Charmonia production in heavy-ion collisions with CMS

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1) Charmonia in heavy-ion collisions

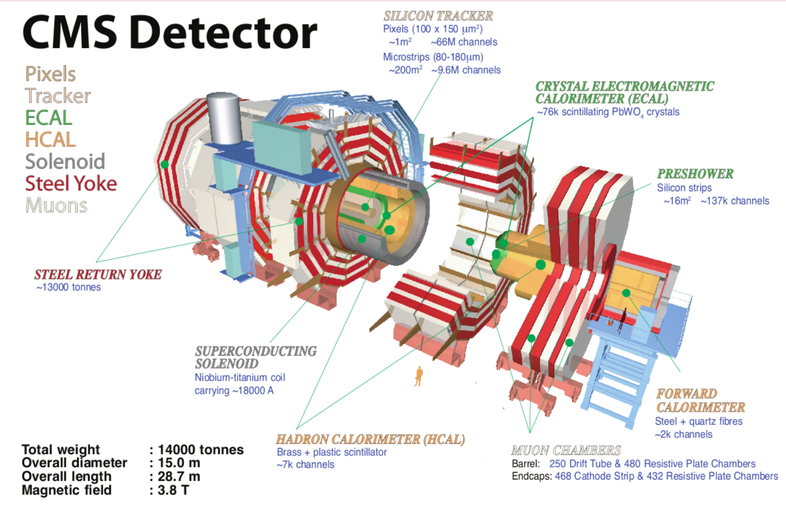
Heavy flavor quarkonium states are important probes of the Quark-Gluon-Plasma (QGP). J/ψ are expected to be suppressed because of the color screening effect in the QGP[1]. But there are other type of predictions: enhanced production with recombination model and reduced production by cold-nuclear-matter effects without QGP. Modifications of the J/ψ production in heavy-ion collisions can be quantified by the nuclear modification factor, R_{AA}.

The elliptic flow of the J/ψ is also a sensitive probe to understand the dynamics of the heavy-ion collision. In a peripheral heavy-ion collision, the overlap region of the colliding nuclei has a geometric anisotropy. A path-length difference for absorption of particles traversing in medium and a asymmetry of pressure gradients are expected to create momentum anisotropy. This effect is reflected in the azimuthal distribution of the particles with respect to the event plane. The second coefficient of the Fourier expansion of the azimuthal angle v_2, describes the anisotropic flow.

The double ratio of ψ(2S) to J/ψ yields in PbPb and pp is expected to be a good observable to understand the final state effects, the color screening and recombination, which would play reciprocal roles in determination of quarkonia yields.

2) CMS Detector

- **Silicon Tracker**
  Good efficiency & purity from low to high p_T
- **Calorimeters**
  High resolution & segmentation
  Large coverage up to |η| = 5.2 (Even larger with CASTOR)
- **Muon system**
  momentum resolution ~ 1.5%
  mass resolution ~ 10%



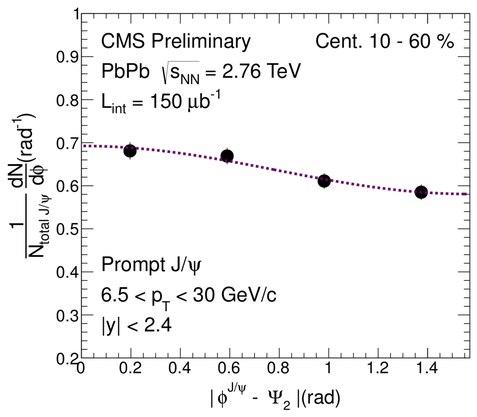
3) Observables and analysis methods

- **v_2 using the event-plane method**

1) $\Psi_2 = \frac{1}{2}\tan^{-1}\left(\frac{\Sigma_i w_i \sin(2\phi_i)}{\Sigma_i w_i \cos(2\phi_i)}\right)$

2) $\frac{1}{N_{total}} \cdot \frac{dN}{d\phi}$ fitted with $\frac{2}{\pi}[1 + 2v_2\cos(2\Delta\phi)]$

3) $v_2 = \frac{v_2^{obs}}{R} = \frac{< \cos[2(\phi - \Psi_2)] >}{< \cos[2(\Psi_2 - \Psi_R)] >}$



- Ψ_2 : Event-by-event azimuthal angle of maximum particle density
- $\Delta\varphi$: $|\varphi_{J/\psi} - \Psi_2|$
- w_i : Weight factor for the transverse energy at φ_i
- R : Resolution correction factor

- **Nuclear modification factor R_{AA}**

$$R_{AA} = \frac{1}{T_{AA}} \cdot \frac{dN_{AA}}{d\sigma_{pp}} = \frac{L_{int}^{pp}}{T_{AA} N_{MB}} \cdot \frac{N_{J/\psi}^{PbPb}}{N_{J/\psi}^{pp}} \cdot \frac{\epsilon_{pp}}{\epsilon_{PbPb}}$$

- T_{AA} : Nuclear overlap function
- N_{MB} : Number of minimum bias events
- $\varepsilon_{pp/PbPb}$: Efficiency of J/ψ
- L_{nt} : Integrated luminosity in pp collisions

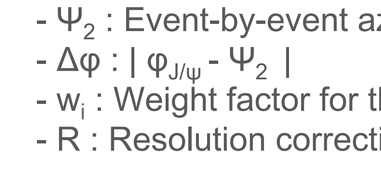
- **Double ratio** $\frac{[N_{\psi(2S)}/N_{J/\psi}]_{PbPb}}{[N_{\psi(2S)}/N_{J/\psi}]_{pp}} = \frac{R_{AA}(\psi(2S))}{R_{AA}(J/\psi)}$

- ψ(2S) R_{AA} can be estimated from the prompt J/ψ R_{AA}.

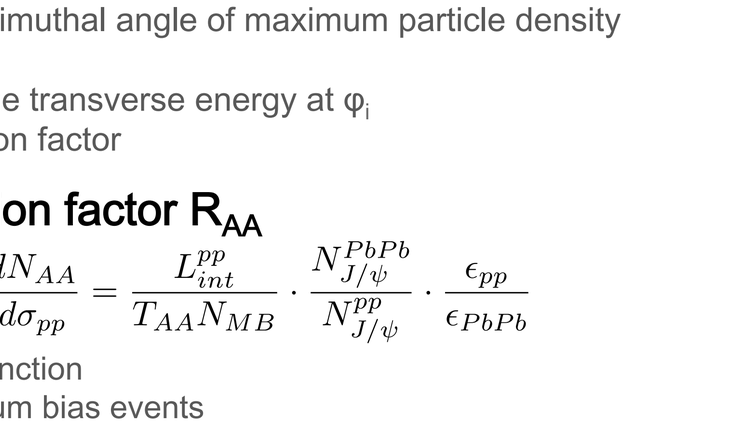
4) Signal Extraction

- **Prompt J/Ψ**

Opposite-sign dimuon invariant mass distributions are fitted with the sum of a Crystal Ball and a Gaussian for signal and an exponential for background. Then together with lifetime distributions, 2D simultaneous fitting is performed to separate non-prompt component.



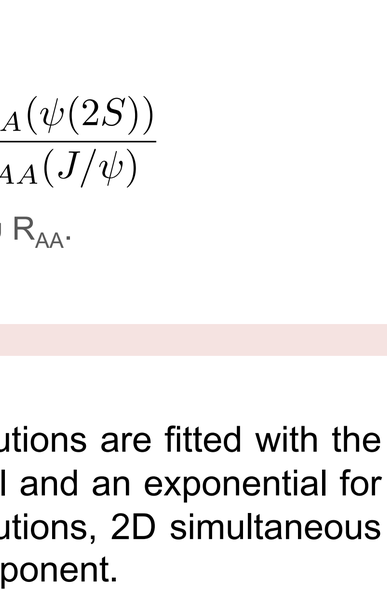
$$l_{J/\psi} = L_{xy}(J/\psi)\frac{m_{J/\psi}}{p_T(J/\psi)}$$



- $l_{J/\psi}$: Pseudo-proper decay length
- L_{xy} : Transverse decay length in the laboratory frame

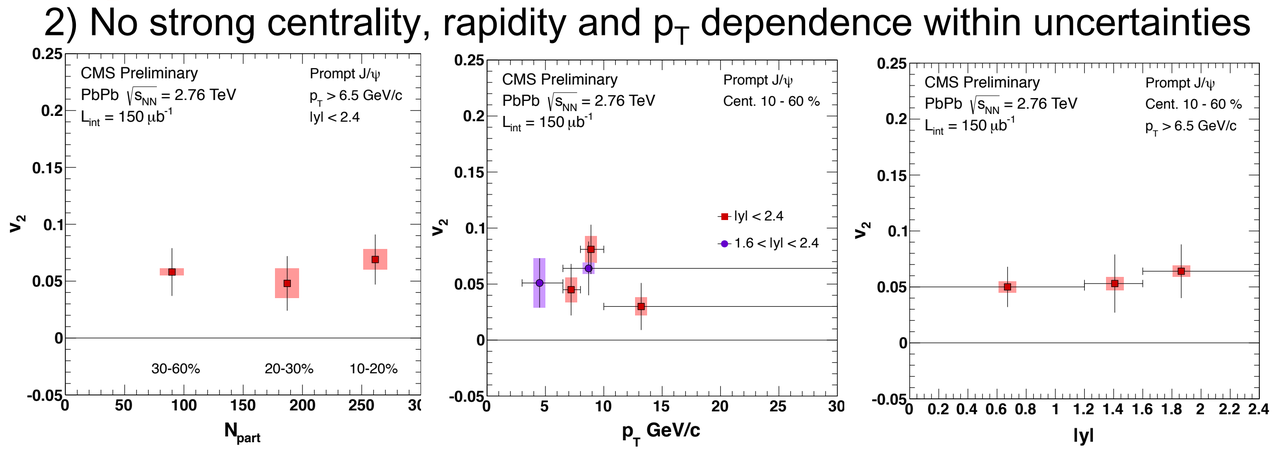
- **Ψ(2S)**

- The sum of a Crystal Ball and a Gaussian is used for J/ψ and ψ(2S) with common CB parameters. The Background is described by Nth order Chebychev polynomials.
- Two kinematic ranges are investigated.
  1) 1.6 < |y| < 2.4, 3 < p_T < 30 GeV/c
  2) |y| < 1.6, 6.5 < p_T < 30 GeV/c

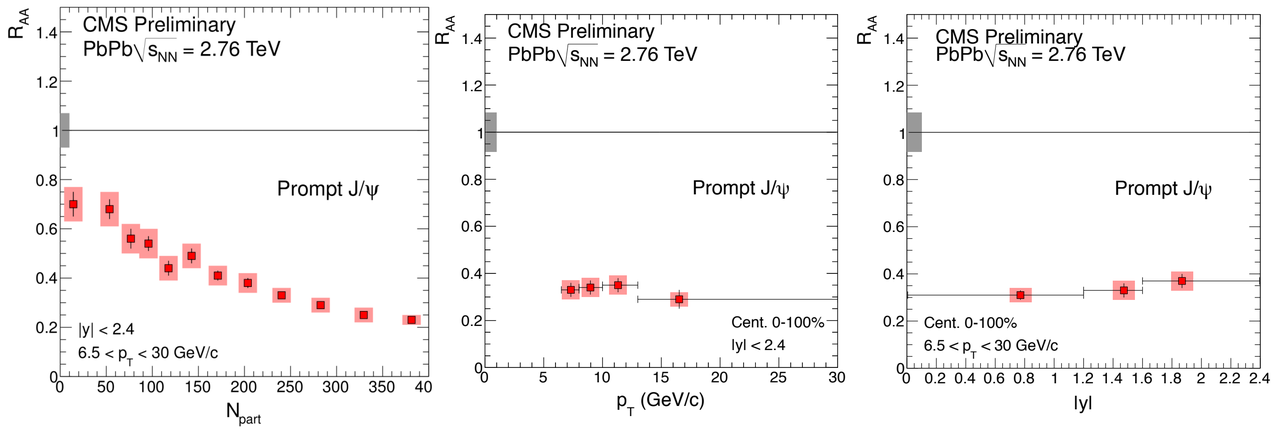


5) Results

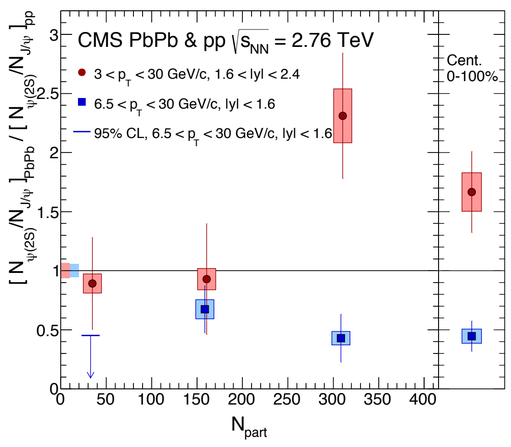
- **Prompt J/ψ has non-zero v_2**
  1) At centrality 10-60%, 6.5 < p_T < 30 GeV/c, |y|< 2.4 regions
     v_2 = 0.054 ± 0.013(*stat.*) ± 0.006(*syst.*)
  2) No strong centrality, rapidity and p_T dependence within uncertainties



- **Prompt J/ψ is suppressed compared to pp**
  1) Strong centrality dependence has been observed.
  2) No rapidity and p_T dependence within uncertainties



- **ψ(2S) : different trends in two kinematic ranges.**
  1) Mid-rapidity (high p_T) : Double ratio is less than 1 in all centrality bins.
     - ψ(2S) is more suppressed than J/ψ.
  2) Forward rapidity (lower p_T) : Double ratio increases with centrality.
     - ψ(2S) may be more enhanced relative to J/ψ than in pp collisions.



[centrality integrated value]

1.67 ± 0.34(*stat.*) ± 0.16(*syst.*)

0.45 ± 0.13(*stat.*) ± 0.06(*syst.*)

3) R_{AA} of ψ(2S)
- Mid-rapidity (high p_T) : 0.13 ± 0.04(*stat.*) + 0.02(*syst.*) ± 0.01(*pp*)
- Forward rapidity (high p_T) : 0.67 ± 0.16(*stat.*) + 0.07(*syst.*) ± 0.07(*pp*)

ψ(2S) is still suppressed relative to pp in both kinematic domains.

Talk : Dongho – Tue. (09:00)

[References]

1) T. Matsui and H. Satz, "J/ψ suppression by quark-gluon plasma formation", *Phys. Lett. B 178 (1986) 416*
2) CMS Collaboration, "Suppression of non-prompt J/ψ, prompt J/ψ, and Y(1S) in PbPb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV ", *JHEP 05 (2012) 063*
3) CMS Collaboration, "J/ψ results from CMS in PbPb collisions, with 150 μb^{-1} data", *CMS PAS-HIN-12-014*
4) CMS Collaboration, "Measurement of the azimuthal anisotropy of prompt J/ψ in PbPb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV ", *CMS PAS-HIN-12-001*
5) CMS Collaboration, "Measurement of prompt ψ(2S) yield ratios in PbPb and pp collisions at $\sqrt{s_{NN}}$ = 2.76 TeV ", *CMS PAS-HIN-12-007*