Multiplicity dependence of J/ψ production in $p+p$ collisions at $\sqrt{s} = 510$ GeV

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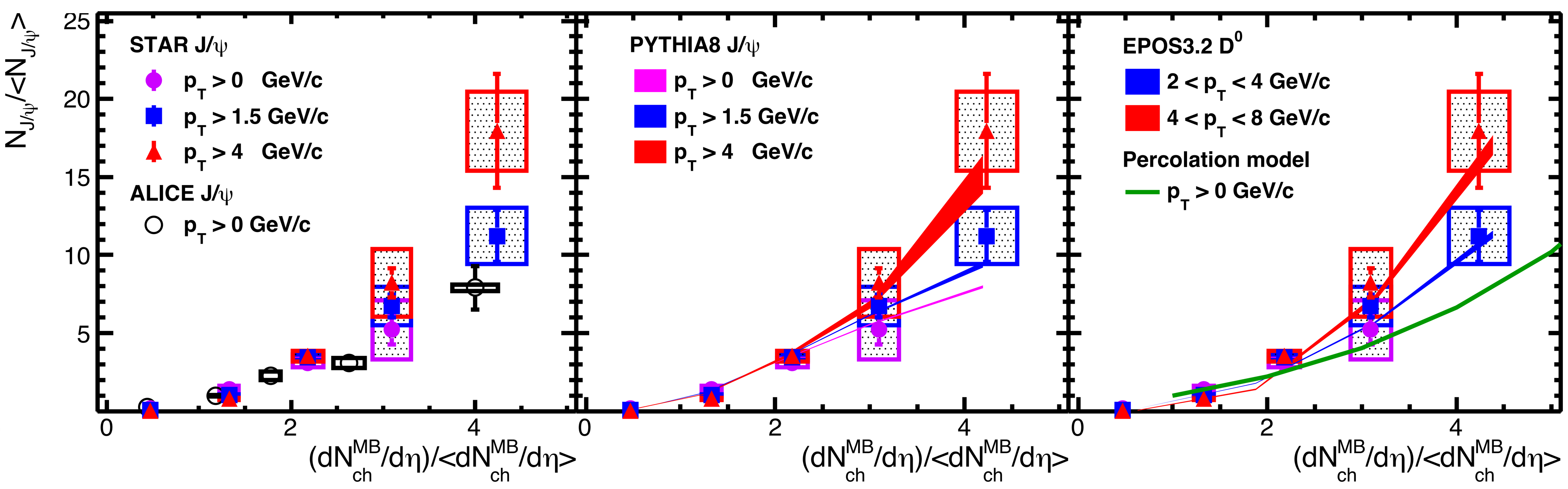
1. Abstract

Studying quarkonium production allows us to probe the properties of strongly interacting matter, such as the quark-gluon plasma and gluonic matter in heavy nuclei. While such probes are widely used, a complete understanding of the quarkonium production mechanism has not yet been achieved, even for $p+p$ collisions. Therefore, quarkonium studies in $p+p$ collisions are essential for advancing the field. Measuring the dependence of self-normalized quarkonium yield on self-normalized charged-particle multiplicity can elucidate the interplay of involved soft- and hard-QCD processes. While proposed explanatory mechanisms, including multi-parton interactions, string screening, and gluon radiation, converge at low values of self-normalized multiplicity, their divergence at higher values emphasizes the potential for new insights by extending experimental reach in multiplicity. Herein we present the status of the measurement of J/ψ production, reconstructed through the dilepton decay channels, in $p+p$ collisions at $\sqrt{s}$ = 510 GeV recorded by the STAR detector in 2017. Final observables include transverse momentum and rapidity distributions, as well as the self-normalized yields as a function of self-normalized charged-particle multiplicity. The presented analysis uses a large sample of quarkonia with increased luminosity compared to previous STAR measurements, therefore both improving precision and extending the measurement to higher multiplicity values.

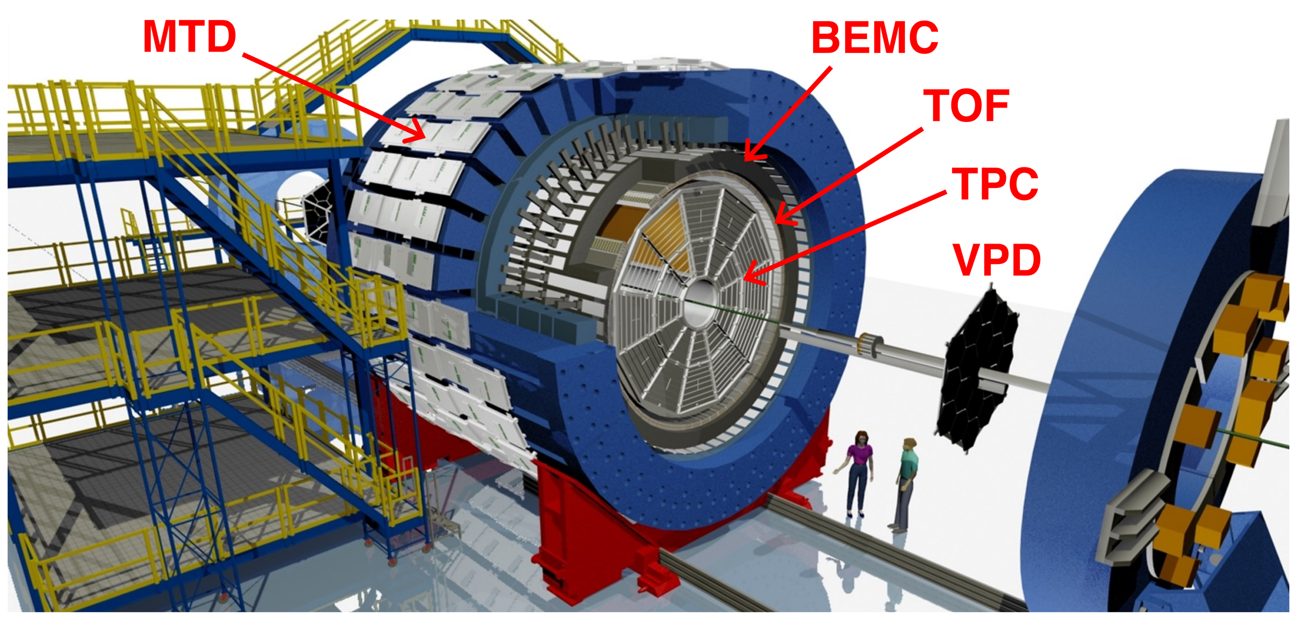
2. Motivation

- Observed linear or faster-than-linear increase in J/ψ yields vs. multiplicity in $p+p$ collisions at RHIC and LHC [1–3]
  - Behavior also seen for Υ and D mesons [4,5]
  - Suggests that hard and soft scattering processes are strongly correlated
- Studies of quarkonium yields vs. multiplicity in $p+p$ collisions provide tests of production models: *e.g.*, Percolation [6], Coherent Particle Production [7], models including Color Glass Condensate, Multiple Partonic Interactions
- 2017 data sample has 4 times higher luminosity than earlier studies at 200 GeV [1]
- Study both e^+e^- and $\mu^+\mu^-$ channels to maximize the transverse momentum (p_T) range



STAR $p+p$ $\sqrt{s}$ = 200 GeV   Refs. [1,2]

3. STAR Detector



Vertex Position Detector
- Minimum-bias Trigger
- Pile-up Rejection
- Vertex Position

Time Projection Chamber
- Tracking and Particle ID (dE/dx)

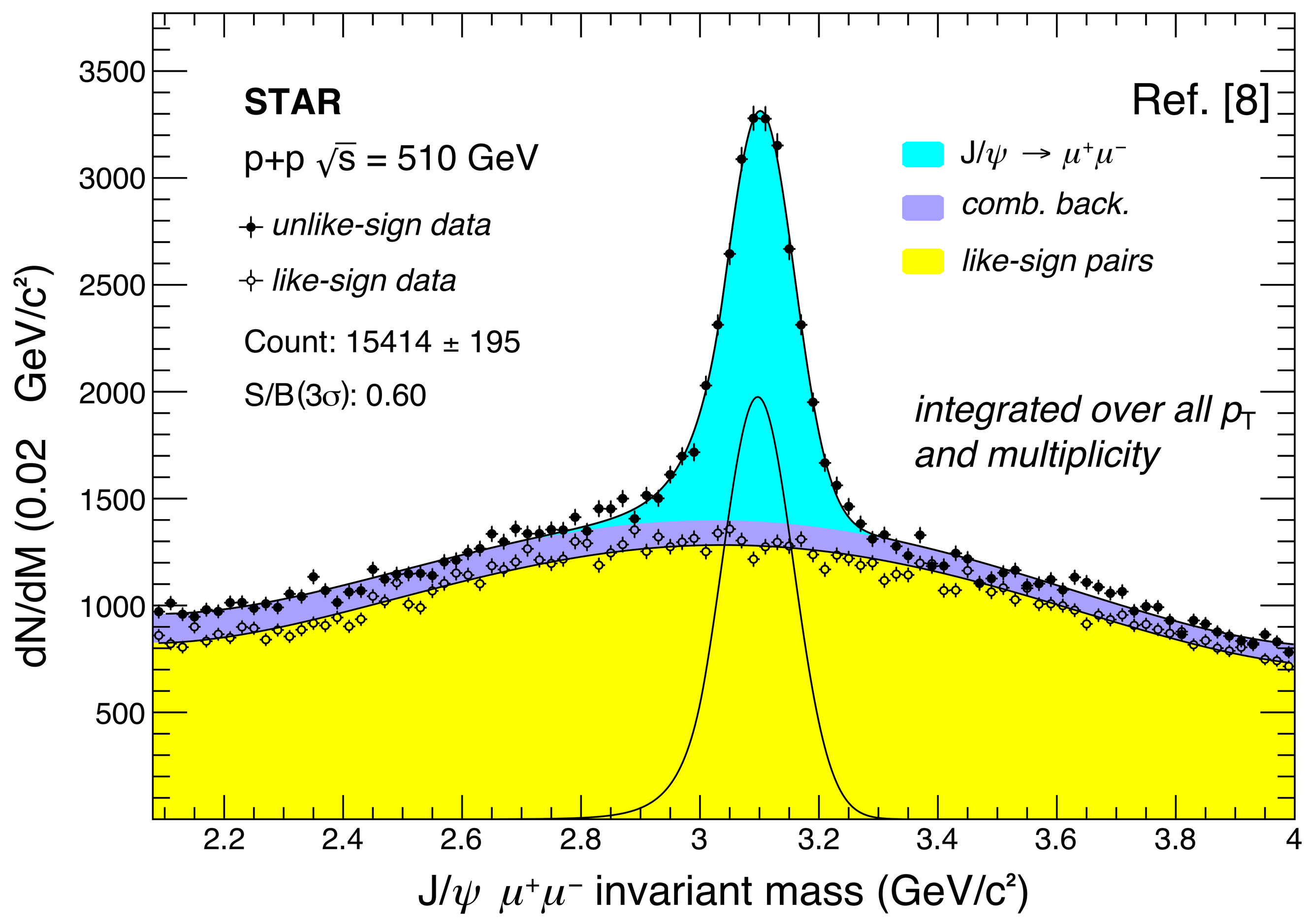
Time-Of-Flight Detector
- Particle ID
- Pile-up Rejection

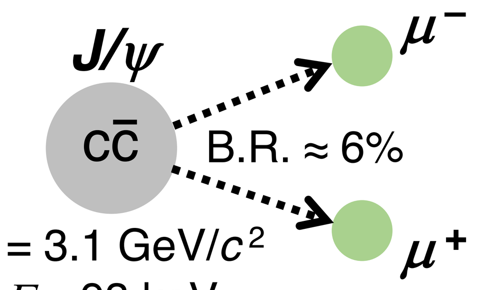
Barrel Electromagnetic Calorimeter
- Energy Measurement
- High-Tower Trigger
- Electron ID (E/pc)

Muon Telescope Detector
- Outside Magnet
- Muon ID and Trigger

STAR Magnet
- Solenoidal Field: 0.5 T

4. Dimuon Decay Channel





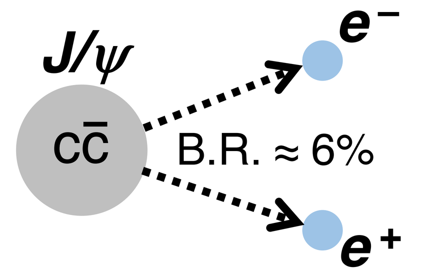
m = 3.1 GeV/c^2
Γ = 93 keV

- Event Selection With Dimuon Trigger
- Track Selection
  - $p_T > 1.2$ GeV/c
  - $|\eta| < 0.8$
  - DCA to primary vertex < 3 cm
- Muon ID
  - TPC: compare dE/dx to expectation: $-2.5 < n\sigma_\pi < 3.5$
  - Extrapolated TPC track matches MTD hit within 20 cm in both longitudinal and azimuthal directions
  - Arrival at MTD: within $[-0.5, +0.75]$ ns of expectation

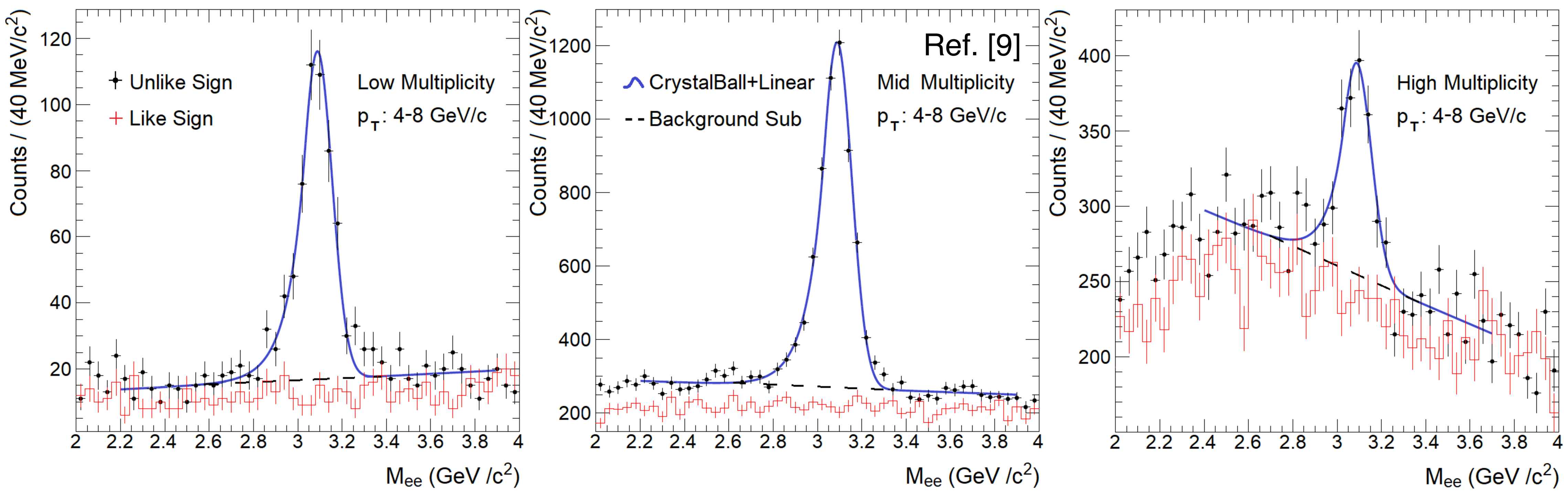
- Perform invariant-mass analysis
  - Divide into multiplicity bins based on number of TPC tracks matched to TOF hits
  - Combinatorial Background: like-charge ($\mu^\pm\mu^\pm$) pairs
  - Fit peak with Crystal-Ball function on top of polynomial background

5. Dielectron Decay Channel

- Event Selection: High-Tower Trigger ($E_T \gtrsim 4.2$ GeV)
- Track Selection
  - $p_T > 200$ MeV/c
  - $|\eta| < 1$
  - DCA to primary vertex < 1 cm
- Electron ID
  - TPC: compare dE/dx to expectation: $-3 < n\sigma_e < -1.9$
  - TOF: $0.97 < \beta < 1.03$
  - BEMC: $E_{tower}/E_{cluster} > 0.5$
  - BEMC: $0.67 < E/pc < 3.33$



- Perform similar invariant-mass analysis to dimuon decay channel



6. Outlook

- Calculating corrections triggering, vertexing, and multiplicity measurement
- Refine multiplicity binning and extend reach to higher multiplicity, where model calculations diverge
- Goal: self-normalized J/ψ yield vs. charged-particle multiplicity
- Complementary Υ study being performed
  - See QM 2023 poster by J. Češka

References:

[1]: STAR, *Phys. Lett. B* **786** 87 (2018)
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[8]: R. Botsford (STAR), APS DNP 2022
[9]: B. Schaefer (STAR), Hard Probes 2023

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