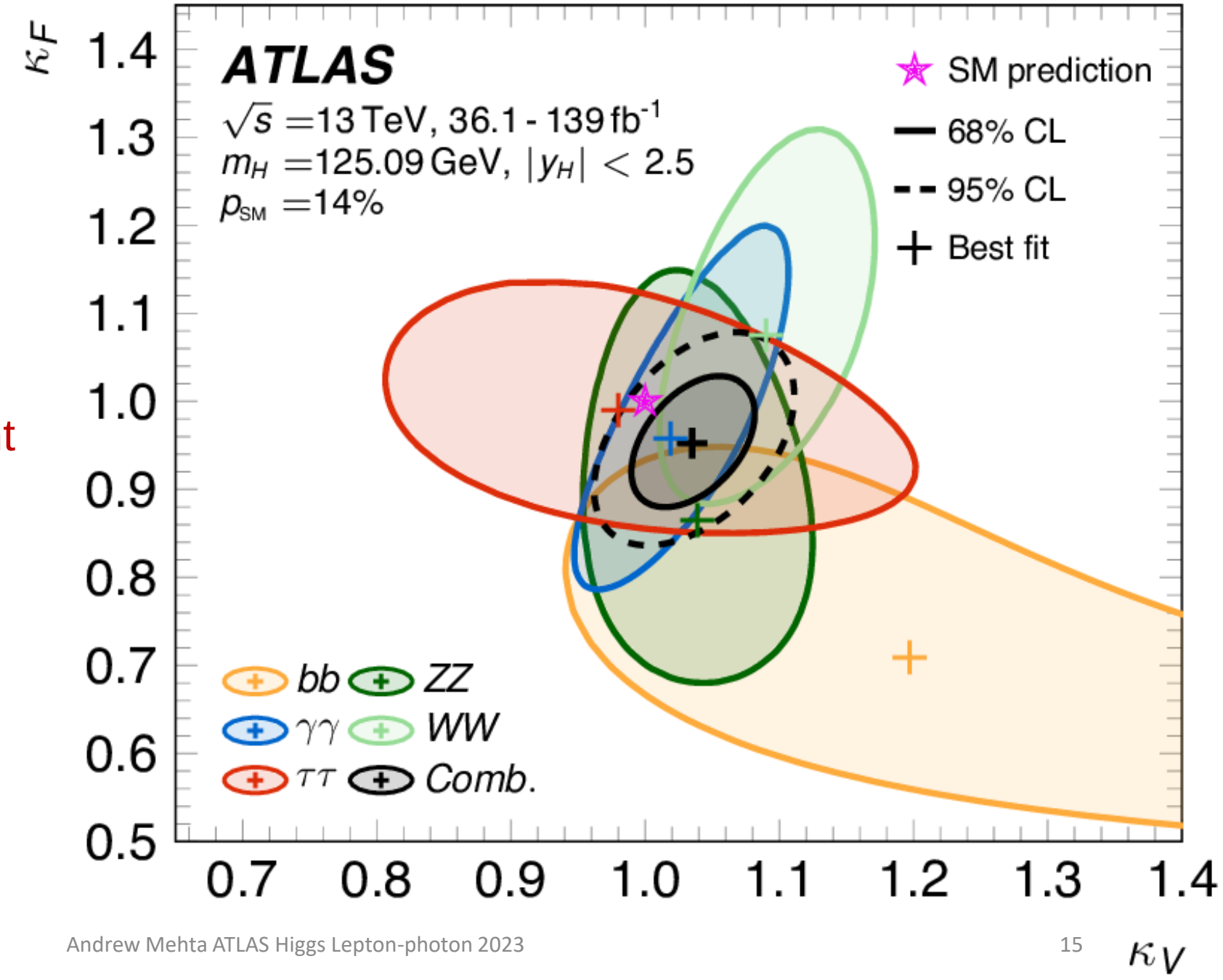
Excellent agreement with the Standard Model



Higgs Couplings

Higgs Fermion- Vector Boson Coupling deviations

Good example of how different channels contribute



Summary

Huge range of Higgs measurements across many decay modes

Each channel has it’s own advages and challenges

First run 3 measurements

Precise measurements of main production processes

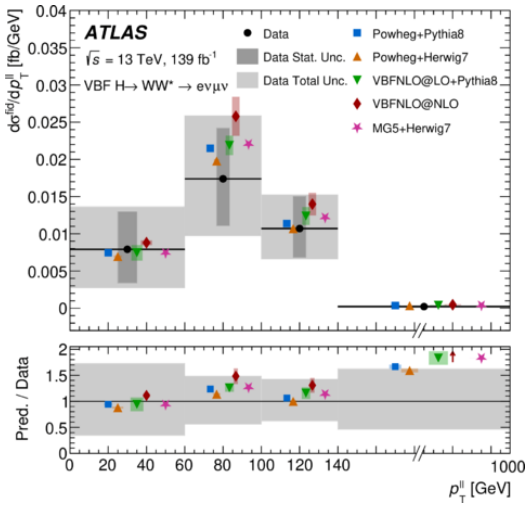
Many channels have differential measurement

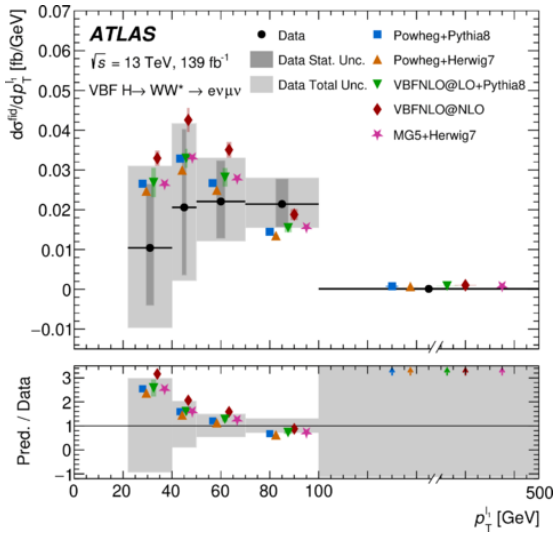
Combination is the ultimate test of the SM Higgs sector

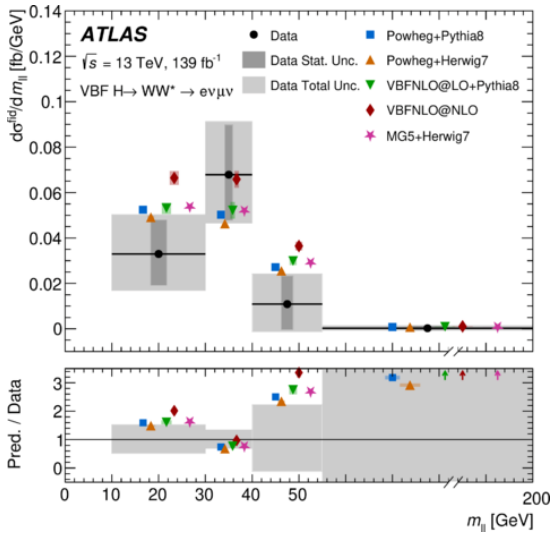
Good agreement between channels

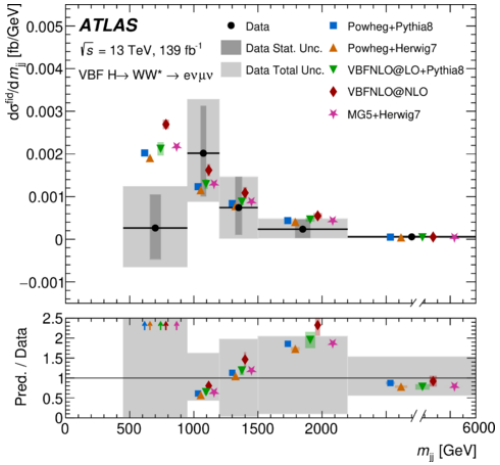
No deviations from SM so far

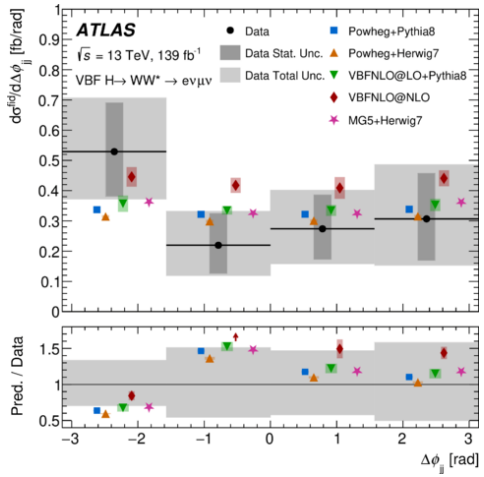
Backup H →WW

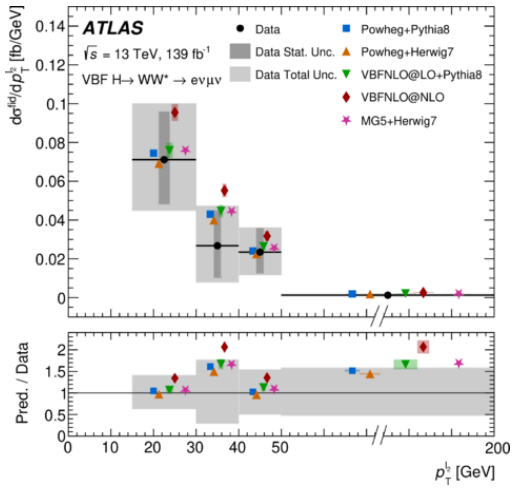

ATLAS
√s = 13 TeV, 139 fb⁻¹
VBF H→ WW* → evμv
Data
Data Stat. Unc.
Data Total Unc.
Powheg+Pythia8
Powheg+Herwig7
VBFNLO@LO+Pythia8
VBFNLO@NLO
MG5+Herwig7
dσ^fid/dp_T^ll [fb/GeV]
Pred. / Data
p_T^ll [GeV]


ATLAS
√s = 13 TeV, 139 fb⁻¹
VBF H→ WW* → evμv
Data
Data Stat. Unc.
Data Total Unc.
Powheg+Pythia8
Powheg+Herwig7
VBFNLO@LO+Pythia8
VBFNLO@NLO
MG5+Herwig7
dσ^fid/dp_T^l [fb/GeV]
Pred. / Data
p_T^l [GeV]

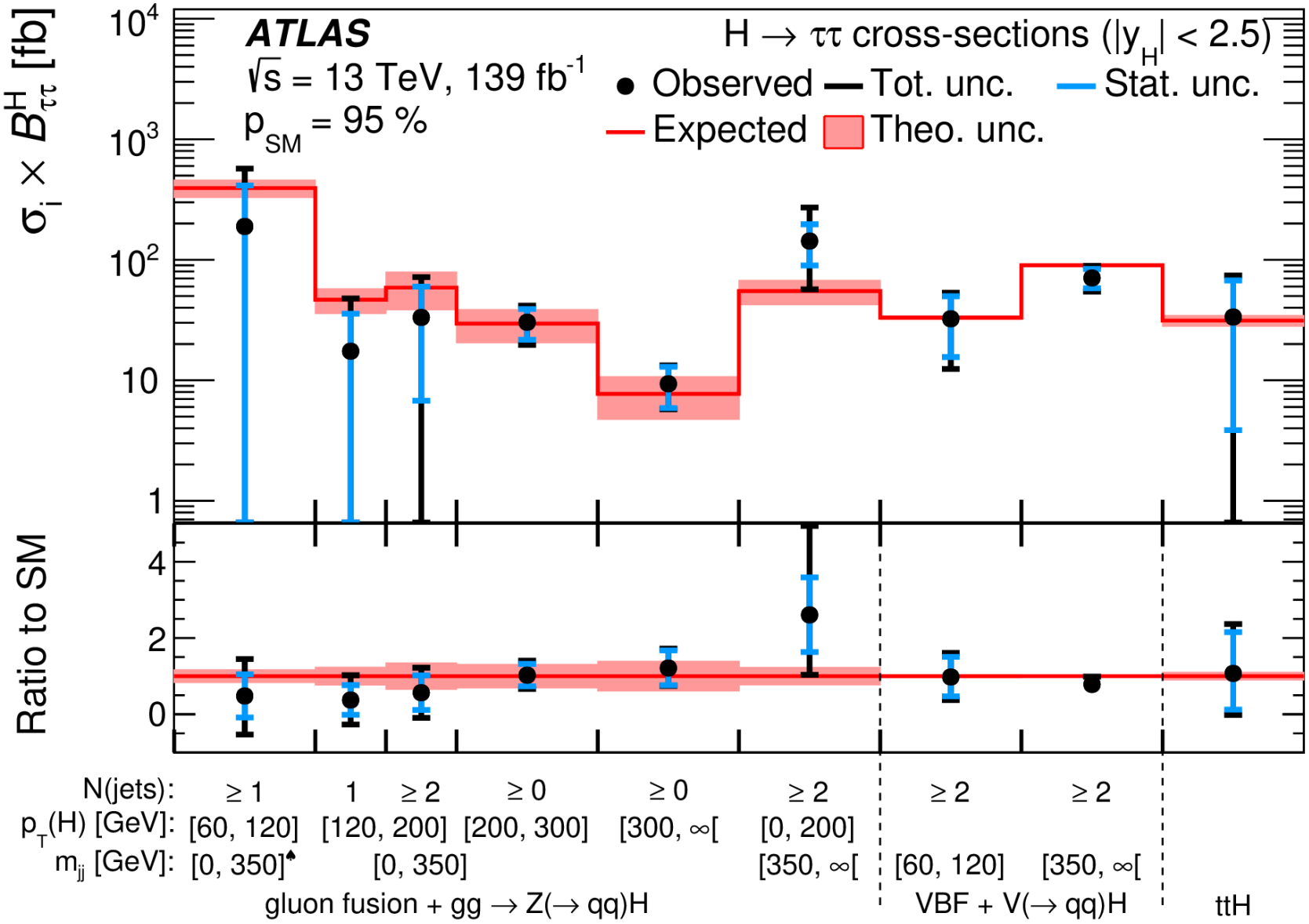

ATLAS
√s = 13 TeV, 139 fb⁻¹
VBF H→ WW* → evμv
Data
Data Stat. Unc.
Data Total Unc.
Powheg+Pythia8
Powheg+Herwig7
VBFNLO@LO+Pythia8
VBFNLO@NLO
MG5+Herwig7
dσ^fid/dm_ll [fb/GeV]
Pred. / Data
m_ll [GeV]


ATLAS
√s = 13 TeV, 139 fb⁻¹
VBF H→ WW* → evμv
Data
Data Stat. Unc.
Data Total Unc.
Powheg+Pythia8
Powheg+Herwig7
VBFNLO@LO+Pythia8
VBFNLO@NLO
MG5+Herwig7
dσ^fid/dm_jj [fb/GeV]
Pred. / Data
m_jj [GeV]


ATLAS
√s = 13 TeV, 139 fb⁻¹
VBF H→ WW* → evμv
Data
Data Stat. Unc.
Data Total Unc.
Powheg+Pythia8
Powheg+Herwig7
VBFNLO@LO+Pythia8
VBFNLO@NLO
MG5+Herwig7
dσ^fid/dΔφ_jj [fb/rad]
Pred. / Data
Δφ_jj [rad]

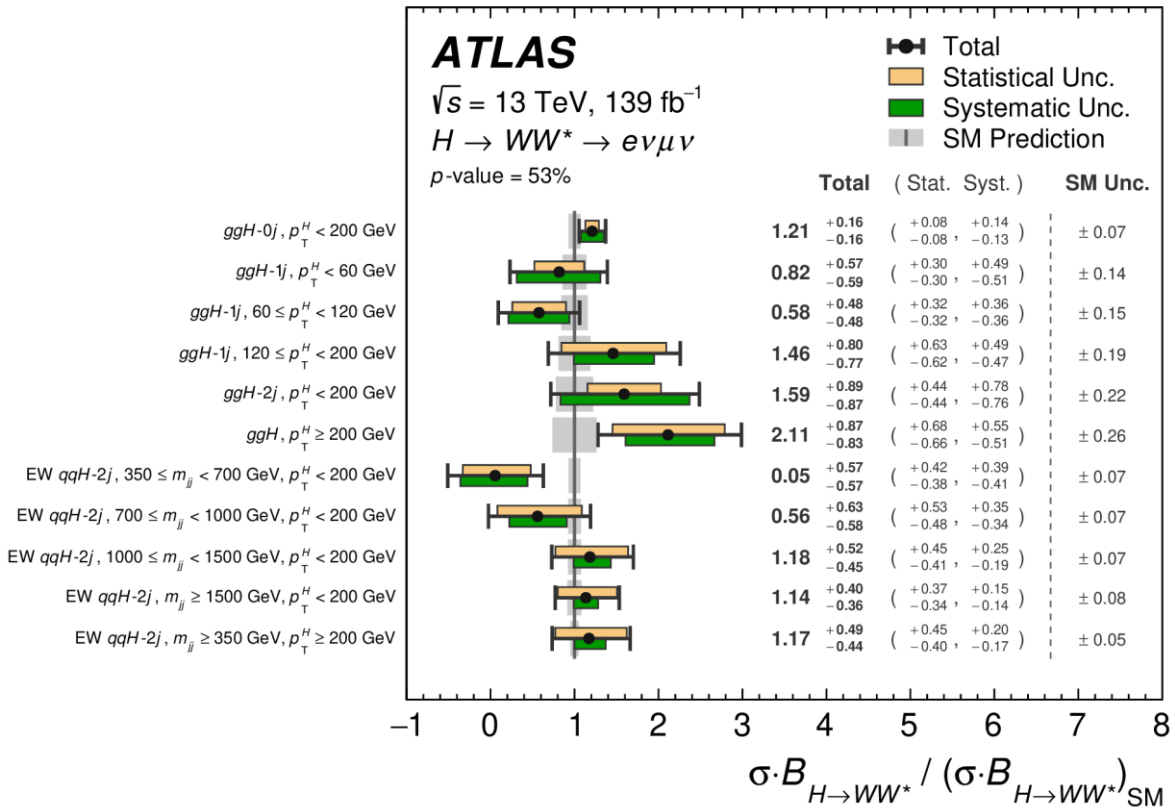

ATLAS
√s = 13 TeV, 139 fb⁻¹
VBF H→ WW* → evμv
Data
Data Stat. Unc.
Data Total Unc.
Powheg+Pythia8
Powheg+Herwig7
VBFNLO@LO+Pythia8
VBFNLO@NLO
MG5+Herwig7
dσ^fid/dp_T^l₂ [fb/GeV]
Pred. / Data
p_T^l₂ [GeV]

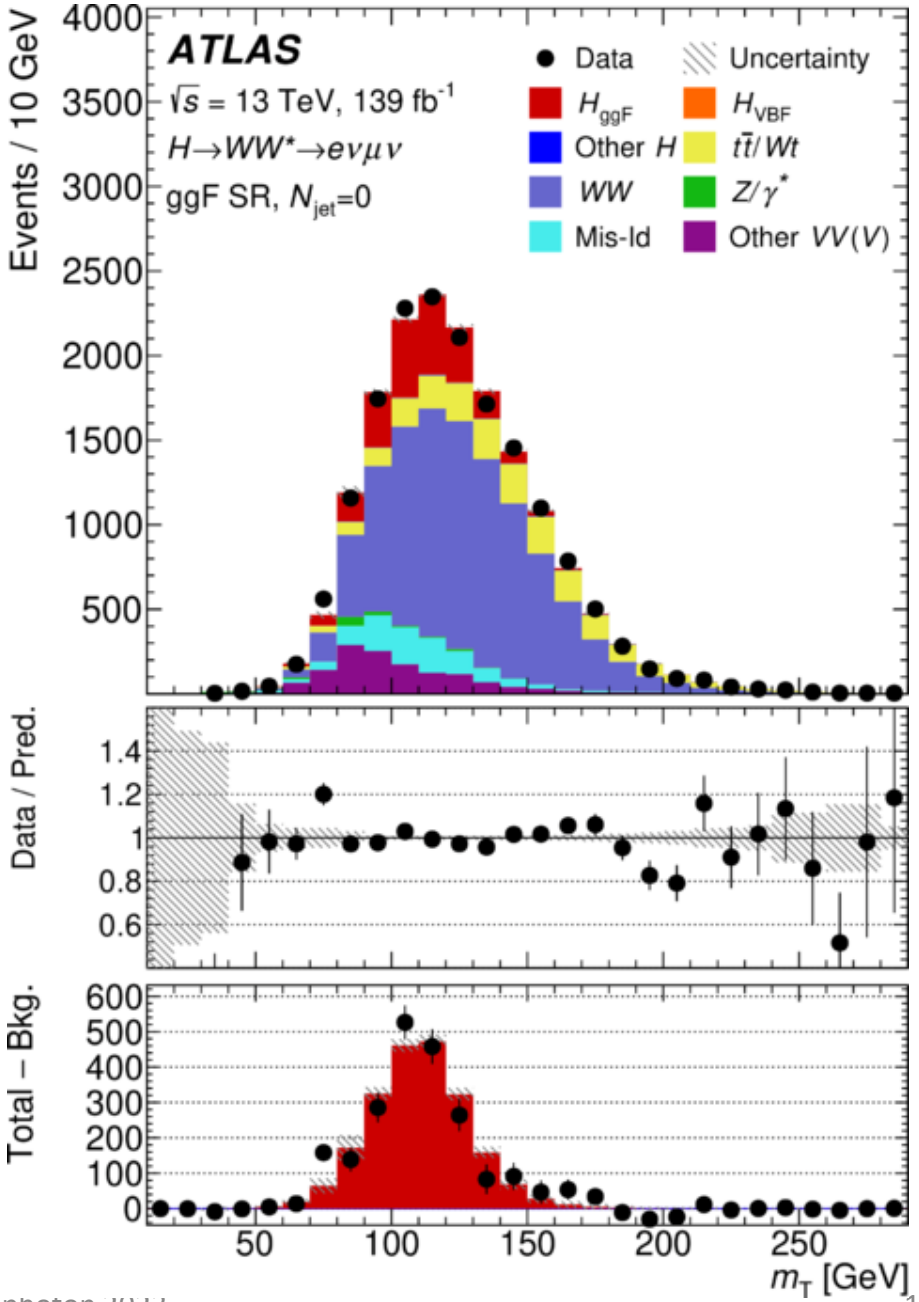
Backup H →ττ Differential



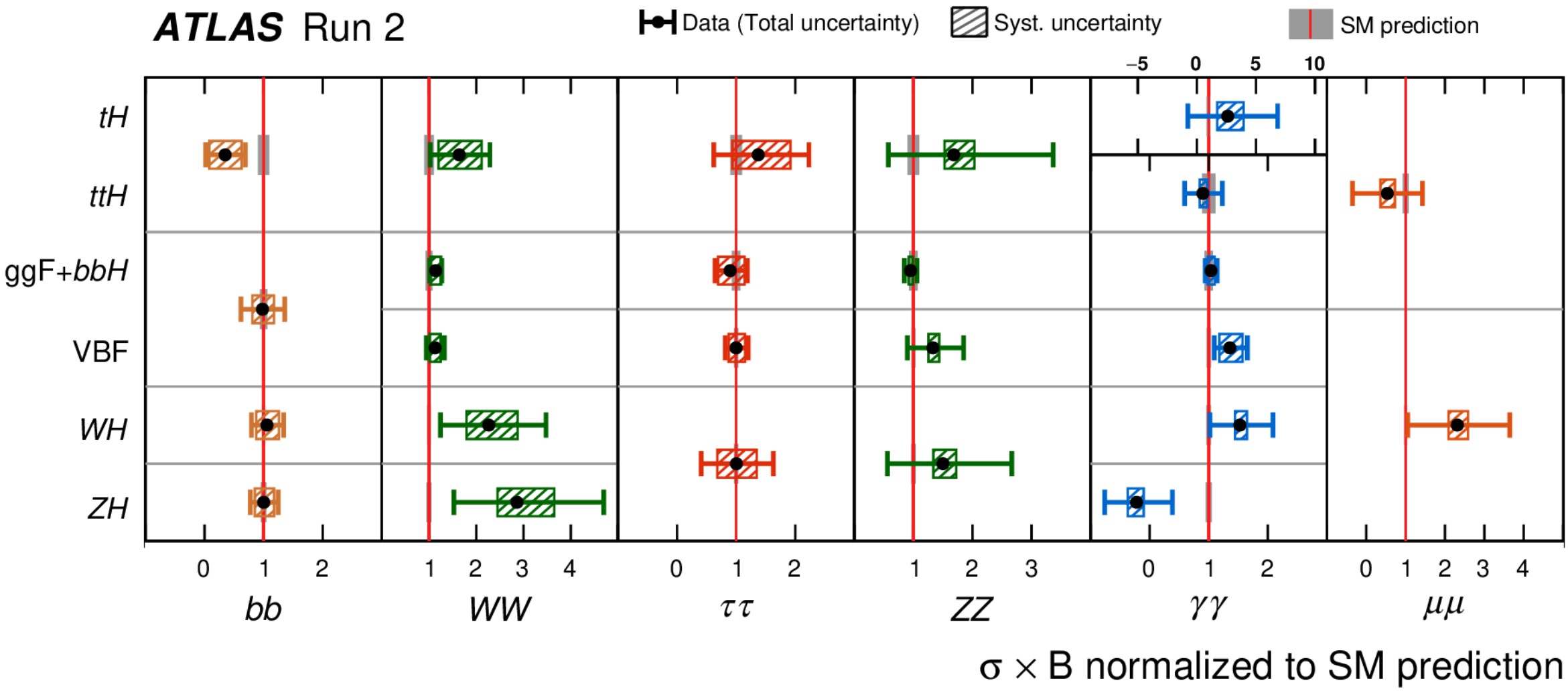
H→WW

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/HIGG-2021-20/

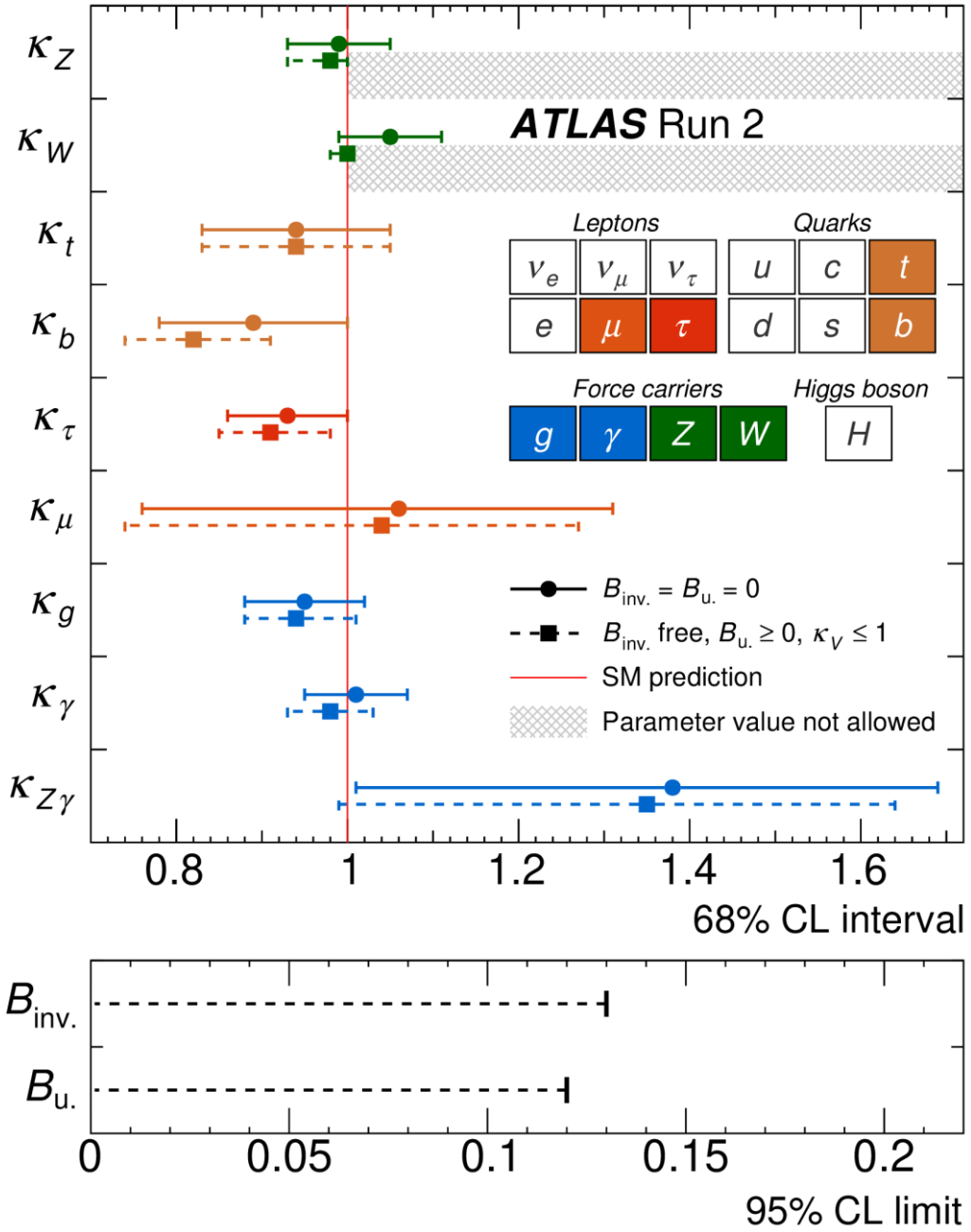




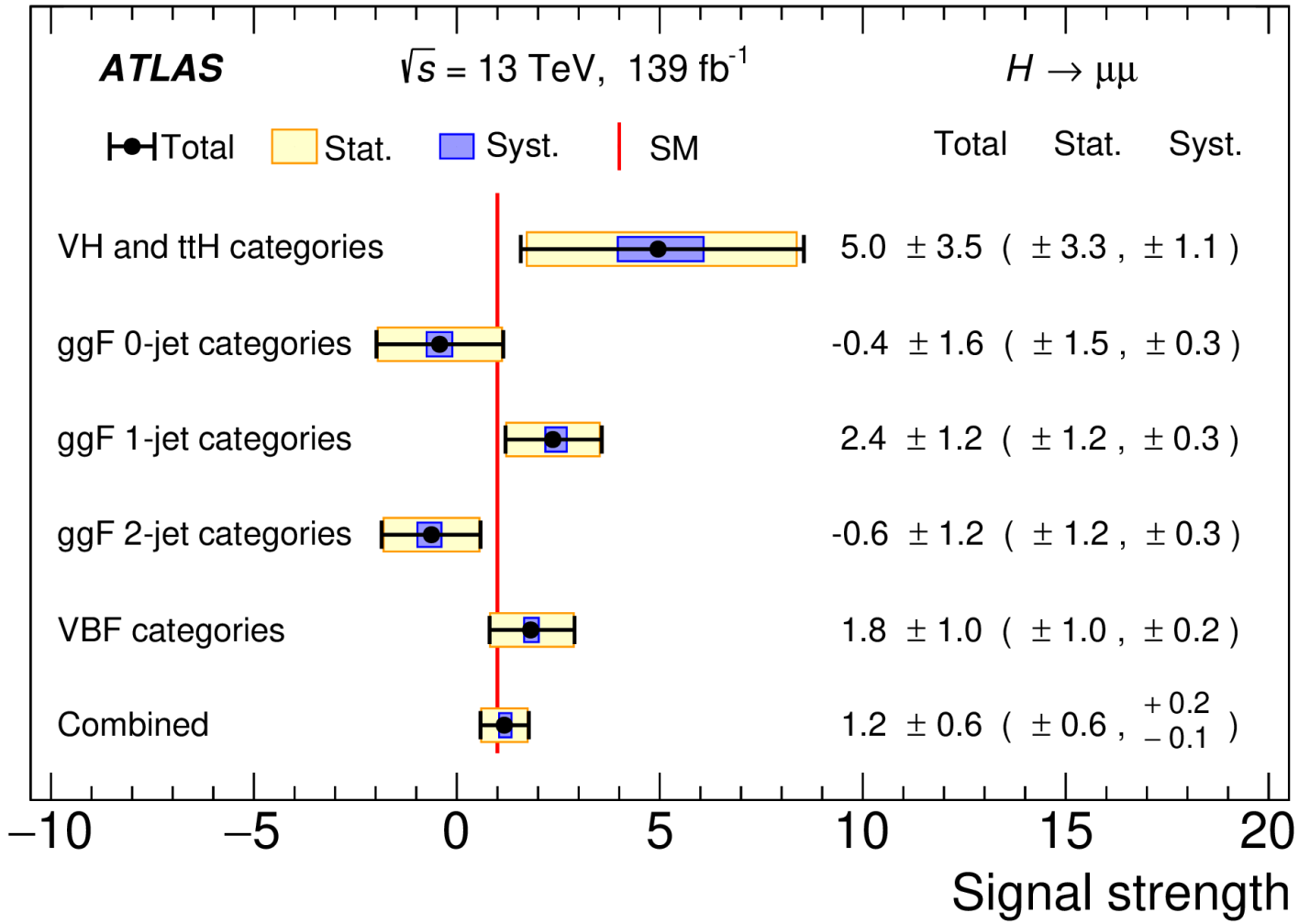
Backup Higgs Combination



Backup Higgs Combination



Backup H →μμ


ATLAS
√s = 13 TeV, 139 fb-1
H → μμ
Total
Stat.
Syst.
SM
Total Stat. Syst.
VH and ttH categories
5.0 ± 3.5 (± 3.3 , ± 1.1)
ggF 0-jet categories
-0.4 ± 1.6 (± 1.5 , ± 0.3)
ggF 1-jet categories
2.4 ± 1.2 (± 1.2 , ± 0.3)
ggF 2-jet categories
-0.6 ± 1.2 (± 1.2 , ± 0.3)
VBF categories
1.8 ± 1.0 (± 1.0 , ± 0.2)
Combined
1.2 ± 0.6 (± 0.6 , +0.2 −0.1)
−10
−5
0
5
10
15
20
Signal strength