

CMS results on diffraction and exclusive production

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- Diffraction \rightarrow exchange of partons from the proton carrying the vacuum quantum numbers \rightarrow Probe diffractive PDFs of the proton (mainly gluons)
- No hadrons in a large rapidity gap adjacent to the scattered proton
- Hard scattering factorization works in diffractive events
- Exclusive photoproduction of quarkonia \rightarrow Clean probe to target hadron structure
- Proton-lead (pPb) collisions particularly interesting for studying photon-proton (γp) interactions

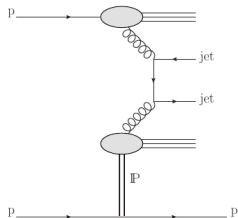
Covered in this talk

- 1 Measurement of dijet production with a leading proton in pp collisions at $\sqrt{s} = 8$ TeV (CMS-PAS-FSQ-12-033; CERN-TOTEM-NOTE-2018-001)
- 2 Exclusive $\rho^0(770)$ photoproduction in ultra-peripheral pPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV (EPJC79(2019)702)
- 3 Exclusive dipion production in pp collisions at $\sqrt{s} = 5.02, 13$ TeV (CMS-PAS-FSQ-16-006)

Diffractive dijets with proton tagging at 8 TeV

First CMS-TOTEM measurement with tagged protons in low pileup pp data at 8 TeV, special beam optics: $\beta^* = 90$ m, 37.5 nb^{-1}

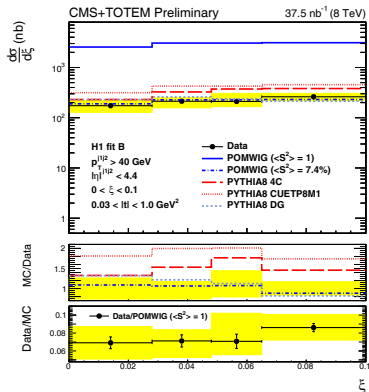
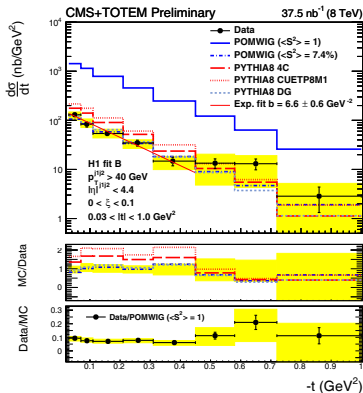
- Dijets in CMS, scattered proton in RP
- Event selection:
 - ▶ At least two jets with $p_T > 40 \text{ GeV}$ & $|\eta| < 4.4$
 - ▶ At least one reconstructed PV
 - ▶ At least one proton in RP: $0 < x_{RP} < 7 \text{ mm}$ & $8.4 < |y_{RP}| < 27 \text{ mm}$
 - ▶ $0.03 < |t| < 1.0 \text{ GeV}^2$ & $0 < \xi_{\text{TOTEM}} < 0.1$
- Backgrounds: Inclusive dijets in coincidence with random RP track from pileup or beam-background proton



TOTEM Roman Pots (RP)

- Movable device, detect beam protons; 147 m & 220 m from IP
- Four momentum transfer squared: $t = (p_f - p_i)^2$
- Fractional momentum loss: $\xi_{\text{TOTEM}} = 1 - \left| \frac{\mathbf{p}_f}{\mathbf{p}_i} \right|$; $\xi_{\text{CMS}}^{\pm} = \frac{\sum(E^i \pm p_z^i)}{\sqrt{s}}$

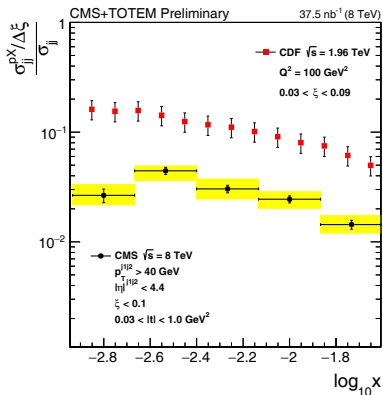
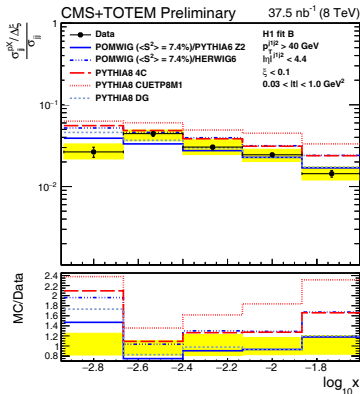
Differential cross section as a function of t & ξ



- PYTHIA8 DG & PomWIG give good description
- PYTHIA8 tunes 4C & CUETP8M1 predict higher contribution
- Fiducial cross section :

$$\sigma_{jj}^{\text{PX}} = 21.7 \pm 0.9 \text{ (stat)}_{-3.3}^{+3.0} \text{ (syst)} \pm 0.9 \text{ (lumi)} \text{ nb}$$

Ratio of diffractive to non-diffractive dijet yields as a function of parton momentum (x)

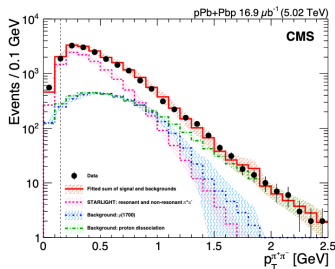


- Ratio of SD to non-diffractive dijet cross section in the fiducial region
- Generally large deviation at low- x
- POMWIG & PYTHIA8 DG gives better description
- Cross section value lower than those from CDF measurements

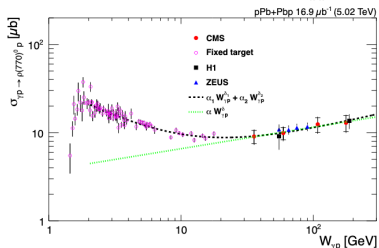
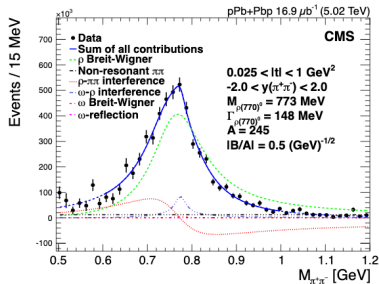
Exclusive $\rho^0(770)$ photoproduction

Exclusive vector meson photoproduction in ultra-peripheral pPb collisions (5.02 TeV) $\gamma p \rightarrow \rho^0(770) \rightarrow \pi^+ \pi^-$

- Experimental signature in CMS:
 - ▶ Events triggered using zerobias conditions
 - ▶ Kinematical selection: Exactly two pion tracks within $|\eta| < 2.0$ associated with the primary vertex
 - ▶ $p_T^{\pi^+ \pi^-} > 0.15$ GeV & $|y_{\pi^+ \pi^-}| < 2.0$
 - ▶ Exclusivity condition: No calorimeter signal (CASTOR, HE, HF, & ZDC)
- Signal process simulated using STARLIGHT including the resonant, non-resonant and interference terms
- Background contributions: non-resonant $\pi^+ \pi^-$, exclusive $\omega(783)$ & $\phi(1020)$, photoproduction of $\rho(1700)$ & proton dissociative events \rightarrow estimated using MC predictions & data-driven methods



Energy dependence of exclusive $\rho^0(770)$ photoproduction

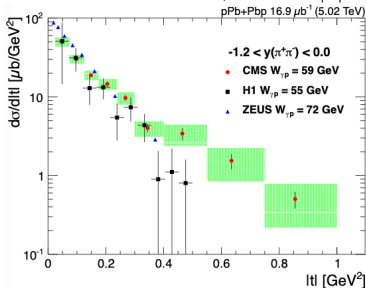
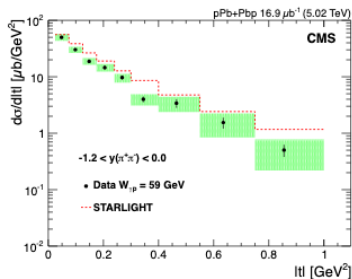


- Invariant mass distribution fitted with Söding formula
- $|B/A|$ & $|C/A|$: non-resonant & $\omega(783)$ contributions w.r.t. resonant $\rho^0(770)$ production
- $|B/A| = 0.50 \pm 0.06$ (stat); $|t| < 0.5$
- H1: 0.57 ± 0.09 (stat); ZEUS: 0.70 ± 0.04 (stat)

- Good agreement with the HERA data & theoretical models
- Integrated cross section: 11.0 ± 1.4 (stat) ± 1.0 (syst) μb

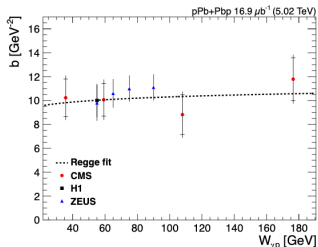
Differential cross section as a function of $|t|$

- Fit $|t|$ spectra using an exponential function: e^{-bt+ct^2} ; $0.025 < |t| < 0.5$



Good agreement with HERA data

- b-slope fitted with Regge formula:
 $b = b_0 + 2\alpha' \ln W_{\gamma p}/W_0^2$
- Parameterizes the dependence of b on collision energy
- Fit to the CMS data alone gives a pomeron slope which is consistent with ZEUS & Regge expectation



Exclusive dipion production at 5.02 & 13 TeV

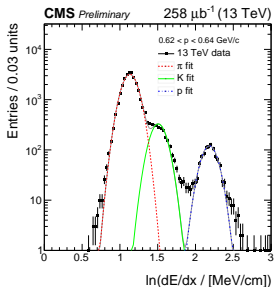
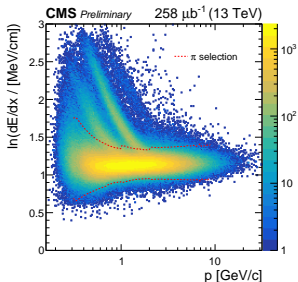
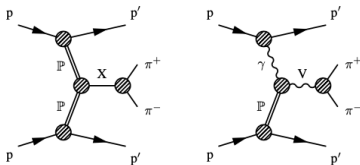
Low pileup data collected using zerobias triggers: $\sqrt{s} = 5.02 \text{ TeV}$, $522 \mu\text{b}^{-1}$;
 $\sqrt{s} = 13 \text{ TeV}$, $258 \mu\text{b}^{-1}$

- Event selection:

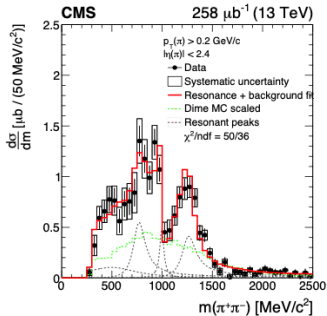
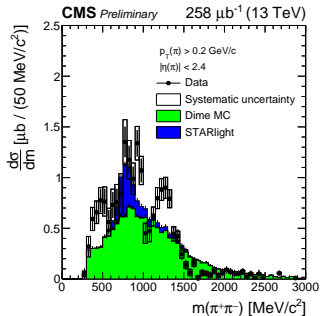
- ▶ Two high-purity tracks
- ▶ Single interaction vertex
- ▶ No activity in calorimeters

- π identification via dE/dx

- Backgrounds: multihadron, exclusive $K^+K^-/p\bar{p}$ & semiexclusive prod.
- Fiducial region: $p_T(\pi) > 0.2 \text{ GeV}$, $|\eta(\pi)| < 2.4$



Differential cross section as a function of invariant mass



$$\sigma^{\pi^+\pi^-}(\sqrt{s} = 5.02 \text{ TeV}) = 19.6 \pm 0.4 (\text{stat}) \pm 3.3 (\text{syst}) \pm 0.01 (\text{lumi}) \mu\text{b}$$

$$\sigma^{\pi^+\pi^-}(\sqrt{s} = 13 \text{ TeV}) = 19.0 \pm 0.6 (\text{stat}) \pm 3.2 (\text{syst}) \pm 0.01 (\text{lumi}) \mu\text{b}$$

- Enhancement in $\rho^0(770)$ region
- Indication of $f_0(500)$, $f_0(980)$ & $f_2(1270)$ resonances
- DIME overestimates the 1500 MeV region
- Fits with interfering Breit-Wigners convoluted with Gaussian
- Extracted cross section for $\rho^0(770)$ in agreement with predictions from STARLIGHT

- A selection of latest results from CMS on the diffractive & exclusive production are presented
- Diffractive dijets with proton tag measured for the first time at the LHC at 8 TeV \rightarrow Combined measurement by CMS & TOTEM
- Results on exclusive vector meson photoproduction in pPb collisions at 5.02 TeV \rightarrow New input to constrain gluon densities
- Exclusive dipion production at 5.02 and 13 TeV \rightarrow $f_0(500)$, $\rho^0(770)$, $f_0(980)$ and $f_2(1270)$ resonances observed