#### LHCP 2013 - First Large Hadron Collider Physics Conference Barcelona

# Photoproduction of J/ψ in Pb+Pb and p+Pb collisions at the LHC with the ALICE detector

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## Ultra peripheral Collisions at the LHC

✓ The EM field of protons and ions at the LHC can be viewed as a beam of quasi real photons



- ✓ The intensity of the photon beam is proportional to Z<sup>2</sup>
- ✓ The virtuality of the photons is restricted by the radius of the emitting particle:  $Q^2 \approx hc/(2\pi R)^2$

 $\succ$  γ from p: Q<sup>2</sup> ≈ (250 MeV)<sup>2</sup>

- $\succ$  γ from Pb: Q<sup>2</sup> ≈ (30 MeV)<sup>2</sup>
- The energy of the photons in the lab system is determined by the boost of the emitting particle

 $\succ$  γ from p: E<sup>γ</sup><sub>max</sub> ≈ 950 GeV

>  $\gamma$  from Pb:  $E_{max}^{\gamma} \approx 50$  GeV

Using Pb+Pb and p+Pb data it is possible to study  $\gamma$ +Pb,  $\gamma$ +p and  $\gamma$ + $\gamma$  collisions at higher center of mass energies than ever before

## Photoproduction of $J/\psi$

- Mass of J/ψ serves as a hard scale for pQCD calculations, which sample the square of the gluon distribution of the target (proton, Pb)
- J/ψ rapidity maps the photon-target center of mass energy
- Has a very clean signature in the leptonic decay channel: two low pt leptons in an otherwise empty detector



 $J/\psi$  photoproduction permits to study perturbatively non linear effects at low x in the gluon distribution of the target (key words: shadowing, saturation)



C A Salgado et al 2012 J. Phys. G: Nucl. Part. Phys. 39 015010

## $J/\psi \rightarrow I^+I^-$ samples in ALICE







### Pb+Pb results

Two ALICE publications:



# Triggering photoproduction of $J/\psi \rightarrow I^+I^-$ in 2011 Pb+Pb

#### UPC central barrel trigger:

• 2 ≤ **TOF** hits ≤ 6 + back-to-back topology

#### **UPC forward trigger:**

• single **muon trigger** with  $p_T > 1 \text{ GeV/c}$ 



# Coherent J/ψ production in Pb+Pb collisions (Forward)

#### From the 2011 Pb+Pb run: Phys.Lett. B718 (2013) 1273-1283

ALICE Collaboration / Physics Letters B 718 (2013) 1273-1283



Coherent J/ $\psi$  photoproduction in ultra-peripheral Pb–Pb collisions at  $\sqrt{s_{\text{NN}}} = 2.76 \text{ TeV}^{\ddagger}$ 

#### ALICE Collaboration

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ABSTRACT

The ALICE Collaboration has made the first measurement at the LHC of  $J/\psi$  photoproduction in ultraperipheral 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 µb<sup>-1</sup>. The cross section for coherent  $J/\psi$  production in the rapidity interval -3.6 < y < -2.6 is measured to be  $d\sigma_{J/\psi}^{Coh}/dy = 1.00 \pm 0.18(stat)_{-0.26}^{+0.24}(syst)$  mb. The result is compared to theoretical models for coherent  $J/\psi$  production and found to be in good agreement with those models which include nuclear gluon shadowing.

 $J/\psi$  with low transverse momentum as expected from coherent production

Forward J/ψ coherent photo-production samples the gluon distribution of Pb nuclei at x≈10<sup>-2</sup>



ALICE Collaboration / Physics Letters B 718 (2013) 1273-1283



#### Coherent J/ $\psi$ production in Pb+Pb collisions (Central Barrel)

#### http://arxiv.org/abs/1305.1467



#### Cross section for coherent J/ψ photoproduction in Pb-Pb collisions

#### Phys.Lett. B718 (2013) 1273-1283 http://arxiv.org/abs/1305.1467



ALICE results are able to distinguish between the different models

LO pQCD models including nuclear gluon shadowing seem to be favored

- AB: Adeluyi and Bertulani, PRC85 (2012) 044904
  These models use LO pQCD scaled by an effective constant to correct for missing contributions.
  MSTW08 assumes no nuclear effects, the other three incorporate nuclear effects according to different PDFs
- ✓ CSS: Cisek, Szczurek, Schäfer PRC86 (2012) 014905
  Color dipole model based on unintegrated gluon distribution of the proton
- STARLIGHT: Klein, Nystrand PRC60 (1999) 01493
  GVDM coupled to a Glauber approach and using HERA data to fix the γp cross section
- GM: Goncalves, Machado, PRC84 (2011) 011902
  Color dipole model, where the dipole nucleon cross section is from the IIM saturation model
- RSZ: Rebyakova, Strikman, Zhalov, PLB 710 (2012)
  252

Based on LO pQCD amplitude for two gluon exchange where the gluon density incorporates shadowing computed in leading twist approximation

## Incoherent J/ψ production in Pb+Pb collisions (Central Barrel)



dN/dM(counts/80 MeV/c<sup>2</sup>) lvl<0.9 30 Opposite sign electron pairs Like sign electron pairs  $N_{\mu} = 61 \pm 14$  $m_{J/\Psi} = 3.080 \pm 0.007 \text{ GeV/c}^2$  $\sigma_{J/\Psi} = 25.0 \pm 1.4 \text{ MeV/c}^2$ **Electron channel** 2.5 3 3.5 4.5 5.5 M<sub>e<sup>+</sup>e<sup>-</sup></sub> (GeV/c<sup>2</sup>) Pb+Pb→Pb+Pb+J/ $\psi$   $\sqrt{s_{NN}}$  = 2.76 TeV dN/dM(counts/40 MeV/c<sup>2</sup>) lyl<0.9 Opposite sign muon pairs Like sign muon pairs  $N_{100} = 91 \pm 15$  $m_{1/4/} = 3.085 \pm 0.007 \text{ GeV/c}^2$  $\sigma_{\rm u/w}$  = 33 ± 6 MeV/c<sup>2</sup> 80 Muon channel 60 2.5 4.5 5 5.5  $M_{\mu^*\mu}$  (GeV/c<sup>2</sup>)

 LM: Lappi, Mantysaari, PRC87 (2013) 032201
 Color dipole model based with Glauber approach and a saturation prescription



## $\gamma + \gamma \rightarrow e^+ + e^-$ production in Pb+Pb (Central Barrel)

#### http://arxiv.org/abs/1305.1467



- $\checkmark\,$  QED process ... but uncertainties due to
  - Higher order corrections because the coupling is enhanced by a factor of Z
  - Nuclear form factor and the minimum momentum transfer in the interaction
- → Different models predict a reduction of the LO cross section up to 30%
- → (see for example: A. J. Baltz, Phys. Rev. C 80 (2009) 034901; Phys. Rev. Lett. 100 (2008) 062302)



- Measurement in two different mass ranges:
  [2.2,2.6] and [3.7,10] GeV/c<sup>2</sup>
- $\checkmark~$  Precision of 12% and 16% respectively
- Data slightly above STARLIGHT, a LO prediction

# ALICE data sets stringent limits on the contribution from high order terms

## p+Pb preview

 $\succ$  Exclusive  $\gamma$ +p production

Coupling to the proton,  $<p_T(J/\psi)> \approx 500 \text{ MeV}$ proton does not break

# J/ψ photoproduction in p+Pb collisions in ALICE



## Summary and outlook

- The LHC, besides p and Pb beams, also offers intense high energetic beams of quasi-real photons
- ✓ ALICE can measure the photoproduction of J/ $\psi$ , using the leptonic channels, in a wide range of rapidities, or equivalently in a wide range of center of mass energies of the  $\gamma$ +p and the  $\gamma$ +Pb systems
- ✓ In LO pQCD models the rapidity of the J/ $\psi$  gives a handle to study the Bjorken-x dependence of the gluon distribution in the target
- ✓ ALICE has measured cross sections for J/ $\psi$  photoproduction at forward and central rapidities in Pb+Pb collisions as well as cross sections for  $\gamma+\gamma \rightarrow e^++e^-$ . These results are a strong constraint to model calculations
- ✓ ALICE also collected data both in p+Pb and Pb+p collisions in three different topologies forward, semi-forward and central which will allow the measurement of J/ $\psi$  photoproduction in  $\gamma$ +p in a wide range of center of mass energies: [20,1000] GeV!
- ✓ The analyses of these data is on going: STAY TUNED!