

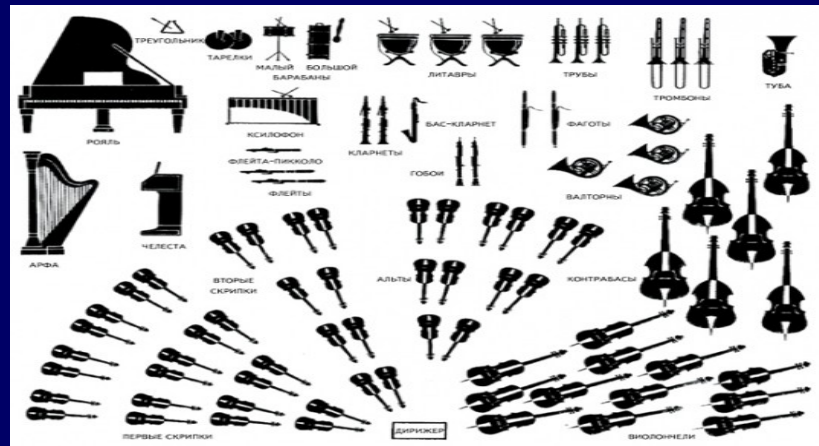


Изучение процессов фоторождения векторных мезонов в эксперименте ALICE (LHC, CERN)



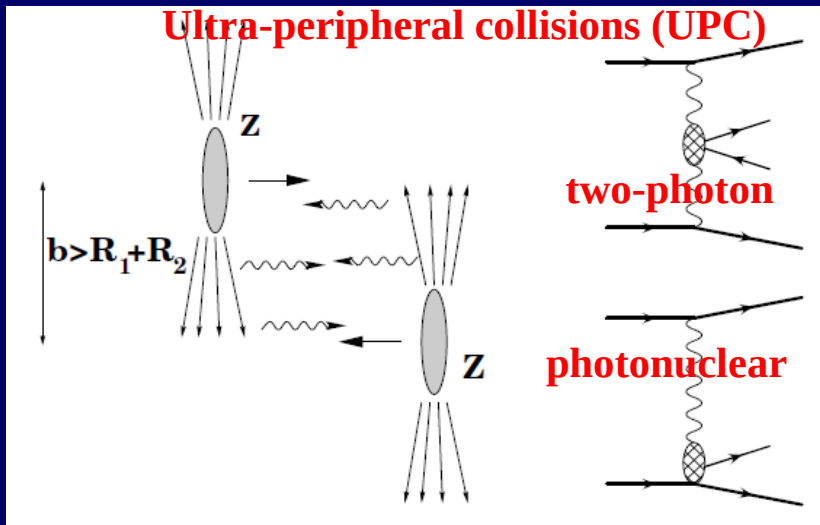
(The study of vector meson photoproduction at the LHC with ALICE)

В. Поздняков, Ю. Вертоградова, Б. Румянцев (ЛФВЭ, ОИЯИ)
Е. Крышень (НИЦ “Курчатовский Институт”, ПИЯФ, Гатчина)
J. G. Contreras Nuno, D. Horak (CZ Prague STU, Czech Republic)*



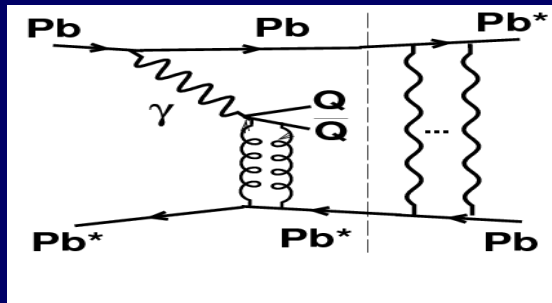
- ультрапериферические столкновения (ultra-peripheral collisions, UPC), эксперимент ALICE, кинематика UPC на примере зарегистрированных UPC;
- мотивация и полученные результаты;
- работы и доклады на конференциях, выдвигаемые на конкурс ОИЯИ по разделу “научно-исследовательские экспериментальные работы”.

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.

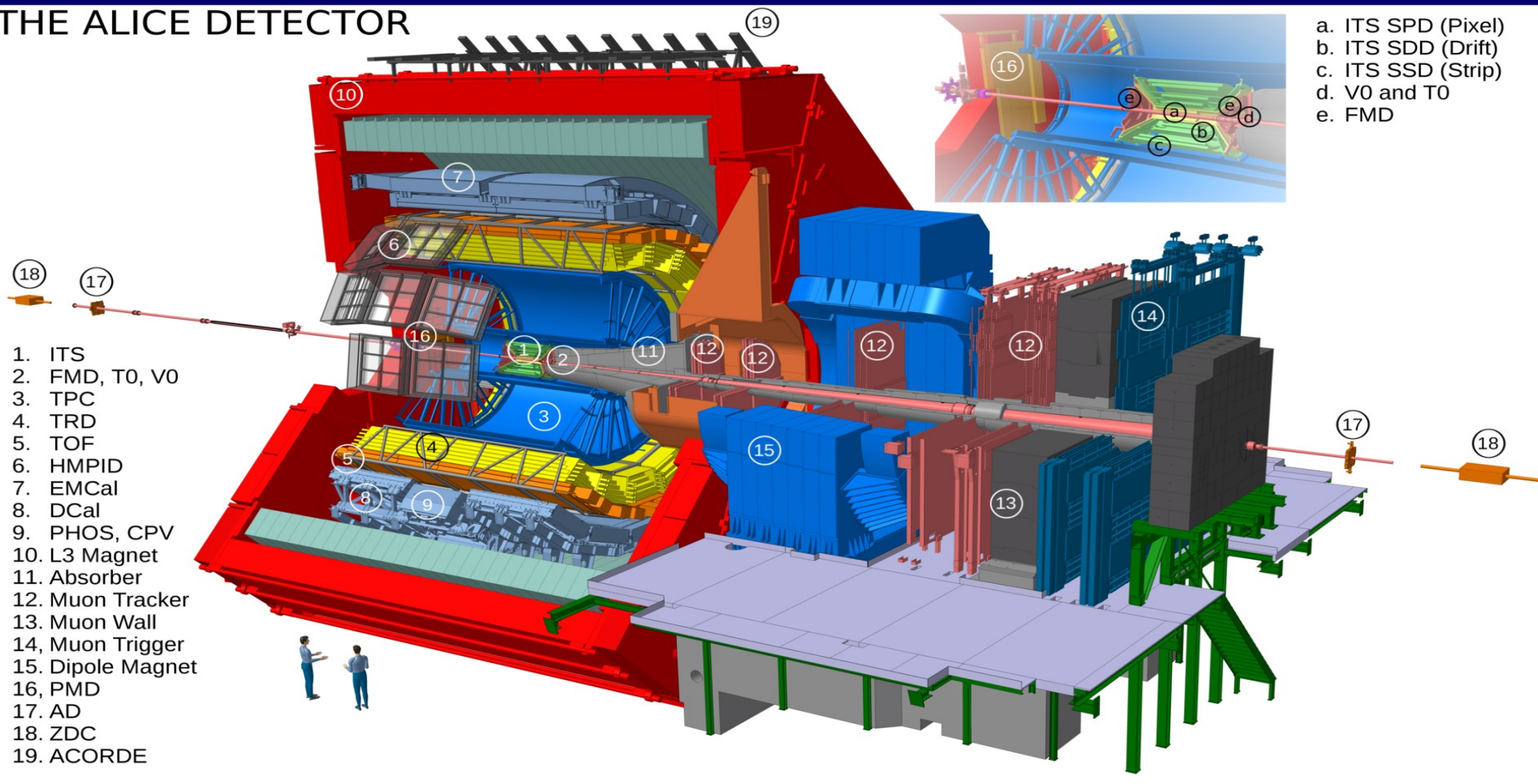
UPC studies address gluon shadowing in nuclei in photoproduction of vector mesons, two-photon processes like light-by-light scattering, dilepton production etc.

UPC review and current status:

- | | |
|--|--|
| A.J. Baltz <i>et al.</i> , Phys.Rept. 458 (2008) 1; | V. Guzey <i>et al.</i> , Eur.Phys.J. C74 (2014) 7; |
| L. Frankfurt <i>et al.</i> , Phys.Lett.B 752 (2016) 51; | E. Kryshen, EPJ Web Conf. 204 (2019) 01011; |
| CMS Collab., Phys.Lett.B 797 (2019) 134826; | ALICE Collab., Phys.Lett. B798 (2019) 134926; |
| S. R. Klein and P. Steinberg, arXiv:2005.01872 [hep-ph] (2020) | |

A Large Ion Collider Experiment (ALICE) at LHC

THE ALICE DETECTOR



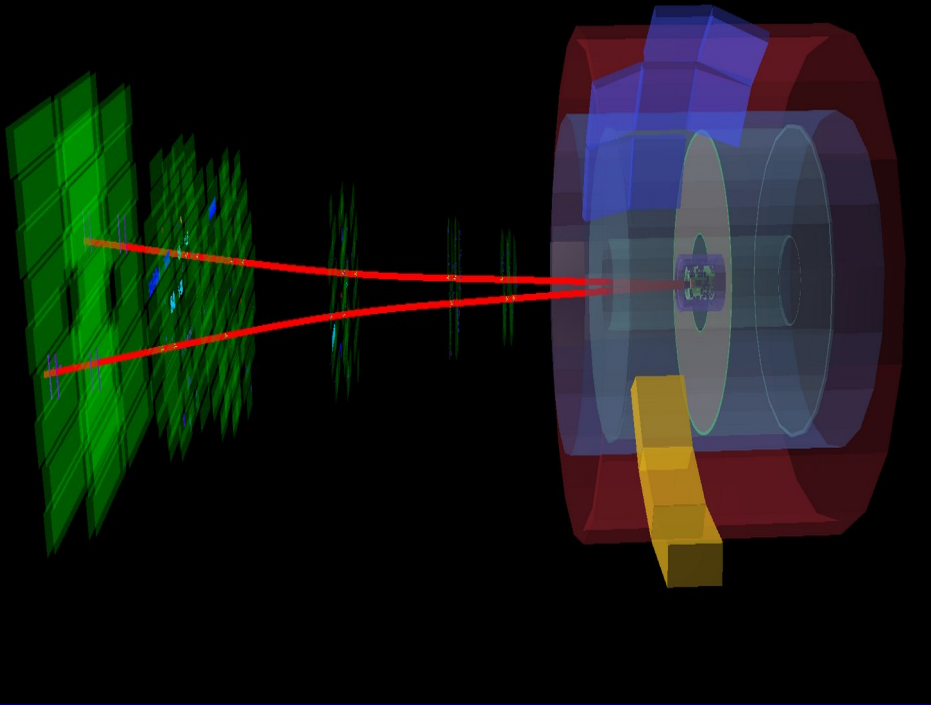
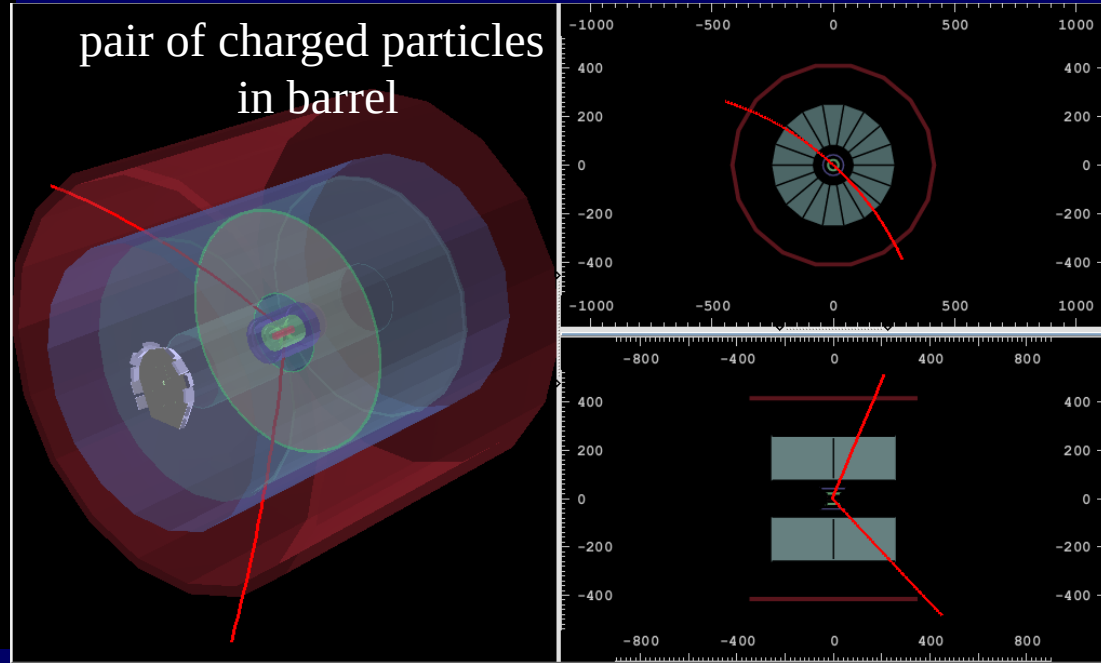
ALICE systems relevant for J/ψ / ρ^0 photoproduction measurements:

- **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.



ALICE

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 J/ψ photoproduction in UPC



ALICE

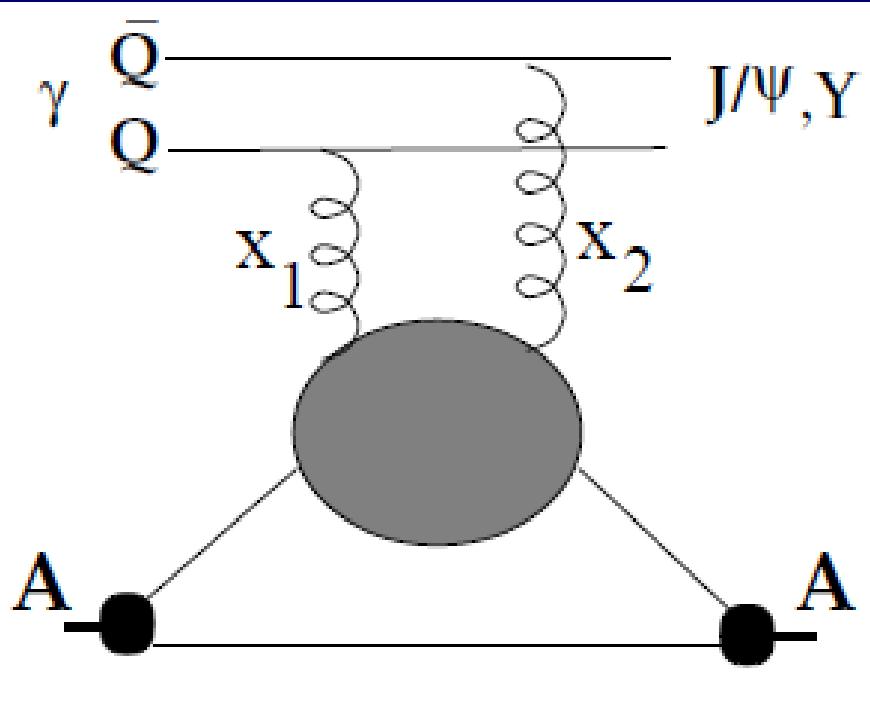
Quarkonium photoproduction ($\gamma A \rightarrow J/\psi A$) at LHC probes high $W_{\gamma p}$ (small x) range.

The leading order cross section (assuming that gluons have \sim same x , i.e. $x_1 \approx x_2$)

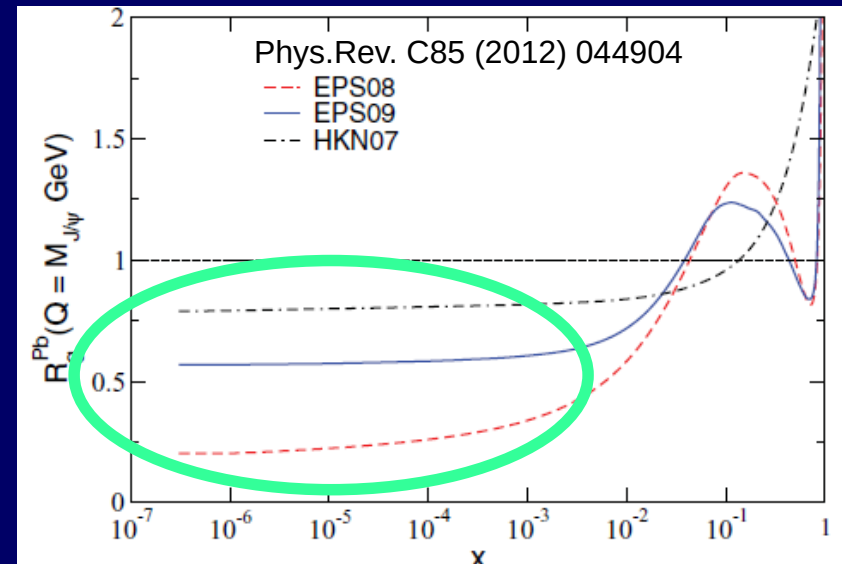
$$\frac{d\sigma_{\gamma A \rightarrow J/\psi A}}{dt} \Big|_{t=0} = \xi_{J/\psi} \left(\frac{16\pi^3 \alpha_s^2 \Gamma_{l+l-}}{3\alpha M_{J/\psi}^5} \right) [xG_A(x, \mu^2)]^2$$

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

extensions of the calculations to NLO are discussed in Flett CA, et al. arXiv:1912.09128 [hep-ph] (2019)



how to properly incorporate nuclear shadowing at small x ?



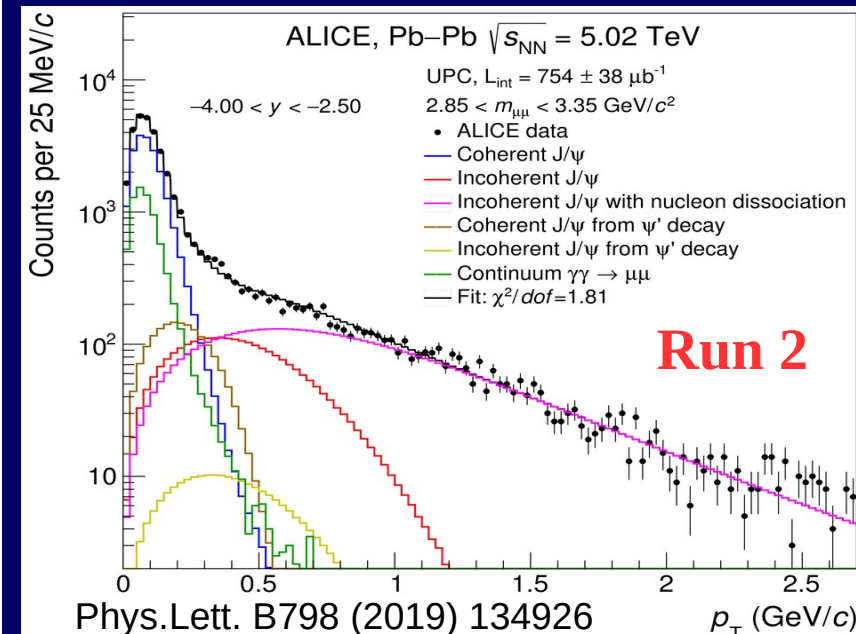
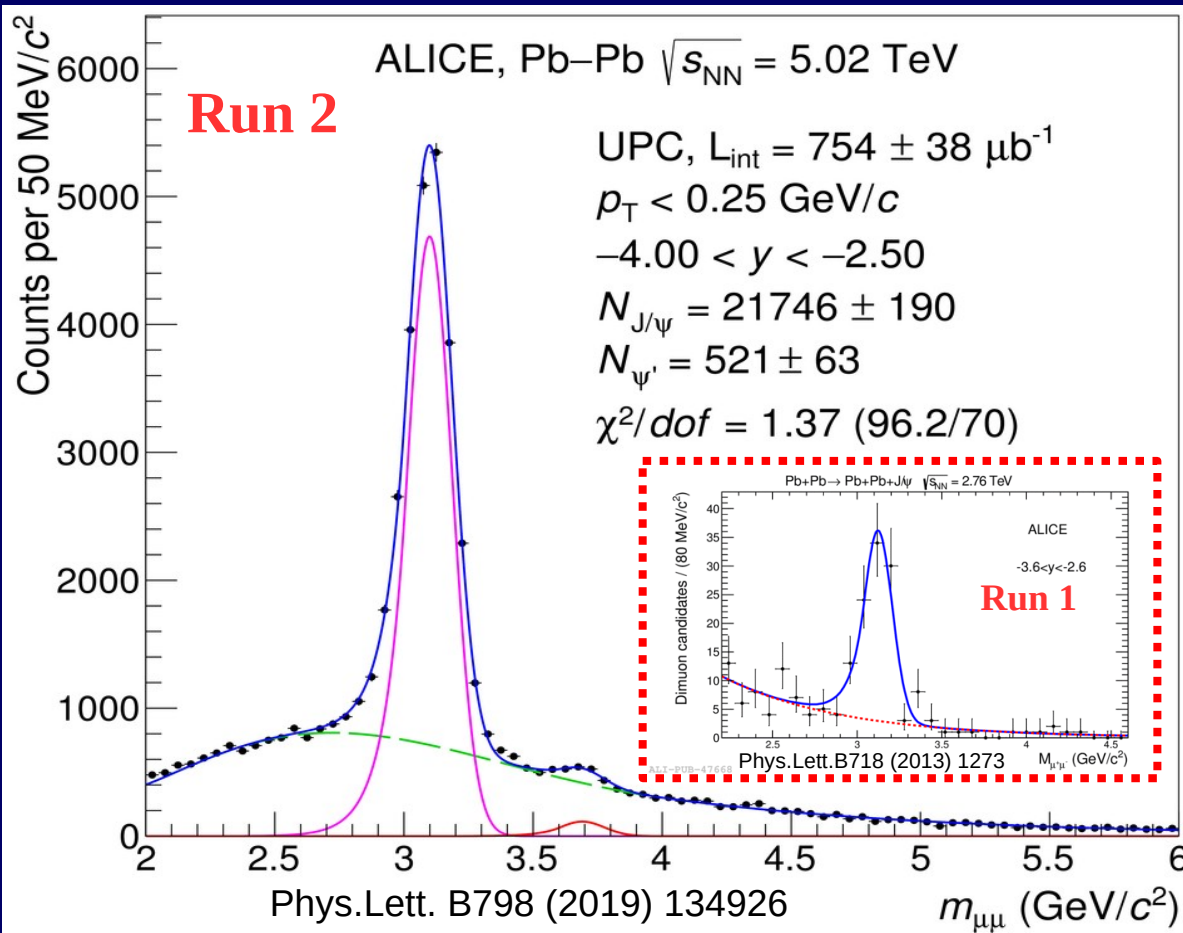
Coherent J/ψ production in ultra-peripheral Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV



ALICE

Increased LHC Run 2 Pb-Pb luminosity ($\int L > 700 \mu\text{b}^{-1}$), larger J/ψ photoproduction cross section and more efficient event triggering provides **~200 times** larger J/ψ yield at forward rapidities as compared to the Run 1 data.

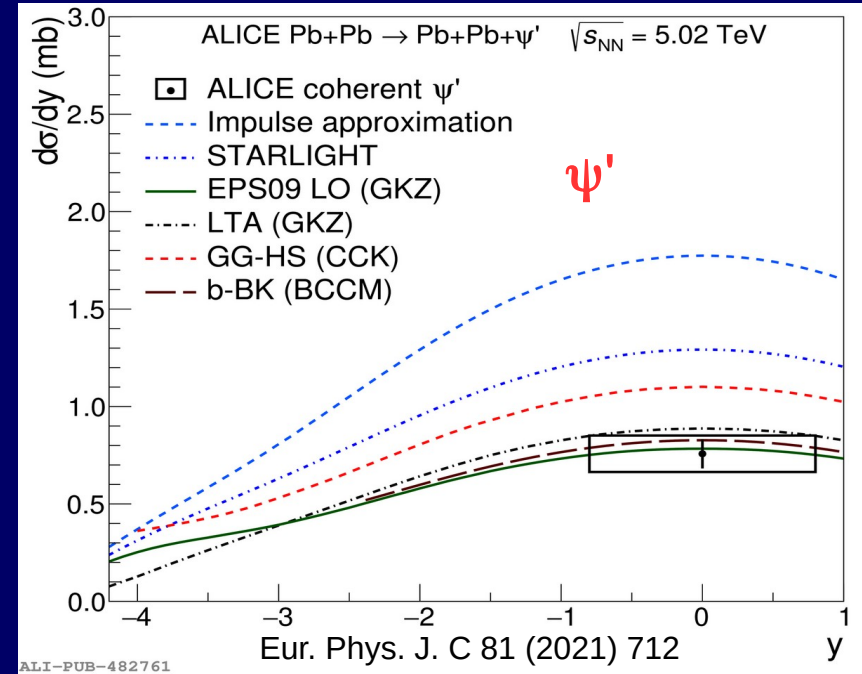
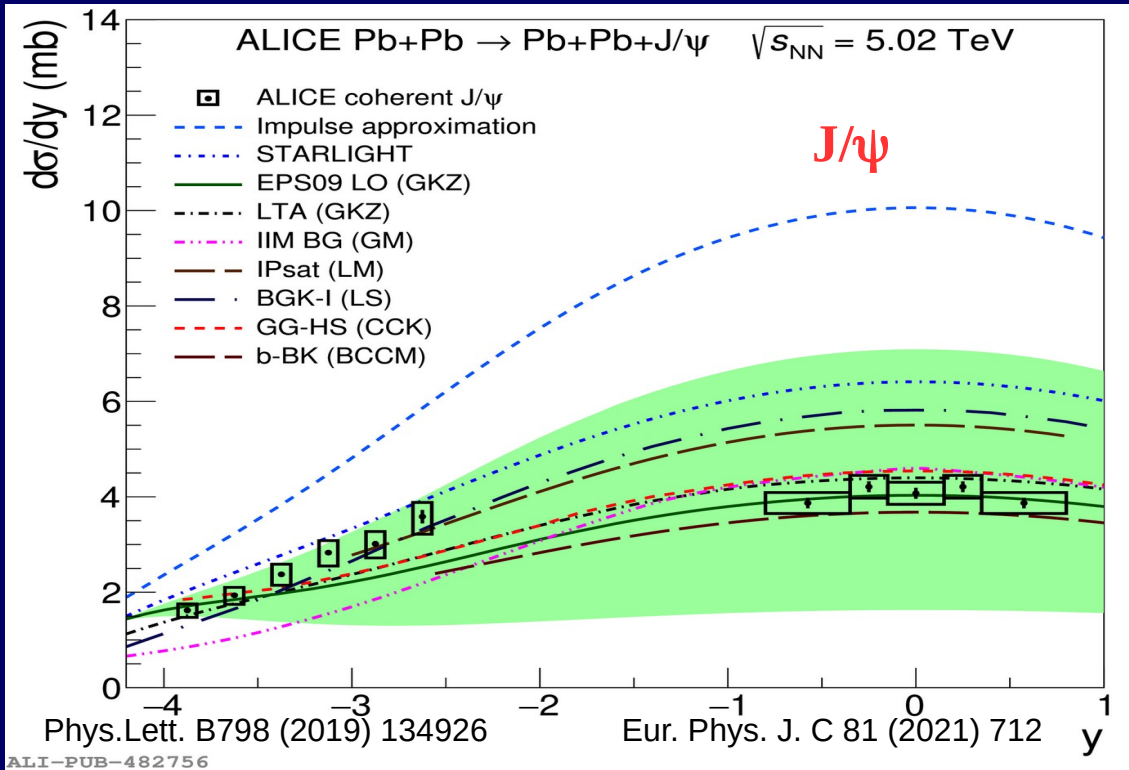
Forward AD detector installed for Run 2 and included into the trigger suppresses background from peripheral heavy-ion collisions.



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 J/ψ photoproduction at forward rapidity in ultra-peripheral Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV

ekryshen on 27 January, 2019 - 08:19

Draft Status: Published

Submission Date: 12 April, 2019

Related Public Paper: [Coherent \$J/\psi\$ photoproduction at forward rapidity in ultra-peripheral Pb-Pb collisions at \$\sqrt{s_{NN}} = 5.02\$ TeV](#)

CERN Report Number: [CERN-EP-2019-069](#)

Reference arXiv: [1904.06272](#)

Journal: Physics Letters B

Accepted date: 8 September, 2019

Article Citation reference: Phys.Lett. B798 (2019) 134926

Publication link: <https://doi.org/10.1016/j.physletb.2019.134926>

Publication date: 16 September, 2019

▼ HEP Data

HEP Data file:  [2019-09-30-hepdata.tar.gz](#)

HEP Data Link: [HEP Data](#)

▼ Submission Form

ID number: 5085

e-group: [alice-paperdraft-id5085](#)

PWG: PWG-UD (Ultraperipheral and Diffraction)

Format: Letter

Approved by PB: 31 January, 2019

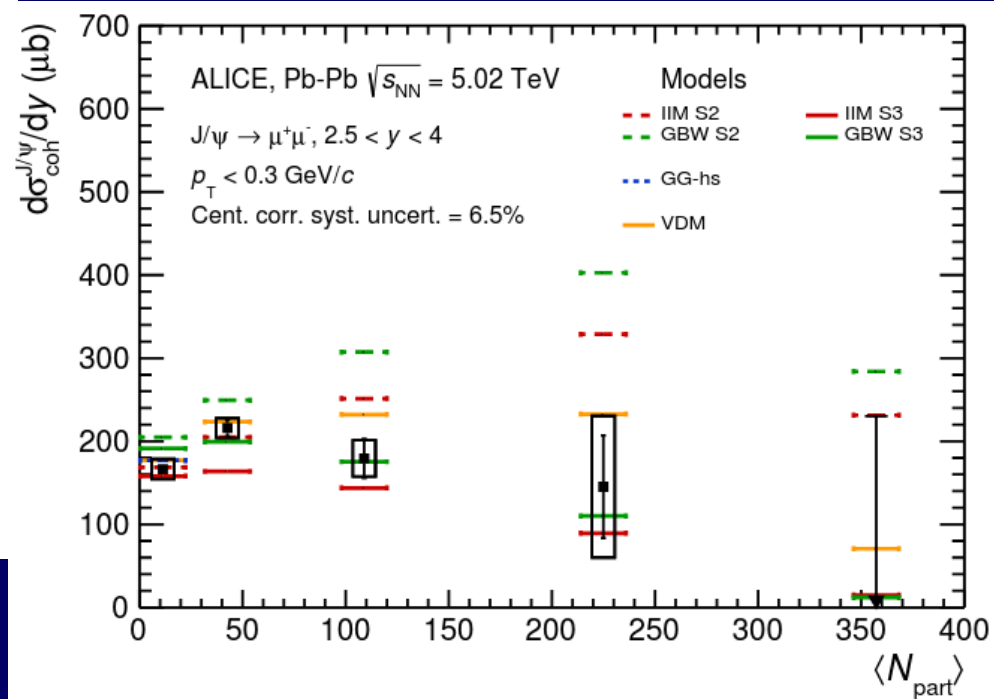
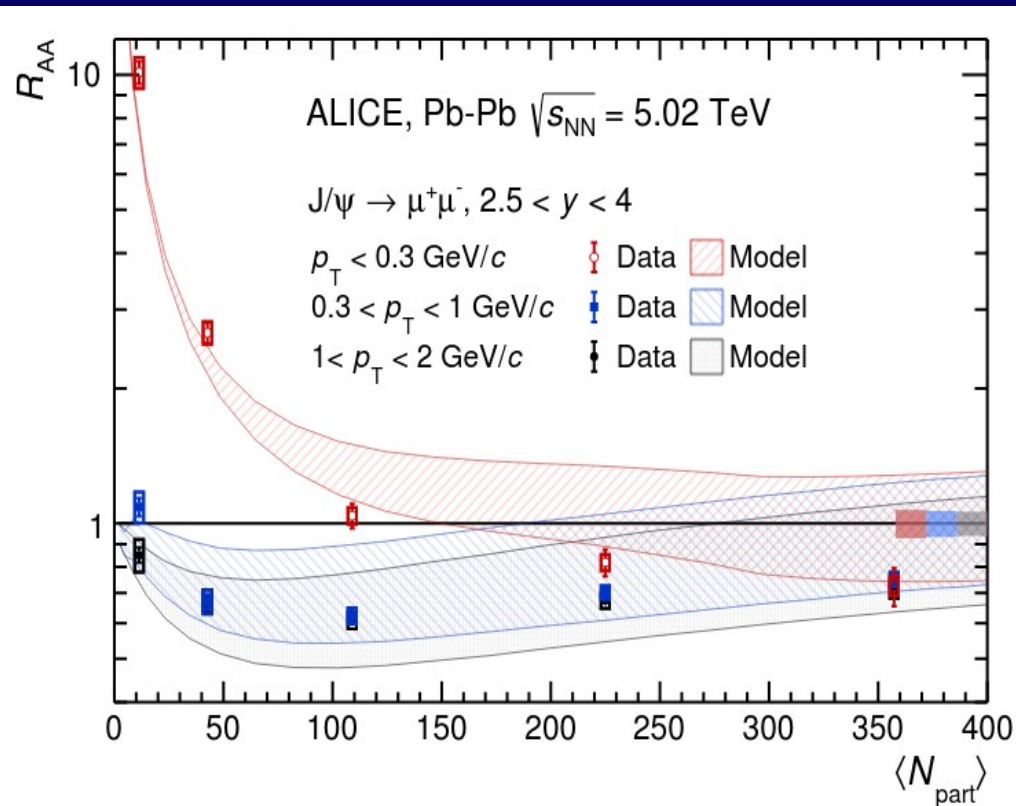
Paper Committee members: Evgeny Kryshen
Orlando Villalobos Baillie
Katie Leanne Graham
Valeriy Pozdnyakov

Coherent production of J/ψ at very low p_T in Pb–Pb UPC



The nuclear modification factor R_{AA} shows a large enhancement of the J/ψ yield for $p_T < 0.3$ GeV wrt to expectations from hadronic production

This excess, which was previously seen in more peripheral collisions, is now confirmed for most of the total hadronic cross section down to at least a level of 30% in centrality.



Photoproduction of low- p_T J/ψ from peripheral to central Pb--Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV

Submitted by obugnon on Thu, 02/11/2021 - 17:24

✓ create/update Published Paper

Draft Status: Submitted

Deadline for comments: 21/03/2022 - 23:59

Submission Date: Fri, 04/22/2022 - 12:00

Related Public Paper: [Photoproduction of low- \$p_T\$ \$J/\psi\$ from peripheral to central Pb–Pb collisions at 5.02 TeV](#)

▼ Article Information

Link to corresponding Note: <https://alice-notes.web.cern.ch/node/1102>

Figure group link: [Figure group](#)

CERN Report Number: [CERN-EP-2022-071](#)

Reference arXiv: <https://arxiv.org/abs/2204.10684>

Journal: Physics Letters B

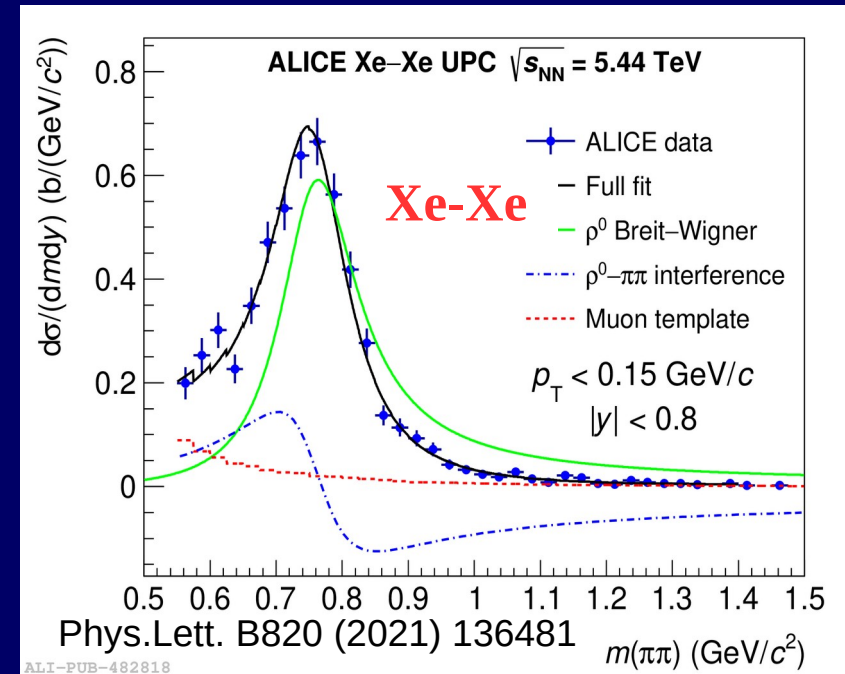
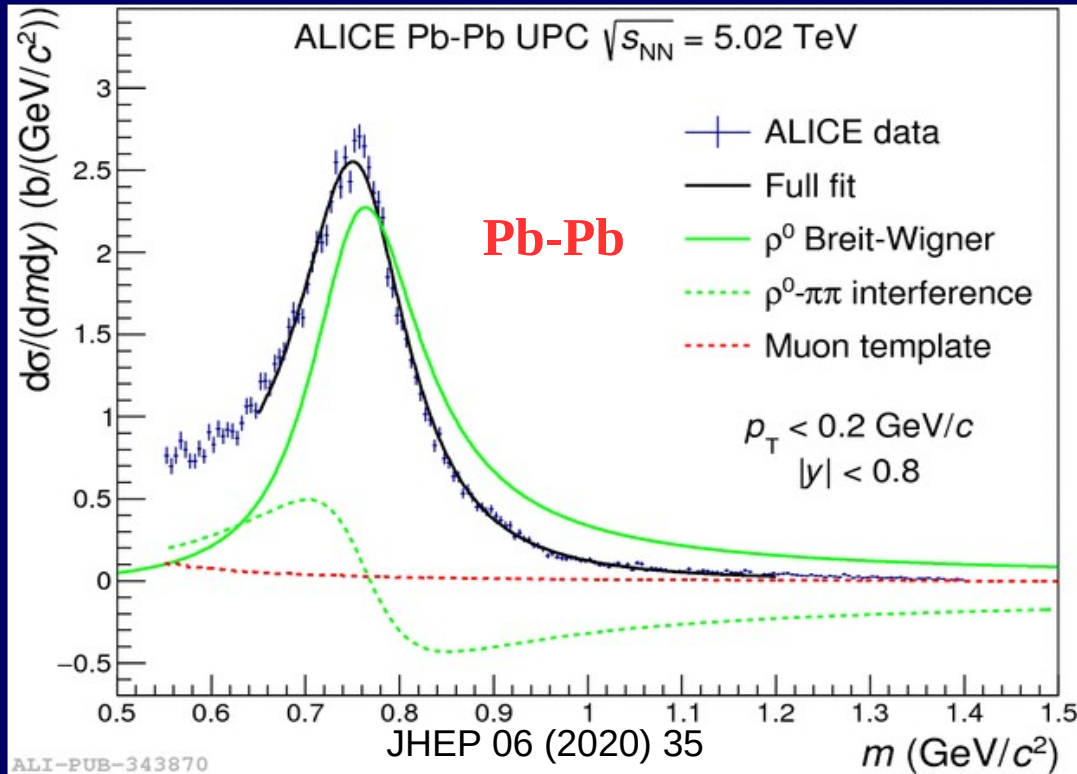
▼ HEP Data

HEP Data file:  [2022-05-20-hepdata.tgz](#)

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.



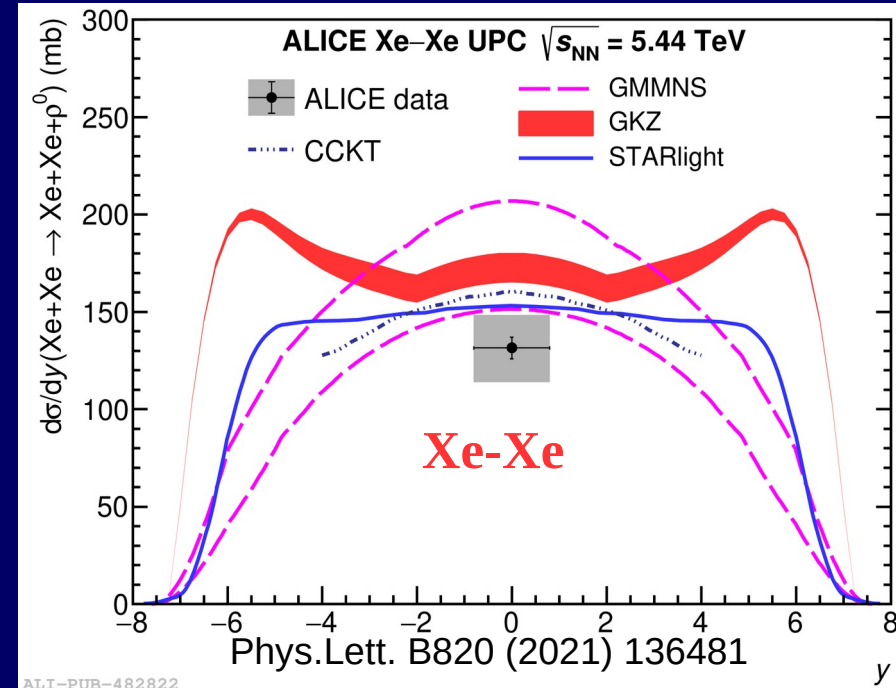
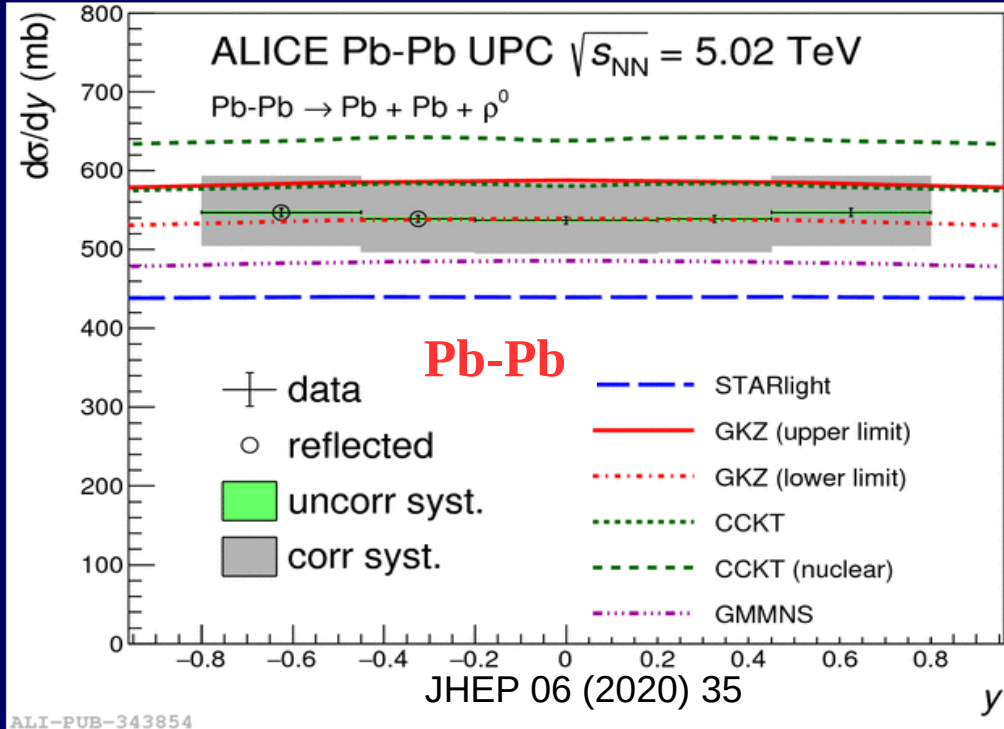
The fit done by Breit-Wigner for resonance shape

- + 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) :

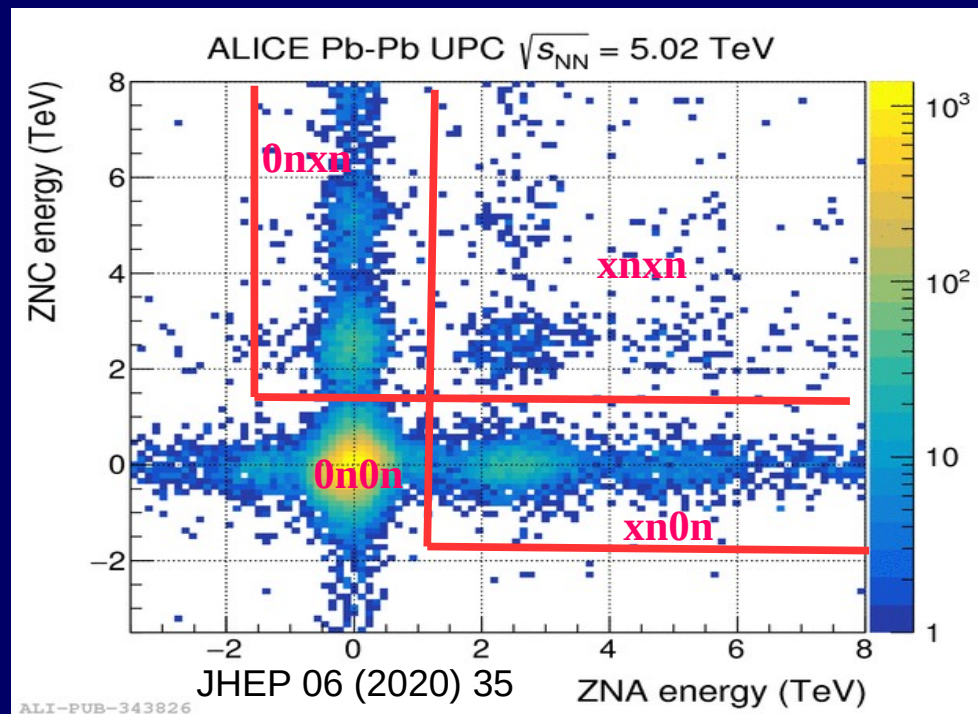
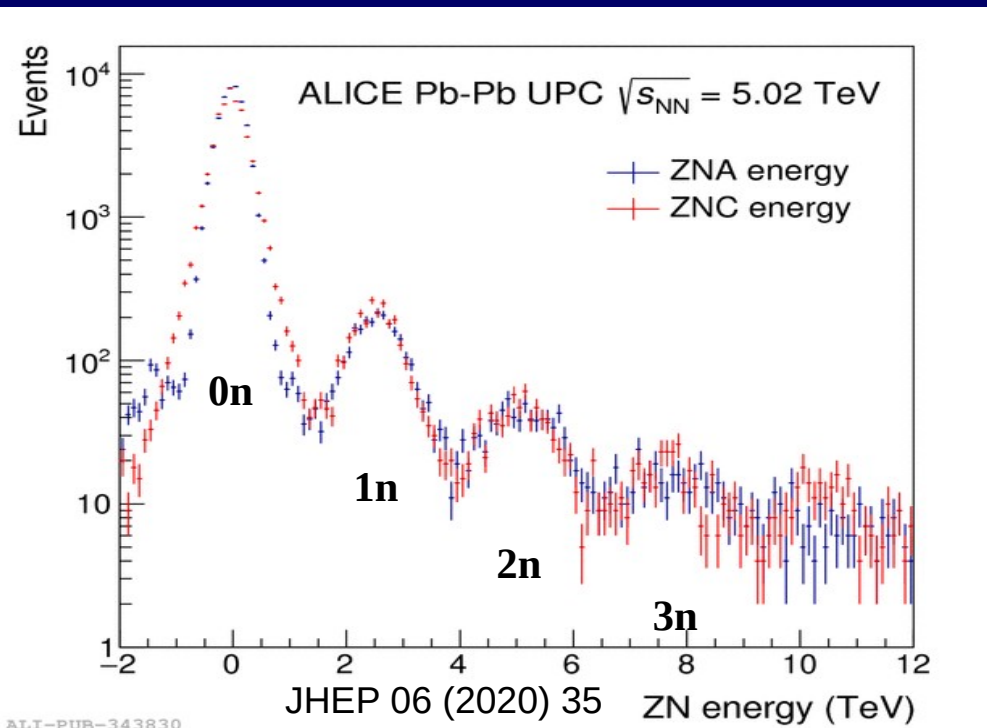
$\gamma+p \rightarrow VM+p$ cross section + the optical theorem + a Glauber-like eikonal formalism.

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

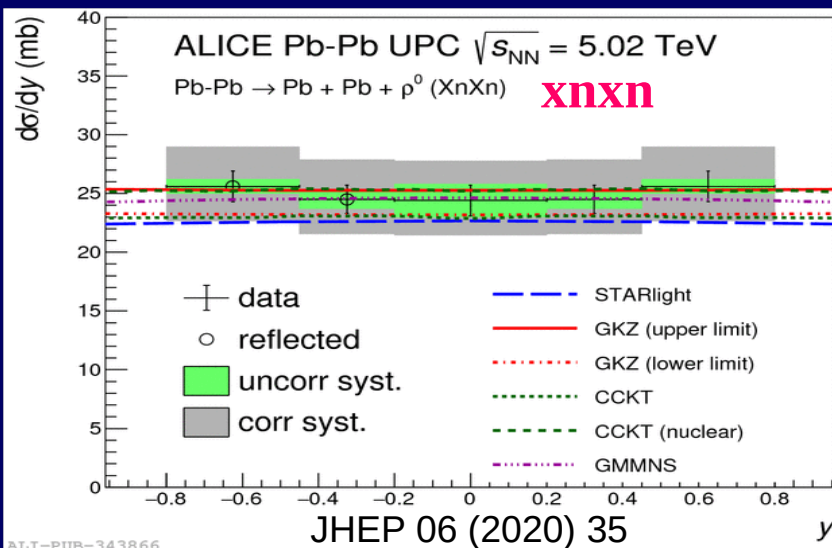
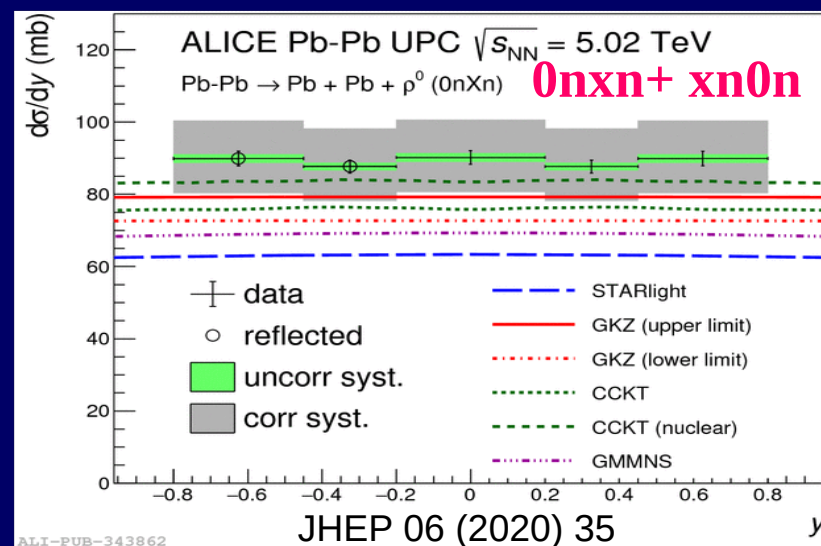
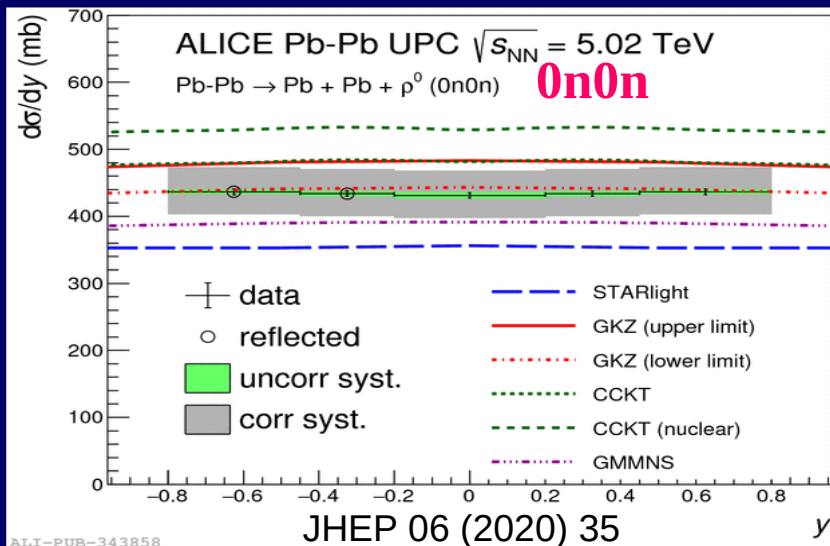
Coherent ρ^0 production in Pb–Pb UPC at $\sqrt{s_{NN}} = 5.02$ TeV (cont'd)

ALICE is equipped with two ZDC detectors (ZNA and ZNC)

- located at either side of interaction point at ± 112.5 m along the z-axis;
- intended for measurement of neutrons at beam rapidity;
- which provide time resolution enough to separate beam–beam and beam–gas interactions;
- which have a good efficiency to detect neutrons coming from electromagnetic dissociation (EMD) with $|\eta| > 8.8$;
- which have a relative energy resolution of around 20% for a neutron which allows to separate events with either zero or a few neutrons at beam rapidities.



Coherent ρ^0 production in Pb-Pb UPC at $\sqrt{s_{NN}} = 5.02$ TeV (cont'd)



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.

Coherent photoproduction of ρ^0 vector mesons in ultra-peripheral Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV

jgcn on 4 April, 2019 - 09:49

Draft Status: Published

Submission Date: 25 February, 2020

Related Public Paper: [Coherent photoproduction of \$\rho^0\$ vector mesons in ultra-peripheral Pb-Pb collisions at \$\sqrt{s_{NN}} = 5.02\$ TeV](#)

Article Information

Link to corresponding Note: <https://alice-notes.web.cern.ch/node/597>
<https://alice-notes.web.cern.ch/node/1021>

CERN Report Number: [CERN-EP-2020-021](#)

Reference arXiv: [2002.10897](#)

Journal: Journal of High Energy Physics

Article Citation reference: JHEP 06 (2020) 035

Publication link: [https://link.springer.com/article/10.1007/JHEP06\(2020\)035](https://link.springer.com/article/10.1007/JHEP06(2020)035)

Publication date: 4 June, 2020

HEP Data

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HEP Data Link: [HEP Data](#)

Submission Form

ID number: 5211

e-group: [alice-paperdraft-id5211](#)

PWG: PWG-UD (Ultrapерipheral and Diffraction)

Format: Regular Paper

Approved by PB: 4 April, 2019

Paper Committee members: Jesus Guillermo Contreras Nuno
Valeriy Pozdnyakov
David Horak

First measurement of coherent ρ^0 photoproduction in ultra-peripheral Xe-Xe collisions at $\sqrt{s_{NN}} = 5.4$ TeV

Submitted by jgcn on Fri, 07/17/2020 - 10:04

Draft Status: Published

Deadline for comments: 23/12/2020 - 23:59

Submission Date: Fri, 01/08/2021 - 12:00

Related Public Paper: [First measurement of coherent \$\rho^0\$ photoproduction in ultra-peripheral Xe-Xe collisions at \$\sqrt{s_{NN}} = 5.44\$ TeV](#)

▼ Article Information

Link to corresponding Note: <https://alice-notes.web.cern.ch/node/1070>

Figure group link: [Figure group](#)

Reference arXiv: <http://arxiv.org/abs/2101.02581>

Journal: Physics Letters B

Article Citation reference: Phys. Lett. B 820 (2021) 136481

Publication link: <https://doi.org/10.1016/j.physletb.2021.136481>

Accepted date :

Fri, 06/25/2021 - 12:00

Publication date: Wed, 07/28/2021 - 12:00

▼ HEP Data

HEP Data file:  [2021-01-26-HEPdata.tar.gz](#)

HEP Data Link: <https://www.hepdata.net/record/ins1839719?version=1>

цикл опубликованных работ, выдвигаемый на конкурс ОИЯИ по разделу
“научно-исследовательские экспериментальные работы” :

- ALICE Collab., “Coherent J/ψ photoproduction at forward rapidity in ultra-peripheral Pb–Pb collisions at $\sqrt{s_{NN}}=5.02$ TeV”, *Phys.Lett. B*798 (2019) 134926;
- ALICE Collab., “Coherent photoproduction of ρ^0 vector mesons in ultra-peripheral Pb–Pb collisions at $\sqrt{s_{NN}}=5.02$ TeV”, *JHEP* 06 (2020) 035;
- ALICE Collab., “First measurement of coherent ρ^0 photoproduction in ultra-peripheral Xe-Xe collisions at $\sqrt{s_{NN}}=5.44$ TeV”, *Phys. Lett. B* 820 (2021) 136481;
- VP, “New results using ultra-peripheral heavy ion collisions with ALICE”, in proceedings of “Rencontres de Moriond 2022: QCD and high energy ”;
- ALICE Collab., “Photoproduction of low- p_T J/ψ from peripheral to central Pb–Pb collisions at $\sqrt{s_{NN}}=5.02$ TeV”, CERN-EP-2022-071, submitted to *Phys. Lett.*

результаты были представлены на конференциях (приведены наиболее значимые):

- VP, “Measurements of vector meson photoproduction with ALICE in ultra-peripheral Pb-Pb collisions at $\sqrt{s_{NN}}=5.02$ TeV”, European Physical Society Conference on High Energy Physics (EPS-HEP) (Venice, Italy, 2017);
- E. Kryshen, “Photoproduction of heavy vector mesons in ultra-peripheral Pb-Pb collisions”, 26th Quark Matter (Chicago, USA, 2017);
- J. G. Contreras Nuno, “Photonuclear production of ρ^0 vector mesons off Xe with ALICE at the LHC”, 27th Quark Matter (Venezia, Italy, 2018);

- E. Kryshen, “Recent ALICE results on coherent J/ψ photoproduction in ultra-peripheral Pb-Pb collisions”, XXVII Workshop DIS2019 (Torino, Italy, 2019);
- J. G. Contreras Nuno, “Vector meson photoproduction in ultraperipheral Pb-Pb collisions in ALICE”, 28th Quark Matter (Wuhan, China, 2019);
- VP, “Vector meson photoproduction in ultra-peripheral Pb-Pb collisions at the LHC with ALICE”, 40th ICHEP (Prague, Czech Republic, 2020);
- E. Kryshen, “Overview of recent ALICE results on ultra-peripheral collisions”, Rencontres de Moriond: QCD and high energy interactions (La Thuile, Italy, 2021);
- VP, “New results using ultra-peripheral heavy ion collisions with ALICE”, Rencontres de Moriond: QCD and high energy interactions (La Thuile, Italy, 2022);
- J. G. Contreras Nuno, “Energy dependence of coherent photonuclear production of J/ψ in ALICE”, XXIX Workshop DIS2022 (Santiago..., Spain, 2022);
- B. Rumyantsev, “Exclusive four charged pion photoproduction in Pb-Pb ultra-peripheral collisions with ALICE”, poster on 29th Quark Matter (Krakow, Poland, 2022)
- VP, “Vector meson photoproduction at the LHC with ALICE”, 30th International Symposium on Lepton Photon Interactions at High Energies (Manchester, UK, 2022);

в заключение,

на конкурс выдвигаются 4 работы коллаборации ALICE (основными авторами которых являются участники творческого коллектива), представленные (перечислены основные конференции) на ICHEP(1 доклад), Moriond (2 доклада), EPS-HEP (1 доклад), Quark Matter (4 доклада), DIS (2 доклада), LPI (1 доклад)