Azimuthal angular decorrelation of dijets in UPC PbPb collisions at 5.02 TeV with CMS
CMS-HIN-18-011

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On behalf of the CMS Collaboration

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Outline

• **Exclusive dijet photoproduction in UPC PbPb @ 5 TeV**

• **Motivation**
  - First step to access novel features of gluon distributions

• **CMS Detector and analysis selections**

• **Results**
  - Comparison with recent theoretical calculations
Motivation

Exclusive dijet photoproduction is directly sensitive to the Wigner and Husimi gluon distributions describing the **multidimensional structure of the gluons** (Hatta, et al, *PRL 116*, 202301 (2016))

Elliptically polarized gluons: ↔ Dijet azimuthal angular correlations

![Diagram](image)

**Second Fourier harmonic** of the azimuthal distribution

where $\phi$ is the angle between $P_T$ and $Q_T$:

$$ v_2 = \langle \cos(2\phi) \rangle, $$

$$ \cos(\phi) = \frac{\vec{Q}_T \cdot \vec{P}_T}{||\vec{Q}_T|| \cdot ||\vec{P}_T||} $$

**Vector sum of 2 jets:**

$$ \vec{Q}_T = \vec{k}_1 + \vec{k}_2 $$

**Vector difference of 2 jets:**

$$ \vec{P}_T = \frac{1}{2}(\vec{k}_1 - \vec{k}_2) $$
2\textsuperscript{nd} Fourier harmonic and theoretical calculation

Recent theoretical calculations by Y. Hatta et al. *PRL 126, 142001 (2021)* performed following the our preliminary results.

- The standard TMD framework is used for resummation.
- Soft gluon emission from the final state jets results in a positive $\langle \cos(2\varphi) \rangle$
- Wigner gluon distributions are neglected
- Photoproduced dijets ($Q_T << P_T$)
CMS Detector

Electromagnetic Barrel Calorimeter (EB): $|\eta| < 1.5$
Electromagnetic Endcap Calorimeter (EB): $1.5 < |\eta| < 3.0$
Hadron Barrel Calorimeter (HB): $|\eta| < 1.3$
Hadron Endcap Calorimeter (HE): $1.3 < |\eta| < 3.0$
Hadron Forward Calorimeter (HF): $3.0 < |\eta| < 5.2$
CMS offers perfect rapidity coverage to measure jets
Analysis selections

- At least one track in the central tracker
- Particle flow jets using the anti-\( k_t \) algorithm with \( R=0.4 \)
- Only two jets \( |\eta_{\text{lab}}| < 2.4, p_{T,1} > 30 \text{ GeV}, p_{T,2} > 20 \text{ GeV} \)
- Veto activity in the forward region \( (2.8 < |\eta| < 5.2) \): HF, HE and EE calorimeters

RAPGAP MC extensively exploited for \( ep \) collisions at HERA
is used for modelling exclusive dijet photoproduction via photon-gluon fusion
Rapidity Gap Selection

\[ \gamma + \text{Pb} \rightarrow \text{jet} + \text{jet} + \text{Pb}^* \] events are asymmetric in dijet rapidity (according to RAPGAP MC).

- Rapidity Gap Selection:
  
  \textit{Forward Rapidity Gap}, \[ \Delta \eta^F = 2.4 - \eta_{\text{max}}, \quad \eta_{\text{max}} - \text{high-purity track with } p_T > 0.2 \text{ GeV} \]

- Two separate data sets are defined:

  Backward Rapidity Gap \[ \Delta \eta^B > \Delta \eta^F, \] and the other \[ \Delta \eta^F > \Delta \eta^B \]

- Samples are merged by changing the rapidity sign of the jets in the \[ \Delta \eta^F > \Delta \eta^B \] dataset.
Exclusivity requirements


No tracker activity far from the jets to reject non-exclusive and two-photon processes.

- $\max[\eta_{\text{jet}} - \eta_{\text{track}}] < 1$
- $\Delta\eta^B > 1.2$

These selections keep 99\% of signal (according to RAPGAP MC) and significantly reduce the remaining non-exclusive background
Good agreement between data and MC.

Photon flux in RAPGAP correctly reproduced for the UPC $\gamma$Pb data.
Dijet kinematics


• The measurement is performed in $Q_T < 25$ GeV

$\Rightarrow 6785$ dijet events pass all analysis selections.

Large momentum transfer regime (DIS-type)

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$\Rightarrow 6785$ dijet events pass all analysis selections.

$\bullet$ $P_T > Q_T$ : “back-to-back limit”
Dijet angular distribution and 2\textsuperscript{nd} Fourier harmonic: Analysis cross checks


- **Toy MC**: back-to-back jets with detector resolution effects $<\cos(2\phi)> \to 1$
- **Mixed events** have no physical correlation: negative $<\cos(2\phi)>$ value
Unfolded angular distribution and 2\textsuperscript{nd} Fourier harmonic


- $<\cos(2\phi)>$ in data is below back-to-back expectation and RAPGAP prediction
- $<\cos(2\phi)>$ rises steadily in the data in contrast to a constant value after $Q_T > 2$ GeV in the theory: DIS vs Photoproduction regime?
Summary

• First measurement of azimuthal anisotropy from UPC Dijets in PbPb at 5 TeV

• First measurement of $\langle \cos(2\phi) \rangle$ connected to the gluon Wigner/Husimi distribution, believed to be the most fundamental gluon distribution

• RAPGAP MC (ep expectation) overestimates the strength of the correlations
  • The data are compared to the latest theory calculation by Y. Hatta et al. (soft-gluon radiation from final-state jets):
    • Good agreement in the average magnitude of the correlations for dijet momentum less than 15 GeV
    • This calculation exhibits a rapid plateau, in contrast of the steady rise observed in the data.

Thank you for your attention!
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Exclusive dijets in UPC PbPb @5 TeV (CMS-HIN-18-011)

Systematic uncertainties:

- Jet Energy Scale Correction (JES): ±2%
- Jet Energy Scale non-closure (JESnc): -5%
- Jet Energy Resolution (JER): 15% for 20 GeV jets
- Jet Angular Resolution (JAR): 0.03 for 20 GeV jets
- Rapidity Gap Selection (PUR): BRG > [0,2]
- Trigger Efficiency (TR)

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