Quarkonium production in ALICE at the LHC

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on behalf of the ALICE Collaboration

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Quarkonium production in ALICE at the LHC

- Probing Quark Gluon Plasma and Cold Nuclear Matter with quarkonia
- First p-Pb measurements at $\sqrt{s_{NN}}$ = 5.02 TeV: J/ψ, ψ(2S) and ϒ(1S)
- Latest Pb-Pb measurements at $\sqrt{s_{NN}}$ = 2.76 TeV: J/ψ and ϒ(1S)

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pp measurements not covered!

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ALICE presentations on quarkonia:

Michael Winn	*Inclusive J/ψ and ψ(2S) production in p-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV*
Francesco Bossù	*ϒ production measurements with ALICE at the LHC*
Igor Lakomov	*Event multiplicity studies of J/ψ production in p-Pb collisions with ALICE at the LHC* (POSTER)

Probing the QGP with quarkonia

Properties of quarkonium states

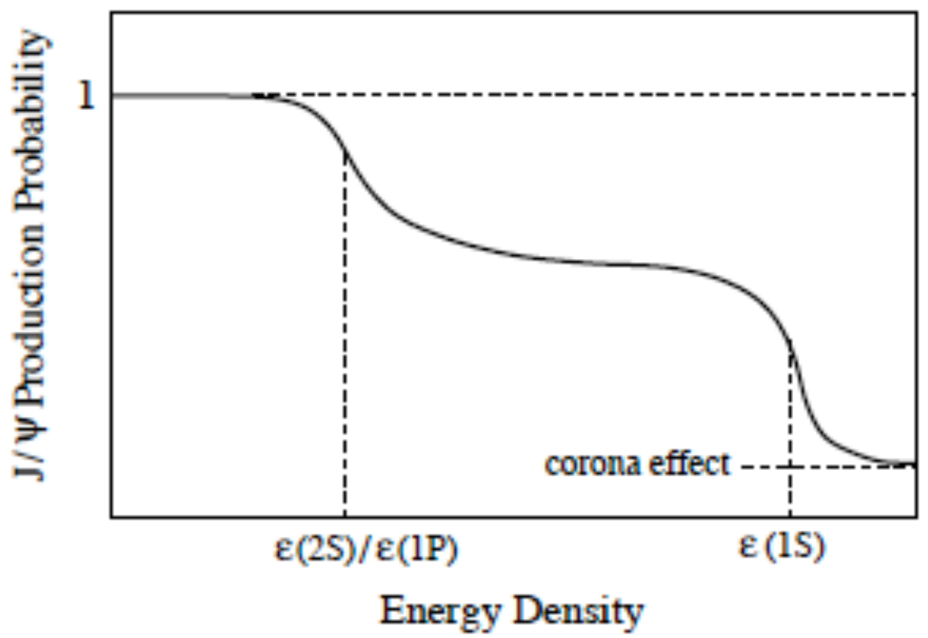
- bound states of heavy quark and anti-quark
- stable and tightly bound
- heavy quark pairs produced in the initial hard partonic collisions ($\tau \simeq 1/\, m_Q \simeq$ 0.05-0.15 fm/c)

From sequential suppression...

- at $T >> 0$, high density of colour charge in the medium induces Debye screening
- at $T > T_D$, melting of quarkonia *Matsui, Satz PLB178(1986)*
- since quarkonia have different binding energy

$\rightarrow$ sequential suppression of quarkonium states *Karsch, Satz Z.Phys.C51 (1991) 209*

prompt J/ψ in pp ≃ 60% direct J/ψ + 30% χ_C + 10% ψ(2S)



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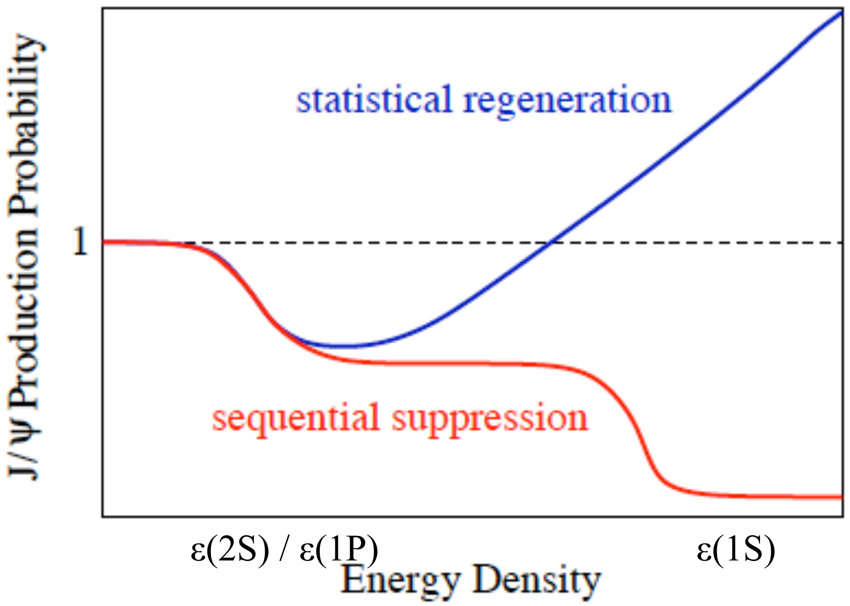


... to regeneration

- total charm cross-section increases with energy
- c and c̄ combination in the QGP or at the phase boundary
  → regeneration of J/ψ
  Braun-Munzinger, Stachel PLB490(2000) *Thews et al. PRC62(2000)*
  ➡ enhancement (depending on open charm cross-section) of J/ψ
  ➡ evidence of thermalization of charm quarks
  ➡ J/ψ inherits charm elliptic flow
- no/small regeneration expected for bottomonia

$$\frac{N_{q\bar{q}}}{event} = \frac{\sigma^{pp}_{q\bar{q}}}{\sigma^{pp}_{inel}} \times N_{coll}$$

ALICE, JHEP 1207 (2012) 191

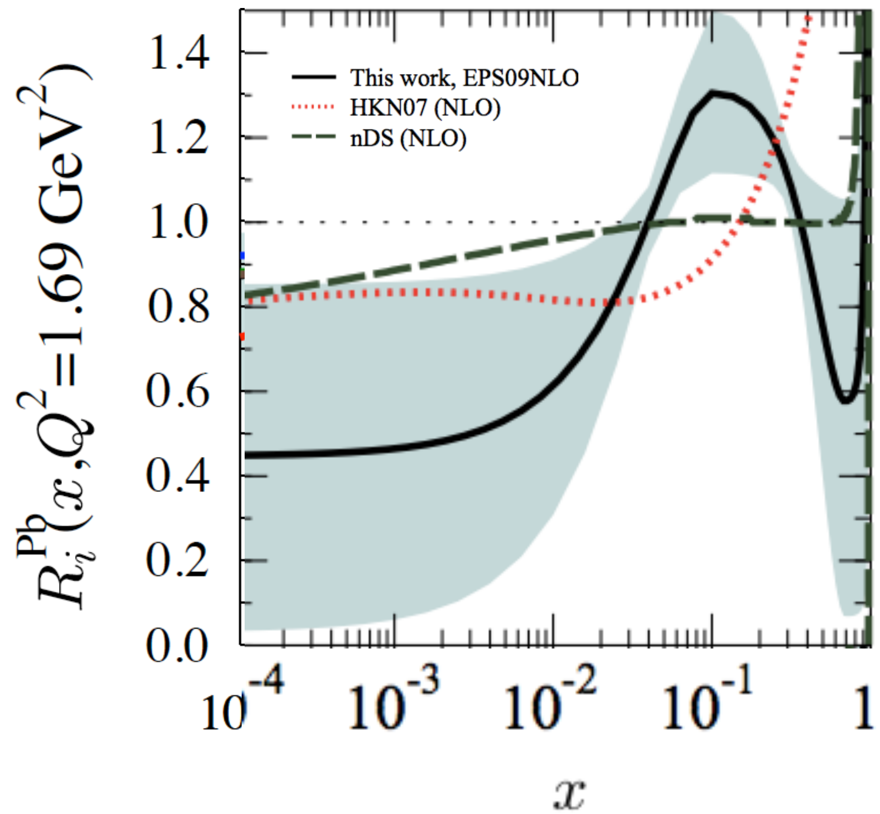
In most central collisions [0-10%]	RHIC 200 GeV	LHC 2.76 TeV
N_{cc}/event	13	115
N_{bb}/event	0.1	3

Effects from cold nuclear matter (CNM)

- Nuclear shadowing (nPDF) or gluon saturation in the nucleus

- Multiple elastic scatterings of partons in the initial state (Cronin effect)

K. Eskola et al., JHEP 0904:065 (2009)

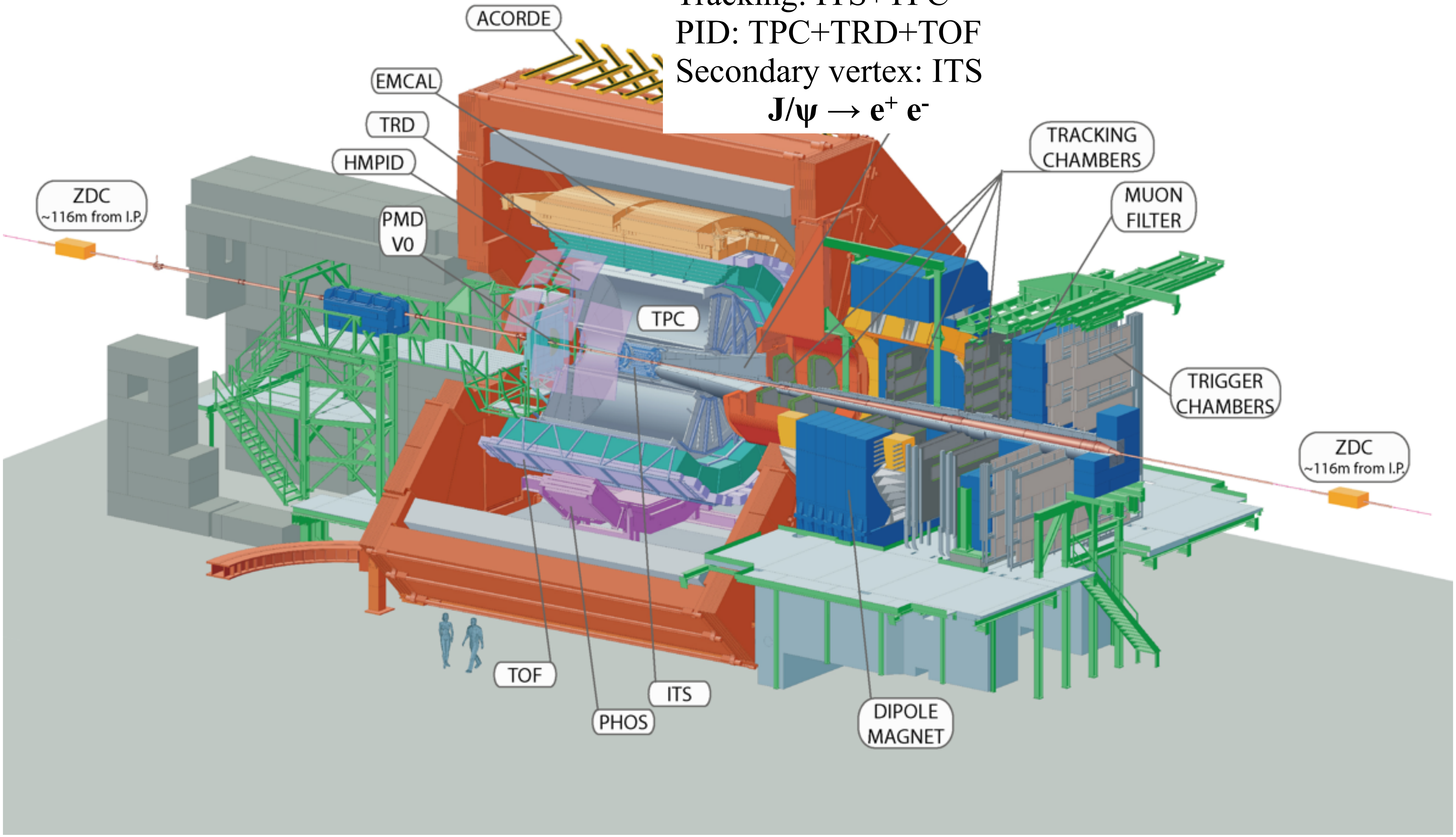


- Coherent induced gluon radiation between initial/final state

- Breakup of quarkonia by collisions with nucleons (nuclear absorption): expected to be small at LHC since the quarkonium formation time is much larger than the crossing time of the colliding nuclei for most of the rapidity range

Quarkonium detection in ALICE

Central barrel: |η| < 0.9
Tracking: ITS+TPC
PID: TPC+TRD+TOF
Secondary vertex: ITS
$J/\psi \rightarrow e^+ e^-$



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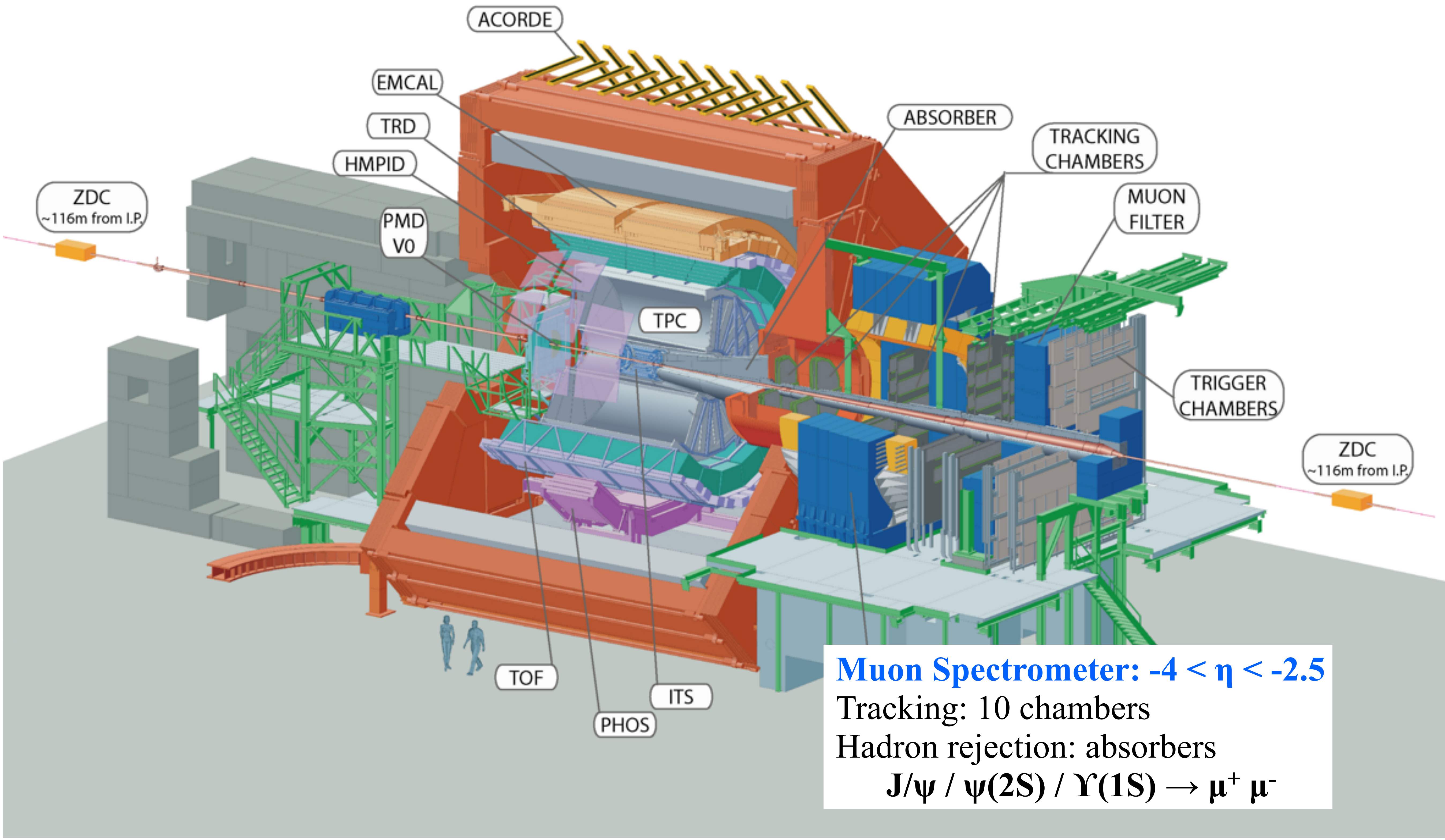


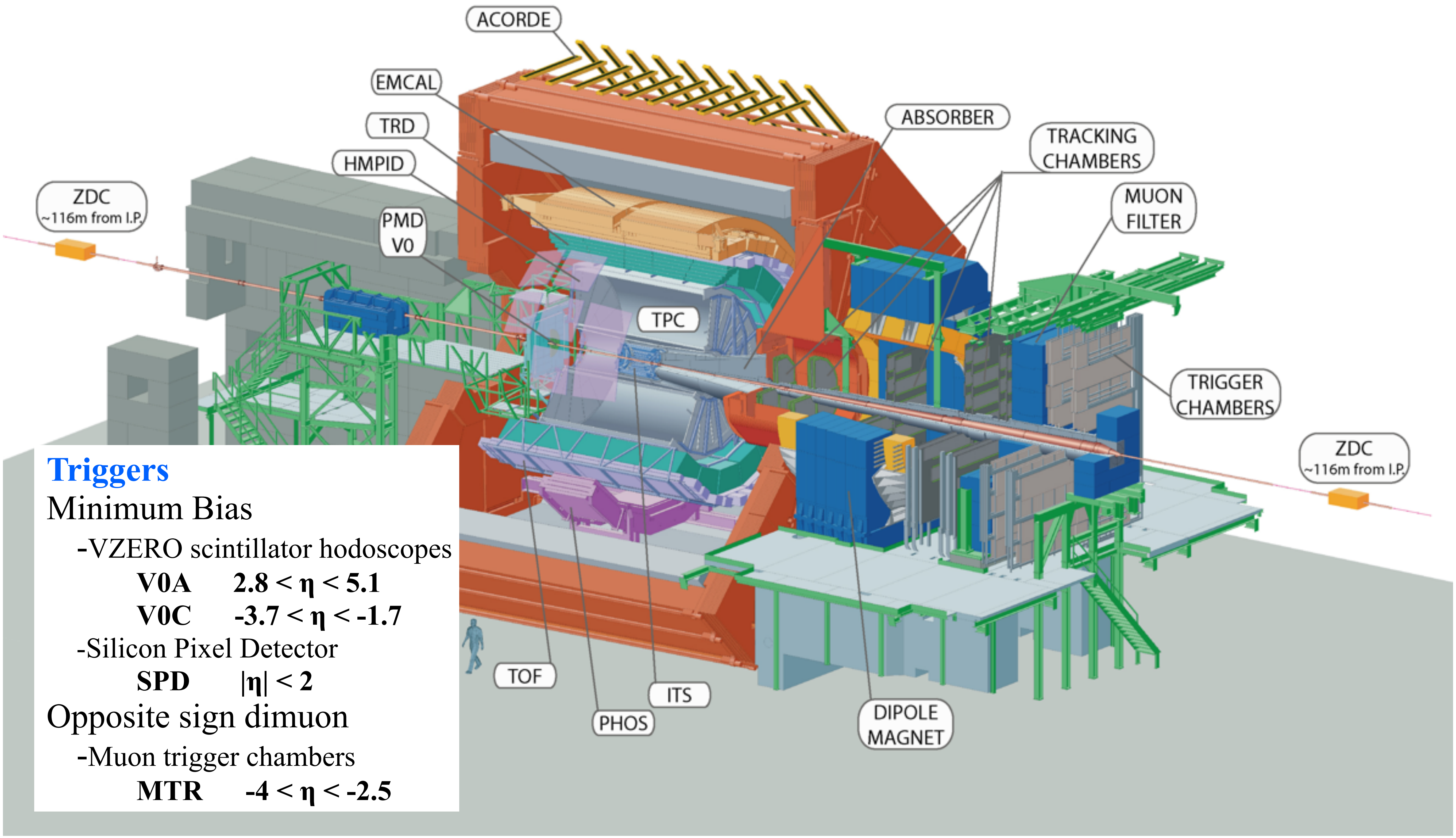
Muon Spectrometer: $-4 < \eta < -2.5$

Tracking: 10 chambers

Hadron rejection: absorbers

J/ψ / $\psi(2S)$ / $\Upsilon(1S) \rightarrow \mu^+ \mu^-$

Quarkonium detection in ALICE



Triggers

Minimum Bias

- -VZERO scintillator hodoscopes
  - **V0A** $2.8 < \eta < 5.1$
  - **V0C** $-3.7 < \eta < -1.7$
- -Silicon Pixel Detector
  - **SPD** $|\eta| < 2$

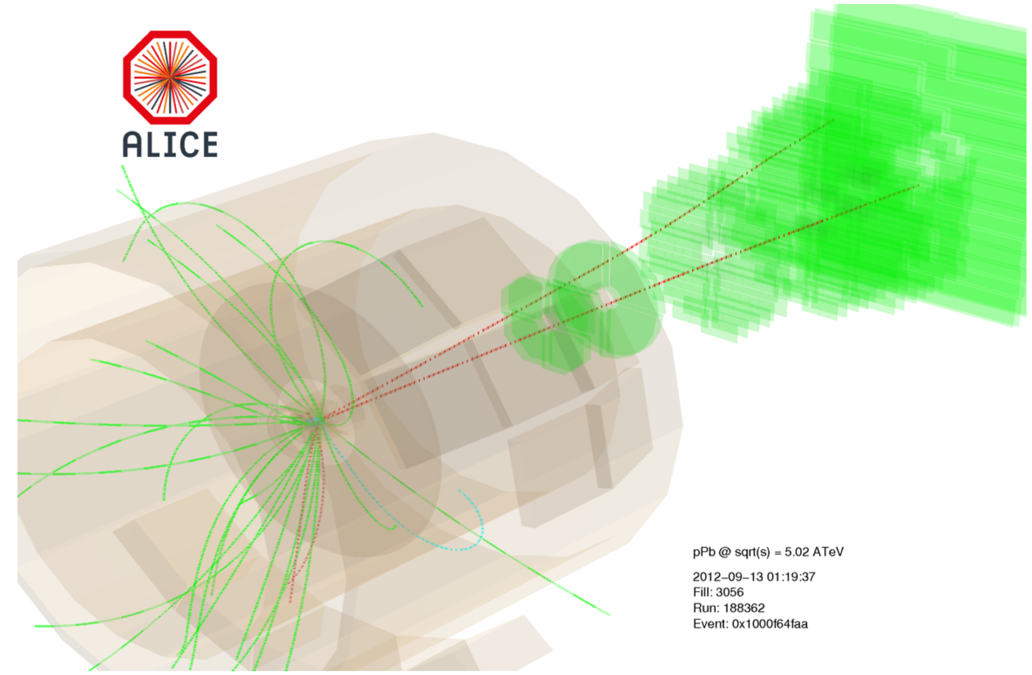
Opposite sign dimuon

- -Muon trigger chambers
  - **MTR** $-4 < \eta < -2.5$

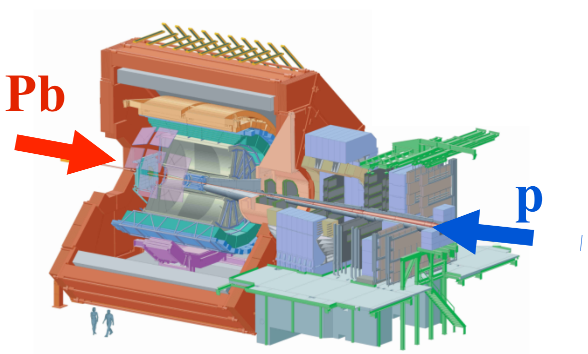
p-Pb measurements

Jan/Feb. 2013 data sample

- p (E_p = 4 TeV) + Pb (E_{Pb} = 1.58 A·TeV) collisions at $\sqrt{s_{NN}}$ = 5.02 TeV: center of mass shifted in rapidity in the proton beam direction by Δy = 0.465
- 2 beam configurations (p-Pb and Pb-p): two rapidity ranges for the Muon Spectrometer



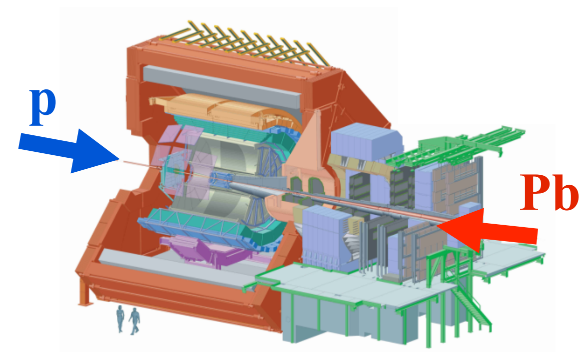
Pb-p



Muon Spectrometer in Pb-going side
Backward rapidity: $-4.46 < y_{cms} < -2.96$

$x^*_{Pb} \simeq 10^{-2} - 10^{-1}$

p-Pb



Muon Spectrometer in p-going side
Forward rapidity: $2.03 < y_{cms} < 3.53$

$x^*_{Pb} \simeq 10^{-5} - 10^{-4}$

Mid-rapidity: $-1.37 < y_{cms} < 0.43$

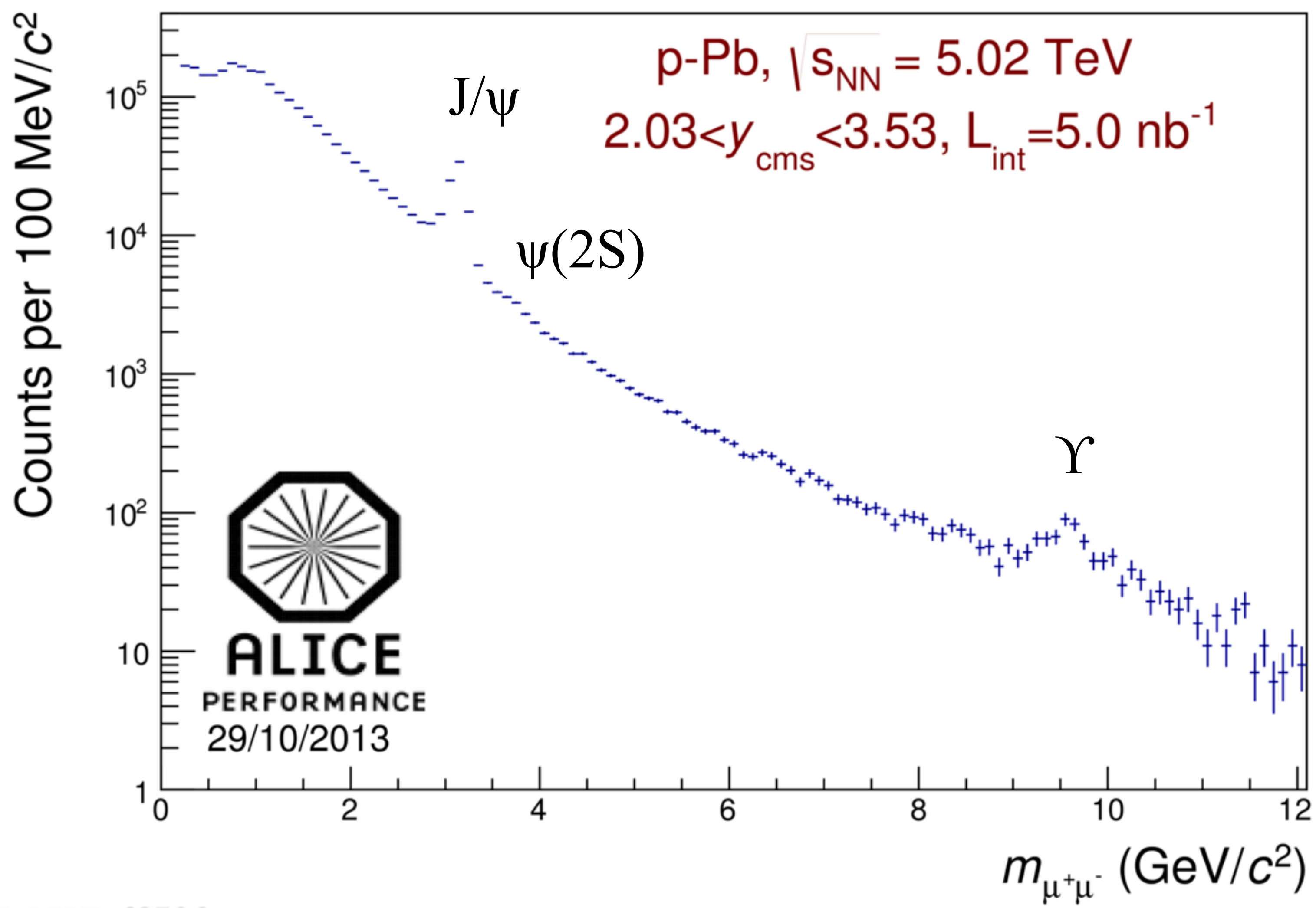
$x^*_{Pb} \simeq 10^{-3}$

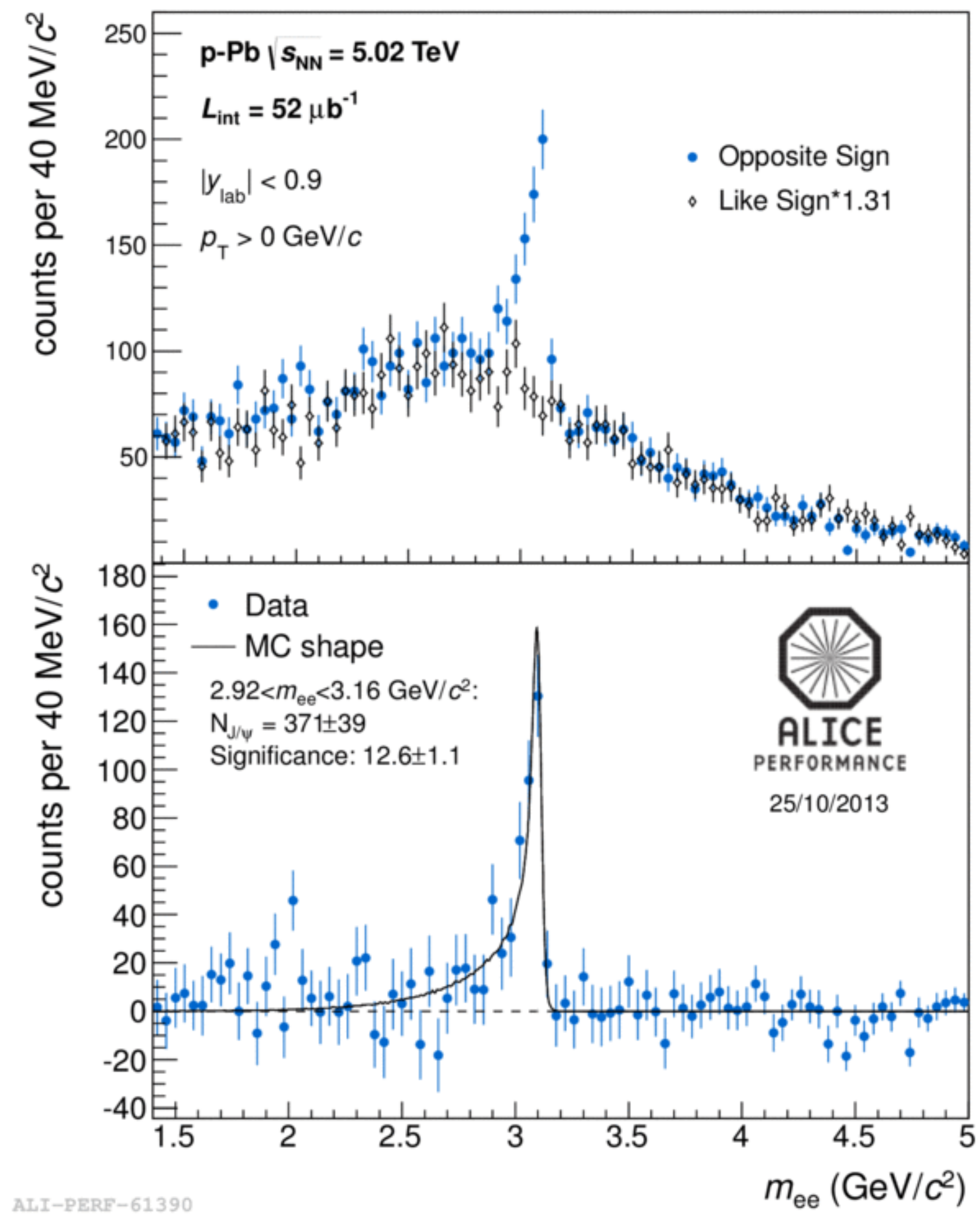
* Momentum fraction of probed gluons in nucleus assuming 2→1 J/ψ / ϒ production mechanism

p-Pb measurements

Triggers

- Minimum Bias (VZERO)
  - 99% efficiency for non single diffractive events
  - p-Pb: L_{int} ($-1.37 < y_{cms} < 0.43$) = 52 μb^{-1}
- Opposite-sign dimuon (VZERO+MTR)
  - p-Pb: L_{int} ($2.03 < y_{cms} < 3.53$) = 5.0 nb^{-1}
  - Pb-p: L_{int} ($-4.46 < y_{cms} < -2.96$) = 5.8 nb^{-1}





Probing cold nuclear matter: observables

Nuclear modification factor R_{pPb}

$$R_{pPb} = \frac{Y_{J/\psi \to \mu\mu}}{\langle T_{pPb} \rangle \, \sigma^{pp}_{J/\psi \to \mu\mu}} \qquad Y_{J/\psi \to \mu\mu} = \frac{N_{J/\psi \to \mu\mu}}{N_{MB} \, A \, \epsilon}$$

No pp reference at $\sqrt{s}$ = 5.02 TeV

→ energy interpolation, rapidity and p_{T} interpolation/extrapolation

→ strategy of interpolation analysis depending on the measurements

→ systematics associated are important

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→ energy interpolation, rapidity and p_{T} interpolation/extrapolation

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Forward to Backward ratio

$$R_{FB}(|y_{cms}|) = \frac{R_{pPb}(y_{cms})}{R_{pPb}(-y_{cms})} = \frac{Y_{pPb}(y_{cms})}{Y_{pPb}(-y_{cms})}$$

pp reference cancels out

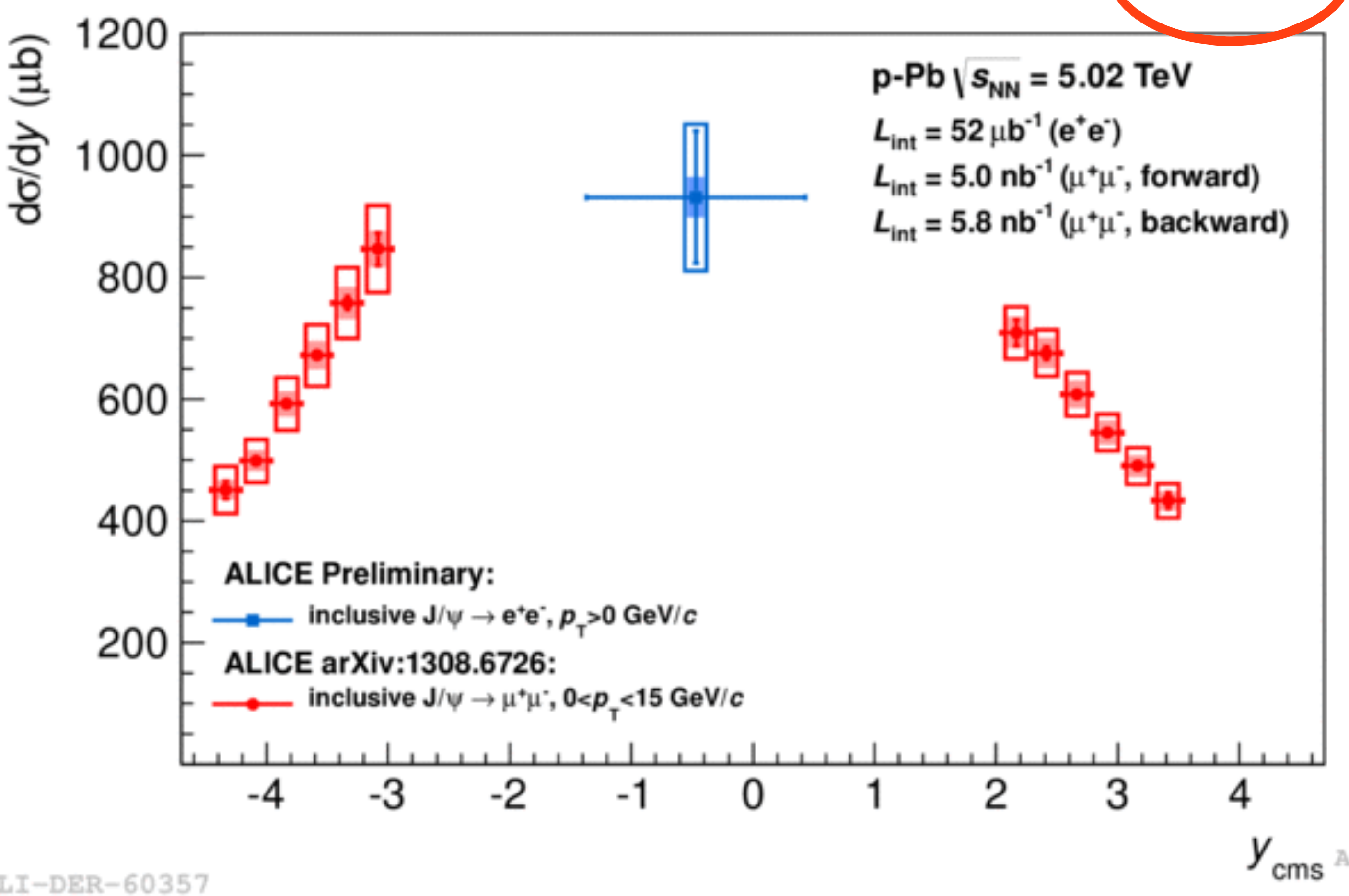
Rapidity range restricted to common range ($2.96<|y_{\mathrm{cms}}|<3.53$): loss of statistics

Comparison to theory is less stringent than R_{pPb}

J/ψ cross-sections vs y and p_T

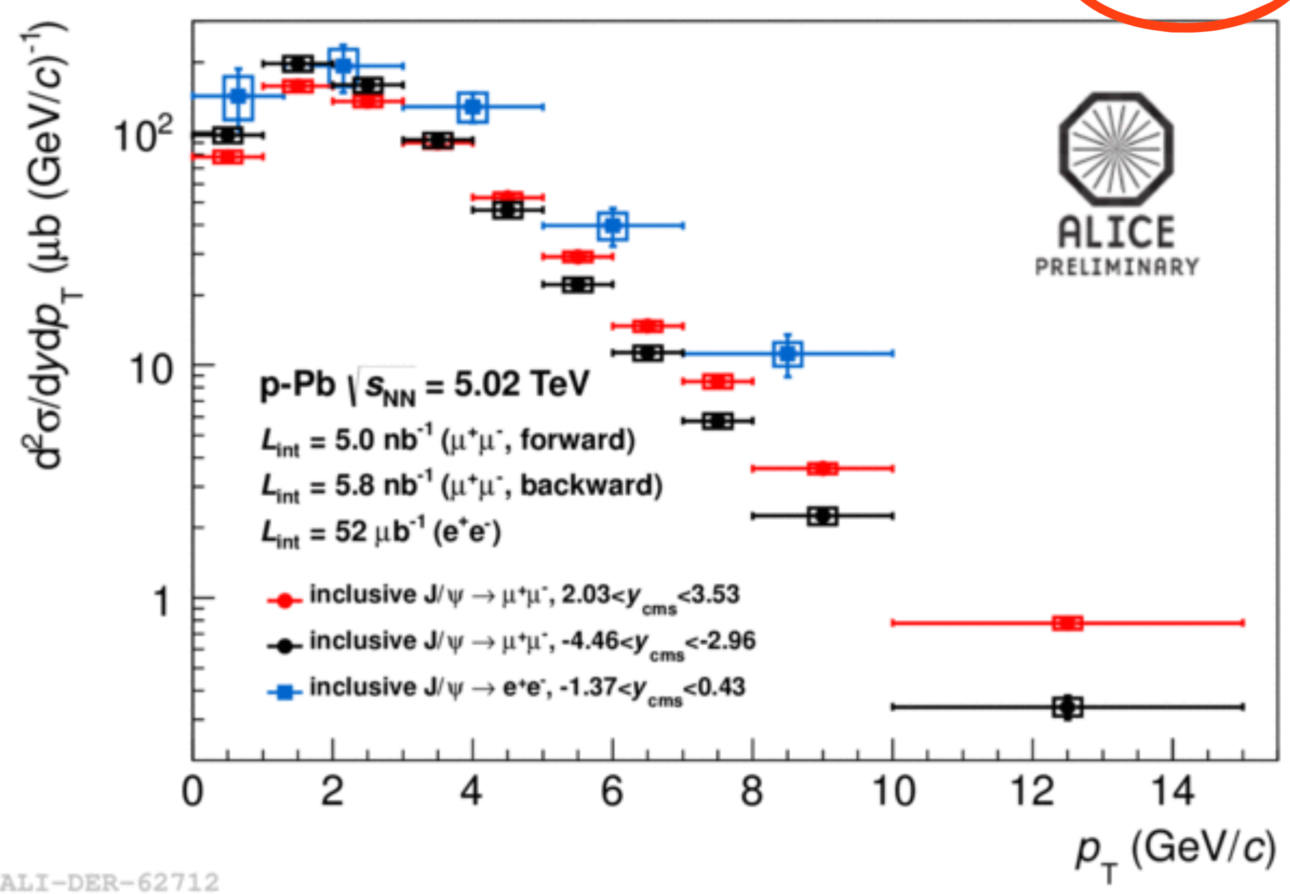
$$\sigma_{J/\psi} = \frac{N_{J/\psi \to l^+ l^-}}{L_{int}\, A\, \epsilon\, BR_{J/\psi \to l^+ l^-}}$$

New



Systematic uncertainties
boxes: uncorrelated
shaded area: (partially) correlated

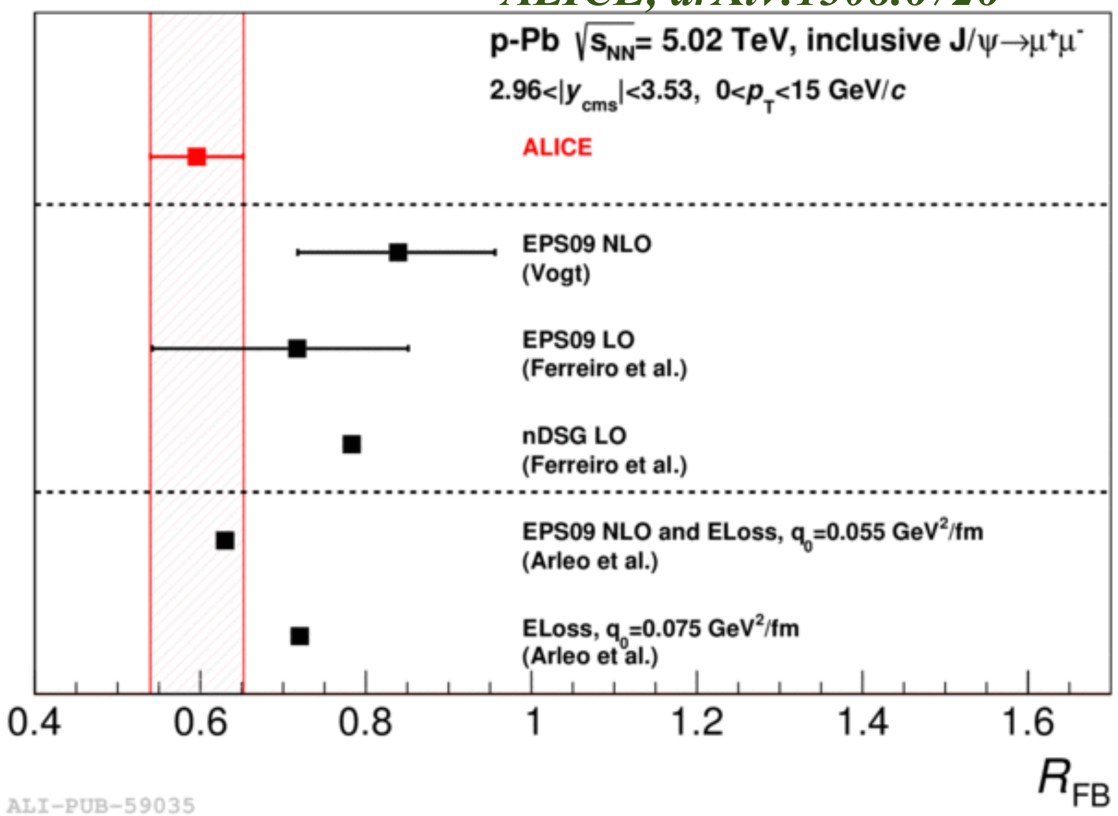
New

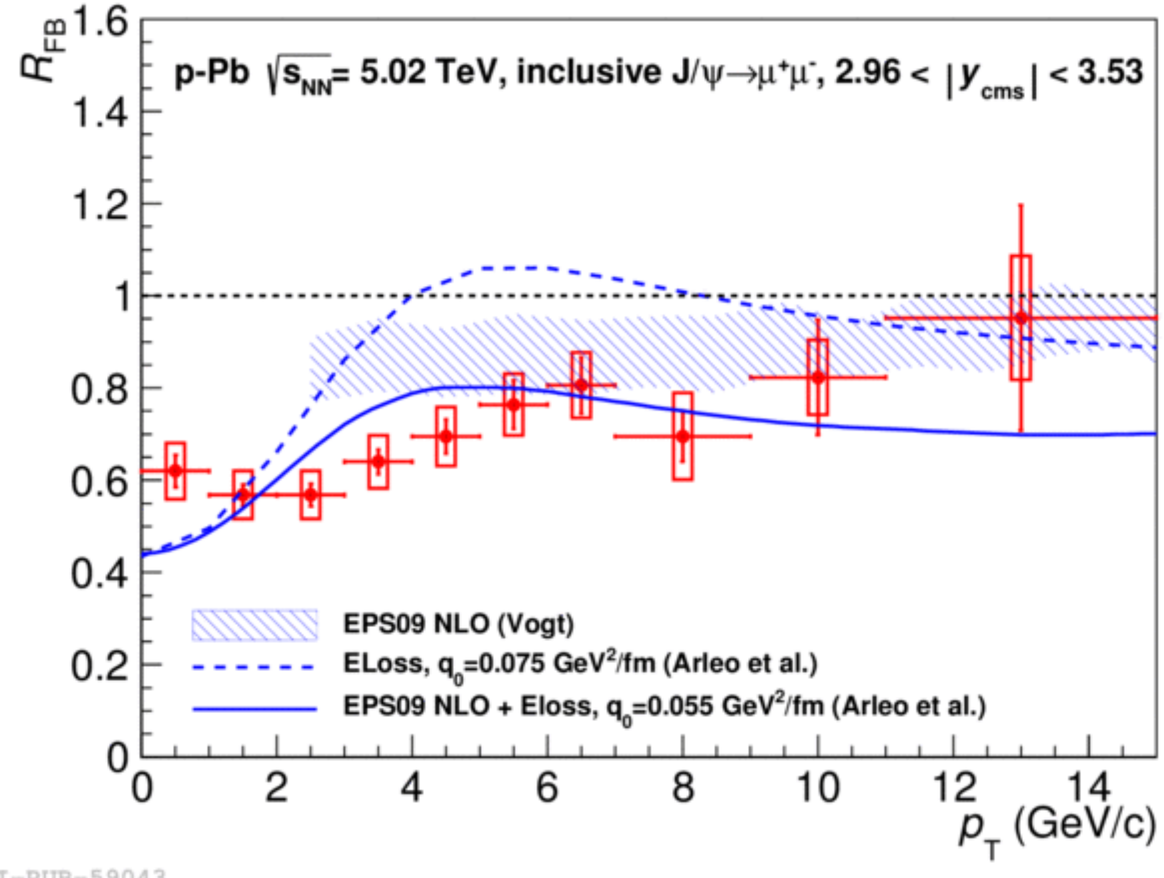


Forward rapidity: lower cross-sections and harder in p_T than at backward rapidity

J/ψ R_{FB} integrated and vs p_T

ALICE, arXiv:1308.6726





R_{FB} decreases at low p_T down to 0.6 and is consistent with unity for $p_T > 10$ GeV/c

B feed-down does not contribute much to this ratio

LHCb, arXiv:1308.6929

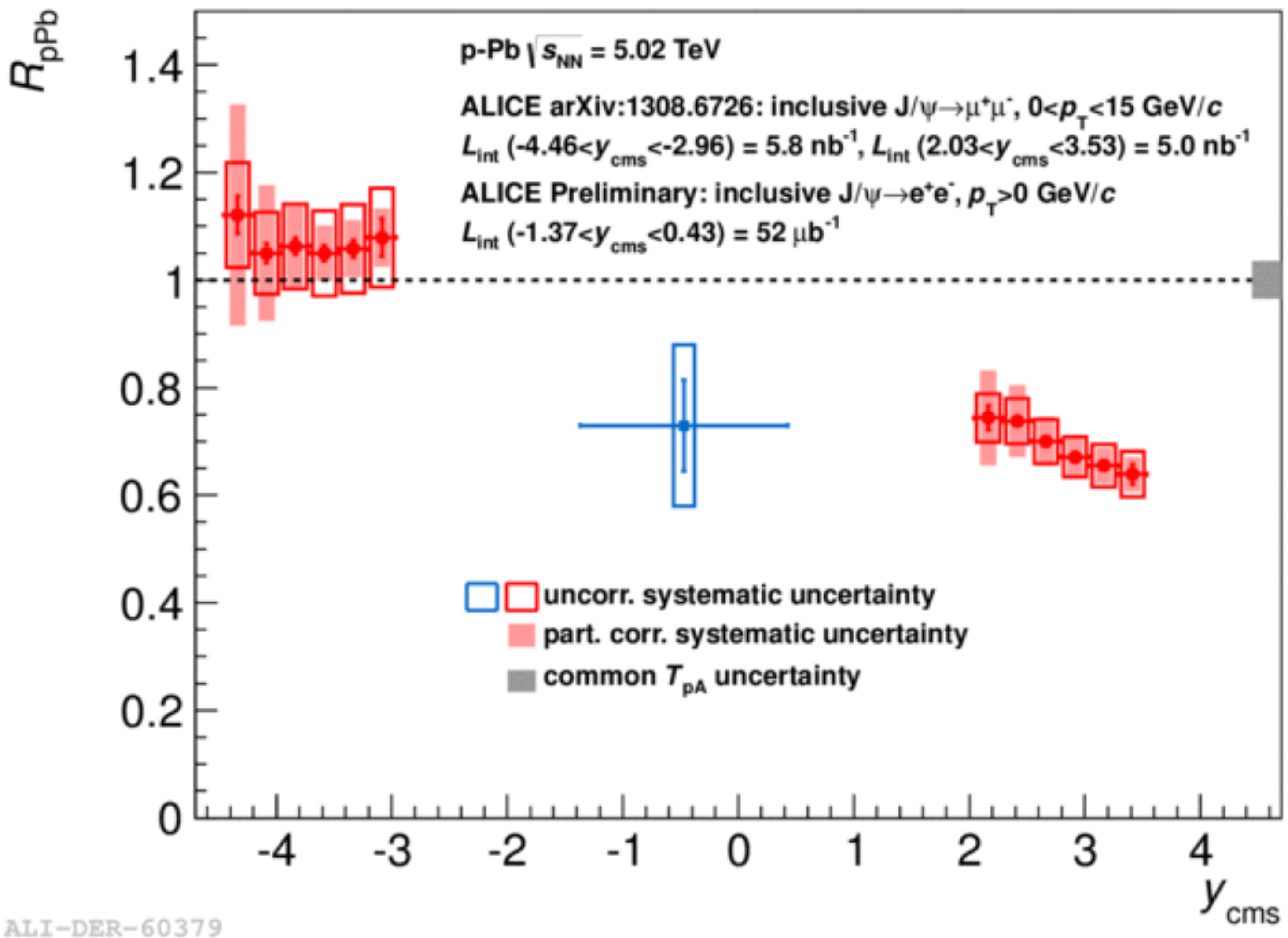
Models:

- Shadowing model CEM + EPS09 NLO (Vogt, arXiv:1301.3395)
- Shadowing model CSM + EPS09/nDSG LO (Ferreiro et al., arXiv:1305.4569)
- Coherent energy loss (Arleo et al., arXiv:1212.0434) with pp data parametrization

Pure shadowing models tend to overestimate the data

Shadowing + energy loss model reproduces fairly well the data but with a steeper p_T dependence at low p_T

J/ψ R_{pPb} vs rapidity



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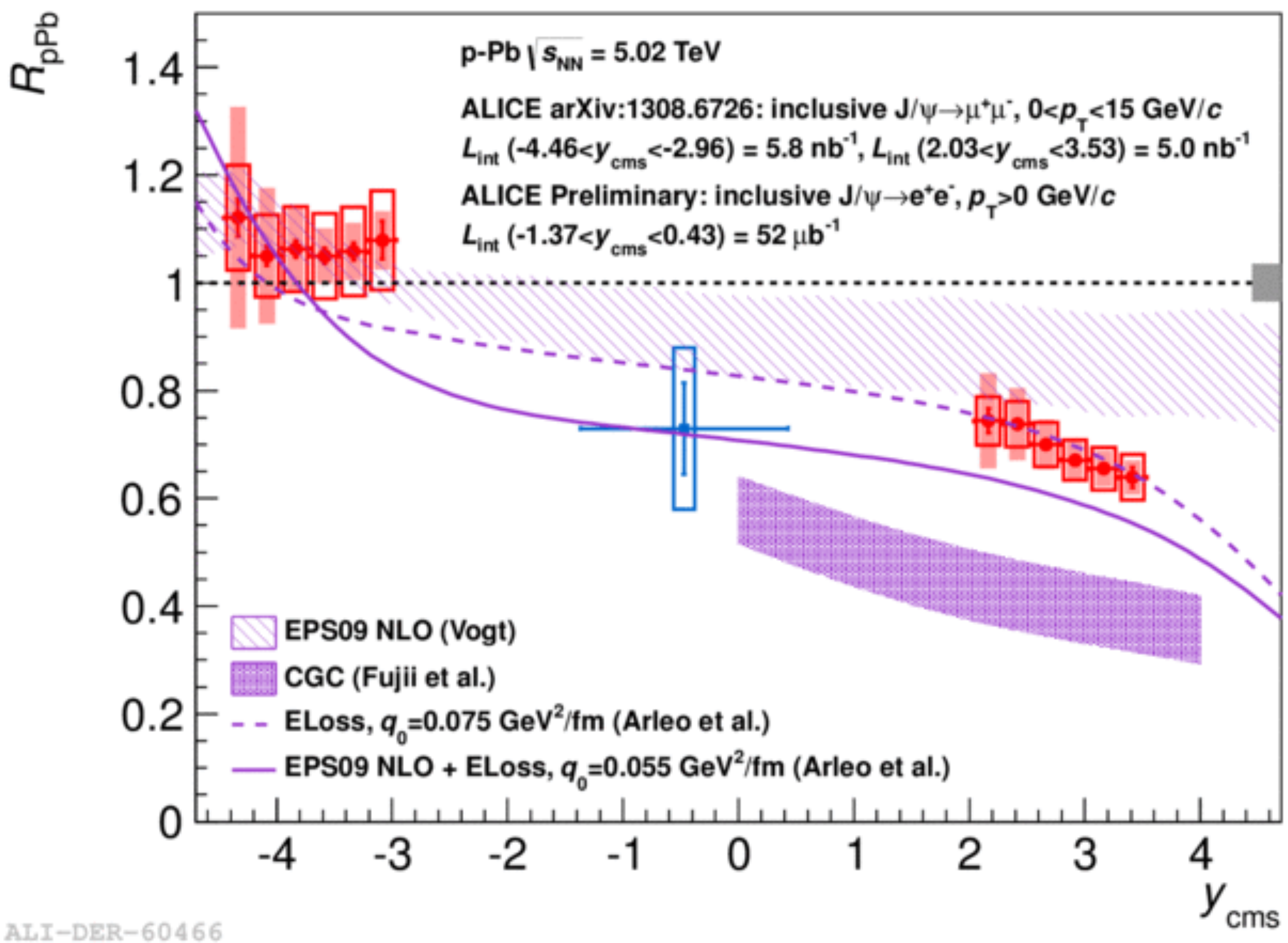

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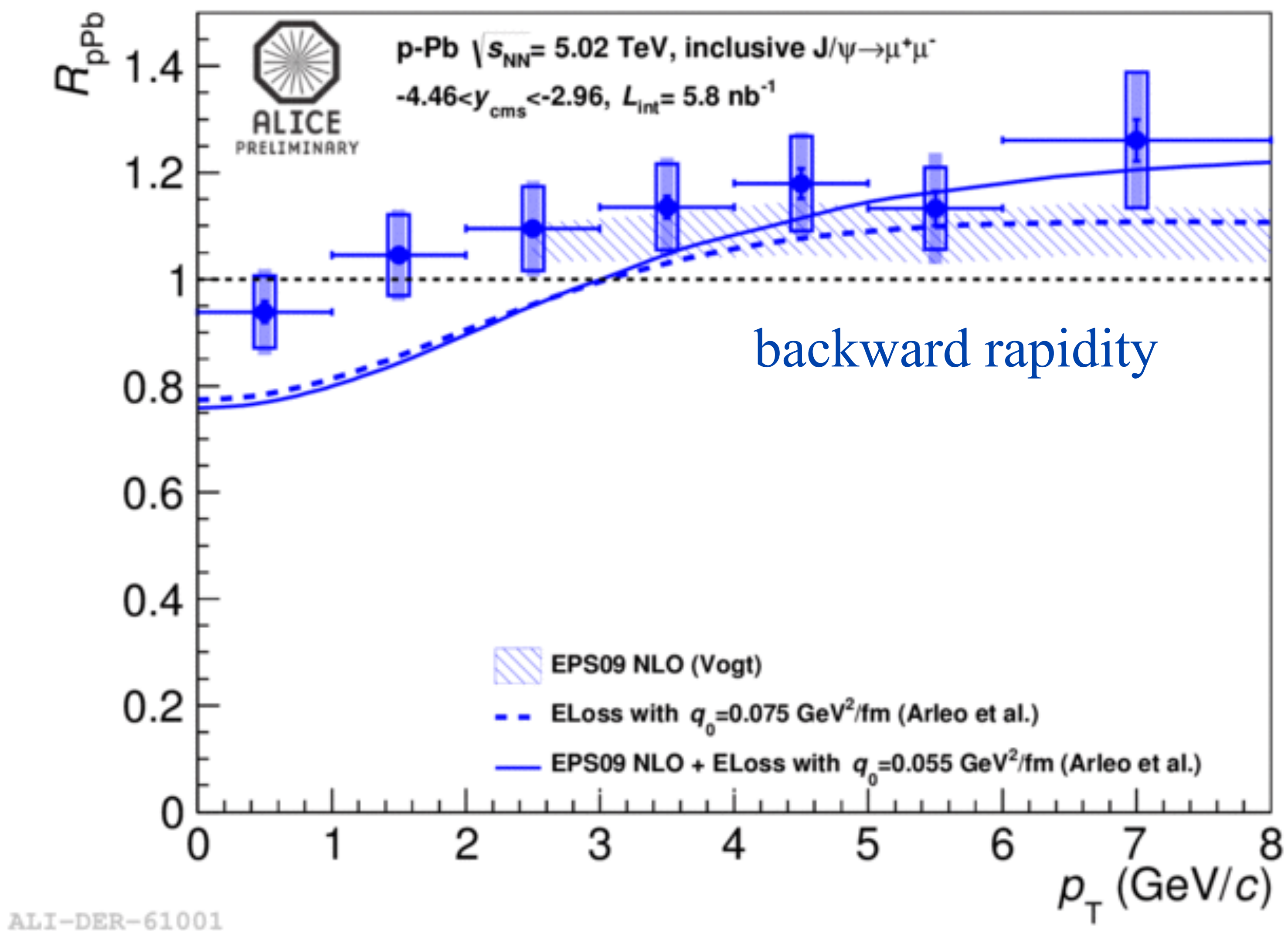
Models
- Shadowing model CEM + EPS09 NLO (Vogt, arXiv: 1301.3395)
- Coherent energy loss (Arleo et al., arXiv:1212.0434) with pp data parametrization
- Gluon saturation (Fuji et al., arXiv: 13042221): Color Glass Condensate framework with CEM LO with saturation scale $Q^2_{s,A}(x = 0.01)$= 0.7-1.2 GeV/c²

Shadowing: backward rapidity data well reproduced, strong shadowing favoured at forward rapidity
Coherent energy loss: y-dependence well reproduced, better agreement with pure energy loss
CGC calculations underestimate the data

J/ψ R_{pPb} vs transverse momentum

New



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Backward rapidity

R_{pPb} shows a small p_T dependence and is close to unity

J/ψ R_{pPb} vs transverse momentum

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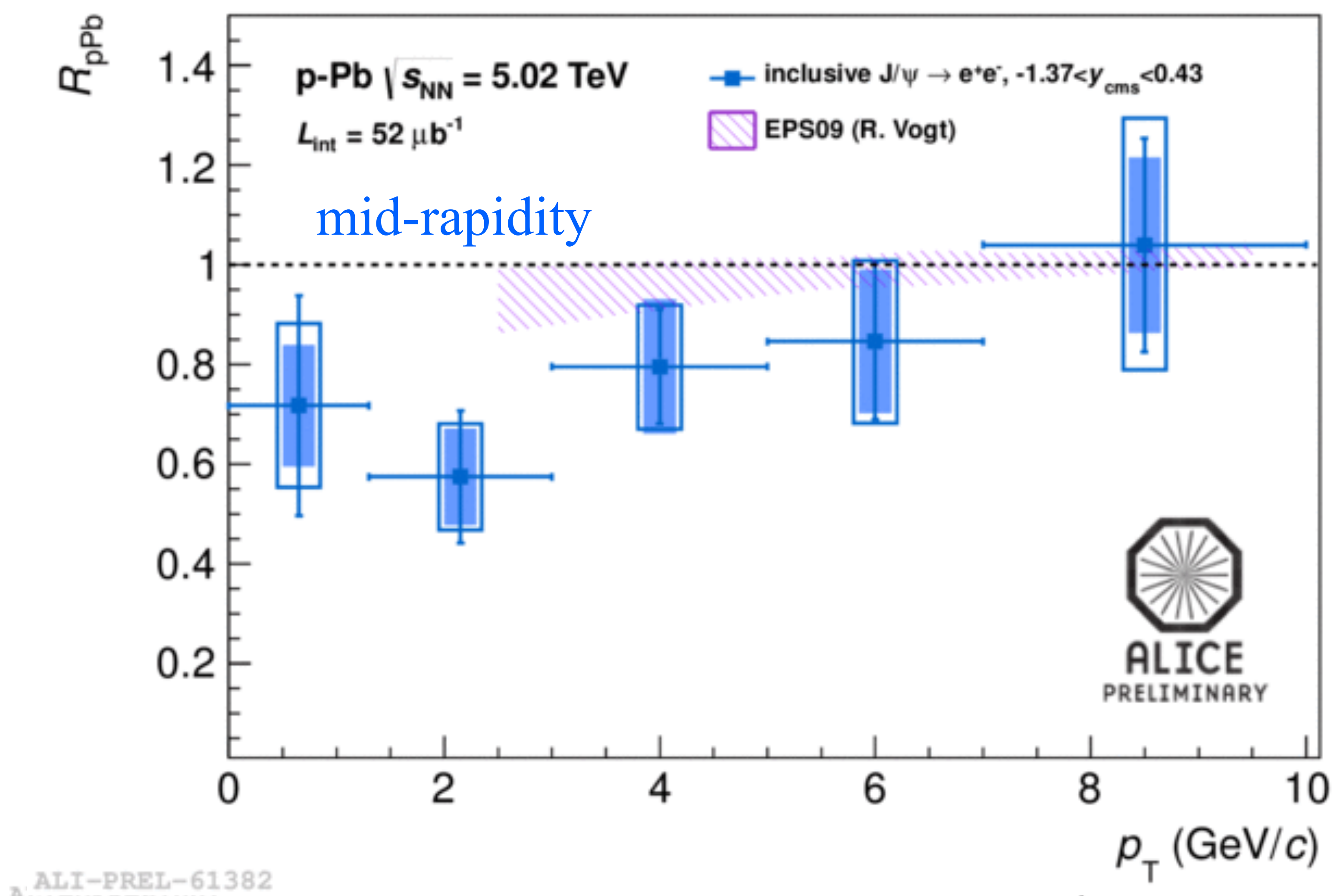

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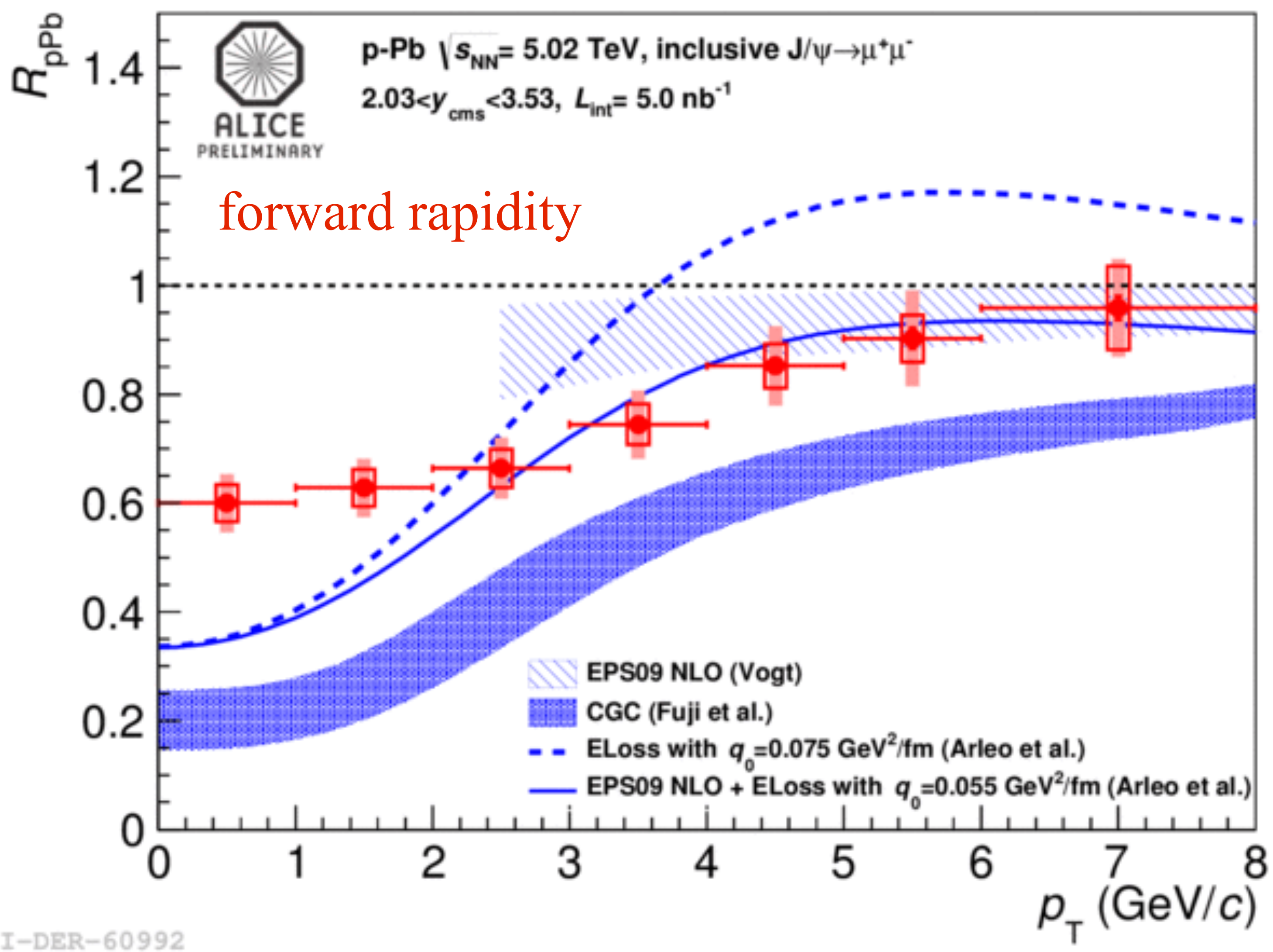
Backward rapidity
- R_{pPb} shows a small p_T dependence and is close to unity

Mid rapidity
- R_{pPb} tends to increase with p_T

J/ψ R_{pPb} vs transverse momentum

New



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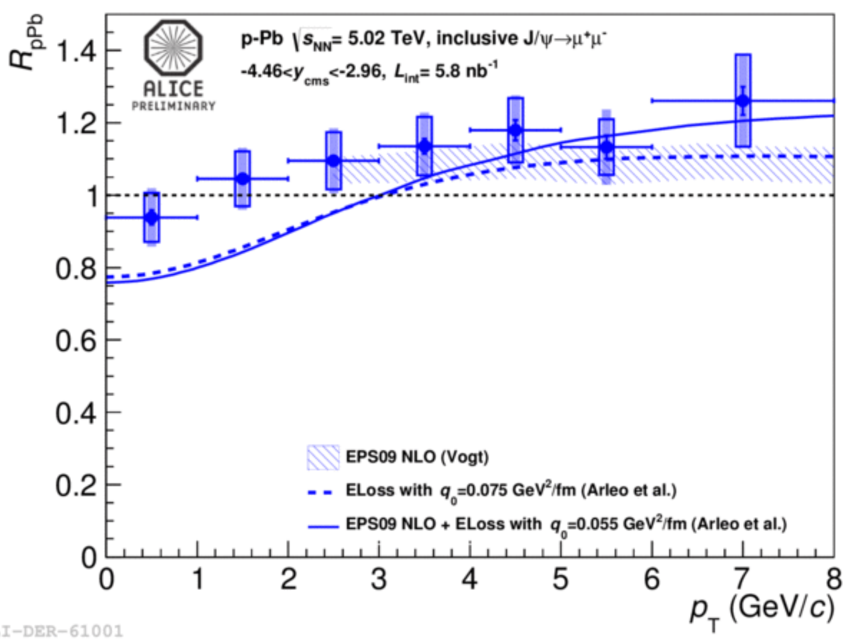
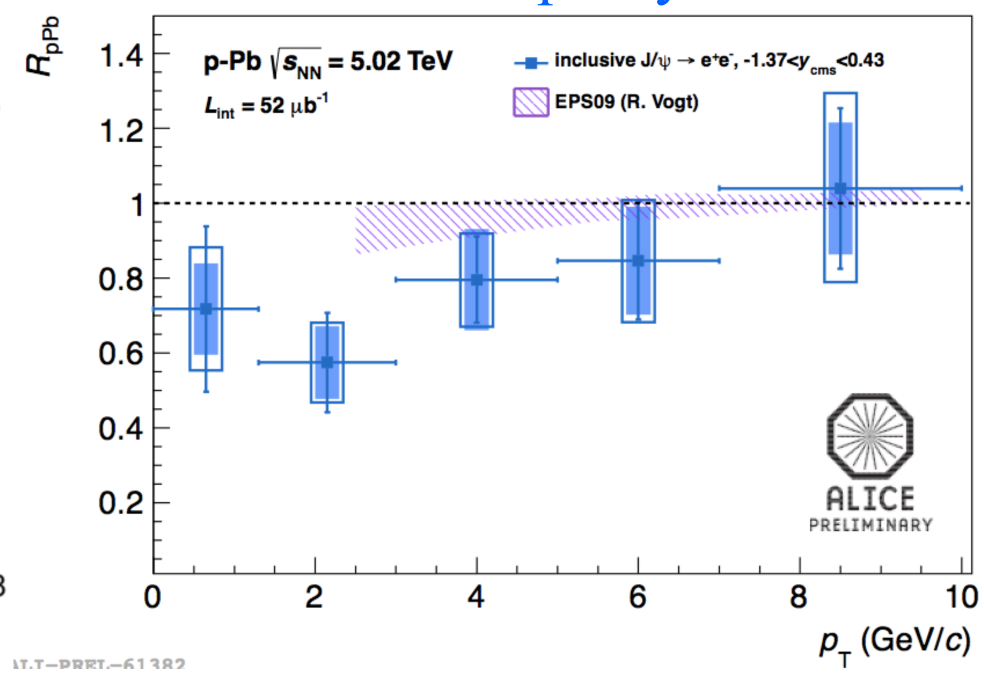
Forward rapidity
R_{pPb} increases with p_T and is compatible with unity for p_T larger than 5 GeV/c

J/ψ R_{pPb} vs transverse momentum New

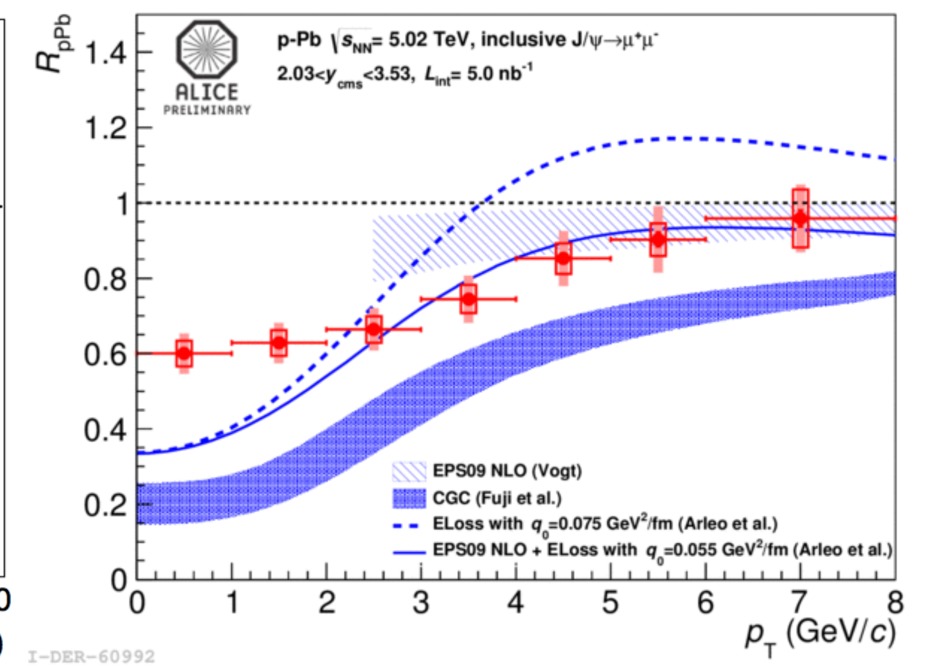
backward rapidity



mid-rapidity



forward rapidity



Backward rapidity

R_{pPb} shows a small p_T dependence and is close to unity

Mid rapidity

R_{pPb} tends to increase with p_T

Forward rapidity

R_{pPb} increases with p_T and is compatible with unity for p_T larger than 5 GeV/c

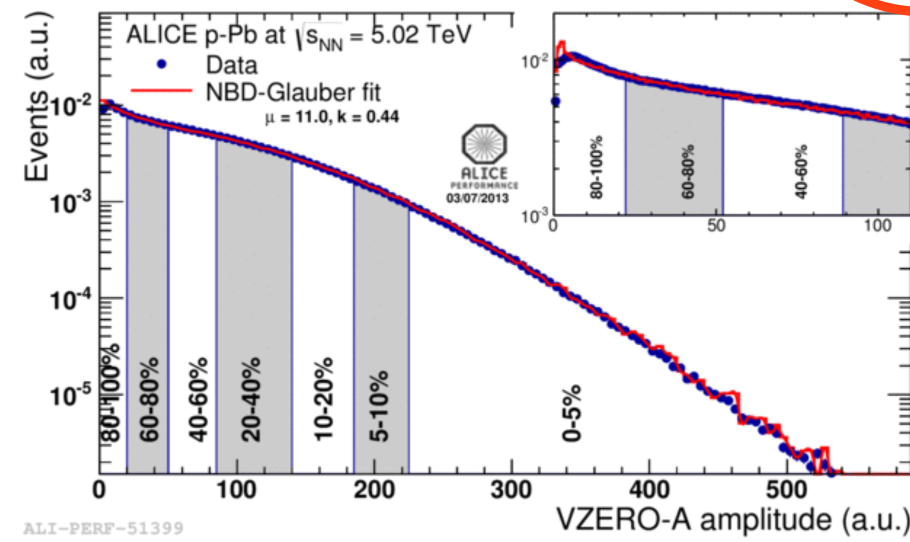
At forward rapidity data favours a strong shadowing
Coherent energy loss model overestimates the suppression at forward rapidity for p_T < 2 GeV/c
CGC calculations underestimate the data in the full p_T range

J/ψ p_T broadening vs event multiplicity

New

$\Delta\langle p_T^2\rangle = \langle p_T^2\rangle_{pPb} - \langle p_T^2\rangle_{pp}$ for different event multiplicity measured with V0A

$\langle p_T^2\rangle_{pp}$ from interpolated pp distributions at $\sqrt{s}$ = 5.02 TeV



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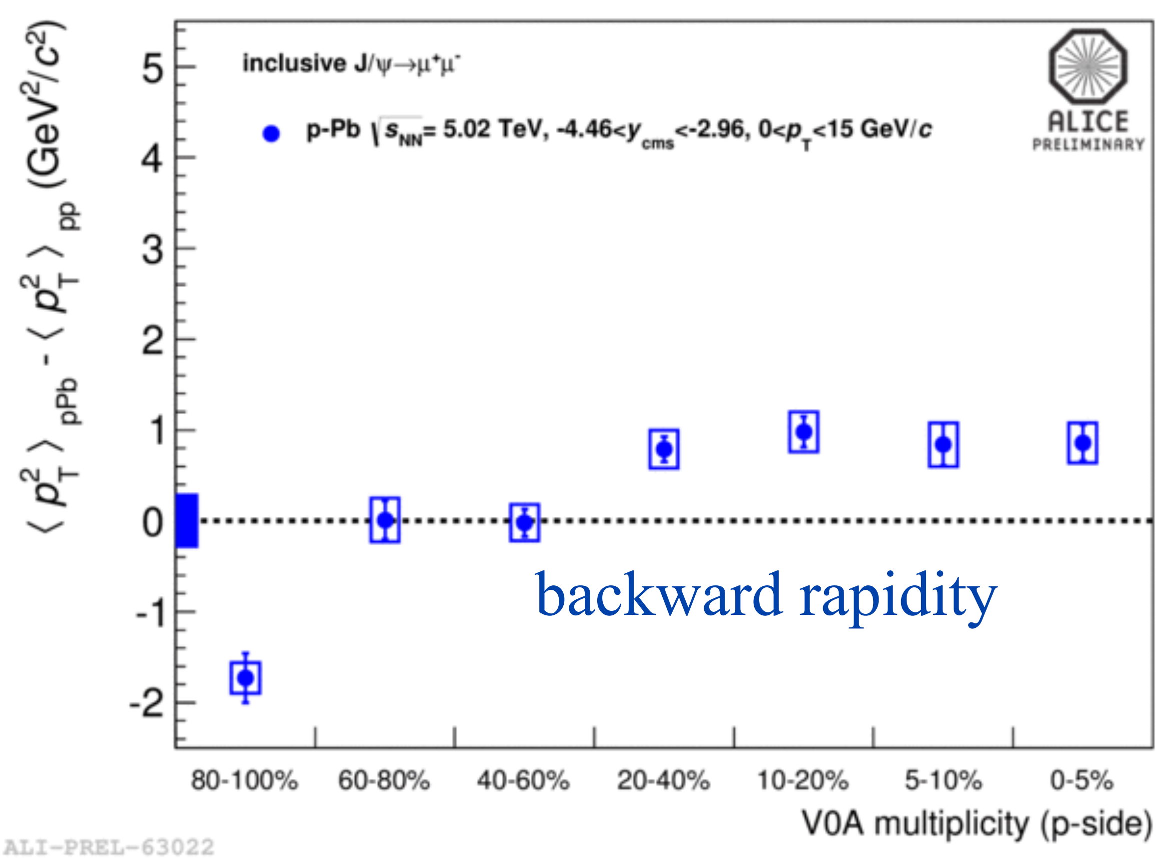

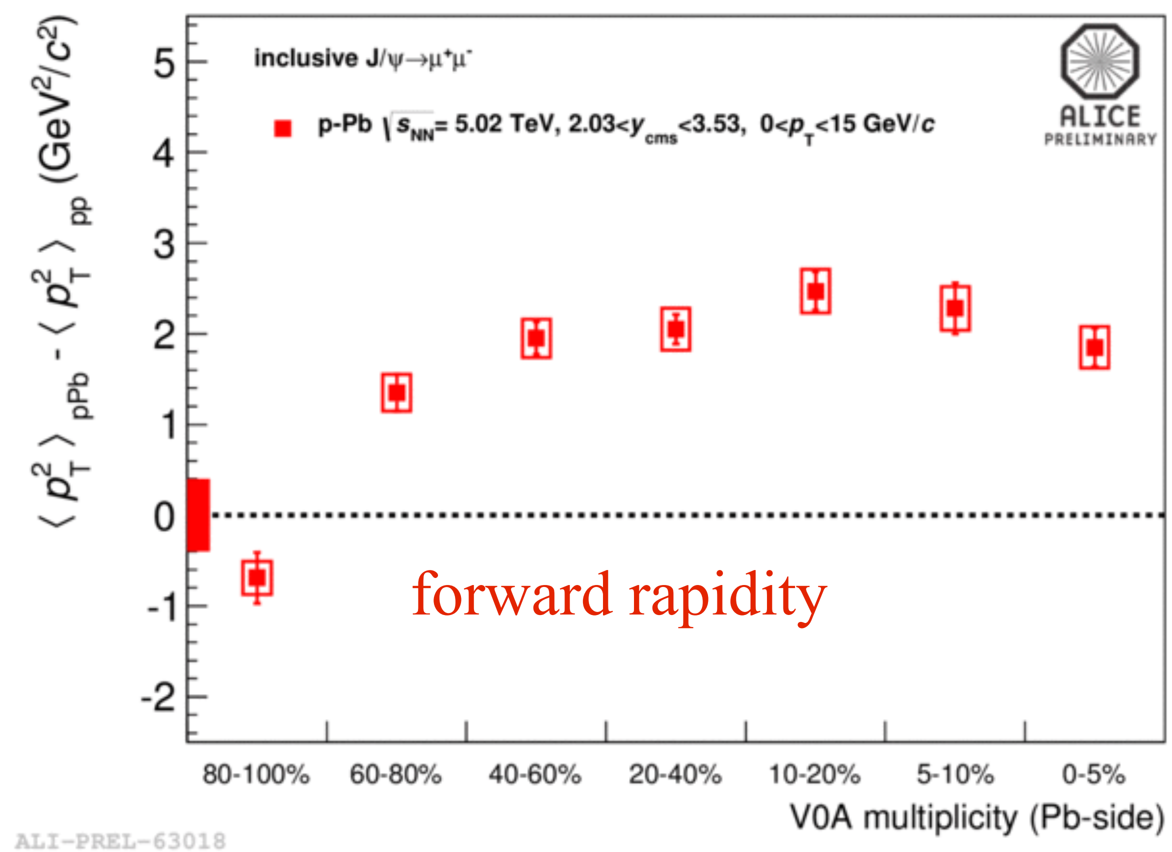

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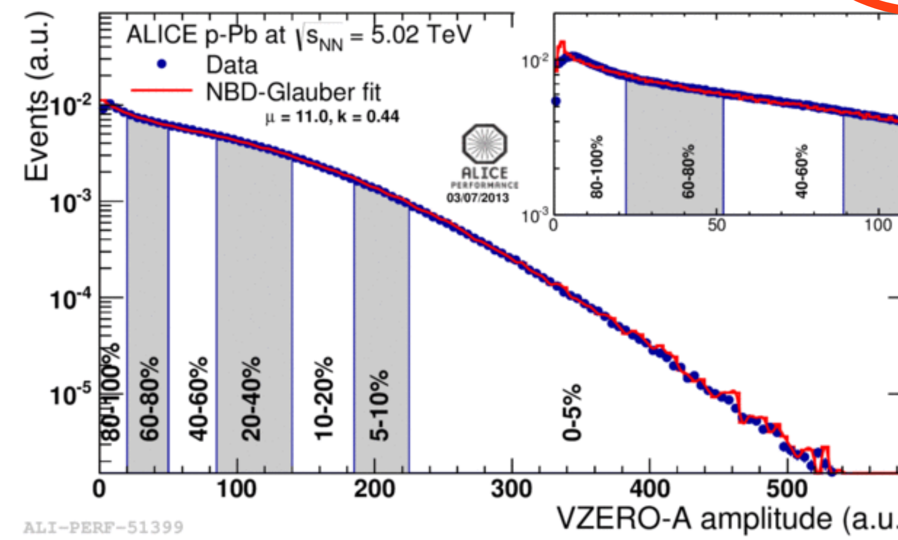

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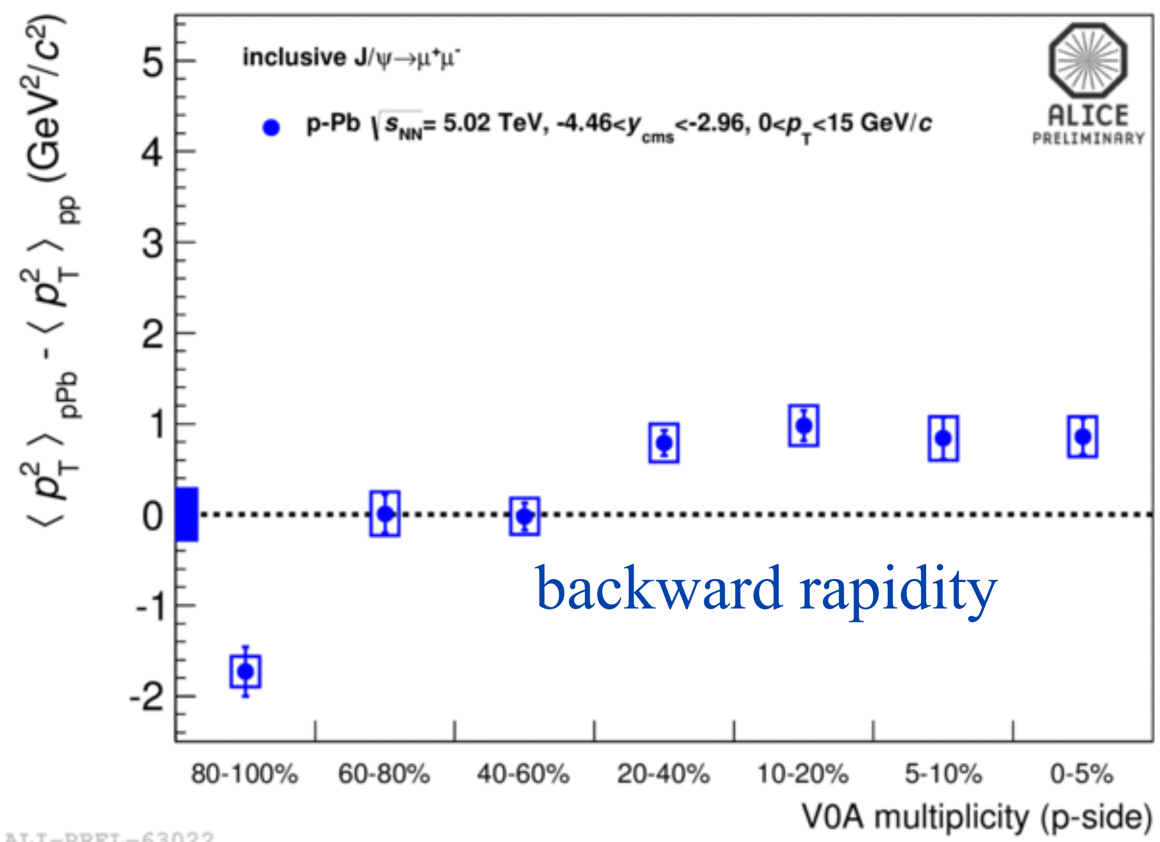
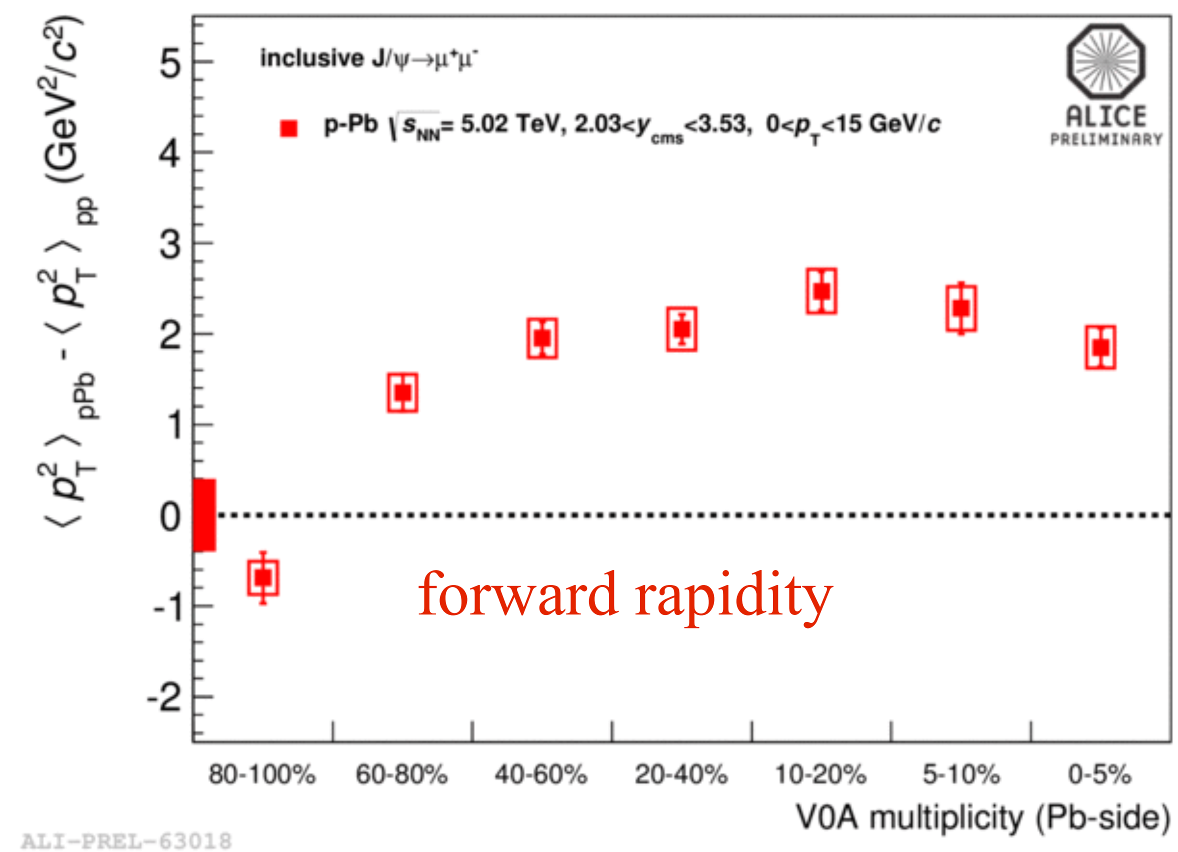
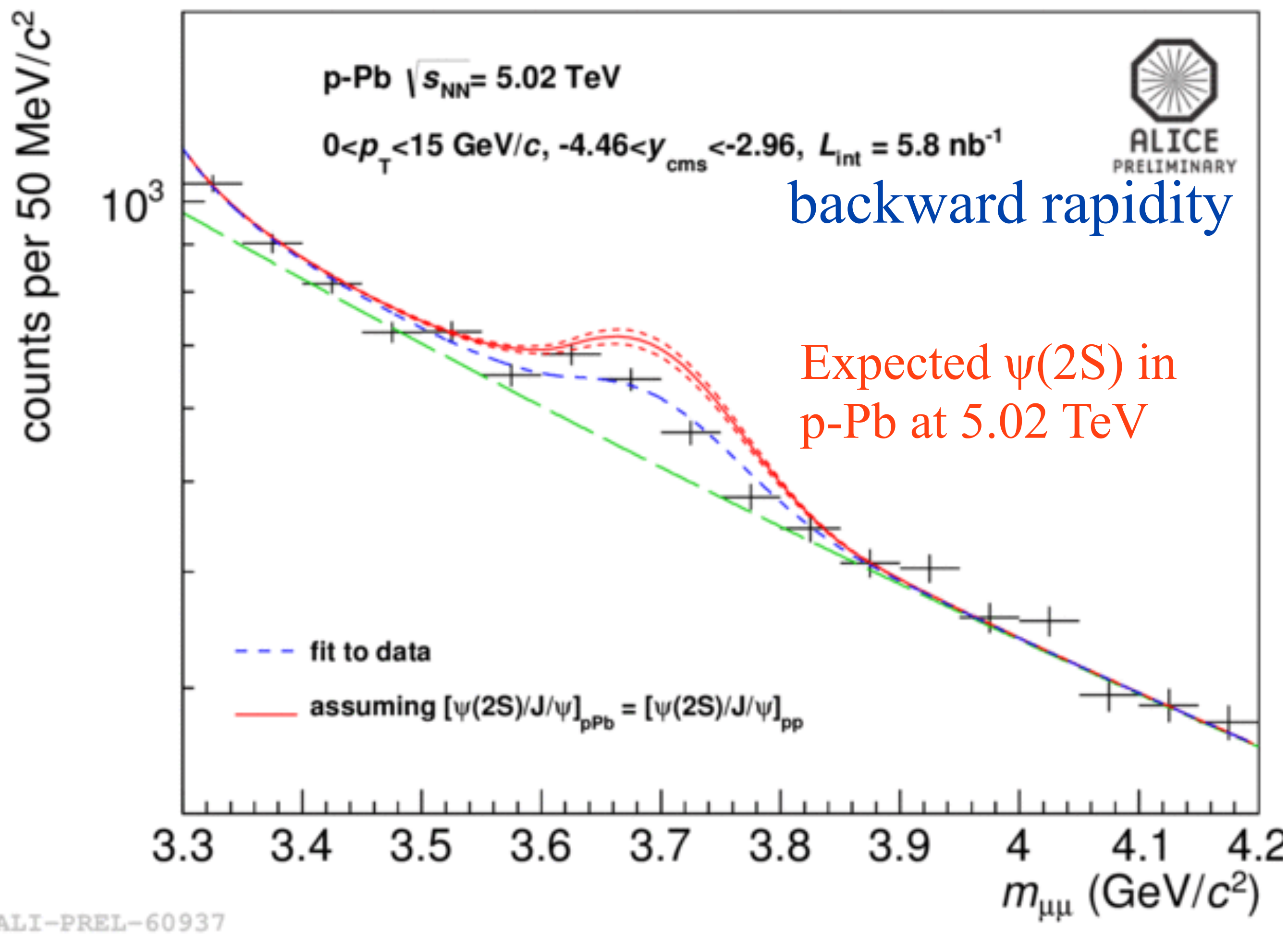
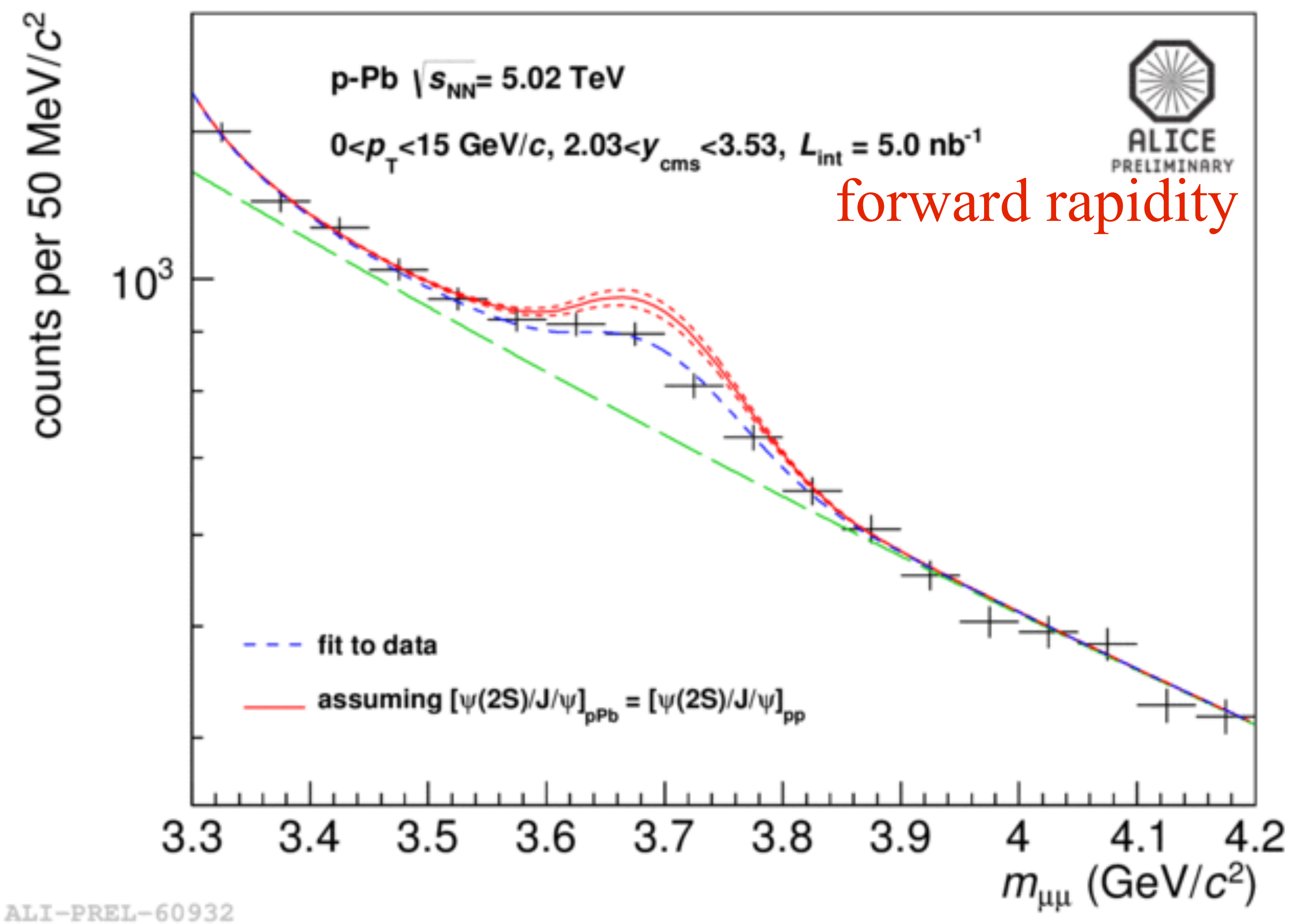




$\Delta\langle p_T^2\rangle$ larger at forward rapidity
$\Delta\langle p_T^2\rangle$ increases with event multiplicity but saturates at 20-40% V0A multiplicity

ψ(2S) measurements in p-Pb: [ψ(2S)/J/ψ] New





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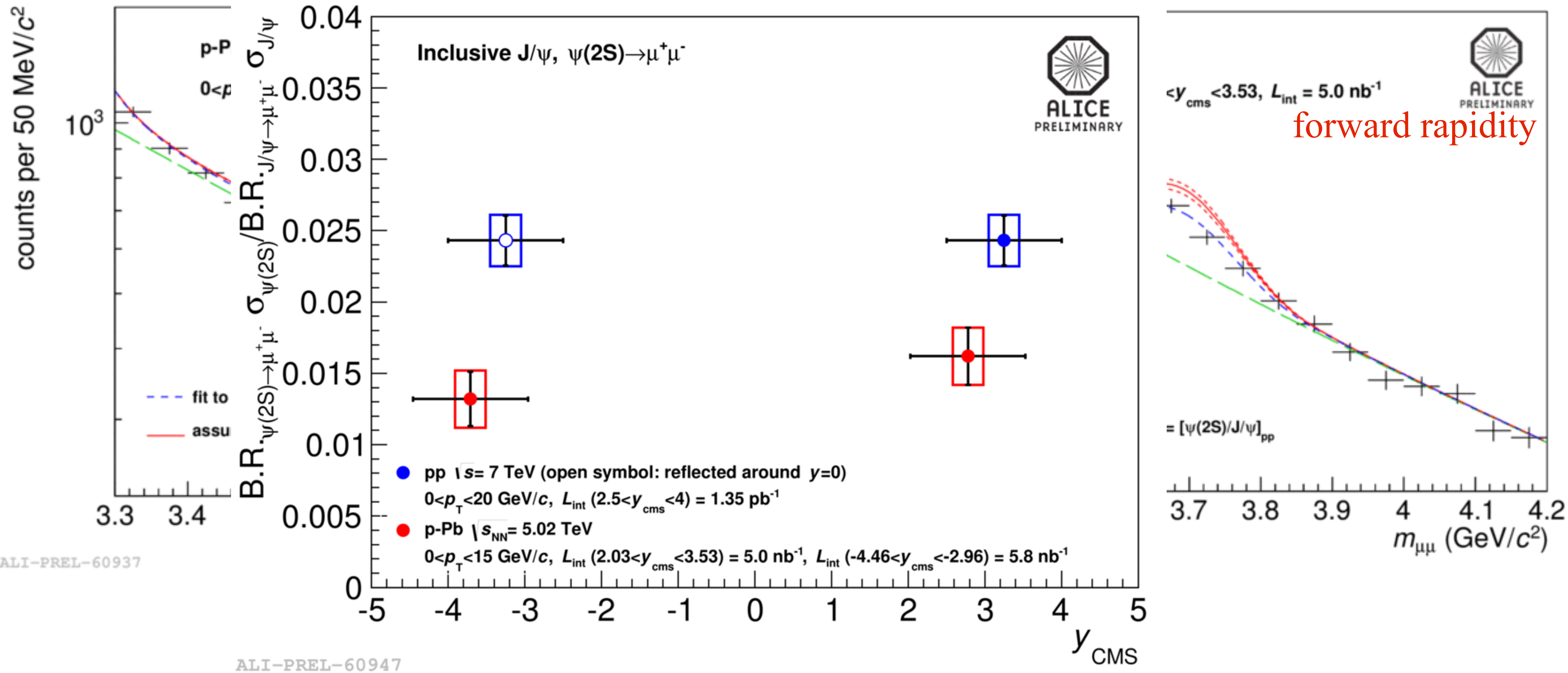
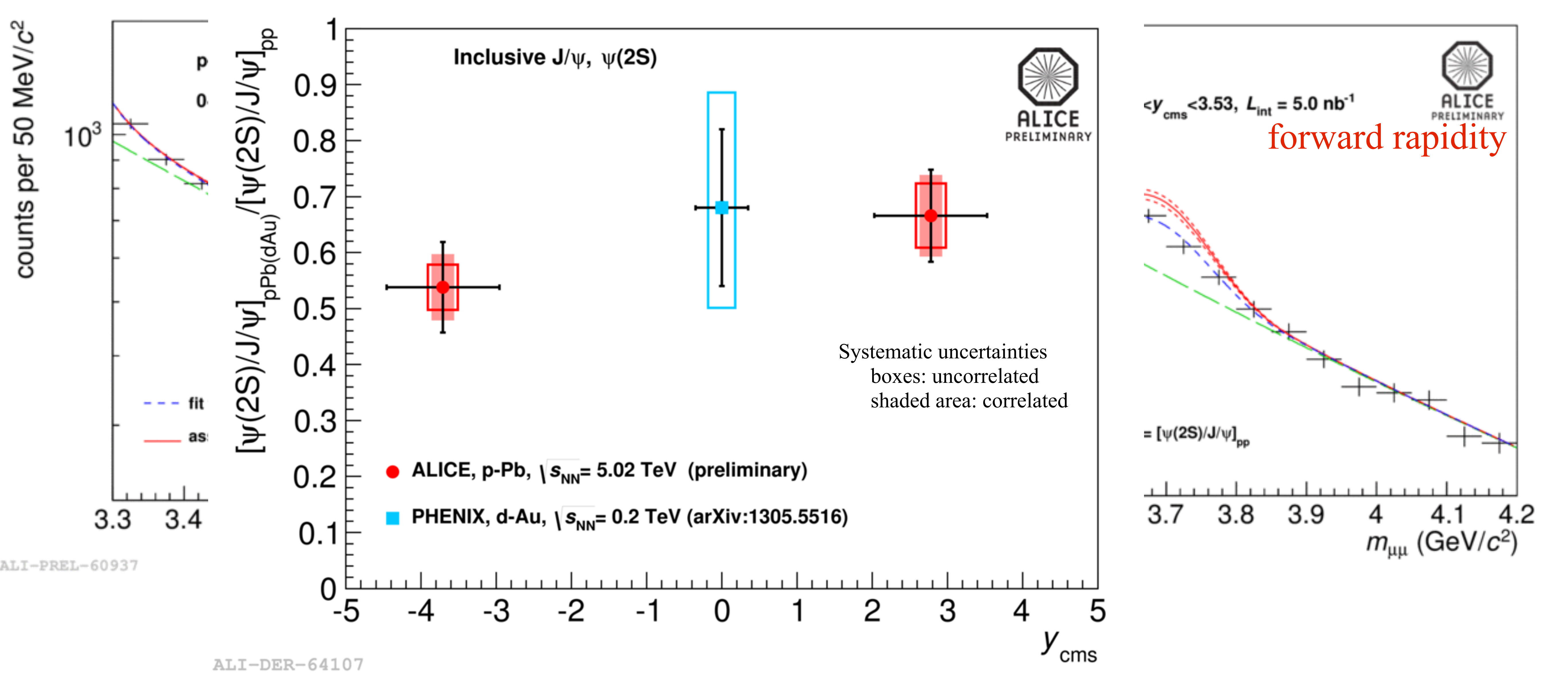


$[\psi(2S)/J/\psi]_{pPb}$ clearly suppressed as compared to pp @ $\sqrt{s}$ = 7 TeV

$\psi(2S)$ measurements in p-Pb: $[\psi(2S)/J/\psi]$ New



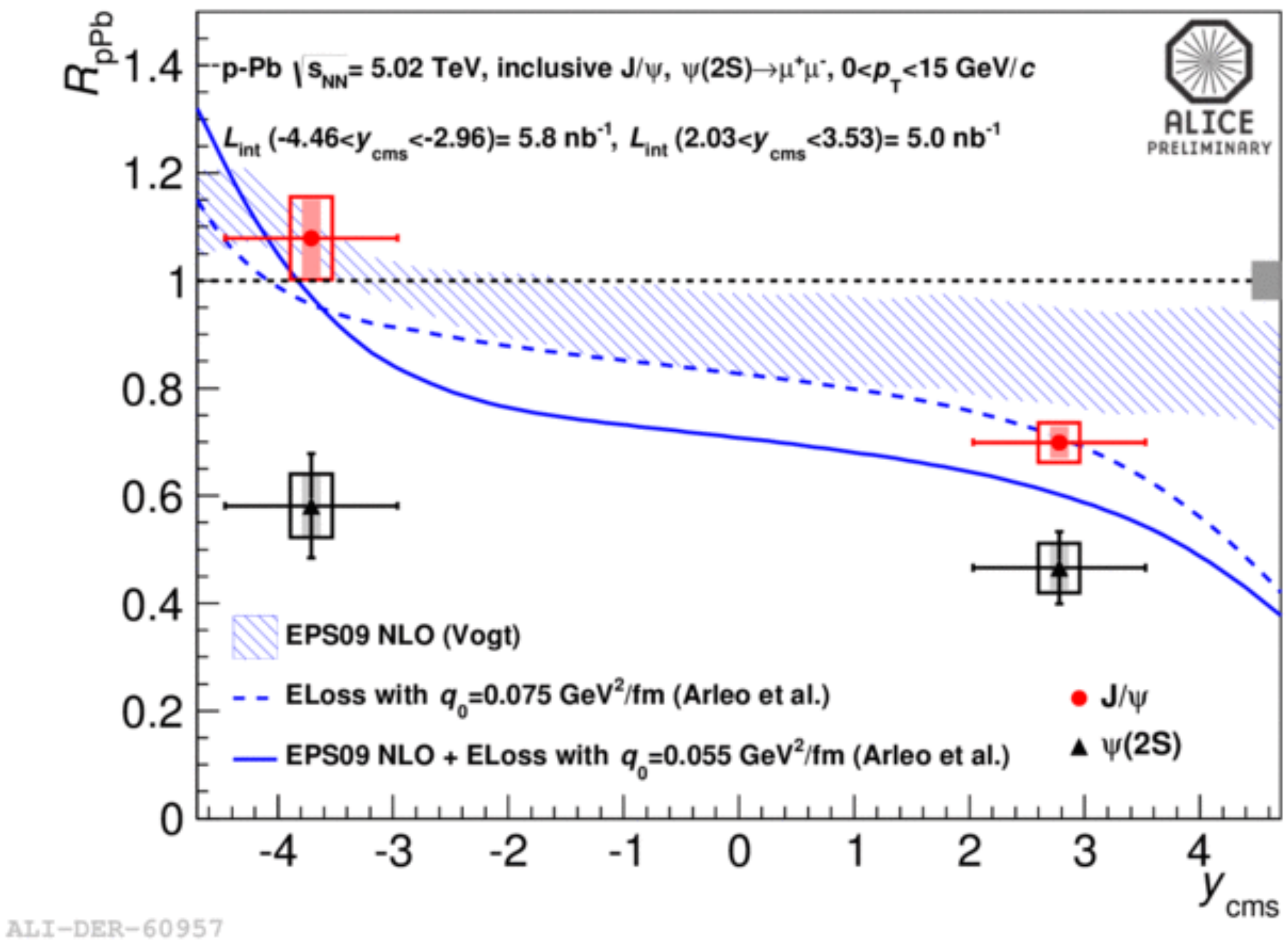
$[\psi(2S)/J/\psi]_{pPb}$ clearly suppressed as compared to pp @ $\sqrt{s}$ = 7 TeV

$\psi(2S)$ to J/ψ suppression also observed at RHIC at mid-rapidity

ψ(2S) measurements in p-Pb: R_{pPb}

New

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



Systematic uncertainties
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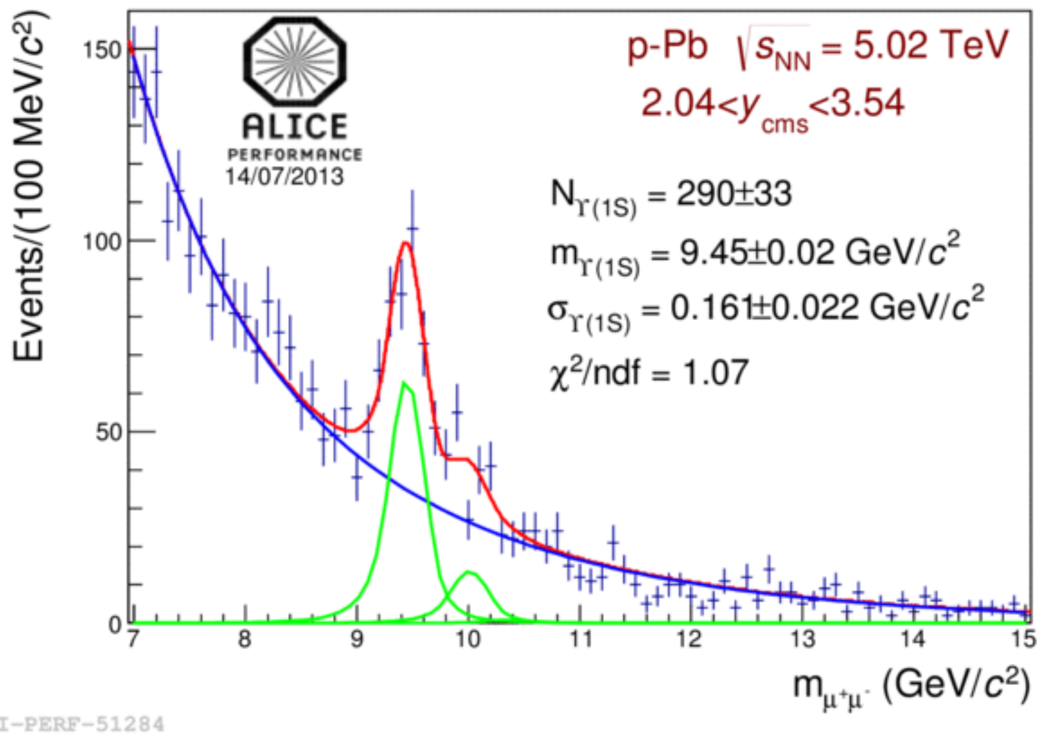
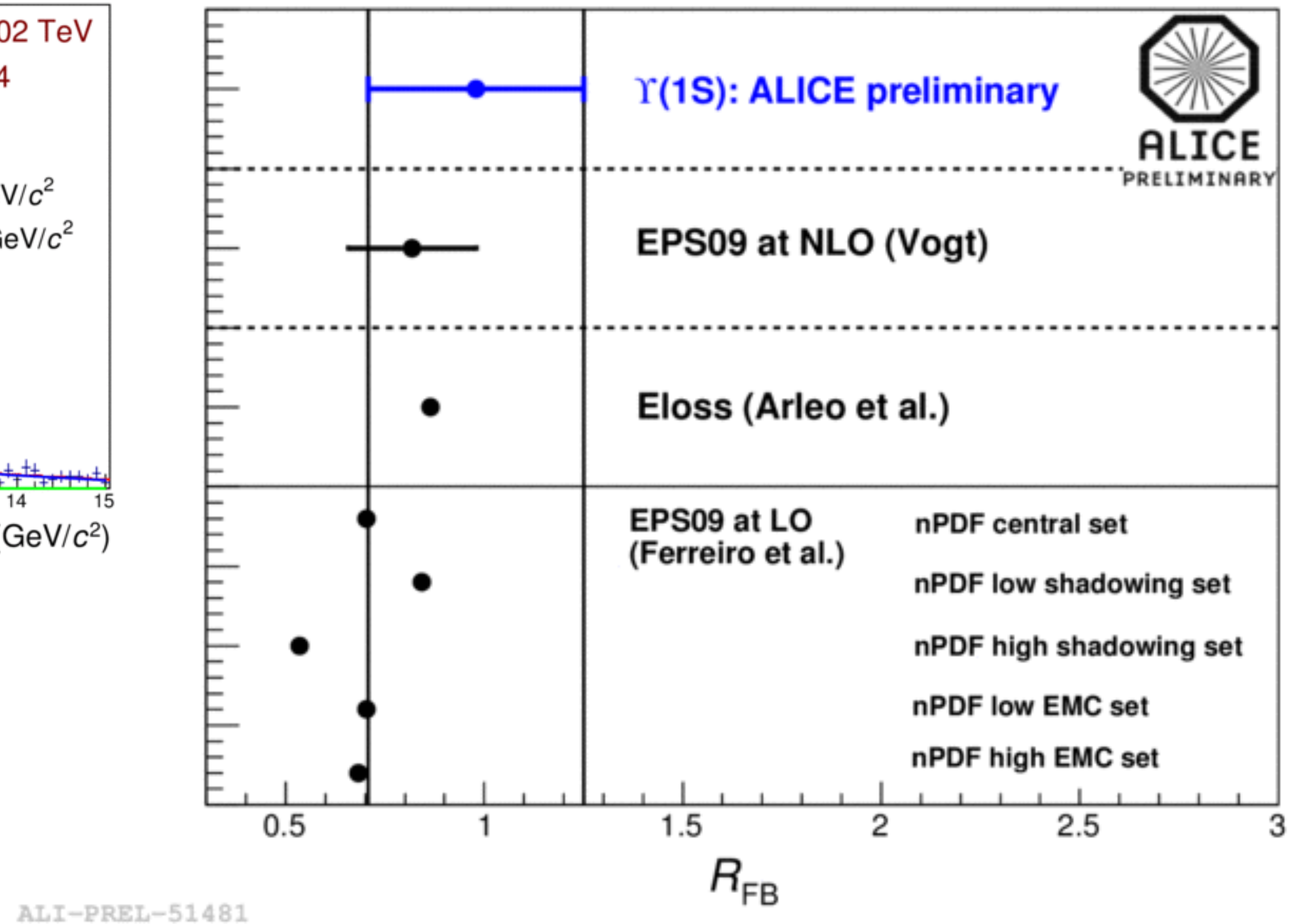
The stronger suppression of ψ(2S) relatively to J/ψ is not described by initial state CNM and coherent energy loss
→ final state effect? Other mechanisms?

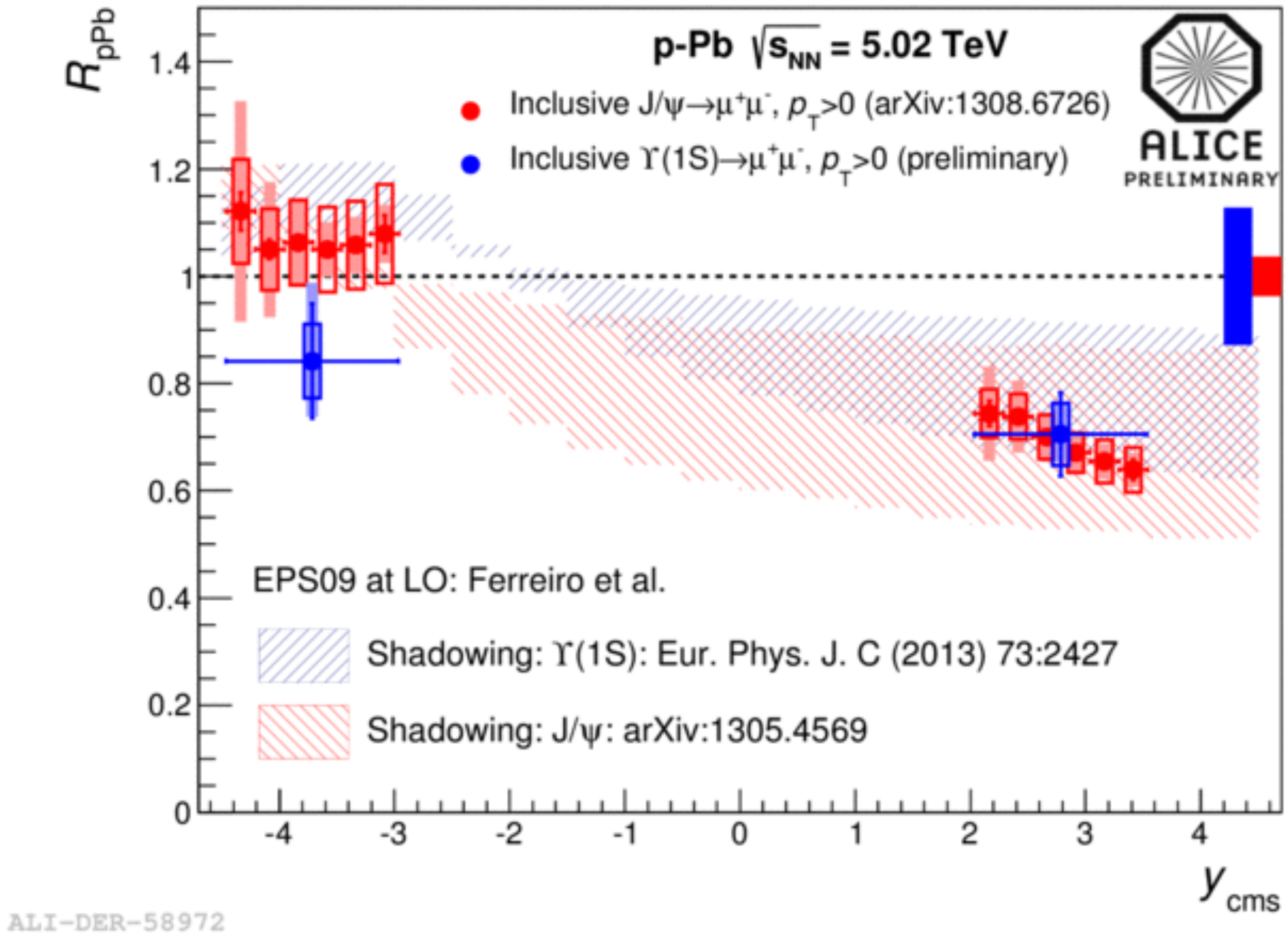
$\Upsilon(1S)$ measurements: R_{FB}





R_{FB} is compatible with unity and larger than the J/ψ R_{FB} = 0.60±0.01(stat)±0.06(syst)
Limited statistics does not allow to discriminate among models

ϒ(1S) measurements: R_{pPb}



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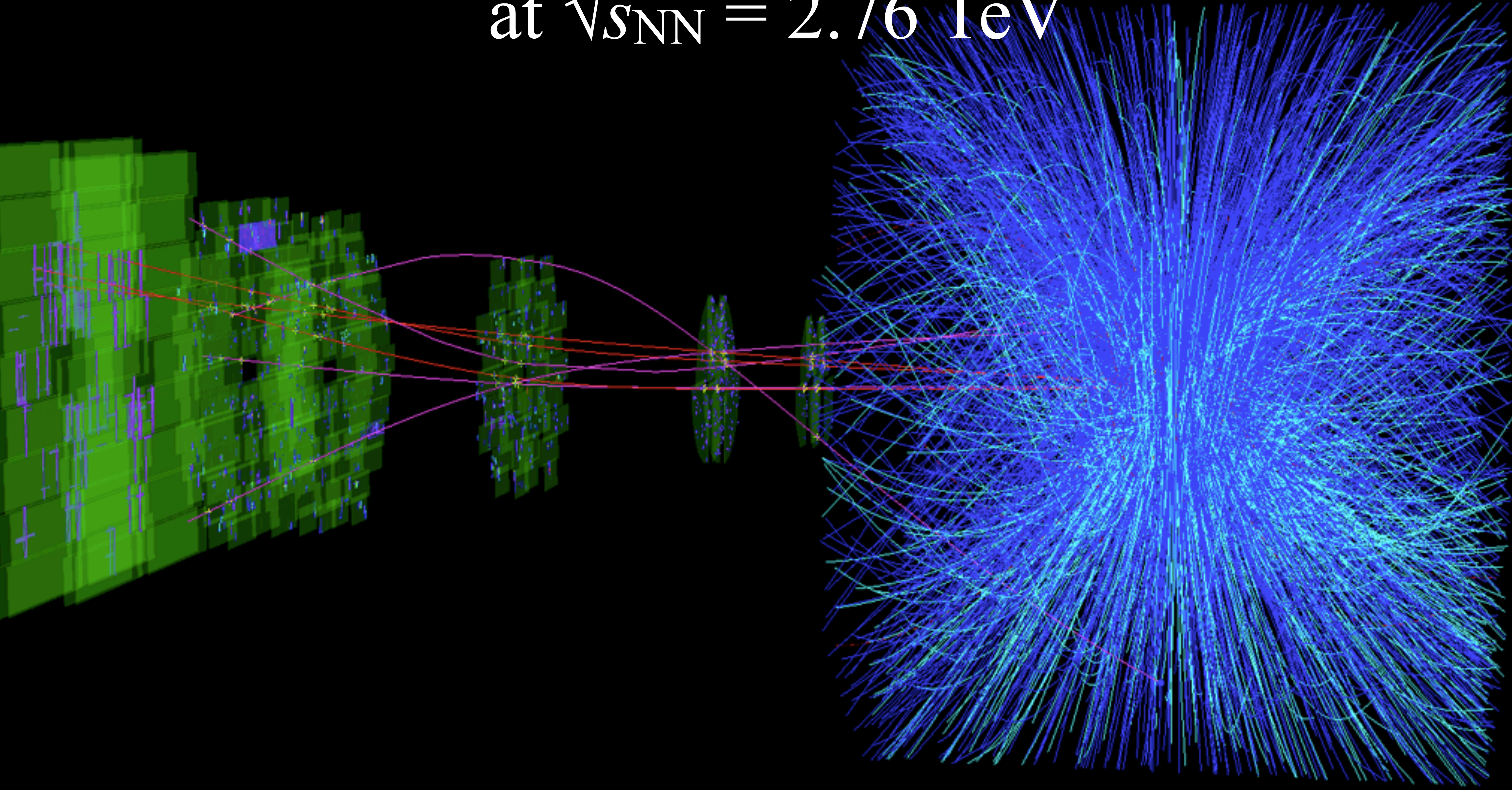
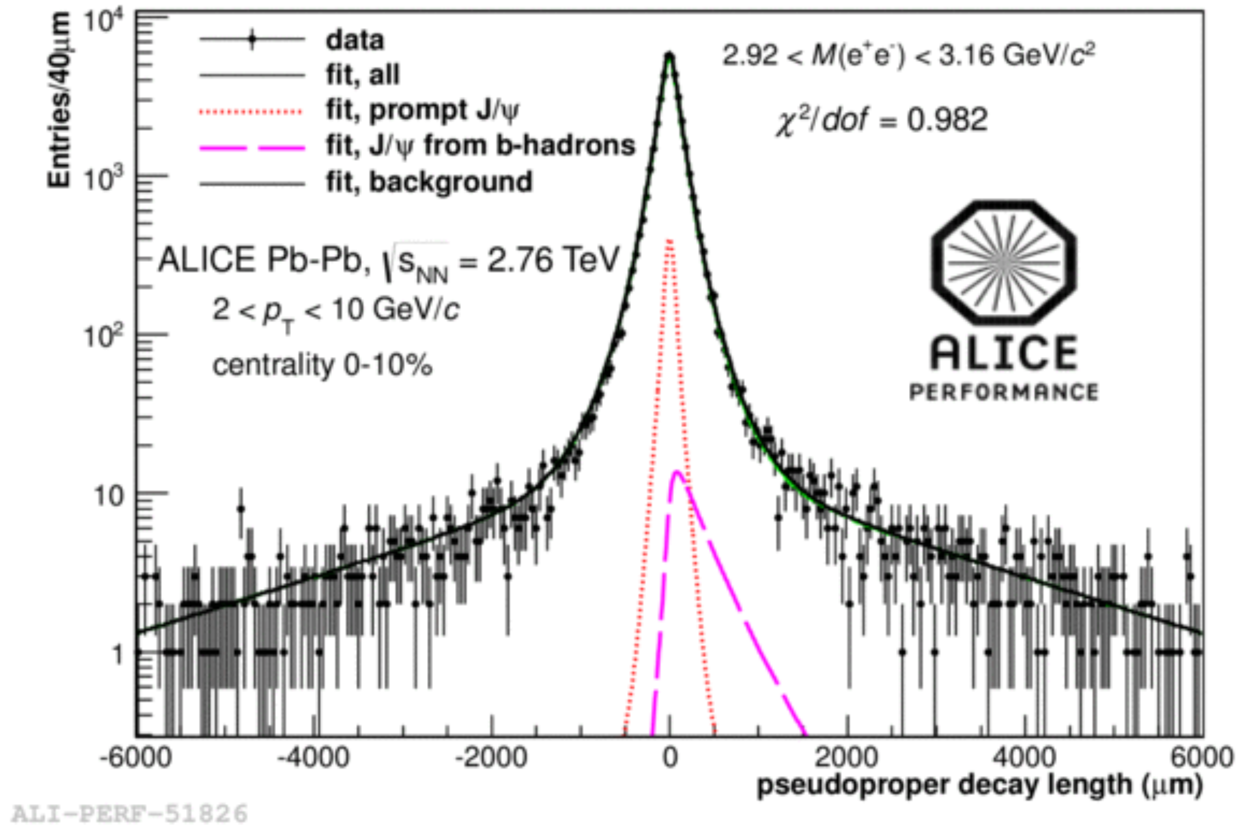
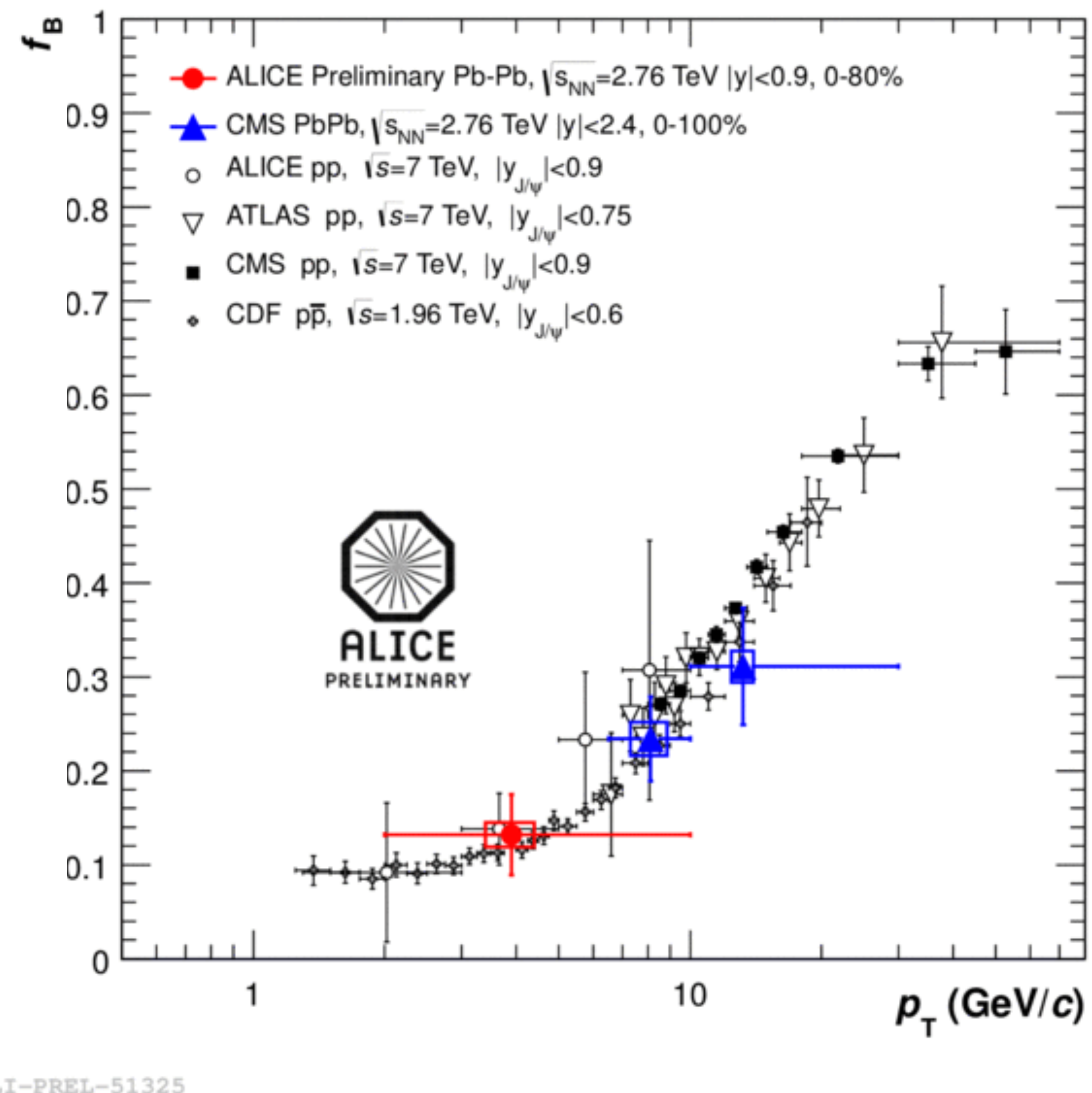
ϒ(1S) seems more suppressed than predicted by shadowing (CEM+EPS09 NLO and CSM EPS09 LO shown here) or coherent energy loss models but in agreement within the large fully correlated uncertainty from pp cross-section energy interpolation

Latest Pb-Pb measurements at $\sqrt{s_{NN}} = 2.76$ TeV



Fraction of non-prompt J/ψ at mid-rapidity





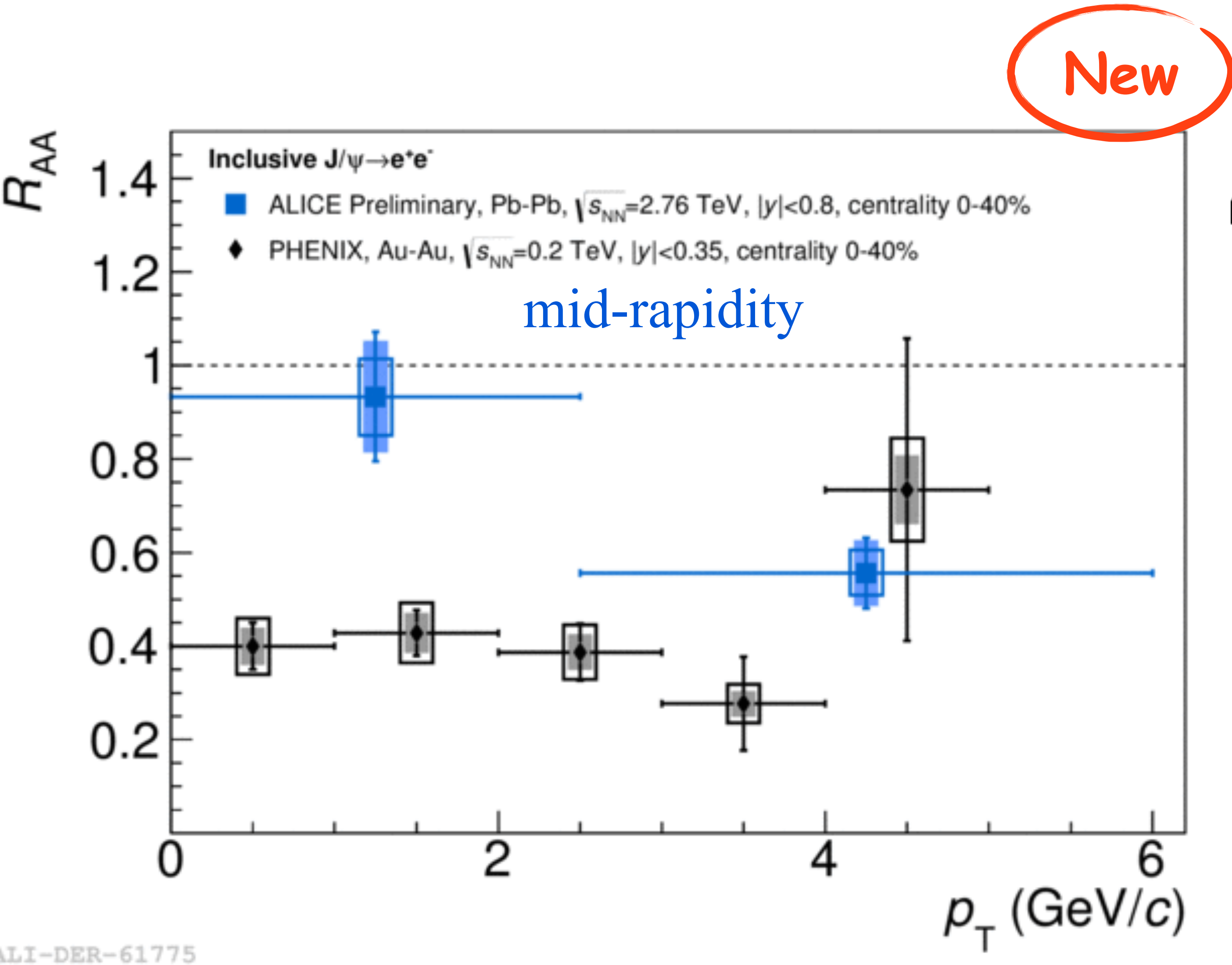
ALICE measured fraction of non-prompt J/ψ at mid-rapidity in Pb-Pb for $2 < p_T < 10$ GeV/c

→ Similar value and p_T dependence in Pb-Pb and pp

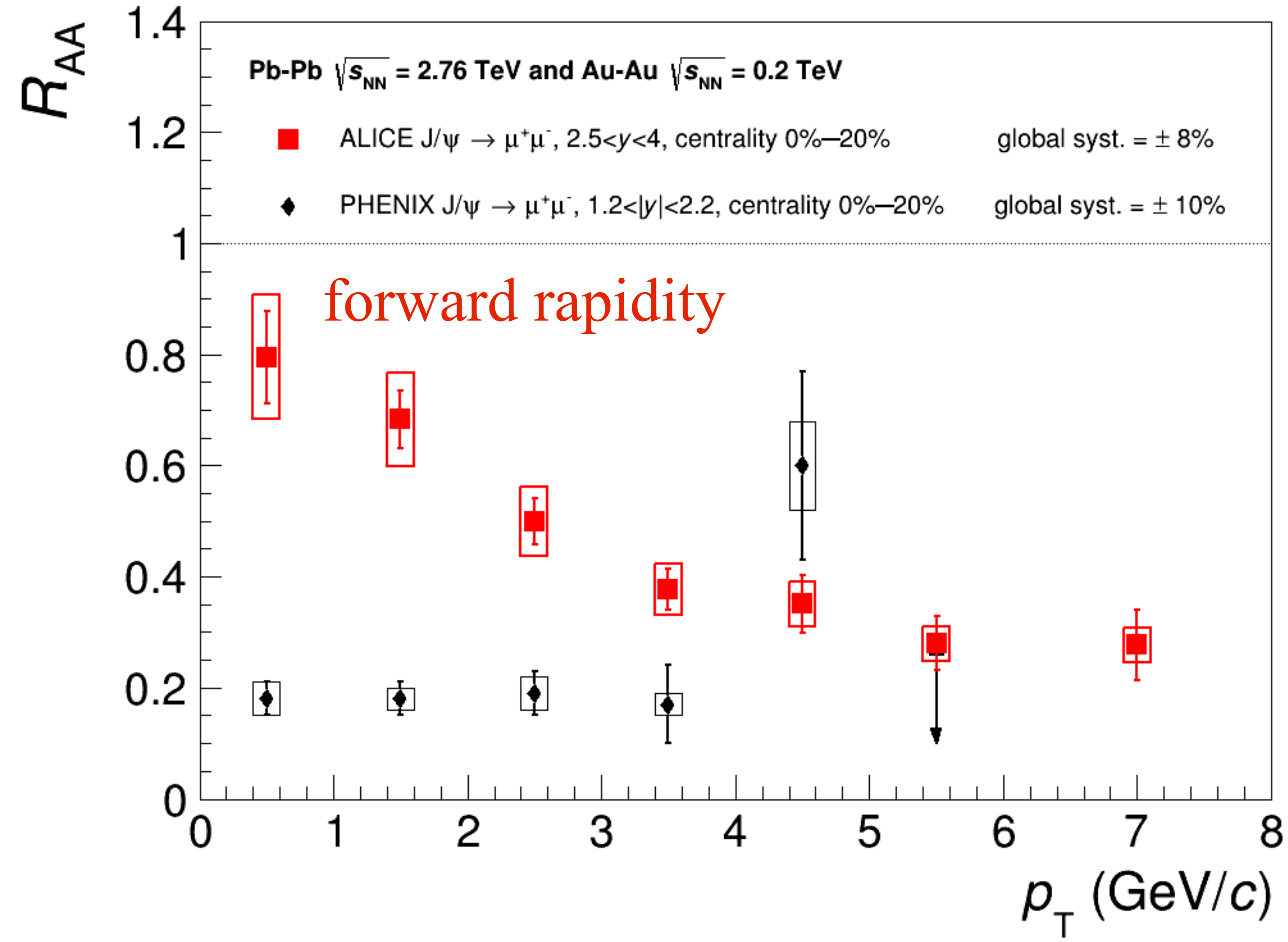
→ B feed-down contribution has a negligible effect on nuclear modification factor at low p_T

R_{AA} on beauty will come shortly!

J/ψ R_{AA} vs p_T for most central collisions

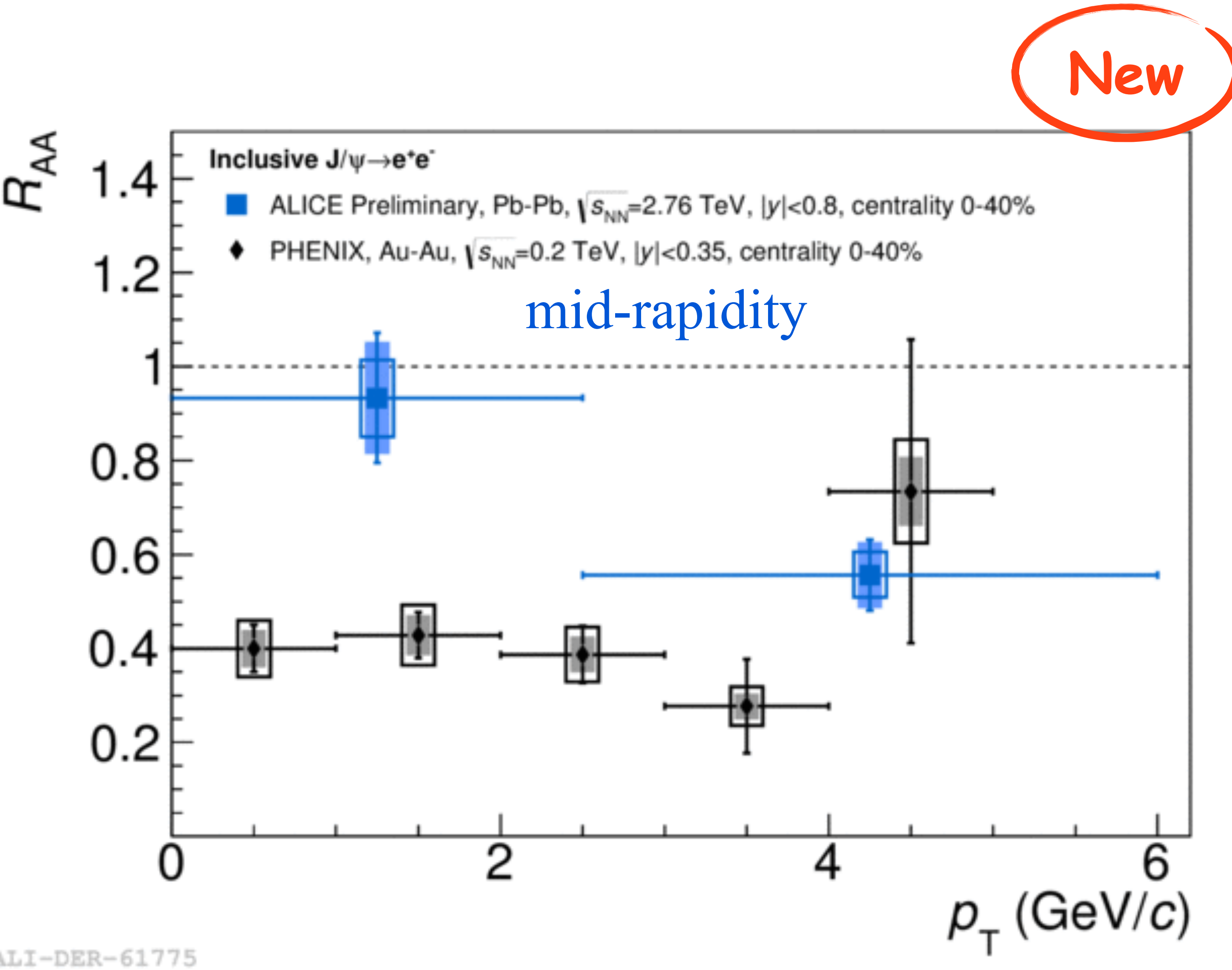


ALICE, arXiv:1311.0214

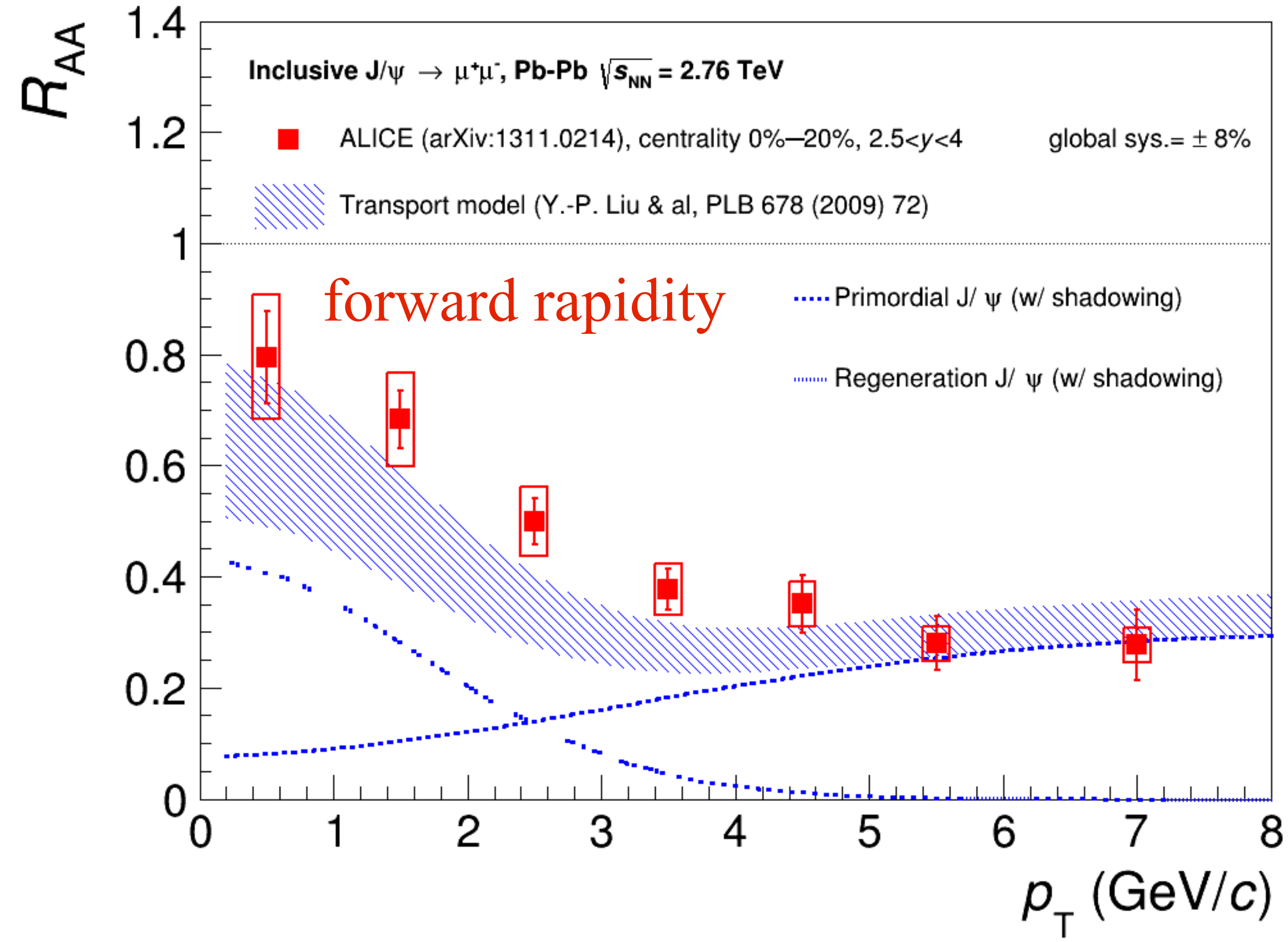


J/ψ less suppressed at low p_T than high p_T
Different p_T dependence of R_{AA} at LHC and RHIC

J/ψ R_{AA} vs p_T for most central collisions



ALICE, arXiv:1311.0214



J/ψ less suppressed at low p_T than high p_T
Different p_T dependence of R_{AA} at LHC and RHIC

Model:

- Transport (Zhao et al.): suppression and regeneration, with or without shadowing

→ Regeneration contribution important for $p_T < 3$ GeV/c and negligible at larger p_T

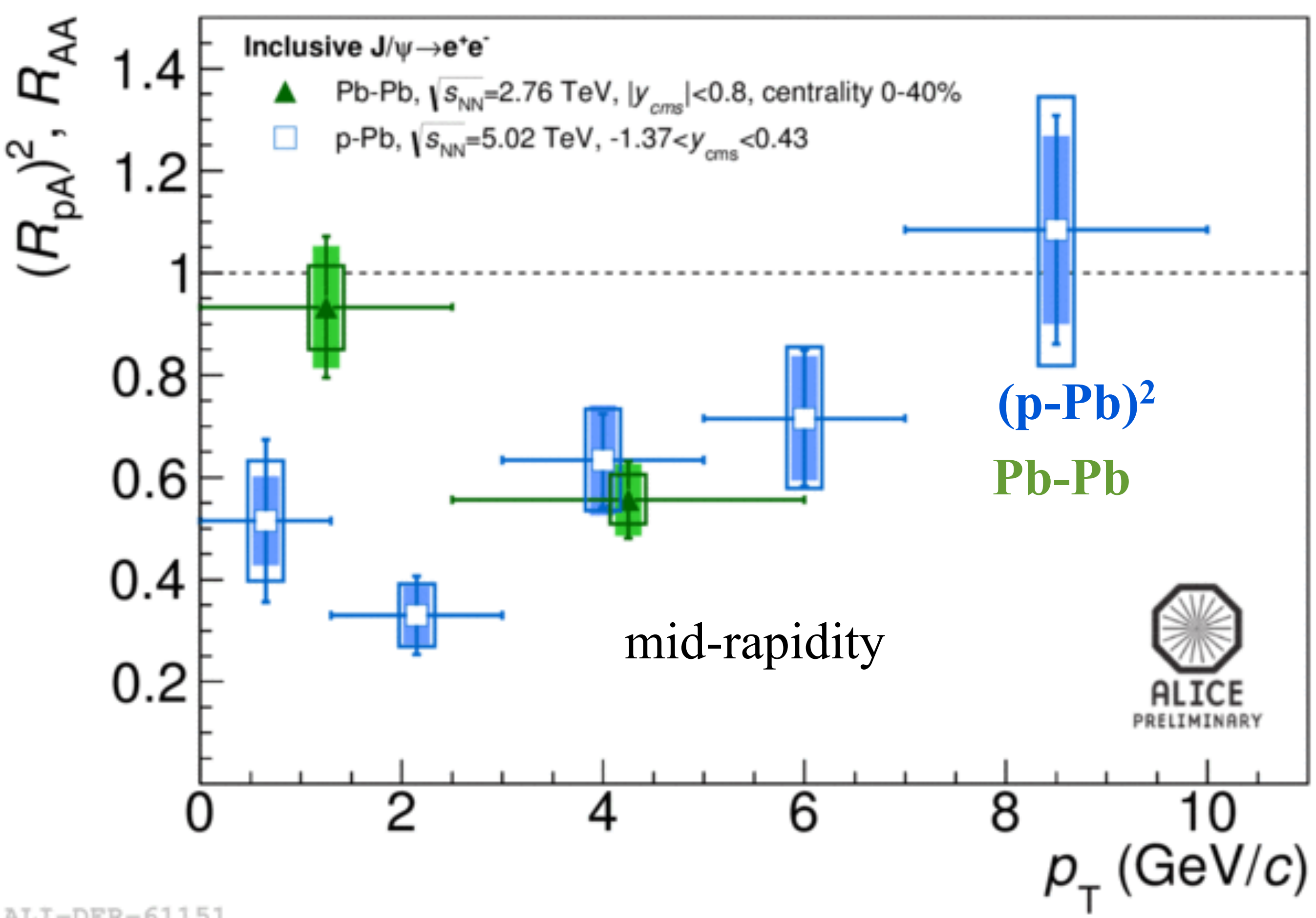
J/ψ p-Pb measurements extrapolated to Pb-Pb

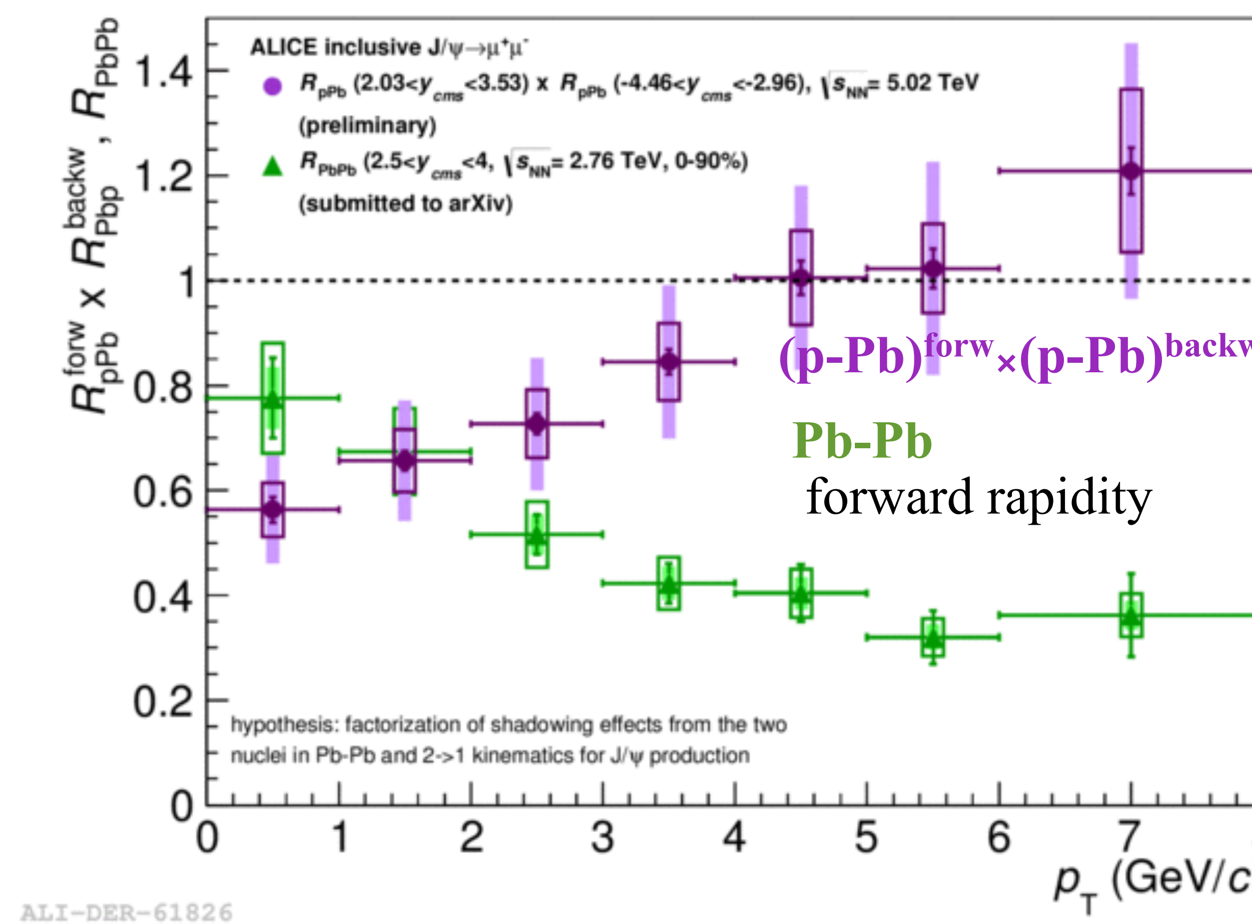
New

Hypothesis

- J/ψ production mechanism (2→1 kinematics) ⇒ similar x_g in Pb for p-Pb@$\sqrt{s_{NN}}$=5.02 TeV and Pb-Pb@$\sqrt{s_{NN}}$=2.76 TeV despite different energies and rapidity domains
- Factorization of shadowing effects in p-Pb and Pb-Pb ⇒ $R_{PbPb}^{Shad} = R_{pPb}(y\geq 0) \times R_{pPb}(y\leq 0)$ ⇒ $S_{J/\Psi} = R_{PbPb} / R_{PbPb}^{Shad}$

Note: R_{PbPb}^{Shad} is integrated over centrality and is compared to R_{PbPb} for different bins in centrality [0-40%] and [0-90%]





At $p_T > 7$ (4) GeV/c at mid (forward) rapidity, small effects from extrapolated shadowing

At low p_T, less or same suppression in Pb-Pb than R_{PbPb}^{Shad}

→ R_{PbPb} enhanced if corrected by such shadowing effects

J/ψ p-Pb measurements extrapolated to Pb-Pb

New

Hypothesis

- J/ψ production mechanism (2→1 kinematics) ⇒ similar x_g in Pb for p-Pb@$\sqrt{s_{NN}}$=5.02 TeV and Pb-Pb@$\sqrt{s_{NN}}$=2.76 TeV despite different energies and rapidity domains
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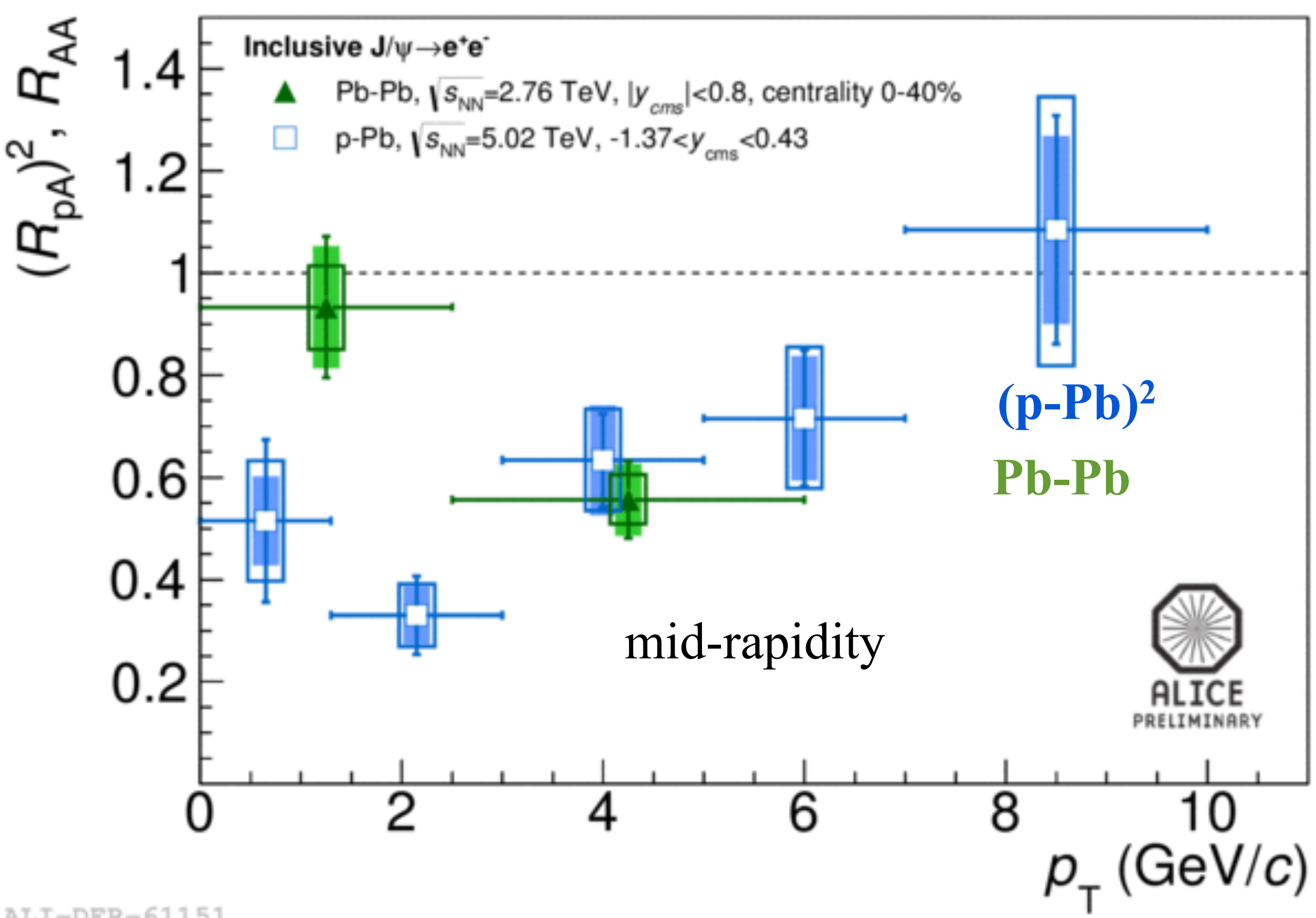

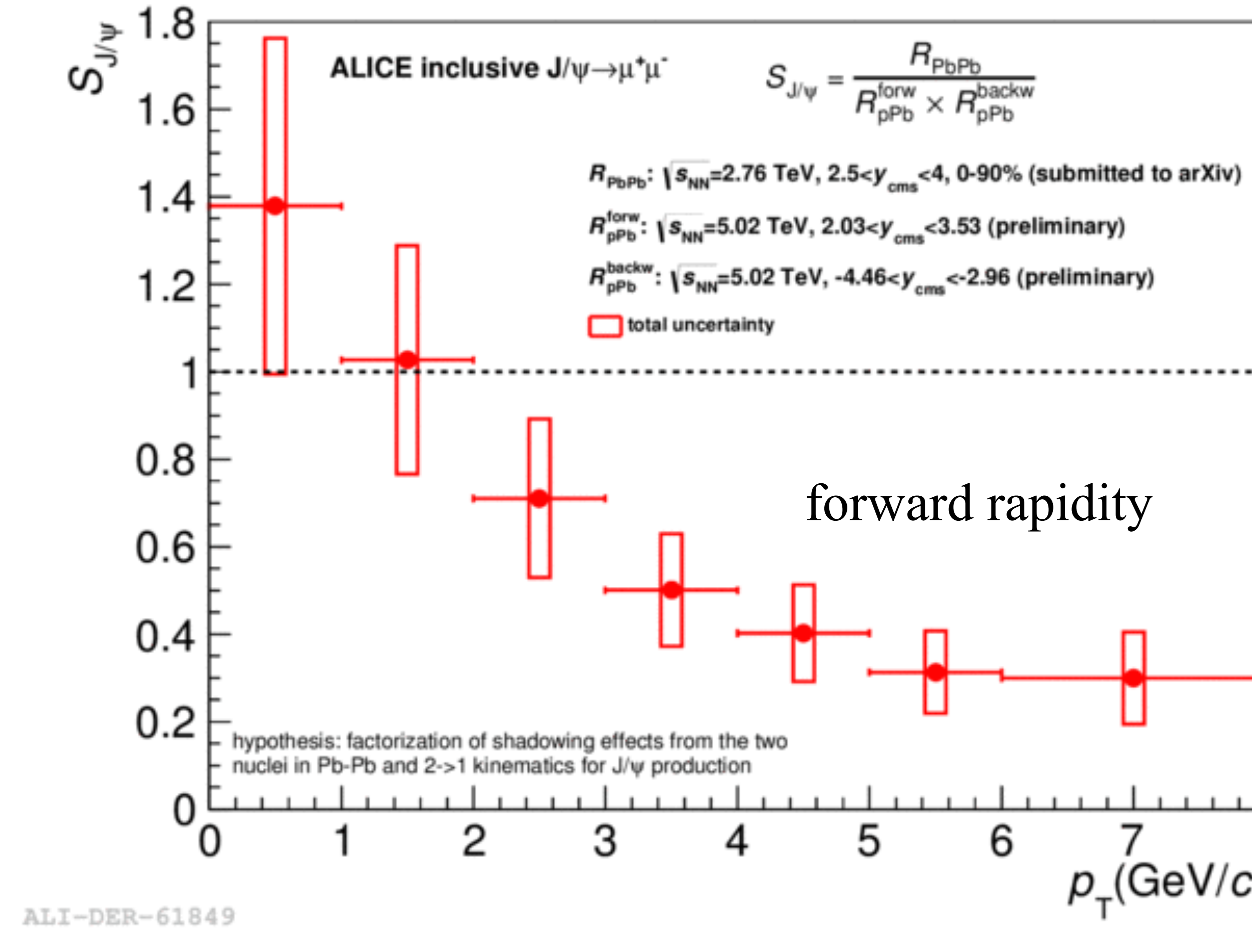

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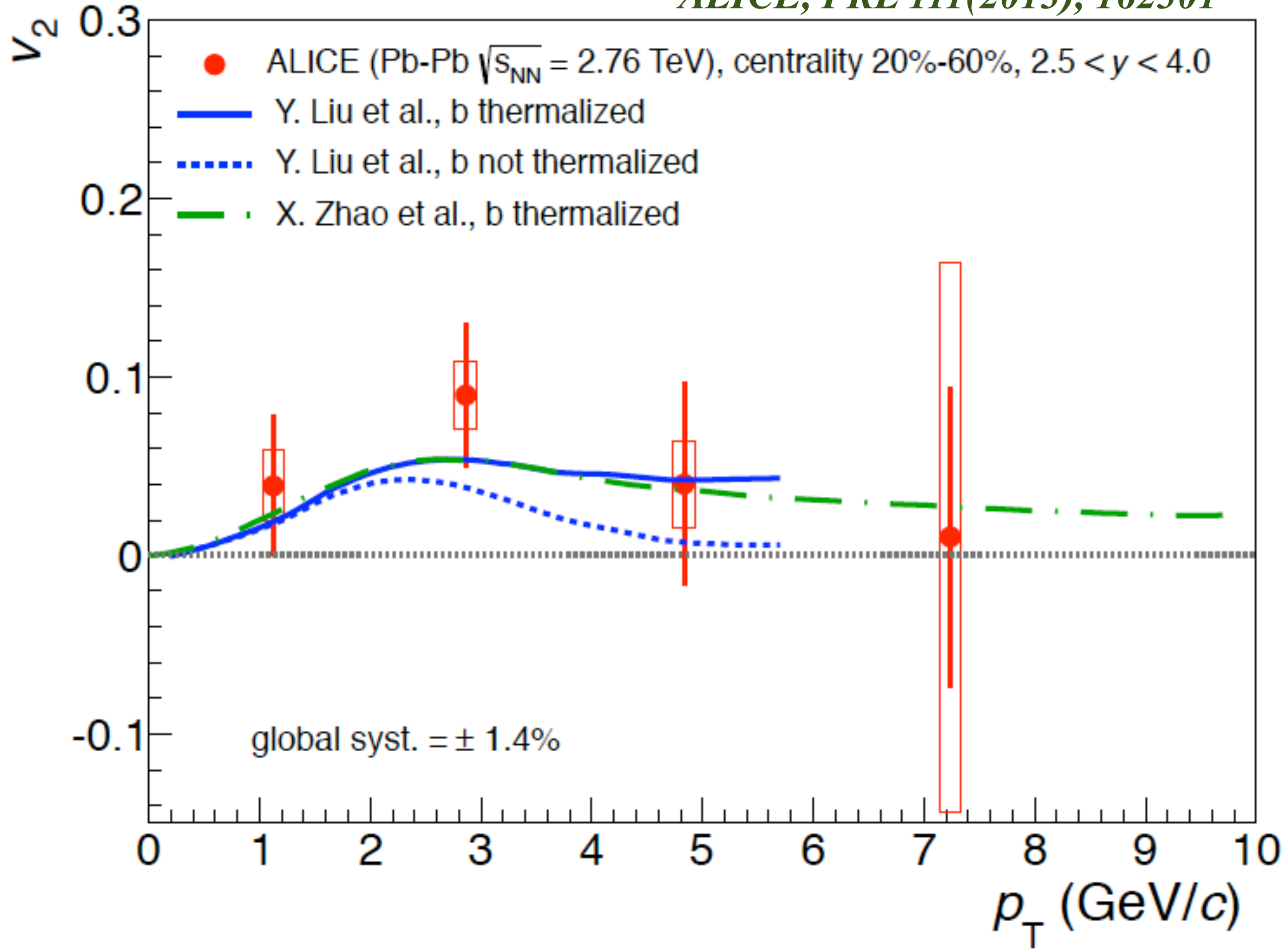
J/ψ v_2 vs p_T

ALICE, PRL 111(2013), 162301



$$v_2(p_T) = \langle cos2(\phi - \Psi)\rangle(p_T)$$

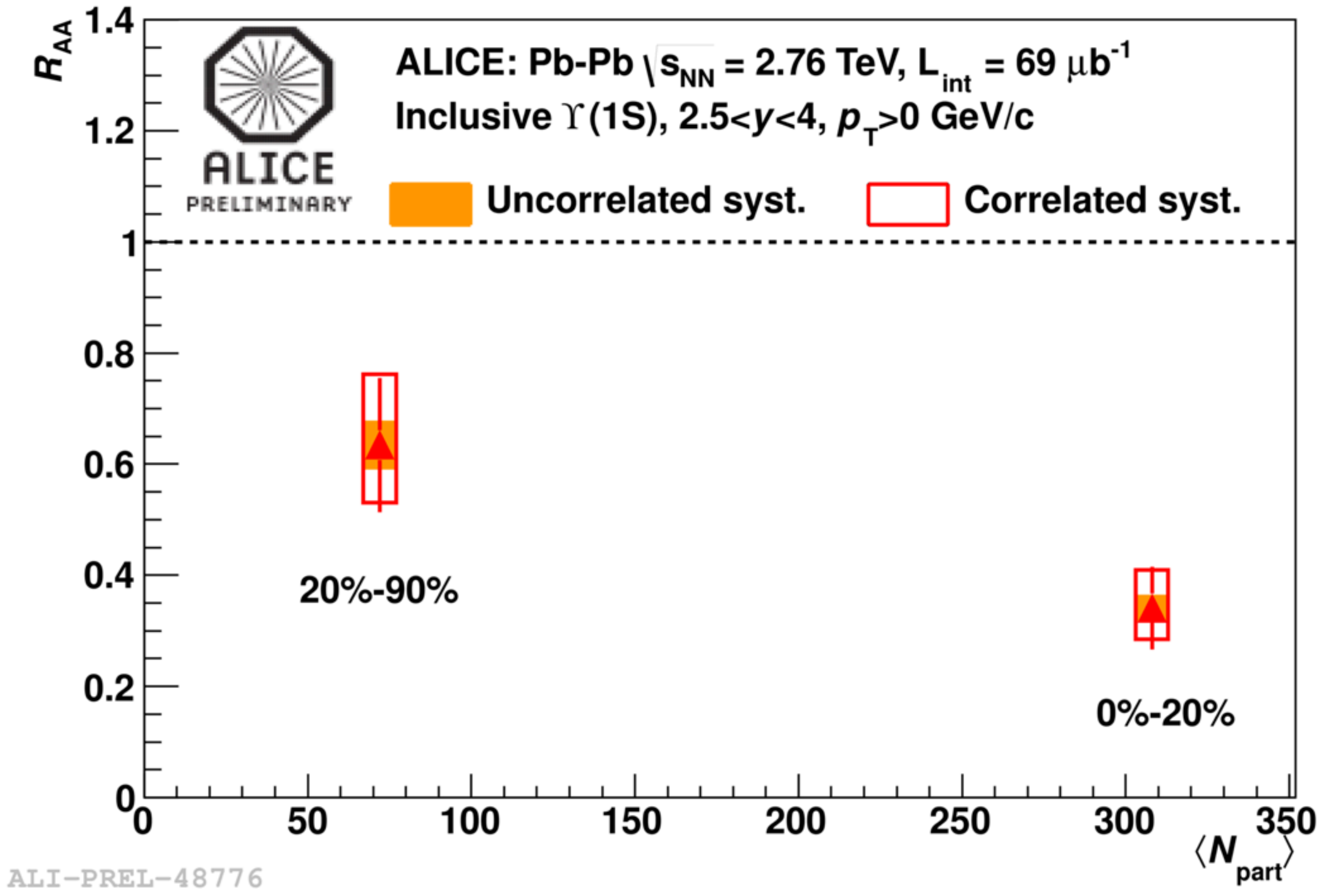
Models:

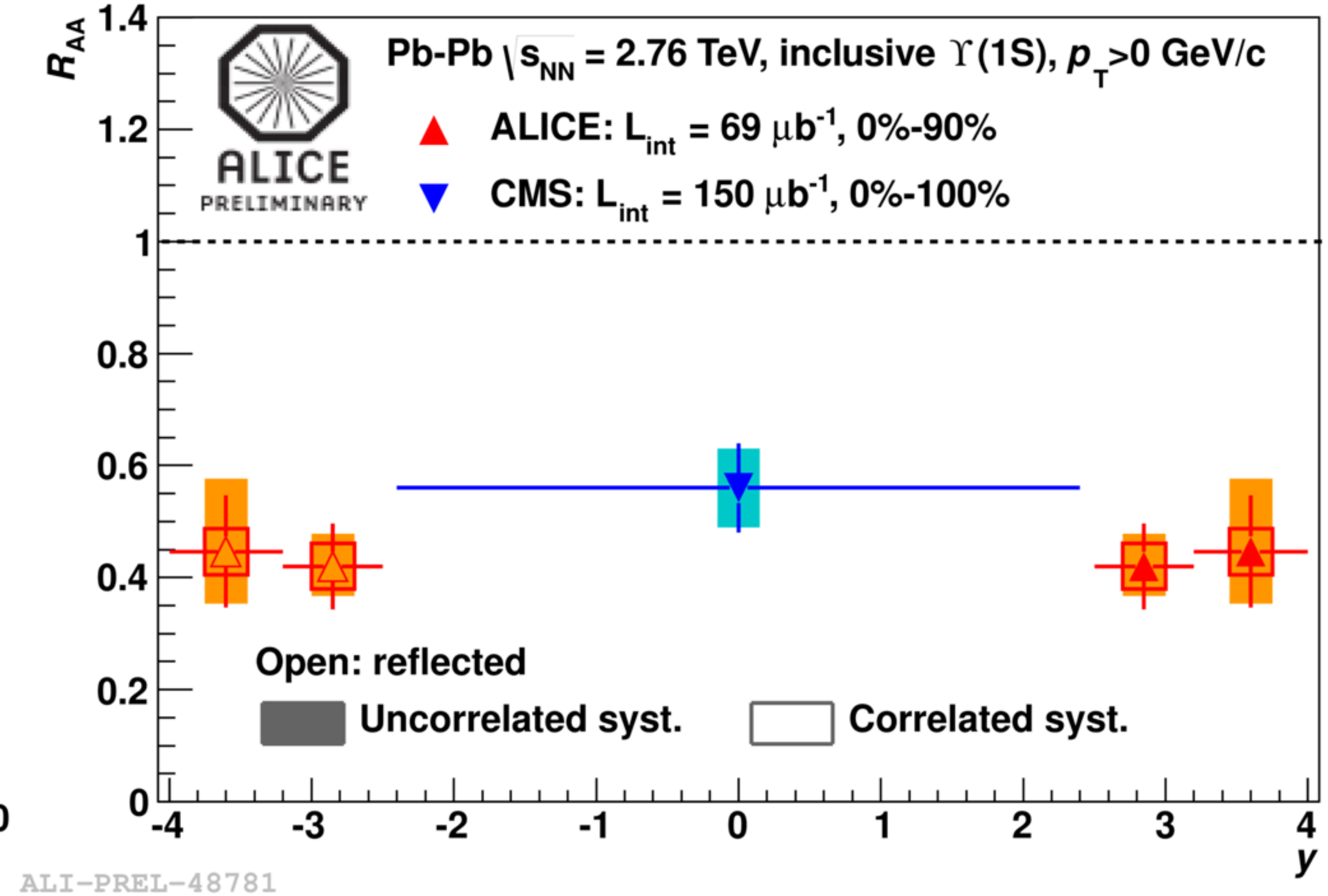
- Transport (Zhao et al./ Liu et al.) models: suppression and J/ψ from regeneration, different $\sigma_{c\bar{c}}$ and/or shadowing hypothesis

Non-zero J/ψ v_2 observed at intermediate p_T for semi-central collisions

v_2 complements R_{AA}: both are qualitatively well described by transport models including regeneration

Υ(1S) measurements at forward rapidity

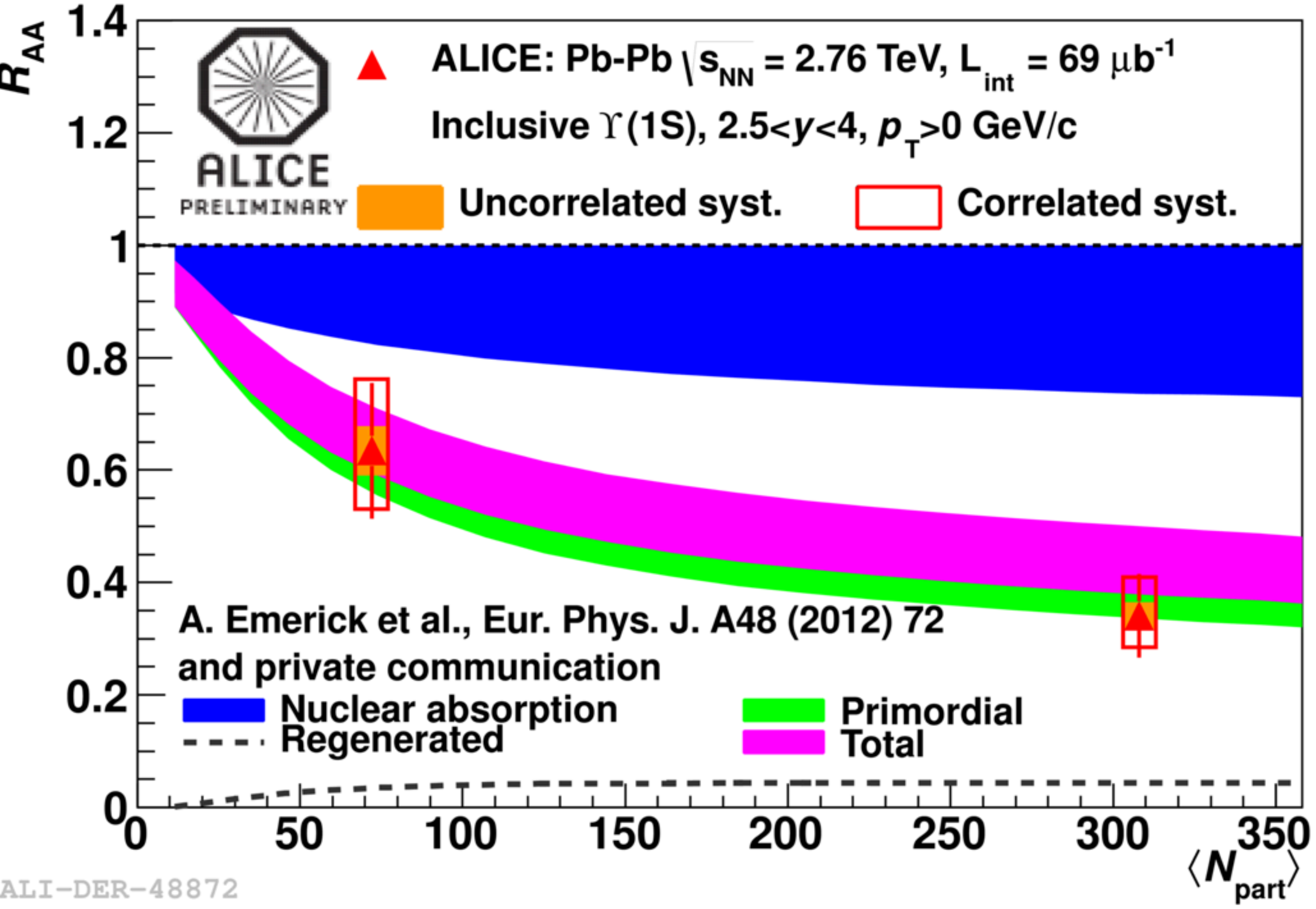


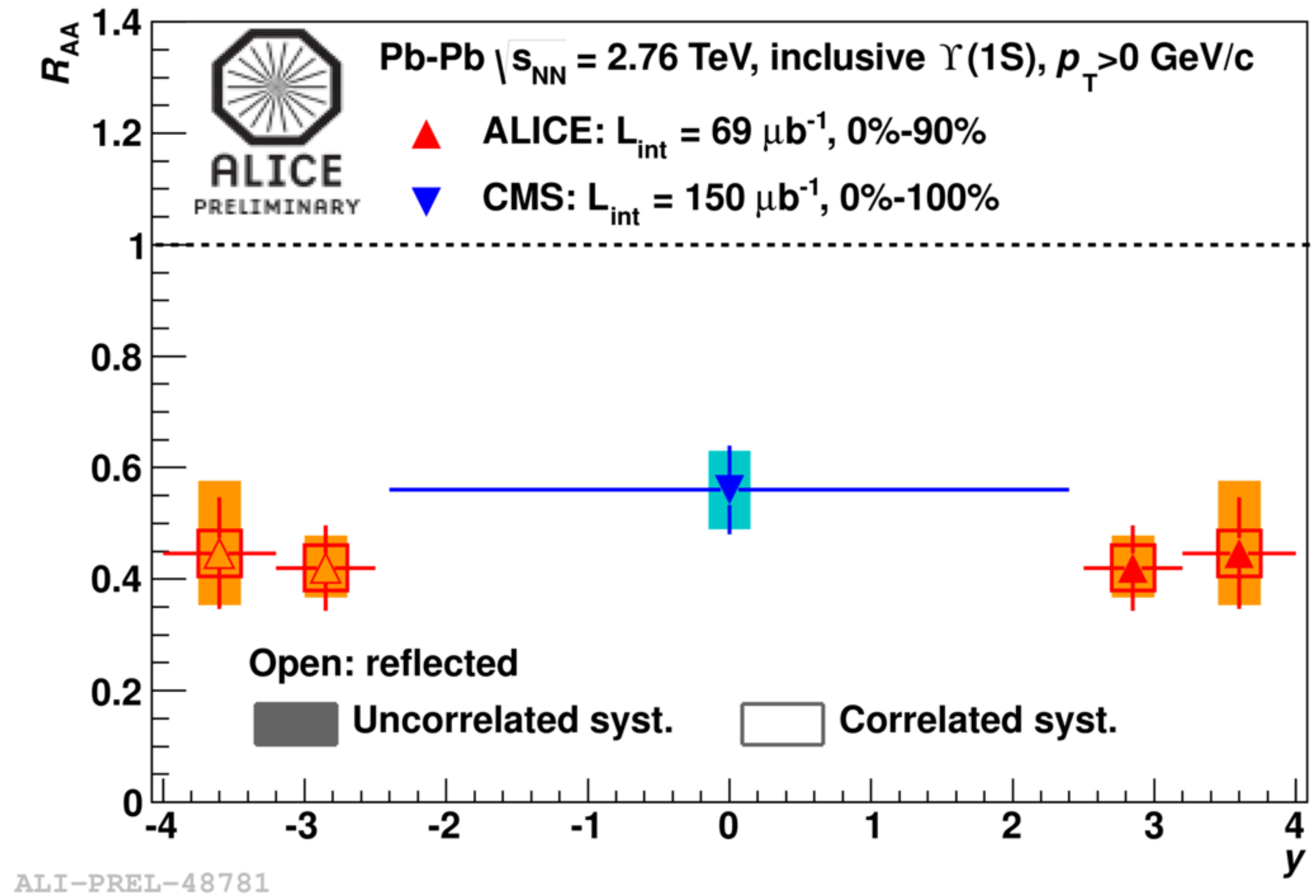


Suppression increases for most central collisions

Small rapidity dependence as compared with CMS

ϒ(1S) measurements at forward rapidity



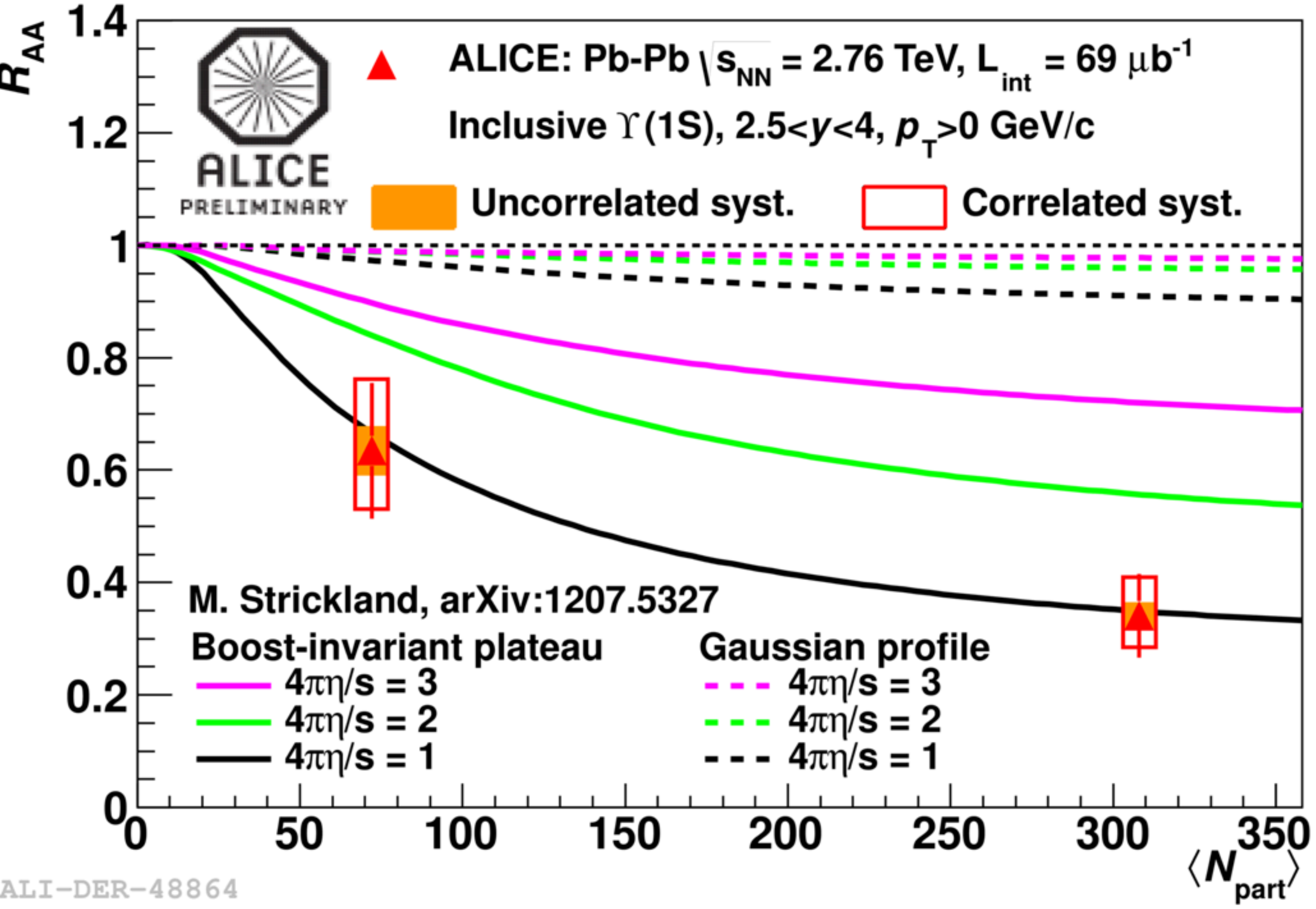


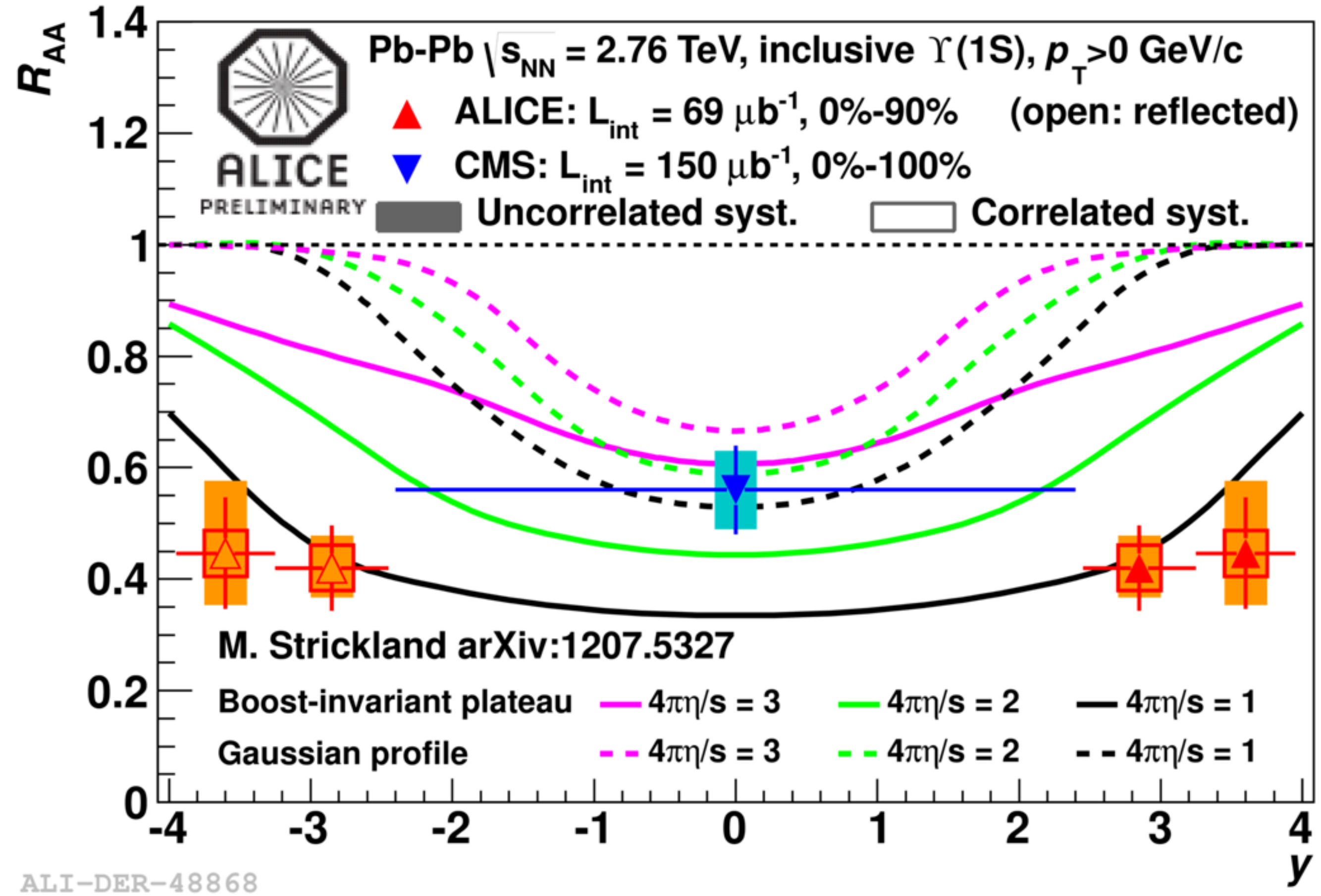
Models:

- Rate equation approach (Emerick et al.): suppression from dissociation and ϒ(1S) regeneration (small contribution), various absorption cross-sections (0 and 2 mb)
- Hydrodynamic model (Strickland): thermal dissociation and dynamic model, different hypothesis for the initial temperature profile suppression and the shear viscosity, no initial or final state cold nuclear effect

Rate equation model in good agreement with ALICE data

Υ(1S) measurements at forward rapidity





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- Hydrodynamic model (Strickland): thermal dissociation and dynamic model, different hypothesis for the initial temperature profile suppression and the shear viscosity, no initial or final state cold nuclear effect

Rate equation model in good agreement with ALICE data

Hydro model reproduces well ALICE data but not both ALICE and CMS data

Conclusions

Quarkonium production is used as a probe of the cold nuclear matter effects in p-Pb and of the hot medium formed in heavy-ion collisions

First p-Pb measurements

- J/ψ measurements support a strong shadowing at forward rapidity and/or the coherent energy loss model
- ψ(2S) suppressed relatively to J/ψ by up to 45% at backward rapidity: final state effect? Other mechanism in p-Pb?
- ϒ(1S) measurements show a similar suppression to the J/ψ but large uncertainties (pp interpolation, limited statistics) do not allow to constrain models

Latest Pb-Pb measurements

- J/ψ : R_{AA} measurements show a different behaviour wrt lower energy measurements. Models including J/ψ production from deconfined charm quarks in the QGP phase reproduce well the R_{AA}. The observation of a non zero v_2 is also in agreement with expectations from (re)generation models.
- ϒ(1S) R_{AA} at forward rapidity: combined with CMS data, results show a suppression with a small rapidity dependence

More measurements to come, stay tuned!

back-up slides

References

Pb-Pb measurements at $\sqrt{s_{NN}}$ = 2.76 TeV

- Centrality, rapidity and transverse momentum dependence of the J/ψ suppression in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV arXiv:1311.0214
- J/ψ Elliptic Flow in Pb-Pb Collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, Phys.Rev.Lett. 111(2013) 162301, arXiv:1303.5880
- J /ψ suppression at forward rapidity in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV Phys.Rev.Lett. 109 (2012) 072301, arXiv:1202.1383

p-Pb measurements at $\sqrt{s_{NN}}$ = 5.02 TeV

- J/Ψ production and nuclear effects in p-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV, arXiv:1308.6726

pp measurements at $\sqrt{s}$ = 2.76 and 7 TeV

- Rapidity and transverse momentum dependence of inclusive J/ψ production in pp collisions at $\sqrt{s}$ = 7 TeV, Phys.Lett.B 704 (2011) 442, arXiv:1105.0380
- Inclusive J/ψ production in pp collisions at $\sqrt{s}$ = 2.76 TeV, Phys.Lett.B 718 (2012) 295, arXiv:1203.3641
- J/ψ production as a function of Charged Particle Multiplicity in pp collisions at $\sqrt{s}$ = 7 TeV, Phys.Lett.B 712 (2012) 165, arXiv:1202.2816
- J/ψ polarization in pp collisions at $\sqrt{s}$ = 7 TeV, Phys.Rev.Lett. 108 (2012) 082001, arXiv:1111.1630
- Measurement of prompt J/ψ and beauty hadron production cross-sections at mid-rapidity in pp collisions, JHEP 11 (2012) 065, arXiv:1205.5880

pp cross-section interpolation at 5.02 TeV

J/ψ cross-section

Forward rapidity:

Energy interpolation of p_T and y-dep. with ALICE forward rapidity data @ 2.76 and 7 TeV
Rapidity extrapolation due to rapidity shift (0.5) in p-Pb
CEM and FONLL calculations used to validate the empirical functions used

ALICE + LHCb, public note in preparation

Mid-rapidity:

Energy interpolation at mid-rapidity with PHENIX @ 200 GeV, CDF @ 1.96 TeV, ALICE @ 2.76 and 7 TeV
$\langle p_T \rangle$ interpolation and p_T extrapolation with both forward and mid-rapidity data from PHENIX @ 200 GeV, CDF @ 1.96 TeV, ALICE @ 2.76 and 7 TeV, CMS @ 7 TeV, LHCb @ 2.76, 7 and 8 TeV

F. Bossù et al., arXiv:1103.2394

[ψ(2S)/J/ψ] ratio

No energy and rapidity dependence of [ψ(2S)/J/ψ] in pp assumed. Systematics evaluated with CDF @ 1.96 TeV and LHCb @ 7 TeV

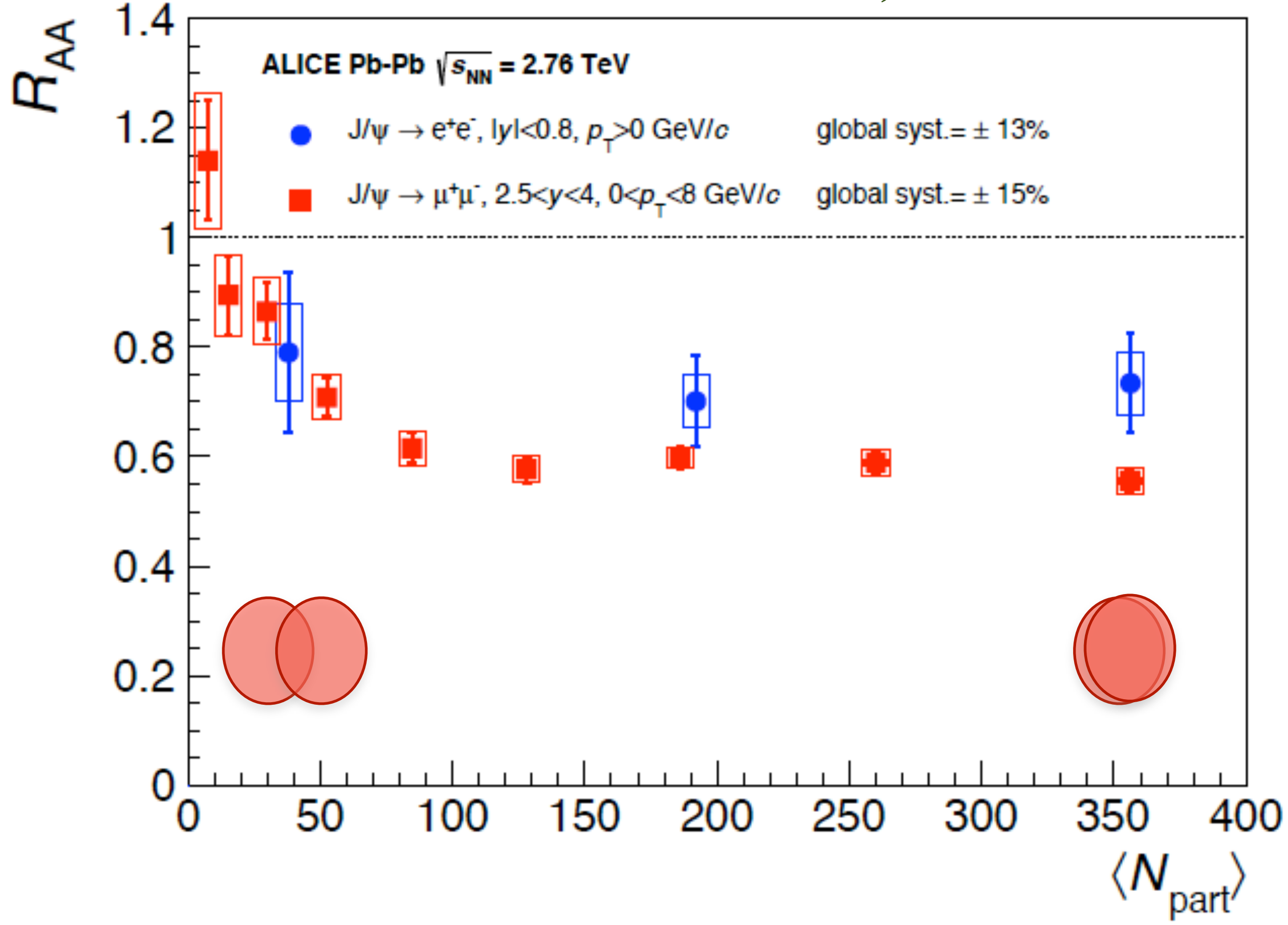
ϒ(1S) cross-section

Energy interpolation with mid-rapidity data from CDF @ 1.8 TeV, D0 @ 1.96 TeV, CMS @ 2.76 and 7 TeV
Rapidity extrapolation: Pythia tunings selected with rapidity dependence of CMS and LHCb @ 7 TeV

	Systematics
J/ψ (y>0)	6-17%
J/ψ (y~0)	16-27%
[ψ(2S)/J/ψ] (y>0)	4 %
ϒ(1S)	13-19%

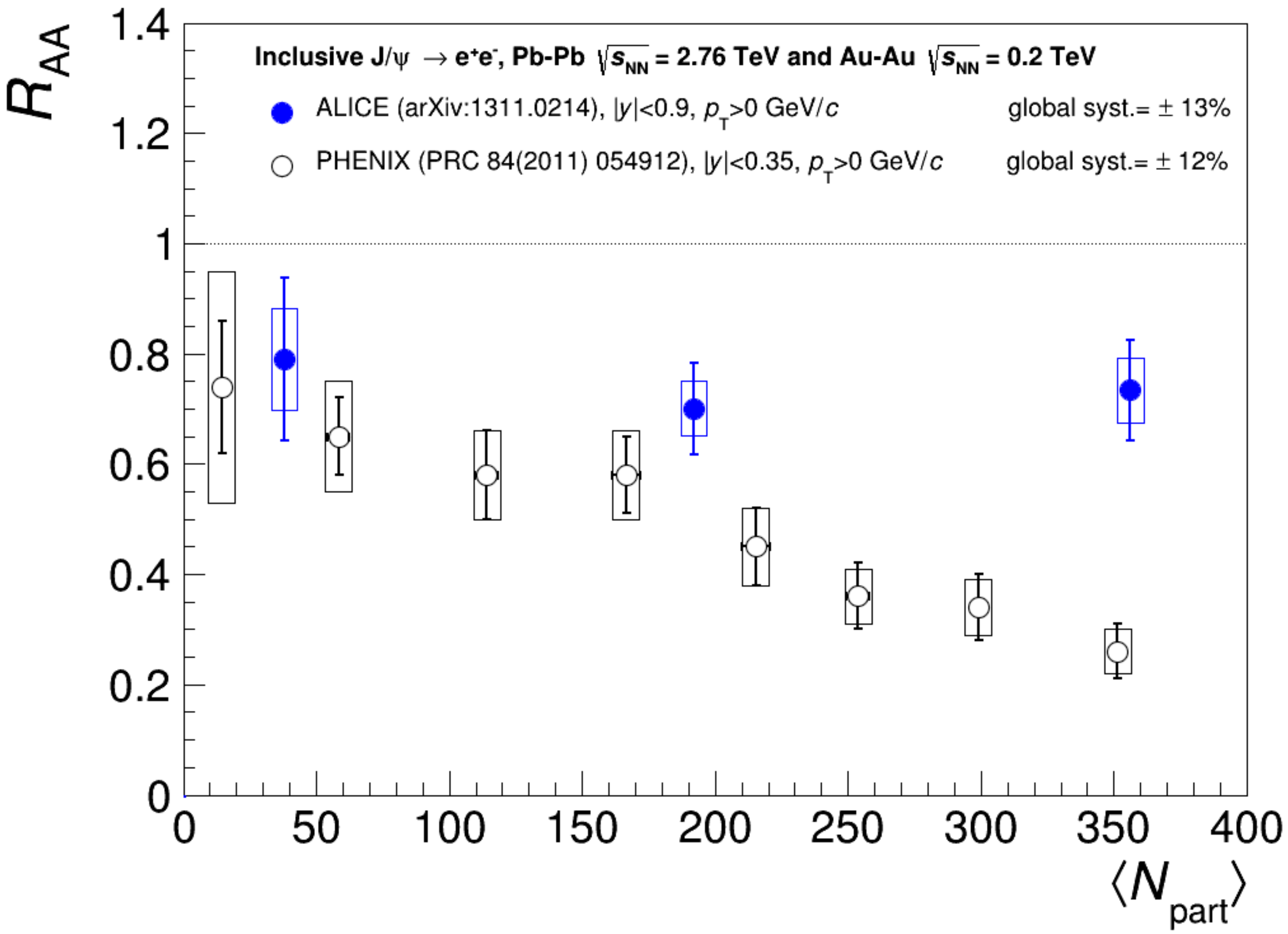
J/ψ R_{AA} vs centrality

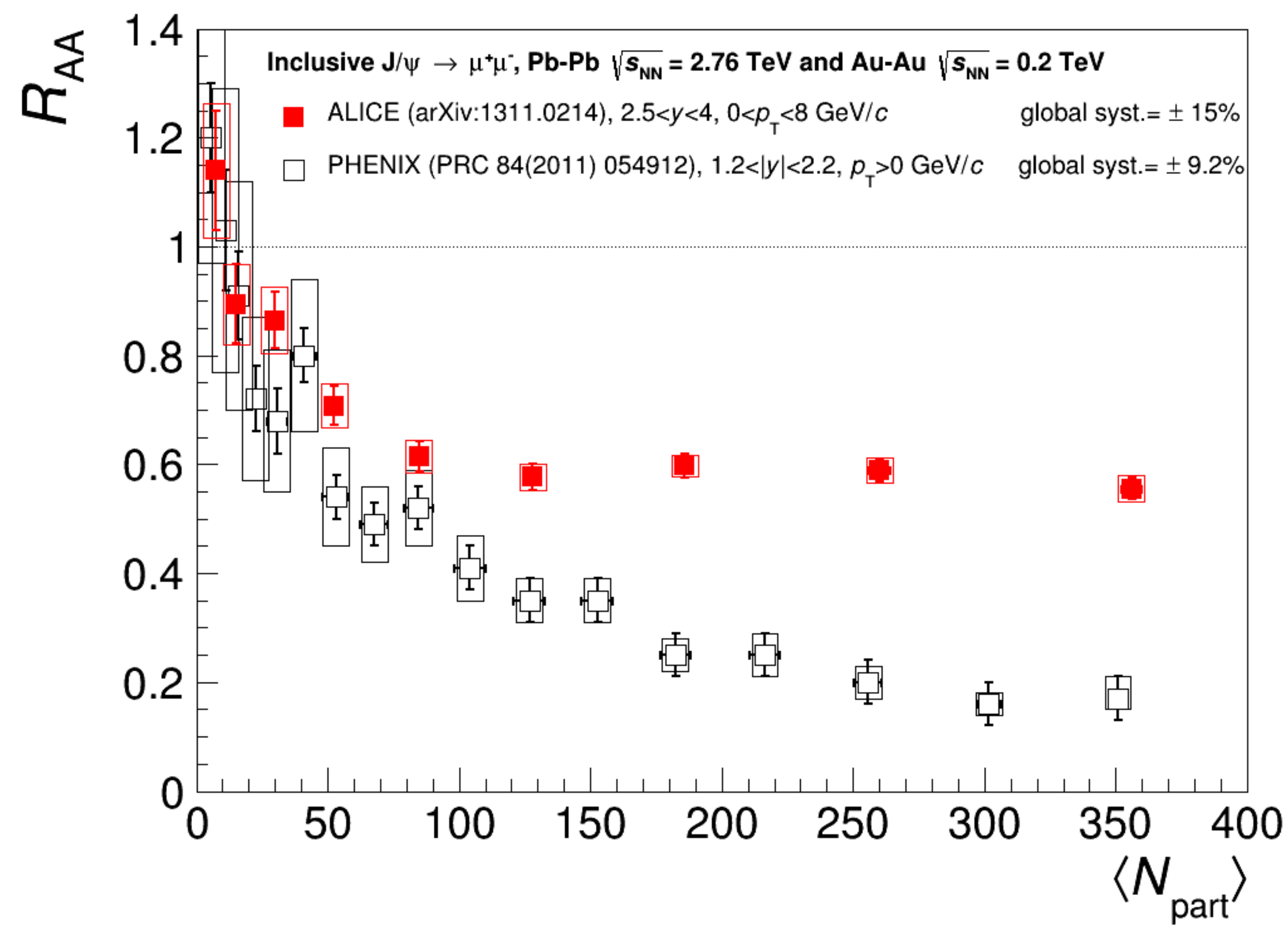
ALICE, arXiv:1311.0214



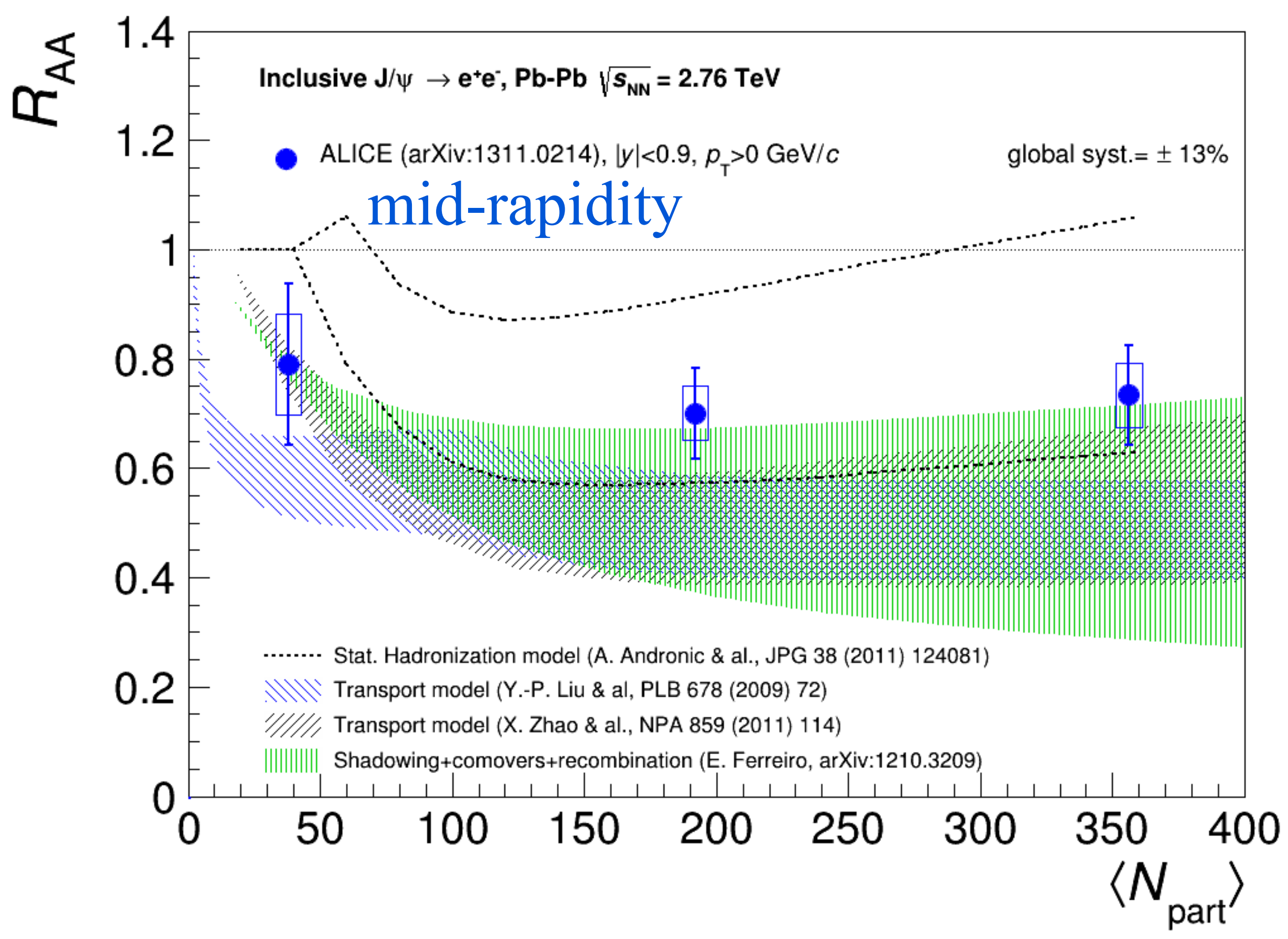
Forward rapidity: clear J/ψ suppression with no centrality dependence for N_{part} > 100
Mid-rapidity: no significant dependence with centrality but large uncertainty
Larger suppression at forward rapidity

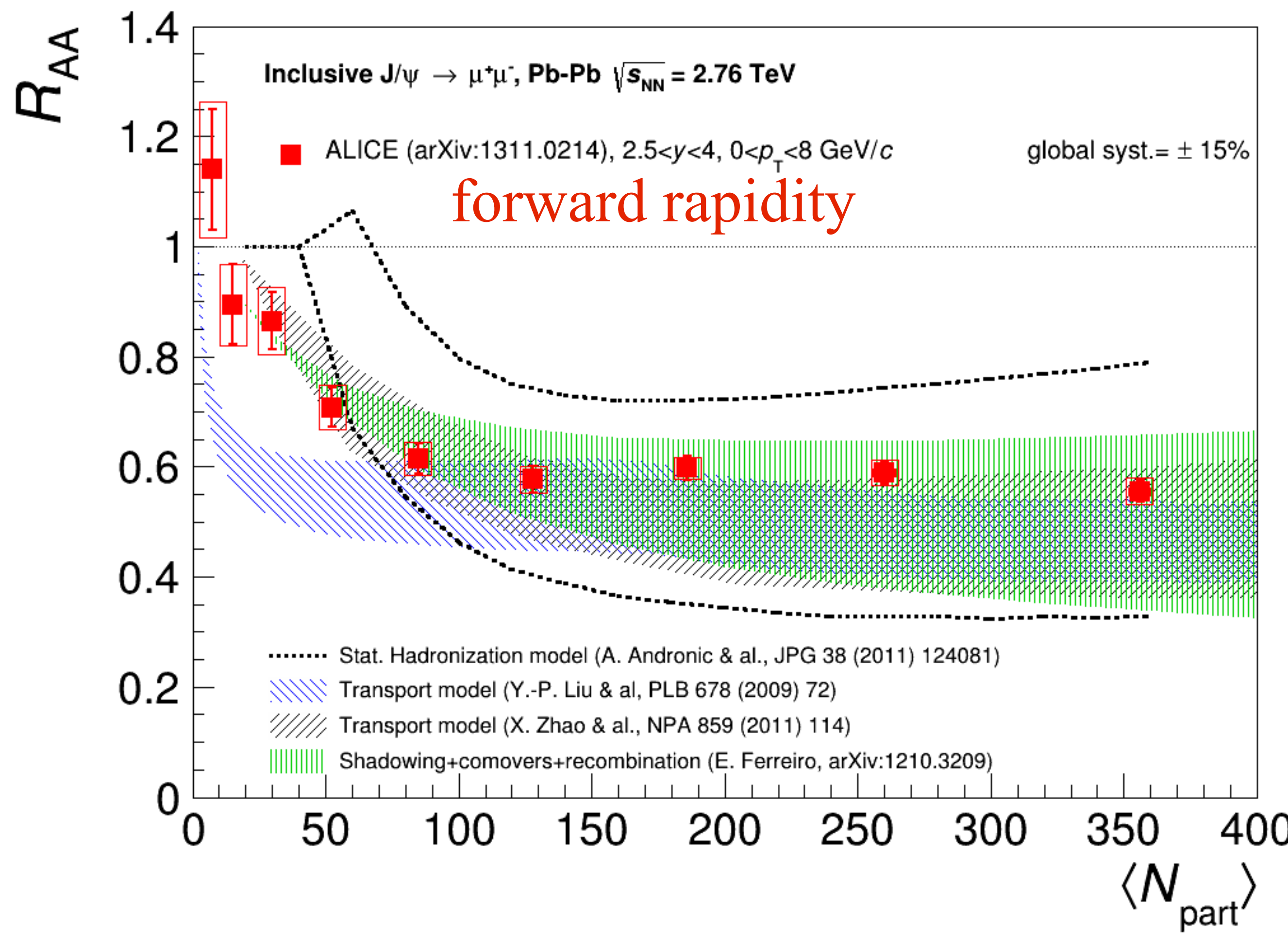
J/ψ R_{AA} vs centrality: comparison with PHENIX





J/ψ R_{AA} vs centrality



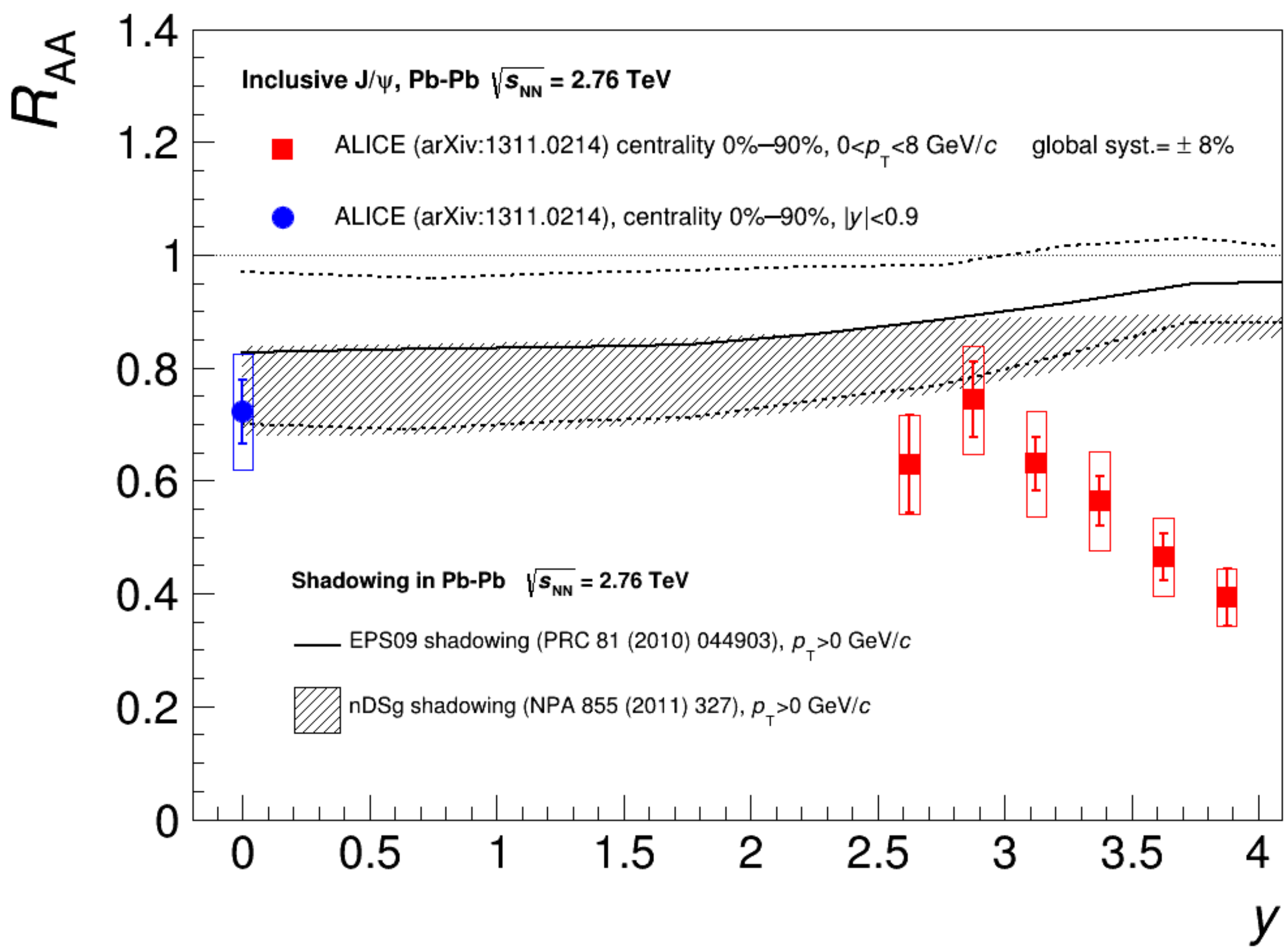


Models:

- Statistical model (Andronic et al.): thermal model, all J/ψ formed at hadronization, different σ_{cc} hypothesis
- Transport (Zhao et al./ Liu et al.) and comovers+recombination (Ferreiro) models: suppression and more than 50% of J/ψ from regeneration for most central events, different σ_{cc} and/or shadowing hypothesis

These models include regeneration mechanism and describe well the data for semi-central and central collisions

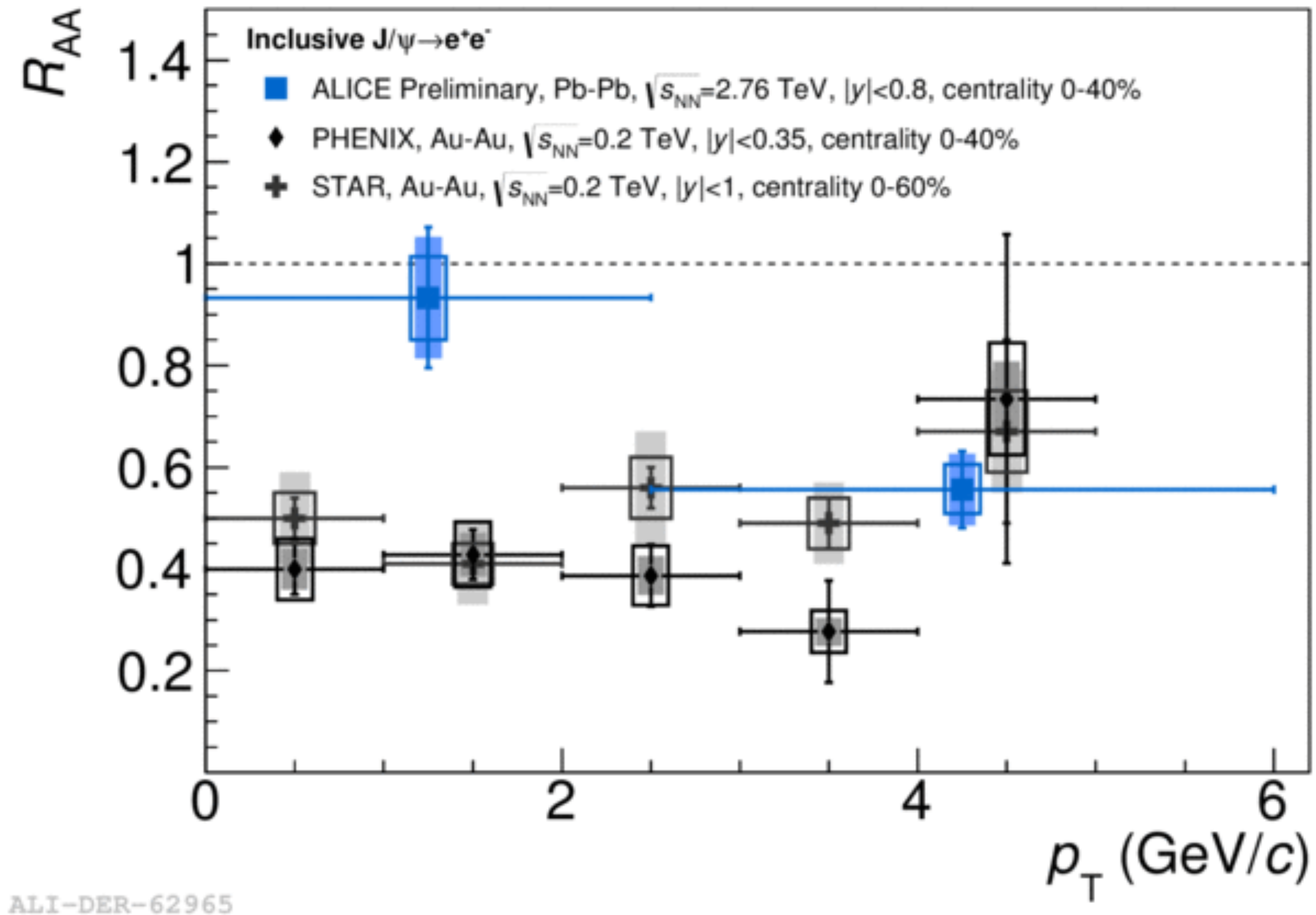
J/ψ R_{AA} vs y



Suppression more important at forward rapidity

Shadowing models do not account for this rapidity decrease of R_{AA}

J/ψ R_{AA} vs p_T at mid-rapidity



p-Pb measurements extrapolated to Pb-Pb

Hypothesis

2→1 kinematics of J/ψ production

Factorization of shadowing effects in p-Pb and Pb-Pb ⇒ $R^{\mathrm{Shad}}_{\mathrm{PbPb}} = R_{\mathrm{pPb}}(x_1) \times R_{\mathrm{pPb}}(x_2)$

Kinematics

p (x_1) + Pb (x_2) → J/ψ (y, p_T) with $x_{1,2} = \sqrt{(m^2+p_T^2)} / \sqrt{s_{NN}} \exp(\pm y_{cms})$

$R_{pPb}(\sqrt{s_{NN}}= 5.02\ \mathrm{TeV}, y<0, p_T) = G(x_1)$

$R_{pPb}(\sqrt{s_{NN}}= 5.02\ \mathrm{TeV}, y>0, p_T) = G(x_2)$

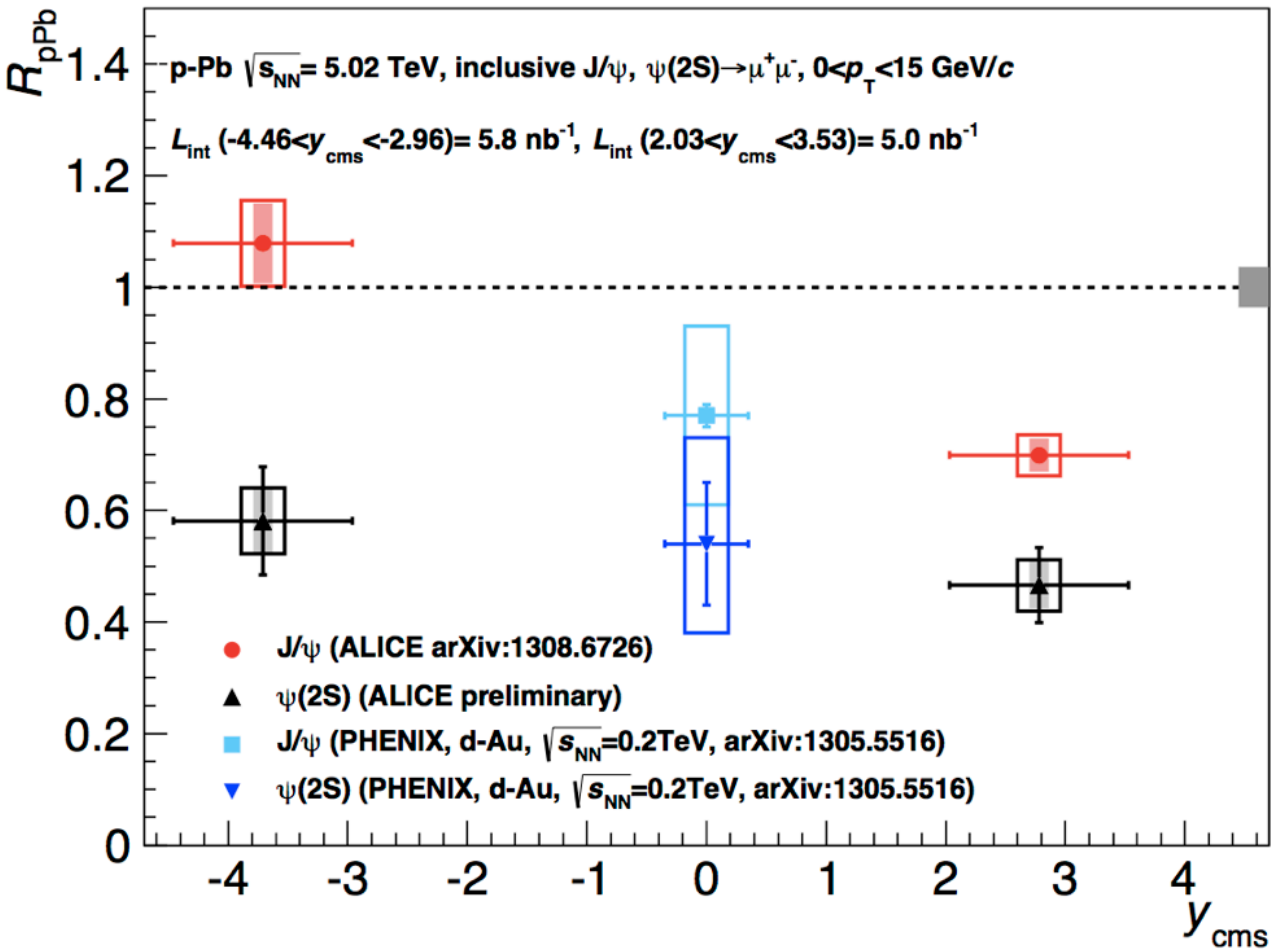
gluon x in nucleus	x_1	x_2
p-Pb @ 5.02 TeV and $-4.46<y_{cms}<-2.96$	$1.2\text{-}5.3\ 10^{-2}$	-
p-Pb @ 5.02 TeV and $2.03<y_{cms}<3.53$	-	$1.9\text{-}8.3\ 10^{-5}$
Pb-Pb @ 2.76 TeV and $2.5<y<4$	$1.2\text{-}6.1\ 10^{-2}$	$2.0\text{-}9.2\ 10^{-5}$
p-Pb @ 5.02 TeV and $-1.37<y_{cms}<0.43$	$4.0\ 10^{-4}\text{-}2.4\ 10^{-3}$	$4.0\ 10^{-4}\text{-}2.4\ 10^{-3}$
Pb-Pb @ 2.76 TeV and $-0.8<y<0.8$	$5.0\ 10^{-4}\text{-}2.5\ 10^{-3}$	$5.0\ 10^{-4}\text{-}2.5\ 10^{-3}$

⇒ gluon momentum fraction x_1, x_2 probed in nucleus similar in p-Pb @ 5.02 TeV and Pb-Pb @ 2.76 TeV

Cold nuclear matter contribution in Pb-Pb

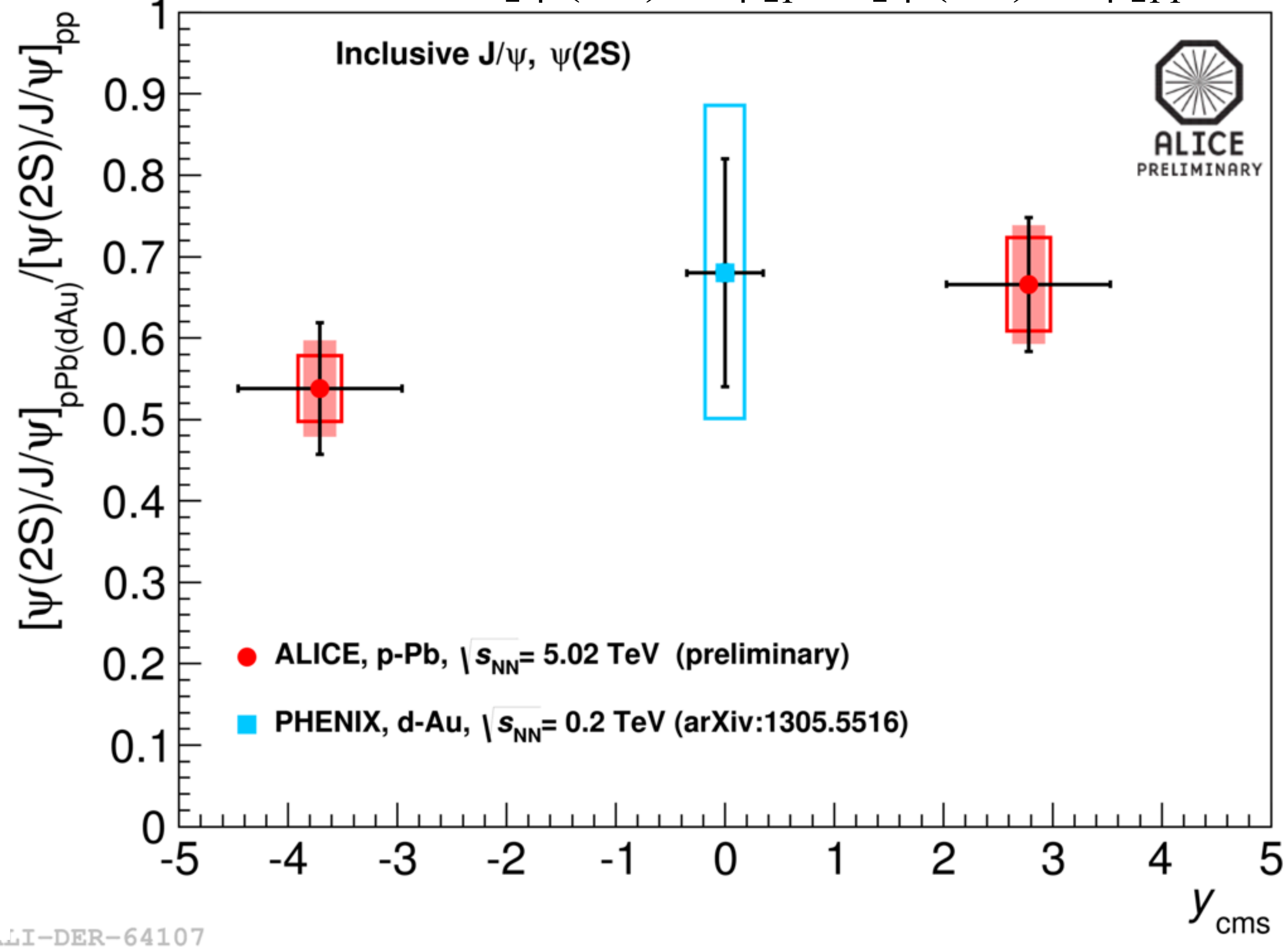
$$R_{PbPb}(\sqrt{s_{NN}}=2.76\ \mathrm{TeV}, y, p_T)$$
$$= G(x_1) \times G(x_2)$$
$$= R_{pPb}(\sqrt{s_{NN}}= 5.02\ \mathrm{TeV}, y<0, p_T) \times R_{pPb}(\sqrt{s_{NN}}= 5.02\ \mathrm{TeV}, y>0, p_T)$$

ψ(2S): comparison to PHENIX

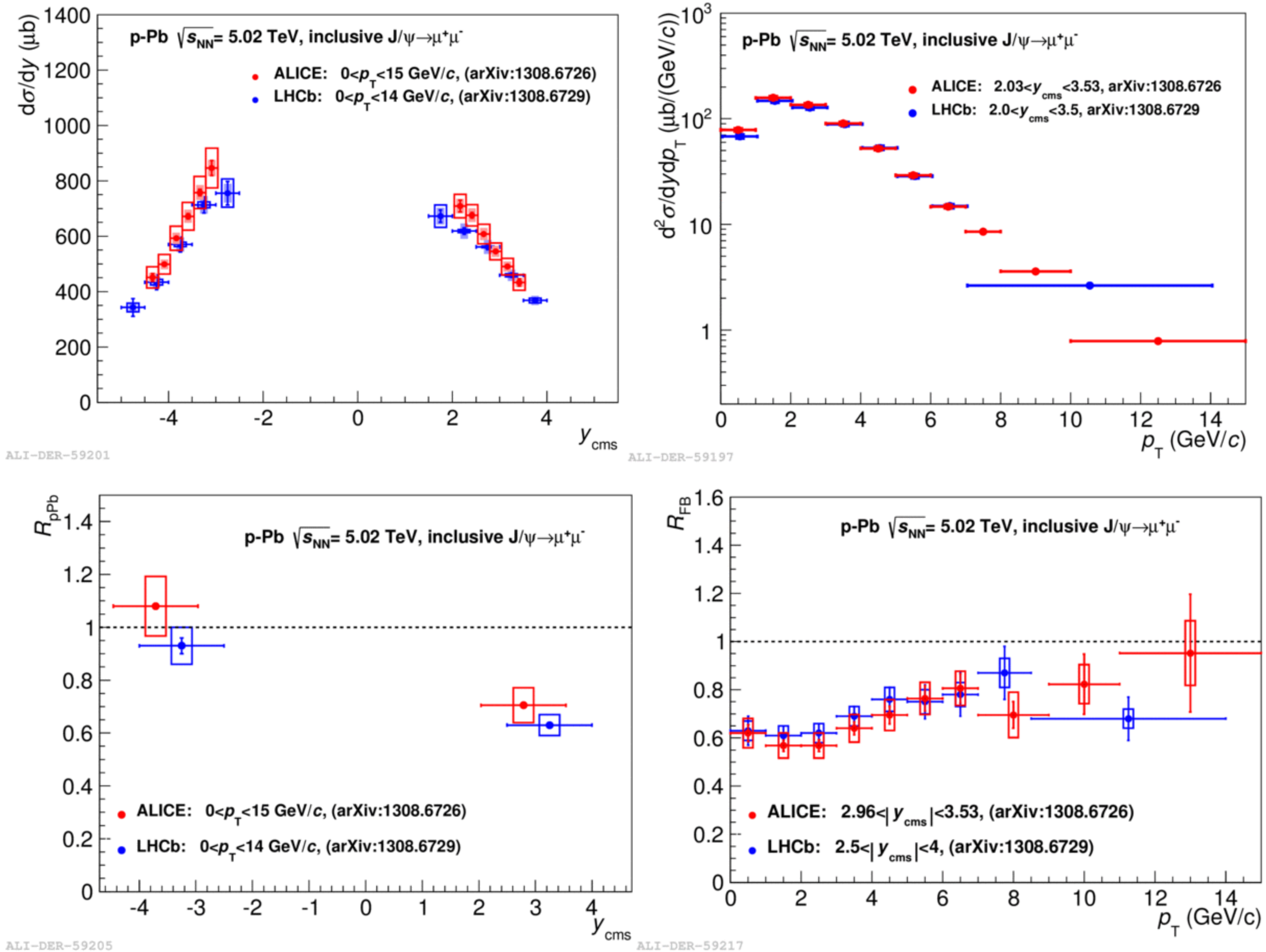


Relative suppression:

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



Inclusive J/ψ in p-Pb: comparison to LHCb



J/ψ R_{pPb} as a function of rapidity