INTERNATIONAL WORKSHOP ON DISCOVERY PHYSICS AT THE LHC
KRUGER 2012

Coherent photoproduction of J/ψ at forward rapidity in Pb–Pb with the ALICE detector

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December 3rd, 2012

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  (ALICE Collaboration, arXiv:1209.3715. Accepted by PLB.)
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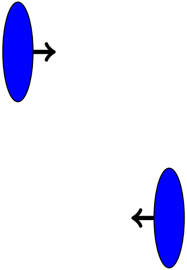
The LHC as γPb collider



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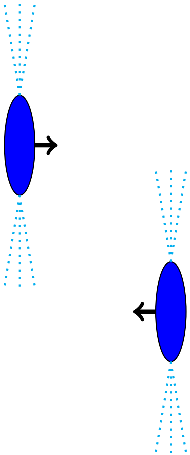

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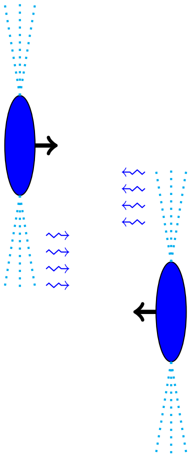

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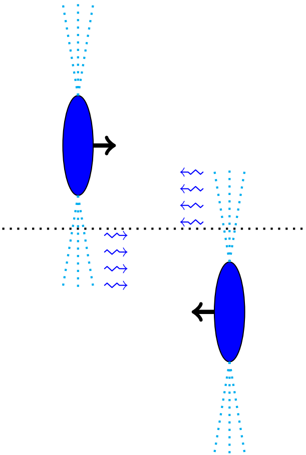

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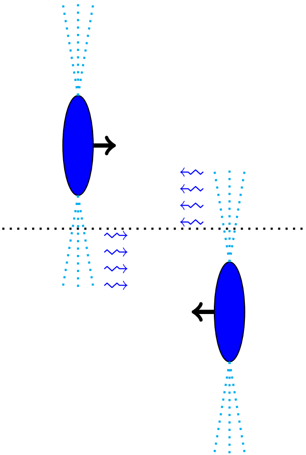

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These processes are called **ultra peripheral collisions** (**UPC**)

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$$p_T \lesssim \hbar c / R_A \approx 30 \text{ MeV}$$

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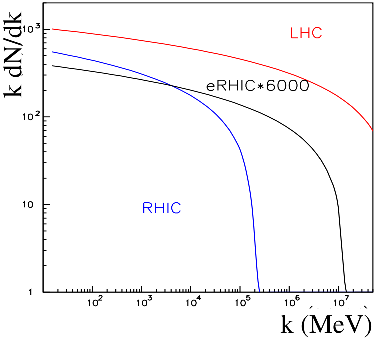
√ The flux decays with photon energy. For the 2011 Pb–Pb run:

$$\sqrt{s_{\gamma A}^{max}} \approx 450 \textbf{ GeV}$$



Photon flux as a function of the photon energy k in the rest frame of the target nucleus;
Fig. 4: Phys. Rep. **458** (2008) 1–171.

Coherent photo–production of J/ψ

$\surd$ The photon interacts **coherently** with the opposite nucleus and produces a single vector meson

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$$y = 0 \Longrightarrow W_{\gamma A} \approx 90\ \mathrm{GeV}$$

$$y = -3 \Longrightarrow W_{\gamma A} \approx \begin{matrix} 400 \\ 20 \end{matrix}\ \mathrm{GeV}$$

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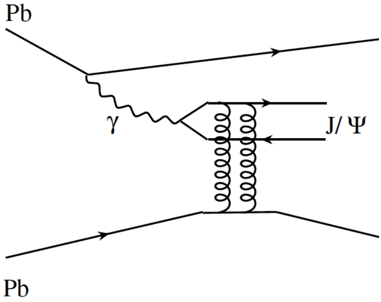
$\surd$ For $y = -3$ the flux of photons at $W_{\gamma A} \approx 400$ GeV is around 4% of the flux at $W_{\gamma A} \approx 20$ GeV

Coherent photo–production of J/ψ in QCD

In **QCD** models this diffractive process is mediated by a two gluon exchange:



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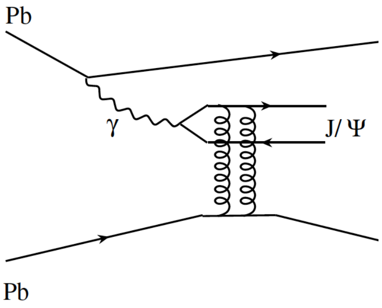

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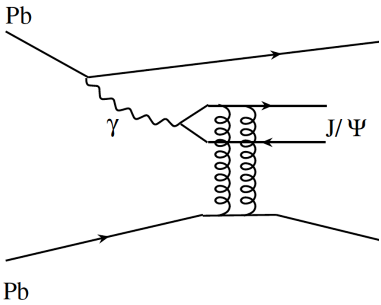

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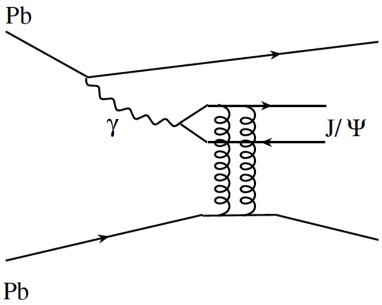

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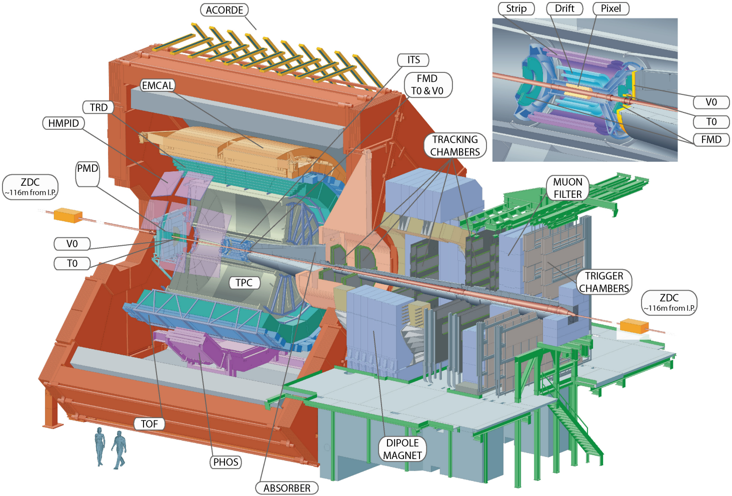
$\surd$ At $y = 0$, values of $x \approx 10^{-3}$ are probed; while at $y = -3$ the process probes $x \approx 10^{-2}$ or $x \approx 10^{-5}$

$\surd$ In this scenario the nuclear gluon distribution and its shadowing can be probed as a function of x varying y

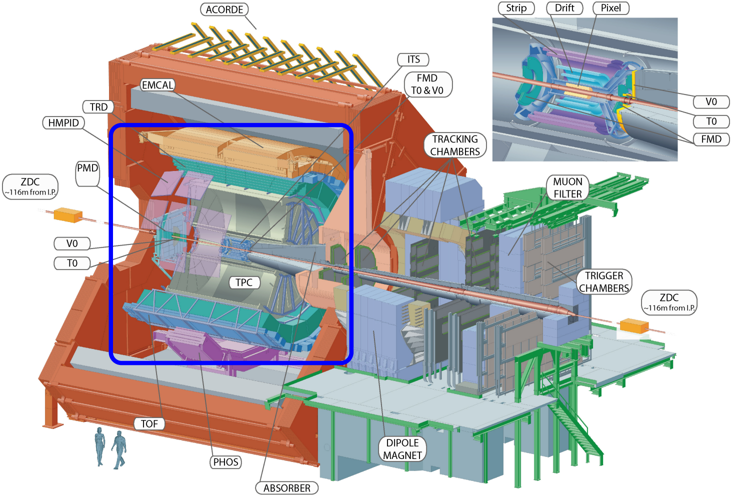
ALICE

Excellent tracking and PID capabilities



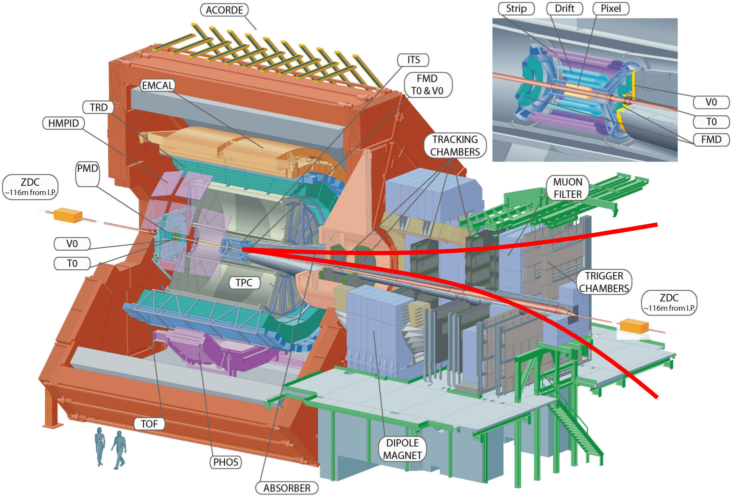
ALICE and J/ψs

At **mid rapidities** ALICE measures J/ψ in the lepton channels, $J/\psi \rightarrow e^+e^-$ and $J/\psi \rightarrow \mu^+\mu^-$, using its PID capabilities



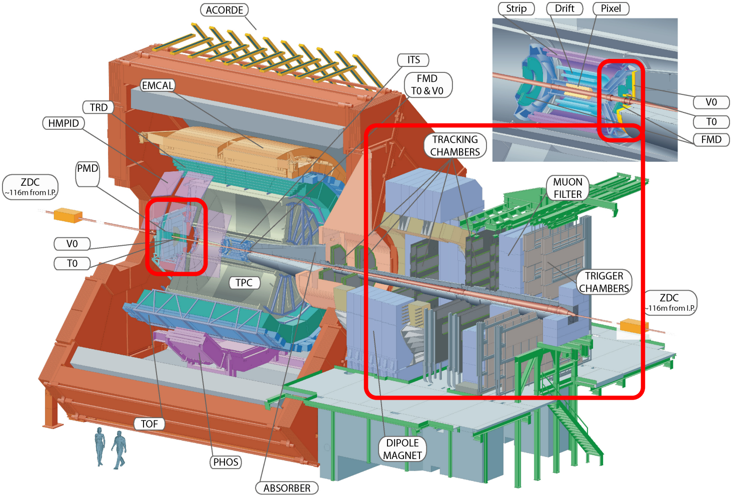
ALICE and J/ψs

At **forward rapidities** ALICE measures $J/\psi \rightarrow \mu^+\mu^-$



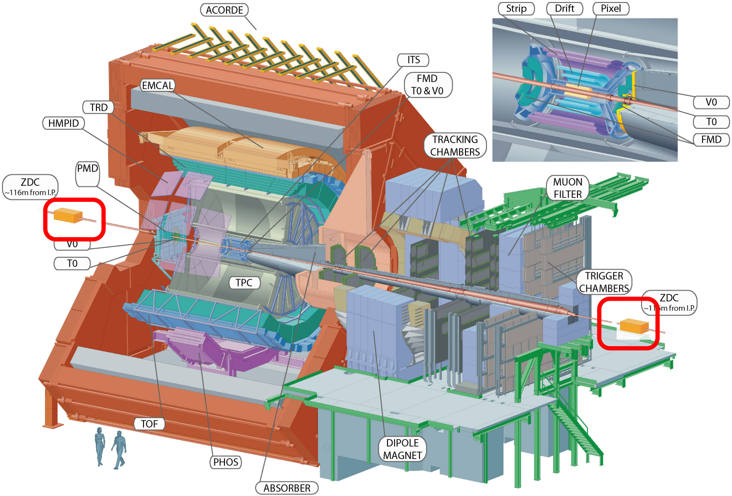
ALICE and J/ψs

The **trigger** uses the muon spectrometer and the VZERO



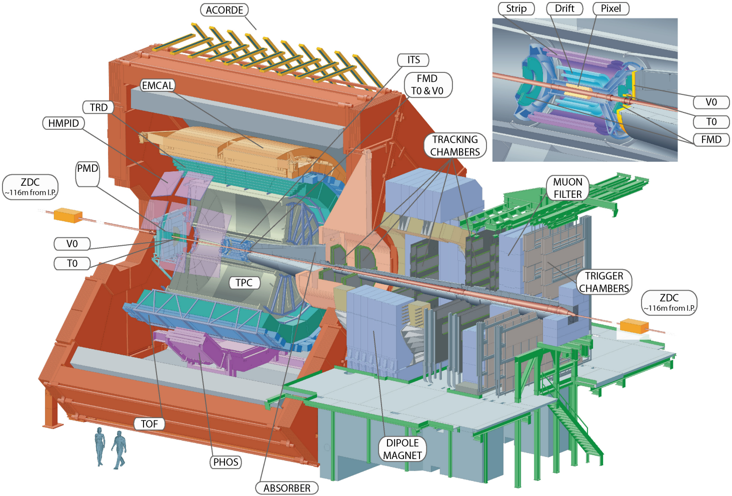
ALICE and J/ψs

The **analysis** also uses the ZDC at $\pm$ 116 m from the IP



ALICE and J/ψs

ALICE can measure the J/ψ **down to zero p_T** in both y ranges



Event selection

Using 55 μb^{-1} collected in Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV during 2011

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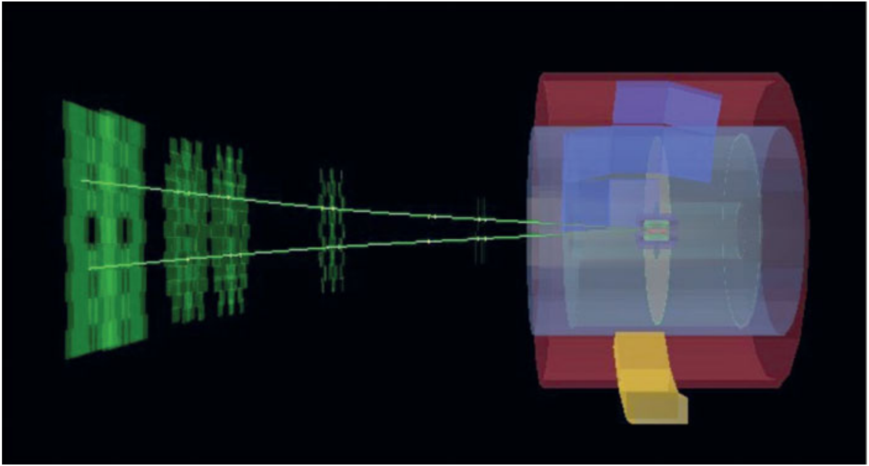
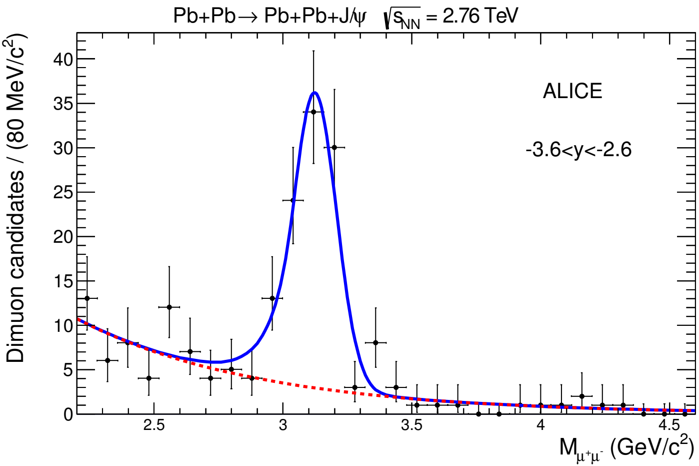
117 events remained with $2.8 < M(\mu^+, \mu^-) < 3.4$ GeV

One typical event

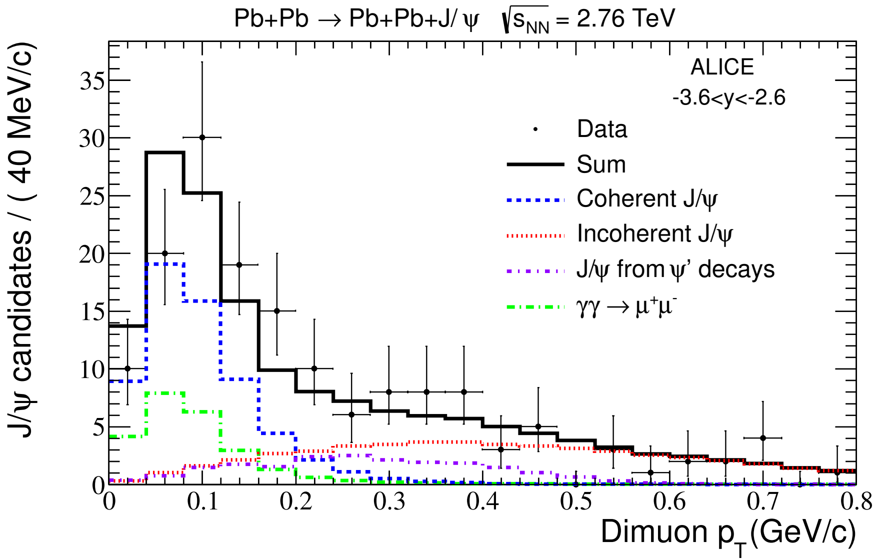


Mass distribution

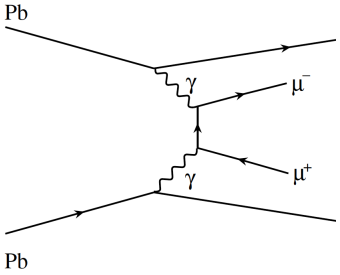


- $\surd$ Like–sign events: 2
- $\surd$ No activity somewhere else
- $\surd$ Signal fitted to a CB shape
- $\surd$ Background to an exponential
- $\surd$ Exponential shape compatible with expectations from $\gamma\gamma \to \mu^+\mu^-$

Contributions around the mass peak



Normalization



$\surd$ Process $\gamma\gamma \rightarrow \mu^+\mu^-$ used:

$$\frac{d\sigma_{\mathrm{coh}}}{dy} = \frac{1}{BR} \cdot \frac{N_{\mathrm{coh}}}{N_{\gamma\gamma}} \cdot \frac{(\mathrm{Acc\ x}\ \epsilon)_{\gamma\gamma}}{(\mathrm{Acc\ x}\ \epsilon)_{\mathrm{coh}}} \frac{\sigma_{\gamma\gamma}}{\Delta y}$$

$\surd$ Standard QED process . . .

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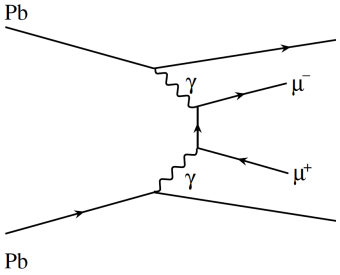

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√ Standard QED process . . . **but**

√ Uncertainty in higher order terms due to coupling $\sim Z\sqrt{\alpha}$

√ Uncertainty on minimum momentum transfer and nuclear form factor

√ Previous experimental results from RHIC also have large uncertainties and can not constraint the theory

Cross section for the photoproduction of coherent J/ψ at forward rapidities in Pb–Pb with the ALICE detector

$\surd$ Measurement at $\sqrt{s_{NN}} = 2.76$ TeV for $p_T < 0.3$ GeV and $-3.6 < y < -2.6$

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√ Systematic uncertainty: **+24/-26 %**

- Dominant contributions.
  Theoretical uncertainty on $\sigma_{\gamma\gamma}$: **20 %**, signal extraction: **+9/-14 %**
- Intermediate contributions.
  Reconstruction efficiency: **6 %**, muon trigger efficiency: **5 %**, acceptance calculation **3 %**
- Small contributions.
  $\gamma\gamma \to e^+e^-$: **2 %**, branching ratio: **1 %**

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$$\frac{d\sigma_{\mathrm{coh}}}{dy} = 1.00 \pm 0.18\ (\mathrm{stat})\ {}^{+0.24}_{-0.26}\ (\mathrm{sys})\quad \mathrm{mb}$$

Theory predictions

$\surd$: The total cross section, $\sigma(PbPb)$, is a convolution of the photon flux and the γA cross section, $\sigma(\gamma A)$

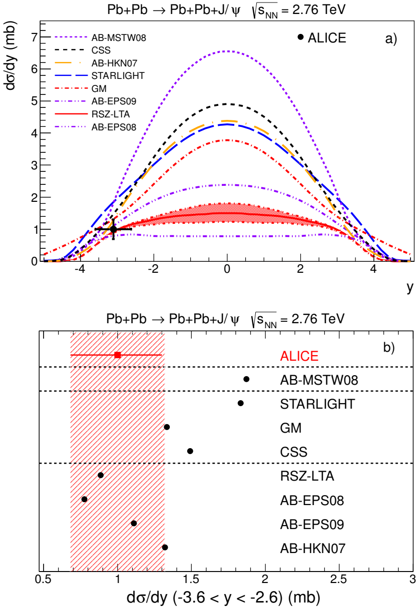
$\surd$ Some differences in the treatment of the photon flux in the different calculations, but numerically the results are similar

$\surd$ The main differences among the predictions come from the assumptions in the computation of $\sigma(\gamma A)$

$\surd$ Active field, **5 recent predictions**:

- S.R. Klein, J. Nystrand, Phys. Rev. C 60 (1999) 014903.
- V.P. Goncalves, M.V.T. Machado, Phys. Rev. C 84 (2011) 011902.
- V. Rebyakova, M. Strikman, M. Zhalov, Phys. Lett. B 710 (2012) 647.
- A. Adeluyi, C.A. Bertulani, Phys. Rev. C 85 (2012) 044904.
- A. Cisek, W. Schafer, A. Szczurek, Phys. Rev. C 86 (2012) 014905.

Comparison with Theory



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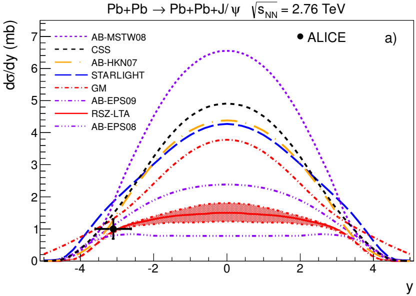

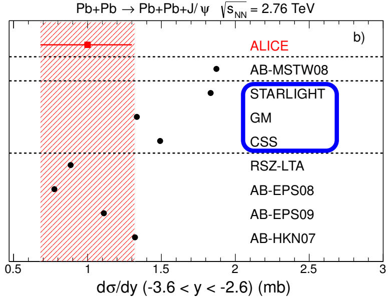

√ STARLIGHT, from Klein and Nystrand, uses a GVDM coupled to a Glauber approach to link the γA to the γp cross section, where the later is obtained from a parameterization of HERA data

√ GM is based on the color dipole model, where the scattering amplitude depends on the nuclear profile and the dipole nucleon cross section, which is taken from the IIM model which incorporates saturation

√ The CSS model uses a Glauber approach and the color dipole nucleon amplitude based on the unintegrated gluon distribution of the proton

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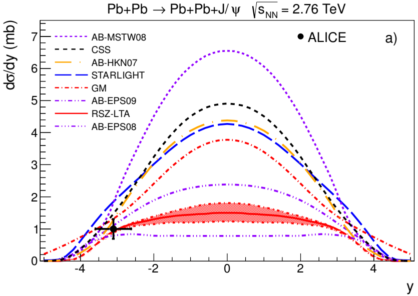

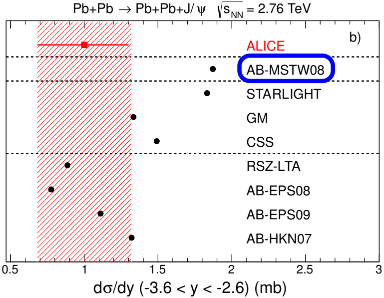

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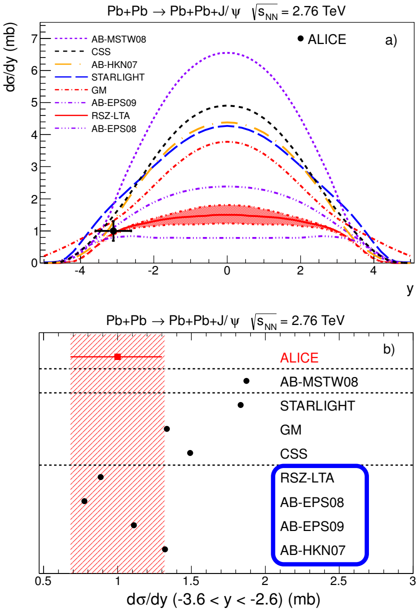

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√ The other AB models incorporate nuclear effects according to the EPS08, EPS09 or HKN07 prescriptions

√ RSZ-LTA is based on the LO pQCD amplitude for two gluon exchange where the nuclear gluon density incorporates shadowing computed in the leading twist approximation

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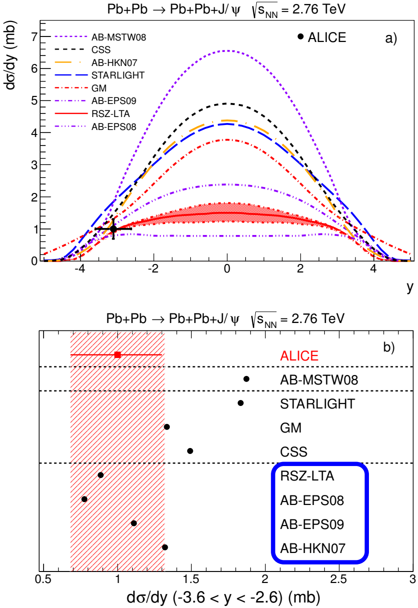

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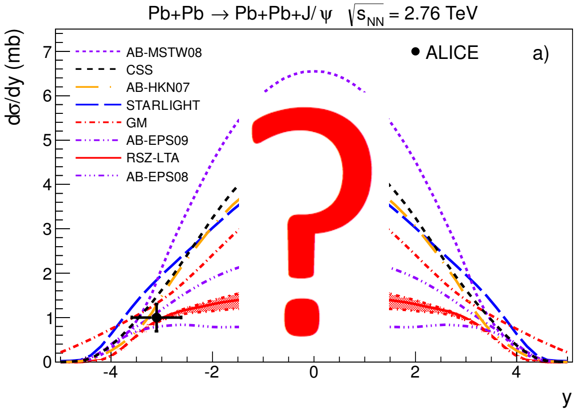
√ The other AB models incorporate nuclear effects according to the EPS08, EPS09 or HKN07 prescriptions

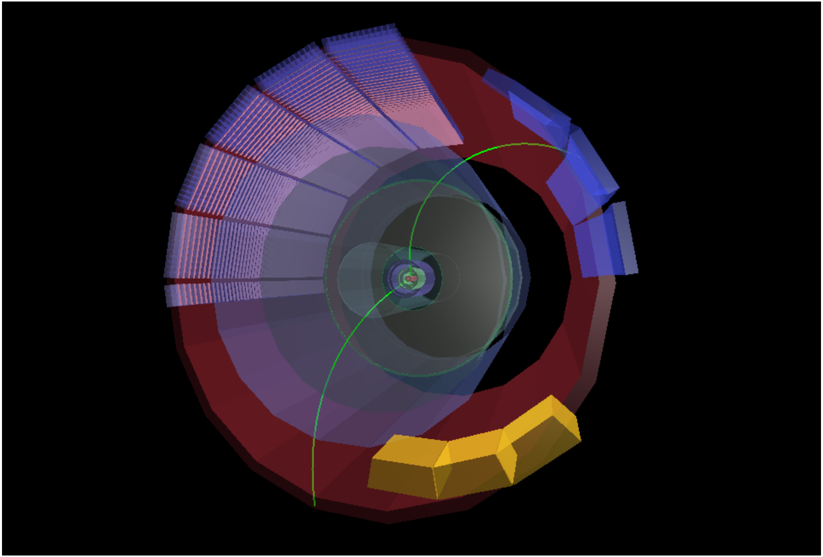
√ RSZ-LTA is based on the LO pQCD amplitude for two gluon exchange where the nuclear gluon density incorporates shadowing computed in the leading twist approximation

Models which incorporate shadowing – with the scale fixed near the mass of the J/ψ – are closer to data

Of things to come: The natural question

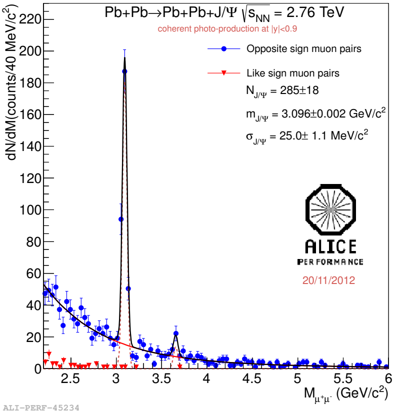


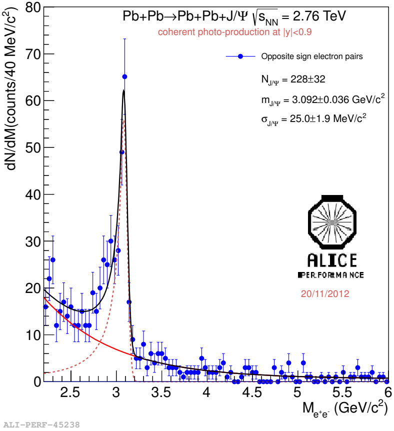
ALICE has the answer



The answer is almost available

√ Using the PID capabilities of ALICE in the central region, it is possible to measure separately $J/\psi \to \mu^+\mu^-$ and $J/\psi \to e^+e^-$





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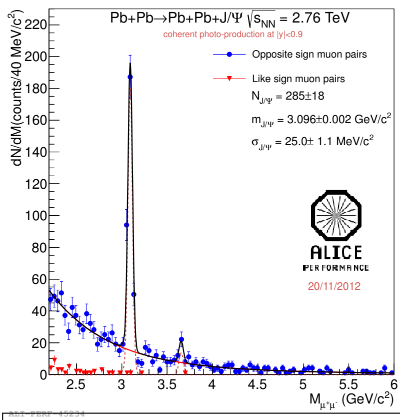

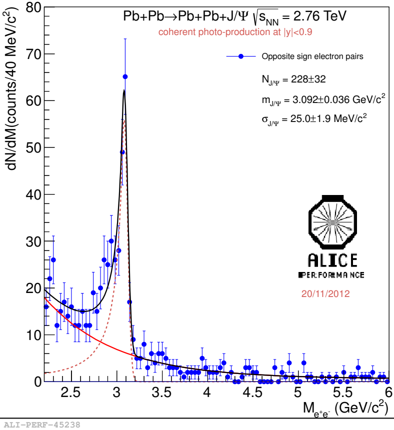

Cross section at $y = 0$ will be ready soon!

Of things to come: UPC in PC?

$\surd$ In principle one could have the same mechanism for peripheral interactions, but overlapped with the accompanying hadronic interaction of the nuclei

$\surd$ No way to disentangle the coherent signal . . .

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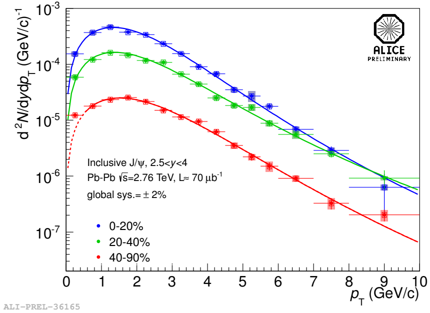

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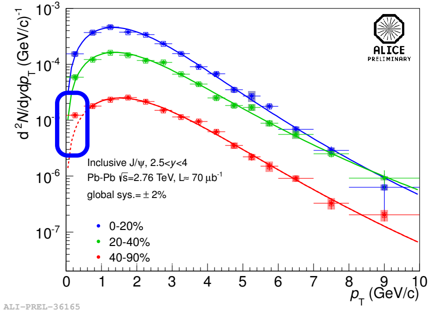

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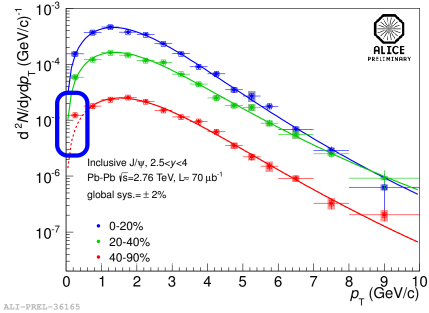

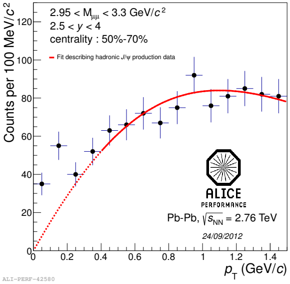

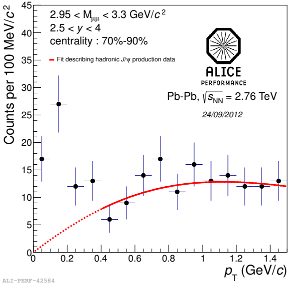

Of things to come: pA collisions at the LHC

√ In January 2013 – just one month and a half to go – the LHC will provide both *pA* and *Ap* collisions

√ As the system is asymmetric it would be possible to disentangle the source and the target at forward rapidities

√ The most probable source will be the lead ion

√ With the planned luminosities it could be possible to access the gluon in the proton down to $x \approx 10^{-5}$

√ More difficult to access the low x nuclear gluon

√ Anyway, exciting times just around the corner!

Of things to come: more UPC at KRUGER 2012

√ Coherent production is also possible for other vector mesons

√ Do not miss Kyrre Skjerdal's talk on Wedenesday at 4:00 pm

Photoproduction of ρ_0 in Ultra-Peripheral Nuclear Collisions at ALICE

Summary

$\surd$ The LHC can also be seen as a γA collider

$\surd$ ALICE has measured the exclusive coherent photo-production of J/ψ at forward rapidities, $-3.6 < y < -2.6$:

$$\frac{d\sigma_{\mathrm{coh}}}{dy} = 1.00 \pm 0.18 \ (\mathrm{stat}) \ \begin{matrix} +0.24 \\ -0.26 \end{matrix} \ (\mathrm{sys}) \quad \mathrm{mb}$$

$\surd$ Five recent theory predictions have been compared to the measurement

$\surd$ Closer to the data are predictions incorporating nuclear gluon shadowing

$\surd$ The measurement at $y = 0$ will be available soon

$\surd$ As well as measurements of coherent ρ photoproduction

$\surd$ And the pA LHC data is about to arrive

$\surd$ **Stay tuned!**