



Charmonium photoproduction in ultra-peripheral and peripheral Pb-Pb and p-Pb collisions with ALICE at the LHC

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Institute for Nuclear Physics, Krakow

XIII Workshop on Particle Correlations and Femtoscopy

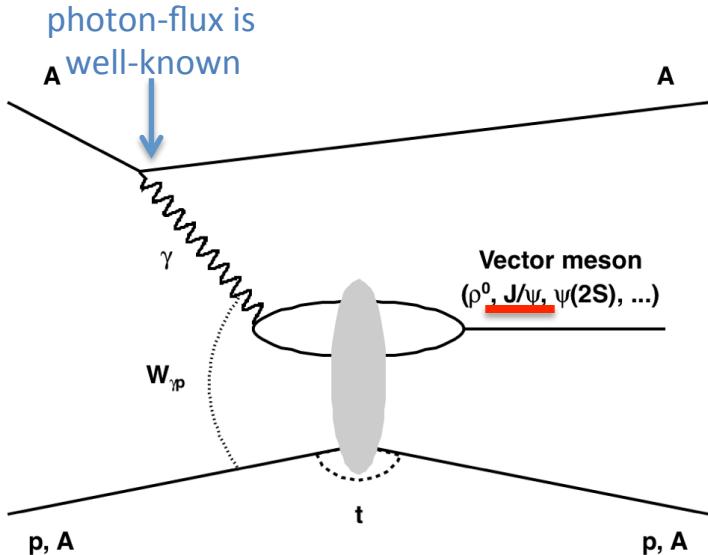
24.05.2018

Overview

- Introduction
- The ALICE detector
- Exclusive J/ψ photoproduction in ultra-peripheral p-Pb collisions
 - at forward, semi-forward, and central rapidities
- Low- p_T J/ψ yield excess in peripheral Pb-Pb collisions
 - at forward rapidities in Pb-Pb @ 2.76 TeV (RUN1)
 - at central rapidities in Pb-Pb @ 5.02 TeV (RUN2)
- Summary

Ultra-peripheral collisions

- Ultra-peripheral collisions (UPC): impact parameter $b > R_1 + R_2$
 - hadronic interactions are strongly suppressed
 - electromagnetic interactions are dominant



- The EM field of protons and of Pb nuclei can be described as a beam of quasi-real photons.
- Number of photons proportional to Z^2
 \rightarrow large photon-flux from Pb ions
- Very clean experimental signature
 - vector mesons with low p_T
 - large rapidity gaps

Ultra-peripheral collisions

- **Coherent**

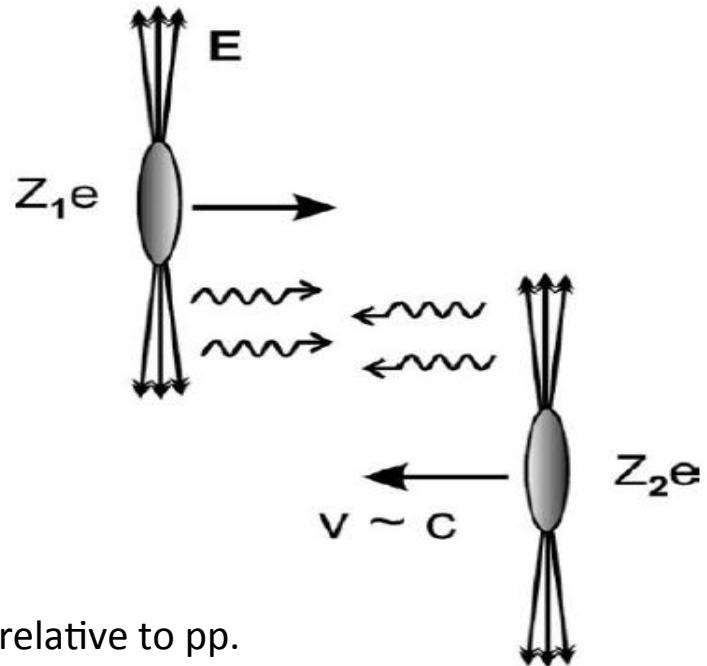
- Photon couples coherently to all the nucleons.
- $J/\psi \langle p_T \rangle \approx 60 \text{ MeV}/c$.
- Target nucleus normally does not break up.

- **Incoherent**

- Photon couples to a part of the nucleus.
- $J/\psi \langle p_T \rangle \approx 500 \text{ MeV}/c$.
- Target nucleus normally does break up.

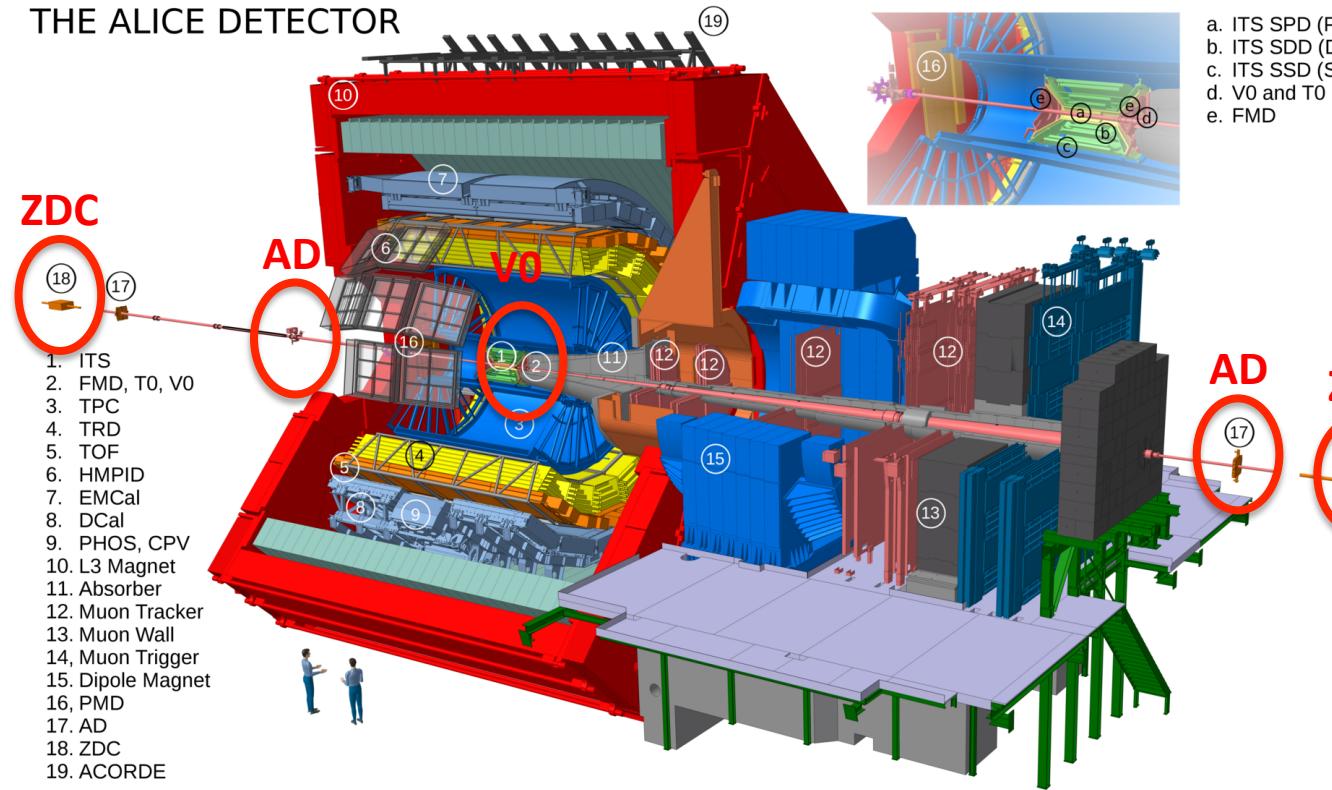
- **p-Pb and Pb-p collisions:**

- Photon from the Pb ion interacts with the proton.
- Flux of virtual photons of Pb is enhanced by a factor of Z^2 relative to pp.
- $(W_{\gamma p})^2 = 2 \times M_{J/\psi} \times \exp(-y) \times E_p$

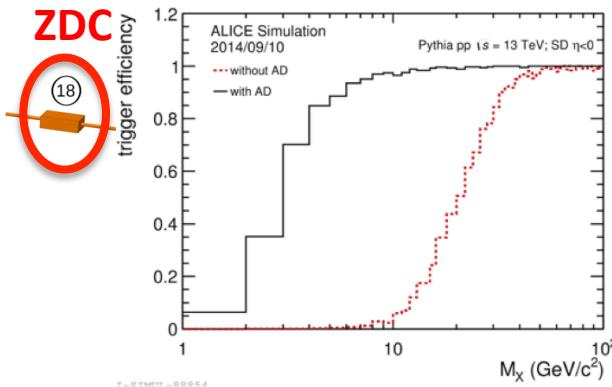


ALICE detector

THE ALICE DETECTOR



In RUN2 the AD detector was added:
 → enhanced sensitivity to low diffractive masses



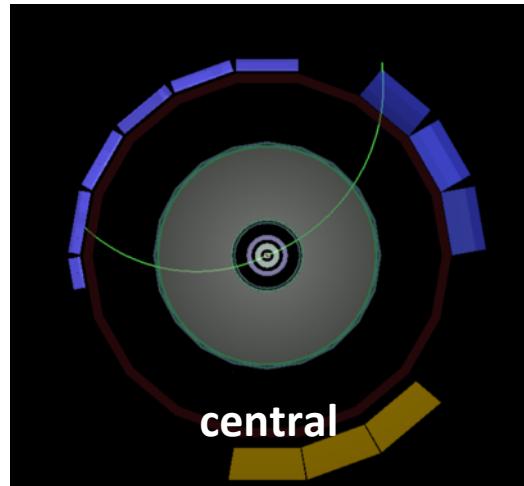
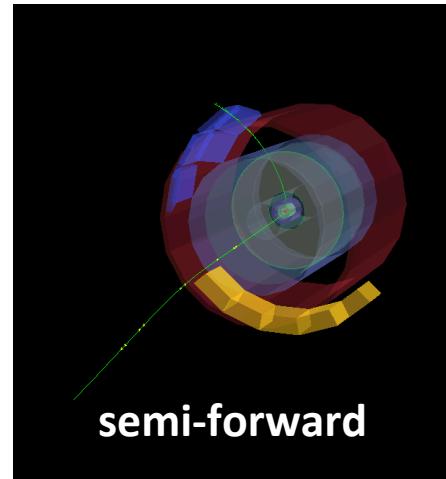
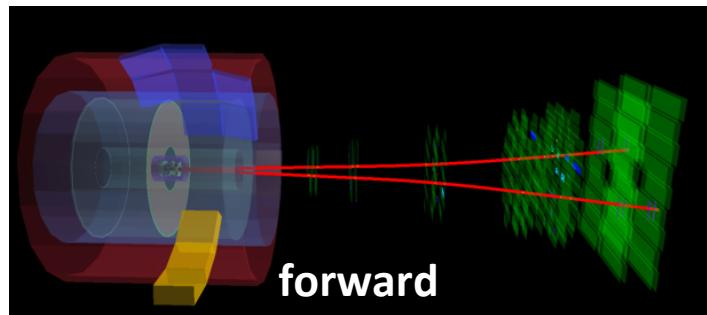
see also [CERN-PH-LPCC-2015-001](#)

Exclusive J/ ψ photo-production in ALICE

forward: both muons in the MUON arm

central: two electrons in the central barrel

semi-forward: one muon in MUON arm and one muon in the central barrel



Exclusive J/ ψ photoproduction in p-Pb

forward:

- ALICE measurements were published in PRL 113 (2014) 232504,
- measurements up to more than twice highest energy reached at HERA.

central:

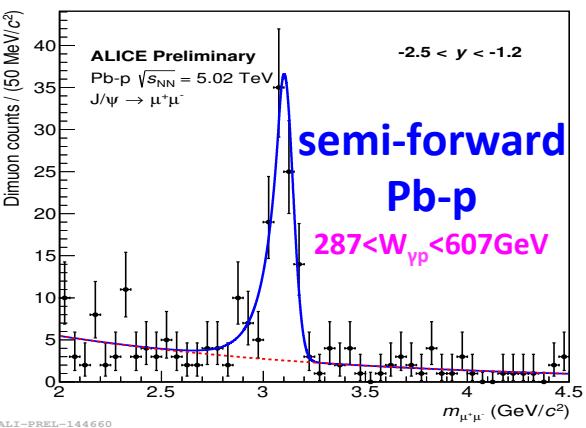
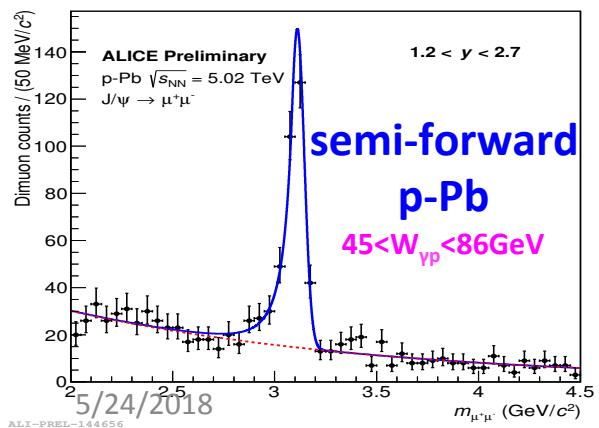
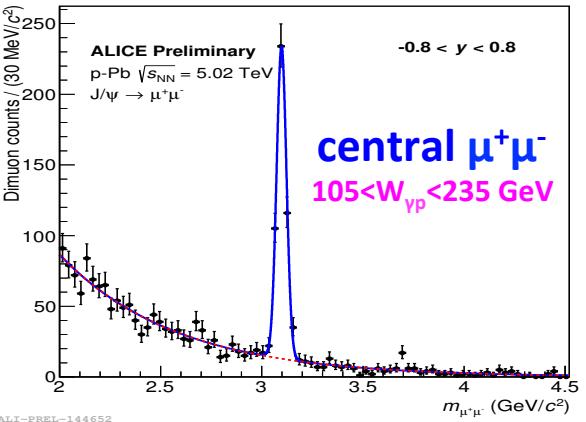
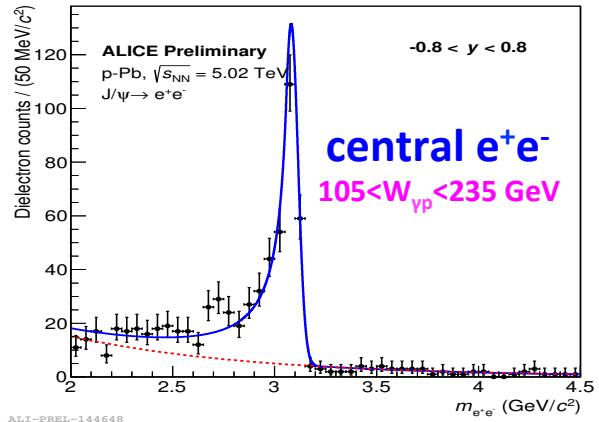
- between 2 and 6 TOF modules triggered, at least two back-to-back,
- two SPD back-to-back tracklets,
- no activity in V0 and less than 6 hits in outer SPD layer.

semi-forward:

- one low- p_T ($> 0.5 \text{ GeV}/c$) muon in the MUON spectrometer,
- in Pb-p: signal in V0C,
- no activity in V0A, <5 hits in V0C, <6 hits in outer SPD layer,
- only for Pb-p: no signal in V0A beam-gas window.

NEW

Exclusive J/ ψ photoproduction in p-Pb



top: mid-rapidity e^+e^- , $\mu^+\mu^-$
 bottom: semi-forward ($\mu^+\mu^-$)

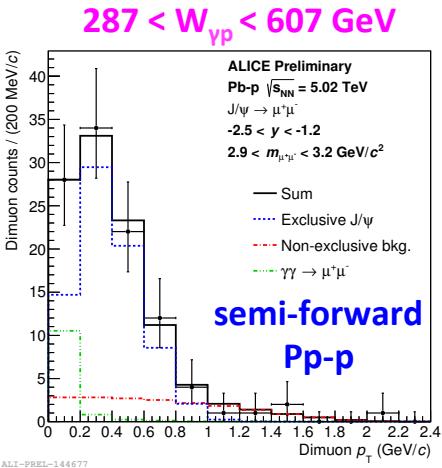
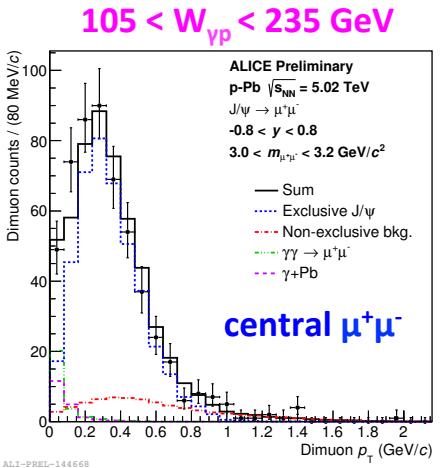
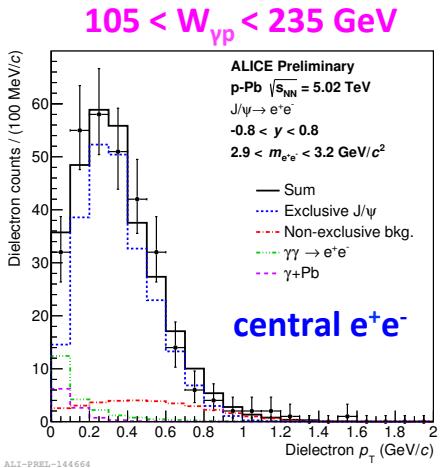
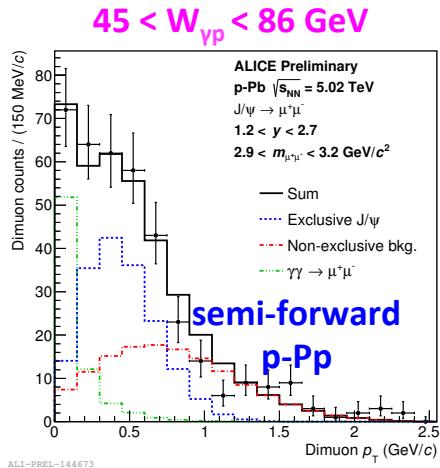
blue – Crystal Ball + Exp. function
 red – Exponential function
 ($\rightarrow \gamma\gamma$ cont. production)

clean signal in all cases

$$(W_{\gamma p})^2 = 2 \times M_{J/\psi} \times \exp(-y) \times E_p$$

$$(E_p = 4000 \text{ GeV})$$

Exclusive J/ ψ photoproduction in p-Pb

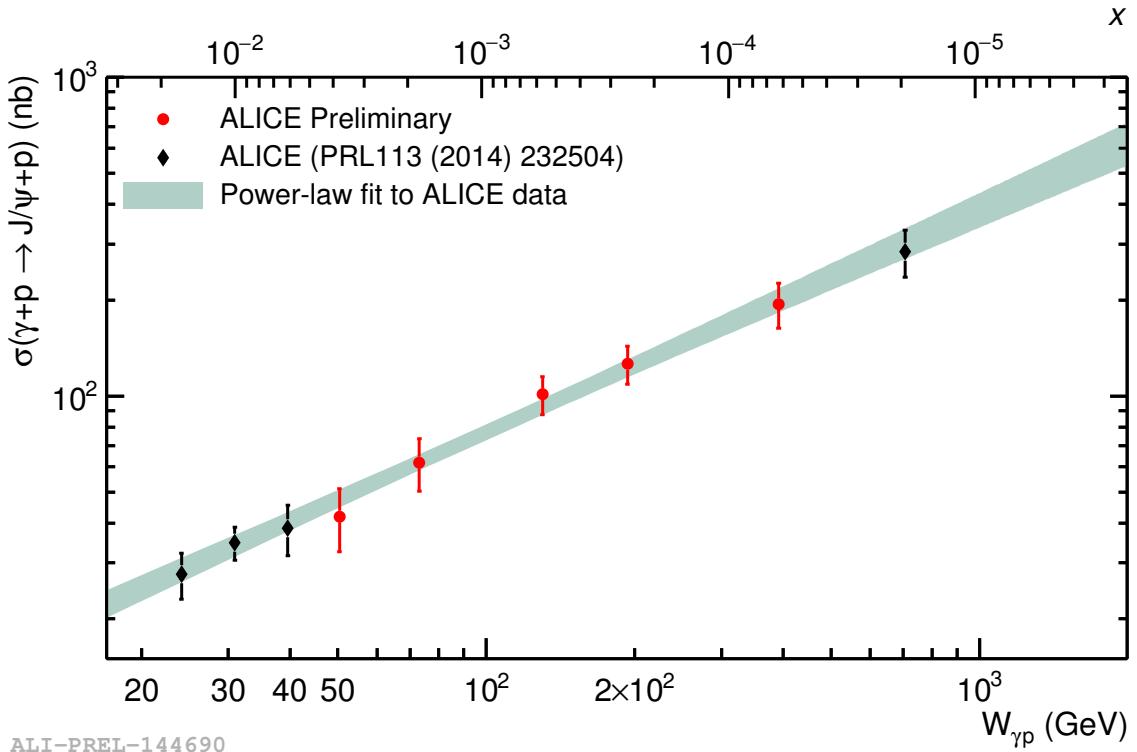


Signal extraction by fit to templates

- exclusive J/ ψ
- non-exclusive bkgd obtained from data
- continuum $\gamma\gamma \rightarrow e^+e^-$, $\mu^+\mu^-$
- $\gamma+Pb$

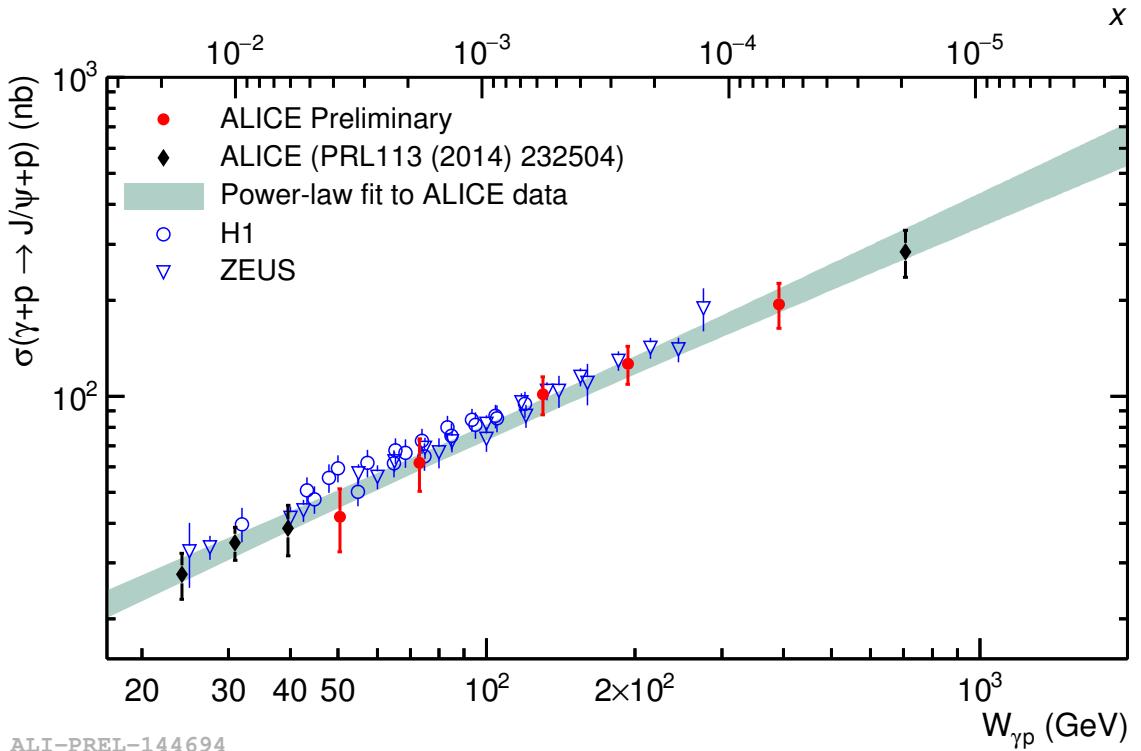
The width of the p_T distribution decreases with energy as seen already at HERA. b increases in $\exp(-bp_T^2)$

Exclusive J/ ψ photoproduction in p-Pb



ALI-PREL-144690

Exclusive J/ ψ photoproduction in p-Pb



ALI-PREL-144694

Exclusive J/ ψ photoproduction in p-Pb

CCT

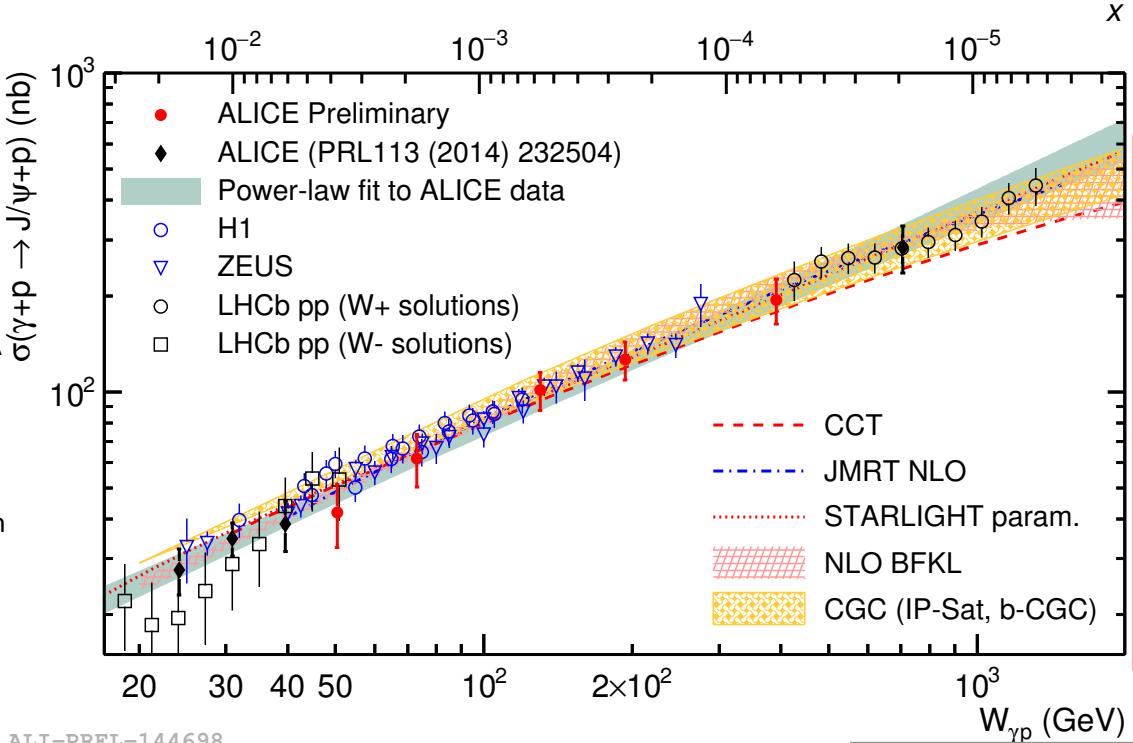
energy-dependent hot
spot model
PLB766 (2017) 186

JMRT NLO
DGLAP formalism +
main NLO contributions
EPJC76 (2016) 633

STARLIGHT
Parameterization of HERA
and fixed-target data
CPhC 212 (2017) 258

NLO-BFKL
proton impact factor from
F2 HERA data
PRD94 (2016) 054002

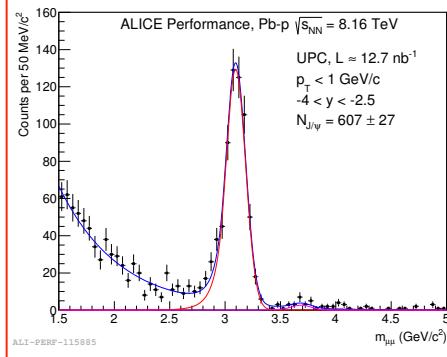
CGC
color-gluon-condensate
models with saturation
PRD90 (2014) 054003
5/24/2018



Good description by all models

for LHCb measurements in pp
at 13 TeV see LHCb-CONF-2016-007

New RUN2 data will
allow ALICE to explore
the region above 1 TeV:



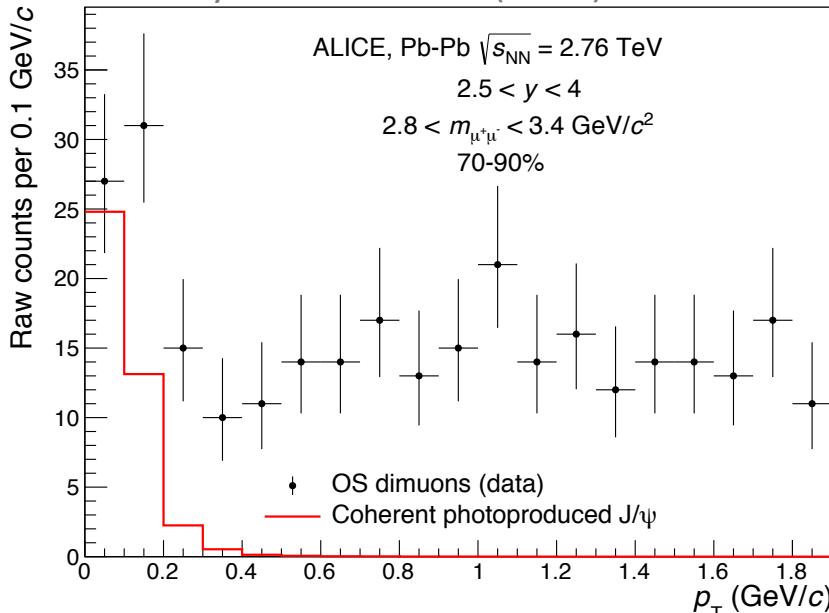
low- p_T J/ ψ yield excess found in Pb-Pb @ 2.76 TeV

In LHC RUN1 ALICE found an excess in the J/ ψ yield for low p_T in peripheral Pb-Pb collisions:

- This excess is interpreted as coherent photo-production.
- Measured cross-sections (assuming it is produced by coherent photoproduction):

Cent. (%)	$N_{AA}^{J/\psi}$	$N_{AA}^{h J/\psi}$	$N_{AA}^{\text{excess } J/\psi}$	$d\sigma_{J/\psi}^{\text{coh}}/dy (\mu\text{b})$
0–10	$339 \pm 85 \pm 78$	$406 \pm 14 \pm 55$	< 251	< 318
10–30	$373 \pm 87 \pm 75$	$397 \pm 10 \pm 61$	< 237	< 290
30–50	$187 \pm 37 \pm 15$	$126 \pm 4 \pm 15$	$62 \pm 37 \pm 21$	$73 \pm 44 {}^{+26}_{-27} \pm 10$
50–70	$89 \pm 13 \pm 2$	$39 \pm 2 \pm 5$	$50 \pm 14 \pm 5$	$58 \pm 16 {}^{+8}_{-10} \pm 8$
70–90	$59 \pm 9 \pm 3$	$8 \pm 1 \pm 1$	$51 \pm 9 \pm 3$	$59 \pm 11 {}^{+7}_{-10} \pm 8$

Phys.Rev.Lett. 116 (2016) 222301



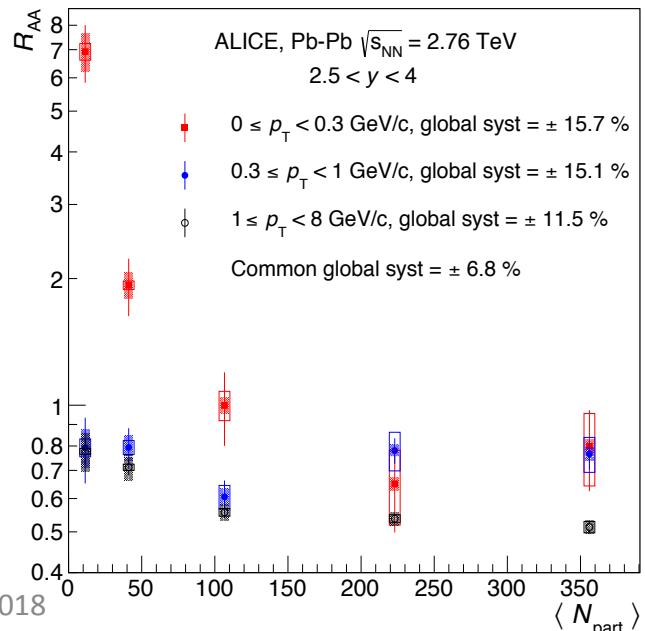
In this presentation: new RUN2 data

low- p_T excess in the J/ ψ yield in Pb-Pb @ 2.76 TeV

Effect of this excess on the J/ ψ R_{AA}:

For low J/ ψ p_T the J/ ψ R_{AA} becomes as large as 7.

PRL 116 (2016) 222301

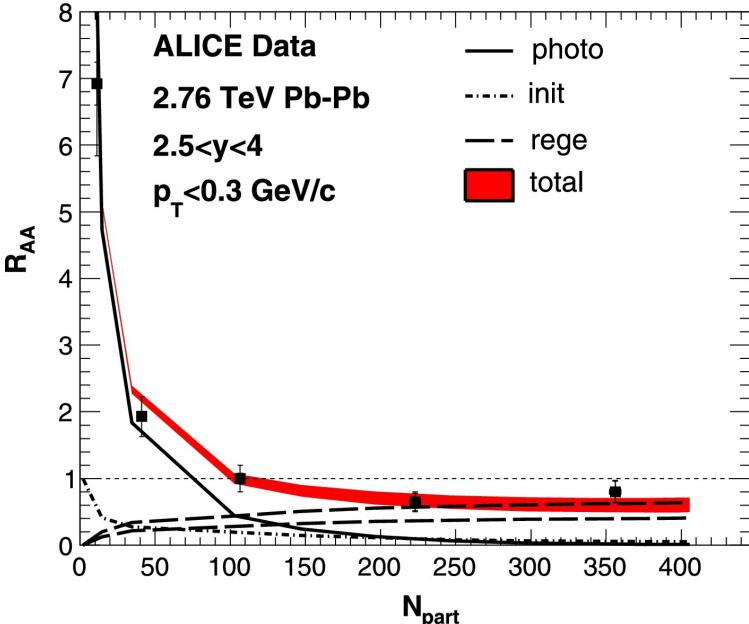


5/24/2018

Calculation with photoproduction + hydro

$$\frac{dN_\Psi}{dy} = \int d\mathbf{x}_T w \tilde{n}_\gamma(w, b) \sigma_{\gamma A \rightarrow \Psi A} f^{\text{norm}}(\mathbf{x}_T) \Gamma_{\text{QGP}}(\mathbf{x}_T) + (y \rightarrow -y \text{ term}) \quad (2)$$

PLB 777 (2018) 399-405, arXiv:1801.01677

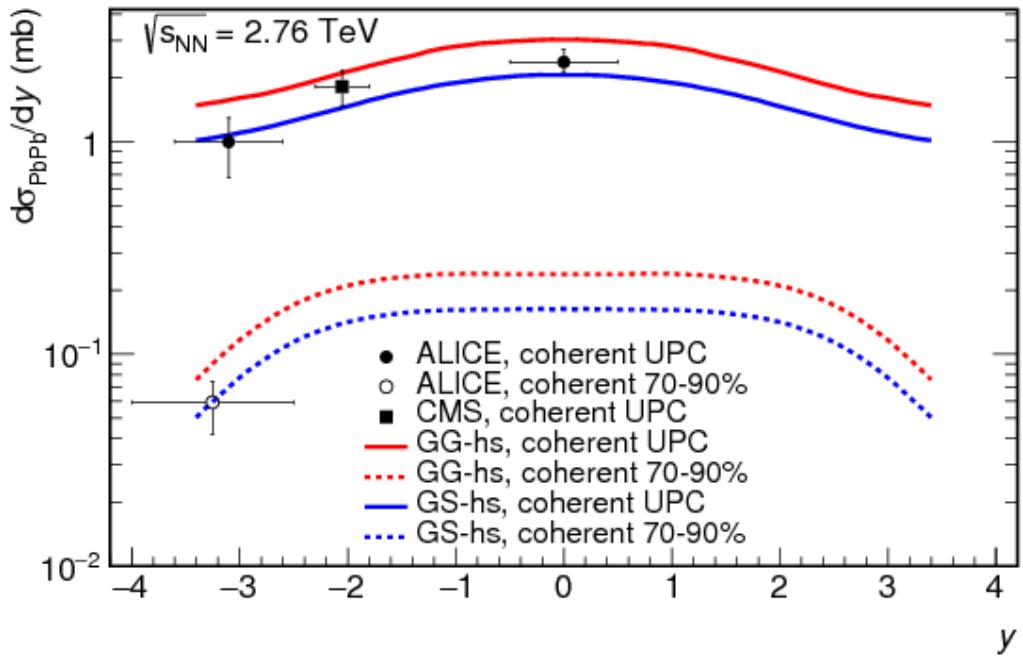


14

low- p_T excess in the J/ ψ yield in Pb-Pb @ 2.76 TeV

Energy-dependent hot-spot model calculations:

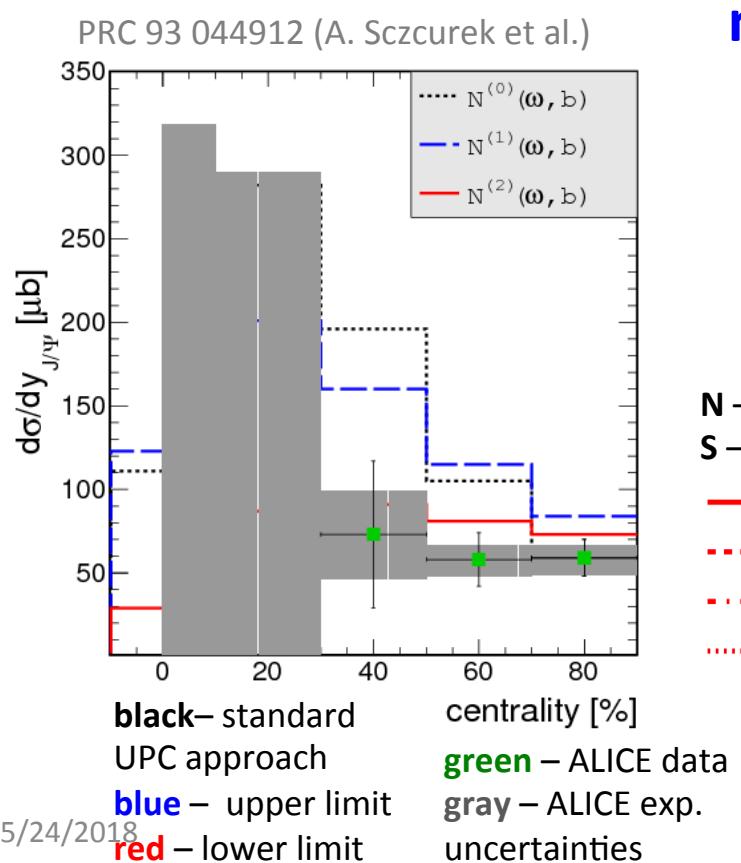
PRC 97 (2018) 024901 (Cepila et al.)



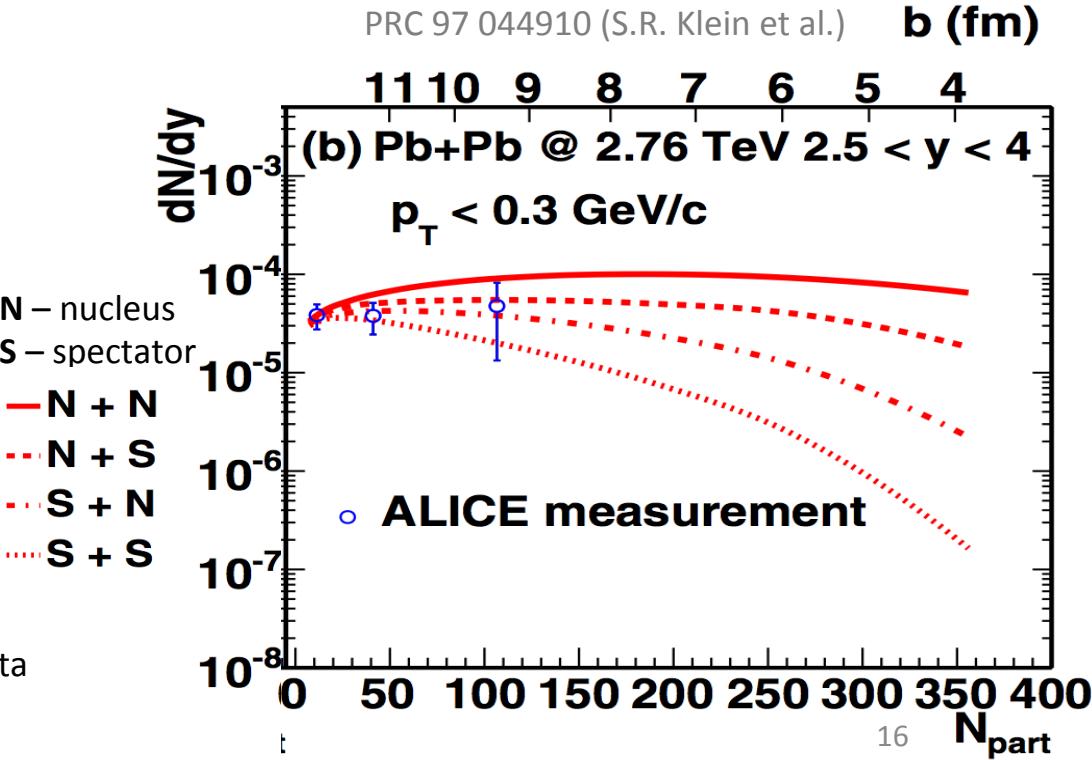
GS – geometric scaling
 GG – Gribov-Glauber

Best agreement for
 the Gribov-Glauber
 calculations

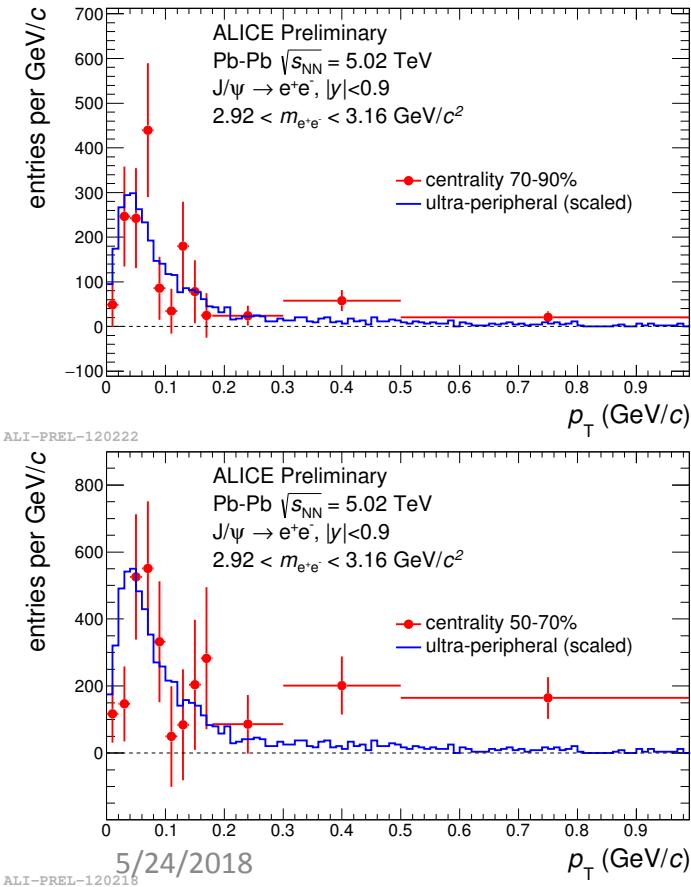
low- p_T excess in the J/ ψ yield in Pb-Pb @ 2.76 TeV



more model calculations

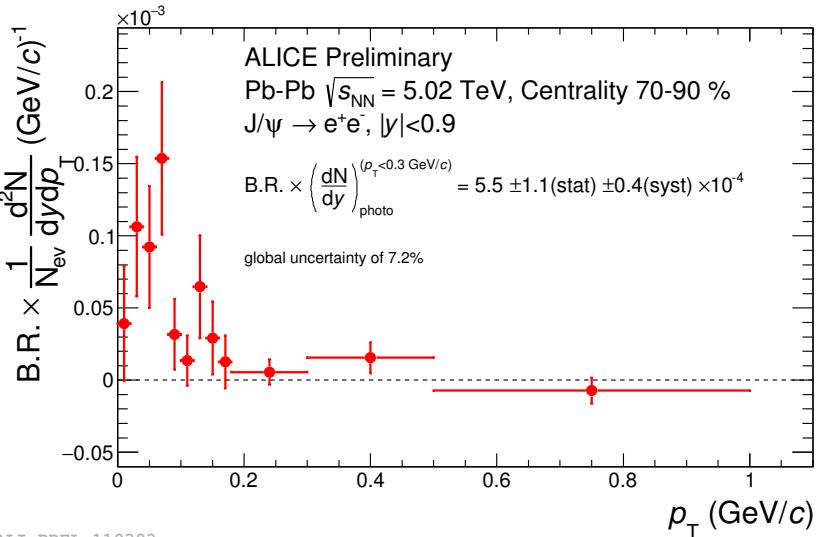


low- p_T excess in the J/ ψ yield in Pb-Pb @ 5.02 TeV



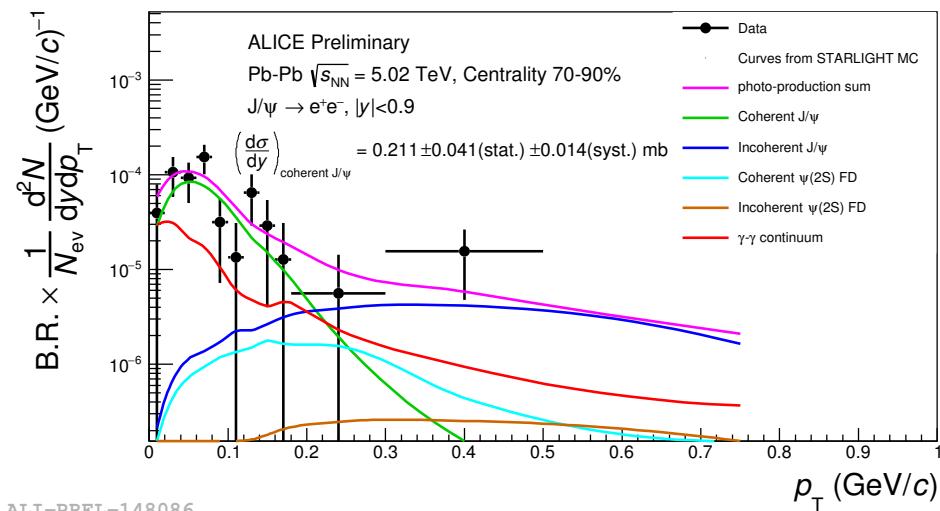
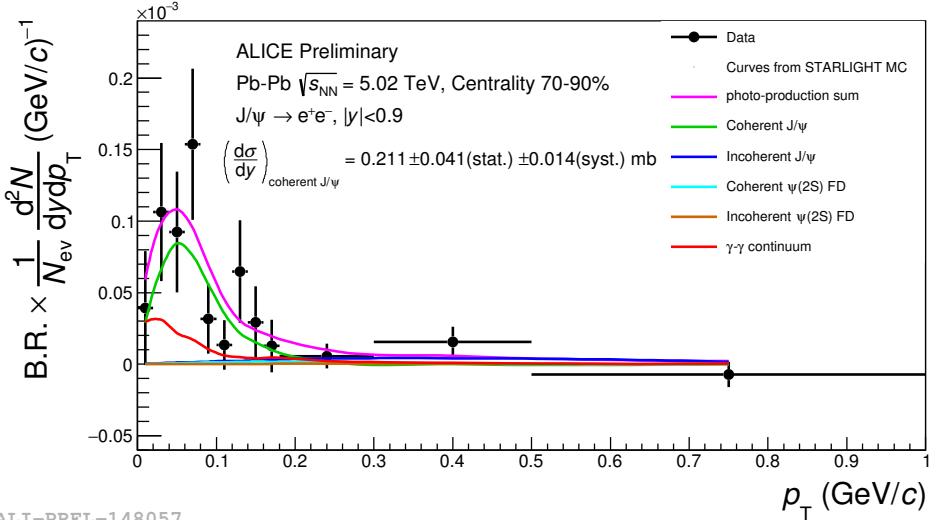
An excess in the J/ψ yield at low p_T has also been found in RUN2 data:

- Left: $J/\psi p_T$ in peripheral collisions compared to UPC,
- Bottom: corrected yield after subtraction of the hadronic contribution by event mixing.



$p_T(e^\pm) > 1$ GeV/ c
electron PID using
TPC dE/dX

low- p_T excess in the J/ ψ yield in Pb-Pb @ 5.02 TeV

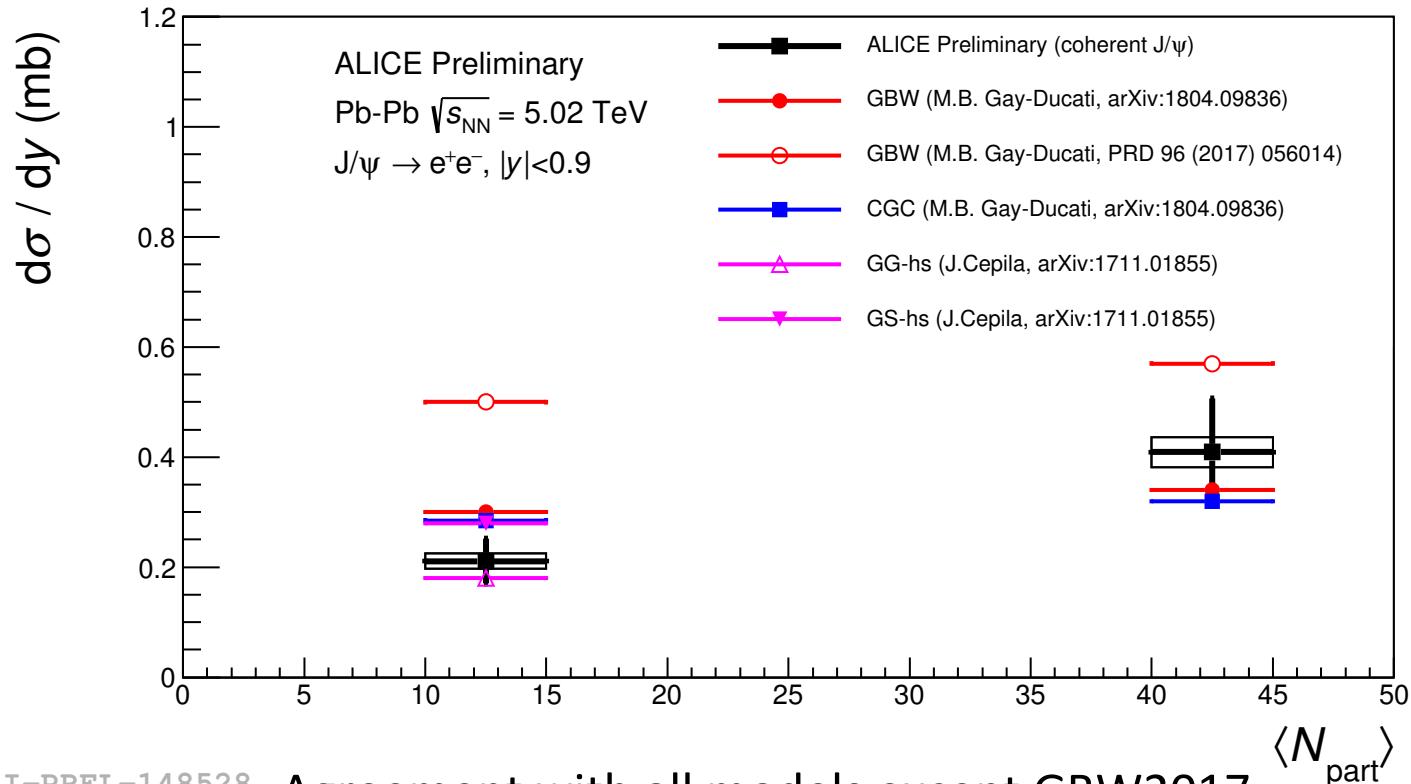


Corrected J/ ψ yields vs. J/ ψ p_T for 70-90% centrality with template fits:

- coherent + incoherent J/ ψ ; continuum $\gamma\gamma \rightarrow e^+e^-$;
- coherent + incoherent feed-down from $\Psi(2S)$.

50-70% centrality → Appendix

low- p_T excess in the J/ ψ yield in Pb-Pb @ 5.02 TeV



GBW 2017
 γ flux with nuclear overlap

GBW 2018
 γ flux corrected

CGC
 color-glass condensate

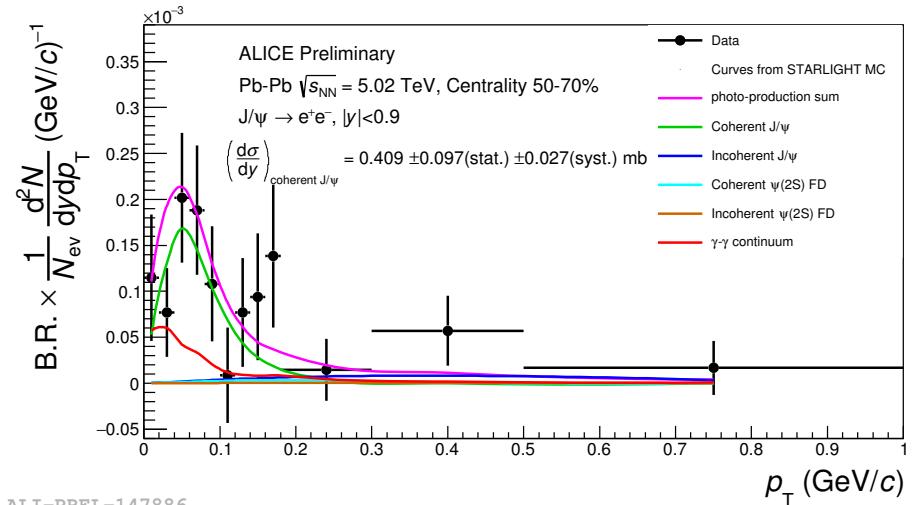
GC-hs, GS-hs
 energy-dependent hot-spot models:
 GC – geometric scaling
 GG – Gribov-Glauber

Summary

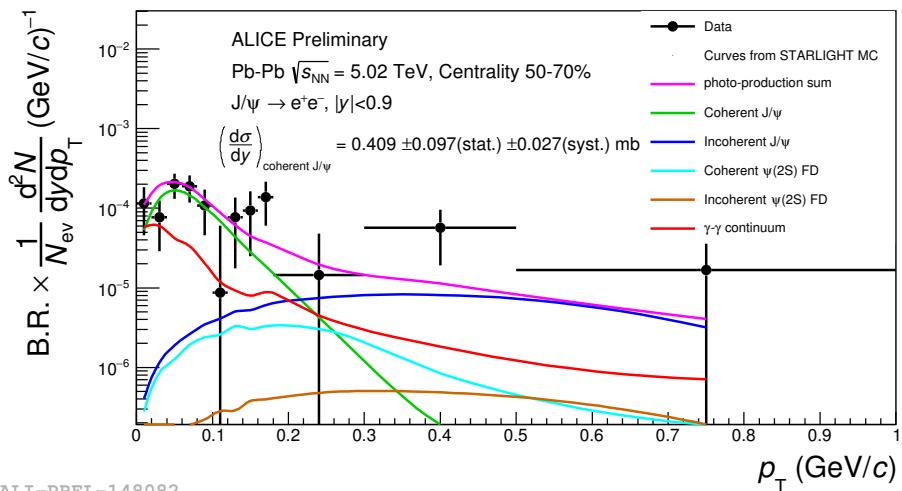
- Exclusive J/ ψ photoproduction in p-Pb collisions:
 - The ALICE γp center of mass energy range is from 20 GeV to 700 GeV.
 - New RUN2 data extends this energy range to above 1 TeV.
 - Agreement with HERA data and with LHCb solutions and with all models independent of the inclusion of saturation.
- An excess in the J/ ψ yield in peripheral Pb-Pb collisions at low p_T was found:
 - Assuming this excess is produced by photoproduction its cross section was measured both for RUN1 and RUN2 data and compared to model calculations.
 - The J/ ψ R_{AA} for small J/ ψ p_T becomes as large as 7 due to this effect.

Appendix

low- p_T excess in the J/ ψ yield



ALI-PREL-147886

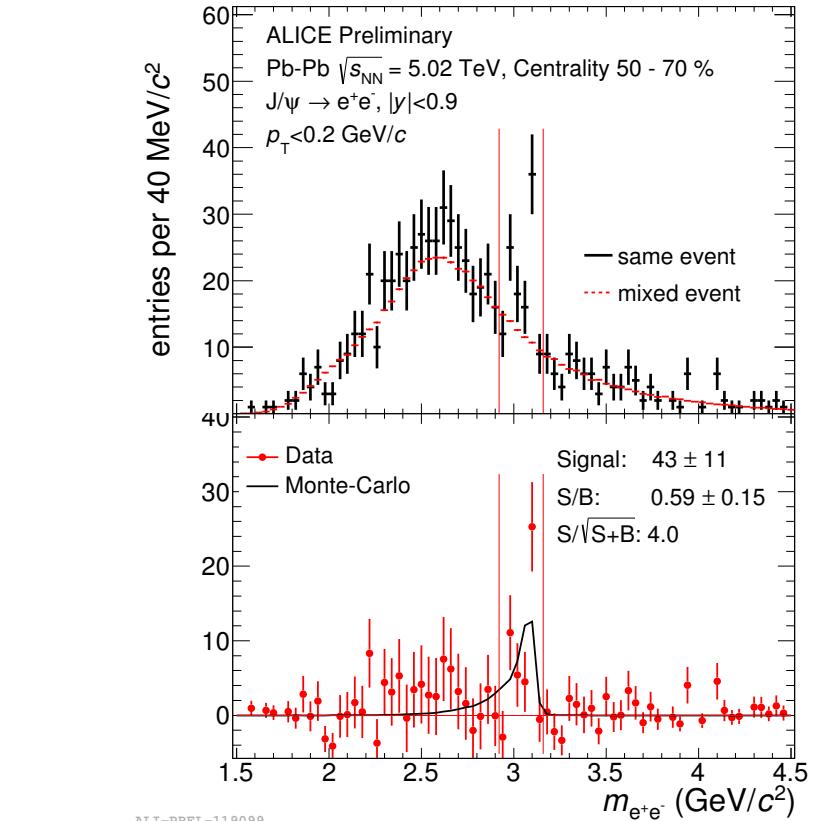
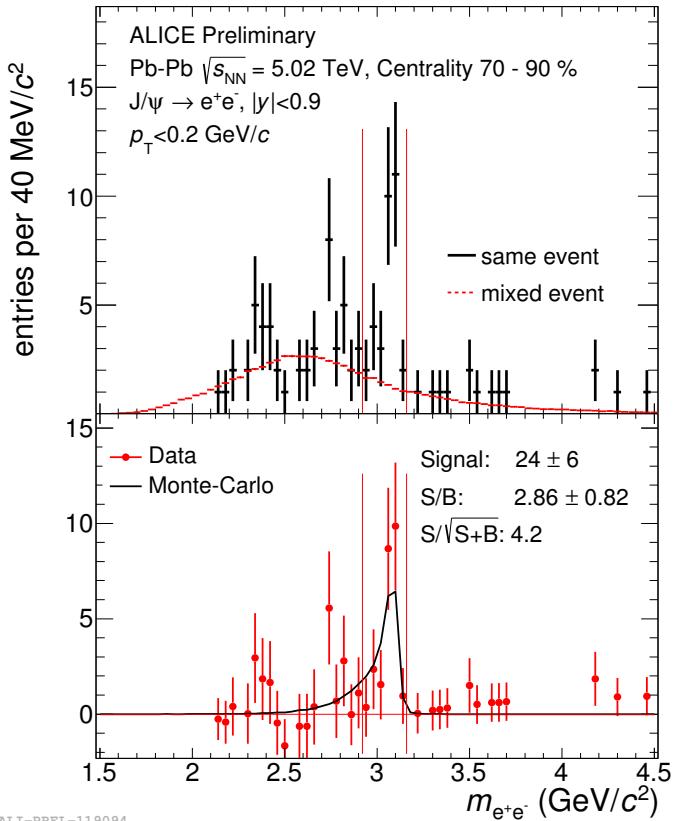


ALI-PREL-148082

Corrected J/ ψ yields vs. J/ ψ p_T for 50-70% centrality with template fits:

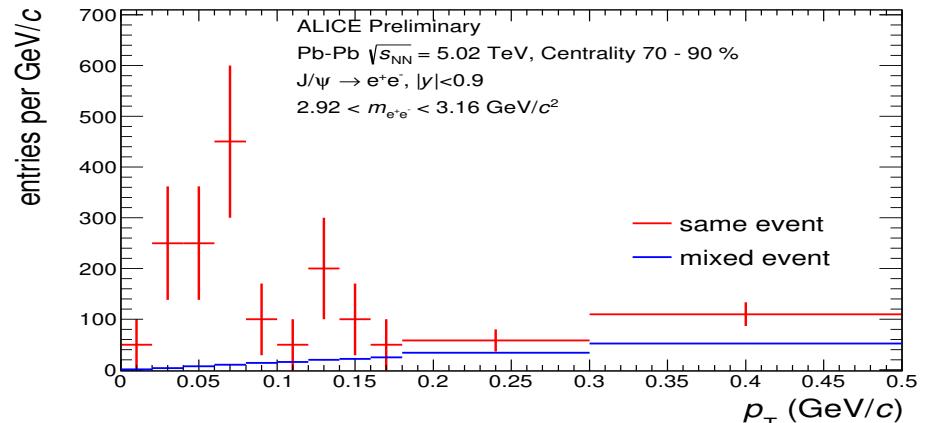
- coherent + incoherent J/ ψ ; continuum $\gamma\gamma \rightarrow e^+e^-$;
- coherent + incoherent feed-down from $\Psi(2S)$.

low- p_T excess in the J/ ψ yield

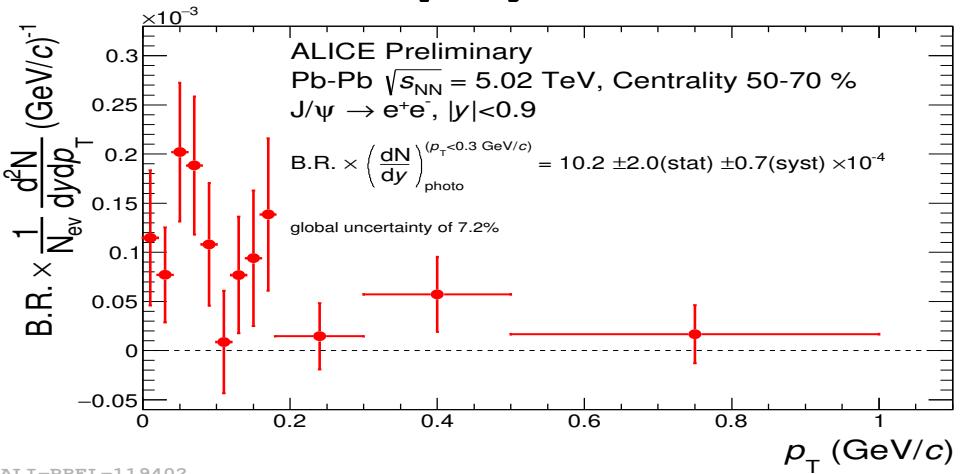


Event mixing

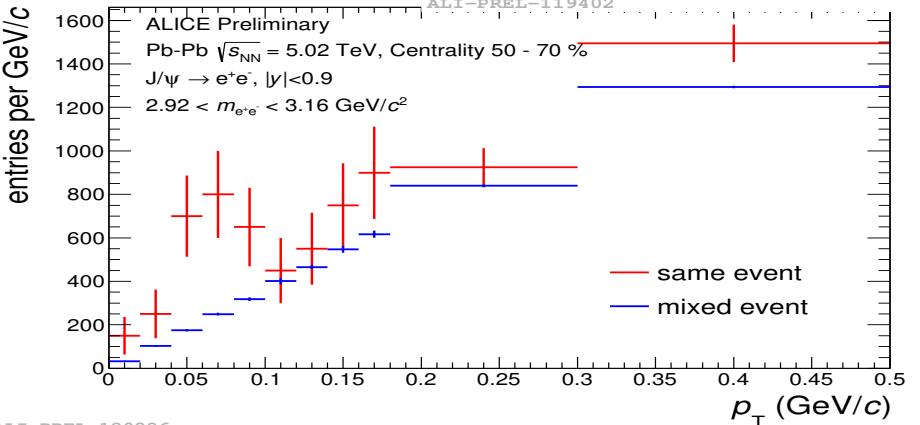
low- p_T excess in the J/ ψ yield



ALI-PREL-120230



Event mixing



5/24/2018

ALI-PREL-120226