



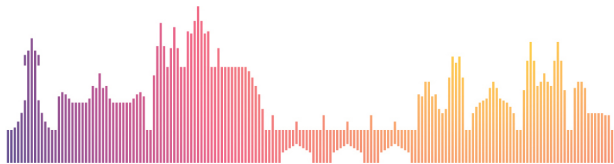
Search For New Physics Using Final States With Photons In CMS

ICHEP 2020

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July 28, 2020

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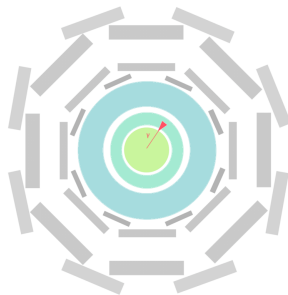


Introduction

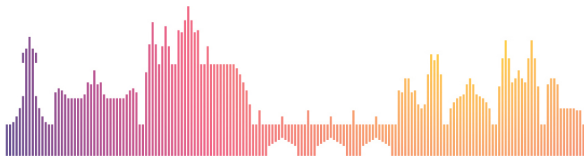
The study of final states with photons has been instrumental in the search of BSM signatures – also thanks to the precision of the CMS detector in measuring photons.

- See [CMS photon performance talk](#)
- See [CMS ECAL performance talk](#)

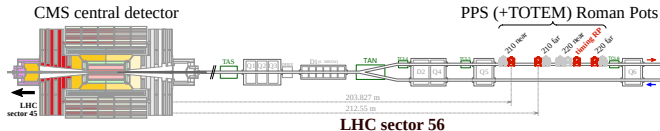
Analysis	Integrated Luminosity	Code	Status
Diphotons with CT-PPS	9.4 fb ⁻¹ (2016)	EXO-18-014	NEW
Dark photons in VBF Higgs	137 fb ⁻¹ (2016-2018)	EXO-20-005	NEW
LLP decaying to photons	70.1 fb ⁻¹ (2016-2017)	PRD 100, 112003	NEW



Analysis #1: Exclusive diphotons with intact protons



Search for Exclusive Diphotons with Intact Protons

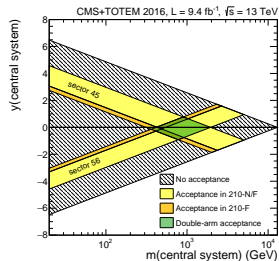
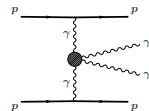


Proton tagging provides the **strongest sensitivity** to study anomalous quartic gauge couplings (AQGCs)

- Using the CMS and TOTEM **Precision Proton Spectrometer** (CT-PPS, now PPS), we can measure all final state particles in the light-by-light (LbL) scattering process
- Conservation of momentum allows for kinematical matching of the forward and central systems, providing a very strong background suppression
- Measure fractional momentum loss ξ , which can be translated into mass and rapidity

$$m_{pp} = \sqrt{s\xi_1\xi_2}, \quad y_{pp} = \frac{1}{2} \log(\xi_1/\xi_2)$$

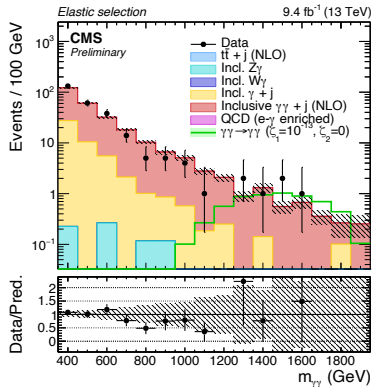
- See **CMS PPS Talk** for more



Search for Exclusive Diphotons with Intact Protons

Search for BSM contributions to the LbyL cross-section

- Using 9.4 fb^{-1} of data from 2016
- $m_{\gamma\gamma} > 350 \text{ GeV}$, $p_T > 75 \text{ GeV}$,
 $1 - |\Delta\phi|/\pi < 0.005$
- Require both protons to be detected in CT-PPS
- No candidate with forward protons found with an expected background prediction of $0.23^{+0.08}_{-0.04}$ events.



Search for Exclusive Diphotons with Intact Protons

An upper limit is set on the exclusive diphoton process of 3.0 fb within CT-PPS fully efficient acceptance range in mass and rapidity, leading to the **first ever collider limits** on the four-photon AQGC.

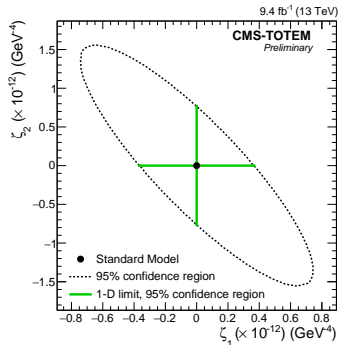
Limits are extracted in the context of an EFT extension with dimension-8 operators

$$\mathcal{L}_{4\gamma} = \zeta_1 F_{\mu\nu} F^{\mu\nu} F_{\rho\sigma} F^{\rho\sigma} + \zeta_2 F_{\mu\nu} F^{\nu\rho} F_{\rho\lambda} F^{\lambda\mu}$$

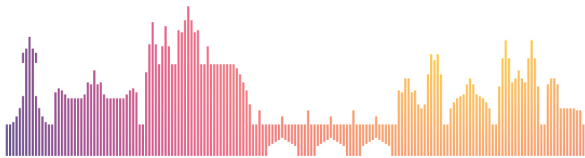
where the following limits are set on the coupling parameters

$$|\zeta_1| < 3.7 \times 10^{-13} \text{GeV}^{-4} \quad (\zeta_2 = 0)$$

$$|\zeta_2| < 7.7 \times 10^{-13} \text{GeV}^{-4} \quad (\zeta_1 = 0)$$

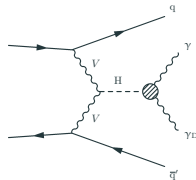


Analysis #2: VBF Higgs decaying to a dark photon

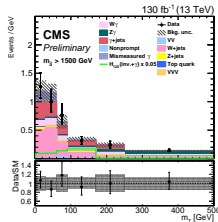
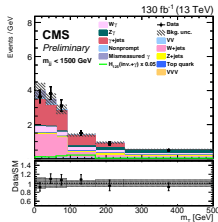


Search for VBF Higgs Decaying to a Dark Photon

Search for a Higgs boson produced by vector boson fusion (VBF) decaying to a photon and an undetected particle.

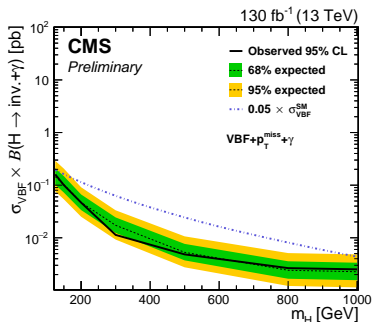


- The branching fraction for the process shown in the diagram can be as high as 5%¹
- Using the full Run II dataset: 130 fb⁻¹
- The Higgs is accompanied by two jets with a large gap in pseudorapidity, allowing for discrimination against SM backgrounds
- Different selection cuts based on year and trigger
- Data are well described by background estimate



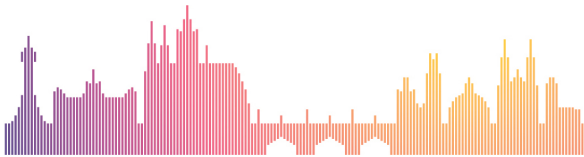
¹Phys. Rev. D 90, 055032 (2014)

Search for VBF Higgs Decaying to a Dark Photon



- 801 events observed with a background prediction of 799.3 ± 124.6
- The product of σ_{VBF} and $\mathcal{B}(H \rightarrow \text{invisible} + \gamma)$ is excluded between 2 fb – 150 fb for m_H from 125 GeV – 1000 GeV.
- For more CMS results see [exotic Higgs decays](#) and [dark matter](#) talks at ICHEP2020.

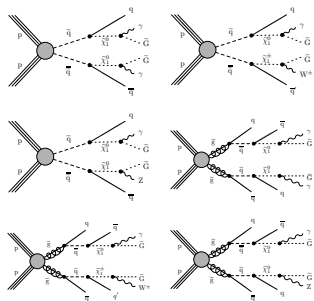
Analysis #3: Search for LLPs decaying to photons



Search for LLPs decaying to photons

Many BSM theories predict neutral particles with long lifetimes. This study explores a SUSY benchmark scenario of a neutralino decaying to a gravitino and a “delayed” photon. For more on LLP see [CMS LLP talk](#).

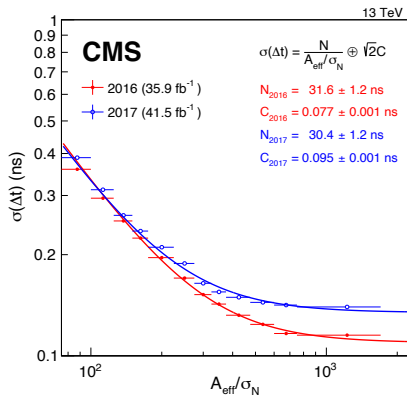
- Using 77.4 fb^{-1} of data from 2016-2017
- The photon selection requires $p_T^\gamma > 70 \text{ GeV}$, tight photon ID
- Because of their displaced vertices and resulting trajectories, signal photons have delayed arrival times and non-normal impact angles in the CMS ECAL
- Special photon isolation criteria are developed for this analysis.



Search for LLPs decaying to photons

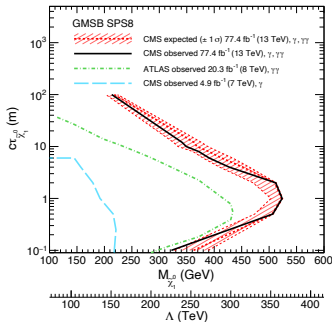
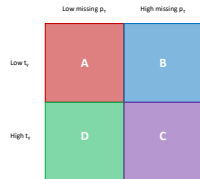
Dedicated CMS ECAL study to determine timing resolution

- Signal photons tend to arrive in the ECAL up to 10 ns later than photons produced at the primary vertex.
- Using $Z \rightarrow e^+e^-$ events, the time resolution between neighboring ECAL crystals as a function of amplitude is understood
- $\sigma(\Delta t)$ and A_{eff} correspond to the time resolution and effective amplitude, respectively



Search for LLPs decaying to photons

- Signal extraction performed using “ABCD” method where bin C is the signal enriched region
- Limits are given as a function of neutralino proper decay length ($c\tau_{\tilde{\chi}_1^0}$) and mass ($M_{\tilde{\chi}_1^0}$)
- Limits are increased on the decay length by an **order of magnitude** and increased on the mass by 100 GeV with respect to Run I results from CMS and ATLAS



Conclusion

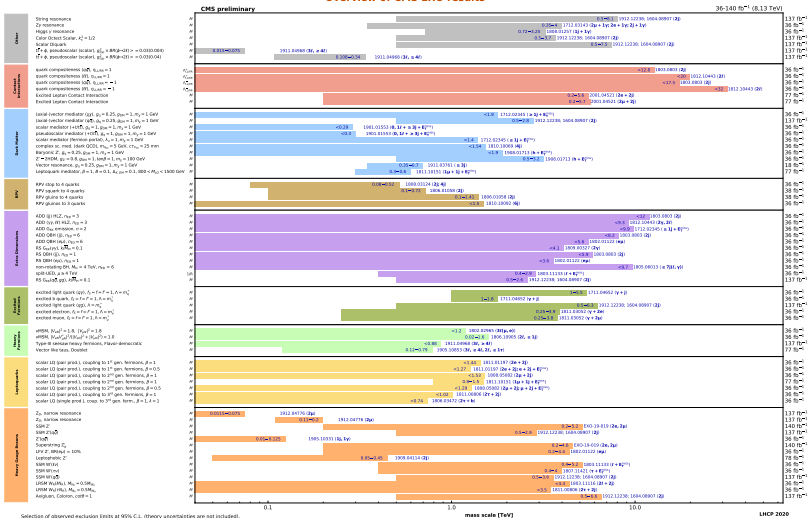
Photons are good candidates to searches for new physics, and we've seen three new CMS results utilizing photons.

- Search for high-mass exclusive diphoton events with intact protons sets **first limits** of four-photon anomalous coupling
- Search for VBF Higgs decaying to a dark photon leads to **enhanced limits** on the cross-section between $\sim 2 - 150$ fb for $125 \text{ GeV} < m_H < 1000 \text{ GeV}$
- Search for long lived particles decaying to photons increases the limits on the neutralino proper decay length by an **order of magnitude**

Done 😊

Conclusion

Overview of CMS EXO results



Selection of observed exclusion limits at 95% C.L. (theory uncertainties are not included)

LHCP 2020