Forward rapidity ψ(2S) production in p-Pb and Pb-Pb collisions with ALICE

Marco Leoncino*, Università and INFN, Torino
(*On behalf of the ALICE collaboration)

Outline

Charmonia in the medium

The ALICE detector

Data taking conditions

Results in p–Pb and Pb–Pb collisions

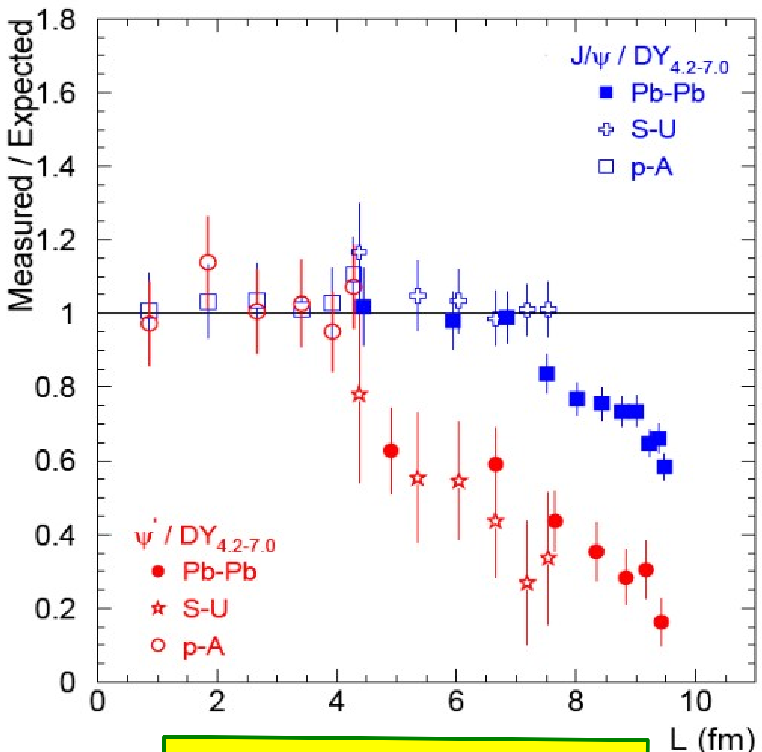
Charmonia in the medium: A-A collisions

Nucleus-nucleus (A-A) collisions: Hot (and Cold) Nuclear Matter effects

Color screening: suppression of quarkonia (high color density in a QGP)

Recombination: at high collision-energies $c\bar{c}$ pairs are produced abundantly (recombination probability $\propto N^2_{c\bar{c}}$)

Cold Nuclear Matter effects: also present in A-A collisions



NA50 Collaboration
Eur. Phys. J. C 49 (2007)

The dissociation is expected to depend on the binding of the charmonium state

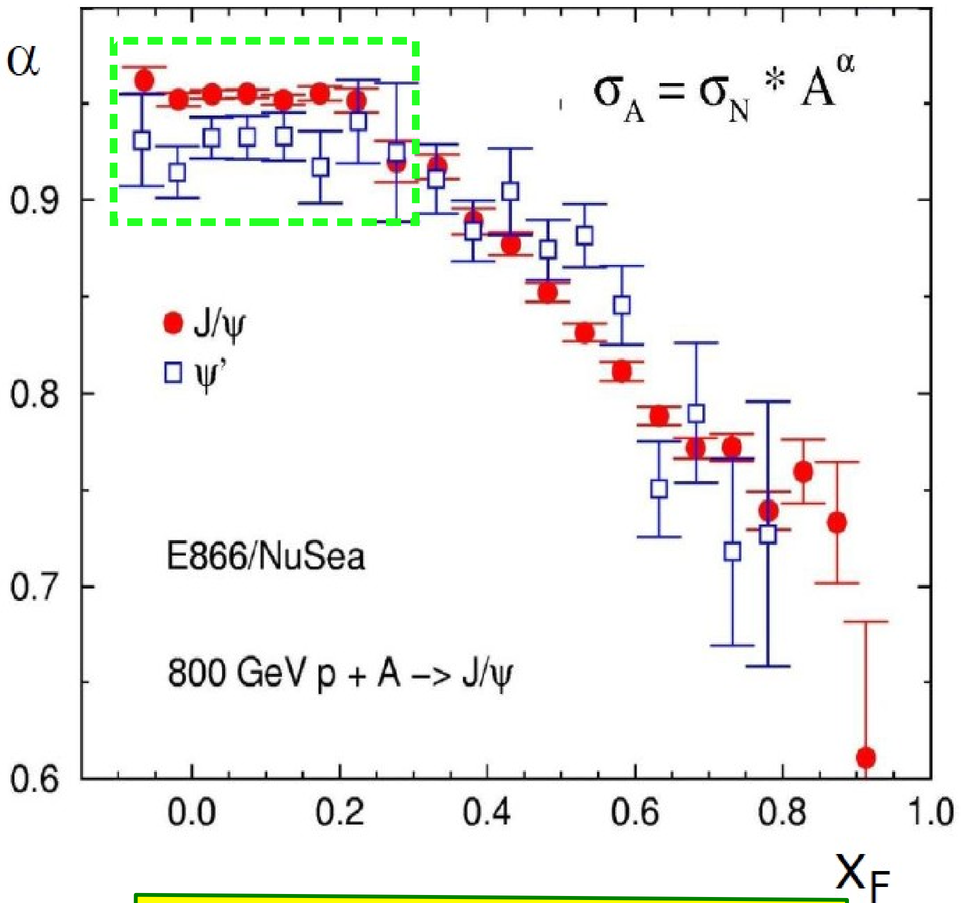
NA50 results in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 17 GeV show that the loosely bound ψ(2S) is more suppressed compared to strongly bound J/ψ, in agreement with a sequential melting scenario

Charmonia in the medium: p-A collisions

Proton-nucleus (p-A) collisions: Cold Nuclear Matter effects

Initial/final state: shadowing, energy loss, $c\bar{c}$ pair break-up
(the $c\bar{c}$ pair break-up should be negligible at the LHC energies)

Intriguing results already at lower energies(NA50, E866, HERA-B)



E866 Collab., PRL 84 (2000) 3256

E866 results in 800 GeV p-A collisions at:

x_F~0 (central rapidity)

show that the ψ(2S) is slightly more suppressed compared to the J/ψ

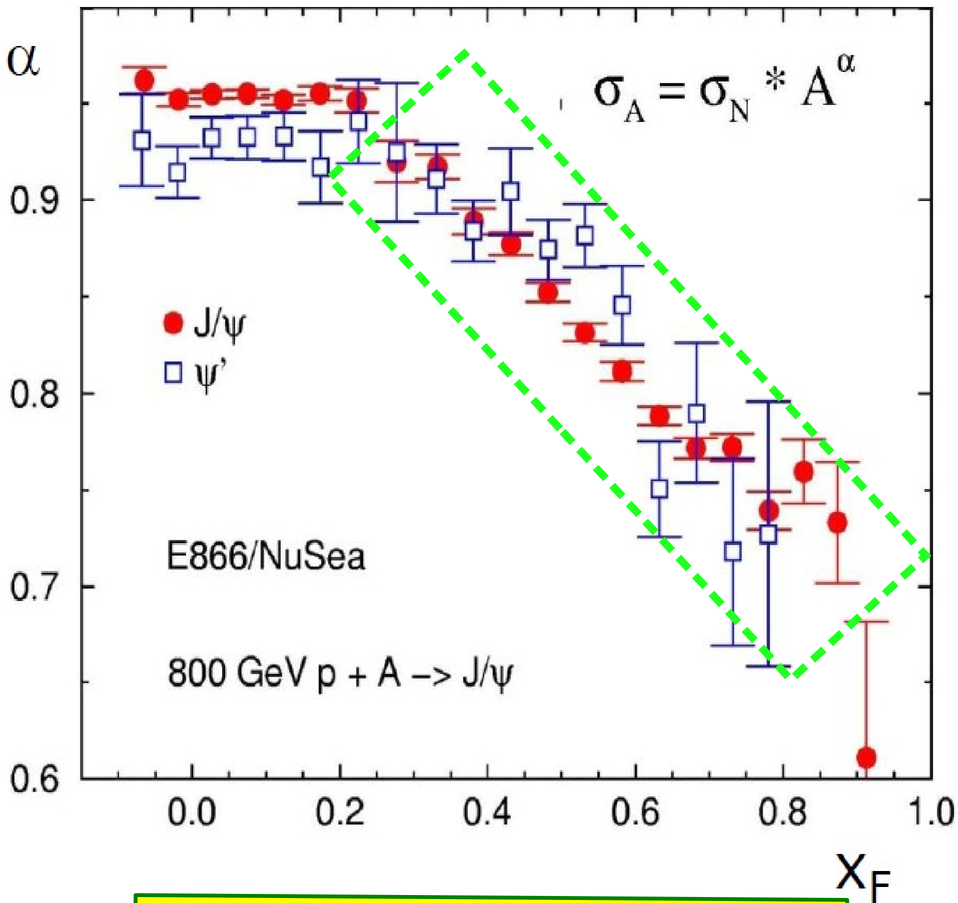
$\tau_c > \tau_f$ fully formed resonance traversing the nucleus

Charmonia in the medium: p-A collisions

Proton-nucleus (p-A) collisions: Cold Nuclear Matter effects

Initial/final state: shadowing, energy loss, $c\bar{c}$ pair break-up
(the $c\bar{c}$ pair break-up should be negligible at the LHC energies)

Intriguing results already at lower energies (NA50, E866, HERA-B)



E866 Collab., PRL 84 (2000) 3256

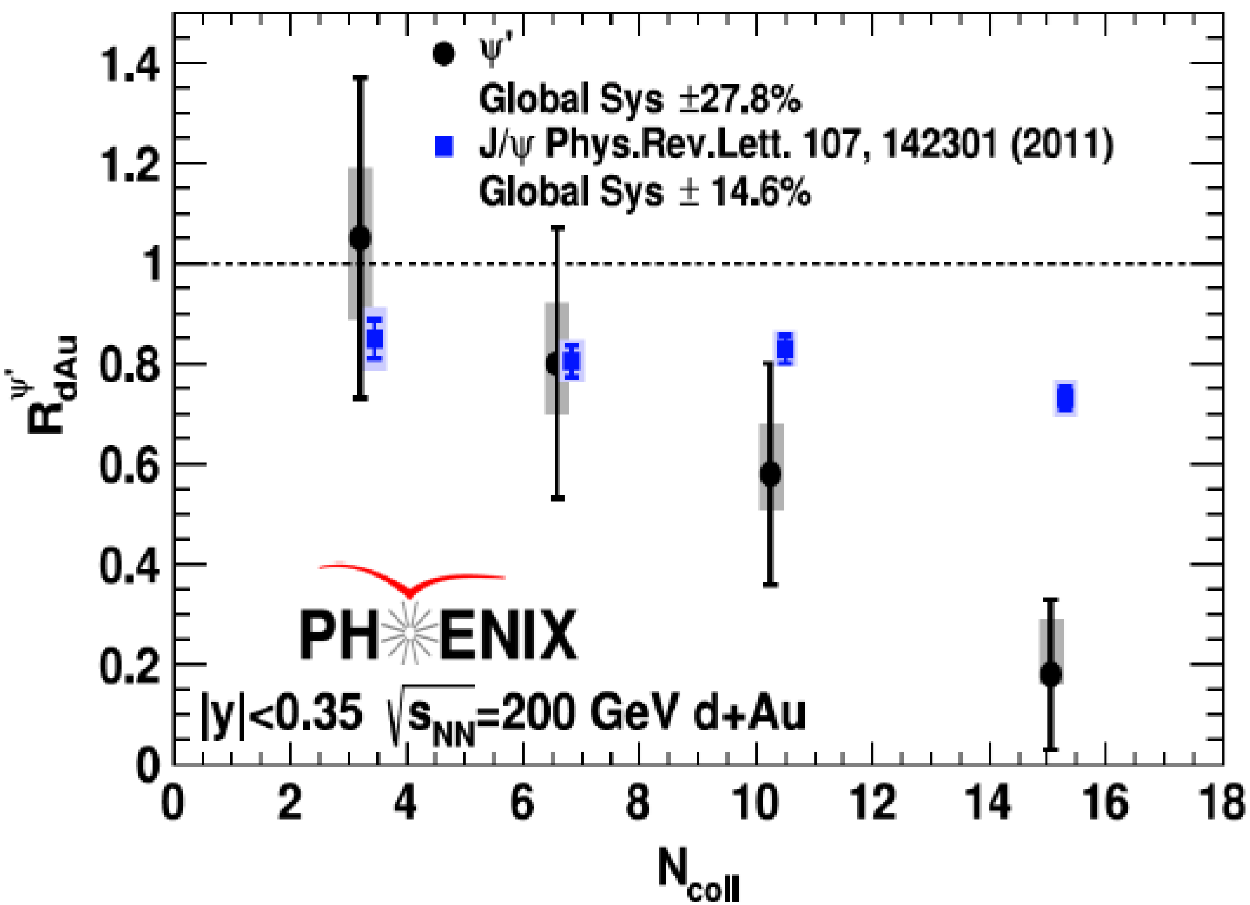
E866 results in 800 GeV p-A collisions at

x_F≥0.2 (forward rapidity)

show that the ψ(2S) suppression trend is similar to the J/ψ

$\tau_c < \tau_f$ the influence of the nuclear matter on the pre-hadronic state is independent of the particular resonance being produced

Charmonia in the medium: p-A collisions

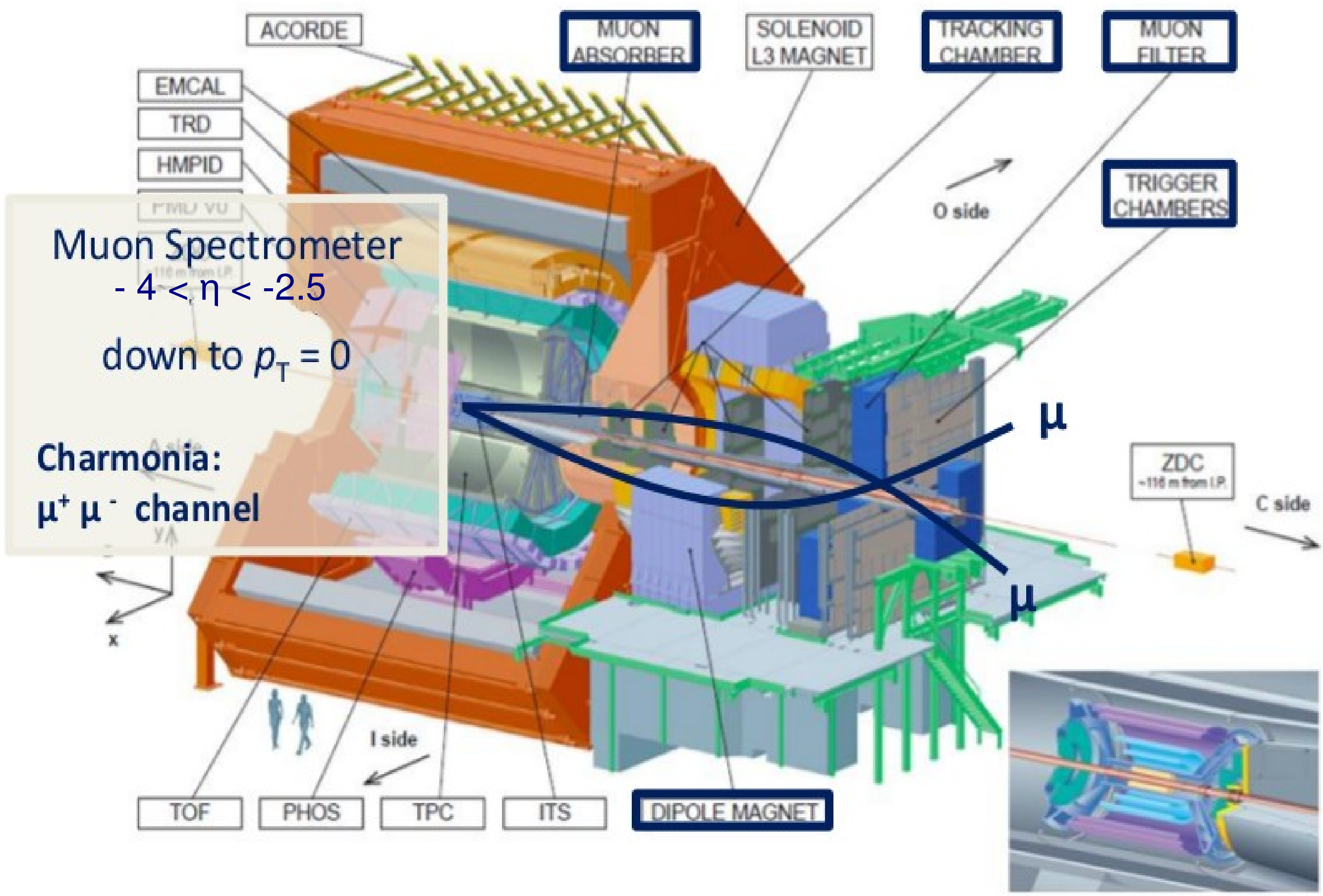


PHENIX Collab., PRL 111 (2013) 202301

PHENIX result in d-Au collisions at $\sqrt{s_{NN}}$ = 200 GeV show a stronger ψ(2S) suppression than that of the J/ψ: the strong ψ(2S) suppression is unexpected because at RHIC $\tau_c < \tau_f$

The ALICE detector

The inclusive ψ(2S) production is studied in the $\mu^+\mu^-$ decay channel



Forward muon spectrometer: ψ(2S) → $\mu^+\mu^-$

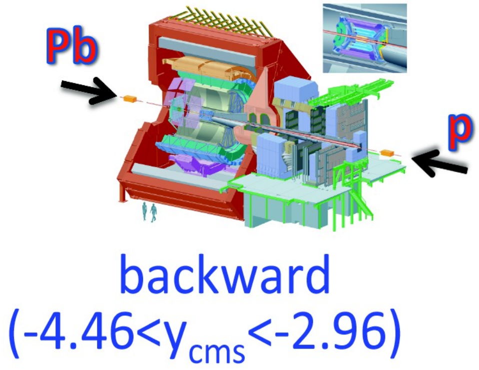
Muons identified and tracked in the muon spectrometer (10 planes of tracking chambers, 2 stations of trigger chambers, absorber system, dipole magnet)

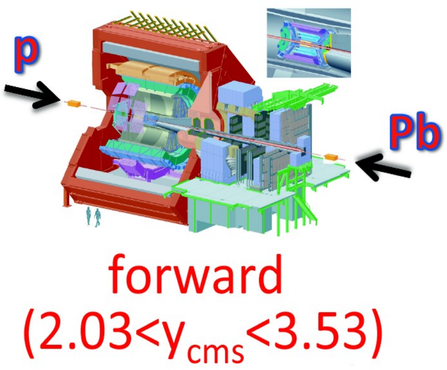
Data samples

p-Pb collisions

2013 data sample, $\sqrt{s_{NN}}$ = 5.02 TeV

Beam energy asymmetry (E_p=4 TeV, E_{Pb}=1.58 A·TeV, A=208) causes a shift in rapidity: two y_{cms} ranges studied, inverting the LHC beams direction





$L_{int}^{forward}$ = 5.01±0.19 nb^{-1}

$L_{int}^{backward}$ = 5.81±0.18 nb^{-1}

Pb-Pb collisions

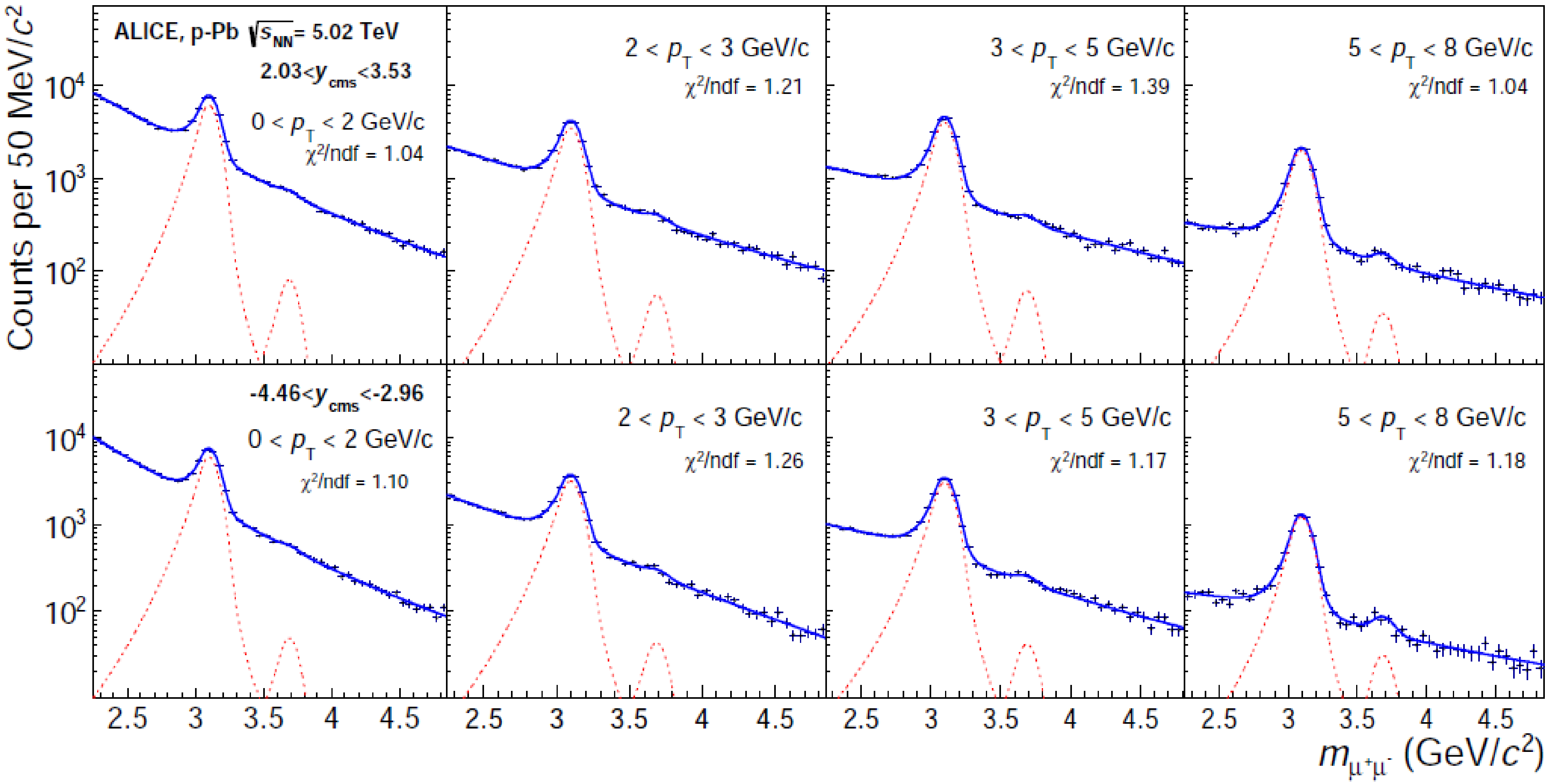
2011 data sample, $\sqrt{s_{NN}}$ = 2.76 TeV, L_{int} = 68.8±0.9 μb^{-1}

pp reference

2011 data sample, $\sqrt{s}$ = 7 TeV, L_{int} = 1.35±0.07 pb^{-1}

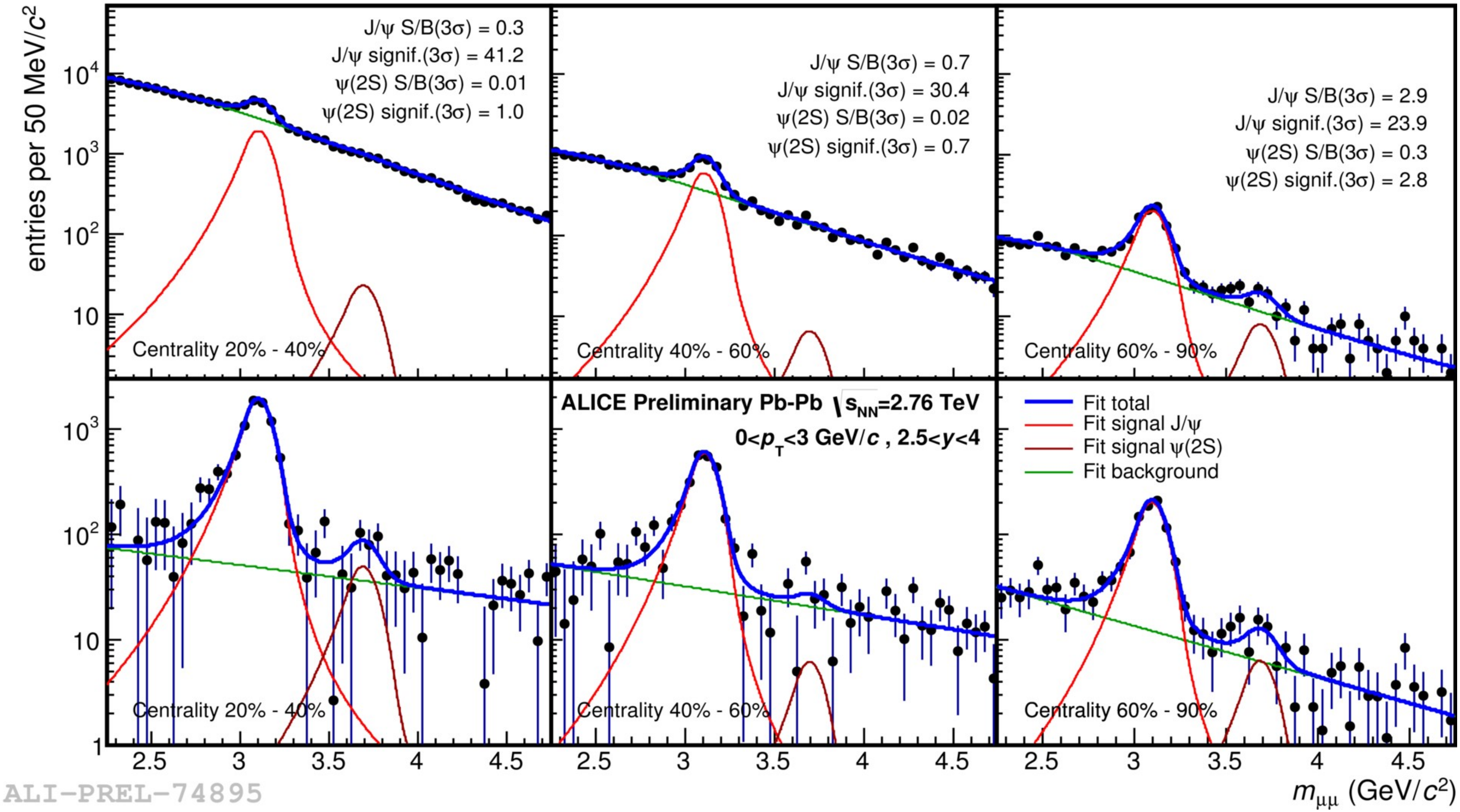
Invariant mass spectra: p-Pb

arXiv:1405.3796



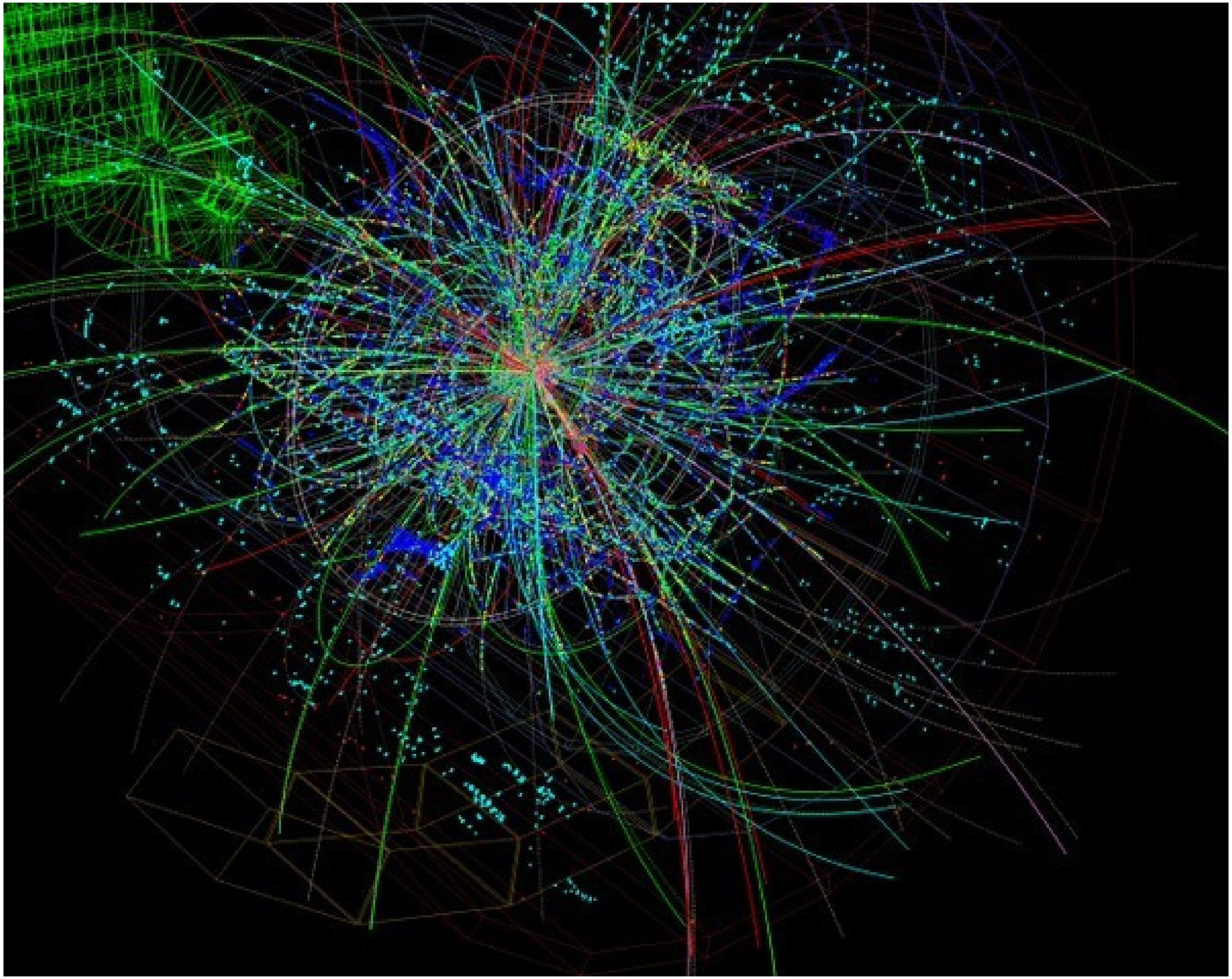
- Extraction of ψ(2S) yields via a fit to the opposite sign invariant mass spectra based on signal and background shapes
- sizeable statistics in p-Pb allows for differential studies

Invariant mass spectra: Pb-Pb



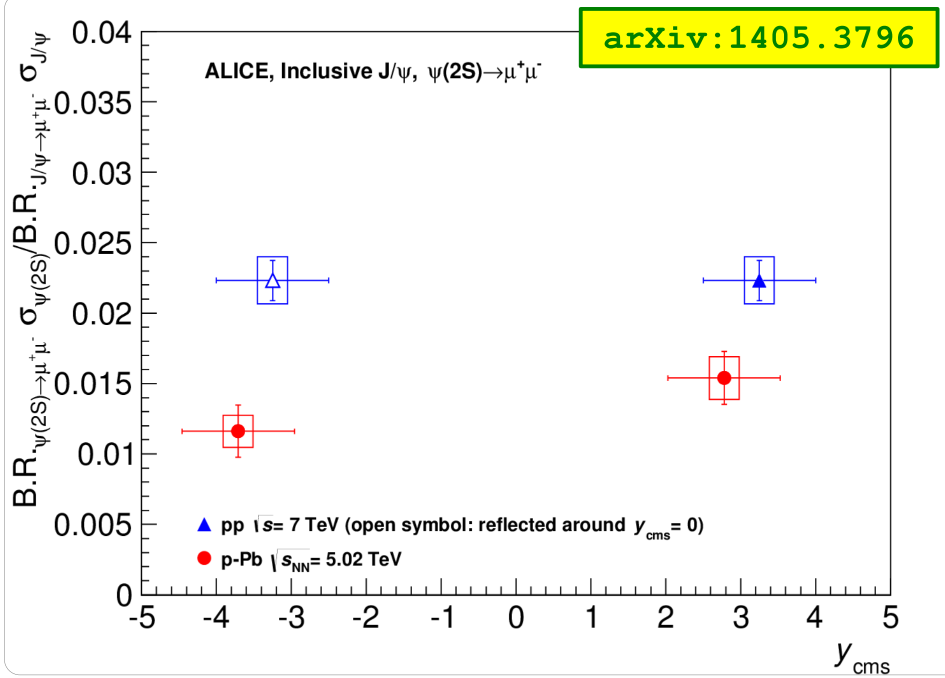
In Pb-Pb collisions signal extraction is limited by statistics and low S/B

p-Pb collisions



An event in p-Pb collision, reconstructed with the ALICE detector

$\psi(2S)/J/\psi$ and $[\psi(2S)/J/\psi]_{pPb}/[\psi(2S)/J/\psi]_{pp}$

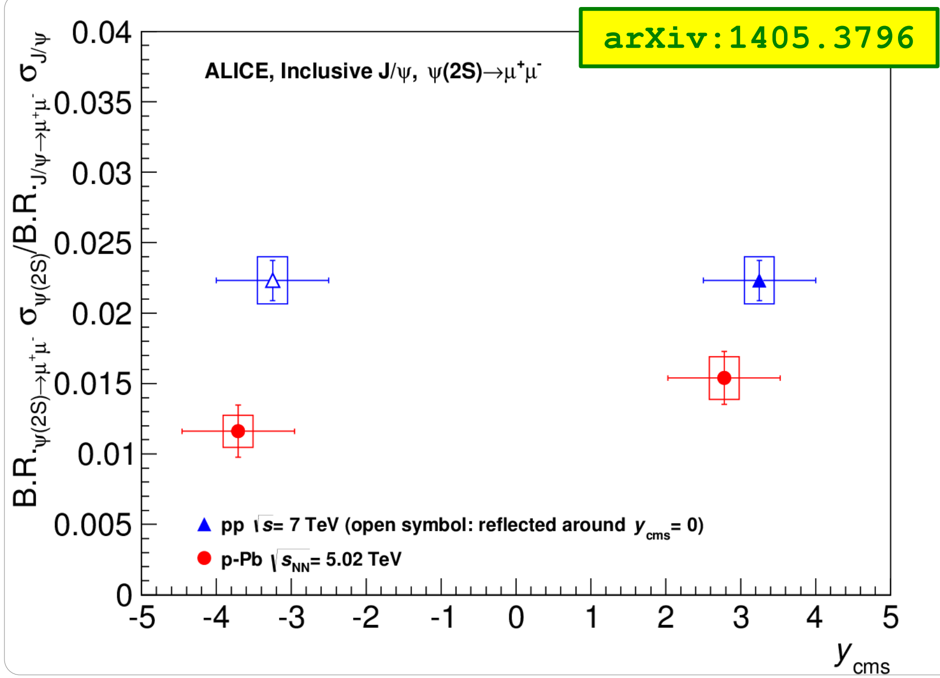


$\psi(2S)/J/\psi$ ratio

Stronger* $\psi(2S)$ suppression (compared to the J/ψ) in p-Pb with respect to $\sqrt{s}$=7 TeV pp collisions

* 2.0 σ-level at forward-y
* 3.2 σ-level at backward-y

$\psi(2S)/J/\psi$ and $[\psi(2S)/J/\psi]_{pPb}/[\psi(2S)/J/\psi]_{pp}$



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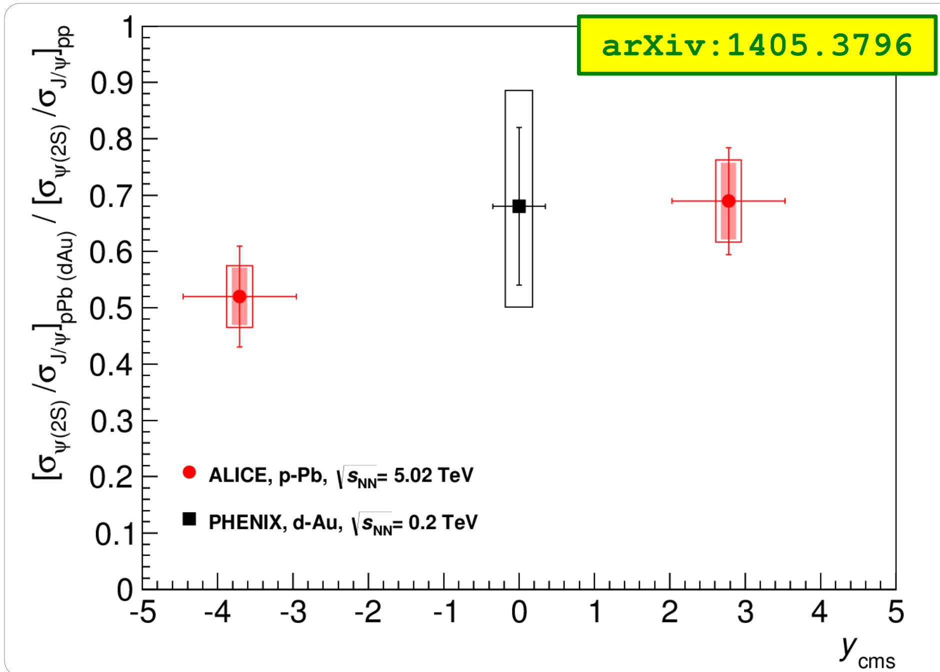
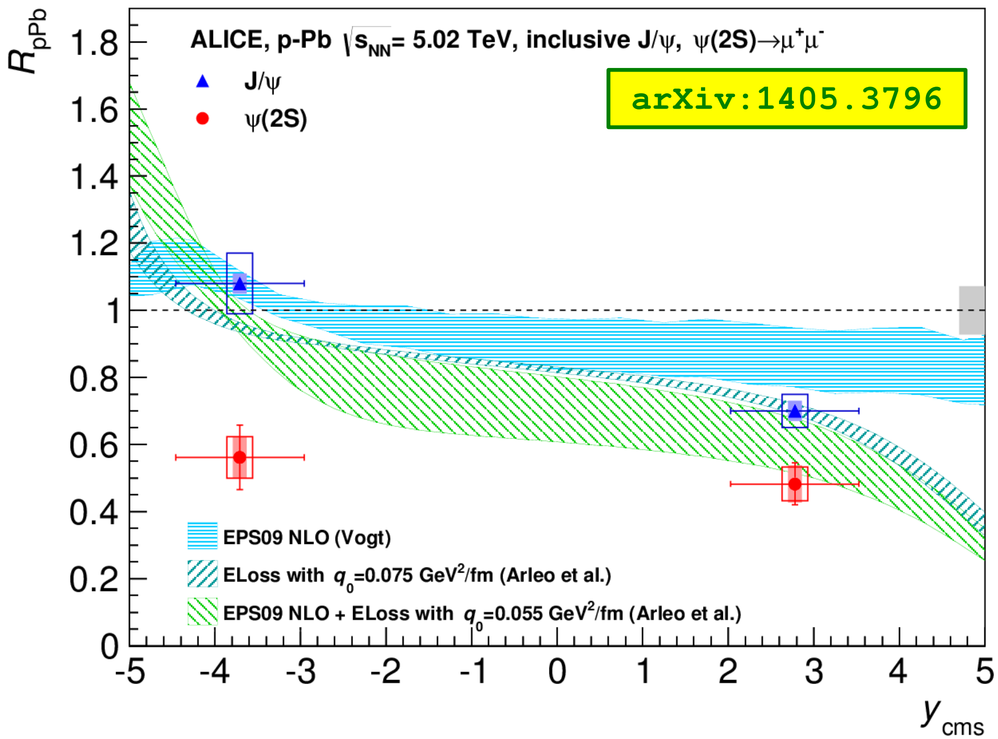


$[\psi(2S)/J/\psi]_{pPb}/[\psi(2S))/J/\psi]_{pp}$

PHENIX results (PRL 111 (2013) 202301) in d-Au collisions at $\sqrt{s_{NN}}$=0.2 TeV at midrapidity are qualitatively similar to ALICE measurements

The collision energy is different in pp and p-Pb collisions: possible dependences on the energy and y are included in the systematics

$\psi(2S)\, R_{pPb}$ as a function of rapidity



ψ(2S) nuclear modification factor

→ Stronger ψ(2S) suppression compared to the J/ψ

→ Same shadowing and coherent energy loss expected for both the J/ψ and the ψ(2S)

→ Theoretical predictions (based on shadowing and on energy loss) do not describe the observed ψ(2S) suppression

The suppression of ψ(2S) can be quantified using the nuclear modification factor:

$$R_{pA}^{\psi(2S)} = \frac{\sigma_{pA}^{\psi(2S)}}{A_{Pb}\cdot\sigma_{pp}^{\psi(2S)}}$$

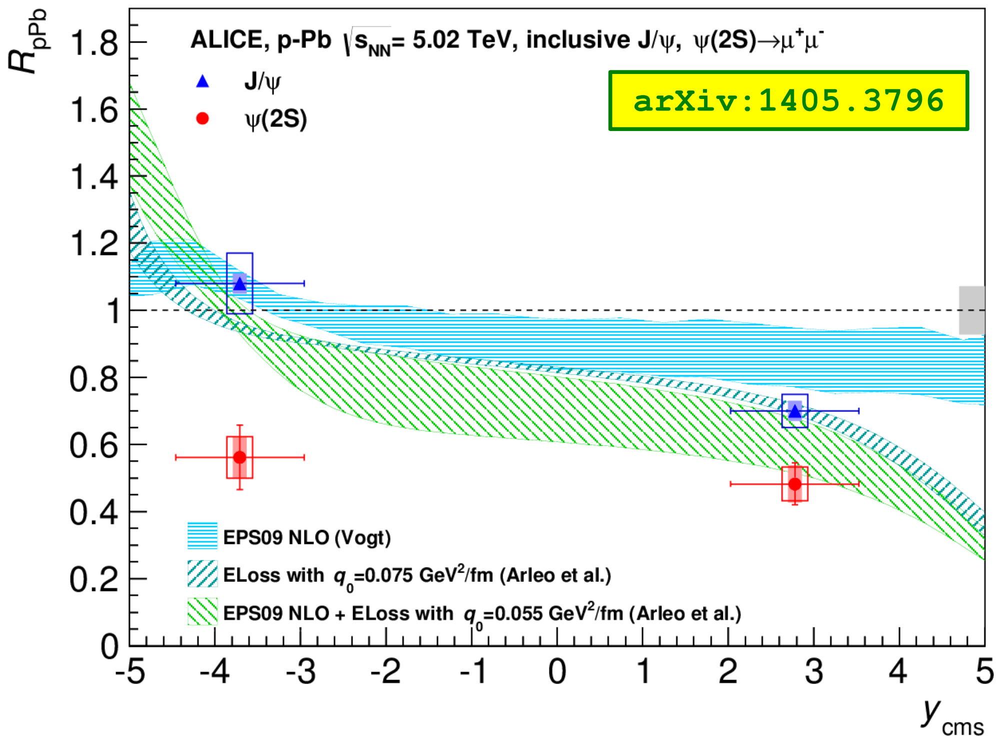
"general" definition

$$R_{pPb}^{\psi(2S)} = R_{pPb}^{J/\psi}\,\frac{\sigma_{pPb}^{\psi(2S)}}{\sigma_{pPb}^{J/\psi}}\,\frac{\sigma_{pp}^{J/\psi}}{\sigma_{pp}^{\psi(2S)}}$$

formula used in this analysis

Is this effect related to the breakup of the weakly bound ψ(2S) in the nuclear medium?

$\psi(2S)\, R_{pPb}$ as a function of rapidity



$$\tau_c = \frac{\langle L \rangle}{\beta_z \gamma}$$

τ_c and τ_f references:

PRC 87,054910 (2013)

Phys. Rev. Lett. 111 (2013) 202301

<L> = average length of nuclear matter traversed by the $c\bar{c}$ pair

β = $\tanh y^{rest}_{c\bar{c}}$

γ = $E_{c\bar{c}}/m_{c\bar{c}}$

The ψ(2S) breakup is possible if the resonance:

formation time < crossing time

$\tau_f \sim$ (0.05–0.15) fm/c < τ_c

→ **forward-y:** $\tau_c \sim 10^{-4}$ fm/c

breakup effects are excluded

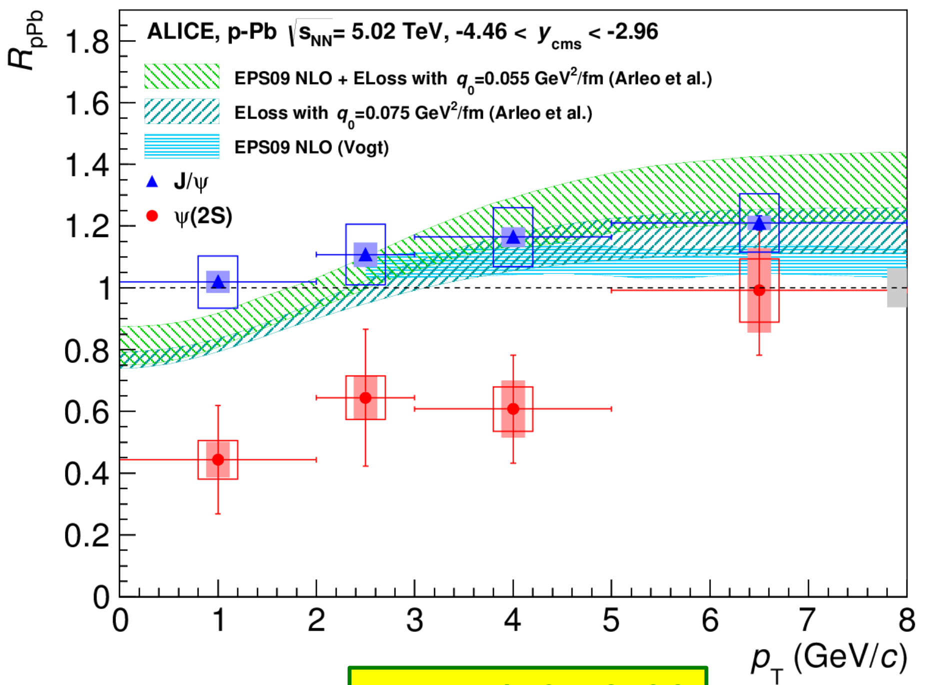
→ **backward-y:** $\tau_c \sim 7\cdot 10^{-2}$ fm/c

($\tau_f \sim \tau_c$) breakup effects can hardly explain the big difference between J/ψ and ψ(2S) R_{pPb}

Other final state effects related to the hadronic matter are required to describe the stronger ψ(2S) suppression

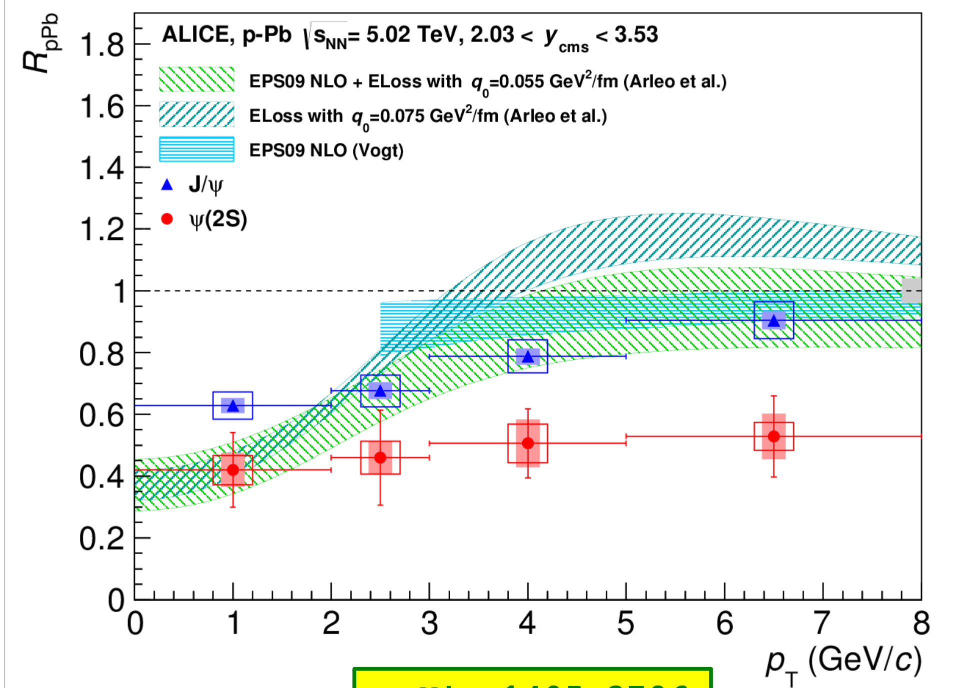
ψ(2S) R_{pPb} as a function of p_T

Backward rapidity



arXiv:1405.3796

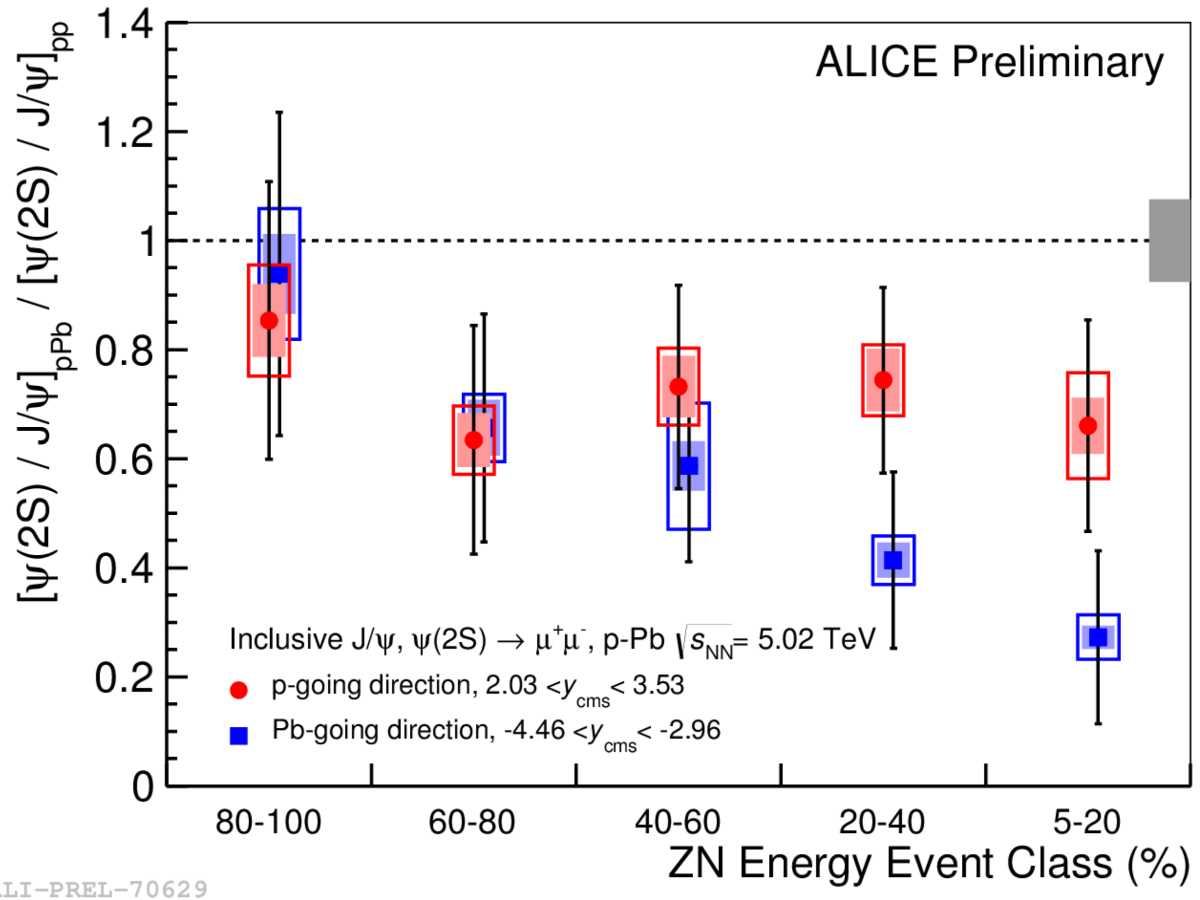
Forward rapidity



arXiv:1405.3796

- The available statistics allow to study the ψ(2S) R_{pPb} in p_T bins
- Crossing time "sampling", at backward rapidity: τ_c~0.07 fm/c (at p_T=0 GeV/c) – τ_c~0.03 fm/c (at p_T=8 GeV/c)
- The ψ(2S) is more suppressed than the J/ψ
- Theoretical models, in fair agreement with the J/ψ, overestimate the ψ(2S) result

$\psi(2S)/J/\psi|_{pPb}/\psi(2S)/J/\psi|_{pp}$ vs event activity



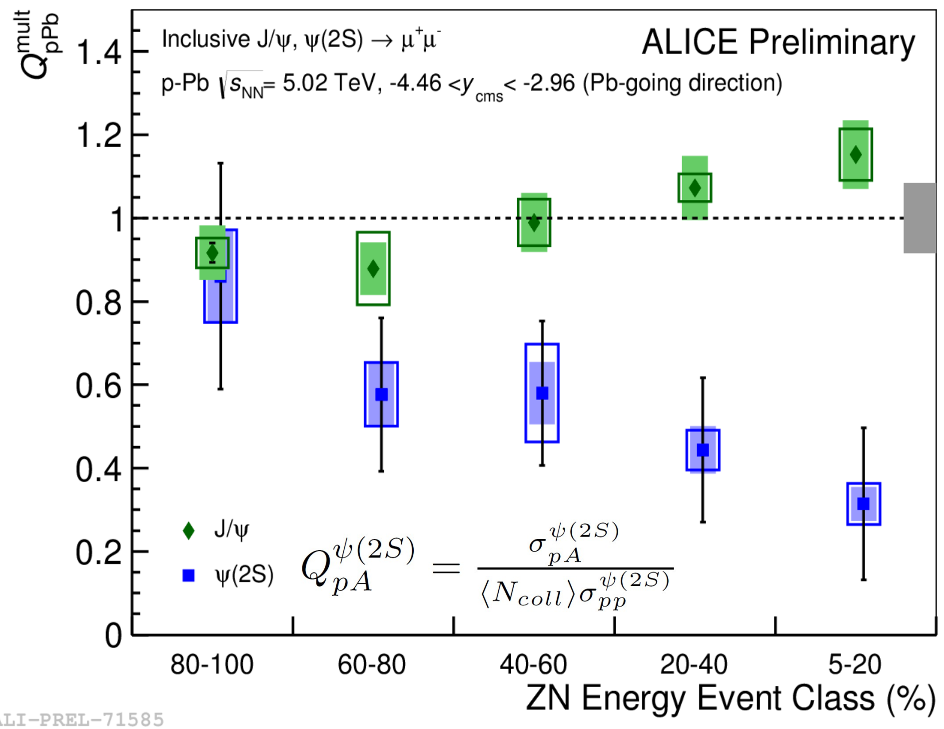
→ The $[\psi(2S)/J/\psi]_{pPb}/[\psi(2S)/J/\psi]_{pp}$ ratio has also been studied as a function of the event activity

→ At backward rapidity the $\psi(2S)$ is more suppressed than the J/ψ for large event activities

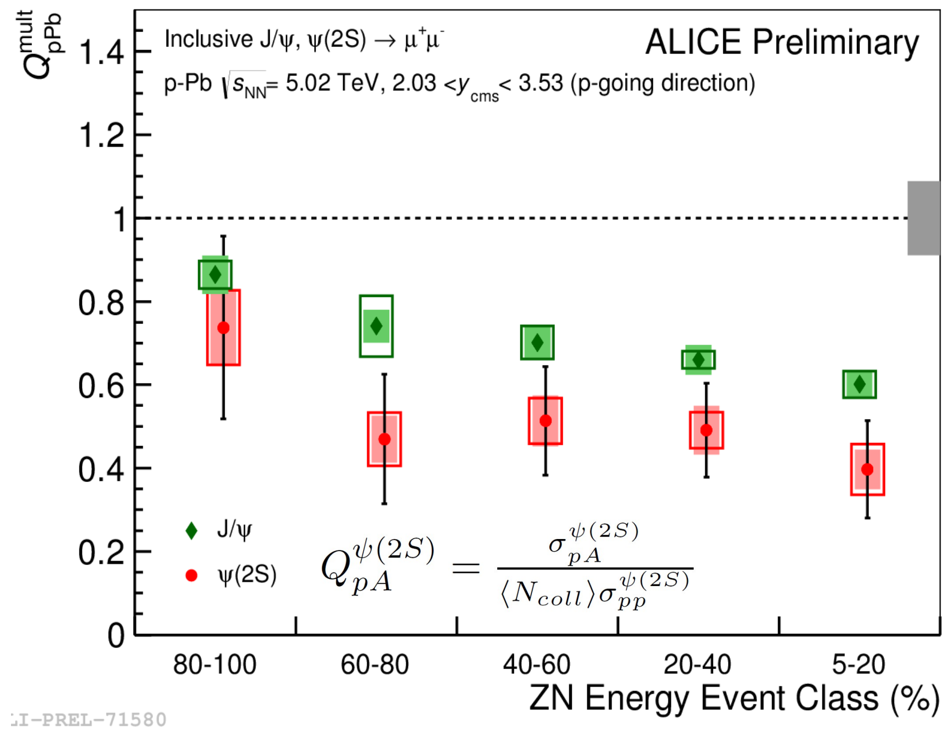
→ Another hint that final state effects can affect the $\psi(2S)$ production

ψ(2S) Q_{pPb} vs event activity

Backward rapidity



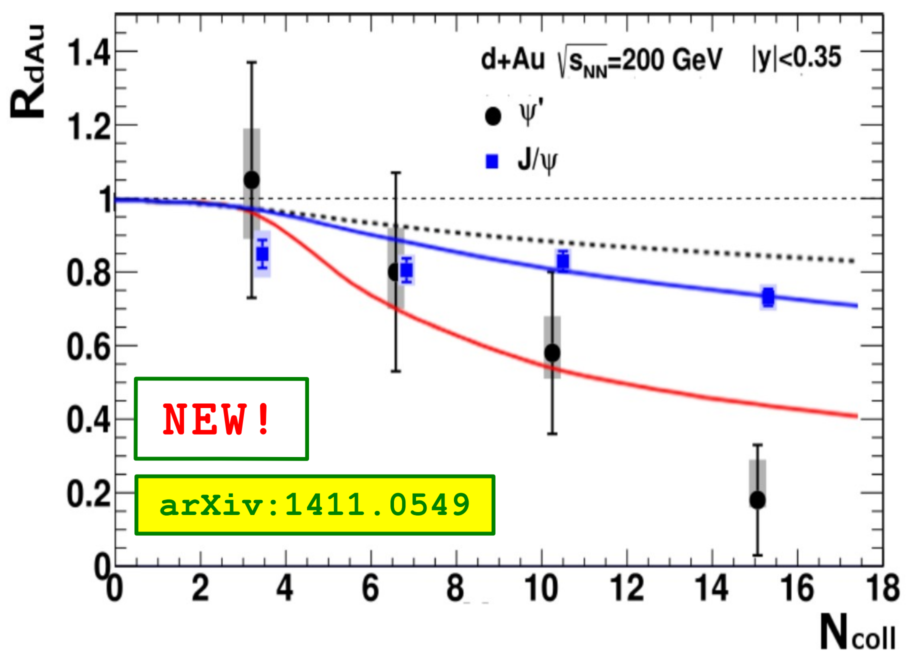
Forward rapidity



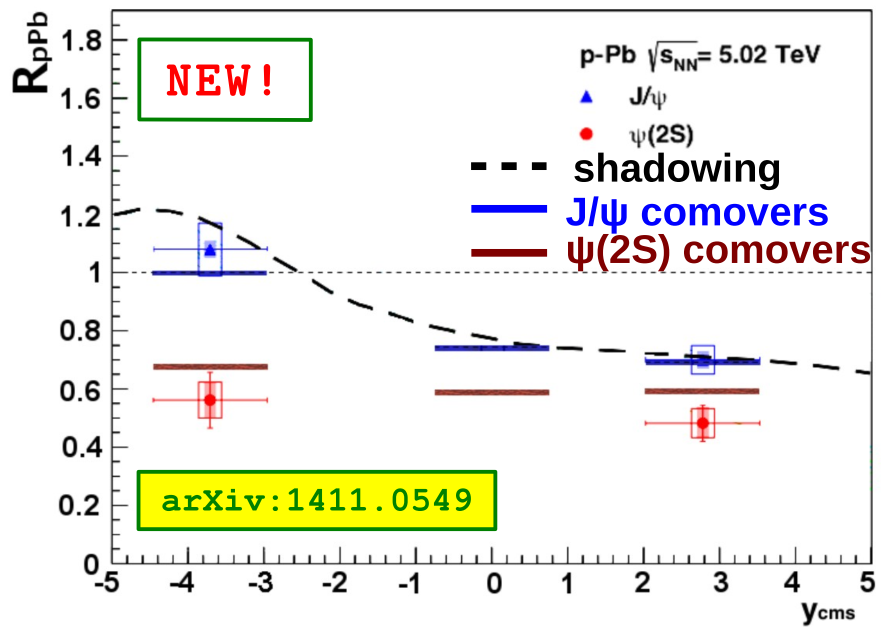
- Q_{pPb} variable instead of R_{pPb} (possible bias from the centrality estimator), as a function of the event activity
- At backward rapidity the ψ(2S) and J/ψ Q_{pPb} trends are different: the ψ(2S) Q_{pPb} decreases with increasing event activities
- At forward rapidity the Q_{pPb} trend is similar for J/ψ and ψ(2S)

Interaction with comovers (E. Ferreiro)

PHENIX

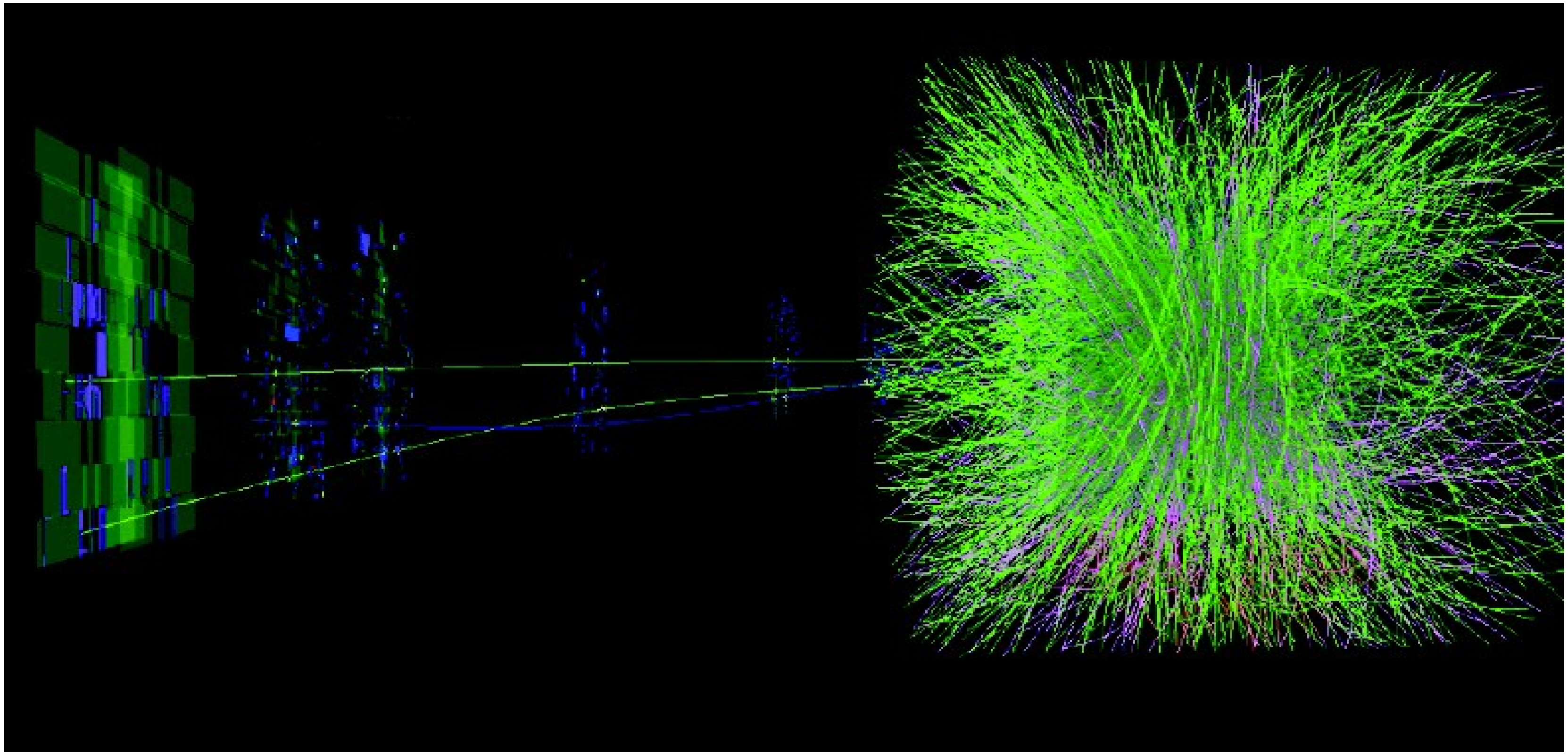


ALICE



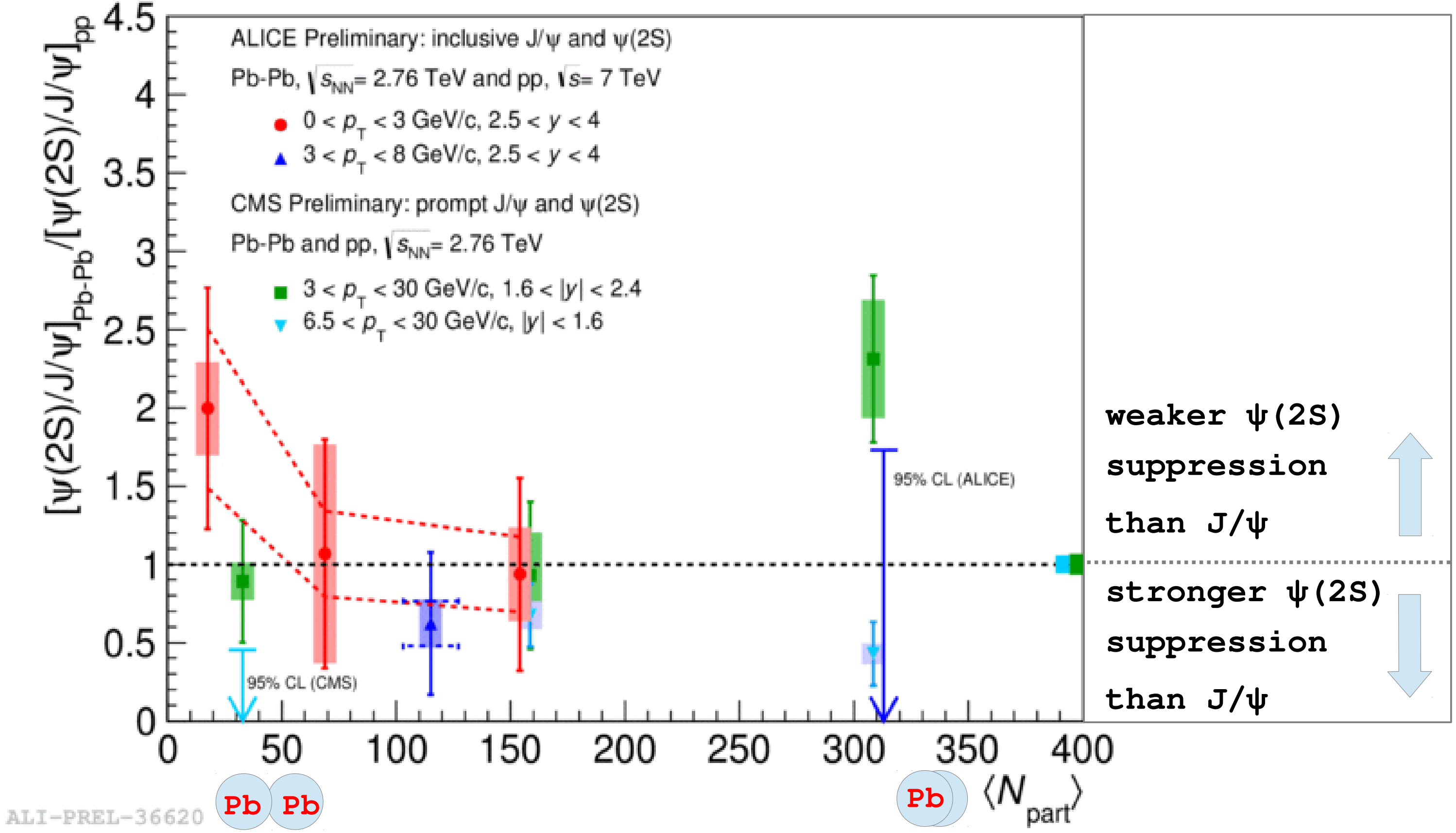
- Suppression caused by scattering of the resonance with produced particles that travel along with the $c\bar{c}$ pair
- the comovers dissociation effects are stronger:
  - for the ψ(2S) than the J/ψ (the ψ(2S) has larger size than J/ψ)
  - with increasing centrality and at backward rapidity due to higher comover density
- model based on comover interactions + EPS09 shadowing is in fair agreement with PHENIX and ALICE data

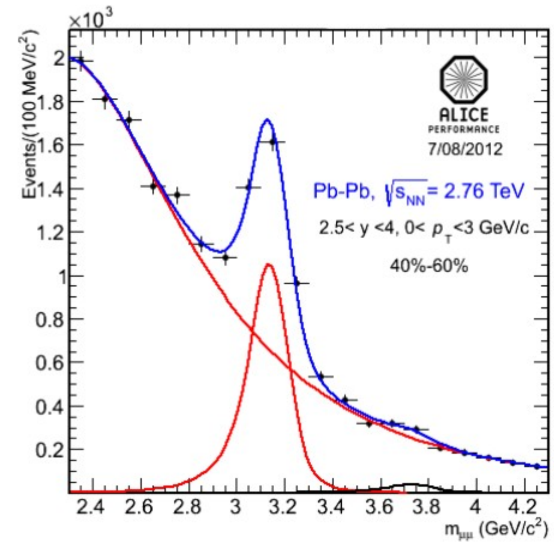
Pb–Pb collisions



An event in Pb-Pb collision, reconstructed with the ALICE detector

$\psi(2S)/J/\psi|_{PbPb}/\psi(2S)/J/\psi|_{pp}$





S/B 0.01-0.3 from central to peripheral collisions

- → $\psi(2S)$ yields extracted in two p_T bins as a function of the centrality
- → main sources for systematics: signal extraction, MC p_T and y input shapes for Acc x Eff calculation
- → improved agreement between ALICE and CMS data (new pp CMS reference)
- → the limited $\psi(2S)$ statistics do not allow a firm conclusion about the $\psi(2S)$ behavior in Pb-Pb collisions

The ALICE Collaboration has studied the $\psi(2S)$ production in pp, p–Pb and Pb–Pb collisions

The ALICE Collaboration has studied the ψ(2S) production in pp, p–Pb and Pb–Pb collisions

In p–Pb collisions the ψ(2S) is more suppressed with respect to pp than the J/ψ. Theoretical predictions based on shadowing and/or energy loss do not describe data

The ALICE Collaboration has studied the ψ(2S) production in pp, p-Pb and Pb-Pb collisions

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Limited statistics in Pb-Pb collisions prevent from firm conclusions on the ψ(2S) behavior

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Limited statistics in Pb-Pb collisions prevent from firm conclusions on the ψ(2S) behavior

Waiting for new data from LHC RUN2!

Quarkonia in the medium: other ALICE talks

J/ψ results in p–Pb and Pb–Pb

(Igor Lakomov)

Bottomonium results in p–Pb and Pb–Pb

(Javier Castillo Castellanos)

Heavy quarkonium results in pp

(Hugo Pereira Da Costa)

Thank you!

Backup slides

Charmonia: a brief introduction

Charmonia are bound states of **charm-anticharm** heavy quarks

CHARMONIUM PROPERTIES:

- Smaller than light hadrons, different E_b ($E_b^{J/\psi} \sim 0.6$ GeV, $E_b^{\psi(2S)} \sim 0.05$ GeV)
- Reconstructed via their dilepton decay:

$$\text{B.R. } J/\psi \rightarrow \mu^+\mu^- = (5.93 \pm 0.06) \cdot 10^{-2}$$

$$\text{B.R. } \psi(2S) \rightarrow \mu^+\mu^- = (7.8 \pm 0.9) \cdot 10^{-3}$$

Sensitive to the medium created in the collisions

CHARMONIUM PRODUCTION MECHANISMS:

- Production via hard scattering of gluons
- Decay from higher charmonium states

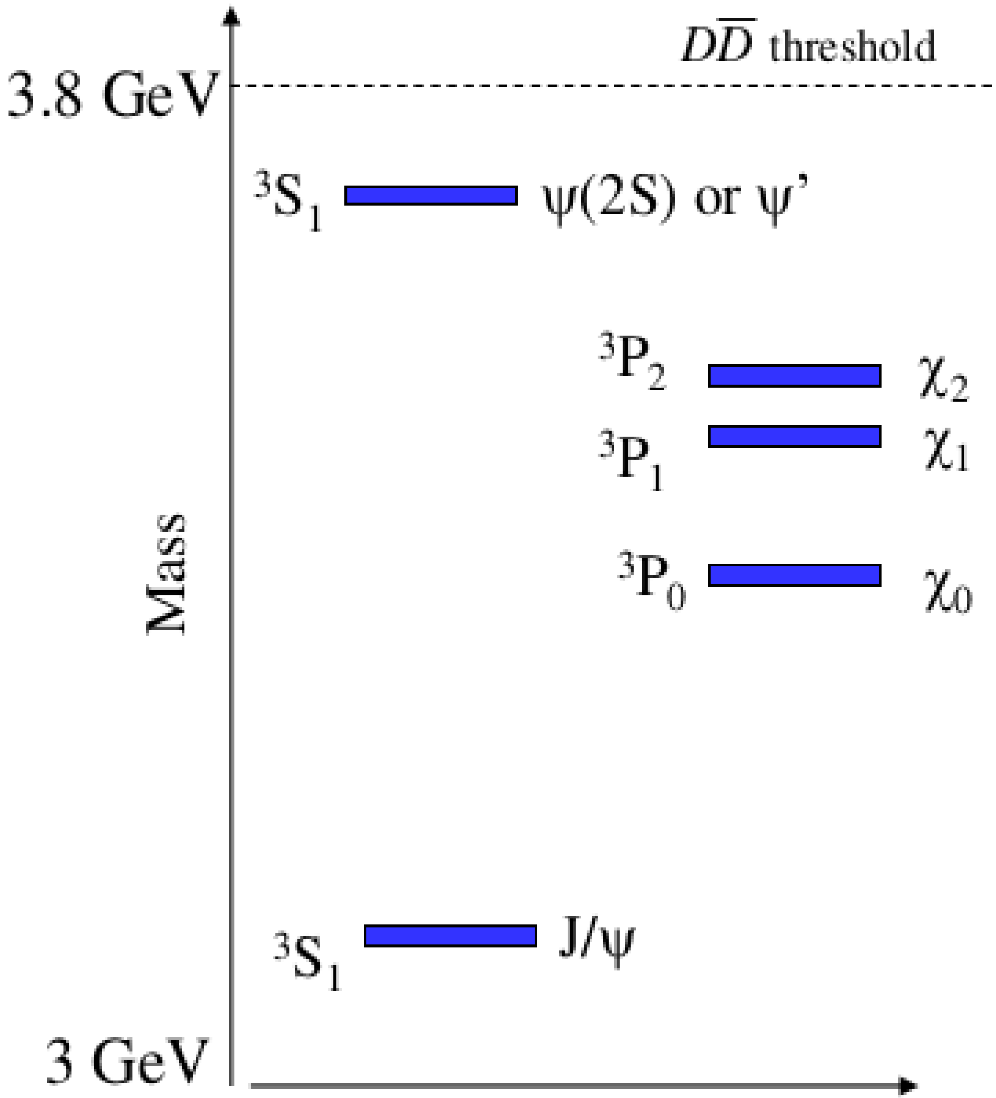
} "**prompt**" production

- Decay from b-mesons ("b-decay")

} "**non-prompt**" production

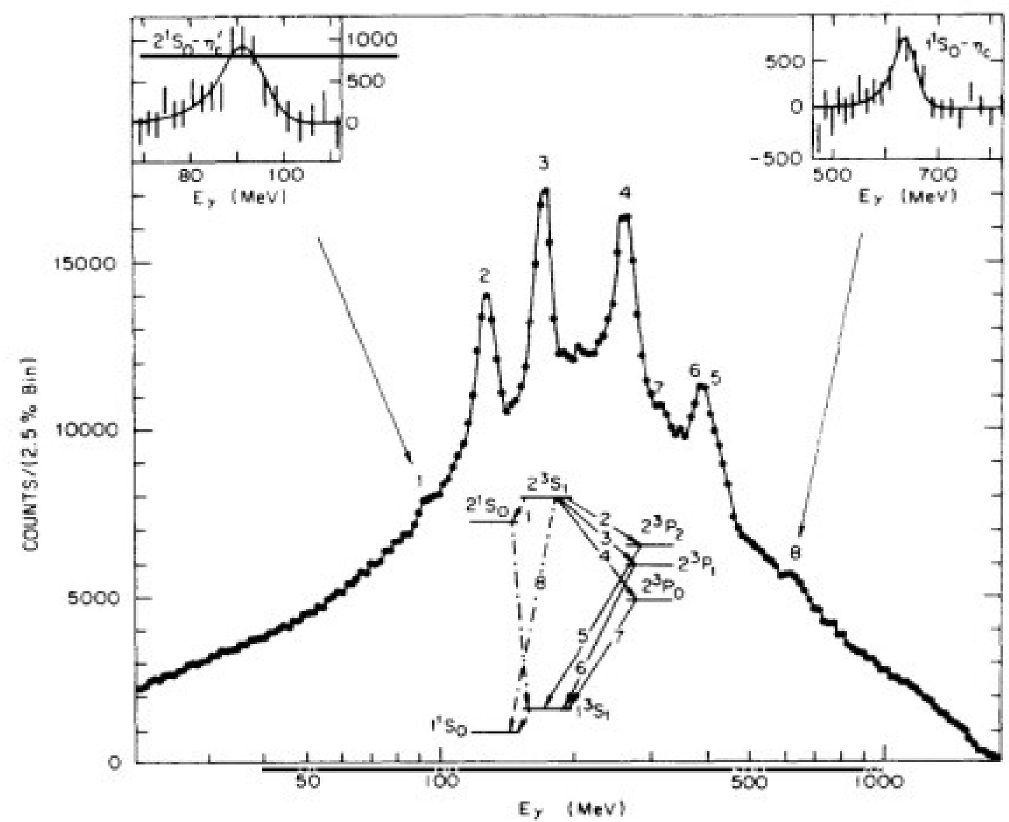
Prompt + non-prompt = Inclusive production

Charmonium family



state	J/ψ	χ_c	ψ(2S)
Mass(GeV)	3.10	3.53	3.69
ΔE (GeV)	0.64	0.20	0.05
r_o(fm)	0.25	0.36	0.45

Crystal Ball



Charmonium decays

$J/\psi(1S)$ DECAY MODES

	Mode		Fraction (Γ_i/Γ)	Scale factor/ Confidence level
Γ_1	hadrons		(87.7 ± 0.5) %	
Γ_2	virtual $\gamma \to$ hadrons		(13.50 ± 0.30) %	
Γ_3	$g g g$		(64.1 ± 1.0) %	
Γ_4	$\gamma g g$		(8.8 ± 1.1) %	
Γ_5	$e^+ e^-$		(5.94 ± 0.06) %	
Γ_6	$e^+ e^- \gamma$	[a]	$(8.8 \pm 1.4) \times 10^{-3}$	
Γ_7	$\mu^+ \mu^-$		(5.93 ± 0.06) %	

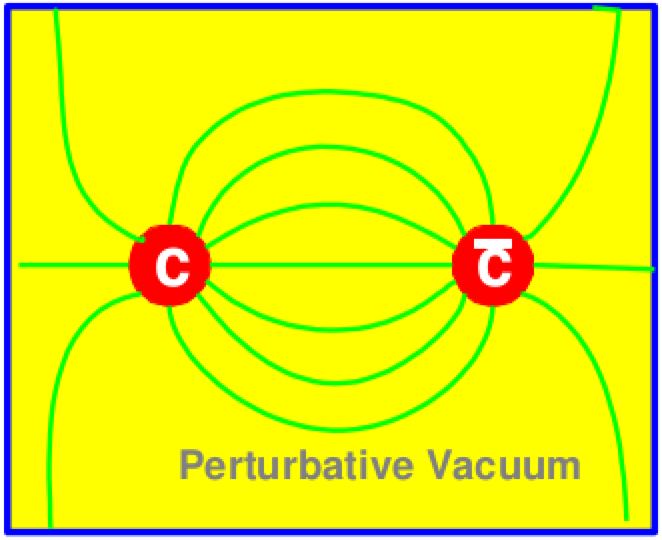
$\psi(2S)$ DECAY MODES

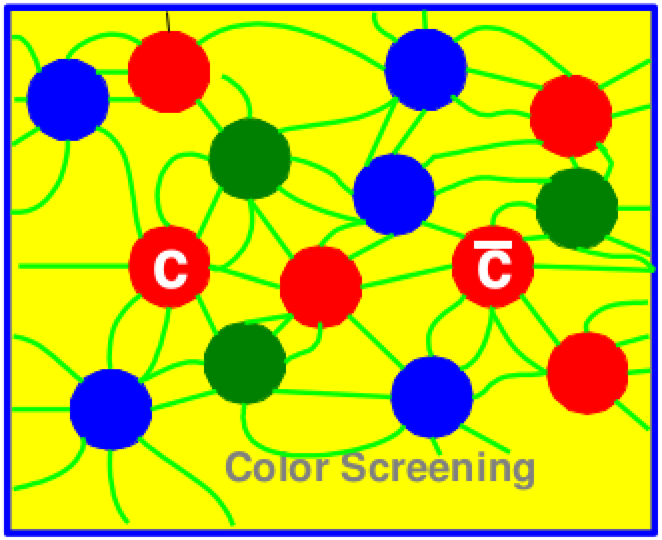
	Mode	Fraction (Γ_i/Γ)	Scale factor/ Confidence level
Γ_1	hadrons	(97.85 ± 0.13) %	
Γ_2	virtual $\gamma \to$ hadrons	(1.73 ± 0.14) %	S=1.5
Γ_3	$g g g$	(10.6 ± 1.6) %	
Γ_4	$\gamma g g$	(1.03 ± 0.29) %	
Γ_5	light hadrons	(15.4 ± 1.5) %	
Γ_6	$e^+ e^-$	$(7.73 \pm 0.17) \times 10^{-3}$	
Γ_7	$\mu^+ \mu^-$	$(7.7 \pm 0.8) \times 10^{-3}$	
Γ_8	$\tau^+ \tau^-$	$(3.0 \pm 0.4) \times 10^{-3}$	

Quarkonia production mechanisms

- In the **Color-Singlet Model** perturbative QCD is used to model the production of on-shell heavy quark pairs,with the same quantum numbers as the quarkonium into which they hadronize
- In the **Color Evaporation Model**, the production cross section of a given quarkonium state is considered proportional to the cross section of its constituting heavy quark pair, integrated from the sum of the masses of the two heavy quarks to the sum of the masses of the lightest corresponding mesons (D or B)
- In the framework of **Non Relativistic QCD**, contributions to the quarkonium cross section from the heavy-quark pairs produced in a color-octet state are also taken into account, in addition to the color-singlet contributions described above

Charmonium suppression in the QGP



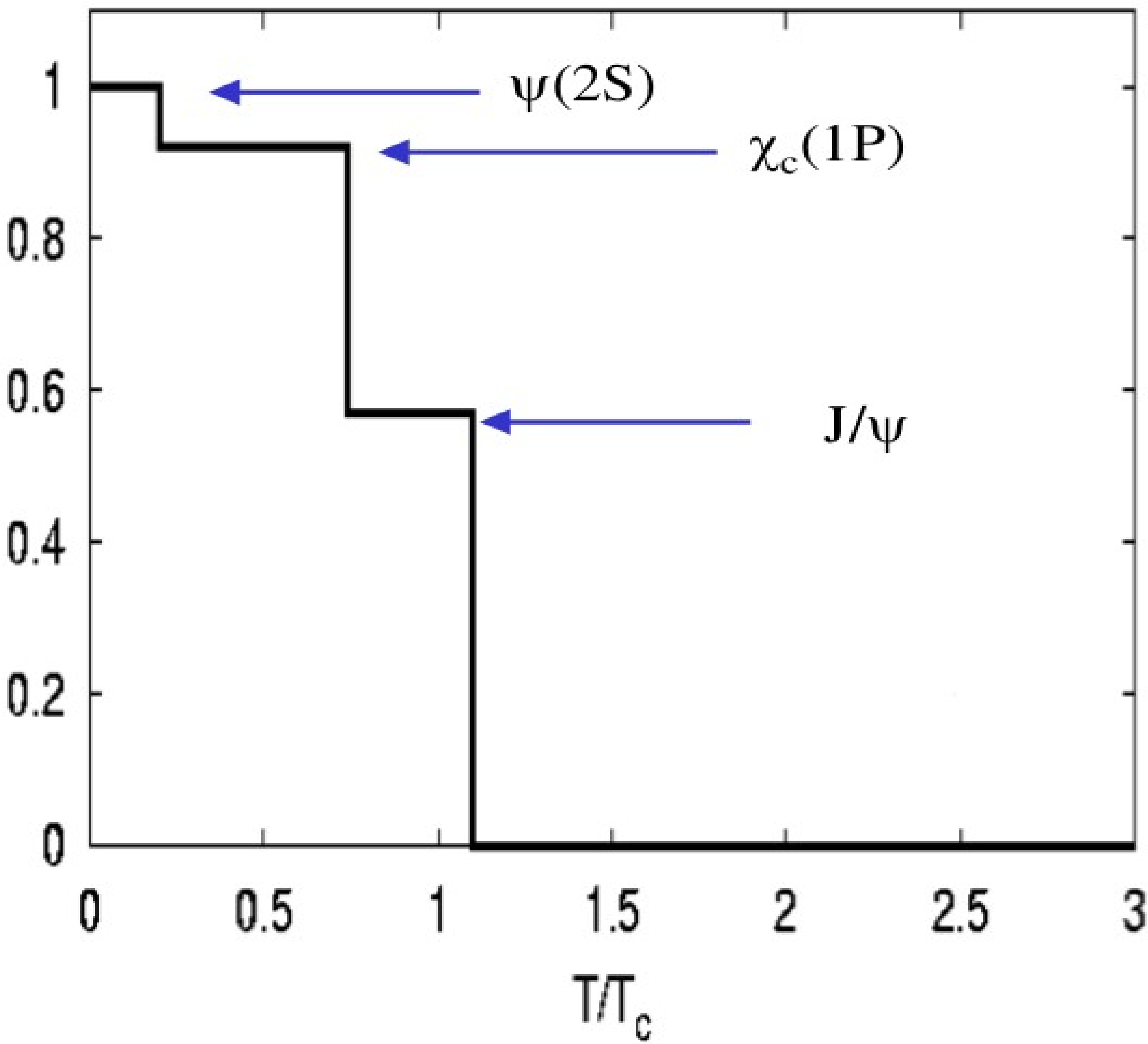


$$V(r) = -\frac{\alpha}{r} + kr \quad \Rightarrow \quad V(r) = -\frac{\alpha}{r} e^{-r/\lambda_D}$$

$$\lambda_D(PQCD) = \frac{1}{\sqrt{\left(\frac{N_c}{3} + \frac{N_f}{6}\right) g^2 T}}$$

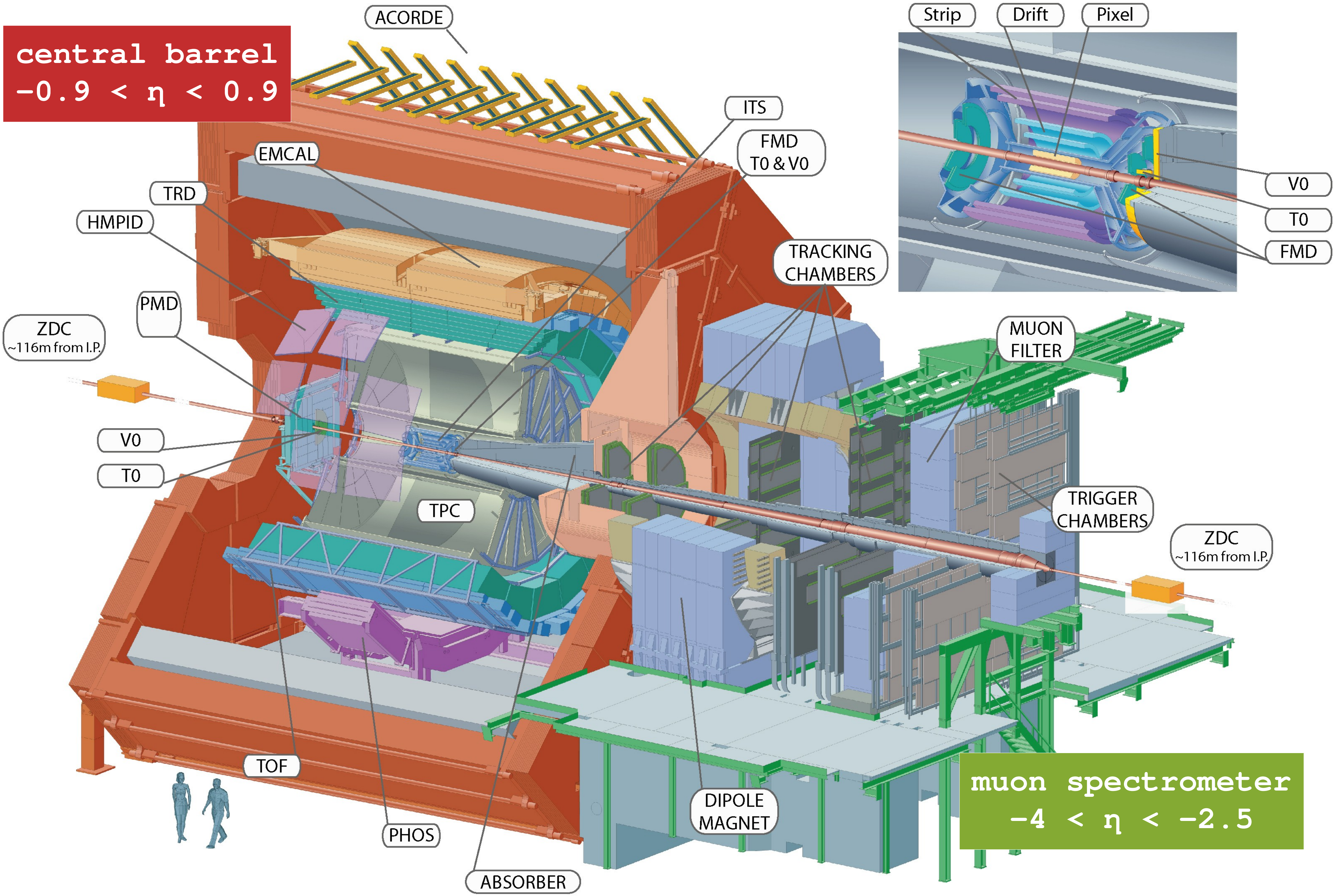
$(g^2 = (\pi/3)\,\alpha)$

Charmonium sequential melting



The ALICE detector

central barrel
$-0.9 < \eta < 0.9$

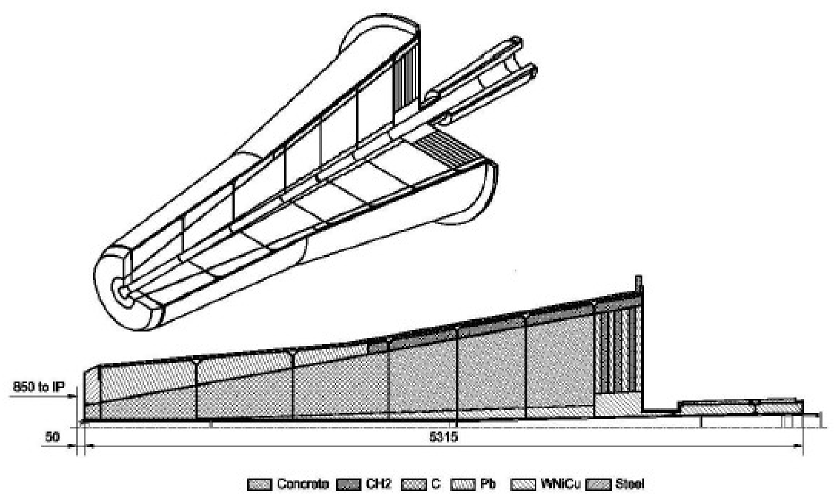


muon spectrometer
$-4 < \eta < -2.5$

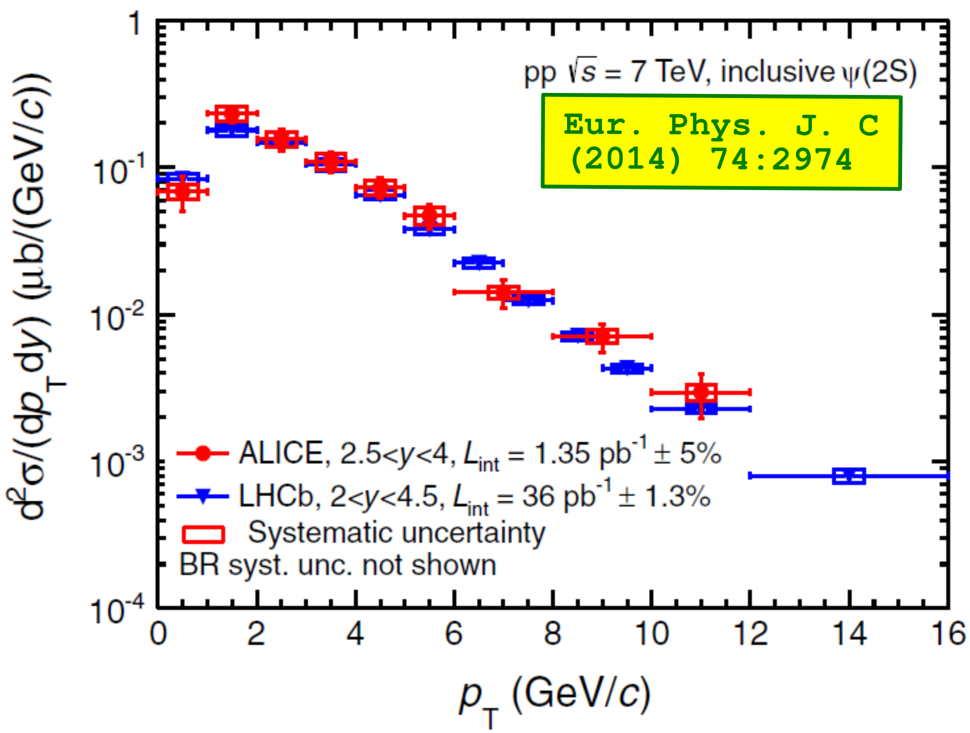
Standard selection criteria

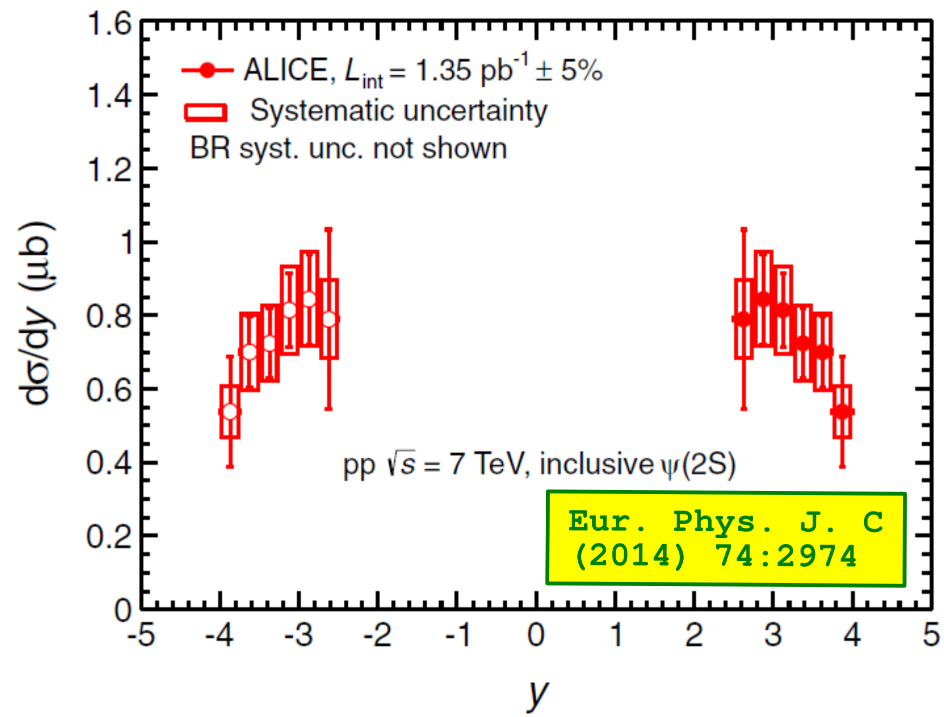
The following criteria are applied to remove hadrons escaping (or produced) in the front absorber, muons from pion and kaon decays and fake muon tracks, before performing the signal extraction:

- muon trigger-tracking matching;
- tracks are in the range: $-4 \leq \eta_{lab} \leq -2.5$
- track radial position at the absorber end is in the range: $17.6 \leq R_{abs} \leq 89.5$ cm
- dimuon rapidity is in the range: $2.5 \leq y_{lab} \leq 4$



ψ(2S) differential cross section in pp





→ The ψ(2S) production cross section, in pp collisions, have been studied in p_T and y intervals:

$$\sigma = \frac{1}{L_{\rm int}} \frac{N}{{\rm BR}_{\mu^+\mu^-} \times \langle A\varepsilon \rangle}$$

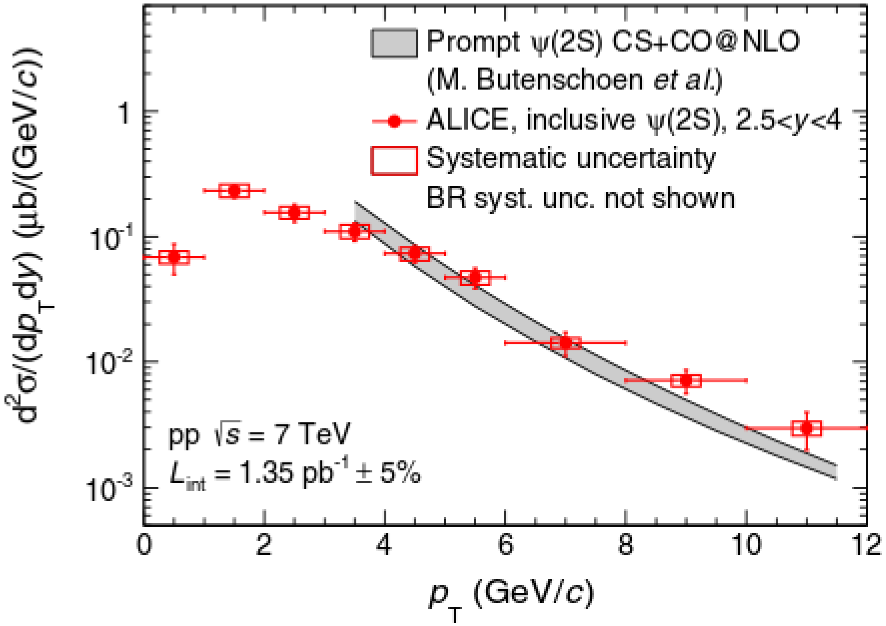
(L_{int}= integrated luminosity, BR(ψ(2S)→$\mu^+\mu^-$=0.78±0.09%, Aε=detector acceptance-efficiency)

→ LHCb results, obtained in a slightly different y range, are also shown
Results are in a good agreement with ALICE

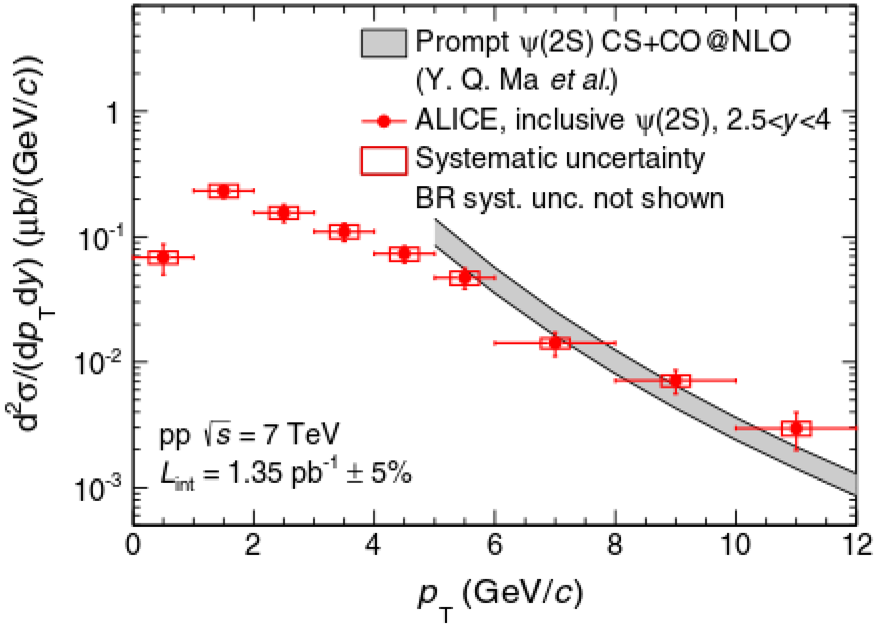
→ pp data useful to build reference for p-Pb and Pb-Pb studies

ψ(2S) in pp: comparison to models

Eur. Phys. J. C (2014) 74:2974

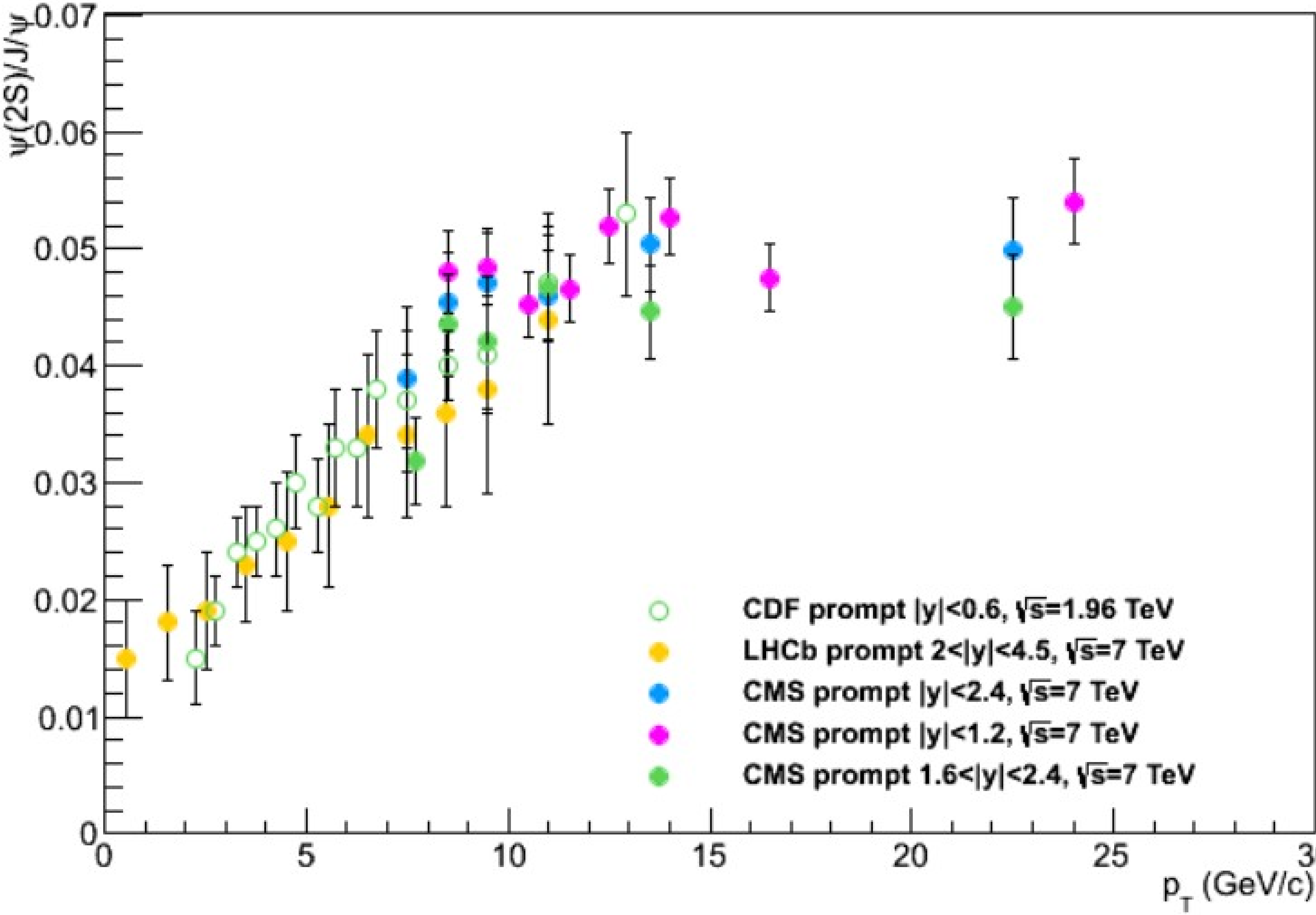


Eur. Phys. J. C (2014) 74:2974



- → comparison the inclusive ψ(2S) differential production cross section to two NRQCD production at NLO (left: arXiv:1105.0820, right: arXiv:1012.1030)
- → both calculations show reasonable agreement with data

ψ(2S)/J/ψ in pp collisions

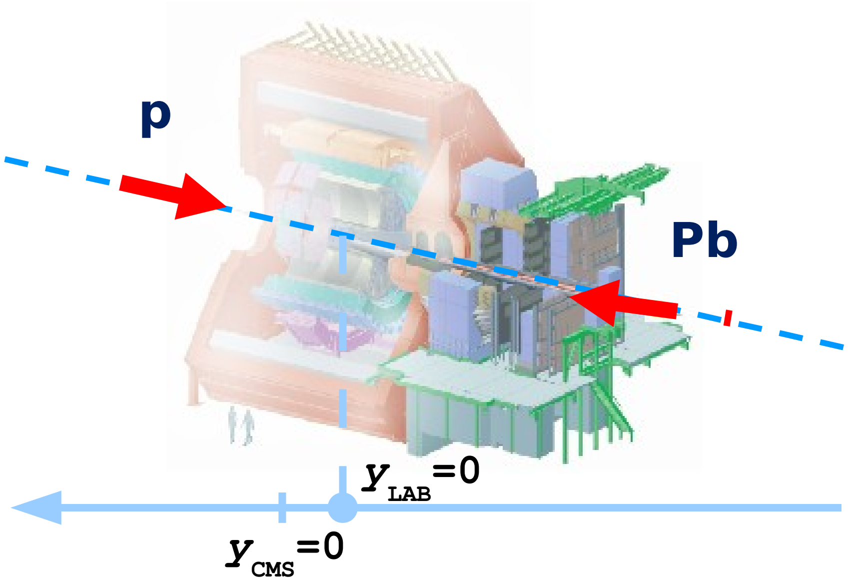


2013 p-Pb run

Beam energy asymmetry (E_p=4 TeV, E_{Pb}=1.58 A·TeV) causes a shift in rapidity:

$$|\Delta y_{CMS}| = 0.5 \log (Z_{Pb}A_p / Z_p A_{Pb}) = 0.465$$

p-Pb: proton beam moving towards the muon arm. L_{int} = 5.0 nb^{-1}

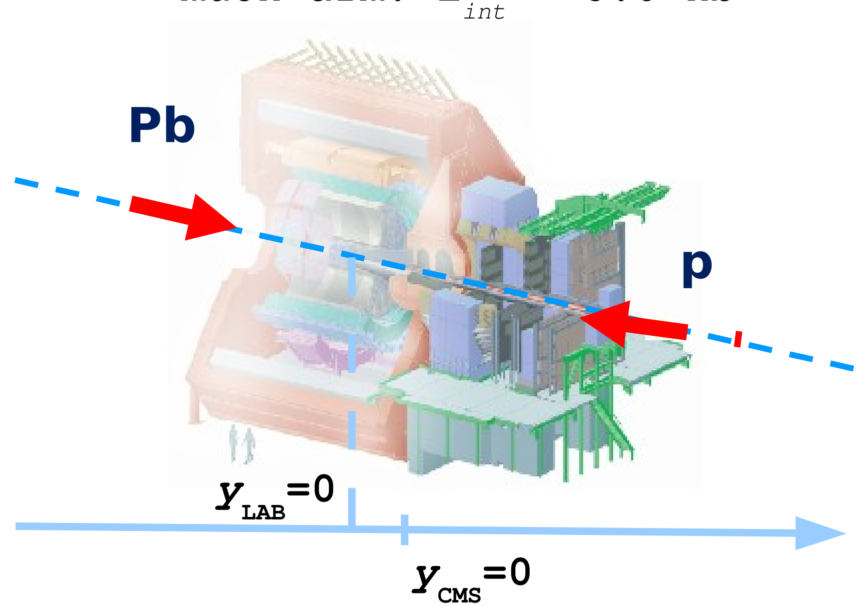


Forward rapidity configuration

(in the centre of mass frame)

$2.03 < y_{CMS} < 3.53$

Pb-p: lead beam moving towards the muon arm. L_{int} = 5.8 nb^{-1}



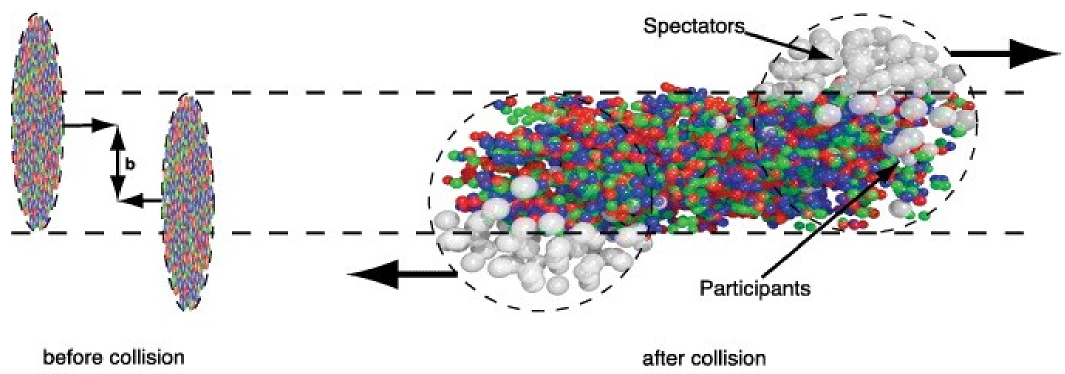
Backward rapidity configuration

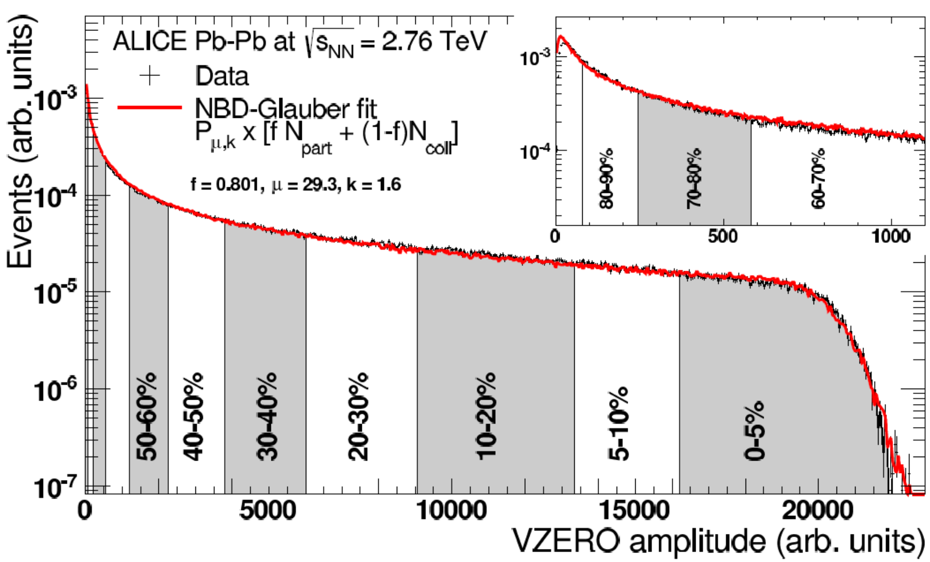
(in the centre of mass frame)

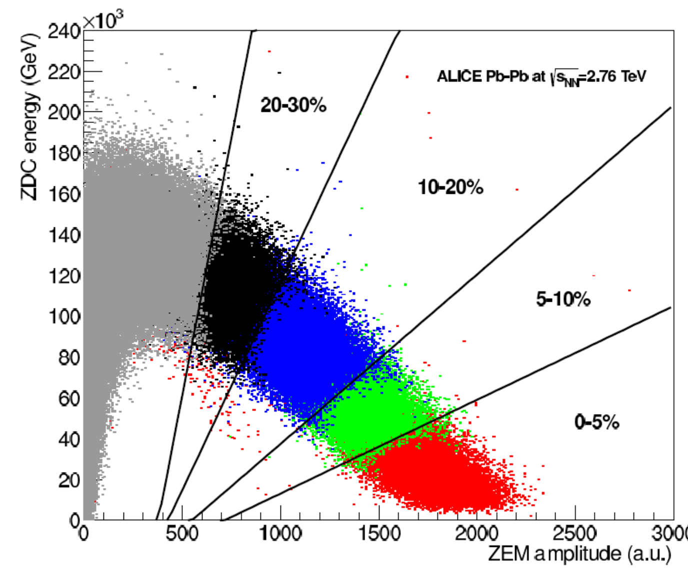
$-4.46 < y_{CMS} < -2.96$

Centrality in Pb-Pb collisions

Phys. Rev. C 88, 044909 (2013)

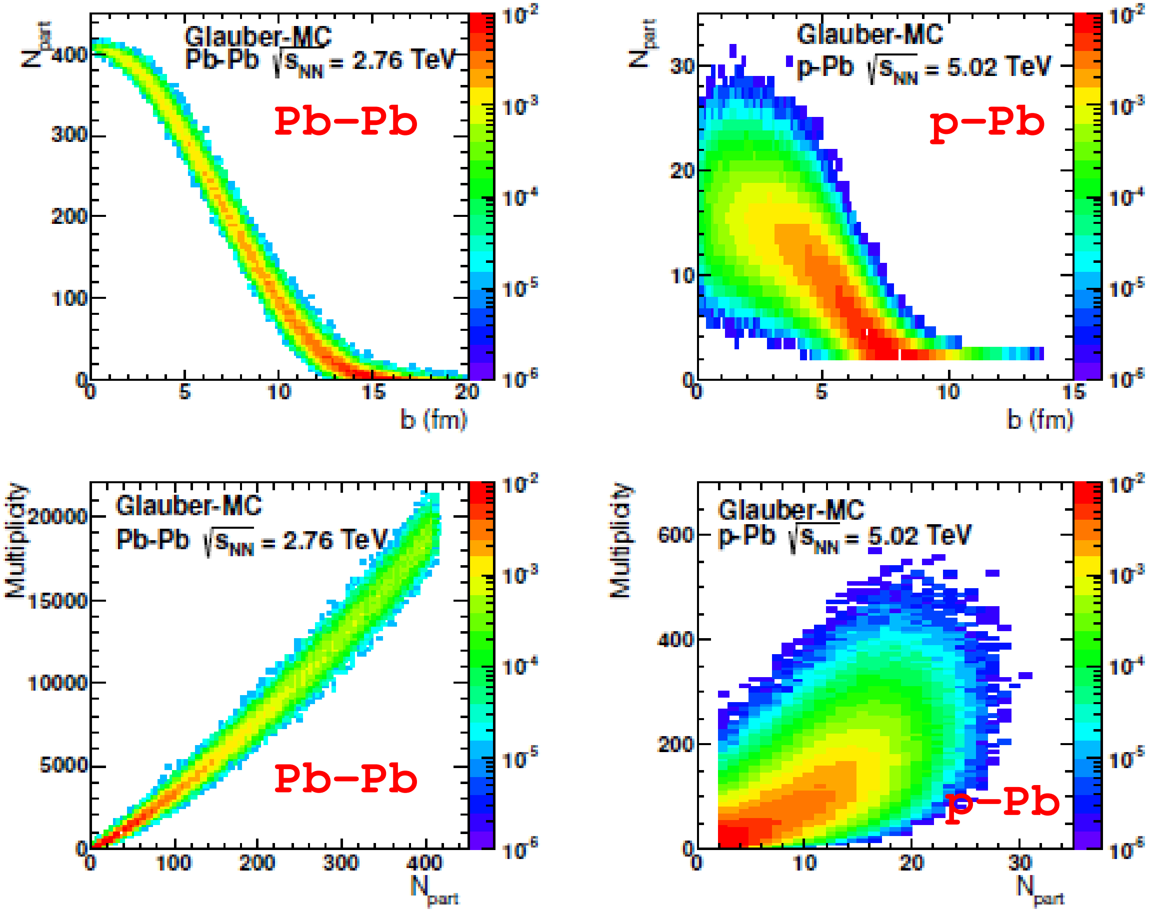






- → VZERO amplitude and Glauber model used to determine centrality percentiles (0-90%)
- → Alternative definition based on ZDC+ZEM (0-30%)

Centrality in p-Pb collisions (1)



Missing correlation between N_{part} and impact parameter (b) in p–Pb collisions

Missing correlation between N_{part} and multiplicity in p–Pb collisions

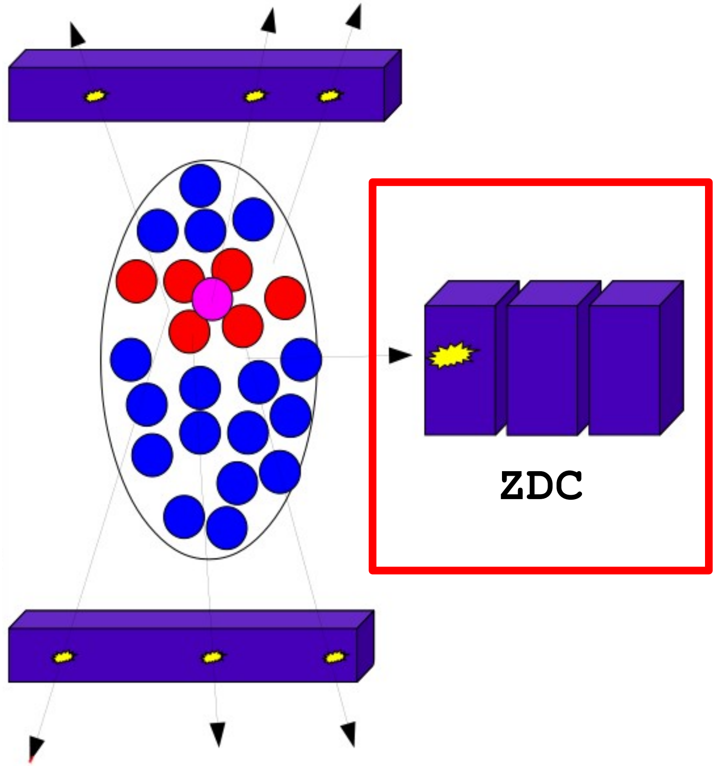
→ Bias when using estimators based on multiplicity (VZERO-A amplitude)

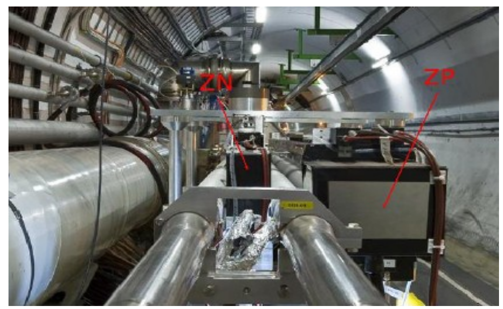
→ The range of multiplicities used to select the centrality in p–Pb collisions is of similar magnitude as the fluctuations

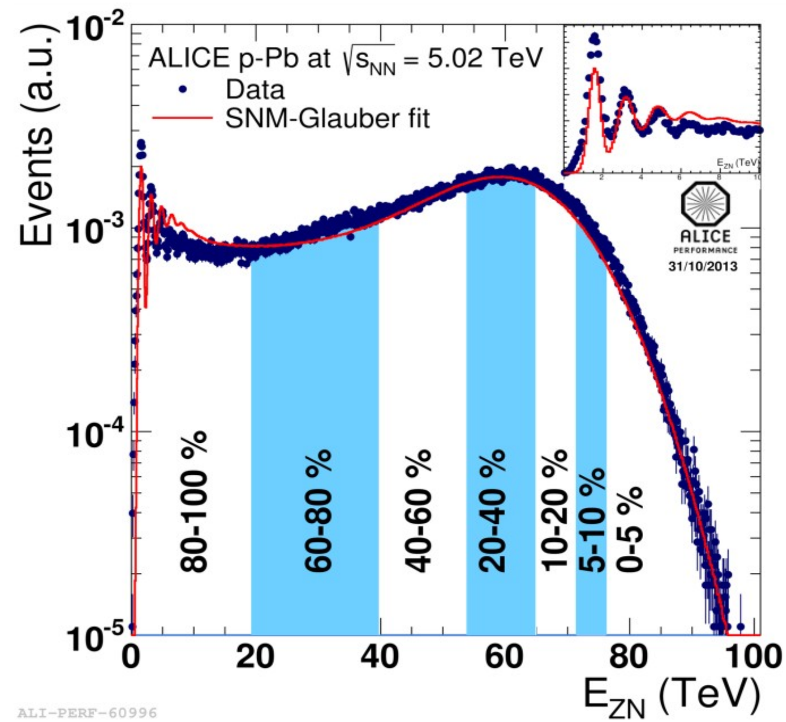
→ Centrality selection based on multiplicity may select a biased sample of nucleon-nucleon collisions

A.Toia's talk QM14

Centrality in p-Pb collisions (2)







- Zero Degree Calorimeters detect slow nucleons, which are monotonically related to N_{coll} (and can be used as centrality estimator)
- "Black" nucleons: $\beta < 0.25$, "gray" nucleons: $0.25 < \beta < 0.7$
- ZDC provide centrality estimation ~without biases, because of the large η-separation fromt the central part of ALICE
- Glauber + Slow Nuclear Model for Zero-Degree Energy

A.Toia's talk
QM14

ψ(2S) signal extraction

1) Fit of the opposite-sign dimuon invariant mass spectra:

→ Signal: extended Crystal Ball and pseudo-Gaussian functions

→ Background: variable width Gaussian and polynomial·exponential functions

→ ψ(2S) position and width are tied to the J/ψ:

$$m_{\psi(2S)} = m_{J/\psi} + (m^{MC}_{\psi(2S)} - m^{MC}_{J/\psi})$$

$$\sigma_{\psi(2S)} = \sigma_{J/\psi} \cdot (\sigma^{MC}_{\psi(2S)} / \sigma^{MC}_{J/\psi})$$

2) Systematic uncertainty on the signal extraction:

→ A large number of fits to the invariant mass spectra is performed using various combinations of signal shapes, background shapes, start/end point of the fit range

→ Final ψ(2S) yield is obtained as the average of the results of the fits

→ Systematic uncertainty on the signal is obtained as the RMS of the distribution

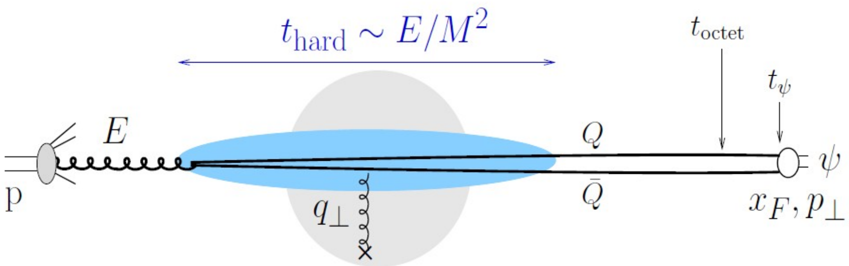
Shadowing (Int. J. Mod. Phys. E22 (2013) 1330007)

Results are obtained in the CEM at NLO in the total cross section. In the CEM, the quarkonium production cross section is a fraction F_C of all $Q\overline{Q}$ pairs below the $H\overline{H}$ threshold where H is the lowest mass heavy-flavor hadron:

$$\sigma_C^{\rm CEM}(s) = F_C \sum_{i,j} \int_{4m^2}^{4m_H^2} ds \int dx_1\, dx_2\; f_i^p(x_1,\mu_F^2)\; f_j^p(x_2,\mu_F^2)\; \hat\sigma_{ij}(\hat s,\mu_F^2,\mu_R^2)$$

- → $ij = q\overline{q}$ or gg
- → $\hat\sigma_{ij}(\hat s)$ is the $ij \to Q\overline{Q}$ subprocess cross section
- → F_C is fit to the forward J/ψ cross section data on only p , Be, Li, C, and Si targets

Energy loss (JHEP 1303 (2013) 122)



The heavy quark $Q\bar{Q}$ pair of mass M is produced in a color octect state within the time $\tau_{Q\bar{Q}} \sim 1/M$ and remain color octet for a time $\tau_{octect} >> \tau_{Q\bar{Q}}$

The $Q\bar{Q}$ pair arises from the splitting of an incoming gluon, followed by a rescattering in the nucleus

$$\omega \frac{dI}{d\omega} = \frac{N_c \alpha_s}{\pi} \left\{ \ln\left(1 + \frac{\ell^2_{\perp A} E^2}{M^2_\perp \omega^2}\right) - \ln\left(1 + \frac{\Lambda^2_p E^2}{M^2_\perp \omega^2}\right) \right\} \Theta(\ell^2_{\perp A} - \Lambda^2_p)$$

→ $\Delta q^2_\perp \equiv \ell^2_\perp \simeq \hat{q}\, L$ momentum broadening through the nucleus A, $M_\perp = (M^2 + p^2_\perp)^{\frac{1}{2}}$ transverse mass of the $Q\bar{Q}$ pair and $\Lambda^2_p = \max(\Lambda^2_{QCD}, \ell^2_{\perp p})$

→ Average energy loss: $\Delta E \propto E$.

→ Energy loss is coherent: neither a purely initial nor final state effect

→ $\hat{q}_0 = 0.075 \pm 0.005\ \mathrm{GeV}^2/\mathrm{fm}$: transport coefficient, is the only parameter, extracted from E866 data

Interactions with comovers (arXiv:1411.0549)

The rate equation that governs the density of charmonium at a given transverse coordinate *s*, impact parameter *b* and rapidity *y* obeys the expression:

$$\tau \frac{d\rho^{\psi}}{d\tau}(b,s,y) = -\sigma^{co-\psi}\,\rho^{co}(b,s,y)\,\rho^{\psi}(b,s,y)$$

$\sigma^{co-\psi}$ is the cross section of charmonium dissociation due to interactions with the comoving medium of transverse density $\rho^{co}(b,s,y)$

$$S^{co}_{\psi}(b,s,y) = \exp\left\{-\sigma^{co-\psi}\,\rho^{co}(b,s,y)\,\ln\left[\frac{\rho^{co}(b,s,y)}{\rho_{pp}(y)}\right]\right\}$$

$S^{co}_{\psi}(b,s,y)$ is the survival probability of the resonance interacting with comovers (the interaction stops when the densities have diluted, reaching the value of the p+p density at the same energy)

$$\rho^{co}(b,s,y) = n(b,s)\,S^{sh}_{co}(b,s)\,\frac{3}{2}(dN^{pp}_{ch}/dy)$$

- $n(b,s)$ number of binary nucleon-nucleon collisions per unit transverse area at given impact parameter
- S^{sh}_{co} shadowing of the parton distribution functions in a nucleus that aects the comover multiplicity
- 3/2 factor to account for neutral comovers
- $\rho_{pp}(y) = \frac{3}{2}(dN^{pp}_{ch}/dy)/\pi R^2_p$ (comover density in pp) R_p is the proton radius

τ_c (PRC 87, 054910,2013)

Average time the $c\bar{c}$ pair spends in the nucleus for several experiments and targets

Experiment	$\sqrt{s_{NN}}$ (GeV)	A	y_{beam}	y_{cm}	L (fm)	$\langle p_T \rangle$ GeV/c	τ (fm/c)
PHENIX	200	Au	5.36	-2.08-2.32	4.36	1.90	0.283 - 0.0035
HERA-B	41.6	W	7.58	0.0	4.26	1.36	0.178
E866	38.8	W	7.44	-0.39-2.1	4.26	1.32	0.283 - 0.024
NA50	29.1	W	6.87	0.0	4.26	1.22	0.258
NA50	27.4	Pb	6.75	0.0	4.44	1.20	0.286
NA3	19.4	Pt	6.06	0.0	4.34	1.14	0.396
NA60	17.3	Pb	5.82	0.3	4.44	1.12	0.339