

photon-photon physics at CMS

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How do we measure photon-photon processes?

pp:

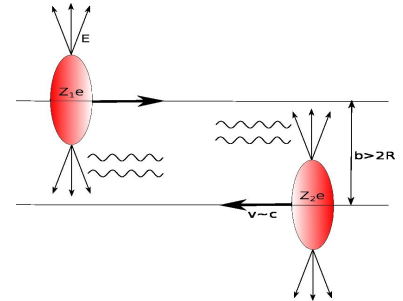
- In pp interactions, QCD production of $\gamma\gamma \rightarrow \gamma\gamma$ dominates at low invariant mass and QED component at high $\gamma\gamma$ invariant mass [1]. The same is qualitatively true for $\gamma\gamma \rightarrow WW/ZZ/Z\gamma$.

UPC PbPb:

- Photon flux $\sim Z^4$ \rightarrow $\gamma\gamma$ luminosities \gg pp ones at low invariant mass
- Electromagnetic interactions dominates over strong interactions.

Why?

- Search for new physics in EFT approach.
- Precision physics
- Used to tune MC predictions



[1] S. Fichtel, G. von Gersdorff, B. Lenzi, C. Royon, M. Saimpert, JHEP 02 (2015) 165 - Light-by-light scattering with intact protons at the LHC: from standard model to new physics.

Exclusive $\gamma\gamma \rightarrow WW$ at 13 TeV (CMS and TOTEM Collaborations)

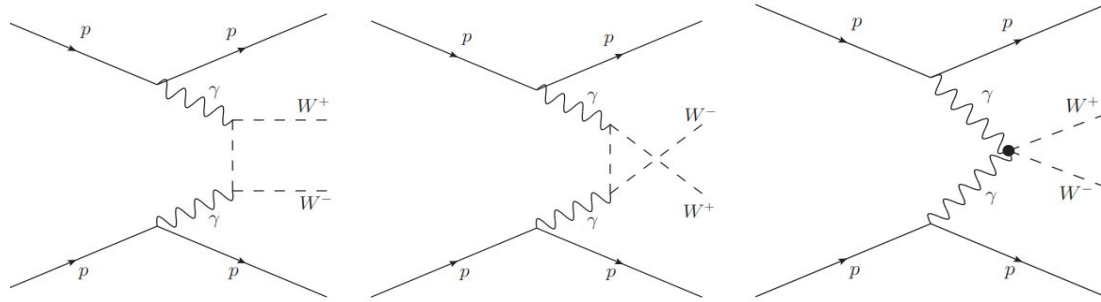
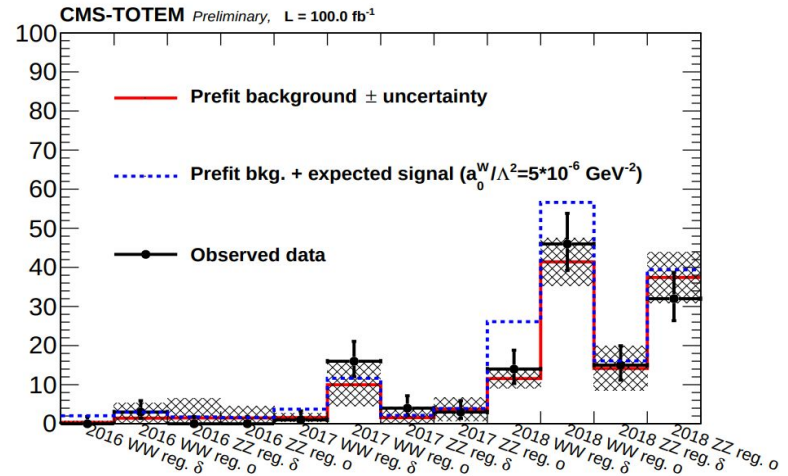
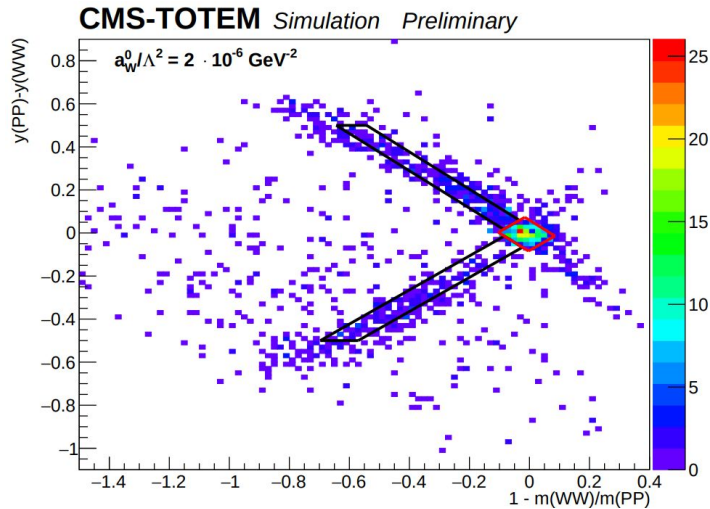


Fig.1 SM Feynman diagrams of $\gamma\gamma \rightarrow WW$ production with intact protons.

- Photon induced processes with intact protons in forward regions
- SM prediction is small in the high $m(WW)$ region.
- Excesses over prediction

- Measurement of $WW\gamma\gamma$ quartic coupling is particularly sensitive to deviations from the Standard Model (SM) and searches for new physics.

- Bosons reconstructed as a single “fat” jet and forward proton reconstruction using the PPS detector.
- signal regions :
 - both protons matched to jets (signal region δ)
 - One proton matched only (signal region o)
- Fit to 12 signal regions, categorized by year.

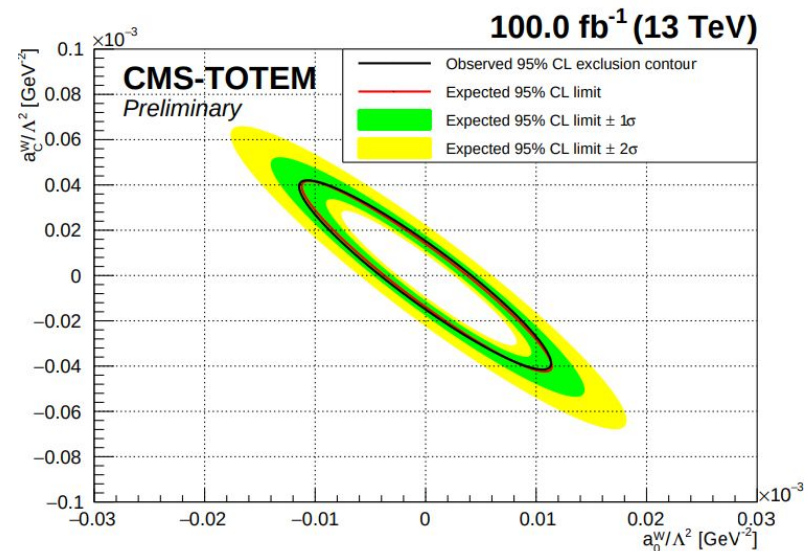


[1] Search for exclusive $\gamma\gamma \rightarrow WW$ and $\gamma\gamma \rightarrow ZZ$ production in final states with jets and forward protons e-Print: CDS CERN SMP-21-014

aQGC limits (CMS and TOTEM Collaborations)

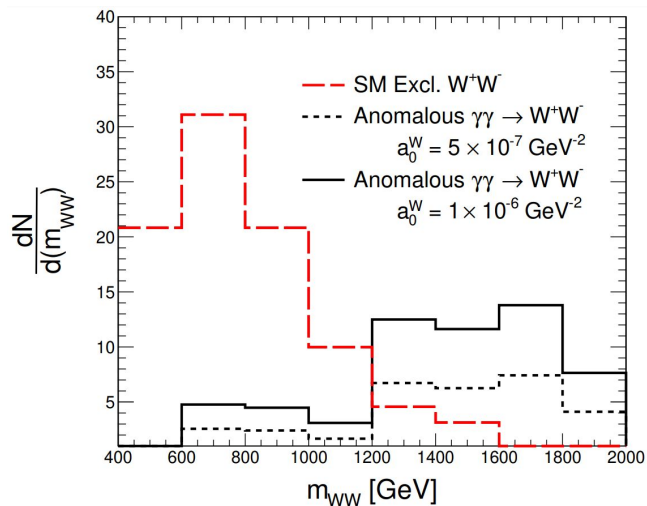
Coupling	Observed (expected) 95% CL upper limit	Clipping
$ a_0^W/\Lambda^2 $	$4.3 (3.9) \times 10^{-6} \text{ GeV}^{-2}$	-
$ a_C^W/\Lambda^2 $	$1.6 (1.4) \times 10^{-5} \text{ GeV}^{-2}$	-
$ a_0^Z/\Lambda^2 $	$0.9 (1.0) \times 10^{-5} \text{ GeV}^{-2}$	-
$ a_C^Z/\Lambda^2 $	$4.0 (4.5) \times 10^{-5} \text{ GeV}^{-2}$	-
$ a_0^W/\Lambda^2 $	$5.2 (5.1) \times 10^{-6} \text{ GeV}^{-2}$	1.4 TeV
$ a_C^W/\Lambda^2 $	$2.0 (2.0) \times 10^{-5} \text{ GeV}^{-2}$	1.4 TeV

- New limits on quartic anomalous couplings
- Unitarity violation occurs in WW at 1.4 TeV and in ZZ at 1.1 TeV
- invariant mass threshold in jet triggers results in no clipping value for ZZ
- limits 15-20x more stringent than Run 1 $\gamma\gamma \rightarrow WW/ZZ$



study of exclusive WW production

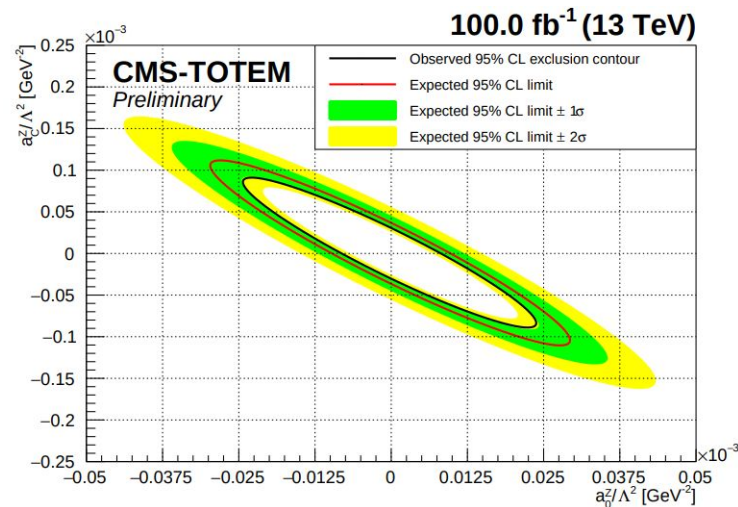
$$\mathcal{L}_6^{\text{eff}} = -\frac{e^2}{8} a_0^W F_{\mu\nu} F^{\mu\nu} W^{+\alpha} W_{\alpha}^{-} - \frac{e^2}{16} a_C^W F_{\mu\alpha} F^{\mu\beta} (W^{+\alpha} W_{\beta}^{-} + W^{-\alpha} W_{\beta}^{+})$$



- Anomalous coupling contributions appear at high $m(WW)$ compared with SM prediction.
- FPMC

Exclusive $\gamma\gamma \rightarrow ZZ$ at 13 TeV (CMS and TOTEM Collaborations)

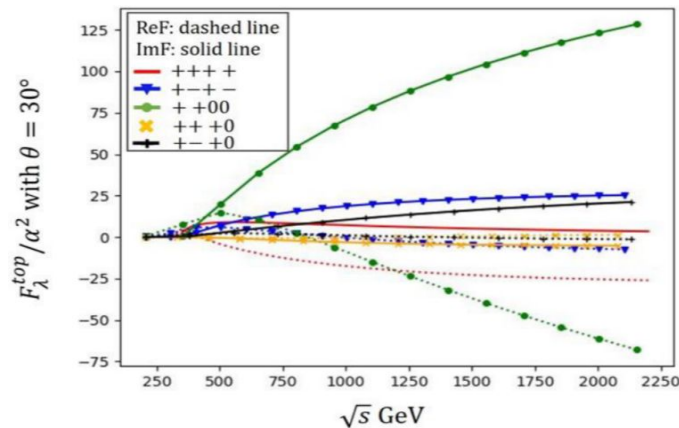
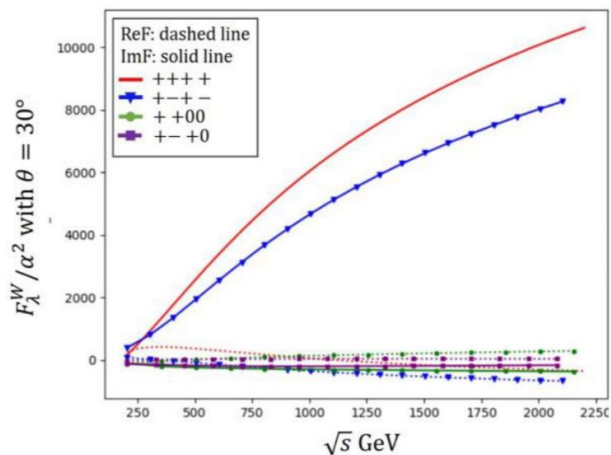
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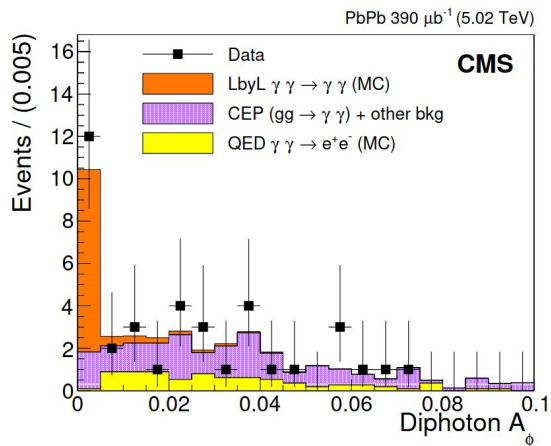
study of exclusive ZZ production

- Neutral particle processes are forbidden in the SM physics



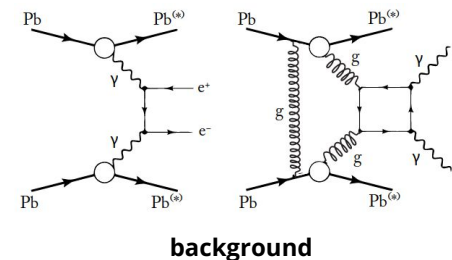
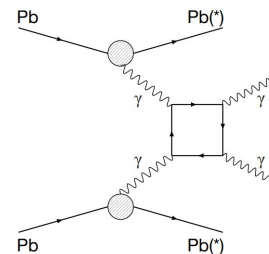
$\gamma\gamma \rightarrow \gamma\gamma$ (LbL) in UPC PbPb

- First direct evidence of light-by-light process by ATLAS 0.48nb^{-1} [4]
- Evidence for $\gamma\gamma \rightarrow \gamma\gamma$, in ultraperipheral PbPb collisions at 5.02TeV with CMS data 0.39nb^{-1} [5]



* The fiducial cross-section is measured to be $\sigma(\gamma\gamma \rightarrow \gamma\gamma) = 120 \pm 46$ (stat) ± 12 (theo) nb

consistent with the SM prediction of 116 ± 12 nb [6]



[4]ATLAS Collaboration. Evidence for light-by-light scattering in heavy-ion collisions with the ATLAS detector at the LHC. Nature Phys., 13(9):852–858, 2017. doi: 10.1038/nphys4208.

[5] CMS Collaboration. Evidence for light-by-light scattering and searches for axion-like particles in ultraperipheral PbPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV. Phys. Lett. B, 797: 134826, 2019. doi: 10.1016/j.physletb.2019.134826.

[6]D. d’Enterria, G. da Silveira, Phys.Rev.Lett. 111 (2013) 080405 - Observing light-by-light scattering at the Large Hadron Collider.

Summary

- Exclusive $\gamma\gamma \rightarrow \mathbf{WW/ZZ}$ no significant deviation from Standard Model observed
- New aQCC limits