Charmonium suppression in Pb-Pb collisions from CMS

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The 9th International Workshop
on Heavy Quarkonium
IHEP, Beijing, China, Apr 23rd, 2013

Contents

- Motivation of the study
- CMS detector(Muon reconstruction mechanism)
- Results (until Quark Matter 2012)
  - Charmonia
    - prompt J/ψ
    - non-prompt J/ψ
    - ψ(2S)
  - Bottomonia – Υ(1S, 2S, 3S)

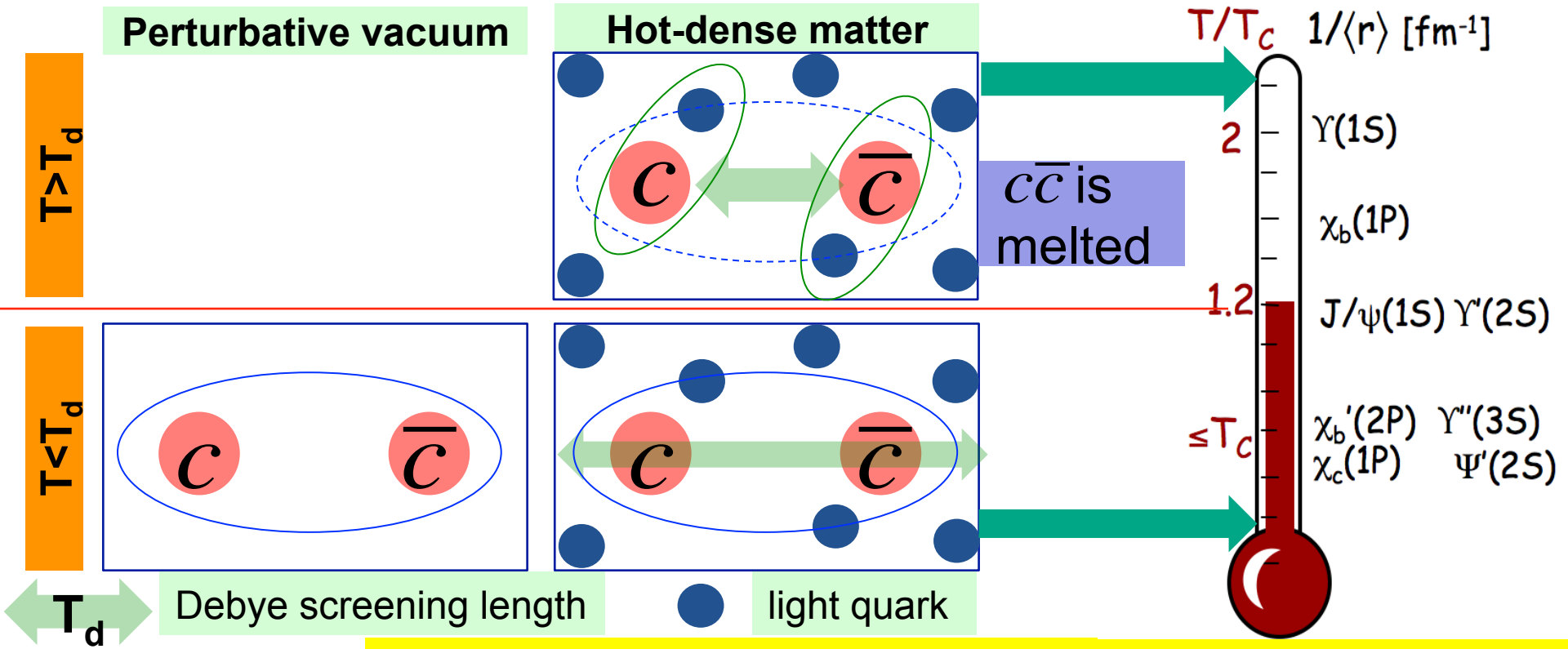
  : Byungsik Hong's talk (Next session, 3rd talk)
- Summary

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**
- **Use sequential melting of the quarkonia states as the thermometer of the hot and dense matter**



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

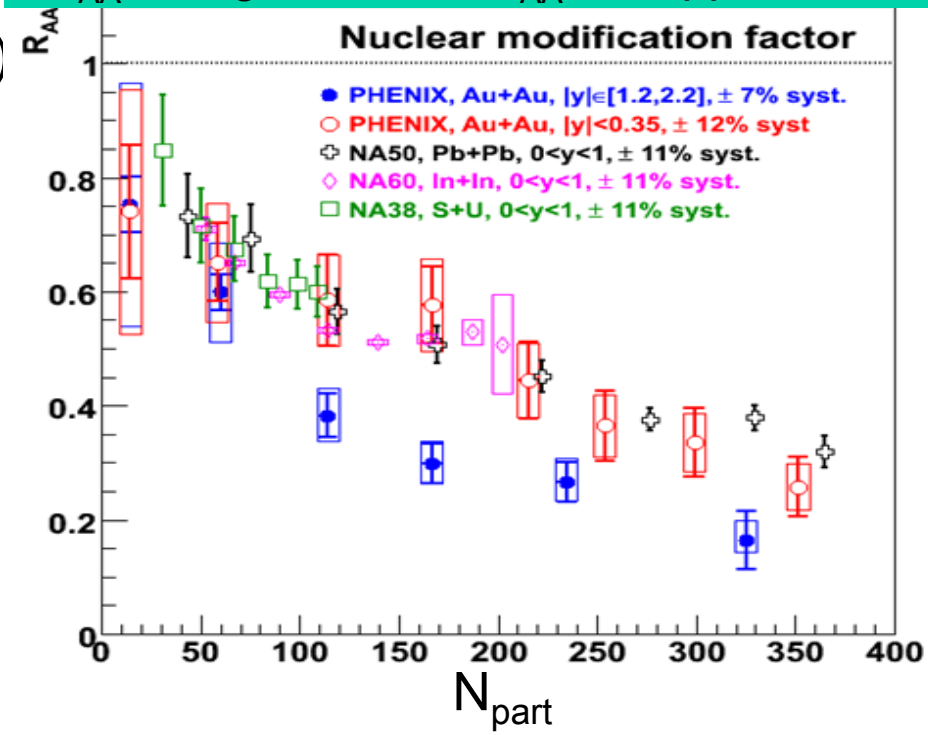
Mocsy, EPJ C 61 (2009) 705

Experimental motivation

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

- **Puzzles from SPS and RHIC**
  - Similar J/ψ suppression at SPS(< 20 GeV) and RHIC(200 GeV)
  - Suppression does not increase with local energy density
    R_{AA}(forward) < R_{AA}(mid)
  - Possible answers
    - regeneration?
    - cold nuclear matter effects?

R_{AA} : Nuclear Modification Factor
R_{AA}>1:regeneration, R_{AA}<1:suppression

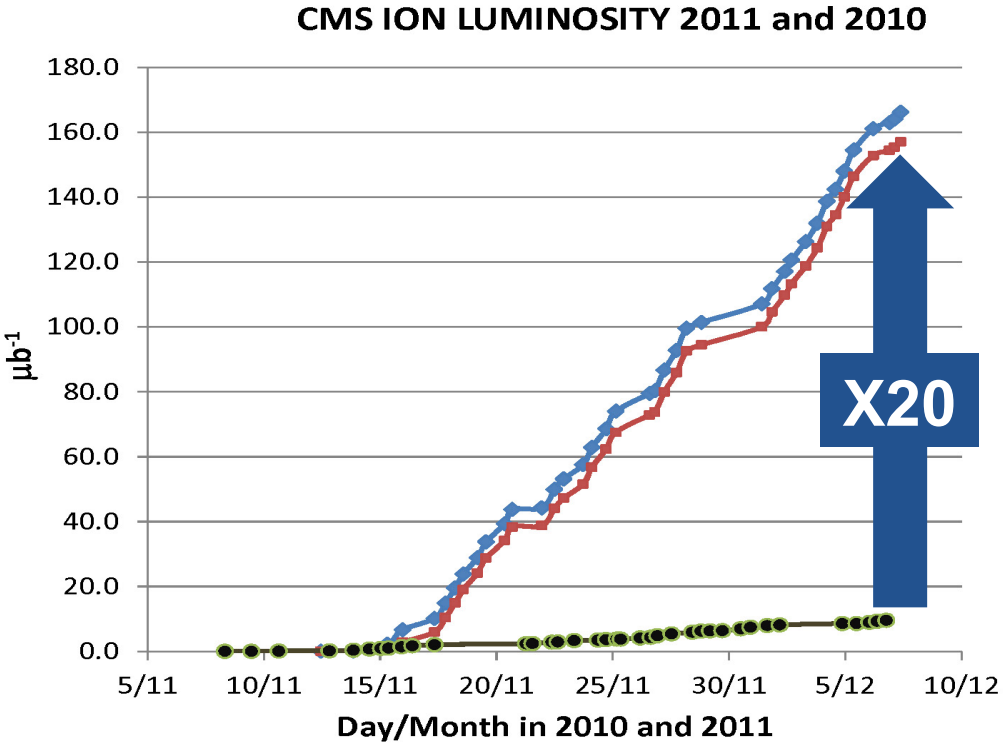


- **LHC can give the hint**
  - higher energy(PbPb@2.76 TeV, pPb@5.02 TeV)
  - higher luminosity(peak instant luminosity : 0.5 Hz/μb@PbPb)
  - more charm (possible to regenerate)
  - more bottom → a new probe : ϒ

Summary of Pb-Pb collision from LHC

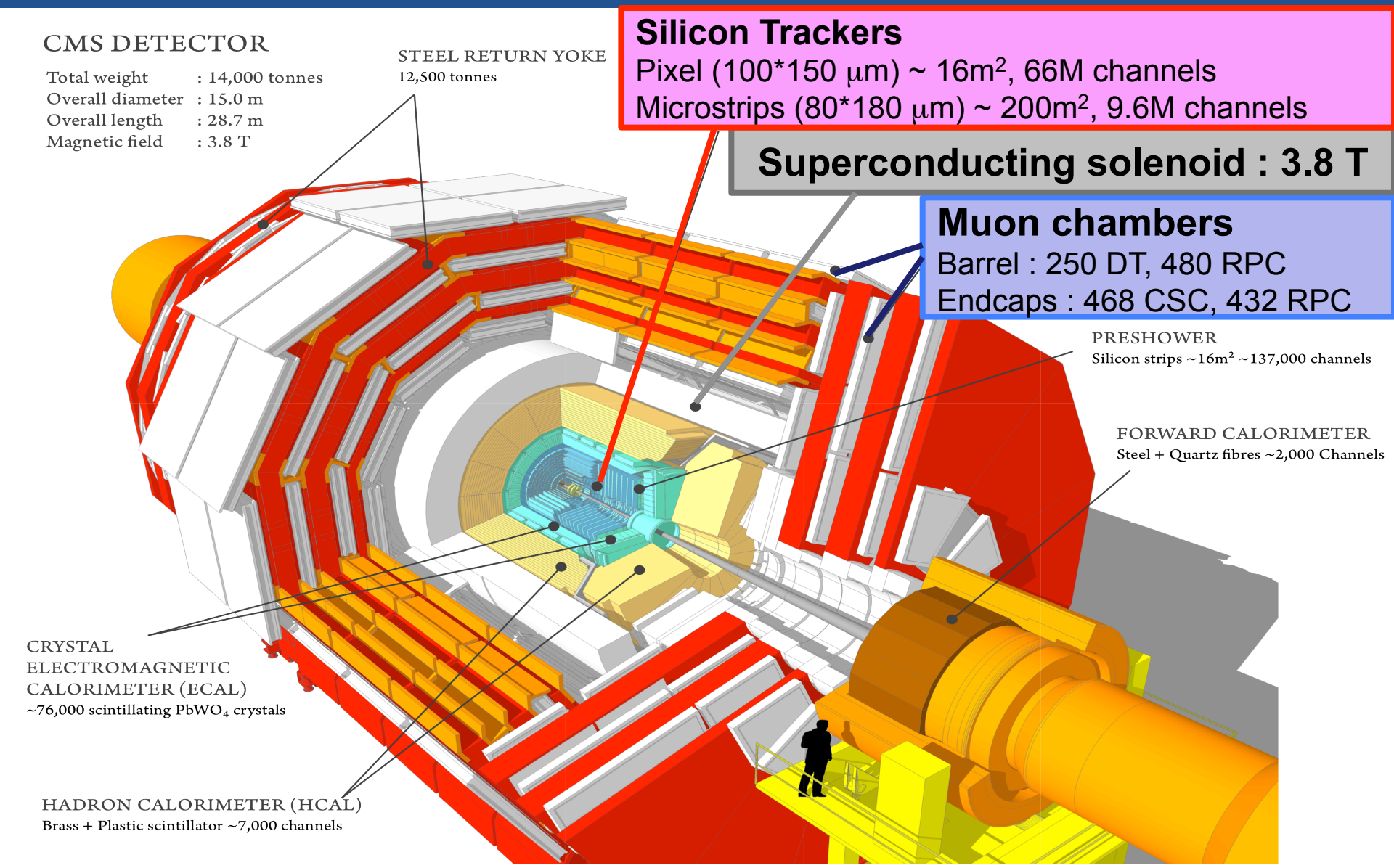
- **Pb-Pb collision**
  - 2.76 TeV per nucleon pair
  - ~1 month per year

  in 2010, 2011
  - Integrated luminosity
    - 2010 : 7.28 μb^{-1}
    - 2011 : 157.6 μb^{-1} recorded



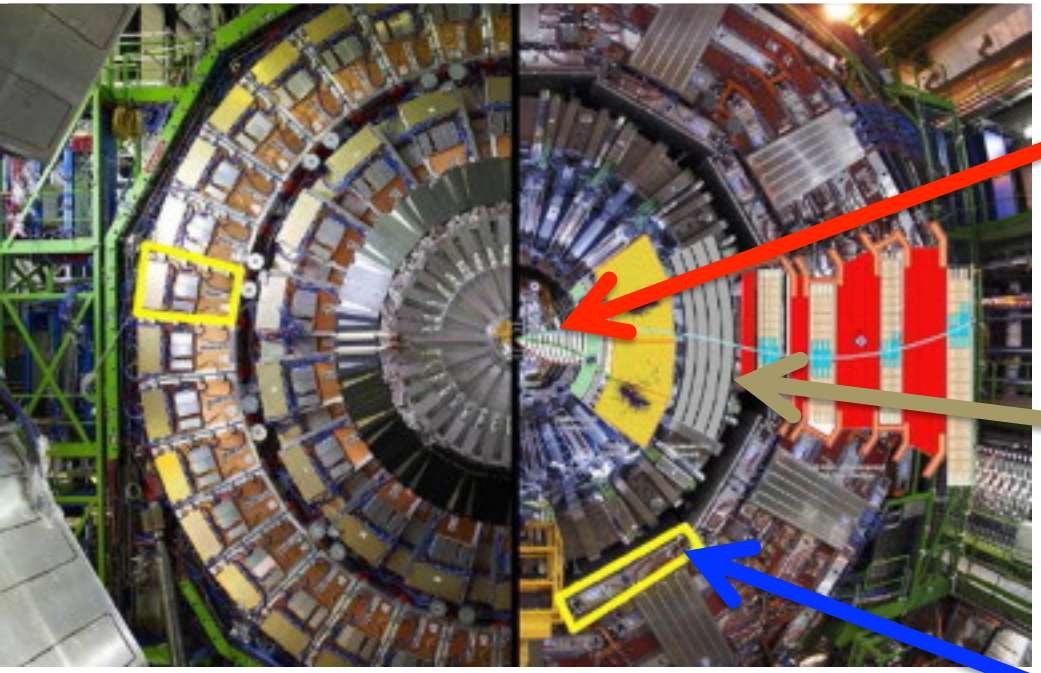
- **pp collision@2.76 TeV per nucleon**
  - For comparison with Pb-Pb collision@2.76 TeV per nucleon pair
  - Equivalent statistics compared to the integrated luminosity of the 2010 HI run

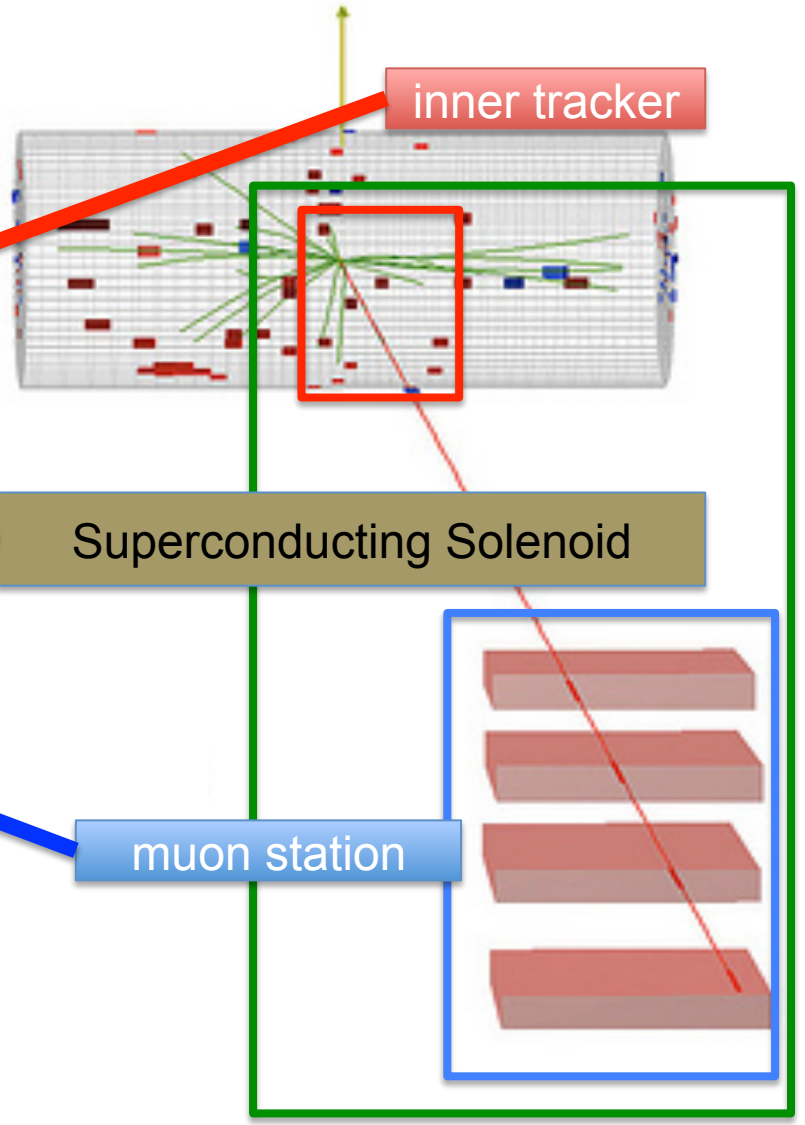
CMS detector



CMS muon reconstruction mechanism

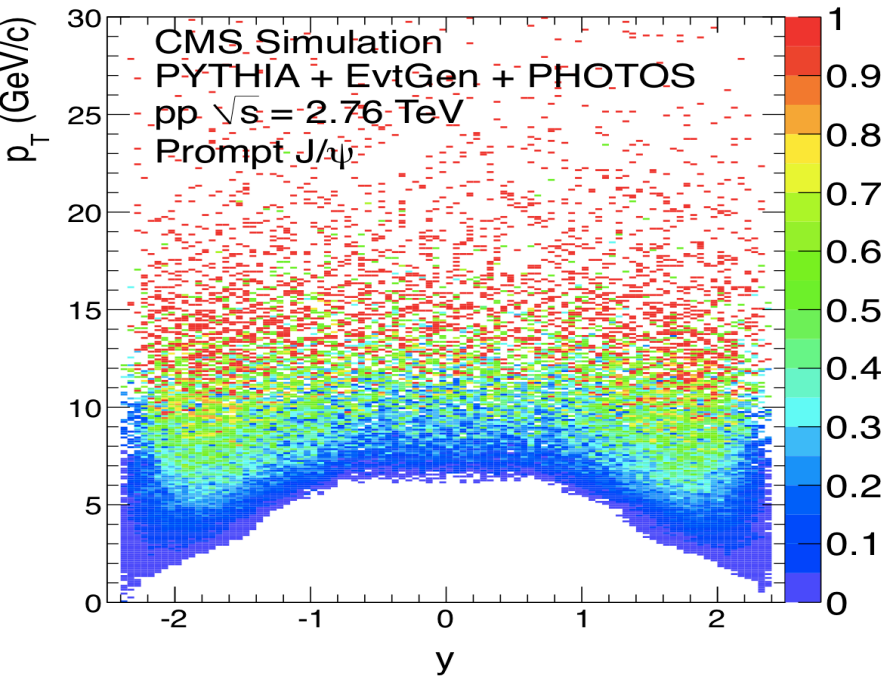
Endcap **Barrel**



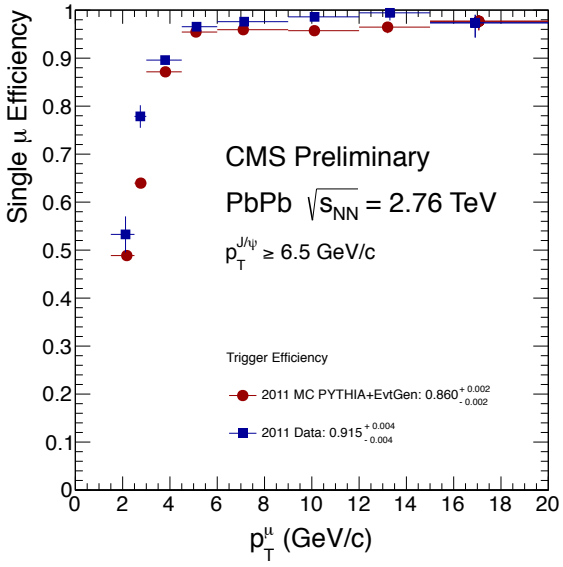


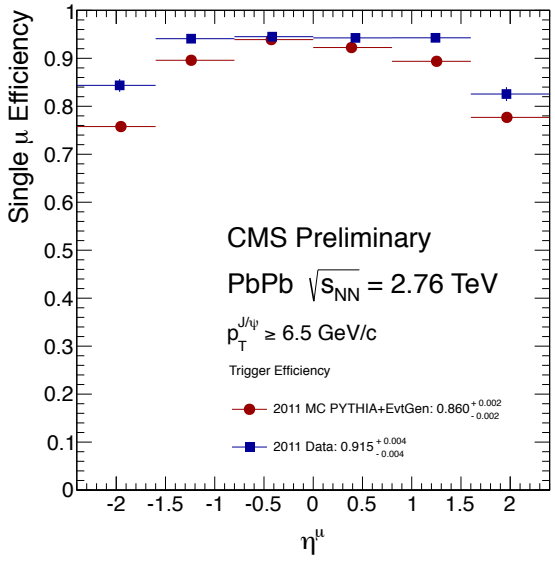
- **Global muons reconstructed with information from inner tracker and muon stations**
- **Apply with additional further muon ID quality cut (χ^2, # of hits)**

Acceptance and Efficiency



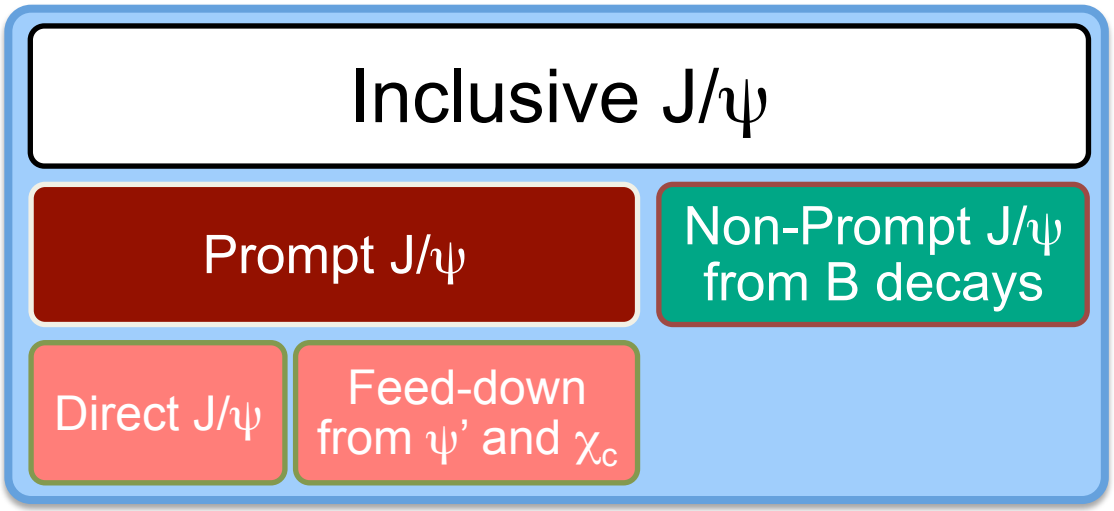
- Because of the magnetic field and energy loss (2~3 GeV) in the iron yoke, Global muons need minimum p_μ to reach the muon stations
  (3~5 GeV, depending on η)
- Limits J/ψ acceptance
  - mid-rapidity: $p_{T,\,J/\psi}$>6.5 GeV/c
  - forward: $p_{T,\,J/\psi}$>3 GeV/c

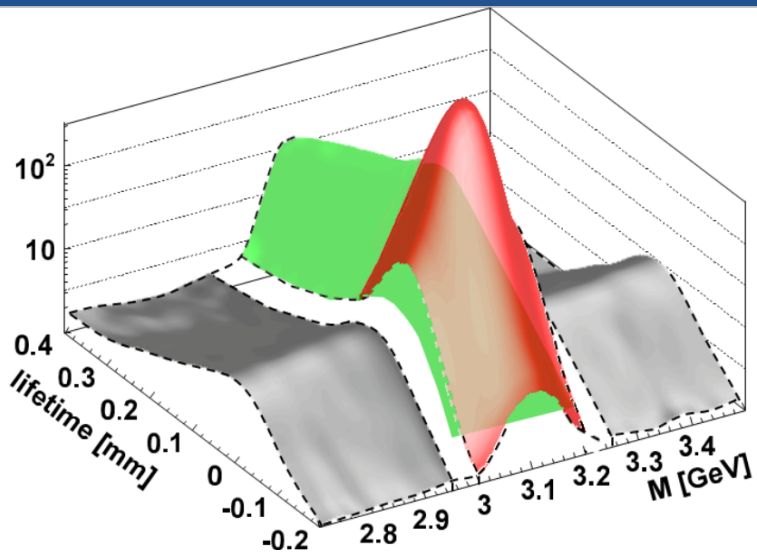




- Efficiencies are evaluated with MC
- Crosschecked with tag-and-probe method in data and MC

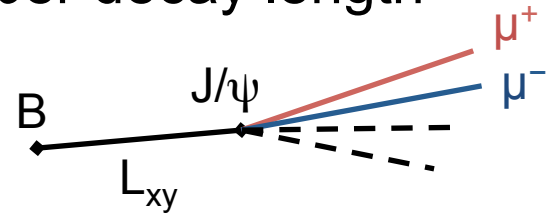
Prompt, non-prompt J/ψ signal extraction

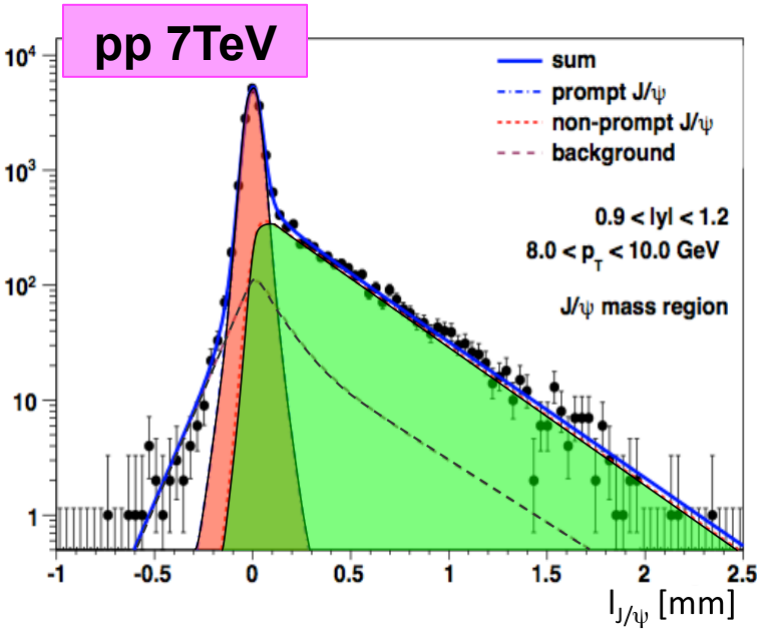




- **Reconstruct $\mu^+\mu^-$ vertex**
- **Separation of prompt and non-prompt J/ψ**
  - by 2D simultaneous fit of $\mu^+\mu^-$ mass and pseudo-proper decay length

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

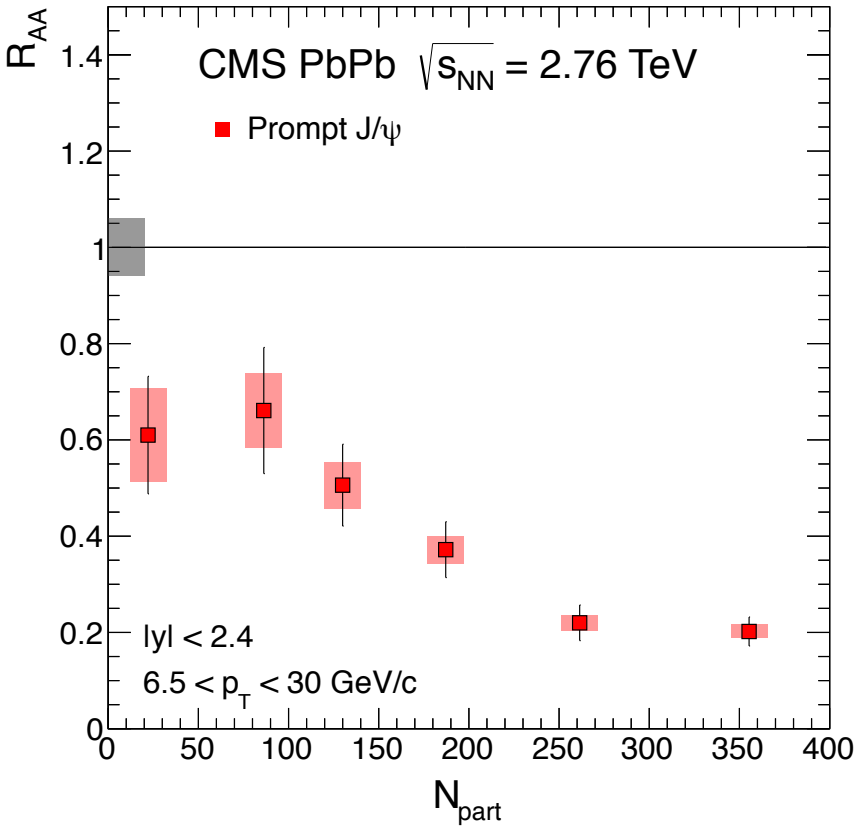




Prompt J/ψ R_{AA} : centrality dependence

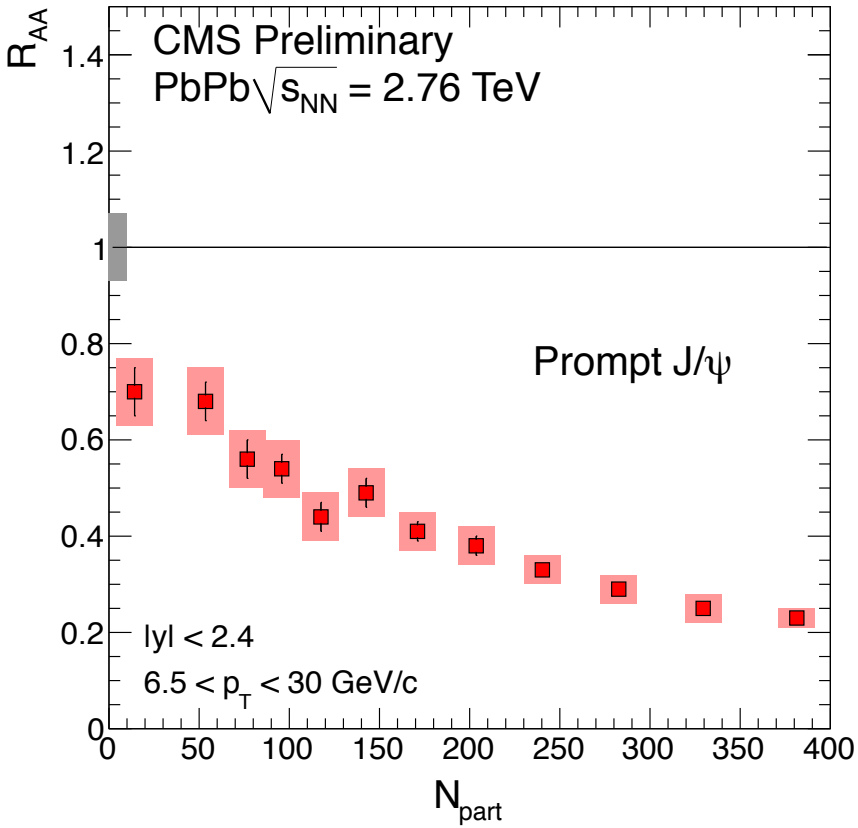
2010

JHEP 1205 (2012) 063



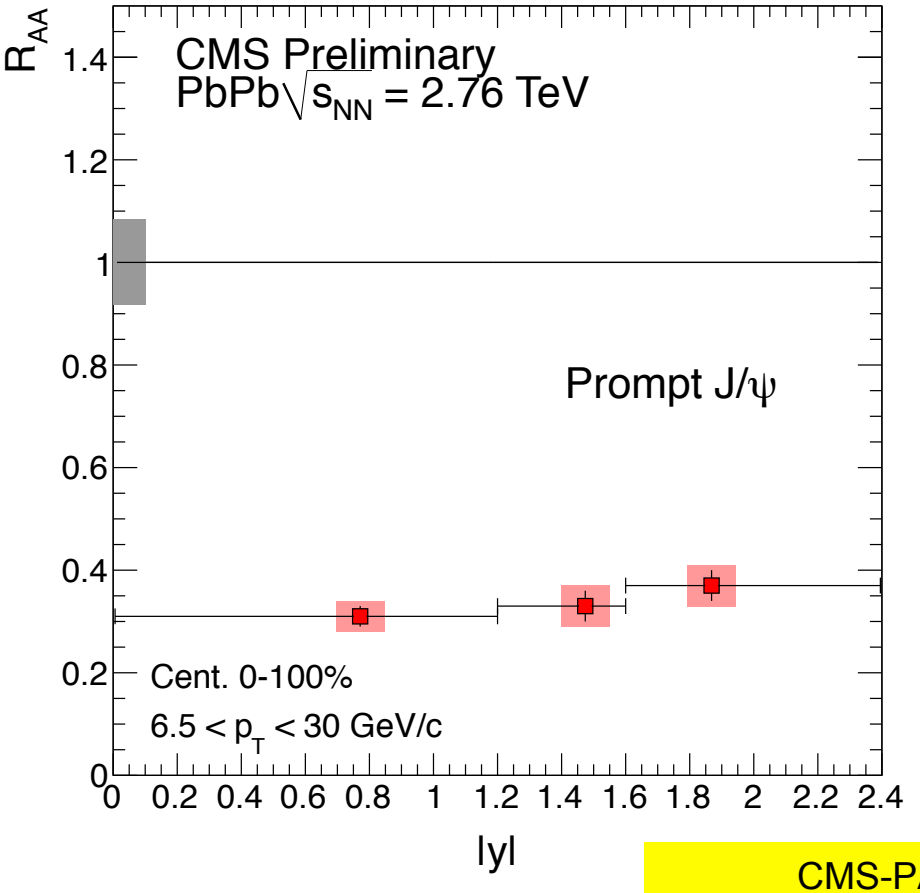
2011

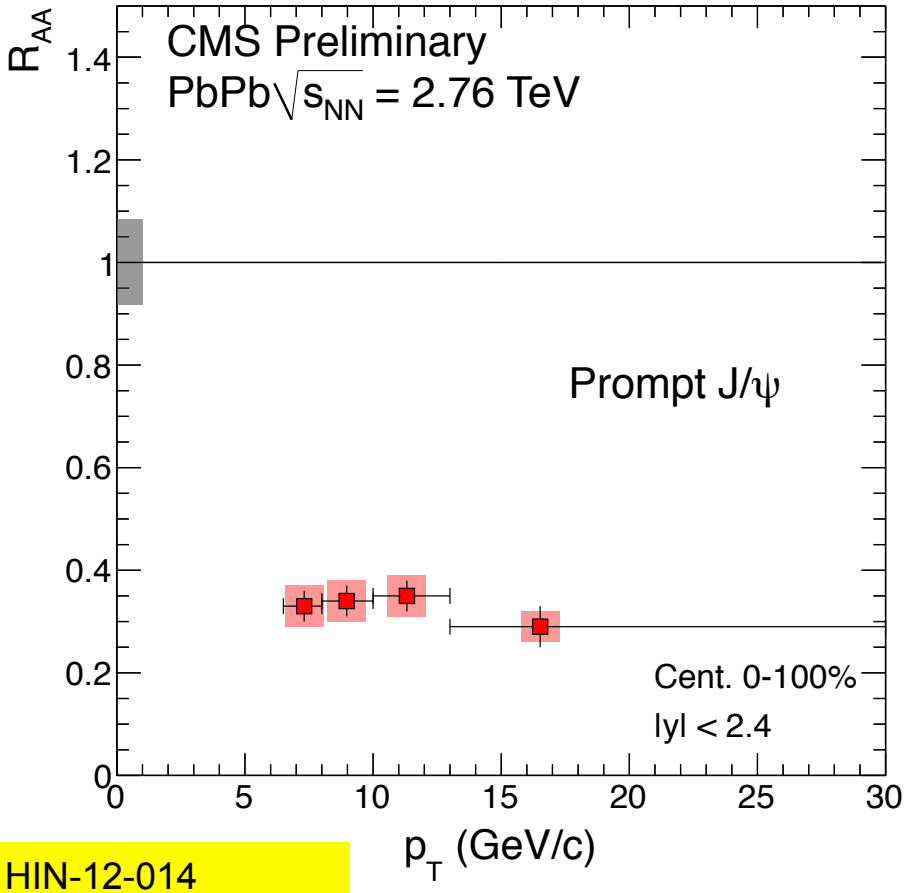
CMS-PAS HIN-12-014



- With more statistics binning is more finer
- Suppressed by factor 5 in most central collision

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



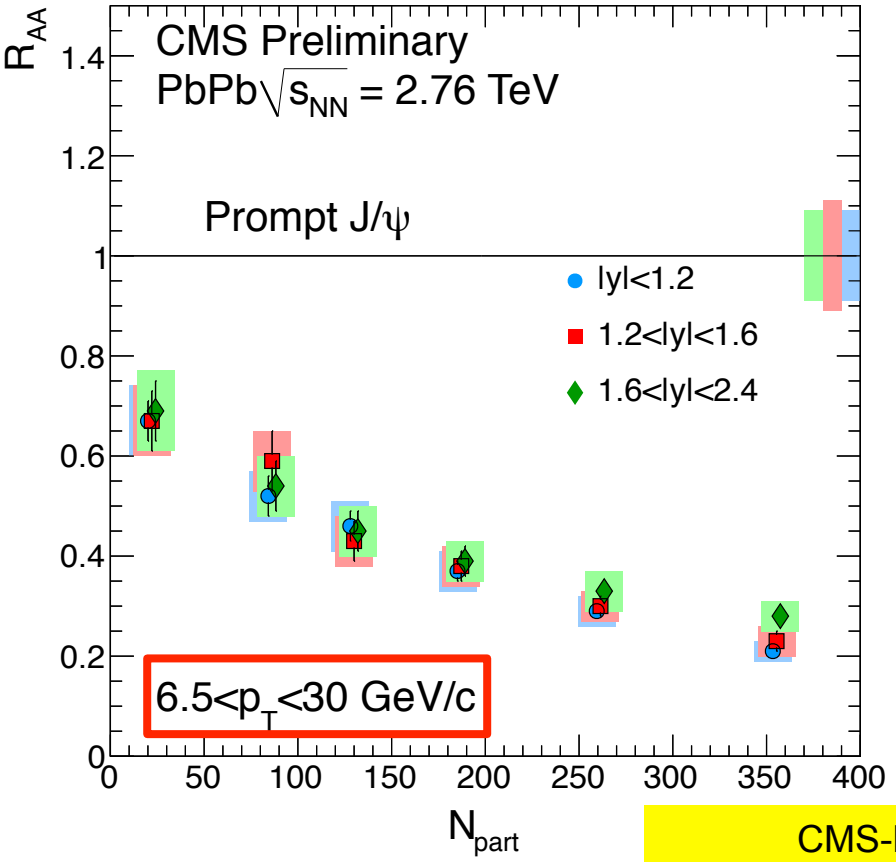


CMS-PAS HIN-12-014

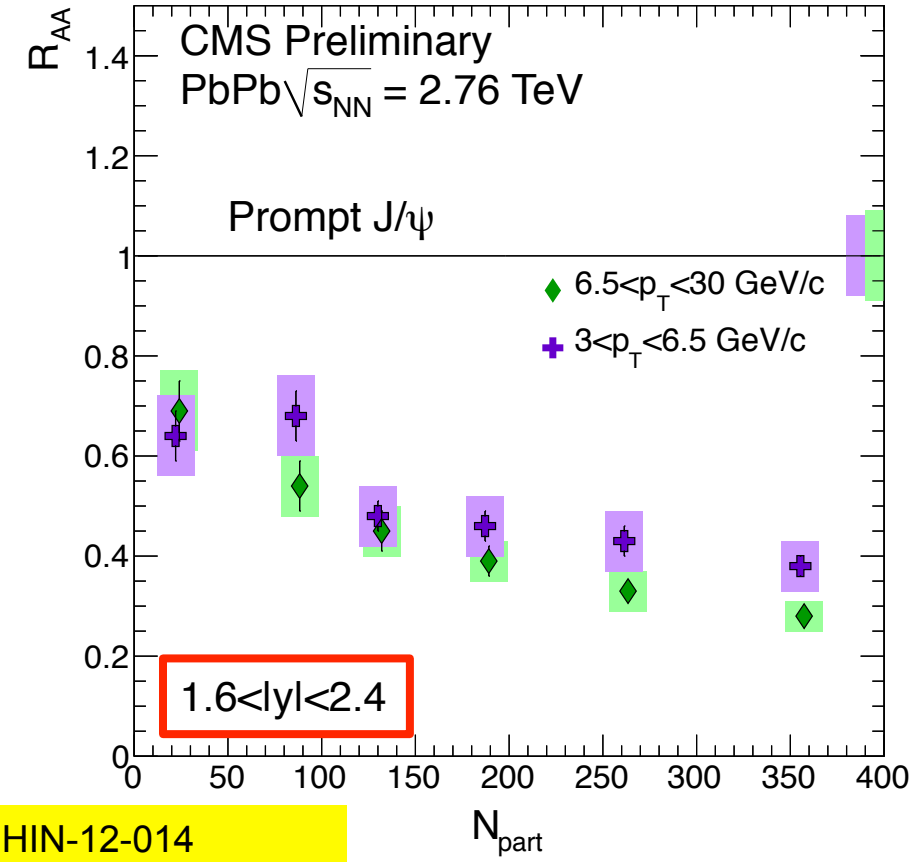
- No strong dependence on p_T and rapidity

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

Rapidity dependence



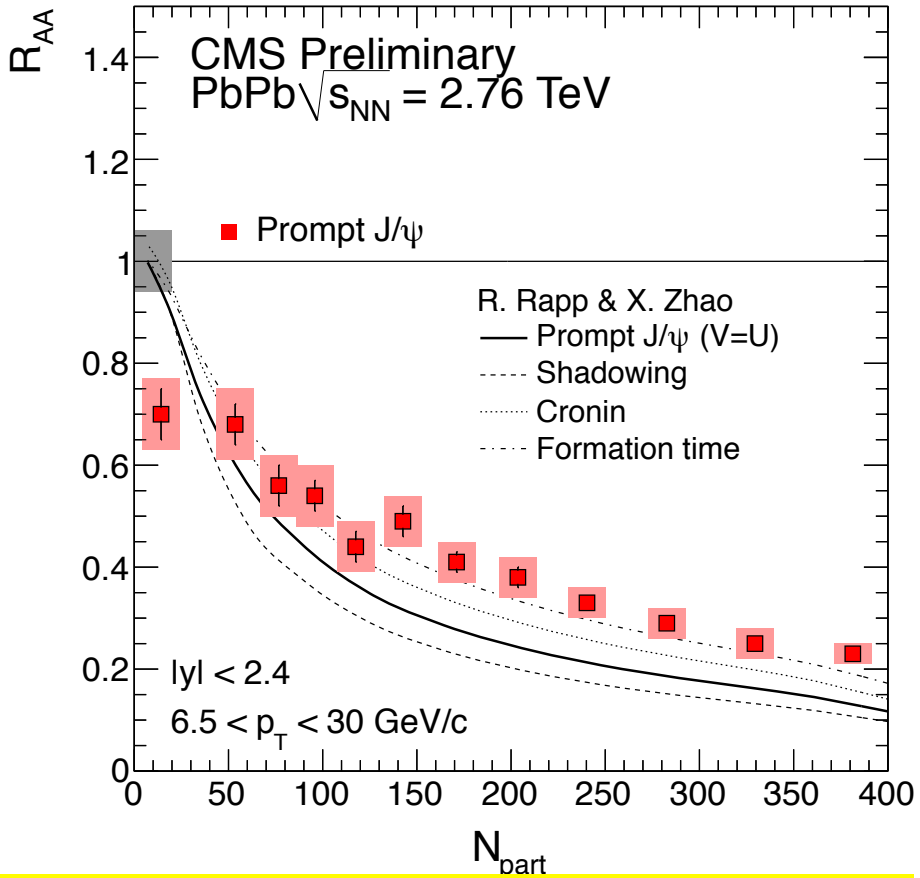
p_T dependence



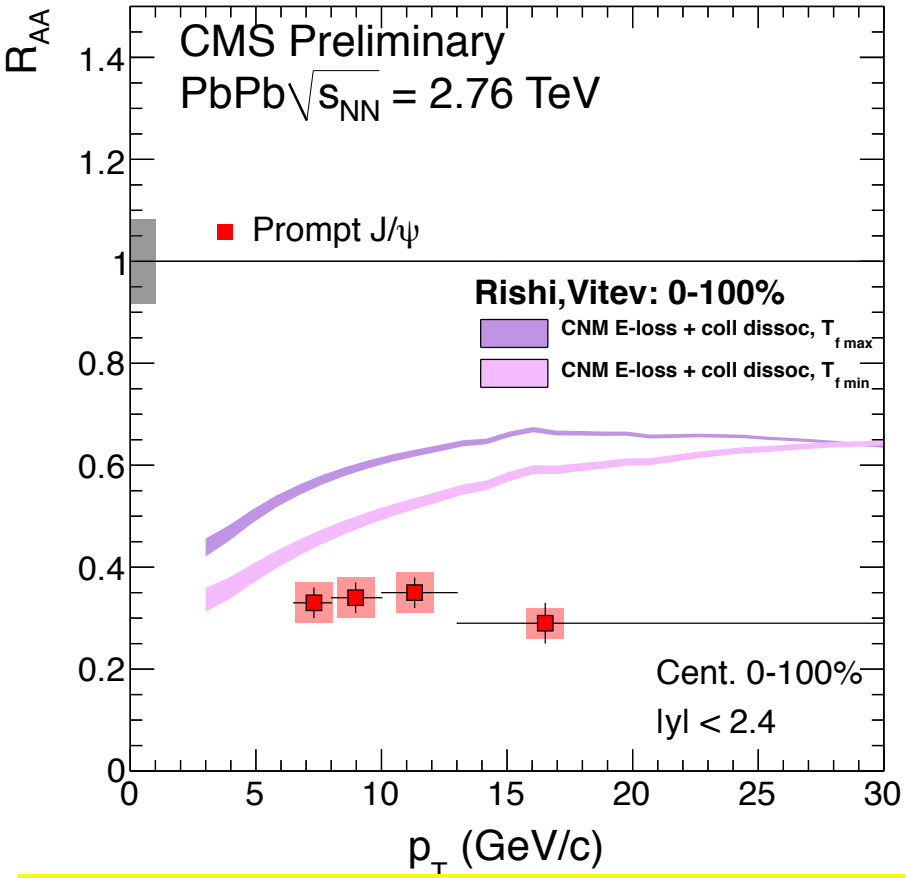
CMS-PAS HIN-12-014

- No strong dependence on rapidity at higher p_T region
- At forward rapidity region, there might be suppression of lower p_T J/ψ

Prompt J/ψ R_{AA} : theory comparison



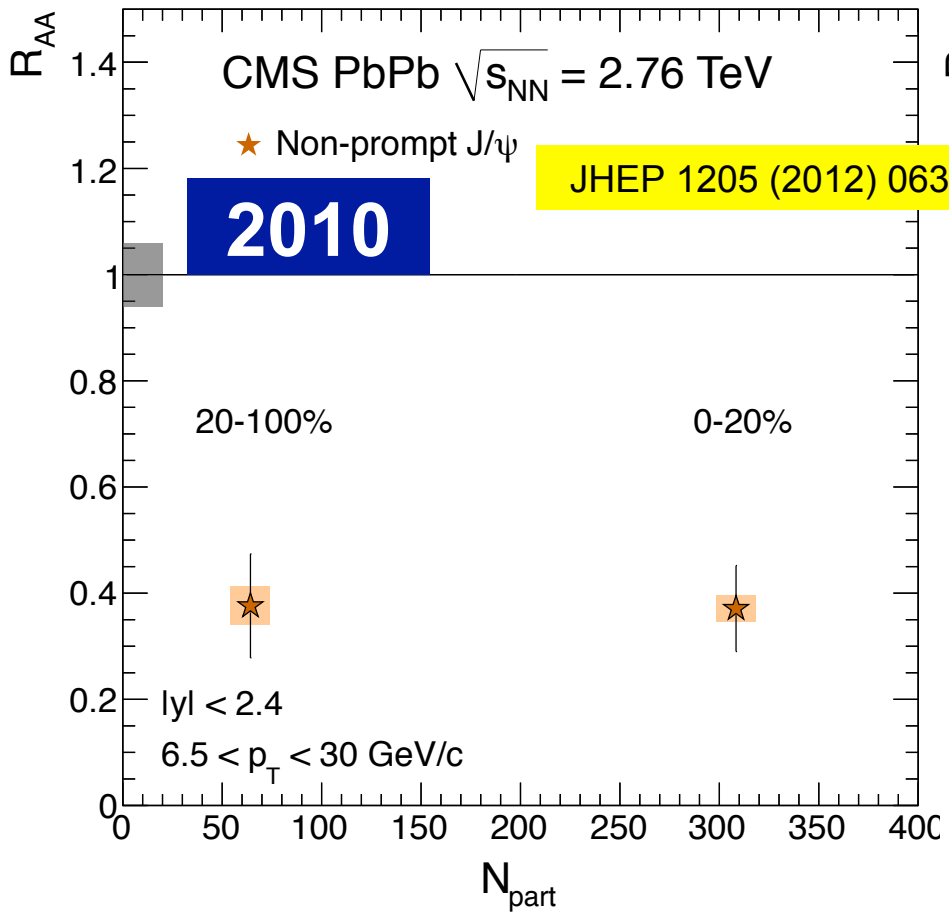
NPA 859 (2011) 114 + private communication

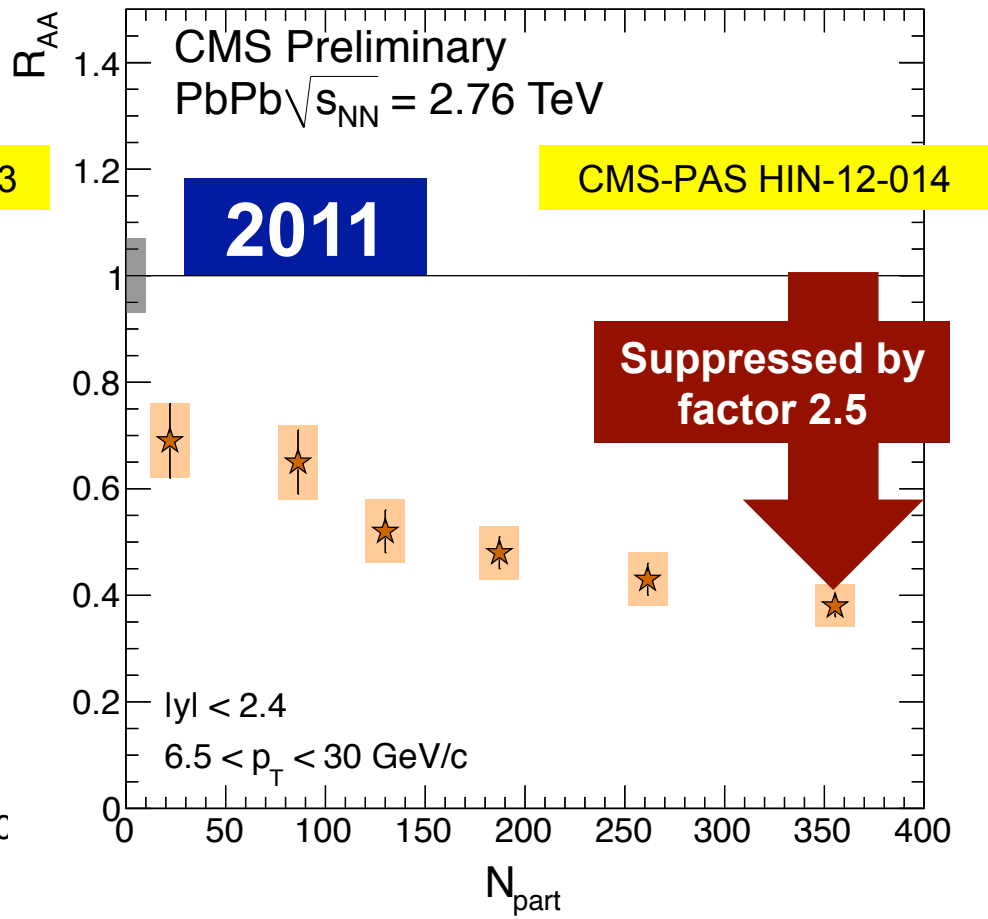


arXiv:1203.0329 + private communication

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

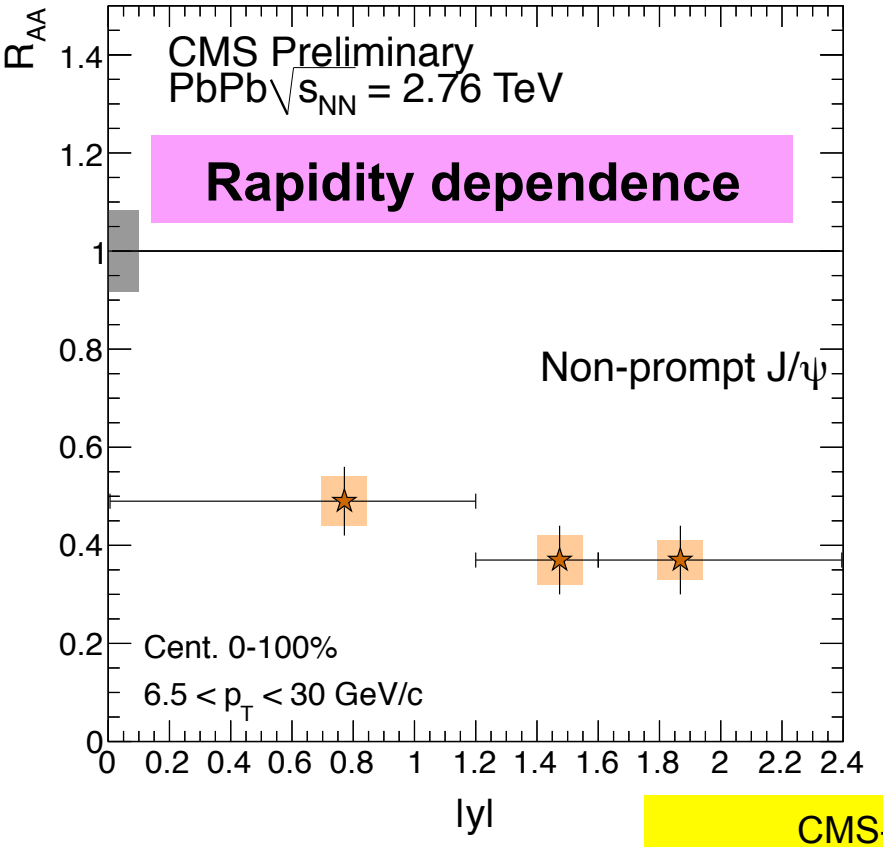
non-prompt J/ψ R_{AA} : centrality dependence

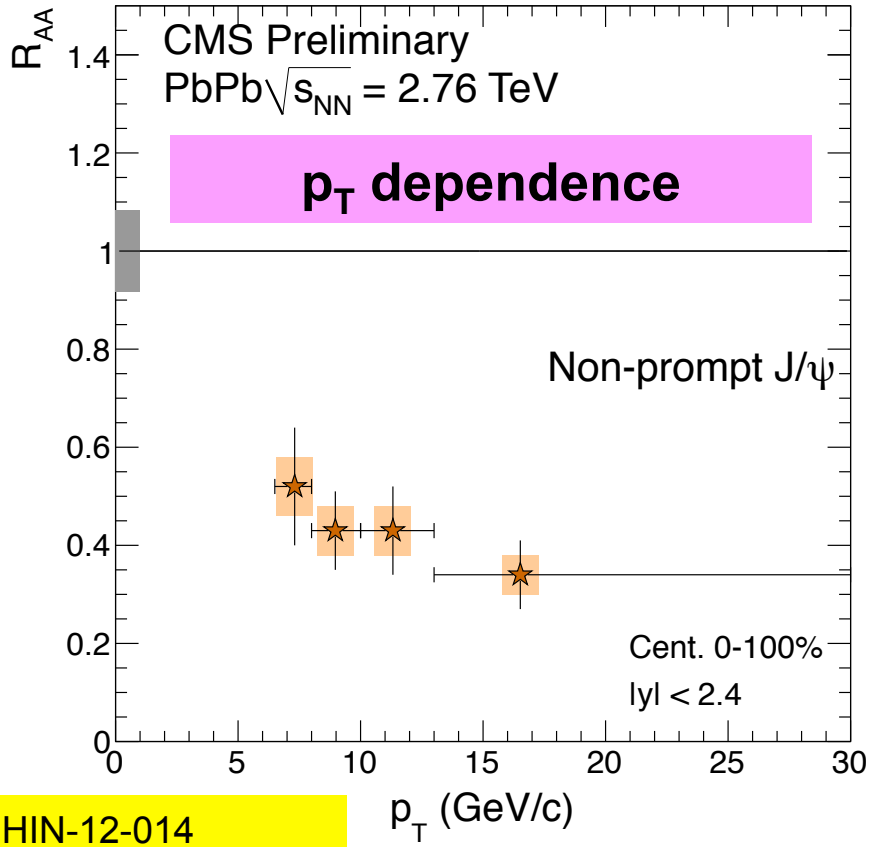




- With more statistics we observed the centrality dependent suppression of non-prompt J/ψ.
- Directly measuring the b-quark energy loss in the medium

non-prompt J/ψ R_{AA} : y and p_T dependence





CMS-PAS HIN-12-014

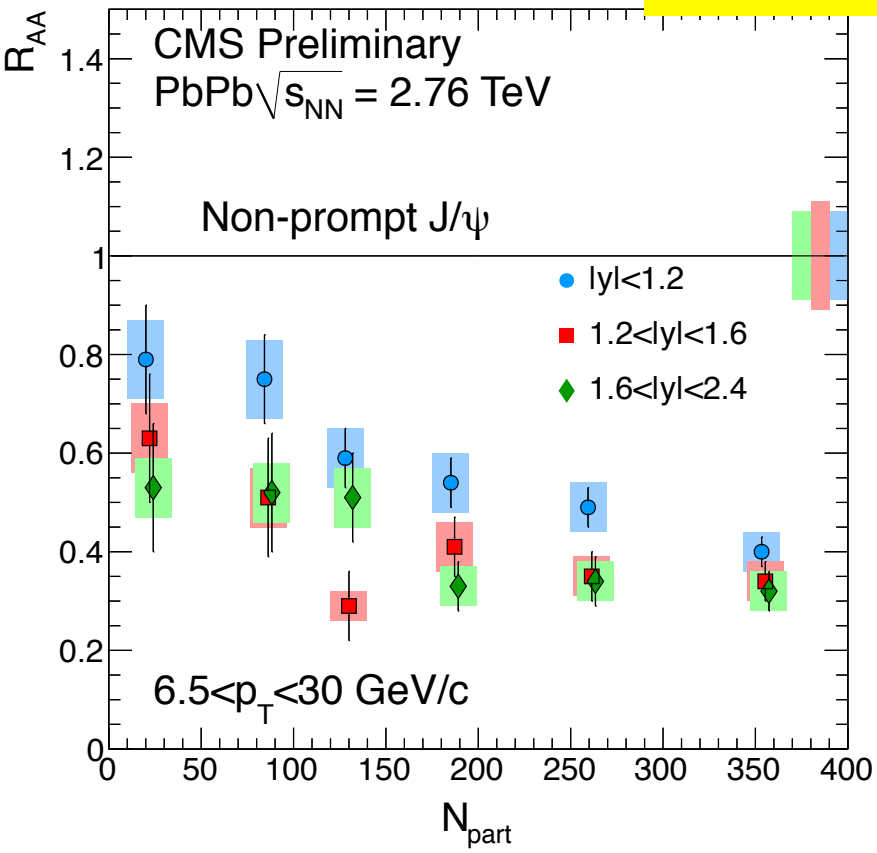
- non-prompt J/ψ is less suppressed in mid-rapidity region than in forward region
- non-prompt J/ψ in lower p_T is slightly less suppressed than in higher p_T

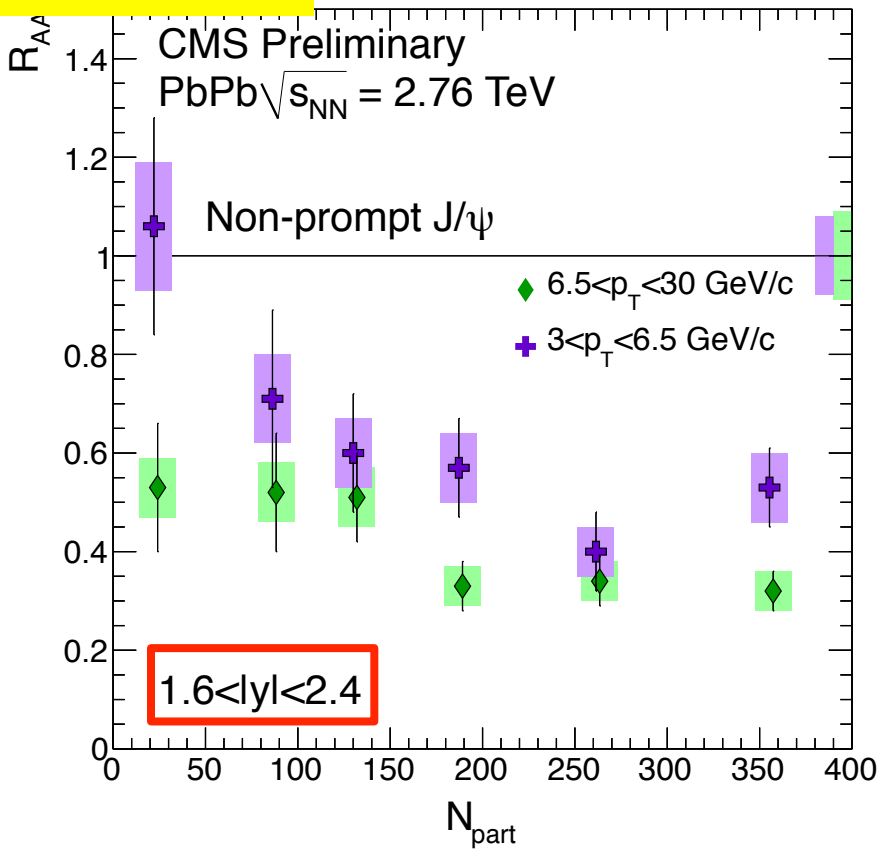
non-prompt J/ψ R_{AA} : y & p_T dependence on centrality

Rapidity dependence

p_T dependence

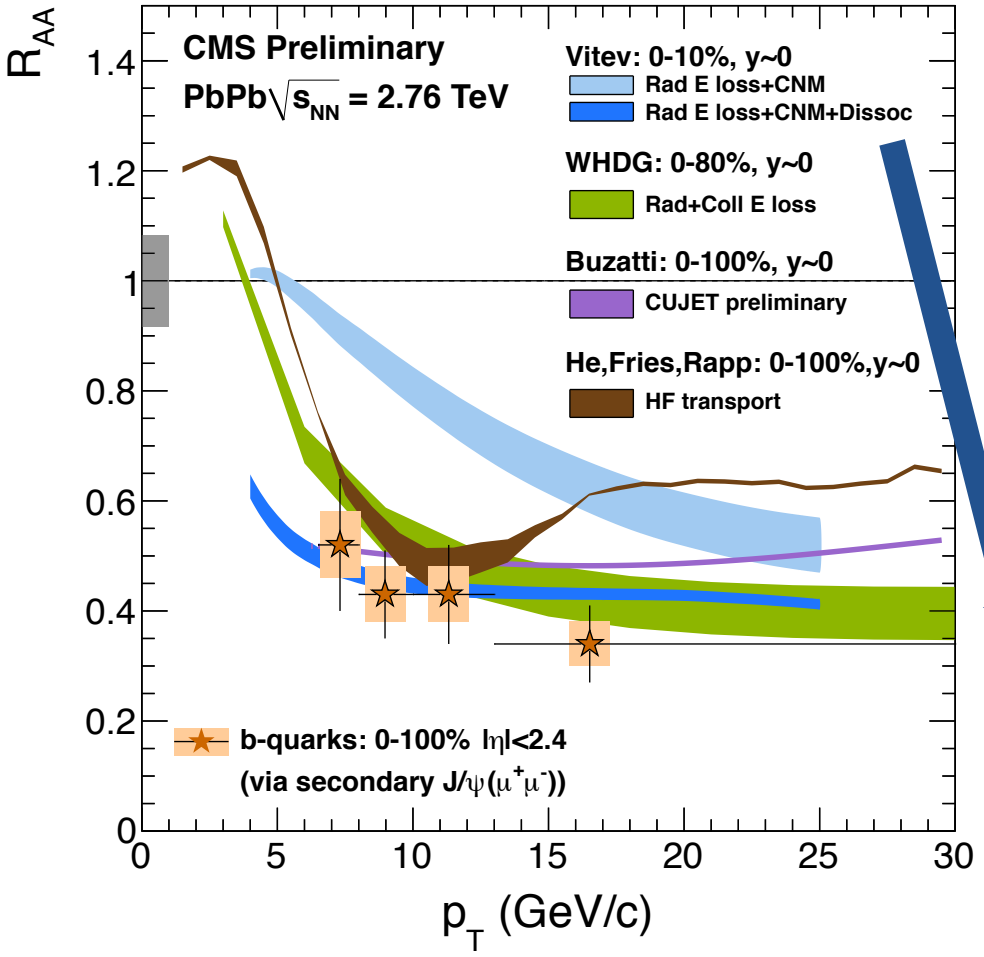
CMS-PAS HIN-12-014





- All rapidity bins at high p_T region show centrality dependent suppression
- In the 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

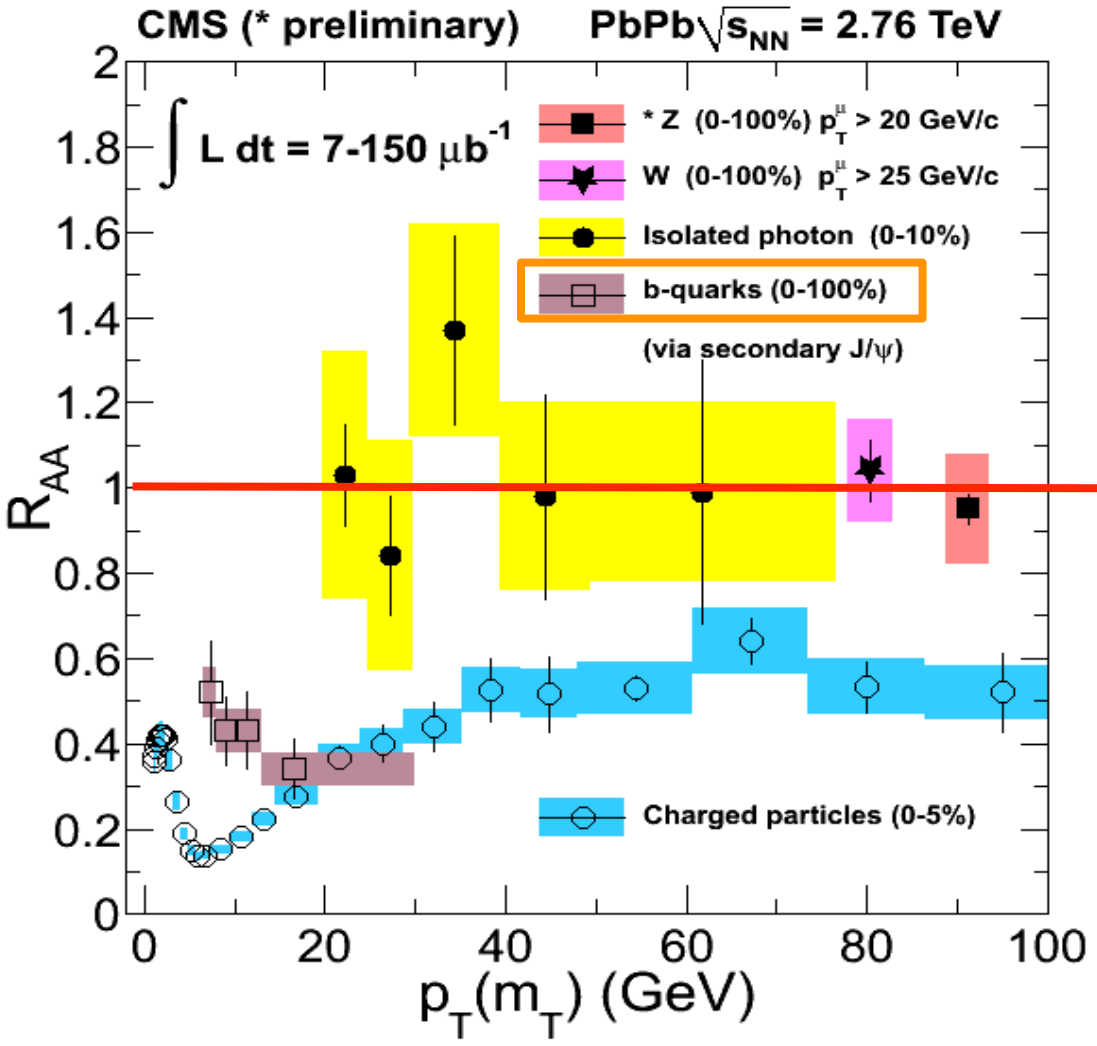


- For theory comparison, need to shift non-prompt J/ψ p_T to higher p_T side : J/ψ p_T < B p_T
- Within large uncertainties, data is described with various theoretical scenarios.
- Model involving only radiative energy loss and cold nuclear matter effects clearly fails to describe the data

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

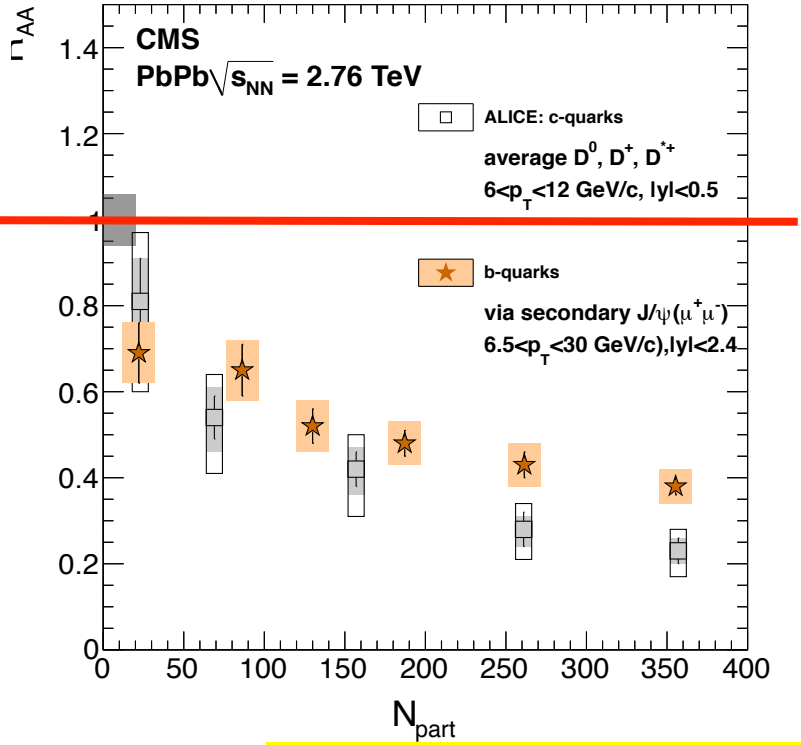
b-quark R_{AA} compared with other particles

CMS Highlights from Gunther Roland@QM12



In central collisions

$R_{AA}^{charm} < R_{AA}^{bottom}$



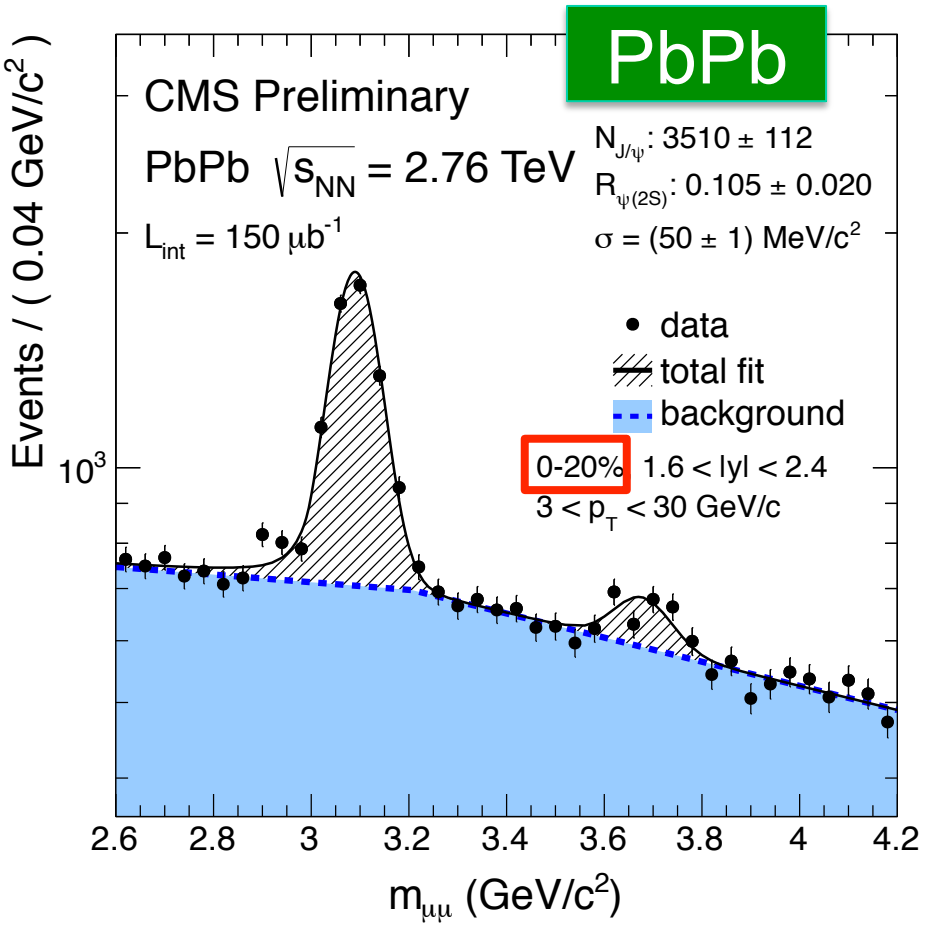
ALICE : arXiv:1203.2160
CMS : CMS-PAS HIN-12-014

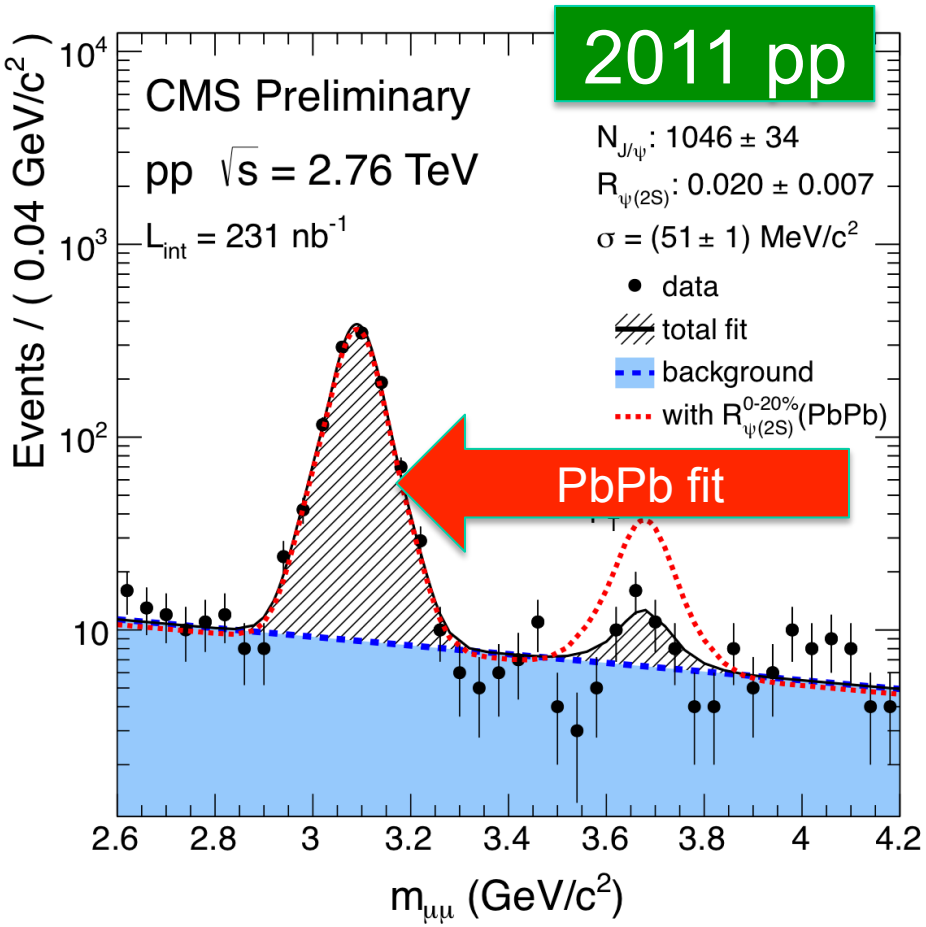
b-quark is suppressed distinctly

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

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

PAS CMS-HIN-12-007





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

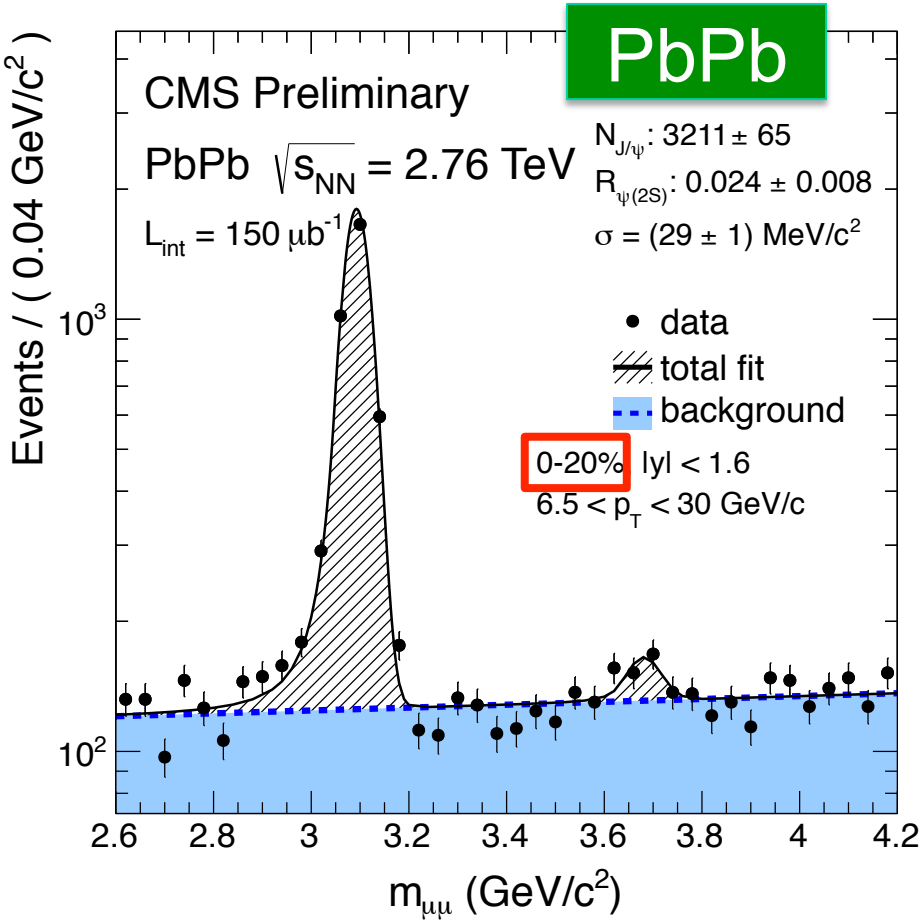
$R_{\psi(2S)}^{PbPb} \sim 5 \times R_{\psi(2S)}^{pp}$

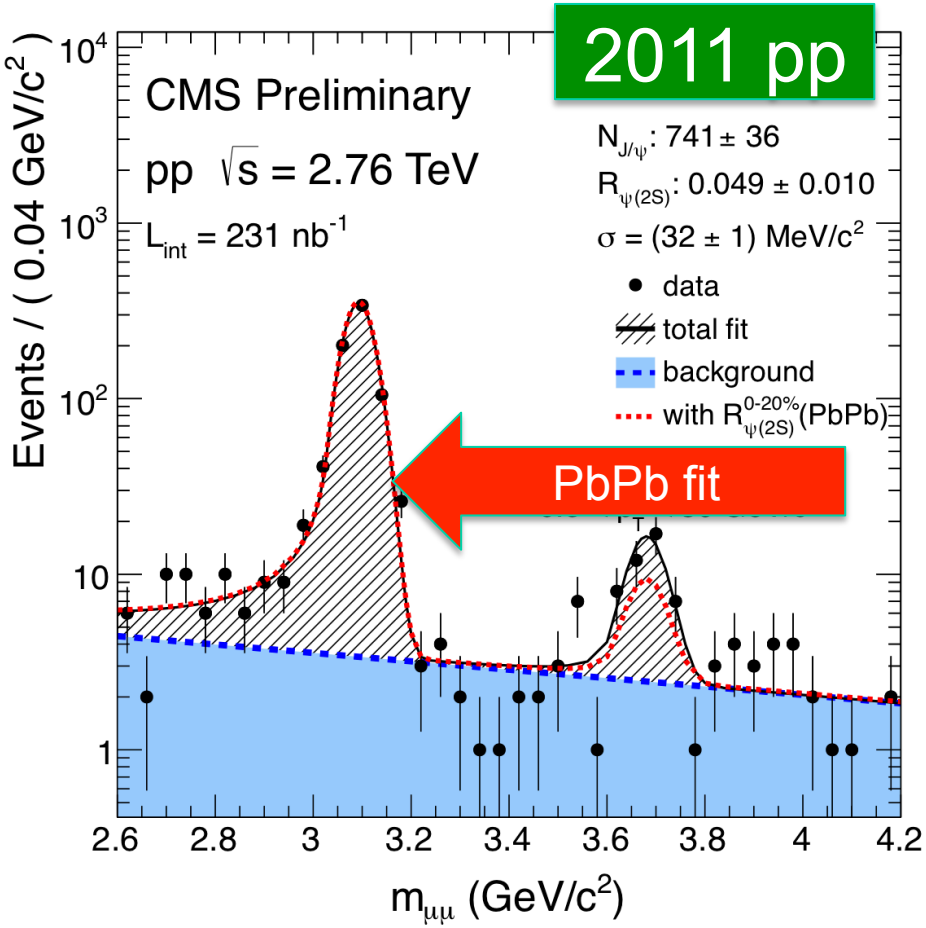
limited by pp statistics

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

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

PAS CMS-HIN-12-007



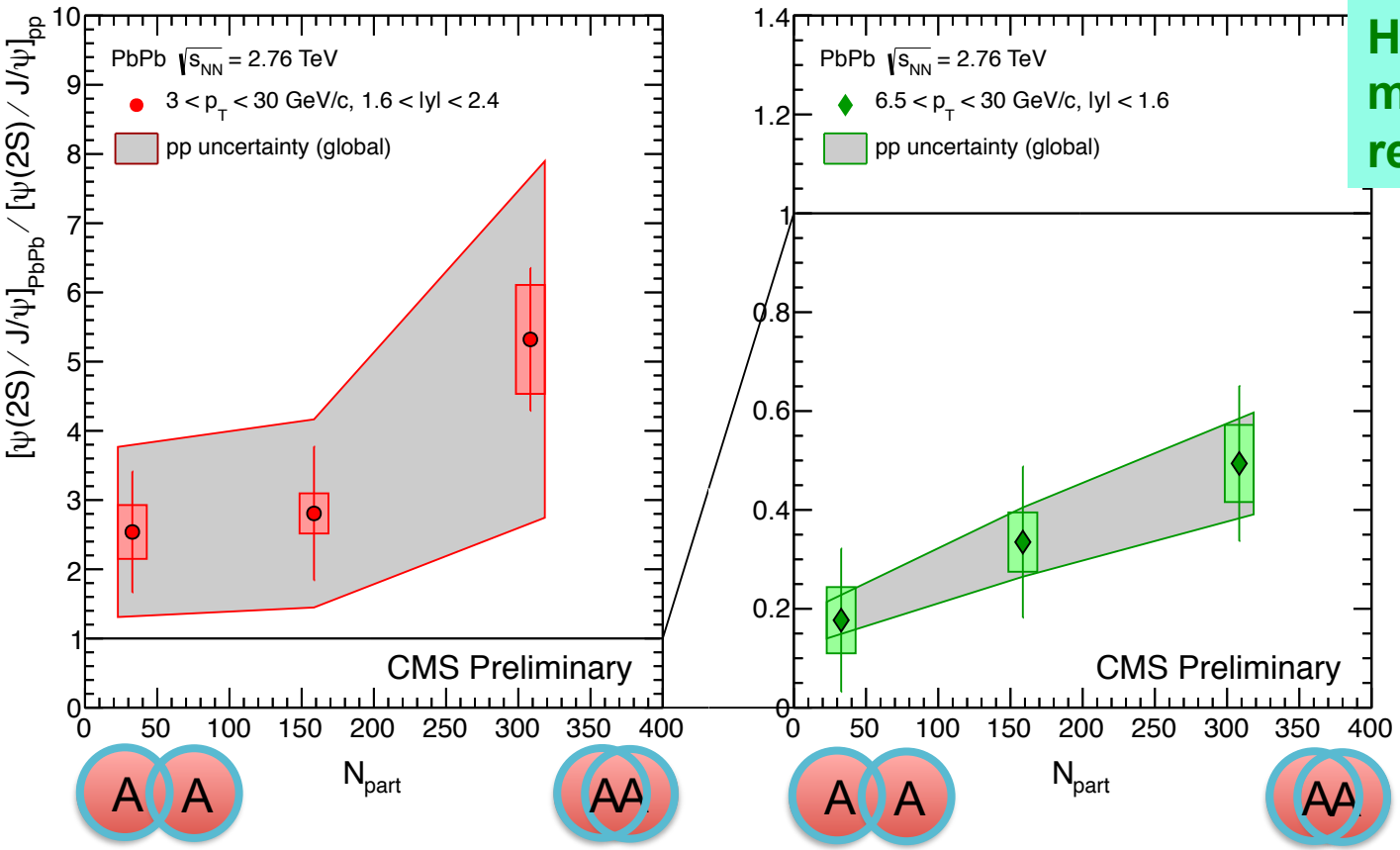


$R_{\psi(2S)} = N_{\psi(2S)} / N_{J/\psi}$

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

ψ (2S) results

Low-pT, forward region



High-pT, mid-rapidity region

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

limited by pp statistics from 2011 pp data

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

CMS-PAS HIN-12-007

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

Summary

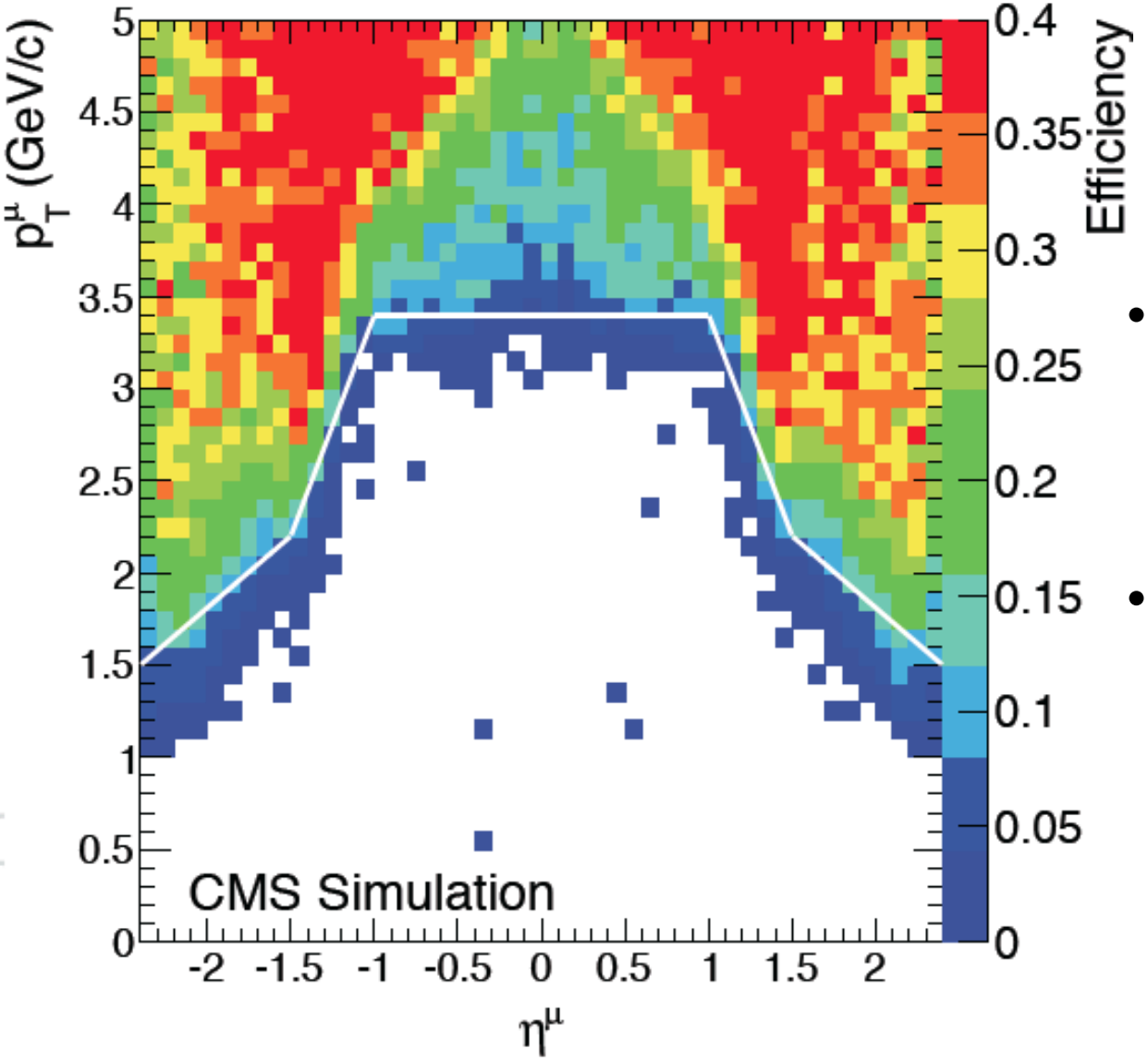
- CMS measured the suppression of prompt J/ψ from 2.76 TeV PbPb collisions.
- Also the suppression of non-prompt J/ψ is measured and this indicates the suppression of the bottom quark in heavy-ion collisions
- In Low-p_T, forward region, the enhancement of ψ(2S) relative to prompt J/ψ is observed, but need to more statistics in pp collisions.
- With new 5.02 TeV pPb collision data and enhanced 2.76 TeV pp data, CMS is doing the charmonia analysis.

Thank you for your attention

谢谢

BACK UP

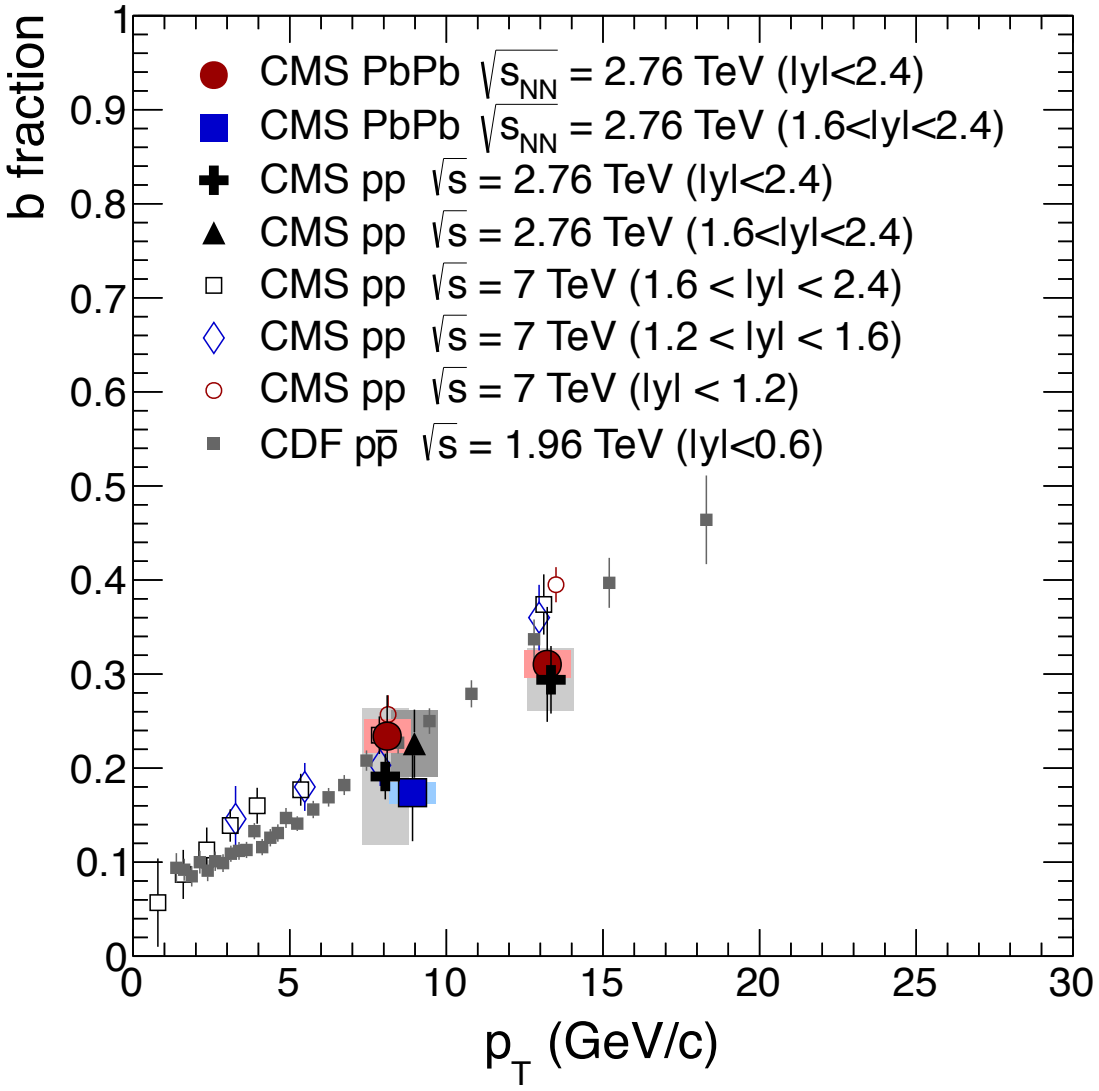
Acceptable region for single muon



- Choose the region which the single muon efficiency is larger than 0.1
- Upper than white line

JHEP 1205 (2012) 063

b fraction of J/ψ production



Summary of 2013 pPb & pp collision

- proton-Pb ion collisions (2013. Jan. ~ Feb)
  - Beam Energy : 5.02 TeV/nucleon (proton : 4 TeV, Pb ion : 1.58 TeV)
  - Asymmetry collision, boosted to Pb ion backward direction
  - Beam configuration

Beam 2(B2) → **- η CMS + η** ← **Beam 1(B1)**

  - Pbp(B1:p,B2:Pb ion) collision : Jan. 20th ~ 30th
    - acceptance : - 2.4 ~ + 1.46
    - Integrated luminosity : 18.4 nb^{-1}
  - pPb(B1:Pb ion,B2:p) collision : Feb. 2nd ~ 10th
    - Change beam direction requested by ALICE
    - acceptance : - 1.46 ~ + 2.4
    - Integrated luminosity : 12.5 nb^{-1}
- proton-proton collisions (Feb. 11th ~ 14th)
  - For the reference to pPb, PbPb data
  - Beam energy : 2.76 TeV/proton
  - Integrated luminosity : 5.41 pb^{-1}