Higgs 2021, 18th-22th Oct. 2021

New Higgs results from ATLAS

(wrt previous edition of this conference)

O(40) results (either completely new, or published version, etc.)

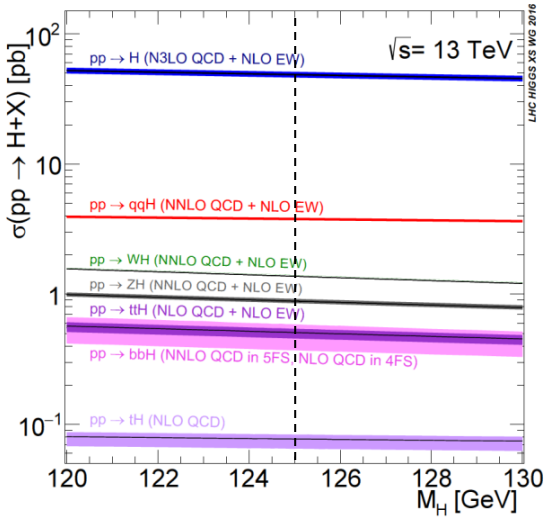
→Could not be exhaustive on all results:
-a bit of arbitrary on choice items shown
-missing items are in appendice (topic covered in wildcard talk not discussed here)

Details in dedicated talks in the conference by experts on the topics

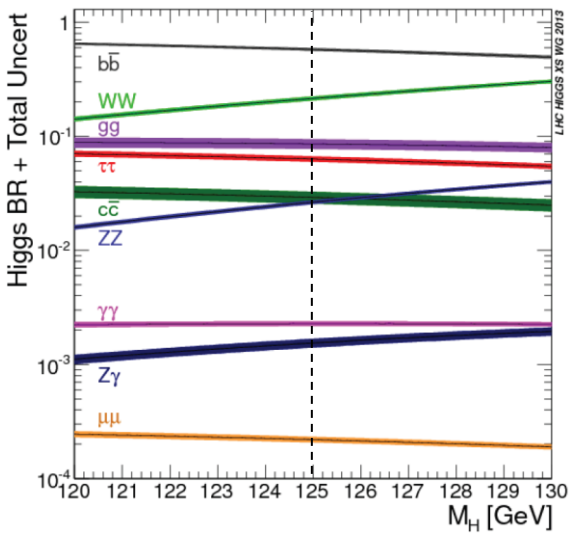
Marc Escalier, IJCLab Orsay/France, on behalf of ATLAS Collaboration

Generalities (flashed slide)

- Production (SM)



- Decay (SM)



YR4, arxiv: 1610.07922 [hep-ph]
YR3, arxiv: 1307.1347 [hep-ph]

Signal strengths, scale factor μ, κ framework

- Direct (dis-)agreement SM 🙂
- f(ref.): model, precision ☹
- higher sys. error ☹

$\mu=(\sigma \times BR)/(\sigma \times BR)_{SM}$

$$\sigma(i \to H \to f) = \kappa_i^2 \sigma_i^{SM} \frac{\kappa_f^2 \Gamma_f^{SM}}{\kappa_H^2 \Gamma_H^{SM}}$$

Simplified Template Cross-Section (STXS)

- 'Simplified' : indep. decay mode 🙂 →easy to combine
- Reduced th. sys. error 🙂
- region detector acceptance $|y_H|<2.5$ 🙂 →reduced model dependency
- Enhance sensitivity for BSM models 🙂

$\sigma(i \to H)_{\text{phase space (truth bins)}}$

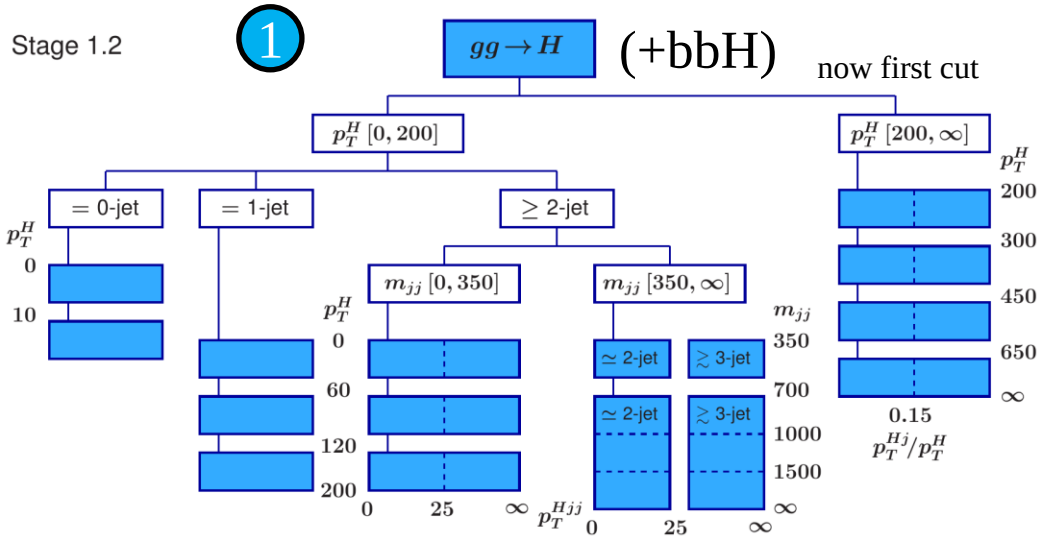
Fiducial / differential cross-sections

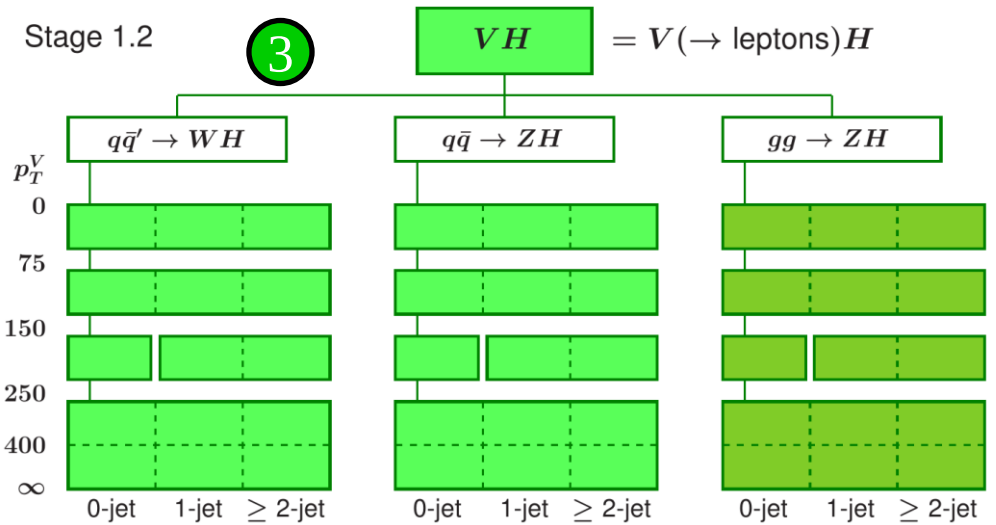
- Specific to decay mode ☹ →not easy to combine
- region detector acceptance 🙂 →tiny model dependency
- Reduced th. syst. error 🙂

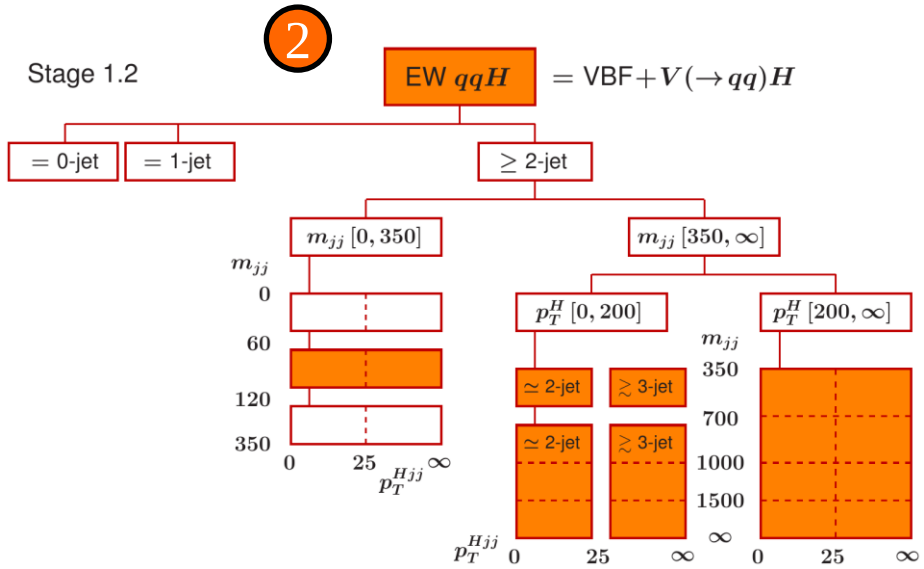
$\sigma(i \to H \to j)_{\text{phase space}}$

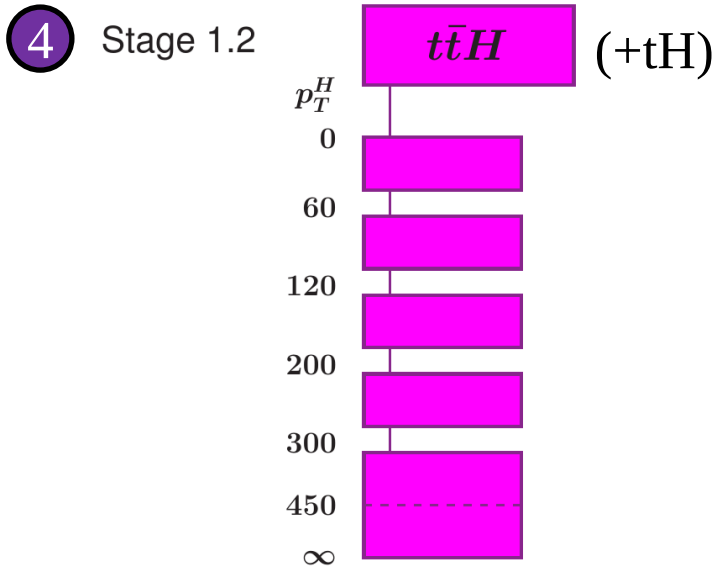
STXS stage 1.2 (flashed slide)

(energy variable units : [GeV])









H_{125}

H→WW*→eνμν

ATLAS-CONF-2021-014
March 2021

- Large BR 🙂 bad resolution (MET) ☹️

- Signature

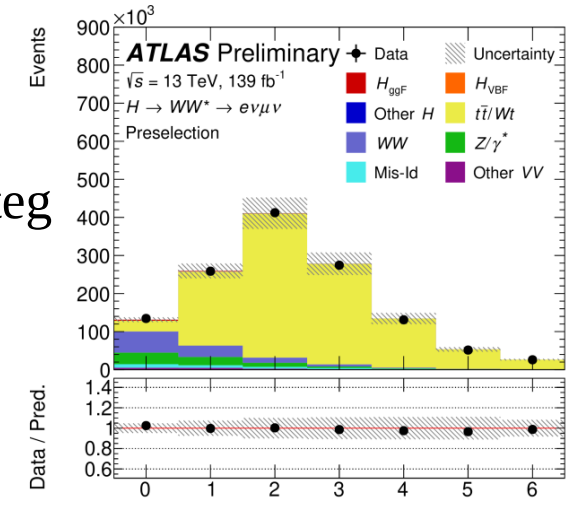
e, μ (suppr. DY), MET (suppr. DY)
close leptons (spin correlations)

- Categories

#jet, ggH/VBF, kinematics: mirroring STXS

- Background

WW, top, etc.
Varies a lot w/ categ
Data-driven

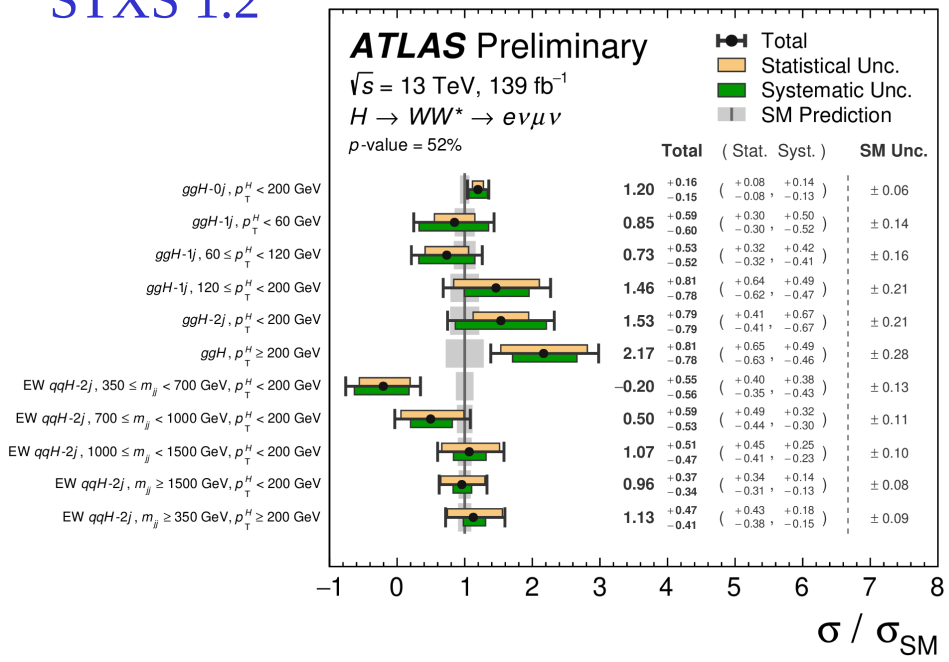


- Prod. modes

$\mu_{ggH}=1.20\ ^{+0.16}_{-0.15}$
$\mu_{VBF}=0.99\ ^{+0.24}_{-0.20}$

Dominated by syst.

- STXS 1.2



- ggH+2 j, probe mix {0^{++} (SM), 0^{-+}}
- VBF, probe HVV=f(polarisation)

CERN-EP-2021-096 (36.1 fb-1)
EPJC Sept. 2021

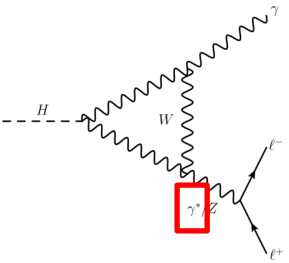
Results consistent w/ SM
1st analysis on topic

$H \to \gamma^* \gamma \to ll\gamma$, low m_{ll}

PLB 819, 136412 (2021)
March-May 2021

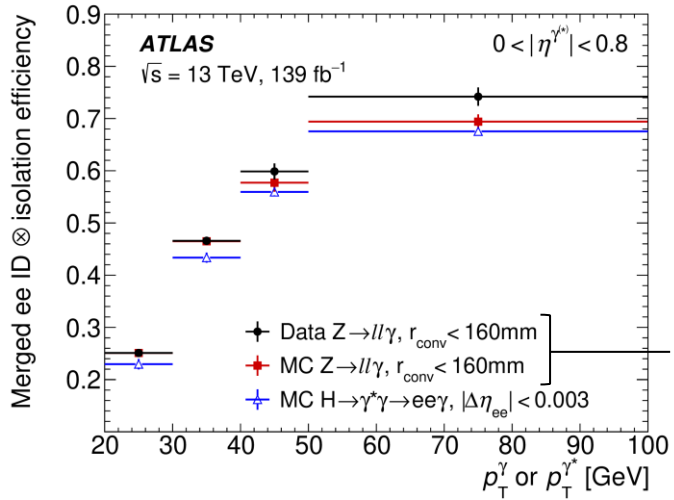
- Complementary to $H \to Z\gamma$ ($m_{ll} \approx m_Z$)

$Z_{obs}=2.2\ \sigma$ ($Z_{exp}=1.2\ \sigma$) PLB 809, 135754 (2020)



- m_{ll}<30 GeV (suppr. Z)
  Dalitz dominated
  m_{ll}: exclude $m_{J/\psi}$, $m_{\Upsilon(nS)}$
- $(\theta \sim m/p_T) \Leftrightarrow$ e: often 1 cluster EM
  →dedicated trigger/id

≥2 leptons (e, μ), OS same flav. [resolved]
or
=1 merged-ee (2 tracks) [merged]
Validated w/ low-R conv. γ



(FSR γ)
from $Z \to ll\gamma$

- Background : llγ

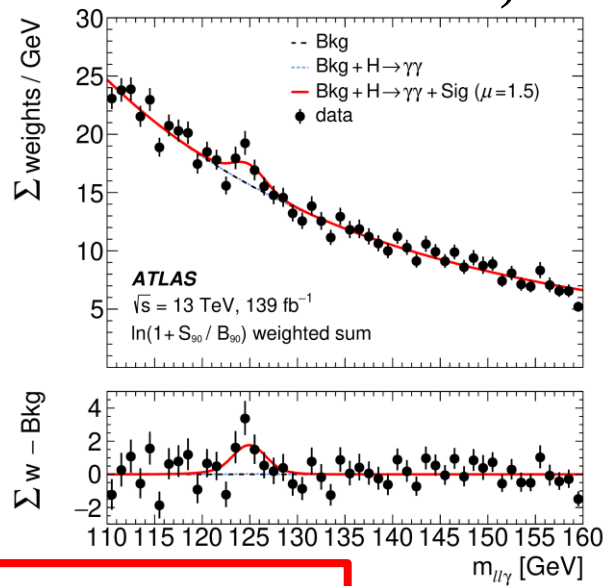
Parametrised/directly fit data
$H \to \gamma\gamma$ w/ conversion (ee category)
same shape as signal

- Categories

(process, resolved/merged, lepton flavour)

- Final DV (Discriminative Variable)

$m_{ll\gamma}$



$Z_{obs}=3.2$ ($Z_{exp}=2.1$)
$\Leftrightarrow$ Evidence
$\mu = 1.5 \pm 0.5\ (stat)\ ^{+0.2}_{-0.1}\ (sys)$

VH, H→bb

- highest BR, but high bkg

V(νν/lν/ll): suppr. multijets

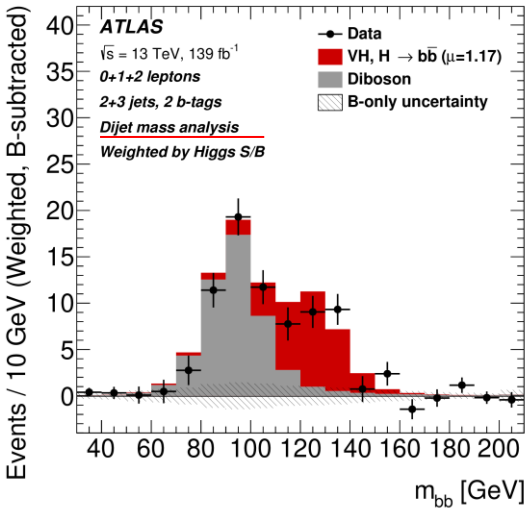
Resolved

- b-jet correction: σ ↓ 20-40 %

Final DV: BDT

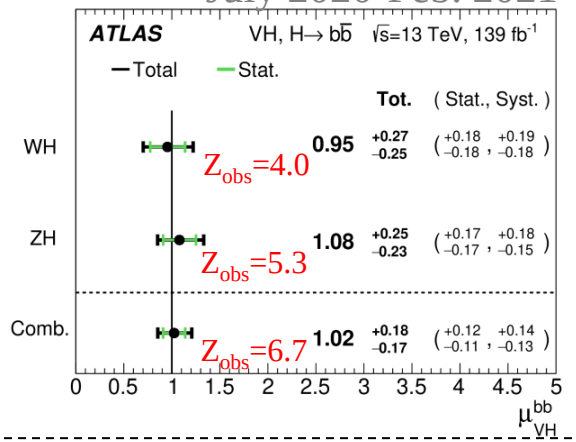
Categories: #l, #jets, p_T^V

- Validation: m_{bb} + VZ



EPJC 81, 178 (2021)

July 2020-Feb. 2021



Boosted topology ≥1 J=jj (2 track-jets)

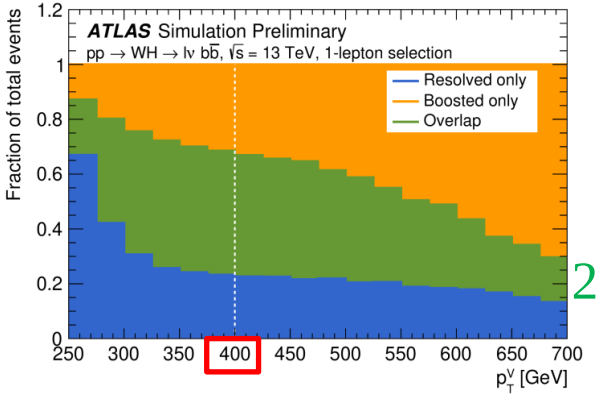
$p_T^{V,t}$≥250 GeV, including $p_T^{V,t}$ ≥400 GeV

Z_{obs}=2.1 (Z_{exp}=2.7)

PLB 816, 136204 (2021)

Aug. 2020-May 2021

Combination



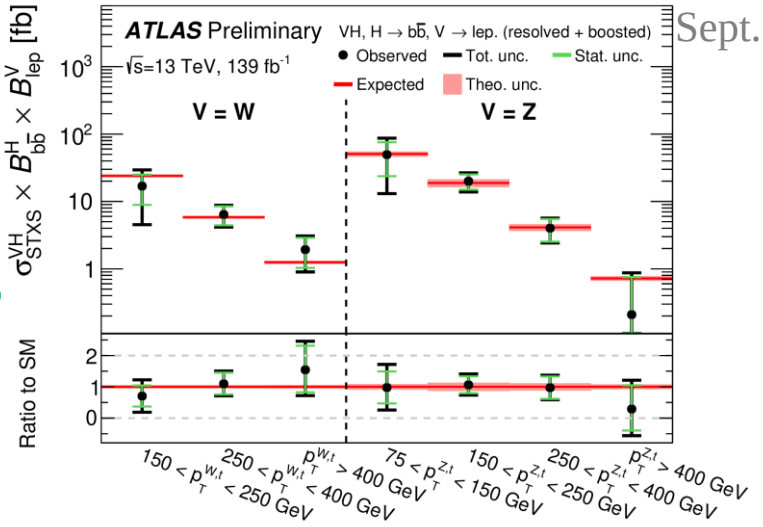
25 %

Resolved (R=0.4) Boosted (R=1.0)

- STXS 1.2

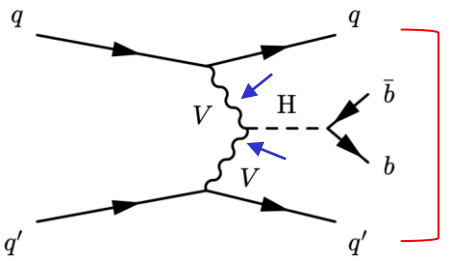
ATLAS-CONF-2021-051

Sept. 2021



VBF and boosted all prod., H→bb

- VBF



Large Δη gap
No colour flow
(suppr. hadr. activity)

Final DV m_{bb}

Categories fwd/central jets + NN

- Results

EPJC 81, 537 (2021)
Nov. 2020-June 2021

Z_{obs}=2.6
Z_{exp}=2.8
$\mu=0.95^{+0.38}_{-0.36}$ dominated by stat

STXS p_T^H>200 GeV (BSM): no deviation

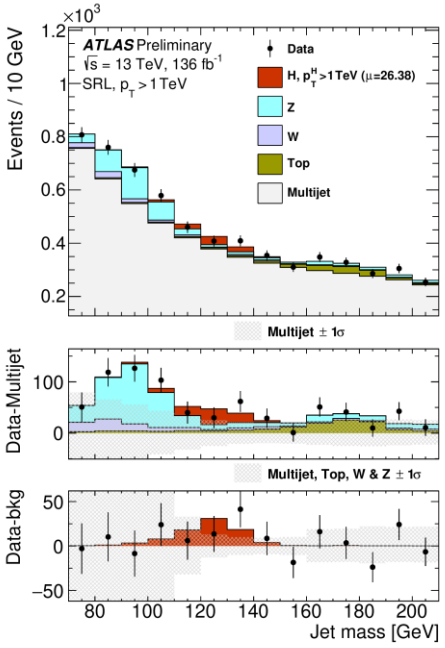
- Combined w/ VBF H(bb)+γ (Z_{obs}=1.0 σ)
(JHEP 03, 268 (2021), 132 fb^{-1})

Z_{obs}=2.9
Z_{exp}=2.9

- Boosted all prod. modes

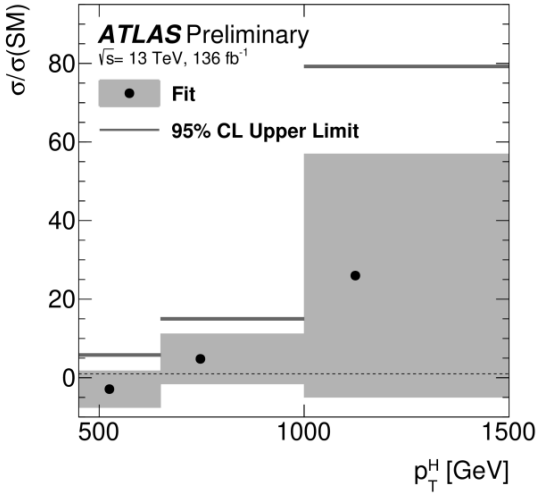
p_T^H>450 GeV (even p_T^H>1 TeV bin)
H→bb reco as single large R jet
b-tagging for contained tracks

First ATLAS study
w/ H→bb very high p_T
and no particular production mode



ATLAS-CONF-2021-010
March 2021

- Limits 95 % CL



H→cc

ATLAS-CONF-2021-021
June 2021

2nd quark generation

V(νν/lν/ll)H(cc)

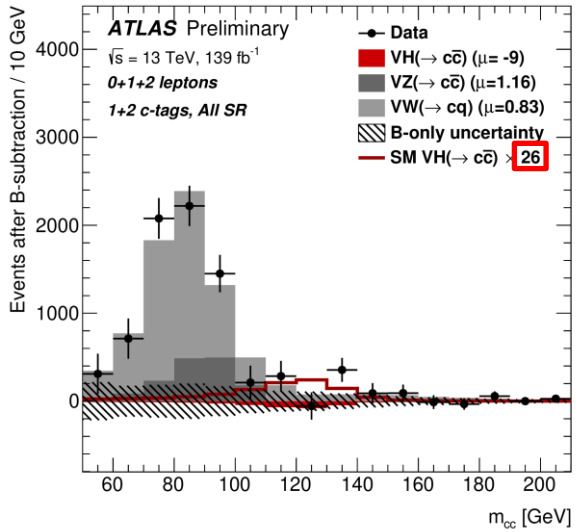
- c-tagging: MVA

eff(c)=27 %
eff(b)=8 %
eff(j)=1.6 %

- Categories

#leptons, #jets, #c, p_T^V

- Final DV



$$\mu_{VH(c\bar{c})}(\kappa_c) = \frac{\kappa_c^2}{1 + B^{SM}_{H\to c\bar{c}}(\kappa_c^2 - 1)}$$

- Limit μ

obs: 26xSM
exp: 31xSM

- $|\kappa_c|$

limit 95 %
obs: <8.5
exp: <12.4

- Validation

(different selection)
VZ(cc), VW(cq)
Z_{obs}=2.6, Z_{obs}=3.8
(Z_{exp}=2.6, Z_{exp}=4.6)

H→ττ

ATLAS-CONF-2021-044
July 2021

- 3rd generation Yukawa coupling to leptons

- **Signature**

MET (τ decay)
≥1 jet (suppr. bkg + categ)

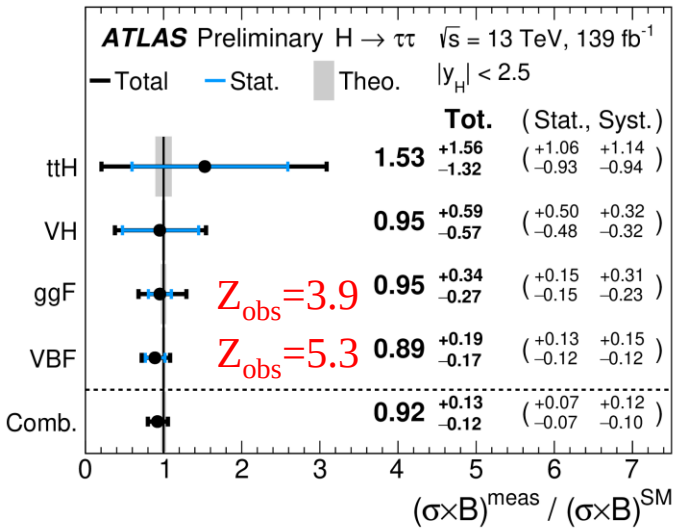
- **Background**

Z(ττ)+j, top, etc.

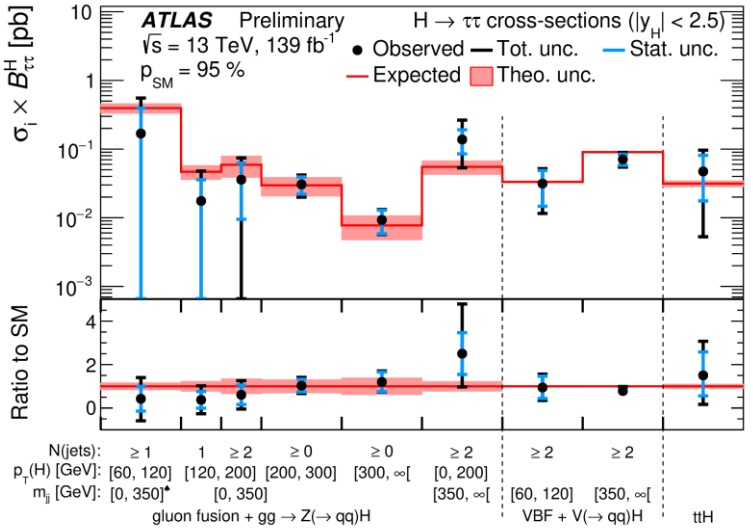
- **Categorization**

Mirror STXS: f(p_T(H), #jets)

- μ_i



- STXS



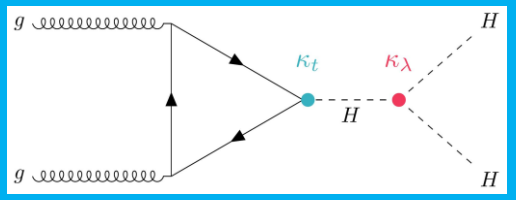
Syst. dominated by th. signal modelisation

HH

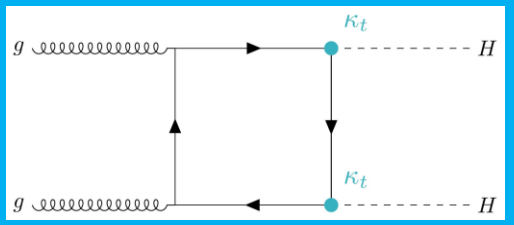
(flashed slide)

- **Non-resonant** (in the HH)

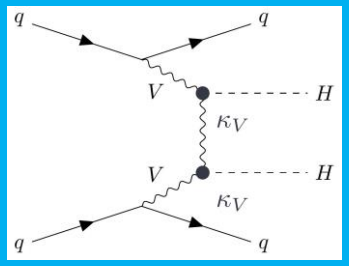
ggF

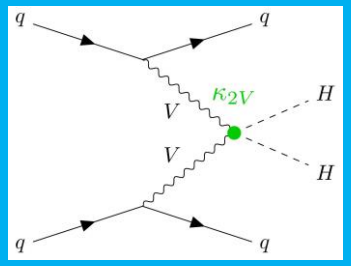


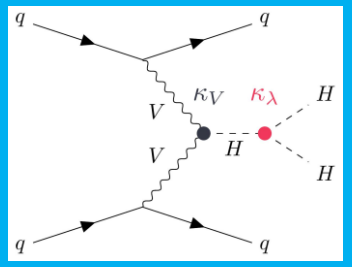
« - »
(SM)



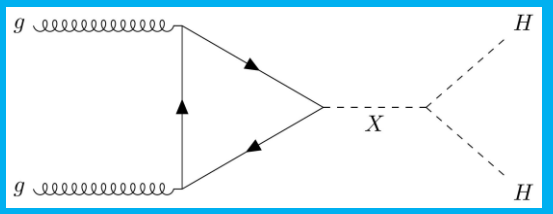
VBF

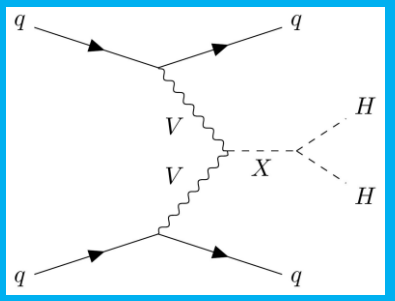


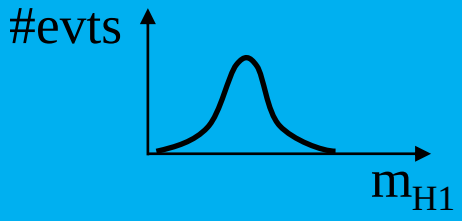


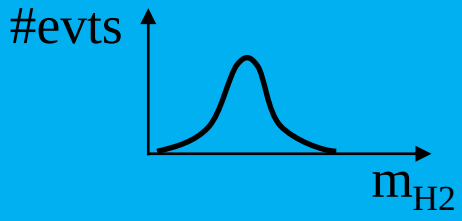


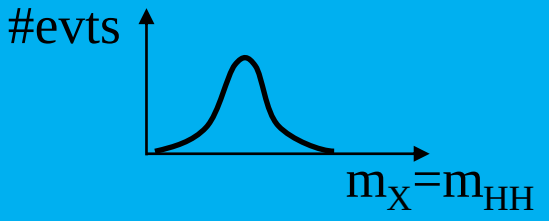
- **Resonant**











- Restricting to $H_{125}H_{125}$ (aa not reviewed in this category)
- Formally, HH may be classified as

$pp \rightarrow H_{125}H_{125}$ for non-resonant or $pp \rightarrow BSM \rightarrow H_{125}H_{125}$ for resonant

→prefer a specific thematic HH

HH searches

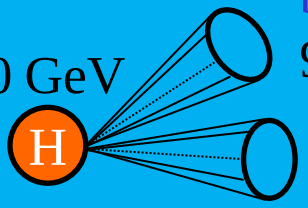
Non-resonant

- bb bb — ATLAS-CONF-2021-035, July 2021

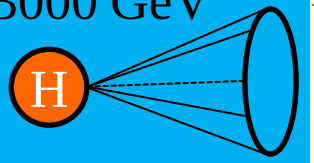
Largest rate
Final DV: m_{HH}

Non-resonant: no new results since previous edition

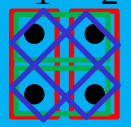
resolved
251-1500 GeV



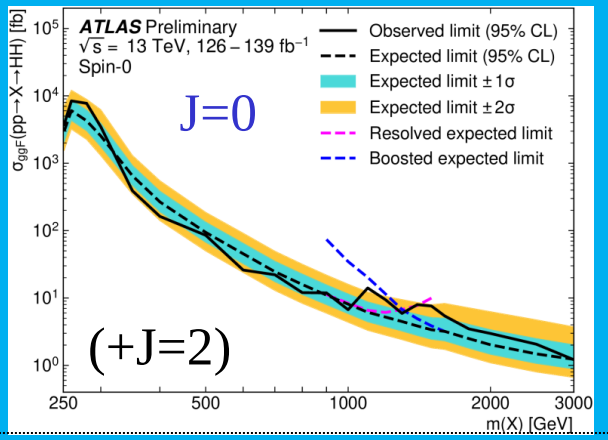
boosted
900-3000 GeV



H_1 H_2



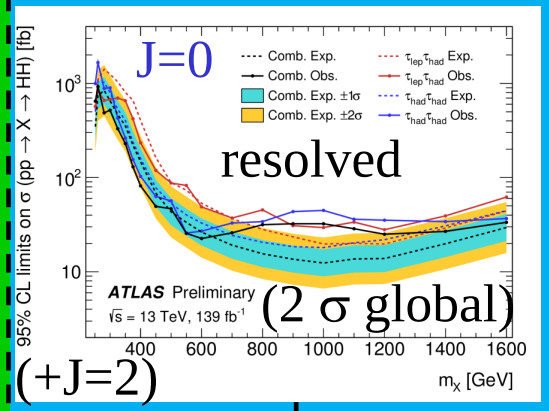
Pairing: BDT

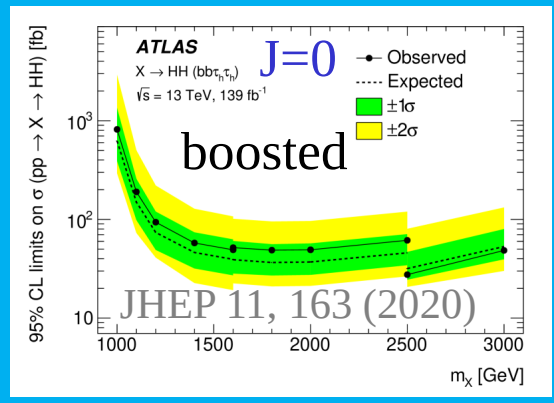


- $bb\tau\tau$ ($\tau_{had}\tau_{had}$, $\tau_{had}\tau_{lep}$) — ATLAS-CONF-2021-030, July 2021

Intermediate rate
Final DV: MVA

Limits σ(HH→bbττ)
obs: 4.7xSM
exp: 3.9xSM

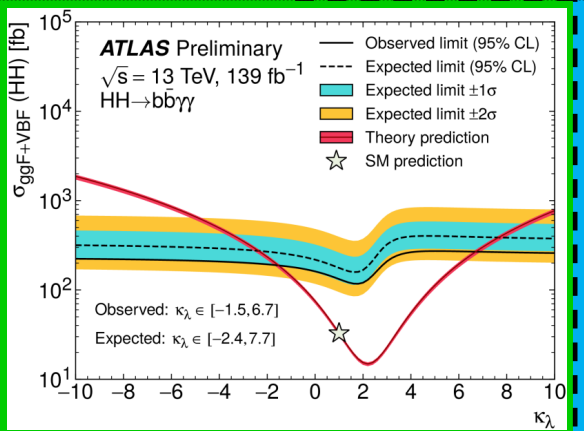


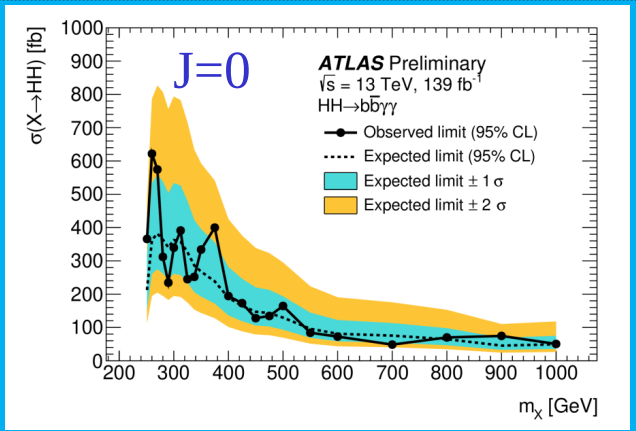


- bb γγ — ATLAS-CONF-2021-016, March 2021

Very low rate
Final DV: $m_{\gamma\gamma}$

- Limit
  obs : 4.1xSM
  exp: 5.5xSM
- κ_λ limit
  obs : [-1.5, 6.7]
  exp : [-2.4, 7.7]

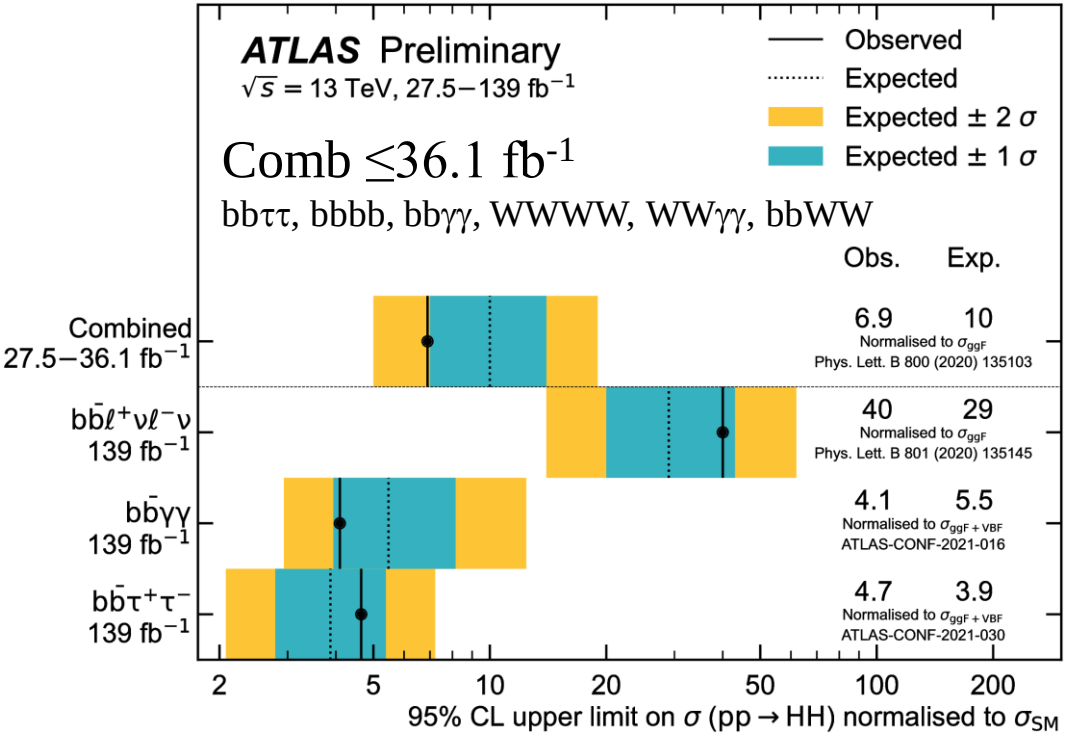




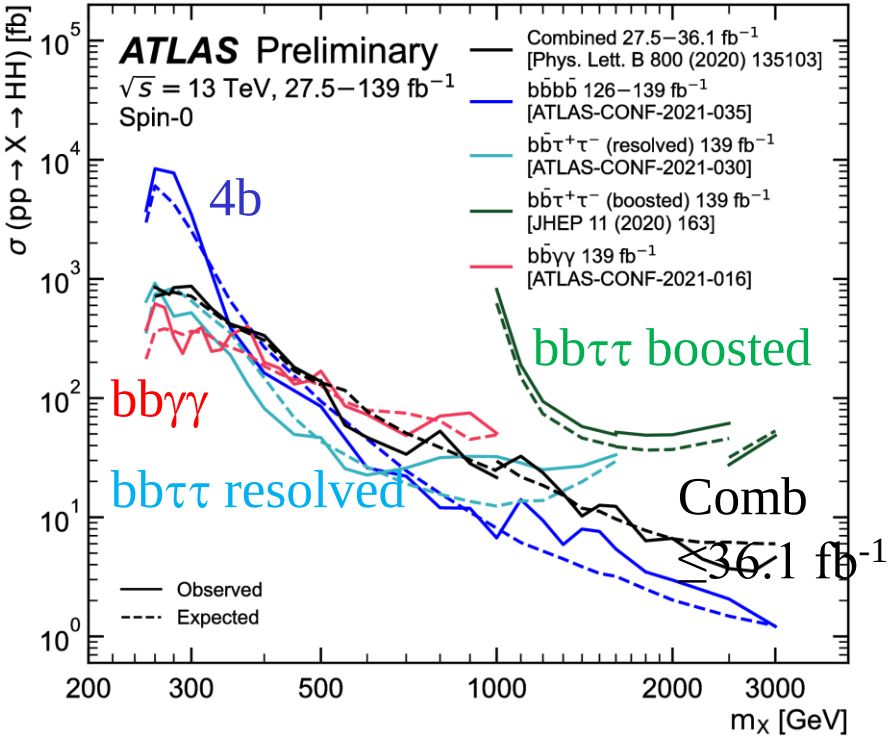
Individual channels Full Run 2 (+partial comb.)

ATL-PHYS-PUB-2021-031
July 2021

Non-resonant



Resonant



$pp \rightarrow H_{125} \rightarrow BSM$

$pp \rightarrow BSM_{\neq H} \rightarrow H$

$pp \rightarrow BSM\ H$

Analyses below are moved to backup in order to respect time constraints (20') :
(but described in detailed talks) :

H→aa
NMSSM, $Z(ll)H(\tilde{\chi}_2^0\tilde{\chi}_1^0 \rightarrow a(bb)\ \tilde{\chi}_1^0\tilde{\chi}_1^0)$
H→ZX→4l, H→XX→4l, X={J=0: s, A, J=1: Z_d}
H→Z(ll)a, Z(ll)η_c, Z(ll)J/ψ
A→Z(ll)H, H→bb, H→WW
Doubly charged $H^{\pm\pm}$

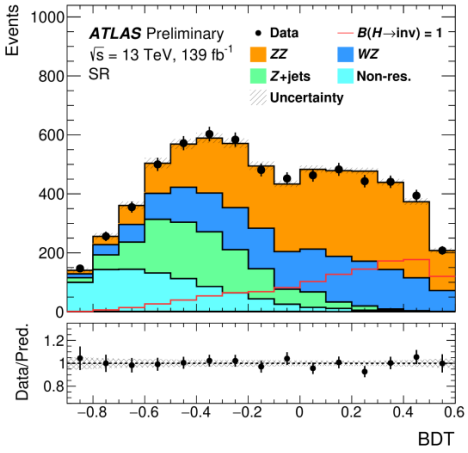
H_{125}→inv and dark matter

ATLAS-CONF-2021-029
July 2021

- H_{125} mediator Z(ll)H(χχ), DM(χ), scalar/Majorana fermion

Signature: 2 l + MET

Bkg dominated by ZZ : CR 4l



95 % limit BR(H→inv)

obs: 18 %

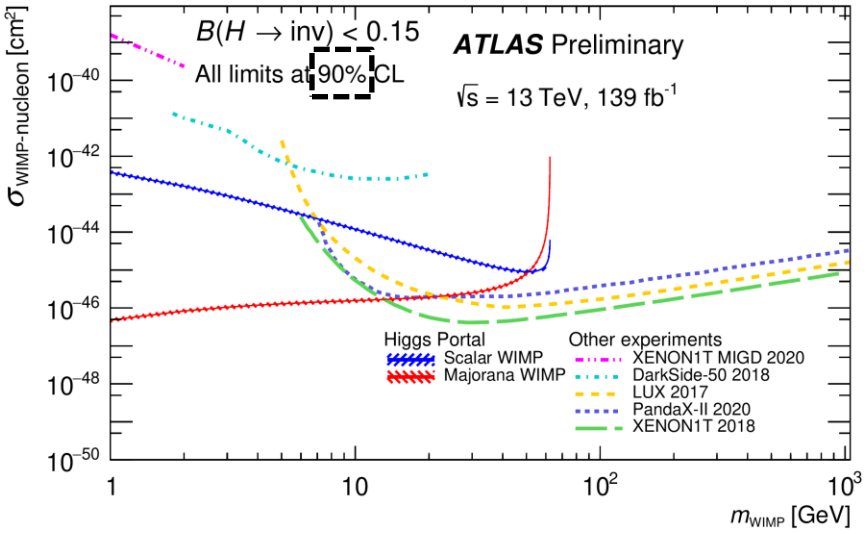
exp: 18 %

(Run 1+2 comb, ATLAS-CONF-2020-052

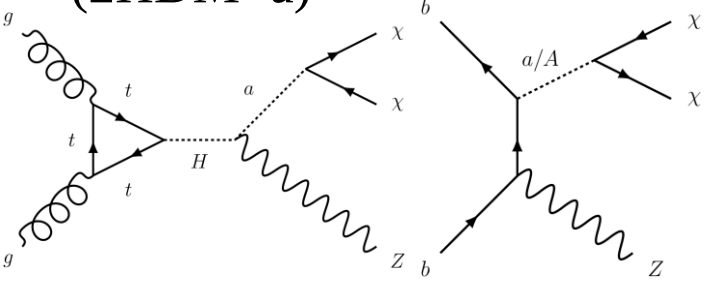
obs: 11 %, exp: 11 %)

Complementary to direct searches

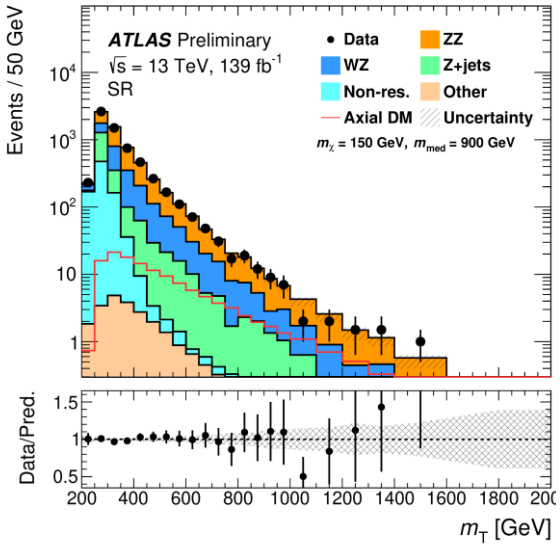
Interpretation: $\sigma_{DM\text{-}nucleon}=f(m_{WIMP})$



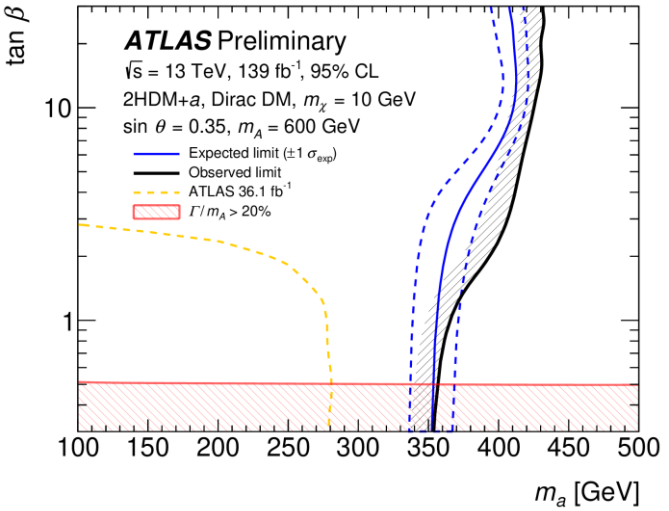
- Pseudo-scalar mediator a (2HDM+a)



$$m_{\mathrm{T}} = \sqrt{\sqrt{m_Z^2 + (p_{\mathrm{T}}^{\ell\ell})^2} + \sqrt{m_Z^2 + (E_{\mathrm{T}}^{\mathrm{miss}})^2} - (\vec{p}_{\mathrm{T}}^{\ell\ell} + \vec{E}_{\mathrm{T}}^{\mathrm{miss}})^2}$$



Exclusion limits

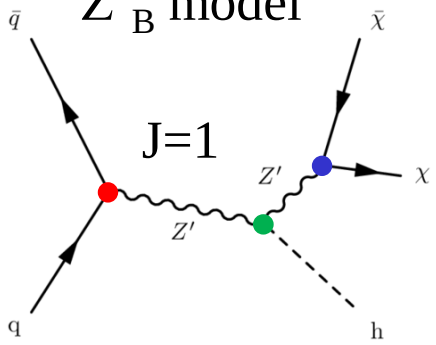


Dark matter/Mono-H, $H_{125} \rightarrow \gamma\gamma$

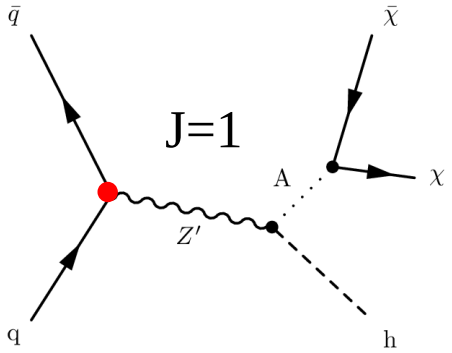
JHEP 10, 13 (2021)
Avril-Oct. 2021

DM: Dirac fermion

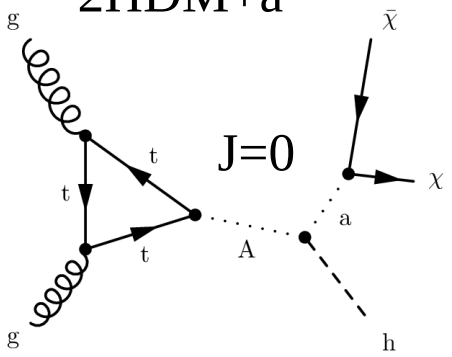
Z'_B model



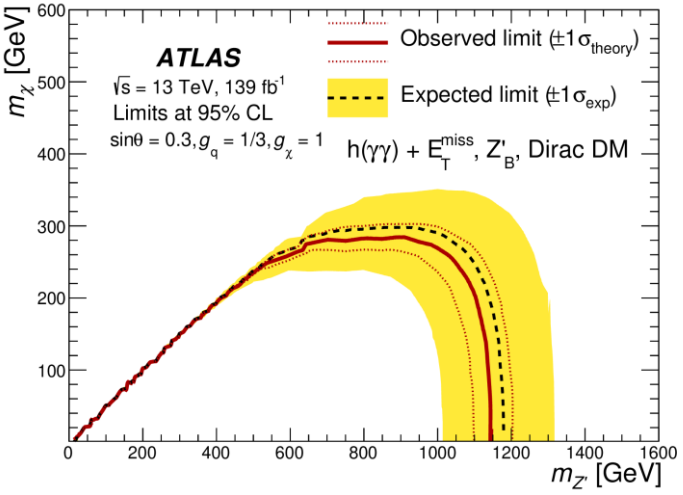
Z'-2HDM model

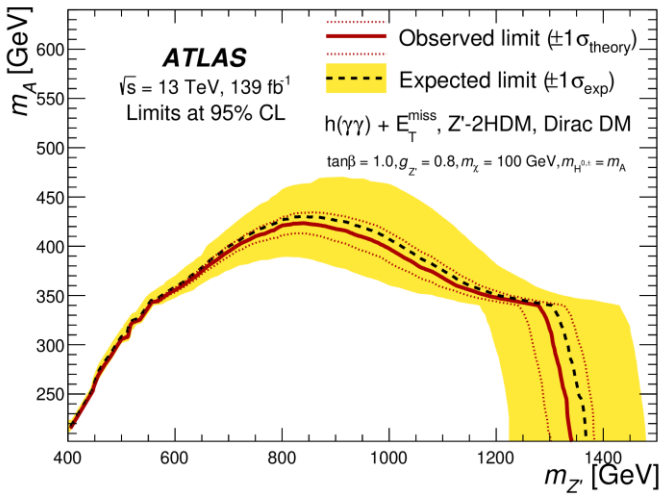


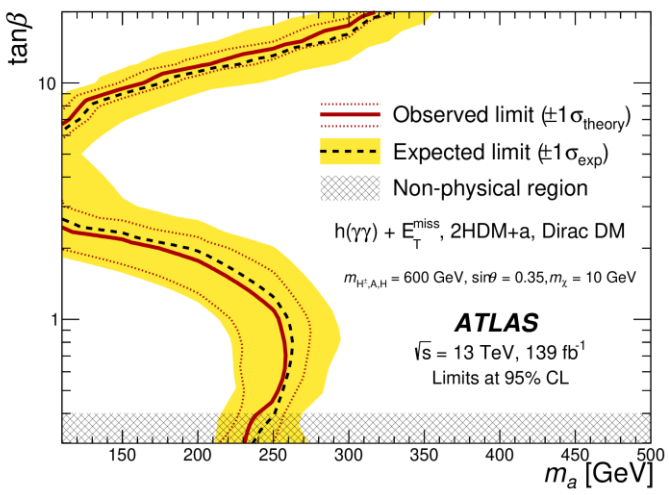
2HDM+a



BDT($p_T^{\gamma\gamma}$, MET significance)







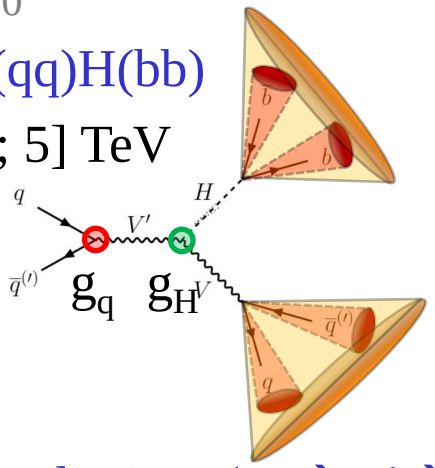
V'→VH, HVT, J=1

PRD 102, 112008 (2020)
Jul.-Dec. 2020

ATLAS-CONF-2021-026
June 2021

- V'→W(qq)H(bb)

$m_{V'} \in [1.5 ; 5]$ TeV



m_{JJ} (1-b, 2-b)

Large-R jets J(jj) +jet substructure

Final DV

m_{WH}

- W'→W(lν)H(bb)

$m_{W'} \in [0.4 ; 5]$ TeV

- Exclusion limits σ(pp→V'→VH) [95 % CL]

A: $m_{W'(Z')} < 2.90\ (2.20)$ TeV

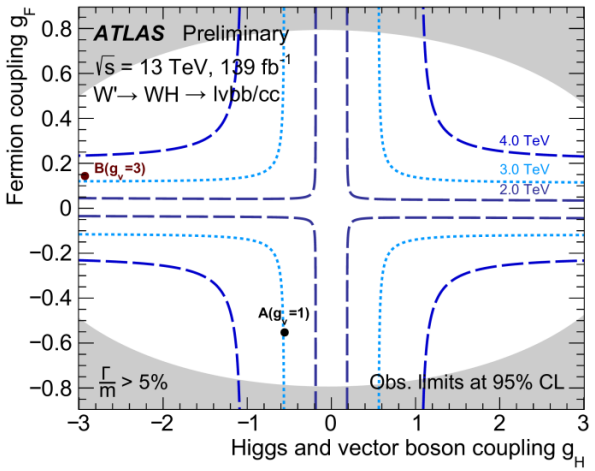
B: $m_{W'(Z')} < 3.20\ (2.65)$ TeV

… σ(pp→W'→WH) [95 % CL]

A: Obs: $m_{W'} < 2.95$ TeV

B: Obs: $m_{W'} < 3.15$ TeV

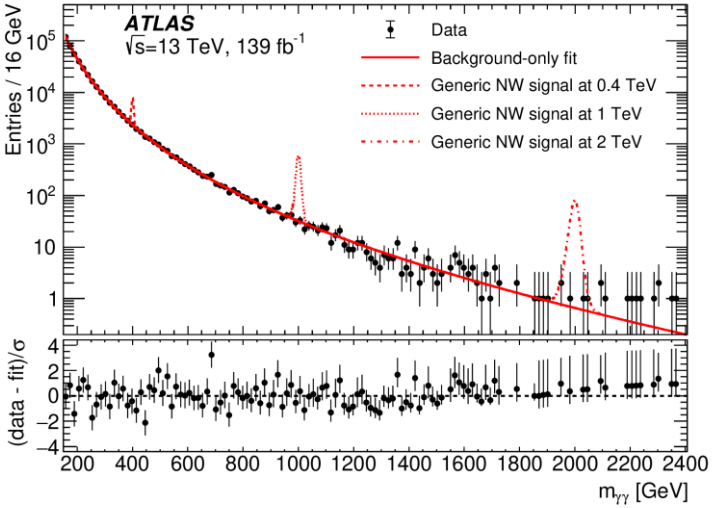
- Exclusion contour in $\{g_H, g_F\}$



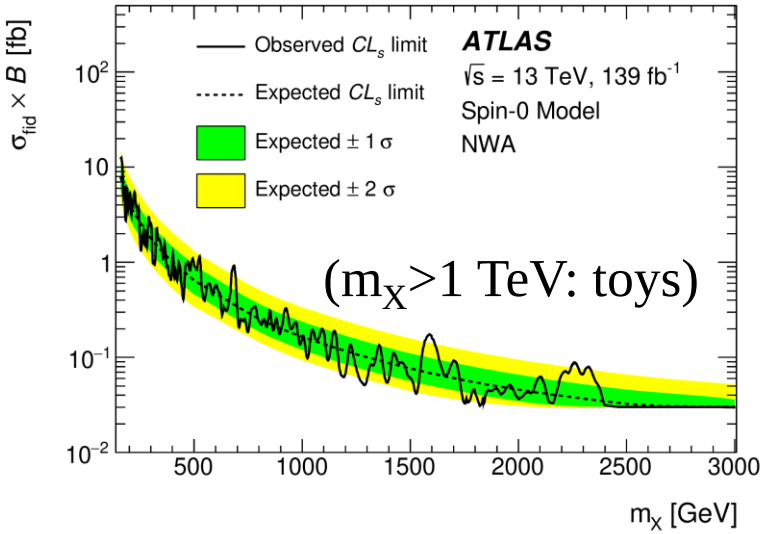
High mass X: X→γγ, X→ZZ→llll, llνν

- X→γγ J=0: NWA: 160-3000 GeV
  LWA: Γ: [0 ; 10 %]: 400-2800 GeV

PLB, 822, 136651 (2021)
Mar.-Nov. 2021



- Limits



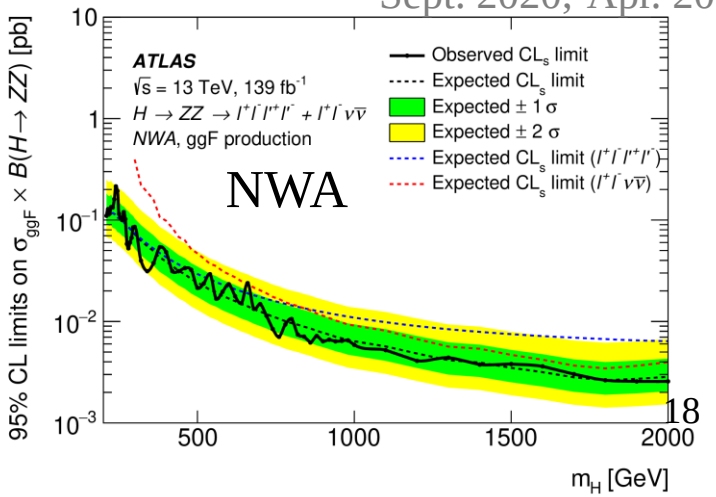
- X→ZZ→llll, llνν

J=0: NWA (ggH, VBF): 200-2000 GeV
+LWA (ggH): Γ/m_H=0.01-0.15 (400-2000 GeV)

+Exclusion limits contour 2HDM (I, II)

- Limits

EPJC 81, 332 (2021)
Sept. 2020,-Apr. 2021

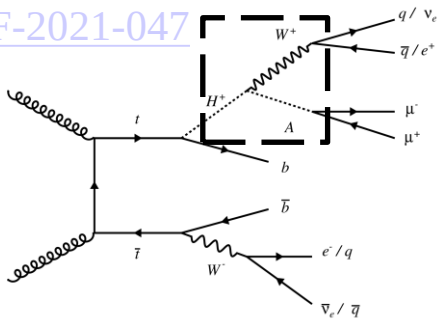


Singly charged Higgs $H^{\pm}$

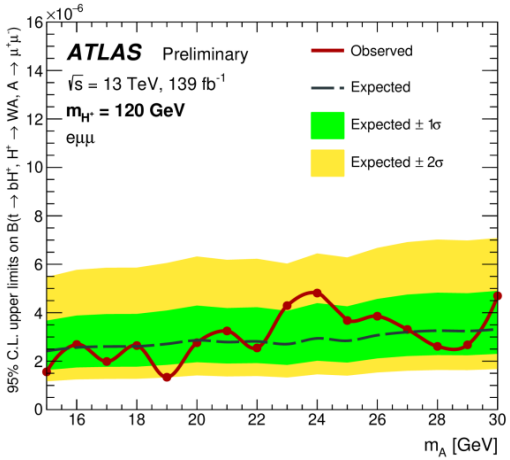
- $H^{\pm} \rightarrow W^{\pm}A$ (120-160 GeV)

ATLAS-CONF-2021-047

August 2021

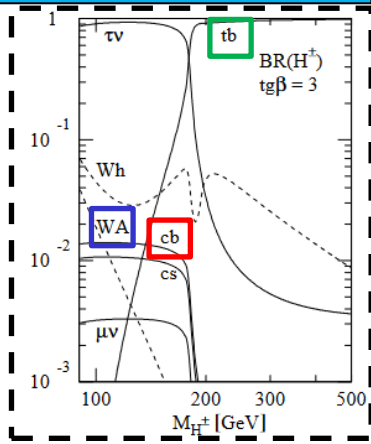


- Limit



2HDM I

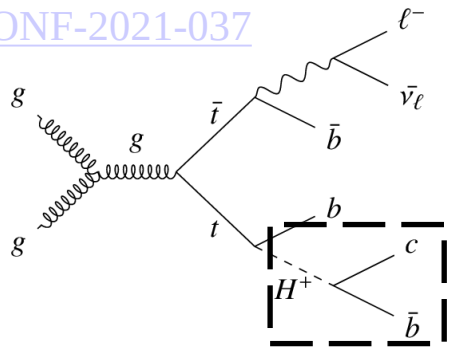
lower limit on tan β



- $H^{+} \rightarrow cb$ (60-160 GeV)

ATLAS-CONF-2021-037

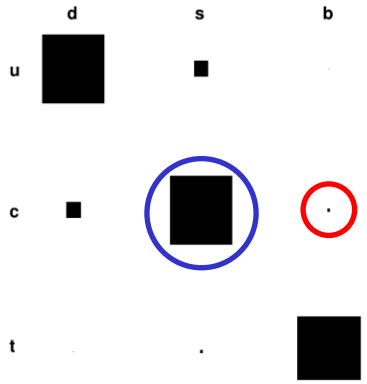
July 2021



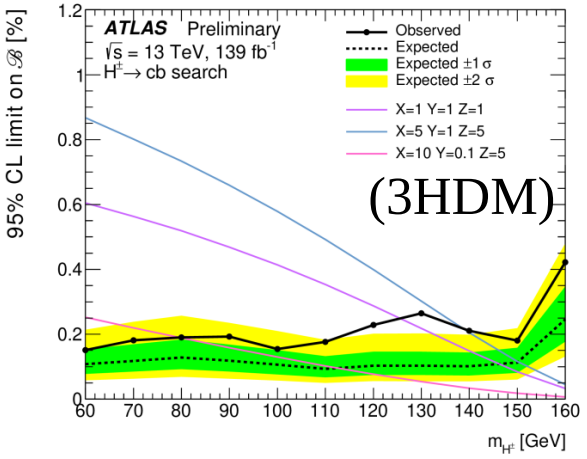
tt bkg (80 %) ↓

(W→cb)<< w/ $H^{\pm} \rightarrow$ cs, $H^{\pm} \rightarrow \tau\nu$

V_{CKM}



- Limit



Sens. ↑ x5

Conclusion

- Significant progress since Higgs 2020, ≈40 results. Could not cover all of them.
- Evidence H→γ*γ→llγ, STXS added for a few channels
- VH, H→bb combination resolved/boosted, inclusive very high p_T^H
- HH: full Run 2 for some channels since Higgs 2020
- BSM searches
- Follow wildcard talk and detailed talks on ATLAS analyses from experts on the topics

A: Wildcard [A]

A: ATLAS results
A+C: ATLAS+CMS results

- Single Higgs (H/'1-H')

A+C: SM Higgs-boson properties: mass, width, CP
A: H→bb
A: H→ττ
A: H+top
A+C: Higgs dσ/dX, σ_{fid}, σ_{tot}
A+C: Higgs couplings, STXS measurements
A: STXS, dσ/dX, σ_{fid} H→WW
A: STXS, dσ/dX, σ_{fid} H→γγ
A: STXS, dσ/dX, σ_{fid} H→4l
A+C: Quark Yukawa interactions
A+C: Yukawa leptons
A: CP Higgs
A: EFT
A+C: EFT Higgs
A+C: EFT results from Higgs and beyond
A+C: Exotic/invisible decays Higgs

- Double Higgs (HH)

A: HH
A: HH full Run 2
A: HH→bbττ

pp→$BSM_{\neq H}$→H, pp→BSM H
A: Low/high-mass resonances
A: Searches additional Higgs
A+C: additional scalar
A: Exotics/rare Higgs decays

Prospects
A+C: Modelling S, B: needs
A+C: Higgs Run 3, Run 4 and beyond

References

≥June 2021
Jan.-May 2021
Nov-Dec 2020

H_{125}

diboson

- $H \rightarrow WW^* \rightarrow e\nu\mu\nu$, Run 2, $\sqrt{s}$=13 TeV, L=139 fb^{-1}, ATLAS-CONF-2021-014, released March 2021, published May 2021
- $H \rightarrow WW$+jj, CP, polarisation, Run 2, $\sqrt{s}$=13 TeV, L=36.1 fb^{-1}, CERN-EP-2021-096, submitted EPJC Sept. 2021
- $H \rightarrow ll\gamma$, Run 2, $\sqrt{s}$=13 TeV, L=139 fb^{-1}, PLB 819, 136412 (2021), submitted March 2021, published May 2021

difermions

- VH $H \rightarrow bb$, Run 2, $\sqrt{s}$=13 TeV, L=126 fb^{-1}, EPJC 81, 178 (2021), submitted July 2020, published Feb. 2021
- VH $H \rightarrow bb$, boosted, Run 2, $\sqrt{s}$=13 TeV, L=139 fb^{-1}, PLB 816, 136204 (2021), submitted Aug. 2020, published May 2021
- VH $H \rightarrow bb$ combination, Run 2, $\sqrt{s}$=13 TeV, L=139 fb^{-1}, ATLAS-CONF-2021-051, released Sept. 2021
- VBF $H \rightarrow bb$, Run 2, $\sqrt{s}$=13 TeV, L=126 fb^{-1}, EPJC 81, 537 (2021), submitted: Nov. 2020, published June 2021
- VBF $H \rightarrow bb + \gamma$, Run 2, $\sqrt{s}$=13 TeV, L=132 fb^{-1}, JHEP 03, 268 (2021), submitted October 2020, published March 2021
- Inclusive $H \rightarrow bb$, extremal p_T, Run 2, $\sqrt{s}$=13 TeV, L=136 fb^{-1}, ATLAS-CONF-2021-010, submitted March 2021

- $H \rightarrow cc$, Run 2, $\sqrt{s}$=13 TeV, L=139 fb^{-1}, ATLAS-CONF-2021-021, released June 2021
- $H \rightarrow \tau\tau$, Run 2, $\sqrt{s}$=13 TeV, L=139 fb^{-1}, ATLAS-CONF-2021-044, released July 2021
- $H \rightarrow \mu\mu$, Run 2, $\sqrt{s}$=13 TeV, L=139 fb^{-1}, PLB 812, 135980 (2021), submitted July 2020, published Dec. 2020

References

≥June 2021
Jan.-May 2021
Nov-Dec 2020

$H_{125}H_{125}$

- Resonant H(bb)H(bb), Run 2, √s=13 TeV, L≤139 fb^{-1}, ATLAS-CONF-2021-035, released July 2021
- Non resonant, Resonant H(bb)H(ττ), Run 2, √s=13 TeV, L=139 fb^{-1}, ATLAS-CONF-2021-030, released July 2021
- Resonant H(bb)H($\tau_{had}\tau_{had}$) boost, Run 2, √s=13 TeV, L=139 fb^{-1}, JHEP 11, 163 (2020), submitted July 2020, published Nov. 2020
- Resonant H(bb)H(γγ), Run 2, √s=13 TeV, L=139 fb^{-1}, ATLAS-CONF-2021-016, released March 2021
- HH summary, Run 2, √s=13 TeV, L=27.5-139 fb^{-1}, ATL-PHYS-PUB-2021-031, released July 2021

pp→H_{125}→BSM

- H→Z(ll)a, Z(ll)η_c, Z(ll)J/ψ, Run 2, √s=13 TeV, L=139 fb^{-1}, PRL 125, 221802 (2020), submitted Apr., published Nov. 2020
- H→aa→bbμμ, Run 2, √s=13 TeV, L=139 fb^{-1}, CERN-EP-2021-157, submitted Oct. 2021 to PRD
- H→aa→bbbb, Run 2, √s=13 TeV, L=36 fb^{-1}, PRD 102, 112006 (2020), submitted May 2020, published Dec. 2020
- Z(ll)H→inv, 2HDM+a, Run 2, √s=13 TeV, L=139 fb^{-1}, ATLAS-CONF-2021-029, released July 2021
- Dark matter combination, Run 2, √s=13 TeV, L=139 fb^{-1}, ATLAS-CONF-2021-036, released July 2021
- NMSSM, $Z(ll)H(\tilde{\chi}_2^0\tilde{\chi}_1^0 \rightarrow a\,\tilde{\chi}_1^0\tilde{\chi}_1^0)$, Run 2, √s=13 TeV, L=139 fb^{-1}, CERN-EP-2021-098, submitted Sept. 2021 to JHEP
- H→XX→4l, H→ZX →4l, Run 2, √s=13 TeV, L=139 fb^{-1}, ATLAS-CONF-2021-034, released August 2021
- H→WW, Run 2, √s=13 TeV, L=36.1 fb^{-1}, CERN-EP-2021-096, submitted Sept. 2021 to EPJC

References

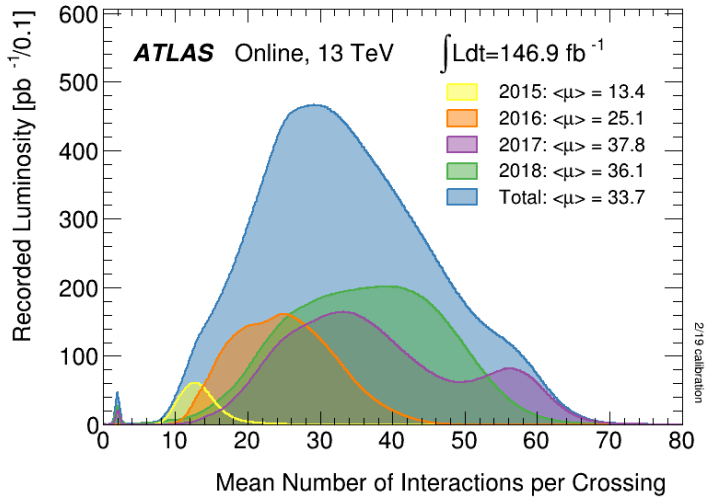
≥June 2021
Jan.-May 2021
Nov-Dec 2020

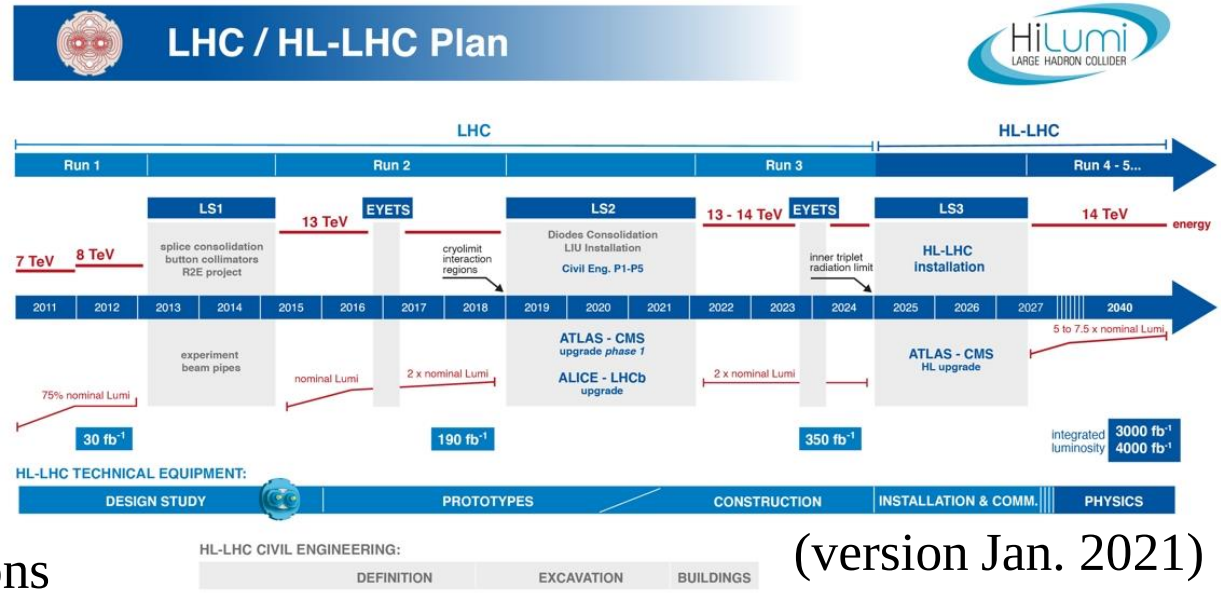
$pp \rightarrow BSM_{\neq H} \rightarrow H$, and $pp \rightarrow BSM\ H$

- Mono-H, $H \rightarrow \gamma\gamma$, Run 2, $\sqrt{s}$=13 TeV, L=139 fb^{-1}, JHEP 10, 13 (2021), submitted Avril 2021, published Oct. 2021
- $V' \rightarrow VH$, qqbb, Run 2, $\sqrt{s}$=13 TeV, L=139 fb^{-1}, PRD 102, 112008 (2020), submitted Jul. 2020, published. Dec. 2020
- $W' \rightarrow WH$, Run 2, $\sqrt{s}$=13 TeV, L=139 fb^{-1}, ATLAS-CONF-2021-026, released June 2021
- $Z' \rightarrow H(bb)+\gamma$, Run 2, $\sqrt{s}$=13 TeV, L=139 fb^{-1}, PRL 125, 251802 (2020), submitted Aug. 2020, published Dec. 2020)
- $X \rightarrow \gamma\gamma$, Run 2, $\sqrt{s}$=13 TeV, L=139 fb^{-1}, PLB, 822, 136651 (2021), submitted Mar., published Nov. 2021
- $X \rightarrow ZZ \rightarrow llll$, $ll\nu\nu$, Run 2, $\sqrt{s}$=13 TeV, L=139 fb^{-1}, EPJC 81, 332 (2021), submitted Sept. 2020, published Apr. 2021
- $A \rightarrow Z(ll)H(bb)$, $\rightarrow Z(ll)H(WW)$, Run 2, $\sqrt{s}$=13 TeV, L=139 fb^{-1}, EPJC 81, 396 (2021), submitted Nov. 2020, published May 2021
- $H^{\pm} \rightarrow cb$, Run 2, $\sqrt{s}$=13 TeV, L=139 fb^{-1}, ATLAS-CONF-2021-037, released Aug. 2021
- $H^{\pm} \rightarrow tb$, Run 2, $\sqrt{s}$=13 TeV, L=139 fb^{-1}, JHEP 06, 145 (2021), submitted Feb., published June 2021
- $H^{\pm} \rightarrow W^{\pm}A \rightarrow W^{\pm}(e\nu)\mu\mu$, Run 2, $\sqrt{s}$=13 TeV, L=139 fb^{-1}, ATLAS-CONF-2021-047, released Sept. 2021
- $H^{\pm\pm}$, Run 2, $\sqrt{s}$=13 TeV, L=139 fb^{-1}, JHEP 06, 146 (2021), submitted Jan., published June 2021
- Summary hMSSM, Run 2, $\sqrt{s}$=13 TeV, L=139 fb^{-1}, ATL-PHYS-PUB-2021-030, released July 2021
- Summary Exotics Higgs, Run 2, $\sqrt{s}$=13 TeV, L=139 fb^{-1}, ATL-PHYS-PUB-2021-008, released March 2021

backup

Generalities (flashed)



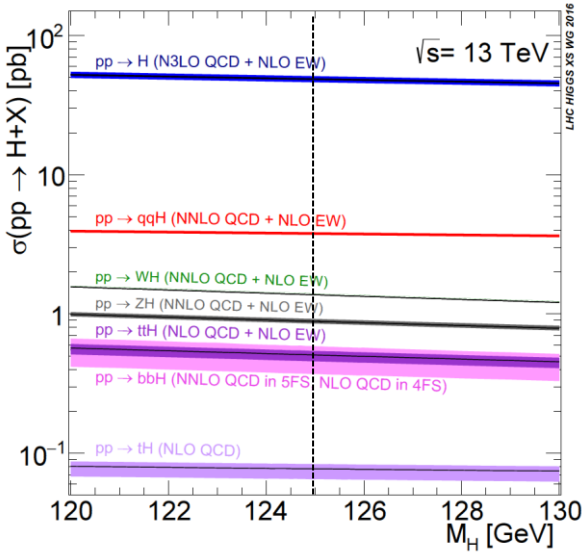


(version Jan. 2021)

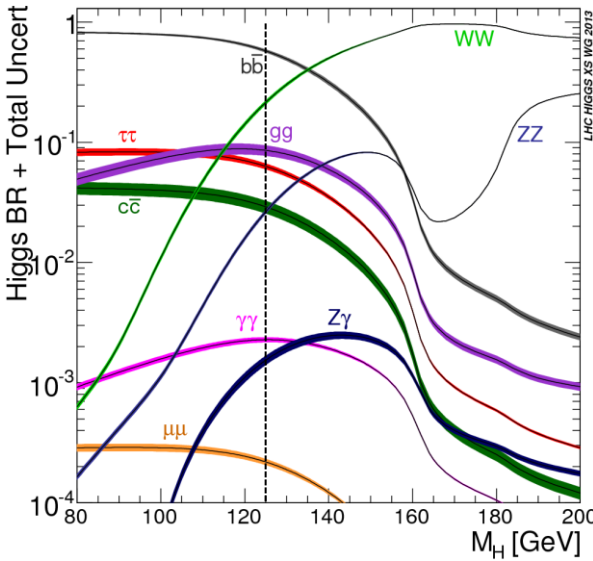
Detector working in excellent conditions

Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	92 M	95.7%
SCT Silicon Strips	6.3 M	98.6%
TRT Transition Radiation Tracker	350 k	97.2%
LAr EM Calorimeter	170 k	100 %
Tile Calorimeter	5200	99.5%
Hadronic End-Cap LAr Calorimeter	5600	99.7%
Forward LAr Calorimeter	3500	99.8%
LVL1 Calo Trigger	7160	99.9%
LVL1 Muon RPC Trigger	383 k	100%
LVL1 Muon TGC Trigger	320 k	99.9%
MDT Muon Drift Tubes	357 k	99.7%
CSC Cathode Strip Chambers	31 k	93.0%
RPC Barrel Muon Chambers	383 k	93.3%
TGC End-Cap Muon Chambers	320 k	98.9%
ALFA	10 k	99.9%
AFP	430 k	97.0%

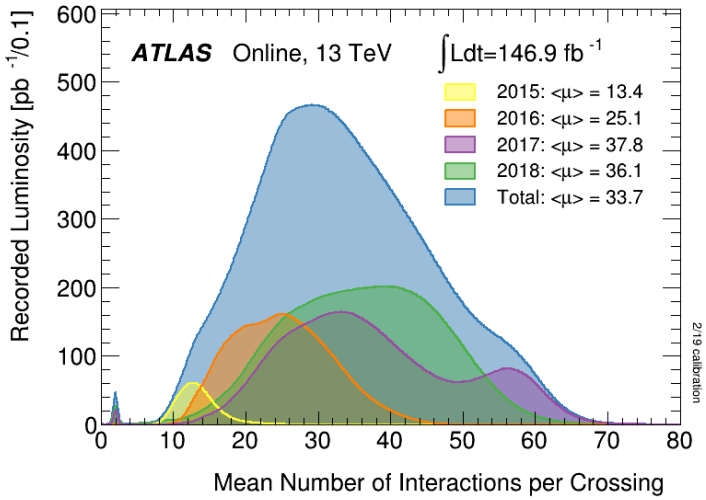
- Production (SM)

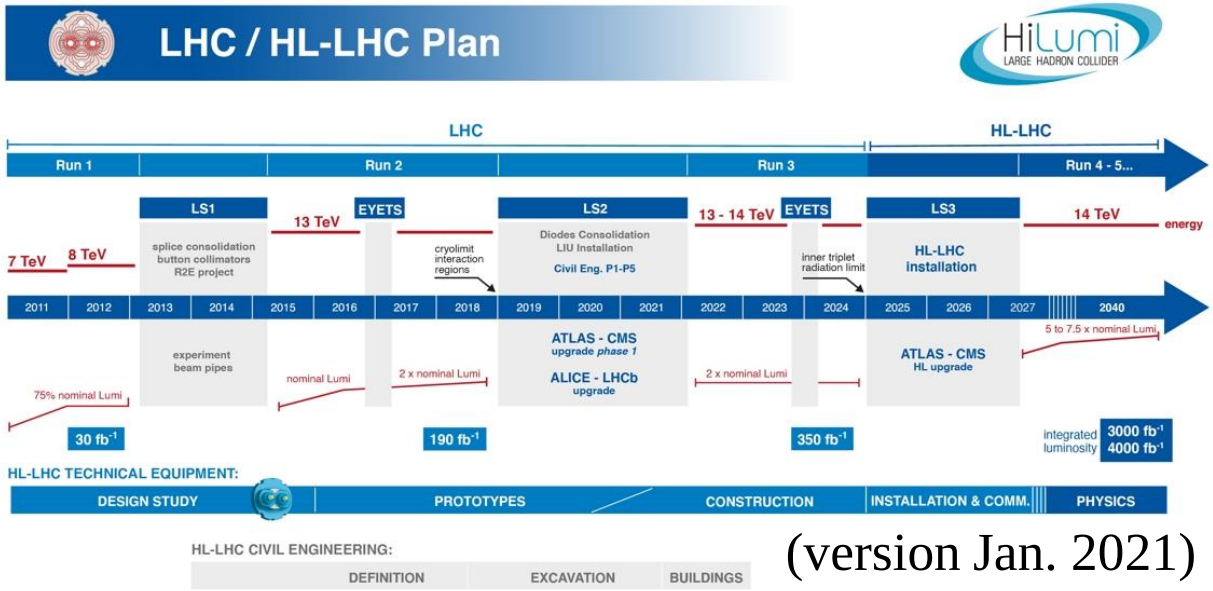


- Decay (SM)



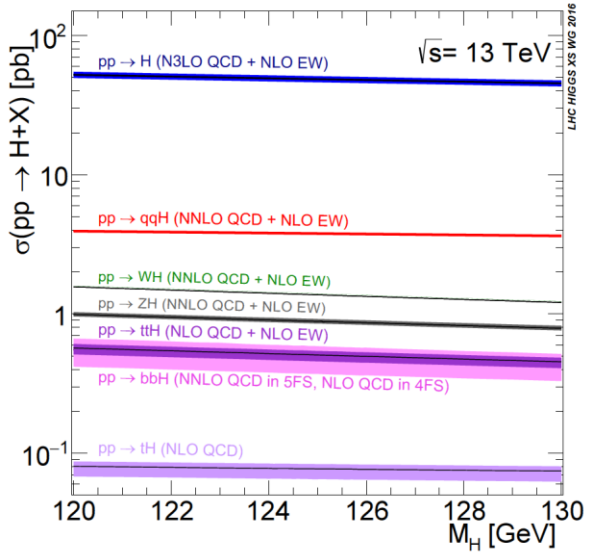
Generalities (flashed)



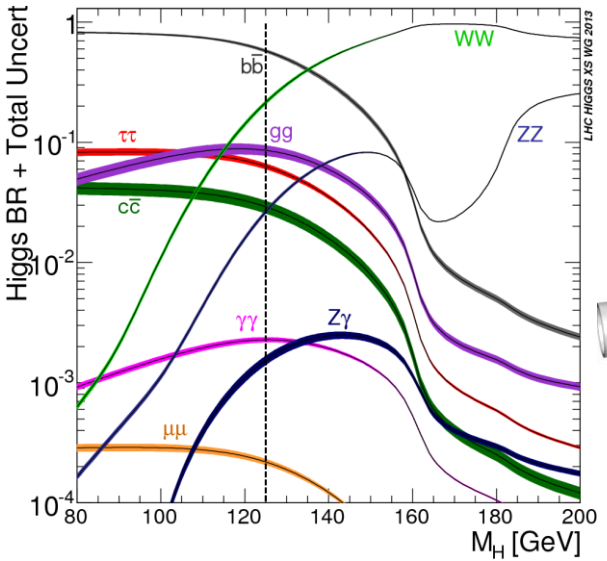


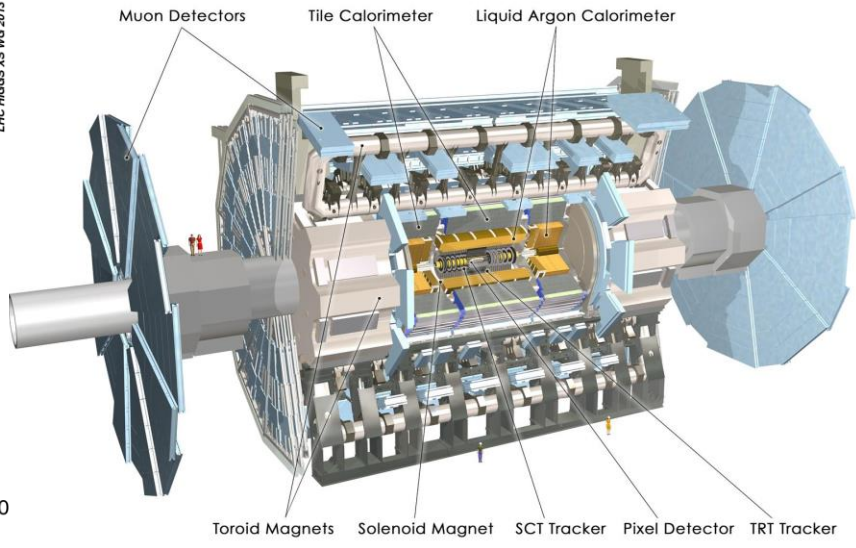
(version Jan. 2021)

- Production



- Decay





H_{125}

H→WW*→eνμν

ATLAS-CONF-2021-014
March 2021

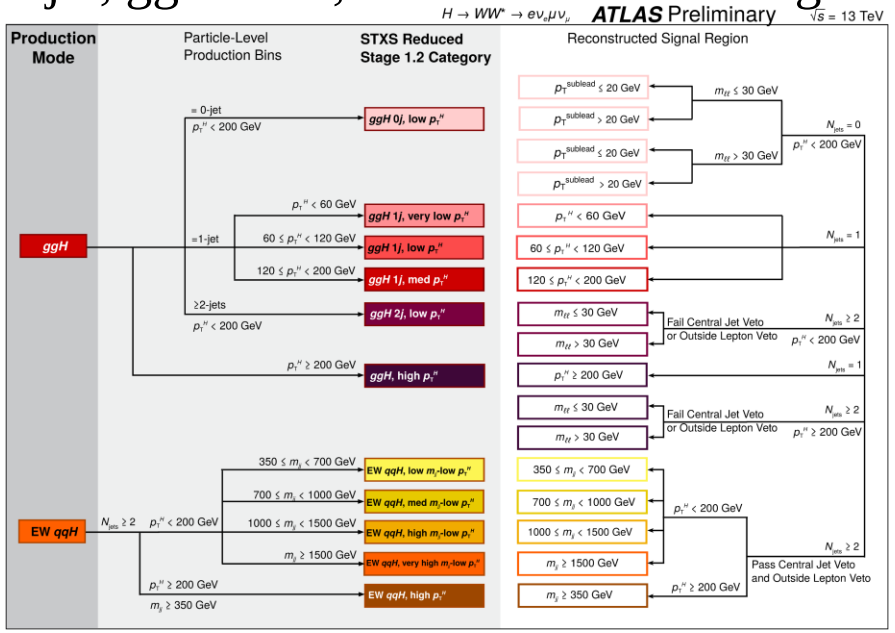
- Large BR 🙂 bad resolution (MET) ☹

- Signature

e, μ (suppr. DY), MET (suppr. DY)
close leptons (spin correlations)

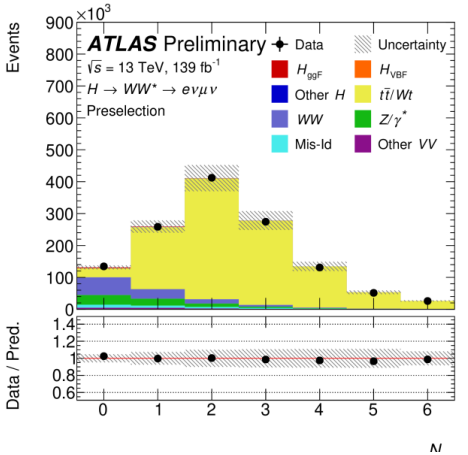
- Categories

#jet, ggH/VBF, kinematics: mirroring STXS

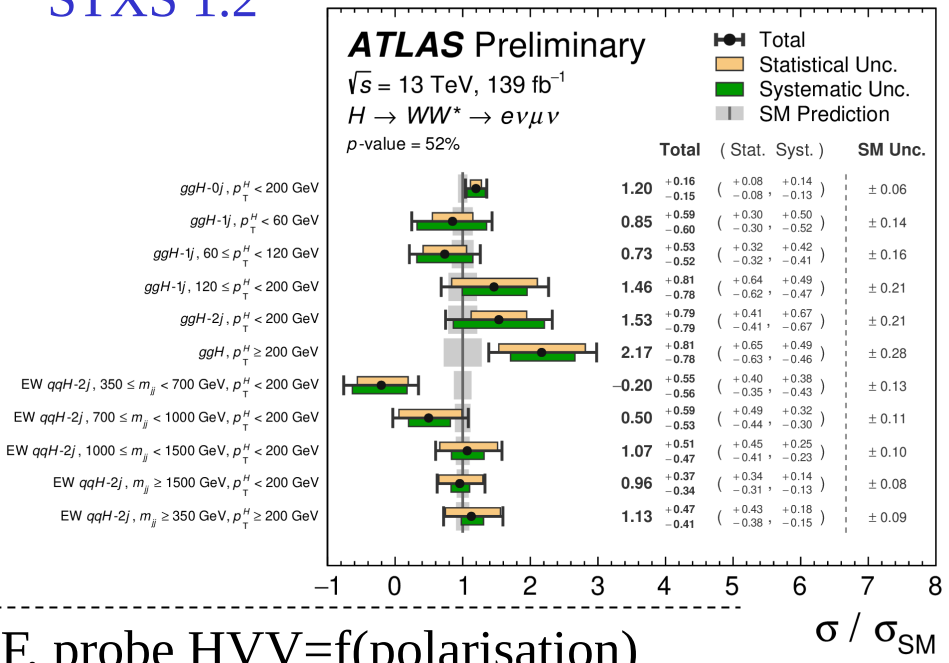


- Background

WW, top, etc.
Varies a lot w/ categ
Data-driven



- STXS 1.2



- ggH+2 j, probe mix {0^{++} (SM), 0^{-+}}
- VBF, probe HVV=f(polarisation)

CERN-EP-2021-096 (36.1 fb^{-1})
EPJC Sept. 2021

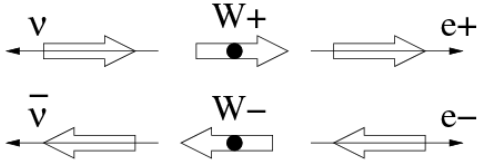
Results consistent w/ SM
1st analysis on topic

H→WW*→eνμν

Run 2, √s=13 TeV, L=139 fb^{-1}, ATLAS-CONF-2021-014

- Selection

=2 l, (e, μ) (suppr. DY), OS, p_T>22, 15 GeV
m_{ll}>10 GeV (suppr. DY→ττ, & low mass resonances)
MET cut (suppr. DY)
Veto events w/ b-jet p_T>20 GeV (suppr. top)
Close leptons (spin correlations)



Cut=f(topology) (suppr. WW, top, DY)

Categories: #jet, ggH/VBF, mirroring STXS

Bkg=f(category) ; data-driven

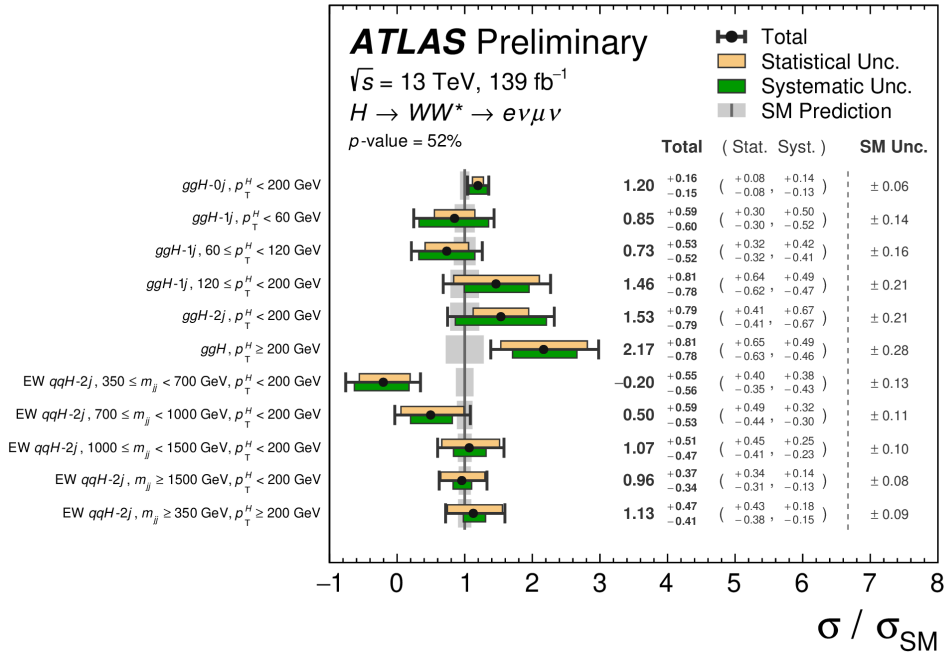
- Final DV : m_T(ll) [ggH], DNN [VBF]

Simultaneous fit SR+CR

- Prod. modes

$\mu_{ggH}=1.20\ ^{+0.16}_{-0.15}$
$\mu_{VBF}=0.99\ ^{+0.24}_{-0.20}$ Dominated by syst.

- STXS stage 1.2

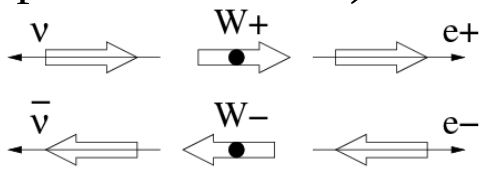


H→WW*→eνμν m_H=125.09 GeV

Run 2, √s=13 TeV, L=139 fb^{-1}, ATLAS-CONF-2021-014

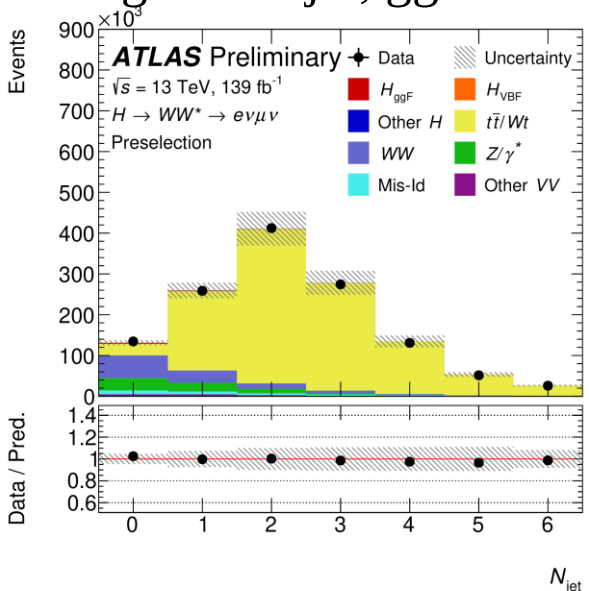
- Selection

=2 l, (e, μ) (suppr. DY), OS, p_T>22, 15 GeV
m_{ll}>10 GeV (suppr. DY→ττ, & low mass resonances)
MET cut
Veto events w/ b-jet p_T>20 GeV (suppr. top)
Close leptons (spin correlations)



Cut=f(topology)

Categories: #jet, ggH/VBF, mirroring STXS



Bkg=f(category)
data-driven

- Final DV : m_T(ll) [ggH], DNN [VBF]

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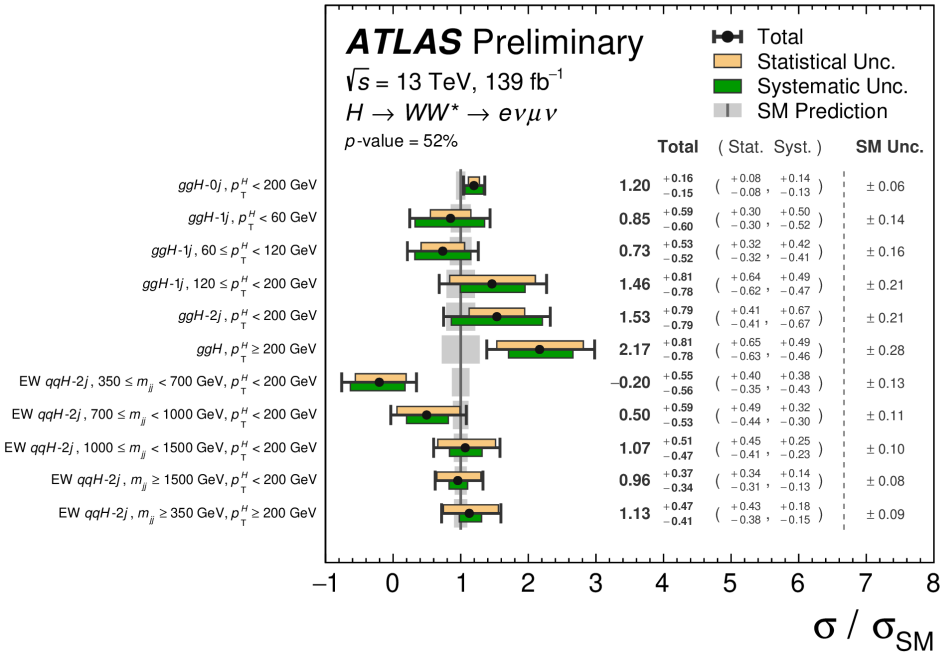
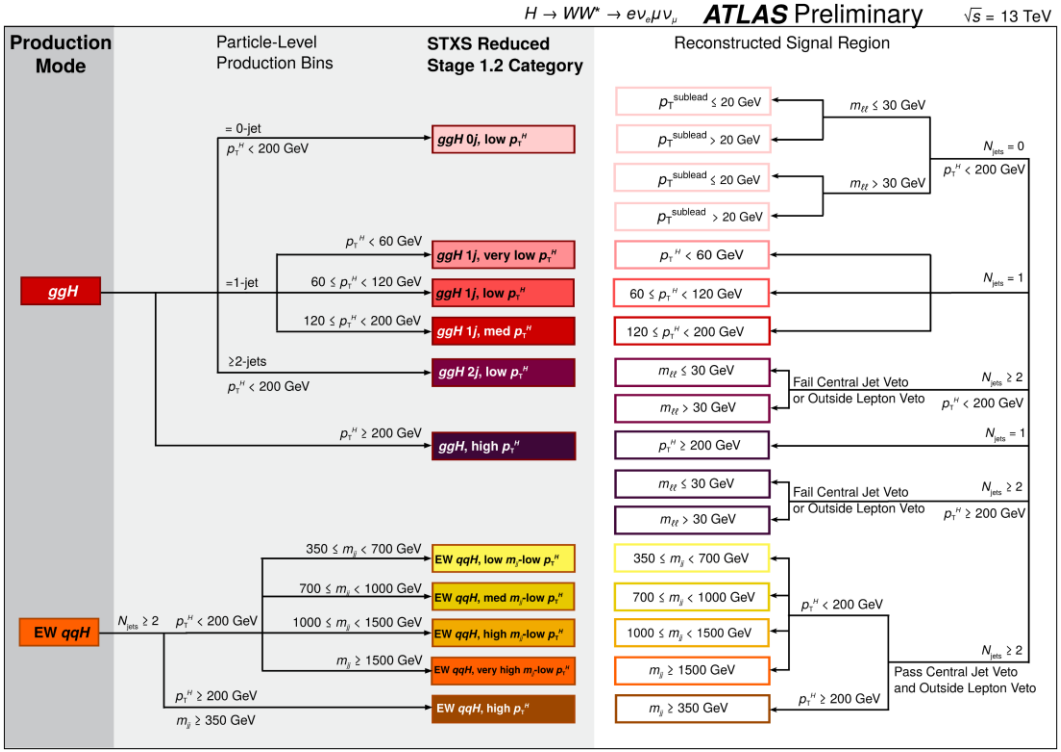
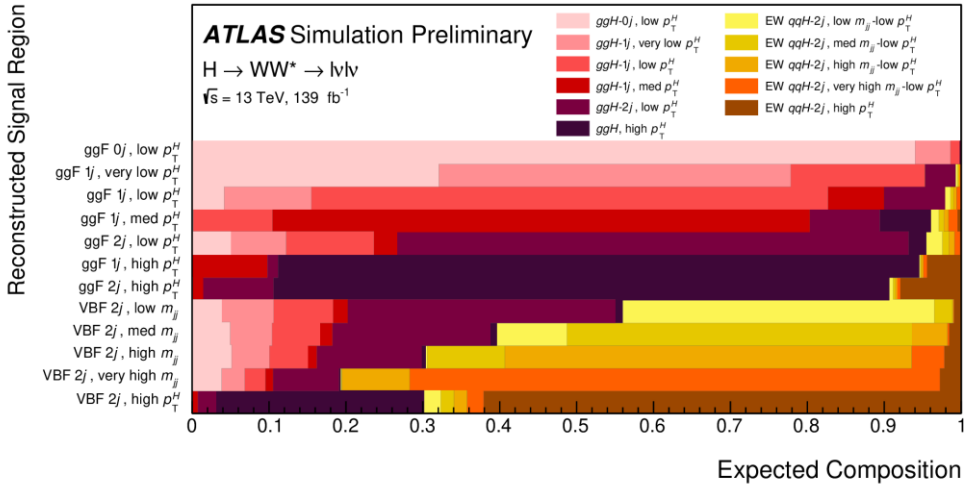


H→WW*→eνμν

ATLAS, Run 2, √s=13 TeV, L=139 fb^{-1}, ATLAS-CONF-2021-014



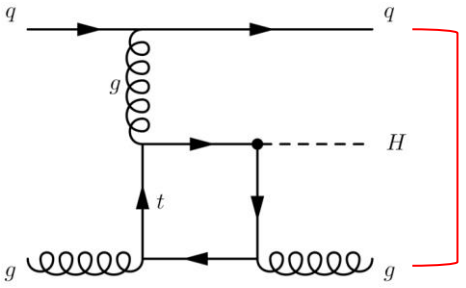


H→W(eν)W(μν)+jj, CP, polarisation

- Higgs: scenario mixture: tan α : mix {0^{++} (SM), 0^{-+}}
- Coupling HVV=f(polarisation)

assume std HVV

ggH

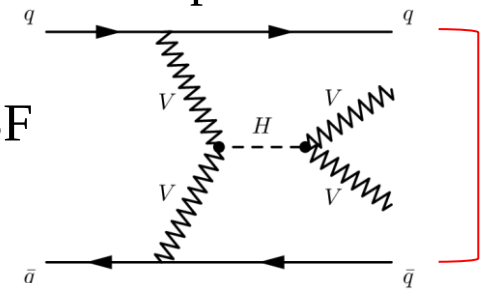


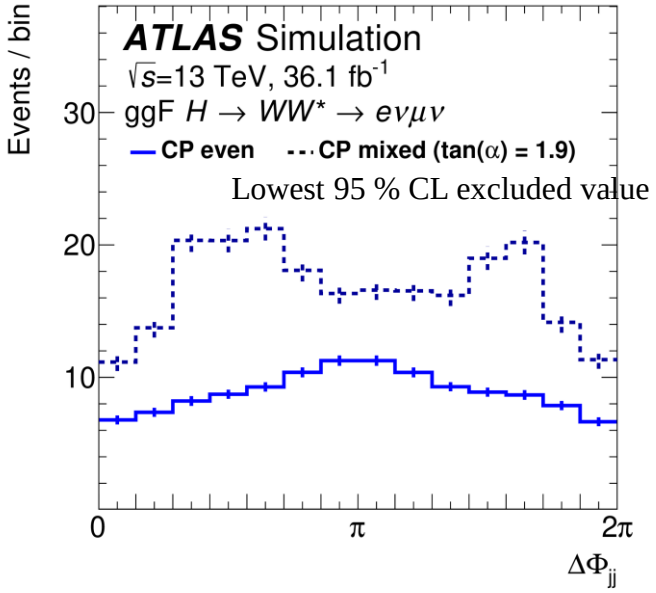
$\Delta\Phi_{jj}$

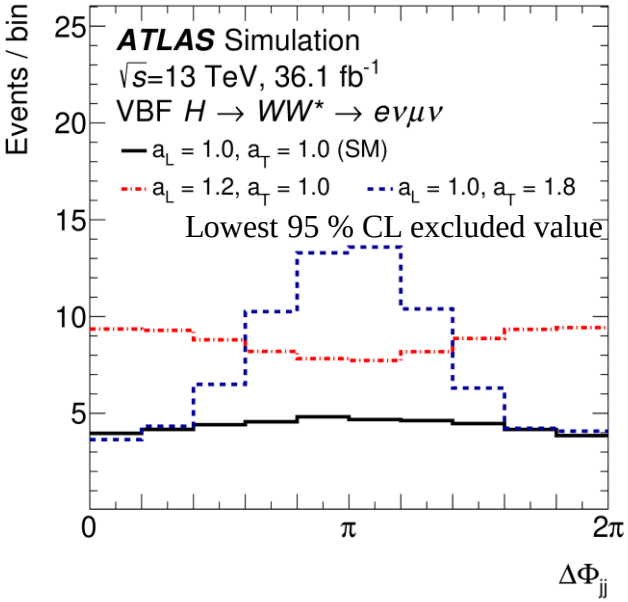
(shape & rate)

Assume pure CP-even H (V_T, V_L)

VBF







$$a_L = \frac{g_{HV_LV_L}}{g_{HVV}}$$

$$a_T = \frac{g_{HV_TV_T}}{g_{HVV}}$$

(SM: 1, 1)

Translated in Lorentz-invariant PO κ_{VV}, ε_{VV} (SM: 1, 0)

$\tan\alpha = 0.0 \pm 0.4\,(stat) \pm 0.3\,(sys)$

$$\kappa_{VV} = 0.91^{+0.10}_{-0.18}\,(stat)\,^{+0.09}_{-0.17}\,(syst)$$

$$\varepsilon_{VV} = 0.13^{+0.28}_{-0.20}\,(stat)\,^{+0.08}_{-0.10}\,(syst)$$

(other profiled)

Results consistent w/ SM

Run 2, √s=13 TeV, L=36.1 fb^{-1}, CERN-EP-2021-096

First analysis on this topic

H→W(eν)W(μν)+jj, CP, polarisation

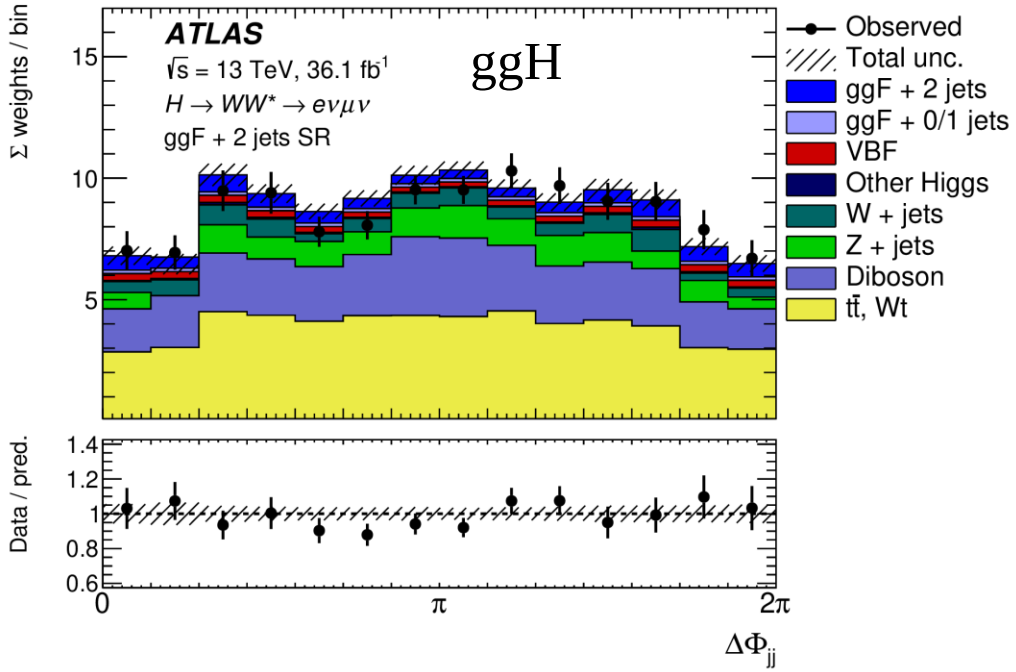
$$\mathcal{L}_0^{loop} = -\frac{g_{Hgg}}{4}\left(\kappa_{gg}\cos(\alpha)G^a_{\mu\nu}G^{a,\mu\nu} + \kappa_{gg}\sin(\alpha)G^a_{\mu\nu}\tilde{G}^{a,\mu\nu}\right)H$$

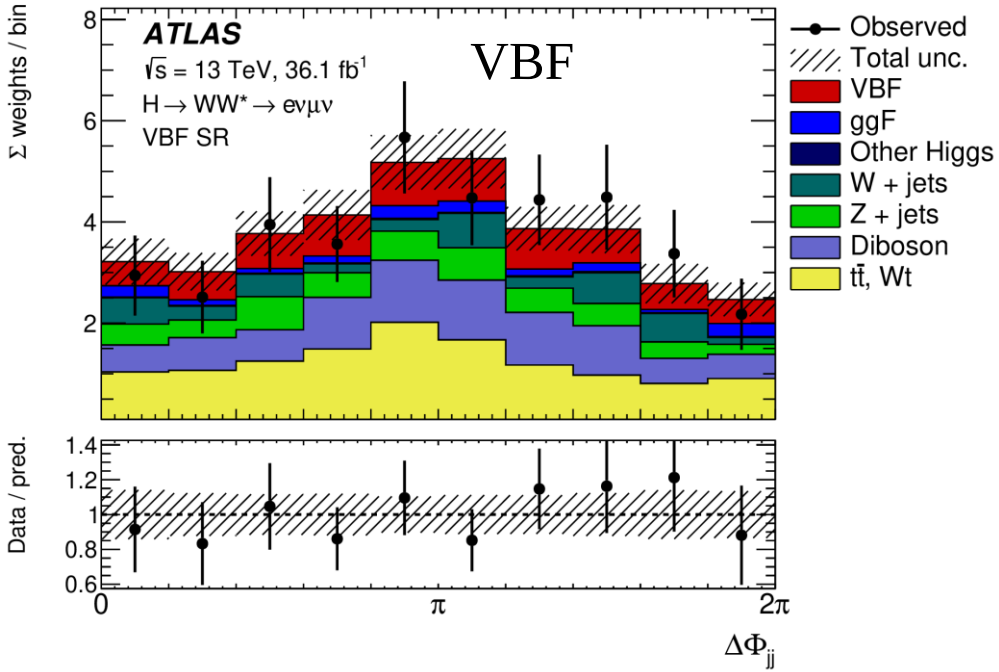
SM CP-even CP-odd

Run 2, √s=13 TeV, L=36.1 fb^{-1}, CERN-EP-2021-096

- Selection

=2 OS ≠ flavour leptons, m_{ll}>10 GeV
Veto events/ b-jet (suppr. top)
$m_{\tau\tau}$<66 GeV (suppr. Z(ττ))
BDT
+topology (ggH/VBF)
Bkg data-driven



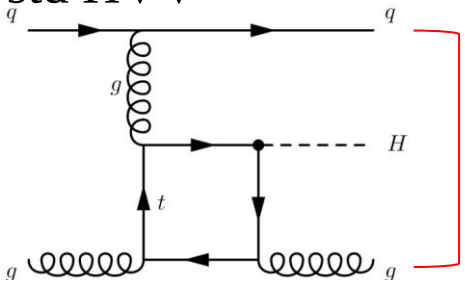


H→W(eν)W(μν)+jj, CP, polarisation

- Higgs: scenario mixture

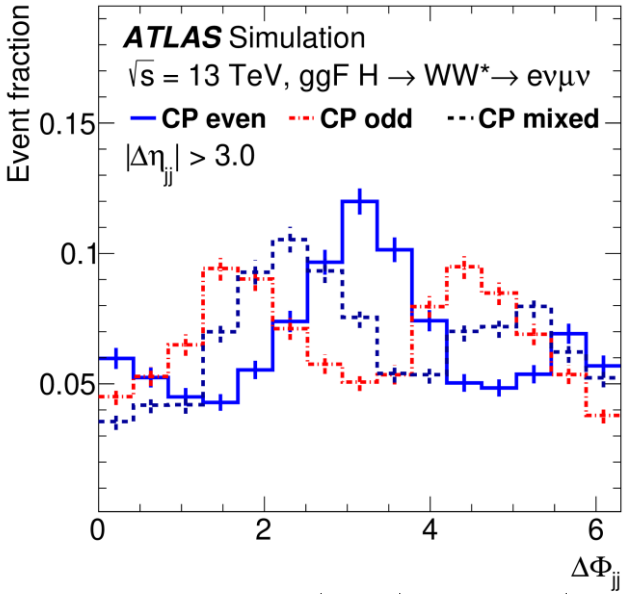
tan α : mix {0^{++} (SM), 0^{-+}}
assume std HVV

ggH



$\Delta\Phi_{jj}$

(shape & rate)

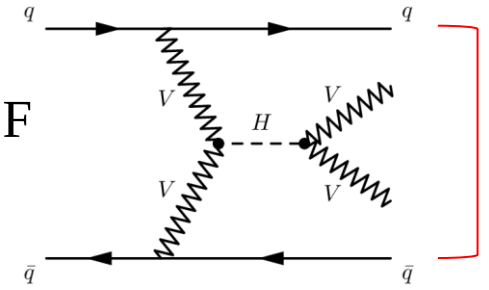


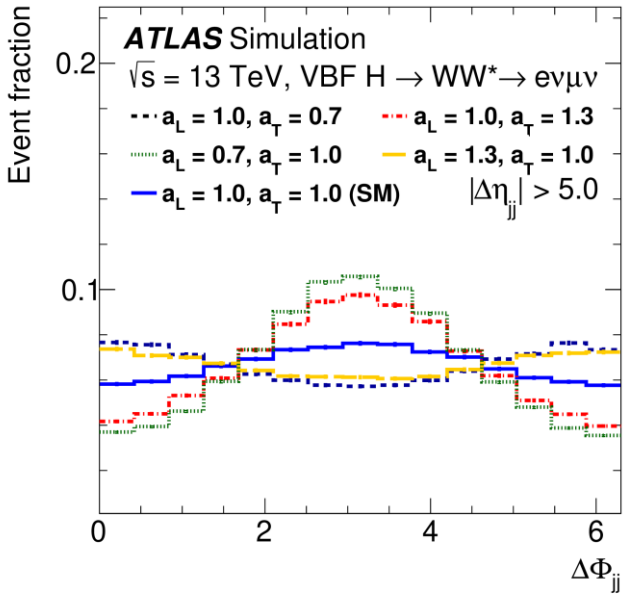
tan α=0.0 ± 0.4 (stat) ± 0.3 (sys)

- Coupling HVV=f(polarisation)

Assume pure CP-even H (V_T, V_L)

VBF





$$a_L = \frac{g_{HV_LV_L}}{g_{HVV}}$$

$$a_T = \frac{g_{HV_TV_T}}{g_{HVV}}$$

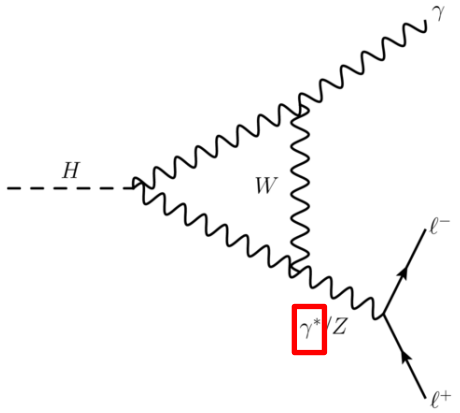
Translated in Lorentz-invariant PO κ_{VV}, ε_{VV}

Results consistent w/ SM

First analysis on this topic

Run 2, √s=13 TeV, L=36.1 fb^{-1}, CERN-EP-2021-096

$H \to \gamma^* \gamma \to ll\gamma$, low m_{ll}



m_{ll}<30 GeV
Dalitz dominated
(FSR negligible)

- Background : $ll\gamma$

- Selection

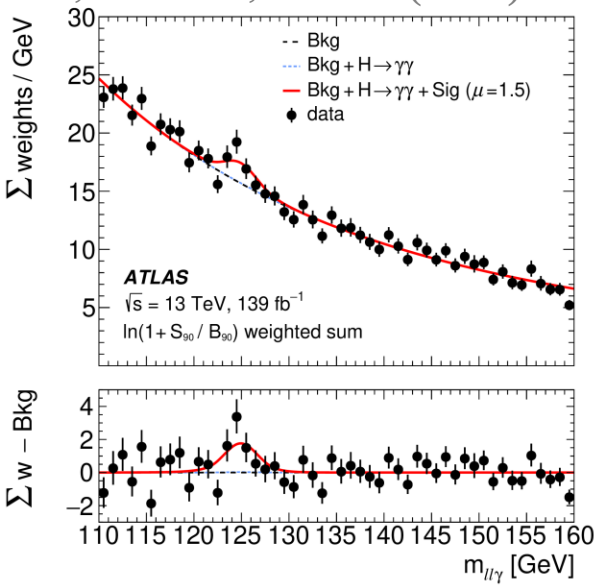
≥1 γ, p_T>0.3 $m_{ll\gamma}$
≥2 l (e, μ), OS same flav., or =1 merged-ee (θ~m/p_T)
p_T=f(flavour, resolved/merged)
p_T(ee)>0.3 $m_{ll\gamma}$
m_{ll}<30 GeV (suppr. Z)
Veto few ll resonances (suppr. J/ψ, suppr. Y(nS))
$m_{ll\gamma}$∈[110 ; 160] GeV

Categories (event topology, lepton flavour)

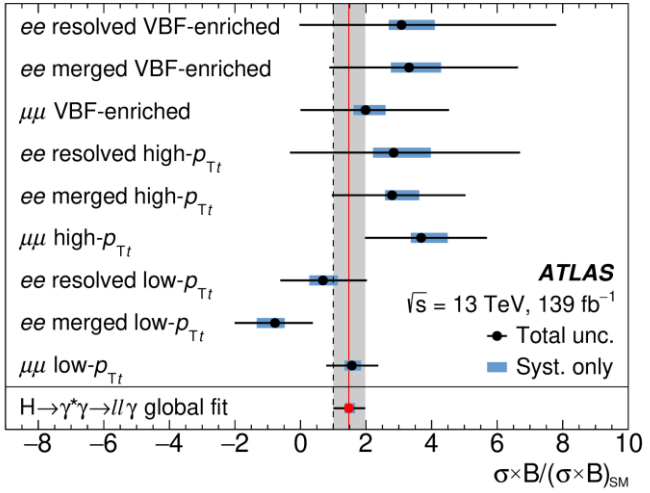
Run 2, √s=13 TeV, L=139 fb^{-1}, PLB 819, 136412 (2021)

- Final DV

$m_{ll\gamma}$



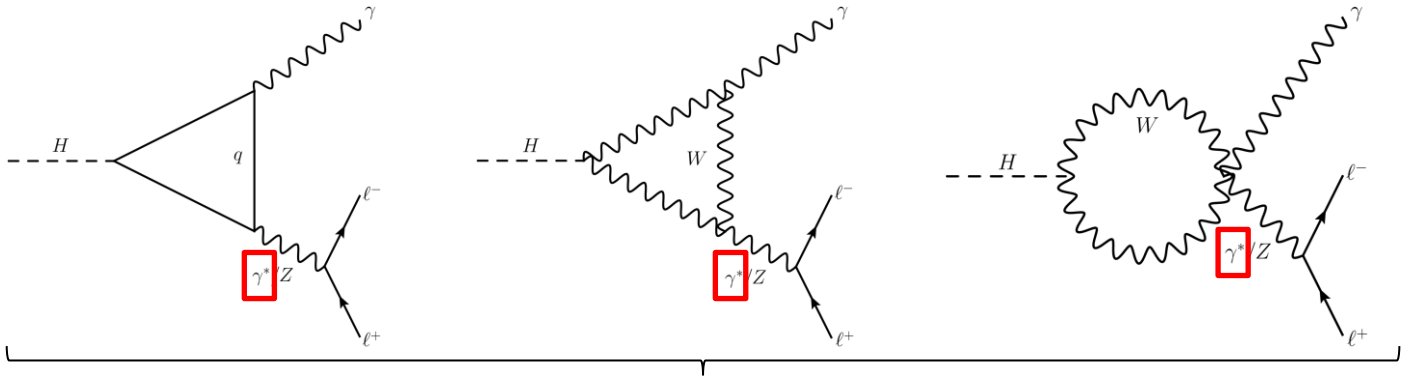
Z_{obs}=3.2 (Z_{exp}=2.1)⇔first evidence



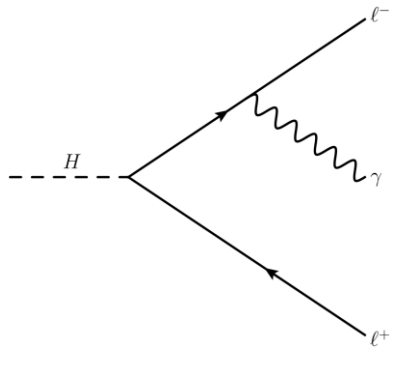
$\mu = 1.5 \pm 0.5\ (\text{stat})\ ^{+0.2}_{-0.1}\ (\text{sys})$

$H \rightarrow \gamma^{*}\gamma \rightarrow ll\gamma$, low m_{ll}

Run 2, $\sqrt{s}$=13 TeV, L=139 fb^{-1}, Phys. Lett. B 819, 136412 (2021)



Dalitz decay



FSR

H(γγ): couplings

$|y_H|<2.5$

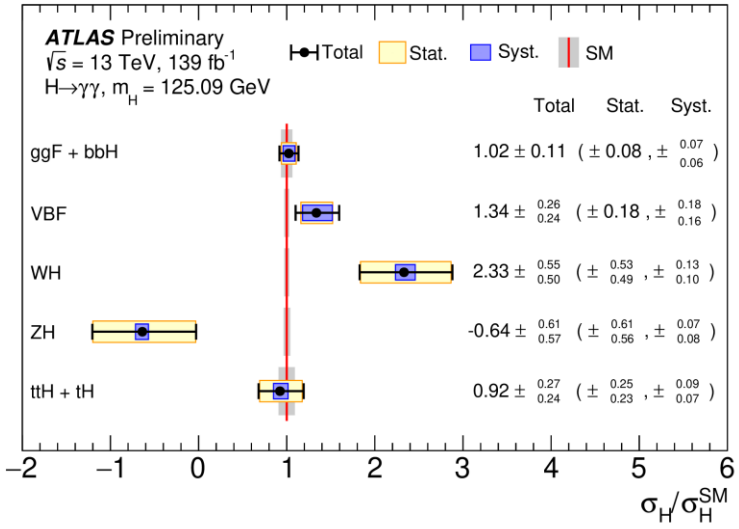
- Selection

2 photons tight isolated
Categorisation⇔STXS

- Background

γγ, γj, jj
Direct fit on data
(ABCD for estimating composition)

- Final DV: $m_{\gamma\gamma}$
- μ: 1.09 +/- 0.10
- μ_i



Z_{obs} (Z_{exp})

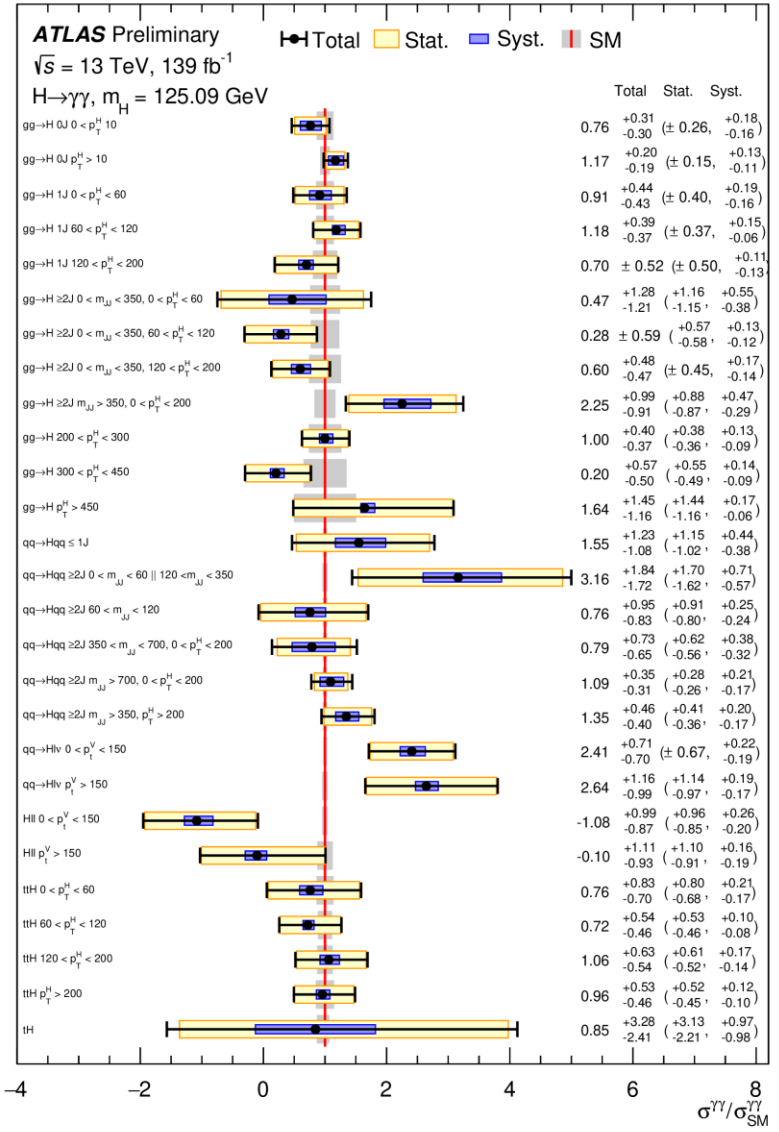
7.5 (6.1)

5.6 (2.8)

4.7 (5.0)

Run 2, √s=13 TeV, L=139 fb^{-1}, ATLAS-CONF-2020-026

- STXS

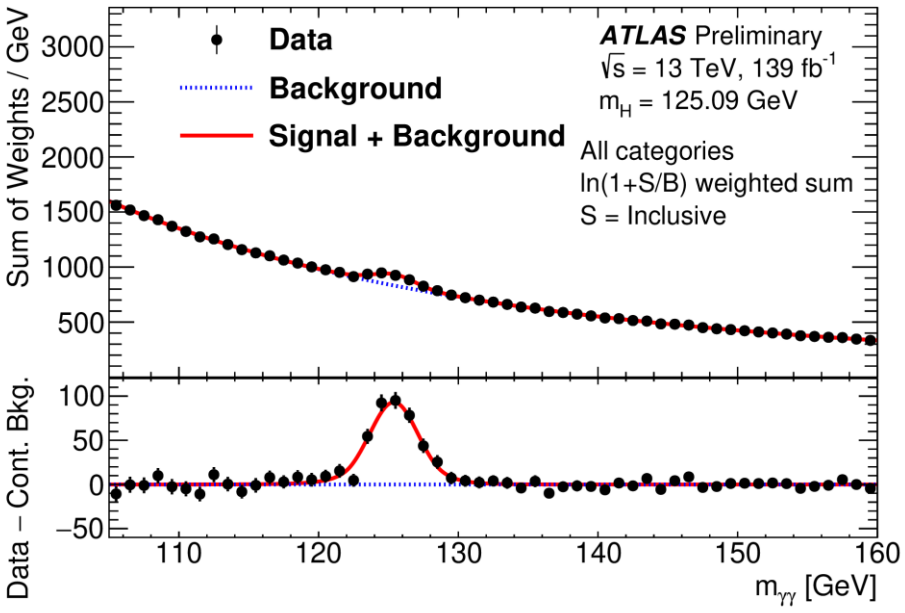


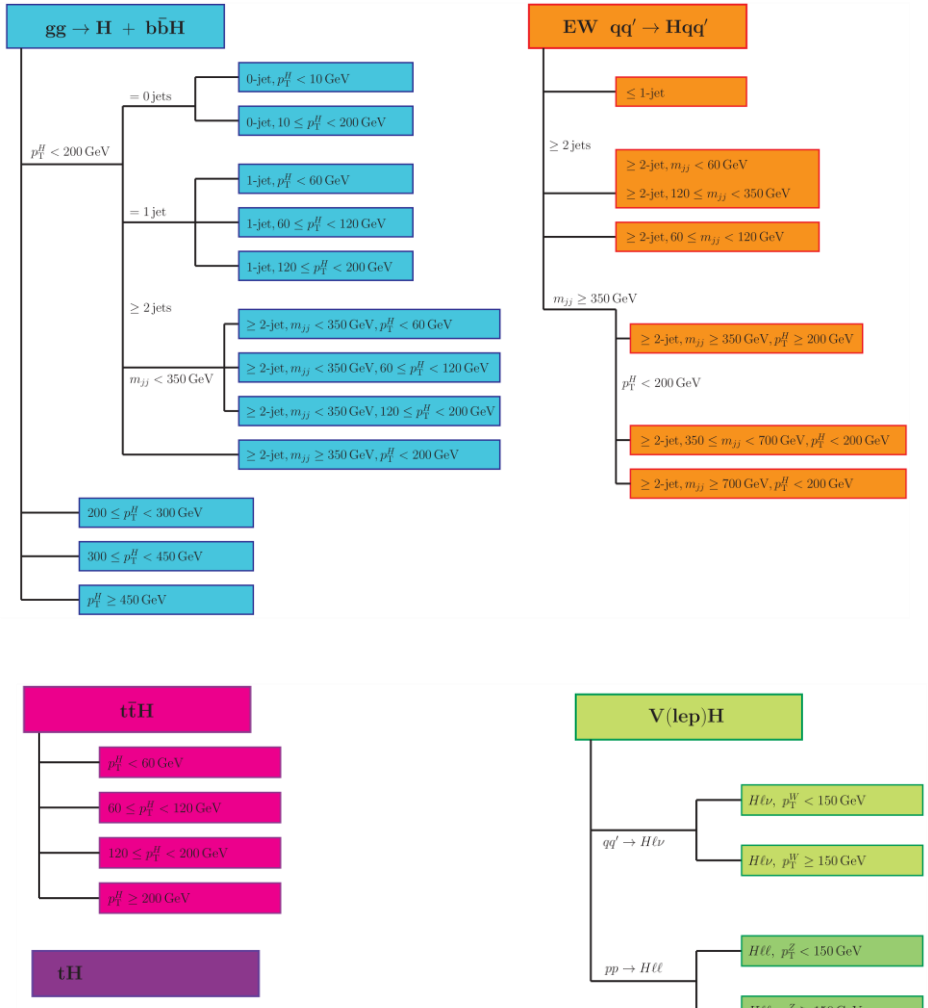
No significative discrepency wrt SM

H(γγ): couplings

$|y_H|<2.5$

Run 2, $\sqrt{s}$=13 TeV, L=139 fb^{-1}, ATLAS-CONF-2020-026



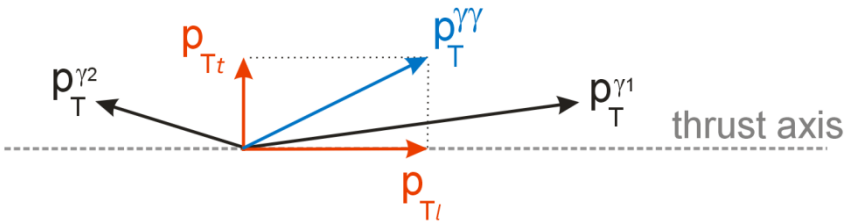


p_{Tt}

- $p_{T\gamma\gamma}$ category used historically for fermiophobic analysis
  drawback : turn-on effect on invariant mass

$$\hat{t} = (\vec{p_T}(\gamma_1) - \vec{p_T}(\gamma_2))/|\vec{p_T}(\gamma_1) - \vec{p_T}(\gamma_2)|$$

- new variable : p_{Tt} : transverse projection of $p_{T\gamma\gamma}$ on thrust axis



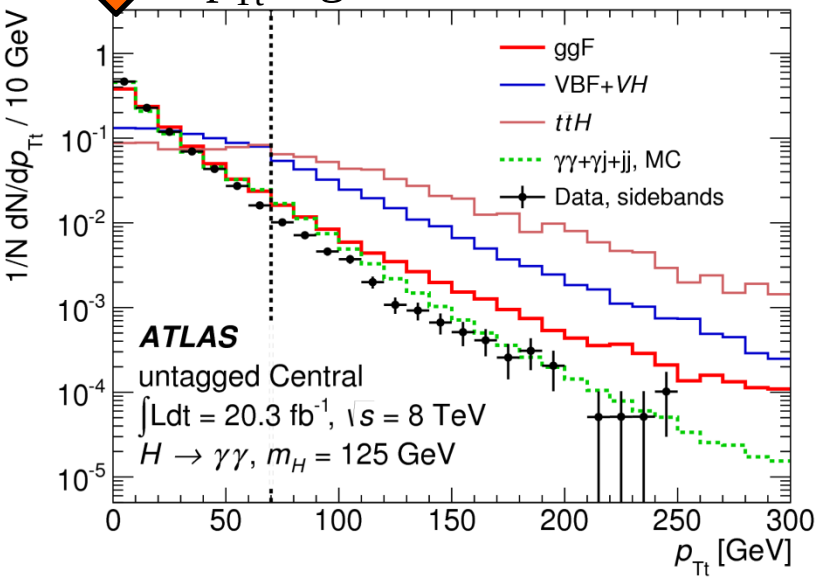
threshold p_{Tt} : 70 GeV

Sensitivity gain : 5-10 % (f(m_H))

Advantages

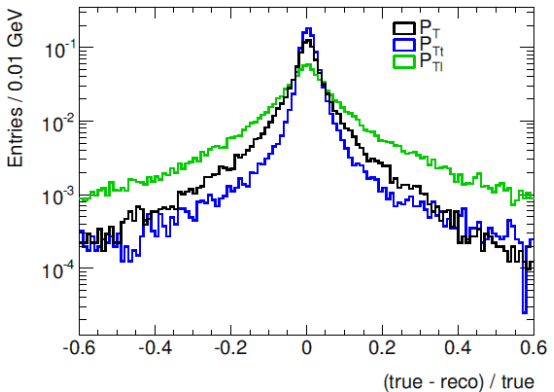
- discriminant against bkg

p_{Tt} higher for VBF, VH, ttH



- Less correlated to $m_{\gamma\gamma}$
- Less sensitive to resolution effects

high $p_{T\gamma\gamma}$: $\Delta\alpha$ << : similar to $p_{T\gamma\gamma}$
low $p_{T\gamma\gamma}$: $\Delta\alpha$ >> ⇔small angle {thrust ; $\gamma\gamma$}
-uncert. long.. : δp_T x cos (small angle)
-transv. : δp_T x sin (small angle)
→low effect

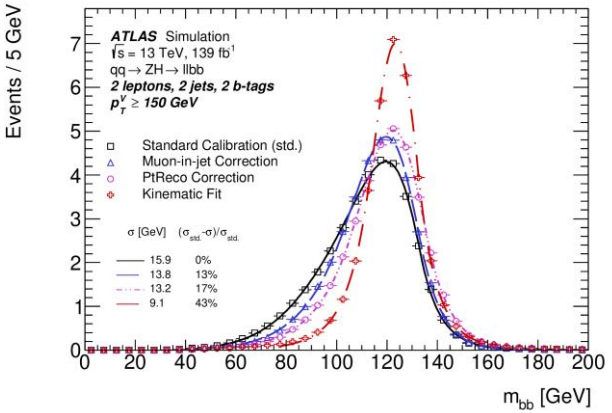


VH, H→bb

m_H=125 GeV

V(νν/lν/ll): suppr. Multijets
Probe BSM (high p_T^V)

Run 2, √s=13 TeV, L=126 fb^{-1}, EPJC 81, 178 (2021)



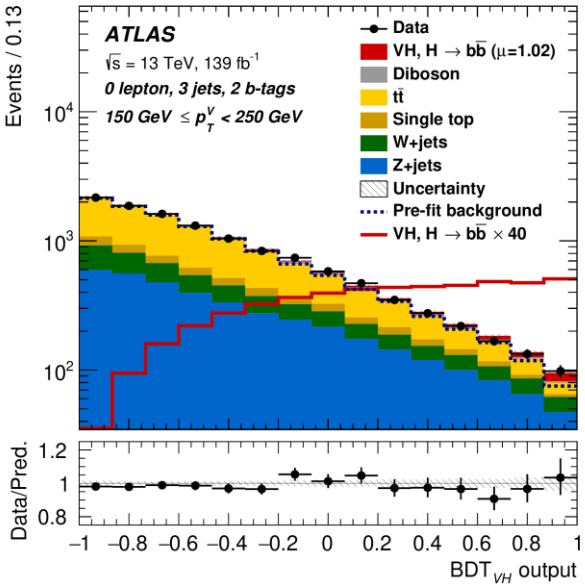
- Bkg (data-driven)

f(category)
Primary: V+HF, top
Secondary: 1-t, VV, multijets

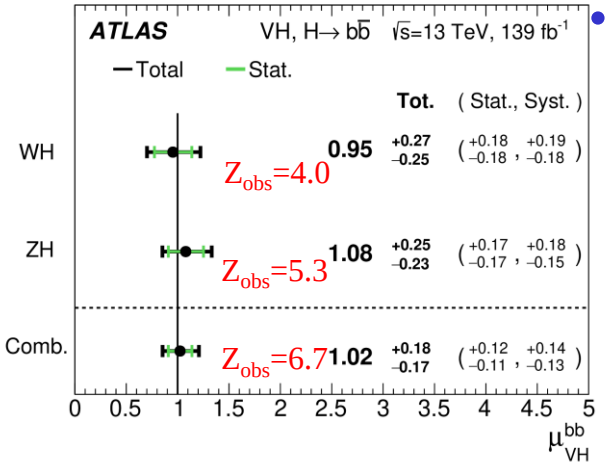
- Selection

b-jet correction: σ ↓ 20-40 %
=2 b-jets (R=0.4), ≥1 p_T>45 GeV
BDT
Categories: #l, #jets, p_T^V

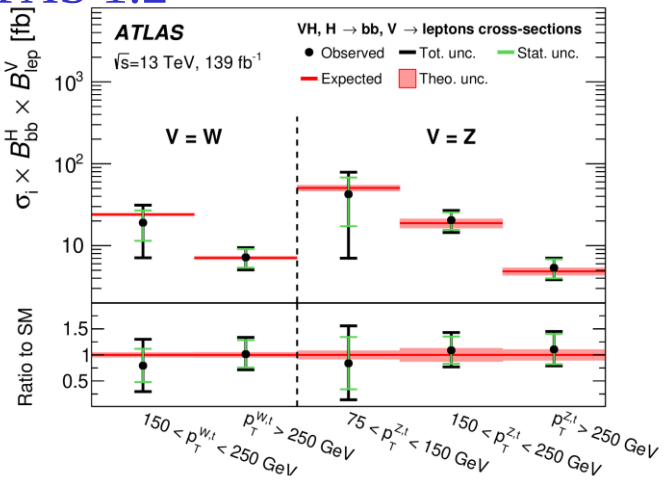
- final DV



- μ_i



- STXS 1.2



- STXS=f(EFT) [SMEFT, Warsaw]
- Validation: m_{bb} + VZ

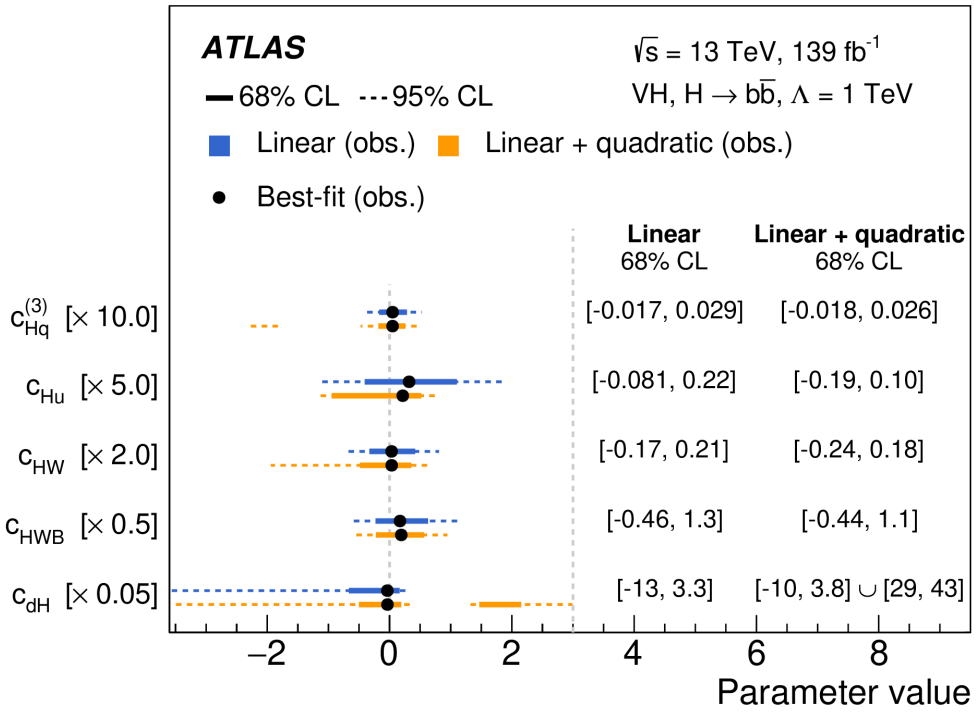
Boosted topology ≥1 J=jj (2 track-jets), $p_T^{V,t}$≥250 GeV, including $p_T^{V,t}$≥400 GeV
Z_{obs}=2.1 (Z_{exp}=2.7), no deviation wrt SM

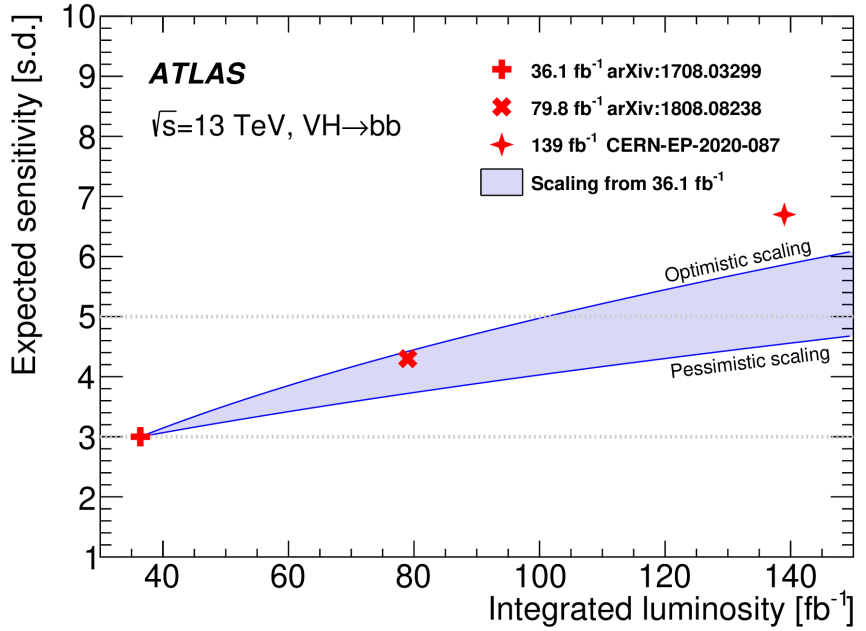
Run 2, √s=13 TeV, L=139 fb^{-1}, PLB 816, 136204 (2021)

VH, H→bb

Run 2, √s=13 TeV, L=126 fb^{-1}, EPJC 81, 178 (2021)

Wilson coefficient	Operator	Impacted vertex	
		Production	Decay
c_{HWB}	$\mathcal{Q}_{HWB} = H^\dagger \tau^I H W^I_{\mu\nu} B^{\mu\nu}$	HZZ	
c_{HW}	$\mathcal{Q}_{HW} = H^\dagger H W^I_{\mu\nu} W_I^{\mu\nu}$	HZZ, HWW	
$c^{(3)}_{Hq}$	$\mathcal{Q}^{(3)}_{Hq} = (H^\dagger i\overleftrightarrow{D^I_\mu} H)(\bar{q}_p \tau^I \gamma^\mu q_r)$	$qqZH, qq'WH$	
$c^{(1)}_{Hq}$	$\mathcal{Q}^{(1)}_{Hq} = (H^\dagger i\overleftrightarrow{D_\mu} H)(\bar{q}_p \gamma^\mu q_r)$	$qqZH$	
c_{Hu}	$\mathcal{Q}_{Hu} = (H^\dagger i\overleftrightarrow{D_\mu} H)(\bar{u}_p \gamma^\mu u_r)$	$qqZH$	
c_{Hd}	$\mathcal{Q}_{Hd} = (H^\dagger i\overleftrightarrow{D_\mu} H)(\bar{d}_p \gamma^\mu d_r)$	$qqZH$	
c_{dH}	$\mathcal{Q}_{dH} = (H^\dagger H)(\bar{q} d H)$		Hbb





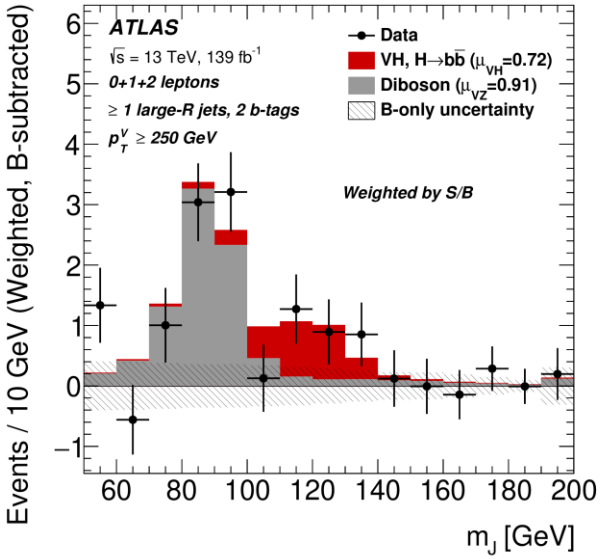
VH, H→bb, boosted regime

m_H=125 GeV

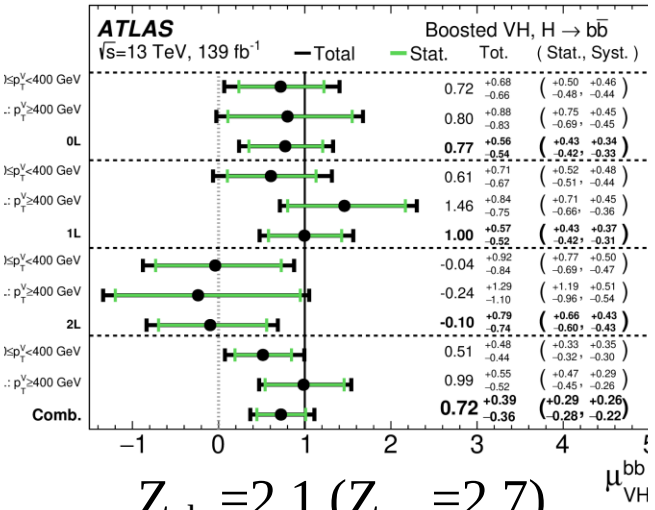
p_T^V>250 GeV

Run 2, √s=13 TeV, L=139 fb^{-1}, PLB 816, 136204 (2021)

- final DV

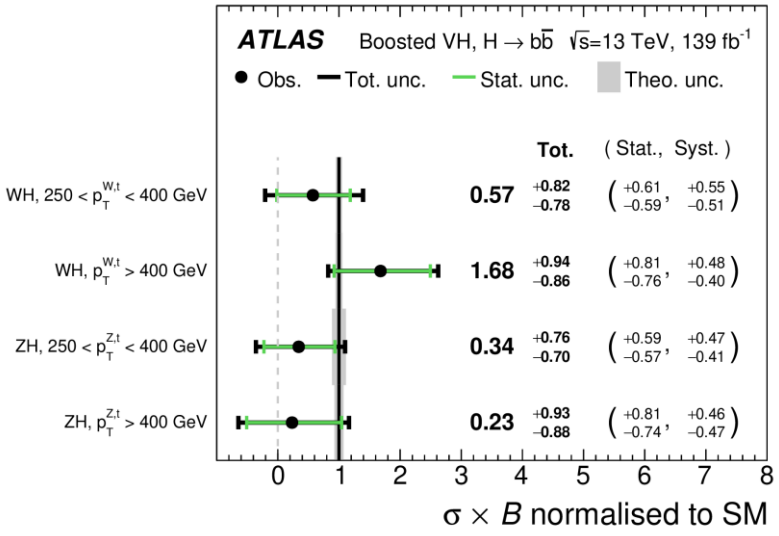


- Production modes

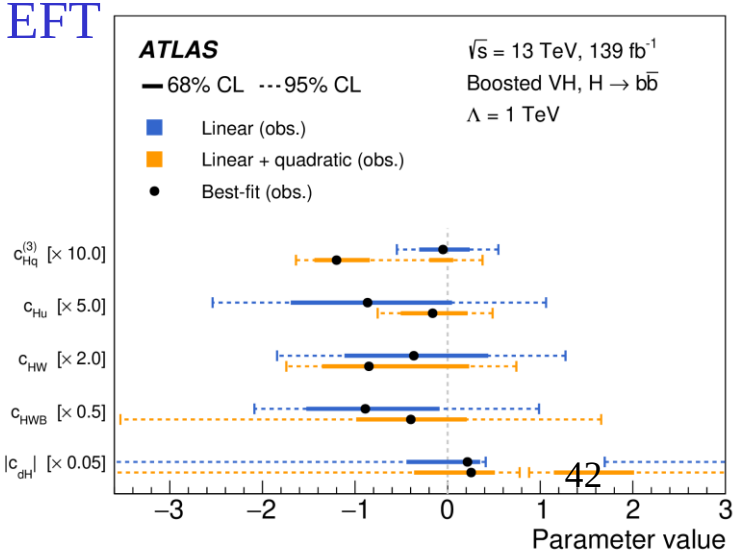


Z_{obs}=2.1 (Z_{exp}=2.7)

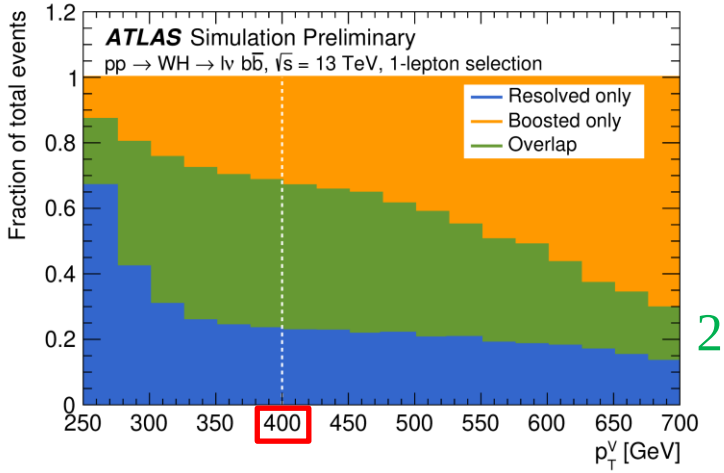
- STXS



- EFT



Combination VH, H→bb



25 %

Resolved (R=0.4) Boosted (R=1.0)

Motivated also by STXS boundaries (reco categories mirroring truth bins)

Run 2, √s=13 TeV, L=139 fb^{-1}, ATLAS-CONF-2021-051

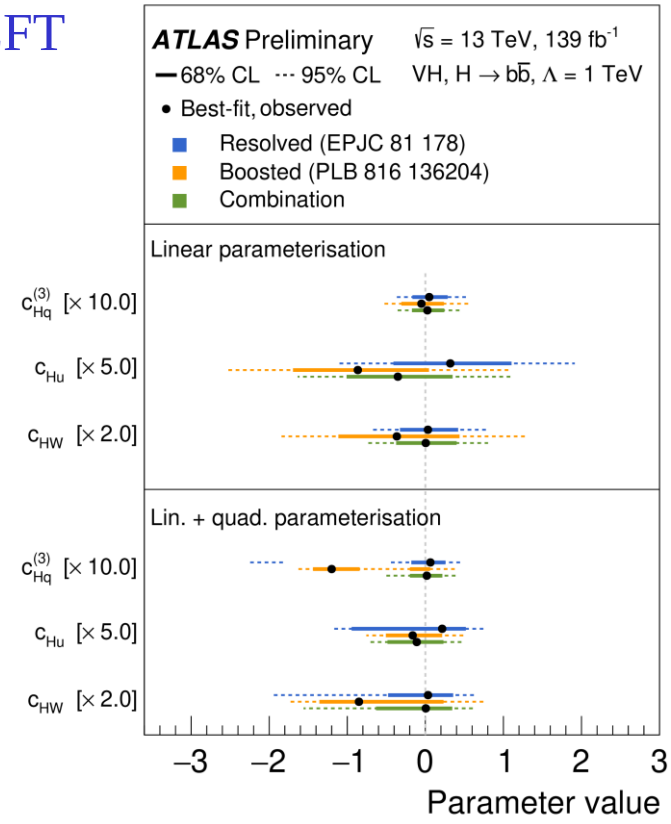
- μ_i

$\mu_{VH}=1.00^{+0.18}_{-0.17}$, $Z_{obs}=6.4$ ($Z_{exp}=6.3$)

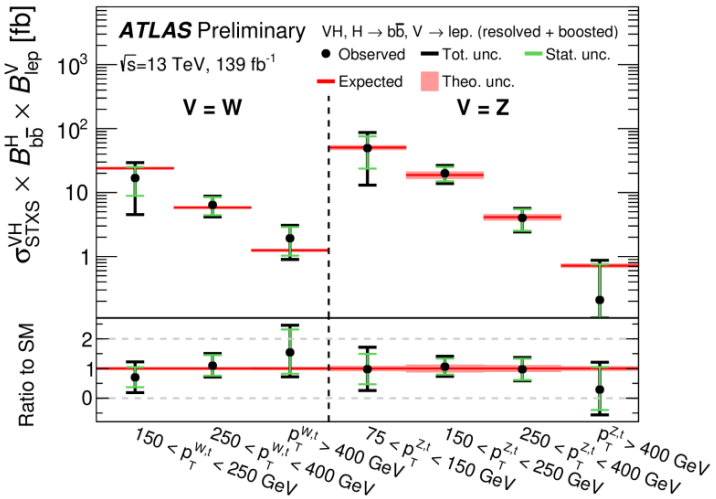
$\mu_{WH}=1.03^{+0.28}_{-0.27}$, $Z_{obs}=4.1$ ($Z_{exp}=3.9$)

$\mu_{ZH}=0.97^{+0.25}_{-0.23}$, $Z_{obs}=4.6$ ($Z_{exp}=5.0$)

- EFT

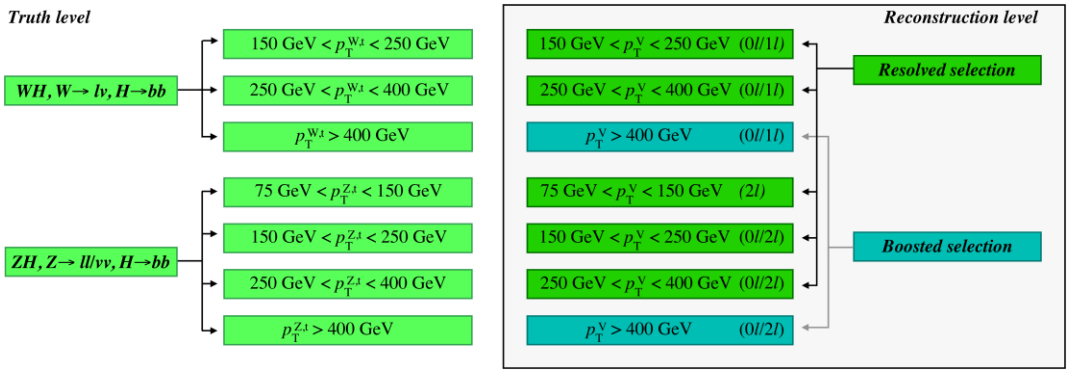


- STXS 1.2

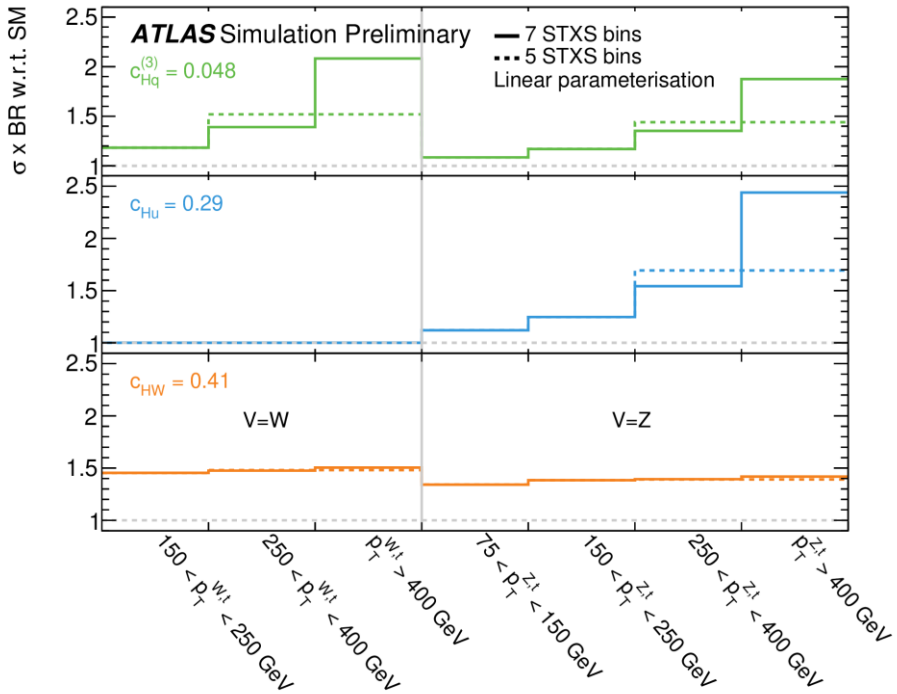


Combination VH, H→bb

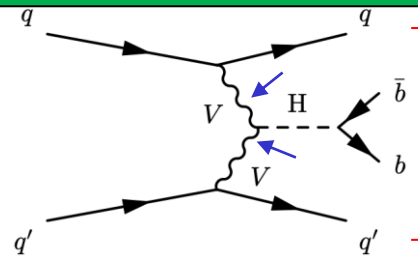
- STXS 1.2



- EFT

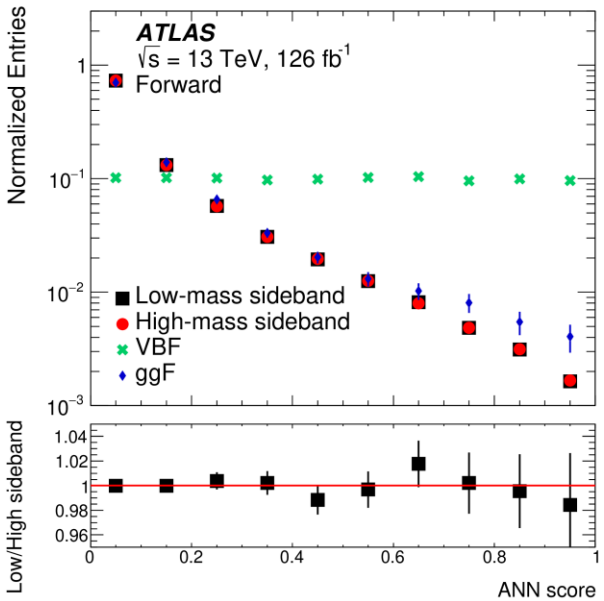


VBF, H→bb



Large Δη gap
No colour flow
(suppr. hadr. activity)

Run 2, √s=13 TeV, L=126 fb^{-1}, EPJC 81, 537 (2021)



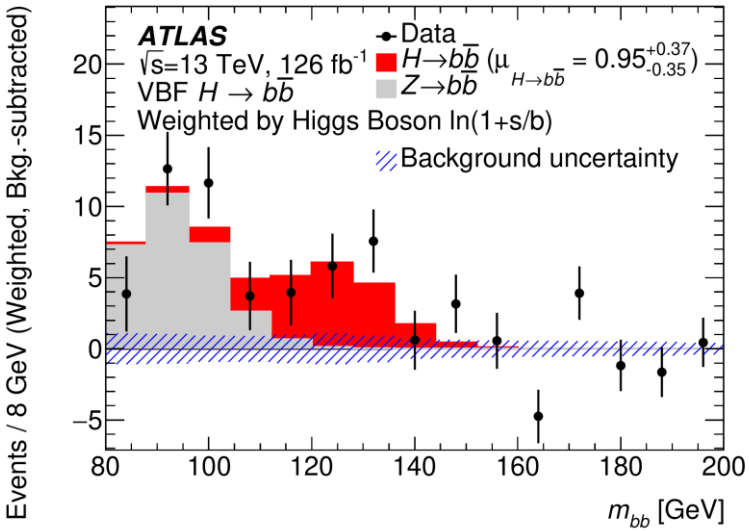
- Background

Primary: QCD multijets, Z(bb)
Data-driven

- Selection

b-tagging: BDT (MV2c10)
b jet correction : $\sigma(m_{bb})\downarrow$ 20 %
p_T^{bb}>150 GeV (avoid shaping m_{bb})
Categories fwd/central jets + NN

- Final DV



- Results

Z_{obs}=2.6
Z_{exp}=2.8

Bonus STXS truth bin
p_T^H>200 GeV (BSM)
→no deviation

$\mu=0.95^{+0.38}_{-0.36}$ dominated by stat

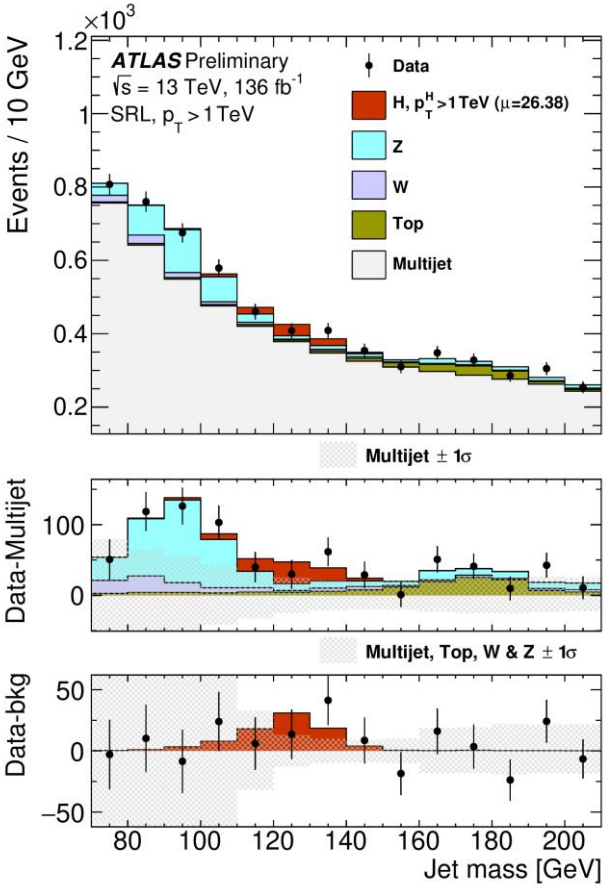
- Combined w/ VBF H(bb)+γ (Z_{obs}=1.0 σ)
(JHEP 03, 268 (2021), 132 fb^{-1})

Z_{obs}=2.9 σ
Z_{exp}=2.9 σ

Very high p_T, H→bb, all prod. modes

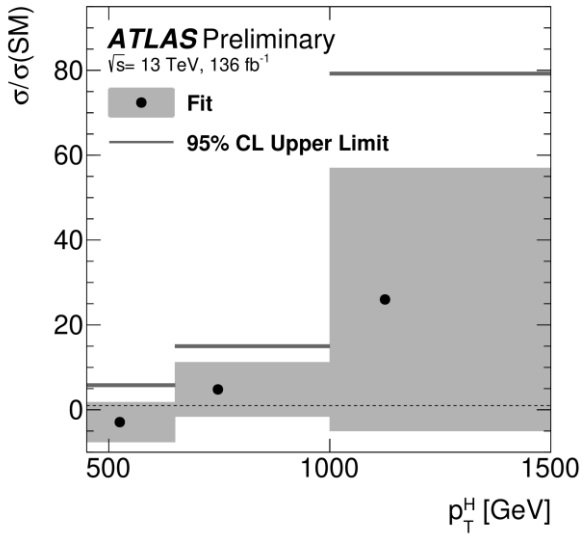
- p_T^H>450 GeV (even p_T^H>1 TeV bin)
- H→bb reconstructed as single large R jet

b-tagging for contained tracks



- Limits 95 % CL

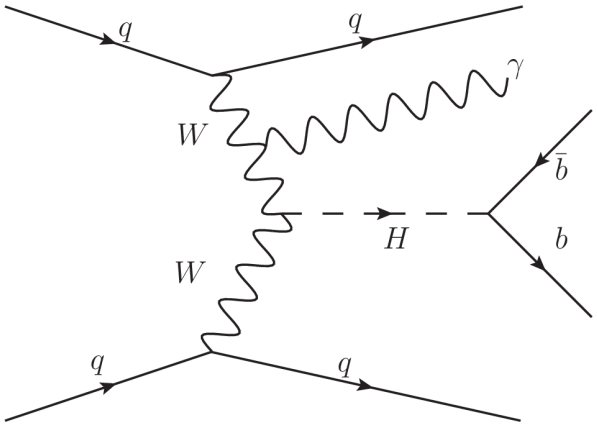
ATLAS-CONF-2021-010



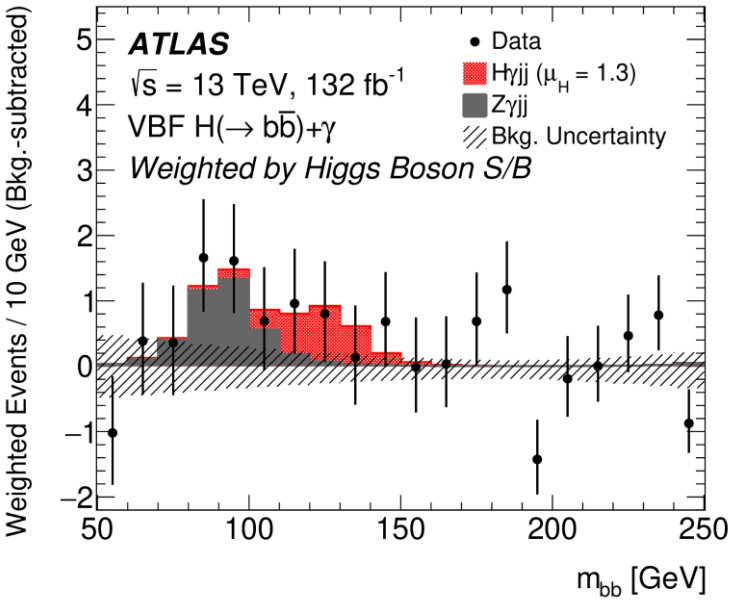
First ATLAS study w/ H→bb very high p_T and no particular production mode

H→bb w/ VBF + photon

Run 2, √s=13 TeV, L=132 fb^{-1}, JHEP 03, 268 (2021)
October 2020



Z_{obs}=1.3 (Z_{exp}=1.0)



H→cc

V(νν/lν/ll)H(cc)

Run 2, √s=13 TeV, L=139 fb^{-1}, ATLAS-CONF-2021-021

- c-tagging

DL1$_c$, veto b (MV2)
eff(c)=27 %
eff(b)=8 %
eff(j)=1.6 %

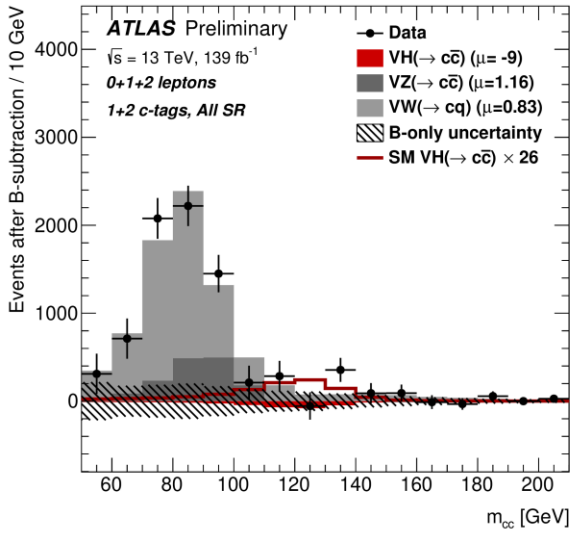
- Selection

p_T^V>75 GeV
≥2 jets
1 signal j w/ p_T>45 GeV
signal j=highest p_T central j
Veto b-jet for non-signal j (⊥ VH(bb))
ΔR(j,j)<thr for signal jets

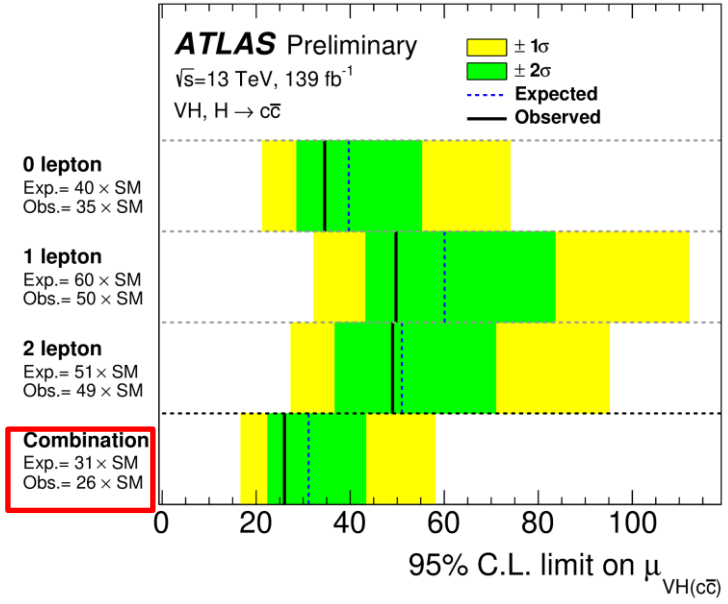
- Categories

-0, 1, 2-leptons
-2, 3 jets
-1, 2 c
-p_T^V (for 2-l)
+CRs

- Final DV



- Limit μ



- $|\kappa_c|$

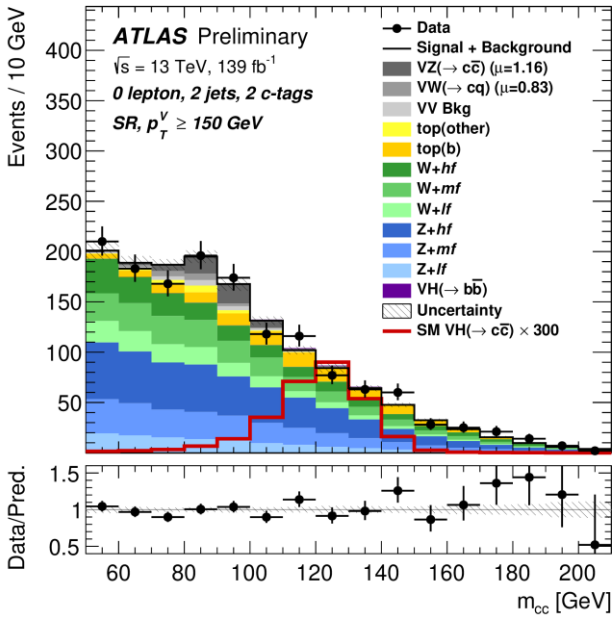
limit 95 %
obs: <8.5
exp: <12.4

$$\mu_{VH(c\bar{c})}(\kappa_c) = \frac{\kappa_c^2}{1 + B^{SM}_{H\to c\bar{c}}(\kappa_c^2 - 1)}$$

- Validation

VZ(cc), VW(cq)

H→cc


ATLAS Preliminary
√s = 13 TeV, 139 fb-1
0 lepton, 2 jets, 2 c-tags
SR, p_T^V ≥ 150 GeV
Data
Signal + Background
VZ(→ cc̄) (μ=1.16)
VW(→ cq) (μ=0.83)
VV Bkg
top(other)
top(b)
W+hf
W+mf
W+lf
Z+hf
Z+mf
Z+lf
VH(→ bb̄)
Uncertainty
SM VH(→ cc̄) × 300
Events / 10 GeV
Data/Pred.
m_cc [GeV]

H→ττ

$\tau_e\tau_\mu$, $\tau_l\tau_{had}$, $\tau_{had}\tau_{had}$

Run 2, $\sqrt{s}$=13 TeV, L=139 fb^{-1}, ATLAS-CONF-2021-044

- Background

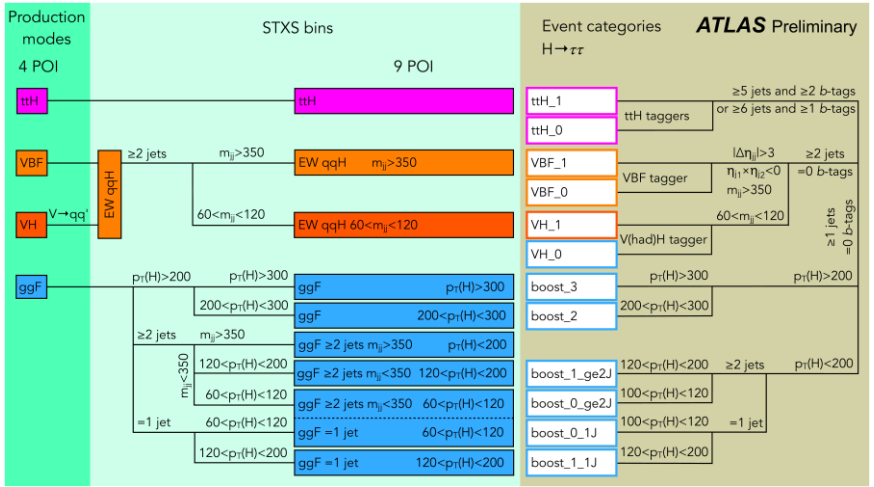
Primary: Z(ττ)+j, top
Secondary: Z(ll)+j, W+j
Modelling : MC+data-driven

- Selection

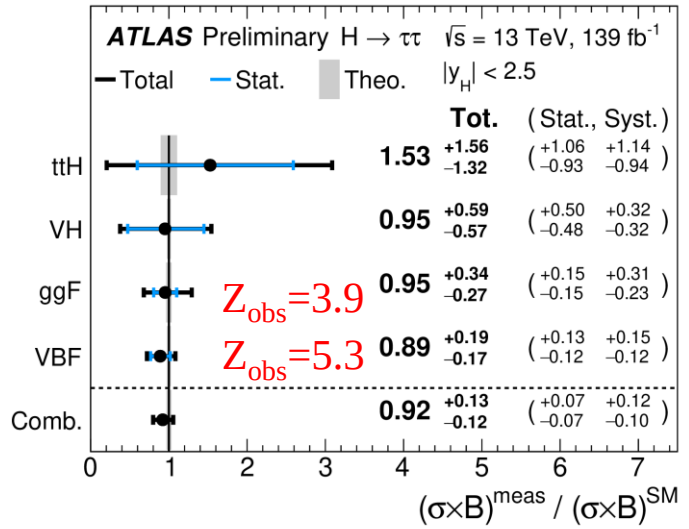
≥1 jet (suppr. bkg + categorisation)
MET>20 GeV (ν)
OS τ, inv. mass, angular cuts, veto b-jet, (apart ttH categ.)

- Categorization

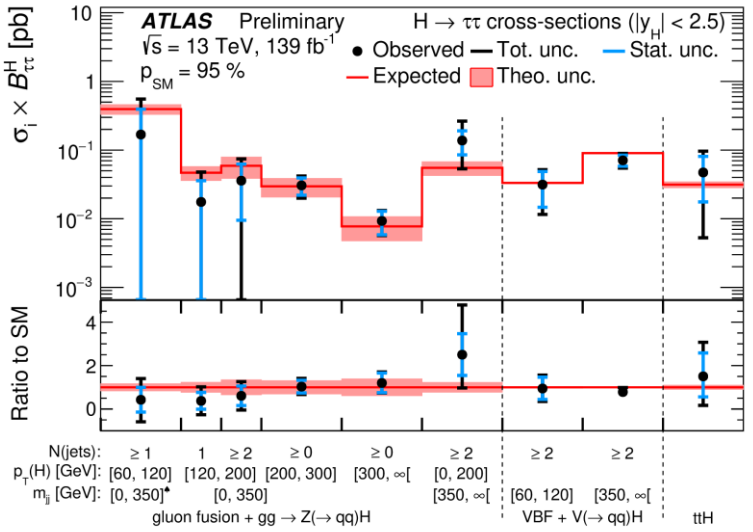
STXS 1.2 : f(p_T(H), #jets)



- μ_i



- STXS



H→μμ

m_H=125.09 GeV

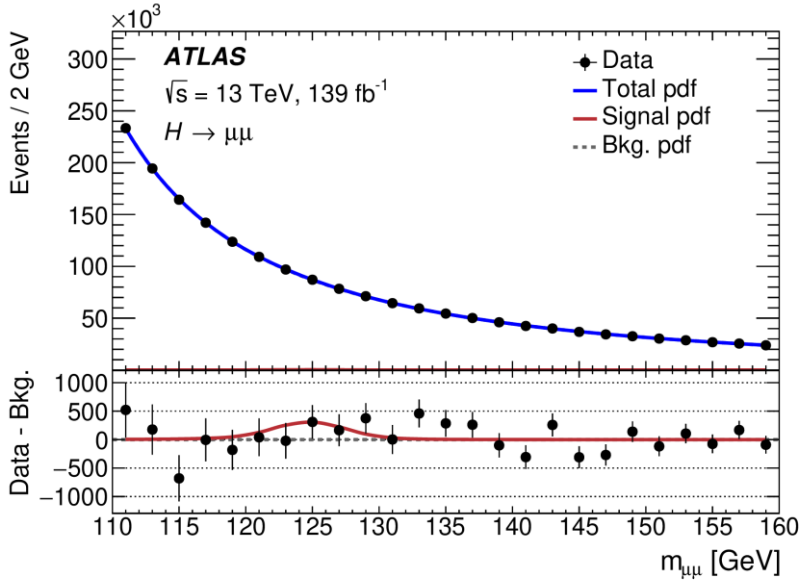
Run 2, √s=13 TeV, L=139 fb^{-1}, PLB 812, 135980 (2021)

- Bkg

inclusive: Drell-Yan
VH, ttH: VV, tt, 1-t, etc.

- Selection

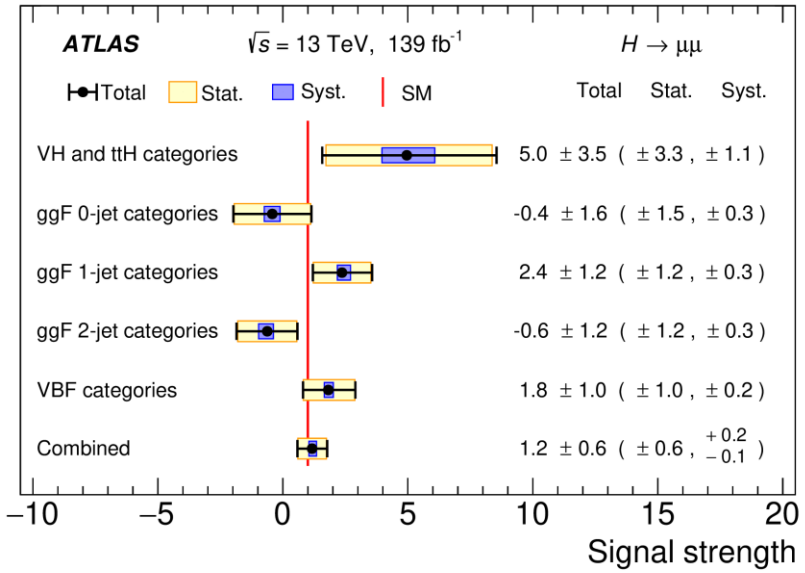
≥2 OS μ
BDT
Categorization (20): ttH, VH, VBF, ggH



- Results

Z_{obs}=2.0
Z_{exp}=1.7
Uncertainty dominated by stat.

Sensitivity x 2.5 wrt 36.1 fb^{-1}
analysis: x 2 (stat), +25 % (analysis)



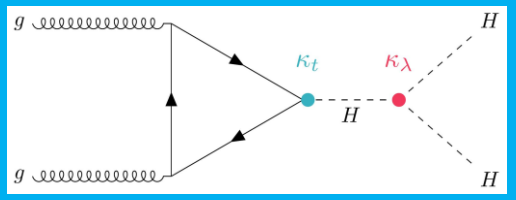
HH

HH

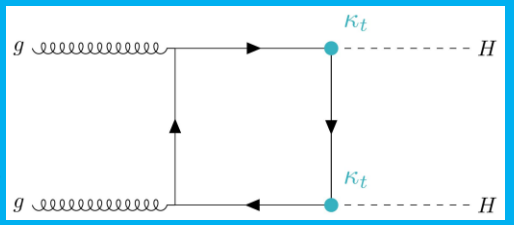
(flashed)

- **Non-resonant** (in the HH)

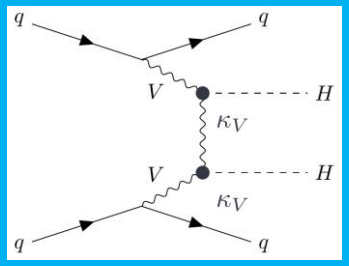
ggF

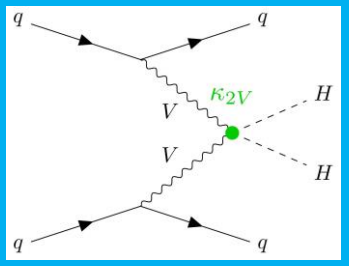


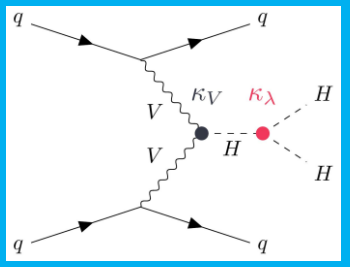
« - »
(SM)



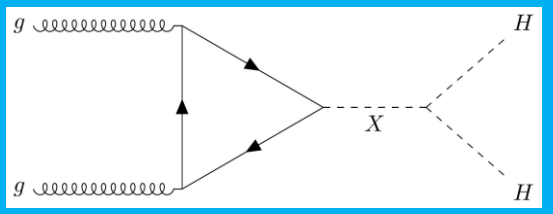
VBF

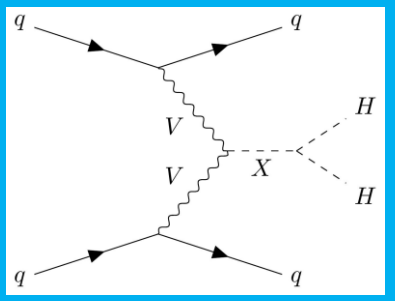


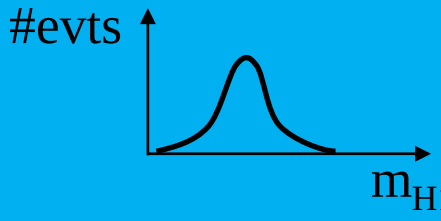


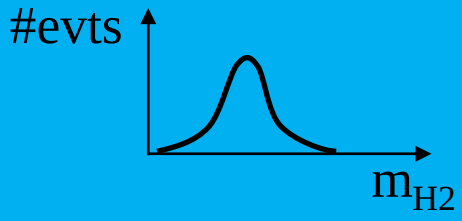


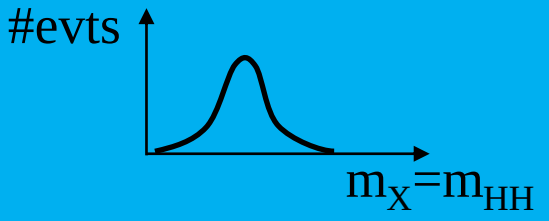
- **Resonant**











- Restricting to $H_{125}H_{125}$ (aa not reviewed in this category)
- Formally, HH may be classified as

$pp \rightarrow H_{125}H_{125}$ for non-resonant or $pp \rightarrow BSM \rightarrow H_{125}H_{125}$ for resonant

→prefer a specific thematic HH

Non-resonant HH searches Resonant

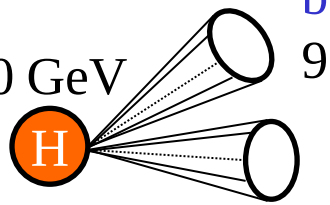
- bb bb — ATLAS-CONF-2021-035, July 2021

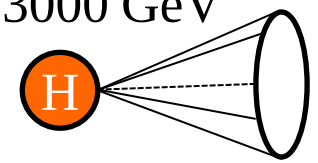
Largest rate

Final DV: m_{HH}

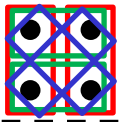
resolved
251-1500 GeV

boosted
900-3000 GeV



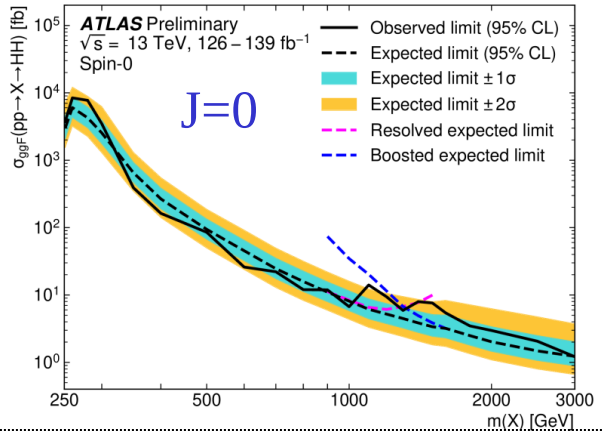


H_1 H_2



Pairing: BDT

(+J=2)

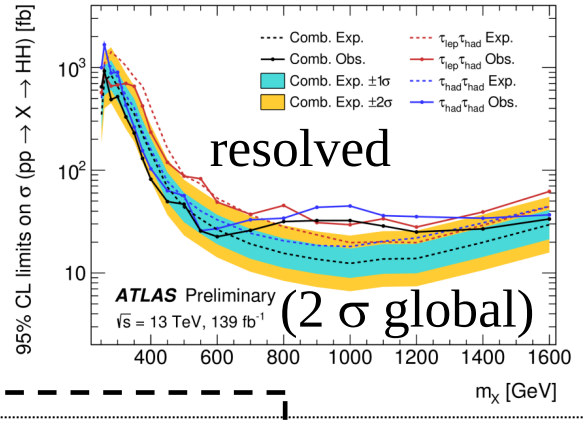


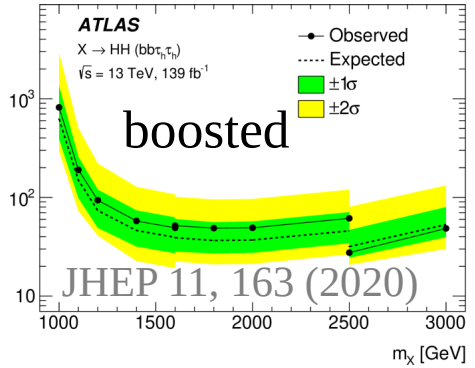
- bbττ ($\tau_{had}\tau_{had}$, $\tau_{had}\tau_{lep}$) — ATLAS-CONF-2021-030, July 2021

Intermediate rate

Final DV: MVA

Limits σ(HH→bbττ)
obs: 4.7xSM
exp: 3.9xSM



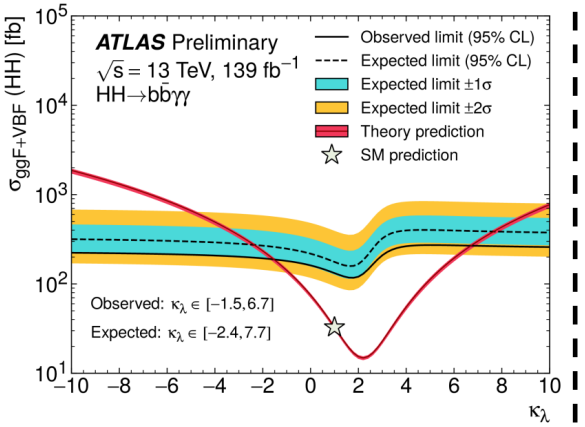


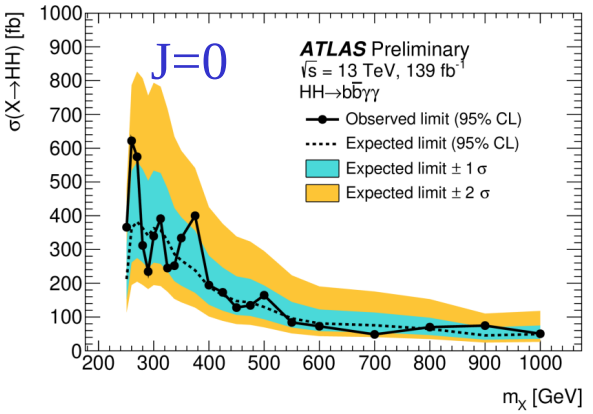
- bb γγ — ATLAS-CONF-2021-016, March 2021

Very low rate

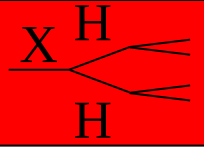
Final DV: $m_{\gamma\gamma}$

- Limit
  obs : 4.1xSM
  exp: 5.5xSM
- κ_λ limit
  obs : [-1.5, 6.7]
  exp : [-2.4, 7.7]





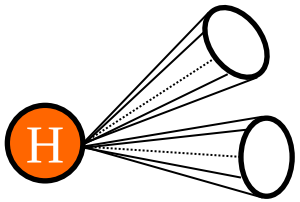
Resonant X→H(bb)H(bb), J=0, J=2

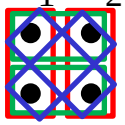


gg initiated, m_H=125 GeV

Run 2, √s=13 TeV, L≤139 fb^{-1}, ATLAS-CONF-2021-035

- Resolved: $m_X \in [251 ; 1500]$ GeV





H_1 H_2 $(\Sigma p_T)_1 > (\Sigma p_T)_2$

Pairing: BDT

eff: ≥65 %

$|\Delta\eta_{HH}|$<1.5 (suppr. multijets)

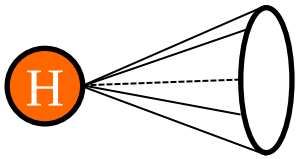
top veto (X_{Wt}<1.5)

Kinematic regions SR, VR, CR (X_{HH})

$$X_{HH} = \sqrt{\left(\frac{m(H_1) - 120\,\text{GeV}}{0.1 \times m(H_1)}\right)^2 + \left(\frac{m(H_2) - 110\,\text{GeV}}{0.1 \times m(H_2)}\right)^2}$$

Final DV: corrected m_{HH}

- boosted: $m_X \in [900 ; 3000]$ GeV



≥2 large-R jets, p_T>250 GeV

$|\eta|$<2.0, m_H>50 GeV, ≥1track jet (b)

≥1 H w/ p_T>450 GeV

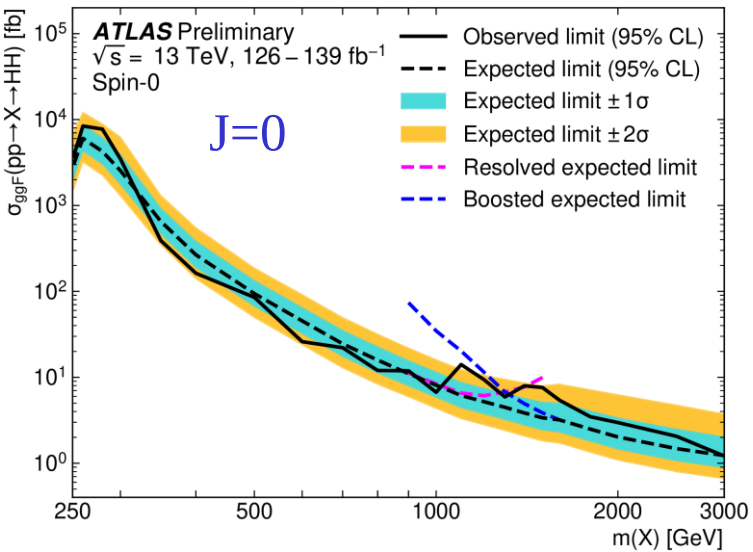
$|\Delta\eta_{HH}|$<1.3 (suppr. multijets)

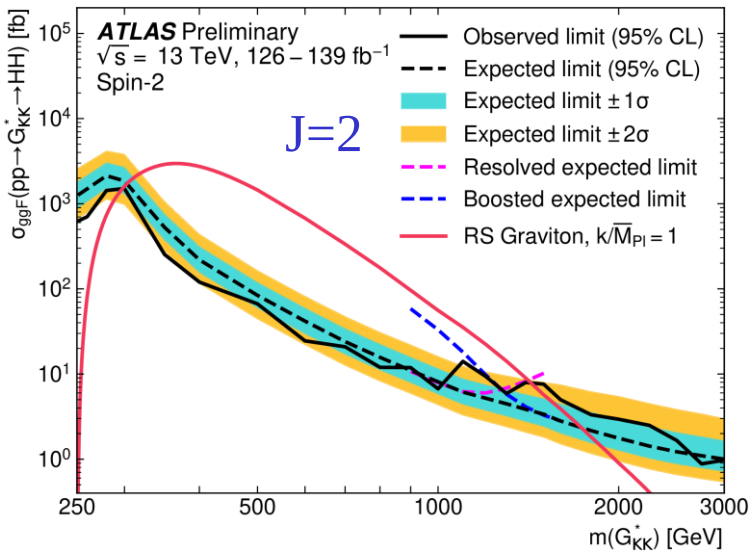
Categories #jets & b-tag status

Kinematic regions SR, VR, CR (X_{HH})

$$X_{HH} = \sqrt{\left(\frac{m(H_1) - 124\,\text{GeV}}{0.1 \times m(H_1)}\right)^2 + \left(\frac{m(H_2) - 115\,\text{GeV}}{0.1 \times m(H_2)}\right)^2}$$

Final DV: m_{HH}





- broader m_{HH} at low mass+deficit

Excl. region of mass for RS

HH→bbbb

gg HH

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Non Resonant Limit (xSM)

Observed	-2σ	-1σ	Expected	$+1\sigma$	$+2\sigma$
12.9	11.1	14.9	20.7	30.0	43.6

Resonant (superseeded)

VBF HH

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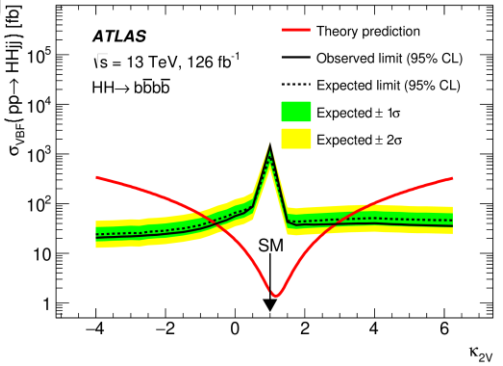
Non Resonant Limit (xSM)

	Observed	-2σ	-1σ	Expected	$+1\sigma$	$+2\sigma$
σ_{VBF} [fb]	1460	510	690	950	1330	1780
$\sigma_{VBF}/\sigma_{VBF}^{SM}$	840	290	400	550	770	1030

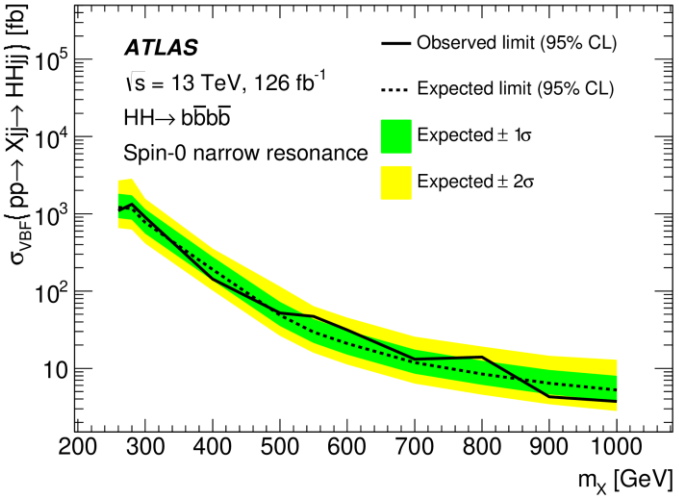
- Limits c_{2V} at 95 % CL

obs: [-0.56 ; 2.89]

exp: [-0.67 ; 3.10]



Resonant



Non-resonant and resonant H(bb)H(ττ)

$\tau_{had}\tau_{had}$, $\tau_{had}\tau_{lep}$ resolved
m_H=125 GeV

- Bkg

Top, Z+j, W+j, VV, 1-H, multijets
Data-driven from CR, simulation

- Selection

$\tau_{had}\tau_{had}$
=2 b-jets, p_T>45, 20 GeV, 2OS $\tau_{had\text{-}vis}$
veto additional leptons
$m_{\tau\tau}^{MMC}$>60 GeV

$\tau_{had}\tau_{lep}$
=2 b-jets, =1 e or μ, OS $\tau_{had\text{-}vis}$
$m_{\tau\tau}^{MMC}$>60 GeV
m_{bb}<150 GeV (suppr. tt)

- Final DV: MVA

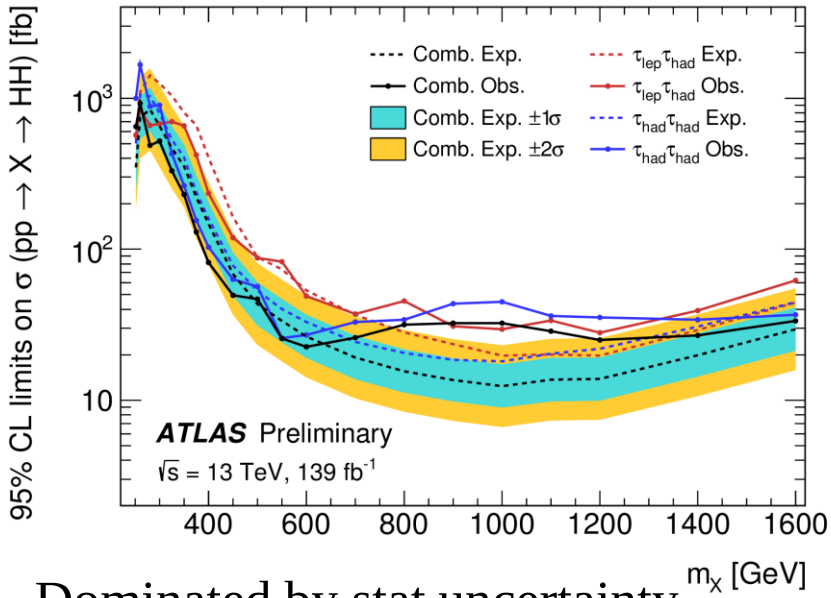
Run 2, $\sqrt{s}$=13 TeV, L=139 fb^{-1}, ATLAS-CONF-2021-030

- Non-resonant analysis (gg, qq)

Limits σ(HH→bbττ)
obs: 4.7xSM
exp: 3.9xSM

- Resonant analysis, J=0

$m_X \in [251 ; 1600]$ GeV



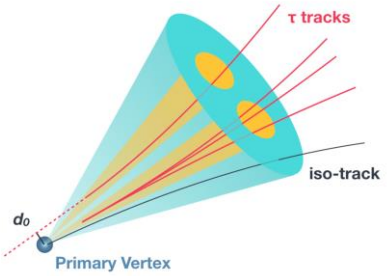
- Dominated by stat uncertainty
- Largest excess: m_X=1 TeV

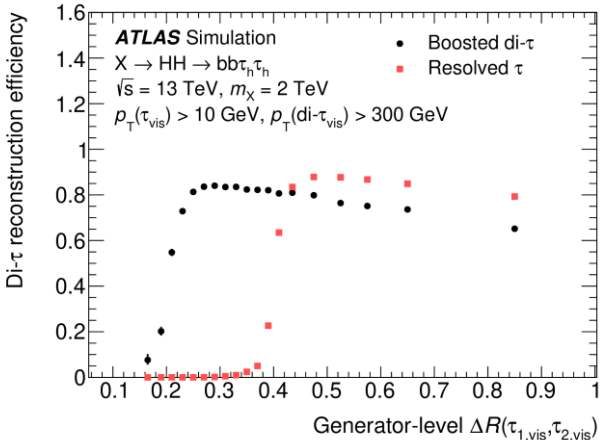
Z_{loc}=3.0 (Z_{glob}= 2.0)

Boosted resonant H(bb)H(ττ)

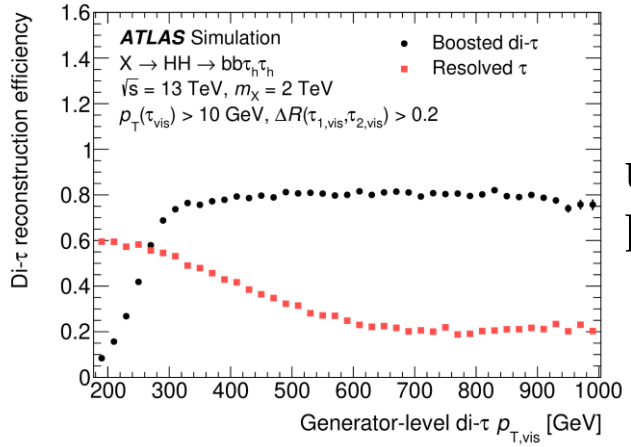
- ττ tagger for boosted $\tau_{had}\tau_{had}$ (1^{st} time in ATLAS) Run 2, $\sqrt{s}$=13 TeV, L=139 fb^{-1}, JHEP 11, 163 (2020)

Seed by large-R jet p_T>300 GeV
Recluster in sub-jets R=0.2
+BDT signal/q-g jets



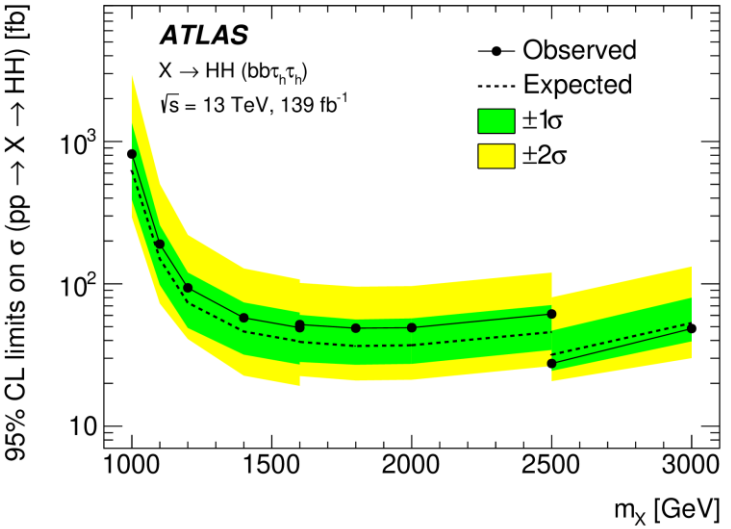


useful at
low ΔR(τ,τ)



useful at
high p_T

Application to gg→X→ H(bb)H(ττ), J=0
WP: eff boosted $\tau_{had}\tau_{had}$=60 %



Change selection at 1.6 and 2.5 TeV

H(bb)H(γγ): non-resonant, resonant

Run 2, √s=13 TeV, L=139 fb^{-1}, ATLAS-CONF-2021-016

- γγ part following H(γγ) analysis

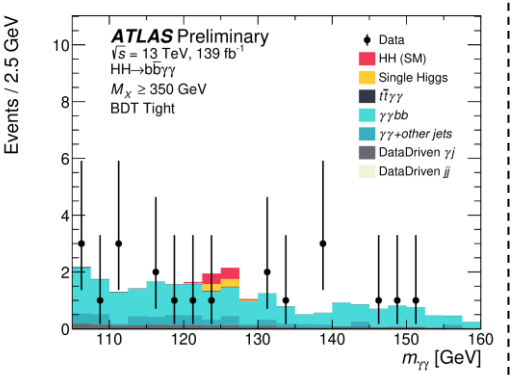
≥2 jets, p_T>25 GeV, |η|<2.5 (central), b-tagged
<6 central jets (|η|<2.5)
$m_{bb\gamma\gamma}^{*}=m_{bb\gamma\gamma}-m_{bb}-m_{\gamma\gamma}+250$ GeV

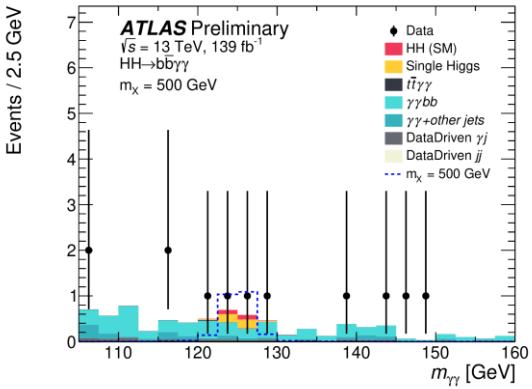
- Non Resonant

4 categories BDT=f(tight, κ_λ)

- Resonant

J=0, Scalar



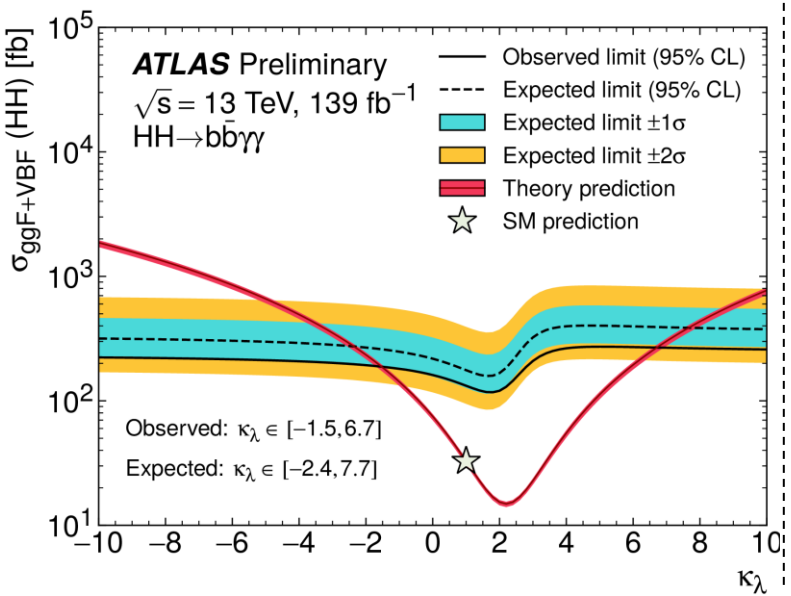


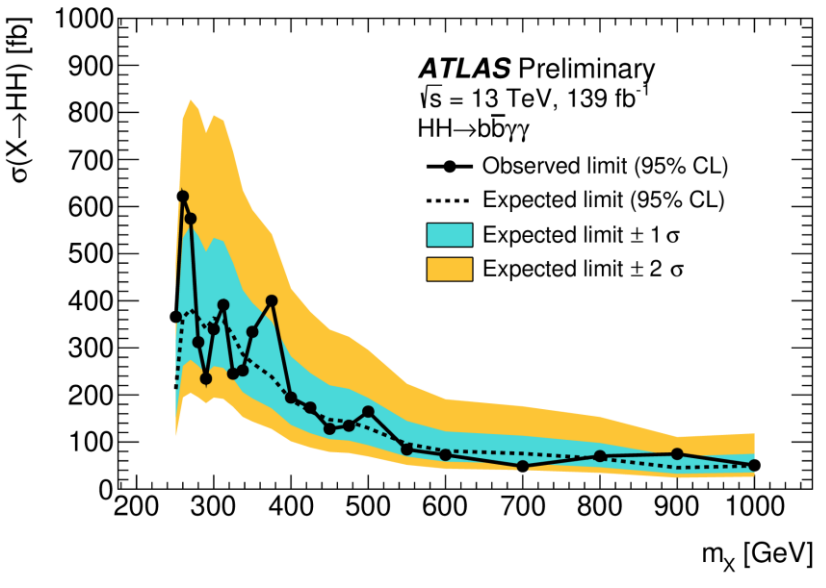
- 95 % CL Limit

obs : 4.1xSM
exp: 5.5xSM

- κ_λ limit

obs : [-1.5, 6.7]
exp : [-2.4, 7.7]





$pp \rightarrow H_{125} \rightarrow BSM$

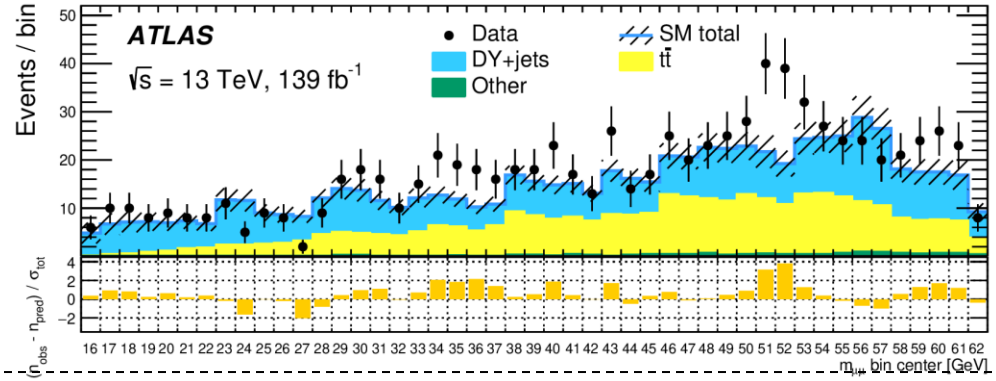
H→aa

Pseudo-scalar a

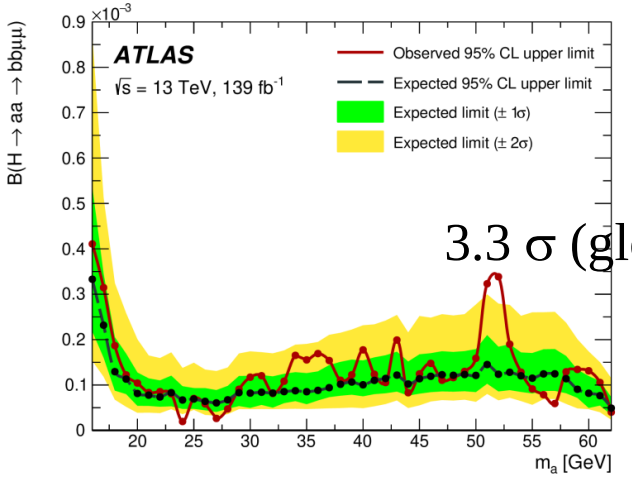
- H→aa→bbμμ, $m_a \in [16 ; 62]$ GeV, **inclusive** Run 2, $\sqrt{s}$=13 TeV, L=139 fb^{-1}, CERN-EP-2021-157

Kinematic fit+cuts: constrain m_{bb} to $m_{\mu\mu}$
MET<60 GeV (suppr. tt)
Cut BDT

- Counting experiment



- Exclusion limits (95 % CL)

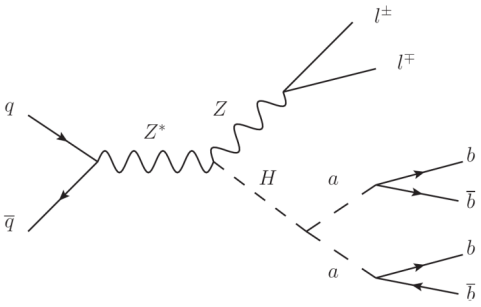


3.3 σ (global: 1.7 σ)

↓ x2-5 wrt 36.1 fb^{-1} (x2: dataset, x2 MVA)

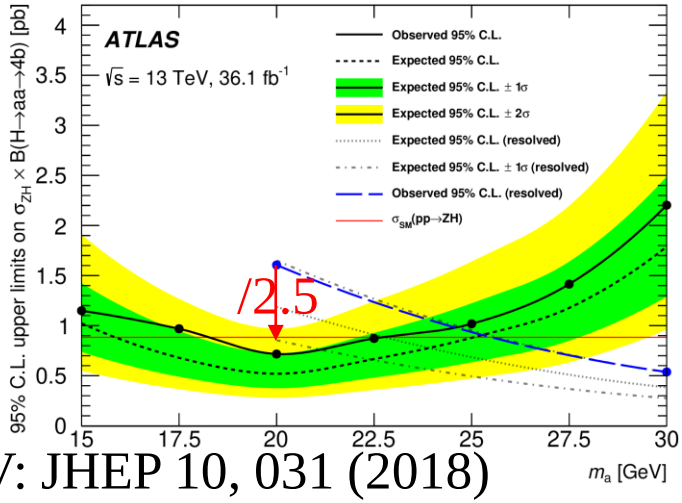
- ZH(aa→bbbb), $m_a \in [15 ; 30]$ GeV

Run 2, $\sqrt{s}$=13 TeV, L=36 fb^{-1}, PRD 102, 112006 (2020)



(θ~m/p_T)
R=0.8

Counting experiment



Complementary to $m_a \in [20 ; 60]$ GeV: JHEP 10, 031 (2018)

H→aa→bbμμ

Pseudo-scalar a, $m_a \in [16 ; 62]$ GeV

Run 2, $\sqrt{s}$=13 TeV, L=139 fb^{-1}, CERN-EP-2021-157

- Selection

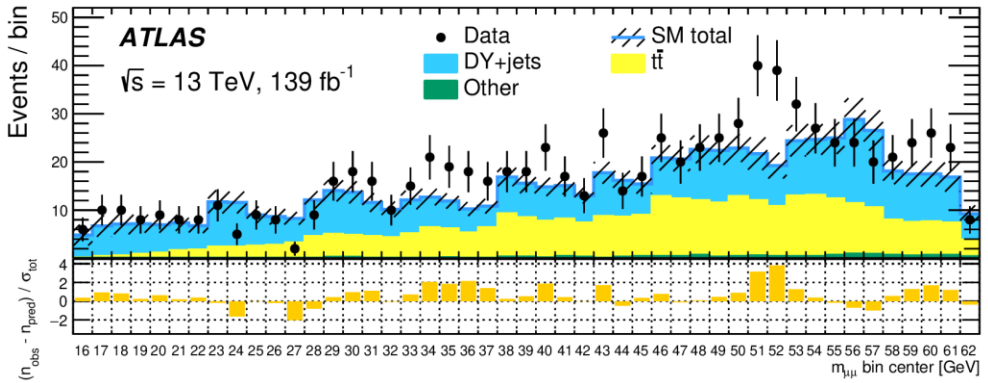
=2 μ OS p_T=f(trigger)
$15<m_{\mu\mu}<65$ GeV
=2 b-jets, $p_T>20$ GeV

Kinematic fit+cuts: constrain m_{bb} to $m_{\mu\mu}$
MET<60 GeV (suppr. tt)
Cut BDT

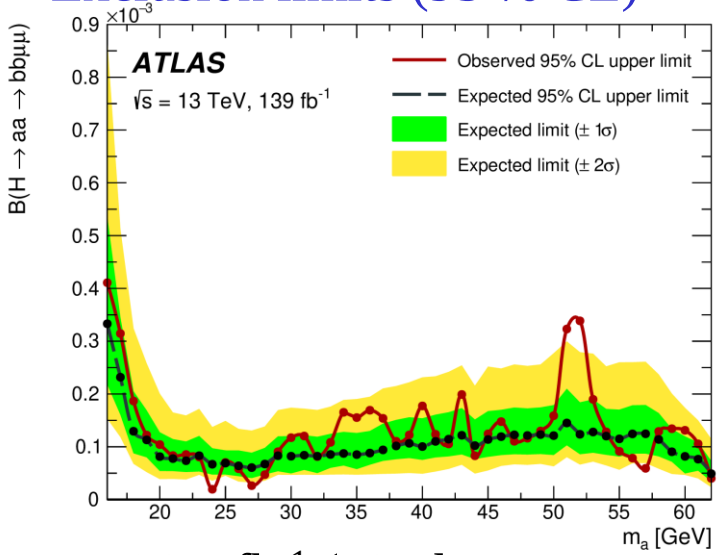
- Background

Primary: DY, tt: CR
Secondary: VV, 1-t, tt: MC

- Counting experiment



- Exclusion limits (95 % CL)



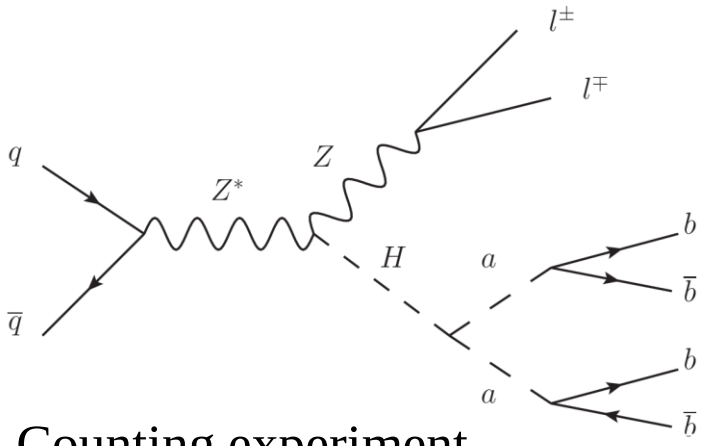
↓ x2-5 wrt 36.1 fb^{-1} (x2: dataset, x2 MVA)

Largest excess : 3.3 (global: 1.7) at $m_{\mu\mu}$=52 GeV

H→aa→bbbb

Pseudo-scalar a, $m_a \in [15 ; 30]$ GeV

Run 2, $\sqrt{s}$=13 TeV, L=36 fb^{-1}, PRD 102, 112006 (2020)

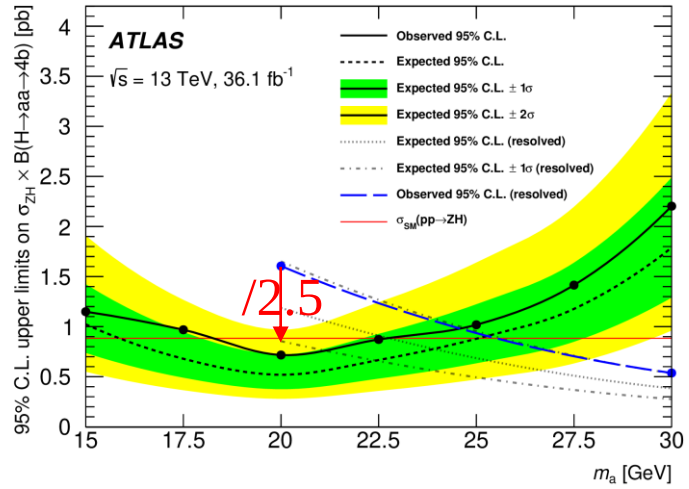


($\theta \sim m/p_T$)
R=0.8

- Selection

$m_{ll} \in [85 ; 100]$ GeV
$m_a \approx m_a$ (within 25 GeV)
m_{aa} compatible w/ m_H

Counting experiment



Complementary to $m_a \in [20 ; 60]$ GeV: JHEP 10, 031 (2018)

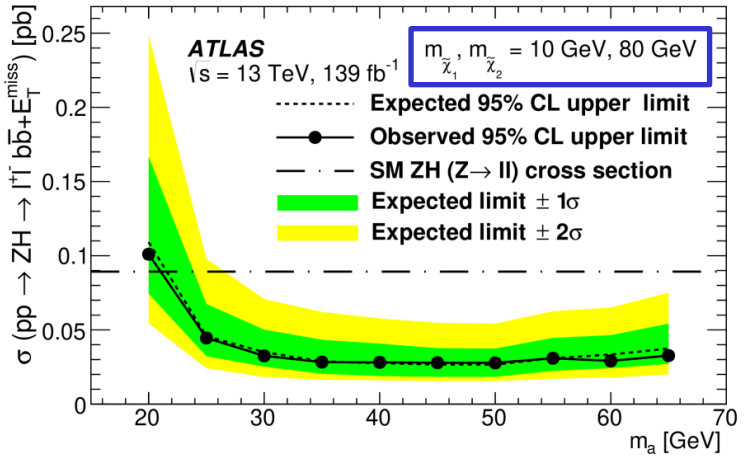
Other BSM searches

- NMSSM, $Z(ll)H(\tilde{\chi}_2^0\tilde{\chi}_1^0 \rightarrow a(bb)\ \tilde{\chi}_1^0\tilde{\chi}_1^0)$

$m_a \in [20\ ;\ 65]$ GeV

Run 2, √s=13 TeV, L=139 fb^{-1}, CERN-EP-2021-098

example



- limit BR$(H \rightarrow \tilde{\chi}_2^0\tilde{\chi}_1^0) = 31\ \%$ (95 % CL)

For $m_a \in [35\ ;\ 55]$ GeV, $m_{\tilde{\chi}_1^0} = 10\ GeV, m_{\tilde{\chi}_2^0} = 80\ GeV$

(assuming SM ZH, BR$(\tilde{\chi}_2^0 \rightarrow a\ \tilde{\chi}_1^0) = 100\ \%$, BR$(a \rightarrow bb) = 100\ \%$)

uncertainty dominated by stat

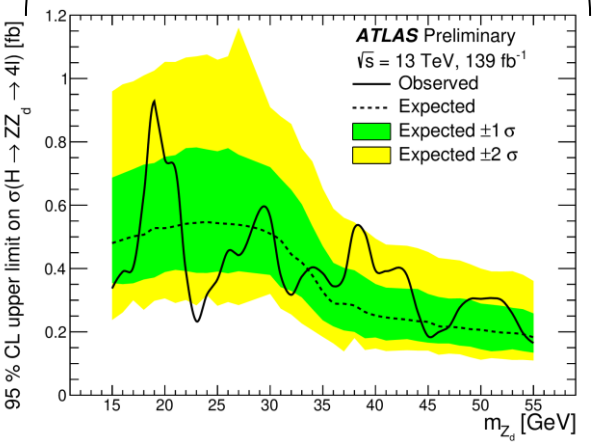
- First limit on this exotic decay from LHC

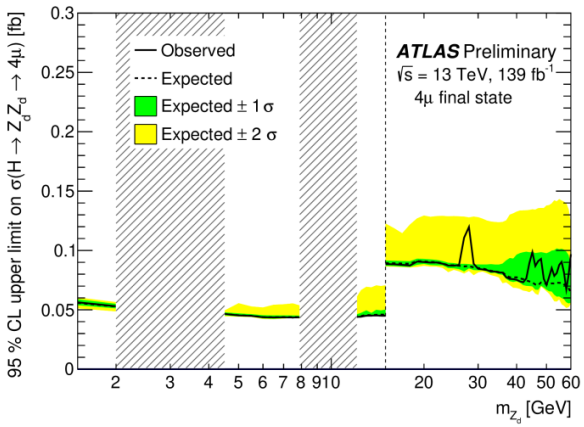
Run 2, √s=13 TeV, L=139 fb^{-1}, ATLAS-CONF-2021-034

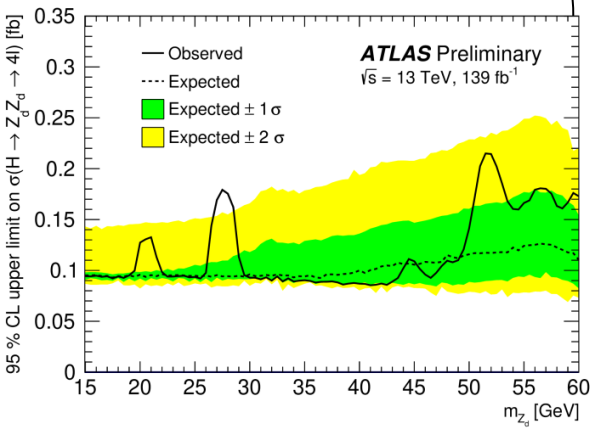
- H→ZX→4l

H→XX→4l

X={J=0: s, A, J=1: Z_d}







NMSSM, $Z(ll)H(\tilde{\chi}_2^0\tilde{\chi}_1^0 \rightarrow a(bb)\tilde{\chi}_1^0\tilde{\chi}_1^0)$

$Z(ll)H(\tilde{\chi}_2^0\tilde{\chi}_1^0 \rightarrow a\,\tilde{\chi}_1^0\tilde{\chi}_1^0)$
a→bb, $m_a \in [20 ; 65]$ GeV

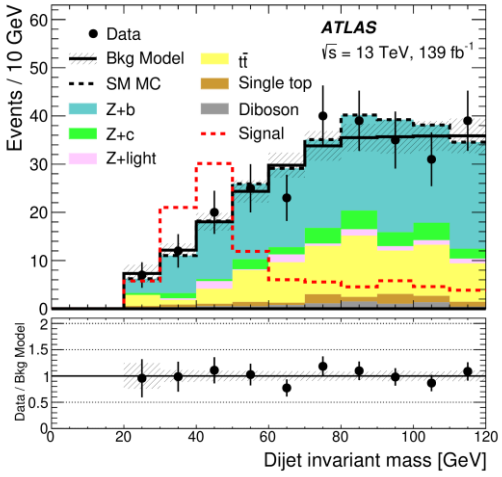
Run 2, √s=13 TeV, L=139 fb^{-1}, CERN-EP-2021-098

- Bkg: Z+HF, tt

- Selection

=2 l, OS same flavour, veto add. l
$81<m_{ll}<101$ GeV
≥2 j $p_T>20$ GeV, 1 b-tagged, $20<m_{jj}<120$ GeV
MET>100 GeV
etc.

- Final DV: m_{jj}

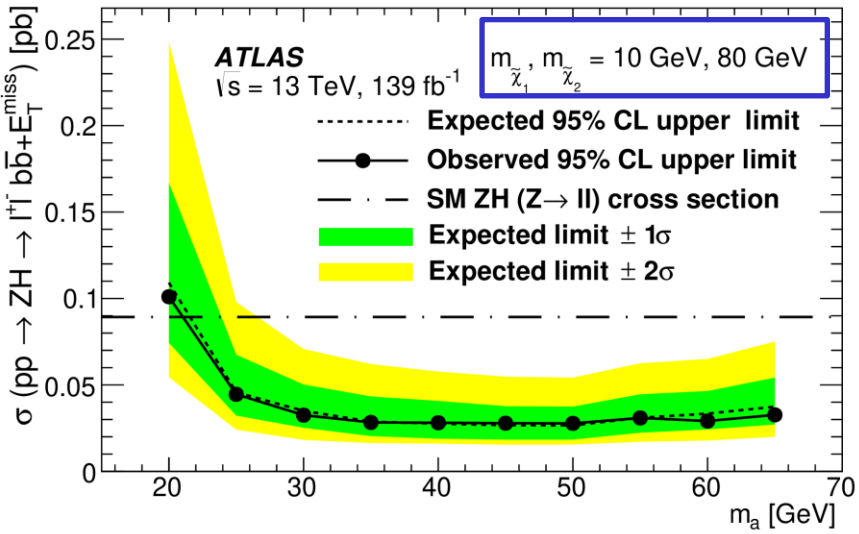


$(m_a, m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_2^0}) = (45\ GeV, 10\ GeV, 80\ GeV)$

- 3D scan in $(m_a, m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_2^0})$

uncertainty dominated by stat

example



- limit BR$(H \rightarrow \tilde{\chi}_2^0\tilde{\chi}_1^0) = 31$ % (95 % CL)

For $m_a \in [35 ; 55]$ GeV, $m_{\tilde{\chi}_1^0} = 10\ GeV, m_{\tilde{\chi}_2^0} = 80\ GeV$

(assuming SM ZH, BR$(\tilde{\chi}_2^0 \rightarrow a\,\tilde{\chi}_1^0) = 100$ %, BR$(a \rightarrow bb) = 100$ %)

- First limit on this exotic decay from LHC

H→ZX→4l, H→XX→4l,

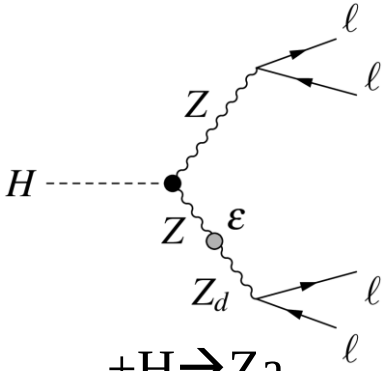
Dark matter X={J=0: s, A, J=1: Z_d}

Run 2, √s=13 TeV, L=139 fb^{-1}, ATLAS-CONF-2021-034

Hypercharge portal

H_{125}→ZX→4l

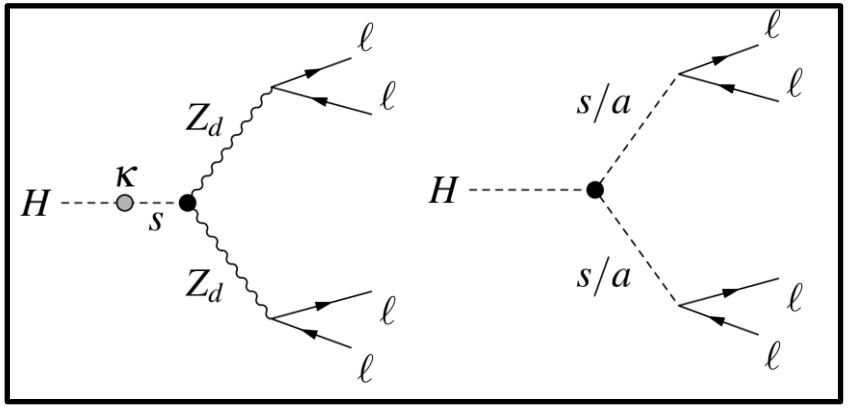
15<m_X<55 GeV



+H→Za

Higgs portal

H_{125}→XX →4l

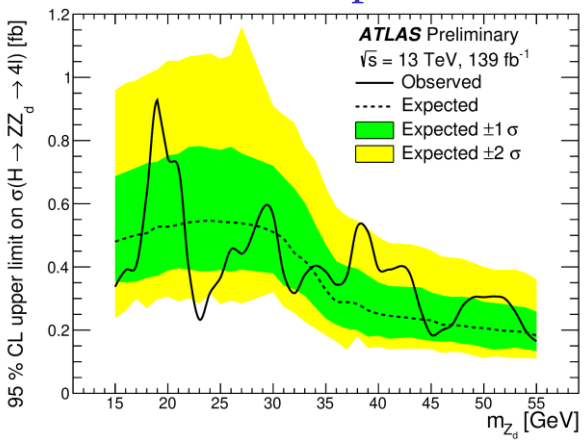


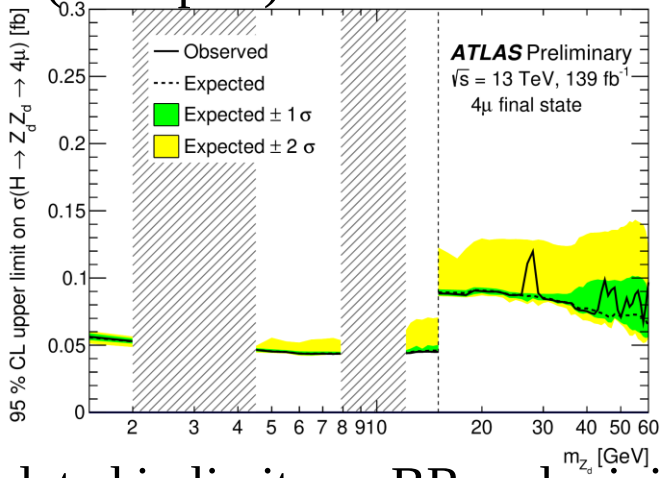
Higgs→scalars

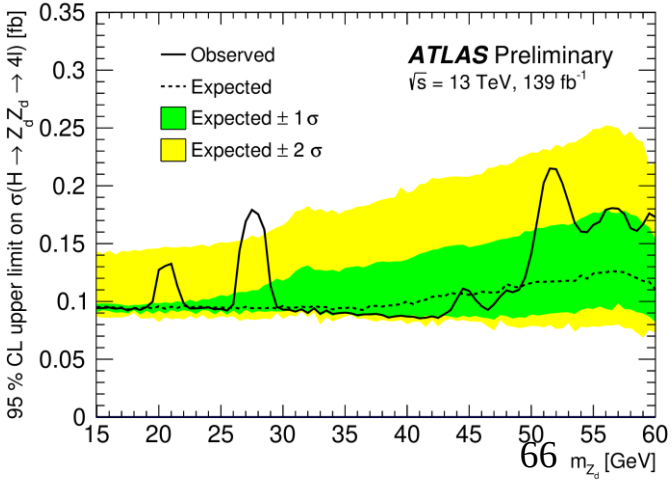
4μ: 1<m_X<15 GeV (LM)

4l: 15<m_X<60 GeV (HM)

- model-independent limits (examples)







Translated in limits on BR and mixing parameters

H→Z(ll)a, Z(ll)η_c, Z(ll)J/ψ

Run 2, √s=13 TeV, L=139 fb^{-1}, PRL 125, 221802 (2020)

- Light boson, m<4 GeV

extended scalar or cc, decay jets

- Selection

≥2 OS e or μ, p_T>18 GeV, ≥1 p_T>27 GeV

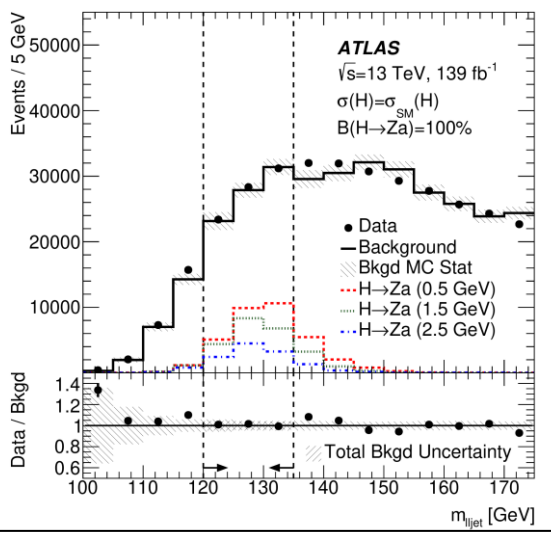
$m_{ll} \in [81 ; 101]$ GeV

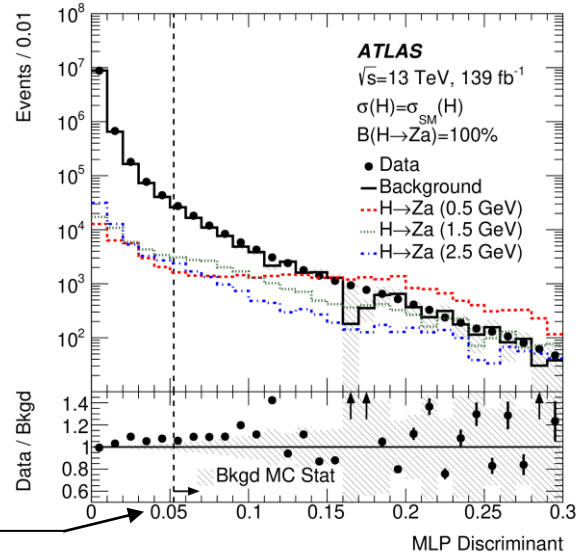
a/cc decay: 1-jet (θ~m/p_T), p_T>20 GeV

+regression NN

120<m_{llj}<135 GeV

NN discrimination + cut, Counting





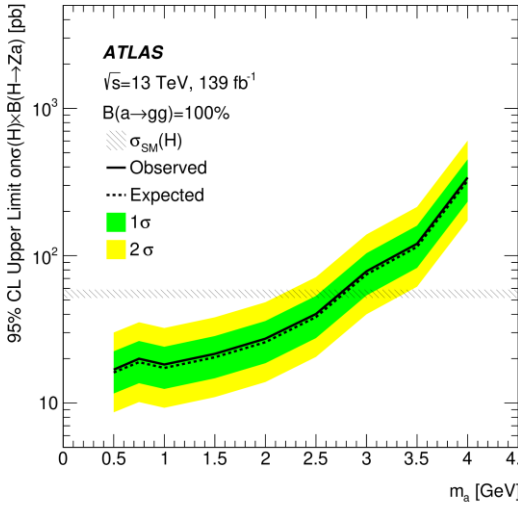
- Background

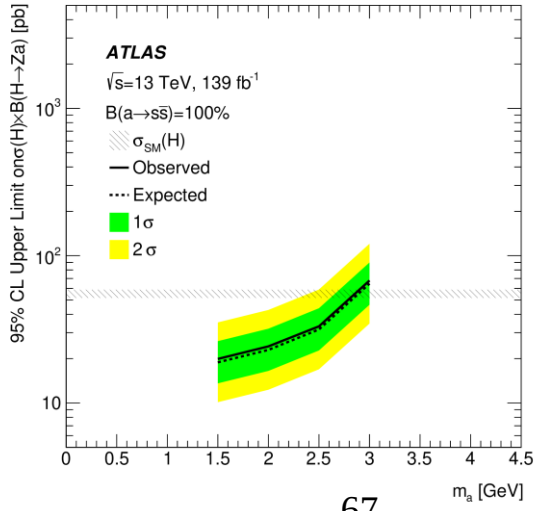
Z+jets (CR ABCD)

- Limits (95 % CL)

σ(pp→H)BR(H→Z Q/a)

	Z(ll)η_c	Z(ll)J/ψ	H→Z(ll)a
obs:	110 pb	110 pb	17-340 pb
exp:	100 pb	100 pb	16-320 pb





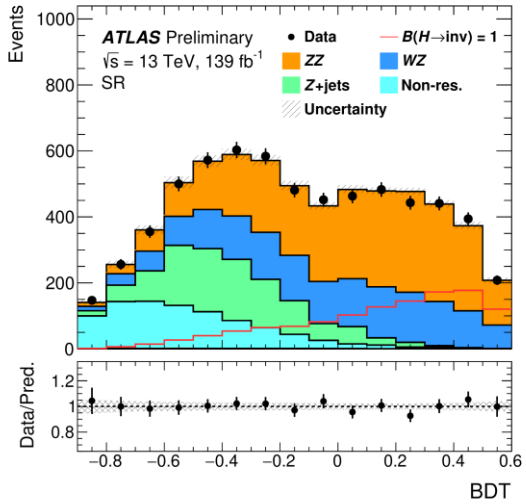
First direct limit of H_{125} to this decay

H→invisible: DM-SM coupling

- H_{125} mediator

Run 2, √s=13 TeV, L=139 fb^{-1}, ATLAS-CONF-2021-029

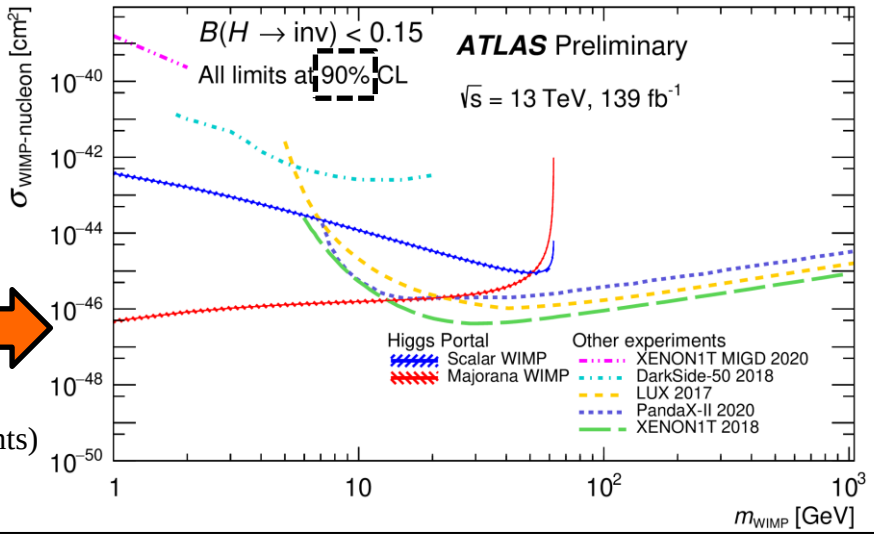
Z(ll)H(χχ), DM (χ): scalar/Majorana



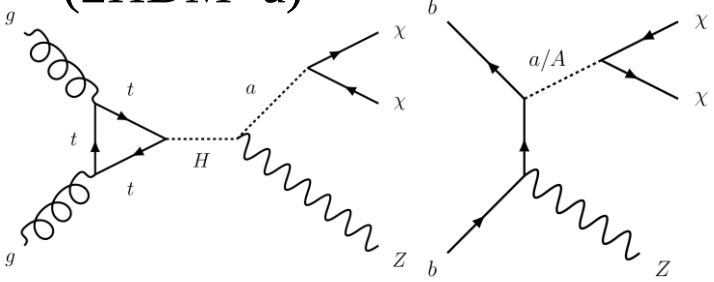
95 % limit BR(H→inv)
obs: 18 %
exp: 18 %

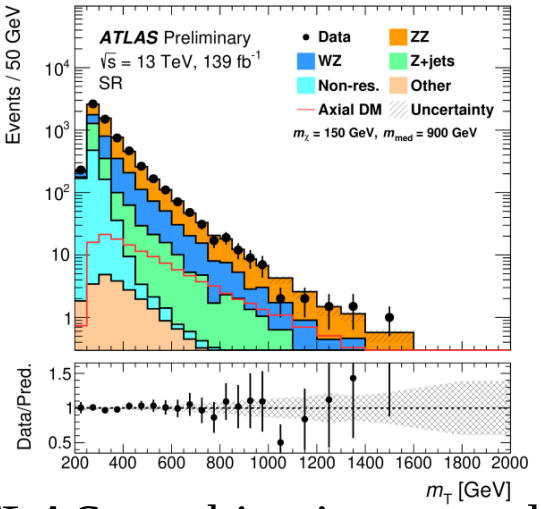
Competitive in low m_{DM}
With direct measurements
(low sensitivity w/ recoil measurements)

Interpretation: $\sigma_{DM\text{-}nucleon}=f(m_{WIMP})$

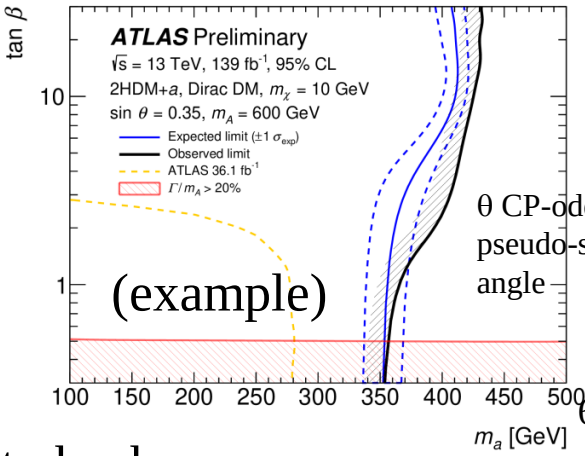


- Pseudo-scalar mediator a (2HDM+a)





Exclusion limits



(example)

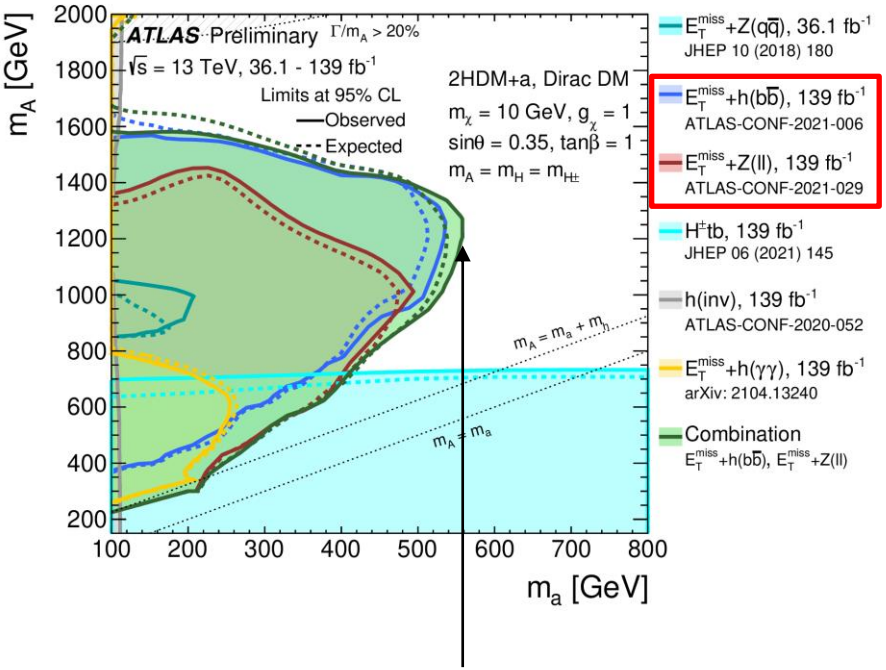
θ CP-odd pseudo-scalar mixing angle

DM ATLAS combination moved to backup

Dark matter : ATLAS combination

Run 2, $\sqrt{s}$=13 TeV, L=139 fb^{-1}, ATLAS-CONF-2021-036

MET+h(bb), MET+Z(ll), MET+h(γγ), $H^{\pm}$→tb, H(inv), etc.
Combination+interpretation in 2DHM(II)+a(χχ)



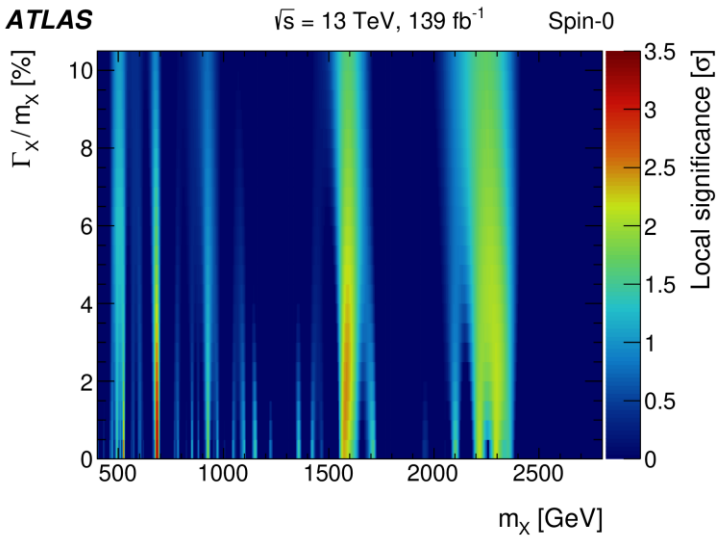
+other planes

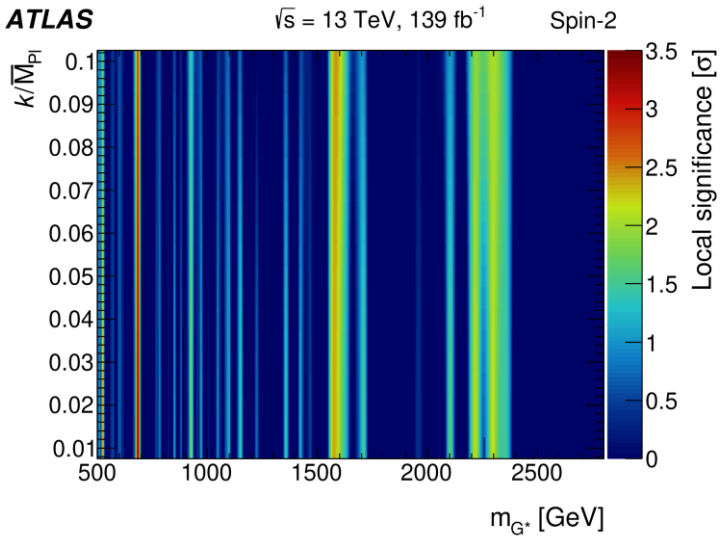
Exclusion $m_a \leq 560$ GeV for $m_A=m_H=m_{H\pm}=1.2$ TeV, sin θ =0.35, tan β =1.0

pp→BSM H

X→γγ

Run 2, √s=13 TeV, L=139 fb^{-1}, PLB, 822, 136651 (2021)





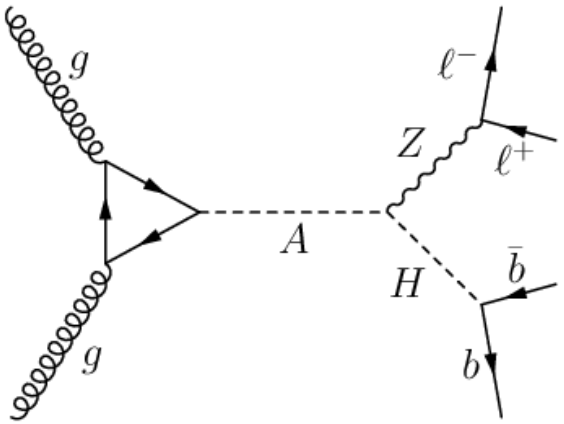
A→Z(ll)H, H→bb, H→WW

CP-odd, A

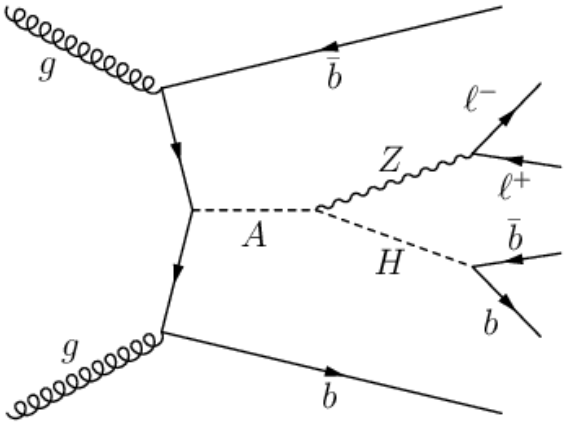
Run 2, $\sqrt{s}$=13 TeV, L=139 fb^{-1}, EPJC 81, 396 (2021)

A→Z(ll)H, H→bb

ggA



bbA



H: NWA

A : $\Gamma \approx \Gamma_{exp}$ or higher

- Final DV: m_{llbb}
- Selection

=2 e or 2 μ, OS (not required for electrons)

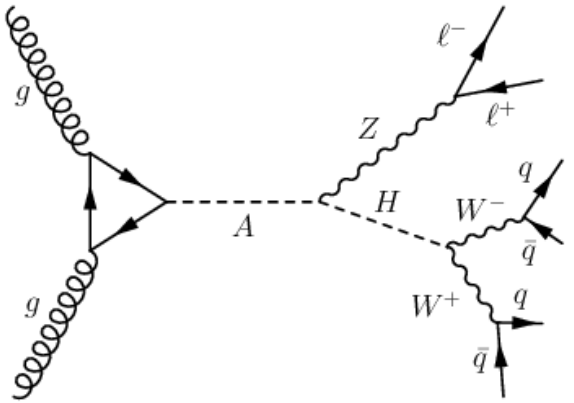
$m_{ll} \in [80 ; 100]$ GeV

≥2 b (llbb) or ≥4 jets (llWW)

Channel specific selection

A→Z(ll)H, H→WW

ggA



W→jj: jet combinatorics if bbA

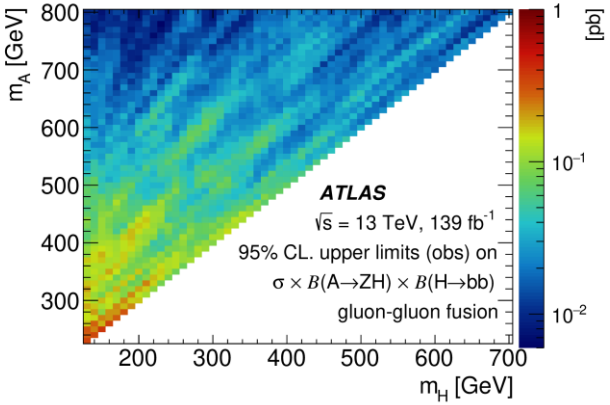
- Final DV: m_{ll4q}

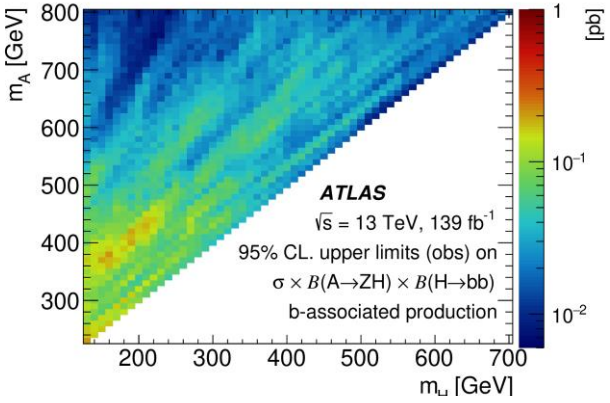
+other tan β, m_H

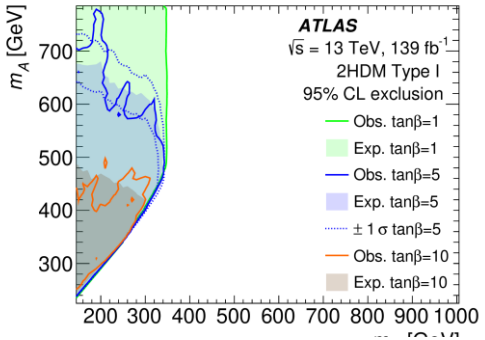
A→Z(ll)H, H→bb, H→WW

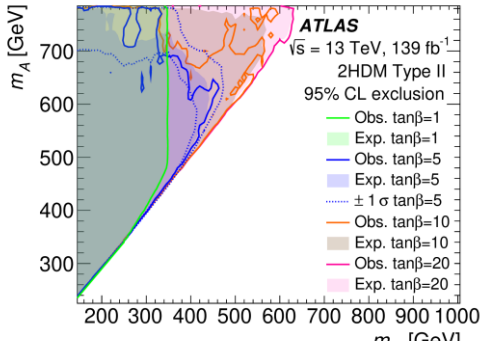
Run 2, √s=13 TeV, L=139 fb^{-1}, EPJC 81, 396 (2021)

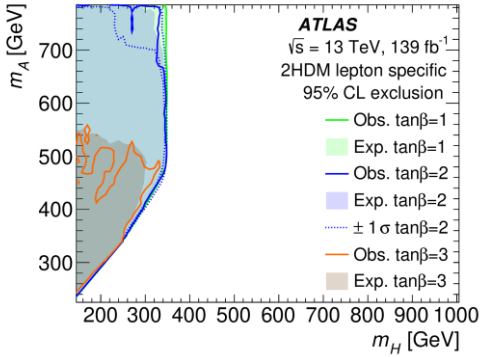
A→Z(ll)H, H→bb

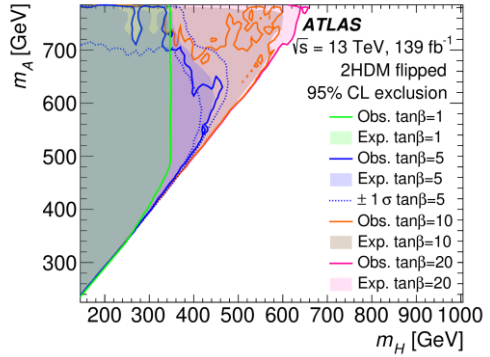




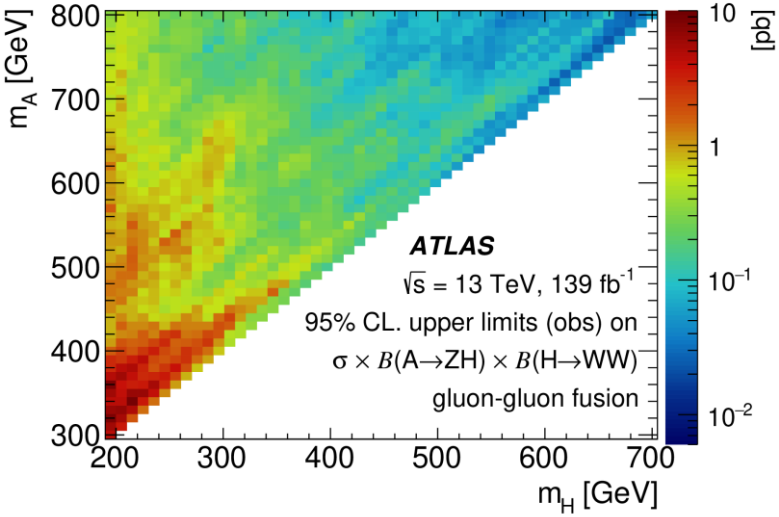


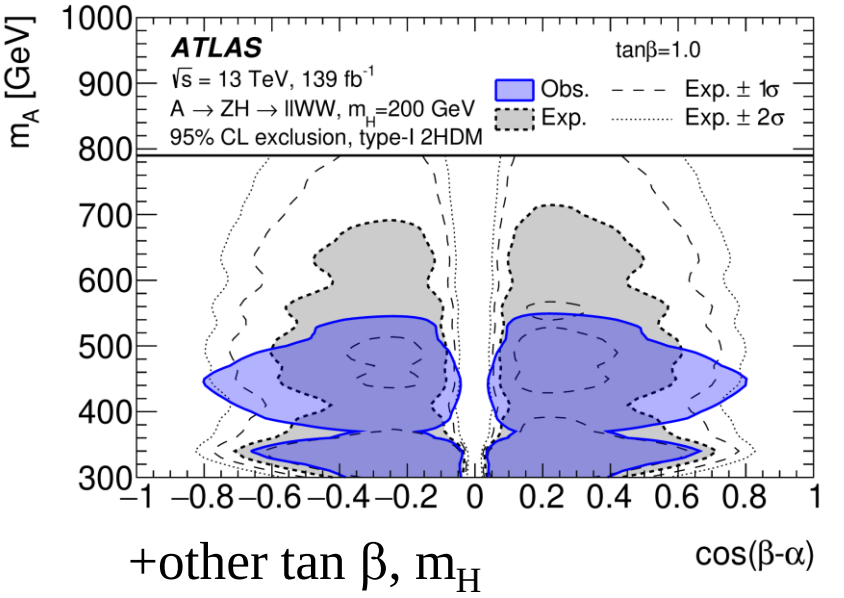






A→Z(ll)H, H→WW





+other tan β, m_H

$pp \rightarrow BSM_{\neq H} \rightarrow H$

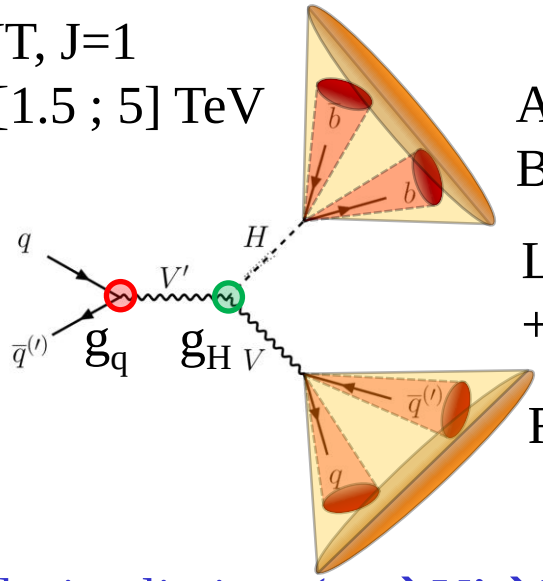
and

$pp \rightarrow BSM\ H$

V'→VH, qqbb

- HVT, J=1

$m_{V'} \in [1.5 ; 5]$ TeV



A: g_q=-0.55, g_H=-0.56 ; g_V=1

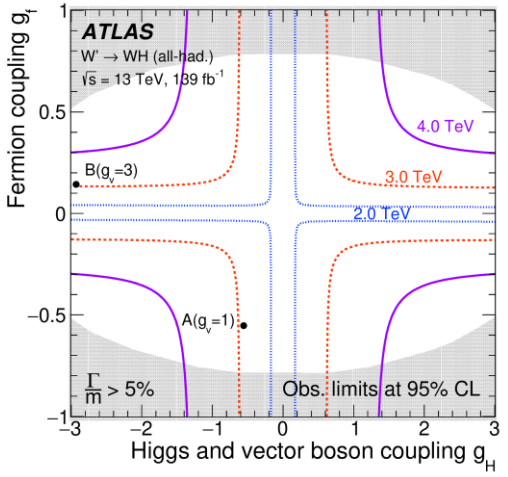
B: g_q=0.14, g_H=-2.9 ; g_V=3

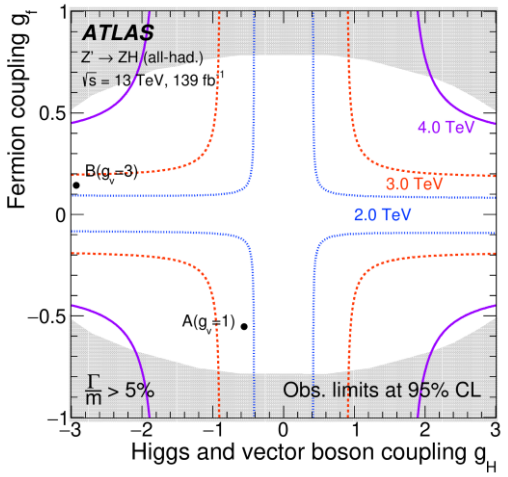
Large-R jets J(jj)
+jet substructure

Final DV: m_{JJ} (1-b, 2-b)

Run 2, √s=13 TeV, L=139 fb^{-1}, PRD 102, 112008 (2020)

- Exclusion contour in {g_H, g_F}

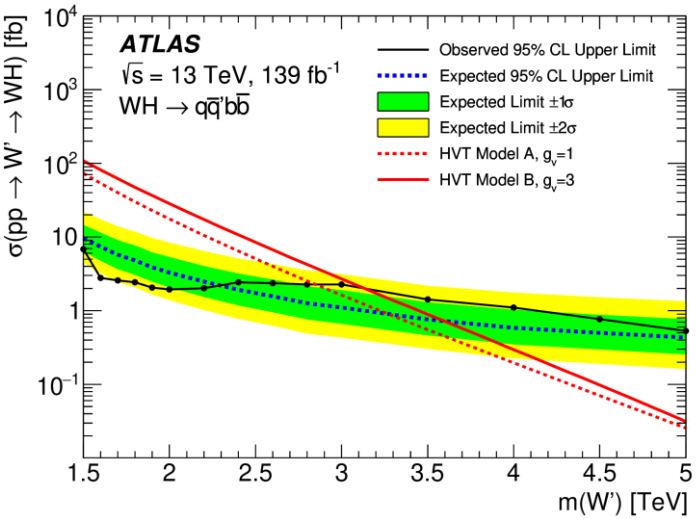


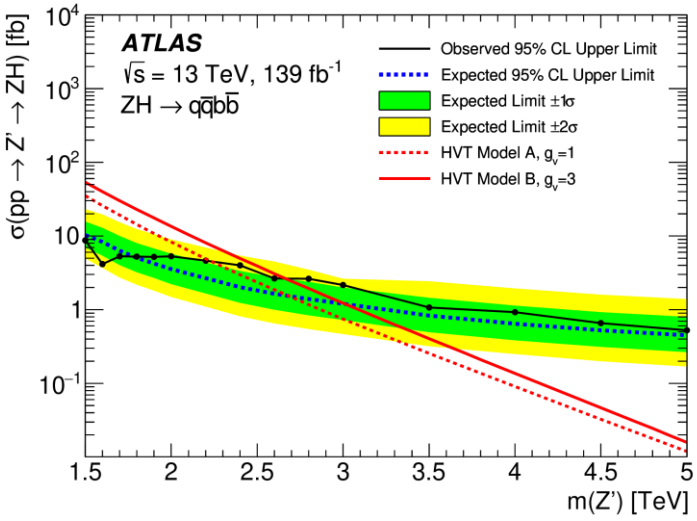


- Exclusion limits σ(pp→V'→VH) [95 % CL]

A: $m_{W'\,(Z')}$<2.90 (2.20) TeV

B: $m_{W'\,(Z')}$<3.20 (2.65) TeV



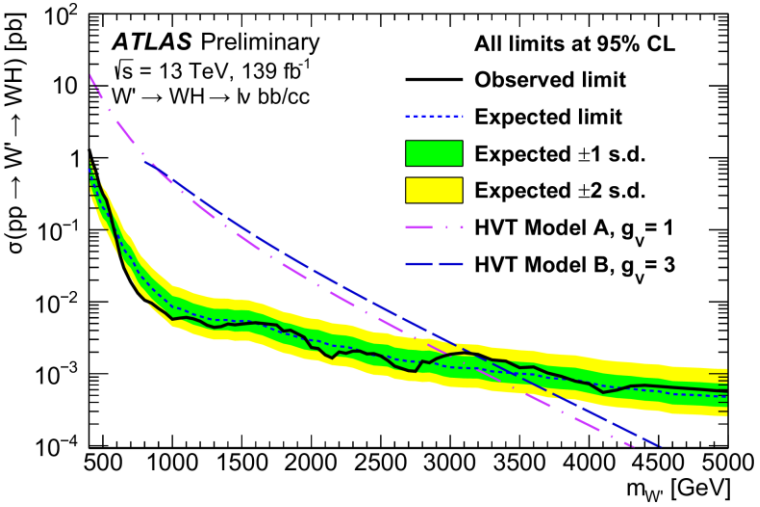


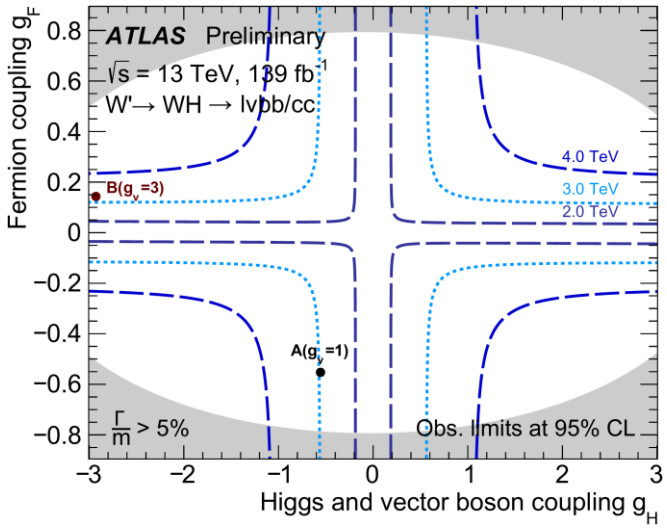
V'→VH, qqbb ; W'→WH, lνbb

Run 2, √s=13 TeV, L=139 fb^{-1}, ATLAS-CONF-2021-026

- W'→WH, lνbb

A: g_V=1, B: g_V=3





95 % limit σ : 1.3 pb-0.56 fb in 400-5000 GeV
exclude $m_{W'}$<2.95 TeV ; 3.15 TeV respectively for HVT model A ; B

Z'→H(bb)+γ

- J=1, m_X=700-4000 GeV

Run 2, √s=13 TeV, L=139 fb^{-1}, PRL 125, 251802 (2020)

Collimated b-jets

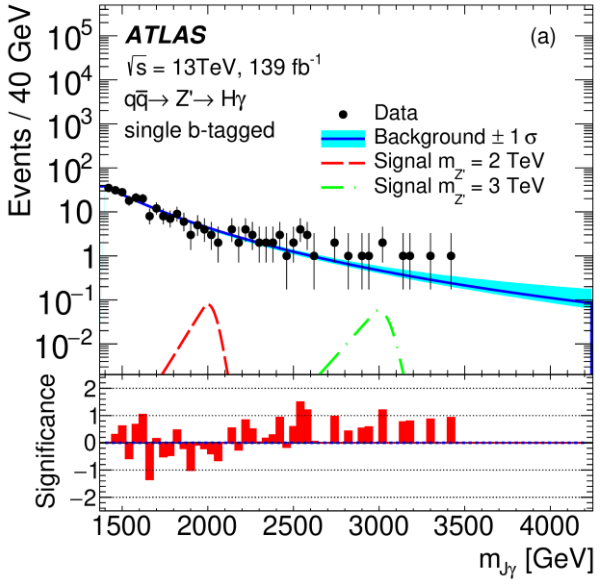
2 categories b-tagging

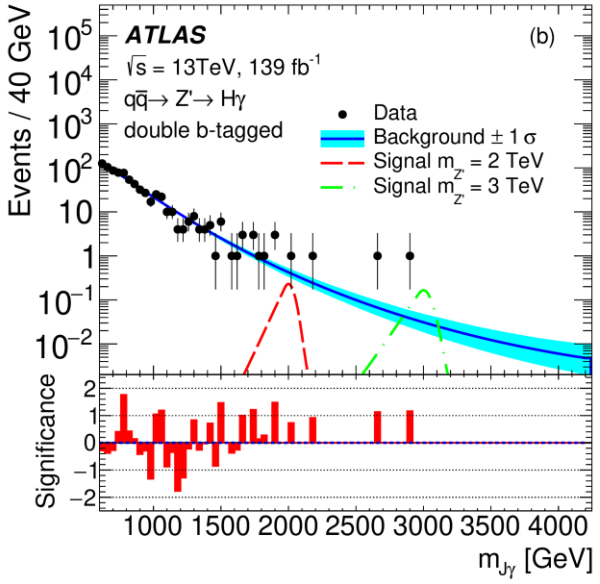
- Selection

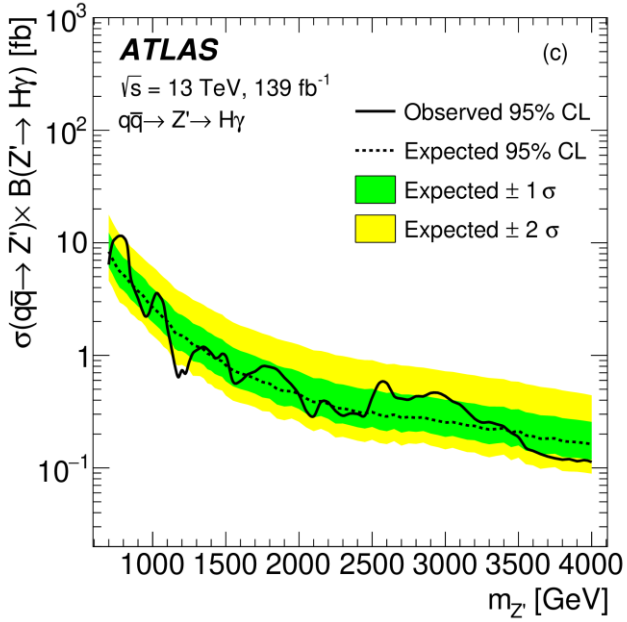
≥1 γ p_T>200 GeV, tight isolated

≥1 J (R=1.0), m_J compatible m_H, identify 2 b-quarks

- Final DV: $m_{J\gamma}$







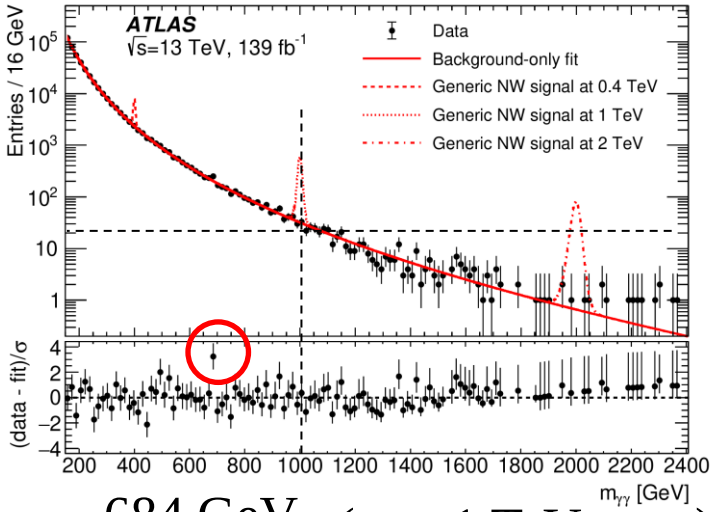
X→γγ

J=0: NWA: 160-3000 GeV

LWA: Γ: [0 ; 10 %]: 400-2800 GeV

+J=2 (not covered by presentation)

PLB, 822, 136651 (2021)



684 GeV (m_X>1 TeV: toys)

- Selection

≥2 γ, E_T>22 GeV, |η|<2.37, tight, isolated

$E_T/m_{\gamma\gamma}$>0.3 GeV (leading) ; 0.25 (subleading)

- Background

γγ, γj (jj) : direct fit data (+ABCD spurious signal, FD)

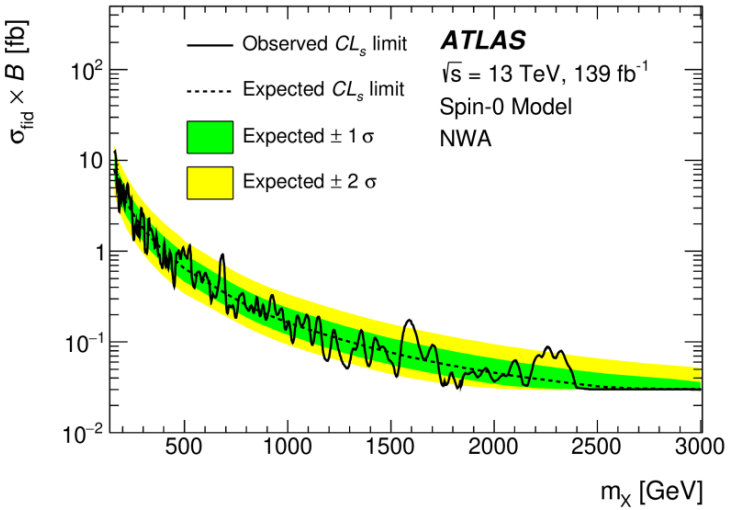
- p_0=f(m_X, Γ_X ; k/$\bar{M}_{Pl}$)

Highest excess:

J=0, NWA: 3.29 (glob. 1.30)

J=2, NWA: 3.29 (glob. 1.36)

- Limits



X→ZZ→llll, llνν

J=0: NWA (ggH, VBF): 200-2000 GeV

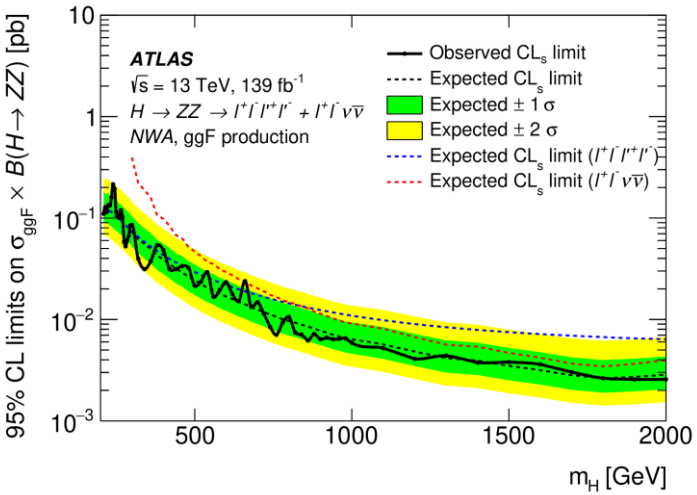
Run 2, √s=13 TeV, L=139 fb^{-1}, EPJC 81, 332 (2021)

+LWA (ggH): Γ/m_H=0.01-0.15 (400-2000 GeV)

+J=2 (not covered by presentation)

- Limits

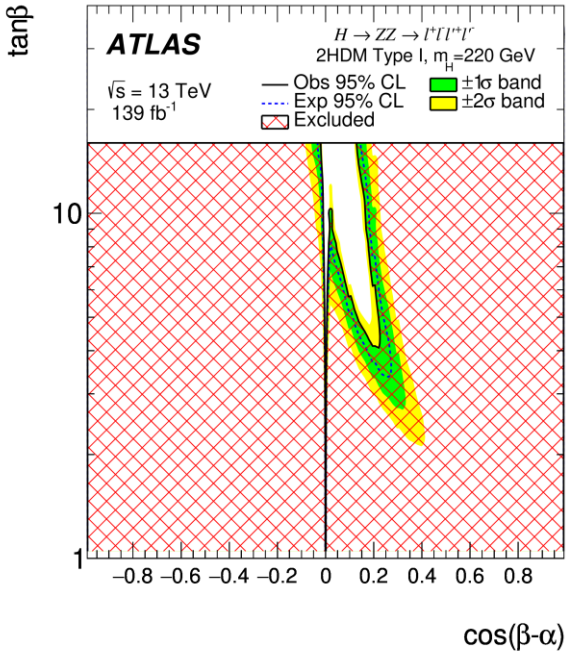
NWA

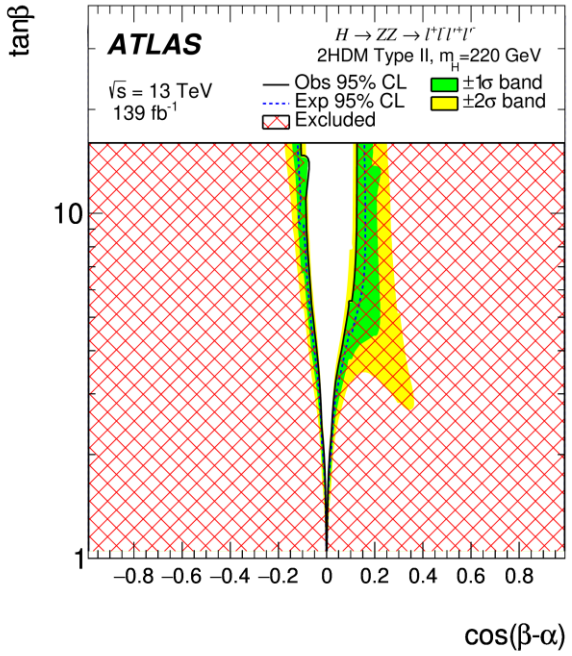


+VBF

+LWA: Γ/m_H=0.01-0.15

- Exclusion contour 2HDM





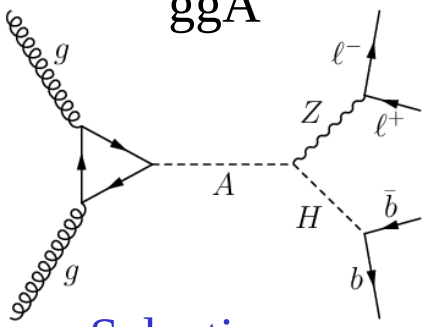
A→Z(ll)H, H→bb, H→WW

CP-odd A; A : $\Gamma \approx \Gamma_{exp}$ or higher, H: NWA

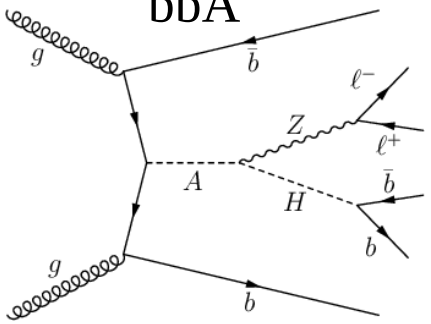
Run 2, $\sqrt{s}$=13 TeV, L=139 fb^{-1}, EPJC 81, 396 (2021)

A→Z(ll)H, H→bb

ggA



bbA



- Selection

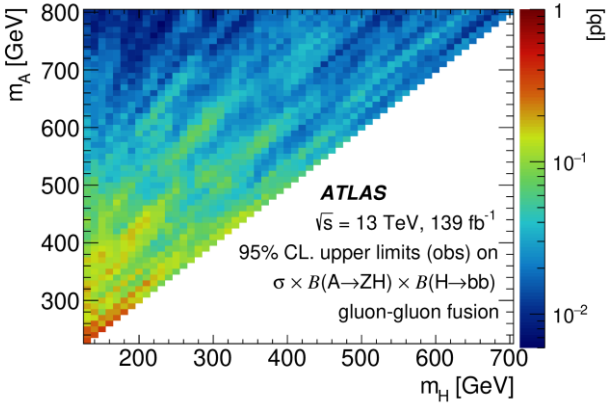
=2 e or 2 μ, OS (not required for electrons)

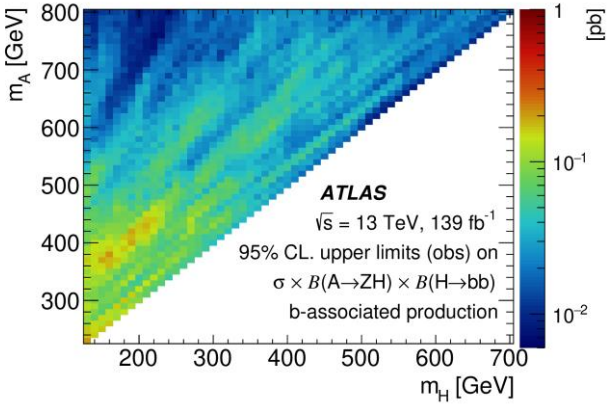
$m_{ll} \in [80 ; 100]$ GeV

≥2 b (llbb) or ≥4 jets (llWW)

Channel specific selection

- Final DV: m_{llbb}

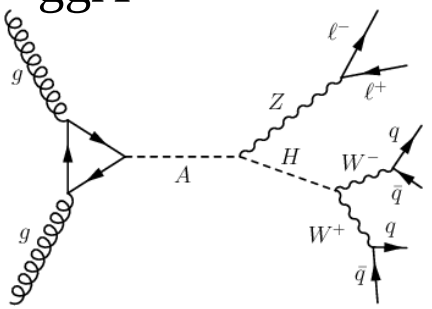




+interpretation 2HDM

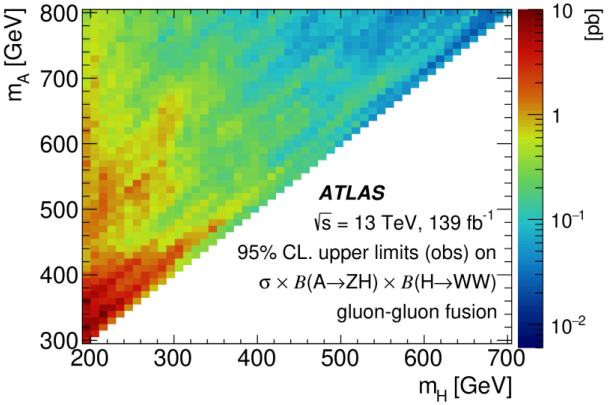
A→Z(ll)H, H→WW

ggA



W→jj: jet combinatorics if bbA

- Final DV: m_{ll4q}



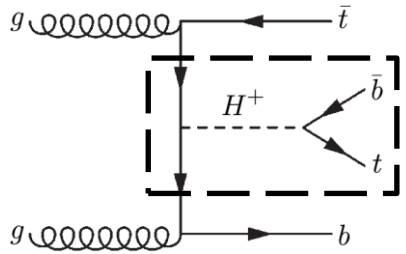
Singly charged Higgs $H^{\pm}$

- $H^+ \rightarrow tb$ (200-2000 GeV)

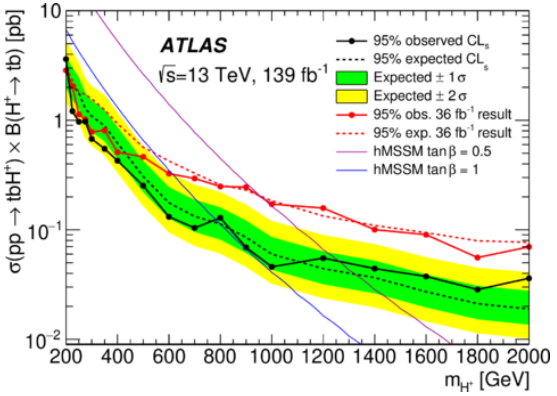
JHEP 06, 145 (2021)

Feb, June 2021

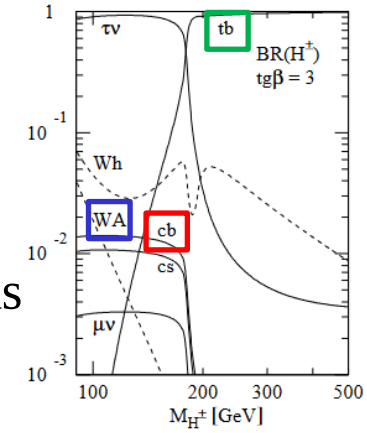
1 W→lν, 1 W→jj



Limit



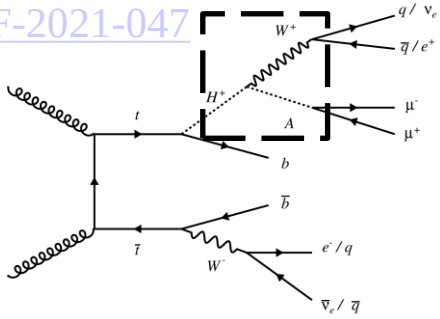
Interpretation
hMSSM,
MSSM in benchmarks



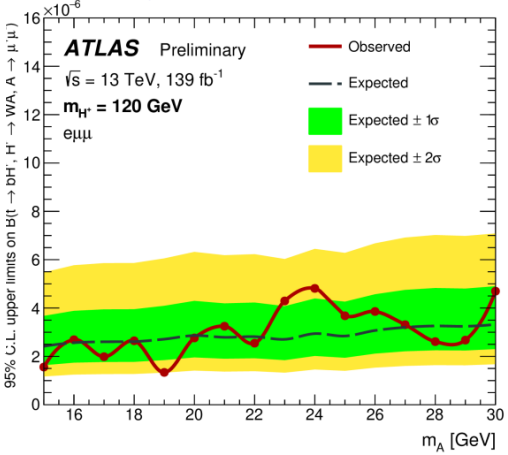
- $H^{\pm} \rightarrow W^{\pm}A$ (120-160 GeV)

ATLAS-CONF-2021-047

August 2021



Limit

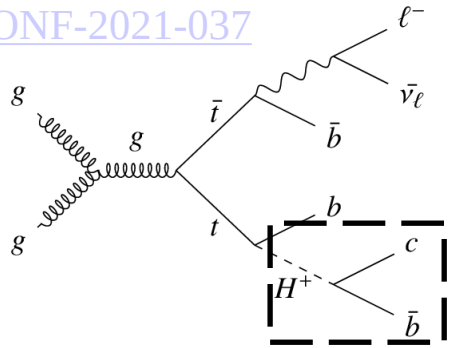


2HDM I
lower limit on tan β

- $H^+ \rightarrow cb$ (60-160 GeV)

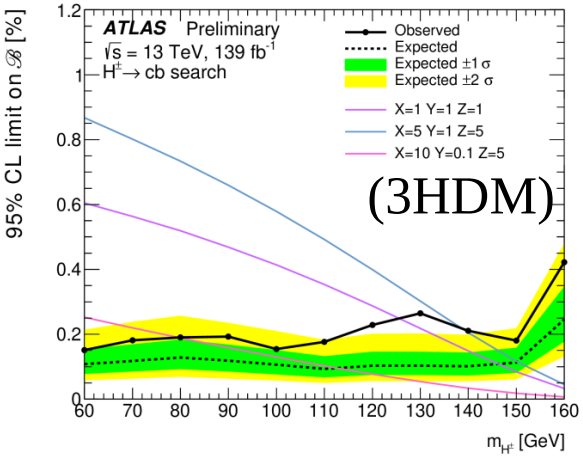
ATLAS-CONF-2021-037

July 2021



tt bkg (80 %) ↓
(W→ij)
<< w/ $H^{\pm} \rightarrow cs$, $H^{\pm} \rightarrow \tau\nu$

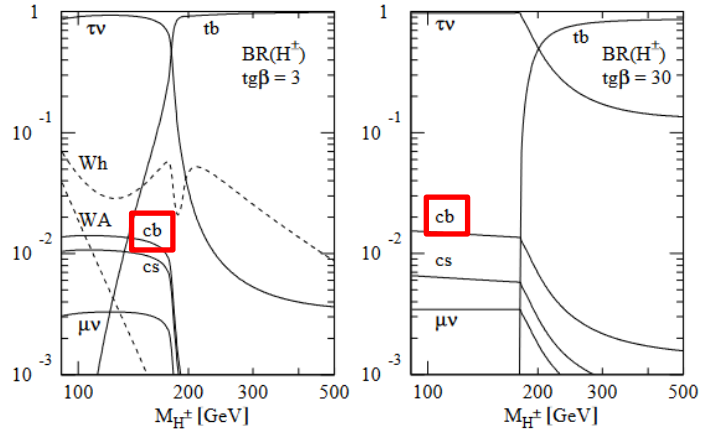
Limit



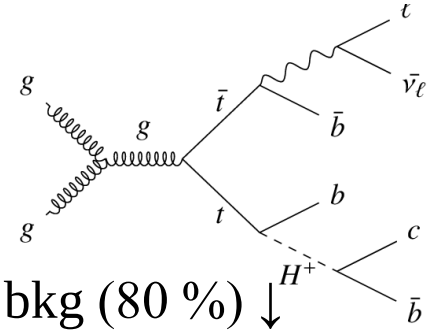
Sens. ↑ x5

$H^{\pm} \rightarrow cb$

- $m_{H^{\pm}} \in [60 ; 160]$ GeV

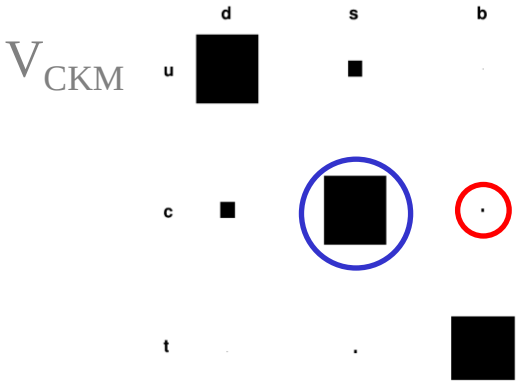


tt, $t \rightarrow H^{+}b$



$H^{\pm} \rightarrow cb$: tt bkg (80 %) ↓

tt bkg ($W \rightarrow ij$)<< w/ $H^{\pm} \rightarrow cs$, $H^{\pm} \rightarrow \tau\nu$



Run 2, $\sqrt{s}$=13 TeV, L=139 fb^{-1}, ATLAS-CONF-2021-037

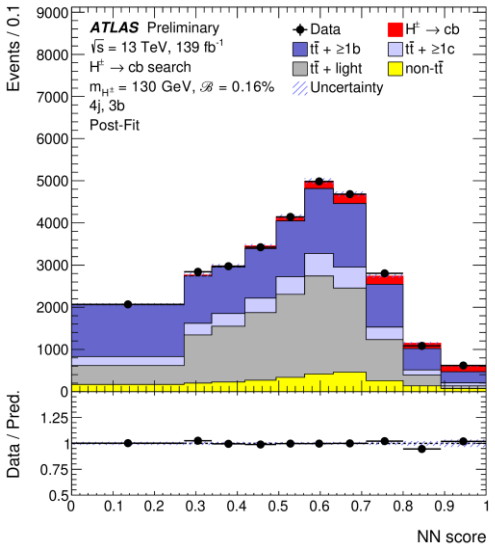
- Selection

=1 e or μ, p_T>28 GeV

≥2 jets, p_T≥25 GeV, ≥2 b-tagged (DL1r, 5 OP)

NN used for fit

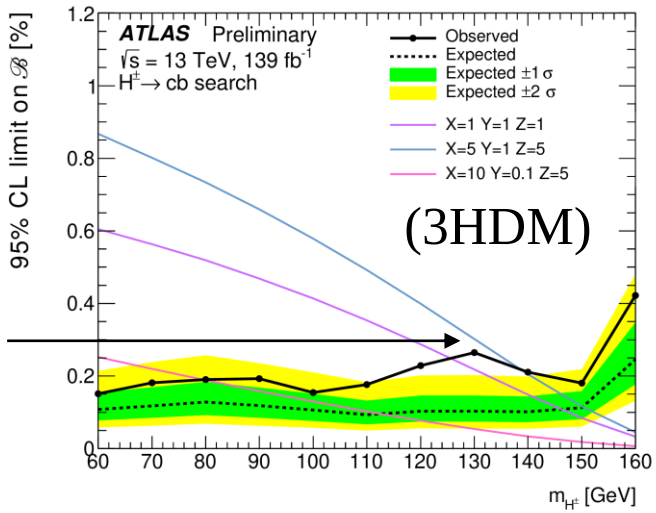
Categories #j (4, 5, 6), #b (3, ≥4), CR



- 95 % limit BR

obs: 0.15 %-0.42 %

exp: 0.09 %-0.25 %



Largest excess:

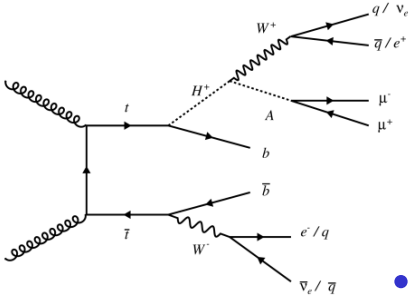
Z_{local}: 3

(Z_{global}:1.6)

Sensitivity ↑ x5 wrt previous analyses (CMS, $\sqrt{s}$=8 TeV)

$H^{\pm} \rightarrow W^{\pm} A \rightarrow W^{\pm}(e\nu)\mu\mu$

tt production



Run 2, $\sqrt{s}$=13 TeV, L=139 fb^{-1}, ATLAS-CONF-2021-047

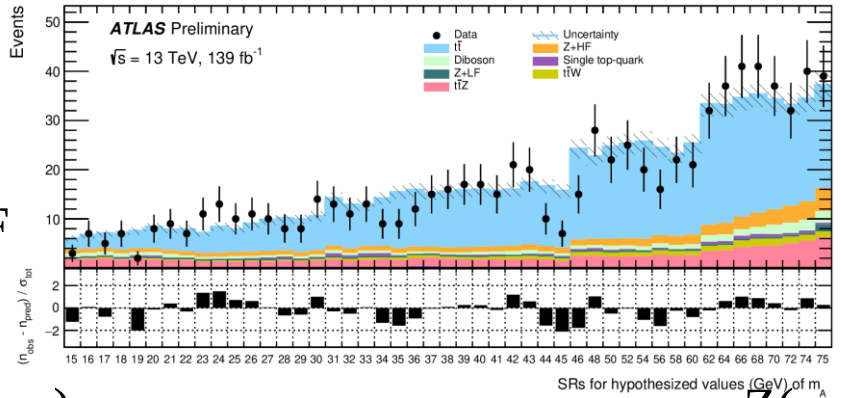
- **Selection**

=2 μ OS, $m_{\mu\mu} \in [12 ; 77]$ GeV
=1 e p_T>20 GeV
≥3 j p_T>20 GeV, ≥1 b-tagged
m_{H+} not used (poor resolution)

- **Background**

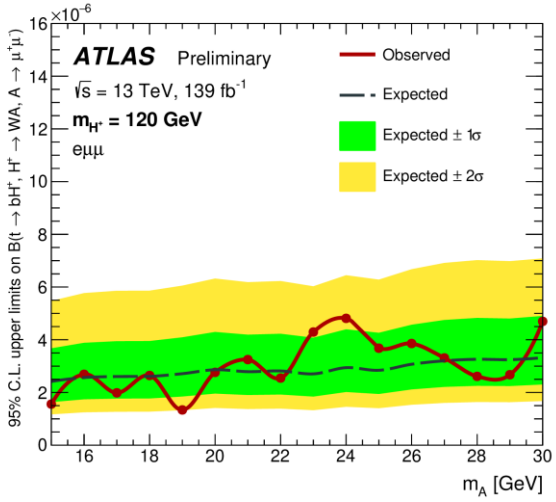
Primary: tt
Secondary: ttZ, Z+HF
Data-driven, CR

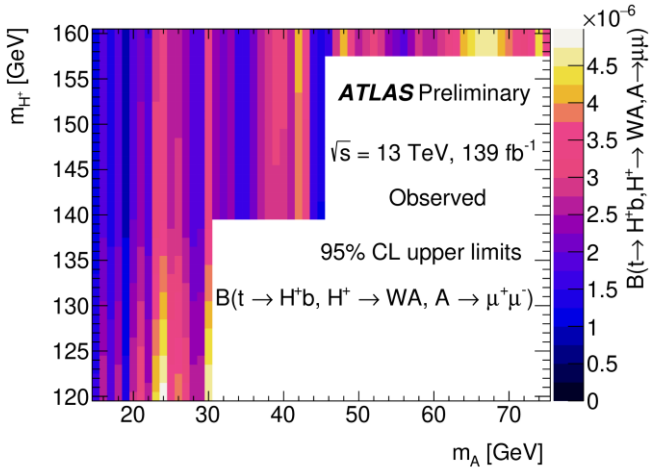
- **Counting experiment** (cut $m_{\mu\mu}$ wdw)



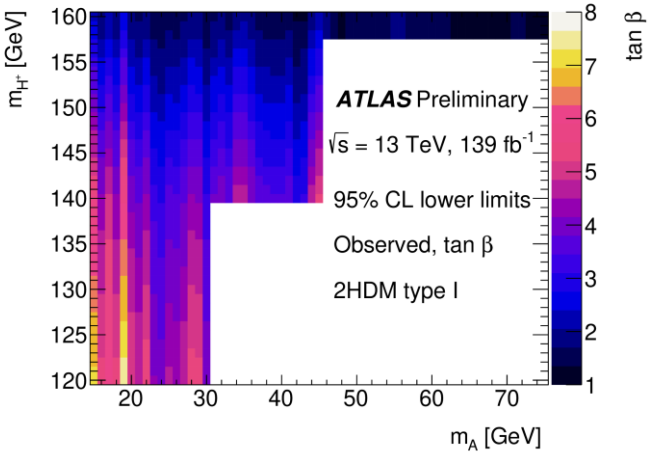
Y(μμ) Z(μμ)

- **Limits**



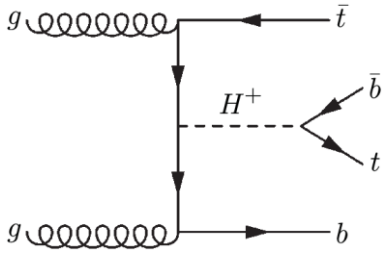


2HDM I, lower limit on tan β



(several m_{H+} & interpolations)

$H^+ \rightarrow tb$



$H^+ \rightarrow tb$, $t \rightarrow Wb$
1 $W \rightarrow l\nu$, 1 $W \rightarrow jj$
NWA,
interf. ttbb neglected

Run 2, $\sqrt{s}$=13 TeV, L=139 fb^{-1}, JHEP 06, 145 (2021)

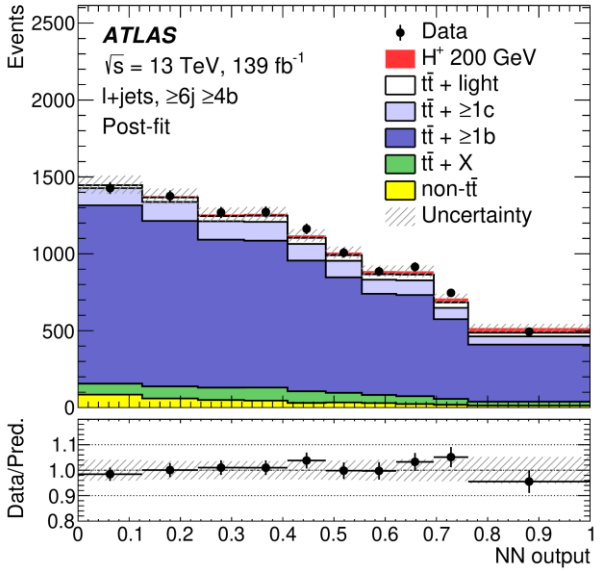
- Selection

=1 e or μ, pT>27 GeV
≥5 jets p_T>25 GeV, ≥3 b (MV2c10)
NN
Categories #j, #b

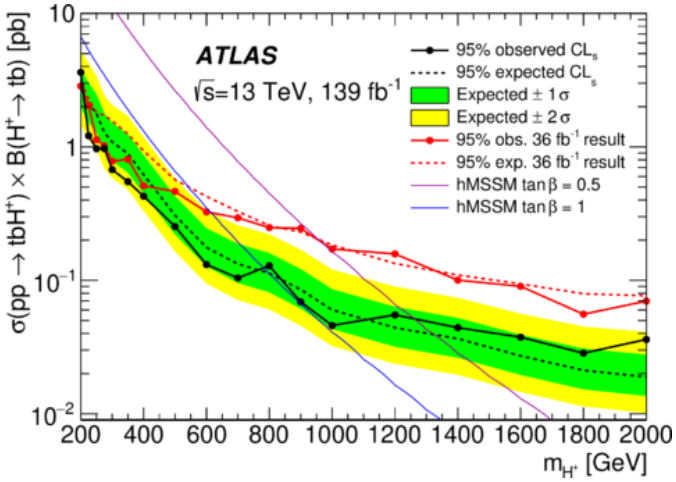
- Background

dominated by tt+j
Data-driven (reweighting)

- Final DV



- Limits



- Interpretation

hMSSM
MSSM, m_h^{125}
MSSM, $m_h^{125}(\tilde{\chi})$
MSSM, $m_h^{125}(\tilde{\tau})$
MSSM, m_h^{125} (alignement)
MSSM, m_h^{125} (CPV)

Broader exclusion of phase space

Doubly charged $H^{\pm\pm}$

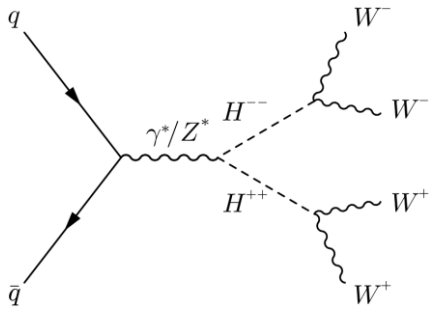
JHEP 06, 146 (2021)
Jan.-June 2021

- Type-II seesaw model

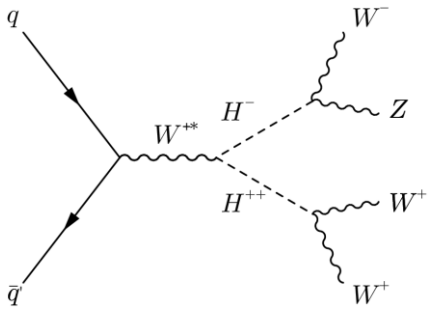
$$\begin{pmatrix}\bullet\\ \bullet\end{pmatrix} + \begin{pmatrix}\bullet\\ \bullet\end{pmatrix}$$

Mixing: $H^{\pm\pm}$, $H^{\pm}$, A^0, H^0, h^0 (SM-like Higgs)

Pair : $H^{++}H^{--}$



associated H^-H^{++}



$\leftarrow H^{\pm\pm}\rightarrow W^{\pm}W^{\pm} \rightarrow$
$H^{\pm}\rightarrow W^{\pm}Z \rightarrow$

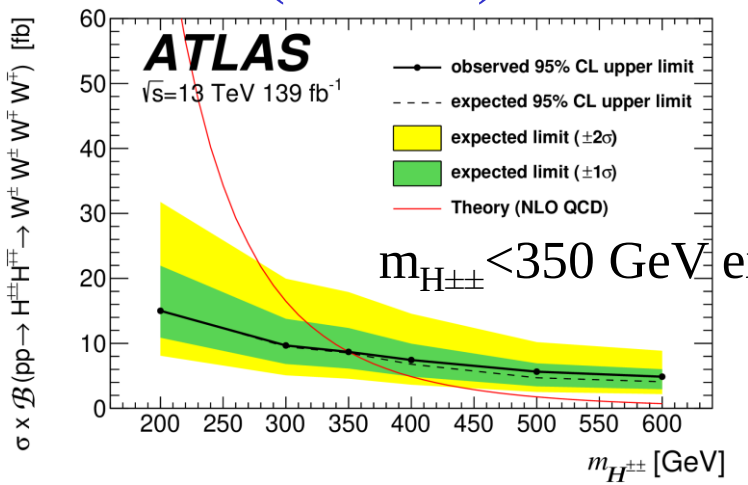
Th/exp constraint parameters

$m_{H^{\pm\pm}} < m_{H^{\pm}}$-100 GeV ; $|m_{H^{\pm\pm}}-m_{H^{\pm}}| \leq 5$ GeV

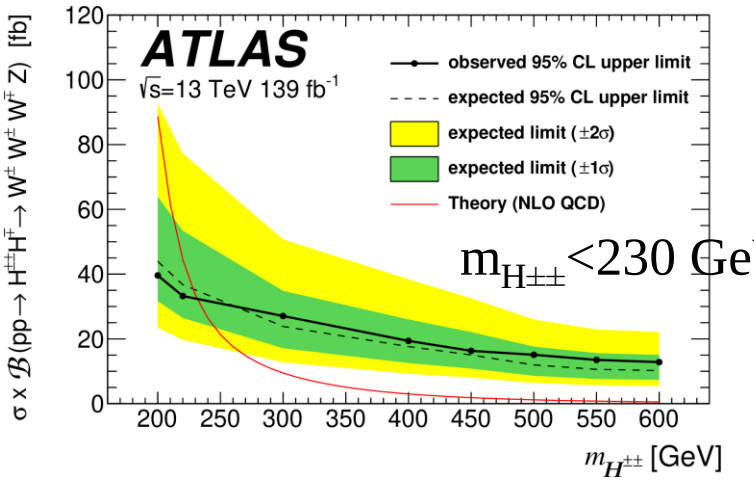
- Final state: multileptons, 2 l same charge, MET

Counting experiment

- Limits (95 % CL)



$m_{H^{\pm\pm}}$<350 GeV excluded



$m_{H^{\pm\pm}}$<230 GeV excluded

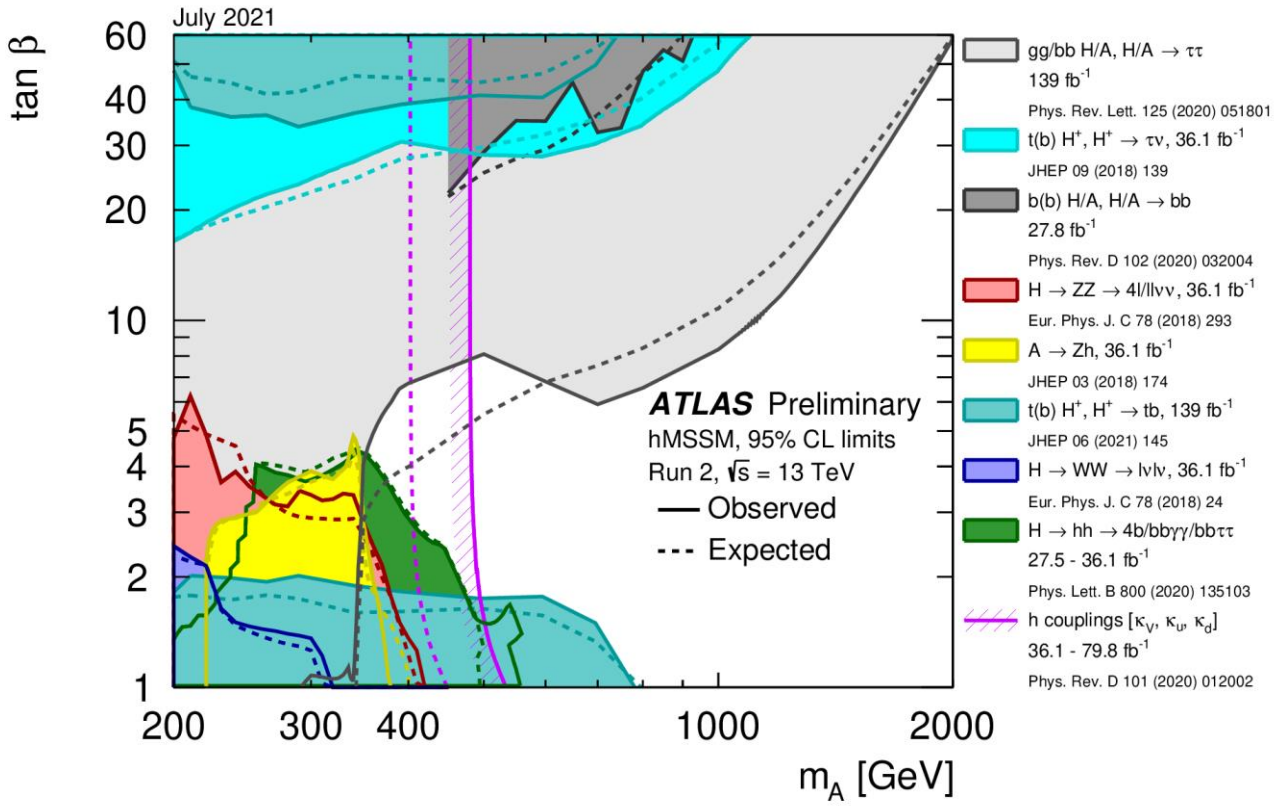
hMSSM summary

Run 2, $\sqrt{s}$=13 TeV, L=139 fb^{-1}, ATL-PHYS-PUB-2021-030

- hMSSM (habemous MSSM ?)

m_h~125 GeV

→(tan β, m_A) enough to describe phase space



Exotic Higgs summary H→XY

April 2021 (no inclusion of later analyses)

Run 2, √s=13 TeV, L=139 fb^{-1}, ATL-PHYS-PUB-2021-008

Remark : constraint BR(H→undetected)<16 % (95 % CL) from Higgs combination

		Leptons			Bosons			Quarks			X	Mesons							
		$e^{\pm}$	$\mu^{\pm}$	$\tau^{\pm}$	Z	W	γ	q/g	c	b	Inv.	ϕ,ρ	$J/\psi,\Upsilon$	$\ell^{\pm}\ell^{\mp}$	$\tau^{\pm}\tau^{\mp}$	$q\bar{q}/gg$	$\gamma\gamma$	$b\bar{b}$	Other
Y	$e^{\mp}$	[12]	[12]	[13]															
	$\mu^{\mp}$	LFV	[14]	[13]															
	$\tau^{\mp}$			SM															
	Z/Z^*				SM		[15]				–	–	[3]	[7]	–	[3]	–	–	–
	W/W^*					SM													–
	γ						SM				[16]	[17]	[18]	[19]	–	–	–	–	–
	q/g							–	–	–									
	c								[20]										
	b									SM									
	Inv.										[21]			–	–	–	–	–	–
	ϕ,ρ											–	–						
	$J/\psi,\Upsilon$												–						
	$\ell^{\pm}\ell^{\mp}$													[7]	[10]	–	–	[2]	–
	$\tau^{\pm}\tau^{\mp}$														–	–	–	–	–
	$q\bar{q}/gg$															–	[6]	–	–
	$\gamma\gamma$																[9]	–	–
	$b\bar{b}$																	[4, 5]	–
	Other																		Many LLP

Model independent limits: pseudo-scalar, 2HDM+S types I, II, III, IV

Run 1

Partial Run 2

Full Run 2