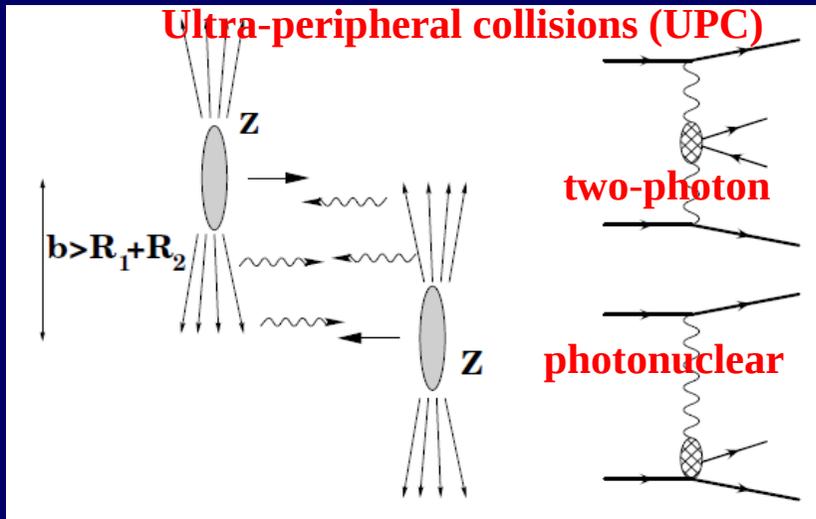
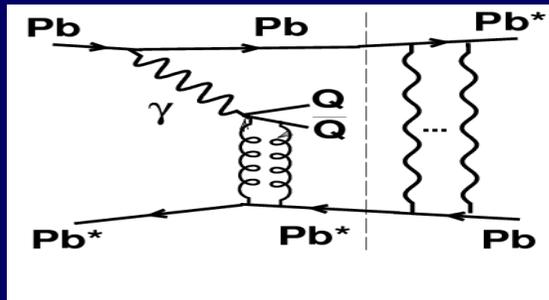


UPC of heavy ions



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:

A.J. Baltz *et al.*, Phys.Rept. 458 (2008) 1;

L. Frankfurt *et al.*, Phys.Lett.B 752 (2016) 51;

CMS Collab., Phys.Lett.B 797 (2019) 134826;

S. R. Klein and P. Steinberg, arXiv:2005.01872 [hep-ph] (2020)

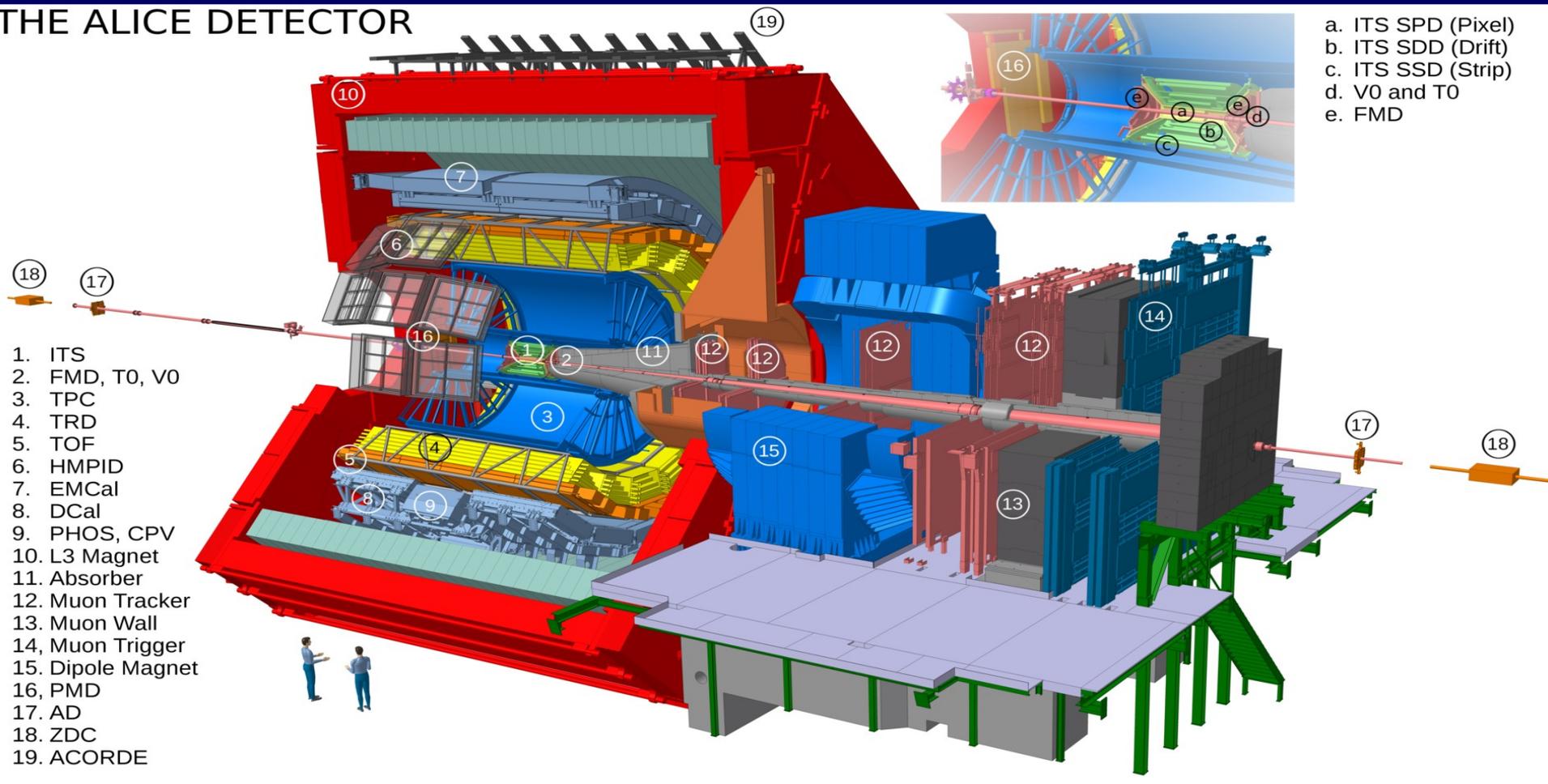
V. Guzey *et al.*, Eur.Phys.J. C74 (2014) 7;

E. Kryshen, EPJ Web Conf. 204 (2019) 01011;

ALICE Collab., Phys.Lett. B798 (2019) 134926;

A Large Ion Collider Experiment (ALICE) at LHC

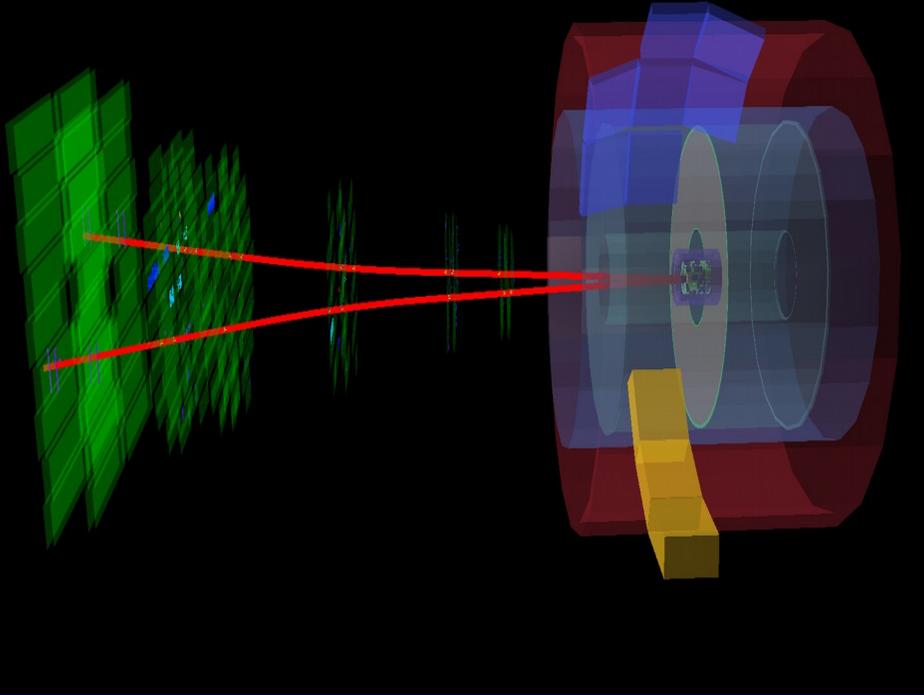
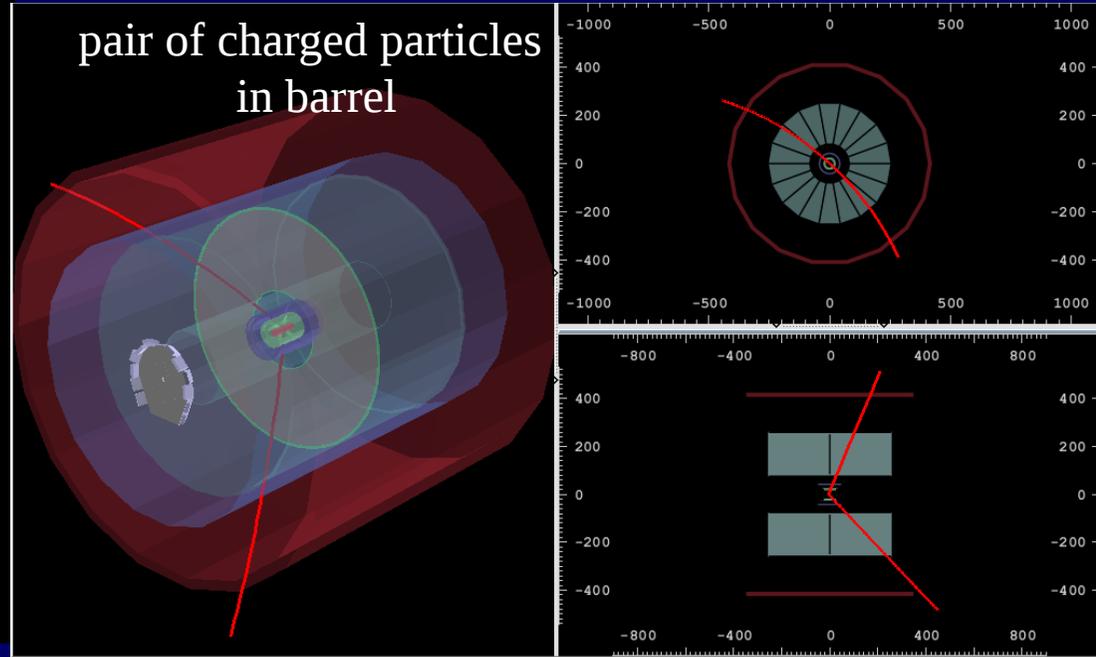
THE ALICE DETECTOR



ALICE systems relevant for J/ψ / ρ^0 photoproduction measurements:

- **Muon spectrometer** (item 12 on scheme) / **TPC** (3) to reconstruct J/ψ or ρ^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.

forward dimuons

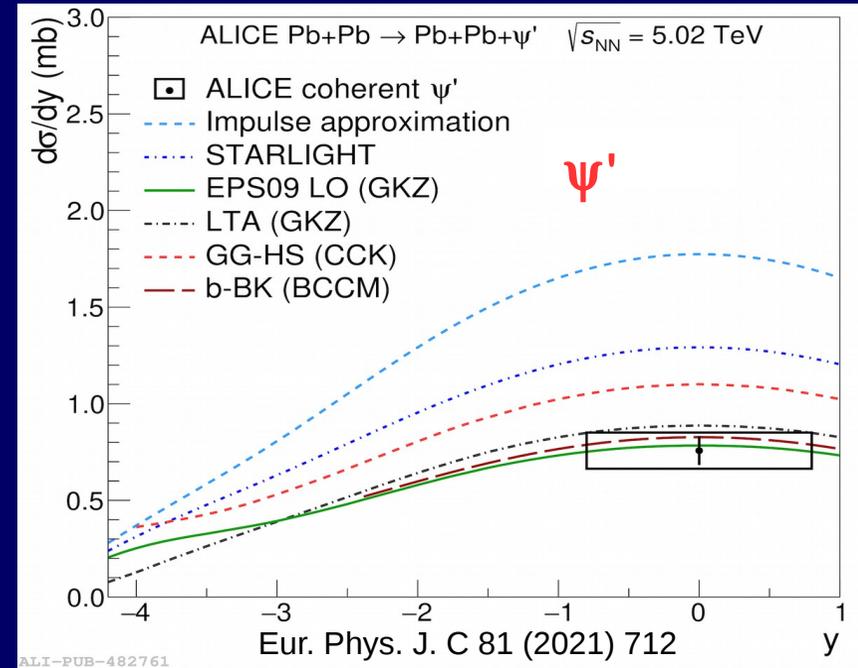
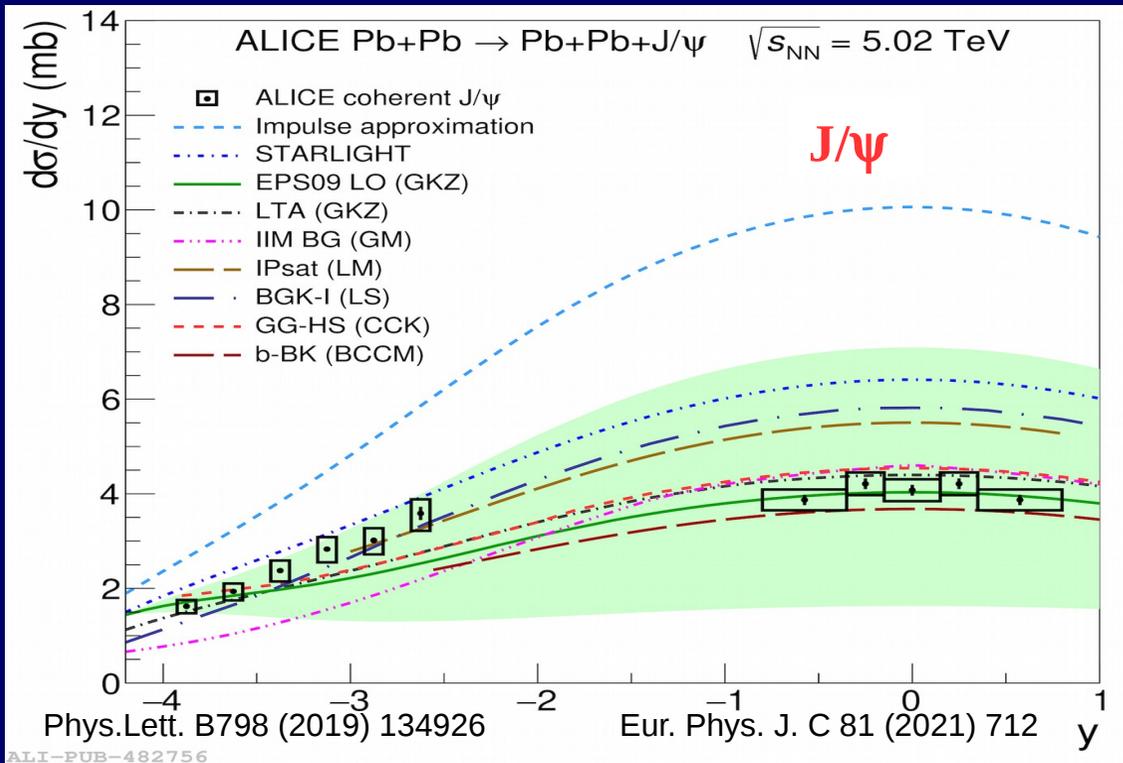
pair of charged particles
in barrel

- 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/ψ and ψ' in Pb–Pb UPC



ALICE



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

Comput. Phys. Commun. 212 (2017) 258

PRC93 (2016) 055206

PRC93 (2016) 055206

PRC 90 (2014) 015203, JPG 42 (2015) 105001

PRC 83 (2011) 065202, PRC 87 (2013) 032201

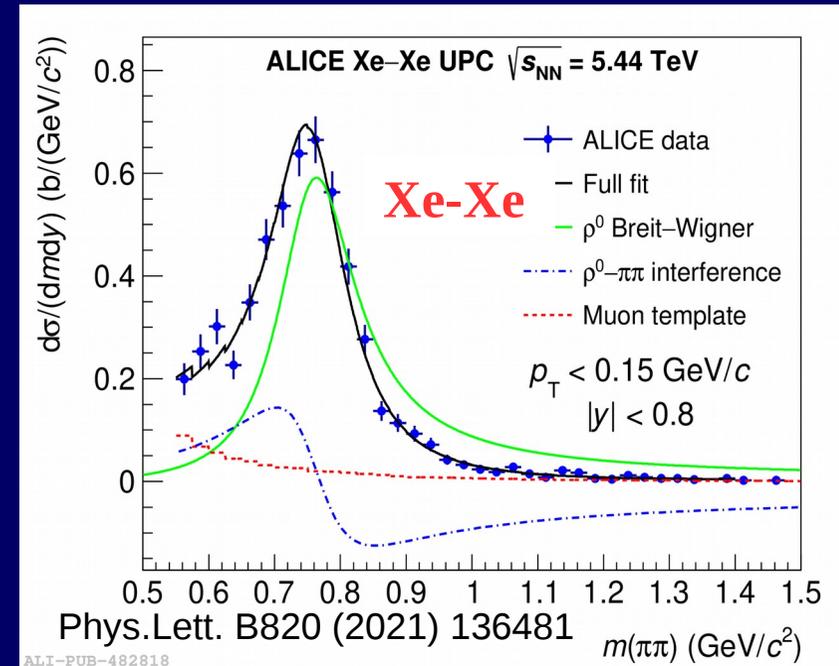
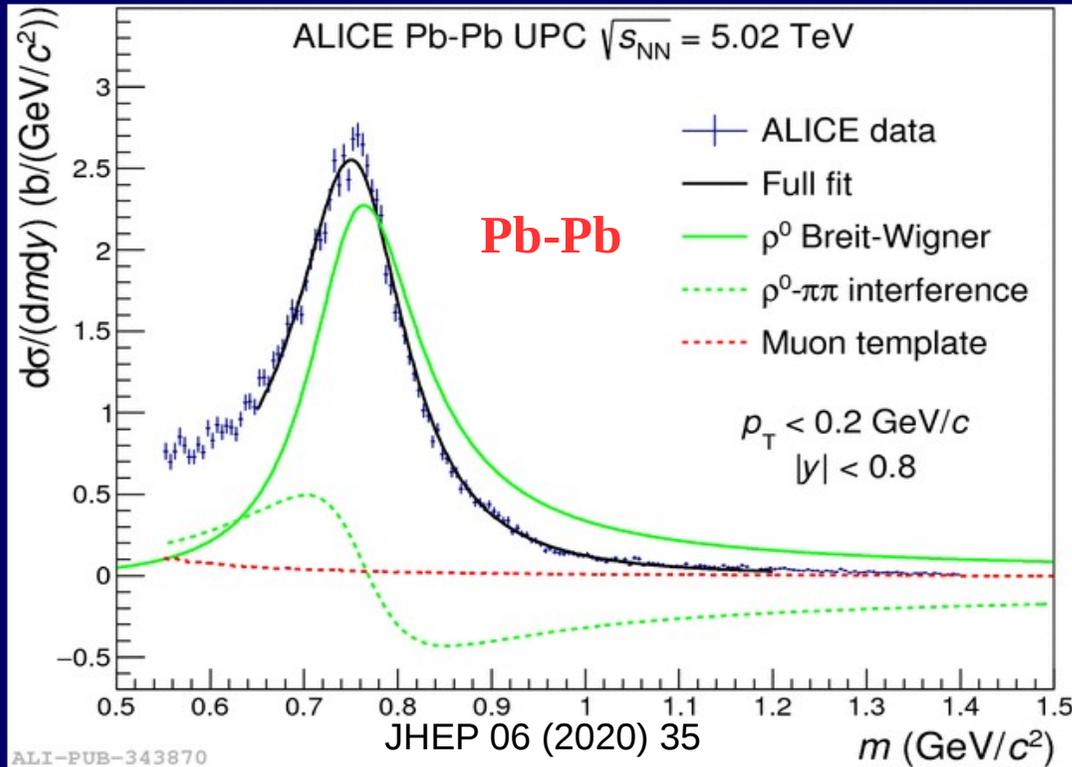
PL B766 (2017) 186, PRC 97 (2018), 024901

Phys. Rev. C 99, 044905 (2019)

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

Coherent ρ^0 production in Pb-Pb and Xe-Xe UPC with LHC Run 2 data

Photonuclear production of ρ^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.



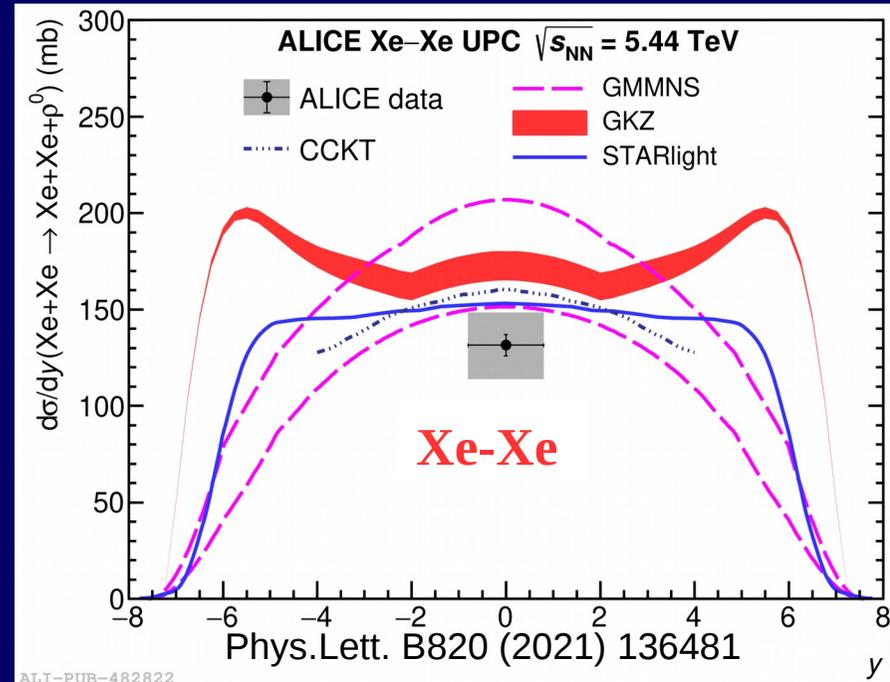
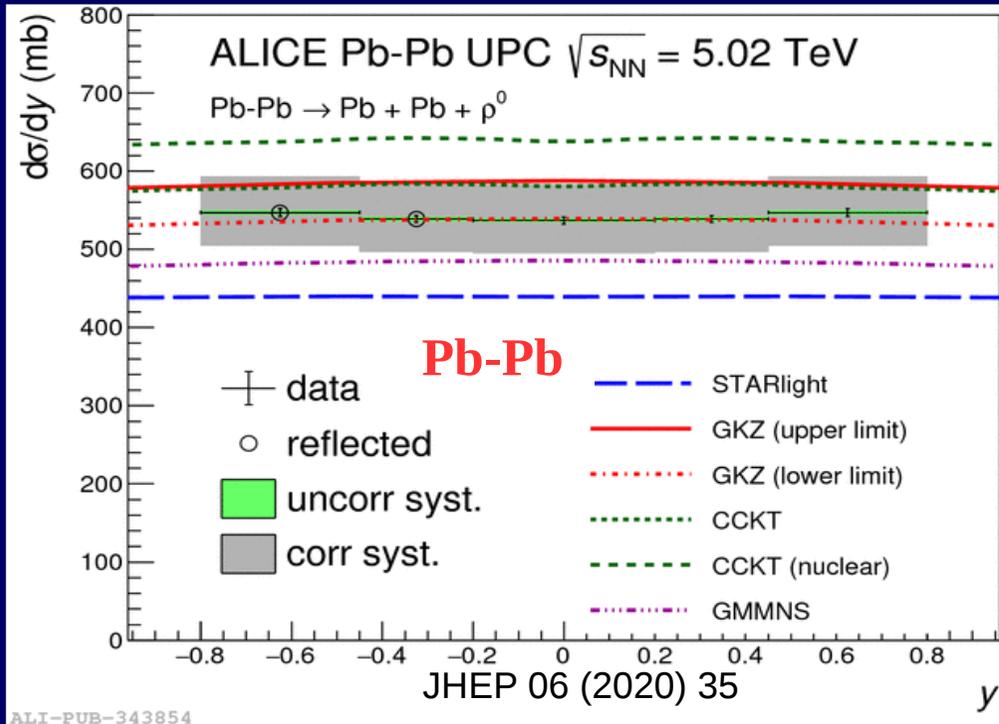
The fit done by Breit-Wigner for resonance shape

- + constant term for direct pair production
- + interference between them
- + dimuons from $\gamma\gamma$ interactions.

Coherent ρ^0 production in Pb–Pb and Xe–Xe UPC with LHC Run 2 data



ALICE



GKZ (V. Guzey, E. Kryshen and M. Zhalov, Phys. Rev. C93 (2016) 055206):

Vector Meson Dominance model + Gribov-Glauber model of nuclear shadowing for fluctuations of the photon-nucleons interaction;

CCKT (J. Cepila, J. G. Contreras, M. Krelina, and J.D. Tapia Takaki, Nucl. Phys. B934 (2018) 330–340):

colour-dipole model + gluons “hot spots” of the structure of the nucleon in the transverse plane +Glauber model;

GMMNS (Goncalves, Machado, Morerira, Navarra and dos Santos, Phys. Rev. D96 (2017) 094027):

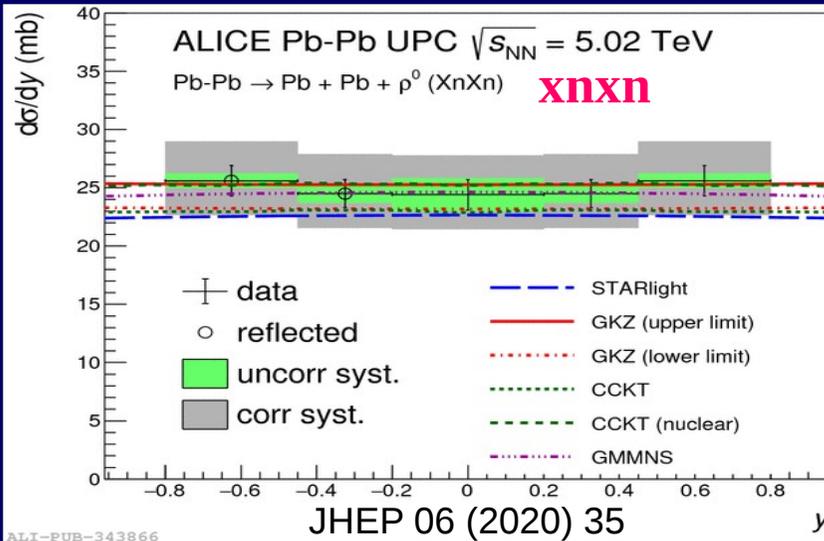
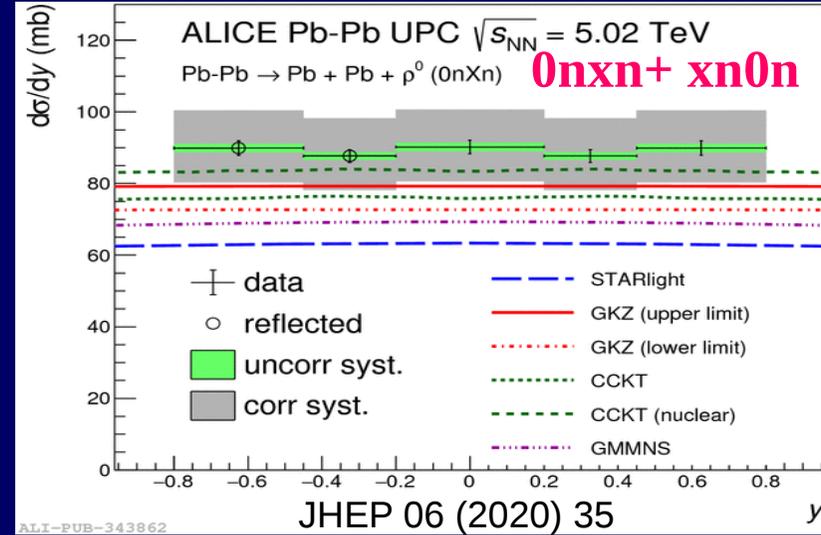
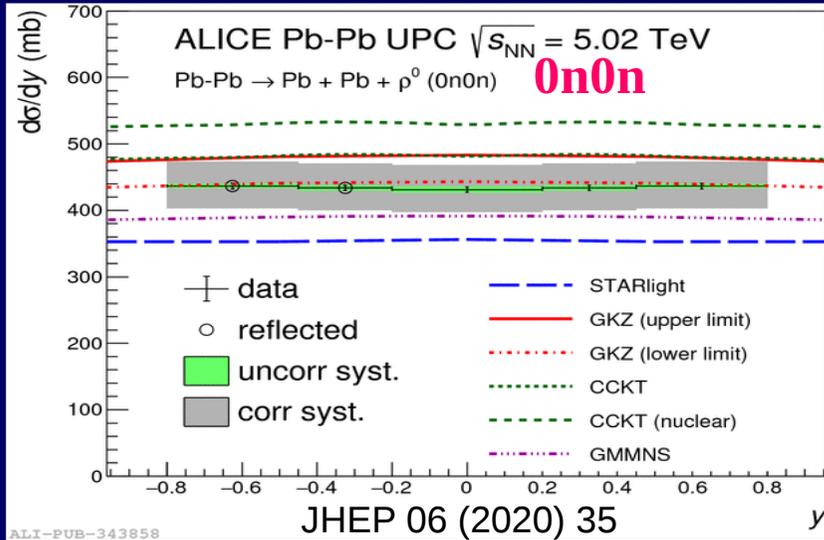
Iancu-Itakura-Munier (IIM) approach for gluon saturation + colour-dipole model;

STARLIGHT (S.Klein, J.Nystrand et al. Comp. Phys. Comm. 212 (2017) 258) :

$\gamma+p \rightarrow VM+p$ cross section + the optical theorem + a Glauber-like eikonal formalism.

Calculations based on **colour-dipole** approach and on **Gribov-Glauber shadowing** approach **provide good agreement** with the data.

Coherent ρ^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/ψ and ρ^0 photoproduction is a tool to learn about the dynamics of γA interactions and the gluon content of nuclei;
 - cross sections of coherent forward and midrapidity J/ψ photoproduction were measured in Pb–Pb UPC collisions at $\sqrt{s_{NN}} = 5.02$ TeV. The result implies moderate gluon shadowing in nuclei;
 - ψ' production at mid-rapidity Pb–Pb UPC was studied;
 - rapidity dependence of the coherent ρ^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 ρ^0 production in Xe–Xe UPC is measured
- and much more data expected at LHC Run 3 which will start this year.