

## Vector Boson Scattering and diboson production with the ATLAS Detector and EFT interpretations

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#### **Motivation**

- Electroweak-boson self-interactions are rare processes that are:
  - an probe to the Standard Model predictions
  - a portal to Physics Beyond the standard model, through the Effective Field Theories
- In this talk, I will focus on ATLAS Run-II measurements with integrated luminosity 139 fb<sup>-1</sup> of:
  - EW Z(II/vv)γjj
  - WW+>=1jet
    - Dim-6 EFT interpretations
  - Dim-6 EFT combination of various measurements



# Vector Boson Scattering

## **VBS signature at LHC**

#### **Event topology**

- Two energetic jets with large dijet mass (m<sub>ii</sub>) and high rapidity separation
- Diboson system, centrally produced with respect to the two forward jets



## $Z(\rightarrow II)\gamma jj$ : Selection and Background



<sup>5</sup> 

using euv events

## Z(→II)γjj: Results



• Strategy: fit of the mjj in the Signal and QCD regions

#### Results

- Measured signal strength with observed significance 10σ
  - µEWK=0.95+-0.08(stat.)+-0.11(syst.)
- EWK cross section predicted from Madgraph5+PYTHIA
  - $\sigma_{EW}(pred) = 4.73 \pm 0.01 \text{ (stat.)} \pm 0.15(PDF)+0.23-0.22(scale) \text{ fb}$
- Fiducial cross-section in the signal phase space measured with 13% overall uncertainty
  - $\sigma_{EW}(obs.) = 4.49 \pm 0.40 \text{ (stat.)} \pm 0.42 \text{(syst.) fb}$

## Electroweak $Z(\rightarrow vv)\gamma jj$ production

- 1st Observation of EW Zyjj process in neutrino channels at ATLAS with 5.2 $\sigma$  significance
- Selection of events:
  - all events containing leptons are vetoed
- Main background:
  - QCD  $Z(\rightarrow \nu\nu)\gamma$  + jets and  $W(\rightarrow \ell\nu)\gamma$  + jets events in which the lepton from the W decay is lost mostly because it falls outside of the pT or  $\eta$  acceptance



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## Z(→vv)γjj: Results

 Fit strategy: 4-bin mjj distributions in SR and CRs. Backgrounds are constrained in the fit in the signal region and the respective control regions

$\mu_{Z\gamma_{ m EW}}$	$\beta_{Z\gamma_{ m strong}}$	$\beta_{W\gamma}$
$1.03 \pm 0.25$	$1.02 \pm 0.41$	$1.01 \pm 0.20$

Measured signal strength with observed significance 5.2σ

 $\mu_{EW}$  = 1.03 ± 0.25

- Theoretical fid. cross section:  $\sigma_{EW}(pred) =$ 1.27 ± 0.01 (stat.) ± 0.17(QCD MadGraph scale) ±0.03(PDF) fb
- Measured fiducial cross-section:  $\sigma_{EW}$ = 1.31 ± 0.2 (stat) ± 0.2 (syst) fb



# Diboson

# W+W- + ≥ 1 Jets Inclusive Measurement

- Measurement of WW pair production with a jet inclusive phase space.
- First time at LHC, differential measurements performed in jet-inclusive phase space
- Serves as portal to BSM interpretations since it is sensitive to TGCs



# W+W- + ≥ 1 Jets: Selection and Background

#### Selection

- eµ channel only
- b-jet veto to reduced large top background
- m<sub>eµ</sub> > 85 MeV to suppress Drell-Yan background as well as H→WW resonance

#### **Background Estimation**

- Main source of background is the top contribution
  - ttbar is estimated with data-driven method, considering two control regions with exactly 1 b-tag and exactly 2 b-tags
- Drell-Yan contribution is estimated using the MC
- Fake leptons: data-driven method
- Single top and diboson background estimated using MC

 $\sigma_{fid}\text{=}258\pm4$  (stat.)  $\pm$  25 (syst.) fb with overall uncertainty 10%



# EFT Dim-6 operator in W+W- + ≥ 1 Jets

EFT:SM expansion to higher order terms

$$\mathcal{L} = \mathcal{L}_{SM} + \sum_{i} \frac{c_i}{\Lambda^2} O_i + \sum_{j} \frac{c_j}{\Lambda^4} O_j + O_k$$

- Experimental Approach to EFTs 

   associate the operators to couplings between bosons and fermions
  - Triple gauge couplings can be parametrized in terms of Dim-6 operators
- Final state sensitive to Dim-6 operator Qw→ constraint on Cw
- m<sub>eµ</sub> used as a discriminant in an enhanced phase space with p<sub>T</sub><sup>lead.jet</sup> > 200 GeV



Jet $p_{\rm T}$	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]

# EFT Dim-6 combination: WW, WZ, 4I, and Zjj

• Combined EFT interpretation of differential measurements of the following leptonic final states:

Final state	Dataset	Diff. input distributions
WW	36 fb-1	pTlead. lepton
WZ	36 fb-1	mTWZ
4leptons	139 fb-1	mZ2
Zjj	139 fb-1	Δφϳϳ

- Linear combinations of the Dim-6 EFT coefficients are constrained
  - Including only linear terms
  - Including both linear and quadratic terms





- LHC Run2 provides a large amount of pp collision data at a higher center-of-mass energy, giving rise to the observation sensitivity of the gauge boson self-couplings
- New ATLAS measurements of VBS and diboson using the Full Run2 data set with integrated luminosity 139 fb-1 are presented:
  - Z(II) $\gamma$  VBS, Z(vv) $\gamma$  VBS observations with 10 $\sigma$  and 5.2 $\sigma$  respectively
  - WW+>=1jet differential cross sections and
  - EFT interpretations



# W+W- + ≥ 1 Jets: Differential Cross-section

- Differential cross sections obtained using iterative Bayesian unfolding approach
- Various differential distributions
- Good agreement among the MC predictions and data

