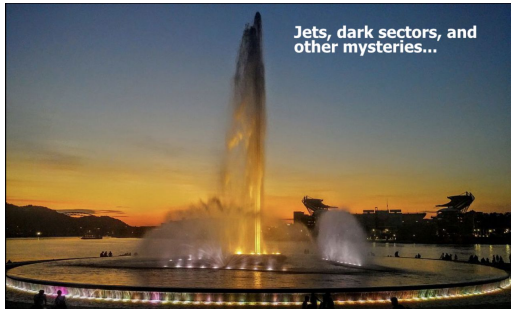


Measurements of Processes Sensitive to Quartic Electroweak Couplings in ATLAS

John McGowan, on behalf of the ATLAS Collaboration

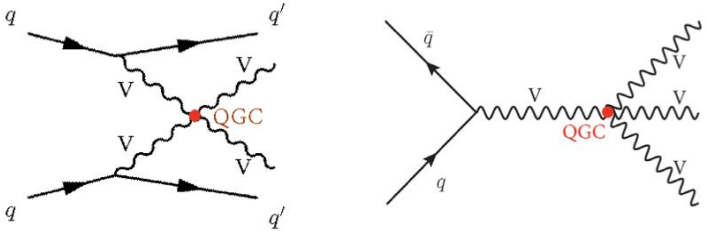
ATLAS EXPERIMENT

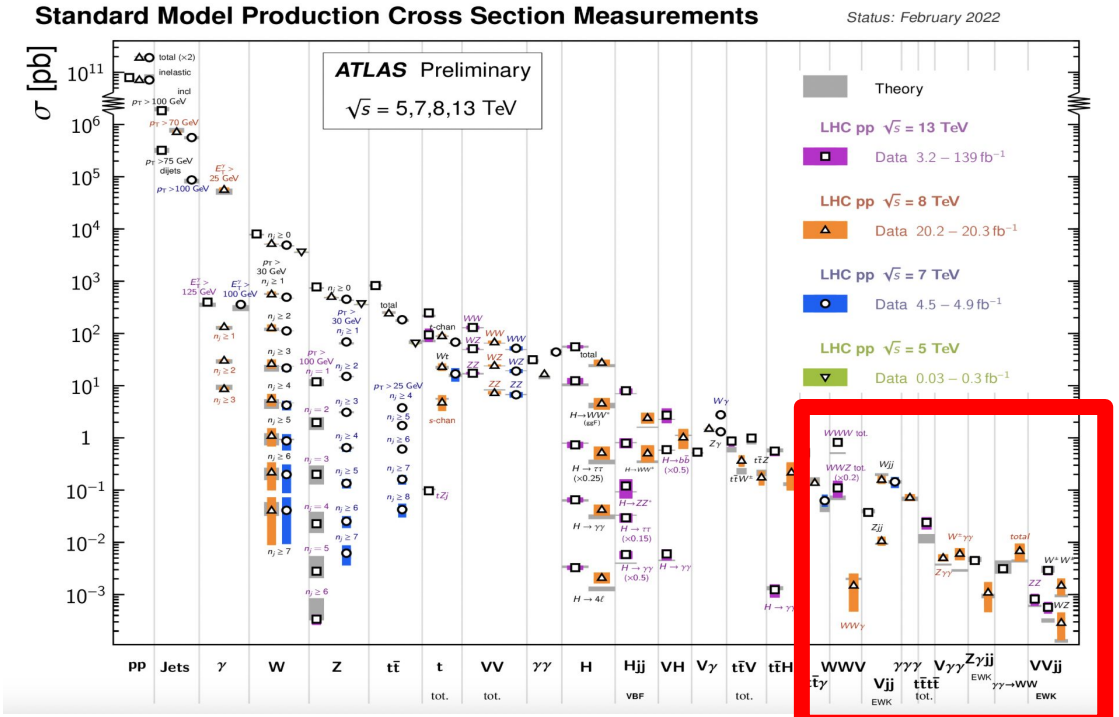
Pheno 2023

McGill UNIVERSITY

Quartic Electroweak Couplings

- VBS and triboson production are sensitive to quartic gauge boson couplings
- Measurements only possible in the LHC era.





[ATL-PHYS-PUB-2022-009]

Motivation

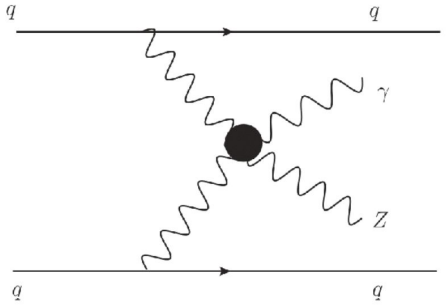
- Quartic gauge boson self interaction completely determined by the electroweak SM
- Powerful probe for new physics!

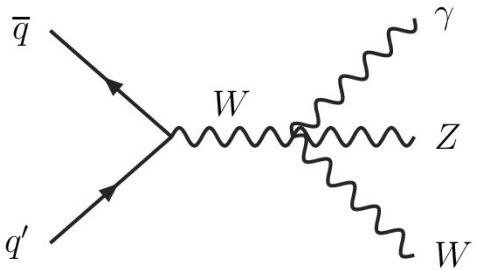
$$\mathcal{L}_{EFT} = \mathcal{L}_{SM} + \sum_{d>4} \sum_{i} \frac{\tilde{c}_i}{\Lambda^{d-4}} \mathcal{O}_i$$

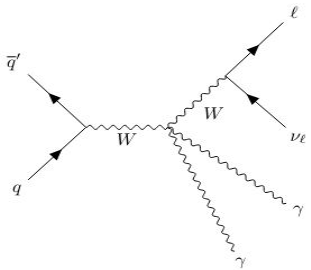
	$WWWW$	$WWZZ$	$WW\gamma Z$	$WW\gamma\gamma$	$ZZZZ$	$ZZZ\gamma$	$ZZ\gamma\gamma$	$Z\gamma\gamma\gamma$	$\gamma\gamma\gamma\gamma$
$\mathcal{O}_{S,0}$, $\mathcal{O}_{S,1}$	✓	✓			✓				
$\mathcal{O}_{M,0}$, $\mathcal{O}_{M,1}$,$\mathcal{O}_{M,6}$,$\mathcal{O}_{M,7}$	✓	✓	✓	✓	✓	✓	✓		
$\mathcal{O}_{M,2}$,$\mathcal{O}_{M,3}$, $\mathcal{O}_{M,4}$,$\mathcal{O}_{M,5}$		✓	✓	✓	✓	✓	✓		
$\mathcal{O}_{T,0}$,$\mathcal{O}_{T,1}$,$\mathcal{O}_{T,2}$	✓	✓	✓	✓	✓	✓	✓	✓	✓
$\mathcal{O}_{T,5}$,$\mathcal{O}_{T,6}$,$\mathcal{O}_{T,7}$		✓	✓	✓	✓	✓	✓	✓	✓
$\mathcal{O}_{T,8}$,$\mathcal{O}_{T,9}$					✓	✓	✓	✓	✓

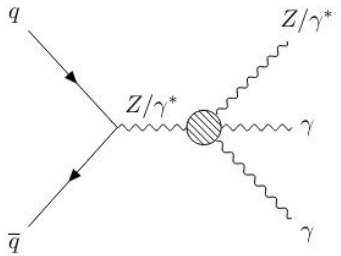
Overview of Recent Results

- VBS
  - Electroweak Z(**νν**)γ jj production
  - aQGC Re-interpretation of $W^{\pm}Zjj$ and $W^{\pm}W^{\pm}jj$
- Triboson Production
  - Zγγ
  - $W^{\pm}\gamma\gamma$
  - $W^{\pm}Z\gamma$

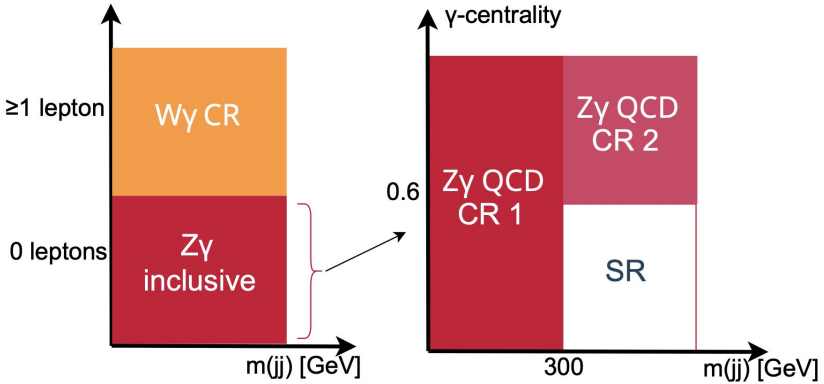


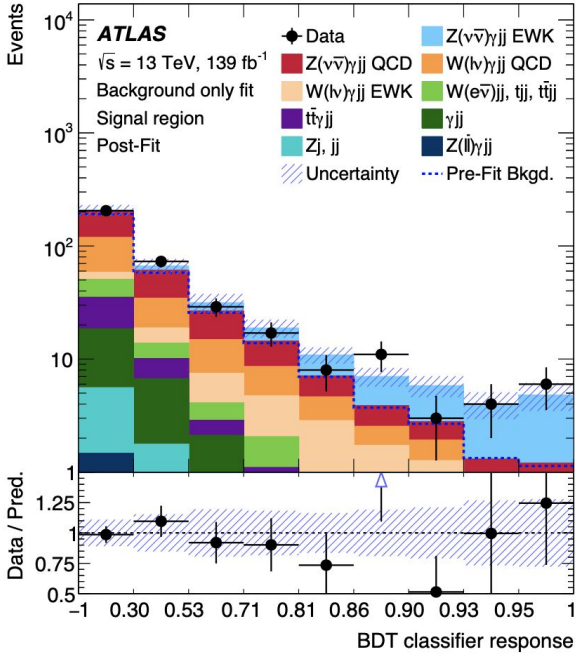






Electroweak Z(**νν**)γ jj Production





- E_T^{γ} > 150 GeV, MET > 120 GeV
- Signal modelled with Madgraph@LO with scale variations @NLO from VBFNLO
- QCD Backgrounds constrained in data CRs
- MET and mis-ID γ from data-driven estimates
- Observed (expected) significance: 3.2 σ (3.7σ)
- 6.3σ (6.6σ) in combination with low E_T^{γ} measurement

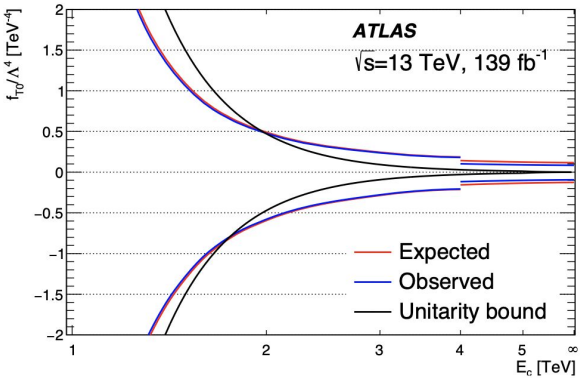
$$\sigma^{\text{pred}}_{Z\gamma\text{EWK}} = 0.98 \pm 0.02\,(\text{stat.}) \pm 0.09\,(\text{scale}) \pm 0.02\,(\text{PDF})\ \text{fb}$$

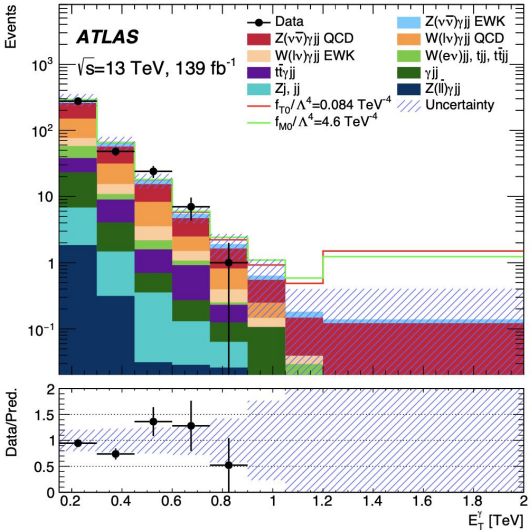
$$\sigma_{Z\gamma\text{EWK}} = 0.77^{+0.34}_{-0.30}\ \text{fb}$$

CERN-EP-2022-138: Accepted by JHEP

EFT Interpretation

- Limits on T0, T5, T8, T9, M0, M1, M2 dim-8 EFT operator coefficients
- Clipping used for unitarized limits: remove anomalous signal at particle level for $M_{Z\gamma} > E_c$

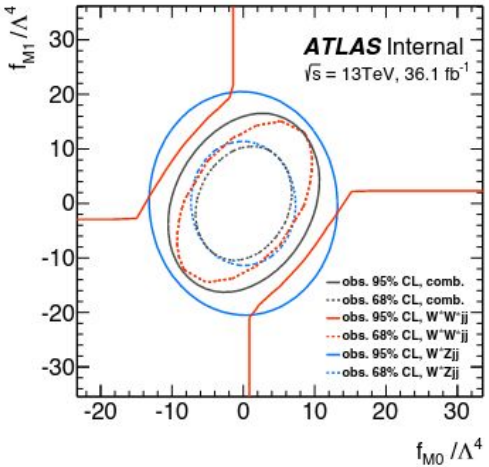


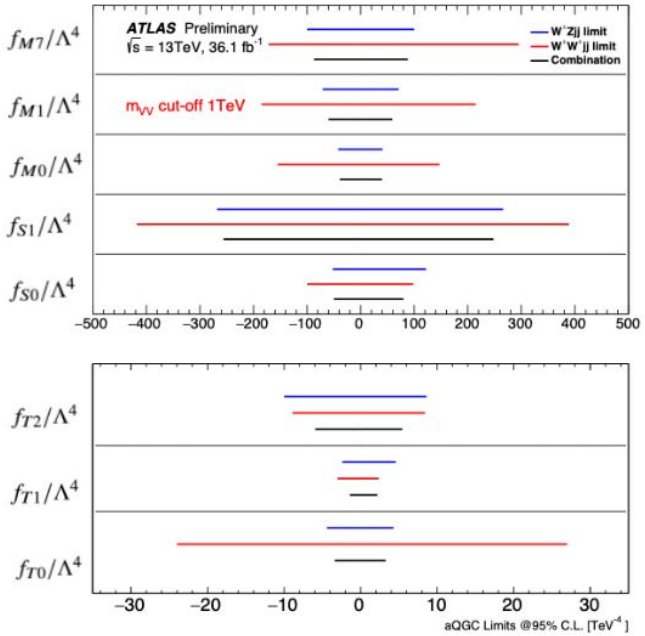


Coefficient	E_c [TeV]	Observed limit [TeV^{-4}]	Expected limit [TeV^{-4}]
f_{T0}/Λ^4	1.7	$[-8.7, 7.1] \times 10^{-1}$	$[-8.9, 7.3] \times 10^{-1}$
f_{T5}/Λ^4	2.4	$[-3.4, 4.2] \times 10^{-1}$	$[-3.5, 4.3] \times 10^{-1}$
f_{T8}/Λ^4	1.7	$[-5.2, 5.2] \times 10^{-1}$	$[-5.3, 5.3] \times 10^{-1}$
f_{T9}/Λ^4	1.9	$[-7.9, 7.9] \times 10^{-1}$	$[-8.1, 8.1] \times 10^{-1}$
f_{M0}/Λ^4	0.7	$[-1.6, 1.6] \times 10^{2}$	$[-1.5, 1.5] \times 10^{2}$
f_{M1}/Λ^4	1.0	$[-1.6, 1.5] \times 10^{2}$	$[-1.4, 1.4] \times 10^{2}$
f_{M2}/Λ^4	1.0	$[-3.3, 3.2] \times 10^{1}$	$[-3.0, 3.0] \times 10^{1}$

aQGC Re-interpretation of $W^{\pm}Zjj$ and $W^{\pm}W^{\pm}jj$

- Re-interpretation of $W^{\pm}Zjj$ (Phys. Lett. B 793 (2019) 469) and $W^{\pm}W^{\pm}jj$ (Phys. Rev. Lett. **123**, 161801)
- 1-D and 2-D limits for S0, S1, T0, T1, T2, M0, M1, M7



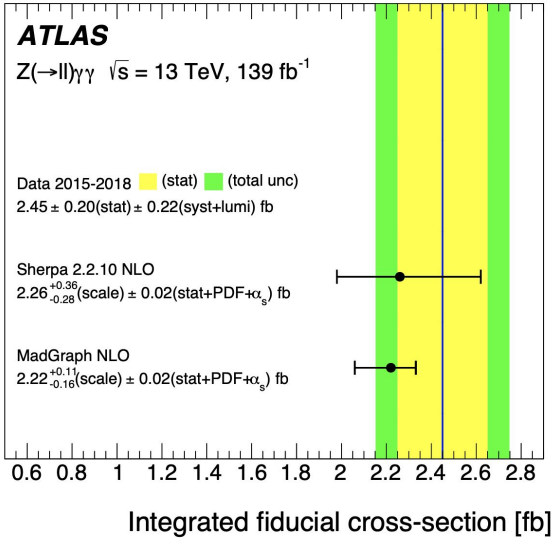


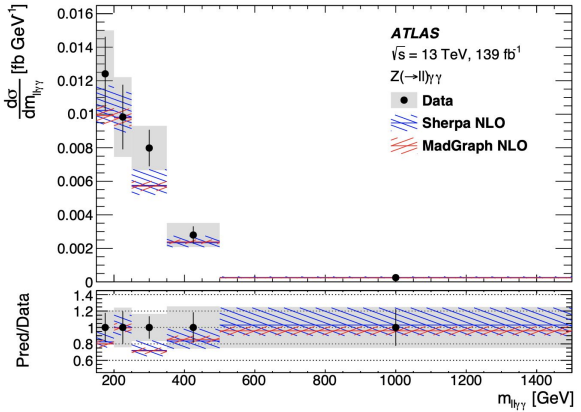
ATL-PHYS-PUB-2023-002

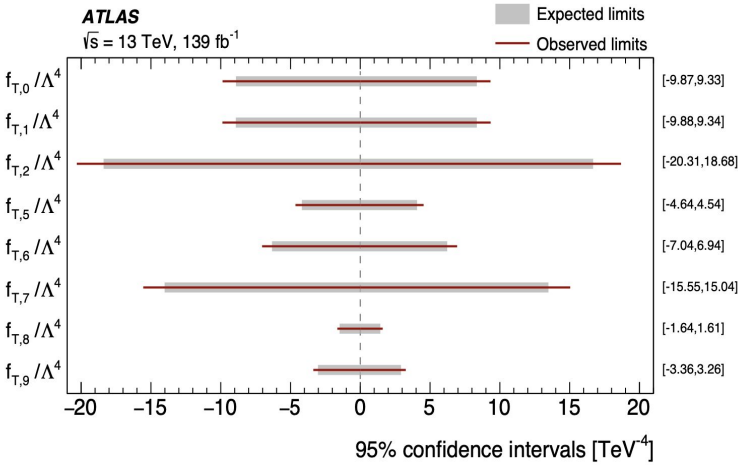
$Z\gamma\gamma$ Production

- Signal region defined by MII + min (M_{lly1},M_{lly2}) > 2 M_Z
- ISR dominated

- Integrated and differential cross sections in M_{ll}, $M_{\gamma\gamma}$, $p_T^{ll\gamma\gamma}$, p_T^{ll}, $E_T^{\gamma 1}$, $E_T^{\gamma 2}$ and comparison with NLO predictions from SHERPA 2.2.10 and MadGraph
- Limits on T0, T1, T2, T5, T6, T7, T8, T9 dim-8 EFT operator coefficients

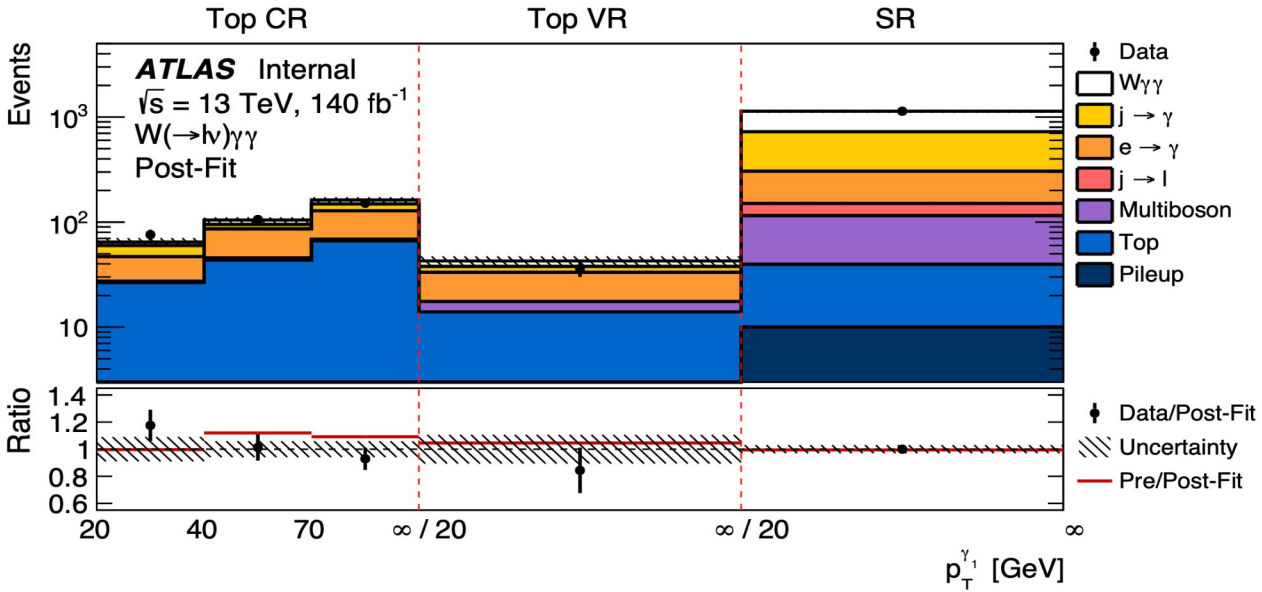






CERN-EP-2022-192
Accepted by EPJC

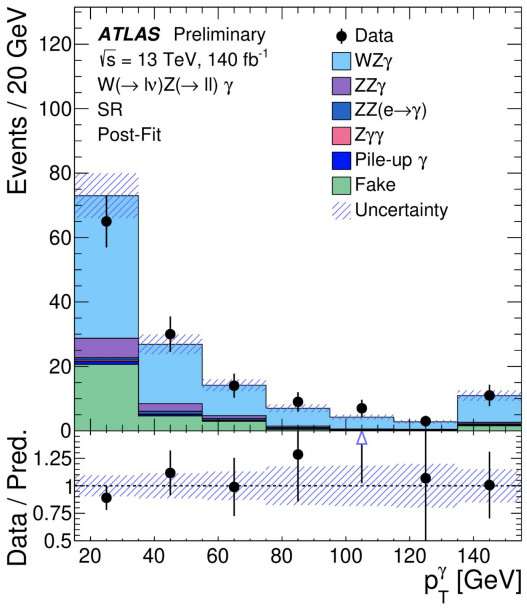
$W^{\pm}\gamma\gamma$ Production

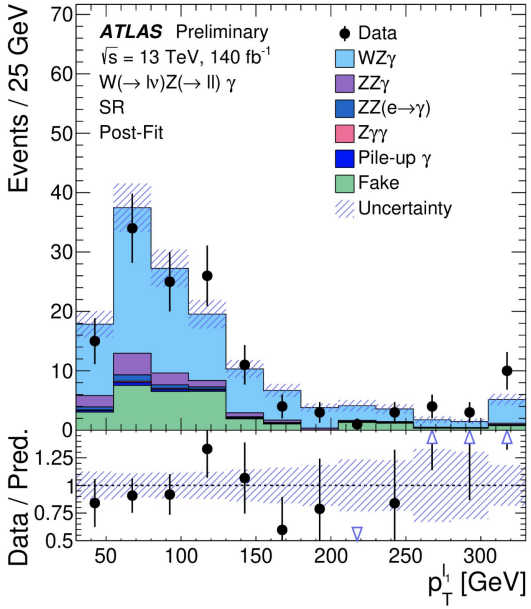


- First observation!
- 5.6 σ (5.6 σ) observed (exp.)
- Signal process modelled with SHERPA 2.2.10
- Large jet and electron photon mis-ID backgrounds estimated with data driven method.
- $tt\gamma$ background normalization fit in CR

$$\sigma_{\text{fid}} = 12.2^{+2.1}_{-2.0}\ \text{fb} \qquad \sigma_{\text{pred}} = 12.02 \pm 0.31\ \text{fb}$$

$W^{\pm}Z\gamma$ Production





- First observation!
- Signal process modelled with SHERPA 2.2.11
- 6.3σ (5.0σ) observed (exp.)
- Jet to Photon and lepton mis-ID backgrounds estimated with data driven method.
- ZZ and $ZZ\gamma$ background normalization fit in CR

σ^{obs} = 2.01±0.30(stat.)±0.16(syst.)fb

$\sigma^{pred.}$ = 1.50±0.06fb

ATLAS-CONF-2023-014

Conclusions

- VBS and Triboson Production are sensitive to Quartic Electroweak couplings.
- Uniquely possible in the LHC Era
- Sensitive to aQGC
- Many new results in ATLAS run 2:
  - Electroweak Z(**νν**)γ jj production
  - aQGC Re-interpretation of $W^{\pm}Zjj$ and $W^{\pm}W^{\pm}jj$
  - $Z\gamma\gamma$
  - $W^{\pm}\gamma\gamma$
  - $W^{\pm}Z\gamma$
- More to come!

Backup