Recent results on ultra-peripheral collisions at the LHC with ALICE

Ritsuya Hosokawa for the ALICE collaboration
Creighton University in US
e-mail: r.hosokawa@cern.ch

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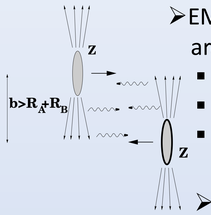
Ultra-Peripheral Collisions (UPC) and coherent photoproduction

- The collisions with the impact parameter larger than the sum of colliding nuclei radii
  - EM induced processes are dominant
    - Photon-Photon
    - Photon-Nucleus (nucleon)
    - The EM field acts as quasi-real photons
  - Hadronic interactions are largely suppressed



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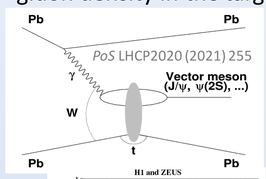
- The photon flux $\propto Z^2$ (Z: atomic number)

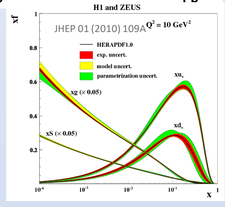
- The cross section is proportional to the square of gluon density in the target at LO

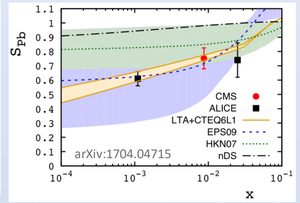


- The Bjorken-x is:

$$x = \frac{M_V}{\sqrt{s_{NN}}}\exp(-y)$$

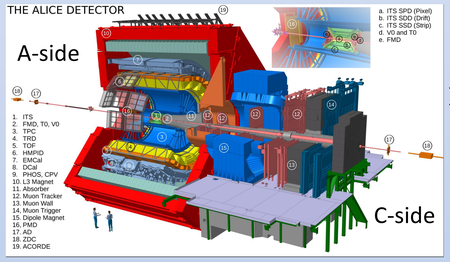
M_V : Mass of a vector meson

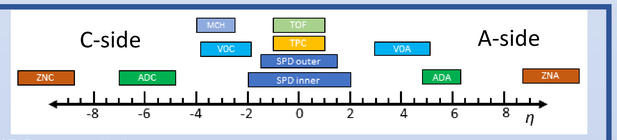




- Excellent probe of the gluonic structure in nuclei at low Bjorken-x
  - Gluon saturation
  - Nuclear shadowing

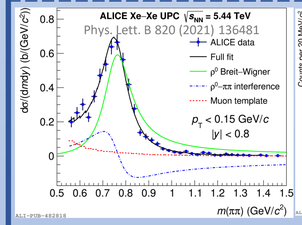
ALICE detector and signal extraction

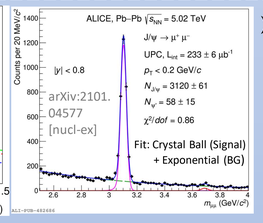




- UPC event triggers
  - Mid rapidity ($|y| < 0.8$)
    - Back-to-back hits on the SPD
    - Back-to-back hits on the TOF (for J/ψ measurements)
  - Forward rapidity ($-4 < y < -2.5$)
    - Unlike-sign di-muon trigger at the forward muon spectrometer (MCH) coverage
  - Veto by the forward scintillation detectors (V0 and AD)

- Tracking
  - TPC + ITS ($|y| < 0.8$)
  - MCH ($-4 < y < -2.5$)
- Particle identification at $|y| < 0.8$
  - Energy loss in the TPC per unit length (dE/dx)
- Forward neutron detection
  - ZDC





- Signals are extracted by fitting the mass spectra
  - Low p_T requirement on the $\pi^+\pi^-$ pairs (ρ^0) and e^+e^-, $\mu^+\mu^-$, p^+p^- pairs (J/ψ) where the coherent production is dominant
    - The mass spectrum of $\pi^+\pi^-$ pairs fits with the combination of ρ^0 peak, $\gamma\gamma \to \mu^+\mu^-$ (and $\gamma\gamma \to \pi^+\pi^-$), and $\rho^0 - \pi^+\pi^-$ interference
    - The fraction of pions from $\gamma\gamma \to \pi^+\pi^-$ is comparable with the results of HERA and STAR
- Incoherent fraction is assessed by fitting the pair p_T spectra with a MC (STARlight) template

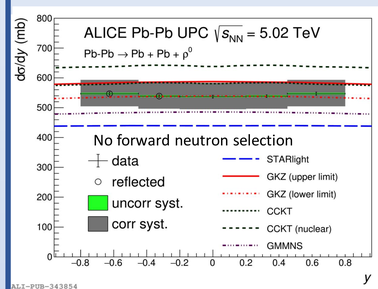
Summary

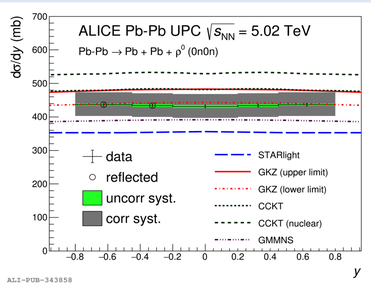
- The photoproduction cross sections of ρ^0 in Pb–Pb and Xe–Xe UPC are measured at $\sqrt{s_{NN}}$ = 5.02 and $\sqrt{s_{NN}}$ = 5.44 TeV respectively
  - This is the first measurement of coherent ρ^0 production in Xe–Xe ultra-peripheral collisions
  - The A dependence is studied using Pb–Pb, Xe–Xe UPC, and H1 data
- The photoproduction cross section and its t-dependence of J/ψ in Pb–Pb UPC is measured at $\sqrt{s_{NN}}$ = 5.02 TeV
  - The result agrees with models incorporating moderate nuclear gluon shadowing
  - The $|t|$-dependence is described by models including shadowing or saturation
- Measurements with larger data sample expected in the LHC Run 3 would be able to distinguish the best model

Results

❑ ρ^0 measurements

- Sensitive to nuclear shadowing and to the approach to the black-disc limit of QCD
- Production cross section at $|y| < 0.8$
  - The first measurement of ρ^0 cross section in Xe–Xe UPC
  - The cross sections in Pb–Pb UPC are measured dividing the events by forward neutron emission (0n0n, 0nXn and XnXn)
- Dependence on atomic number (A)
  - Consistent with a power-law behavior with a slope of 0.96 ± 0.02
  - The result is far from the black-disc limit at this energy of $W_{\gamma A}$ = 65 GeV





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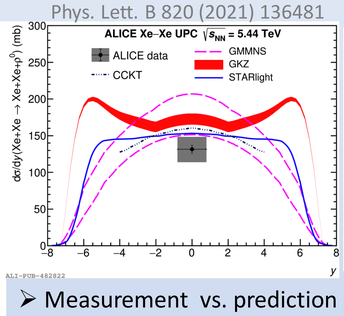

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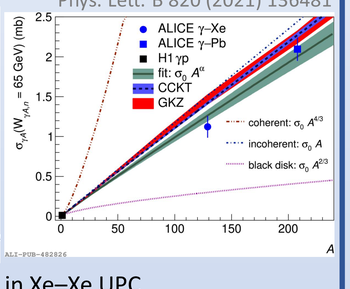
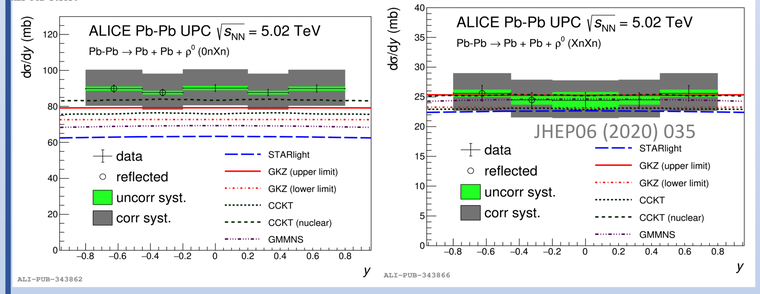


- Measurement vs. prediction in Xe–Xe UPC
  - All the compared predictions overestimate the cross section within 1-2 σ standard deviation

- Measurement vs. prediction in Pb–Pb UPC
  - The agreement between the models and the measured data appears in most cases satisfactory with large uncertainty
    - Particularly, GKZ, which based on a vector-dominance model + Gribov-Glauber model of nuclear shadowing, gives good description



❑ J/ψ measurements

- Production cross section at $|y| < 0.8$ and at $-4 < y < -2.5$
  - The central value of a calculation based on the EPS09 LO of the nuclear shadowing data (solid green line) gives good description
  - Predictions of LS and LM, both based on color dipole + CGC models, well reproduce the cross section at $-4 < y < -2.5$ but they overestimate at $|y| < 0.8$
- $|t|$-dependence
  - The square of the momentum transferred between the incoming and outgoing target nucleus
    - To investigate the transverse gluonic structure at low Bjorken-x
  - The results are well described by the models including shadowing (LTA) or saturation (b-BK)