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Towards the incoherent J/ψ photoproduction cross section

David Grund
FNSPE CTU in Prague

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- Motivation: why are we interested in **ultra-peripheral collisions (UPCs)**?
- Phenomenological background: energy-dependent hot-spot model
- Previous measurement by ALICE (the Run 1)
- Analysis of the Run 2 data (2018) - first steps

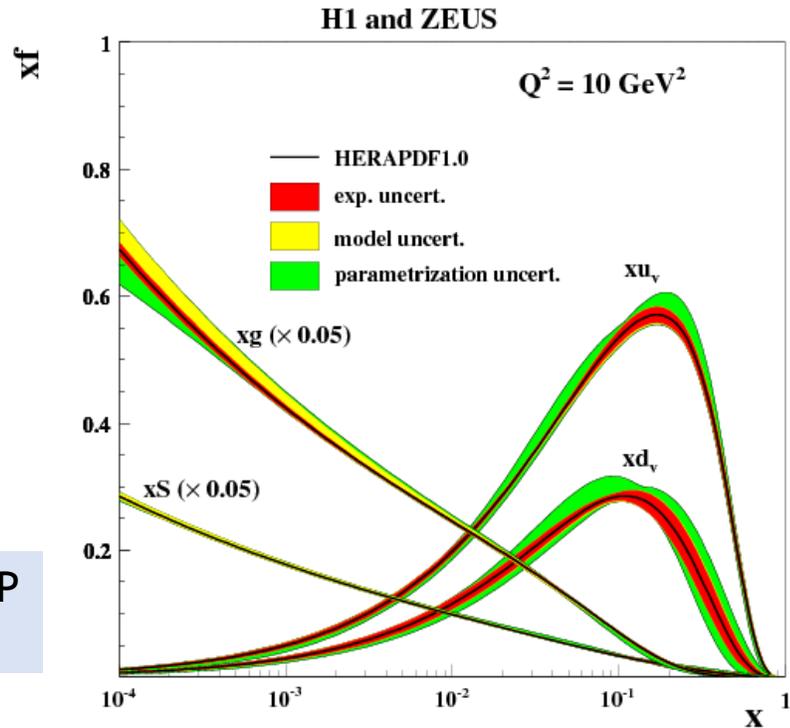
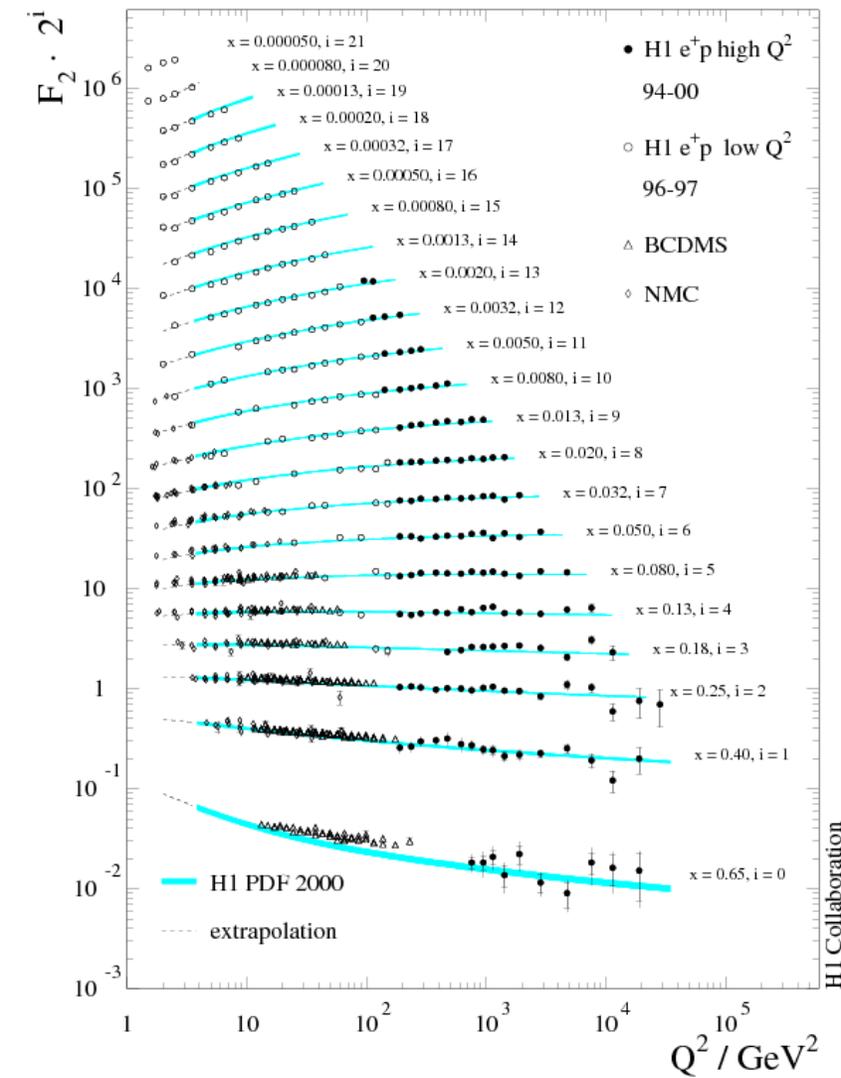
Structure of hadrons



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- HERA measured very precisely the longitudinal structure of protons
- The gluon contribution grows rapidly towards lower Bjorken x (high energy)
- Gluon saturation: will this growth stop at some energy?

H1, Eur. Phys. J. C 30 (2003) 1-32



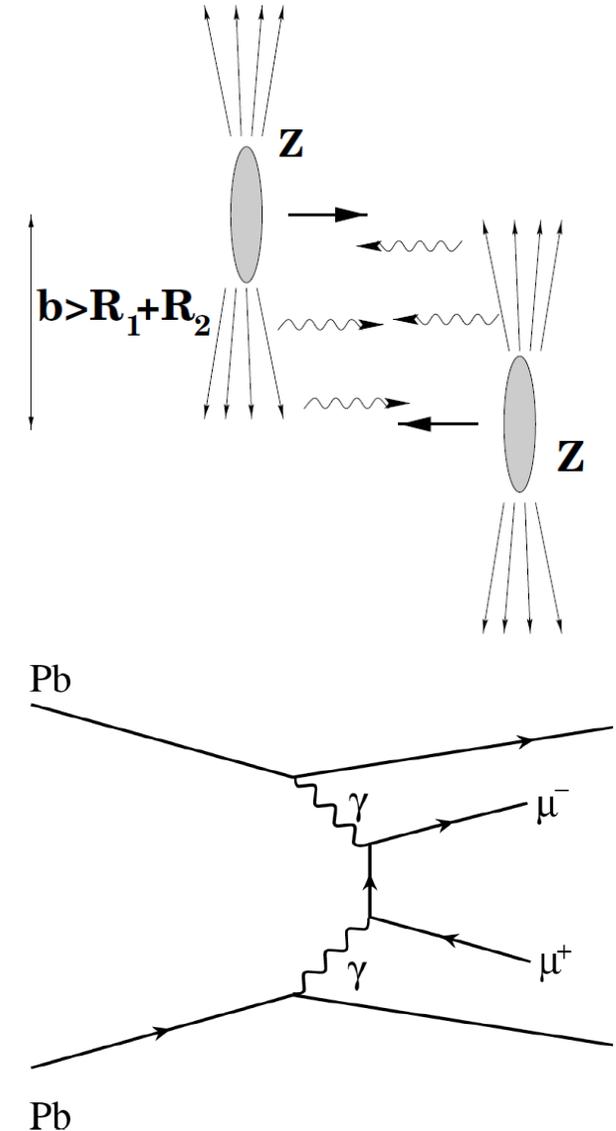
H1 and ZEUS, JHEP (2010) 1001:109

Ultra-peripheral collisions



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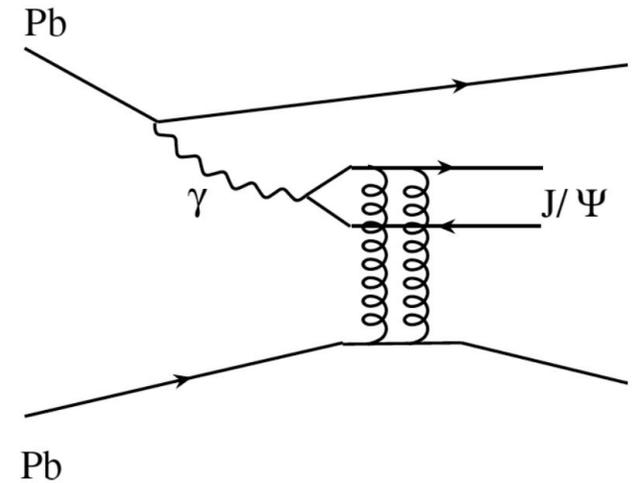
- Collisions at which $b >$ sum of the radii of the projectiles
- Interaction induced by a virtual photon (QCD short-ranged)
- Two-photon processes
 - E.g. creation of a lepton pair
- **Vector meson photoproduction (VMP)**
 - Coherent: γ interacts with the whole nucleus
 - Incoherent: γ interacts with a single nucleon
- Both sensitive to the gluon distribution in the target
- Scattering angle of the J/ψ traces the energy (x) evolution
- Nucleus $>$ nucleon \Rightarrow
 p_T of coherent $J/\psi < p_T$ of incoherent J/ψ



Vector meson photoproduction

- Process can be factorised into:
 - The photon flux (QED)
 - Photon-target hadron interaction (QCD)
- **Colour dipole model**
 - A photon fluctuates into a quark-antiquark pair which interacts with the target via an exchange of gluons
- In a Good-Walker formalism:

Type of a process	Sensitive to
Coherent	The average over target configurations
Incoherent	The variance over target configurations



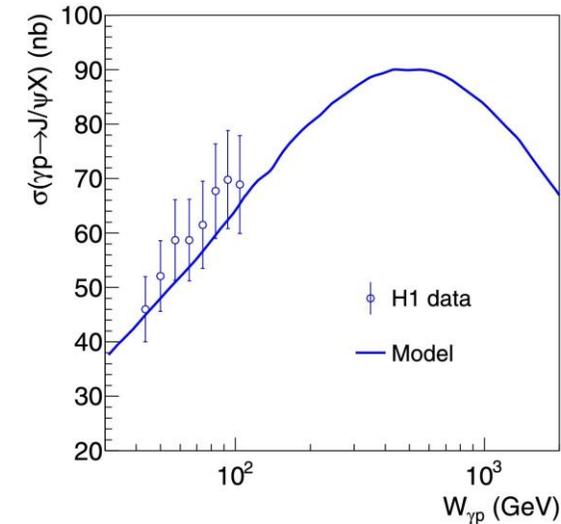
The incoherent process is sensitive to **fluctuations** in the transverse structure of hadrons

Energy-dependent hot-spot model

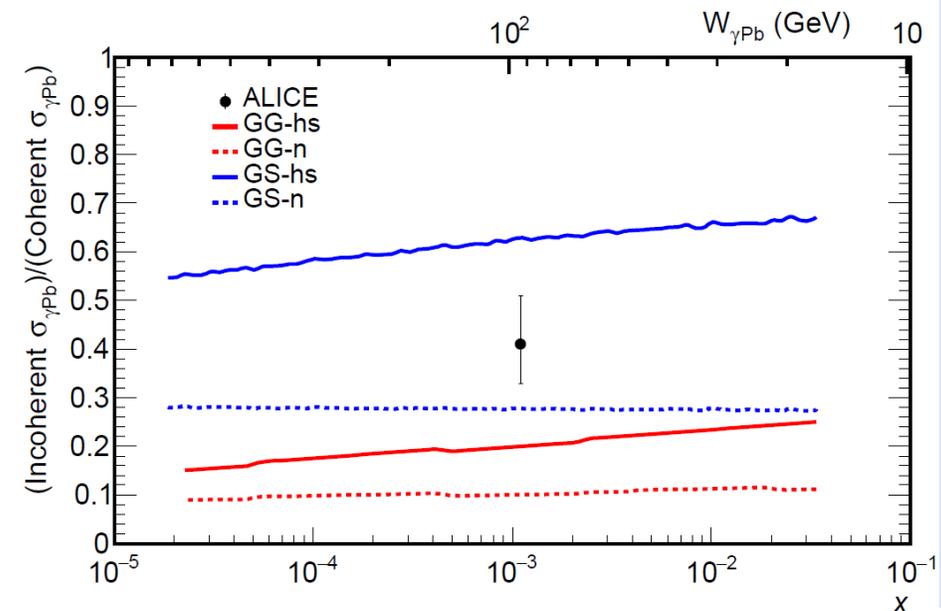


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- Originally applied to γ -p collisions
 - Proton structure described in terms of high-gluon-density Gaussian hot spots
 - Number of hot spots increases with the energy of the collisions
 - The model is able to predict the effects of gluon saturation!
- An extension to **Pb-Pb** collisions
 - A x -dependence of the ratio of the incoherent to coherent cross section introduced

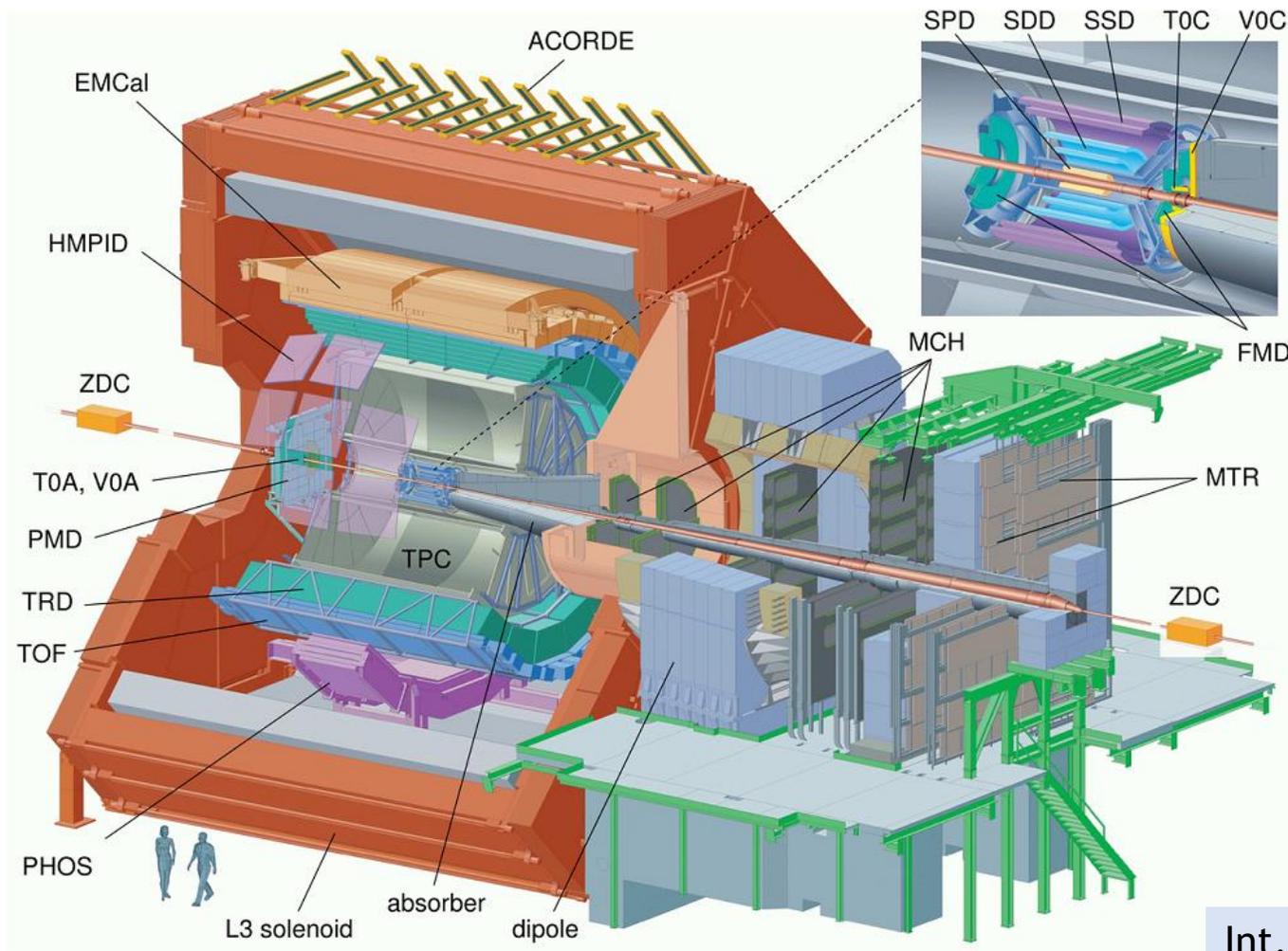


PLBB 766 (2017) 186



Phys. Rev. C 97, 024901 (2018)

- UPCs and photoproduction of vector mesons extensively studied at ALICE



Detectors necessary for measuring UPCs in central rapidity:

- Inner Tracking System
- Time Projection Chamber
- Time-Of-Flight detector

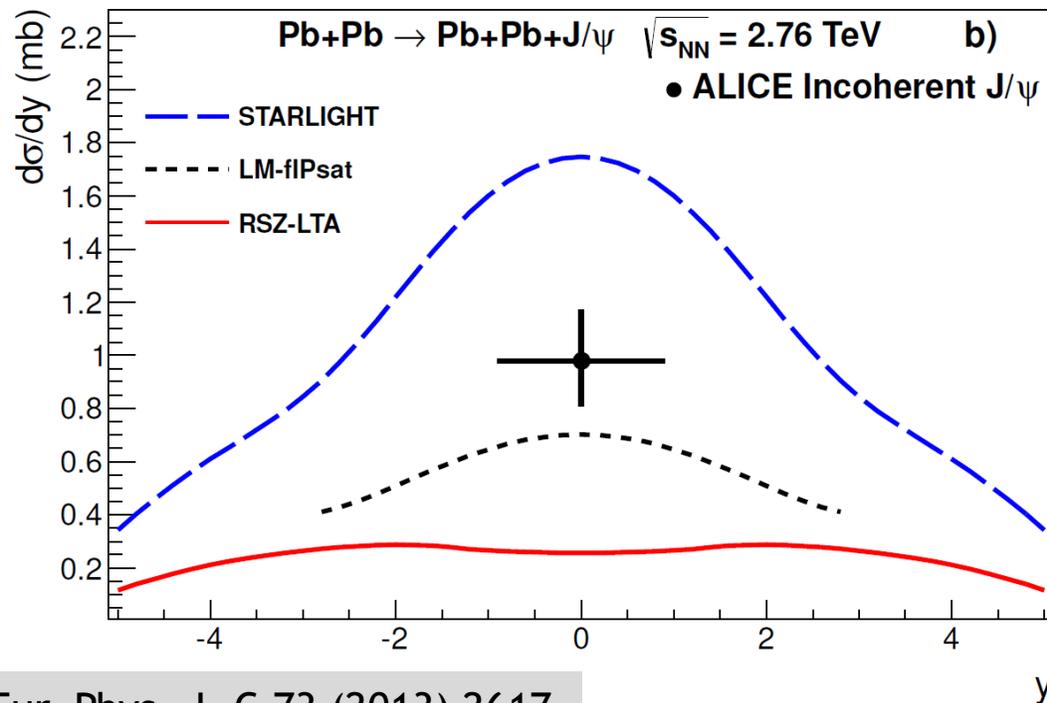
Forward supporting detectors:

- The V0
- The ALICE Diffractive
- Zero Degree Calorimeters

Int. J. Mod. Phys. A 29 (2014) 1430044

Previous measurement by ALICE

- The only measurement of the incoherent photoproduction of J/ψ with ALICE based on the data from 2011 (the Run 1)
- Pb-Pb UPCs at $\sqrt{s_{NN}} = 2.76$ TeV
- Both the electron and muon decay channels of J/ψ analysed in central rapidity region, $|y| < 0.9$



Eur. Phys. J. C 73 (2013) 2617

- About 90 (60) J/ψ candidates found in incoherent-enriched samples of muon (electron) pairs
- Calculated incoherent cross section:
 $0.98^{+0.19}_{-0.17}$ (sta + sys) mb
- None of the presented models was in accordance with the result

- Data from the periods LHC18q (123 runs) and LHC18r (96 runs)
- Pb-Pb UPCs at $\sqrt{s_{NN}} = 5.02$ TeV
- The ultimate goal will be to extract the cross section of incoherent J/ψ photoproduction:

$$\frac{d\sigma_{J/\psi}^{\text{incoh}}}{dy} = \frac{N_{J/\psi}^{\text{incoh}}}{(\text{Acc} \times \varepsilon)_{J/\psi} \cdot BR(J/\psi \rightarrow l^+l^-) \cdot L_{\text{int}} \cdot \Delta y}$$

Signal extraction ✓

- Things to do:
 - Acceptance and efficiency correction
 - Background subtraction
 - Systematic uncertainties

Integrated luminosity ✓

Selection of UPC events



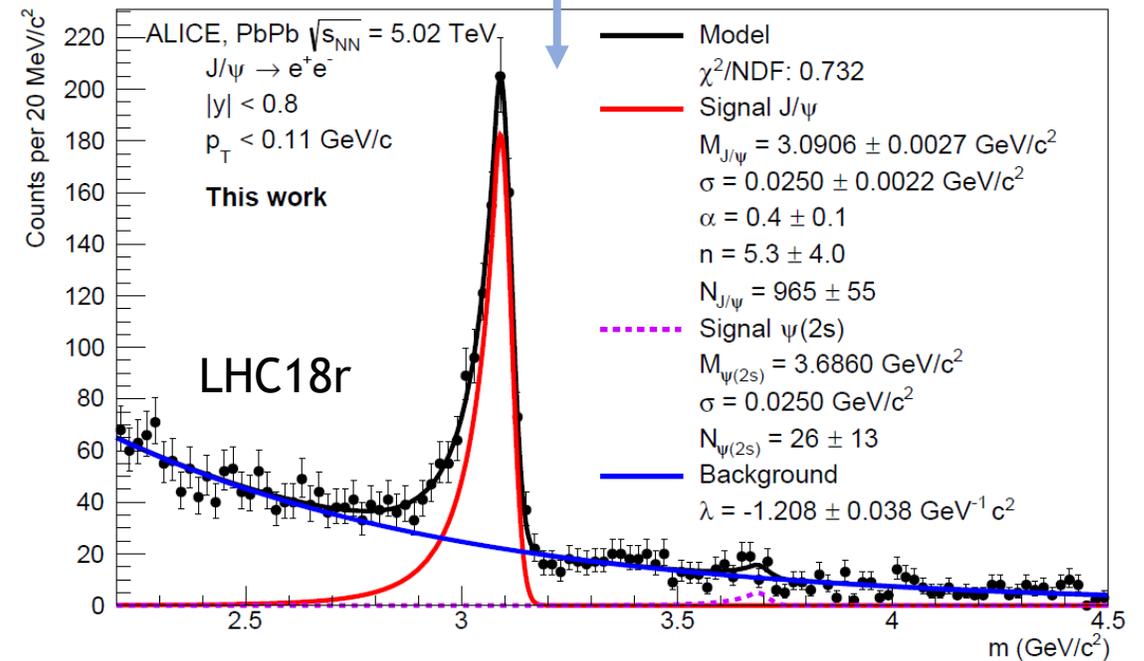
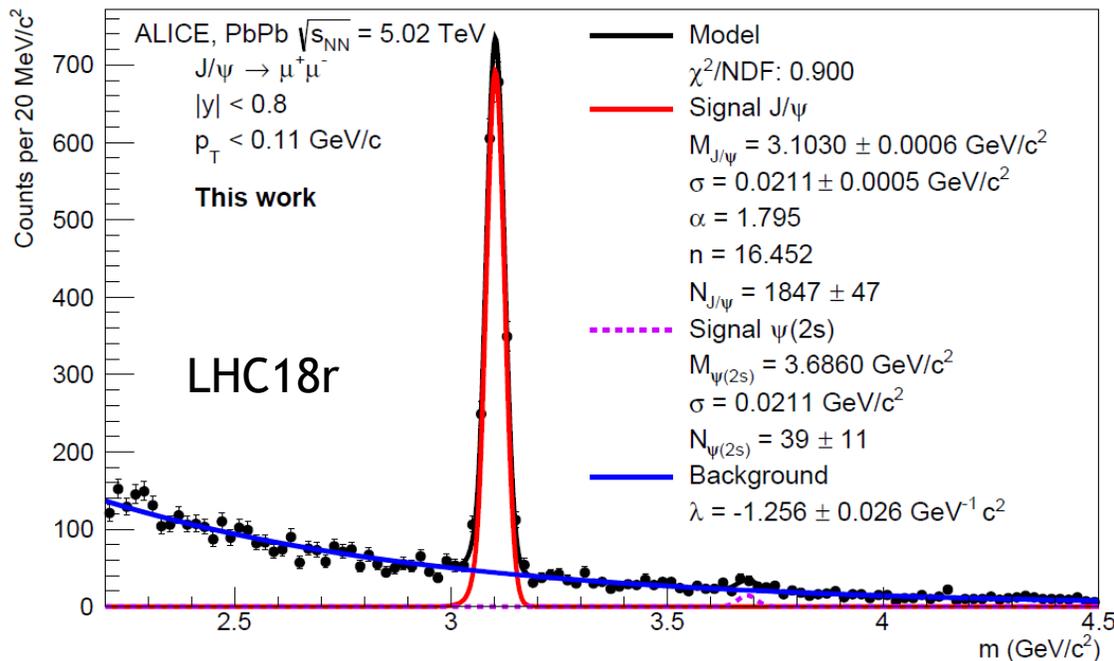
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	Selection	LHC18q	LHC18r
According to both SPD & ITS	Two good central tracks	981184	1521030
	CCUP31 trigger	835170	1441881
	Dilepton invariant mass $m \in (2.2, 4.5) \text{ GeV}/c^2$	20749	34009
To reject events with potential hadronic contamination	ADA offline veto	20718	33830
	ADC offline veto	20700	33690
	V0A offline veto	17896	28962
	V0C offline veto	16106	26153
Central rapidity ($x = 2.4 \times 10^{-4}$)	Dilepton rapidity $ y < 0.8$	15859	25744
	Pseudorapidity of both tracks $ \eta < 0.8$	12769	20509
	Opposite charges	11582	18562
	$\mu^+ \mu^-$ pairs only	7525	11953
	Dilepton invariant mass $m \in (3.0, 3.2) \text{ GeV}/c^2$	2952	4552

Then additional p_T cuts...

Coherent-enriched sample

- $p_T < 0.11$ GeV/c
- Extracted to make a comparison with the existing (Roman's) analysis
 - Benchmarking successful
- Invariant mass fits of dimuons and dielectrons
 - PDF = CB(J/ψ) + CB(ψ') + exponential



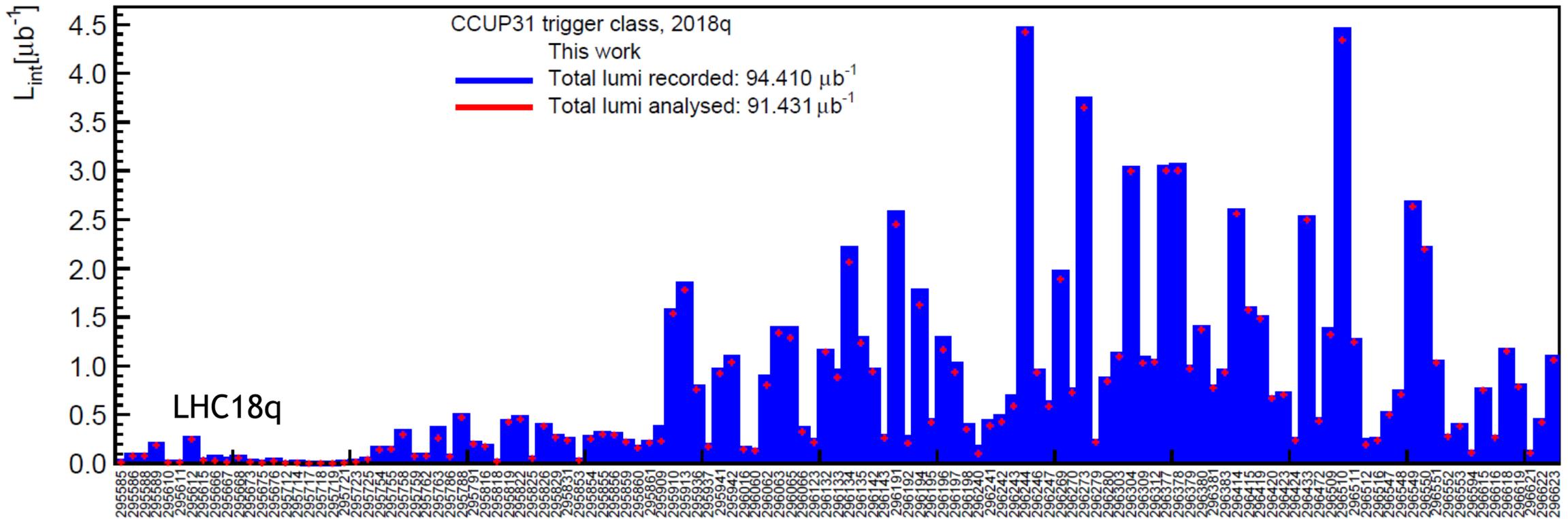
Note a lower resolution of the electron sample

Luminosity calculation



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- CCUP31 trigger: !0VBA !0VBC !0UBA !0UBC 0STG 0OMU
- Analysed luminosity = scaling of recorded values from the trending files
- In total, both periods yielded: $L_{\text{int}} = 238.7 \mu\text{b}^{-1}$

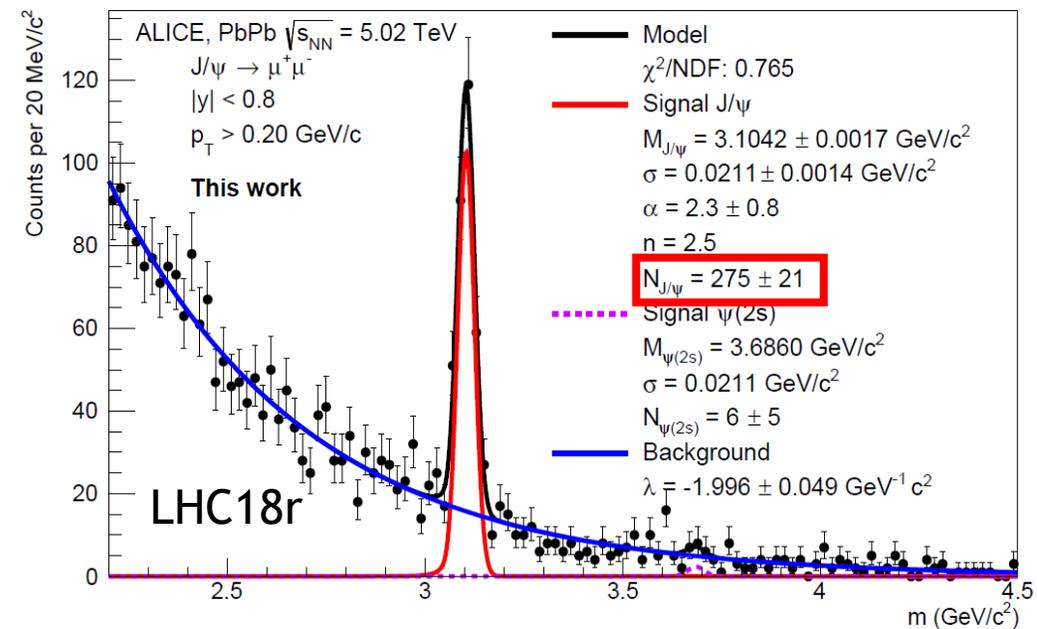
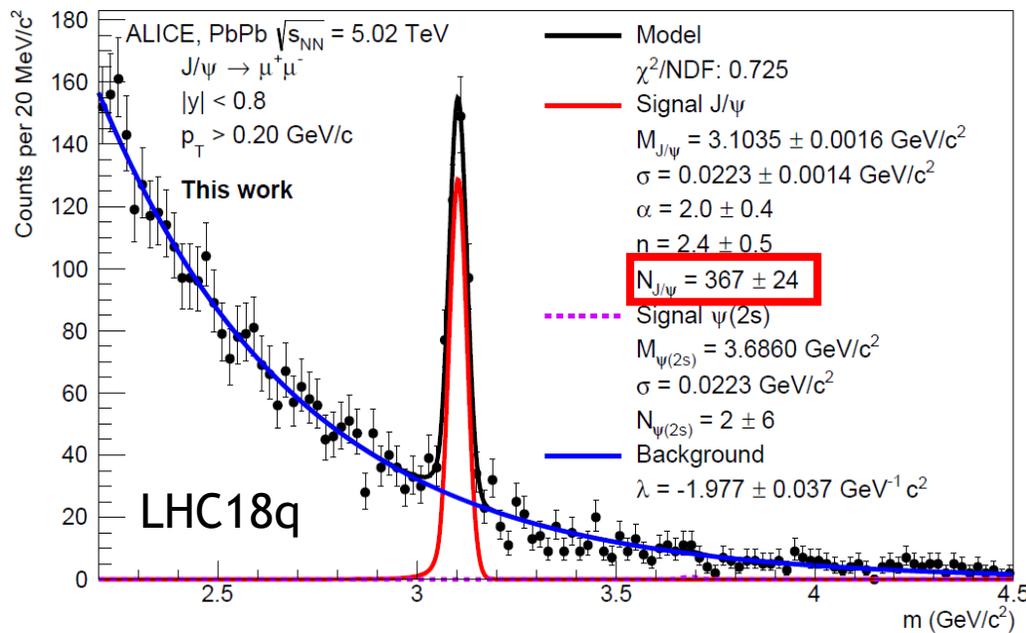


Incoherent-enriched sample



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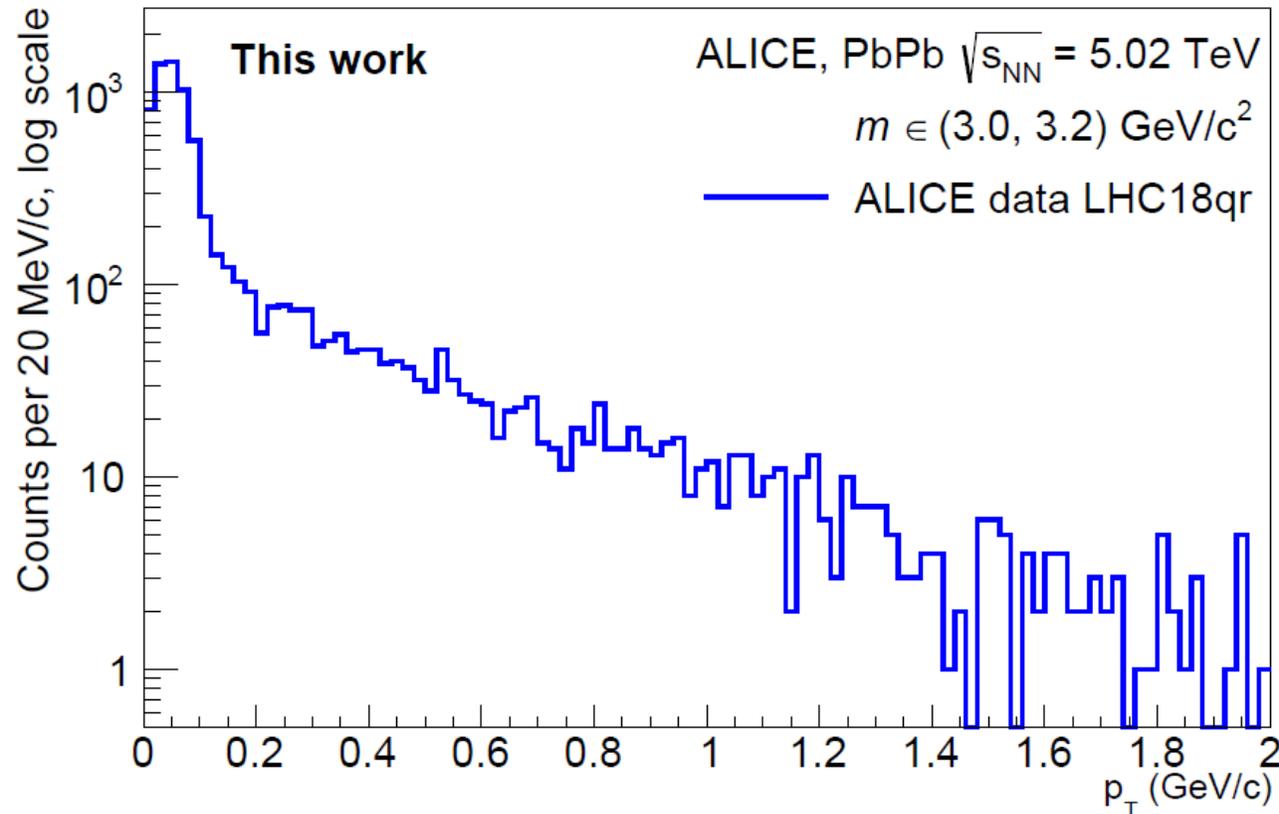
- $p_T > 0.2 \text{ GeV}/c$
- N_{incoh} in midrapidity almost **eight times higher** compared with the previous analysis at $\sqrt{s_{\text{NN}}} = 2.76 \text{ TeV}$
- This could substantially reduce the statistical error
- More systematic studies to reduce the systematic uncertainty could be performed



p_T distribution



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- One of the next steps: to **fit the distribution** using the MC simulations
- To subtract the background from coherent events, continuum production and feed-down

- UPCs constitute a powerful tool for studying the structure of hadrons
 - Can help to examine the phenomena of high-energy QCD, such as **gluon saturation**
- The incoherent VMP is sensitive to **fluctuations of the transverse hadron structure**
- A **considerable increase of incoherent events** in the Run 2 data
 - Statistical errors can be reduced
- The goal is to extract the incoherent cross section
- In the future: measure also at forward rapidity (dominated by $x > 10^{-2}$) and study the energy evolution using the MFT



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Thank you for your attention

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- J. Cepila, J. G. Contreras, J. D. Tapia Takaki: Energy dependence of dissociative J/Psi photoproduction as a signature of gluon saturation at the LHC, Phys. Lett. B766, 186-191 (2017).
- J. Cepila, J. G. Contreras, M. Krelina: Coherent and incoherent J/Psi photonuclear production in an energy-dependent hot-spot model, Phys. Rev. C97(2), 024901 (2018).
- E. Abbas et al.: Charmonium and e+e- pair photoproduction at mid-rapidity in ultra-peripheral Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV, The European Physical Journal C73(11), 2617 (2013).