Coherent J/Ψ photoproduction and polarization in UPC and peripheral Pb–Pb collisions with ALICE

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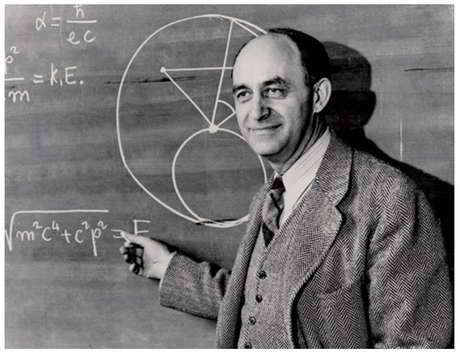
European Physical Society
Conference on High Energy Physics
21-25 August 2023
EPS HEP2023 HAMBURG

Photon-induced processes in heavy-ion collisions



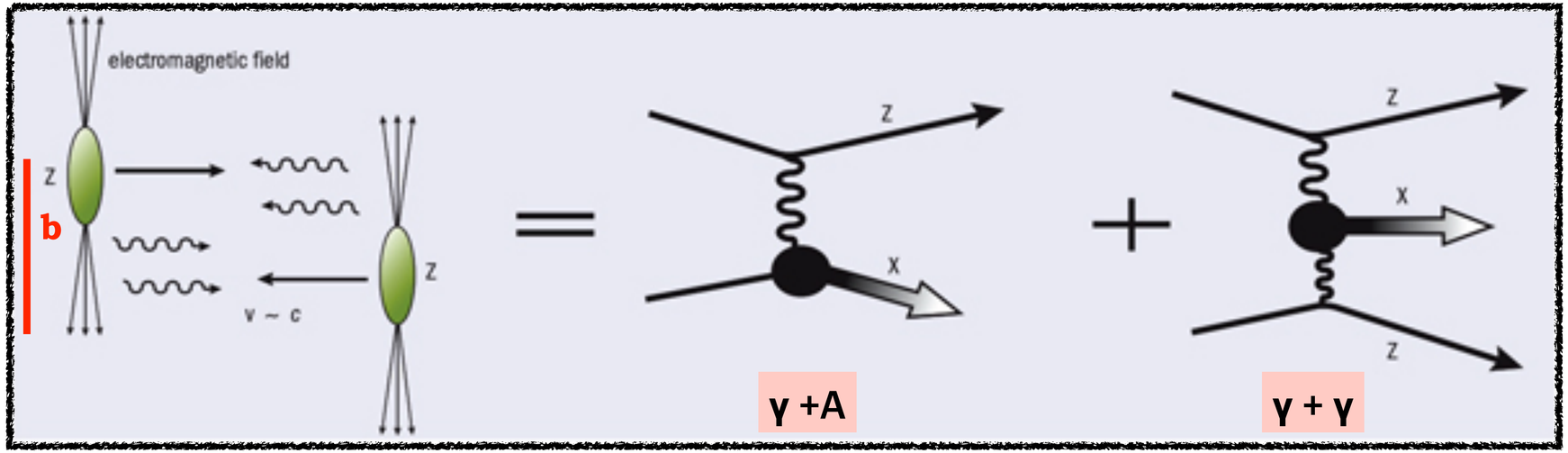
Equivalent photon approximation : electromagnetic field ~ photon flux [1]

Later, the method was extended to relativistic region known as **Weizsacker-Williams Methods** [2],[3]

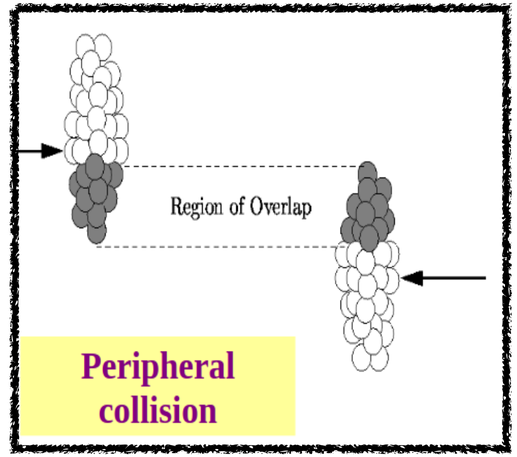
[1] E. Fermi, Nuovo Cim.,2:143-158, arXiv:hep-th/0205086 (1925)
[2] C.F. von Weizsacker, Z. Phys. 88, 612 (1934)
[3] E. J. WILLIAM S, Kgl. Danske Videnskab. Selskab Mat.-Fys. Medd. 13, 4 (1935)]

LHC: Photon-Photon and Photon-Hadron Collider at the highest available energies

UltraPeripheral Collisions (UPCs) : b ≥ R_1+ R_2



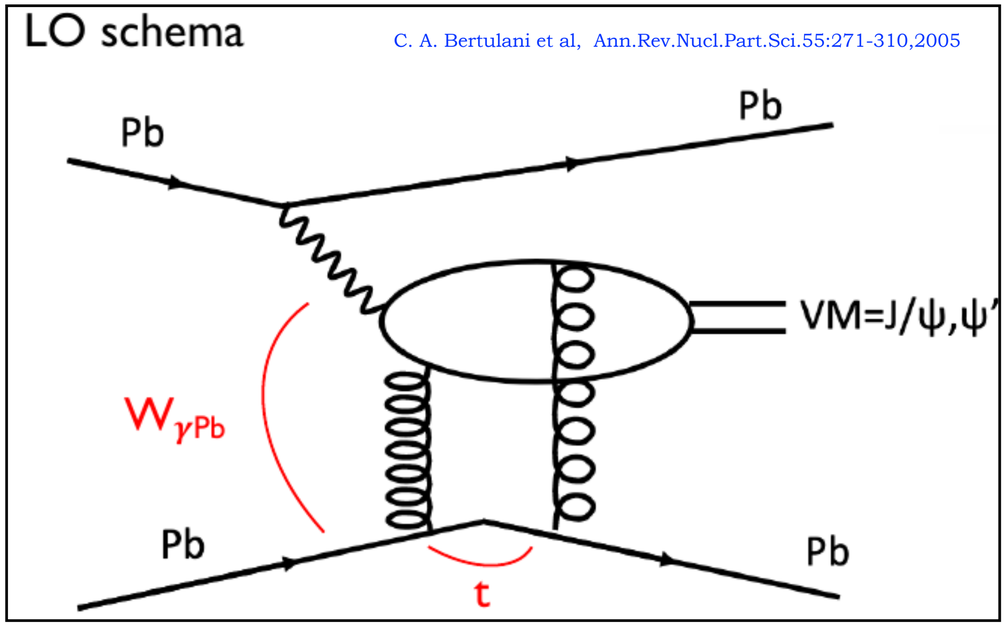
Peripheral Collisions (PCs) : b large and b ≤ R_1+ R_2



- **Hadronic interactions are suppressed**
- **Electromagnetic interactions are dominant**
- **Photon flux density** $\propto Z^2$

Photon-induced (γ +A) processes are present both in UPCs and PCs with nuclear overlap

Vector Meson (VM) photoproduction in HICs



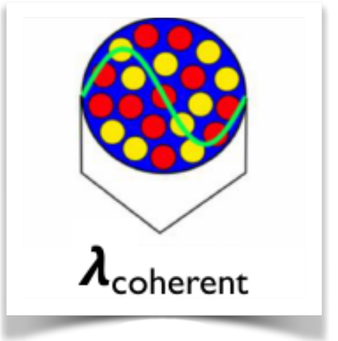
LO : Leading order

$W_{\gamma Pb}$: Center-of-mass energy of photon-lead system

t : Mandelstam variable = - $p_{\perp}^2$

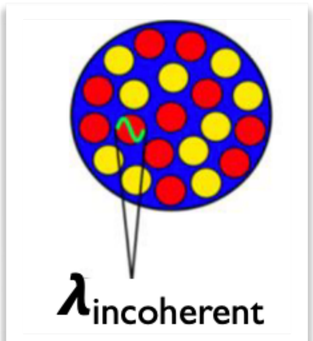
Coherent photoproduction:

- ☑ Photon (γ) couples coherently to all nucleons
- ☑ $\langle p_T \rangle^{J/\Psi}$ ~ 1/R ~ 60 MeV/c
- ☑ Usually no breaking of target



Incoherent photoproduction:

- ☑ Photon (γ) couples to single nucleon
- ☑ $\langle p_T \rangle^{J/\Psi}$ ~ 500 MeV/c
- ☑ Usually target nucleus breaks



$$x = \frac{m_{J/\psi}}{\sqrt{s_{NN}}} \exp(\pm y)$$

- ☐ **Clean experimental signature and production of VM at very low p_T (coherent case)**
- ☐ **Gives access to gluon distributions in nuclei at low Bjorken-x ($10^{-5} < x < 10^{-2}$ at LHC energies)**

The ALICE apparatus

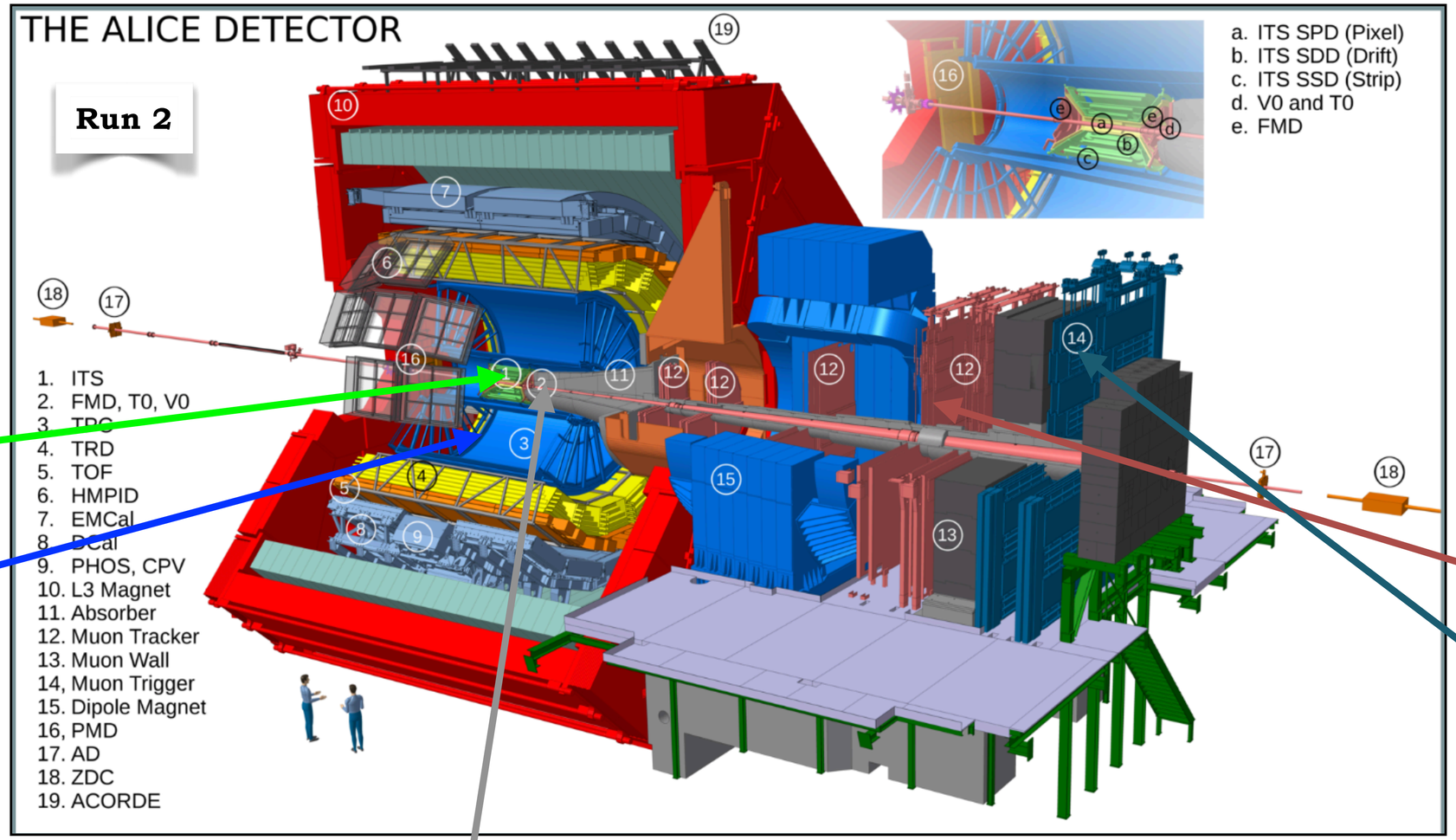
Data sample : 2015 + 2018 Pb—Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV

Central barrel:
$|y| < 0.9$

J/Ψ —> e^+e^-

ITS : Tracking, vertex reconstruction

TPC : Tracking, Particle indentification (PID)



Muon Spectrometer :
$2.5 < y < 4.0$

J/Ψ —> $\mu^+\mu^-$

Muon tracker : tracking

Muon trigger : triggering

V0 : triggering, centrality determination, background rejection

A. Caliva, Highlights from ALICE, 23/08/2023

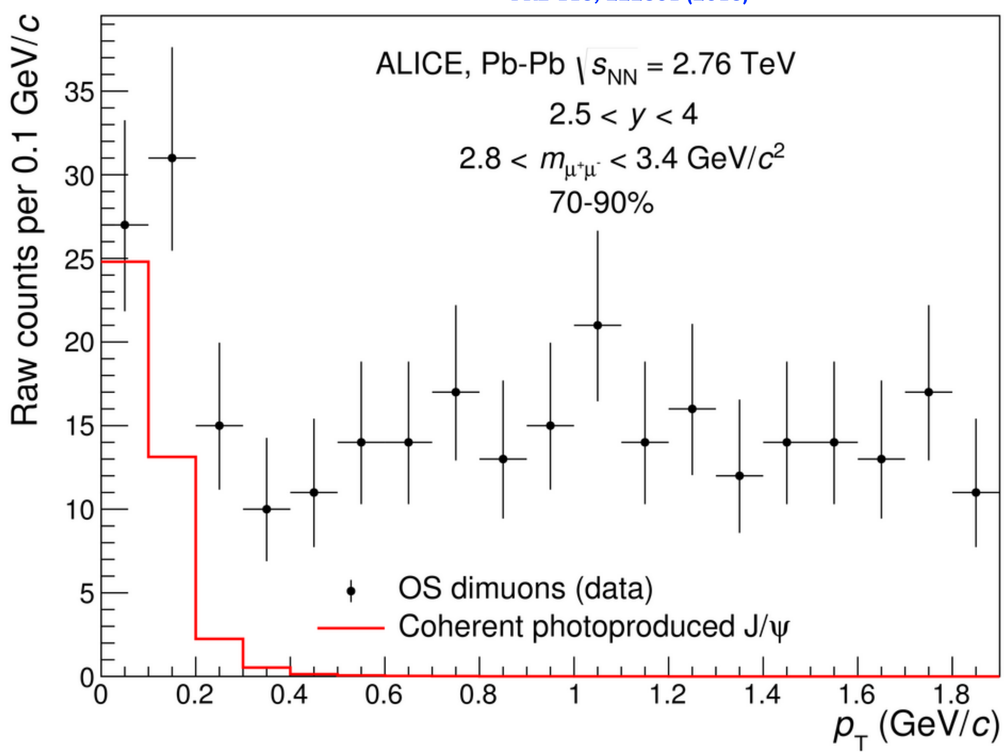
H .Sharma, Recent charmonium measurements in Pb–Pb collisions with ALICE, 21/08/2023
W. Guo, Quarkonium production and polarization in pp collisions with ALICE, 23/08/2023

photoproduced VM in Pb—Pb collisions in PCs

Experimental signatures

PCs = Peripheral Collisions = with nuclear overlap

PRL 116, 222301 (2016)

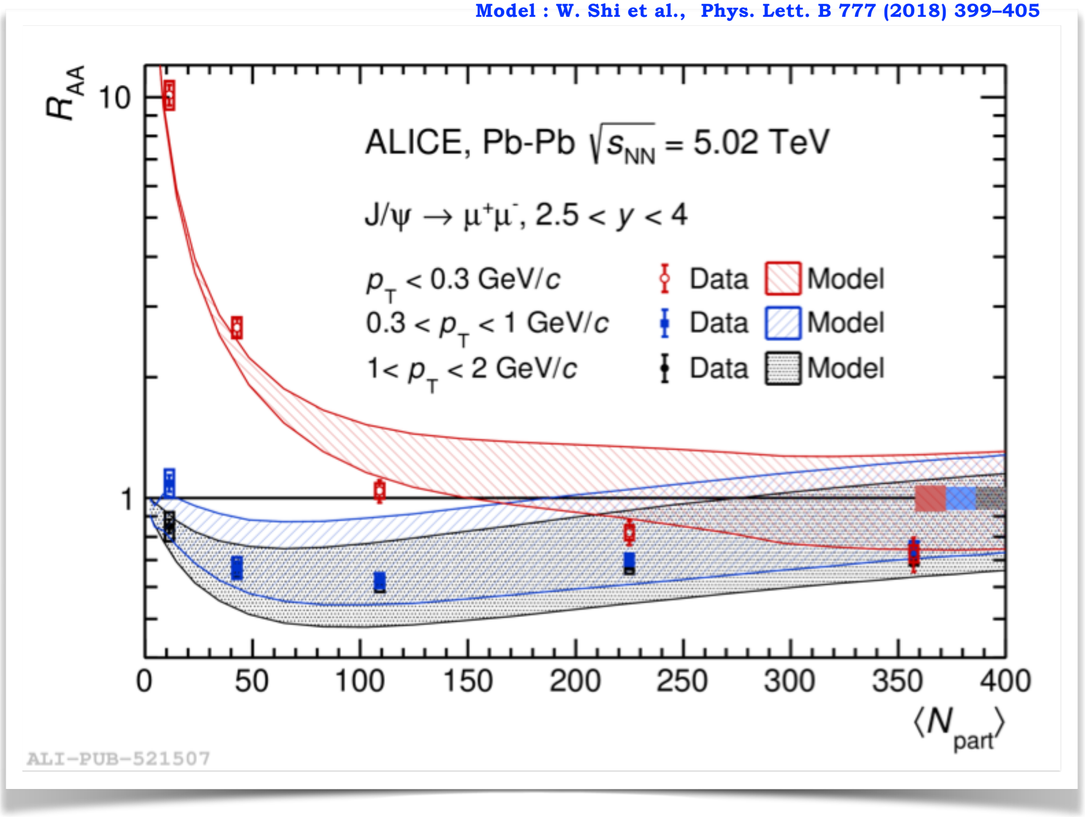


STARlight MC : Comp. Phys. Comm. 212 (2017) 258.

$$R_{AA} = \frac{Y_{J/\psi}^{Pb-Pb}}{< T_{AA} > \sigma_{J/\psi}^{pp}}$$

arXiv:2204.10684

Model : W. Shi et al., Phys. Lett. B 777 (2018) 399–405



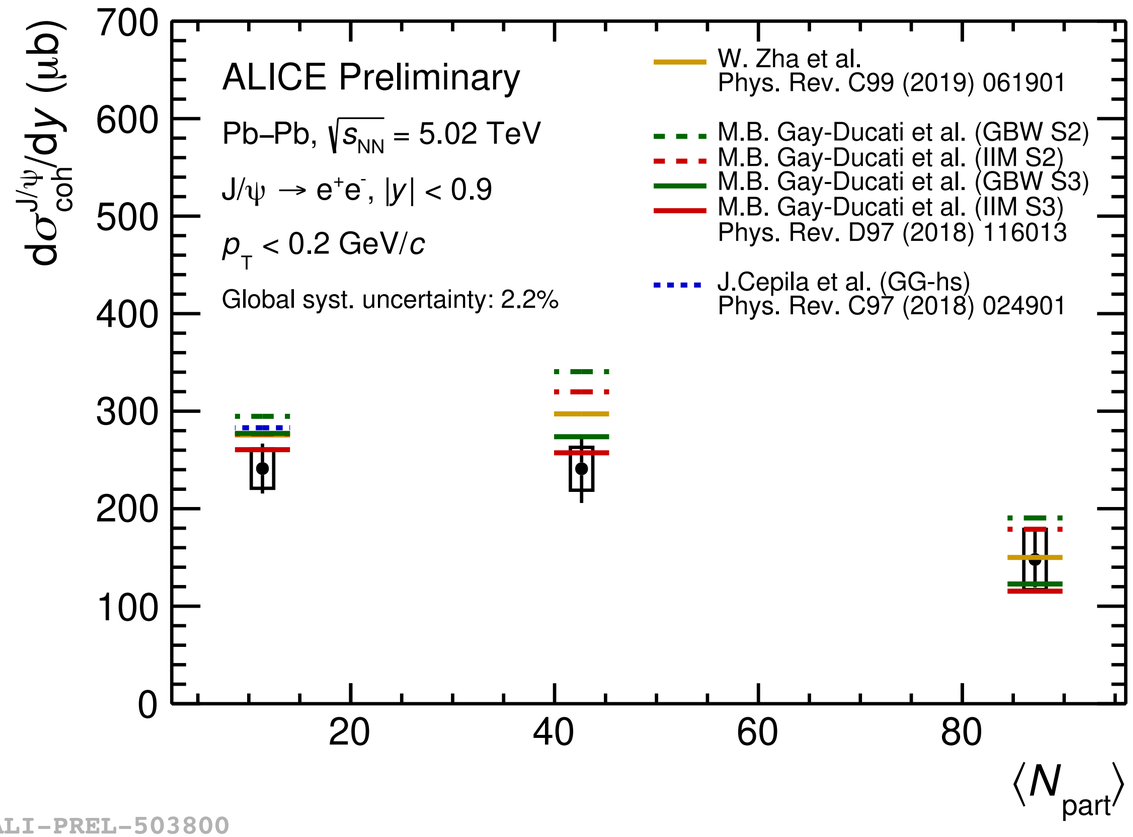
- Very **low-p_T J/ψ excess** in peripheral Pb—Pb collisions measured in ALICE at forward y and at $\sqrt{s_{NN}}$ = 2.76 TeV (significance = 5.4σ) and 5.02 TeV (24σ) for 70-90 % -> Interpreted as **coherent photoproduction**

- Similar observation confirmed by other experiments, STAR Collaboration: PRL 123, 132302, 2019 , and LHCb Collaboration: PRC105. 2022, L032201

Coherent VM photoproduction vs. centrality in PCs

PCs = Peripheral Collisions = with nuclear overlap

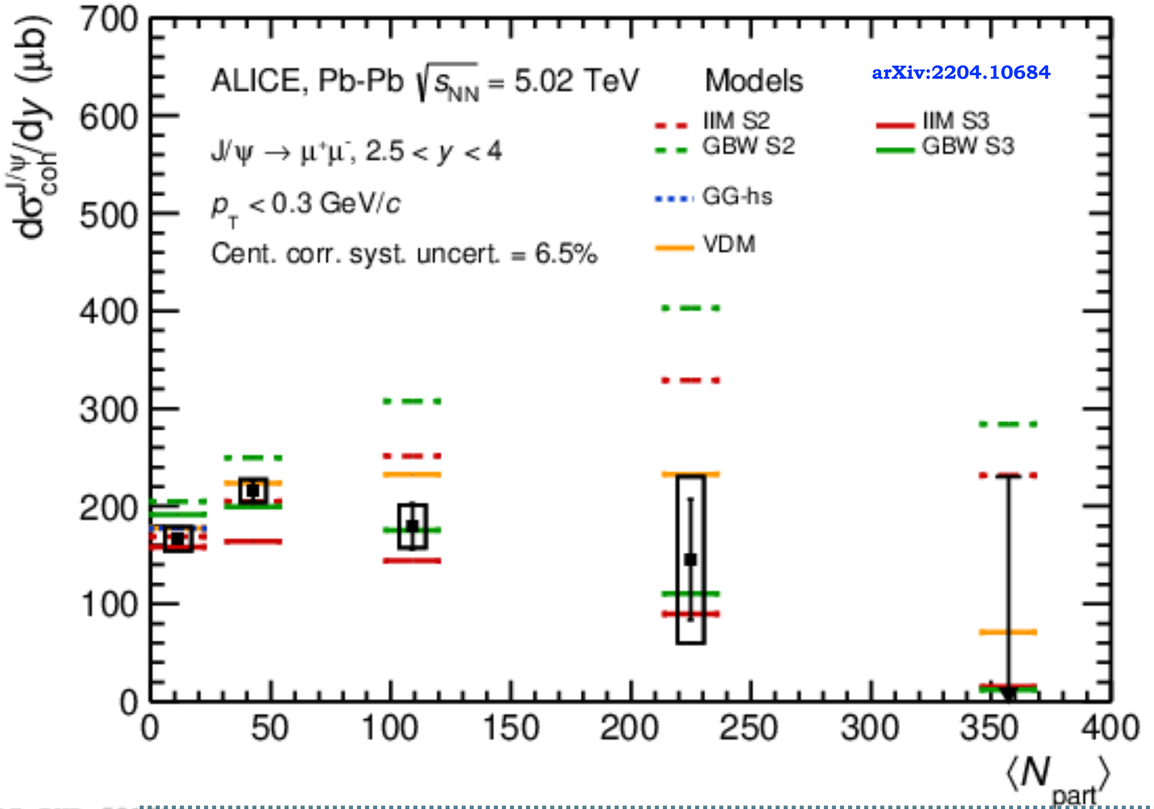
midrapidity ($|y| < 0.9$)



ALI-PREL-503800

Centrality	70-90%	50-70%	40-50%

Forward rapidity ($2.5 < y < 4.0$)



ALI-PUB-525511

Centrality	70-90%	50-70%	30-50%	10-30%	0-10%

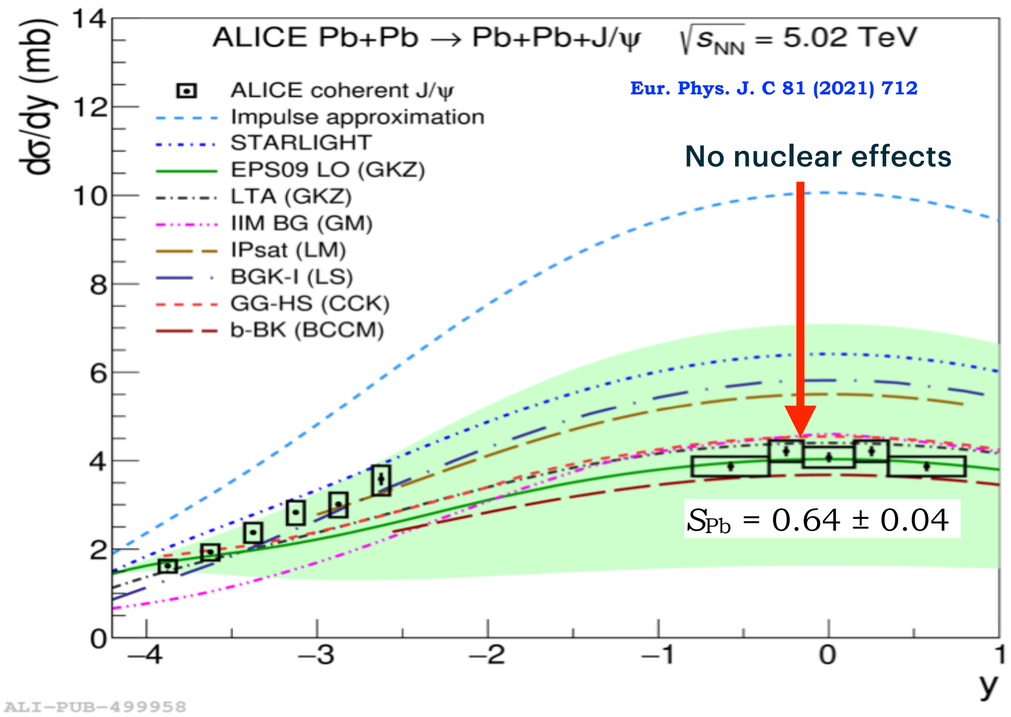
Caveat : No normalization to centrality interval width

- **No centrality dependence** of the coherent J/ψ photoproduction cross section within uncertainties
- All models (**with different assumptions on the treatment of the nuclear overlap**) describe qualitatively the magnitude of the cross section

Coherent VM photoproduction cross section

Rapidity differential, UPC

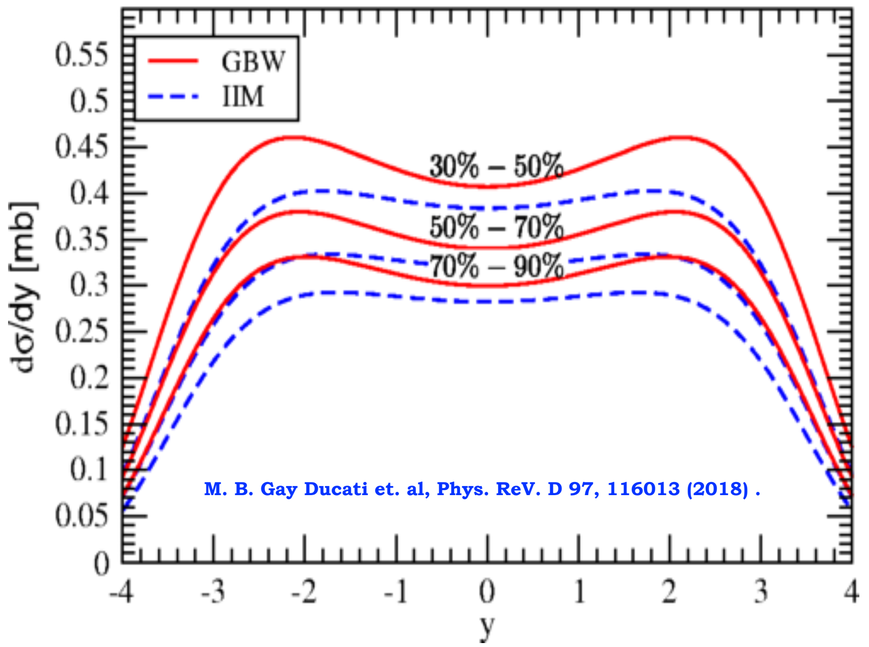
UPC and Pb–Pb collisions with nuclear overlap (PCs)



Nuclear suppression factor (shadowing)

$$S_{\mathrm{Pb}} = \sqrt{\frac{\sigma_{\gamma \mathrm{Pb}}}{\sigma^{\mathrm{IA}}_{\gamma \mathrm{Pb}}}}$$

Model predictions: for PCs

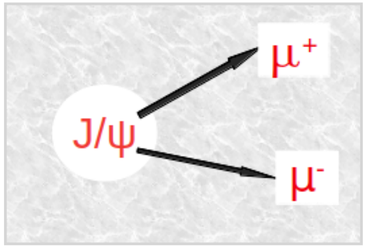


- **None of the models in UPC** is able to fully describe the rapidity dependence of the J/ψ cross section, Eur. Phys. J. C 81 (2021) 712
- Nuclear gluon shadowing of **S_{Pb} = 0.64 ± 0.04** for Bjorken-*x* (~ 10^{-3}) at mid-y w.r.t **impulse approximation (IA) calculation (neglect nuclear effects)**
- **GBW and IIM** show strong centrality/rapidity, dependence, M. B. Gay Ducati et. al, Phys. ReV. D 97, 116013 (2018) .

New

First measurement of y-differential coherent J/ψ photoproduction at forward rapidity with nuclear overlap

J/Ψ Signal : different y intervals

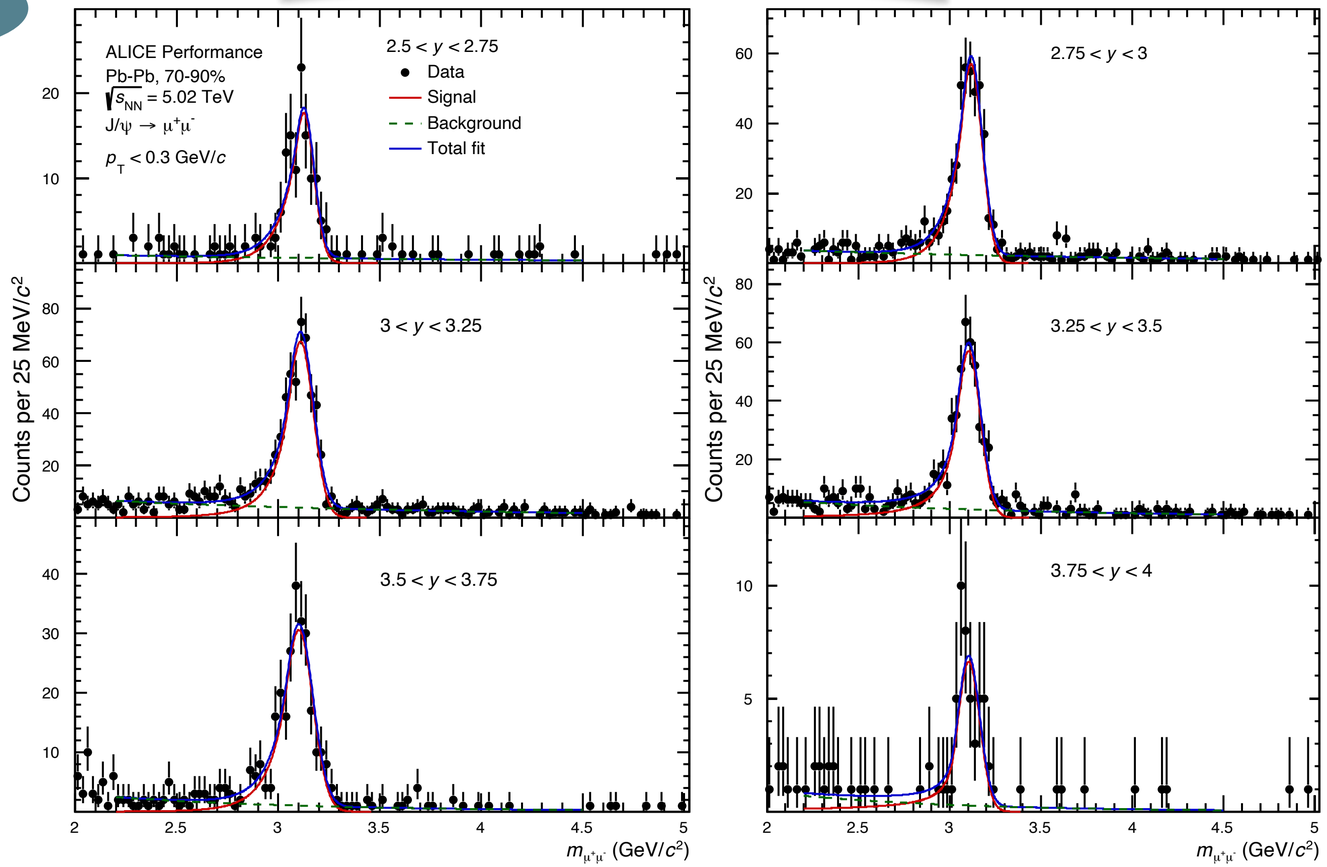


J/ψ is reconstructed from its decay daughters using invariant mass quantity

$$m^2 = E^2 - \vec{p}^2 = (E_{\mu^+} + E_{\mu^-})^2 - (\vec{p_{\mu^+}} + \vec{p_{\mu^-}})^2$$

centrality 70-90 %, p_T < 0.3 GeV/c

New

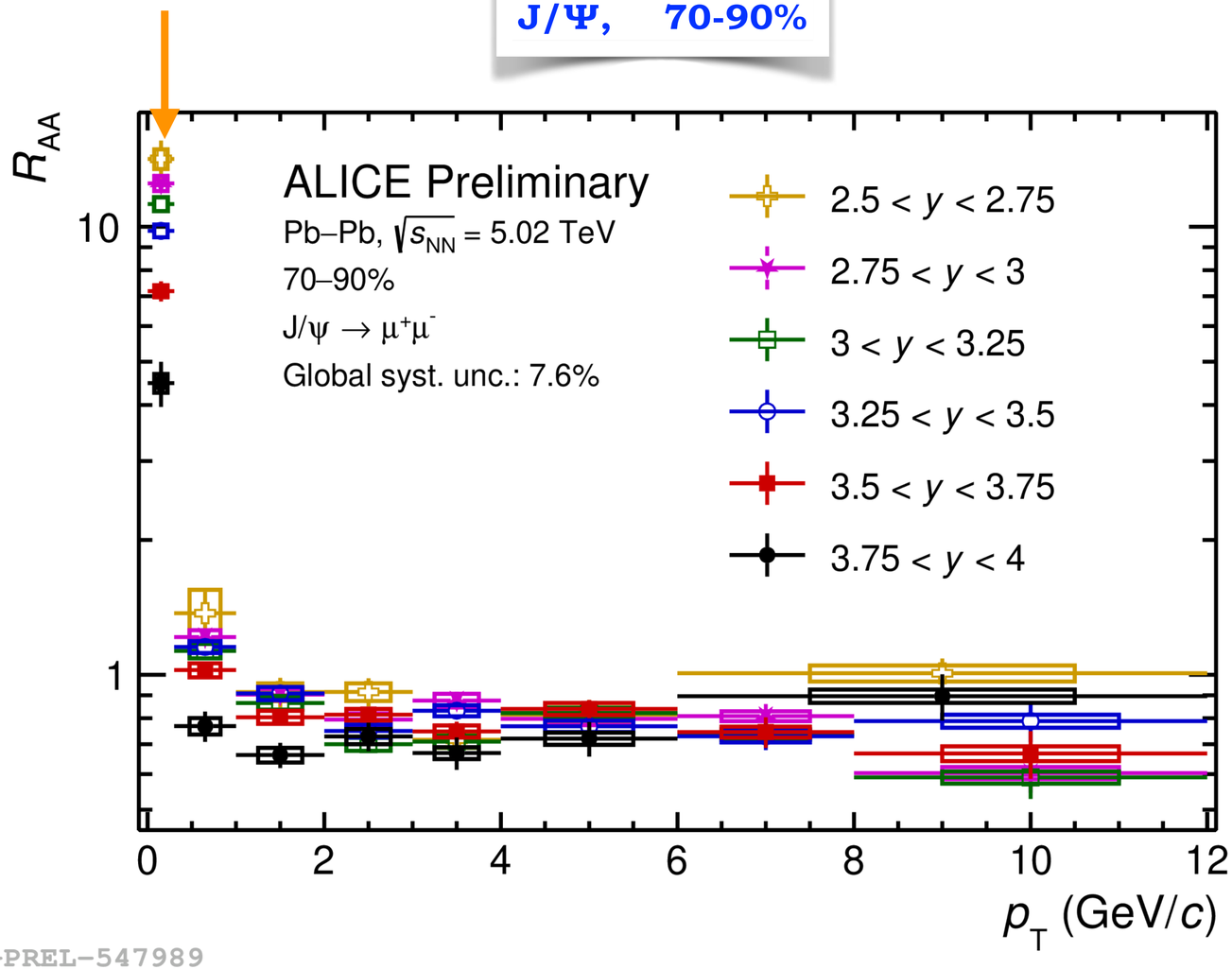


ALI-PERF-538924

Nuclear modification factor (R_{AA}) : Evolution with p_T and y

PCs = Peripheral Collisions = with nuclear overlap

New



ALI-PREL-547989

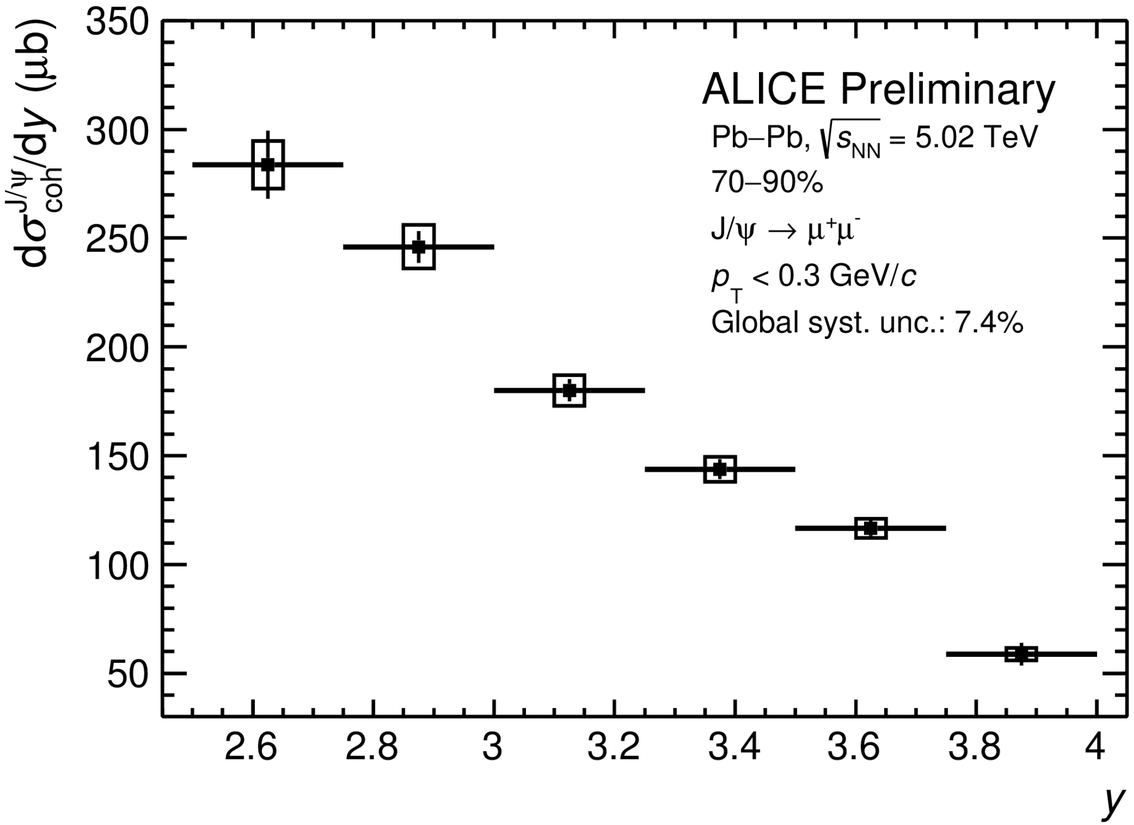
$$R_{AA} = \frac{Y^{Pb-Pb}_{J\psi}}{< T_{AA} > \sigma^{pp}_{J/\psi}}$$

- A **dramatic increase in the R_{AA}** at low p_T (< 0.3 GeV/c) is observed w.r.t hadroproduction
  - -> Excess of the J/Ψ yield due to coherent photoproduction
- A **clear hierarchy in y is observed** at low p_T , the most forward interval (3.75 < y < 4) is the least enhanced

Coherent J/Ψ photoproduction cross section vs. rapidity in PCs

PCs = Peripheral Collisions = with nuclear overlap

New



ALI-PREL-548022

- **Strong rapidity dependence** of the J/Ψ photoproduction cross section

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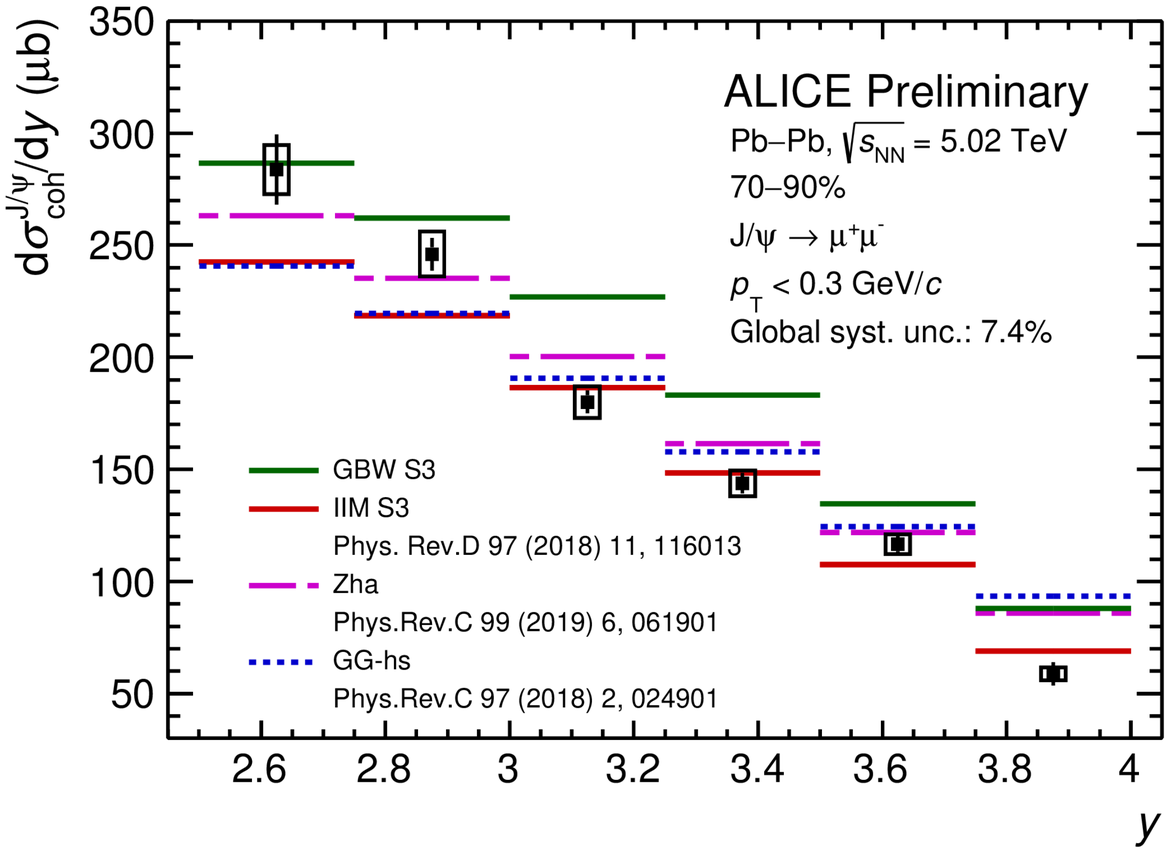
Coherent J/Ψ photoproduction cross section vs. rapidity in PCs

PCs = Peripheral Collisions = with nuclear overlap

New



ALI-PREL-547942

- **Strong rapidity dependence** of the J/Ψ photoproduction cross section

- Models reproduce **qualitatively the magnitude of the cross section,** but none of them catch the rapidity dependence in the full range (similar observation as UPC, i.e GG-hs model) **Eur. Phys. J. C 81 (2021) 712**

- **Models :**

[1] GG-hs : photon flux with constraints on impact parameter range

J. Cepila et al., Phys. Rev.C 97 (2018) 2, 024901

[2] Zha : Assumptions on the coupling between photon and pomeron (Nucleus +Spectator) W Zha et al., Phys. Rev. C 99 (2019) 6, 061901

[3] IIM /GBW

S1 : no relevant modification w.r.t UPC calculations

S2 : only photon reaching the spectator region are considered

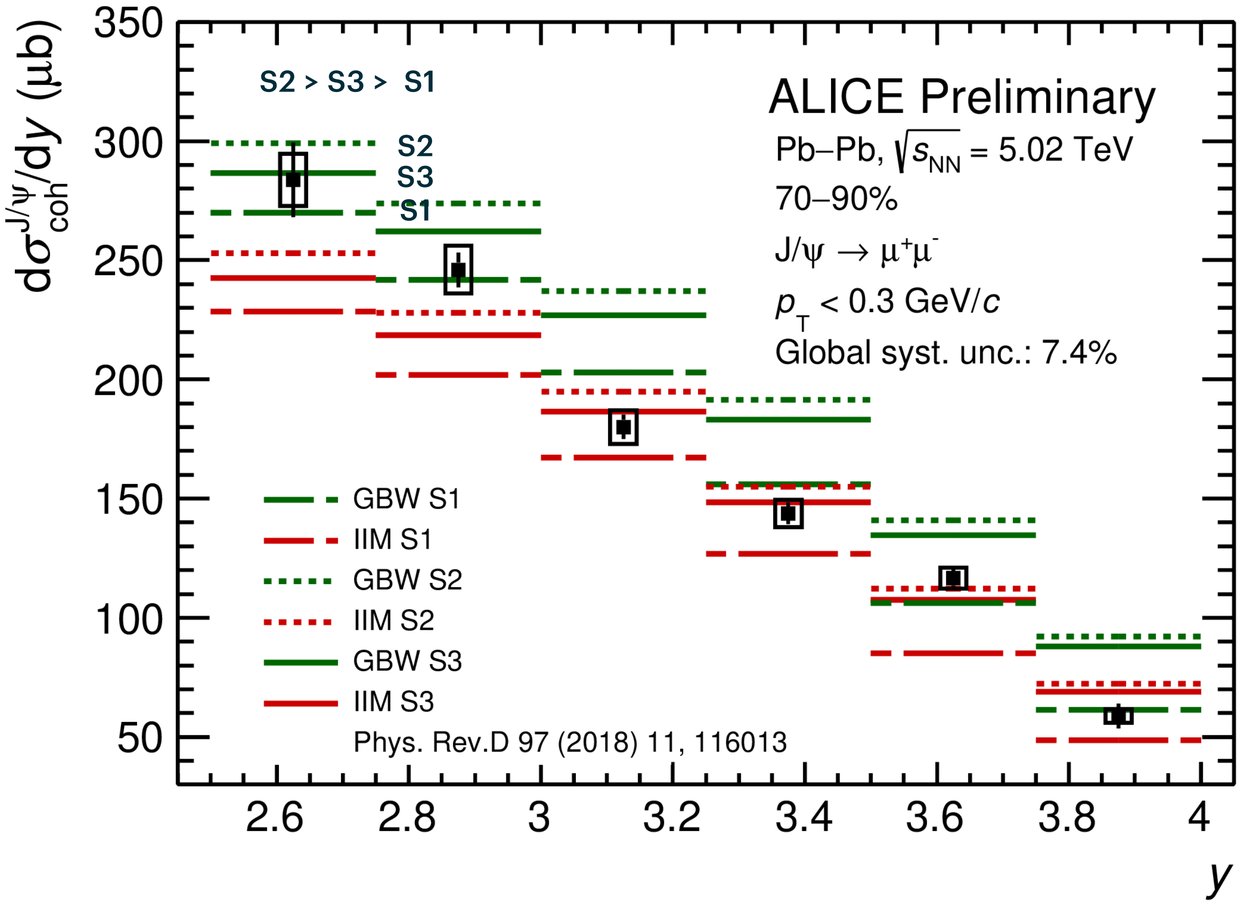
S3: S2 + photonuclear cross section modified

M. B. Gay Ducati et al., Phys. Rev. D. 97 (2018) 116013

Coherent J/Ψ photoproduction cross section vs. rapidity in PCs

PCs = Peripheral Collisions = with nuclear overlap

New



ALI-PREL-547985

- **Strong rapidity dependence** of the J/Ψ photoproduction cross section
- Models reproduce **qualitatively the magnitude of the cross section,** but none of them catch the rapidity dependence in the full range (similar observation as UPC, i.e GG-hs model) **Eur. Phys. J. C 81 (2021) 712**

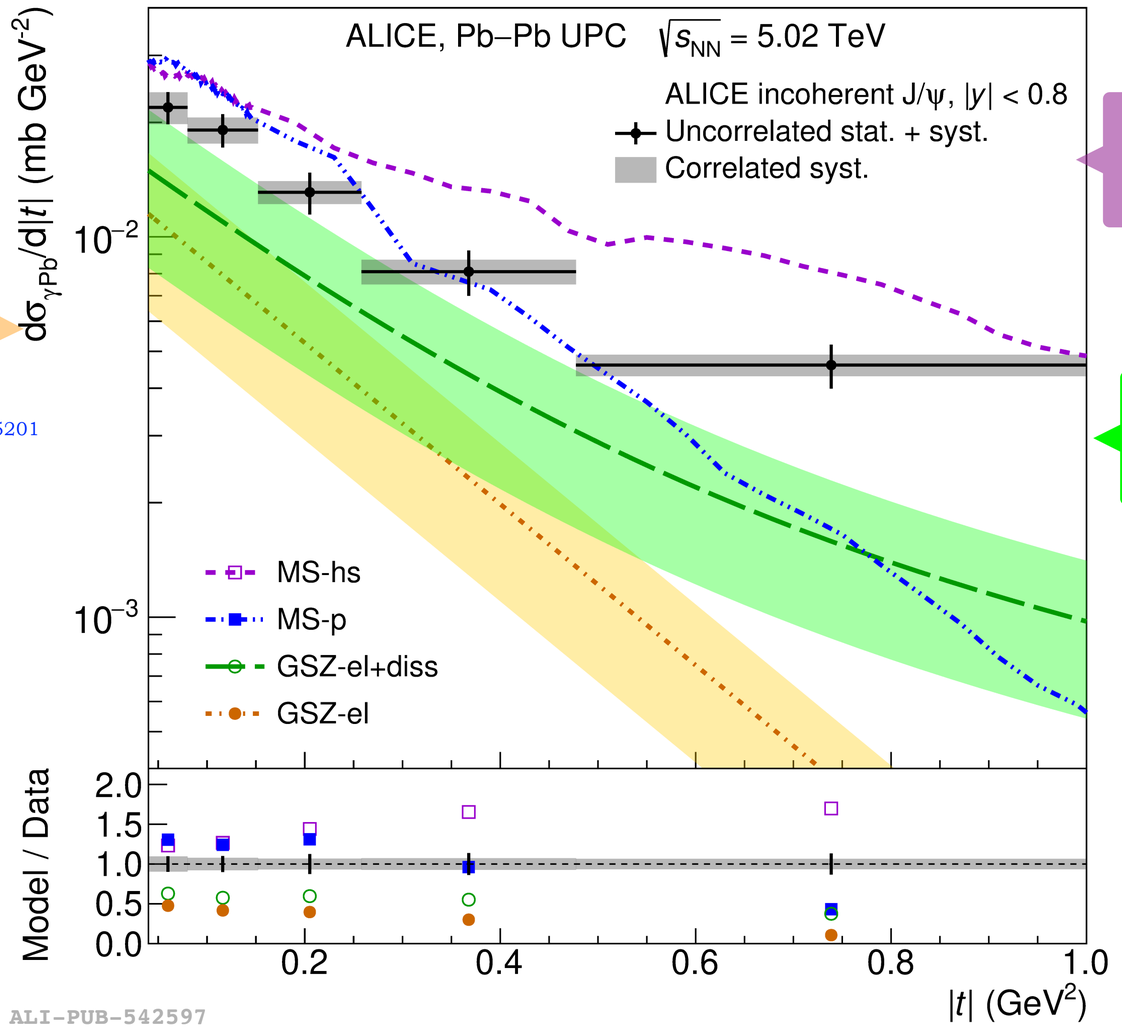
[3] IIM /GBW

- — - S1 : no relevant modification w.r.t UPC calculations
- - - - S2 : only photon reaching the spectator region are considered
- —- S3: S2 + photonuclear cross section modified

M. B. Gay Ducati et al., Phys. Rev. D. 97 (2018) 116013

t-dependence incoherent photoproduction cross section in UPC

arXiv:2305.06169



GSZ-el :production off nucleons elastic part (from HERA data) + Shadowing

V. Guzey et al., Phys. Rev. C 99 (2019) 015201

MS-hs: subnucleon fluctuations (hot spots fluctuating event by event) + saturation

H. Mäntysaari et al., Phys. Lett. B 772 (2017) 832–838

Saturation model : H. Kowalski et al. Phys. Rev. D 68 (2003) 114005

GSZ-el -diss: production off nucleons including dissociation (Shadowing+ elastic part from HERA data)

V. Guzey et al., Phys. Rev. C 99 (2019) 015201
Shadowing : N. Armesto, *J. Phys. G* 32 (2006) R367–R394

MS-p : subnucleon fluctuations not considered + saturation

H. Mäntysaari et al., Phys. Lett. B 772 (2017) 832–838

$|t| = p_\perp^2 =$ related to the transverse size of the target

- Models including fluctuations in subnucleon scale give reasonably good description of the measurement

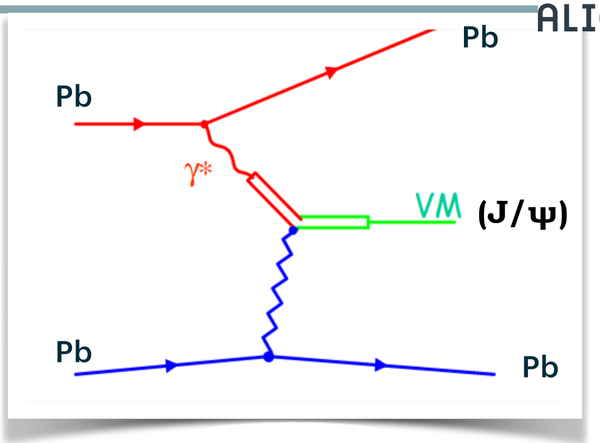
  —> suggests **nuclear gluon density is not static at high energies**

Polarization : Coherent vector meson photoproduction

s-channel helicity conservation (SCHC): **helicity of photon transferred to vector meson (J/ψ)**

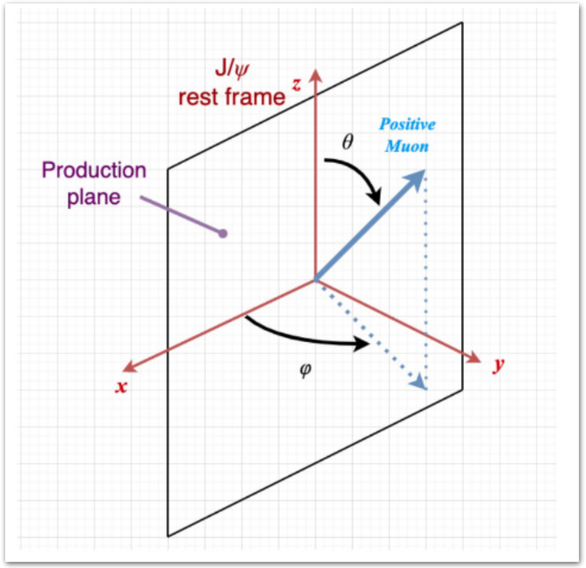
Vector meson (VM) has retained same helicity and polarization as that of the initial photon that interacted with the target

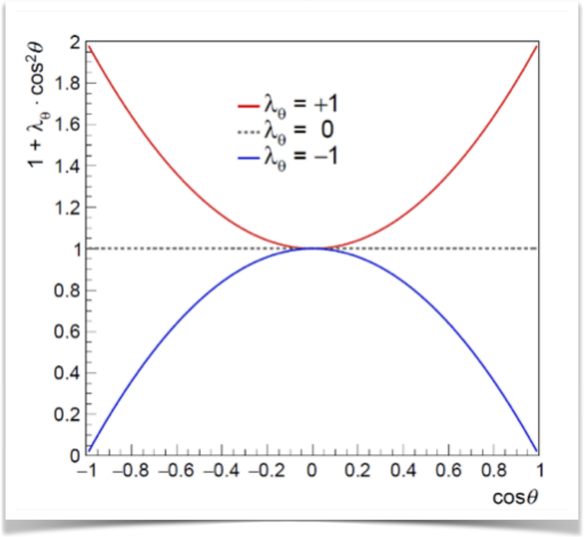
F.J. Gilman, Phys. Lett. B 31 (1970) 387-390
E. V. Kuraev, JETP Lett. 68 (1998) 696-703



Polarization refers to ***the particle spin alignment with respect to a chosen direction***

Helicity frame
***z*-axis (polarisation axis):** flight direction of the J/ψ in its rest frame





Dilepton decay angular distribution

$$W(\cos\theta,\phi) \propto \frac{1}{3+\lambda_\theta} \cdot (1 + \lambda_\theta \cos^2\theta + \lambda_\phi \sin^2\theta \cos 2\phi + \lambda_{\theta\phi} \sin 2\theta \cos\phi)$$

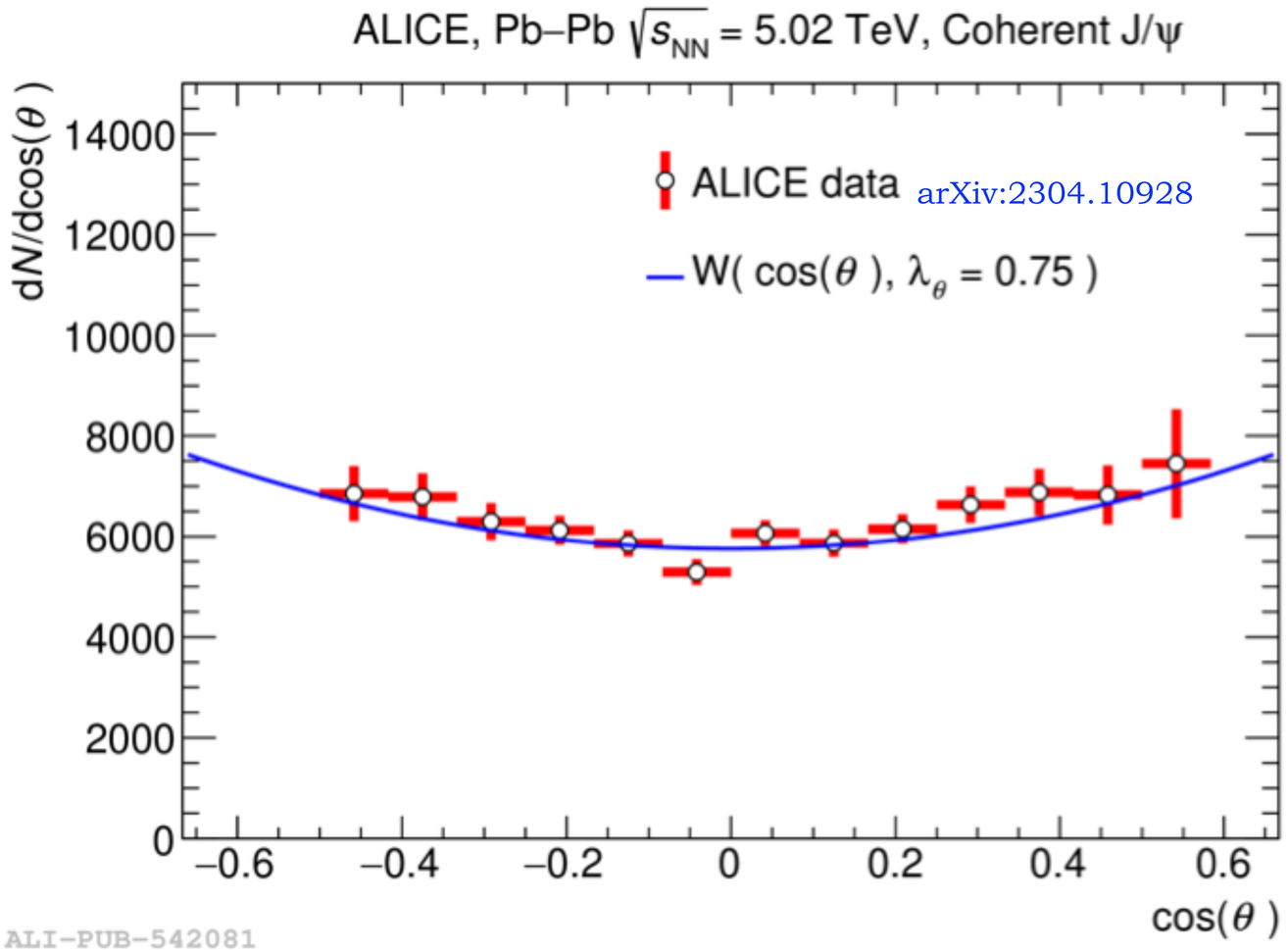
P. Faccioli et al., Eur.Phys.J.C69:657-673, 2010

$(\lambda_\theta, \lambda_\phi, \lambda_{\theta\phi}) = (0,0,0) \Rightarrow$ No polarization

$(\lambda_\theta, \lambda_\phi, \lambda_{\theta\phi}) = (+1,0,0) \Rightarrow$ Transverse polarization

$(\lambda_\theta, \lambda_\phi, \lambda_{\theta\phi}) = (-1,0,0) \Rightarrow$ Longitudinal polarization

Polarization : Coherent vector meson photo production in UPC



Coherently photoproduced J/ψ in UPCs at $\sqrt{s_{NN}}$ = 5.02 TeV, arXiv:2304.10928

- ☑ Transversely polarized
- ☑ Consistent with SCHC hypothesis

Can we see similar observation for J/ψ at low p_T (< 0.3 GeV/c) in Pb—Pb collisions with nuclear overlap (70–-90 %) ?

Additional challenge w.r.t UPC measurement : Deal with a contamination from hadronic J/ψ

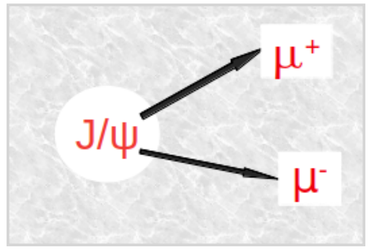
New

First measurement of inclusive J/ψ polarization for p_T < 300 MeV/c at forward rapidity in Pb—Pb collisions with nuclear overlap

Dukhishyam Mallick EPS-HEP, 21-25 August, 2023 dukhishyam.mallick@cern.ch

J/Ψ Signal : different cosθ intervals

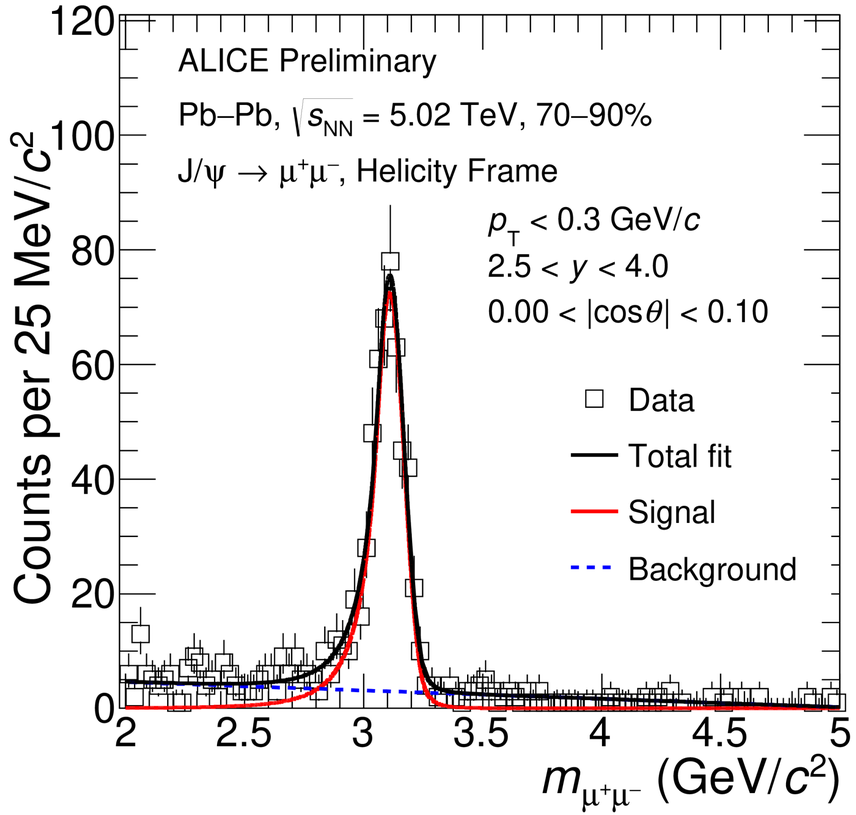
J/ψ is reconstructed from its decay daughters using invariant mass quantity



$$m^2 = E^2 - \vec{p}^2 = (E_{\mu^+} + E_{\mu^-})^2 - (\vec{p_{\mu^+}} + \vec{p_{\mu^-}})^2$$

centrality 70–90 %, p_T < 0.3 GeV/c

New



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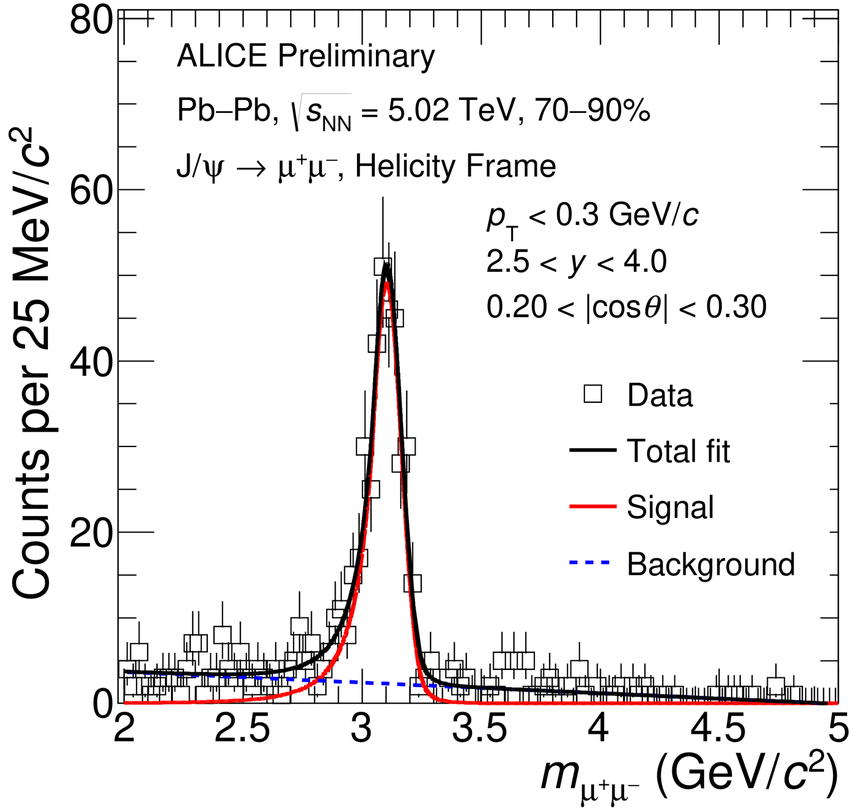

ALI-PREL-546765

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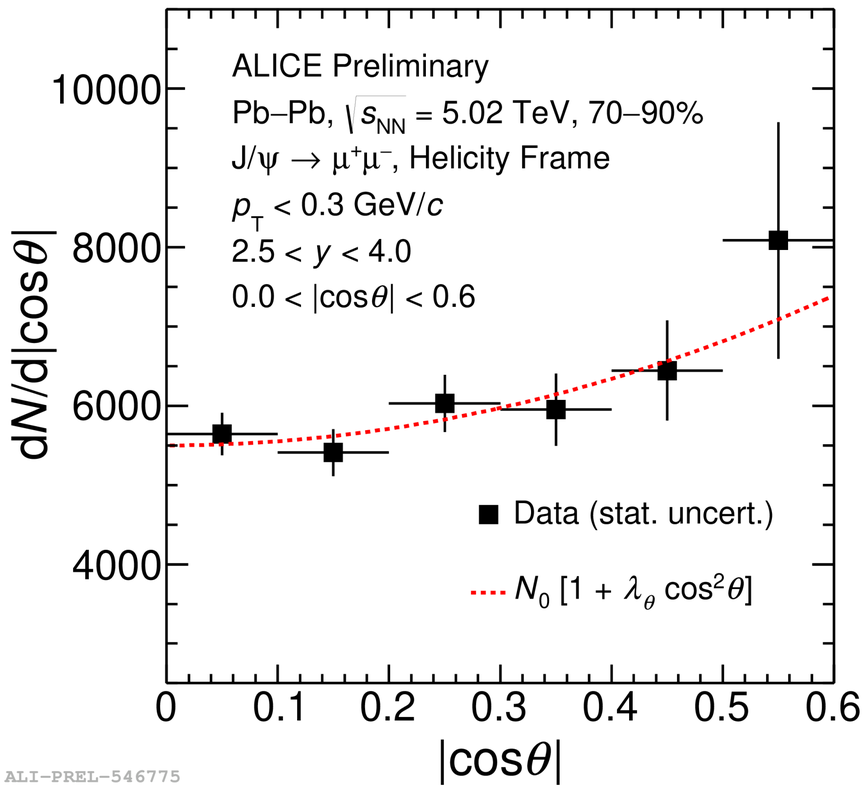
Inclusive J/Ψ polarization in Pb–Pb collisions with nuclear overlap in PCs

New

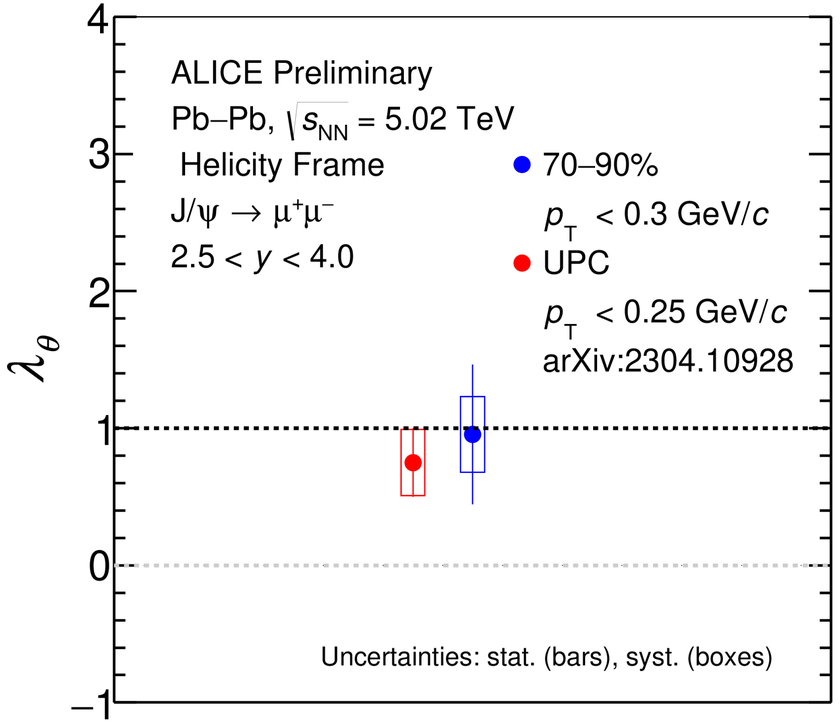
J/Ψ, 70–90%, p_T < 0.3 GeV/c



ALI-PREL-546775

PCs = Peripheral Collisions = with nuclear overlap

New



ALI-PREL-546778

- Inclusive measurement of the **J/ψ polarization is compatible with transverse polarization** within ~ 1.6σ.
- λ_θ value consistent with UPC measurement within uncertainties => Indication in favor of **SCHC**
- Polarization measurement is another way to **probe the production mechanisms** at low p_T

  (contribution of **coherent photoproduction is ~ 76.8%** , as discussed in arXiv:2204.10684)

Summary and outlook

Peripheral collisions (PCs) :

- First measurement of ***y*-differential coherent J/ψ photoproduction cross section** in Pb—Pb collisions with nuclear overlap at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV
  - A **rapidity dependence of the coherent J/psi photoproduction** cross section is observed
  - **Models based on UPC calculations and modified to account for the nuclear overlap region** qualitatively describe the measurement

- First measurement of **inclusive J/Ψ polarization for p_{T} < 300 MeV/*c*** in Pb—Pb collisions with nuclear overlap at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV
  - Results consistent with **transverse polarization (SCHC scenario)** and in line with dominant photoproduction mechanisms at play at low p_{T}

Ultra Peripheral collisions (UPCs) :

- First measurement of ***t*-dependent incoherent J/ψ photoproduction cross section** in Pb—Pb collisions with UPC
  - Suggests model including **subnucleon quantum fluctuations** describe the measurement

Summary and outlook

Outlook :

- Extraction of coherent J/Ψ **photonuclear cross section ($\sigma_{\gamma Pb}$)** in two Bjorken-x regions using both UPC and PC results
  - — Permits to solve the ambiguity of photon emitter, J.G. Contreras, Phys. Rev. C 96, 015203 (2017)

- With Run 3 : Improved **precision of the coherent J/Ψ photoproduction** measurements
  - — Towards more central collisions at both mid and forward y
  - — Double differential measurements as a function of centrality and rapidity
  - — Better significance of polarization measurements and access to other vector mesons

Back up

Vector Meson (VM) photo production in HICs with nuclear overlap

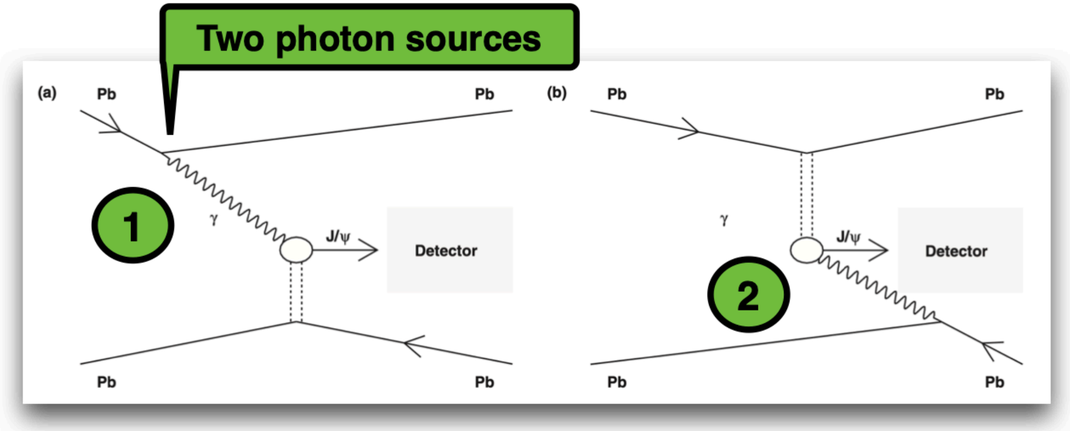
An idea to disentangling the low and high x_g contributions in J/ψ photoproduction

Measured cross section from Pb-Pb collisions

Photon flux at rapidity ±y in the impact parameter range (b1,b2)

$$\frac{d\sigma_{\mathrm{PbPb}}}{dy} = n_\gamma(y; b_{1,2})\sigma_{\gamma\mathrm{Pb}}(y) + n_\gamma(-y; b_{1,2})\sigma_{\gamma\mathrm{Pb}}(-y)$$

Photonuclear cross section: QCD!



Theoretical challenge :

Current available theoretical approach is based on UPC -like model with modified γ flux and/or modified $\sigma_{\gamma Pb}$ to account for overlap

A novel way to $\sigma_{\gamma Pb}$ when combined to UPC measurement? (see J.G. Contreras, Phys. Rev. C 96, 015203 (2017), Zha et al. , Phys. Rev. C97 (2018) 4, 044910)

Caveat: need to understand time ordering of the interaction and theoretical open questions related to the treatment of the nuclear overlap

Survival of coherence condition for a broken nuclei ? Only spectator nucleons participating to coherence ?

Ref : https://indi.to/NRwVH

Vector Meson (VM) photo production in HICs with nuclear overlap

At forward rapidities 2 dominates (95% of the cross section)

Guzey et al, Phys.Lett. B726 (2013) 290-295

At midrapidity both contributions are equal, no problem

What we measure | What we want | What we want

$$\frac{d\sigma_{\mathrm{PbPb}}}{dy} = n_\gamma(y;\{b\})\sigma_{\gamma\mathrm{Pb}}(y) + n_\gamma(-y;\{b\})\sigma_{\gamma\mathrm{Pb}}(-y)$$

1 2

Photonuclear cross sections at two rapidities, i.e. Bjorken-x

How to extract the photonuclear cross section if the photon fluxes are known?

Perform two independent measurements at the same rapidity, but different impact parameter, then solve the equations.

$$\left(\frac{d\sigma_{\mathrm{PbPb}}}{dy}\right)_A = n_\gamma(y;\{b\}_A)\sigma_{\gamma\mathrm{Pb}}(y)+n_\gamma(-y;\{b\}_A)\sigma_{\gamma\mathrm{Pb}}(-y)$$

$$\left(\frac{d\sigma_{\mathrm{PbPb}}}{dy}\right)_B = n_\gamma(y;\{b\}_B)\sigma_{\gamma\mathrm{Pb}}(y)+n_\gamma(-y;\{b\}_B)\sigma_{\gamma\mathrm{Pb}}(-y)$$

For example, use peripheral and ultra-peripheral collisions

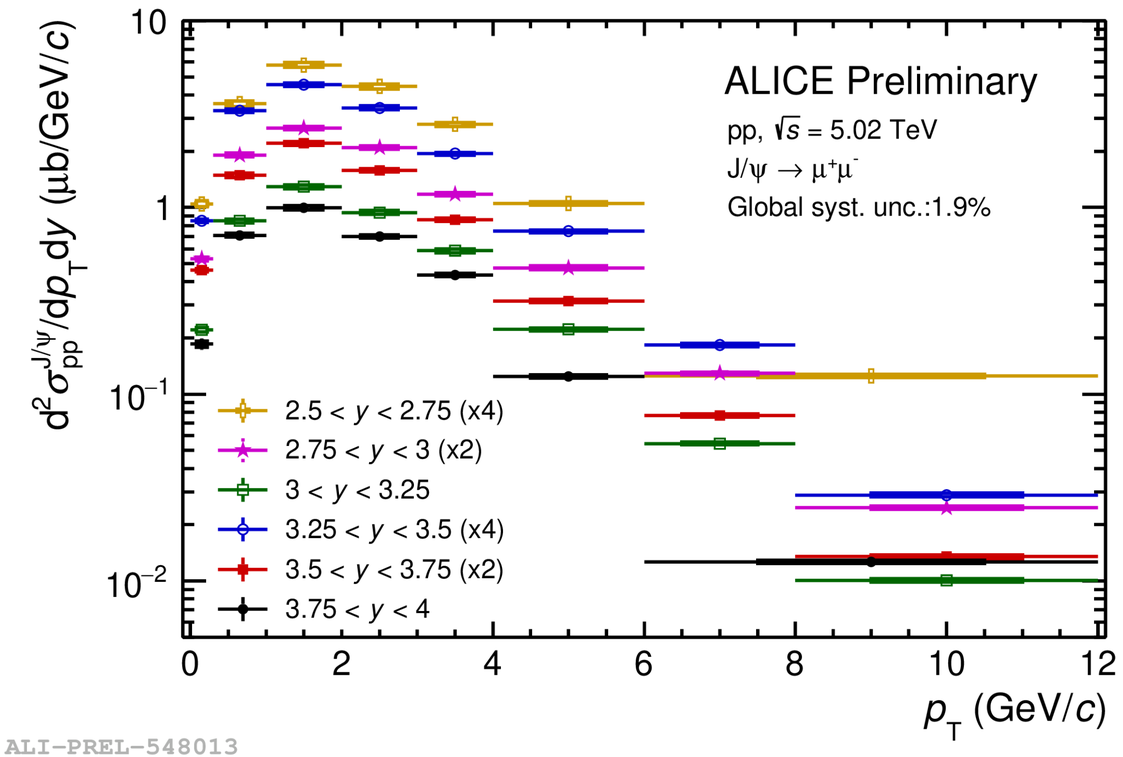
JGC, PRC **96**, 015203 (2017)

Ref : https://indi.to/NRwVH

p_T differential raw yield vs. rapidity

New

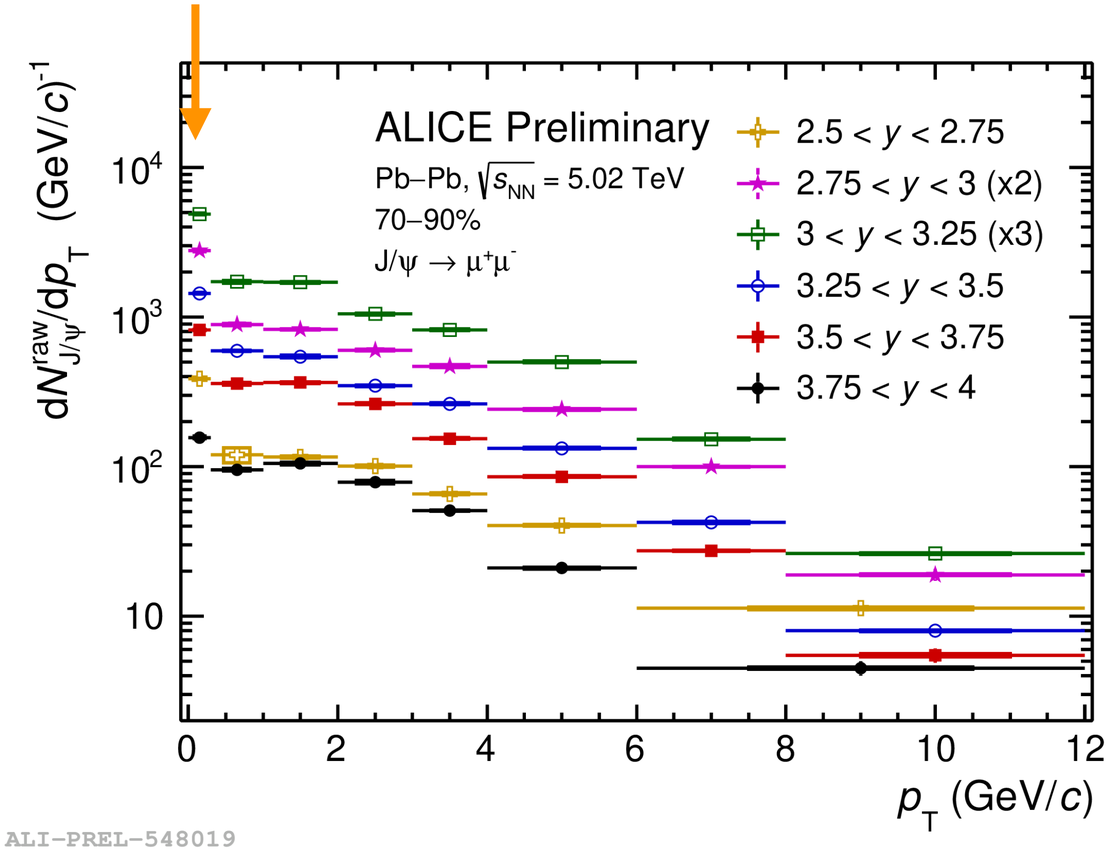
pp collisions



ALI-PREL-548013

New

Pb-Pb collisions



ALI-PREL-548019

- Excess of the J/Ψ yield as a function of rapidity at low p_T (< 0.3 GeV/c) is observed w.r.t hadroproduction in peripheral Pb-Pb collisions

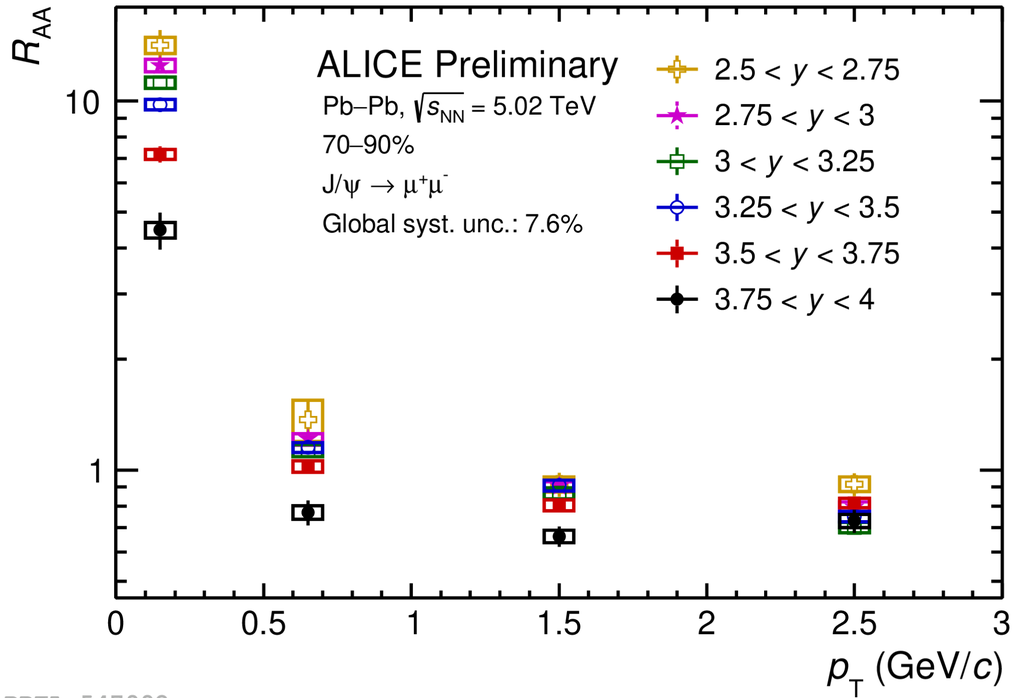
Model Assumptions

GBW/IIM : Phys. Rev. D. 97 (2018) 116013

— γ flux : γ reaching the overlap region not considered [b-dependent area]
S2: no modification in $\sigma_{\gamma Pb}$
S3: no overlap for calculation of $\sigma_{\gamma Pb}$

Zha : Phys. Rev. C 99 (2019) 6, 061901
— Spectator coupling hypothesis (different coupling between photon and Pomeron:)

GG-hs : Phys. Rev.C 97 (2018) 2, 024901
— γ flux with constraints on impact parameter range



ALI-PREL-547992

Table 5: Photonuclear cross sections extracted from the UPC measurements using the procedure described in the text. The quoted uncertainties are uncorrelated (unc.), correlated (corr.), caused by migrations across neutron classes (mig.) and by variations of the flux fractions in the different classes (flux frac.). The lines separate the different ranges in $|y|$. Note that two photonuclear cross sections in each rapidity interval are anti-correlated.

y	$W_{\gamma Pb,n}$ (GeV)	$\sigma_{\gamma Pb}$ (μb)	unc. (μb)	corr. (μb)	mig. (μb)	flux frac. (μb)
$3.5 < y < 4$	19.12	8.84	0.30	0.68	0.02	0.04
$-4 < y < -3.5$	813.05	57.32	20.77	7.57	6.41	6.56
$3 < y < 3.5$	24.55	13.89	0.23	1.08	0.05	0.08
$-3.5 < y < -3$	633.21	46.58	6.61	5.73	3.77	3.63
$2.5 < y < 3$	31.53	16.89	0.59	1.32	0.11	0.18
$-3 < y < -2.5$	493.14	44.68	6.38	5.15	2.73	2.97
$0.2 < y < 0.8$	97.11	21.73	5.12	3.12	4.32	2.73
$-0.8 < y < -0.2$	160.10	25.00	7.33	4.88	5.43	3.91
$-0.2 < y < 0.2$	124.69	24.15	0.69	1.37	0.50	0.06

Vector meson Polarization : Experimental status

ρ^0 meson measurement : consistent with SCHC

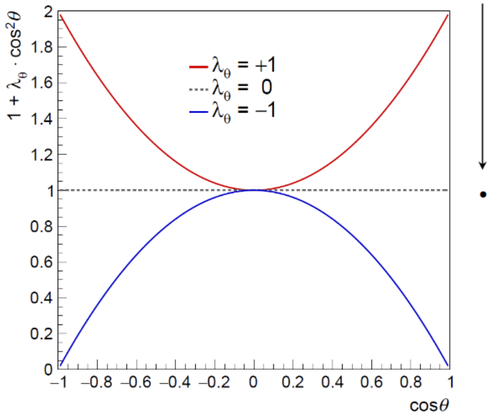
Phys. Rev. D 7, 3150, (1970) by SLAC Collaboration
Z. Phys. C 53, 581–594, (1992) by CERN SPS

ρ^0 [1] , ω[2] and φ [3] photoproduction by CLAS Collaboration : SCHC violation
[1] Eur. Phys. J. A 39, 5–31, (2009)
[2] Int. J. Mod. Phys. Conf. Ser. 26,1460063, (2014)
[3] Phys.Rev.C 90, 019901, (2014**)**

ρ0 photoproduction by STAR Collaboration : consistent with SCHC
Phys. Rev. C 77 (2008) 034910

Exclusive J/ψ photoproduction by H1 and ZEUS collaborations : consistent with SCHC
[1] Eur. Phys. J. C 46 , 585–603 (2006)

[2] Nucl. Phys. B 695, 3–37 (2004)



Do we see similar observation for J/ψ at low p_T (< 0.3 GeV/c) in Peripheral Pb-Pb collisions with nuclear overlap?

✓ Is the **J/ψ transversely polarized** and therefore obey **the SCHC hypothesis** ?

✓ Another way to test the **production mechanism** at the origin of the J/ψ **very low p_T excess**

✓ Also **complementary to the UPCs** measurement

$$r_{00}^{04} = \frac{1-\lambda_\theta}{3+\lambda_\theta}$$

$$r_{1,-1}^{04} = \frac{\lambda_\varphi}{2} \cdot (1 + r_{00}^{04}) .$$

Observables : Extract angular variables and spin density matrix element

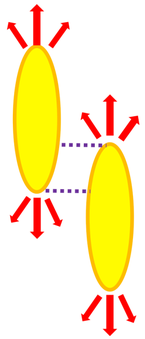
Results from UPC

- Impulse approximation: Photoproduction data from protons, does not include nuclear effects except coherence
- STARlight: Photoproduction data from protons + Vector Meson Dominance model, includes multiple scattering but no gluon shadowing [Klein, Nystrand et al: Comput. Phys. Commun. 212 (2017) 258]
- EPS09: parametrization of nuclear shadowing data [Guzey, Kryshen, Zhalov, PRC93 (2016) 055206]
- LTA: nuclear shadowing [Guzey, Kryshen, Zhalov, PRC93 (2016) 055206]
- IIM BG, IPsat, BGK-I: Color dipol-based approaches [Goncalves, Machado et al.: PRC 90 (2014) 015203, JPG 42 (2015) 105001], [T. Lappi, H. Mäntysaari, PRC 83 (2011) 065202; 87 (2013) 032201]
- GG-HS: Color dipole + hot spots [Cepila, Contreras et al. PRC97 (2018) 024901]
- LS: Color dipole model [Luszczak, Schafer: PRC 99, 044905 (2019)]
- b-BK: Color dipole + Balitsky-Kovchegov equation

Techniques for the photon direction ambiguity

Peripheral photoproduction:

- $b < R_1 + R_2$
- Hadronic interactions + photoproduction



- Simultaneously use UPC and peripheral results to get rid of the ambiguities!

$$\frac{d\sigma^{P}_{PbPb}}{dy} = n_P(\gamma,+y)\cdot\sigma_{\gamma Pb}(+y) + n_P(\gamma,-y)\cdot\sigma_{\gamma Pb}(-y)$$
$$\frac{d\sigma^{U}_{PbPb}}{dy} = n_U(\gamma,+y)\cdot\sigma_{\gamma Pb}(+y) + n_U(\gamma,-y)\cdot\sigma_{\gamma Pb}(-y)$$

J.G. Contreras PRC 96 (2017) 015203

Coherent J/ψ with neutron emission

$$\frac{d\sigma^{0N0N}_{PbPb}}{dy} = n_{0N0N}(\gamma,+y)\cdot\sigma_{\gamma Pb}(+y) + n_{0N0N}(\gamma,-y)\cdot\sigma_{\gamma Pb}(-y)$$
$$\frac{d\sigma^{0NXN}_{PbPb}}{dy} = n_{0NXN}(\gamma,+y)\cdot\sigma_{\gamma Pb}(+y) + n_{0NXN}(\gamma,-y)\cdot\sigma_{\gamma Pb}(-y)$$

y	n_γ(0n0n)	n_γ(0nXn+Xn0n)	n_γ(XnXn)	$\sigma^{IA}_{\gamma Pb}$ (μb)
$3.5 < y < 4$	178.51	18.18	6.34	10
$3 < y < 3.5$	162.99	18.19	6.34	14
$2.5 < y < 3$	147.46	18.19	6.34	19
$0.2 < y < 0.8$	77.88	17.88	6.33	48
$-0.2 < y < 0.2$	62.86	17.47	6.27	58
$-0.8 < y < -0.2$	48.31	16.75	6.18	71
$-3 < y < -2.5$	3.91	4.97	2.78	176
$-3.5 < y < -3$	1.22	2.15	1.42	215
$-4 < y < -3.5$	0.26	0.61	0.48	262

ALICE, arXiv:2305.19060