J/ψ production measurements in p+p and p+A collisions at $\sqrt{s_{NN}}$ = 200 GeV through the di-muon channel at STAR

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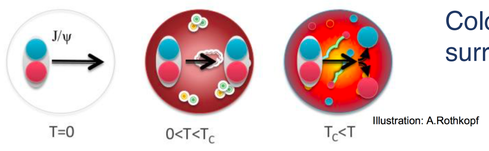
Abstract

Quarkonium production is an important tool to study the properties of the Quark-Gluon Plasma (QGP) formed in relativistic heavy-ion collisions. In particular, suppression of the J/ψ meson production due to the color-screening effect was proposed as a direct evidence of the QGP formation. However, interpretation of the J/ψ suppression in heavy-ion collisions requires knowledge of cold nuclear matter effects and will benefit from a better understanding of the J/ψ production mechanism. By comparing J/ψ production cross-section and polarization in p+p and p+Au collisions, the cold nuclear matter effects can be studied in detail. Moreover, J/ψ polarization is sensitive to the J/ψ production mechanism, and its measurement can help distinguish among different models. The STAR experiment at RHIC recorded large samples of p+p and p+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV for charmonium studies utilizing the trigger provided by the Muon Telescope Detector. In this poster, we will present the recent measurements of the J/ψ production in p+p collisions. The results will be compared to model calculations. Furthermore, we will present measurements of the nuclear modification factor for J/ψ over a broad kinematic range in p+Au collisions, to quantify the cold nuclear matter effects.

Motivation

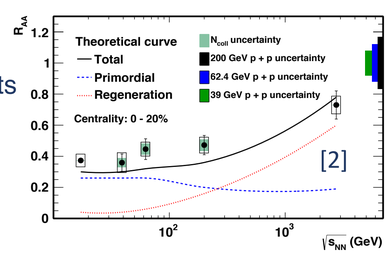


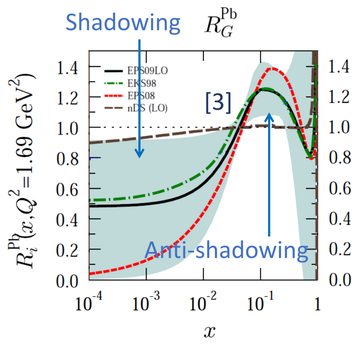
Color-screening: quark-antiquark potential is screened by surrounding partons, leading to dissociation

- J/ψ suppression was proposed as a proof of QGP formation[1]

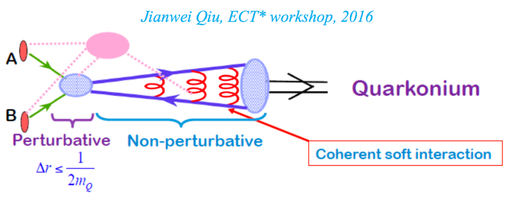
However
Other effects come into play:

- Cold nuclear matter (CNM) effects
  - Measurements in p+A
- Regeneration and dissociation
  - RAA measurements
- Feed down
  - Ψ(2S), χ_c, B





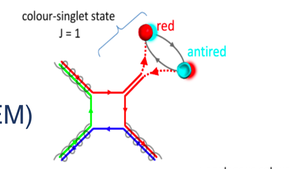
- J/ψ production mechanism in elementary collisions is not fully understood

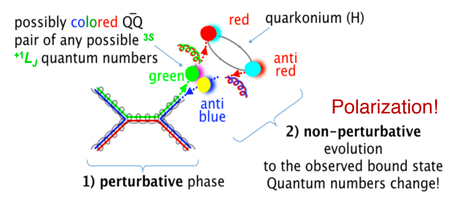


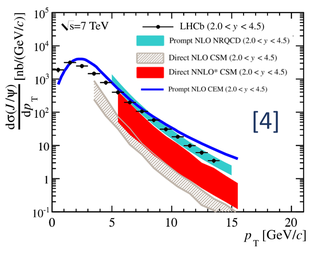
QCD factorization:

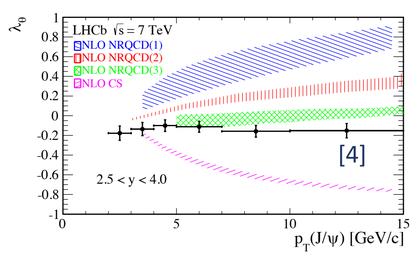
- Long distance process: no full-QCD description of quarkonium formation,
  - Model dependent;
  - Input from experiments needed.

- Different models on the market
  - Color Singlet Model (CSM)
  - Color Evaporation Model (CEM)
  - NRQCD approach
  - CGC+NRQCD



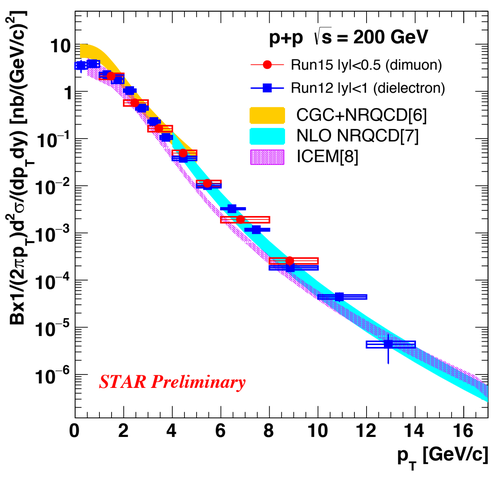




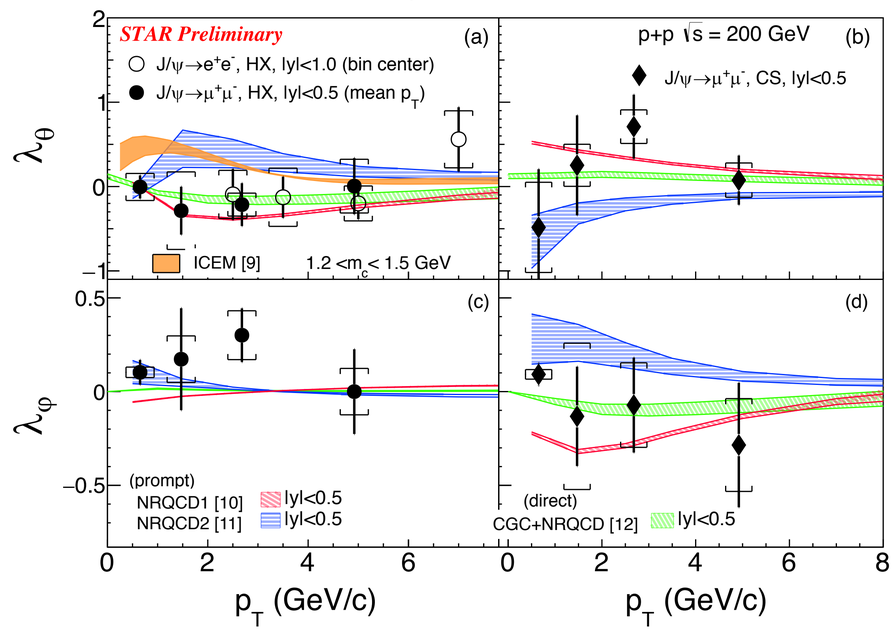


- Measurements of quarkonium polarization provides crucial constraints on production mechanism
- Helps to shrink the uncertainty on p_T spectrum measurements

J/ψ production in p+p@200 GeV



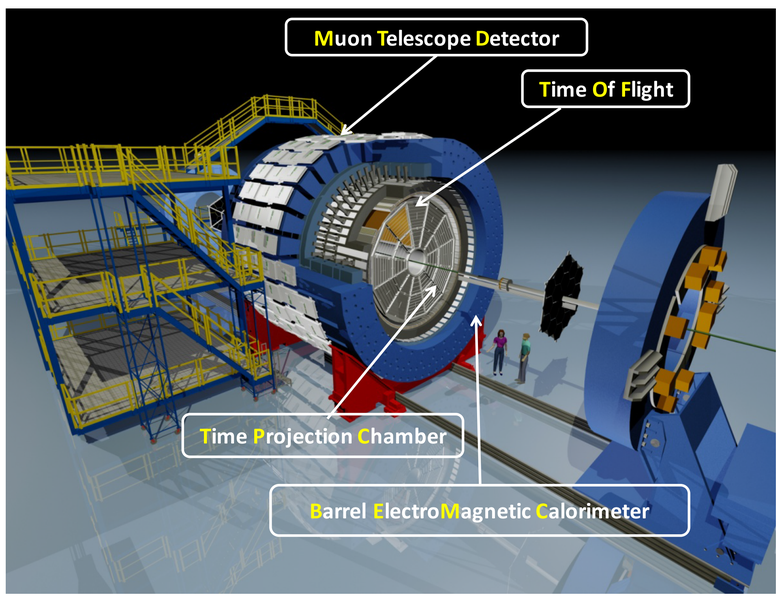
- Inclusive J/ψ cross section is measured for $0 < p_T < 14$ GeV/c
- CGC+NRQCD together with NLO NRQCD (prompt J/ψ) can qualitatively describe data in the full p_T range within uncertainties
  - There seems tension towards very low p_T
- Improved CEM model (direct J/ψ) describes data well at low p_T
  - Data are above ICEM calculation at $3.5 < p_T < 12$ GeV/c
- B-hadron feed-down needs to be taken into account

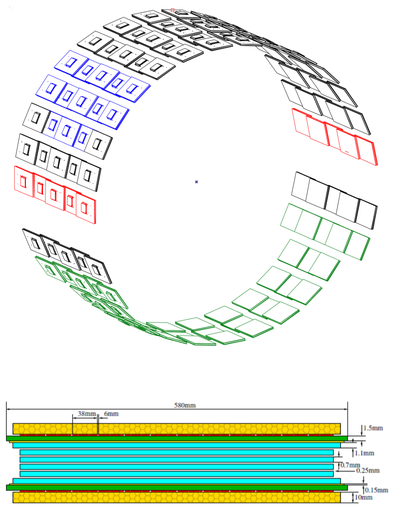


Model	χ^2/ndf	p-value
ICEM	11.14/4	0.03
NRQCD1	15.14/16	0.51
NRQCD2	23.55/16	0.10
CGC+NRQCD	7.11/16	0.97

- J/ψ polarization measured in both Helicity and Collins-Soper frames
- While no model can be ruled out definitively based solely on the data presented, the CGC+NRQCD gives the best description overall
- Better precision is needed to distinguish models or constrain LDMEs

STAR Experiment





- Top right: A schematic view of the entire Muon Telescope Detector (MTD) system. MTD covers 45% in φ and $|\eta| < 0.5$. It is used to trigger on and identify muons which emit less Bremsstrahlung radiation compared to electrons.
- Bottom right: A schematic side-view of the Multi-gap Resistive Plate Chambers with long readout strips (LMRPC) used in the MTD design: time resolution ~100 ps and spatial resolution ~1-2 cm[5].

J/ψ production in p+Au@200 GeV

EPS09+NLO, Ma & Vogt, Private Comm.
nCTEQ, EPS09+NLO, Lansberg Shao, Eur. Phys. J. C 77 (2017) no.1, 1
Comp. Phys. Comm. 198 (2016) 238-259
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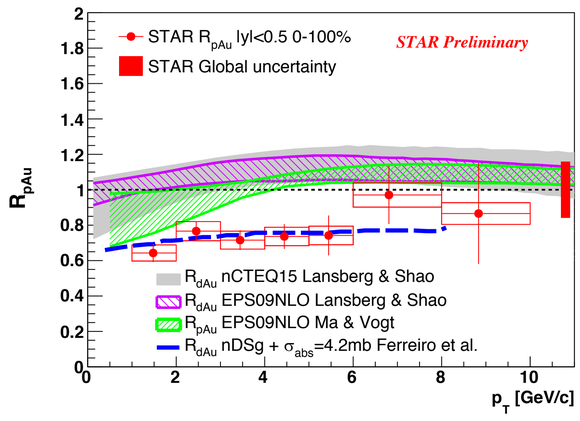
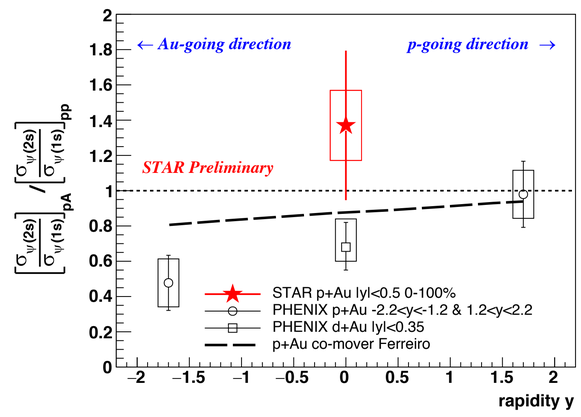


- First J/ψ R_{pAu} measurement at RHIC
- Model calculations with only nPDF effect can touch the upper limit of data within uncertainties
- Data favor a model calculation including an additional nuclear absorption effect on top of the nPDF effect

PHENIX p+Au, PRC 95 (2017) 034904
PHENIX d+Au, PRL111 (2013) 202301
Co-mover calculation, Ferreiro (2016) private communication
Calculation based on PLB 749 (2015) 98-103



- First $[\sigma_{\psi(2S)}/\sigma_{\psi(1S)}]_{pAu}/[\sigma_{\psi(2S)}/\sigma_{\psi(1S)}]_{pp}$ measurement at mid-rapidity at RHIC

1.37 ± 0.42(stat) ± 0.19(sys)

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