Measurement ~~Production~~ and Suppression of J/Ψ and ϒ states in PbPb collisions in CMS

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On behalf of the CMS Collaboration

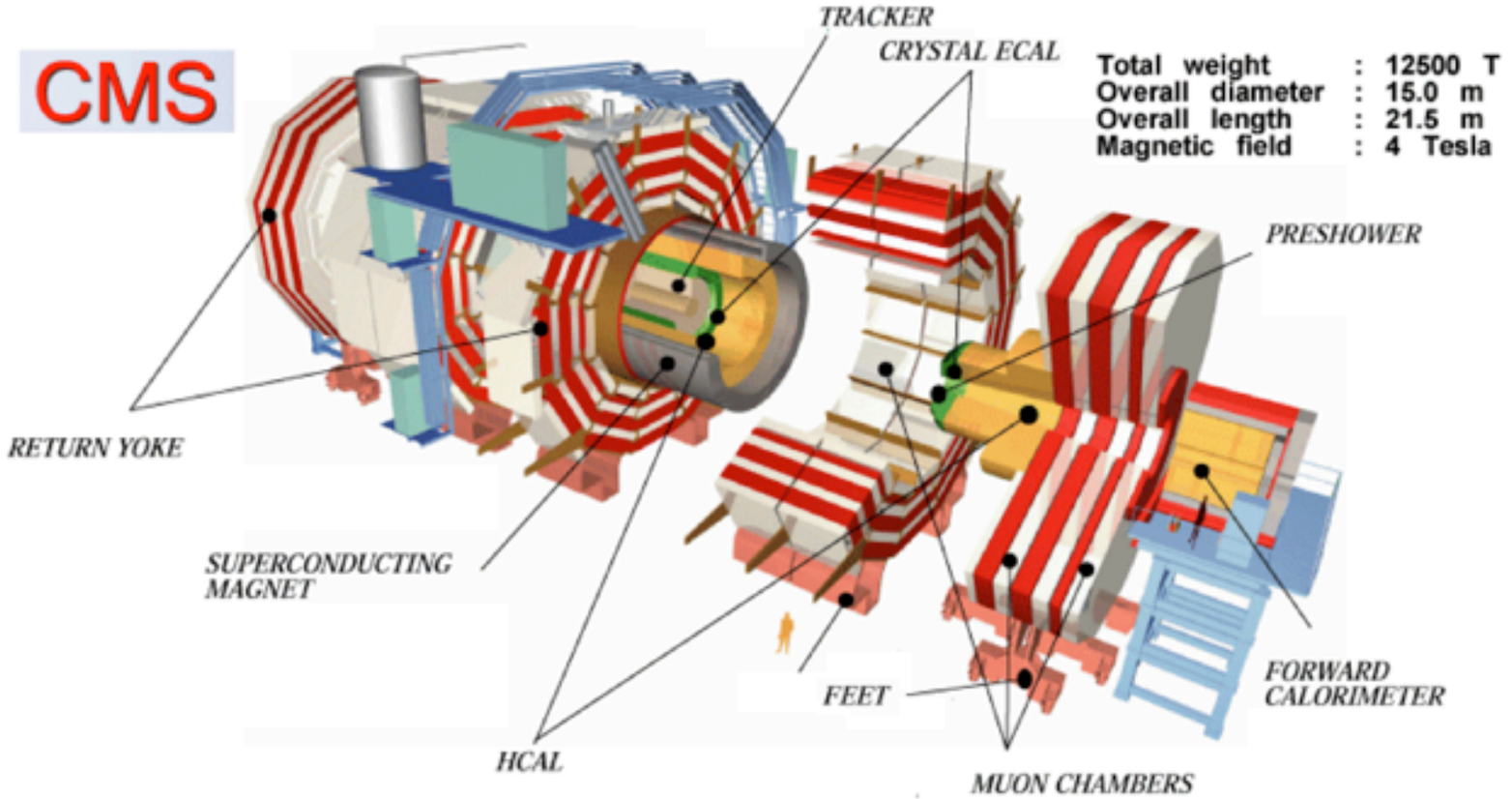
Outline

- Detection in CMS
  - the CMS detector
  - Muon reconstruction

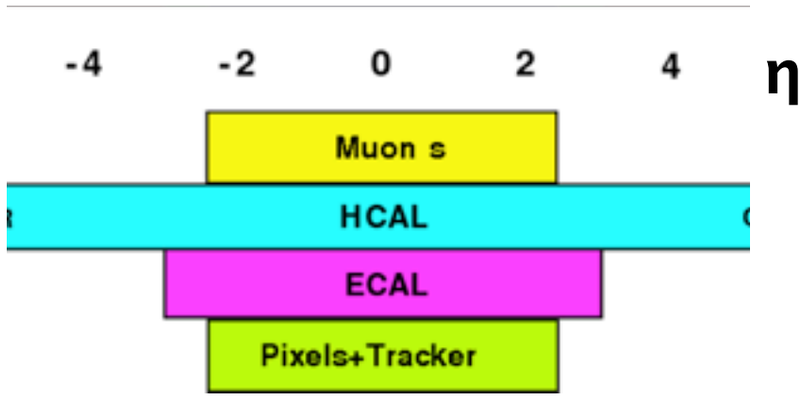
- Physics results (2010 PbPb data)
  - J/ψ, prompt and non-prompt
  - Upsilon

- Summary

Detector: the CMS at the LHC

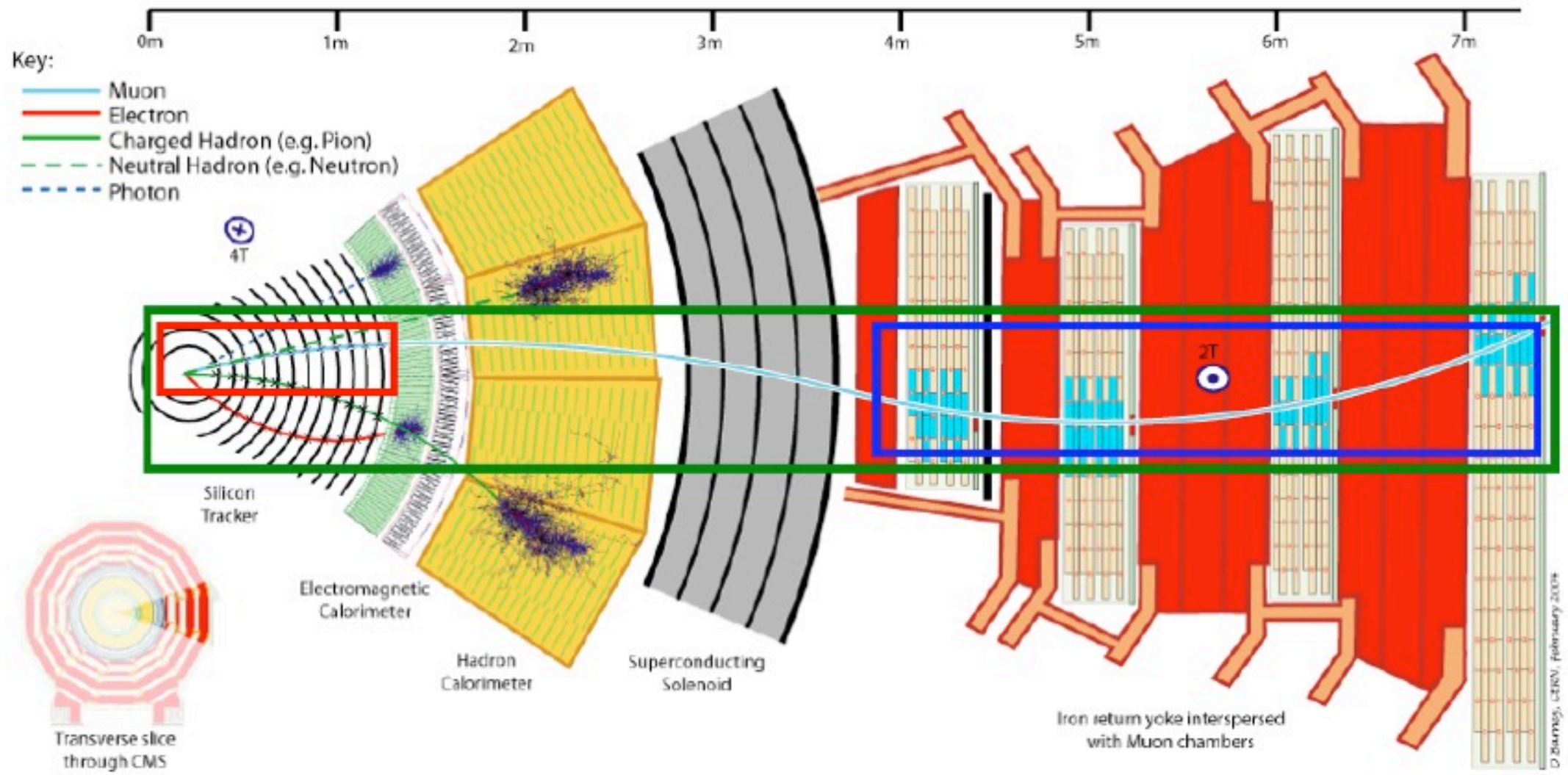


- Structure:
  - Tracker+calorimeters (HCAL and ECAL) inside the solenoid coil
  - Muon detectors embedded in the flux return iron yoke of the magnet
  - Large acceptance
    - 2π in azimuth
    - Si-tracker $|\eta|<2.5$
    - ECAL $|\eta|<3.0$, HCAL $|\eta|<5.2$
    - Muon detectors $|\eta|<2.4$



- High resolution
  - Granularity of the Si-pixel layer+3.8T mag field ~ $\Delta p_T/p_T < 1.5\%$

Muons

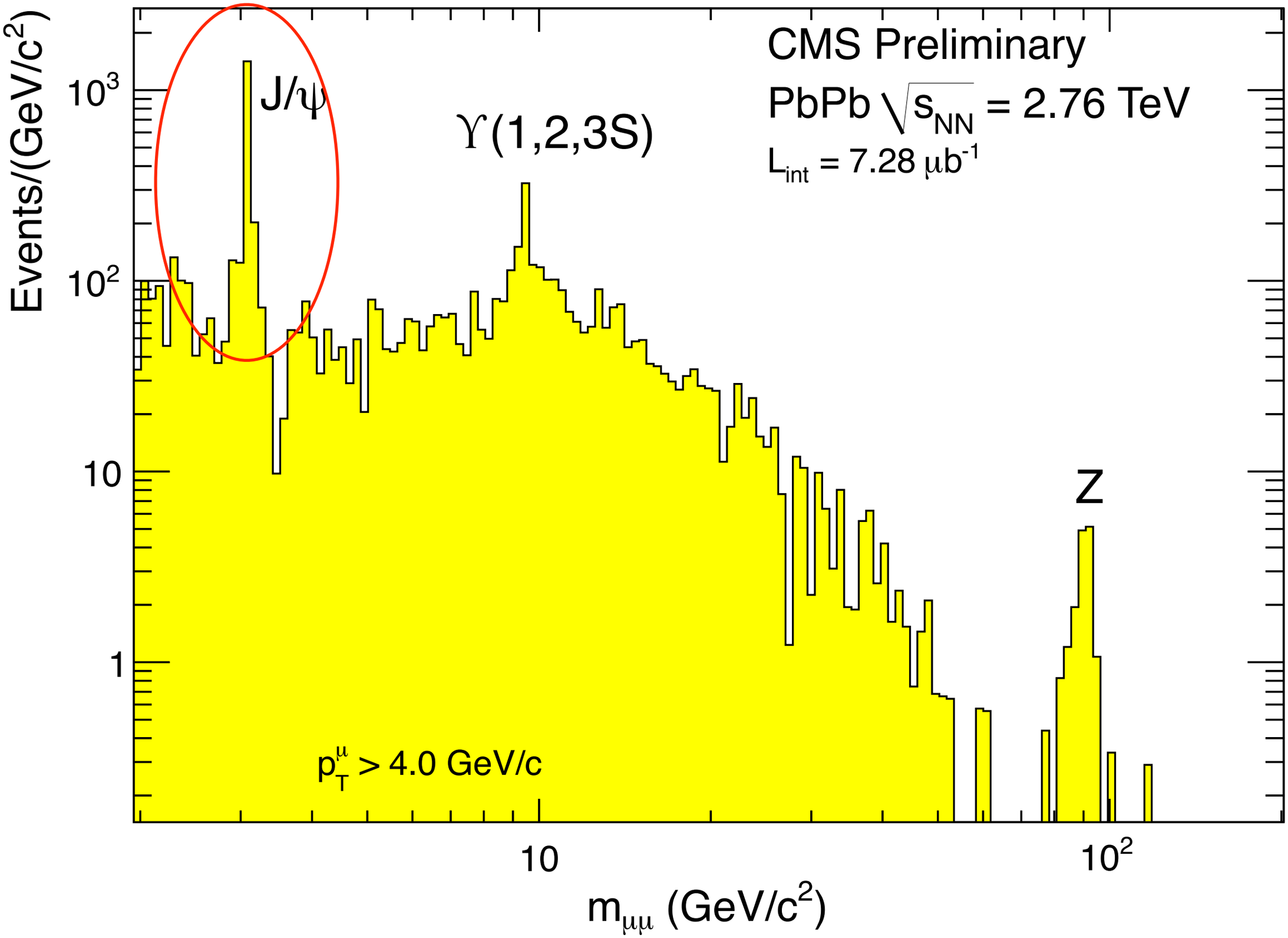


- Global muons = tracker + muon stations informations
  - need p ≳ 3 GeV to reach muon stations + 2-3 GeV to compensate for the en loss in the absorber
  - ID cuts at ana level:
    - reco both inside-out and outside-in
    - #hits in the tracker, $\chi 2$, DCA, etc

Table 2: Minimum p and p_T to reach first Muon station

$\eta = -\ln\tan\frac{\theta}{2}$	R_T^{min}	$p_T^{min} = 0.3BR_T^{min}$	$p^{min} = p_T^{min}/\sin\theta$
$0 \le \lvert\eta\rvert \le 1.2$	4 m	4.8 GeV/c	4.8-8.7 GeV/c
$1.2 \le \lvert\eta\rvert \le 1.5$	3 m	3.6 GeV/c	6.5-8.5 GeV/c $\oplus$ $\overbrace{2GeV}^{\text{Loss in barrel}}$ to $\underbrace{3GeV}_{\text{Loss on endcaps}}$
$1.5 \le \lvert\eta\rvert \le 2.4$	1 m	1.2 GeV/c	2.8-6.7 GeV/c

Muon pairs in PbPb at $\sqrt{s_{NN}} = 2.76$ TeV



J/ψ in PbPb at $\sqrt{s_{NN}} = 2.76$ TeV

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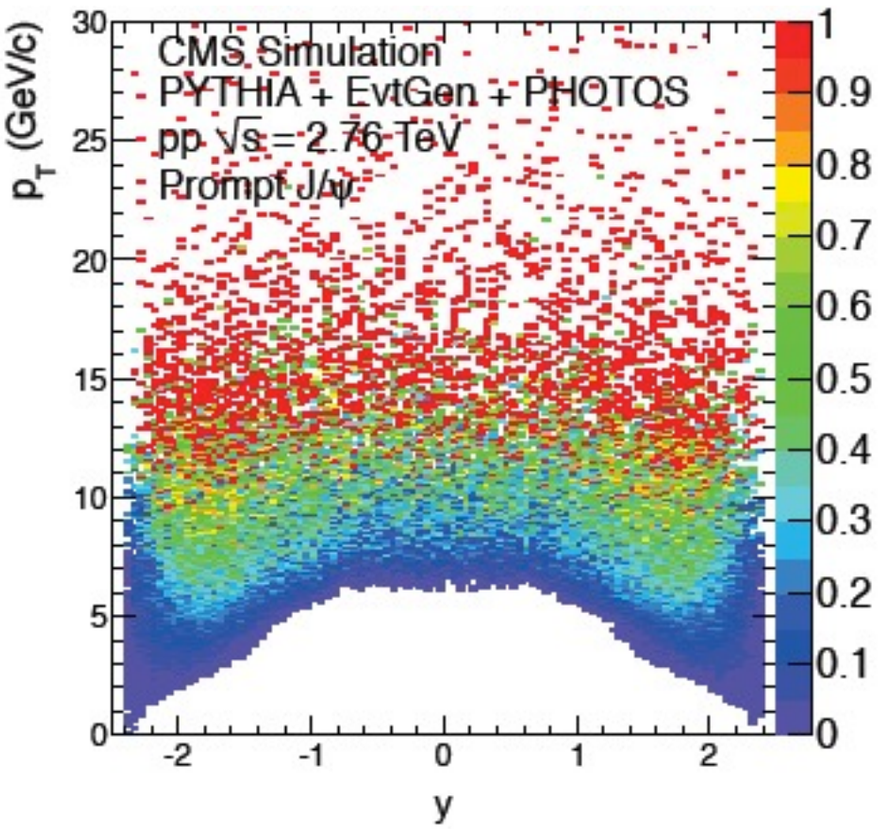

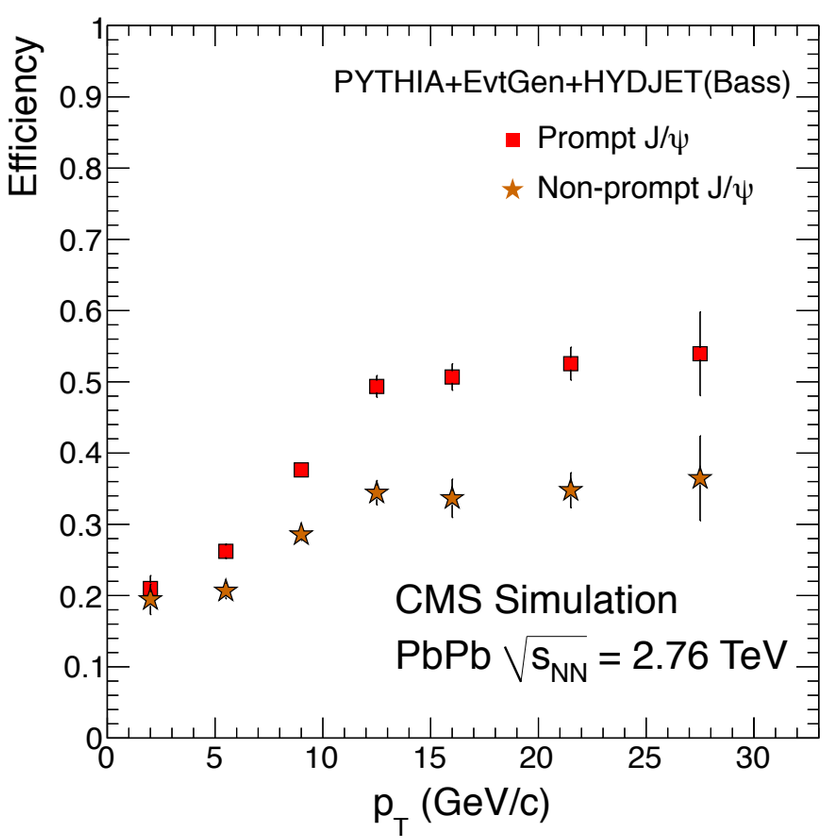

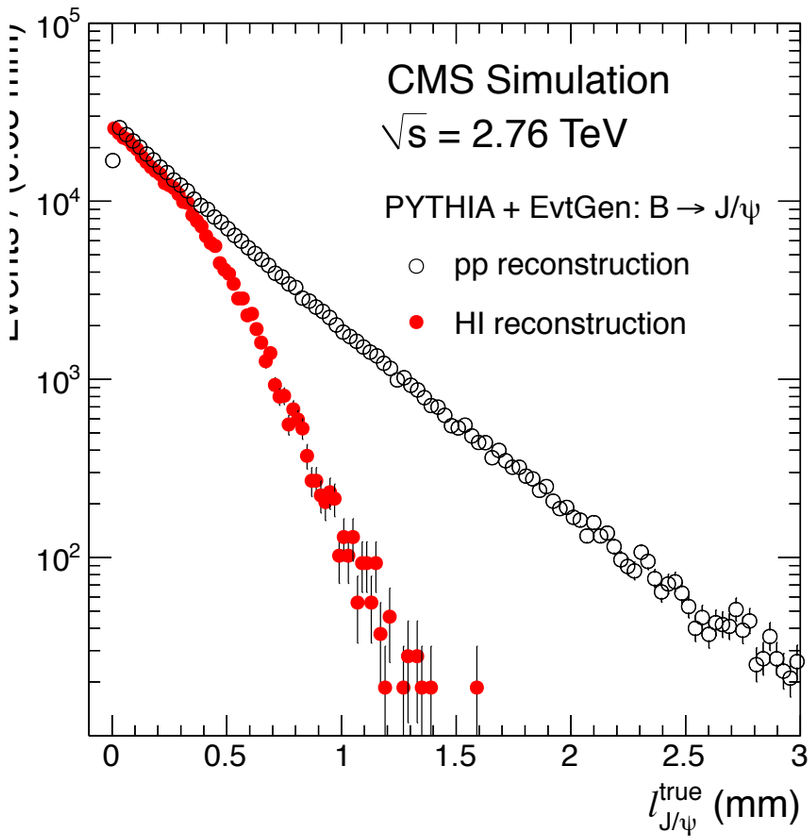

- Separate prompt & non-prompt J/ψ
- Efficiencies from Monte Carlo
  - Simulate signal with "realistic" PYTHIA
  - Embed signal in min. bias event simulated with HYDJET (also in data)
  - Validated MC by comparing efficiencies measured with "Tag & Probe" in MC and data
- HI tracking algorithm uses vertex constraint
  - Smaller efficiency for non-prompt than for prompt J/ψ
  - Effect increases with p_T

Prompt vs. non-prompt J/ψ

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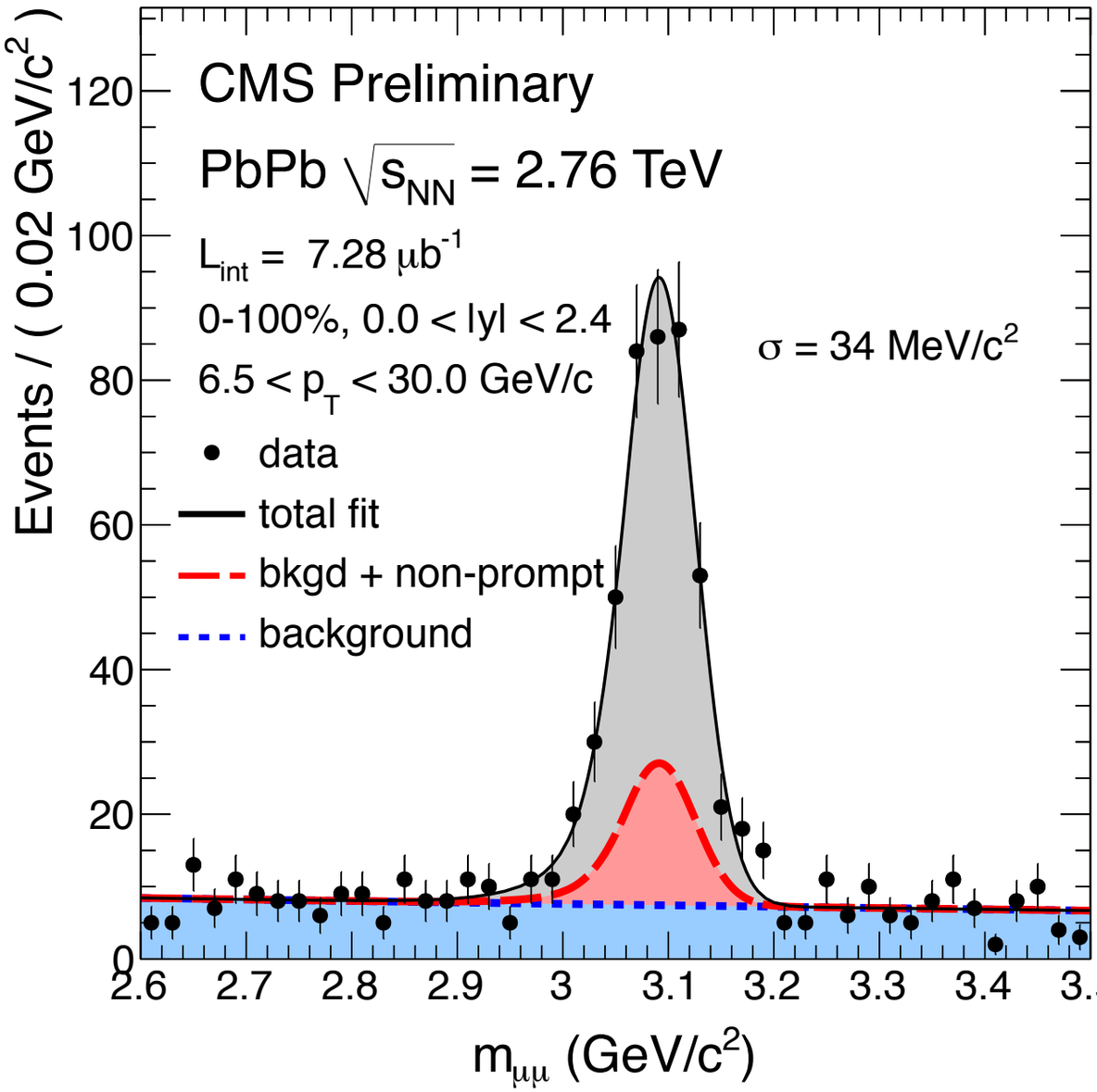
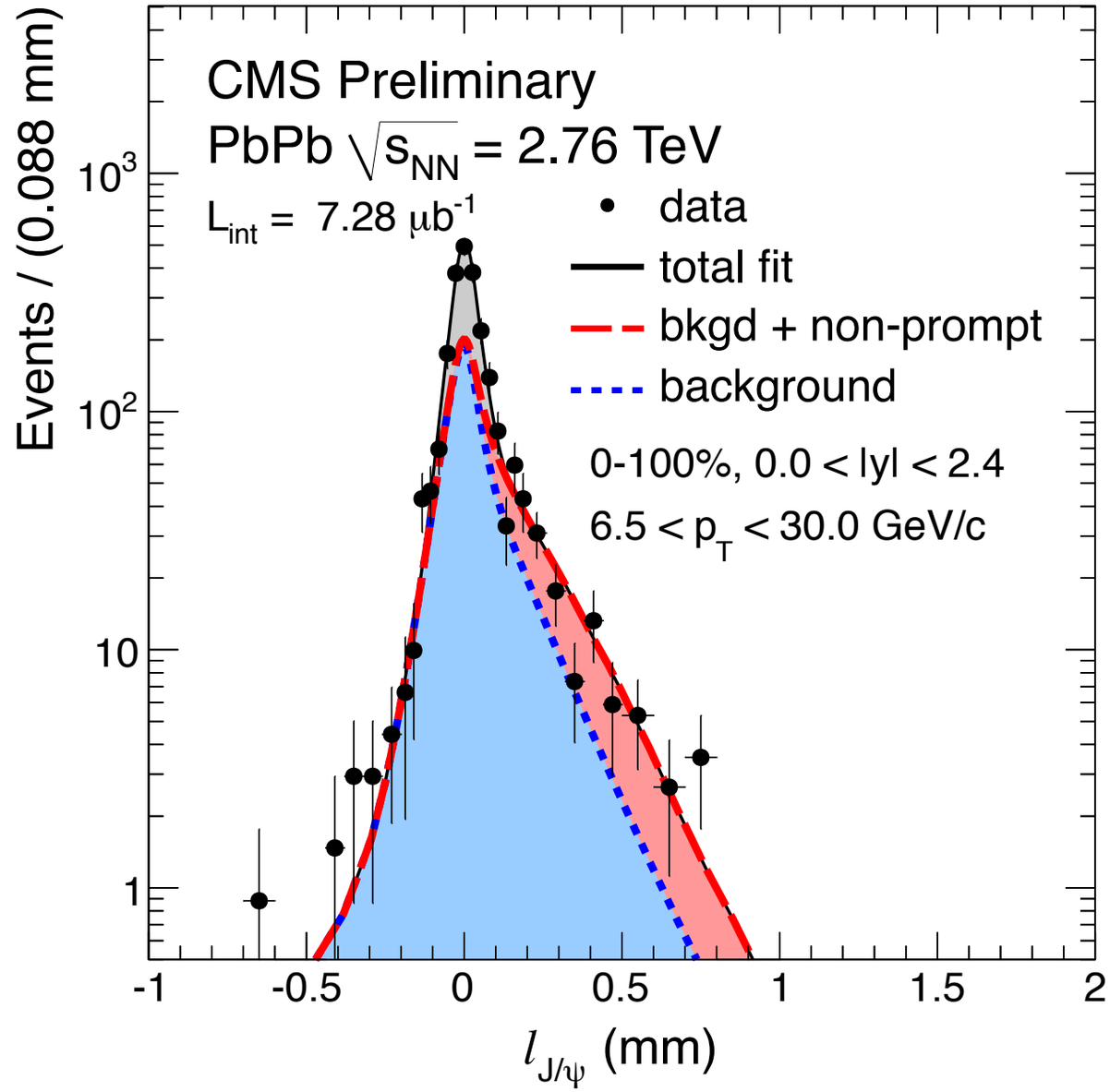
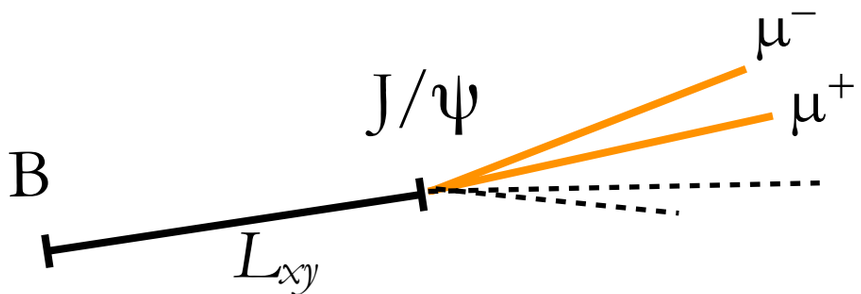




- Reconstruct $\mu^+\mu^-$ vertex and calculate the most probable transverse decay length, L_{xy}

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



- Simultaneous fit of $\mu^+\mu^-$ mass and pseudo-proper decay length

R_{AA} : Prompt J/ψ

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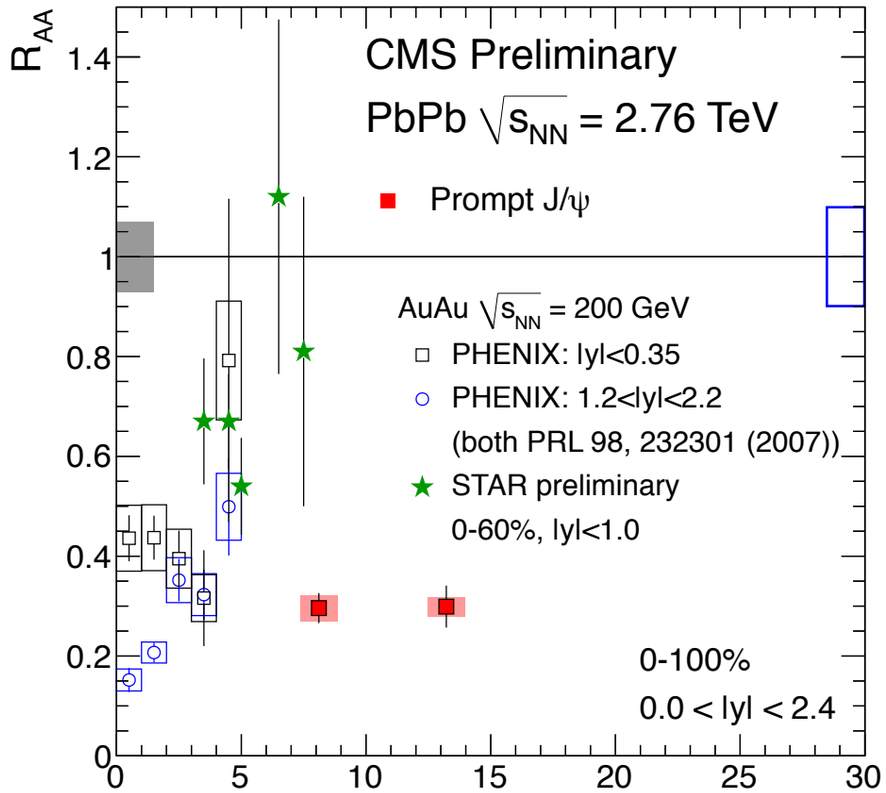
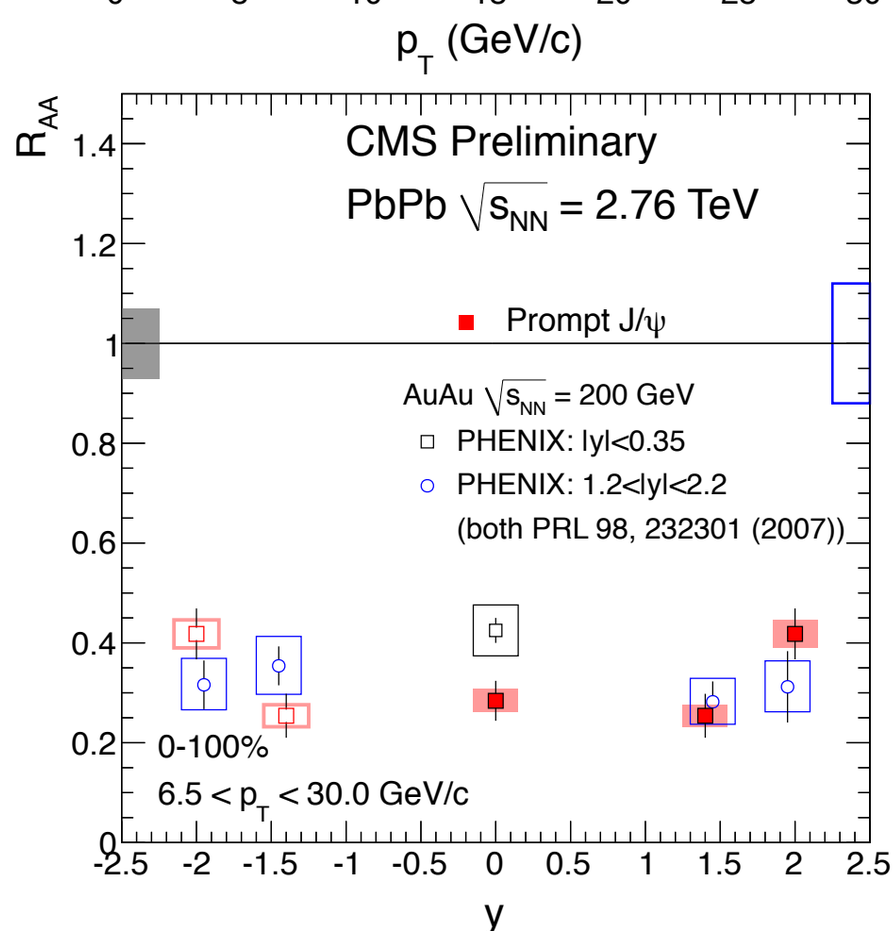
$$R_{AA} = \frac{\mathcal{L}_{pp}}{T_{AA} N_{\mathrm{MB}}} \frac{N_{\mathrm{PbPb}}(J/\psi)}{N_{pp}(J/\psi)} \frac{\varepsilon_{pp}}{\varepsilon_{\mathrm{PbPb}}(\mathrm{cent})}$$

- CMS: $p_T > 6.5$ GeV/c
  - ➡ Factor 3 suppression
- STAR: $p_T > 5.0$ GeV/c
  - ➡ no suppression at midrapidity

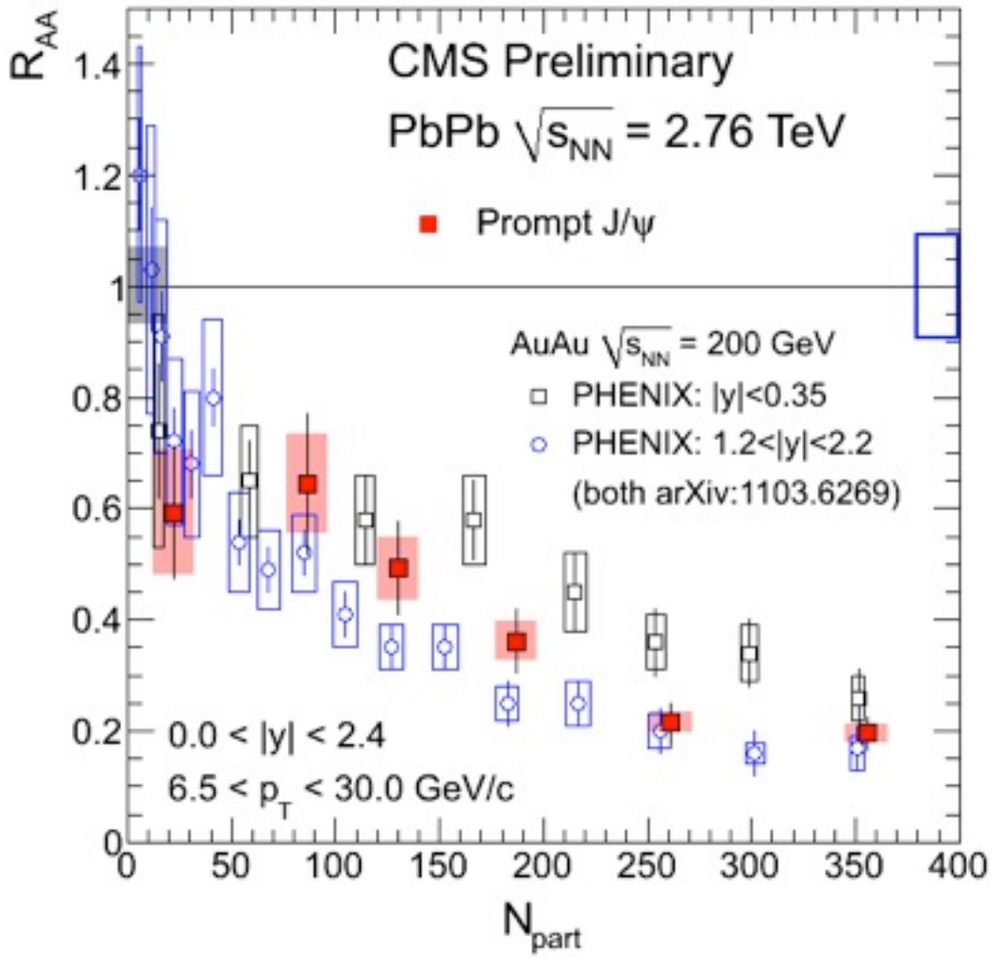


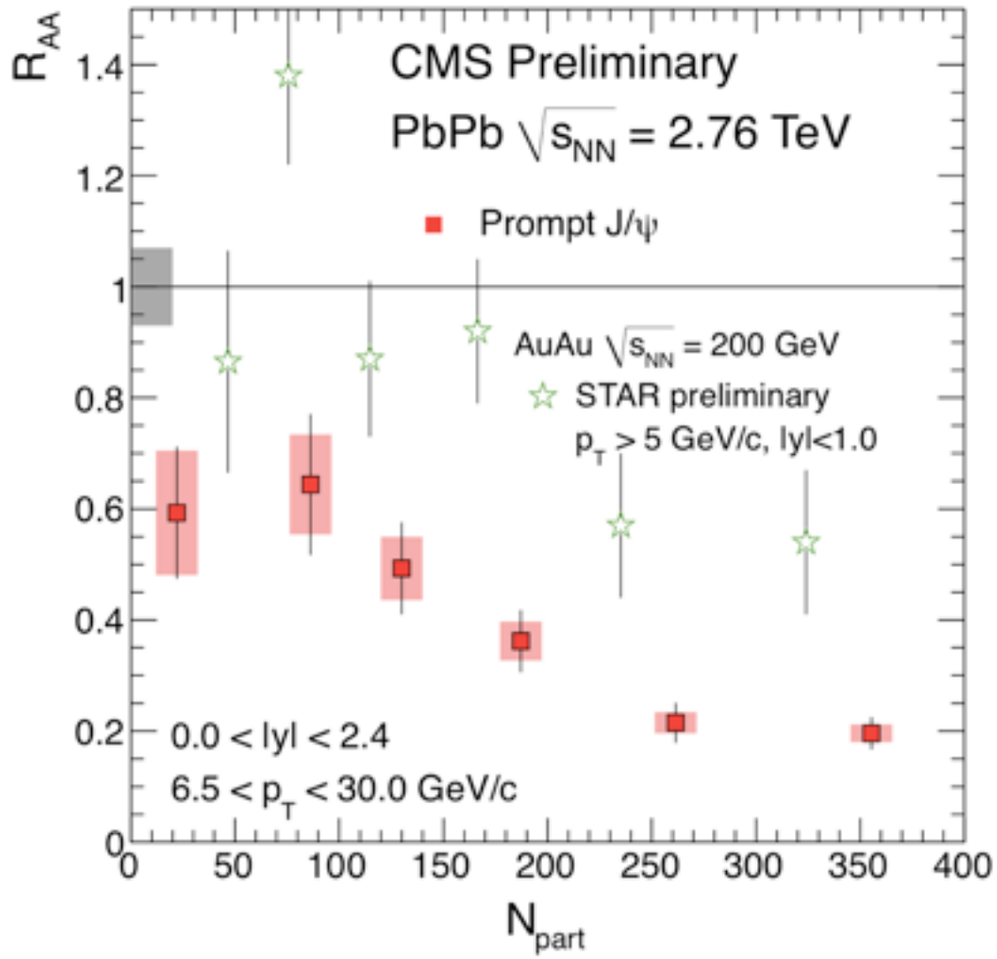
- CMS: $p_T > 6.5$ GeV/c
  - ➡ Trend to less suppression at forward rapidity
- PHENIX: $p_T < 5.0$ GeV/c
  - ➡ opposite rapidity dependence



R_{AA} : Prompt J/ψ

CMS PAS HIN-10-006





- CMS Prompt J/ψ (p_T>6.5GeV/c)
  - 0-10% suppressed by factor 5 with respect to pp
  - 50-100% suppressed by factor ~1.6

- RHIC
  - PHENIX, low p_T (<5GeV/c): similar suppression
  - STAR, high p_T, (>5GeV/c): less suppression

Non-prompt J/ψ in PbPb at $\sqrt{s_{NN}} = 2.76$ TeV CMS PAS HIN-10-006

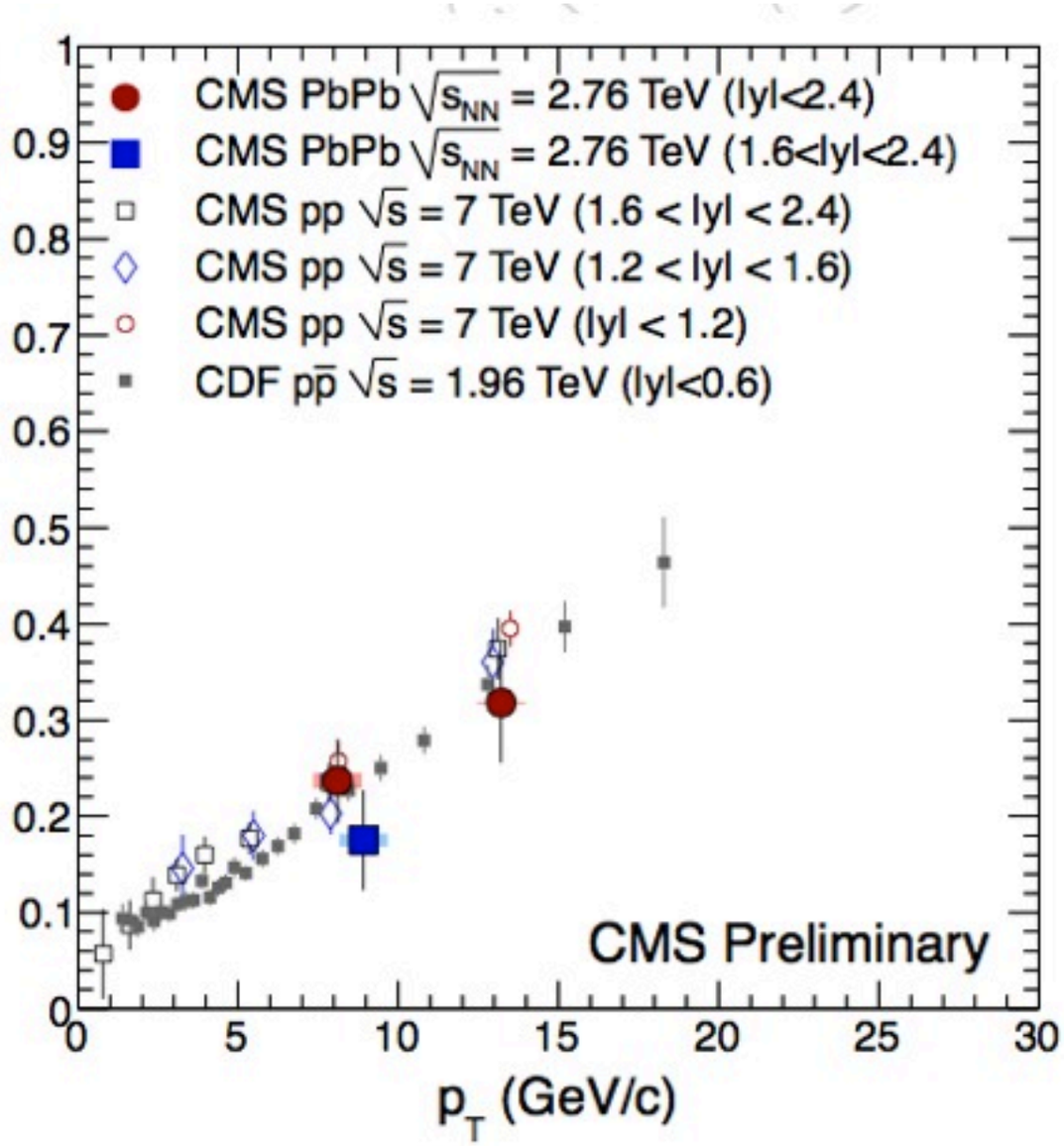
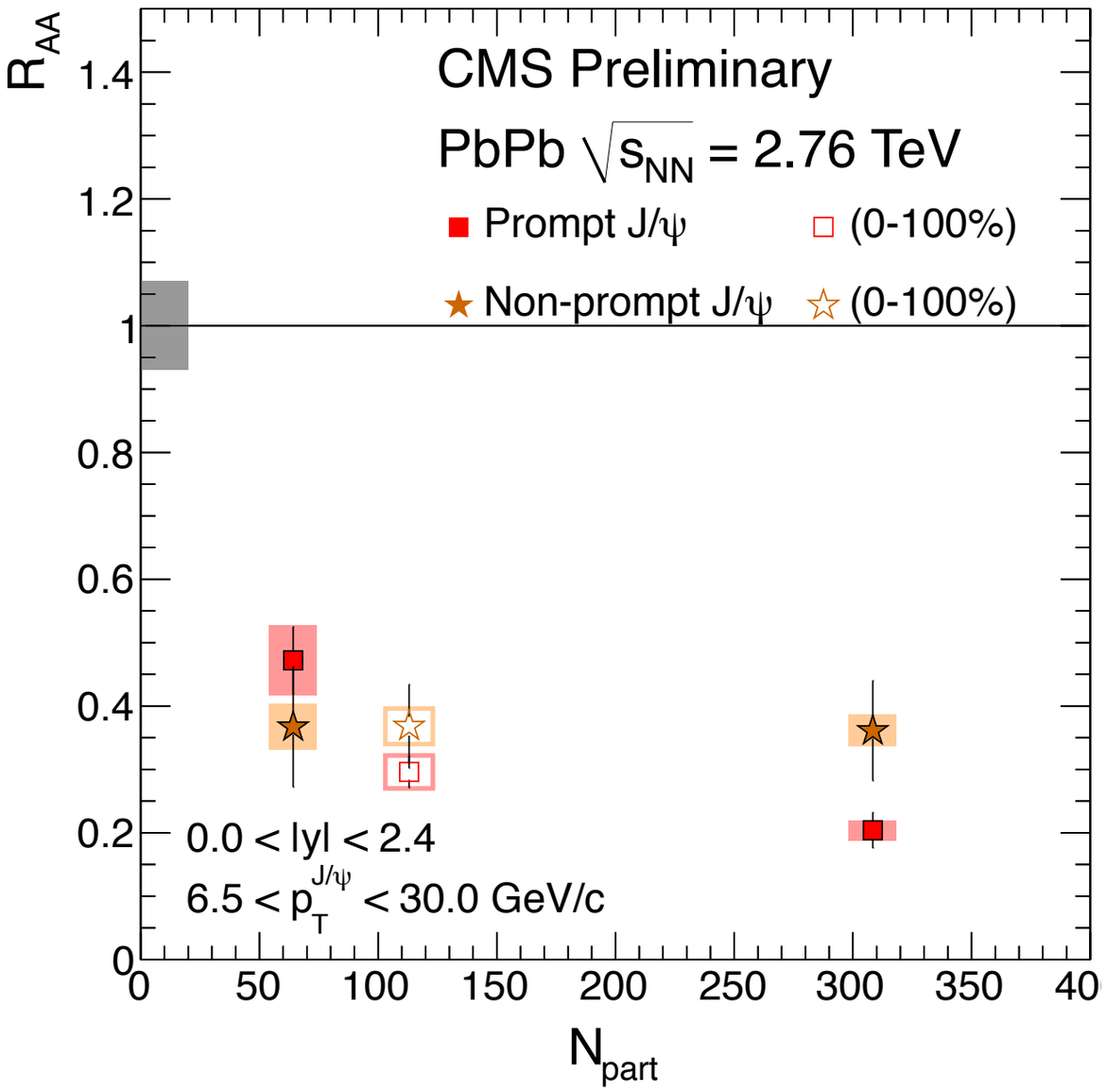


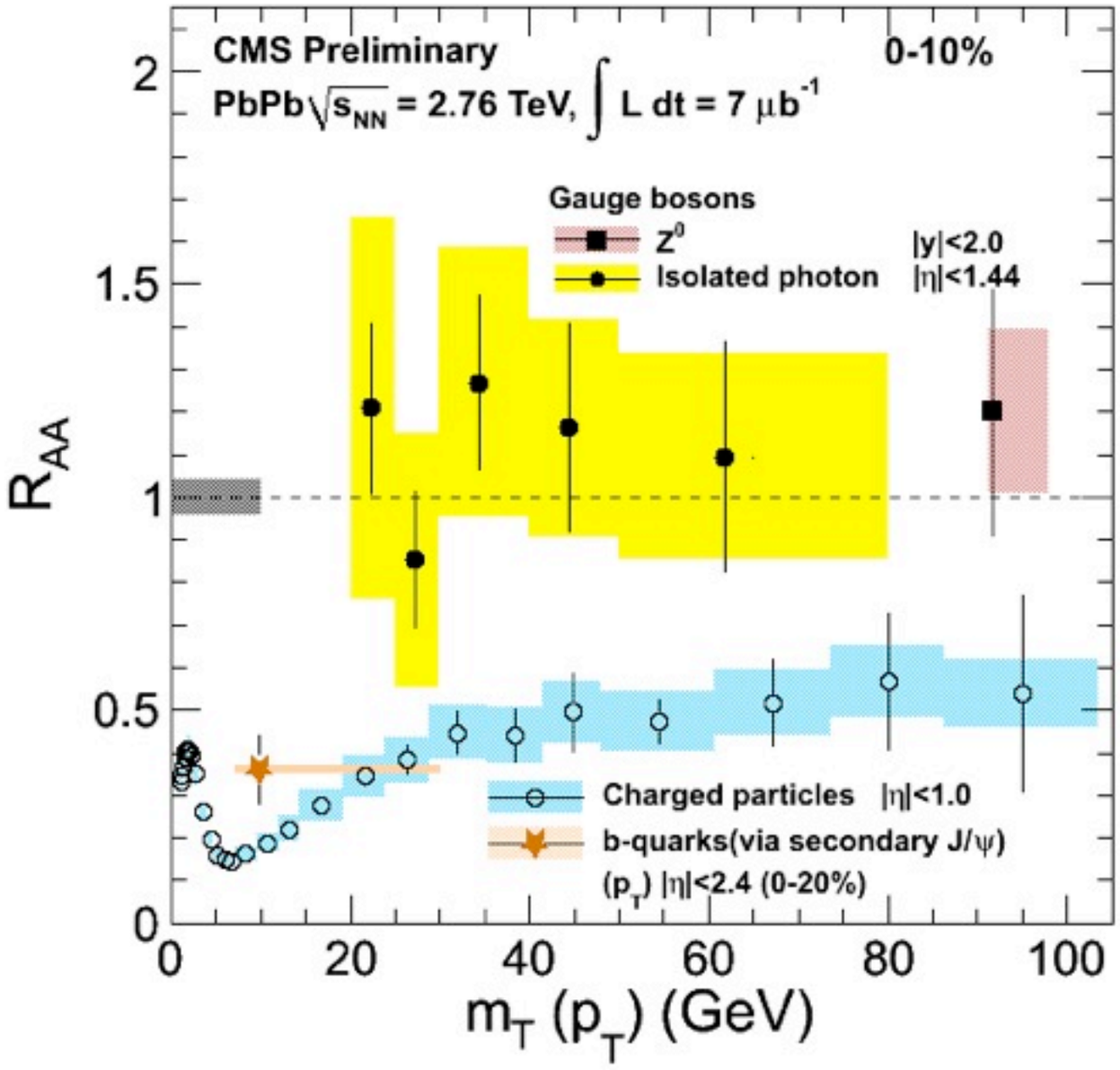
Figure 19: B-fraction of J/ψ production in PbPb at 2.76 TeV as function of p_T for the rapidity bin $|y| < 2.4$ *(red circles)* and $1.6 \leq |y| < 2.4$ *(black squares)*. The data are compared to B-fractions measured by CDF in $p\bar{p}$ at $\sqrt{s} = 1.96$ TeV [15] and CMS in pp at $\sqrt{s} = 7$ TeV [21].

- Careful when comparing R_{AA} of prompt J/ψ (CMS) and inclusive J/ψ (others)

R_{AA} : Non-prompt J/ψ

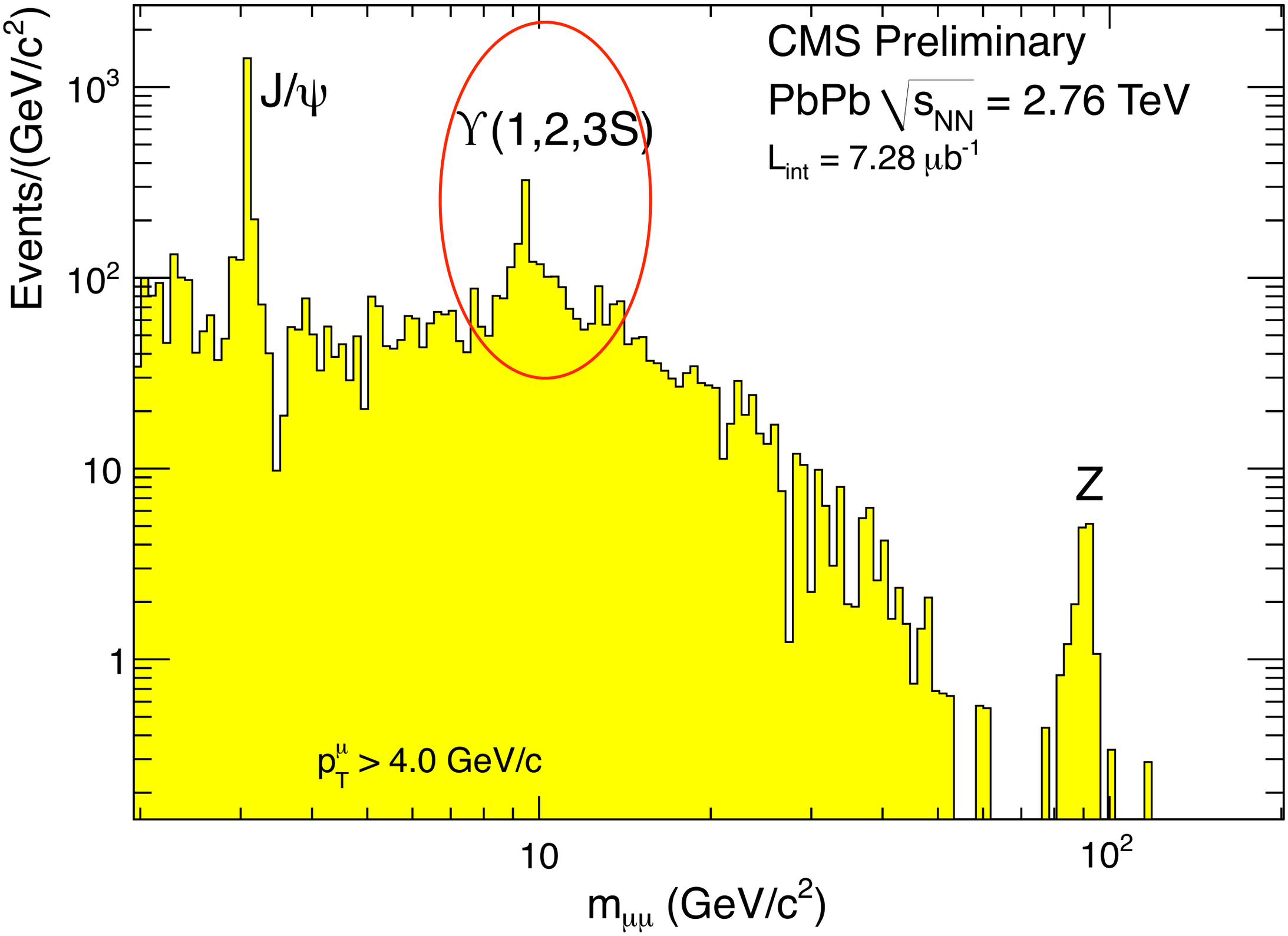
PRL 106, 212301 (2011)
CMS PAS HIN-10-006
CMS PAS HIN-11-002
CMS PAS HIN-10-005





- Suppression of non-prompt J/ψ observed in min. bias and central PbPb collisions
  - ➡ No centrality dependence
- First indications of high-pT b-quark quenching!

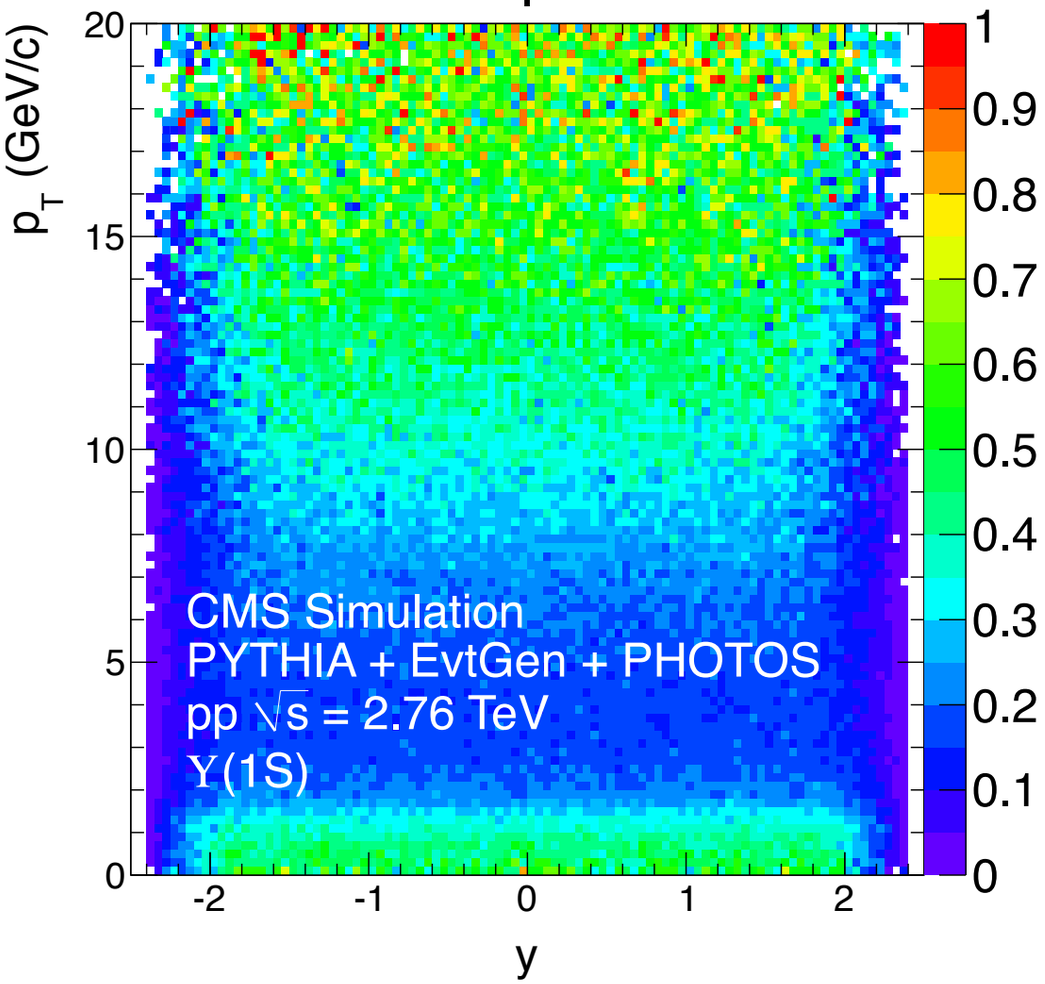
Muon pairs in PbPb at $\sqrt{s_{NN}} = 2.76$ TeV



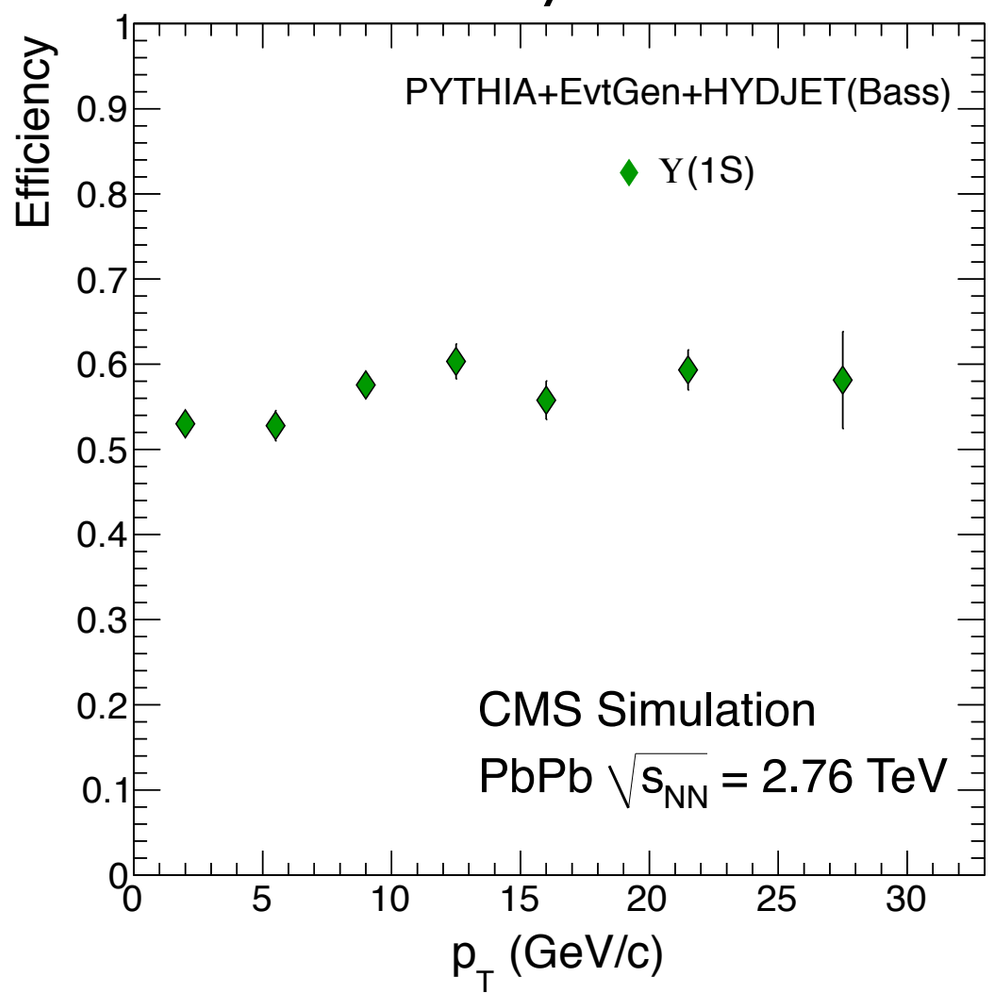
Υ(nS) in PbPb at $\sqrt{s_{NN}}$ = 2.76 TeV

CMS PAS HIN-10-006

Acceptance



Efficiency

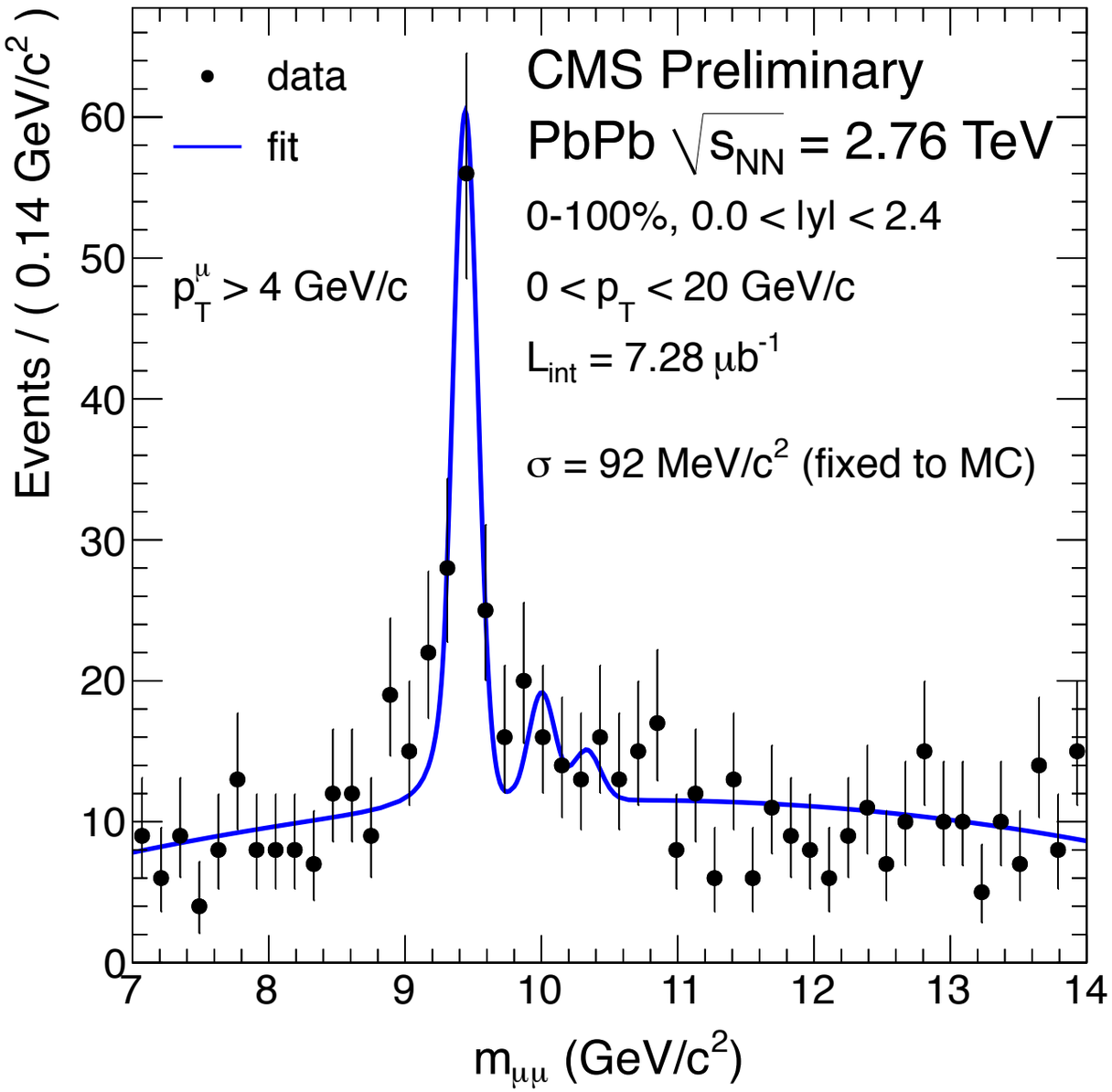


- Acceptance to p_T = 0 GeV/c
- Efficiencies from Monte Carlo
  - ➡ Validated with data driven method

Υ(nS) in PbPb at $\sqrt{s_{NN}}$ = 2.76 TeV

CMS PAS HIN-10-006

- Signal shape:
  - ➡ sum of three Crystal Ball functions
- Background:
  - ➡ 2nd order polynomial
- Free parameters:
  - ➡ Υ(1S) mass
  - ➡ Υ(1S) yield
  - ➡ Υ(2S+3S)/Υ(1S) yield ratio
  - ➡ Υ(3S)/Υ(2S) yield ratio
  - ➡ background shape
- Fixed:
  - ➡ Mass ratios of higher states fixed to PDG
  - ➡ Υ(1S) resolution fixed from MC: 92 MeV/c2
    - Consistent with fits when leaving resolution free (both in pp and PbPb)
  - ➡ Resolution of higher states fixed to scale with mass ratio $\sigma_{2S} = m_{2S}/m_{1S}\ \sigma_{1S}$
  - ➡ Crystal Ball radiative tail fixed to MC
  - ➡ Peak separation fixed to PDG

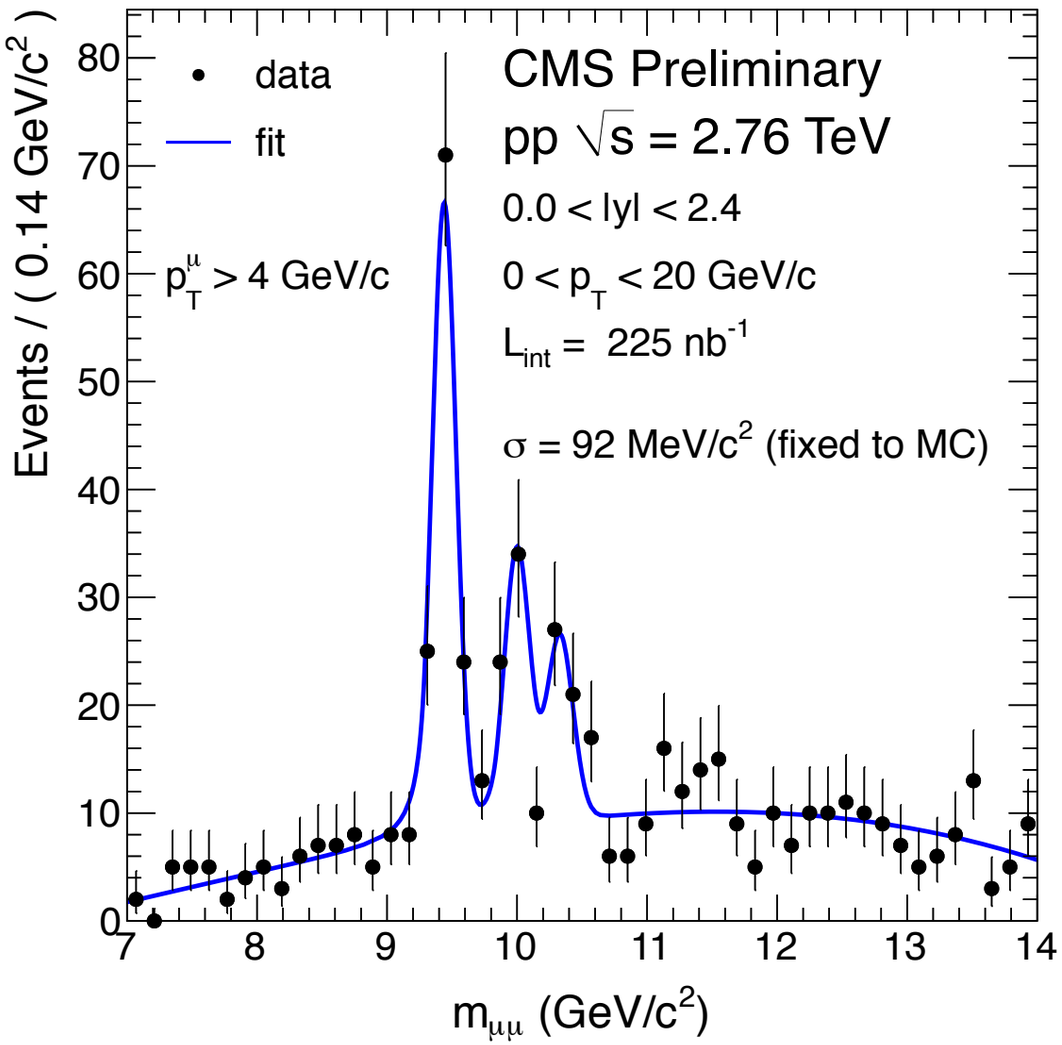


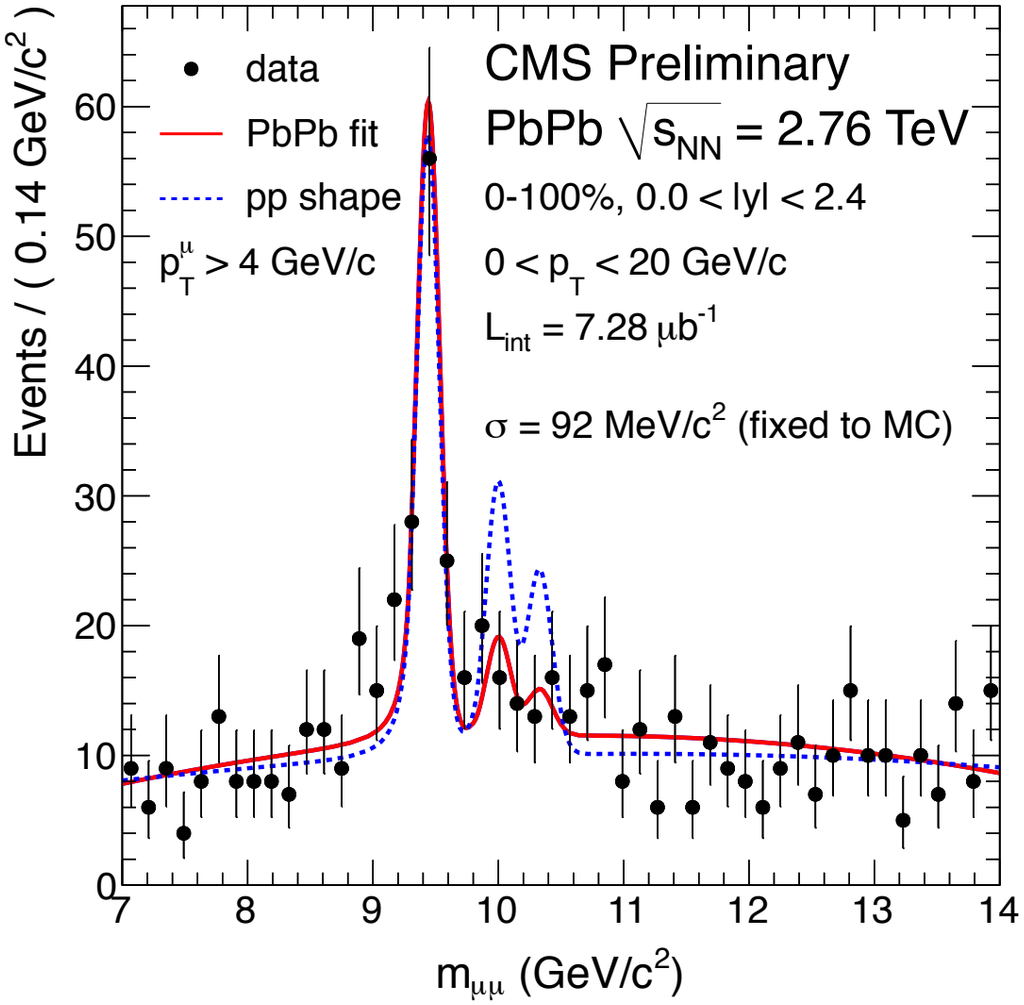
$$N_{\Upsilon(1S)} = 86 \pm 12$$

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

R_{AA} : [Υ(2S+3S)/Υ(1S)]

PRL 107 (2011) 052302





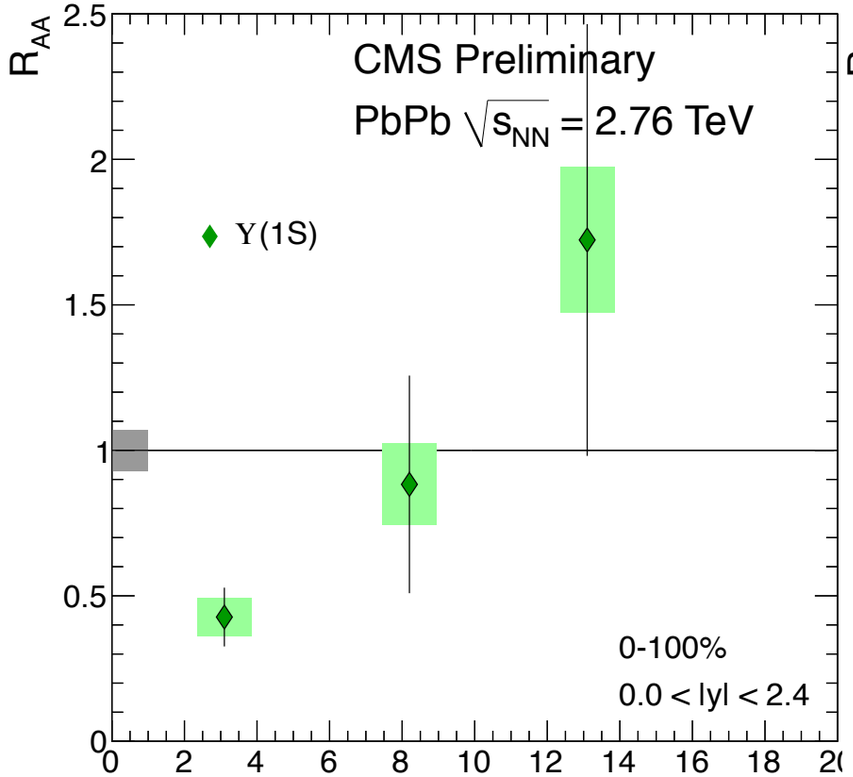
- Measure Υ(2S+3S) production relative to Υ(1S) production
- Simultaneous fit to pp and PbPb data at 2.76 TeV

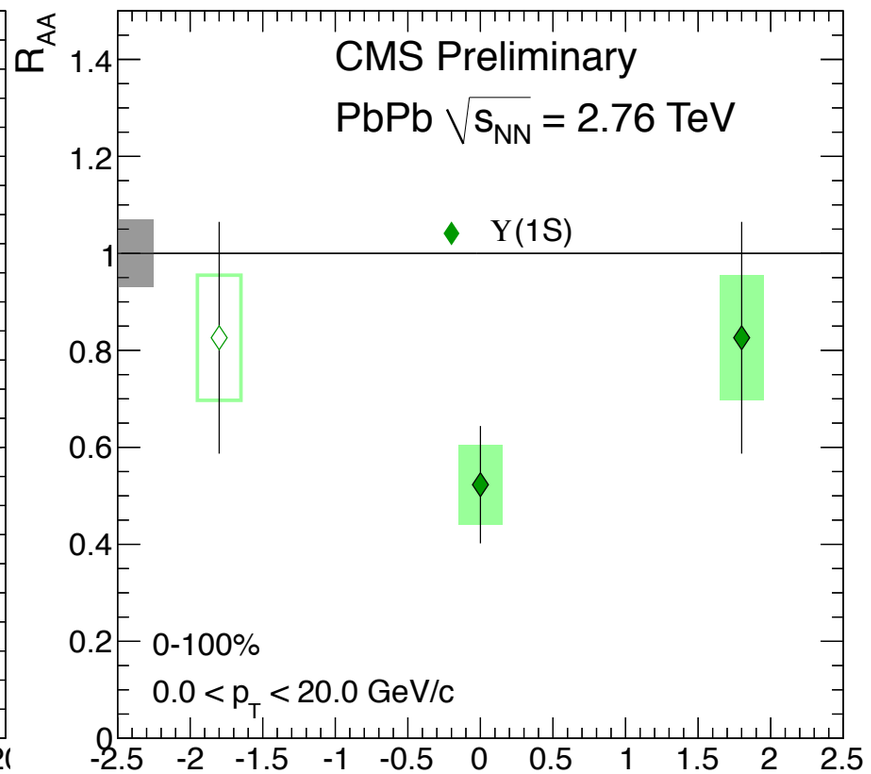
$$\frac{\Upsilon(2S+3S)/\Upsilon(1S)|_{\mathrm{PbPb}}}{\Upsilon(2S+3S)/\Upsilon(1S)|_{pp}} = 0.31^{+0.19}_{-0.15} \pm 0.03$$

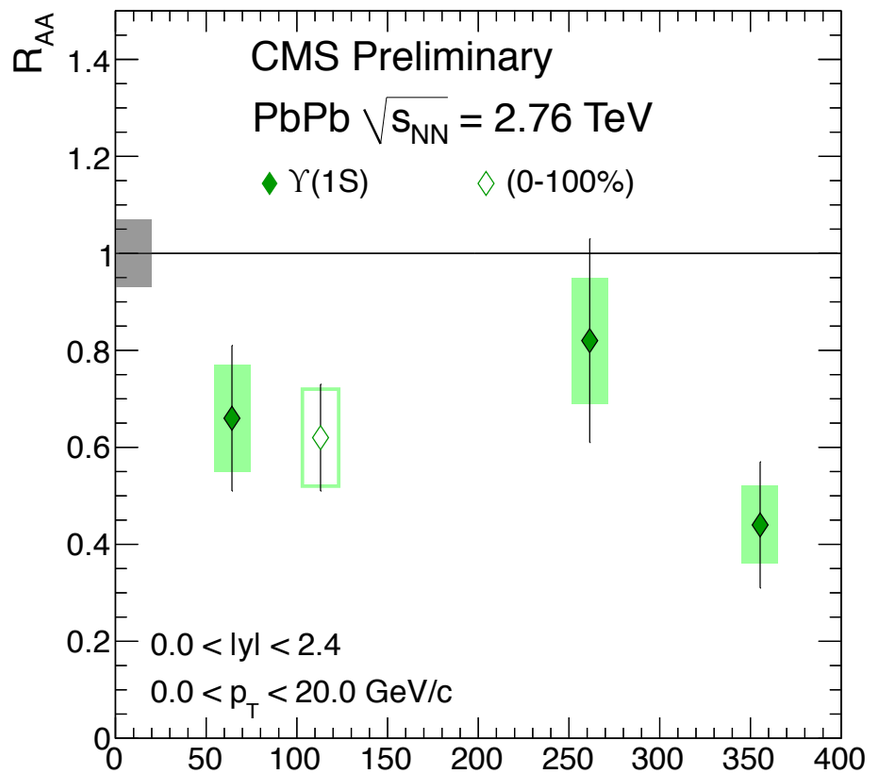
- Probability to obtain measured value, or lower, if the real double ratio is unity, has been calculated to be less than 1%

R_{AA}: Υ(1S)

CMS PAS HIN-10-006





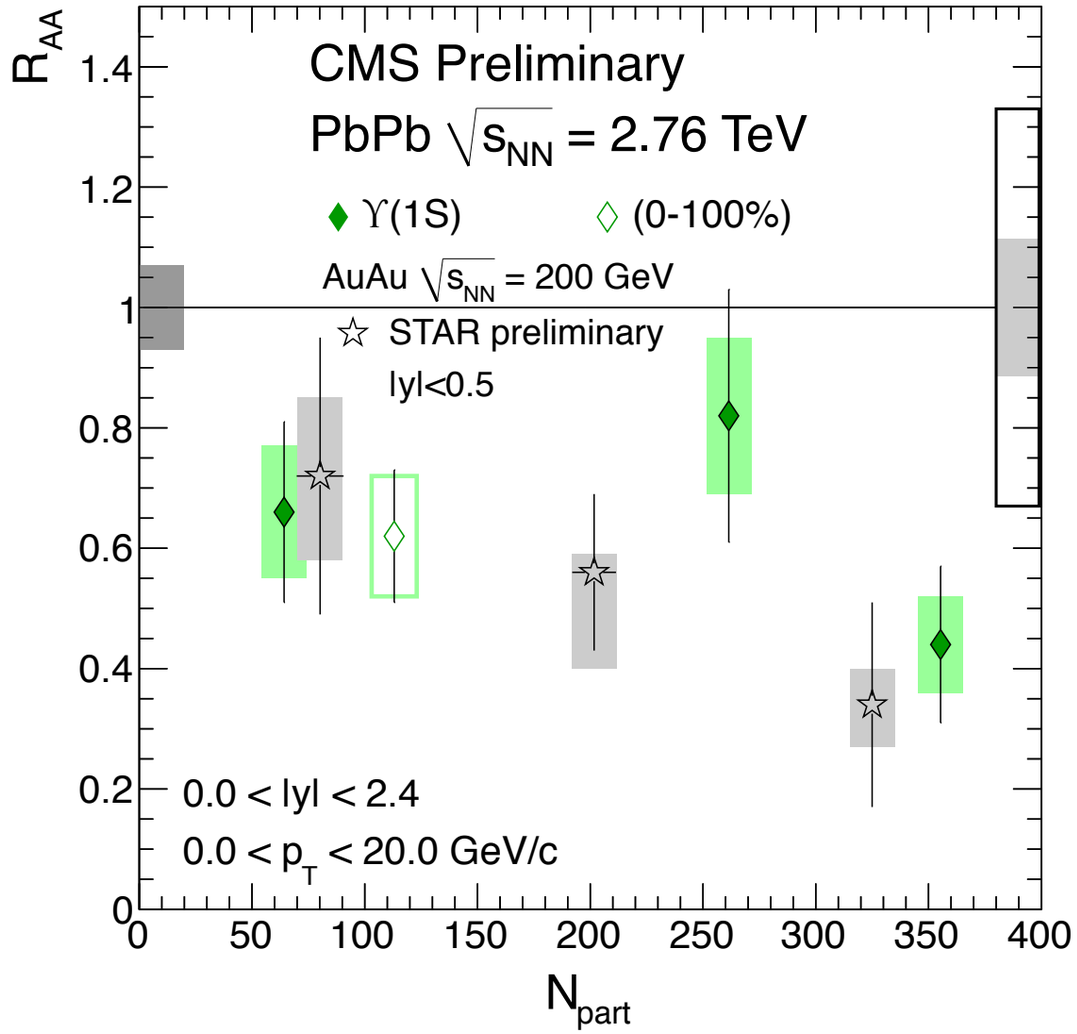


- CMS: Υ(1S)
  - ➡ p_T: suppressed at low values
  - ➡ rapidity: hint of a dependence of suppression (similar to J/Ψ)
  - ➡ centrality: suppressed by factor ~2.3 in 0–10%

- Large feed down contribution from excited states (χ_b, Υ(2S), Υ(3S))
  - ➡ Observed Υ(1S) suppression consistent with melting of excited states only

$R_{AA}: \Upsilon(1S)$

CMS PAS HIN-10-006



- STAR: Υ(1S+2S+3S) (arXiv:1109.3891)

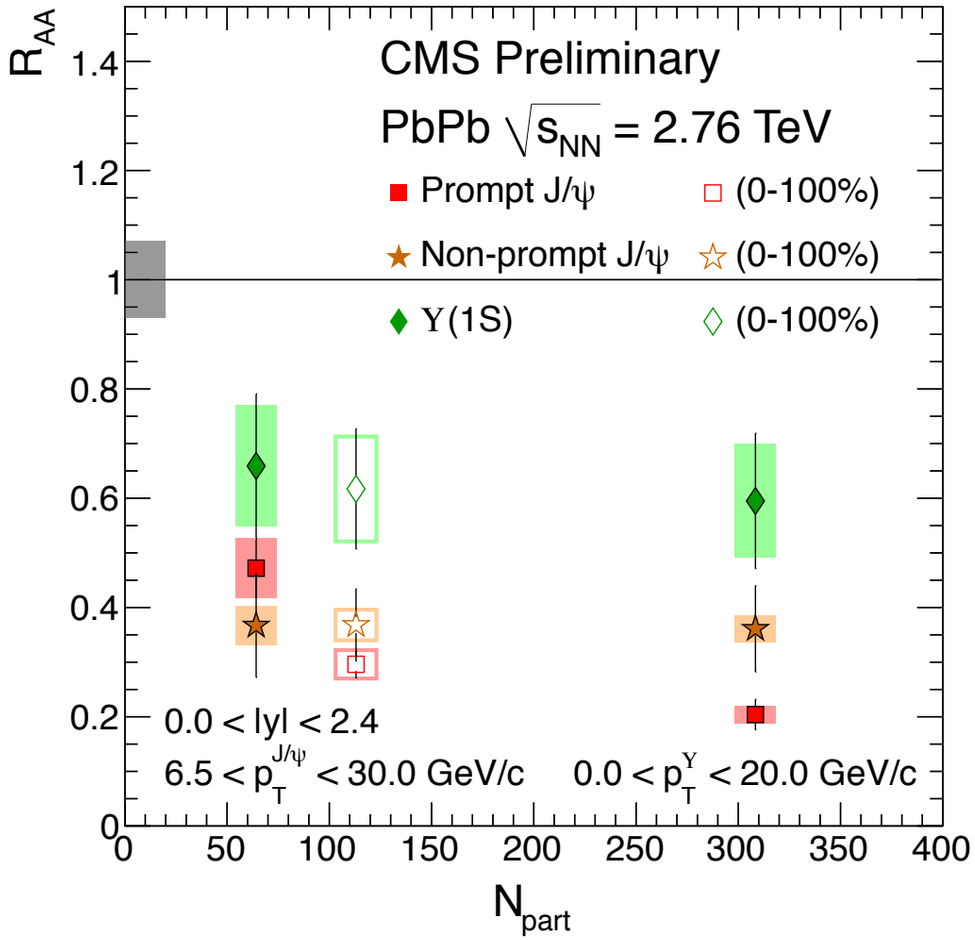
$$R_{AA}(\Upsilon(1\mathrm{S}+2\mathrm{S}+3\mathrm{S})) = 0.56 \pm 0.21^{+0.08}_{-0.16}$$

- CMS: Υ(1S+2S+3S) (0–100%):

$$R_{AA}(\Upsilon(1\mathrm{S}+2\mathrm{S}+3\mathrm{S})) = R_{AA}(\Upsilon(1\mathrm{S})) \times \frac{1+\Upsilon(2\mathrm{S}+3\mathrm{S})/\Upsilon(1\mathrm{S})|_{\mathrm{PbPb}}}{1+\Upsilon(2\mathrm{S}+3\mathrm{S})/\Upsilon(1\mathrm{S})|_{\mathrm{pp}}}$$

$$= 0.62 \times \frac{1+0.24}{1+0.78} \approx 0.43$$

Summary



- In PbPb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV:
  - Onia:
    - Prompt J/ψ suppressed
    - Υ(1S) suppressed, and suppression consistent with melting of excited states only
    - Υ(2S+3S) suppressed relative to Υ(1S)
  - b-quark:
    - J/ψ from B decays suppressed

My thoughts on production and such ..

- Reference crisis
  - ➡ pp, pA, AA
- Stop staring at Raa