



FFM



ALICE



$208\text{Pb}$

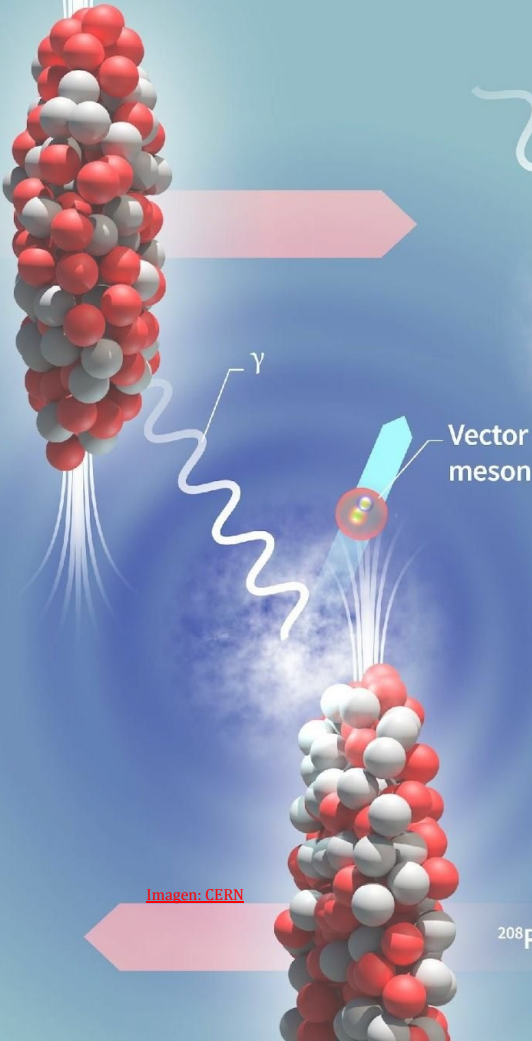


Imagen: CERN

$208\text{Pb}$

# Four-pions states in ultra-peripheral collisions with ALICE



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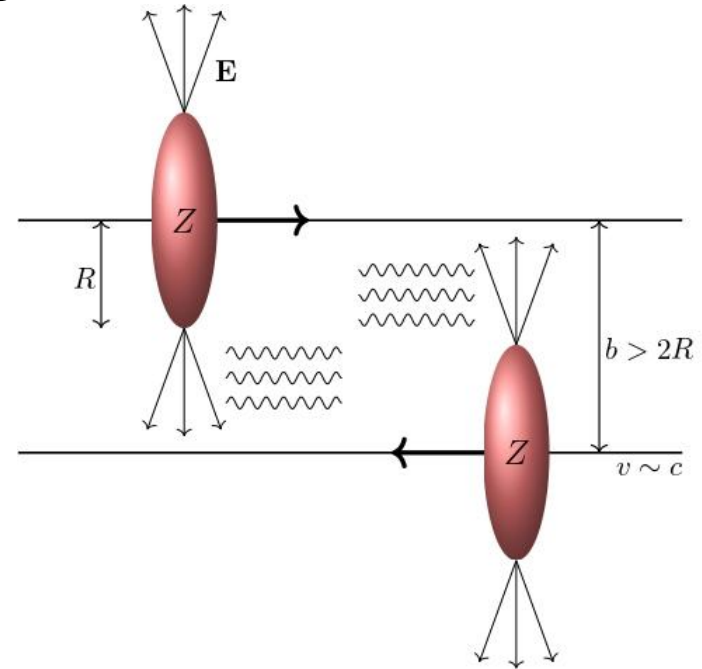
2026 CFNS Summer School on the Physics of the Electron-Ion Collider  
Stony Brook University, New York, USA, June 12, 2026



# • Ultra-peripheral collisions

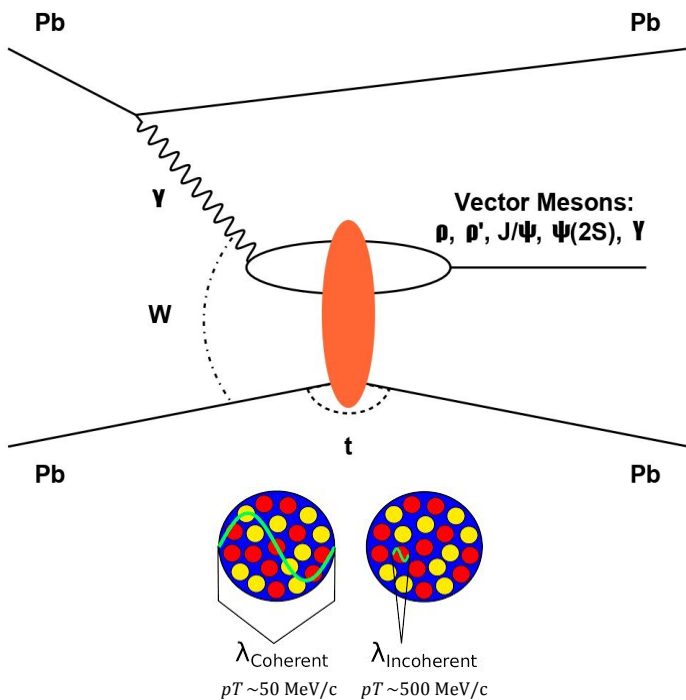
- UPCs = Ultra-Peripheral Collisions

- Impact parameter  $b > 2R$ .
- Heavy nuclei have a strong **EM field** that can be **described as a flux of photons**.
- Photon fluxes enhanced  $\sim Z^2$ .
- **Hadronic interactions suppressed.**
- Cleaner events.





# • Vector meson photoproduction

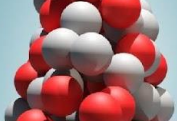


The photon fluctuates to a  $q\bar{q}$  system, typically a Vector Meson (VM).

Two possible types of processes:

- **Coherent:** the  $\gamma$  interacts with the nucleus as a whole.
- **Incoherent:** the  $\gamma$  interacts with one nucleon.

VM  $pT$  is related to the target size  $\sim 1/R$ .



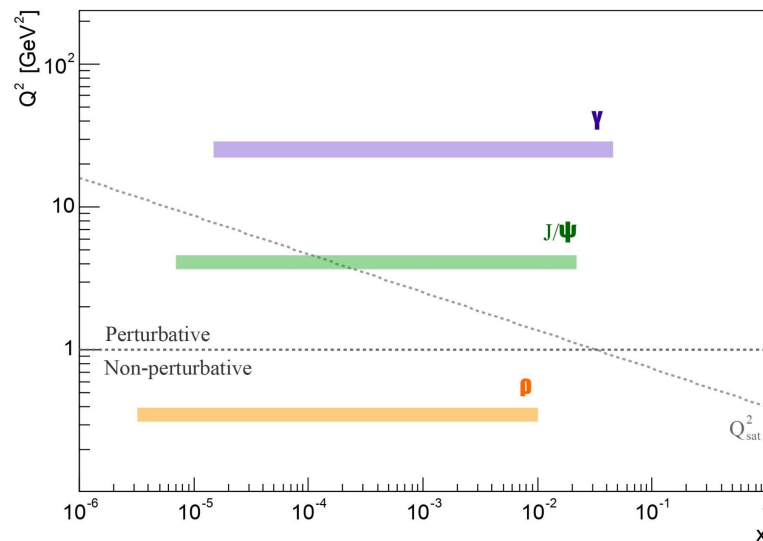
# • Excited $\rho$ photoproduction

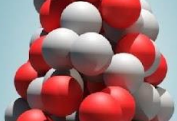
Coherent photoproduction of VMs is a **great tool** to **study the nuclear structure**. The  $\rho$  has been explored in ALICE, CMS, STAR and H1.

As in the case of other VMs, it is reasonable to expect the existence of an **excited state of the  $\rho$** .

- ALICE investigates the excited  $\rho' \rightarrow \pi^+\pi^-\pi^+\pi^-$  state in Pb–Pb UPCs. [10.1016/j.physletb.2025.140006](https://arxiv.org/abs/10.1016/j.physletb.2025.140006)

Such studies of VMs can help to probe **the transition** between **perturbative** and **non-perturbative** QCD.





# • Coherent $4\pi$ in ALICE Run 2

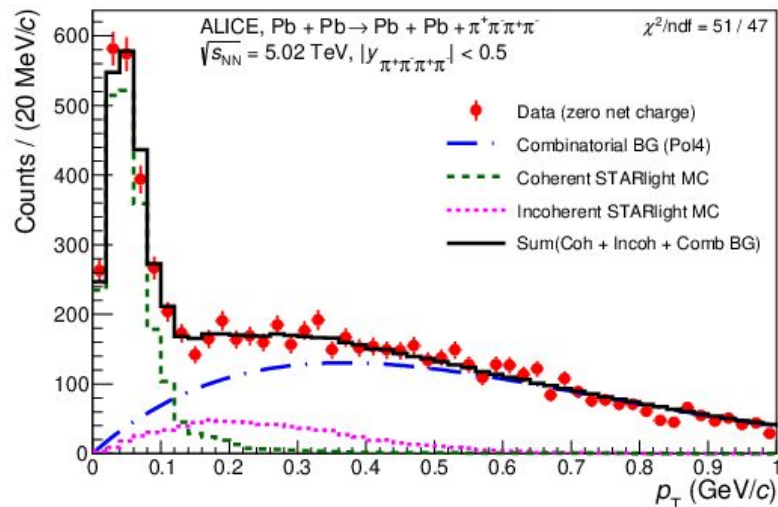
Search for the excited  $\rho$  resonance in the  $4\pi$  decay channel in UPCs.

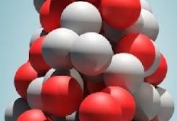
Event selection:

- Exactly 4 good tracks with zero net charge
- Event  $pT < 150 \text{ MeV}/c$
- Event mass  $0.8 < m < 2.5 \text{ GeV}/c^2$

Data sample:

- Pb-Pb collisions at 5.02 TeV,  $\mathcal{L} = 622 \pm 16/\text{mb}$ .

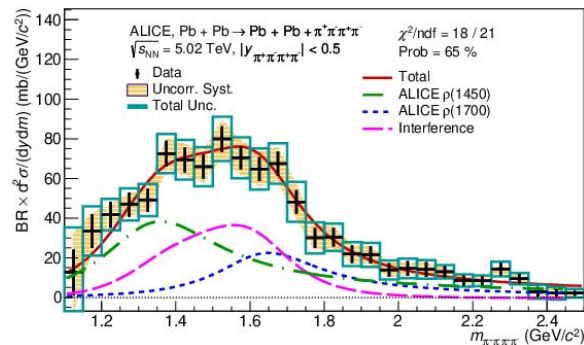
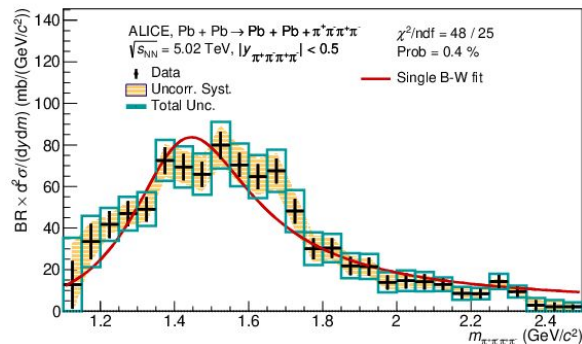


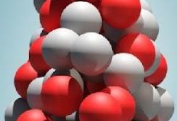


# • Coherent $4\pi$ in ALICE Run 2

- **STAR** measured excited  $4\pi$  indicated that **single resonance** do not fully explains the data. [10.1103/PhysRevC.81.044901](https://arxiv.org/abs/10.1103/PhysRevC.81.044901)
- **H1** recent preliminary suggested presence of a **single broad resonance**. [H1prelim-18-011](https://arxiv.org/abs/1801.01111)

ALICE data show good agreement with theoretical models ([KGTT](https://arxiv.org/abs/10.1103/PhysRevC.81.044901)) seem to favor the **two interfering resonances scenario** but they are **not rule out any scenario**. See: [10.1103/wpbg-h511](https://arxiv.org/abs/10.1103/wpbg-h511).





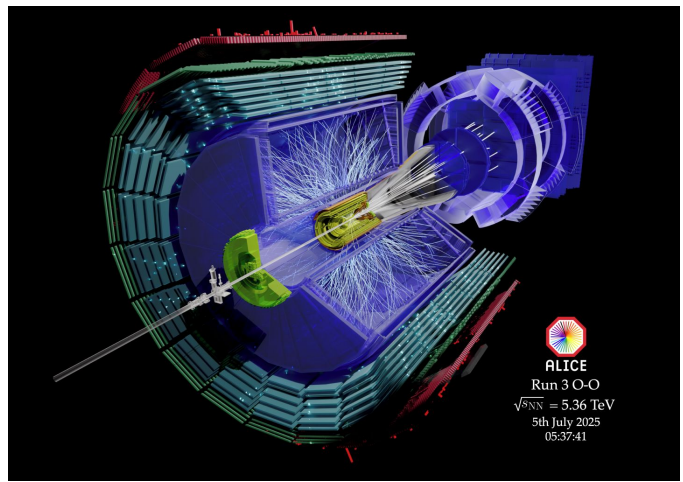
# • Coherent $4\pi$ in ALICE Run 3

During the LHC LS2, ALICE introduced several upgrades:

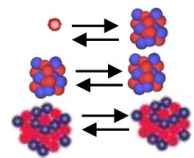
- New detectors
- New online/offline software  $O^2$
- **$\times 50$  increase in statistics**
- **Data taking in continuous readout!**

**Pb-Pb** data sample several  $O(1000)$  larger than in LHC Run 2.

**Light Ions 2025** (pO and OO).



<u>Light Ion Run</u>	Target	Recorded
p-O	5 nb <sup>-1</sup>	7.2 nb <sup>-1</sup>
O-O	0.5 nb <sup>-1</sup>	5.01 nb <sup>-1</sup>
Ne-Ne	0.1 nb <sup>-1</sup>	0.87 nb <sup>-1</sup>



*pO, OO and Ne-Ne*



# • Coherent $4\pi$ in ALICE Run 3

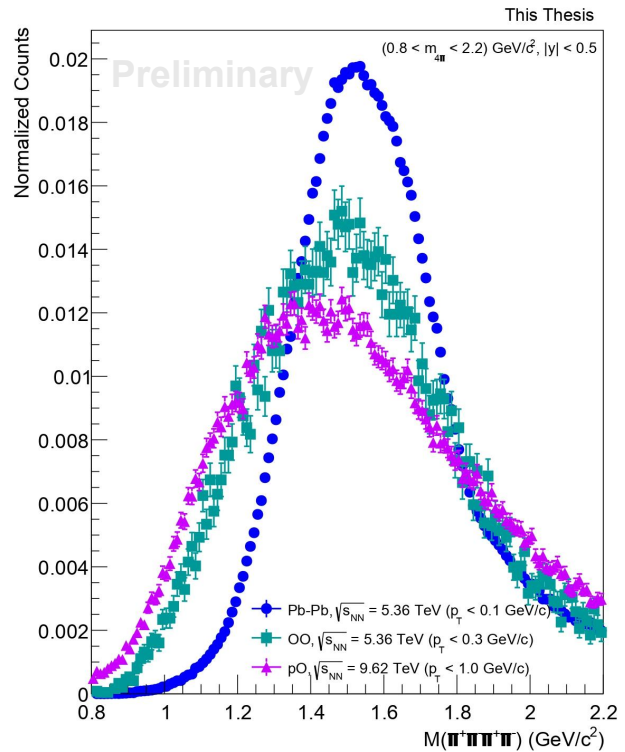
Event selection parameters:

- Event cuts (UPCs)
- Track cuts (Quality)
- System cuts (4-pion)

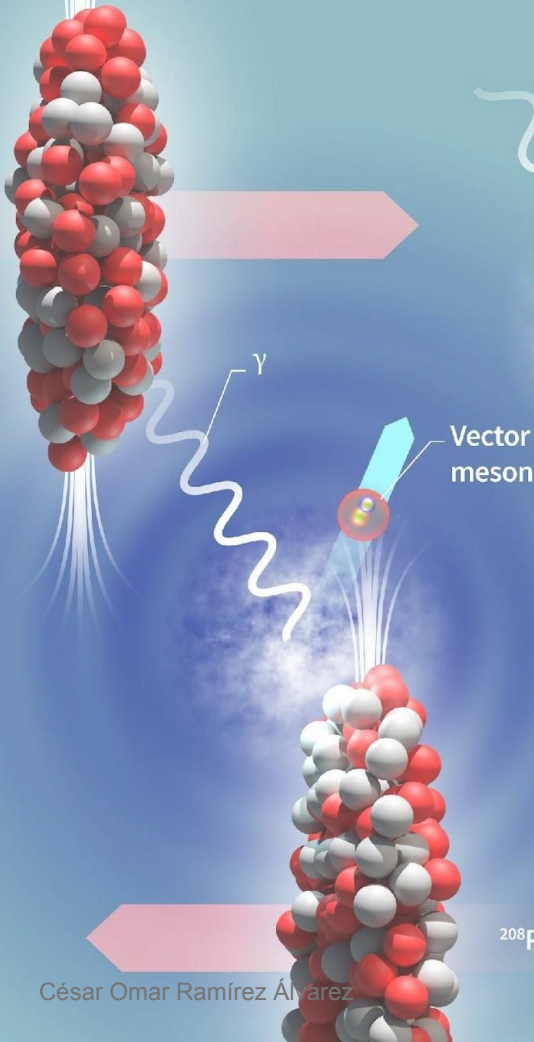
Datasets by SingleGap.

- UD\_LHC23\_pass5\_SingleGap @ 5.36 TeV
- UD\_LHC25ad\_apass2\_SingleGap @ 9.62 TeV
- UD\_LHC25ae\_apass2\_SingleGap @ 5.36 TeV

The invariant mass distribution of the four-pion system **shows a  $\rho'$  peak around  $\sim 1.5 \text{ GeV}/c^2$**  across the three systems.



$^{208}\text{Pb}$



## Summary

- First LHC measurement of excited  $\rho$  in the  $4\pi$  decay channel in UPCs.
- The data from Run 2 do not rule out any scenario.
- Analysis of the LHC Run 3 dataset ongoing.

Special thanks to Prof. D. Tapia-Takaki for his support.

Photon energy

¡Gracias!