CNM effects at LHC energies: a look at at heavy quarkonium data in p-Pb collisions

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INT Seattle, October 8 2014

- Charmonia and bottomonia in p-Pb: what is available from run-1 ?
- Some “delicate” items: prompt vs inclusive, reference pp cross sections….
- Results and discussion of the comparison with models (ALICE-centric)
- From p-Pb to Pb-Pb; CNM extrapolations

LHC: p-Pb data taking

- Carried out on January/February 2013

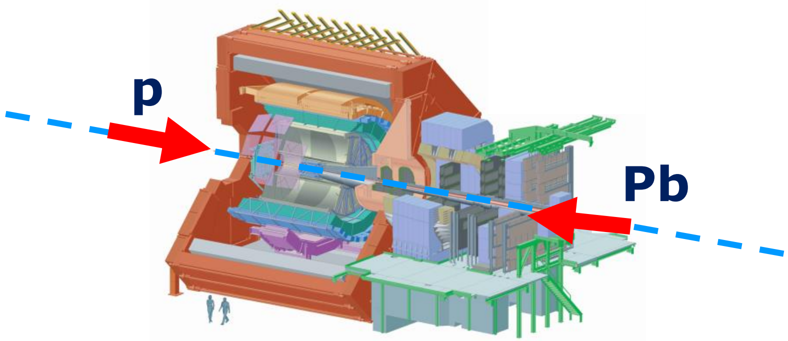
  Beam energy: $\sqrt{s_{NN}}$ = 5.02 TeV

  Energy asymmetry of the LHC beams (E_p = 4 TeV, E_{Pb}= 1.58 A·TeV)

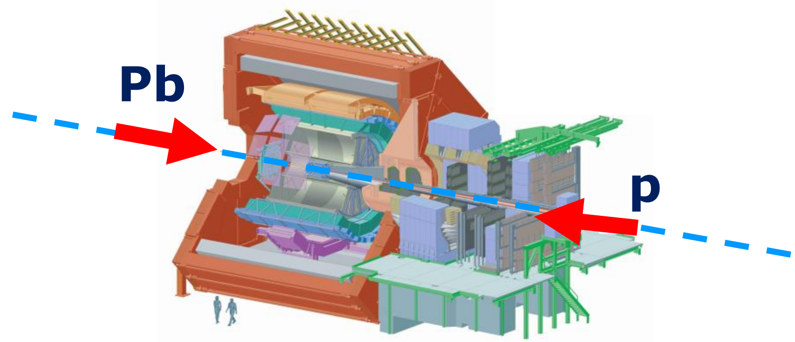
  → rapidity shift Δy= 0.465 in the proton direction

  Beam configurations:

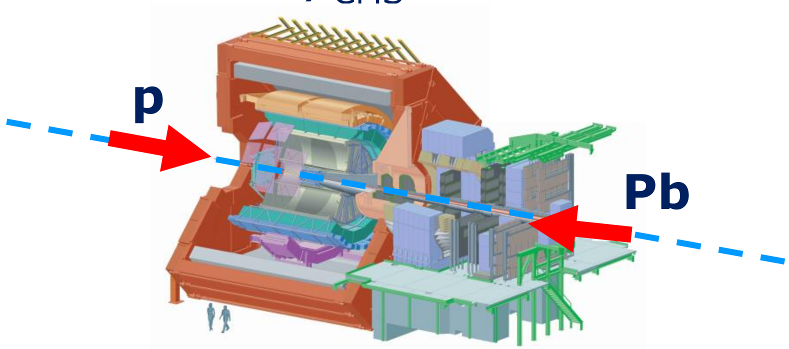
  Data collected with two beam configurations (swapping the beams)



$2.03 < y_{CMS} < 3.53$



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



$-1.37 < y_{CMS} < 0.43$

- Integrated luminosities (ALICE)
  - 5.01 ± 0.17 nb^{-1} (p-Pb sample, forward rapidity)
  - 51.4 ± 1.6 μb^{-1} (p-Pb sample, mid-rapidity)
  - 5.81 ± 0.18 nb^{-1} (Pb-p sample, backward rapidity)

Summary of charmonium results

J/ψ	ALICE	CMS	LHCb
R_{pA} vs y	♦		♦
R_{pA}^{prompt} vs y			♦
R_{pA} vs p_T	♦		
Q_{pA} vs centr.	♦		
Rel. yield vs $N_{ch}(E_T)$	♦		

$\psi(2S)$	ALICE	CMS	LHCb
R_{pA} vs y	♦		
R_{pA}^{prompt} vs y			
R_{pA} vs p_T	♦		
Q_{pA} vs centr.	♦		
Rel. yield vs $N_{ch}(E_T)$			

Additionally

- ALICE
- Double ratios $\psi(2S)/J/\psi$
  - vs y
  - vs p_T
  - vs centrality

- ALICE ←→ LHCb: similar forw./backw. y-range (slightly larger for LHCb)
- Satisfactory for forw/backw J/ψ, fairly good for $\psi(2S)$, CMS results will be welcome

Summary of bottomonium results

$\Upsilon(1S)$	ALICE	CMS	LHCb
R_{pA} vs y	♦		♦
R_{pA}^{prompt} vs y			
R_{pA} vs p_T			
Q_{pA} vs centr.			
Rel. yield vs $N_{ch}(E_T)$		♦	

$\Upsilon(2S)$	ALICE	CMS	LHCb
R_{pA} vs y			
R_{pA}^{prompt} vs y			
R_{pA} vs p_T			
Q_{pA} vs centr.			
Rel. yield vs $N_{ch}(E_T)$		♦	

$\Upsilon(3S)$	ALICE	CMS	LHCb
R_{pA} vs y			
R_{pA}^{prompt} vs y			
R_{pA} vs p_T			
Q_{pA} vs centr.			
Rel. yield vs $N_{ch}(E_T)$		♦	

Additionally

- CMS
- Double ratios
  $\Upsilon(2S)/\Upsilon(1S)$
  $\Upsilon(3S)/\Upsilon(1S$
  - Integrated
  - vs $N_{ch}(E_T)$

- Just scratching the surface
  → more data needed

Estimating the pp reference

- No pp data available for the moment at $\sqrt{s}$=5.02 TeV
- Negotiations with the machine for having a short pp run in fall 2015
- Problem
  - If a short run is chosen (few days)
    → Take those days from the "pp period", get low L_{int}
  - If a longer run is needed (few weeks)
    → Take those days from the "Pb-Pb period", get large L_{int}

  → Delicate balance

- Look in some detail at the procedure for J/ψ at forward/backward y
- ALICE/LHCb joint task force → converge on an interpolation procedure using pp data at $\sqrt{s}$ = 2.76, 7 and 8 TeV

Experiment	$\sqrt{s}$ [TeV]	process	$\sigma(J/\psi)$ [μb]
ALICE	2.76	inclusive	$3.34 \pm 0.13 \pm 0.27$
ALICE	7	inclusive	$6.78 \pm 0.04 \pm 0.64$
LHCb	2.76	inclusive	$3.48 \pm 0.06 \pm 0.27$
LHCb	7	inclusive	$6.55 \pm 0.01 \pm 0.37$
LHCb	8	inclusive	$7.59 \pm 0.01 \pm 0.55$

Typical uncertainties on existing data: up to ~10%, dominated by systematics

LHCb-CONF-2013-013; ALICE-PUBLIC-2013-002

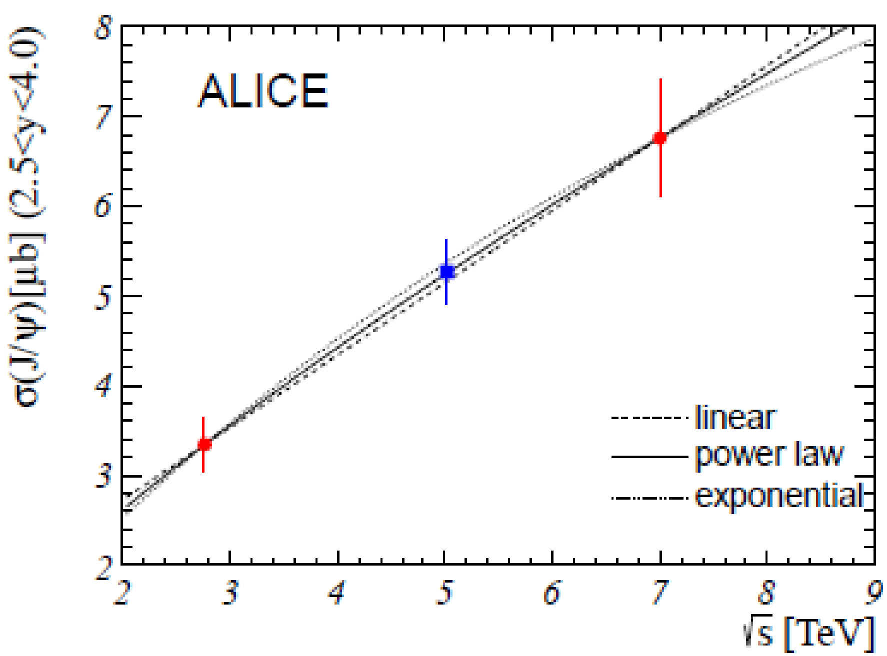
Interpolation procedure

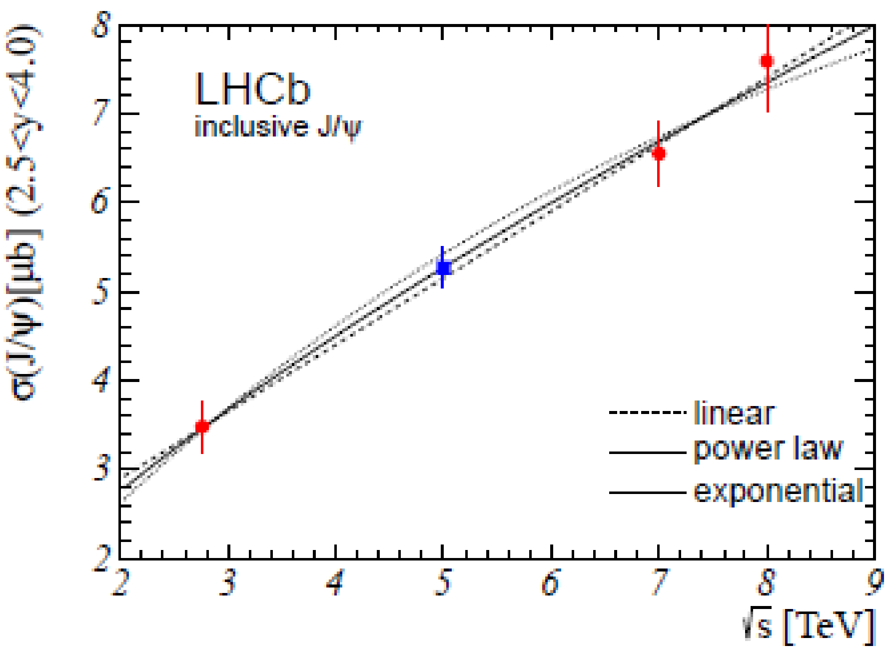
- Interpolation procedure makes use of
  - Empirical approach
  - Theoretical calculations (LO CEM and FONLL)

$$\sigma(\sqrt{s}) = \begin{cases} p_0 + \sqrt{s}\,p_1 & \text{linear} \\ (\sqrt{s}/p_0)^{p_1} & \text{power law} \\ p_0(1 - \exp(-\sqrt{s}/p_1)) & \text{exponential}\,. \end{cases}$$

model	cross-section [μb]
linear	5.17 ± 0.41
power law	5.26 ± 0.40
exponential	5.38 ± 0.40
average	$5.28 \pm 0.40 \pm 0.10$

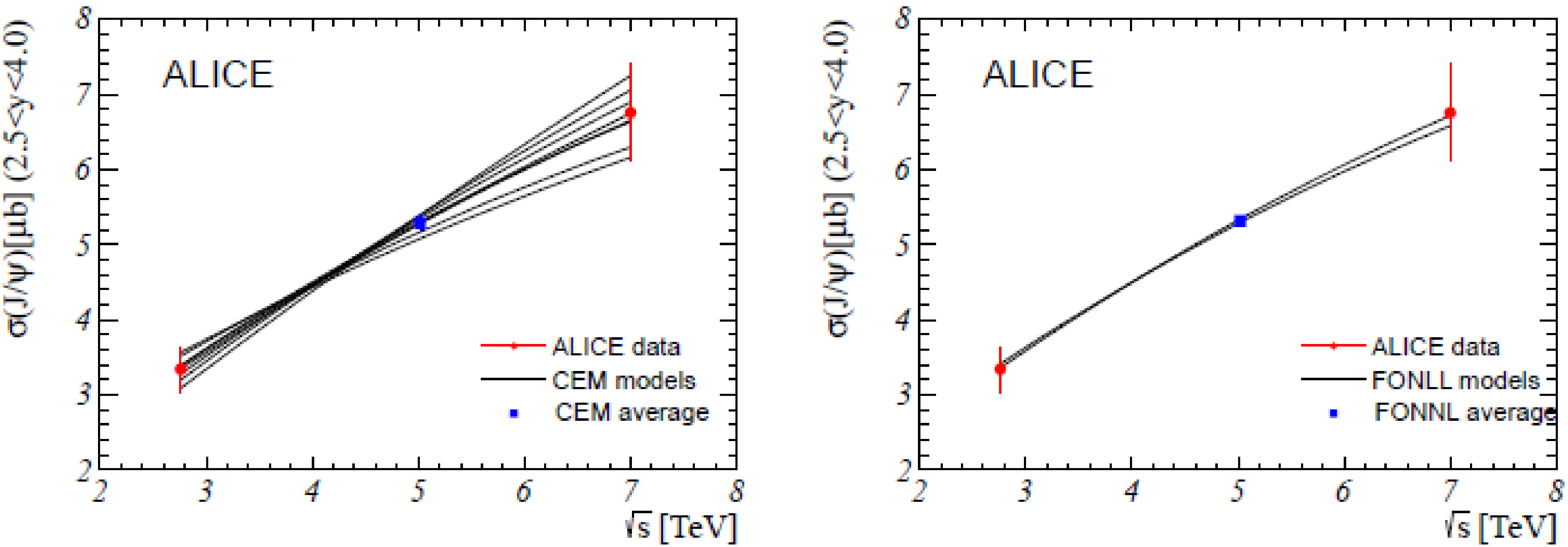
Small relative spread
Max. deviation → syst unc.





Interpolation procedure

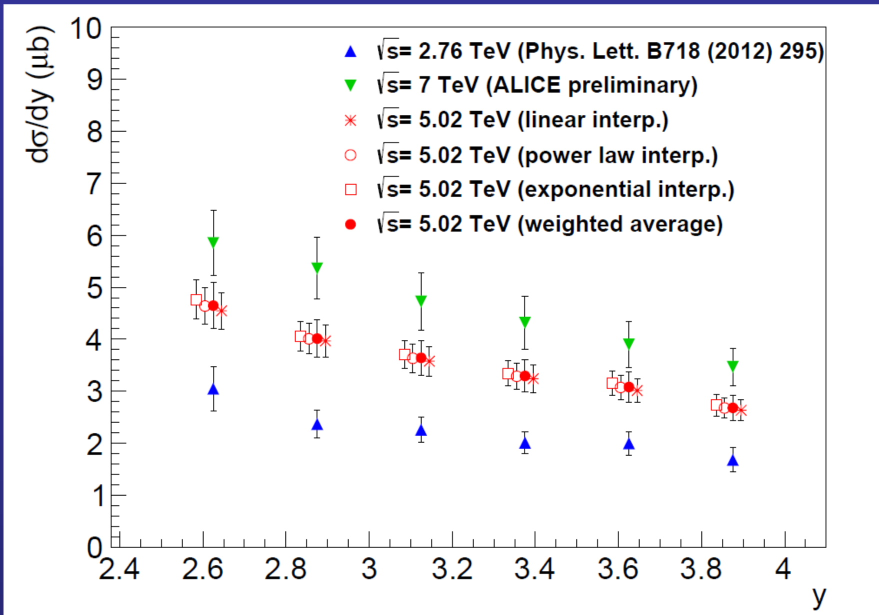
- ❑ Calculate cross sections at $\sqrt{s}$ = 2.76, 5 and 7 TeV using CEM and FONLL
- ❑ Fix the normalization in order to fit existing 2.76 and 7 TeV data
- ❑ Re-normalize 5 TeV calculation using the fit results



- ❑ Use maximum difference between CEM/FONLL and empirical fit as a further uncertainty

$$\sigma_{\rm incl} = 5.28 \pm 0.40_{\rm exp} \pm 0.10_{\rm inter} \pm 0.05_{\rm theo}\,\mu{\rm b} = 5.28 \pm 0.42\,\mu{\rm b}\,.$$

Rapidity dependence

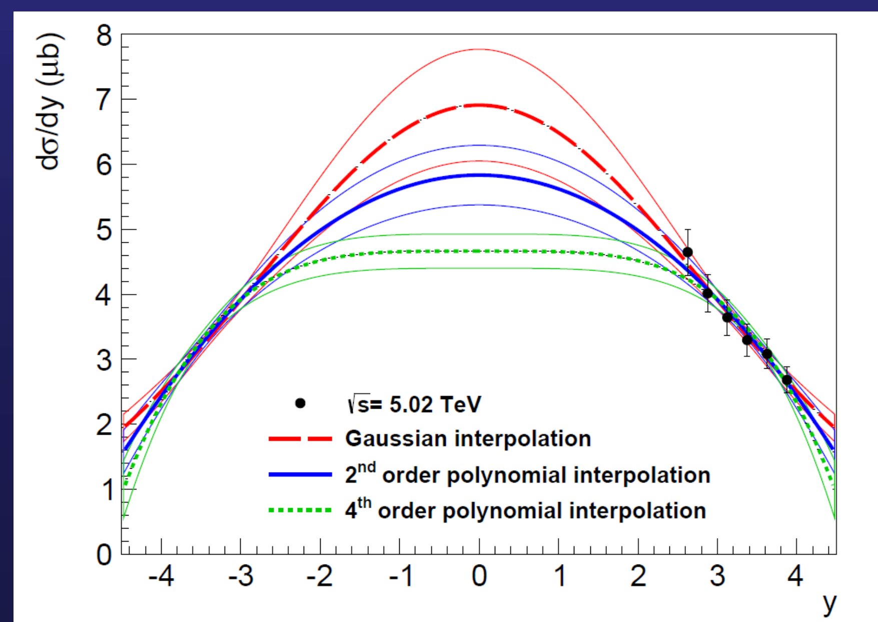


- First interpolate bin-per-bin the measured cross sections, with the same procedure used for the integrated results

- The pp and p-Pb y-coverage is not exactly the same (up to 0.5 units mismatch)
  → Extrapolate with various empirical functions

	$d\sigma/dy$ (μb), $\sqrt{s} = 5.02$ TeV
$2.03 < y < 2.28$	$4.72 \pm 0.28 \pm 0.26 \pm 0.42 \pm 0.12$
$2.28 < y < 2.53$	$4.53 \pm 0.25 \pm 0.25 \pm 0.24 \pm 0.11$
$2.53 < y < 2.78$	$4.30 \pm 0.20 \pm 0.23 \pm 0.11 \pm 0.04$
$2.78 < y < 3.03$	$4.02 \pm 0.16 \pm 0.22 \pm 0.01 \pm 0.11$
$3.03 < y < 3.28$	$3.70 \pm 0.12 \pm 0.20 \pm 0.04 \pm 0.09$
$3.28 < y < 3.53$	$3.36 \pm 0.10 \pm 0.18 \pm 0.06 \pm 0.08$
$2.03 < y < 3.53$	$4.12 \pm 0.18 \pm 0.23 \pm 0.11 \pm 0.10$

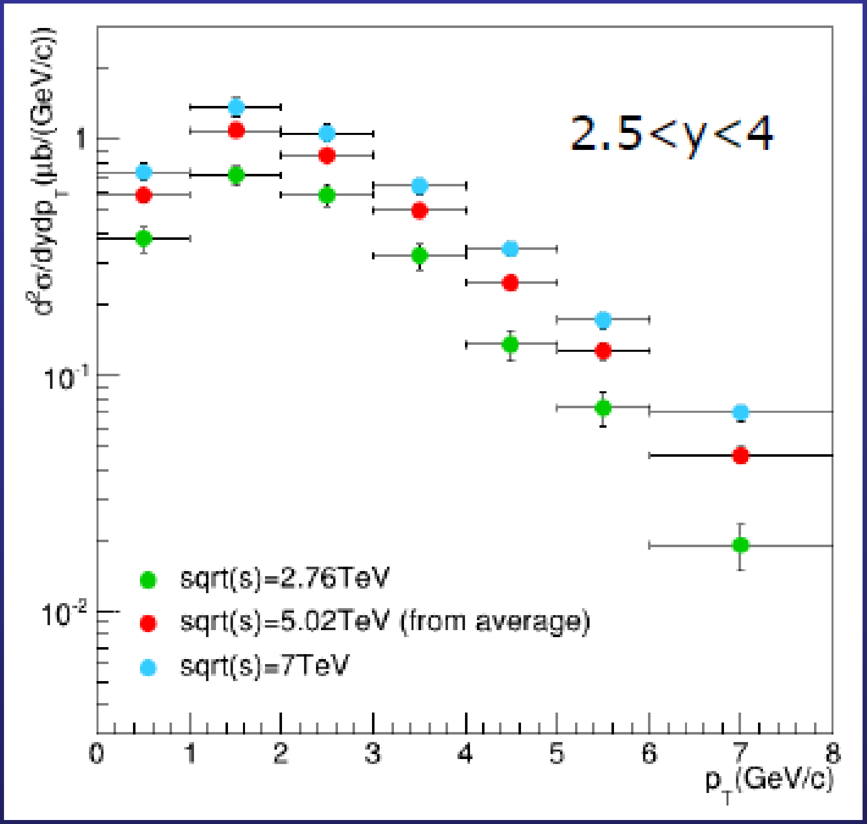
y-uncorrelated
y-correlated
fit dispersion
theoretical



p_T dependence

- Forward rapidity analysis
  → 3-step procedure

1) √s-interpolation (between 2.76 and 7 TeV) of $d^2\sigma/dydp_T$
2) Account for rapidity "mismatch" via empirical shapes (as for y-dependence)
3) (small) correction for $\langle p_T \rangle$ dependence on rapidity



- Central rapidity analysis

1) Empirical √s-interpolation at y=0 (data by PHENIX, CDF, ALICE)
1a) neglect small y-shift in p-Pb wrt pp (negligible wrt uncertainties)
2) Use scaling properties of p_T distributions plotted vs $p_T/\langle p_T \rangle$
   (get $\langle p_T \rangle$ at 5 TeV from an interpolation of mid-rapidity results at various √s)

ψ(2S) interpolation

- $R_{pPb}^{\psi(2S)}$ is obtained via the double ratio with respect to J/ψ

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

- Problem: no reference pp ratio at √s = 5 TeV
  - Solution: use ALICE √s = 7 TeV results, estimating the √s-dependence of the ratio ψ(2S)/J/ψ → small
  - Verified by
    - Extrapolating the ALICE value of the ratio at √s = 7 TeV from forward to central rapidity (use Gaussian y-shape from J/ψ data and y_{max} scaling for ψ(2S))
    - Interpolating linearly (or via exponential or polynomial) between CDF and ALICE to √s = 5 TeV, y=0
    - Extrapolating to √s = 5 TeV, forward-y
- Get a 4% difference between √s = 7 TeV and √s = 5 TeV at forward-y
- Take conservatively an 8% systematic uncertainty

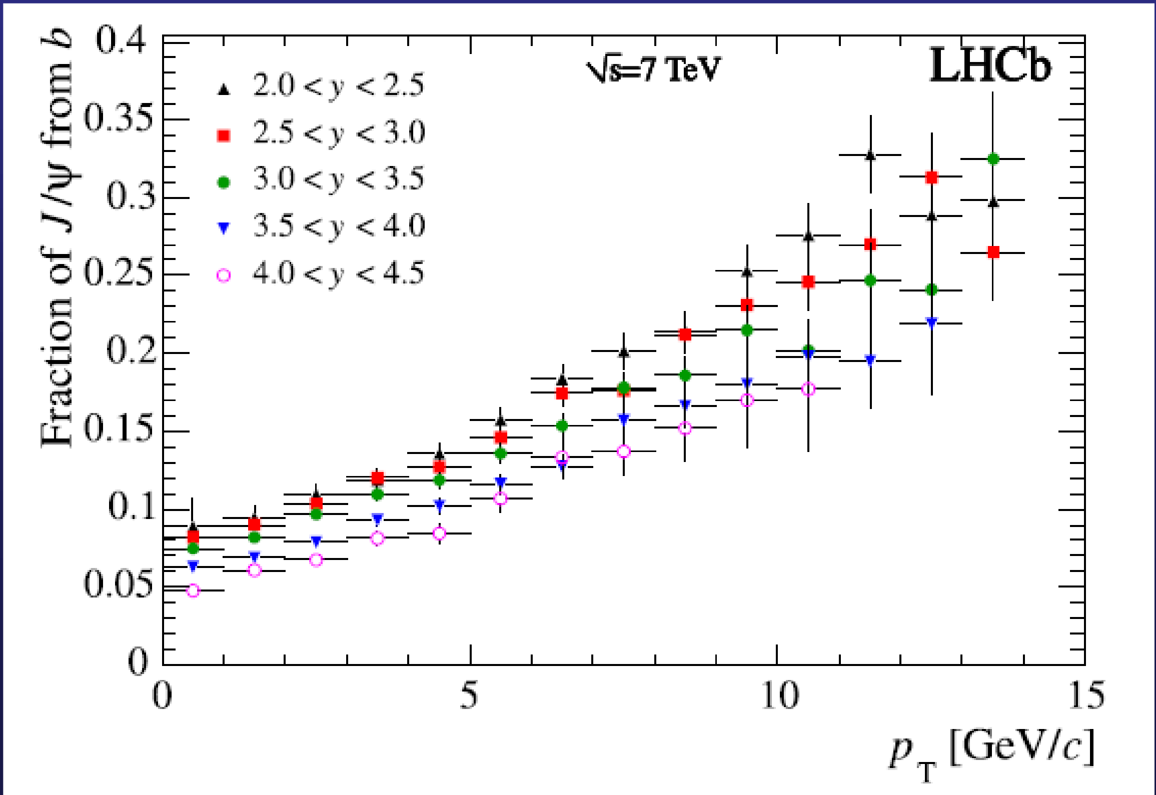
Prompt vs inclusive R_{pA}

- LHCb and CMS can separate the J/ψ component from B-decays thanks to their tracking capability in the vertex region (Si detectors)
- ALICE can do that at midrapidity but NOT at forward rapidity
  - This limitation will be overcome after LS2 → Muon Forward Tracker

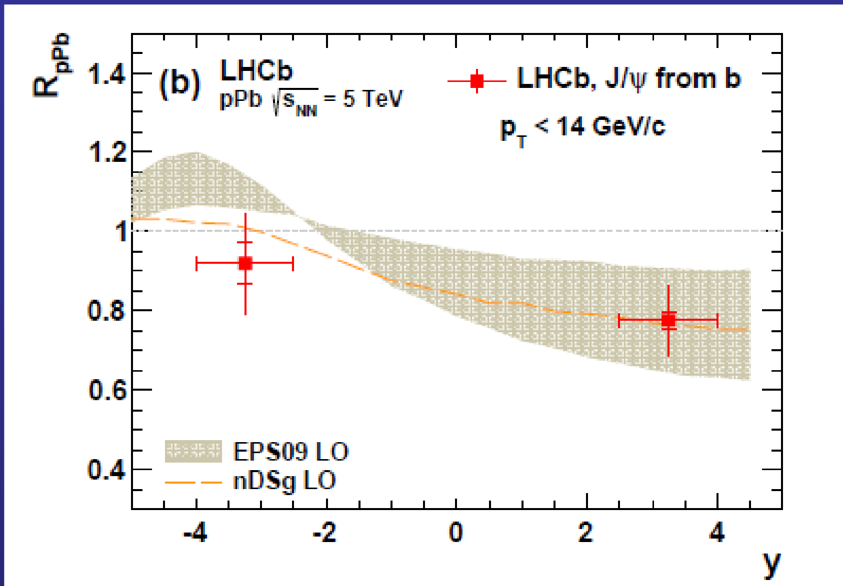
- Can the presence of J/ψ from B-decays create a sizeable difference between $R_{pA}^{inclusive}$ and R_{pA}^{prompt} ?

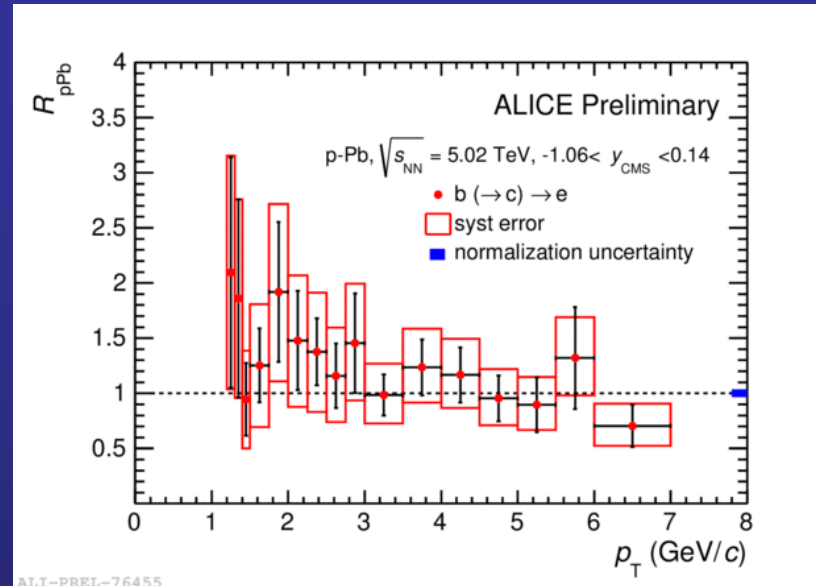
$$R_{pA}^{prompt} = \frac{R_{pA}^{inclusive} - R_{pA}^{non-prompt} \cdot f_b}{1 - f_b}$$

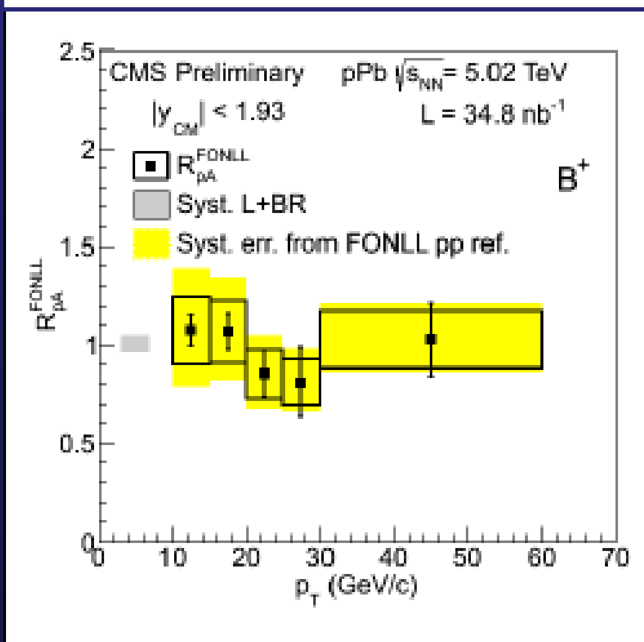
- f_B increases with p_T
- f_B decreases with y



R_{pA} for open beauty





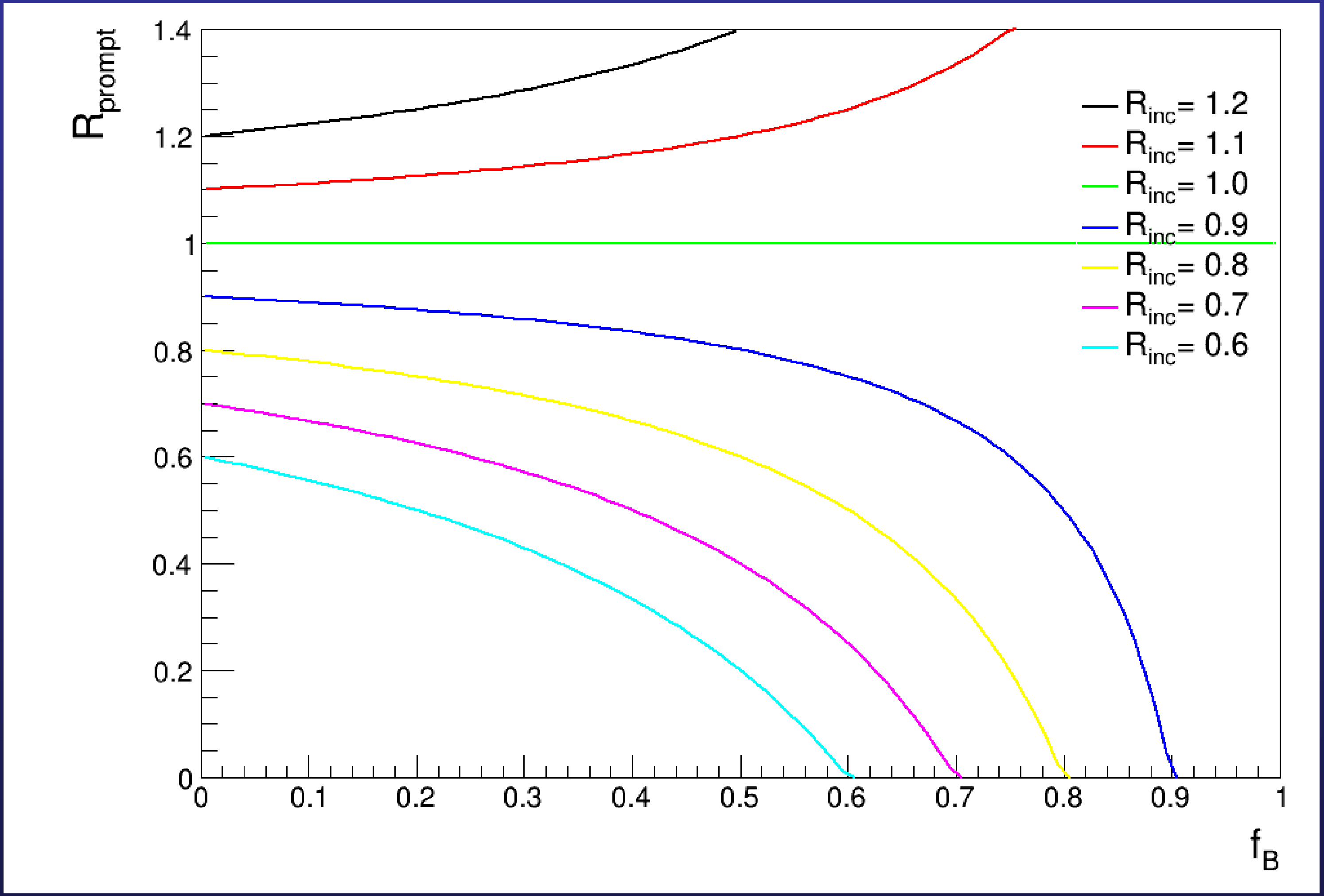


- ❑ Results from
  - ❑ LHCb (forward y, low p_T)
  - ❑ ALICE (central y, low p_T)
  - ❑ CMS (central y, high p_T)

show no strong effects in pPb collisions

From R_{pA}^{incl} to R_{pA}^{prompt}

- Assume $R_{pA}^{non\text{-}prompt} = 1$

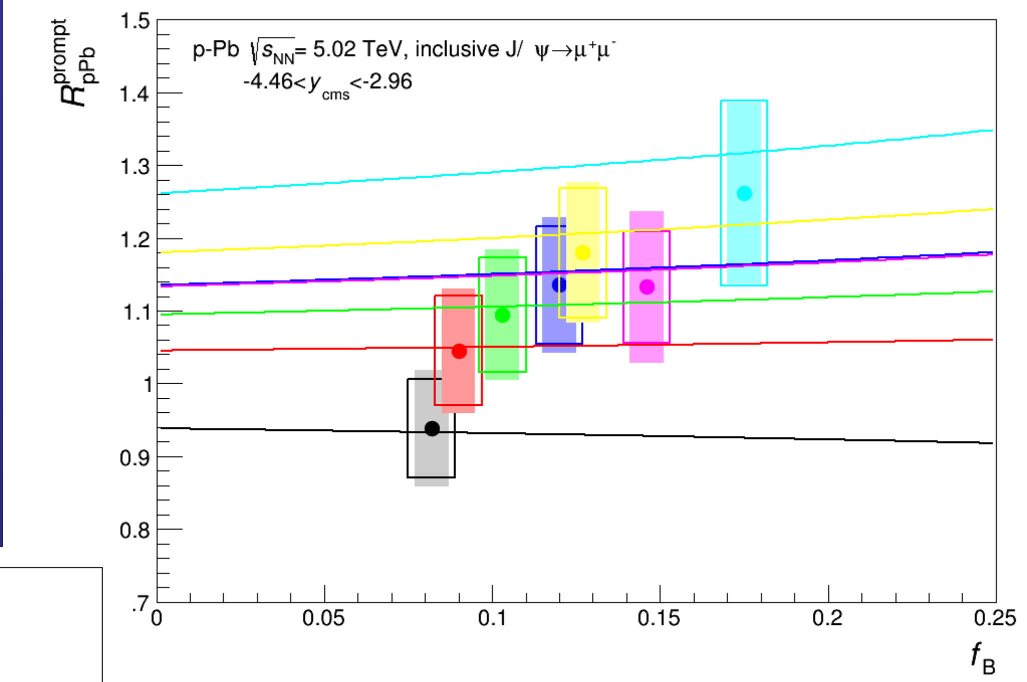


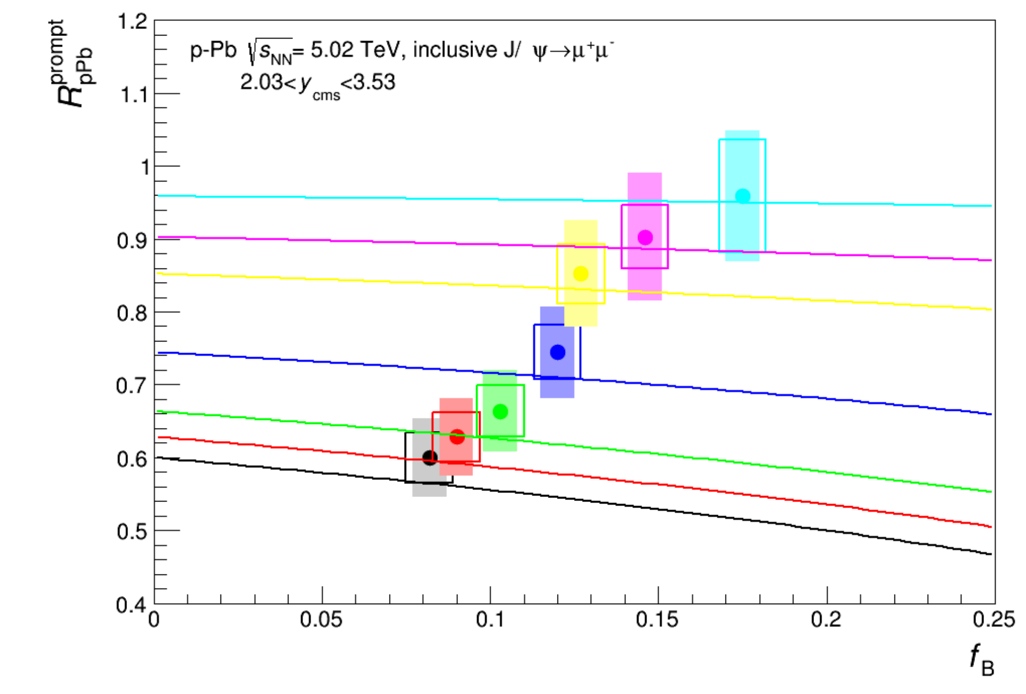
- The value of R_{pA}^{prompt} can differ significantly from R_{pA}^{prompt} at large f_b

Is the difference significant for ALICE?

❑ Exercise

1) Assume $R_{pPb}^{non\text{-}prompt}=1$
2) Plot R_{pPb}^{prompt} vs f_b for the values of $R_{pPb}^{inclusive}$ measured by ALICE
3) Plot the ALICE point at the f_B value corresponding to the p_T where the measurement is performed



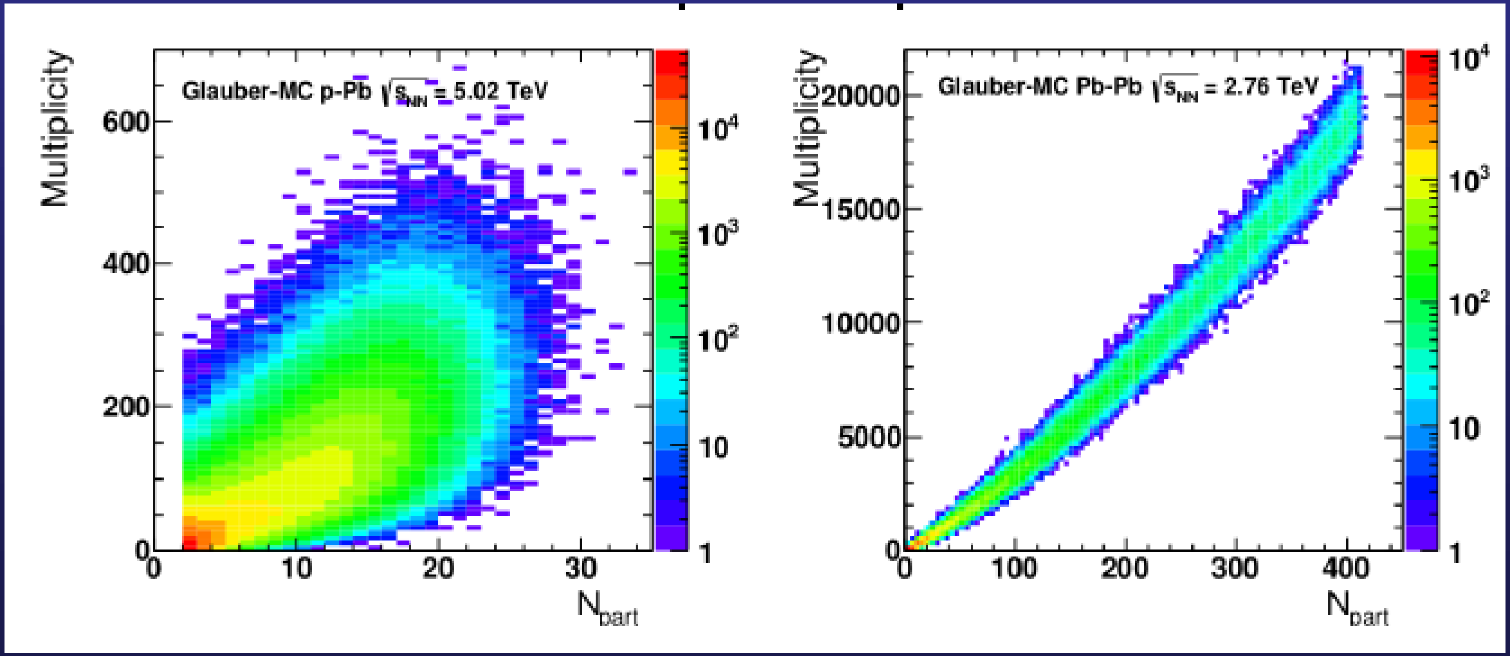


❑ Result

For ALL the p_T range accessible to ALICE, the difference between $R_{pPb}^{inclusive}$ and the calculated R_{pPb}^{prompt} is smaller than the uncertainties

p-Pb results vs "centrality"

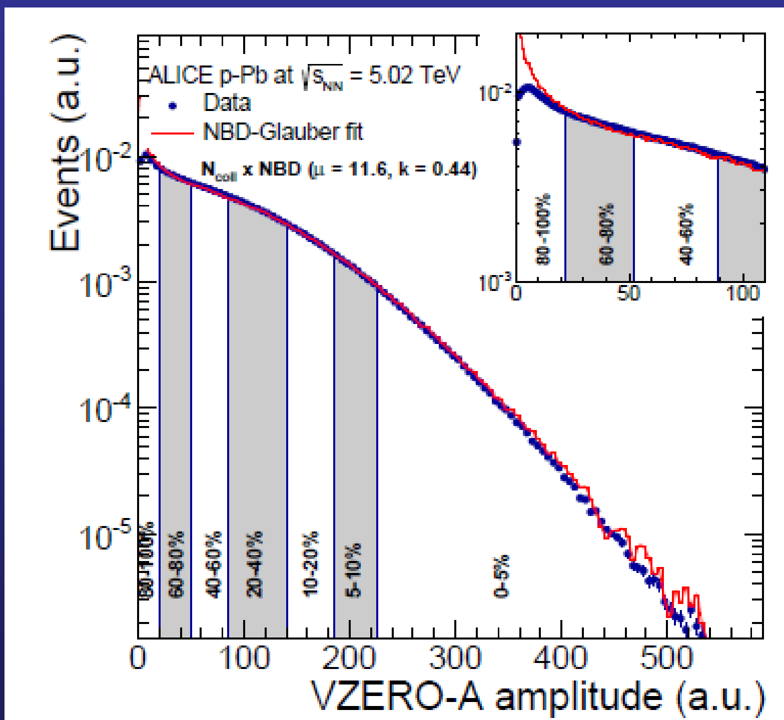
- Fixed-target experiments
  - Simply use different targets to "tune" the amount of nuclear matter crossed by the probe under study
  - No need to develop dedicated algorithms to slice results in centrality
- Collider experiments
  - Each change of nucleus implies several days of tuning
  - Impractical, need to define centrality classes

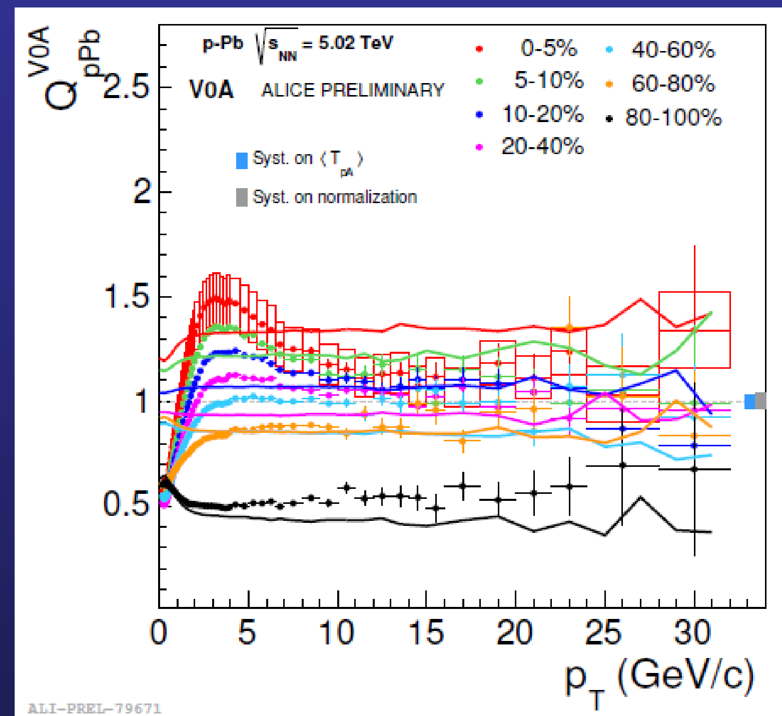


- Loose correlation between N_{part} and typical centrality-related observables

Biases on centrality determination

- Various centrality **estimators** can be used, e.g.
  - Number of **tracklets** at $|\eta_{lab}|<1.4$ (CL1)
  - **Signal amplitude** on scintillator hodoscope $2<\eta_{lab}<5.1$ (V0A)
  - Signal from **slow nucleons** in ZeroDegree Calorimeters (ZDC)



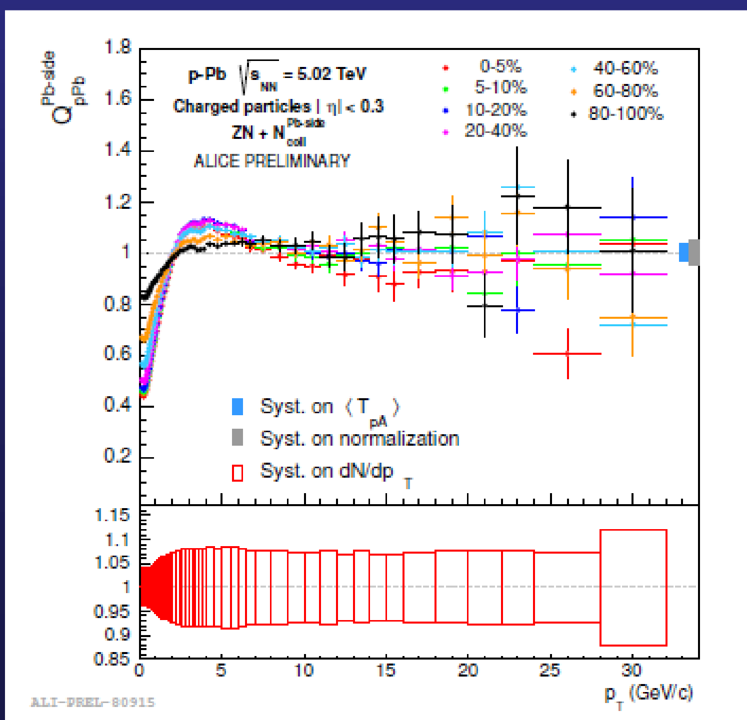


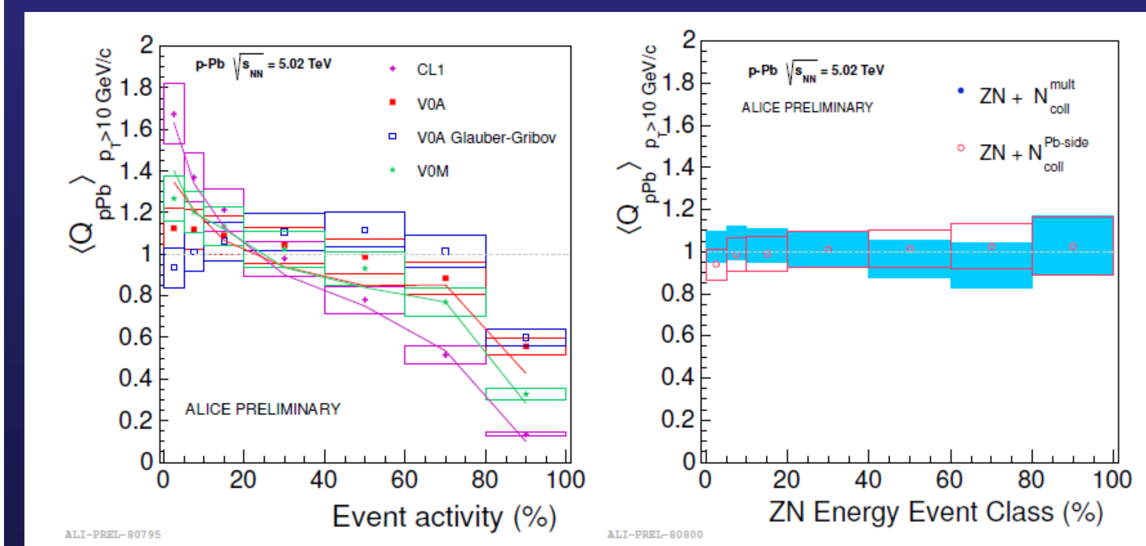
- When N_{coll} is obtained from **CL1** and **V0A** estimators → significant **bias**
- Biases related to several effects
  - Large **fluctuations** on **multiplicity** at fixed N_{part}
  - **Jet veto** effect (from hard processes in peripheral collisions)
  - **Geometric bias** (related to increasing b_{NN} in peripheral collisions)

Hybrid method

- It has been found that the bias is larger when the rapidity gap between the considered probe and the centrality estimator becomes small

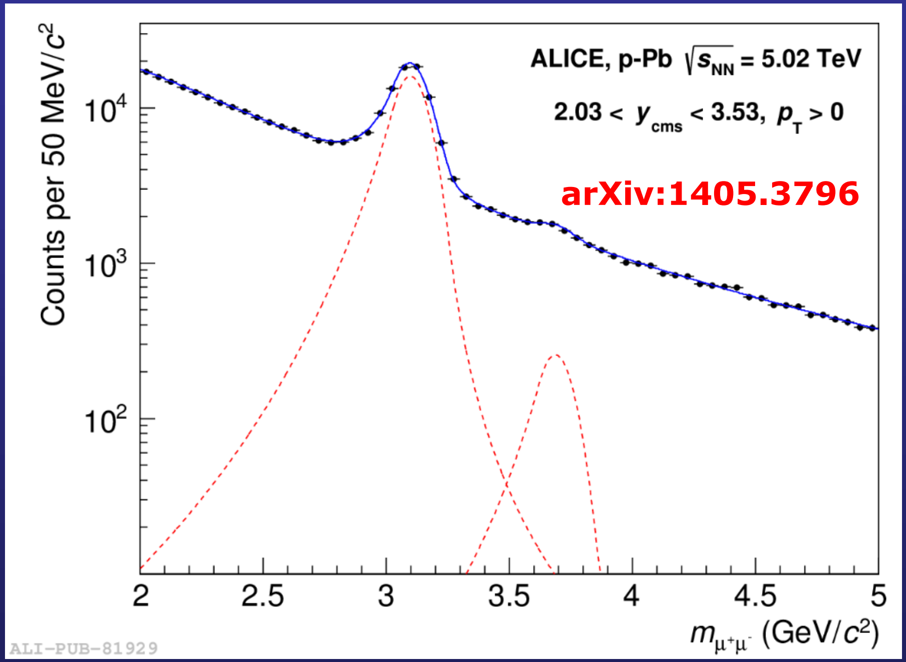
- Solution: use the ZDC (very large y) to slice in centrality → no bias on particle production at central rapidity
- However, the connection between slow-nucleon signal and centrality is not so well established → take the N_{coll} distribution from each ZDC-selected bin assuming $dN/d\eta$ at mid-rapidity is $\propto N_{part}$ (or that the target-going charged particle multiplicity is $\propto N_{part}$)

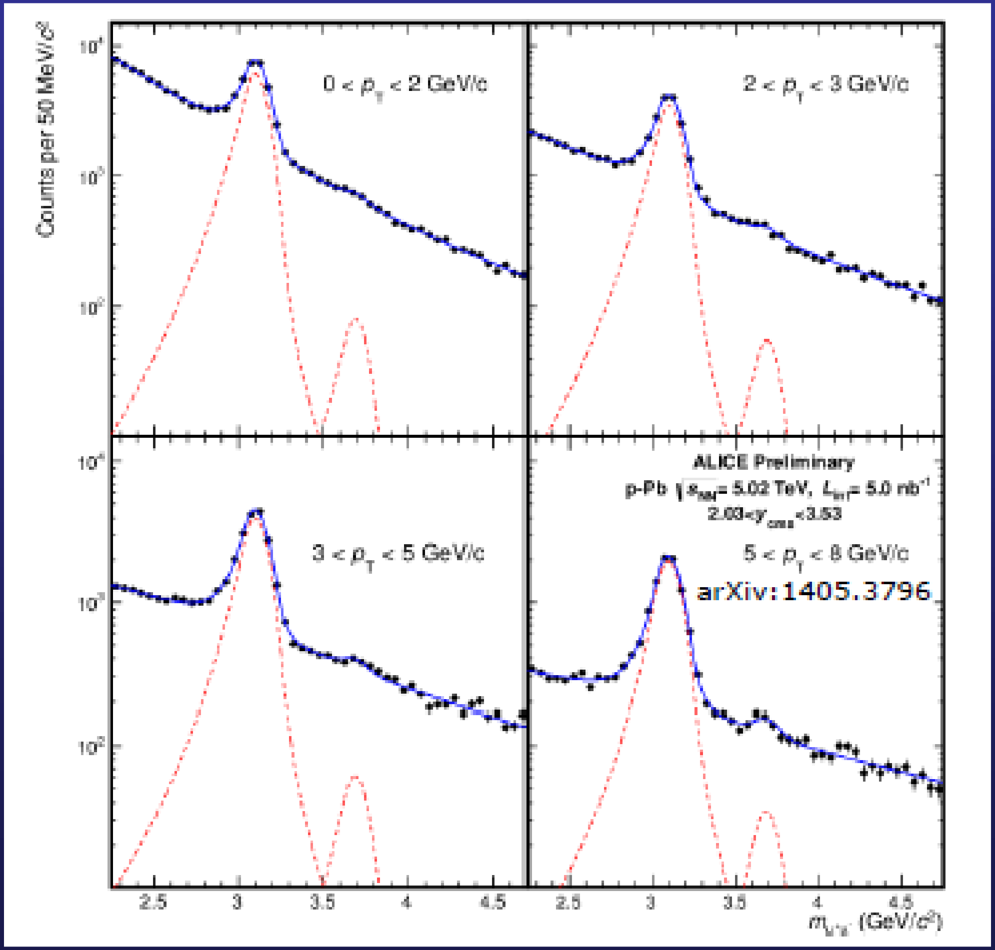




Now, to the results…

- Number of signal events
- Forward rapidity → fit of the invariant mass spectra (CB2 + background)



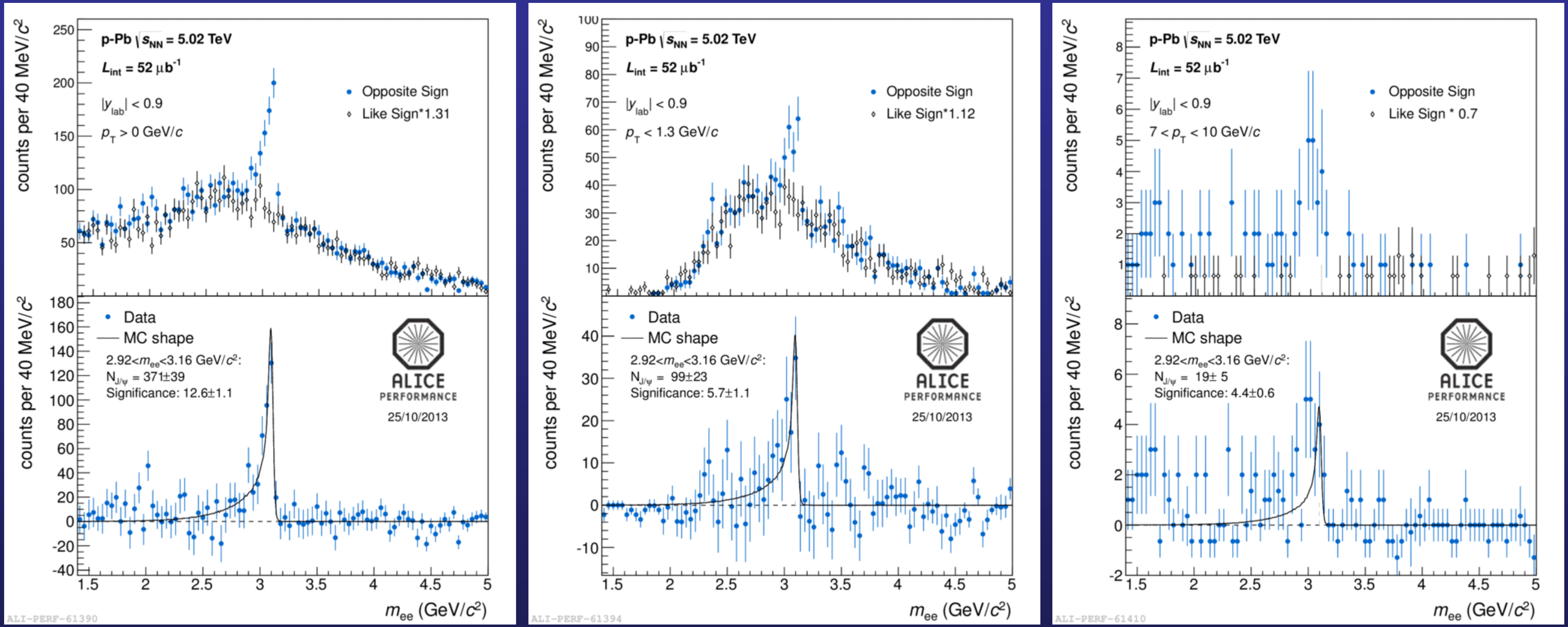


- Low ψ(2S) statistics at high p_T, but better S/B

- $N_{J/\psi}$~ 67000, $N_{\psi(2S)}$~1100 (p-Pb)
- $N_{J/\psi}$~ 57000, $N_{\psi(2S)}$~700 (Pb-p)

Mid-rapidity J/ψ

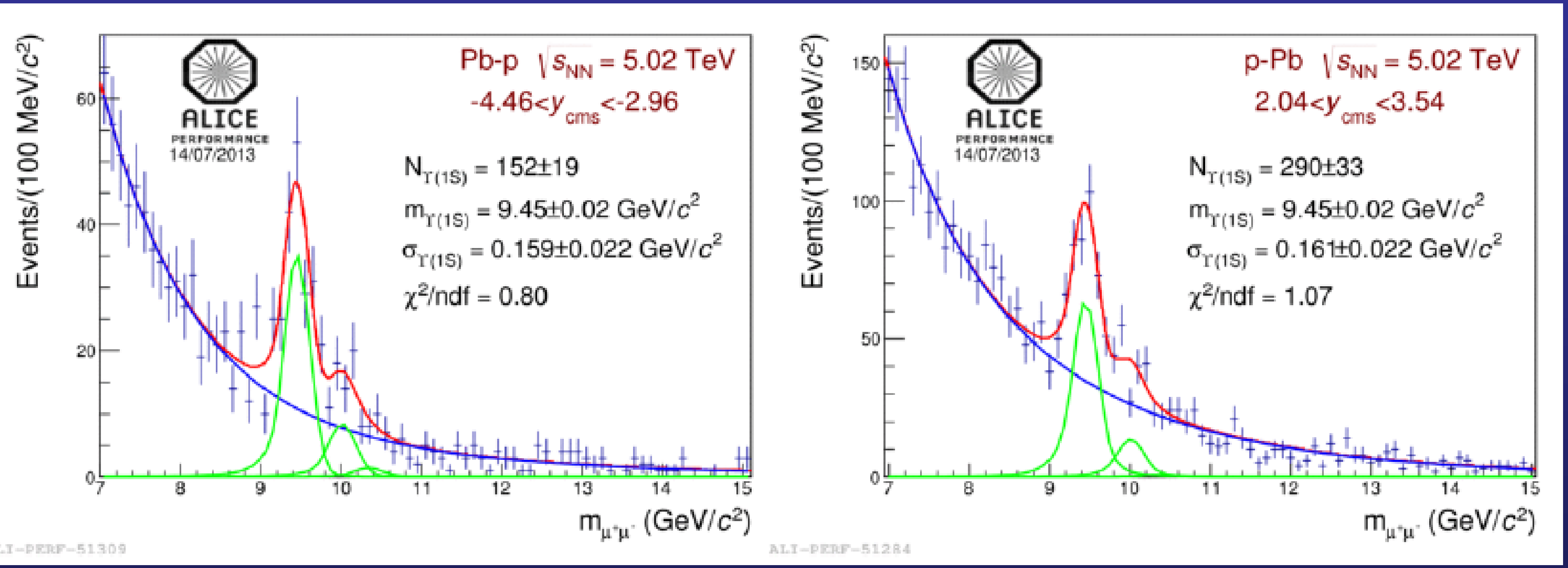
- ❑ Background through mixed-events
- ❑ Normalized to same-event sample in the continuum region



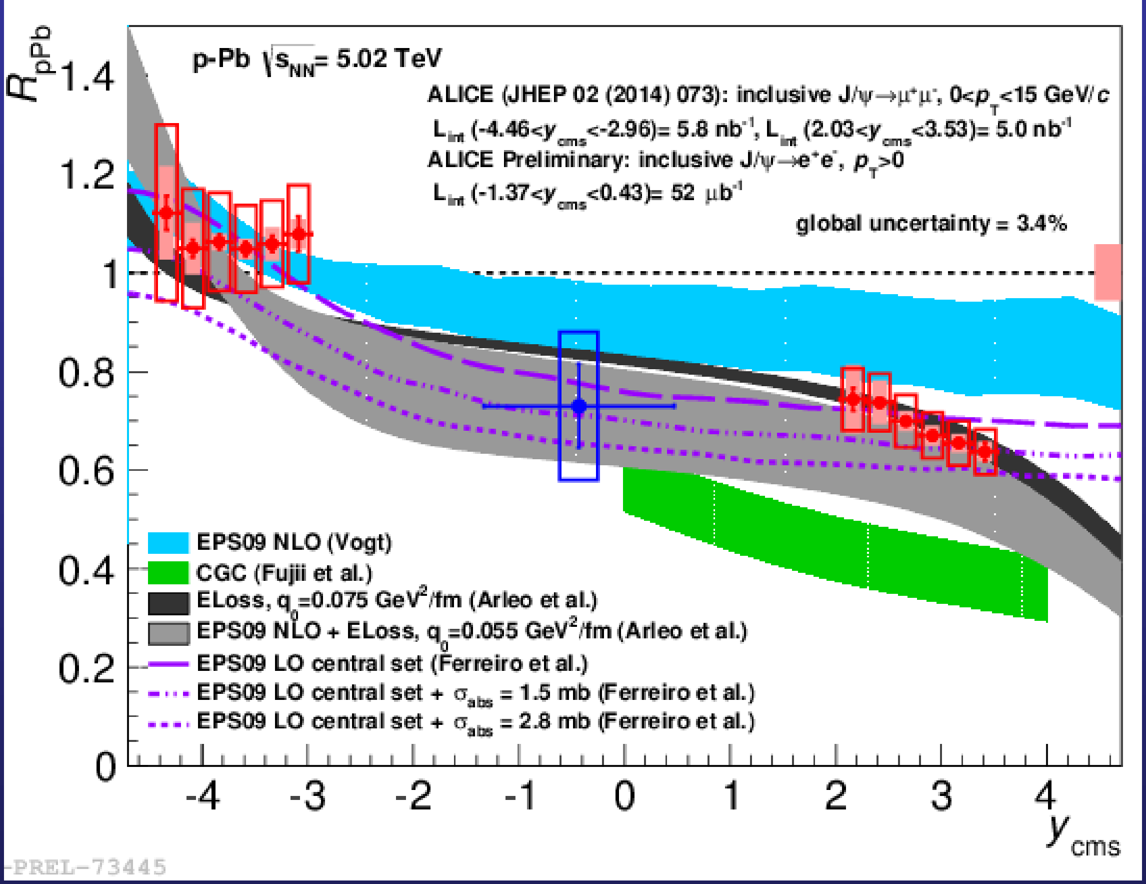
- ❑ Less statistics than at forw/backw y (no trigger on electron pairs)

Bottomonia

- ϒ(1S) : enough statistics for two rapidity bins → to be published
- ϒ(2S) peak has a ~3σ significance



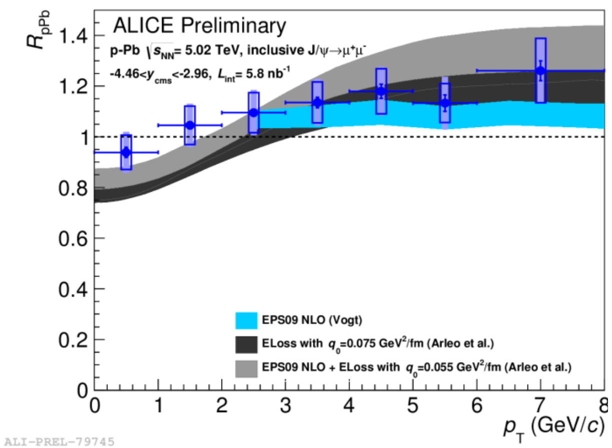
J/ψ results: R_{pPb} vs y



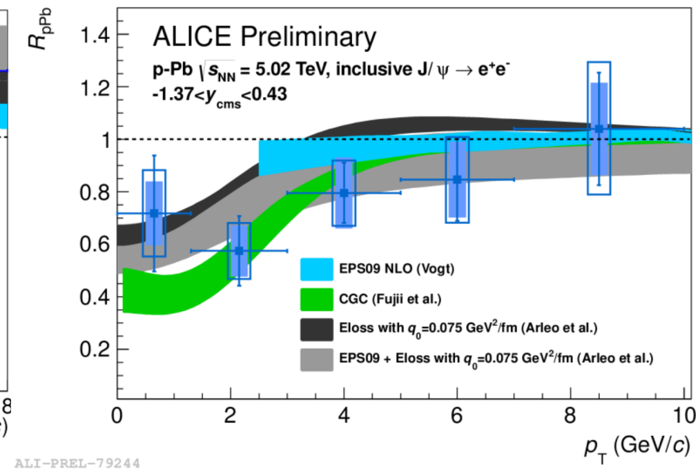
- Strong suppression at forward and mid-y: no suppression at backward y
- Data are consistent with models including shadowing and/or energy loss
- Color Glass Condensates (CGC) inspired models underestimate data
- Dissociation cross section σ_{abs}<2 mb cannot be excluded

J/ψ results: R_{pPb} vs p_T

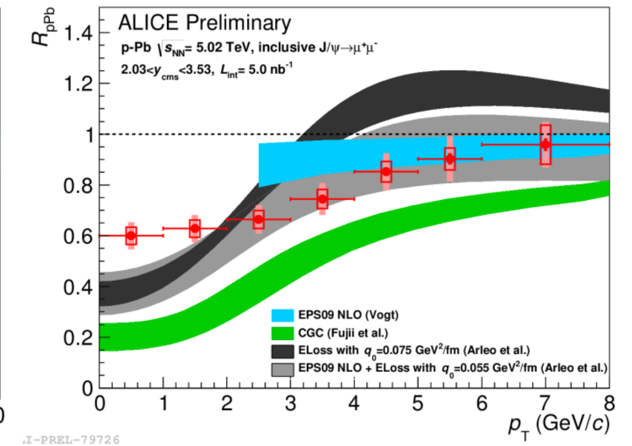
backward-*y*



mid-*y*



forward-*y*



- The p_T dependence of J/ψ R_{pPb} has been studied in the three *y* ranges

- backward-*y*: negligible p_T dependence, R_{pA} compatible with unity
- mid-y: small p_T dependence, R_{pA} compatible with unity for p_T>3GeV/c
- forward-y: strong R_{pA} increase with p_T

- Comparison with theory:
- Data consistent with pure shadowing calculations and with coherent energy loss models (overestimating J/ψ suppression at low p_T, forward-*y*)
- CGC calculation overestimate suppression at forward-*y*

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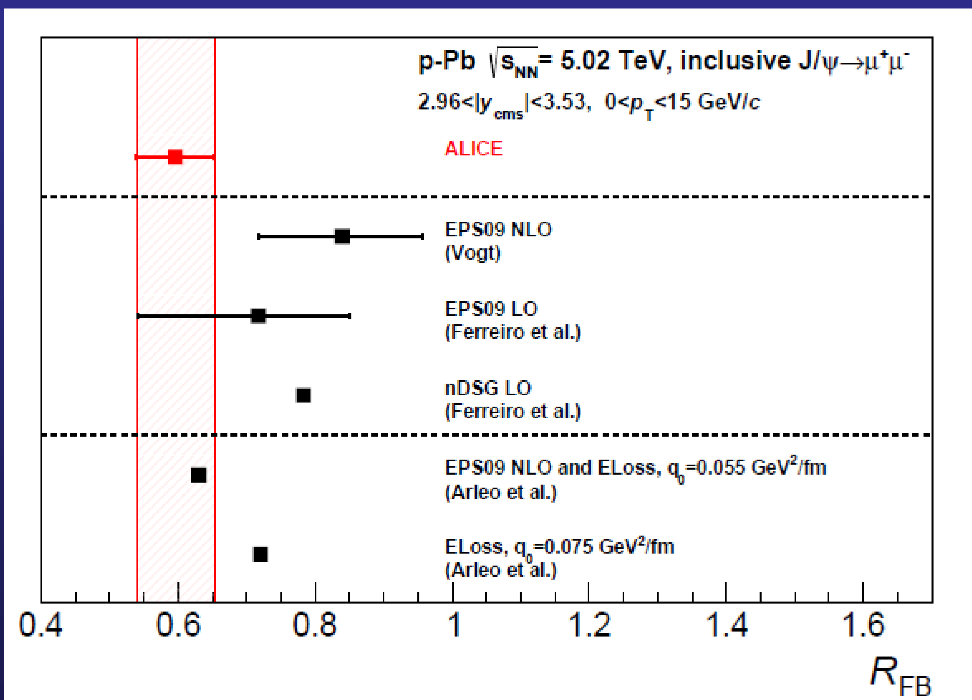
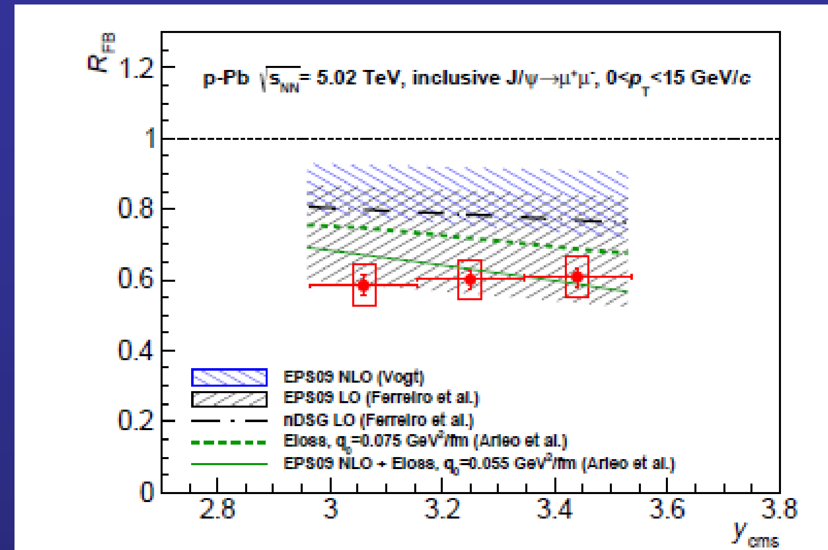
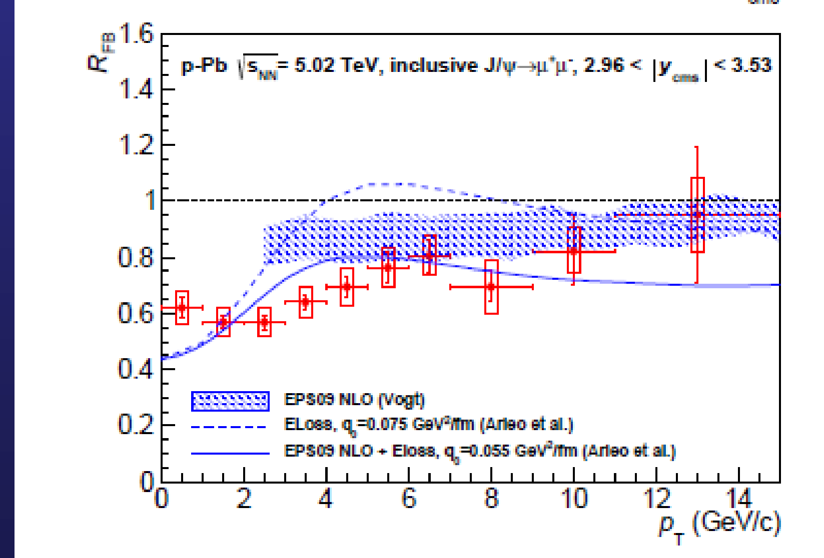
Forward/backward ratio: R_{FB}

- The ratio of the forward and backward yields in the common y-range $2.96<|y_{cms}|<3.53$ is free from the reference-related uncertainties

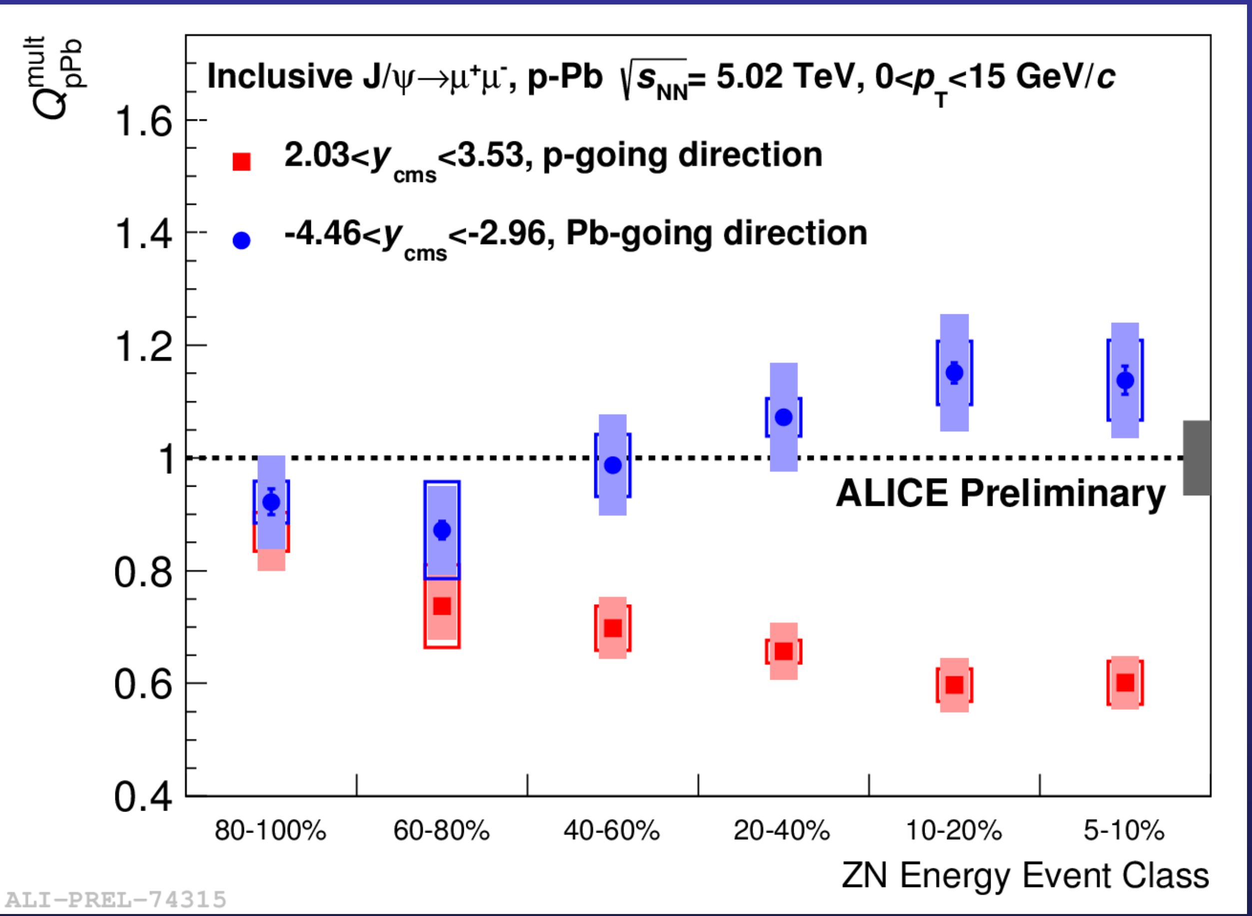






- Less sensitive than R_{pPb} to the comparison with theory models, as there can be agreement with models that systematically overestimate or underestimate R_{pPb}

Event activity dependence: Q_{pPb}



$$Q_{pA}^{J/\psi} = \frac{Y_{pA}^{J/\psi}}{\langle T_{pA} \rangle \sigma_{pp}^{J/\psi}}$$

- At forward-y, strong J/ψ Q_{pA} decrease from low to high event activity
- At backward-y, Q_{pA} consistent with unity, event activity dependence not very significant

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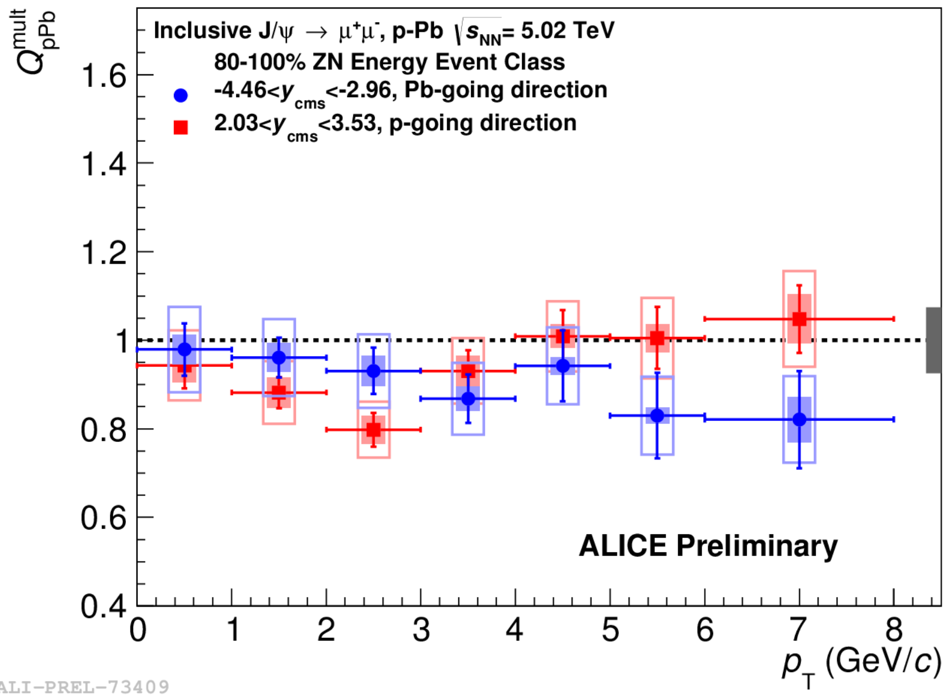
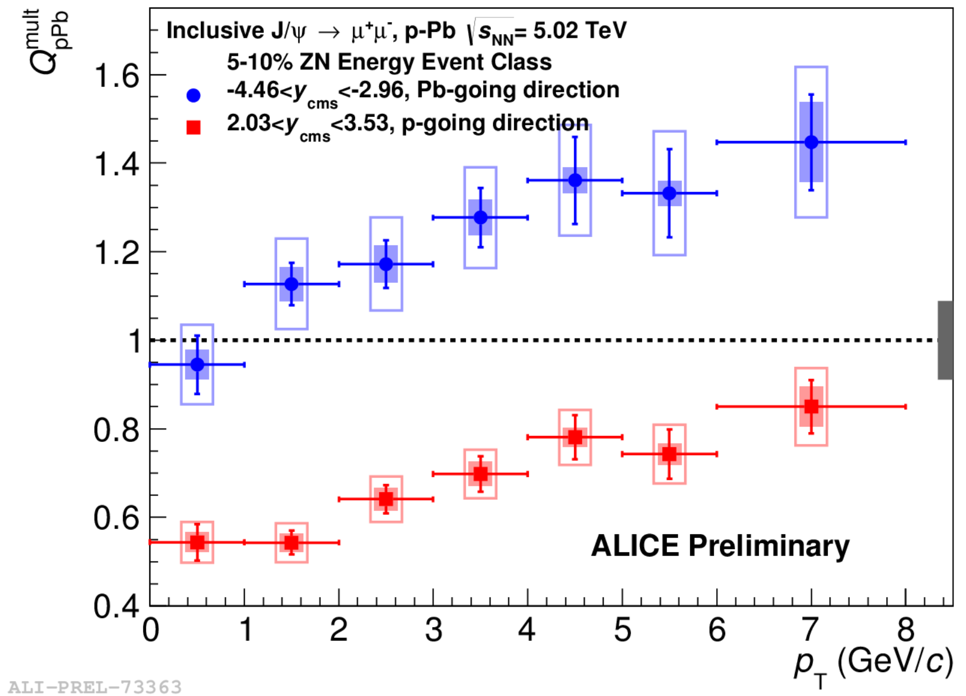
Q_{pPb} vs p_T

80-100% event activity

5-10% event activity





- ❑ Q_{pA} shows a strong dependence on event activity, y and p_T
- ❑ Low event activity classes: similar backward and forward-y behaviour, consistent with no modification, with a negligible p_T dependence
- ❑ High event activity classes: p_T-dependent Q_{pA} behaviour. Difference between forward and backward-y is larger for increasing event activity class

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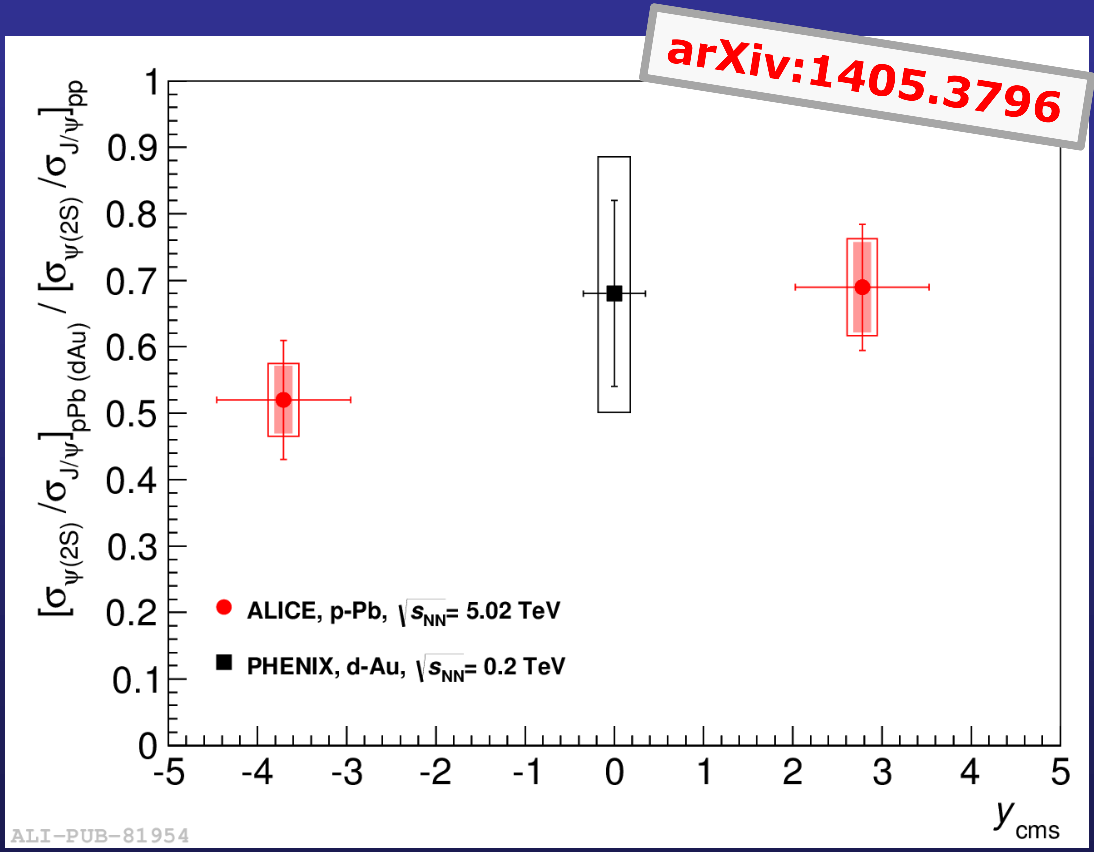
$\psi(2S)/J/\psi$

- A strong decrease of the $\psi(2S)$ production in p-Pb, relative to J/ψ, is observed with respect to the pp measurement ($2.5<y_{cms}<4$, $\sqrt{s}$=7TeV)



- The double ratio allows a direct comparison of the J/ψ and $\psi(2S)$ production yields between experiments
- Similar effect seen by PHENIX in d-Au collisions, at mid-*y*, at $\sqrt{s_{NN}}$=200 GeV

Line: statistical uncertainty
Shaded box: partially correl. syst. unc.
Open box: uncorrelated syst. uncertainty

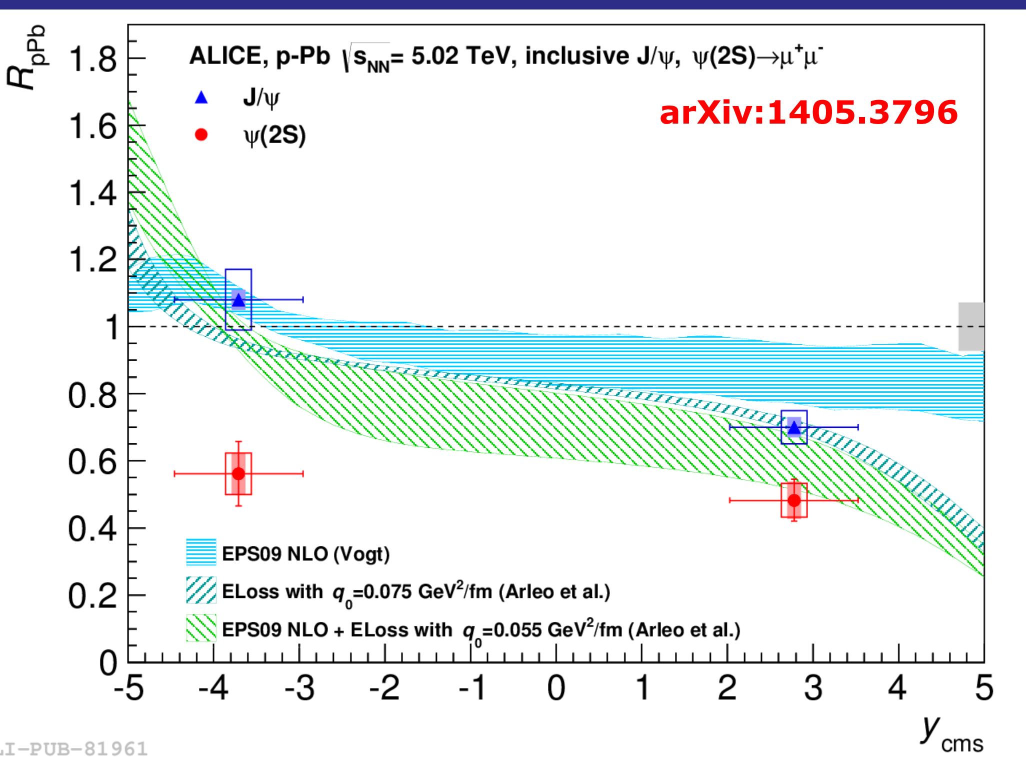
- $[\psi(2S)/J/\psi]_{pp}$ variation between ($\sqrt{s}$=7TeV, $2.5<y<4$) and ($\sqrt{s}$=5.02TeV, $2.03<y<3.53$ or $-4.46<y<-2.96$) evaluated using CDF and LHCb data (amounts to 8% depending on the assumptions → included in the systematic uncertainty)

$\psi(2S)$ R_{pPb} vs y_{cms}

- The $\psi(2S)$ suppression with respect to binary scaled pp yield can be quantified with the nuclear modification factor

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

(again, used $\sqrt{s}$=7TeV pp ratio including an 8% systematic uncertainty related to the different kinematics)



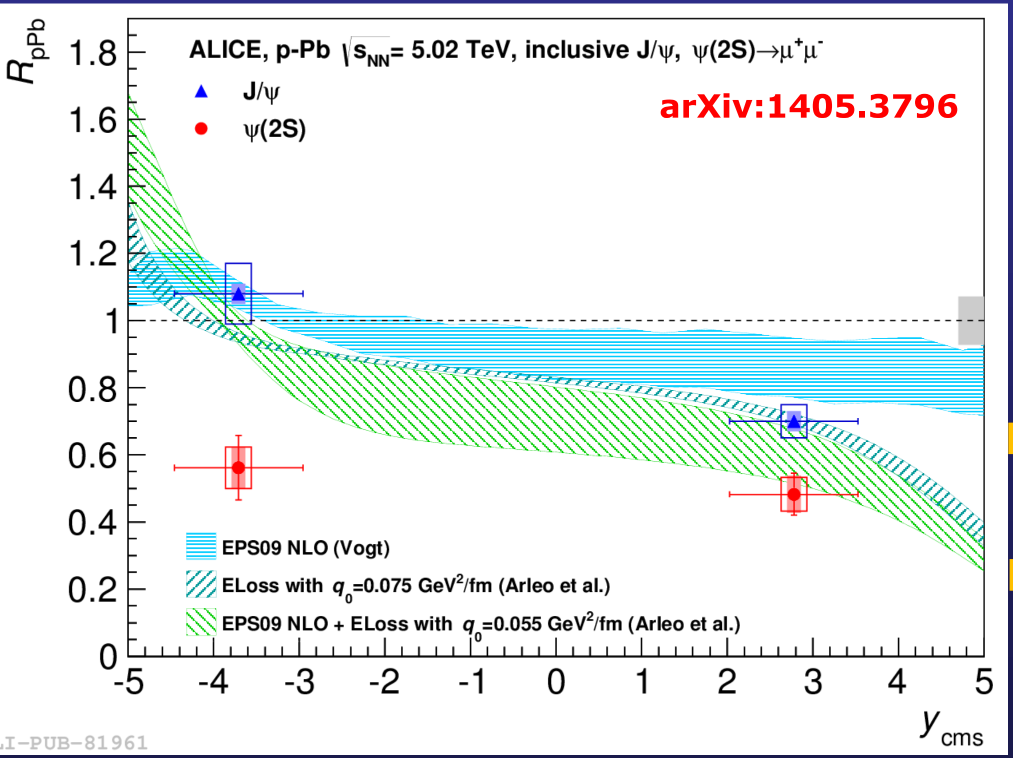
- $\psi(2S)$ suppression is stronger than the J/ψ one and reaches a factor ~2 wrt pp
- Same initial state CNM effects (shadowing and coherent energy loss) expected for both J/ψ and $\psi(2S)$

Theoretical predictions in disagreement with $\psi(2S)$ result

Other mechanisms needed to explain $\psi(2S)$ behaviour?

$\psi(2S)$ R_{pPb} vs y_{cms}

- The $\psi(2S)$ suppression with respect to binary scaled pp yield can be quantified with the nuclear modification factor
  - Can the stronger suppression of the weakly bound $\psi(2S)$ be due to break-up of the fully formed resonance in CNM?



possible if formation time (τ_f ~0.05-0.15fm/c) < crossing time (τ_c)

forward-*y*:
$\tau_c \sim 10^{-4}$ fm/c
backward-*y*:
$\tau_c \sim 7 \cdot 10^{-2}$ fm/c

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

D. McGlinchey, A. Frawley and R.Vogt, PRC 87,054910 (2013)

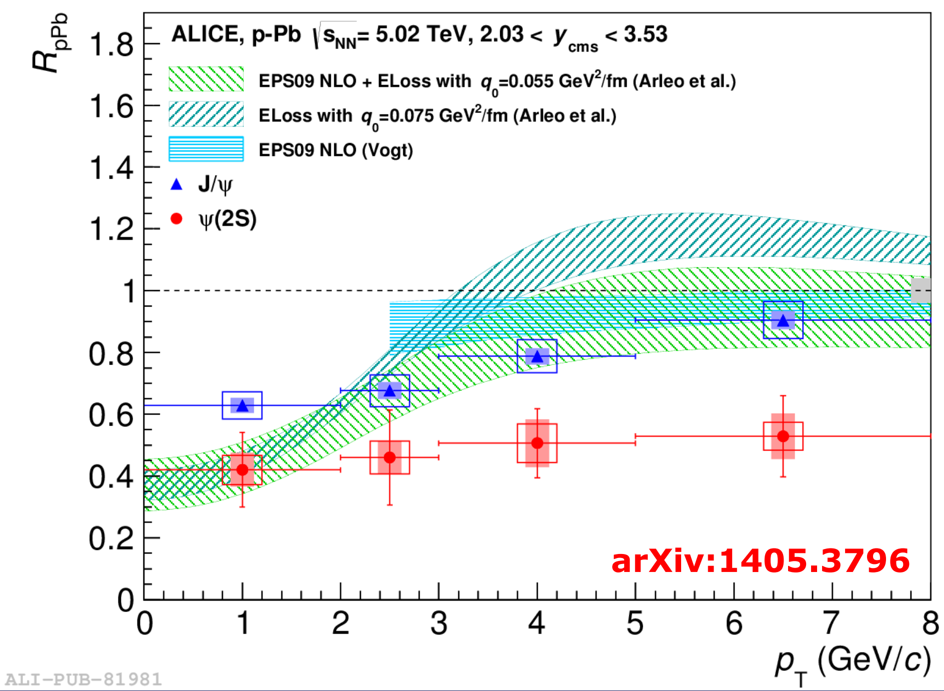
➡ break-up effects excluded at forward-*y*

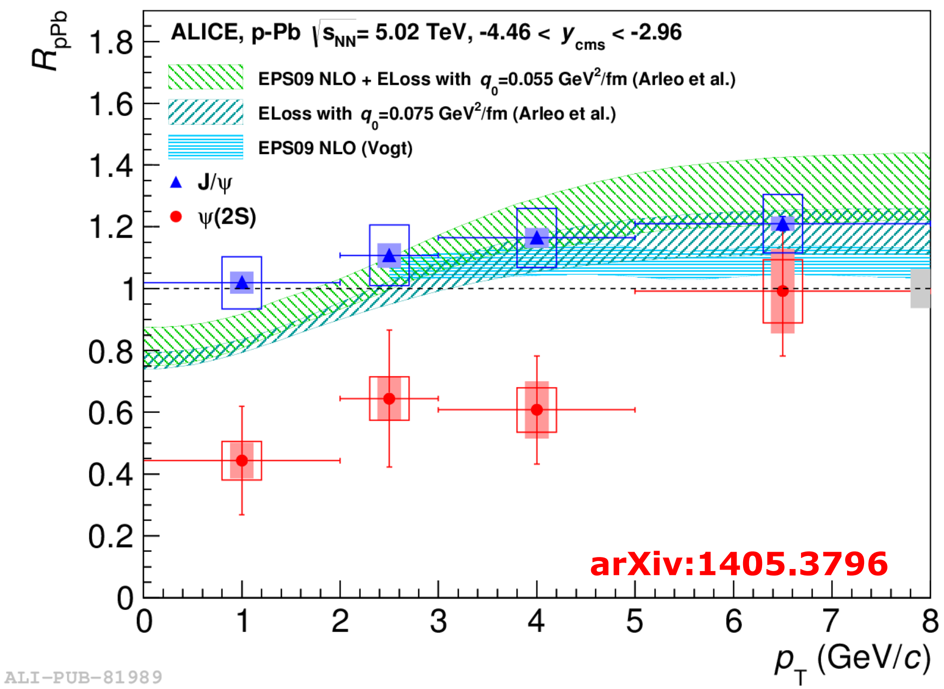
➡ at backward-*y*, since $\tau_f \sim \tau_c$, break-up in CNM can hardly explain the very strong difference between J/ψ and $\psi(2S)$ suppressions

- Final state effects related to the (hadronic) medium created in the p-Pb collisions?

$\psi(2S)$ R_{pPb} vs p_T

- The p_T-dependence of the R_{pPb} has also been investigated



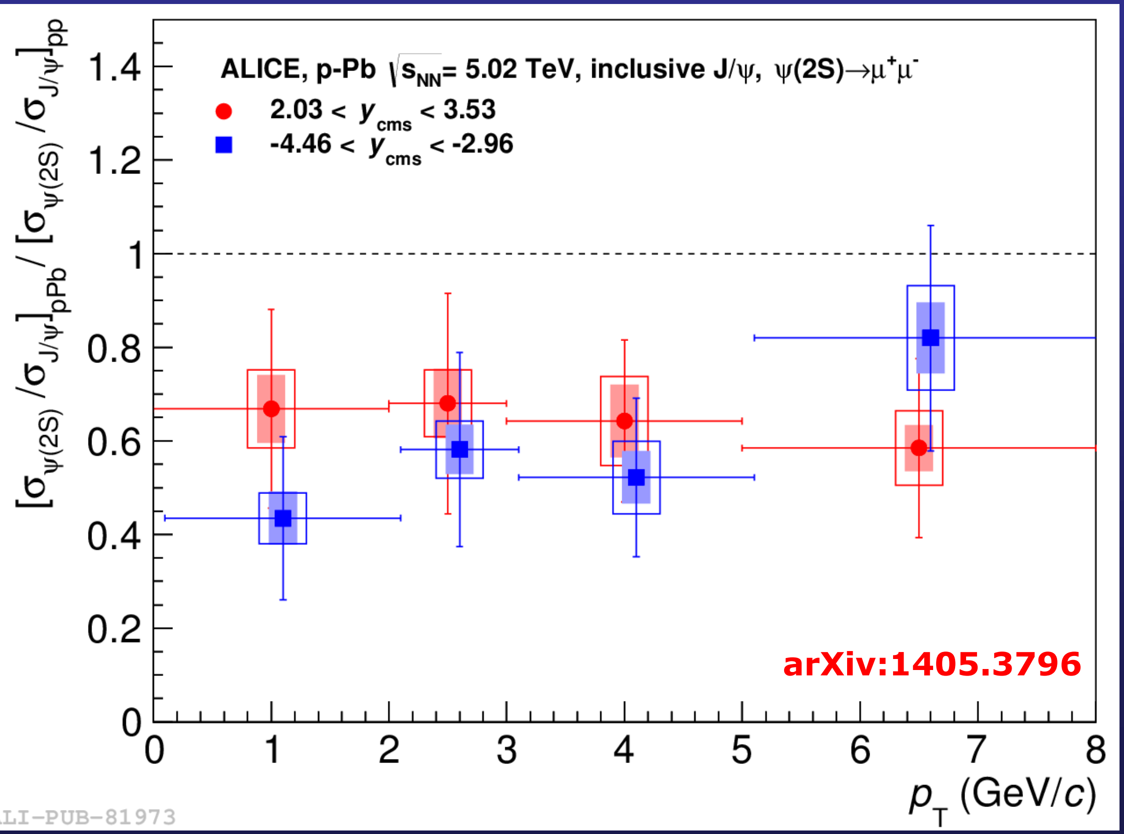


- As already observed for the p_T-integrated results, $\psi(2S)$ is more suppressed than the J/ψ

- Theoretical models are in fair agreement with the J/ψ, but clearly overestimate the $\psi(2S)$ results

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

- The sizeable $\psi(2S)$ statistics in p-Pb collisions allows the differential study of $\psi(2S)$ production vs p_T
  - Different p_T correspond to different crossing times, with τ_c decreasing with increasing p_T



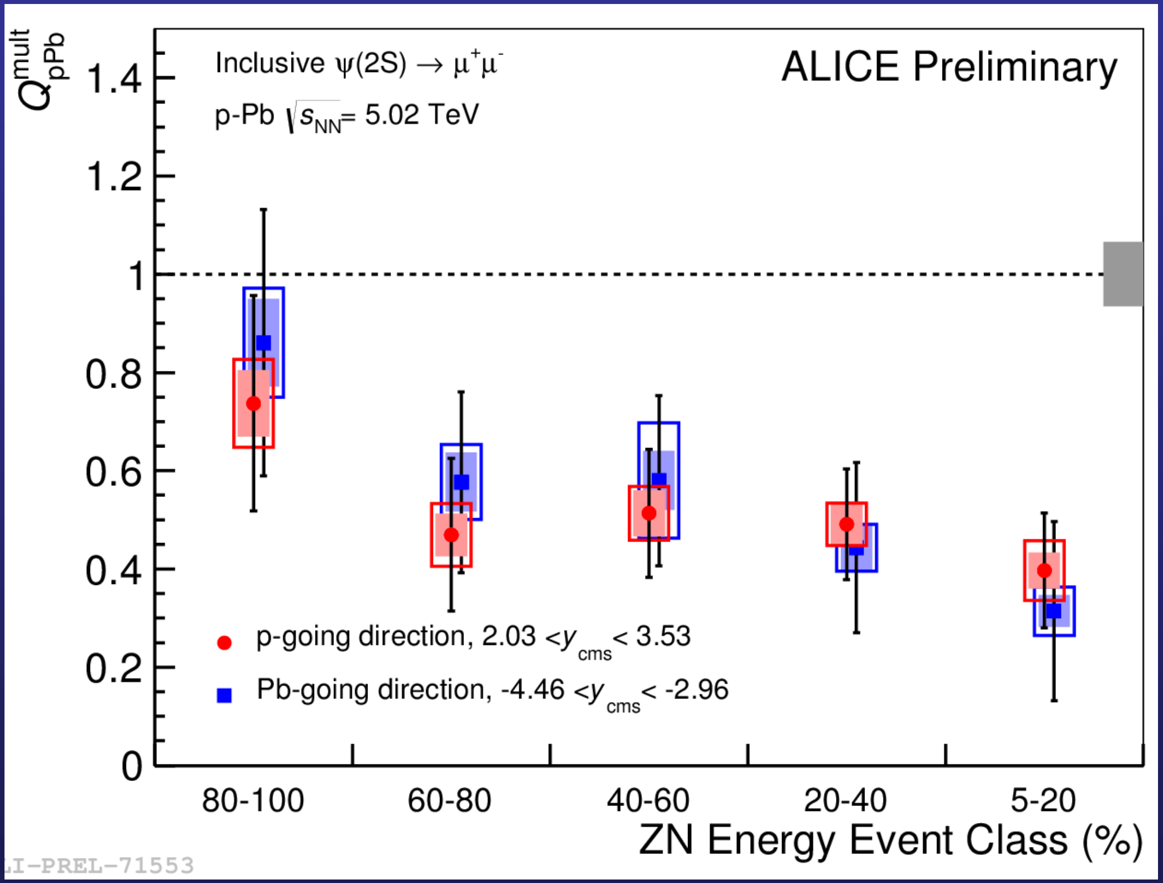
backward-y: τ_c~0.07 (p_T=0) and ~0.03 fm/c (p_T=8 GeV/c)

- if $\psi(2S)$ breaks-up in CNM, the effect should be more important at backward-y and low p_T

- No clear p_T dependence is observed at y<0, within uncertainties

ψ(2S) Q_{pPb} vs event activity

- The ψ(2S) Q_{pA} is evaluated as a function of the event activity



Q_{pA} instead of R_{pA} due to potential bias from the centrality estimator, which are not related to nuclear effects

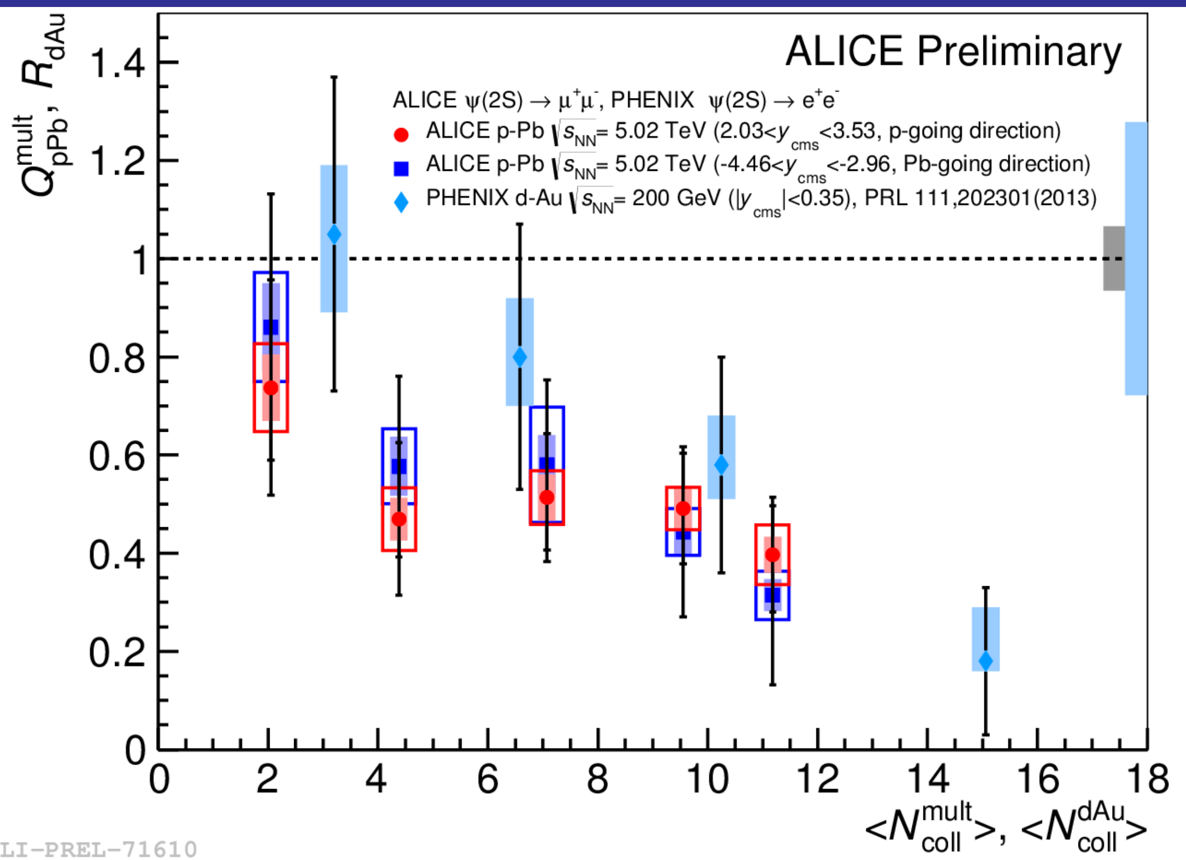
$$Q_{pA}^{\psi(2S)} = Q_{pA}^{J/\psi} \times \frac{\sigma_{pA}^{\psi(2S)}}{\sigma_{pA}^{J/\psi}} \times \frac{\sigma_{pp}^{J/\psi}}{\sigma_{pp}^{\psi(2S)}}$$

with $$Q_{pA}^{J/\psi} = \frac{Y_{pA}^{J/\psi}}{T_{pA}^{mult} \cdot \sigma_{pp}^{J/\psi}}$$

- Clear ψ(2S) suppression, increasing with event activity, both in p-Pb and Pb-p collisions
- Rather similar ψ(2S) suppression at both forward and backward rapidities

ψ(2S) Q_{pPb} vs event activity

- The ψ(2S) Q_{pA} is evaluated as a function of the event activity



Q_{pA} instead of R_{pA} due to potential bias from the centrality estimator, which are not related to nuclear effects

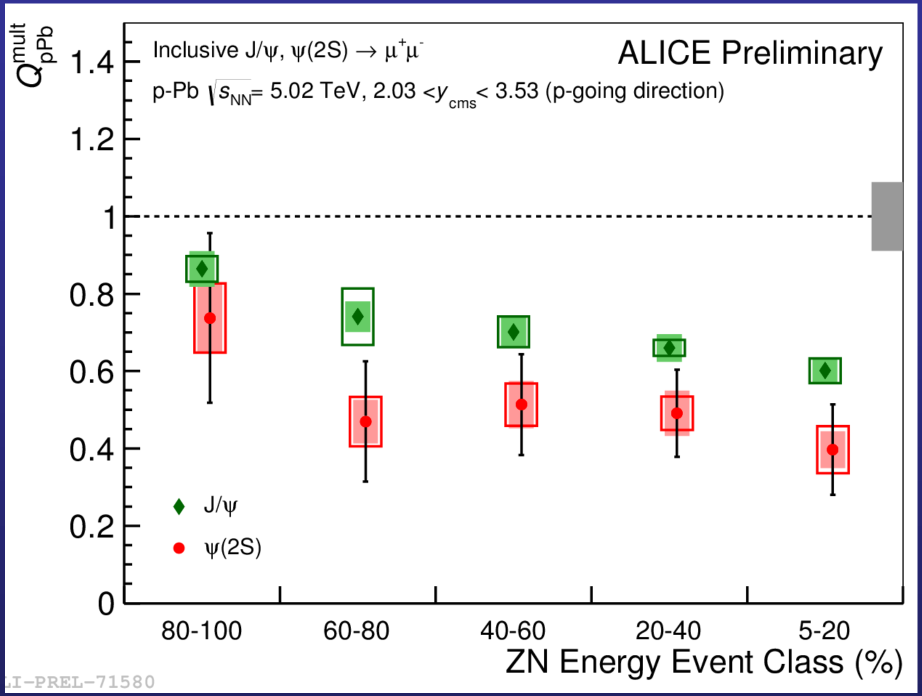
$$Q_{pA}^{\psi(2S)} = Q_{pA}^{J/\psi} \times \frac{\sigma_{pA}^{\psi(2S)}}{\sigma_{pA}^{J/\psi}} \times \frac{\sigma_{pp}^{J/\psi}}{\sigma_{pp}^{\psi(2S)}}$$

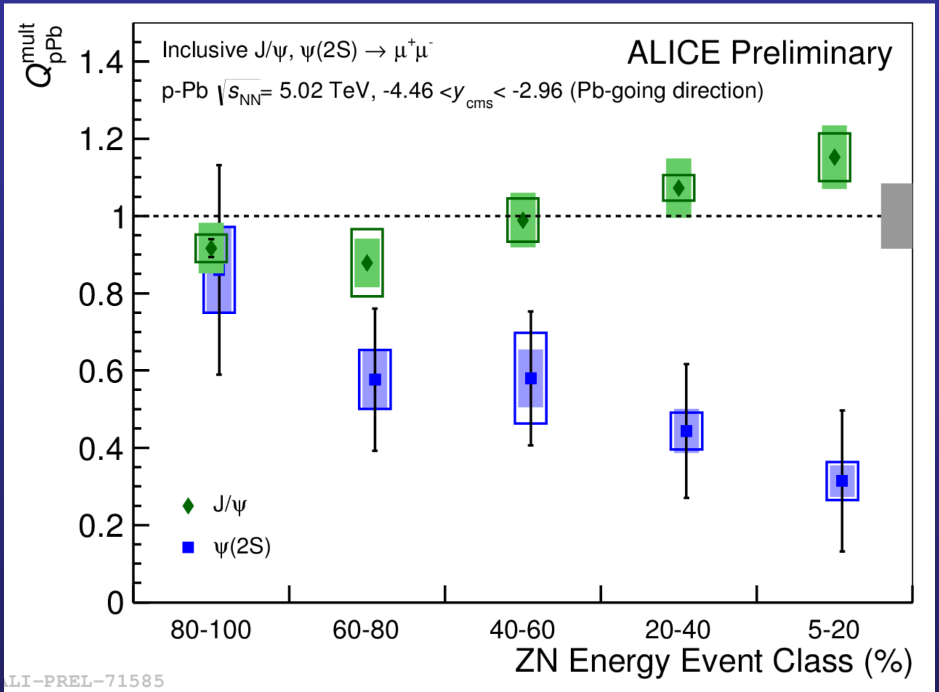
with $$Q_{pA}^{J/\psi} = \frac{Y_{pA}^{J/\psi}}{T_{pA}^{mult} \cdot \sigma_{pp}^{J/\psi}}$$

- Rather similar ψ(2S) suppression, increasing with N_{coll}, for both ALICE and PHENIX results

J/ψ and ψ(2S) Q_{pPb} vs event activity

- J/ψ and ψ(2S) Q_{pA} are compared vs event activity

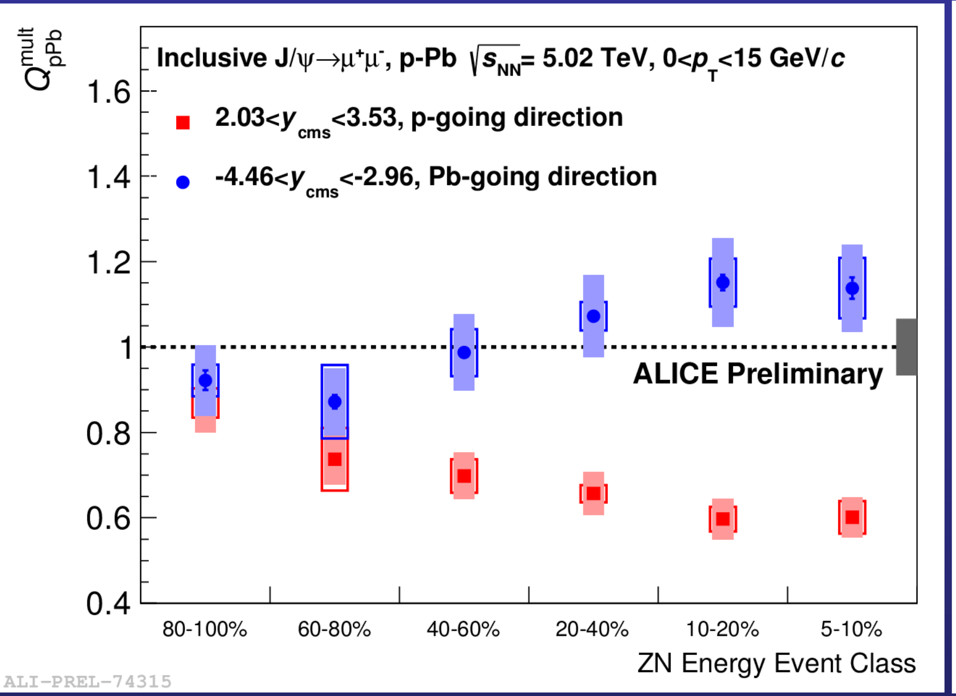


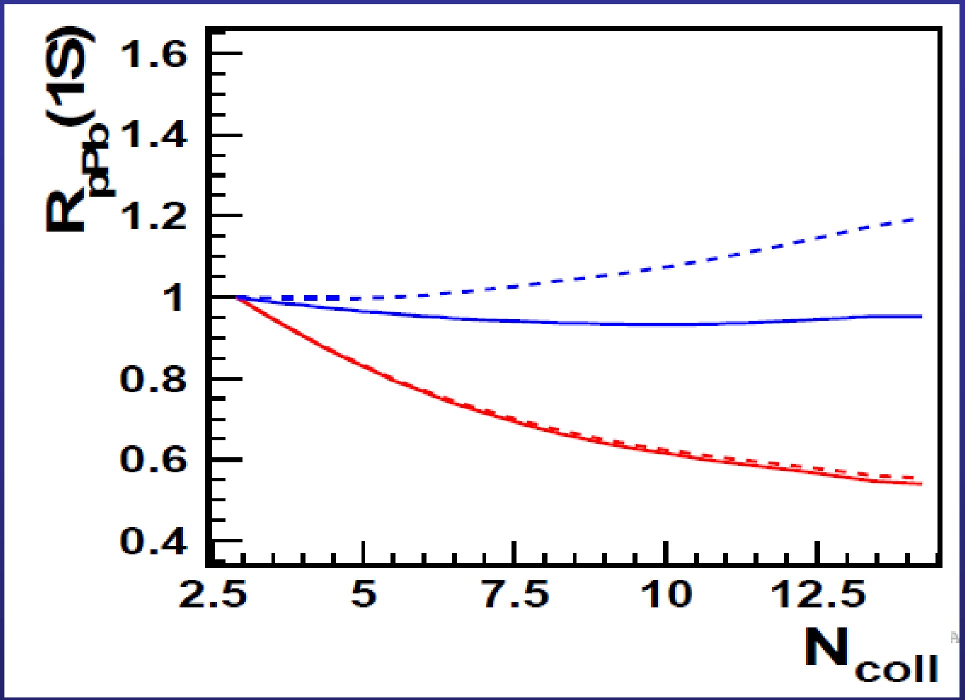


- forward-*y:* J/ψ and ψ(2S) show a similar decreasing pattern vs event activity
- backward-*y:* the J/ψ and ψ(2S) behaviour is different, with the ψ(2S) significantly more suppressed for largest event activity classes

→ Another hint for ψ(2S) suppression in the (hadronic) medium?

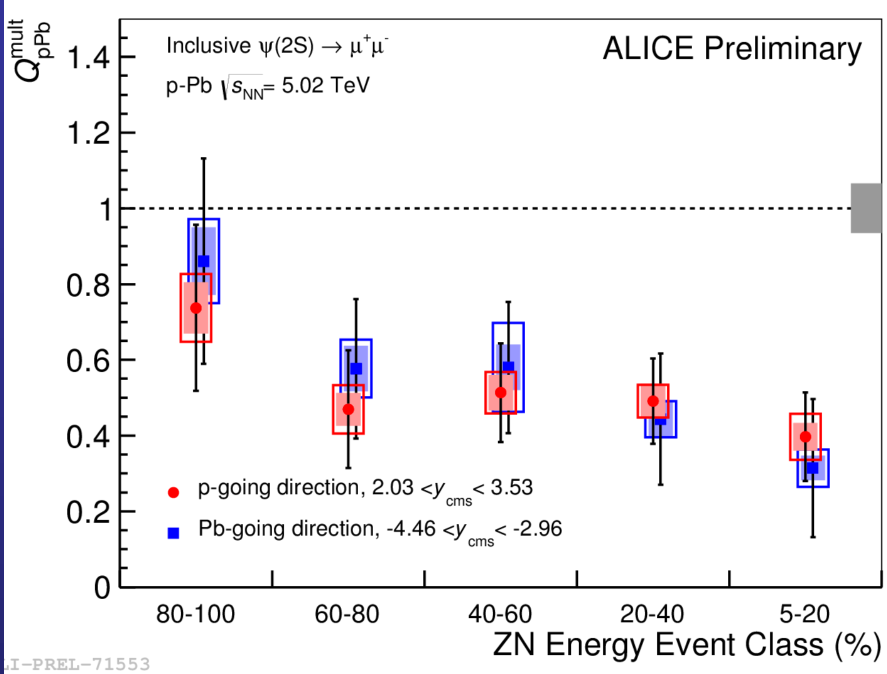
J/ψ: recent news (Elena)

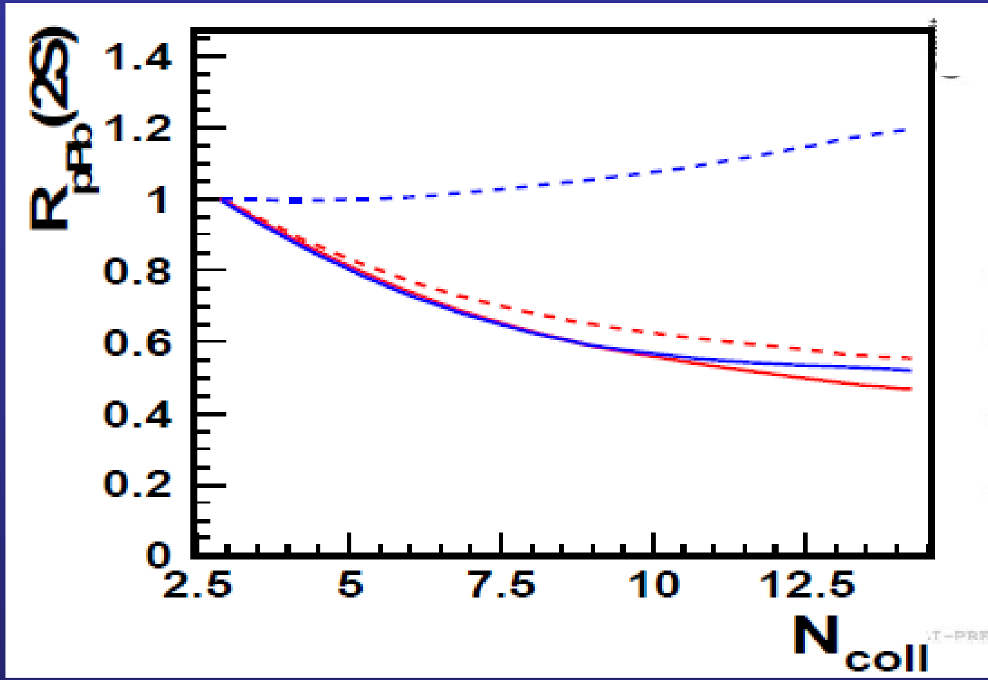




- The inclusion of an "effective" comover cross section $\sigma_{co\text{-}J/\psi}$=0.65 mb on top of nuclear shadowing gives qualitative agreement with data
- Same comover cross section from SPS to LHC ?
- Looks like a fortuitous accident, seen the differences in
  - Nature of the medium
  - Absence of modeling of time evolution
- Or there is some deeper meaning to that ?

ψ(2S) looks good too



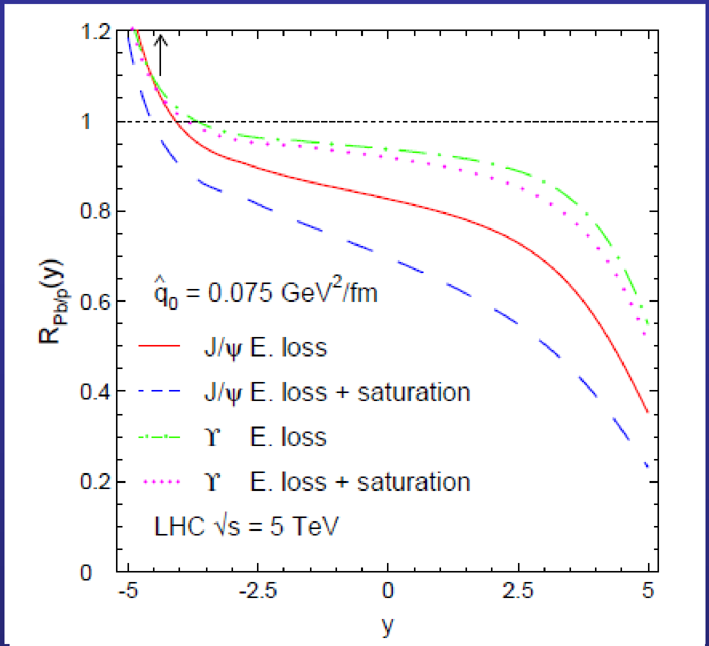


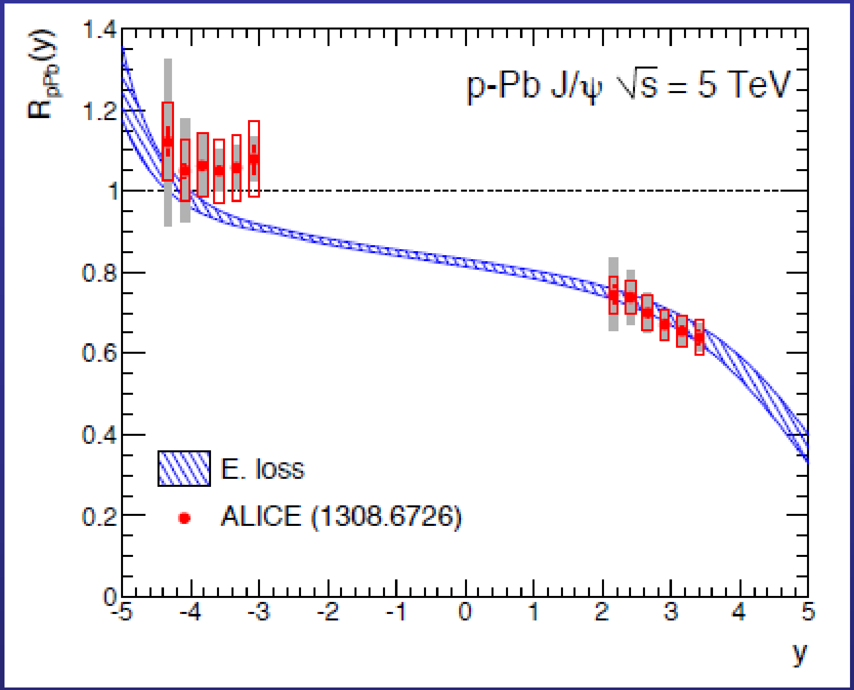
- Factor 10 larger comover cross section for ψ(2S)
  → May be justified by geometrical considerations, but…
  does the "medium" see any difference between a ccbar evolving to a J/ψ or to a ψ(2S) before the resonance is formed ?

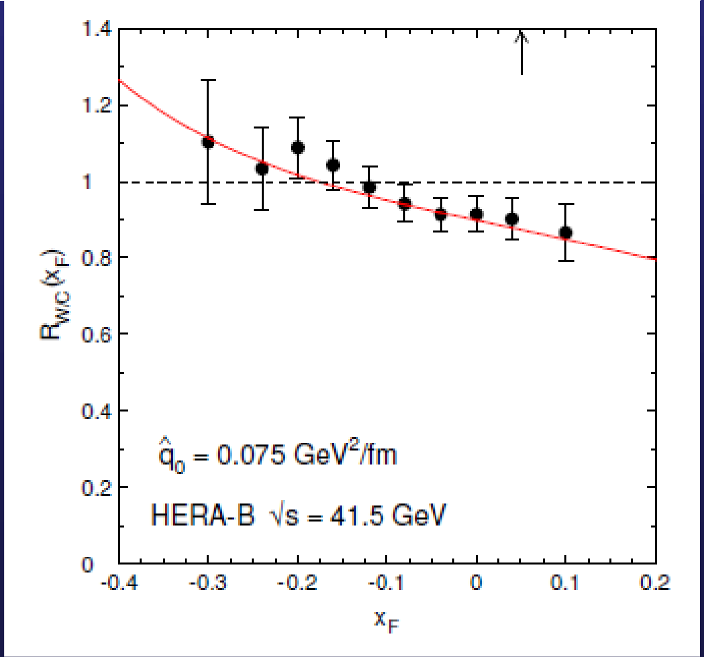
- Anyway excellent qualitative agreement!
- Comparison using the same x-axis variable mandatory

- Interplay between modeling of expansion (between τ_0 and freeze-out), comover density and comover cross section values. Can the data give constraints here?

Energy loss approach (François)





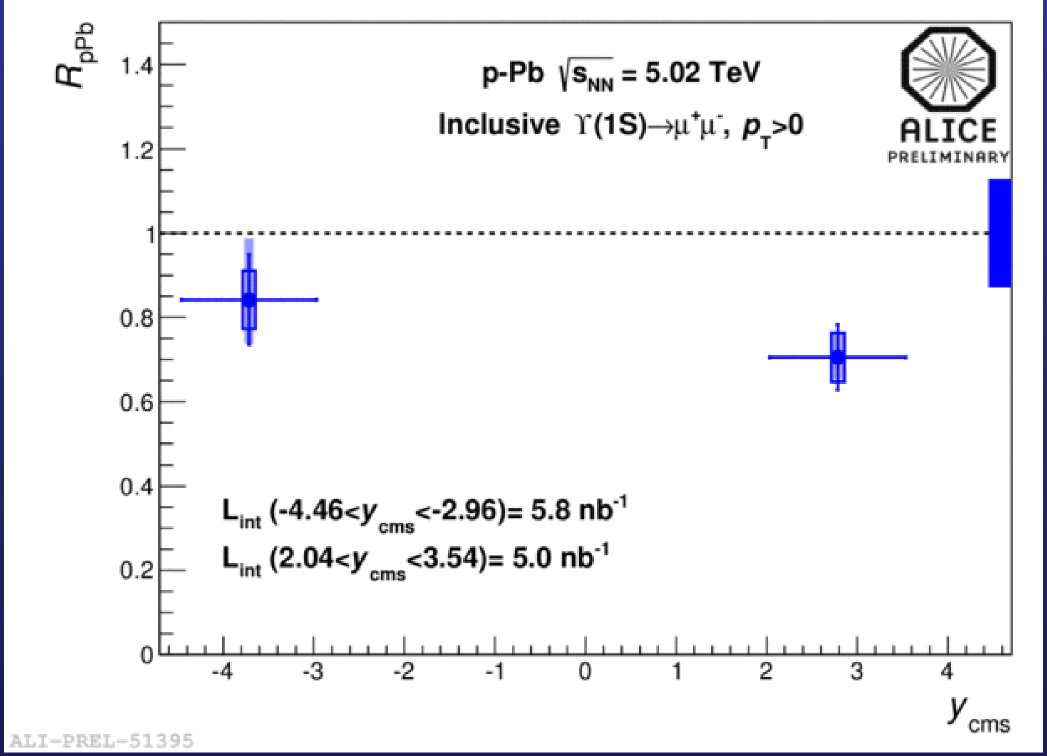


- y-range covered at LHC: well inside the "applicability" region
- Good description in a pure E_{loss} approach
- Interplay with shadowing/saturation ?

- The model works well also where it should not!
  - By chance ?
  - Or is there a deeper meaning?

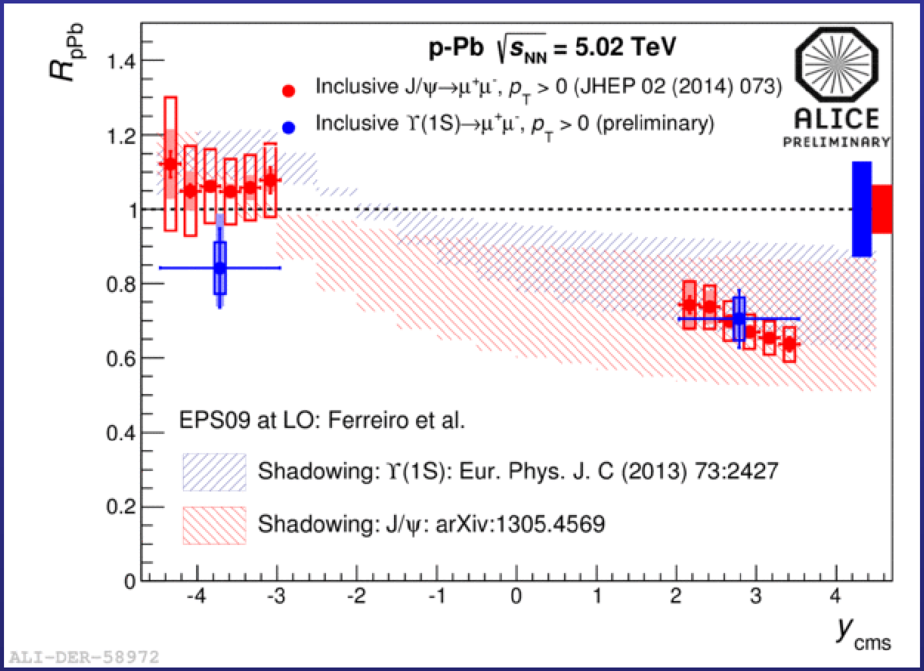
Υ(1S) results

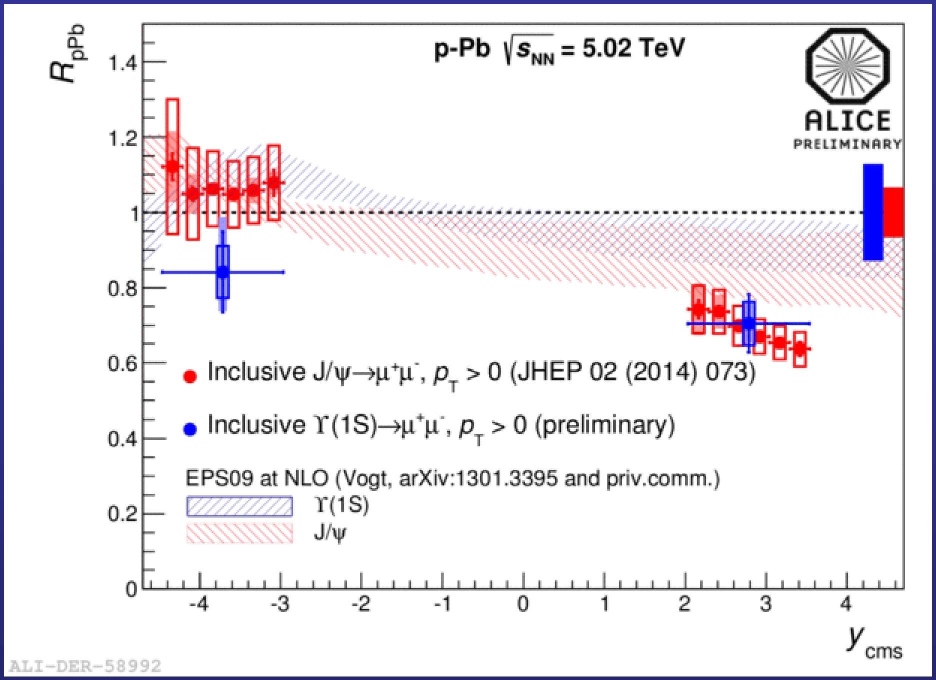
- Reference pp cross sections obtained via energy interpolation at mid-rapidity, using CDF@1.8 TeV, D0@1.96 TeV, CMS@2.76 TeV, CMS@7 TeV data + forward-y extrapolation using various PYTHIA tunes
- Alternative approach using LHCb data for final release of the results



- Consistent with no suppression at backward rapidity
- Indications of suppression at forward rapidity

ϒ(1S): model comparisons





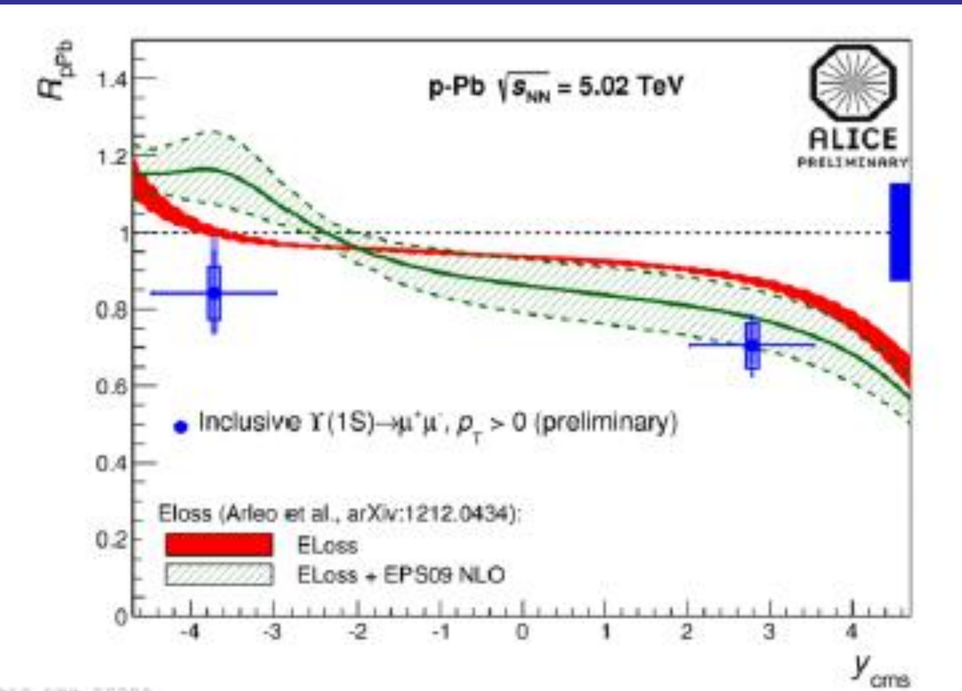
Ferreiro et al. [EPJC 73 (2013) 2427]

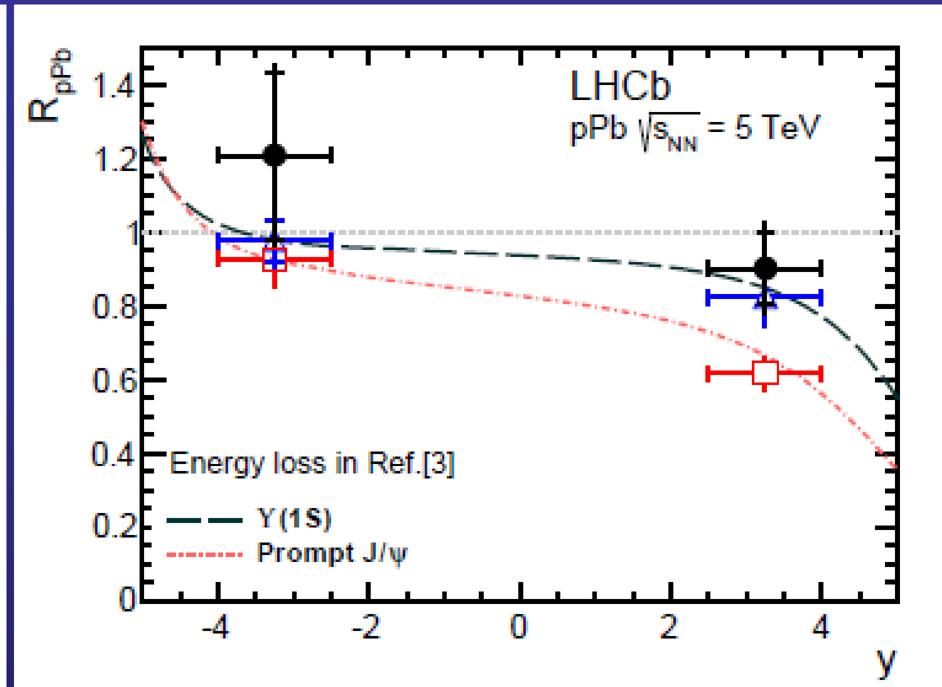
- Generic 2→2 production model at LO
- EPS09 shadowing parameterization at LO
- Fair agreement with measured R_{pPb}, although slightly overestimated in the antishadowing region

Vogt [arXiv:1301.3395]

- CEM production model at NLO
- EPS09 shadowing parameterization at NLO
- Fair agreement with measured R_{pPb} within uncertainties, although slightly overestimated it

More comparisons





- ❑ Arleo et al. [JHEP 1303 (2013) 122]
  - Model including a contribution from coherent parton energy loss, with or without shadowing (EPS09)
  - Forward: Better agreement with E_{Loss} and shadowing
  - Backward: Better agreement with E_{Loss} only

- ❑ LHCb results are systematically above the ALICE ones, although within uncertainties

- ❑ Clear situation where more data are mandatory

CNM effects from p-Pb to Pb-Pb

- x-values in Pb-Pb $\sqrt{s_{NN}}$=2.76 TeV, $2.5<y_{cms}<4$ { $2 \cdot 10^{-5} < x < 9 \cdot 10^{-5}$; $1 \cdot 10^{-2} < x < 6 \cdot 10^{-2}$ }

- x-values in p-Pb $\sqrt{s_{NN}}$=5.02 TeV, $2.03 < y_{cms} < 3.53$ → $2 \cdot 10^{-5} < x < 8 \cdot 10^{-5}$
- x-values in p-Pb $\sqrt{s_{NN}}$=5.02 TeV, $-4.46 < y_{cms} < -2.96$ → $1 \cdot 10^{-2} < x < 5 \cdot 10^{-2}$

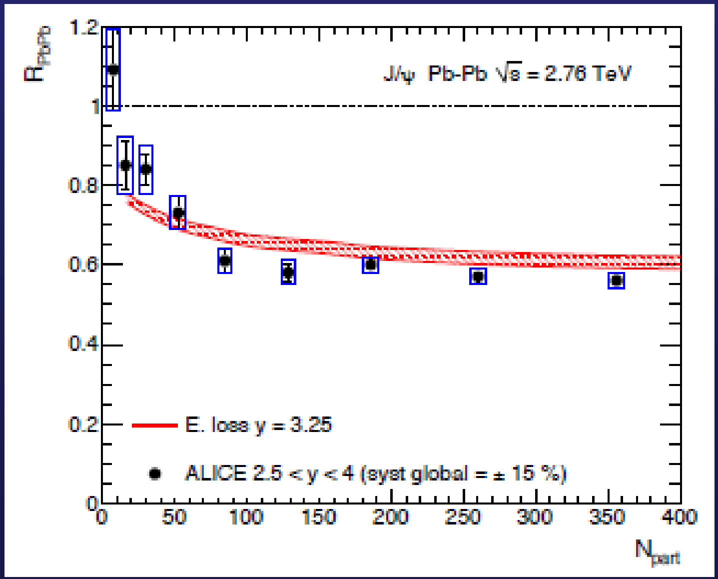
→ Partial compensation between $\sqrt{s_{NN}}$ shift and y-shift

- If CNM effects are dominated by shadowing
  - $R_{PbPb}^{CNM} = R_{pPb} \times R_{Pbp} = 0.75 \pm 0.10 \pm 0.12$
  - $R_{PbPb}^{meas} = 0.57 \pm 0.01 \pm 0.09$

  } "compatible" within 1-σ

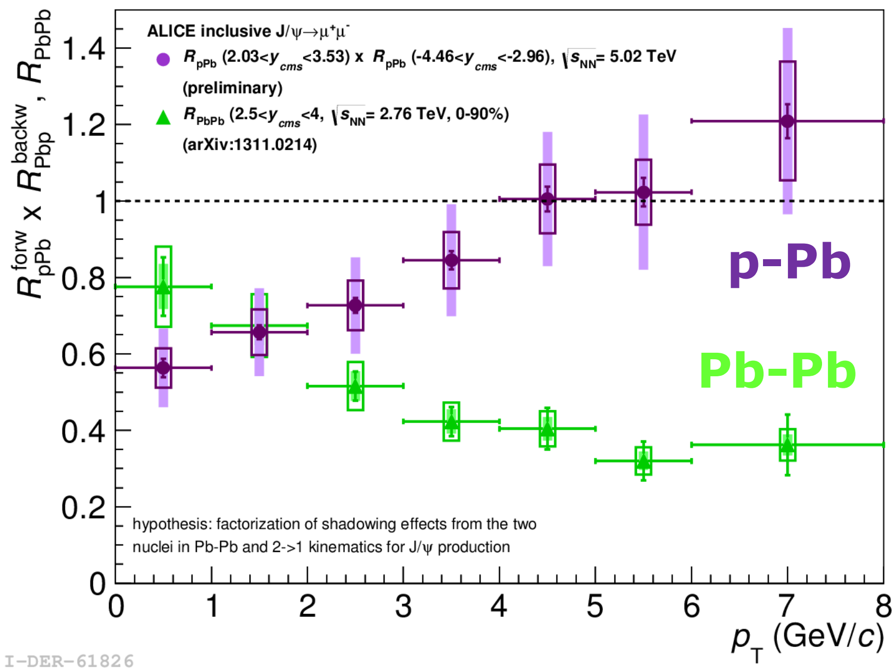
- Same kind of "agreement" in the energy loss approach

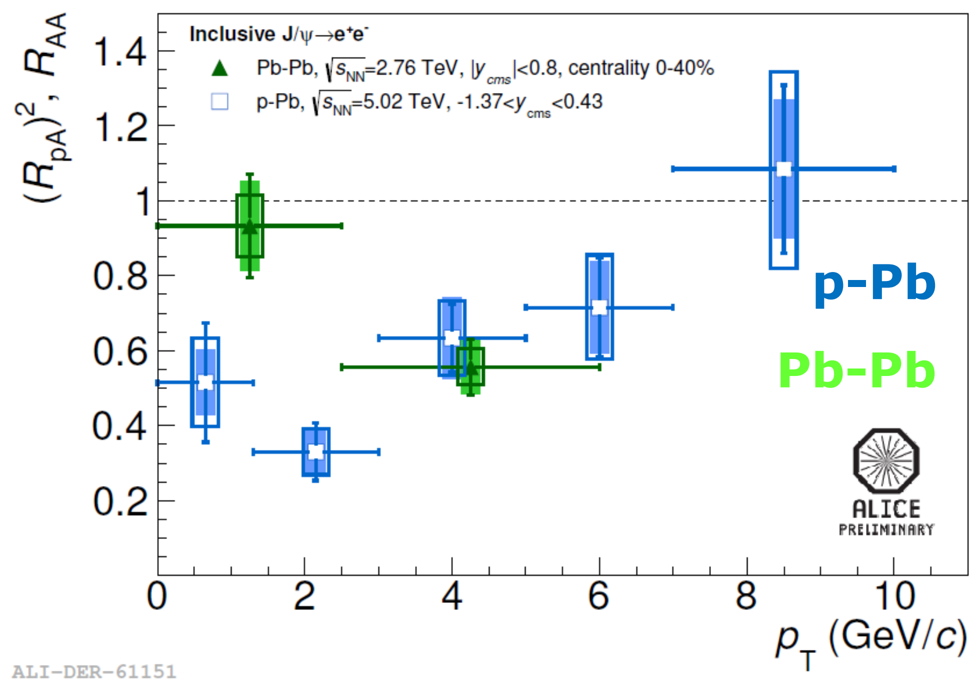
  …which does not exclude hot matter effects which partly compensate each other



p_T-dependence

- Perform the extrapolation as a function of p_T





- No more "agreement" between Pb-Pb and CNM extrapolations
- High-p_T suppression is not related to CNM effects
- At low p_T CNM suppression is of the same size of the effects observed in Pb-Pb: recombination ?

Conclusions

- Rather extensive set of results from LHC run-1 in p-Pb are available

  - For J/ψ, differential studies vs p_T, y and centrality with good statistics
  - For ψ(2S), statistics is smaller but interesting results anyway
  - CMS results at high-p_T and mid-rapidity would be welcome

  - For ϒ states, a larger data set would be beneficial

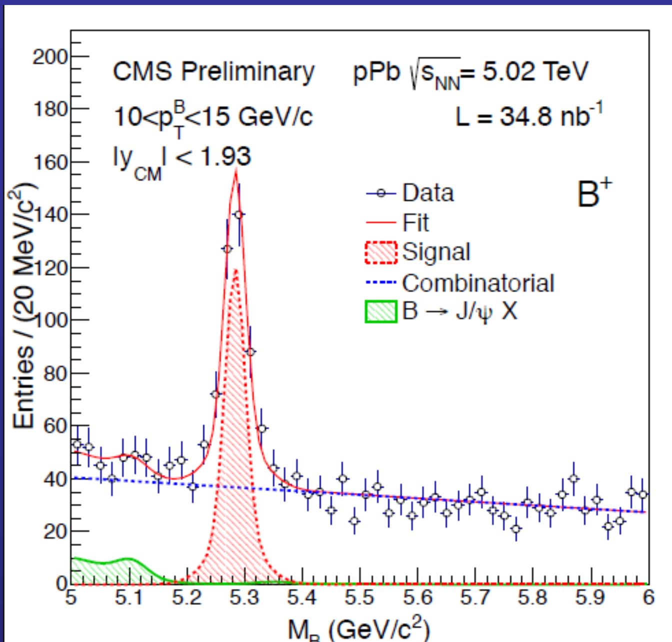
  - Question: better running again at $\sqrt{s_{NN}}$ = 5 TeV or go to $\sqrt{s_{NN}}$ = 8 TeV ?
    Discussion with machine and experiments ongoing, inputs useful

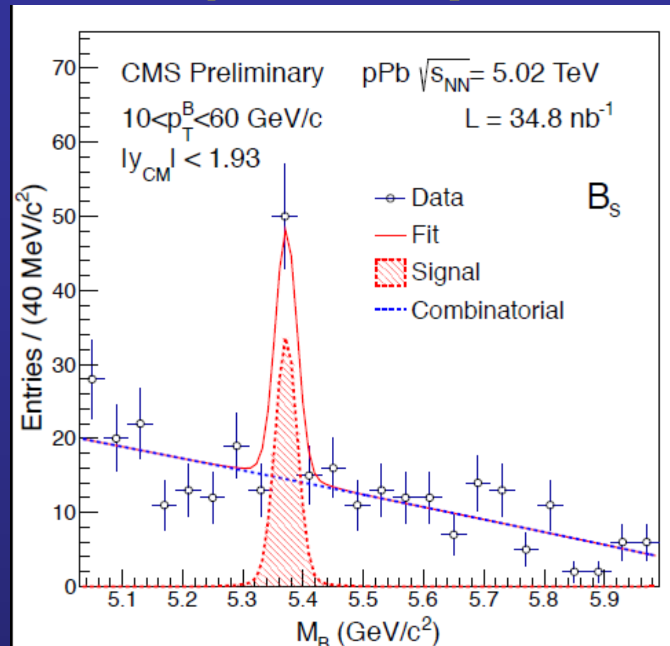
- Comparisons with theory models

J/ψ: qualitative agreement with energy loss (+ shadowing?), no (or small) extra-absorption
ψ(2S): evidence for extra-suppression at backward-y (comovers?)
ϒ states : more data needed for a meaningful comparison

Backup

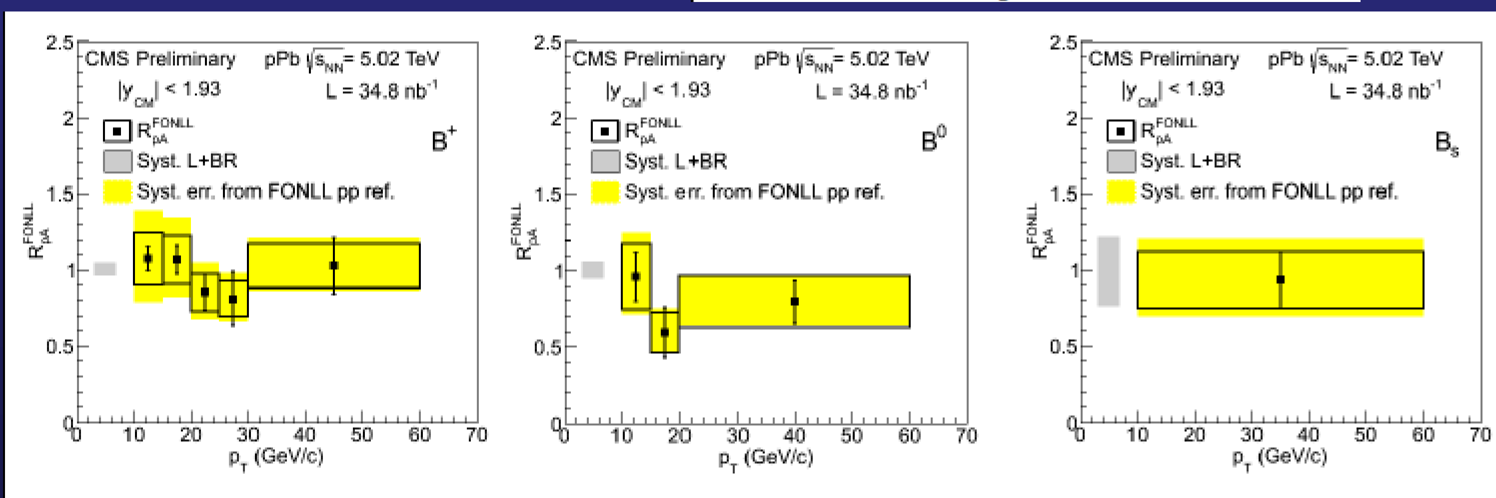
Direct B in p-Pb (mid-y)





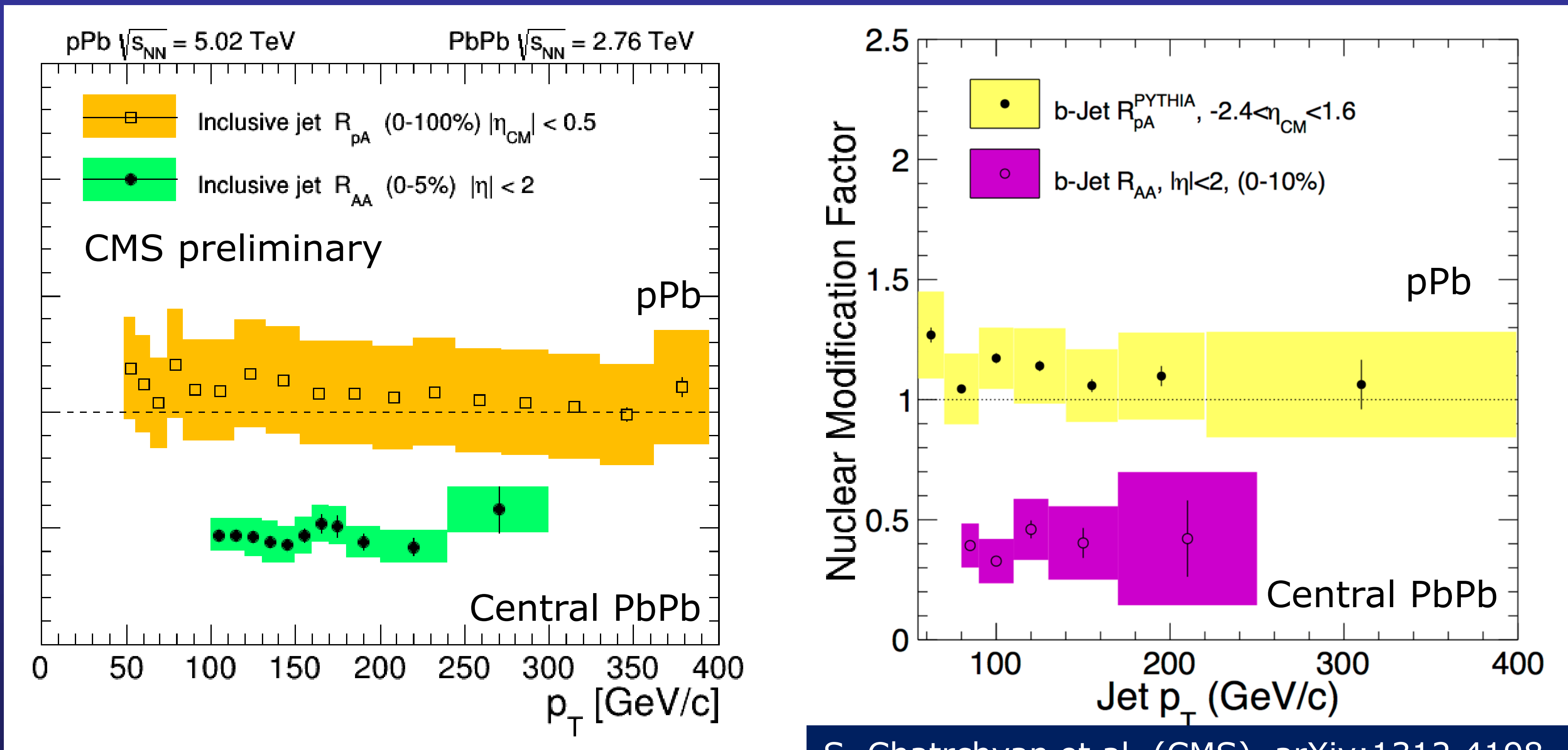
$B^+ \to J/\psi\ K^+$
$B^0 \to J/\psi\ K^*$
$B_S \to J/\psi\ \varphi$

$\langle p_T \rangle > 10$ GeV/c



- ❑ Use FONLL for pp reference cross section
- ❑ R_{pA}^{FONLL} is compatible with unity for all three B-mesons

R_{pPb} & R_{AA} for jets and b jets



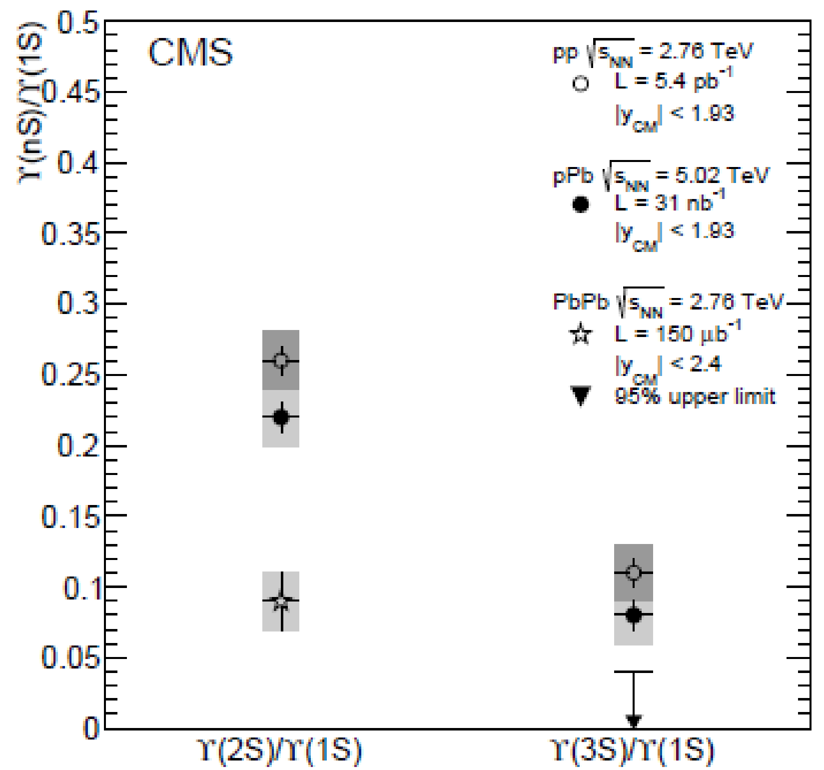
S. Chatrchyan et al. (CMS), arXiv:1312.4198

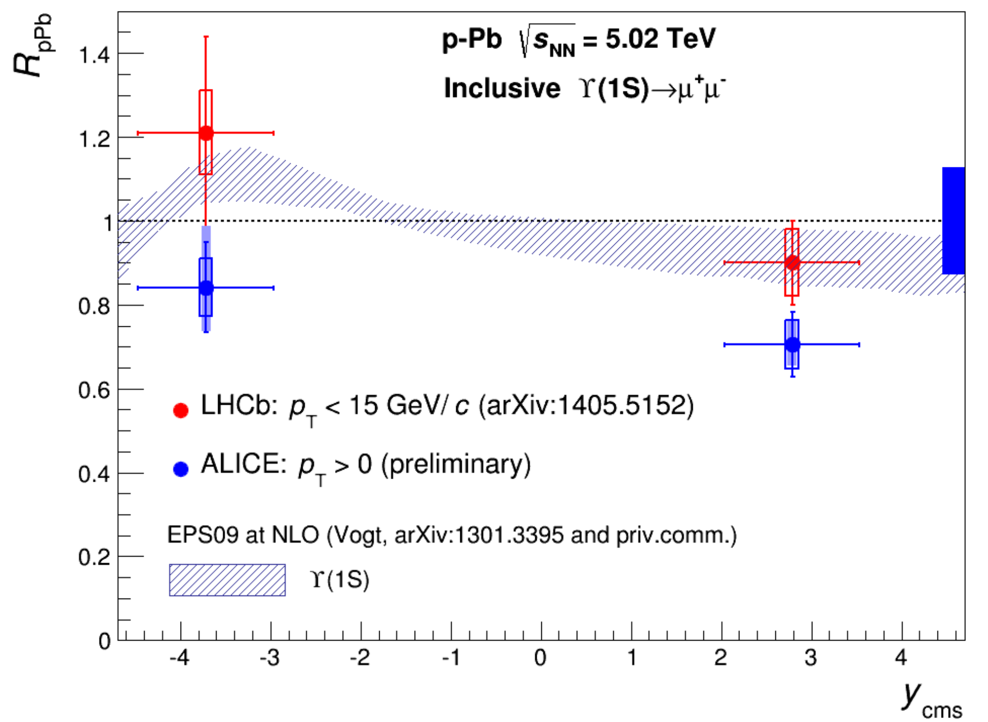
- Discriminating variable → Flight distance of the secondary vertex
- b-jet fraction → template fits to secondary vertex inv. mass distributions

- b-jet R_{AA} is much smaller than R_{pPb} → strong in-medium effects
- No jet modification in p-Pb collisions
- No flavour dependence of the effect

Do not forget CNM…

- In the Υ sector, the influence of CNM effects is small

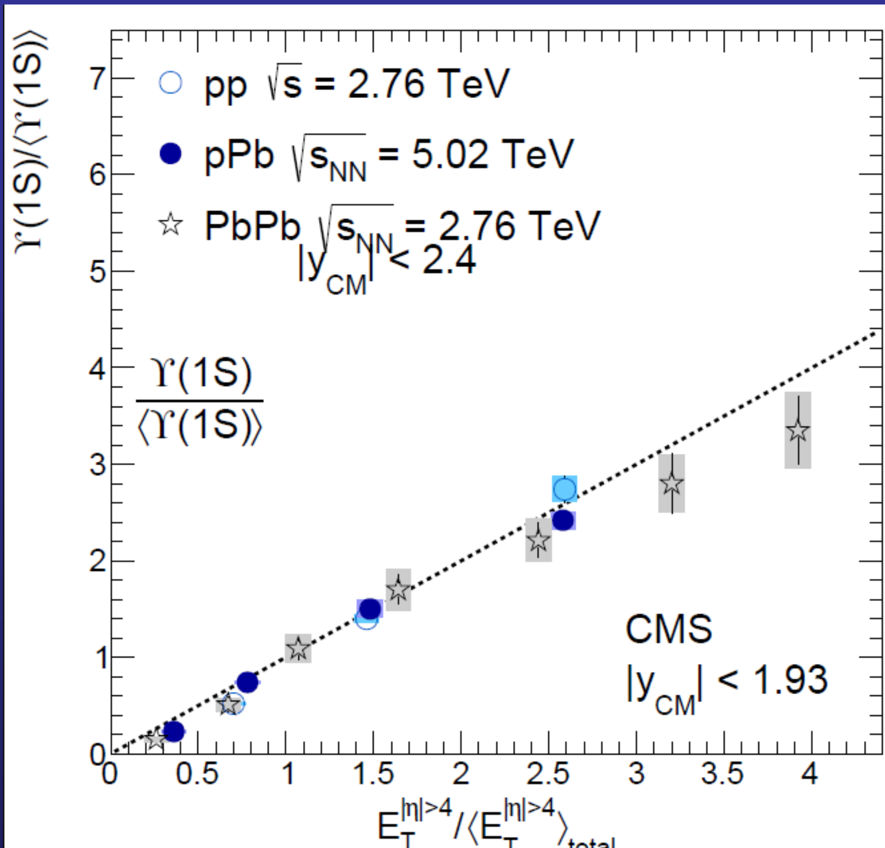


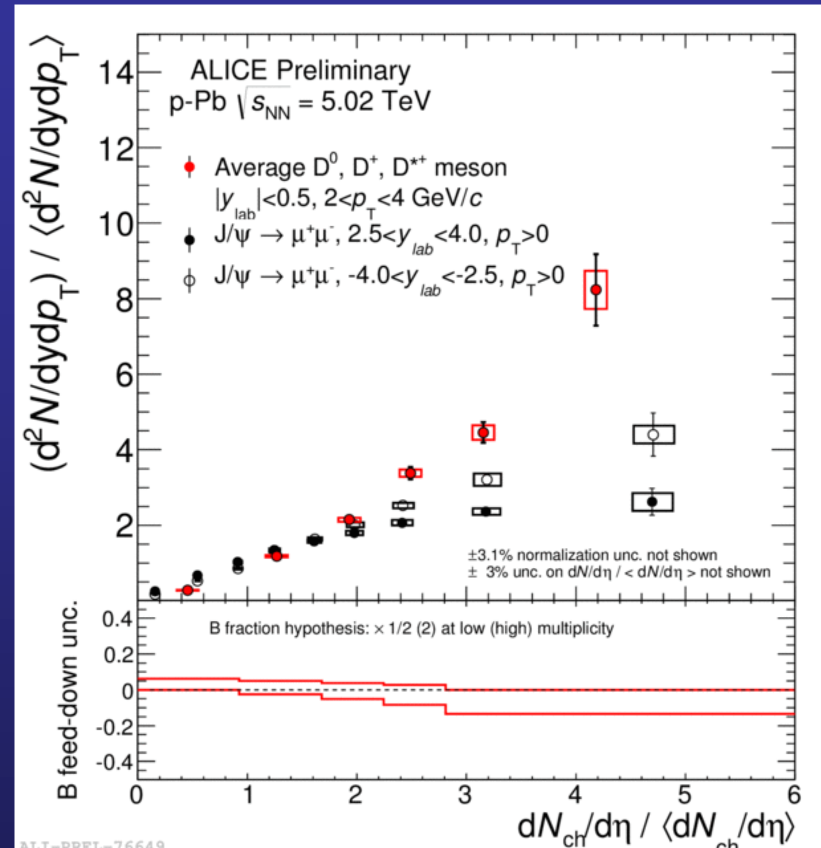


S. Chatrchyan et al.(CMS), JHEP 04(2014) 103

- Hints for suppression of $\Upsilon(1S)$ at forward rapidity?
- (Small) relative suppression of $\Upsilon(2S)$ and $\Upsilon(3S)$ wrt $\Upsilon(1S)$ at mid-rapidity
- Qualitative agreement with models within uncertainties
- CNM cannot account for all of the effect observed in Pb-Pb

Evolution of relative yields: pp, p-Pb, Pb-Pb





S. Chatrchyan et al.(CMS), JHEP 04(2014) 103

- Strong correlation of charmonia/bottomonia/open charm relative yields as a function of quantities related to the hadronic activity in the event
- Observation related to the role of MPI in pp also in the hard sector ?