J/ψ photoproduction dans ALICE

Daniel Tapia Takaki

IPN Orsay (CNRS-IN2P3)

Étretat 2012: Rencontres QGP France

Étretat, Normandy, France, 26 September 2012

Latest ALICE results

IPN INSTITUT DE PHYSIQUE NUCLÉAIRE ORSAY — UNIVERSITÉ PARIS SUD Comprendre le monde, construire l'avenir® — cnrs IN2P3 Les deux infinis — ALICE

J/ψ measurements in ultra-peripheral Pb+Pb collisions with ALICE

Daniel Tapia Takaki

On behalf of the ALICE Collaboration

Diffraction 2012

International Workshop on Diffraction in High Energy Physics

Puerto del Carmen, Lanzarote, Canary Islands (Spain)

12 September 2012

1

Presented for the first time at **Diffraction 2012**

12 Sept

Cornell University Library

arXiv.org > nucl-ex > arXiv:1209.3715 — Search or Arti

Nuclear Experiment

Coherent J/Psi photoproduction in ultra-peripheral Pb-Pb collisions at \sqrt{s_NN} = 2.76 TeV

ALICE Collaboration

(Submitted on 17 Sep 2012)

The ALICE collaboration has made the first measurement at the LHC of J/Psi photoproduction in ultra-peripheral Pb-Pb-collisions at \sqrt{s_NN} = 2.76 TeV. The J/Psi is identified via its dimuon decay in the forward rapidity region with the muon spectrometer for events where the hadronic activity is required to be minimal. The analysis is based on an event sample corresponding to an integrated luminosity of about 55 mub-1. The cross section for coherent J/Psi production in the rapidity interval -3.6 < y < -2.6 is measured to be dsigma/dy = 1.00 +/- 0.18 (stat) +0.24/-0.26 (syst) mb. The result is compared to theoretical models for coherent J/Psi production and found to be in good agreement with models which include nuclear gluon shadowing.

Subjects: **Nuclear Experiment (nucl-ex)**; High Energy Physics - Experiment (hep-ex); High Energy Physics - Phenomenology (hep-ph)
Report number: CERN-PH-EP-2012-270
Cite as: arXiv:1209.3715 **[nucl-ex]**
(or arXiv:1209.3715v1 **[nucl-ex]** for this version)

Submission history

From: Joakim Nystrand [view email]
[v1] Mon, 17 Sep 2012 16:34:43 GMT (151kb)

Put on arXiv: **1209.3715** CERN-PH-EP-2012-270

17 Sept

Sent to PLB

Plan of this talk

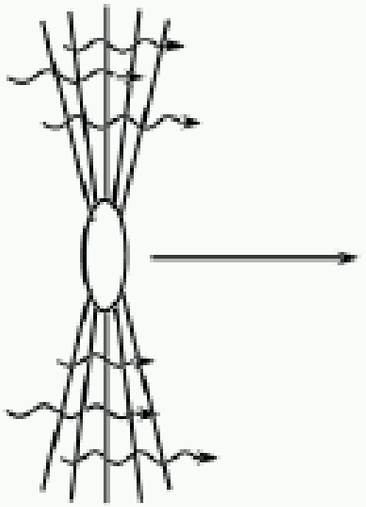
- **Ultra-Peripheral (heavy-ion) Collisions**
  - What are UPC
  - Why at the LHC
  - Why at ALICE

Coherent J/ψ cross section in UPC Pb-Pb

- Trigger strategy and analysis steps
- Differential cross section measurement
- Model comparisons

Summary and Outlook

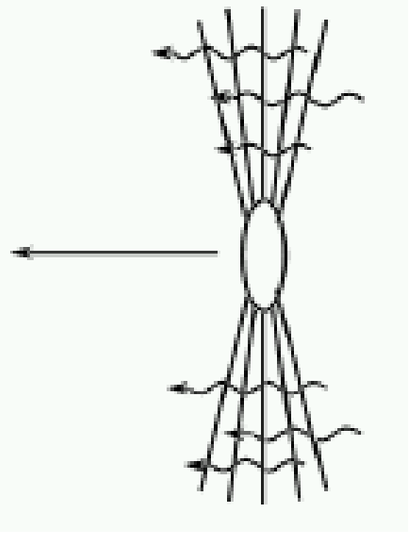
Why ultra-peripheral heavy-ion collisions



Two ions (or protons) pass by each other with impact parameters $b > 2R$. **Hadronic interactions are strongly suppressed**

Number of photons scales like Z^2 for a single source ⇒ exclusive particle production in heavy-ion collisions dominated by electromagnetic interactions.

The virtuality of the photons → $1/R \sim 30$ MeV/c



See talks by W. Schaefer, and M. Melo Machado

Coherent production:

Photon couples coherently to all nucleons

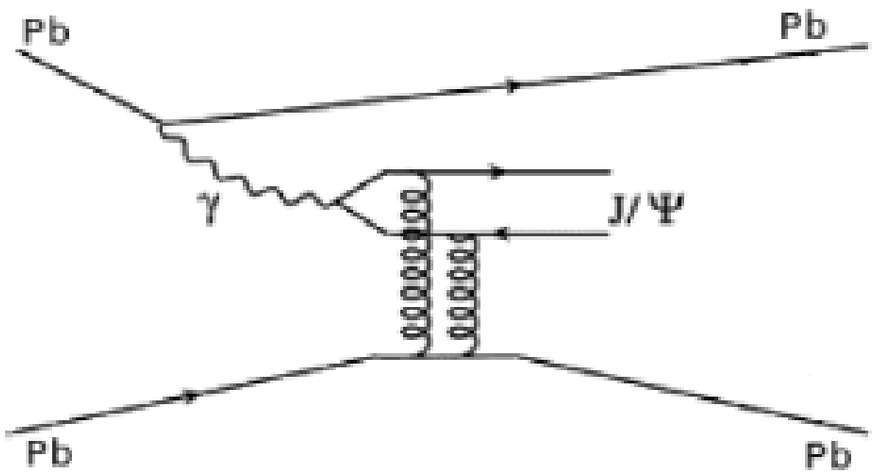
$\langle p_T \rangle \sim 60$MeV/$c$; target nucleus normally does not break up

Incoherent production

Photon couples to a single nucleon

Quasi-elastic scattering off a single nucleon

$\langle p_T \rangle \sim 500$ MeV/c



$\gamma + p \rightarrow J/\psi + p$

modelled in pQCD: exchange of two gluons with no net-colour transfer

A big jump in energy ...

RHIC: $W_{\gamma N,max} \sim 34$ GeV

HERA: $W_{\gamma N,max} \sim 300$ GeV

LHC: $W_{\gamma N,max}$ reaches up to 950 GeV !

Why J/ψ photo-production at LHC

ALICE

Probe the gluon distribution of the nuclei → low Bjorken-*x* poorly known

Total J/ψ cross section: 23 mb (STARLIGHT) *vs* 10.3 mb Rebyakova, Strikman and Zhalov

$$\frac{d\sigma_{\gamma T \to J/\psi T}(t=0)}{dt} = \frac{16\Gamma_{ee}\pi^3}{3\alpha_{em}M_{J/\psi}^5}\left[\alpha_s(\mu^2)xG_T(x,\mu^2)\right]^2$$

At leading order pQCD, depends quadratically on the gluon distribution

Models differ by the way photo-nuclear interaction is treated...

STARLIGHT
http://starlight.hepforge.org

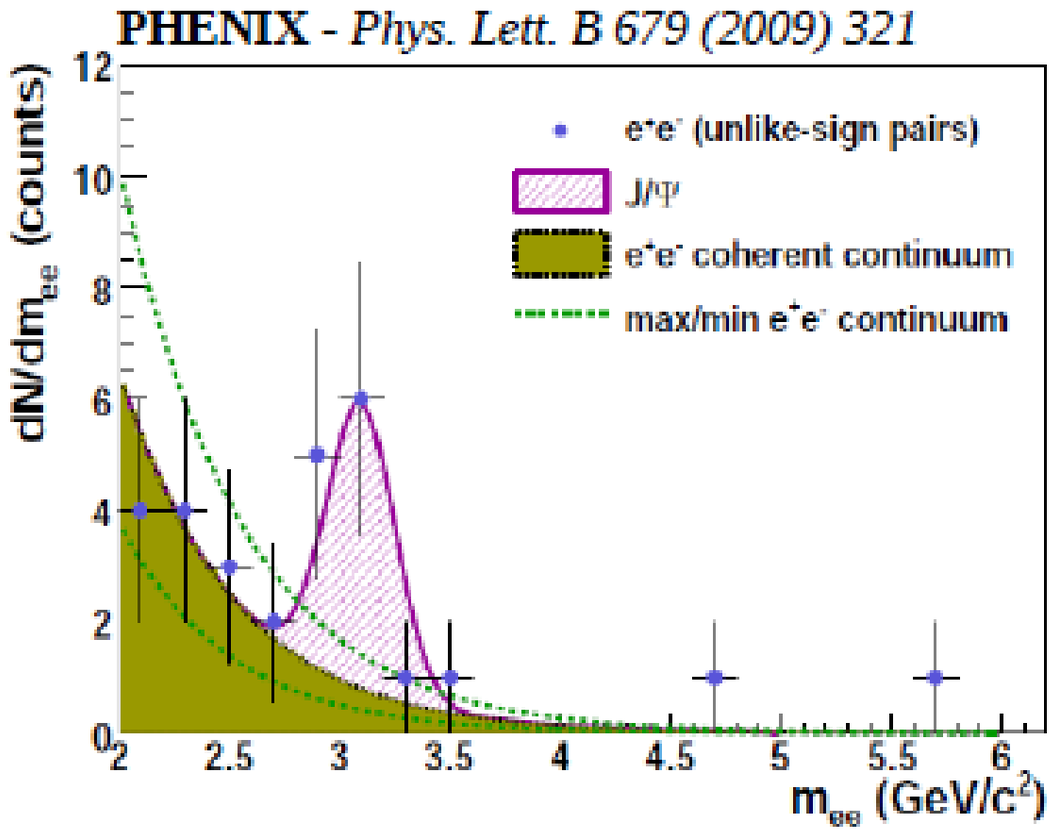
Adeluyi and Bertulani (AB)
Phys. ReV. C 85 (2012) 044904

Goncalves and Machado (GM)
Phys. ReV C 84 (2011) 011902

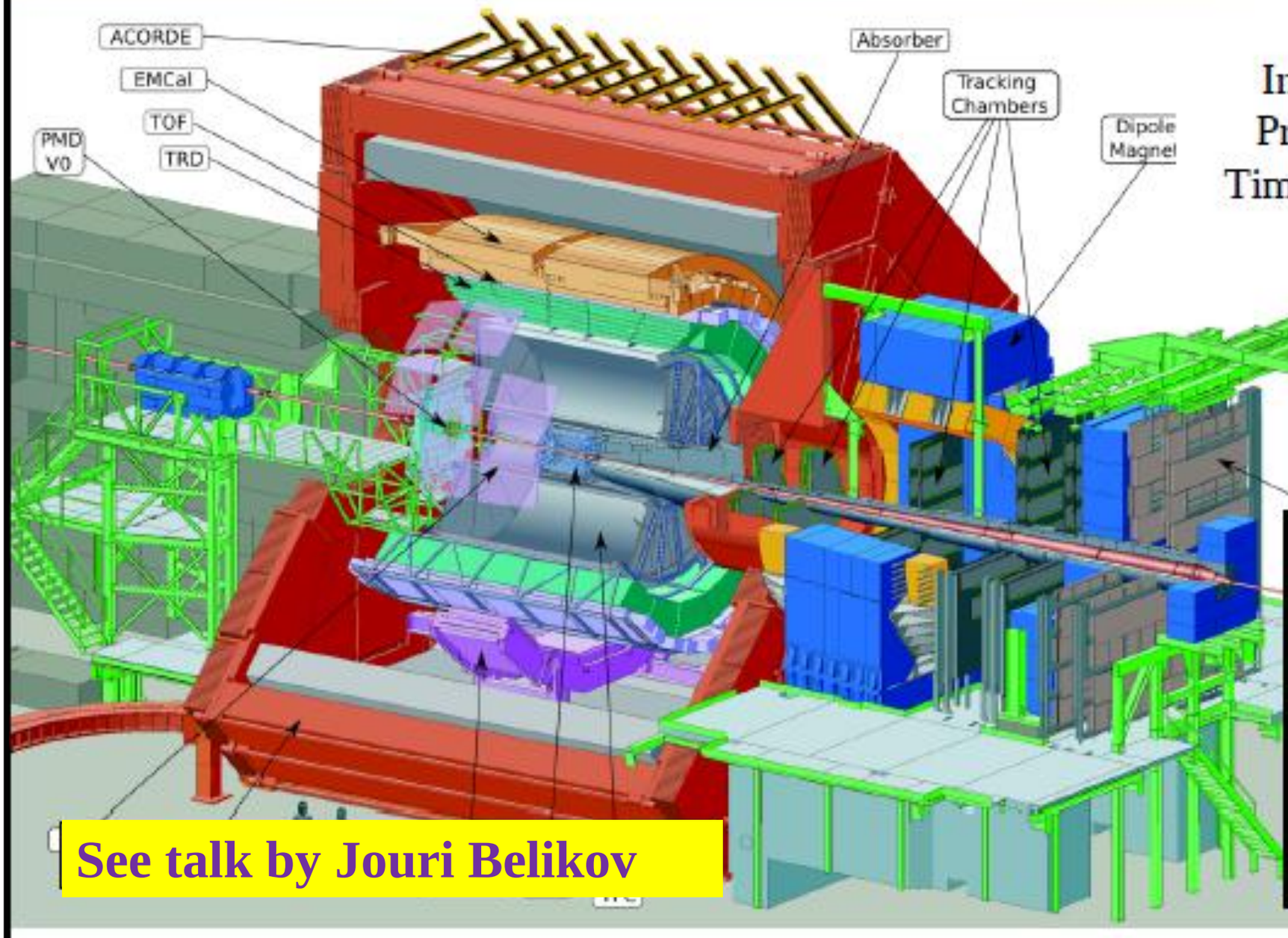
Cisek, Szczurek, Schafer (CSC)
Phys. ReV. C 86 (2012) 014905

Rebyakova, Strikman and Zhalov (RSZ)
Phys. Lett. B 710 (2012) 252

Five model predictions available
– published in the last two years-
only one measurement in J/ψ UPC so far



Quarkonia measurements at ALICE



Central rapidity ALICE

Inner Tracking (ITS), Time Projection Chamber (TPC), Time-of-Flight, TRD, EMCAL

$|\eta| < 0.9$

Forward rapidity

Muon Spectrometer

$-4 < \eta < -2.5$

UPC forward trigger

it requires

a) a single muon trigger above 1 GeV/c p_T

b) at least one hit in VZERO-C

c) no hits in VZERO-A

See talk by Jouri Belikov

Forward detectors used in this analysis:

VZERO-A: $2.8<\eta<5.1$; VZERO-C: $-3.7<\eta<-1.7$

ZDC: 116 m on either side of the IP

ALICE can measure J/ψ mesons down to zero p_T

Exclusive J/ψ analysis at **forward rapidity**

Results from 2011 Pb-Pb

Integrated luminosity ~ 55 μb^{-1}

Event selection

Beam gas and hadronic rejection (VZERO and ZDC)

SPD to veto activity at central rapidity

MUON selection

Muon track matching

$-3.7 < \eta^{\mu} < -2.5$

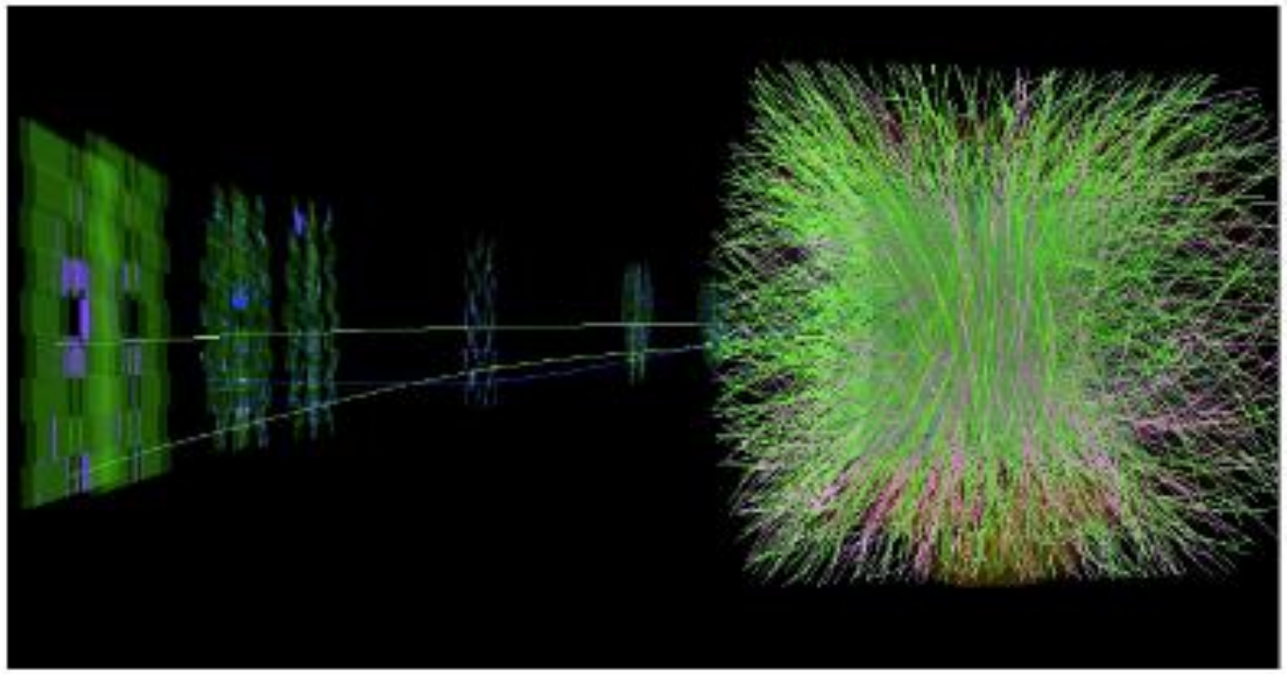
$17.5 < R_{abs} < 89.5$ cm; radial position at end of absorber

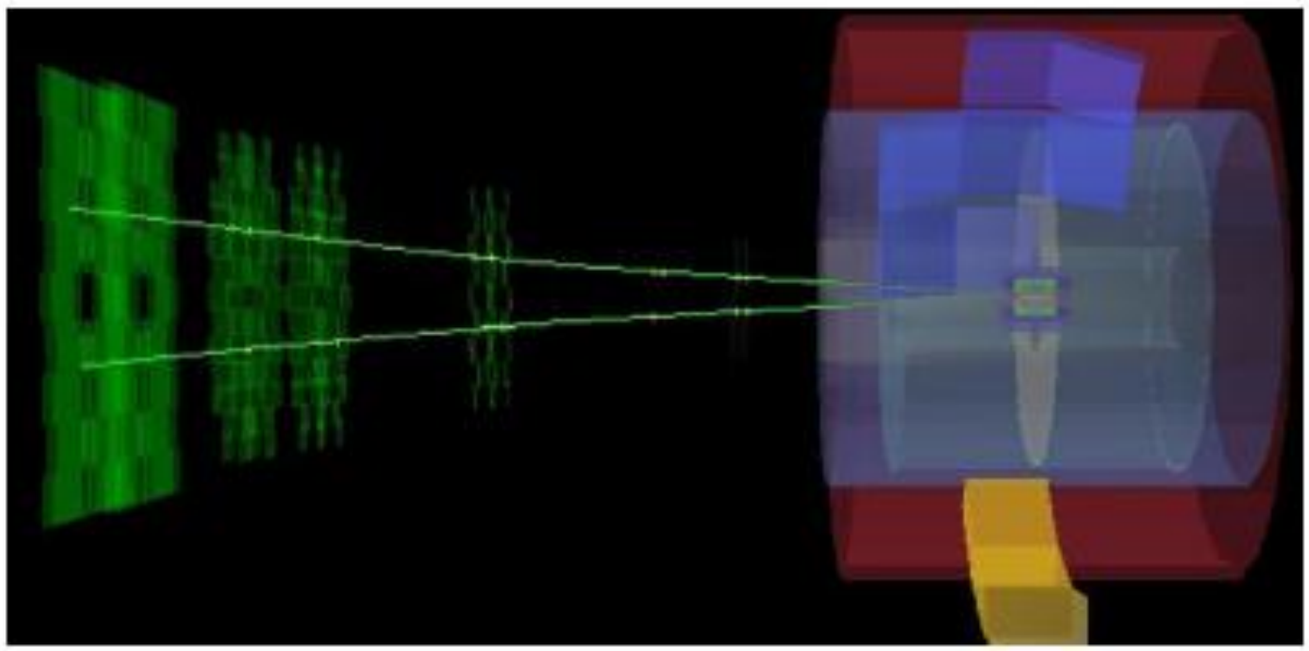
$-3.6 < y < -2.6$

1 opposite sign dimuon

Dimuon $p_T < 0.3$ GeV/c

Exclusive J/ψ analysis at **forward rapidity**





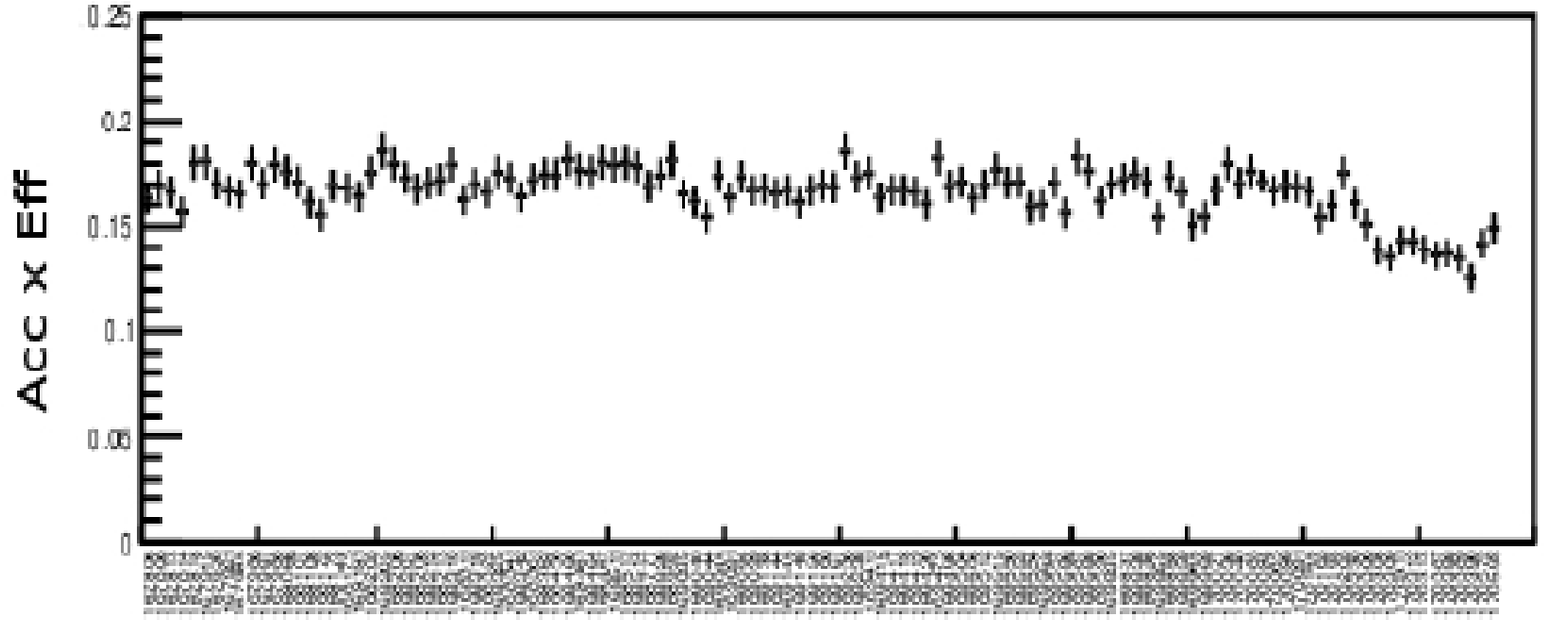
From a typical inclusive J/ψ candidate in Pb-Pb collisions...

....to an exclusive J/ψ candidate

Selected events are rather clean.

Only 6 J/ψ events out of 117 have 1 SPD tracklet → not removed as this level of activity is consistent with random hit combination (electronic noise)

Acc *x* Eff corrections



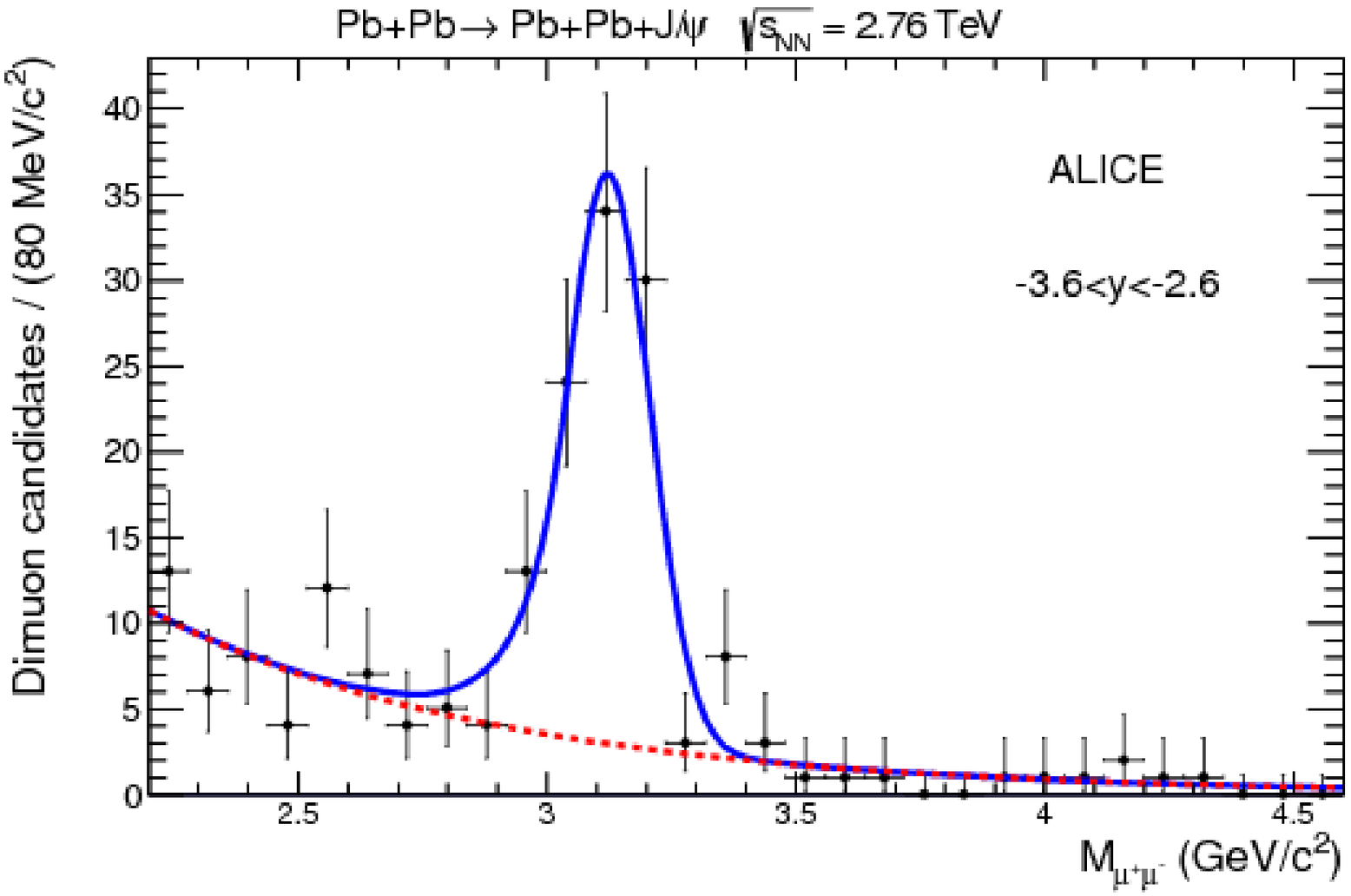
Realistic MC simulations for J/ψ events

- STARLIGHT generator used as input
- Residual misaligment
- Time-dependent conditions of tracking/trigger chambers
- Assumed J/ψ is transversaly polarised → consistent with previous measurements by ZEUS/H1

Acc x Eff ~ 17% for coherent J/ψ

Signal yield extraction

Exactly two oppositely charged muons



Only two like-sign pairs → Combinatorial background <2% at 90% CL around J/ψ mass

Fitting functions: Crystal Ball and exponential

$$N_{\text{yield}} = 96 \pm 12(\text{stat}) \pm 6(\text{syst})$$

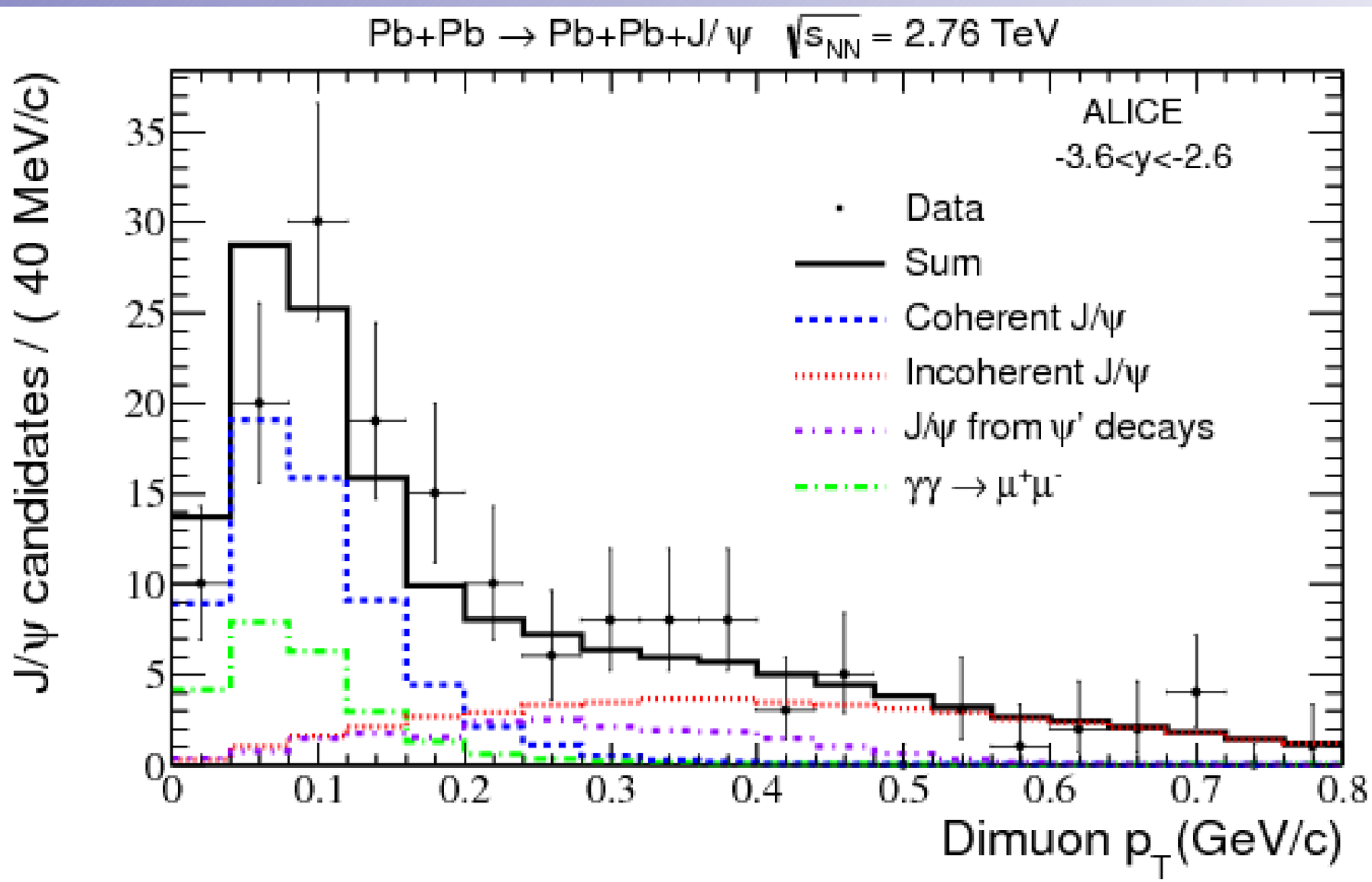
Exponential slope parameter

Data: -1.40 +/- 0.20 $\text{GeV}^{-1}c^2$

MC($\gamma\gamma \to \mu^+\mu^-$): -1.39 +/- 0.01 $\text{GeV}^{-1}c^2$

→ An additional indication that background is under control in this kinematic region

p_T distribution for J/ψ candidates



The coherent J/ψ signal is clearly visible

$$N_{J/\psi}^{coh} = 78 \pm 10(stat)^{+7}_{-11}(syst)$$

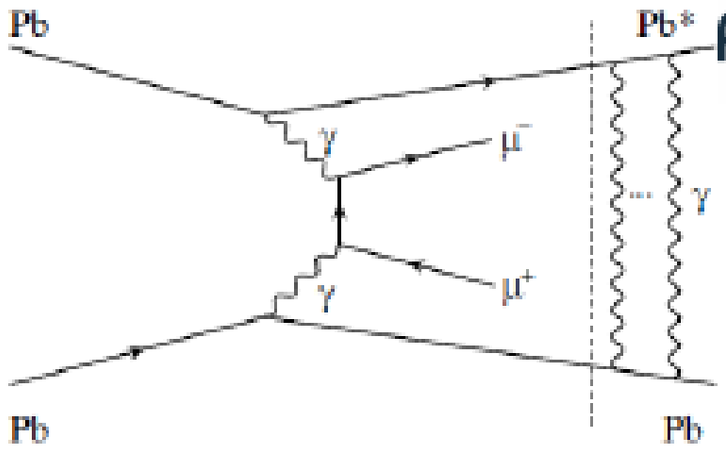
Four physics processes:

- Coherent J/ψ
- Incoherent J/ψ
- J/ψ from ψ' decays
- γγ → μ⁺μ⁻

Coherent J/ψ differential cross section

We use the QED continuum pair production ($\gamma+\gamma \rightarrow \mu^+\mu^-$) for normalisation

$$\frac{d\sigma^{coh}_{J/\psi}}{dy} = \frac{1}{BR(J/\psi \rightarrow \mu^+\mu^-)} \cdot \frac{N^{coh}_{J/\psi}}{N_{\gamma\gamma}} \cdot \frac{(Acc \times \varepsilon)_{\gamma\gamma}}{(Acc \times \varepsilon)_{J/\psi}} \cdot \frac{\sigma_{\gamma\gamma}}{\Delta y}$$



Standard QED process,but there are some caveats...

1. Uncertainty from higher order terms :

Photon coupling to the nuclei is $Z\alpha^{1/2}$ rather than $\alpha^{1/2}$. Here Z=82

Either negligible effect or a 16% reduction in the $\gamma+\gamma$ cross section

2. Uncertainty on minimum momentum transfer and nuclear form factor

3. Previous experimental results:

STARLIGHT predictions in good agreement to STAR/PHENIX measurements, but their experimental results have uncertainties between 20-30%

Theoretical uncertainty on $\gamma+\gamma \rightarrow \mu^+\mu^-$ is 20%

Systematic uncertainties

Source	Value
Theoretical uncertainty in $\sigma_{\gamma\gamma}$	20%
Coherent signal extraction	$^{+9}_{-14}$ %
Reconstruction efficiency	6%
RPC trigger efficiency	5%
J/ψ acceptance calculation	3%
two-photon $e^+ e^-$ background	2%
Branching ratio	1%
Total	$^{+24}_{-26}$ %

Normalisation

Signal extraction, f_I,and f_D

Muon tracking/trigger efficiency

Initial p_T and *y* from models

Correlated QED process in triggered events. One of the electrons hitting VZERO-A thus vetoing the event. Measured using control triggers

Coherent J/ψ differential cross section

$$\mathrm{d}\sigma^{\mathrm{coh}}_{J/\psi}/\mathrm{d}y = 1.00 \pm 0.18(\mathrm{stat})^{+0.24}_{-0.26}(\mathrm{syst})\ \mathrm{mb}$$

-3.6<y<-2.6
p_T<0.3 GeV/*c*

Theoretical predictions

1. AB-MSTW08 - No nuclear effects
All nucleons contribute to the scattering $d\sigma/dt$ at $t=0$ scales with A^2

2. STARLIGHT, CM and CSS Glauber approach to calculate the number of nucleons contributing to the scattering. Dependence on total J/ψ-nucleon cross section

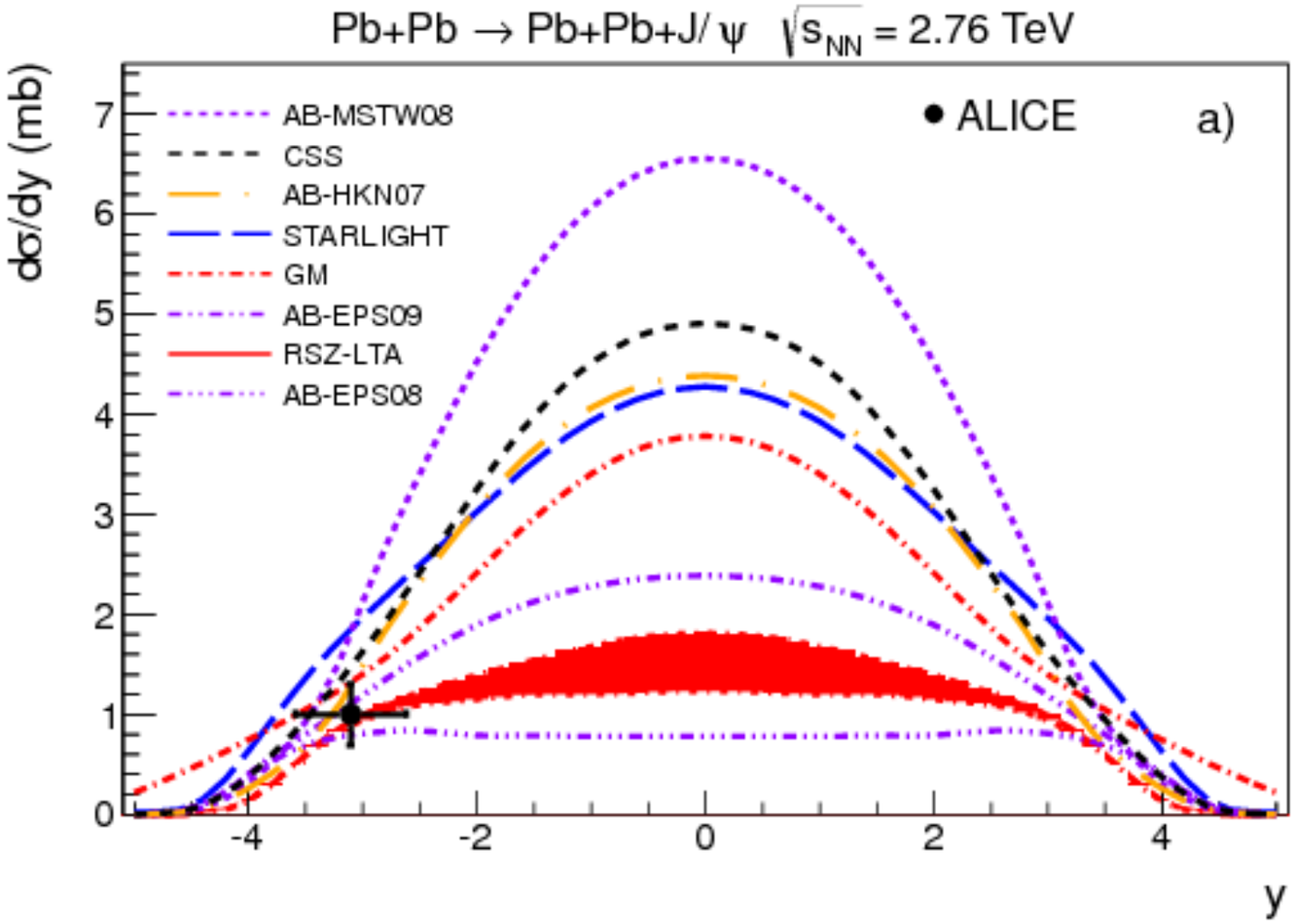
3. Partonic models (AB-EPS08, AB-EPS09, AB-HKN07, RSZ-LTA)
Cross section proportional to the nuclear gluon distribution squared

Data *vs* theoretical predictions

1. AB-MSTW08 - No nuclear effects
All nucleons contribute to the scattering dσ/dt at t=0 scales with A^2

2. STARLIGHT, CM and CSS Glauber approach to calculate the number of nucleons contributing to the scattering. Dependence on total J/ψ-nucleon cross section

3. Partonic models (AB-EPS08, AB-EPS09, AB-HKN07, RSZ-LTA)
Cross section proportional to the nuclear gluon distribution squared



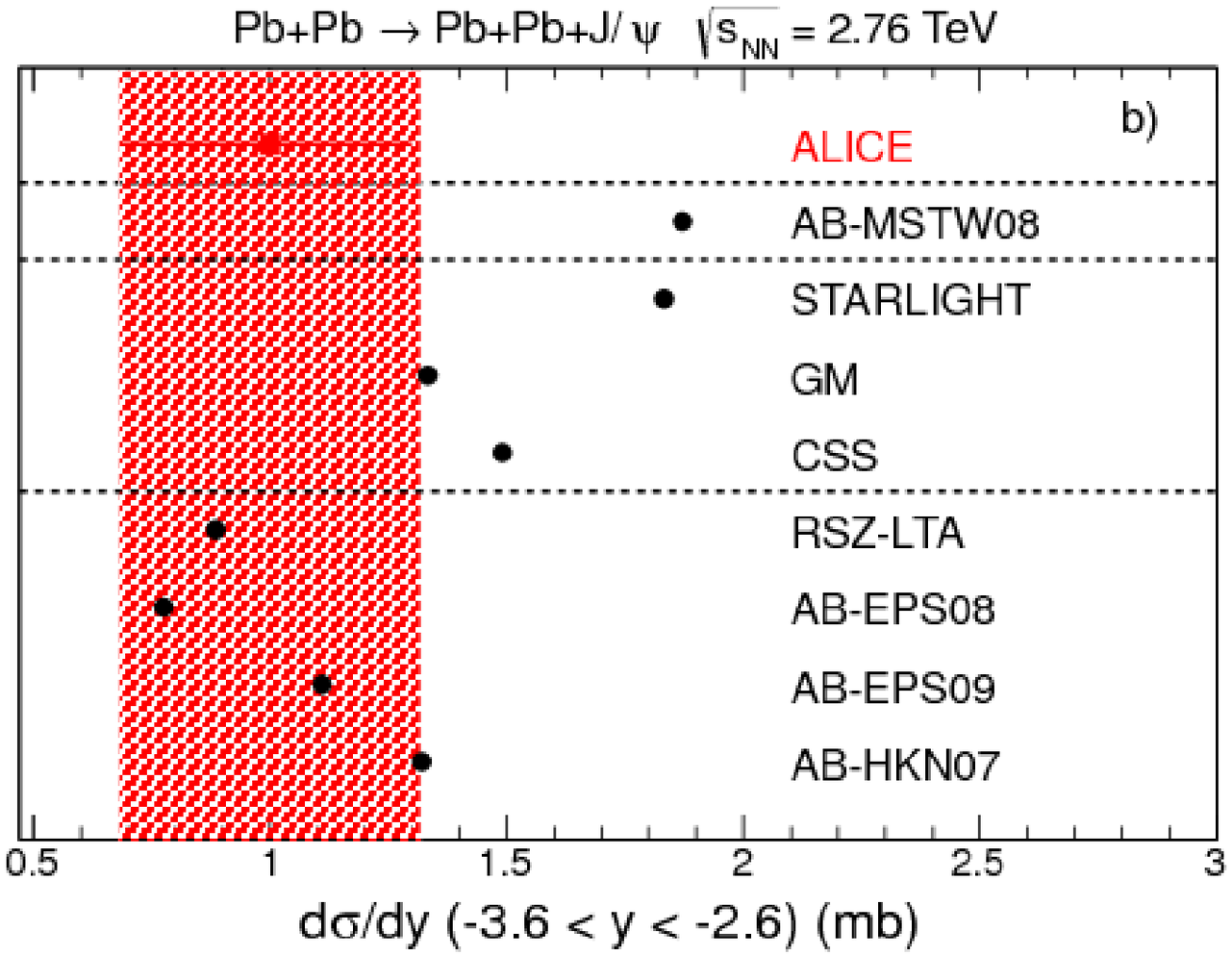
Most forward J/ψs in UPC Pb-Pb at LHC are from low photon-proton c.m.s. energy

Either nucleus can serve as photon emitter or photon target, at forward rapidity (-3.6<y<-2.6), x~10^{-2} and x~10^{-5}

The error is the quadratic sum of the statistical and systematic errors

Data *vs* theoretical predictions

Integrated cross section

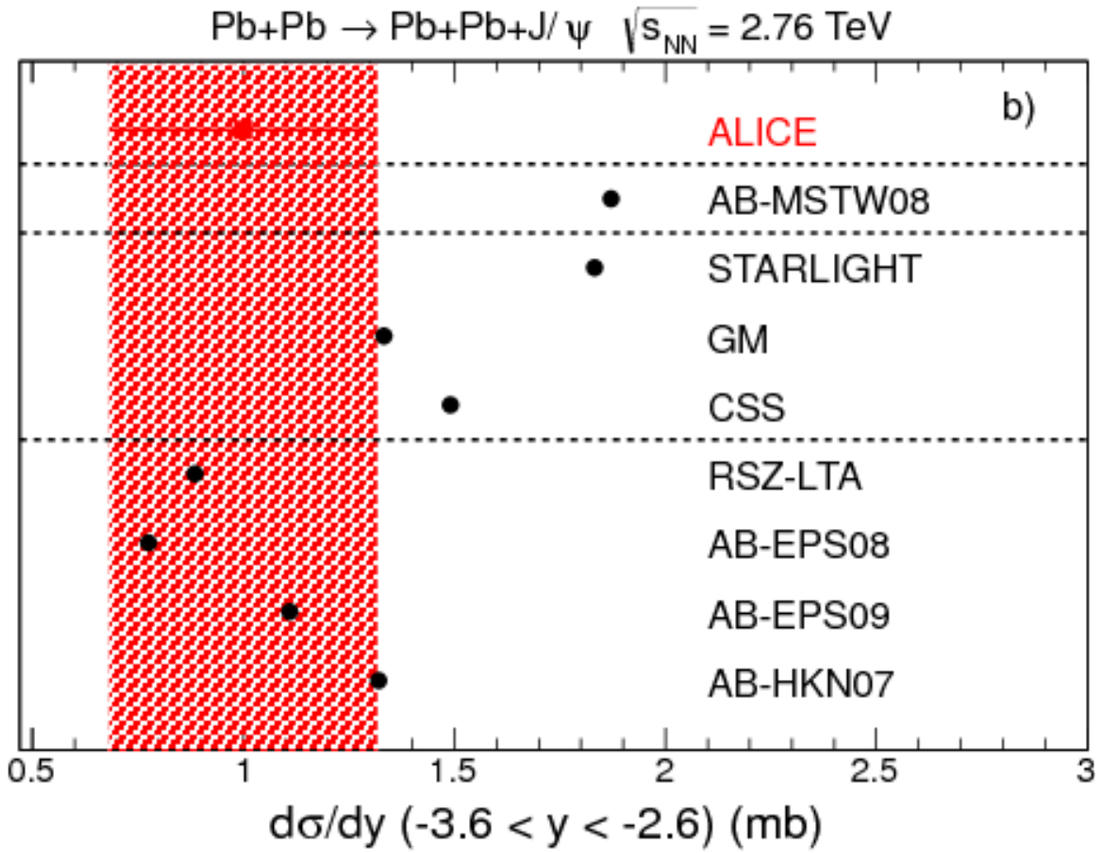


Largest deviations (3σ):
STARLIGHT and AB-MSTW08

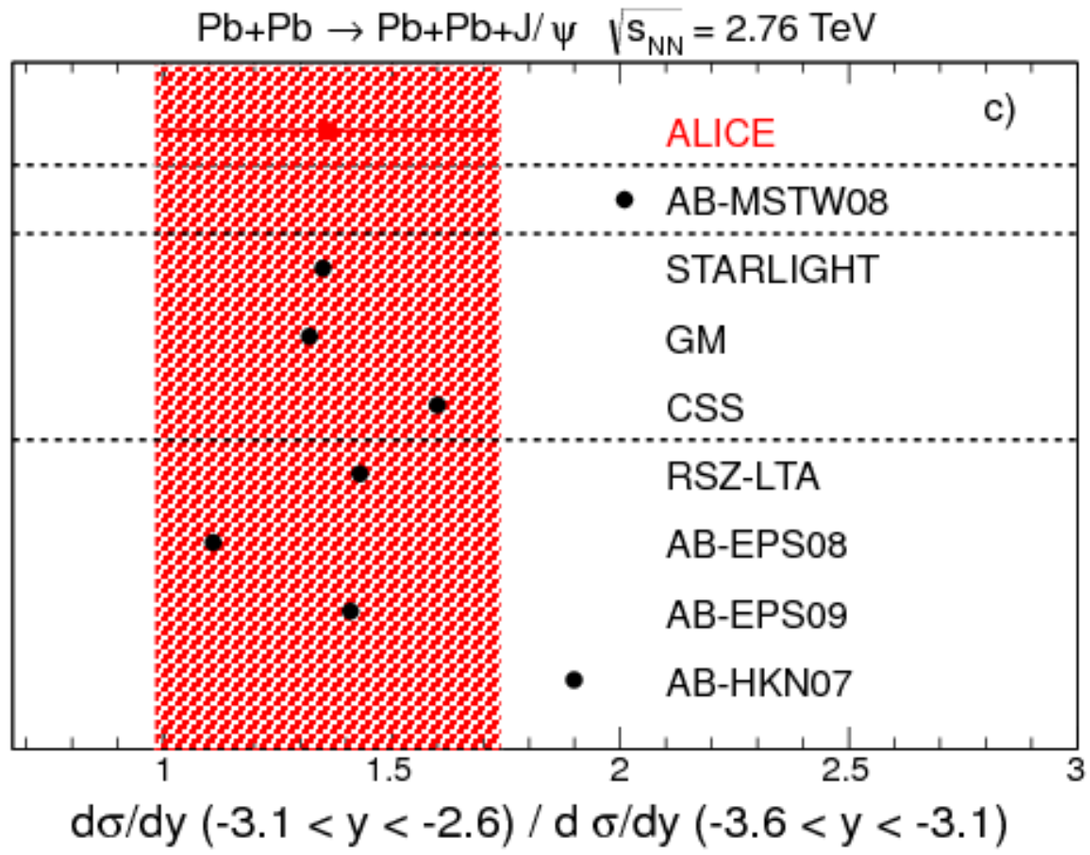
Best agreement (1σ):
RSZ-LTA, AB-EPS08 and AB-EPS09

Data *vs* theoretical predictions

Integrated cross section



Ratio of dσ/dy



$$R = \sigma(-3.1 < y < -2.6)/\sigma(-3.6 < y < -3.1) = 1.36 \pm 0.36(\text{stat}) \pm 0.19(\text{syst})$$

Largest deviations (3σ):
STARLIGHT and AB-MSTW08

Best agreement (1σ):
RSZ-LTA, AB-EPS08 and AB-EPS09

More than 1.5σ deviations:
AB-MSTW08 and AB-HKN07

Summary and conclusions

- **ALICE** has made the first LHC measurement on J/ψ photoproduction in ultra-peripheral Pb-Pb collisions at 2.76 TeV, per nucleon pair

- **Coherent J/ψ differential cross section**

$$\mathrm{d}\sigma^{\mathrm{coh}}_{J/\psi}/\mathrm{d}y = 1.00 \pm 0.18(\mathrm{stat})^{+0.24}_{-0.26}(\mathrm{syst})\ \mathrm{mb}$$

-3.6<y<-2.6
p_T<0.3 GeV/*c*

- AB-MSTW08 is strongly disfavoured. It assumes that the forward scatting cross section scales with the number of nucleons squared. STARLIGHT cross section is also disfavoured

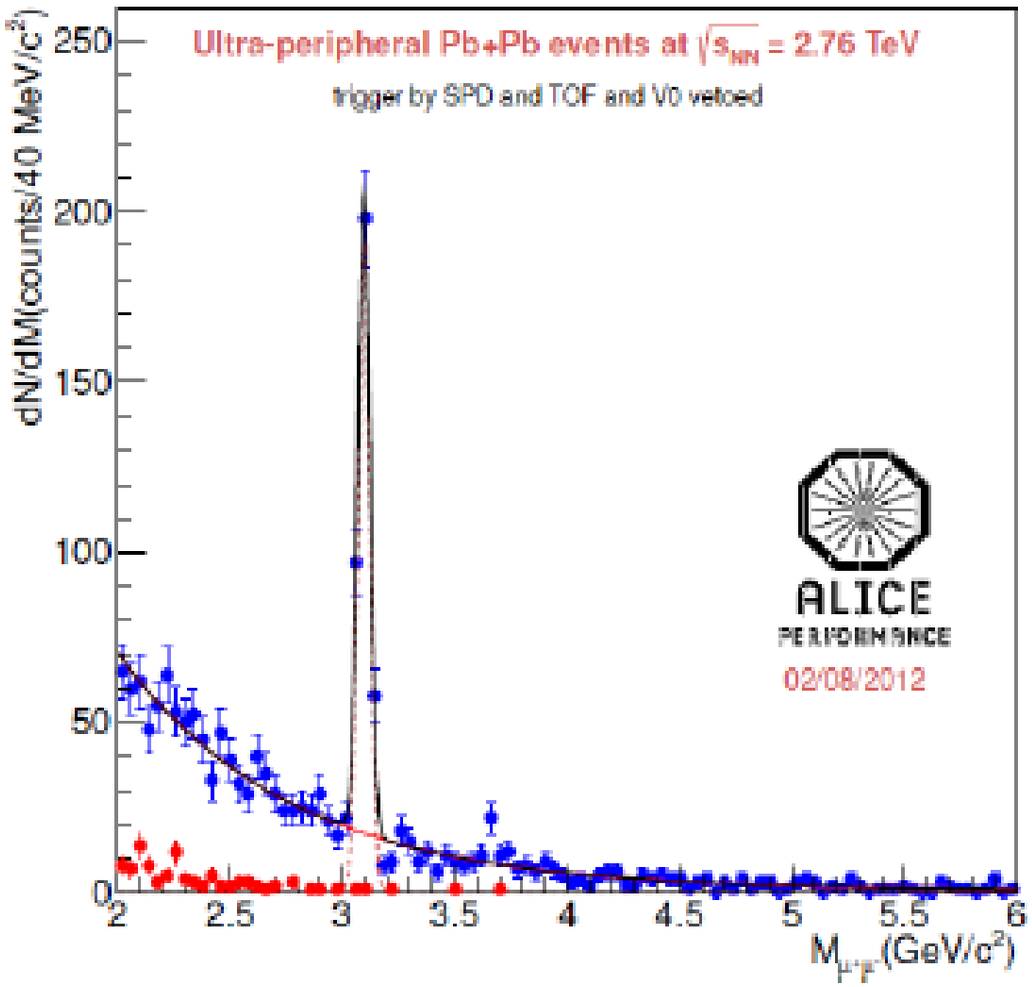
Put on arXiv:**1209.3715**
CERN-PH-EP-2012-270
17 Sept. Sent to PLB

- Best agreement is found with models that include nuclear gluon shadowing (RST-LTA, AB-EPS08, AB-EPS09)

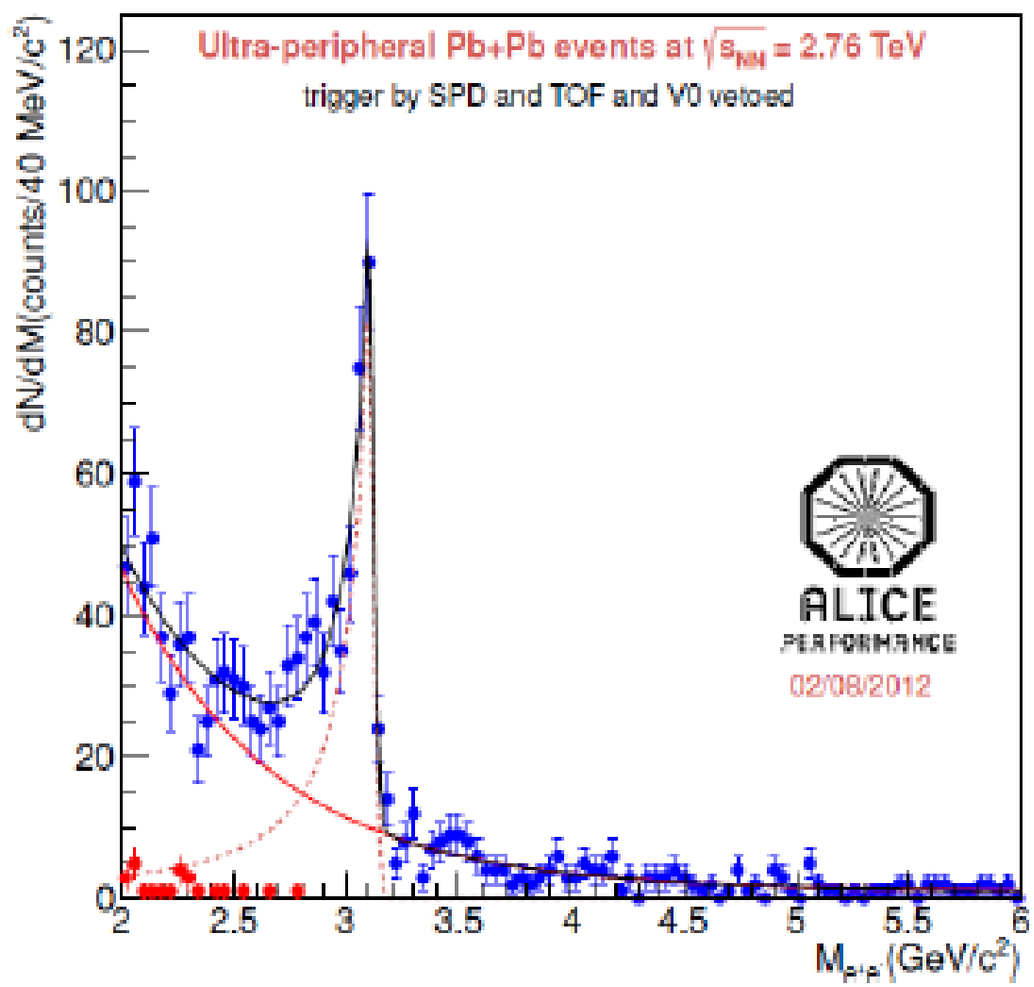
One more thing...

J/ψ photo-production at **central rapidity**

Analysis ongoing



Dimuon channel



Dielectron channel

UPC-like analyses at ALICE

- **Pb-Pb collisions**
  - –J/ψ photoproduction at forward rapidity → done
  - – J/ψ and ρ^0 photoproduction at central rapidity → ongoing
  - –J/ψ photoproduction at peripheral inclusive collisions → see Antoine's talk
- **p-p collisions**
  - – Elastic J/ψ and two-photon photoproduction at forward rapidity → ongoing
- **p-Pb and Pb-p collisions → data to be collected in 2013**
  - – J/ψ photoproduction and two-photon both central/forward rapidity

Additional slides

Coherent production?!

Four physics processes:

- Coherent J/ψ
- Incoherent J/ψ
- J/ψ from ψ' decays
- $\gamma\gamma \rightarrow \mu^+\mu^-$

$$N^{\mathrm{coh}}_{\mathrm{J}/\psi} = \frac{N_{\mathrm{yield}}}{1 + f_I + f_D}$$

Feed-down (f_D):

for example, ψ' decays to J/ψ $\pi^+\pi^-$

$$f_D^P = \frac{\sigma_{\psi'} \cdot BR(\psi' \rightarrow \mathrm{J}/\psi + \mathrm{anything}) \cdot (\mathrm{Acc} \times \varepsilon)^P_{\psi' \rightarrow \mathrm{J}/\psi}}{\sigma_{\mathrm{J}/\psi} \cdot (\mathrm{Acc} \times \varepsilon)_{\mathrm{J}/\psi}}$$

Three polarisation scenarios for ψ' decays were considered:

- No polarisation (NP)
- Full longitudinal polarisation (L)
- Full transverse polarisation (T)

According to STARLIGHT

$$f_D^{NP} = 11.9\%,\ f_D^T = 9.3\%,\ f_D^L = 16.8\%$$

According to RSZ

$$f_D^{NP} = 5.5\%,\ f_D^T = 4.3\%,\ f_D^L = 7.9\%$$

Thus, we took as the best estimate

$f_D = (11 \pm 6)\%$

J/ψ Incoherent fraction (f_I)

According to STARLIGHT

$f_I = 0.12$

According to RSZ

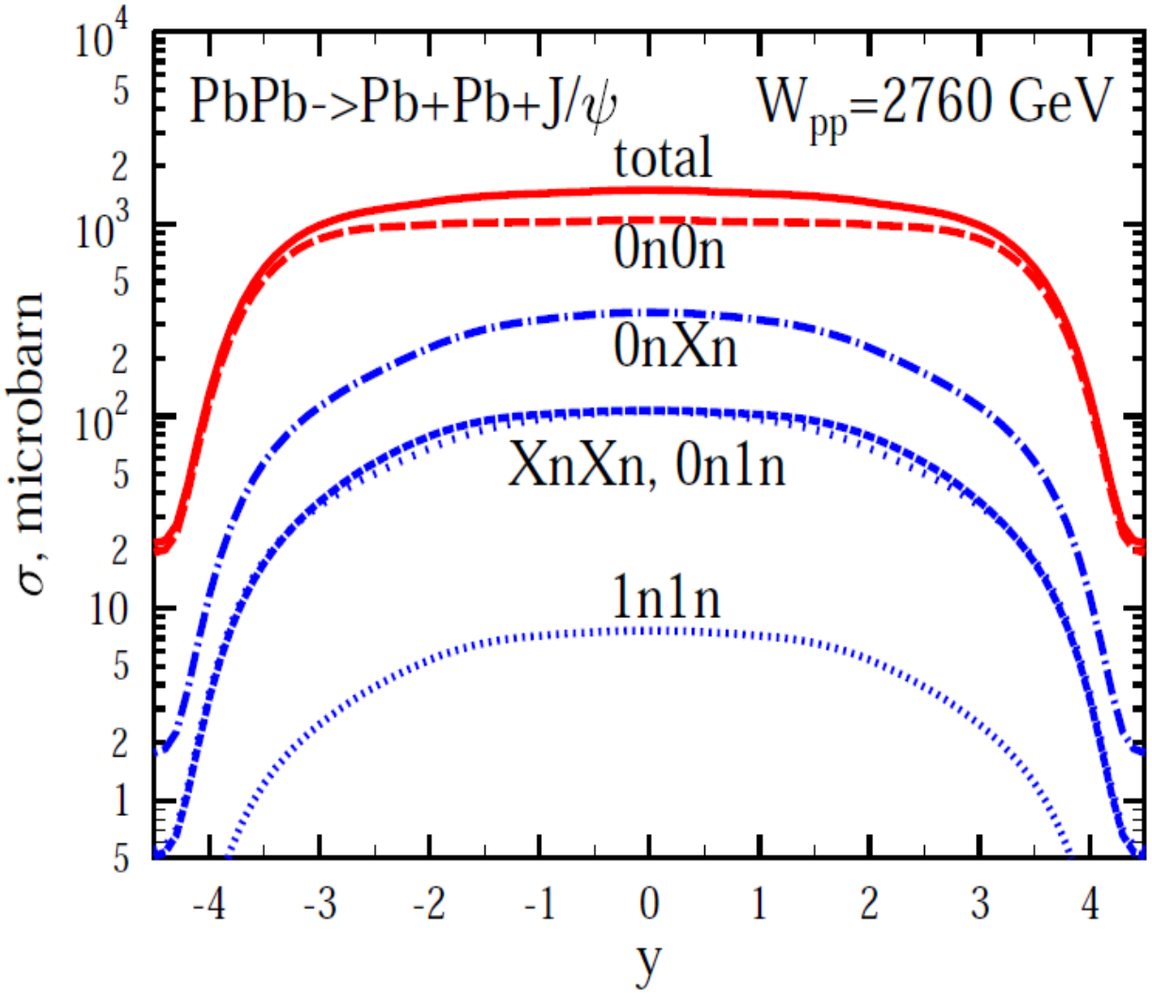
$f_I = 0.08$

Using data ...

$f_I = 0.26 \pm 0.05$ ⇒ $f_I = 0.12^{+0.14}_{-0.04}$

New at the LHC: Dependence on neutron emission

Using Zero Degree Calorimeters (ZDC) it is possible to select coherent production with ion excitation, where neutrons are emitted from at least one of the nuclei



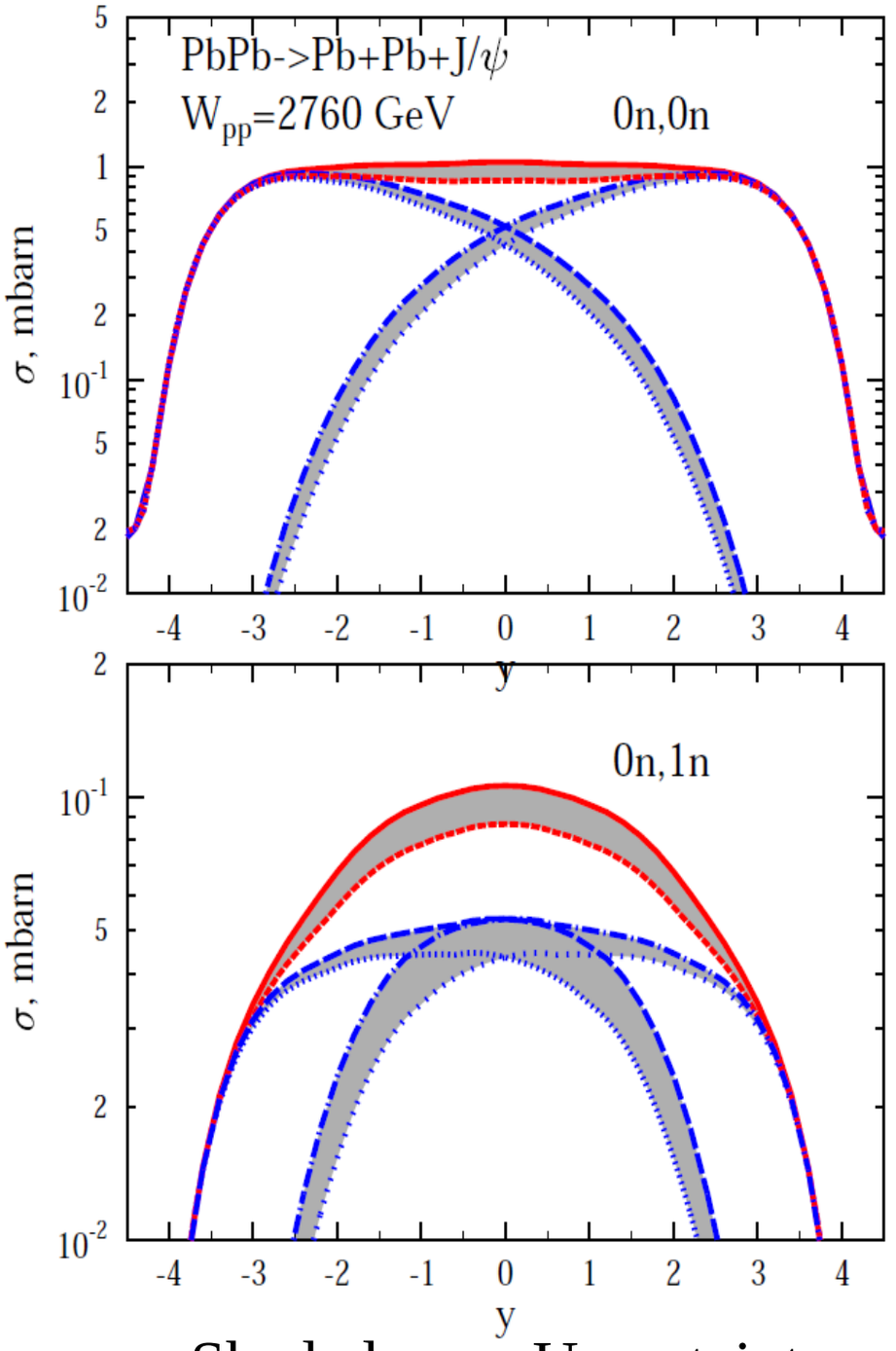
Different configurations:

1n1n: one neutron emission by each ion;

XnXn: emission of several neutrons;

0n1n and 0nXn: excitation and decay of one of the ions, and

0n0n: no neutron emission



V. Rebyakova, M. Strikman and M. Zhalov
ArXiv:1109.0737, Sept 2011

Shaded area: Uncertainty on nuclear gluon shadowing