Double parton scattering in ultraperipheral collision with vector meson production

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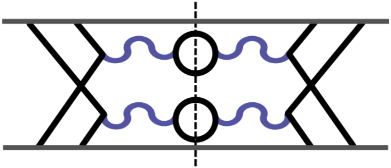
What is Double parton scattering?

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



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

Pocket Formula

$$\sigma^{DPS}_{A,B} = \frac{m}{2} \frac{\sigma^{SPS}_{A} \sigma^{SPS}_{B}}{\sigma_{eff}}$$

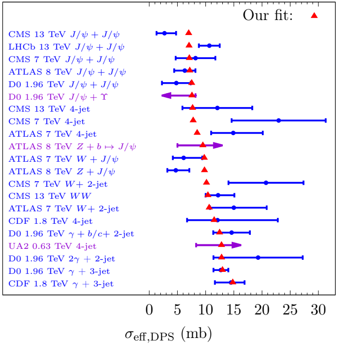
$m = 1$ Equal final states;

$m = 2$ Different final states.

First questions

- How to evaluate the σ_{eff}?
- Is it **universal** for every process?
- What **kind of collisions** we are talking about?

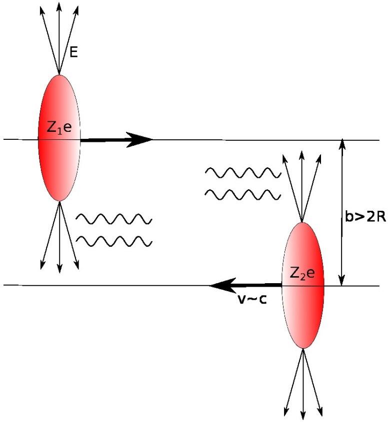
Experimental results for σ_{eff} in central collisions:



E. Huayra, J. V. C. Lovato and E. G. de Oliveira, JHEP **09**, 177 (2023).

But for Ultraperipheral Collisions?

What is Ultraperipheral Collisions?

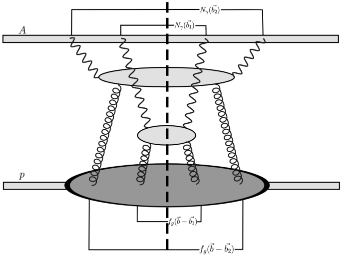


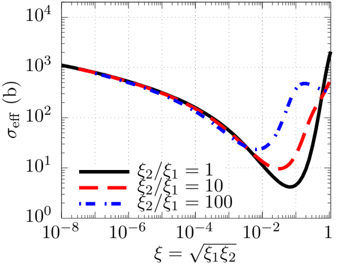
- Interactions are between "quasi–real" photons;
- The interaction is predominantly electromagnetic;

$2\gamma + 2g$ in the initial state

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

$c\bar{c}b\bar{b}$ DPS production:

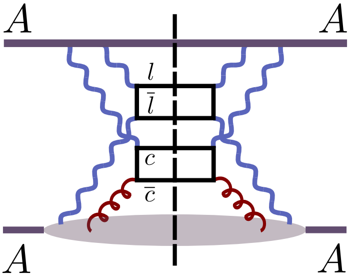




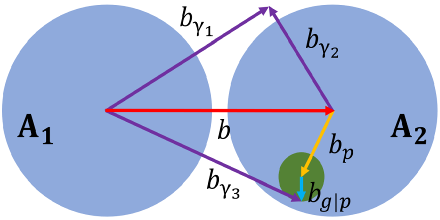
- The region of the smallest value is where the photon ξ is found more easily inner the target proton;
- The effective cross section shows a complex **dependence with the energy fraction** carried by the photon from the nucleus projectile;

$3\gamma + 1g$ in the initial state

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



- 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:

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

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;

Effective cross section

Overlap function of the two photons:

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

Overlap function of the photon and gluon:

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

Effective cross section:

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

Pocket formula

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

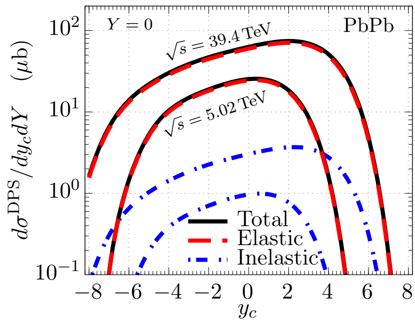
and

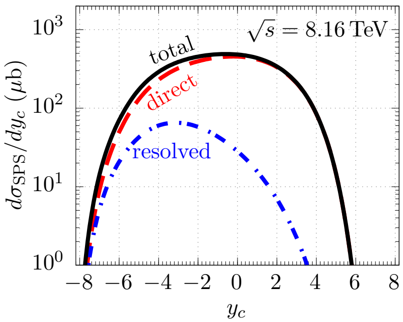
$$\frac{d^2\Sigma_{\gamma\gamma\to l\bar{l}}}{dY dM} = \xi_1 \overline{N}_{\gamma_1}(\xi_1) \xi_2 \overline{N}_{\gamma_2}(\xi_2) \int \frac{dp_{l\perp}^2}{M^2} \frac{d\hat{\sigma}_{\gamma\gamma\to l\bar{l}}}{dp_{l\perp}^2} \,.$$

Pocket formula

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

Cross section shape of the dimuon production in SPS





- The larger asymmetry in the DPS cross section is caused by the ξ dependency in the σ_{eff};
- DPS is not a simple rescale of the SPS;

DPS in UPC with J/Ψ production and proton dissociation

First considerations:

- In our formalism we need a parton level cross section;
- Once the gluon comes from the proton, this one must dissociates;

Experimental motivations:

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

ALICE

CERN-EP-2023-059
29 March 2023

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

ALICE Collaboration[*]

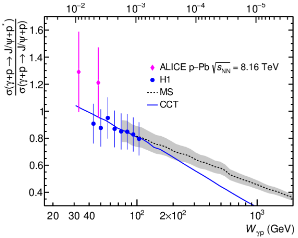
Two proposals

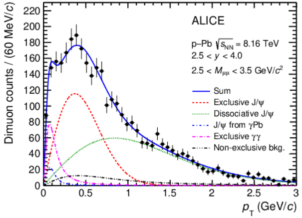
$p + A \rightarrow J/\Psi + \mu^{-}\mu^{+} + p^{*} + A$

- $3\gamma + 1g$ in the initial state;
- Is it possible to distinguish elastic muons from inelastic one?

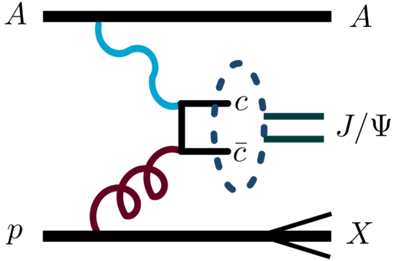
$p + A \rightarrow J/\Psi + J/\Psi + p^{*} + A$

- $2\gamma + 2g$ in the initial state;
- Is it possible to distinguish the dissociative J/Ψ from the exclusive one?

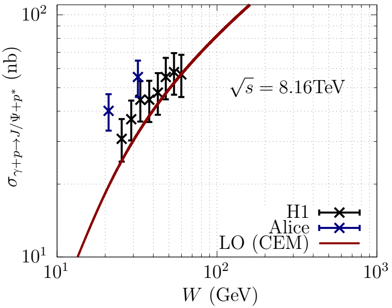


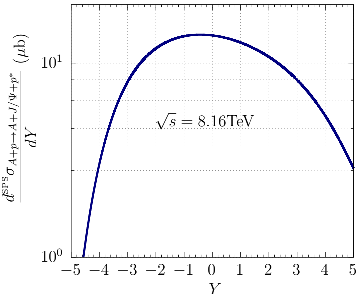


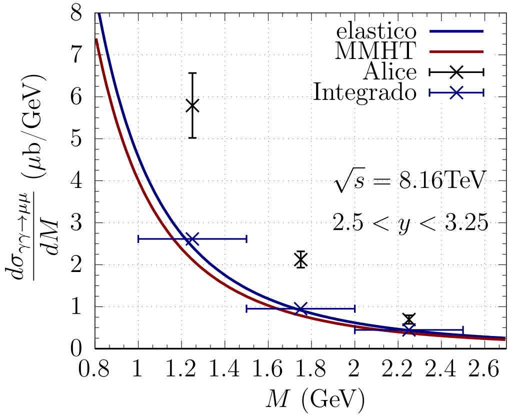
J/Ψ production in SPS



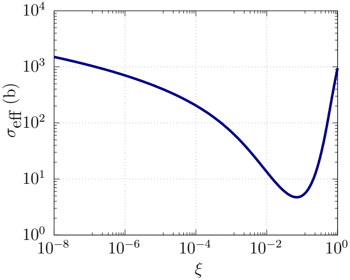
Rapidity range	$\sigma^{\text{diss}}_{J/\Psi}$ (μb) by Alice $\sigma^{\text{diss}}_{J/\Psi}$ (μb) by us
$(2.5, 4)$	$10.43 \pm 0.57 \pm 1.39$ 11.22

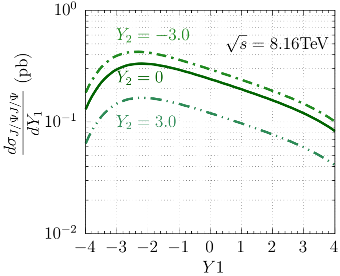






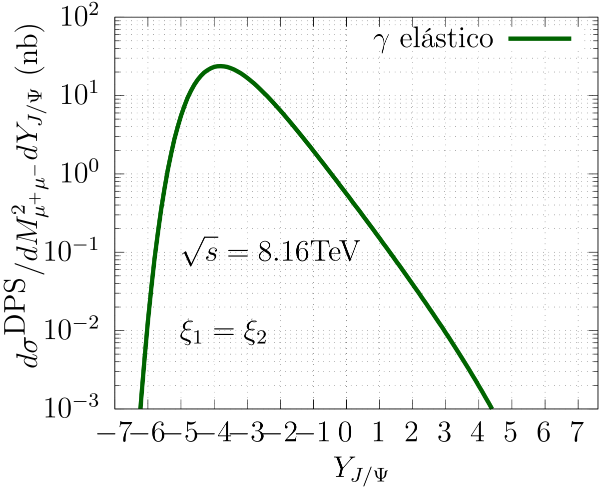
- The elastic contribution estimated by photon PDF agrees with our results;
- Bought disagrees considerable with the Alice results;





- We can consider a dissociative J/Ψ and an exclusive one in the final state;

Preliminary results of the J/Ψ+dimuon cross section via DPS



Conclusions

- 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 σ_{eff} with 3γ e g in the initial state in UPC.
- We have found a **mensurable** σ^{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**;
- Considering the vector meson production we are able to investigate the dissociative proton;
- Maybe our results can be seen as a experimental **motivation** to near future measurements involving **DPS in UPCs**;

Thank you!

PPGFSC

CAPES

CNPq
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Thanks the organize comitee for the support!

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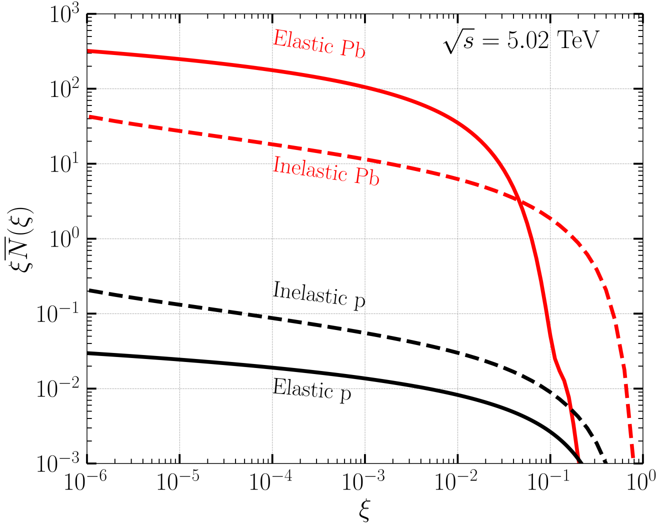
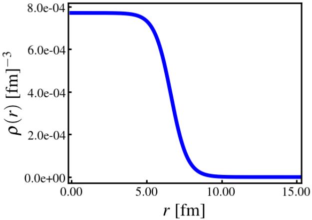
Elastic and Inelastic photon flux in p and A



Parametrização de Wood–Saxon:

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



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

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

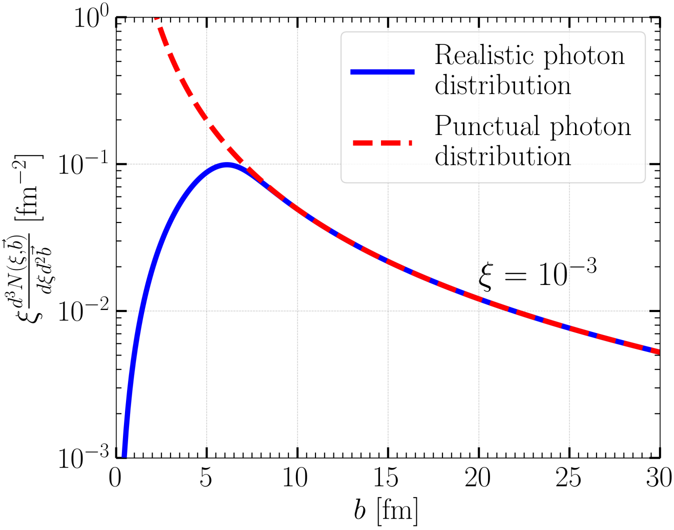
Fator de forma:

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

Fluxo de fótons do núcleo para fator de forma genérico:

$$\omega \frac{dN}{d\omega d^2 b}(\omega, b) = \frac{Z^2\alpha}{\pi^2} \left| \int_0^\infty dq_t \frac{q_t^2 F\left(q_t^2 + \frac{\omega^2}{\gamma^2}\right)}{q_t^2 + \frac{\omega^2}{\gamma^2}} J_1(bq_t) \right|^2.$$

Fluxo de fótons do núcleo



Distribuição de glúons no núcleo

Distribuição de glúons no núcleon:

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

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

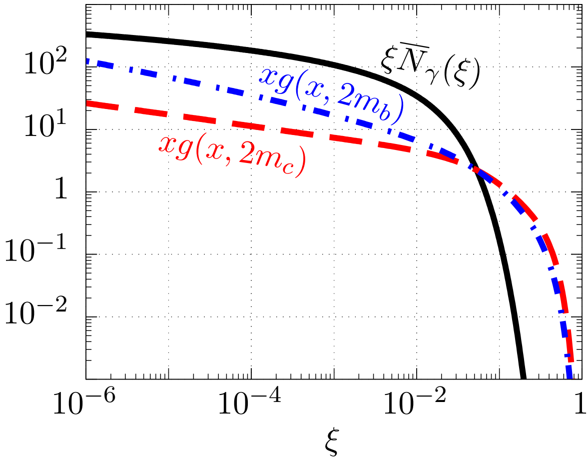
com $\Lambda = 1.5$GeV.

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

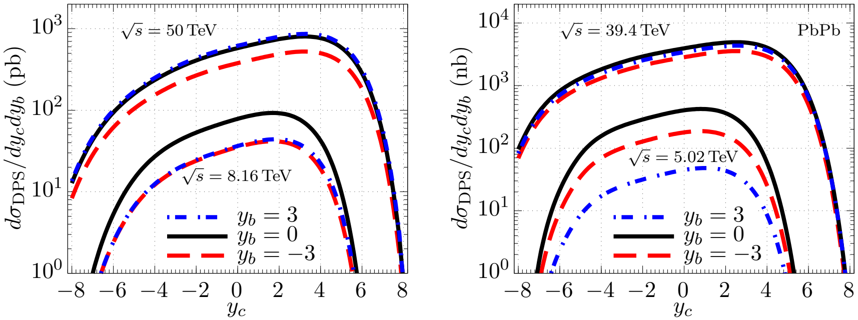
Seção de choque partônica para o dilépton:

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

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

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

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



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: