# Ultra-peripheral collisions in ALICE experiment

Jaroslav Adam On behalf of ALICE Collaboration

Creighton University, Omaha



**College of Arts and Sciences** 



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Ultra-peripheral collisions in ALICE experiment

### Ultra-peripheral collisions – making L $\gamma$ HC and L $\gamma\gamma$ C



- Impact parameter is larger than the sum of nuclear radii
- Electromagnetic field of protons and ions behaves like a beam of quasi-real photons
- Photon beam intensity is proportional to Z<sup>2</sup>
- Photoproduction in  $\gamma p$  and  $\gamma Pb$  interactions
- QED processes in  $\gamma\gamma$  interactions

The LHC works as a photon-hadron and photon-photon collider

#### Photoproduction of coherent $J/\psi$ in Pb-Pb



• Amount of nuclear gluon shadowing is given by  $R_g^A(x, Q^2) = \frac{g_A(x, Q^2)}{Ag_p(x, Q^2)}$ , the scale is  $Q^2 = M_{J/\psi}^2/4$ 

LHC probes Bjorken- $x \sim 10^{-2} - 10^{-5}$ , shadowing region with large uncertainties

# Exclusive $J/\psi$ photoproduction in p-Pb

- The  $J/\psi$  is produced in photon-proton interaction at CM energy  $W_{\gamma p}$
- According to HERA the cross section monotonically increases as σ ∝ W<sup>δ</sup><sub>γp</sub>
- Bjorken-*x* of probed gluons is  $x = \left(\frac{M_{J/\psi}}{W_{\gamma p}}\right)^2$
- At higher W<sub>γp</sub> energies we see more gluons at lower Bjorken-x



At some high  $W_{\gamma p}$  there should be enough gluons to interact with themselves, the density should saturate

Measurements at different  $W_{\gamma p}$  energies are sensitive to behavior of gluon distribution in protons

# The ALICE experiment

In ALICE we measure  $J/\psi$  in decays to lepton pairs, three possible configurations:



 Leptons in central detector



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spectrometer

## Coherent $J/\psi$ in muon spectrometer



- Clean, high statistics data sample ( $\sim$ 50× more  $J/\psi$  than in Run 1)
- Also signal of  $\psi(2S)$  at  $3\sigma$  significance

Fit to  $p_T$  distribution around  $J/\psi$  mass allows extraction of coherent  $J/\psi$  signal

#### Cross section of coherent $J/\psi$ in Pb-Pb



Calculations with moderate gluon shadowing are consistent with the data (EPS09 LO and CGC LM)

#### Impulse approximation

- Assuming no nuclear effects to gluon density
- **STARLIGHT**, VDM + Glauber approach
  - CPC 212 (2017) 258-268
- **EPS09 LO (GKZ)**, EPS09 gluon parametrization
  - PRC 93 (2016) 055206
- LTA (GKZ), Leading Twist Approximation
  - PRC 93 (2016) 055206
- CGC (GM)/BCGC, Color dipole model
  - PRC 90 (2014) 015203, JPG 42 (2015) 105001
- CGC LM, Color dipole model + IPsat
  - PRC 83 (2011) 065202, PRC 87 (2013) 032201

### Exclusive $J/\psi$ cross section in p-Pb



Photon-proton energy W<sub>γp</sub> is given by the J/ψ rapidity y:

 $W_{\gamma p}^2 = 2 E_p M_{J/\psi} e^{-y}$ 

- Power-law fit  $\sigma \propto W_{\gamma p}^{\delta}$  is compatible with HERA results
- pQCD and dipole models describe the data

So far no change in cross section behavior from HERA to LHC energies (maximum energy increased by more than a factor of 2 with the ALICE data)

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ALICE: PRL 113, 232504 (2014)

#### Energy dependence of exclusive $J/\psi$ photoproduction

Data over three orders of magnitude in Bjorken-*x* of probed gluons



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#### Summary and outlook

- Study of photon-hadron and photon-photon collisions L $\gamma$ HC and L $\gamma\gamma$ C
- Observed moderate gluon shadowing via coherent  $J/\psi$  photoproduction
- Energy dependence of photon-proton cross section measured to energies twice the HERA top energy
- Measurements on  $J/\psi$  in photon-proton interactions in other rapidity intervals from Run 1 close to publication
- Also UPC cross section measurements on light  $\rho^0$  mesons and  $\gamma\gamma$  to  $e^+e^-$  pairs
- New data from Run 2, currently being analyzed:
  - Incoherent  $J/\psi$ , polarization studies
  - $J/\psi$  in p-Pb up to  $W_{\gamma p} \sim$  1.5 TeV
  - First UPC data on  $J/\psi \rightarrow p\bar{p}$
- Stay tuned!