J/ψ and $\psi(2S)$ production in pp and PbPb collisions at 5.02 TeV with ATLAS

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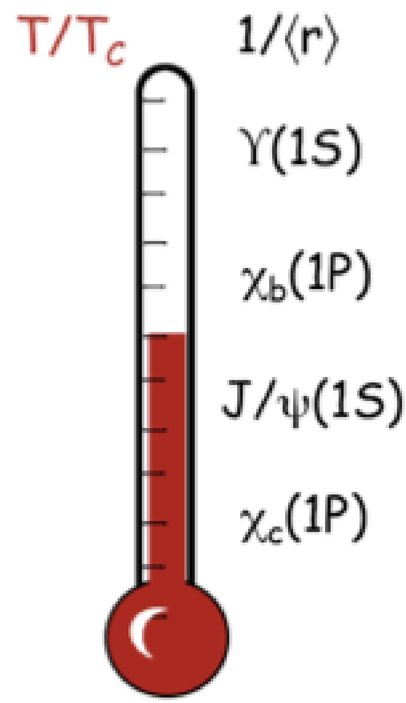
Motivation

Charmonia, bound states of c and $\bar{c}$ quarks, could be a unique probe to study the hot, dense system created in nucleus-nucleus (A+A) collisions.

Different quarkonia states are expected to "melt" at different temperatures.

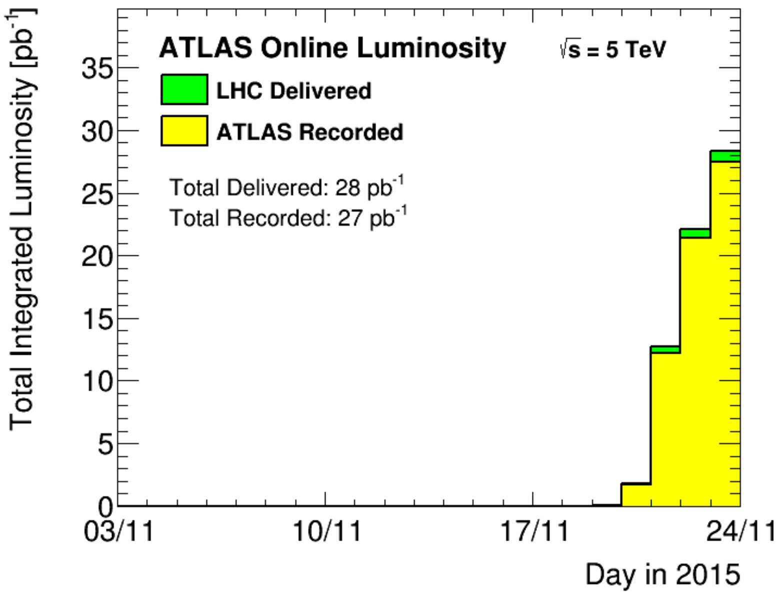
Important parts for quarkonia suppression in heavy ion collisions:

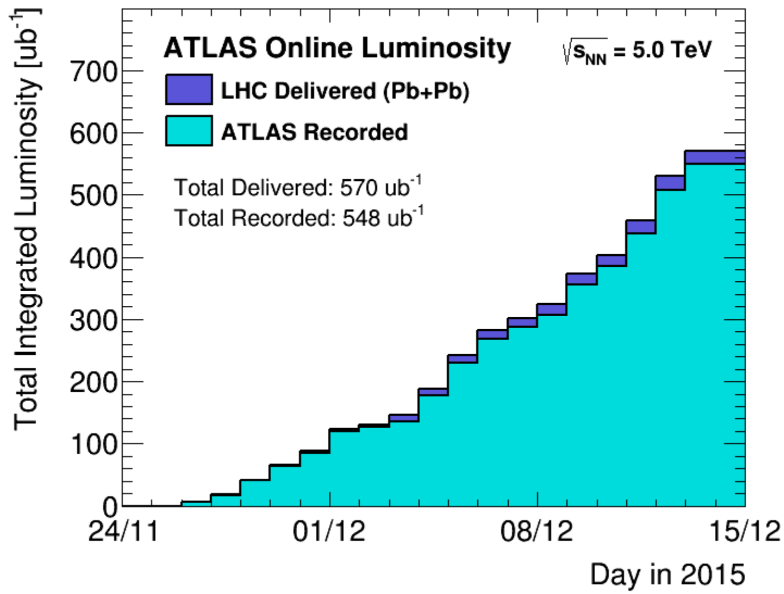
- color screening
- Recombination



Data

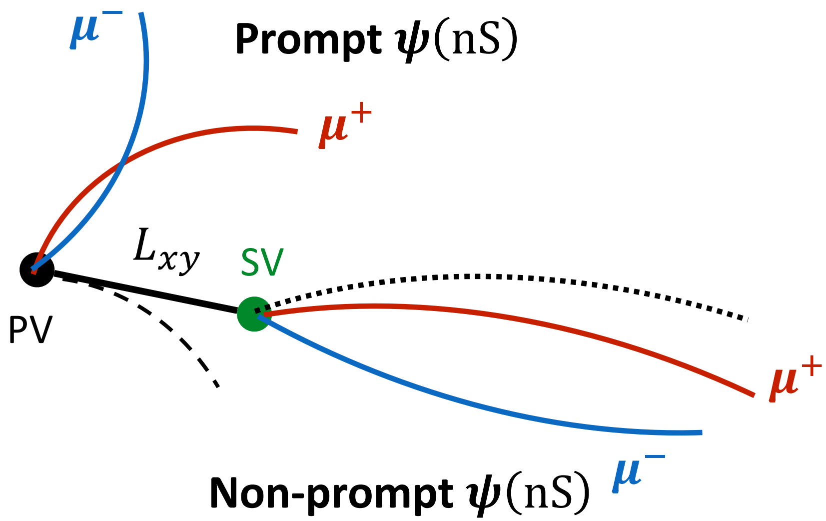
This analysis uses data from pp and Pb+Pb collisions at 5.02 TeV recorded by ATLAS in 2015.





The integrated luminosity of the analyzed samples is 0.49 nb-1 for Pb+Pb collisions and 25 pb-1 for pp collisions.

Methodology



Prompt

Produced from short-lived QCD decays (including feed-down from other charmonium states)

Non-prompt

Produced in the decays of long lived b-hadrons - displaced decay vertex

Pseudo-proper decay time

$$\tau(\mu\mu) = L_{xy} m(\mu\mu)/p_T(\mu\mu)$$

Corrected cross section

Ncorr is corrected by acceptance, trigger and reconstruction efficiencies event by event

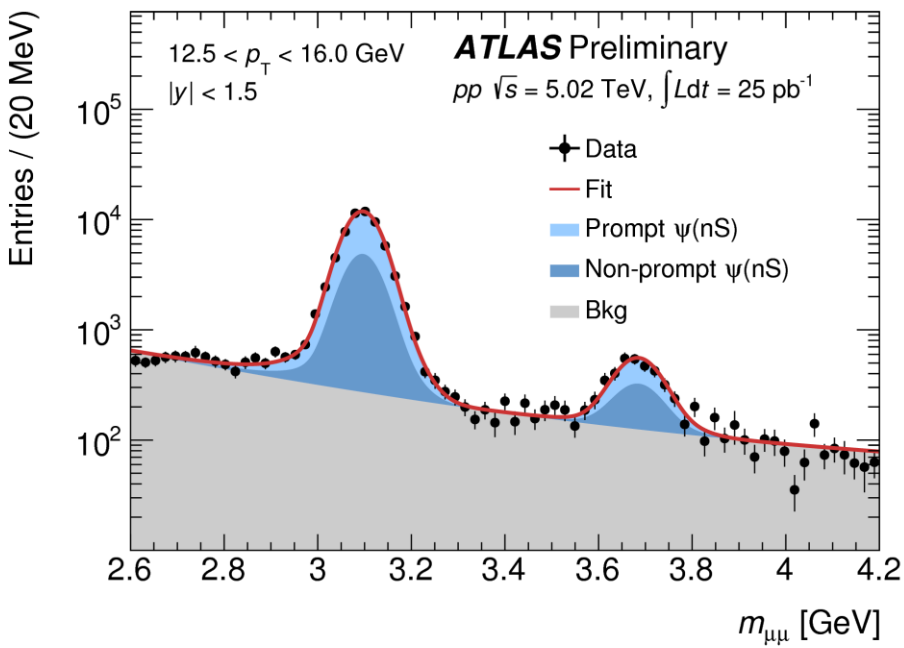
$$\frac{d^2\sigma(pp \to \psi)}{dp_T dy} \times \mathcal{B}(\psi \to \mu^+\mu^-) = \frac{Ncorr_\psi^p}{\Delta p_T \Delta y \times \int \mathcal{L}dt}$$

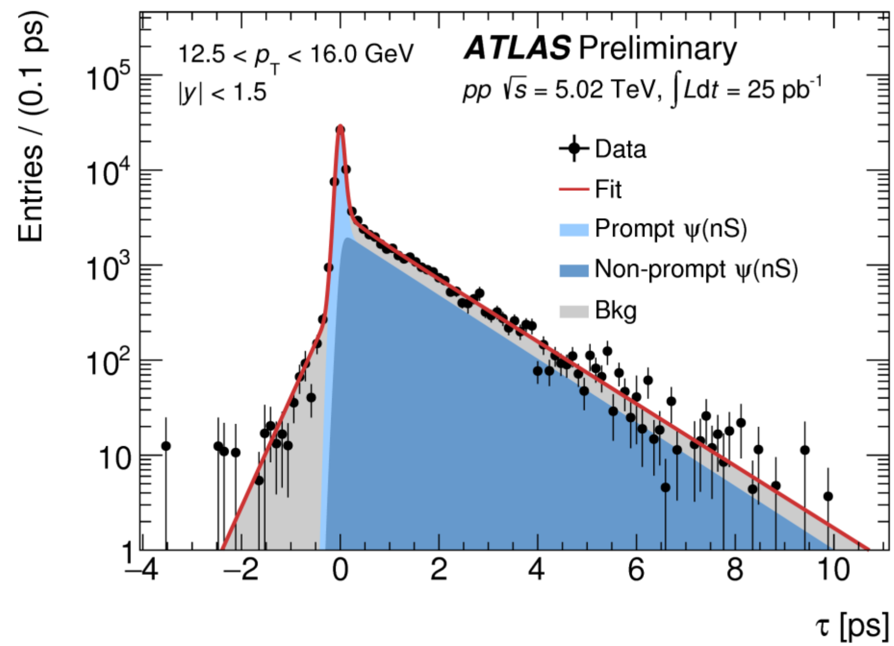
$$\frac{d^2\sigma(pp \to b\bar{b} \to \psi)}{dp_T dy} \times \mathcal{B}(\psi \to \mu^+\mu^-) = \frac{Ncorr_\psi^{np}}{\Delta p_T \Delta y \times \int \mathcal{L}dt}$$

$$Ncorr_\psi^{p(np)} = \frac{N_\psi^{p(np)}}{\mathcal{A} \cdot \epsilon_{trig} \cdot \epsilon_{reco}}$$

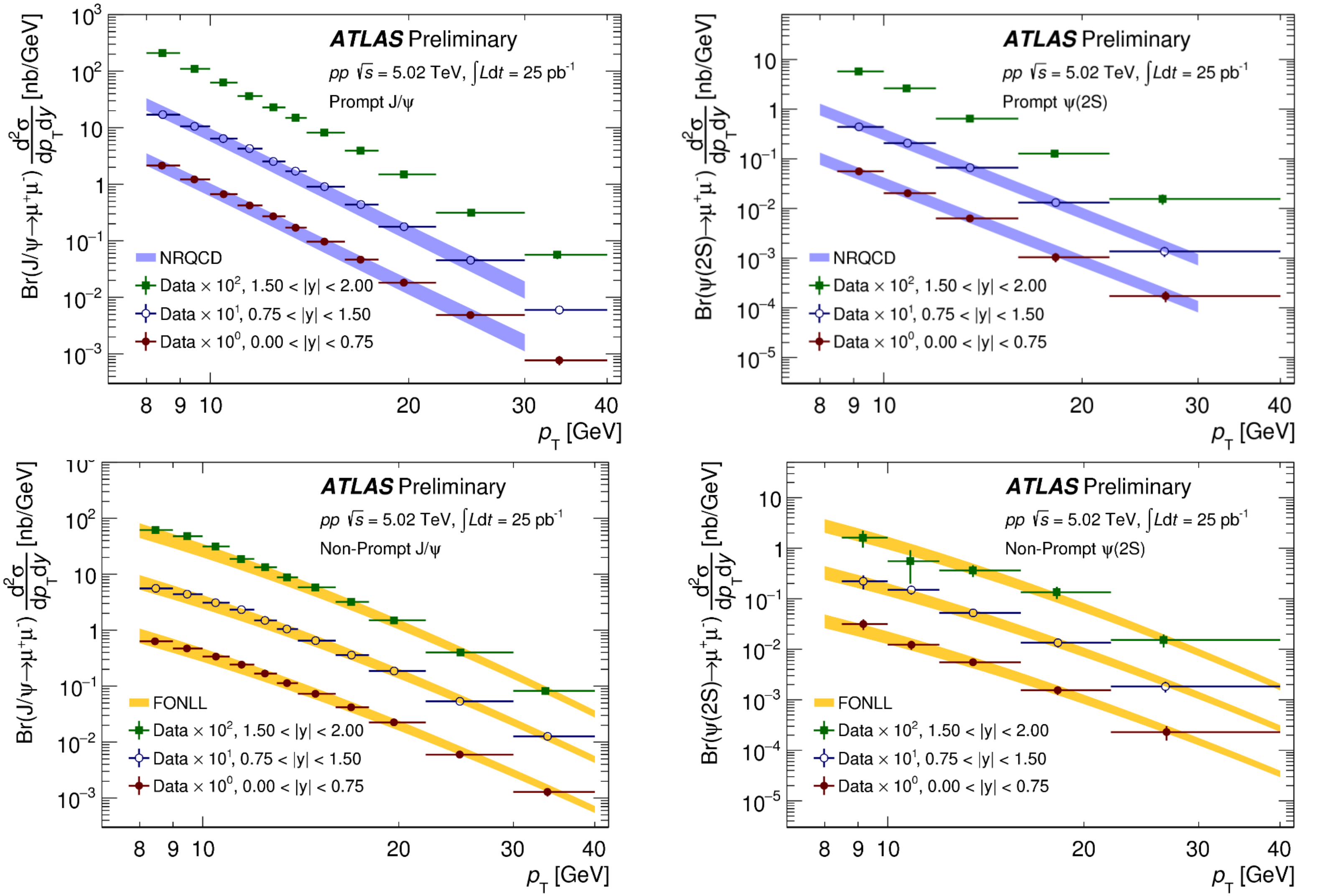
Fit method

Simultaneously fit the invariant mass and pseudo-proper decay time, and get the number of events from the fits.



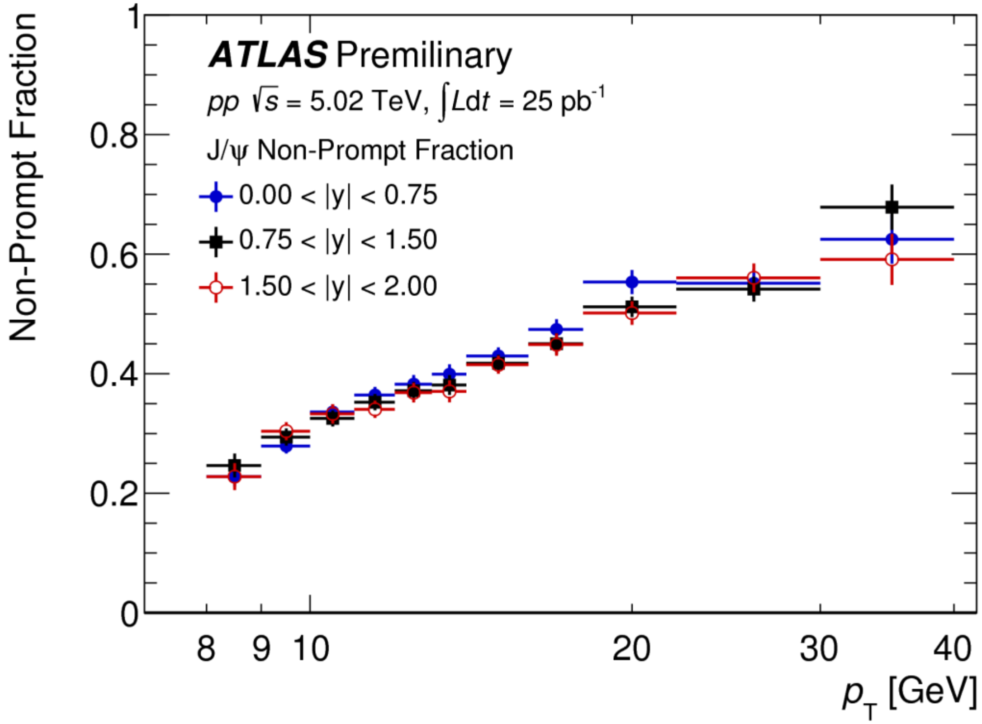


Cross section



The data are in good agreement with the predictions.

Non-prompt fraction



$$f_{NP}^{\psi(nS)} = \frac{N_{\psi(nS)}^{np,corr}}{N_{\psi(nS)}^{np,corr} + N_{\psi(nS)}^{p,corr\prime}}$$

The non-prompt fraction has strong p_T dependence and behaved nearly same in different rapidities.

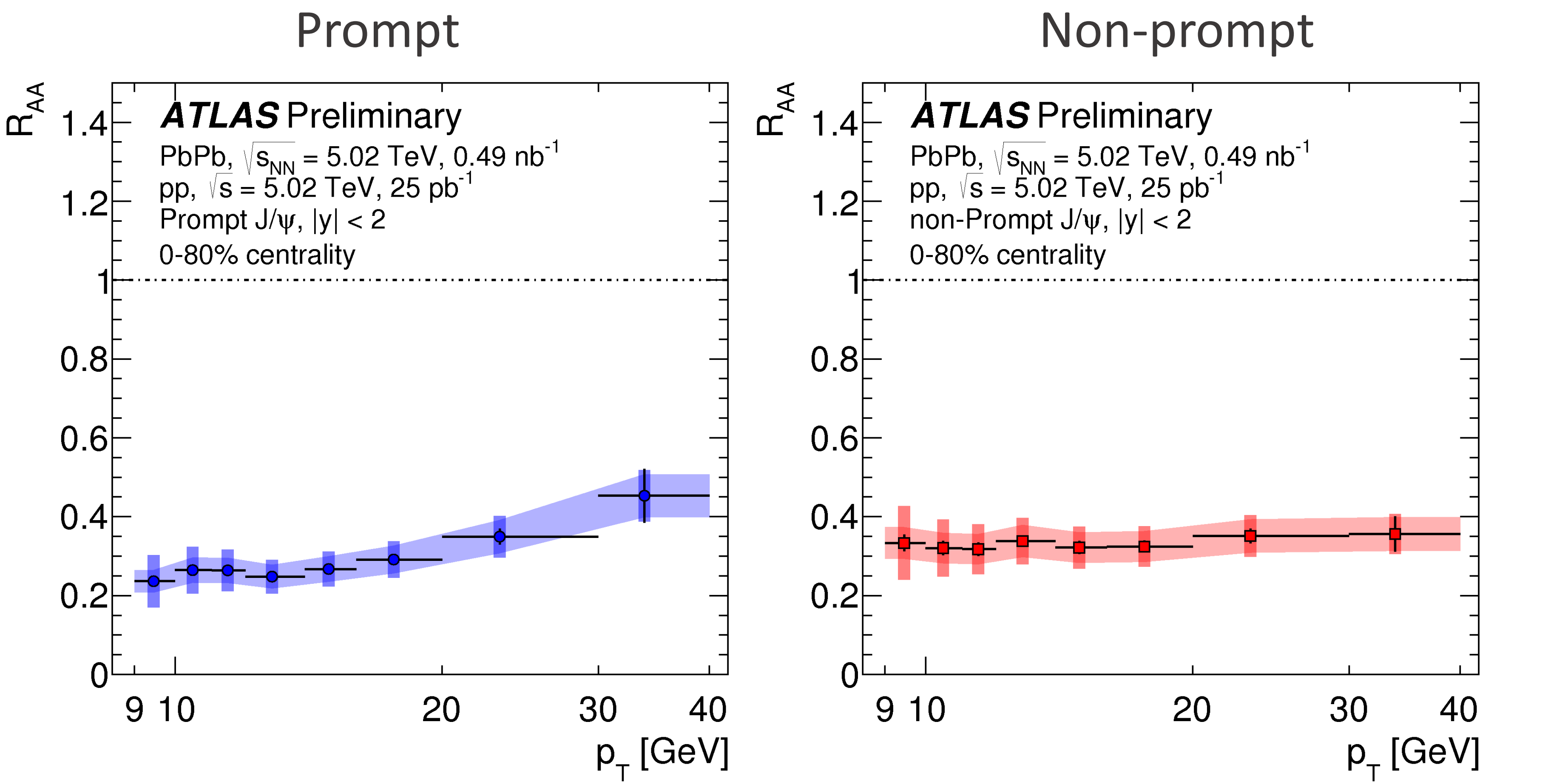
Nuclear modification factor

The suppression of charmonium states is quantified by the nuclear modification factor which can be defined for a given centrality class as:

$$R_{AA} = \frac{N_{AA}}{\langle T_{AA} \rangle \sigma^{pp}}$$

N_{AA}: per-event yield of charmonium states measured in A+A collisions
$\langle T_{AA} \rangle$: mean nuclear thickness function
σ^{pp}: cross section for the production of the corresponding charmonium states in pp collisions at the same energy

$R_{AA}^{J/\psi} - p_T$

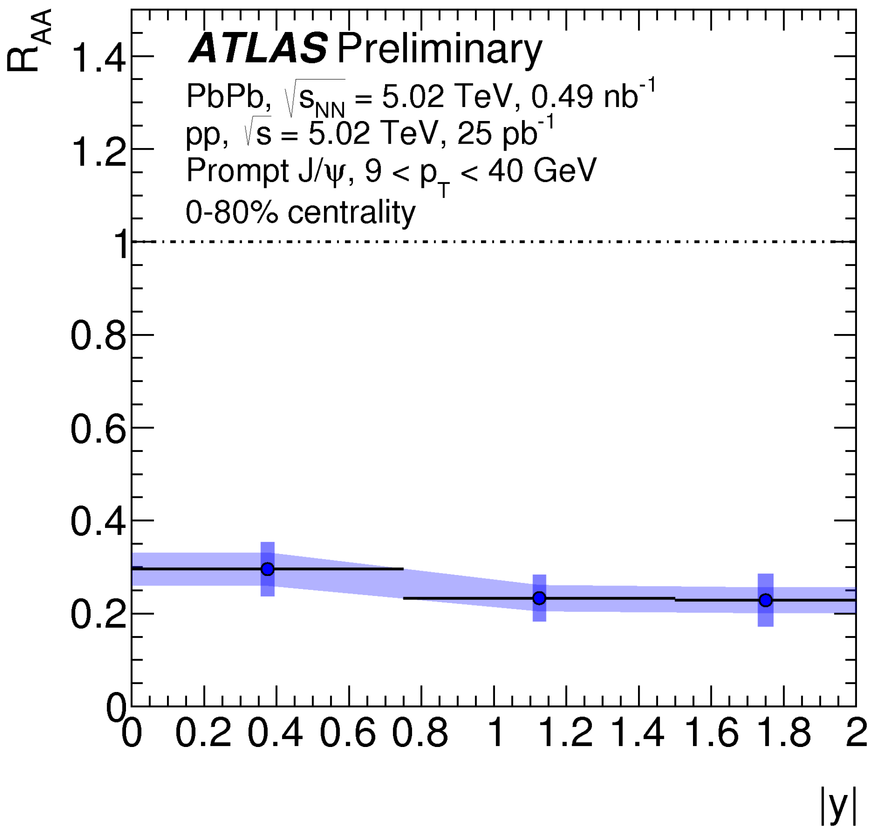


A small increase in R_{AA} with increasing p_T

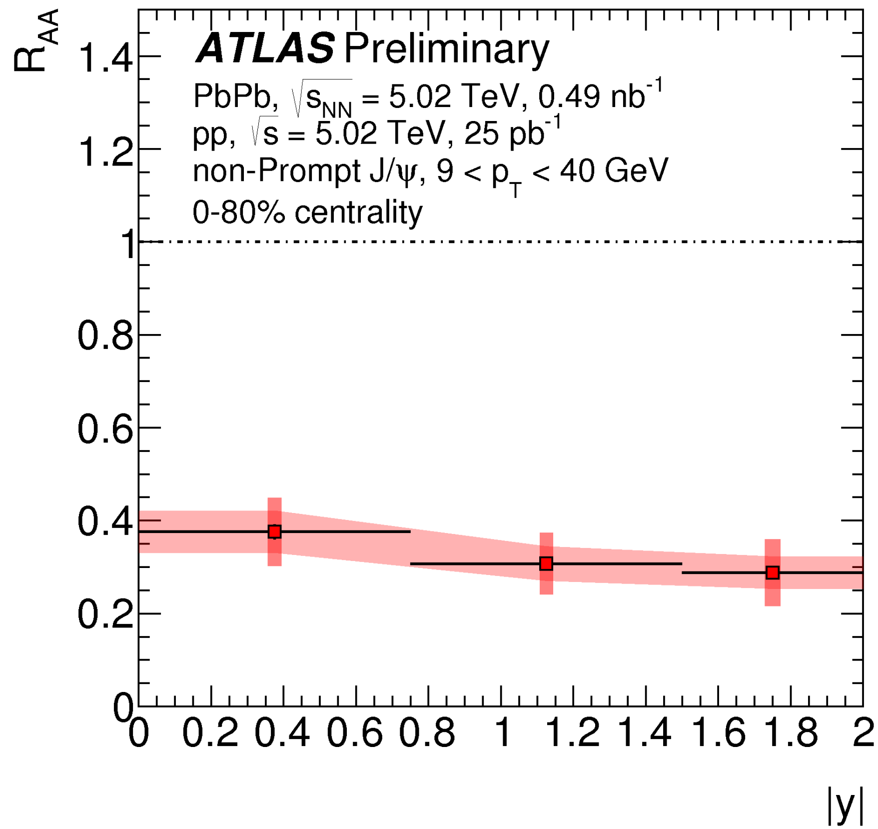
To be constant in p_T

$R_{AA}^{J/\psi}$ – |y|

Prompt



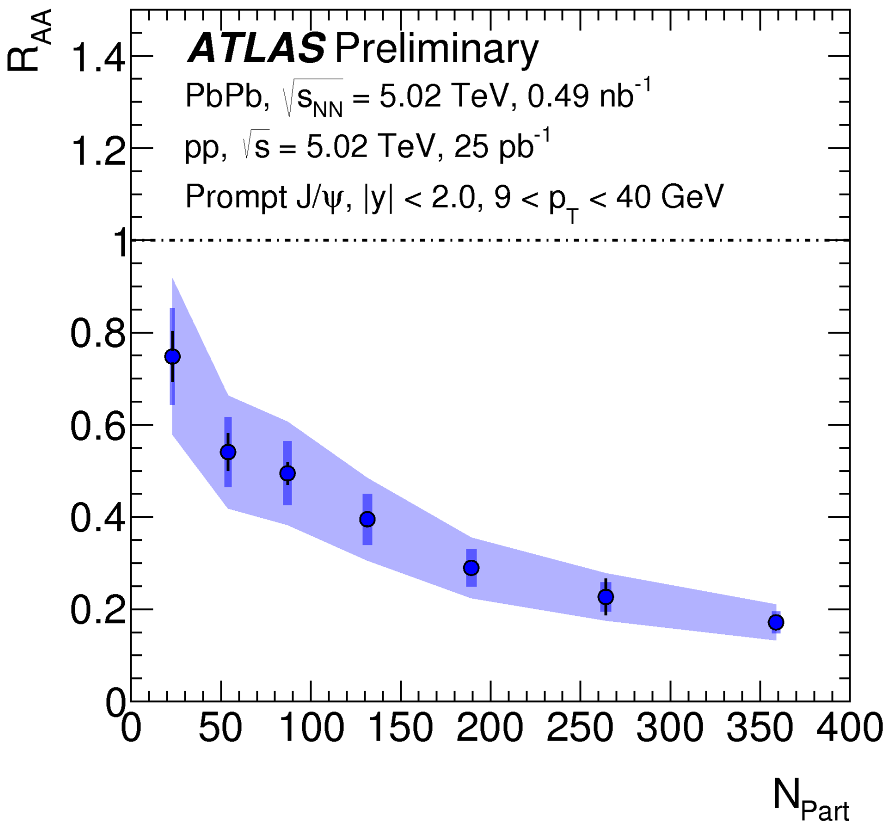
Non-prompt



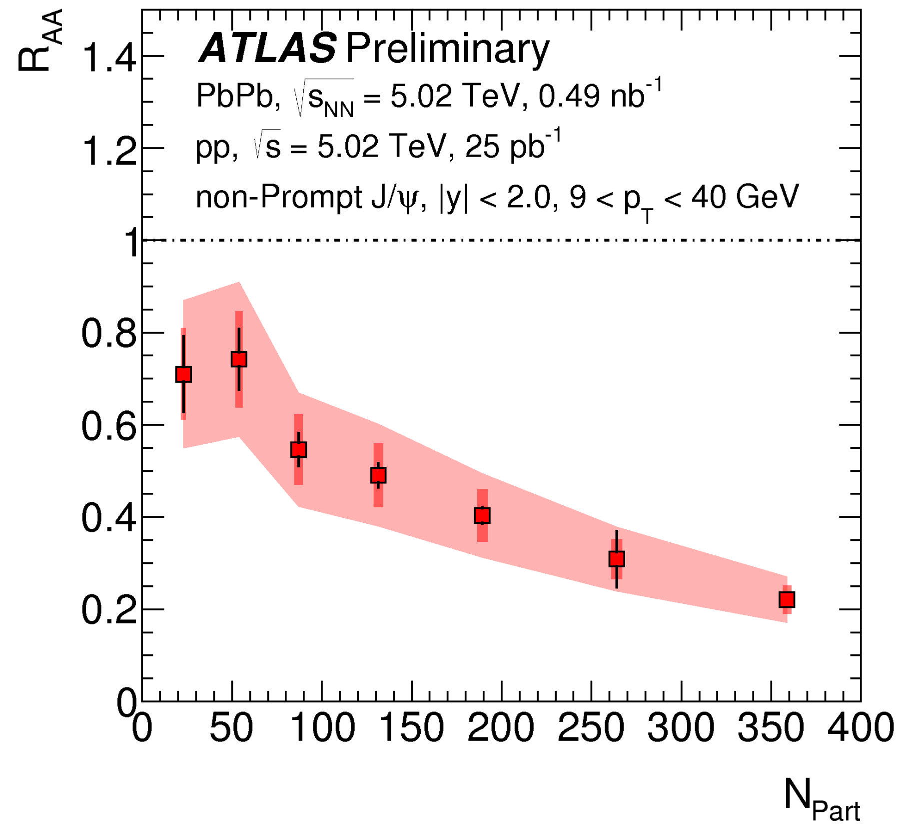
R_{AA} is essentially constant as a function of rapidity.

$R_{AA}^{J/\psi} - N_{part}$

Prompt



Non-prompt

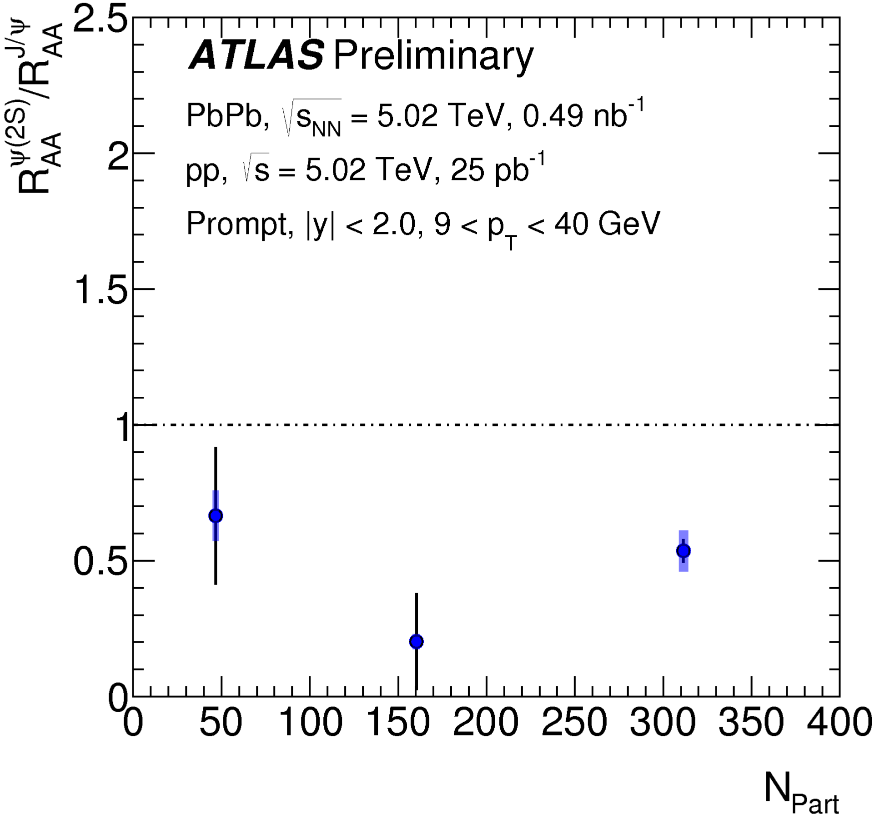


The production of J/ψ is most strongly suppressed in central collisions

N_{part}: number of participants for production of mesons

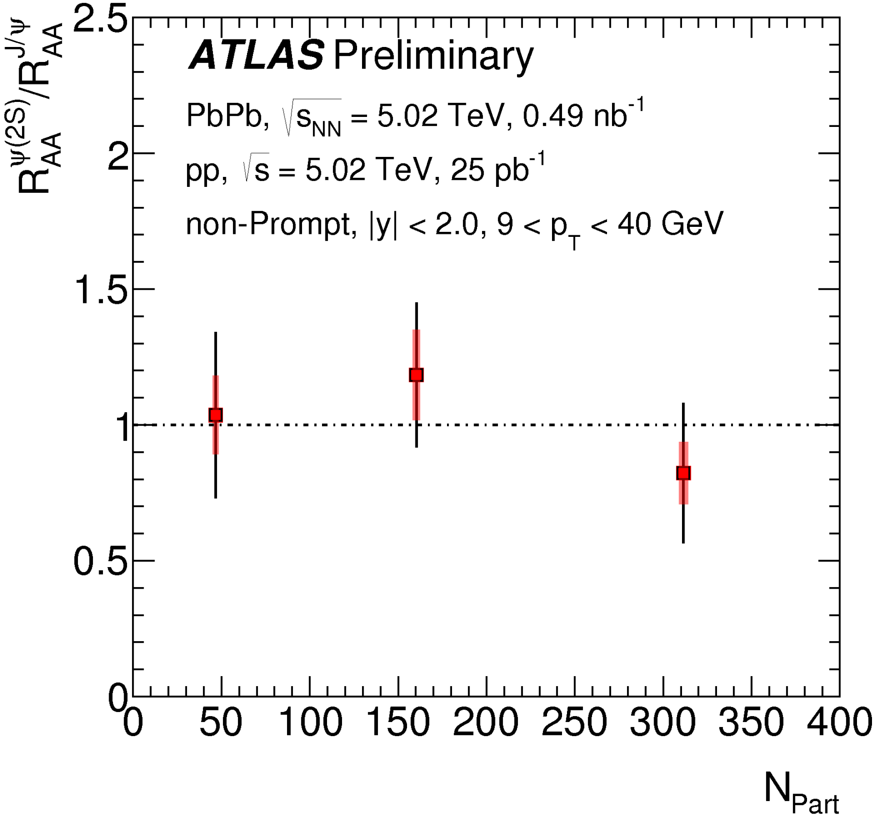
Double Ratio

Prompt



Stronger suppression of ψ(2S) with respected to J/ψ

Non-prompt



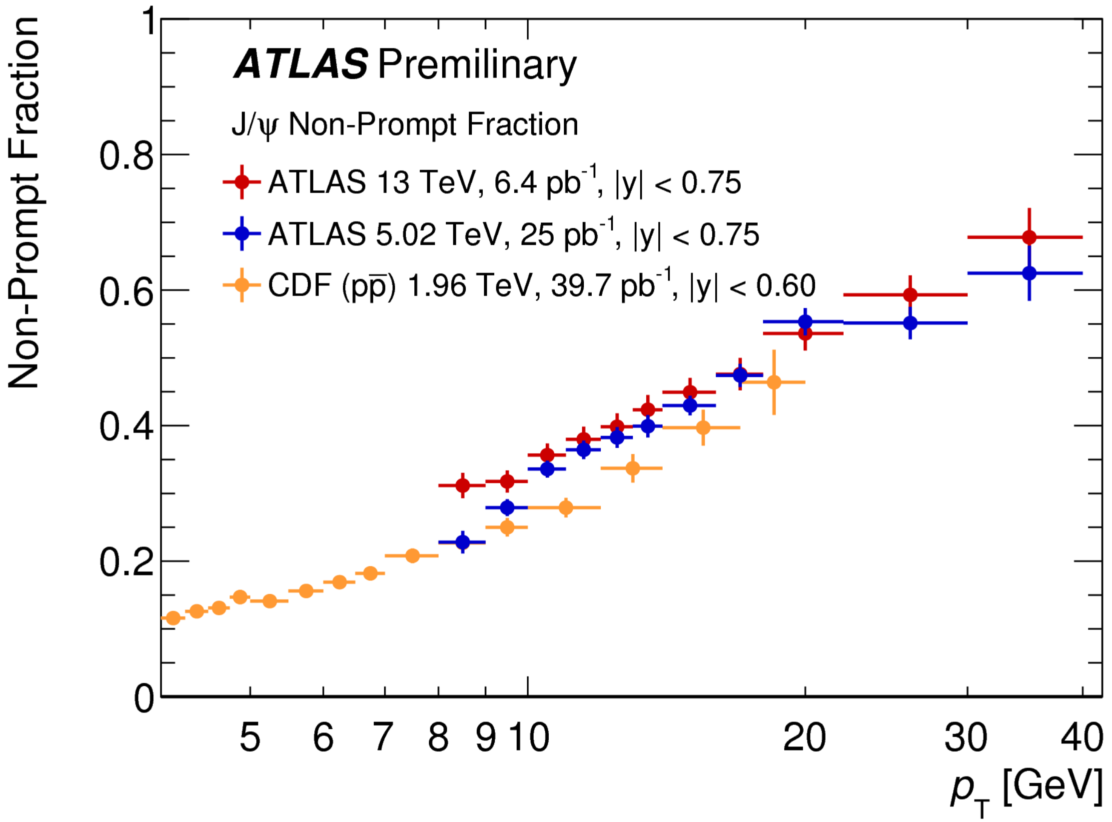
consistent with unity

Summary

- In pp collisions, for cross sections, the predictions are found to be in good agreement with the observed data points.
- A strong suppression of both prompt and non-prompt J/Ψ and $\Psi(2S)$ mesons is observed.
- For non-prompt mesons, double ratio values consistent with unity. For prompt mesons, the values are below unity.

backup

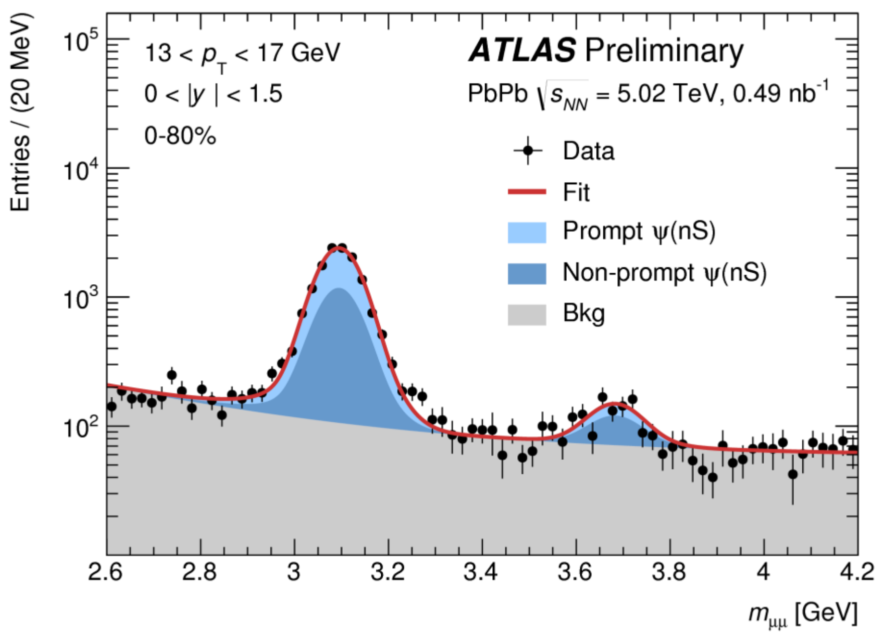
Non-prompt fraction

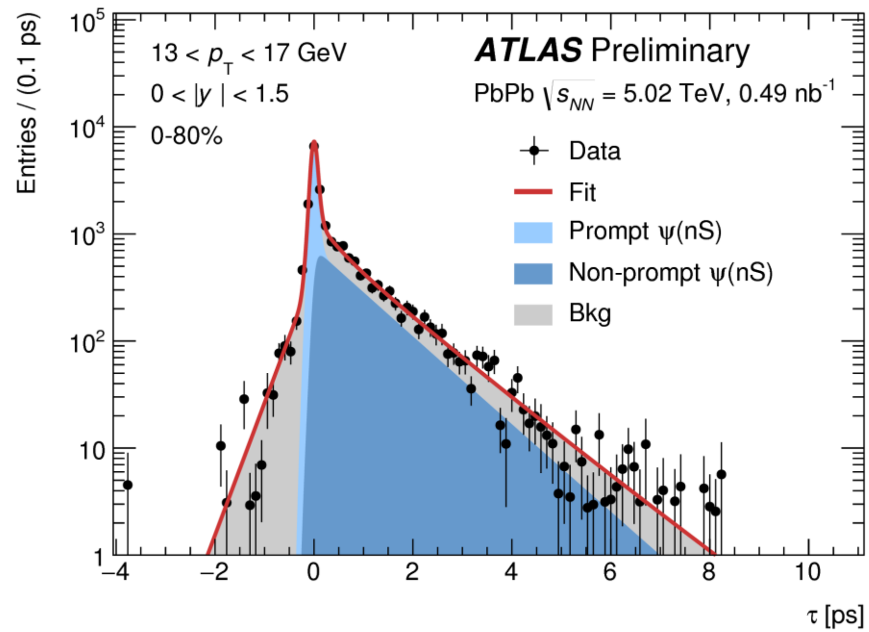


In **proton-proton collisions**, the values of non-prompt fraction agreed well between 5.02 TeV and 13 TeV.

Simultaneous Fits

For Pb+Pb collisions:

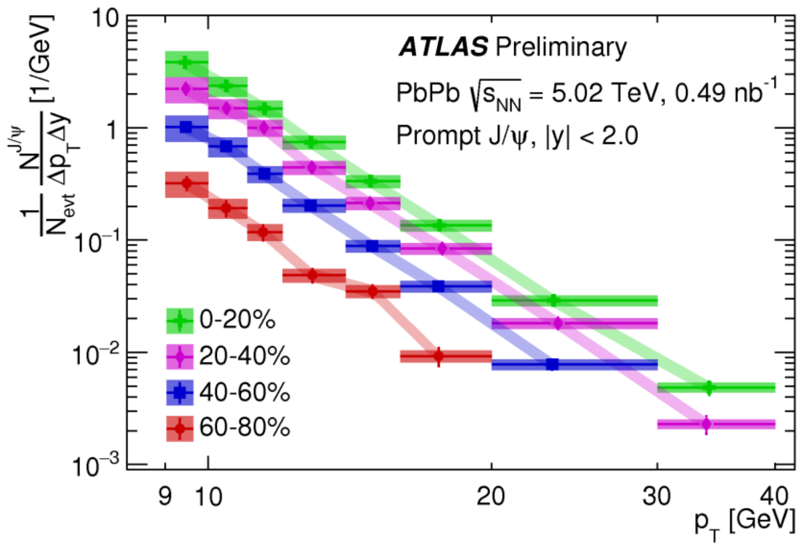


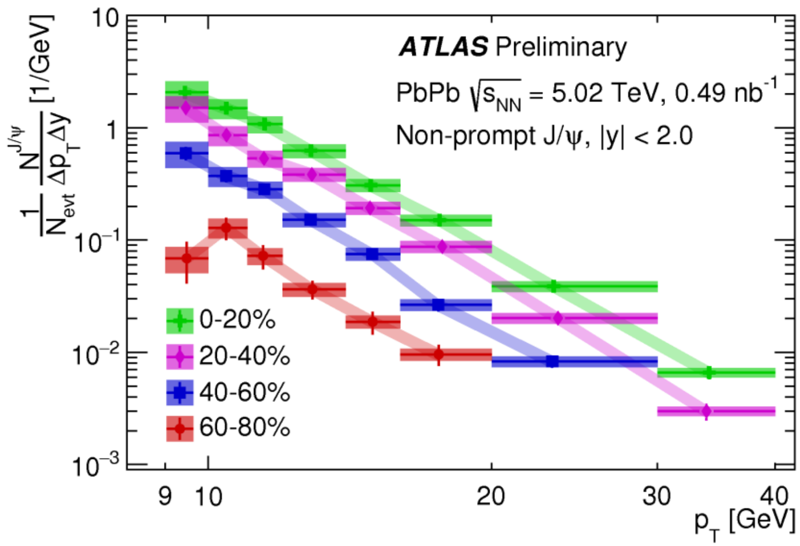


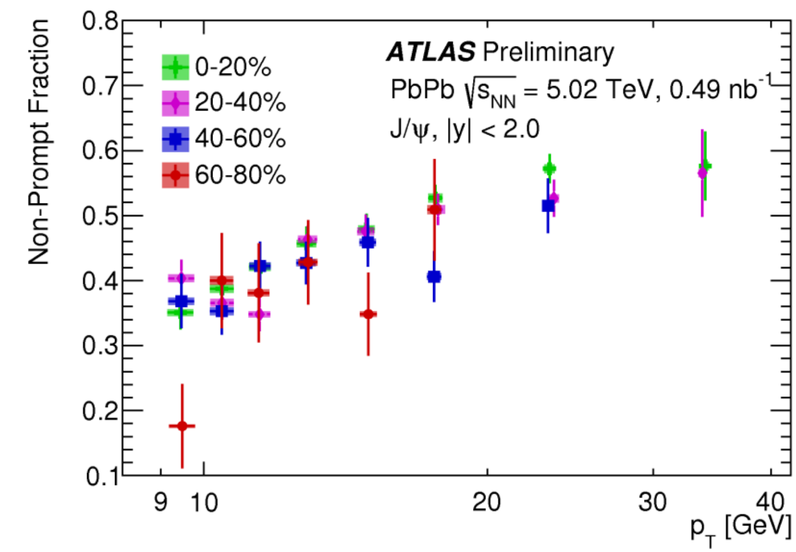
$$PDF(m,\tau) = \sum_{i=1}^{7} k_i f_i(m) \cdot h_i(\tau) \otimes g(\tau)$$

i	Type	Source	$f_i(m)$	$h_i(\tau)$
1	J/ψ	P	$\omega_i \mathrm{CB}_1(m) + (1-\omega_i)\mathrm{G}_1(m)$	$\delta(\tau)$
2	J/ψ	NP	$\omega_i \mathrm{CB}_1(m) + (1-\omega_i)\mathrm{G}_1(m)$	$\mathrm{E}_1(\tau)$
3	$\psi(2S)$	P	$\omega_i \mathrm{CB}_2(m) + (1-\omega_i)\mathrm{G}_2(m)$	$\delta(\tau)$
4	$\psi(2S)$	NP	$\omega_i \mathrm{CB}_2(m) + (1-\omega_i)\mathrm{G}_2(m)$	$\mathrm{E}_2(\tau)$
5	Bkg	P	flat	$\delta(\tau)$
6	Bkg	NP	$\mathrm{E}_3(m)$	$\mathrm{E}_4(\tau)$
7	Bkg	NP	$\mathrm{E}_5(m)$	$\mathrm{E}_6(\lvert\tau\rvert)$

Results for Pb+Pb collisions



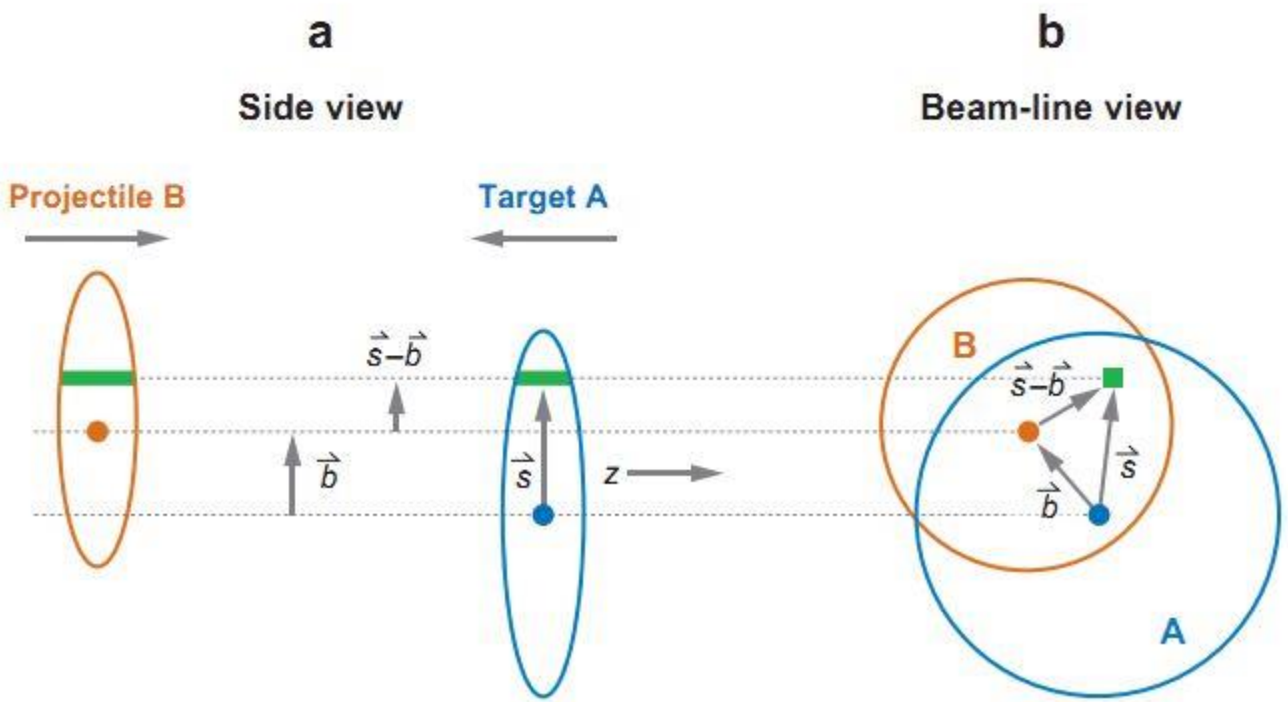




$N^{J/\psi}$: number of J/ψ

N_{evt}: number of events measured in minimum bias data for each centrality class

T_{AB}



The probability per unit transverse area of a given nucleon being located in the target flux tube is

$$\hat{\mathrm{T}}_{\mathrm{A}}(\boldsymbol{s}) = \int \hat{\rho}_A(\boldsymbol{s}, z_A) dz_A$$

$\hat{\rho}_A(\boldsymbol{s}, z_A)$ is the probability per unit volume, normalized to unity, for finding the nucleon at location $(\boldsymbol{s}, z_A)$.

Thickness function: $$\hat{\mathrm{T}}_{\mathrm{A}B}(\boldsymbol{b}) = \int \hat{\mathrm{T}}_{\mathrm{A}}(\boldsymbol{s}) \hat{\mathrm{T}}_B(\boldsymbol{s} - \boldsymbol{b}) d^2 s$$

$\hat{\mathrm{T}}_{\mathrm{A}}(\boldsymbol{s}) \hat{\mathrm{T}}_B(\boldsymbol{s} - \boldsymbol{b}) d^2 s$ gives the joint probability per unit area of nucleons being located in the respective overlapping target and projectile flux tubes of differential area $d^2 s$.