# Measurement of electroweak production of Wγ System and two jets in proton-proton collisions at $\sqrt{s}$ = 13 TeV with CMS

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## Introduction & Motivation

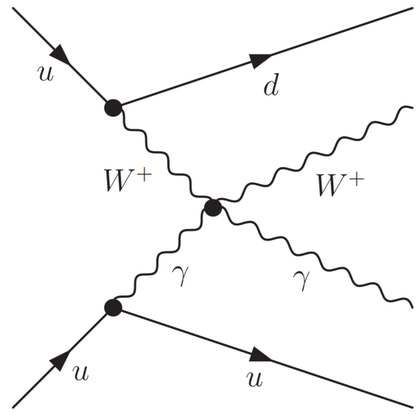
Vector Boson Scattering (VBS) processes are commonly known with unique features to probe new physics beyond the SM (BSM). [1]

Both ATLAS and CMS measured VBS Wγ process using data collected at $\sqrt{s}$ = 8 and 13 TeV, corresponding to integrated luminosity of approximately 20 $fb^{-1}$ and 36 $fb^{-1}$. [2] [3]

The VBS Wγ measurement using full LHC Run2 samples with 138 $fb^{-1}$ is still a missing part, which could give higher precision on SM and better limits on BSM.

## Strategies

- Candidate events have one identified lepton, $E_T^{miss}$, one identified photon, two jets with large rapidity separation and di-jet mass.
- Measure fiducial cross section and unfolded differential cross section.
- Search for anomalous quartic gauge coupling (aQGC) using EFT approach.



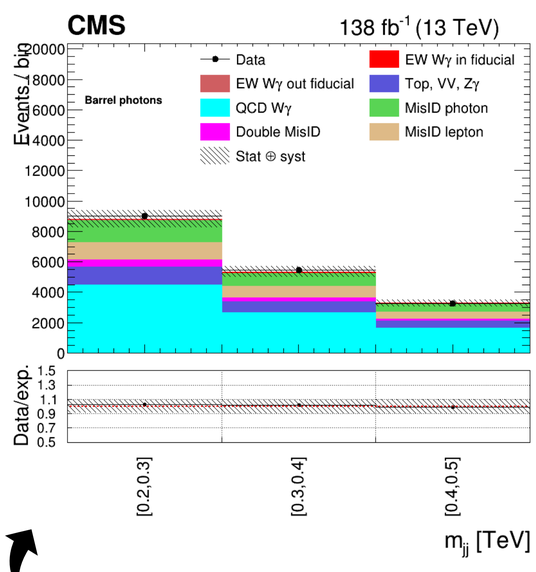

## Objects & Event Selections

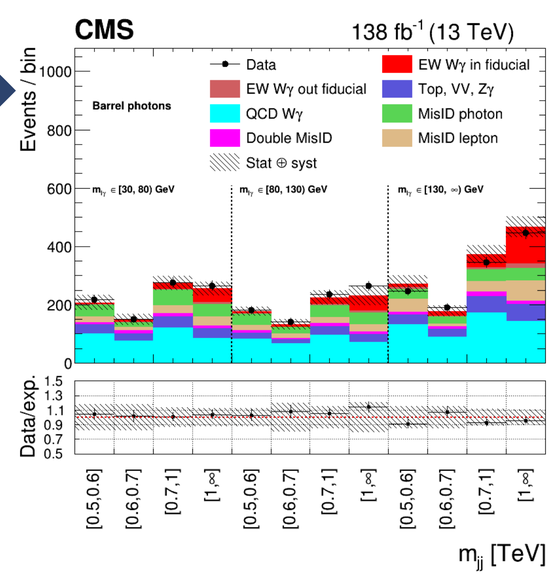
| Objects & Preselection | |
|---|---|
| Leptons | One μ (e) in each channel, second lepton veto<br>μ: Cut-based Tight (Loose) ID/ISO for selected (veto) μ<br>e: Cut-based Tight (Veto) ID/ISO for selected (veto) e<br>$P_T > 30$ (20) GeV for selected (veto)<br>$\lvert\eta\rvert < 2.4/2.5$ (μ/e) |
| Photons | Cut-based medium ID, $P_T > 20$ GeV,<br>excluding $1.444 < \lvert\eta\rvert < 1.566$ |
| Jets | 2 AK4 CHS jets, $P_T > 50$ GeV, $\lvert\eta\rvert < 4.7$ |
| Wγjj system | $E_T^{miss} > 30$ GeV, $M_T(W) > 30$ GeV, btag jets veto,<br>$\lvert M_{e\gamma} - M_Z\rvert > 10$ GeV |

- **Control Region:** 200 GeV < $M_{jj}$ < 500 GeV
- **Signal Region:** $M_{jj}$ > 500 GeV, $\lvert\Delta\eta_{jj}\rvert > 2.5$,, $M_{W\gamma} > 100$ GeV, $\eta^*_{W\gamma} < 1.2$, dphi > 2.0

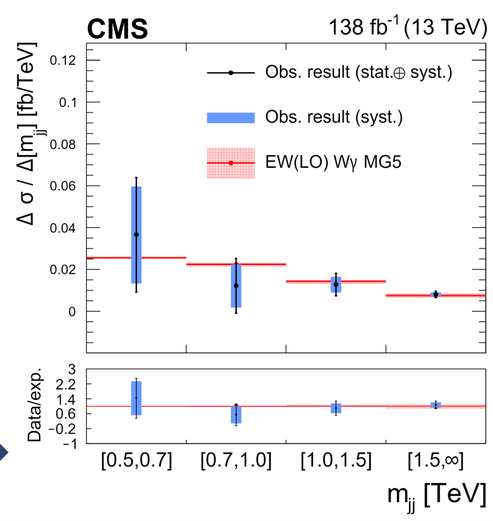
**Feature of VBS process : large invariant mass and $\Delta\eta_{jj}$ of two jets**

- The 2D distributions used in the fit (for barrel photons)




- The photon $m_{jj}$ distribution in the control region for data and from background estimations (for barrel photons)
- Differential cross sections for the EW Wγjj production.



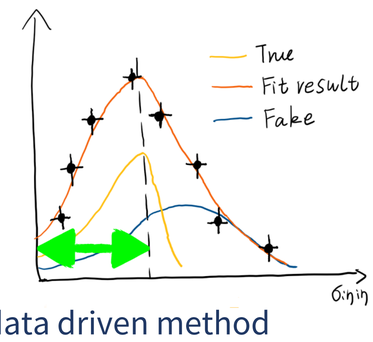

## Triggers & datasets

- Electrons: Standard Single Electron trigger with electron $p_T$ above 27 GeV (2016) and 32 GeV (2017-2018)
- Muons: Standard Single Muon trigger with muon $p_T$ above 24 GeV (2016, 2018) and 27 GeV (2017)
- **Signal MC:** EW Wγjj samples using MG5 generated in LO with **leptonic** (=e/μ) decay W boson plus one photon and two jets with $M_{jj} > 120$ GeV.
- **bkg MC:** QCD Wγjj generated by MG5 in NLO using FxFx jet merging. Top, $t\bar{t}\gamma$, Zγ, and VV backgrounds are simulated by Madgraph, pythia and powheg.

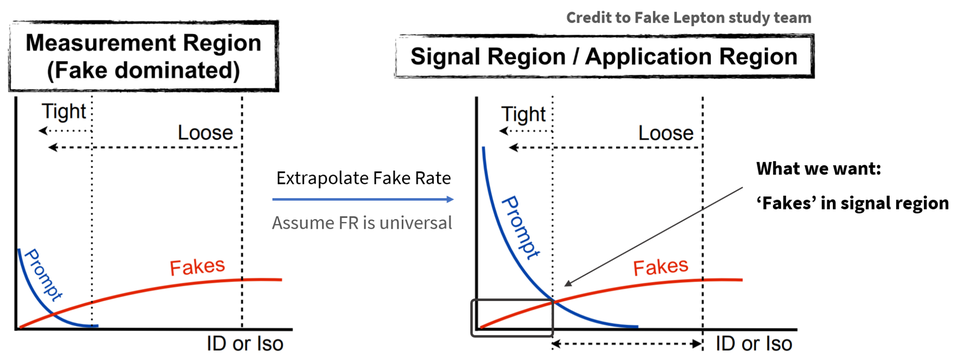
## Background modelling

- Non-prompt photon:

  template-fit data driven method



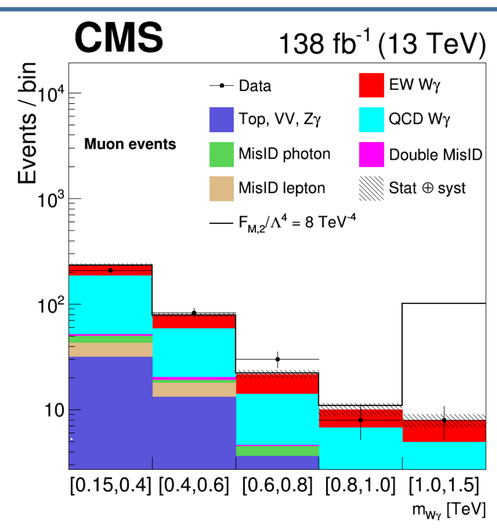

- Non-prompt lepton: tight-to-loose data driven method

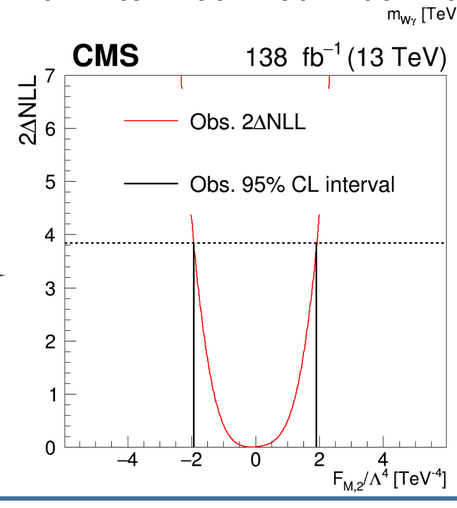



## Dimension 8 EFT model

- $\mathcal{L} = \mathcal{L}_{SM} + \Sigma_i \frac{F_i}{\Lambda^4} \mathcal{O}_i$
- Eboli and Gonzalez-Garcia parametrization. [4]
- Additionally require $P_T^{\gamma} > 100$ GeV and $M_{jj} > 800$ GeV.
- Samples generated with reweighting method.

| Expected. limit | Observed. limit | $U_{bound}$ |
|---|---|---|
| $-5.1 < f_{M0}/\Lambda^4 < 5.1$ | $-5.6 < f_{M0}/\Lambda^4 < 5.5$ | 1.7 |
| $-7.1 < f_{M1}/\Lambda^4 < 7.4$ | $-7.8 < f_{M1}/\Lambda^4 < 8.1$ | 2.1 |
| $-1.8 < f_{M2}/\Lambda^4 < 1.8$ | $-1.9 < f_{M2}/\Lambda^4 < 1.9$ | 2.0 |
| $-2.5 < f_{M3}/\Lambda^4 < 2.5$ | $-2.7 < f_{M3}/\Lambda^4 < 2.7$ | 2.7 |
| $-3.3 < f_{M4}/\Lambda^4 < 3.3$ | $-3.7 < f_{M4}/\Lambda^4 < 3.6$ | 2.3 |
| $-3.4 < f_{M5}/\Lambda^4 < 3.6$ | $-3.9 < f_{M5}/\Lambda^4 < 3.9$ | 2.7 |
| $-13 < f_{M7}/\Lambda^4 < 13$ | $-14 < f_{M7}/\Lambda^4 < 14$ | 2.2 |
| $-0.43 < f_{T0}/\Lambda^4 < 0.51$ | $-0.47 < f_{T0}/\Lambda^4 < 0.51$ | 1.9 |
| $-0.27 < f_{T1}/\Lambda^4 < 0.31$ | $-0.31 < f_{T1}/\Lambda^4 < 0.34$ | 2.5 |
| $-0.72 < f_{T2}/\Lambda^4 < 0.92$ | $-0.85 < f_{T2}/\Lambda^4 < 1.0$ | 2.3 |
| $-0.29 < f_{T5}/\Lambda^4 < 0.31$ | $-0.31 < f_{T5}/\Lambda^4 < 0.33$ | 2.6 |
| $-0.23 < f_{T6}/\Lambda^4 < 0.25$ | $-0.25 < f_{T6}/\Lambda^4 < 0.27$ | 2.9 |
| $-0.60 < f_{T7}/\Lambda^4 < 0.68$ | $-0.67 < f_{T7}/\Lambda^4 < 0.73$ | 3.1 |




## Results and Conclusion

- **Electroweak Wγjj fiducial cross section**: $23.5^{+4.9}_{-4.7}$ **fb**. **The inclusive cross section for Wγjj production** in the same fiducial region: $113 \pm 13$ **fb**. Differential cross sections are measured with the distributions unfolded to the parton level.
- Constraints are placed on aQGC in terms of dimension-8 EFT operators. **Most Stringent limits** to date on the aQGC parameters $f_{M,2-5}/\Lambda^4$ **and** $f_{T,6-7}/\Lambda^4$

Reference:
[1] G. Burdman et al., Phys. Rev. D 78 (2008) 075028.
[2] CMS Collaboration, JHEP 06 (2017) 106.
[3] CMS Collaboration, Phys. Lett. B 811 (2020) 135988
[4] Eduardo da Silva Almeida et al., Phys. Rev. D 101, 113003 (2020)