New physics results with the CMS Precision Proton Spectrometer

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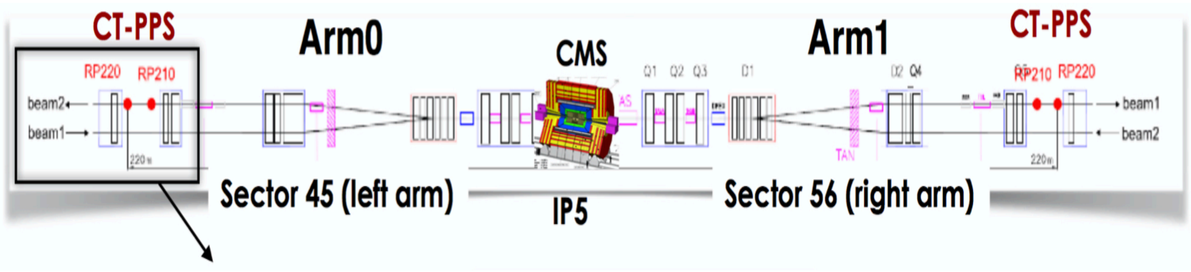
The CMS Precision Proton Spectrometer (PPS)



PPS is a CMS subdetector, initially called CT-PPS, born as a collaborative project between the CMS and TOTEM experiments..
The detector has been designed to extend the physics program of CMS to Central Exclusive Processes (CEP) in the standard high-luminosity running of LHC

PPS makes it possible to determine the fractional momentum loss of the scattered protons.

1. **Tracking Detector**
   a. TOTEM Strip Detectors
   b. 3D Pixel Detectors

   → For Proton Momentum Measurement

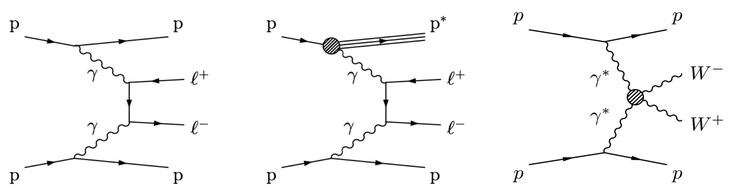
2. **Timing Detector**
   a. Diamond Detectors
   b. Ultra-Fast Silicon Detector Planes (UFSD)

   → For PileUp (PU) Rejection

JHEP 07 (2018) 153

Observation of proton-tagged, central (semi)exclusive production of high-mass lepton pairs in pp collisions at 13 TeV with the CMS-PPS

Motivation



Production of lepton pairs by $\gamma\gamma$ fusion

The process $pp \to p\ell^+\ell^- p^*$,with $\ell^+\ell^-$ a muon or an electron pair produced at midrapidity with mass larger than 110 GeV, has been observed for the first time at the LHC in pp collisions at $\sqrt{s} = 13$ TeV. One of the two scattered protons is measured in the CMS precision proton spectrometer, which operated for the first time in 2016. The second proton either remains intact or is excited and then dissociates into a low-mass state p^*, which is undetected.

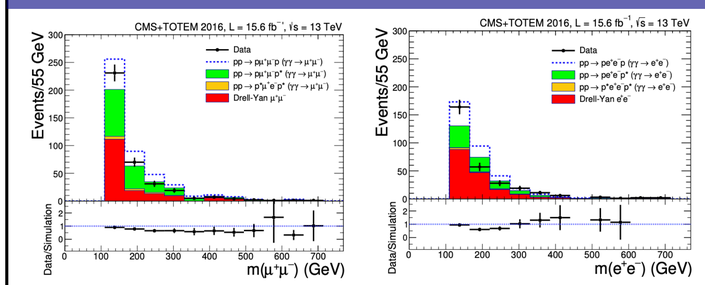
Central exclusive dilepton production is interesting because deviations from the theoretically well-known cross section may be an indication of new physics, whereas central semiexclusive processes constitute a background to the exclusive reaction when the final-state protons are not measured

(Semi)exclusive dilepton production has been previously studied at the Fermilab Tevatron and at the CERN LHC, but at lower masses and never with a proton tag. In this analysis, forward protons are reconstructed in CMS-PPS.

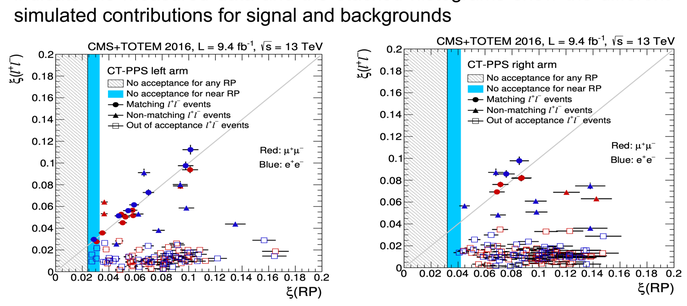
The aim of this analysis is
- Better understanding Central Dilepton Production
- Check the performance of CMS-PPS

JHEP 07 (2018) 153

Results



Dimuon (left) and dielectron (right) invariant mass. Points with error bars indicate the measured data and the stacked histograms show the different simulated contributions for signal and backgrounds



Correlation between the fractional values of the proton momentum loss measured in the central dilepton system, $\xi(\ell^+\ell^-)$ and in the RPs, $\xi(RP)$, for both RPs in each arm combined. The 45 (left) and 56 (right) arms are shown. The hatched region corresponds to the kinematical region outside the acceptance of both the near and far RPs, while the shaded (pale blue) region corresponds to the region outside the acceptance of the near RP.

Conclusion

in this analysis, $\gamma\gamma \to \mu^+\mu^-$ and $\gamma\gamma \to e^+e^-$ production together with forward protons reconstructed in the CT-PPS have been studied by using a sample of $9.4\ fb^{-1}$collected in proton-proton collision at $\sqrt{s} = 13$ TeV.

The Roman Pot alignment and LHC optics corrections have been determined using a high statistics sample of forward protons.

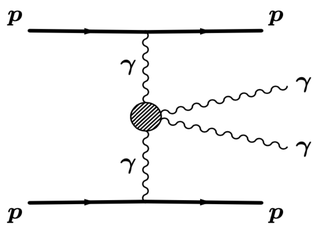
A total of 12 $\gamma\gamma \to \mu^+\mu^-$and 8 $\gamma\gamma \to e^+e^-$ events are observed with dilepton invariant mass larger than 110 GeV, and a forward proton with consistent kinematics.

This corresponds to an excess larger than five standard deviations over the expected back-ground from double-dissociative and Drell-Yan dilepton processes.

The result represents the first observation of proton-tagged γγ collisions at the electroweak scale. The present data demonstrate the excellent performance of CT-PPS and its potential for high-mass exclusive (proton-tagged) measurements.

First search for exclusive di-photon production at high mass with intact protons in pp collisions at √s = 13 TeV

Motivation



Diphoton production via photon exchange with intact protons in the final state.

When two photons interact through an intermediate charged particle loop to create two different outgoing photons, the process is known as light-by-light (LbyL) scattering. The observation of this phenomenon has been sought after in laboratory experiments for decades, and has been studied indirectly by the measurement of the anomalous magnetic moment of the muon.

The LbyL scattering process, which can be studied at the electroweak energy scale and higher in proton-proton collisions at the LHC, is of great interest because of its sensitivity to physics beyond the standard model.

A fully efficient extension of the SM Lagrangian using charge-parity conservation operators, as used for $\gamma\gamma W^+W^-$ quartic coupling, results in a minimum eight-dimensional term for four-photon coupling.. This term contains two ζ parameters. Λ represents the new physics scale. The present measurement is sensitive to values of Λ of the order of a few TeVs.

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$$\zeta_{1,2} = a_{1,2}^{\gamma\gamma}/\Lambda^4$$

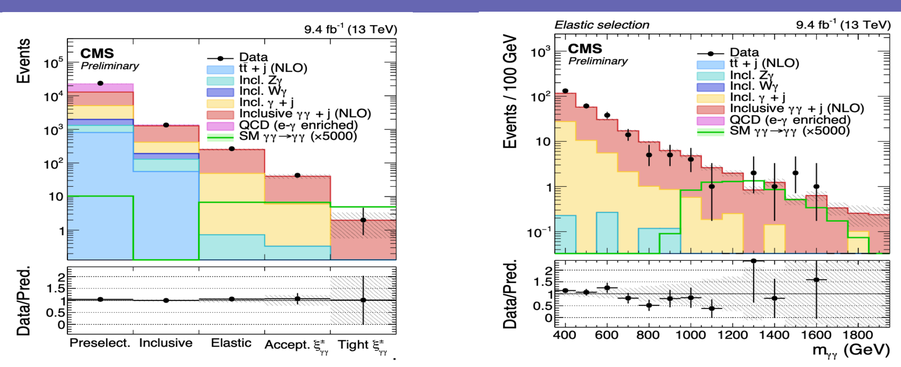
$$|\zeta_1| < 3.7 \times 10^{-13}\ \text{GeV}^{-4}$$

$$|\zeta_2| < 7.7 \times 10^{-13}\ \text{GeV}^{-4}.$$

diphoton acoplanarity

$$a \equiv 1 - |\Delta\phi_{\gamma\gamma}/\pi|$$

Results



(Left) Number of simulated and observed events for the various selection regions. The shaded bands show the statistical uncertainty on the MCs added in quadrature. All selection regions are sequential from left to right except for the inclusive region which is a background control region. The signal selection region is denoted as " Tight $\xi^{\pm}_{\gamma\gamma}$ "

(Right) Invariant mass distribution of the diphoton pairs for the elastic selection region with events satisfying $1 - |\Delta\phi_{\gamma\gamma}/\pi| < 0.005$. The hatched bands indicate the statistical uncertainty on simulated samples added in quadrature.

Conclusion

CMS-PPS has proven the feasibility of continuously operating a near-beam proton spectrometer at a high- luminosity hadron collider. $\gamma\gamma \to \gamma\gamma$ process was searched for with the requirement of forward proton tags for the first time, using 9.4 fb−1 of luminosity collected at a 13 TeV center-of- mass energy at the LHC. No events were observed with a pair of proton tracks compatible with the diphoton kinematics, above a background prediction of 0.23 and 0.43 events for the 2σ and 3σ windows, respectively. This provides the first limit at the electroweak scale for the SM production cross section, and places limits on anomalous couplings for the four-photon interaction based on an effective field theory extension of the SM.