Measurements of ψ(2S) production in Pb—Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV with ALICE at the LHC

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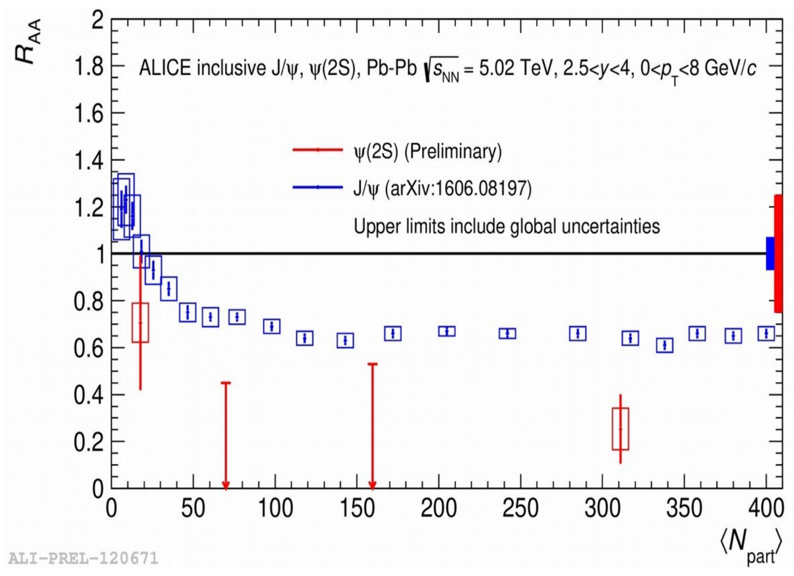
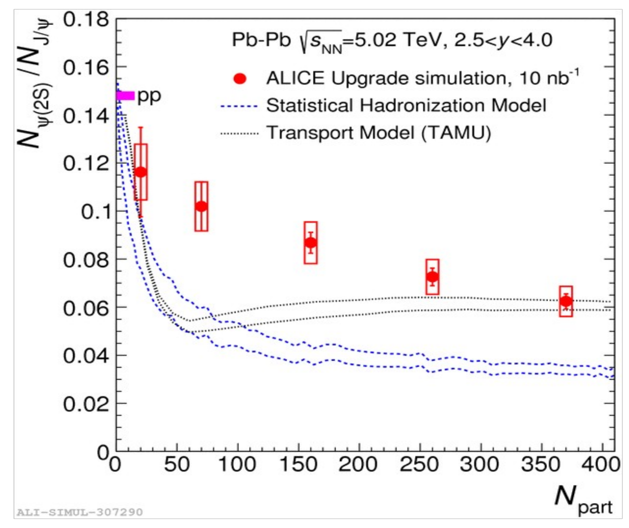
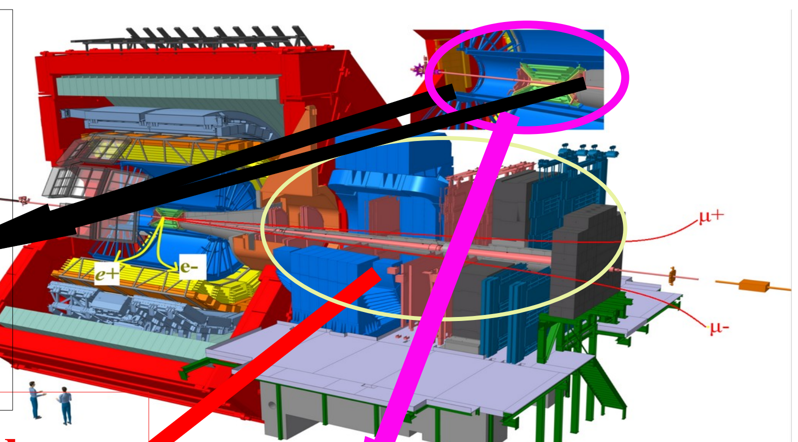
INTRODUCTION





- At high energy density (~ 1GeV/fm³) nuclear matter undergoes a phase transition from a confined state to a state of deconfined quarks and gluons, called quark-gluon plasma (QGP).
- In the presence of the QGP, quarkonia show suppression due to the Debye screening and dissociation. Hence quarkonia can be used as a probe to study the deconfined medium.
- Sequential dissociation of quarkonia states in medium according to their binding energies leads to stronger suppression of ψ(2S) with respect to J/ψ.
- Recombination of charmonium states at LHC due to large charm quark densities observed for J/ψ at $\sqrt{s_{NN}}$ = 5.02 TeV [1].
- ψ(2S)-to-J/ψ ratio measurements weakly dependent on charm production cross section employed as inputs to the models in Pb—Pb collisions ⟶ **important constraints on models [3,4] .**
- Hint for stronger suppression of ψ(2S) compared to J/ψ observed with ALICE preliminary data using 2015 Pb—Pb statistics; however large uncertainties prevent a strong conclusion.
- **New ALICE results available including 2018 Pb—Pb sample (~3 times higher statistics), provide more precise results.**

ALICE DETECTOR



V0 detectors (V0A: 2.8 < η < 5.1 & V0C: -3.7 < η < -1.7)

Triggering, background rejection and centrality estimation in Pb—Pb collisons

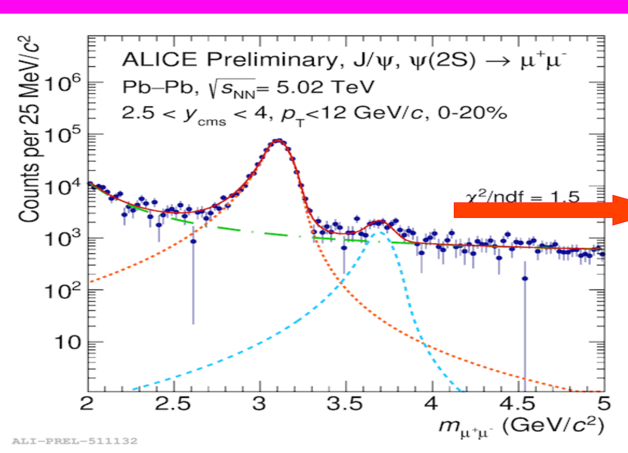
Muon tracking and trigger chambers

Inclusive J/ψ, ψ(2S) ⟶ μ⁺μ⁻

-4.0 < η < -2.5

SPD : primary vertex determination

ANALYSIS DETAILS



The ψ(2S) raw yield in Pb-Pb is obtained by fitting the invariant mass spectra after combinatorial background subtraction with mixed-event technique; several functions used for describing signal and residual background shapes.

- Acceptance times efficiency corrections computed through a realistic monte carlo simulation (p_T and y distributions of J/ψ and ψ(2S) tuned on data).
- Reference measurement is obtained from the study of ψ(2S) cross sections in pp collisons at $\sqrt{s}$ = 5.02 TeV [2].

REFERENCES

1. .J Adam et al., ALICE Collaboration, *Phys. Lett.* **B 766** (2017) 212.
2. S. Acharya et al., ALICE Collaboration, **arXiv:2109.15240.**
3. X. Du. and R.Rapp, *Nucl. Phys.* **A943** (2015) 147.
4. A. Andronic et al., *Nature* ***561*** no. **7723** (2018) 321.

OBSERVABLES

Nuclear modification factor (R_{AA})

$$R_{AA}=\frac{Y_{AA}^{\psi(2S)}}{\langle T_{AA}\rangle \cdot \sigma_{pp}^{\psi(2S)}}$$

where $Y^{\psi(2S)}_{AA}$ is the ψ(2S) corrected yield in AA, $\sigma^{\psi(2S)}_{pp}$ is the cross section in pp collisions and T_{AA} is the nuclear overlap function.

Ratio of ψ(2s)-to-J/ψ

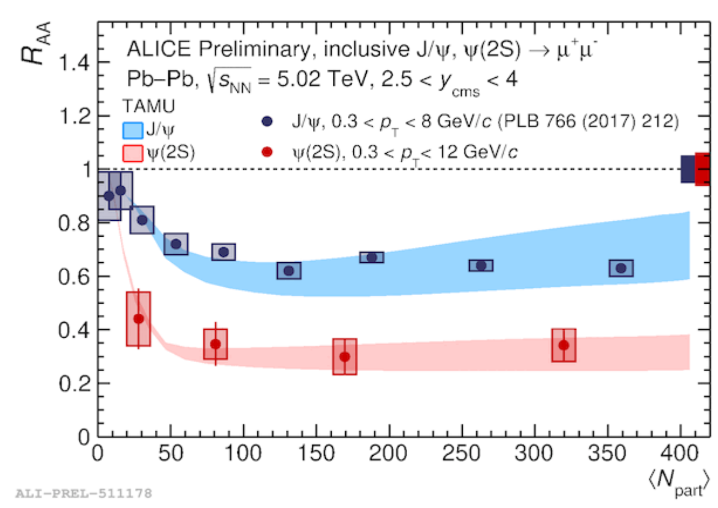
$$Single\ Ratio=\frac{BR\,\sigma_{\psi(2S)}}{BR\,\sigma_{J/\psi}}$$

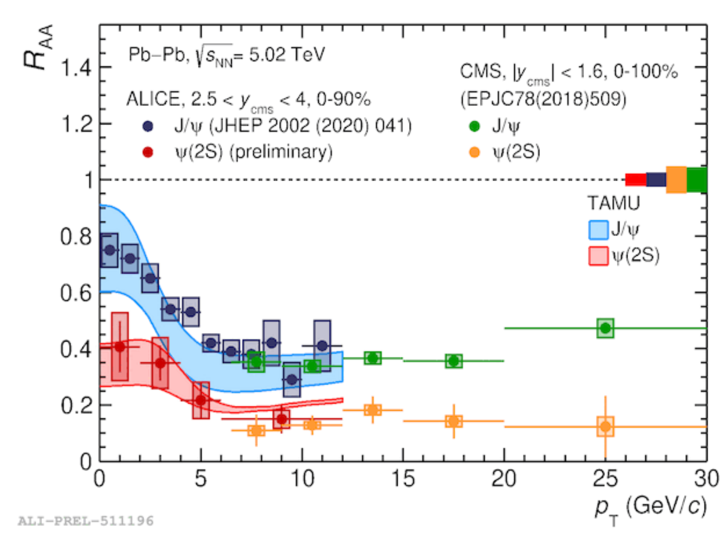
$$Double\ Ratio=\frac{[\sigma_{\psi(2S)}/\sigma_{J/\psi}]_{PbPb}}{[\sigma_{\psi(2S)}/\sigma_{J/\psi}]_{pp}}$$

BR is the branching ratio of J/ψ, ψ(2S)⟶ μ⁺μ⁻

$\sigma_{J/\psi}$ & $\sigma_{\psi(2S)}$ represent the cross section of both states.

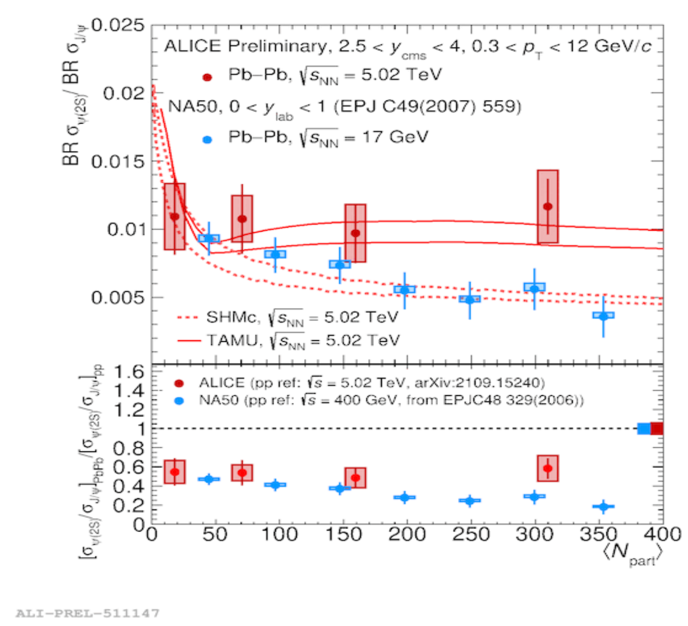
R_{AA} VS p_T & CENTRALITY

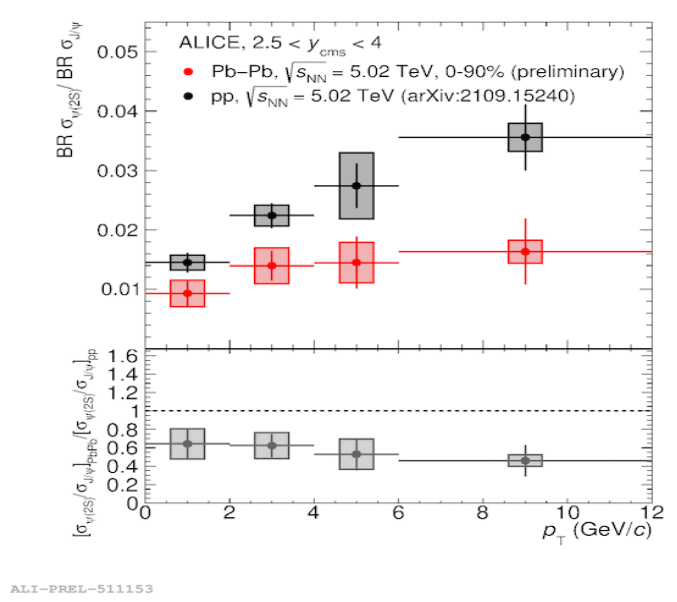




- ψ(2S) significantly suppressed as a function of p_T and centrality, and shows stronger suppression than the J/ψ.
- Increasing trend of R_{AA} towards low p_T and suppression at high-p_T observed for both charmonium states..
- TAMU model [3], which includes charmonium regeneration, reproduces the centrality and p_T dependence of R_{AA} for both J/ψ and ψ(2S).
- Good agreement between CMS and ALICE data in common p_T range, in spite of different rapidity coverage.

DOUBLE & SINGLE RATIOS VS p_T & CENTRALITY





- Significant suppression of ψ(2S)-to-J/ψ ratio in Pb-Pb with respect to pp
- No significant centrality or p_T dependence is observed.
- TAMU model [3] reproduces the cross section ratios over centrality, while SHM [4] tends to underestimate the data in central Pb—Pb collision.

CONCLUSIONS

- No significant p_T or centrality dependence of the ψ(2S)- to-J/ψ double ratio observed within the uncertainties.
- The ψ(2S) R_{AA} shows a significant decrease as a function of p_T as expected from the contribution of charm quark regeneration at low p_T .
- Comparison of J/ψ and ψ(2S) R_{AA} with transport and statistical hadronisation models shows a fair agreement within uncertainties.
- Transport model, that includes recombination of charm quarks in the QGP phase, better reproduces the ψ(2S)-to-J/ψ ratio for central events.