Measurement of exclusive vector meson photoproduction in pPb collisions with the CMS experiment

Kousik Naskar

On behalf of the CMS collaboration

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Vector Meson photoproduction in UPC

Photon-Nuclear Interaction (Signal)

Photon-Photon Interaction

Proton (and/or Lead) dissociation (Background)
Probing the target's gluon density

- Region of interest for PDFs in pPb:
  - Gluon distribution in the proton at low Bjorken-\(x\) (10\(^{-2}\) to 10\(^{-4}\)) and search for saturation effects

- Nuclear shadowing in UPC PbPb

In leading logarithmic approximation of pQCD

\[
\left. \frac{d\sigma_{\gamma p\rightarrow \gamma pVM}}{dt} \right|_{t=0} = C(\mu^2)[xG(x, \mu^2)]^2
\]
Region of interest in CMS:
- $W_{\gamma p}: 29 - 213$ GeV for $\rho^0$
- and 91-826 GeV for $\Upsilon$

$x = \left(\frac{M_{VM}}{W_{\gamma p}}\right)^2,$

$W_{\gamma p}^2 = 2E_p M_{VM} \exp(\pm y)$
Exclusive \( \Upsilon \) in ultraperipheral pPb at 5.02 TeV


CMS

Events/0.08 GeV

Dimuon \( p_T \) cut: \( 0.1 < p_T < 1.0 \) GeV/c

- Low \( p_T \) cut to have good signal/background ratio, high \( p_T \) cut to suppress background from inclusive \( \Upsilon \) and Proton Dissociation (PD)
\[ p_T^2 \text{ differential cross-section} \]

**Result for } \Upsilon(nS):** \[ b = 6.0 \pm 2.1 \text{(stat.)} \pm 0.3 \text{ (syst.) GeV}^{-2} \]

**Consistent with ZEUS measurement for } \Upsilon(1S):** \[ b = 4.3_{-1.3}^{+2.0} \text{ (stat.) GeV}^{-2} \]  

**Exponential slope-b provides information on the transverse density profile of the proton**

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<table>
<thead>
<tr>
<th>( p_T^2 \text{ (GeV)}^2 )</th>
<th>( B_{\Upsilon(nS) \rightarrow \mu^+ \mu^-} \text{ d} \sigma_{\Upsilon(nS)} / \text{d} p_T^2 \text{ nb} / (\text{GeV})^2 )</th>
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Rapidity dependence

$\Rightarrow$ Consistent with theoretical predictions

- JMRT model: pQCD calculations at LO and NLO [JHEP 11 (2013) 085]


Fit parameters of power law dependent cross section: $\sigma_{\gamma}(W_{\gamma p}) = A \times (W/400)^\delta$

- **CMS result**: $\delta = 1.08 \pm 0.42$, $A = 690 \pm 184$ pb
- **ZEUS result**: $\delta = 1.2 \pm 0.8$ [PLB 680 (2009) 4]

$\Rightarrow$ It is consistent with other experimental results and most predictions

Combined fit to all measurements (black line) disfavour the LO pQCD calculations [JHEP 11 (2013) 085]
Exclusive $\rho$ in ultraperipheral pPb at 5.02 TeV


- Complex signal extraction due to the interference with the $\omega(783)$ meson
Results: Exclusive $\rho(770)^0$ photoproduction at 5.02 TeV

Left plot is fitted with an exponential function $A e^{-b|t| + c|t|^2}$

- CMS result: $b = 9.2 \pm 0.7$ (stat.) GeV$^{-2}$, $c = 4.6 \pm 1.6$ (stat.) GeV$^{-4}$

From Regge formula $b = b_0 + 2\alpha \ln(W_{\gamma p}/W_0)^2$

- CMS result: $\alpha = 0.28 \pm 0.11$ (stat) $\pm 0.12$ (syst) GeV$^{-2}$,

Scaling with the photon-proton energy

- Cross-section: $\sigma = 11 \pm 1.4 \text{ (stat) } \pm 1.0 \text{ (syst) } \mu b$
  (within $W_{\gamma p} : 29 - 213 \text{ GeV and } 0 < |t| < 0.5 \text{ GeV}^2$)

- Results consistent with measurements at HERA [EPJC 2 (1998) 247, NPB 463 (1996) 3]

- Fit parameters of power law dependent cross section: $\sigma_p (W_{\gamma p}) = \alpha \times (W_{\gamma p})^\delta$

  $\delta = 0.24 \pm 0.13 \text{ (stat) } \pm 0.04 \text{ (syst)}$
Summary and Outlook

- 1\textsuperscript{st} measurement of $\Upsilon(nS)$ and $\rho(770)^0$ photoproduction in pPb collisions

- These cross-section measurements provide constraints on the evolution of the gluon density in the proton at low Bjorken-$x$

- Stay tuned for new exclusive quarkonium measurements with the large Run 2 data samples!
Thank you for attention!
CMS Detector

- Total weight: 14,000 tones
- Overall diameter: 15 m
- Overall length: 28.7 m
- Magnetic field: 3.8 T

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**Muon**
- $|\eta| < 2.4$

**ECAL**
- $|\eta| < 3.0$

**HCAL**
- $|\eta| < 5.2$

**TRACKER**
- $|\eta| < 2.5$
Data from pPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV in 2013

- Integrated luminosities: 32.6 nb$^{-1}$ for $\Upsilon$ and 16.9 $\mu$b$^{-1}$ for $\rho$

### $\Upsilon$ selection

- **Mass cut:** $9.1 < \text{Mass}_{\mu\mu} < 10.6$ GeV
- **Exclusivity Cut:**
  - $(N_{\text{Tracks}} = 2, \text{trk } p_T > 0.1$ GeV/c)
  - Leading tower Energy in HF calorimeter $< 5.0$ GeV

### Muon selection

- **Single muon Cut:**
  - To have good muon efficiency
  - $\mu^+, \mu^- p_T > 3.3$ GeV/c, $|\eta| < 2.2$

### $\Upsilon$ selection

- **Dimuon $p_T$ Cut:**
  - Low $p_T$ cut to have good signal/background ratio, high $p_T$ cut to suppress background from inclusive $\Upsilon$ and Proton Dissociation (PD)
  - Dimuon $p_T$: $0.1 < p_T < 1.0$ GeV/c

### $\rho(770)^0$ selection

- **Mass cut:** $0.5 < \text{Mass}_{\pi\pi} < 1.2$ GeV
- **Exclusivity Cut:**
  - Opposite sign 2 tracks of pion in an event ($N_{\text{Tracks}} = 2$)
  - Leading tower Energy in HF $< 3.0$ GeV, HE $< 1.95$ GeV
  - CASTOR $< 9$ GeV, ZDC $< 500$ GeV, ZDC $< 2000$ GeV

### Pion selection

- **Single muon Cut:**
  - To have good pion efficiency
  - $\pi^+, \pi^- p_T^{\text{Leading}} > 0.4$ GeV/c and $p_T^{\text{Subleading}} > 0.2$ GeV/c, $|\eta| < 2.0$

### $\rho^0$ selection

- **$(\pi^+\pi^-) p_T$ Cut:**
  - Low $p_T$ cut to have good signal/background ratio, high $p_T$ cut to suppress background from inclusive $\rho$ and Proton Dissociation (PD)
  - $(\pi^+\pi^-) p_T^2$: $0.025 < p_T^2 < 1.0$ GeV$^2$/c$^2$