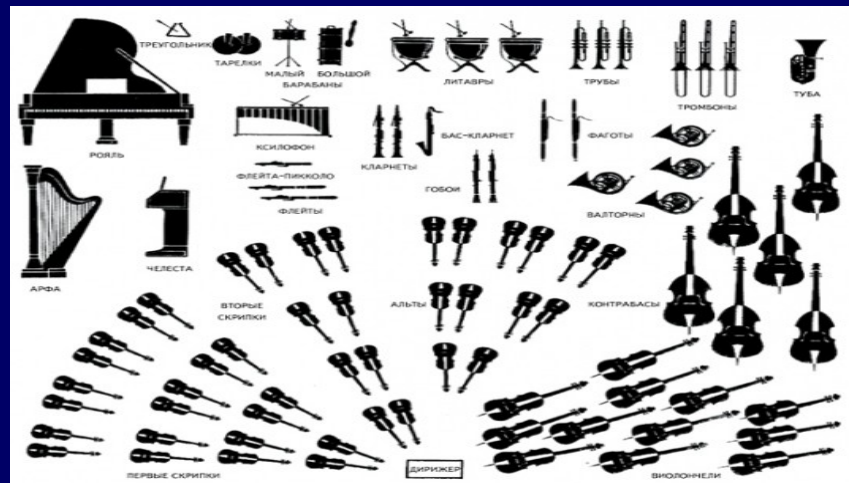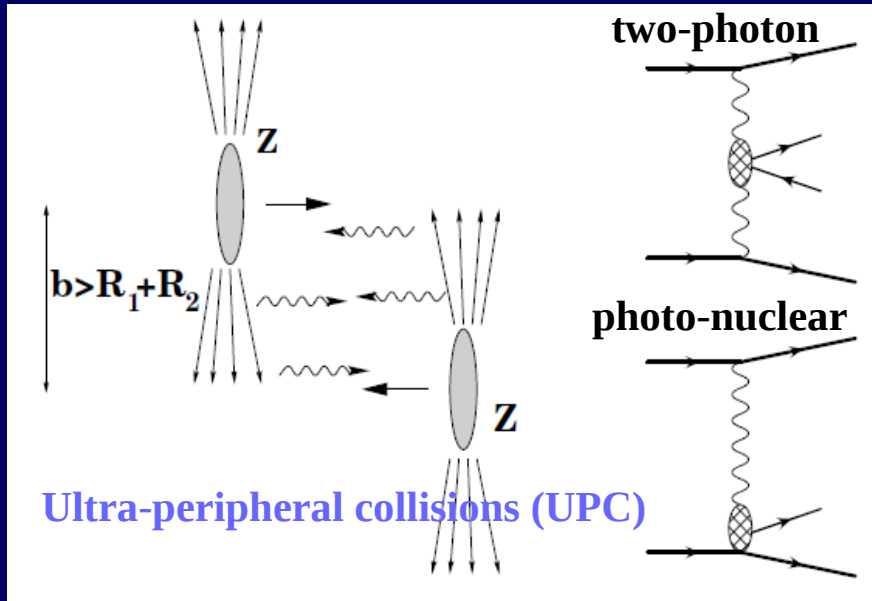*Measurements of vector meson photoproduction with ALICE in ultra-peripheral Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV*

Valery Pozdnyakov for the ALICE Collaboration
Joint Institute for Nuclear Research, Dubna, Russia

Ultra-Peripheral Collisions (UPC) of heavy ions

ALICE

two-photon

photo-nuclear

Ultra-peripheral collisions (UPC)

$b > R_1 + R_2$

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

Photon - a coherent superposition of hadronic fluctuations into a vector meson (VM) that subsequently interact with the target. VM photoproduction (photon-Pomeron exchange) occurs either coherently off whole nucleus ($p_T \sim 30$ MeV) or incoherently off nucleons ($p_T \sim 300$ MeV)

Coherent photoproduction on nuclear targets is a tool to study properties of the VM interactions with nucleons
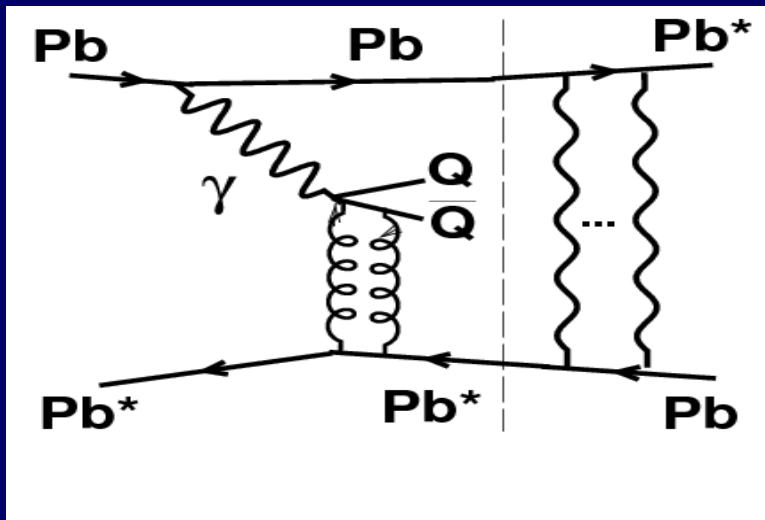
Large charges of colliding ions lead to the production of huge photon fluxes and UPC can be accompanied by another photon exchange (right side of the plot) leading to EM nuclei excitation with subsequent neutron emission which can be detected (in Zero Degree Calorimeter) together with scattered vector meson.

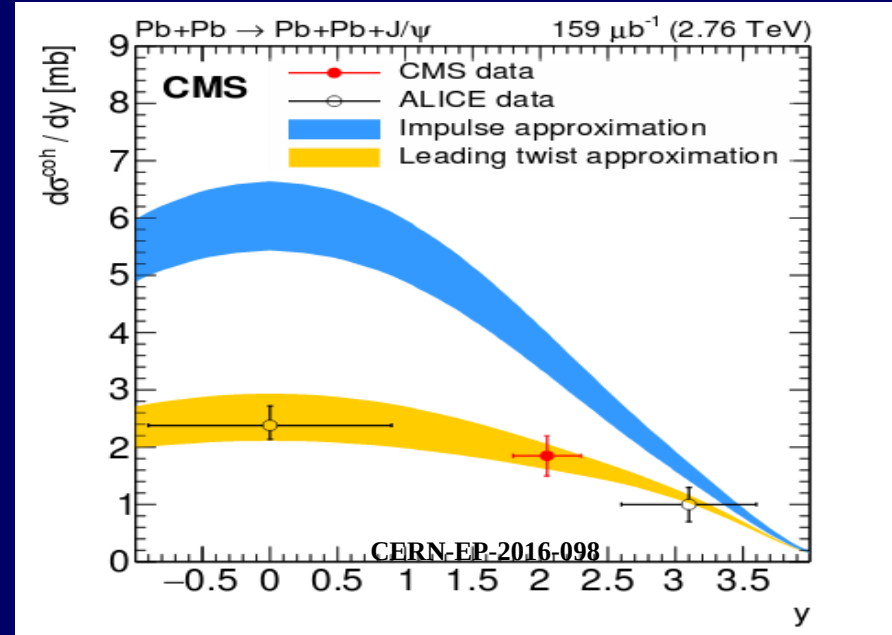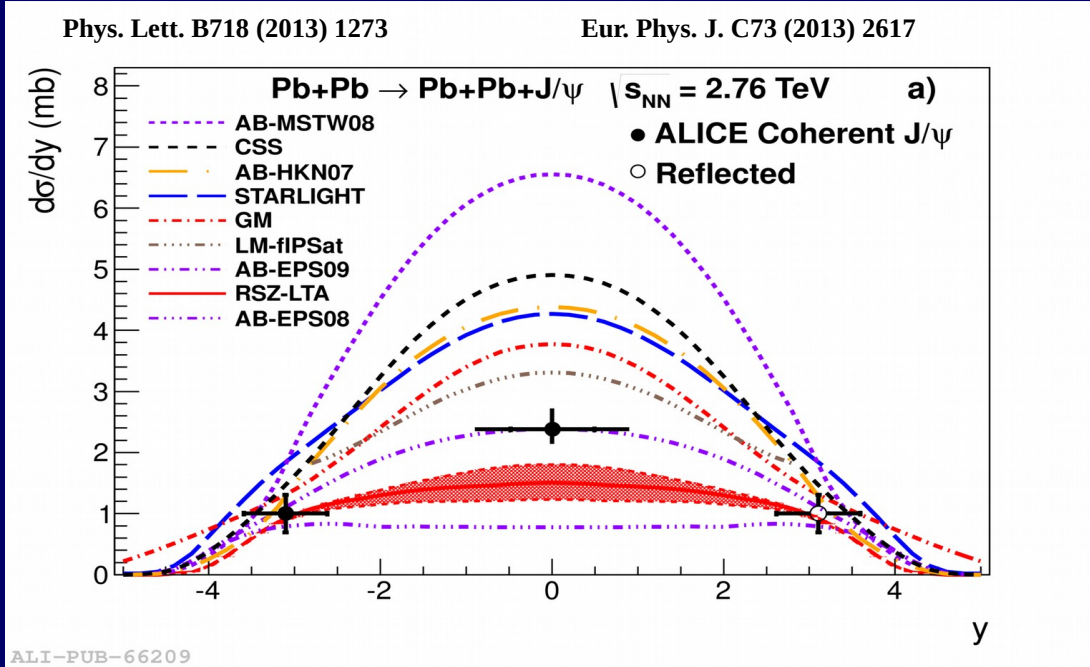UPC studies are mainly intended to address gluon shadowing in nuclei

UPC review : A.J. Baltz et al., Phys.Rept. 458 (2008) 1

Phys. Lett. B718 (2013) 1273   Eur. Phys. J. C73 (2013) 2617
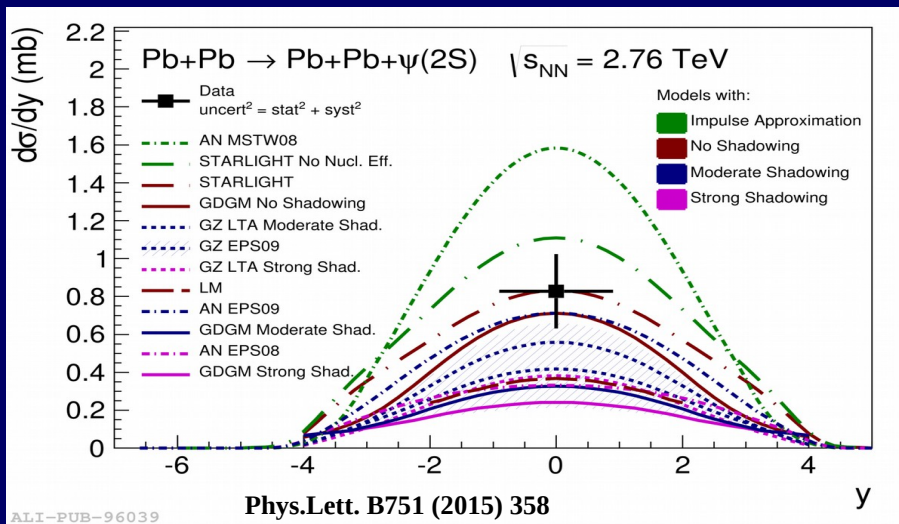

CERN-EP-2016-098

Phys.Lett. B751 (2015) 358

Both the ALICE and CMS measurements support calculations which include a moderate shadowing of gluons in nuclei
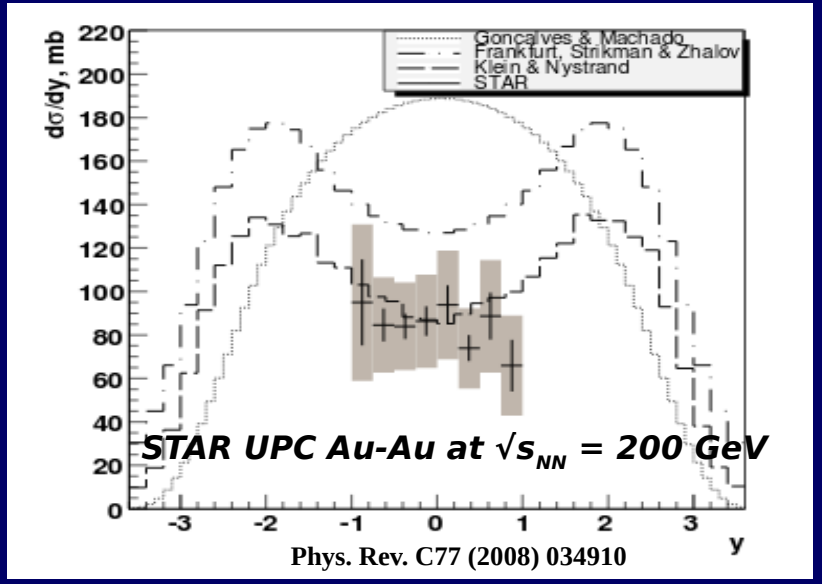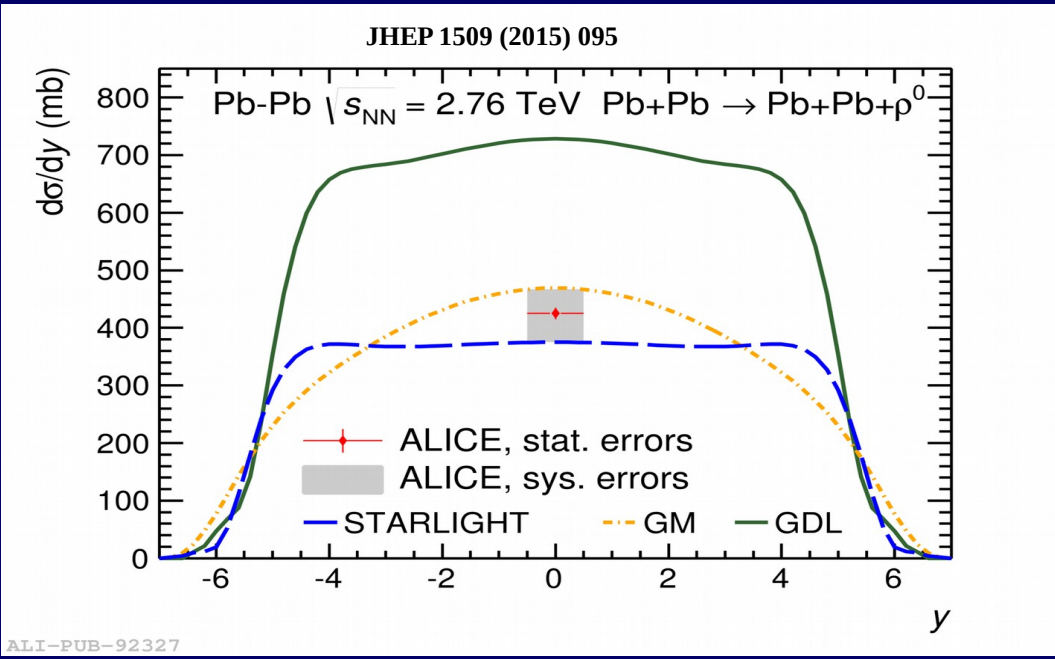
while the models with all nucleons involved the scattering and those with a strong shadowing are disfavored

Coherent ρ^0 photoproduction in UPC

JHEP 1509 (2015) 095

Pb-Pb $\sqrt{s_{NN}}$ = 2.76 TeV Pb+Pb → Pb+Pb+ρ^0

ALICE, stat. errors
ALICE, sys. errors
STARLIGHT — GM — GDL

ALI-PUB-92327

STAR UPC Au-Au at $\sqrt{s_{NN}}$ = 200 GeV

Goncalves & Machado
Frankfurt, Strikman & Zhalov
Klein & Nystrand
STAR

Phys. Rev. C77 (2008) 034910
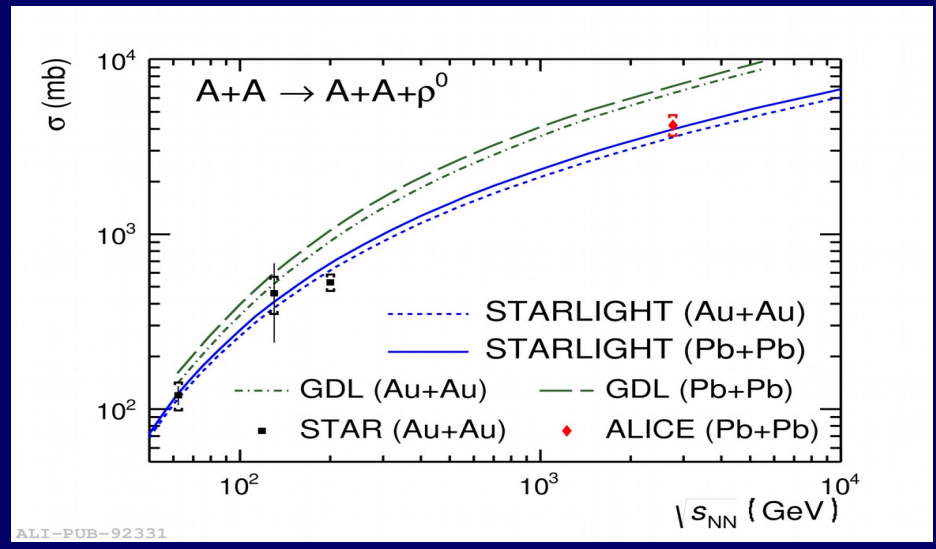
GM (V.Goncalves and M.Machado, Phys.Rev. C80 (2009) 054901) dipole approach and phenomenological models based on Color Glass Condensate
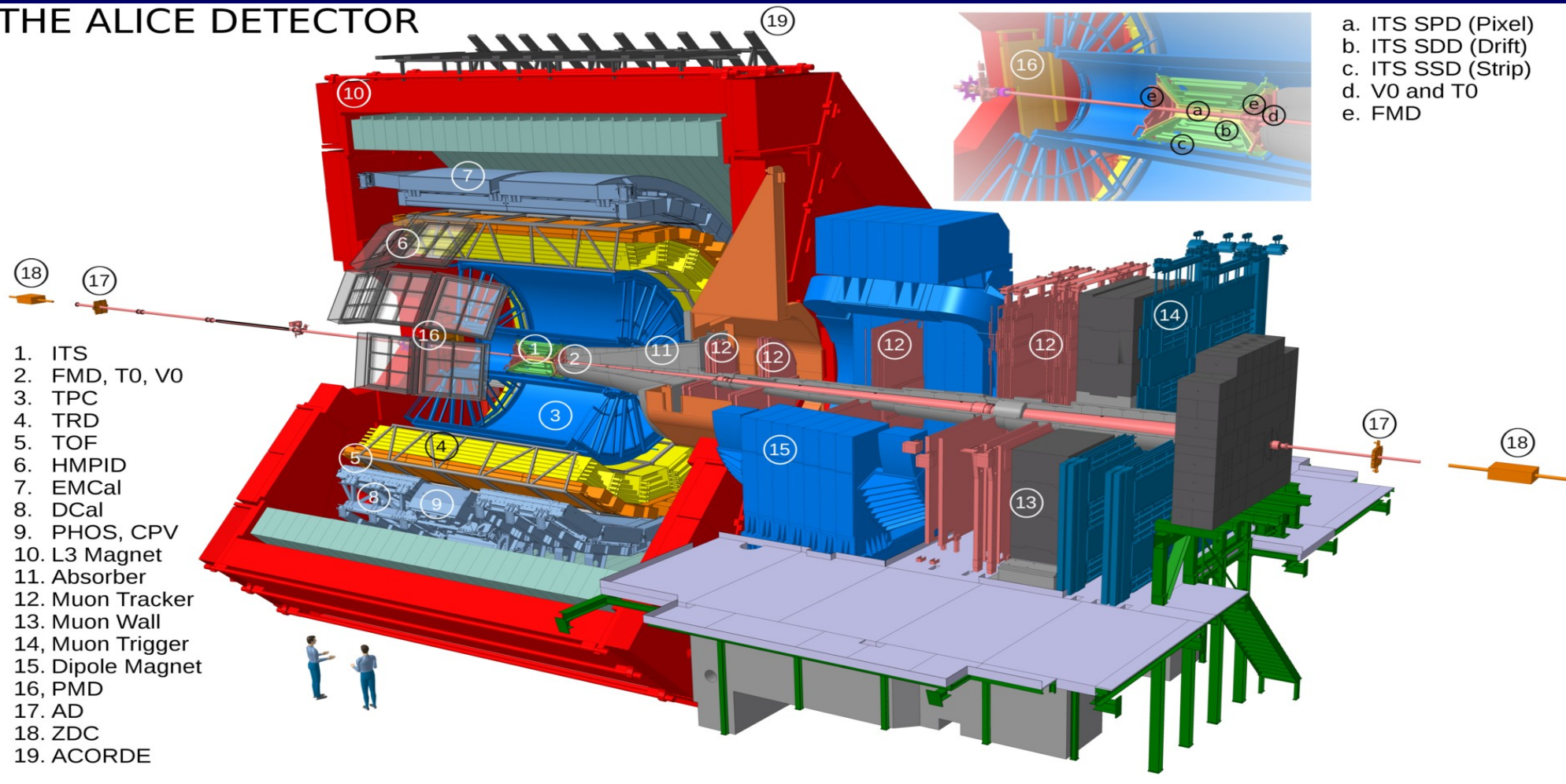Both GDL (L.Frankfurt, M.Strikman and M. Zhalov, Phys.Lett. B537 (2002) 51) and STARLIGHT (S.Klein, J.Nystrand et al. Comput.Phys.Commun. 212 (2017) 258) models use photon-proton cross section as input for calculations but different approaches to gamma-nucleon cross sections
Updated GDL calculations (Phys. Lett. B 752 (2016) 51) now shown

A+A → A+A+ρ^0

STARLIGHT (Au+Au)
STARLIGHT (Pb+Pb)
GDL (Au+Au) — GDL (Pb+Pb)
STAR (Au+Au) — ALICE (Pb+Pb)

ALI-PUB-92331

THE ALICE DETECTOR

a. ITS SPD (Pixel)
b. ITS SDD (Drift)
c. ITS SSD (Strip)
d. V0 and T0
e. FMD

1. ITS
2. FMD, T0, V0
3. TPC
4. TRD
5. TOF
6. HMPID
7. EMCal
8. DCal
9. PHOS, CPV
10. L3 Magnet
11. Absorber
12. Muon Tracker
13. Muon Wall
14. Muon Trigger
15. Dipole Magnet
16. PMD
17. AD
18. ZDC
19. ACORDE

ALICE systems relevant for J/ψ and ρ^0 photoproduction measurements:
- Muon spectrometer/TPC to reconstruct muons /electrons from J/ψ decays;
- ITS (silicon detectors) and TPC to reconstruct pions from ρ^0 decays;
- Trigger detectors: Silicon Pixels, V0, AD, TOF and trigger chambers of the muon spectrometer;
- Zero Degree Calorimeters (ZDC) to detect neutrons from nucleus EM dissociation

forward J/ψ into di-muons
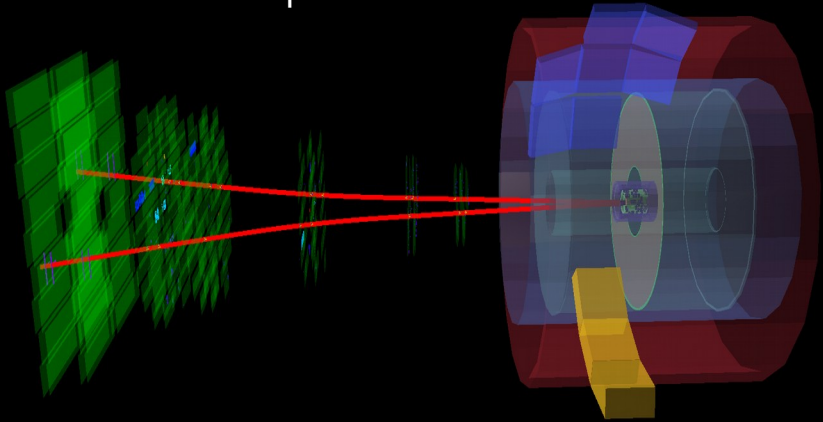
mid-rapidity ρ^0
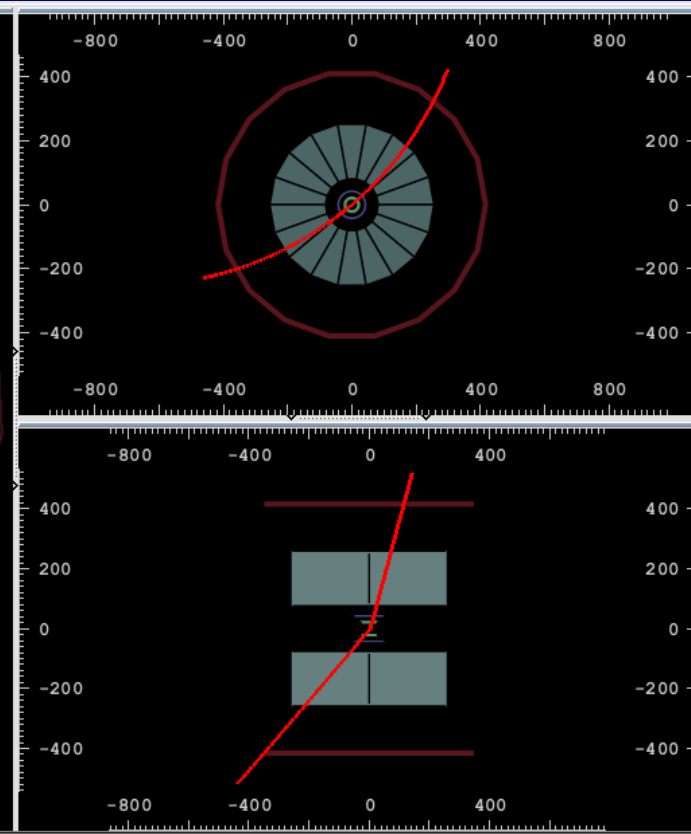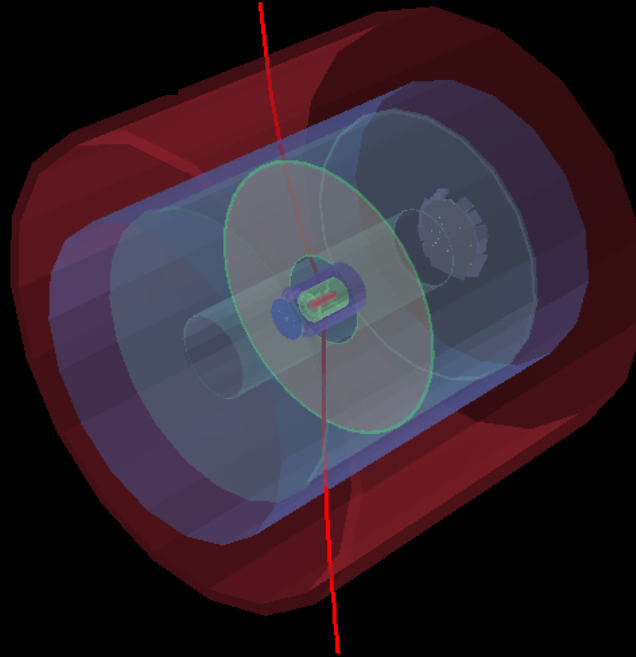
Main features of UPC VM photoproduction:
- exclusive events, only VM decay particles detected
- momentum balance of final state particles

The selected data contain two unlike-sign particles passing 'track quality requirements' with no activity in V0, AD detectors and pair p_T < 100 MeV

The events were recorded by new topological Silicon-Pixel-Detector trigger
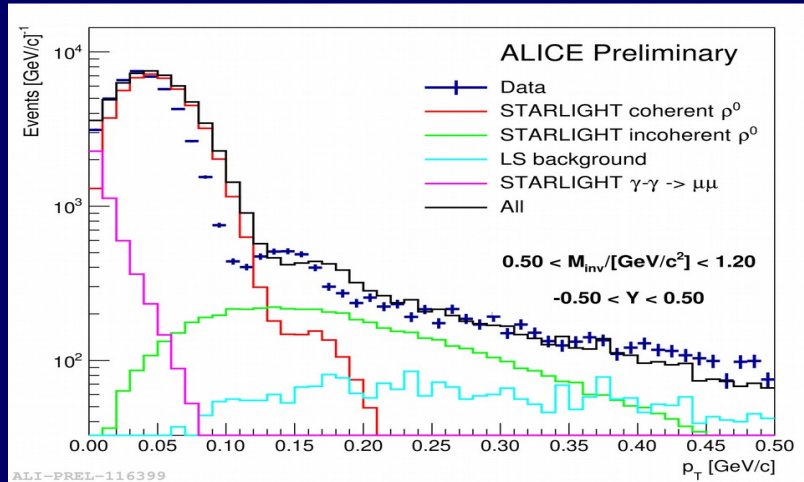
Comments to pair p_T spectra (arbitrary normalized)

- second diffractive peak (~150 MeV) of ρ⁰ photoproduction is well seen in the data;
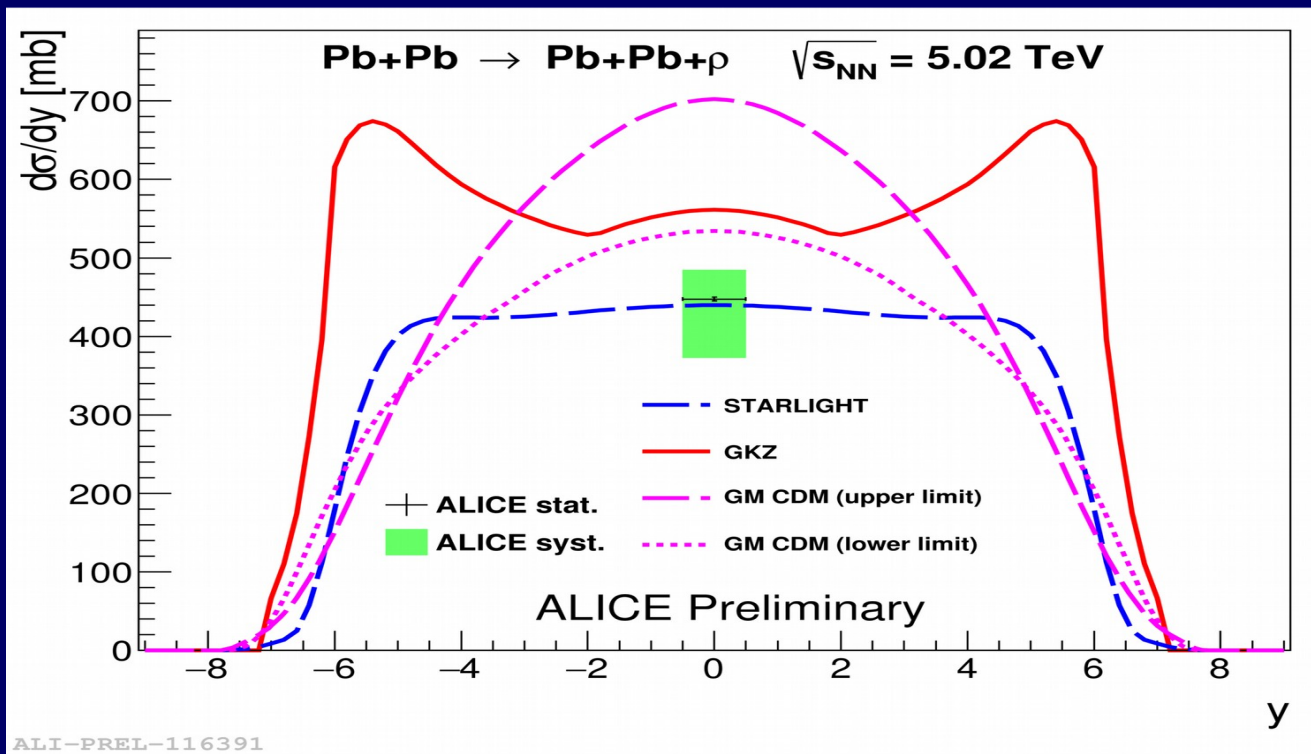- a cut on pair p_T < 100 MeV keeps most of coherent ρ⁰
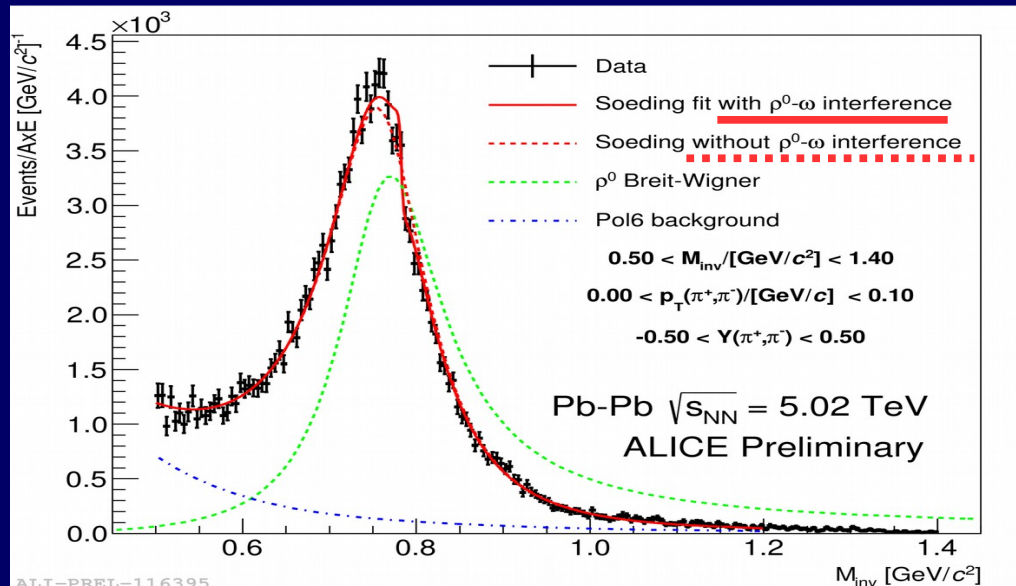
Fit by
Breit-Wigner
+ constant term for the direct di-pion production
+ interference between them
+ di-muons from gamma-gamma interactions.

The fit was done with ω contribution as well

Coherent ρ^0 production in ultra-peripheral Pb–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV

Coherent ρ^0 photoproduction cross section for ρ^0 rapidity within domain [-0.5, 0.5] was measured to be
$$d\sigma/dy = 448 \pm 2 \text{ (stat) } +38/-75 \text{ (syst) mb}$$
The result agrees with STARLIGHT model based on Color Dipole Model (Phys.Rev. C80 (2009) 054901)

Both GKZ (modified VMD+Glauber+γN cross sections from HERA, Phys. Rev. C 93 (2016) 055206) and
GM (dipole approach+Color Glass Condensate, Phys.Rev. C80 (2009) 054901)
calculations are about three sigma above the measurement

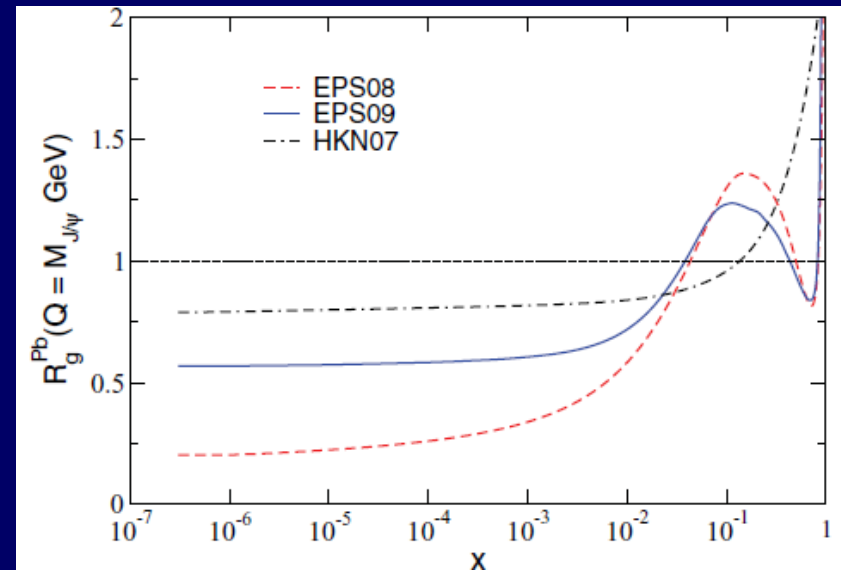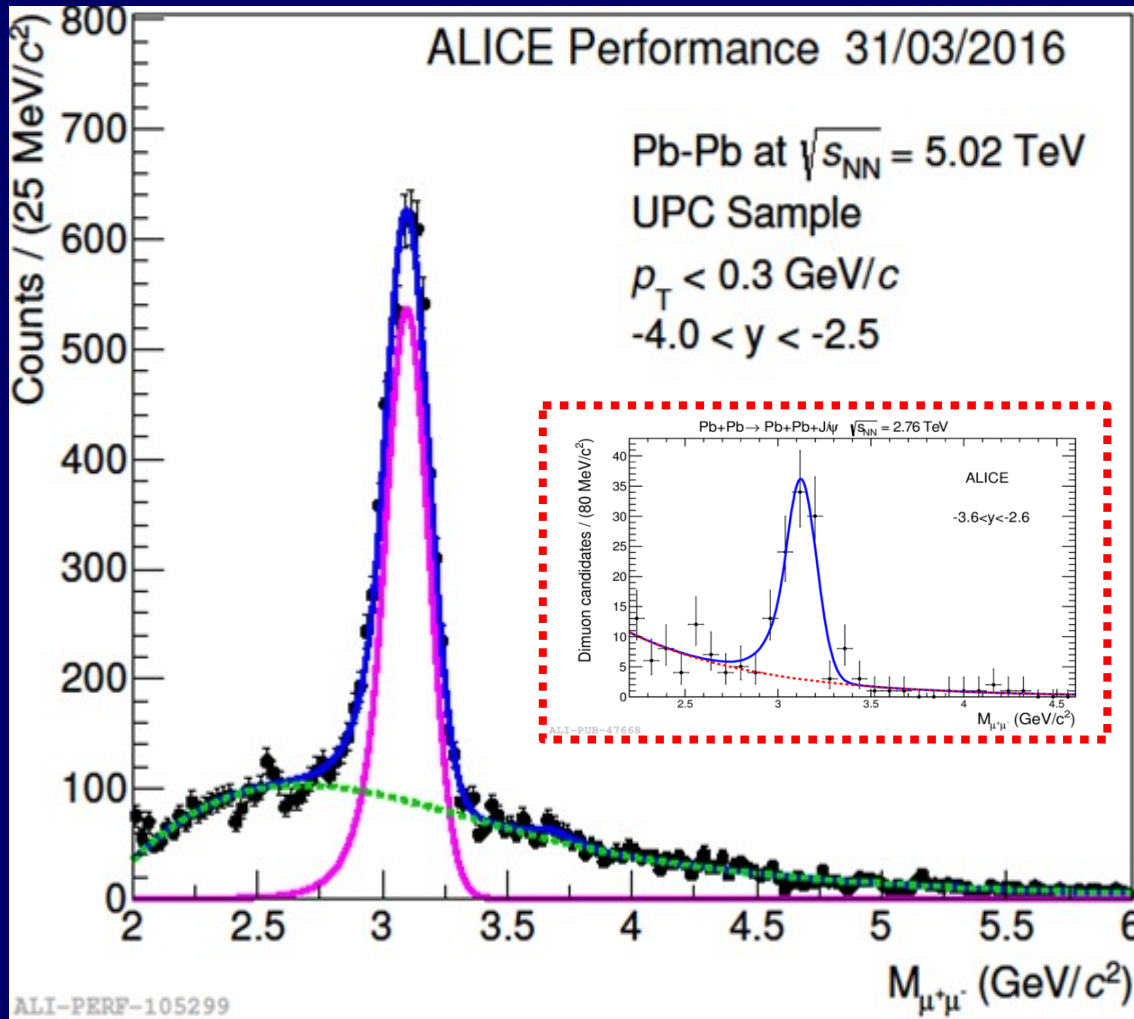**ALICE**
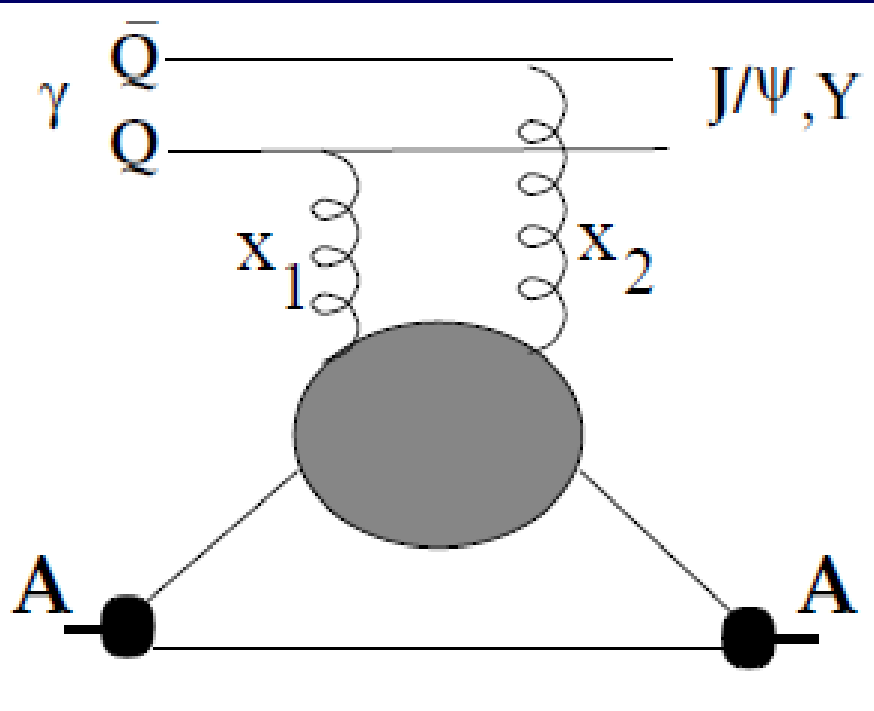
Quarkonium photoproduction (γA → J/ψ A) at LHC probes high $W_{\gamma p}$ (small x) range.

$$\left.\frac{d\sigma_{\gamma A \to J/\Psi A}}{dt}\right|_{t=0} = \xi_{J/\Psi}\left(\frac{16\pi^3\alpha_s^2\Gamma_{l+l^-}}{3\alpha M_{J/\Psi}^5}\right)[xG_A(x,\mu^2)]^2$$

M. G. Ryskin, Z. Phys. C57 (1993), 89

Main theoretical issue is how to properly incorporate nuclear shadowing

Increased LHC Run-2 Pb-Pb luminosity (Pb-Pb run corresponds to ∫L > 200 μb⁻¹) together with larger J/ψ photoproduction cross section provides ~50 times as larger J/ψ yield as compared to the Run-1 data (built-in plot).

Forward AD detector, installed for Run-2 and included into the trigger suppress a background from peripheral heavy-ion collisions and it provides much cleaner sample as compared to the Run-1 data.

Coherent J/ψ production in ultra-peripheral Pb–Pb collisions at √s_NN = 5.02 TeV
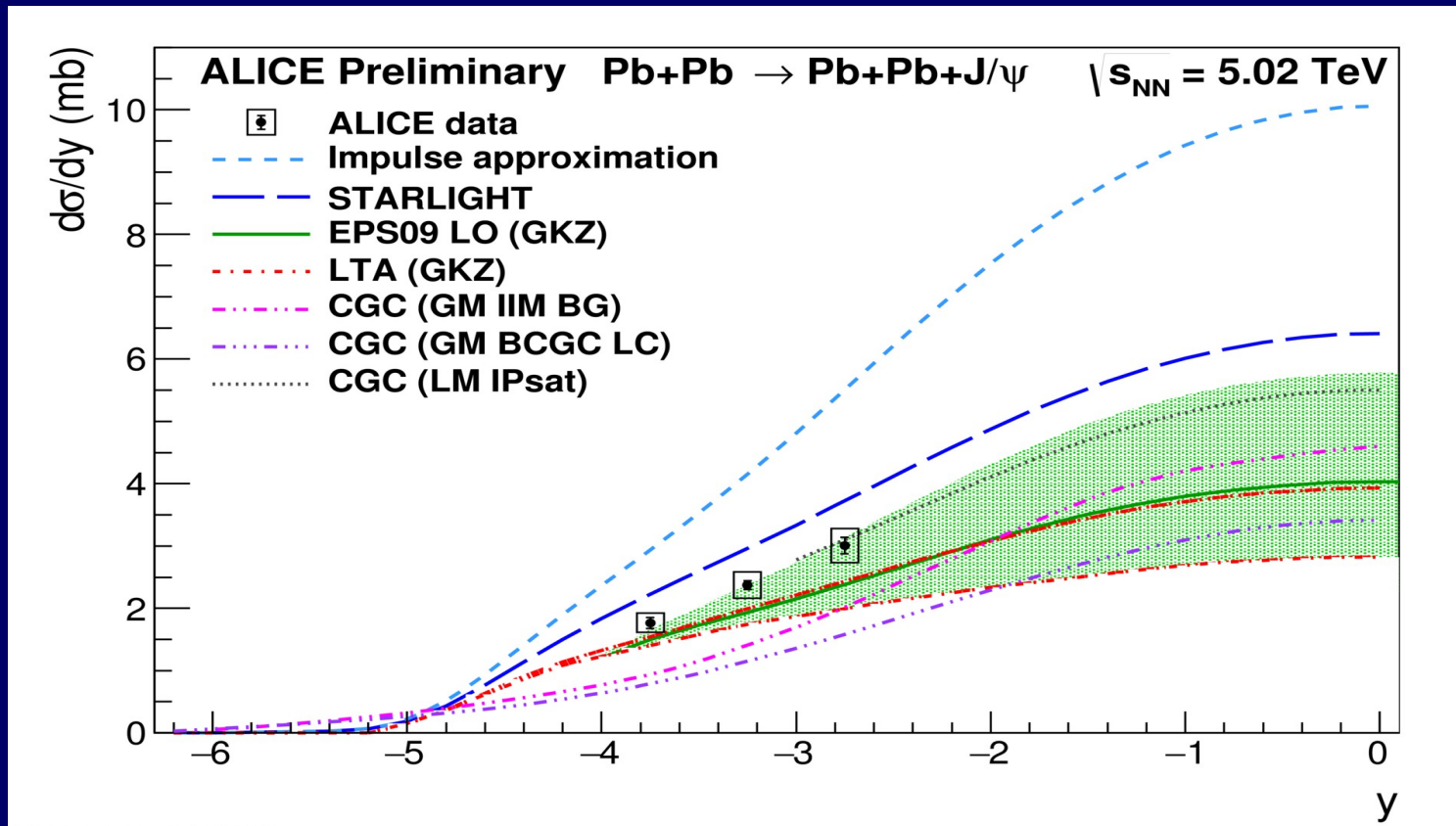
no nuclear effects, impulse approximation
VDM + Glauber, STARLIGHT, Comput. Phys. Commun. 212 (2017) 258
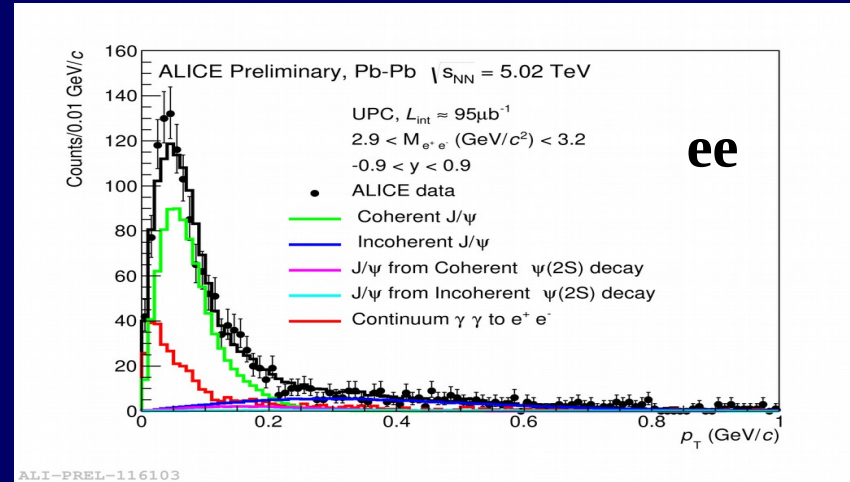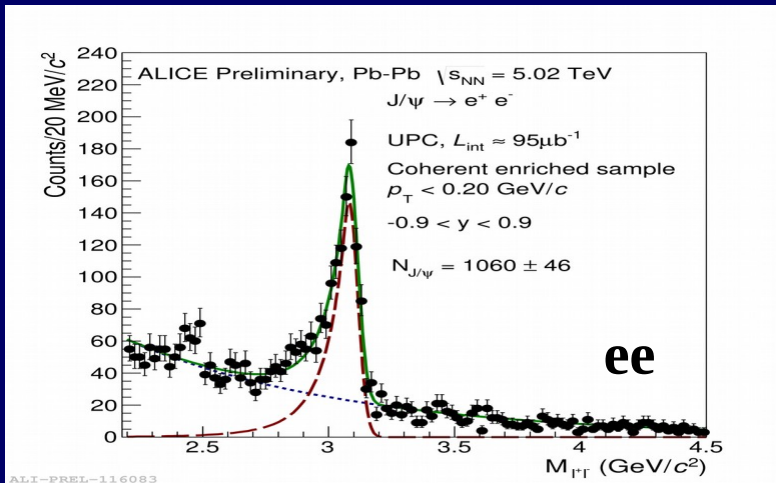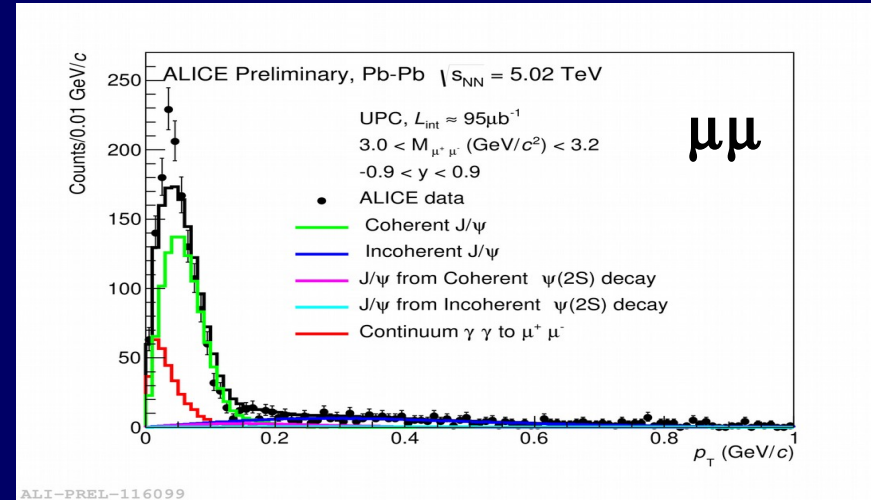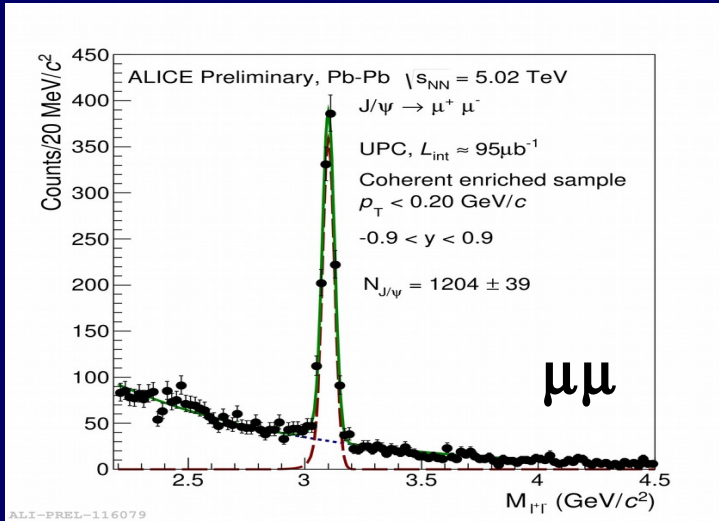EPS09 shadowing / Leading Twist Approximation, PRC93 (2016) 055206
Color dipole + IIM / bCGC CGC, PRC 90 (2014) 015203, JPG 42 (2015) 105001
Color dipole model + IPSat CGC, PRC 83 (2011) 065202, PRC 87 (2013) 032201

Coherent J/ψ photoproduction cross section agrees with moderate gluon shadowing in nuclei
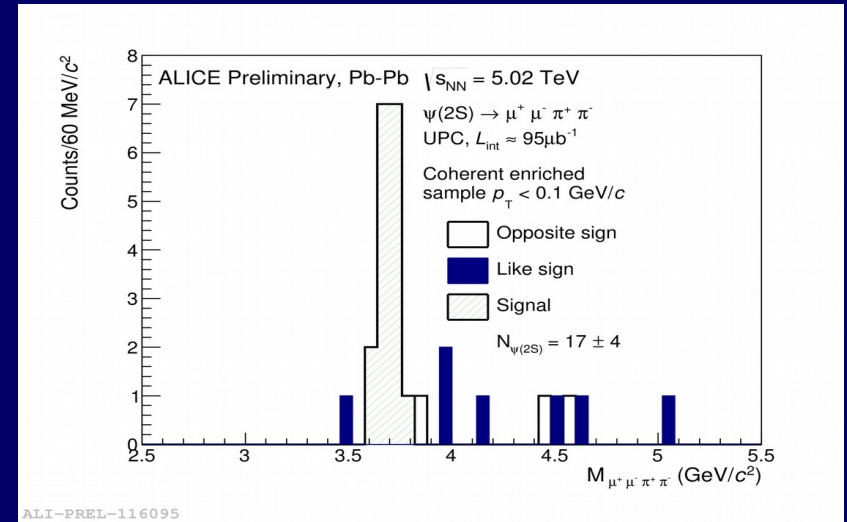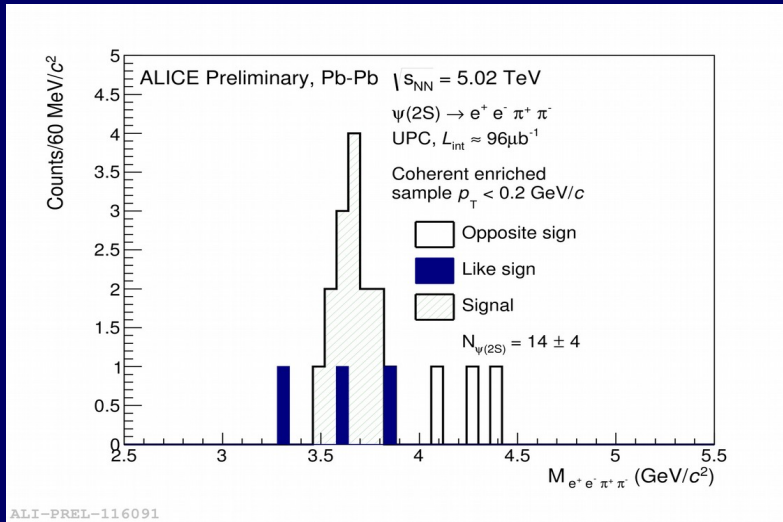
Mid-rapidity J/ψ photoproduction

Coherent mid-rapidity J/ψ production in UPC is well seen in both muon and electron decay channels

Further measurements on VM photoproduction in Pb-Pb UPC with Run-2 data

## mid-rapidity ψ' photoproduction

## photoproduction of J/ψ with subsequent decay into proton-antiproton
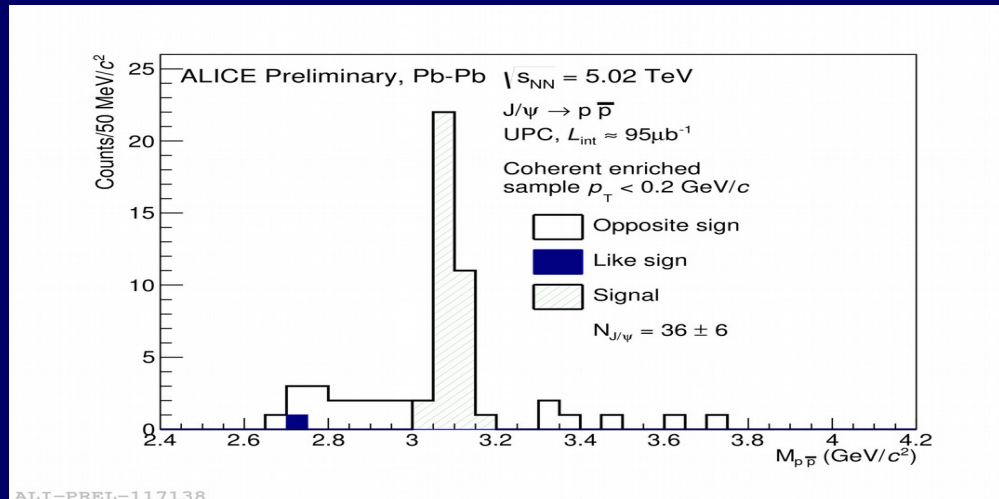
ALICE

Large enough statistics of the collected data and high efficient Zero Degree Calorimeter in the ALICE setup allow us to split the data sample according to presence/absence of neutrons, coming from single or mutual electromagnetic dissociation processes
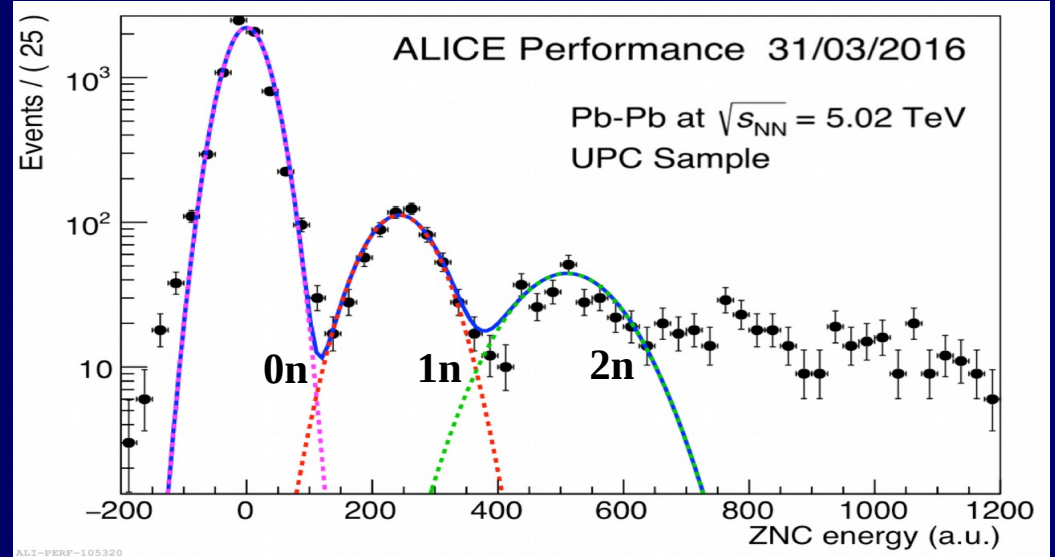
incoherent part (VM p_T > 150 MeV) of 0nXn case as a probe of small-x gluon nPDF.

Events with opposite directions of J/ψ and neutrons (high-energy photoproduction) can be influenced by gluon shadowing in nuclei at $x \approx 10^{-4}$
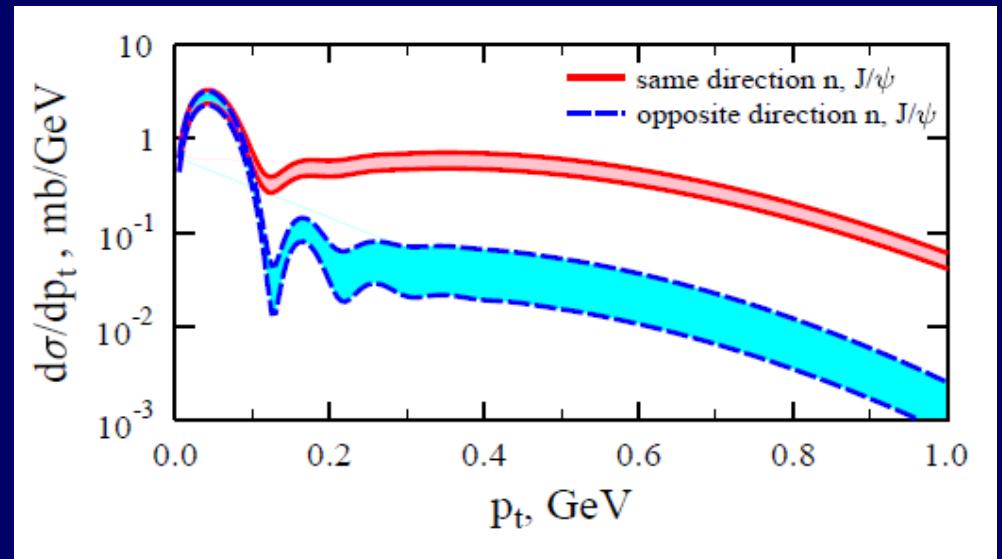
V. Guzey, M. Strikman, M. Zhalov, Eur.Phys.J. C74 (2014) 7, 2942

Conclusions and outlook

Analysis of the coherent photoproduction is a tool to learn the dynamics of high-energy γA interactions and to study gluon nPDF

Ultra-peripheral Pb–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV were studied with the ALICE experimental data, collected during LHC Run-2

Preliminary ALICE results on the coherent ρ^0 photoproduction cross section are presented. The result agrees with STARLIGHT model

Cross section of coherent J/ψ production in ultra-peripheral Pb–Pb collisions is measured. The result supports calculations with moderate gluon shadowing in nuclei

More studies of the UPC processes (mid-rapidity both coherent and incoherent J/ψ and ψ' production, UPC reactions accompanied by single/mutual EM dissociation) are ongoing, news will come soon