Recent CMS EFT activities

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5th General Meeting of the LHC EFT Working Group

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Introduction

CMS EFT program

→ aiming to probe new interactions in all sectors of the SM

Top quark physics

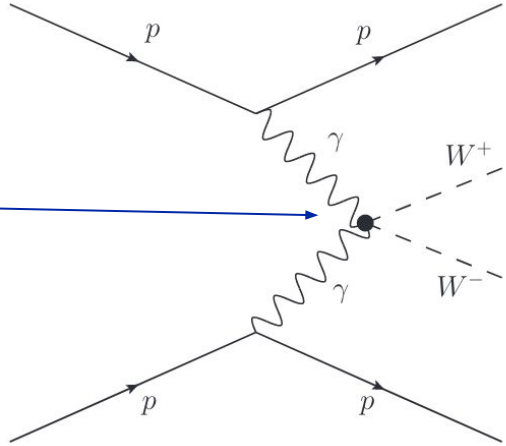
Higgs boson physics

Electroweak physics

Electroweak results

New physics in light-by-light scattering

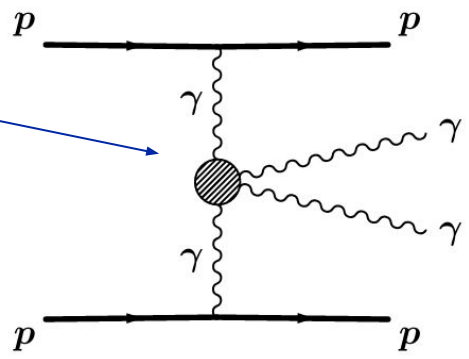
- Light by light scattering allows to probe new interactions quartic gauge couplings with photons
- ɣɣWW and ɣɣZZ interactions
  - Also probed in VBS interactions → later in this talk
  - Covered in Matthew's talk in the last LHC EFT Working Group meeting



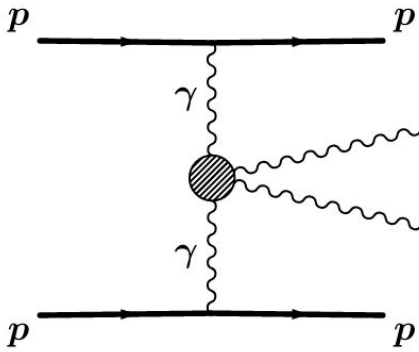
In this talk

- ɣɣɣɣ interactions explored in EXO-21-007
  - Predicted in models with heavy scalars
  - Possible in the SM but highly suppressed in our kinematic regime
  - Can be generated by two dimension 8 operators
  - Interpretation in terms of axion models

$$\mathcal{L}_{4\gamma} \begin{cases} \zeta_1 F_{\mu\nu}F^{\mu\nu}F_{\rho\sigma}F^{\rho\sigma} \\ \zeta_2 F_{\mu\nu}F^{\nu\rho}F_{\rho\lambda}F^{\lambda\mu} \end{cases}$$



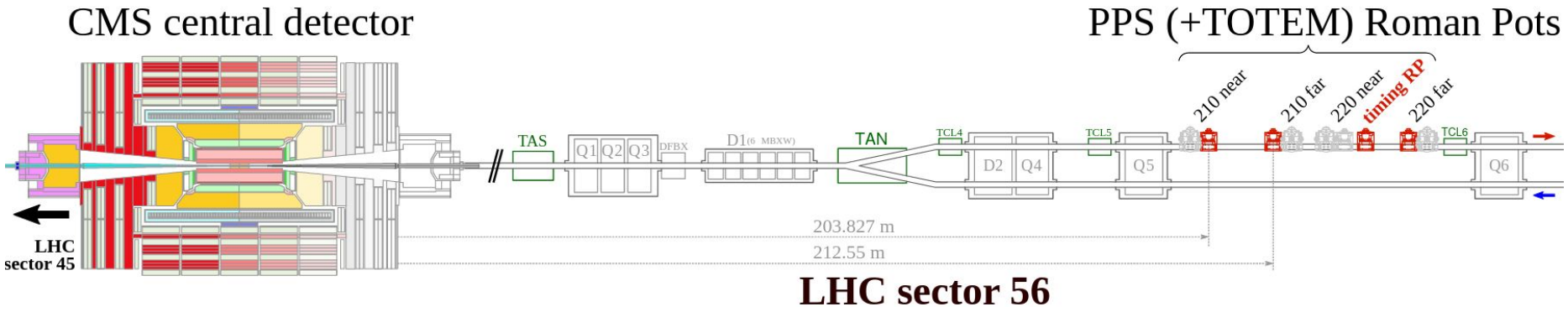
Analysis - main strategy and CTTPS



- Searching for diphoton events in associated to a pair of (intact) protons
- Protons measured in the CT-PPS detector
- The protons can be correlated with the CMS collision profiting from the beam optics

$\xi = \frac{\Delta p}{p}$ → proton fractional momentum loss

$m_{pp} = \sqrt{s\xi_p^+\xi_p^-}$ → mass of the central system

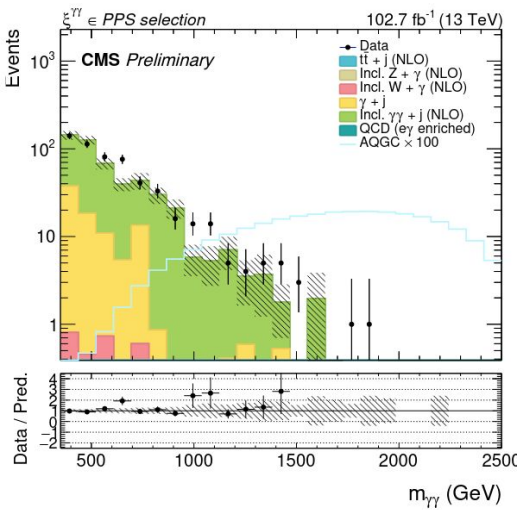


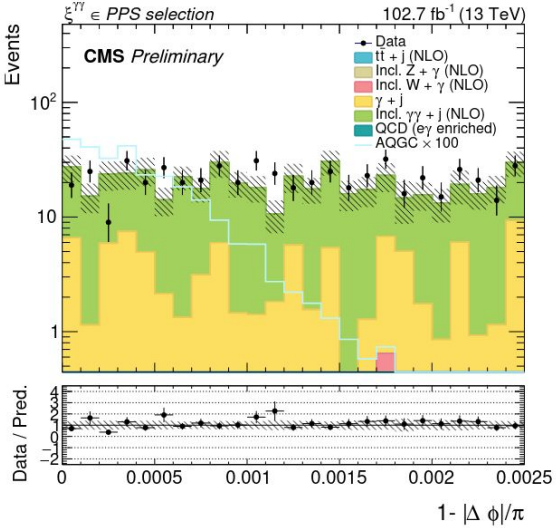
Analysis - selection

- Selecting events with two photons in the CMS detector
  - Large transverse momentum: p_T > 75 (100) GeV
  - $m_{\gamma\gamma} > 350\,\mathrm{GeV}$
- Momentum of photons consistent with the PPS acceptance

$$\xi^{\pm}_{\gamma\gamma} = \frac{1}{\sqrt{s}} \sum_{i=1}^{2} p_{\mathrm{T}}^{\gamma_i} e^{\pm\eta_{\gamma_i}} \quad \in [0.02, 0.2]$$

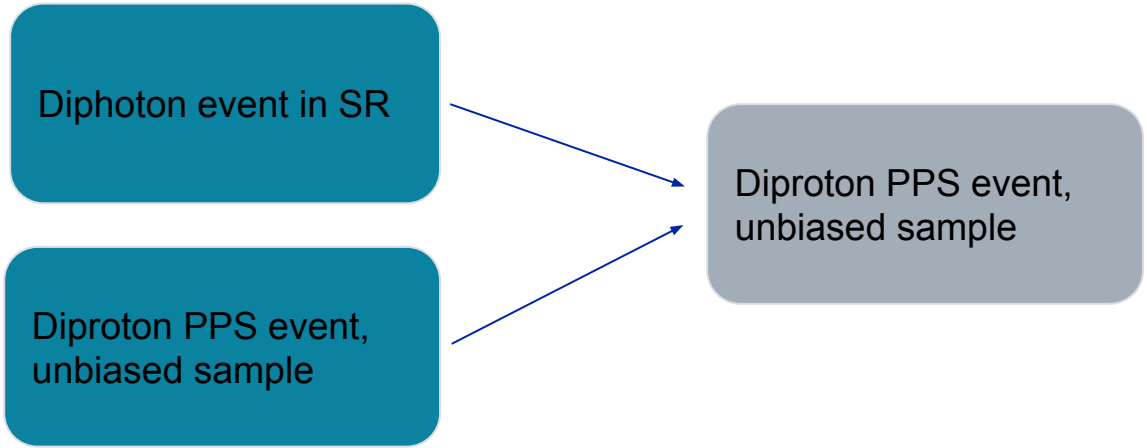
- Photons required to be back to back $1 - |\Delta\phi|/\pi < 0.0025$
- Protons are required to be the acceptance of the PPS





Analysis - background estimation

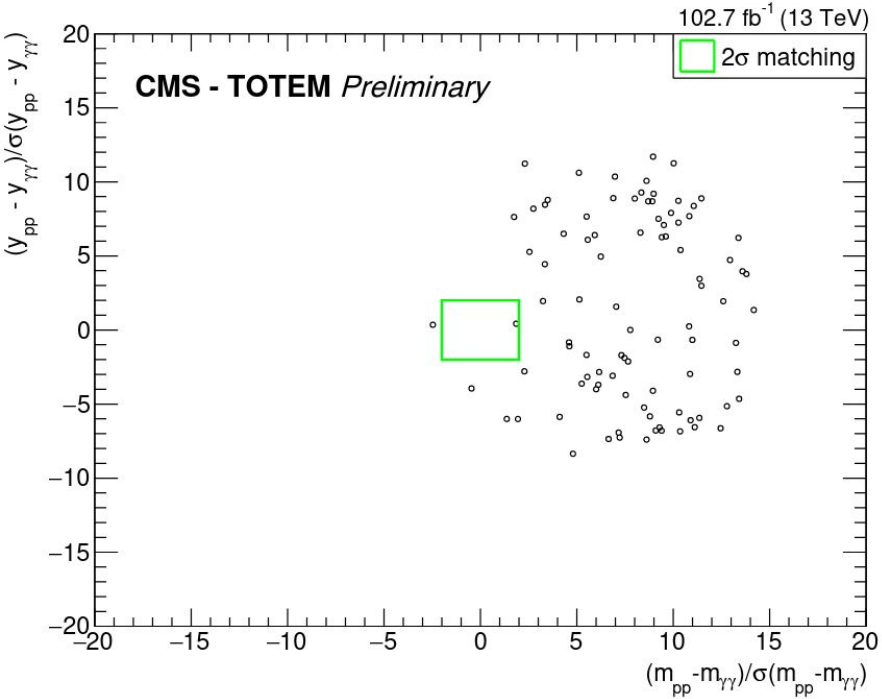
- Background dominated by accidental “correlations” between diphoton pair and pile-up events
- Pile-up and diphoton production are independent phenomena
- Background estimated using event-mixing techniques



Signal region and result

- Events selected requiring 2-sigma compatibility
  - On m_{pp} and $m_{\gamma\gamma}$
  - On y_{pp} and $y_{\gamma\gamma}$

- **Observed 1 event**
- Expected 1.10 ± 0.24 background events
- No significant deviation :(
- **Upper-limit on fiducial cross-section → < 0.61 fb**

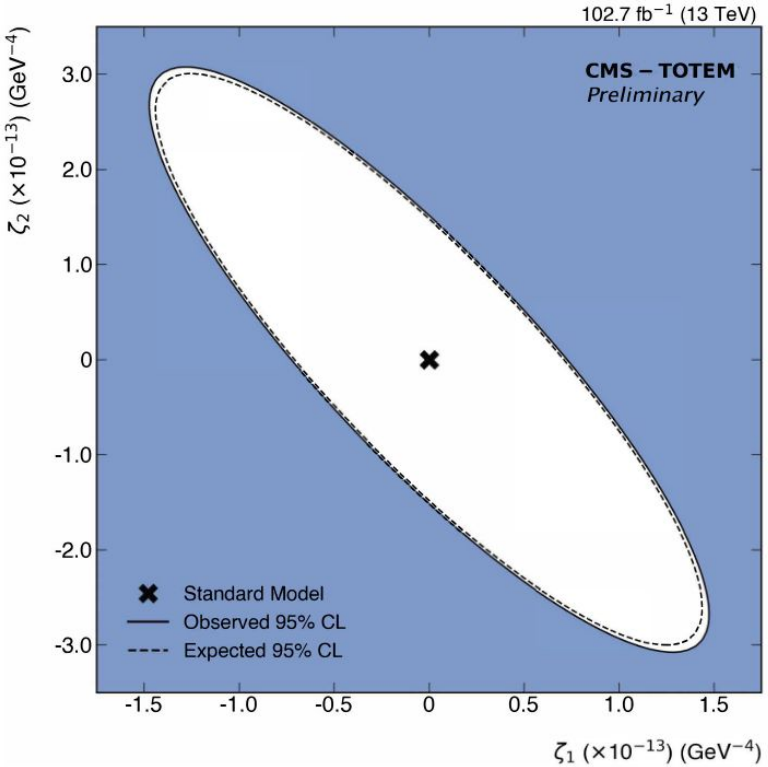


Interpretation

- Exclusive diphoton production rate depends on the WCs
  - Accounting for interference between the signals

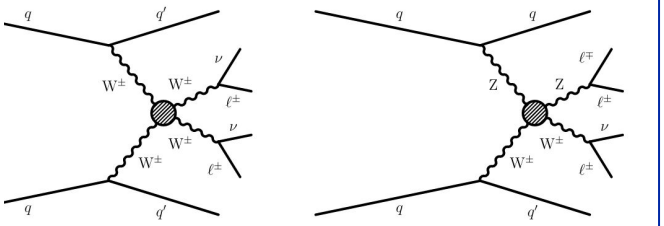
$$\frac{d\sigma}{d\Omega} = \frac{1}{16\pi^2 s}\left(s^2+t^2+st\right)^2\left[48\zeta_1^2+40\zeta_1\zeta_2+11\zeta_2^2\right]$$

- Acceptance and efficiency as a function of ξ_1 and ξ_2 estimated using simulations
- Excluding WCs larger than 10^{-13} GeV^{-4}

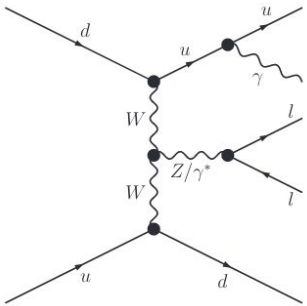


Results on VBS production

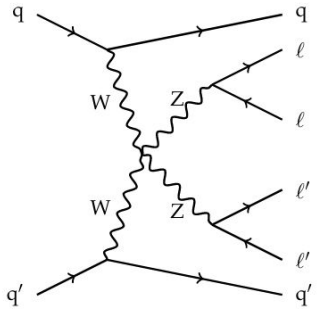
- Very interesting processes, direct access to QGC and TGC
- Quite complete program of measurements performed in CMS



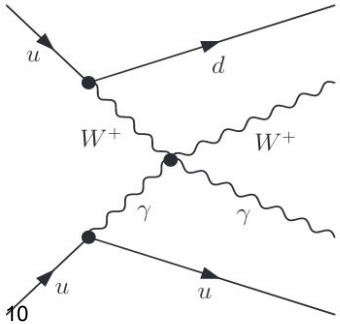
WZ + jj and $W^{\pm}W^{\pm}$+jj production: 2005.01173



Zɣ + jj production: 2002.09902



ZZ + jj production: 2008.07013



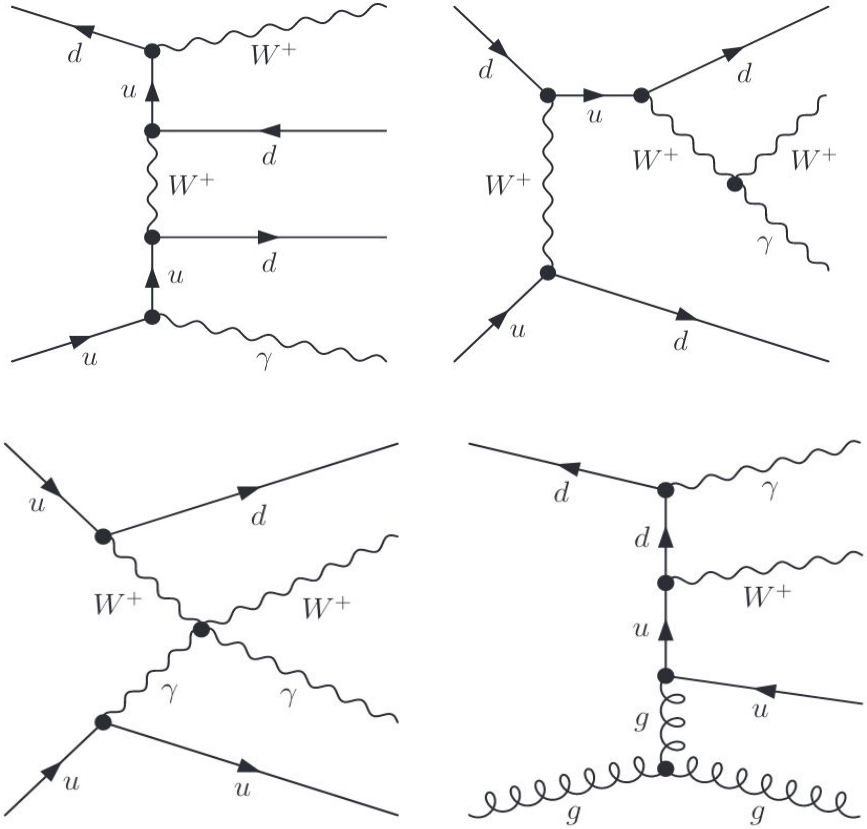
Wɣ + jj production: SMP-21-011

Covered in this talk

- Future plans discussed in Matteo's talk in the afternoon

Wγ + 2jet production

- Interesting process → receiving contributions from QCD, QED, aTGC and aQGC diagrams
- Electroweak production observed with 2016 data, reporting full Run 2 measurement now
- Measuring:
  - Inclusive cross-section
  - Differential cross-section
  - Limits on dimension 8 operators



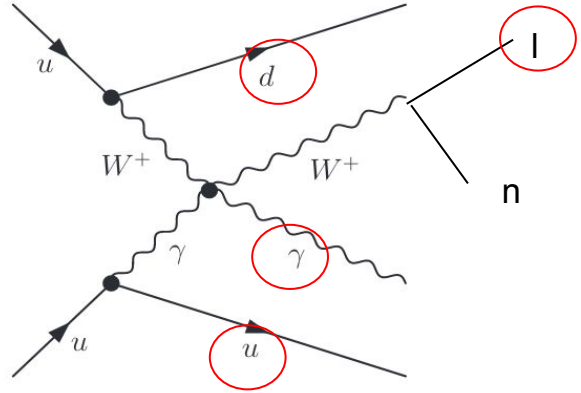
Event selection and background estimation

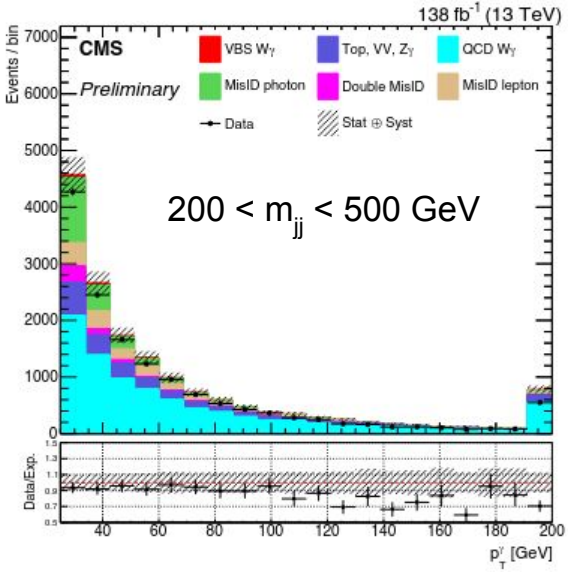
Event selection

- Requiring 1 lepton + 1 photon
- $m_{jj} > 500$ GeV, $\Delta\eta_{jj} > 2.5$, $m_{W\gamma} > 100$ GeV
  ← VBS-like topology
- $|y_{W\gamma}-(y_{j1}-y_{j2})/2|<1.2$, $|\Phi_{W\gamma}-\Phi_{jj}| > 2$
  ← balance Wɣ and dijet system

Background estimation

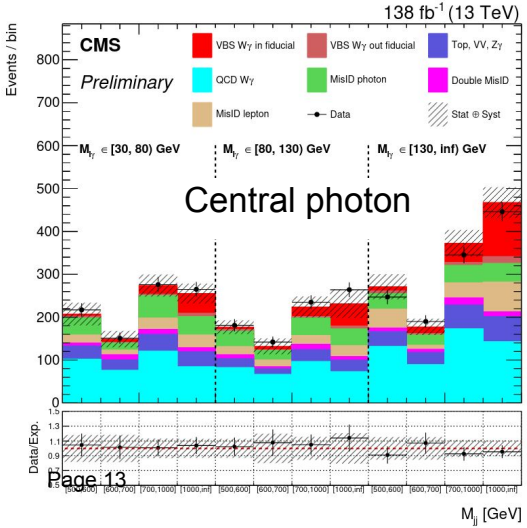
- Misidentified photon and leptons
  - Using data-driven techniques
- Remaining background dominated by QCD Wɣ production → estimated with simulations

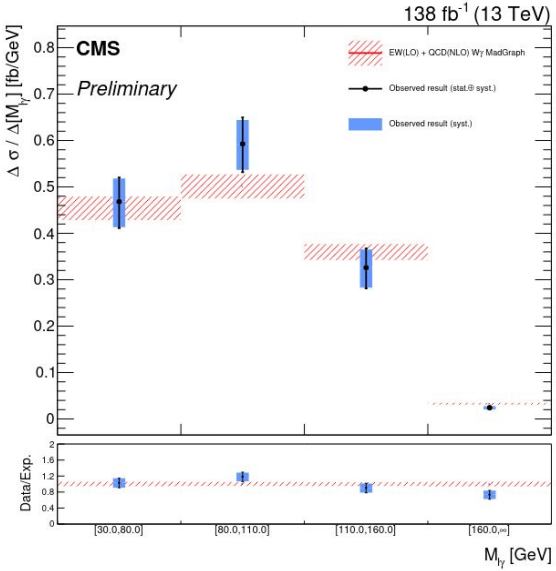


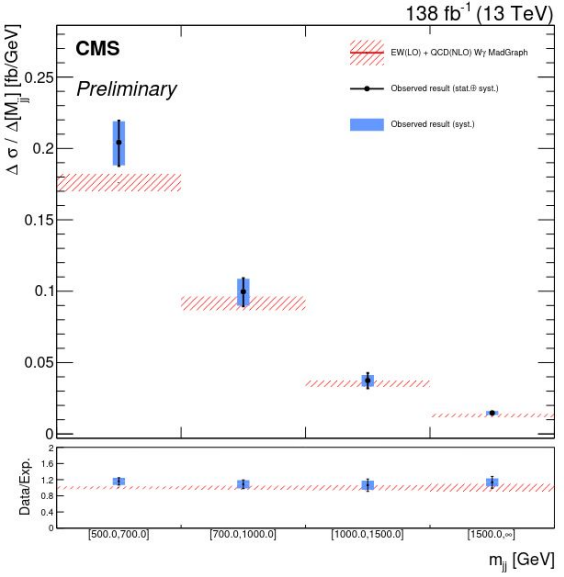


Inclusive and differential cross-section

- Measuring the electroweak production cross-section
- Inclusive xs obtained fitting m_{jj} and $m_{l\gamma}$
- $W\gamma$ EWK production established with 6.0 (6.8) observed (expected) s.d.
- $\sigma^{fid}_{ewk} = 19.2\ ^{+4.0}_{-3.9}$ fb, $\mu = 0.88^{+0.19}_{-0.18}$, consistent with prediction
- QCD+EWK cross-section also measured consistently with SM
- Differential measurement also performed



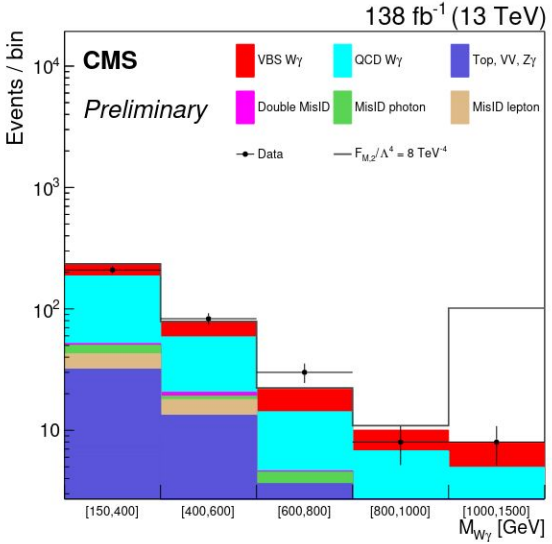


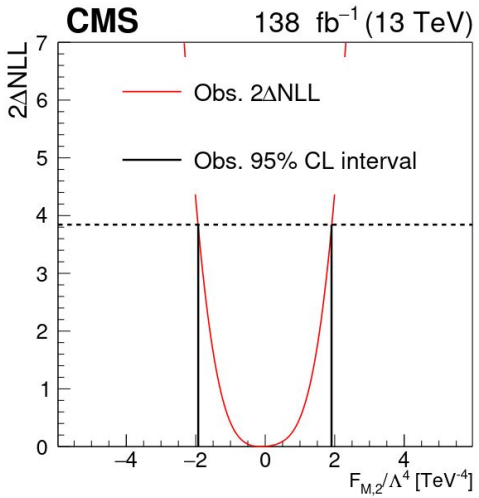


Anomalous coupling interpretation

- Tighter selection to optimize sensitivity
- Yield parametrized as a function of Wilson coefficient → quadratic dependence
- Signal efficiency and acceptance included in simulations
- Setting limits on different dimension 8 operators
  - L_{MX} → two field strength + 2 (DH)
  - L_{TX} → four field strengths

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

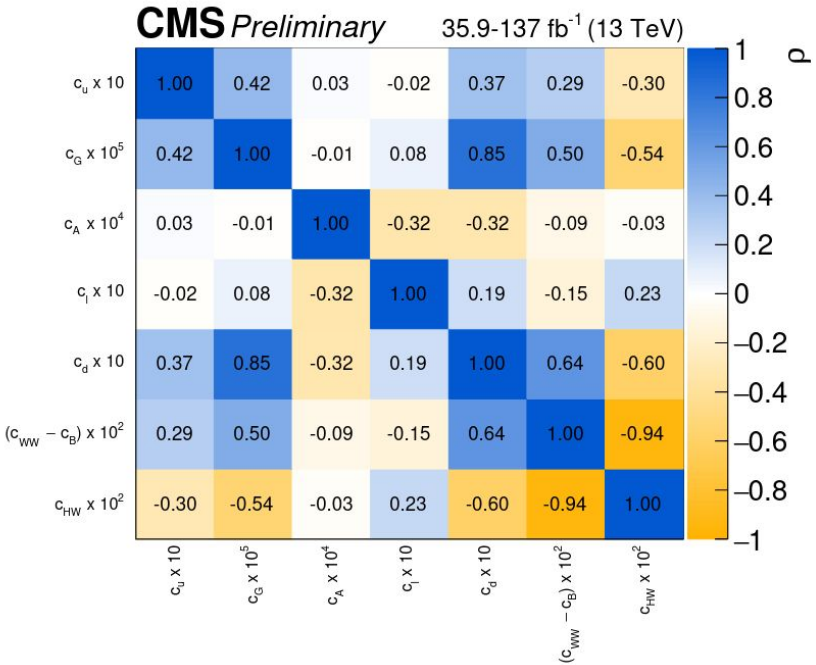


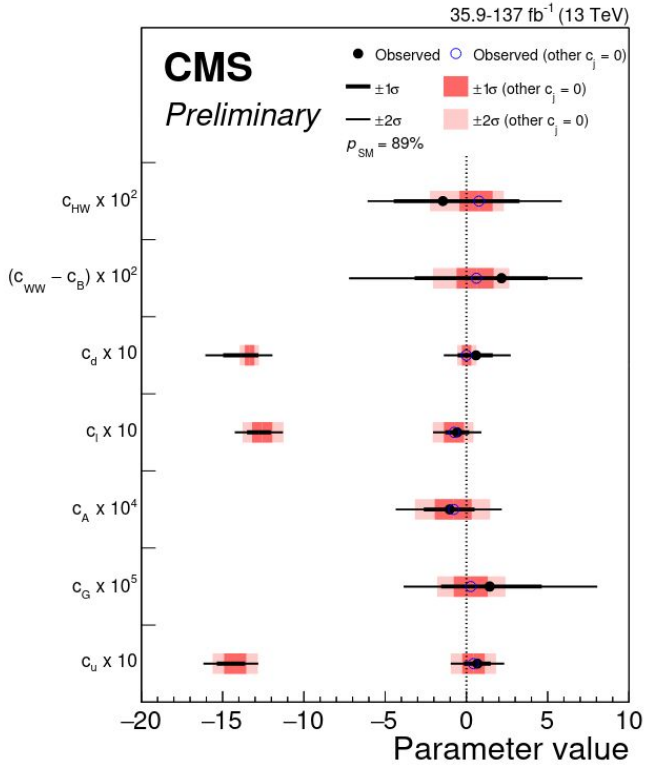


Higgs and top physics results

Latest Higgs results - STXS interpretation

- Program of Higgs measurements in the STXS with outstanding constraining power
- Latest results performed in the HEL
- Probing 7 independent WCs



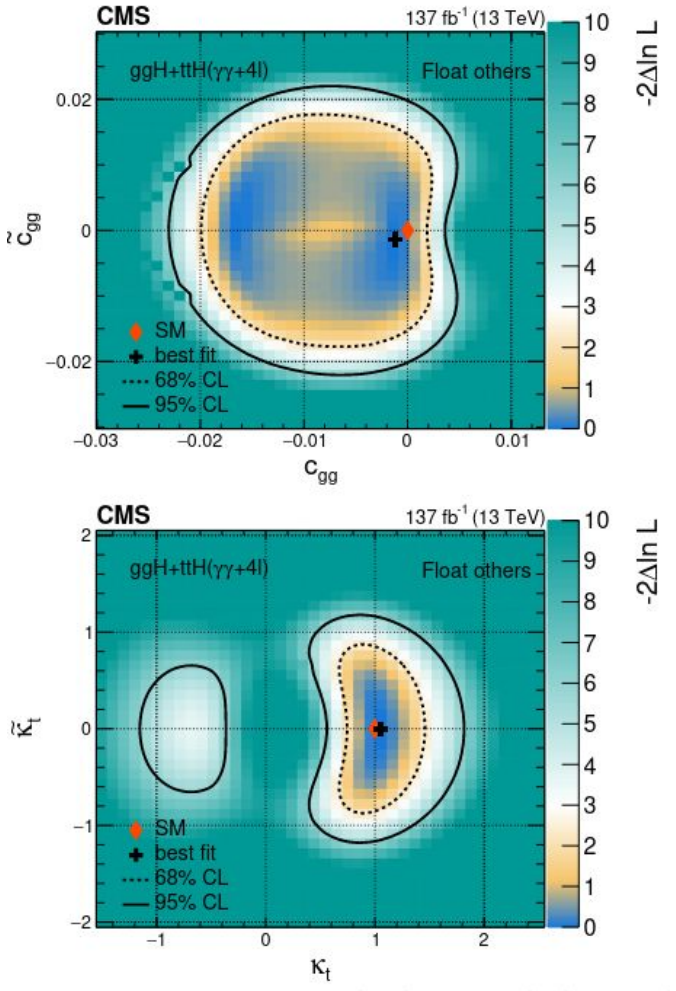


Latest Higgs results - direct measurement

- Also probing Higgs interactions directly using anomalous couplings → can be rotated to SMEFT
- Using H→ZZ decays and ttH(γγ)
- Constraining all parameters simultaneously

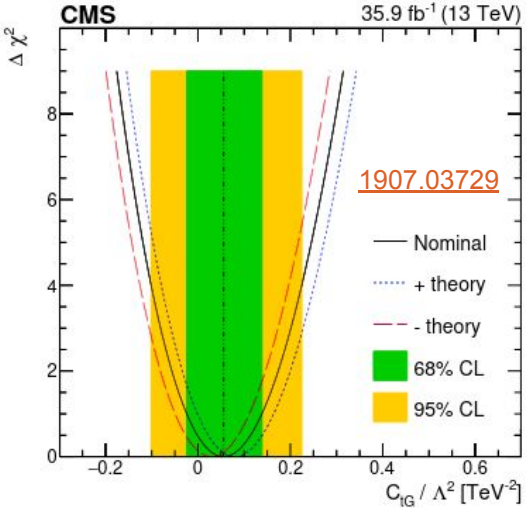
$$A(\mathrm{HV_1V_2}) = \frac{1}{v}\left[a_1^{\mathrm{VV}} + \frac{\kappa_1^{\mathrm{VV}} q_{\mathrm{V1}}^2 + \kappa_2^{\mathrm{VV}} q_{\mathrm{V2}}^2}{\left(\Lambda_1^{\mathrm{VV}}\right)^2} + \frac{\kappa_3^{\mathrm{VV}} (q_{\mathrm{V1}} + q_{\mathrm{V2}})^2}{\left(\Lambda_{\mathrm{Q}}^{\mathrm{VV}}\right)^2}\right] m_{\mathrm{V1}}^2 \epsilon_{\mathrm{V1}}^* \epsilon_{\mathrm{V2}}^* + \frac{1}{v} a_2^{\mathrm{VV}} f_{\mu\nu}^{*(1)} f^{*(2),\mu\nu} + \frac{1}{v} a_3^{\mathrm{VV}} f_{\mu\nu}^{*(1)} \tilde{f}^{*(2),\mu\nu},$$

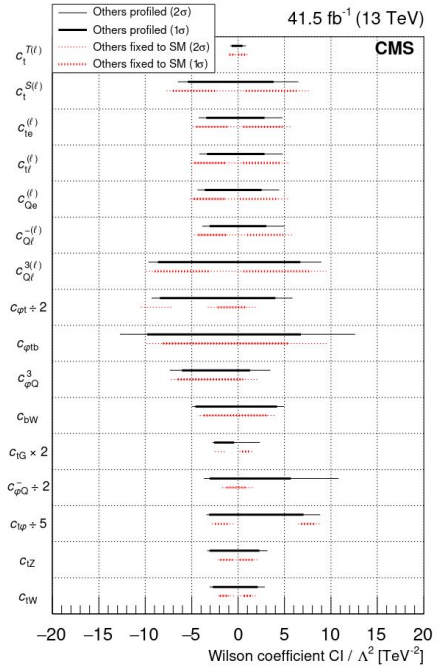
$$A(\mathrm{Hff}) = -\frac{m_{\mathrm{f}}}{v}\overline{\psi}_{\mathrm{f}}\left(\kappa_{\mathrm{f}} + \mathrm{i}\tilde{\kappa}_{\mathrm{f}}\gamma_5\right)\psi_{\mathrm{f}}$$



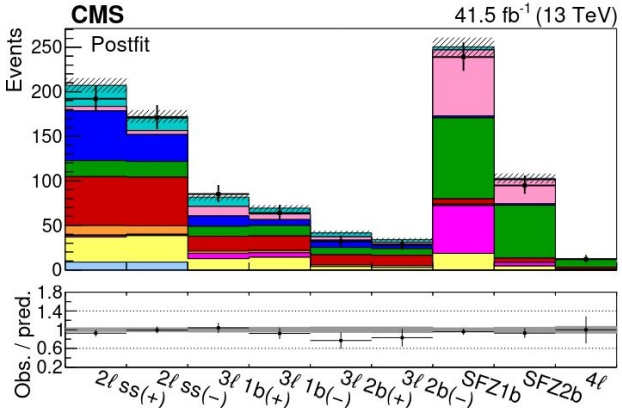
Recent top quark results

- Probing top quark in all possible fronts
- Reinterpretation of top quark spin correlation measurements →
- Direct measurement in associated top production
  - Suitable for tricky final state, using full experimental info

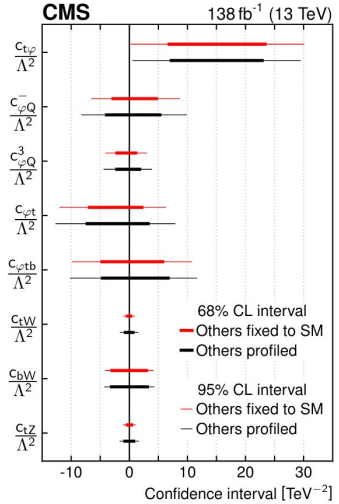




Multilepton channel (ttH, ttZ, ttW, tH, tZq)
2012.04120



Boosted ttH/Z(bb)
2208.12837



Conclusions

- CMS is developing a strong program of EFT measurements
- Looking at all possible directions
  - Electroweak physics
  - Top quark sector
  - Higgs physics
- Unfortunately, not seeing large deviations, but instead setting strong constraints
- **Keep posted for many more interesting results**