Recent Quarkonia results from CMS

Hyunchul Kim
(Korea University)
for the CMS Collaboration

The 4th Asian Triangle Heavy Ion conference, Busan, Korea
Nov 15th, 2012

Contents

Overview of heavy-ion results from CMS : Byungsik Hong's plenary talk (Nov. 14th 14:30)

- Motivation of the study
- Muon reconstruction mechanism in CMS
- Results (2010 analysis → 2011 analysis)
  - Charmonia – prompt J/ψ, $\psi(2S)$
  - Open heavy-flavor – non-prompt J/ψ
  - Bottomonia – $\Upsilon(1S, 2S, 3S)$
- Summary

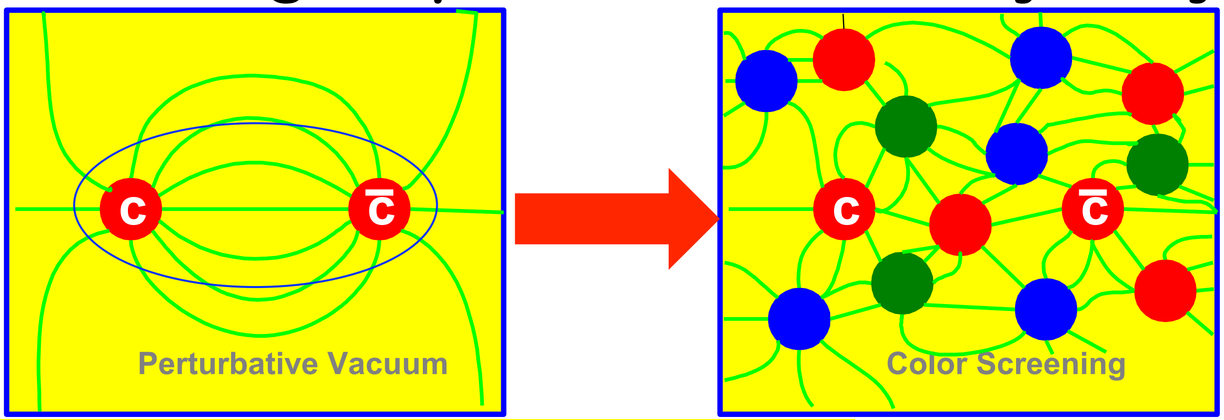
Based on the result from Quark Matter 2012

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsHIN

Theoretical motivation

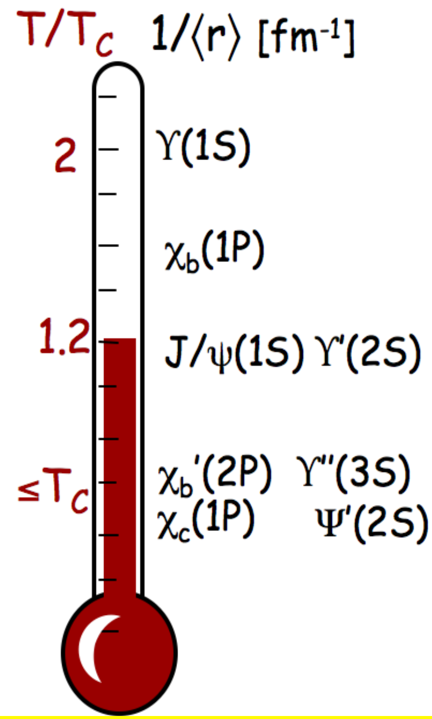
From Matsui & Satz PLB 178 (1986) 416

- **Heavy quarks produced in the initial hard-scattering process**
- **Melting of quarkonia caused by Debye screening**



E. Scomparin, CERN seminar (06/11/2012)

- **Different bound states of quarkonia which binding energy and radius lead to** **sequential melting of the states** **with increasing temperature**

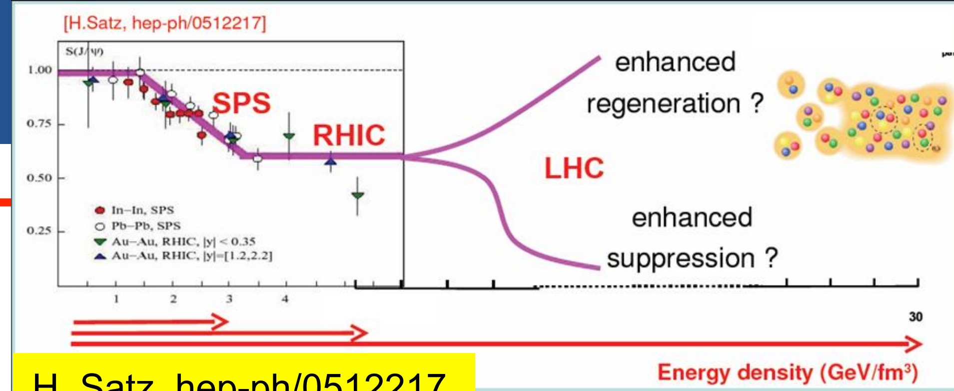


Mocsy, EPJ C 61 (2009) 705

Experimental motivation

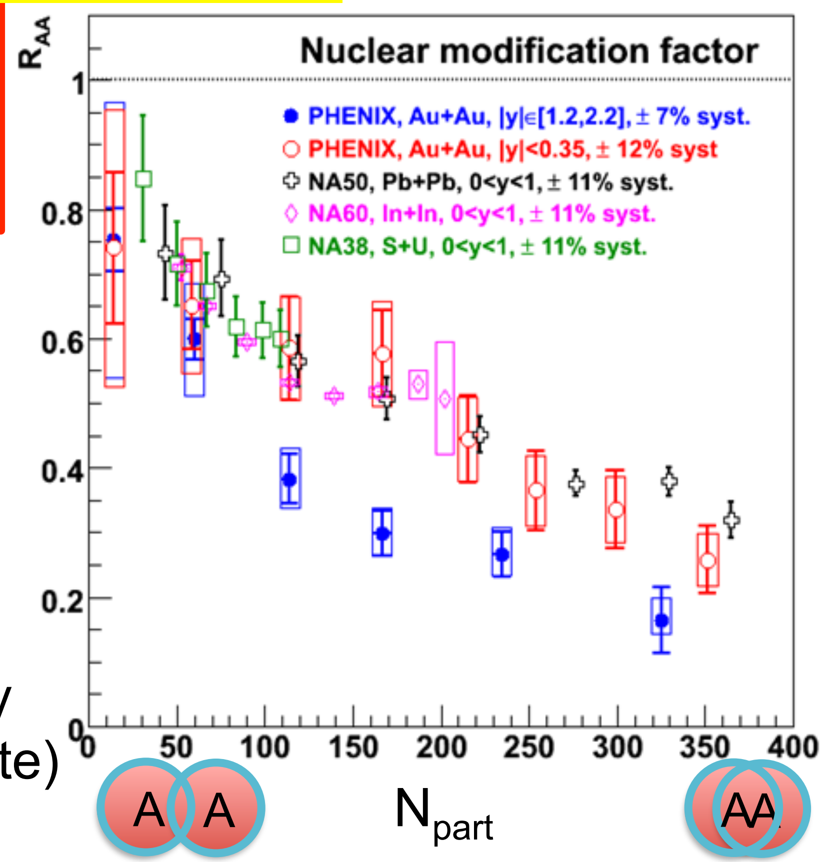
Puzzles

- **Similar J/ψ suppression at the SPS and RHIC**
  - despite 10× higher $\sqrt{s_{NN}}$
- **Suppression does not increase with local energy density**
  - R_{AA}(forward)<R_{AA}(mid)



H. Satz, hep-ph/0512217

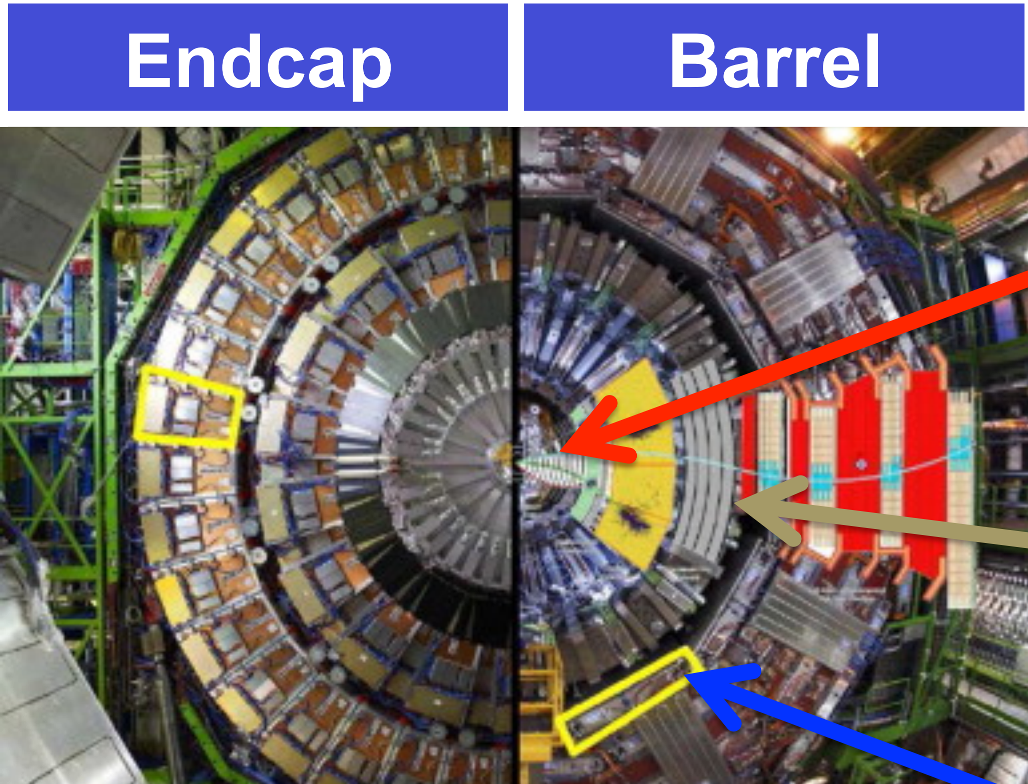
- **Possible ingredients**
  - regeneration
  - cold nuclear matter effects

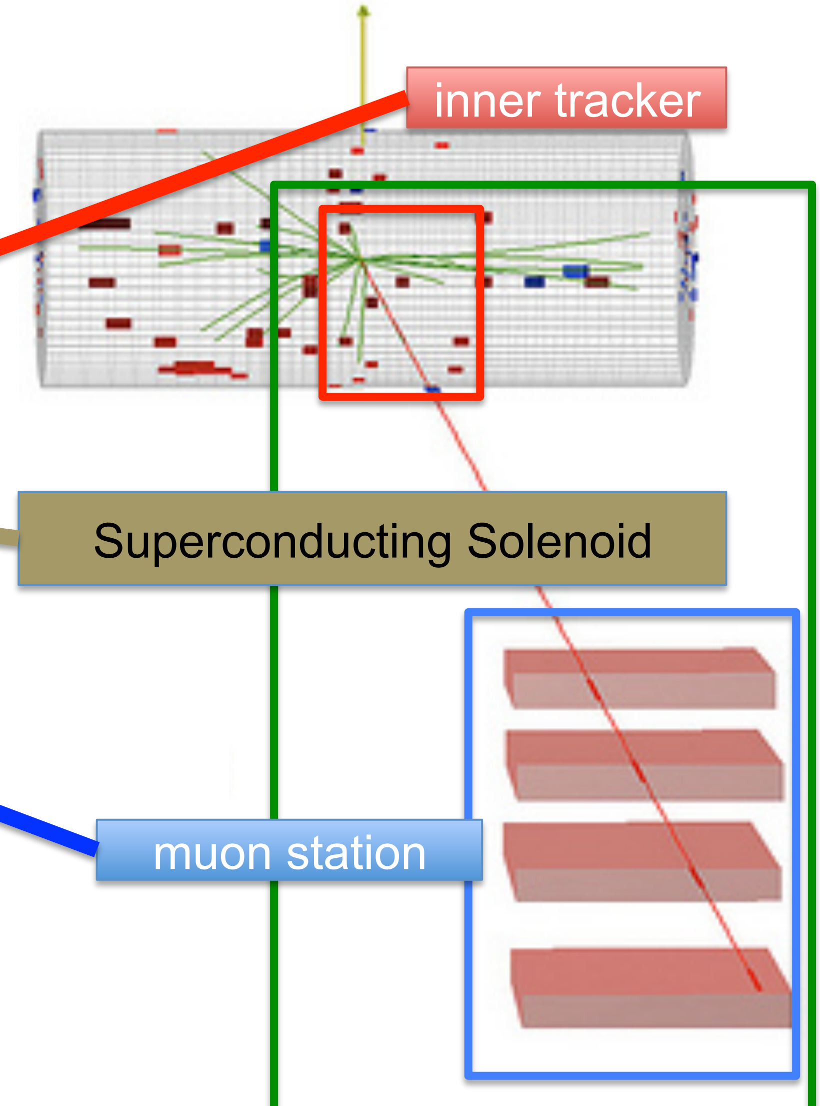


- **We expect the hint from LHC**
  - >10x higher energy + higher luminosity
  - more # of charm (possible to regenerate)
  - more # of bottom → a new probe : ϒ

PHENIX, PRL 98 (2007) 232301
PRC 84 (2011) 054912
SPS from Scomparin @ QM06

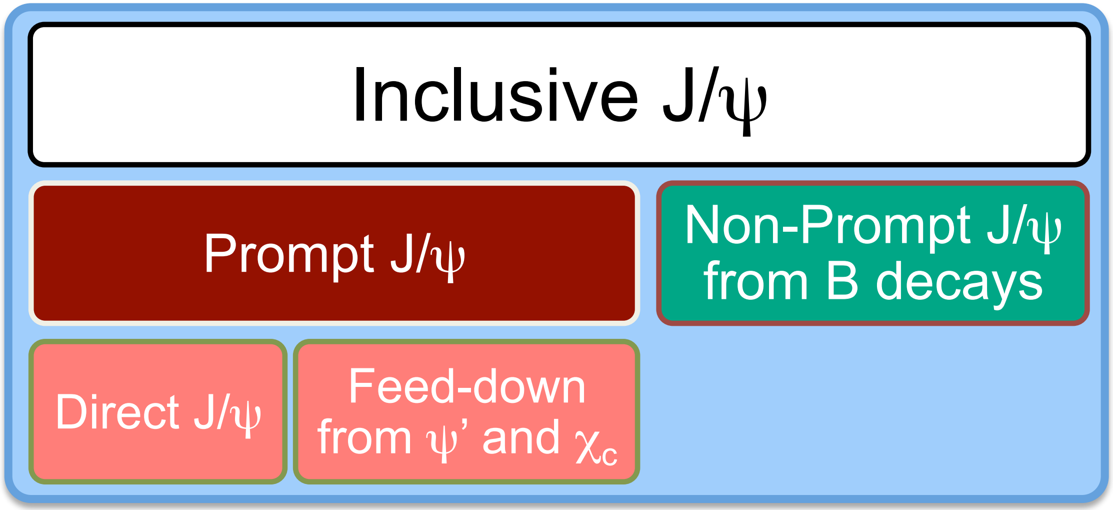
CMS muon reconstruction mechanism

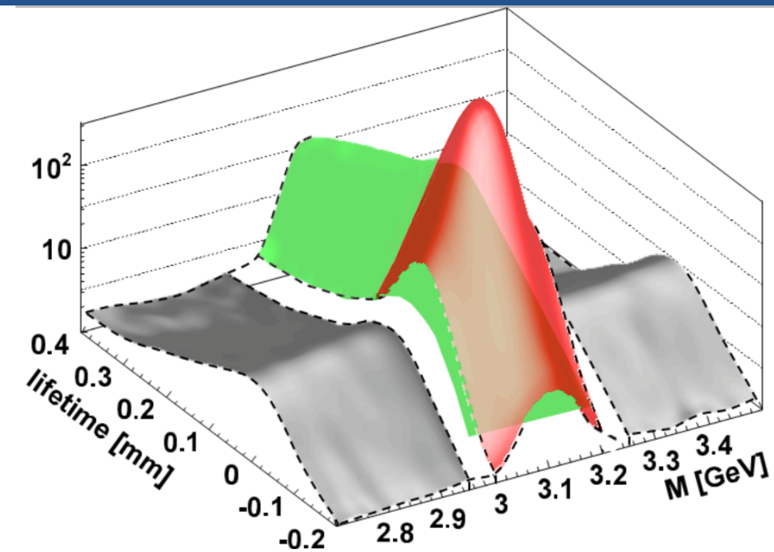




- **Global muons reconstructed with information from inner tracker and muon stations**
- **Further muon ID based on track quality (χ^2, # of hits)**

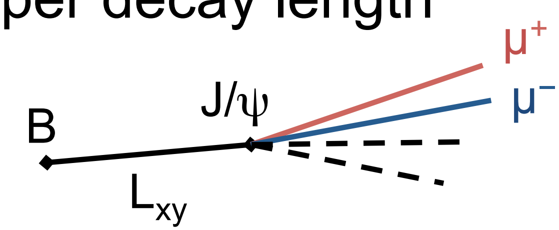
Prompt, non-prompt J/ψ signal extraction

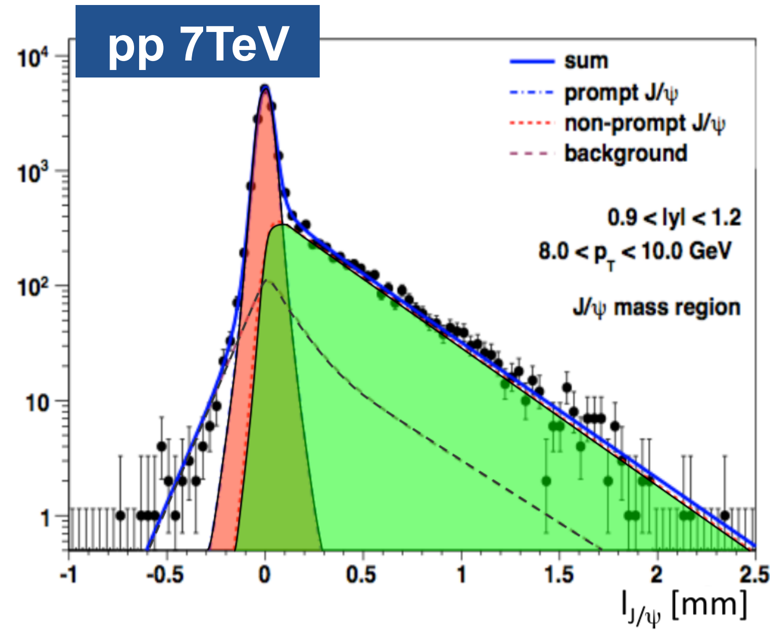




- **Reconstruct $\mu^+\mu^-$ vertex**
- **Separation of prompt and non-prompt J/ψ**
  - by 2D simultaneous fit of $\mu^+\mu^-$ mass and pseudo-proper decay length

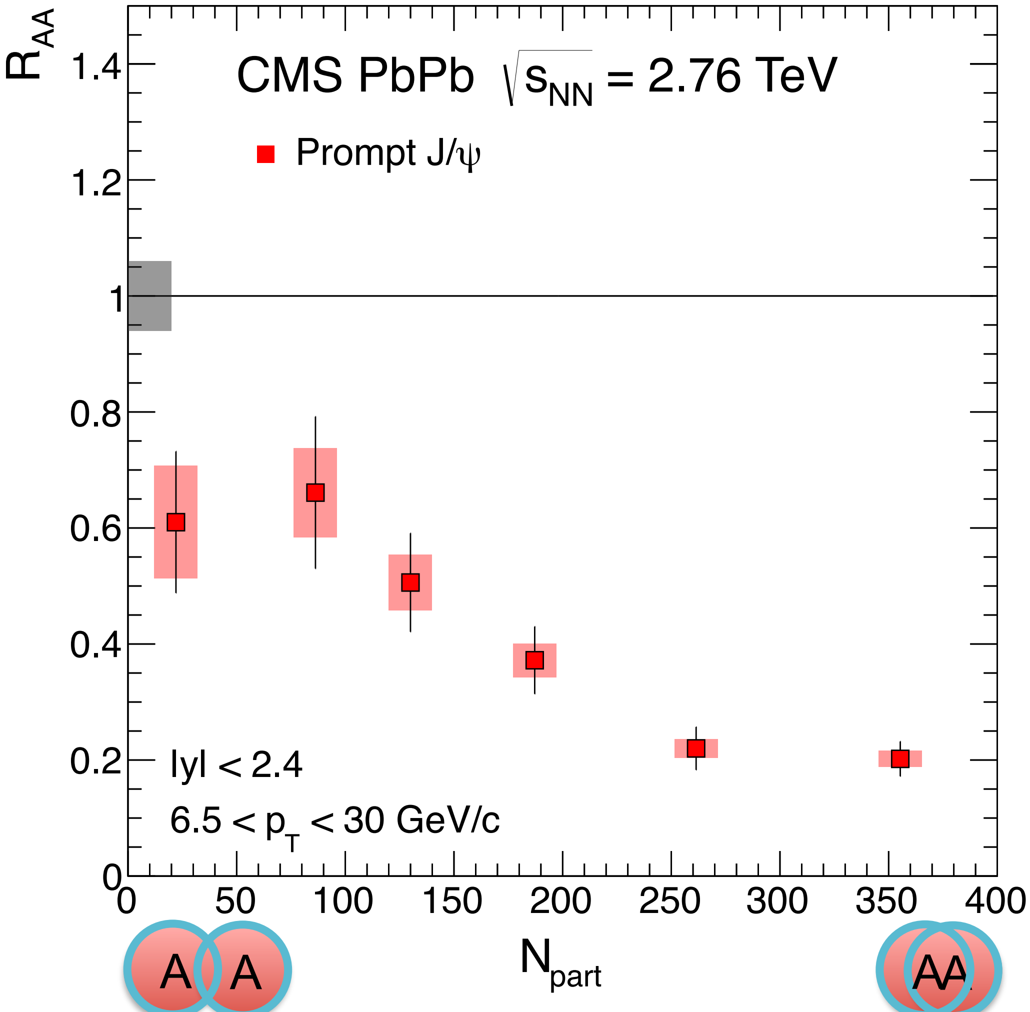
$$\ell_{J/\psi} = L_{xy}\frac{m_{J/\psi}}{p_T}$$

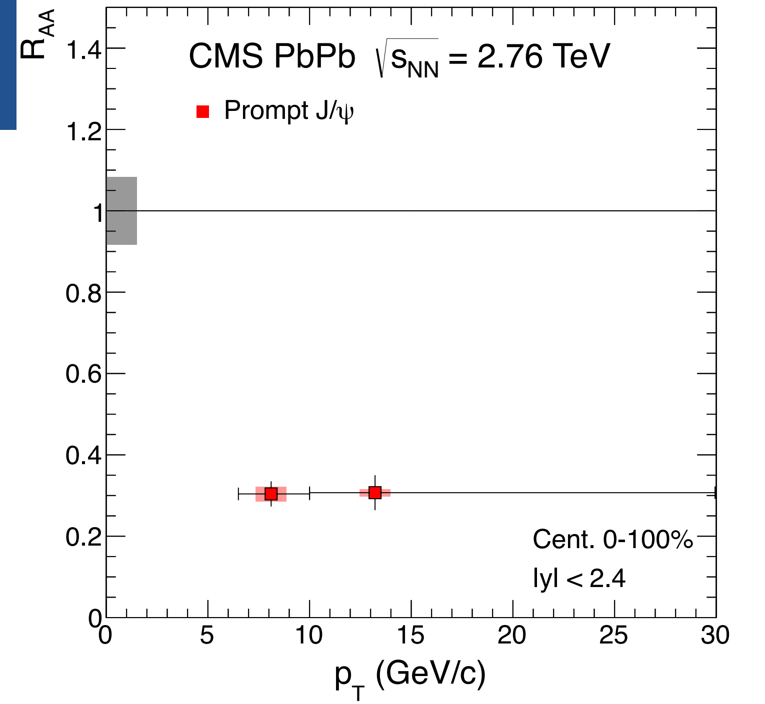


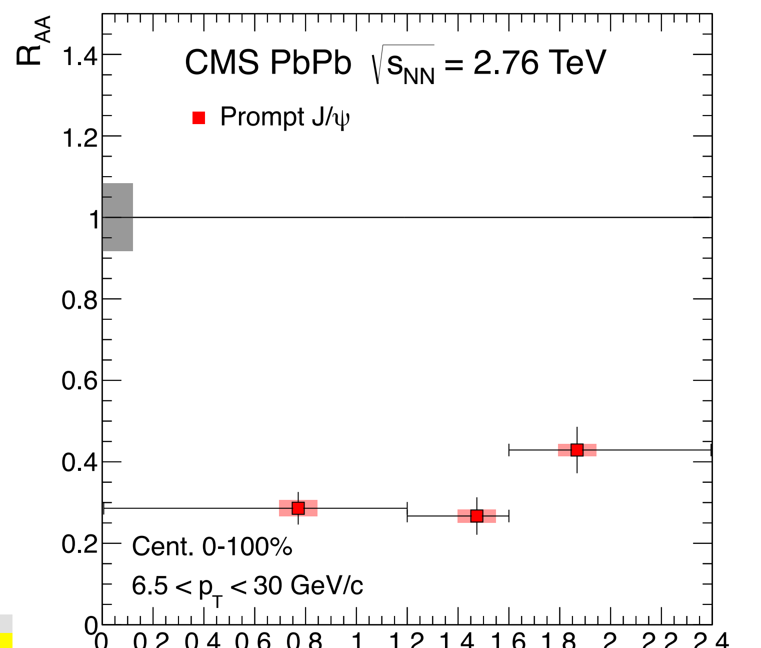


Prompt J/ψ R_{AA} results (2010)

$$R_{AA} = \frac{\mathcal{L}_{pp}}{T_{AA} N_{MB}} \frac{N_{PbPb}(J/\psi)}{N_{pp}(J/\psi)} \frac{\epsilon_{pp}}{\epsilon_{PbPb}}$$

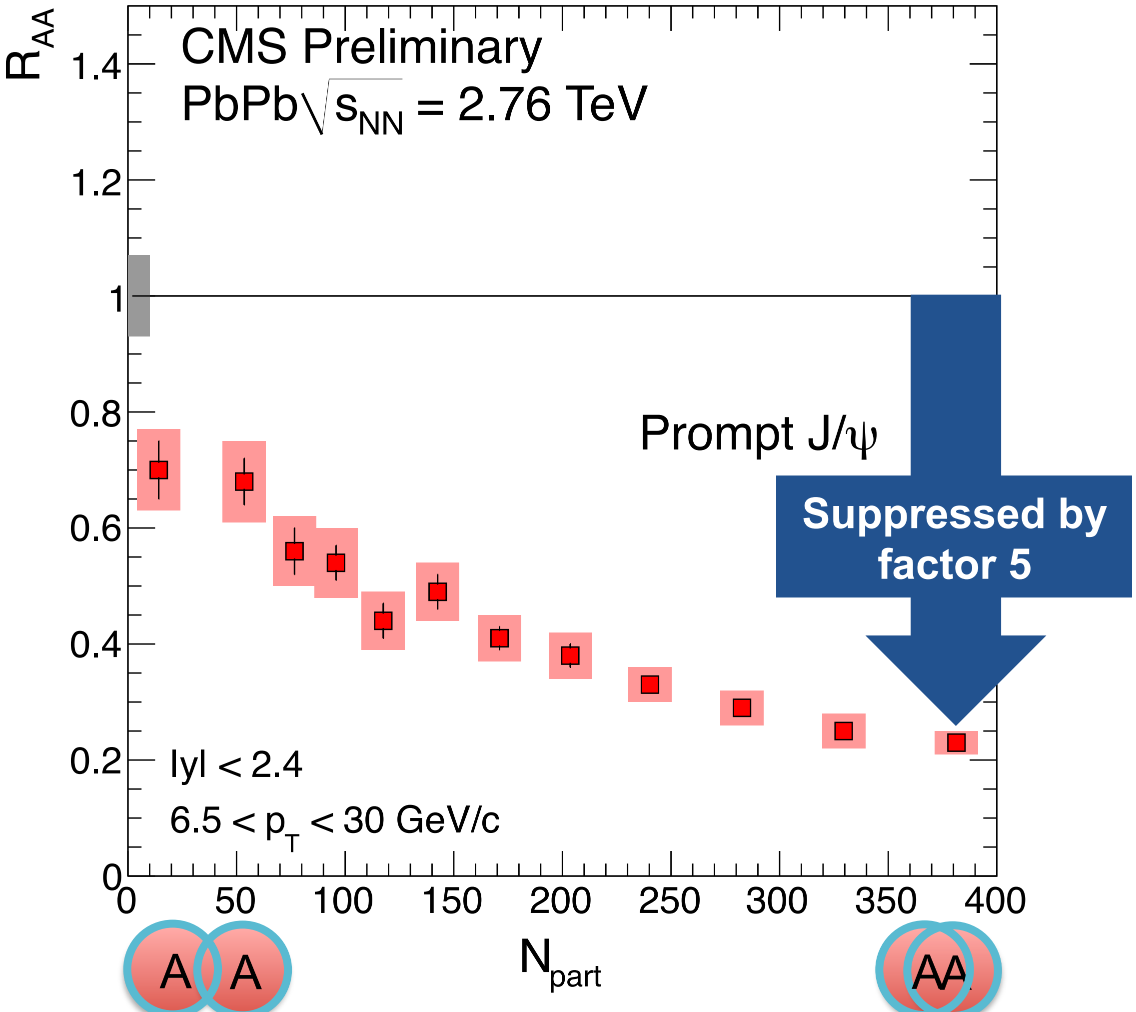


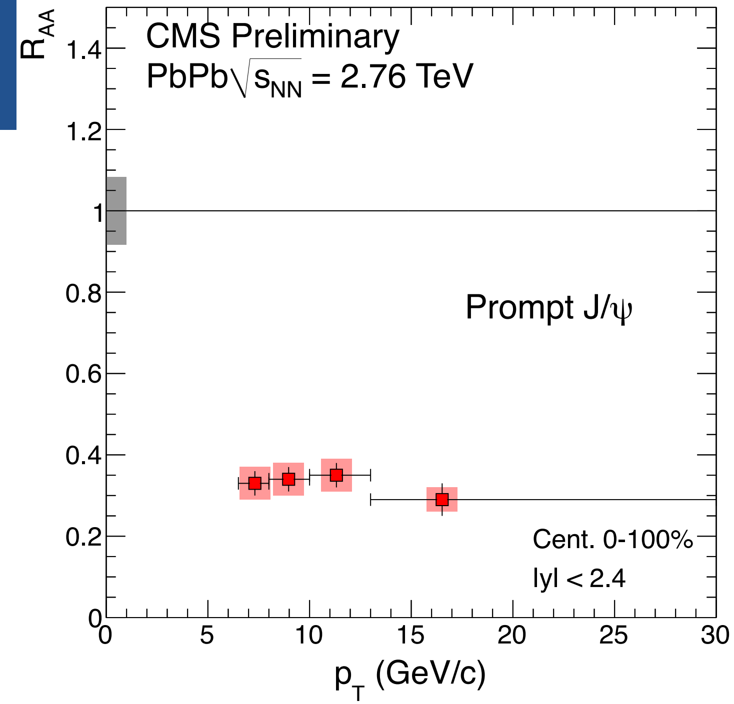


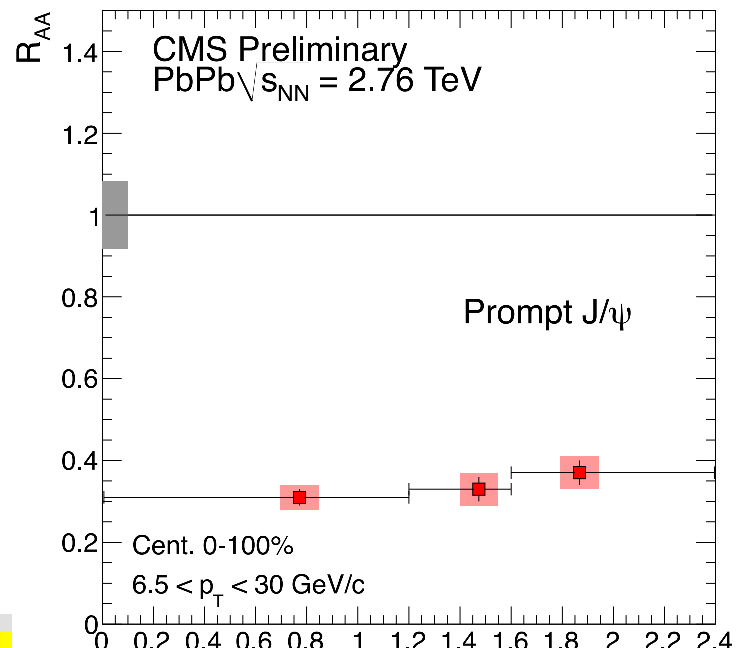


Prompt J/ψ R_{AA} results (2011)

$$R_{\mathrm{AA}} = \frac{\mathcal{L}_{\mathrm{pp}}}{T_{\mathrm{AA}} N_{\mathrm{MB}}} \frac{N_{\mathrm{PbPb}}(J/\psi)}{N_{\mathrm{pp}}(J/\psi)} \frac{\epsilon_{\mathrm{pp}}}{\epsilon_{\mathrm{PbPb}}}$$

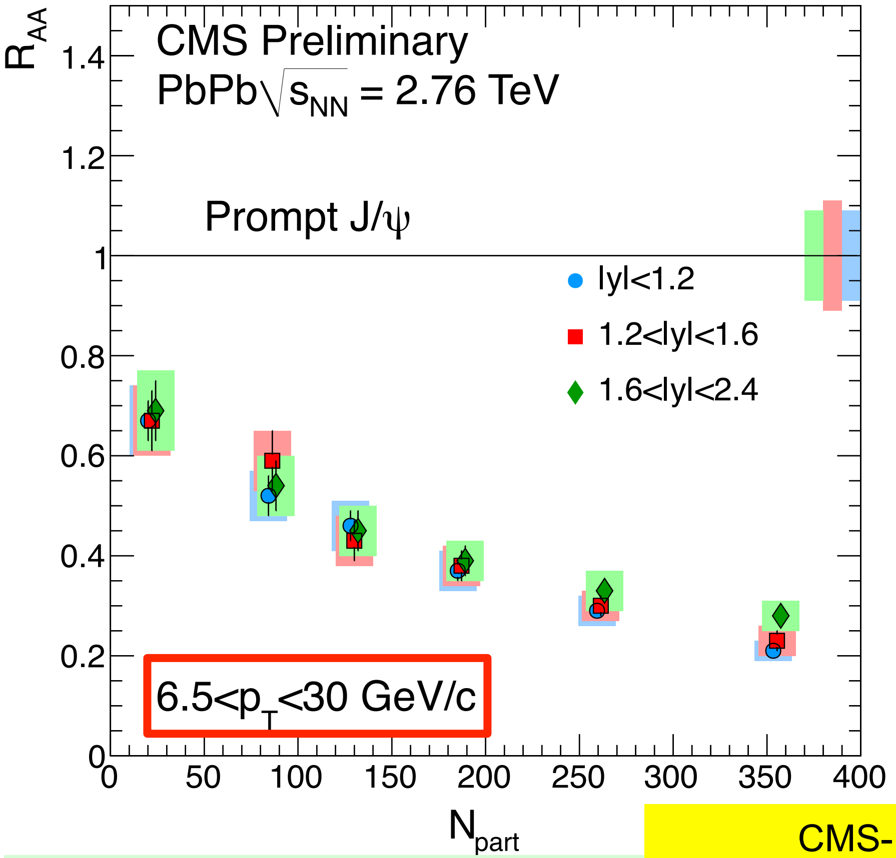






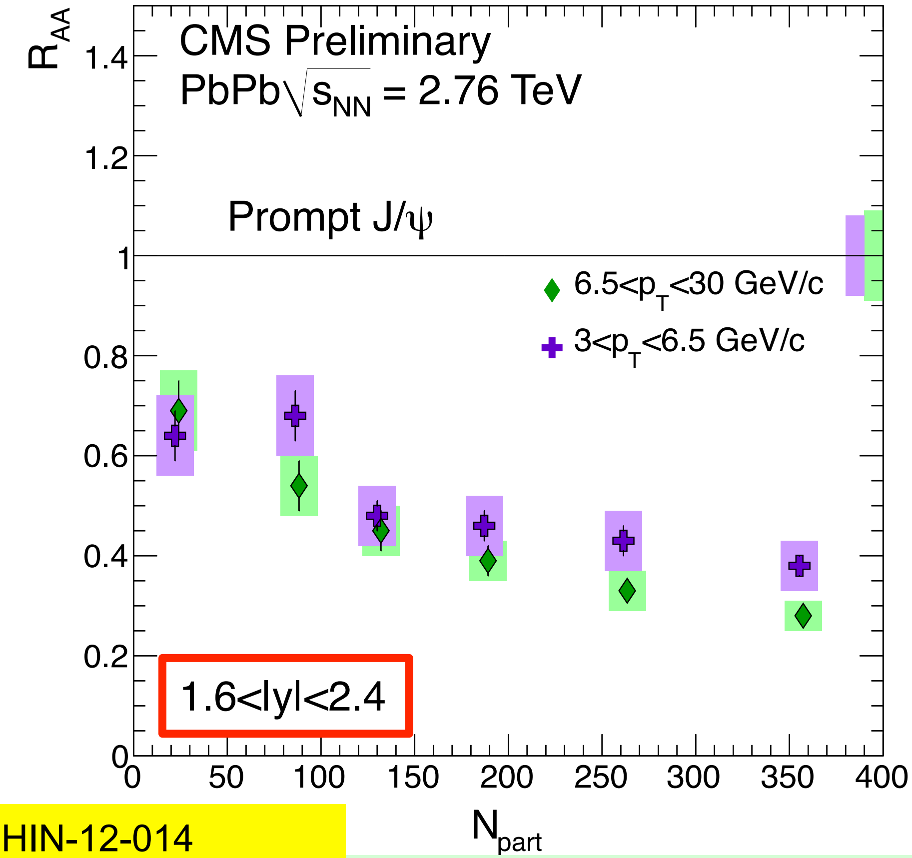
Prompt J/ψ R_{AA} : y & p_T dependence on centrality

Rapidity dependence



No strong dependence on rapidity

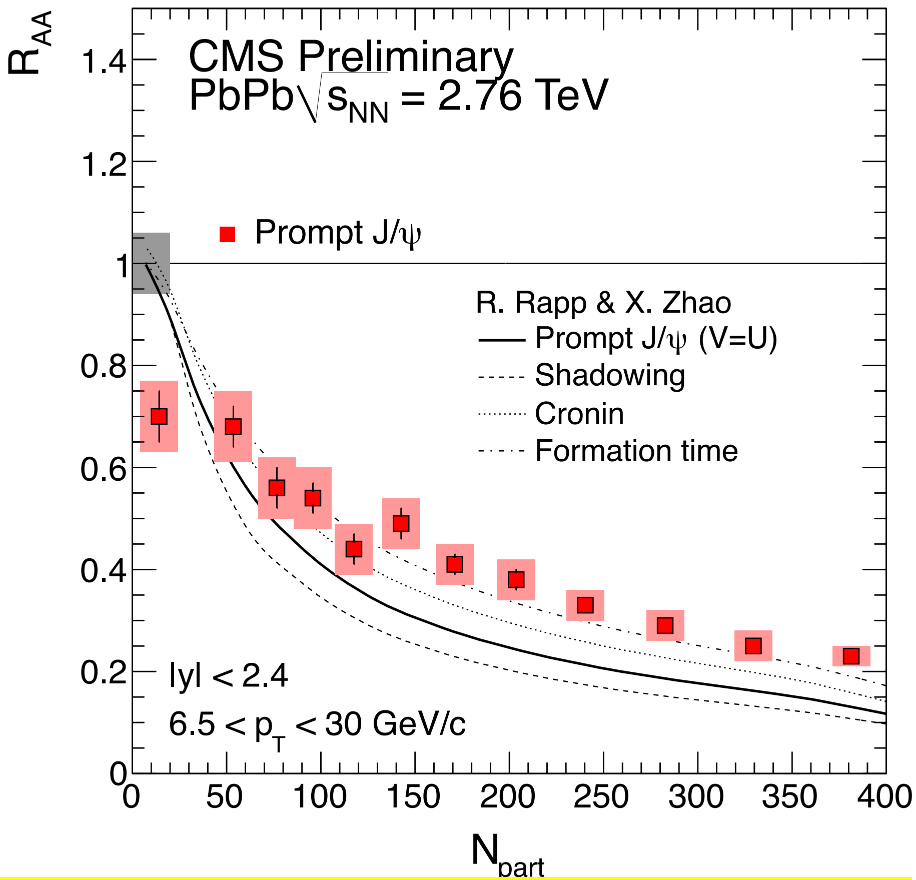
p_T dependence



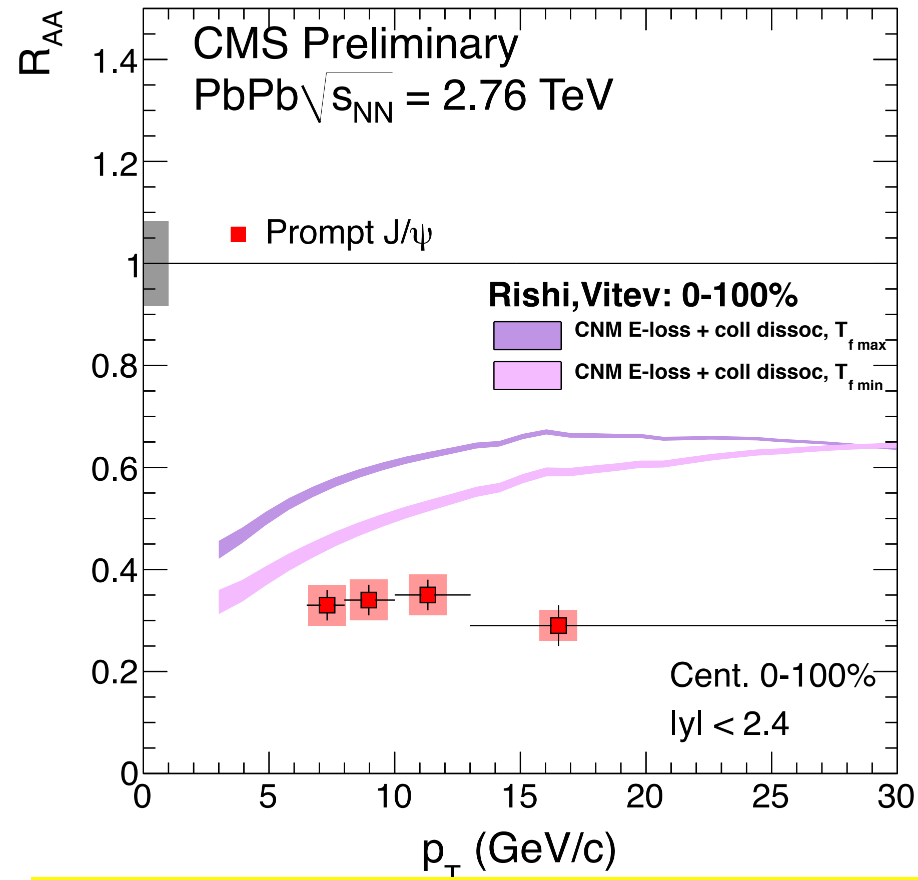
CMS-PAS HIN-12-014

Hint of less suppression at lower p_T

Prompt J/ψ R_{AA} : theory comparison



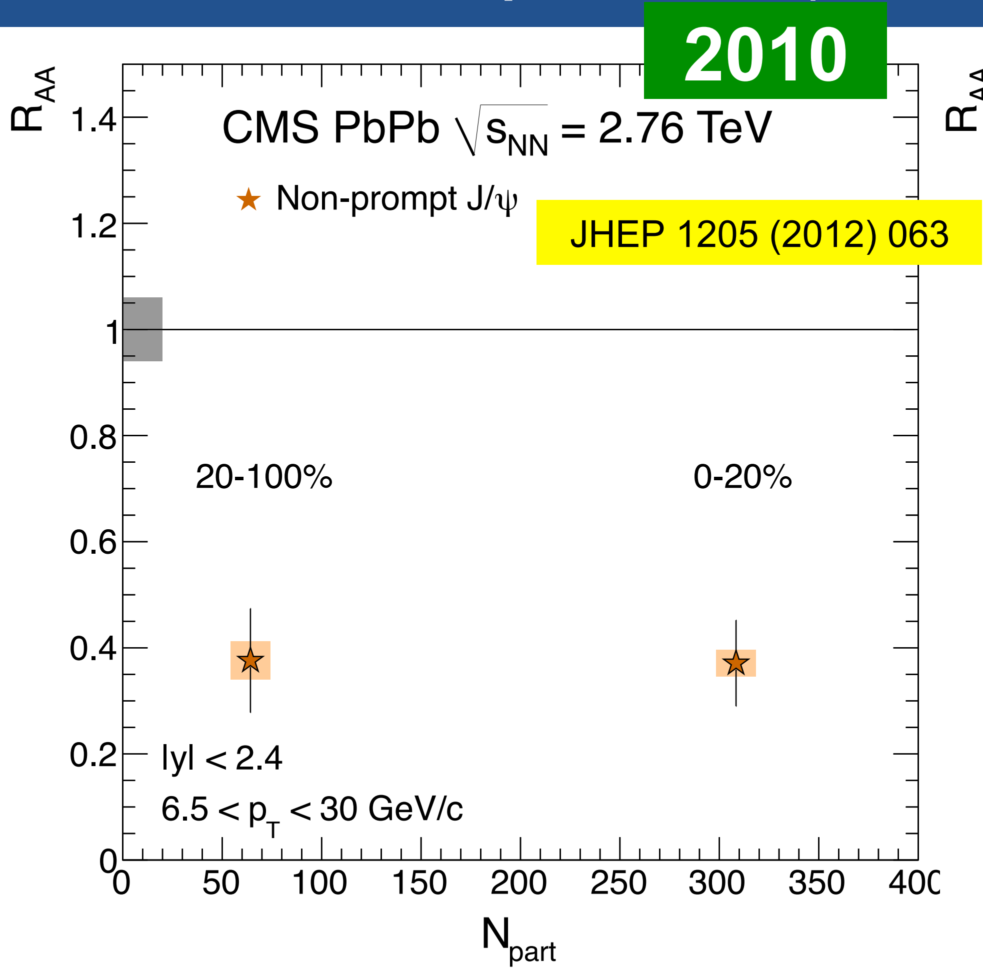
NPA 859 (2011) 114 + private communication

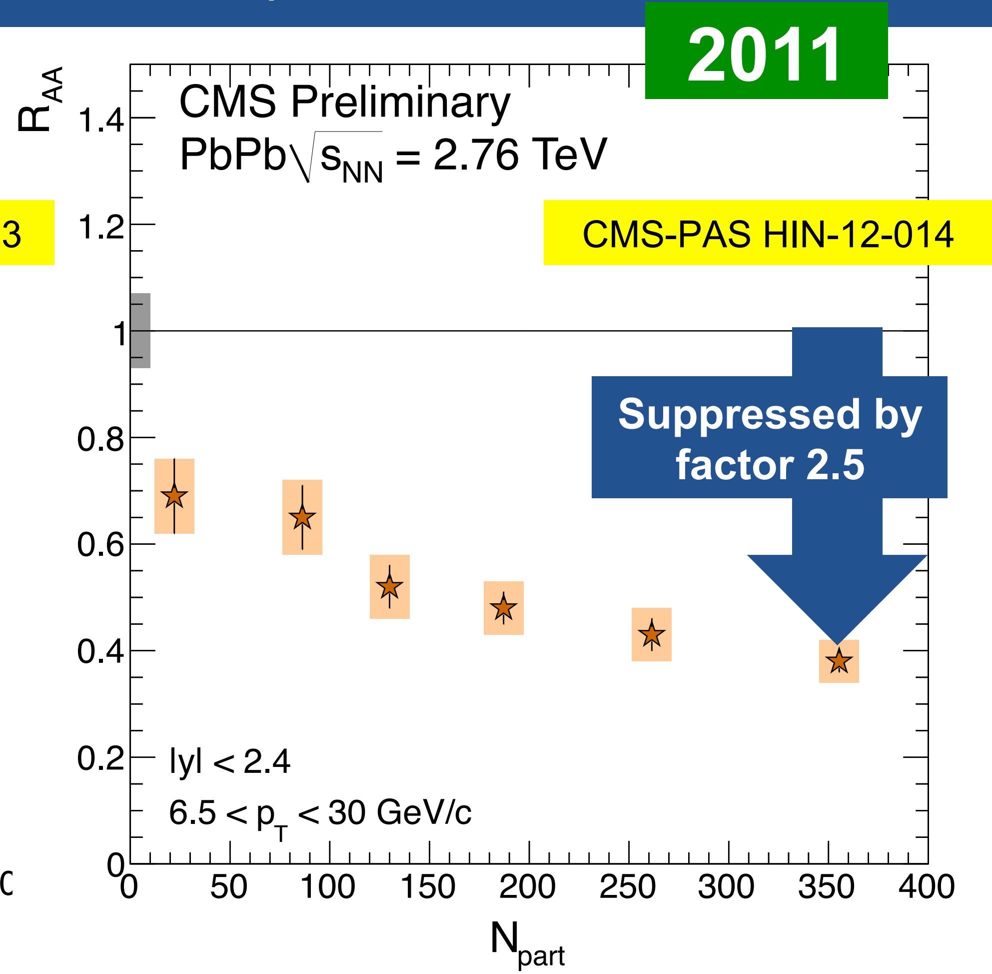


arXiv:1203.0329 + private communication

- No need for regeneration to describe data at high p_T region
- Treatment of quarkonia energy loss similarly as open flavor energy loss, without color-octet included, is not supported by data

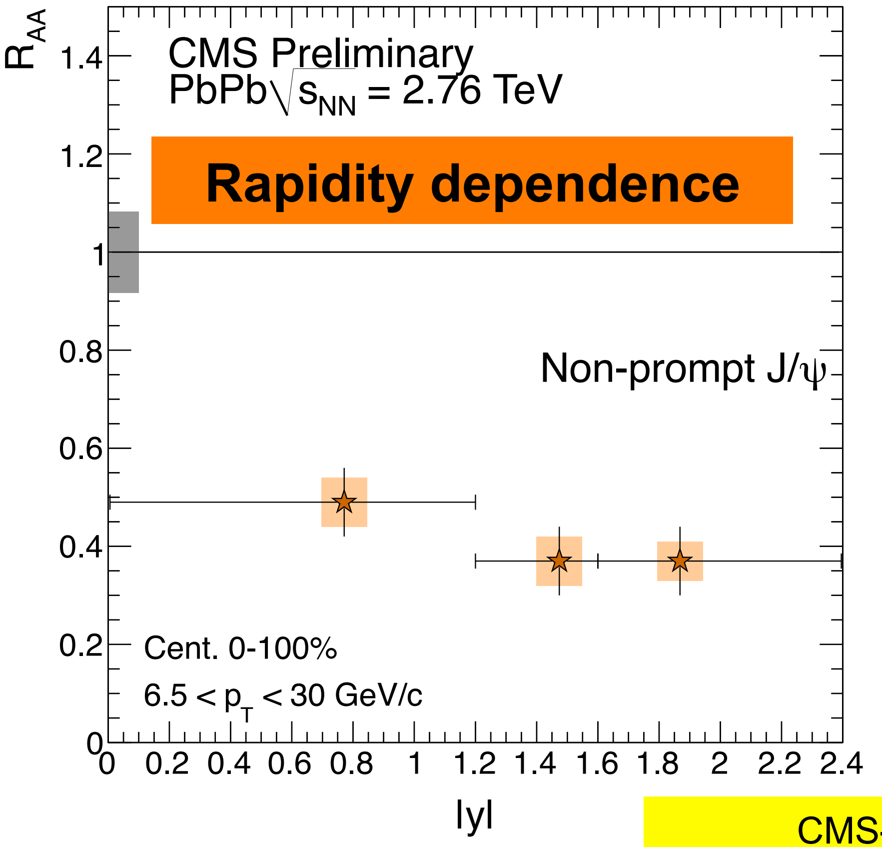
non-prompt J/ψ results (2010, 2011)

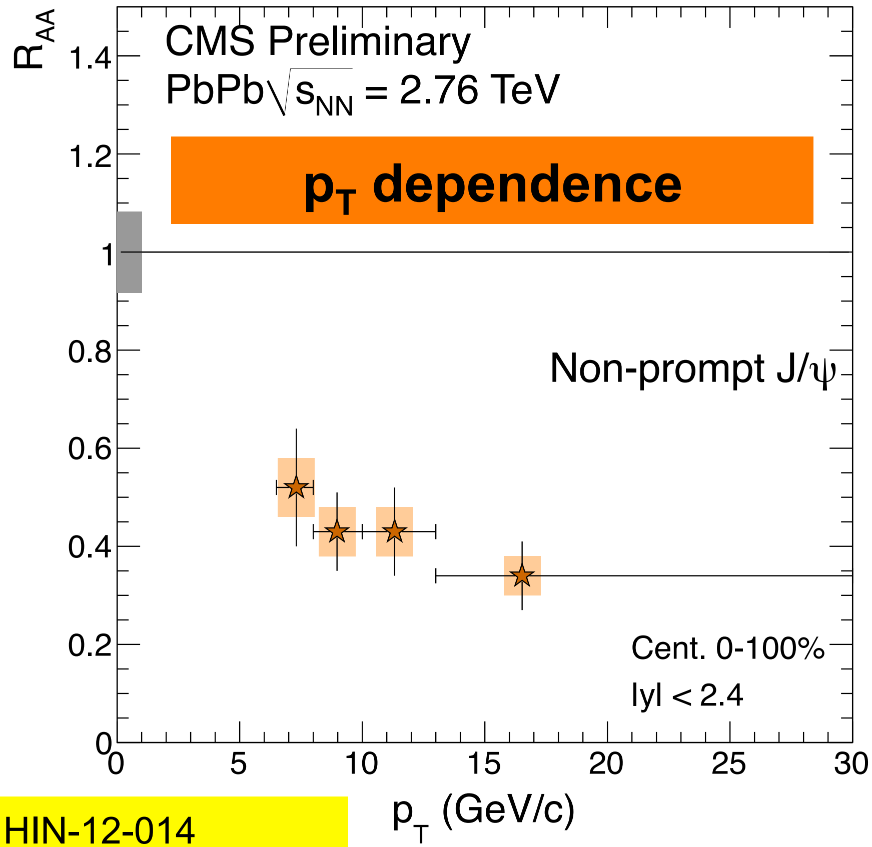




- Centrality dependent suppression of non-prompt J/ψ is observed
- Directly measuring the b-quark energy loss in the medium

non-prompt J/ψ results (2011)



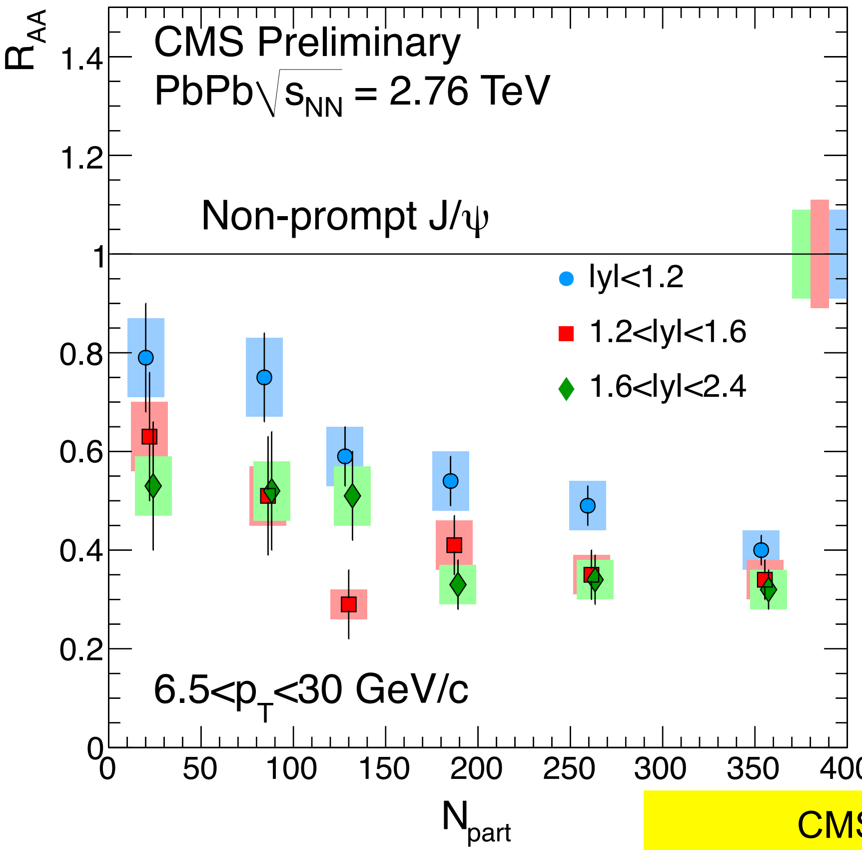


CMS-PAS HIN-12-014

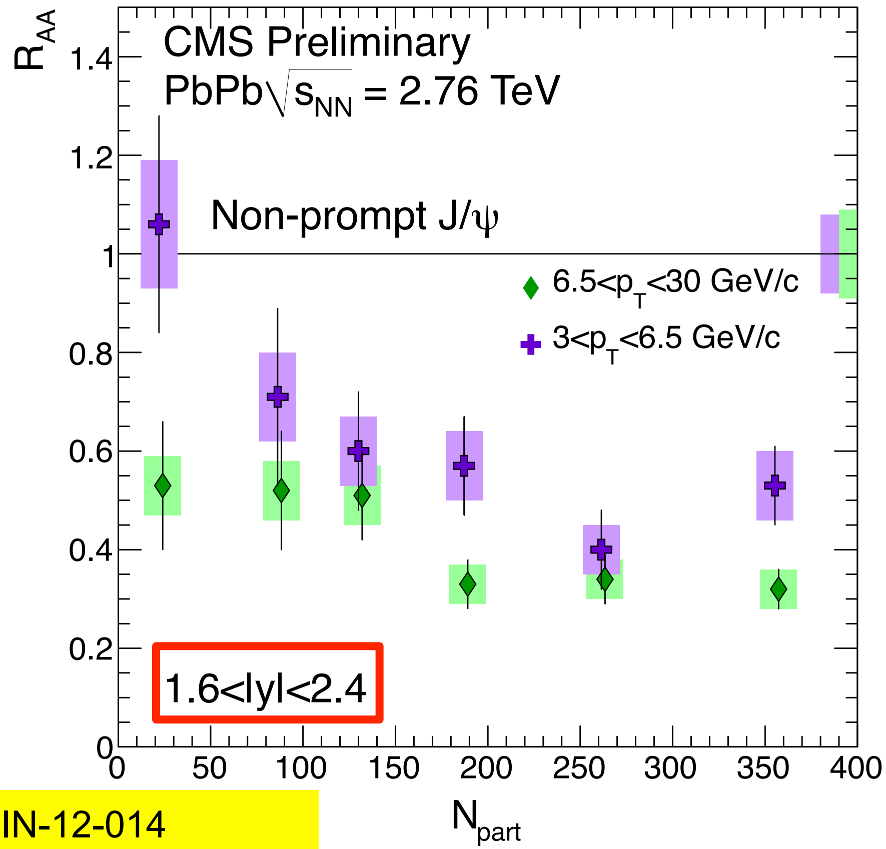
- In mid-rapidity region, non-prompt J/ψ is less suppressed than in forward region
- non-prompt J/ψ in low p_T is slightly less suppressed than in high p_T

non-prompt J/ψ R_{AA} : y & p_T dependence on centrality

Rapidity dependence



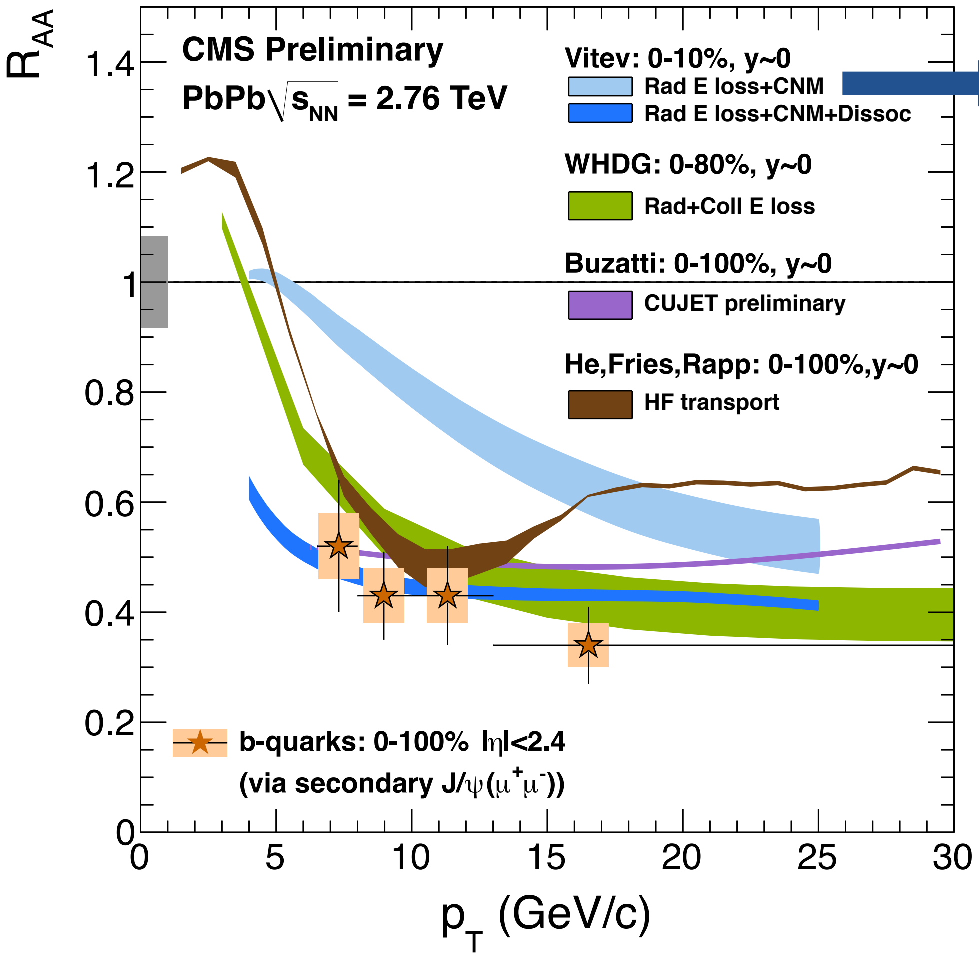
p_T dependence



CMS-PAS HIN-12-014

- In forward region, low p_T J/ψ has strong centrality dependence and less suppressed than high p_T J/ψ

non-prompt J/ψ R_{AA} : theory comparison



Model involving only radiative energy loss and cold nuclear matter effects clearly fails to describe the data

Vitev: J. Phys.G35 (2008) 104011 + private communications

Horowitz: arXiv:1108.5876 + private communications

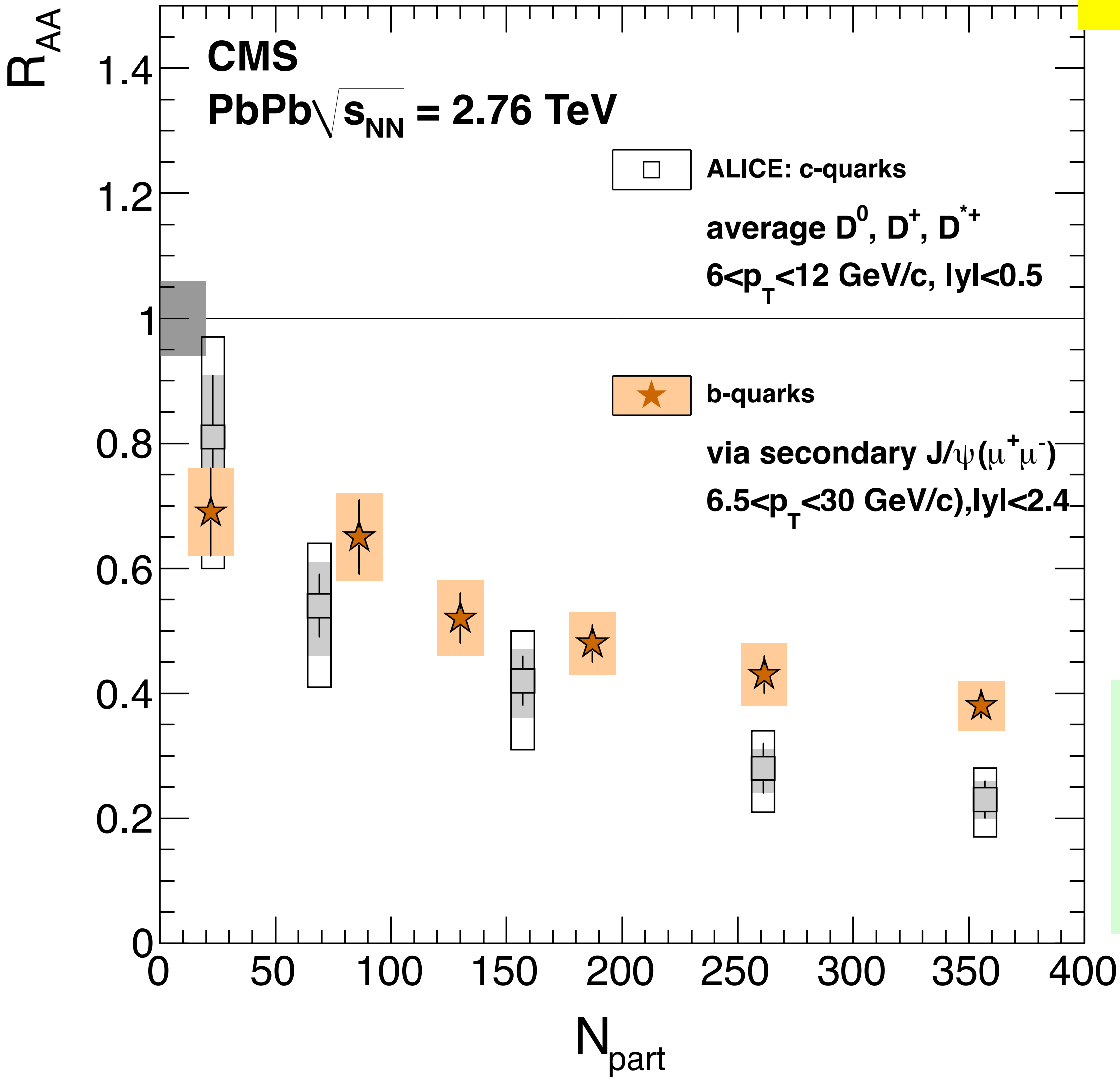
Buzzatti, Gyulassy: arXiv: 1207.6020+ private communications

He, Fries, Rapp: PRC86(2012)014903+ private communications

Within large uncertainties, data is described with various theoretical scenarios.

Comparison with ALICE results

arXiv:1203.2160, CMS-PAS HIN-12-014

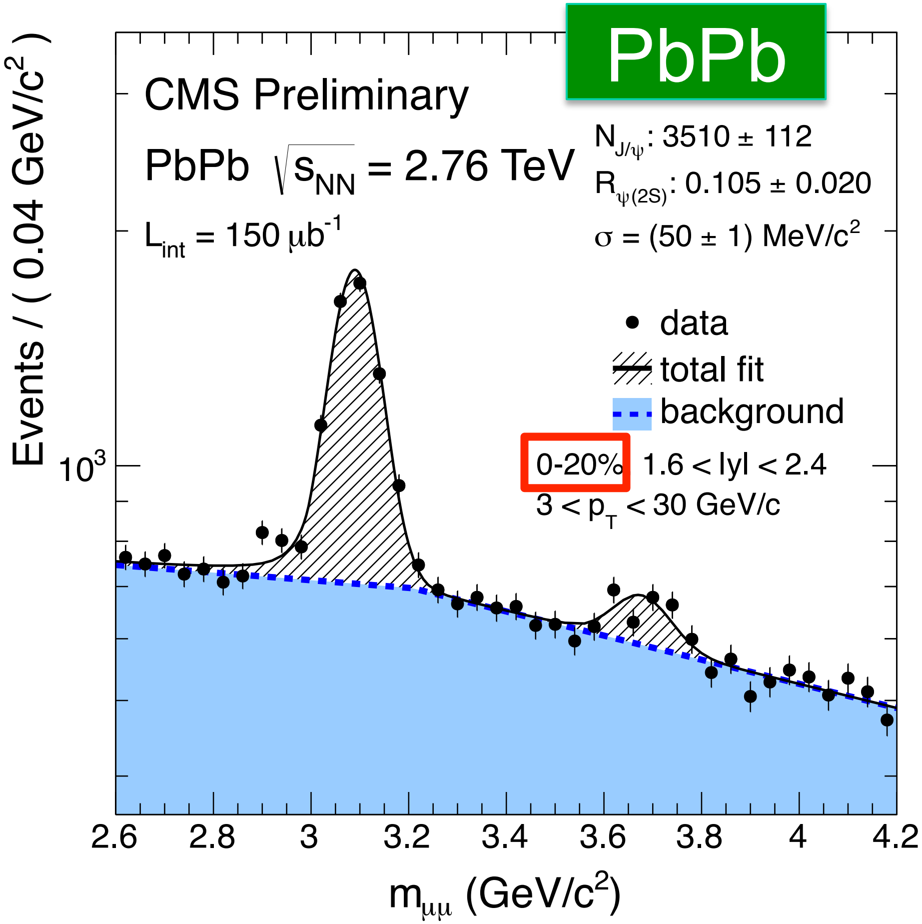


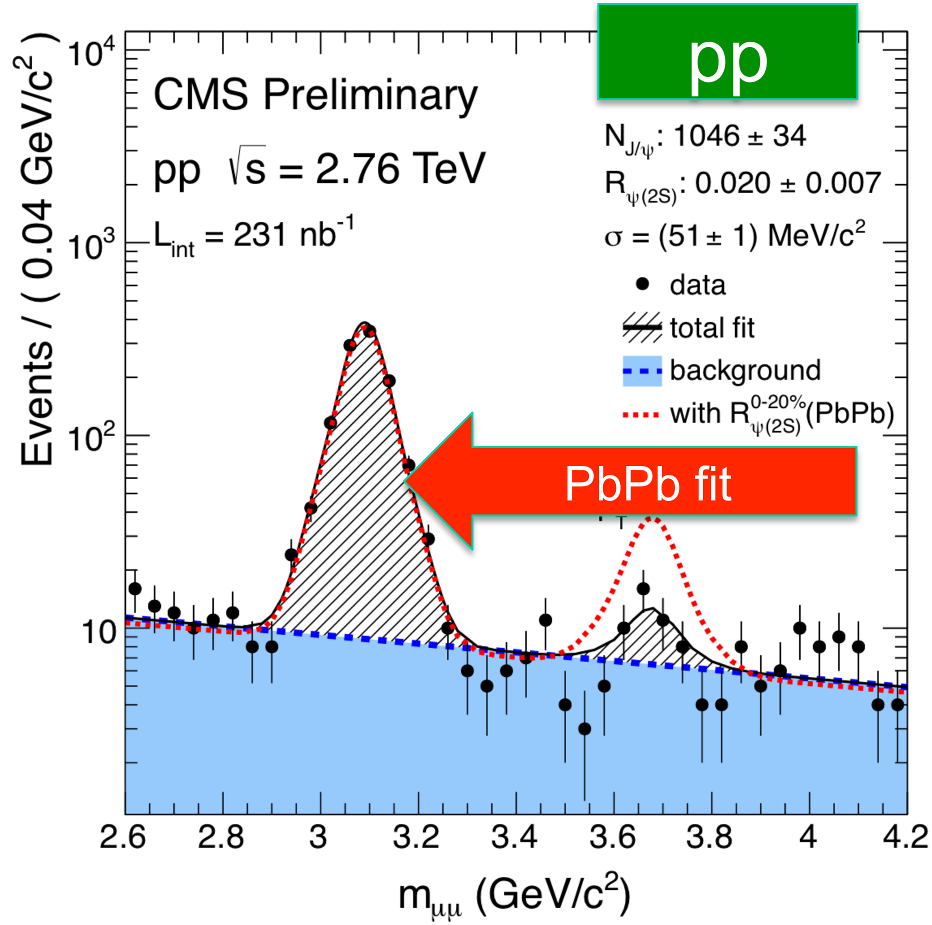
- In central collisions, $R_{AA}^{charm} < R_{AA}^{bottom}$

$\psi(2S)$ in pp & PbPb at $\sqrt{s_{NN}}$ = 2.76 TeV (2011)

Low-p_T, forward region (p_T>3 GeV/c and 1.6<|y|<2.4)

PAS CMS-HIN-12-007





$R_{\psi(2S)} = N_{\psi(2S)} / N_{J/\psi}$

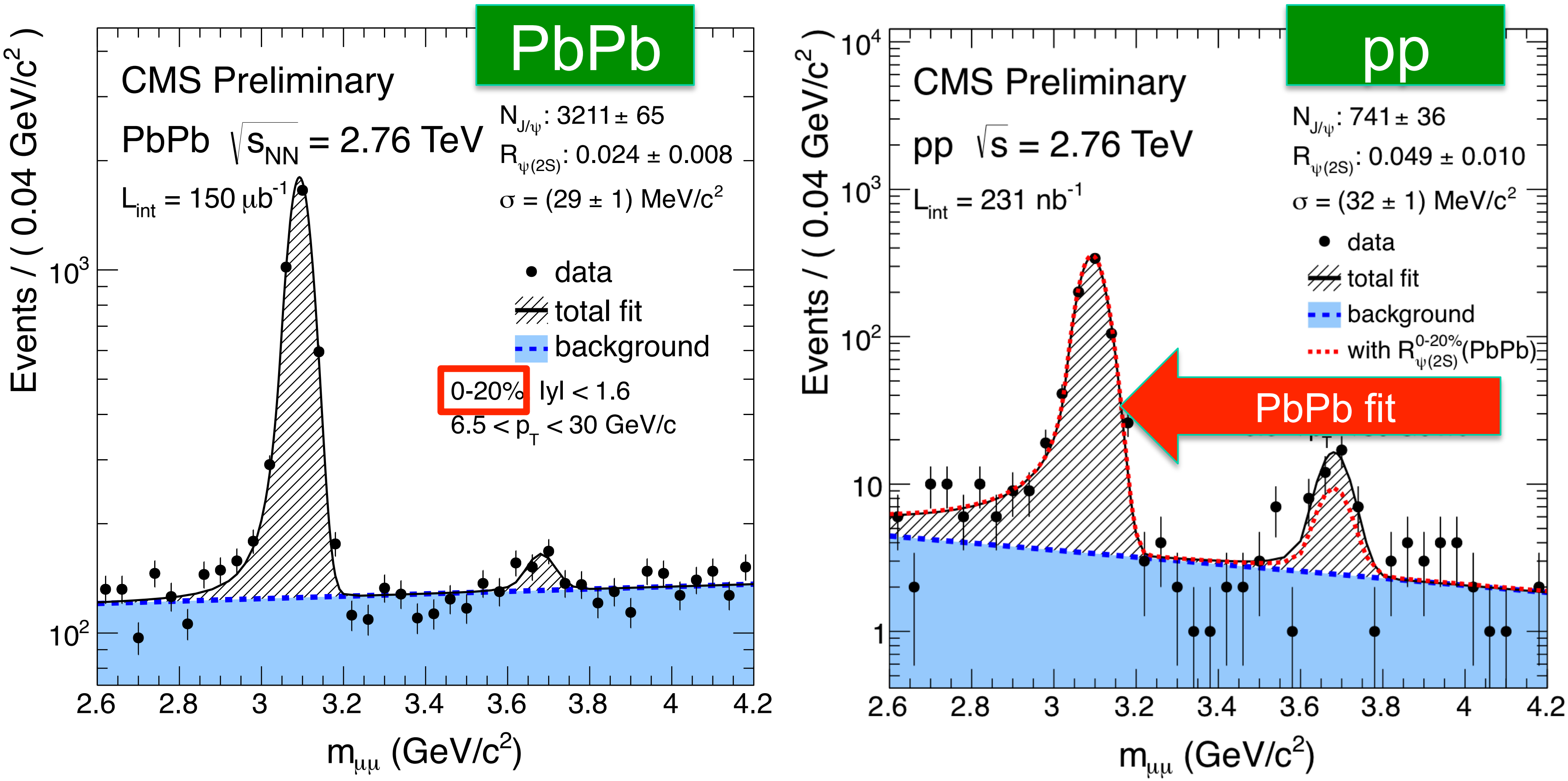
$R_{\psi(2S)}^{PbPb} \sim$ **5** $\times R_{\psi(2S)}^{pp}$

limited by pp statistics

ψ(2S) in pp & PbPb at $\sqrt{s_{NN}}$ = 2.76 TeV (2011)

High-p_T, mid-rapidity region (p_T>6.5 GeV/c and |y|<1.6)

PAS CMS-HIN-12-007



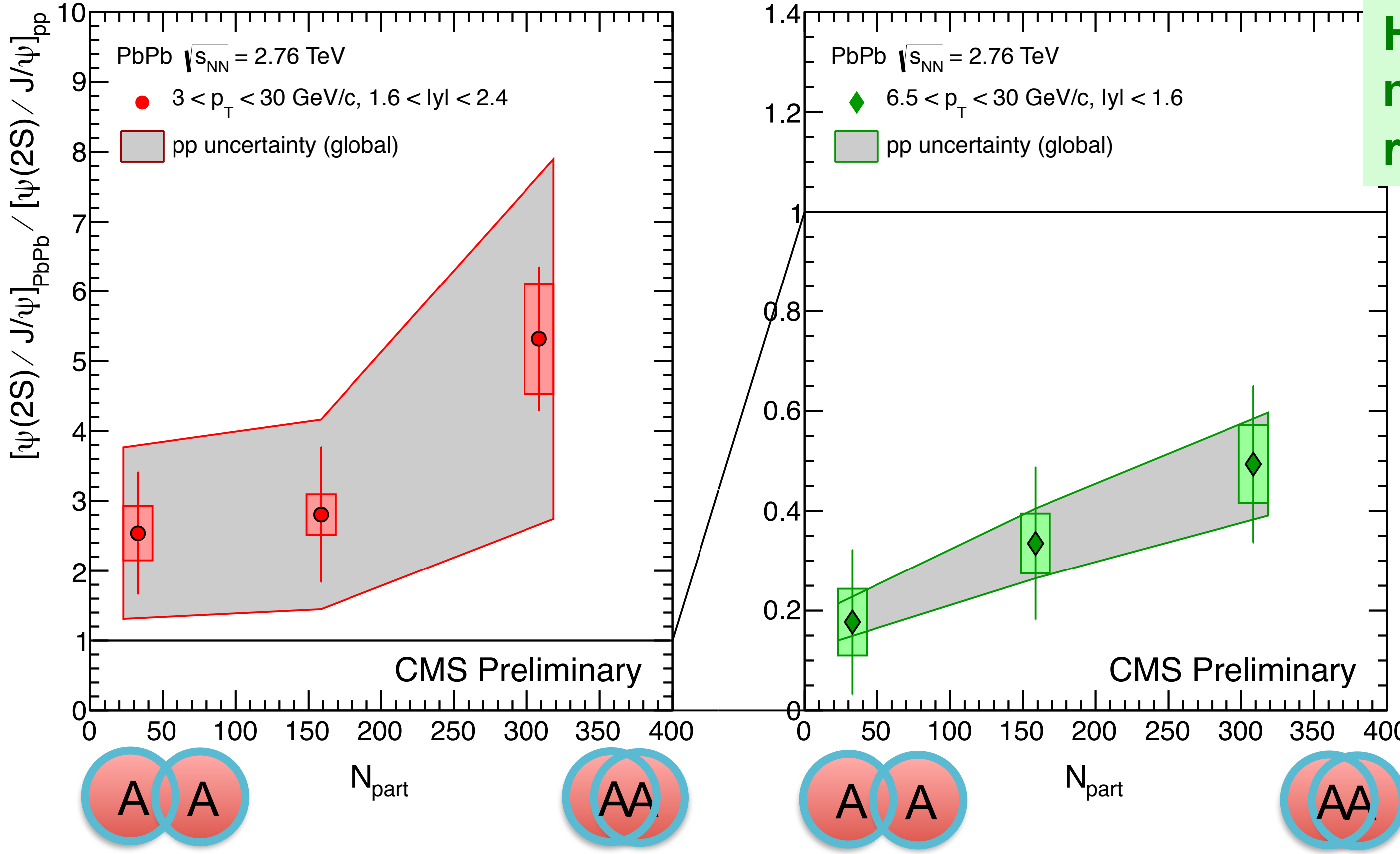
$R_{\psi(2S)} = N_{\psi(2S)} / N_{J/\psi}$

$R_{\psi(2S)}^{PbPb} \sim$ **0.5** $\times R_{\psi(2S)}^{pp}$

ψ (2S) results (2011)

Low-pT, forward region

High-pT, mid-rapidity region



$$\frac{N_{\psi(2S)}/N_{J/\psi}|_{PbPb}}{N_{\psi(2S)}/N_{J/\psi}|_{pp}} = \frac{R_{AA}(\psi(2S))}{R_{AA}(J/\psi)}$$

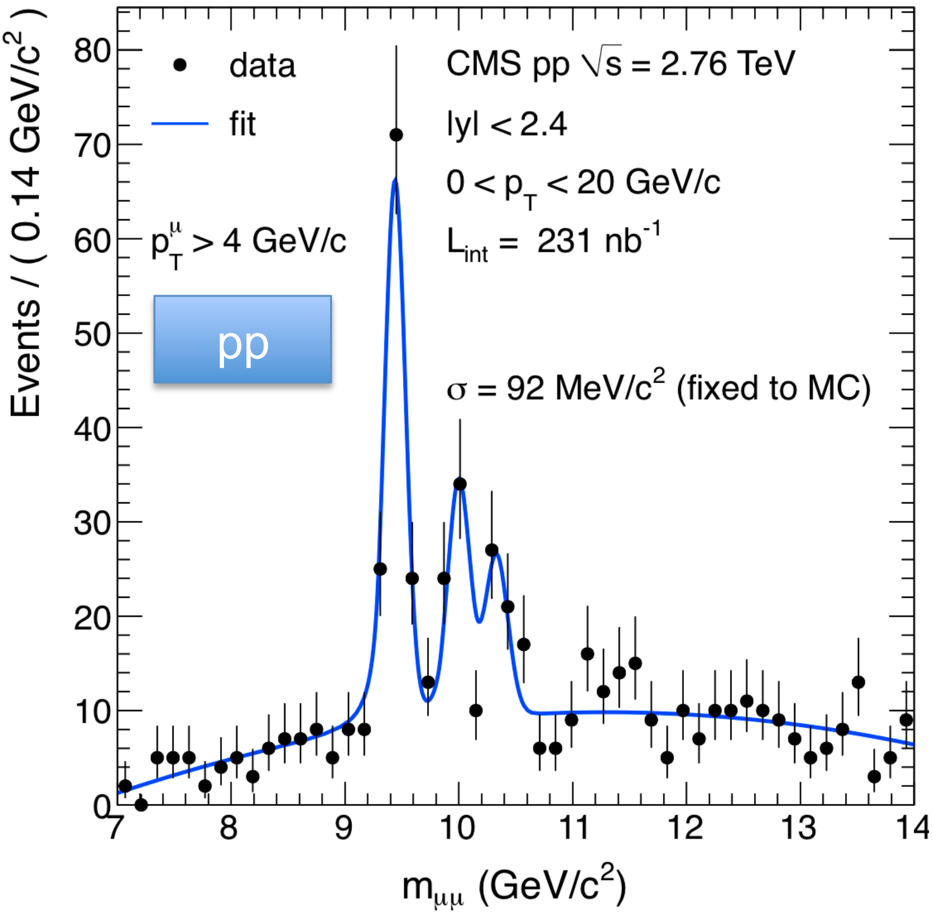
$$R_{AA}^{0-100\%}(\psi(2S)) = 1.54 \pm 0.32(\mathrm{stat}) \pm 0.22(\mathrm{syst}) \pm 0.76(\mathrm{pp})$$

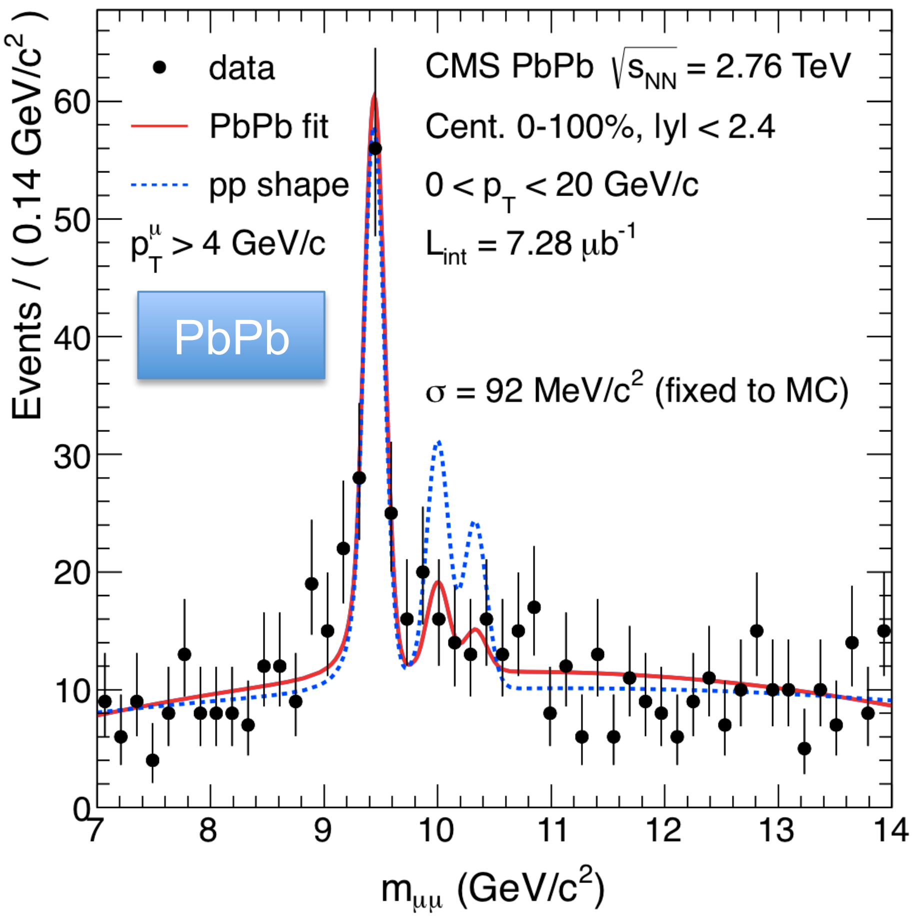
limited by pp statistics

CMS-PAS HIN-12-007

$$R_{AA}^{0-100\%}(\psi(2S)) = 0.11 \pm 0.03(\mathrm{stat}) \pm 0.02(\mathrm{syst}) \pm 0.02(\mathrm{pp})$$

Υ results (2010)





$N_{\Upsilon(2S+3S)}/N_{\Upsilon(1S)}|_{pp} = 0.78^{+0.16}_{-0.14} \pm 0.02$

$N_{\Upsilon(2S+3S)}/N_{\Upsilon(1S)}|_{PbPb} = 0.24^{+0.13}_{-0.12} \pm 0.02$

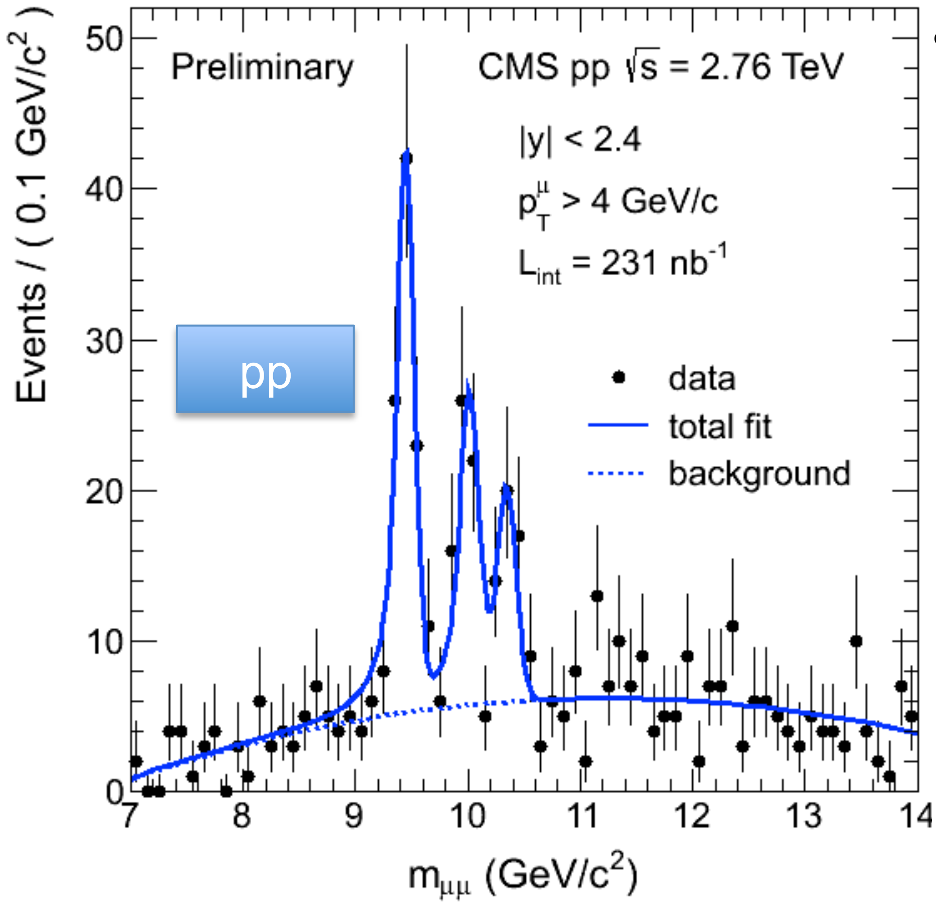
Double ratio

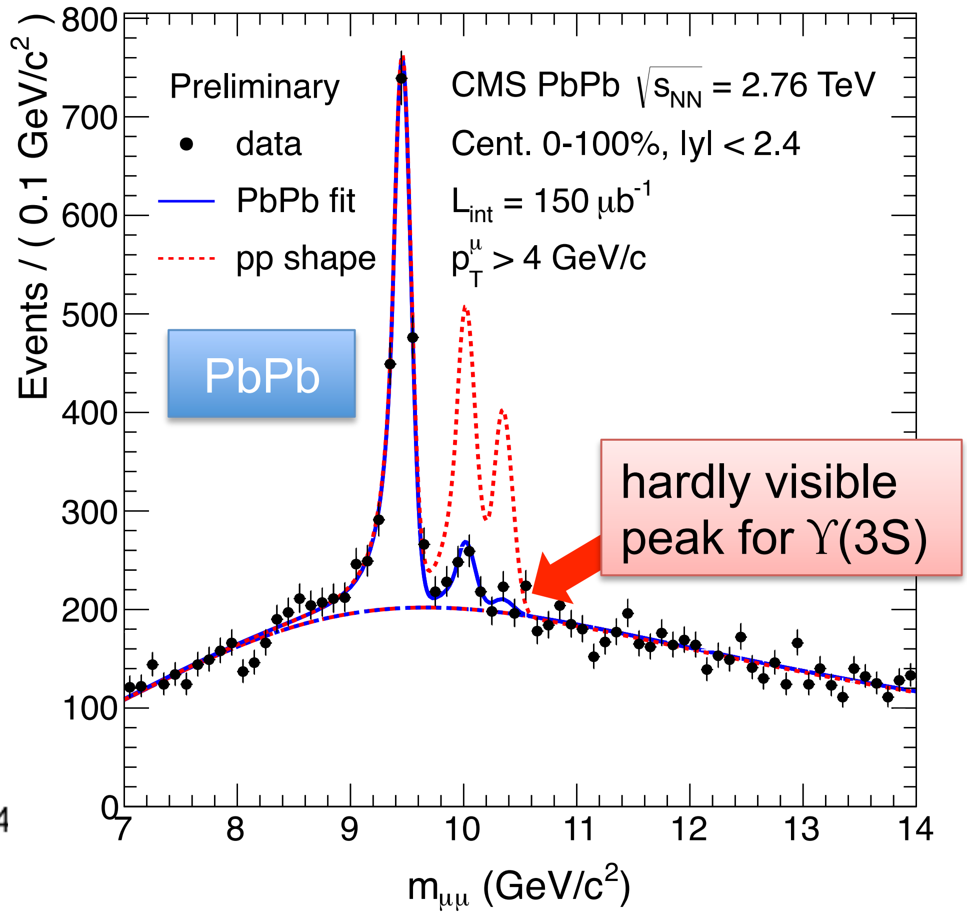
$$\frac{N_{\Upsilon(2S+3S)}/N_{\Upsilon(1S)}|_{PbPb}}{N_{\Upsilon(2S+3S)}/N_{\Upsilon(1S)}|_{pp}} = 0.31^{+0.19}_{-0.15} \pm 0.03$$

PRL 107 (2011) 052302

Υ (2S+3S) is relatively suppressed with Υ (1S)

Υ results (2011)





$$N_{\Upsilon(2S)}/N_{\Upsilon(1S)}|_{pp} = 0.56 \pm 0.13(\text{stat.}) \pm 0.02(\text{syst.})$$
$$N_{\Upsilon(3S)}/N_{\Upsilon(1S)}|_{pp} = 0.41 \pm 0.11(\text{stat.}) \pm 0.04(\text{syst.})$$

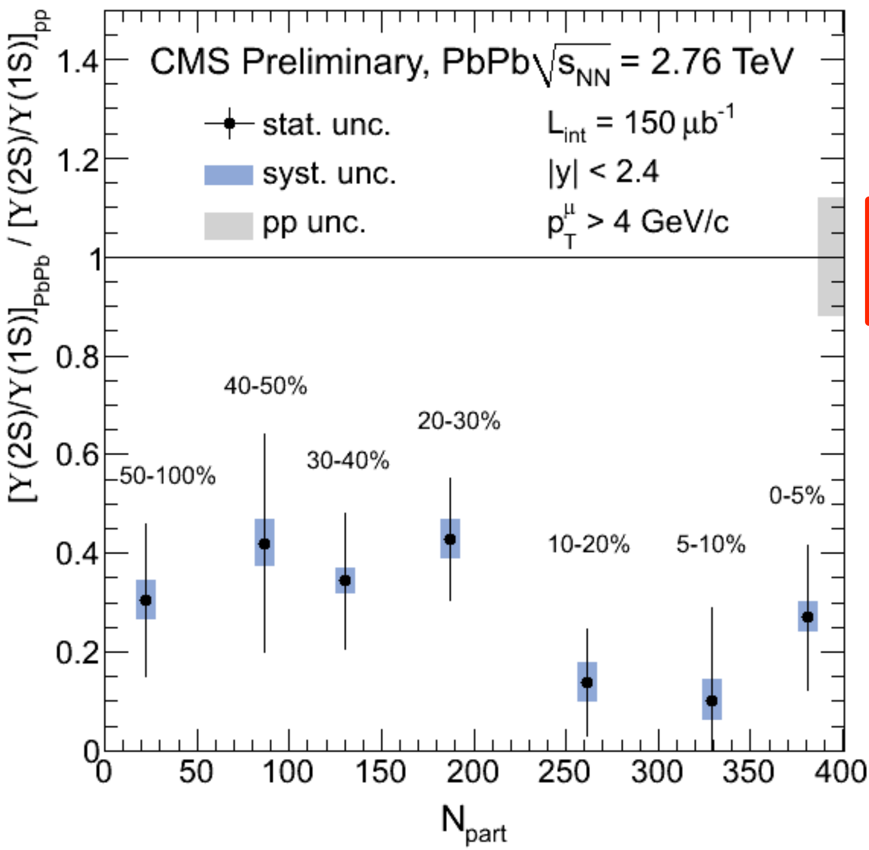
$$N_{\Upsilon(2S)}/N_{\Upsilon(1S)}|_{\text{PbPb}} = 0.12 \pm 0.03(\text{stat.}) \pm 0.02(\text{syst.})$$
$$N_{\Upsilon(3S)}/N_{\Upsilon(1S)}|_{\text{PbPb}} = 0.02 \pm 0.02(\text{stat.}) \pm 0.02(\text{syst.})$$
$$< 0.07 \text{ at } 95\% \text{ C.L.}$$

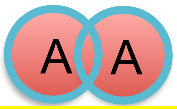
With improved statistics, separate Υ (2S) and Υ (3S)

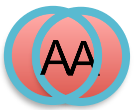
arXiv:1208.2826 (accepted by PRL)

Υ (nS) / Υ (1S) Double ratio (2011)

Υ(2S) / Υ(1S)







arXiv:1208.2826
(accepted by PRL)

- **Measured Υ(2S) double ratio vs. centrality**
  - centrality integrated:

$$\frac{N_{\Upsilon(2S)}/N_{\Upsilon(1S)}|_{PbPb}}{N_{\Upsilon(2S)}/N_{\Upsilon(1S)}|_{pp}} = 0.21 \pm 0.07(\mathrm{stat.}) \pm 0.02(\mathrm{syst.})$$

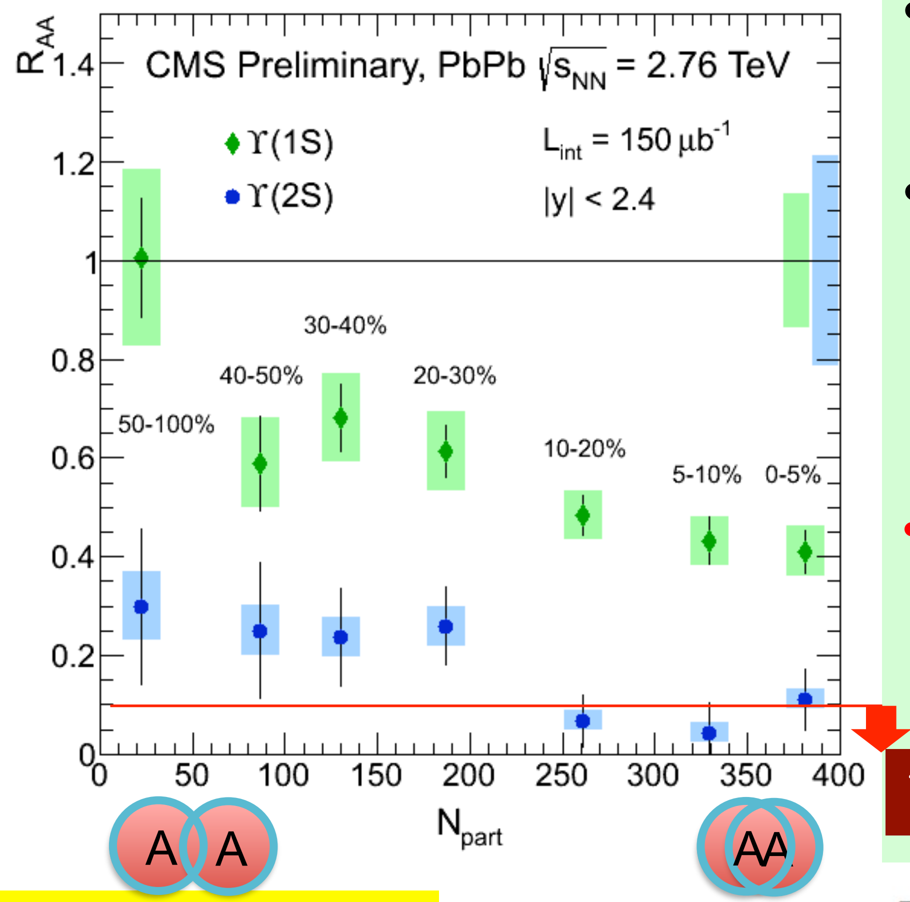
  - no strong centrality dependence
- **Upper limit on Υ(3S)**
  - peak at PbPb is hard to distinguish : set the upper limit
  - centrality integrated:

$$\frac{N_{\Upsilon(3S)}/N_{\Upsilon(1S)}|_{PbPb}}{N_{\Upsilon(3S)}/N_{\Upsilon(1S)}|_{pp}} = 0.06 \pm 0.06(\mathrm{stat.}) \pm 0.06(\mathrm{syst.})$$

$$< 0.17 \text{ at } 95\% \text{ C.L.}$$

Υ(nS) R_{AA} (2011)

$$R_{AA} = \frac{\mathcal{L}_{pp}}{T_{AA} N_{\mathrm{MB}}} \frac{N_{\mathrm{PbPb}}(\Upsilon(\mathrm{nS}))}{N_{pp}(\Upsilon(\mathrm{nS}))} \frac{\varepsilon_{pp}}{\varepsilon_{\mathrm{PbPb}}}$$



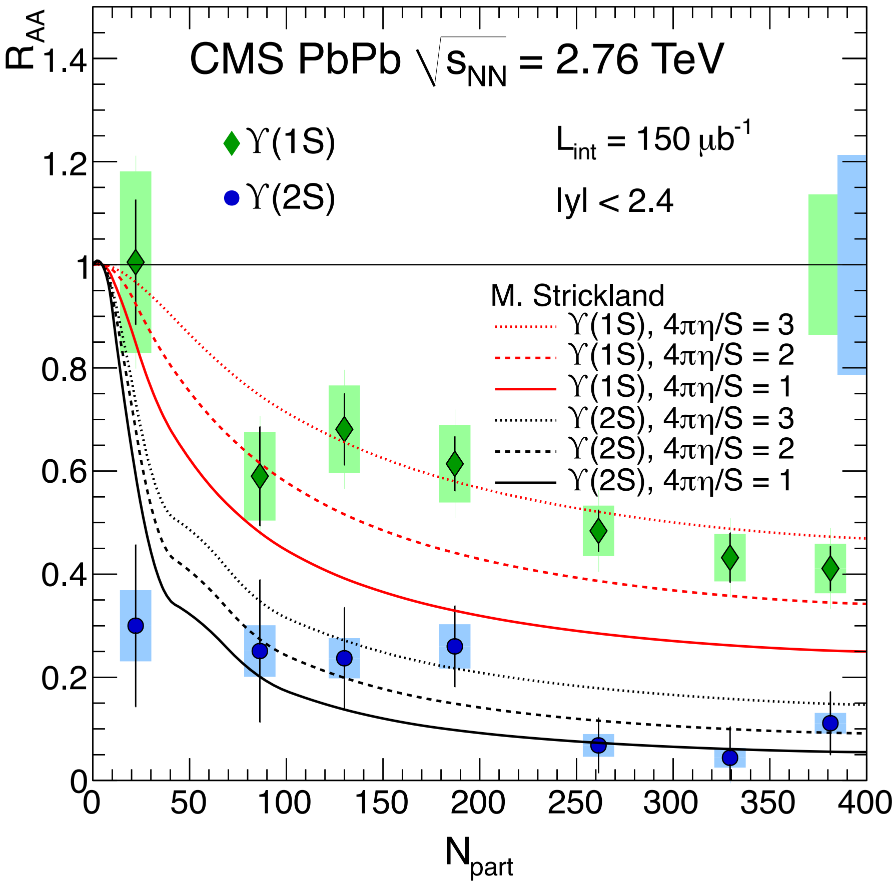
arXiv:1208.2826
(accepted by PRL)

- first results on Υ(2S) R_{AA}
- similar suppression pattern between Υ(1S) and Υ(2S)
- Υ(1S) suppression is consistent with suppression of excited state only considering ~50% feed down
- **Υ(1S) R_{AA} > Υ(2S) R_{AA} > Υ(3S) R_{AA}**

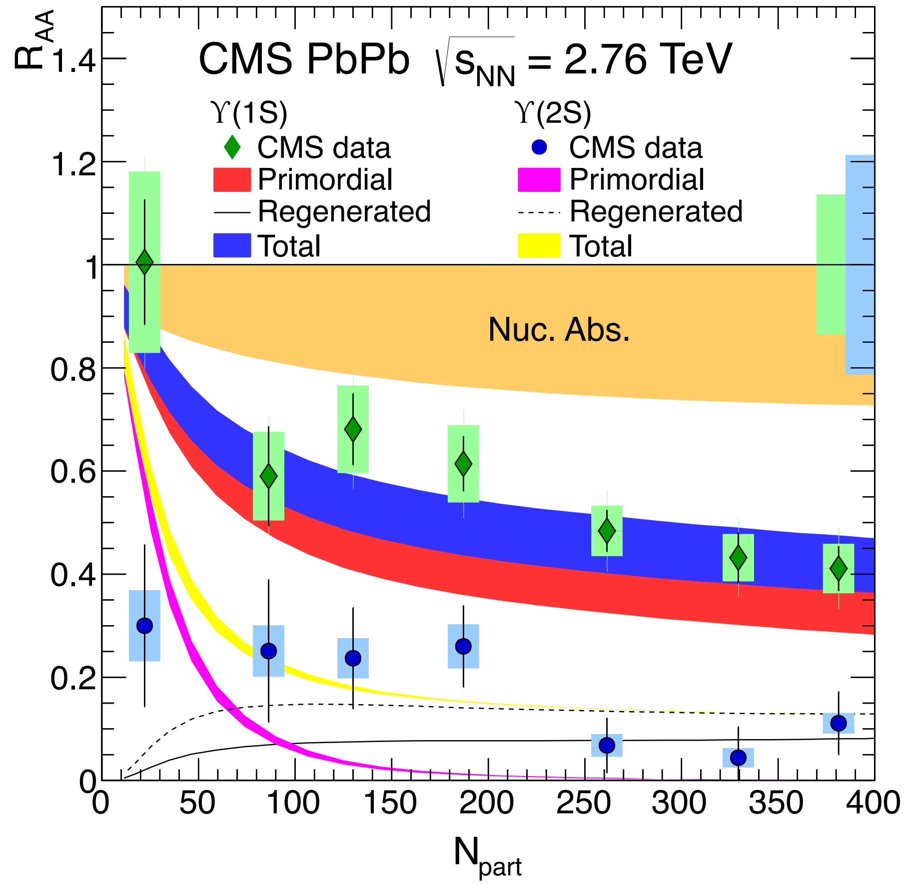
Υ(3S) R_{AA} (95% C.L.)

$$R_{AA}(\Upsilon(1S)) = 0.56 \pm 0.08\,(\text{stat.}) \pm 0.07\,(\text{syst.})$$
$$R_{AA}(\Upsilon(2S)) = 0.12 \pm 0.04\,(\text{stat.}) \pm 0.02\,(\text{syst.})$$
$$R_{AA}(\Upsilon(3S)) = 0.03 \pm 0.04\,(\text{stat.}) \pm 0.01\,(\text{syst.})$$
$$< 0.10 \quad (95\%\ \text{C.L.}).$$

Υ(1S) and Υ (2S) R_{AA} : theory comparison



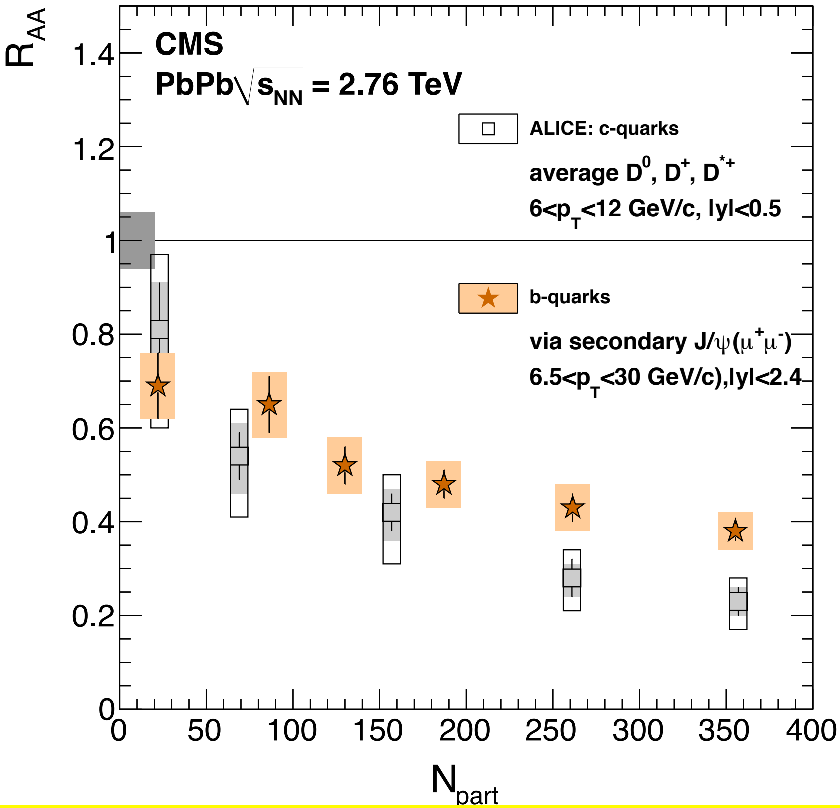
arXiv : 1207.5327v2

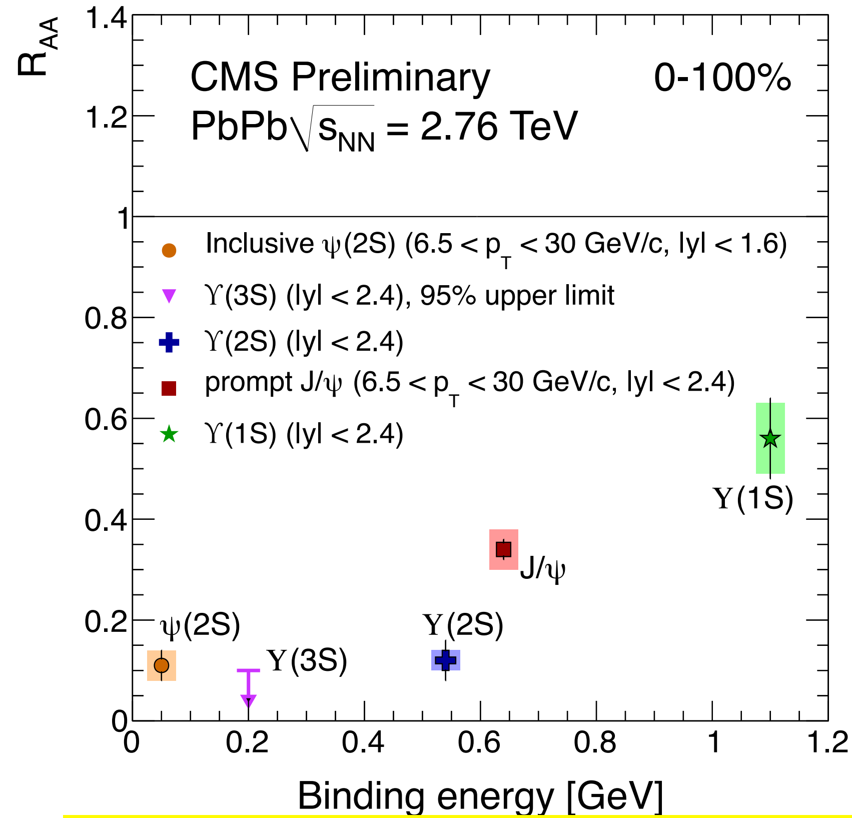


Eur.Phys.J.A48 (2012) 72

Υ(1S) and Υ(2S) results are consistent with the theoretical model within uncertainties

Summary





ALICE : JHEP 1209 (2012) 112
CMS : CMS-PAS HIN-12-014

Υ(nS) : arXiv:1208.2826(accepted by PRL)
ψ(2S) : CMS-PAS HIN-12-007
J/ψ : CMS-PAS HIN-12-014

- In central collisions, $R_{AA}^{charm} < R_{AA}^{bottom}$
- CMS results show the sequential melting of quarkonium states
  - Hot and cold matter effects have not been disentangled yet.
  - pPb run will be important to quantify cold nuclear matter effects.

We will prepare and expect the result from pPb collisions in 2013.


ATHIC
Thank you
고맙습니다