# Double parton scattering in ultraperipheral collision

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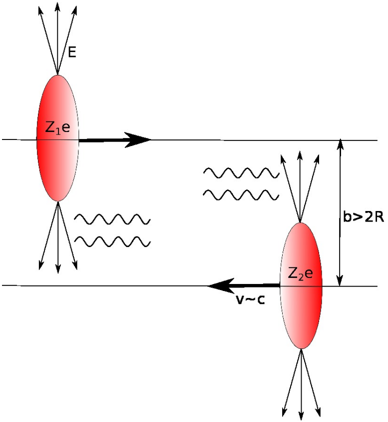
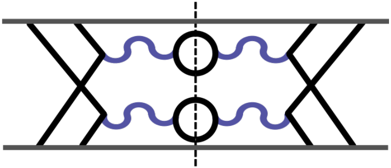
# Contents

# Ultraperipheral Collisions




- Interactions are between "quasi–real" photons;
- The interaction is predominantly electromagnetic;

**Double Drell-Yan production as a example of the DPS:**



**Pocket Formula**

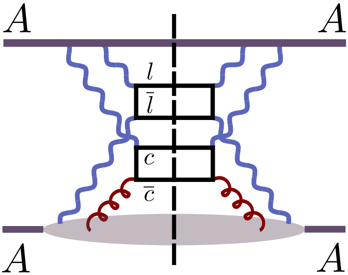
$$\sigma_{A,B}^{\text{DPS}} = \frac{m}{2}\frac{\sigma_A^{\text{SPS}}\sigma_B^{\text{SPS}}}{\sigma_{\text{eff}}}$$

- Independent interactions;
- Simultaneously interaction occurring in the same collision;

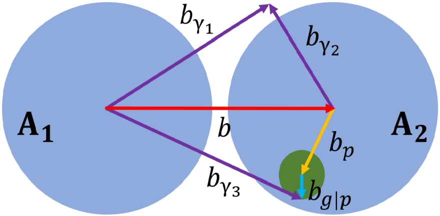
| | |
|---|---|
| $m = 1$ | Equal final states; |
| $m = 2$ | Different final states. |

# Production of $c\bar{c}l^+l^-$

E. Huayra, E. G. de Oliveira, R. Pasechnik and B. O. S., Phys. Rev. D **104**, (2021).




- Three photons and one gluons in the initial state;
- Probe the gluons distribution of the nucleus;
- Probe the photons distribution of the nucleus;
- The target nucleus which provide the gluon is allowed to break;




**General equation:**

$$\frac{d^5\sigma^{\rm DPS}_{AA\to AXc\bar{c}l\bar{l}}}{dy_c dy_{\bar{c}} dp^2_{c\perp}\, dYdM} = \int d^2\vec{b}\,\Theta(b-2R_A)\int d^2\vec{b}_{\gamma_1}\int d^2\vec{b}_{\gamma_3}\int d\xi_1 d\xi_2 d\xi_3 dx$$
$$\times N_{\gamma_1\gamma_3}(\xi_1,\vec{b}_{\gamma_1};\xi_3,\vec{b}_{\gamma_3})P^{\rm A}_{\gamma_2 g}(\xi_2,\vec{b}_{\gamma_2};x,\vec{b}_g)$$
$$\times \frac{d\hat{\sigma}_{\gamma g\to c\bar{c}}}{dp^2_{c\perp}}\int \frac{dp^2_{l\perp}}{M^2}\frac{d\hat{\sigma}_{\gamma\gamma\to l\bar{l}}}{dp^2_{l\perp}}\,.$$

# Correlation between parton distributions

**Photons distributions of the projectile nucleus:**

$$N_{\gamma_1\gamma_3}(\xi_1, \vec{b}_{\gamma_1}; \xi_2, \vec{b}_{\gamma_3}) = \Theta(b_{\gamma_1} - R_A)\Theta(b_{\gamma_3} - R_A)N_{\gamma_1}(\xi_1, \vec{b}_{\gamma_1})\, N_{\gamma_3}(\xi_3, \vec{b}_{\gamma_3}).$$

- This nucleus stays intact;
- Punctual parametrization of the electromagnetic charge;
- In the high energy limit, we do not considered correlations between the photons;

**Photon and gluon distribution of the target nucleus:**

$$P^{A}_{\gamma_2 g}(\xi_2, \vec{b}_{\gamma_2}; x, \vec{b}_g) = N_{\gamma_2}(\xi_2, \vec{b}_{\gamma_2})\, G^{A}_{g}(x, \vec{b}_g).$$

- This nucleus is allowed to break;
- Realistic parametrization of the electromagnetic charge;
- We do not considered correlations between the photon and the gluon;

**Thickness function of the two photons:**

$$T_{\gamma_1\gamma_2}(\xi_1, \xi_2, \vec{b}) = \frac{\int d^2\vec{b}_{\gamma_1}\Theta(b_{\gamma_1} - R_A)N_{\gamma_1}(\xi_1, \vec{b}_{\gamma_1})N_{\gamma_2}(\xi_2, \vec{b}_{\gamma_1} - \vec{b})}{\overline{N}_{\gamma_1}(\xi_1)\,\overline{N}_{\gamma_2}(\xi_2)}$$

**Thickness function of the two photons:**

$$T_{\gamma_3 g}(\xi_3, \vec{b}) = \frac{1}{\overline{N}_{\gamma_3}(\xi_3)} \int d^2\vec{b}_p \int d^2\vec{b}_{\gamma_3}\Theta(b_{\gamma_3} - R_A)\, N_{\gamma_3}(\xi_3, \vec{b}_{\gamma_3}) \\ \rho_{2\mathrm{D}}(\vec{b}_p) f_g(\vec{b}_{\gamma_3} - \vec{b}_p - \vec{b})\,.$$

**Effective cross section:**

$$\sigma_{\text{eff}}^{AA}(\xi_1, \xi_2, \xi_3)^{-1} = \int d^2\vec{b}\, T_{\gamma_1\gamma_2}(\xi_1, \xi_2, \vec{b})\, T_{g\gamma_3}(\xi_3, \vec{b})\Theta(b - 2R_A)\,.$$

# Pocket formula

$$\frac{d^3\Sigma_{\gamma g\to c\bar{c}}}{dy_c dy_{\bar{c}} dp_{c\perp}^2} = \xi_3 \overline{N}_{\gamma_3}(\xi_3) A x g(x) \frac{d\hat{\sigma}_{\gamma g\to c\bar{c}}}{dp_{c\perp}^2}\,,$$

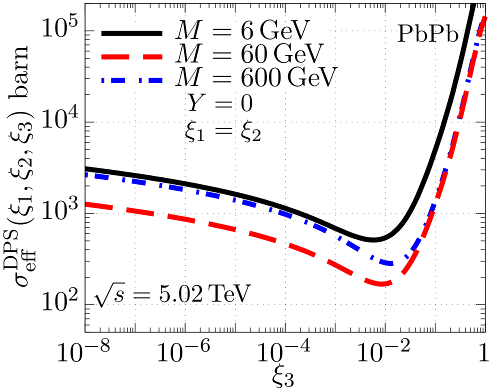
and

$$\frac{d^2\Sigma_{\gamma\gamma\to l\bar{l}}}{dY dM} = \xi_1 \overline{N}_{\gamma_1}(\xi_1) \xi_2 \overline{N}_{\gamma_2}(\xi_2) \int \frac{dp_{l\perp}^2}{M^2} \frac{d\hat{\sigma}_{\gamma\gamma\to l\bar{l}}}{dp_{l\perp}^2}\,.$$

**Pocket formula**

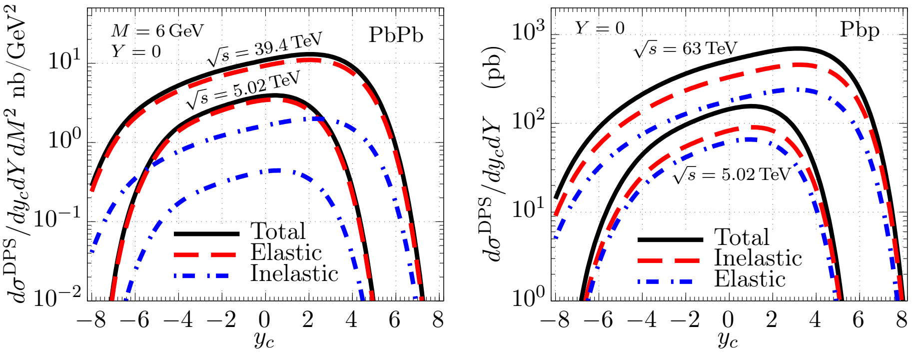
$$\frac{d^5\sigma^{\mathrm{DPS}}_{AA\to AXc\bar{c}l\bar{l}}}{dy_c dy_{\bar{c}} dp_{c\perp}^2\, dY dM} = \frac{1}{\sigma_{\mathrm{eff}}^{AA}(\xi_1,\xi_2,\xi_3)} \frac{d^3\Sigma_{\gamma g\to c\bar{c}}}{dy_c dy_{\bar{c}} dp_{c\perp}^2} \frac{d^2\Sigma_{\gamma\gamma\to l\bar{l}}}{dY dM}\,.$$

# Effective cross section



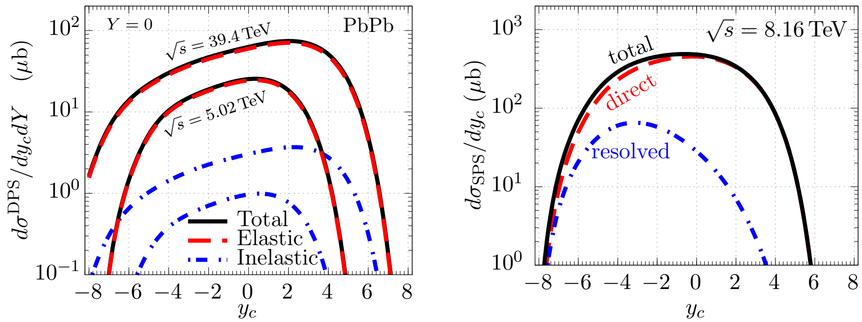

- The region of the smallest value is where the photon $\xi_3$ is found more easily inner the target nucleus;
- For small or too large $\xi_3$ the photon rarely overlaps with the gluons;

# DPS production of $c\bar{c}l^-l^+$ in $AA$ and $pA$ collisions



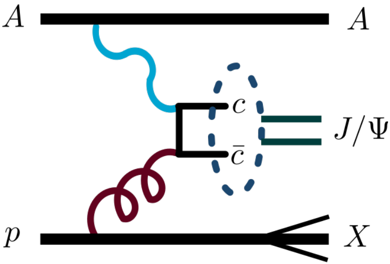

- Inelastic contribution is much smaller for the for the $AA$ collision;
- Cross section is orders of magnitude larger in $AA$ collision in contrast to the $pA$ collision;

# Cross section shape of the dimuon production in SPS



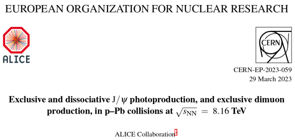

- The larger asymmetry in the DPS cross section is caused by the $\xi$ dependency in the $\sigma_{\text{eff}}$;
- DPS is not a simple rescale of the SPS;

# $J/\Psi$ production in SPS




- The measurements of the $J/\Psi$ are more accurate;
- In a parton level we can not consider a pomeron exchange;
- CEM in LO is the easiest way to evaluate the cross section;

# Experimental data


EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

ALICE

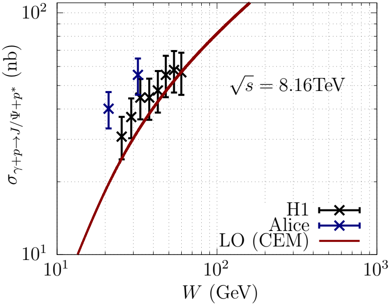
CERN

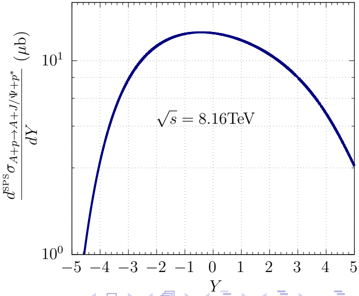
CERN-EP-2023-059
29 March 2023

**Exclusive and dissociative J/ψ photoproduction, and exclusive dimuon production, in p–Pb collisions at $\sqrt{s_{\rm NN}} = 8.16$ TeV**

ALICE Collaboration

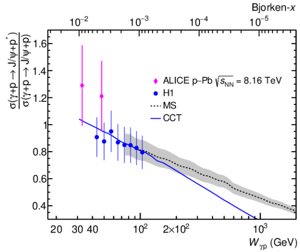
| Rapidity range | $\sigma^{\rm diss}_{J/\Psi}$ ($\mu$b) by Alice<br>$\sigma^{\rm diss}_{J/\Psi}$ ($\mu$b) by us |
|---|---|
| $(2.5, 4)$ | $10.43 \pm 0.57 \pm 1.39$<br>$11.22$ |



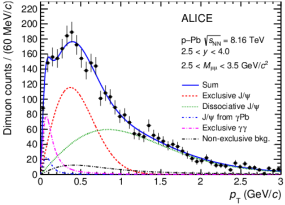



# di$J/\Psi$ production via DPS

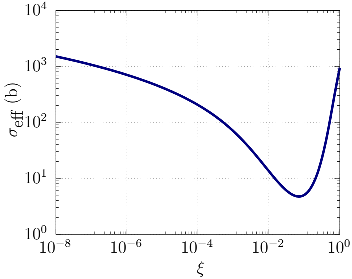
- Is the dissociative $J/\Psi$ predominant over the exclusive one?

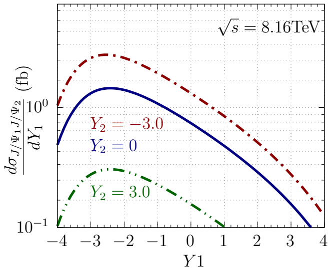



- Is it possible to distinguish the dissociative $J/\Psi$ from the exclusive one?



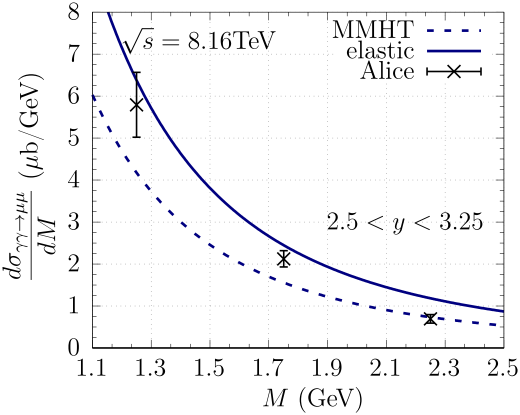
# Preliminary results of the di$J/\Psi$ cross section via DPS




- The result is smaller than we naively expected;
- Some improvements can be done;
- We can consider a dissociative $J/\Psi$ and an exclusive one in the final state;

# Perspective




- The next step is to build a effective cross section considering the production of a dimuon and a $J/\Psi$ via DPS;

- We have explored the poorly known **photons density inside the nucleus in UPCs** and the correlation with the gluons density;
- We have evaluated for the **first time** the $\sigma_{\text{eff}}$ with $3\gamma$ e $g$ in the initial state in UPC.
- We have found a **mensurable** $\sigma^{\text{DPS}}$ considering the LHC and FCC;
- With the new experimental results we are able to **test** our procedure to evaluate a DPS cross section in the UPCs and to make **new predictions**;
- Maybe our results can be seen as a experimental **motivation** to near future measurements involving **DPS in UPCs**;

# Thank you!

PPGFSC

CAPES

CNPq
Conselho Nacional de Desenvolvimento Científico e Tecnológico

fapesc
Fundação de Amparo à Pesquisa e Inovação do Estado de Santa Catarina

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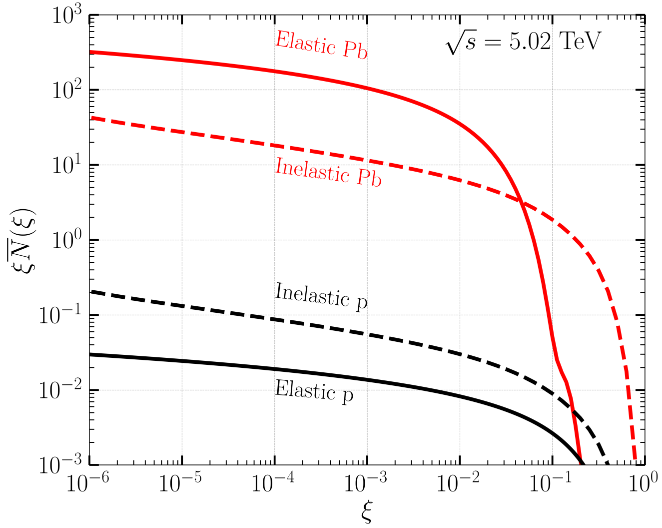
# Elastic and Inelastic photon flux in $p$ and $A$



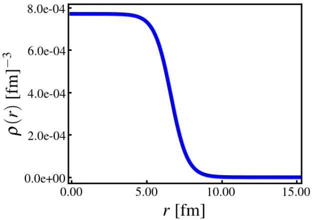
# Distribuição das cargas

**Parametrização de Wood–Saxon:**

$$\rho(r) = \frac{\rho_0}{1+\exp\left(\frac{r-c}{a}\right)},$$

$c = 6.63\text{fm}; \qquad a = 0.546 \text{ fm};$

$$\int \rho(\mathbf{r}) d^3\mathbf{r} = 1, \qquad \rho_0 = 7,71 \cdot 10^{-4} \text{ fm}^{-3}.$$



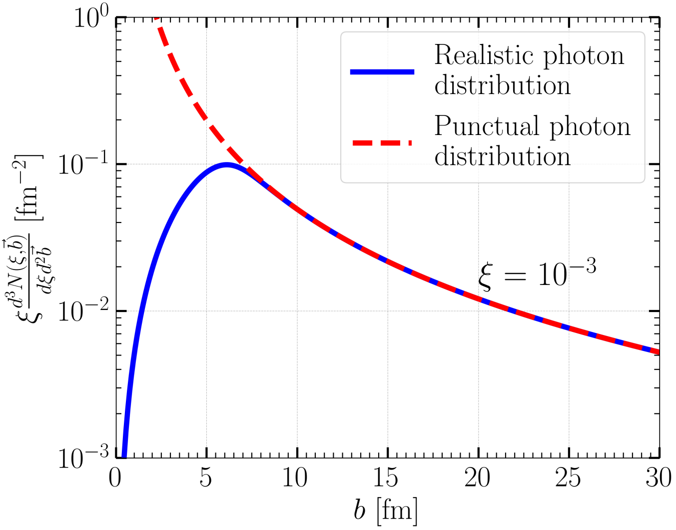

**Fator de forma:**

$$F(\mathbf{q}^2) = 4\pi \int_0^\infty dr \frac{\rho_0 r}{1+e^{(r-c)/a}} \frac{\sin(q\cdot r)}{q}.$$

**Fluxo de fótons do núcleo para fator de forma genérico:**

$$\omega \frac{dN}{d\omega d^2 b}(\omega, b) = \frac{Z^2\alpha}{\pi^2} \left| \int_0^\infty dq_t \frac{q_t^2 \mathrm{F}\left(q_t^2 + \frac{\omega^2}{\gamma^2}\right)}{q_t^2 + \frac{\omega^2}{\gamma^2}} \mathrm{J}_1(bq_t) \right|^2 .$$

# Fluxo de fótons do núcleo



# Distribuição de glúons no núcleo

**Distribuição de glúons no núcleon:**

$$G_g(x, \vec{b}) = g(x) f_g(\vec{b}),$$

$$f_g(\vec{b}) = \frac{\Lambda^2}{2\pi}\frac{\Lambda b}{2} K_1(\Lambda b), \qquad \int d^2\vec{b} f_g(\vec{b}) = 1\,,$$

com $\Lambda = 1.5\text{GeV}$.

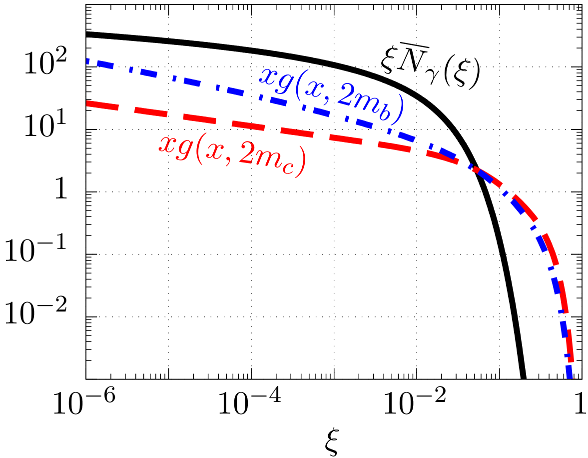
**Densidade de glúons no núcleo:**

$$\rho_{2D}(\vec{b}) \equiv \int dz\, \rho(\vec{r}) = \int dz\, \frac{\rho_0}{1 + e^{\frac{\sqrt{b^2+z^2}-c}{a}}},$$

**Distribuição de glúons no núcleo integrada no parâmetro de impacto do próton:**

$$G_g^{\mathrm{A}}(x, \vec{b}_g) = A g(x) \int d^2\vec{b}_p \delta^{(2)}(\vec{b}_g - \vec{b}_p - \vec{b}_{g|p}) \rho_{2D}(\vec{b}_p) f_g(\vec{b}_{g|p}).$$

# Distribuição de glúons




- Distribuição de glúons do próton em duas escalas — $2m_c$ e $2m_b$;
- Distribuição de fótons fora do núcleo;

**Seção de choque partônica para o dilépton:**

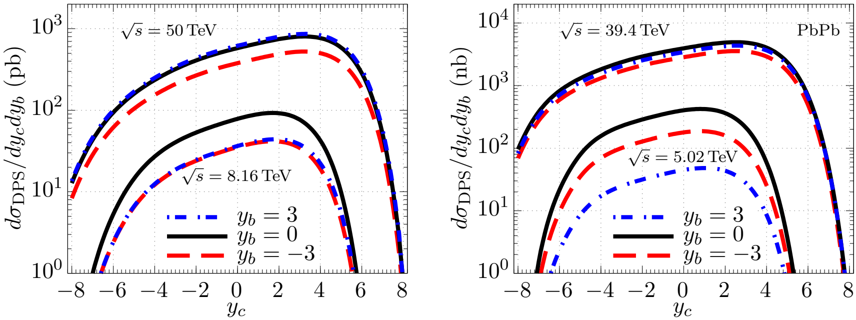
$$\frac{d^2\hat{\sigma}_{\gamma\gamma\to l\bar{l}}}{dYdM^2} = \frac{\xi_1\xi_2}{M^2}\int dp_t^2 \frac{d^2\hat{\sigma}_{\gamma\gamma\to l\bar{l}}}{dp_t^2}\delta\left(\xi_1 - \frac{M}{\sqrt{s}}e^{Y}\right)\left(\xi_2 - \frac{M}{\sqrt{s}}e^{-Y}\right).$$

**Seção de choque partônica para $c\bar{c}$:**

$$\frac{d^3\hat{\sigma}_{\gamma g\to c\bar{c}}}{dy_c dy_{\bar{c}} dp_{c\perp}^2} = \frac{1}{\sqrt{1-4(m_c^2+p_{c\perp}^2)/\hat{s}}}\frac{d\hat{\sigma}_{\gamma g\to c\bar{c}}}{d\hat{t}}\delta\left(y_c - \frac{1}{2}\ln\left(\frac{\xi\hat{u}}{x\hat{t}}\right)\right)$$
$$\times\ \delta\left(y_{\bar{c}} - \frac{1}{2}\ln\left(\frac{\xi\hat{t}}{x\hat{u}}\right)\right).$$

$$\xi_3, x = \frac{\sqrt{m_c^2+p_{c\perp}^2}}{\sqrt{s}}\left(e^{\pm y_c}+e^{\pm y_{\bar{c}}}\right).$$

# DPS production of $b\bar{b}c\bar{c}$ in $AA$ and $pA$ collisions




**Effective cross section evaluated for the first time in UPCs.**


E. Huayra, E. G. de Oliveira and R. Pasechnik, Eur. Phys. J. C **79**, 880 (2019).

E. Huayra, E. G. de Oliveira and R. Pasechnik, Eur. Phys. J. C **80**, 772 (2020).

**Exemplo de contaminação SPS para a produção de duplo Drell-Yan:**