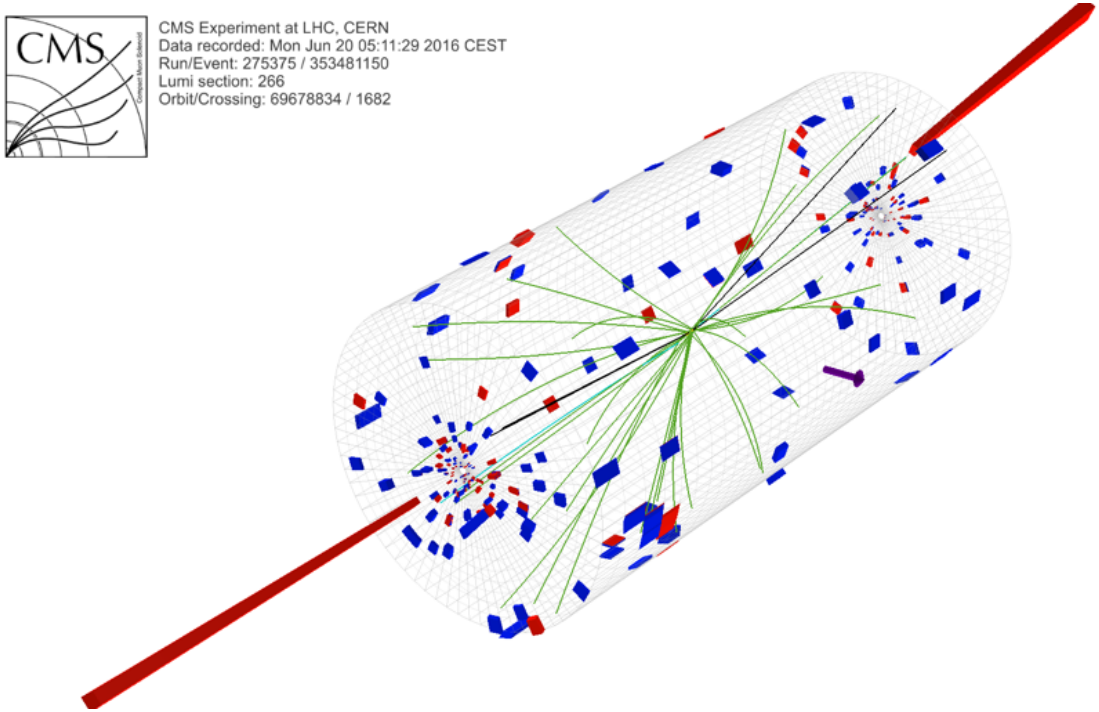
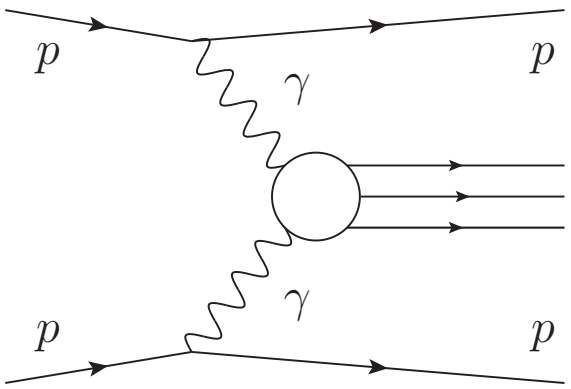
Photon Photon Physics in CT-PPS

Justin Williams

On behalf of the CMS and TOTEM Collaborations



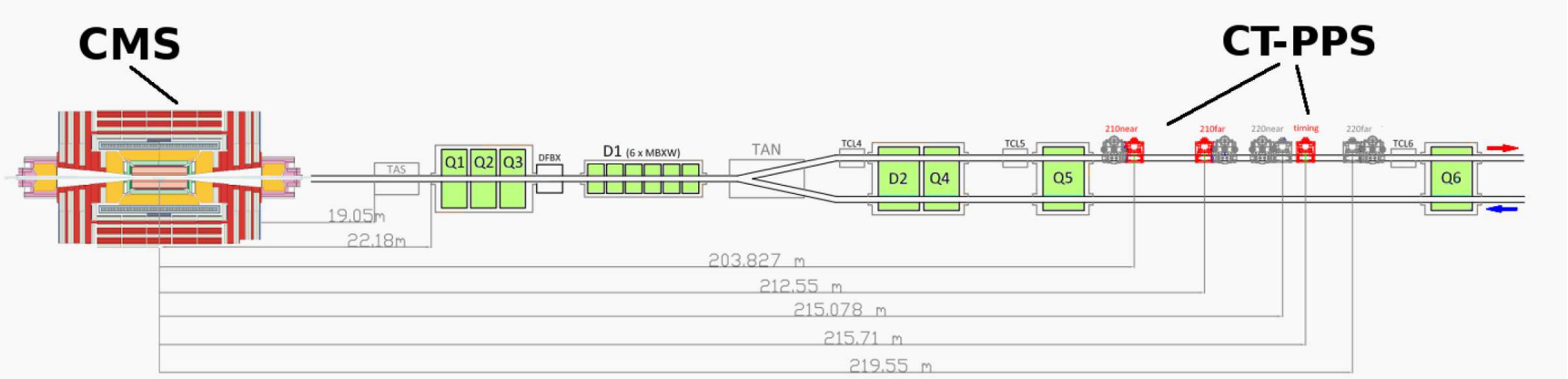
Overview



- LHC can be used as a $\gamma\gamma$ collider
- CT-PPS provides an opportunity for new searches and measurements
- Possibility of a very strong background suppression using intact protons
- Discussion of
    1. CT-PPS
    2. Measurements
    3. Anomalous Couplings

CMS-TOTEM Precision Proton Spectrometer

What is CT-PPS?

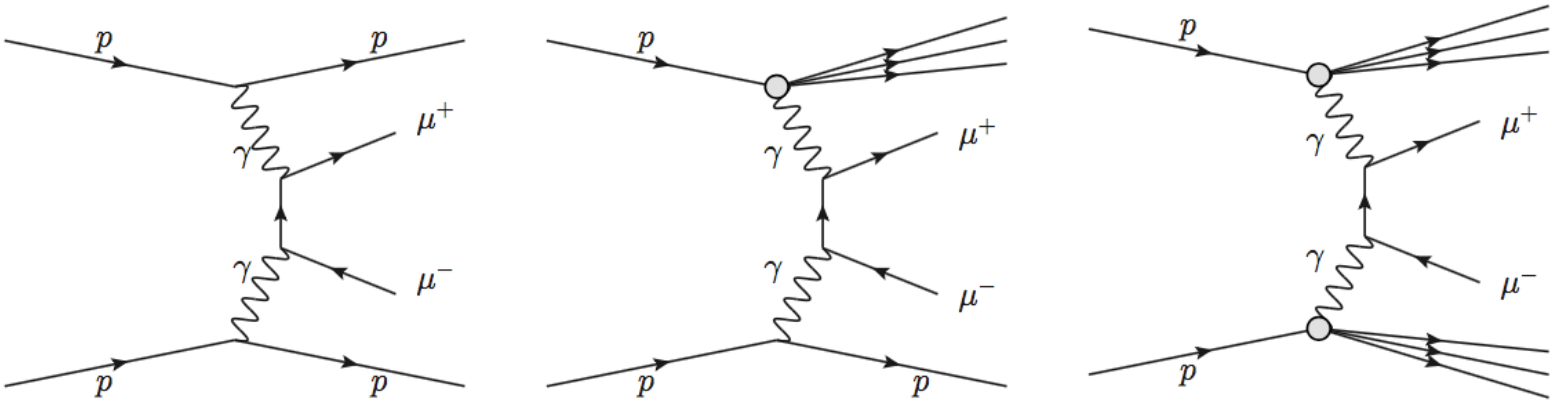


- Joint CMS and TOTEM project[1]
- LHC magnets bend scattered protons outside of the beam envelope
- Intact protons are detected a few mm from the beamline
- Detect protons at about $\pm$ 200 m from IP5
- Roman Pot detectors measure ξ of protons
- Collected 15 fb^{-1} of data in 2016

[1] https://cds.cern.ch/record/1753795

Measurements

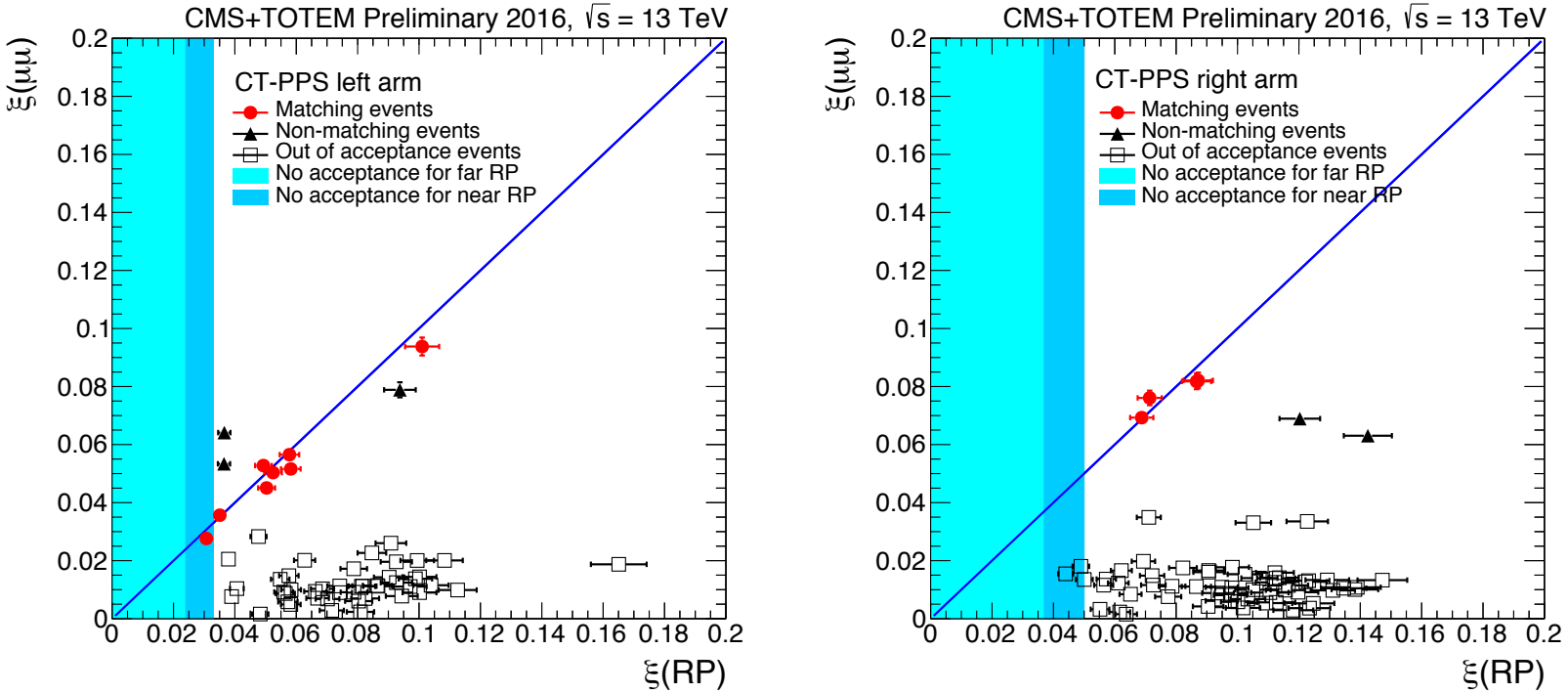
Dimuon Analysis in CT-PPS



- CMS - TOTEM preliminary results[2]
- It is with regular optics and pile up conditions
- First measurement of the process at high mass with intact protons
- Proof that the alignment, optics, and analysis are working

[2] *CMS-PAS-PPS-17-001 ; TOTEM-NOTE-2017-003*

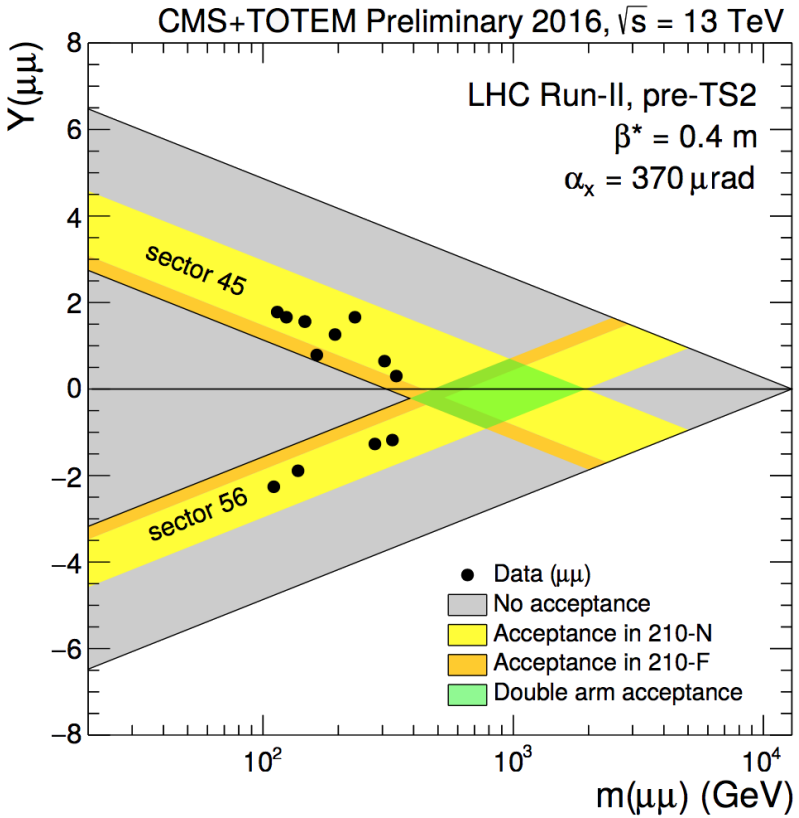
Dimuon Analysis in CT-PPS



- 17 events have $\xi(\mu\mu)$ consistent with RP acceptance[3]
- 12 of these have $\xi(\mu\mu)$ that matches ξ(RP) (red points)
- Background of 1.47±0.06 (stat.)±0.52 (syst.)

[3] *CMS-PAS-PPS-17-001 ; TOTEM-NOTE-2017-003*

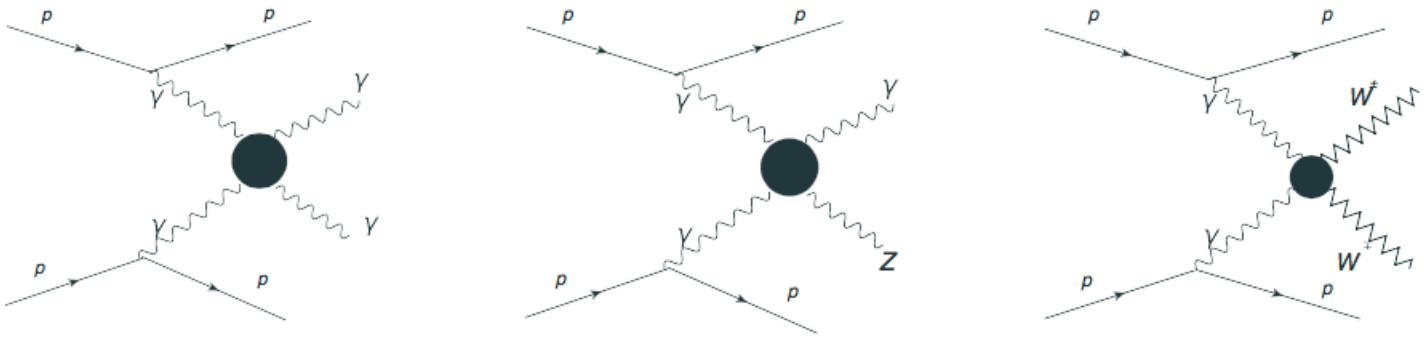
Dimuon Analysis in CT-PPS



- Dimuon invariant mass and rapidity within expected range of acceptance
- Highest mass event - 342 GeV
- Shows that alignment, proton tagging, trigger, etc. are understood and working

Anomalous Coupling Search

Anomalous Quartic Coupling



- Photon emission → Photon fusion → Intact outgoing protons
- This is an <u>exclusive</u> process
- We will focus on $\gamma\gamma \to \gamma\gamma$

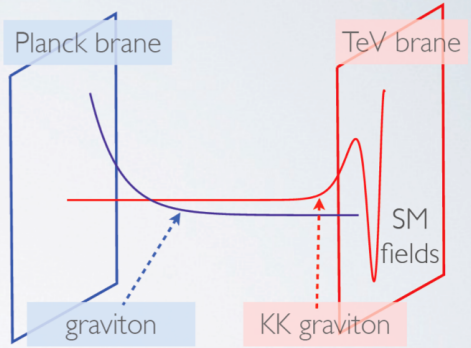
Motivations

- BSM Physics by studying electroweak symmetry breaking
- Predicted by Composite Higgs and Extra-Dimensional models
- Couplings can be probed independently of models
- Application: Polarizable Dark Particle[4]

✘ Warped Extra Dimensions solve hierarchy problem of SM

✘ 5th dimension bounded by two branes

✘ SM on the visible (or TeV) brane



✘ The Kaluza Klein modes of the graviton couple with TeV strength

$$\mathcal{L}^{\gamma\gamma h} = f^{-2}\, h^{\mathrm{KK}}_{\mu\nu}\, (\tfrac{1}{4}\eta_{\mu\nu}F^2_{\rho\lambda} - F_{\mu\rho}F_{\rho\nu})$$

$$f \sim \mathrm{TeV} \qquad m_{\mathrm{KK}} \sim \text{few TeV}$$

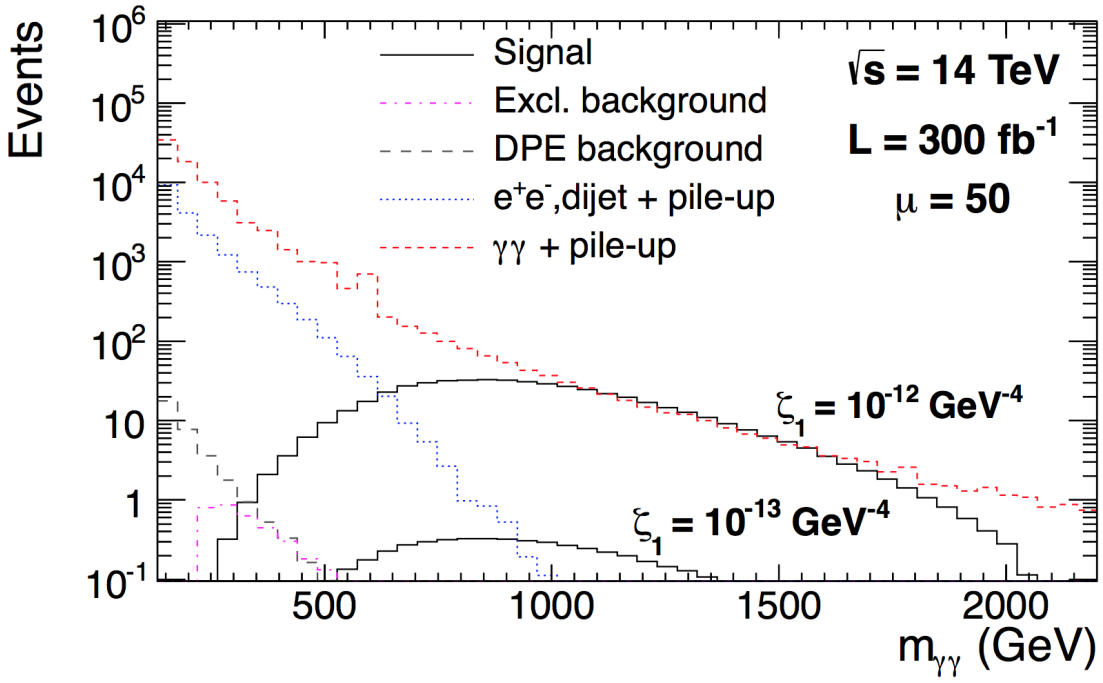
✘ Effective 4-photon couplings $\zeta_i \sim 10^{-14} - 10^{-13}\ \mathrm{GeV}^{-2}$ possible

✘ The radion can produce similar effective couplings

[4] *Shining Light On Polarizable Dark Particles. arXiv:1609.01762v1*

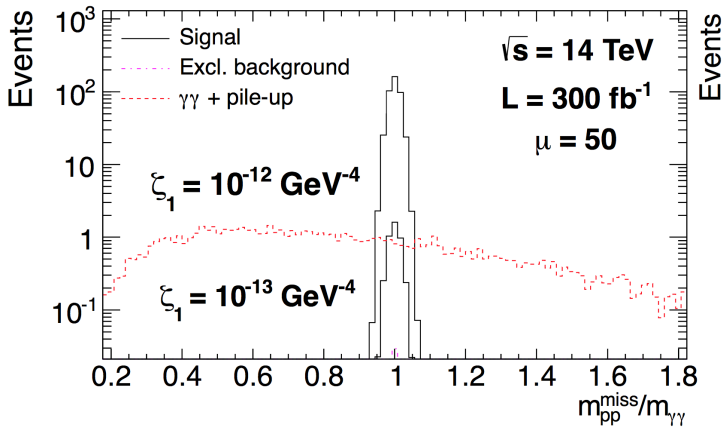
Backgrounds

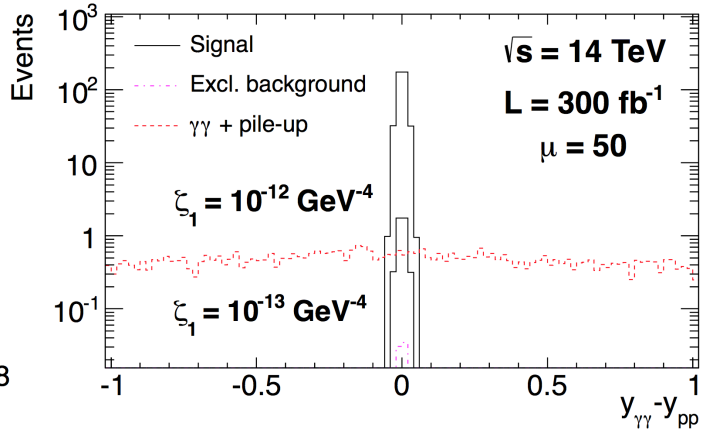
- Requesting two protons identified in forward detectors + two converted photons in central detector
- All backgrounds considered (Double Pomeron Exchange diphoton production, H→ $\gamma\gamma$,exclusive $\gamma\gamma$ production, dilepton + dijet misidentification, PU, Drell-Yan, ...)[5]
- Pile up is the main source of background



[5] *JHEP 02, 165 (2015)*

Dealing With Pile Up





Cut / Process	Signal (full)	Signal with (without) f.f (EFT)	Excl.	DPE	DY, di-jet + pile up	$\gamma\gamma$ + pile up
$[0.015 < \xi_{1,2} < 0.15,$ $p_{T1,(2)} > 200, (100)$ GeV$]$	65	18 (187)	0.13	0.2	1.6	2968
$m_{\gamma\gamma} > 600$ GeV	64	17 (186)	0.10	0	0.2	1023
$[p_{T2}/p_{T1} > 0.95,$ $\lvert\Delta\phi\rvert > \pi - 0.01]$	64	17 (186)	0.10	0	0	80.2
$\sqrt{\xi_1\xi_2 s} = m_{\gamma\gamma} \pm 3\%$	61	16 (175)	0.09	0	0	2.8
$\lvert y_{\gamma\gamma} - y_{pp}\rvert < 0.03$	60	12 (169)	0.09	0	0	0

- All values corresponding to 300 fb^{-1}
- No background after selection cuts without timing information
- Proton tagging is vital for exclusivity cuts

Summary

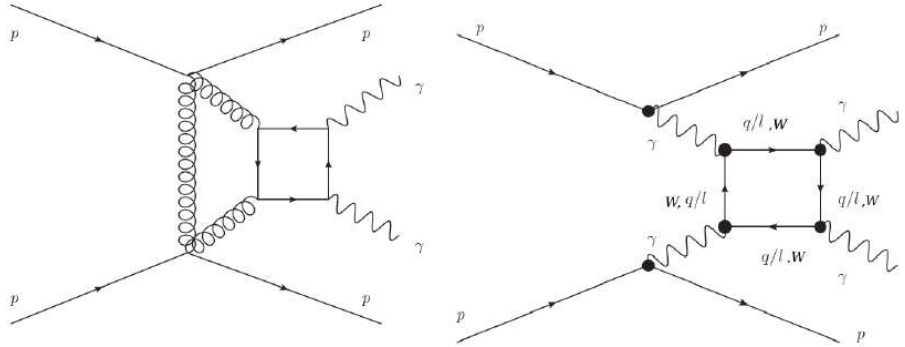
Summary

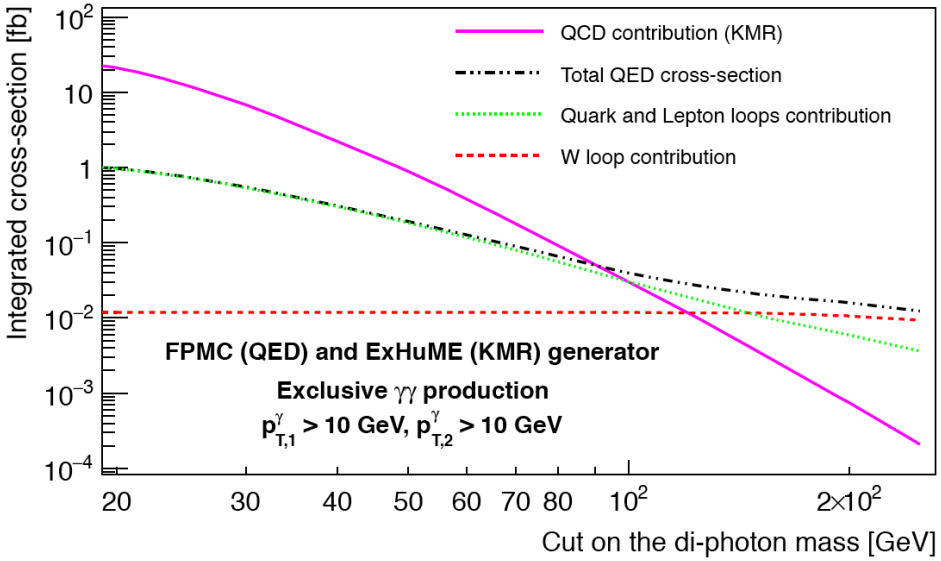
- With its 2016 operation, CT-PPS has proven for the first time the feasibility of operating a near-beam proton spectrometer at a high luminosity hadron collider on a regular basis
- First evidence of $\gamma\gamma \to \mu\mu$ with single proton tag
- CT-PPS allows us to probe BSM diphoton production in a model independent way
- Any observed anomalous coupling event is signal
- CT-PPS has $\sim$ 15 fb^{-1} data and is currently acquiring more

Questions?

Backup Slides - Standard Model $\gamma\gamma$ Exclusive Production

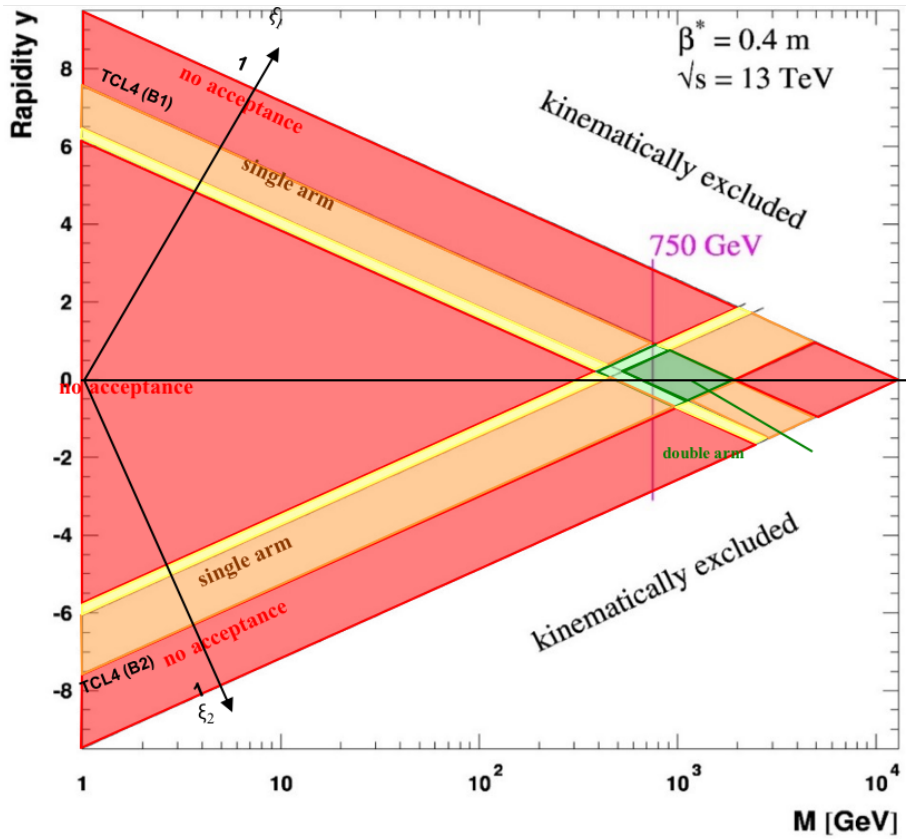
- QED process dominates at high $m_{\gamma\gamma}$
- Cross section is well known
- W boson loop is the most significant at high $m_{\gamma\gamma}$



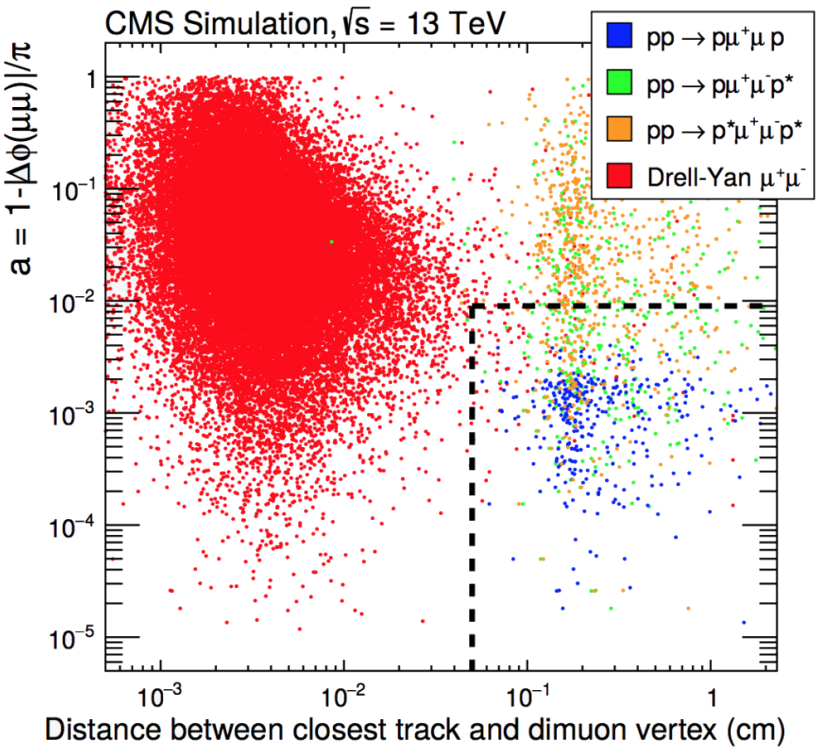


Proton Acceptance

- Roman Pots measures fractional momentum loss (ξ) of protons
- Acceptance for both protons
  - Mid rapidity
  - 350 GeV $<$ m_{pp} $<$ 2000 GeV
- Acceptance for single proton
  - Forward Rapidity
  - Lower masses

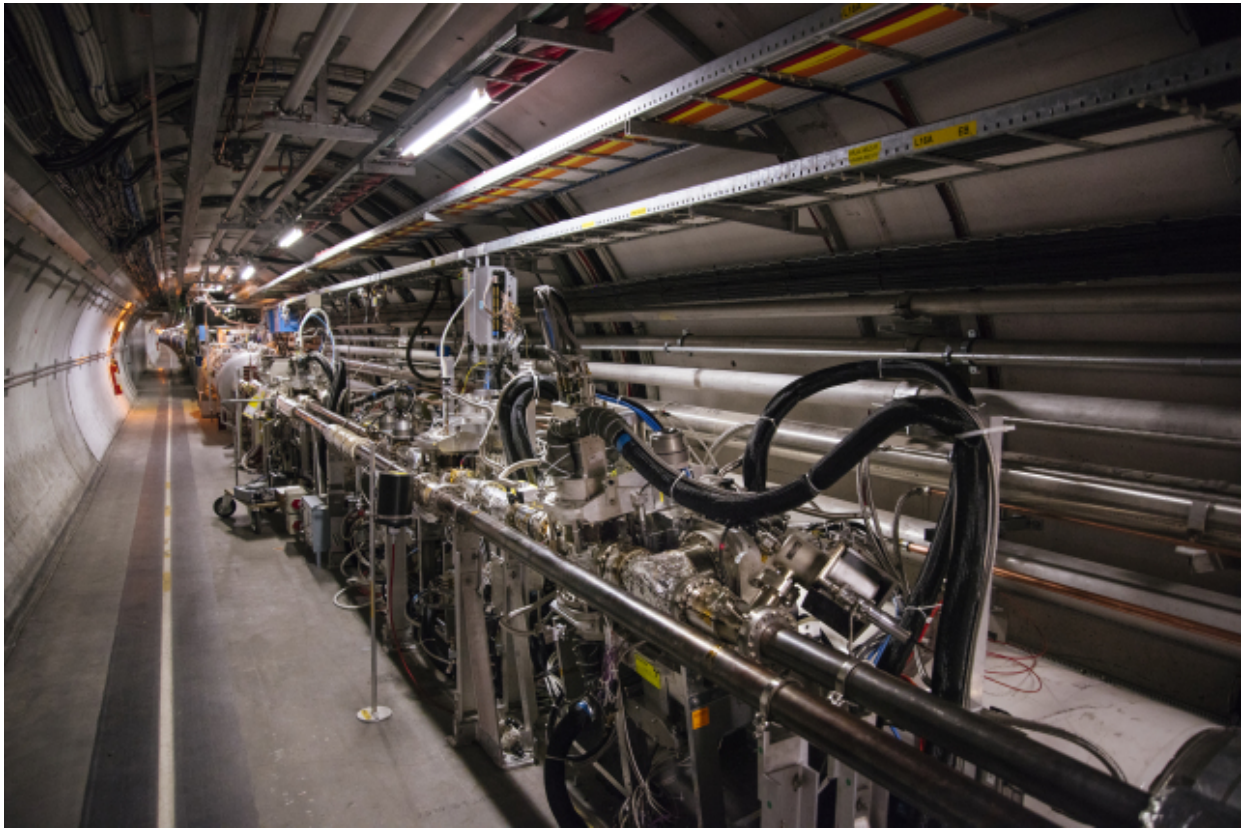


Event Selection

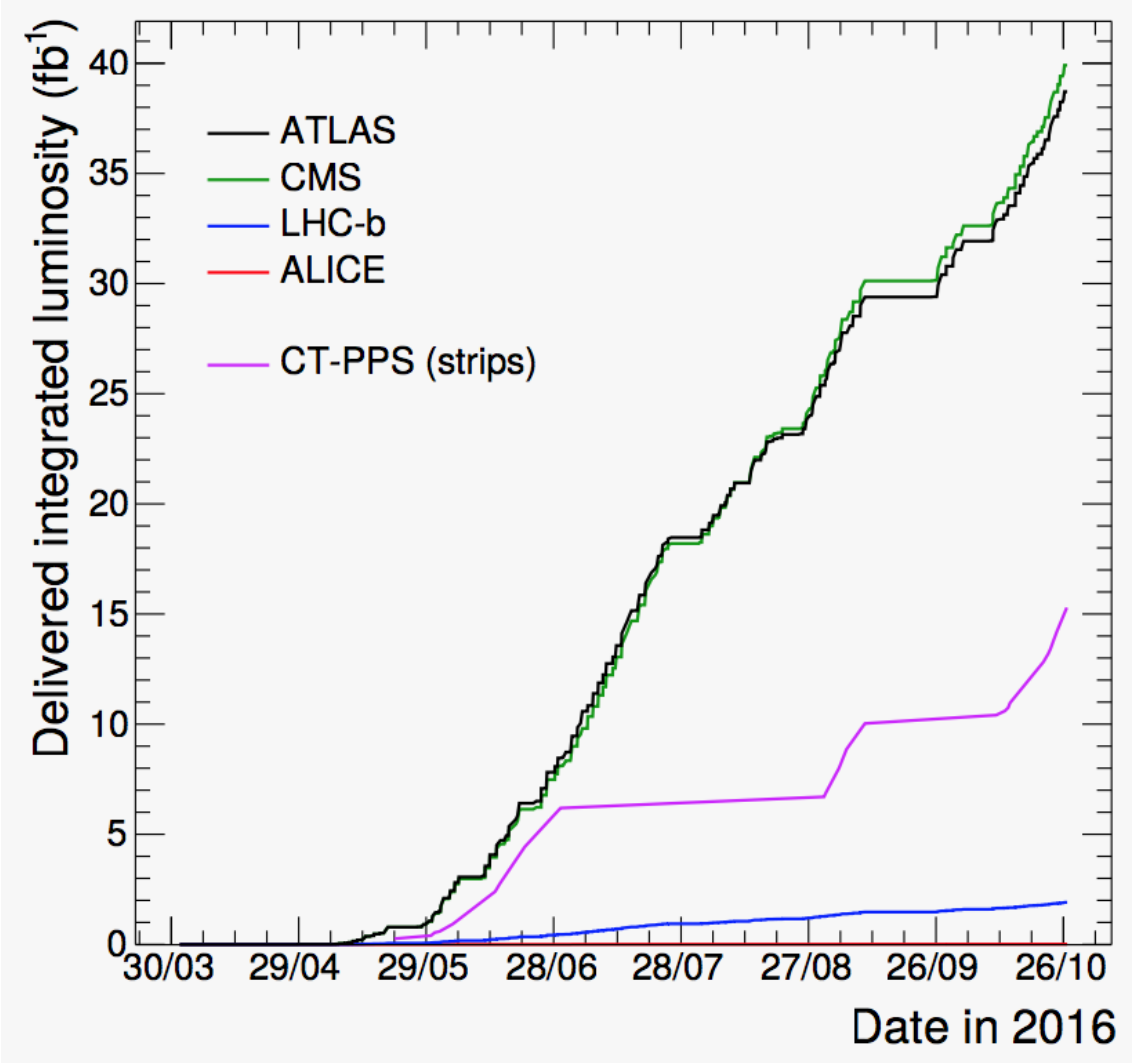


- Request pair of opposite sign muons with
  - pT $>$ 50 GeV
  - $M_{\mu\mu} > 110$ GeV (Above Z boson peak)
- Selection based on the cleanliness of the dimuon vertex

Backup slides - CTPPS



Backup slides - Data



References I

1. Search for new physics in high mass diphoton events in proton-proton collisions at 13TeV , Tech. Rep. CMSPAS-EXO-15-004 (CERN, Geneva, 2015).
2. S. Fichet, G. von Gersdorff, B. Lenzi, C. Royon, and M. Saimpert, JHEP 02, 165 (2015), arXiv:1411.6629 [hep-ph].
3. S. Fichet, G. von Gersdorff, O. Kepka, B. Lenzi, C. Royon, and M. Saimpert, Phys. Rev. D89, 114004 (2014), arXiv:1312.5153 [hep-ph].
4. M. Boonekamp, R. Peschanski, and C. Royon Phys. Rev. Lett. 87, 251806
5. E. Chapon, C. Royon, and O. Kepka, Anomalous Quartic WW$\gamma\gamma$, ZZ$\gamma\gamma$, and Trilinear WWγ, couplings in two-photon processes at High Luminosity at the LHC, Phys. Rev. D 81, 074003 (2010).