Measurement of coherent exclusive J/ψ production in ultraperipheral Pb+Pb collisions at 5.36 TeV with the ATLAS detector

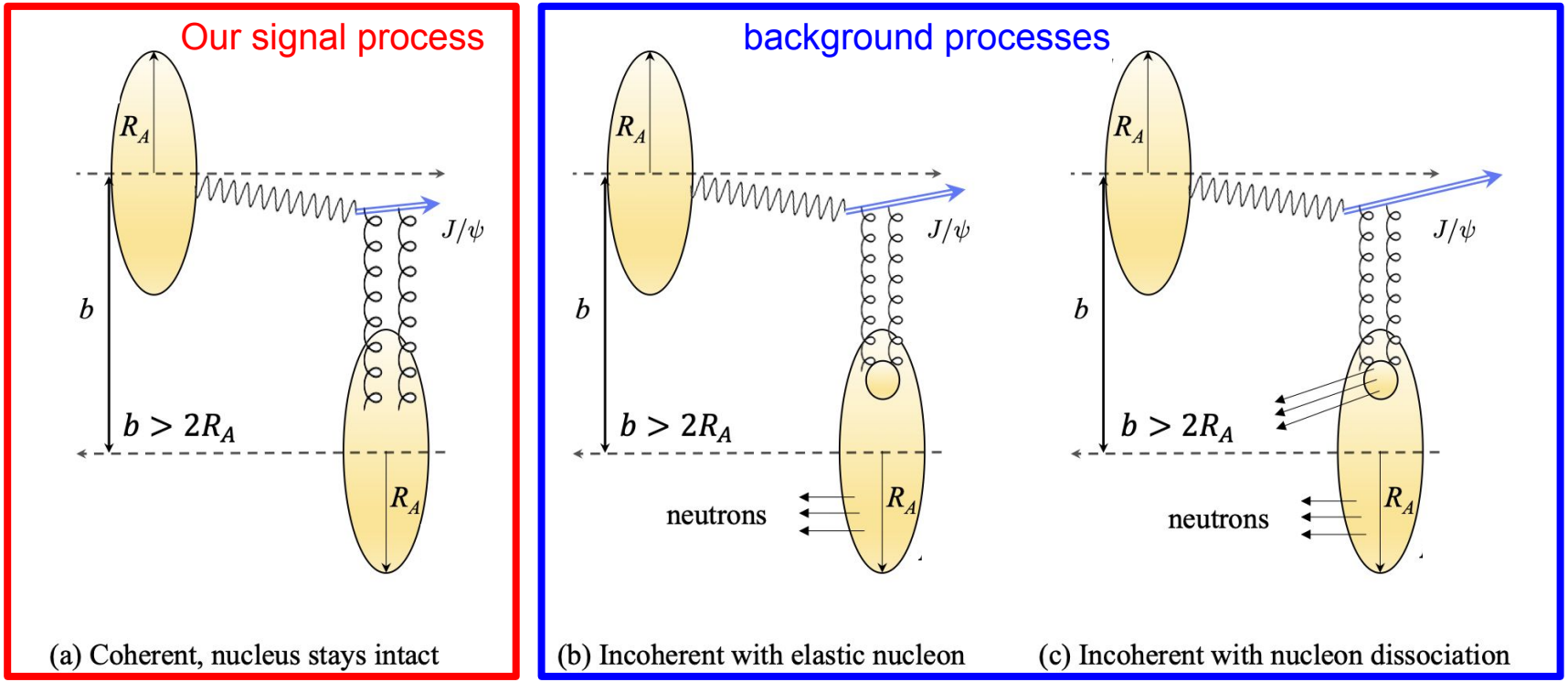
arXiv:2509.04135

Paweł Rybczyński
AGH University of Krakow
on behalf of the ATLAS Collaboration

XVIII Polish Workshop on Relativistic Heavy-Ion Collisions: Strange and Heavy Flavour Physics

Process of interest

adapted from [arXiv:2311.13632]



Motivation

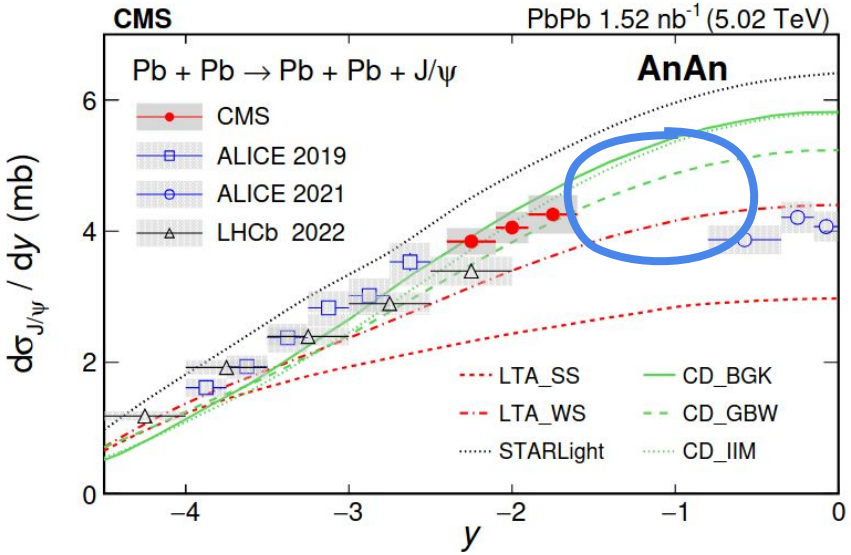
Process sensitive to nuclear gluon dynamics at low-x.

Filling the gap in measurements for 0.8<y<1.6.

Focusing on **dimuon** decay channel.

Key experimental challenge in measurement: triggering on low-p_T leptons.

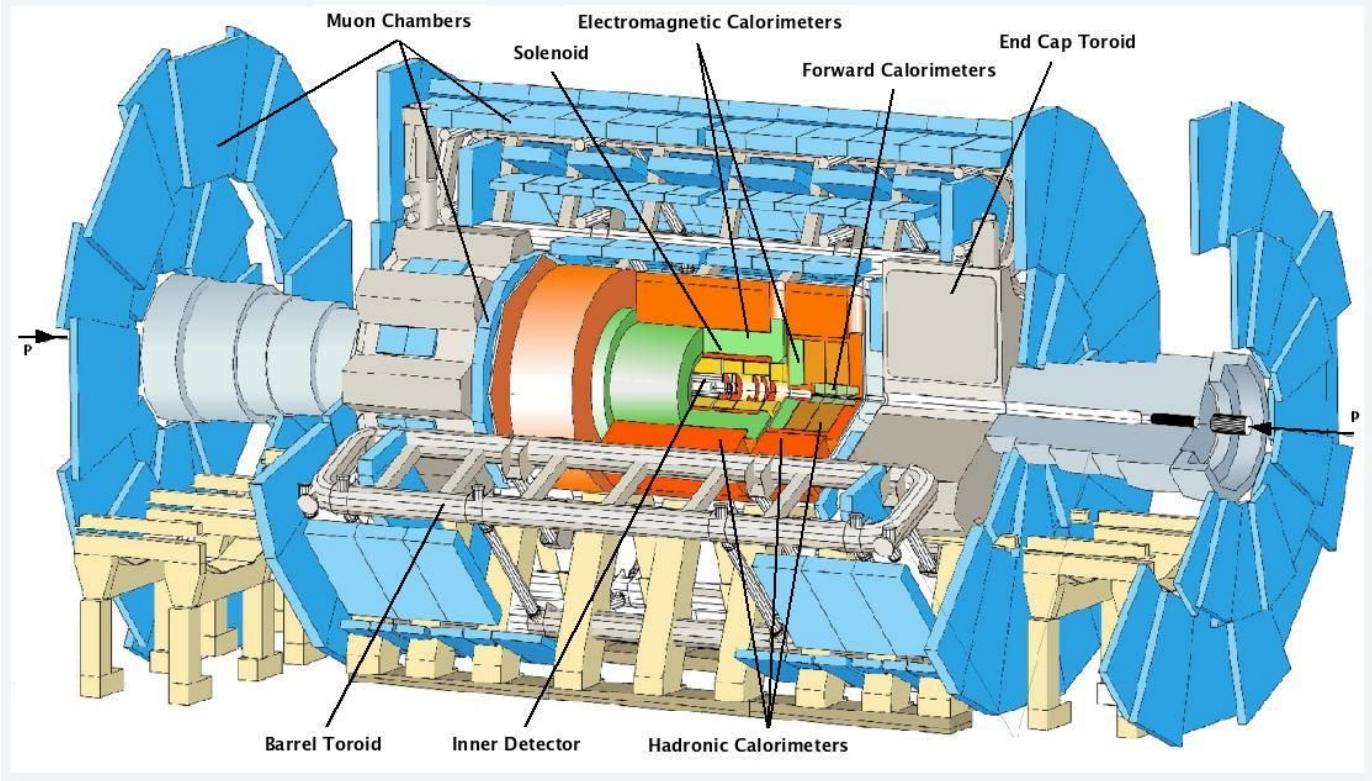
[arXiv:2303.16984]



The measurement is performed in 5 J/ψ rapidity intervals:

|y|<0.5, 0.5<|y|<1, 1<|y|<1.5, 1.5<|y|<2, 2<|y|<2.5.

ATLAS detector



Inner Detector coverage (available phase space):

- $|\eta|<2.5$
- $p_T>0.1$ GeV

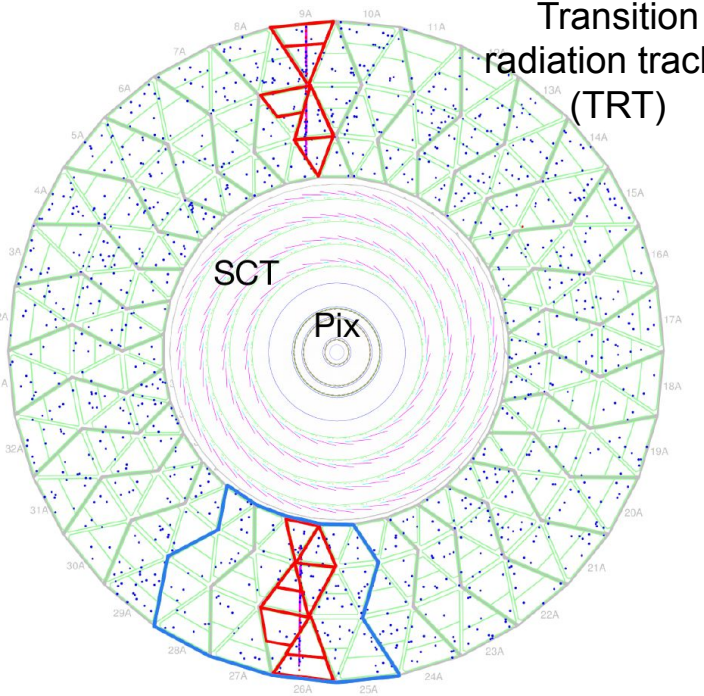
Muon trigger/ identification:

- above $p_T \sim 4$ GeV

Calorimeter coverage:

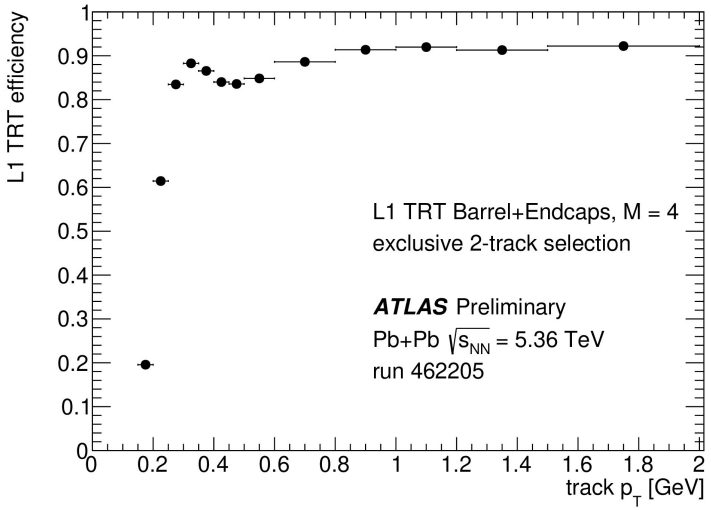
- $|\eta|<4.9$

TRT Fast-OR trigger



[ATL-INDET-PUB-2009-002]

[2023 heavy-ion run performance plots]



New in Run 3! → Use of TRT trigger for heavy-ion UPC.

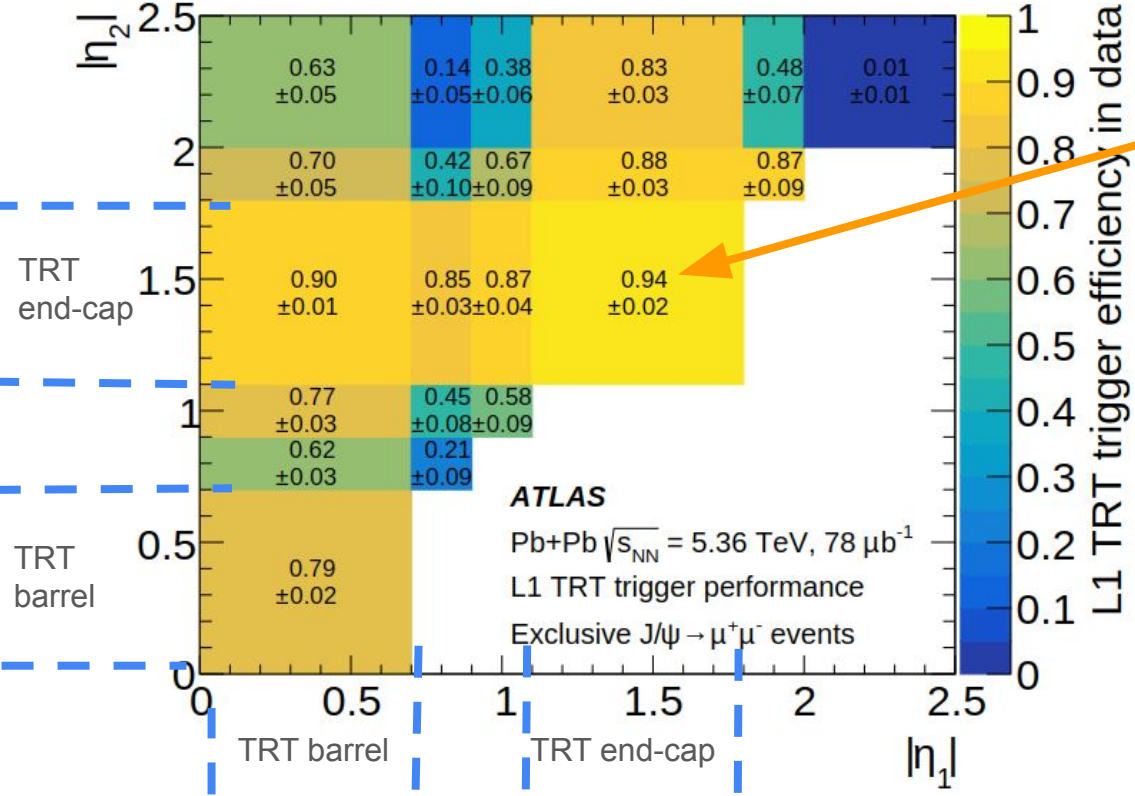
TRT high threshold (HT) hits used for triggering instead of electron identification.

High threshold lowered so that any MIP produces HT hits.

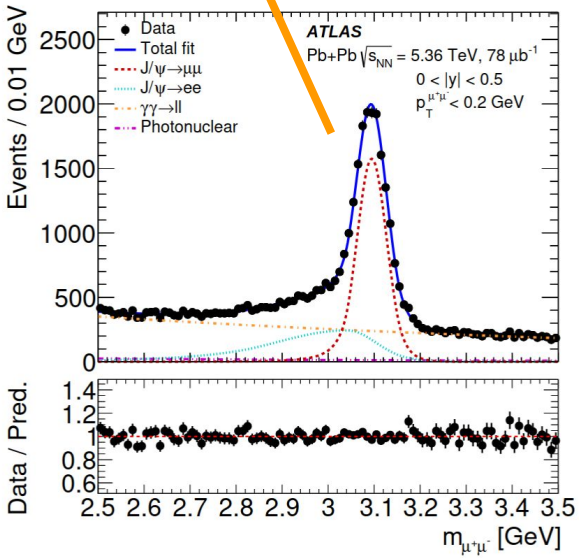
Allows to trigger directly on low-p_T tracks.

Trigger efficiency for low-p_T muon pairs

Coherent J/ψ→μμ events with single ion dissociation are used as reference (triggered by ZDC at L1).



$\epsilon = N_{TRT\&ref}/N_{ref}$



Data analysis

Data from **2023 heavy-ion run** is used → **78 μb^{-1} integrated luminosity.**

Signal and main background samples are modeled by **STARlight** (and interfaced with Pythia8 for QED FSR).

Trigger selection:

- positive **decision of the TRT trigger**,
- no more than 20 GeV of transverse energy detected in the calorimeters
- no more than 5 GeV of transverse energy detected in the forward calorimeters ($3.1<|\eta|<4.9$)
- 1-5 tracks with $p_T>1$ GeV
- no more than 15 tracks with $p_T>0.2$ GeV

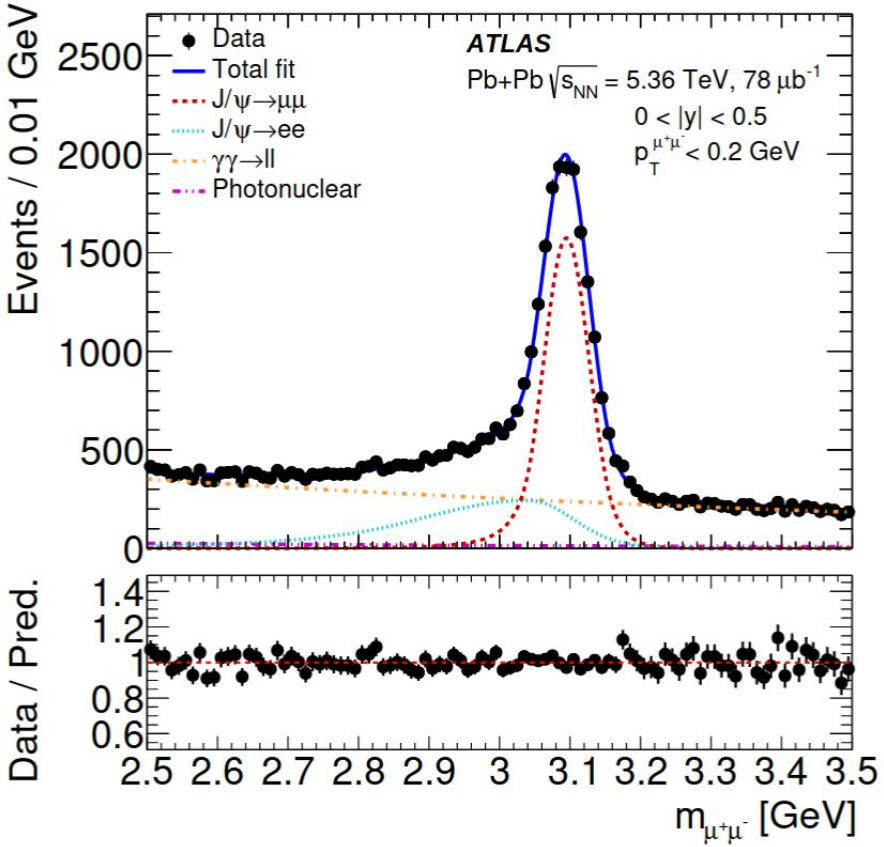
Offline event selection:

- exactly 2 opposite sign tracks of good quality,
- $|\eta|<2.5$, $p_T>1$ GeV.

Signal region definition:

- $2.9 \text{ GeV} < m^{t1,t2} < 3.2 \text{ GeV}$,
- $p_T^{t1,t2} < 0.2$ GeV

Fits to 2–track system invariant mass



Mass distribution for events with **$p_T(\mu_1,\mu_2)$<0.2 GeV.**

Dilepton continuum modeled with exponential function.

J/ψ modeled with Crystal Ball functions.

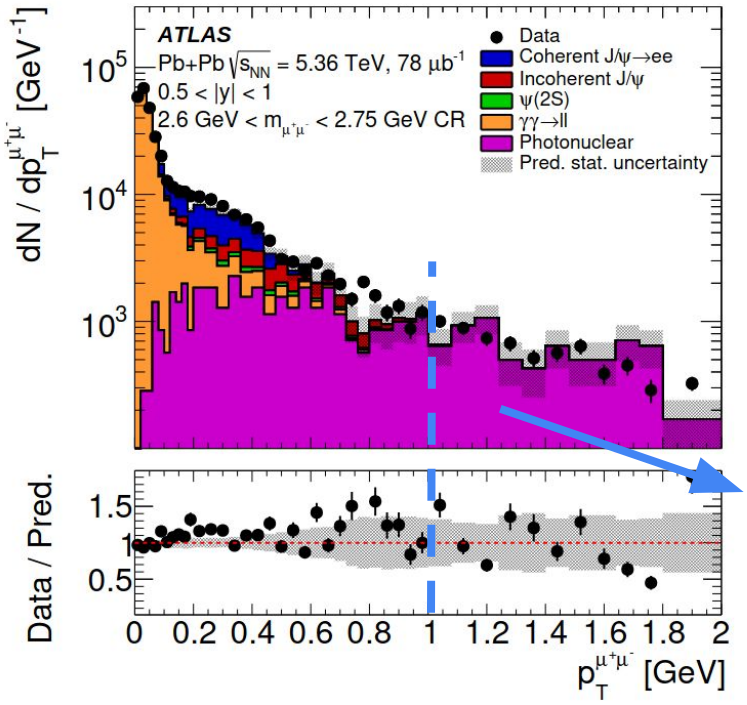
Shapes are fixed from **fits to MC** simulated samples.

In **fit to data** only the **normalizations** are allowed to change + the slope of the $\gamma\gamma \rightarrow \ell^+\ell^-$ exponent.

Photonuclear background

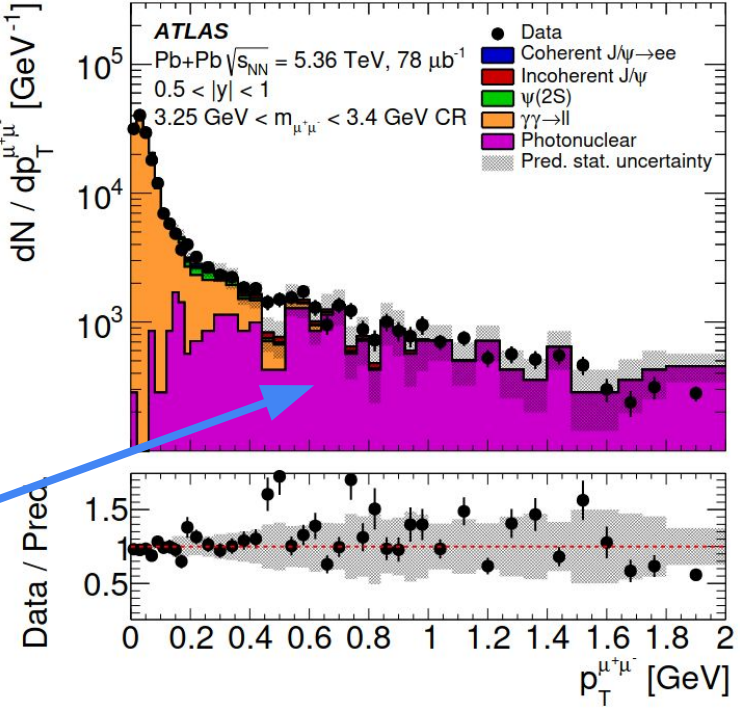
Photonuclear combinatorics modeled by data-driven “same-sign” templates.

High-mass sideband used for cross-check



The “same-sign” templates are normalized to data in low-mass sideband region at high system p_T.

Normalization taken from low-mass sideband.



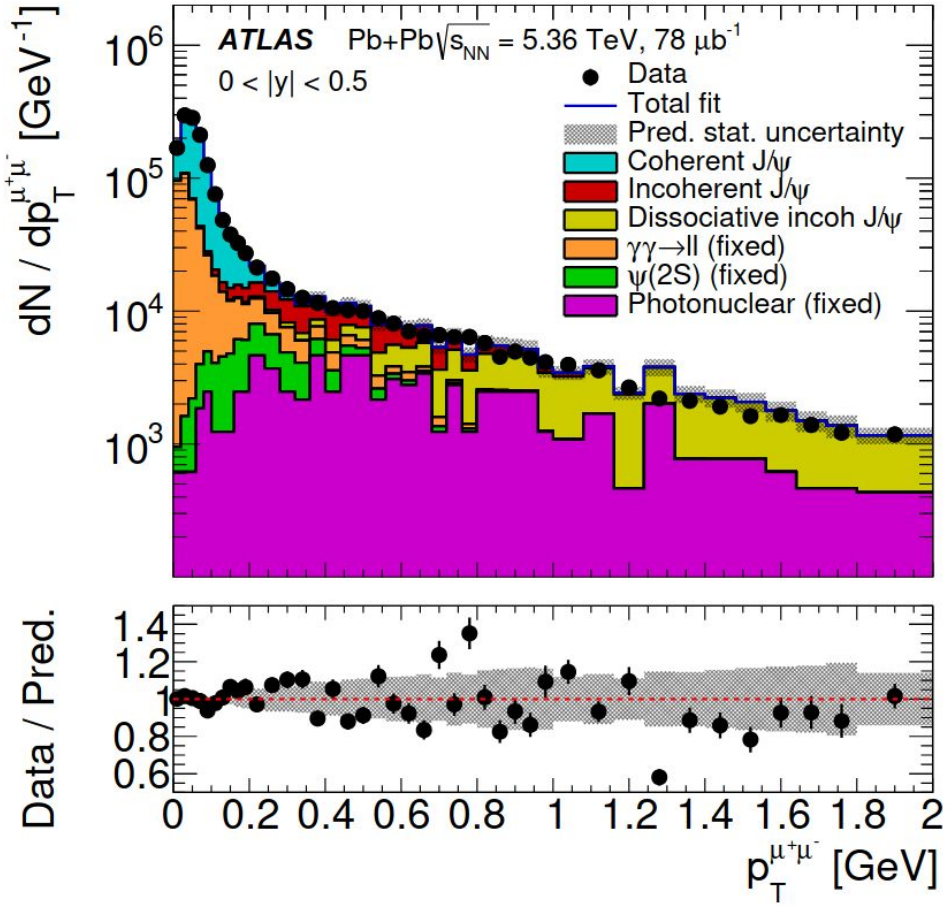
p_T fits

The coherent contribution to the UPC J/ψ→μμ yield is extracted from fits to the p_T distribution (in **2.9 - 3.2 GeV** track system invariant mass region).

In the fit, the: dilepton continuum, ψ(2S), and photonuclear combinatorial background templates are kept fixed.

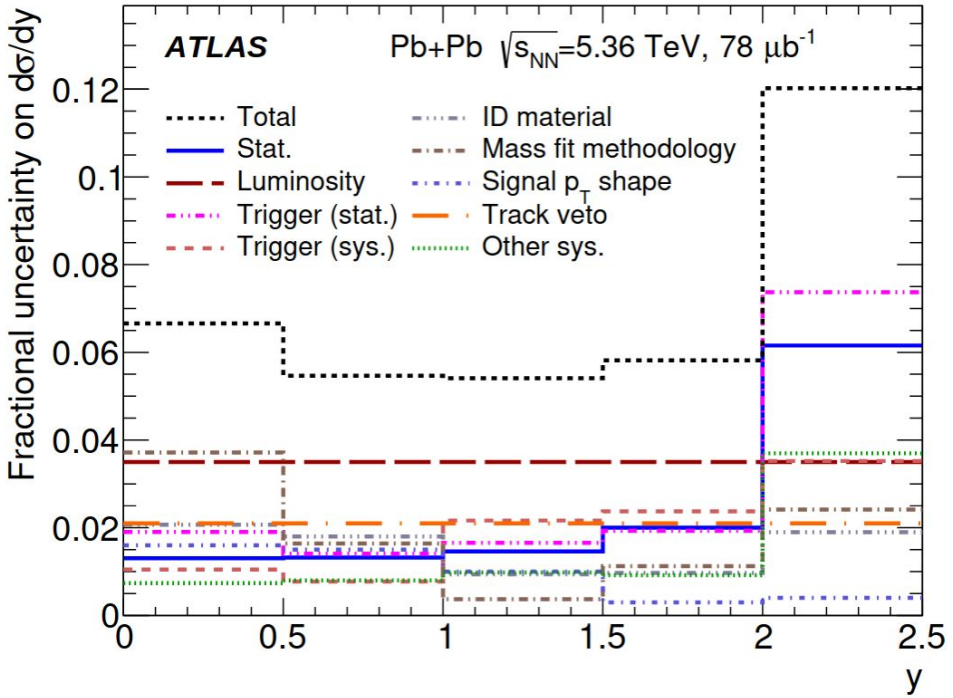
Dissociative incoherent contribution is parametrized (from HERA) with:

$$\frac{dN}{dp_T} \sim 4 b_{pd} p_T^2 \left(1 + \frac{b_{pd}}{n_n} p_T^2\right)^{-(n_n+1)}$$



Systematic uncertainties

- Trigger → L1 TRT trigger efficiency SFs variations
- ID material → detector material modeling
- Mass fit methodology → electron to muon ratio fixed according to MC predictions
- Signal p_T shape → reweighting of the simulated p_T shape using LHCb measurements
- Track veto → 4 tracks allowed in the selection



Uncertainty **limited** mainly **by luminosity.**

Full correlation matrix will be provided in the follow up paper.

Absolute rapidity interval	0–0.5	0.5–1	1–1.5	1.5–2	2–2.5
$J/\psi \to \mu^+\mu^-$ $m_{\mu^+\mu^-}$ lineshape	1.4%	1.2%	0.7%	0.7%	0.6%
$J/\psi \to e^+e^-$ $m_{\mu^+\mu^-}$ lineshape	0.7%	0.6%	0.3%	0.2%	0.1%
$p_T^{\mu^+\mu^-}$ shape	0.1%	0.1%	0.1%	0.2%	0.3%
Total ID material unc. on signal yield	2.1%	1.8%	0.9%	1.0%	0.8%

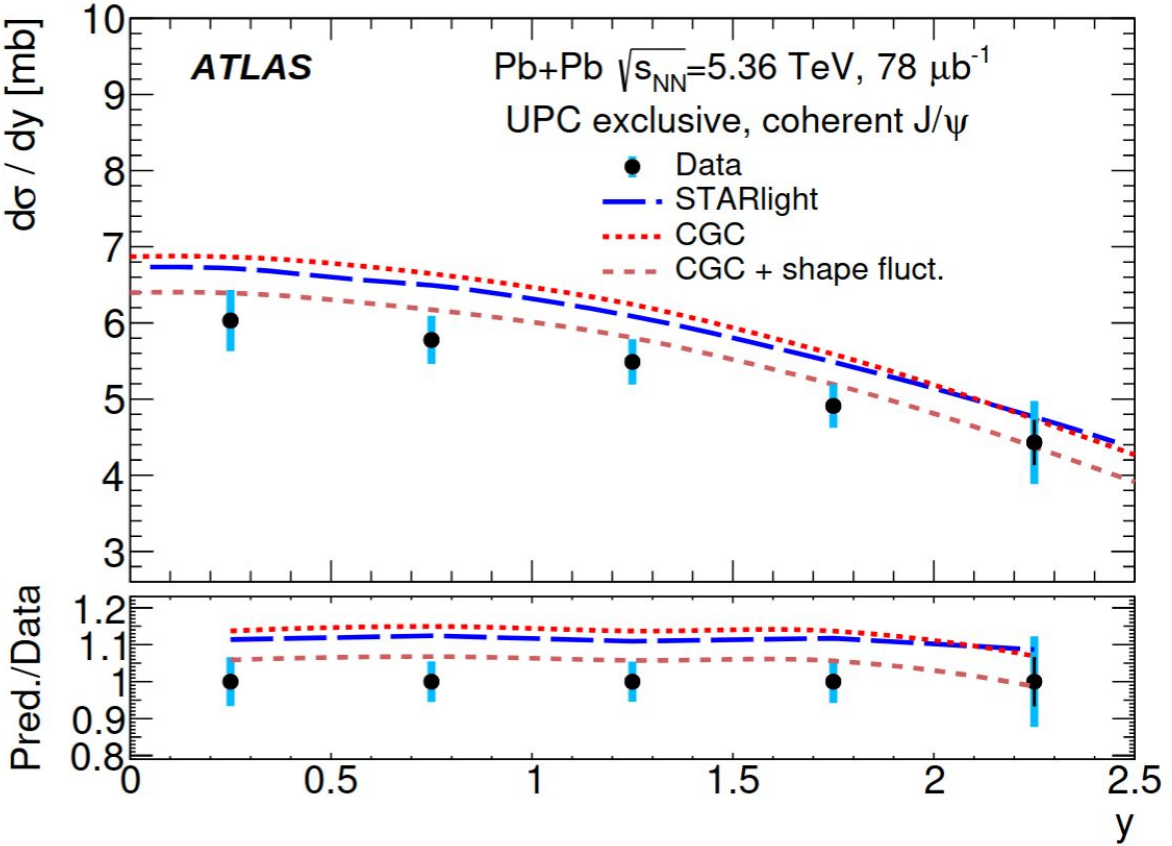
Measured cross-sections

$$\frac{d\sigma}{dy} = \frac{N^{coh}_{J/\psi\to\mu\mu}}{A \times C \times BR \times \mathcal{L}_{int} \times \Delta y}$$

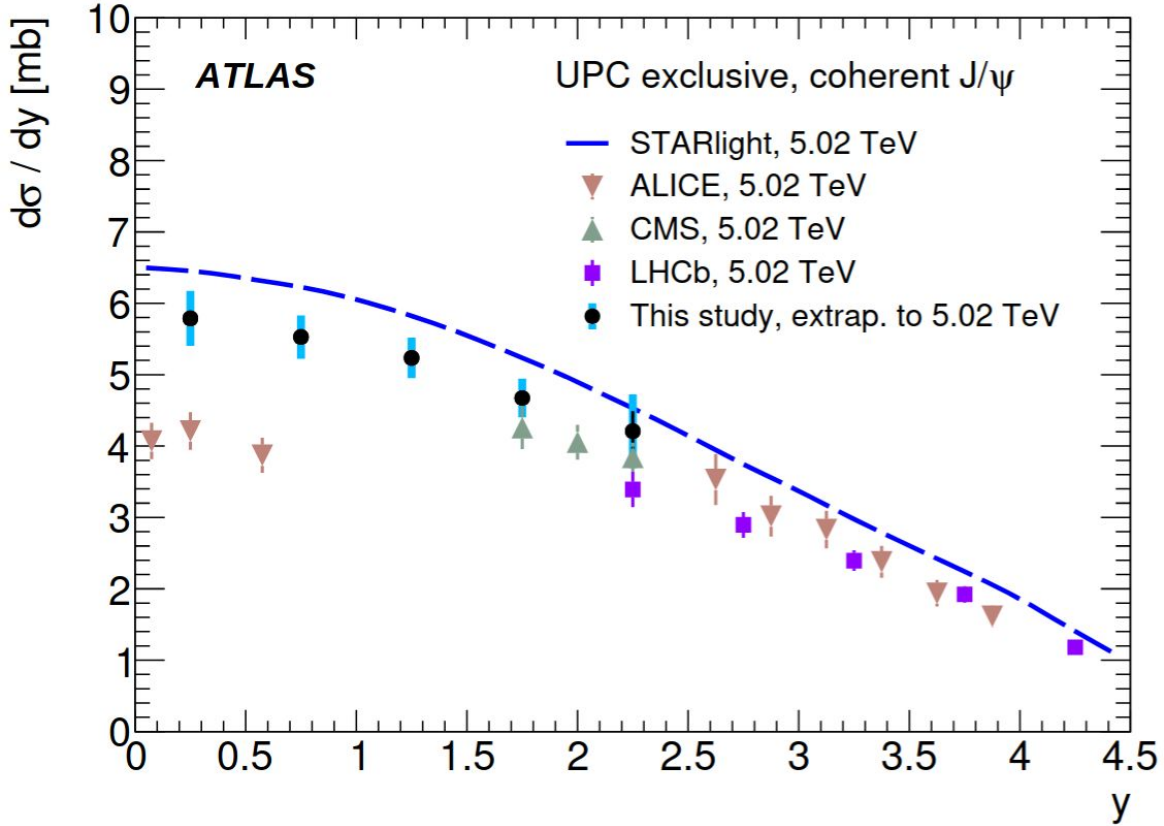
Comparison with two models is shown.

Both models use HERA $\gamma p \to J/\psi p$ data as an input.

In addition, the CGC model includes the effect of nucleon shape fluctuations.



Extrapolation to 5.02 TeV



Extrapolation of this measurements from 5.36 TeV to 5.02 TeV using STARlight predictions (about -5% correction).

Good agreement with other experiments is observed at larger rapidities.

Significant difference between ATLAS and ALICE at low rapidities.

Summary

1. First ATLAS measurement of coherent J/ψ production in UPC.
2. Differential cross-section measured in |y|<2.5.
3. Results demonstrate a good performance of L1 TRT trigger achieved in Run 3.
4. Tension between ATLAS and ALICE observed at mid-rapidity.
5. Prospects for future: photonuclear J/ψ production cross-section measurement as a function of γPb center of mass energy.

NATIONAL SCIENCE CENTRE POLAND

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AGH RESEARCH UNIVERSITY EXCELLENCE INITIATIVE

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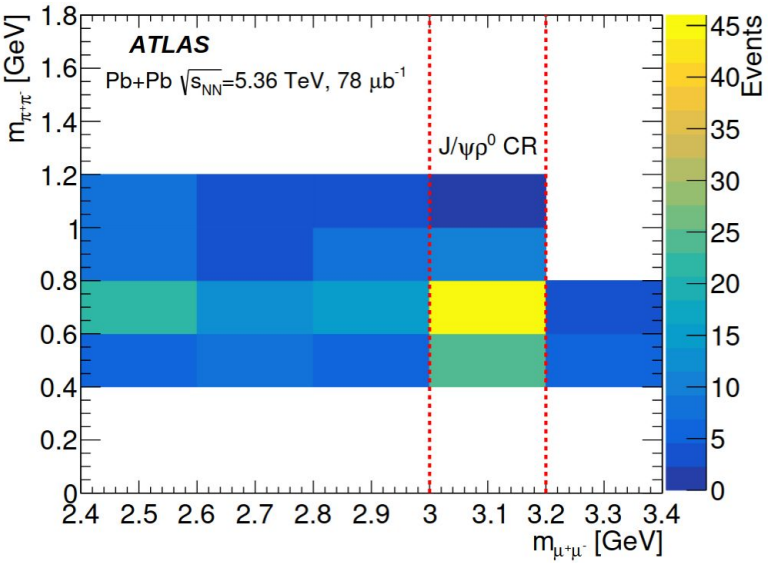
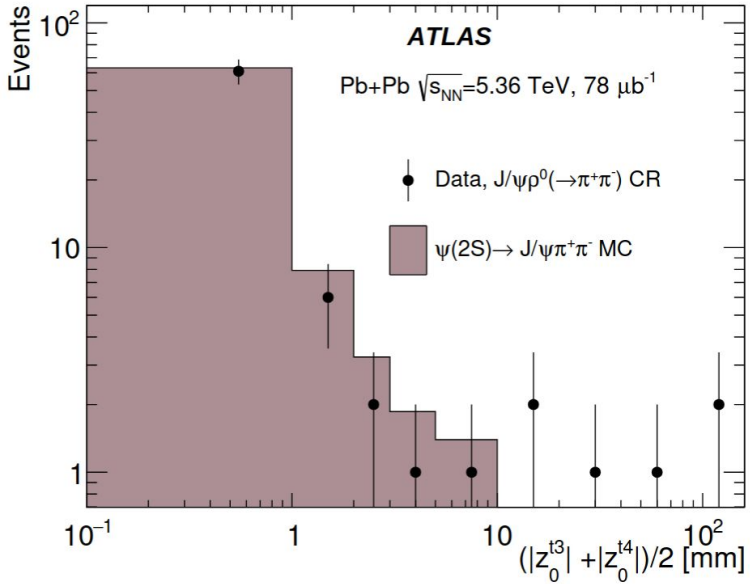
Backup

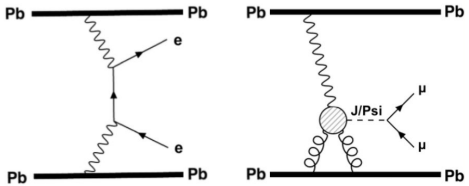
Coinciding UPC processes

Clear J/ψ+ρ_0 signal is observed.



To get the ratio of J/ψ+ρ_0 from **same/separate** Pb+Pb collision, we can study if pairs come from the proximity of J/ψ vertex.





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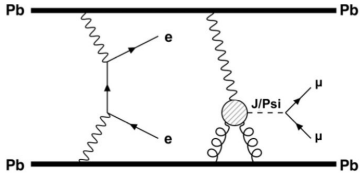
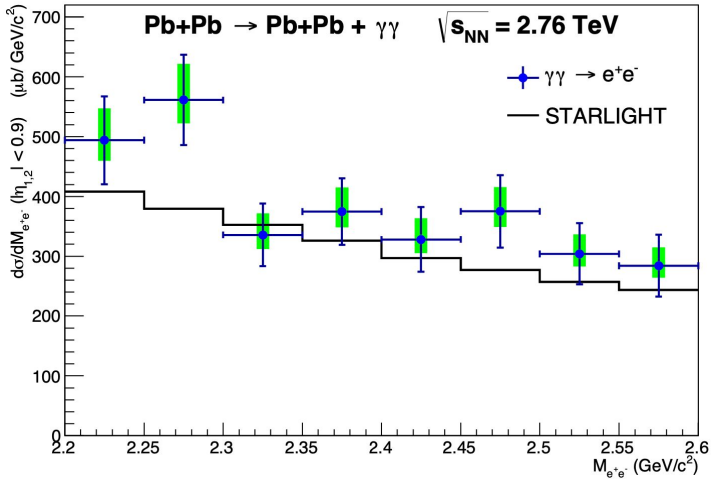


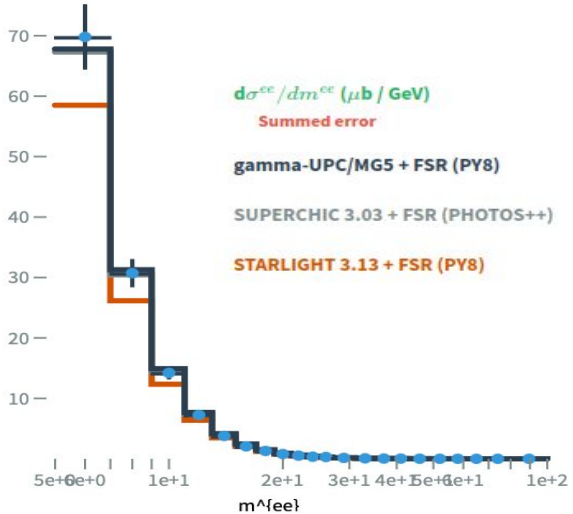
Cross-check of the $\gamma\gamma \rightarrow \ell^+\ell^-$ background (absolute rate)

It is found that the $\gamma\gamma \rightarrow \ell^+\ell^-$ predictions, normalized using cross-sections from STARlight, underpredict the observed yields by approximately 20%.

This discrepancy is consistent with previous observations of the $\gamma\gamma \rightarrow \ell^+\ell^-$ process in Pb+Pb UPC at low dilepton invariant masses.



[arXiv:1305.1467]



[arXiv:2412.15413]