Vector meson photoproduction at the LHC with ALICE

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– an introduction to the physics of ultra-peripheral collisions (UPC);
– coherent production of $J/\psi$ and $\psi'$ in Pb–Pb UPC;
– coherent $\rho^0$ production in Pb–Pb and Xe–Xe UPC with LHC Run 2 data.
UPC of heavy ions

The LHC in heavy-ion mode →
powerful source of quasi-real photons with intensity $\sim Z^2$.

Photon →
a vector meson (VM) →
scatter off a target
either coherently off whole nucleus ($VM p_T \sim 30$ MeV/c)
or incoherently off nucleons ($VM p_T \sim 300$ MeV/c).

NB there is bidirectional photon ambiguity in case of heavy ions

Large $Z$ →
huge photon fluxes →
UPC can be accompanied by another photon exchange →
EM nuclei excitation →
neutron emission detected in Zero Degree Calorimeters.

UPC studies address gluon shadowing in nuclei in photoproduction of vector mesons,
two-photon processes like light-by-light scattering, dilepton production etc.

**UPC review and current status:**

E. Kryshen, EPJ Web Conf. 204 (2019) 01011;
ALICE systems relevant for $J/\psi / \rho^0$ photoproduction measurements:

- **Muon spectrometer** (item 12 on scheme) /TPC (3) to reconstruct $J/\psi$ or $\rho^0$ decays;
- **Trigger detectors**: ITS SPD (1), V0 (2), AD (17), TOF (5) and muon trigger chambers (14);
- **Zero Degree Calorimeters** (18) to detect neutrons from nucleus EM dissociation.
Main features of UPC vector meson photoproduction:
- exclusive events, only vector meson decay particles detected;
- transverse momentum balance of final state particles.
Coherent production of $J/\psi$ and $\psi'$ in Pb–Pb UPC

- Impulse approximation: no nuclear effects
- STARLIGHT: Vector Meson Dominance model + Glauber model for nuclear effects
- EPS09 parametrization of nuclear shadowing (GKZ)
- Leading Twist Approximation of nuclear shadowing (GKZ)
- GM: color dipole + IIM / bCGC Color Glass Condensate(CGC) model
- IPSat (LM): color dipole + CGC
- GG-HS (CCK): color dipole + energy dependent hot-spot model
- BGK-I (LS): color dipole + CGC

EPS09 (GKZ) and GG-HS (CCK) models, implying moderate gluon shadowing in nuclei, describe both coherent $J/\psi$ and $\psi'$ photoproduction cross sections at similar level of the shadowing.

Pozdnyakov V.
Coherent $\rho^0$ production in Pb–Pb and Xe-Xe UPC with LHC Run 2 data

Photonuclear production of $\rho^0$ in heavy ion UPC at the LHC has a large cross section which makes it a good tool to study the approach to the black-disk limit of QCD.

The fit done by Breit-Wigner for resonance shape

+ constant term for direct pair production
+ interference between them
+ dimuons from $\gamma\gamma$ interactions.
Coherent $\rho^0$ production in Pb–Pb and Xe-Xe UPC with LHC Run 2 data


Calculations based on colour-dipole approach and on Gribov-Glauber shadowing approach provide good agreement with the data.
Coherent $\rho^0$ production in Pb–Pb UPC vs electromagnetic dissociation of nuclei

Agreement both with models based on colour-dipole approach and with Gribov-Glauber shadowing.

The models for EMD accompanying VM photoproduction describe the measured cross sections for different neutron emission classes which are sensitive to different impact parameter ranges.
Conclusions

– analysis of $J/\psi$ and $\rho^0$ photoproduction is a tool to learn about the dynamics of $\gamma A$ interactions and the gluon content of nuclei;

– cross sections of coherent forward and midrapidity $J/\psi$ photoproduction were measured in Pb–Pb UPC collisions at $\sqrt{s_{NN}} = 5.02$ TeV. The result implies moderate gluon shadowing in nuclei;

– $\psi'$ production at mid-rapidity Pb–Pb UPC was studied;

– rapidity dependence of the coherent $\rho^0$ production cross section in Pb–Pb UPC at $\sqrt{s_{NN}} = 5.02$ TeV was measured for different cases of EMD accompanying VM photoproduction. The cross sections are compared with the main available models;

– for the first time the cross section of coherent $\rho^0$ production in Xe–Xe UPC is measured and much more data expected at LHC Run 3 which will start this year.