Exclusive and dissociative J/ψ photoproduction off protons with ALICE in pPb Collision

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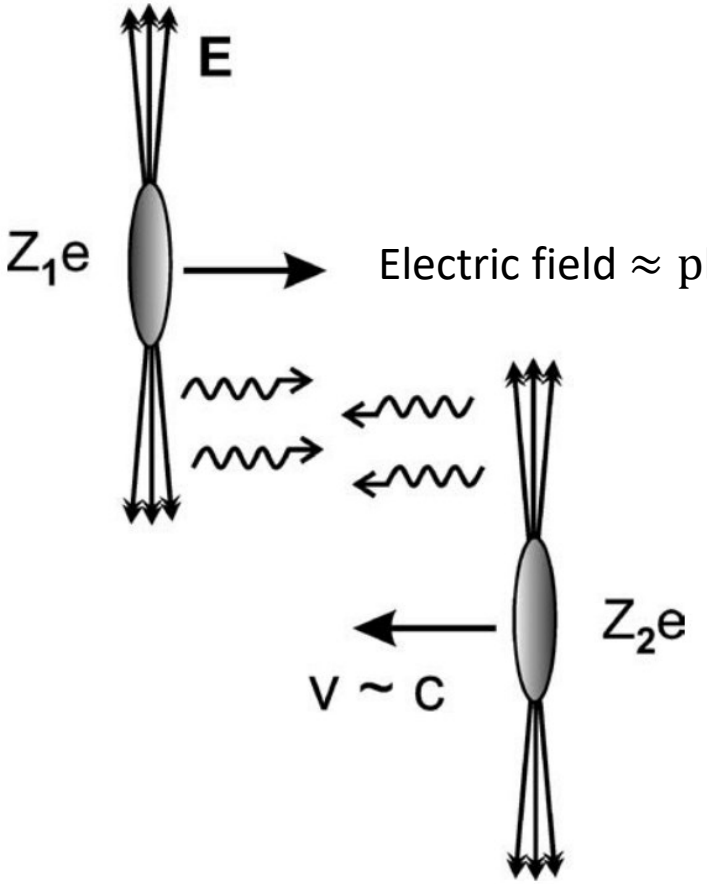
10th Workshop of the APS Tropical Group on Hadronic Physics
April 13, 2023

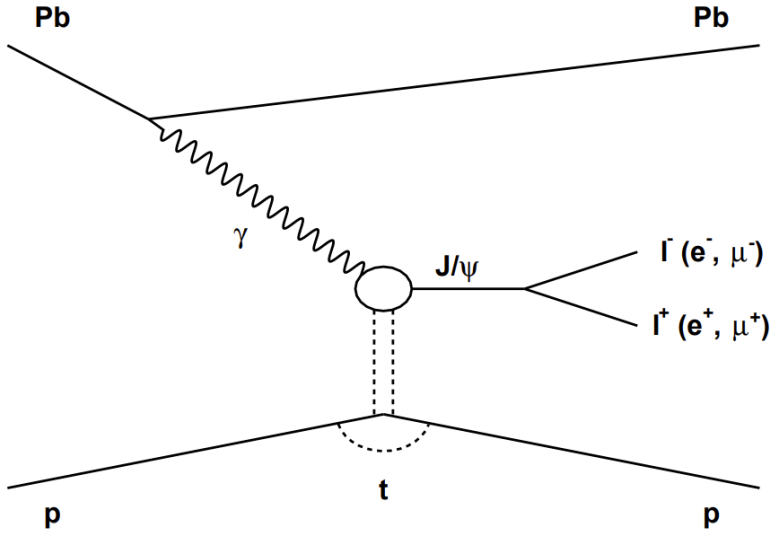
Vector meson photoproduction in UPCs



Ultra peripheral collisions
b > 2R

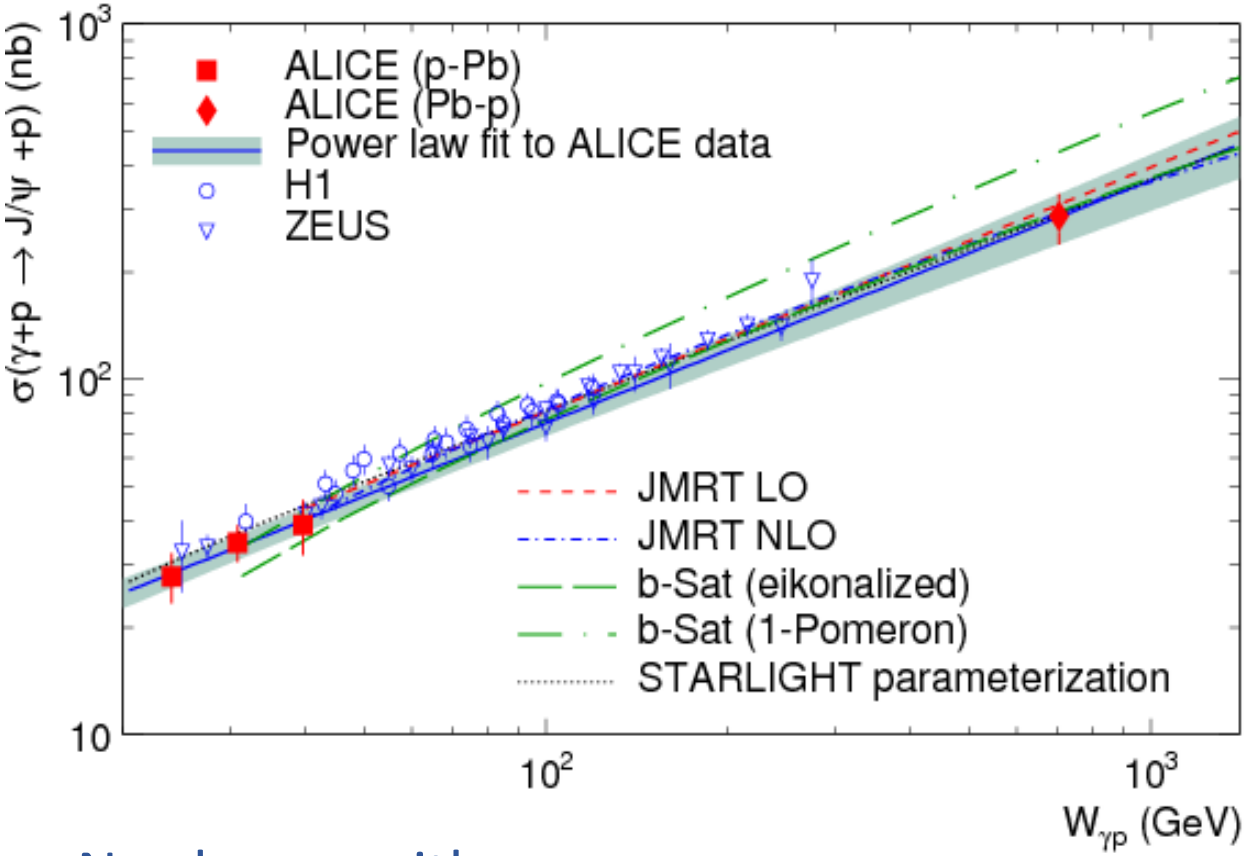
- Photon fluctuates into quark and anti-quark pair producing vector mesons (VM) in the final state
- Photon can scatter off
  - **coherently** off whole nucleus (VM p_T~30MeV/c)
  - or **incoherently** off nucleons (VM p_T~300 MeV/c)
  - UPC can be accompanied by another photon exchange, results in nuclei excitation
- ALICE has studied UPC physics in PbPb and pPb collisions

Energy dependence of exclusive J/ψ photoproduction



- Deviations from the HERA power-law trend predicted as signatures of saturation

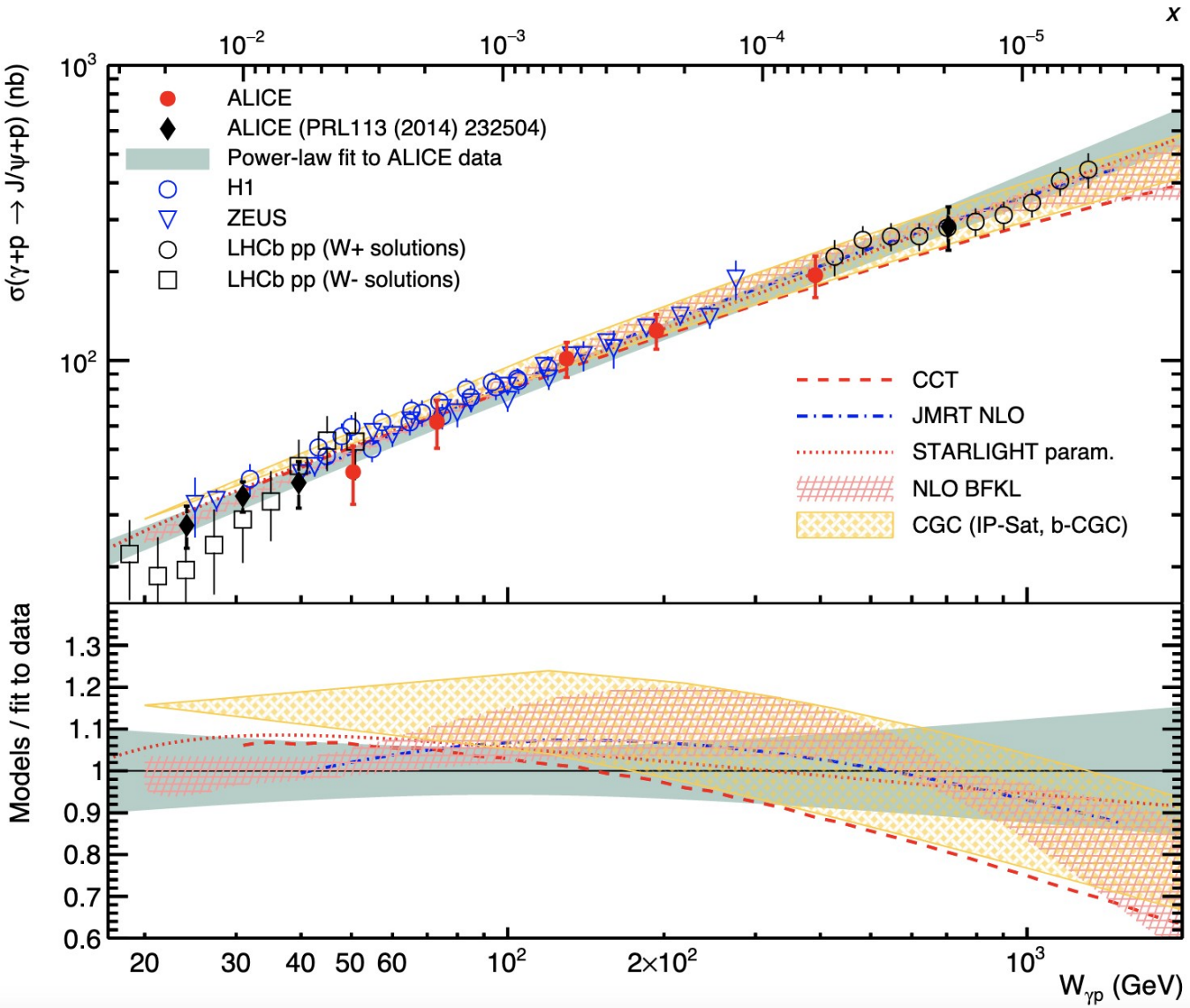
Phys. Rev. Lett. 113 (2014) 23, 232504



No change with
respect to HERA power-law growth observed
at low energies up to 700 GeV

Energy dependence of exclusive J/ψ photoproduction

Eur. Phys. J. C 79 (2019) 5, 402



The second UPC pPb study using ALICE Run 1 data provided additional points

UPC pPb collisions have no ambiguity on the photon energy!

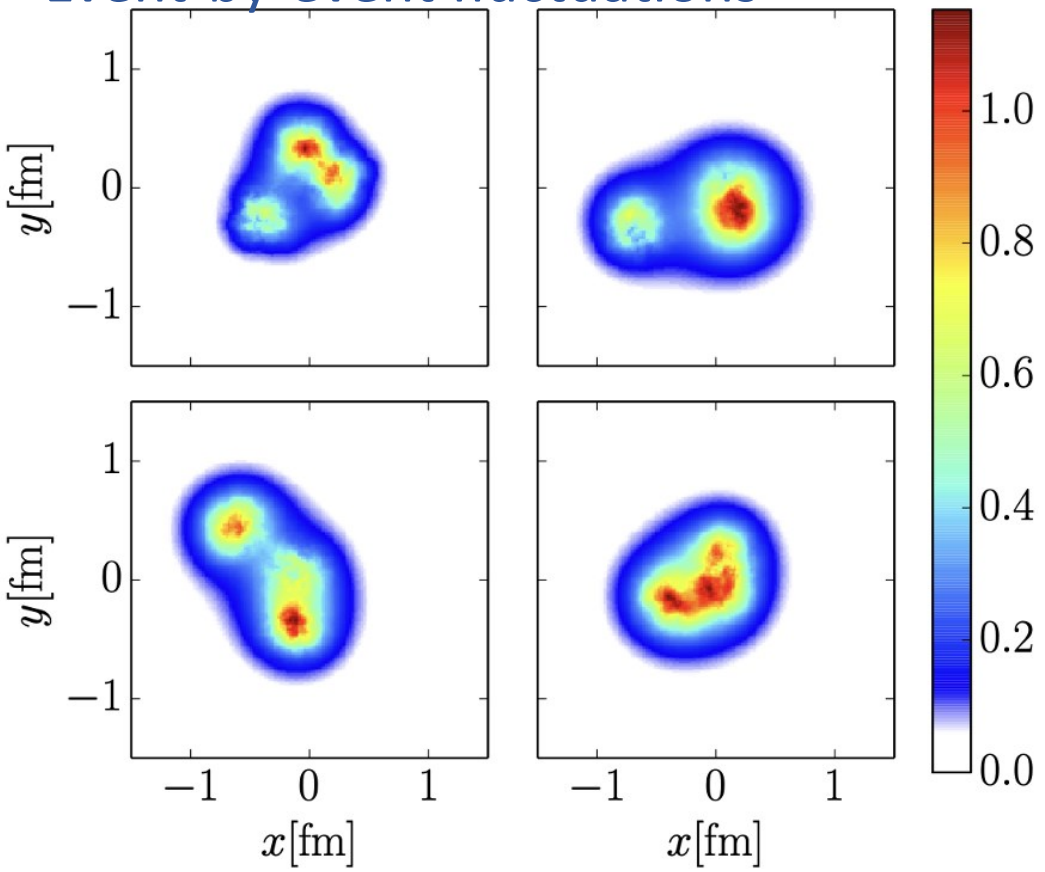
$$W^2_{\gamma p} = 2E_p M_{J/\psi} e^{\pm y}$$

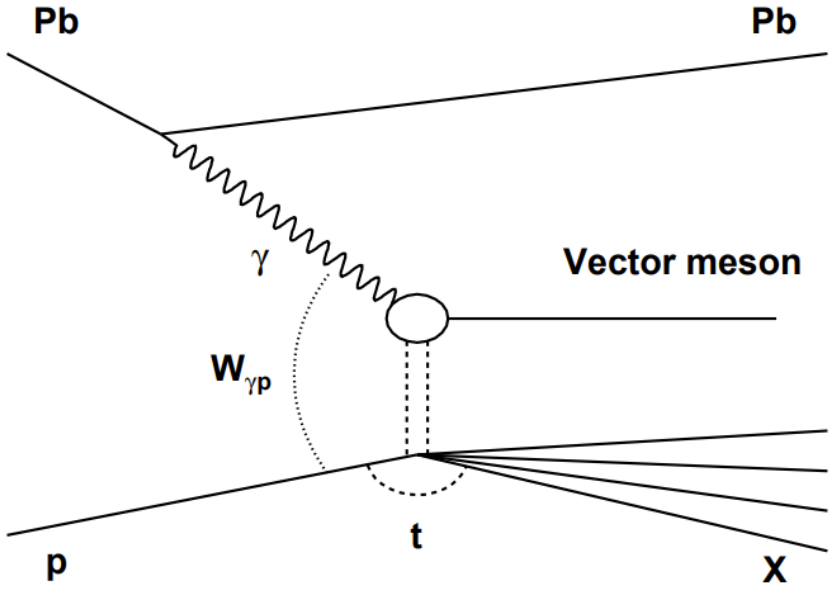
$$\frac{d\sigma}{dy} = n(+y)\sigma(\gamma p, +y) + n(-y)\sigma(\gamma p, -y)$$

Dissociative J/ψ photoproduction

- Energy dependence is a clear signature of gluon saturation!

Event-by-event fluctuations





In the Good-Walker approach, sensitive to subnucleonic fluctuations of the gluon density

$$\frac{d\sigma(\gamma p \to \mathrm{J}/\psi Y)}{dt} = \frac{R_g^2}{16\pi}\left(\left\langle\left|A(x,Q^2,\vec{\Delta})\right|^2\right\rangle - \left|\left\langle A(x,Q^2,\vec{\Delta})\right\rangle\right|^2\right)$$

H. Mantysaari and B. Schenke,
Phys. Lett. B772 (2017) 832
J. Cepilia, J.G. Contreras and D. Tapia Takaki
Phys. Lett. B 766 (2017) 186-191

ALICE results using Run 2 data presented in this talk

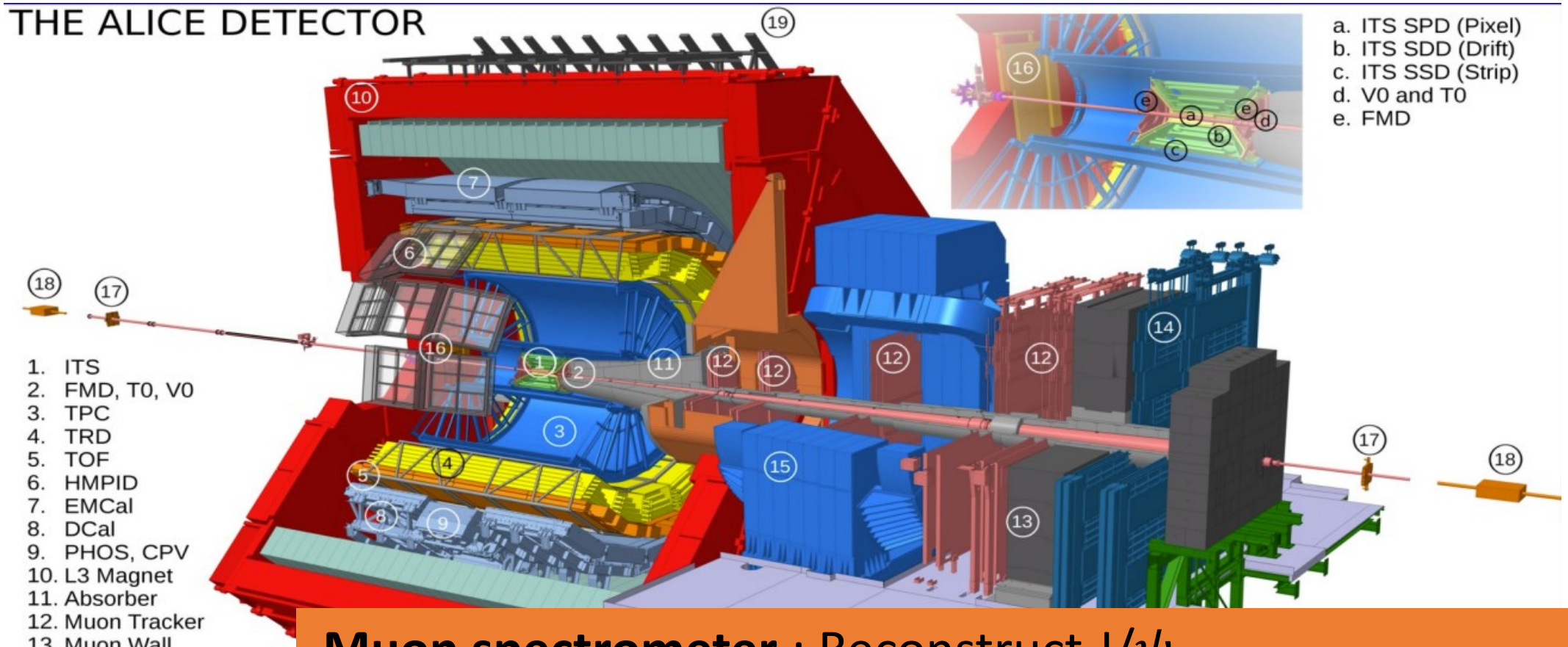
- Energy dependence of exclusive J/ψ in UPC pPb
- Measured σ(exclusive J/ψ) / σ(dissociative J/ψ) as a function of W(γp)

For the first time at hadronic colliders!

- Energy dependence of dissociative J/ψ in UPC pPb

See talk by D. Tapia Takaki on new ALICE UPC results on PbPb
https://indico.jlab.org/event/667/contributions/12275/

A Large Ion Collider Experiment (ALICE)



Muon spectrometer : Reconstruct J/ψ

Trigger detectors: V0, AD and Muon Trigger Chambers

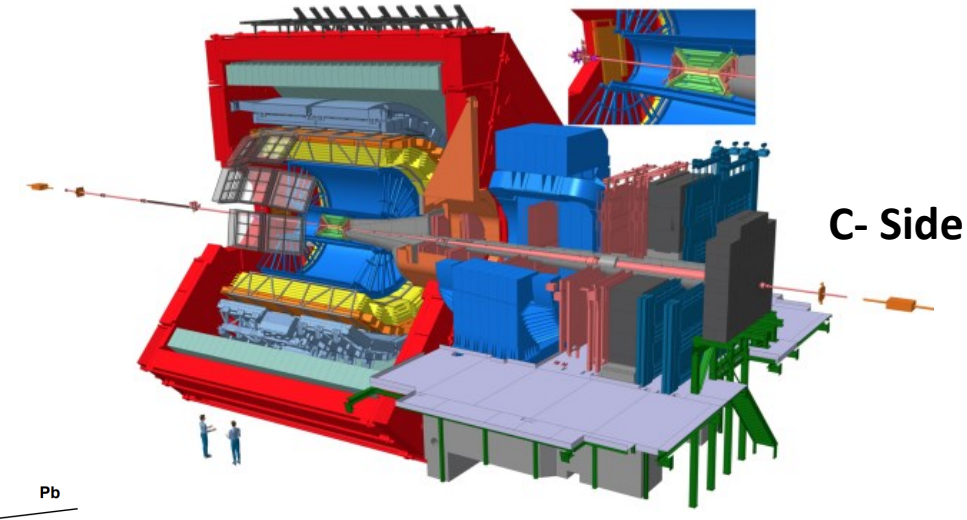
Zero Degree Calorimeters : Detect neutrons

Exclusive and dissociative J/ψ photoproduction off protons

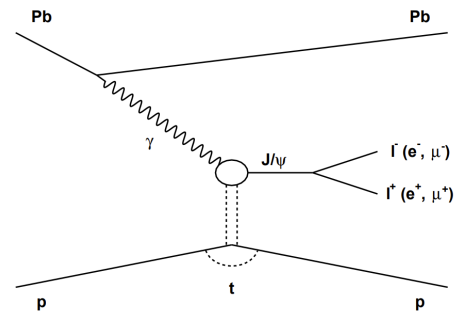
2016 p–Pb data at 8.16 TeV

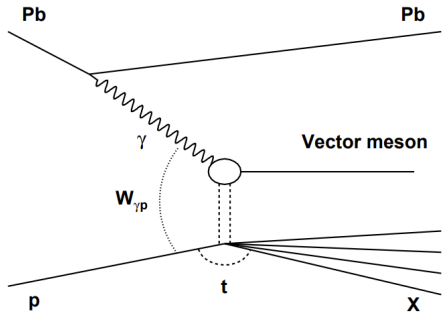
- ADA veto
- V0A veto
- V0C empty or in beam timing
- Single muon with low Pt (0.5 GeV/c)
- Exactly two muons
- Opposite-sign muons
- $-4.0 < \eta < -2.5$
- 17.5 cm < R_{abs} < 89.5 cm
- Muon track matched to muon trigger
- p×DCA criterion for each muon passed
- $-4.0 < y_{\mu\mu} < -2.5$
- $P_T^{\mu\mu}$ < 3 GeV/c

A- Side



C- Side





No activity proton side (VOC and ADC vetoed)

No activity in Pb side (V0A, ADA and ZDC vetoed)

No activity Pb side (ADA vetoed)

Exclusive and dissociative J/ψ photoproduction off protons

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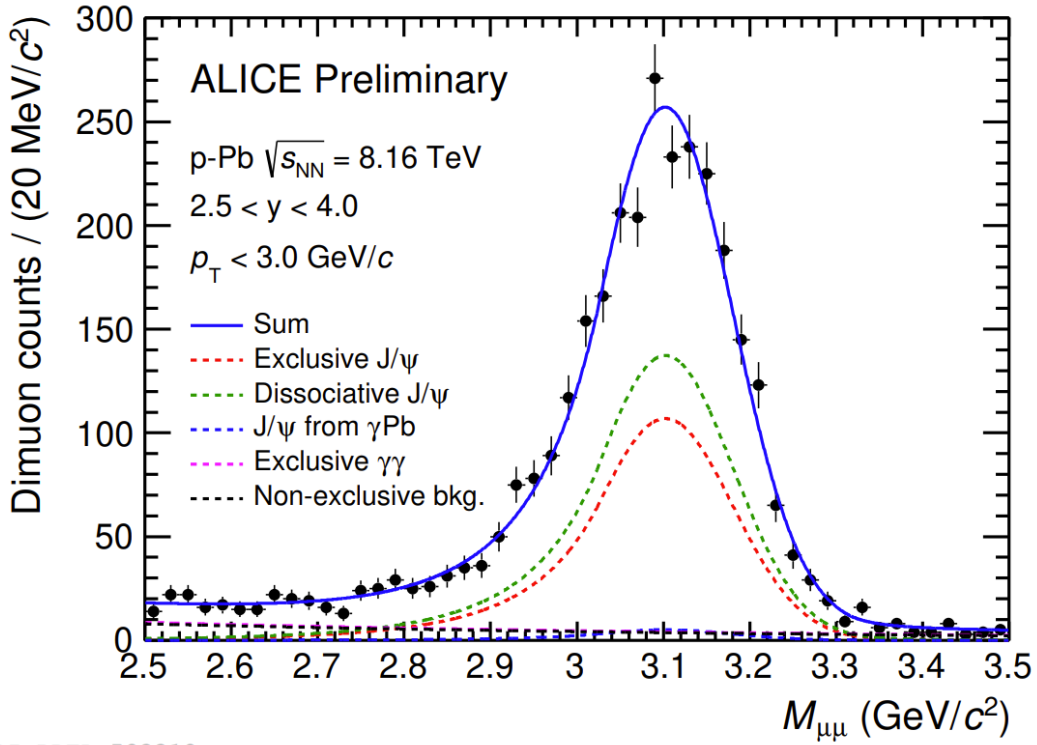
- $P_T^{\mu\mu}$ < 3 GeV/c

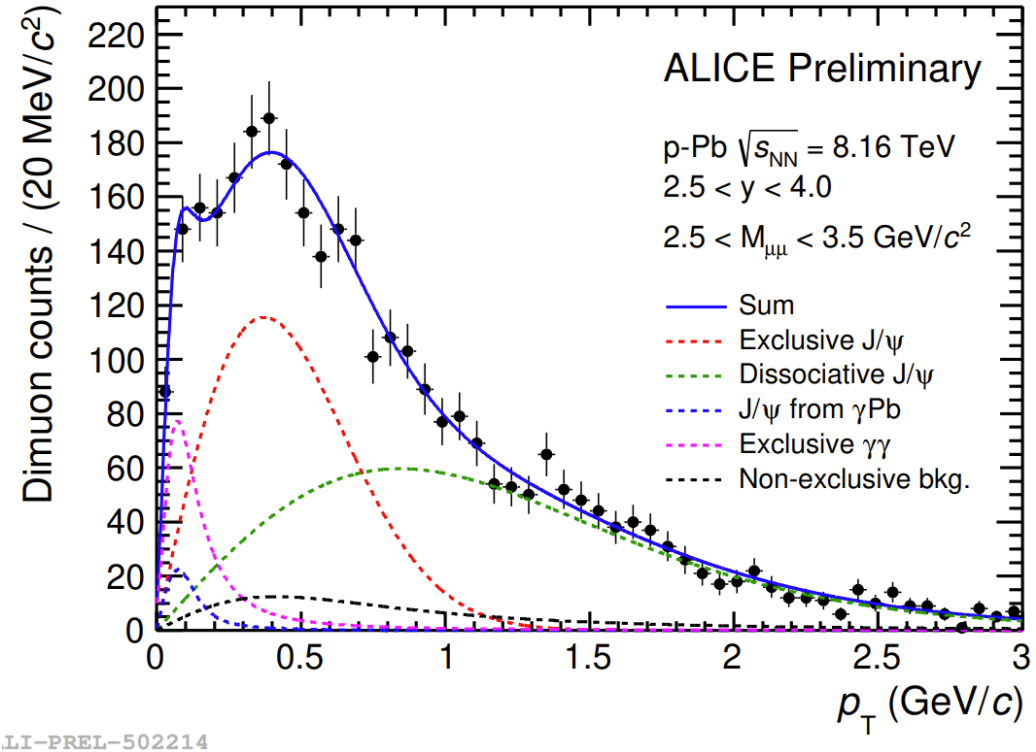
Selection	LHC16r
Events analysed	14687514
Triggered	12227445
Two good tracks	20439
Opposite electric charge	16482

Selection	LHC16r
Events after preselection	16482
No beam-beam activity in ZN Pb-side	15336
No beam-beam activity in AD Pb-side	15321
No beam-beam activity in V0 Pb-side	14221
No extra beam-beam activity in V0 p-side	7582
Less than 3 tracklets in SPD	7059

Yield extraction



ALI-PREL-502210



LI-PREL-502214

- Signal was extracted by simultaneously fitting Invariant Mass and P_T Distribution
- 2.5 GeV/c^2 < M < 3.5 GeV/c^2 , p_T < 3 GeV/c
- Yield was extracted using un-binned log-likelihood fit

Rapidity range	Number of exclusive J/ψ	Number of dissociative J/ψ
$2.5 < y < 4.0$	1180 ± 84	1515 ± 83
$2.5 < y < 3.25$	629 ± 54	768 ± 55
$3.25 < y < 4.0$	564 ± 53	733 ± 52

Exclusive and dissociative J/ψ photoproduction systematic uncertainties

Signal	Source	Mass range (GeV/c^2)	Value (%)
All	Luminosity		1.8%
	Tracking efficiency		1%
	Matching efficiency		1%
	Pile-up correction		0.2%
	Total common		**2.3%**
J/ψ only	Muon trigger efficiency		1.1%
	Branching ratio		0.55%
	Photon flux		2%
	$\delta(1+f_D)$		1.1%
	V0C veto		2.6% (excl.), 12.7% (diss.)
	Signal extraction	(2.5, 3.5)	from 3.6% to 5.5% (excl.), from 2.9% to 4.4% (diss.)
	Total		**from 5.6% to 7.0% (excl.), from 13.5% to 13.9% (diss.)**
$\frac{\sigma^{diss}}{\sigma^{exc}}$	V0C veto		12.7%
	Signal extraction		from 6.2% to 7.6%
	Total		**from 14.1% to 14.8%**

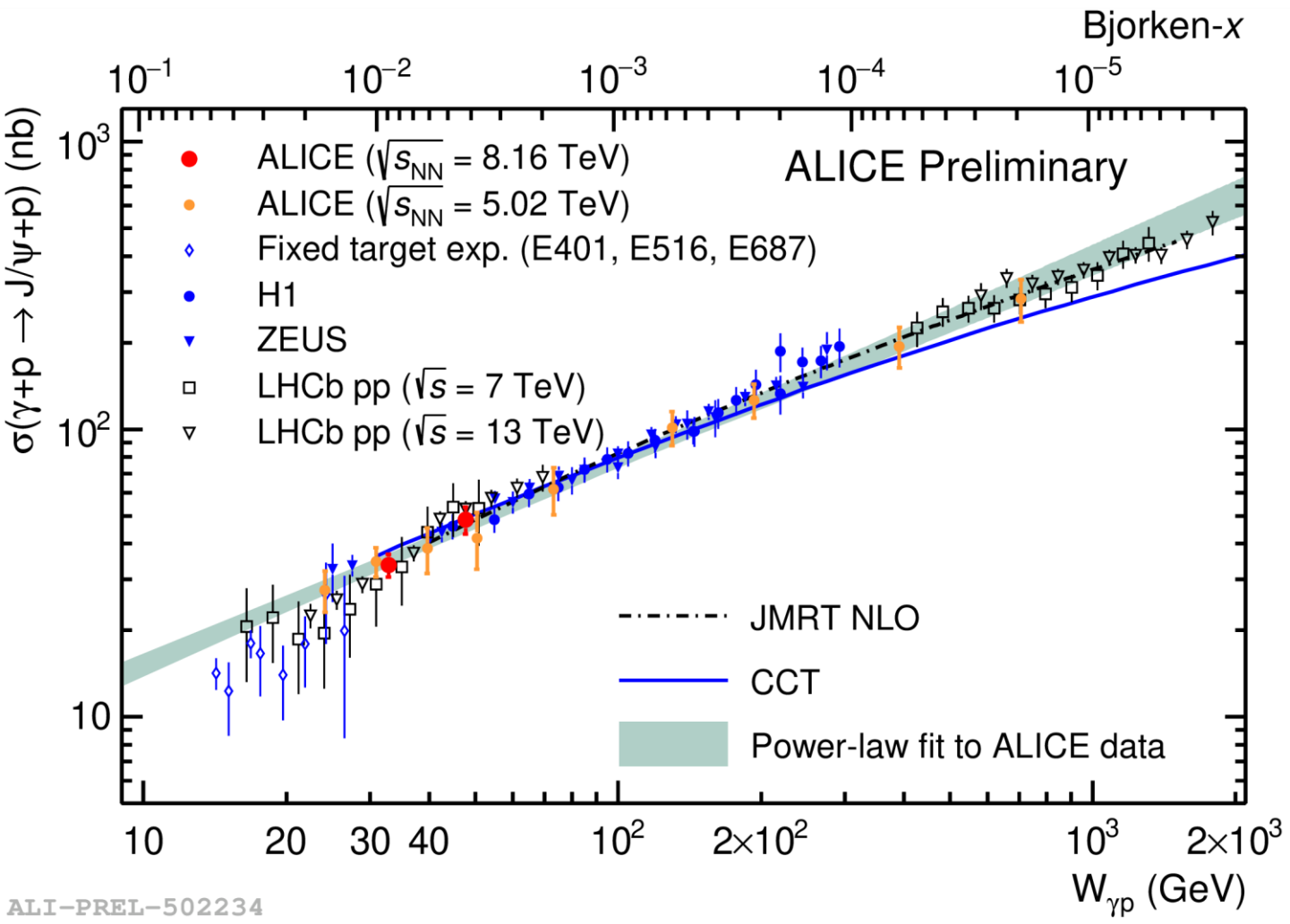
Cross-section measurement

$$\frac{d\sigma}{dy}(p+Pb \to p^{(*)}+Pb+J/\psi) = \frac{N_{J/\psi}}{(A\times\varepsilon)^{J/\psi}\times(1+f_D)\times\mathscr{L}\times\varepsilon_{veto}\times BR\times\Delta y},$$

Exclusive J/ψ study

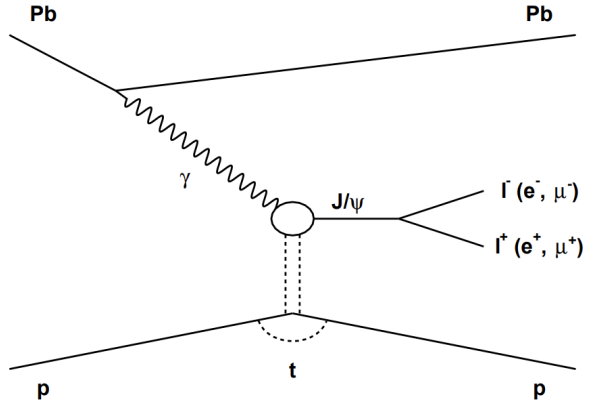
rapidity range	mean energy W (GeV)	$\sigma(\gamma p)$ (mid selection)	$\sigma(\gamma p)$ (STARlight)	$\sigma(\gamma p)$ (HERA)
$2.5 < y < 4.0$	39.8	$40.4 \pm 2.9 \pm 2.5$	43.8 ± 0.1	46.9 ± 1.7
$2.5 < y < 3.25$	47.7	$48.5 \pm 4.2 \pm 3.1$	49.4 ± 0.2	53.0 ± 2.0
$3.25 < y < 4.0$	32.8	$33.7 \pm 1.7 \pm 2.5$	38.1 ± 0.2	41.2 ± 1.5

Exclusive J/ψ photoproduction off protons



$27 < W_{\gamma p} < 57$ GeV

$5 \times 10^{-3} < x < 2 \times 10^{-2}$



- *Cepila, Contreras and Tapia Takaki model*
  Phys. Lett. B 766 (2017) 186

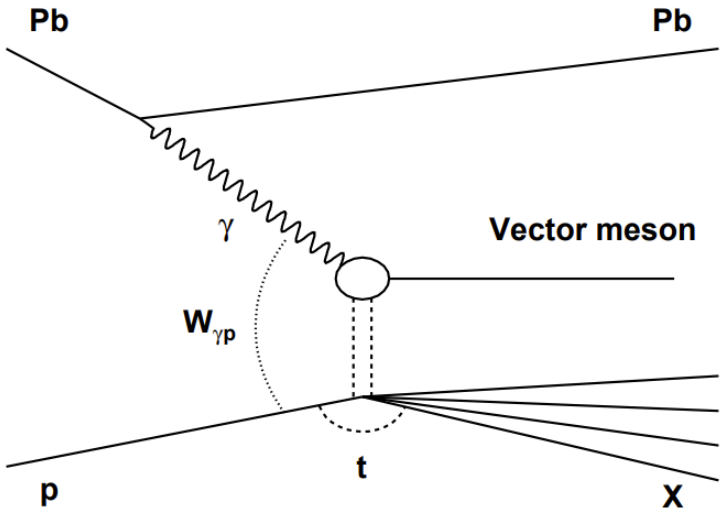
Cross-section Calculation

$$\frac{d\sigma}{dy}(p+Pb \to p^{(*)}+Pb+J/\psi) = \frac{N_{J/\psi}}{(A\times\varepsilon)^{J/\psi}\times(1+f_D)\times\mathscr{L}\times\varepsilon_{veto}\times BR\times\Delta y},$$

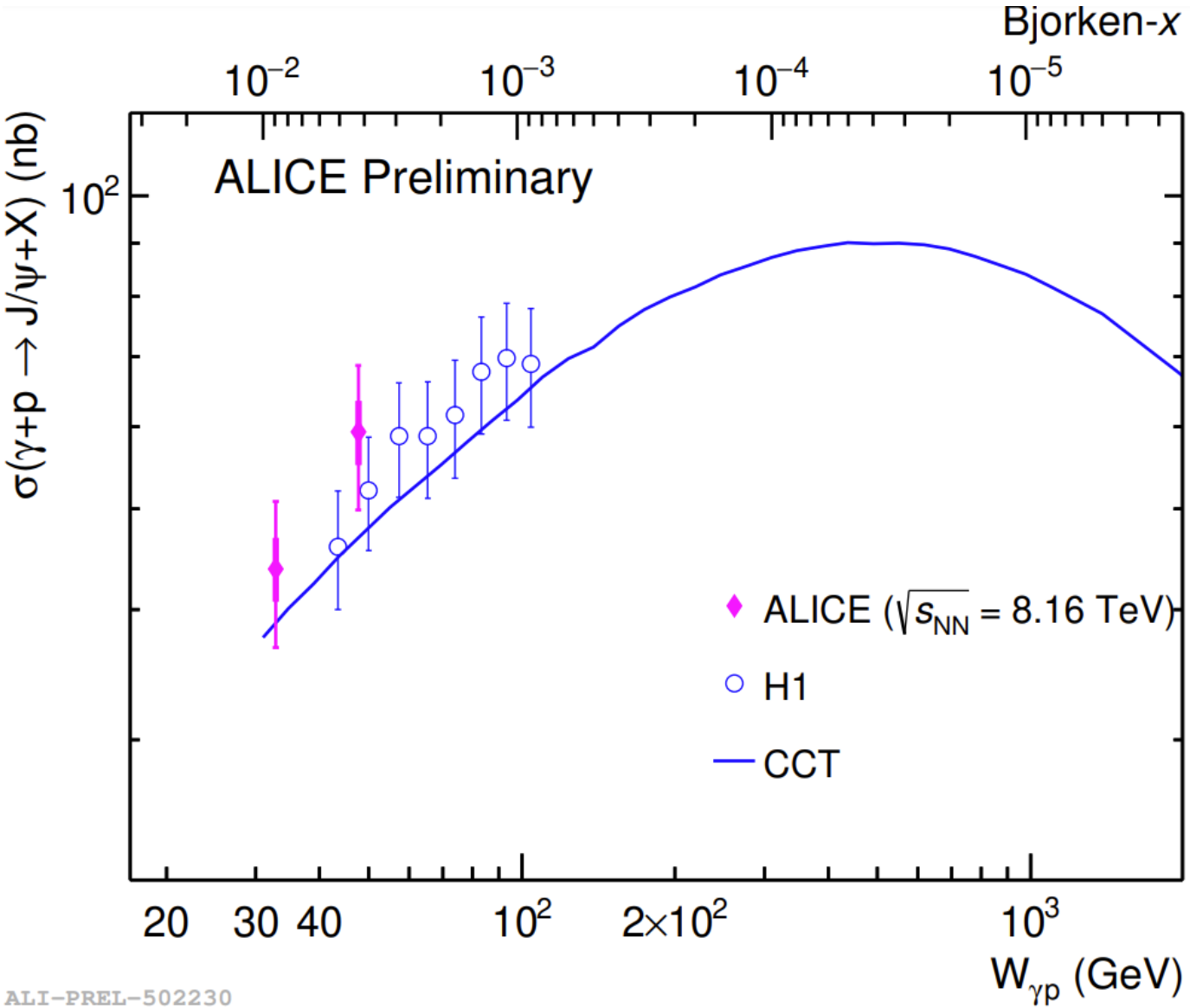
Dissociative Photoproduction of J/ψ

rapidity range	mean energy W (GeV)	$\sigma(\gamma p)$ (mid selection)	$\sigma(\gamma p)$ (HERA)
$2.5 < y < 4.0$	39.8	$51.8 \pm 2.8 \pm 7.2$	46.9 ± 5.0
$2.5 < y < 3.25$	47.7	$59.3 \pm 4.2 \pm 8.4$	50.6 ± 5.4
$3.25 < y < 4.0$	32.8	$43.8 \pm 3.1 \pm 6.3$	43.2 ± 4.6

Energy dependence of dissociative J/ψ

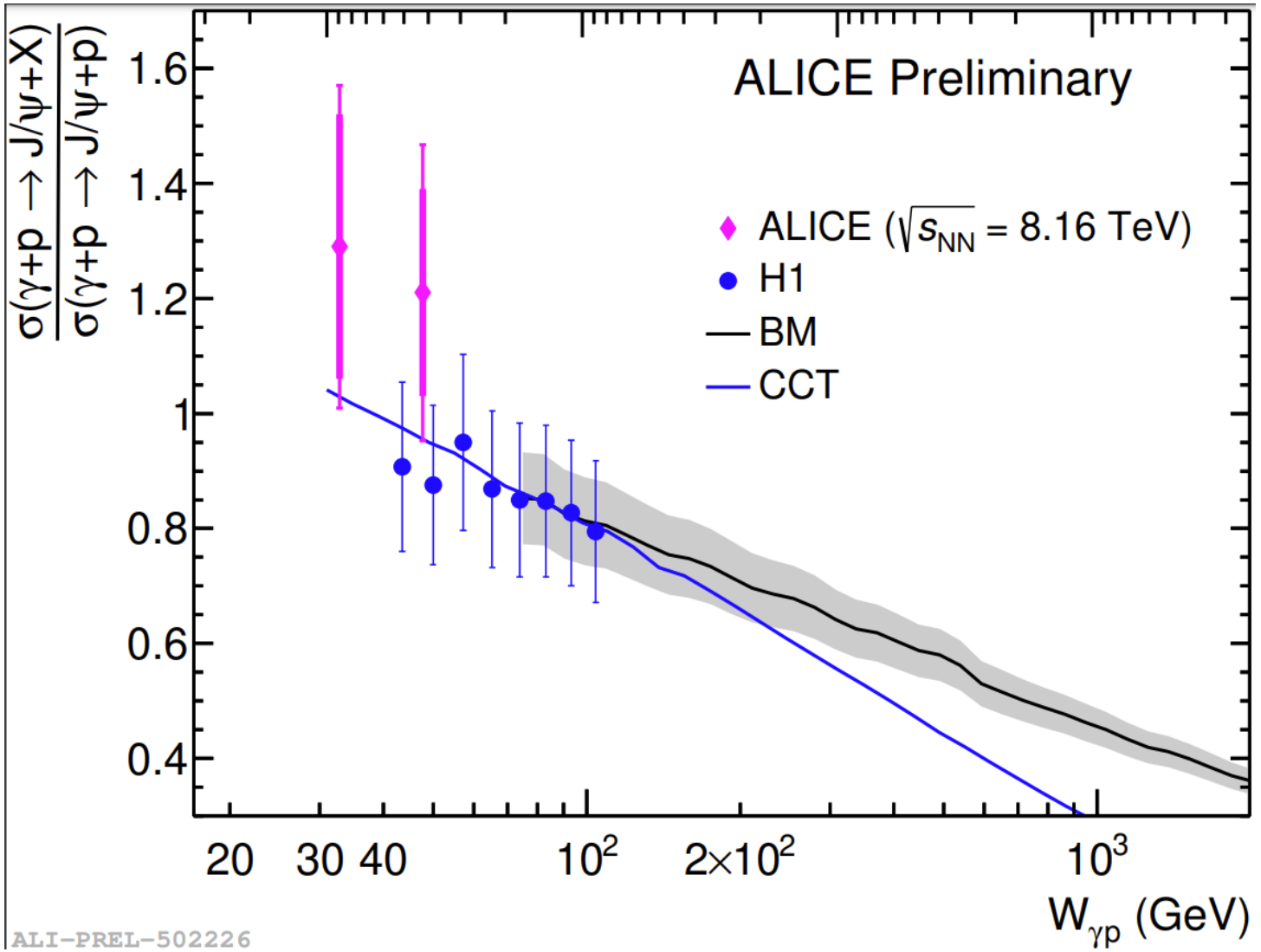


- *Cepila-Contreras-Takaki model*
  Phys. Lett. B 766 (2017) 186
- *H. Mantysaari and B. Schenke,*
  Phys. Rev. D 98 no. 3, (2018) 034013
- *H1 measurement Eur,*
  Phys. J. C 73 (2013) 6, 2466



ALI-PREL-502230

Energy dependence of dissociative-to-exclusive J/ψ



First measurement of J/ψ with proton dissociation at hadronic colliders!

New data from Run 3 (continuous readout) will significantly improve the precision and energy reach

Summary

- Photoproduction of exclusive and dissociative J/ψ cross sections off protons was measured in ALICE
- Cross-section measurement of exclusive J/ψ agrees with power law dependence on $W_{\gamma p}$ for HERA and LHC experiments
- First measurement of dissociative photoproduction of J/ψ was performed at LHC
- Continuous readout mode and upgrade detectors will increase statistics and precision for UPC J/ψ in Run 3 and 4