Production of J/ψ and ψ(2S) in p+p collisions at √s = 510 GeV from the STAR experiment

Chan-Jui Feng, *for the STAR Collaboration*

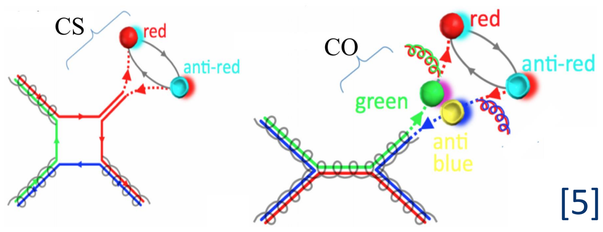
National Cheng Kung University

Abstract

Measurements of the production cross sections of charmonia, namely J/ψ and ψ(2S), in hadron+hadron collisions provide valuable information about yet unsolved questions on the quarkonium production mechanism. The Solenoid Tracker At RHIC (STAR) is a major high-energy nuclear physics experiment at the Relativistic Heavy Ion Collider. The Muon Telescope Detector, which provides trigger and identification capability for muons, enables to study quarkonia in the $\mu^+ \mu^-$ decay channel which is less affected than the e^+e^- channel by bremsstrahlung energy loss in the detector material. In this poster, we report on the measurements of invariant yields, as well as their ratio as a function of p_T in p+p collisions at √s = 510 GeV using data recorded in 2017 by the STAR experiment. It is the first differential measurement of the ψ(2S) to J/ψ yield ratio as a function of p_T from the STAR experiment. The results are compared with the calculation from the Improved Color Evaporation Model.

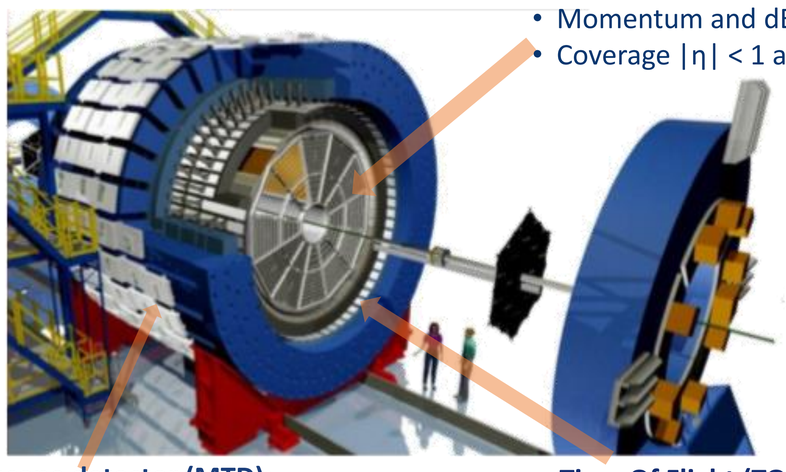
Motivation:

- The mechanism of quarkonium formation in hadron+hadron collisions is not fully understood
- Popular models on the market:
  - Non-relativistic QCD (NRQCD) [1]
    - Includes Color Octet Mechanism (COM) [2]
  - Color Singlet Model (CSM) [3]
  - Color Evaporation Model (CEM) / Improved CEM [4]
- High-precision measurements of quarkonium production cross sections are indispensable for discrimination between different models



[5]

The STAR experiment:



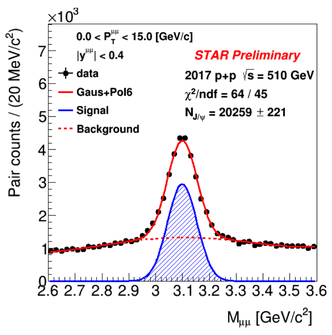
Time Projection Chamber (TPC):
- Momentum and dE/dx measurement
- Coverage |η| < 1 and full azimuth

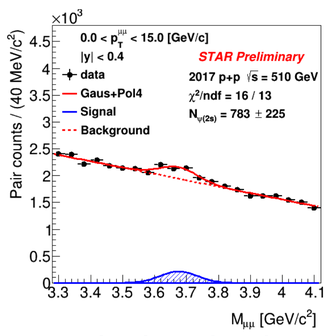
Muon Telescope detector (MTD):
- Trigger on and identify muons
- Coverage |η| < 0.5 and ~45% in ϕ

Time Of Flight (TOF):
- Particle identification
- Coverage |η| < 1 and full azimuth

Charmonium reconstruction via dimuon decay channel:

- Raw signals of J/ψ and ψ(2S):





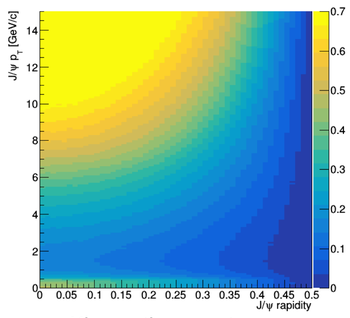
- Corrected J/ψ and ψ(2S) numbers are calculated using event-by-event weighting method to apply acceptance and efficiency corrections:

$$BR(meson \to \mu^+ + \mu^-) \times \frac{d^2N}{dp_T dy} = \frac{N^{corrected}_{meson \to \mu^+ + \mu^-}}{\Delta p_T^{meson} \cdot \Delta y^{meson}}$$

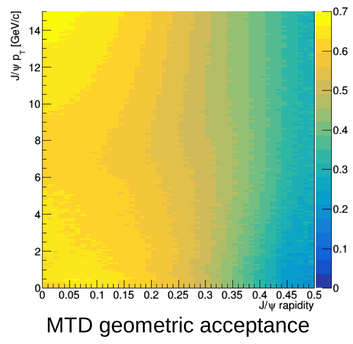
$$N^{corrected}_{meson} = \sum_i^{N^i_{meson}} w_i$$

$$w^{-1} = A(p_T^{meson}, y^{meson}) \times \varepsilon^1_{reco.}(p_T^{\mu^1}, \eta^{\mu^1}, \phi^{\mu^1}) \times \varepsilon^2_{reco.}(p_T^{\mu^2}, \eta^{\mu^2}, \phi^{\mu^2})$$

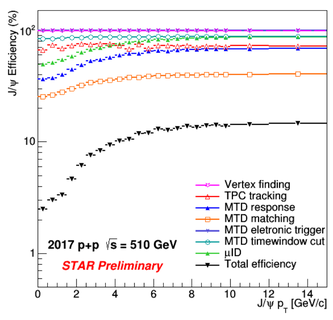
- Acceptance and efficiencies:
  - Example for zero polarization:



Kinematic acceptance

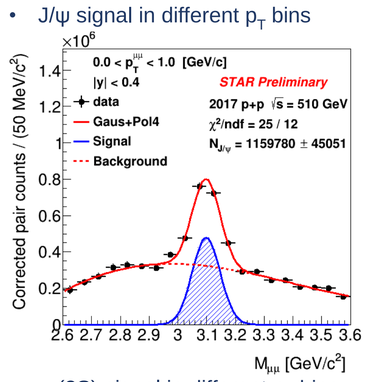


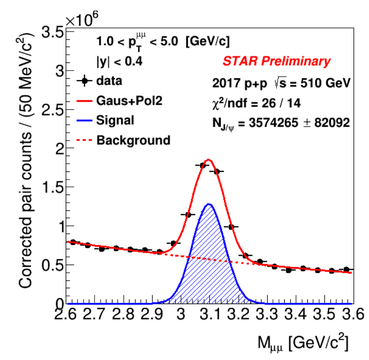
MTD geometric acceptance

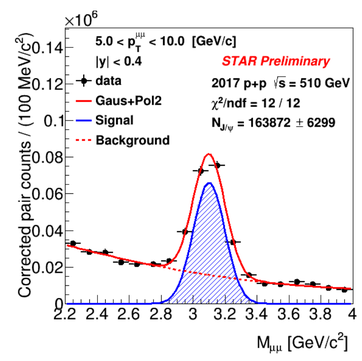


Signal extraction:

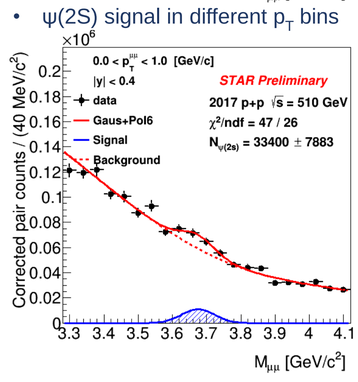
- Efficiency-corrected J/ψ and ψ(2S) → $\mu^+\mu^-$ signals:
  - J/ψ signal in different p_T bins

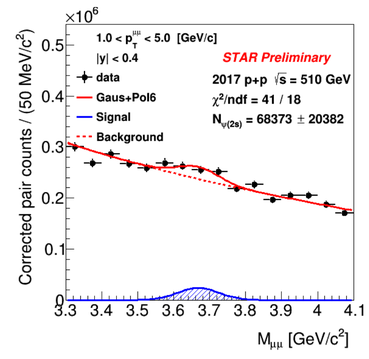


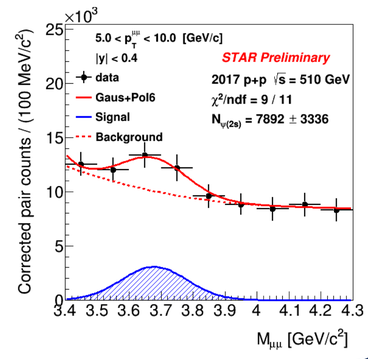




  - ψ(2S) signal in different p_T bins

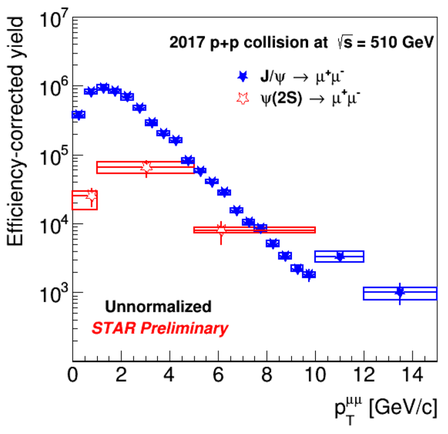


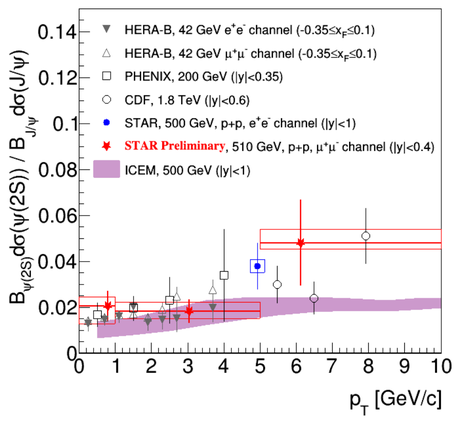


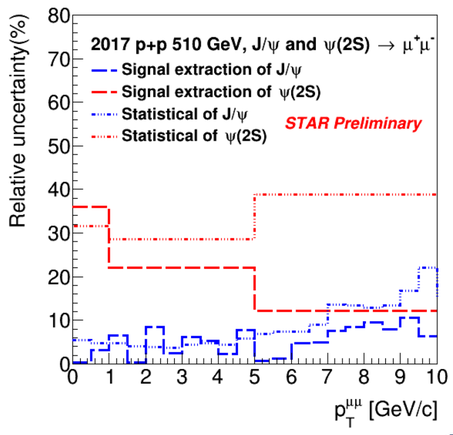


Results:

- J/ψ and ψ(2S) – efficiency-corrected yields:
  - Large data sample from 2017
- ψ(2S) / J/ψ yield ratio:
  - Extracted in three p_T bins
  - Systematic uncertainties canceled, except for uncertainties related to signal extraction (from varying signal and background models)
  - Consistent with the published STAR 2013 results [7]







Conclusions:

- Preliminary results of J/ψ and ψ(2S) efficiency-corrected yields in p+p collisions at √s = 510 GeV were obtained from the STAR 2017 data
- The first p_T differential measurement of the ψ(2S) to J/ψ yield ratio by STAR follows the world-data trend

Outlook:

- Final results on J/ψ and ψ(2S) cross sections as a function of p_T
- Evaluate polarization effects of J/ψ and ψ(2S) on efficiency calculations

References:

[1] Y. Ma, K. Wang and K. Chao: Phys. Rev. Lett. 106 (2011) 042002
[2] W. Tang and M. Vanttinen: Phys. Rev. D54 (1996) 4349-4355
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[5] C. Biino: Cristina Biino's Talk (FPCP2013)
[6] Y. Ma and R. Vogt: Phys. Rev. D94 (2016) 114029
[7] J. Adam "et al.,": Phys. Rev. D100 (2019) 052009

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