Quarkonia with CMS

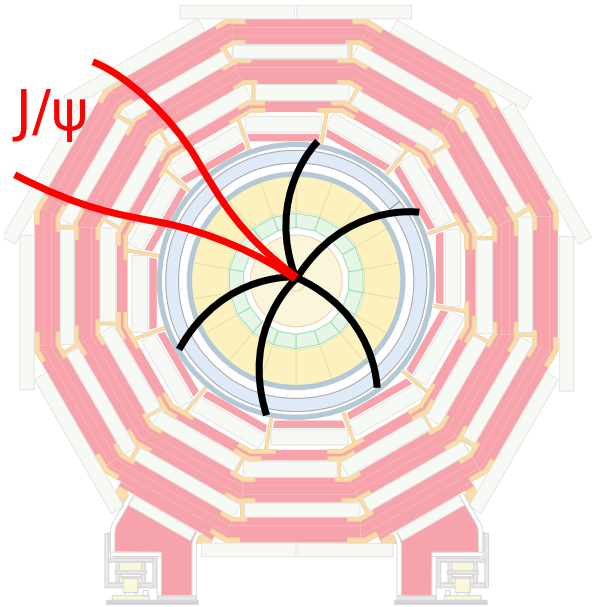
in pp, pPb and PbPb collisions

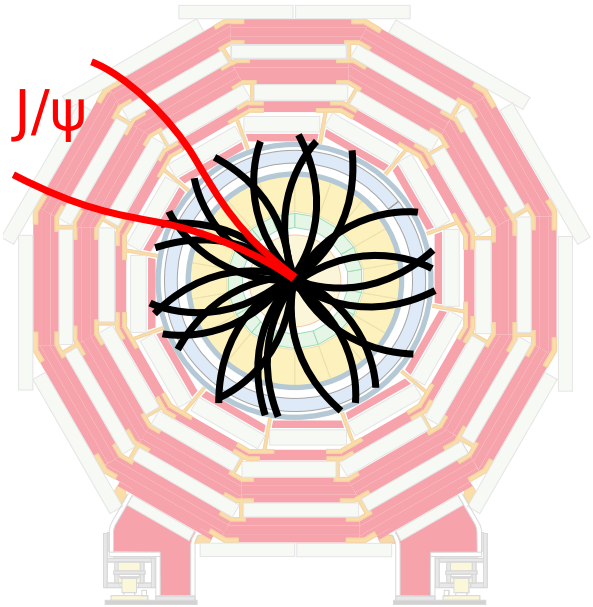
Émilien Chapon
on behalf of the CMS experiment

CERN

WPCF 2017
XII Workshop on Particle Correlations and Femtoscopy

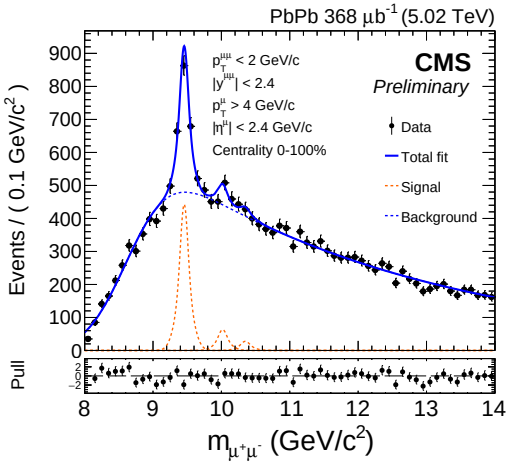
Introduction





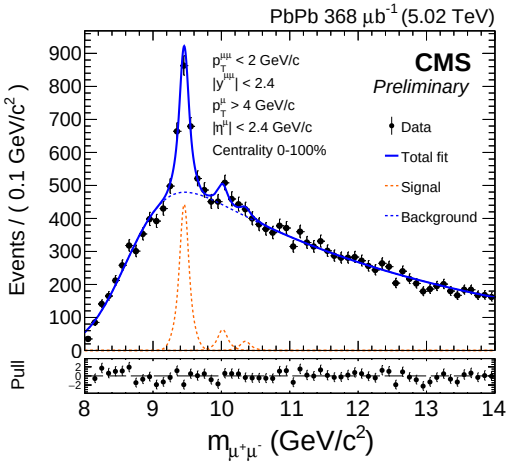
- Quarkonia: bound state of heavy quark-antiquark
  - J/ψ, ψ(2S), Υ(1S,2S,3S)
- "Long" lifetime: probing the medium evolution
- Wide variety of effects: nPDF, energy loss(es), Debye screening, recombination...
- Affected by the event multiplicity / activity

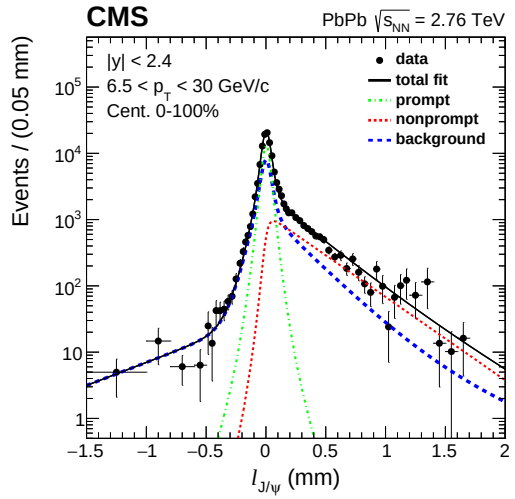
Signal extraction



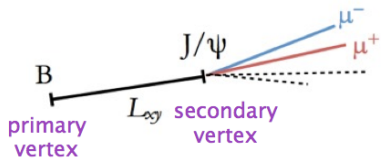
- Extract the different resonances (J/ψ, ψ(2S), Υ(nS)) from a fit to $M_{\mu+\mu-}$

Signal extraction

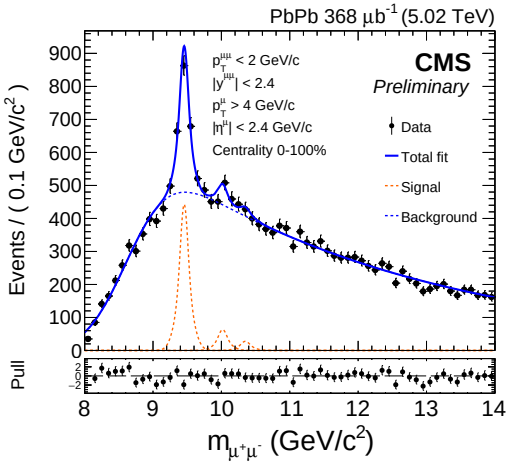


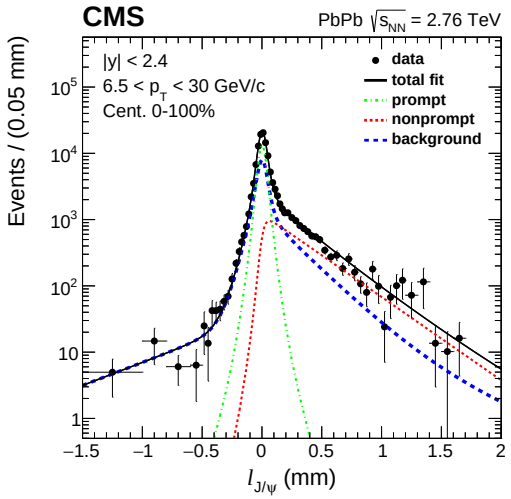


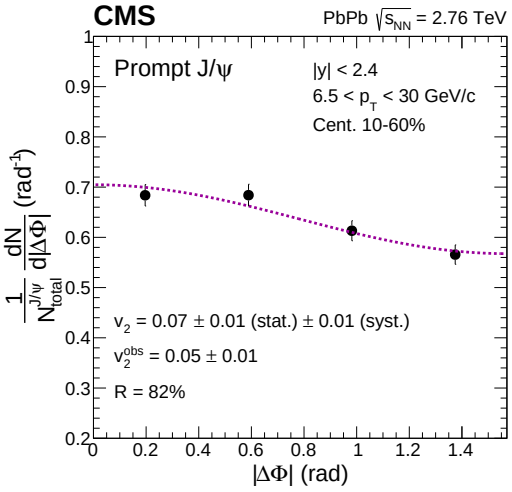
- Extract the different resonances (J/ψ, ψ(2S), Υ(nS)) from a fit to $M_{\mu^+\mu-}$
- B meson feedown for charmonia: 2D fit of ($M_{\mu^+\mu-}$, $\ell_{J/\psi}$)



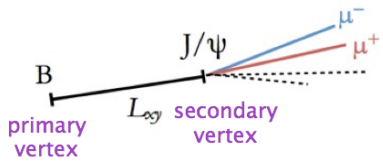
Signal extraction







- Extract the different resonances (J/ψ, ψ(2S), Υ(nS)) from a fit to $M_{\mu^+\mu^-}$
- B meson feedown for charmonia: 2D fit of ($M_{\mu^+\mu^-}$, $\ell_{J/\psi}$)
- v_2: fit of $\Delta\Phi$(J/ψ, event plane)



Outline

1. Small systems: pp and pPb collisions

2. PbPb collisions

Outline

Cross sections: prompt J/ψ in pPb (5.02 TeV)

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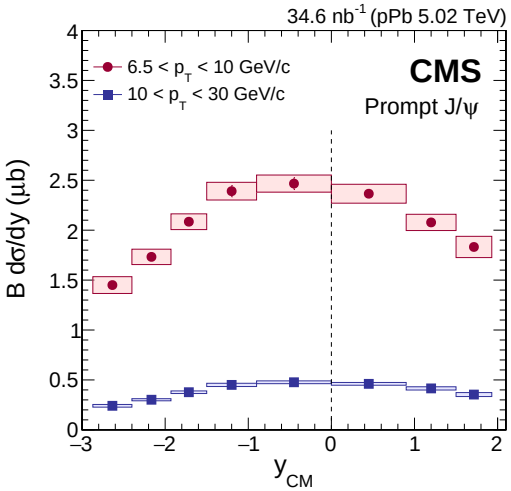

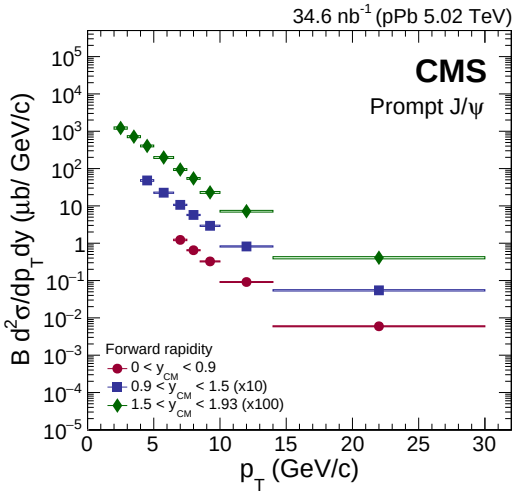

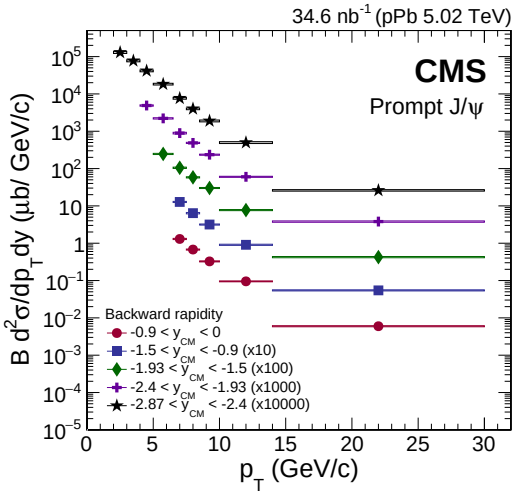

- Cross sections are the first ingredient
- Measured over a wide kinematic range ($2 < p_T < 30\,\text{GeV}/c$, $-2.87 < |y_{CM}| < 1.93$)
- Important direct input to production models

Nuclear modification factors: prompt J/ψ (5.02 TeV)

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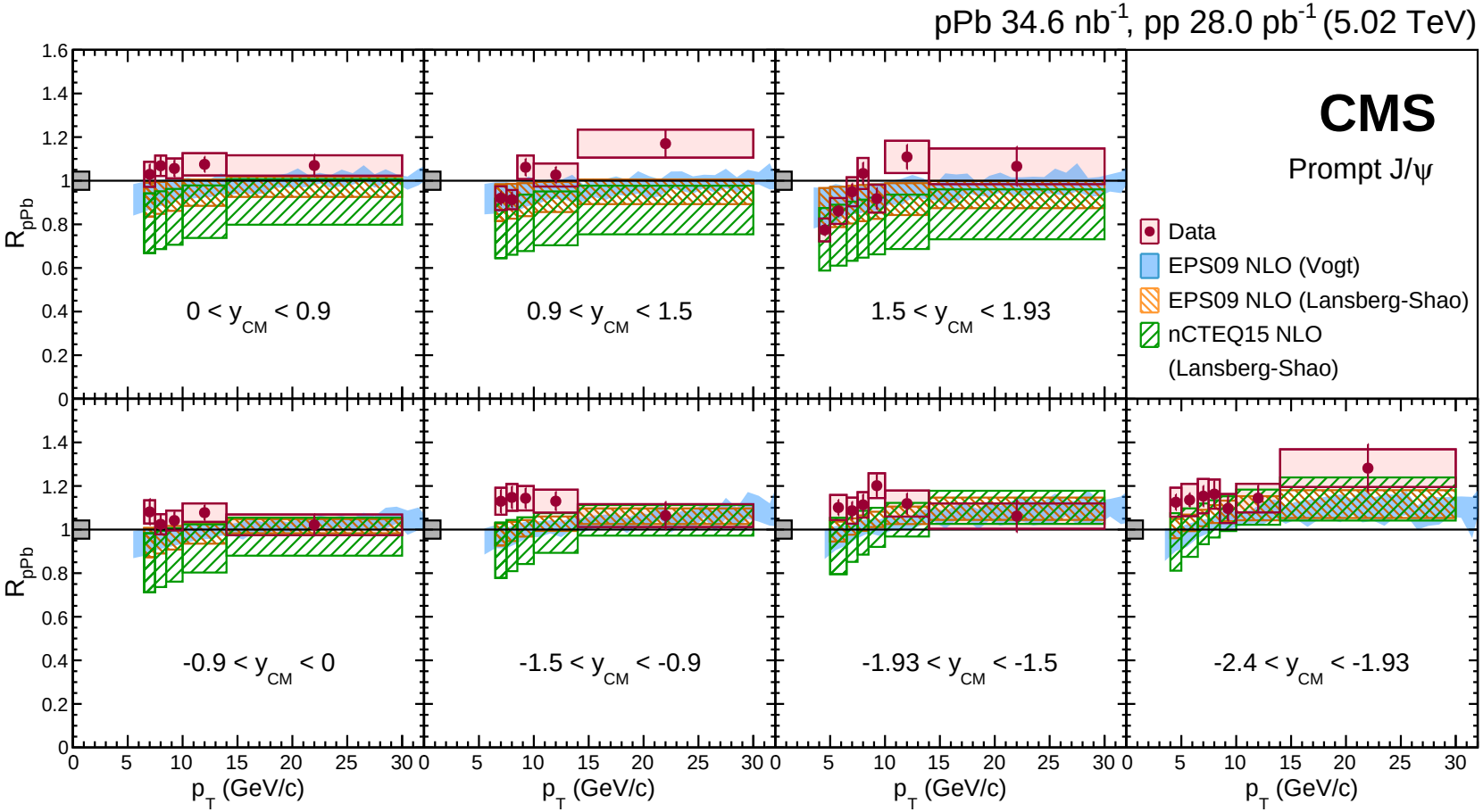
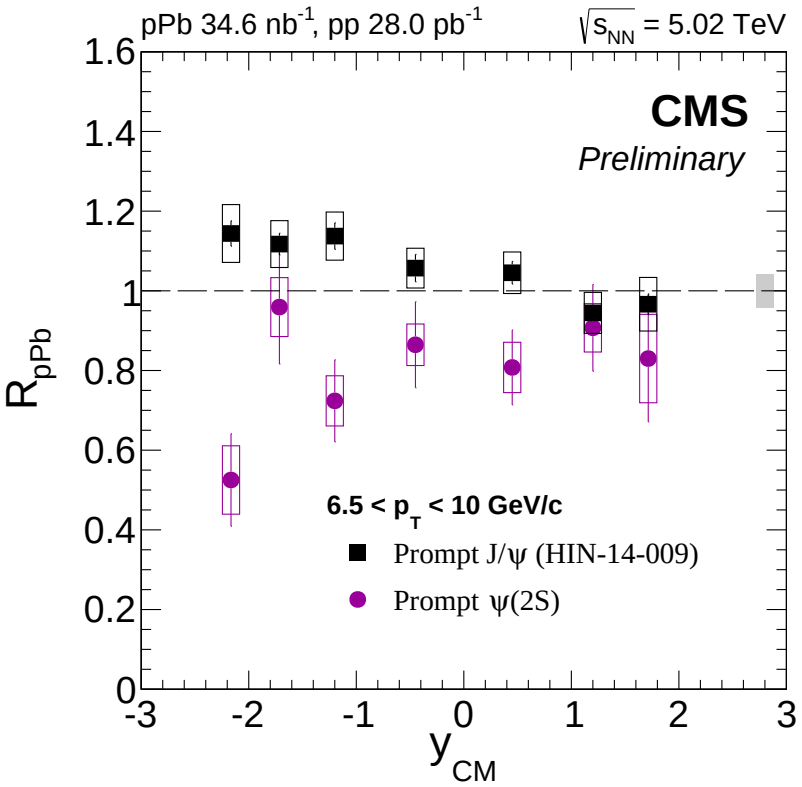
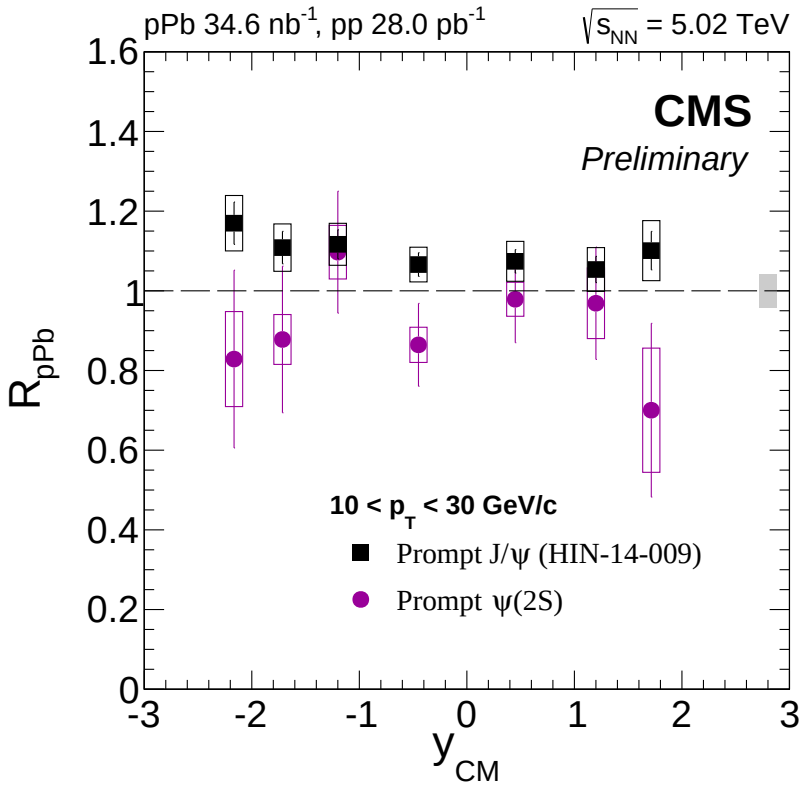


- Nuclear modification factor compared to different nPDF models
- Constraining nPDFs... or is this all there is?

Excited vs. ground state: ψ(2S) vs J/ψ (5.02 TeV)

CMS-PAS-HIN-16-015

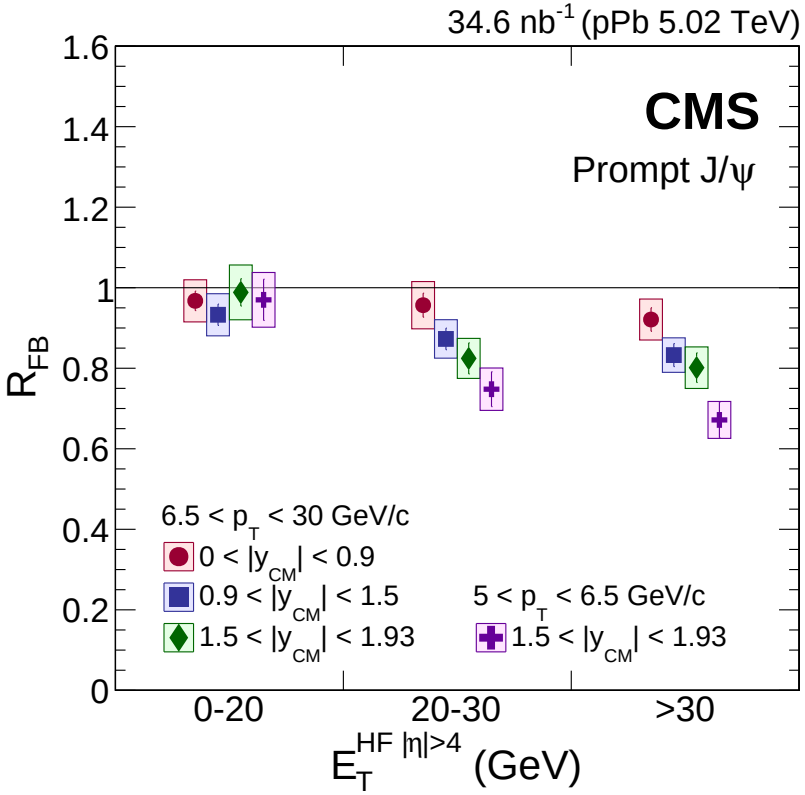




- Expecting similar effects from nPDF for J/ψ and ψ(2S)
- Hint for a different modification in the data
- Is the more "fragile" ψ(2S) destructed by the event multiplicity?

Event activity dependence: $R_{FB}(J/\psi)$ (5.02 TeV)

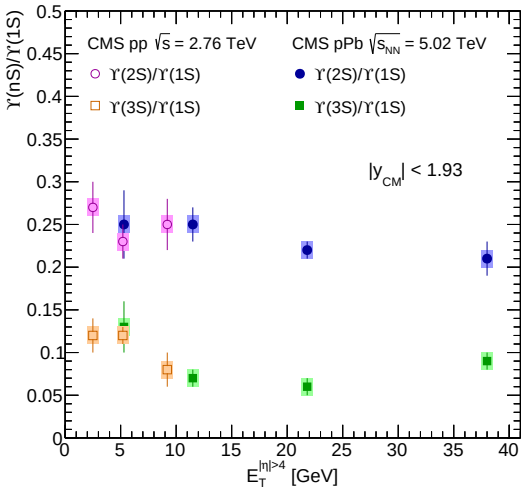
EPJC 77 (2017) 269

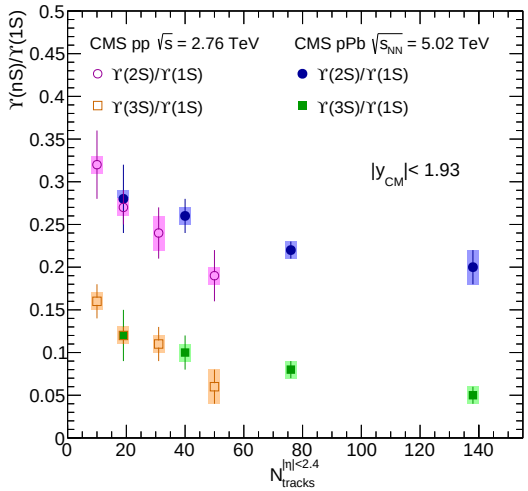


- Some dependence of the forward-backward ratio with forward activity
- More pronounced in the forward region
- Hinting to other nuclear effects beyond nPDF?

Event activity dependence: excited bottomonium states (5.02 TeV, 7 TeV)

JHEP 04 (2014) 103, CMS-PAS-BPH-14-009

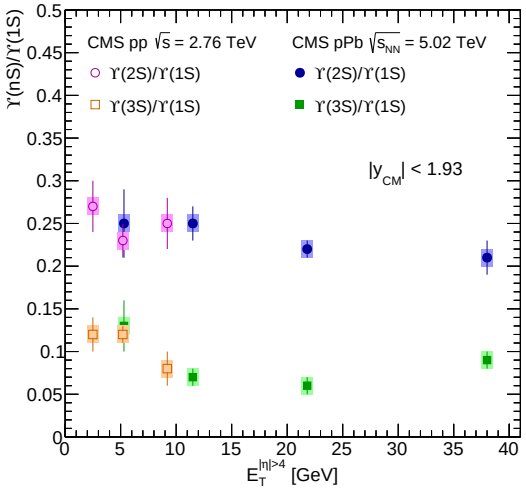


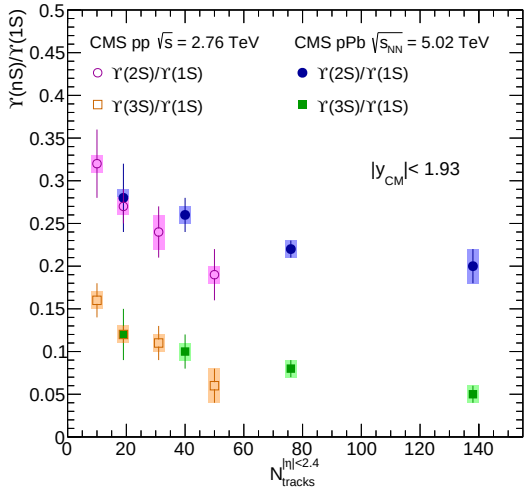


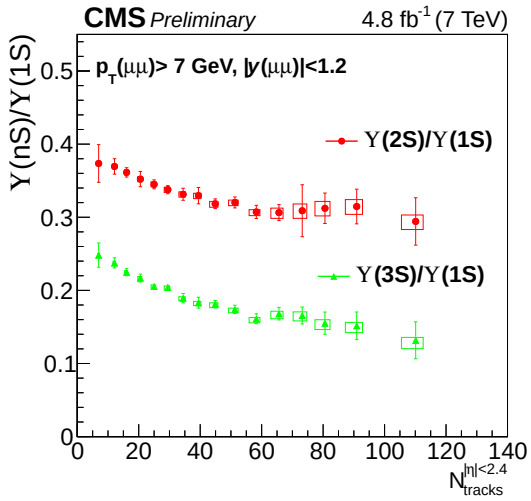
- No significant dependence of the Υ(nS)/Υ(1S) ratio with E_{HF}
- Some dependence with N_{tracks} (both in pp and pPb!)

Event activity dependence: excited bottomonium states (5.02 TeV, 7 TeV)

JHEP 04 (2014) 103, CMS-PAS-BPH-14-009





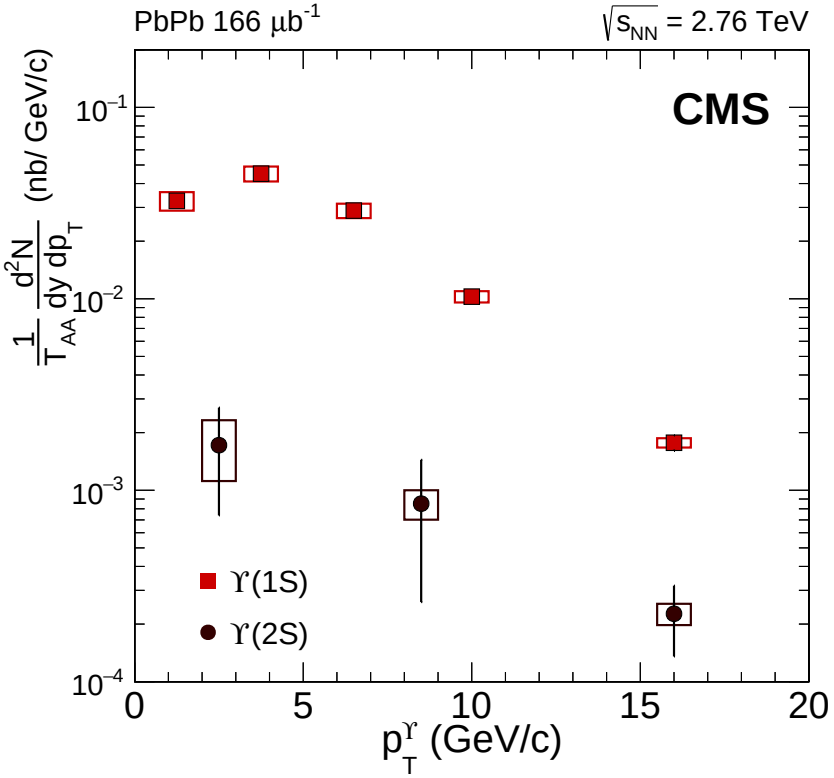


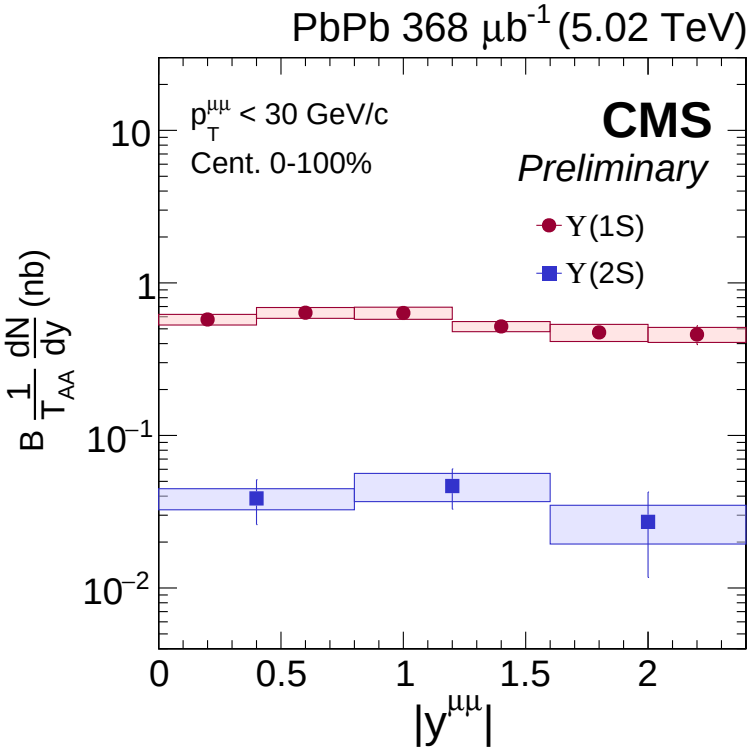
- No significant dependence of the Υ(nS)/Υ(1S) ratio with E_{HF}
- Some dependence with N_{tracks} (both in pp and pPb!)
- Confirmed in a larger pp data sample

Outline

Cross sections: Υ(nS) in PbPb (2.76 TeV, 5.02 TeV)

PLB 770 (2017) 357, CMS-PAS-HIN-16-023





- Differential cross sections, at 2.76 TeV and 5.02 TeV

Nuclear modification factors: J/ψ (2.76 TeV)

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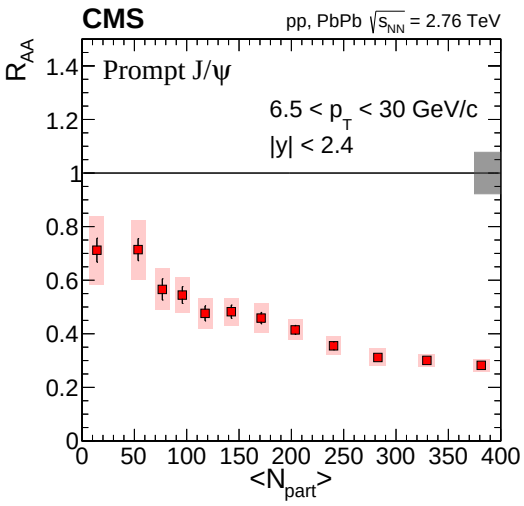
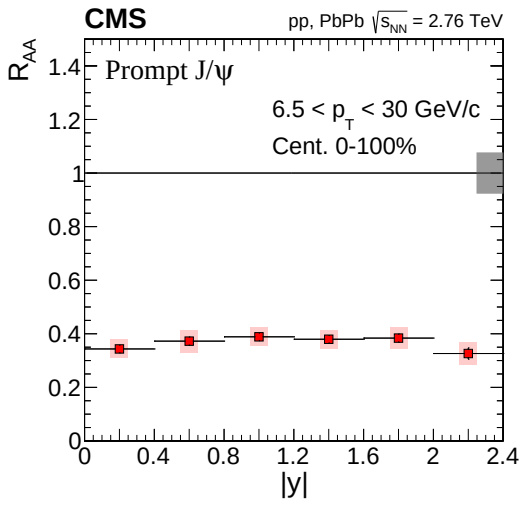
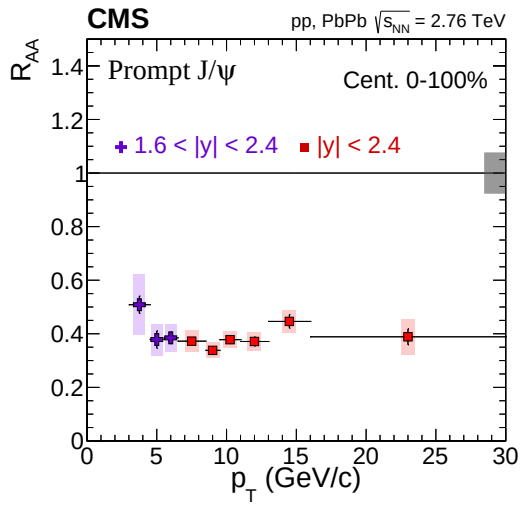


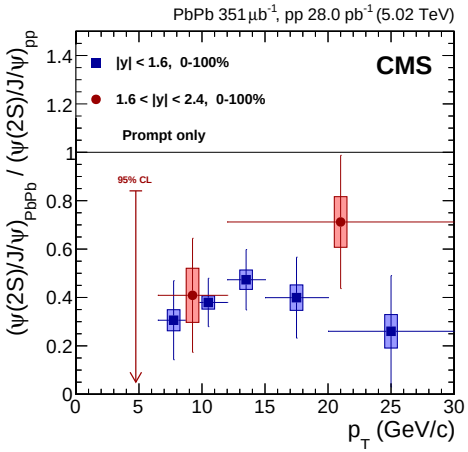


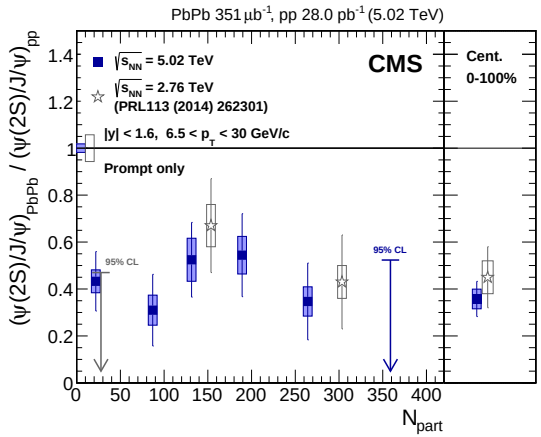


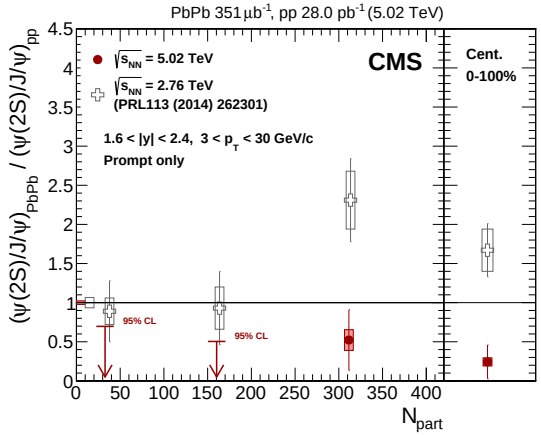
- Prompt J/ψ production is suppressed in all measured bins
- Larger suppression for central events
- No significant p_T or rapidity dependence in the measured kinematic range

J/ψ, ψ(2S): excited vs ground state (2.76 TeV, 5.02 TeV)

PRL 118 (2017) no.16, 162301



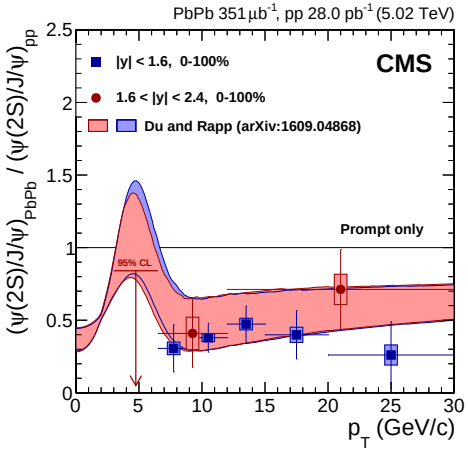


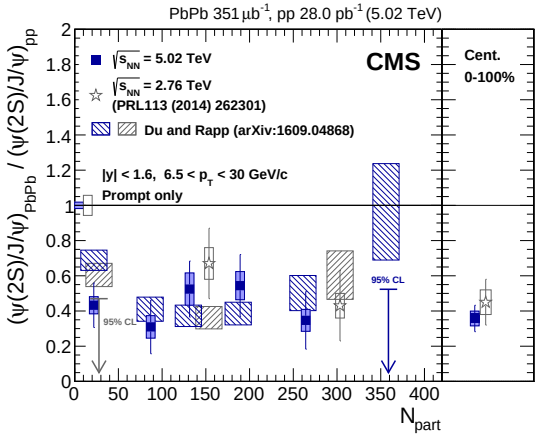


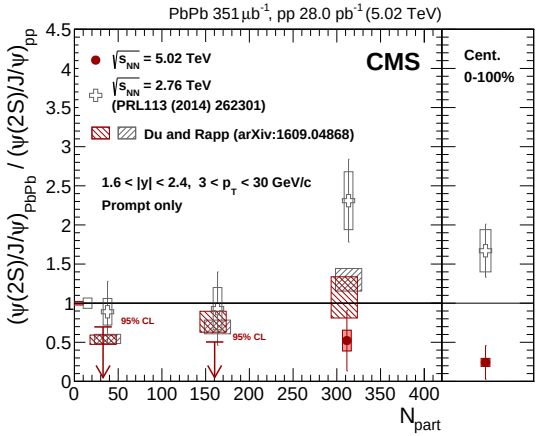
- Larger ψ(2S) suppression: sequential ordering?
- Hint for a different behaviour with energy

J/ψ, ψ(2S): excited vs ground state (2.76 TeV, 5.02 TeV)

PRL 118 (2017) no.16, 162301

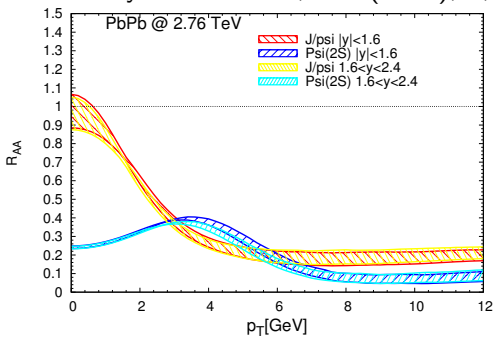






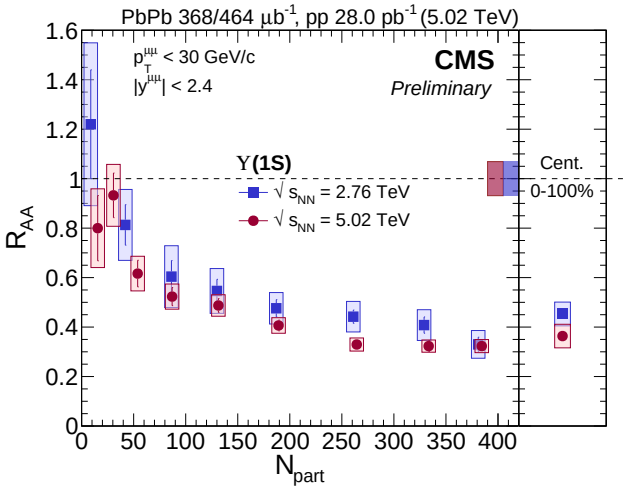
- X. Du and R. Rapp: ψ(2S) regenerated later than J/ψ in the fireball evolution

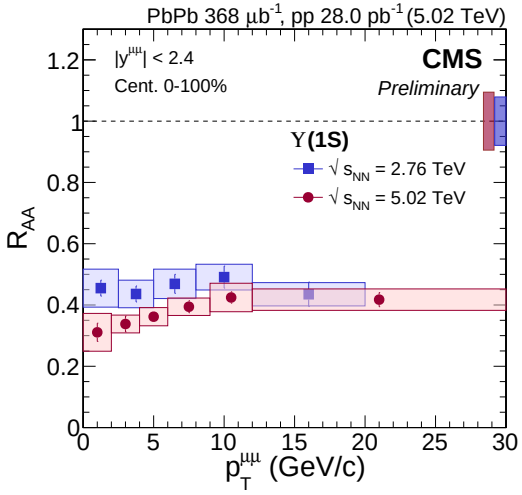
J. of Phys. Conf. Ser., 779 (2017), 1, 012042

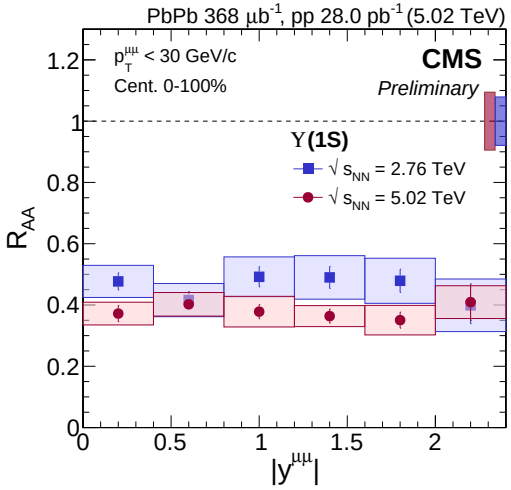


Nuclear modification factors: Υ(1S) (2.76 TeV, 5.02 TeV)

CMS-PAS-HIN-16-023



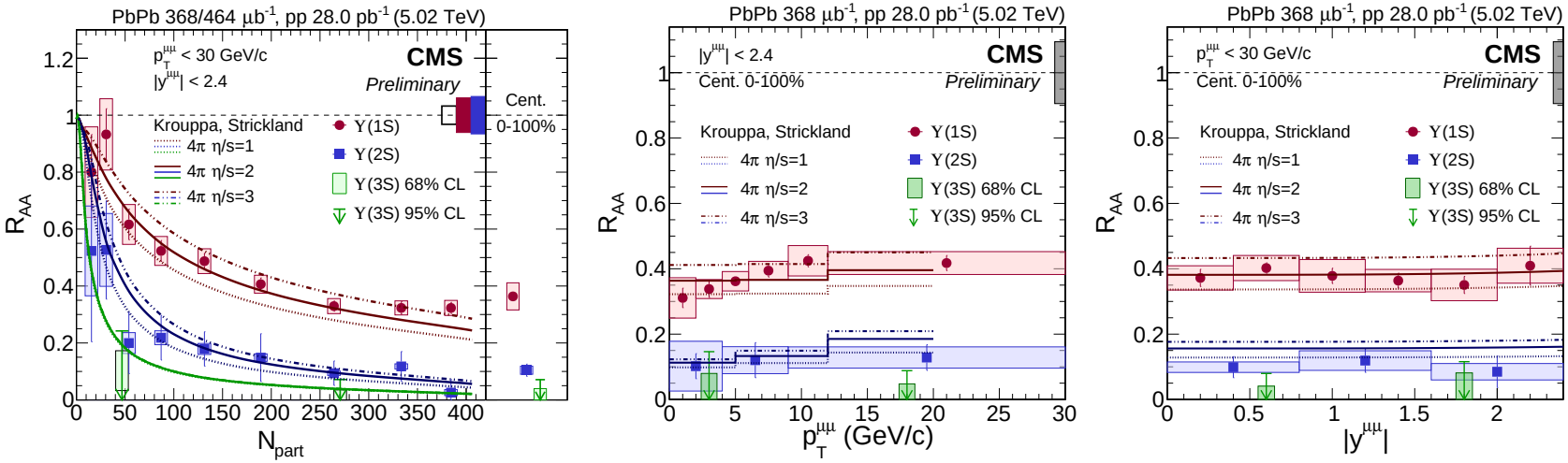




- Larger suppression for central events, no significant kinematic dependence
- 2.76 TeV vs 5.02 TeV: hint for an energy dependence?

Υ(nS): excited vs ground state (5.02 TeV)

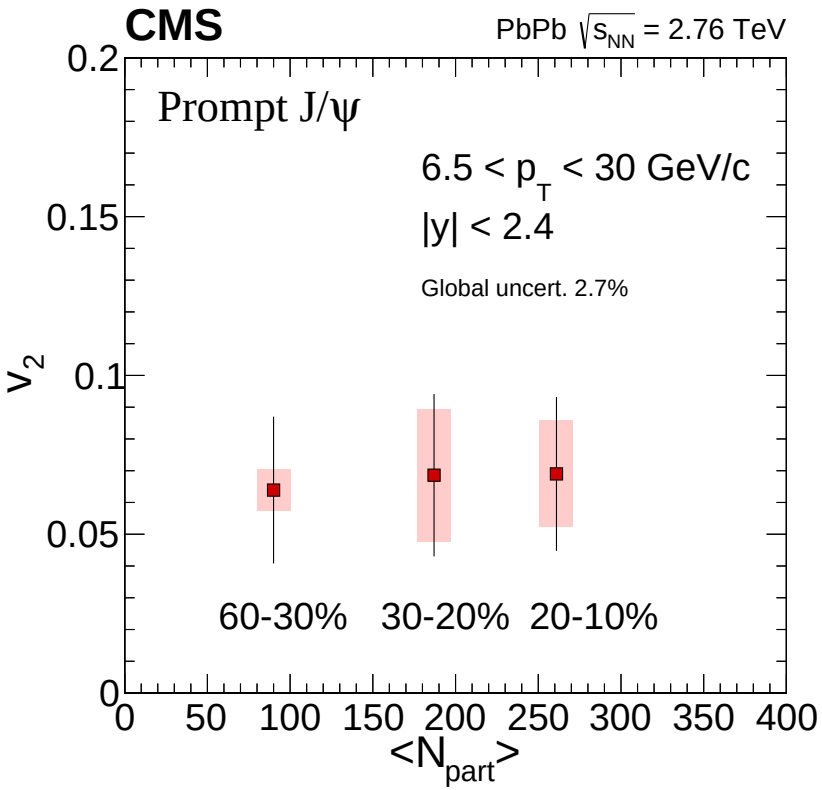
CMS-PAS-HIN-16-023

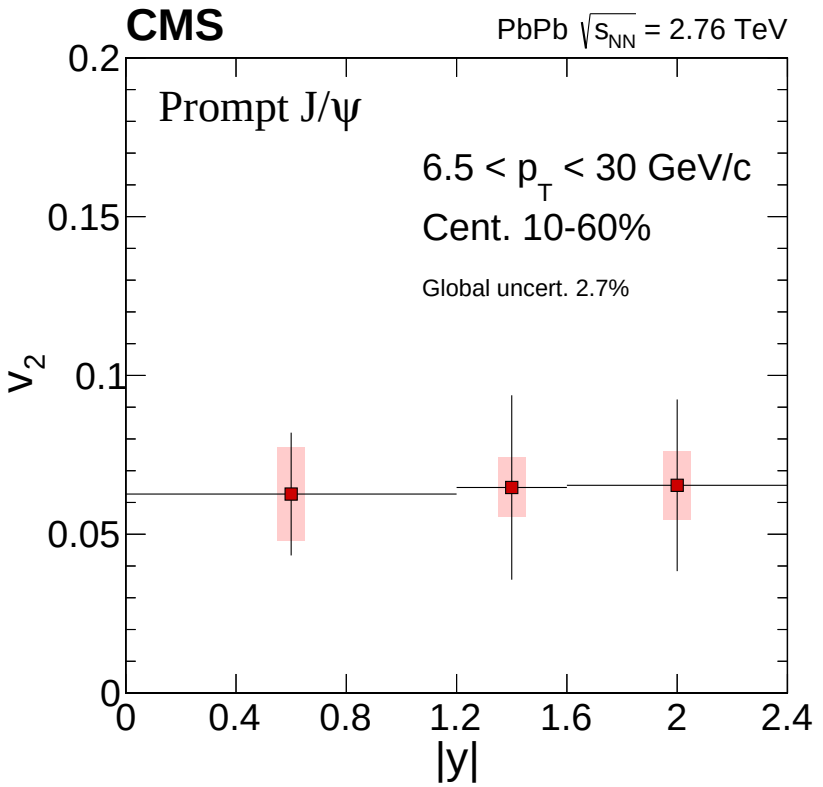


- Clear ordering of the three states:
  $R_{AA}(\Upsilon(3S)) < R_{AA}(\Upsilon(2S)) < R_{AA}(\Upsilon(1S))$
- More weakly bound states melt more easily
- Υ(3S) still unobserved in PbPb collisions
- Comparison with an hydrodynamic model

J/ψ flow (2.76 TeV)

EPJC 77 (2017) 252





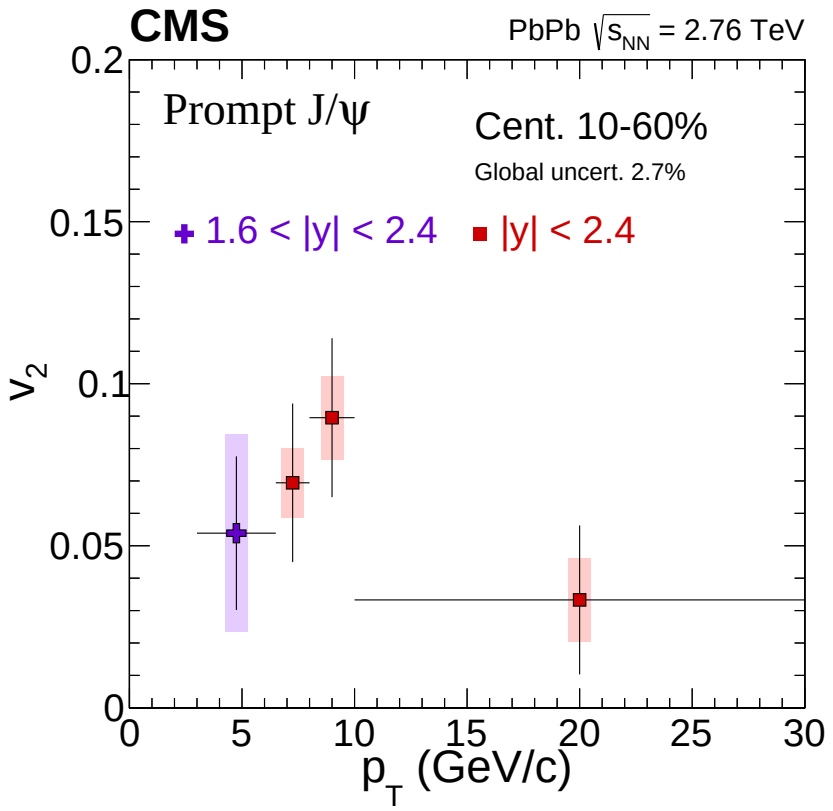
$|y| < 2.4$, $6.5 < p_T < 30$ GeV/c, 10–60% centrality:

$$v_2 = 0.066 \pm 0.014(\text{stat}) \pm 0.014(\text{syst}) \pm 0.002(\text{global})$$

- Significant non-zero v_2 (3.3σ)

J/ψ flow (2.76 TeV)

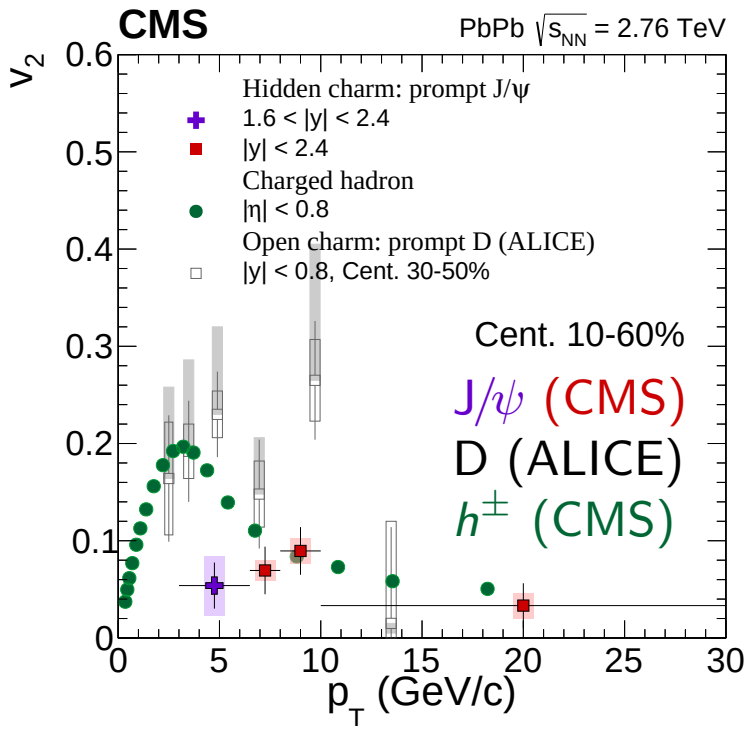
EPJC 77 (2017) 252



- No significant p_T dependence

J/ψ flow (2.76 TeV)

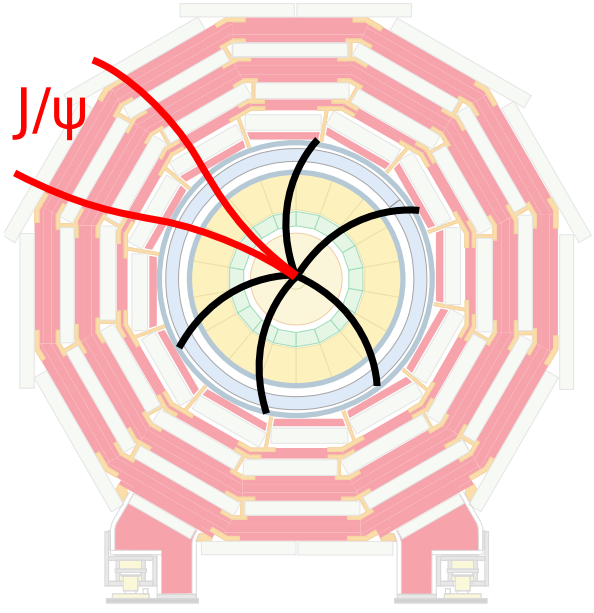
EPJC 77 (2017) 252

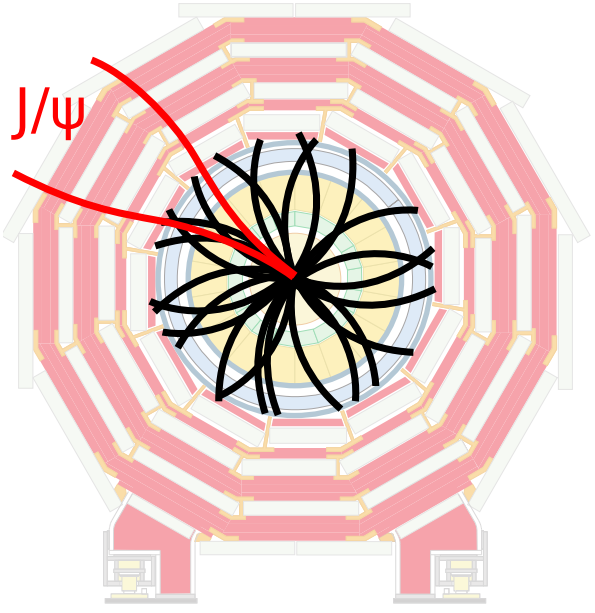


Comparing hidden charm (prompt J/ψ, CMS) to open charm (D, ALICE):

- Smaller v_2 at low p_T, similar at high p_T?
- Flavour independence of energy-loss path-length dependence?

Summary





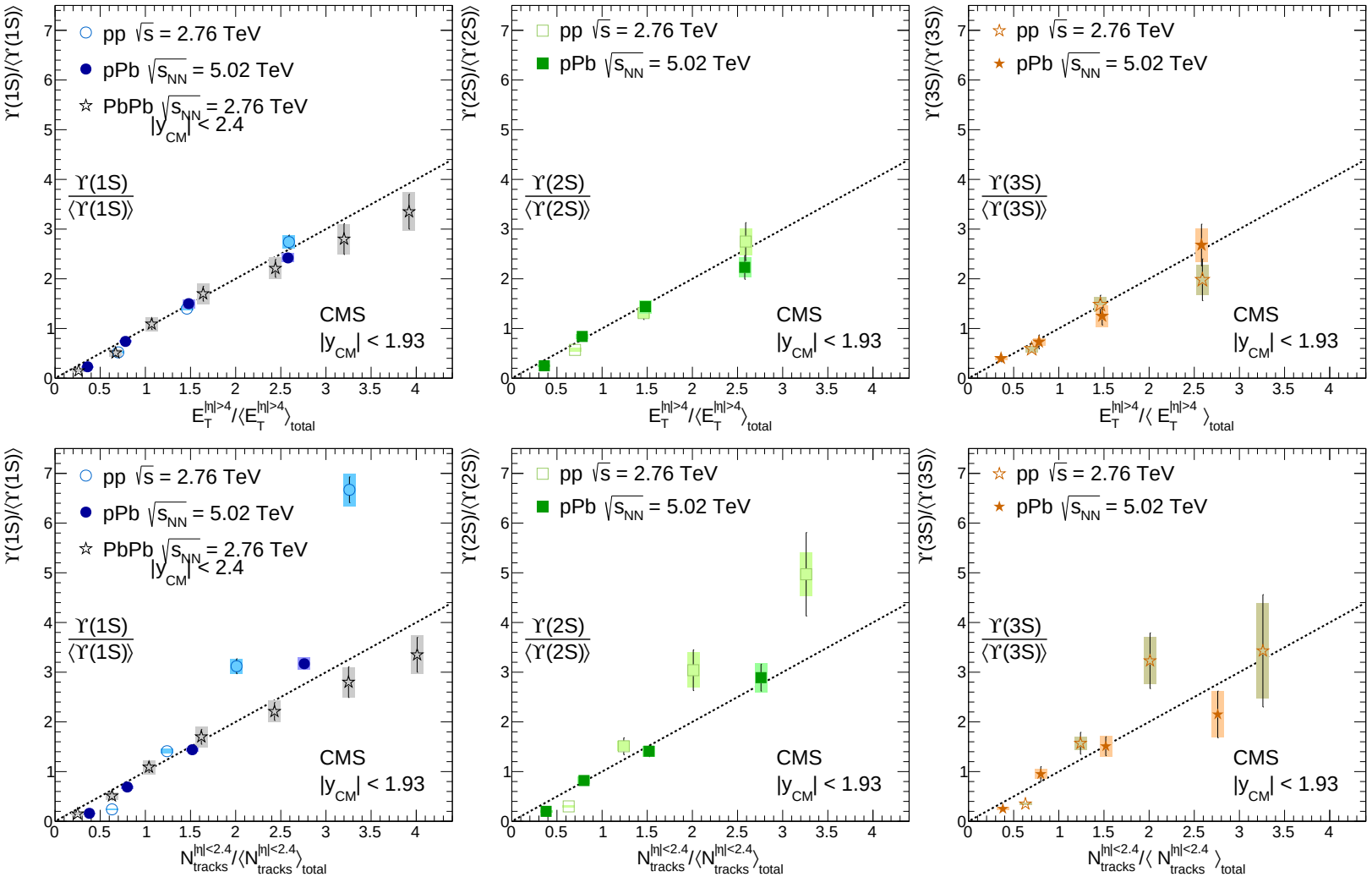
Quarkonia in heavy ion collisions: a large toolbox for studying nuclear effects

- Measuring cross sections and ratios: production mechanism
- pPb collisions and event activity studies: is there more than nPDFs?
- PbPb collisions: sequential melting? Charm flows!

Additional material

Event activity dependence of Υ(nS) production: self-normalised ratios

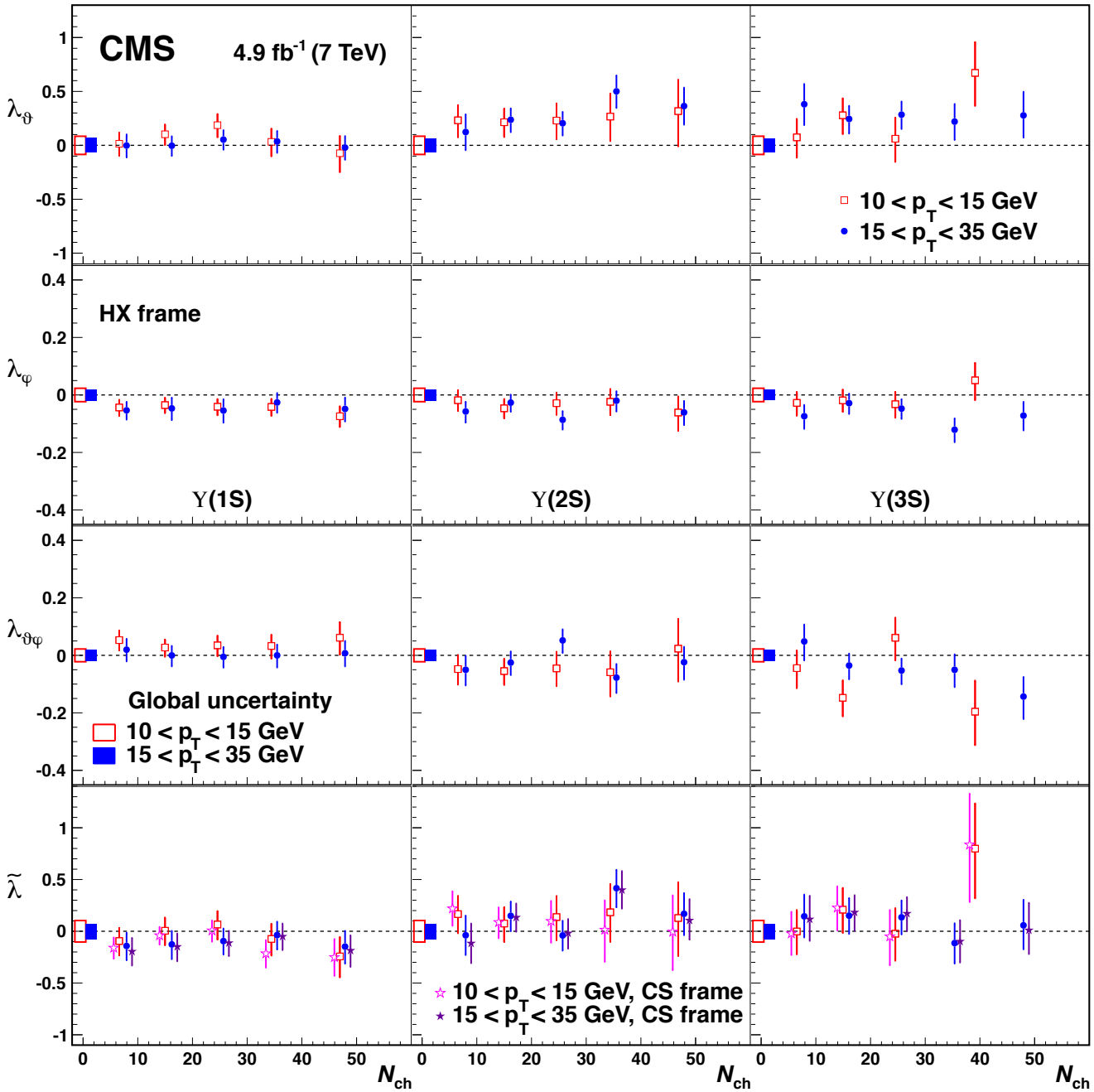
JHEP 04 (2014) 103



Event activity dependence of Υ(nS) polarisation in pp

7 TeV

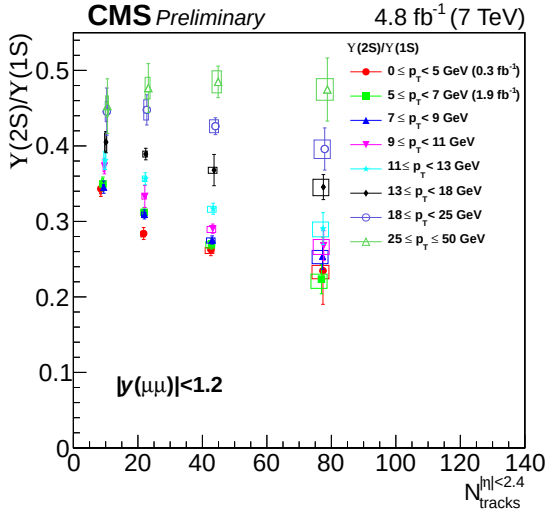
PLB 761 (2016) 31

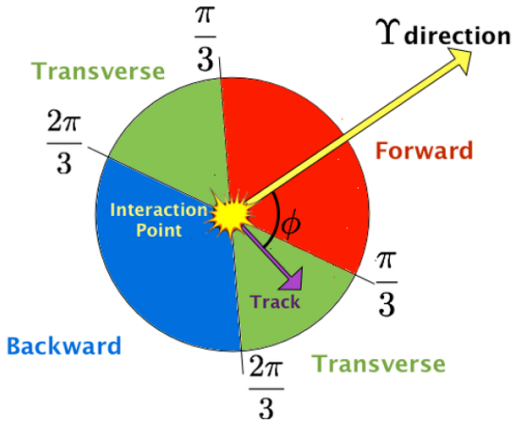


Event activity dependence of Υ(nS) production in pp

7 TeV

CMS-PAS-BPH-14-009





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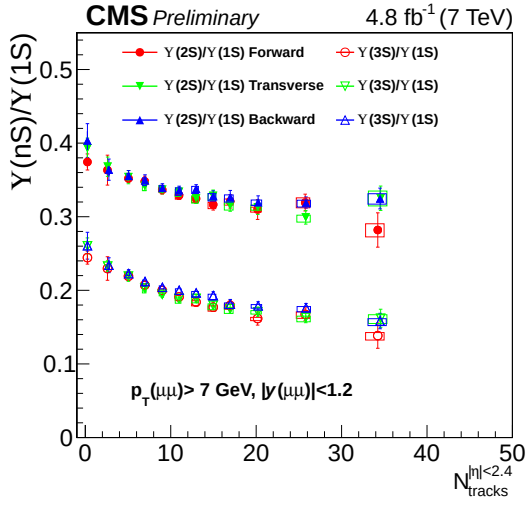

(b)