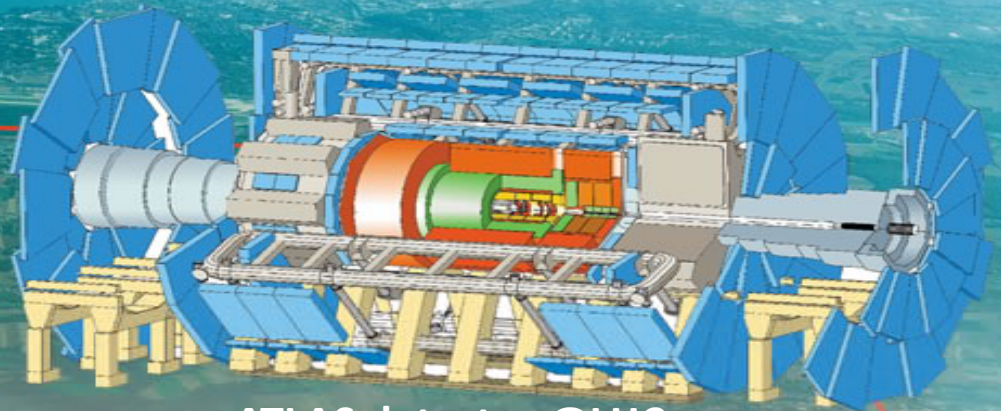
Vector-boson fusion, vector-boson scattering and diboson production at ATLAS



ATLAS detector @LHC

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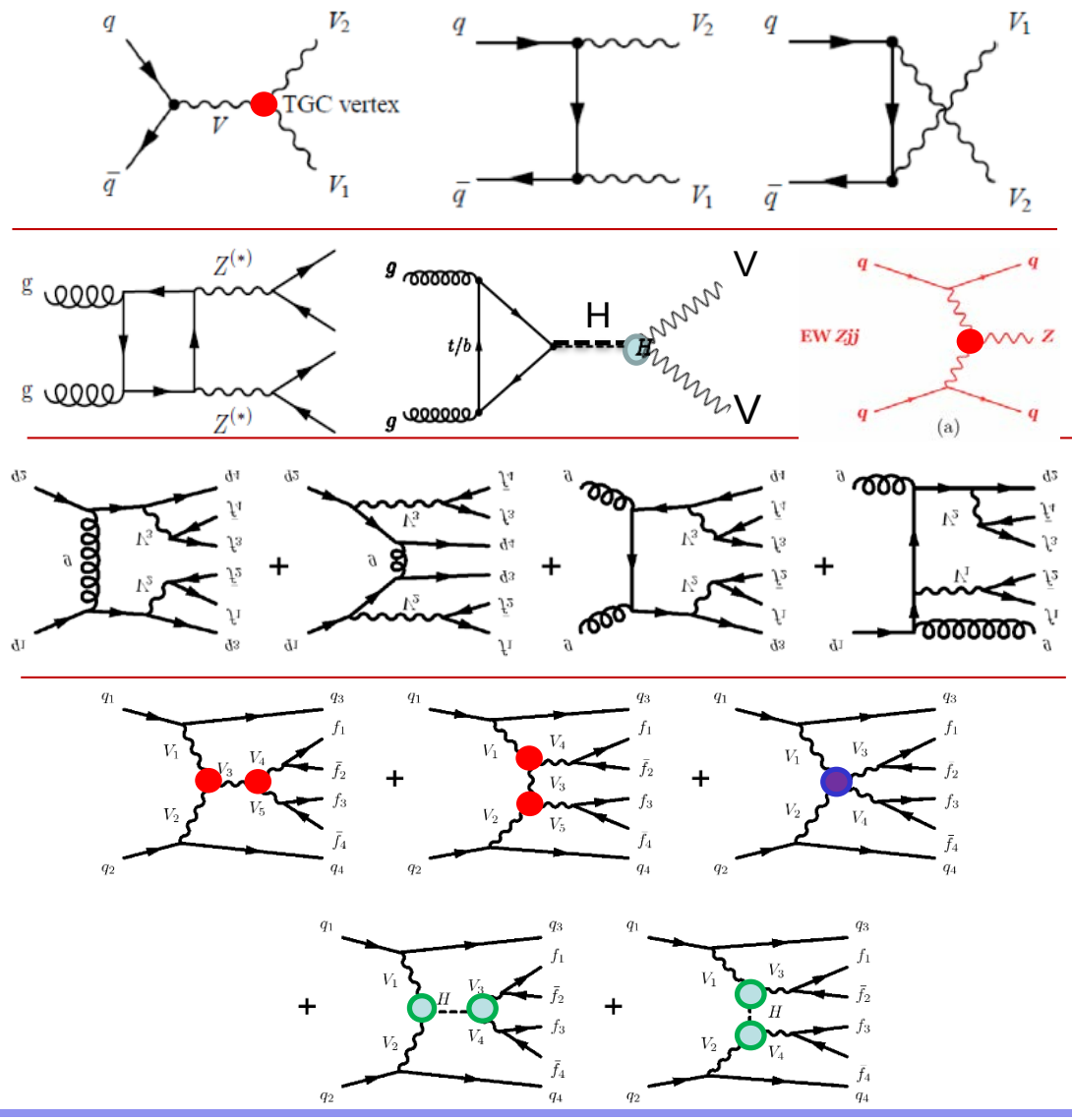
ICNFP2020, Greece, Sept. 2020

Introduction

- Vector-boson scattering and fusion is the production of V(V) (V= W/Z/γ) involving EW triple and quartic gauge couplings, and Higgs boson exchange at tree level. Provides a test of EW Symmetry Breaking - still to be proven that presence of discovered Higgs boson preserves the unitarity of the longitudinal polarised VV scattering.
- VBS/VBF processes measurement at energy frontier is important to test the SM through the interplay of electroweak and QCD
- Strong (+ EW) interactions result in irreducible background for pure EW processes
- Clean signature with two forward jets with large dijet invariant mass and |Δη| gap



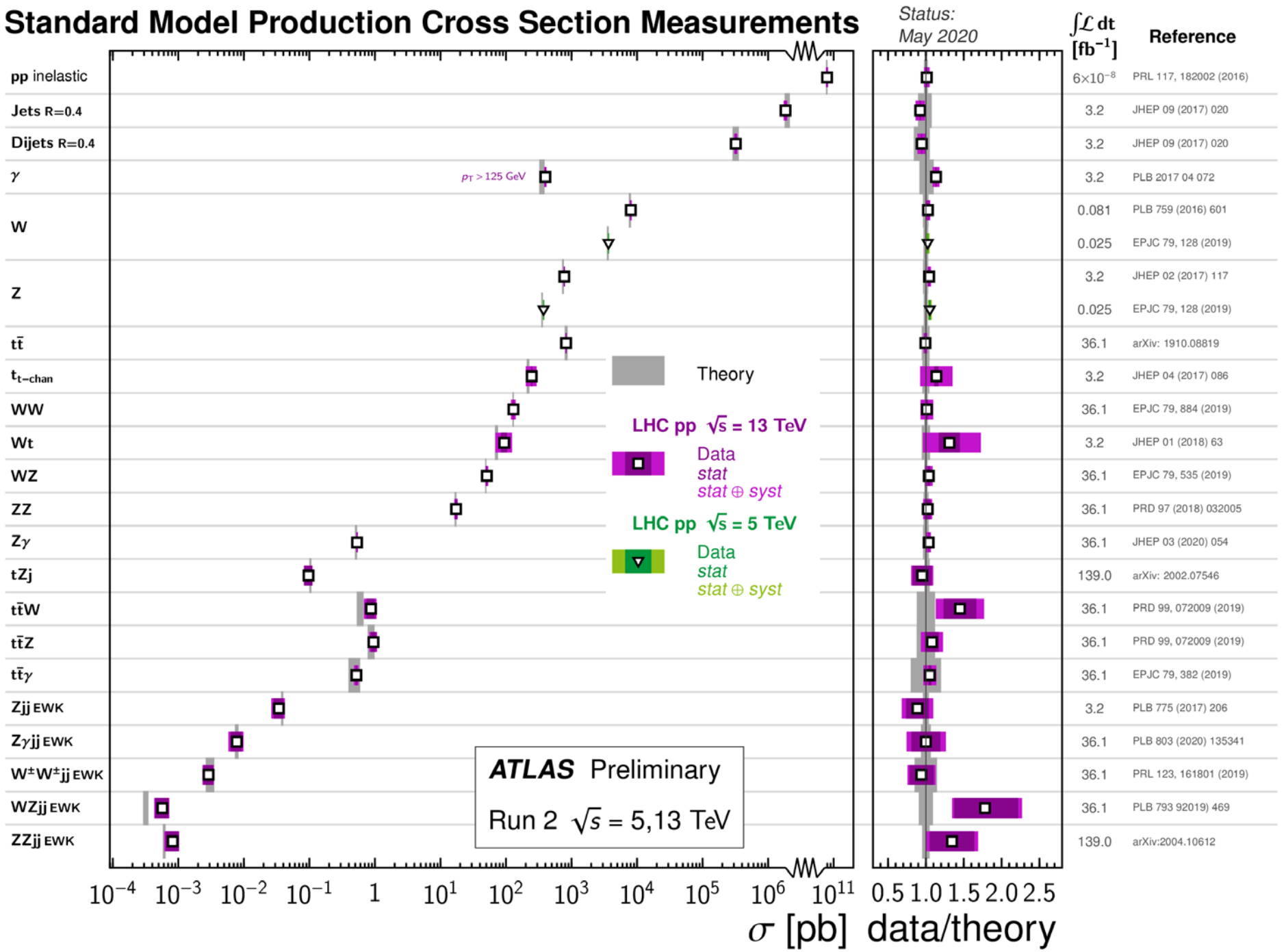
This talk will present diboson, and VBS/VBF production measurements with ATLAS Run 2 data involving neutral gauge bosons (**Z, γ**)

Precision measurement with dibosons

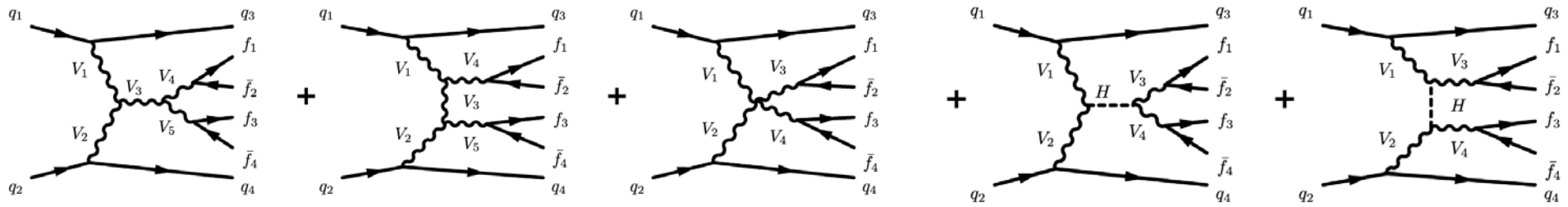
Inclusive 4l, Zγ

Observations of VBS/VBF rare productions

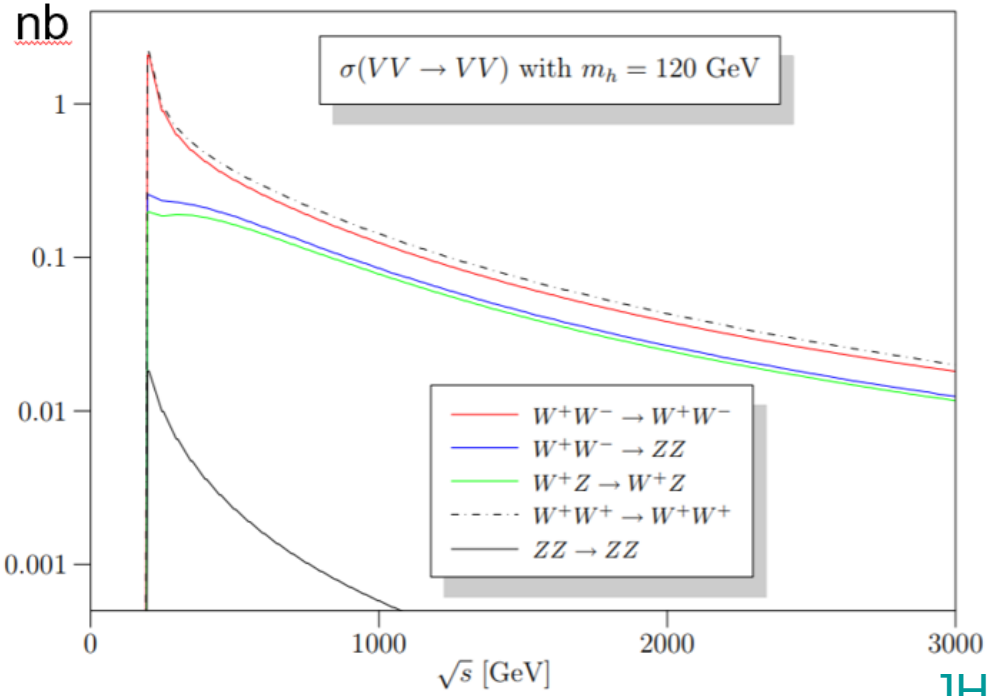
ZZjj, Zγjj, Zjj



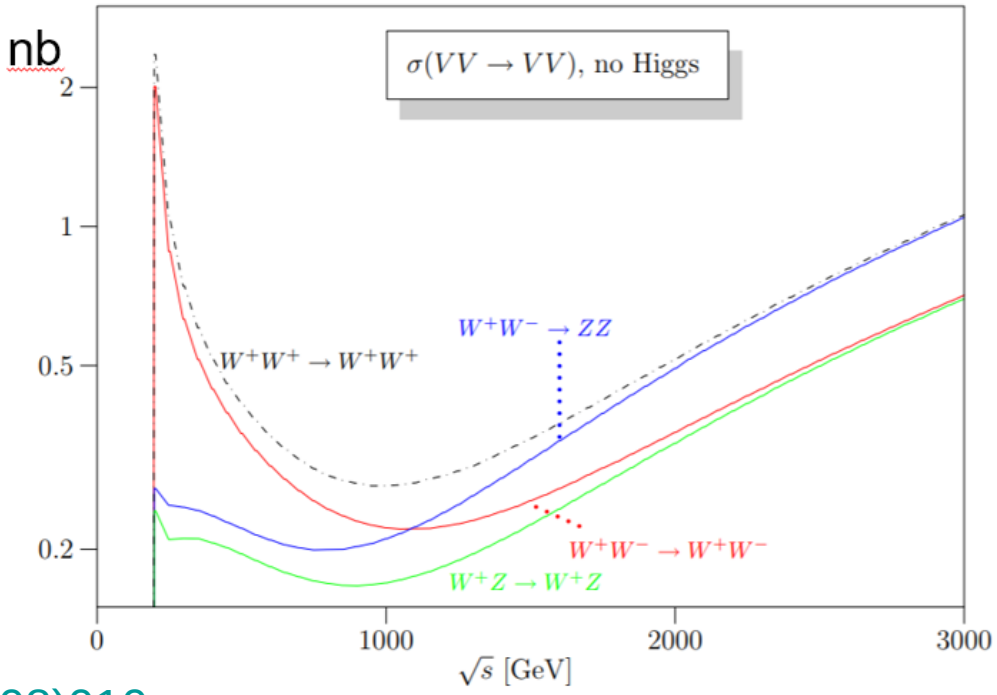
An Important Test of EW Symmetry Breaking



SM VV scattering processes with low mass Higgs (120 GeV)



SM VV scattering processes w/o a Higgs boson



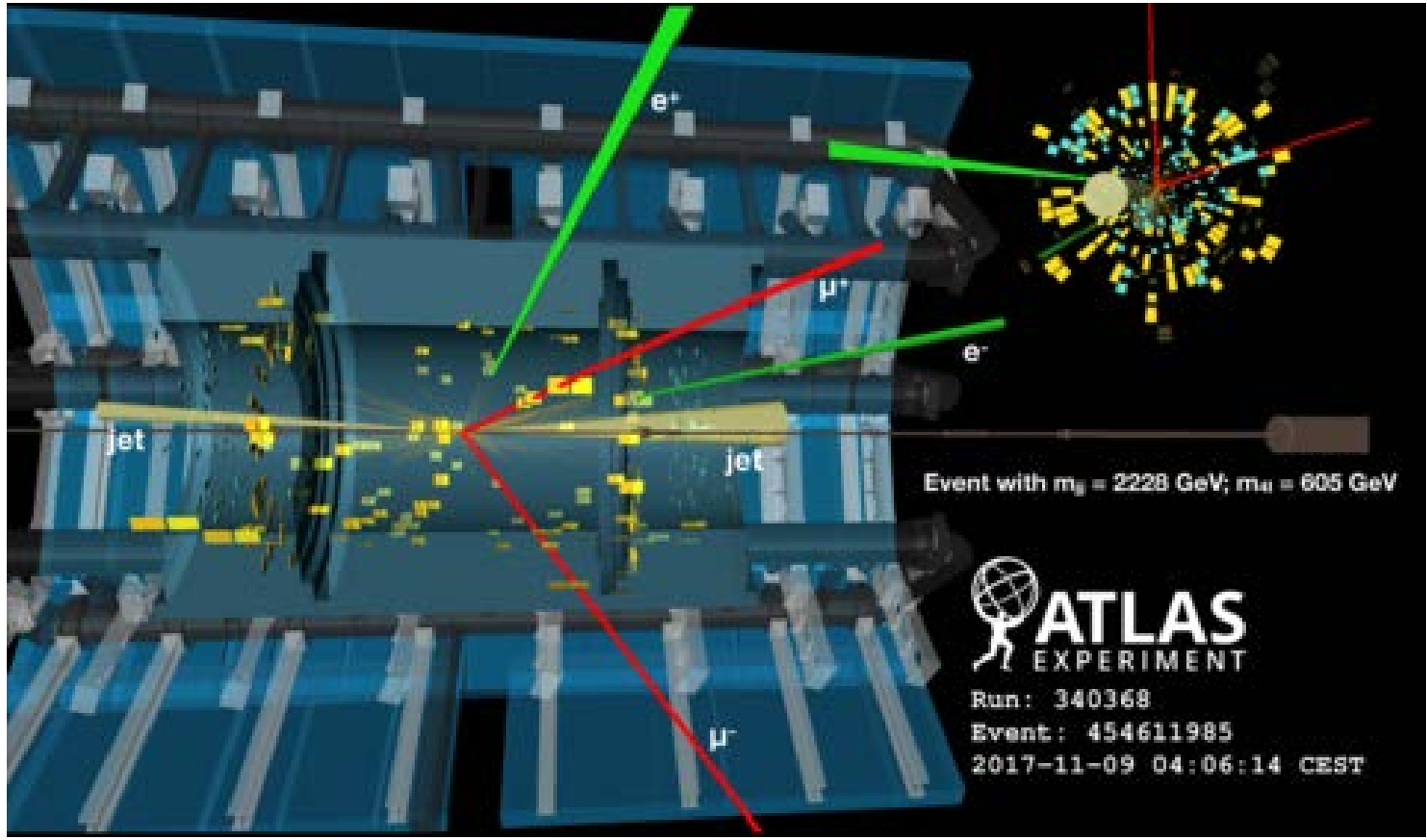
JHEP11(2008)010

Observation of EW ZZjj Production

- Two Z bosons decaying leptonically
  - ZZ→ 4l (4e, 2e2μ, 4μ)
  - ZZ→2l2ν (2e2ν, 2μ2ν)
- Two Jets in forward/backward regions
  - Large rapidity separation
  - Large invariant mass
- Clean experimental signature
- Large theoretical uncertainties in modeling jets (up to 20% for ZZ + 2 jets)

ATLAS **arXiv:2004.10612**

With 139 fb^{-1} data (13 TeV), collected by ATLAS in Run 2



An event display of a ZZjj→ 4l jj event candidate

ZZjj Analysis Strategy

arXiv:2004.10612

- Low m_{jj} or $|\Delta Y|<2$ control regions used to constrain the modelling of the QCD ZZjj component
- **ZZjj signal simulation models:** MadGraph5@LO+Pythia8 for EW ZZjj, Sherpa 2.2.2 for QCD ZZ+0, 1j@NLO+2,3,4j@LO; impact of interference component assigned as syst. on the EW signal
- Multivariate discriminant based on gradient BDT used to extract electroweak ZZjj component

Event Selection

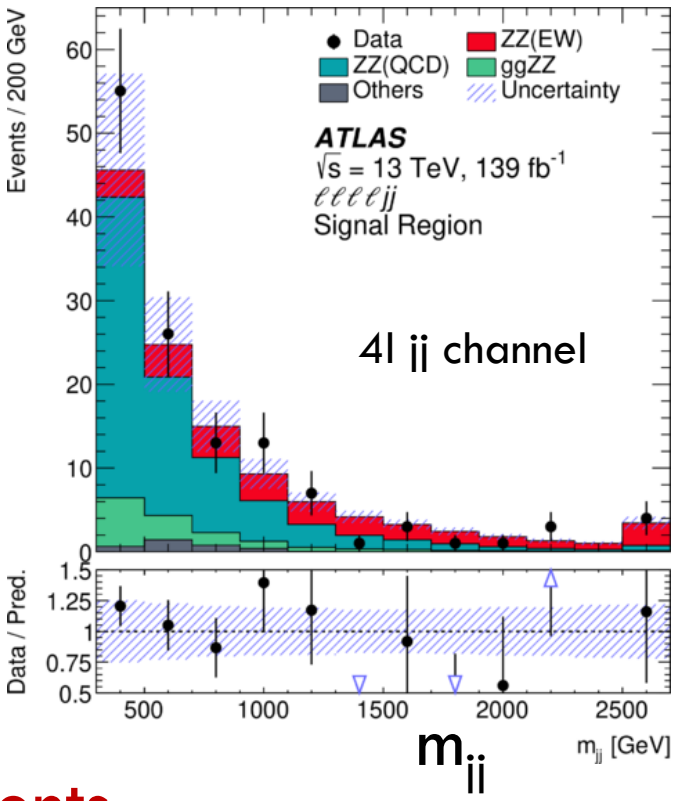
	$\ell\ell\ell\ell jj$	$\ell\ell\nu\nu jj$
Electrons	$p_{\mathrm{T}} > 7$ GeV, $\lvert\eta\rvert < 2.47$ $\lvert d_0/\sigma_{d_0}\rvert < 5$ and $\lvert z_0 \times \sin\theta\rvert < 0.5$ mm	Common for 2 channels
Muons	$p_{\mathrm{T}} > 7$ GeV, $\lvert\eta\rvert < 2.7$ $\lvert d_0/\sigma_{d_0}\rvert < 3$ and $\lvert z_0 \times \sin\theta\rvert < 0.5$ mm	$p_{\mathrm{T}} > 7$ GeV, $\lvert\eta\rvert < 2.5$ Common for 2 channels
Jets	$p_{\mathrm{T}} > 30$ (40) GeV for $\lvert\eta\rvert < 2.4$ ($2.4 < \lvert\eta\rvert < 4.5$)	$p_{\mathrm{T}} > 60$ (40) GeV for the leading (sub-leading) jet
ZZ selection	$p_{\mathrm{T}} > 20, 20, 10$ GeV for the leading, sub-leading and third leptons Two OSSF lepton pairs with smallest $\lvert m_{\ell^+\ell^-} - m_Z\rvert + \lvert m_{\ell'^+\ell'^-} - m_Z\rvert$ $m_{\ell^+\ell^-} > 10$ GeV for lepton pairs $\Delta R(\ell,\ell') > 0.2$ $66 < m_{\ell^+\ell^-} < 116$ GeV	$p_{\mathrm{T}} > 30$ (20) GeV for the leading (sub-leading) lepton One OSSF lepton pair and no third leptons $80 < m_{\ell^+\ell^-} < 100$ GeV No b-tagged jets $E_{\mathrm{T}}^{\mathrm{miss}}$-significance > 12
Dijet selection	Two most energetic jets with $y_{j_1} \times y_{j_2} < 0$ $m_{jj} > 300$ GeV and $\Delta y(jj) > 2$	Common for 2 channels $m_{jj} > 400$ GeV and $\Delta y(jj) > 2$

Measured Inclusive ZZjj σ vs Prediction

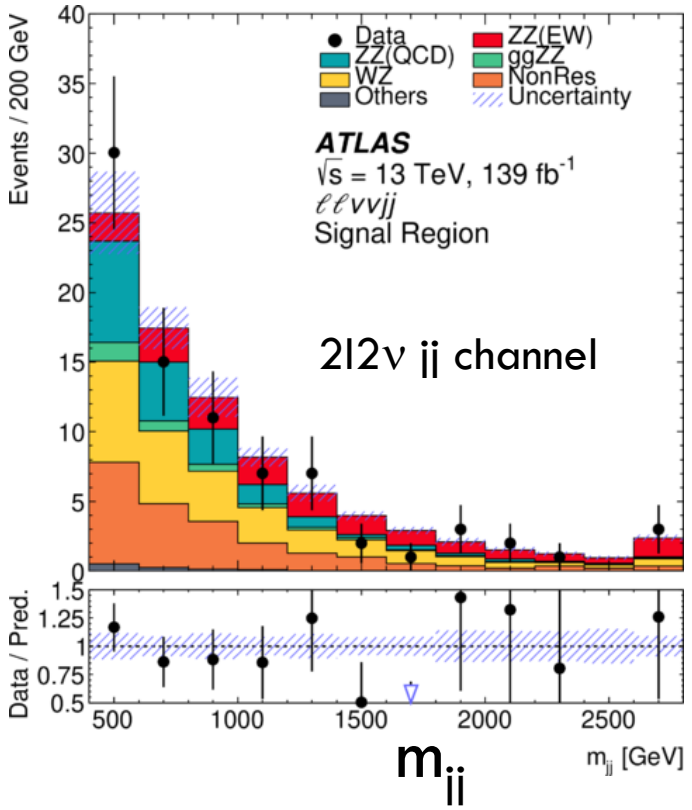
arXiv:2004.10612

Selected ZZjj events, data vs. MC

Process	$\ell\ell\ell\ell jj$	$\ell\ell\nu\nu jj$
EW $ZZjj$	20.6 ± 2.5	12.3 ± 0.7
QCD $ZZjj$	77 ± 25	17.2 ± 3.5
QCD $ggZZjj$	13.1 ± 4.4	3.5 ± 1.1
Non-resonant-$\ell\ell$	–	21.4 ± 4.8
WZ	–	22.8 ± 1.1
Others	3.2 ± 2.1	1.2 ± 0.9
Total	114 ± 26	78.4 ± 6.2
Data	127	82



m_{jj}



m_{jj}

Inclusive ZZjj cross-section measurements

	Measured fiducial σ [fb]
$\ell\ell\ell\ell jj$	$1.27 \pm 0.12(\text{stat}) \pm 0.02(\text{theo}) \pm 0.07(\text{exp}) \pm 0.01(\text{bkg}) \pm 0.03(\text{lumi})$
$\ell\ell\nu\nu jj$	$1.22 \pm 0.30(\text{stat}) \pm 0.04(\text{theo}) \pm 0.06(\text{exp}) \pm 0.16(\text{bkg}) \pm 0.03(\text{lumi})$

SM	Predicted fiducial σ [fb]
$\ell\ell\ell\ell jj$	$1.14 \pm 0.04(\text{stat}) \pm 0.20(\text{theo})$
$\ell\ell\nu\nu jj$	$1.07 \pm 0.01(\text{stat}) \pm 0.12(\text{theo})$

Currently, statistic dominant the measurement uncertainties, but the theoretical modeling uncertainty is larger

Extract the EW ZZjj Component

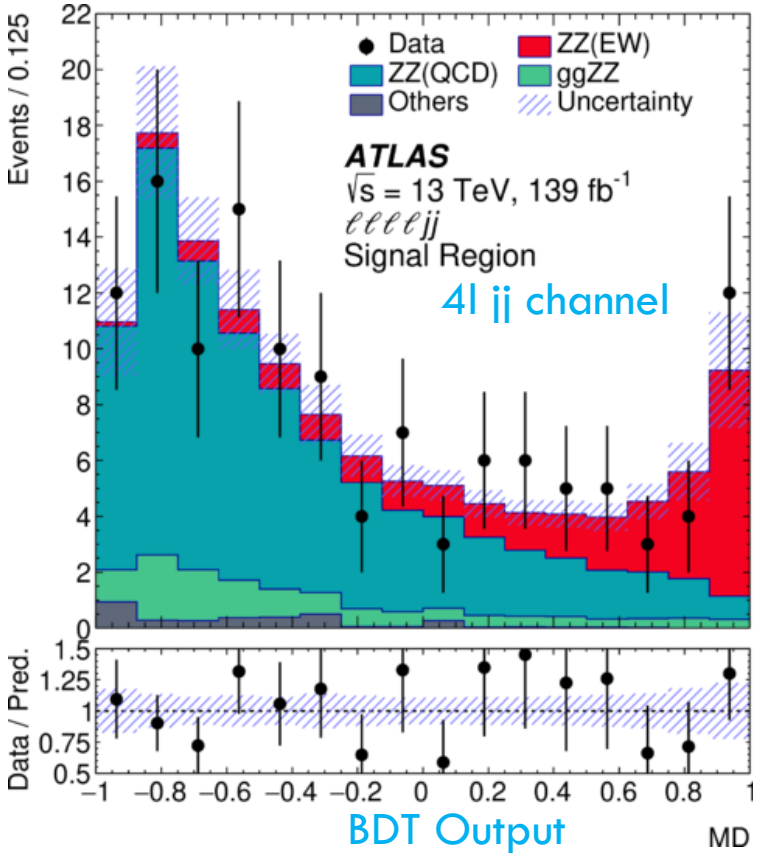
arXiv:2004.10612

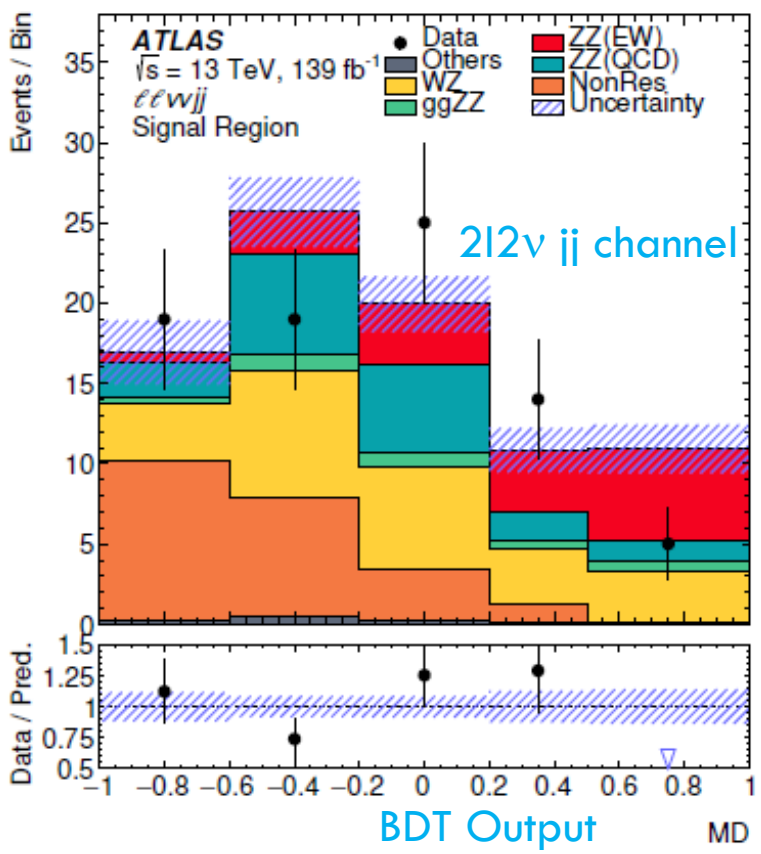
- The first-ever measurement of the EW VBS process with the ZZjj channel, a rare and very important process

  Significance: **5.5σ**

- One of the smallest cross sections measured by ATLAS

  σ_{EW}^{ZZjj} = **0.82 ± 0.21 fb**





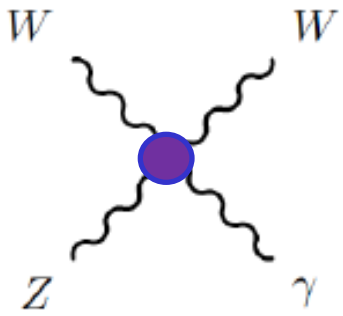
	μ_{EW}	$\mu_{QCD}^{\ell\ell\ell\ell jj}$	Significance Obs. (Exp.)
$\ell\ell\ell\ell jj$	1.5 ± 0.4	0.95 ± 0.22	5.5 (3.9) σ
$\ell\ell\nu\nu jj$	0.7 ± 0.7	–	1.2 (1.8) σ
Combined	1.35 ± 0.34	0.96 ± 0.22	5.5 (4.3) σ

Measurement of Zγjj Production

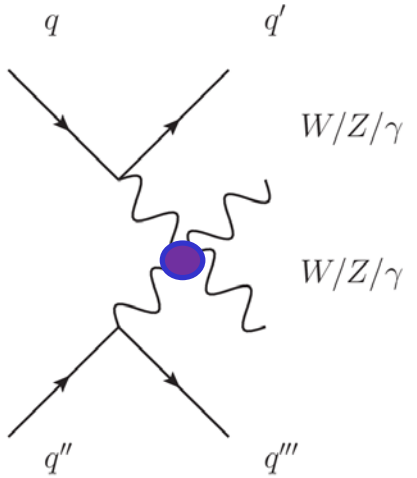
Phys. Lett. B 803 (2020) 135341

arXiv:1910.09503

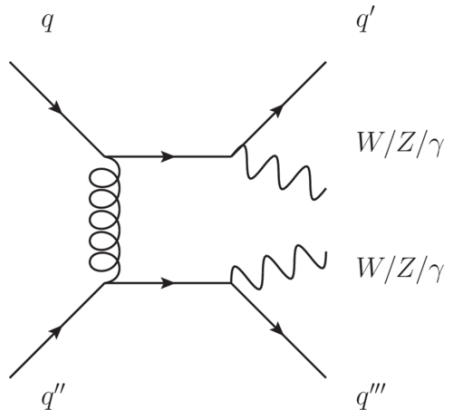
- Measure VBS Zγjj electroweak production cross-section (36.1 fb^{-1} at 13 TeV)
  - Sensitive to quartic gauge coupling



  - Major background from QCD VBS process



EW Zγjj diagram



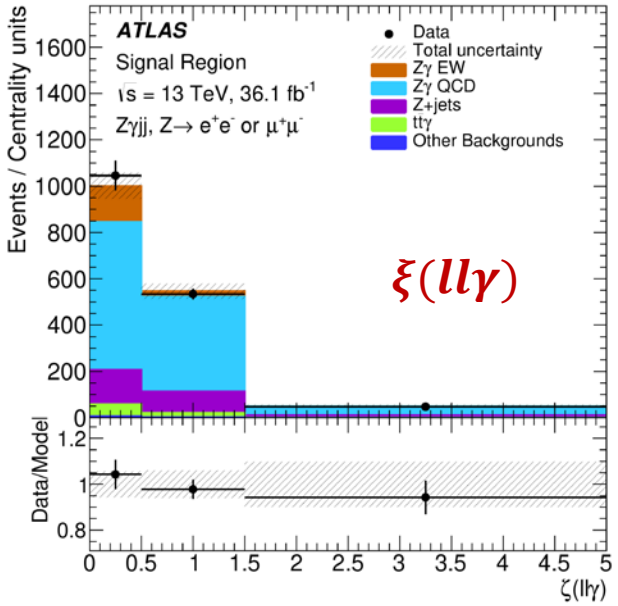
QCD-induced Zγjj diagram

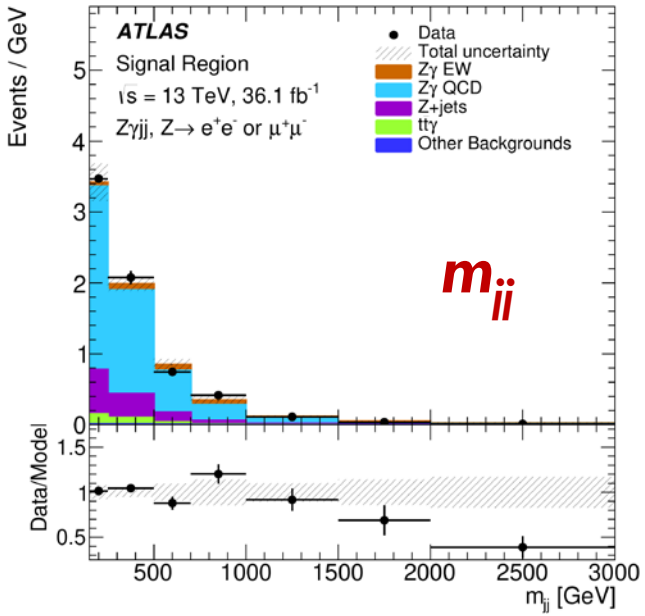
Zγjj Event Selection

Phys. Lett. B 803 (2020) 135341

- A central $\{ll\gamma\}$ system
  - ➢One Z→ ee, μμ
  - ➢One γ not from final state radiation
- Two jets
  - ➢Large rapidity separation
  - ➢Large invariant mass
- No b-jet (CR: $N_{bjet}>0$)
- **Signal region** $|\Delta\eta_{jj}| > 1$

$$\zeta(\ell\ell\gamma) = \left| \frac{y_{\ell\ell\gamma} - (y_{j_1} + y_{j_2})/2}{(y_{j_1} - y_{j_2})} \right| < 5$$



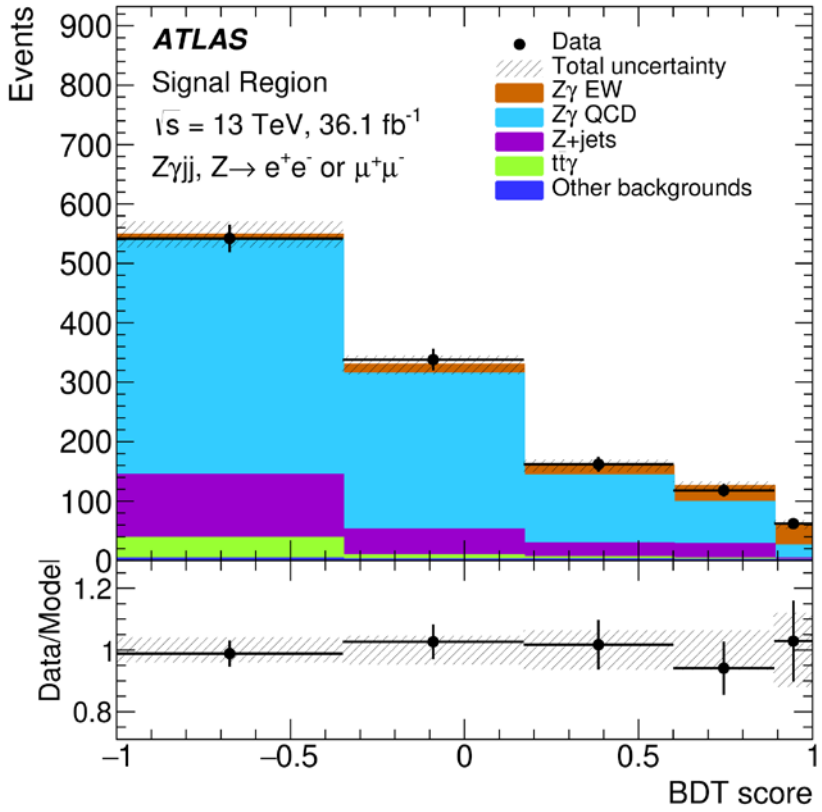


Selected Events	SR		*b*-CR	
Data	1222		388	
Total expected	1222	±35	389	±19
$Z\gamma jj$–EW (signal)	104	±26	5	± 1
$Z\gamma jj$–QCD	864	±60	82	± 9
Z+jets	200	±40	19	± 4
$t\bar{t}+\gamma$	48	±10	280	±21
Other backgrounds	7	± 1	4	± 1

Evidence of EW Zγjj Production at LHC

Phys. Lett. B 803 (2020) 135341

BDT score distribution in SR



- Likelihood fit using BDT score distribution in SR and b-jet multiplicity distribution in CR to extract the EW **Zγjj** signal strength. Observed and expected significance: **4.1σ (3.8σ).**
- **Cross section derived from signal strength**

MadGraph5_aMC@NLO 2.3.3
used to predict number of EW Zγjj events

$$\mu_{Z\gamma jj-EW} = \frac{N^{data}_{Z\gamma jj-EW}}{N^{MC}_{Z\gamma jj-EW}}$$

Fiducial electroweak $Z\gamma jj$ cross-section

$$\sigma^{\text{fid.}}_{Z\gamma jj-\text{EW}} = 7.8 \pm 1.5\,(\text{stat.}) \pm 1.0\,(\text{syst.})\,^{+1.0}_{-0.8}\,(\text{mod.})\ \text{fb}$$

$$\sigma^{\text{fid., MadGraph}}_{Z\gamma jj-\text{EW}} = 7.75 \pm 0.03\,(\text{stat.}) \pm 0.20\,(\text{PDF} + \alpha_S) \pm 0.40\,(\text{scale})\ \text{fb}$$

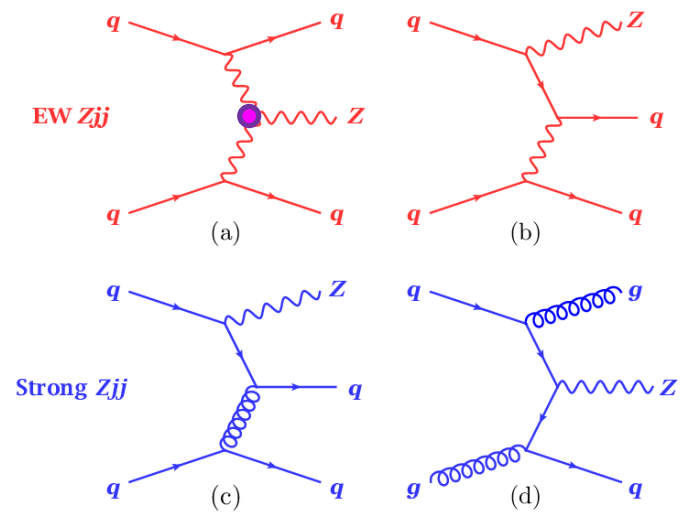
$$\sigma^{\text{fid., Sherpa}}_{Z\gamma jj-\text{EW}} = 8.94 \pm 0.08\,(\text{stat.}) \pm 0.20\,(\text{PDF} + \alpha_S) \pm 0.50\,(\text{scale})\ \text{fb}$$

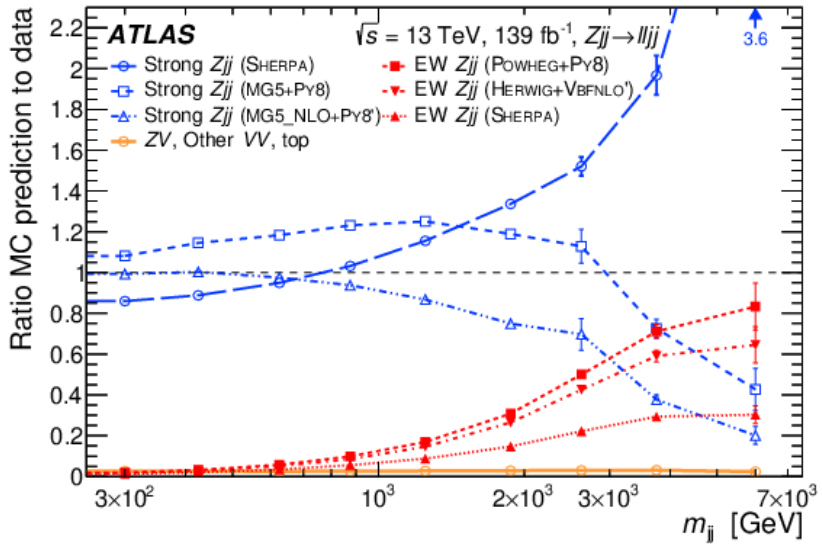
Fiducial inclusive $Z\gamma$+2 jet cross-section

$$\sigma^{\text{fid.}}_{Z\gamma jj} = 71 \pm 2\,(\text{stat.})\,^{+9}_{-7}\,(\text{syst.})\,^{+21}_{-17}\,(\text{mod.})\ \text{fb}$$

$$\sigma^{\text{fid., MadGraph+Sherpa}}_{Z\gamma jj} = 88.4 \pm 2.4\,(\text{stat.}) \pm 2.3\,(\text{PDF} + \alpha_S)^{+29.4}_{-19.1}\,(\text{scale})\ \text{fb}.$$

VBF Zjj Production at the LHC





Signal

arXiv:2006.15458 (139 fb^{-1})

- Z boson delays to ee and μμ
- Two jets in forward/backward region
  - Large rapidity separation
  - Large invariant mass
- No jets in the rapidity gap between j_1 and j_2

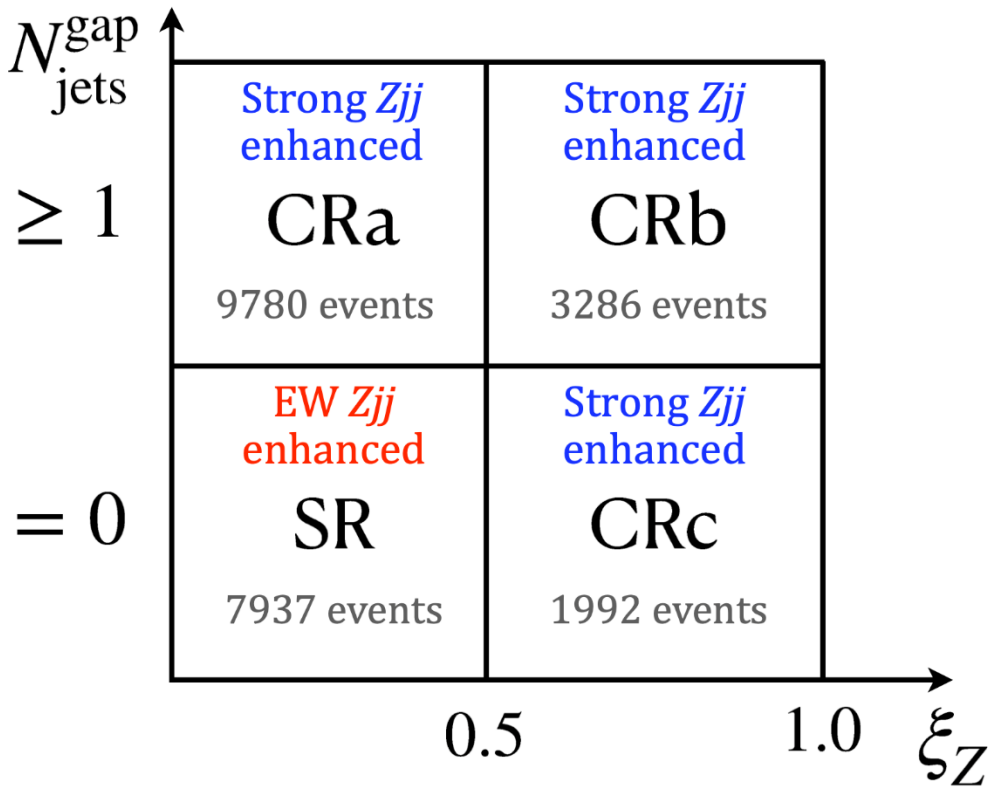
The largest irreducible background

- Strong Zjj production
- Theoretical modeling of strong Zjj production is poor, particularly in high-mass m_{jj} signal enriched region
- Different MC generators used for comparison

Constrain the Background in Control Regions

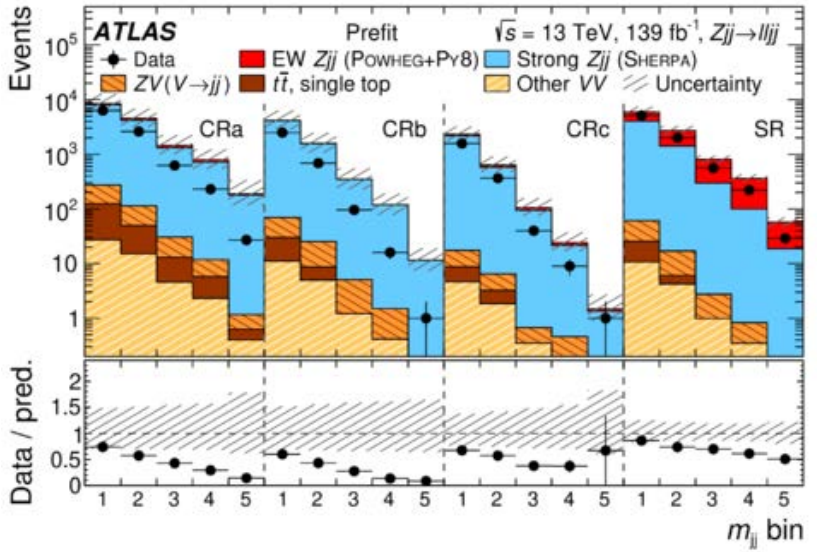
- Modeling of the QCD Z +2 jets contribution constrained using data in dedicated control region
- Data-driven constraint transferred into the signal region using Monte Carlo
- The interference is treated as EW syst.

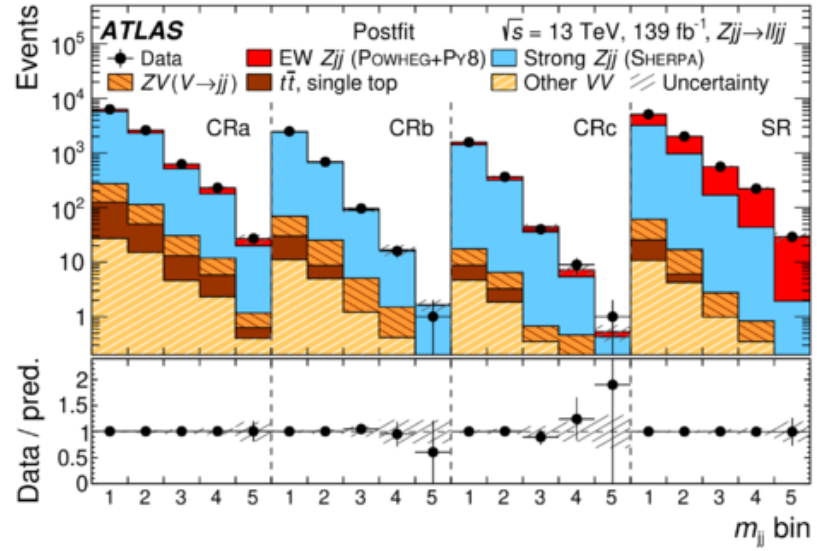
arXiv:2006.15458



Definition of the signal region (SR) and control regions (CRa, CRb, CRc) used in the extraction of the electroweak component

$$\xi_Z = |y_{\ell\ell} - 0.5(y_{j1} + y_{j2})|/|\Delta y_{jj}|$$





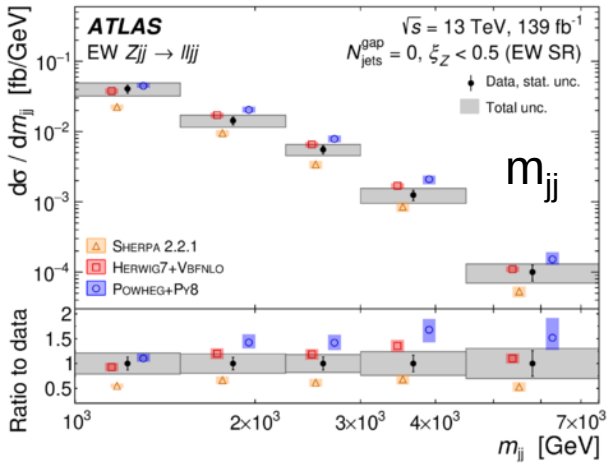
Zjj Differential Cross-Sections

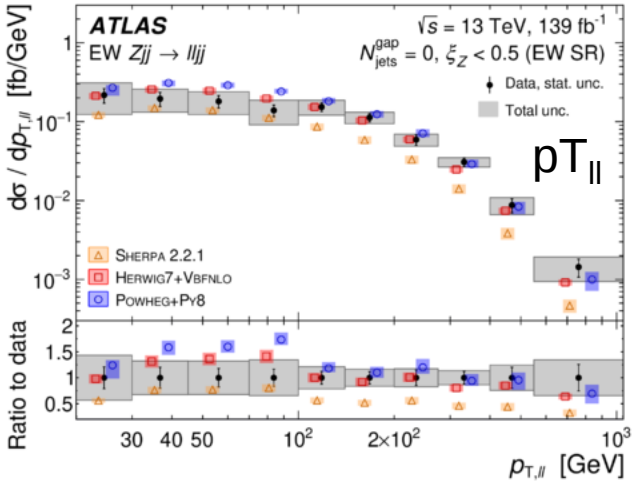
arXiv:2006.15458

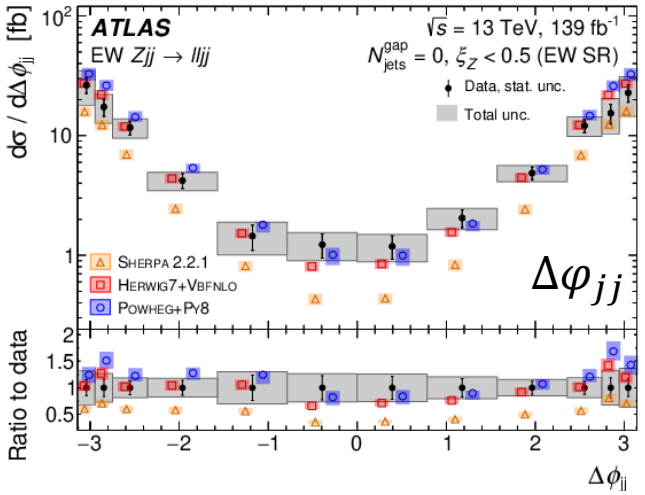
Integrated cross section of EW Zjj: $\sigma = 37.4 \pm 3.5 \pm 5.5\ fb$

Compare to prediction: $\sigma = 39.5 \pm 3.4(scale) \pm 1.2(PDF)$ *fb* (from Herwig7+VBFNLO)

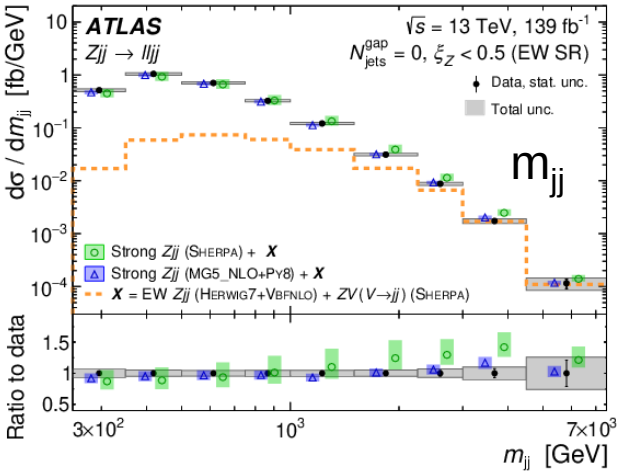
EW VBF Zjj differential cross-sections

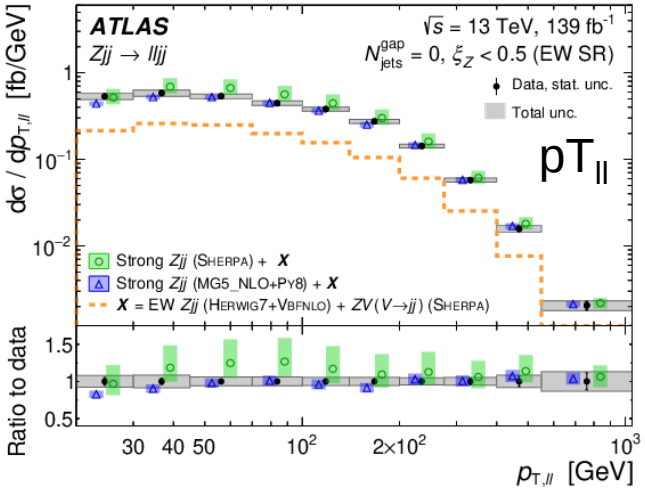


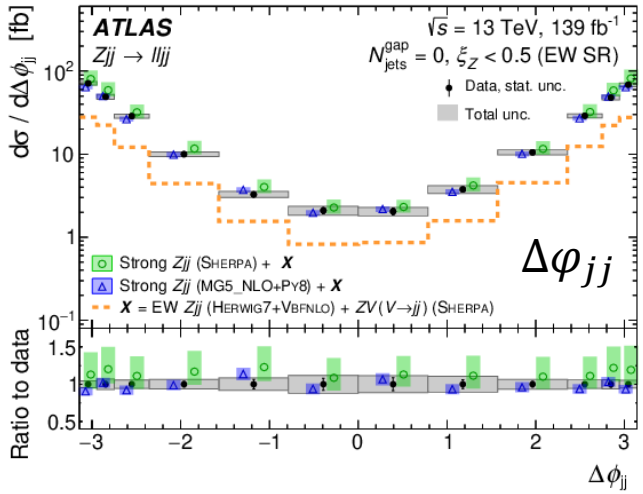




Inclusive Zjj differential cross-sections

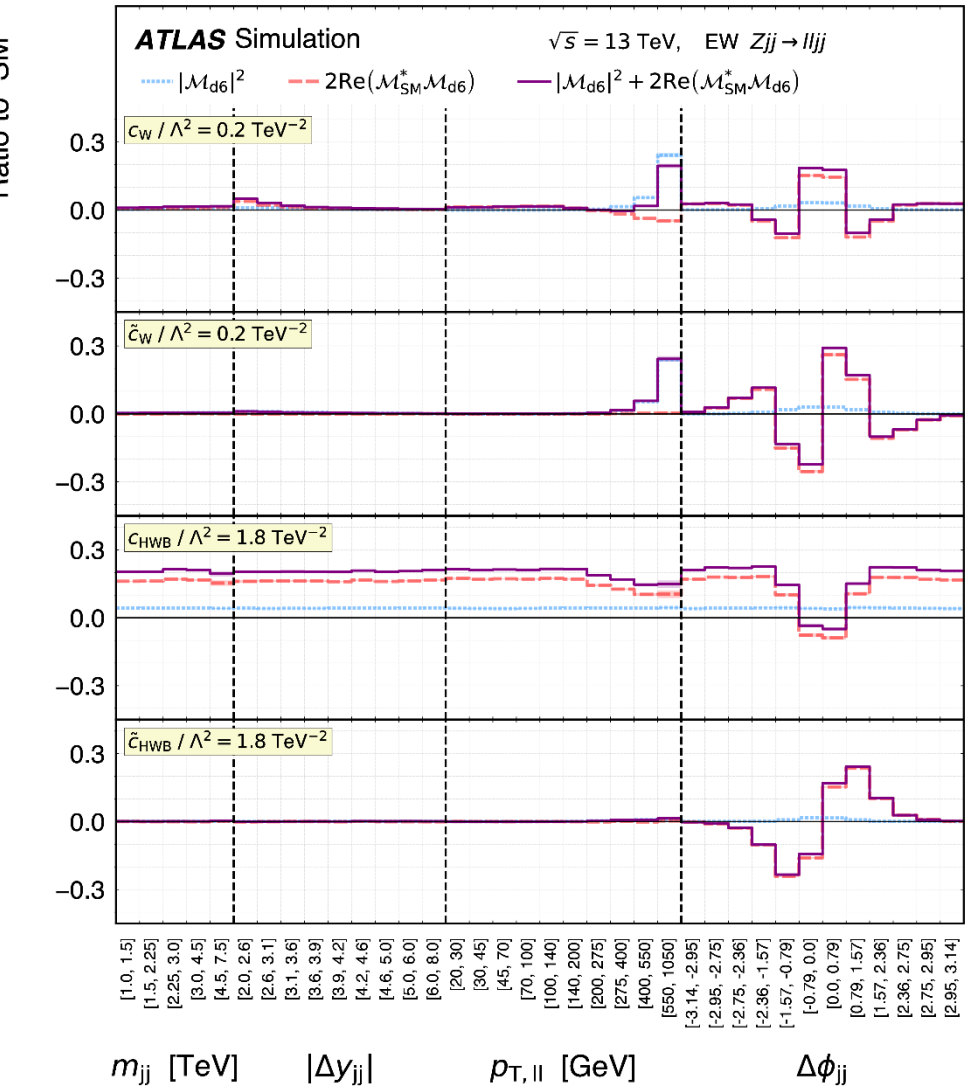






Effective Field Theory Interpretation

arXiv:2006.15458



The anomalous interactions are introduced with effective Lagrangian

$$\mathcal{L}_{\text{eff}} = \mathcal{L}_{\text{SM}} + \sum_i \frac{c_i}{\Lambda^2} O_i$$

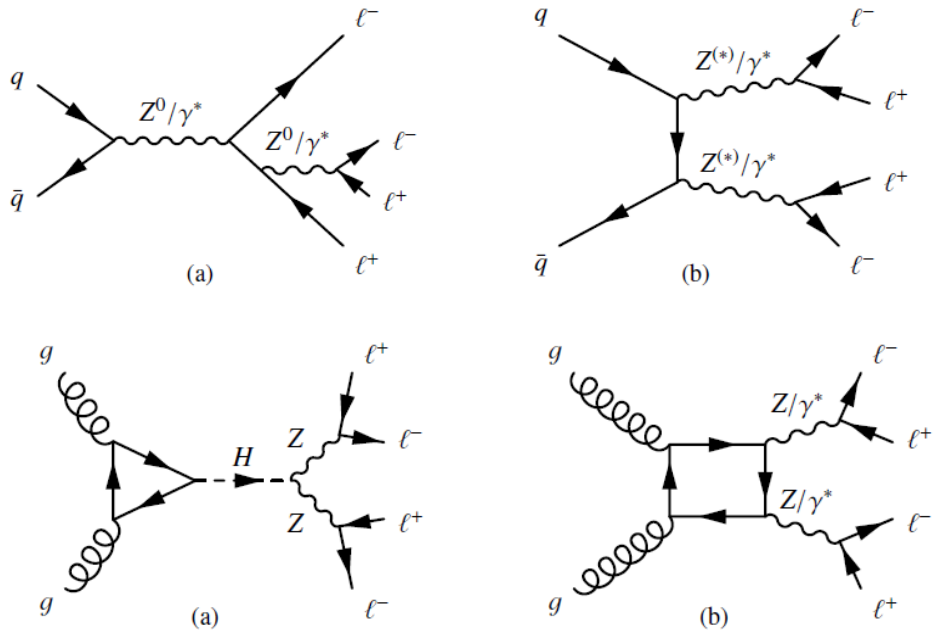
the O_i are dimension-six operators

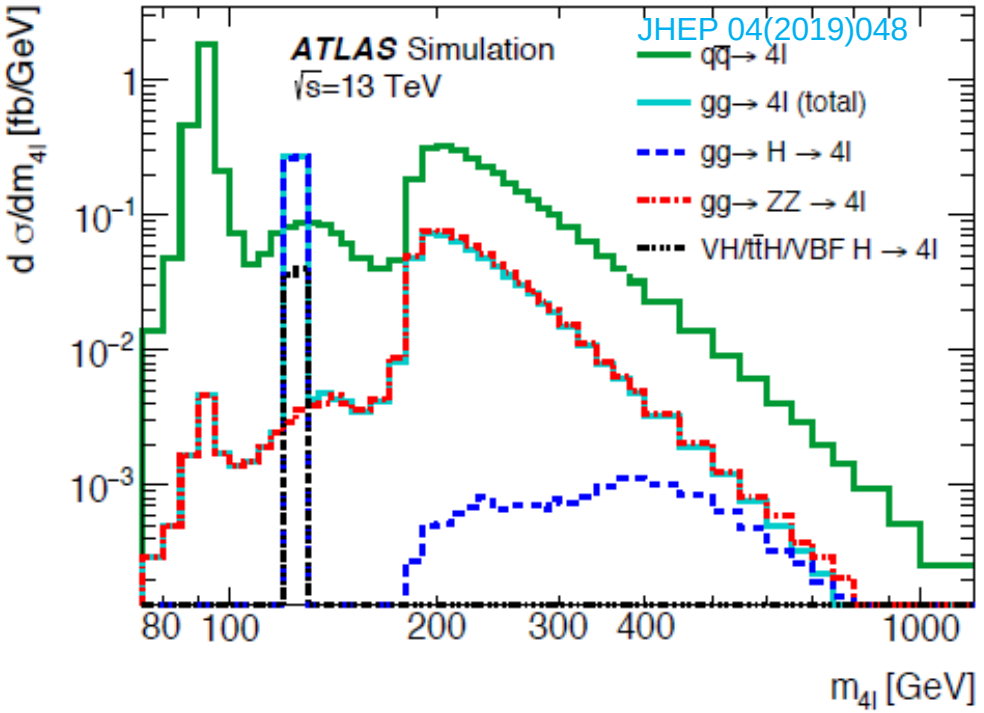
Two CP-even and CP-odd operators are tested using SMEFTsim +MG5+Pythia8. Sensitivity to CP-odd operators through the parity-odd observable $\Delta\Phi_{jj}$

Wilson coefficient	Includes $\lvert\mathcal{M}_{d6}\rvert^2$	95% confidence interval [TeV^{-2}] Expected	Observed	p-value (SM)
c_W/Λ^2	no	[−0.30, 0.30]	[−0.19, 0.41]	45.9%
	yes	[−0.31, 0.29]	[−0.19, 0.41]	43.2%
$\tilde{c}_W/\Lambda^2$	no	[−0.12, 0.12]	[−0.11, 0.14]	82.0%
	yes	[−0.12, 0.12]	[−0.11, 0.14]	81.8%
c_{HWB}/Λ^2	no	[−2.45, 2.45]	[−3.78, 1.13]	29.0%
	yes	[−3.11, 2.10]	[−6.31, 1.01]	25.0%
$\tilde{c}_{HWB}/\Lambda^2$	no	[−1.06, 1.06]	[0.23, 2.34]	1.7%
	yes	[−1.06, 1.06]	[0.23, 2.35]	1.6%

Inclusive 4l Differential σ Measurement

ATLAS-CONF-2020-042 With 139 fb^{-1} data





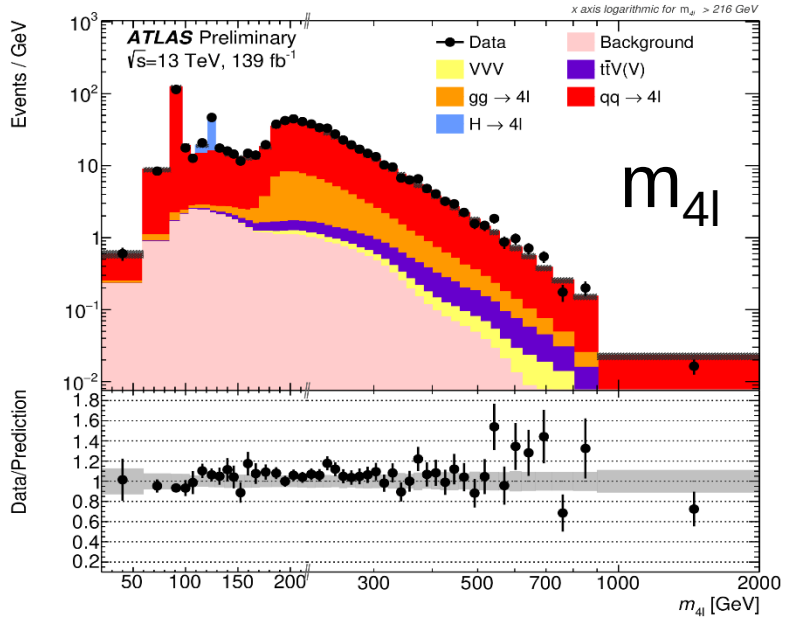
- Physics with 4l production is very rich. Depending on the invariant mass of the four leptons, the dominant underlying process behind their creation can be the decay of a Z boson, a Higgs boson that decays via two Z bosons, or the electroweak production of a Z-boson pair.
- Destructive interference between Higgs production and the continuum ZZ production through box diagram allowing constrain the off-shell Higgs production coupling to probe the Higgs nature width;
- Interpretation of BSM physics

Event Selection & 4l Cross Section

Select

- Lepton pT > 20, 10, 5(7), 5(7) GeV for μ (e)
- Any pair m_{ll} > 5 GeV, and ΔR(l,l) > 0.05

Events	Region				
	Full	$Z \to 4\ell$	$H \to 4\ell$	Off-shell ZZ	On-shell ZZ
$q\bar{q} \to 4\ell$	6100 ± 500	1490 ± 120	128 ± 10	800 ± 60	3640 ± 280
$gg \to 4\ell$	680 ± 90	10.8 ± 2.9	3.9 ± 0.7	49 ± 6	620 ± 80
$H \to 4\ell$	245 ± 20	2.16 ± 0.18	207 ± 17	33.5 ± 3.1	1.98 ± 0.2
VVV	35 ± 14	0.018 ± 0.008	0.13 ± 0.05	2.1 ± 0.8	33 ± 13
$t\bar{t}V(V)$	123 ± 19	1.37 ± 0.22	1.2 ± 0.2	15.5 ± 2.4	105 ± 16
Background	330 ± 50	44 ± 8	26 ± 5	129 ± 20	139 ± 31
Total Pred.	7500 ± 500	1540 ± 110	367 ± 19	1030 ± 60	4530 ± 290
Data	7755	1452	379	1095	4828



$\mathcal{B}_{Z\to 4l} = (4.41 \pm 0.30) \times 10^{-6}$

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- Measured ZZ→4l production cross sections $\frac{\Delta\sigma}{\sigma}$ ~3.3%
- Agree well with SM prediction

	Region				
	Full	$Z \to 4\ell$	$H \to 4\ell$	Off-shell ZZ	On-shell ZZ
Measured fiducial cross-section [fb]	88.9 ±1.1 (stat.) ±2.3 (syst.) ±1.5 (lumi.) ±3.0 (total)	22.1 ±0.7 (stat.) ±1.1 (syst.) ±0.4 (lumi.) ±1.3 (total)	4.76 ±0.29 (stat.) ±0.18 (syst.) ±0.08 (lumi.) ±0.35 (total)	12.4 ±0.5 (stat.) ±0.6 (syst.) ±0.2 (lumi.) ±0.8 (total)	49.3 ±0.8 (stat.) ±0.8 (syst.) ±0.8 (lumi.) ±1.3 (total)
SHERPA	86±5	23.6±1.5	4.57±0.21	11.5±0.7	46.0±2.9
POWHEG + PYTHIA8	83±5	21.2±1.3	4.38±0.20	10.7±0.7	46.4±3.0

Unfolded 4l, and 2l Mass Spectra

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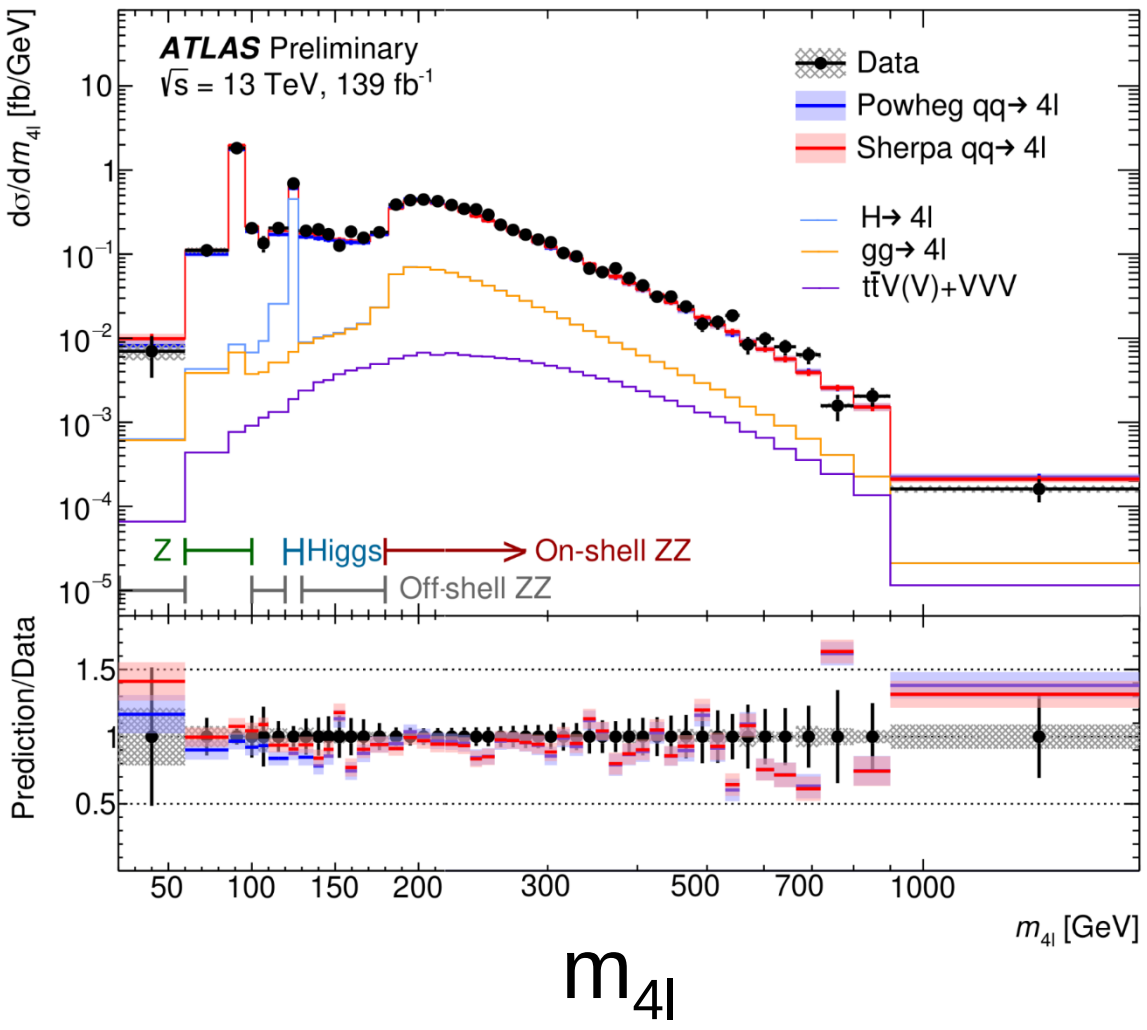
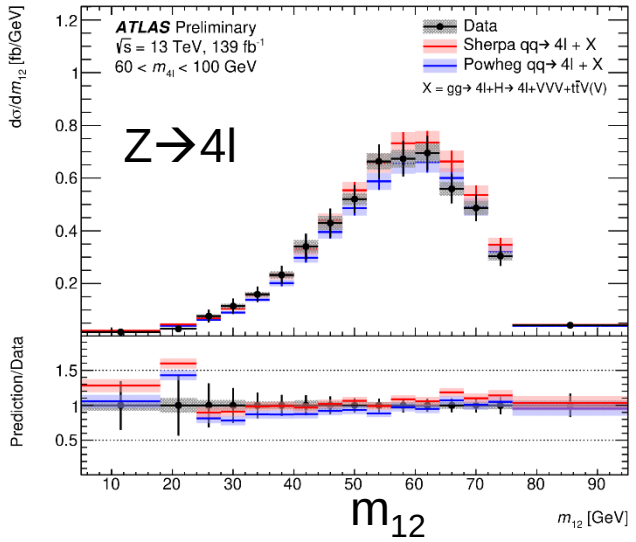
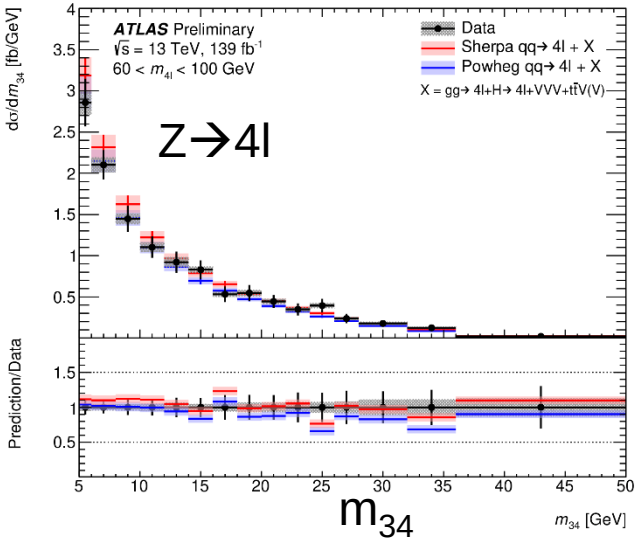


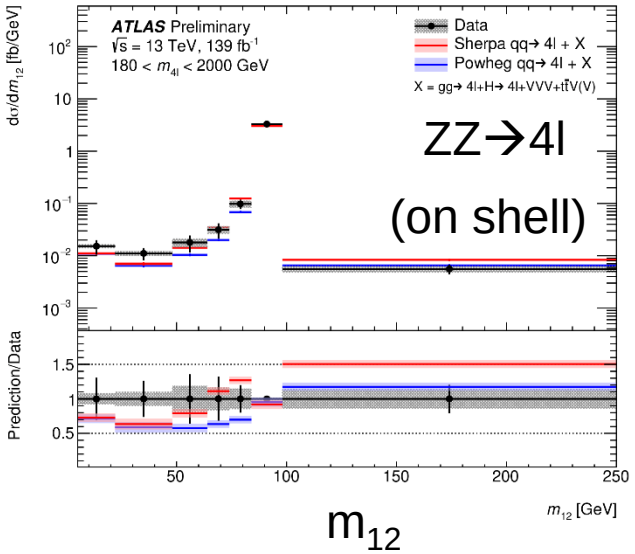
m4l



m12



m34



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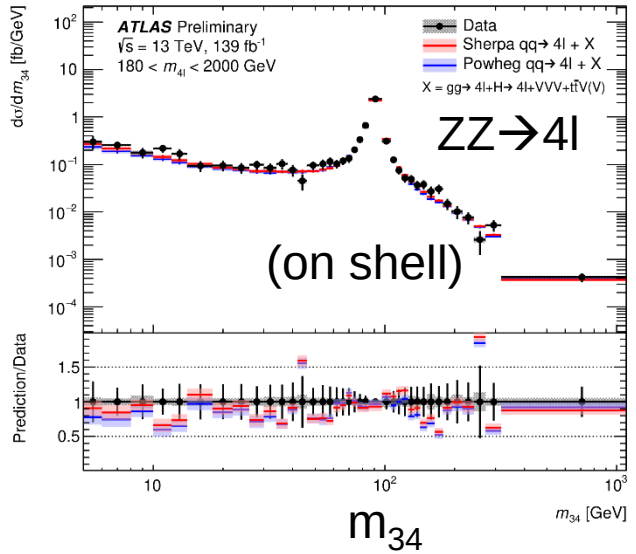

m34

Differential pT and Angular Cross Sections

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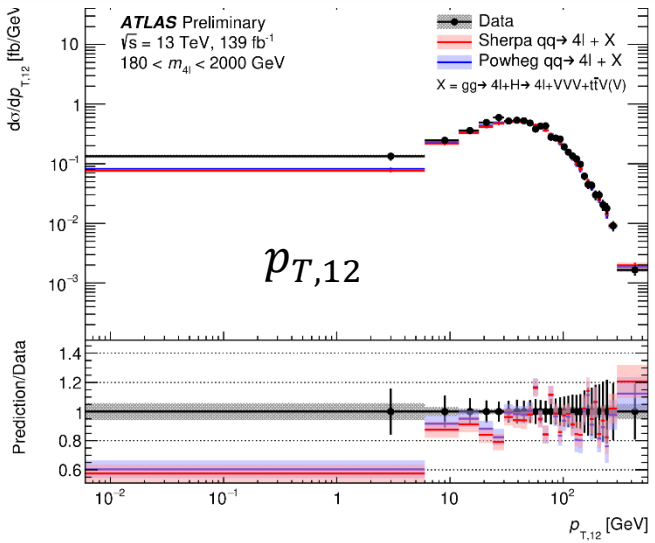

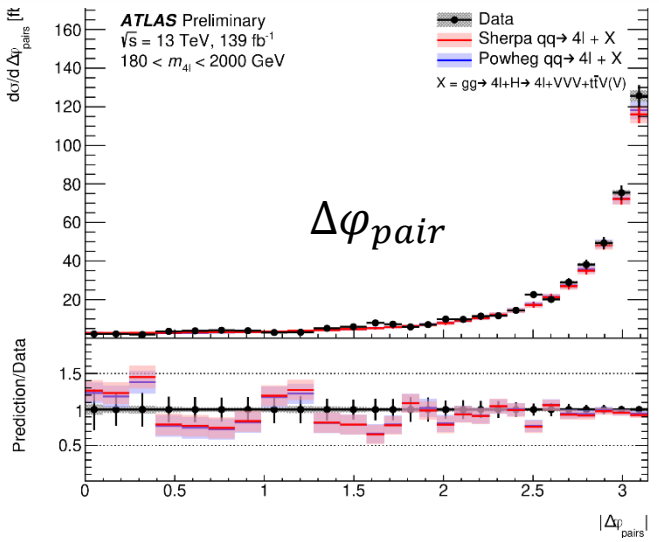

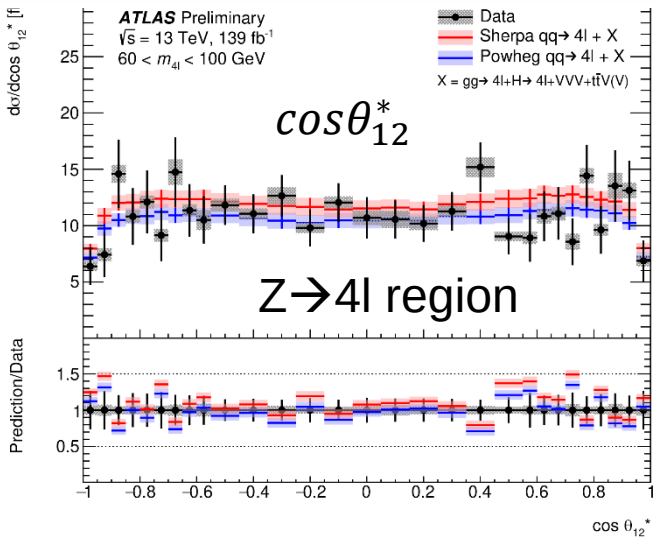

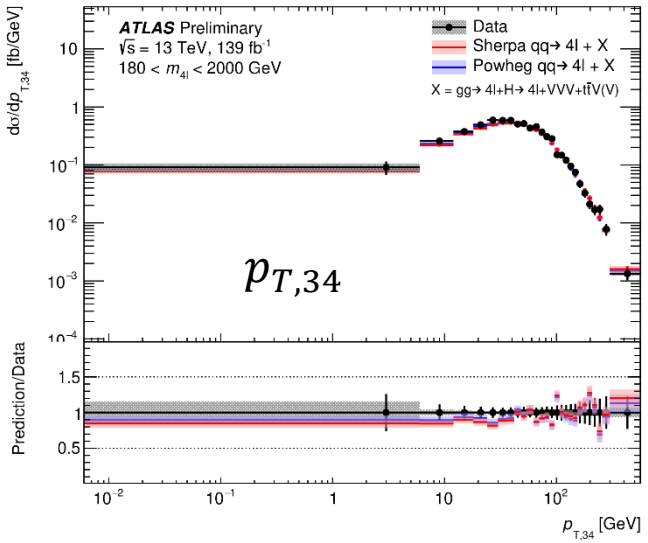

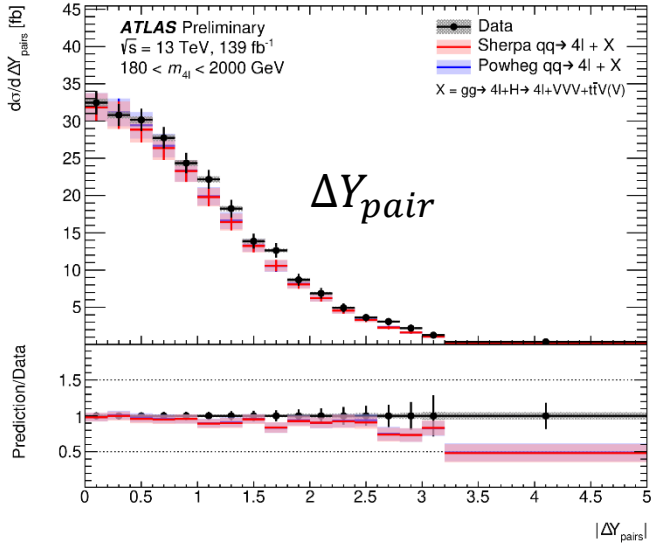

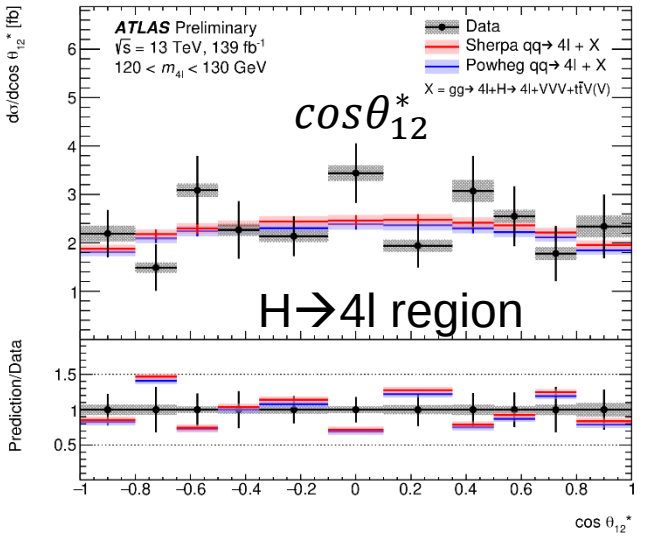

BSM Interpretation from Inclusive 4l Data

The B-L Gauge Model [JHEP **08** (2018) 181]

A simple extension of the SM and based on symmetry groups:

$$SU(3)_c \times SU(2)_L \times U(1)_Y \times U(1)_{B-L},$$

B-L denotes baryon-number - lepton-number to include heavy RH neutrinos in the theory.

- The new gauge Field Z' is corresponding to $U(1)_{B-L}$, which can decay to RH neutrinos, and SM fermions
- The $U(1)_{B-L}$ spontaneously broken by an exotic Higgs boson h_2 which can decay to ZZ or Z'Z' with the gauge bosons decaying to lepton pairs.

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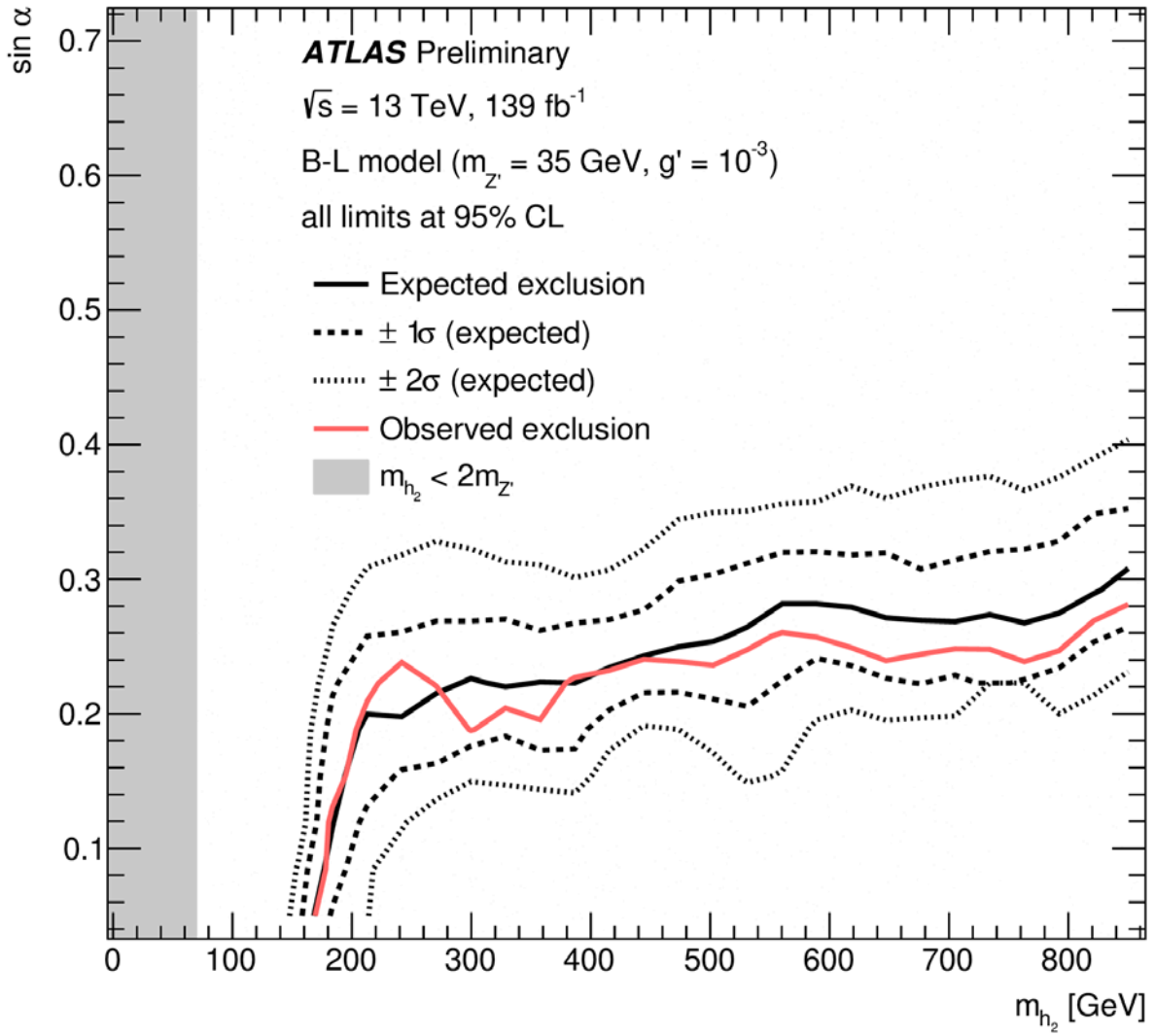
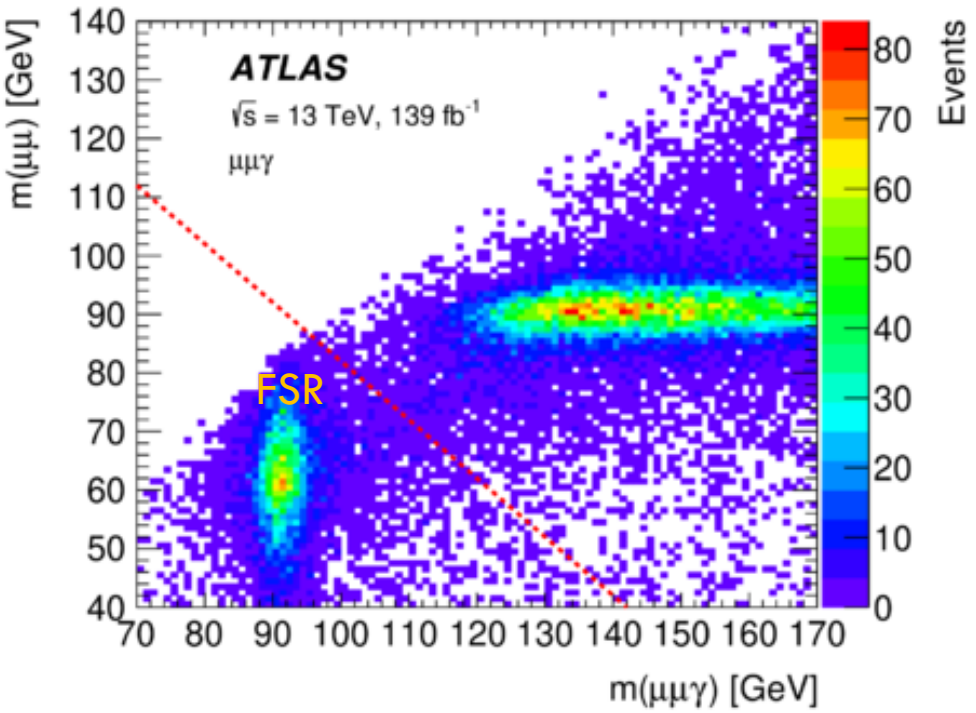
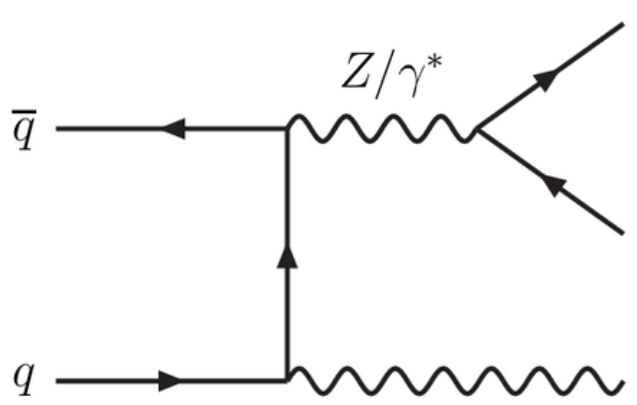


Inclusive Zγ Measurement

JHEP 03 (2020) 054 With 139 fb^{-1} data

- Test SM: measurements of σ^{total}, and σ^{diff} with high precision
- Major background in H→Zγ search
- $m_{ll}+m_{ll\gamma} > 182$ GeV to suppress FSR

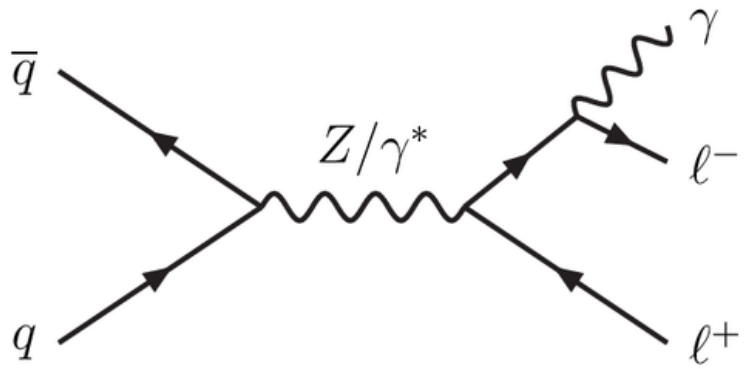




Require lepton pT>30, 25 GeV

Require γ pT>30 GeV

Signal Diboson Zγ signal



Background: Z→ll with FSR photon

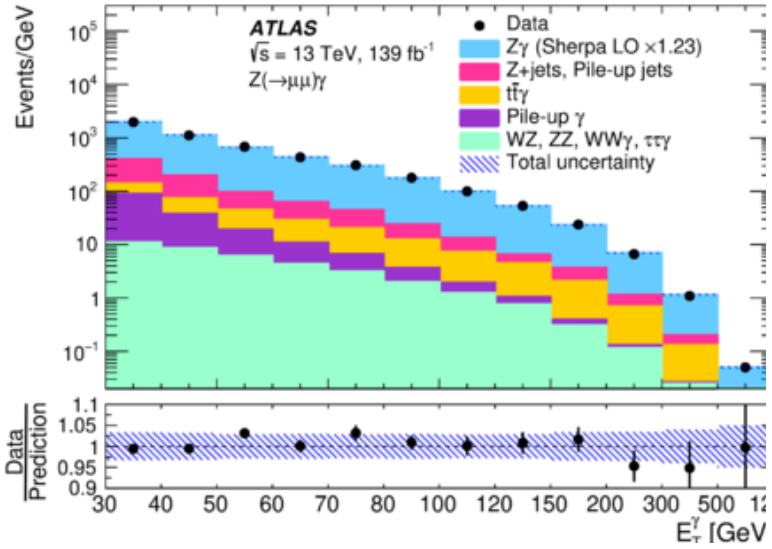
Zγ Kinematic Variable Distributions

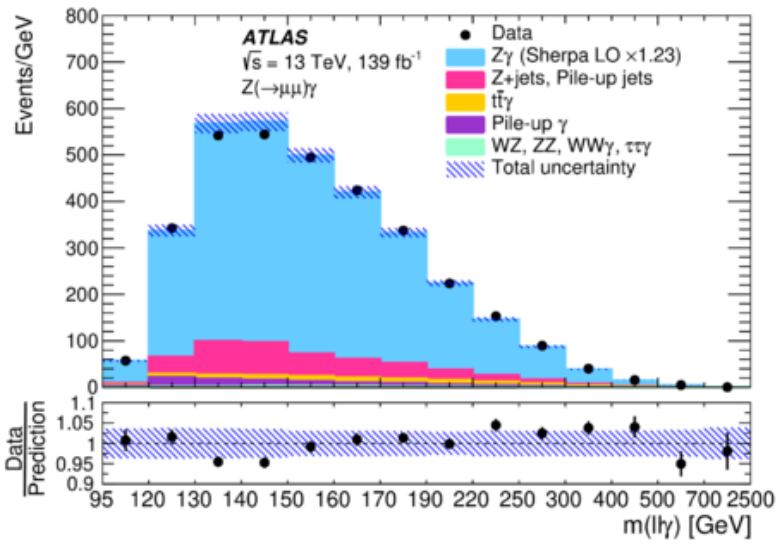
JHEP 03 (2020) 054 With 139 fb^{-1} data

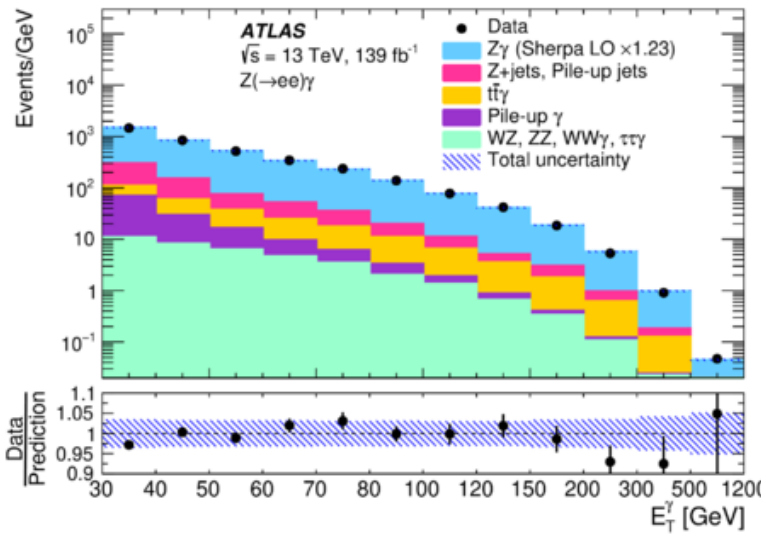
Zγ event selection

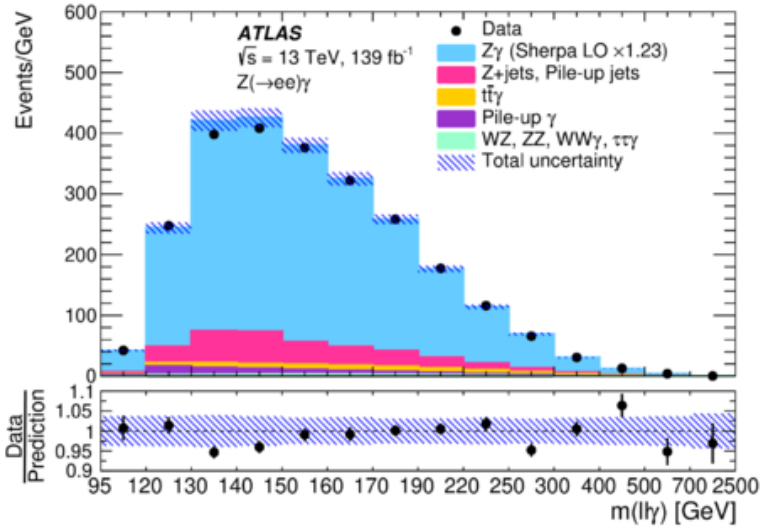
Photons	Electrons/Muons
$E_{\mathrm{T}}^{\gamma} > 30$ GeV	$p_{\mathrm{T}}^{\ell} > 30, 25$ GeV
$\lvert\eta^{\gamma}\rvert < 2.37$	$\lvert\eta^{\ell}\rvert < 2.47$
$E_{\mathrm{T}}^{\mathrm{cone0.2}}/E_{\mathrm{T}}^{\gamma} < 0.07$	dressed leptons
$\Delta R(\ell,\gamma) > 0.4$	
Event selection	
$m(\ell\ell) > 40\,GeV$	
$m(\ell\ell) + m(\ell\ell\gamma) > 182\,GeV$	

- The largest background come from jet fake γ, estimate from data using sidebands
- Pile-up induced background: Z and γ from different collisions in one LHC BC (25ns)



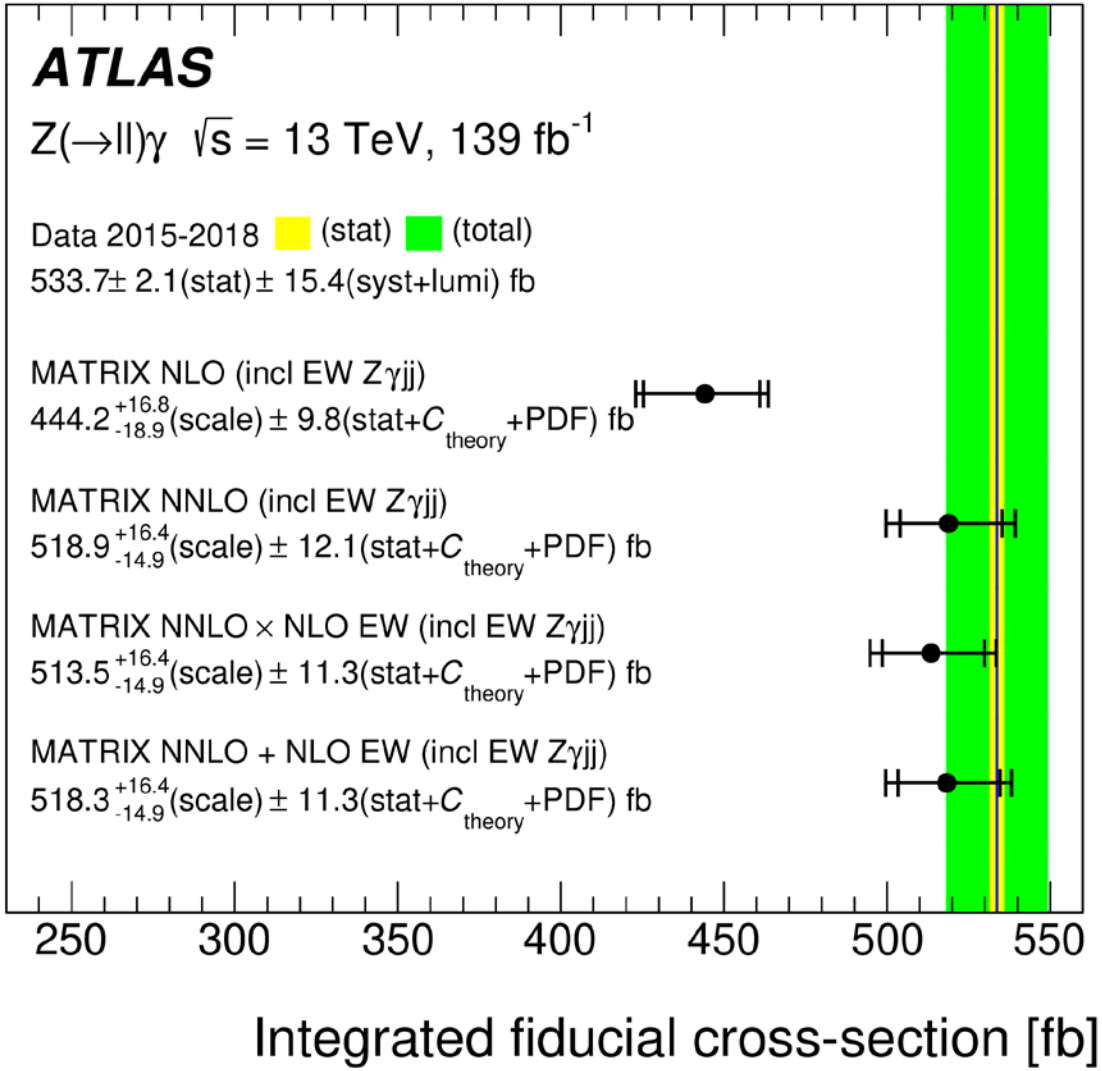






Integrated Fiducial Cross Section Measurement

JHEP 03 (2020) 054



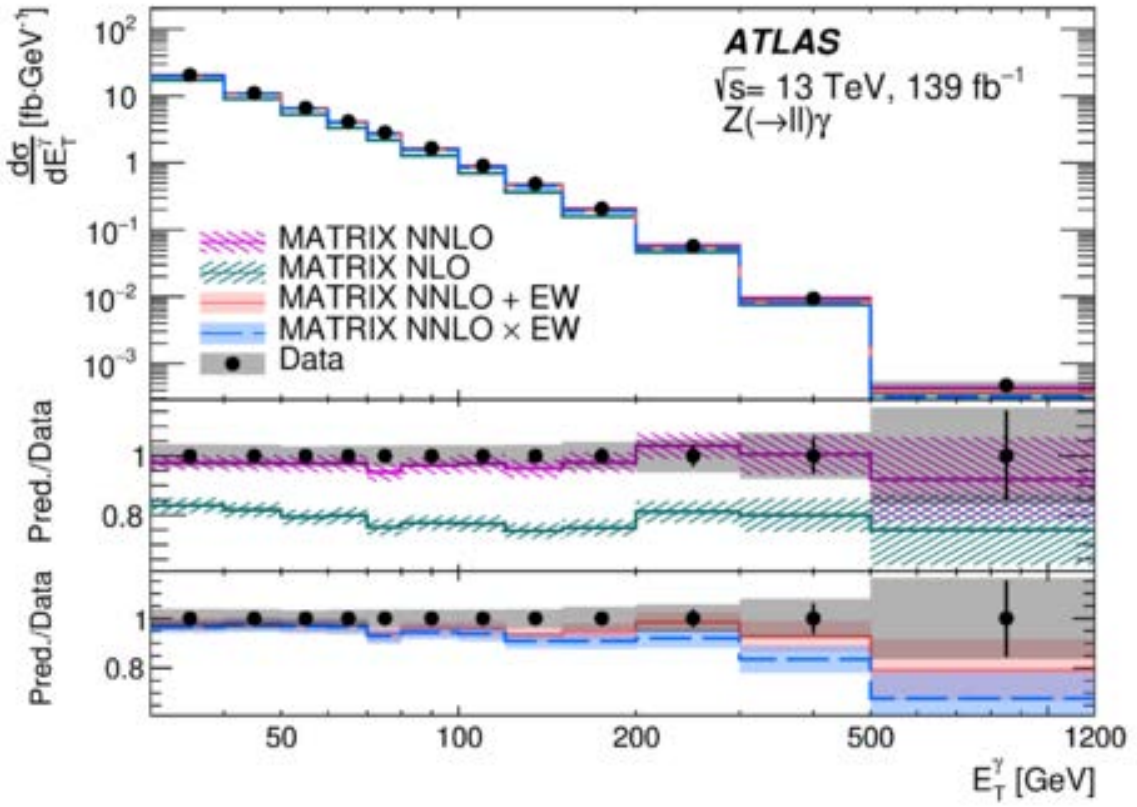
Source	Uncertainty [%] $e^+e^-\gamma$	Uncertainty [%] $\mu^+\mu^-\gamma$	Correlation
Trigger efficiency	–	0.2	no
Photon identification efficiency	1.0		yes
Photon isolation efficiency	0.9		yes
Electron identification efficiency	1.4	–	no
Electron reconstruction efficiency	0.3	–	no
Electron–photon energy scale	0.9	0.6	partial
Muon isolation efficiency	–	0.4	no
Muon identification efficiency	–	0.7	no
Z + jets background	1.3		yes
Pile-up background	0.6		yes
Other backgrounds	0.8	0.7	partial
Monte Carlo event statistics	0.4	0.4	no
Integrated luminosity	1.7		yes
Systematic uncertainty	3.2	2.9	
Statistical uncertainty	0.6	0.5	
Total uncertainty	3.2	3.0	

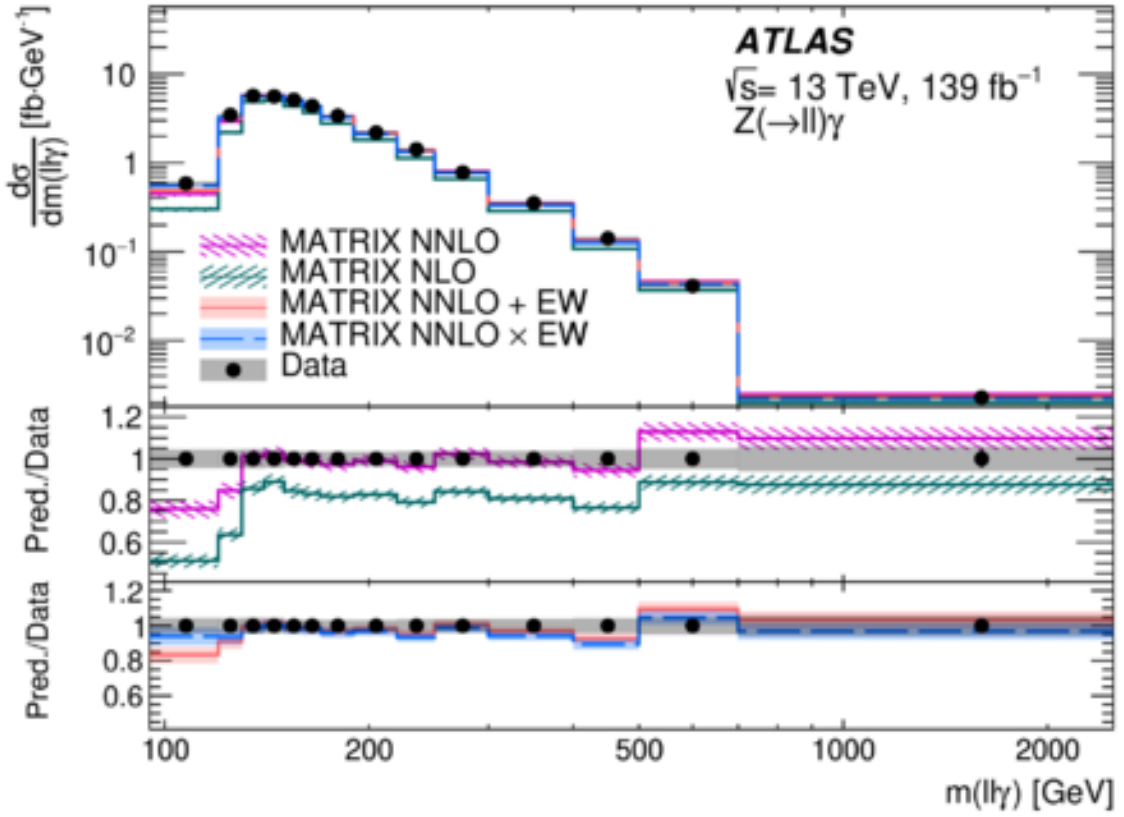
Total uncertainty ~3%

$Z\gamma$ Differential Cross Section Measurements

JHEP 03 (2020) 054

- Differential cross sections with respect to $E_T{}^{\gamma}$,η^{γ},$m_{ll\gamma}$, $pT^{ll\gamma}$, $pT^{ll\gamma}/m(ll\gamma)$ and $\Delta\varphi(\mathrm{ll},\gamma)$ are all measured
- Both NLO EW and NNLO QCD corrections for $Z\gamma$ cross-section are computed & included





Summary

New ATLAS results on V(V)jj and VV productions are presented:

- With the large Run 2 dataset **rare** EW VBS processes are observed first time in the $ZZjj$ and $Z\gamma jj$ channels. While the VBF Zjj production having higher cross section precision differential cross sections are measured in detail, and search for anomalous triple-gauge coupling is performed with EFT framework
- Inclusive $4l$ production, a process with very rich phenomenology, is studied in detail. Differential cross sections in different mass regions, each corresponding to a dominant production process, are measured with good precision, allowing physicists to set limits on new physics.
- The diboson $Z\gamma$ production cross section measurement reached precision at **3%** level!

Backup Slides

$Z\gamma$ observed events vs predicted events

	$e^+e^-\gamma$	$\mu^+\mu^-\gamma$
N_{obs}	41343	54413
$N_{Z+\text{jets}}$	4130 ± 440	5470 ± 580
(includes $N_{\text{PU,jets}}$	870 ± 170	1140 ± 230)
$N_{\text{PU},\gamma}$	1030 ± 210	1360 ± 270
$N_{t\bar{t}\gamma}$	1650 ± 250	1980 ± 300
N_{WZ}	254 ± 76	199 ± 60
N_{ZZ}	64 ± 19	102 ± 31
$N_{WW\gamma}$	92 ± 28	112 ± 34
$N_{\tau\tau\gamma}$	46 ± 15	39 ± 12
$N_{\text{obs}} - N_{\text{bkg}}$	34080 ± 590	45150 ± 750

Table 3: Summary of the observed number of events (N_{obs}), and the estimated number of background events ($N_{Z+\text{jets}}, N_{\text{PU},\gamma}, N_{t\bar{t}\gamma}, N_{WZ}, N_{ZZ}, N_{WW\gamma}, N_{\tau\tau\gamma}$), in the $e^+e^-\gamma$ and $\mu^+\mu^-\gamma$ signal regions. The $N_{Z+\text{jets}}$ background estimate includes a contribution from jets from pile-up interactions, $N_{\text{PU,jets}}$, which is also shown separately. In all cases, the uncertainty is the combination of the statistical and systematic uncertainties. The bottom row gives the number of observed events after subtracting the sum, N_{bkg}, of all estimated background contributions.

Zjj Events – Data vs. Prediction

Sample	$Z \to ee$	$Z \to \mu\mu$
Data	10 870	12 125
EW Zjj (POWHEG+PY8)	$2670 \pm 120 \pm 280$	$2740 \pm 120 \pm 290$
EW Zjj (SHERPA)	$1280 \pm 60 \pm 140$	$1350 \pm 60 \pm 150$
EW Zjj (HERWIG7+VBFNLO′)	$2290 \pm 100 \pm 210$	$2350 \pm 100 \pm 220$
Strong Zjj (SHERPA)	$13\,500 \pm 600 \pm 4500$	$15\,100 \pm 600 \pm 5000$
Strong Zjj (MG5+PY8)	$13\,140 \pm 480 \pm$ N/A	$14\,810 \pm 540 \pm$ N/A
Strong Zjj (MG5_NLO+PY8′)	$8800 \pm 300 \pm 1000$	$10\,000 \pm 400 \pm 1200$
ZV ($V \to jj$)	$179 \pm 8 \pm 6$	$178 \pm 8 \pm 6$
Other VV	$45 \pm 2 \pm 2$	$45 \pm 2 \pm 2$
$t\bar{t}$, single top	$92 \pm 8 \pm 6$	$98 \pm 8 \pm 6$
$W(\to \ell\nu)$+jets, $Z(\to \tau\tau)$+jets	negligible	negligible