Theory curves for J/psi in pPb

Yongsun Kim

Interesting talks in SQM

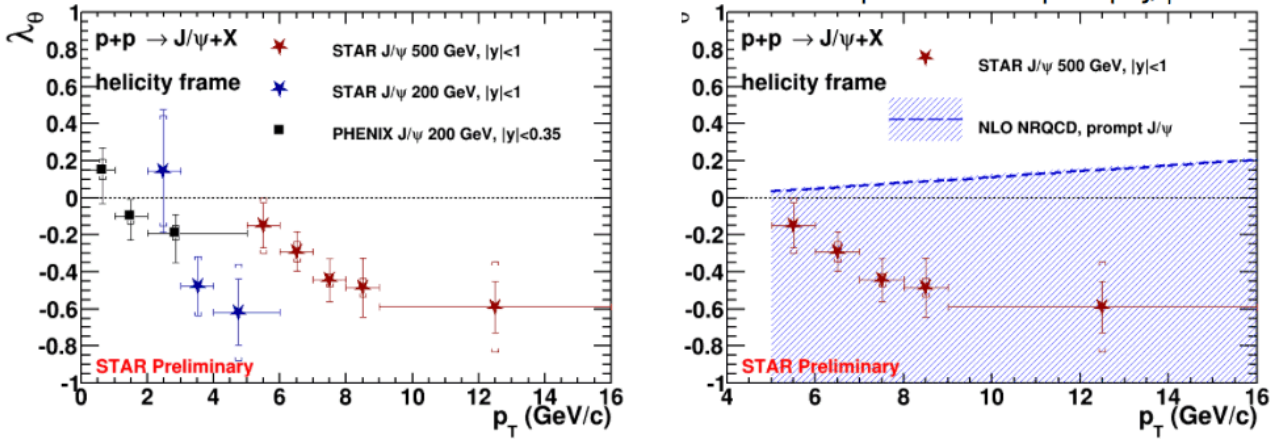
- https://indico-new.jinr.ru/conferenceTimeTable.py?confId=34#20150706

- Heavy quarkonia from lattice QCD by Rothkopf
- J/psi and psi' suppression in pA collisions by Lansberg
- J/psi and psi(2S) measurements in pp collisions at 200, 500GeV with the STAR experiment by Trzeciak

J/psi polarization in STAR 500GeV pp

- Non-zero polarization at high X_T

J/Ψ polarization in p+p 500 GeV



- Similar trend observed in 500 and 200 GeV p+p collisions
- Measurement extended to higher p_T range, $5 < p_T < 16$ GeV/c
- Data can help to constrain color-octet Long-Distance Matrix Elements

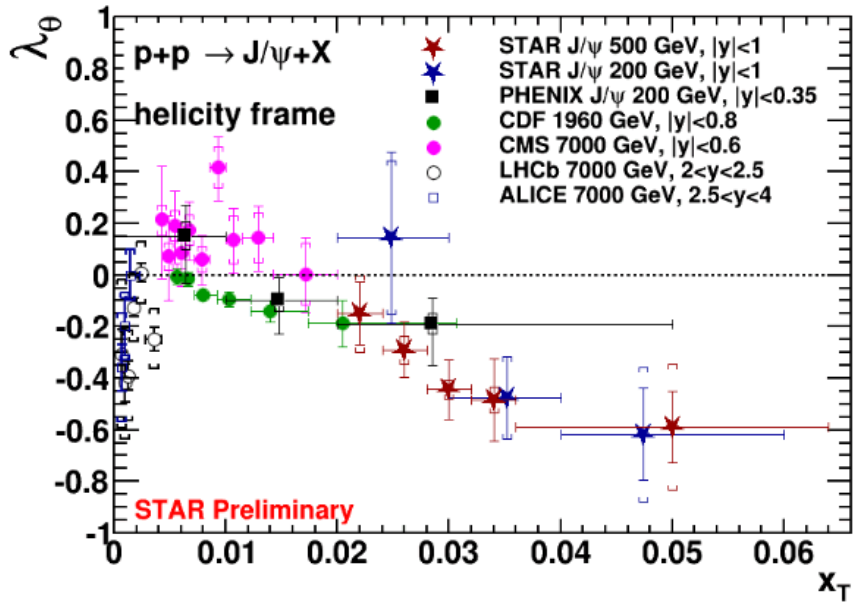
NLO NRQCD:
Phys. Rev. Lett. 108 (2012) 242004, Phys.Rev. D90 (2014) 1, 014002, Phys.Rev.Lett 112 (2014) 18, JHEP 1505 (2015) 103
And private communication

July 10, 2015 *Barbara Trzeciak, SQM 2015* 15

J/psi polarization in STAR 500GeV pp

- Non-zero polarization at high X_T

λ_θ parameter in HX frame



- Common trend towards strong negative values with increasing x_T

- x_T = 0.02 in 5TeV PbPb = 50GeV. Doable analysis!

Lansberg's talk

Impact of the Nuclear Modification of the Gluon Densities on J/ψ production in pPb collisions at $\sqrt{s_{NN}} = 5$ TeV

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[b] *Laboratoire Leprince Ringuet, École polytechnique, CNRS/IN2P3, 91128 Palaiseau, France*
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We update our previous studies of nuclear-matter effects on J/ψ production in proton-nucleus for the recent LHC pPb runs at $\sqrt{s_{NN}} = 5$ TeV. We have analysed the effects of the modification of the gluon PDFs in nucleus, using an exact kinematics for a $2 \to 2$ process, namely $g + g \to J/\psi + g$ as expected from LO pQCD. This allows us to constrain the transverse-momentum while computing the nuclear modification factor for different rapidities, unlike with the usual simplified kinematics. Owing to the absence of measurement in pp collisions at the same $\sqrt{s_{NN}}$ and owing to the expected significant uncertainties in yield interpolations which would hinder definite interpretations of nuclear modification factor –R_{pPb}–, we have derived forward-to-backward and central-to-peripheral yield ratios in which the unknown proton-proton yield cancel. These have been computed without and with a transverse-momentum cut, *e.g.* to comply with the ATLAS and CMS constraints in the central-rapidity region.

Introduction.— In this brief report, we proceed to an update of our earlier studies [1] of the nuclear-matter effects on the production of J/ψ in proton-nucleus at RHIC for the LHC experimental conditions. In these previous studies, we have indeed shown that the way to accurately evaluate the parton kinematics –and thus the nuclear shadowing– depends on the J/ψ partonic-production mechanism. Doing so, we could go beyond other J/ψ-production studies in pA collisions [2] in which it was assumed that the $c\bar{c}$ pair was produced by a $2 \to 1$ partonic process where the colliding gluons necessarily carried intrinsic transverse momentum k_T, entirely transferred to the quarkonium final state.

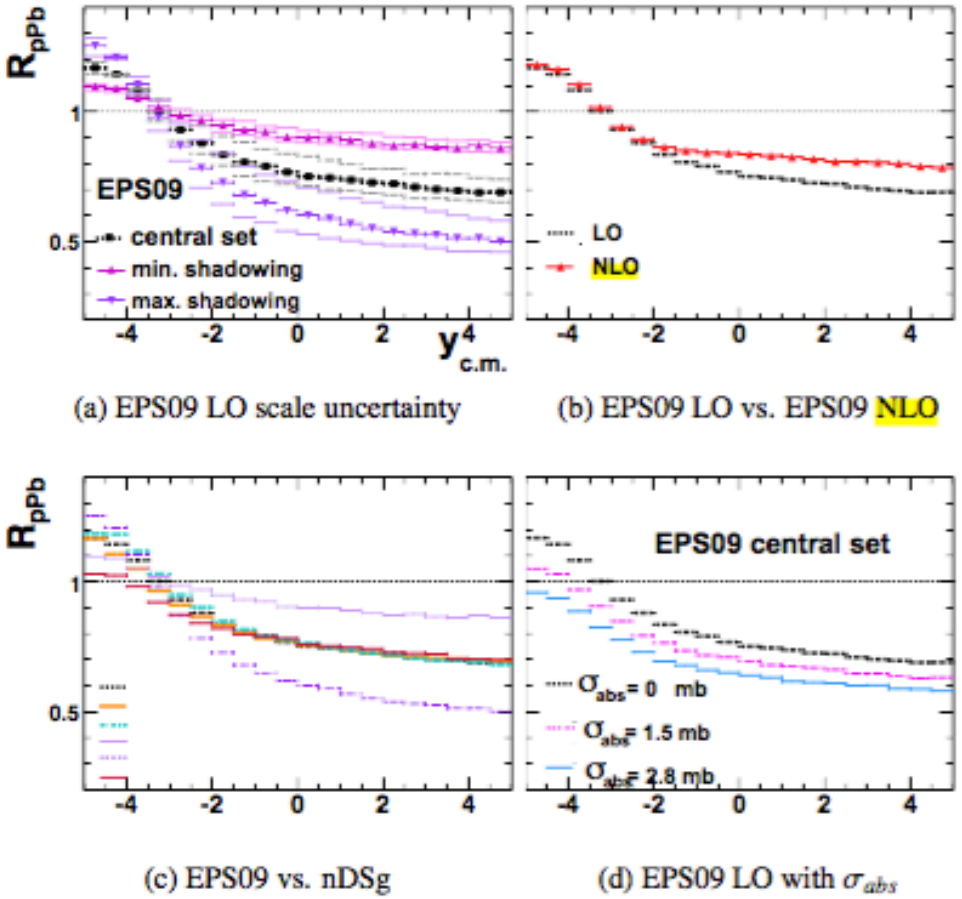
Our earlier works –as well as this update– account for a kinematics corresponding to a $2 \to 2$ partonic process for J/ψ

We therefore present here our results for proton-lead collisions at 5 TeV. We have studied the effect nuclear modification of the gluon PDFs on the J/ψ yield and as illustration of possible additional effects that of the so-called effective absorption –the break-up of the pre-resonant pair along its way off the lead nucleus–.

Other phenomena as such the Cronin effect, coherent power corrections and nuclear-matter-induced energy loss may also be at work. The latter effect is the subject of recent active activities [16, 17] whose conclusions may seem contradictory. As such and since this work has only as ambition to provide updated predictions at LHC energies based on [1], we have not considered these effects.

Theoretical framework. We have thus used our probe

NLO vs LO R_{pPb}



(a) EPS09 LO scale uncertainty

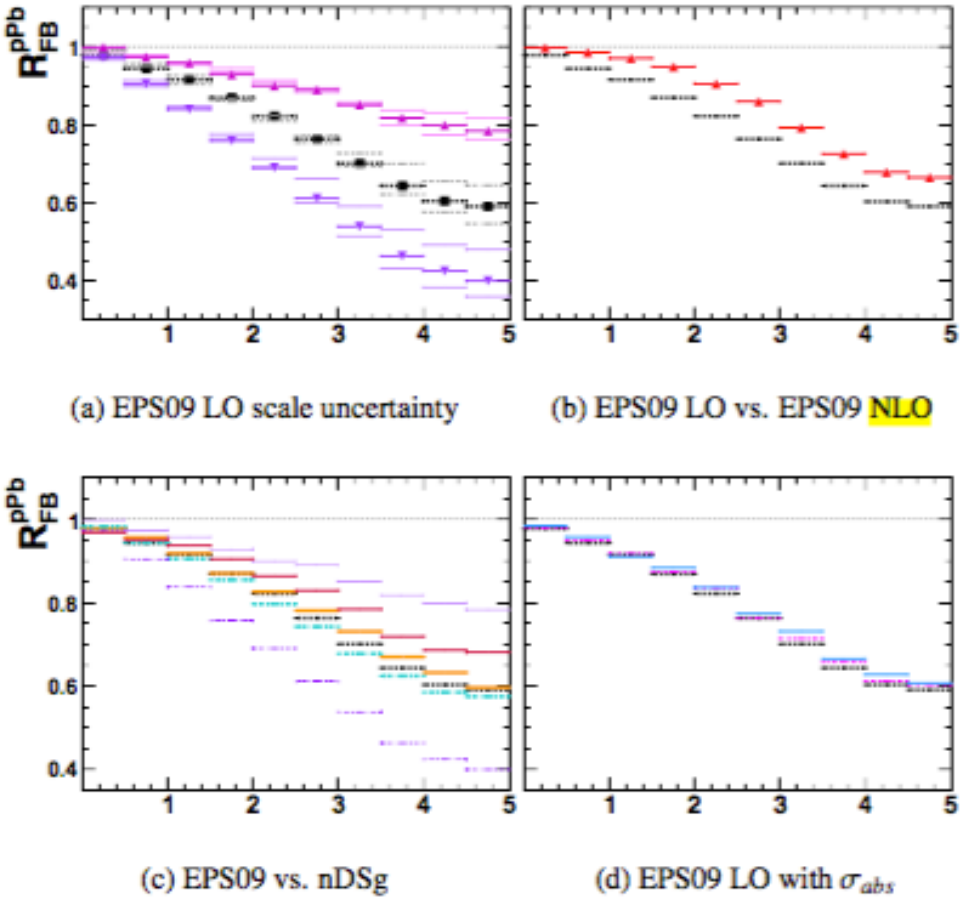
(b) EPS09 LO vs. EPS09 NLO

(c) EPS09 vs. nDSg

(d) EPS09 LO with σ_{abs}

FIG. 2: (Color online) Illustration of the uncertainties in the prediction of the J/ψ nuclear modification factor in pPb collisions, R_{pPb}, at $\sqrt{s_{NN}}$ = 5 TeV vs. y. (a) effect of the unknown factorisation scale taken to be $(0.75, 1, 2) \times m_T$, (b) central curves from EPS09 at LO and NLO, (c) extremal curves from EPS09 compared to nDSg (same color code as in Fig. 1), (d) effect of the unknown effective $c\bar{c}$ break up cross section for $t_f \gg R_{Pb}$.

NLO vs LO R_{FB}



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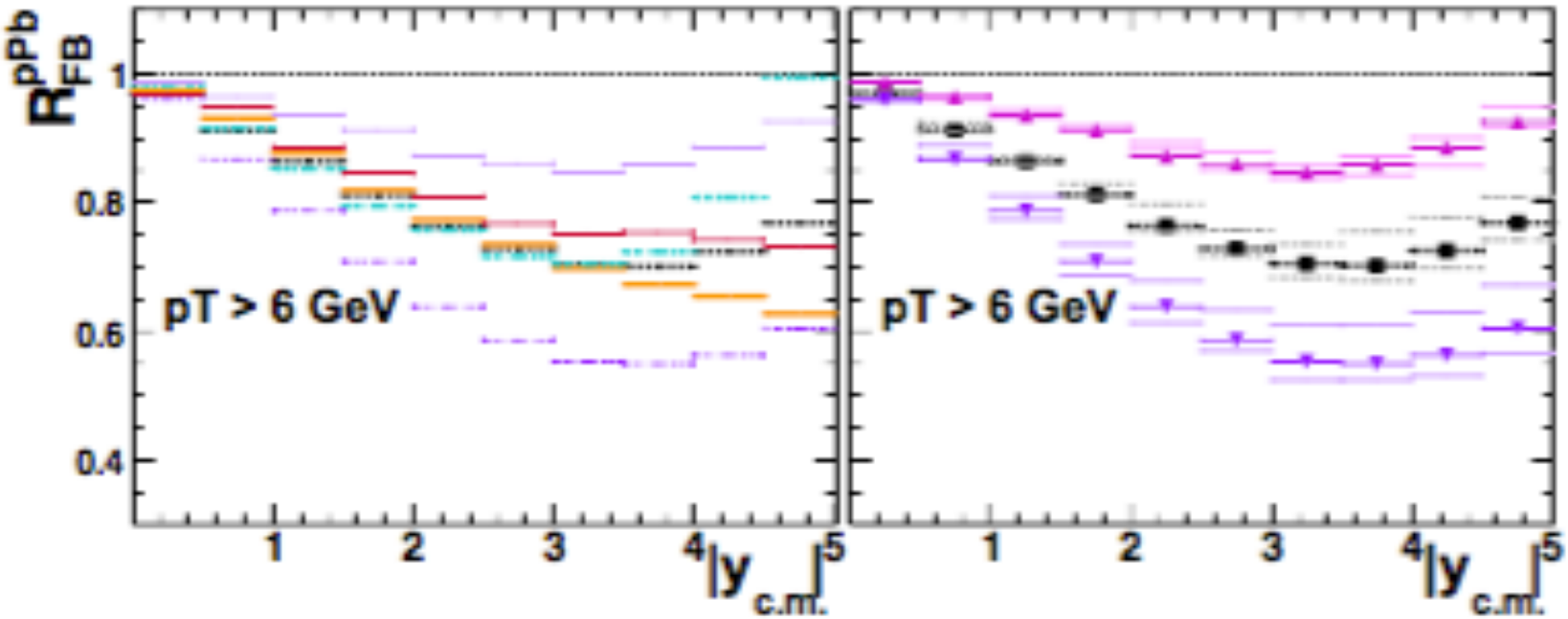
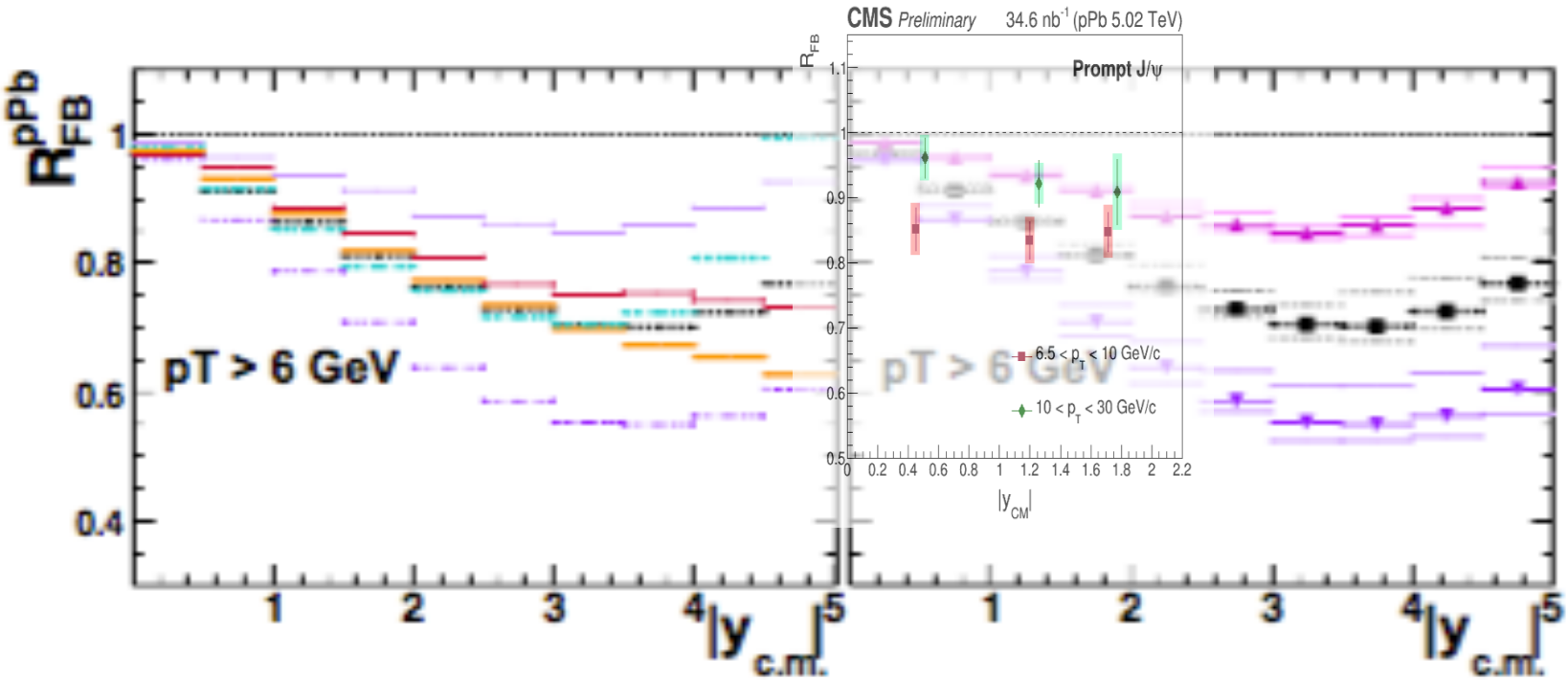
LO Prediction in R_{FB} , pT>6GeV



(c) R_{FB} for P_T > 6 GeV: EPS09LO vs. nDSg

(d) R_{FB} scale uncertainty for P_T > 6 GeV

LO Prediction in R_{FB} , pT>6GeV



(c) R_{FB} for P_T > 6 GeV: EPS09LO vs. nDSg

(d) R_{FB} scale uncertainty for P_T > 6 GeV

Centrality dependence in ALICE and ATLAS

CERN-PH-EP-2015-158
June 26 2015

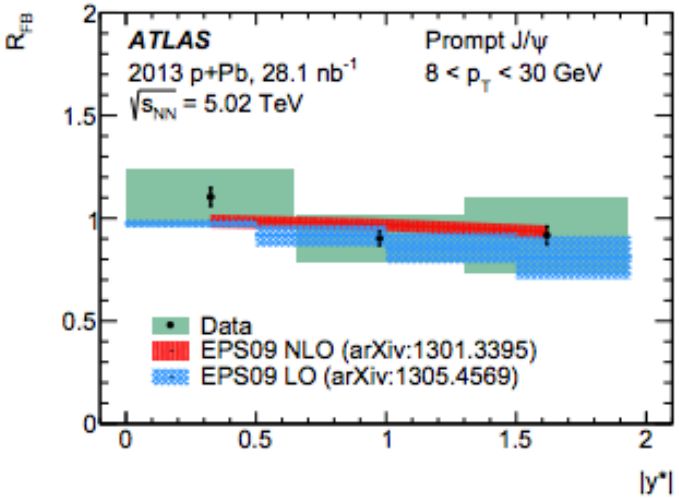
Centrality dependence of inclusive J/ψ production in p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV

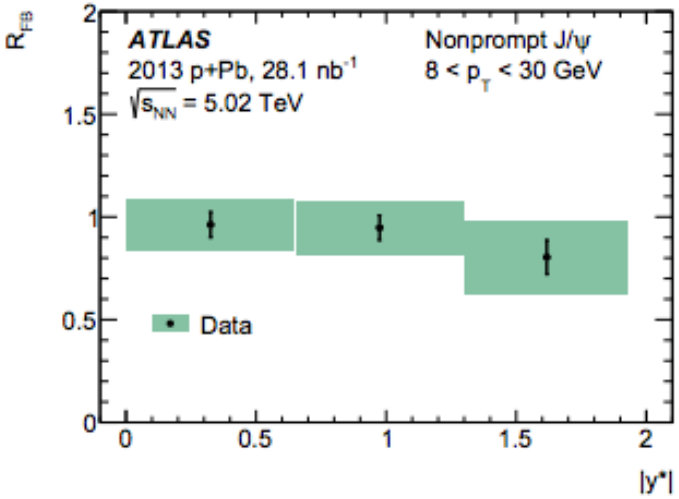
ALICE Collaboration*

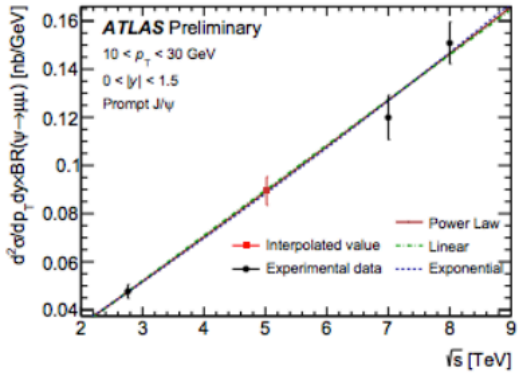
Abstract

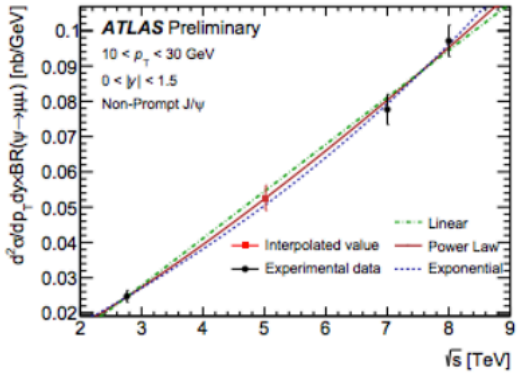
We present a measurement of inclusive J/ψ production in p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV as a function of the centrality of the collision, as estimated from the energy deposited in the Zero Degree Calorimeters. The measurement is performed with the ALICE detector down to zero transverse momentum, p_T, in the backward ($-4.46 < y_{cms} < -2.96$) and forward ($2.03 < y_{cms} < 3.53$) rapidity intervals in the dimuon decay channel and in the mid-rapidity region ($-1.37 < y_{cms} < 0.43$) in the dielectron decay channel. The backward and forward rapidity intervals correspond to the Pb-going and p-going direction, respectively. The p_T-differential J/ψ production cross section at backward and forward rapidity is measured for several centrality classes, together with the corresponding average p_T and p_T^2 values. The nuclear modification factor, Q_{pPb}, is presented as a function of centrality for the three rapidity intervals, and, additionally, at backward and forward rapidity, as a function of p_T for several centrality classes. At mid- and forward rapidity, the J/ψ yield is suppressed up to 40% compared to that in pp interactions scaled by the number of binary collisions. The degree of

ATLAS result and interpolation





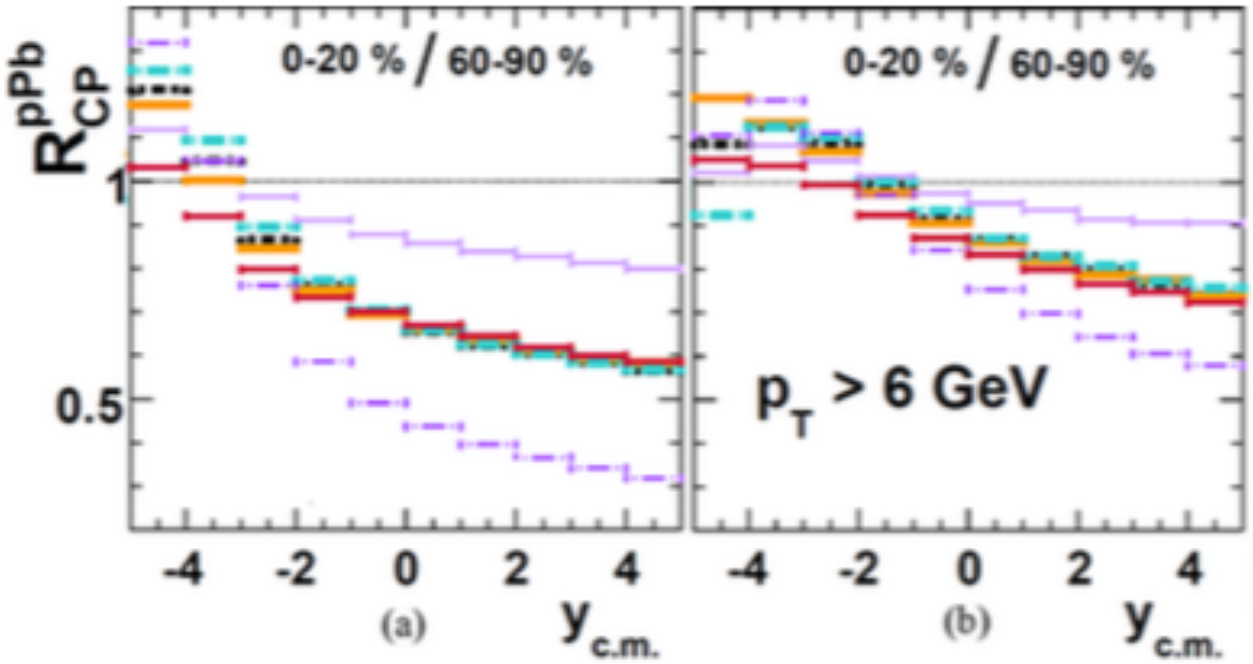




$$\sigma(\sqrt{s}) = \begin{cases} p_0 + \sqrt{s}p_1 & \text{linear} \\ (\sqrt{s}/p_0)^{p_1} & \text{power law} \\ p_0(1-\exp(-\sqrt{s}/p_1)) & \text{exponential} \end{cases}$$

Interpolation in CMS seems to be very hard due to limited manpower.
Maybe RCP

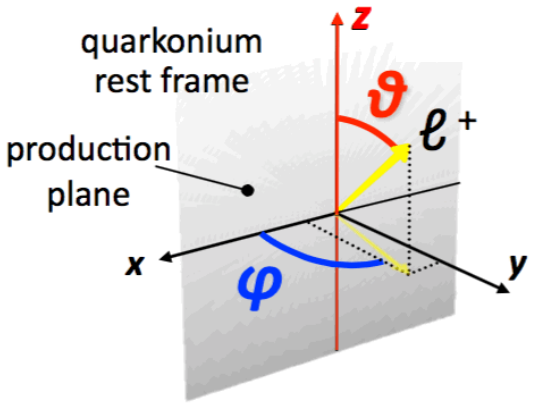
R_{CP}



Backup

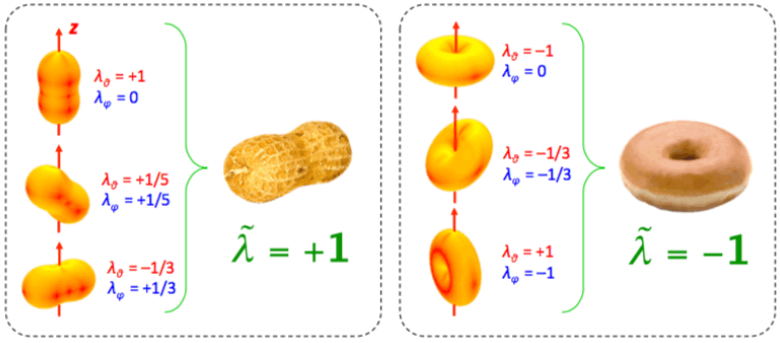
Polarization of Υ in p+p at 7TeV

- Modification of polarization can be thought of as the signal of interaction exerted during the formation of $Q\bar{Q}$ bound state ➔ final state effect
- Polarization of Υ states propagates to the anisotropic angular distribution of the decayed muons
- $\tilde{\lambda}$, frame independent variable, was used to quantify the distribution shape
- Dependence on particle multiplicity in p+p collisions was investigated to find the correlation with surrounding hadrons



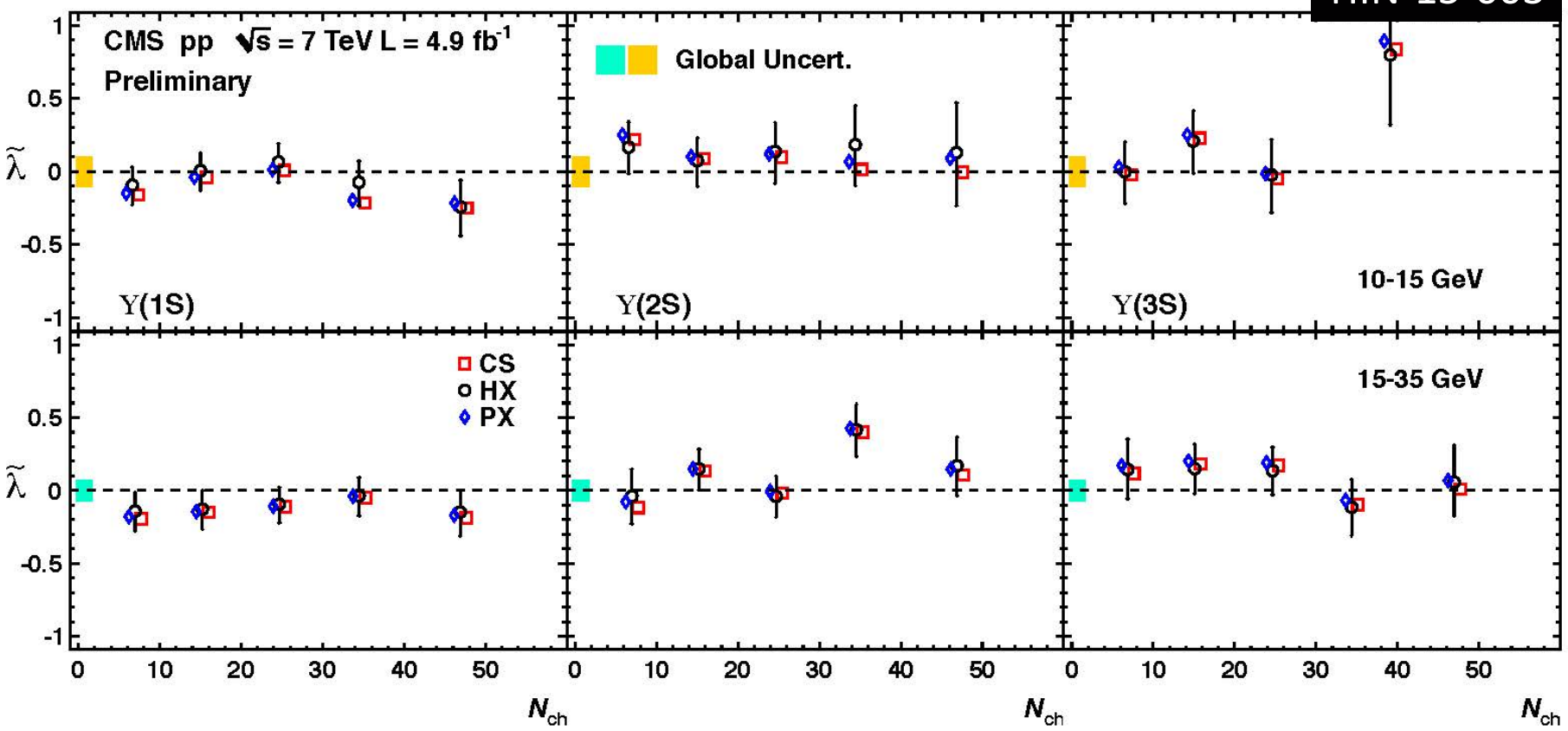
$$W(\cos\vartheta, \varphi|\vec{\lambda}) = 1 + \lambda_\theta \cos^2\vartheta + \lambda_\varphi \sin\vartheta\cos 2\varphi + \lambda_{\vartheta\varphi} \sin 2\vartheta \cos\varphi$$

$$\tilde{\lambda} = \frac{\lambda_\vartheta + 3\lambda_\varphi}{1 - \lambda_\varphi}$$



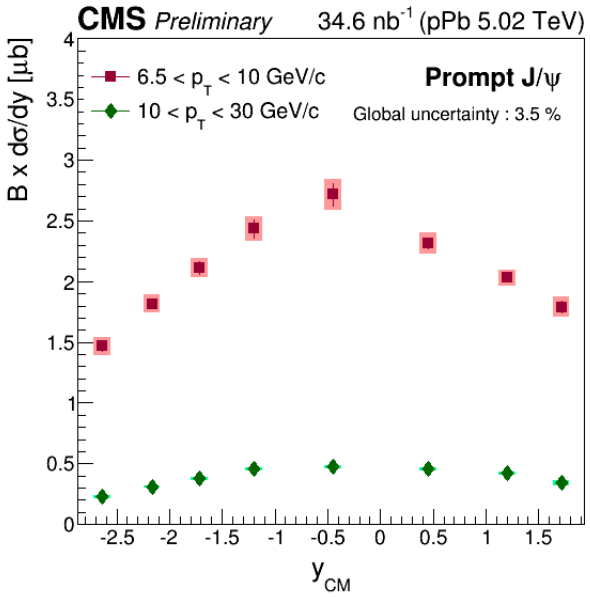
Polarization of Υ in p+p at 7TeV

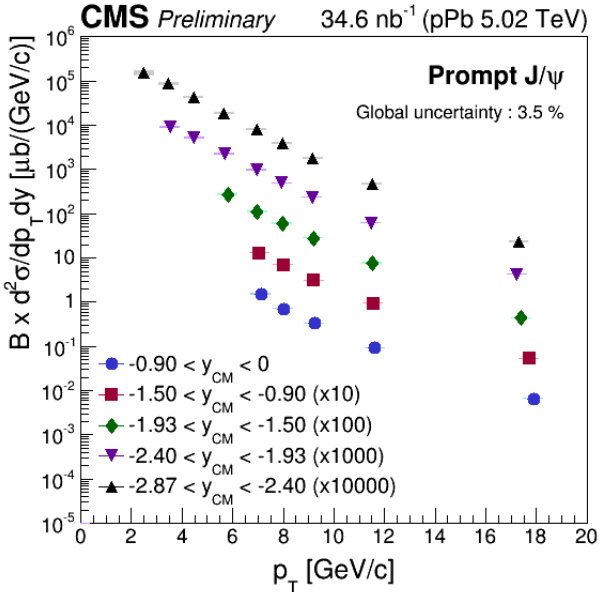
HIN-15-003

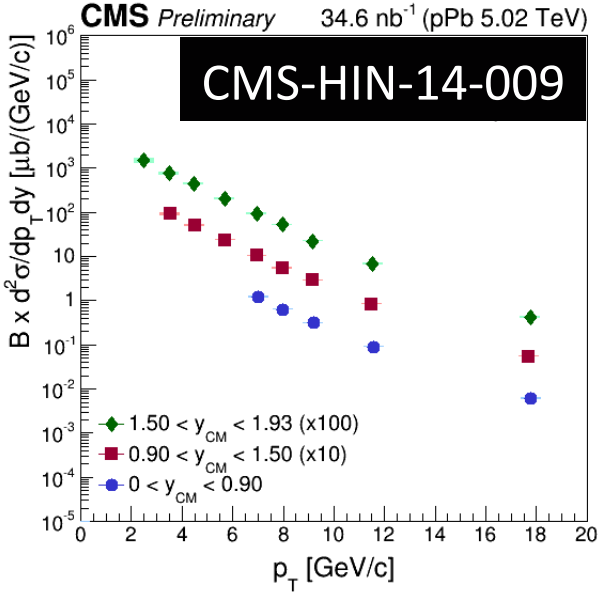


- Y polarizations were shown to remain near the unpolarized limit, with no significant dependence on particle multiplicity
- The result excludes the case of intense modification of quarkonium production processes by underlying events

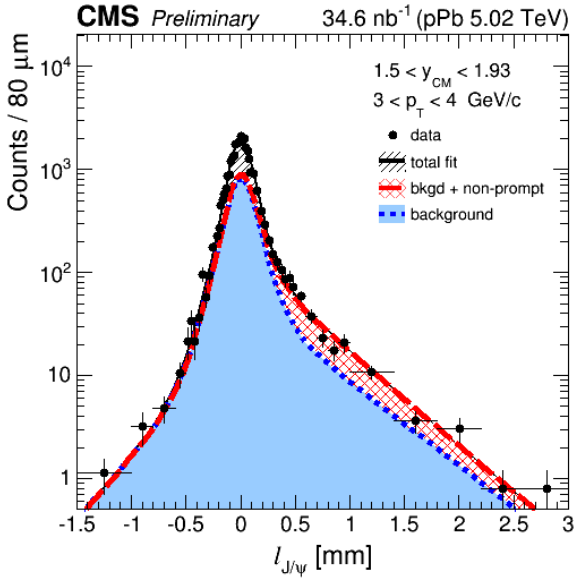
J/ψ in p+Pb

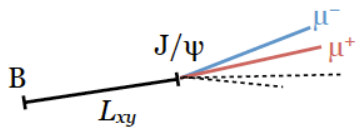




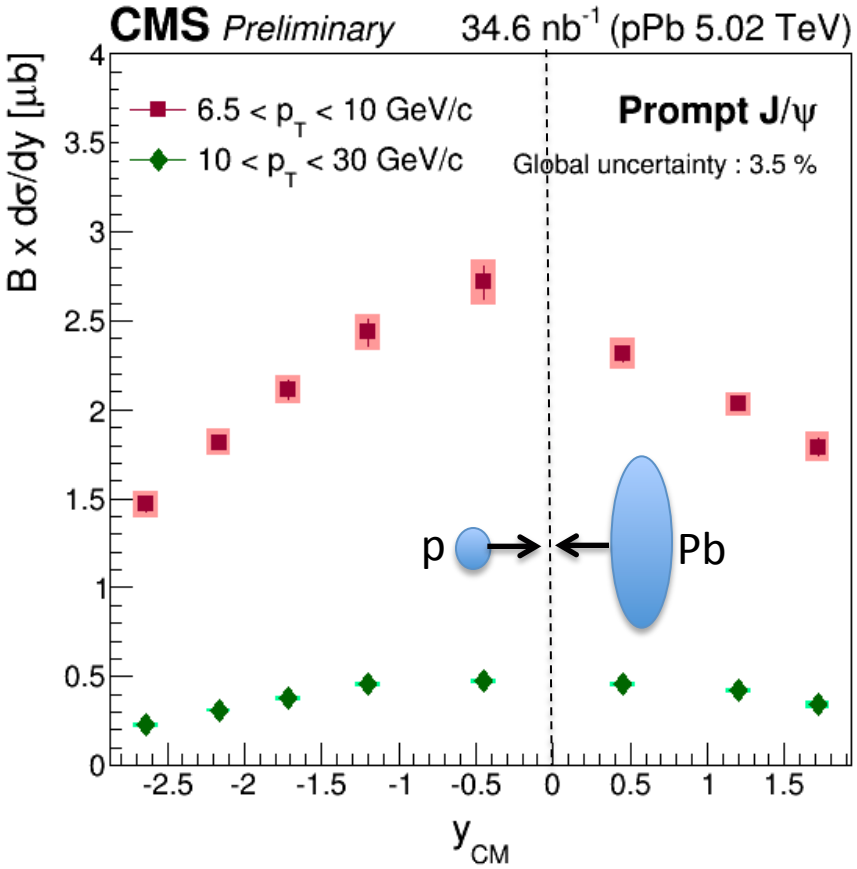


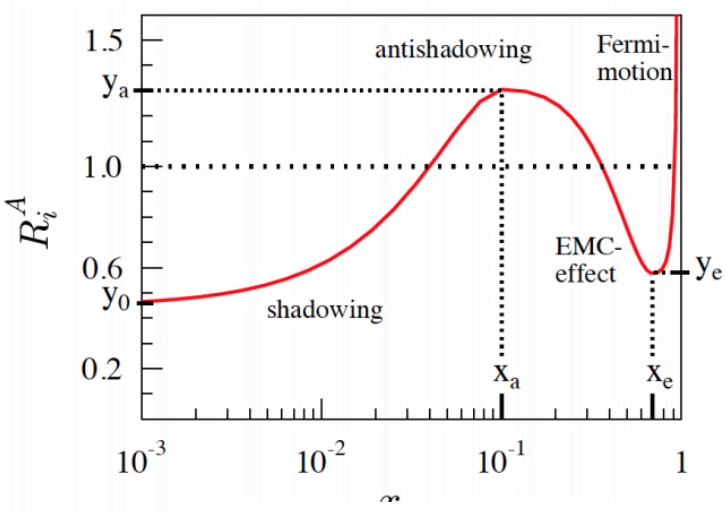
- CMS measured the double differential cross-section of J/ψ
- Non-prompt J/ψ (from B meson) are separated using decay length recognition





Lessons from J/ψ cross-section in p+Pb



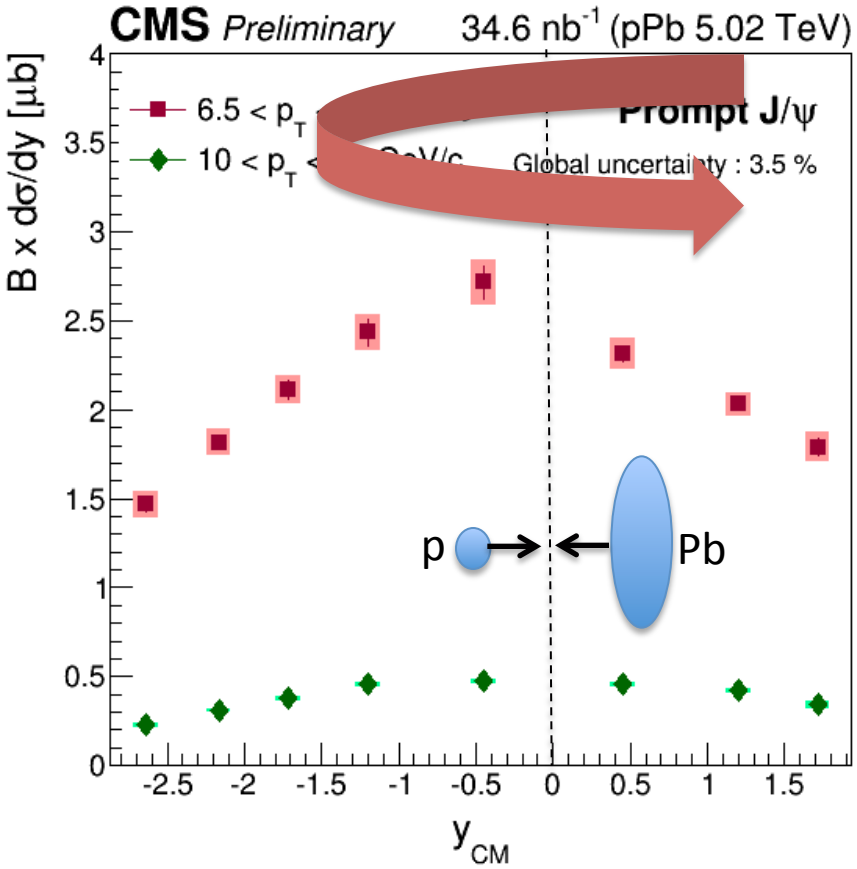


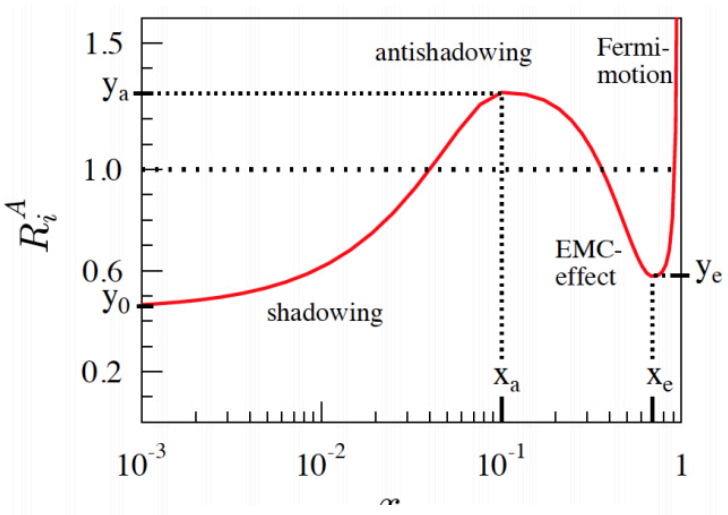
$$x_{1,2} = \frac{\sqrt{m^2_{J/\psi} + p^2_{T\,J/\psi}}}{\sqrt{s}} \cdot e^{\pm y}$$

CMS covers : $10^{-4} < x_2 < 10^{-2}$
In case of 2 -> 1 process

- Gluon distribution directly reflects to (p_T, y) distribution of prompt J/ψ
- Modification of PDF can be probed by asymmetry of J/ψ yield between p-going direction and pb-going direction

Lessons from J/ψ cross-section in p+Pb





$$x_{1,2} = \frac{\sqrt{m_{J/\psi}^2 + p_{T\,J/\psi}^2}}{\sqrt{s}} \cdot e^{\pm y}$$

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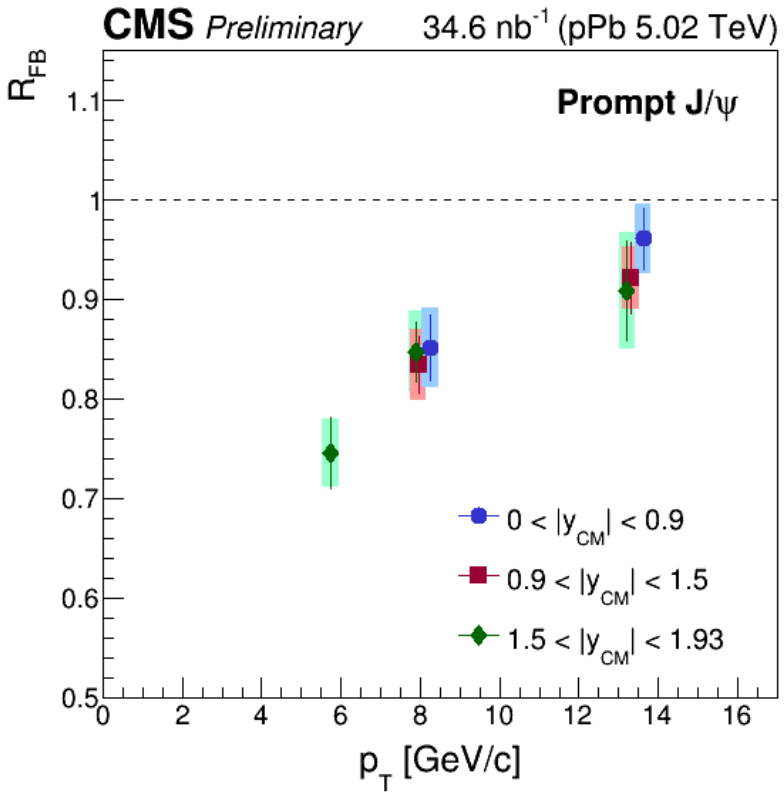
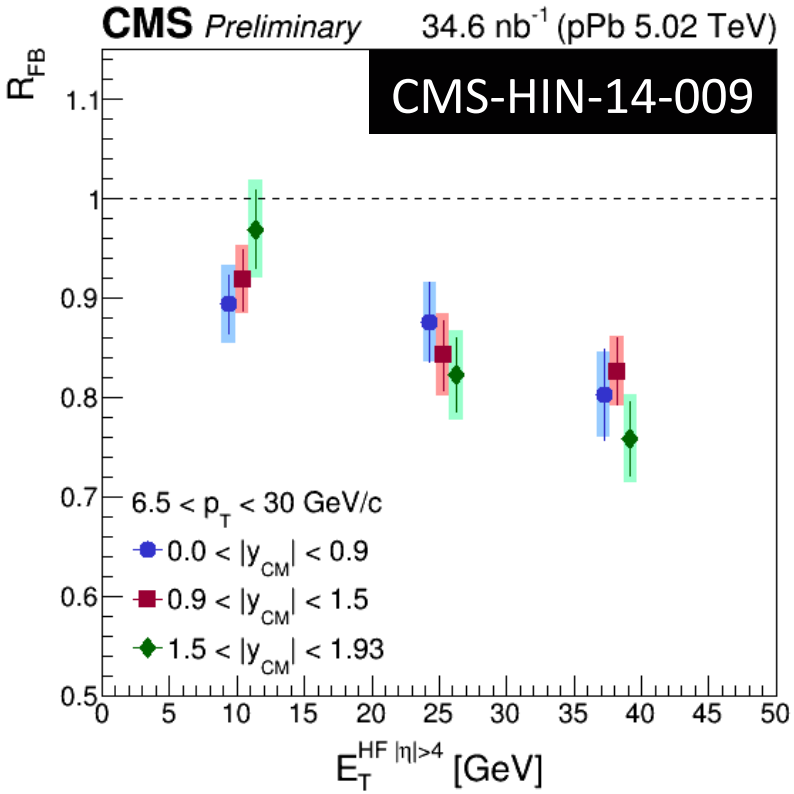
In case of 2 -> 1 process

- Gluon distribution directly reflects to (p_T, y) distribution of prompt J/ψ
- Modification of PDF can be probed by asymmetry of J/ψ yield between p-going direction and pb-going direction
- Let's fold plot around y_{CM}=0 to compare Forward/Backgrward yields, **R_{FB}**

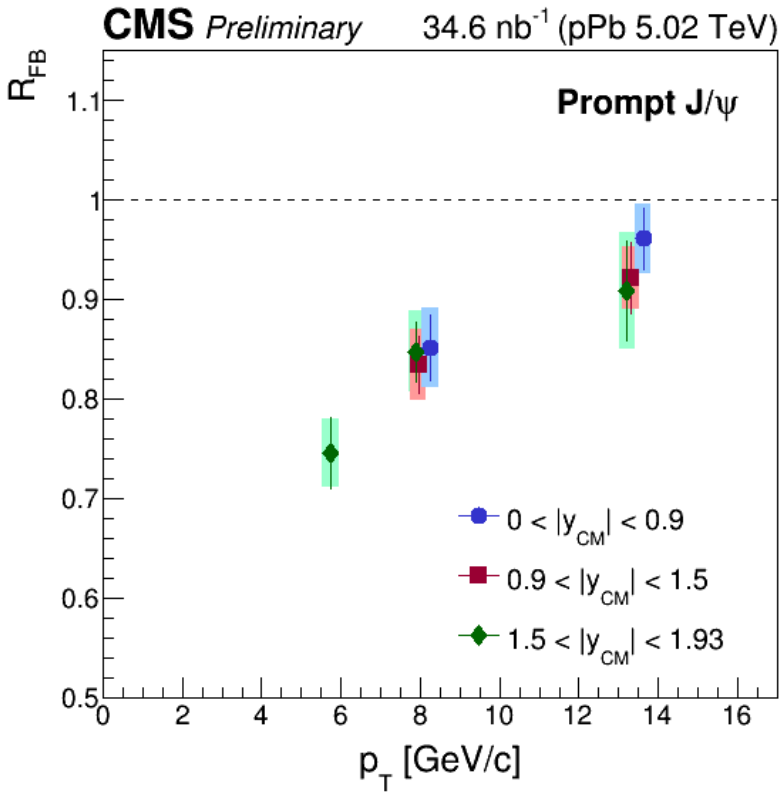
Lessons from J/ψ cross-section in p+Pb

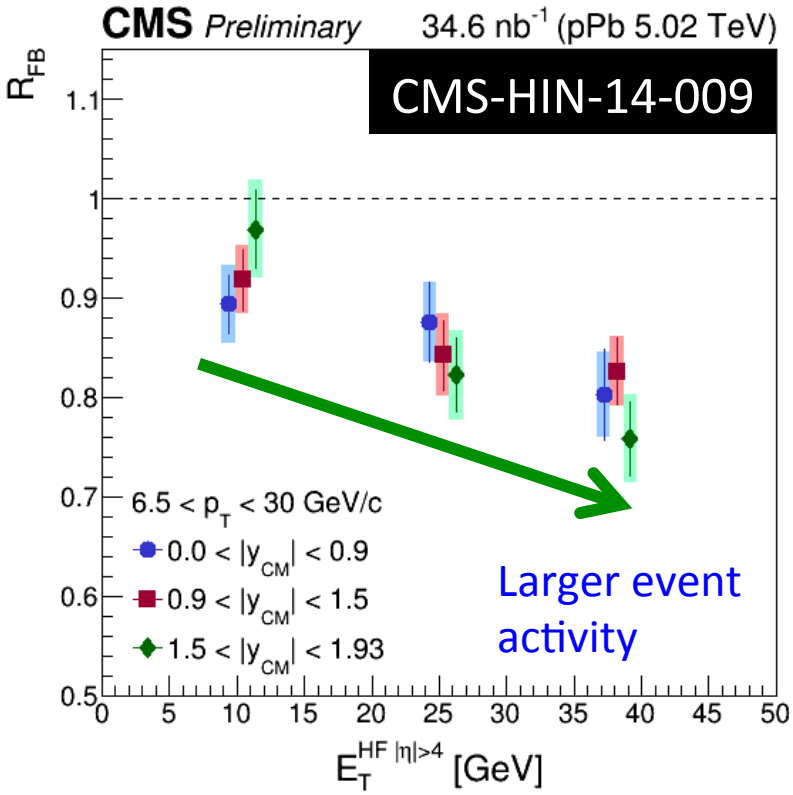




- (Left) The R_{FB} monotonically decreases for low p_T confirming significant modification of PDF.

Lessons from J/ψ cross-section in p+Pb

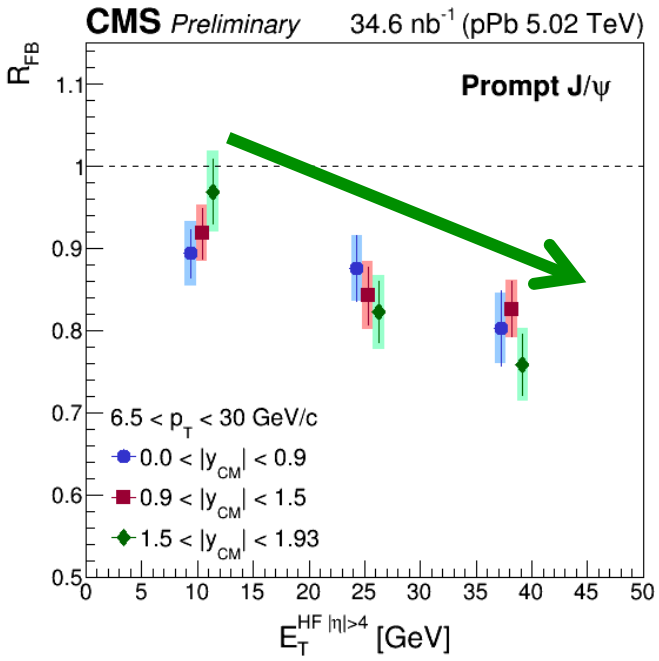




- (Left) The R_{FB} monotonically decreases for low p_T confirming significant modification of PDF.
- (Right) Measured R_{FB} as a function of event activity* to investigate centrality dependence. Asymmetry is enhanced for higher event activity bins

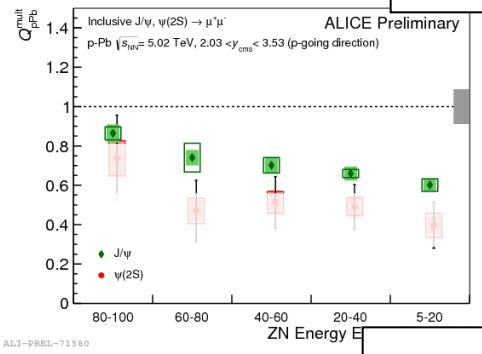
*Event activity = transverse energy deposited in forward calorimeter 4<|η|<5.2

Lessons from J/ψ cross-section in p+Pb

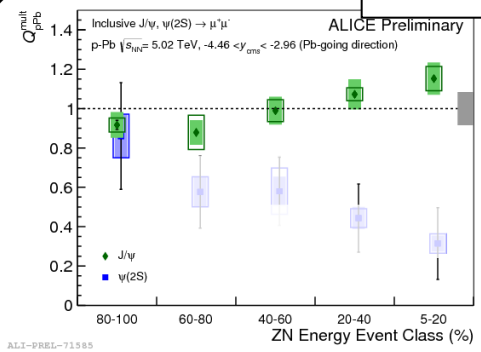


Consistent with ALICE J/ψ result ➔

ALICE forward



ALICE backward



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- (Right) Measured R_{FB} as a function of event activity* to investigate centrality dependence. Asymmetry is enhanced for higher event activity bins

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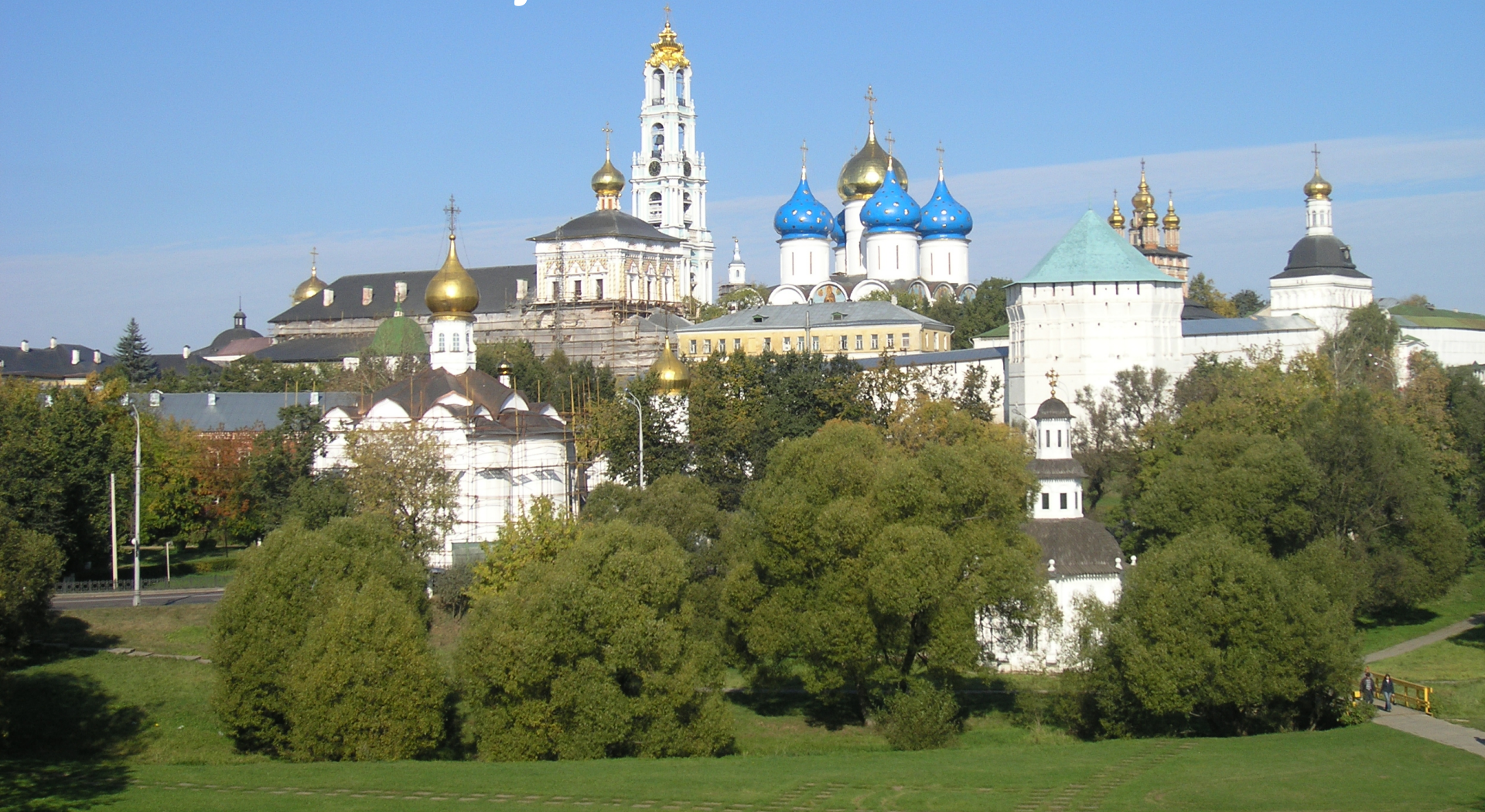
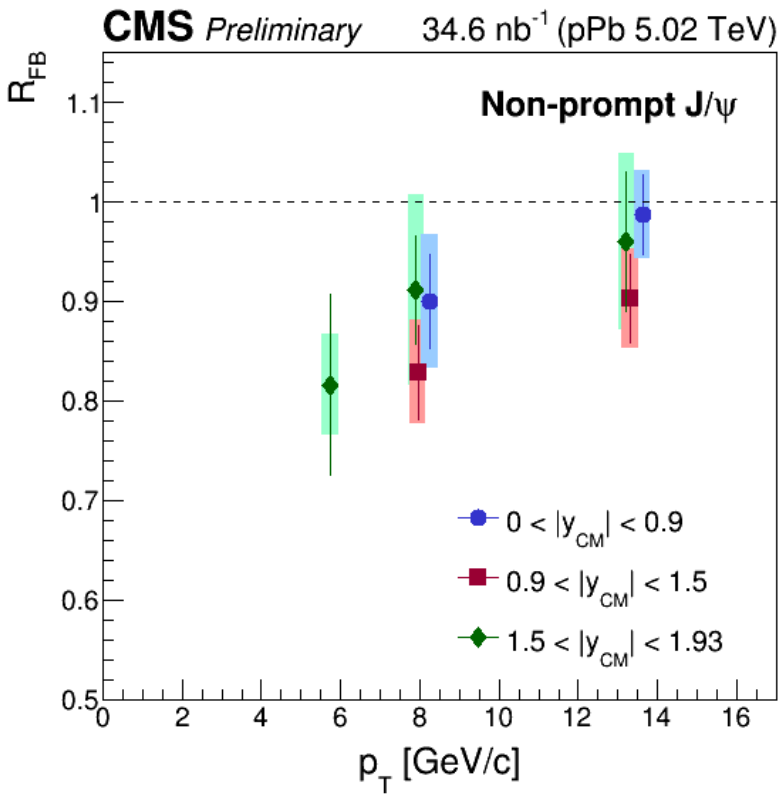
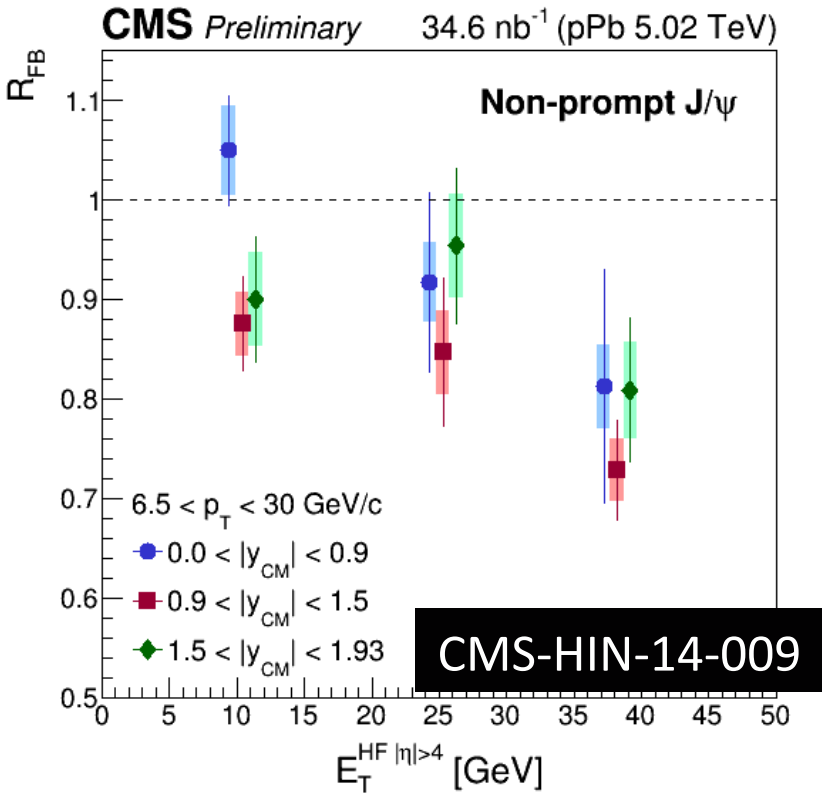
Part III

- Modification of heavy quarks in p+Pb collision
- B meson and B jet



Result of non-prompt J/ψ (feed from B meson)



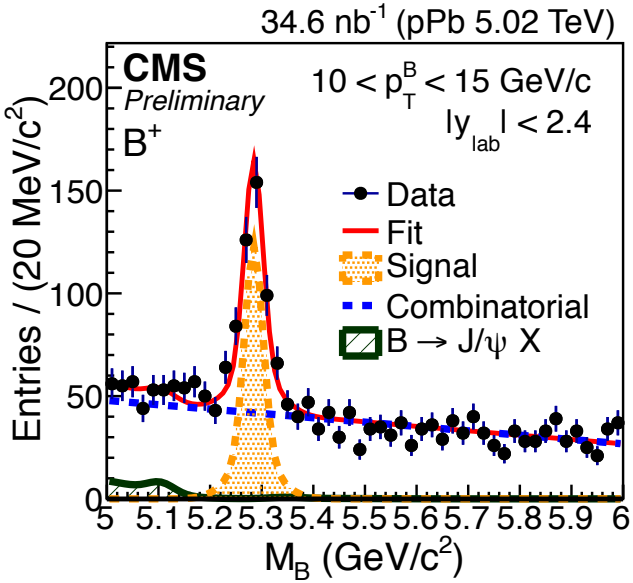


- Non-prompt J/ψ results show same trend with prompt J/ψ, but the effect is less significant by larger uncertainty

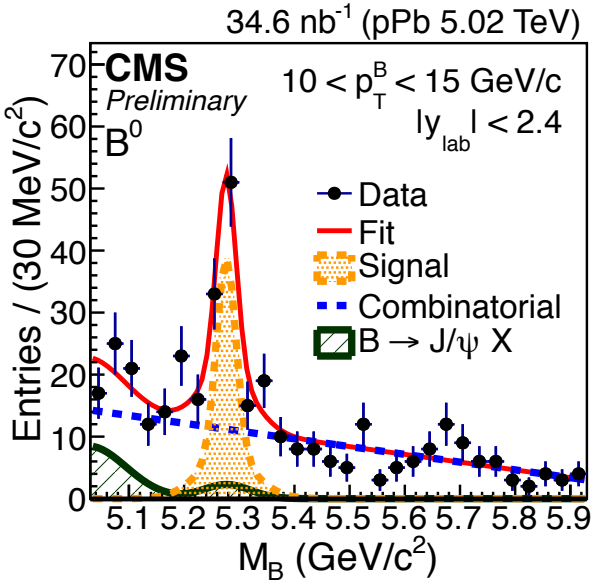
Fully reconstructed B-meson

Non-prompt J/ψ combined with…

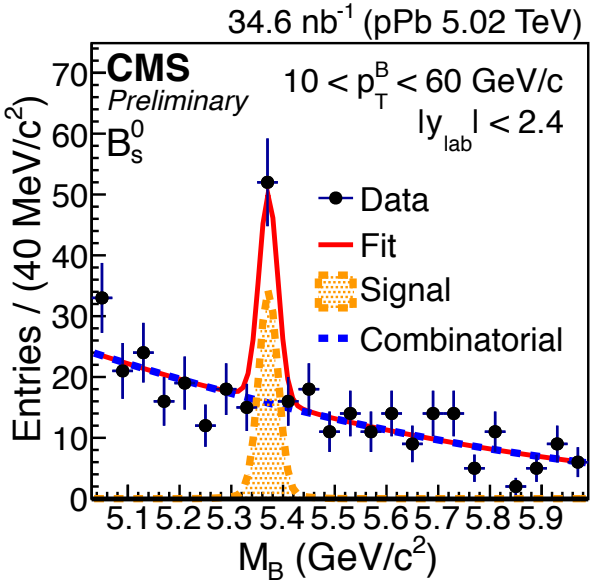
…K^+



…K^*_0 ($K^+ + \pi^-$)



…Φ ($K^+ + K^-$)

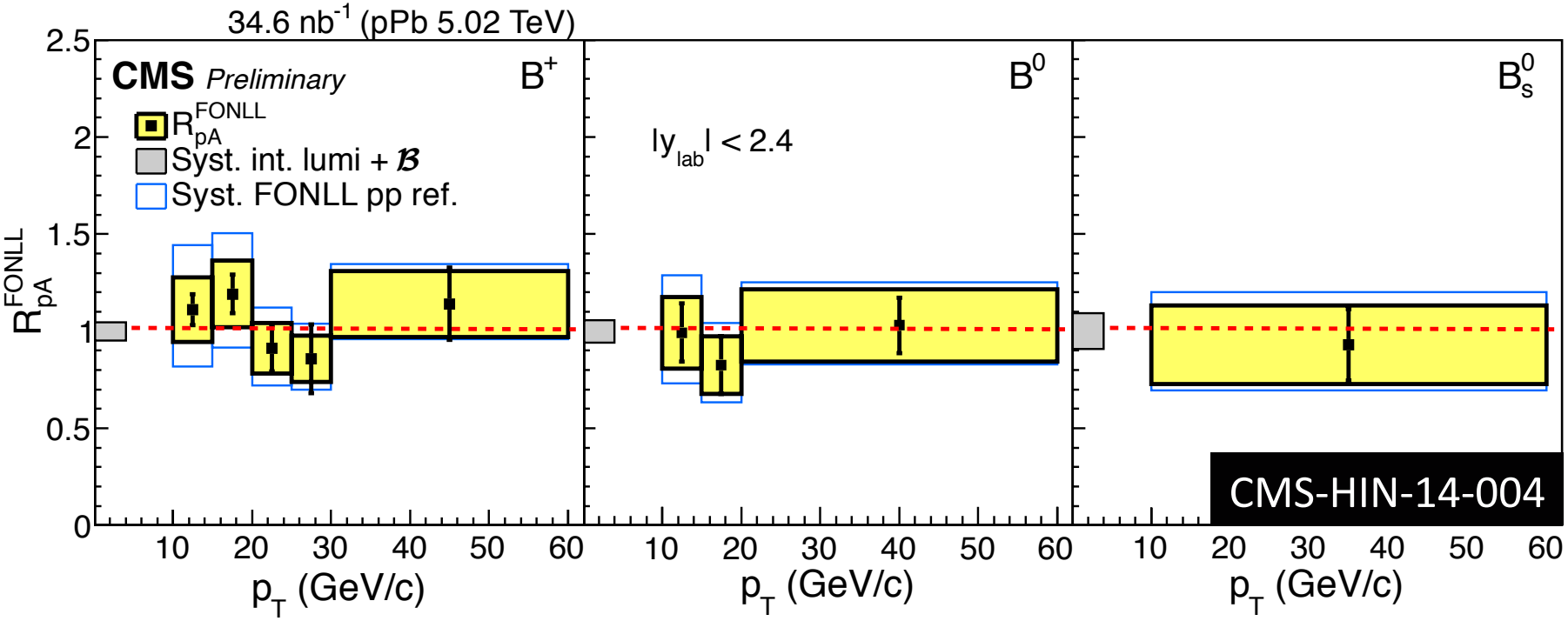


CMS-HIN-14-004

- Two kinds of background rejected to extract signal
  - (1) Combinatorial backgrounds
  - (2) Peaking structure by mis-identification of decay-channel

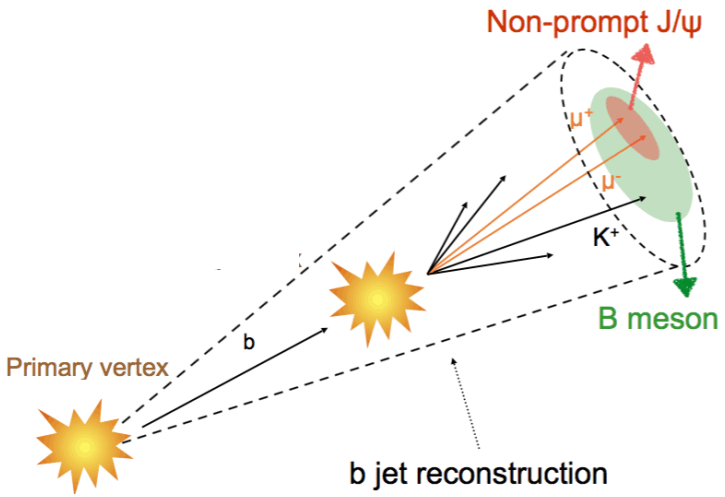
Fully reconstructed B-meson

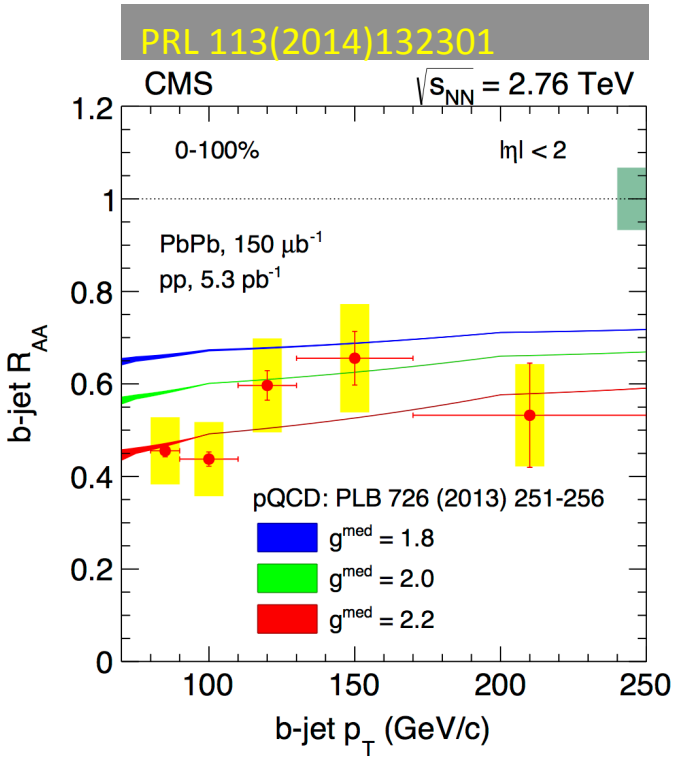
Non-prompt J/ψ combined with…



- Largest uncertainty source is the p+p reference from FONLL calculation
- R_{pPb} is consistent with unity within uncertainty
- No significant suppression of B quark observed in p+Pb

Different b-quark reconstruction

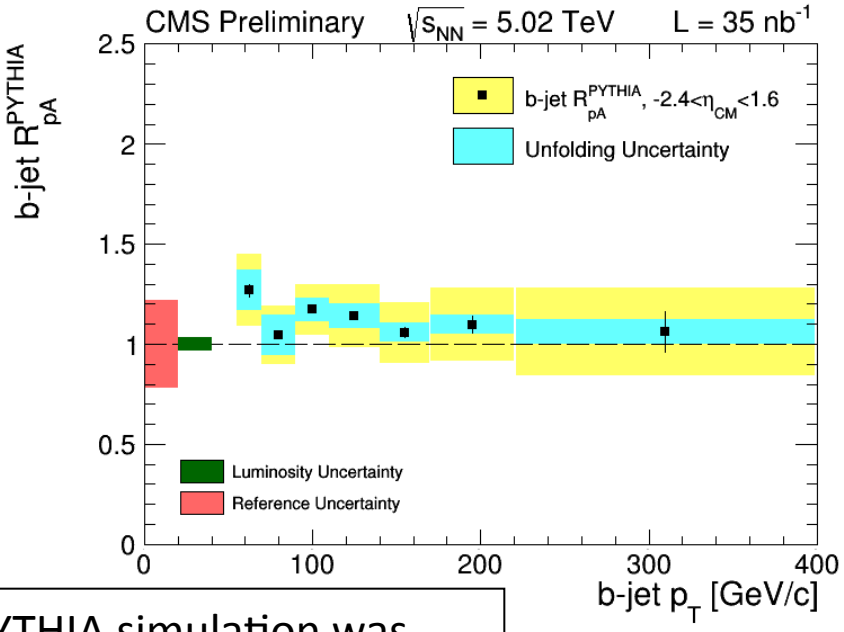


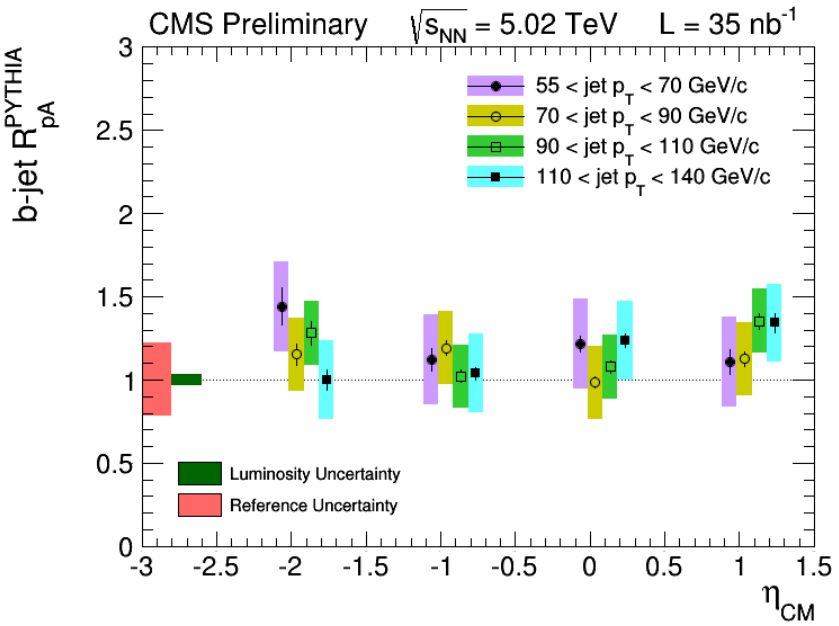


- B Jet can be reconstructed using secondary vertex of charged particles in jet cone
- Big advantage of high statistics by Branching Ratio factors
  - BR(B->J/ψ +X) x BR(J/ψ -> μμ) ~ O(1000)
- We already reported preliminary b-jet results of PbPb in SQM2013

B jets in p+Pb

CMS-HIN-14-007





PYTHIA simulation was used for p+p reference

- R_{pPb} is consistent with unity within uncertainty
- Consistent with exclusive B meson measurement
- Suppression observed in Pb+Pb is not coming from cold/initial nuclear effect

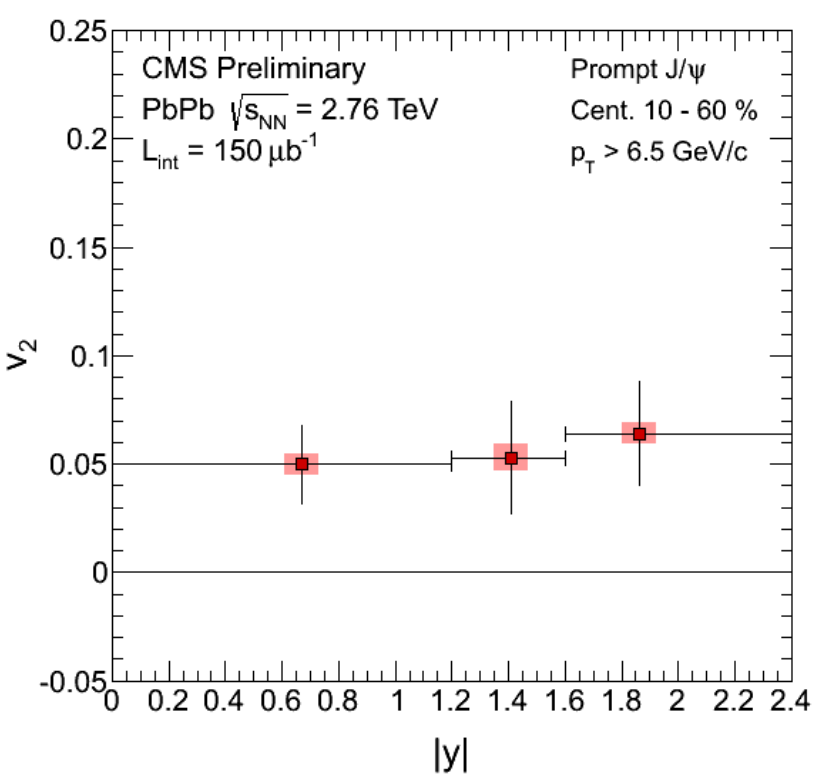
Summary

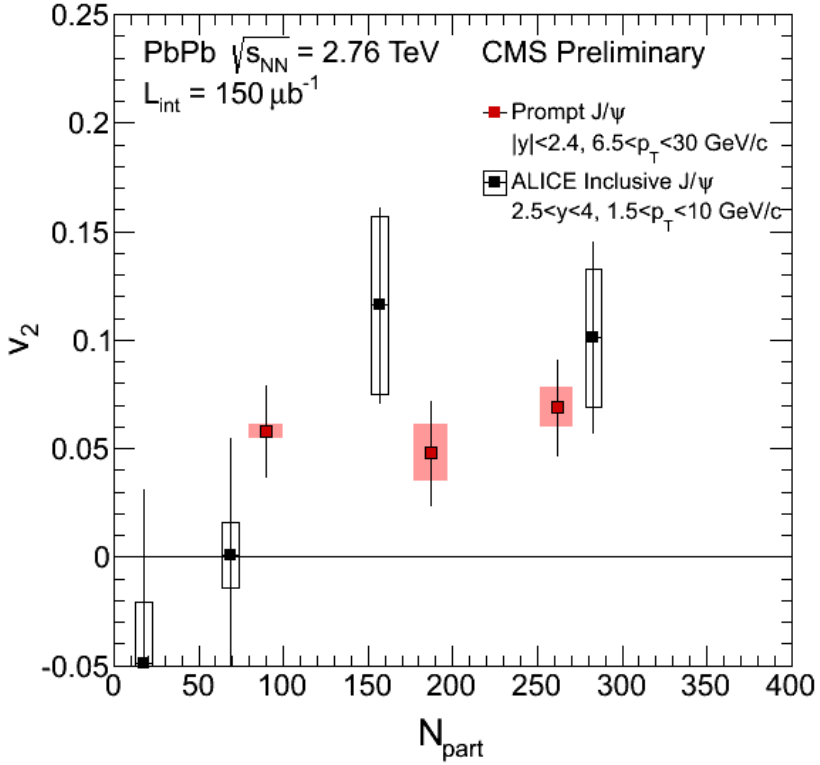
- CMS collaboration extensively measured J/ψ, ψ(2S), ϒ(nS), b meson and b jet in Pb+Pb and p+Pb
- The suppression pattern of excited states of charmonia and bottomonia observed in Pb+Pb can constrain theoretical models of quarkonia's interaction with medium
- R_{pA} results of B meson and b-jet confirms that the strong suppression in PbPb is final state effect
- R_{pA} of ϒ and R_{FB} of J/ψ show a clear signals of cold nuclear matter effect which is moderate than modification in Pb+Pb
- The cold nulcear matter effect of both bottomonia and charmonia has strong correlation with the event activity, indicating the collisional centrality dependence
- Thanks for your attention

BACK UP

Flow of prompt J/ψ

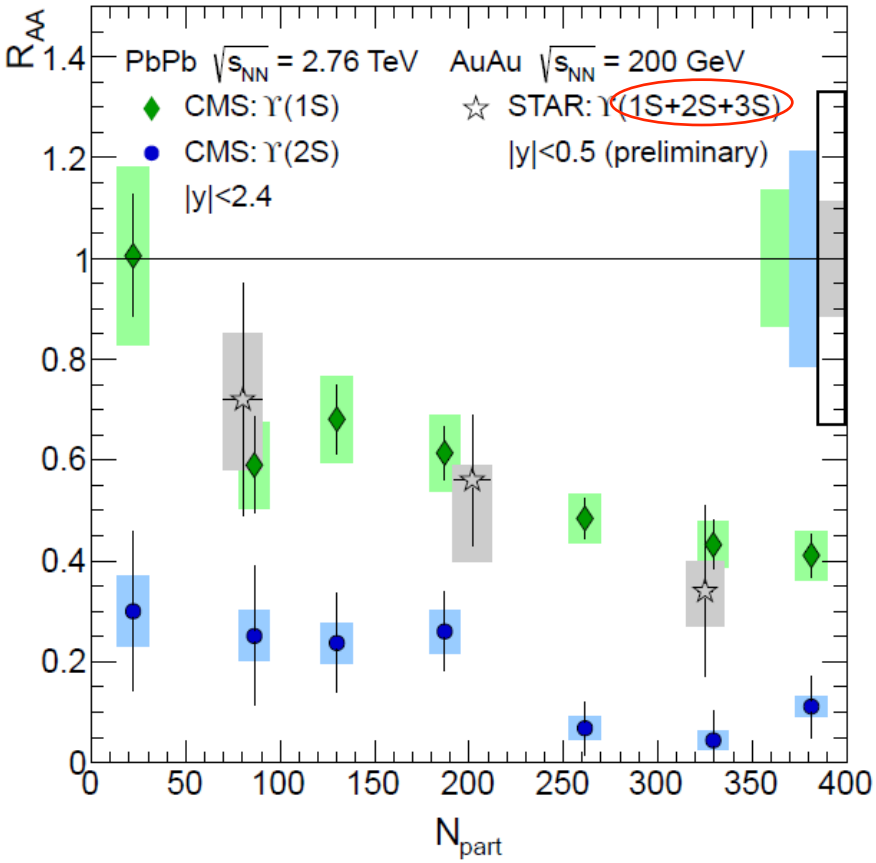
CMS PAS HIN-12-001 Released on Nov. 2013





- Observation of non-zero J/ψ v_2 (or azimuthal asymmetry) supports the medium induced suppression as well as path length dependence

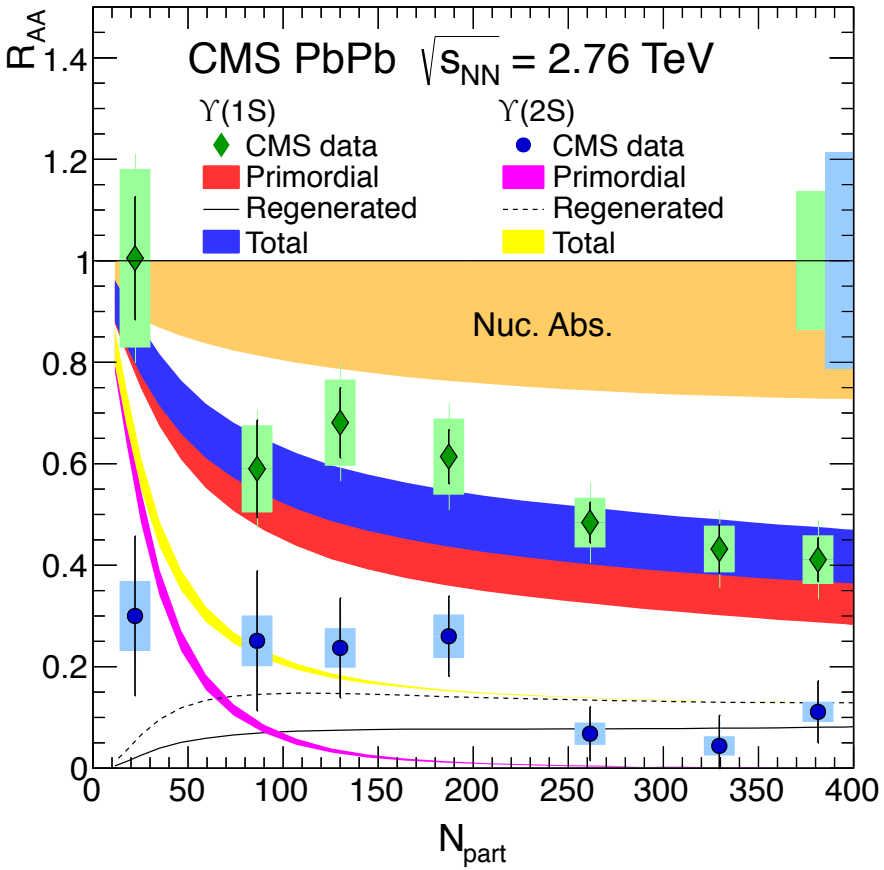
RAA Comparison with RHIC



For Au+Au collisions at 200GeV :

R_{AA} [ϒ(1S+2S+3S)] = $0.56_{\pm 0.21 \pm 0.16 \pm 0.08}$
(STAR arXiv:1109.3891)

RAA Comparison with theory



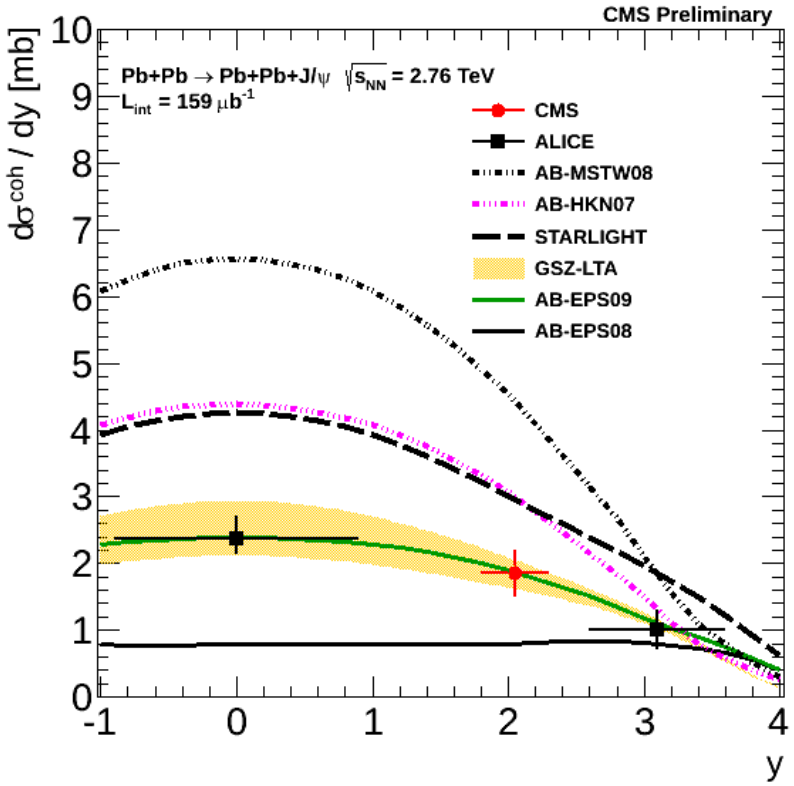
Model calculations:
A. Emerick, X. Zhao & R. Rapp, EPJA 48, 72 (2012)

The data is consistent with the strong Υ binding scenario assuming
- Small regeneration for Υ(1S).
Suppression is mostly primordial
Mostly consistent with data
- Regeneration is dominant in central collisions for Υ(2S)

- Large uncertainty in nuclear absorption! ← can be constrained by pPb data

- Note that T = 610MeV is tuned in this model

nPDF probed via PbPb



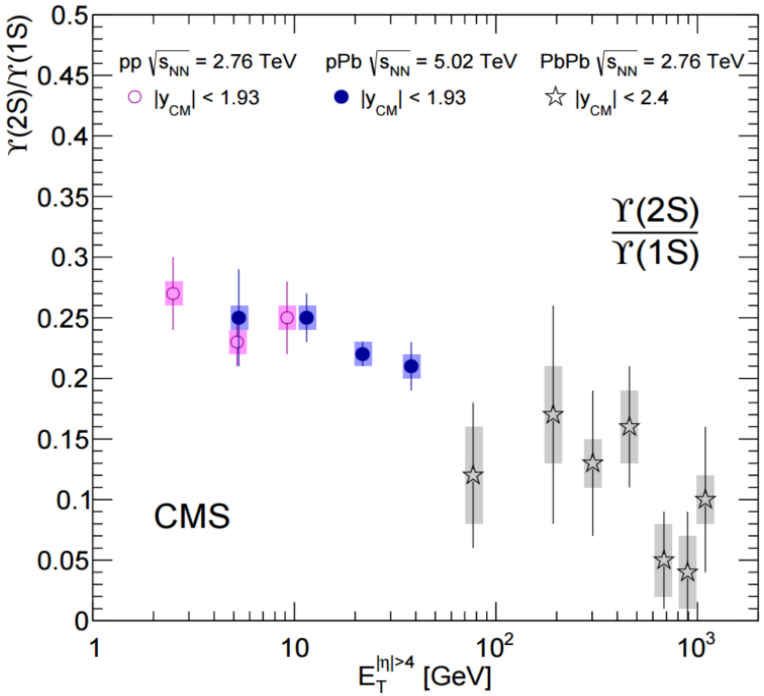
The result, accompanied with ALICE data, favors the models containing moderate gluon shadowing.

➔ Powerful constraint initial state modification models covering wide rapidity range

ALICE result in EPJC 73 (2013) 2617

Event activity dependence of ϒ yield

Vs. forward calorimeter transverse energy

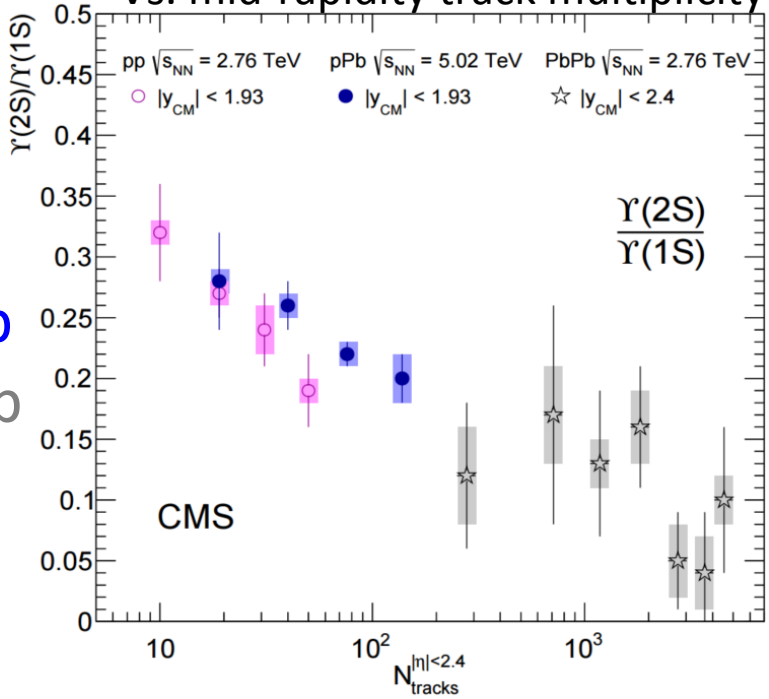


p+p

p+Pb

Pb+Pb

Vs. mid-rapidity track multiplicity



CNM effect observed in 1991