Charmonium production in p-Pb and Pb-Pb collisions with CMS

Mihee Jo on behalf of the CMS Collaboration
Laboratoire Leprince-Ringuet,
École polytechnique (France)

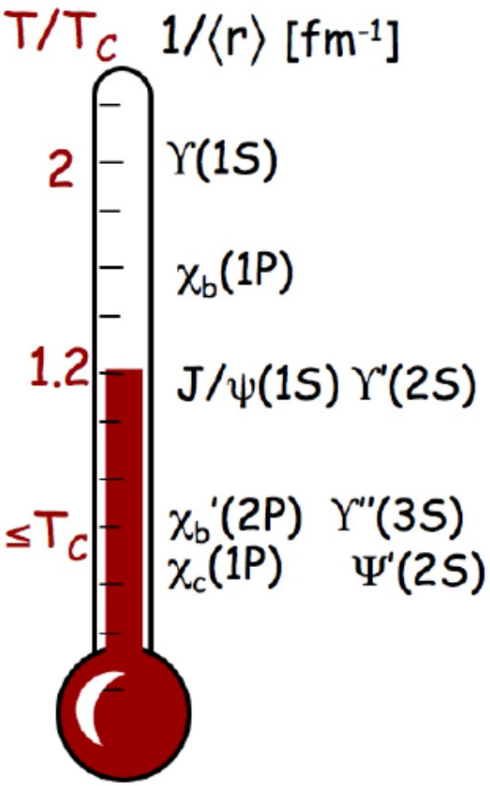
QWG 2016
7 June 2016

Quarkonia as a thermometer

- Different binding energies of quarkonium states
  → Sequential melting of the states with increasing medium temperature

- Charmonia in the medium
  - Need to separate prompt from non-prompt
  - Regeneration and Cold-Nuclear-Matter effect need to be considered

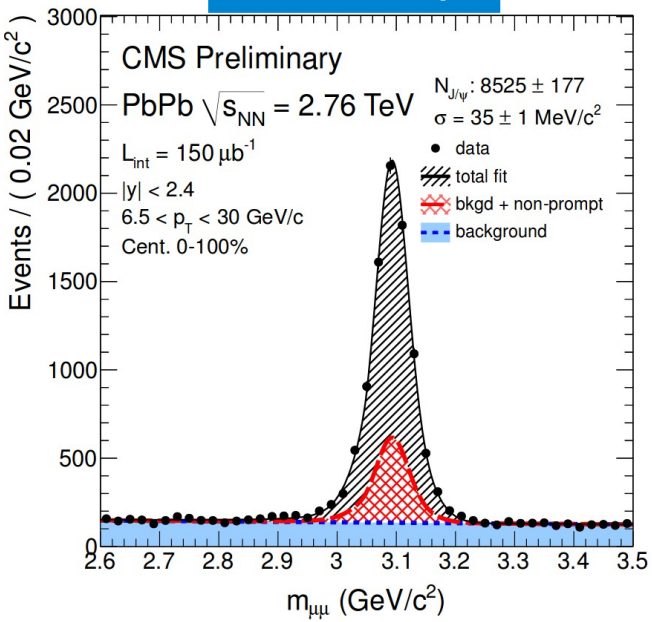
PbPb 2.76 TeV, 160μb^{-1}	Prompt J/ψ R_{AA}: CMS-HIN-12-014 Prompt J/ψ v_2: CMS-HIN-12-001 Prompt ψ(2S): PRL 113 (2014)262341 J/ψ in UPC: arXiv:1605.06966 (submitted to PLB)
pPb 5.02 TeV, 35nb^{-1}	J/ψ production: CMS-HIN-14-009



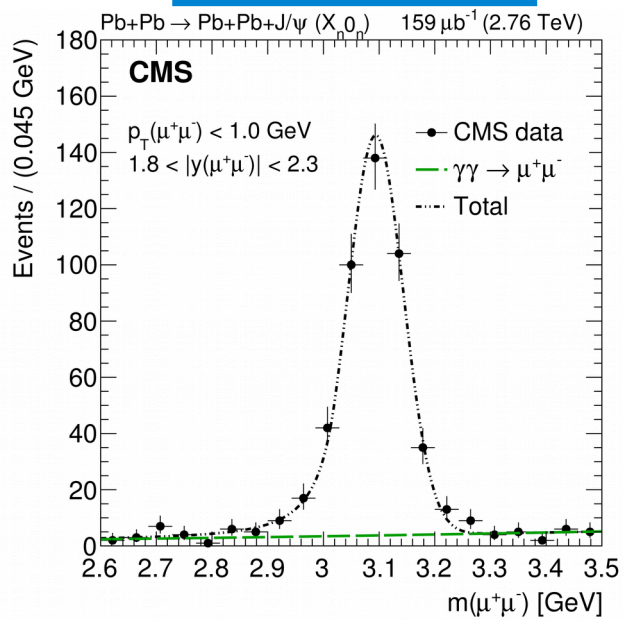
EPJC 61 (2009) 705

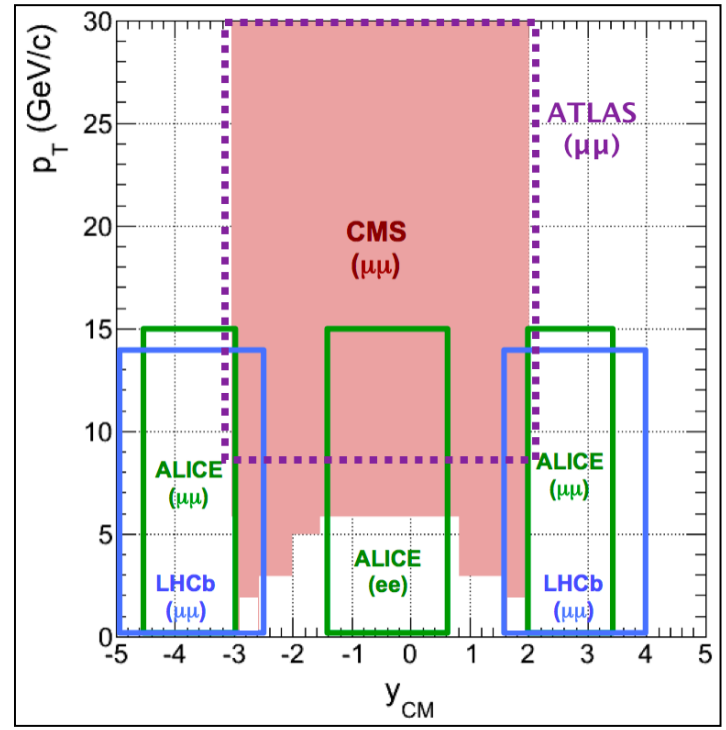
Prompt charmonia reconstructed via $\mu^+\mu^-$

PbPb, J/ψ

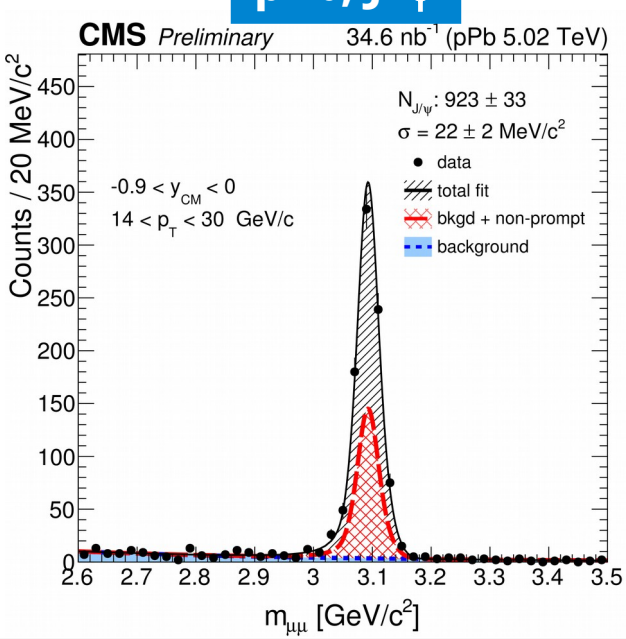


PbPb UPC, J/ψ

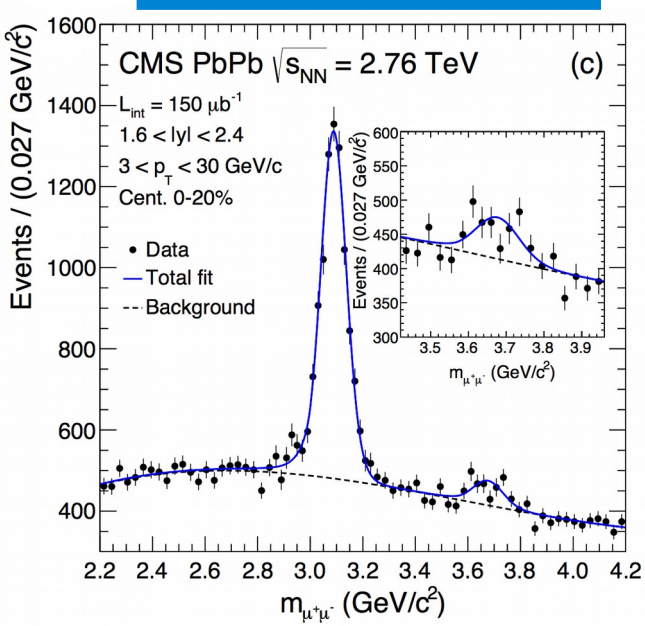




pPb, J/ψ



PbPb, J/ψ & ψ(2S)



- Coverages of J/ψ in pPb by LHC experiments

Nuclear modification factor, R_{AA}

- Nuclear modification factor, R_{AA}
  - The ratio of AA results to the reference pp results, normalized by number of binary collisions in AA collisions

$$R_{AA} = \frac{1}{\langle N_{coll} \rangle} \frac{\sigma_{AA}}{\sigma_{pp}} = \frac{L_{pp}}{T_{AA} N_{MB}} \frac{N_{PbPb}}{N_{pp}} \frac{\varepsilon_{pp}}{\varepsilon_{PbPb}}$$

  - $R_{AA} = 1$ → No modifications in AA collisions compare to pp collisions
  - $R_{AA} < 1$ → Suppression in AA collisions
  - $R_{AA} > 1$ → Enhancement in AA collisions

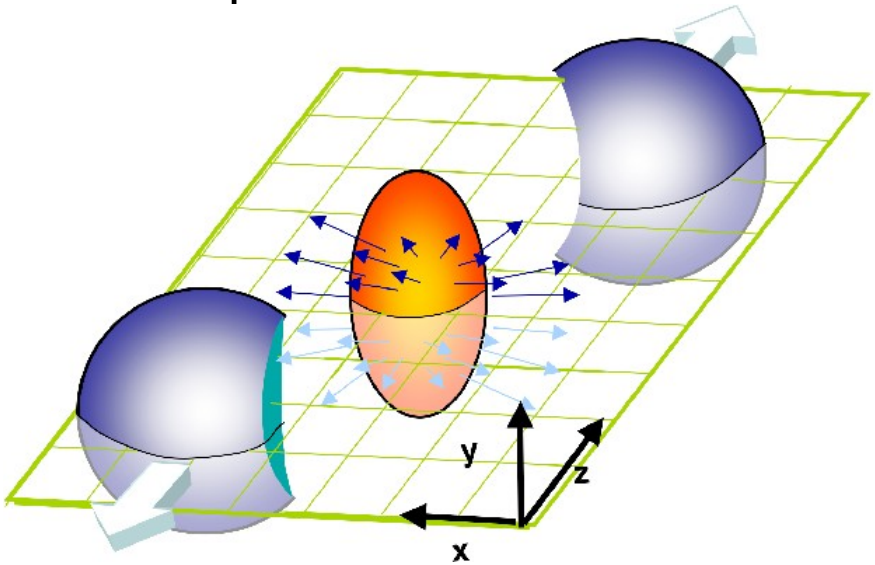
Elliptic flow, v_2

- Elliptic flow, v_2
  - The azimuthal anisotropy with respect to the event plane

$$E\frac{d^3N}{d^3p} = \frac{1}{2\pi}\frac{d^2N}{p_T dp_T dy} \times \left(1 + \sum_{n=1}^{\infty} 2v_n(p_T, y)\cos\left[n\left(\varphi - \Psi_{\mathrm{R}}\right)\right]\right)$$

  - The 2nd Fourier coefficient in the expansion is the elliptic flow

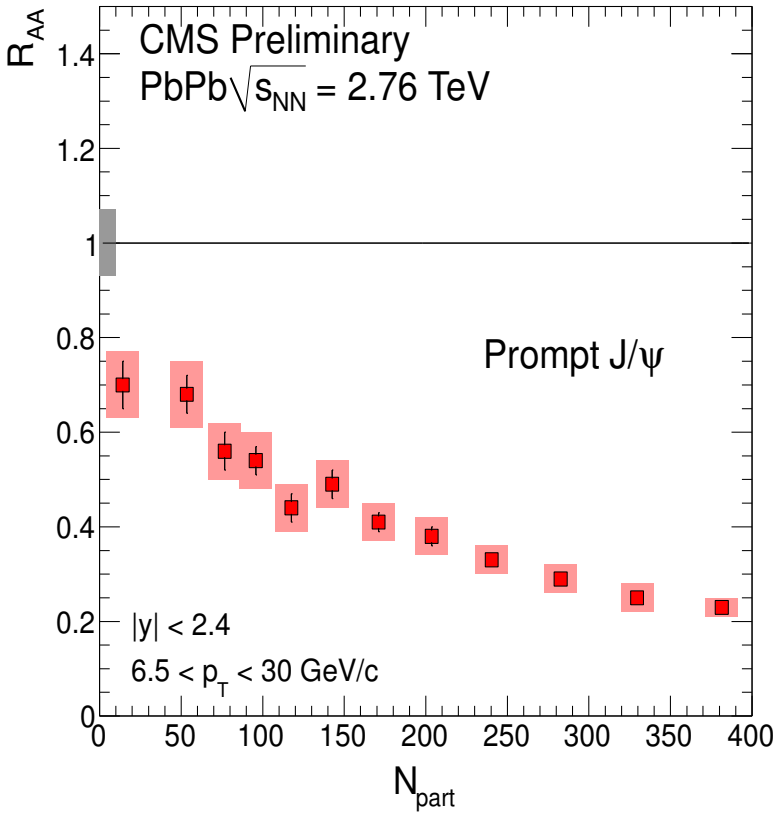
$$1 + 2v_2\cos(2\Delta\phi)$$

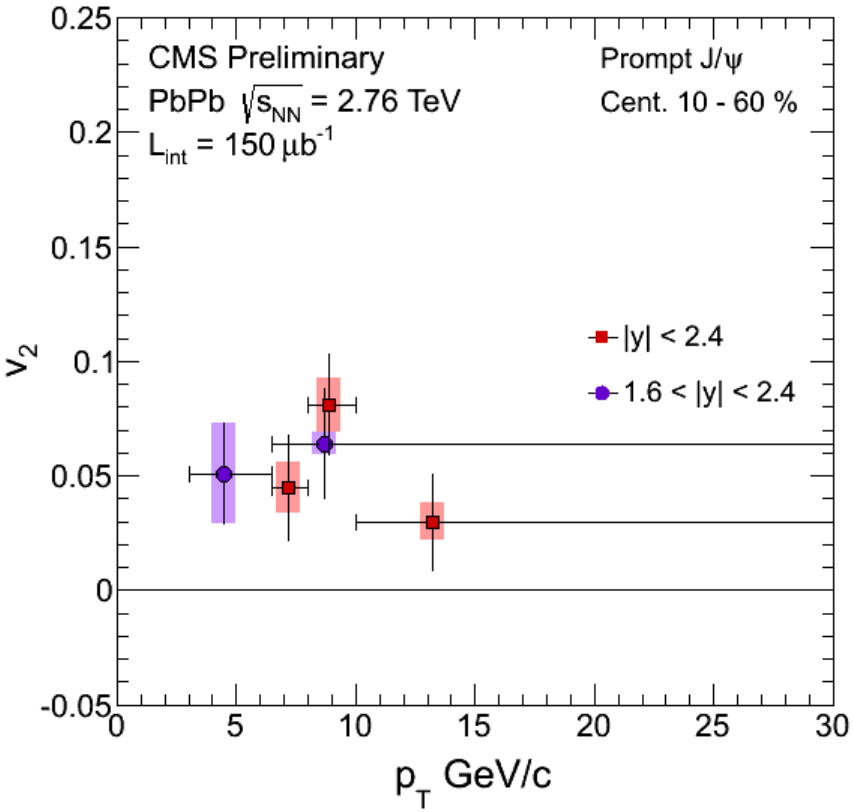


  - Non-zero v_2 at low p_T
    - Stronger pressure gradients across the short axis

      → Asymmetry in the collective flow
  - Non-zero v_2 at high p_T
    - Path-length dependent absorption of particle traversing the reaction zone

Charmonia in PbPb : Ground state (1S)

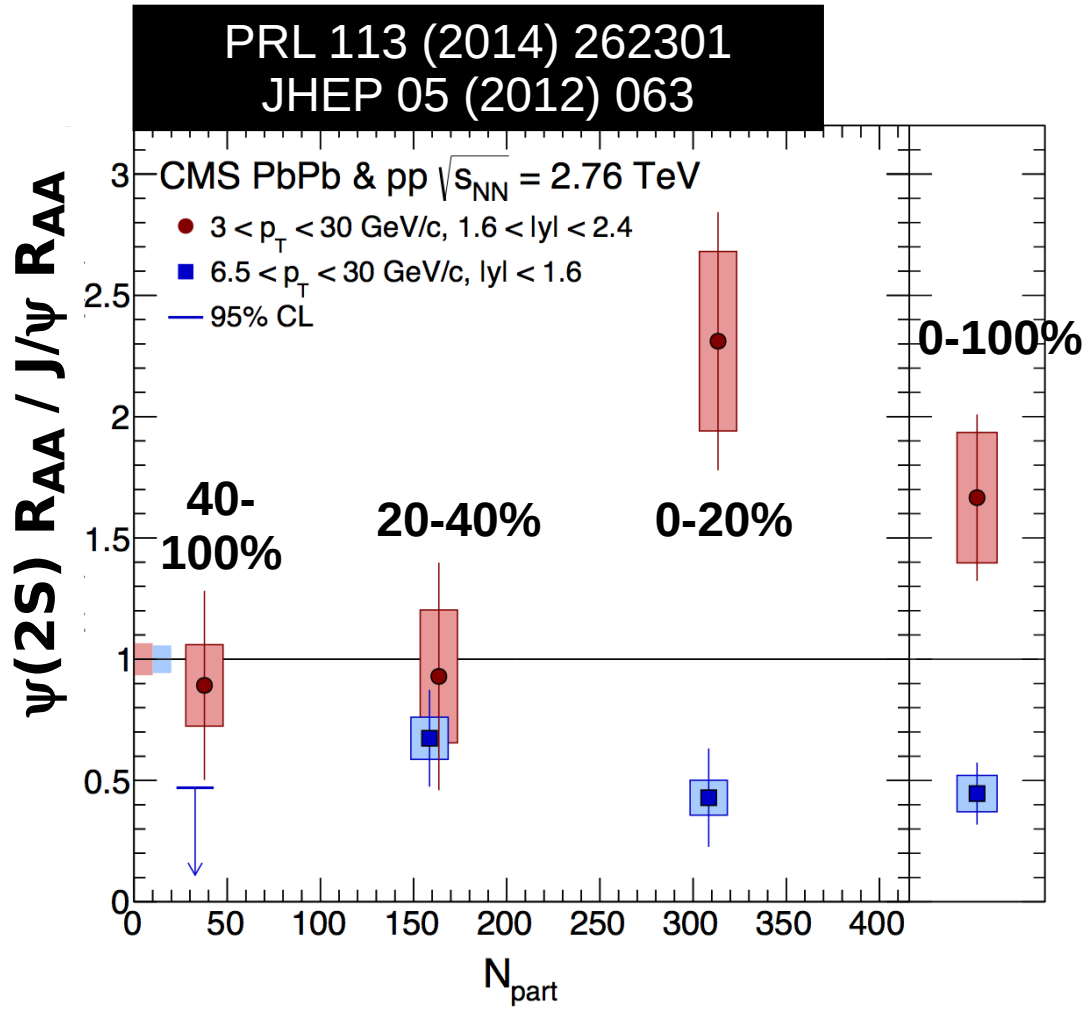




- Strong evidence of medium induced modification of quarkonia
- Path length dependent suppression up to high p_T

CMS-PAS-HIN-12-001
CMS-PAS-HIN-12-014

PbPb : ψ(2S) suppressed like J/ψ?

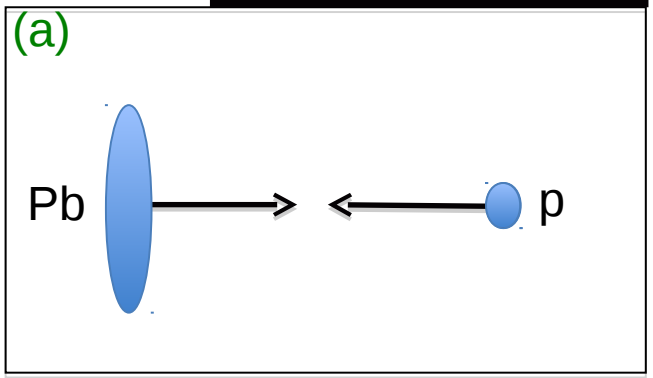


- In naïve sequential suppression picture, excited state must be more suppressed than the ground state, as observed in Υ(nS)
- However, ψ(2S) is less suppressed than J/ψ in forward, low p_T
  - Low p_T ψ(2S) can have non-negligible recombination with respect to debye screening

Probing CNM effects

- Cold Nuclear Matter effects
  - Modification of PDF
  - Nuclear absorption
  - Energy loss inside nucleus
  - And more

CMS-HIN-14-009



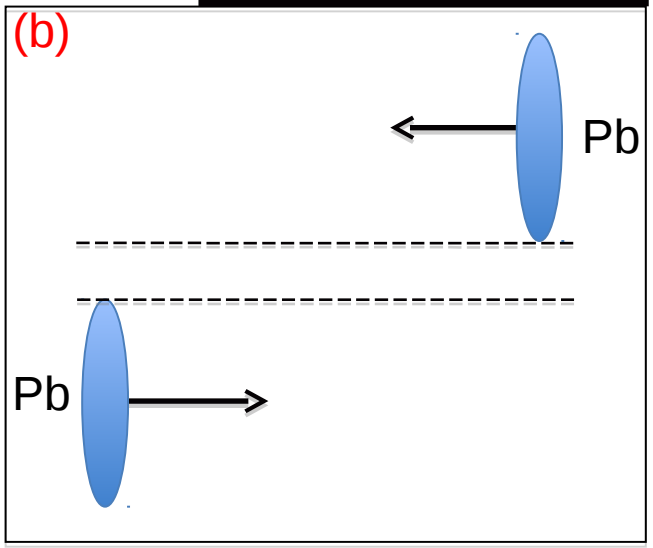
- Charmonia can probe CNM effects via J/ψ production in…

  (a) pPb collisons

  (b) Ultra Peripheral Collisions

  : Impact parameter larger than sum of radii of nuclei.

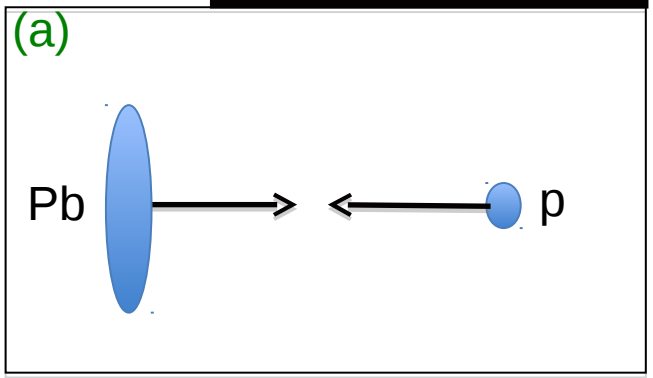
arXiv:1605.06966



Probing CNM effects

- Cold Nuclear Matter effects
  - Modification of PDF
  - Nuclear absorption
  - Energy loss inside nucleus
  - And more

CMS-HIN-14-009



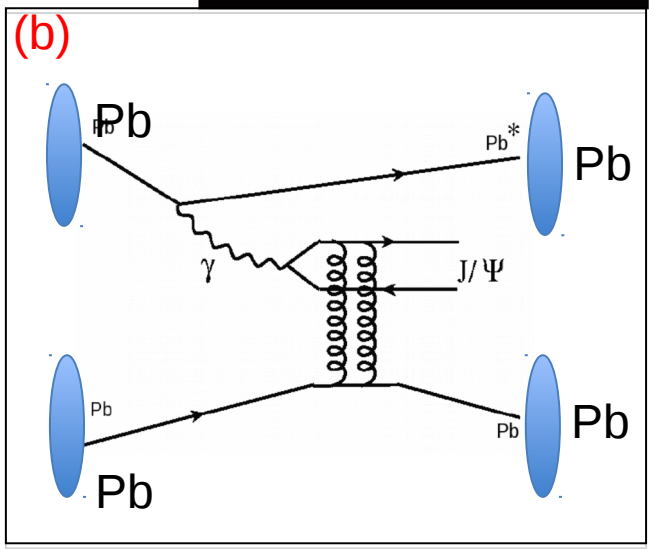
- Charmonia can probe CNM effects via J/ψ production in…

  (a) pPb collisons

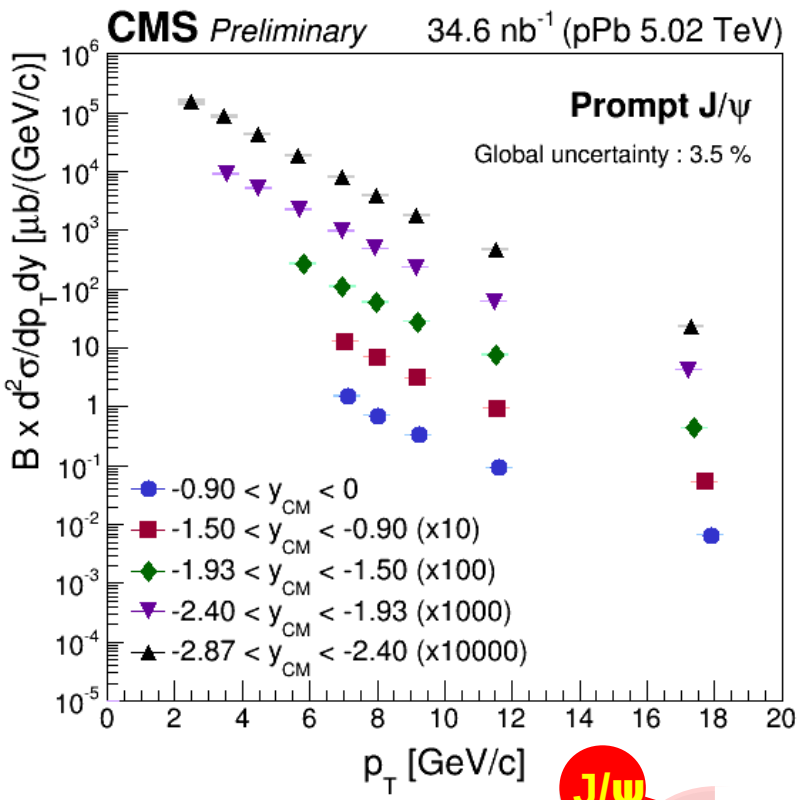
  (b) Ultra Peripheral Collisions
  - EM disassociation of nucleus
  - Cross section scaled by (gluon density)^2

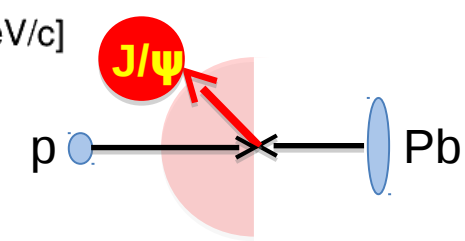
  ➔ **nPDF information**

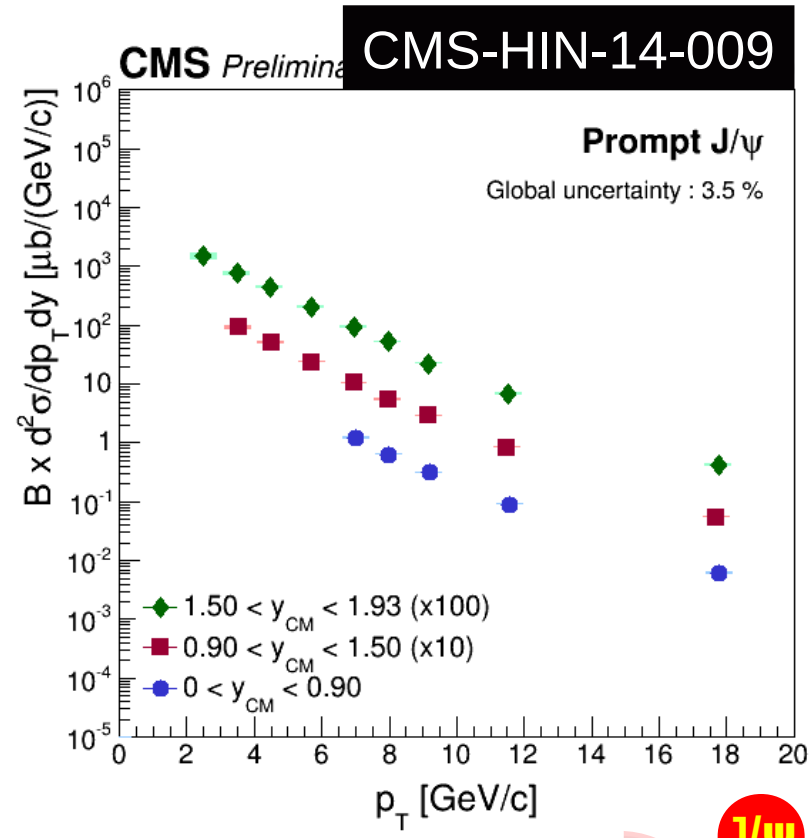
arXiv:1605.06966

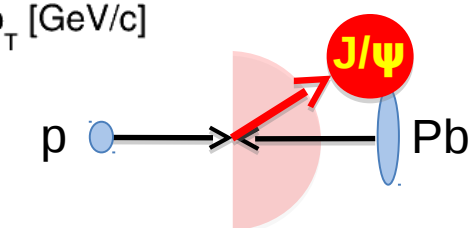


J/ψ in pPb



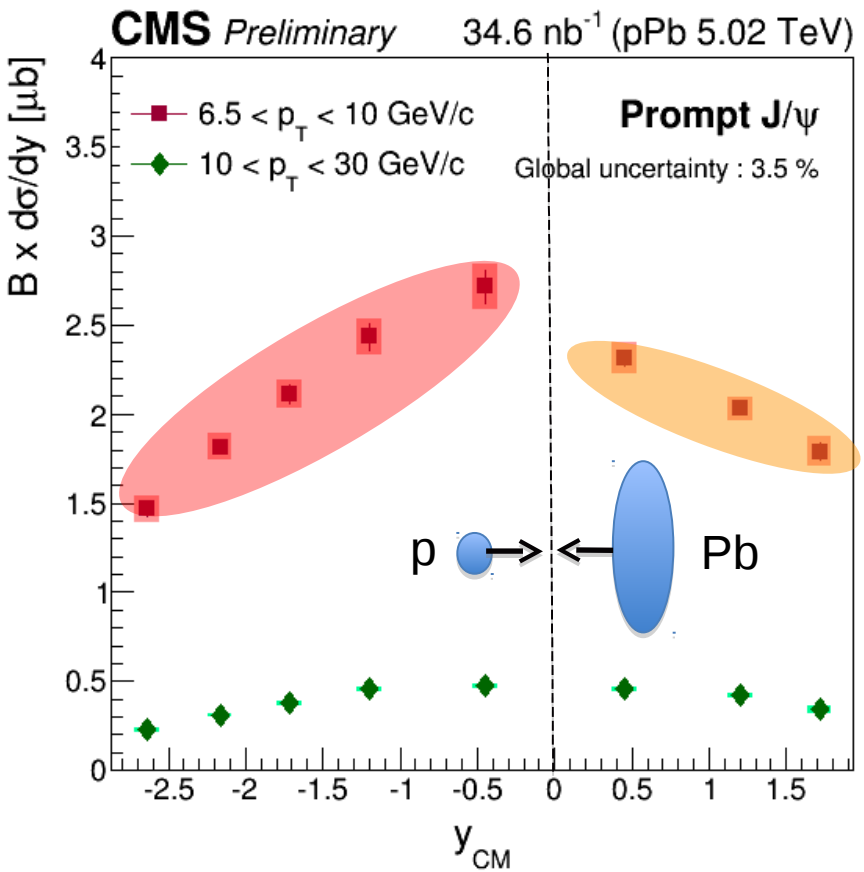






- Double differential cross-section for a wide kinematic range
  - p_T [2, 30] GeV/c, y_{CM} [-2.87, 1.93]

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



- Cross section as a function of rapidity at
  - Low p_T [6.5, 10] GeV/c
  - High p_T [10, 30] GeV/c

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

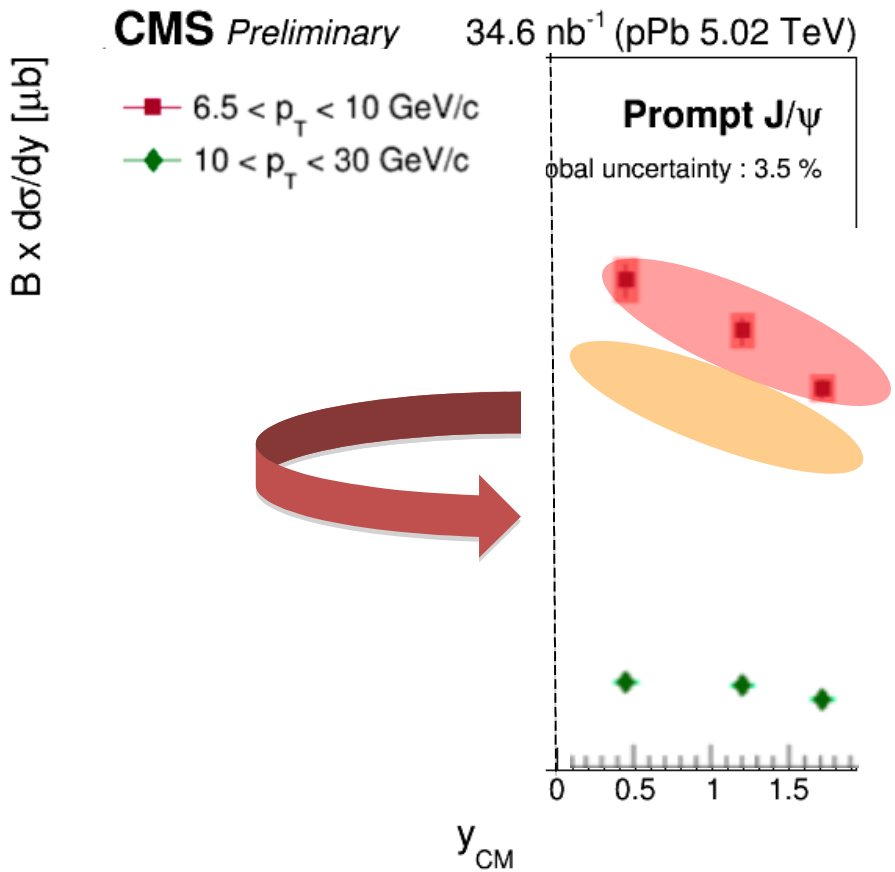
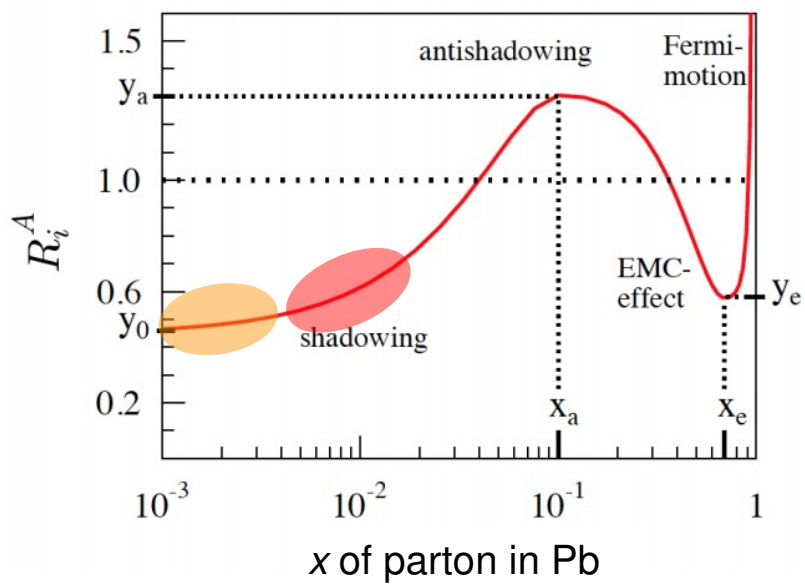
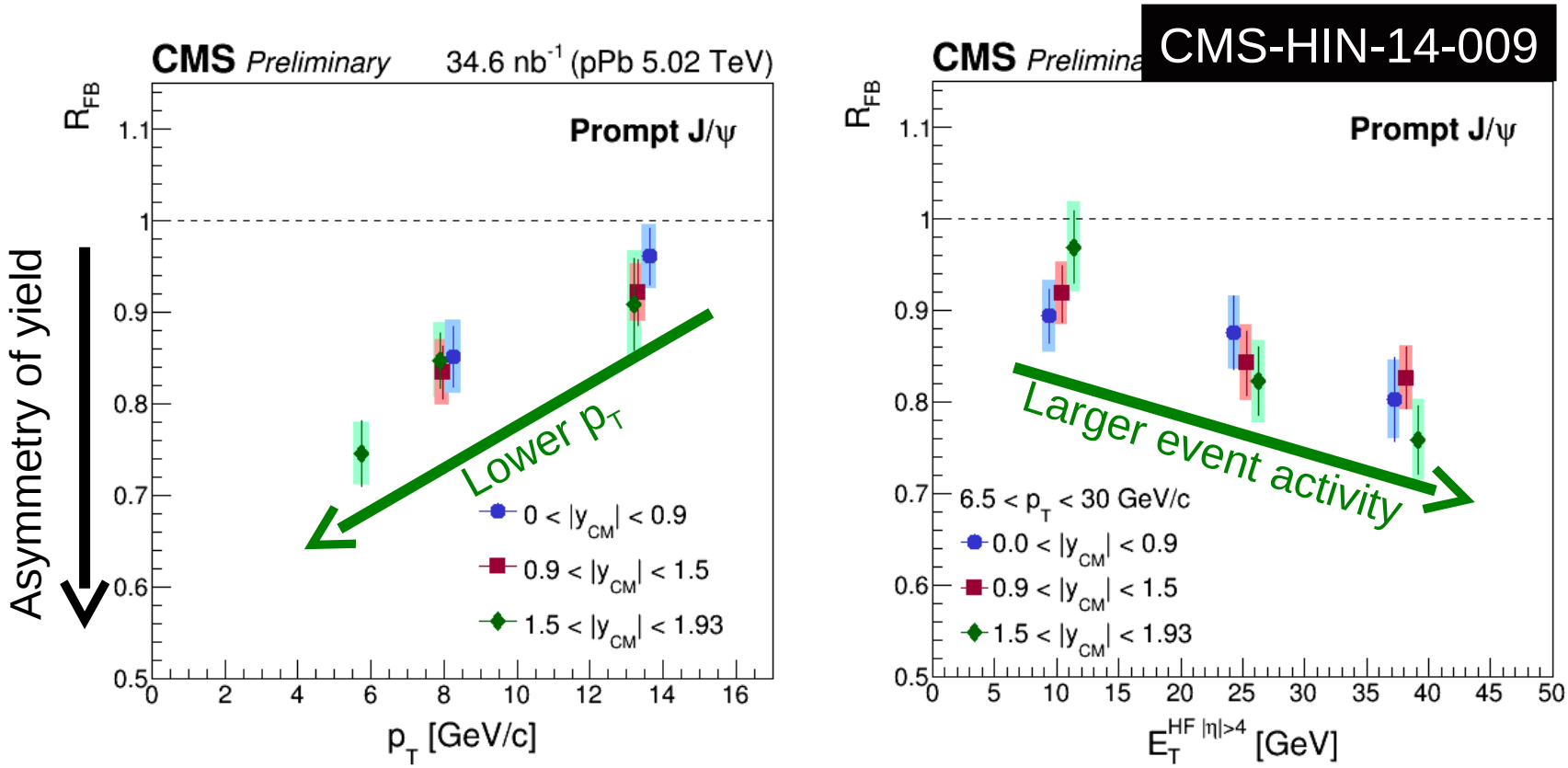


Illustration of nPDF fit
JHEP 0904 (2009) 065



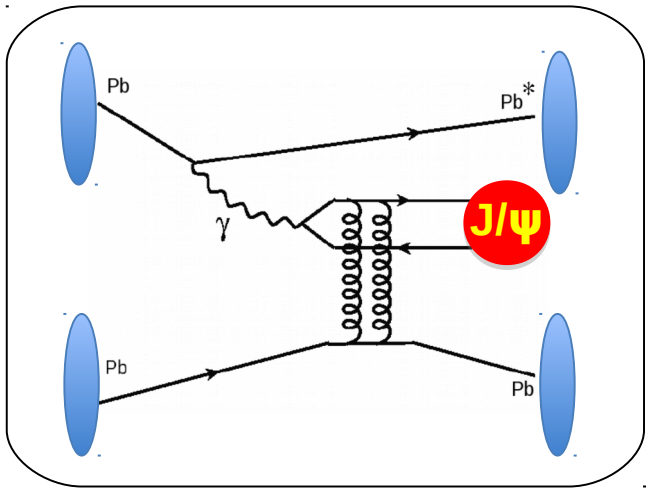
- Fold plot around y_{CM}=0 → A clear asymmetry at low p_T
- Consistent picture with nuclear shadowing
- $R_{FB}(|y|)$ = [yield in +y]/[yield in -y] for systematic approach

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



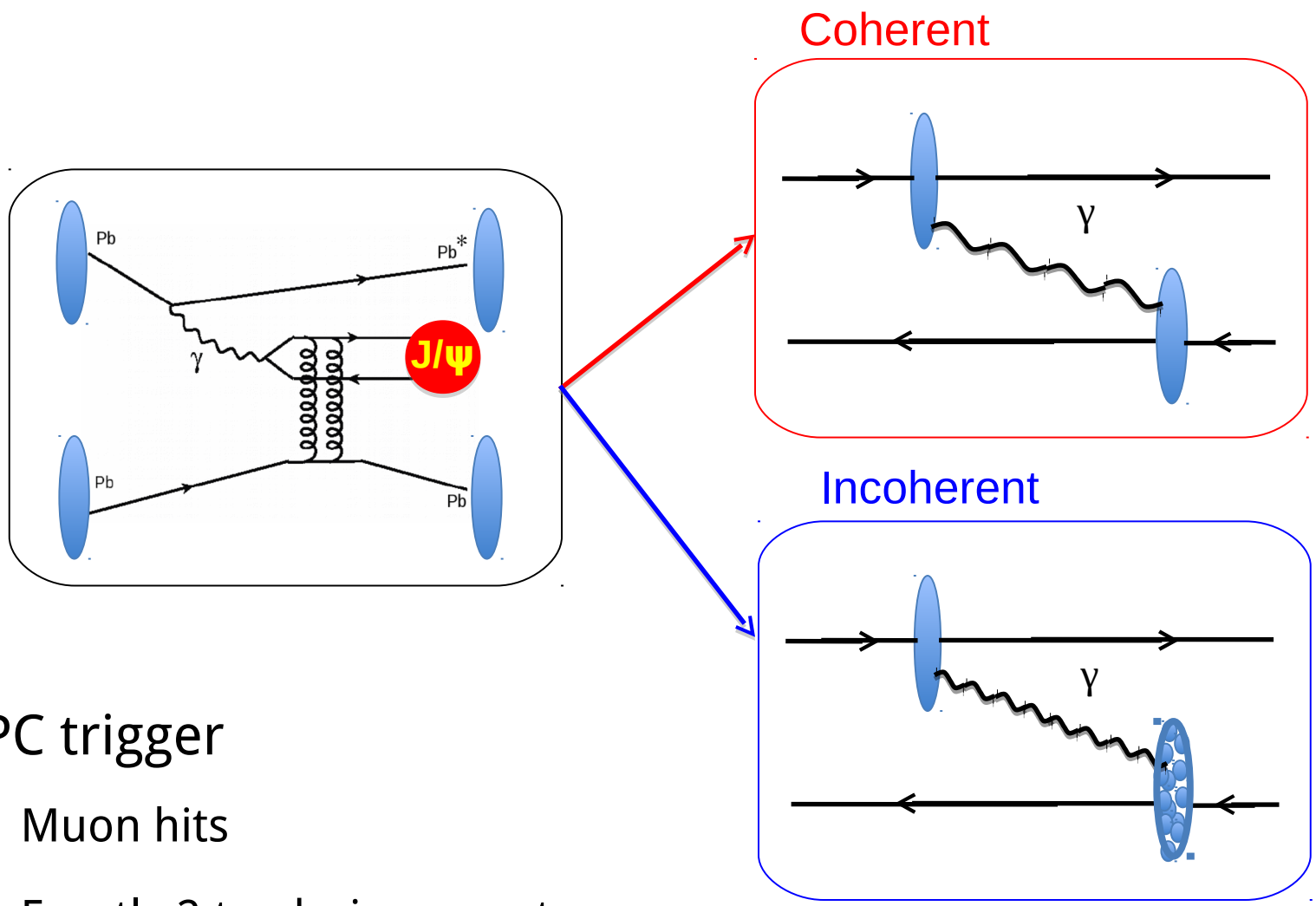
- Significant forward-to-backward asymmetry found
- Stronger at low p_T at high rapidity
- The effect is enhanced for larger activity events
  - Event activity measured by forward calorimeter $4<|\eta|<5.2$

J/ψ in UPC



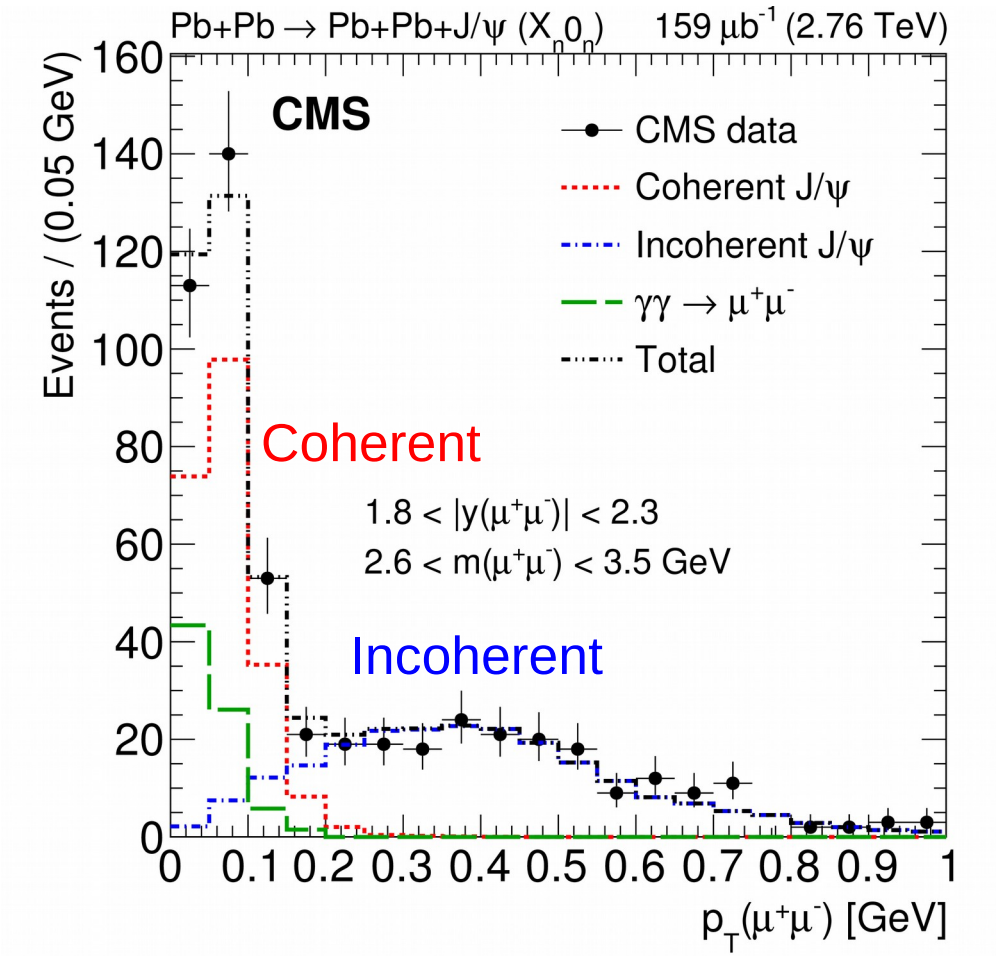
- UPC trigger
  - Muon hits
  - Exactly 2 tracks in a event
  - No activity in Ecal, Hcal
  - Neutron detection in Zero Degree Calorimeter

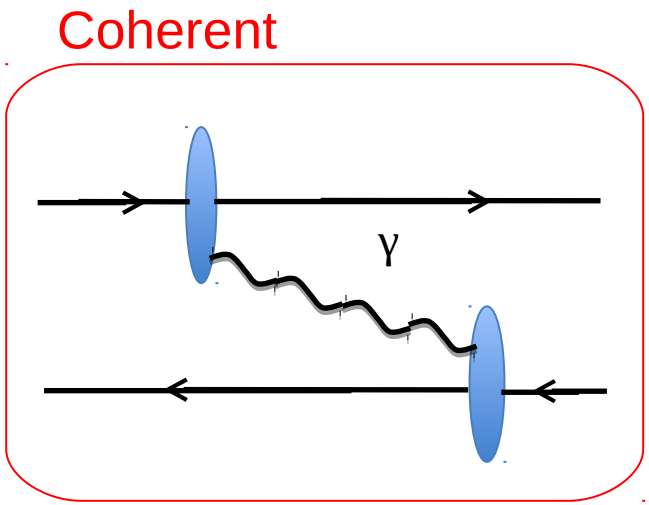
J/ψ in UPC

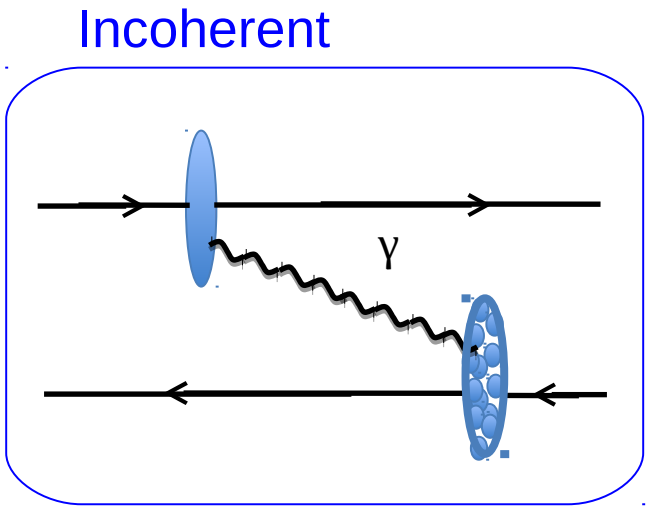


- UPC trigger
  - Muon hits
  - Exactly 2 tracks in a event
  - No activity in Ecal, Hcal
  - Neutron detection in Zero Degree Calorimeter

J/ψ in UPC



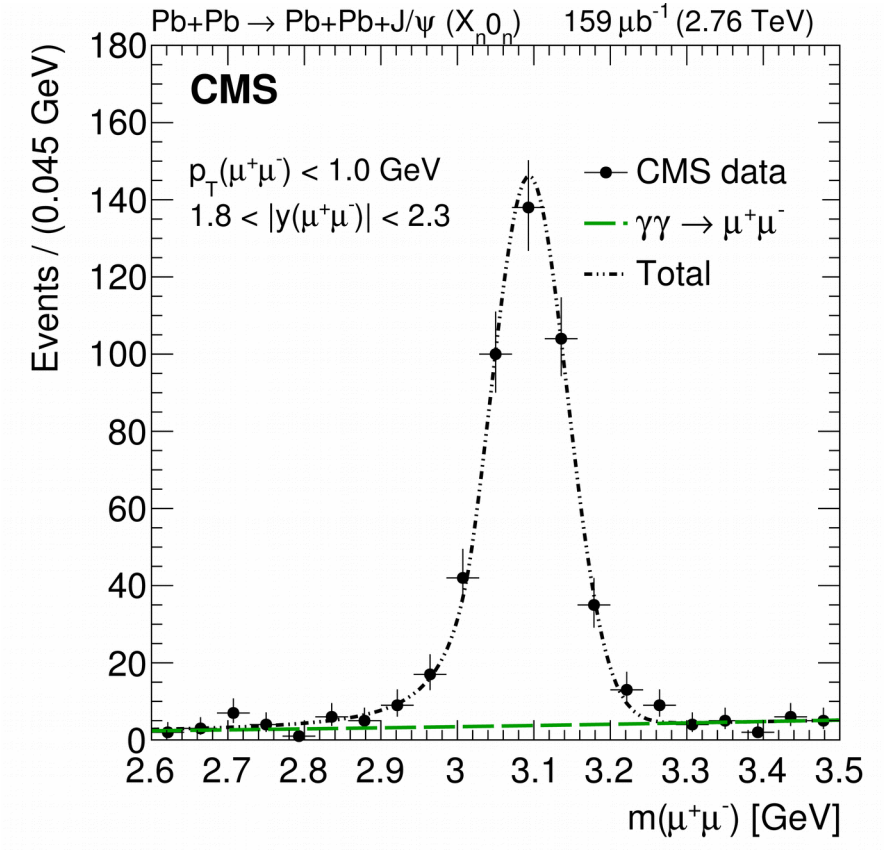


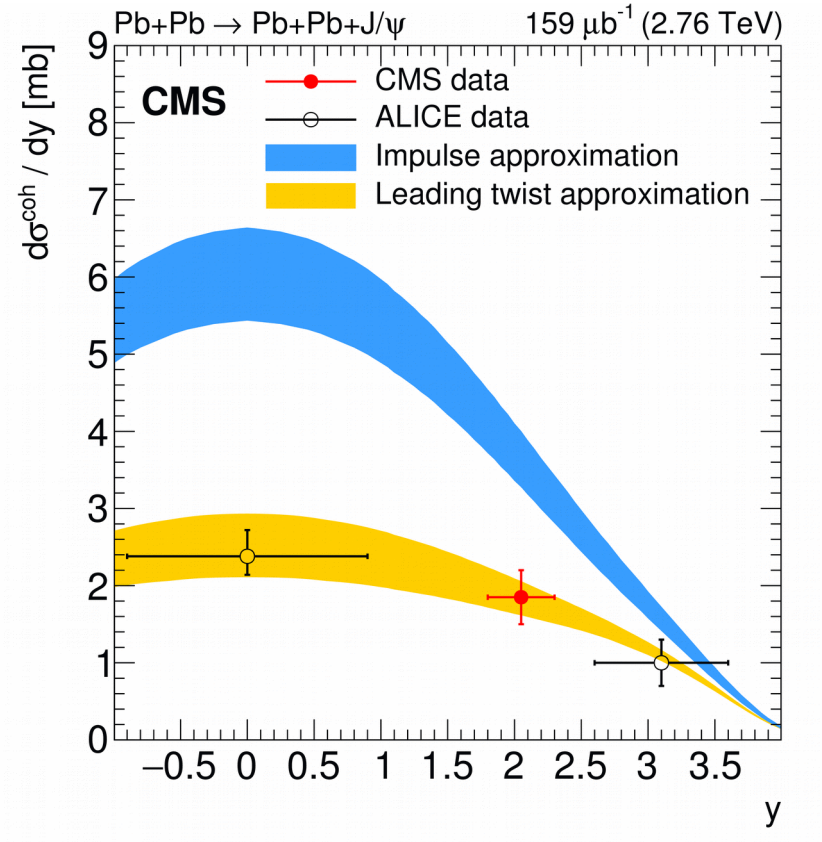


- Coherent J/ψ
  - Dominant for p_T < 150MeV/c
  - Measured p_T up to 1GeV/c and fit using MC template (STARLIGHT)

arXiv:1605.06966

Cross section compared to nPDF models





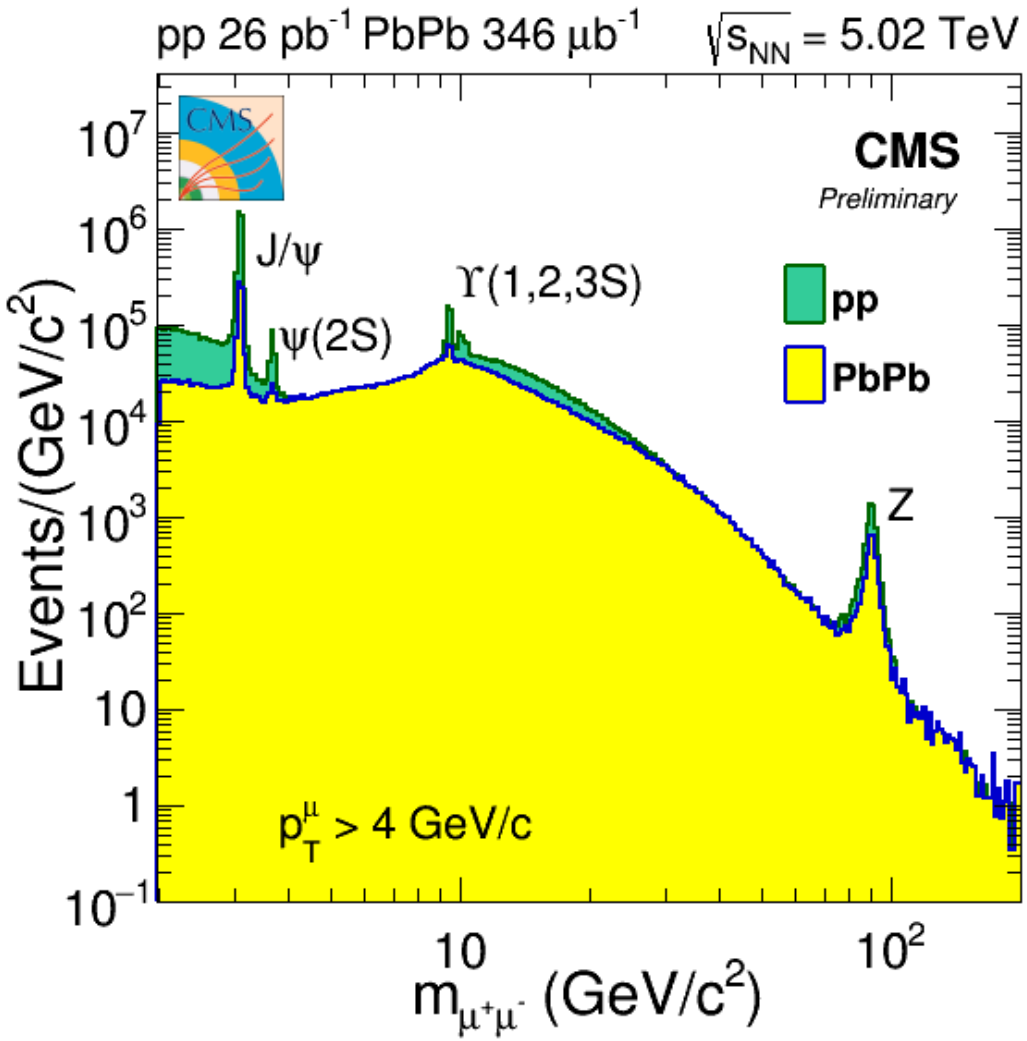
- Accompanied by ALICE data, the CMS results favors moderate nuclear shadowing models (AB-EPS09, GSZ-LTA) at low Q^2

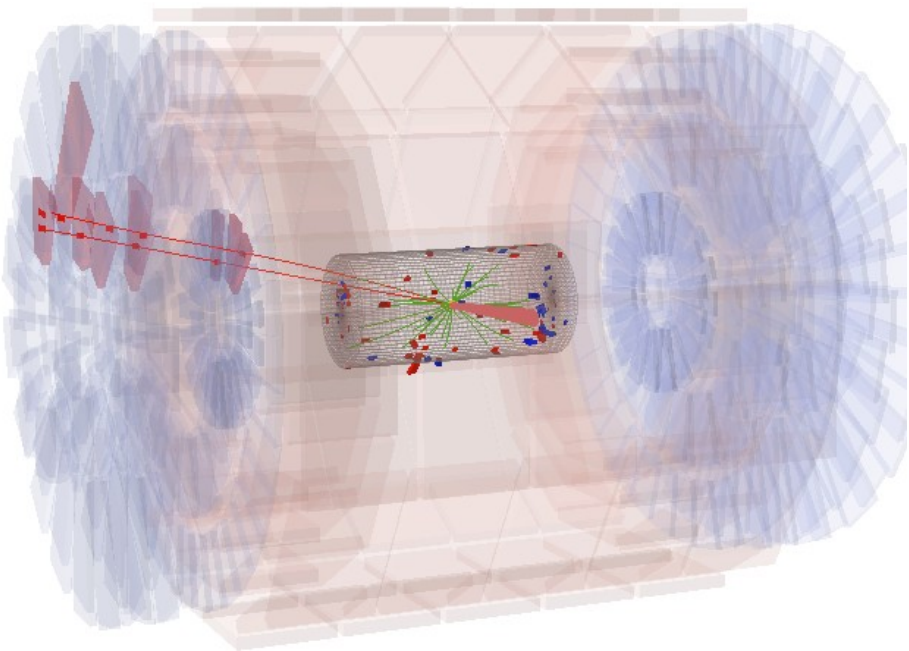
Summary

- During the Run I period of LHC, CMS collaboration produced a variety of charmonium results in pp, pPb and PbPb
- Observed suppression of J/ψ and ψ(2S) in PbPb
  - Suppression pattern depends on p_T, rapidity
- Cold Nuclear matter effect probed in pPb
  - Significant forward-to-backward asymmetry at low p_T
  - Phenomena enhanced for bigger event activity
- Measurement of coherent J/ψ in PbPb UPC
  - Provides a constraint to nPDF models

- Please stay tuned and excited for quarkonia results from CMS Run II!

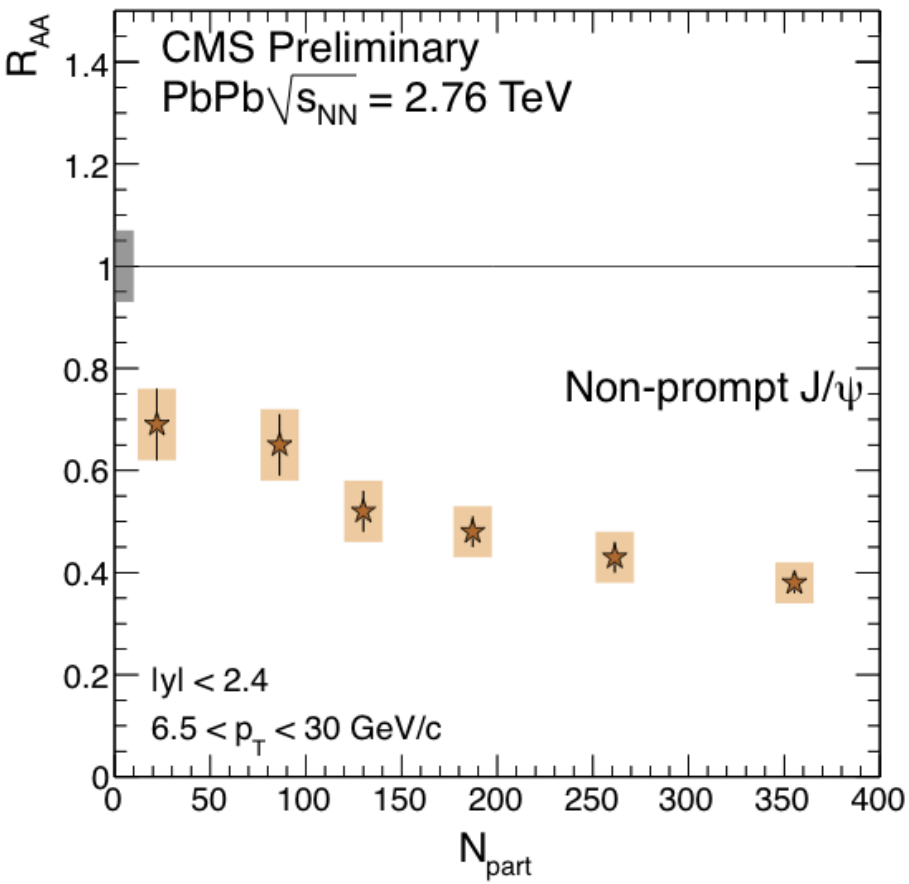
2015 PbPb 5.02 TeV runs and dimuons

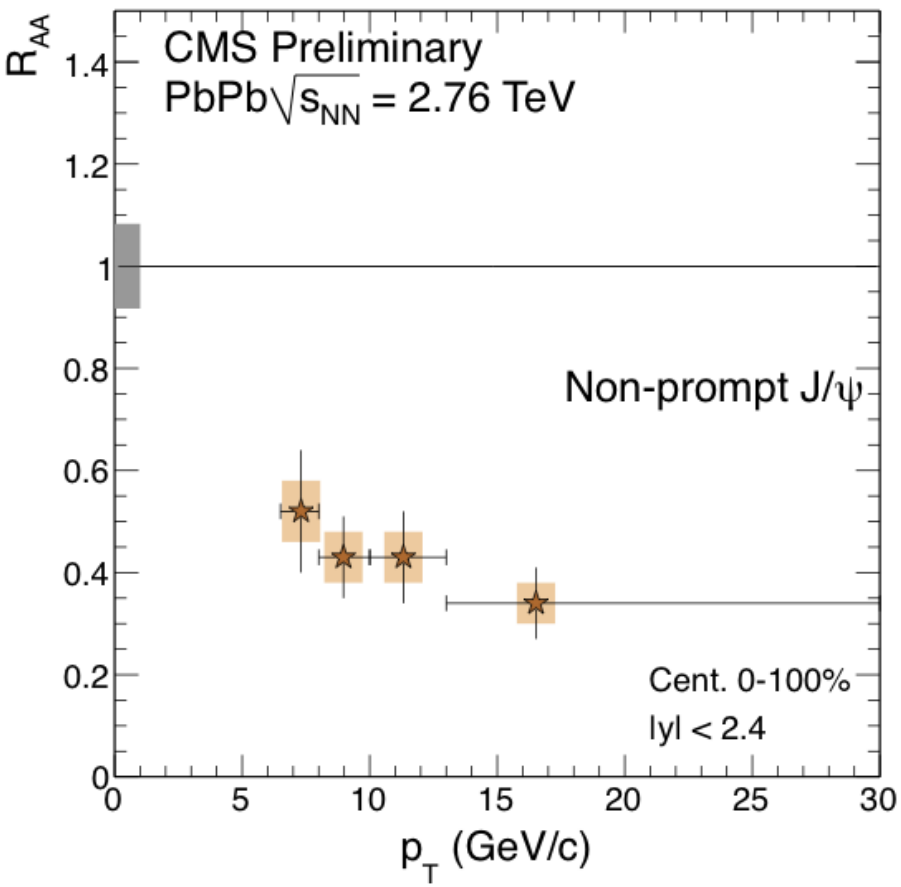
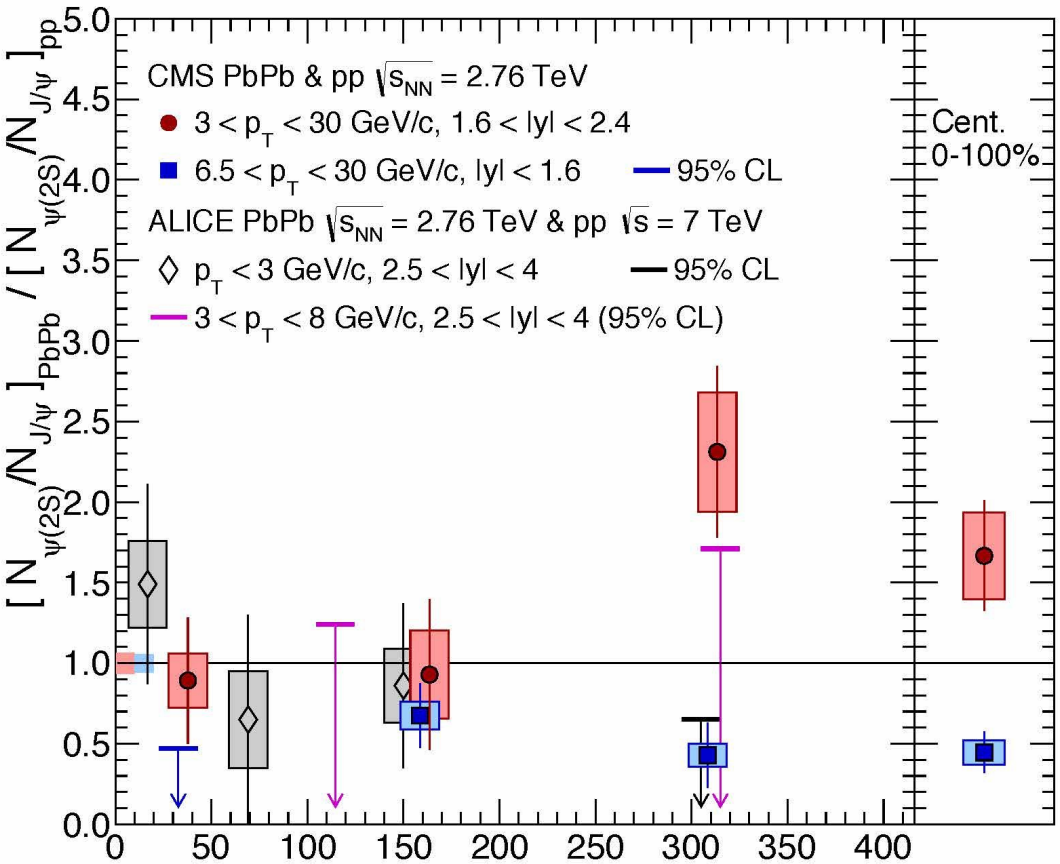




Back up

Non-prompt J/ψ R_{AA} at 2.76 TeV





ψ(2S) to J/ψ ratio in CMS and ALICE