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Double Vector Meson in photon - induced interactions at the LHC

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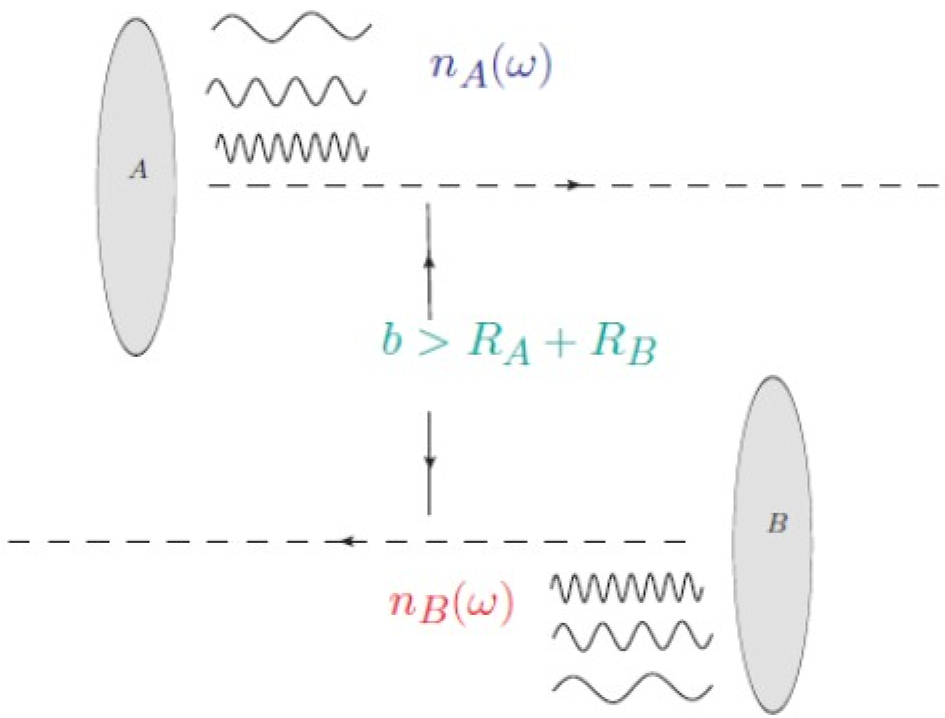
LHC = Photon collider



1. γh Processes: $\sigma(h_1 h_2 \to X) = n_h(\omega) \otimes \sigma^{\gamma h \to X}(W_{\gamma h})$
2. $\gamma\gamma$ Processes: $\sigma(h_1 h_2 \to X) = n_1(\omega) \otimes n_2(\omega) \otimes \sigma^{\gamma\gamma \to X}(W_{\gamma\gamma})$

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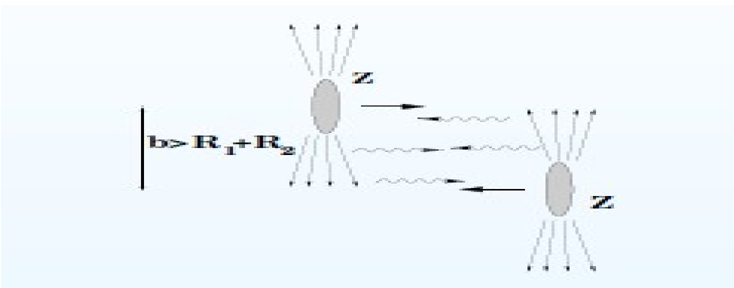

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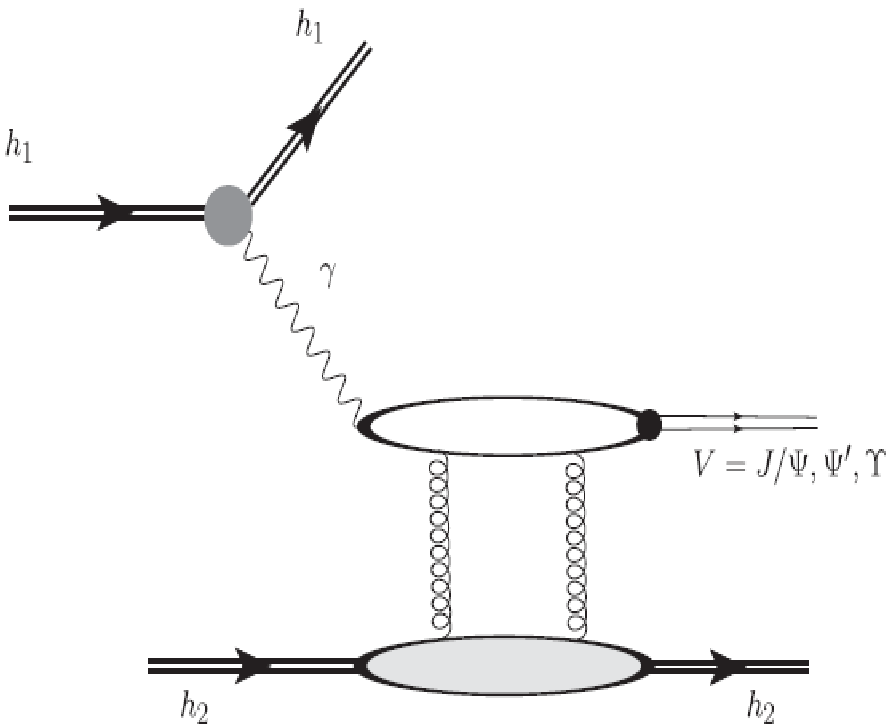
Center of mass energies

LHC	pp	$W_{\gamma p} \lesssim 8390$ GeV	$W_{\gamma\gamma} \lesssim 4504$ GeV
LHC	$pPb(Ar)$	$W_{\gamma A} \lesssim 1500\,(2130)$ GeV	$W_{\gamma\gamma} \lesssim 260\,(480)$ GeV
LHC	$PbPb$	$W_{\gamma A} \lesssim 950$ GeV	$W_{\gamma\gamma} \lesssim 160$ GeV
HERA	ep	$W_{\gamma p} \lesssim 200$ GeV	–

Photoproduction in pp, pA and AA collisions at LHC probes a unexplorated regime of photon – hadron center of mass energies.

Probing the QCD dynamics at high energies in photon - induced interactions at the LHC

Exclusive vector meson production in photon-hadron interactions:



* Sensitive to the description of the QCD dynamics;

* Sensitive to the description of the spatial distribution of the gluons in the target;

$$\frac{d\sigma\,[h_1 + h_2 \to h_1 \otimes V \otimes h_2]}{d^2b dy} = \left[\omega N_{h_1}(\omega, b)\,\sigma_{\gamma h_2 \to V \otimes h_2}(\omega)\right]_{\omega_L} + \left[\omega N_{h_2}(\omega, b)\,\sigma_{\gamma h_1 \to V \otimes h_1}(\omega)\right]_{\omega_R}$$

[a] VPG, Bertulani, PRC65, 054905 (2002)

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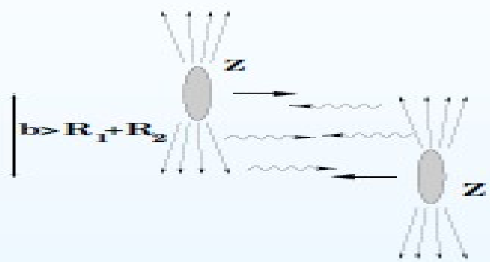

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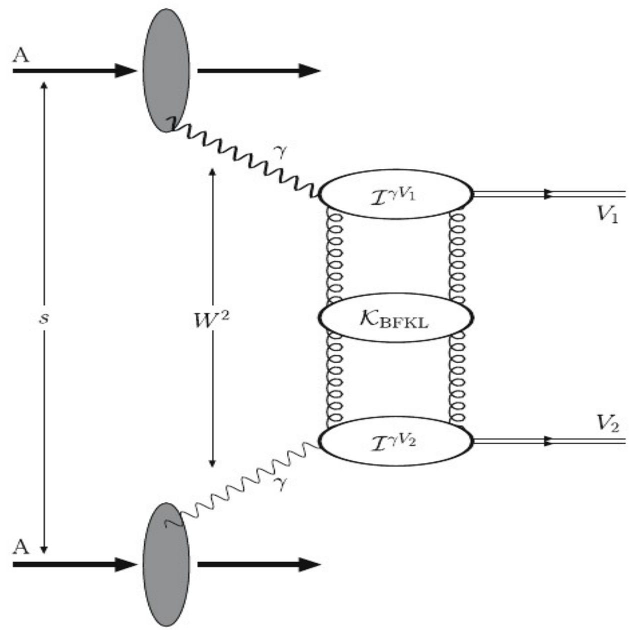
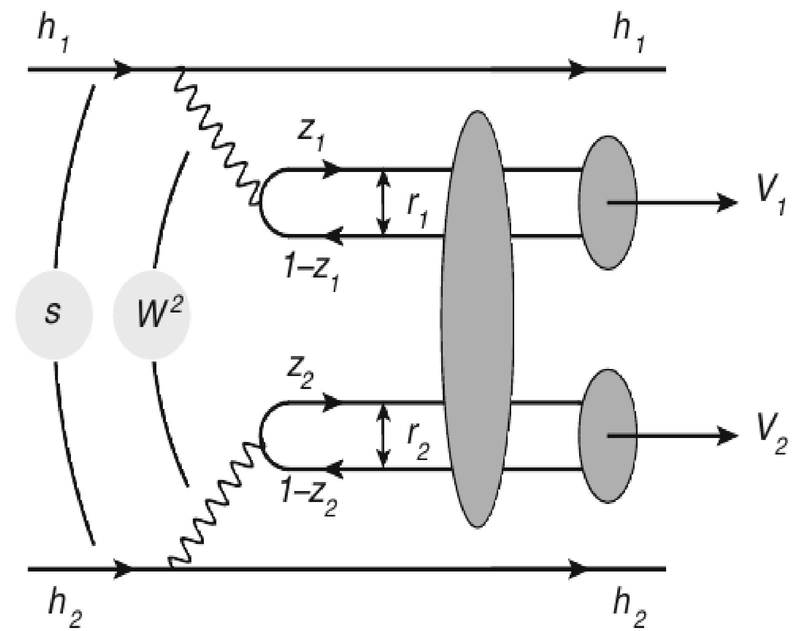
LHC allow us to probe the particle production by photon - photon interactions in a energy range unexplored by LEP and higher than that proposed for the ILC and FCC e+e-.

Probing the QCD dynamics at high energies in photon - induced interactions at the LHC

Double vector meson in photon - photon interactions:





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THE EUROPEAN PHYSICAL JOURNAL C

The QCD pomeron in ultraperipheral heavy ion collisions: V. Double vector meson production in the BFKL approach

V.P. Gonçalves[1], M.V.T. Machado[2,3,a], W.K. Sauter[3]

Eur. Phys. J. C (2016) 76:103
DOI 10.1140/epjc/s10052-016-3931-1
THE EUROPEAN PHYSICAL JOURNAL C
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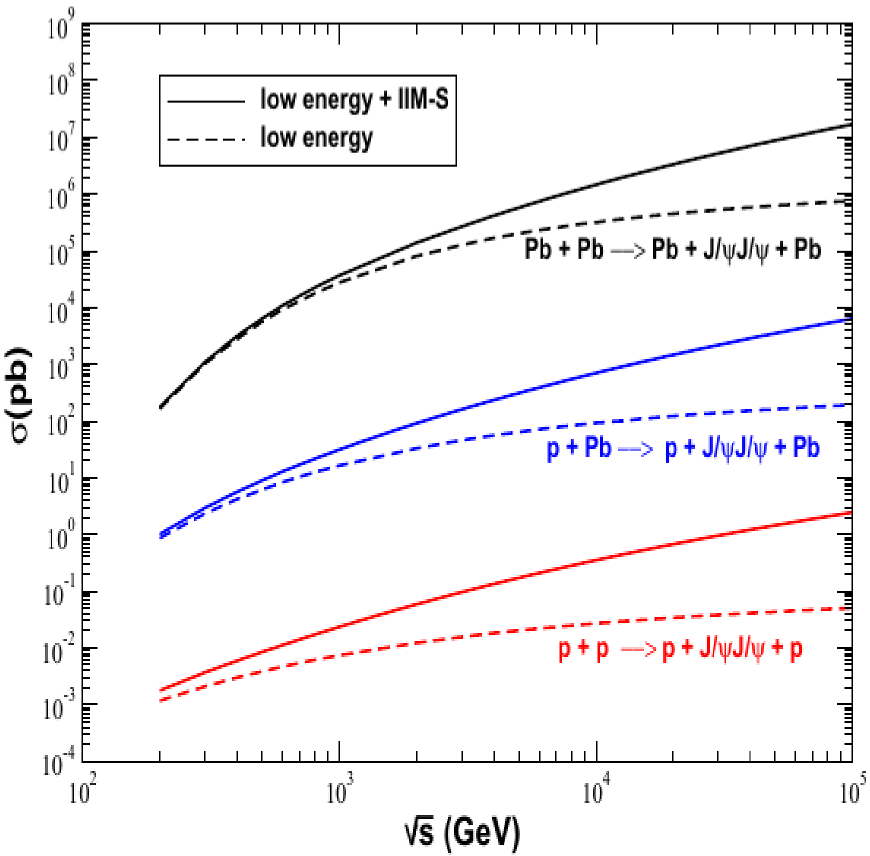
Regular Article - Theoretical Physics

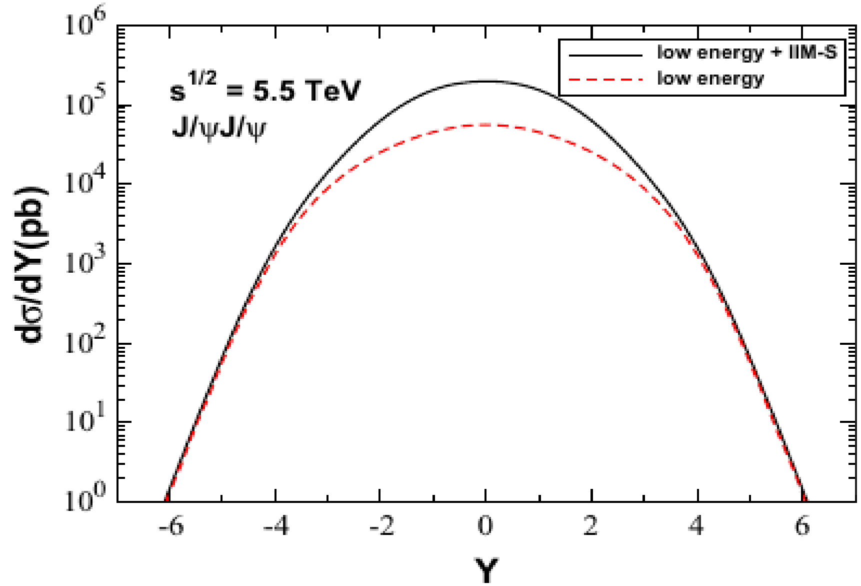
Double vector meson production in $\gamma\gamma$ interactions at hadronic colliders

V. P. Gonçalves[1,2,a], B. D. Moreira[3], F. S. Navarra[3]

Probing the QCD dynamics at high energies in photon - induced interactions at the LHC

Double vector meson in photon - photon interactions:



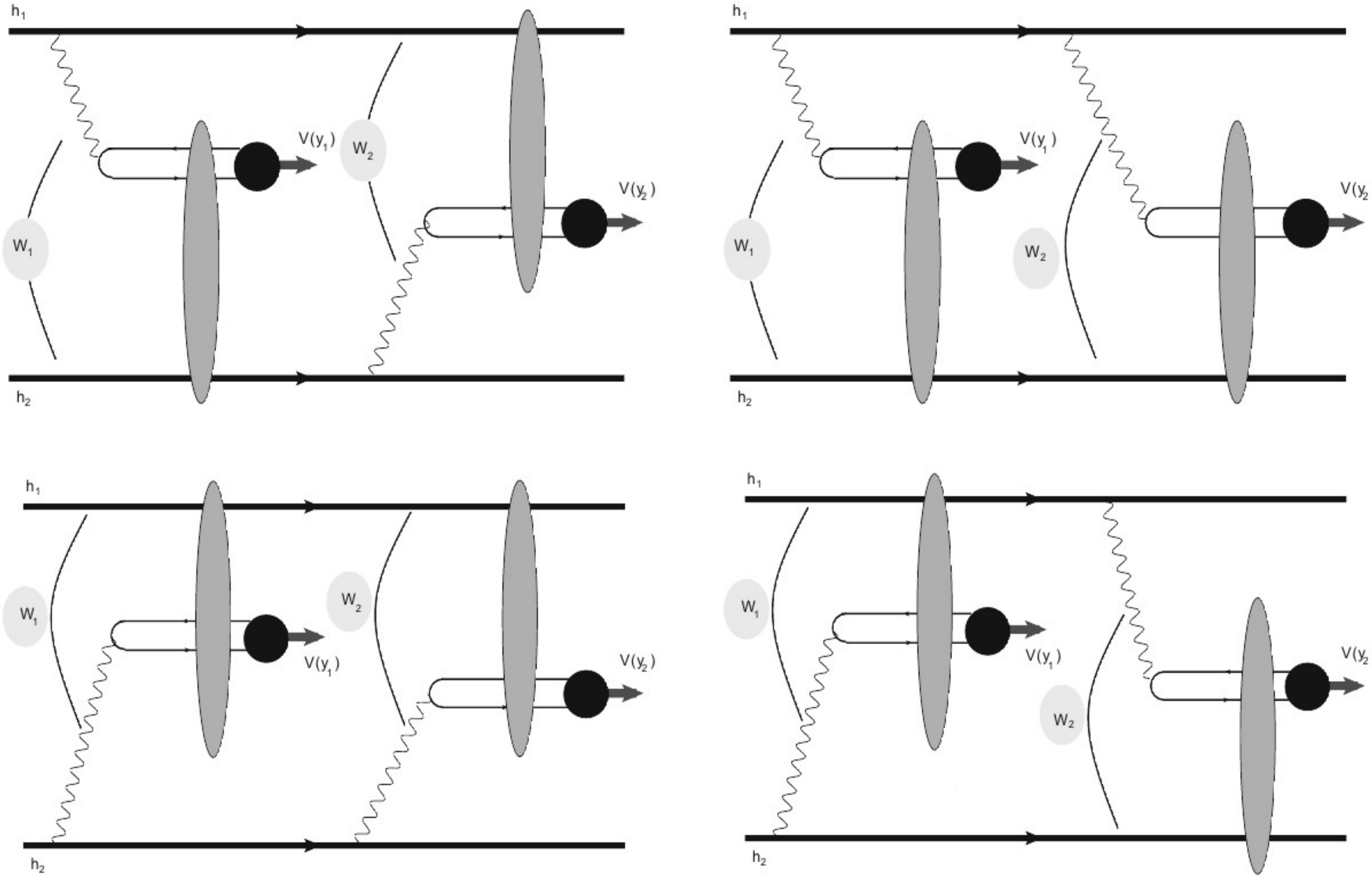


	Low energy	Low energy + IIM-S
PbPb ($\sqrt{s} = 500$ GeV)	0.33×10^6	0.33×10^6
PbPb ($\sqrt{s} = 2.76$ TeV)	1.27×10^6	1.39×10^6
PbPb ($\sqrt{s} = 5.5$ TeV)	1.73×10^6	1.97×10^6
PbPb ($\sqrt{s} = 39$ TeV)	3.11×10^6	4.35×10^6

(*) Values em nb.

In this talk:

Double vector meson in photon - hadron interactions via the **DOUBLE SCATTERING MECHANISM (DSM):**



(*) VPG, Moreira, Navarra, EPJC76, 388 (2016) and Azevedo, VPG, Moreira, arXiv:2210.04861 [hep-ph]

Basic Ideas:

* Because the cross sections for the vector meson photoproduction and the photon fluxes are so large, the probability of having multiple interactions in a single nucleus-nucleus encounter is nonnegligible;

* First estimates performed by Klein/Nystrand (1999) and Kluzek-Kawenda/Szczurek (2013) demonstrated that the associated cross sections for the double vector meson production are large and that a experimental analysis could be feasible;

* Neglecting correlations, the pair production probability can be expressed in terms of the single production probability, with the associated differential cross section being given by:

$$\boxed{\frac{\mathrm{d}^2\sigma_{h_1h_2\to h_1V_1V_2h_2}}{\mathrm{d}y_1\mathrm{d}y_2} = \mathcal{C}\int_{b_{\min}} \frac{\mathrm{d}\sigma\ [h_1+h_2\to h_1V_1h_2]}{\mathrm{d}^2b\mathrm{d}y_1} \times \frac{\mathrm{d}\sigma\ [h_1+h_2\to h_1V_2h_2]}{\mathrm{d}^2b\mathrm{d}y_2}\,\mathrm{d}^2b}$$

$\mathcal{C}$ is equal to 1 (1/2) for $V_1 \neq V_2$ ($V_1 = V_2$)

Main formulae:

$$\frac{d\sigma\,[PbPb \to Pb \otimes V \otimes Pb]}{d^2 b dy_V} = \omega N_{Pb}(\omega, b)\,\sigma_{\gamma Pb \to V \otimes Pb}\,(\omega)$$

One has that:

$$\sigma(\gamma Pb \to V Pb) = \int_{-\infty}^{0} \frac{d\sigma}{dt}\,dt = \frac{1}{16\pi}\int_{-\infty}^{0} |\mathcal{A}_T^{\gamma Pb \to V Pb}(x, \Delta)|^2\,dt$$

In the dipole picture, the scattering amplitude is given by

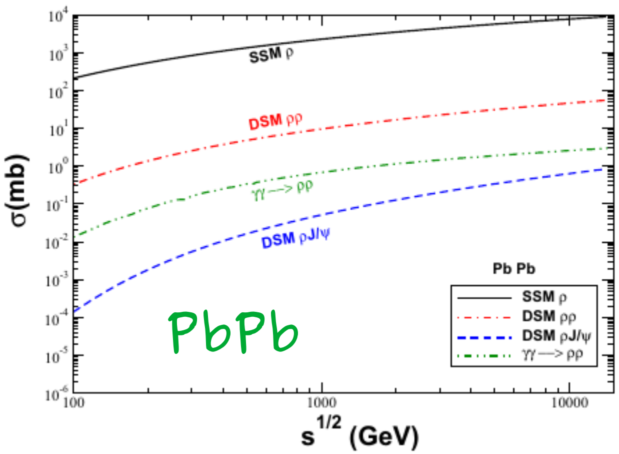
$$\mathcal{A}_T^{\gamma Pb \to V Pb}(x, \Delta) = i \int dz\, d^2\boldsymbol{r}\, d^2\boldsymbol{b}_A e^{-i[\boldsymbol{b}_A - (1-z)\boldsymbol{r}].\boldsymbol{\Delta}}\,(\Psi^{V*}\Psi)_T\; 2\mathcal{N}_{Pb}(x, \boldsymbol{r}, \boldsymbol{b}_A)$$

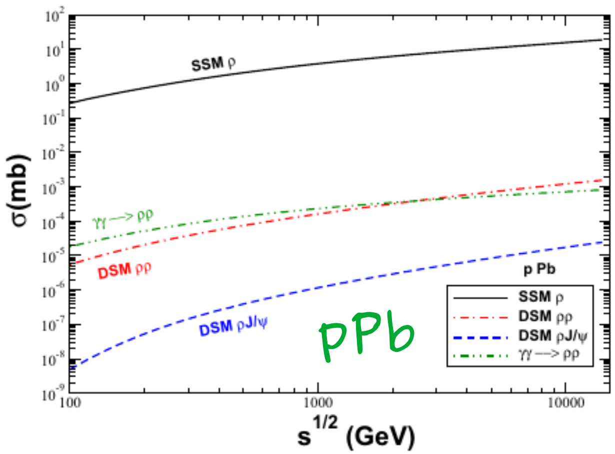
In our analysis, one has assumed the Gaus-LC model for the overlap function and the Glauber - Gribov formula for the dipole - nucleus scattering amplitude:

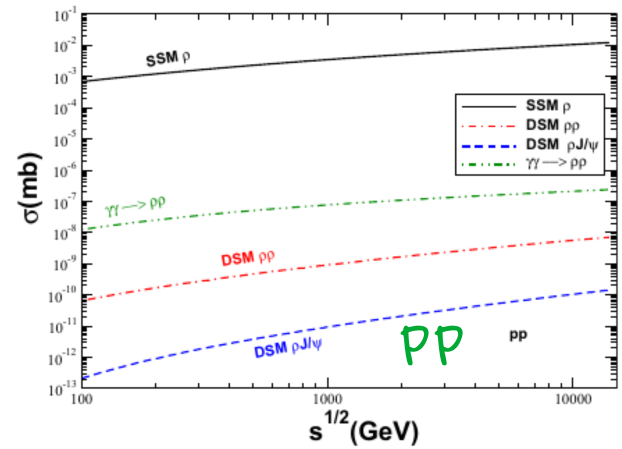
$$\mathcal{N}_A(x, \boldsymbol{r}, \boldsymbol{b}_A) = 1 - \exp\left[-\frac{1}{2}\,\sigma_{dp}(x, \boldsymbol{r}^2)\,T_A(\boldsymbol{b}_A)\right]$$

Double vector meson production at hadronic colliders: Photon - photon x Double scattering mechanism

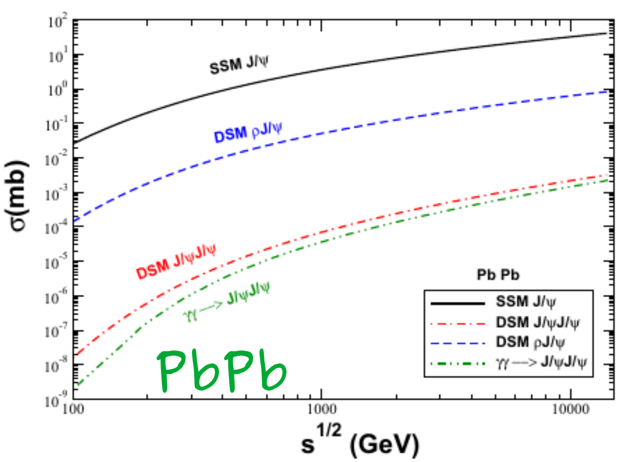
Double ρ production:

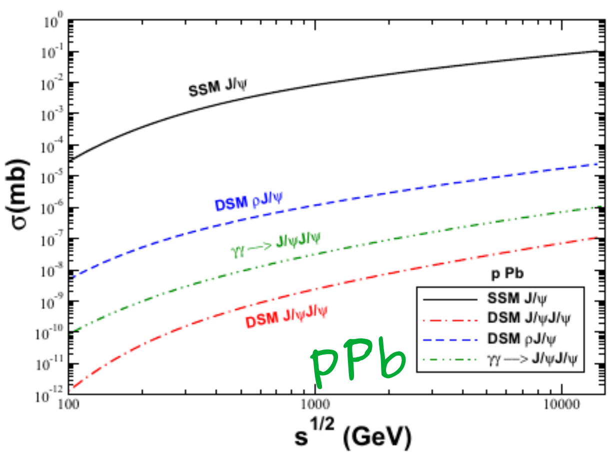


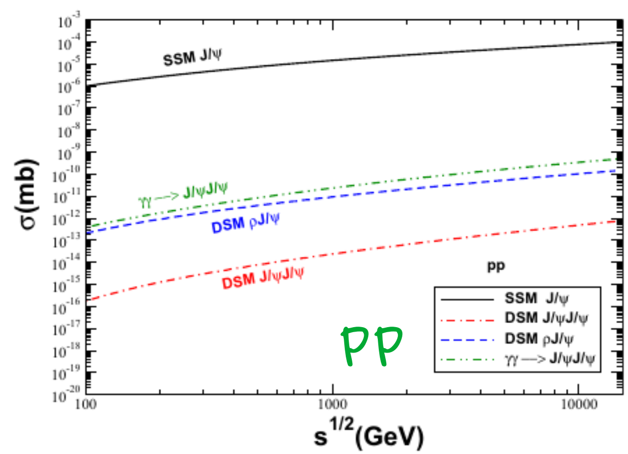




Double J/Ψ production:







Double vector meson production at hadronic colliders:
Photon - photon x Double scattering mechanism

Table 1 Total cross sections for the double vector meson production considering the double-scattering and two-photon mechanisms and different center-of-mass energies considering the full kinematical range covered by the LHC

Final state	Mechanism	$PbPb$ $\sqrt{s} = 2.76$ TeV	$PbPb$ $\sqrt{s} = 5.5$ TeV	pPb $\sqrt{s} = 5$ TeV	pp $\sqrt{s} = 7$ TeV	pp $\sqrt{s} = 14$ TeV
$J/\Psi J/\Psi$	DSM	402.301 nb	1054.951 nb	28.473 pb	3.223×10^{-4} pb	7.256×10^{-4} pb
	$\gamma\gamma$	235.565 nb	658.589 nb	310.194 pb	0.2412 pb	0.4793 pb
$\rho\rho$	DSM	21.150 mb	29.421 mb	702.595 nb	4.354 pb	7.083 pb
	$\gamma\gamma$	1.389 mb	1.973 mb	536.432 nb	182.442 pb	237.006 pb

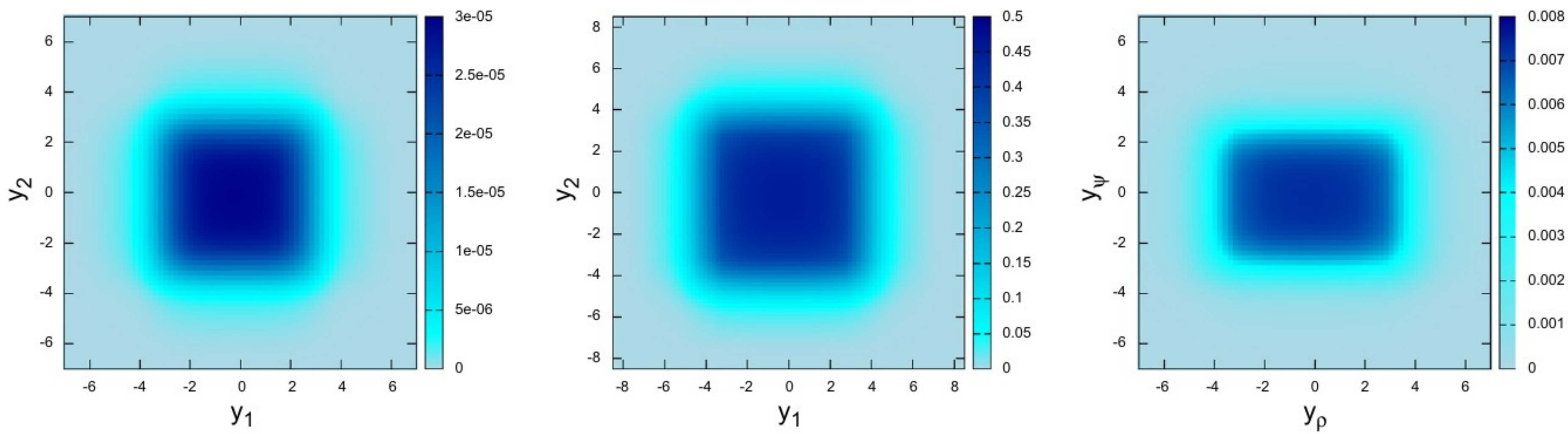


Fig. 4 Double differential rapidity distribution for the $J/\Psi J/\Psi$ (*left panel*), $\rho\rho$ (*middle panel*) and $\rho J/\Psi$ (*right panel*) production in γh interactions at $PbPb$ collisions ($\sqrt{s} = 5.5$ TeV) by the double-scattering mechanism

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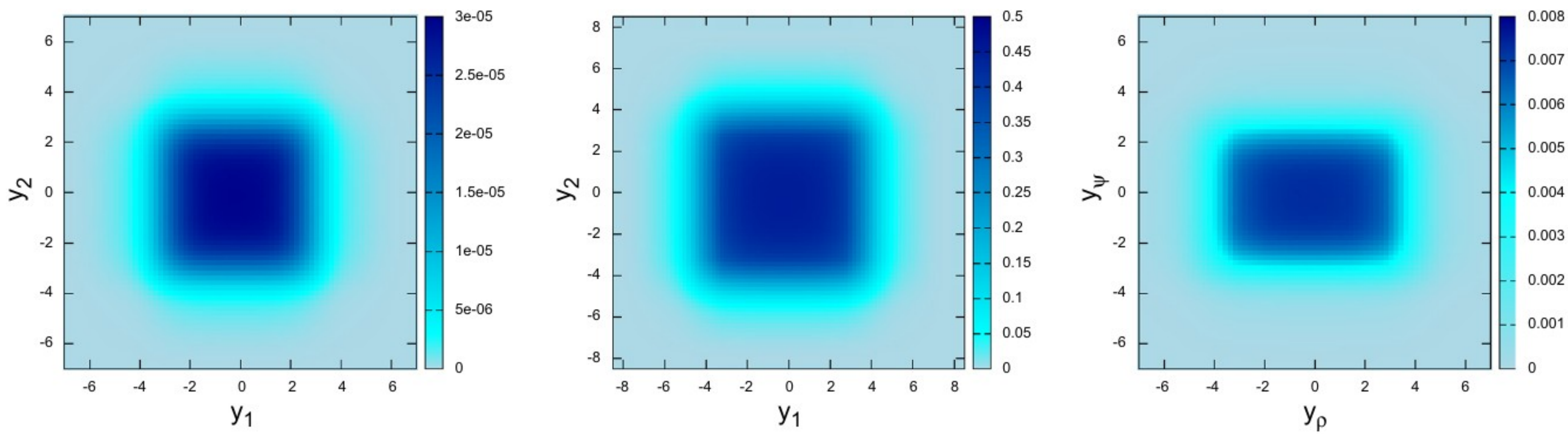

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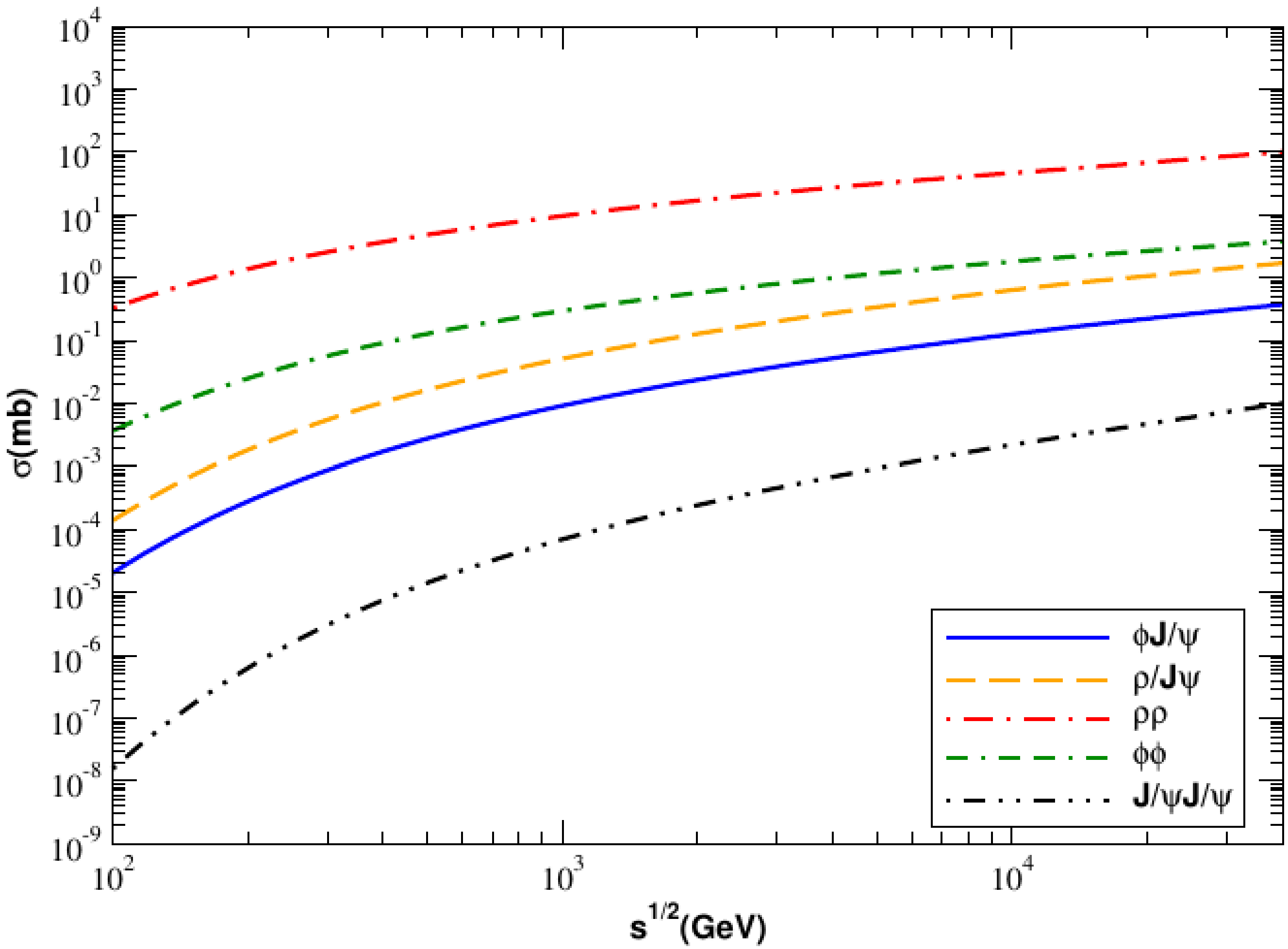
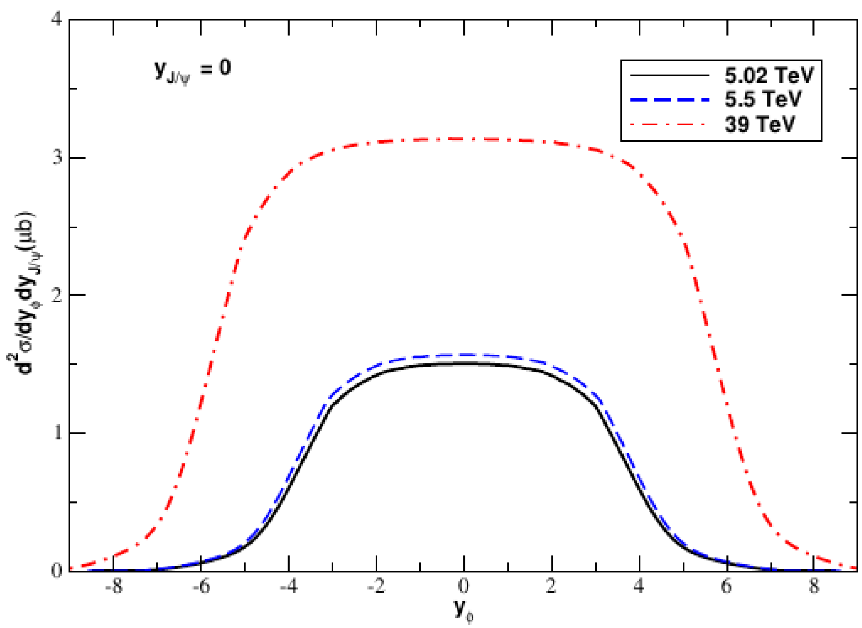
Double vector meson production in PbPb Collisions via the double scattering mechanism

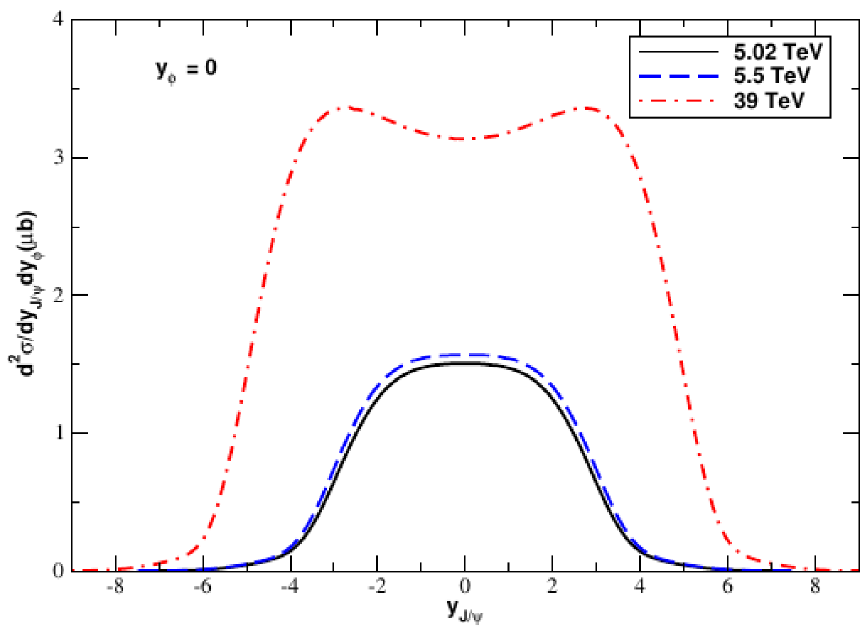


Associated Φ and J/Ψ production in PbPb Collisions

	LHC ($\sqrt{s} = 5.02$ TeV)	LHC ($\sqrt{s} = 5.5$ TeV)	FCC ($\sqrt{s} = 39$ TeV)
Full rapidity range	65.60	72.00	365.00
$-2.5 \leq y_{\phi,J/\Psi} \leq 2.5$	33.60	35.50	80.30
$2.0 \leq y_{\phi,J/\Psi} \leq 4.5$	2.30	2.70	18.70

TABLE I: Total cross sections in μb for the associated ϕ and J/Ψ production in ultraperipheral $PbPb$ collisions at the LHC and FCC energies considering distinct rapidity ranges for the mesons in the final state.





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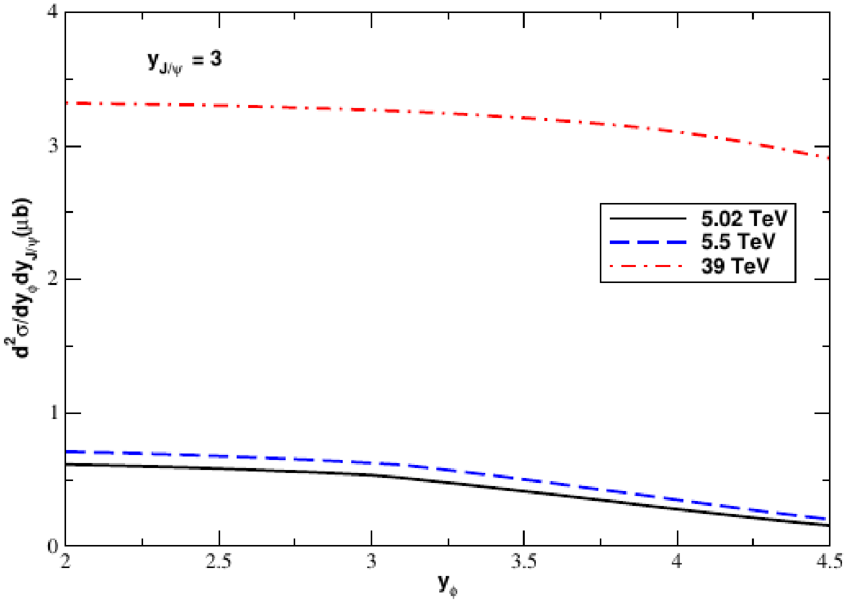

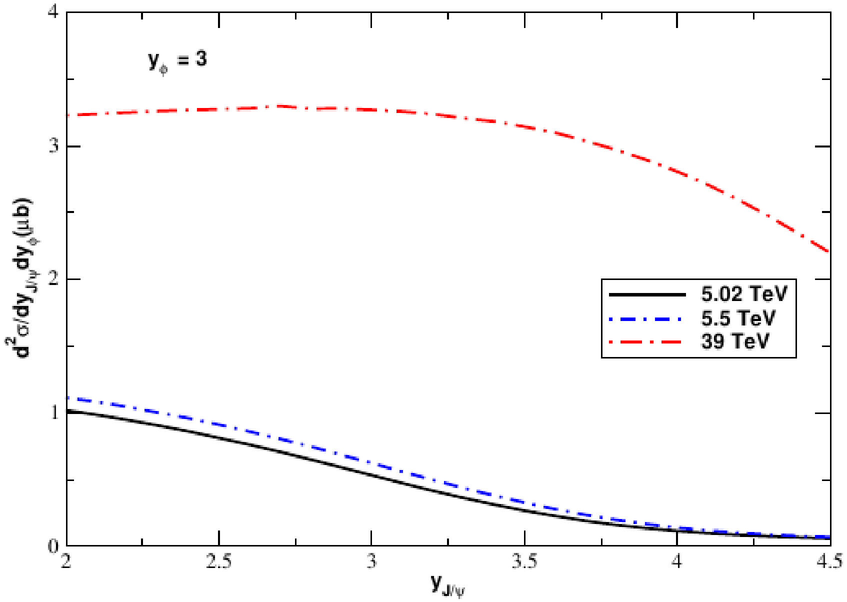

Summary

- Photon – induced interactions can be used to constrain the physics in a unexplorated energy regime.
- In recent years, several studies have analyzed the single vector meson photoproduction in photon – hadron interactions at the RHIC, LHC and FCC.
- However, complementary studies can be performed through the analysis of the double vector meson production in photon – photon and photon – hadron interactions.
- Our results indicate that the double scattering mechanism dominates in PbPb collisions and that a future experimental analysis of this process is feasible.

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Thank you for your attention!