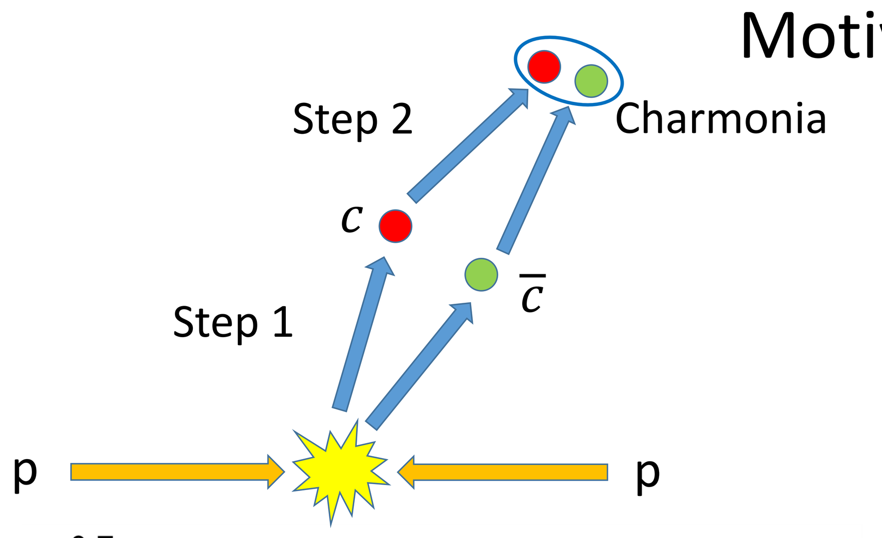
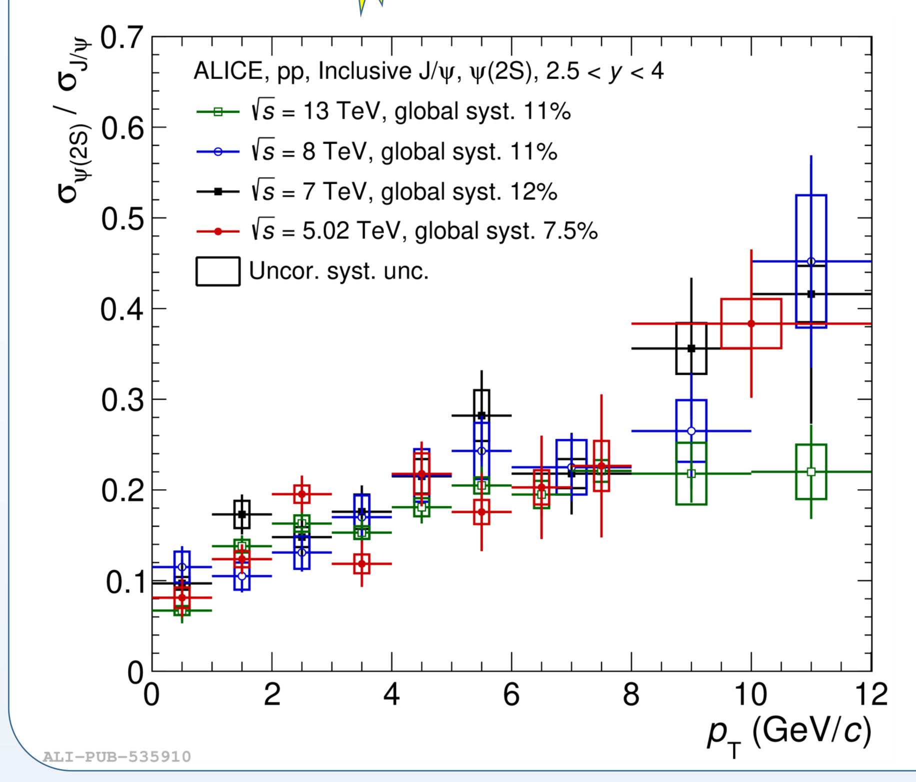
Measurements of inclusive ψ(2S) to J/ψ ratio at midrapidity in pp collisions at $\sqrt{s}$ = 13.6 TeV with ALICE

Yuan Zhang, for the ALICE Collaboration
University of Science and Technology of China
yuan.z@cern.ch

Motivation

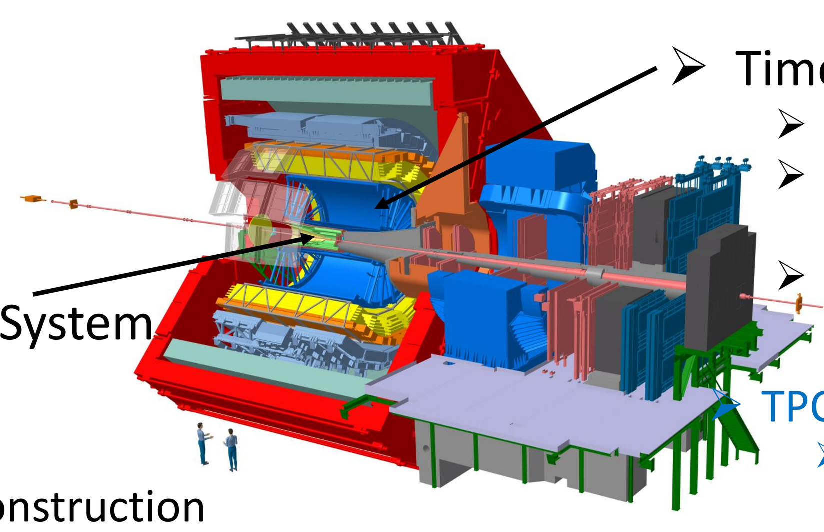


- Crucial for studying charmonium production mechanisms and testing different QCD-based models.
  - Heavy-quark production (perturbative QCD)
  - Formation of the bound charmonium states (non-perturbative QCD)
- Study the rapidity dependence of charmonium production by comparing to similar measurements at forward rapidity at the same collision energy[1].
- Used as reference for studying AA collisions.



ALICE detector (Run 2 configuration and Run 3 upgrade)

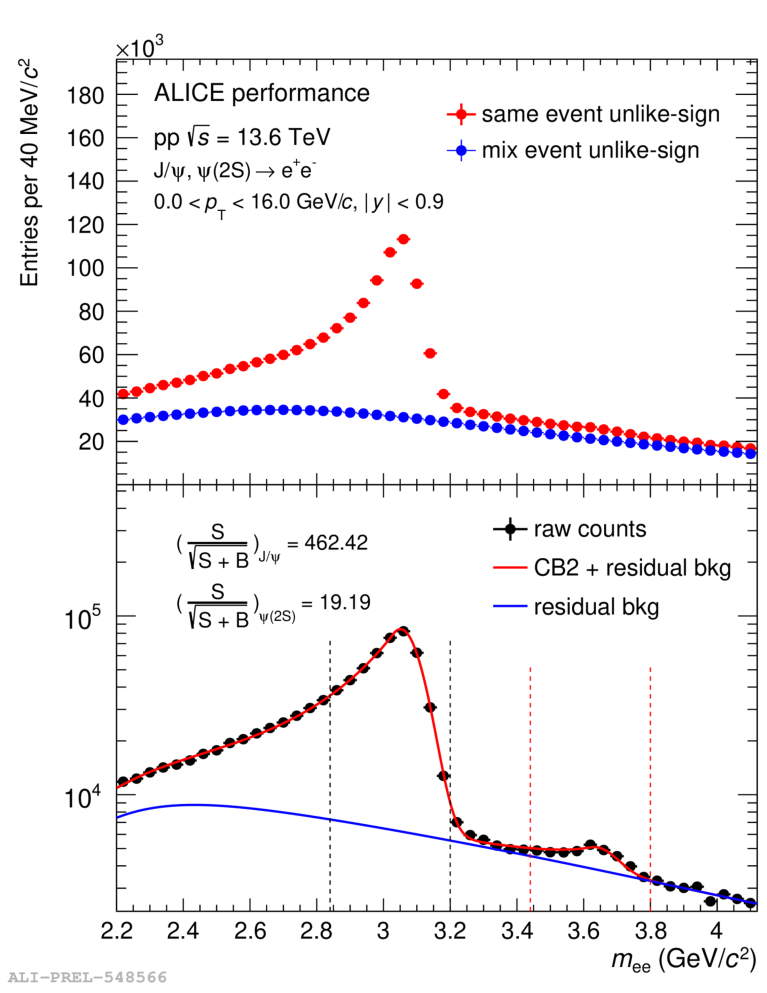
- Inclusive quarkonia are reconstructed in e⁺e⁻ channel at midrapidity (|y| < 0.9) down to p_T = 0.



- Time Projection Chamber (TPC)
  - Tracking
  - Particle identification via dE/dx measurement
  - Momentum measurement
- Inner Tracking System (ITS)
  - Tracking
  - Vertex reconstruction
- ITS upgrade:
  - 6 layers ⟹ 7 layers equipped with Monolithic Active Pixel Sensors (MAPS).
  - Radius of innermost layer: 39 mm ⟹ 23mm.
  - Material budget for each of the 3 innermost layers: 1.15% ⟹ 0.35%.
- TPC upgrade:
  - Readout chambers replaced with Gas Electron Multiplier (GEM) chambers.

Enable continuous readout of Pb–Pb events at an interaction rate up to 50 kHz (~10² w.r.t. run 2).

Data analysis procedure



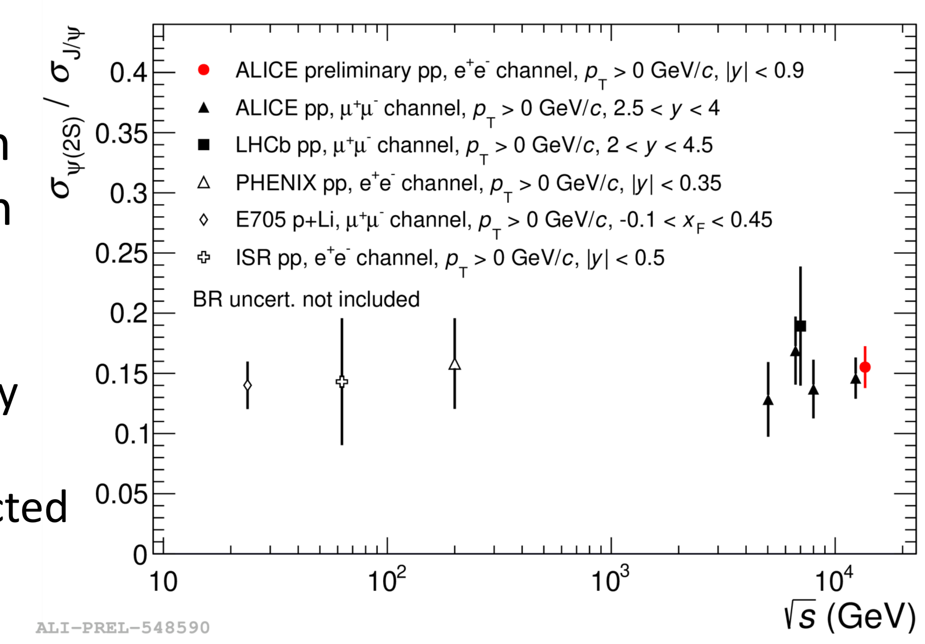
- Dataset:
  - pp collisions at $\sqrt{s}$ = 13.6 TeV collected in 2022 with the ALICE upgraded detector.
  - 524×10^9 minimum-bias (MB) events collected thanks to the continuous readout.
- Electron identification via TPC dE/dx.
- Signal extraction:
  - Combinatorial background is subtracted using mixed-event unlike-sign method.
  - Residual background: second order polynomial function divided by an exponential function.
  - Signal shapes are described by Double Crystal Ball functions. Possible differences between the J/ψ and ψ(2S) shapes are assigned as systematic uncertainties.
- Efficiency correction:
  - Tracking efficiency and efficiency related to the choice of the signal mass window largely cancel out in the ψ(2S)-to-J/ψ ratio. Residuals are assigned as systematic uncertainties.
  - PID efficiency is assessed using a data-driven approach.
  - Acceptance effects are corrected with a MC simulation.

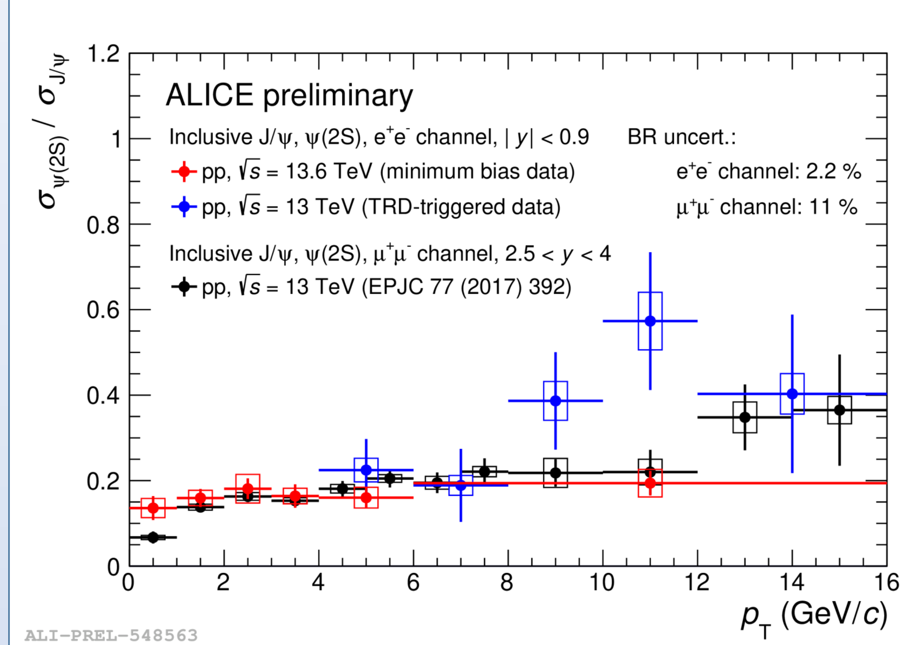
Results

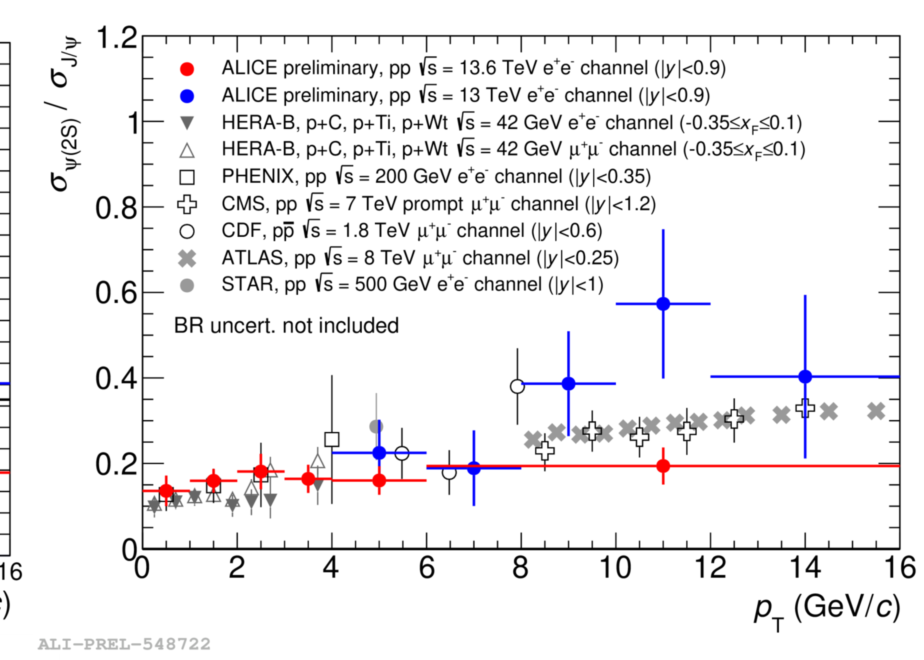
$$\frac{\sigma_{\psi(2S)}}{\sigma_{J/\psi}} = \frac{N_{\psi(2S)}}{N_{J/\psi}} \frac{(A\times\varepsilon)_{J/\psi}}{(A\times\varepsilon)_{\psi(2S)}} \frac{BR_{J/\psi\to ee}}{BR_{\psi(2S)\to ee}}$$

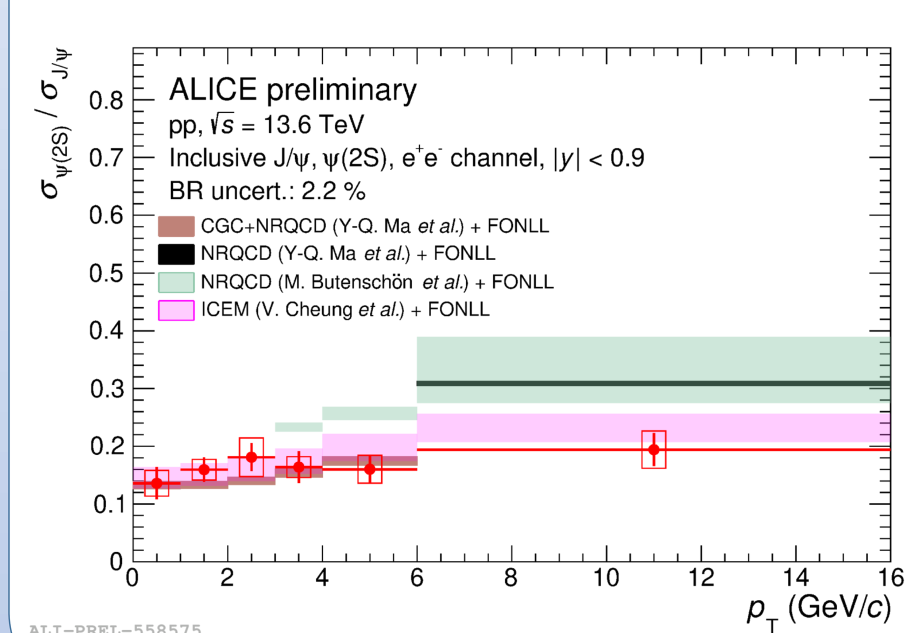
- N: raw counts.
- $A \times \varepsilon$: acceptance times efficiency
- BR: Branching ratio

- The measured p_T-integrated ratio without BR uncertainty is 0.155 ±0.010(stat.) ±0.014(syst.)
- The results (red points) are shown together with existing results from ALICE at forward rapidity and from other experiments [1-10].
  - In agreement with other results.
  - No significant energy and rapidity dependence.
  - Slight p_T dependence (also expected from models).









- Comparison with models[11-14]:
  - NRQCD overestimates the ratio at high p_T, but CGC + NRQCD describes the ratio at low and intermediate p_T.
  - ICEM can reproduce the data.

Summary and outlook

- The ψ(2S)-to-J/ψ ratio is measured in pp collision at $\sqrt{s}$ = 13.6 TeV at midrapidity.
  - In agreement with other results.
  - A slight p_T dependence (also expected from models).
  - No significant energy and rapidity dependence.
  - Comparison with models[11-14].
    - NRQCD overestimates the ratio.
    - CGC + NRQCD describes the ratio at low and intermediate p_T.
    - ICEM can reproduce the data.
- Provides a reference for investigating the quark-gluon plasma in nucleus-nucleus collisions and the cold nuclear matter effects in proton-nucleus collisions.
- The prompt and non-prompt ψ(2S)-to-J/ψ ratio as well as the cross section of prompt/non-prompt charmonia will be measured in Run 3.

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