UNIVERSITÀ DEGLI STUDI DI TRIESTE

INFN Istituto Nazionale di Fisica Nucleare

Multibosons results from CMS

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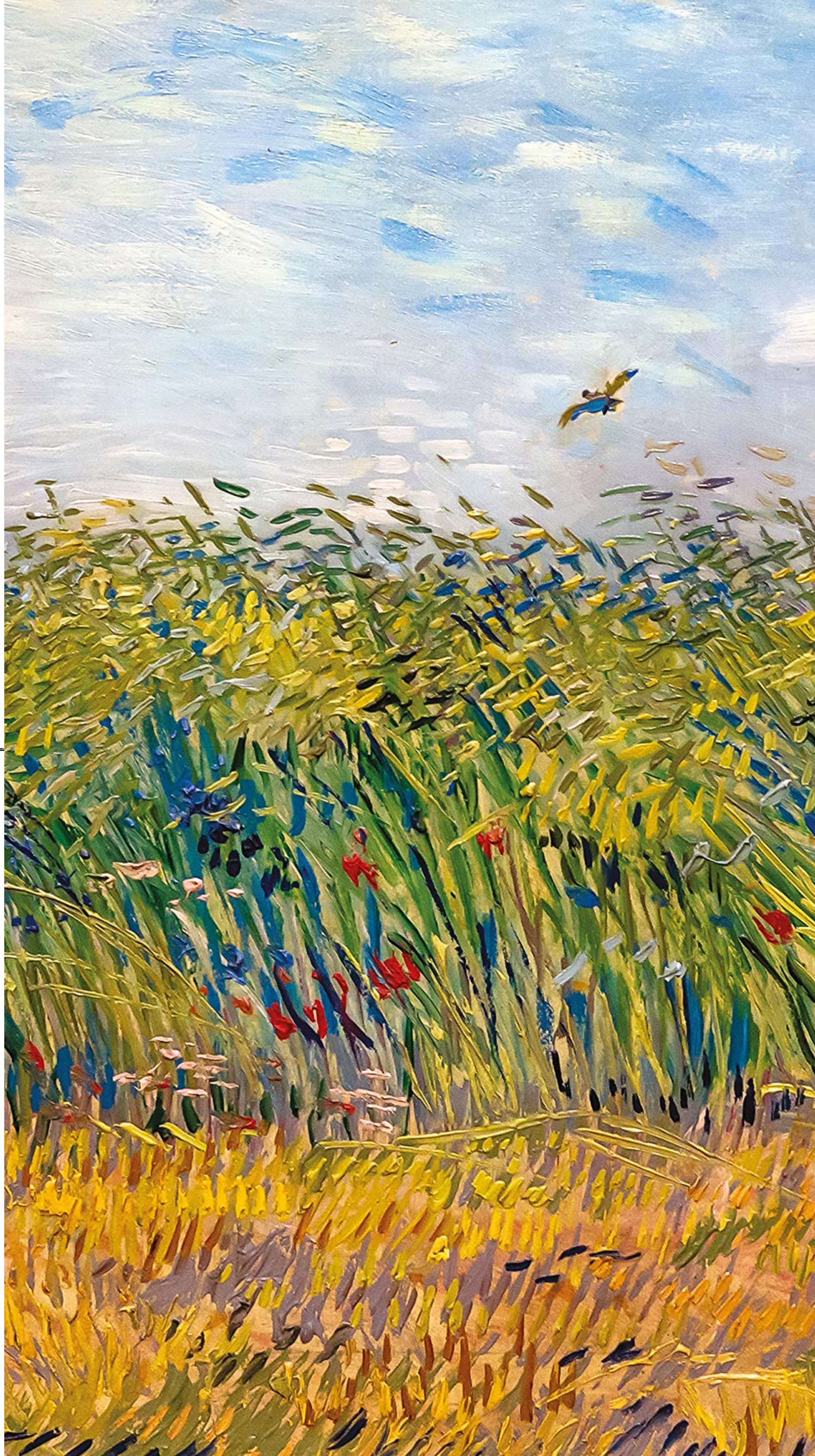
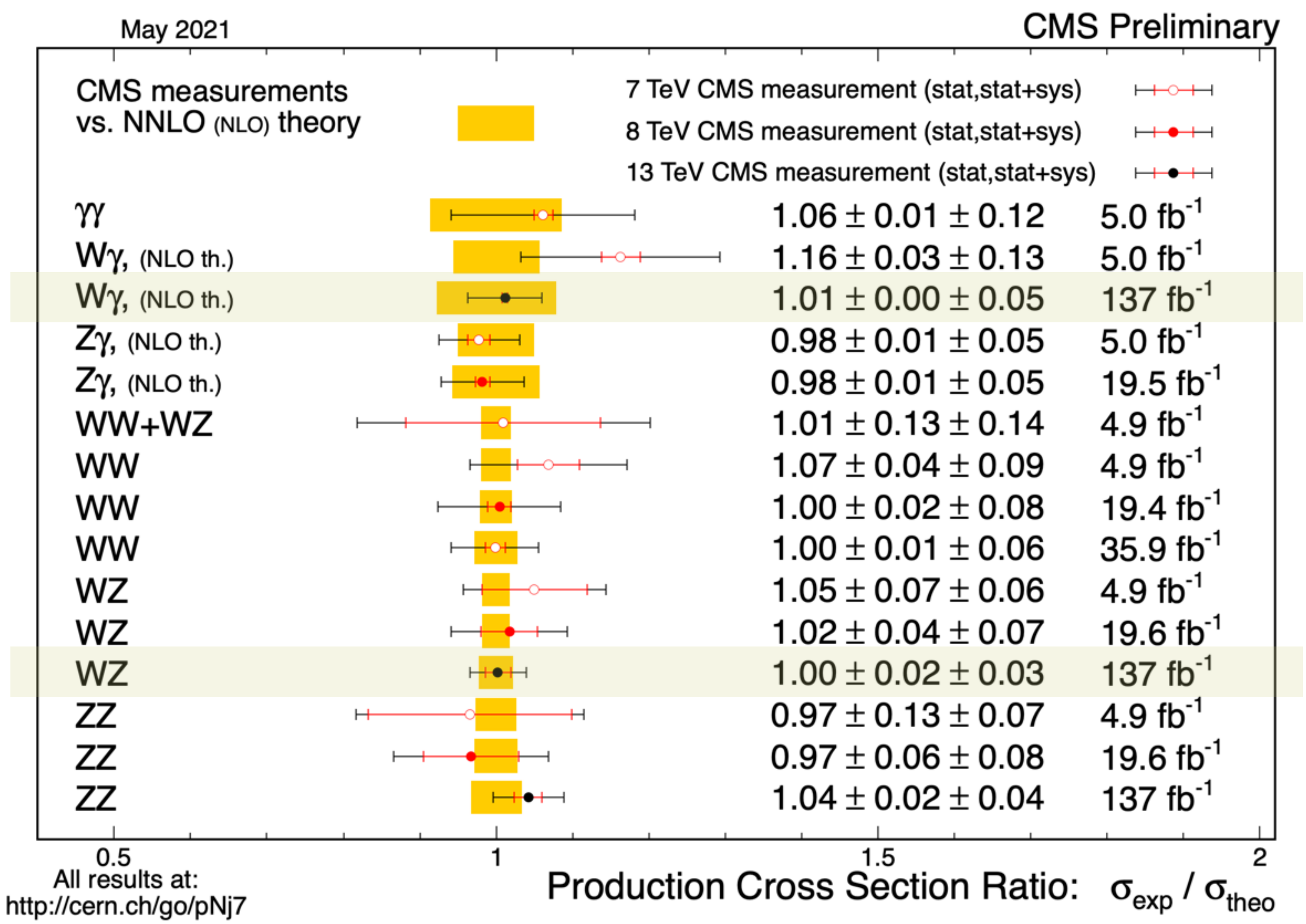
Giulia Sorrentino
On behalf of the CMS Collaboration



Why multibosons?

- High sensitivity to variations in Standard Model (SM) gauge couplings, making them a powerful experimental tool to test the behavior of the SM electroweak sector
- Multibosons (especially dibosons) cross sections are among the most accessible physical observables at the working energies of LHC
- High purity final states (multileptonic, leptons+photons)
- Multiboson final states are important backgrounds for several SM and BSM processes



Brand new results presented today!

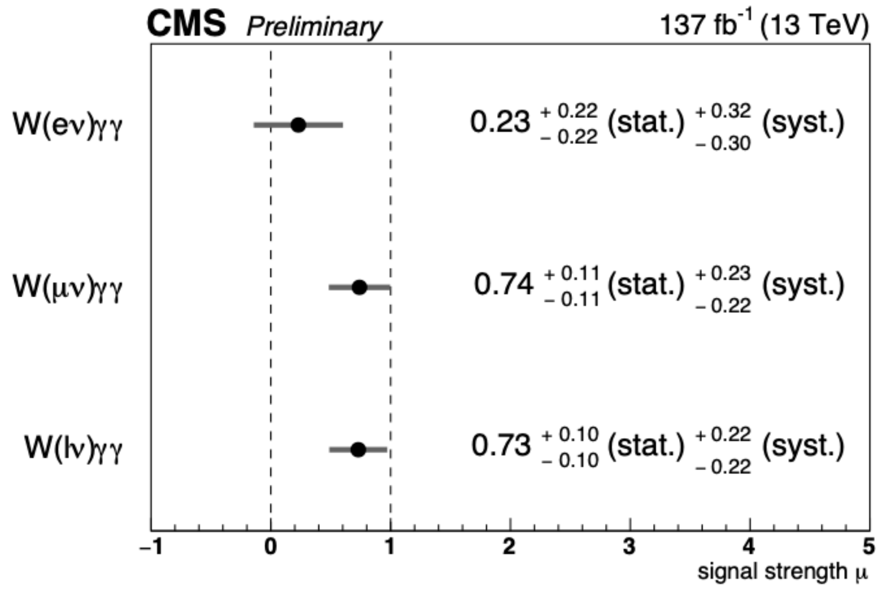
+Vγγ @13TeV

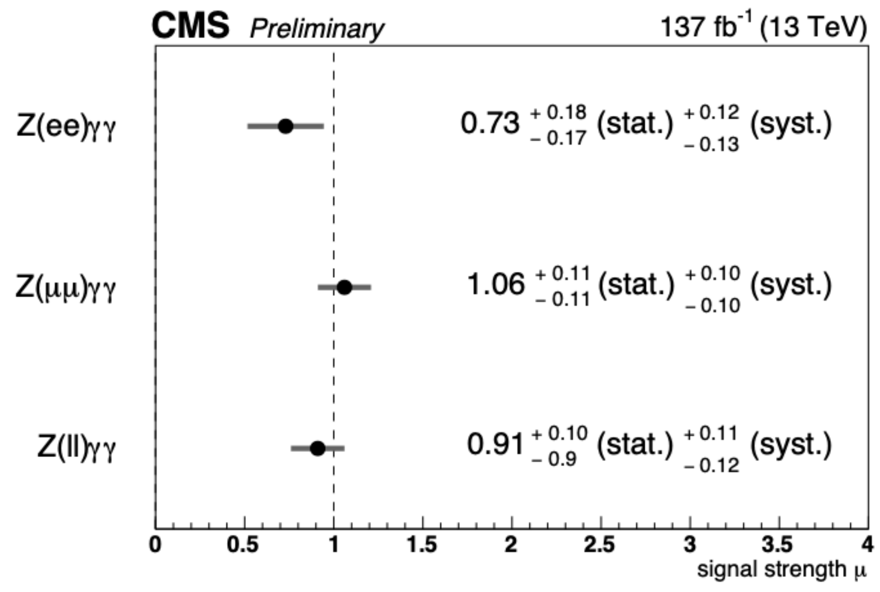
+VV @5.02TeV

Vγγ

arXiv 2105.12780

- Cross sections and limits on aQGCs in EFT framework
- **Main background**: jet-photon and electron-photon misidentification (data-driven)
- **Other backgrounds**: true photons contribution from tγ, ttγ, ttγγ, VVγ (from MC)
- Signal significance and signal strength obtained by fitting diphoton p_T distributions
- Main systematic uncertainties come from estimation of jet-photon bkg and photon SFs.





Combined observed significance is 3.1σ for Wγγ and 4.8σ for Zγγ

pp collisions@13 TeV
137 fb^{-1} (Full Run2)

Wγγ selection

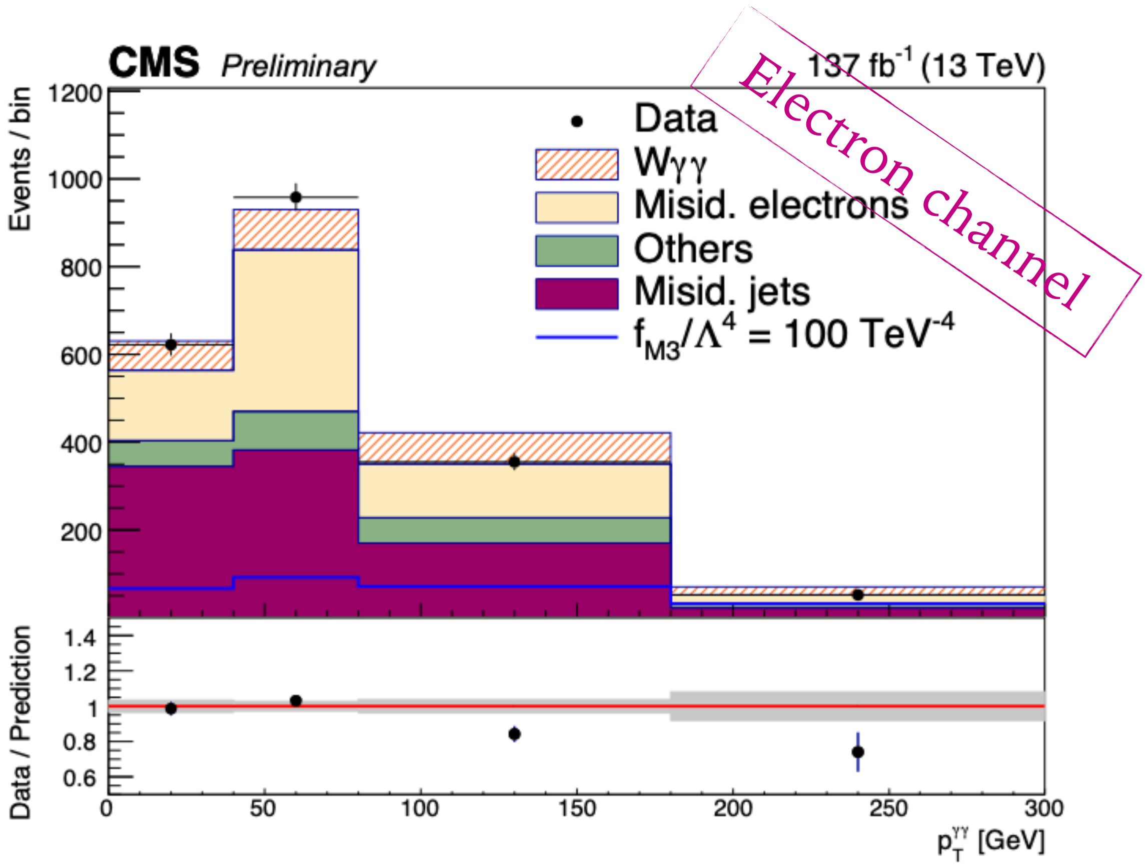
- At least 2 isolated and identified photons with $p_T > 20$ GeV
- Exactly one lepton
- $p_T^e > 35$ GeV
- $p_T^\mu > 30$ GeV

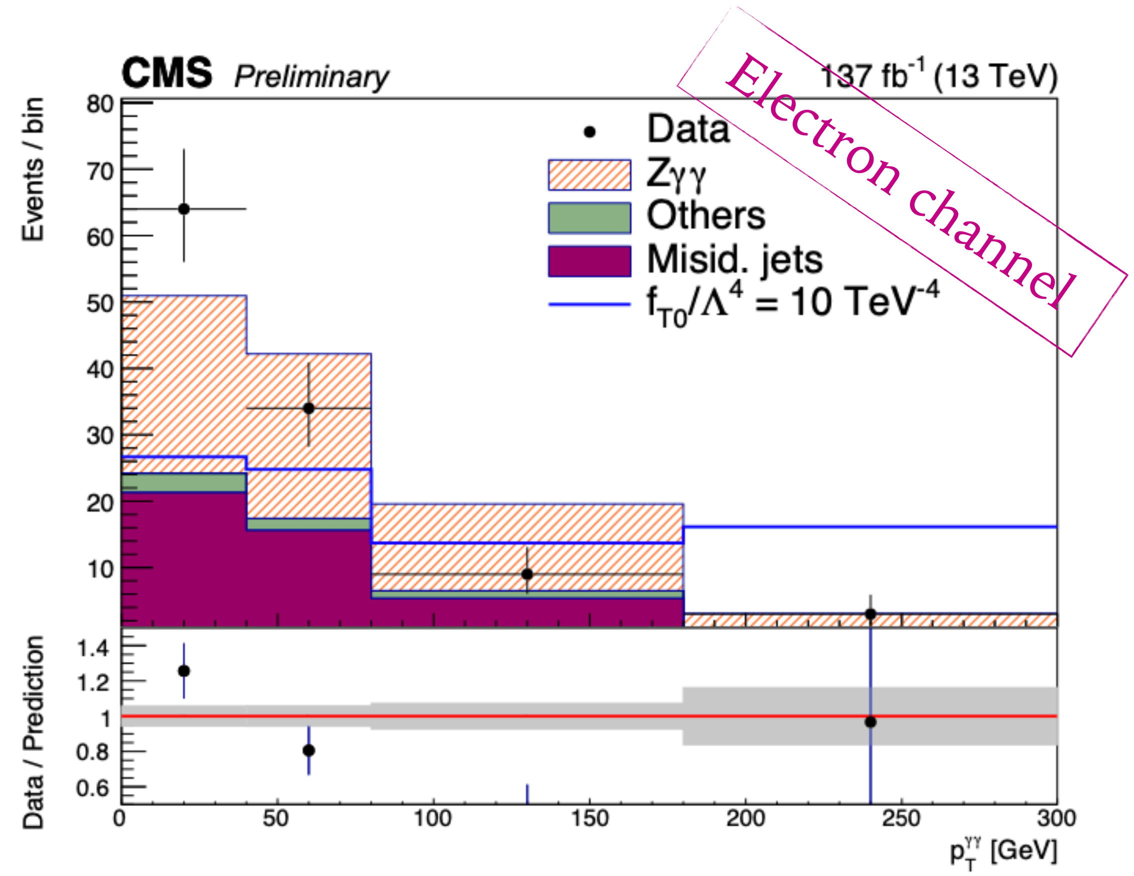
Zγγ selection

- At least 2 isolated and identified photons with $p_T > 20$ GeV
- Exactly 2OSSF leptons
- $p_T^{e(\mu)}$ (lead) > 35 (30) GeV
- $p_T^{e/\mu}$ (sublead) > 15 GeV
- $m_{ll} > 55$ GeV

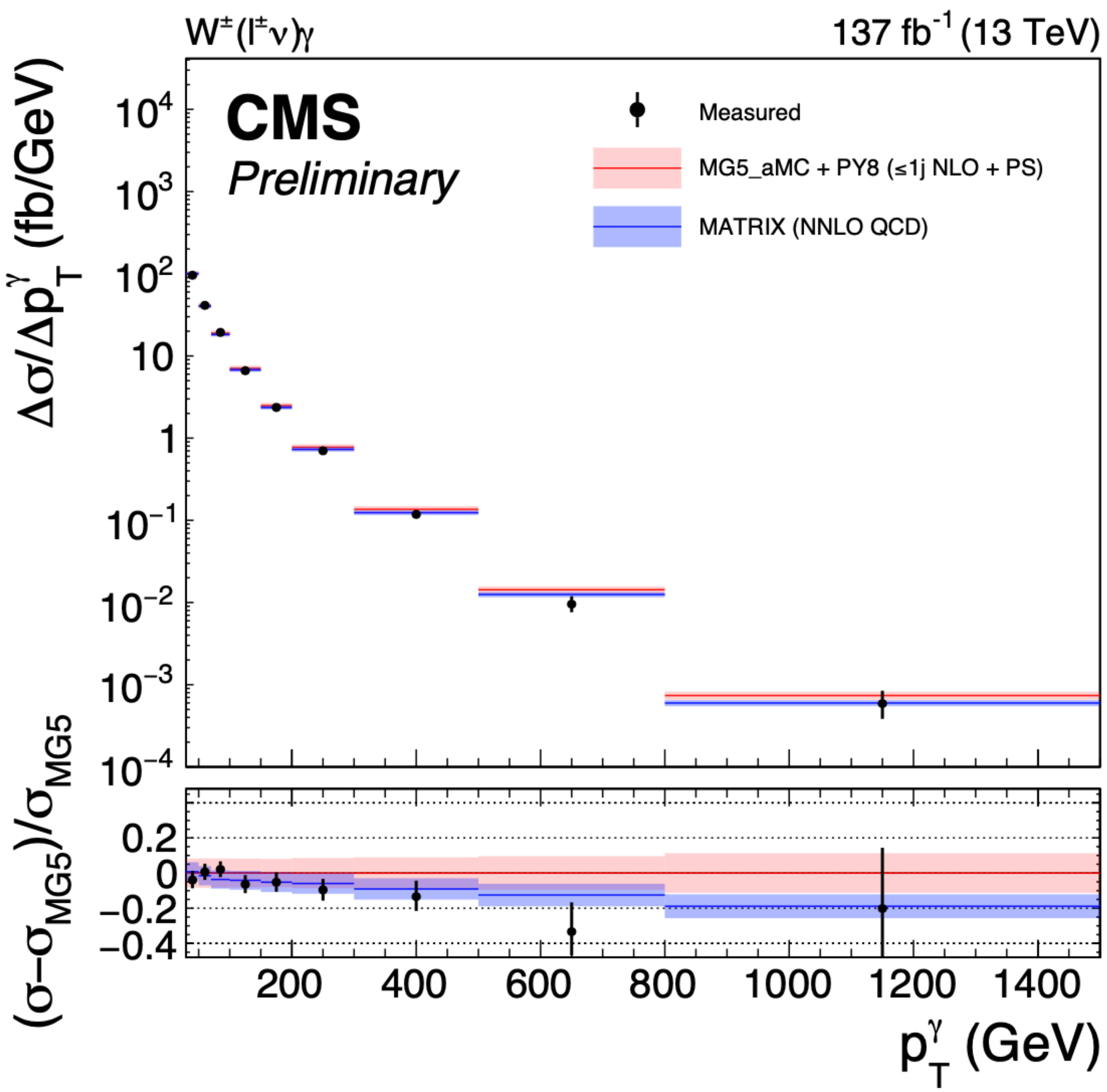
Vγγ

- Vγγ signal samples and other backgrounds are generated at NLO with MADGRAPH5 aMC@NLO





- Predictions for aQGCs are obtained by including a set of MadGraph weights, corresponding to the presence of the anomalous couplings, to the Vγγ reference samples
- Distributions are fitted and limits on aQGCs are extracted
  - First limits extraction on Zγγ aQGCs by CMS
  - Improvement wrt old Wγγ limits extracted at 8 TeV by a factor 10



- Systematic experimental uncertainties (main come from jet-photon, electron-photon and lepton misidentification) dominate in low p_T bins, statistical uncertainty dominates in highest bin
- Tendency towards the lower values of the MATRIX prediction at high p_T

pp collisions@13 TeV
137 fb^{-1} (Full Run2)

Event selection

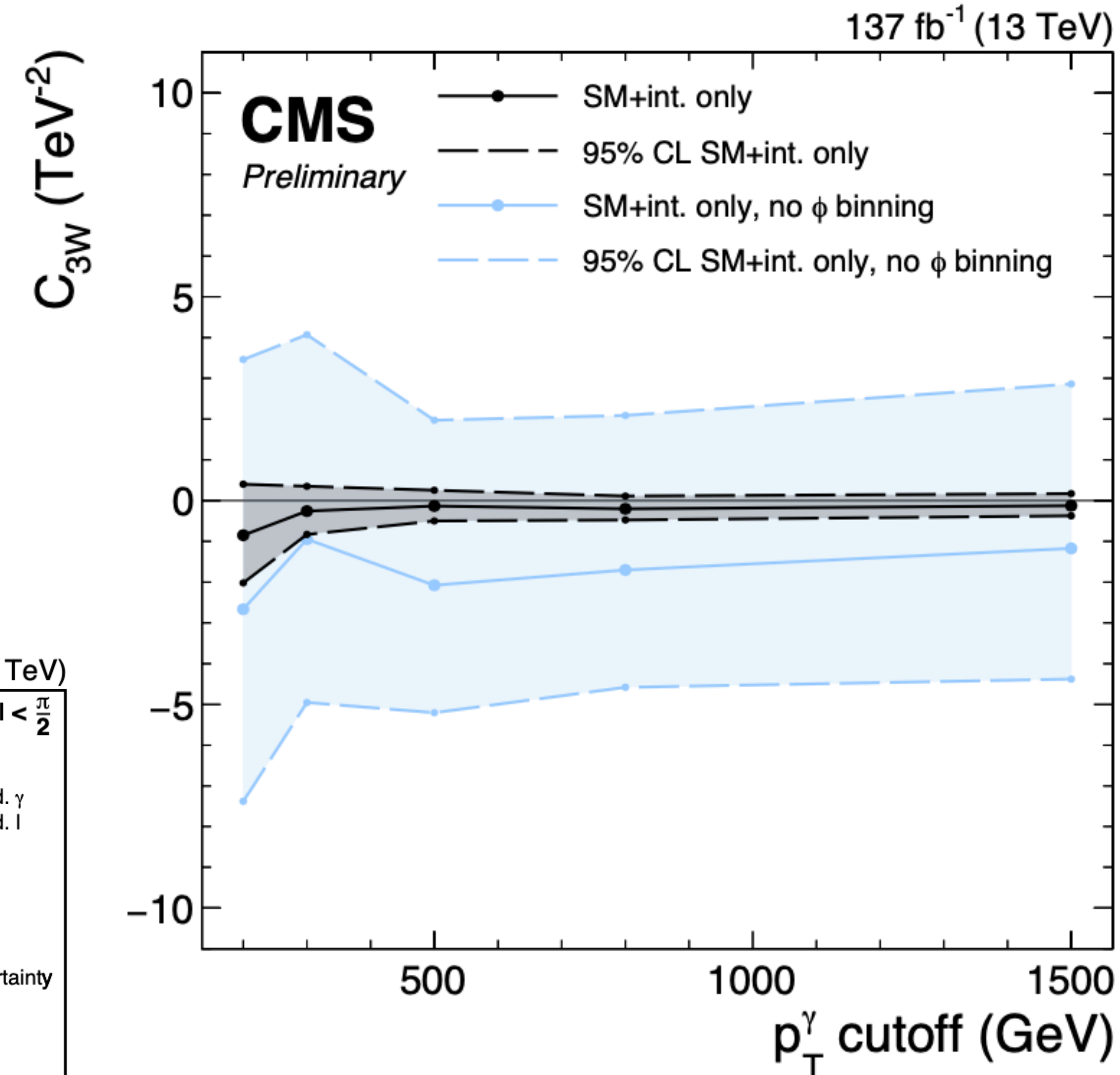
- $p_T^\gamma > 30$ GeV
- $\Delta R(l,\gamma) > 0.7$
- $p_T^{e(\mu)} > 35$ (30) GeV
- $p_T^{miss} > 40$ GeV

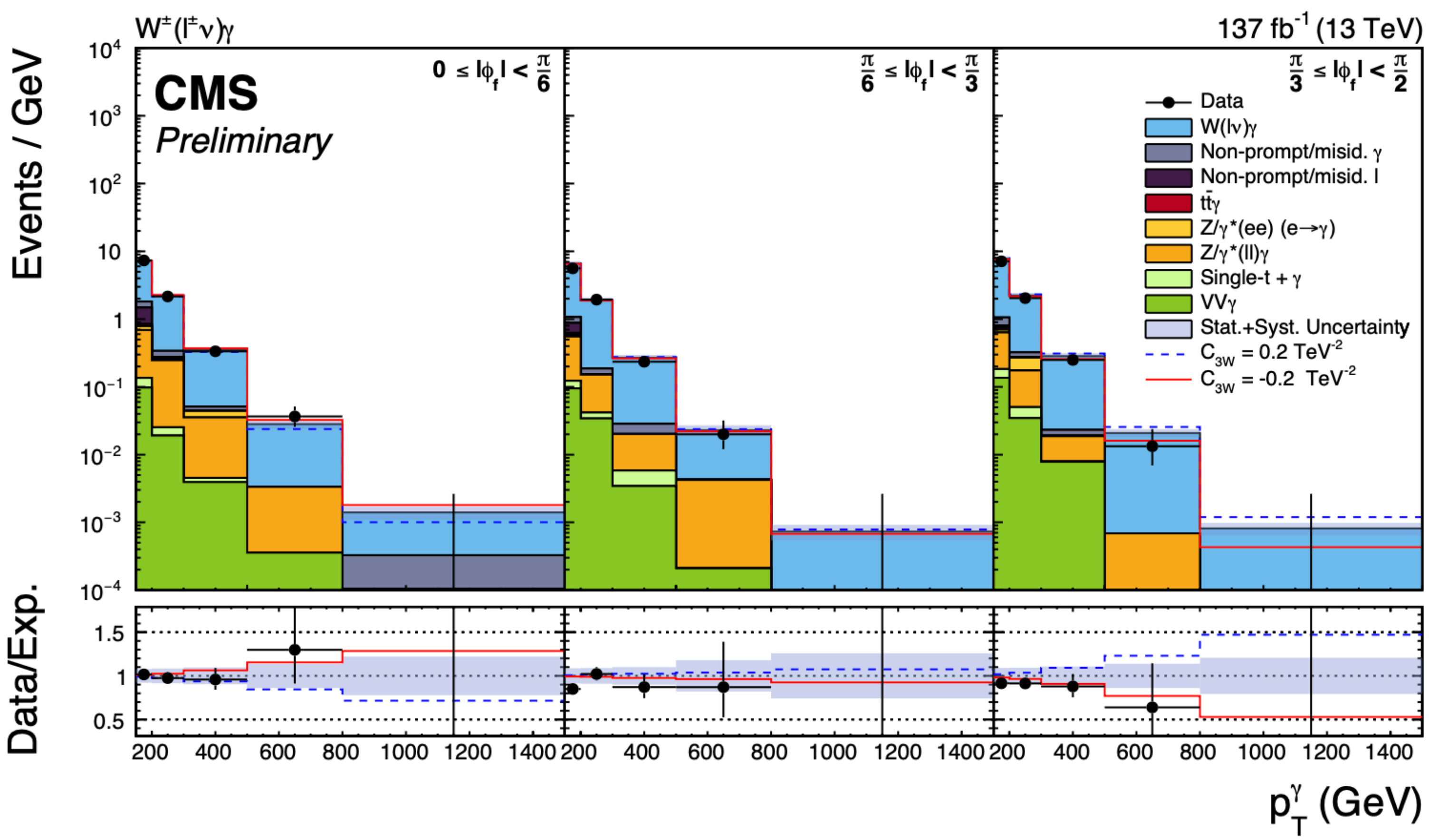
- Differential cross sections and limits on aTGCs (interference resurrection)
- Prompt-prompt background: processes containing prompt leptons and photons, as $Z/\gamma^*(ll)\gamma$, $tt\gamma$, $t\gamma$, $WV\gamma$ (from MC). Samples produced with MADGRAPH5 aMC@NLO and POWHEG.
- Nonprompt-prompt background: jet-photon and electron-photon misidentification; prompt photon+non-prompt or misidentified lepton events (data-driven)

Wγ

In the high energy limit ($E > m_W$), possible BSM modifications to the cross section are not detectable when considering observables inclusive over decay angles (i.e. W or photon p_T)

- **Novel two-dimensional approach**:
  - Simultaneous measurement of the photon p_T and of the azimuthal angle of the charged lepton
  - Special reference frame, defined by a Lorentz boost to the c.o.m. frame of the Wγ system





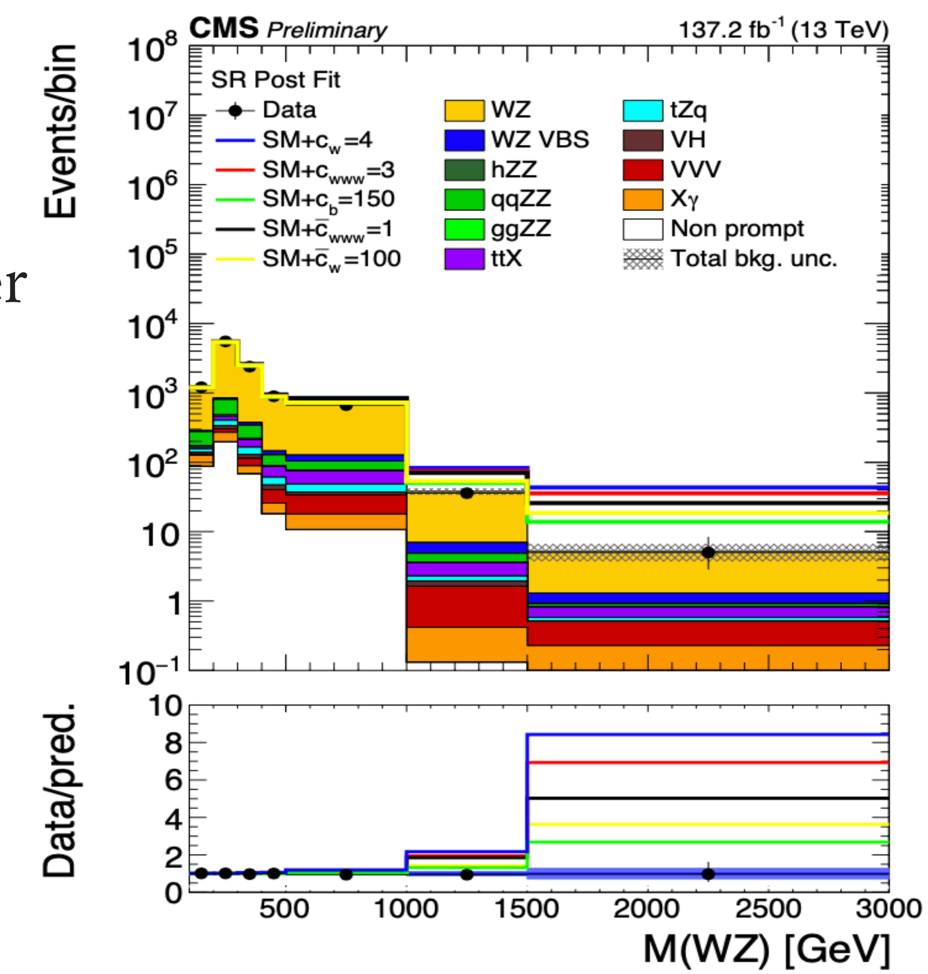
Sensitivity is enhanced by up to a factor of ten compared to a measurement using transverse momentum alone!

- **Reducible background**: Z+jets and tt production (data-driven)
- **Irreducible background**: ZZ, ttZ, tZq, and Xγ (from MC)
- Total production and fiducial cross sections measurements (dominated by systematic uncertainties, mainly lepton efficiencies)

$$\sigma_{tot}(pp \to WZ) = 50.6 \pm 1.9 \text{ pb}$$

- Favours NNLO QCDxNLO EWK MATRIX computations $\sigma_{MATRIX} = 50.7^{+1.1}_{-1.0}$ (scale) pb over NLO QCD POWHEG ones $\sigma_{POWHEG} = 42.5^{+1.6}_{-1.4}$ (scale) ± 0.6 (PDF) pb

- Constraints on aTGC stronger than previous analysis by a factor 2
- Measurements of boson polarization observables



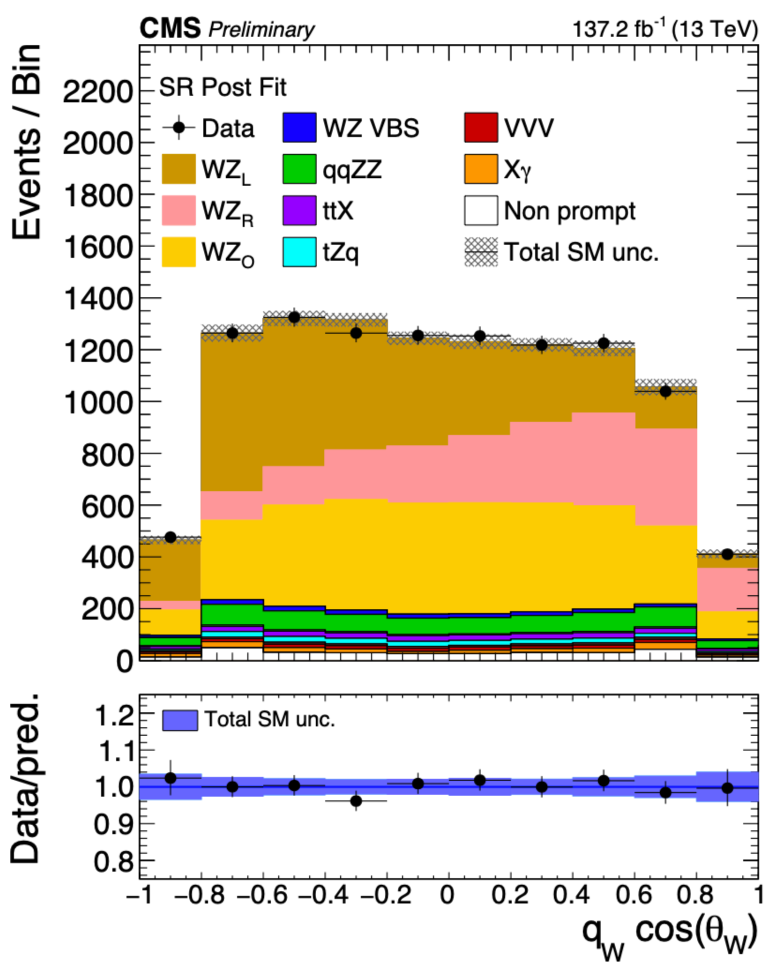
pp collisions@13 TeV
137 fb^{-1} (Full Run2)

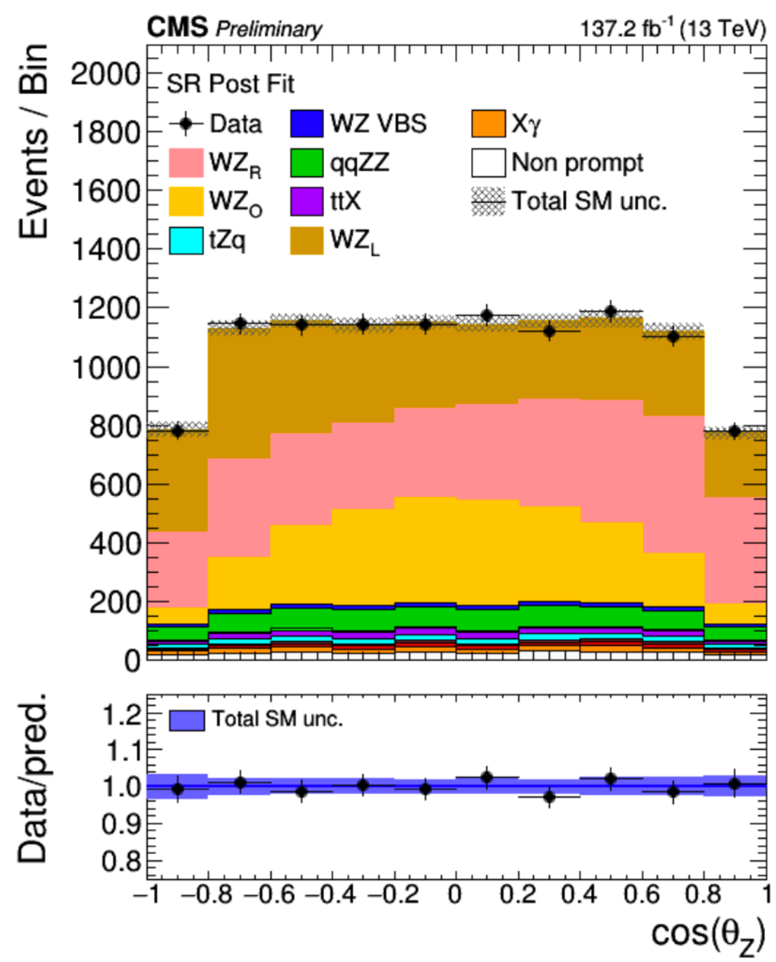
Event selection

- Exactly three light, isolated, and well identified leptons
- At least one OSSF pair
- $p_T(l_{Z1}) > 25$ GeV
- $p_T(l_{Z2}) > 10$ GeV
- $p_T(l_W) > 25$ GeV
- $p_T^{miss} > 30$ GeV
- $|m(l_{Z1} + l_{Z2}) - m_Z| < 15$ GeV
- $m(l_{Z1} + l_{Z2} + l_W) > 100$ GeV

WZ

- The behavior of the spin of massive vector bosons is heavily dependent on their production mechanism.
- Processes in which a scalar boson (Higgs or a possible new particle) decays into a vector boson pair tend to yield higher proportions of longitudinally polarized vector bosons w.r.t. non-resonant diboson production → **anomalies in the boson spin observables could lead to indirect evidence of new physics**



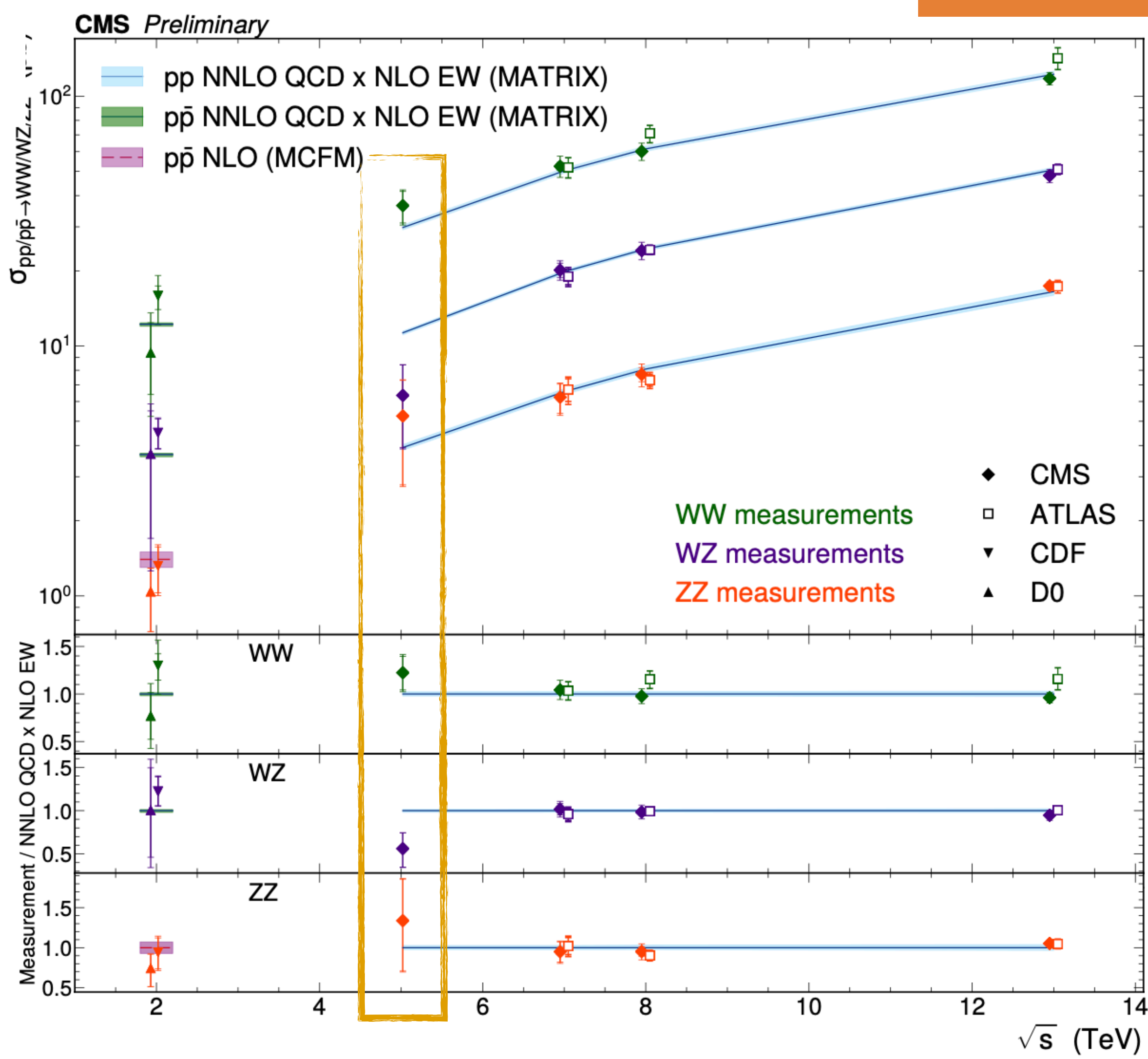


Significance computed over the hypothesis of transversal polarization-only SM

- Longitudinally polarized Z bosons observed (»5σ)
- **First observation of longitudinally polarized W bosons in the WZ channel (5.6σ)**

Fitting procedure relies on MC templates, built using generator level information on polarization angle $\theta_{W(Z)}$

CMS-PAS-SMP-20-012



- Total cross sections measurements (dominated by statistical errors)
- All backgrounds — yielding prompt leptons in the final state as tt, single top, DY and VV production, conversions and charge-flips — estimated from MC
- Good agreement with NNLO QCD×NLO EW predictions from MATRIX

pp collisions@5.02 TeV
304 pb^{-1} (Special lowPU Run)

WW

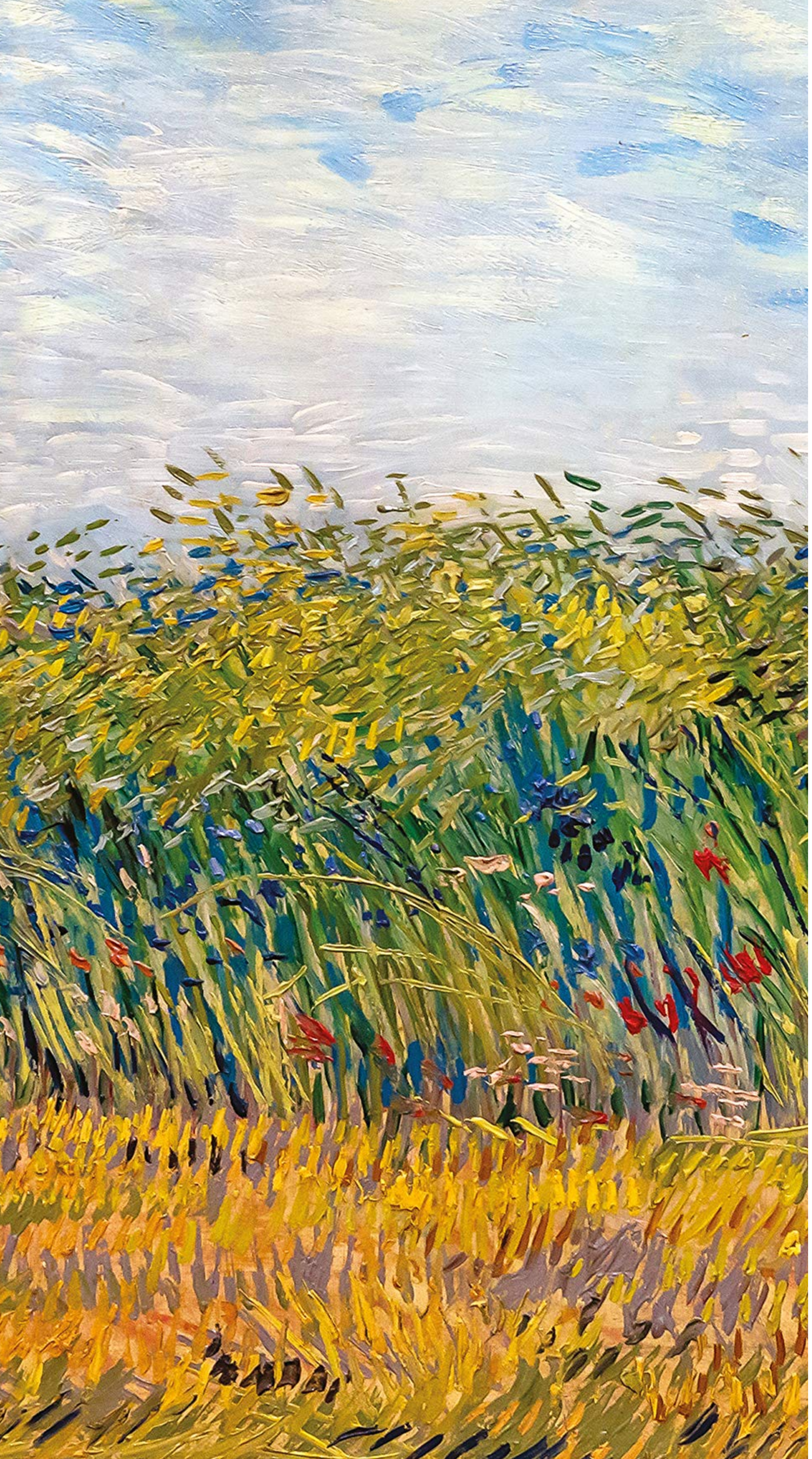
- Exactly 2 OS and different flavors leptons
- $\Delta\varphi(l,l') < 2.8$
- $p_T^{lead(sublead)} > 20\ (10)$ GeV
- $p_T(l,l') > 20$ GeV
- $p_T^{miss} > 20$ GeV

WZ

- Exactly 3 leptons with at least one OSSF pair
  - $|m(l_{Z1}+l_{Z2}) - m_Z| < 30$ GeV
  - $p_T\ (l_W) > 20$ GeV
  - $m(l_{Z1},l_{Z2},l_W) > 100$ GeV
- Exactly 2 muons
  - $p_T^{lead(sublead)} > 20\ (10)$ GeV
  - $p_T^{miss} > 25$ GeV

ZZ

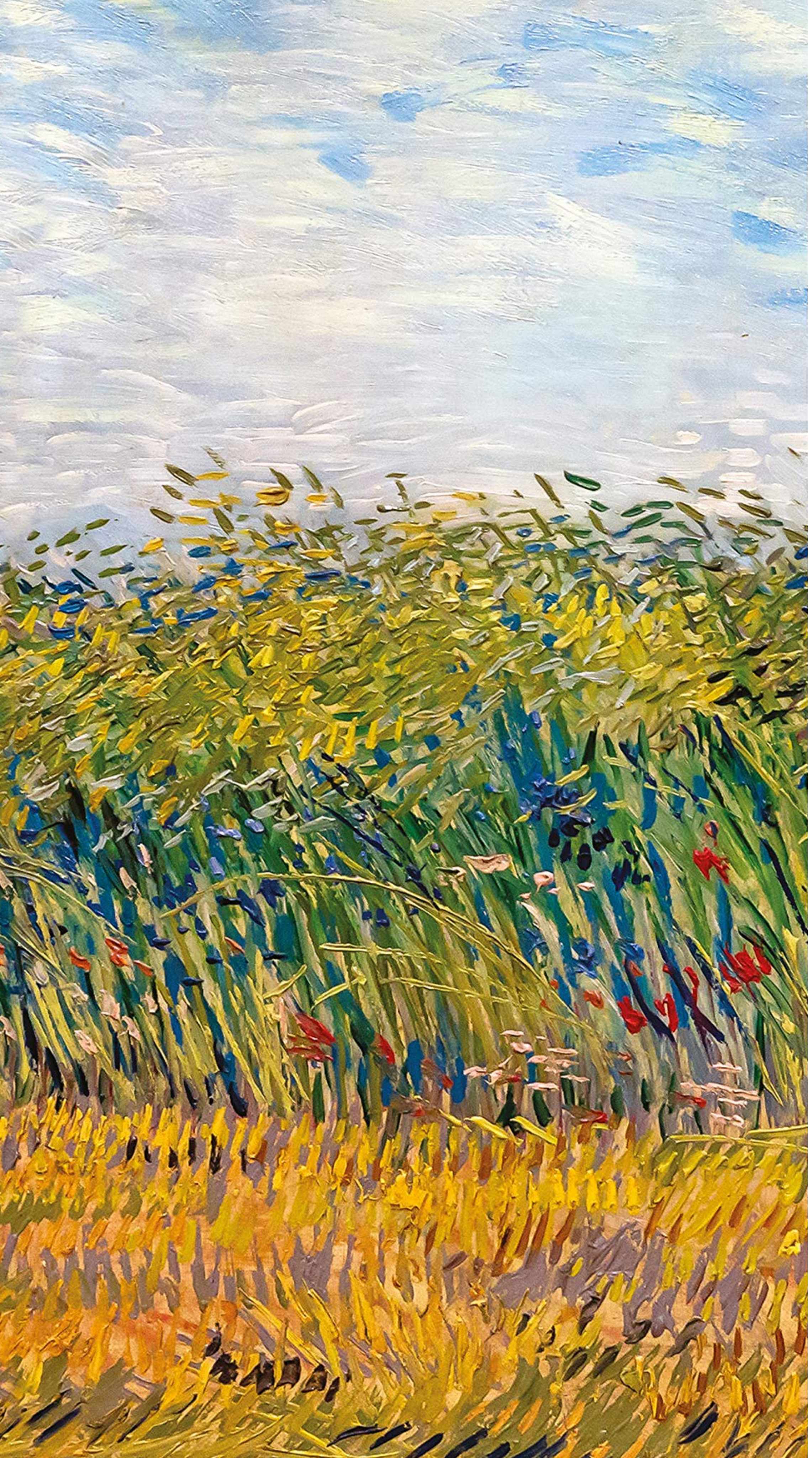
- Exactly 4 leptons with $p_T > 8$ GeV
- Exactly 2 OSSF leptons
  - $p_T^{lead(sublead)} > 20\ (10)$ GeV
- $|m(l,l') - m_Z| < 10$ GeV
- $|p_T^{miss} - p_T^Z|/p_T^Z < 0.3$
- $-p_T^{miss} \times \cos(\Delta\Phi(p_T^{miss},p_T^Z)) > 50$GeV



Summary and conclusions

- Wide range of multiboson precisions measurements provided by CMS
  - Cross section measurements in good agreement with NLO (and NNLO where available) theoretical predictions
  - More stringent constraints on aGCs have been provided, exploiting novel approaches and larger datasets
  - First observation of longitudinally polarized W bosons in the WZ channel @13TeV
- Many other dibosons and tribosons analysis on the way (Zγ cross section and aTGCs measurements @13TeV)

Stay tuned!



Backup

Wγ-Interference resurrection

- EFT Lagrangian:

$$\mathcal{L}_{\text{EFT}} = \mathcal{L}_{\text{SM}} + \sum_i C_i^{(6)} \mathcal{O}_i^{(6)} + \sum_i C_i^{(8)} \mathcal{O}_i^{(8)} + \cdots$$

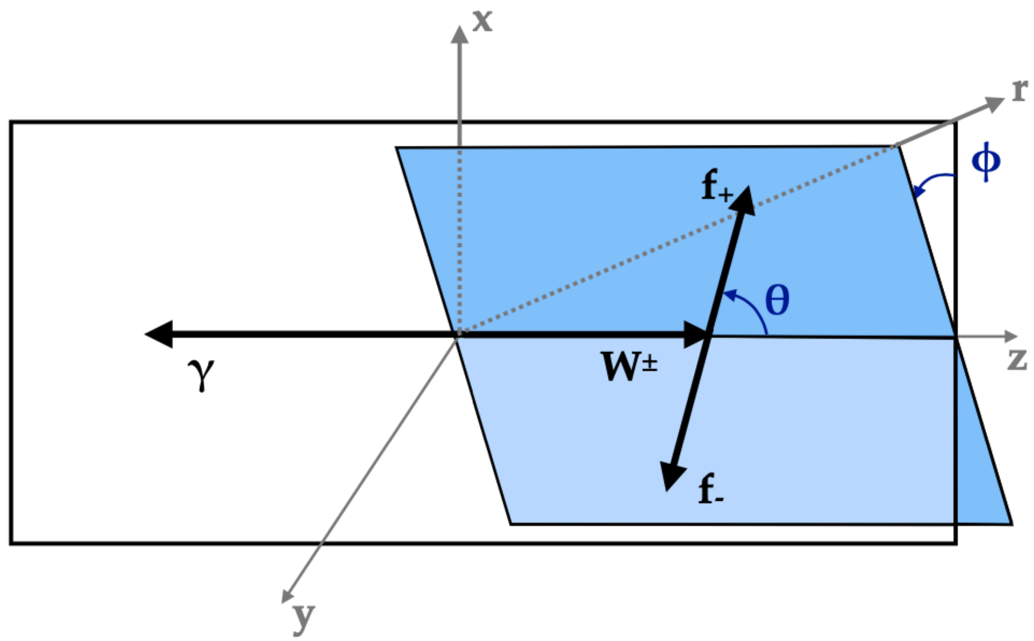
- Operator of interest:

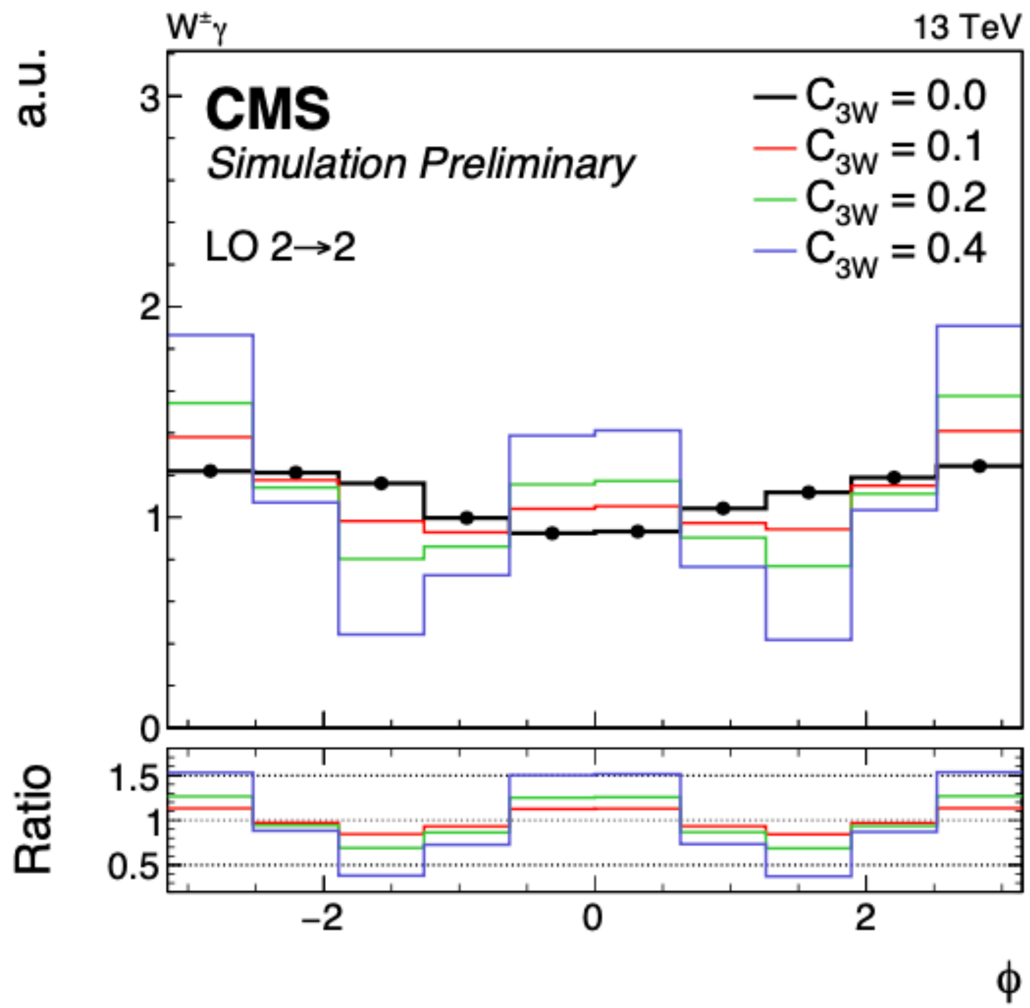
$$\mathcal{O}_{3W} = \epsilon^{ijk} W_\mu^{i\nu} W_\nu^{j\rho} W_\rho^{k\mu}$$

- Modification to the xsec in the presence of new operator:

$$\sigma(C_{3W}) = \sigma_{\text{SM}} + C_{3W}\sigma_{\text{int}} + C_{3W}^2 \sigma_{\text{BSM}}$$

Interference term





- Lorentz boost to the center-of-mass frame along direction r
- The z axis is chosen as the W boson direction in this frame, y is given by $r\hat{} \times z\hat{}$
- φ and θ are the azimuthal and polar angles of f_+

CMS detector