2022 RHIC/AGS ANNUAL USERS' MEETING

From RHIC to EIC

At the QCD Frontiers

This meeting will be held virtually.
June 7–10, 2022

Measurement of J/ψ and ψ(2S) at forward and backward rapidity in p+p, p+Al, p+Au, and ^{3}He+Au collisions

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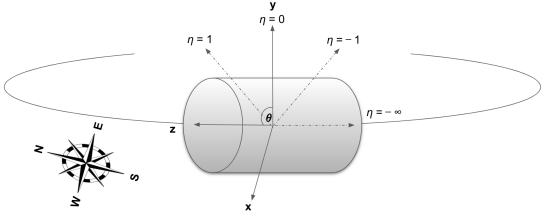
Thesis Advisor: Anthony Frawley

Brief Introduction



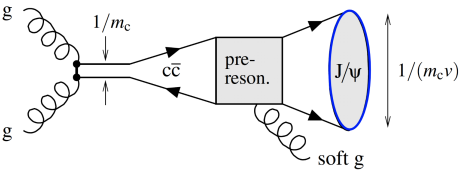
Inclusive $J/\psi \rightarrow \mu^+\mu^-$

Sources of Signal

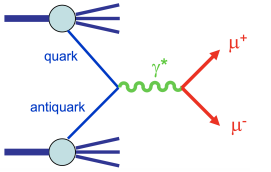
- ggf for Charmonium production
- Feedown from χ_c and ψ(2s)
- Contributions from B–meson decays

Sources of Background

- Dimuons from Drell Yan
- Open heavy flavor decays
  - Predominantly D, $\bar{\text{D}}$–meson decays
- Dimuon pairs kinematically unrelated
  - Hadrons misidentified as muons
  - Muons from prompt π/K decays



B → J/ψ + X

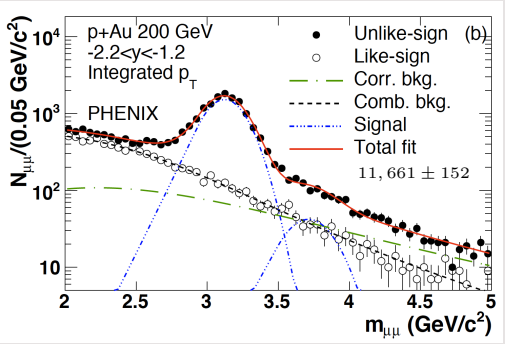


D → μ + X

π → μ + X
K → μ + X

From top: [1] ggf, [2] B decays, [3] Drell Yan, [4] Correlated hadronic decays, [5] Uncorrelated π/K decays

Dimuon Reconstructed Mass Distribution



- Unlike-sign reconstructed muon pairs
- Like-sign reconstructed muon pairs
  - Estimate of combinatorial background
- Correlated background
  - Open heavy flavor, Drell Yan, etc.
- Fit to the combinatorial background
- J/ψ, ψ(2S) Crystal Ball fits
- Total fit

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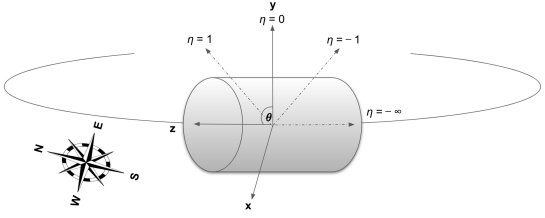
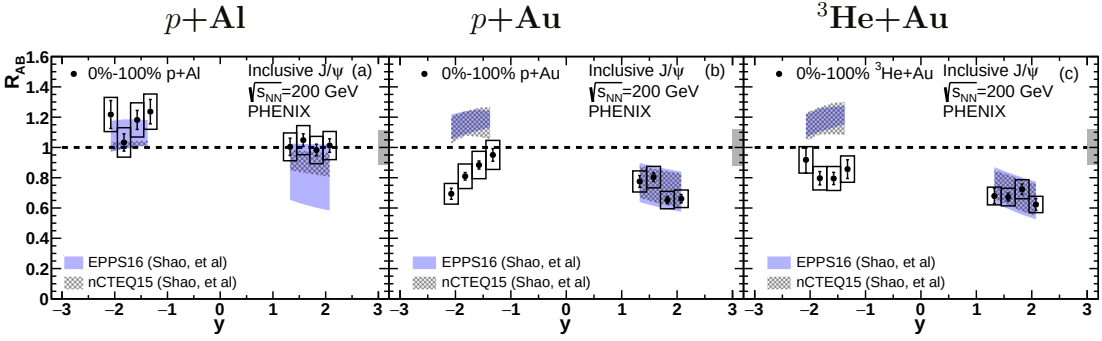
Results of J/ψ Measurements



J/ψ Modification vs. Rapidity (0-100%)



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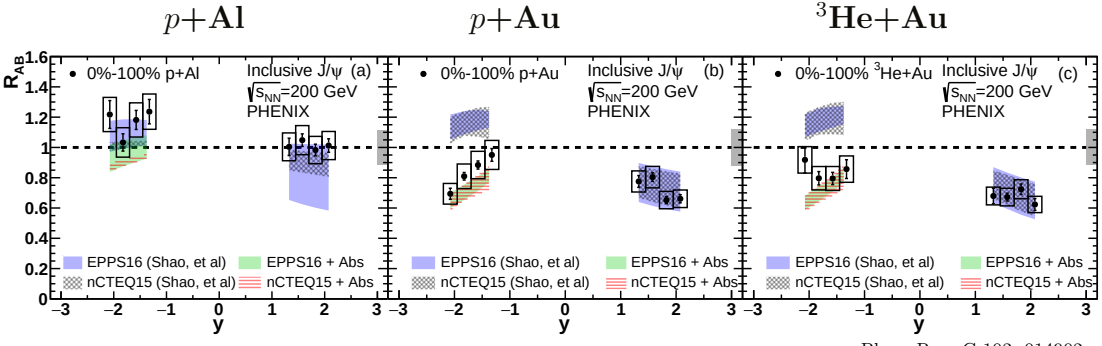
- nPDF nCTEQ15 and EPPS16 predictions reweighted using LHC data
  - Agree well with data at forward rapidity
  - Do not agree at backward rapidity for Au target
- **Shadowing only**

J/ψ Modification vs. Rapidity (0-100%)



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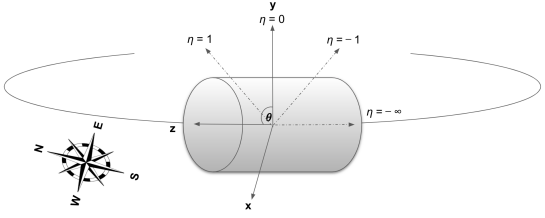
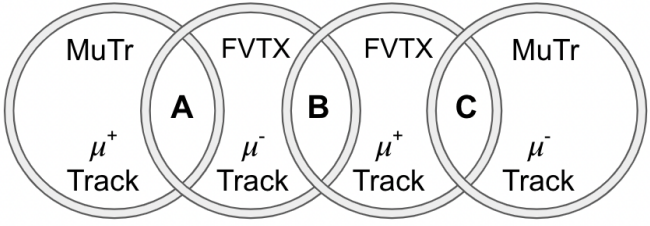
- nPDF nCTEQ15 and EPPS16 predictions reweighted using LHC data
  - Added a nuclear absorption estimate at backward rapidity
    - Describe data reasonably well
- **Shadowing + Nuclear Absorption**

Results of ψ(2S) Measurements

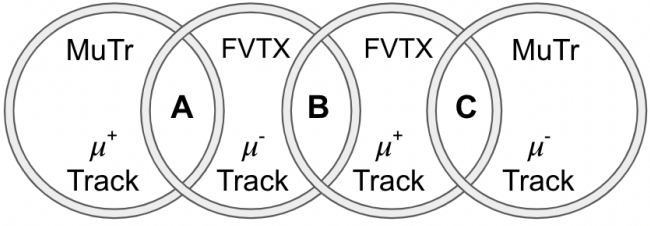


Single FVTX-Matched Muon Pairs



- The idea to utilize single-FVTX matched muon pairs suggested by PHENIX collaborators
  - One muon track has momentum determined by the FVTX detector, and the other track has momentum determined by the MuTr detector
- Combining muon pairs from sets A, B, and C roughly doubled available statistics

Single FVTX-Matched Muon Pairs



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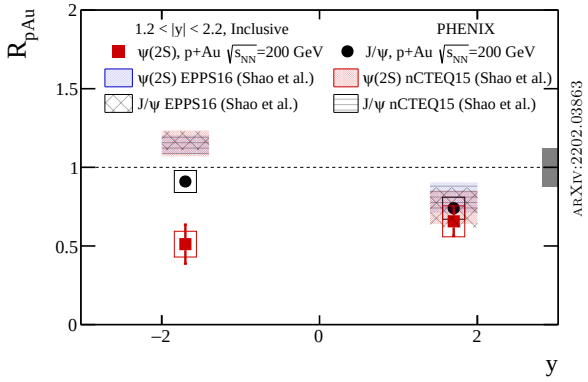
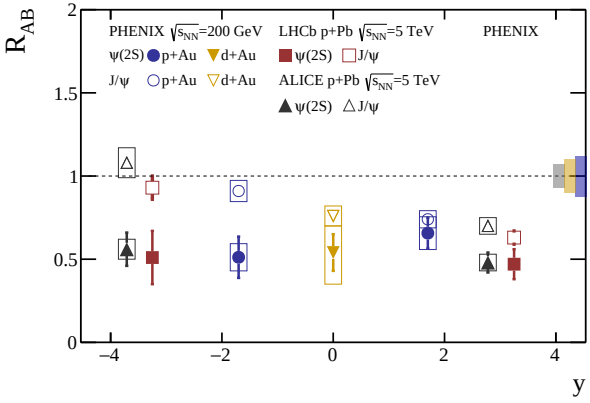
Thank you to Cesar da Silva, Jin Huang, Sanghoon Lim & Dave Morrison

Charmonia Nuclear Modification in p+Au Collisions



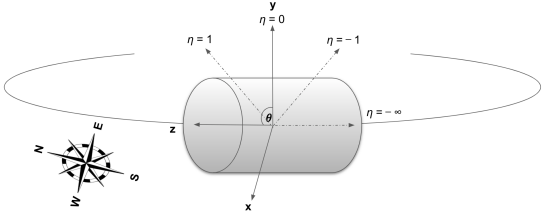
- At forward rapidity, J/ψ and ψ(2S) modification show similar suppression
  - Data well described by EPPS16 and nCTEQ15 shadowing predictions
- At backward rapidity, nPDF effects alone cannot describe ψ(2S) modification

J/ψ, ψ(2S) Modification at RHIC and LHC



- At forward rapidity, J/ψ nuclear modification similar to ψ(2S) nuclear modification
- Stronger suppression observed for ψ(2S) at bkwd rapidity supports final state effects

Thank You!

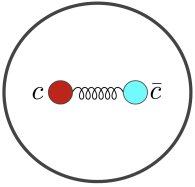


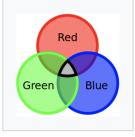
J/ψ Properties

Quantity	**Value**
Electric Charge	0
Mass	3.096916 GeV/c^2
Charm quark mass	1.275 GeV/c^2
Spin	1
Lifetime	10^{-21} seconds
B$\mu\mu$	6%
radius	0.25 fm
ψ(2s) radius	0.45 fm
proton radius	0.8 fm
Au nuclei radius	7 fm

Charmonium Formation at RHIC

- Quarkonia is a short-lived bound state of quark- antiquark pairs $(c\bar{c}, b\bar{b})$
- Charmonium is bound state of charm-anticharm pairs
- Transitions can be made to lower states through photon emission
- Gluon gluon fusion (ggf) produces charm-anticharm quark pairs
  $\sim 2\%$ of all created $c\bar{c}$ pairs at RHIC will form Charmonium states
- $c\bar{c}$ pairs that form Charmonium occur with total energy below the threshold for strong decays
  - $c\bar{c}$ pair has small relative velocity $v/c \ll 1$





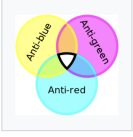


Image Credit: Wikipedia Color Charge

Cold Nuclear Matter Effects in p+A Systems

1. **Gluon Shadowing/Anti-Shadowing:**
   Modification (suppression/enhancement) of heavy quark cross section due to modifications of the gluon structure function in the target
2. **Nuclear Break-up:**
   The break up of the bound J/ψ (or precursor state) in collisions with other target nucleons passing through J/ψ production point
3. **Cronin Effect:**
   Modification of the J/ψ p_T distribution due to multiple elastic scattering of partons
4. **Parton Energy Loss:**
   The projectile gluon experiences multiple scattering passing through the target prior to J/ψ production, reducing the J/ψ rapidity