ALICE Measurements on ρ^0 Photoproduction in Pb-Pb Ultra-peripheral Collisions

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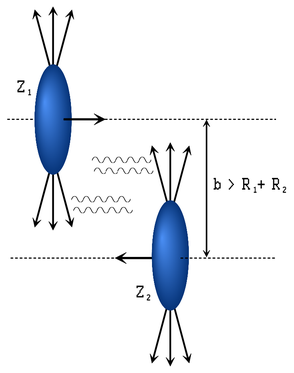
Abstract

The powerful photon fluxes of relativistic nuclei provide a possibility to study photonuclear and two-photon interactions in ultra-peripheral collisions (UPC) where the nuclei do not overlap and no strong nuclear interactions occur. Within the Vector Meson Dominance Model (VDM), the ρ^0 contribution prevails in the QCD part of the photon structure function and $\gamma + A \rightarrow \rho^0 + A$ process in heavy-ion UPC is a tool to test the, so-called, black disk regime where the target nucleus appears like a black disk and the total $\rho^0 + A$ cross section reaches its limit. RHIC and first LHC results have deviated from some Glauber+VDM calculations, which thus call for new data. ALICE reports measurements on ρ^0 photoproduction cross sections in Pb-Pb UPC with data taken at $\sqrt{s_{NN}}$ =2.76 TeV and new measurements with data taken at $\sqrt{s_{NN}}$ =5.02 TeV. The mid-rapidity cross section of coherent ρ^0 photoproduction is measured, and it is compared to theoretical models.

What is UPC?



- EM field of a relativistic particle acts as a beam of **quasi-real photons**
- Intensity of EM field proportional to Z_1^2 and Z_2^2
- **Impact parameter** larger than a sum of radii of incoming particles = UPC
- EM interactions:
  - photon – photon
  - photon– nucleus (proton)

Fig. 1: *Ultra-peripheral collision*

- $\rho^0(770)$ $(\frac{u\bar{u}-d\bar{d}}{\sqrt{2}})$ measured at mid-rapidity 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 $W_{\gamma Pb}$
- From transverse momentum $\vec{\Delta}^2 = -t$

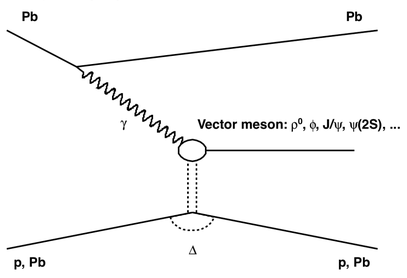


Fig. 2: *Production diagram of a Rho0 meson in Pb-Pb UPC*

Motivation

- ρ^0 gives the dominant contribution to the **hadronic structure** of the photon
- **Previous measurements** at $\sqrt{s_{NN}} = 2.76$ TeV by ALICE [1]
  - STARLIGHT and GM (Gonçalves and Machado) models are compatible with measurement, but GDL (Glauber-Donnachie-Landshoff) is about factor 2 higher than data
  - "further work is needed to understand this process"

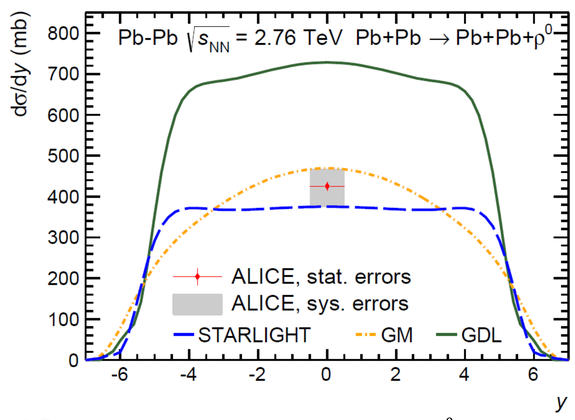


Fig. 3: *The cross section for coherent photoproduction of ρ^0 in ultra-peripheral collisions for the three models compared with the ALICE result. [1]*

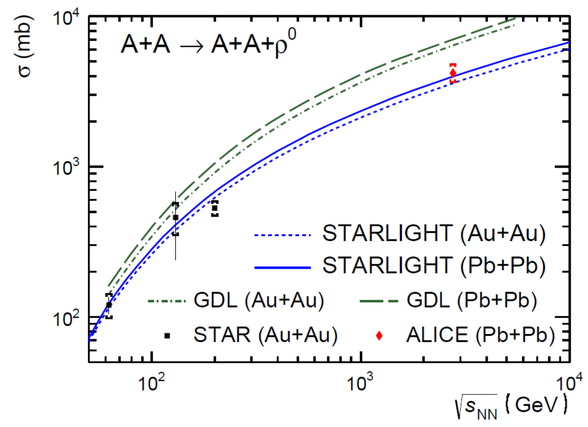
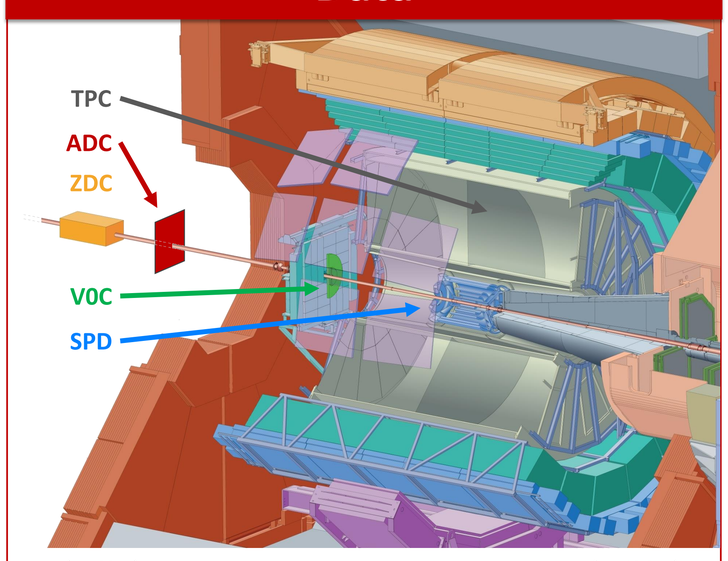


Fig. 4: *Excitation function for coherent and exclusive ρ^0 production. The results from ALICE and STAR are compared with the STARLIGHT and GDL predictions for Pb–Pb and Au–Au. [1]*

Data



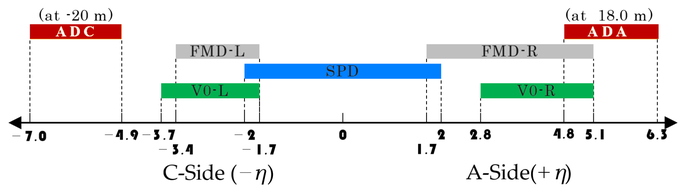


Fig. 5: *Schematic model and pseudorapidity of ALICE detectors used in analysis*

- **Data**
  - Run 2 Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV
- Event **selection**
  - Find **two** good reconstructed **tracks**
  - With **low pair-p_T**
  - Back-to-back events (topological trigger)
  - Decays into **pions** (~100%) particle identification via dE/dx using Time Projection Chamber (**TPC**)
  - **Veto** on activity in the rest of the detector
- UPC **trigger**
  - **V0** veto
  - **AD** veto
  - **SPD** topology (Fig. 6)

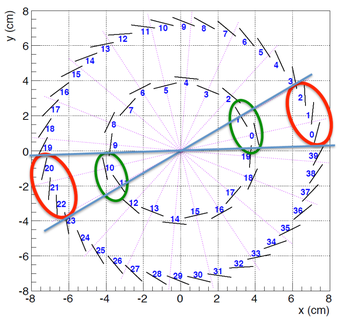


Fig. 6: *Topological trigger in SPD*

- Trigger related **correction factors**
  - Main failure of vetos due to soft EM processes
  - Estimated using unbiased trigger to compute the pile-up probability as a fuction of interaction rate
- The **acceptance and efficiency** estimated using two different Monte Carlo generators (STARLIGHT and a flat MC) and GEANT simulation of ALICE

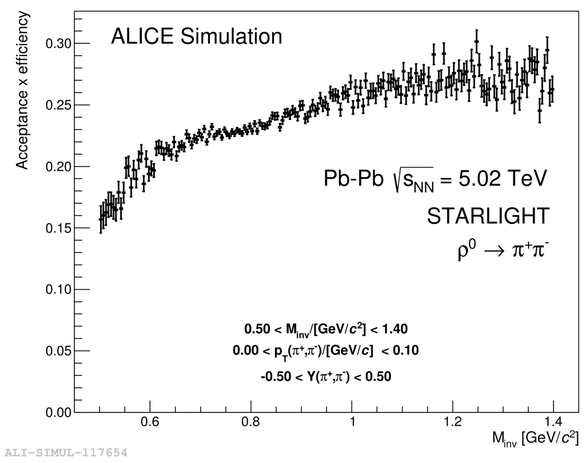


Fig. 7: *Acceptance and efficiency estimated using STARLIGHT MC*

Signal Extraction

- First and second **diffractive peaks** from ρ^0 clearly visible in the p_T spectrum (Fig. 8.)
- STARLIGHT MC models the **p_T distribution** using nuclear form factor – some deviations observed

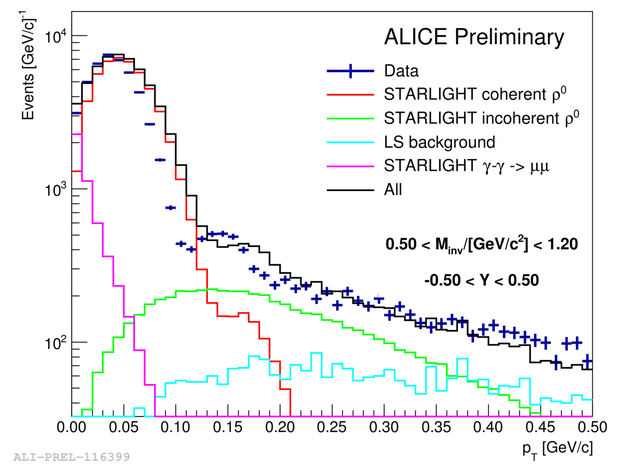


Fig. 8: *p_T spectrum of analysed sample and various contributions to it*

- **Mass distribution** described by the model: (Fig. 9.)
  - $\frac{d\sigma}{dm_{\pi\pi}} = |A \cdot BW + B + C \cdot e^{i\phi} \cdot BW|^2 + N \cdot \mathrm{pol6}$
  - **Background** from $\gamma\gamma \rightarrow \mu\mu$ fixed from MC
  - Number of candidates obtain using integration of Breit-Wigner (BW) part in range $(2m_\pi; M_\rho + 5\Gamma_\rho)$
- ρ^0 mass and width fixed to the PDG values

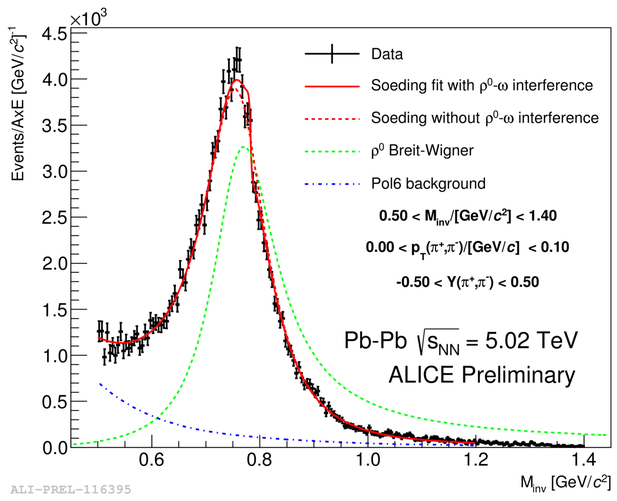


Fig. 9: *Invariant mass distribution of unlike-sign pion pairs with different fit contributions*

Results

- Mid-rapidity **cross section** compared to models (Fig. 10)
  - $d\sigma/dy = (448 \pm 2(\mathrm{stat})^{+38}_{-75}(\mathrm{syst}))$ [mb]
  - Predictions by **STARLIGHT** [2], Gonçalves and Machado using Color Dipole Model (**CDM**) [3,4] and Guzey, Kryshen, Zhalov (**GKZ**) [5] reported
  - Result compatible with STARLIGHT model

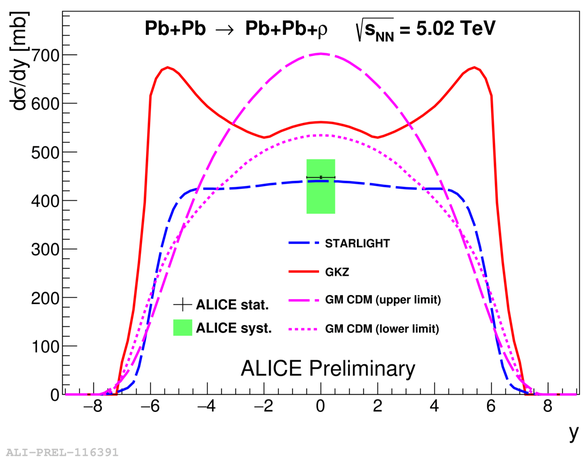


Fig. 10: *Differential cross section at mid-rapidity compared to models*

References

[1] Coherent ρ^0 photoproduction in ultra-peripheral Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV, ALICE Collaboration. JHEP 1509 (2015) 095.
[2] STARlight: A Monte Carlo simulation program for ultra-peripheral collisions of relativistic ions, Klein S. R., Nystrand J., et al. Comput.Phys.Commun. 212 (2017) 258-268.
[3] Photoproduction of ρ^0 meson in ultraperipheral heavy ion collisions at the BNL RHIC and CERN LHC. V. P. Gonçalves and V. T. Machado, Phys. Rev. C 80, 054901 (2009).
[4] Light vector meson photoproduction in hadron-hadron and nucleus-nucleus collisions at energies available at the CERN Large Hadron Collider. G. Sampaio dos Santos and M. V. T. Machado. Phys. Rev. C 91, 025203 (2015)
[5] Coherent photoproduction of vector mesons in heavy ion ultraperipheral collisions: Update for run 2 at the CERN Large Hadron Collider. V. Guzey, E. Kryshen, M. Zhalov. Phys. Rev. C 93, 055206 (2016).

Conclusions

We estimate the cross section of ρ^0 photoproduction at mid-rapidity at $\sqrt{s_{NN}} = 5.02$ TeV. The measured cross section is compatible with STARLIGHT predictions within 1σ.

Models based on Color Dipole Model [3,4] and a VMD calculations [5] overestimate the data.