# Coherent photoproduction of $\rho$ in oxygen–oxygen collisions

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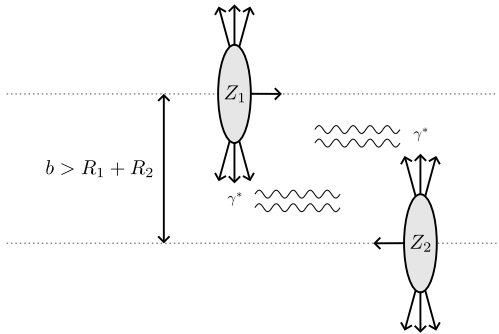
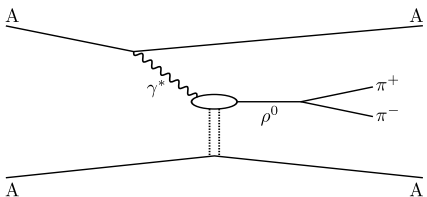
# Ultra-peripheral collisions

- collisions with $b > R_1 + R_2$
  - short range interactions suppressed, long range interactions (EM) may occur
- Lorentz contracted EM fields of particles treated as fluxes of photons
  - mediate photon–photon and photonuclear interactions



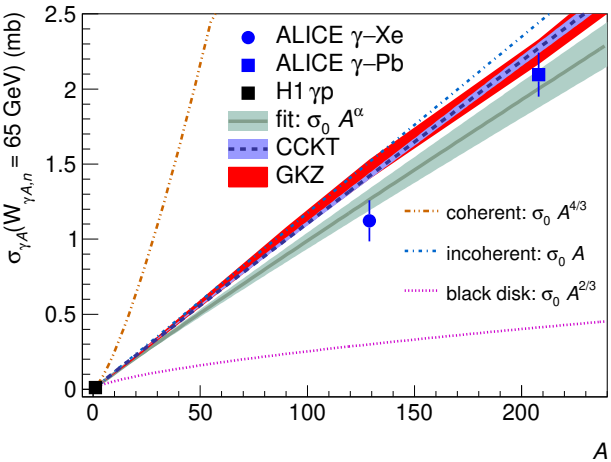
# Coherent vector meson photoproduction




$$\frac{\mathrm{d}\sigma_{\mathrm{AA}}(y)}{\mathrm{d}y} = N_{\gamma/\mathrm{A}}(y,M)\sigma_{\gamma\mathrm{A}}(y) + N_{\gamma/\mathrm{A}}(-y,M)\sigma_{\gamma\mathrm{A}}(-y)$$

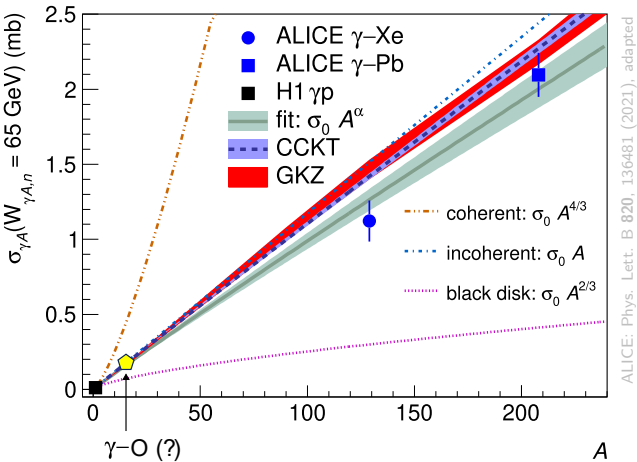
- cross section sensitive to nuclear gluon distributions $\Longrightarrow$ probe into low-$x$ phenomena (nuclear shadowing, gluon saturation, ...)

# $A$-dependence of coherent $\rho^0$ production




- distance from coherent limit signals pronounced QCD dynamical effects
  - seemingly well reproduced by models
- black disk limit not yet reached
- n.b. closeness to incoherent limit purely coincidental

# $A$-dependence of coherent $\rho^0$ production




- $\gamma$O data may provide a constraint for $A$-dependence at lower values of $A$

# LHC O–O run

- intermediate collision system between pp and heavy-ion systems
- oxygen ions readily available in the ion source, candidate for potential future lighter-ion Runs
- proposal for a 1 week run[1] at 6.37–7.00 TeV yielding 0.5–1.0 $\mathrm{nb}^{-1}$
  - currently scheduled[2] for 2024
  - n.b. p–O running also considered (LHCb and astroparticle research)

[1] Bruce *et al.*: Proc. IPAC'21, 53–56 (2021)

[2] Bruce: Ions – outlook for 2023 and beyond (2023)

# STARlight model and program

- model[1] based on generalised vector dominance, relies on experimental data from HERA as input

$$\sigma(\gamma \mathrm{p} \to \mathrm{Vp}) \implies \left\{ \begin{array}{c} \text{GVDM} \\ \text{eikonalisation} \\ \text{optical theorem} \\ \text{Glauber calculation} \end{array} \right\} \implies \sigma(\mathrm{AA} \to \mathrm{AAV})$$

- implemented in the STARlight MC generator[2]
- user-defined parameters used in the calculation of cross sections and subsequent generation of MC events

[1] Klein, Nystrand: Phys. Rev. C **60**, 014903 (1999)

[2] Klein *et al.*: Comput. Phys. Commun. **212**, 258–268 (2017)

# Dataset setup

- STARlight interfaced with the $O^2$ framework with a GEANT 4 simulation of the ALICE detector
  - n.b. detector model imperfect, knowledge is improving

- 2500 $\rho^0 \to \pi^+\pi^-$ events from $^{16}_{8}\mathrm{O}$ collisions
  - generated locally $\implies$ limited number of events
  - clean setup (fully coherent sample, no requirement on ion breakup, no interference, etc.), decay products covering $-4.0 < \eta < 1.5$

- 10000 $\rho^0 \to \pi^+\pi^-$ events from $^{208}_{82}\mathrm{Pb}$ collisions
  - setup largely similar to O–O dataset, decay product $\eta$ adjusted to $|\eta| < 1.5$
  - newer dataset $\implies$ possibly introduced effects not present in the O–O dataset

# Analysis

- analysis served largely a preparatory function
- main objective was the determination of acceptance times efficiency corrections for $m$, $p_{\mathrm{T}}$, and $y$ distributions
  - describe the influence of detector properties and the analysis procedure on collected data
  - determined from MC data

$$\mathrm{A}\times\mathrm{E} = \frac{N_{\mathrm{reconstructed}}(\text{full event selection})}{N_{\mathrm{generated}}(\text{rapidity selection})}$$

  - explored two methods of statistical uncertainty calculation

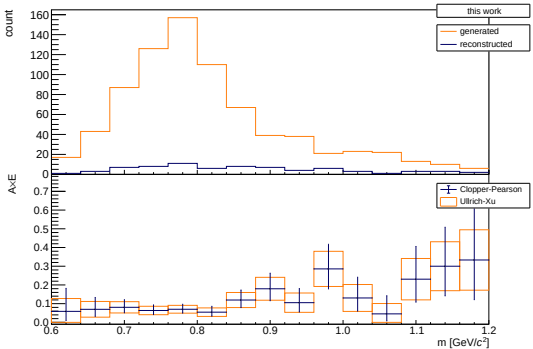
# Event selection criteria

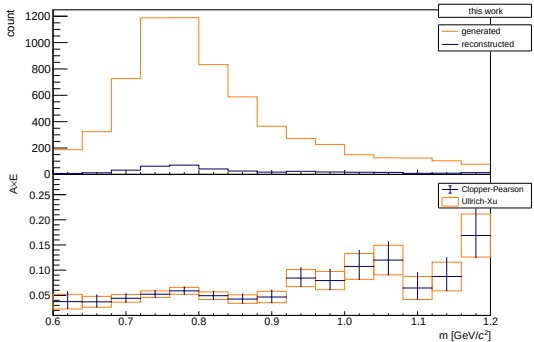
- two tracks of opposite charge
- $|n\sigma_{\pi^{\pm}}| < 5$ TPC PID
- track quality data studied but not used for further track selection

- pion pair $|y| < 0.8$, $p_{\mathrm{T}} < 0.17$ GeV/$c$, $m \in (0.6, 1.2)$ GeV/$c^2$
  - $p_{\mathrm{T}}$ selection adjusted to 0.12 GeV/$c$ for Pb dataset (accounts for lower $\langle p_{\mathrm{T}} \rangle$)

| dataset | produced in $\lvert y \rvert < 0.8$ | events passing selections |
|---|---|---|
| O | 858 | 73 |
| Pb | 7153 | 368 |

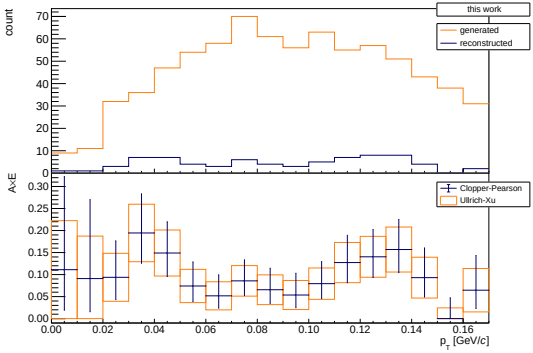
# Mass spectra A×E

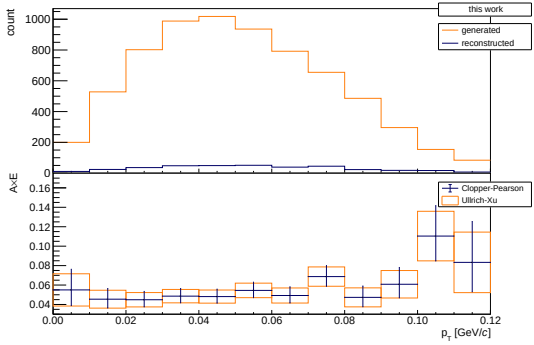



- A×E relatively flat around the $\rho^0(770)$ pole mass at just under 10% for O–O and approximately 5% for Pb–Pb, tails affected by large statistical uncertainties

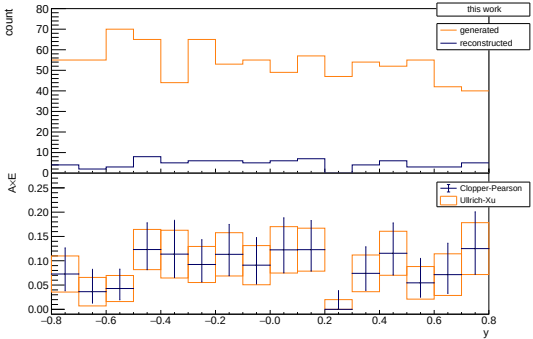
# Transverse momentum spectra A×E

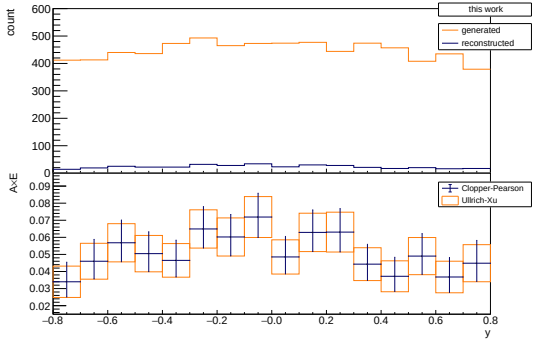



- A×E for O–O difficult to interpret due to large uncertainties (overall values around 10%), Pb–Pb response relatively flat around the peak maximum, just under 5%

# Rapidity spectra A×E




- current event selection yields a relatively flat rapidity A×E with similar values of 10 and 5%, respectively

# Results summary and outlook

- limited sample size led to large statistical uncertainties (especially for O–O)
- computed A$\times$E values overall lower than expected
  - exact cause not certain, suspected are software issues (ITS–TPC track matching problems, ambiguities in assignment of tracks to collisions)
- apparent discrepancy between the two studied datasets
  - possibly caused by the improvements in the detector description for the simulated Pb–Pb sample

- outlook
  - refinement of analysis
  - further testing on real Pb–Pb data or larger simulated O–O datasets
  - pre-prepared framework will (hopefully) facilitate implementation on real data

# Thank you for your attention!

# Backup

# Predicted $\rho^0$ photoproduction yield

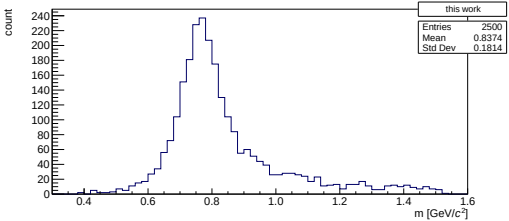
- full parameter setup and fill scheme not yet finalised
- STARlight predictions[1] for a $L_{\text{int}} = 1\ \text{nb}^{-1}$ run at $\sqrt{s_{\text{NN}}} = 6.37$ TeV (detector acceptance taken as 7%)
  - $\sigma_{\text{coherent}} = 9.2$ mb $\implies \approx$ 650,000 coherent events
  - $\sigma_{\text{incoherent}} = 6.8$ mb $\implies \approx$ 470,000 incoherent events
- great potential for studies of incoherent photoproduction

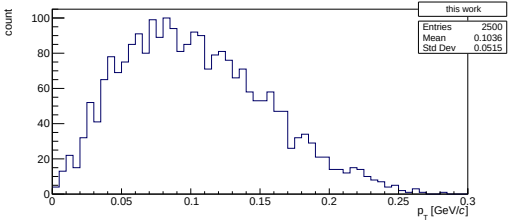
[1] ALICE: ALICE-PUBLIC-2021-004 (2021)

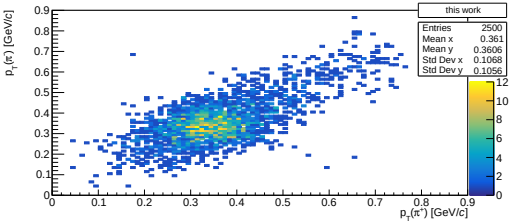
# O–O dataset setup

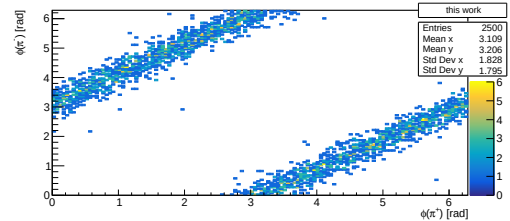
| parameter | value | parameter | value |
|---|---|---|---|
| BEAM_1_Z | 8 | PT_MAX | 3 |
| BEAM_1_A | 16 | CUT_ETA | 1 |
| BEAM_2_Z | 8 | ETA_MIN | -4 |
| BEAM_2_A | 16 | ETA_MAX | 1.5 |
| BEAM_1_GAMMA | 3864.32 | PROD_MODE | 3 |
| BEAM_2_GAMMA | 3864.32 | N_EVENTS | 2500 |
| W_MAX | -1 | PROD_PID | 113 |
| W_MIN | -1 | BREAKUP_MODE | 5 |
| W_N_BINS | 50 | INTERFERENCE | 0 |
| RAP_MAX | 10 | IF_STRENGTH | 1 |
| RAP_N_BINS | 200 | INT_PT_MAX | 0.24 |
| CUT_PT | 0 | INT_PT_N_BINS | 120 |
| PT_MIN | 1 | XSEC_METHOD | 1 |

# O–O generator-level data

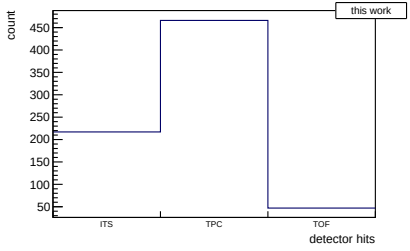


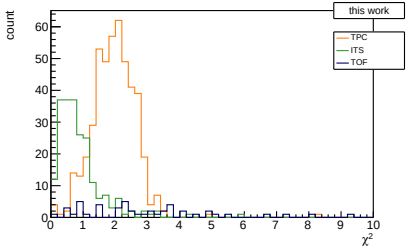



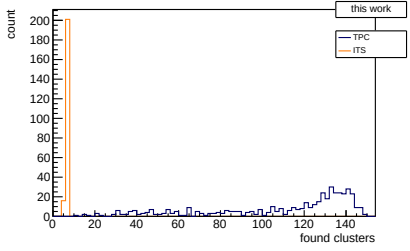



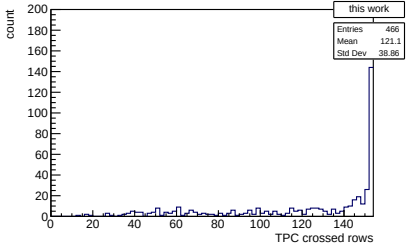



# O–O events track selection data



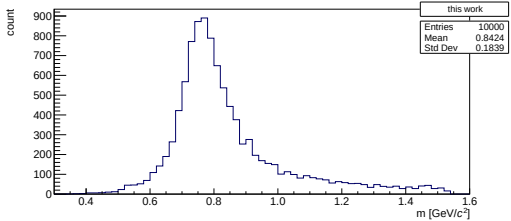



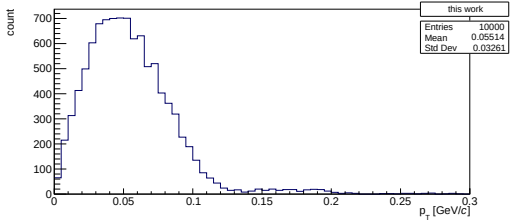



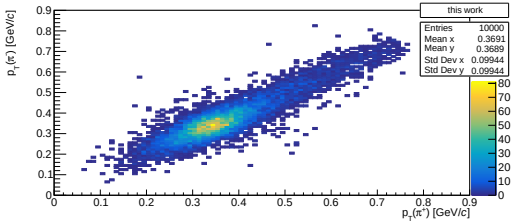
# Pb–Pb dataset setup

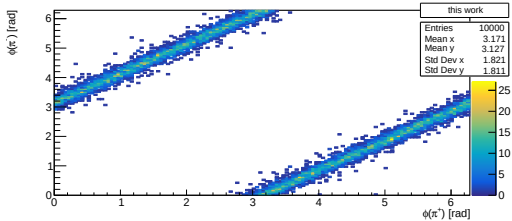
| parameter | value | parameter | value |
|---|---|---|---|
| BEAM_1_Z | 82 | PT_MAX | 3 |
| BEAM_1_A | 208 | CUT_ETA | 1 |
| BEAM_2_Z | 82 | ETA_MIN | -1.5 |
| BEAM_2_A | 208 | ETA_MAX | 1.5 |
| BEAM_1_GAMMA | 2705.37 | PROD_MODE | 3 |
| BEAM_2_GAMMA | 2705.37 | N_EVENTS | 10000 |
| W_MAX | -1 | PROD_PID | 113 |
| W_MIN | -1 | BREAKUP_MODE | 5 |
| W_N_BINS | 50 | INTERFERENCE | 0 |
| RAP_MAX | 1.5 | IF_STRENGTH | 0.05 |
| RAP_N_BINS | 200 | INT_PT_MAX | 0.24 |
| CUT_PT | 0 | INT_PT_N_BINS | 120 |
| PT_MIN | 0.01 | XSEC_METHOD | 1 |

# Pb–Pb generator-level data



# Pb–Pb events track selection data