

## Quarkonia chapter

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# Chapter organisation

The proposed chapter outline is the following (implemented in Overleaf):

- ① Introduction
- ② Charmonia in PbPb collisions
- ③ Bottomonia in PbPb collisions
- ④ Quarkonia in pp and pPb collisions

**Note:** in pp we don't plan to discuss inclusive cross sections, but will discuss multiplicity-dependent studies.

In the following we will go through the list of figures for each section.

**Note:** not an exhaustive list of theoretical predictions – more models may come



# List of figures: charmonia in PbPb collisions (1/2)

- prompt  $J/\psi$   $v_2$  vs  $p_T$ , for 30–50%:  $|y| < 0.9$ ,  $1.6 < |y| < 2.4$ ,  $2.5 < |y| < 4$ 
  - **Available:** ALICE projection, theory (Rapp et al, Zhuang et al). **Ongoing:** CMS projection.
- prompt  $J/\psi$   $R_{AA}$  vs  $p_T$  ( $|y| < 2.4$ ) at high  $p_T$ 
  - **Available:** theory (Vitev et al). **Ongoing:** CMS projection.
- prompt  $J/\psi$  polarisation?
  - **Available** projection from the ALICE Lol.



## List of figures: charmonia in PbPb collisions (2/2)

- prompt  $\psi(2S)$   $v_2$  vs.  $p_T$ 
  - Available: theory (Rapp et al)
- prompt  $\psi(2S)$   $R_{AA}$  (and yields) vs.  $N_{part}$  ( $p_T$  integrated)
  - Available: ?
- prompt  $\psi(2S)/J/\psi$  vs.  $N_{part}$ :  $|y| < 0.9(2.4)$ ,  $2.5 < |y| < 4$ 
  - Available: ALICE projection, theory (Rapp et al, SHM).
- prompt  $\psi(2S)$  (and  $J/\psi$ , or ratio) vs.  $p_T$  (at low and high  $p_T$ )
  - Available: theory (Vitev et al, Rapp et al, SHM).
- $R_{AA}$  of  $\chi_c(1P)$ ,  $X(3872)$  vs  $p_T$  for  $|y| < 2.4$ 
  - Ongoing studies in CMS, theory for  $\chi_c(1P)$  (SHM, Rapp et al)



# List of figures: bottomonia in PbPb collisions

List of figures, for  $\Upsilon(1S,2S,3S)$ , all for  $|y| < 2.4$  and  $2.5 < |y| < 4$ :

- $R_{AA}$  (and yields?) vs  $p_T$ ,  $R_{AA}$  vs  $y$  for 0–10%, 0–100%
  - Available: theory (Strickland et al, Rapp et al). Ongoing: CMS projection, ALICE projection, theory (Brambilla et al).
- $v_2$  vs  $p_T$  30–50%
  - Available: theory (Rapp et al, SHM), Ongoing: ALICE projection
- $\Upsilon(1S,2S,3S)$   $R_{AA}$  vs  $N_{part}$ 
  - Available: CMS projection, theory (Strickland et al, Rapp et al). Ongoing: LHCb with full simulation, ALICE projection, theory (Brambilla et al).
- $\Upsilon(2S,3S)/\Upsilon(1S)$  vs  $N_{part}$ 
  - Available: ?

Also a figure on the prospects for the  $B_c$  meson? (or HF chapter)



# List of figures: quarkonia in pp and pPb collisions

- prompt  $J/\psi$   $v_2$  and  $v_3$  (separately for negative and positive  $y_{CM}$ )
  - (Available: ALICE projection, theory (Zhuang et al). Ongoing: CMS projection)
- prompt  $J/\psi$  vs  $N_{ch}$  (also in pp)
  - Available: theory (Venugopalan et al)
- $R_{pA}$  vs  $p_T$  for excited states:  $\psi(2S)$ ,  $\Upsilon(2S,3S)$ ,  $\chi_c(1P)$  (separately for negative and positive  $y_{CM}$ )
  - Available: theory (NRQCD, E.loss, comovers, CGC)

To be also discussed: SMOG results from LHCb



# Additional inputs

## $c\bar{c}$ cross section

- A study from Anton ([link](#)) gives  
 $d\sigma_{c\bar{c}}/dy(\text{PbPb}, |y| < 0.5) = 0.52 \pm 0.19 \text{ mb}$ ,  
 $d\sigma_{c\bar{c}}/dy(\text{PbPb}, 2.5 < |y| < 4.0) = 0.334 \pm 0.19 \text{ mb}$ .
- Proposal for HL-LHC: keep these central values and assume  $\pm 10\%$  (optimistic) or  $\pm 15\%$  (realistic) uncertainties

## Luminosity for pPb

- Proposal:  $500 \text{ nb}^{-1}$  in pPb to allow a precise measurement of the  $p_T$  and  $y$  dependence of  $J/\psi$   $v_2, v_3$

## Other theoretical inputs

- Need for common quarkonium melting scenarios (T / spectral functions), anchored in current lattice QCD knowledge
- Common (equivalent) treatment of the underlying dynamics (hydro-based)



# Summary

- Outline of the chapter in place with list of figures
- Private git fork repository for easier collaboration between the main contributors
- Identified ingredients to theoretical calculations
- Will now start writing and include existing figures
- Some more projections and predictions expected for the final report

CERN e-group for discussions and updates: `hllhc-wg5-quarkonia`

