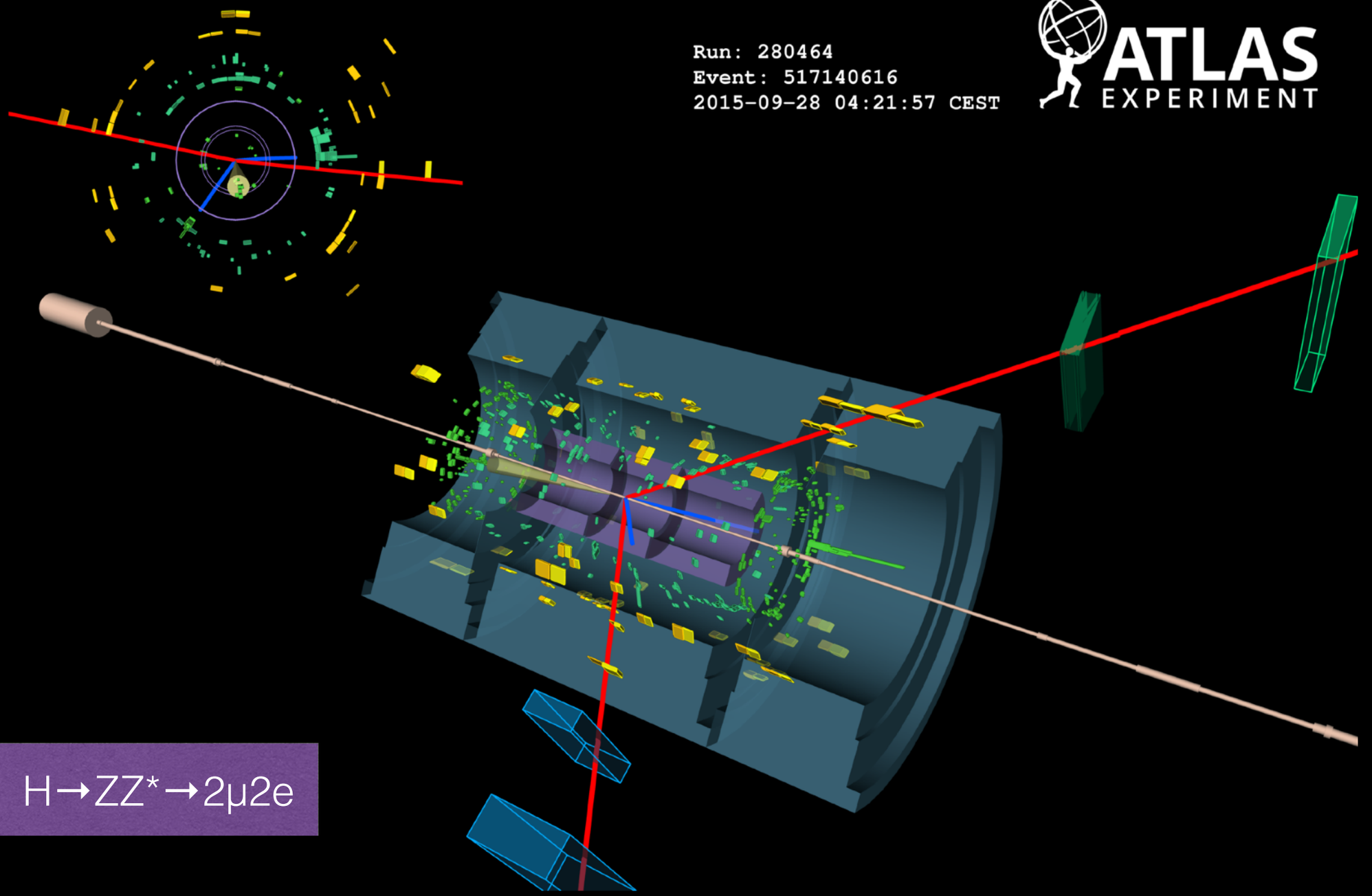


Cross section and couplings measurements with the ATLAS detector for the 125 GeV Higgs Boson

Hannah Herde (Brandeis University),
on behalf of the ATLAS Collaboration

In this talk:

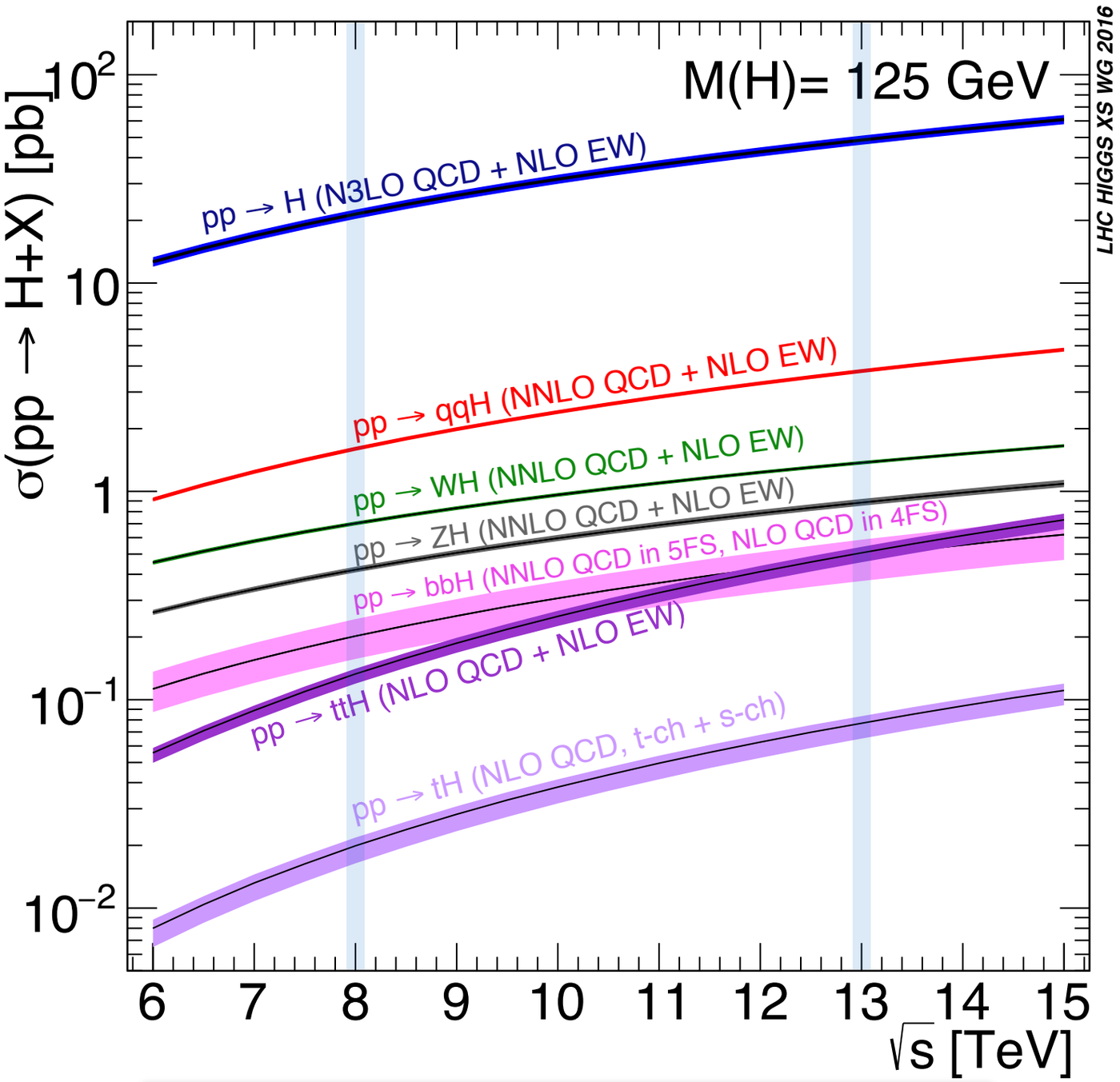
★ SM predictions for 125 GeV Higgs

★ Cross sections and couplings

- $H \to \gamma\gamma$, $H \to ZZ^* \to 4\ell$, $H \to WW^* \to \ell\nu\ell'\nu$

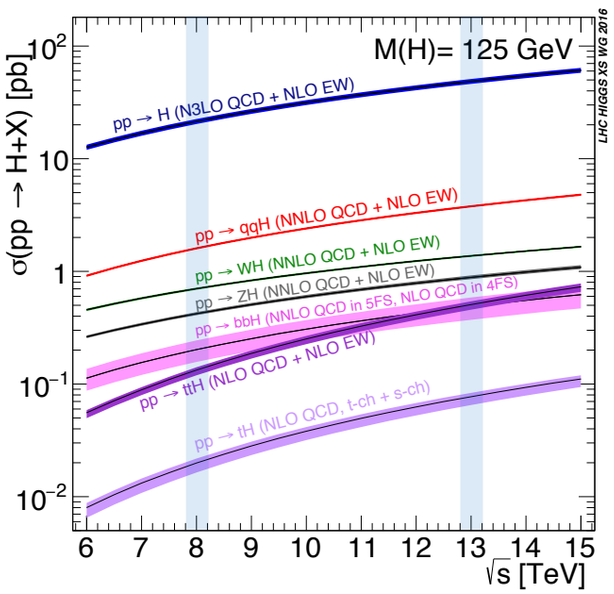
★ Searches for $t\bar{t}H$ production and $H \to b\bar{b}$ decay

Higgs Expectations at $\sqrt{s}$ = 13 TeV

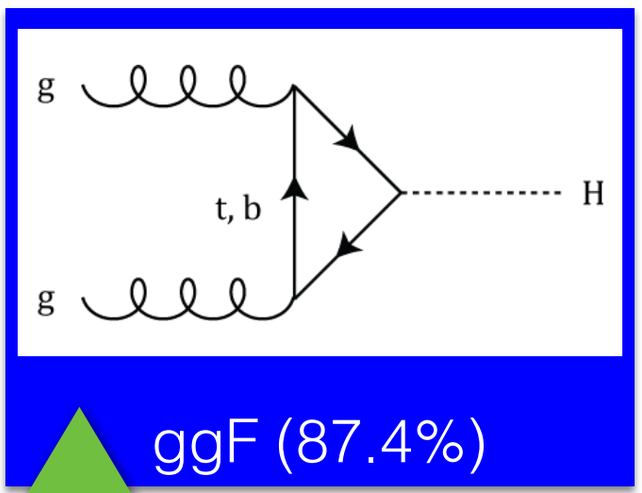


$\sigma_{\sqrt{s}\,=\,13\ \mathrm{TeV}} / \sigma_{\sqrt{s}\,=\,8\ \mathrm{TeV}} \sim 2.3$

Production modes

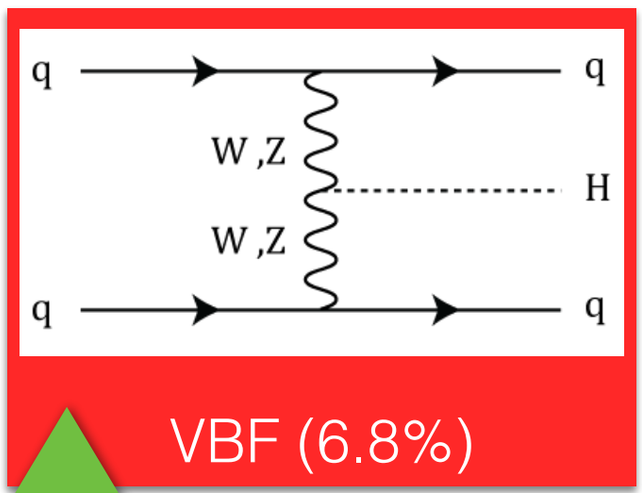


Run I ⟶ Run II



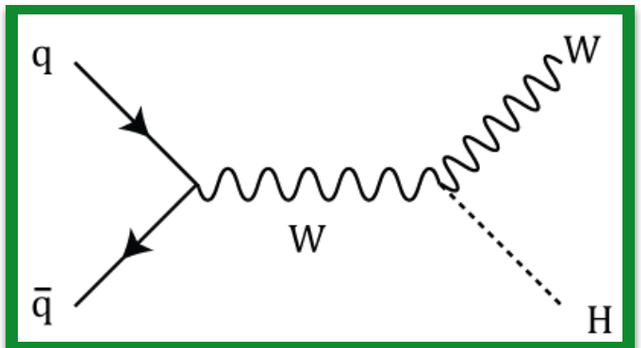
ggF (87.4%)

2.3x



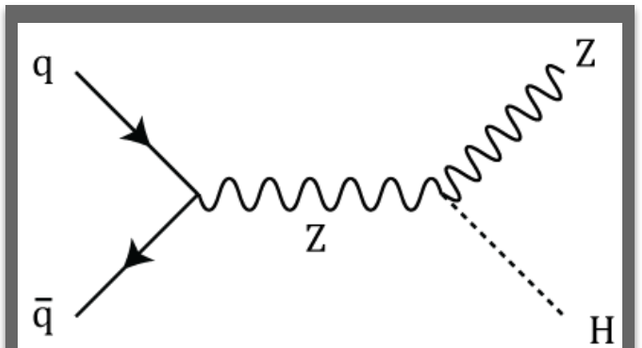
VBF (6.8%)

2.4x



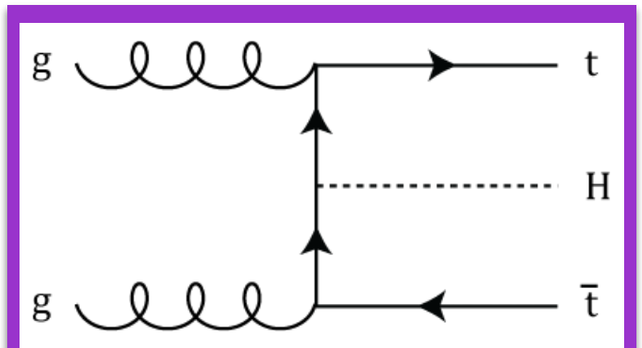
WH (2.5%)

2.0x



ZH (1.6%)

2.1x

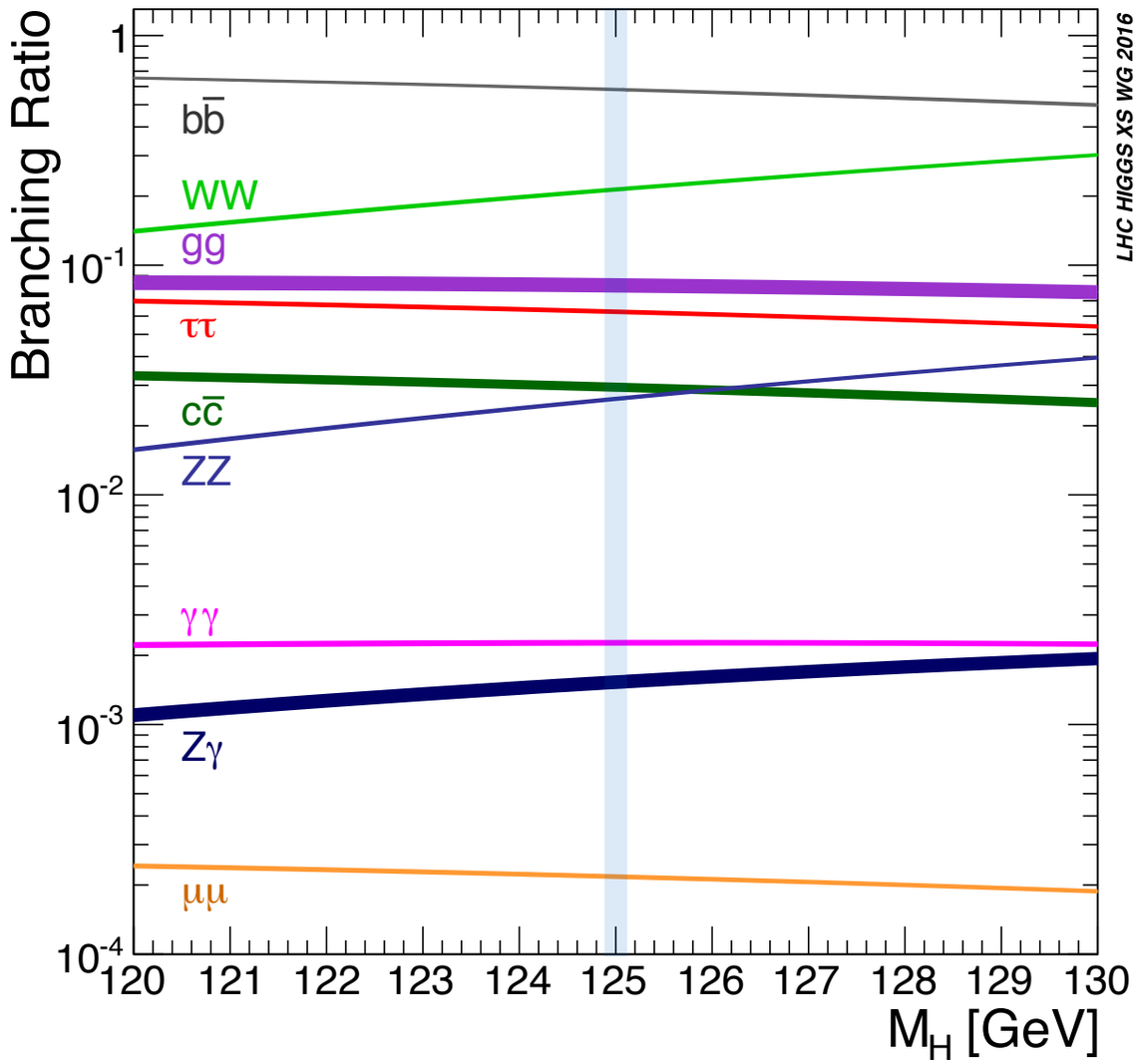


ttH (0.9%)

3.9x

Observed production modes: ggF, VBF

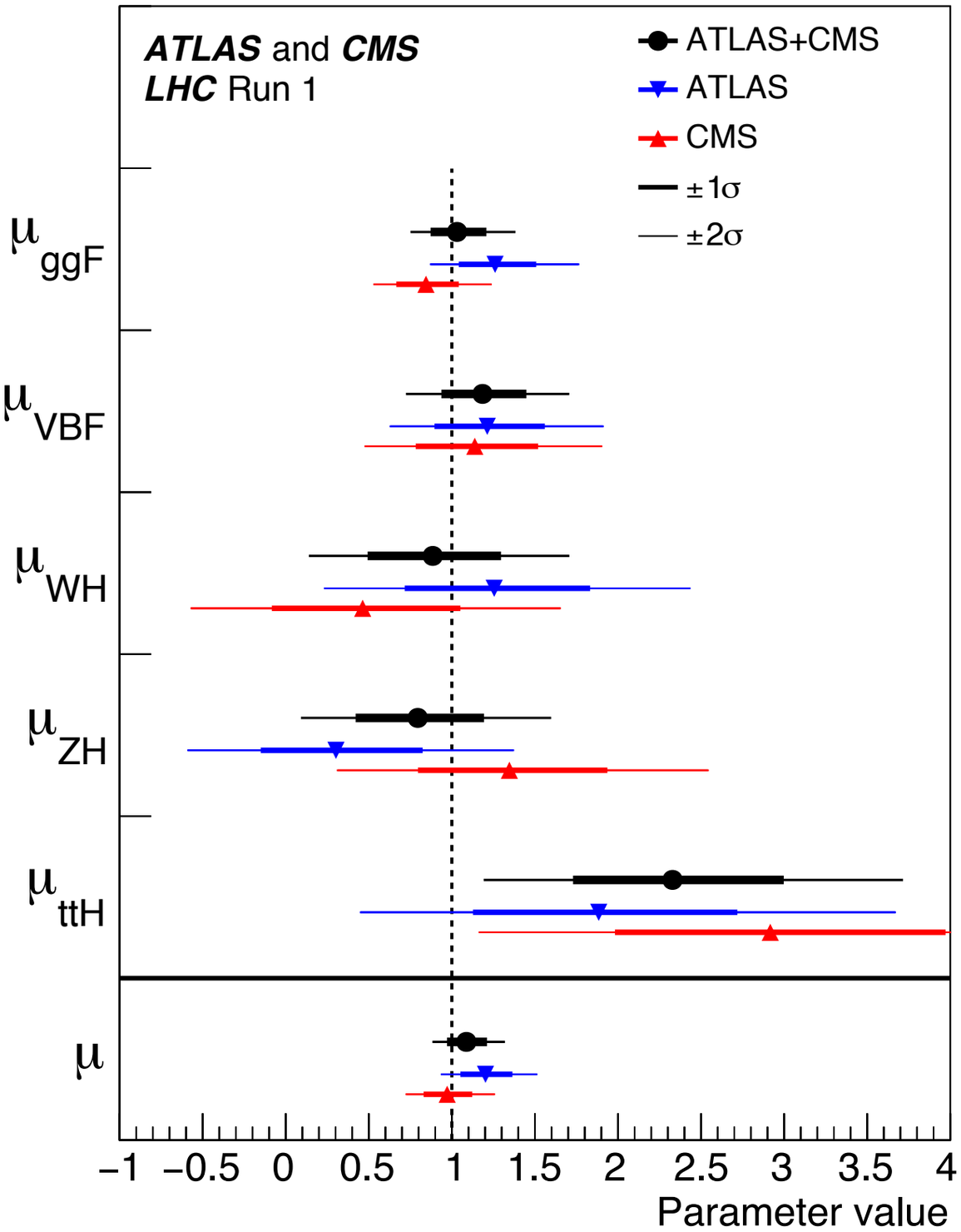
Higgs decay channels

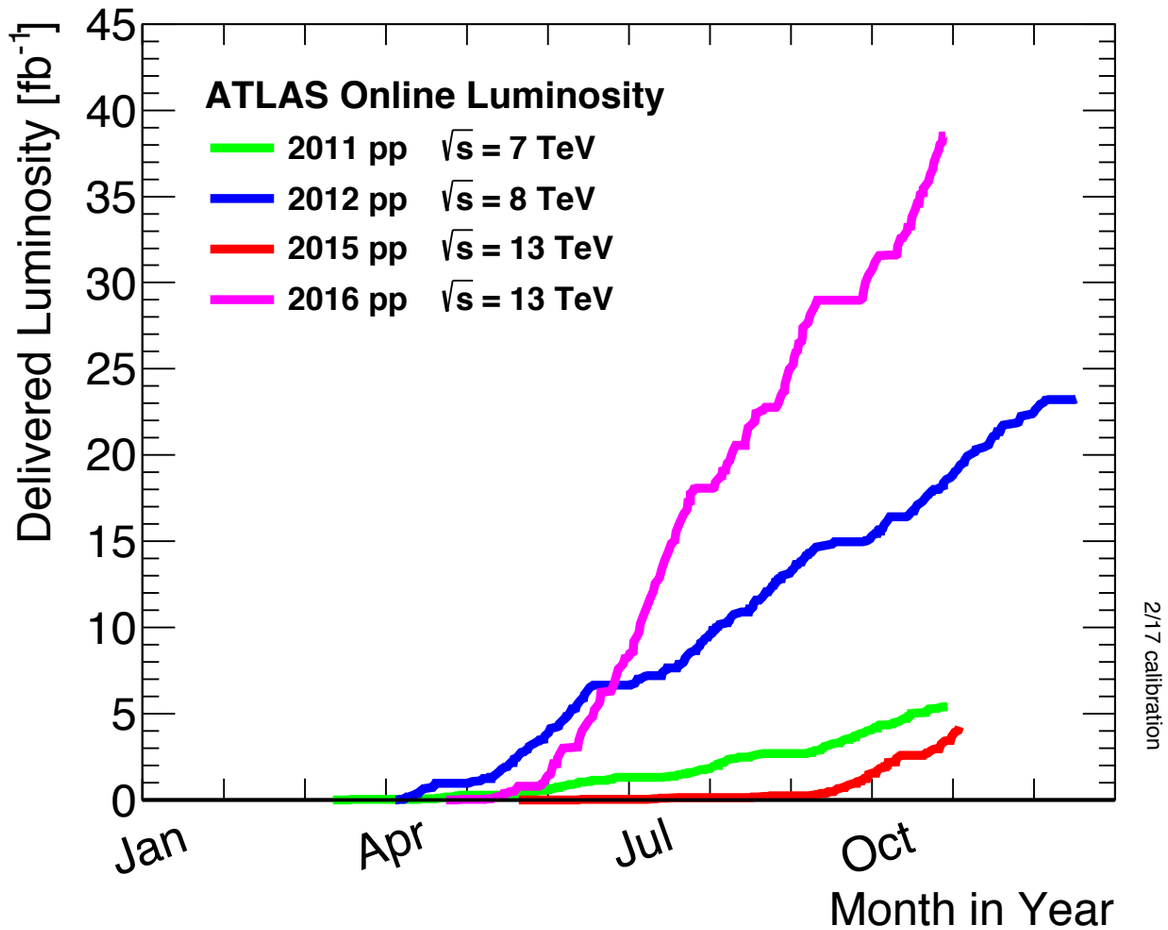


	Channel	$\mathcal{B}(m_H$=125 GeV)
Observed	$H\to ZZ^*\to 4\ell$	0.0124%
	$H\to\gamma\gamma$	0.23%
	$H\to WW^*\to \ell\nu\ell'\nu$	1.06%
	$H\to\tau\tau$	6%
Search	$H\to b\bar{b}$	58%
	$H\to\mu\mu$	0.022%

JHEP (2016) 2016: 45.

Situation at end of Run I





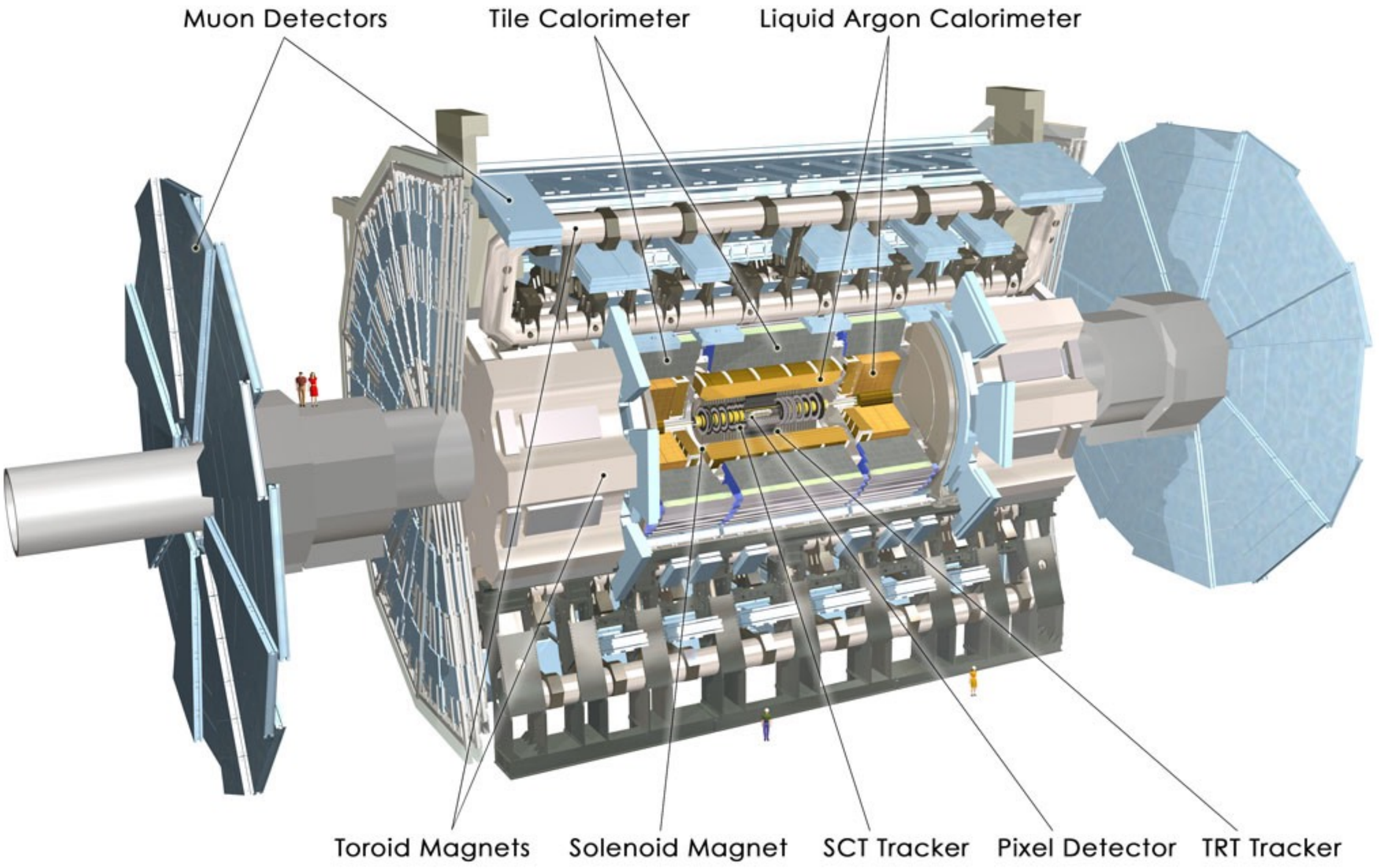
Most results here with partial Run II dataset (~13 fb^{-1})

Signal strength

$\mu = \sigma/\sigma_{SM}$

μ = 1 is SM

Anatomy of ATLAS



13.3 fb^{-1}

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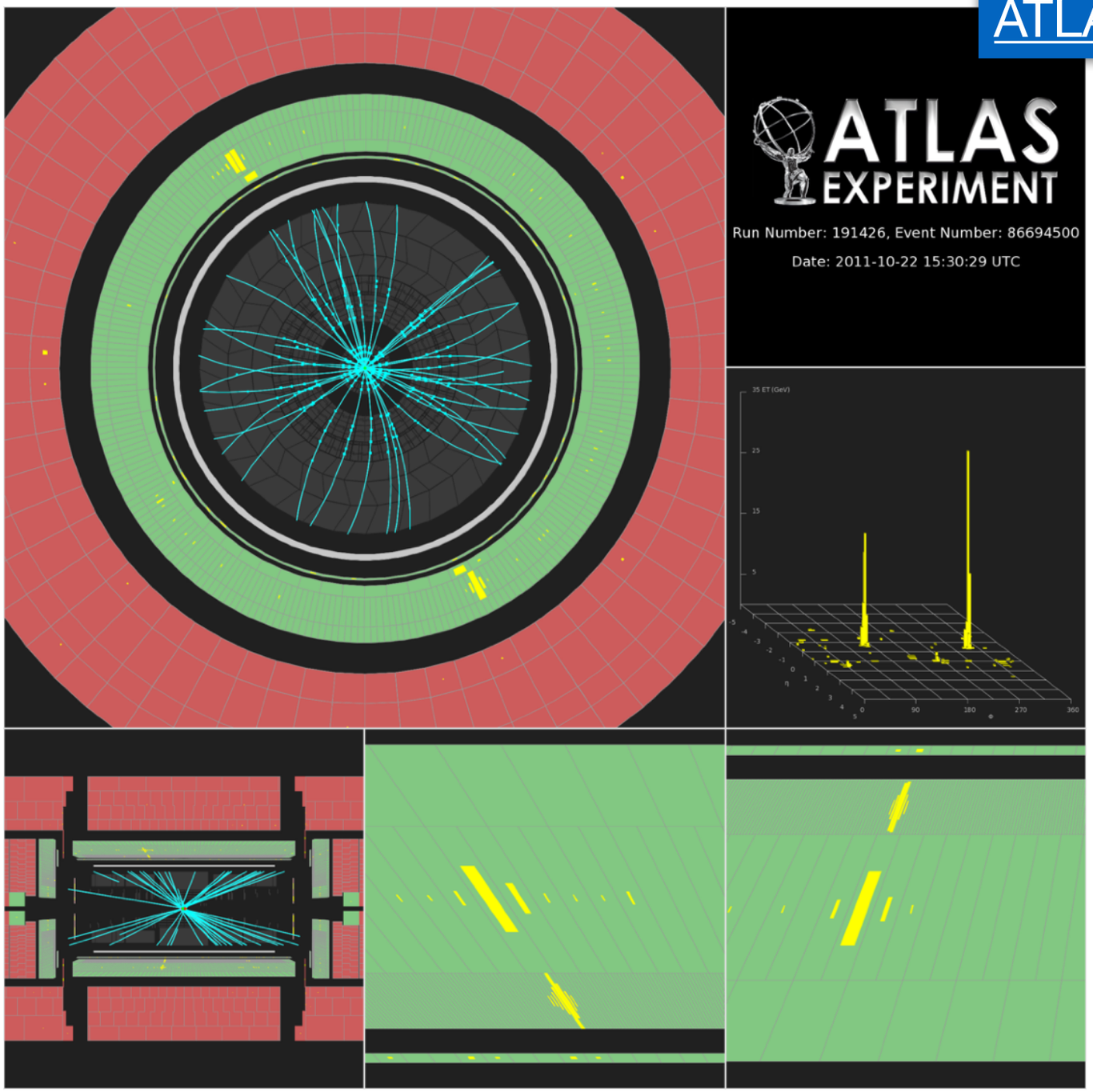

$H \rightarrow \gamma\gamma$

Bump in $\gamma\gamma$ continuum; Rare decay

$\mathcal{B}(m_H$=125 GeV) = 0.23%

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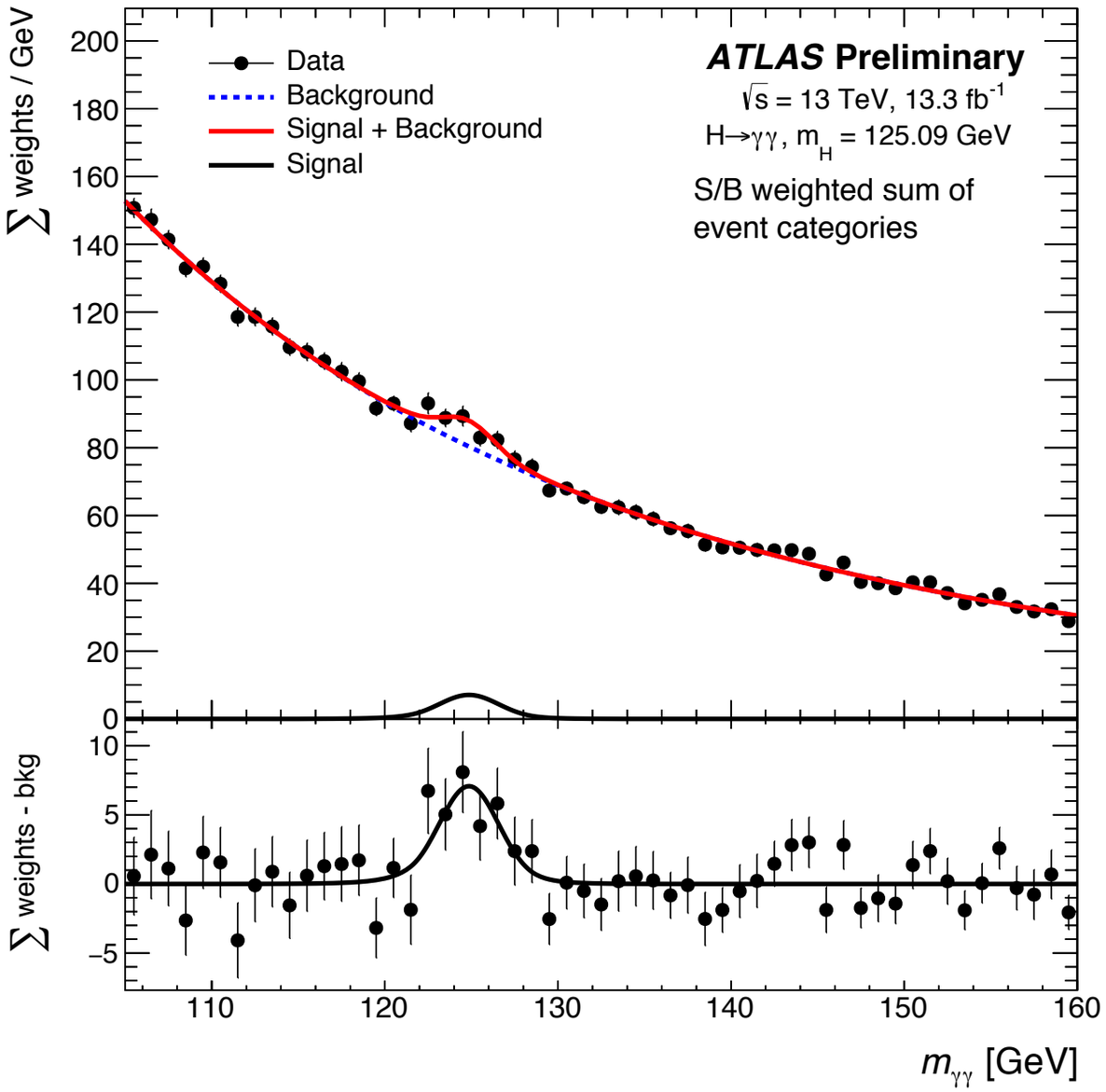
H→γγ analysis strategy



★ 105 < $m_{\gamma\gamma}$ < 160 GeV

★ $p_T^{\gamma 1}$>0.35 $m_{\gamma\gamma}$ & $p_T^{\gamma 2}$>0.25 $m_{\gamma\gamma}$

★ $|\eta|$ < 1.37 or 1.52 < $|\eta|$ < 2.37

★ **Signal extraction** from $m_{\gamma\gamma}$ spectrum, modeling background with analytic function

★ **Neural network** for vertex discrimination to improve mass peak resolution

Bkg	%
γγ	79%
γj	19%
jj	2.5%

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H→γγ fiducial volumes

★ "Baseline" fiducial volume = fiducial inclusive region

★ Two more volumes defined to improve VBF, VH sensitivity

	diphoton baseline	VBF enhanced	single lepton
Photons	$\|\eta\| < 1.37$ or $1.52 < \|\eta\| < 2.37$ $p_{\mathrm{T}}^{\gamma_1} > 0.35\, m_{\gamma\gamma}$ and $p_{\mathrm{T}}^{\gamma_2} > 0.25\, m_{\gamma\gamma}$		
Jets	- - -	$p_{\mathrm{T}} > 30\,\mathrm{GeV}$, $\|y\| < 4.4$ $m_{jj} > 400\,\mathrm{GeV}$, $\|\Delta y_{jj}\| > 2.8$ $\|\Delta\phi_{\gamma\gamma,jj}\| > 2.6$	- - -
Leptons	-	-	$p_{\mathrm{T}} > 15\,\mathrm{GeV}$ $\|\eta\| < 2.47$

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Fiducial cross sections

★ Fiducial volume mimics selection from reconstruction to minimize **model dependence**

★ Account for trigger, reconstruction, identification efficiencies and resolution effects with bin-by-bin unfolding assuming m_H = 125.09 GeV

★ Signal extracted with **unbinned likelihood fit** to $m_{\gamma\gamma}$ spectrum in bins of observables

Fiducial region	Measured cross section (fb)	SM prediction (fb)
Baseline	$43.2 \pm 14.9\,(\text{stat.}) \pm 4.9\,(\text{syst.})$	$62.8\,^{+3.4}_{-4.4}$ [N^{3}LO + XH]
VBF-enhanced	$4.0 \pm 1.4\,(\text{stat.}) \pm 0.7\,(\text{syst.})$	2.04 ± 0.13 [NNLOPS + XH]
single lepton	$1.5 \pm 0.8\,(\text{stat.}) \pm 0.2\,(\text{syst.})$	0.56 ± 0.03 [NNLOPS + XH]

13.3 fb^{-1}

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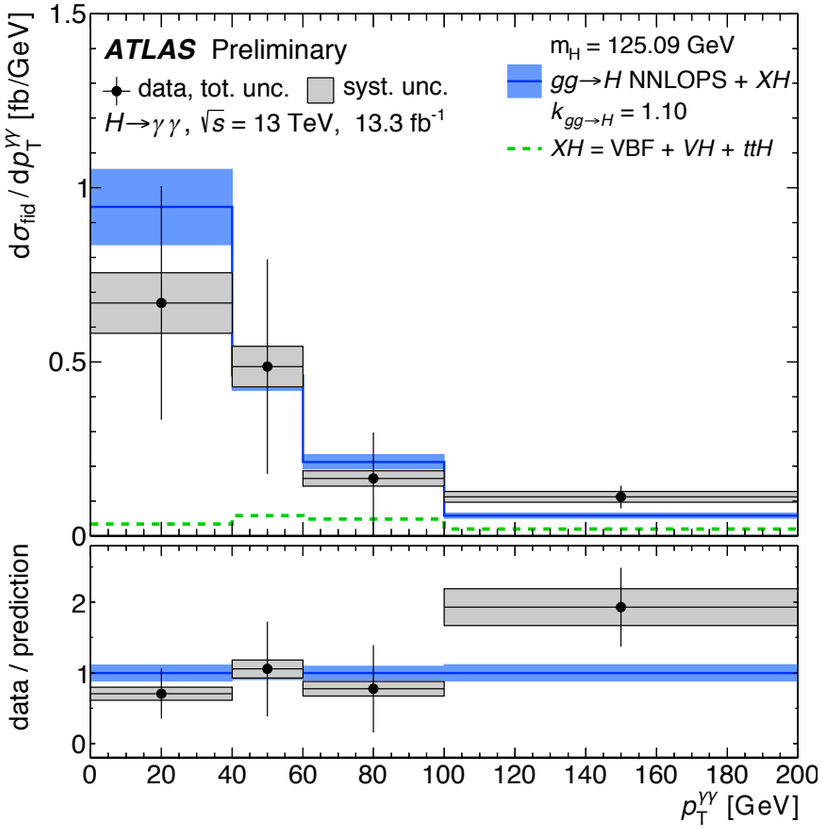
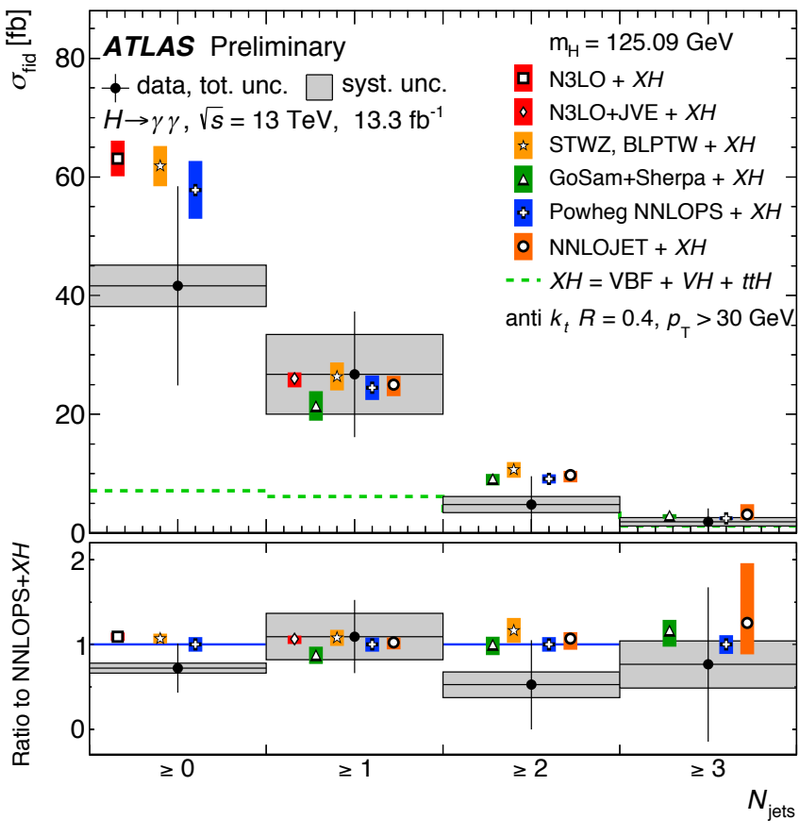
Differential cross sections

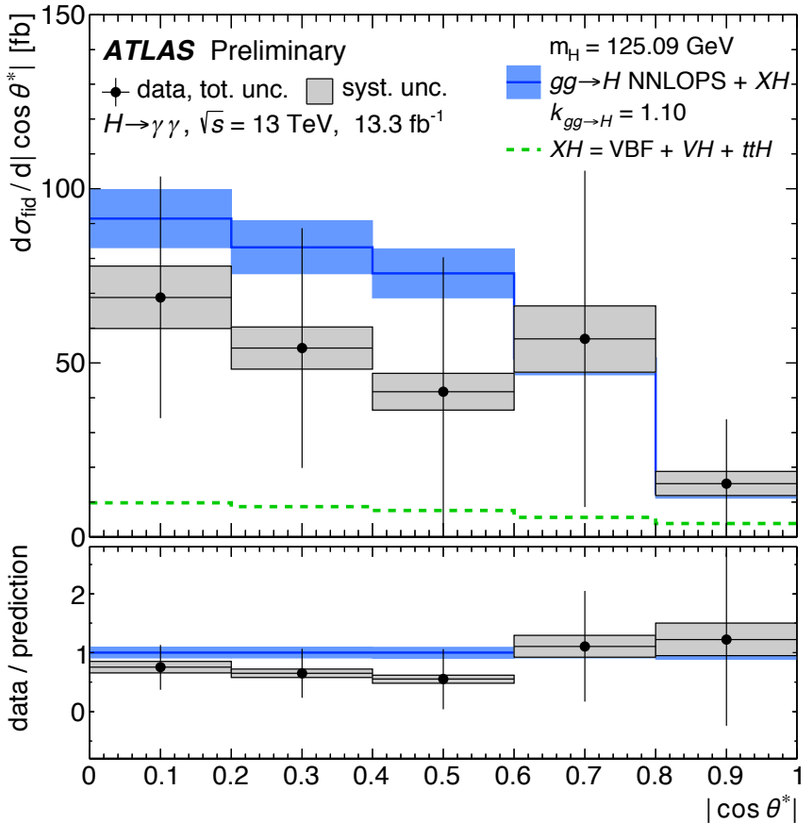
$p_T^{\gamma\gamma}$

N_{jets}

$|cos\theta^*|$







★ Observables: $p_T^{\gamma\gamma}$, $|y_{\gamma\gamma}|$, $|cos\theta^*|$, $\Delta\phi_{jj}$, N_{jets}, m_{jj}, $p_{T,J1}$

★ Probing kinematics, spin, parity, production mode

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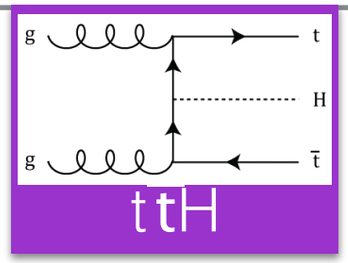
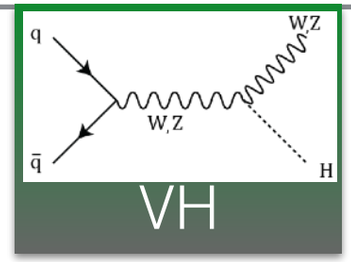
H→γγ event categories for couplings

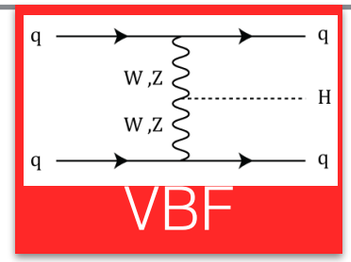


2 categories:
1) ≥1 top decays leptonically
2) Both tops decay hadronically



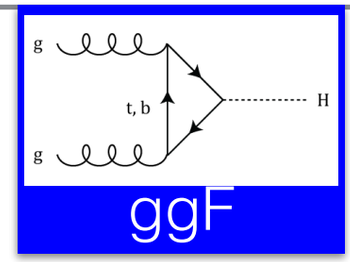
5 categories:
1) Dilepton: ZH, Z→ℓℓ
2) One lepton: WH, W→ℓν
3) VH E_T^{miss}: ZH, Z→νν, W→ℓν (no ℓ found)

VH → hadrons, split with BDT
4) VH hadronic tight
5) VH hadronic loose



2 categories:
- ≥2 hadronic jets
- 2 leading jets define VBF system
- $\Delta\eta_{jj} > 2$
- $|\eta_{\gamma\gamma} - 0.5(\eta_{j1}+\eta_{j2})| < 5$
- BDT

1) VBF tight: high BDT score
2) VBF loose



4 categories:
- Separated according to expected $m_{\gamma\gamma}$ resolution and S/B

$\lvert\eta\rvert$\p_{Tt}	< 70 GeV	> 70 GeV
< 0.95	central low-p_{Tt}	central high-p_{Tt}
> 0.95	forward low-p_{Tt}	forward high-p_{Tt}

★ 13 exclusive categories, split with increasing expected production cross section

★ Then grouped to measure couplings

13.3 fb^{-1}

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Simplified template cross sections

★ Assuming m_H = 125.09±0.24 GeV

★ Restricted to $|y_H| < 2.5$

★ σ_{VHlep} x $\mathcal{B}(H\to\gamma\gamma)$ from leptonic decays of vector bosons

- W→ℓν
- Z→ℓℓ (ℓ = e, μ)
- Z→νν

★ σ_{VHhad} x $\mathcal{B}(H\to\gamma\gamma)$ from hadronic decays of vector bosons

$$\sigma_{ggH} \times \mathcal{B}(H \to \gamma\gamma) = 63\ ^{+30}_{-29}\ \text{fb}$$
$$\sigma_{\text{VBF}} \times \mathcal{B}(H \to \gamma\gamma) = 17.8\ ^{+6.3}_{-5.7}\ \text{fb}$$
$$\sigma_{\text{VHlep}} \times \mathcal{B}(H \to \gamma\gamma) = 1.0\ ^{+2.5}_{-1.9}\ \text{fb}$$
$$\sigma_{\text{VHhad}} \times \mathcal{B}(H \to \gamma\gamma) = -2.3\ ^{+6.8}_{-5.8}\ \text{fb}$$
$$\sigma_{t\bar{t}H} \times \mathcal{B}(H \to \gamma\gamma) = -0.3\ ^{+1.4}_{-1.1}\ \text{fb}$$

More on simplified template XS in LHCXSWG YR4 Ch III.2

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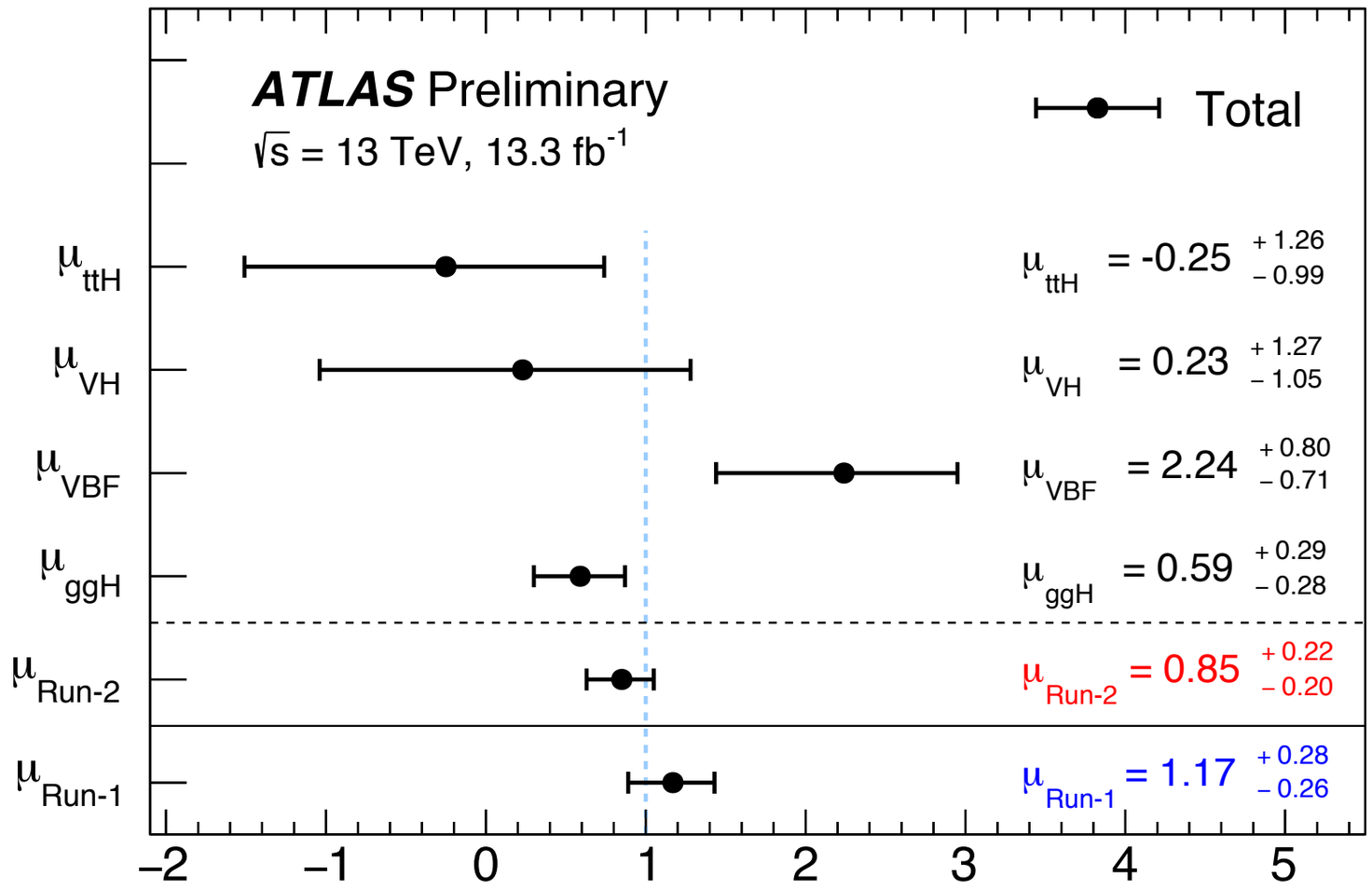
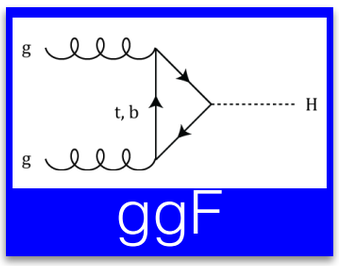
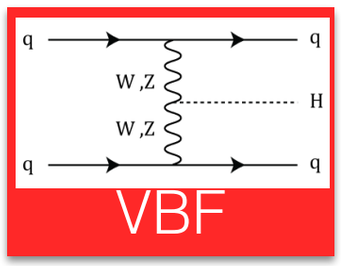
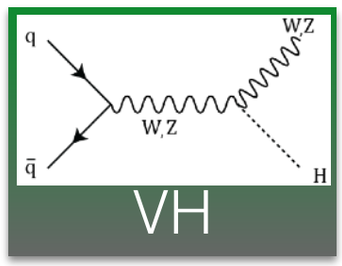
Coupling measurements

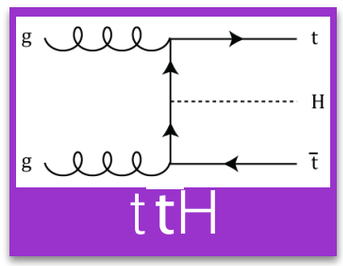


Signal Strength







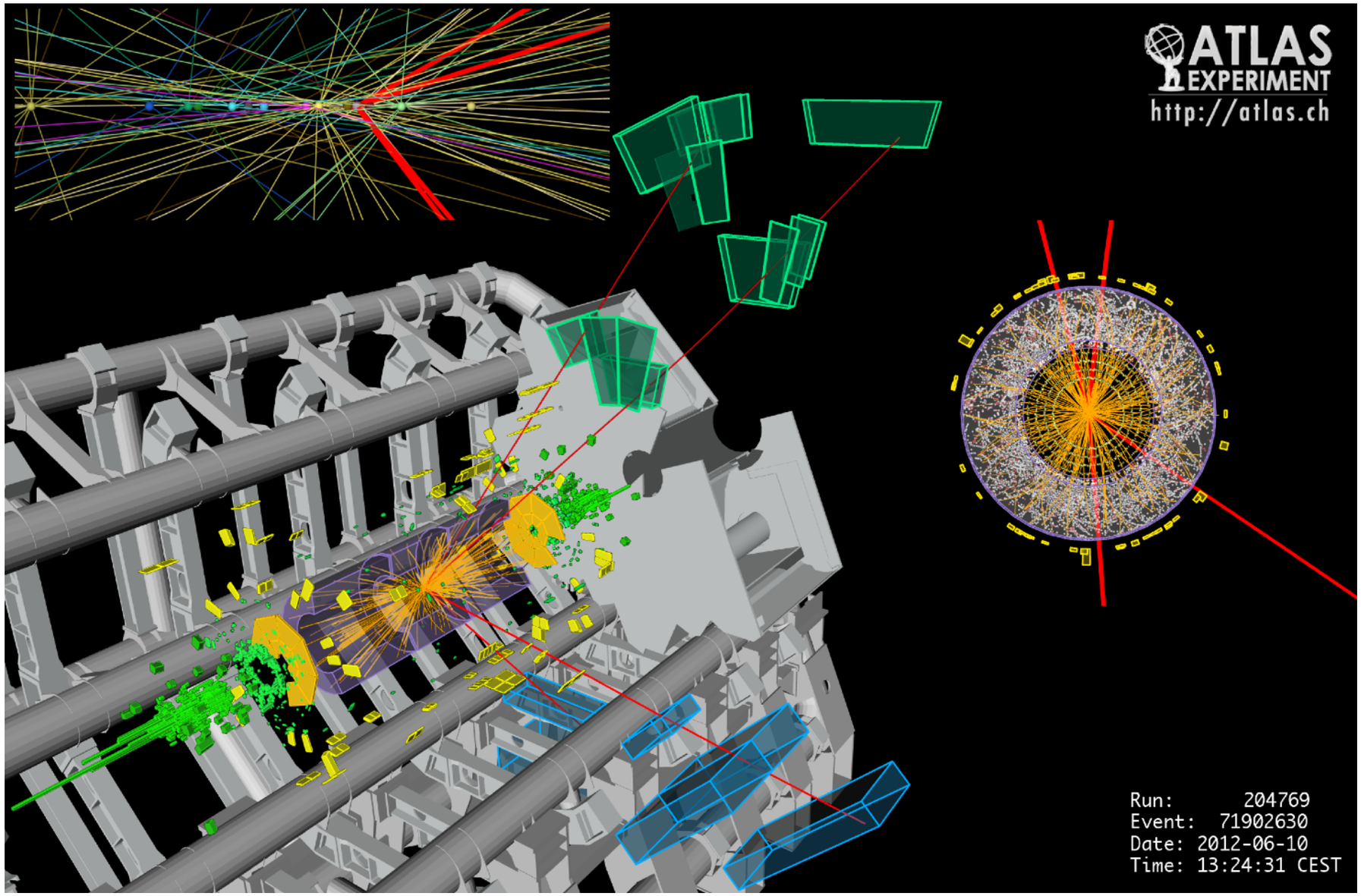


$$\sigma_{ggH} \times \mathcal{B}(H \to \gamma\gamma) = 65\ ^{+32}_{-31}\ \text{fb}$$

$$\sigma_{\text{VBF}} \times \mathcal{B}(H \to \gamma\gamma) = 19.2\ ^{+6.8}_{-6.1}\ \text{fb}$$

$$\sigma_{VH} \times \mathcal{B}(H \to \gamma\gamma) = 1.2\ ^{+6.5}_{-5.4}\ \text{fb}$$

$$\sigma_{t\bar{t}H} \times \mathcal{B}(H \to \gamma\gamma) = -0.3\ ^{+1.4}_{-1.1}\ \text{fb}$$

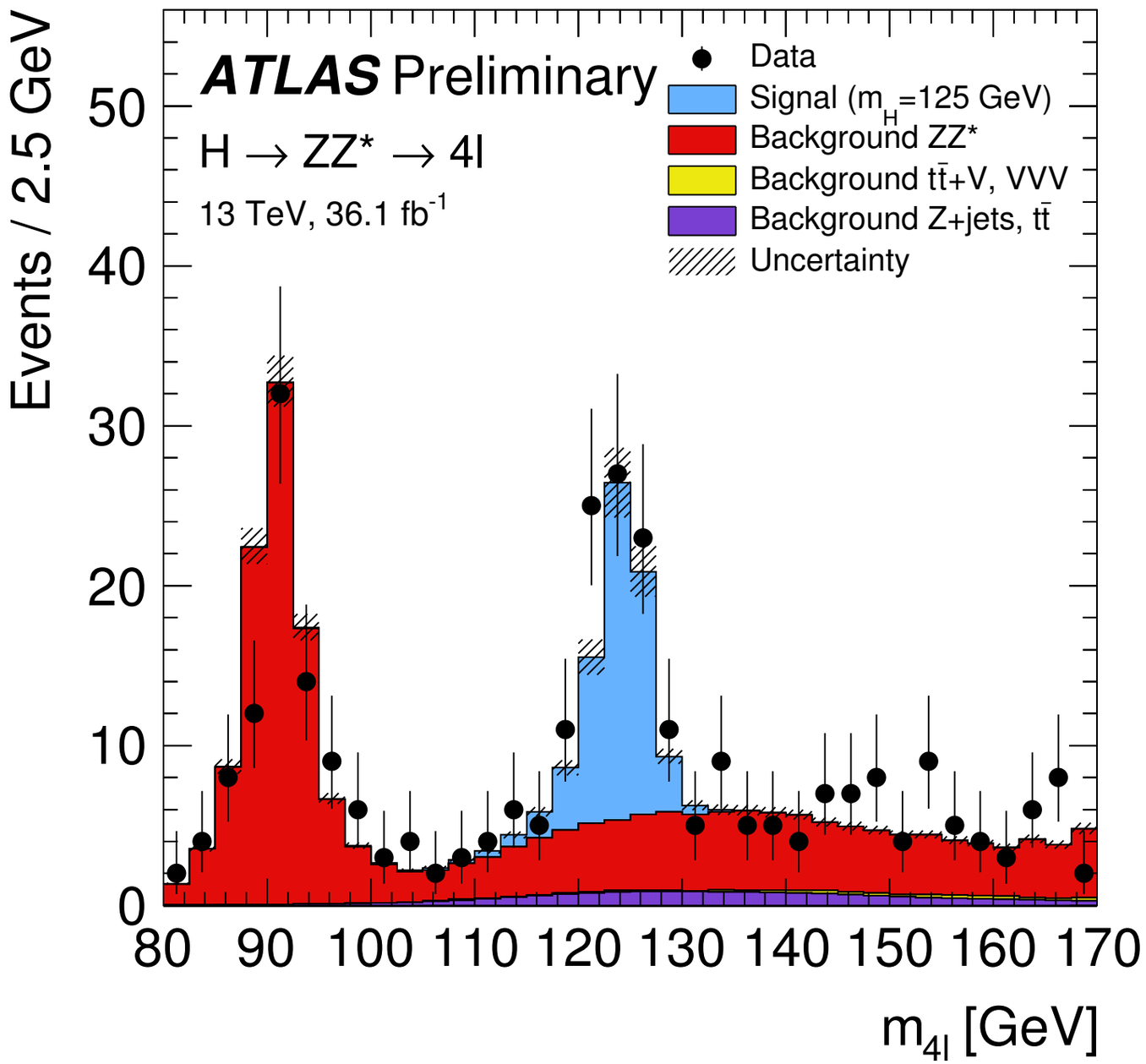


$H \rightarrow ZZ^* \rightarrow 4\ell$

Narrow peak on smooth background; Small statistics

S/B ~ 2, $\mathscr{B}(m_H=125\ \text{GeV}) = 0.0124\%$

H→ZZ*→4ℓ analysis strategy



★ Loose lepton ID to maximize efficiency and acceptance

★ 115 < $m_{4\ell}$ < 130 GeV

★ p_T^{μ} > 5 GeV, $|\eta|$ < 2.7

★ p_T^{e} > 7 GeV, $|\eta|$ < 2.47

★ Selection acceptance ~50% total phase space

Bkg	Estimate approach
SM ZZ*	simulation
Zj, $t\bar{t}$, triboson	from data

ATLAS-CONF-2017-032

H→4ℓ fiducial volume

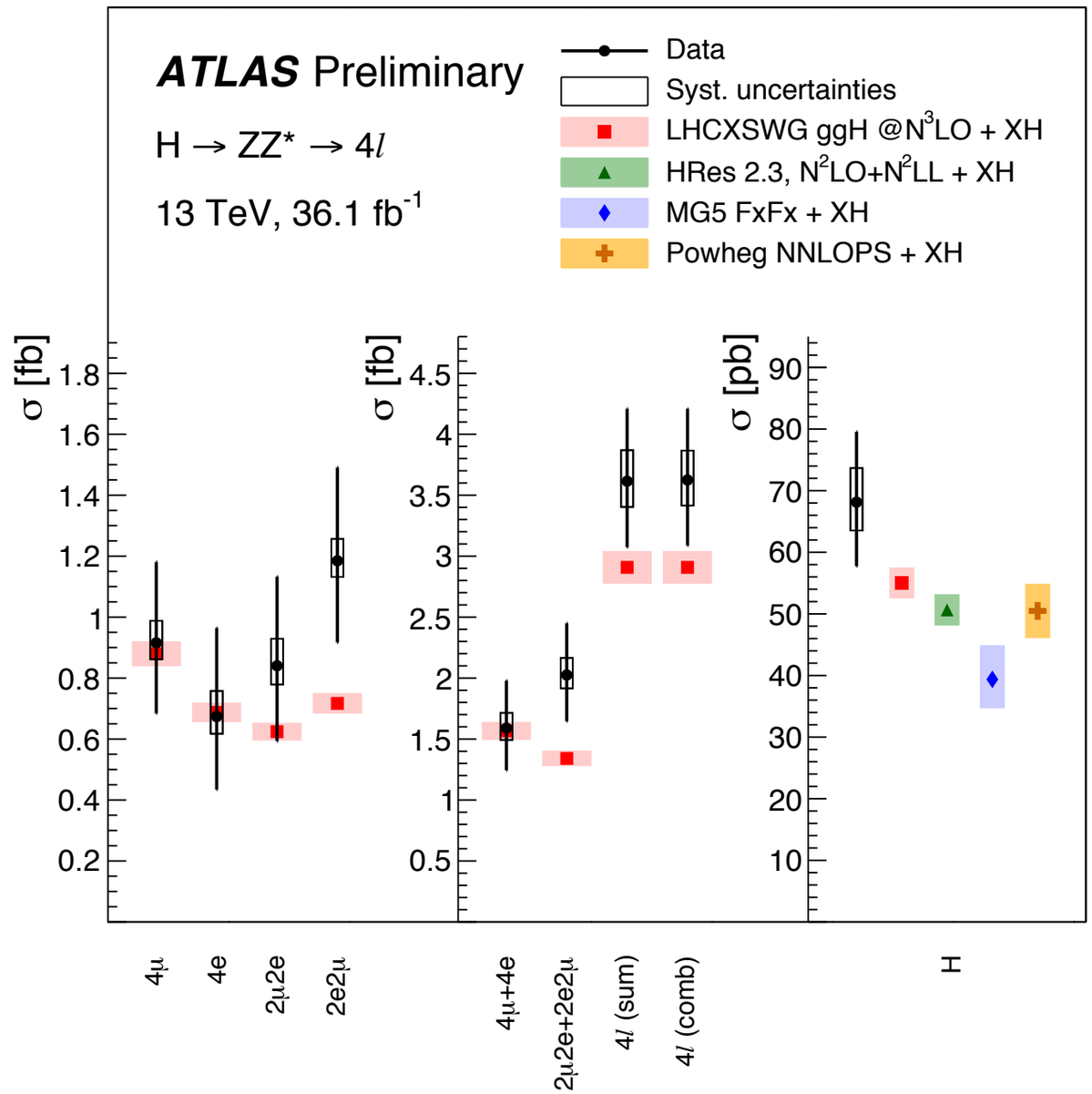
Acceptance ~ 50%

Leptons and jets	
Muons:	$p_{\mathrm{T}} > 5$ GeV, $\lvert\eta\rvert < 2.7$
Electrons:	$p_{\mathrm{T}} > 7$ GeV, $\lvert\eta\rvert < 2.47$
Jets:	$p_{\mathrm{T}} > 30$ GeV, $\lvert y\rvert < 4.4$
Jet-lepton overlap removal:	$\Delta R(\mathrm{jet}, \ell) > 0.1\,(0.2)$ for muons (electrons)
Lepton selection and pairing	
Lepton kinematics:	$p_{\mathrm{T}} > 20, 15, 10$ GeV
Leading pair (m_{12}):	SFOS lepton pair with smallest $\lvert m_Z - m_{\ell\ell}\rvert$
Subleading pair (m_{34}):	remaining SFOS lepton pair with smallest $\lvert m_Z - m_{\ell\ell}\rvert$
Event selection (at most one quadruplet per channel)	
Mass requirements:	$50 < m_{12} < 106$ GeV and $12 < m_{34} < 115$ GeV
Lepton separation:	$\Delta R(\ell_i, \ell_j) > 0.1\,(0.2)$ for same- (different-) flavour leptons
J/ψ veto:	$m(\ell_i, \ell_j) > 5$ GeV for all SFOS lepton pairs
Mass window:	$115\ GeV < m_{4\ell} < 130$ GeV

ATLAS-CONF-2017-032

Fiducial cross sections

Acceptance x Efficiency = 16% (4e) - 31% (4μ)



★ Signal extracted with **profile likelihood template fit** to $m_{4\ell}$ spectrum

★ Corrected for detector resolution and efficiency

★ Same flavor and opposite flavor cross sections extracted to probe sensitivity to interference between all same-flavor leptons in final state (SM: ~10% effect)

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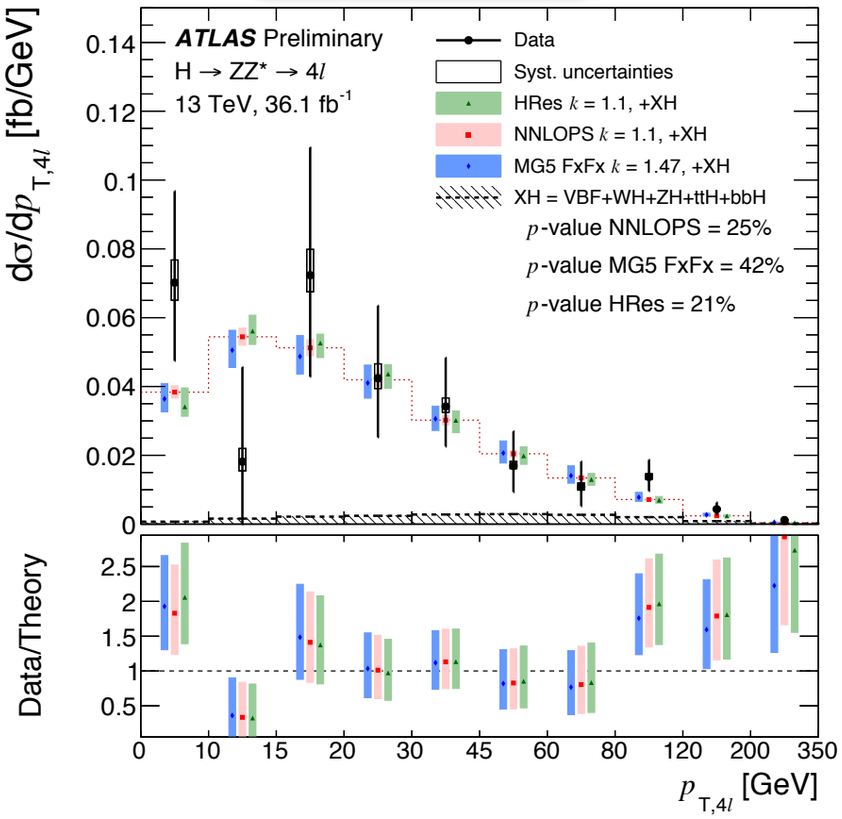
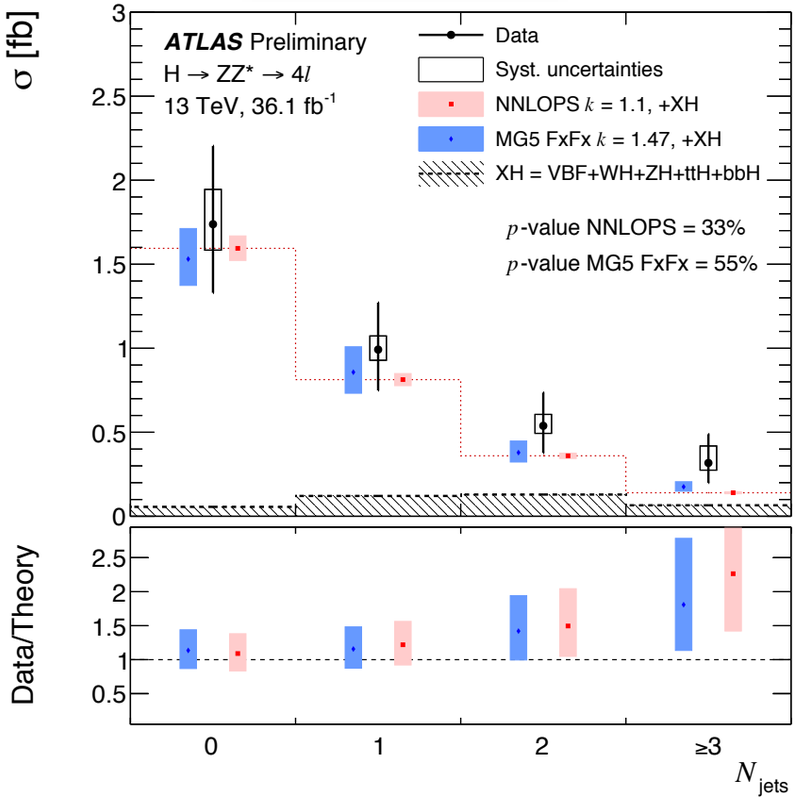
Differential cross sections

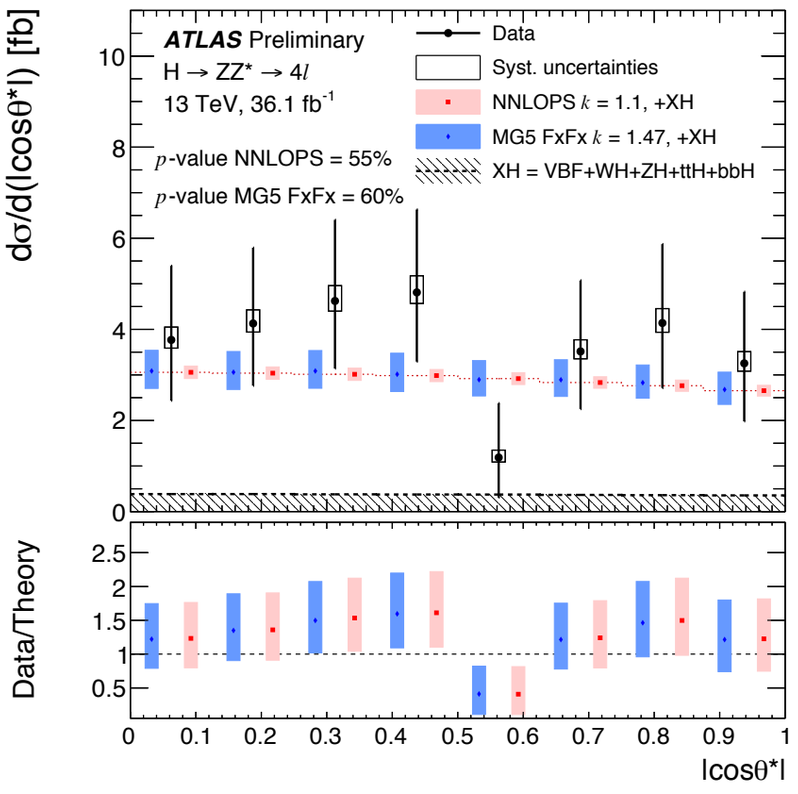
$p_T^{4\ell}$



N_{jets}



$|cos\theta^*|$



★ Observables: $p_T^{4\ell}$, $|y_{4\ell}|$, $|cos\theta^*|$, $\Delta\phi_{jj}$, m_{12}, m_{34}, N_{jets}, m_{jj}, $p_{T,J1}$

★ Probing kinematics, *pp* collision PDFs, spin, parity, production mode, perturbative QCD

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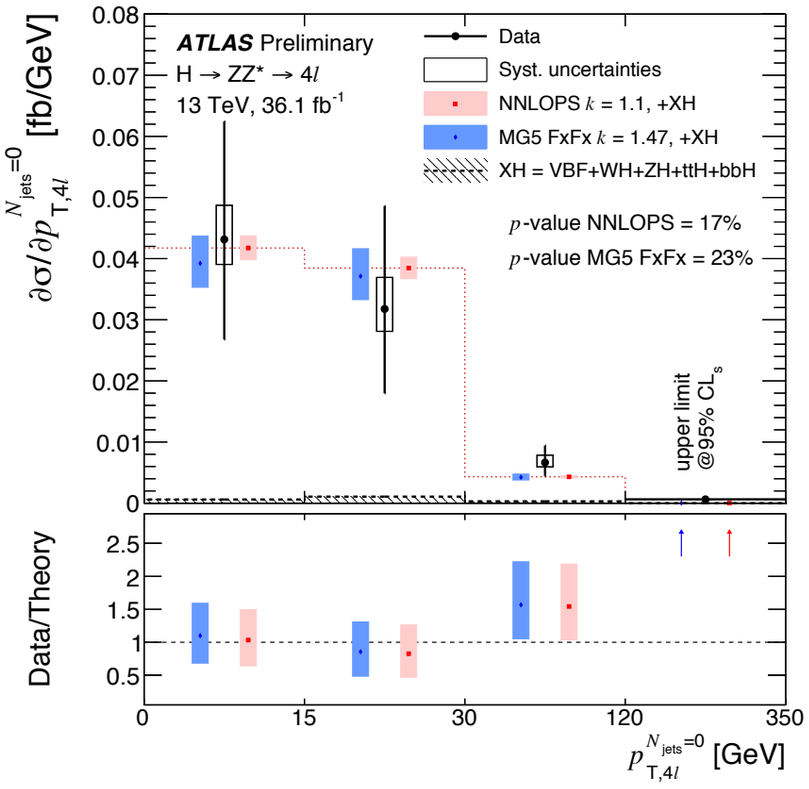
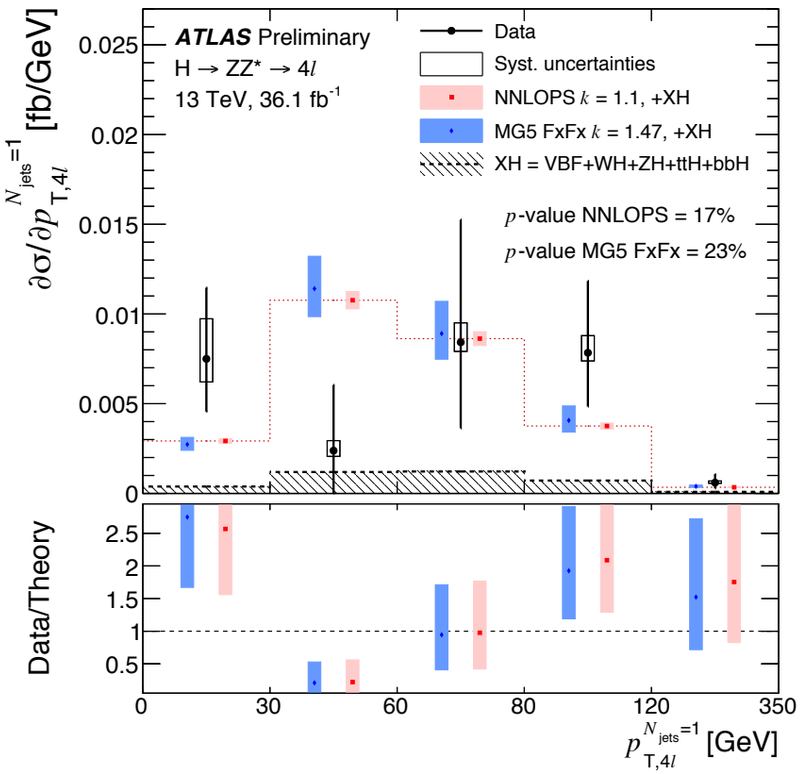
Double differential cross sections

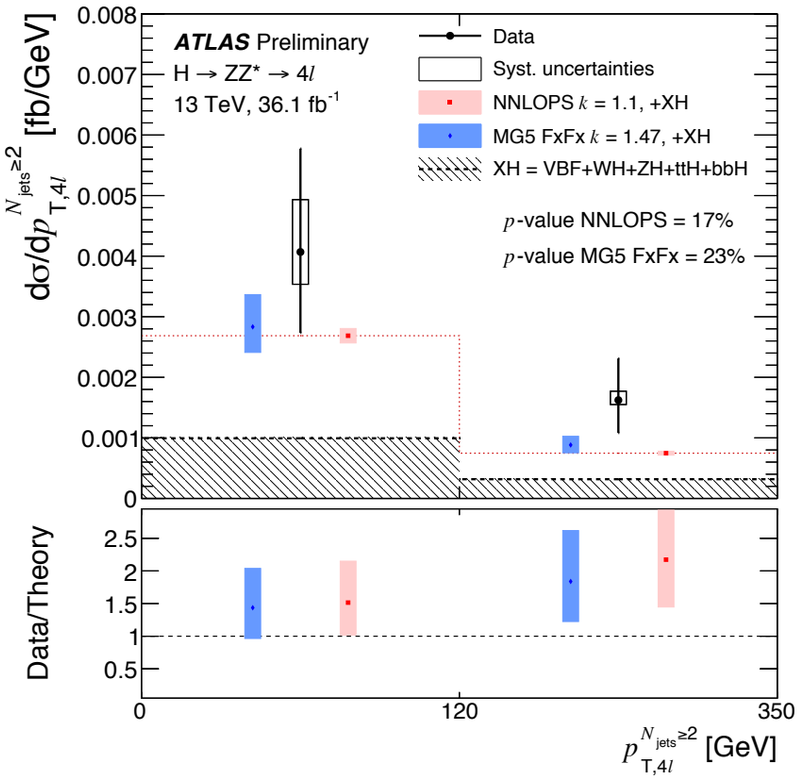
N_{jets}=0



N_{jets}=1



$N_{jets}\geq$2



★ Probe perturbative QCD for different production modes

14.8 fb^{-1}

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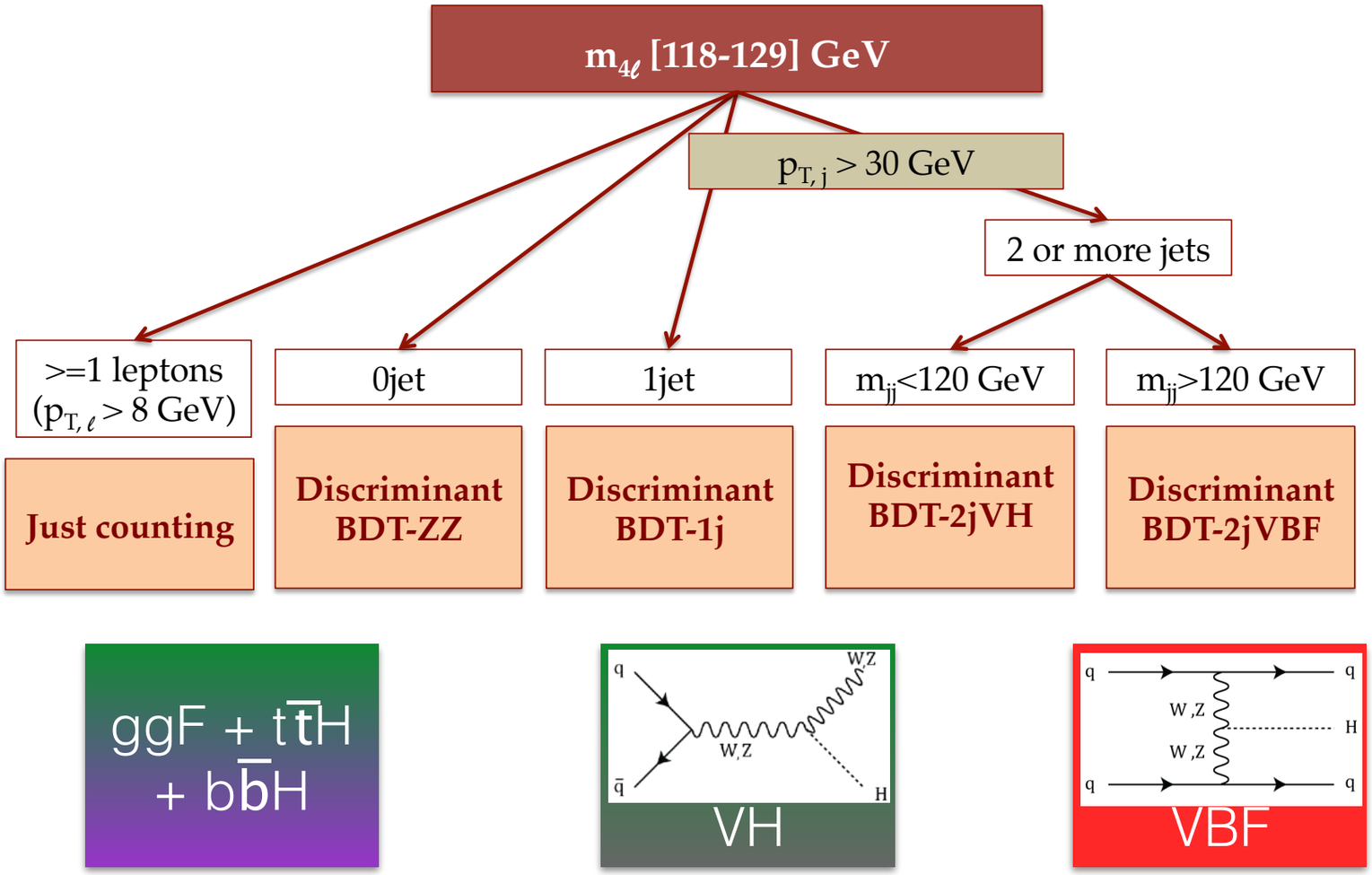
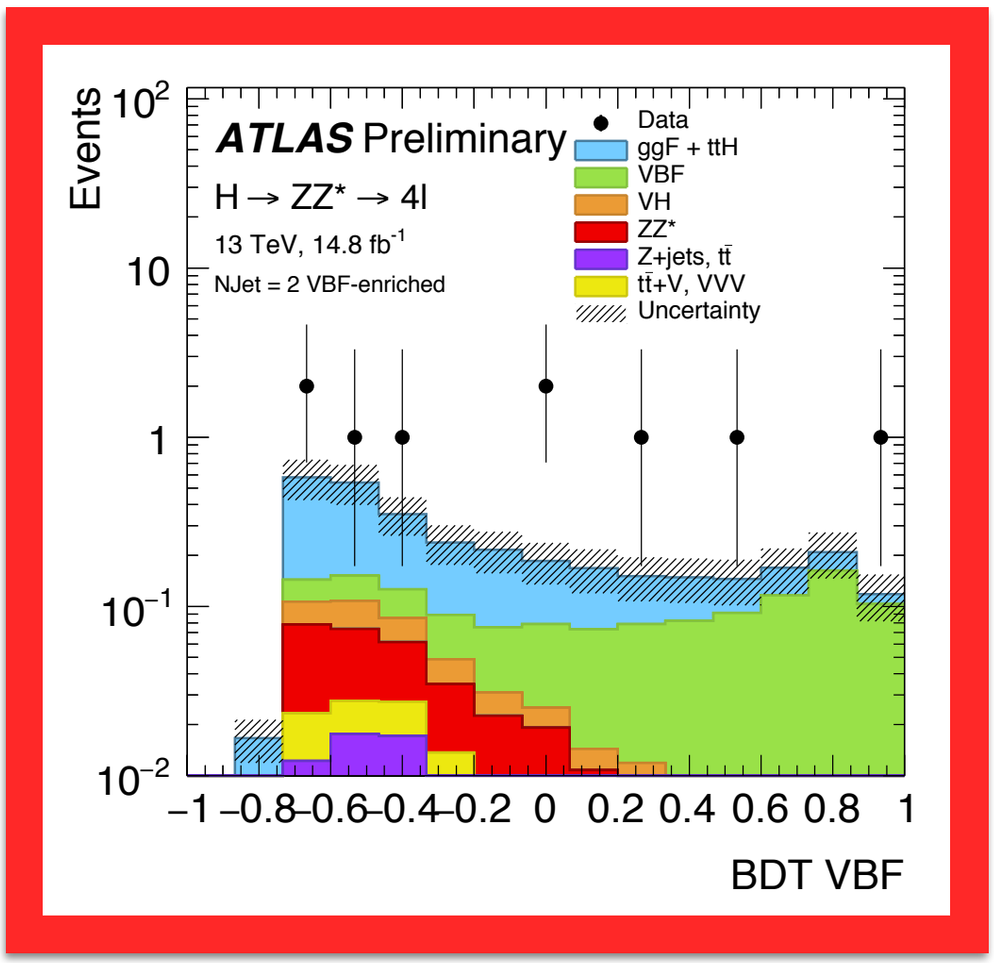
H→4ℓ event categories for couplings

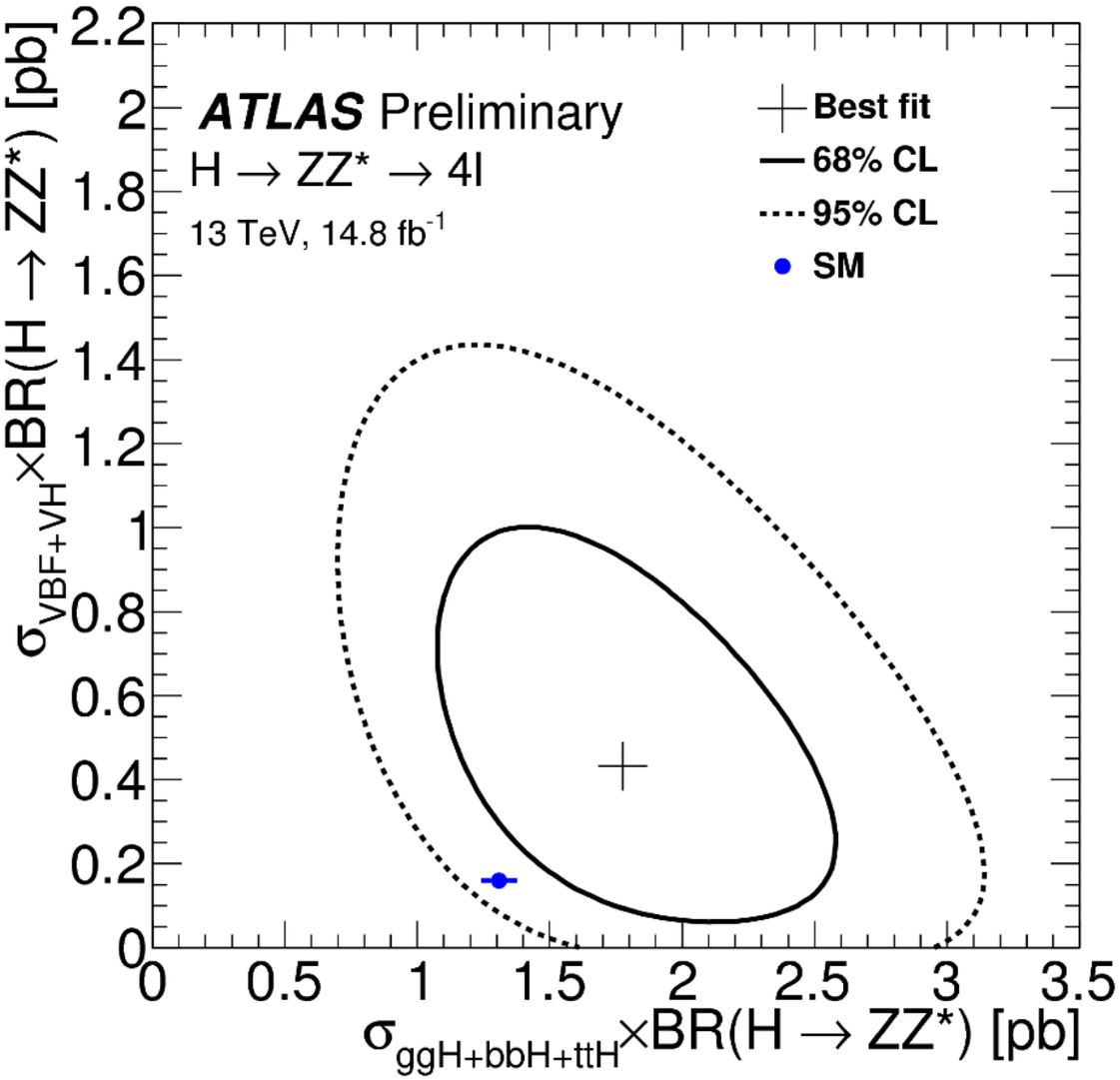




14.8 fb^{-1}

ATLAS-CONF-2016-079

Coupling measurements



Observed

$$\sigma_{\mathrm{ggF}+b\bar{b}H+t\bar{t}H} \cdot \mathcal{B}(H \to ZZ^*) = 1.80^{+0.49}_{-0.44}\ \mathrm{pb}$$

$$\sigma_{\mathrm{VBF}} \cdot \mathcal{B}(H \to ZZ^*) = 0.37^{+0.28}_{-0.21}\ \mathrm{pb}$$

$$\sigma_{\mathrm{VH}} \cdot \mathcal{B}(H \to ZZ^*) = 0^{+0.15}\ \mathrm{pb}$$

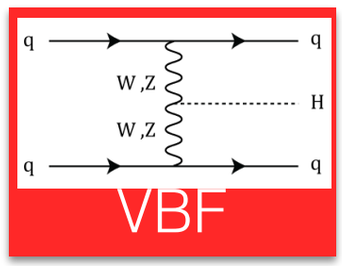
Expected

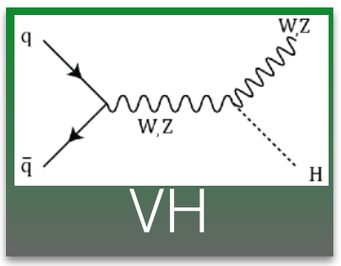
$$\sigma_{\mathrm{SM,ggF}+b\bar{b}H+t\bar{t}H} \cdot \mathcal{B}(H \to ZZ^*) = 1.31 \pm 0.07\ \mathrm{pb}$$

$$\sigma_{\mathrm{SM,VBF}} \cdot \mathcal{B}(H \to ZZ^*) = 0.100 \pm 0.003\ \mathrm{pb}$$

$$\sigma_{\mathrm{SM,VH}} \cdot \mathcal{B}(H \to ZZ^*) = 0.059 \pm 0.002\ \mathrm{pb}$$

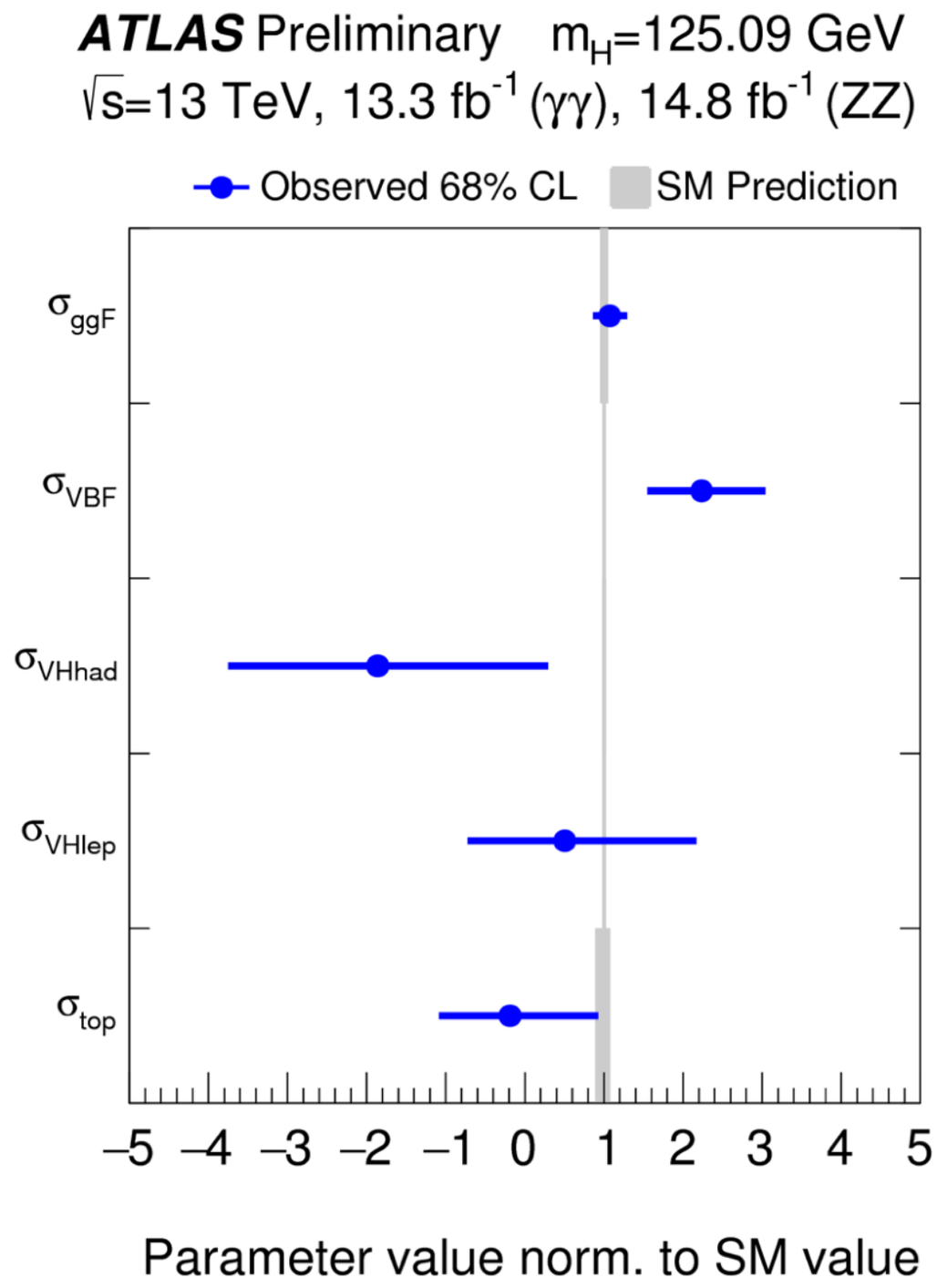
ggF + $t\bar{t}H$ + $b\bar{b}H$



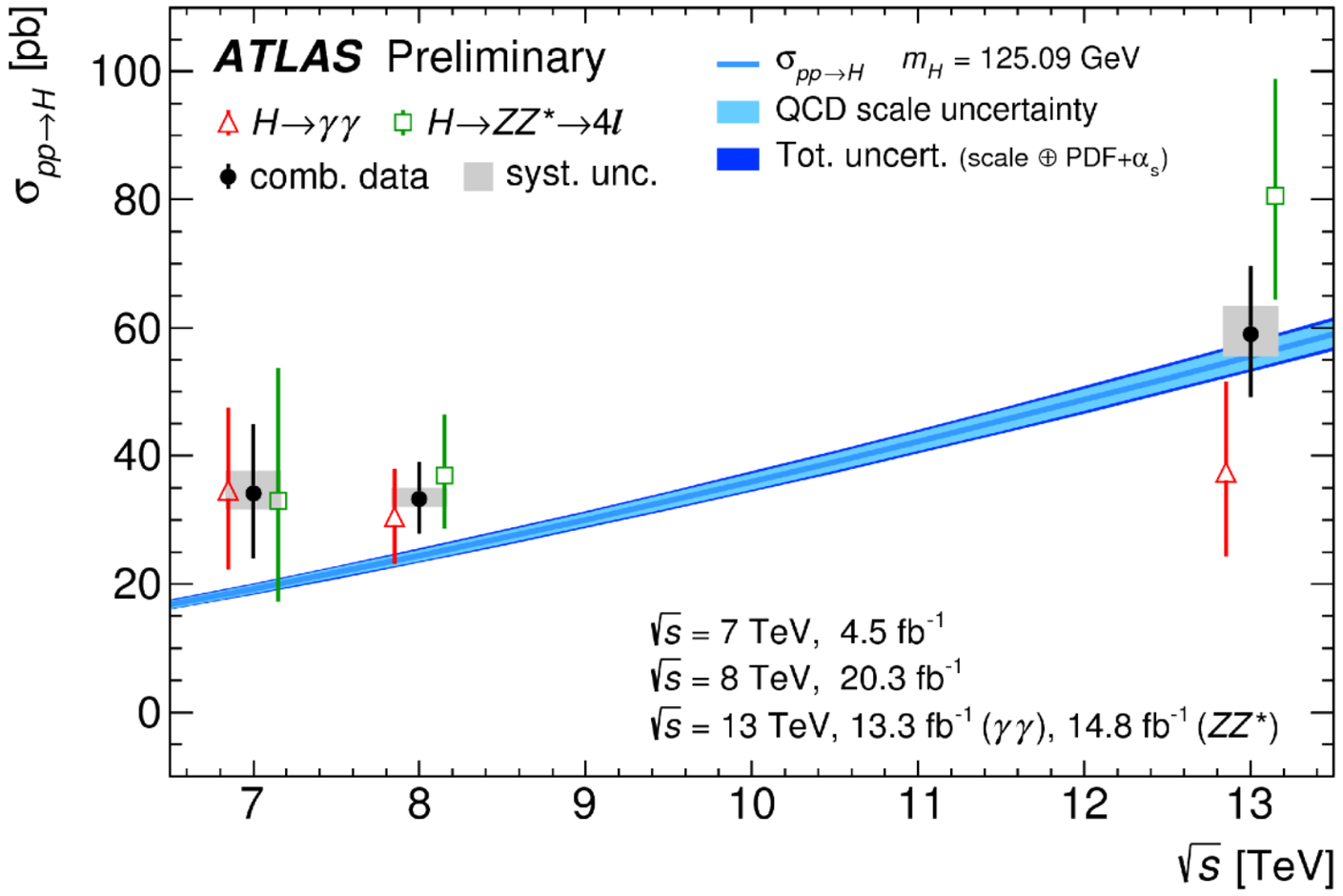


ATLAS-CONF-2016-081

γγ/4ℓ combination

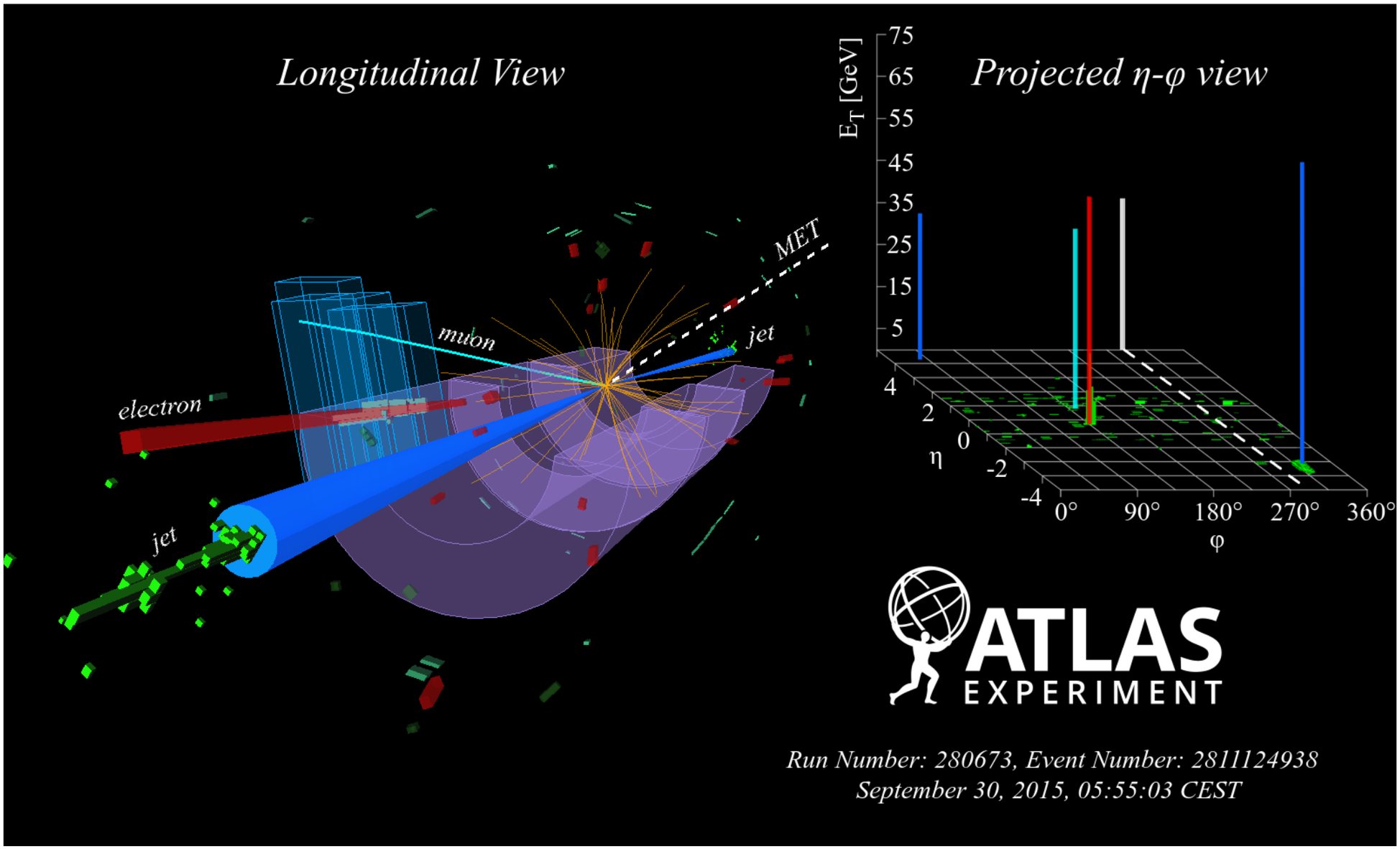


σ_{tot} vs $\sqrt{s}$ trends with SM



5.8 fb^{-1}

ATLAS-CONF-2016-112



H→WW*→ℓνℓ'ν

Abundant decay…and abundant backgrounds

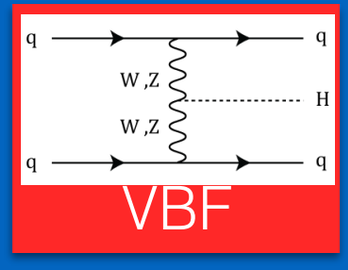
$\mathcal{B}(m_H=125\ \text{GeV}) = 1.06\%$

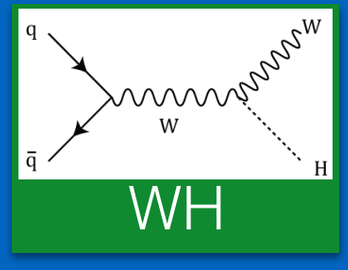
5.8 fb^{-1}

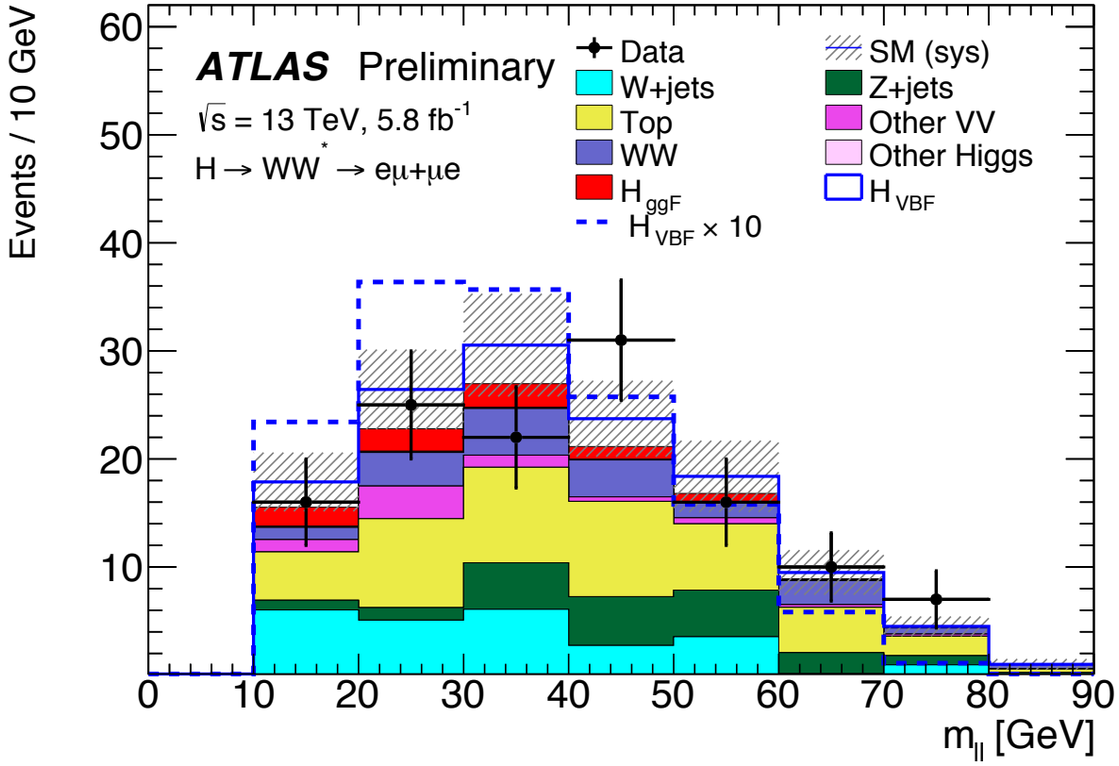
ATLAS-CONF-2016-112

H→WW*→ℓνℓ'ν analysis strategy

Concentrate on VBF, WH production → event topology distinguishes signal from backgrounds







★ Selection designed to suppress backgrounds (Top, Vj, WW, Z→ττ, ggF, VV)

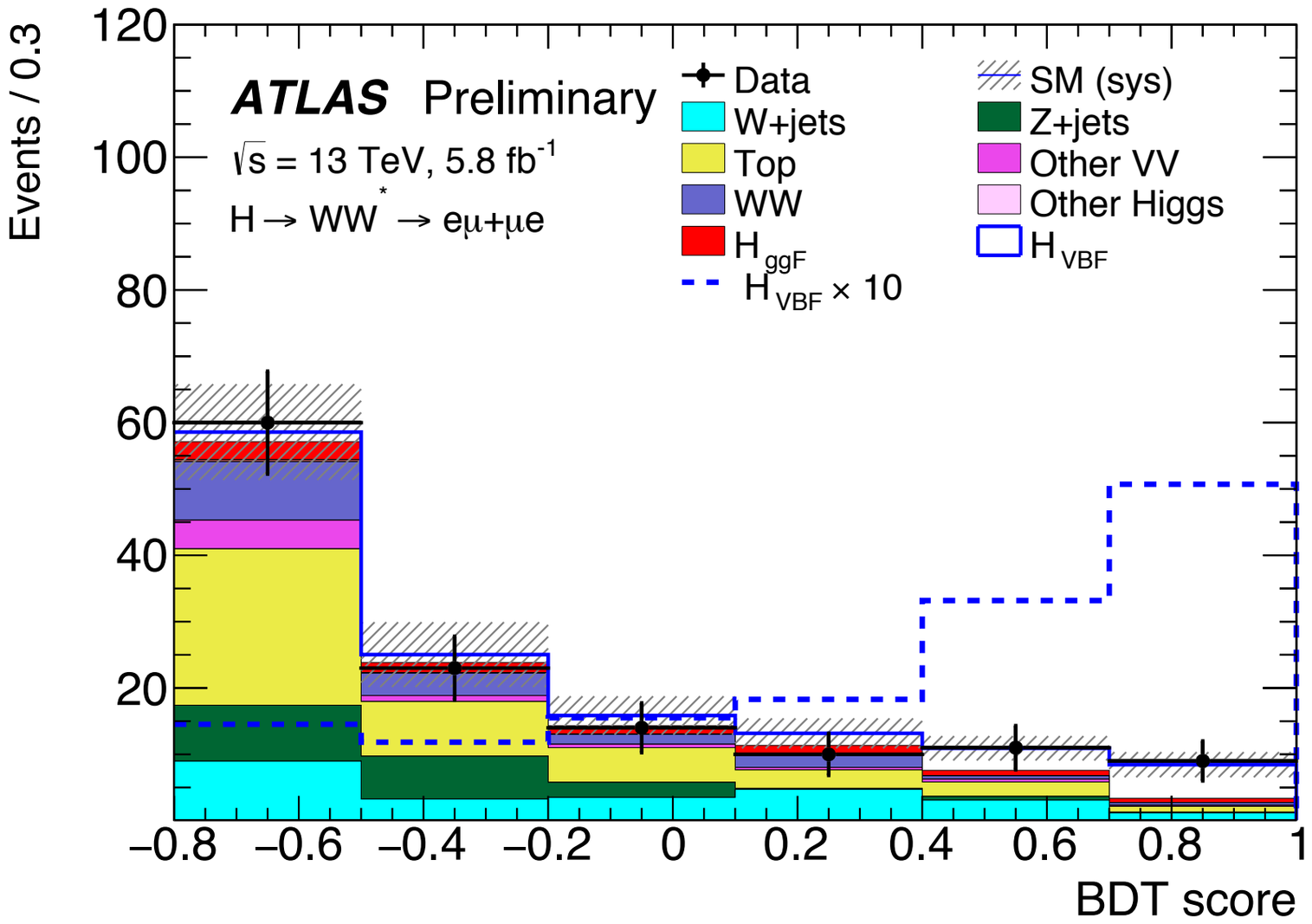
- ggF not considered → high QCD multi-jet backgrounds ∴ treated as background
- Top, Z→ττ estimated from data (rest from simulation)

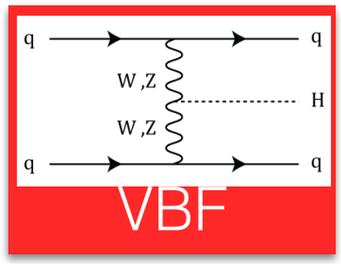
★ Multivariate discriminant (BDT) in VBF channel

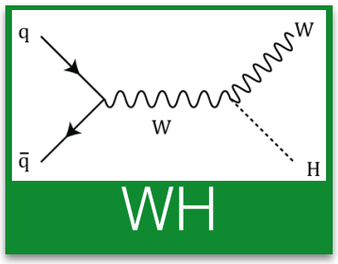
5.8 fb^{-1}

ATLAS-CONF-2016-112

Observed signal strength and significance

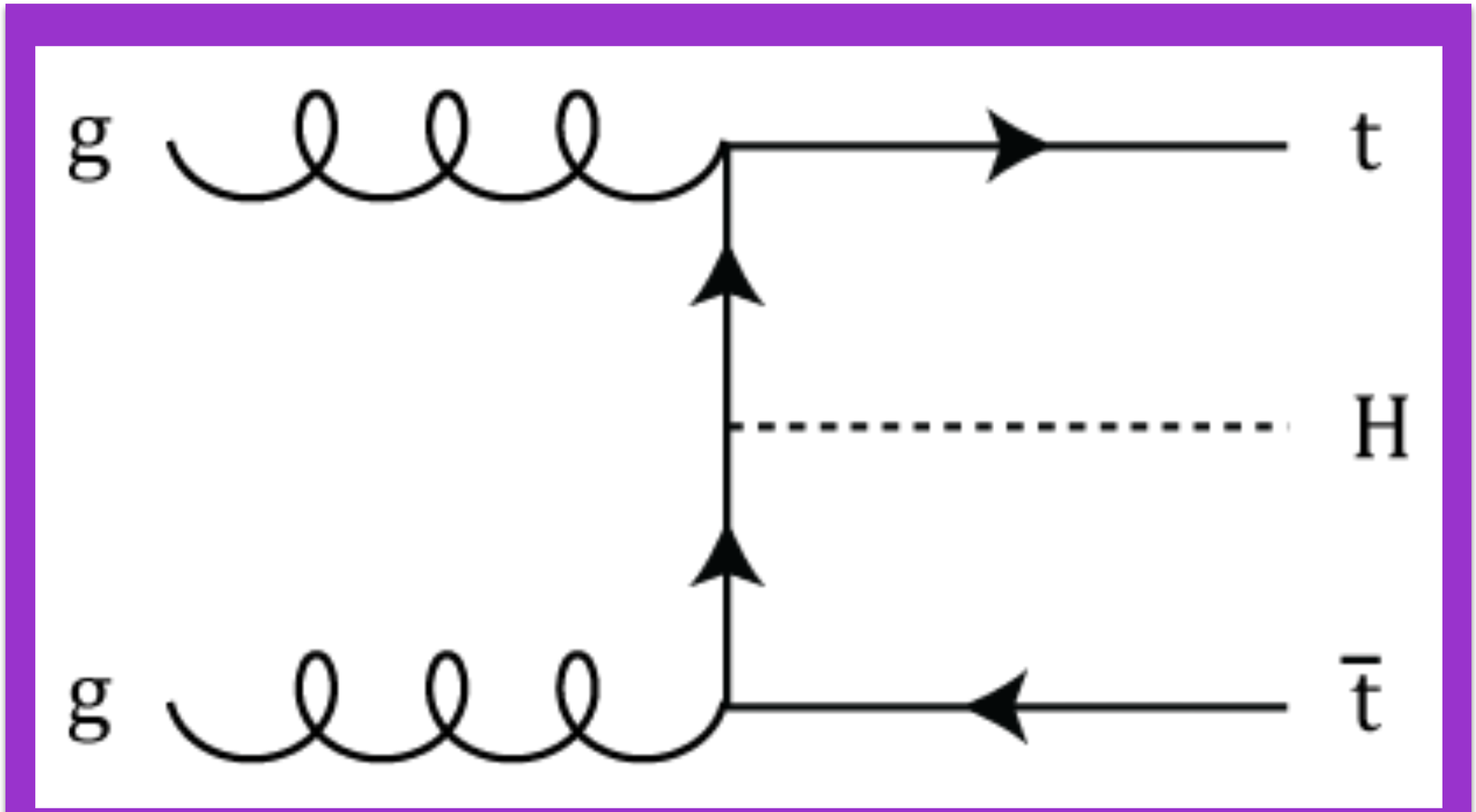






★ Observed significance < 2σ
→ upper limits at 95% CL

- lim($\sigma_{VBF} \times \mathcal{B}$) = 3.0 pb &
  lim($\sigma_{WH} \times \mathcal{B}$) = 3.3 pb



$t\bar{t}H$ (0.9%)

Search for $t\bar{t}H$ production

Direct probe of top-Higgs Yukawa coupling
SM predicts 3.9x more common at 13 TeV compared to 8 TeV

13.2-13.3 fb^{-1}

ATLAS-CONF-2016-068

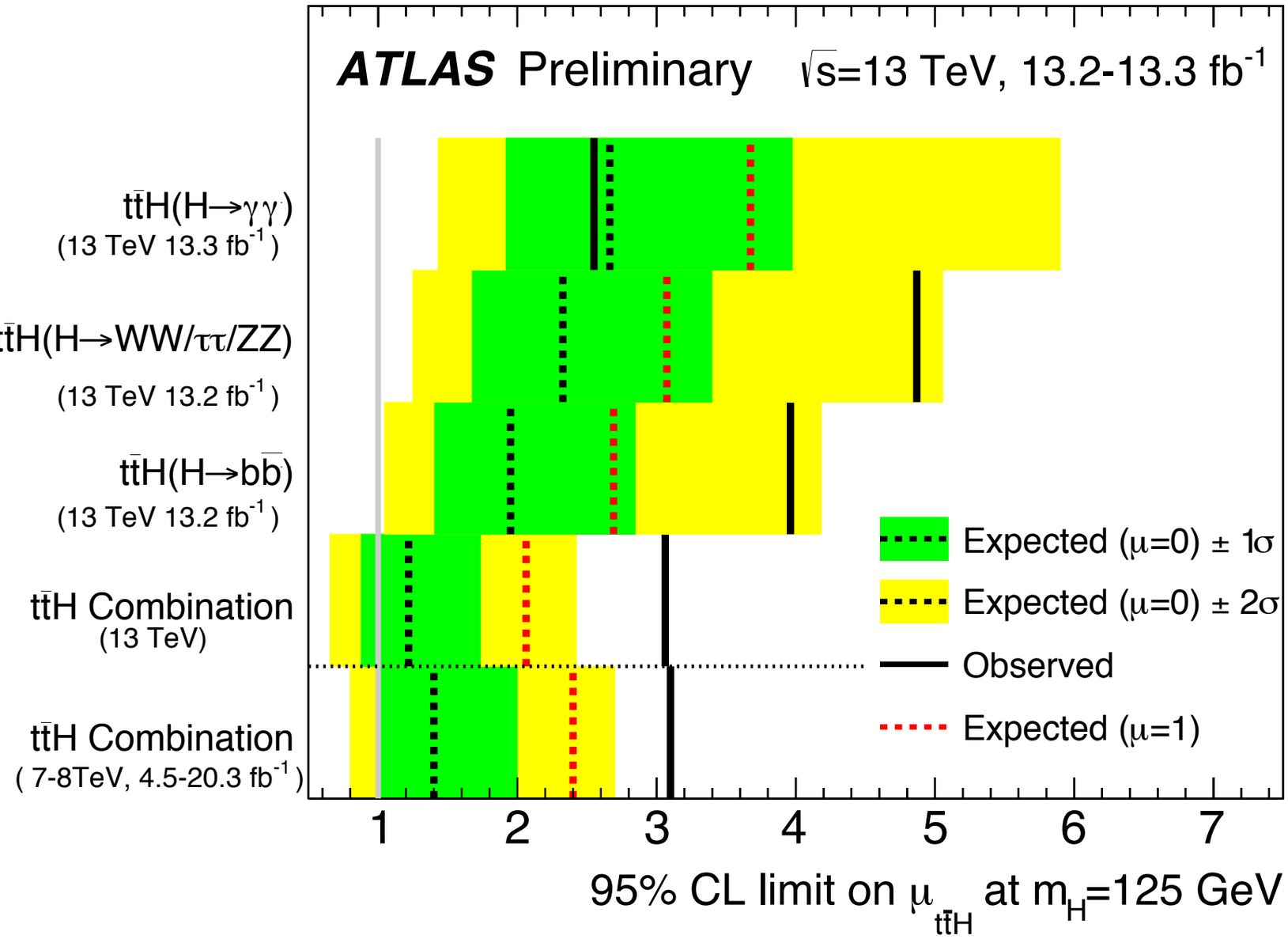
Combined search: $t\bar{t}H$ production

Diphoton

Multilepton

$t\bar{t}H(H\to b\bar{b})$

Combo

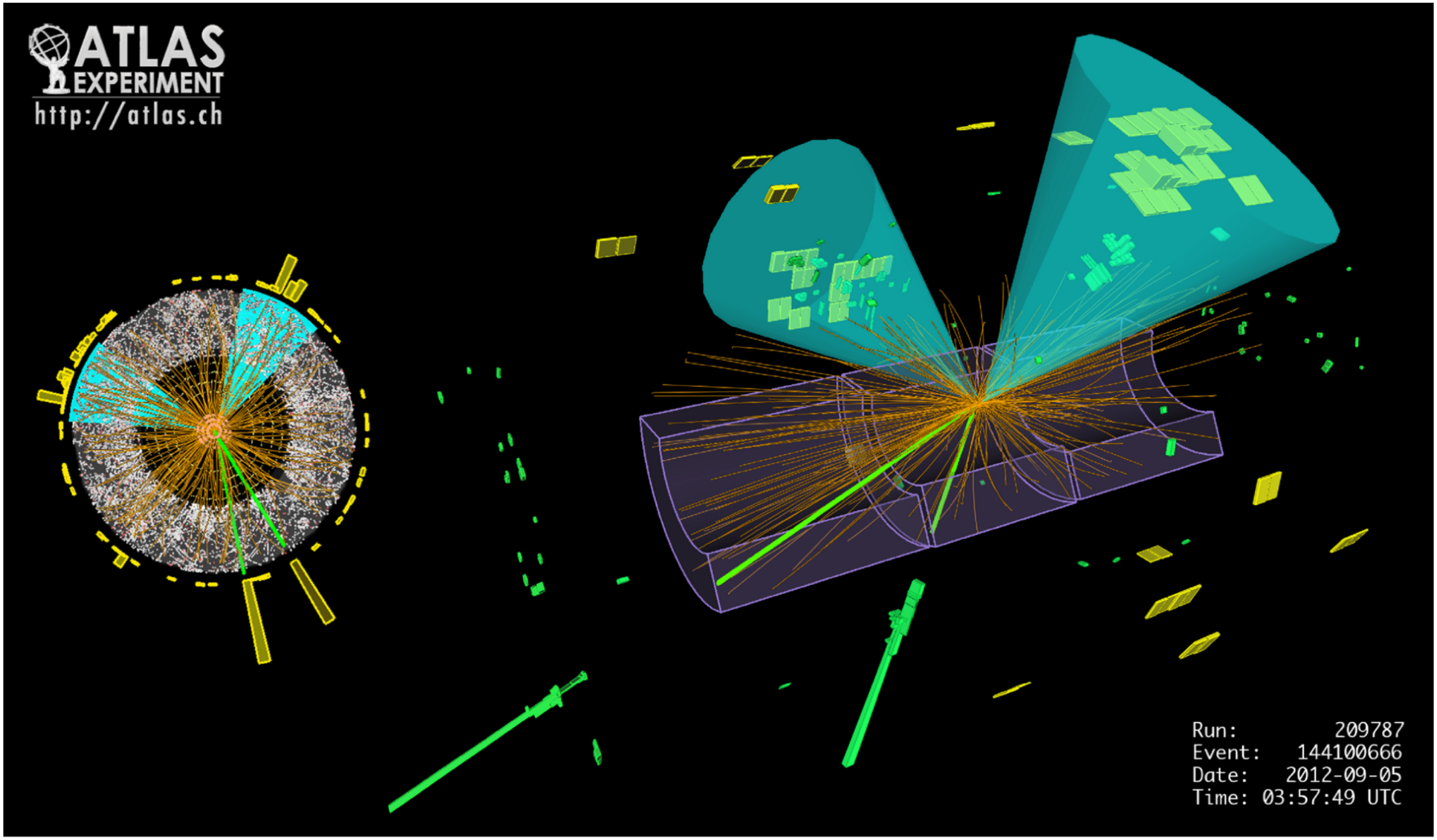


	Expected Significance
Run I	1.5σ
Run II	1.8σ

Run II observed significance = 2.8σ

13.2/12.6 fb^{-1}

ATLAS-CONF-2016-091, ATLAS-CONF-2016-063



Search for H→b$\bar{\text{b}}$ decays

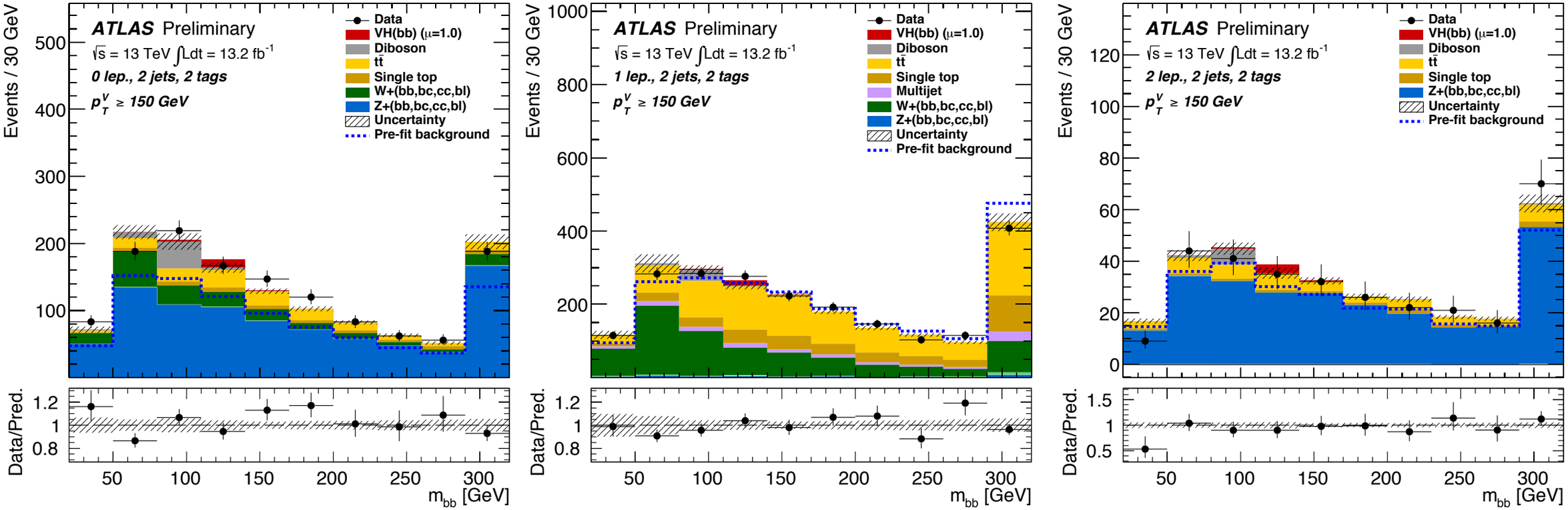
Common decay pathway plagued by tremendous backgrounds

$\mathcal{B}(m_H$=125 GeV) = 58%

13.2 fb^{-1}

ATLAS-CONF-2016-091

Search for VH→b$\bar{\text{b}}$



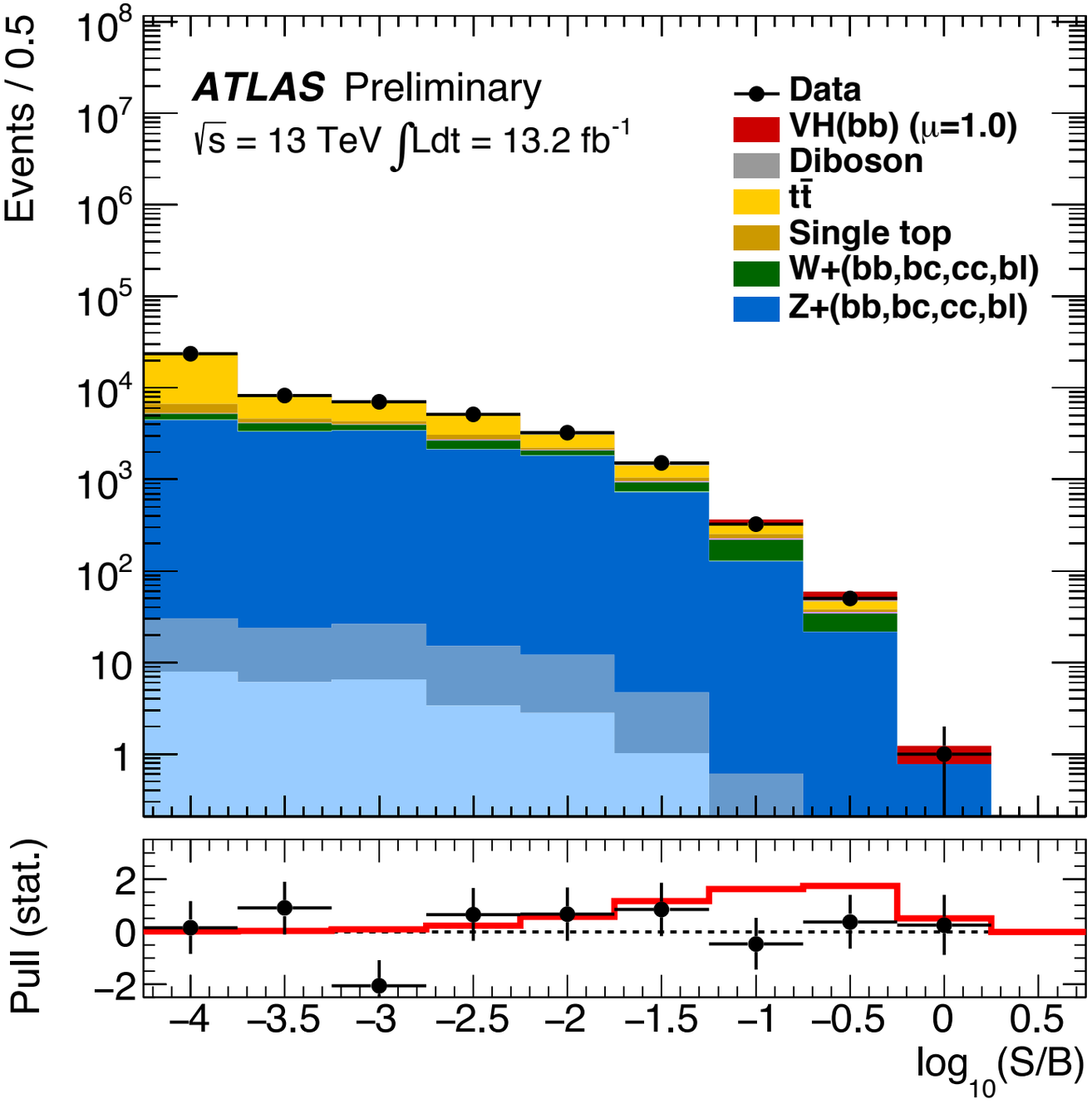
★ $m_{b\bar{b}}$ binned in 2-jets and 3-jets x 0, 1, 2 leptons

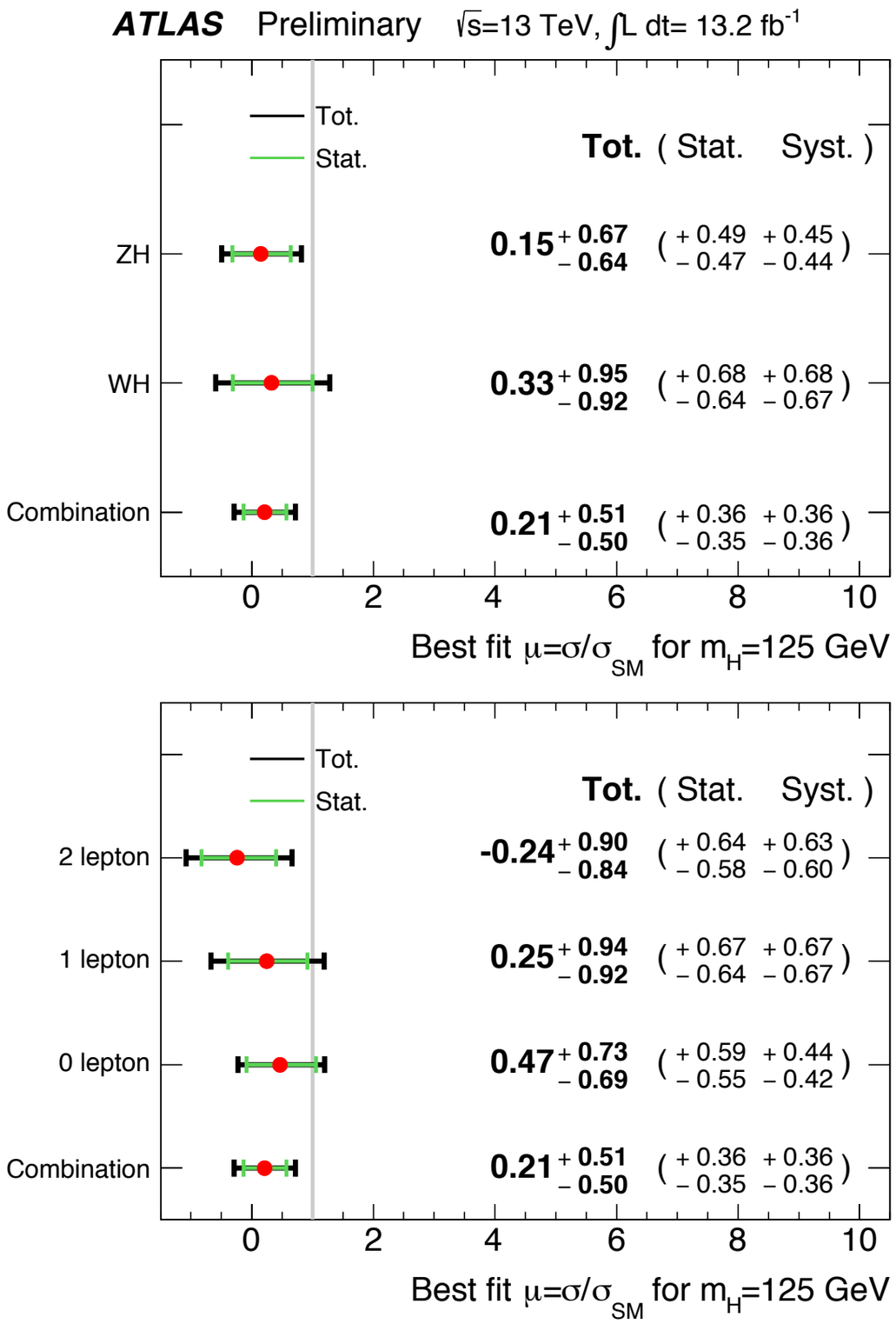
★ p_T^V > 150 GeV (V = W, Z)

★ b$\bar{\text{b}}$ QCD production is major background

ATLAS-CONF-2016-091

Search for VH→b$\bar{b}$: Results



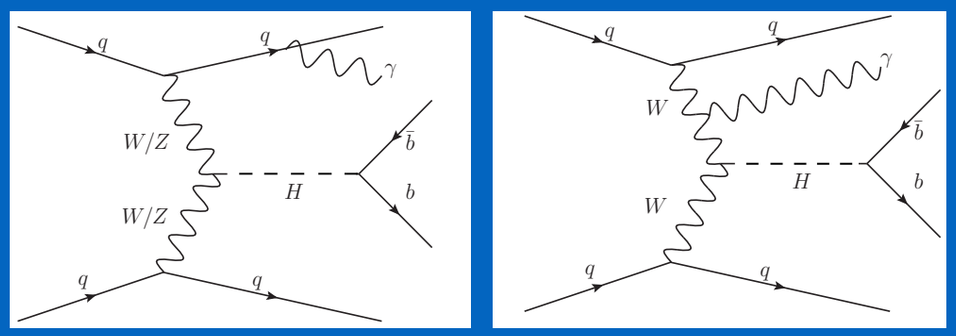


12.6 fb^{-1}

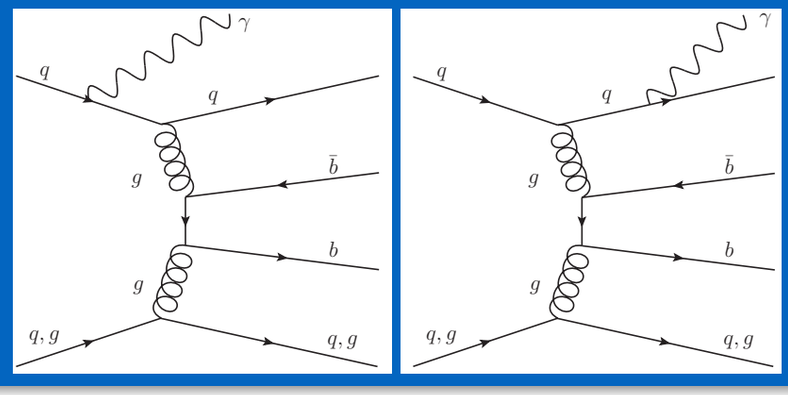
ATLAS-CONF-2016-063

Search for VBF H→b$\bar{b}$

Signal



Background



★ Signature: 2 b-jets, 2 high-energy forward jets (VBF), high-p_T ɣ

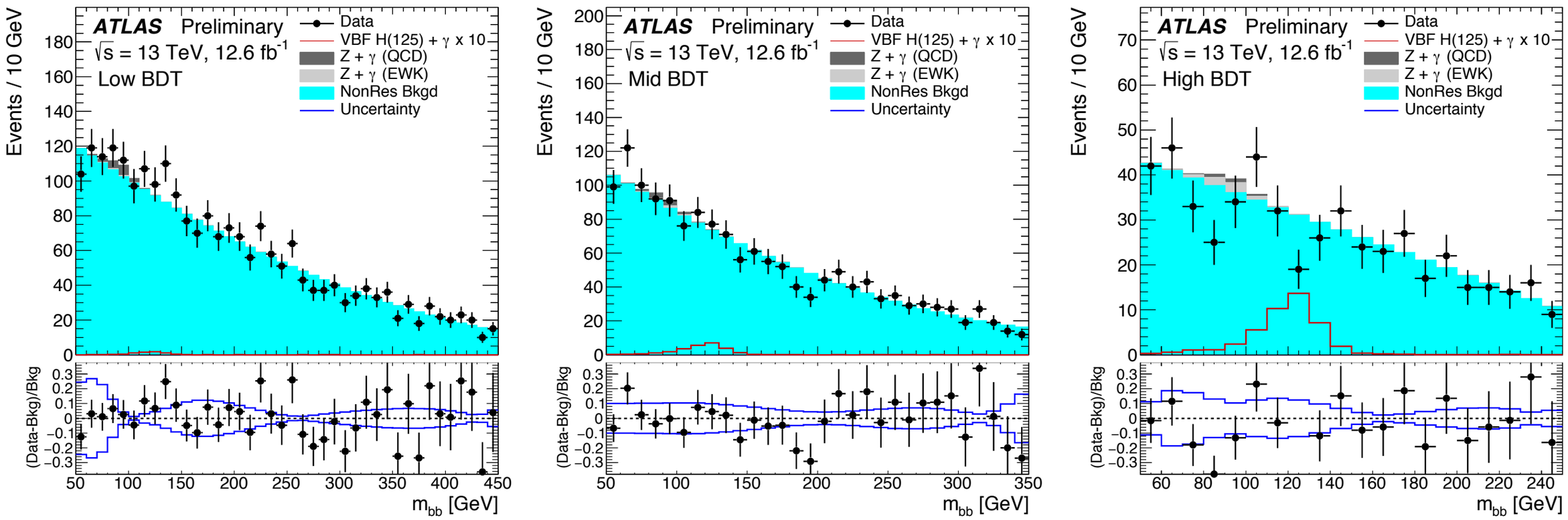
- trigger on ɣ
- gluon-induced component of b$\bar{b}$ɣjj bkg naturally suppressed
- Destructive interference suppresses central ɣ emission by bkg processes
- Selected events passed to BDT to further separate signal and non-resonant multi-jet background

★ non-resonant QCD = dominant bkg

12.6 fb^{-1}

ATLAS-CONF-2016-063

Search for VBF H→b$\bar{\text{b}}$: Results

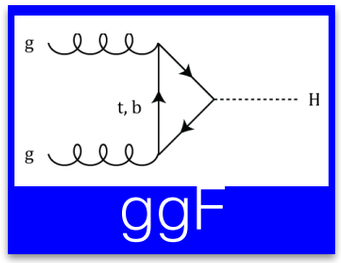
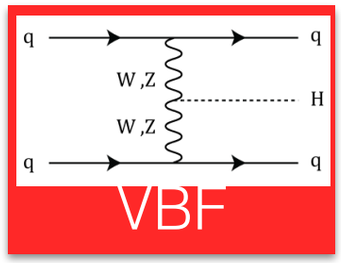
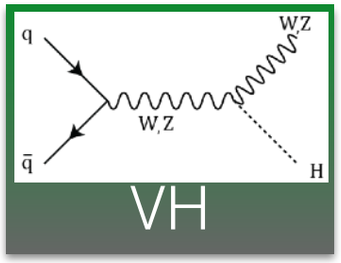
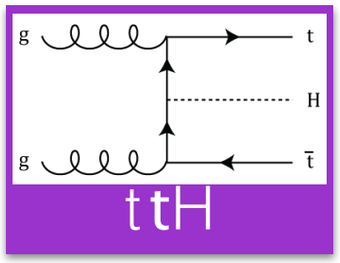


Result	$H(\to b\bar{b}) + \gamma jj$
Expected significance	0.4
Expected p-value	0.4
Observed p-value	0.9
Expected limit	$6.0^{+2.3}_{-1.7}$
Observed limit	4.0
Observed signal strength μ	$-3.9^{+2.8}_{-2.7}$

★ Signal strength μ extracted with profile likelihood fit to $m_{\text{b}\bar{\text{b}}}$ spectrum

★ Largest systematics from background analysis with BDT

Summary

Decay \ Prod.	 ggF	 VBF	 VH	 ttH	**Inclusive**
H→γγ	$\mu=0.59^{+0.29}_{-0.28}$	$\mu=2.24^{+0.80}_{-0.71}$	$\mu=0.23^{+1.27}_{-1.05}$	$\mu=-0.25^{+1.26}_{-0.99}$	$\mu=0.85^{+0.22}_{-0.20}$
H→ZZ*→4ℓ	$\sigma_{ggF+b\bar{b}H+t\bar{t}H}\bullet\mathcal{B}=1.80^{+0.49}_{-0.44}$ pb	$\sigma_{VBF}\bullet\mathcal{B}=0.37^{+0.28}_{-0.21}$ pb	$\sigma_{VH}\bullet\mathcal{B}=0^{+0.15}$ pb	—	$\sigma_{fid}^{4\ell}=3.62^{+0.59}_{-0.54}$ fb
H→WW*→ℓνℓν	—	lim(σ•$\mathcal{B}$), 95% C.L. = 3.0 pb	WH lim(σ•$\mathcal{B}$),95% C.L. = 3.3 pb	—	—
Search: $t\bar{t}H$	—	—	—	Observed signif. = 2.8σ	—
Search: VH→$b\bar{b}$	—	—	Observed signif. = 0.42σ	—	—
Search VBF H→$b\bar{b}$	—	lim(σ•$\mathcal{B}$), 95% C.L. = 4x SM expectation	—	—	—

Summary

★ 2015-2016 LHC season already exceed Run I sensitivity to Higgs processes

★ 13 TeV fiducial, differential cross sections and coupling measurements support SM across multiple channels

★ 2017 LHC season just started! Stay tuned!

References

★ Run I Results: JHEP (2016) 2016: 45.

★ H→γγ: ATLAS-CONF-2016-067

★ H→ZZ*→4ℓ: ATLAS-CONF-2017-032, ATLAS-CONF-2016-079

★ H→γγ/H→ZZ*→4ℓ Combination: ATLAS-CONF-2016-081

★ H→WW*→ℓνℓν: ATLAS-CONF-2016-112

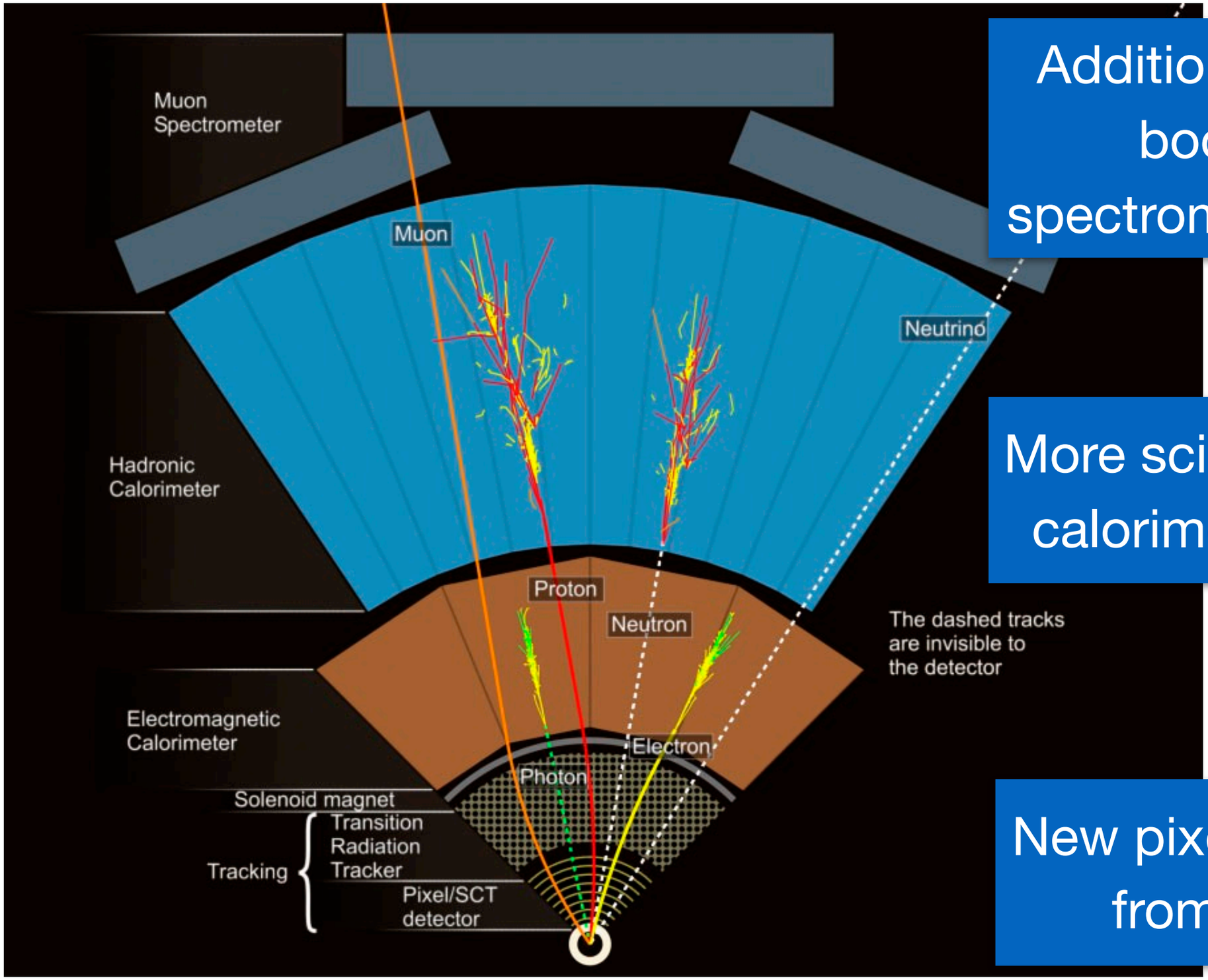
★ Combined search for $t\bar{t}H$ production: ATLAS-CONF-2016-068

★ VH→$b\bar{b}$: ATLAS-CONF-2016-091

★ VBF H→$b\bar{b}$: ATLAS-CONF-2016-063

Backup

New for Run II



Additional chambers boost muon spectrometer coverage

More scintillators boost calorimeter coverage

New pixel layer 3.3 cm from beamline

13.3 fb^{-1}

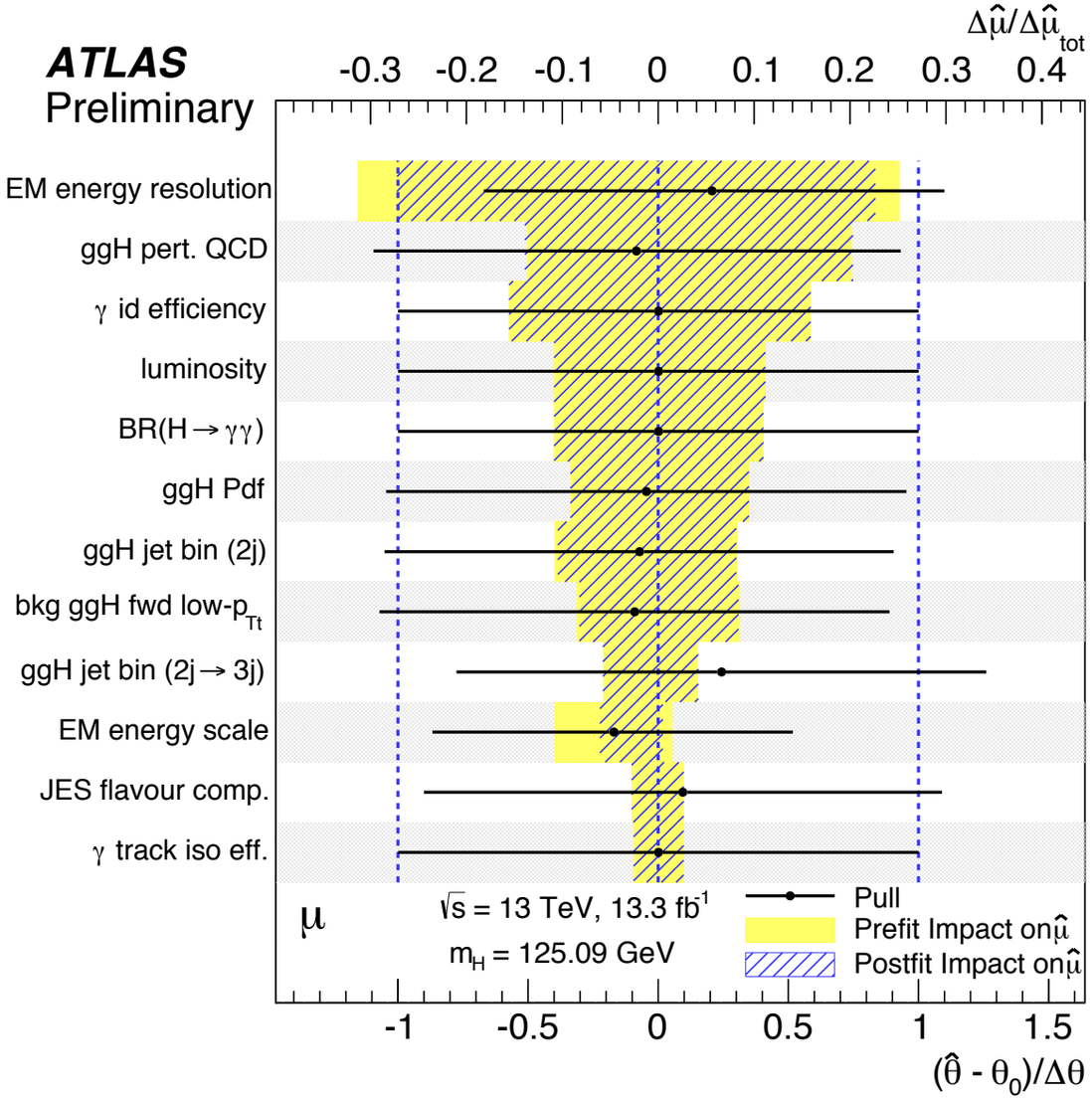
ATLAS-CONF-2016-067

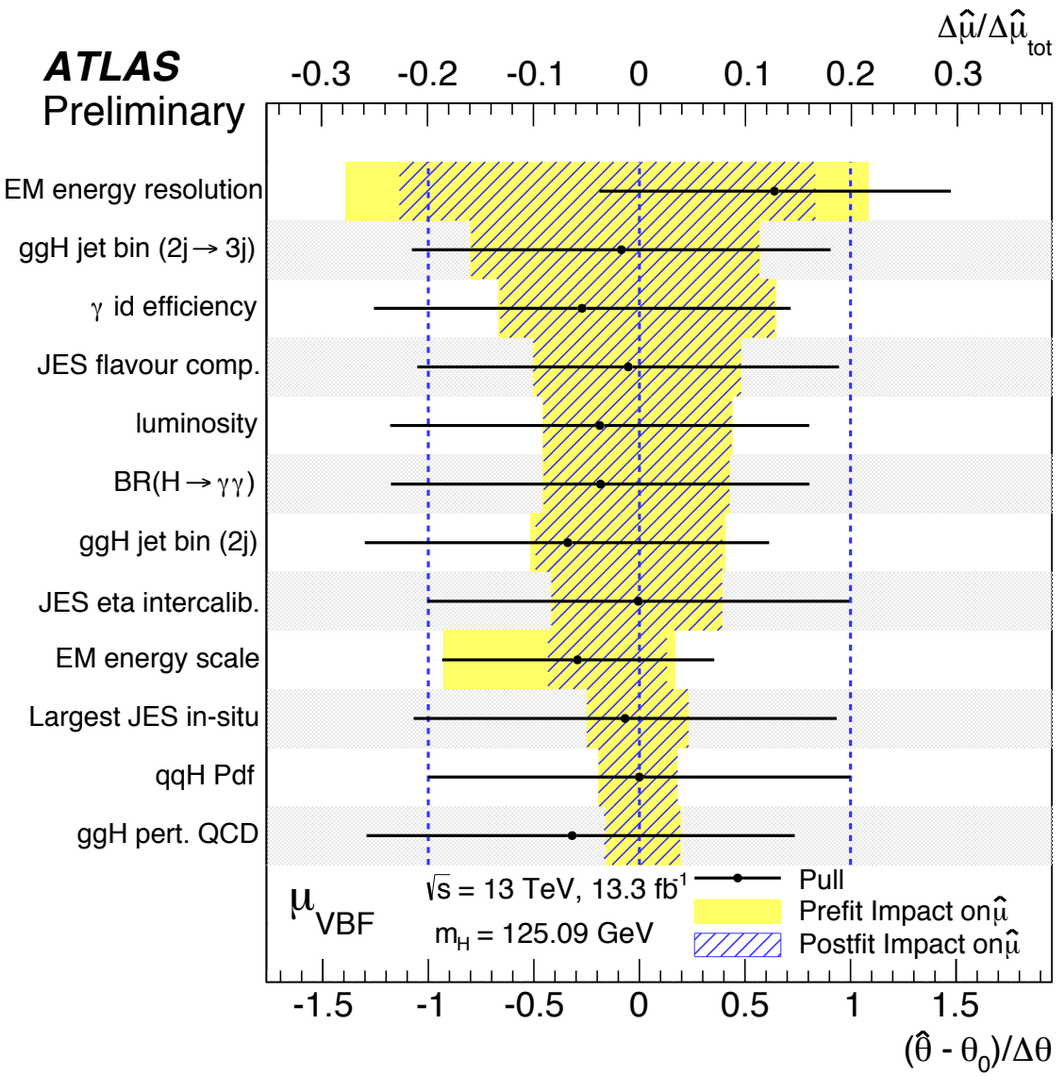
H→γγ Event Selection

	diphoton baseline	VBF enhanced	single lepton
Photons	$\|\eta\| < 1.37$ or $1.52 < \|\eta\| < 2.37$ $p_{\mathrm{T}}^{\gamma 1} > 0.35\, m_{\gamma\gamma}$ and $p_{\mathrm{T}}^{\gamma 2} > 0.25\, m_{\gamma\gamma}$		
Jets	-	$p_{\mathrm{T}} > 30\,\mathrm{GeV}$, $\|y\| < 4.4$	-
	-	$m_{jj} > 400\,\mathrm{GeV}$, $\|\Delta y_{jj}\| > 2.8$	-
	-	$\|\Delta\phi_{\gamma\gamma,jj}\| > 2.6$	-
Leptons	-	-	$p_{\mathrm{T}} > 15\,\mathrm{GeV}$ $\|\eta\| < 2.47$

ATLAS-CONF-2016-067

H→γγ Pulls

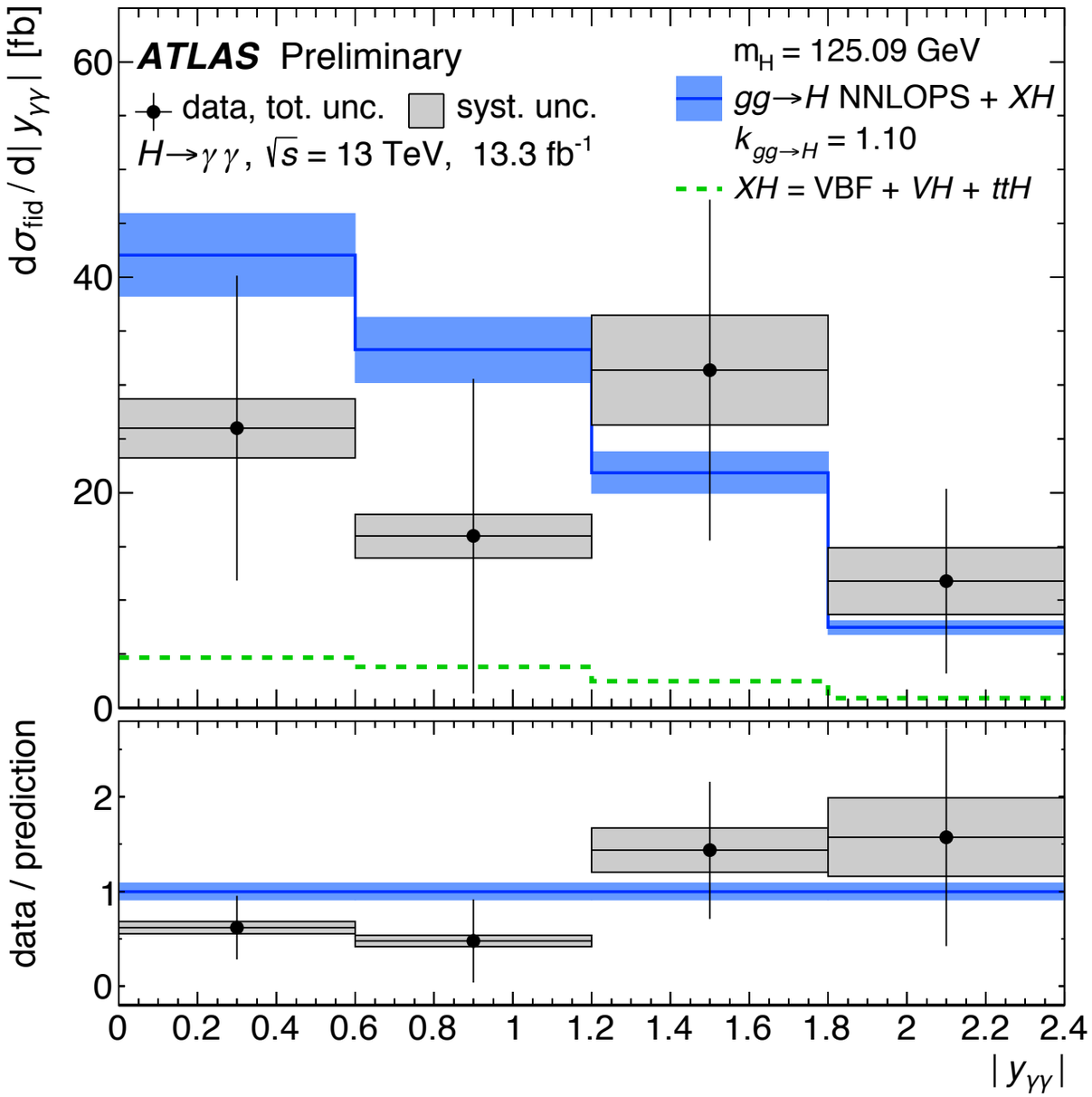




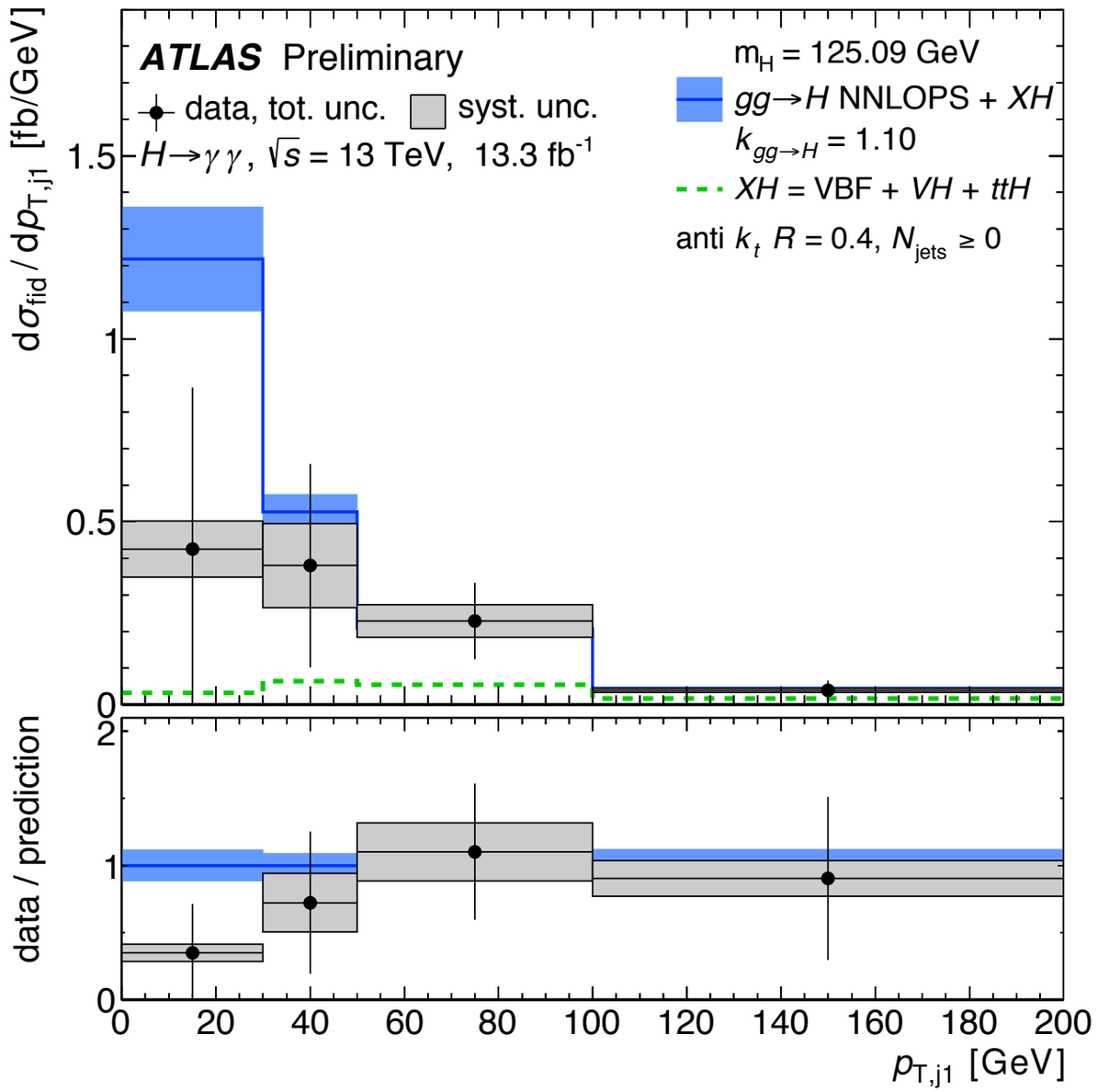
ATLAS-CONF-2016-067

H→γγ: Differential cross sections

$|y_{\gamma\gamma}|$



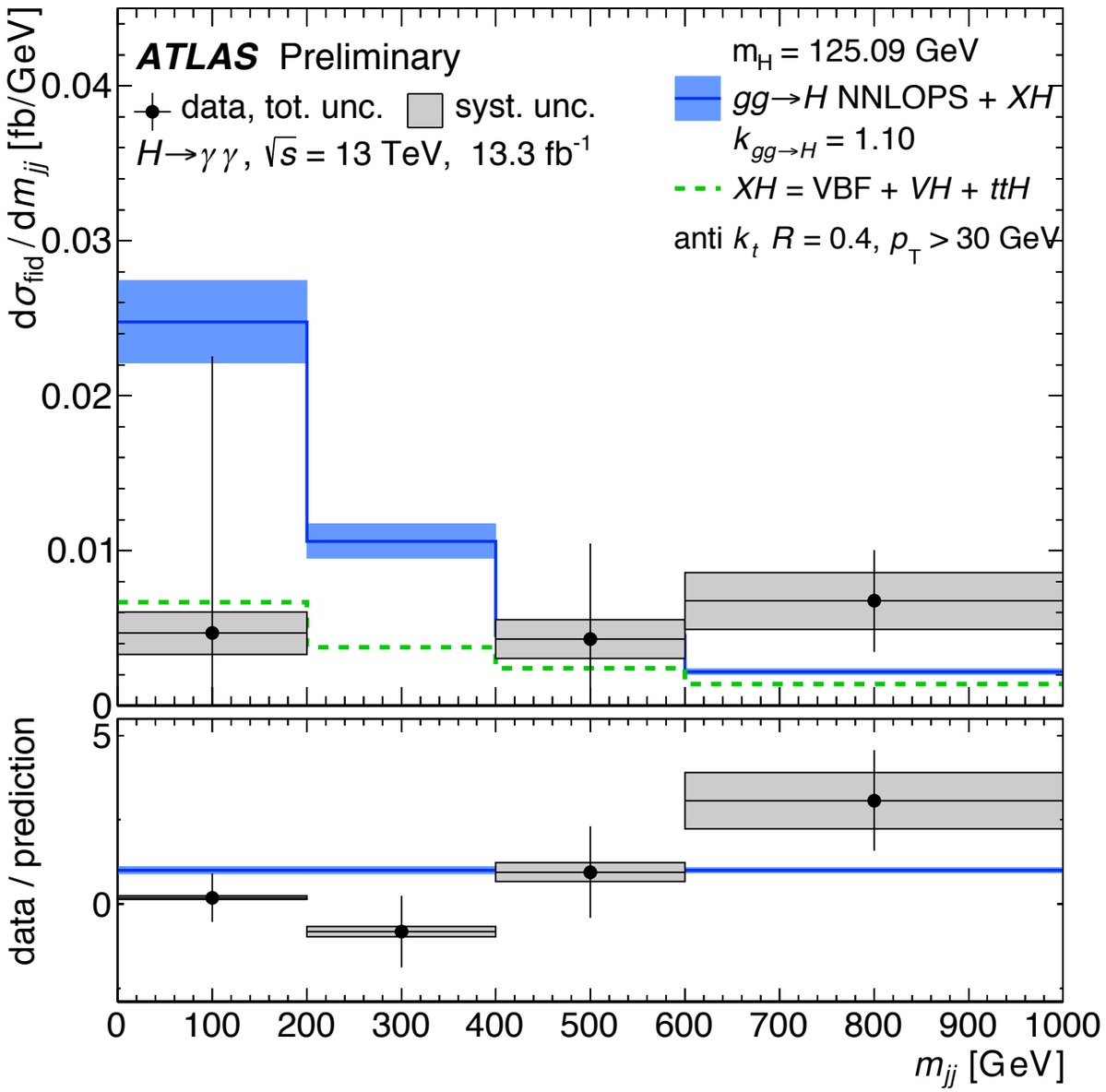
$p_{T,J1}$



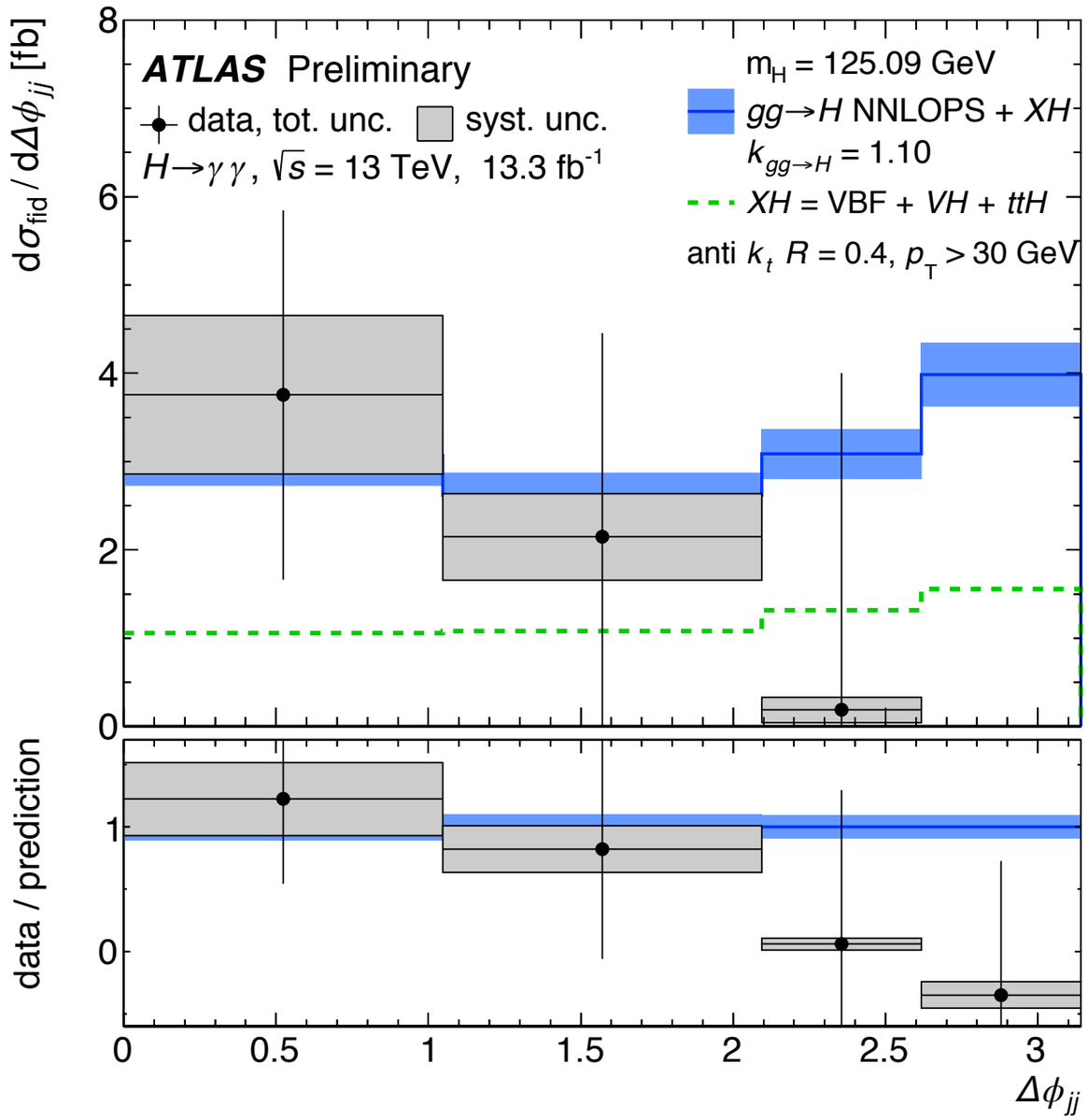
ATLAS-CONF-2016-067

H→γγ: Differential cross sections

m_{jj}

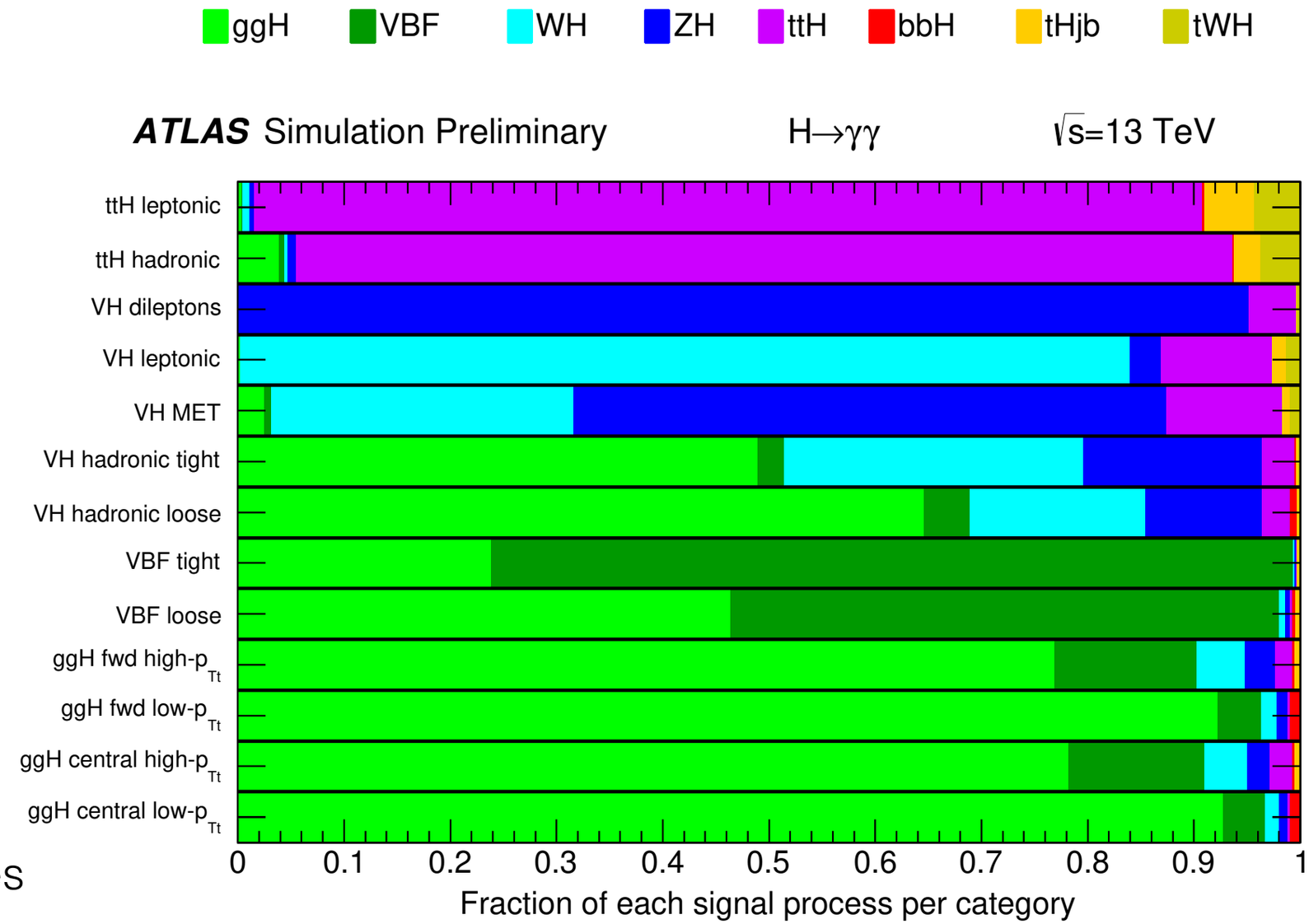


$\Delta\phi_{jj}$



ATLAS-CONF-2016-067

H→γγ event categories



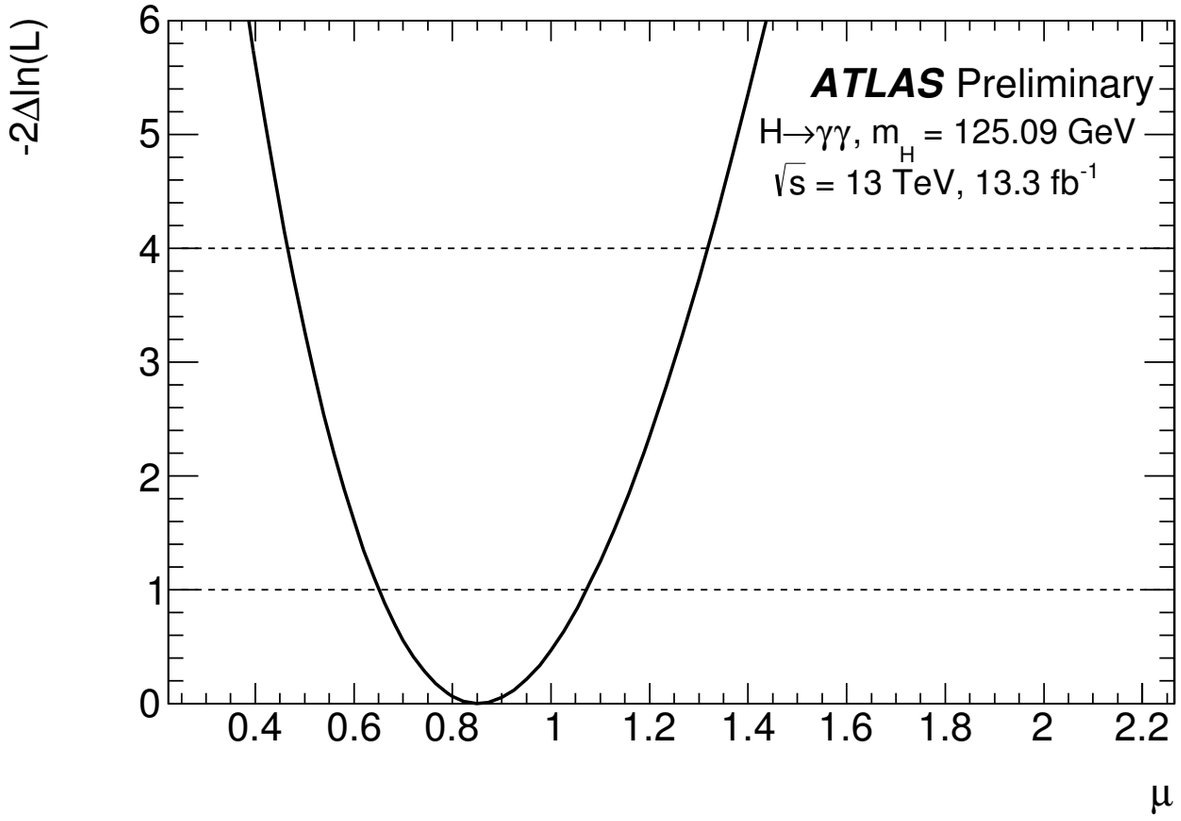
★13 categories

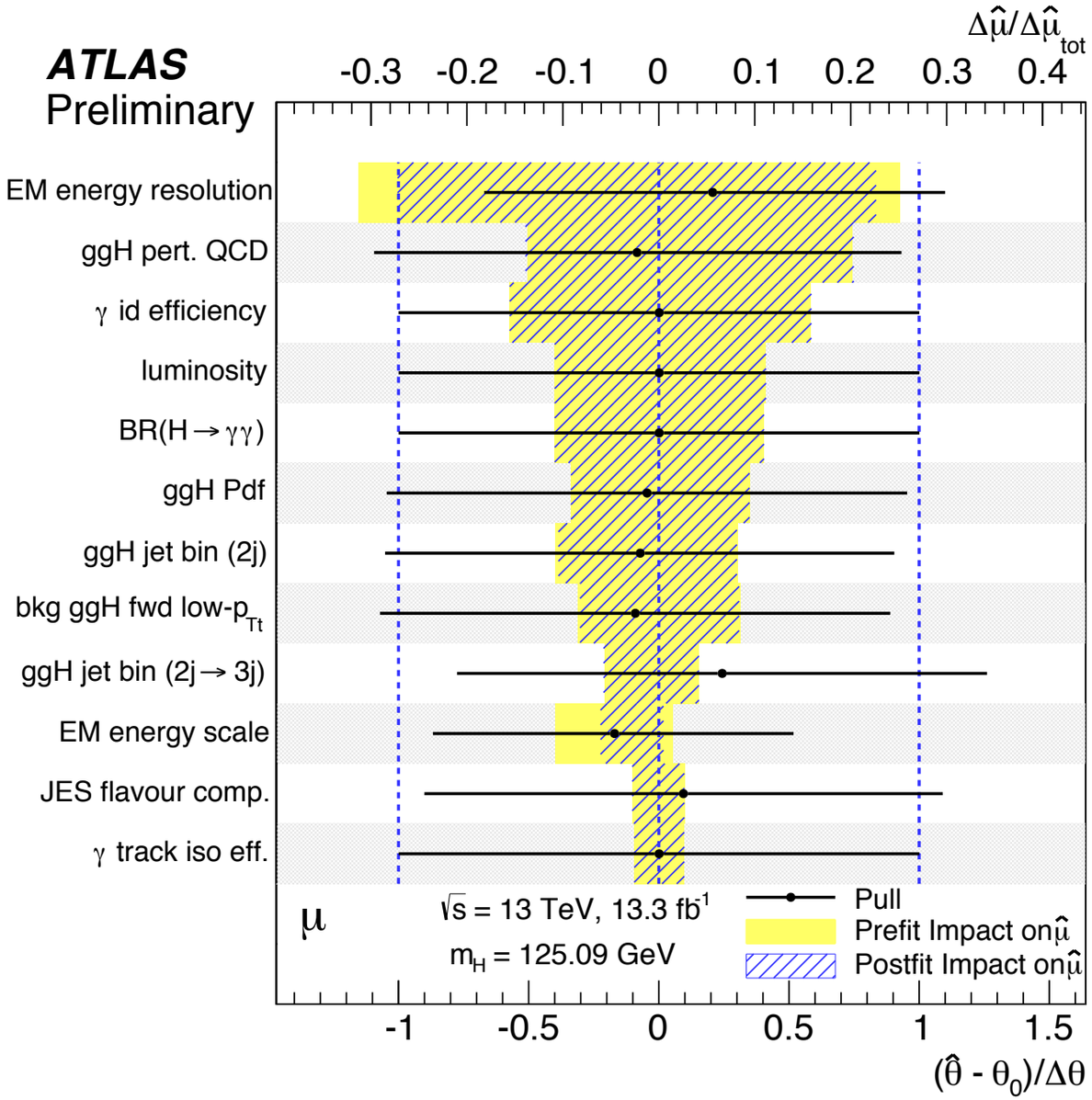
- enriched in production mode
- based on S/B and resolution

★ Measure simplified template cross sections, total production mode cross sections, corresponding signal strength

ATLAS-CONF-2016-067

H→γγ: Inclusive signal strength





H→4ℓ Event Selection

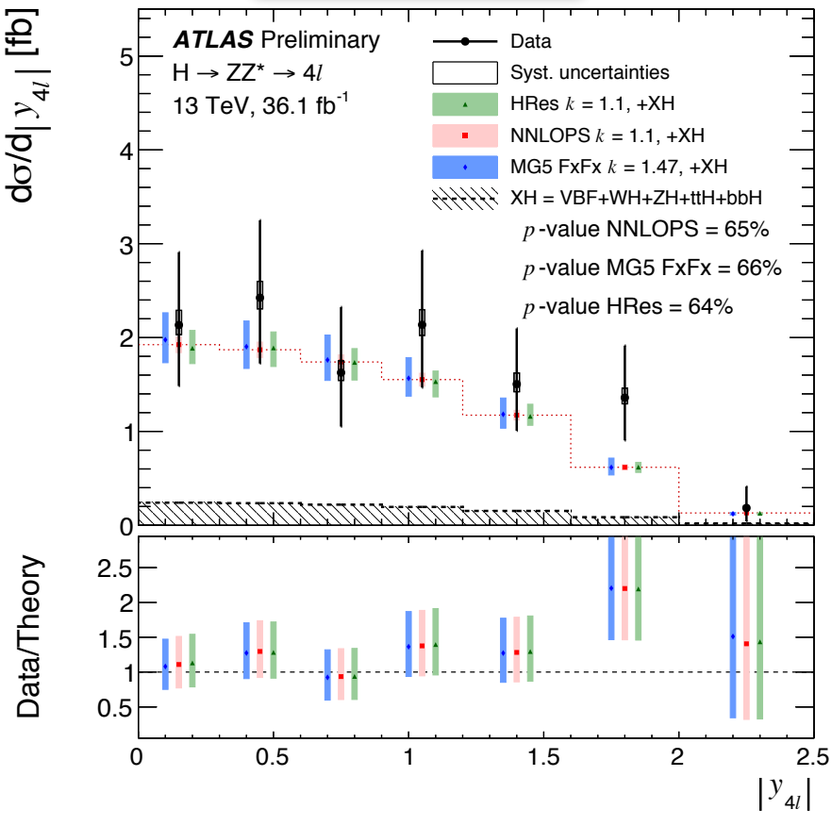
Leptons and Jets requirements	
Electrons	
Loose Likelihood quality electrons with hit in innermost layer, $E_{\mathrm{T}} > 7GeV$ and $\lvert\eta\rvert < 2.47$	
Muons	
Loose identification $\lvert\eta\rvert < 2.7$	
Calo-tagged muons with $p_{\mathrm{T}} > 15\,GeV$ and $\lvert\eta\rvert < 0.1$	
Combined, stand-alone (with ID hits if available) and segment tagged muons with $p_{\mathrm{T}} > 5\,GeV$	
Jets	
anti-k_t jets with $p_{\mathrm{T}} > 30GeV$, $\lvert\eta\rvert < 4.5$ and passing pile-up jet rejection requirements	
Event Selection	
Quadruplet Selection	Require at least one quadruplet of leptons consisting of two pairs of same flavour opposite-charge leptons fulfilling the following requirements: p_{T} thresholds for three leading leptons in the quadruplet - $20, 15$ and $10GeV$ Maximum of one calo-tagged or standalone muon per quadruplet Select best quadruplet to be the one with the (sub)leading dilepton mass (second) closest the Z mass Leading dilepton mass requirement: $50\,GeV < m_{12} < 106\,GeV$ Sub-leading dilepton mass requirement: $12 < m_{34} < 115GeV$ Remove quadruplet if alternative same-flavour opposite-charge dilepton gives $m_{\ell\ell} < 5\,GeV$ $\Delta R(\ell, \ell') > 0.10$ (0.20) for all same(different)-flavour leptons in the quadruplet
Isolation	Contribution from the other leptons of the quadruplet is subtracted Muon track isolation ($\Delta R \leq 0.30$): $\Sigma p_{\mathrm{T}}/p_{\mathrm{T}} < 0.15$ Muon calorimeter isolation ($\Delta R = 0.20$): $\Sigma E_{\mathrm{T}}/p_{\mathrm{T}} < 0.30$ Electron track isolation ($\Delta R \leq 0.20$) : $\Sigma E_{\mathrm{T}}/E_{\mathrm{T}} < 0.15$ Electron calorimeter isolation ($\Delta R = 0.20$) : $\Sigma E_{\mathrm{T}}/E_{\mathrm{T}} < 0.20$
Impact Parameter Significance	Apply impact parameter significance cut to all leptons of the quadruplet. For electrons : $\lvert d_0/\sigma_{d_0}\rvert < 5$ For muons : $\lvert d_0/\sigma_{d_0}\rvert < 3$
Vertex Selection	Require a common vertex for the leptons $\chi^2/\mathrm{ndof} < 6$ for 4μ and < 9 for others.

36.1 fb^{-1}

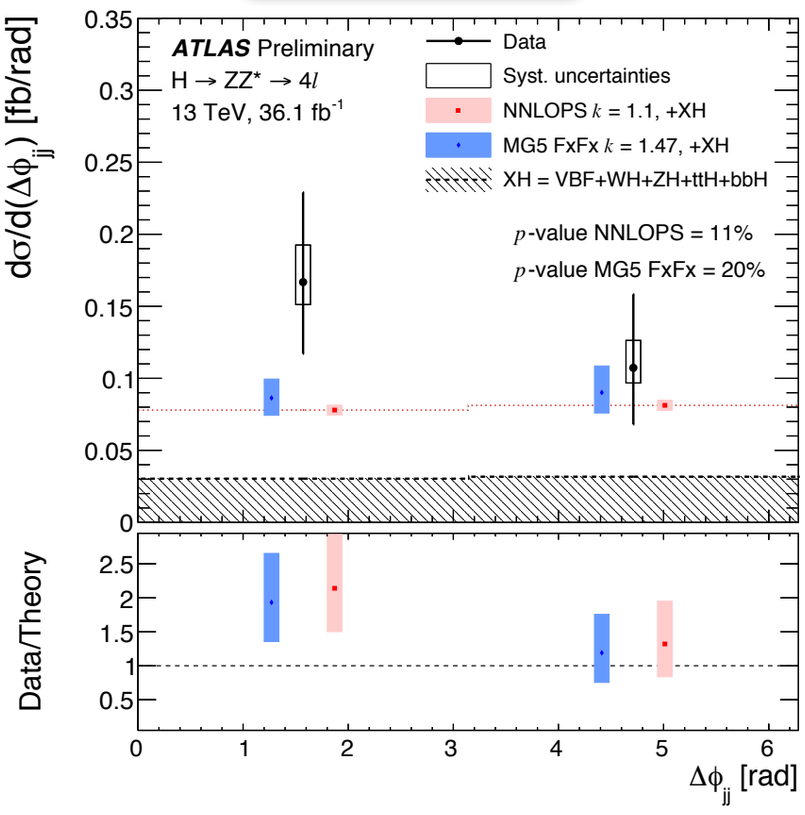
ATLAS-CONF-2017-032

H→4ℓ: Differential cross sections

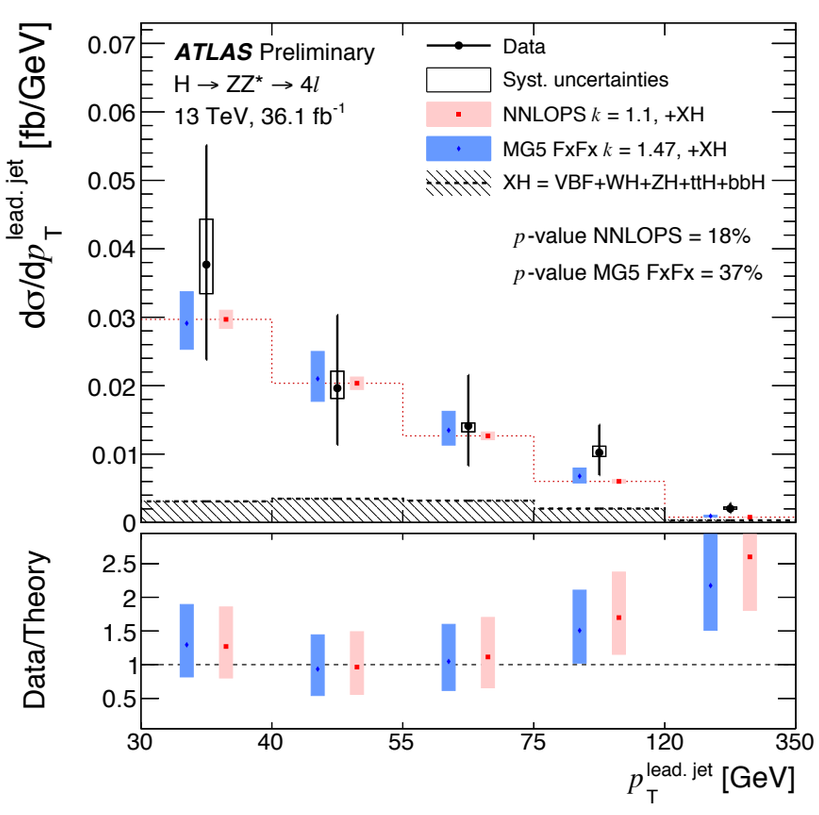
$|y_{4\ell}|$



$\Delta\phi_{jj}$



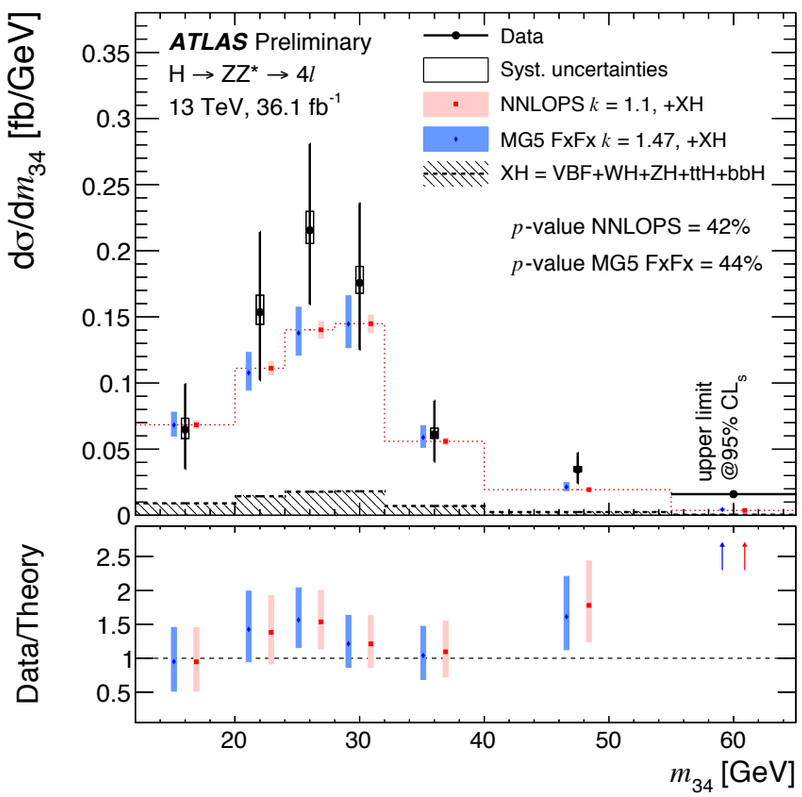
$p_{T,J1}$



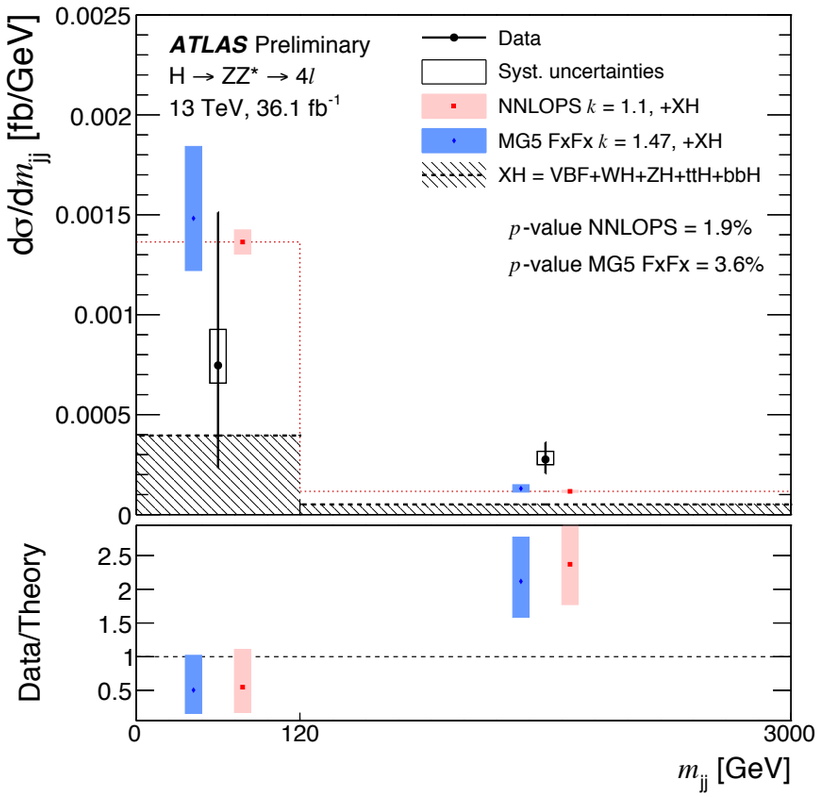
ATLAS-CONF-2017-032

H→4ℓ: Differential cross sections

m_{34}



m_{jj}



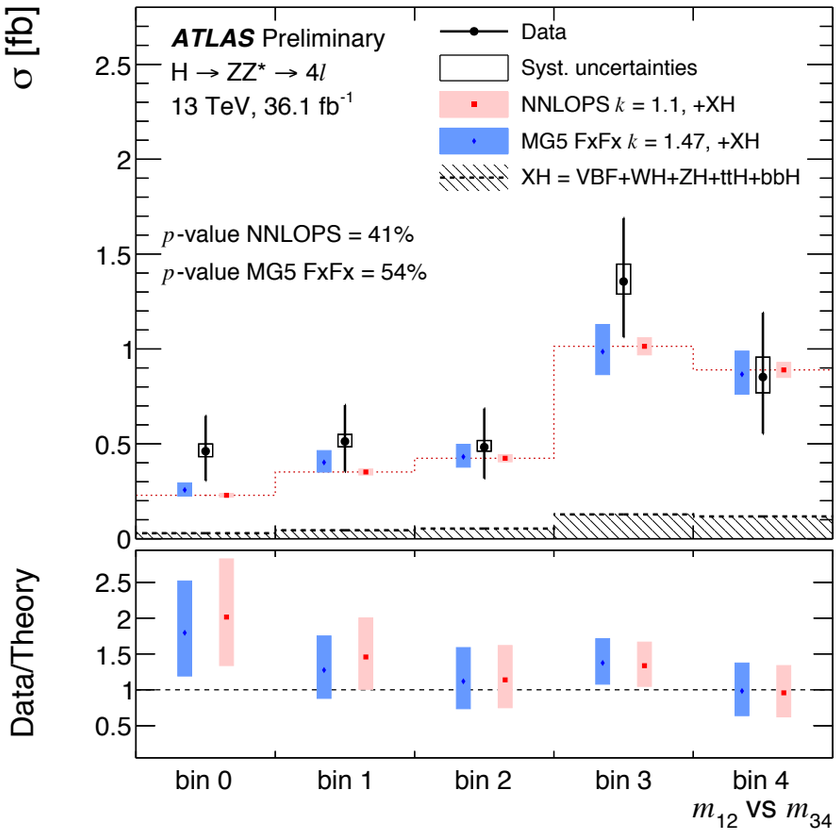
ATLAS-CONF-2017-032

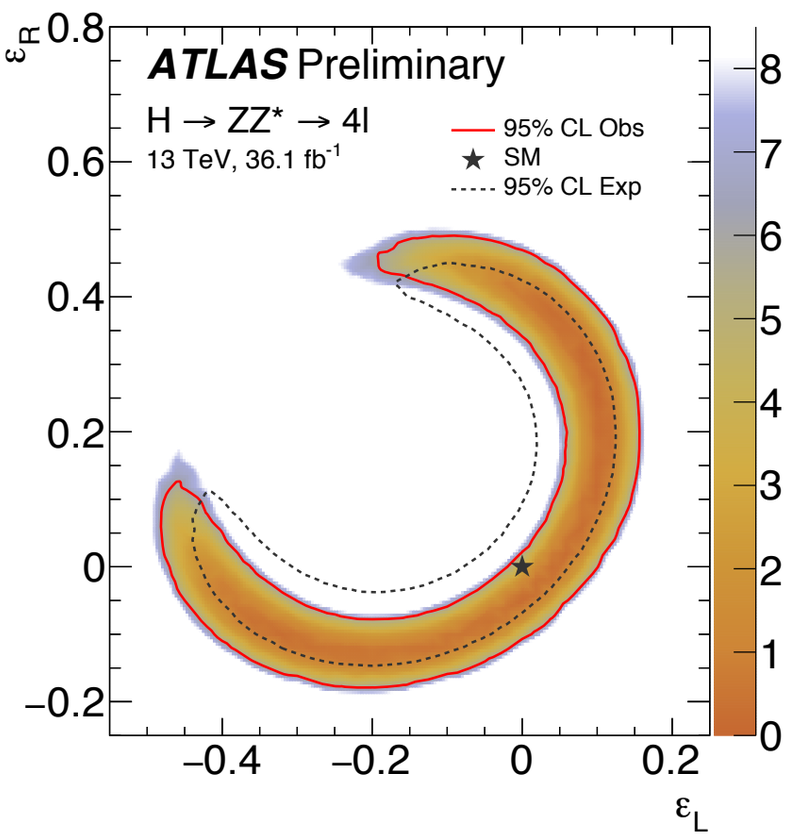
H→4ℓ: Double differential cross sections

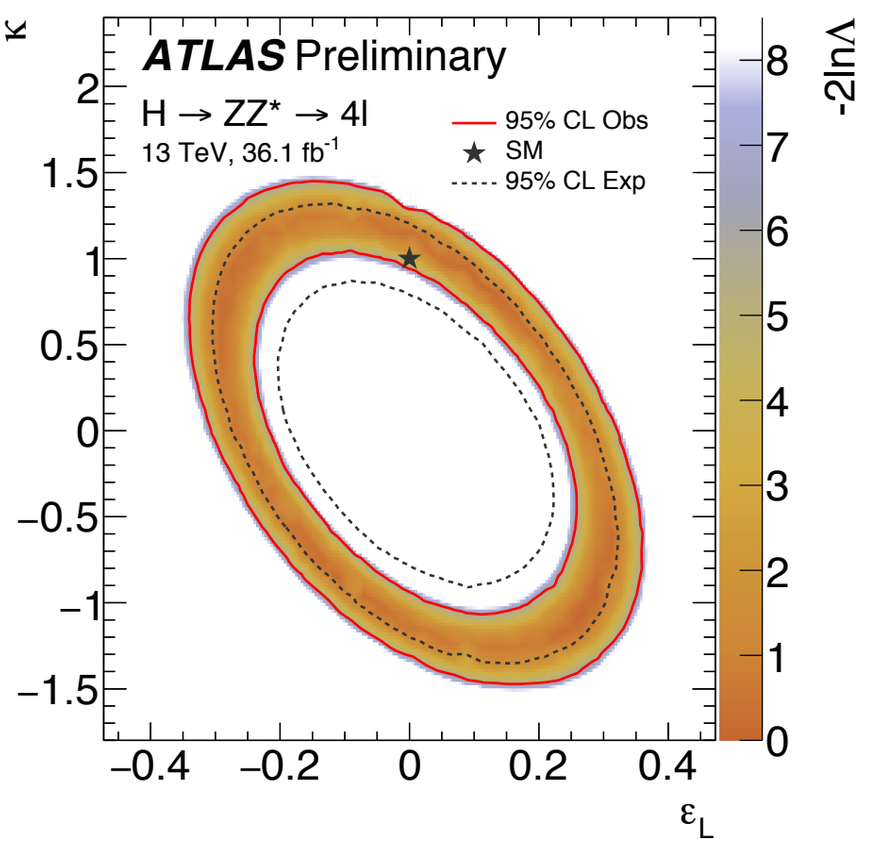
m_{12} vs m_{34}

ε_L vs ε_R

ε_L vs K







5.8 fb^{-1}

ATLAS-CONF-2016-112

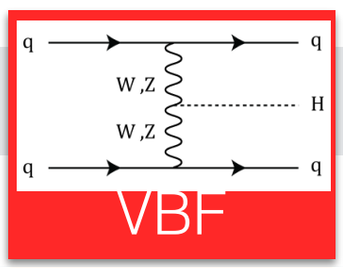
H→WW*→ℓνℓν Selection

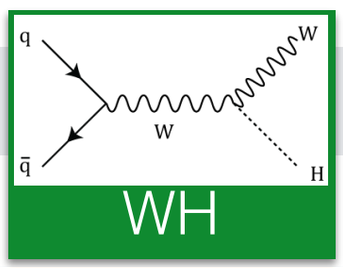
★ Concentrate on VBF, WH production modes → event topology distinguishes from background

★ Selection designed to suppress backgrounds (Top, Vj, WW, Z→ττ, ggF, VV)

- Opposite flavour leptons to reject Drell-Yan continuum production
- Tight lepton ID and isolation
- *b*-jet veto to reject top quark processes

VBF Criteria	WH Critera
Exactly 1 e and 1 μ, Opposite charge pair	3 isolated leptons with E_T^{miss}>50 GeV
Explicit Z→ττ veto	Total charge ±e
$N_{jets}\geq 2$	$N_{jets}\leq 1$
No *b*-jets	Z veto
BDT	





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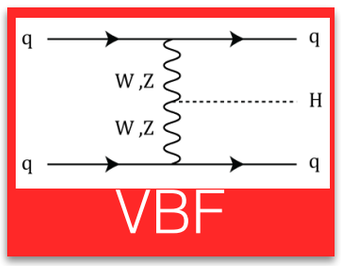
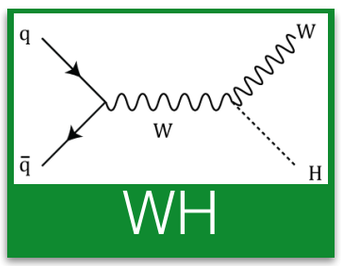
ATLAS-CONF-2016-112

H→WW*→ℓνℓν Selection



	Signal region	$Z \to \tau\tau$ CR	Top-quark CR
Preselection	Two isolated leptons ($\ell = e, \mu$) with opposite charge $p_{\mathrm{T}}^{\mathrm{lead}} > 25GeV$ ($p_{\mathrm{T}}^{\mathrm{lead}} > 22GeV$ for muons in 2015), $p_{\mathrm{T}}^{\mathrm{sublead}} > 15GeV$ $m_{\ell\ell} > 10GeV$, $N_{\mathrm{jet}} \geq 2$		
	$N_{b\text{-jet}} = 0$	$N_{b\text{-jet}} = 0$	$N_{b\text{-jet}} = 1$
A BDT is trained at this level. Eight discriminant variables are used: $\Delta\phi_{\ell\ell}$, $m_{\ell\ell}$, m_{T}, Δy_{jj}, m_{jj}, $p_{\mathrm{T}}^{\mathrm{tot}}$, $\sum_{\ell,j} m_{\ell j}$, and $\eta_{\ell}^{\mathrm{centrality}}$			
Selection	$m_{\tau\tau} < 66.2GeV$	$\lvert m_{\tau\tau} - m_Z \rvert < 25GeV$	–
	–	$m_{\ell\ell} < 80GeV$	–
	OLV applied, CJV applied, BDT > -0.8		
	SR1: $-0.8 <$ BDT < 0.7	–	–
	SR2: $0.7 <$ BDT ≤ 1	–	–



Category	Z-dominated SR ≥ 1 SFOS pair	Z-depleted SR no SFOS pair
Preselection	Three isolated leptons (p_{T} >15 GeV) total charge $= \pm 1$ ≥ 1 lepton matches to the trigger	
Background Rejection	$N_{\mathrm{jet}} \leq 1$, $N_{b\text{-jet}} = 0$	
	$E_{\mathrm{T}}^{\mathrm{miss}} > 50$ GeV	–
	$\lvert m_{\ell^+\ell^-} - m_Z \rvert > 25$ GeV	$Z/\gamma^* \to ee$ veto
	$m_{\ell^+\ell^-}^{\mathrm{max}} < 200$ GeV	
	$m_{\ell^+\ell^-}^{\mathrm{min}} > 12$ GeV	$m_{\ell^+\ell^-}^{\mathrm{min}} > 6$ GeV
$H \to WW^* \to \ell\nu\ell\nu$ topology	$\Delta R_{\ell_0\ell_1} < 2.0$	

5.8 fb^{-1}

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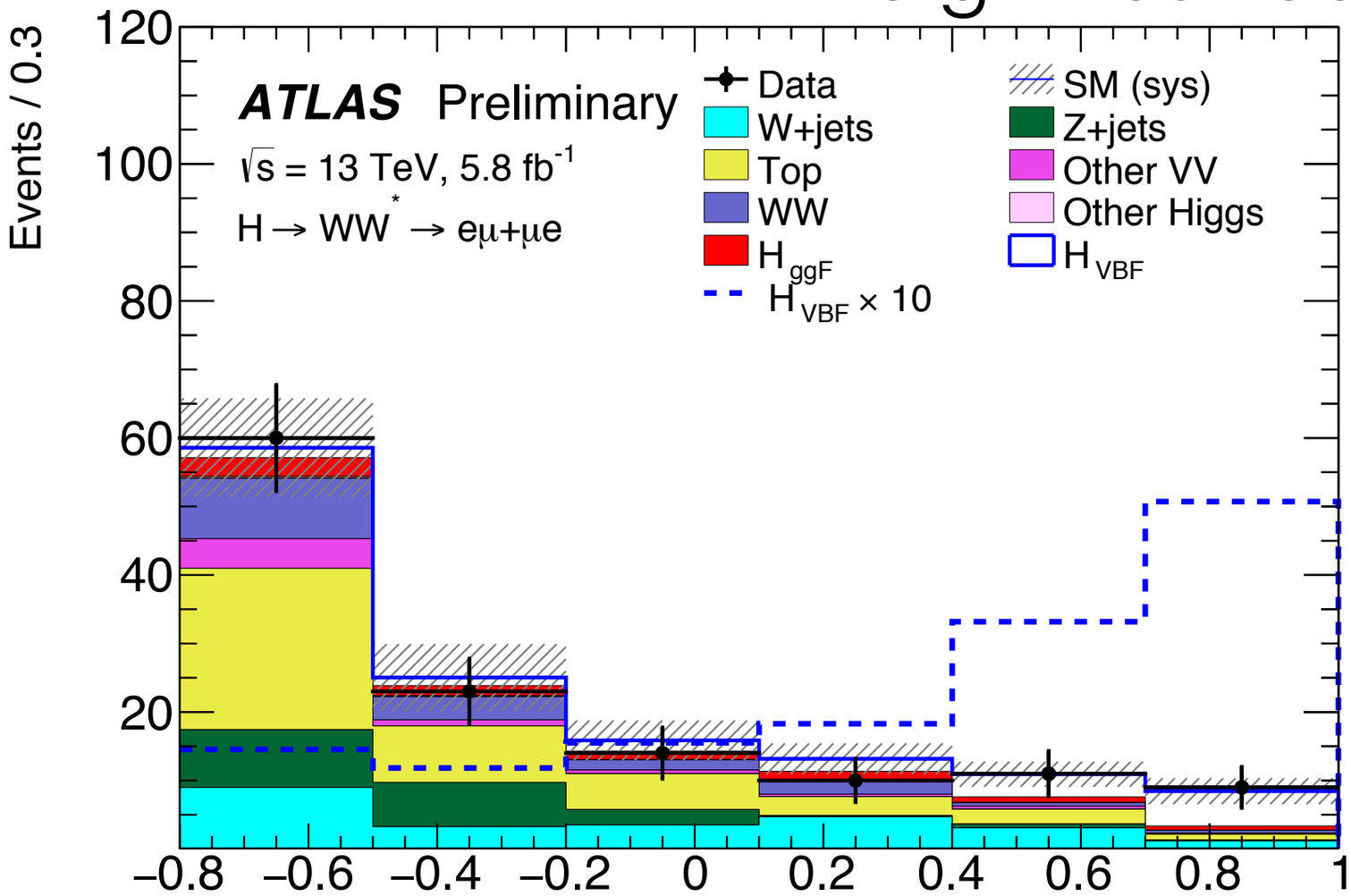
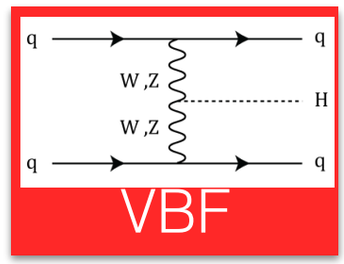
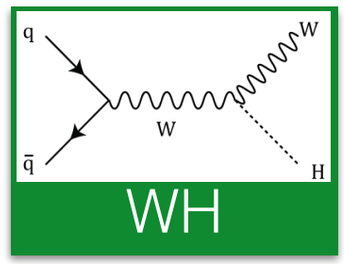
H→WW*→ℓνℓν: Observed signal strength and significance







★ Observed significance < 2σ
→ upper limits at 95% CL

- lim($\sigma_{VBF} \times \mathcal{B}$) = 3.0 pb &
  lim($\sigma_{WH} \times \mathcal{B}$) = 3.3 pb

★ Agrees with SM

$$\sigma_{VBF} \cdot \mathcal{B}_{H \to WW^*} = 1.4^{+0.9}_{-0.7} pb \qquad \mu_{VBF} = 1.7^{+1.1}_{-0.9}$$

$$\sigma_{WH} \cdot \mathcal{B}_{H \to WW^*} = 0.9^{+1.3}_{-1.2} pb \qquad \mu_{WH} = 3.2^{+4.4}_{-4.2}$$

ATLAS-CONF-2016-068

Combined search: $t\bar{t}H$ production

	$H \to \gamma\gamma$		$H \to (WW, \tau\tau, ZZ)$				$H \to b\bar{b}$	
Analysis strategy	Narrow signal peak: fit to diphoton mass spectrum ($m_{\gamma\gamma}$)		Small signal and background: counting experiment				Moderate signal in large background: multivariate techniques	
Channels	leptonic	hadronic	2ℓSS	3ℓ	2ℓSS+$1\tau_{\text{had}}$	4ℓ	single lepton	dilepton
Control regions	-		-				(4j,2bj) (5j,2bj) (4j,3bj) (4j,4bj) ($\geq$ 6j,2bj) (5j,3bj)	(3j,2bj) (4j,2bj)
Signal regions	$m_{\gamma\gamma}$		(ee) (eμ) ($\mu\mu$) AND ($\geq$ 5j,$\geq$ 1bj)	(3j,$\geq$ 2bj OR $\geq$ 4j,$\geq$ 1bj)	($\geq$ 4j,$\geq$ 1bj)	($\geq$ 2j,$\geq$ 1bj)	(5j,$\geq$ 4bj) ($\geq$ 6j,3bj) ($\geq$ 6j,$\geq$ 4bj)	(3j,3bj) ($\geq$ 4j,3bj) ($\geq$ 4j,$\geq$ 4bj)

ATLAS-CONF-2016-068

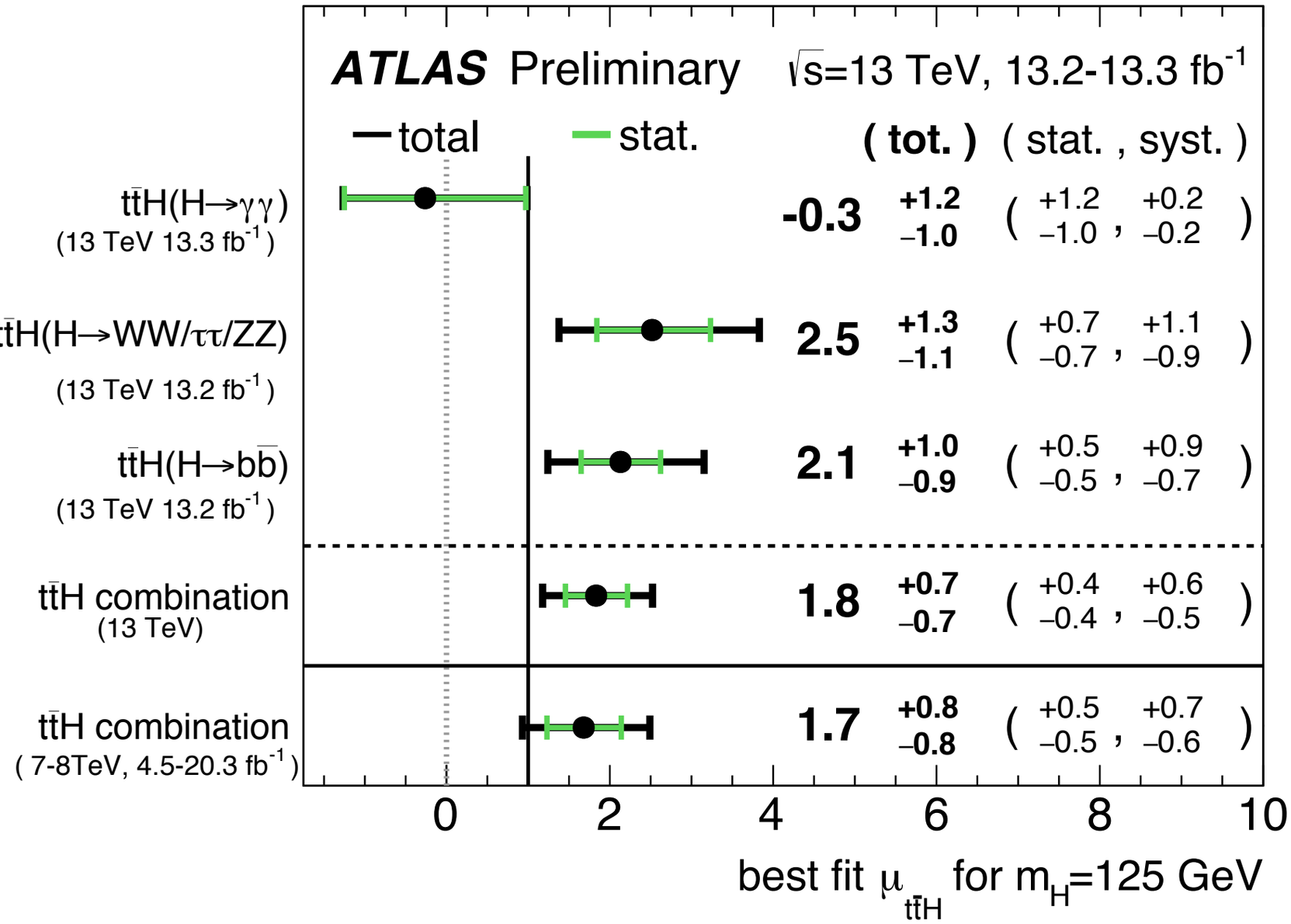
Combined search: $t\bar{t}H$ production

Diphoton

Multilepton

$t\bar{t}H(H\rightarrow b\bar{b})$

Combo



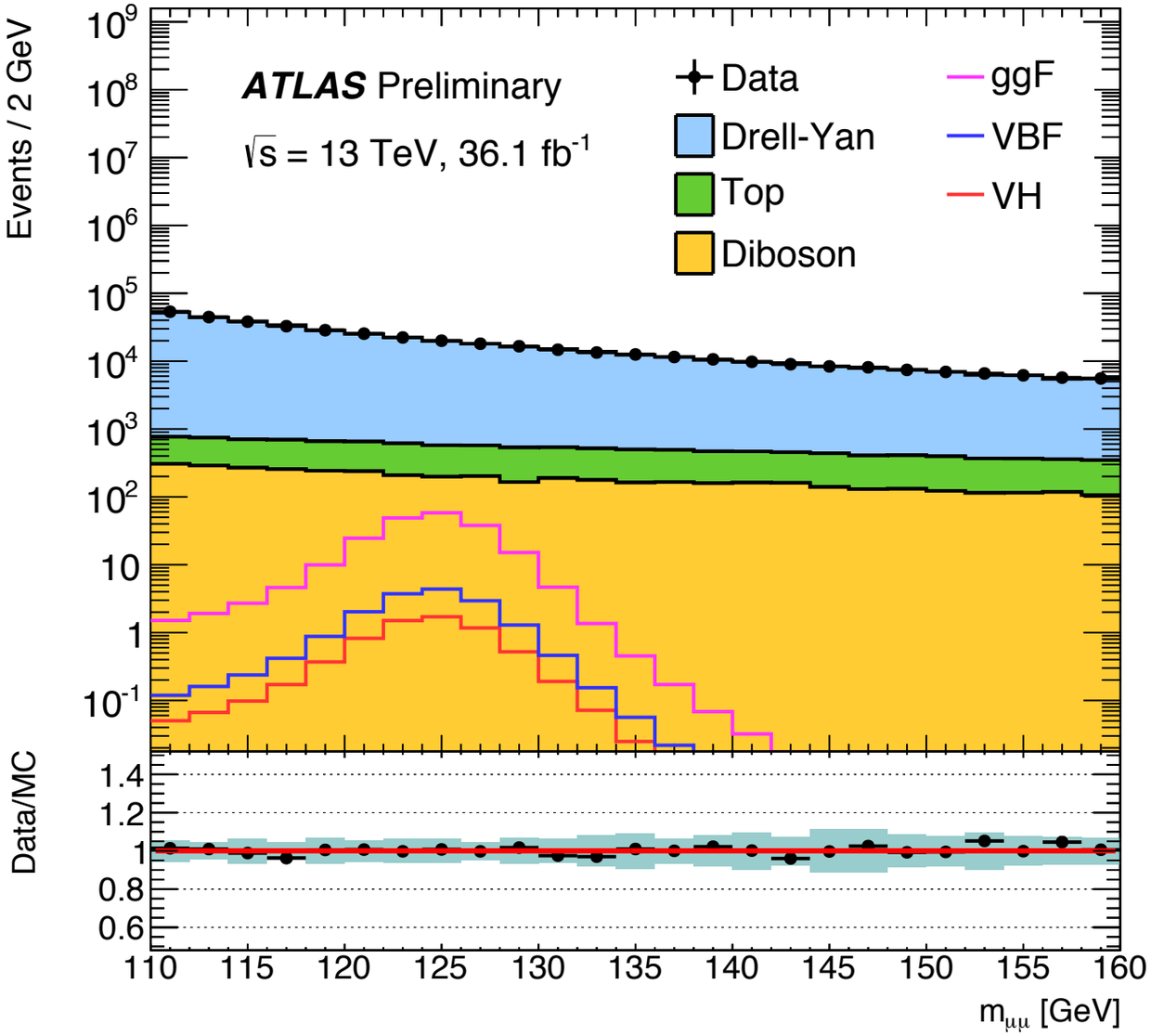
	Expected Significance
Run I	1.5σ
Run II	1.8σ

Run II observed significance = 2.8σ

36.1 fb^{-1}

Submitted to Phys. Rev. Lett.

Search for H→μμ



- ★ Very small predicted production cross section
- ★ Measure coupling to second-generation fermions
- ★ Clean signal expected, some backgrounds (Drell-Yan)

Upper limit, given m_H = 125 GeV, 95% C.L	Observed (x σ_{SM})	Expected (x σ_{SM})
σ•$\mathscr{B}$ @ 13 TeV	3.0	3.1
σ•$\mathscr{B}$ combined with 7-8 TeV	2.8	2.9