Heavy Meson Coherent Photoproduction in (Ultra)-Peripheral AA Collisions

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Outlook

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- Rapidity Distribution and R_{AA}
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- Summary

GFPAE

Introduction

Motivation

Review-UPC

Review-UPC

Review-UPC

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Scenario 1

Scenario 2

Scenario 3

RAA

Summary

ALICE Measurements - J/ψ

- The Average Rapidity Distribution

$$\left.\frac{d\sigma}{dy}\right|_{2.5<y<4.0} = \frac{1}{\Delta y}\int_{2.5}^{4.0}\frac{d\sigma}{dy}dy \quad (1)$$

- ALICE measurements [1]

$p_T < 0.3$ GeV/c and $\sqrt{s_{NN}} = 2.76$ TeV

Cent.%	$N_{AA}^{J/\psi}$	$N_{AA}^{hJ/\psi}$	$N_{AA}^{\text{excess}J/\psi}$	$d\sigma^{\text{coh}}_{J/\psi}/dy$ [μb]
0-10	339±85±78	406±14±55	<251	<318
10-30	373±87±75	397±10±61	<237	<290
30-50	187±37±15	126±4±15	62±2±5	$73 \pm 44^{+26}_{-27} \pm 10$
50-70	89±13±2	39±2±5	50±14±5	$58 \pm 16^{+8}_{-10} \pm 8$
70-90	59±9±3	8±1±1	51±9±3	$59 \pm 11^{+7}_{-10} \pm 8$

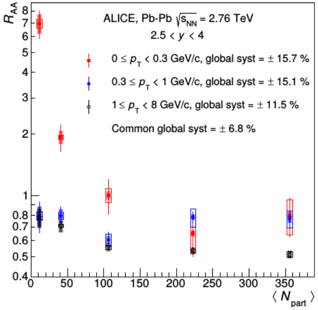
- $N_{AA}^{J/\psi} \rightarrow$ raw number of J/ψ.
- $N_{AA}^{\text{excess}J/\psi} \rightarrow$ excess of J/ψ.
- $N_{AA}^{hJ/\psi} \rightarrow$ raw hadronic number of J/ψ.

[1] ALICE Collaboration, J. Adam et al., Phys. Rev. Lett. 116, 222301, (2016)

ALICE Measurements - J/ψ

- The nuclear modification factor (R_{AA}) is given by [2]

$$R_{AA}^{hJ/\psi} = \frac{N_{AA}^{J/\psi}}{BR_{J/\psi \to l^+l^-} \cdot N_{events} \cdot (A \times \varepsilon)_{AA}^{J/\psi} \cdot \langle T_{AA} \rangle \cdot \sigma_{pp}^{hJ/\psi}}, \quad (2)$$



- $N_{AA}^{J/\psi} \to$ raw number of J/ψ
- $BR_{J/\psi \to l^+l^-} = 5.96\%$
- $N_{events}{}^{a} \simeq 10.6 \times 10^7$
- $(A \times \varepsilon)_{AA}^{J/\psi} \sim 11.31\%$
- $\langle T_{AA} \rangle^{b} = \begin{cases} 3.84 \text{ mb}^{-1}, & 30\% - 50\% \\ 0.954 \text{ mb}^{-1}, & 50\% - 70\% \\ 0.17 \text{ mb}^{-1}, & 70\% - 90\% \end{cases}$
- $\sigma_{pp}^{hJ/\psi} = 0.0514 \mu b$

[a] ALICE Coll., B. Abelev et al., PLB734, 314, (2014)
[b] ALICE Coll., B. Abelev et al., PRC88, 044909, (2013)

[2] ALICE Collaboration, J. Adam et al., Phys. Rev. Lett. 116, 222301, (2016)

STAR Measurements - J/ψ

Introduction
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Scenario 1
Scenario 2
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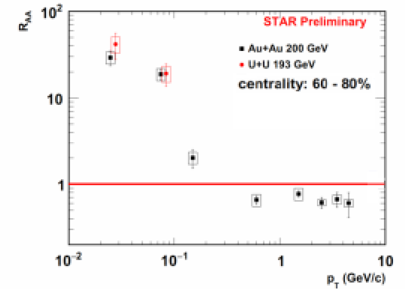
Summary

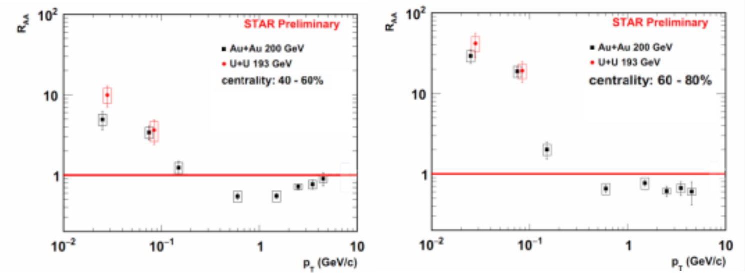
- J/ψ R_{AA} as a function of p_T for mid-rapidity ($|y| < 1$) [3]
- Relevant excess of the J/ψ for Au-Au ($\sqrt{s} = 200$ GeV) and U-U ($\sqrt{s} = 193$ GeV) for $p_T < 0.1$ GeV/c.
- More intense excess for 60%-80% centrality bin.



[3] W. Zha (STAR Collaboration), Journal of Physics: Conference Series 779, 012039 (2017).

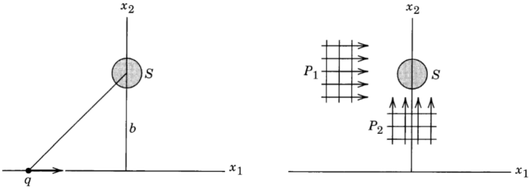
STAR Measurements - J/ψ

- The J/ψ excess is still present for 40%-60% centrality class.
- For more central collision 20%-40% the effect is strongly attenuated.



Theoretical Review of the UPC

- In ultrarelativistic hadronic collisions,



- The cross section for the production of the X state can be written as [4]

$$\sigma_X = \int d\omega \frac{dN(\omega)}{d\omega} \sigma_X^{\gamma}(\omega) \tag{3}$$

- ω $\rightarrow$ photon energy.
- $\frac{dN(\omega)}{d\omega}$ $\rightarrow$ equivalent photon flux (Weizsäcker-Williams).
- $\sigma_X^{\gamma}(\omega)$ $\rightarrow$ photoproduction cross section (colour dipole model).

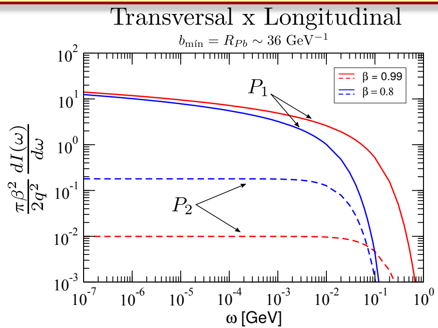
[4] C. A. Bertulani, S. R. Klein and J. Nystrand, Annu. Rev. Nucl. Part. Sci. 55, 271-310 (2005).

Theoretical Review of the UPC

- Transverse (P_1) and Longitudinal ($P2$) contribution [5]:

$$\frac{d^3I_1(\omega,b)}{d\omega d^2b} = \frac{c}{2\pi}\left|E_2(\omega)\right|^2 = \frac{1}{\pi^2}\frac{q^2}{cb^2}\left(\frac{c}{v}\right)^2\left[\left(\frac{\omega b}{\gamma v}\right)^2 K_1^2\left(\frac{\omega b}{\gamma v}\right)\right]$$

$$\frac{d^3I_2(\omega,b)}{d\omega d^2b} = \frac{c}{2\pi}\left|E_1(\omega)\right|^2 = \frac{1}{\pi^2}\frac{q^2}{cb^2}\left(\frac{c}{v}\right)^2\left[\frac{1}{\gamma^2}\left(\frac{\omega b}{\gamma v}\right)^2 K_0^2\left(\frac{\omega b}{\gamma v}\right)\right]$$



[5] J.D. Jackson, *Classical Electrodynamics - Third Edition*, Editor: JOHN WILEY, (1998)

The Equivalent Photon Flux

- For pointlike charge,

$$\frac{dN(\omega)}{d\omega} = \frac{2q^2}{\pi\omega}\left[\zeta_{\text{mín}} K_0(\zeta_{\text{mín}}) K_1(\zeta_{\text{mín}}) - \frac{\zeta_{\text{mín}}^2}{2}\left[K_1^2(\zeta_{\text{mín}}) - K_0^2(\zeta_{\text{mín}})\right]\right]$$

where $\zeta_{\text{mín}} = \omega R_A/\gamma$

- For protons, a form factor is necessary.
- Considering $F(Q^2) = 1/\left(1 + Q^2/0.71\ \text{GeV}^2\right)^2$ [6]

$$\frac{dN(\omega)}{d\omega} = \frac{\alpha_{em}}{2\pi\omega}\left[\ln\Omega - \frac{11}{6} + \frac{3}{\Omega} - \frac{3}{2\Omega^2} + \frac{1}{3\Omega^3}\right]$$

- $\Omega = 1 + 0.71\ \text{GeV}^2/Q^2_{min}$ and $Q^2_{min} \approx (\omega/\gamma)^2$;
- $\gamma = 1/\sqrt{1-\beta^2}$ and $\beta = v/c$.

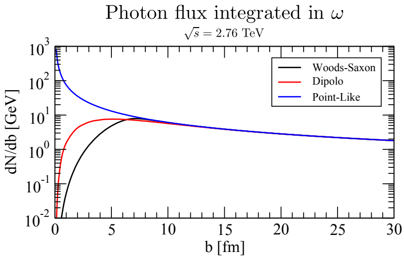
[6] C.F. Perdrisat, V. Punjabi and M. Vanderhaeghen, Prog. Part. Nucl. Phys. 59, 694 (2007).

UPC Collisions

- The photon flux with b-dependence [7]

$$N(\omega, b) = \frac{Z^2 \alpha_{QED}}{\pi^2 \omega} \left| \int_0^\infty dk_\perp k_\perp^2 \frac{F(k^2)}{k^2} J_1(b_1 k_\perp) \right|^2 .$$

where $k^2 = (\omega/\gamma)^2 + k_\perp^2$.



Point Like

- $F(k^2) = 1.$

Dipole Form Factor

- $F_{\mathrm{dip}}(k^2) = \frac{\Lambda^2}{\Lambda^2 + k^2}.$

Woods-Saxon+Yukawa

- $F_{WSY}(k^2) = \frac{4\pi\rho_0}{Ak^3} [\sin(kR_{Pb}) - kR_{Pb}\cos(kR_{Pb})] \left[\frac{1}{1+a^2k^2}\right].$

[7] F. Krauss, M. Greiner and G. Soff, Prog. Part. Nucl. Phys., 39, 503 (1997).

UPC Collisions

- For p-Pb collisions[8] ,

$$N(\omega) = \int_0^\infty db 2\pi b P_{NH}(b) N(\omega, b), \quad (4)$$

  - $P_{NH}(b) = e^{-T_A(b)\sigma_{NN}} \longrightarrow$ probability of having no hadronic interactions.

- Considering the nuclei as hard sphere and $F(k^2) = 1$,

$$\frac{dN(\omega)}{d\omega} = \frac{2}{\pi}\frac{Z^2\alpha_{em}}{\omega}\left[\zeta_{\text{mín}} K_0(\zeta_{\text{mín}}) K_1(\zeta_{\text{mín}}) - \frac{\zeta_{\text{mín}}^2}{2}\left[K_1^2(\zeta_{\text{mín}}) - K_0^2(\zeta_{\text{mín}})\right]\right]$$

  - $\zeta_{\text{mín}} = \frac{\omega R_A}{\gamma}$.

[8] S. Klein and J. Nystrand, Phys. Rev. C60, 014903 (1999).

UPC Collisions

- For Pb-Pb collisions[8],

$$N(\omega) = \int_0^\infty db 2\pi b P_{NH}(b) \int_0^{R_A} \int_0^{2\pi} \frac{r dr d\phi}{\pi R_A^2} N(\omega, b_1),$$

  - $P_{NH}(b) = e^{-T_{AA}(b)\sigma_{NN}} \longrightarrow$ probability of having no hadronic interactions.
  - $b_1^2 = b^2 + r^2 + 2br\cos\phi$
  - Em UPC $\rightarrow N(\omega, |\vec{b} + \vec{r}|) \simeq N(\omega, |\vec{b}|)$

- Considering the nuclei as hard sphere and $F(k^2) = 1$,

$$\frac{dN(\omega)}{d\omega} = \frac{2}{\pi} \frac{Z^2 \alpha_{em}}{\omega} \left[\zeta_{mín} K_0(\zeta_{mín}) K_1(\zeta_{mín}) - \frac{\zeta_{mín}^2}{2} \left[K_1^2(\zeta_{mín}) - K_0^2(\zeta_{mín}) \right] \right]$$

  - $\zeta_{mín} = \frac{2R_A\omega}{\gamma}$.

[8] S. Klein and J. Nystrand, Phys. Rev. C60, 014903 (1999).

The Photonuclear Cross Section

- In the colour dipole formalism,

$$\sigma(\gamma A \to VA) = \frac{|\mathrm{Im}\,\mathscr{A}_{nuc}(x,t=0)|^2}{16\pi}\left(1+\beta(\lambda_{eff})^2\right) R_g^2(\lambda_{eff}) \int_{t_{min}}^{\infty} |F(t)|^2\, dt \qquad (5)$$

  - $F(t)$ - electromagnetic form factor, $t_{min} = \left(M_V^2/2\omega\gamma\right)^2$ and $x = \frac{M_V^2+Q^2}{Q^2+2\omega\sqrt{s_{NN}}}$;
  - $\beta(\lambda_{eff}) = \frac{\mathrm{Re}\,\mathscr{A}_{nuc}(x,t=0)}{\mathrm{Im}\,\mathscr{A}_{nuc}(x,t=0)}$ restores the real contribution of the $\mathscr{A}_{nuc}(x,t=0)$;
  - $R_g^2(\lambda_{eff})$ - skewedness effect.

- The forward scattering amplitude is given by

$$\mathrm{Im}\,\mathscr{A}_{nuc}(x,t=0) = \int\int \frac{d^2r dz}{4\pi}\left(\psi_V^*\psi_\gamma\right)_T \sigma_{\mathrm{dip}}^{\mathrm{nucleus}}(x,r)$$

where

$$\sigma_{\mathrm{dip}}^{\mathrm{nucleus}}(x,r) = 2\int d^2b' \left\{1-\exp\left[-\frac{1}{2}T_A(b')\sigma_{\mathrm{dip}}^{\mathrm{proton}}(x,r)\right]\right\}$$

  - b' - photon-nuclei impact parameter and $T_A(b')$ is the nuclear profile function;
  - $\left(\psi_V^*\psi_\gamma\right)_T$ - photon-meson wave function $\rightarrow$ Boosted Gaussian;
  - $\sigma_{dip}^{proton}(x,r)$ - dipole cross section $\rightarrow$ GBW and CGC models;;

The GBW and CGC dipole models

- The Golec-Biernat and Wüsthoff (GBW) model [9]:

$$\sigma_{q\bar{q}}^{GBW}(x,r) = \sigma_0[1 - \exp(-r^2 Q_s^2(x)/4)]$$

  - $Q_s^2(x) = (x_0/x)^{\lambda_{GBW}}$ is the saturation scale;
  - $\sigma_0 = 29.12$ mb, $x_0 = 0.41 \times 10^{-4}$ and $\lambda_{GBW} = 0.29$.

- The Iancu, Itakura and Munier (CGC) model [10]:

$$\sigma_{q\bar{q}}^{CGC}(x,r) = \sigma_0 \times \begin{cases} \mathcal{N}_0 \left(\frac{rQ_s}{2}\right)^{2(\gamma_s + (1/\kappa\lambda Y) ln(2/rQ_s))} & : rQ_s \leq 2 \\ 1 - e^{-A ln^2(BrQ_s)} & : rQ_s > 2 \end{cases}$$

  - $A = -\frac{\mathcal{N}_0^2 \gamma_0^2}{(1-\mathcal{N}_0)^2 ln(1-\mathcal{N}_0)}$ and $B = \frac{1}{2}(1-\mathcal{N}_0)^{-(1-\mathcal{N}_0)/(\mathcal{N}_0\gamma_s)}$.
  - $Y = \ln(1/x)$, $\gamma_s = 0.73$, $\kappa = 9.9$ and $Q_s(x) = (x_0/x)^{\lambda/2}$.
  - Free parameters: $\sigma_0 = 27.33$ mb, $\mathcal{N}_0 = 0.7$ and $\lambda = 0.22$.

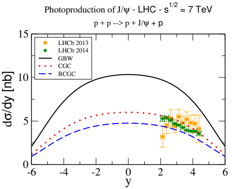
[9] K. G. Biernat and M. Wüsthoff, Phys. Rev. D59, 014017 (1999); Phys. Rev. D60, 114023 (1999).

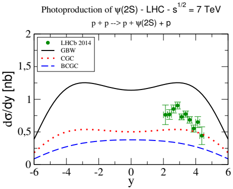
[10] E. Iancu, K. Itakura, and S. Munier, Phys. Lett. B590, 199 (2004).

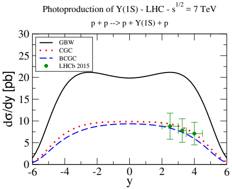
Results for $\sqrt{s} = 7$ TeV in pp collisions

- Comparison of the rapidity distribution for pp collisions with the LHCb data[11]

$$\frac{d\sigma}{dy}(pp \to p \otimes V \otimes p) = \omega \frac{dN_\gamma}{d\omega}\sigma(\gamma p \to Vp) + (y \to -y)$$







- *GBW* model overestimates the data.

Parametrization: M. Kozlov, A. Shoshi and W. Xiang - JHEP 0710 (2007) 020.

- The other models are consistent with the data of J/ψ and $Y(1S)$.

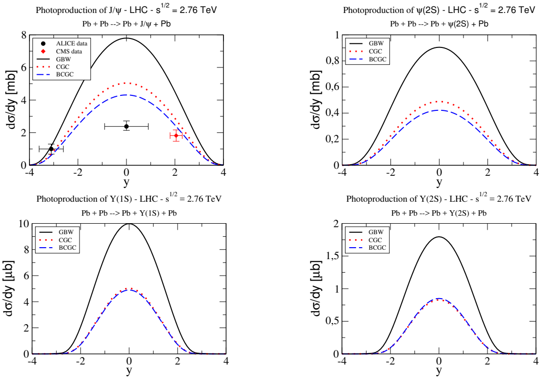
MBGD, F. Kopp, M. V. T. Machado and S. Martins, PRD94, 094023 (2016).

[11] **R. Aaij *et al.*, J. Phys. G40, 045001 (2013); J. Phys. G41, 055002 (2014); JHEP 1509, 084 (2015).**

Results for $\sqrt{s} = 2.76$ TeV in AA collisions

- Comparison of the rapidity distribution for AA collisions with the ALICE data[12]

$$\frac{d\sigma}{dy}(AA \to A \otimes V \otimes A) = \omega \frac{dN_\gamma}{d\omega}\sigma(\gamma A \to VA) + (y \to -y)$$



[12] B. Abelev *et al.*, Phys. Lett. B718, 1273 (2013); E. Abbas *et al.*, Eur. Phys. J. C73, 2617 (2013).

UPC $\Rightarrow$ Peripheral

b-Dependence Photon Flux

- Introduction
- Scenario 1
  - First Approximation
  - Results
- Scenario 2
- Scenario 3
- RAA
- Summary

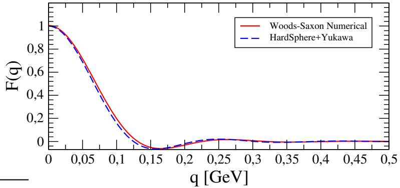
- For peripheral collisions $\rightarrow N(\omega, b)$ with b-dependence [13],

$$\frac{dN(\omega,b)}{d\omega db^2} = \frac{Z^2\alpha_{qed}}{\pi^2\omega}\left|\int d^2k_T k_T^2 \frac{F(k)}{k^2} J_1(k_T b)\right|^2 \quad (6)$$

- Yukawa potential+hard sphere (more realistic for lead) [14],

$$F(k) = \frac{4\pi\rho_0}{Ak^3}\left[\sin\,(kR_A) - kR_A\cos\,(kR_A)\right]\left[\frac{1}{1+a^2k^2}\right]$$

- $k^2 = k_T^2 + \left(\frac{\omega}{\gamma}\right)^2$.
- $\rho_0 = 0.1385$ fm and $a = 0.7$ fm
- A=208 and $R_A = 1.2A^{1/3}$ fm



[13] F. Krauss, M. Greiner and G. Soff, Prog. Part. Nucl. Phys. 39, 503, (1997)

[14] K. T. R. Davies and J. R. Nix, Phys. Rev. C14, 1977 (1976).

Comparing with ALICE data [15]

- Scenario 1:

  - Usual photon flux with b-dependence (Eq. (6));
  - Photonuclear cross section used in UPC (Eq. (5)).

- First results

Average Rapidity Distribution: $2.5 < y < 4.0$

GBW / CGC	$d\sigma^{\text{theo}}_{J/\psi}/dy$ [μb]	$d\sigma^{\text{exp}}_{J/\psi}/dy$ [μb]
30%-50%	353 / 220	$73 \pm 44^{+26}_{-27} \pm 10$
50%-70%	173 / 108	$58 \pm 16^{+8}_{-10} \pm 8$
70%-90%	105 / 65	$59 \pm 11^{+7}_{-10} \pm 8$

Geometric relation:

$$c = \frac{b^2}{4R_A^2}$$

$c \rightarrow$ centrality of the collision.

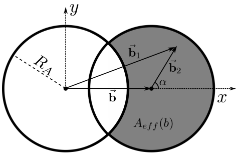
- Excellent agreement in more peripheral region using CGC;
- The results overestimate the data in more central region.

[15] ALICE Collaboration, J. Adam et al., Phys. Rev. Lett. 116, 222301, (2016).

The Effective Photon Flux

- Considering an effective photon flux [16]

$$\sigma_X = \int \omega \frac{dN^{eff}(\omega)}{d\omega} \sigma_X(\omega)$$



- **Hypothesis:** Only spectators interact coherently with the photon.

- In this scenario, $\frac{dN^{eff}(\omega,b)}{d\omega}$ can be described as [17]

$$N^{eff}(\omega, b) = \int N^{usual}(\omega, b_1) \frac{\theta(b_1 - R_A)\theta(R_A - b_2)}{A_{eff}(b)} d^2 b_2 \quad (7)$$

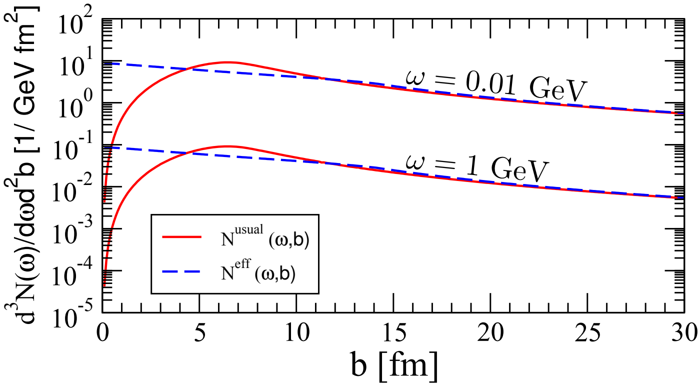
- $A_{eff} = R_A^2\left[\pi - 2\cos^{-1}(b/2R_A)\right] + (b/2)\sqrt{4R_A^2 - b^2}$ and $b_1^2 = b^2 + b_2^2 + 2bb_2\cos(\alpha)$

[16] M. K. Gawenda and A. Szczurek, Phys. Rev. C93, 044912, (2016).

[17] M. B. Gay Ducati and S. Martins, Phys. Rev. D97, 116013, (2018).

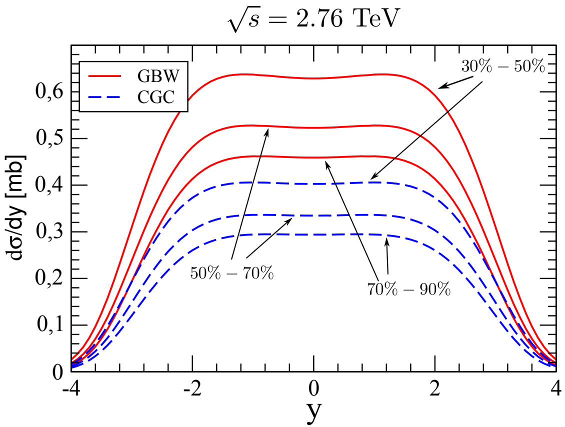
Effective Flux x Usual Flux

- In the ultraperipheral limit, $N^{\text{eff}}(\omega, b) \to N^{\text{usual}}(\omega, b)$.
- In 30%-90%, the photon flux is formed mainly by photons with energy $\omega < 0.2$ GeV.



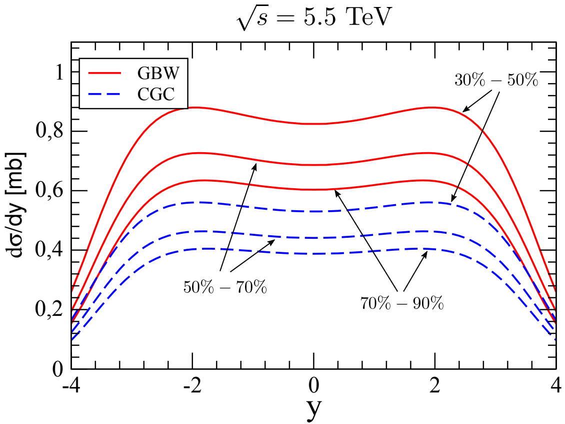
Results for $\sqrt{s} = 2.76$ TeV in AA collisions

- Comparing dipole models:
  - GBW is bigger than CGC by factor ~ 1.5



Results for $\sqrt{s} = 5.5$ TeV in AA collisions

- The relative variation for the different centrality classes is not sensitive to the increase of the energy ($\sqrt{s} = 2.76$ TeV $\rightarrow \sqrt{s} = 5.5$ TeV).



Comparing with ALICE data

- In the scenario 2, we consider
  - Effective photon flux (Eq. (7));
  - Photonuclear cross section used in the UPC (Eq. (5)).
- Comparing with ALICE data,

Average Rapidity Distribution: $2.5 < y < 4.0$

GBW / CGC	$d\sigma^{\text{theo}}_{J/\psi}/dy$ [μb]	$d\sigma^{\text{exp}}_{J/\psi}/dy$ [μb]
30%-50%	236 / 148	$73 \pm 44^{+26}_{-27} \pm 10$
50%-70%	181 / 114	$58 \pm 16^{+8}_{-10} \pm 8$
70%-90%	147 / 92	$59 \pm 11^{+7}_{-10} \pm 8$

- Improvement in more central regions.

The Effective Photonuclear Cross Section

- The forward scattering amplitude is given by

$$\mathrm{Im}\,\mathscr{A}_{nuc}(x,t=0) = \int \frac{d^2 r dz}{4\pi} \left(\psi_V^* \psi_\gamma\right)_T \sigma_{\mathrm{dip}}^{\mathrm{nucleus}}(x,r)$$

where

$$\sigma_{\mathrm{dip}}^{\mathrm{nucleus}}(x,r) = 2\int d^2 b' \left\{1 - \exp\left[-\frac{1}{2} T_A(b')\sigma_{\mathrm{dip}}^{\mathrm{proton}}(x,r)\right]\right\}$$

- For consistency with the construction of $N^{eff}(\omega,b)$, restrict $\sigma_{dip}^{nucleus}(x,r)$:

$$\sigma_{\mathrm{dip}}^{\mathrm{nucleus}}(x,r) = 2\int d^2 b_2 \Theta(b_1 - R_A)\left\{1 - \exp\left[-\frac{1}{2} T_A(b_2)\sigma_{\mathrm{dip}}^{\mathrm{proton}}(x,r)\right]\right\} \quad (8)$$

  - $b_1^2 = b^2 + b_2^2 + 2bb_2\cos(\alpha)$.

Scenario 3

- In the scenario 3, we consider
  - Effective photon flux (Eq. (7));
  - Effective Photonuclear cross section (Eq. (8)).
- Comparing with ALICE data,

Average Rapidity Distribution: $2.5 < y < 4.0$

GBW / CGC	$d\sigma^{\text{theo}}_{J/\psi}/dy$ [μb]	$d\sigma^{\text{exp}}_{J/\psi}/dy$ [μb]
30%-50%	134 / 85	$73 \pm 44^{+26}_{-27} \pm 10$
50%-70%	145 / 91	$58 \pm 16^{+8}_{-10} \pm 8$
70%-90%	138 / 87	$59 \pm 11^{+7}_{-10} \pm 8$

- Better agreement for CGC model.

$V(J/\psi, \psi(2S), Y(1S), Y(2S), Y(3S))$ at $\sqrt{s} = 5.5$ TeV

GBW/CGC	30%-50%	50%-70%	70%-90%
J/ψ [μb]	**S1:** 923.75/585.61 **S2:** 612.73/388.41 **S3:** 349.63/222.14	**S1:** 509.82/323.14 **S2:** 486.28/308.23 **S3:** 387.92/246.78	**S1:** 343.08/217.42 **S2:** 407.51/258.30 **S3:** 381.38/242.21
$\psi(2S)$ [μb]	**S1:** 146.32/77.31 **S2:** 94.96/50.13 **S3:** 54.39/28.82	**S1:** 76.98/40.60 **S2:** 74.40/39.26 **S3:** 59.73/31.71	**S1:** 49.86/26.25 **S2:** 61.55/32.45 **S3:** 57.81/30.59
$\Upsilon(1S)$ [nb]	**S1:** 1034.66/510.45 **S2:** 619.27/304.48 **S3:** 360.19/175.44	**S1:** 416.83/203.95 **S2:** 460.52/225.90 **S3:** 375.12/183.04	**S1:** 221.51/107.17 **S2:** 361.11/176.67 **S3:** 340.93/166.96
$\Upsilon(2S)$ [nb]	**S1:** 197.28/95.07 **S2:** 117.28/56.28 **S3:** 67.66/32.49	**S1:** 77.08/36.75 **S2:** 86.77/41.52 **S3:** 70.56/33.80	**S1:** 39.96/18.77 **S2:** 67.67/32.27 **S3:** 64.02/30.54
$\Upsilon(3S)$ [nb]	**S1:** 95.60/46.46 **S2:** 56.67/27.41 **S3:** 32.71/15.83	**S1:** 36.81/17.67 **S2:** 41.84/20.17 **S3:** 34.05/16.43	**S1:** 18.86/8.90 **S2:** 32.55/15.63 **S3:** 30.80/14.80

Table: Average rapidity distribution in the range $2.5 < y < 4.0$ for the mesons $V(J/\psi, \psi(2S), Y(1S), Y(2S), Y(3S))$ considering the models GBW (left) and CGC (right) for the scenarios 1, 2 e 3, labeled by S1, S2 e S3, respectively.

Nuclear Modification Factor - R_{AA}

$$R_{AA}^{hJ/\psi} = \frac{N_{AA}^{hJ/\psi} + N_{AA}^{\text{excess}J/\psi}}{BR_{J/\psi\to l^+l^-}\cdot N_{events}\cdot (A\times\varepsilon)_{AA}^{J/\psi}\cdot\langle T_{AA}\rangle\cdot\sigma_{pp}^{hJ/\psi}}, \tag{9}$$

- To relate $N_{AA}^{J/\psi}$ with $d\sigma/dy|_{2.5<y<4.0}$, one considers
  - $R_{AA}^{hJ/\psi}(p_T < 0.3\ \text{GeV/c}) = R_{AA}^{hJ/\psi}(1 < p_T < 8\ \text{GeV/c})$ [18];
  - $N_{AA}^{\text{excess}J/\psi} \sim 0.86\times 10^6\,\frac{d\sigma^{\gamma}_{J/\psi}}{dy}$
- This results in

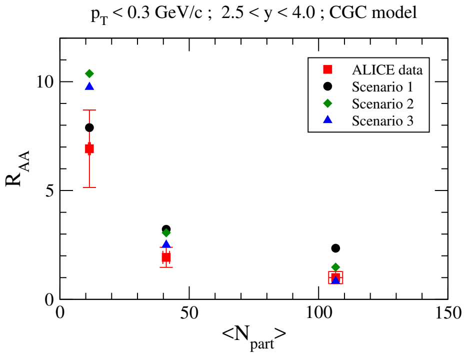
$$N_{AA}^{J/\psi} = \begin{cases} 1.96\times 10^6\,\frac{d\sigma^{\gamma}_{J/\psi}}{dy}, & 30\% - 50\% \\ 1.34\times 10^6\,\frac{d\sigma^{\gamma}_{J/\psi}}{dy}, & 50\% - 70\% \\ 0.96\times 10^6\,\frac{d\sigma^{\gamma}_{J/\psi}}{dy}, & 70\% - 90\% \end{cases} \tag{10}$$

[18] ALICE Collaboration, J. Adam et al., Phys. Rev. Lett. 116, 222301, (2016)

Our results for R_{AA}

- The scenario 1 agrees with the data only in the more peripheral region;

- For the scenarios 2 and 3, better results were achieved for the more central classes;



Summary

- In the ultraperipheral regime:
  - Review of the predictions for $\psi(1S,2S)$ and $Y(1S,2S)$ rapidity distribution, which are consistent with LHCb and ALICE data.
- In the peripheral regime:
  - Three scenarios were constructed by modifying the photon flux and the photonuclear cross section.
  - In general, the effective photon flux and the photonuclear cross section present better agreement with ALICE data;
  - For scenario 2, the rapidity distribution of the J/Ψ was estimated for the centrality classes: 30%-50%, 50%-70% and 70%-90%.
    (M. B. Gay Ducati and S. Martins, Phys. ReV. D 96, 056014, (2017)).
  - In the R_{AA}, the scenario 3 presents interesting results for more central collisions.
    (M. B. Gay Ducati and S. Martins, Phys. Rev. D97, 116013, (2018)).