Search for high-mass exclusive $\gamma\gamma \to WW$ and $\gamma\gamma \to ZZ$ production in proton-proton collisions at $\sqrt{s} = 13$ TeV

INTRODUCTION

Final state: two bosons and scattered protons, which are reconstructed using PPS. Fully hadronic decay modes of the W and Z bosons are studied: gauge bosons are produced with a boost, decay products of each of the bosons are merged into a single large-area jet. Within the SM, quartic couplings involving two-photon production of charged (W$^-$) gauge bosons are allowed at tree level. The $\gamma\gamma \to ZZ$ process is not allowed at tree level and only possible at higher order.

SM cross sections at $\sqrt{s} = 13$ TeV:
- $\gamma\gamma \to WW$: $\sim 50 fb$
- $\gamma\gamma \to ZZ$: $0.05 fb$

SM production concentrated at low values of the $W$ invariant mass, $m(WV)$. Any significant signal over the prediction, particularly in the high $m(WV)$ tails where the expected SM cross section is small, could indicate BSM physics.

The decay products of the boson pair, the so-called central system, are detected by the CMS central detectors, while the protons are measured with the Precision Proton Spectrometer (PPS).

The Precision Proton Spectrometer is a system of near-beam tracking and timing detectors, located in Roman pots (RPs) at about 200 m from the CMS interaction point [1]. The Roman Pots are movable near-beam devices that allow the detectors to be brought very close (within a few mm) to the beam without affecting the vacuum, beam stability, or other aspects of the accelerator operation. The PPS makes it possible to measure the 4-momentum of the scattered protons, along with their time-of-flight from the IR. The proton momenta are measured by two tracking stations on each arm of the spectrometer.

DATA & SIMULATION

The analysis uses data collected at $\sqrt{s} = 13$ TeV between 2016-2018, amounting to a total integrated luminosity $L_{\text{int}} = 100.0 \text{ fb}^{-1}$. BSM signal samples are simulated at LO with the Forward Physics Monte Carlo (FPMC) generator [2] for both the $\gamma\gamma \to WW$ and $\gamma\gamma \to ZZ$ processes.

Backgrounds: main contribution from QCD multijet production (PYTHIA), sub-leading contributions from W/Z+jets (MADGRAPH) and t$\bar{t}$ (POWHEG). Protons, in background events, originate from pileup interactions (estimated from data, not simulated).

Particle interaction and propagation with the central CMS detectors modelled with GEANT4. Forward proton propagation simulated with the so-called 'direct' simulation [3].

SELECTION

Selection on central variables:
- $> 2 V_{\text{clus}}$ tagged AK8 jets ($E_T^{JET} > 0.75$)
- $|\eta(JET)| < 2.5$
- $p_T(JET) > 200 \text{ GeV}$
- $\Delta R(JET) < 1.1$
- $p_T(JET) > 1.3$
- $|\alpha - 0.5| < 0.01$
- $1126 \text{ GeV} < m_{WV} < 2500 \text{ GeV}$
- 1 proton per side of PPS
- $p_T^{\text{pruned}}(JET) > 60$ and 107 GeV

WW/ZZ discrimination:
- $WW$: $m_{WW} < 166.6 \text{ GeV}$
- $ZZ$: $m_{ZZ} < 166.6 \text{ GeV}$

Proton matching: two signal regions defined $\delta$: two protons from signal
\[
\delta = \left[ \frac{\text{p}_{\text{beam}}}{\text{p}_{\text{beam}} - \text{p}_{\text{pruned}}} \right]
\]

BACKGROUND ESTIMATION

Data-driven background estimation: protons from pileup interactions are not well modelled by MC, using data is a necessity.

'ABCD' method:
- Region A: signal region & acoplanarity ($\Delta\phi$) cut
- Region B: signal region & inverted $\Delta\phi$ cut
- Region C: unblinded region & $\alpha$ cut
- Region D: unblinded region & inverted $\alpha$ cut

$N_A = N_B = N_C + N_D$

Consistent results when using a different sideband (e.g. pruned mass) or an event mixing approach. Precision limited by the low amount of events in region B.

RESULTS

No excess with respect to the SM-only expectation found. Upper limits on dimension-6 QCD parameters are set, both under the assumption of all other operators being zero and in a 2D plane. Limits are presented with and without unitarization via clipping at 1.4 TeV.

Results are also converted to dimension-8 operators, either following [4] or assuming all couplings to be zero but one. Folded cross section limits are also derived in the region with $0.04 < \xi < 0.20, m_{WW} > 1 \text{ TeV}$.

- $\sigma(pp \rightarrow pWWp) < 67(53)^{+12}_{-19} \text{ fb}$
- $\sigma(pp \rightarrow pZZp) < 43(26)^{+10}_{-17} \text{ fb}$

References