David Horák

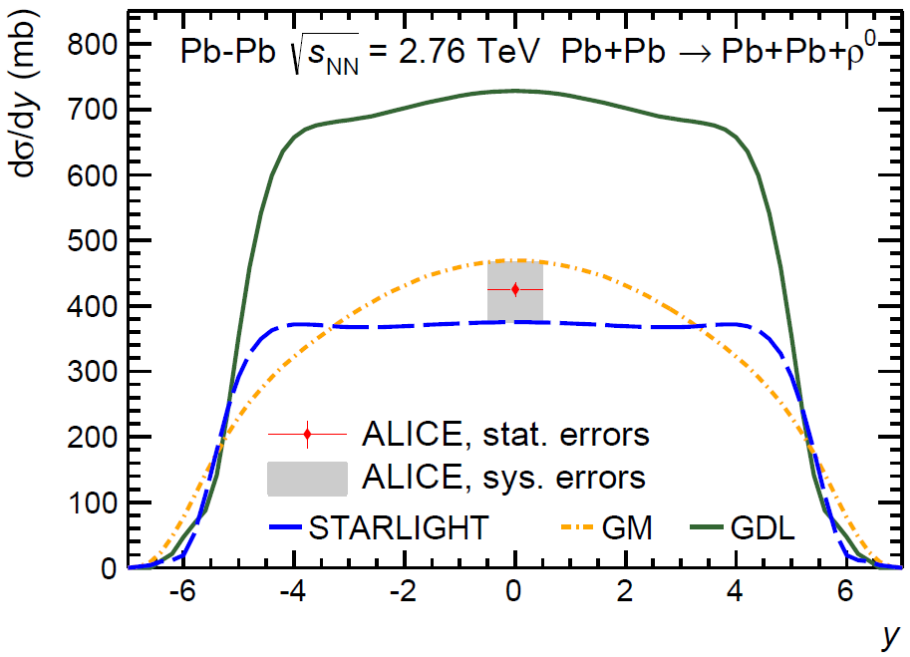
FJFI ČVUT v Praze

Recent results on coherent ρ^0 vector meson photoproduction

Workshop supported by grant SVK30/19/F4

Motivation

- Physics of coherent photoproduction of ρ^0:
  - Photoproduction process: particularly clean probes of hadronic structure
  - Photoproduction of ρ^0: dynamics of QCD at a semi-hard scale
  - Large cross section: possibility to study the approach to the black disk limit of QCD
- ALICE PbPb measurements at $\sqrt{s_{NN}} = 2.76$ TeV [1]



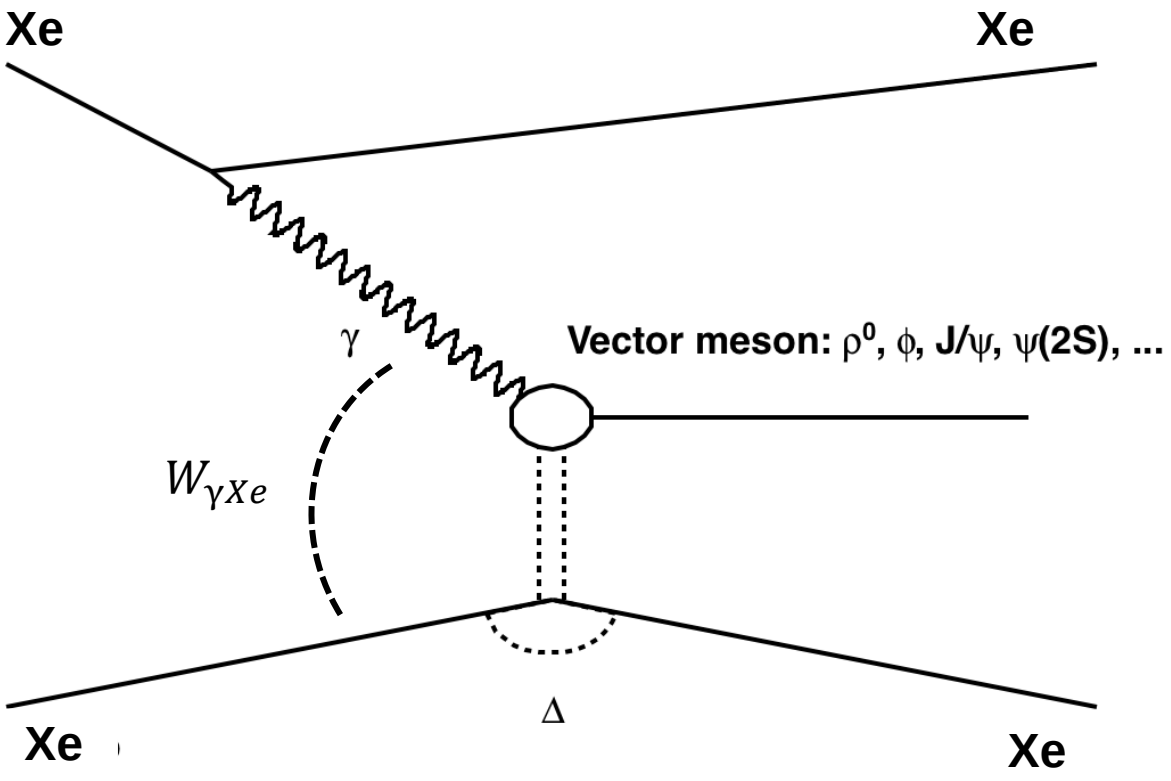
- Highlights of the new measurements (PbPb 2015 at $\sqrt{s_{NN}} = 5.02$ TeV, XeXe 2017 at $\sqrt{s_{NN}} = 5.44$ TeV)
  - More data, better precision: possibility to measure omega contribution, observation of a resonance at high masses
  - Rapidity dependence of the cross section
  - Measurement for different classes of forward neutron activity: possibility to extract the energy dependence of the cross section
  - Xe: target between p and Pb (Au): study the A dependence of cross section

Vector Meson Photoproduction in UPC

- ρ^0 measured in the central barrel by its decay to $\pi^+\pi^-$
  - Coherence condition implies p_T of ρ^0 a few tens of MeV
  - Nothing else in the detector (except possible few forward neutrons)

- Kinematics of ρ^0
  - From ρ^0 rapidity one obtains:
    - $W_{\gamma Xe}^2 = 2E_{Xe}M_\rho e^{\pm y}$
    - $W_{\gamma Xe}$ = γ-Xe energy at CMS
  - From transverse momentum $\vec{\Delta}^2 = -t$

- Strategy
  - Find two tracks with low pair-p_T
  - Veto on activity in the rest of the detector



Analysis Selection Criteria

- Global selection
  - Exactly two good-quality tracks with UPC trigger
  - Opposite charge of tracks – like-sign events used for estimation of combinatorial background
  - PID pion (5 n-sigma circle)
  - Fast-Or trigger decision matched to the tracks

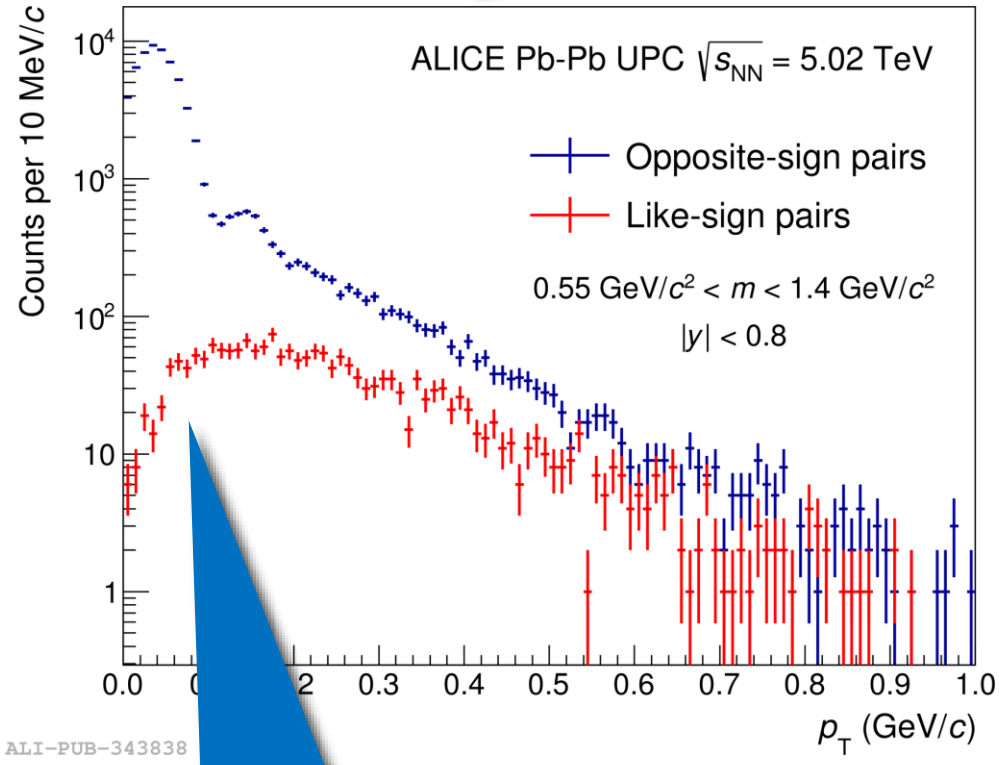
- Kinematic selection
  - Pair-rapidity $|y| < 0.8$
  - Invariant mass $m > 550$ MeV – below we do not distinguish electrons
  - Invariant mass $m < 1500$ MeV
  - Transverse momentum $p_T < 200$ MeV/c – coherent peak below this value

Summary of Rho0 in Pb-Pb UPC

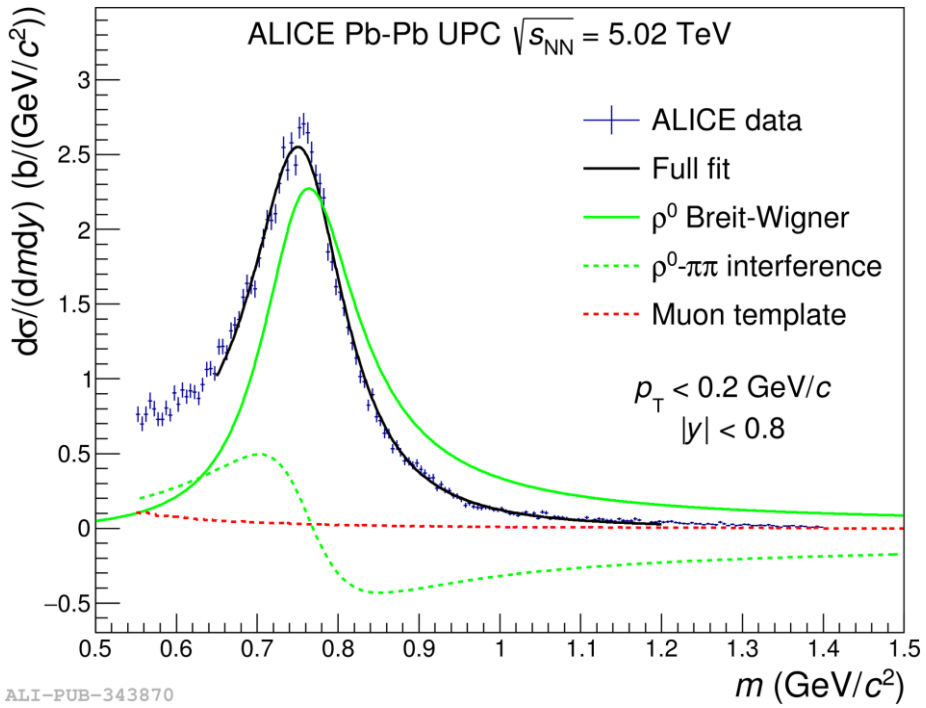
- Paper published in JHEP
  - https://link.springer.com/article/10.1007%2FJHEP06%282020%29035
  - https://arxiv.org/abs/2002.10897

Rho0 Pb-Pb signal

p_T spectrum used for estimation of incoherent ρ^0 contamination



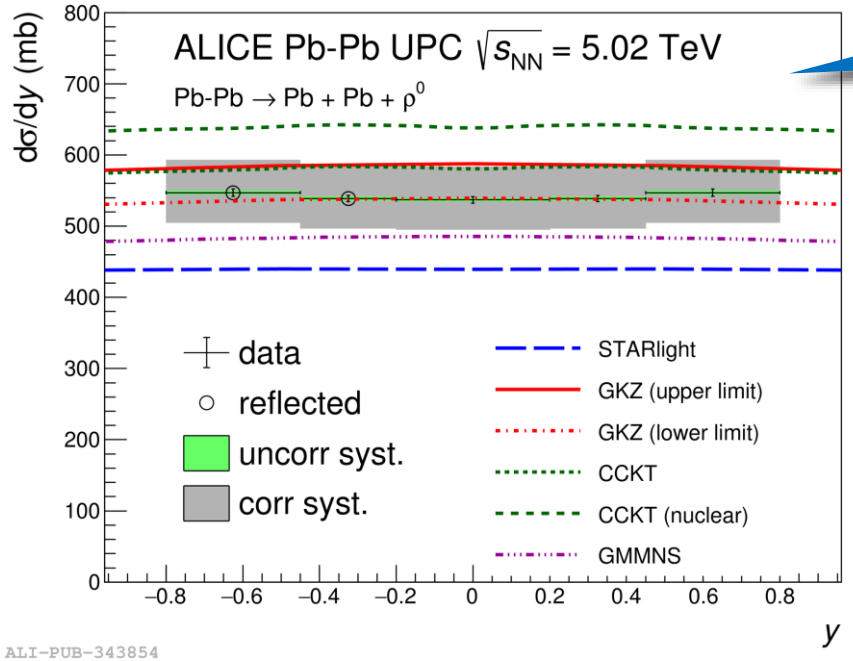
First and second **diffractive peaks** from ρ^0 are clearly visible in the p_T spectrum



Mass distribution described by the model

- $\frac{d\sigma}{dm_{\pi\pi}} = |A \cdot BW + B|^2 + M$
- Background M from $\gamma\gamma \rightarrow \mu\mu$ fixed using STARlight MC
- The values of the mass and width of the ρ^0 are
  (769.5 ± 1.2 (stat.) ± 2.0 (syst.)) MeV/ c^2
  (156 ± 2 (stat.) ± 3 (syst.)) MeV/ c^2
  compatible with PDG

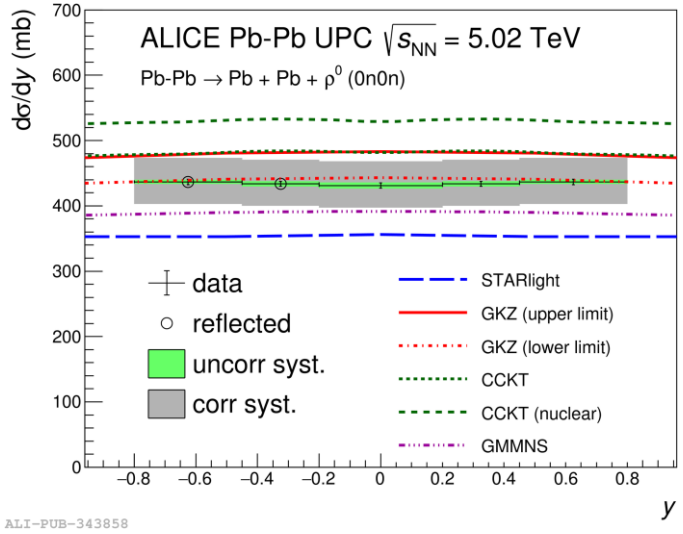
Rho0 Pb-Pb Cross section

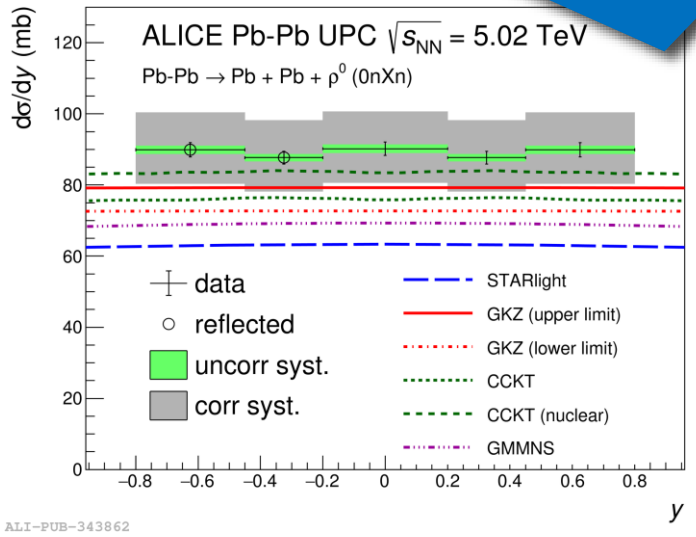


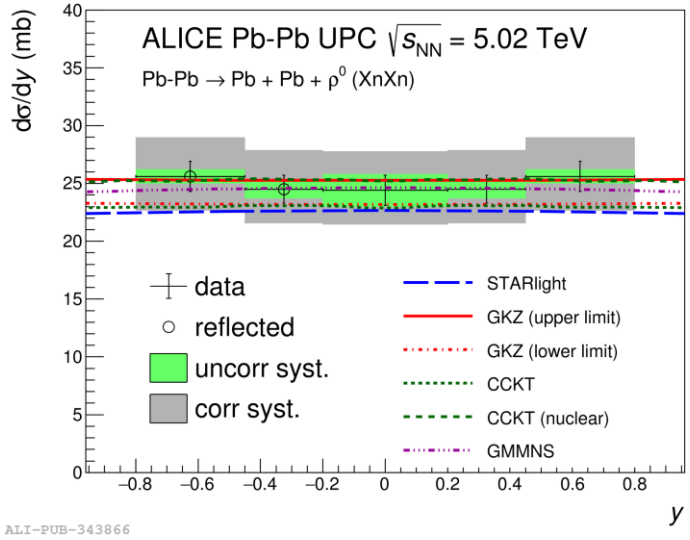
The differential cross section for the coherent photoproduction of ρ^0 as a function of rapidity (symmetry about y=0 assumed) and different neutron emission scenarios

Data consistent with all models at around 2 sigma level:

- **STARlight**: [6] based on the Vector Meson Dominance model and photoproduction off protons; data combined with the Glauber-like approach
- **GKZ**: [7] Guzey, Kryshen, Zhalov predictions based on the modified Vector Meson Dominance model
- **CCKT**: [8] model by Cepila, Contreras, Krelina and Tapia based on the Color-Dipole Model with the structure of a nucleon described by hot-spots
- **GMMNS**: [9] model by Gonçalves, Machado, Morerira and dos Santos based on the IIM implementation of gluon saturation within the Color-Dipole Model

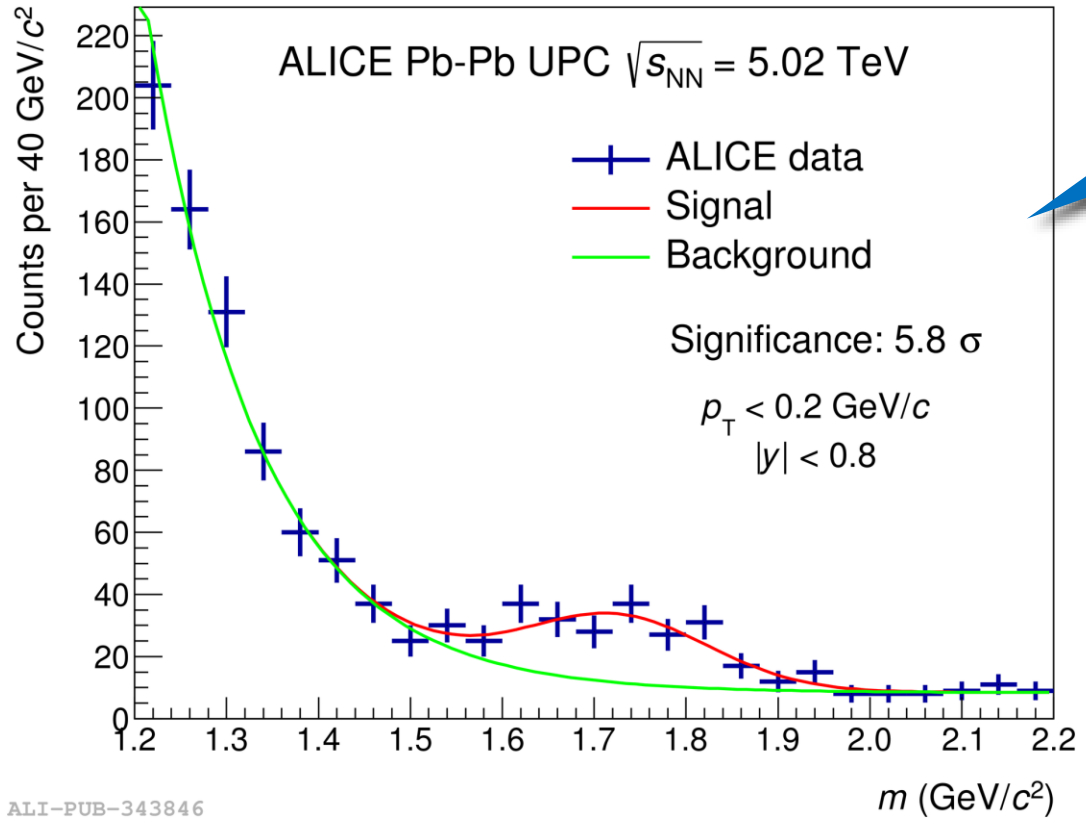


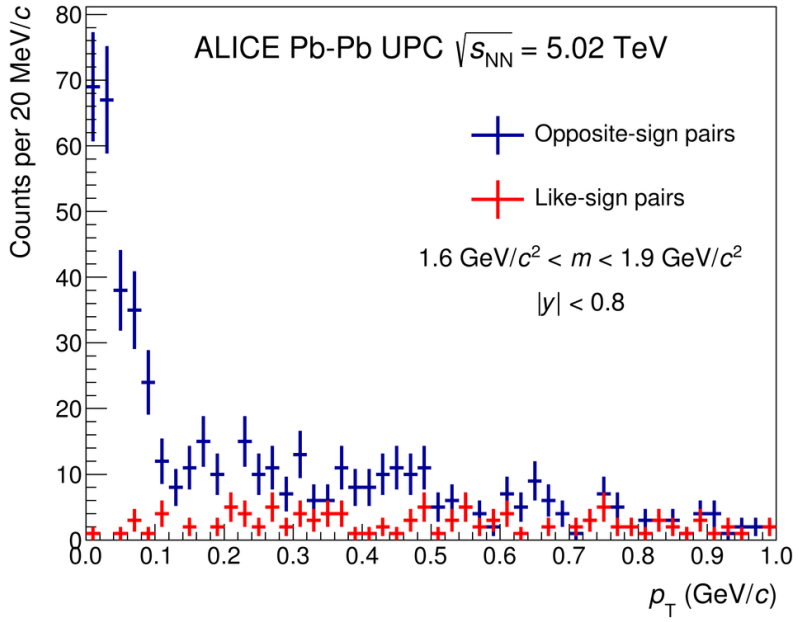




Resonance-like structure at higher masses

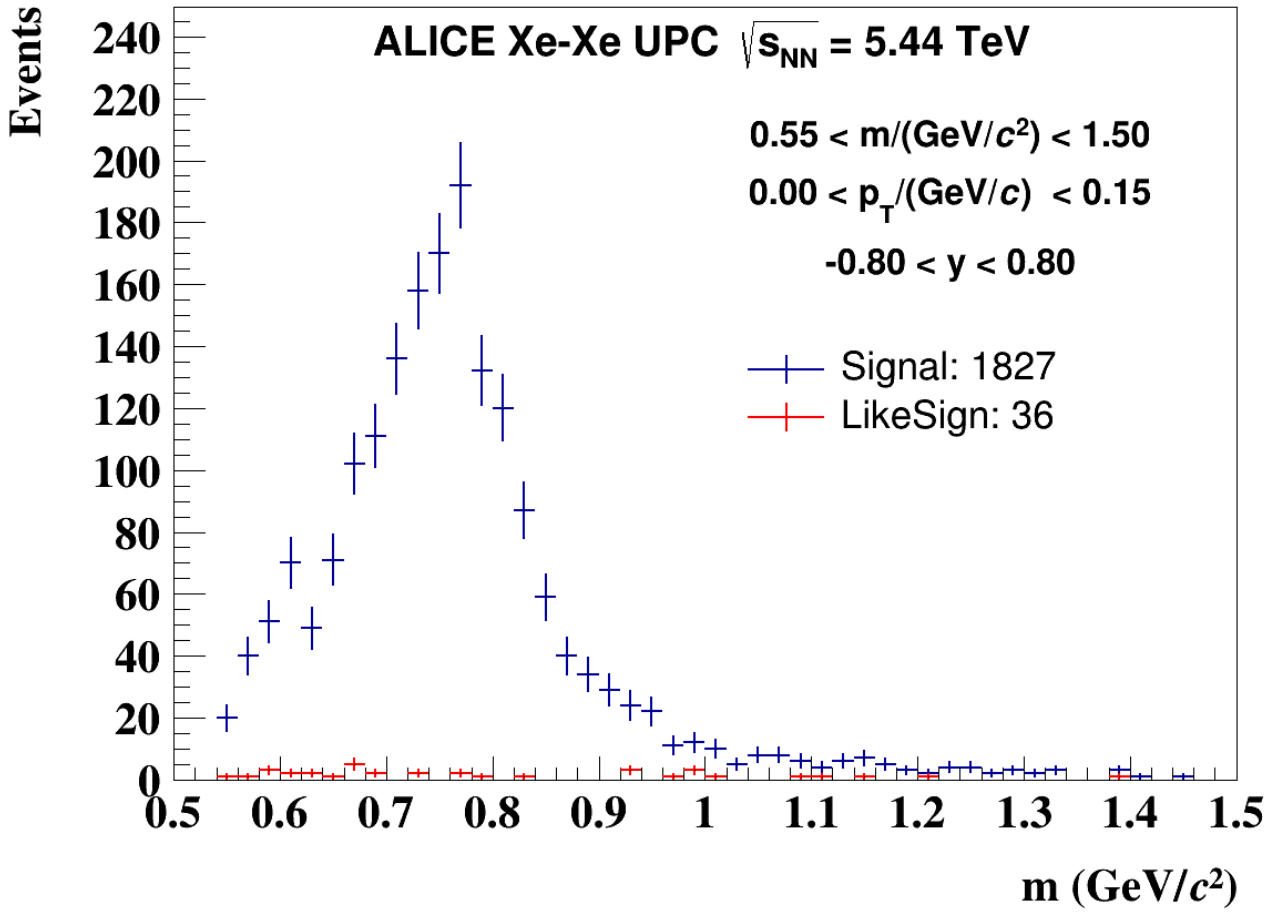
Observed high-mass state with mass of (1725 ± 17) MeV/ c^2 and width (143 ± 21) MeV/c^2 similar to observations of STAR [3] and HERA [4], [5] measurement





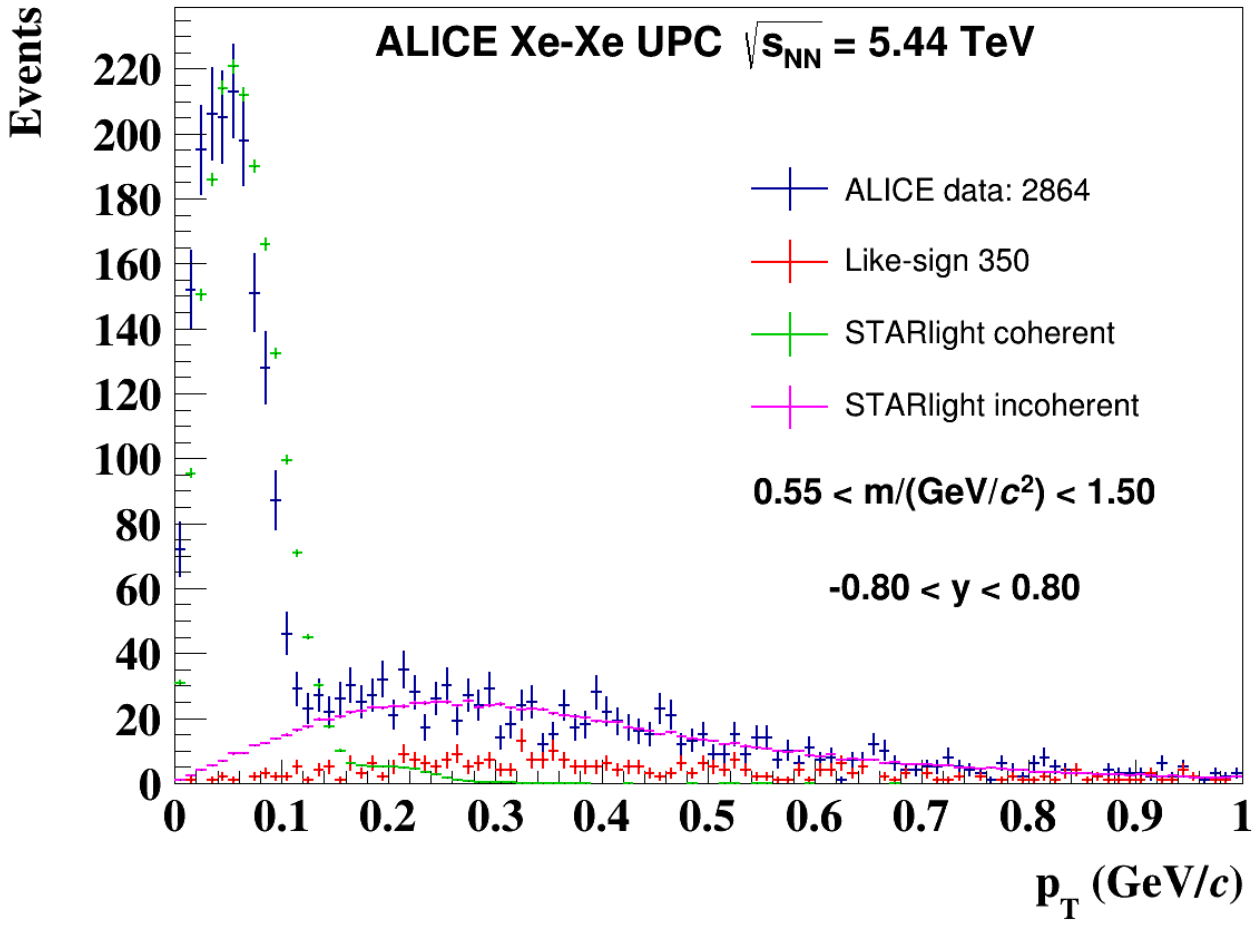
Rho0 in XeXe: Mass distribution

- Invariant mass $m > 550$ MeV
  - below we do not distinguish electrons
- Invariant mass $m < 1500$ MeV
- Smaller statistics compare to PbPb data
- Small contamination from combinatorial background



Rho0 in XeXe: pT distribution

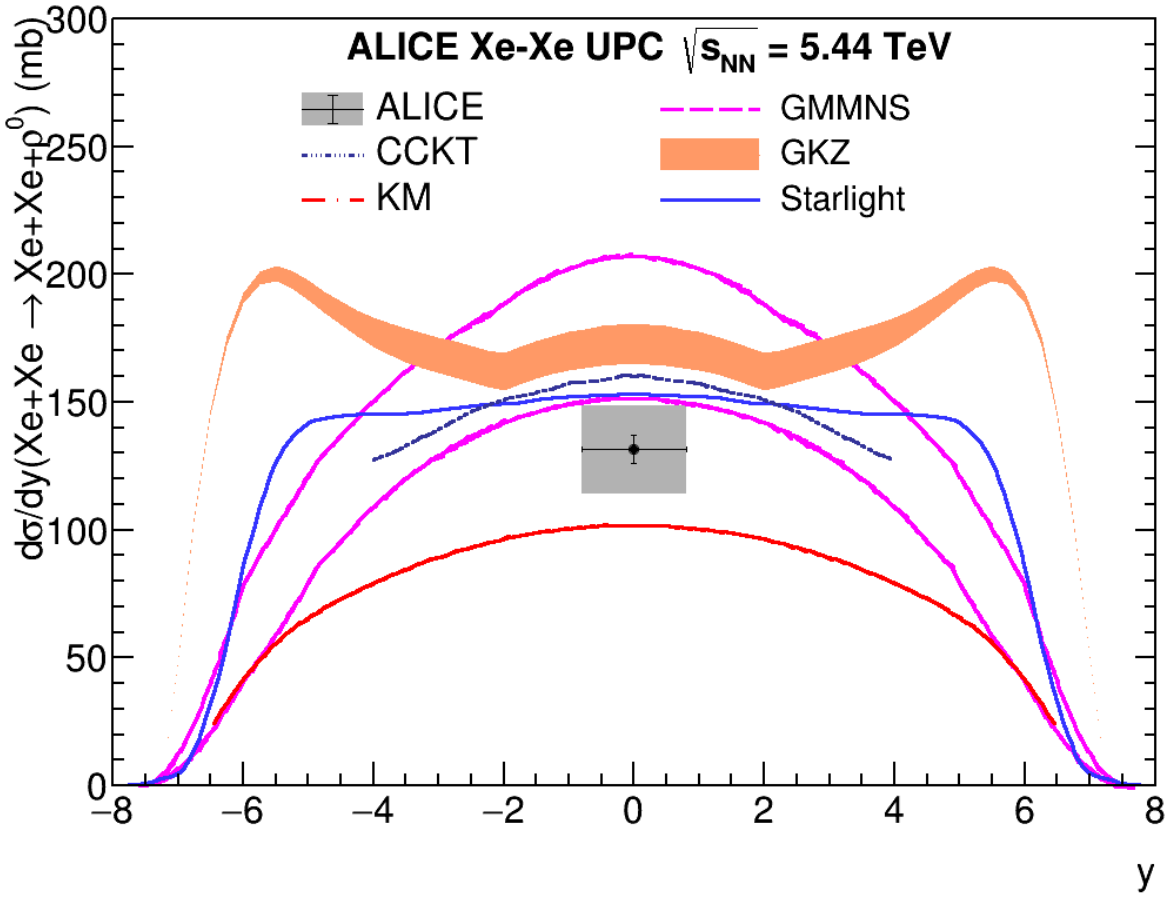
- Nice description by STARlight MC
  - Deviation of the coherent peak as observed in PbPb
- Coherent peak below 0.1 GeV/c
- Tail partially explained by like-sign background
- Larger contamination from incoherent Rho than in PbPb
  - No second difractive peak visible



Rho0 in XeXe:: Cross section

- Cross section: $\frac{d\sigma}{dy} = \frac{N_c \cdot f_{inc} \cdot f_{EMD}}{f_p \cdot \Delta y \cdot L}$

Theoretical predictions sligtly overestimate the data



STARlight. This model is based on a phenomenological description of the exclusive production of ρ^0 vector mesons off nucleons, the optical theorem, and a Glauber-like eikonal formalism, neglecting the elastic part of the elementary ρ^0–nucleon cross section, to describe nuclear effects [4, 5].

GKZ. These predictions by Guzey, Kryshen and Zhalov (GKZ) [6] are based on a modified vector-dominance model, in which the hadronic fluctuations of the photon interact with the nucleons in the nucleus according to the Gribov-Glauber model of nuclear shadowing. In the figure the variations of the prediction on the uncertainty of theory parameters are shown as a band.

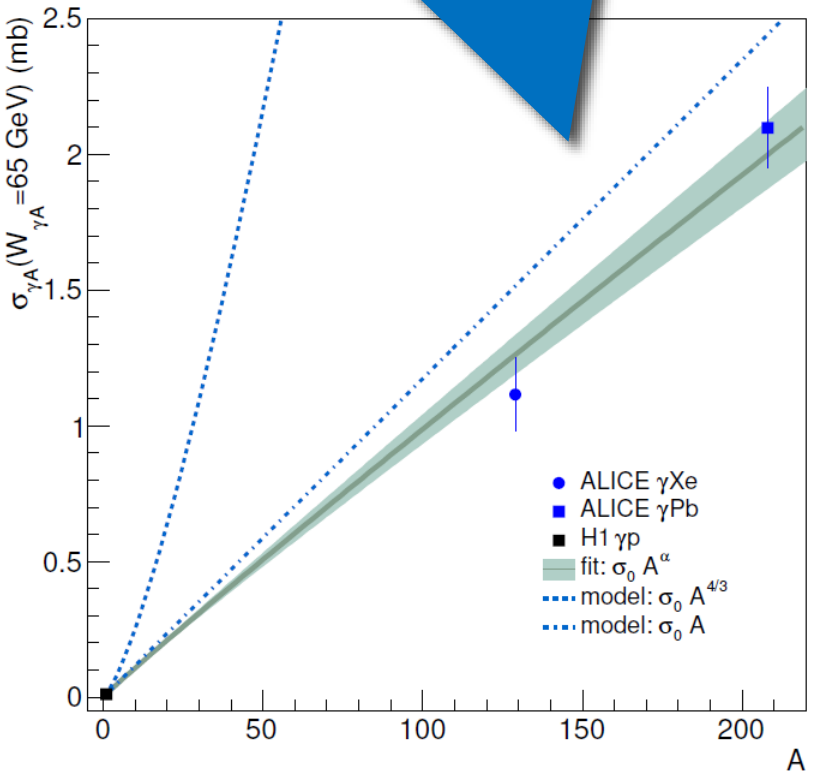
KM. This is a model by Kopp and Machado [7]. The approach is based on the combination of a Glauber-Gribov model to describe nuclear effects (shadowing) and a dipole model for the photon-nucleon cross section. Shown is the prediction based on the IPSAT model [8]. Using

CCKT. This model is based on the colour-dipole model with the structure of the nucleon in the transverse plane described by so-called hot spots, regions of high gluonic density, whose number increases with increasing energy [9, 10]. The nuclear effects are implemented along the ideas of the Glauber model proposed in [11].

GMMNS. This model [12] is based on the IIM [13] implementation of saturation within the colour-dipole model coupled to a boosted-gaussian description of the wave function of the vector meson. The lines bracket the range of predictions when modifying some of the assumptions of the model.

A dependence of the gamma-A cross section

Data from Pb and Xe results fitted using a power-law fit
Generic expectations for full coherence ($A^{4/3}$) and incoherent behaviour (A^1) far away from data.
=> QCD effects are imporatnt



Class	Measured fraction	NOON prediction
0n0n	$(93.25 \pm 0.27)\%$	92.4%
0nXn+Xn0n	$(6.14 \mp 0.23)\%$	6.9%
XnXn	$(0.61 \mp 0.04)\%$	0.7%

Fractions of cross section in neutron classes and its comparison to NOON predictions.
Good agreement!

Summary

- Paper draft is prepared
- Proposed title:
  - First measurement of coherent Rho0 photoproduction in ultra-peripheral Xe–Xe collisions at sqrt(sNN) = 5.44 TeV
- Proposed journal: PLB

- We get the IRC review yesterday!
  - Only minor comments and suggestions

Thank you for your attention!