1. A FEW WORDS ABOUT CT-PPS

- CT-PPS operated for the first time in 2016
- Spectrometer allows measurement of processes in which incoming proton(s) escapes intact after interaction at IP
- Goal: study of central exclusive production in $\gamma\gamma$ or $gg$ collisions by combining CMS and PPS information
- Access to topics from BSM to diffraction

Operation principle: Protons scattered at IP are bent out from beam envelope by LHC magnets. CT-PPS detectors housed along the beamline measure protons a few mm from beam, on both sides of CMS.

2. IDEA AND STRATEGY

Analysis of the first data (9.4 fb$^{-1}$) collected in standard high-luminosity runs.

Study production of lepton pairs by $\gamma\gamma$ fusion.

Two goals:
- Technical: validation of CT-PPS performance and reconstruction
- Physics: first observation of proton-tagged $\gamma\gamma$ collisions at the EWK scale

Key proton variable: relative momentum loss $\xi = \Delta p/p$. $\xi$ can also be derived from leptons $p_T$ and $\eta$:

$$\xi^\pm = \frac{1}{\sqrt{2}} \left( (p_T(l_1)e^{\pm\eta(l_1)}) + (p_T(l_2)e^{\mp\eta(l_2)}) \right)$$

We search for correlation between:
- direct proton $\xi(p)$ measurement by CT-PPS
- dilepton system $\xi(l^+l^-)$ measured by CMS

Main background sources are Drell-Yan and double-dissociative dilepton production. They fake signal signature by overlaying with protons from pileup/break halo.

3. SELECTION

- Pair of opposite sign leptons with $p_T(l) > 50$ and $M(l^+l^-) > 110$ GeV (above Z-peak)

4. PROTON RECONSTRUCTION

Two key components: alignment and optics

Alignment of CT-PPS detectors:
- Step 1: use elastic scattering events from special run to define reference distribution of proton impact positions
- Step 2: calibrate distribution from each fill in physics run

5. BACKGROUND ESTIMATE

- Mean pileup in considered data is $\sim 27$
- Main question: how often pileup protons will by accident have $\xi(p)$ matching with $\xi(l^+l^-)$?
- Typically pileup/break halo protons have low $\xi$ values, and thus are well separated from signal
- To estimate remaining contribution we mix signal and background events
- Sample of background forward protons is obtained from Z-peak events: $80 < M(l^+l^-) < 110$ GeV
- Background protons are mixed with LPAIR MC/data dileptons to estimate background

6. SYSTEMATICS

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<th>CT-PPS</th>
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6. RESULTS

- 12 matching $\mu^+\mu^-$ events
  - Background: $1.49 \pm 0.07$ (stat) $\pm 0.53$ (syst)
- 8 matching $e^+e^-$ events
  - Background: $2.36 \pm 0.09$ (stat) $\pm 0.47$ (syst)

Combined significance $>5.1\sigma$

Summary:
- Observation of proton-tagged $\gamma\gamma$ collisions at the electroweak scale.
- Proven for the first time feasibility of operating a near-beam proton spectrometer at a high-luminosity hadron collider.

Fig. 1: Schematic layout of one arm in 2016 configuration. The other arm is symmetric wrt the CMS IP. LHC magnets are in cyan.

Fig. 2: Signal processes: central exclusive (blue) and seminclusive (green) dilepton production.

Fig. 3: Distribution of the track impact points before and after alignment.

Fig. 4: Correlation between the fractional values of the proton momentum loss measured in the central dilepton system, $\xi(l^+l^-)$, and in the CT-PPS, $\xi(RP)$, for each arm.

Fig. 5: Expected acceptance regions in the rapidity vs. invariant mass plane overlaid with the observed dimuon and dielectron signal candidate events.