PRODUCTION OF D^+D^- MOLECULES IN ULTRAPERIPHERAL $PbPb$ COLLISIONS

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OVERVIEW

Production of D^+D^- molecules in ultraperipheral $PbPb$ collisions

We study the production of exotic charmonium states in photoinduced processes. We are interested in the production of the bound state D^+D^- through ultraperipheral collisions. [1]

[1] This work was presented at the international workshop "Hadron spectroscopy and the new unexpected resonances" funded by the Wilhelm and Else Heraeus Foundation — held from September 22 to 25, 2024.

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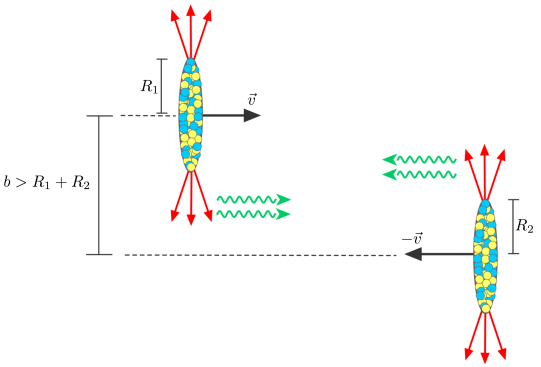

Figure 1: Equivalent photon approximation.

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$$\sigma_{AA}(\sqrt{s}) = \int \sigma_{\gamma\gamma\to(D^+D^-)}(\omega_1,\omega_2)\, N(\omega_1,b_1)\, N(\omega_2,b_2)\, S^2_{abs}(b)\, \frac{W}{2} \mathrm{d}^2b_1\, \mathrm{d}^2b_2 \mathrm{d}W \mathrm{d}Y \qquad (1)$$

- Photoproduction cross section
- Equivalent photon flux
- Absorption effect

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- **Photoproduction cross section**[2]
- Equivalent photon flux
- Absorption effect

$$\sigma_{\gamma\gamma\to(D^+D^-)}(\omega_1,\omega_2) = \frac{32\pi^3\alpha^2F^4(-m_D^2)|\psi(0)|^2}{M_{(D^+D^-)}} \frac{1}{\omega_1\omega_2}\delta(4\omega_1\omega_2 - E^2_{(D^+D^-)})$$

[2] F.C. Sobrinho, L.M. Abreu, C.A. Bertulani and F.S. Navarra, Phys.Rev. D **110**, 034037 (2024)

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- Photoproduction cross section
- **Equivalent photon flux**
- Absorption effect

$$N(\omega,b) = \frac{Z^2\alpha_{em}}{\pi^2\omega b^2}\left[\int_0^\infty u^2 J_1(u) F\left(\sqrt{\frac{u^2+(b\omega/\gamma)^2}{b^2}}\right)\frac{1}{u^2+(b\omega/\gamma)^2}\, du\right]^2$$

$$\sigma_{AA}(\sqrt{s}) = \int \sigma_{\gamma\gamma\to(D^+D^-)}(\omega_1,\omega_2)\, N(\omega_1,b_1)\, N(\omega_2,b_2)\, S^2_{abs}(b)\, \frac{W}{2} \mathrm{d}^2b_1\, \mathrm{d}^2b_2 \mathrm{d}W \mathrm{d}Y \qquad (1)$$

- Photoproduction cross section
- Equivalent photon flux
- **Absorption effect**

$$S^2_{abs}(b) = \begin{cases} 1 \to \text{without absorption} \\ \Theta(|b| - R_1 - R_2) = \Theta(|b_1 - b_2| - R_1 - R_2) \\ 1 - P_H(b) \quad \text{with} \quad P_H(b) = 1 - \exp\left[-\sigma_{nn} \int \mathrm{d}^2r\, T_A(r) T_A(r-b)\right] \end{cases}$$

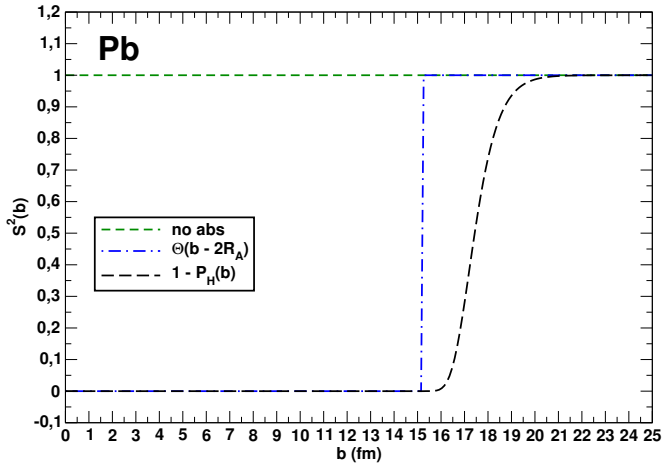

Figure 2: Impact parameter dependence of the absorptive factor.

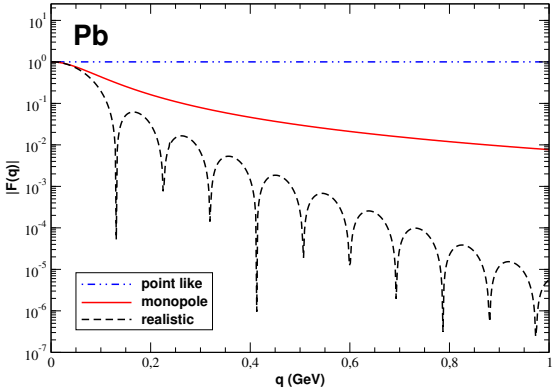

Figure 3: The form factor as a function of transferred momentum of the Pb nucleus.

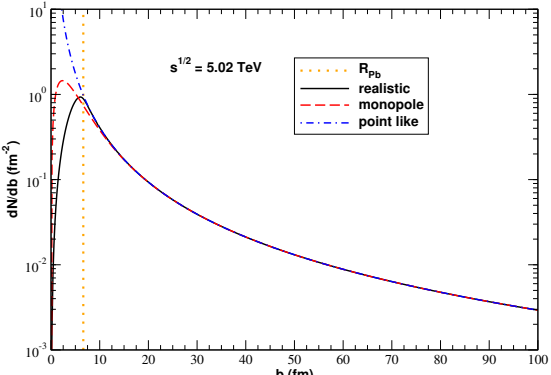

Figure 4: Equivalent photon flux as a function of distance from nucleus center for different form factors.

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RESULTS

OVERVIEW

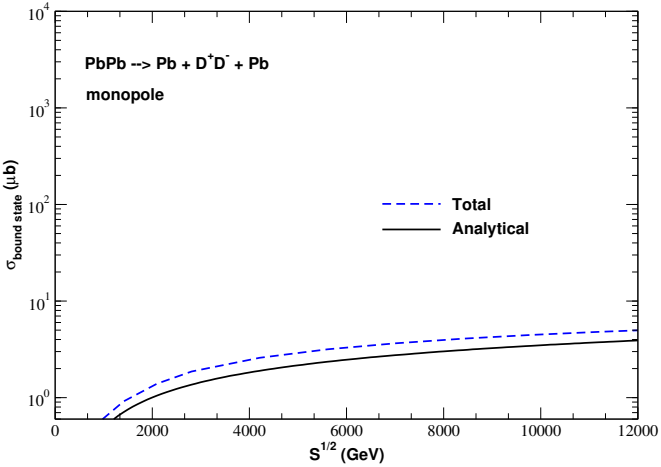

Figure 5: Energy dependence of the total cross section for the D^+D^- bound state photoproduction.

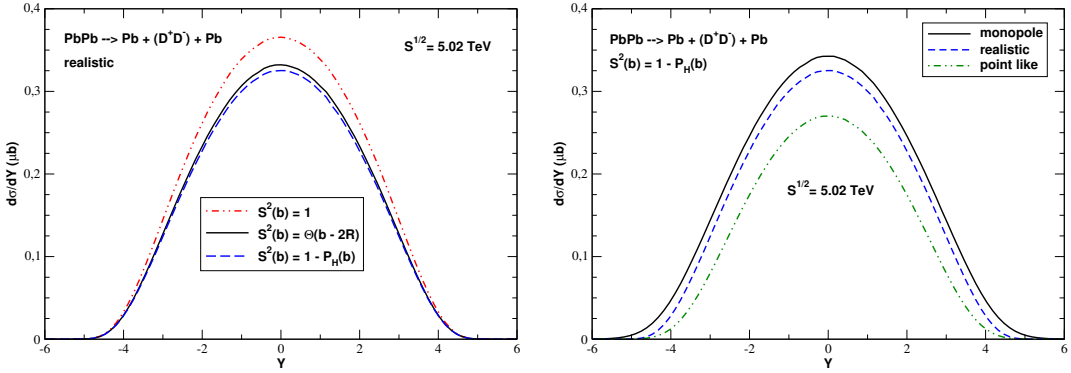

Figure 6: Rapidity distribution D^+D^- bound state.

	σ (point-like)	σ (monopole)	σ (realistic)
$S^2_{abs}(b) = 1 \rightarrow$ no abs	1.40	2.17	1.92
$S^2_{abs}(b) = \Theta(\|b\| - 2R)$	1.32	1.91	1.72
$S^2_{abs}(b) = 1 - P_H(b)$	1.30	1.86	1.68

Table 1: Total cross sections for $D\bar{D}$ production in ultraperipheral $PbPb$ collisions with $\sqrt{s} = 5.02$ TeV (in μb).

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The magnitude of the cross section, is comparable to the value obtained in the literature $(3\,\mu\text{b})$ when considering the contribution of all the diagrams[2].

[2] F.C. Sobrinho, L.M. Abreu, C.A. Bertulani and F.S. Navarra, Phys.Rev. D **110**, 034037 (2024)

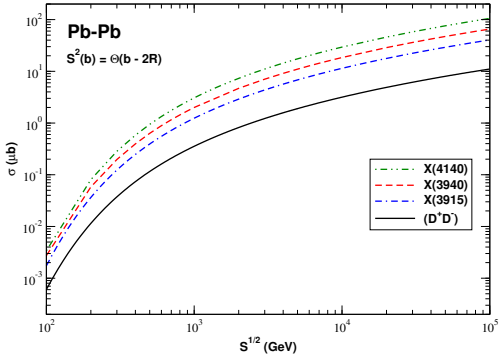


Figure 7: Total cross section for the exotic mesons photoproduction as a function of the energy.

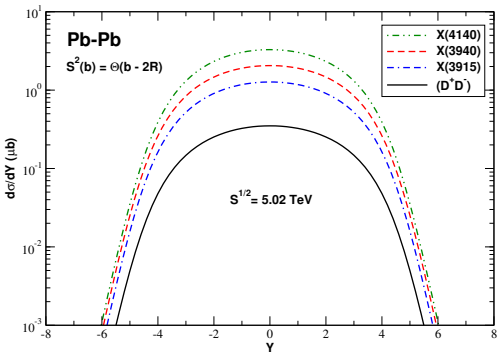
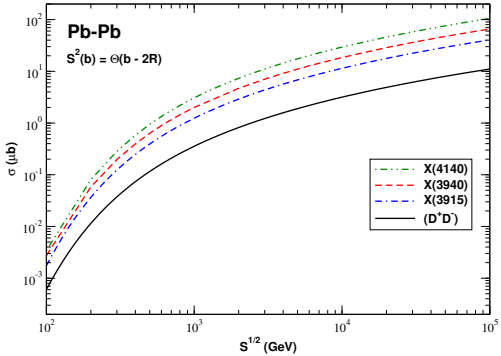


Figure 8: Rapidity distribution of the exotic mesons produced in $\gamma\gamma$ interactions.



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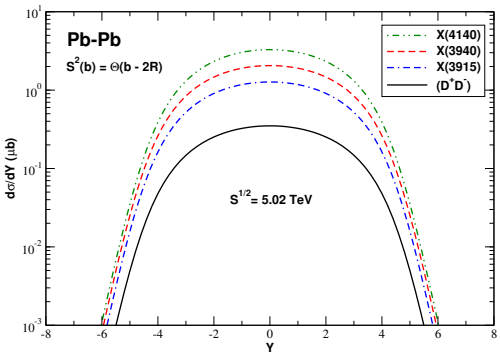

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	$X(3915),\ 0^{++}$	$X(3940),\ 0^{++}$	$X(4140),\ 0^{++}$
$\sigma\ (\mu b)$	6.83	11.06	17.48

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CONCLUSIONS

OVERVIEW

Conclusions

- We have calculated the production of heavy meson molecules in UPC.
- Choosing a realistic absorption effect has little impact.
- The predictions are sensitive to the level of precision used to calculate the photon flux.
- The analytical expression for the cross section $\gamma\gamma \to D^+D^-$ is a good approximation.
- Production of these states by $\gamma\gamma$ interactions in future electron-ion colliders.

THANK YOU FOR YOUR ATTENTION!