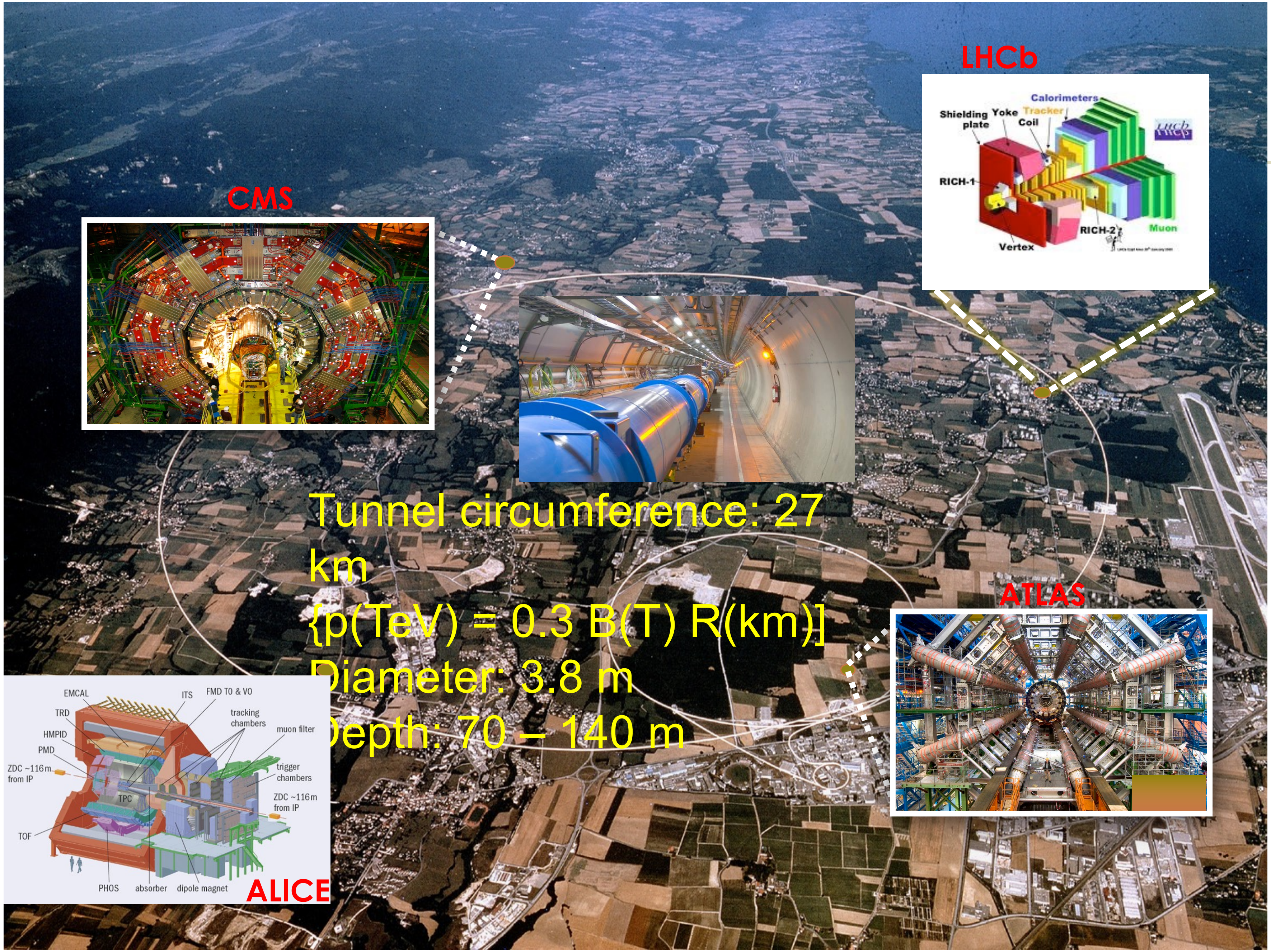
Recent diboson and multiboson results from ATLAS

李冰

山东大学

桂子山粒子物理前沿研究论坛
华中师范大学，10.14, 2023

Experiments at Large Hadron Collider



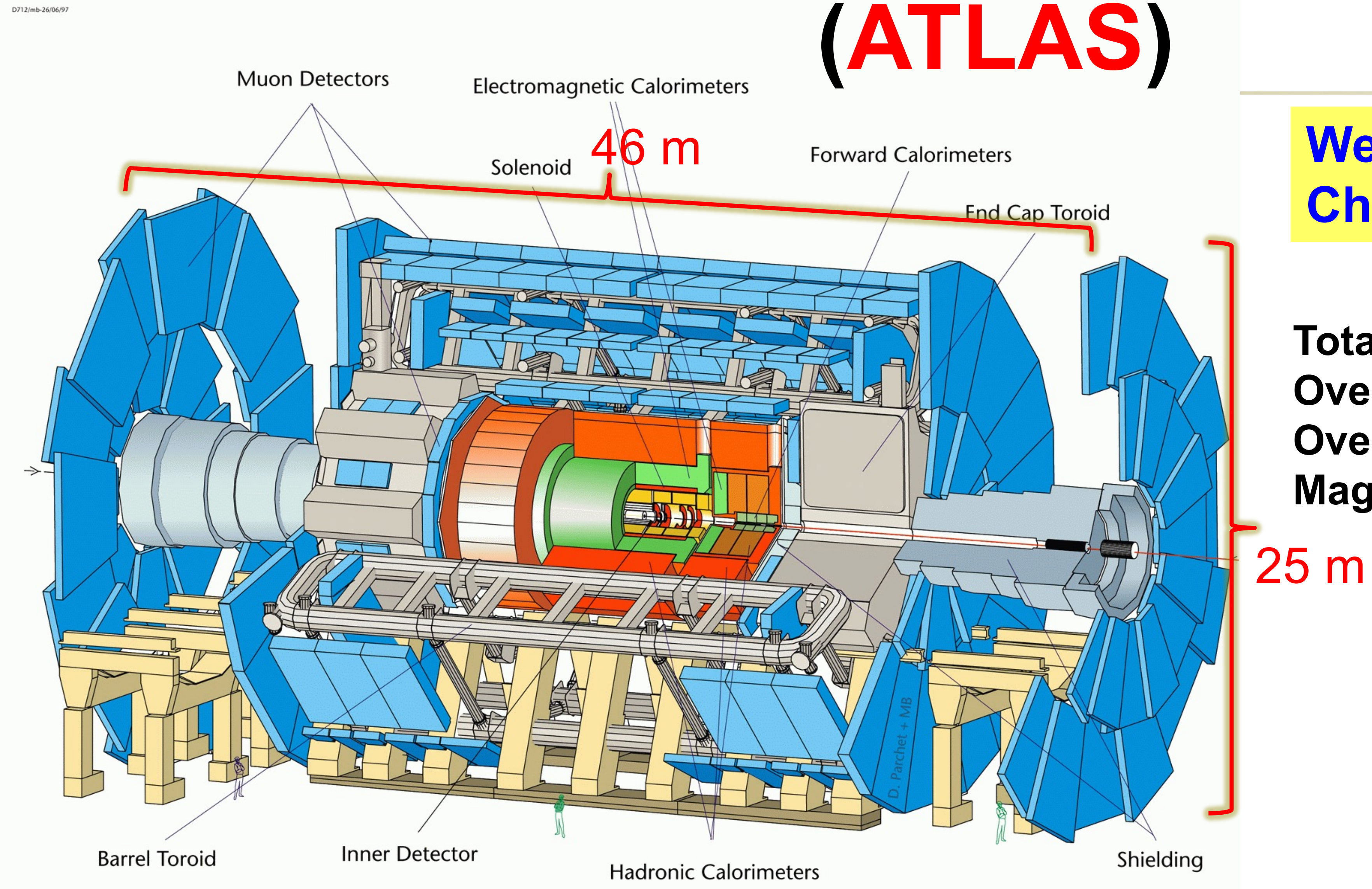
pp collider (also can collide heavy ion particles)

Run 1: 7, 8 TeV

Run 2: 13 TeV

Run 3: 13.6 TeV

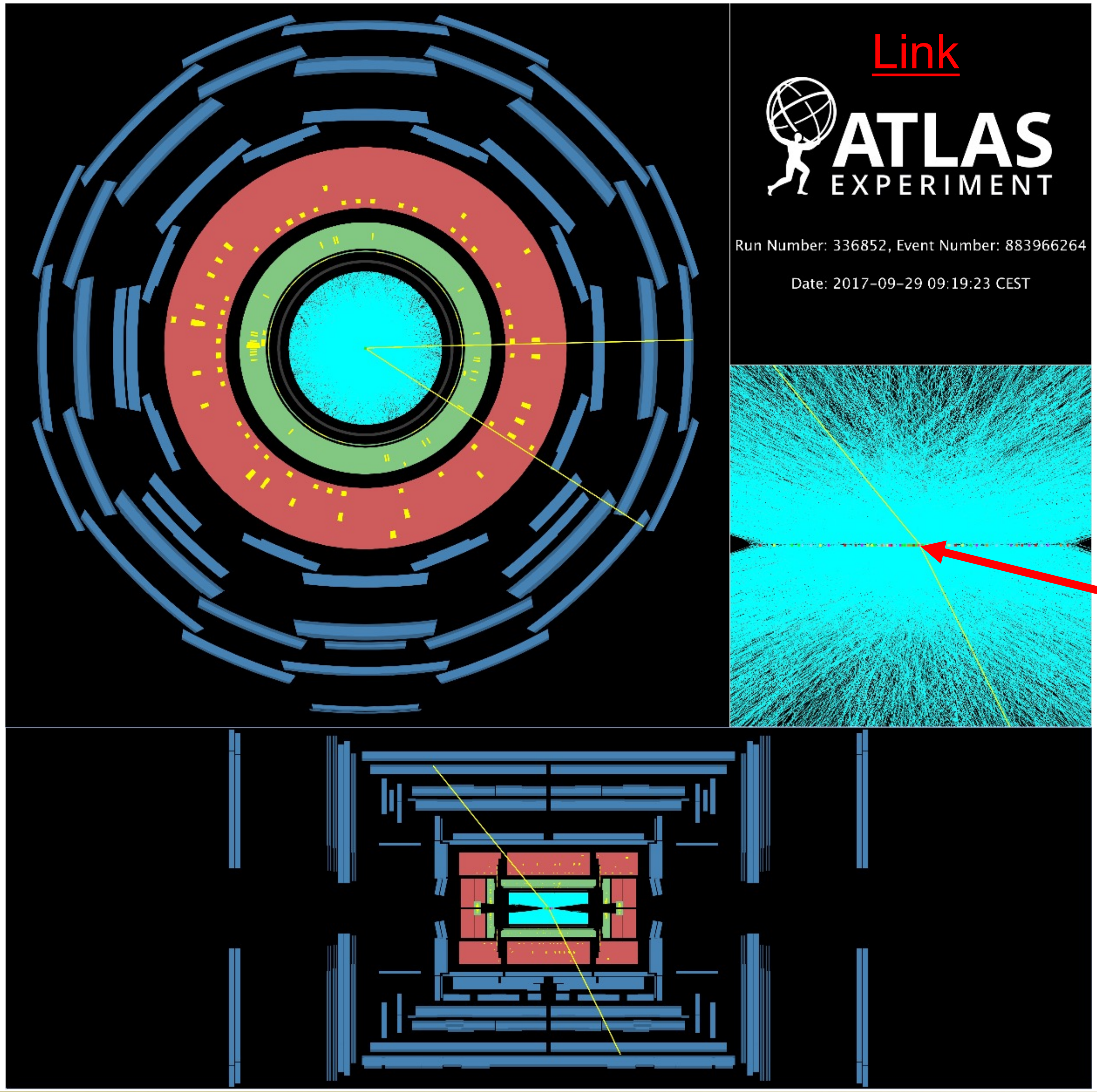
A Toroidal LHC ApparatuS (ATLAS)



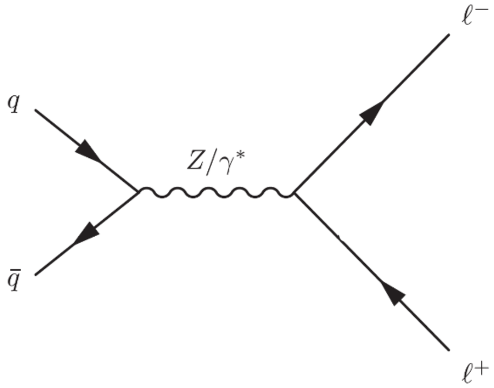
Weight : ~ 7000 tons
Channels: ~ 10^8

Total weight: 7900 T
Overall diameter: 25 m
Overall length: 46 m
Magnet filed: 2, 3-8 Tesla

What's happening inside the detector

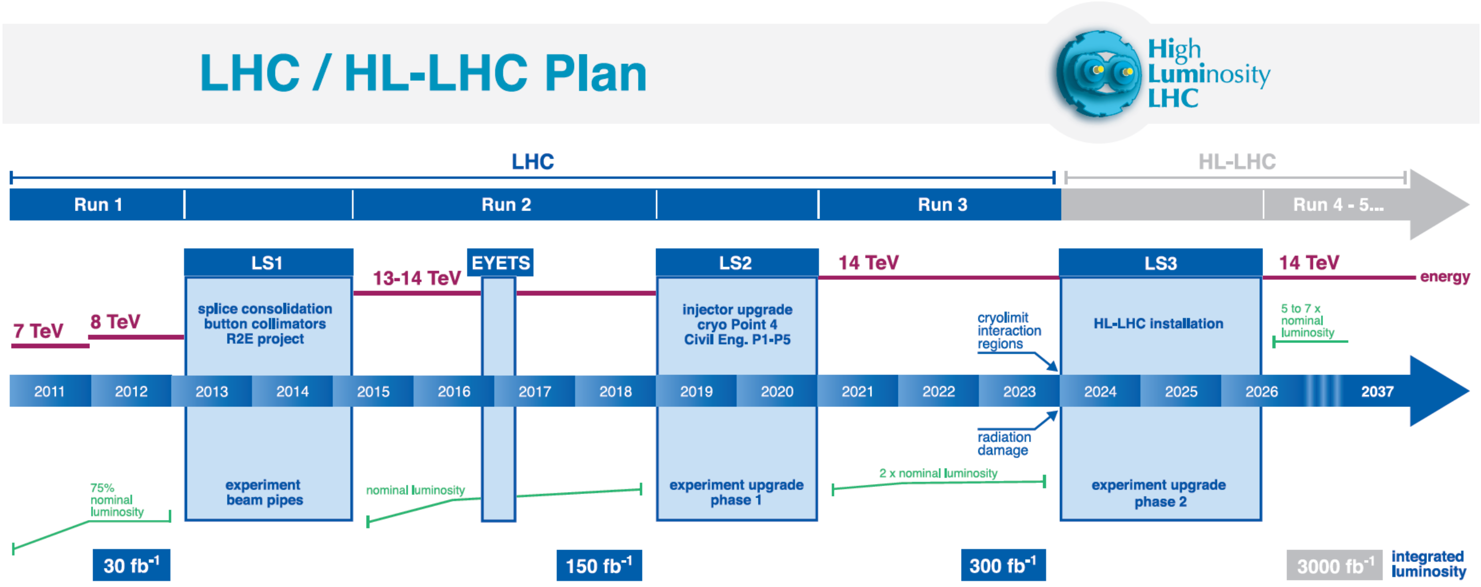


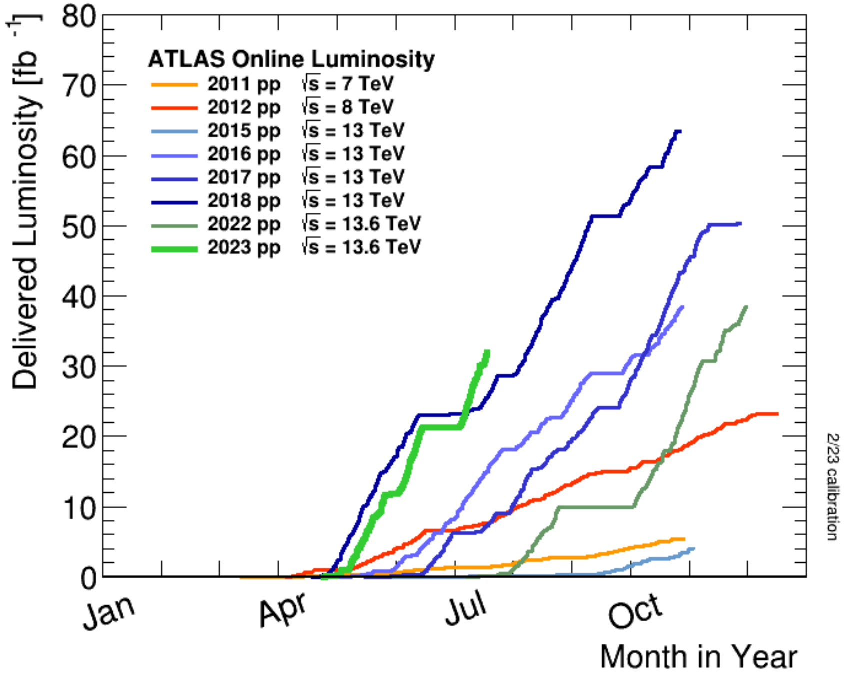
A reconstructed Z→μμ candidate event from the simple physics process

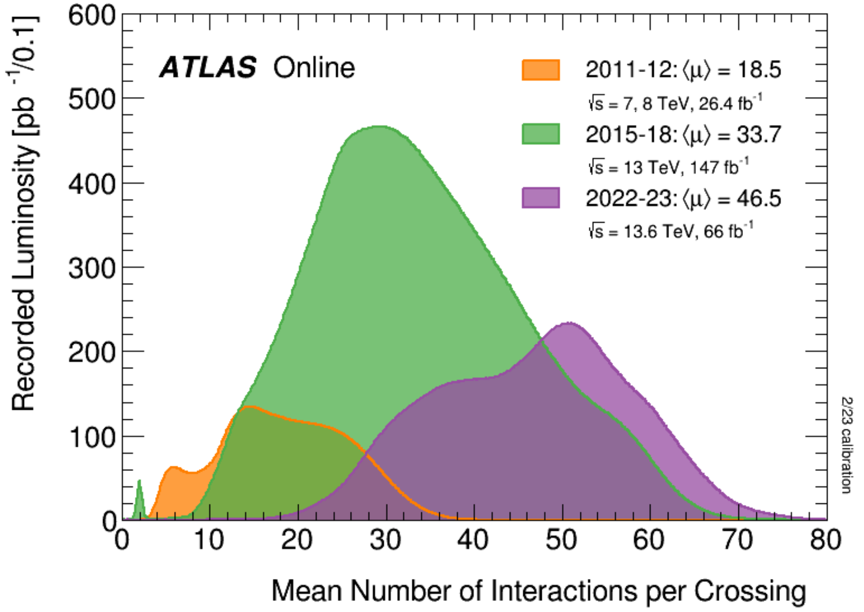


- ✓ Very complicated experimental environments in proton-proton collisions
- ✓ One vertex correctly reconstructed from 66 candidates. Two muons correctly reconstructed and calibrated, from numerous tracks.

ATLAS Run 2 and Run 3







Run 3 plan
Starts in 2021, collide at 14 TeV, deliver 300/fb pp data

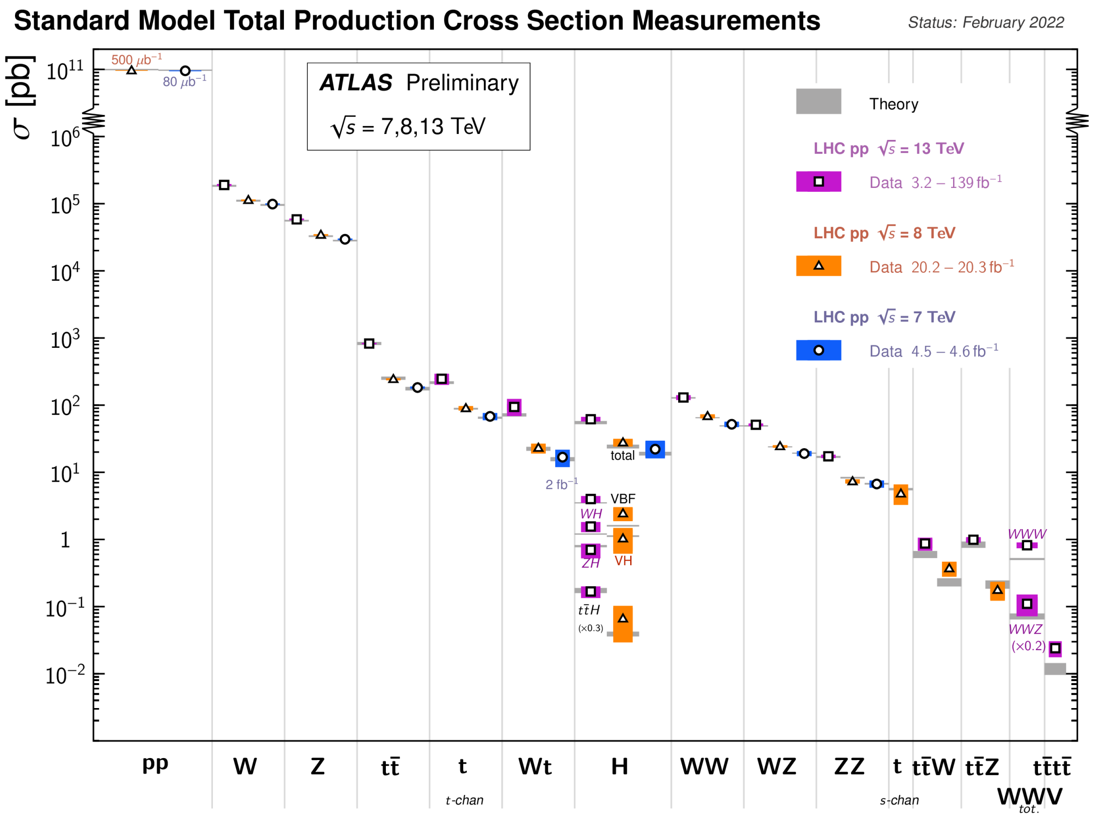
Run 3 reality
Starts in 2022, collide at 13.6 TeV, deliver XX pp data?

Nothing is simple ☺

ATLAS Physics

- SM precision measurements and rare processes
- Higgs (and di-Higgs) measurements and searches
- Searches for new physics beyond SM
- Heavy flavor physics
- Heavy ion physics

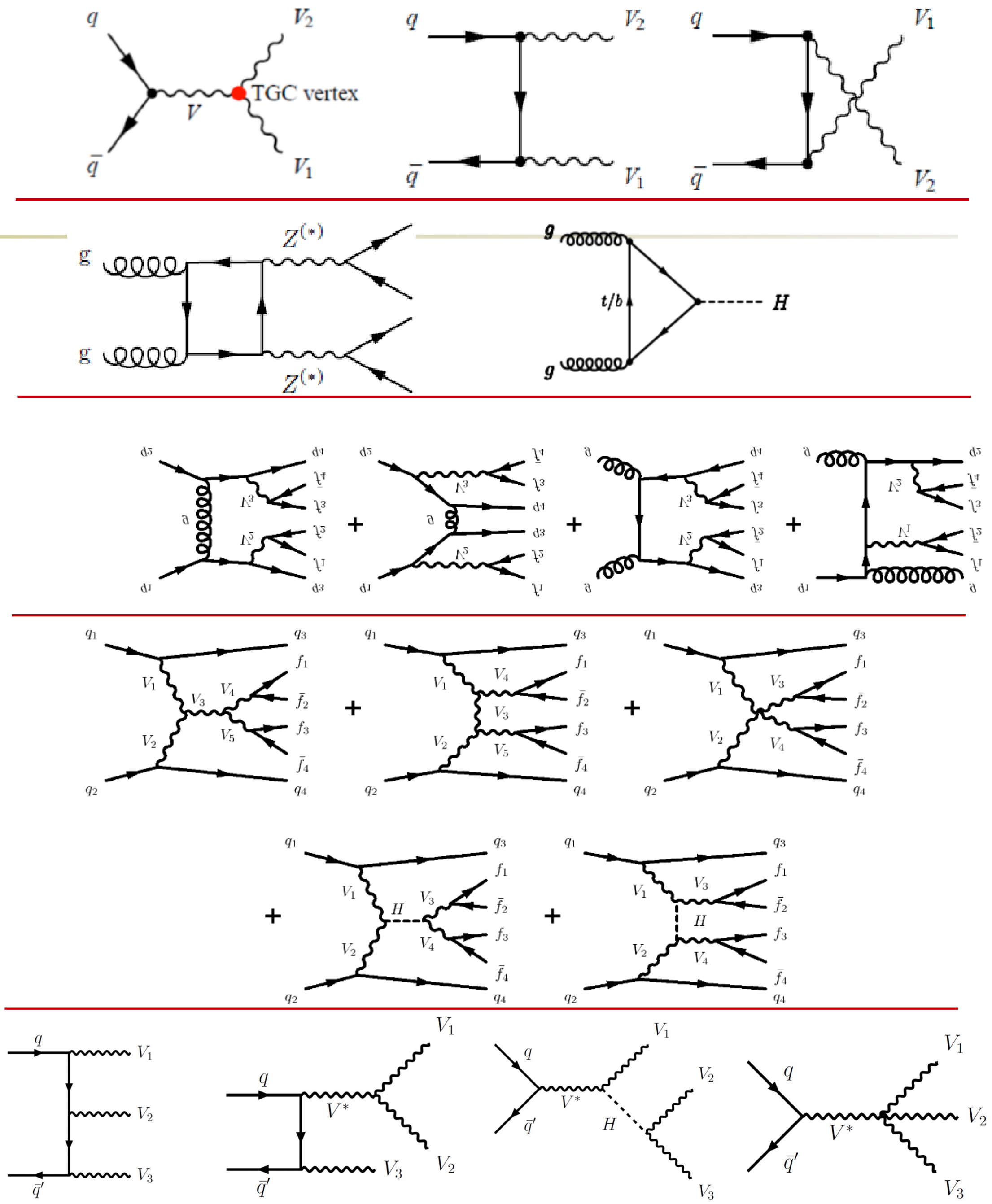
Full list of ATLAS public results



ATLAS summary plots

Multi-boson production

* Measurement of multi-boson productions at LHC is important to test the validity of the SM at TeV scale
  * Many precision differential measurements
  * VBF/S processes with relative lower cross-section, being key process to probe the mechanism of electroweak symmetry breaking (EWSB)
* Involve with Triple or Quartic Gauge Couplings (T/QGCs)
  * To look for vector boson self-couplings
  * Probe new physics through deviations from SM couplings
* EFT interpretation $\mathcal{L}_{\mathrm{SMEFT}} \approx \mathcal{L}_{\mathrm{SM}}^{(4)} + \sum_i \frac{c_i^{(6)}}{\Lambda^2} O_i^{(6)} + \sum_j \frac{c_j^{(8)}}{\Lambda^4} O_j^{(8)}$
* A way to search for high mass resonance decaying to VV final state

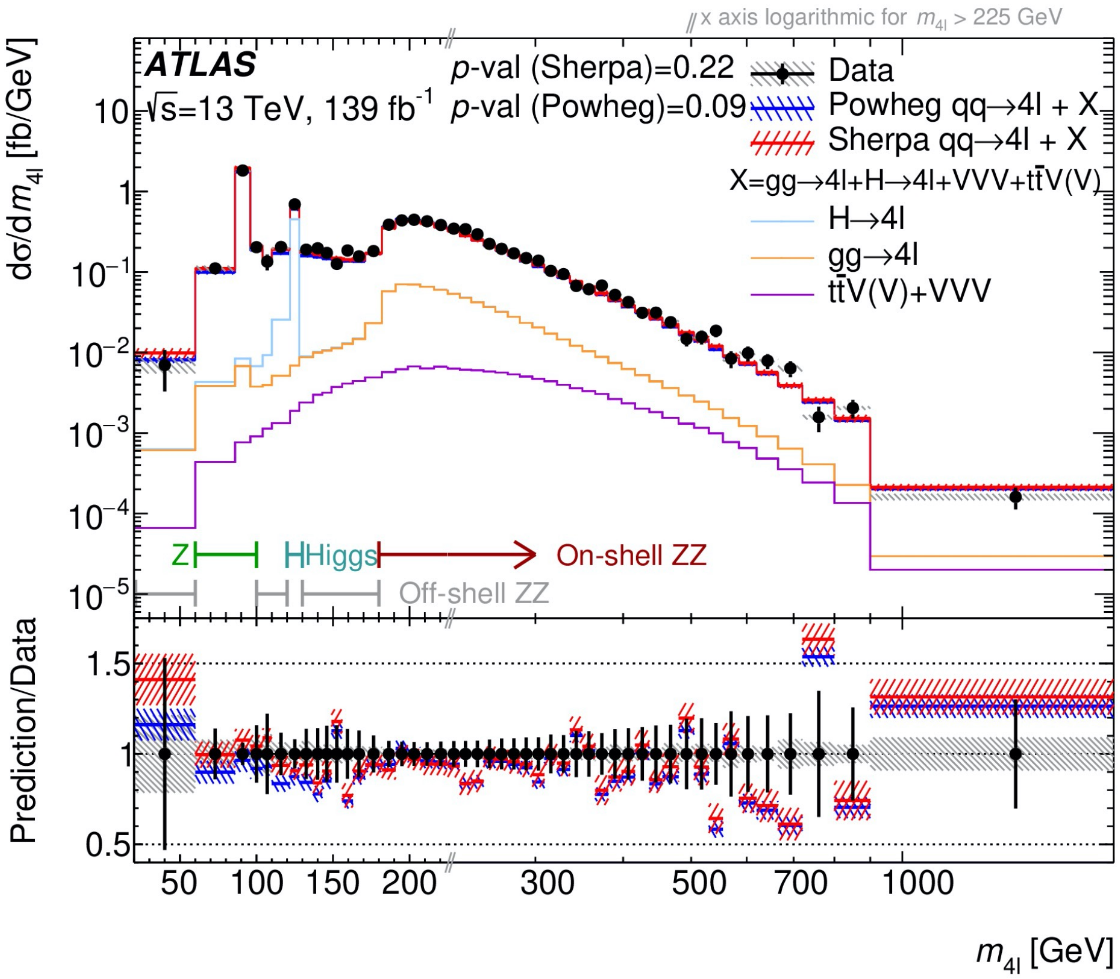


Precision measurements of diboson processes

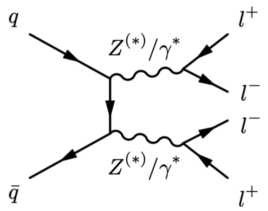
With Run-2 luminosity, ATLAS has been able to provide precision measurements of diboson processes, and start to looking into polarization studies

Inclusive ZZ$^{(*)}$→4l Measurements

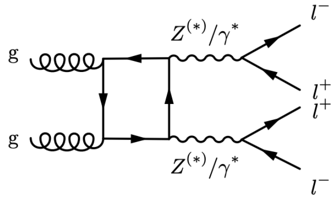
JHEP 07 (2021) 005



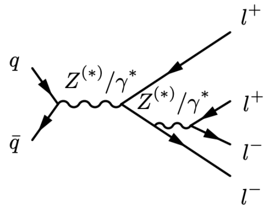
- ✓ Vey rich physics information can be obtained from the four-lepton channel, given the very clean and fully reconstructable final states
- ✓ Very clear structures in the four-lepton mass distributions at different mass regions
- ✓ Z region, Higgs region, on-shell ZZ region and off-shell ZZ region



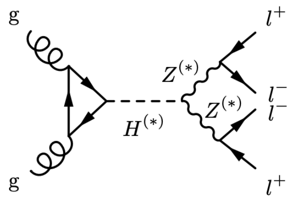
On-shell ZZ region from qq



On-shell ZZ region from gg



Z region

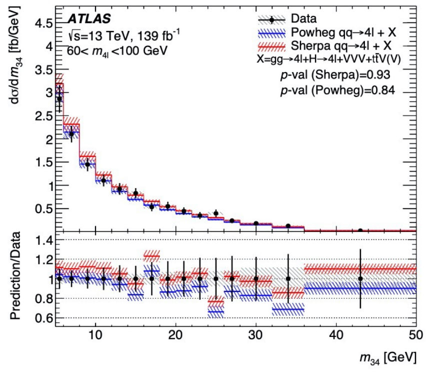


Higgs region

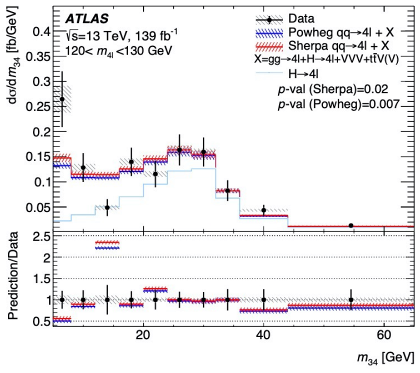
Differential measurements and BSM interpretation

JHEP 07 (2021) 005

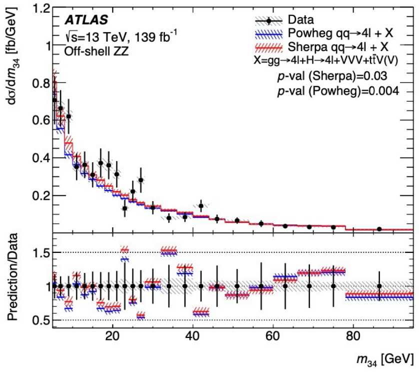
- Differential cross sections measured vs. several variables, in four different m_{4l} region
  - m_{12}, m_{34}, p_T^{12}, p_T^{34}, $\cos\theta_{12}$ …



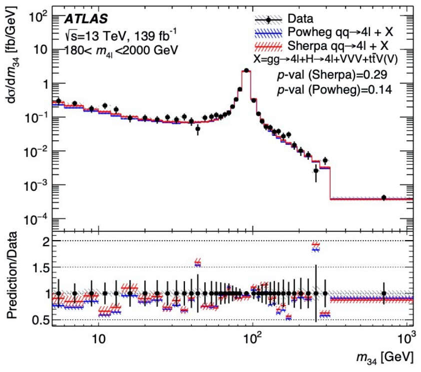
(a) $Z \to 4\ell$ region



(b) $H \to 4\ell$ region

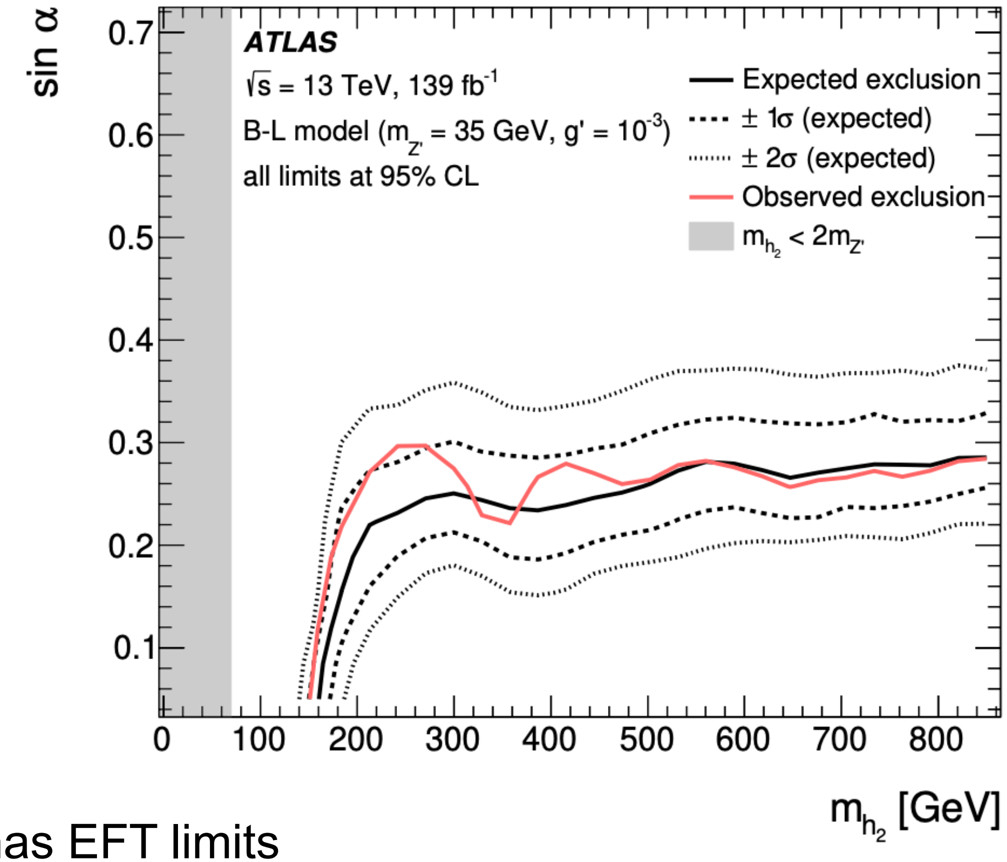


(c) Off-shell ZZ region



(d) On-shell ZZ region

An example for BSM interpretation with a model in which the global baryon-number-minus-lepton-number (B−L) symmetry is treated as a local gauge symmetry and spontaneously broken (JHEP 08 (2018) 181)

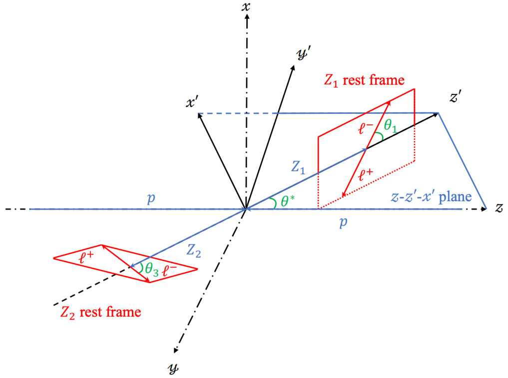


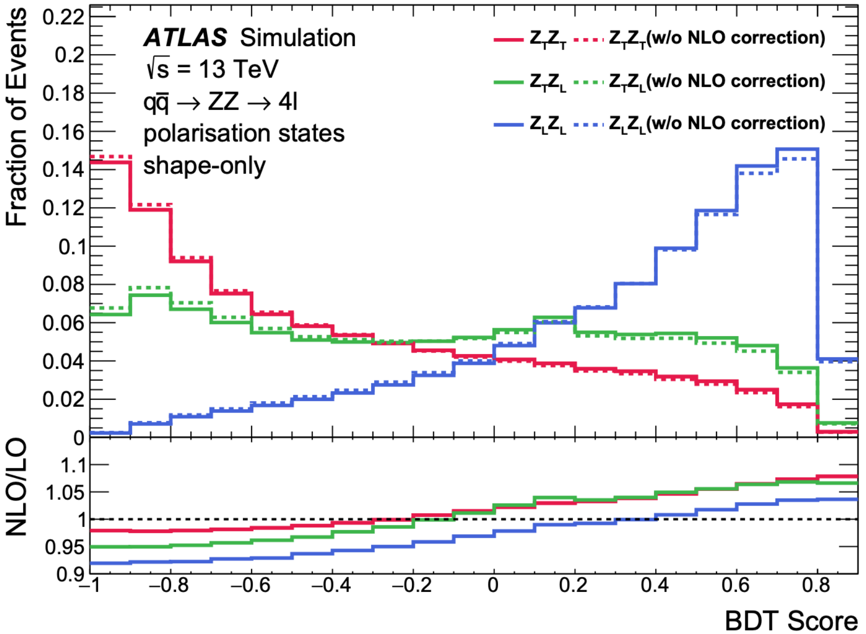
Also has EFT limits

arXiv:2310.04350

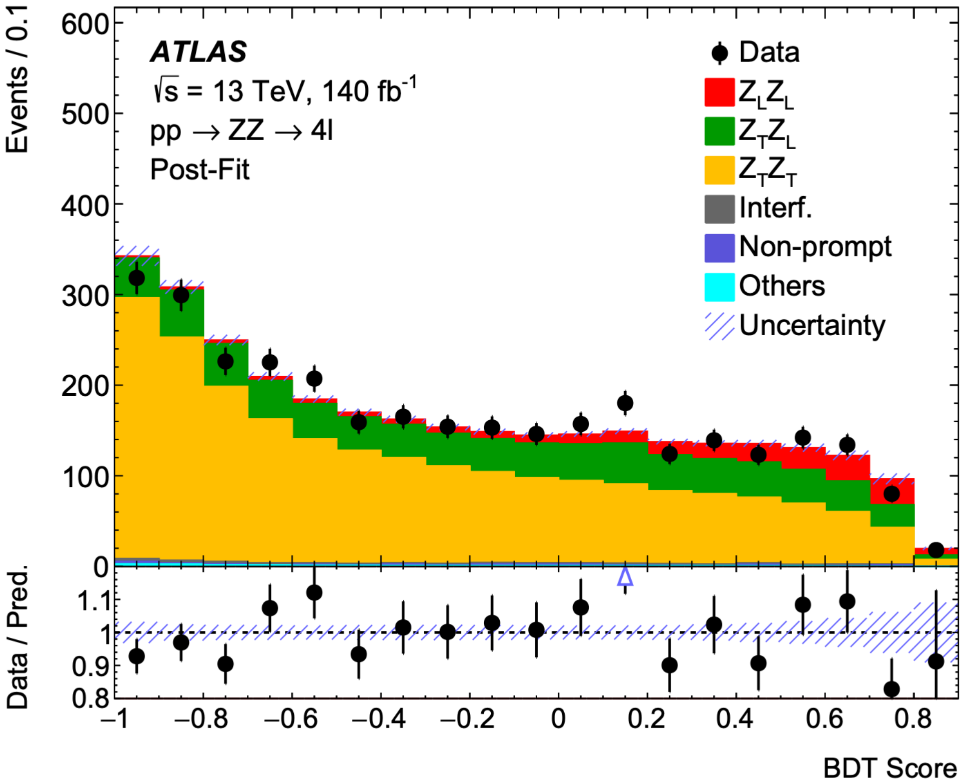
Polarization measurements at ZZ channel

- Using events from the on-shell ZZ region
- Observed 4.3σ for the $Z_L Z_L$, two longitudinally polarized Z bosons





Modelling of different polarization fractions are important for such measurement

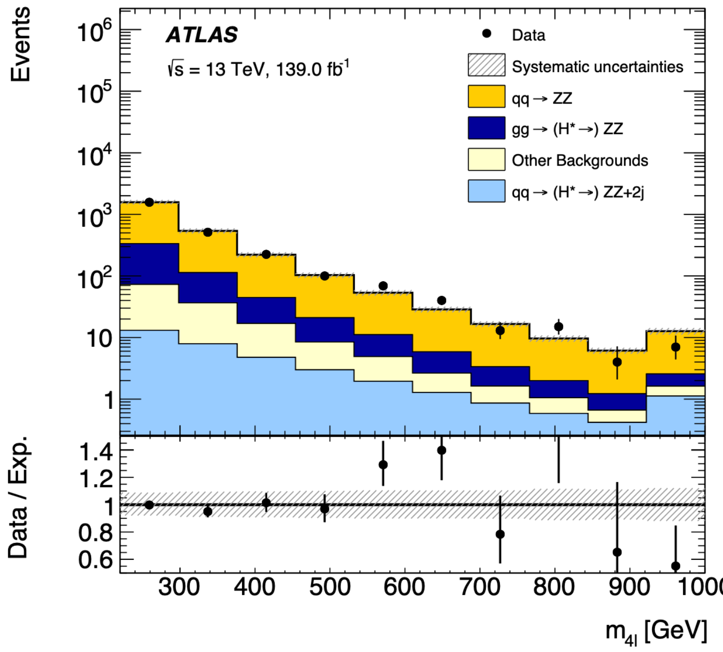


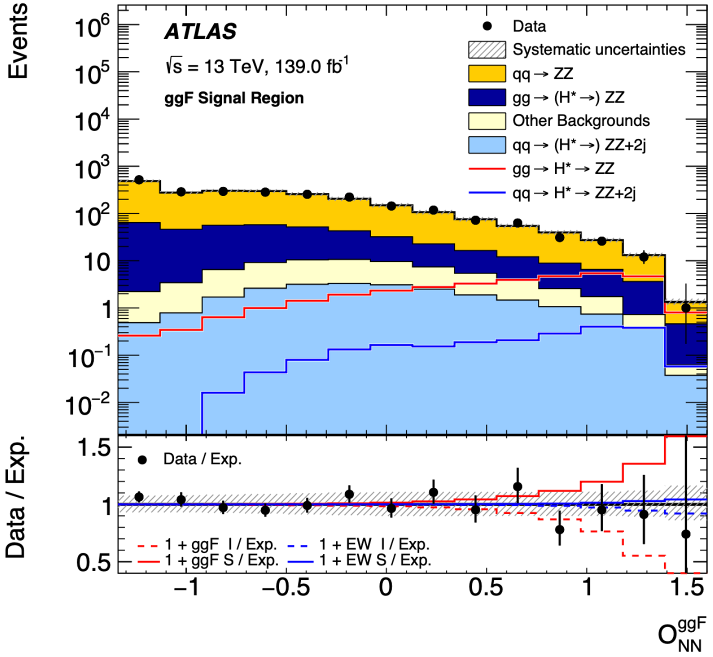
		Pre-fit	Post-fit
ZZ	$Z_L Z_L$	189.3 ± 8.7	220 ± 54
	$Z_T Z_L$	710 ± 29	711 ± 29
	$Z_T Z_T$	2170 ± 120	2147 ± 60
	Interference	33.7 ± 2.8	33.4 ± 2.7
Non-prompt		18.7 ± 7.1	18.5 ± 7.0
Others		20.0 ± 3.7	19.9 ± 3.7
Total		3140 ± 150	3149 ± 57
Data		3149	3149

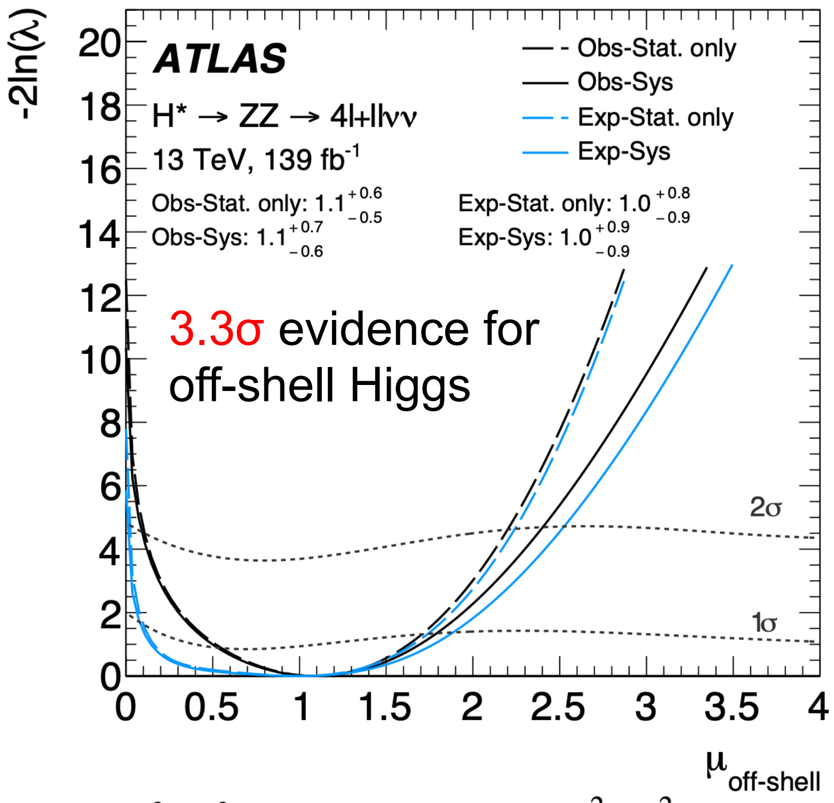
Measuring the Higgs width

arXiv:2304.01532

- With a precise measurement of the qq→ZZ process, the Higgs width could be constraint through its interference effect with the gg box process, under certain assumptions







$$\sigma^{on\text{-}shell}_{gg\to H\to ZZ} \sim \frac{g^2_{ggH} g^2_{HZZ}}{m_H \Gamma_H} \qquad \sigma^{off\text{-}shell}_{gg\to H\to ZZ} \sim \frac{g^2_{ggH} g^2_{HZZ}}{m^2_{ZZ}}$$

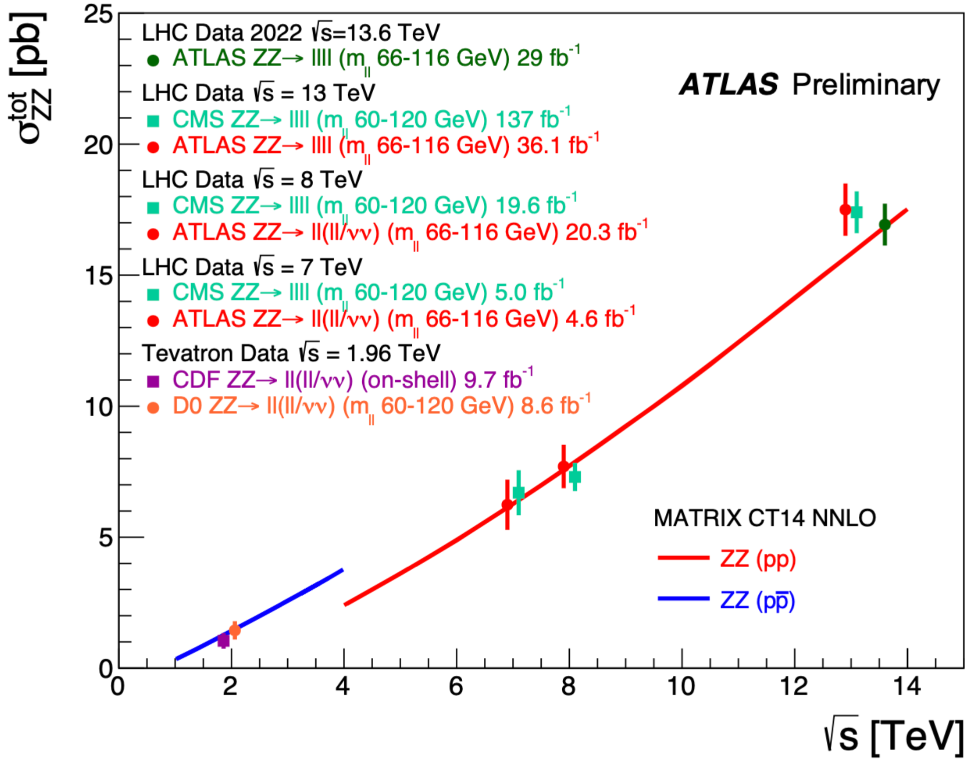
Assuming no BSM effect and combine with on-shell Higgs measurement → measured Higgs total width: 4.5 +3.3 -2.5 MeV

Not possible for direct measurement at LHC due to detector resolution at GeV

ZZ measurement at 13.6 TeV

ATLAS-CONF-2023-062

- Fresh new results with Run-3 data!
- ATLAS introduced new slim data format to deal with the bigger and bigger data size



Dear 13.6 TeV ZZ Cross-Section Team,

Email from ATLAS spokesperson

Congratulations on achieving the first public ATLAS result based on the PHYSLITE format — with the additional bonus of being a Run-3 result!

Following the announcement at the Vancouver ATLAS Week, and also at the ATLAS Weekly meeting, it is my huge pleasure to present you, on behalf of the Physics, Software & Computing Coordinators and ATLAS Management, with the PHYSLITE Champaign Challenge Award.

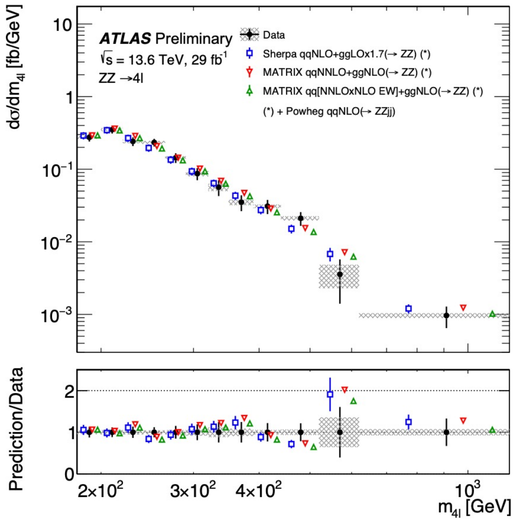
Champaign to be served to the team on Oct. 16 (next Monday)

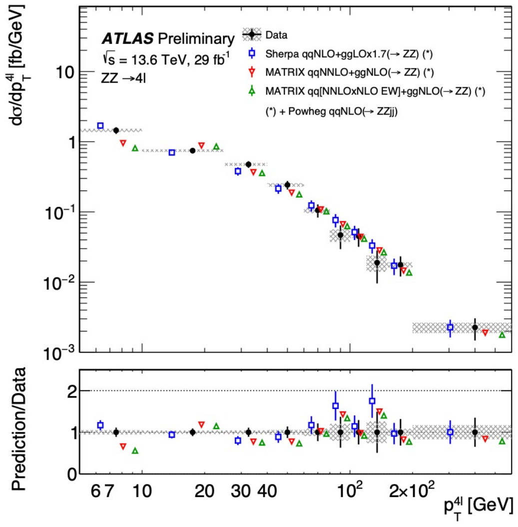
ATLAS measures ZZ production using Run-3 data and a new slim data format

Physics Briefing

25 August 2023 | By ATLAS Collaboration

The ATLAS Collaboration has just released a new measurement of the production cross section of two Z bosons. This highlight result examines data collected during Run 3 of the LHC – with protons colliding at a record energy of 13.6 TeV – and pioneers the use of PHYSLITE – a new, reduced data format that requires significantly less storage.

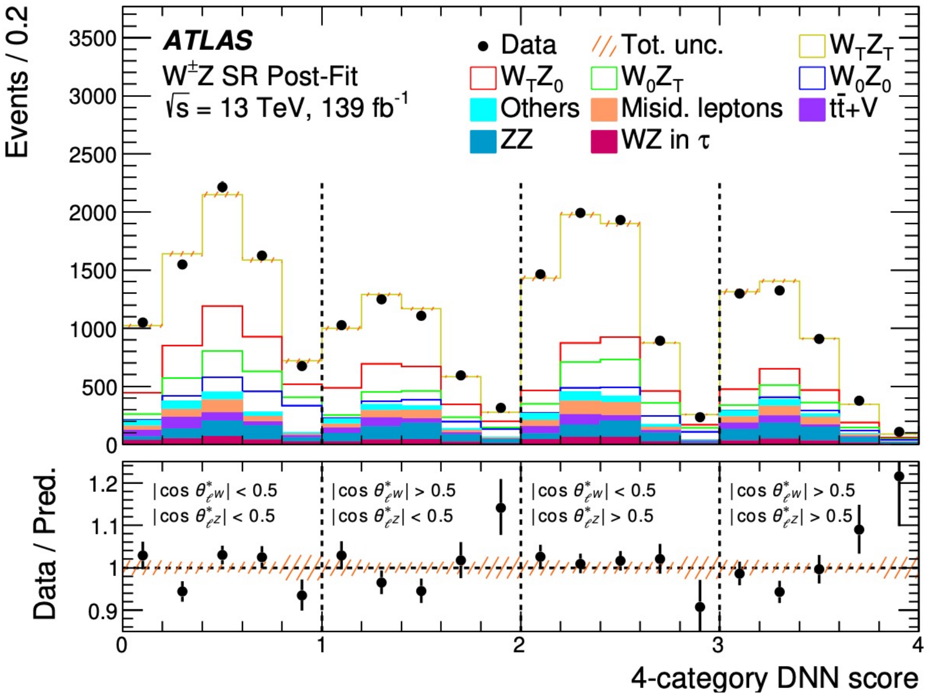


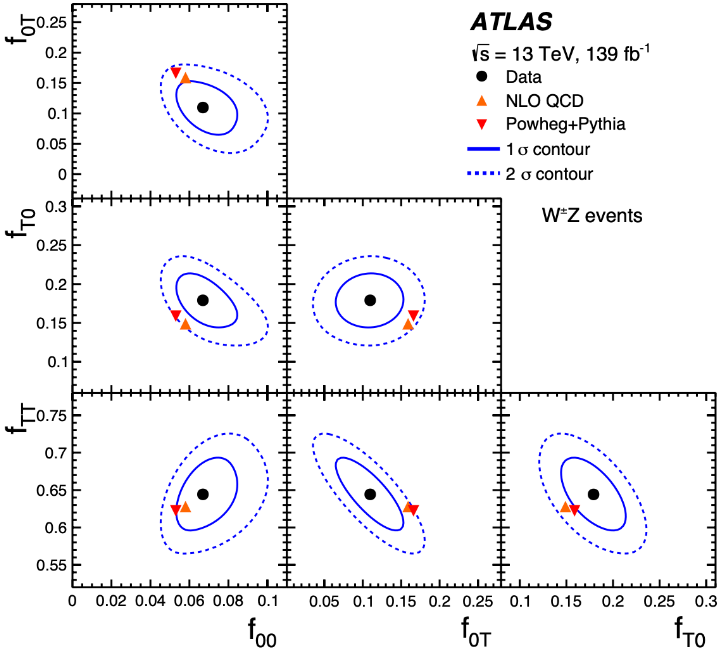


WZ polarization

Phys. Lett. B 843 (2023) 137895
Eur. Phys. J. C 79 (2019) 535

- Longitudinal component is critical to understand the Higgs mechanism and probe VBS unitarization
- ATLAS reports the first measurement of joint polarization, with significance of the double-longitudinal component of 7.1σ



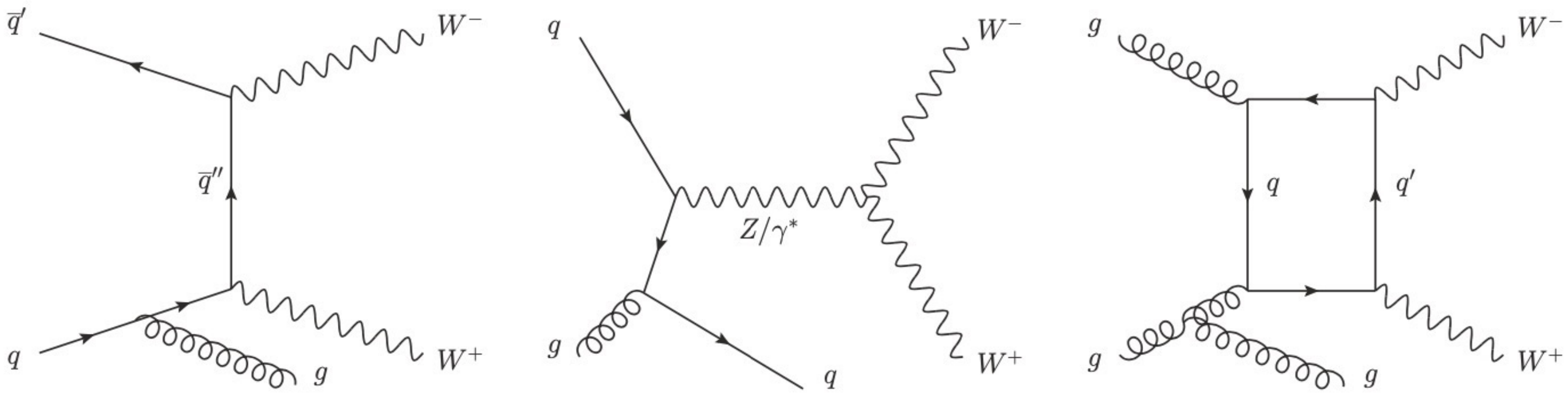


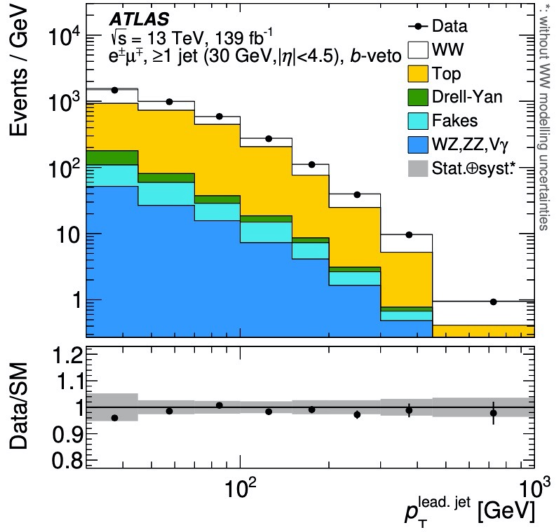
$$f_{00} = 0.067 \pm 0.010,\ f_{0T} = 0.110 \pm 0.029,\ f_{T0} = 0.179 \pm 0.023$$

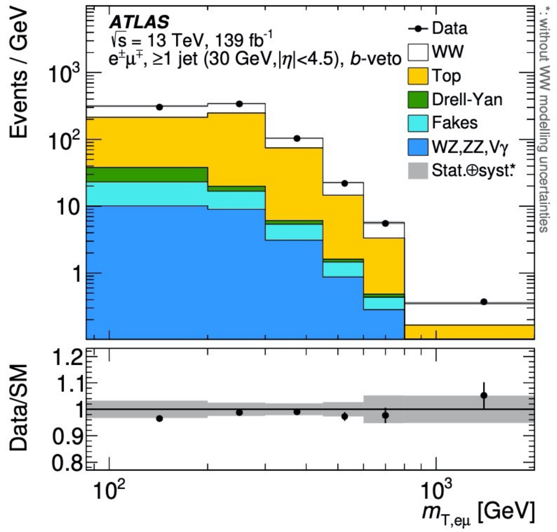
WW (→eνμν) + 1jet

JHEP 06 (2021) 003

- First differential measurements in this final state at the LHC
- Test of perturbative QCD and EW theory
- Dominant background from top processes
  - Estimated with data-driven method
  - Factor of 5 uncertainty reduction w.r.t. MC based



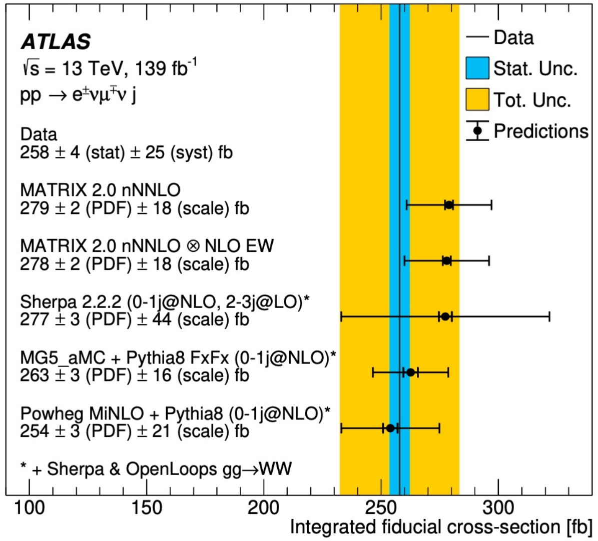




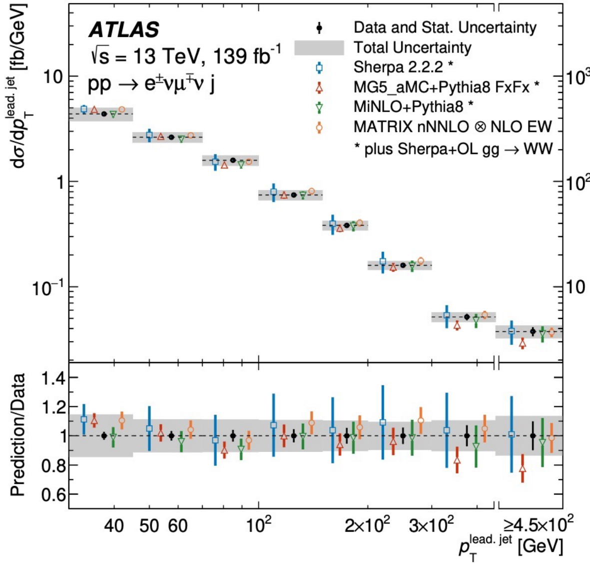
Crosse section measurements and EFT

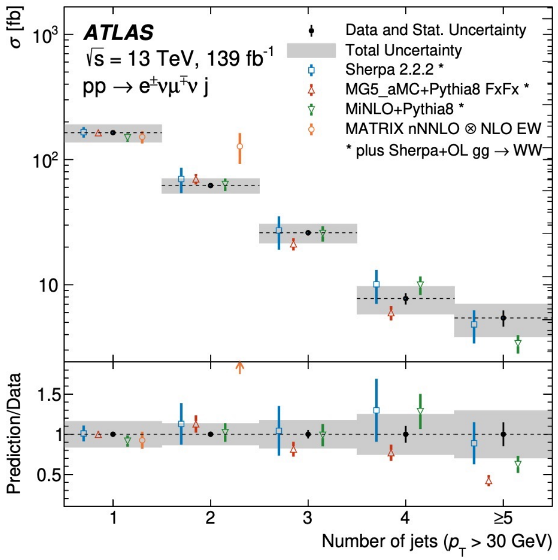
JHEP 06 (2021) 003

Integrated cross section, 10% uncertainty

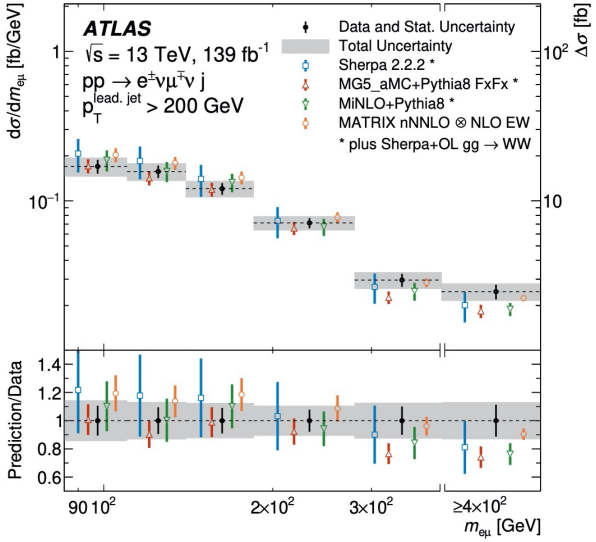


Very good agreement between measurements and SM predictions





Looking into high pT region (leading jet p_T > 200 GeV) Relative contributions from linear terms become larger



Jet p_T	Linear only	68% CI obs.	95% CI obs.	68% CI exp.	95% CI exp.
> 30 GeV	yes	[−1.64, 2.86]	[−3.85, 4.97]	[−2.30, 2.27]	[−4.53, 4.41]
> 30 GeV	no	[−0.20, 0.20]	[−0.33, 0.33]	[−0.28, 0.27]	[−0.39, 0.38]
> 200 GeV	yes	[−0.29, 1.84]	[−1.37, 2.81]	[−1.12, 1.09]	[−2.24, 2.10]
> 200 GeV	no	[−0.43, 0.46]	[−0.60, 0.58]	[−0.38, 0.33]	[−0.53, 0.48]

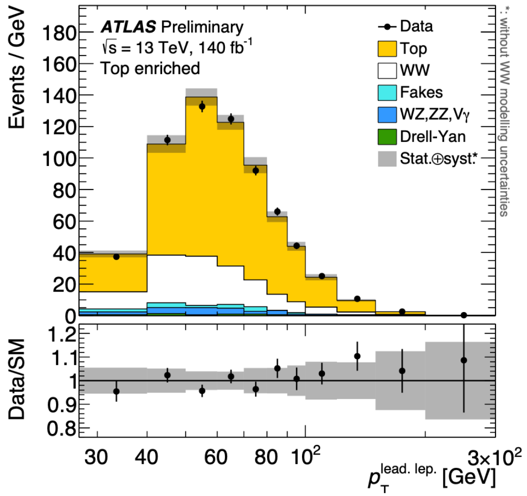
Looking into high pT events for EFT limit

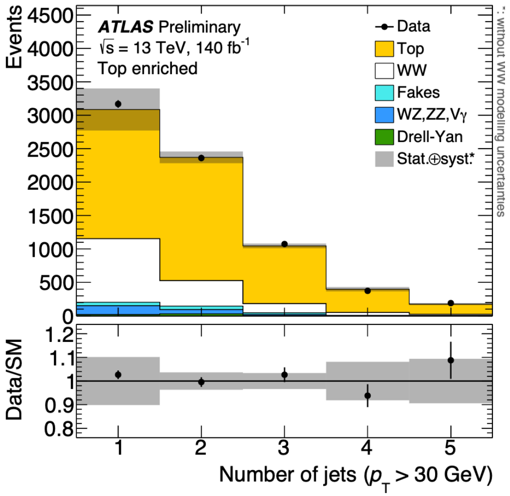
Fit on $m_{e\mu}$

Inclusive WW measurements

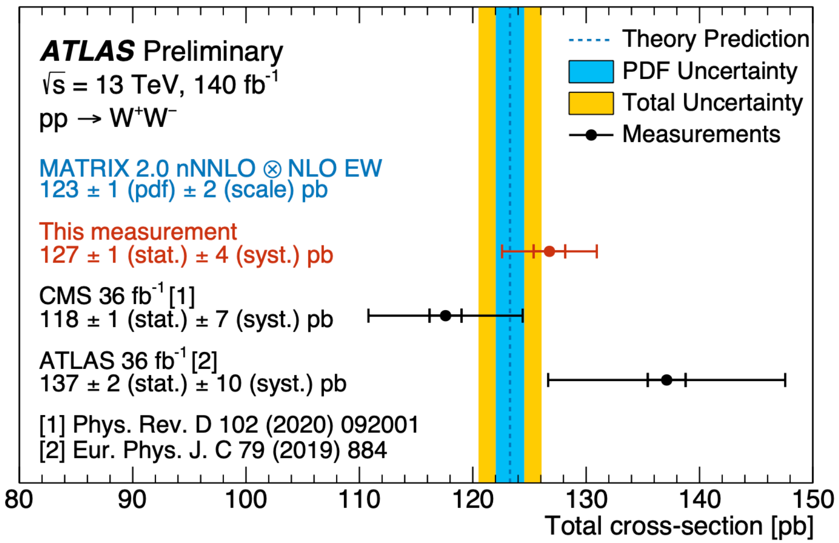
ATLAS-CONF-2023-012

- Jet inclusive phase space, allowing comparison to precise theoretical predictions
- WW decays leptonically to different flavor channels, WW→eνμν
- Dominant background from top processes





Uncertainty source	Effect
Total uncertainty	3.1%
Stat. uncertainty	1.1%
Top modelling	1.6%
Fake lepton background	1.5%
Flavour tagging	0.7%
Other background	0.9%
Signal modelling	1.0%
Jet calibration	0.6%
Luminosity	0.8%
Other systematic uncertainties	0.9%



Dedicated control region to estimate the top background (~80% of total background)

Good control of top systematic

Most precise measurement

Also have differential measurements. Check the CONF note

Observation of photon-induced WW production

Phys. Lett. B 816 (2021) 136190

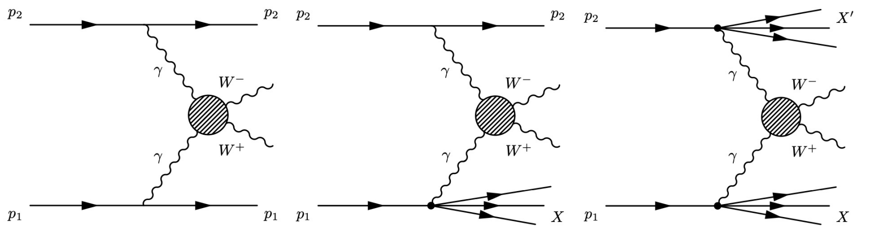
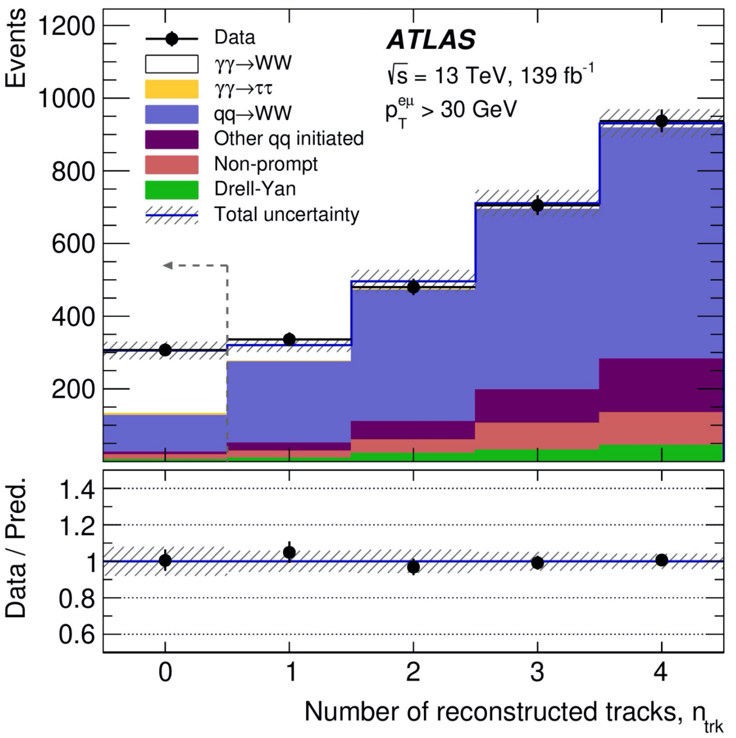


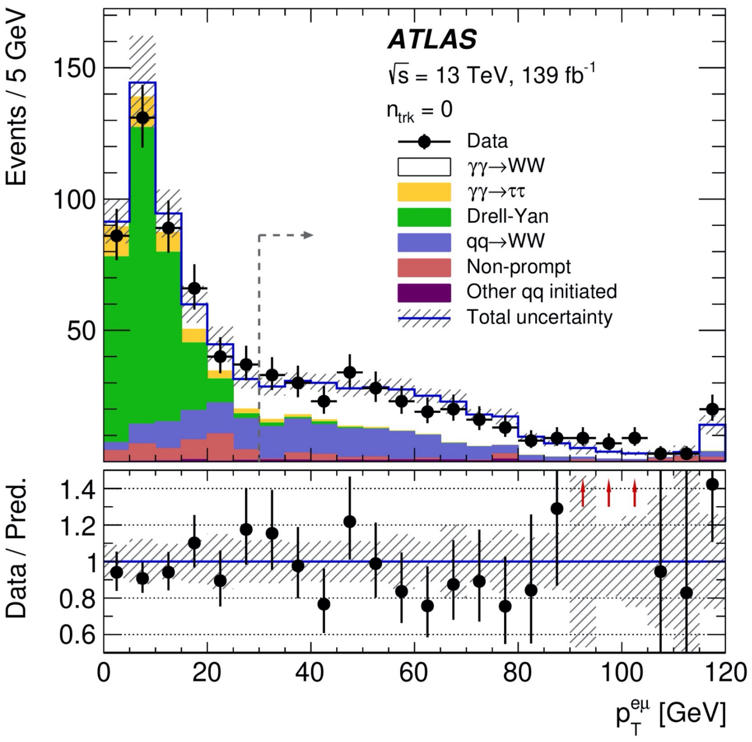
Figure 7: Diagrams for the exclusive $\gamma\gamma \to WW$ production representing the (a) elastic process and the inelastic processes consisting of (b) single-dissociation where one initial proton dissociates (SD) and (c) double-dissociation where both protons fragment (DD). The symbols X and X' denote any additional final state created.

- For the $pp(\gamma\gamma) \longrightarrow p(*)WWp(*)$
  - The final state protons stay either intact or fragments after emitting a photon (elastic, single-dissociative and double-dissociative WW production)
  - Rather clean events (two charged leptons and no additional charged-particle activity) for elastic case
  - In the dissociative cases, remaining charged particles often fall into the forward region beyond tracking detector
- Signal selections
  - eμ pairs with different charges, no tracks near leptons vertex, pT(ll) > 30 GeV (MET proxy)
- Major challenges
  - Modeling of number of charged particles from underlying events for background process
  - Corrected with data measurements of DY→ll production

Cross-section Measurements

[Phys. Lett. B 816 (2021) 136190]





	Signal region	Control regions		
n_{trk}	n_{trk} = 0		$1 \le n_{trk} \le 4$	
$p_T^{e\mu}$	> 30 GeV	< 30 GeV	> 30 GeV	< 30 GeV
$\gamma\gamma \to WW$	174 ± 20	45 ± 6	95 ± 19	24 ± 5
$\gamma\gamma \to \ell\ell$	5.5 ± 0.3	39.6 ± 1.9	5.6 ± 1.2	32 ± 7
Drell–Yan	4.5 ± 0.9	280 ± 40	106 ± 19	4700 ± 400
$qq \to WW$ (incl. gg and VBS)	101 ± 17	55 ± 10	1700 ± 270	970 ± 150
Non-prompt	14 ± 14	36 ± 35	220 ± 220	500 ± 400
Other backgrounds	7.1 ± 1.7	1.9 ± 0.4	311 ± 76	81 ± 15
Total	305 ± 18	459 ± 19	2460 ± 60	6320 ± 130
Data	307	449	2458	6332

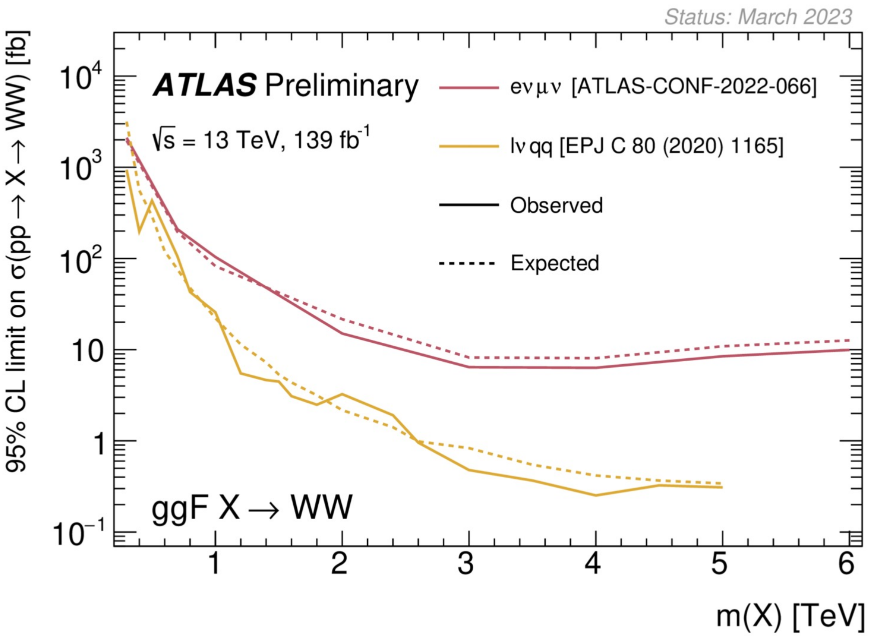
Integrated event yields from different regions are used in profile likelihood fit to get the signal events

Signal strength: $1.33^{+0.14}_{-0.14}\,(\text{stat.})^{+0.22}_{-0.17}\,(\text{syst.})$
Significance: 8.4 σ
Measured fiducial cross-section:
$3.13 \pm 0.31\,(\text{stat.}) \pm 0.28\,(\text{syst.})$ fb

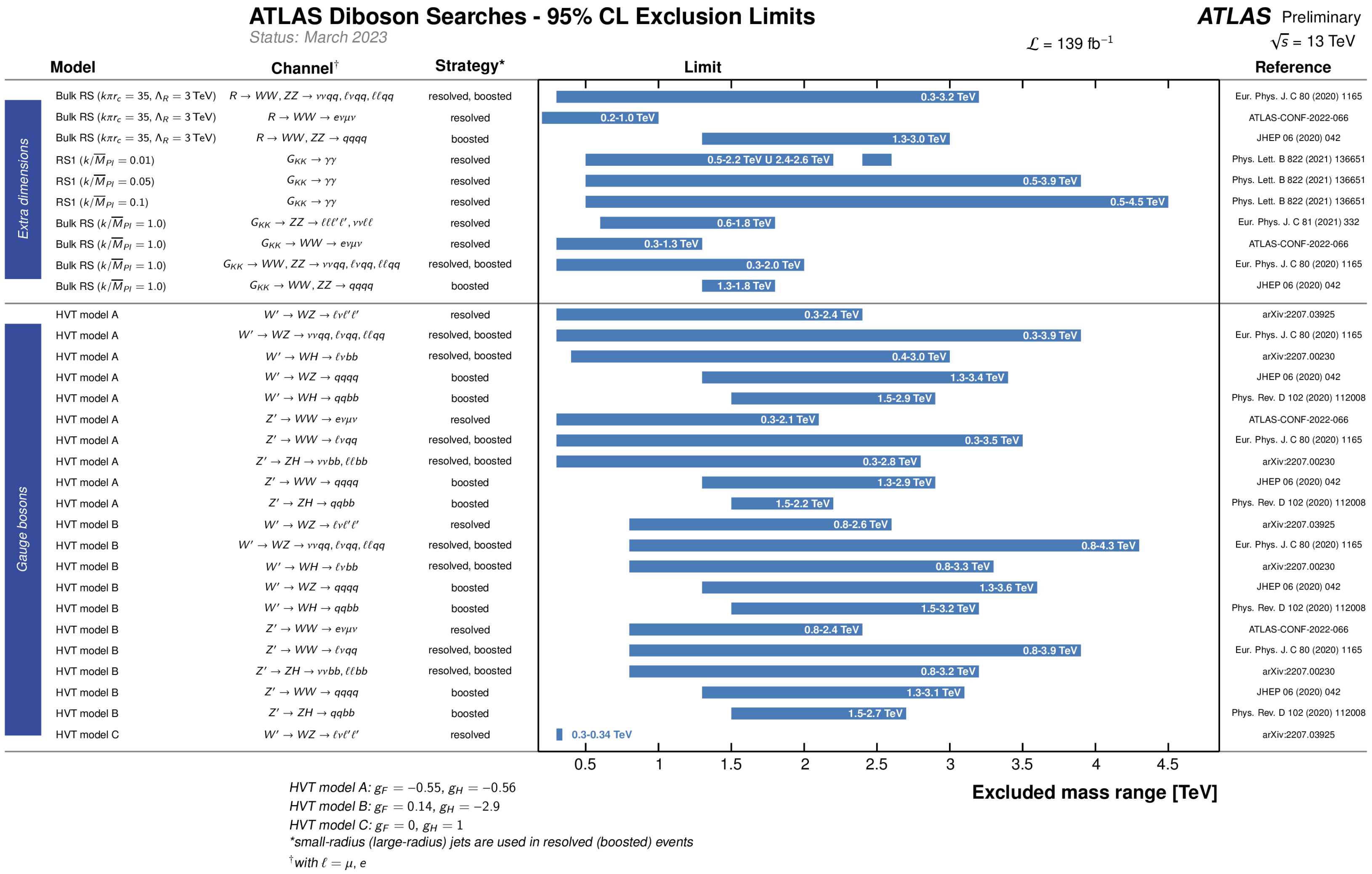
Events categorized into 4 regions based on n_{trk} and pT(eμ)
SR: n_{trk} = 0 and pT(eμ) > 30 GeV
Other 3 CRs to constrain dedicated backgrounds

Searches for BSM decays to VV

ATL-PHYS-PUB-2023-007



One example from WW channel



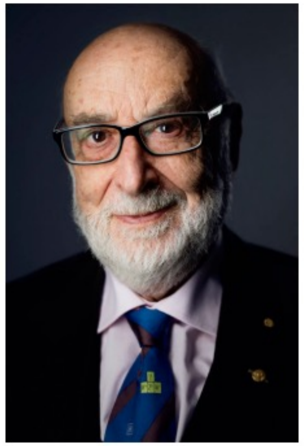
Observation and measurements of vector boson scattering processes

With Run-2 luminosity, ATLAS has been able to observe VBS processes in all major channels, and start to have differential measurements

The Higgs Mechanism and EWSB

- The Higgs boson is special in the SM, as to explain how other particles get their masses
- Known as the "Higgs Mechanism", with a very delicate electroweak symmetry breaking (EWSB)
- From the proton-proton collisions at the LHC, the EWSB can be studied with the vector-boson scattering (VBS) processes

The Nobel Prize in Physics 2013



© Nobel Media AB. Photo: A. Mahmoud

François Englert

Prize share: 1/2

© Nobel Media AB. Photo: A. Mahmoud

Peter W. Higgs

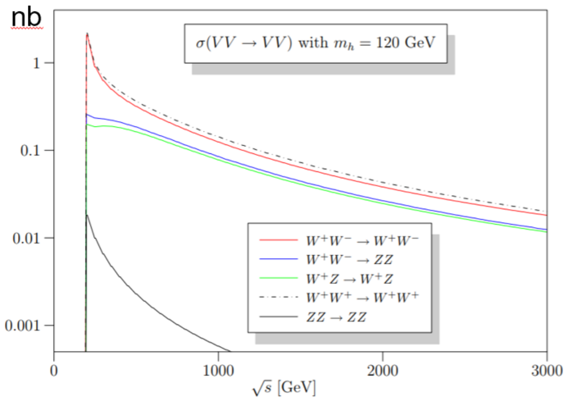
Prize share: 1/2

Link

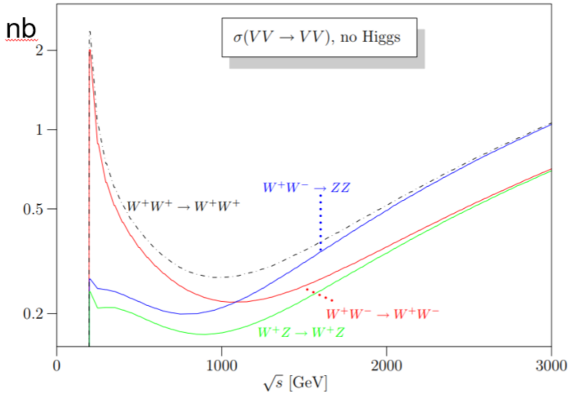
The Nobel Prize in Physics 2013 was awarded jointly to François Englert and Peter W. Higgs "for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider."

The VBS Processes at the LHC

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

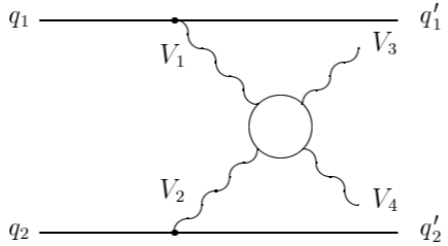


SM VV scattering processes w/o a Higgs boson



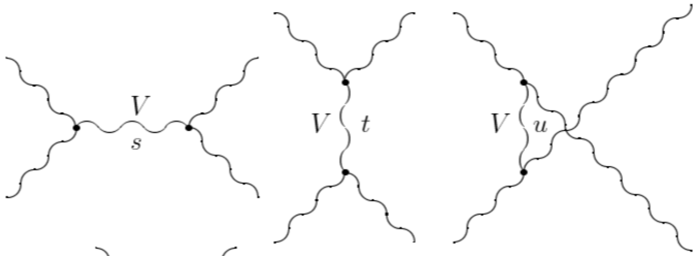
JHEP11(2008)010

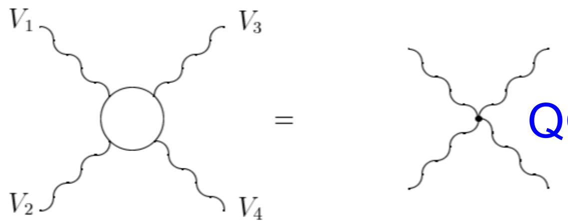
Phys. Rev. D **55**, 7165 – Published 1 June 1997



Rare process

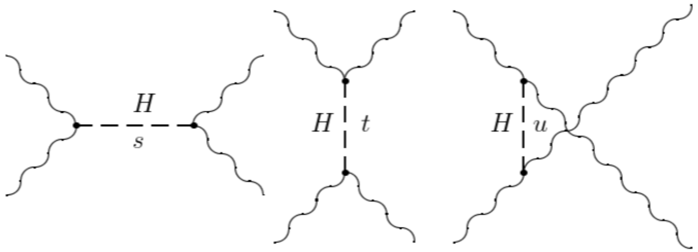
Vector boson couplings





QGC

Higgs couplings

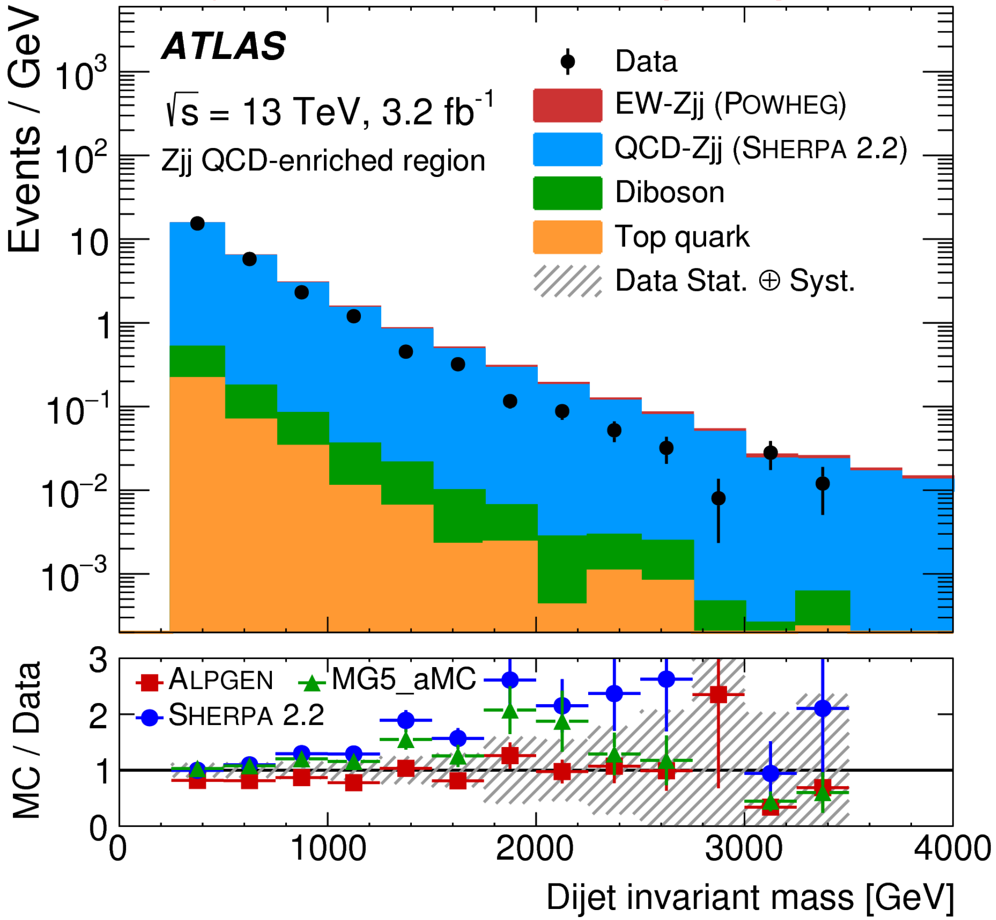


- Involving Quartic Gauge Couplings (QGCs) which is sensitive to new physics
  - Only charged QGCs allowed at Standard Model (SM) tree-level (WWWW, WWZZ, WWZγ, WWγγ)
  - Constraint on anomalous QGCs (aQGCs)
  - Probe new physics through deviations from SM

From VV to VVjj

- Theoretically more complicated mostly due to the jet modelling
  - A typical issue observed by several ATLAS measurements, m_{jj} modelling
  - In most analyses the m_{jj} is corrected to data → introduce additional uncertainty
- Experimentally also challenging
  - Pileup effect in the forward region
  - Lack of detector coverage in the forward region makes it more difficult
  - Will be more challenging at HL-LHC when luminosity further increased

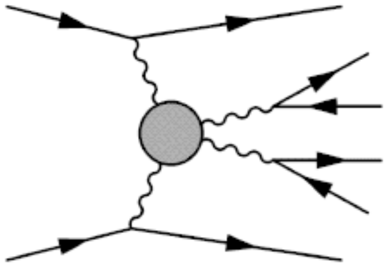
Physics Letters B 775 (2017) 206

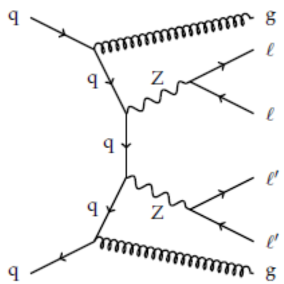


Observation of VBS at the LHC

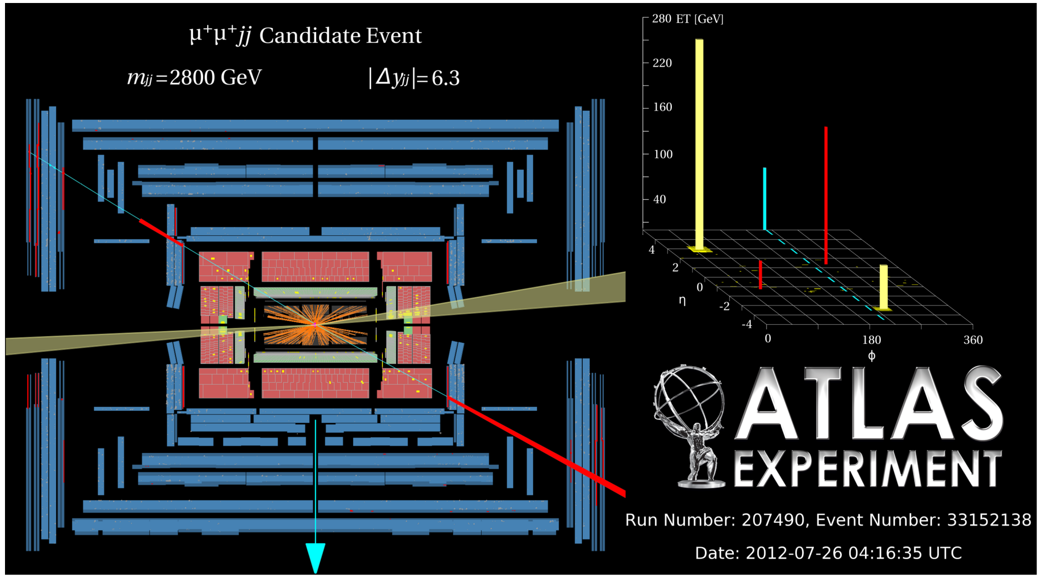
- Two intermediate vector bosons radiated from two incoming quarks
- Final state with decay products from two vector bosons plus two outgoing jets
- In general, two "tag" jets in forward region with large rapidity separation and large invariant mass
- Cross-sections of the EW VBS are small,

  suffer from irreducible QCD VV + 2jets events





The first evidence of these processes at LHC in the same-sign WW channel



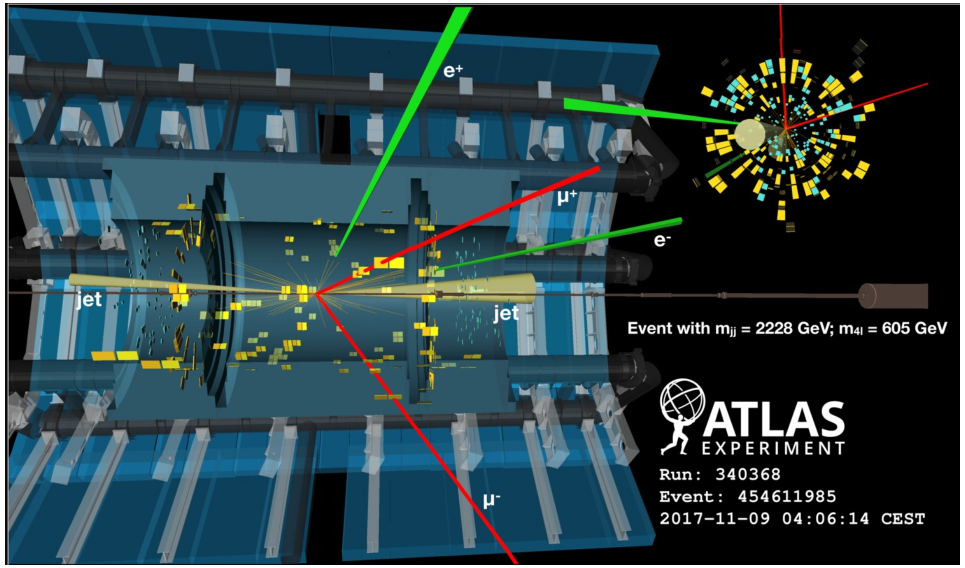
Candidate VBS event from ssWW
Phys. Rev. Lett. **113**, 141803

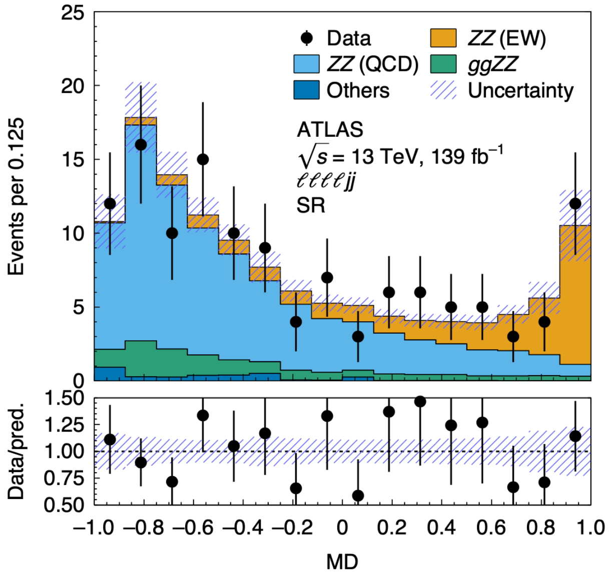
Now have been observed in all major channels during Run-2!

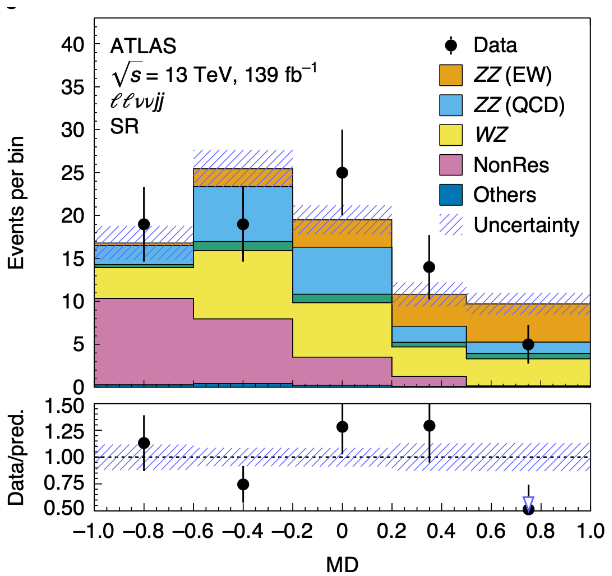
Observation of EW ZZjj

Nature Physics 19, 237–253 (2023)

- Two Z bosons decaying leptonically
  - ZZ → llll (4e, 4μ, 2e2μ)
  - ZZ → llvv (2e2v, 2μ2v)
- Two jets in the back and forward regions
- Clear experimental signatures
- Large modeling uncertainties of the dijets





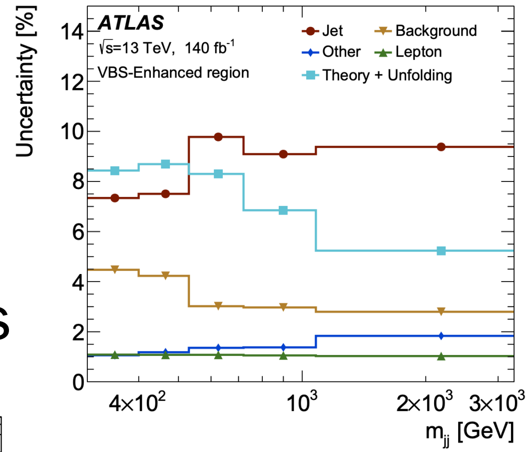


	μ_{EW}	$\mu_{QCD}^{\ell\ell\ell\ell jj}$	Significance obs. (exp.)
ℓℓℓℓjj	0.97±0.27	0.99±0.22	5.5 (5.6) σ
ℓℓννjj	0.7±0.5	–	1.3 (2.1) σ
Combined	0.92±0.24	0.99±0.22	5.7 (5.9) σ

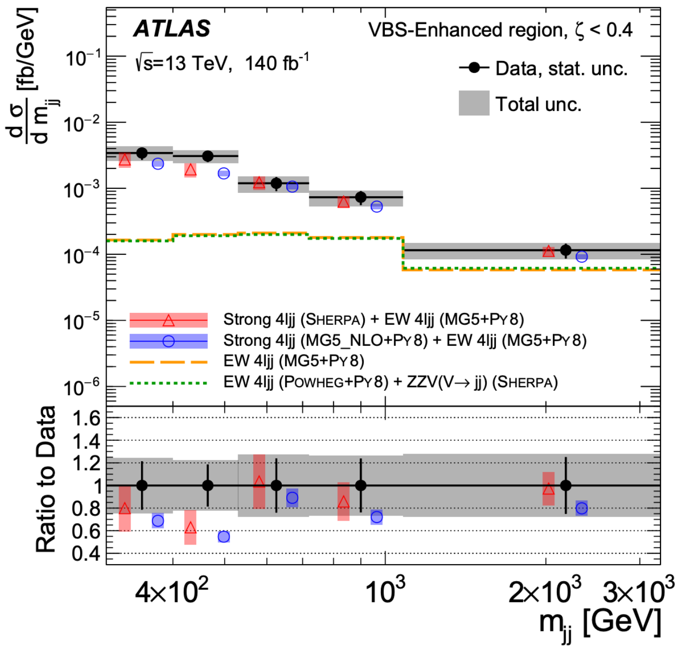
Leads to the first observation of the EW ZZjj production at the LHC arXiv:2308.12324, submitted to JHEP

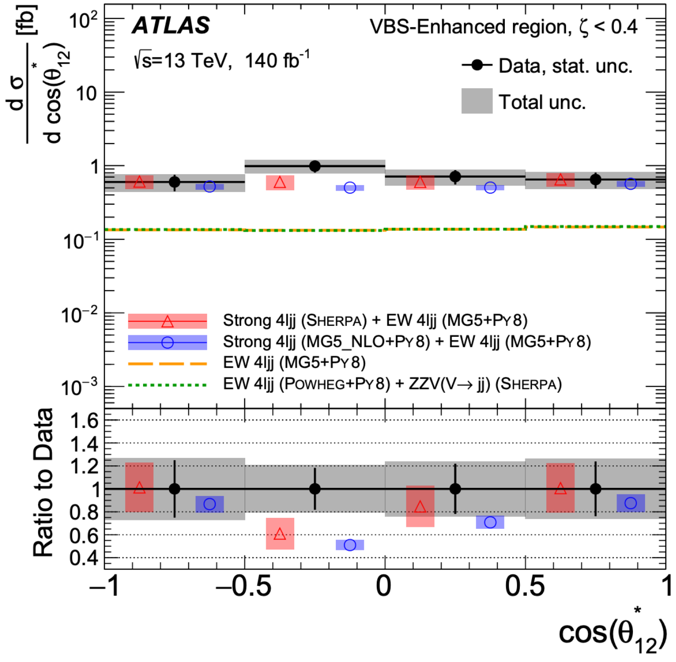
Follow-up measurements in the 4ljj channel

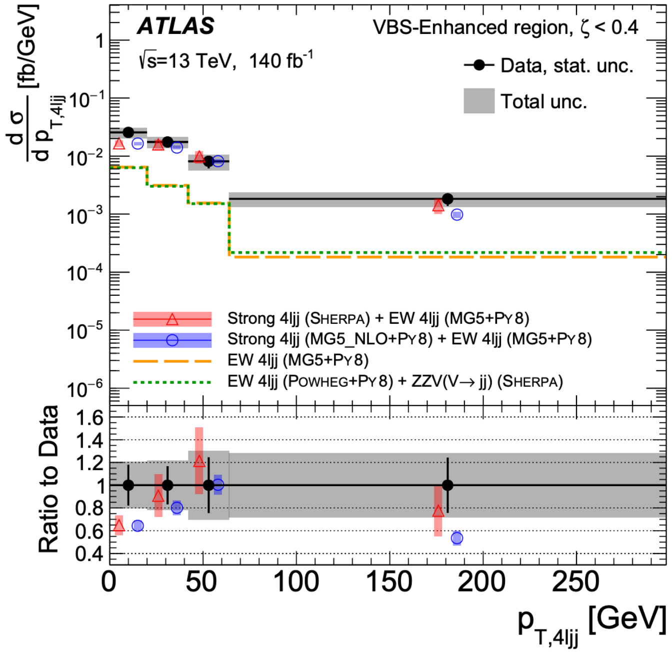
- Differential measurements of EW+QCD processes in the VBS enhanced and suppressed regions
- Several measurements covering the typical VBS variables, polarization and CP sensitive variables, and QCD sensitive variables



Wilson coefficient	$\|\mathcal{M}_{d8}\|^2$ Included	95% confidence interval [TeV^{-4}] Expected	Observed
$f_{T,0}/\Lambda^4$	yes	[-0.98, 0.93]	[-1.00, 0.97]
	no	[-23, 17]	[-19, 19]
$f_{T,1}/\Lambda^4$	yes	[-1.2, 1.2]	[-1.3, 1.3]
	no	[-160, 120]	[-140, 140]
$f_{T,2}/\Lambda^4$	yes	[-2.5, 2.4]	[-2.6, 2.5]
	no	[-74, 56]	[-63, 62]
$f_{T,5}/\Lambda^4$	yes	[-2.5, 2.4]	[-2.6, 2.5]
	no	[-79, 60]	[-68, 67]
$f_{T,6}/\Lambda^4$	yes	[-3.9, 3.9]	[-4.1, 4.1]
	no	[-64, 48]	[-55, 54]
$f_{T,7}/\Lambda^4$	yes	[-8.5, 8.1]	[-8.8, 8.4]
	no	[-260, 200]	[-220, 220]
$f_{T,8}/\Lambda^4$	yes	[-2.1, 2.1]	[-2.2, 2.2]
	no	[-4.6, 3.1]×10^4	[-3.9, 3.8]×10^4
$f_{T,9}/\Lambda^4$	yes	[-4.5, 4.5]	[-4.7, 4.7]
	no	[-7.5, 5.5]×10^4	[-6.4, 6.3]×10^4

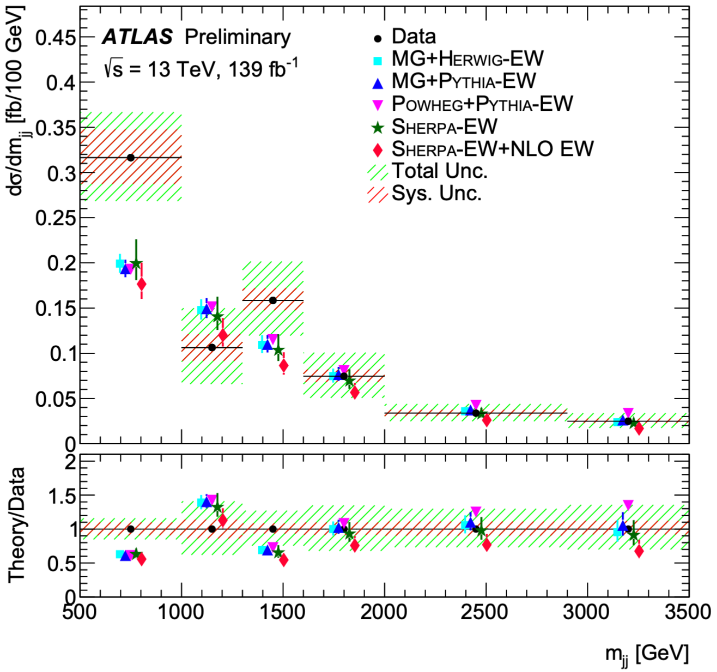


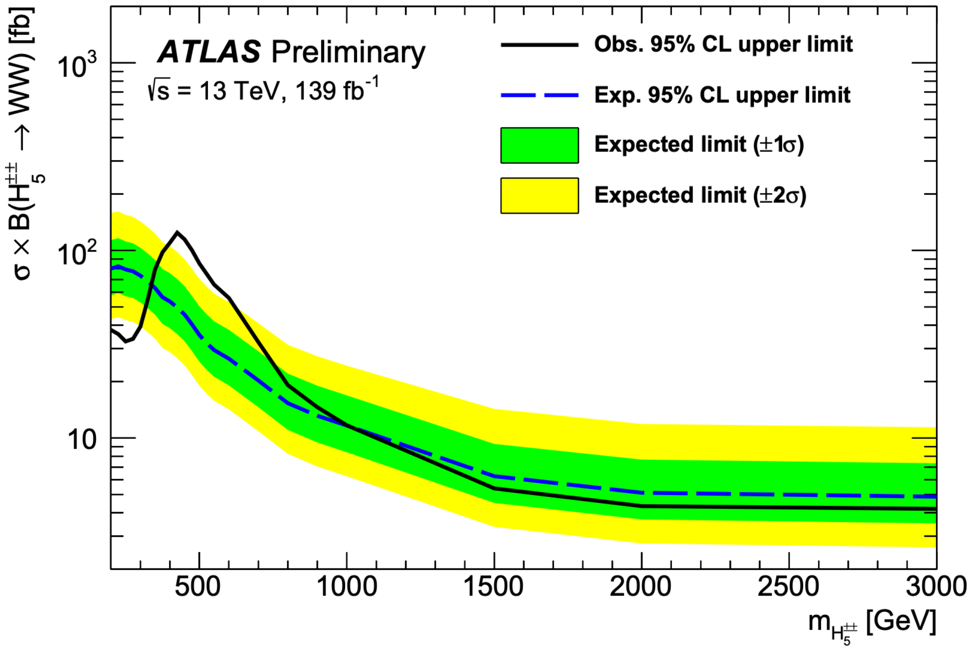


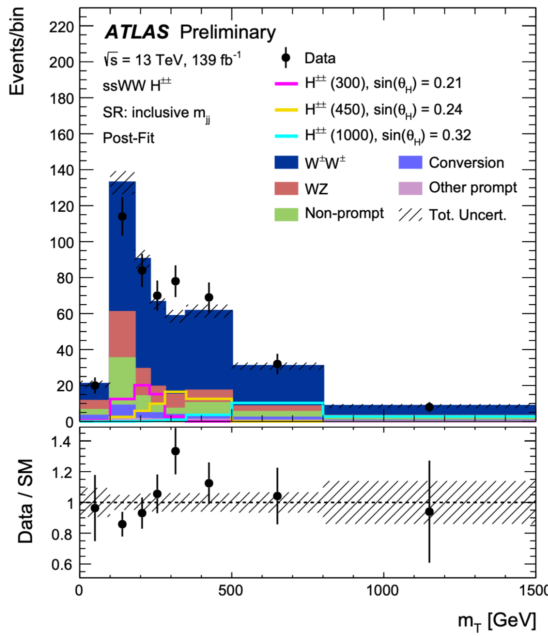


Same-sign WW channel [ATLAS-CONF-2023-023]

- The large majority of backgrounds from the top-related processes have two different-sign leptons in the leptonic decay
- The WWjj events from strong interactions are also largely reduced
- Observation (6.5σ) with partial Run-2 data, Phys. Rev. Lett. 123, 161801
- Differential measurements of the EW process with full Run-2 data







Also set limits on doubly-charged Higgs

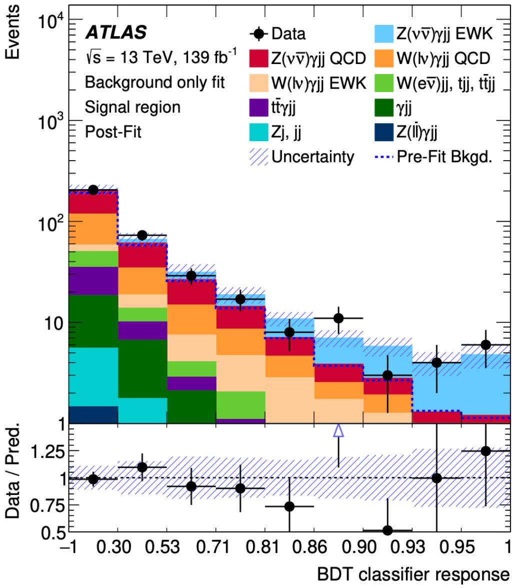
Also has EFT limits

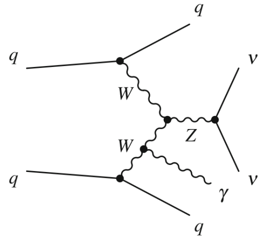
The Zγjj channel

Eur. Phys. J. C 82 (2022) 105
JHEP 06 (2023) 082
arXiv:2305.19142, accepted by PLB

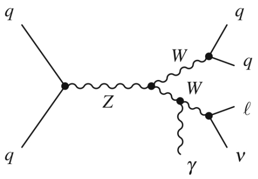
* Observation in both the Z→νν and Z→ll channels

Observe the SM process



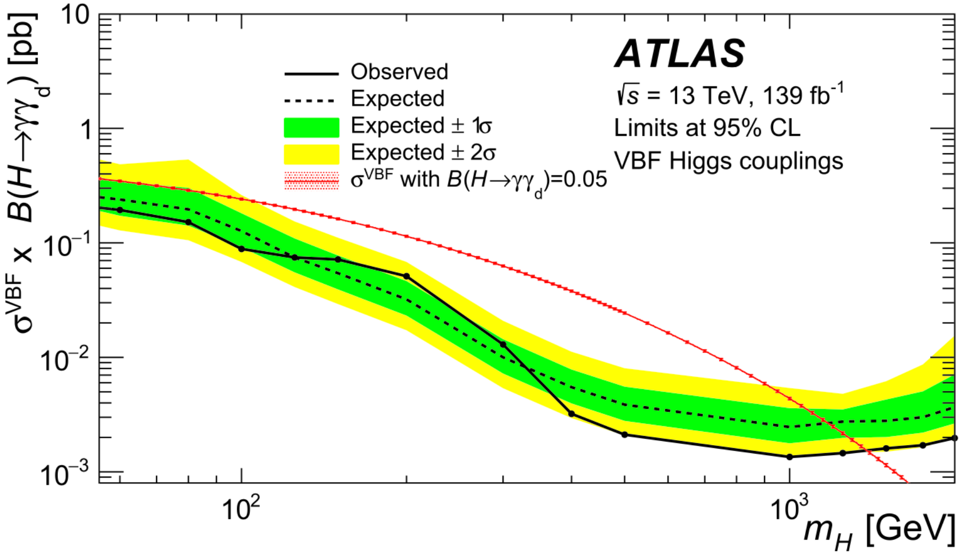


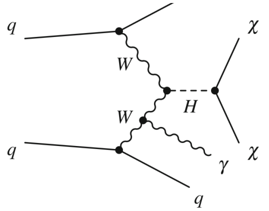
(b) VBF electroweak diagram

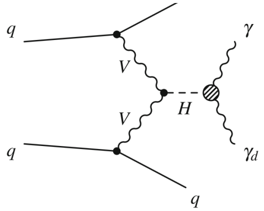


(c) Triboson diagram

Search for Higgs invisible decay and dedicated H to dark photon modelin the Z→νν channel

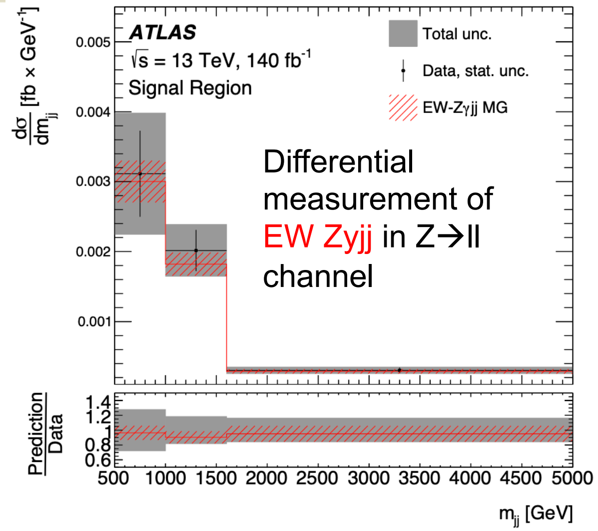




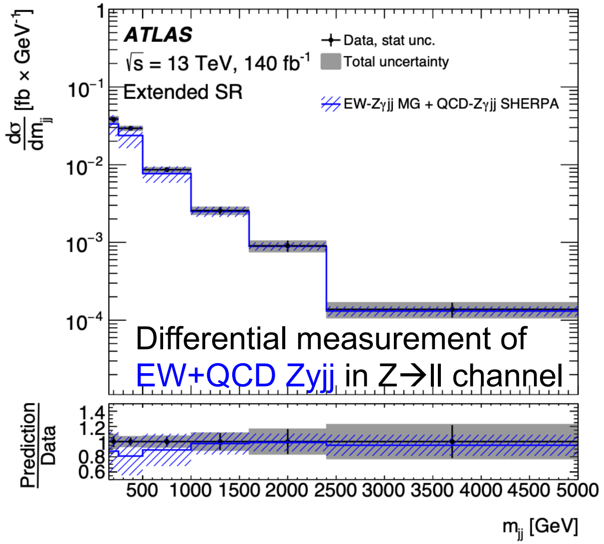


Also has EFT limits

Observed (expected) 95% CL upper limit on Higgs invisible decay is set as 0.37 (0.34)



Differential measurement of EW Zγjj in Z→ll channel

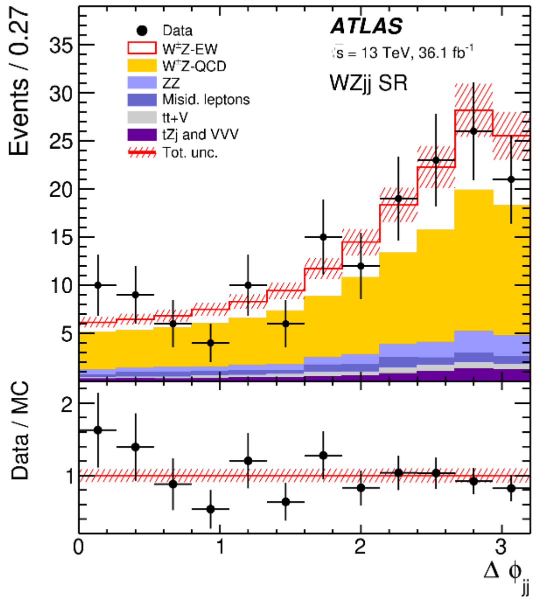


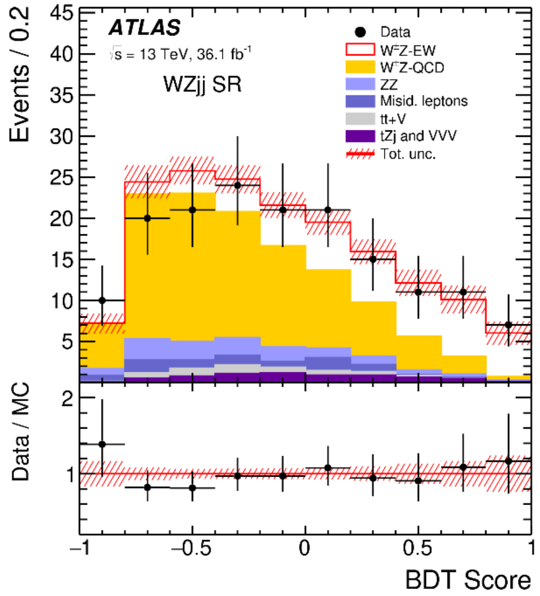
Differential measurement of EW+QCD Zγjj in Z→ll channel

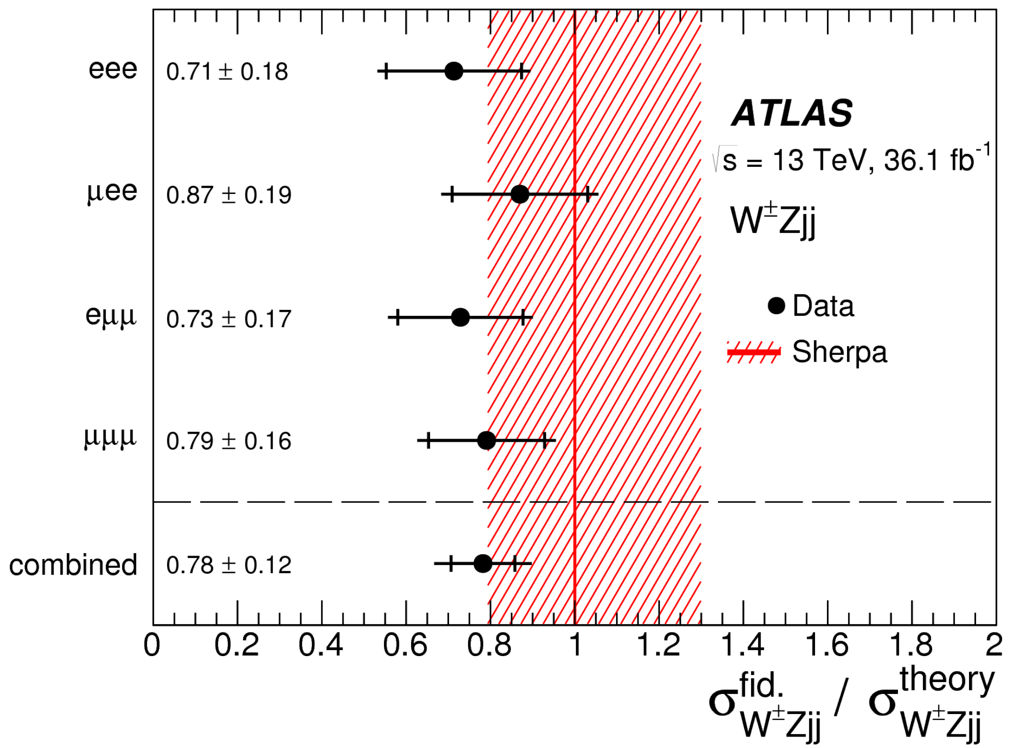
The WZjj channel

Phys. Lett. B 793 (2019) 469

- Only leptonic decays of the W/Z are considered
- A statistical fit on the BDT score is used to extract the EW component
- Observed significance: 5.3 σ







Measured cross section:

$$\sigma_{WZjj\text{-EW}} = 0.57\ ^{+0.14}_{-0.13}\,(\text{stat.})\ ^{+0.07}_{-0.06}\,(\text{syst.})\ \text{fb.}$$

Searching for triboson processes

With Run-2 luminosity, ATLAS has been able to start looking for very rare VVV processes

Observation of WWW production

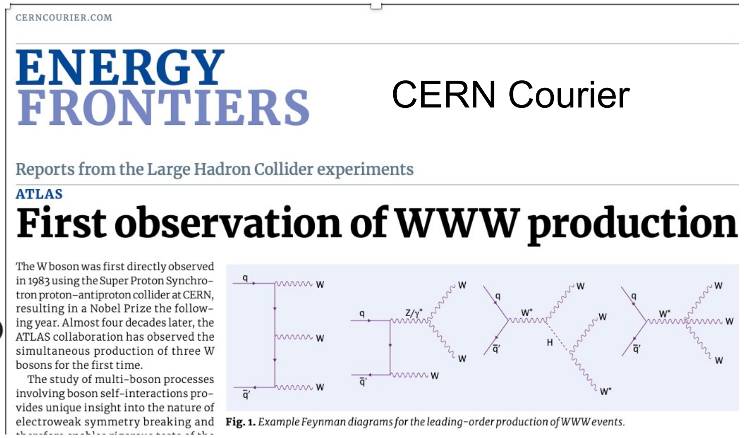
Phys. Rev. Lett. 129 (2022) 061803

- Directly probe the gauge boson self-interactions
- Events with 2 same-sign leptons and two jets, or three charged leptons are considered
- BDT used to discriminate between signal and background
- First observation, 8.0σ

Measured cross section approximately 2.6σ higher than the SM prediction at NLO QCD and LO EW

Measured: $820 \pm 100\,(\text{stat}) \pm 80\,(\text{syst})$ fb

Predicted: 511 ± 18 fb



CERNCOURIER.COM

ENERGY FRONTIERS

CERN Courier

Reports from the Large Hadron Collider experiments

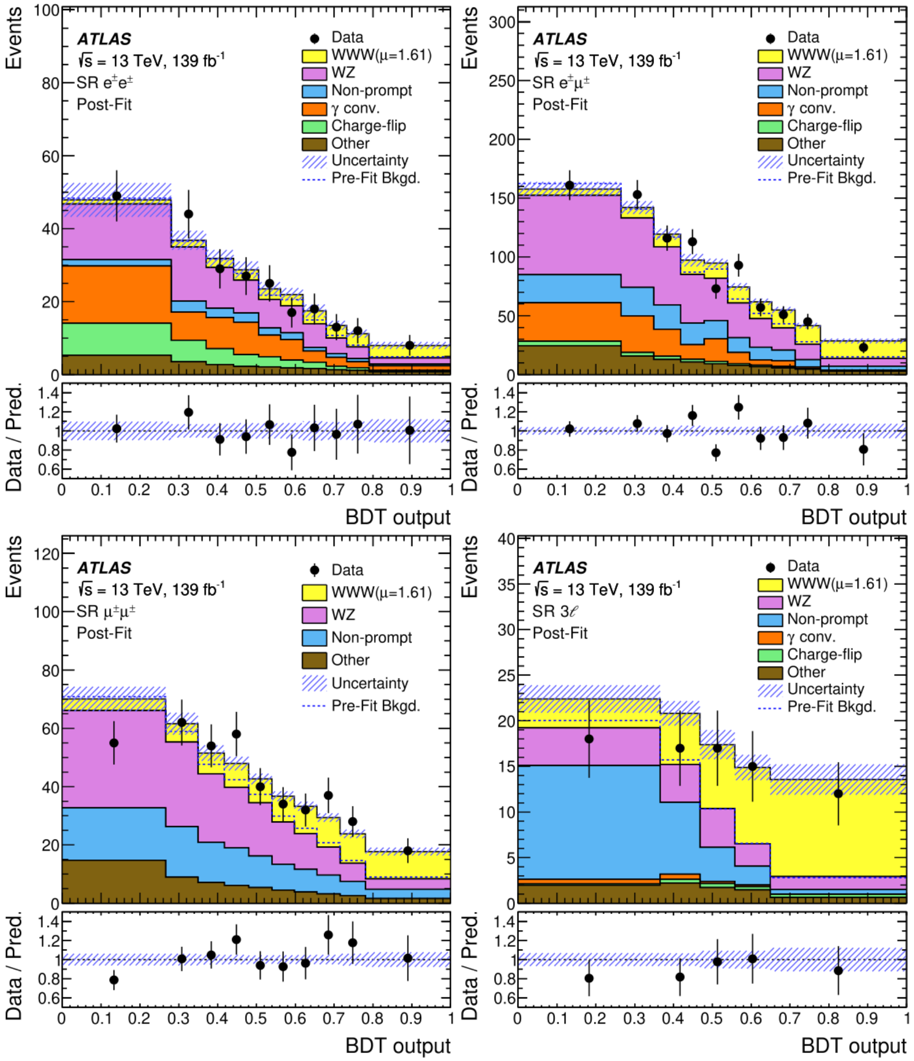
ATLAS

First observation of WWW production

The W boson was first directly observed in 1983 using the Super Proton Synchrotron proton–antiproton collider at CERN, resulting in a Nobel Prize the following year. Almost four decades later, the ATLAS collaboration has observed the simultaneous production of three W bosons for the first time.

The study of multi-boson processes involving boson self-interactions provides unique insight into the nature of electroweak symmetry breaking and

Fig. 1. Example Feynman diagrams for the leading-order production of WWW events.



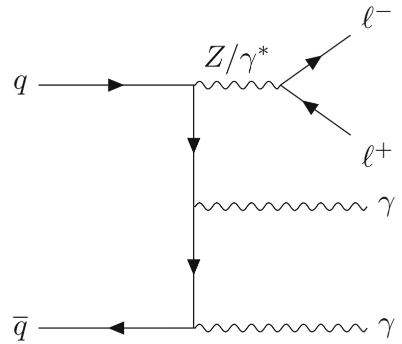
Signal strength consistently high in all channels

be consistent: 1.54 ± 0.76 for $e^{\pm}e^{\pm}$, 1.44 ± 0.39 for $e^{\pm}\mu^{\pm}$, 2.23 ± 0.46 for $\mu^{\pm}\mu^{\pm}$, and 1.32 ± 0.39 for 3ℓ.

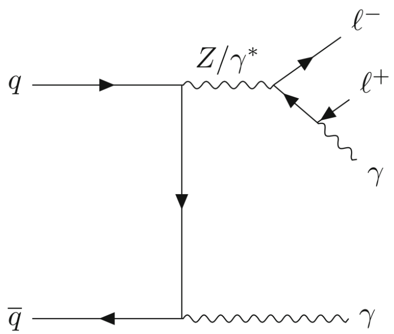
Wγγ, WZγ and Zγγ channels

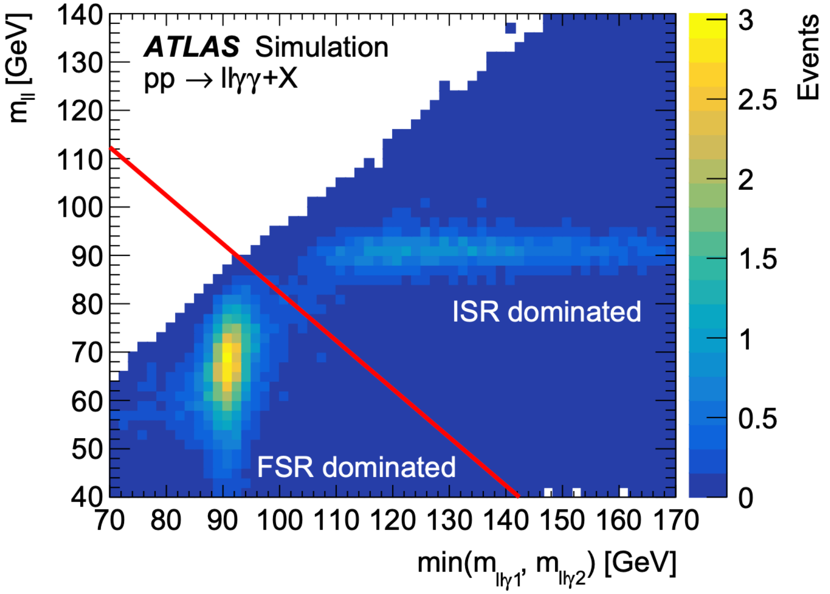
Eur. Phys. J. C 83 (2023) 539
arXiv:2305.16994, submitted to PRL
arxiv:2308.03041, submitted to PLB

Initial state radiation

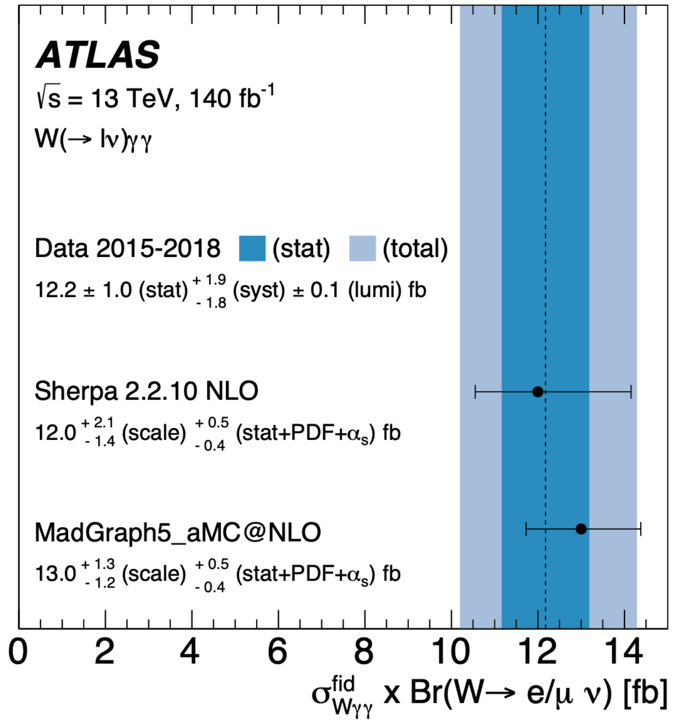


Final state radiation

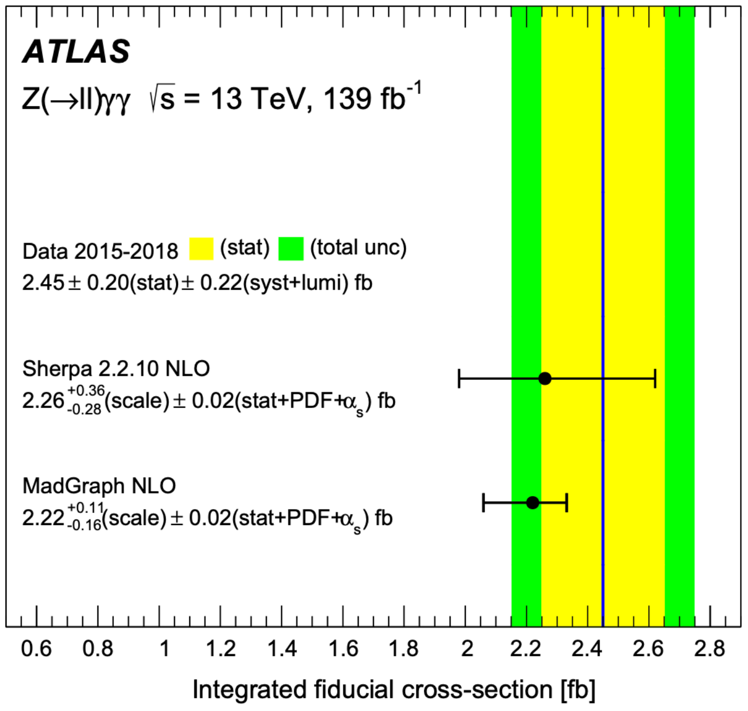




Kinematic cuts applied to reject FSR



Wγγ



Zγγ

WZγ: 6.3σ observation

All agree well with SM predictions

Summary

- An overview of ATLAS multi-boson results
  - Precision measurements of VV processes. Already observed joint-polarization states in certain channels
  - Observation of VBS processes in all major channels
  - Observation of VVV processes in certain channels
  - Searches for new physics

Backup

Electroweak publications (I)

Published

- 13 TeV WWW/WVZ 2015-2017 [PLB 798 (2019) 134913, arXiv:1903.10415]
- 13 TeV Z(ll)γ Full run-2 [JHEP 03 (2020) 054, arXiv:1911.04813]
- 13 TeV VBF Zjj Full run-2 [Eur. Phys. J. C 81 (2021) 163, arXiv:2006.15458]
- 13 TeV $\gamma\gamma$→WW observation [Phys. Lett. B 816 (2021) 136190, arXiv:2010.04019]
- 13 TeV WW+1jet [axXiv:2103.10319, JHEP 06 (2021) 003]
- 13 TeV m4l Full run-2 [JHEP 07 (2021) 005, arXiv:2103.01918]
- 13 TeV Z(vv)γ VBS (in VBF H(inv.)γ) [Eur. Phys. J. C 82 (2022) 105, arXiv:2109.00925]
- 13 TeV WWW Full run-2 [Phys. Rev. Lett. 129 (2022) 061803, arXiv:2201.13045]
- 13 TeV VBS ZZ Full run-2 [Nature Phys. (2023), arXiv:2004.10612]
- 13 TeV Polarization in incl. WZ [Phys. Lett. B 843 (2023) 137895, arXiv:2211.09435]
- 13 TeV Z(vv)γ VBS full run-2 [JHEP 06 (2023) 082, arXiv:2208.12741]
- 13 TeV Z$\gamma\gamma$ Triboson [Eur. Phys. J. C 83 (2023) 539, arXiv:2211.14171]
- 13 TeV Zy+jets (STDM-2020-14) [JHEP 07 (2023) 72, arXiv:2212.07184]

Submitted to the journals

- 13 TeV tau g-2 (STDM-2019-19) [arXiv:2204.13478, accepted by PRL]
- 13 TeV WZy (STDM-2019-17) [arXiv:2305.16994, submitted to PRL]
- 13 TeV VBS Z(->ll)y (STDM-2018-36) [arXiv:2305.19142, accepted by PLB]
- 13 TeV Wyy (STDM-2018-33) [arxiv:2308.03041, submitted to PLB]
- 13 TeV ZZ4ljj (STDM-2020-02) [arXiv:2308.12324, submitted to JHEP]

Electroweak publications (II)

CONF note

13 TeV VBS Z(->ll)y Full run-2 [ATLAS-CONF-2021-038]

8 TeV Z vertex form factor llγ [ATLAS-CONF-2022-046] (conv. of ANA-STDM-2017-05)

13 TeV Polarization in incl. WZ [ATLAS-CONF-2022-046] (conv. of ANA-STDM-2022-01)

13 TeV Zy+jets [ATLAS-CONF-2022-047] (conv. of ANA-STDM-2020-14)

13 TeV Wyy [ATLAS-CONF-2023-005] (conv. of ANA-STDM-2018-33)

13 TeV WZy [ATLAS-CONF-2023-014] (conv. of ANA-STDM-2019-17)

13 TeV WW+0j [ATLAS-CONF-2023-012] (conv. of ANA-STDM-2020-16)

13 TeV ZZ4ljj [ATLAS-CONF-2023-024] (conv. of ANA-STDM-2020-02)

13 TeV VBS same-sign WW [ATLAS-CONF-2023-023] (conv. of ANA-STDM-2018-32)

13 TeV ZZ CP+polarization [ATLAS-CONF-2023-038] (conv. of ANA-STDM-2021-05)

13.6 TeV ZZ4l (ATLAS-CONF-2023-062) [conv. of ANA-STDM-2022-17]

PUB note

yy->WW Upgrade [ATL-PHYS-PUB-2021-026]

Dim-6 EFT Interpretation [ATL-PHYS-PUB-2021-022]

13 TeV Global EFT (joint SM+Higgs) [ATL-PHYS-PUB-2022-037]

13 TeV aQGC Re-interpretation of WWjj&WZjj (ANA-STDM-2019-08) [ATL-PHYS-PUB-2023-002]