Results from the CMS-TOTEM Precision Proton Spectrometer

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1. Introduction

Measurement of processes where protons remain intact after interaction $\rightarrow$ allows study of central exclusive production in $\gamma\gamma \rightarrow X$ or two-gluon exchange processes.

Precision Proton Spectrometer (PPS) designed for operation at standard LHC luminosities and brought online in 2016.

Intact protons are bent out of beam envelope by LHC magnets. Protons are detected with system of near-beam tracking and timing detectors housed in roman pot (RP) units located at about 210 m from IP5 on both sides.

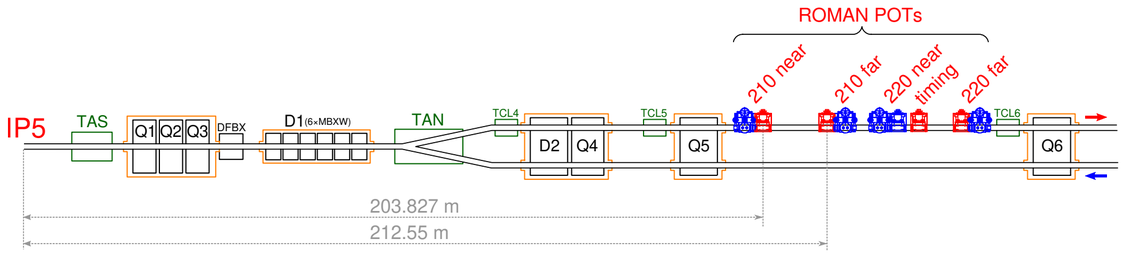


Figure 1: Schematic diagram of one arm of the CMS-TOTEM Precision Proton Spectrometer configuration during 2016. Other arm is symmetric w.r.t. IP5.

2. Photoproduction of dilepton pairs

First physics result with CT-PPS: $pp \rightarrow p(\gamma\gamma \rightarrow \ell^+\ell^-)p^{(*)}$, where ℓ is either a muon or an electron. Analysis based on data-taking in 2016 (9.4 fb^{-1}) at 13 TeV (JHEP07(2018)153).

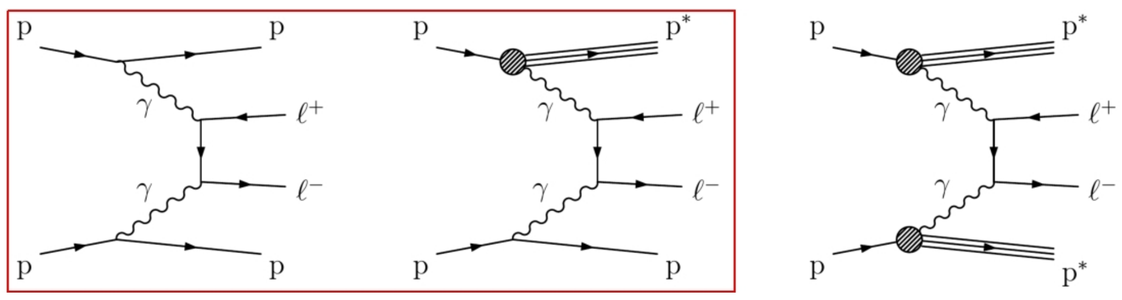


Figure 2: Production of dilepton pairs in photon-exchange processes. From left to right: central exclusive production, single-dissociation and double-dissociation.

Key kinematic variable: fractional momentum loss of the proton $\xi = \Delta p/p$; directly measured with PPS.

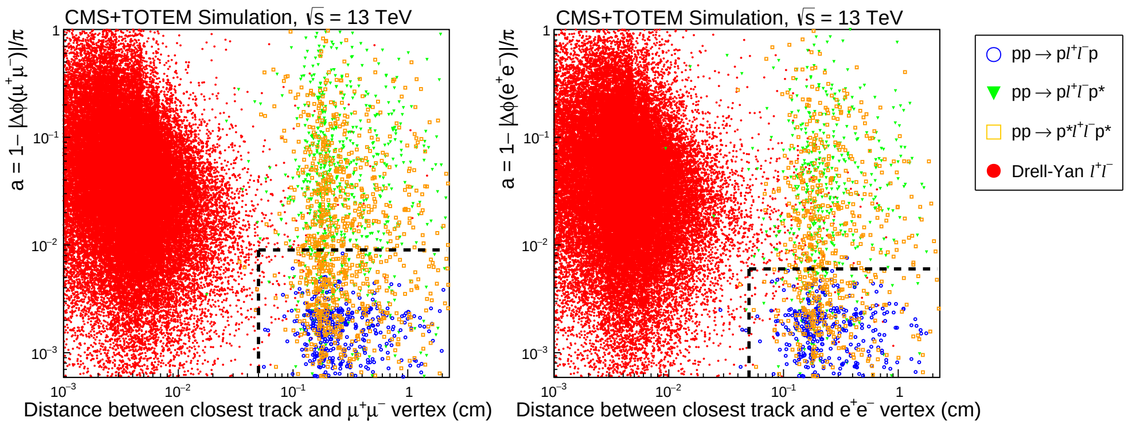
ξ can be estimated with dilepton pair information via

$$\xi^{\pm}(\ell^+\ell^-) = \frac{1}{\sqrt{s}} \times \left(p_T(\ell^+) e^{\pm\eta(\ell^+)} + p_T(\ell^-) e^{\pm\eta(\ell^-)} \right) \quad (1)$$

Strategy: look for correlation between $\xi(\ell^+\ell^-)$ measured with dilepton pair information and $\xi(\mathrm{RP})$ measured with PPS.

3. Event selection

- Pair of opposite-sign lepton pairs with $p_T(\ell) > 50$ GeV and $m(\ell^+\ell^-) > 110$ GeV.
- Veto additional tracks around dilepton vertex (within 0.5 mm).
- Back-to-back pairs: $|1 - \Delta\phi(\mu^+\mu^-)| < 0.009$ (< 0.006 for e^+e^-).
- At least one proton measured in PPS



4. Background treatment

Leading background: Drell-Yan and double-dissociative dilepton production overlapping with uncorrelated beam-halo protons or protons from pileup interactions.

Remaining contribution in signal region is estimated with event mixing.

Expected number of background events

$$\mu^+\mu^- : 1.49 \pm 0.07\,(\mathrm{stat}) \pm 0.53\,(\mathrm{syst}) \quad (2)$$

$$e^+e^- : 2.36 \pm 0.09\,(\mathrm{stat}) \pm 0.47\,(\mathrm{syst}) \quad (3)$$

5. Results

- 12 matching $\mu^+\mu^-$ events (single-arm).
- 8 matching e^+e^- events (single-arm).
- Combined significance of $> 5.1\sigma$.
- No double-proton tag observed (consistent with expectations)

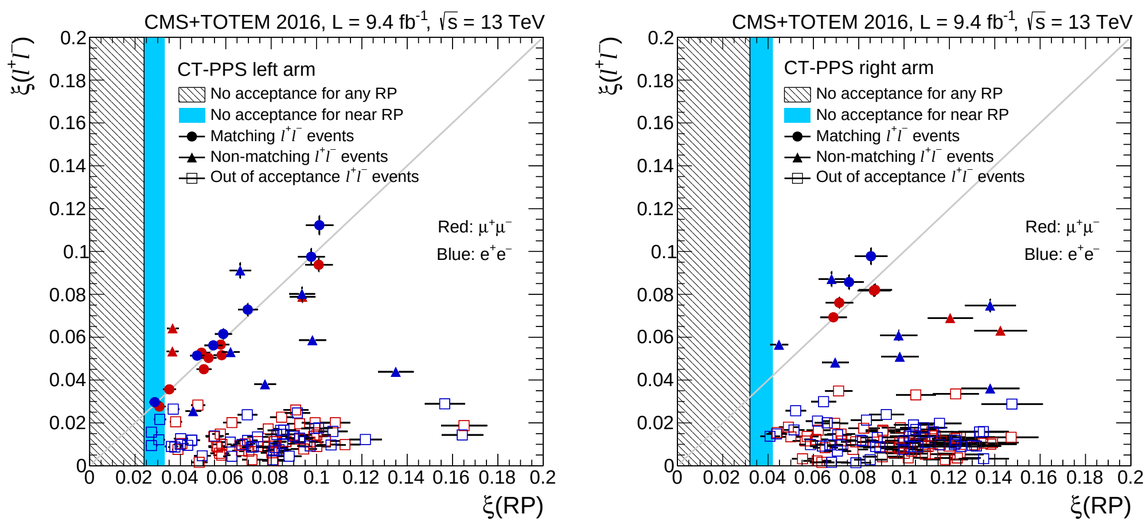


Figure 3: Correlation of $\xi(\ell^+\ell^-)$ measured with central dilepton information and $\xi(\mathrm{RP})$ measured with the PPS for each arm.

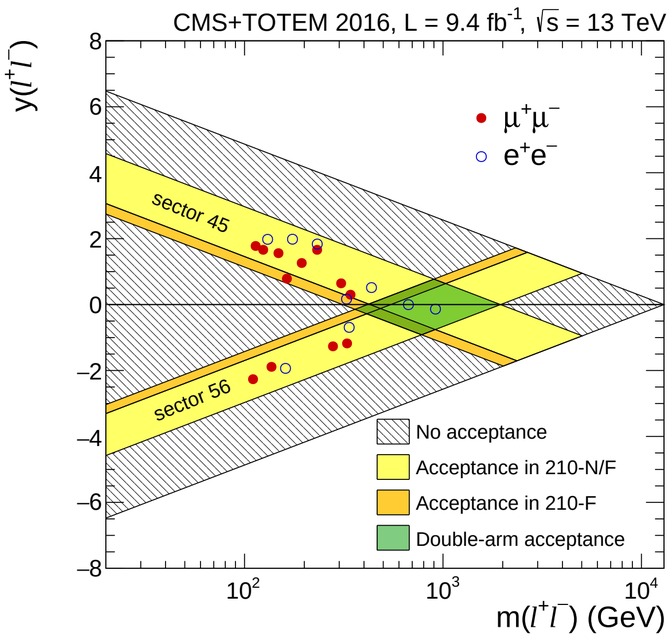


Figure 4: Expected acceptance regions in mass $m(\ell^+\ell^-)$ and rapidity $y(\ell\ell)$ plane of proton-tagged events overlaid with observed dilepton pair candidate events.

6. Conclusions and outlook

- Photon physics above the electroweak energy scale using proton-tagging technique is a reality!
- Feasibility of near-beam proton spectrometer operation at standard luminosities at the LHC.
- Over $\sim$100 fb^{-1} of Run-2 LHC data to analyze!
- Great potential for Beyond the Standard Model searches; sensitive to anomalous quartic gauge couplings $\gamma\gamma\gamma\gamma$, $\gamma\gamma ZZ$, $\gamma\gamma\gamma Z$, $\gamma\gamma W^+W^-$, photoproduction of $t\bar{t}$ pairs, constraints on axion-like particles at large masses, and more!