Measurements of the transverse-momentum-dependent cross sections of J/ψ production at mid-rapidity in proton+proton collisions at √s = 510 and 500 GeV with the STAR detector

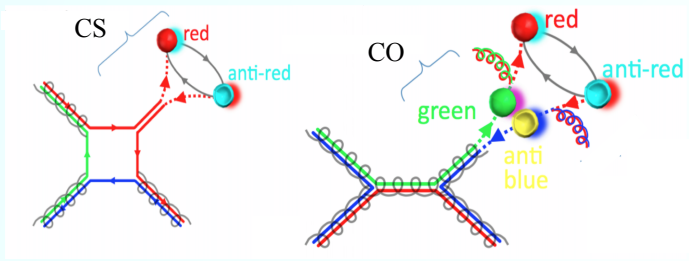
Te-Chuan Huang (for the STAR collaboration)
National Cheng Kung University, Tainan

Abstract:

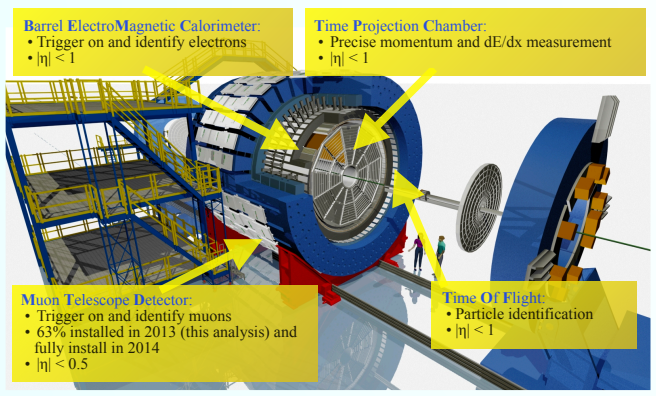
We present measurements of the differential production cross sections of the J/ψ meson as a function of transverse momentum ($p_T^{J/\psi}$) using the $\mu^+\mu^-$ and e^+e^- decay channels in proton+proton collisions at center-of-mass energies of 510 and 500 GeV, respectively, recorded by the STAR detector at the Relativistic Heavy Ion Collider. The measurement from the $\mu^+\mu^-$ channel is for $0 < p_T^{J/\psi} < 9$ GeV/c and rapidity range $|y^{J/\psi}| < 0.4$, and that from the e^+e^- channel is for $4 < p_T^{J/\psi} < 20$ GeV/c and $|y^{J/\psi}| < 1.0$. The ψ(2S) to J/ψ ratio is also measured for $4 < p_T^{e+e-} < 12$ GeV/c in the e^+e^- channel. Model calculations, which incorporate different approaches toward the J/ψ production mechanism, are compared with experimental results and show reasonable agreement within uncertainties. A more discriminating comparison to theoretical models at low p_T can be performed in the future, if the calculations are carried out within our fiducial volume, eliminating the uncertainty due to the J/ψ polarization.

Motivation:

- The production mechanism of heavy quarkonium is not fully understood in hadron+hadron collisions
- Some popular models on the market:
  - Color Singlet Model (CSM)
  - Non-relativistic QCD (NRQCD)
    - Also includes Color Octet Mechanism (COM)
    - + Color Glass Condensate effective theory (CGC) for low p_T
  - Color Evaporation Model (CEM) / Improved CEM
- Quarkonium polarization is also still a unresolved topic
  - Need to describe cross section and polarization simultaneously.



The STAR detector:



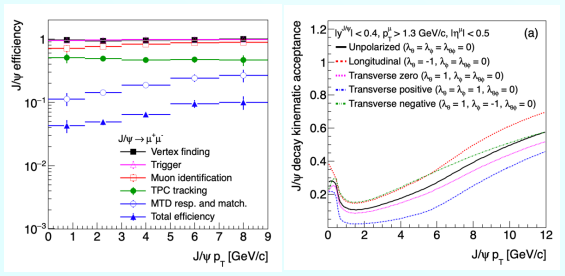
Dimuon decay channel (510 GeV):

- J/ψ cross section is calculated using:

$$\mathrm{BR}(J/\psi \to \mu^+\mu^-) \times \frac{d^2\sigma}{2\pi\, p_T^{J/\psi}\, dp_T^{J/\psi}\, dy} = \frac{N^{\mathrm{corrected}}_{J/\psi\to\mu^+\mu^-}}{\left(2\pi\, p_T^{J/\psi}\right)\cdot \int \mathscr{L} dt \cdot \Delta p_T^{J/\psi} \cdot \Delta y^{J/\psi}}$$

$$N^{\mathrm{corrected}}_{J/\psi} = \sum_i^{N^i_{J/\psi}} w_i \qquad w^{-1} = \mathscr{A} \times \varepsilon_{reco.}$$

- Efficiency, acceptances and the polarization envelope
  - Small MTD η coverage makes the effect of unknown J/ψ polarization much more significant

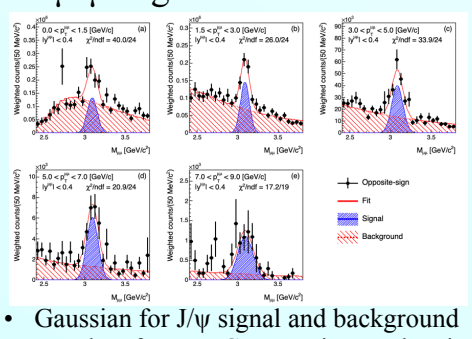


$$\frac{d^2N}{d\cos\theta^* d\phi^*} \propto 1 + \lambda_\theta \cos^2\theta^* + \lambda_\phi \sin^2\theta^* \cos 2\phi + \lambda_{\theta\phi} \sin 2\theta^* \cos\phi^*$$

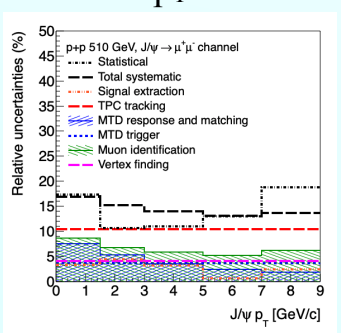
θ^* : polar angle in quarkonium rest frame

ϕ^* : azimuthal angle in quarkonium rest frame

- J/ψ ➔ $\mu^+\mu^-$ signal extraction and uncertainties in each p_T bin



- Gaussian for J/ψ signal and background template from TPC same-sign track pairs



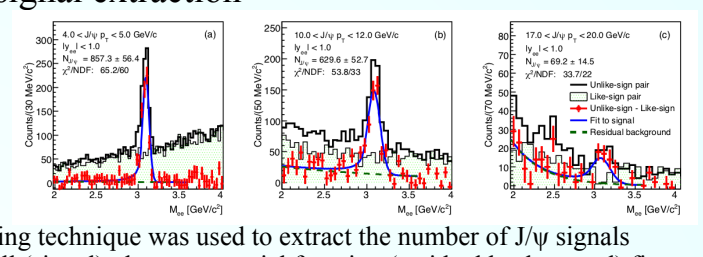
- Dominated by statistical uncertainty

Dielectron decay channel (500 GeV):

- J/ψ cross section is calculated using:

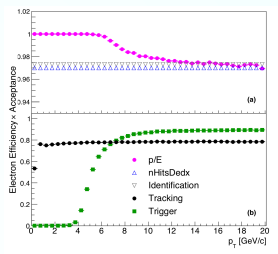
$$\mathrm{BR}(J/\psi \to e^+e^-) \times \frac{d^2\sigma}{2\pi\, p_T dp_T dy} = \frac{N^{\mathrm{raw}}_{J/\psi\to e^+e^-}}{(2\pi\, p_T)\cdot \int \mathscr{L} dt \cdot \mathscr{A}\varepsilon \cdot \Delta p_T \cdot \Delta y}$$

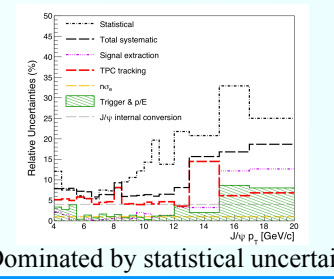
- J/ψ ➔ e^+e^- signal extraction



- Bin counting technique was used to extract the number of J/ψ signals
- Crystal ball (signal) plus exponential function (residual background) fit was performed on the background subtracted mass spectra to correct the counting range efficiency

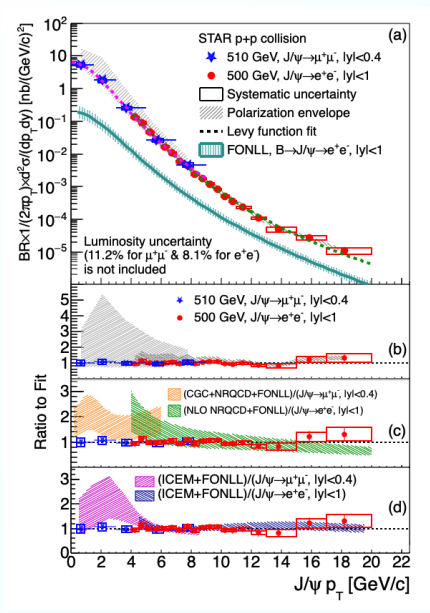
- Detection efficiency of electron and the uncertainties

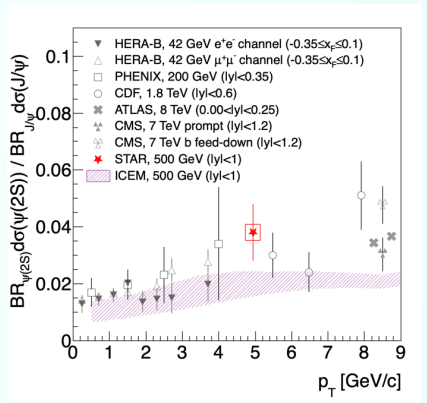




- Dominated by statistical uncertainty

J/ψ cross-section and ψ(2S) to J/ψ ratio compared with models:





- Precise measurements of J/ψ cross-section covered J/ψ p_T from 0 to 20 GeV/c
- Consistent with CGC+NRQCD, NLO NRQCD, and ICEM calculations (B feed-down from FONLL included) with models systematically above the data at low p_T, but within the polarization envelope
- ψ(2S) to J/ψ ratio follows the world trend

Conclusions:

- J/ψ production cross-section for p+p at 510 GeV and 500 GeV are measured with STAR detector via dimuon and dielectron decay channel, respectively.
- Consistent with CGC+NRQCD, NLO NRQCD, and ICEM calculations (B feed-down from FONLL included) with models systematically above the data at low p_T, but within the polarization envelope
- ψ(2S) to J/ψ ratio in p+p at 500 GeV is also measured in dielectron decay channel and it follows the world trend

References:

- CS and CO diagrams: Cristina Biino's Talk (FPCP2013)
- STAR data: [arXiv:1905.06075] submitted to PRD
- CGC+NRQCD model: Phys. Rev. Lett. 113, 192301 (2014)
- NLO NRQCD model: Phys. Rev. Lett. 106, 042002 (2011)
- ICEM model: Phys. Rev. D 94, 114029 (2016)